TESLA - COLLABORATION

Transparencies from the
TESLA Meeting at DESY, March 9 - 11, 1998

March 1998, TESLA 98-06

TESLA Reports are available from:

Deutsches Elektronen-Synchrotron DESY
MHF-SL Group
Katrin Lando
Notkestraße 85
22603 Hamburg
FRG

Phone: (0049/40) 8998 3339
Fax: (0049/40) 8998 4302
e-mail: lando@lando.desy.de or landok@vxdesy.desy.de

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Agenda for the TTF Collaboration Meeting (9th - 11th March 1998)

March 9th, Seminarroom 4a+b, Building 1b - Chair S. Tazzari

9:00 Welcome and Introduction - B.H. Wiik
9:10 Summary of Cavity Tests - M. Pekeler
9:30 Status of First Cryomodule - R. Lange
9:45 Status of Klystrons and Modulators - A. Gamp
10:00 Low Level RF - M. Huening/S. Simrock
10:30 Coffee Break
11:00 Hydroforming of Cavities - H. Kaiser
11:20 New Cryostat Development - C. Pagani
11:40 Cryogenic Supply of TTF (Phase II) - B. Petersen
12:00 Lunch
13:30 Laboratory Reports - Chair B. Aune
IPN/LAL - T. Garvey
CE Saclay - B. Aune
FNAL - H. Edwards
INFN - M. Castellano
BINP Protvino - V. Balakin
Other Reports (as requested)
15:00 Coffee Break
15:30 Status of Controls - K. Rehlich
15:45 Injector Modifications - S. Schreiber
16:00 Status of Laser - I. Will
16:15 DESY RF Gun - K. Floettmann
16:30 Bunch Compressor Status - A. Kabel
16:45 Layout of Undulator Beam Line - U.-C. Mueller
17:00 Undulator Beam Diagnostics - R. Lorenz/G. Schmidt
17:15 Organisation of Working Groups

19:00 Social Event (DESY canteen, ground floor, new part)

March 10th

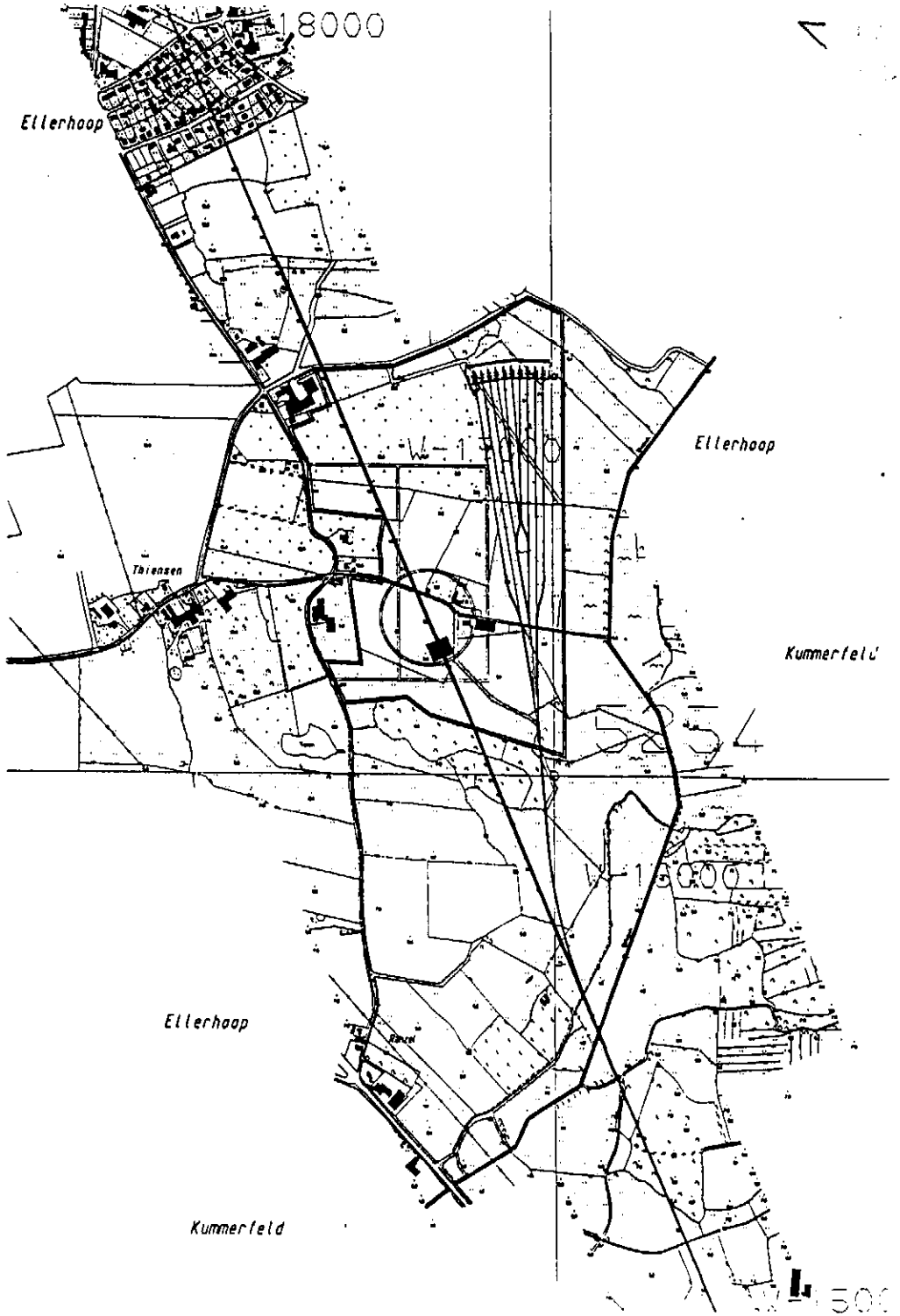
9:00 Working Groups

Linac Operation - Room 4a, Bldg. 1b - (T. Garvey, H. Weise)
Cavity R+D - Room 4b, Bldg. 1b - (D. Bloess, D. Proch)
TESLA 500 - Room 109, Bldg. 25b - (R. Brinkmann)

March 11th, Seminarroom 4a+b, Building 1b

9:00 Summary of Working Groups - Chair H. Edwards
Time Schedule for Cryomodules 2 and 3
10:30 Coffee Break
11:00 Special Seminar
D. Burke (SLAC) - Status of the FFTB

NEUMÜNSTER
Bad Bramstedt
Kaltenkirchen
Henstedt-Ulzburg
Quickborn
NORDERSTEDT
Glückstadt
ELMSHORN
Barmstedt
Uetersen
Tornesch
PINNEBERG
Appen
Rellingen
Halstenbek
Schenefeld
HAMBURG
STADE
WEDEL
Jork
BUXTEHUDE
Naturpark
Aukrug
Hohenlockstedt
Kellinghusen
Hohe Geest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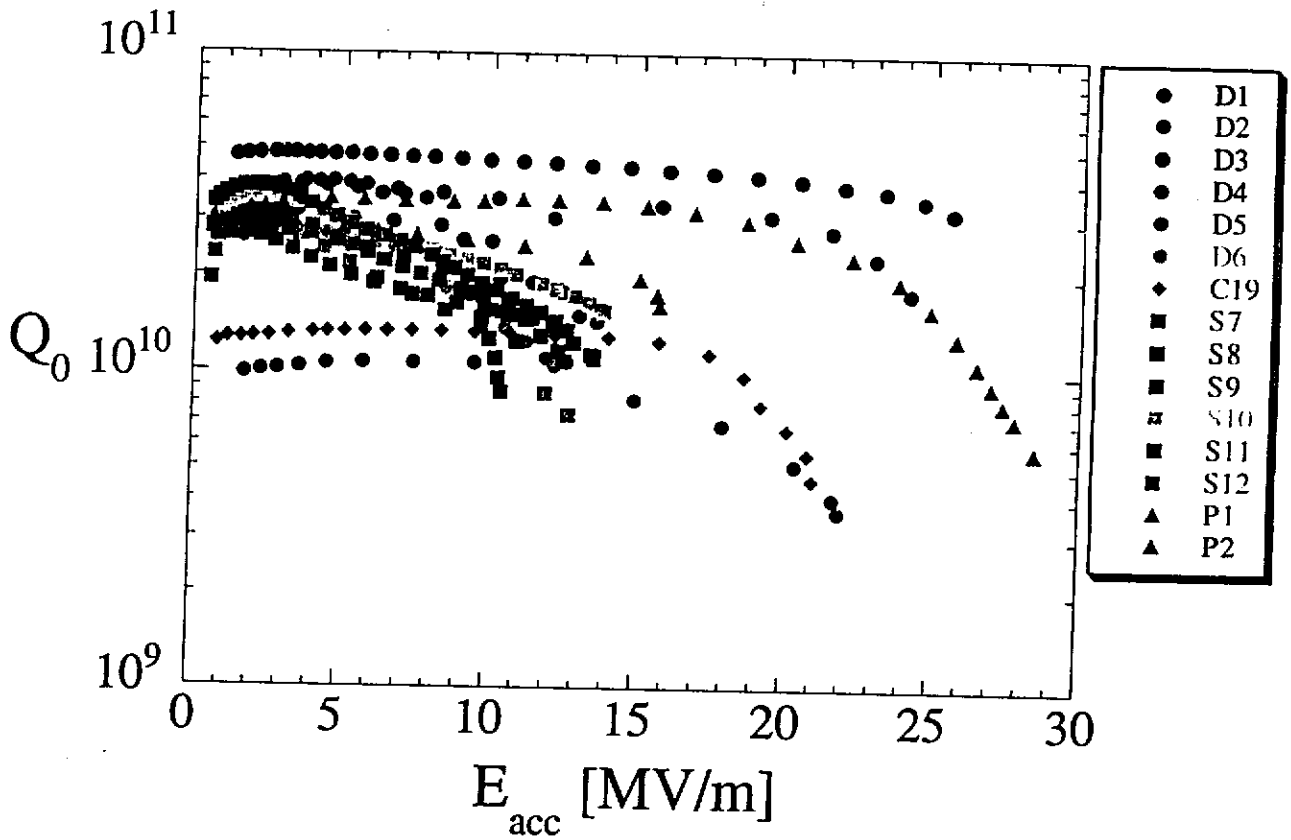
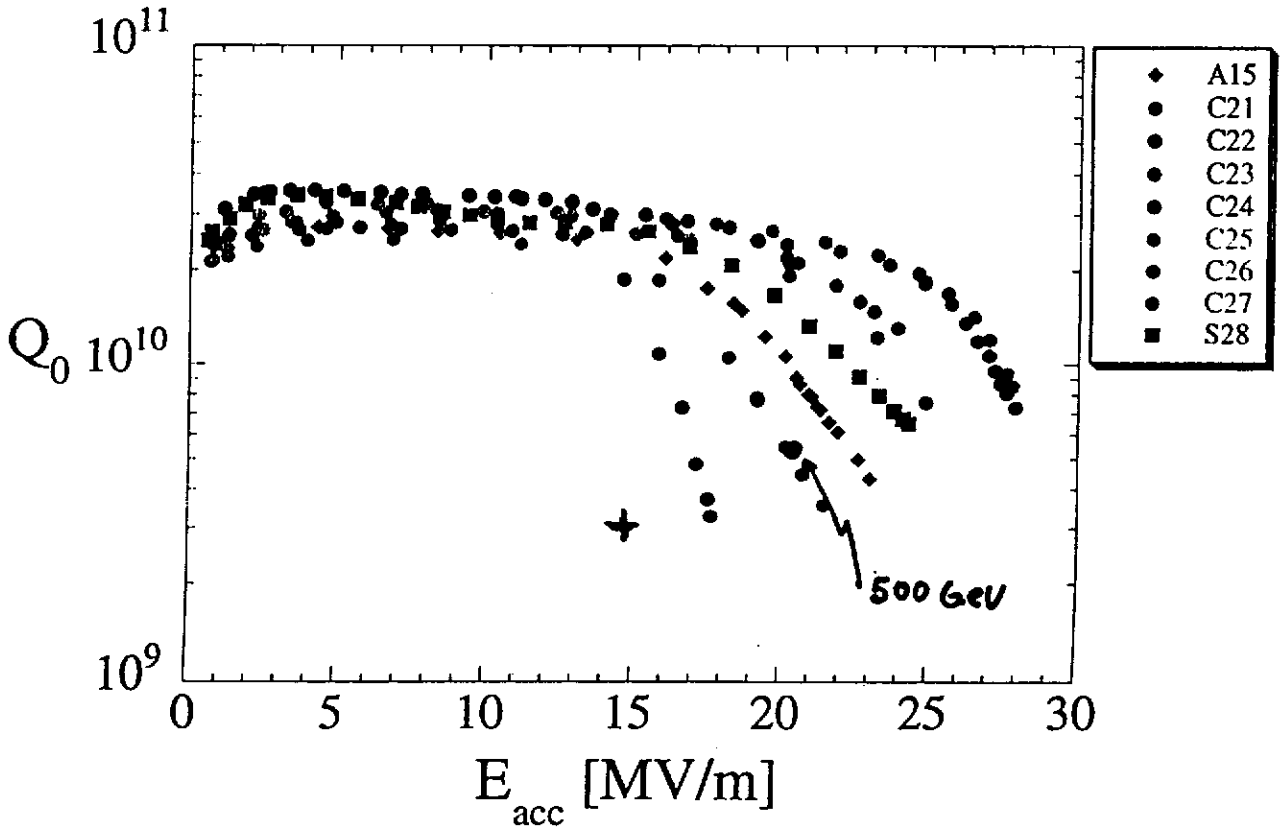


average gradient at $Q_0 > 3\ 10^9 = 16.4$ MV/m

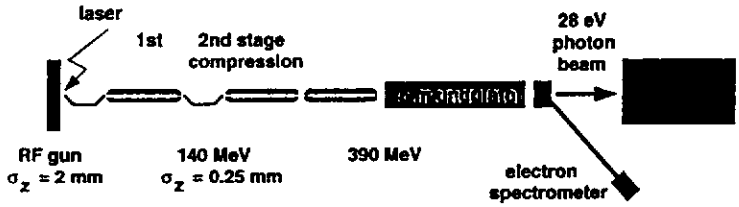


average gradient at $Q_0 > 3\ 10^9 = 23.9$ MV/m

20.6 MV/m ≙ 500 GeV

Program 1998 - 2003

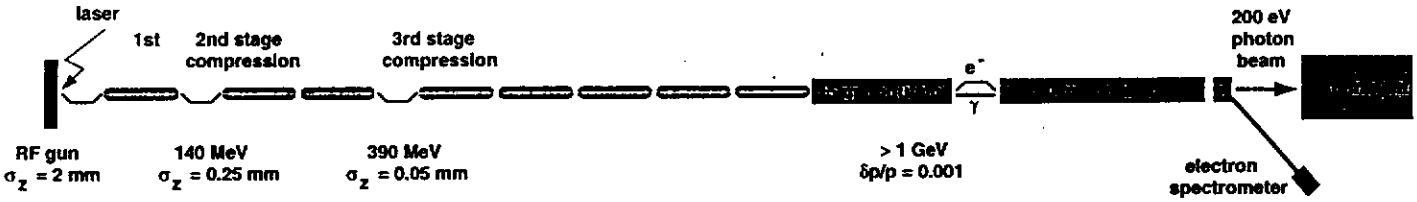
TTF with SASE FEL Proof of Principle Experiment

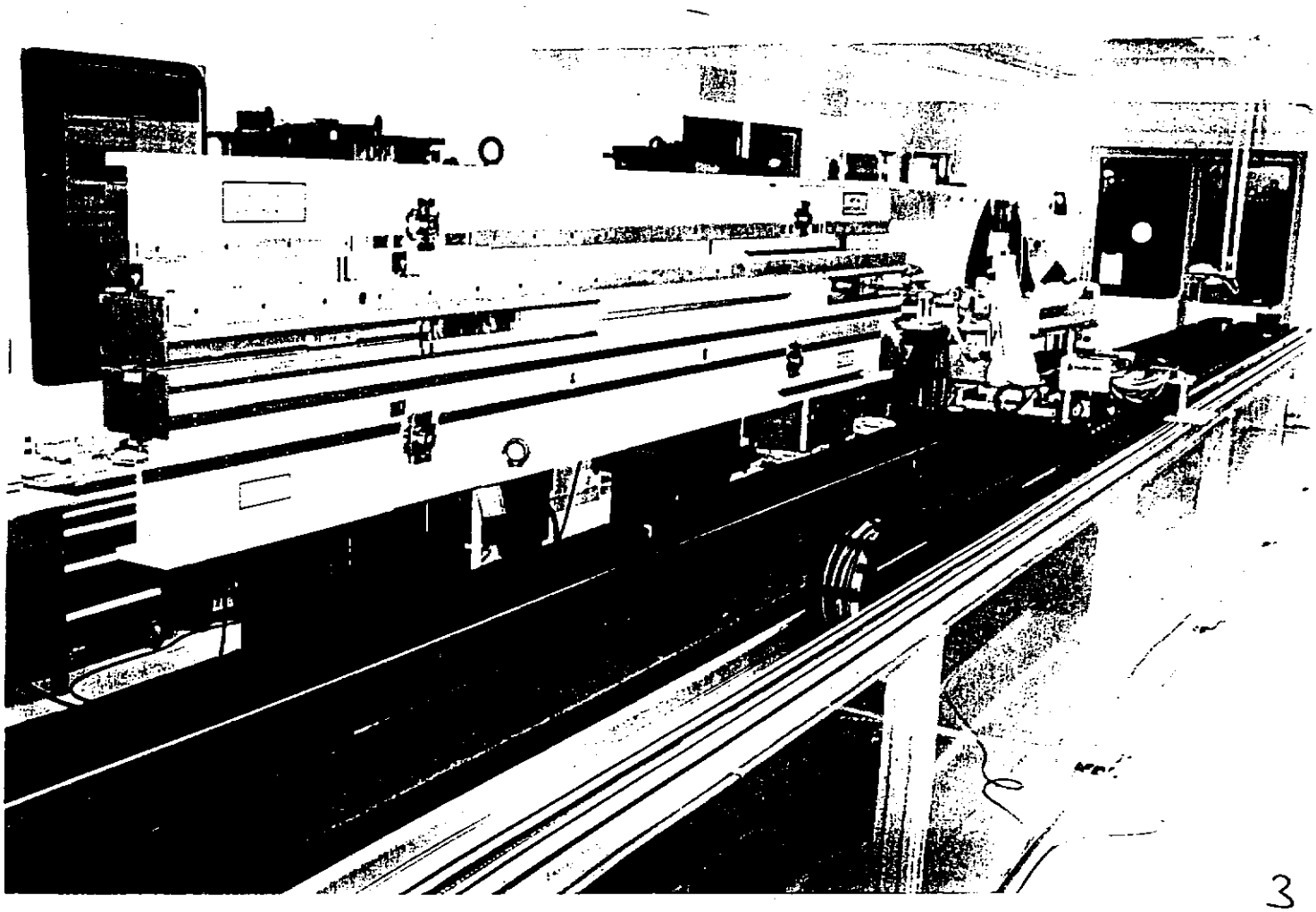


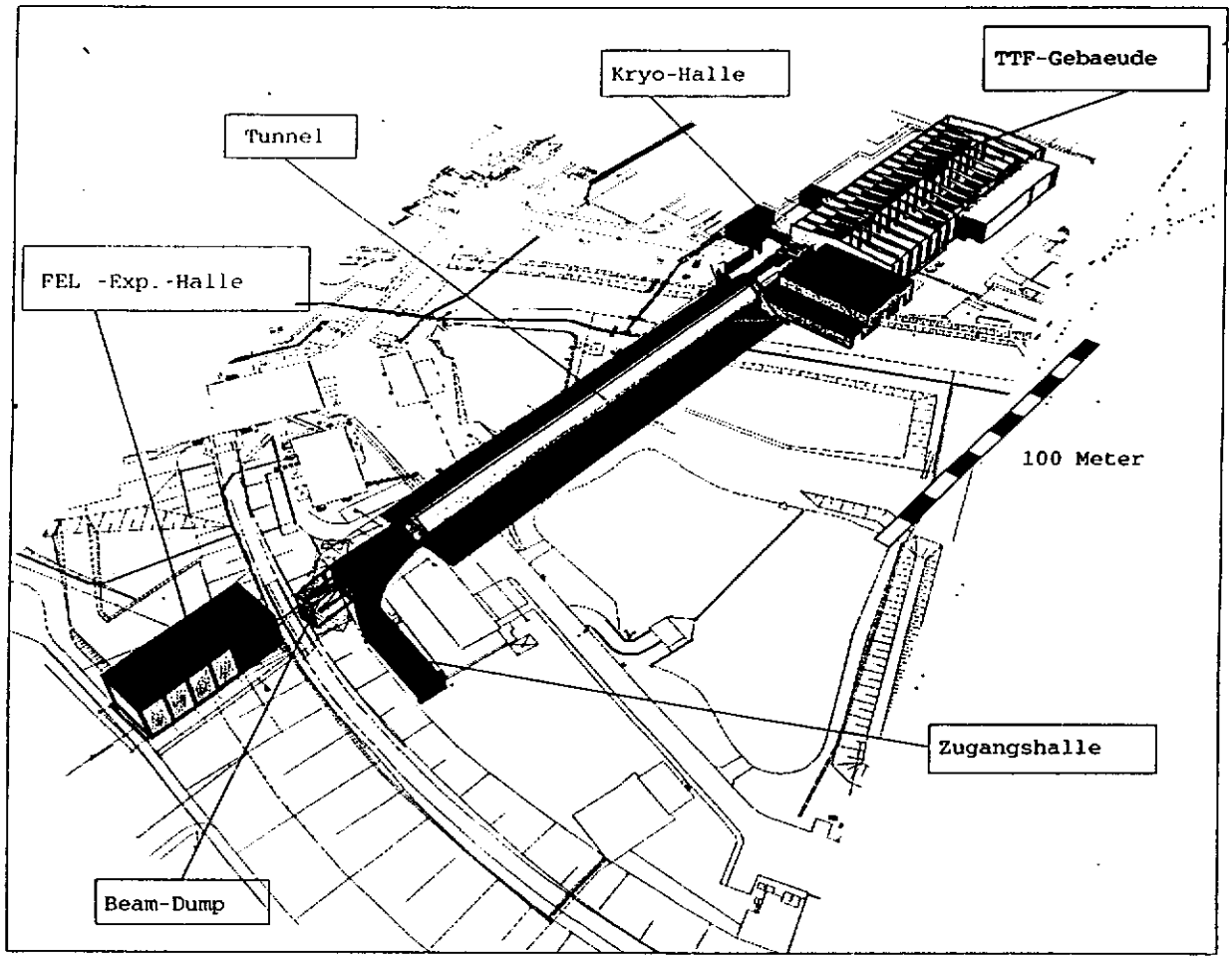
Linac 400 MeV end of 1998
Module #2 E_{acc} ~ 20 MV / m
Module #3 E_{acc} ~ 25 MV / m

SASE FEL Test at λ ~ 40 nm
Undulator ready for installation by the end of 98; test spring 99

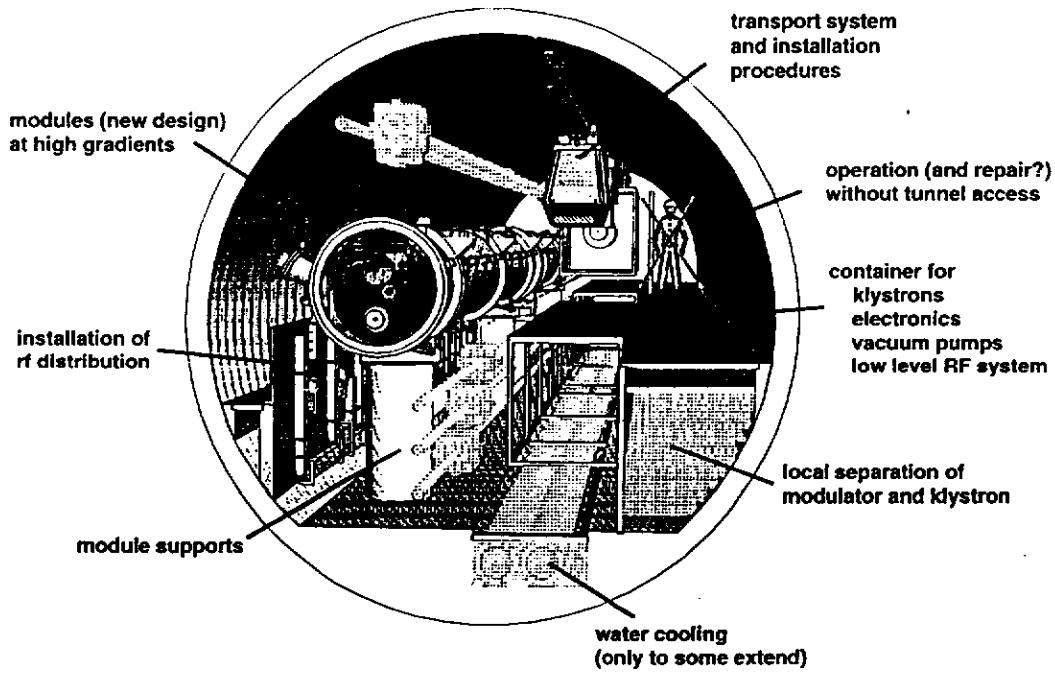
TTF II with SASE FEL User Facility







TTF Linac Extension as TESLA 500 Test Area



not shown: the construction cost of a tunnel like building covered with sand is less than the setup of a long shielded area; a rectangular cross section is also more expensive

H.Weise 11/97

ECFA / DESY Workshop on the TESLA Linear Collider

Organizing Committee
Michael Danilov, Enrique Fernandez, Rolf Heuer, Leif Joensson, Paolo Laurelli, Martin Leenen, Francois Richard, Ron Settles, Torbjorn Sjostrand, Albrecht Wagner, Peter Zerwas

Chairman
David J. Miller, Professor of Physics
Dept. of Physics and Astronomy, University College London
Gower Street, London WC1E 6BT, UK
http://www.hep.ucl.ac.uk/people/djm.html
UCL phone 44 171 380 7152 (fax 7145)
home phone/fax 44 171 627 1913

Charge to the Working Groups

a) Evaluation of new opportunities with a luminosity of $5 \cdot 10^{34}$ or more.
b) Physics programme as a function of energy from 250 GeV to 960 GeV.
c) The need for gamma-gamma and e^+e^- options.
d) Complete the feasibility study begun in late 1996.
e) Identify the needs for detector R&D.
f) Detector layout and technology.

Structure of Working Groups

1. Physics topics; theorists and experimenters working together:
   a) Top quark
   b) QCD, including gamma-gamma
   c) Higgs
   d) SUSY
   e) Electroweak, TGCs etc.
   f) Alternative theories.

2. Standard processes and Monte Carlo generators [for 1a) to 1f)]

3. Detector simulation [for 1a) to 1f)]; based on the reference design from the 1996/7 Conceptual Design Report.

4. Detector performance and R&D; including

   i) presentation of existing R&D programme,
   ii) identification of shortcomings of reference design,
   iii) review of further needs for R&D over whole detector.

5. Machine-detector interface, including provision of background generators for group 3 and 1a) to 1f).

Timescale

Interim Report by the time of the Spring 1999 Meeting in Barcelona (Sitges).
Comparison with the US/Japan studies.
After Sitges meeting focus on the TESLA proposal to be submitted end of 2000.

Meetings

Orsay: April 5/7 - 98

June - 98
November 98
March - 99

Programme Orsay Meeting

Sunday 5 April

14.00	Fernandez	ECFA blessing
14.10	Wiik	Strategic Background
14.40	Ellis	State of Physics now+need for LC
15.25	Brinkmann	Progress with TESLA, incl. where the high luminosity comes from and successful tests on cavities.
16.10	Coffee	
16.40	Settles	Review of features of the reference detector.
17.10	Miller	Goals and organisation of the study. Charges to the working groups.
17.50	???	Group leaders announcements?
19.00	Buffet Dinner	

Monday 6 April

09.00	Groups 1a) to 1c) meet in parallel to plan tasks.
10.45	Coffee
11.15	Groups 1d) to 1f) meet in parallel to plan tasks.
13.00	Lunch
14.30	Groups 2 and 3 meet in parallel to plan tasks.
16.15	Coffee
16.45	Groups 4 and 5 meet in parallel to plan tasks.

Tuesday 7 April

09.00	15 minute talks + 5 minute disc., leaders of groups 1a) to 1f)
11.00	Coffee
11.30	Group 2 (Generators) leader's talk (25+5 minutes)
12.00	Group 3 (Simulation) leader's talk (15+5 minutes)
12.20	Group 4 (Detector perf. and R&D) leader's talk (25+5 minutes)
12.50	Group 5 (Machine detector interface) (15+5 minutes)
13.10	Lunch

CAVITY TEST RESULTS

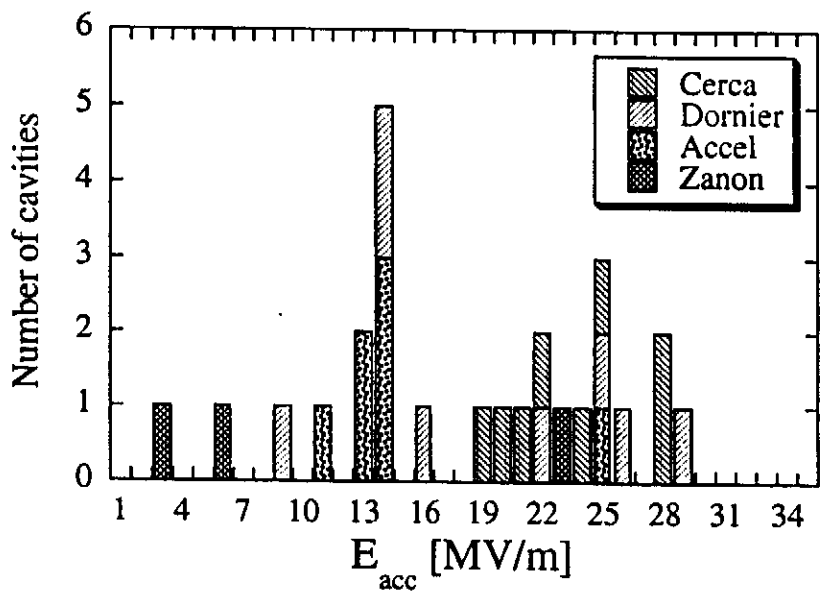
M. Pekeler
TTF-Meeting 9. March 1998

1. Summary of first TTF cavity production
2. HT 800 vs. HT 1400
3. Cavity vacuum
4. Field emission
5. Spun single cell cavity after HT 1400 C

Summary of first cavity production

26 nine-cell cavities from 4 manufacturers tested so far:

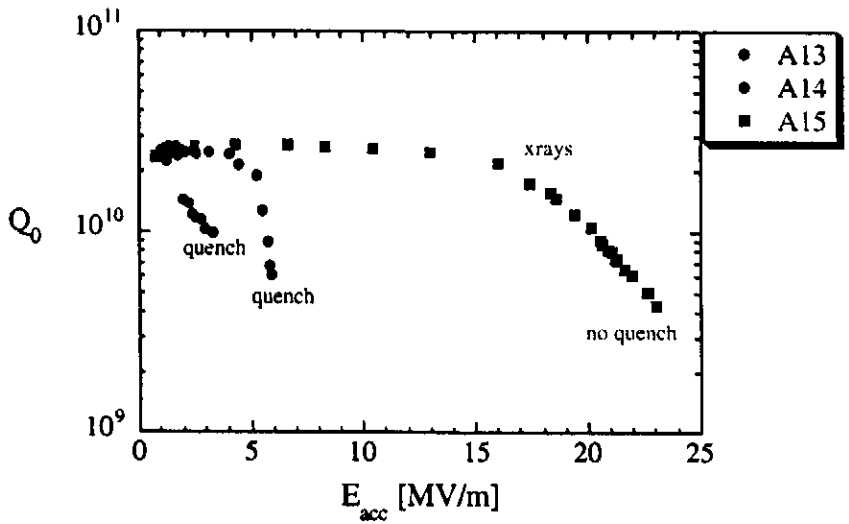
Cerca: C19, C21, C22, C23, C24, C25, C26, C27
Dornier: P1, P2, D1, D2, D3, D4, D5, D6
Accel: S7, S8, S9, S10, S11, S12, S28
Zanon: A13, A14, A15, (missing A16, A17, A18)



All companies can built cavities with E_{acc} > 20 MV/m.

Cavities from Zanon:

All cavities HT 800 C



A13: Welds not done properly. Quench at 3 MV/m at bad equator weld.

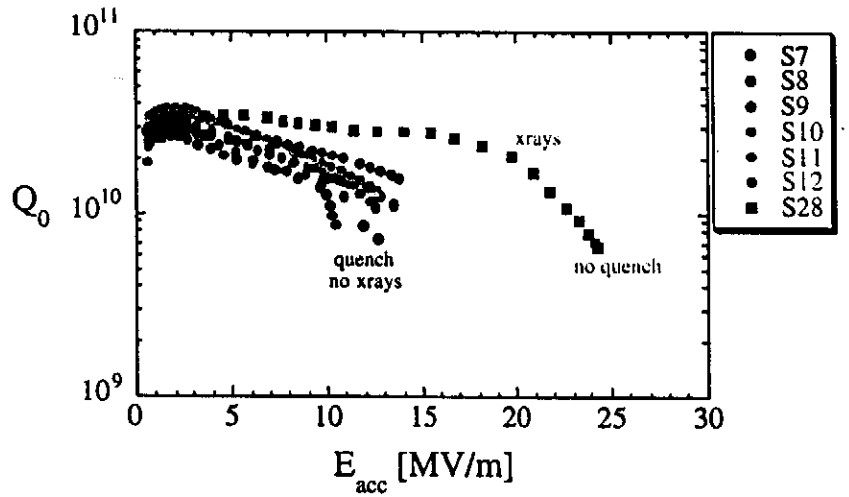
A14: A whole was blown in one equator weld during production. The whole was fixed by plugging in an extra machined niobium piece and overweld it. Quench took place at this repaired weld at 6 MV/m.

A15: Welds still not done under best conditions, no quench observed at 23 MV/m.

A15 will soon be re-measured after HT 1400 C

Accel cavities:

S7 - S12: HT 1400 C
S28: HT 800 C



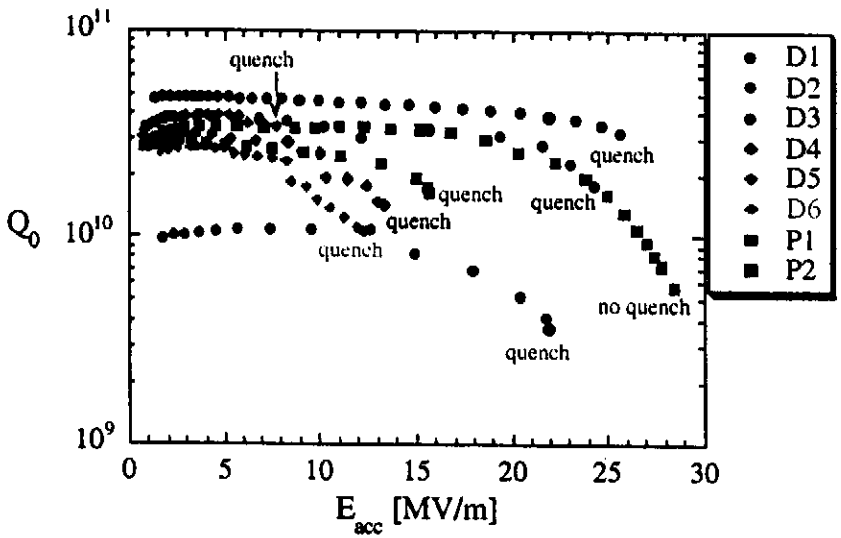
S7 - S12: Systematic error in equator welds lead to a quench in the 10 to 15 MV/m regime

S28: New welding procedures were found. No quench at 25 MV/m

S28 will get correct end groups soon and will be re-measured.

Dornier cavities:

All cavities got HT 1400 C

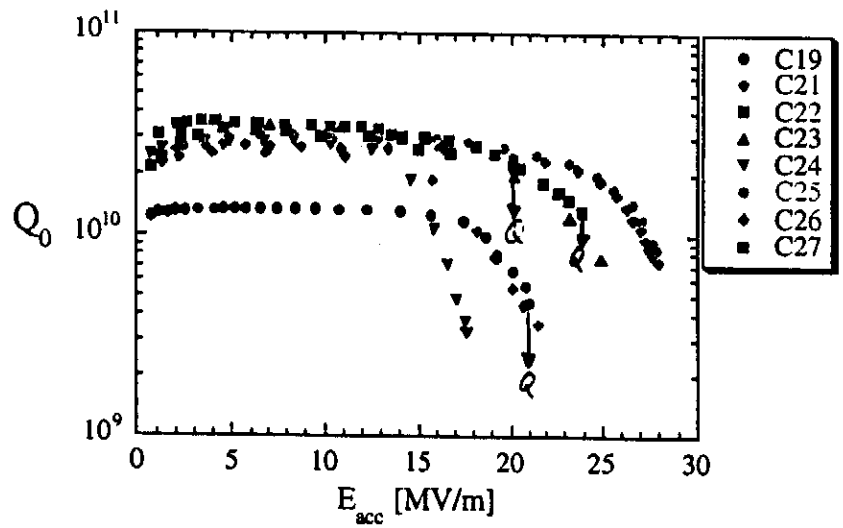


D5: quench located at hot spot far away from equator weld (material inclusion)
D6: quench located at hot spot far away from equator weld (tantalum inclusion)

Eddy current scan of niobium sheets is hoped to avoid material inclusions.

Cerca cavities:

C19:	cups HT at 1400 C
C21, C22, C23, C24, C25:	HT 1400 C
C26, C27:	HT 800 C



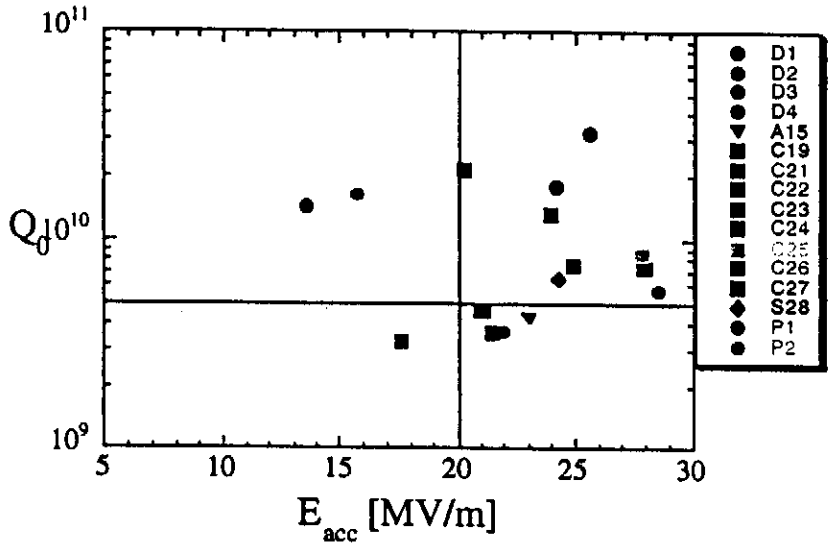
Only C19, C22 and C27 are showing a quench.

C21, C23, C24, C25 and C26 are limited by field emission and available cw RF power.

At Q-drop always x-rays observed.

Cavities without welding errors or proven material inclusions:

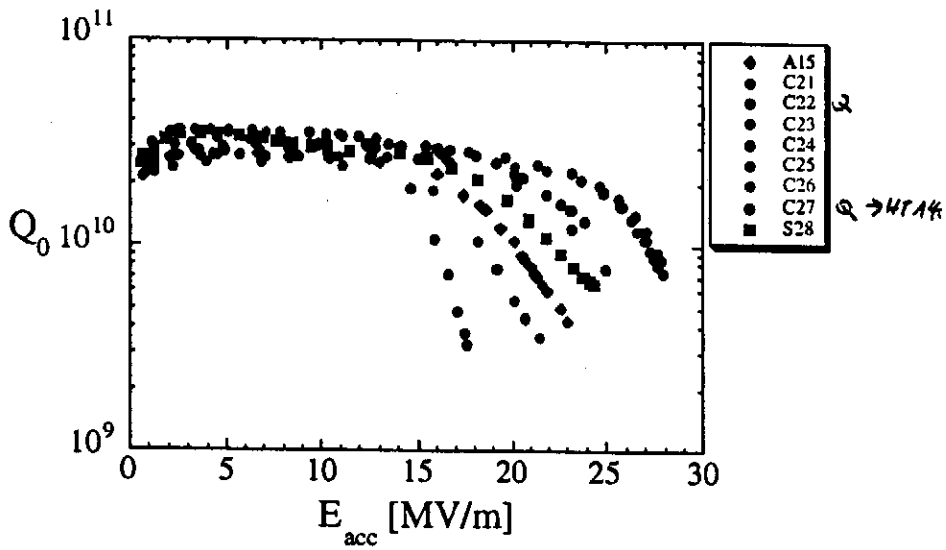
(Excluding D5, D6, S7, S8, S9, S10, S11, S12, A13, A14)



average gradient at Q > 3 E9: 22.6 MV/m

Latest cavities:

All cavities better than TTF goal (15 MV/m @ $Q_0 = 10^9$)



average gradient at $Q_0 > 3\ 10^9$ = 23.9 MV/m

only 2 cavities limited by quench
others limited by field emission
and available CW RF-power!

HT 800 or HT 1400

We tested several cavities after HT 800 and after HT 1400 C

cavity	no HT E limit	HT 800 E limit	HT 1400 E limit	remark
C21	17 BD	21 BD	29 PWR	quench in weld cured by 1400 C
(C22			20 BD	repaired equator weld (whole))
C23		14 PWR	25 PWR	both times no quenches observed also not in mode measurements
C24		19 BD	18 PWR	
C25		24 PWR	28 PWR	quenches in cell 5 and 9 on weld at 25 (26) MV/m cured by HT 1400 C
C26		22 PWR		no quenches observed
C27		24 BD		test after 1400 C soon
A15		23 PWR		no quenches observed

==> 1. no degradation observed so far after HT 1400 C
2. HT 1400 C can cure some quenches (weld)
3. Field emission does not allow to investigate effects above 30 MV/m

S7 - S12: HT 1400 C had no influence on performance:
D5: HT 1400 C did not improve cavity:

==> HT 1400 C : A good cavity becomes a very good one, but a bad cavity remains a bad cavity

Field emission:

With the new fantastic cavities, quenches are not longer number one enemy, now Field emission is the main limitation again.

We normally get field emission below 20 MV/m.

We will soon have a HPP coupler (design W.D. Moeller) which allows an easier mounting in the cleanroom.

We hope that we then can push some of the very good cavities to gradients above 30 MV/m.

But of course, we need more knowledge about avoiding FE.

How can we control our HPR system ?

How can we control our mounting better ? Hopefully new flanges allow better dustfree assembly.

Is dust the whole story or does the residue of acid play a role at high gradients.

Does tumbling or EP help to avoid FE

Does HT 1400 C help avoid FE

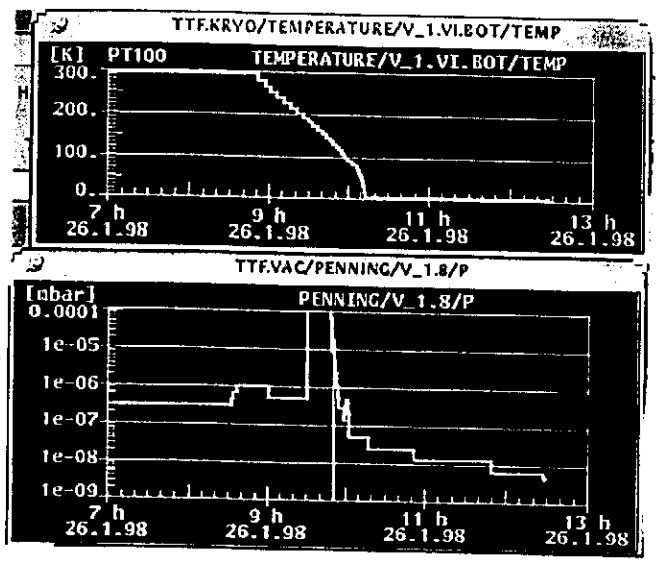
Research in this complicated and difficult area is very important.

Then comes another question:
Is there a Q-drop without FE at high gradients ?
And if so, how to avoid it

(Sometimes we observed multipacting induced quenches in the 16 - 22 MV/m region. It can be very hard to process away this MP. Multipacting is only observed at first power rise.
After room temperature cycle MP has to be processed again.)

Cavity vacuum:

We often observe a huge vacuum burst during cooldown (why ?)



Cavity performance does not change if we cooldown with valve closed or open.

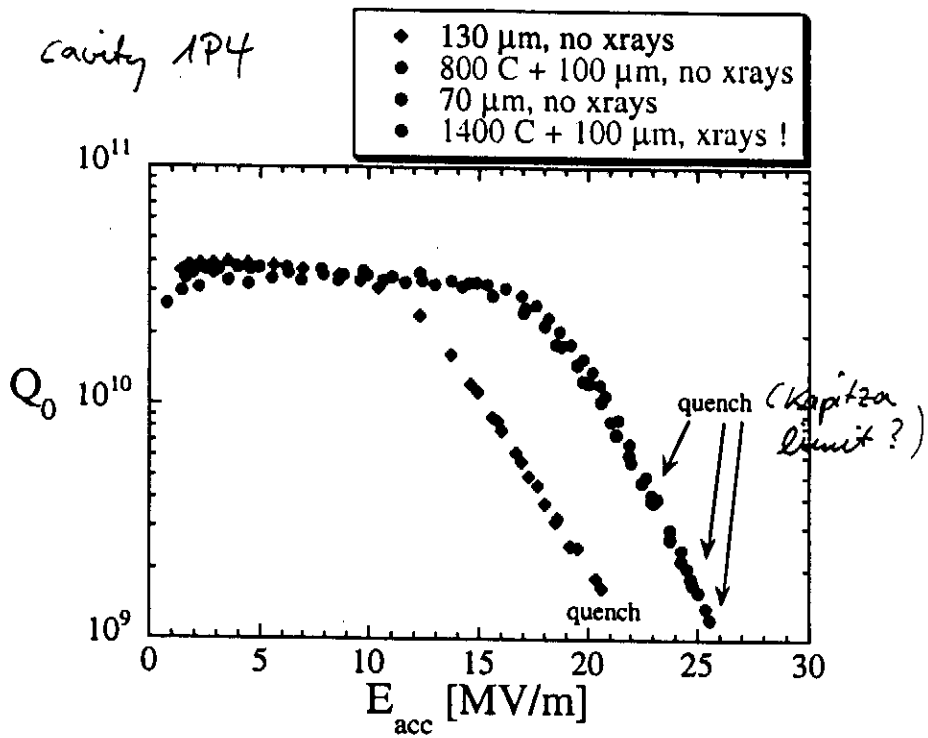
We have observed several times that cavity performance even from cavities > 20 MV/m is not dependent on cavity vacuum, if pressure in the cavity is better than 10^{-5} mbar.

Also "small" amount of observed Hydrocarbons does not seem to hurt even a good cavity.

Things might change for gradients above 35 MV/m.

New result on spun cavity after HT 1400 C

RRR of cavity is now 500, (before HT 1400: RRR = 200)

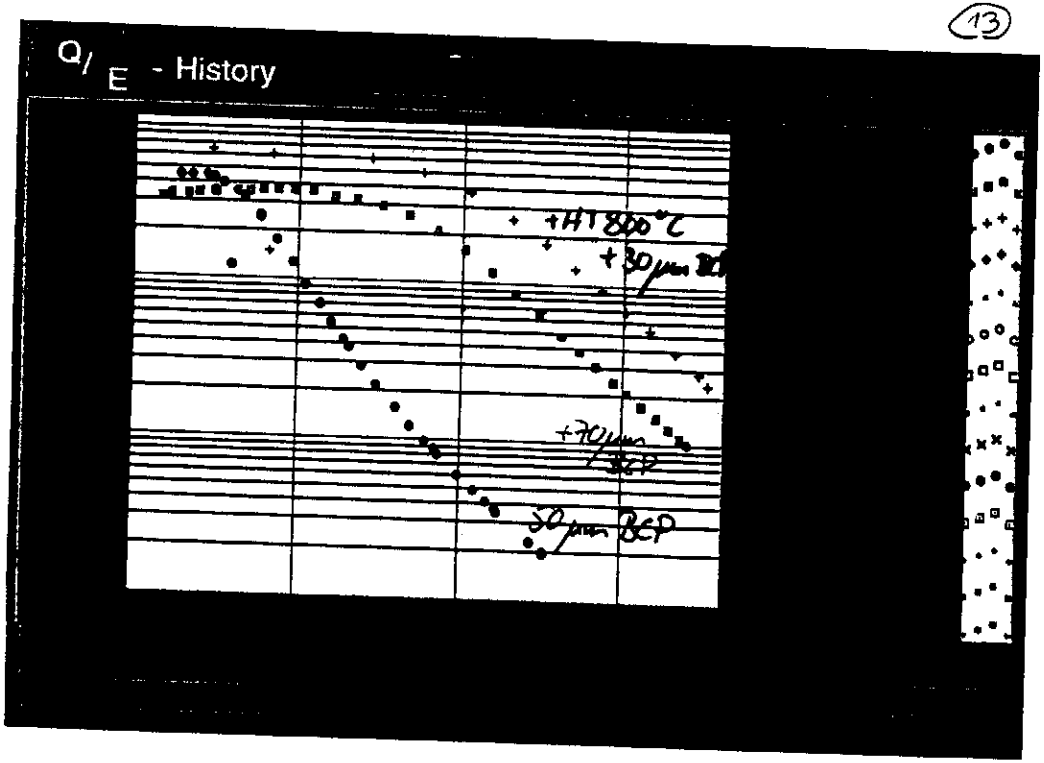


losses at 2 bands close to equator ~ B^8

=> 1. Qdrop above 18 MV/m not dependent on HT or material removal
2. Qdrop must be related to the material (roughness ?)
3. Field emission is second order effect

What to try next ?

Tumbling ? Electro-polishing



Small improvement after HT 800°C

losses at lower in's (all around)

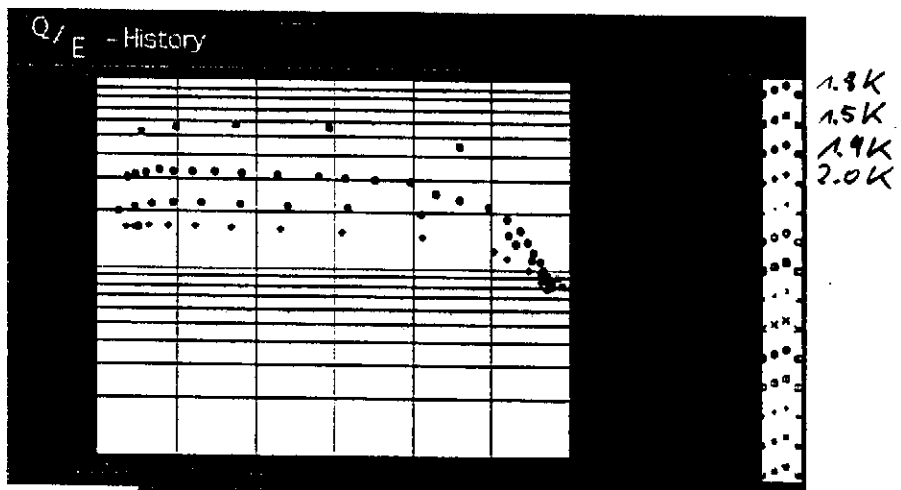
no x-rays observed

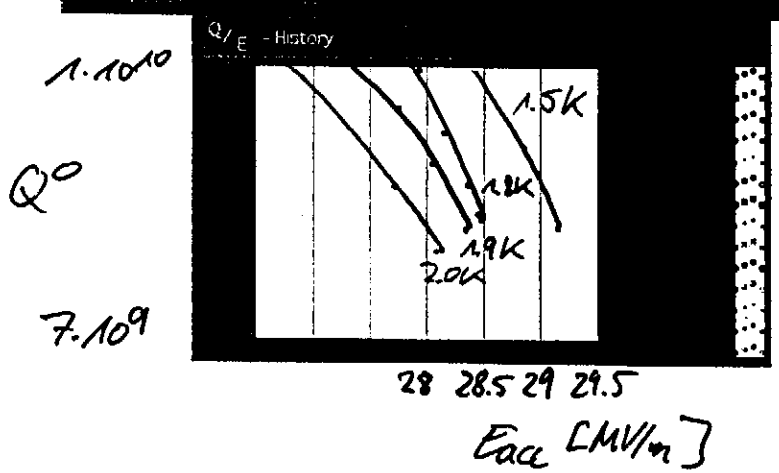
losses ~ B^8

Up to now, the vertical and CHECHIA test were always performed at Tbath = 1.8 K.

Now the Linac is under operation at Tbath = 2 K.
It is much easier to do measurements also in the vertical dewar and in CHECHIA at 2 K now.

If it is clear, that TESLA will be built at 2 K, we should now always measure at Tbath = 2 K.
We have seen so far no degradation in cavity performance between Tbath = 1.8 K and 2K.





Status of First Cryomodule (and Capture)

Capture ⇒ No modifications

Module 1 ⇒ Second Assembly
Third Cool-Down
Stable Operation
Current Tests

TTF-Cryo-Team
-DESY-

TTF-Meeting
Hamburg
9-March-1998

Module 1 Assembly:

10-Dec-97 – 8 in H1 tested tuning-systems installed in Module 1
– Start installation 4K-shield, 80K-shield, cables etc.

15-Dec-97 – Bring in cold-mass into Vac-vessel

19-Dec-97 – All main-couplers are installed

6-Jan-98 – Transportion Module1 to Linac-Position

13-Jan-98 – Detection leak from iso-vac to cav-vac (close to coupler Nr. 7)
⇒ Decision: Continue?

26-Jan-98 – All He-tubes connected
Iso-Vac closed
~16:30 Begin pumping on Iso-Vac

Continuous position-control of the wire-position-monitors

$\Delta y \approx +0.4$ mm $\Delta x = -0.25$ mm

27-Jan-98 – Start pumping cav-vac

30-Jan-98 – Final leak-test vac-vessel ⇒ o.k.
– Final leak-test He-tubes ⇒ o.k.

⇒ Module 1 and Capture ready for cool-down

5 – 16-Feb-98 Warm coupler processing

Third Cool-down / Stable operation

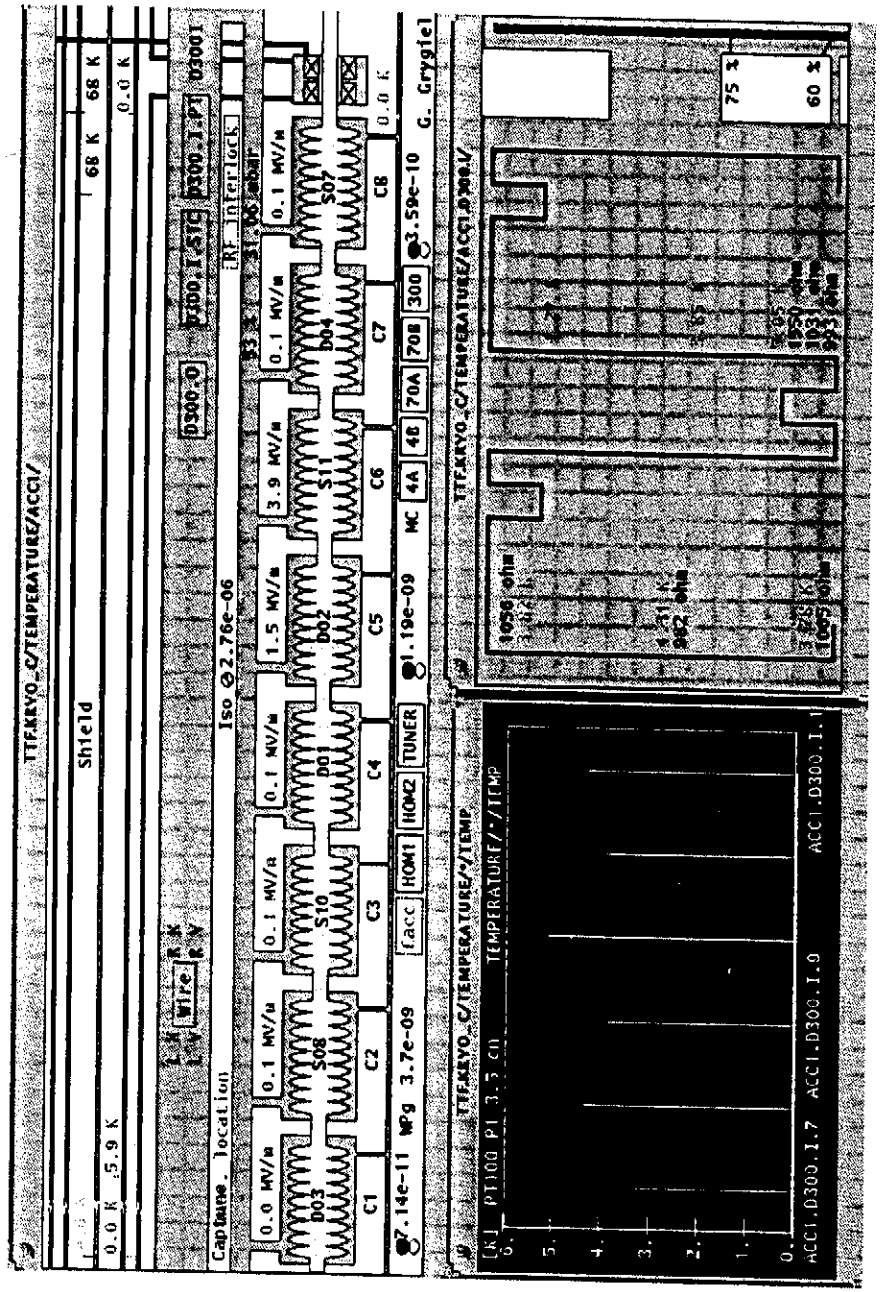
17-Feb-98 ~11:30 Start slow cool-down
Further try with Epics Computer and Epics Application

18-Feb-98 ~10:00 Stop cool-down.
Problems with Epics to big.
~20:00 Continue cool-down with DOOCS-Application

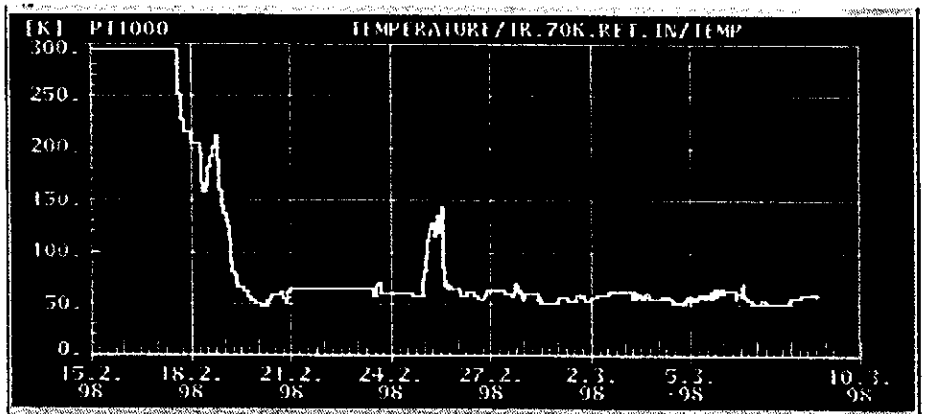
20-Feb-98 Module and Capture stable at 4.4 K
24-Feb-98 " " stable at 2.0 K
25-Feb-98 Break in electr. supply screw compressors

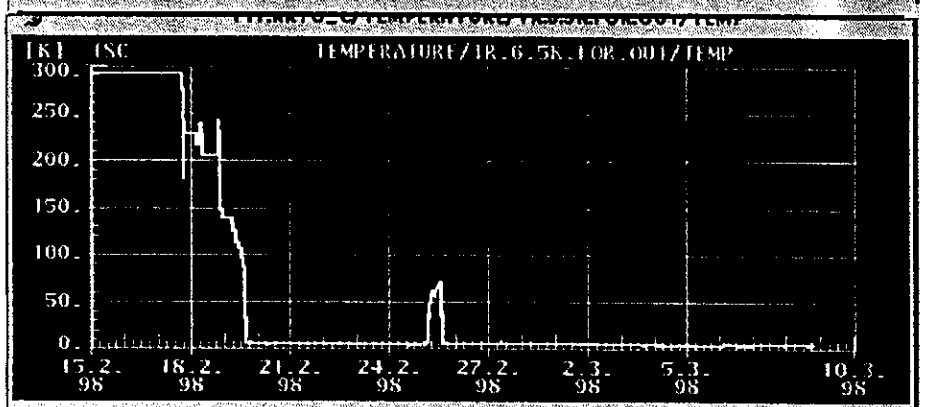
Since 26-Feb-98 Stable operation for module and capture at 2.0 K

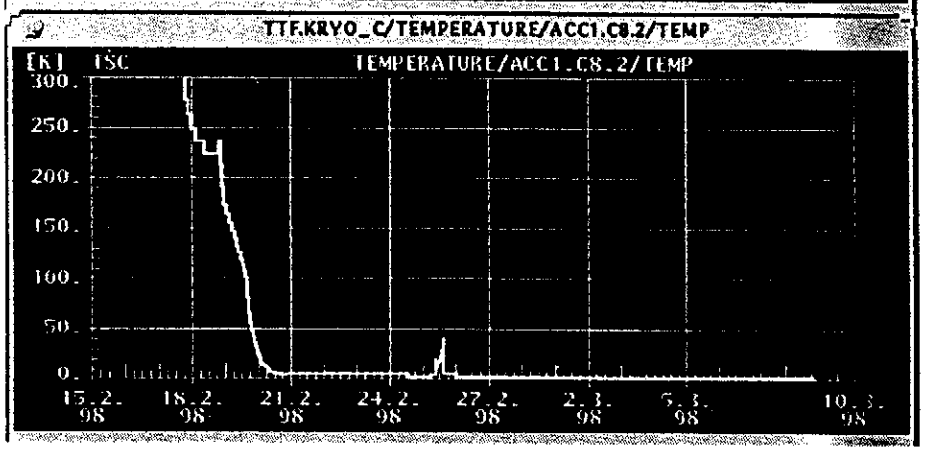
- From the cryogenic point of view no surprises.
- Operation of module and capture with DOOCS-control very simple.
- Banana-effect in 300 mm tube smaller than expected.

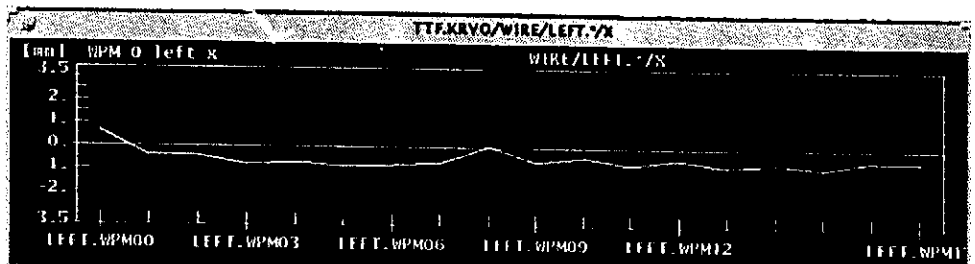


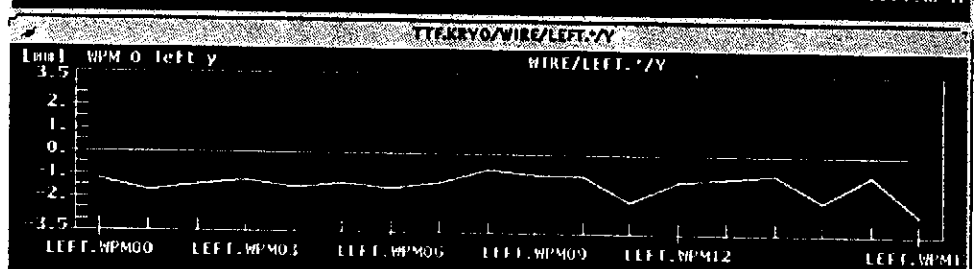
BLANCE@HESPOS, MAR09/1348

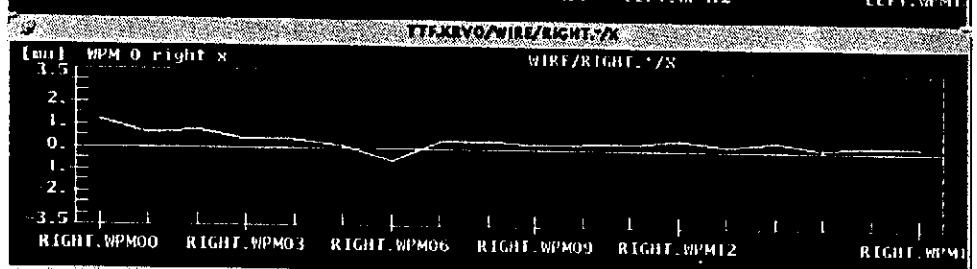


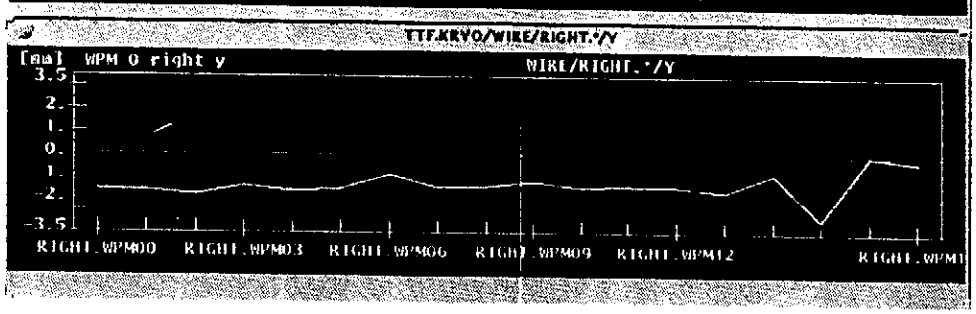




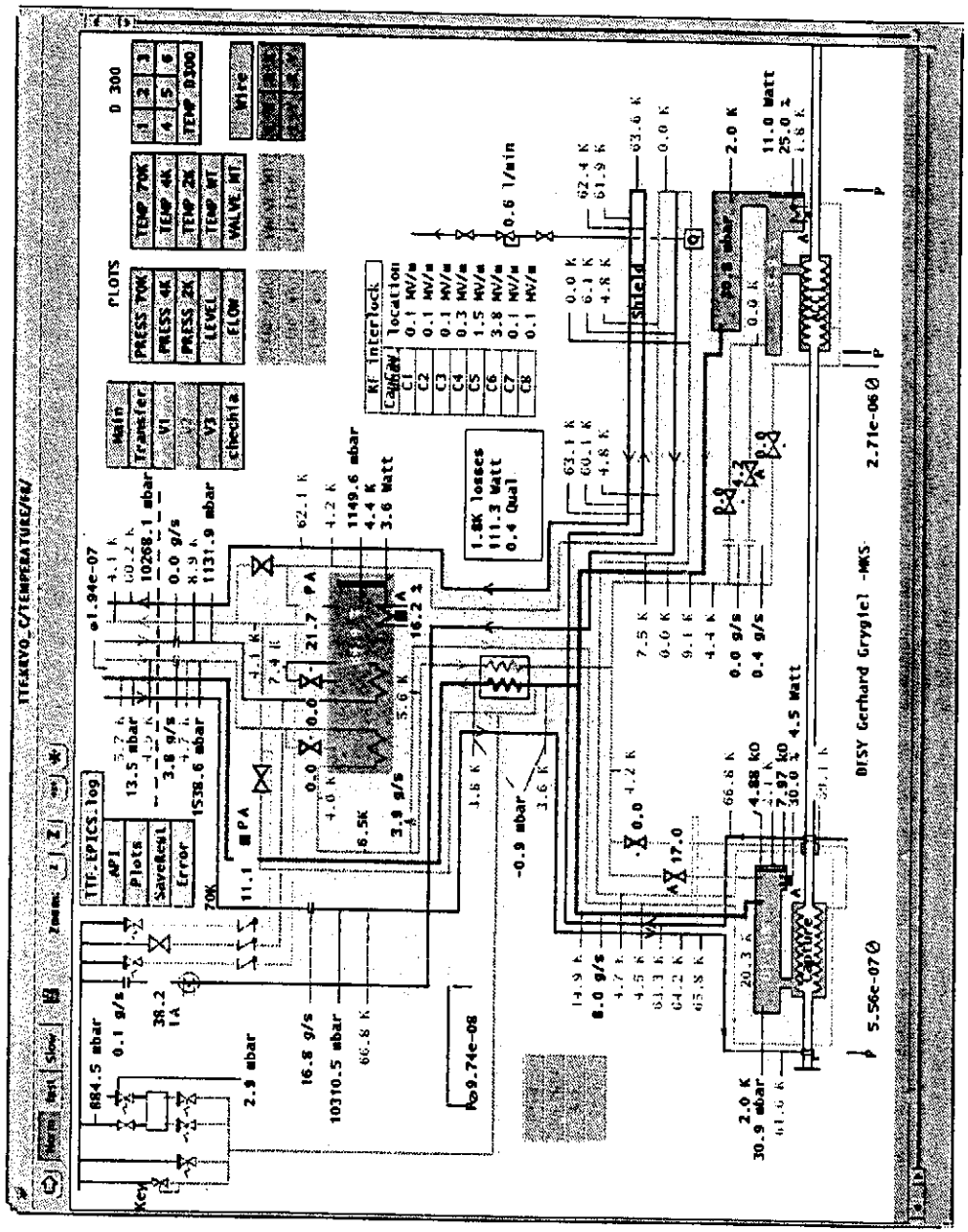








FLANGE@HESPOS, MAKROW17.41



RLANGE@HESPOS, MARDB/13:33

Current tests: Status 7-March-98

- Capture processing has been finished
  operation at 12 MV/m safe
- Gun/beam tests successful

so that we can start:

- processing individual cavities
  one cavity on resonance
- after processing of all cavities
  measurement Q0/Eacc for single cavities
- all cavities on resonance
  measurement Q0/Eacc
- ...

A.Gamp 5.3.98

Status of Klystrons and Modulators

We have now two Modulators and two 5 MW Klystrons running in Hall 3.
Klystron 1 is used for tests in the vertical or horizontal kryostats or for coupler tests. There is also the possibility to use klystron 1 for module 1, as in the past.

RF conditioning of klystron 2 was straightforward.
There were some problems with gas leaks and rf leaks in the wave guide section near the klystron window. Now everything looks good and Klystron 2 is presently used to supply kryomodule 1 with rf.

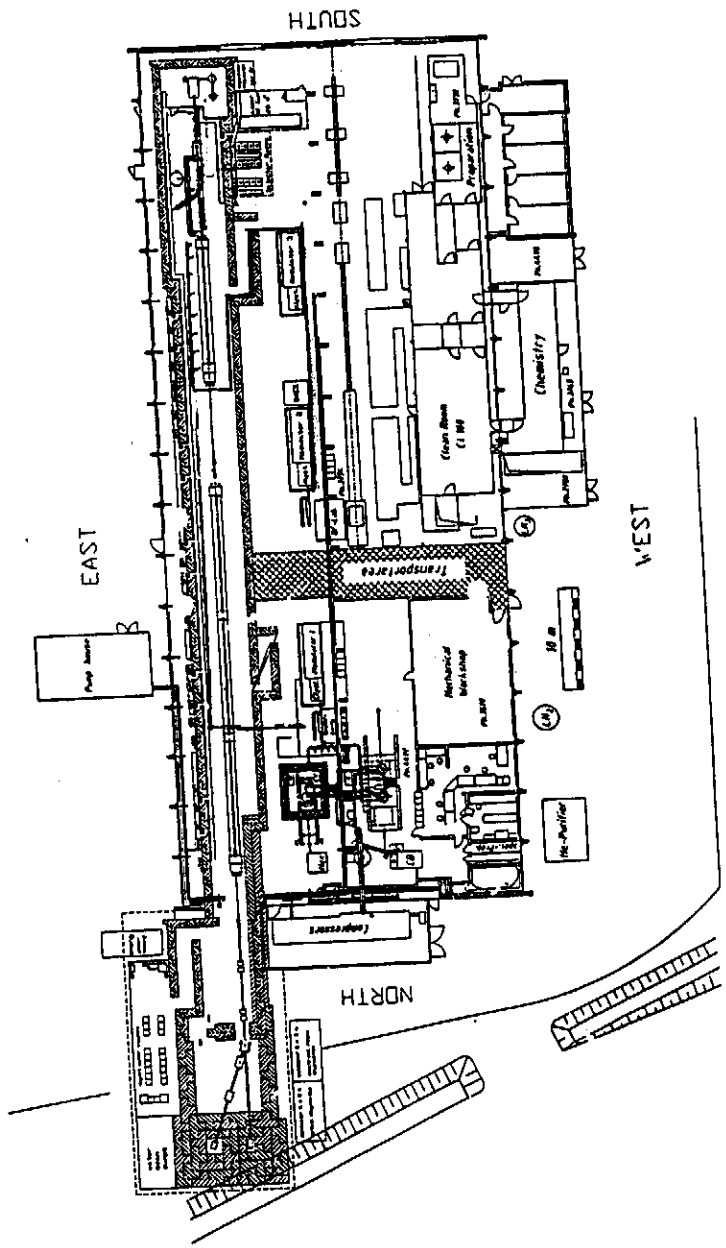
Once the DESY rf gun will be installed this tube can alternatively supply the gun with rf.

The second and the third Modulator are also capable of supplying a 10 MW Multi- beamklystron instead of the normal 5 MW tube.

The FNAL gun together with modulator 3 are expected by the middle of the year. Then modulator three will be used either for the DESY gun or for the FNAL gun.

After installation of modules 2 and 3 klystron one will be needed for them.
Then there is no rf source for HP testing, unless we are able to operate modules 1,2 and 3 with a MBK in modulator 2.

The modulator for the 300 kW klystron was repaired by M. Desmons. It is running well.



Automation of the LLRF Using System Identification

With System Identification one finds a system's structure and parameters by analysing input-output-data.

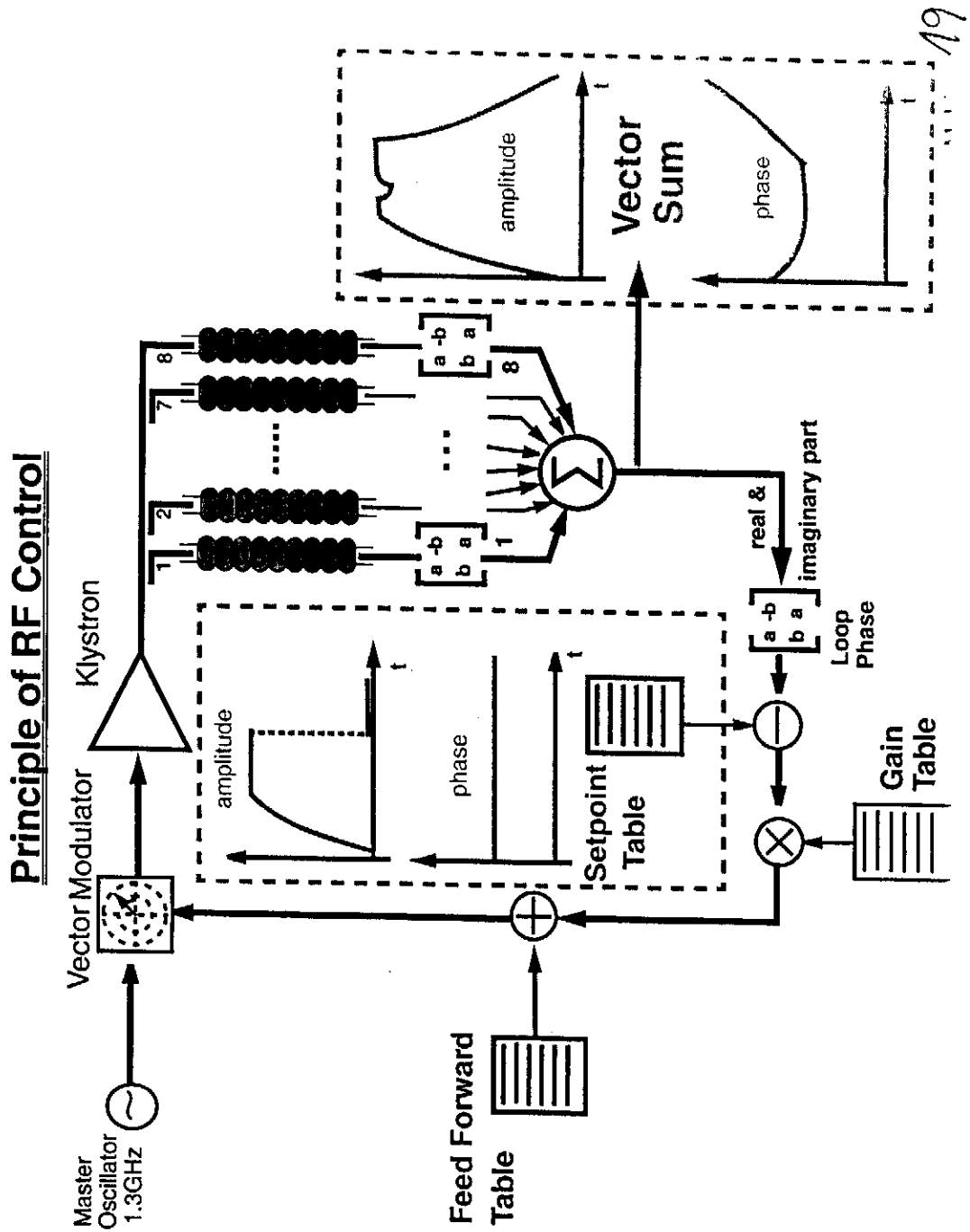
STRUCTURE:

Generally one does not know anything about the system, so one has to check different kinds of models (linear, nonlinear, 1st order, 2nd order ...) and choose the description which fits best with the data taken for identification and -which is very important- with some validation data taken independently.

PARAMETERS:

Since the electro-dynamical model of our cavities is well known we can apply system identification for other purposes:

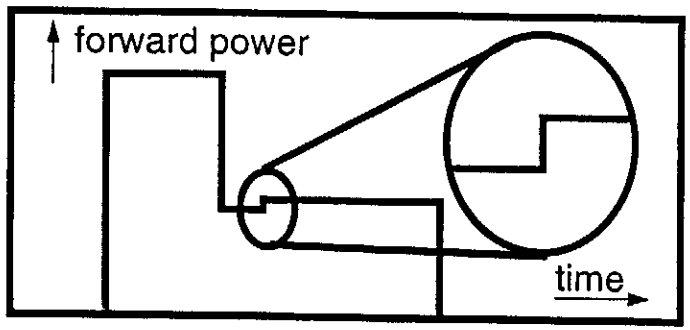
- determine the loop-phase & maximum gain of the system
- detect and adjust the relative phase between the cavities and the beam
- conclude the detuning $\Delta w(t)$ and find the optimal predetuning for each cavity
- cross-check the RF calibrations



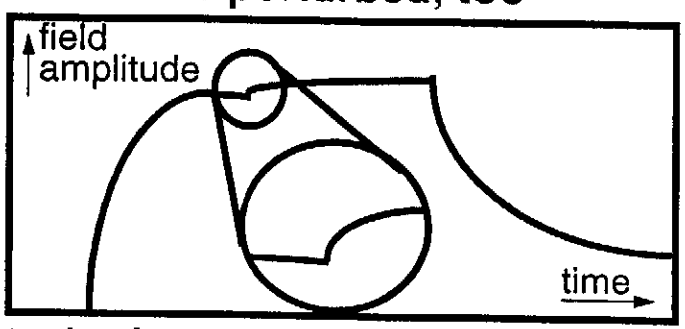
Detecting the Loop Phase

Open Loop

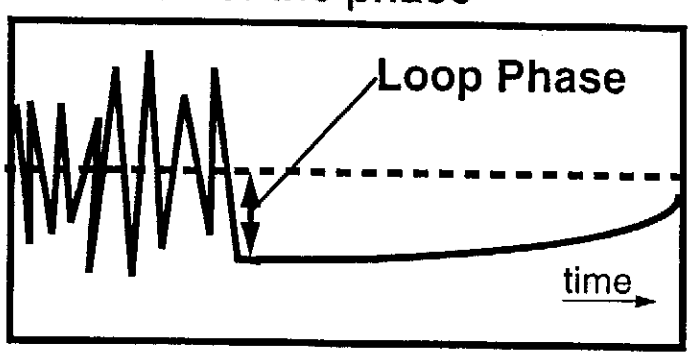
Step on Feedforward = Perturbation



Vectorsum is perturbed, too



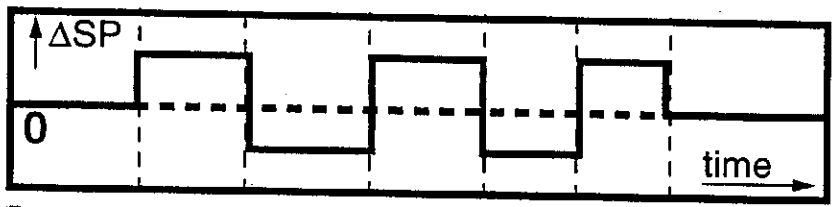
Perturbation of the phase



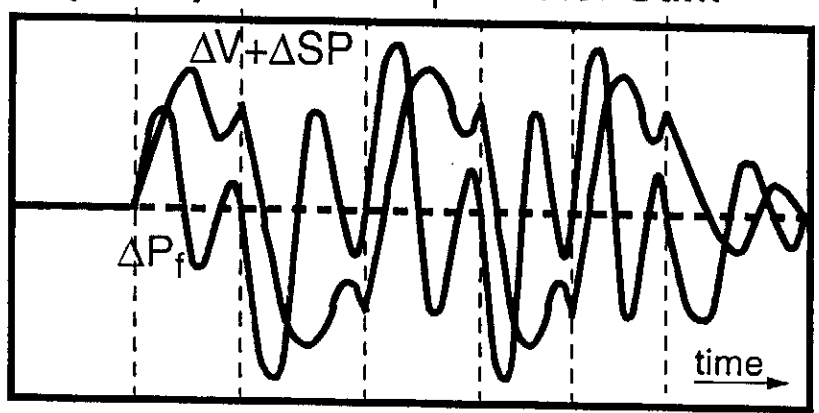
Adjust the Loop Gain

Closed Loop (raise the gain)

Step Sequence on Setpoint Table



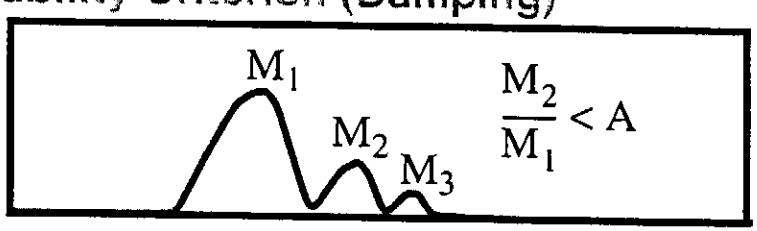
Step Response on P_f / Vector Sum



Performance-Cost Criterion

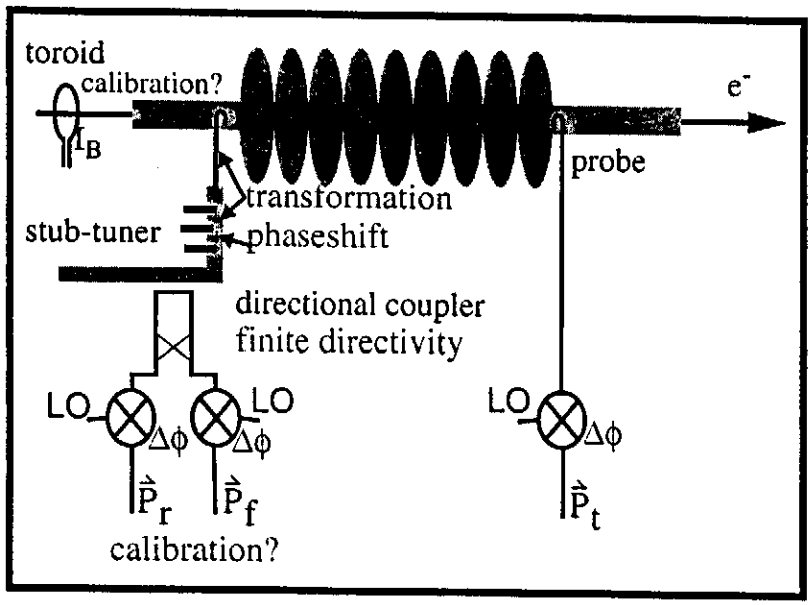
$$P = \sum_{t_k} [(\Delta V_0)^2 + R(\Delta P_f)^2] \rightarrow \min!$$

Stability Criterion (Damping)



Cavity Parameters

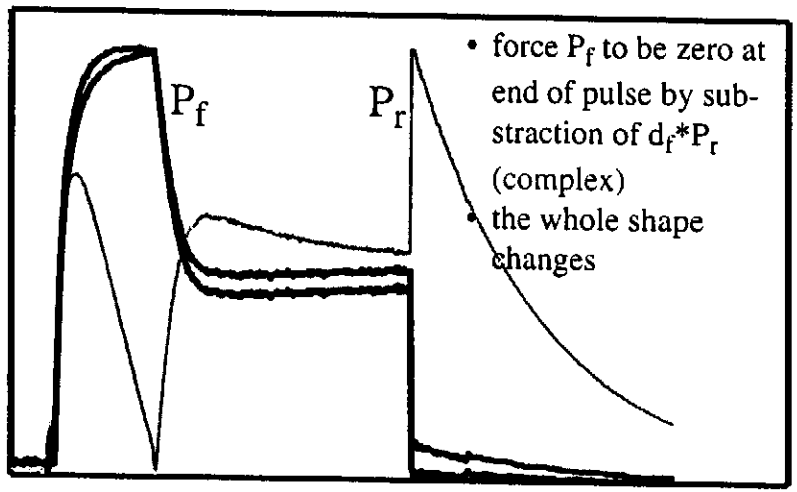
Cavity Signals



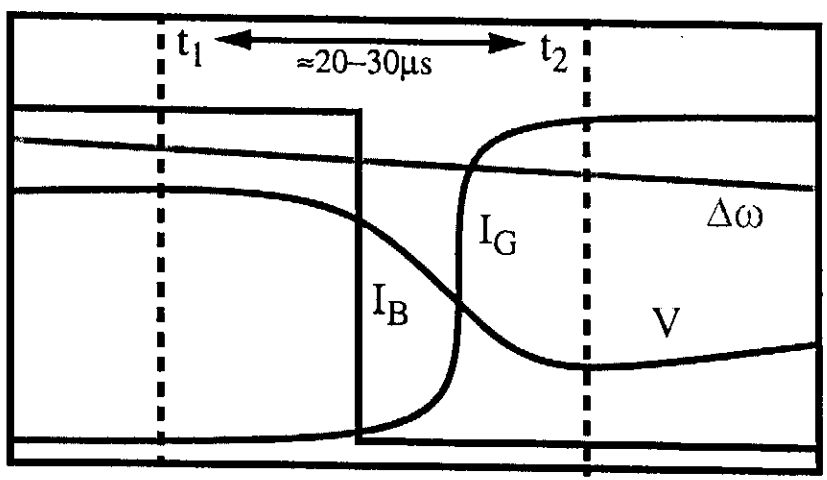
Envelope Equation

$$\dot{\vec{V}} = \begin{bmatrix} -\omega_{1/2} & -\Delta\omega \\ \Delta\omega & -\omega_{1/2} \end{bmatrix} \cdot \vec{V} + R\omega_{1/2} \cdot (\vec{I}_G + \vec{I}_B)$$

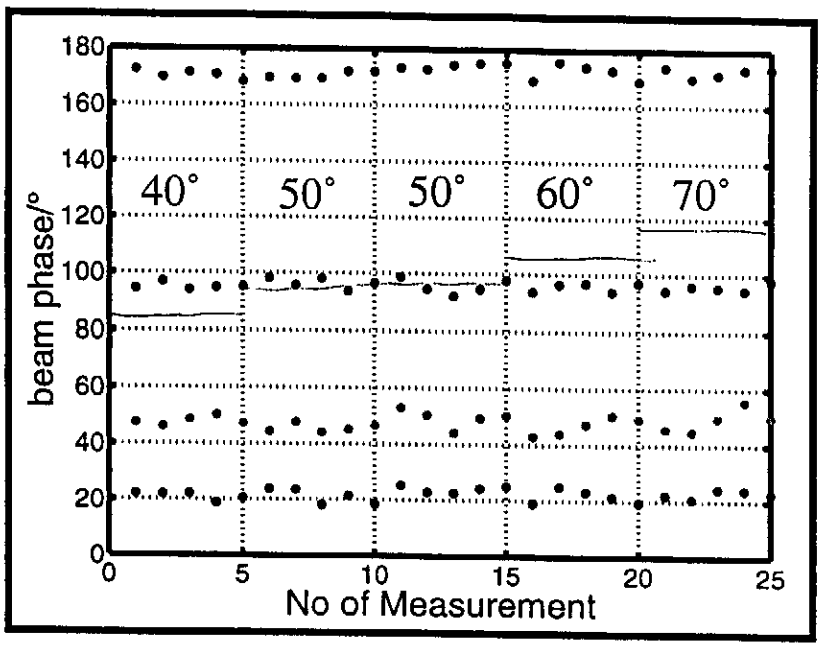
- correct P_f &P_r for the finite directivity,



- conclude Phase of P_f &P_r at Coupler (with respect to LO/later beam)
- find beam phase and shunt impedance R_s

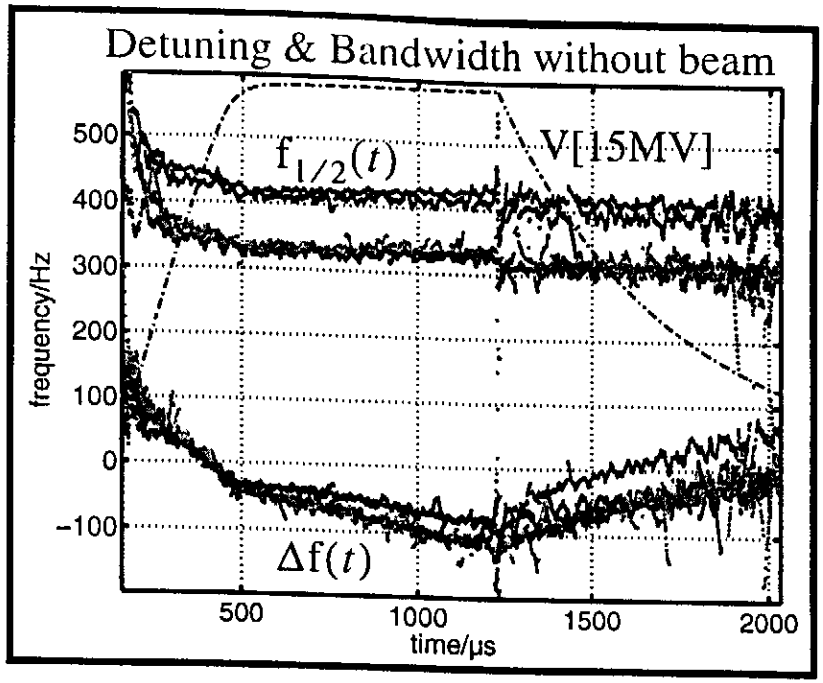


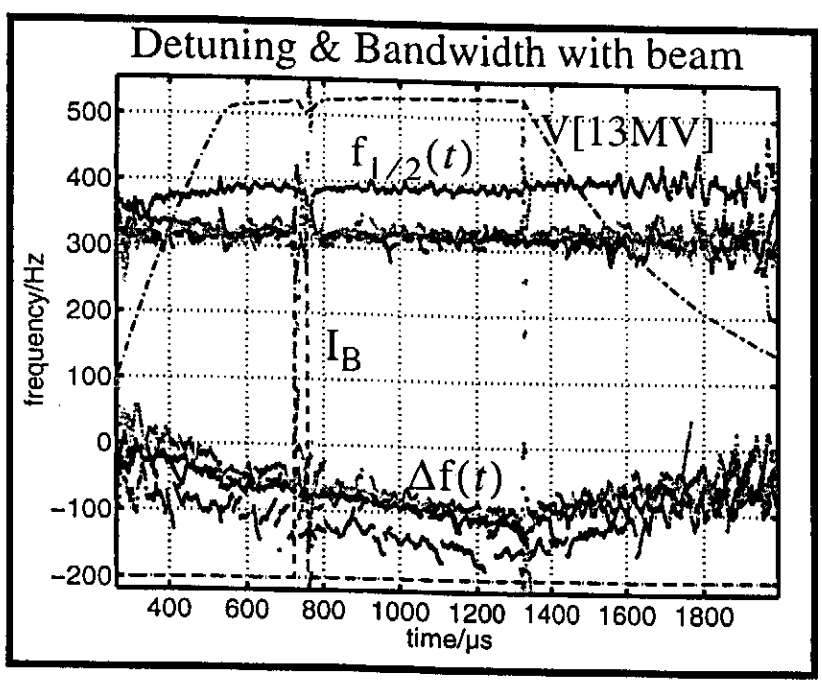
beam phase at different Setpoints (single pulse)



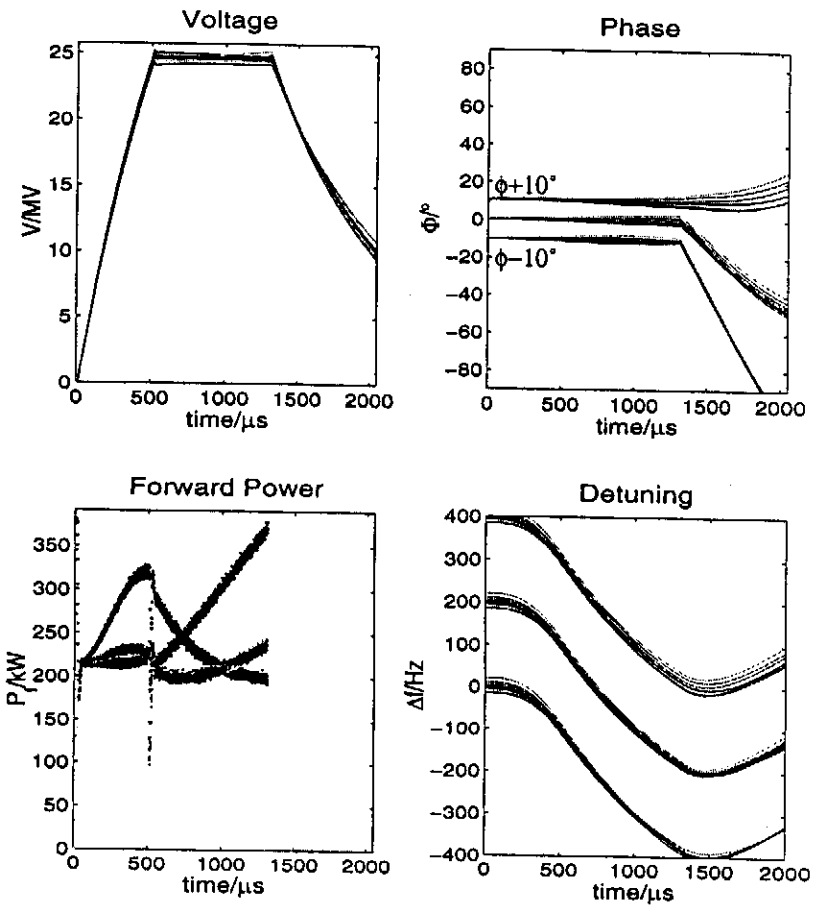
Advantage:

- no special conditions to measure and adjust the beam phase
- monitoring of beam phase / LO-stability during linac operation
- determine the long time RF stability





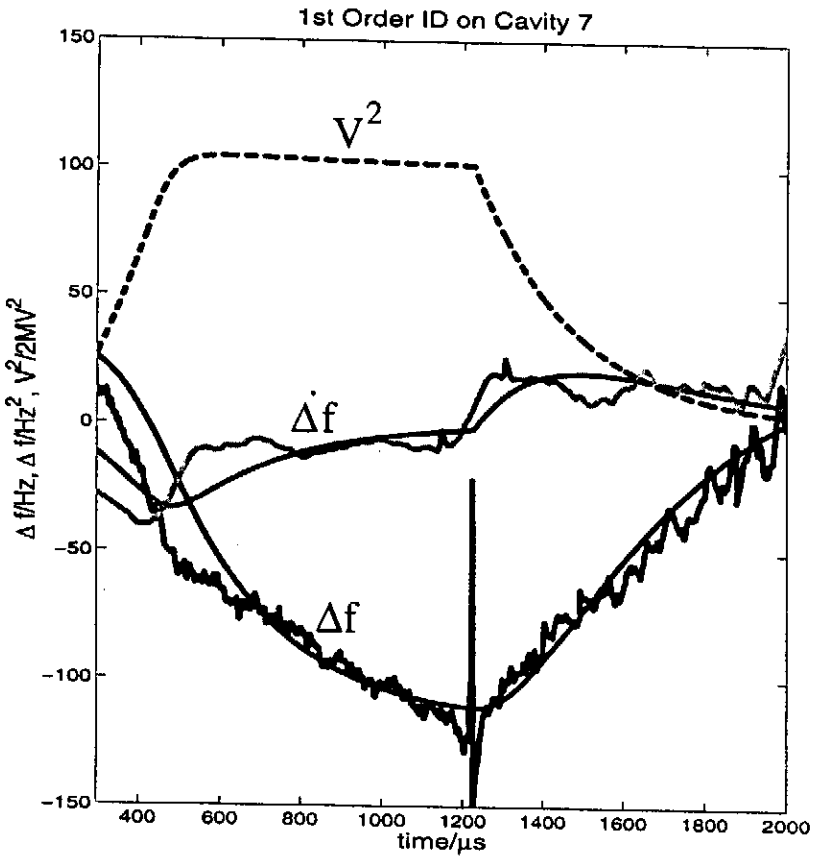
Optimize the Predetuning



Condition for minimizing the Power:

$$\Delta\omega_T = \frac{\sum_{t_k}[\dot{\varphi}V^2 + \omega_{1/2}RVI_b\sin(\varphi-\psi_b) - \Delta\omega V^2]}{\sum_{t_k}V^2}$$

Lorentz-Force-Detuning

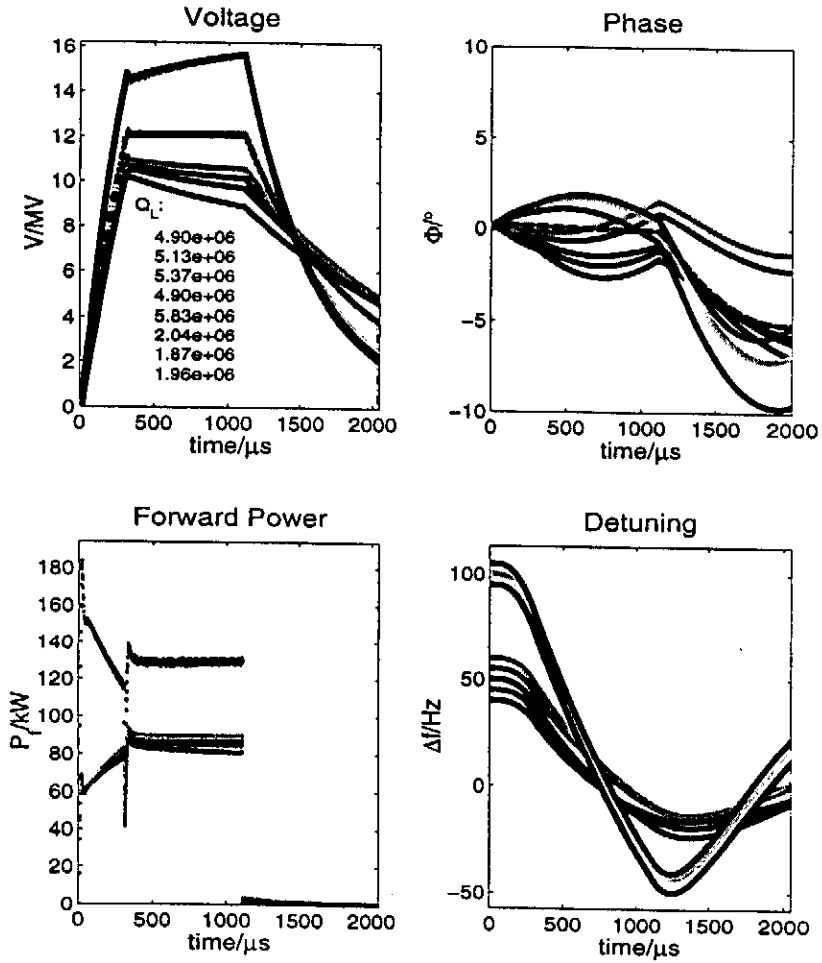


$$\dot{\Delta\omega} = -\frac{\Delta\omega}{\tau} - K\frac{2\pi}{\tau}V^2$$

$$K = 0.73\,\mathrm{Hz/MV^2}$$

$$\tau = 273\,\mu\mathrm{s}$$

Optimize the Performance of Kryo Module One



no attenuators are needed, changes can be done only by using the waveguide-tuners
some interlock has to be installed to prevent quenches

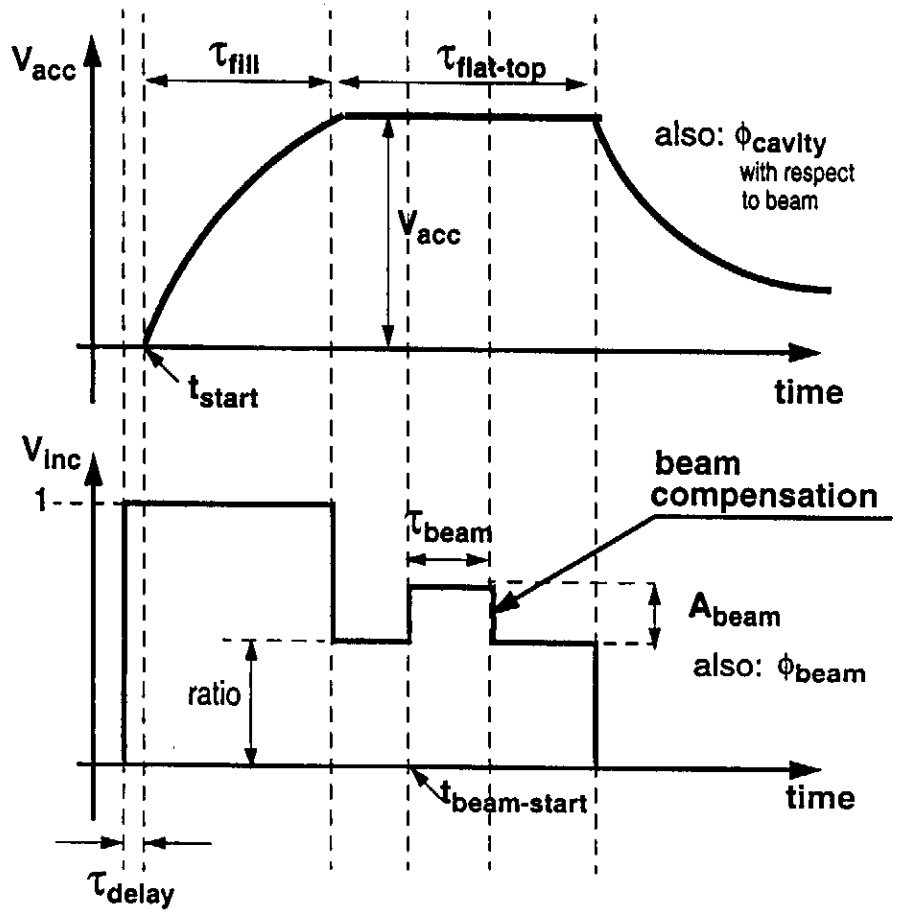
DESY

RF Control Tools

- New Operator Interface
  - Accelerating voltage of module
  - Fill time and flat-top duration
  - Feedforward table parameters
  - Beam compensation (phase and amplitude)
  - Calibrated loop gain
- Calibration Server
  - Cavity field, forward and reflected power
  - Phase with respect to beam, injector and master oscillator
- RF System Database
  - Maximum operable gradients
  - WG tuner transformation and stub position
  - Phases of incident waves
  - Loaded quality factor
  - Q_0 as function of E_{acc}

S.Simrock

Operator interface



other: loop gain calibrated
setpoint offset phase
feedforward offset phase

RF Control Procedures

- Operation with long beam pulses 800 µs
  1. Establish operation with 30 µs pulses
  2. Apply adaptive feedforward
  3. Extrapolate FF for next 30 µs
  4. Increase beam pulse length by 30 µs
  5. If interlock trip occurs : Reset and continue with previous pulse length. If trip occurs again continue with step 1.
  6. Repeat steps 3. and 5.

- Automated Procedures
  - Loop phase adjustment
  - Adaptive feedforward
  - Loop gain adjustment
  - System Identification

DESY

RF System Hardware

- Injector Diagnostics
  - Monitor for 216 MHz signals from buncher, gun grid and beam pickup
  - Monitor for capture cavity amplitude and phase
- Linac RF
  - Phaselocked 10 MHz reference using oscillator with low phase noise. Stability of duty cycle improved.
  - New downconverter boards with surface mount mixers
  - RF Gun Control system being installed
  - Upgrade to 24 cavity control underway. Hardware installed in teststand to verify control algorithm with Smith predictor and simplified Kalman filter.
  - Next generation digital feedback design in progress.

S.Simrock

26

DESY

RF Control Plans

- Study Exception Handling Issues in great detail
  - Quench detection
  - Generation of RF ready signal
  - RF inhibit if 1 MHz clock is missing
  - . . .
- Test improved feedback algorithms
- Develop high level RF control scheme
  - Integration of existing tools including exception handling and fault recovery
  - Automate RF system turn-on procedure
  - . . .

S.Simrock

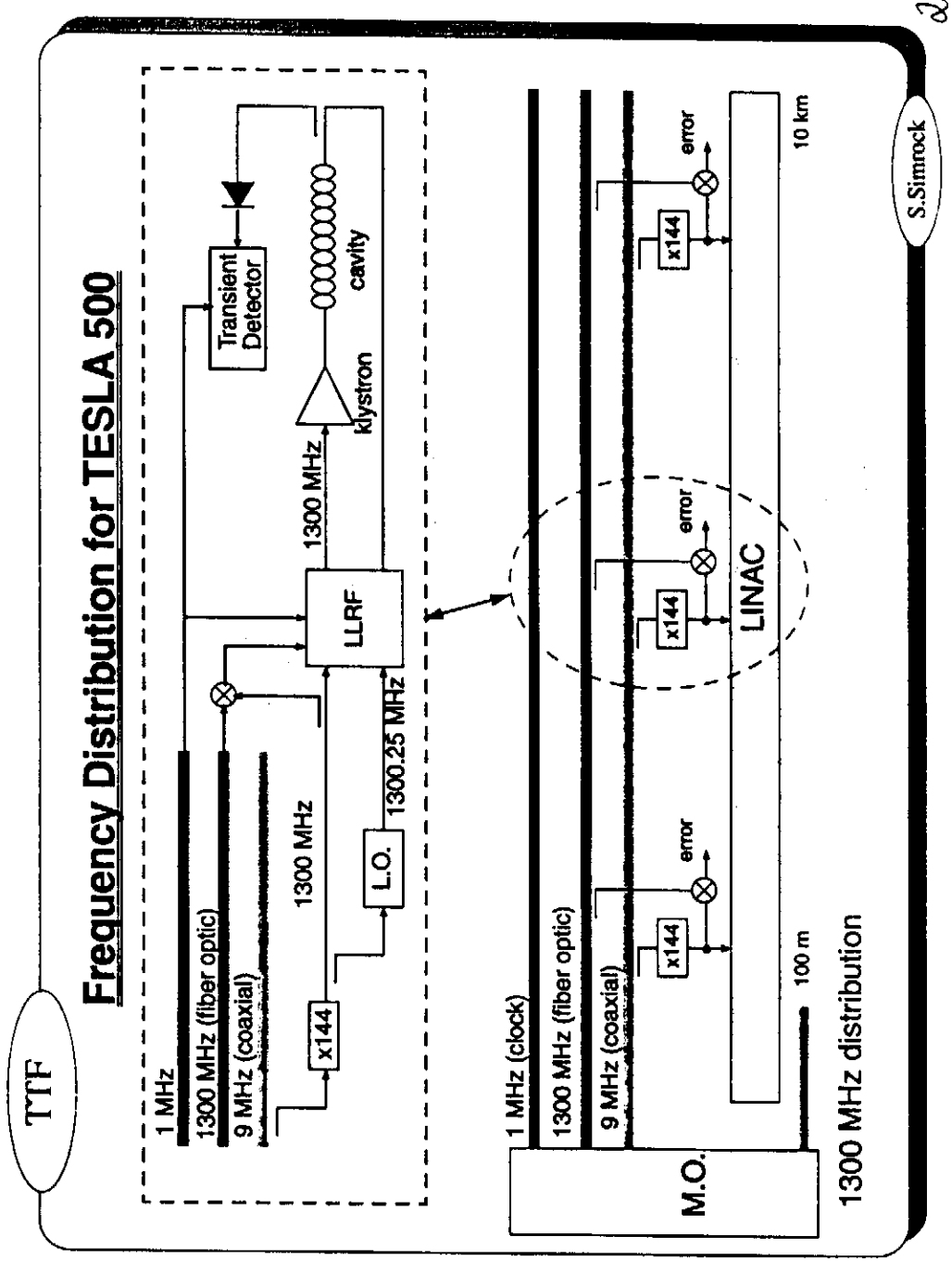
DESY

LLRF Team

Alex Gamp
Serguei Goloborodko
~~Markus Hüning~~
Andreij Kholodnyi
~~Matthias Liepe~~
Tomasz Plawski
Kay Rehlich
~~Thomas Schilcher~~
Stefan Simrock
Jens Sonnenberg
Yurij Tchernoousko

with support of
MHF-P
MHF-SL
FDET
TTF Collaboration

S.Simrock



Status of Hydroforming of Seamless Cavities

H. Kaiser

9 March 1998

Participants

The team at DESY	JINR Moscow	J. Gonin J. Jelezov T. Khabiboulline V. Kuchtiev (formerly) A. Stepanov (")
	DESY	H. Kaiser G. Weichert W. Singer
Institutes		DESY Techical Services GKSS Uni. Wuppertal Uni Bundeswehr
Firms		Butting Dück Heräus - - -

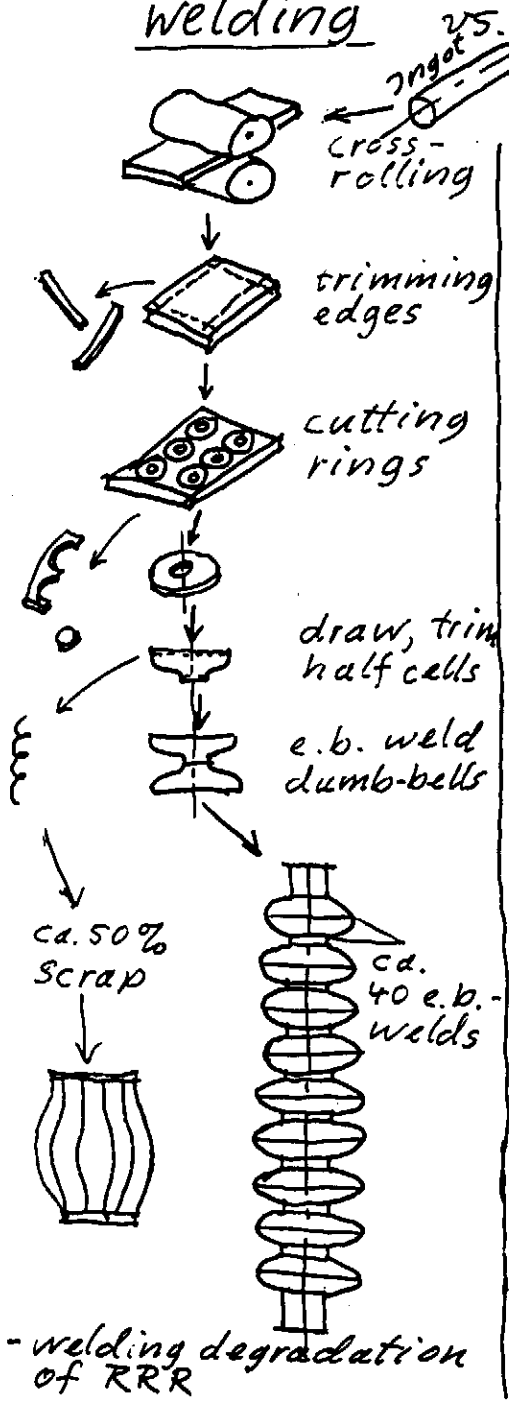
Nb RF-Cavities by:

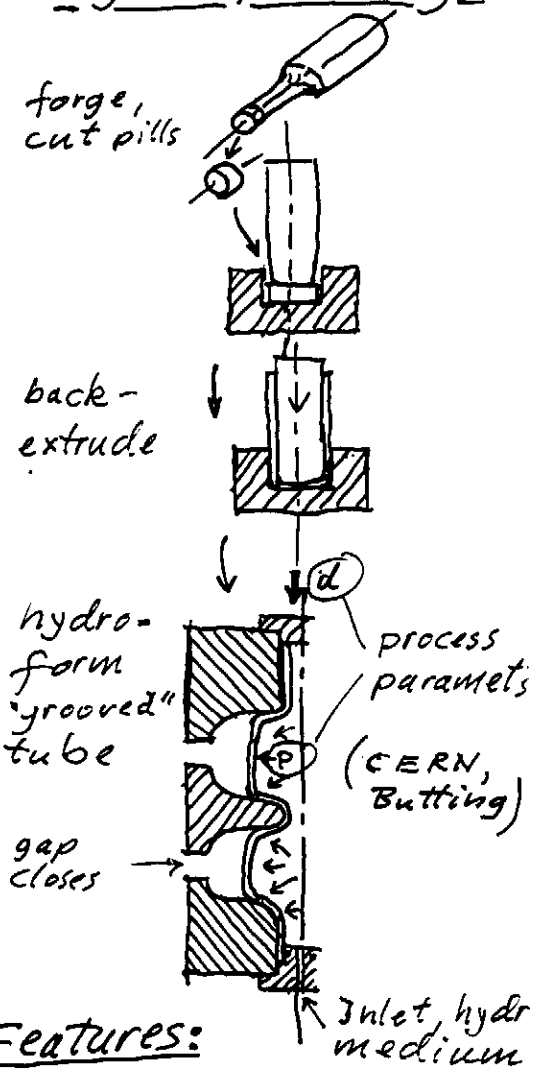
Why go seamless?

expect rel. welded cavities:

Improved performance	Lowered cost
• no welds!	• save on Nb
• reduced risk of RRR-degradation at equator caused by:	• much (ca. 10x) reduced amount of welding
- no reduced risk of N,O-uptake in welding	
- inclusions of foreign matter	

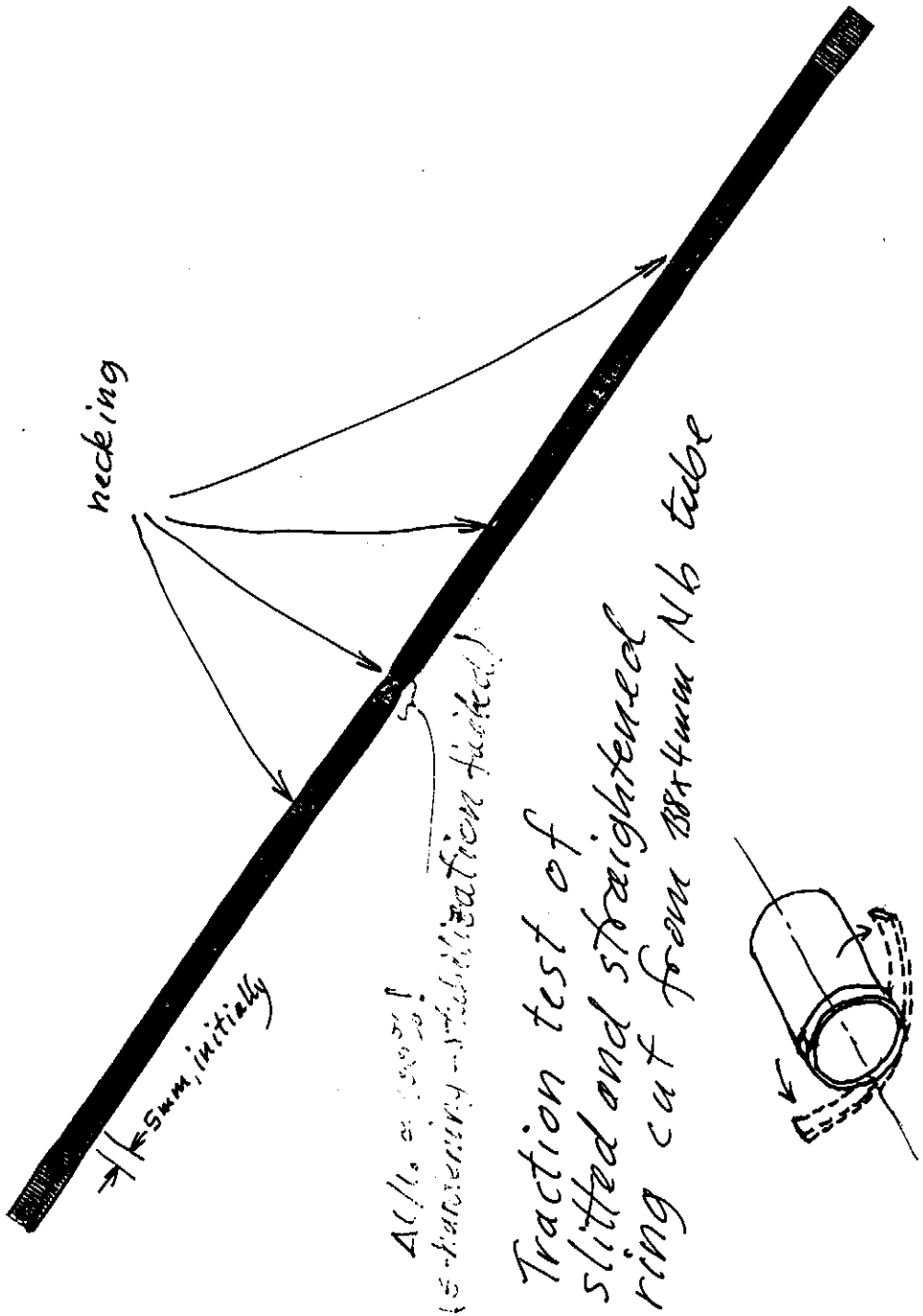
welding vs. hydroforming





Features:

- no cell-welds!
- little scrap
- rel. low fabrication cost
- expected cost reductn: factor of 2



The 3 Main Activities

Study/improvement of Nb-material properties	Computer simulation of forming	Forming experiments
- 1D/2D traction and bulge tests	- optimum p(d)-path	- tests in Cu (1 cell, 2 cell)
- $\epsilon_{max} = \epsilon_{max}(\dot{\epsilon})$?	- controll via p or cell form?	- reduced scale tests: . Iris (1:4) . cell (ca 1:2)
- heat treatment optimization for RRR, forming properties	- iris forming	- tests in Nb . failures . success via trick
- stabilization of tube wall in hydroforming	- optimum starting dia. of tube?	- d(D)-controll of hydroforming
- better formability of less "pure" Nb?	- find wall thickness-distribution for acceptable $\Delta f_{current}$/formability	- computer controll of hydroforming
- Nb-tubes: . welded? . optimum fabrication path? . from powder? . deep drawn? . spun? . extruded?		- 2000 bar water-upgrade

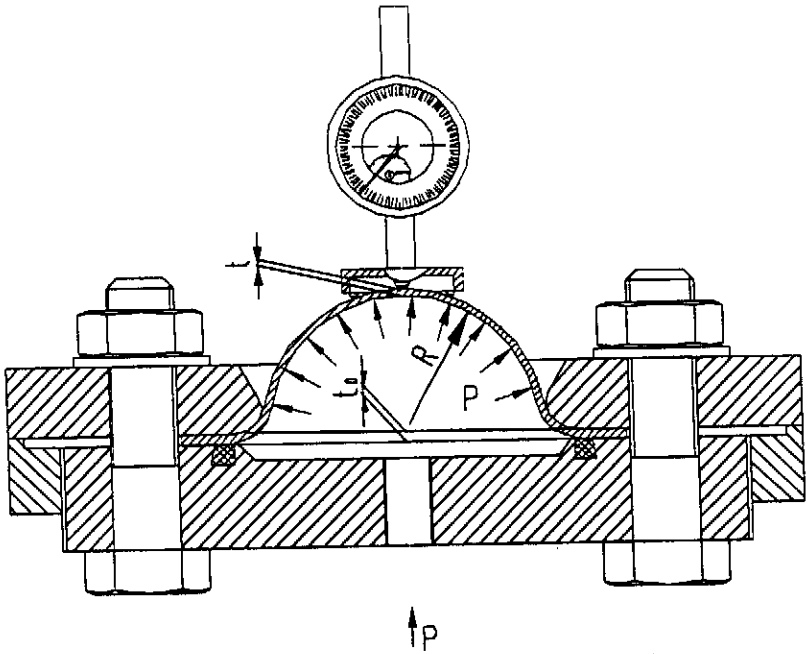


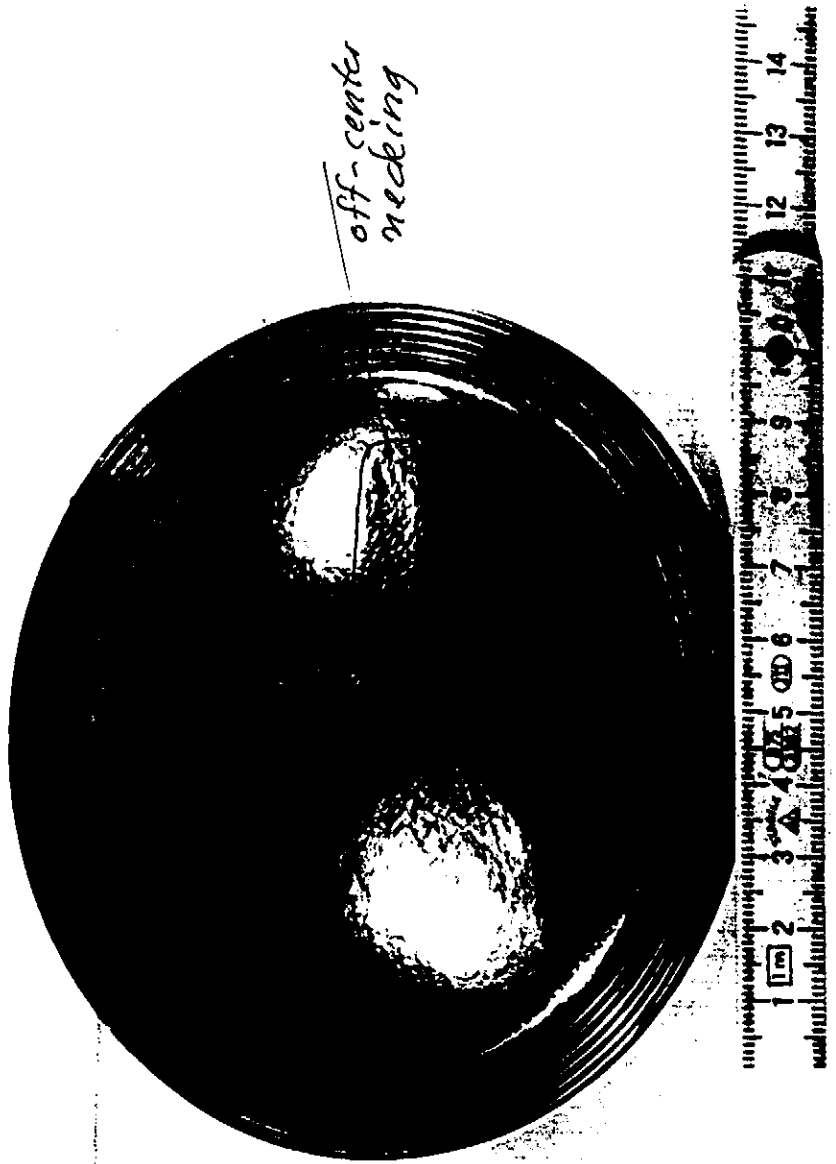
Fig.3 Scheme of the bulging device

At zenith:

$$\left.\begin{aligned} \sigma_{true} &= \frac{P \cdot R}{2t} \\ \epsilon_{true} &= \ln\left(\frac{t}{t_0}\right) \end{aligned}\right\} \text{stress/strain characteristic}$$

$\Downarrow$

FEM-simulation of hydroforming



- fluting, crack parallel to tube axis
flute-thickness varies over circumference

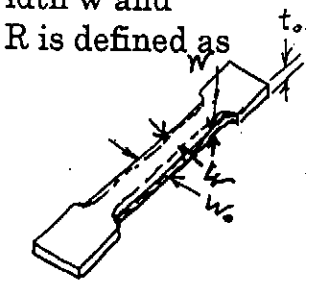
failure crack

fluted wall

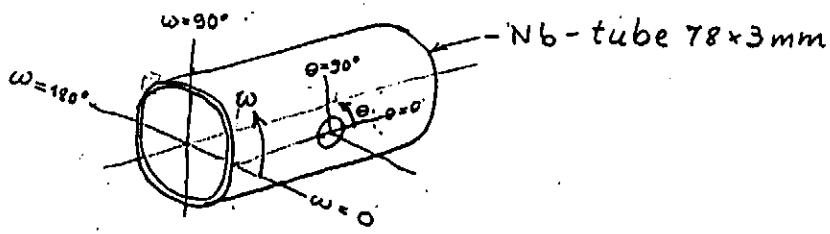
Brokmeier
Uni. Clausthal

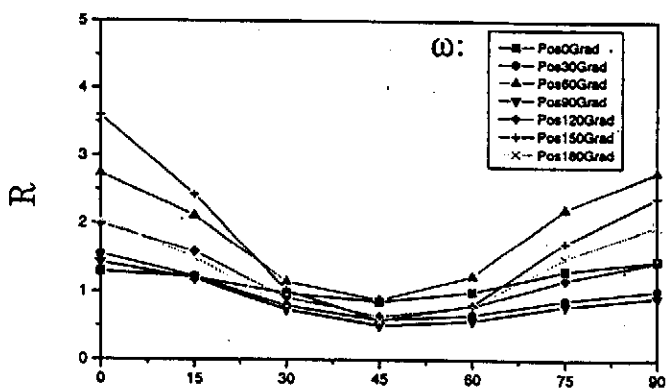
For traction test of strip sample of width w and thichness t the Lankford-parameter R is defined as

$$R = \frac{\ln(w_0 / w)}{\ln(t_0 / t)} \approx \frac{\varepsilon_w}{\varepsilon_t} \text{ for small strain.}$$



For hydroforming the R-value should be constant everywhere in the tube wall. This is not the case:

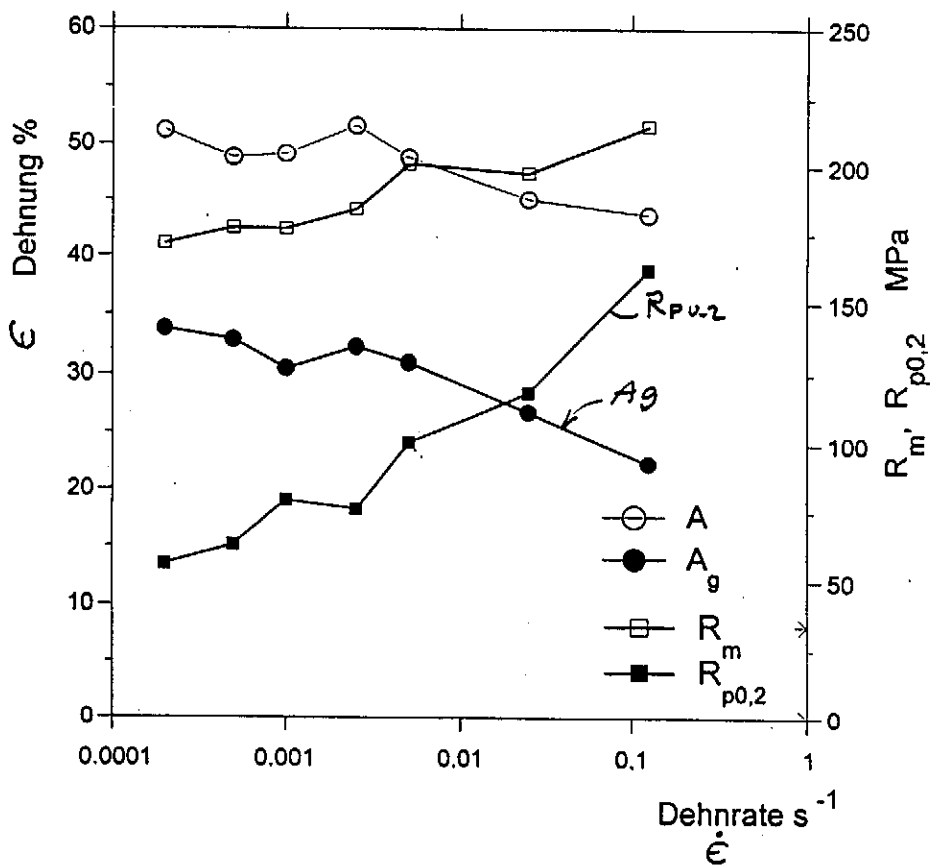




Anisotropy of Lankford-parameter R as function of angle to tube axis Θ and azimuth about tube axis ω. (Measurement by H.-G. Brokmeier by neutron diffraction).

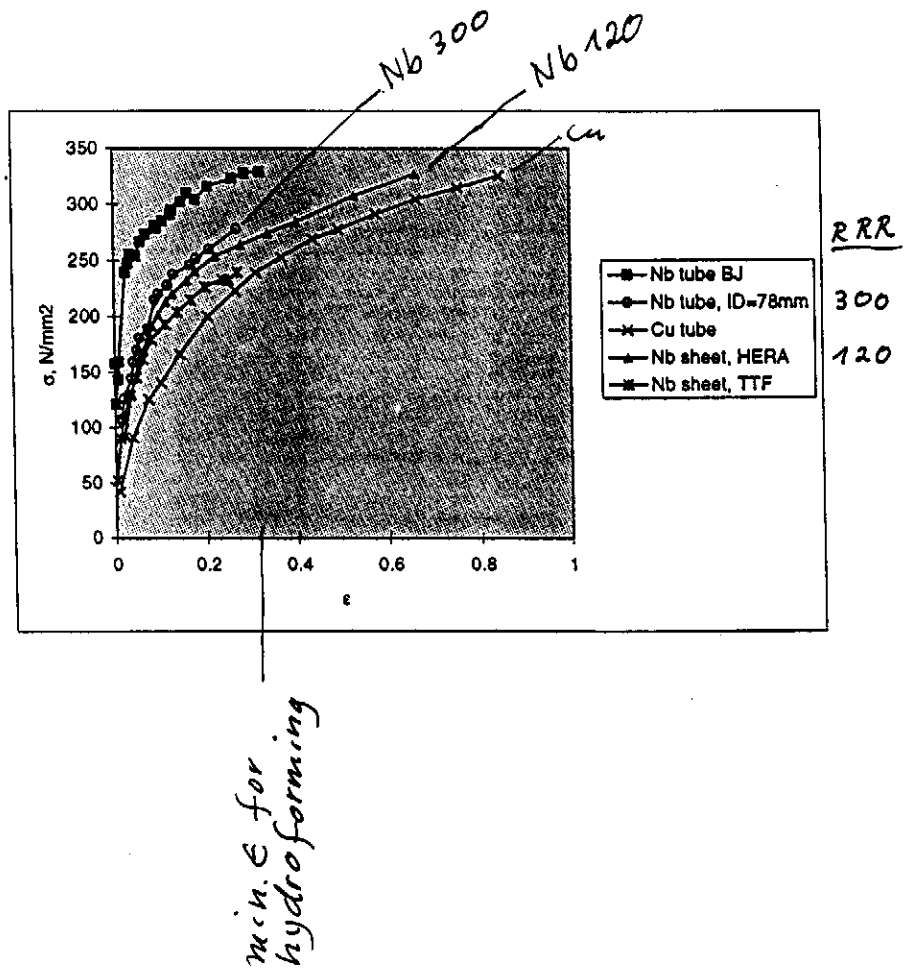
Zugversuche an Niob 120

Prof. Kreye
Uni. Bundeswehr

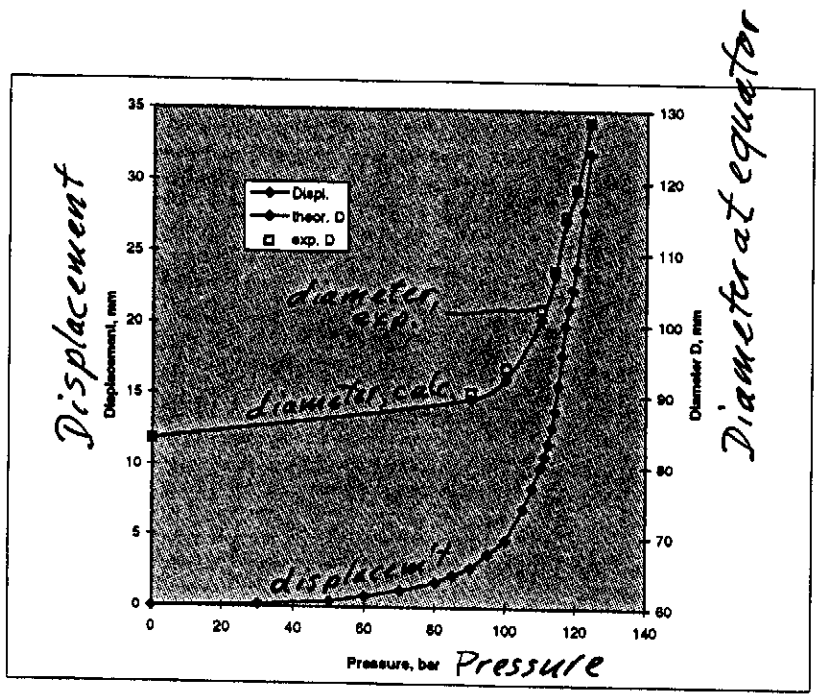


ε vs. $\dot{\varepsilon}$

ZUGDESY2.spf

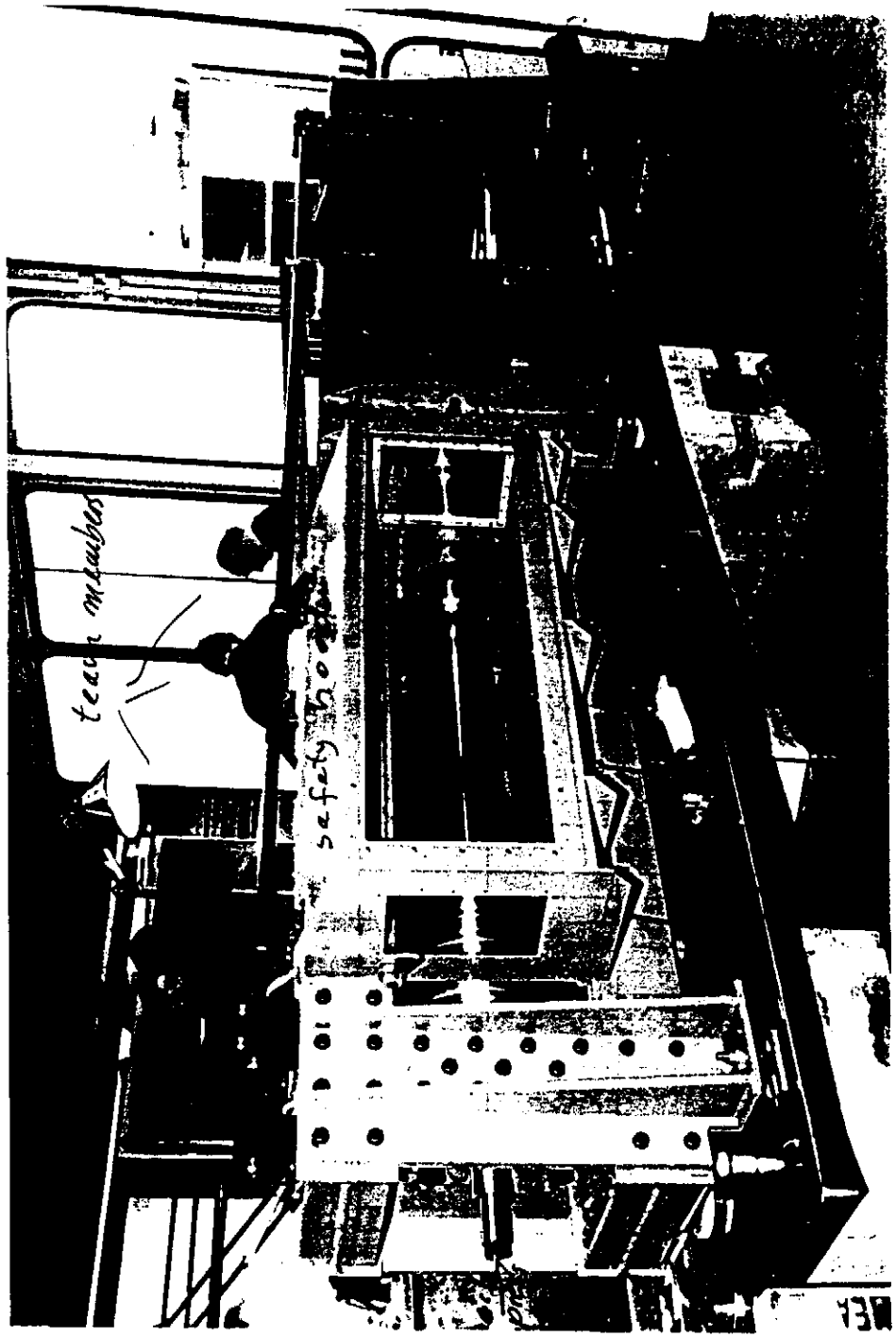


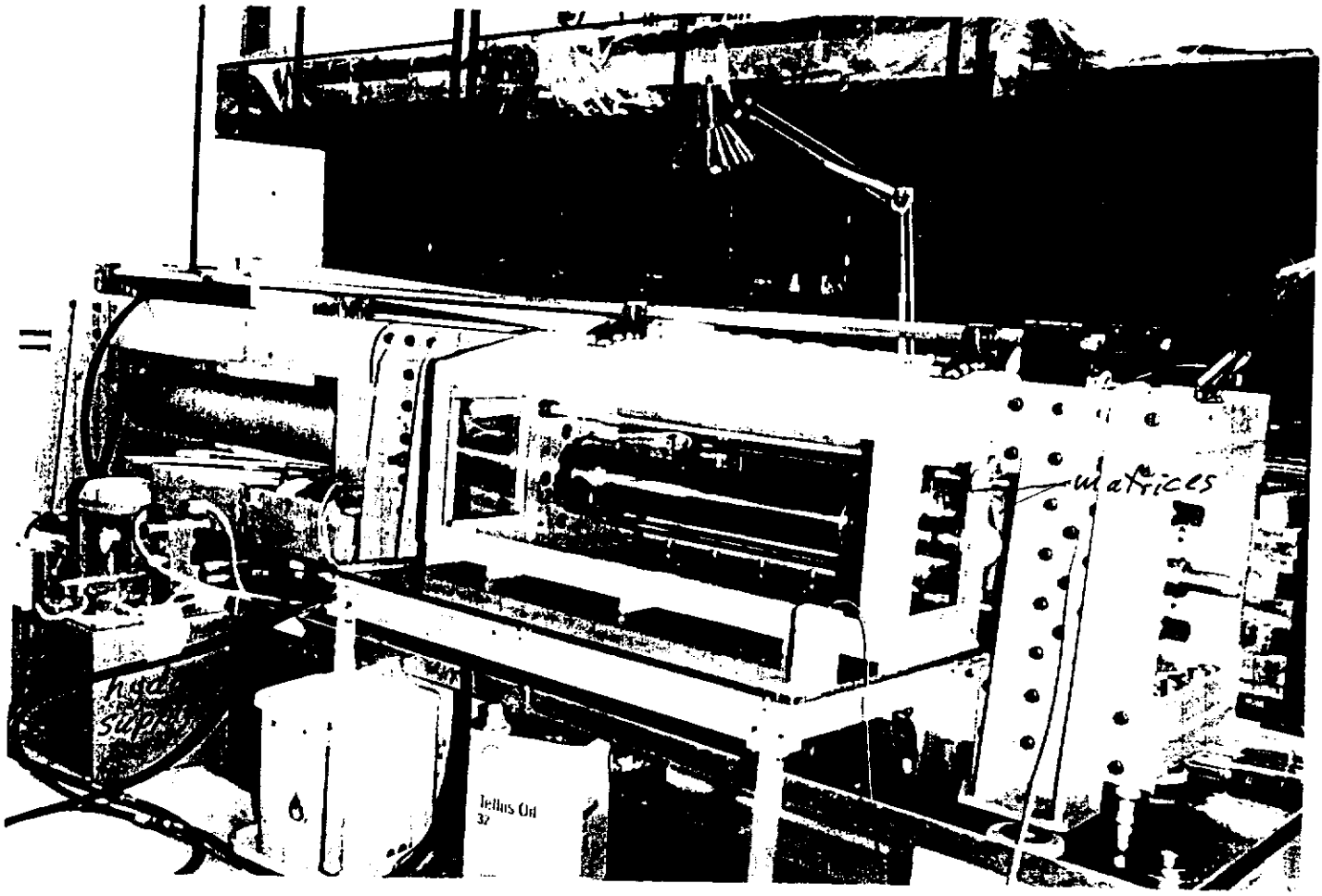
σ(ε) for various materials

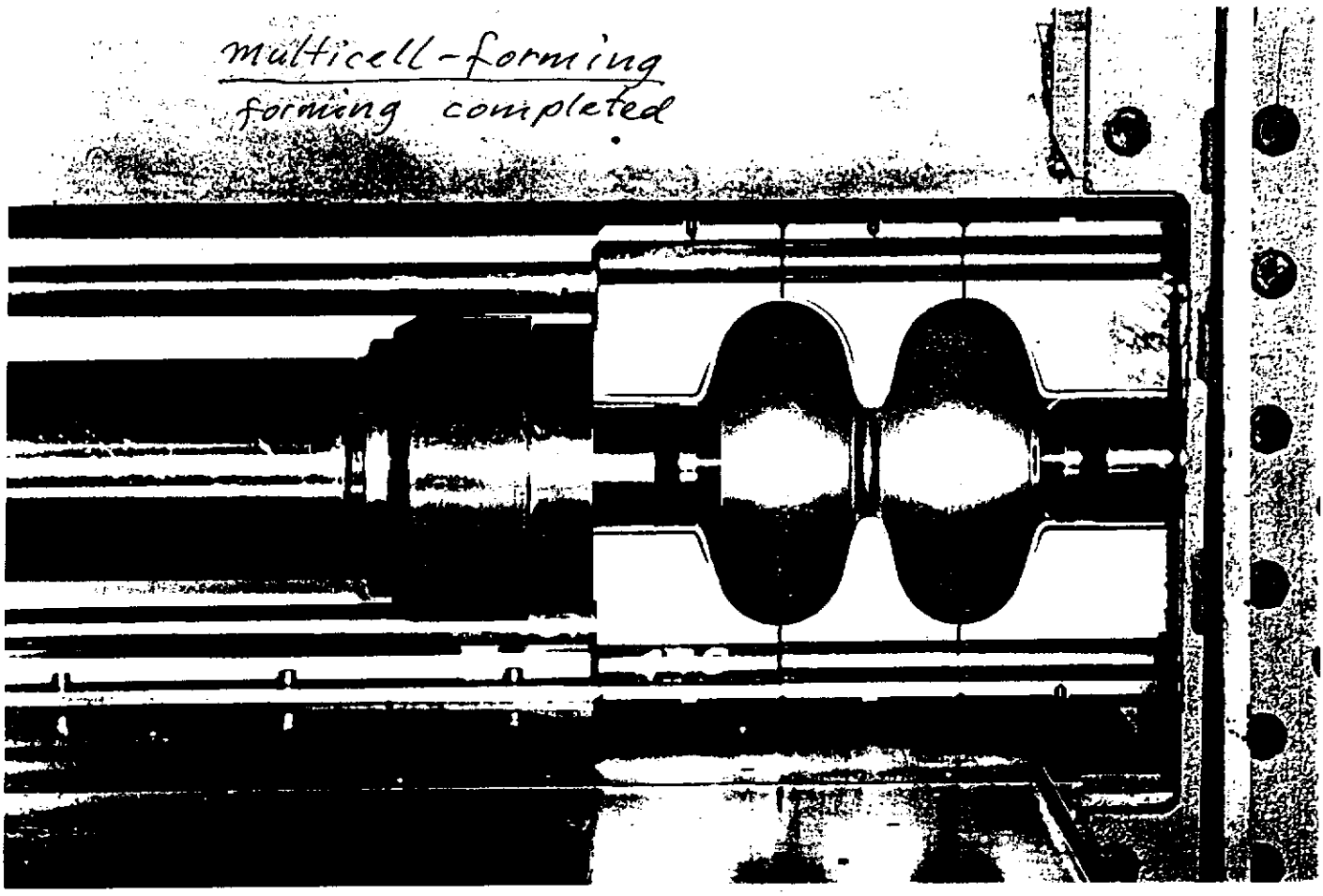


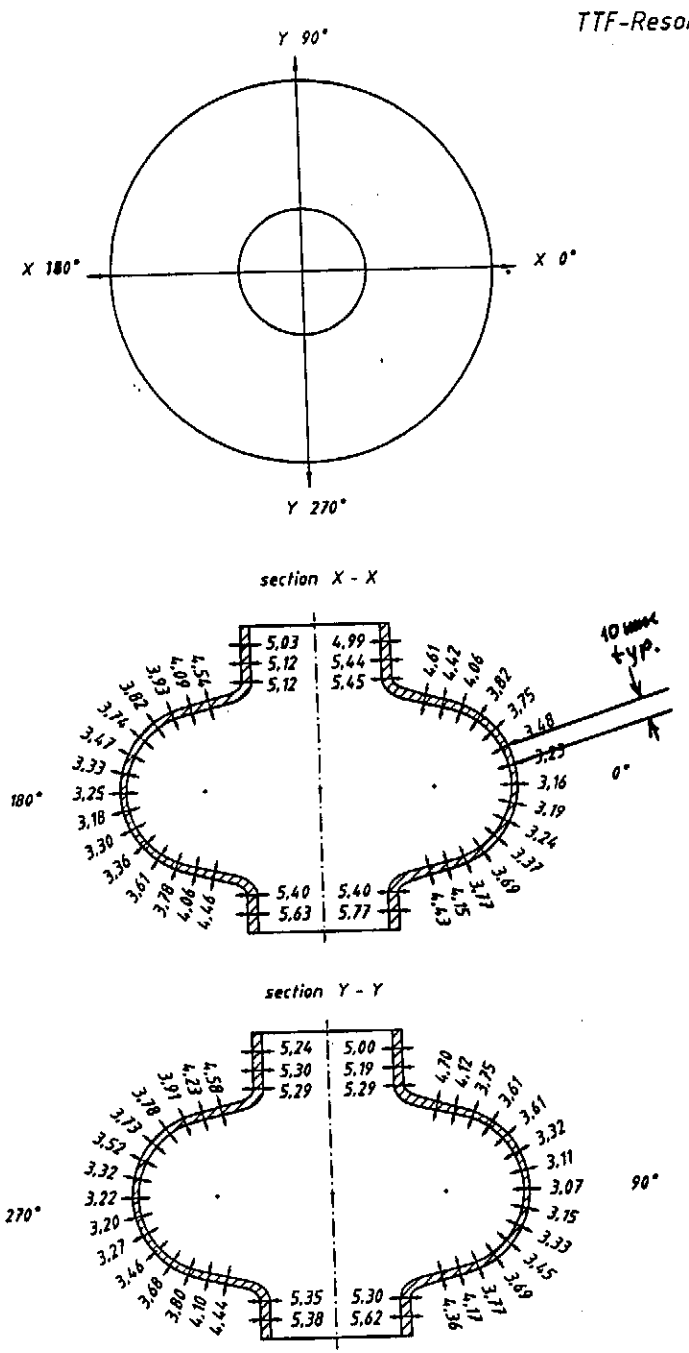
FEM - simulation of hydroforming

A:\LEZOV\BARFSINGER, MAR0312:19



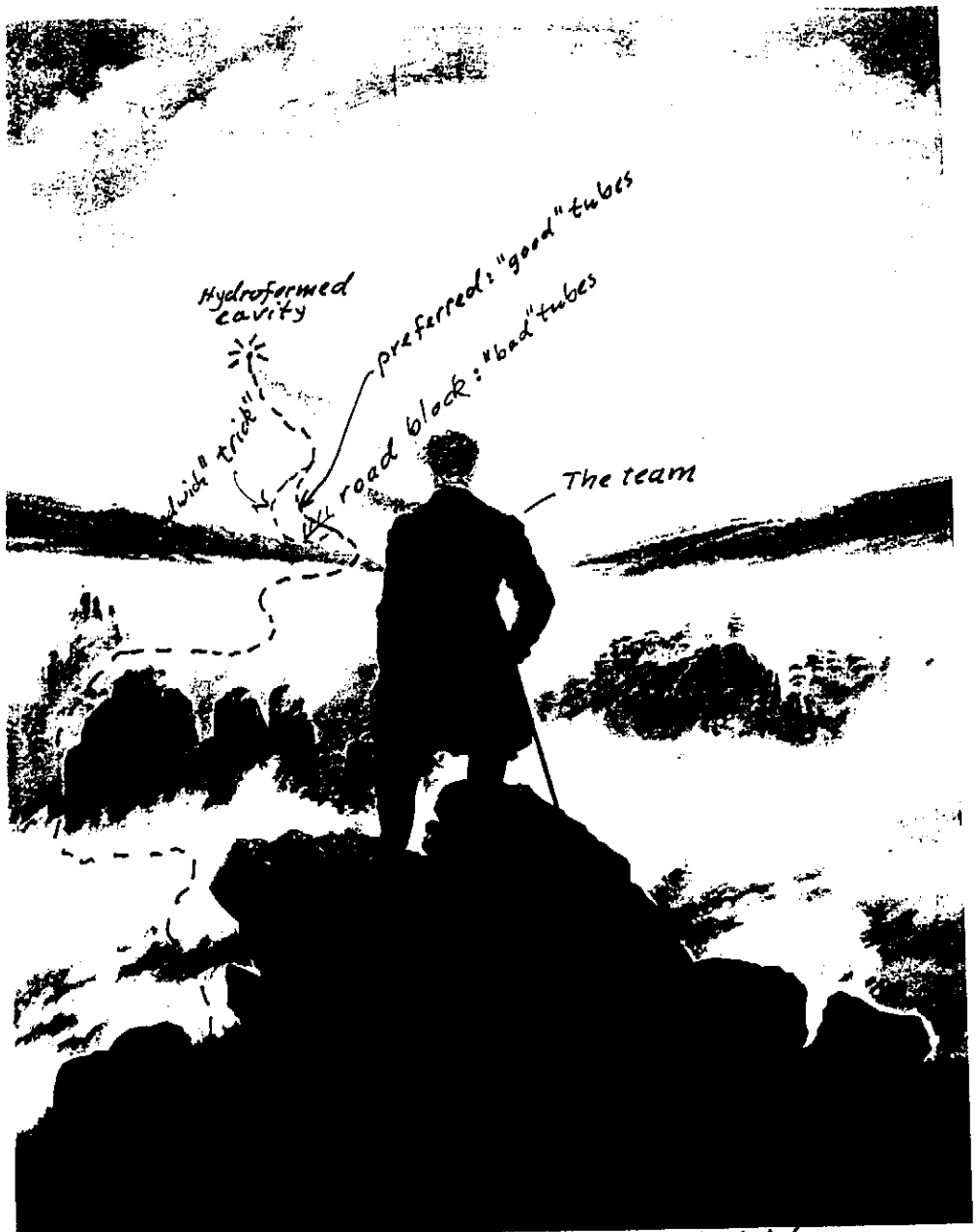

matrices


multicell-forming
forming completed



Future

- half scale Nb tubes made in 6 different ways mid 98
- full size tubes in optim. way end 98
- cavities without jacket/liner spring 99
- 2000 bar H_2O hydraulic mid 98
- computer controll of hydroforming mid 98
- alternate routes for making tubes/cavities



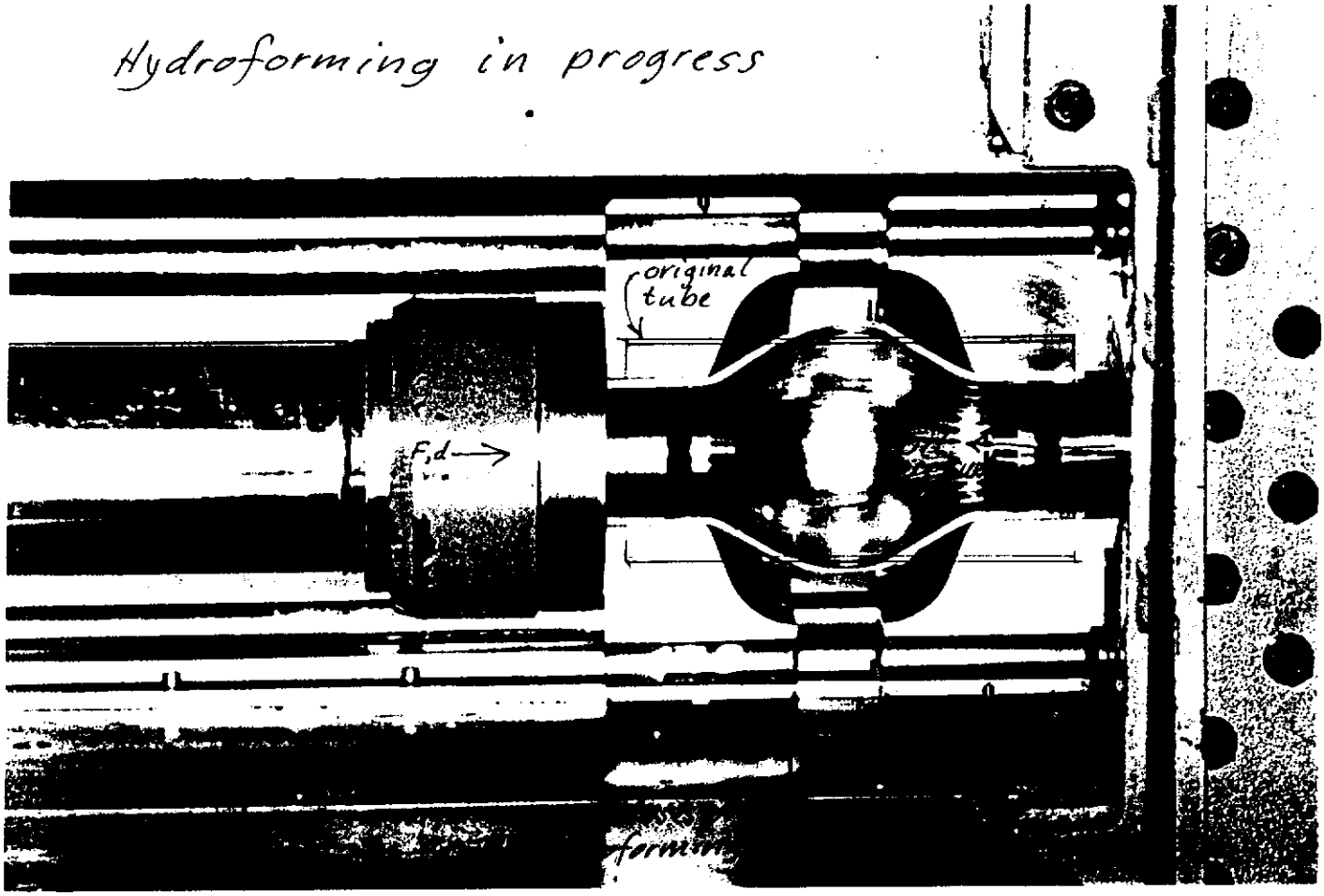
c. D. Friedrich

Nb-tubes/cavities from powder?
(speculative!)

powder of RRR 300
(N+O < 10ppm)

- raw tube by HIP
  - draw, recrystallize
  - hydroform to cavity
- "cold" powder-spraying
  - raw tube
  - raw cavity
    - calibrate by hydroforming

Hydroforming in progress



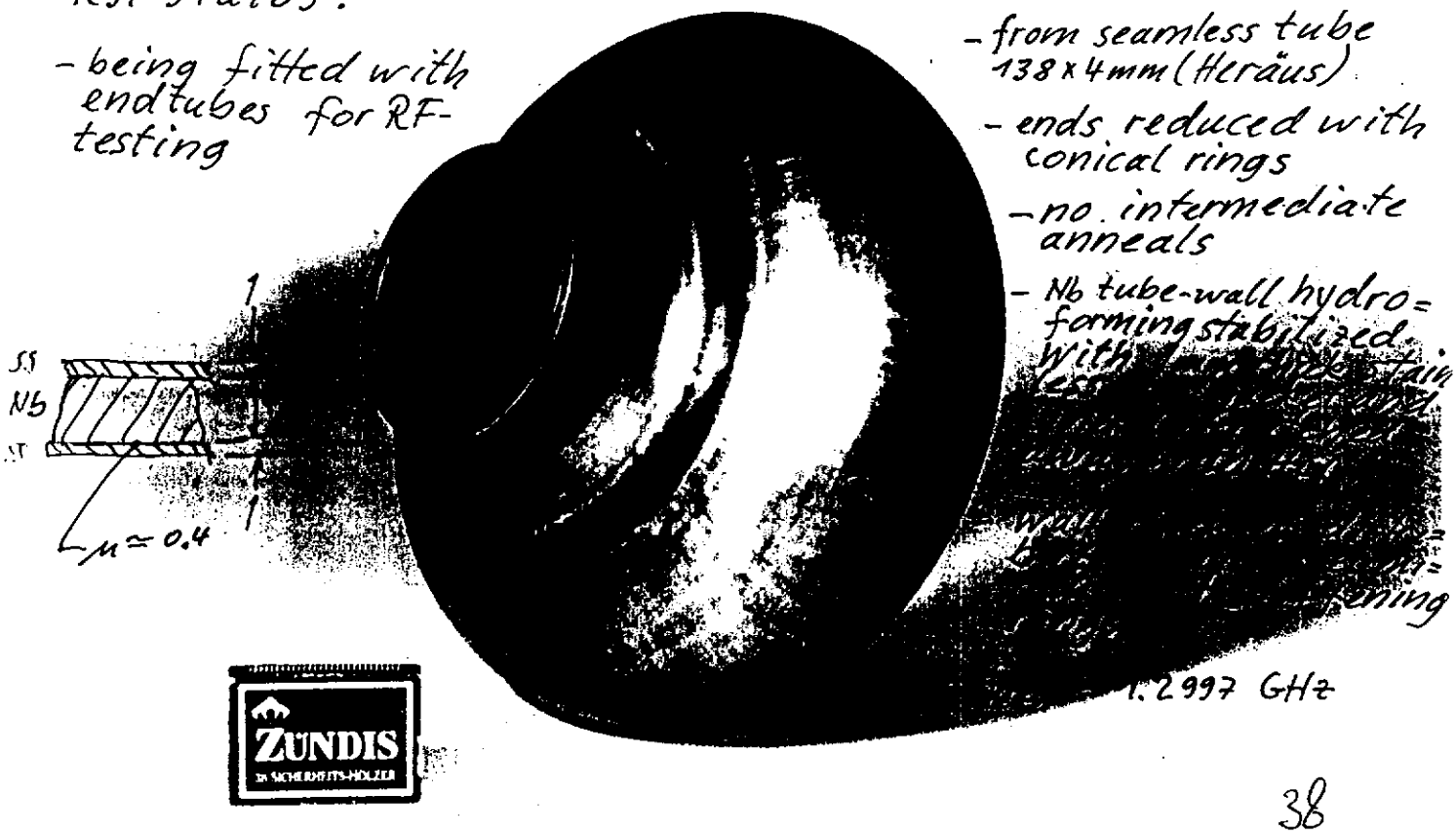
First hydroformed Nb. TESLA-monocell

Test status:

- being fitted with endtubes for RF-testing

Fabrication details:

- from seamless tube 138 x 4 mm (Heräus)
- ends reduced with conical rings
- no. intermediate anneals
- Nb tube-wall hydro-forming stabilized with



ZÜNDIS

New Cryostat Development

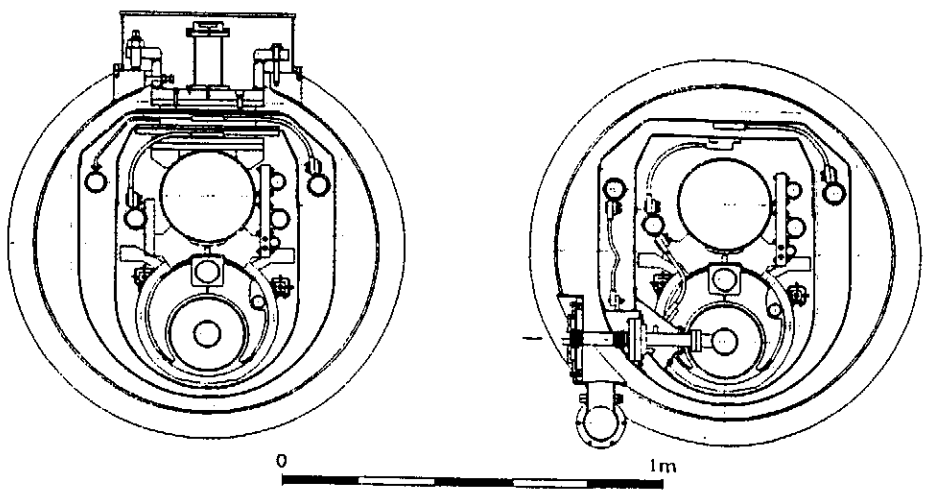
Carlo Pagani

Three Cryostat Generations

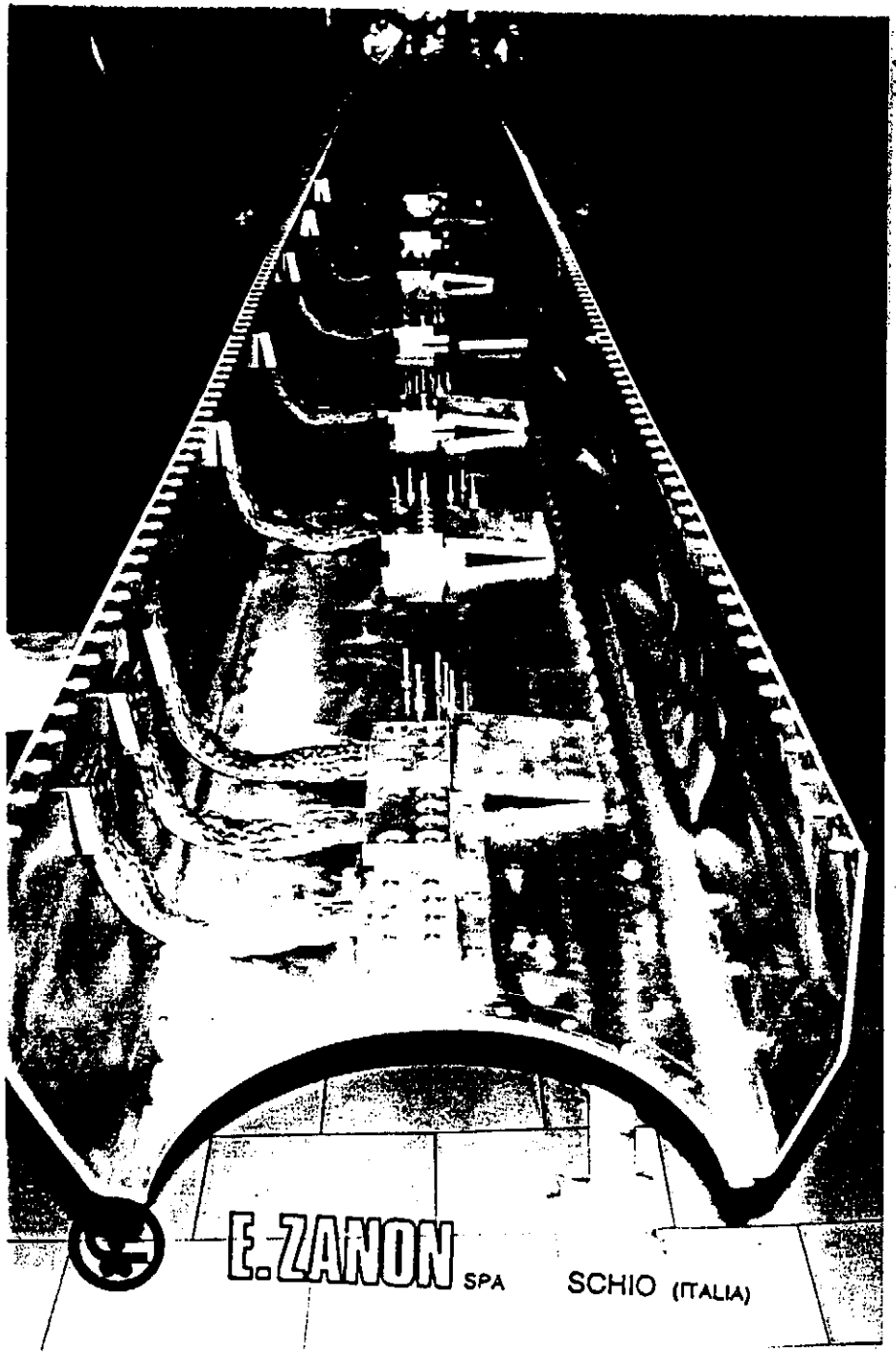
- Cryomodule # 1 — Prototype - Expensive
  - Shields connected with screws and cooled by copper braids
  - Difficult to align - New Assembling Tools
- Cryomodules # 2 & # 3 — 50% Cost Cutting
  - Shields connected and cooled by "finger welding"
  - Improved alignment and tolerances
- Cryomodules # 4 to # 8 — Thinking to TESLA 500
  - Reduced size of the Vacuum Vessel
  - Compatible with "rigid coupler" and "Super-structures"
  - Stiffer against external forces acting on the HeGRP

1st Generation Cryostat

Braid-Cooled Shields



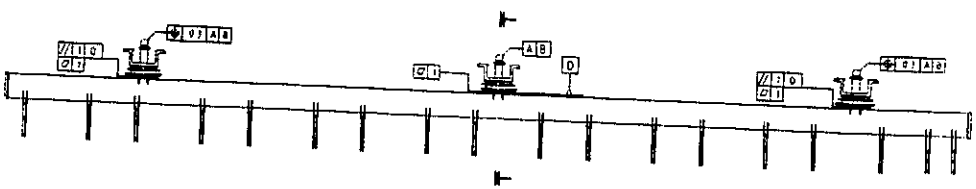
E. ZANON SPA SCHIO (ITALIA)

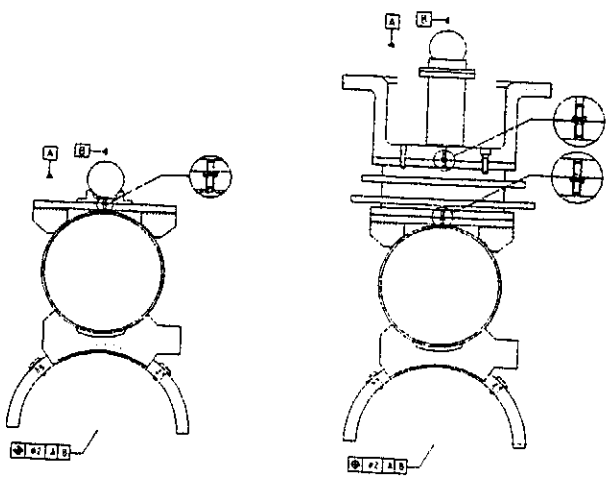


E. ZANON SPA SCHIO (ITALIA)

2nd Generation Cryostat

New fabrication procedure
Improved tolerances





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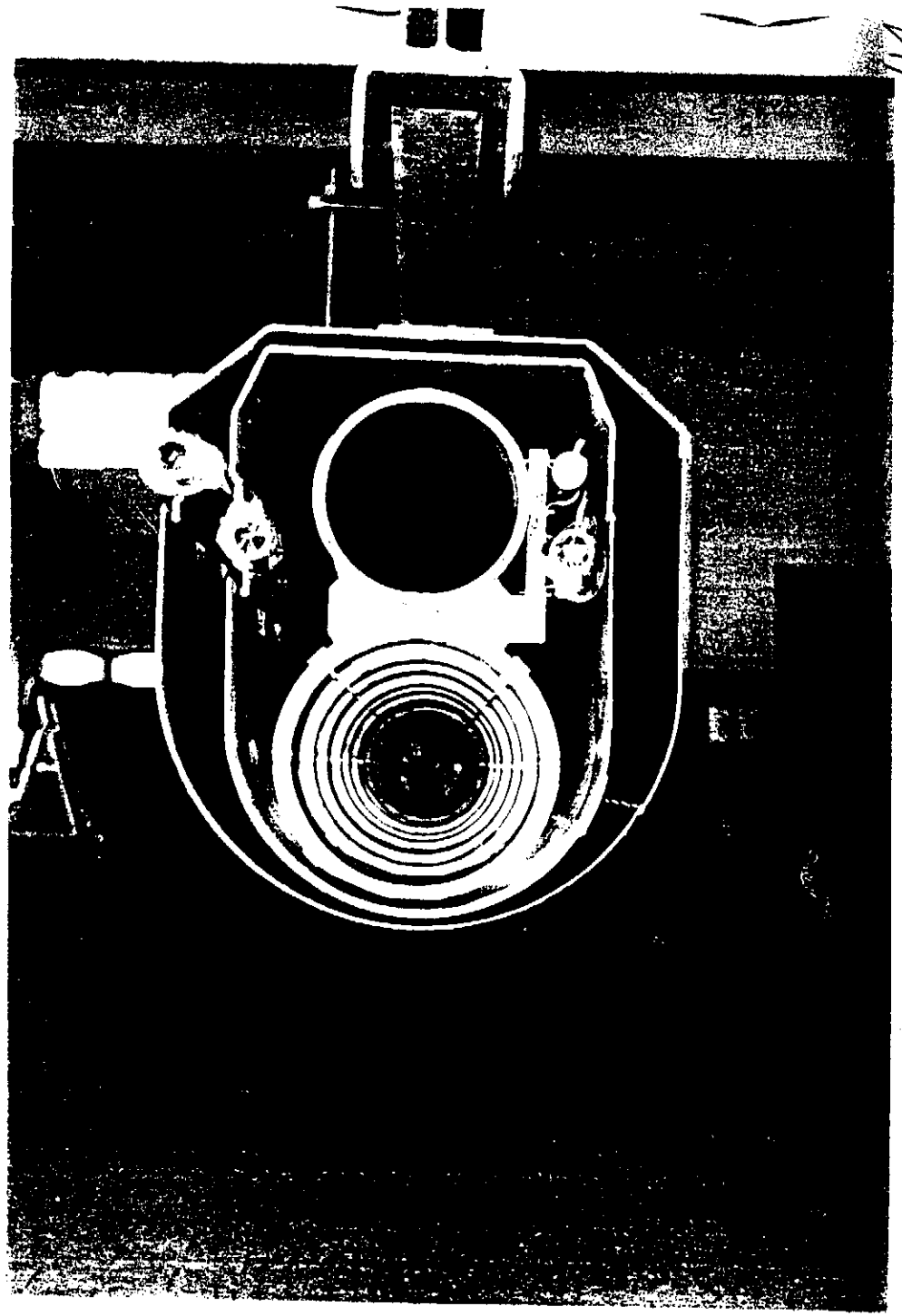
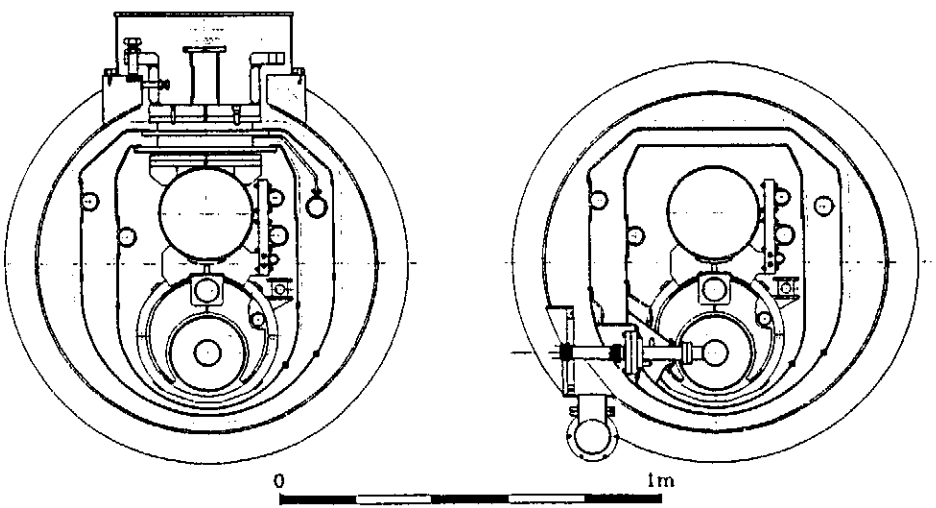


2nd Generation Cryostat

"Finger-Welded" Shields



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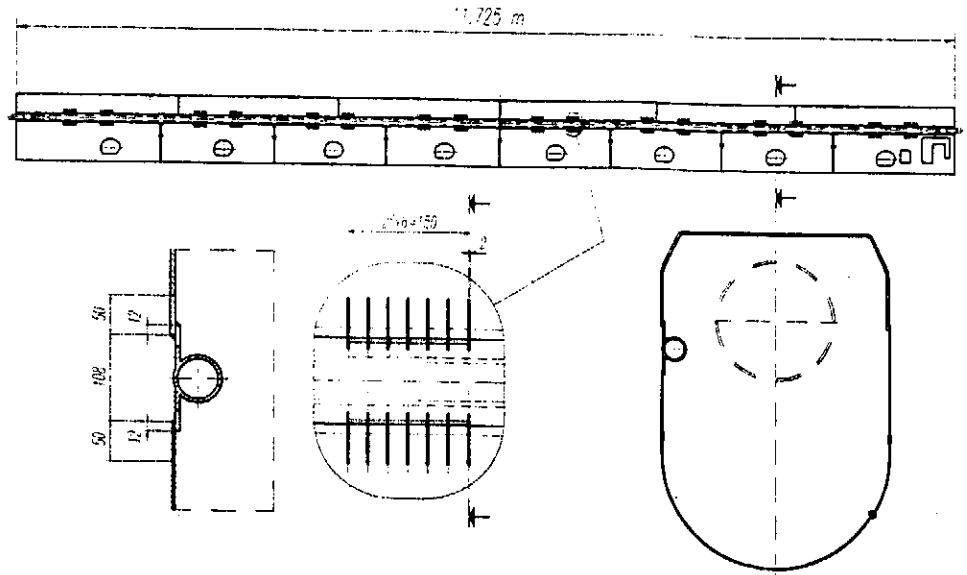
2nd Generation Cryostat

"Finger-Welding" Details



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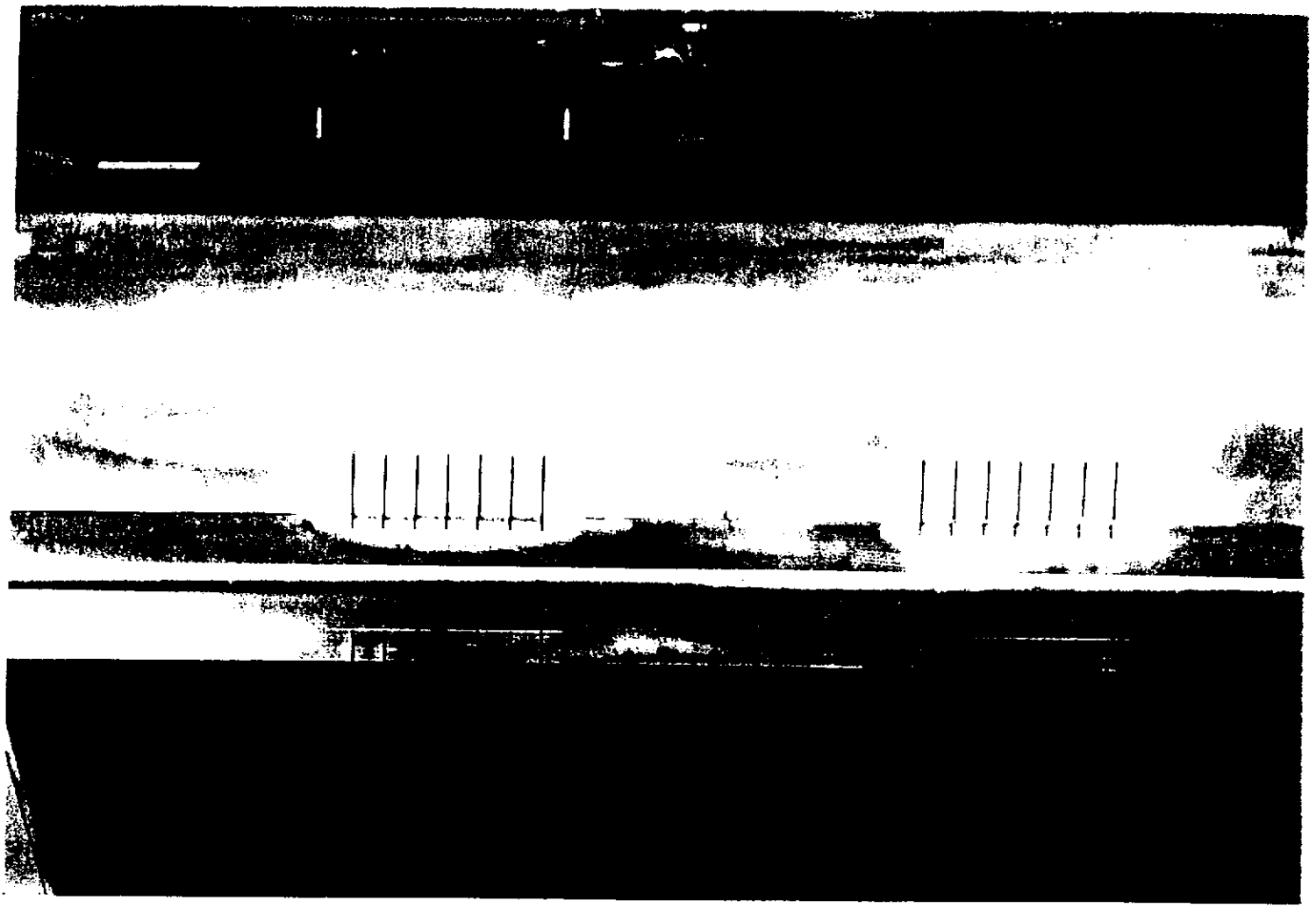

3rd Generation Cryostat

Thinking to TESLA 500

- Reduce the Cross Section **and use a** standard "pipeline" tube
  - Redistribute the internal components
  - Reduce the distances to the minimum
- **Compatible with** "rigid coupler" **and** "Superstructures"
  - Position of the active elements longitudinally free
- Improve the connection **of the active elements to the HeGRP**
  - Poor in the present scheme
- Reduce alignment sensitivity **to the forces on the HeGRP edges**
  - Move the external posts closer to the edges
- **Further** simplify the assembling procedure
  - Simplify coupler cones and braids
  - Reduce by a factor two the shield components
- **System thought for** mass production cost cutting
  - Tolerances reduced to the required ones
  - Simpler components and standard tubes wherever possible

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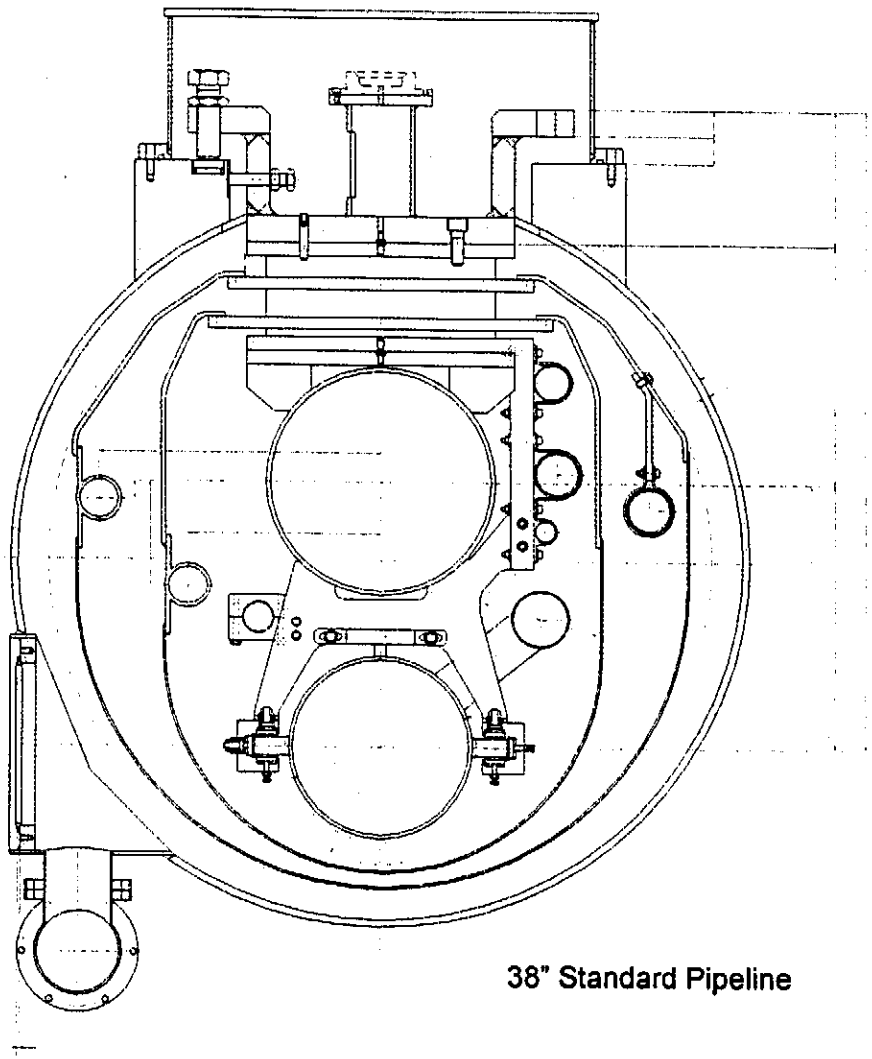
3rd Generation Cryostat

Cross section on Cavity



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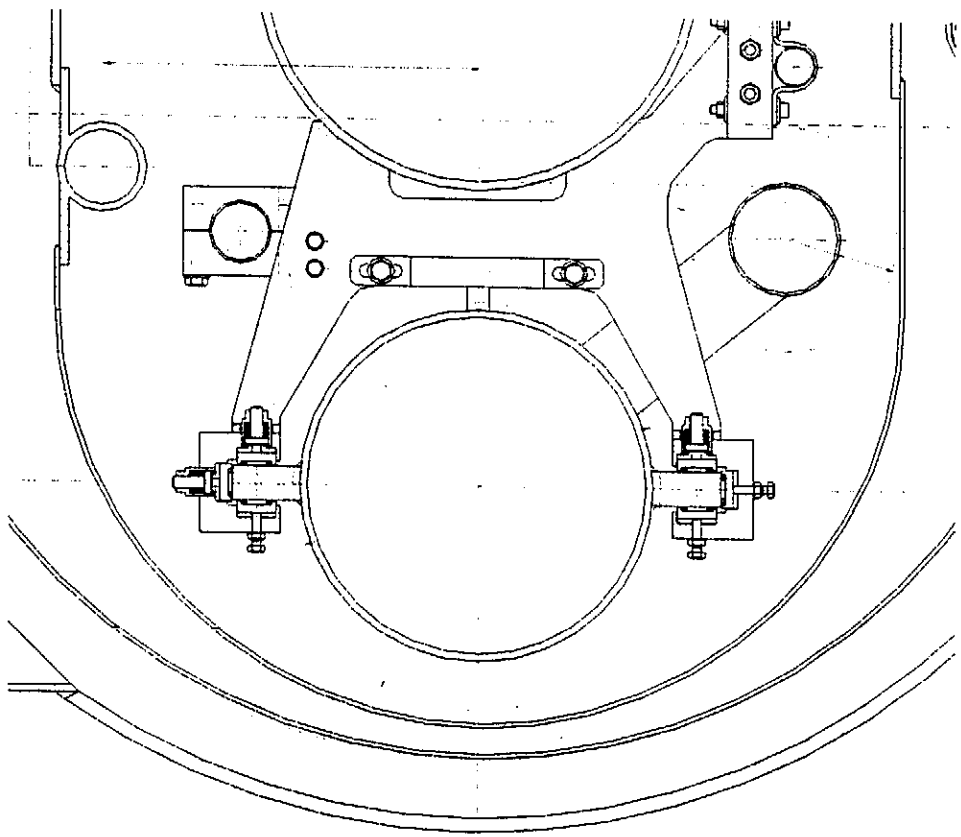
3rd Generation Cryostat

Cross section on Cavity - Sliding fixture detail



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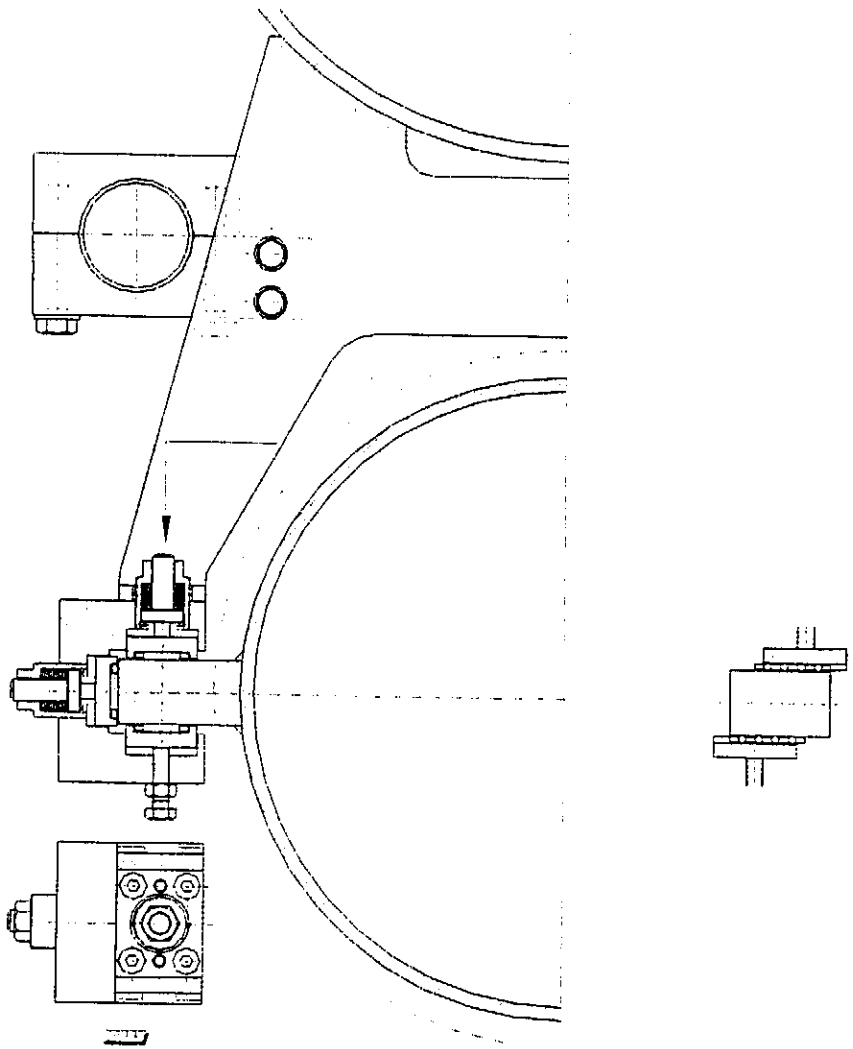
3rd Generation Cryostat

Cross section on Cavity - Sliding fixture detail



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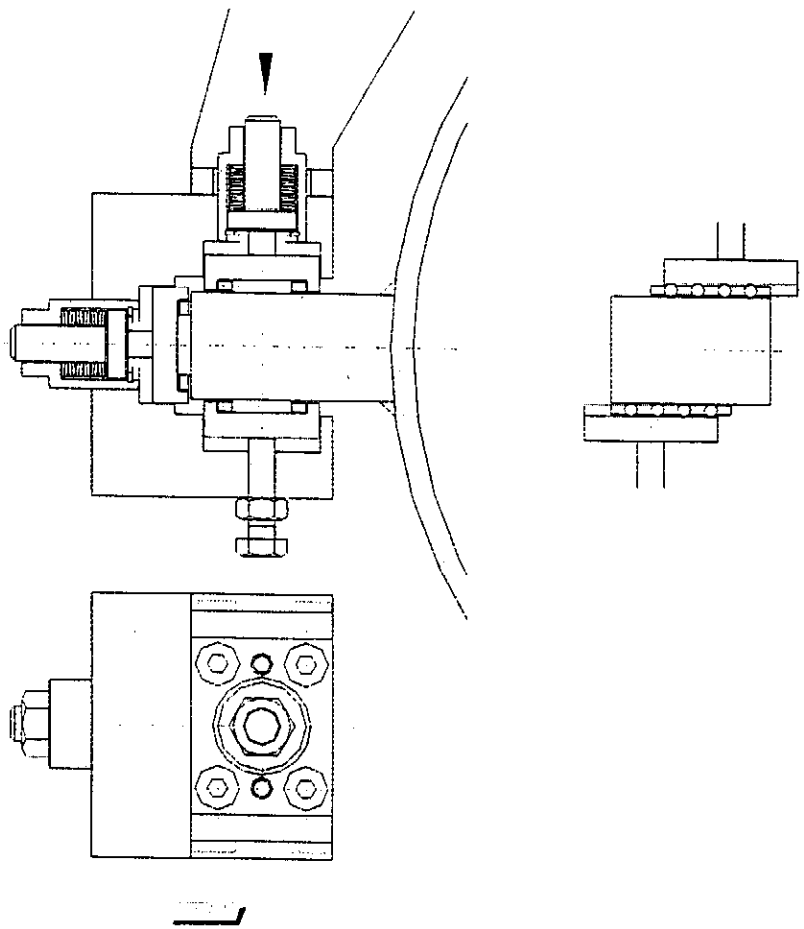
3rd Generation Cryostat

Cross section on Cavity - Sliding fixture detail



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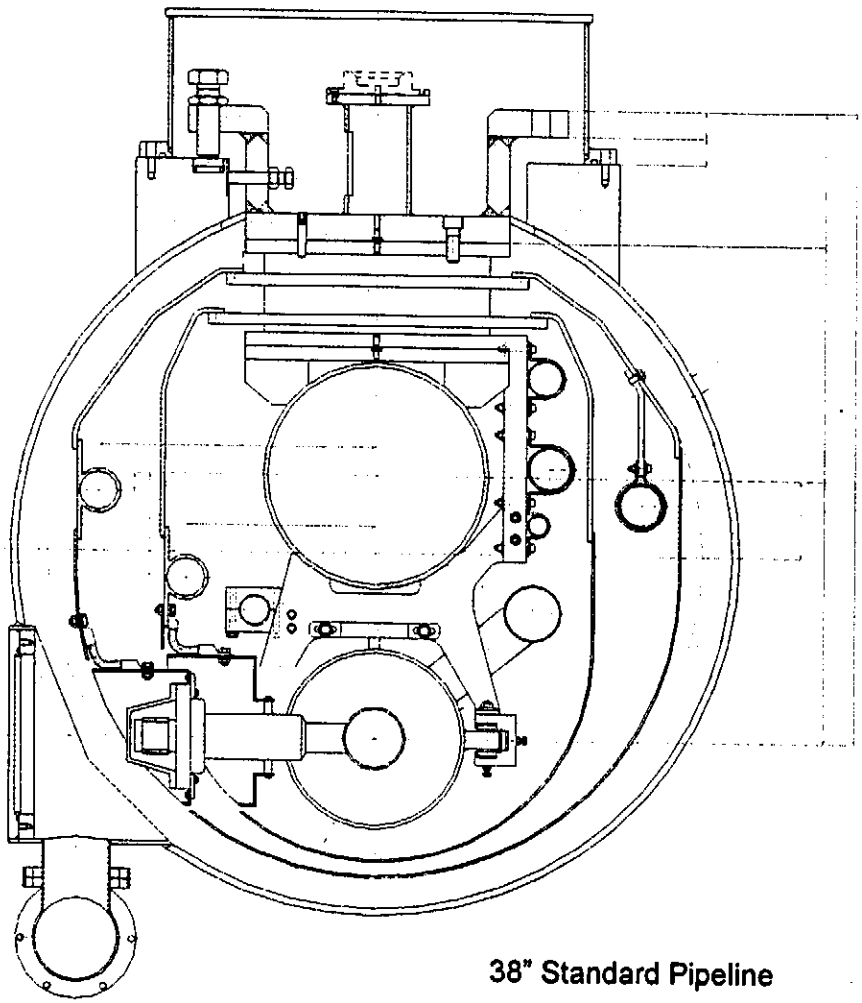
3rd Generation Cryostat

Cross section on Coupler



38" Standard Pipeline

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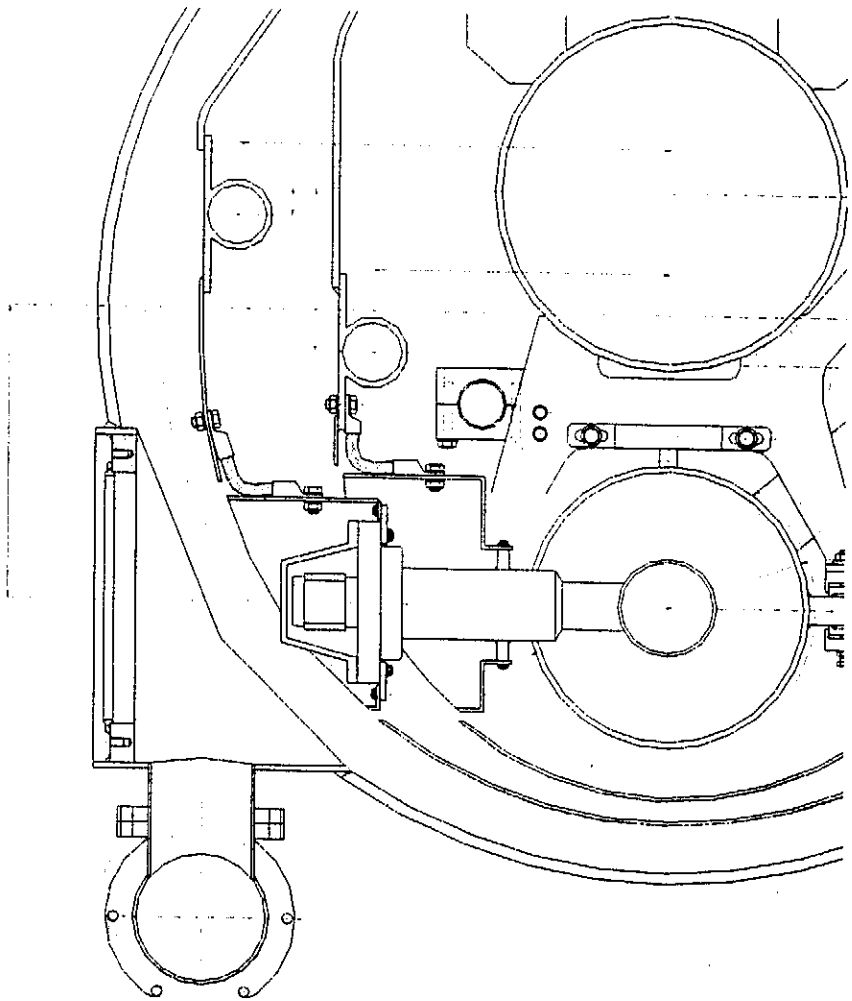
INFN Milano - LASA

3rd Generation Cryostat

Cross section on Coupler - Detail



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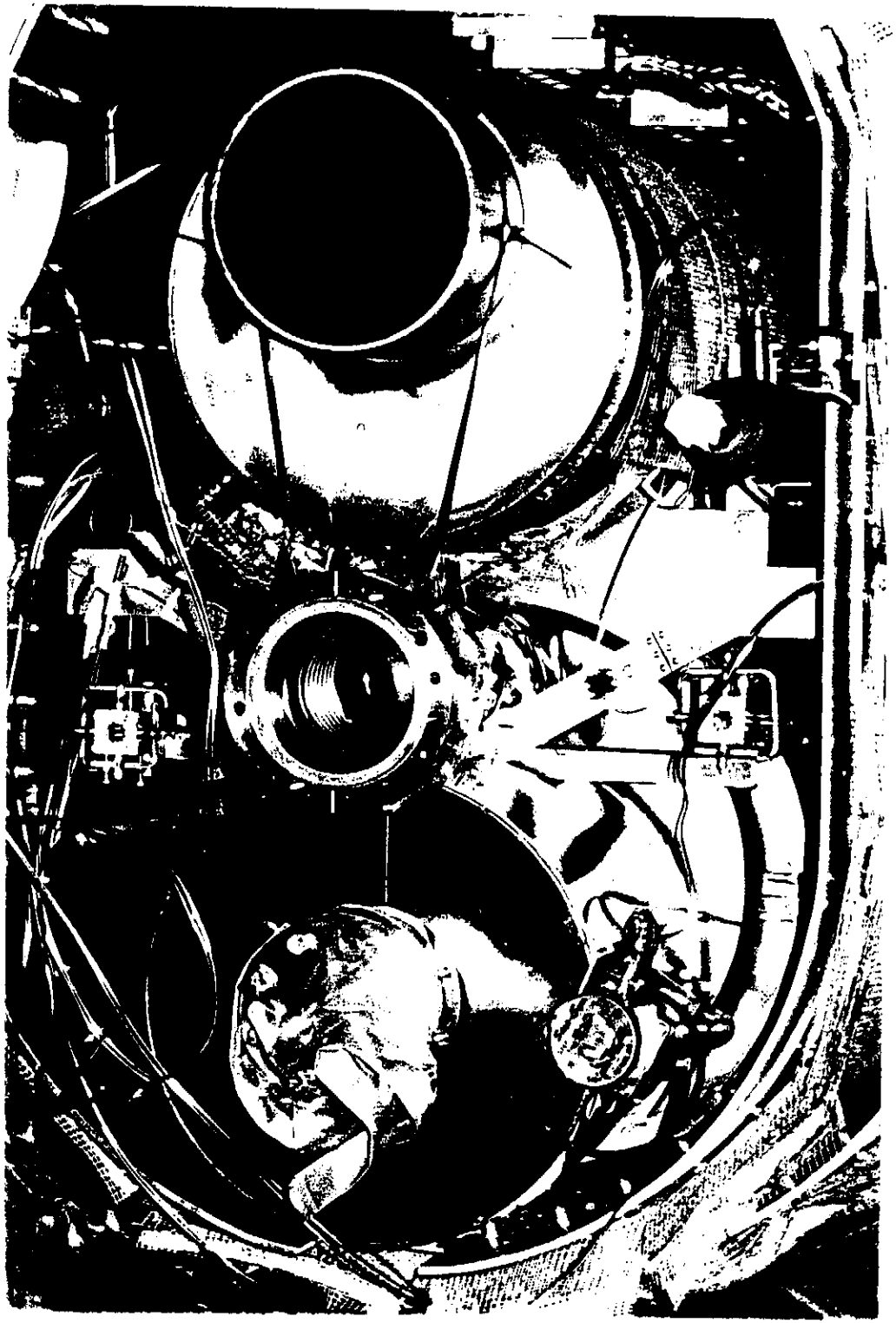
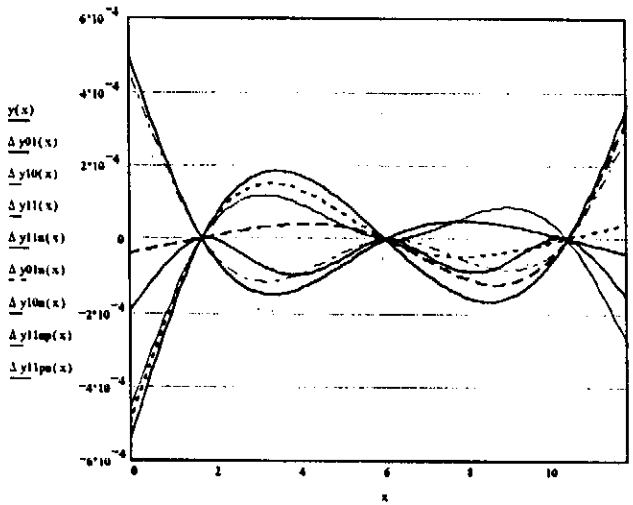
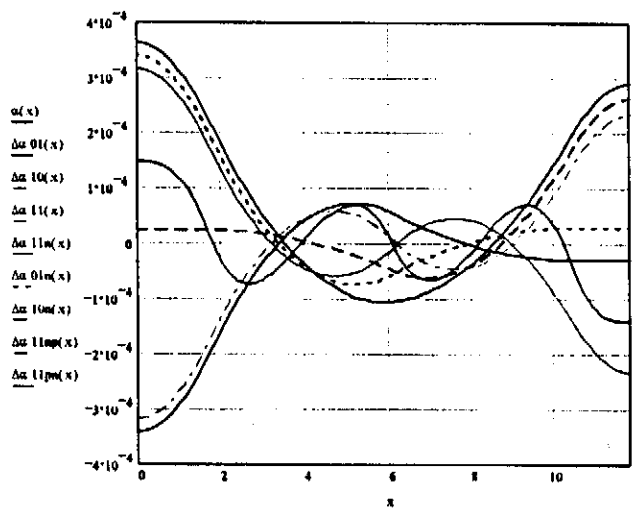


2nd Generation Cryostat

Active element movements for a 1000 N force at the edges





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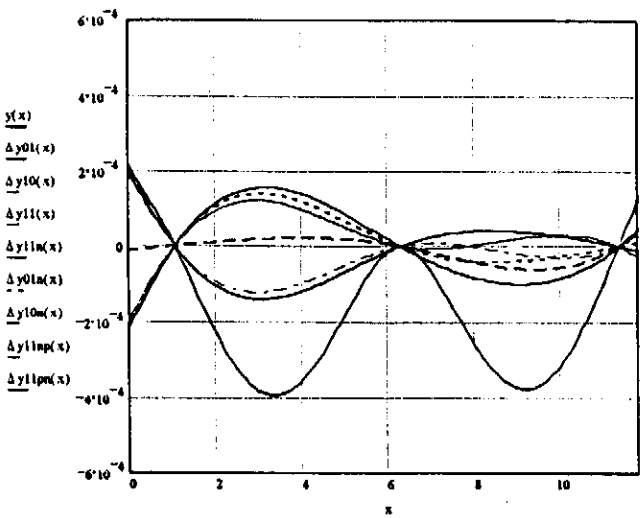
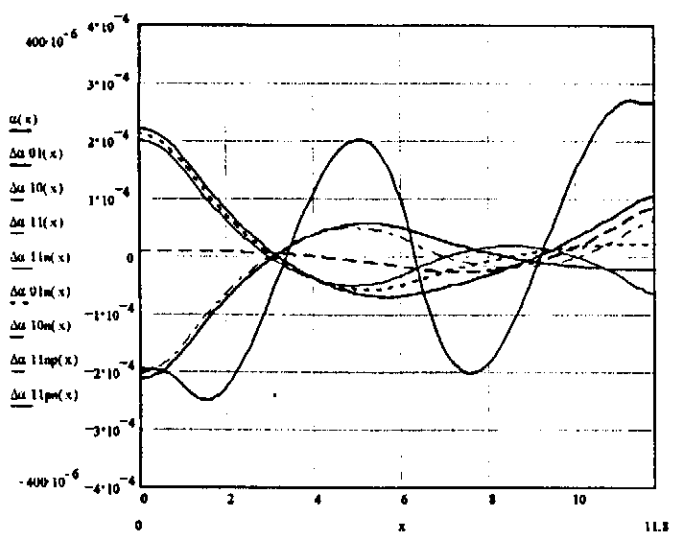
3rd Generation Cryostat

Active element movements for a 1000 N force at the edges





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March TTF meeting notes

Fermilab Report H Edwards 7/3/98

Injector II

Sector 400- Chicane section

installed and working with beam as of last week
- vac, quads, steerers, power supplies, BPM buttons, flags, ICTs
- (quads and steerers are from UCLA)

still need-
- steerers need some insulation repair
- flags need adjustment of height
- ICTs need shields (best if DESY does)

still to come-
- chicane magnets - finished-need magnetic measurements
- slits or pepper pots - need to be designed
- electronics-
  - BPM electronics under construction
  - (should hook up French elec from injI operation)
  - Pulse shape electronics for interface to Quick Digitizers
  - existing design under evaluation

RF Input couplers

Will try to supply 8 (not 6) for Module 2.
Emphasis on getting cold ends first.

4 cold ends at DESY
1 to be shipped this week

Axel reports difficulity in getting flange leak tight.
Mark has just last week begun to experience leaks at the cold ceramics and is looking into it.

Modulator

Mod#3 operational - to remain at Fermilab till InjII gun tests complete and Fermi modulator complete.

Mod#4 Dan Wolff and Howie Pfeffer have reviewed the "miss-matched PFN" and think it is an interesting concept.

Fermilab A0 Activities

The first gun system has been taken apart for installation of the Capture Cavity.

Have had numerous vacuum difficulties with the S12 cavity assembly in the vacuum vessel. Especially with the gate valves.

After assembly a N2 leak was found in the cryostat which necessitated removal of the head at one end. This has been fixed and reinstallation of the Capture cavity in the cave will proceed this week.

Development of "modest" infrastructure continues with: water system, cleanroom area, HPR

Gun

Two are under construction(one for DESY, one for FNAL)
-**Gun B3** has been tuned, braise end plates and WG this week
Should be ready for RF tests early April
-**Gun C1** water passages being machined- should be finished and start RF test May-June
-(trouble with e beam weld on the inside disk- produced cracking and vac leaks in guns B1, B2)

Gun System-
solenoids- coils delivered, assembly early April
10 way cross vac box- complete
gun table- in fabrication, due early April
supports- available
diagnostics- BPM, ICT - available
ICT shield, mirror mounts, Faraday Cup - still to design

Plan
is still to test gun, capture cavity, and chicane system at Fermilab prior to installation at Desy.

Outstanding questions- still
Dark current and cathode spring
emittance growth in chicane

Superconducting RF Activities at the I.P.N. Laboratory (CNRS-IN2P3) Orsay - France

Collaboration with the CEA Saclay and LAL (CNRS Orsay)

- New cavity fabrication techniques:

  Copper plasma sprayed Niobium cavities

  ⇒ *Oral presentation (M. Fouaidy, IPN)*

  R&D Cavity Working Group, Tuesday, the 10 th

- Studies on cavity limitations:

  Qo-slope at high fields: thermometric investigations

  ⇒ *Oral presentation (S. Bousson, IPN)*

  R&D Cavity Working Group, Tuesday, the 10 th

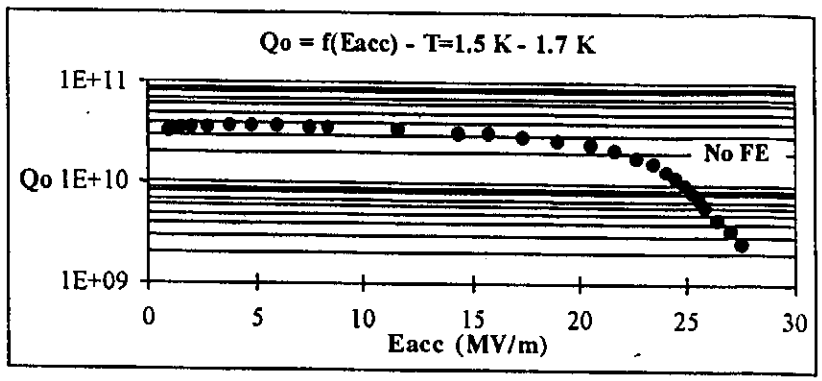
- Cavity test cryostat (CRYHOLAB):

  Horizontal test cryostat for fully equipped 1.3 GHZ, 700 Mhz cavities...

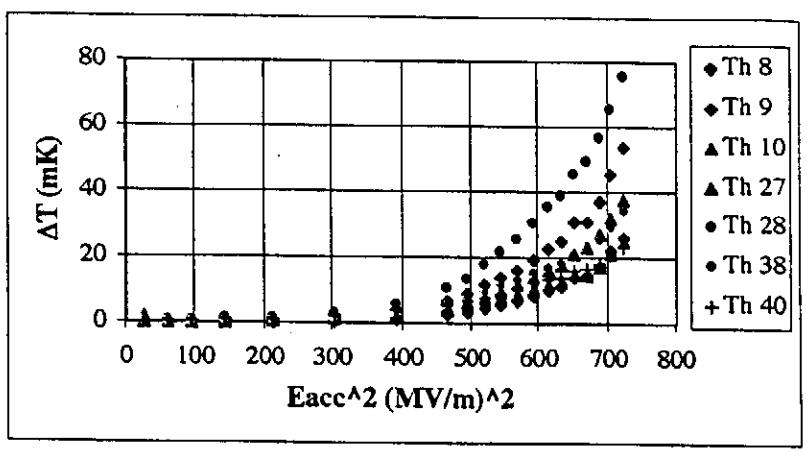
Qo slope at high fields: thermometric investigations

I.P.N. Orsay, CEA Saclay

40 fixed thermometers mounted on single-cell 1.3 Ghz cavities having a strong Qo decrease at high fields with no X-rays detected. Two cavities were tested (C1-05 and C1-10).



Temperature measurements clearly showed non-quadratic heatings versus the accelerating field.

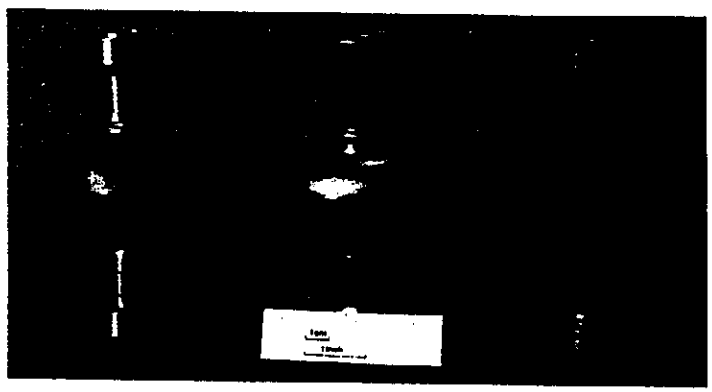


Copper Plasma Sprayed Niobium Cavities

I.P.N. Orsay, LAL Orsay, CEA Saclay

Goal: Fabrication of 1.3. Ghz multicell cavities stiffened with copper deposited by plasma spraying onto Niobium.

First studies: Five 3 Ghz Niobium cavities fabricated by L.A.L.: 0.5 mm thickness, initial RRR = 40, HT at 1200 °C with Ti gettering before plasma spraying (2mm deposited).



First RF tests results:

	Before Cu deposition	With Cu
Cavity # 4	Eacc max = 16.5 MV/m FE, X-rays	Eacc max = 16.5 MV/m no FE
Cavity # 5	Eacc max = 14.5 MV/m no FE	Eacc max = 13.5 MV/m no FE

The cavity performances (Eacc max) are not (or very slightly) affected by the copper deposition.

Global thermal resistance measurements:
The comparison of the global thermal resistance of Nb and Nb/Cu samples tested with a new dedicated experimental cell showed an increase of this parameter.

Numerical simulations of the detuning due to Lorentz forces for bulk Nb and Nb/Cu cavities:

- Show the efficiency of the stiffening obtained with the copper layer.
- Runs are actually performed to find an optimum copper layer shape with 1 mm Nb thickness.

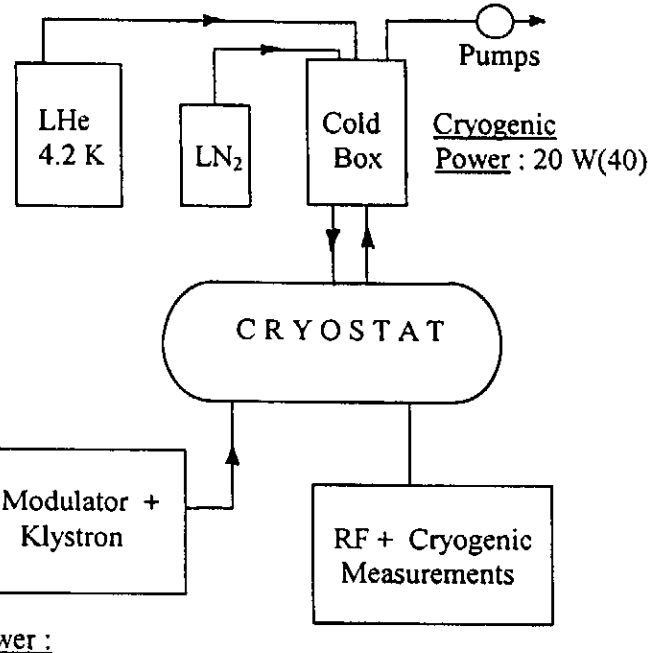
Near Future Study Program:

- The last two 3 Ghz cavities will soon be tested.
- Fabrication of 1.3 Ghz monocell and multicell cavities from RRR≈200 Nb sheets of 1 mm thickness. RF tests before/after copper deposition.
- Mechanical and thermal characterization of samples produced with different deposition parameters.

[redacted]

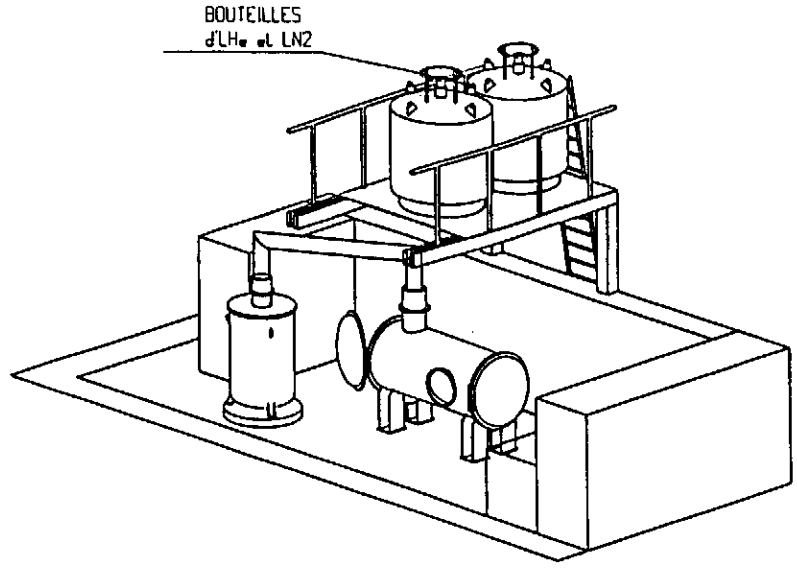
(CRYHOLAB)

- Test of fully equipped cavities (1.3 GHz, 700 MHz, ...) with Helium Tank, Power and HOM couplers, Tuner,...

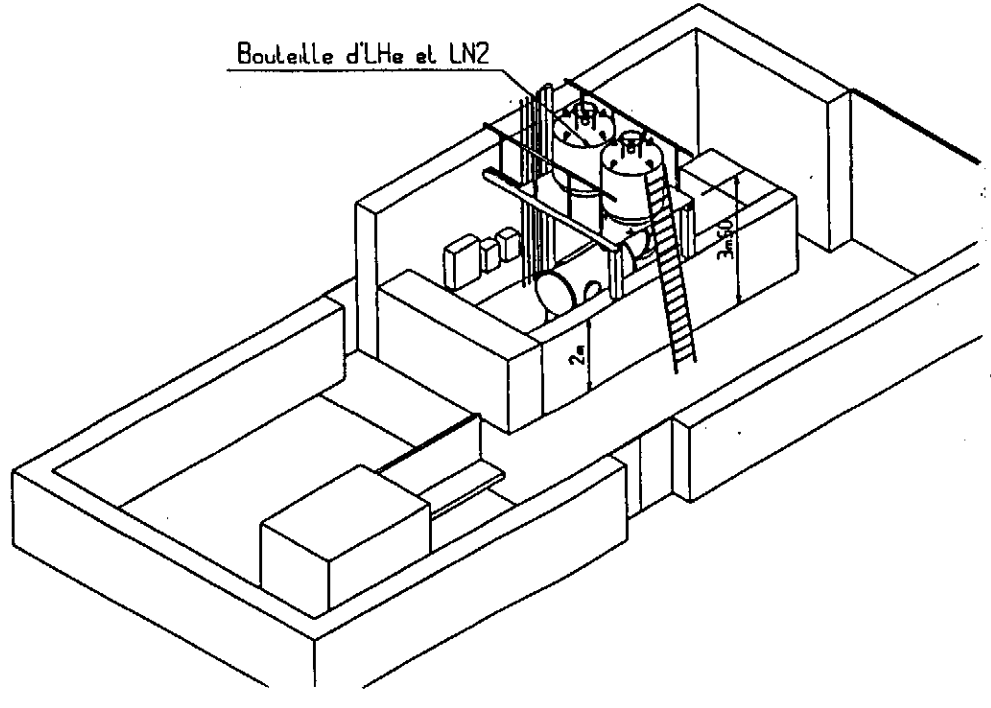


RF Power :

1) 300 KW (10 Hz, 2 ms)
2) 1 MW (1 Hz, 0.5 ms)



IMPLANTATION DE CRYHOLAB



Power Coupler Development

(collaboration Saclay - Orsay)

S. Buhler, S. Chel, M. Desmons, C. Dupery, T. Garvey, P. Lepercq, A. Mosnier, R. Panvier, Ch. Travier.

Ch. Travier will present status in R&D meeting.

End 95 - Installation of High Power test bench equipped with diagnostics (RF, electron, vacuum, optical). 1.5 MW, 0.1 Hz klystron.

- Test of high power waveguide windows.

1996 multipactor calculations
investigations of copper plating techniques
Waveguide to co-axial line transition designs

- Test of Saclay "doorknob" transition (C. Dupery).

1997

- Test of reduced height waveguide transition ϕ 40
- Test of tapered co-axial line ϕ 60 - ϕ 40
- Test of sliding RF contact [for Telescopic Coupler]
- Test of 'reference' window (FNAL conical) in SW and TW

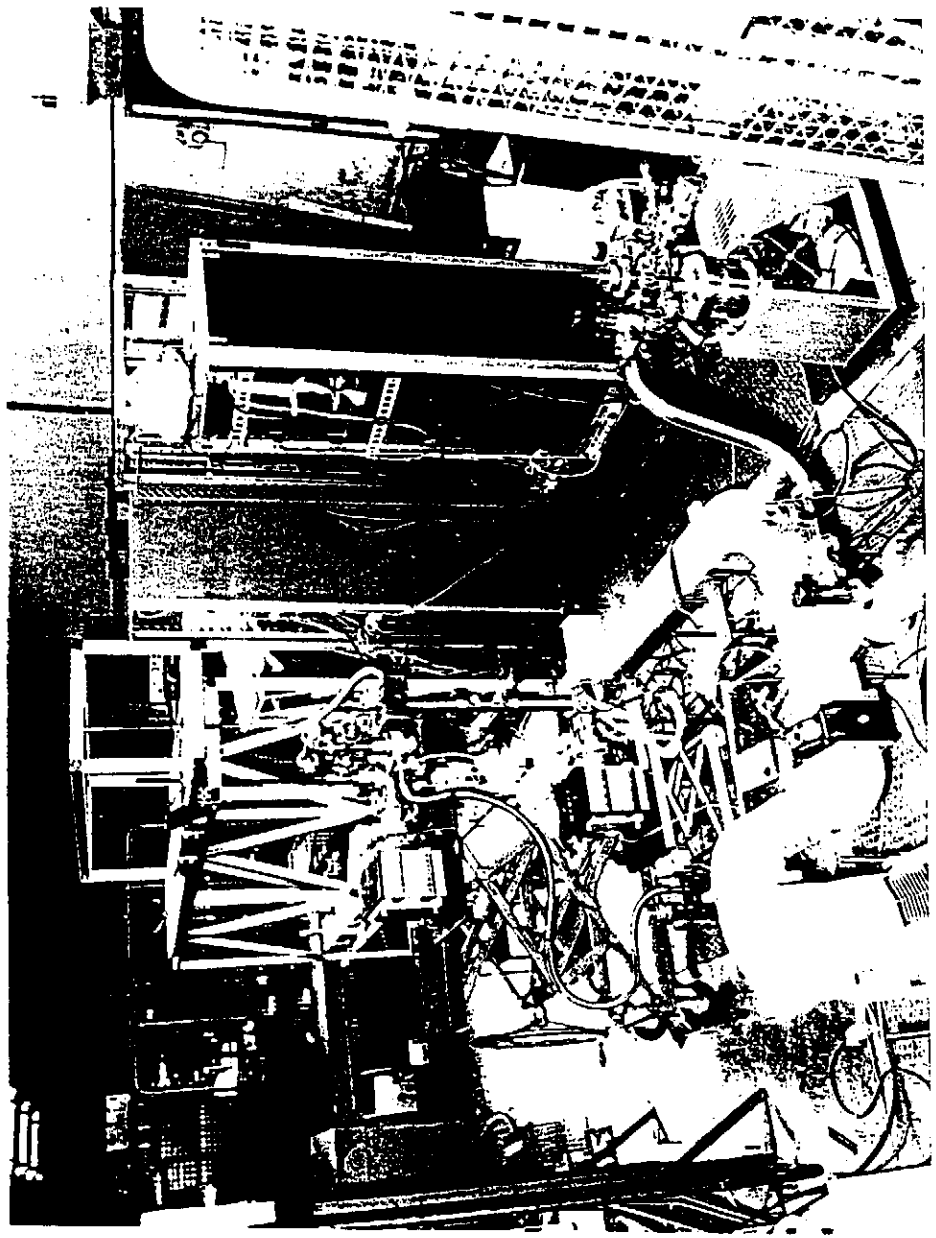
1998

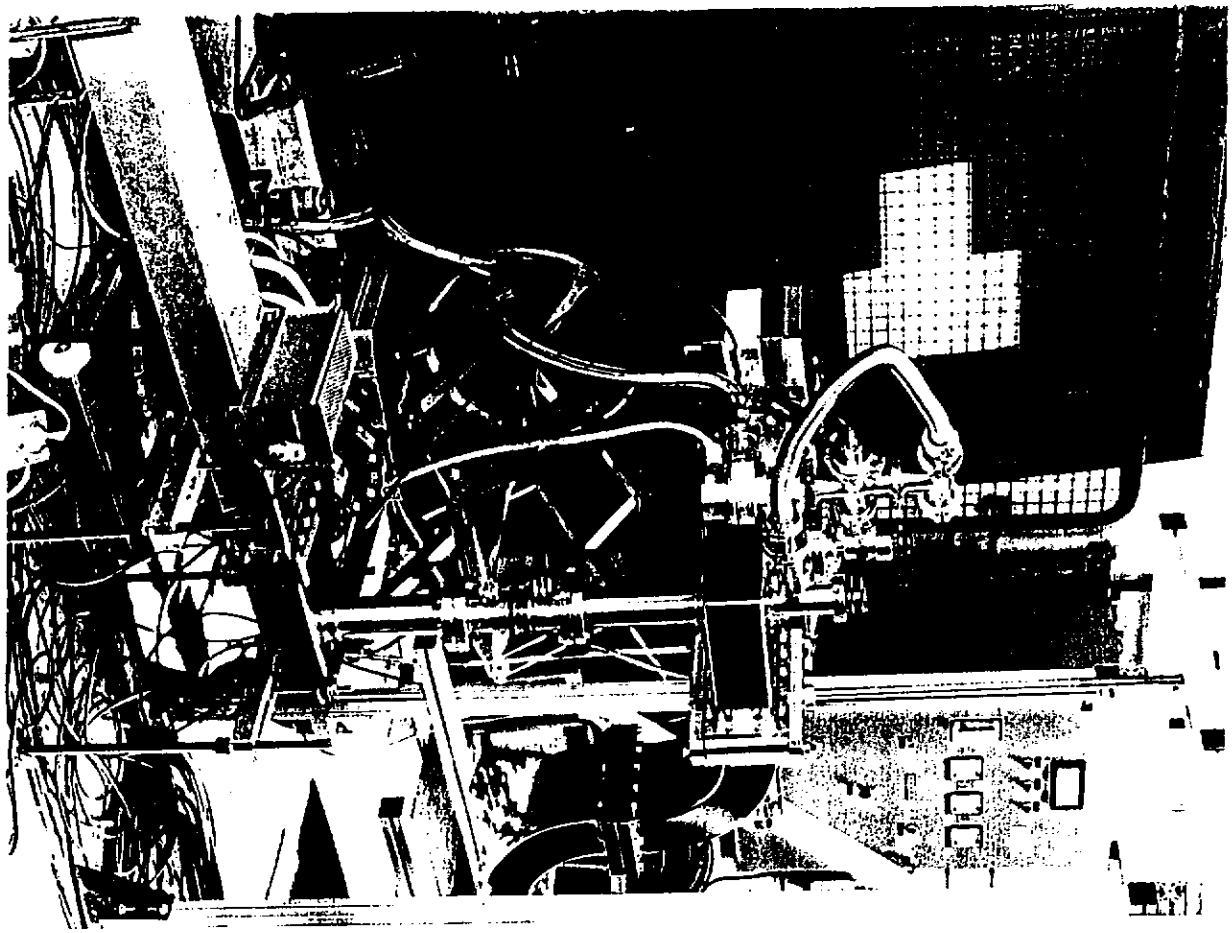
- Test of antenna transition (for use with biased transitions)

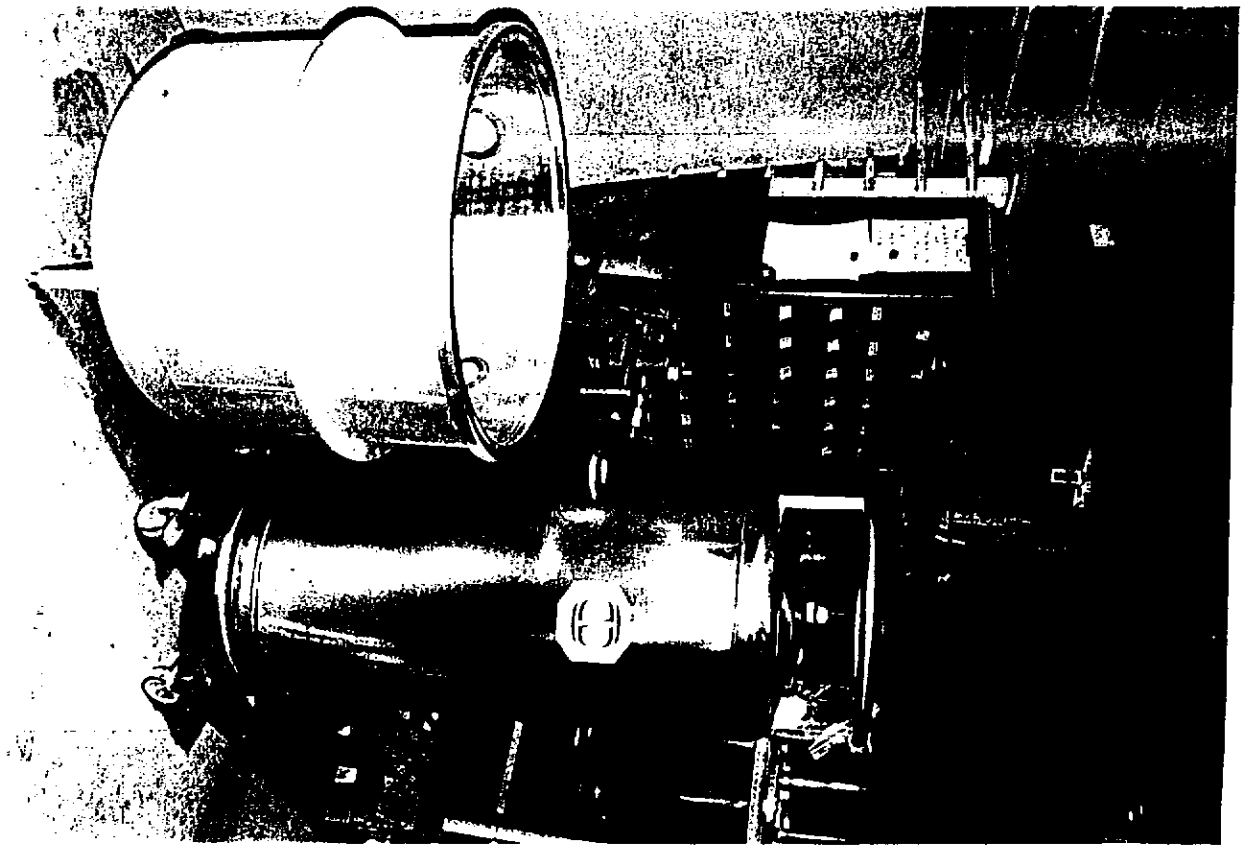
Each test is lengthy due to 0.1 Hz operation and need to sweep frequency power and pulse width.

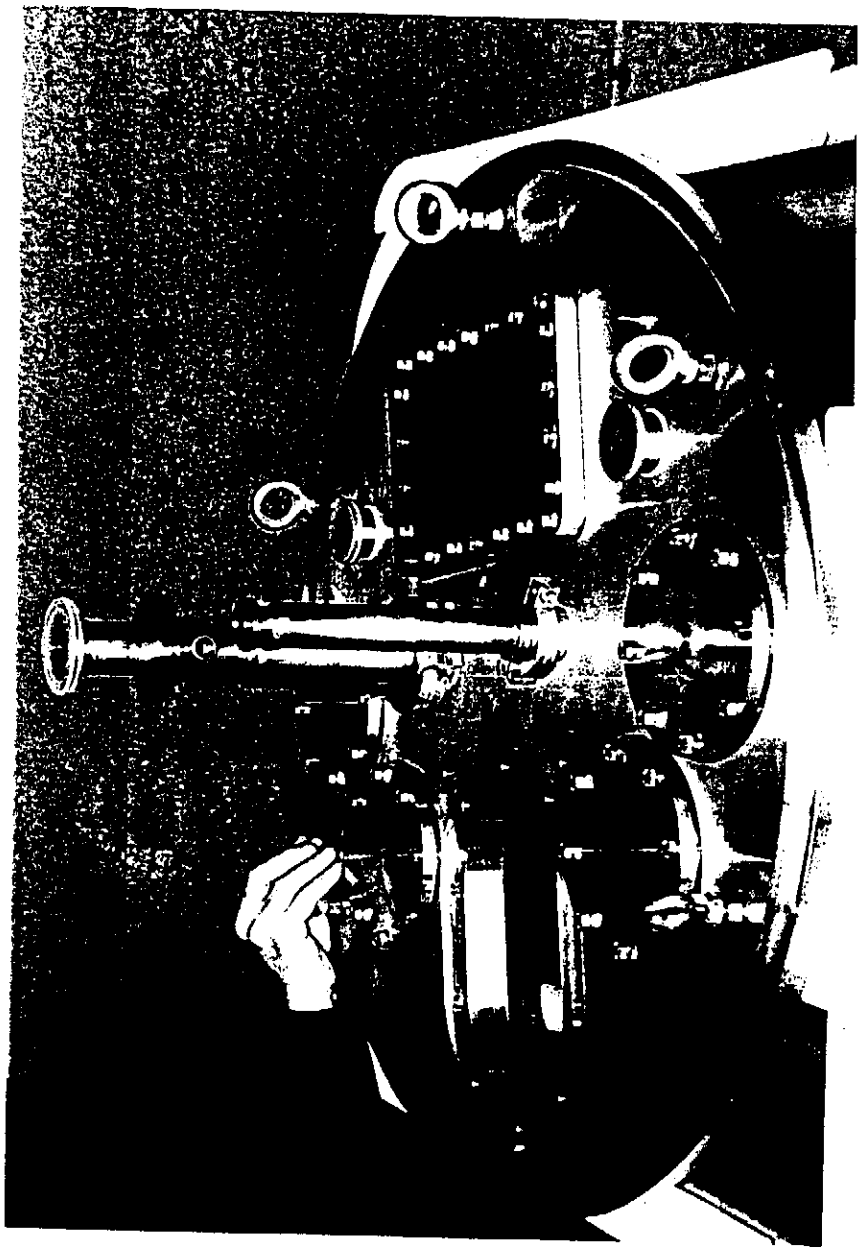
Near future -

Installation of 70 K Cryostat (S. Buhler, R. Panvier)
Test new Saclay window designs ($\lambda/2$, TW.....)
Test LAL DC biased transition.







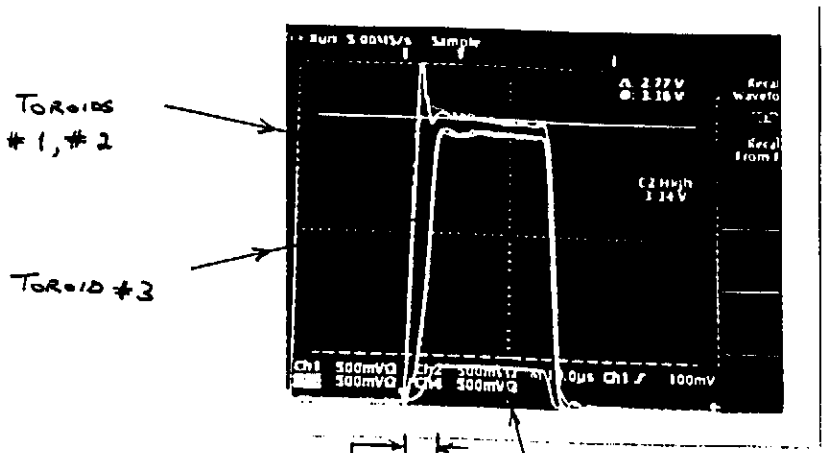


Injector Start-up

B. Anne'
M. Desmons
J. Fuselier
T. Garvey
M. Jablonka
S. Schrieber

Since last meeting - (i) cathode changed
(ii) FNAL/UCLA sector 400 installed.

"Teething" problems – control of flags
– magnet settings



Rise-time difference due to beam loading
→ Corrected using "phase-jump".

Beam dump signal! → adjust optic to make it equal to toroid #3 signal.

- Transition toroid #1 → toroid #3 ~ 97%
- 100% transmission to VS4 ↳ Still some "fine-tuning" needed!
- Nice spectra obtained on SEM-grid.
- Less persistance on VS of analysing line
- Reliable computer control of SHB
- More operator friendly system for CAPCAV.

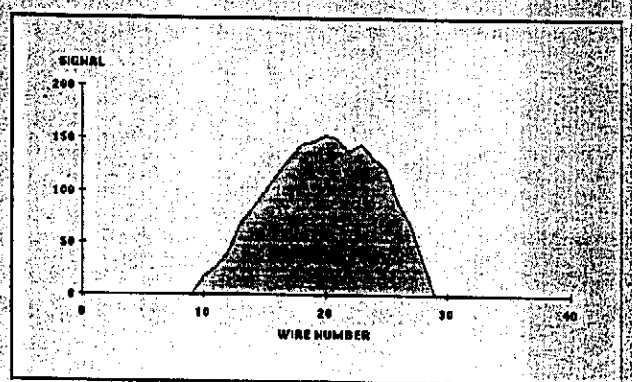
⇒ Encouraging re-start given modifications during 5 month shutdown!

Mar 6, 1998 15:41:31

Noise Profile...

Save Profile...

S.E.M. grid 2INJ1



SAMPLING

0.0 11.9 1000.0

Delay

0.0 119.0 1000.0

Width

VGA start: 1016
VGA length: 1000
DT6: 1135

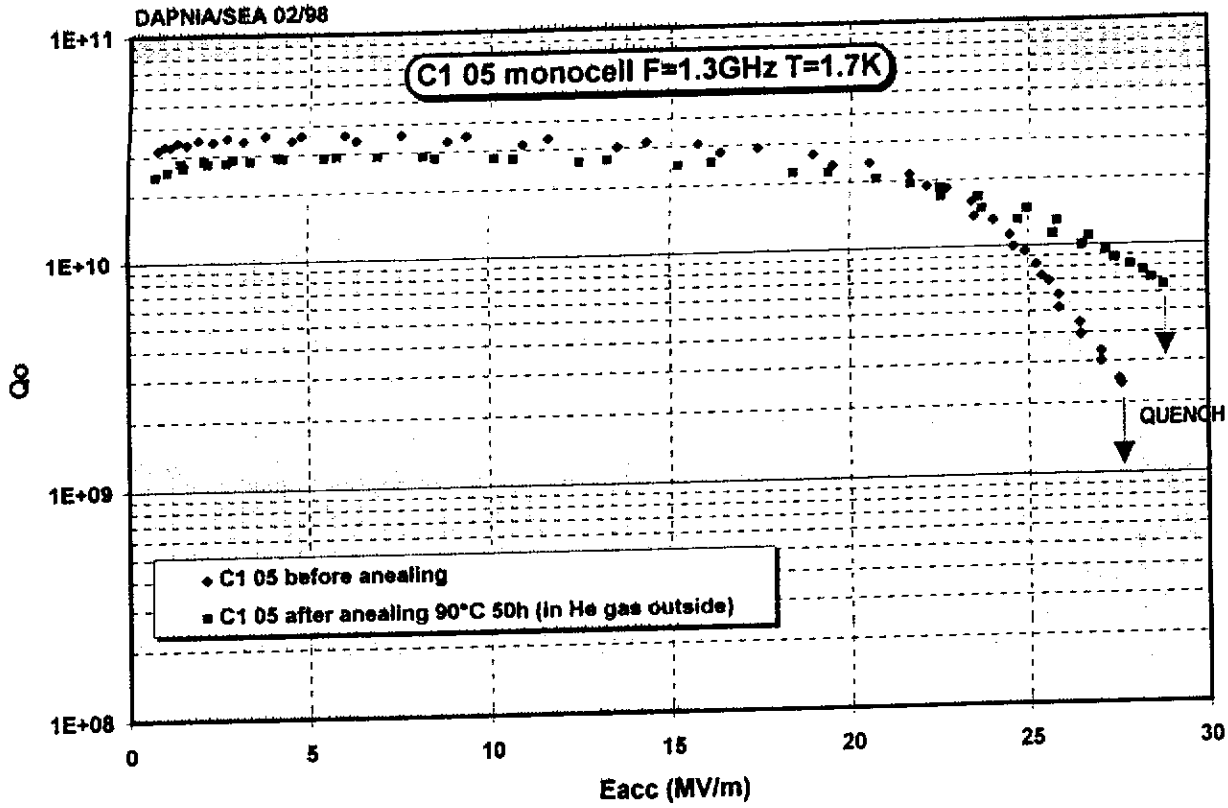
Gain: 4 #Samples: 5 Subtract Noise No Yes

Dipole 9.408 A
Trim Coil −0.104 A
B0 1.1 Gauss
B Hall 0.2 Gauss
Energy 0.00 MeV

Area 3798 Mean 0.77 mm

	mm	%	keV
Sigma	8.56	0.53	0.00
FWHM	26.12	1.61	0.01
Width 90%	27.92	1.72	0.01

65



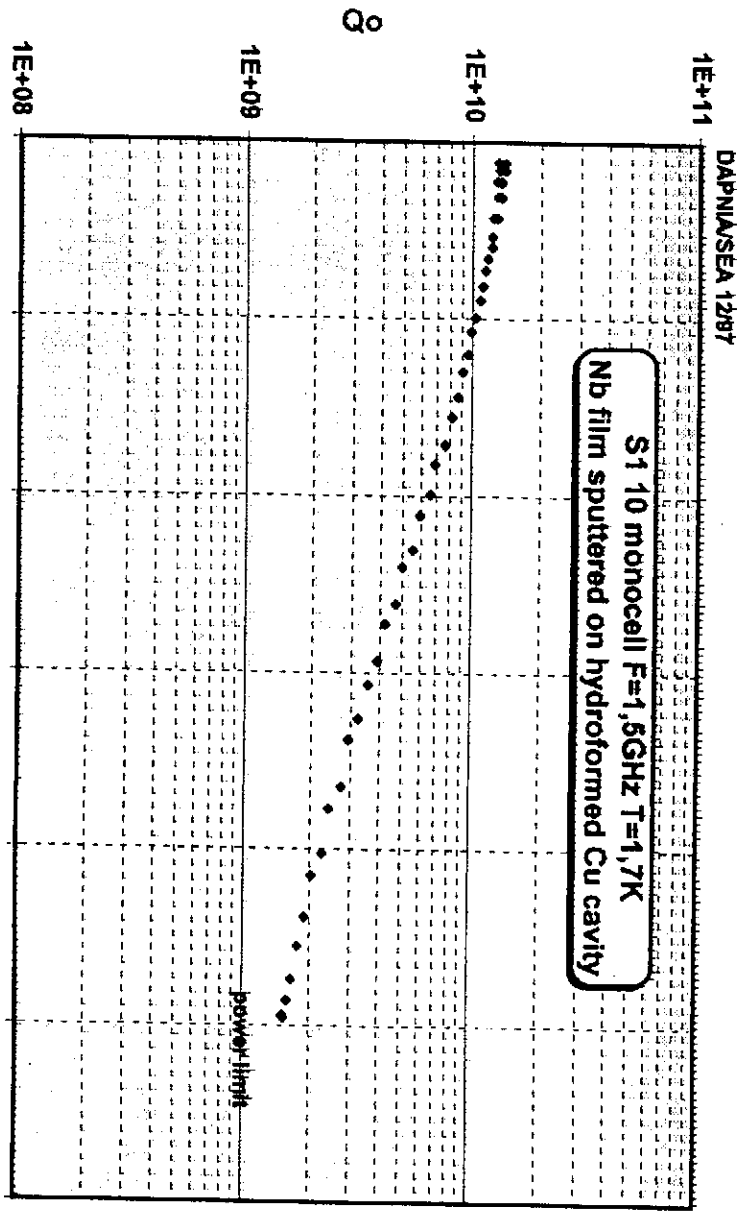
Sacleay Report

- R/D on SRF
- R/D on Couplers
- Beam dynamics
- Components for TTF

Hydroforming

- 2 single cell Cu 1.3 GHz
- 1 single cell Nb " will be tested
  - RRR 20
  - 5 intermediate annealing.

- New tube from RRR200 ingot (Cabot) under fabrication (better isotropy)
- Fabrication of single cell (June)



No e^-. Rinsing 30 bar

Power coupler development

- Test stand is being upgraded
  - cryostat → test elements at 70k
  - second test line → increase number of tests.

⇒ **ready in APRIL**

- New windows are studied
  - $\lambda/2$ window is already fabricated
    ↳ test in April
  - Travelling wave window is studied (3 # designs)
  - TiN coating is investigated (RBS, resistivity measurements)
  - complete coupler design will start soon

Beam Dynamics

* TESLA

→ check of parameters for high α (Alban Mosnier)

→ Fast α monitor based on e^+e^- pair calorimetry (Olivier Napoly / Daniel Schulte)

* TTF Experiments (Stéphane Fartoukh)

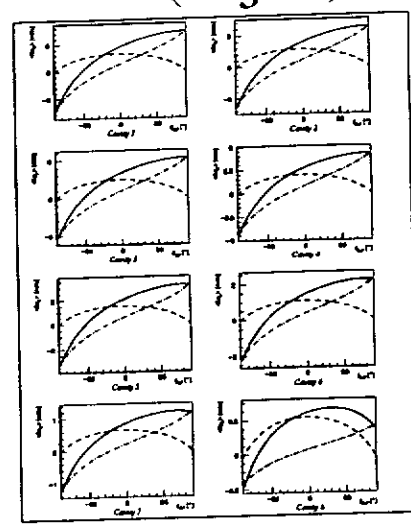
- RF Steering
- Multibunch
  - × V. Balakin
  - × A. Mosnier

RF steering experiment (inj. I)

Hamburg, March 1998

- Two main sources of RF deflections
  - **Cavity misalignments**: effects quasi-independent of the sign of the RF phase.
  - **Coupler effects** proportional to the accelerating gradient and out-of-phase with respect to the accelerating wave:

$$\delta p_\perp = T\,\frac{\Delta E}{E}\,\cos(\phi_{rf} - \phi_0) \quad \text{at the exit of each cavity}$$

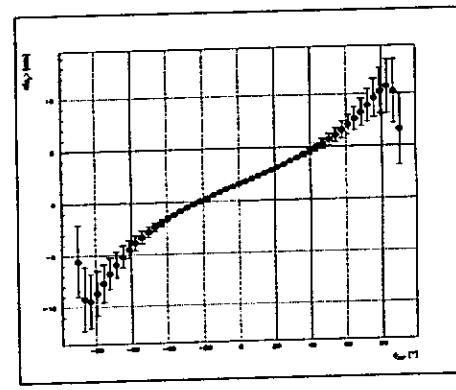


Module ACC1:
E_{in} = 12 MeV
G_{rf} = 15 MV/m
T = 0.66 mrad
ϕ_0 = 68°
------ : only cavity tilt α = 1 mrad
-·-·-·- : only coupler
——— : cavity tilt ⊕ coupler

- Experiments
  1. select one cavity in module ACC1 and detune the other.
  2. vary ϕ_{rf} in the selected cavity and keep the accelerating gradient constant
  3. monitor the beam position vs. ϕ_{rf} at BPM.
  4. Compute the slope at $\phi_{rf} = 0$ of the curve obtained which is proportional to $T.\sin\phi_0$.

or/ and

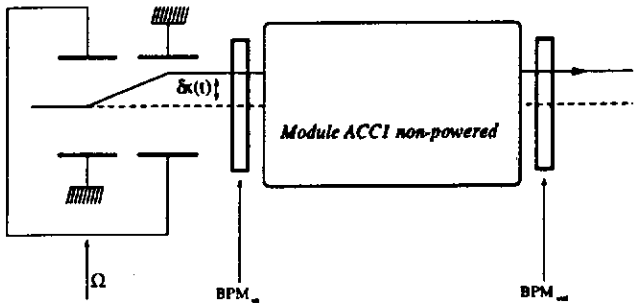
Same experiment with the whole module ACC1.



σ_α = 1 mrad
σ_{dx} = 0.5 mm

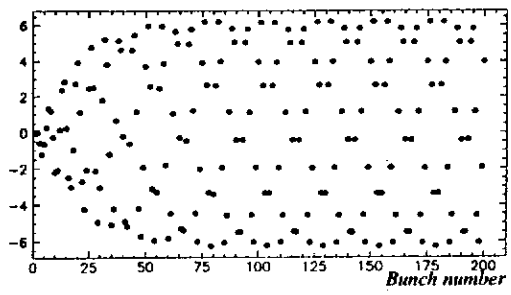
S. Fartoukh
Hamburg, March 1998

Experiment II (V. Balakin)

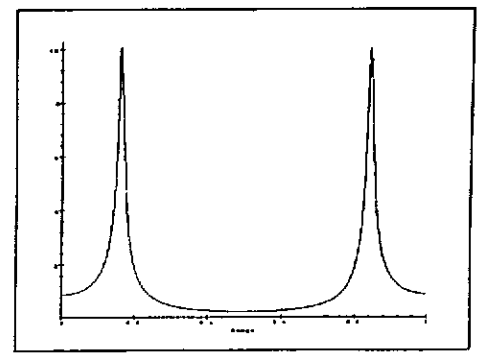


Vary $\Omega \Rightarrow$ Resonance of mode ω at $\omega \pm \Omega_{res} = n\,\omega_b$

$$\delta x_{k,0} = \delta x_0 \sin(k\,\Omega T) \Rightarrow \delta x_{k,BPM} - \delta x_{k,0} \propto \delta x_0 \frac{Q_b}{E_0} \sum_{\substack{\alpha \in \text{modes} \\ i \in \text{cavities}}} \left(\frac{R}{Q}\right)_{\alpha,i} L_{i\to BPM}\, p_r(\omega_{\alpha,i},\Omega)\, \sin(k\,\Omega T - \varphi(\omega_{\alpha,i},\Omega))$$



Signal amplification at BPM location; initial modulation of 10 mm; Q_b = 8 nC; Q-tuned to the TM_{110} mode at 1875 MHz of the first cavity, idle module

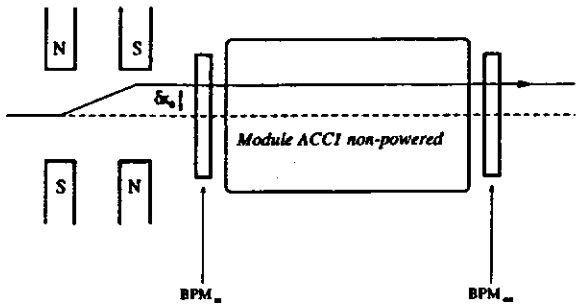


$P_r(\Omega)$ in the range 0-1MHz for the TM_{110} mode (Q = 1.2 10^5).
$P_{max} = Q/(2n\pi) \approx 10$ ($\omega = \pi/2$ at resonance)

Multi-bunch experiments (Inj. II)

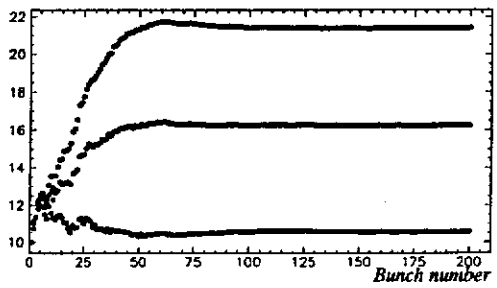
S. Fartoukh
Hamburg, March 1998

Experiment I (A. Mosnier)

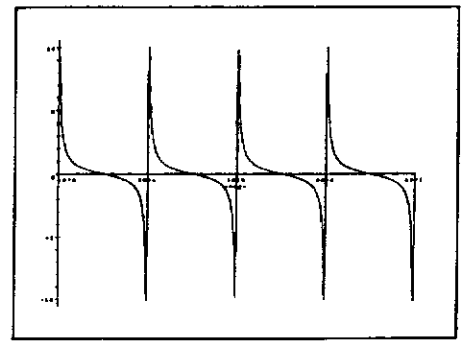


Actuate the cavity tuning system
⇒ Resonance of mode ω at
$\omega_{res} = n\,\omega_b\,(1 \pm 1/2Q)$

$$\delta x_{k,0} = \delta x_0 \Rightarrow \delta x_{k,\mathrm{BPM}} - \delta x_0 \propto \delta x_0 \frac{Q_b}{E_0} \sum_{\substack{\alpha \in \mathrm{modes} \\ i \in \mathrm{cavities}}} \left(\frac{R}{Q}\right)_{\alpha,i} L_{i \to \mathrm{BPM}}\, \mathrm{p_r}(Q_{\alpha,i}, \omega_{\alpha,i})$$



Bunch train at BPM location; bunch injected 10 mm off-axis, Q_b = 8 nC; 0,1 or 2 cavities tuned to the TM_{110} mode, idle module



$P_r(\omega)$ in the range 1873-1877 MHz for the TM_{110} mode ($Q = 1.2\ 10^5$).
$P_r^{max} = Q/(2n\pi) \approx 10$

Tuners

- Fabrication of 20 tuners (modules 2 & 3)
  - 8 Gear boxes with 'good' machined delivered week 14 (1/4)
    ⇒ available after TiN coating ⇒ 15/4
  - 12 Gear boxes 3 weeks later
  - Mechanics: delay
    - first 2 systems delivered week 11
    - 4 week 13 (end March)
- Dampers, experiments
  → At DESY, use of elliptical rotor ⇒ OK
  → modification in power supply (less power dissipated in the motor)

DOG-LEG for Injector

Delivery: mid-April
(length = 400 mm, aperture = 65 mm)

HOM Couplers (modules 2-3)

- Niobium

  - flanges on cavities : available
  - couplers : $\boxed{\text{delay}}$

  ⇒ 8 couplers September
  12 " October

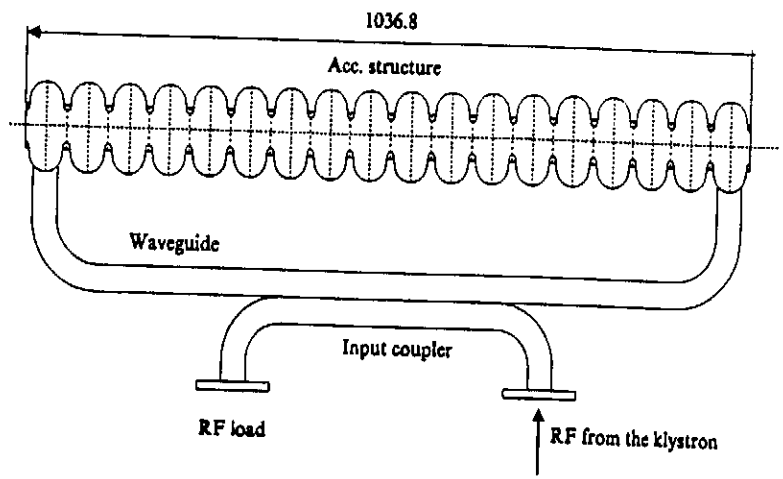
(These couplers will be used on CERCA and ZANON cavities (new series))

Some Estimations of SC structure with a high accelerating gradient

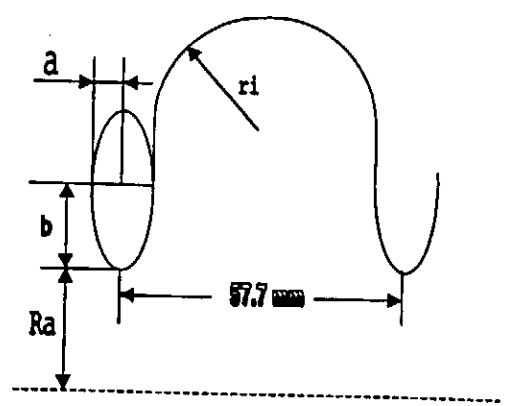
Avrakhov P.V., Balakin V.E., Solyak N.A.
BINP, Protvino, Russia

Travelling Wave Structure

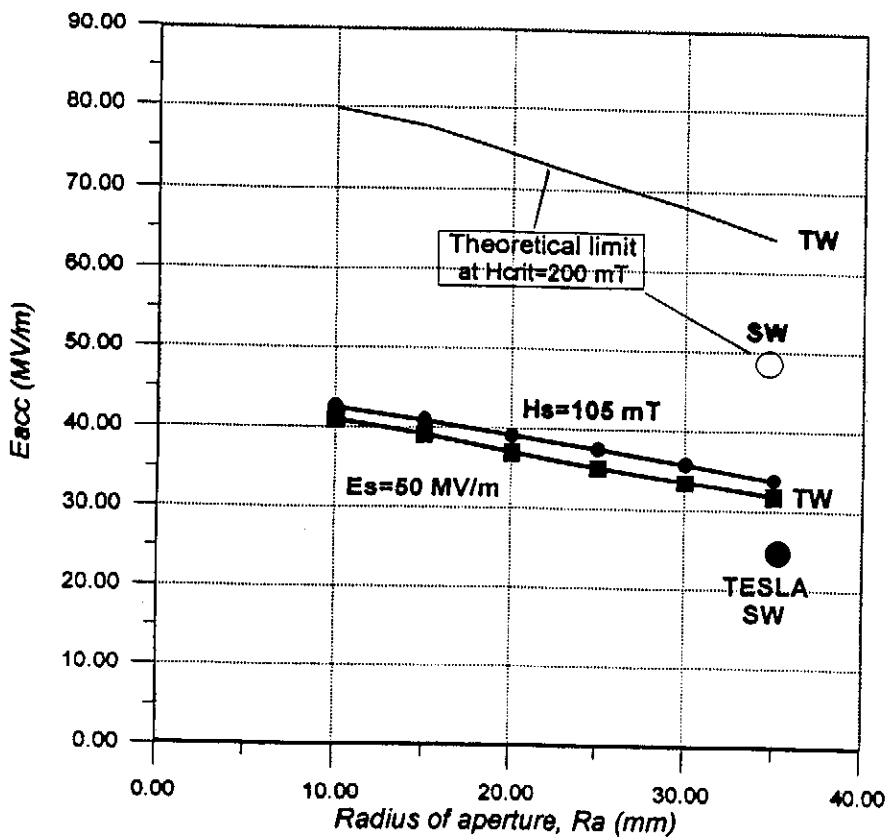
$\pi/2$–mode structure in TWR



Cell geometry



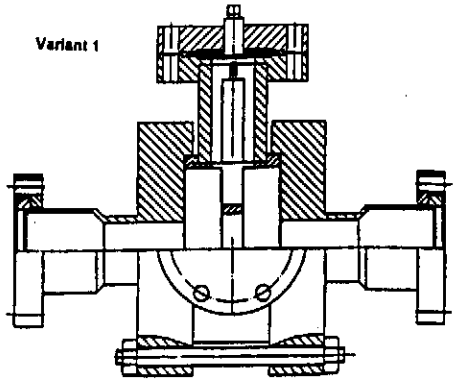
Accelerating gradient of TW structure vs. aperture radius



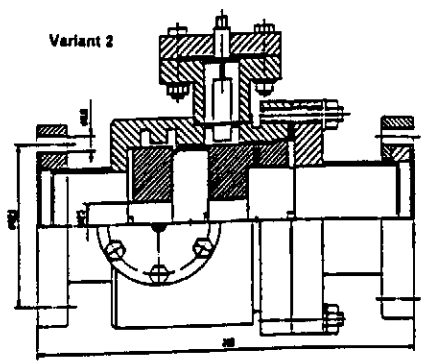
Problems:

- Beam dynamics (wake-fields)
- Supporting of TW regime (Reflection)
- Technology of producing TW structure
- ...

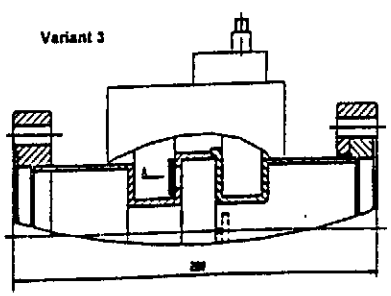
Variant 1



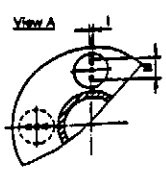
Variant 2



Variant 3



View A



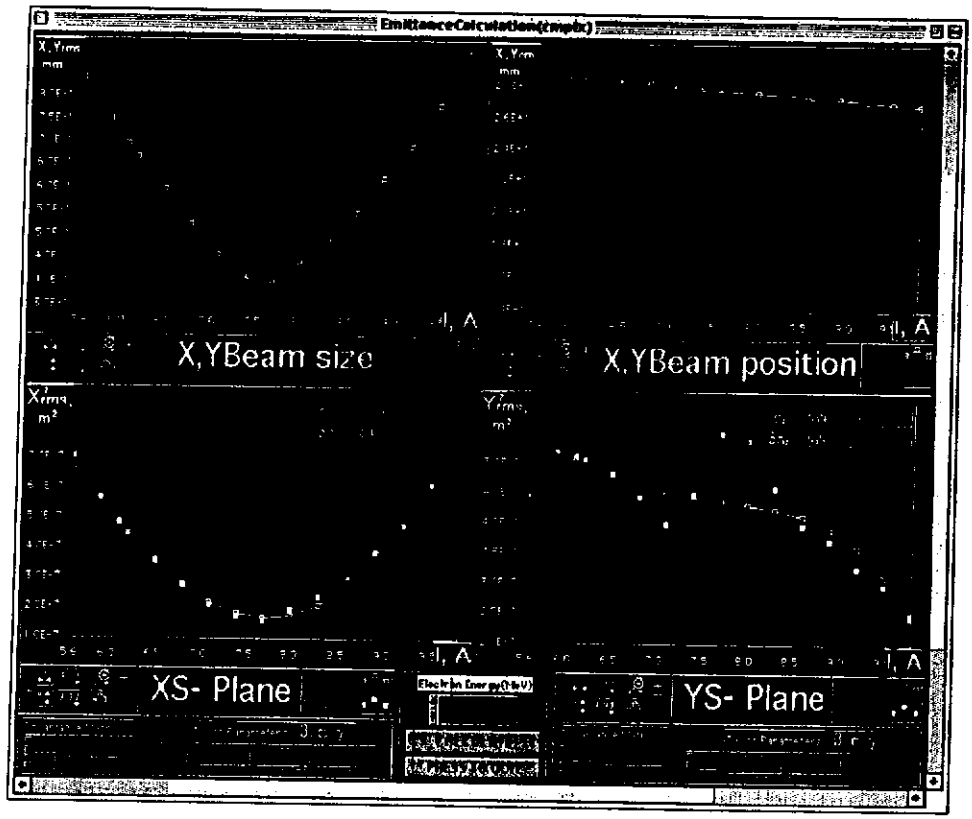
Beam Diagnostics Status and Perspectives

M. Castellano

LNF-INFN

- " Standard" OTR diagnostics
  - three stations have been heavily shielded (BC, 3EXP1, 1EXP3). They have also a much more elegant cover.
  - in these stations Intensified Camera is now usable: time resolved measurements of beam size, position, emittance, energy and energy spread
  - emittance measurement procedure in a given position (i.e. 3EXP1) has been simplified. With a standard CCD camera it will take a few minutes (must be tested with a real beam). It will be possible to correlate emittance to the change of other parameters (RF, transport optics etc)
  - Objectives in the shielded stations can now be controlled from the Control Room (zoom, focus and iris aperture)

- New injector I diagnostics
  - Two stations with stepping motor actuators are now installed in sector 400 (a ceramic screen and a Cerenkov radiator) and can be controlled in the same way as other motorized stations (but only one screen is present).
  - The video signals from all the new stations in the injector may be connected to the video multiplexer and images can be seen and analyzed by the already existing instruments.


X,YBeam size
X,YBeam position
XS- Plane
YS- Plane

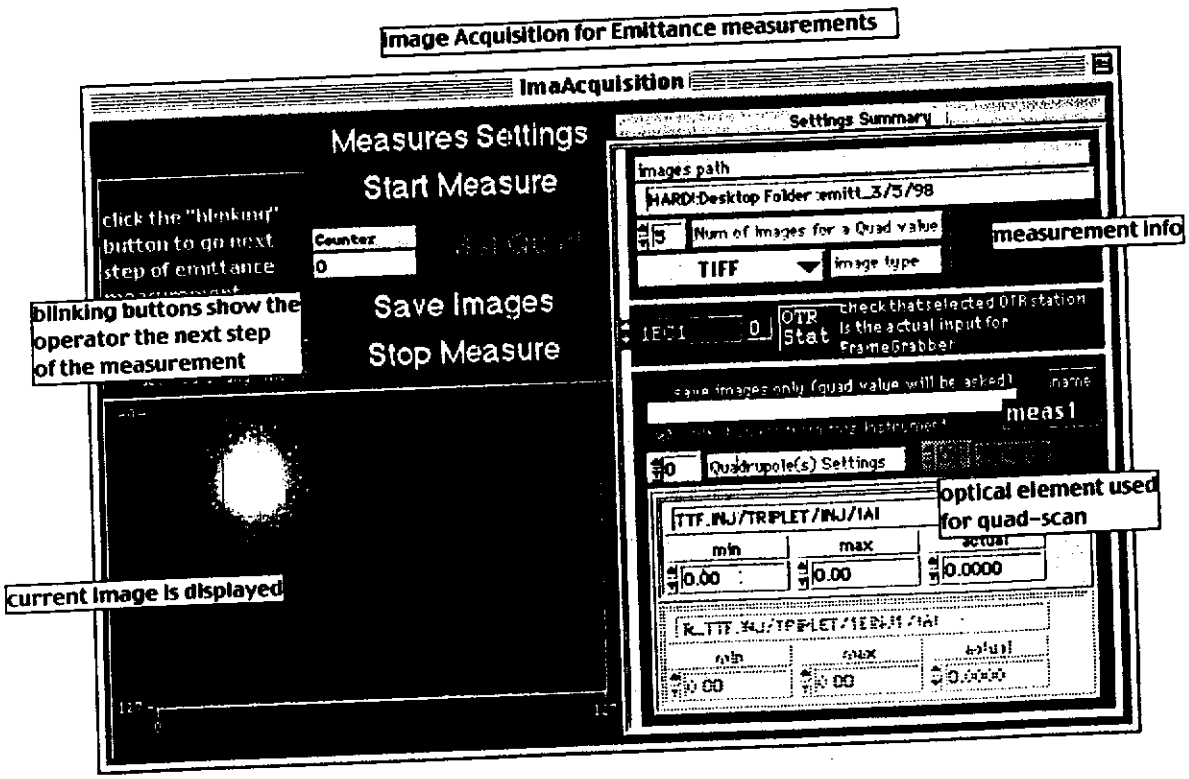
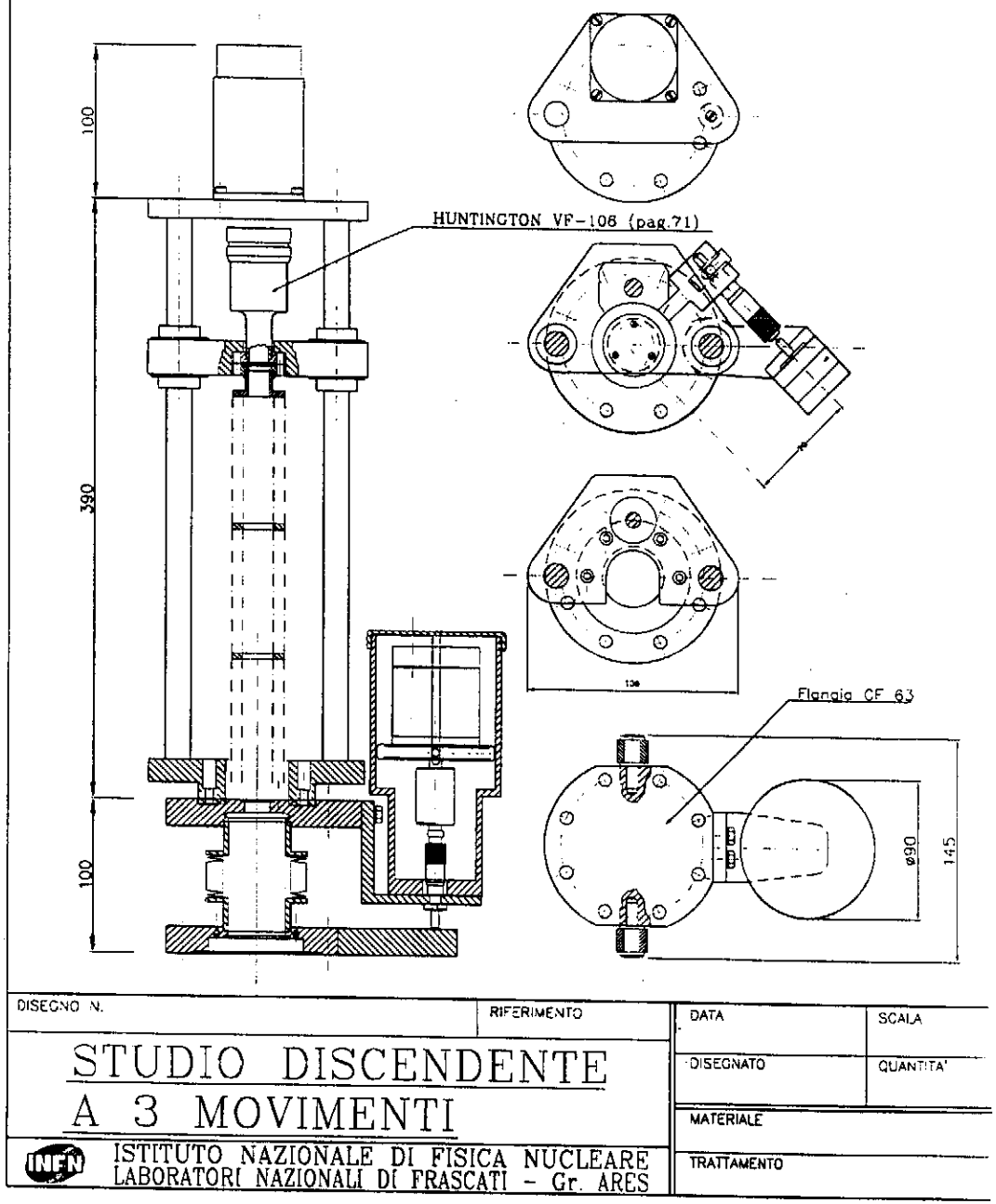


Image Acquisition for Emittance measurements
ImaAcquisition
Measures Settings
Start Measure
click the "blinking" button to go next step of emittance
Counter
0
Save Images
Stop Measure
blinking buttons show the operator the next step of the measurement
current image is displayed
Settings Summary
Images path
HARD:Desktop Folder:emitt_3/5/98
Num of Images for a Quad value
TIFF
image type
measurement info
OTR Stat
check that selected OTR station is the actual input for FrameGrabber
meas1
Quadrupole(s) Settings
optical element used for quad-scan
TTF.INJ/TRIPLET/INJ/1AI
min
max
actual
0.00
0.00
0.0000

- In front of the Cerenkov, a standard CCD camera on a shielded optical table may allow the emittance measurement.

- Injector II diagnostics
  - Four motorized stations are in construction. Each of them will carry more than one screen (OTR, Ceramic, Cerenkov, YAG...?, it must still be defined)
  - A special station is in construction for the pepper-pot slit, but with space for other kind of screens. It must be fully tested in laboratory before installation
  - The Intensified Camera will be needed for single pulse measurements, and the lay-out (position, optics, cabling etc) must be defined

- Bunch Compressor diagnostics
  - A special OTR screen, 10 cm long, is in the design phase. A large window and a movable CCD camera are necessary to cover the large span of the beam with enough resolution
  - This screen, a perfect mirror for infrared radiation, can allow the detection of "edge" radiation from the compressor dipoles, but the interference with the same wavelength OTR radiation must be taken into account



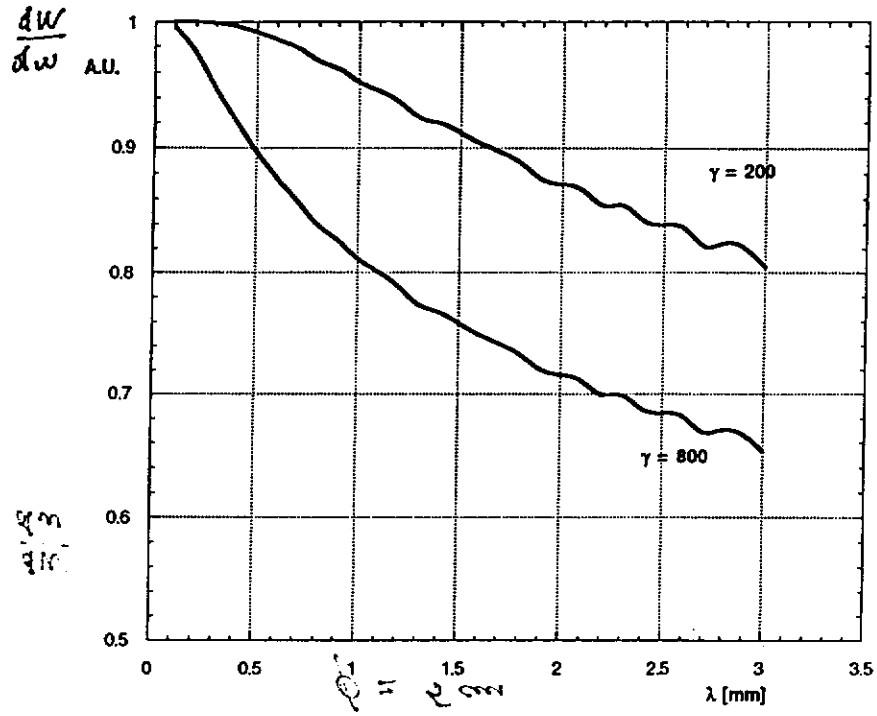
- Strip line electronics
  - The ofset of the strip line electronics has been measured again. Small variations has been found for all but for a single unit. The new values must be inserted for on-line subtraction in the control system. If a very accurate measurement is needed, the real time calibration option must be putted in operation. It requires on/off RF distribution to all the modules

- Bunch length measurement
  - A very precise slit system is being designed for Coherent Diffraction Radiation based bunch length measurement with high density beam (injector II and cryomodules 2 and 3)
  - The effect of the finite size of the screen must be evaluated, even for the Coherent Transition Radiation

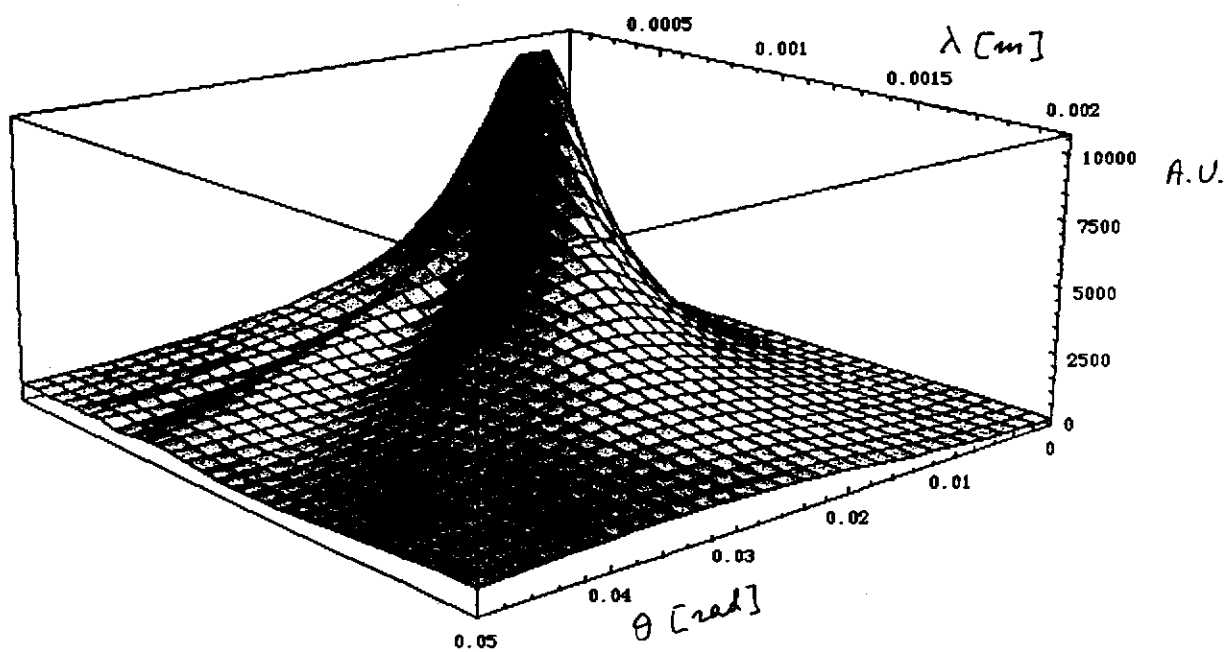
Preparato da I N F.N. 06/03/98

Position	Cable	BPM I.N.F.N.		V(mV) Offset DESY 25/10/1996	V(mV) Offset DESY 25/02/1998	Differenza
Container	EXP1A	2	Hor.:	-4,5	7,0	11,5
			Vert.:	10,5	-0,5	11,0
Container	EXP1C	3	Hor.:	16,0	17,3	1,3
			Vert.:	11,5	8,9	2,6
Container	EXP1B	4	Hor.:	14,0	13,3	0,7
			Vert.:	-19,0	-28,4	9,4
Container	EXP2	5	Hor.:	27,0	-7,2	34,2
			Vert.:	23,0	24,4	1,4
Container	EXP1D	6	Hor.:	30,0	26,5	3,5
			Vert.:	23,0	18,3	4,7
Linac	BC	7	Hor.:	24,5	28,1	2,6
			Vert.:	6,0	1,0	5,0
Linac	ACC2	8	Hor.:	31,0	24,5	6,5
			Vert.:	2,5	1,7	0,8
Linac	ACC3	9	Hor.:	-4,5	-5,0	0,5
			Vert.:	-9,0	-7,5	1,5
Linac	ACC4	10	Hor.:	15,5	16,4	0,9
			Vert.:	12,5	16,5	4,0

$\phi = 5\,cm$



$\gamma = 200 \qquad \phi = 5\,cm$



Cryogenic Supply of TTF/FEL Linac (Phase II)

status: 6.3.1998
DESY –MKS-
B.Petersen

Objectives:

supply of the TTF/FEL linac (8-10 modules) incl. SMES

in parallel operation of:
single cavity tests
single module test

Basic Ideas of the FEL-Cryo Supply:

Capacity of the 900 W / 4.5 K Plant <u>not</u> sufficient

5 K / 4.5 K & 40K / 80 K
Connection to HERA-Plant

2cd <u>warm</u> Helium Compressor Assembly

Keep the TTF-Linac He-Distribution

900 W Plant Operation in parallel

FEL Cryogenic Supply
Main Components

HERA-FEL Distribution Box
HERA-FEL Transferline
FEL Precooler & Distribution Box
HERA-FEL Warm Gas Connection
Helium Compressor Assembly
FEL-Cryo Hall

..... + some transfelines & warm tubing
incl. BCBTL No 2 !

TTF/FEL –Linac („phase II“)
Heat Loads

circuit	40/80 K shield	4,5 K shield	2,0 K bath cooling	2,0 K pumped mass flow	4,5 K liquef action rate
unit	Watt	Watt	Watt	g/s	g/s
FEL calculated	1887	580	120	6.1	2.3
FEL design	2831	870	180	9.2	3.5
resulting heat load (design)	2831	1050			3.5

Large Low Pressure Heat Exchanger included!

reserve capacities of HERA cold boxes (without lumi upgrade)

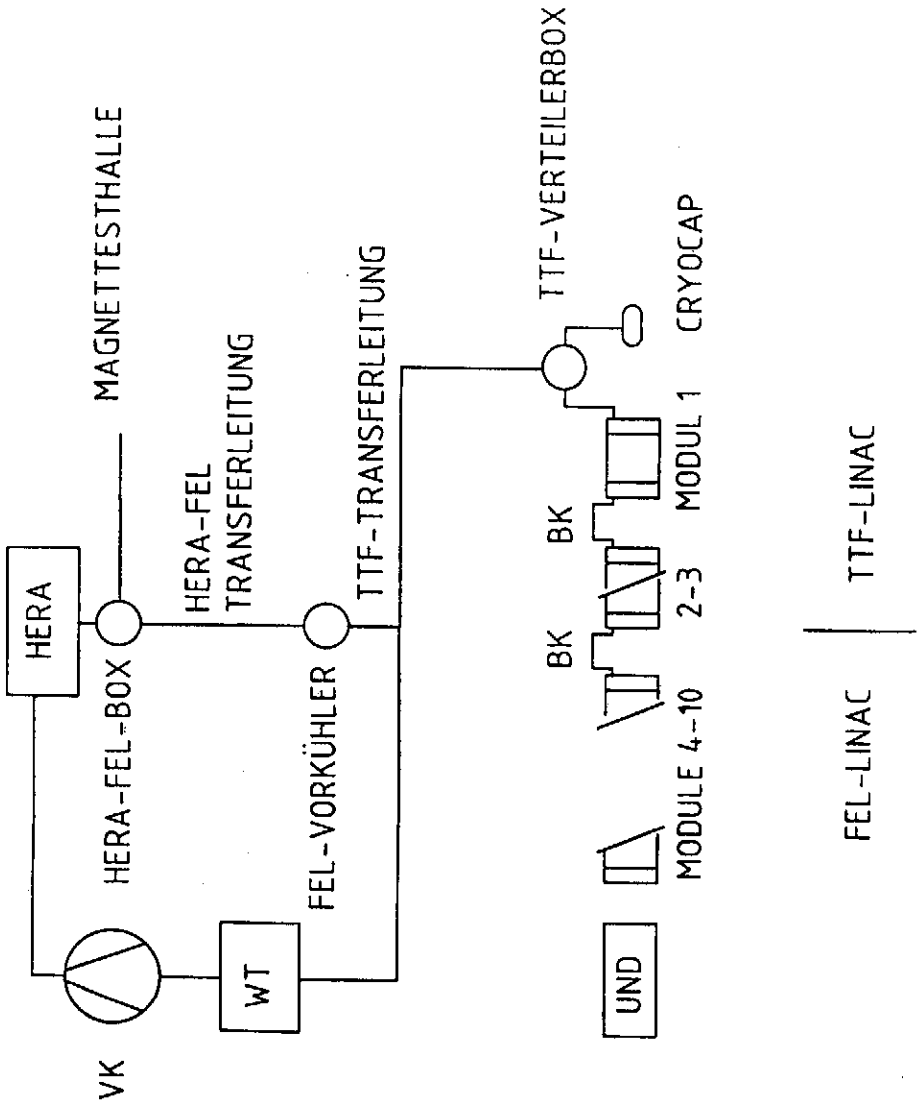
circuit	4,5 K refrigerator	4,5 K refrigerator	4,5 K liquefaction	4,5 K liquefaction	40/80 K shield	40/80 K shield
	Watt	Watt	g/s	g/s	Watt	Watt
	CB NORD	CB SOUTH	CB NORD	CB SOUTH	CB NORD	CB SOUTH
HERA	2605	2886	7,30	6,20	12000	12000
HERMES			0,34		287	
H1	174		1,00		1253	
ZEUS		113		0,84		200
SL cavities		1164		1,60		1769
magnet-testhall	880		0,30		1200	
sum	3659	4163	8,94	8,64	14740	13969
cold-box capacity (nominal)	6500	6500	20,50	20,50	20000	20000
ex-cessive capa-city	2841	2337	11,56	11,86	5260	6031

TTF/FEL phase II cryo supply new plant or HERA connection

some „+“ and „-„

+ = favourable, O = neutral , - = unfavourable

	new FEL-plant	HERA – connection
reserve capacity (FEL)	O	++
cold compressor experience	+	O
operation economy	-	+
operation decoupling FEL -HERA	+	-
costs of cryogenic installations	O	O
costs of infrastructure	--	+
potential for HERA upgrades	O	--
manpower	-	O
result	--	+



4.5 K Heat loads of the FEL-Linac (10 modules, 2 BCs, 1 CC, 25 MV/m, 5 Hz

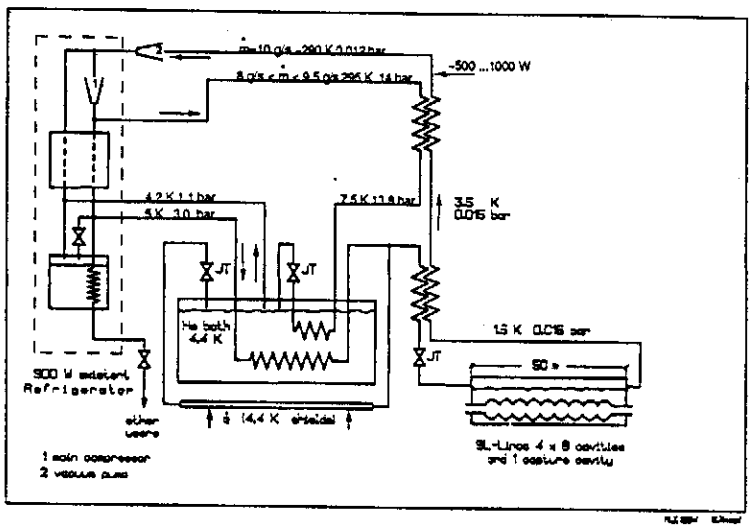
tab. 2 4.5 K Heat loads of the FEL-Linac
(10 modules, 2 BCs, 1 CC, 25 MV/m, 5 Hz)
(refrigeration losses of the HERA connection included)

	4.5 K refrigeration [Watt]	4.5 K liquefaction [g/s]
FEL-Linac + HEX	1270	3.5
FEL-Linac without HEX	850	11.5

tab. 3 : capacities of the HERA-cold-boxes

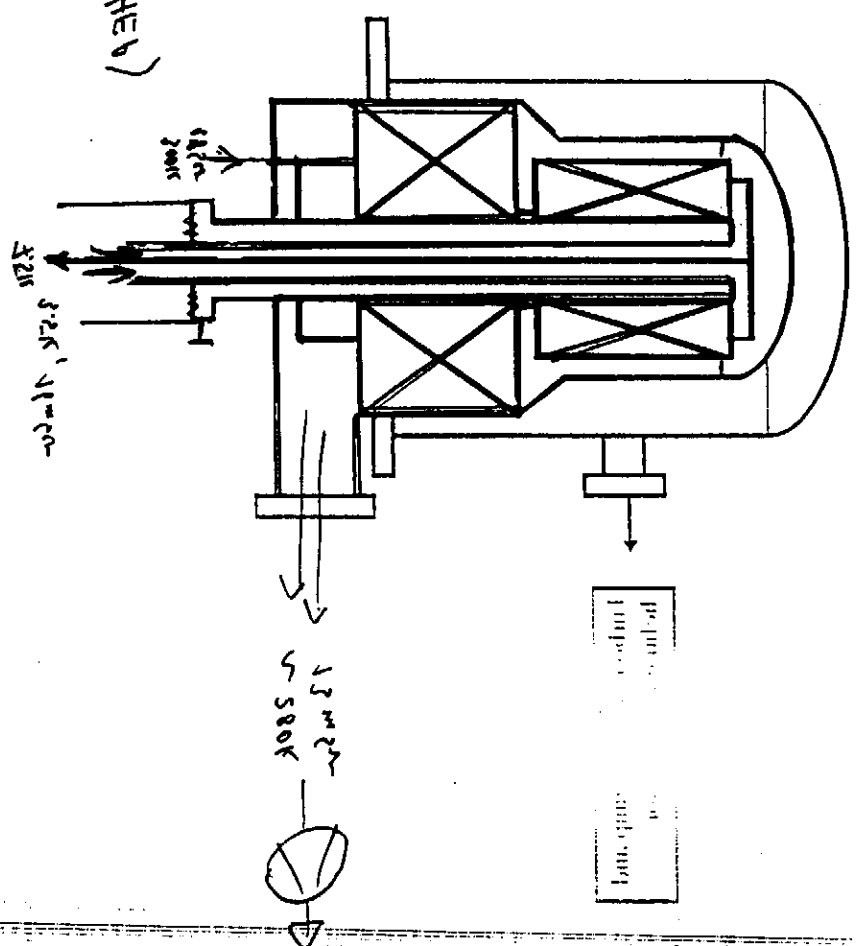
circuit	4,5 K refrigerator	4,5 K refrigerator	4,5 K liquefaction	4.5 K liquefaction	40/80 K shield	40/80 K shield
	Watt	Watt	g/s	g/s	Watt	Watt
	CB NORTH	CB SOUTH	CB NORTH	CB SOUTH	CB NORTH	CB SOUTH
HERA	2605	2886	7,30	6,20	12000	12000
HERMES			0.34		287	
H1	174		1.00		1253	
ZEUS		113		0.84		200
SL Cavities		1164		1.60		1769
Magnet-testhall	880		0.30		1200	
Sum	3659	4163	8.94	8.64	14740	13969
Coldbox capacity nominal	6500	6500	20,50	20,50	20000	20000
rest capacity	2841	2337	11.56	11.86	[illegible]	

The aim of the low pressure heat exchanger (HEX)



liquefaction load → 90 % refrigeration load

100 W @ 1.8 K → 200 W @ 1.8 K



Status of the Large Low Pressure Heat Exchanger (HEX)

contract DESY – IHEP Protvino (Russia)

sub contract: IHEP –Geliymash (Moscow)
TÜV prepproved design in February 1997
spring 1997: Geliymash quitted

review of design / new design by IHEP
preapproved by TÜV February 1998
sub contract with ZIO (Podolsk) April 1998
old:"Zavod Imeni Ordzhonikidze"
new: „Machinery Building Plant of Podolsk"
(ZIO will build the pressure vessel)
IHEP will build the HEX-coil

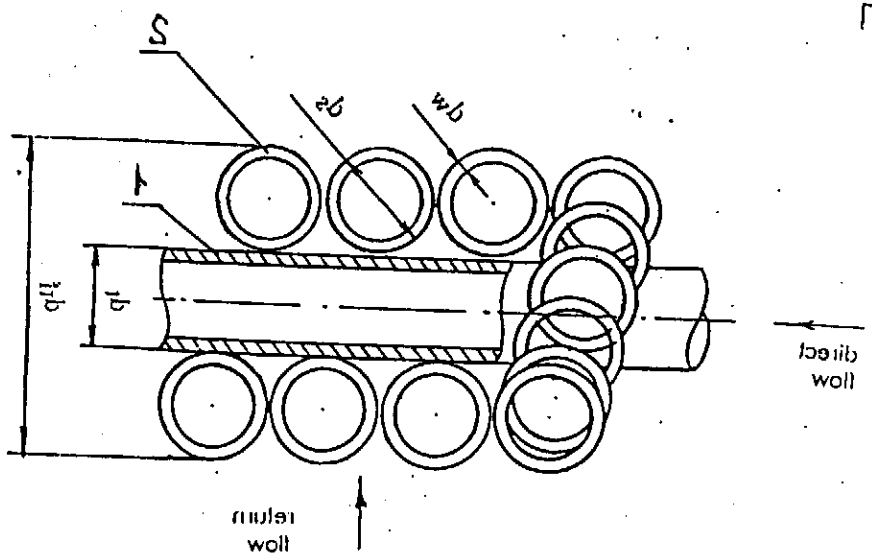


Fig. 2.1. Tube linned with the spiral
1 - tube; 2 - spiral

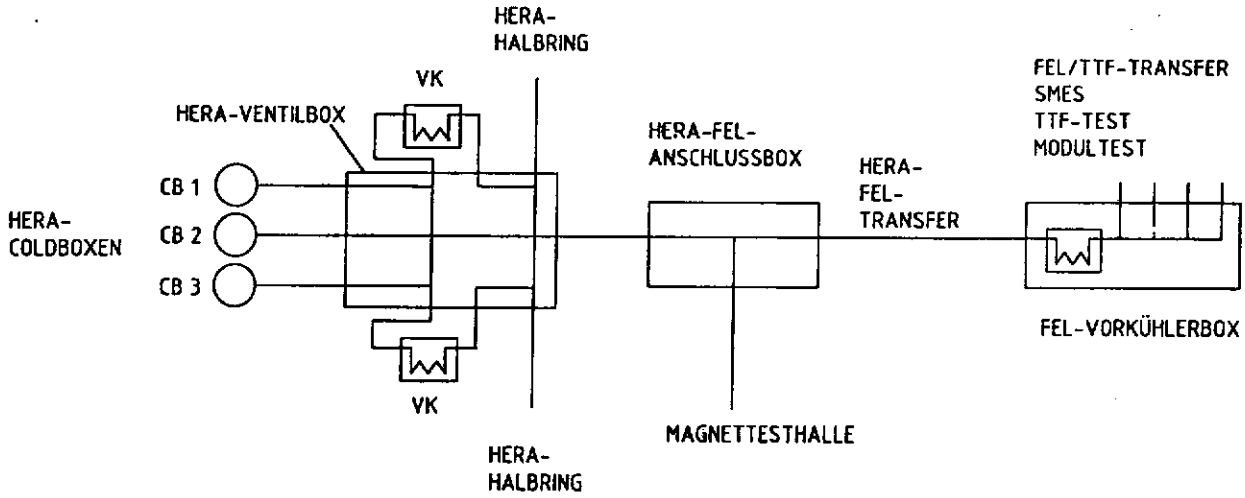
Parameters of the tube:

tube outer diameter d_t, mm - 4
tube wall thickness, mm - 0.4
tube material - copper

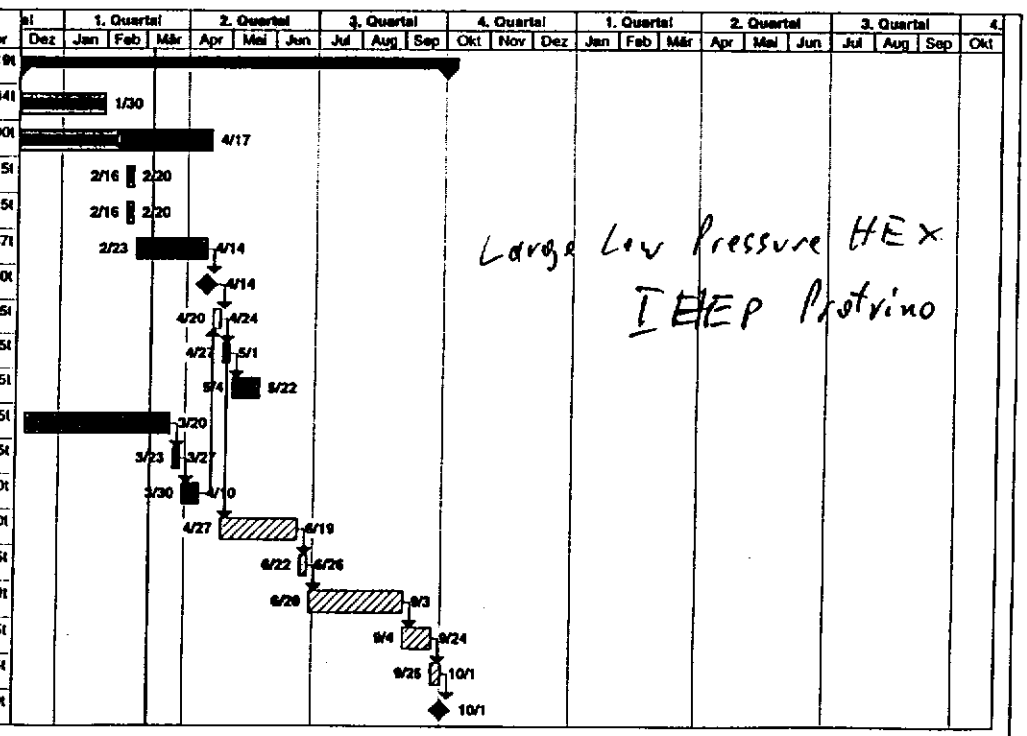
spiral outer diameter d_s, mm - 6.28

wire diameter d_w, mm - 0.8
wire material - copper

coefficient of linning ν - 7.81



Nr.	Vorgangsname	Dauer
1	TTF-HEX	219t
2	TÜV preapproval of drawings	44t
3	preparation of copper tubes	100t
4	definition of test pieces	5t
5	TÜV visit of IHEP	5t
6	ZIO offer	37t
7	contract ZIO/IHEP	0t
8	ZIO certification by TUV	5t
9	welding of HEX supports	5t
10	fabrication of HEX coils	15t
11	IHEP customs licance	75t
12	delivery of materials	5t
13	fabrication of test pieces	10t
14	welding of pressure vessel	40t
15	pressure vessel test & inspection (TÜV)	5t
16	assembly of HEX	49t
17	performance tests HEX	15t
18	delivery of HEX	5t
19	HEX at DESY	0t

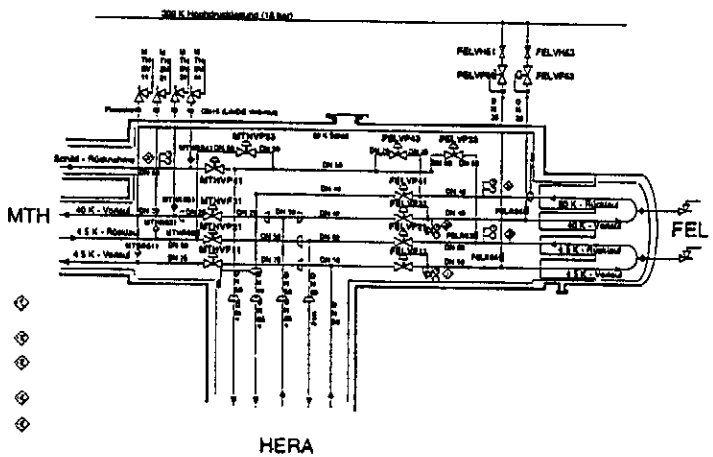


Large Low Pressure HEX
IHEP Protvino

Projekt: TTF-HEXSChedule041297.m
Datum: Fre 3/6

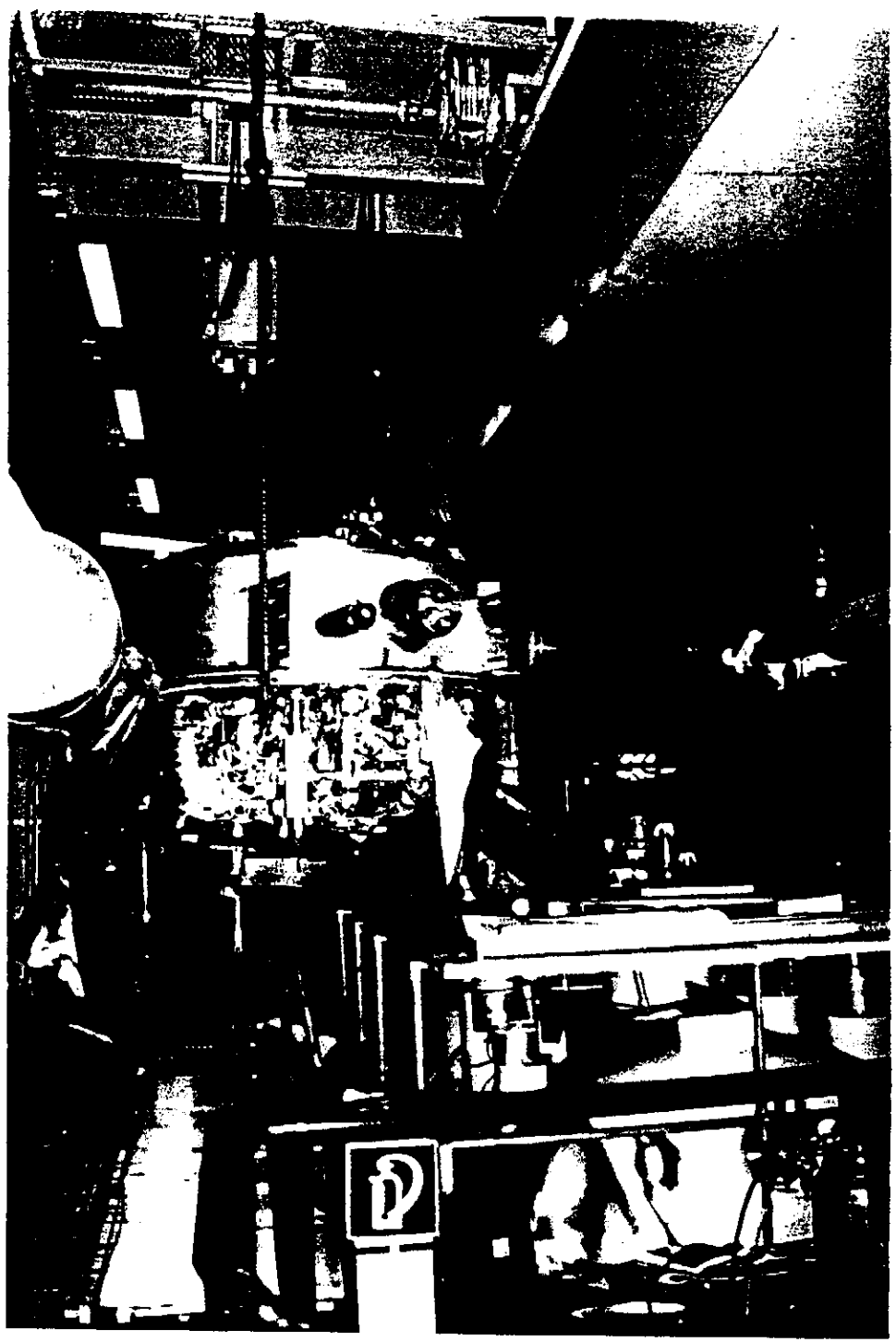
Vorgang		Meilenstein		Rollup-kritischer Vorgang	
Kritischer Vorgang		Sammelvorgang		Rollup-Meilenstein	
In Arbeit		Rollup-Vorgang		Rollup in Arbeit	

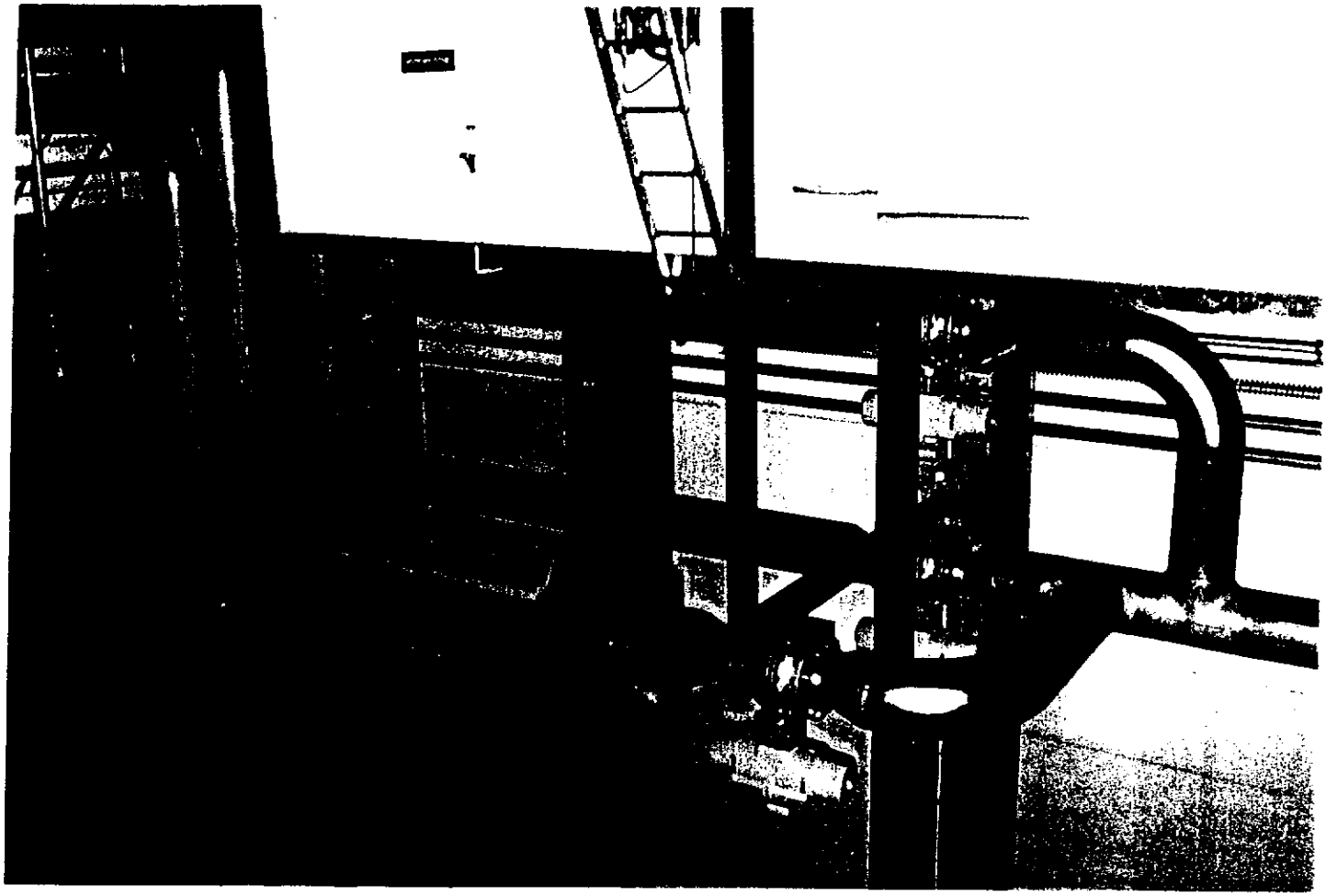
HERA-FEL-Valve-Box
Flow Scheme

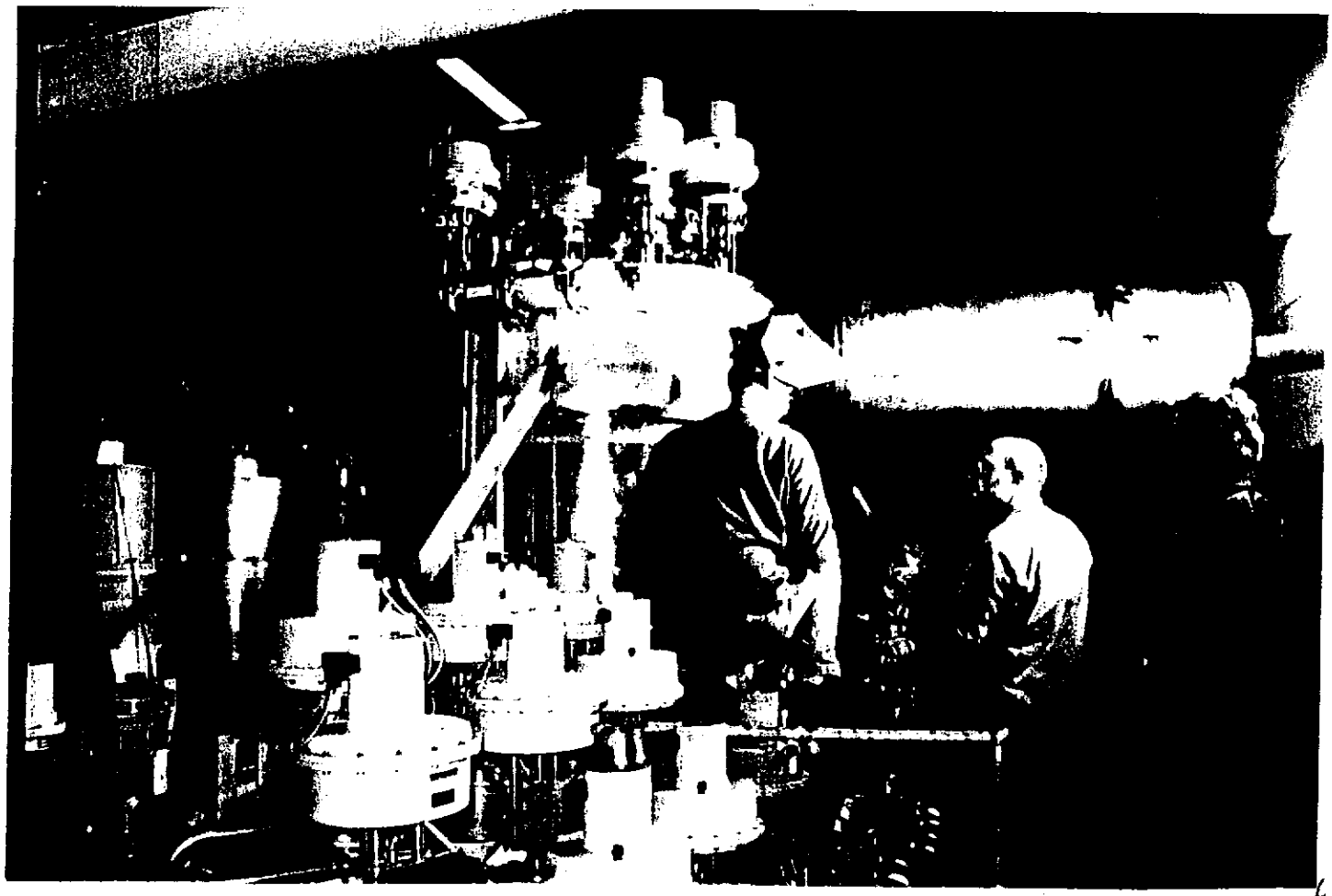


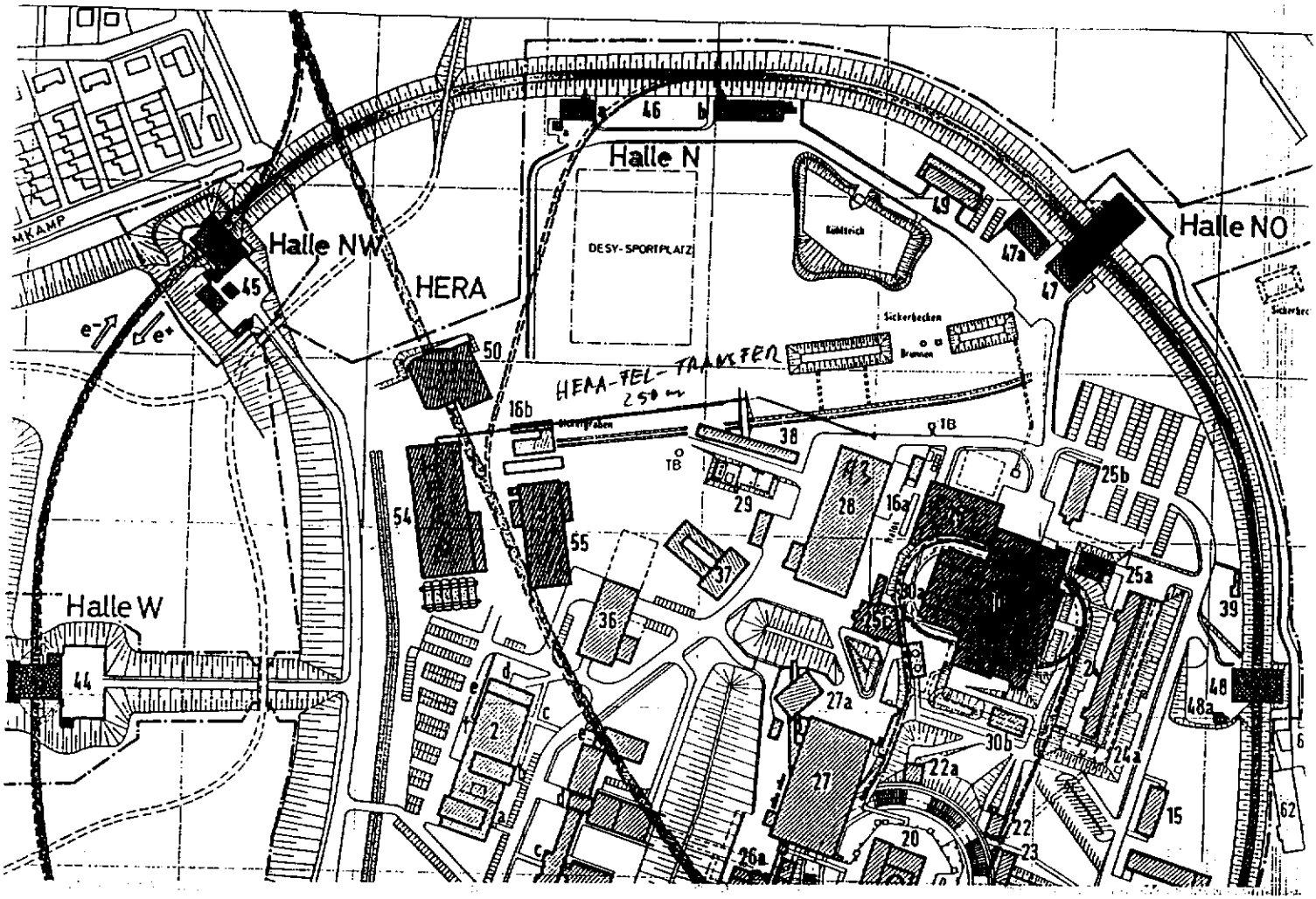
The box is attached to the HERA valve box and splits the 40/80K and the 4.5K circuits to the HERA-FEL-transferline and to the HERA-MTH ´(magnet test facility) transferline.

<u>Status: first cool down in week 10 / 1998 !</u>

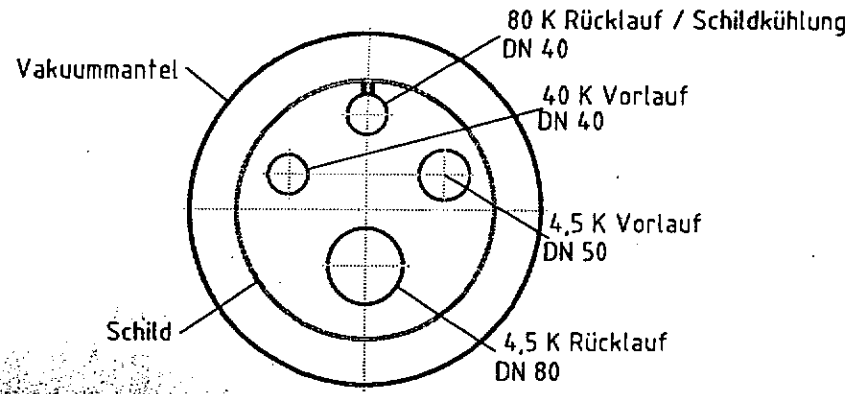


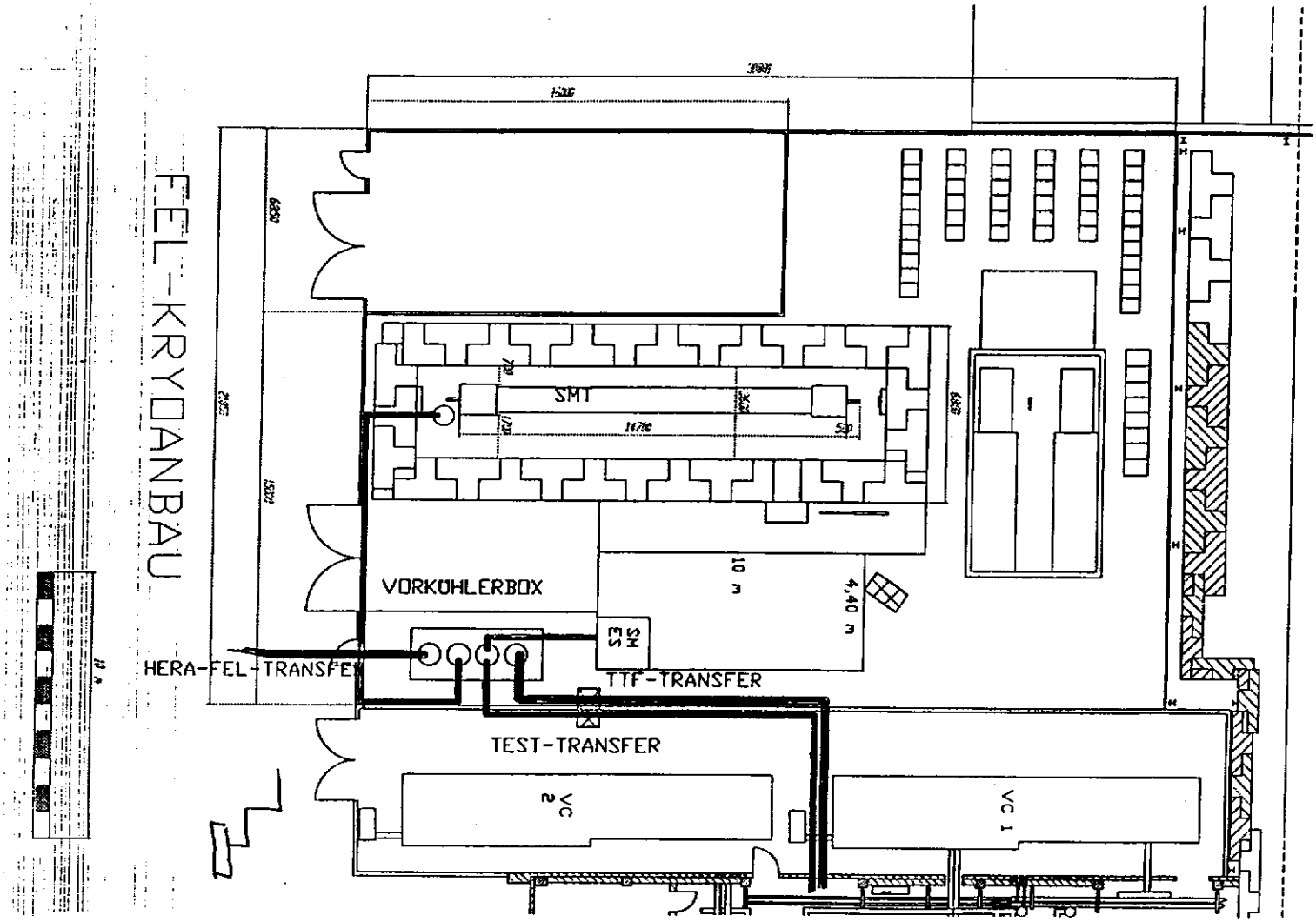


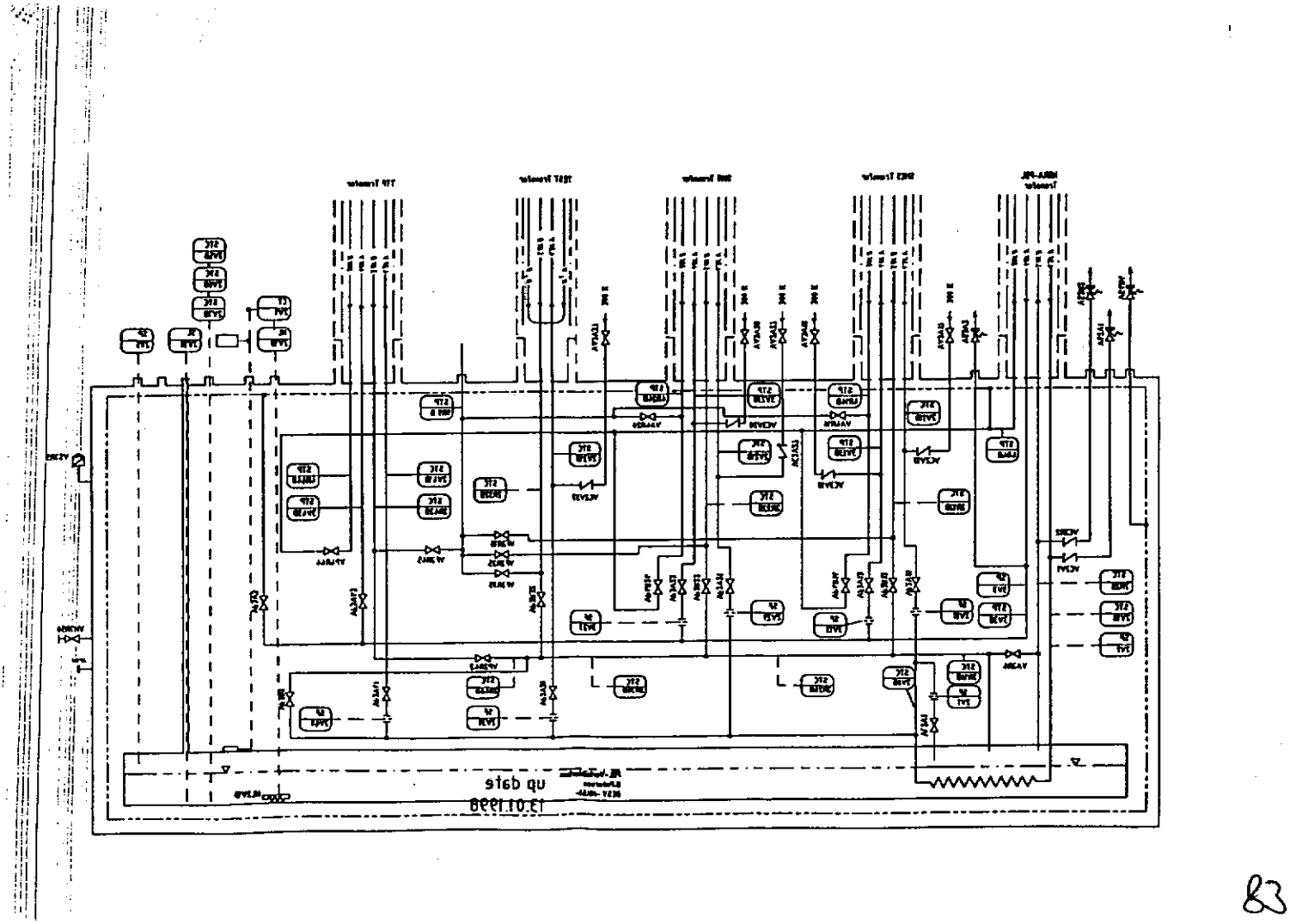




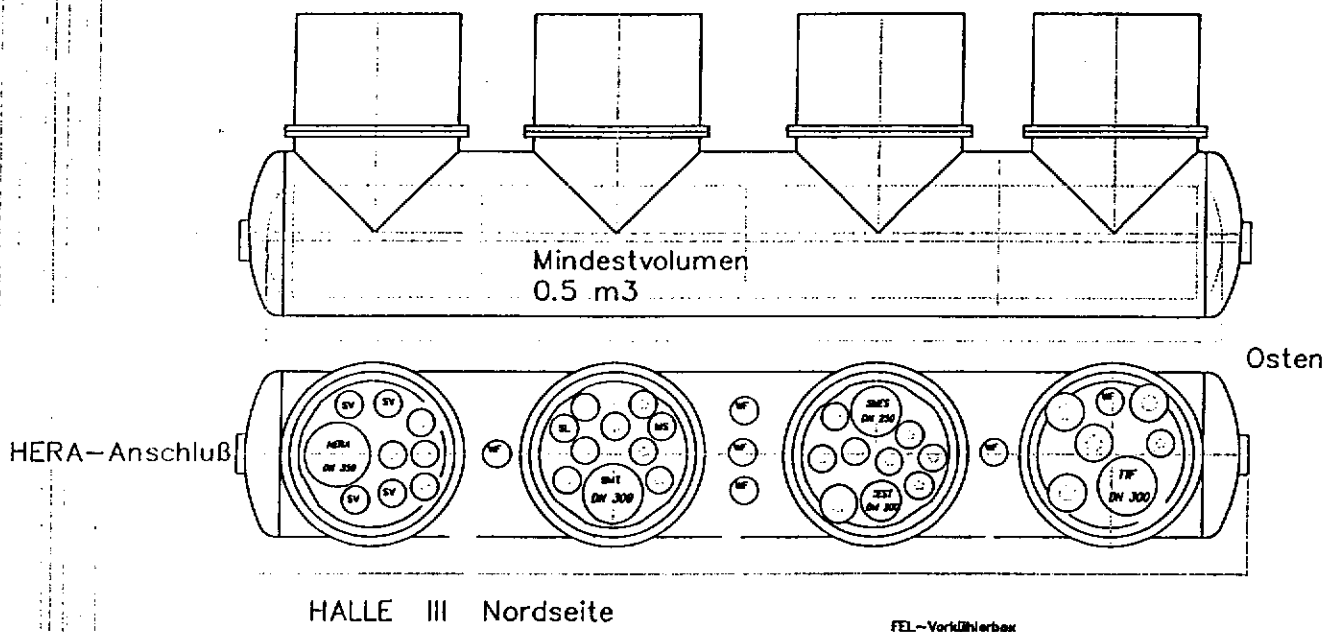
Querschnitt der HERA-FEL-Transferleitung



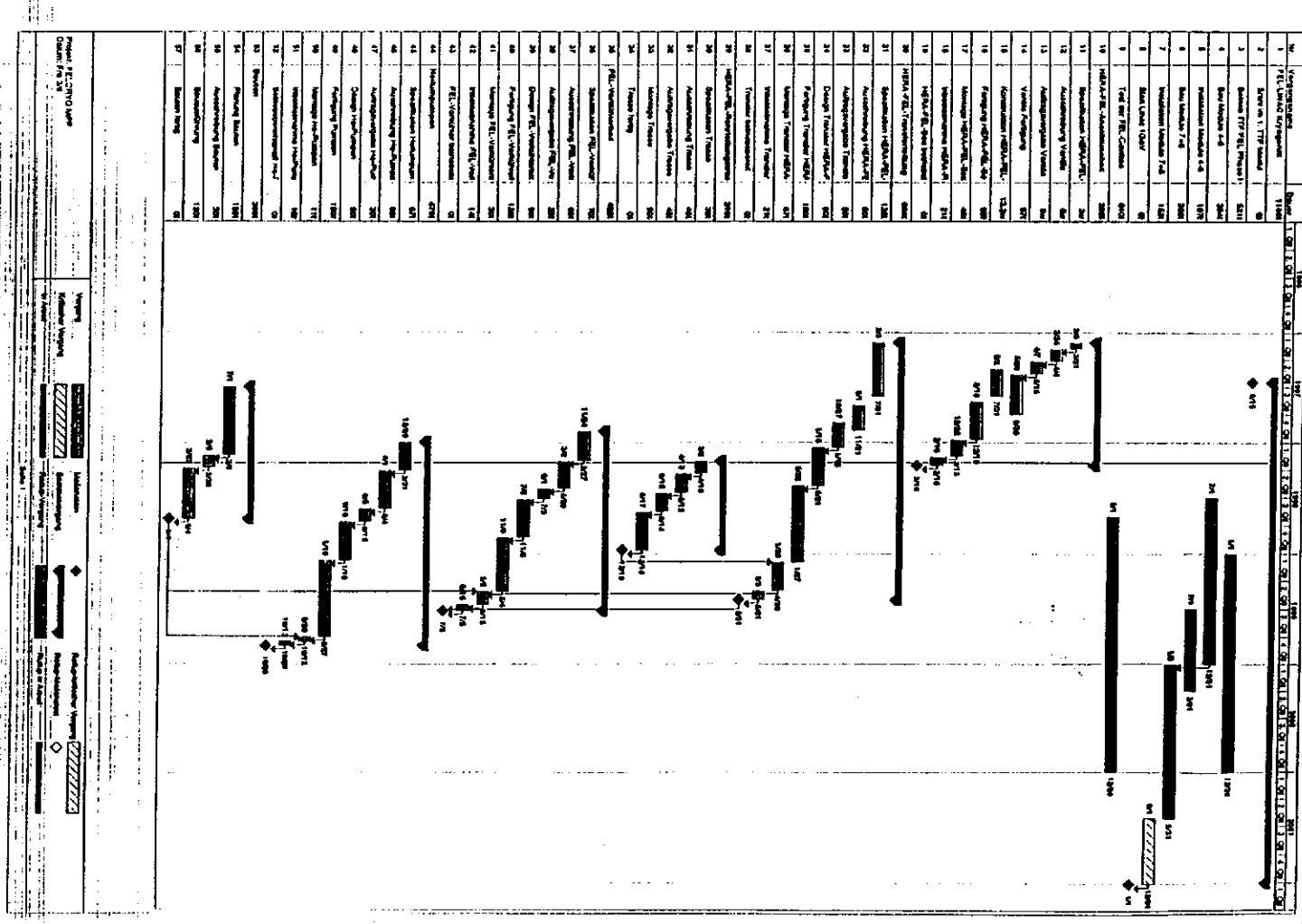

FEL-KRYOANBAU
SMT
VORKÜHLERBOX
HERA-FEL-TRANSFER
TTF-TRANSFER
TEST-TRANSFER
VC 2
VC 1

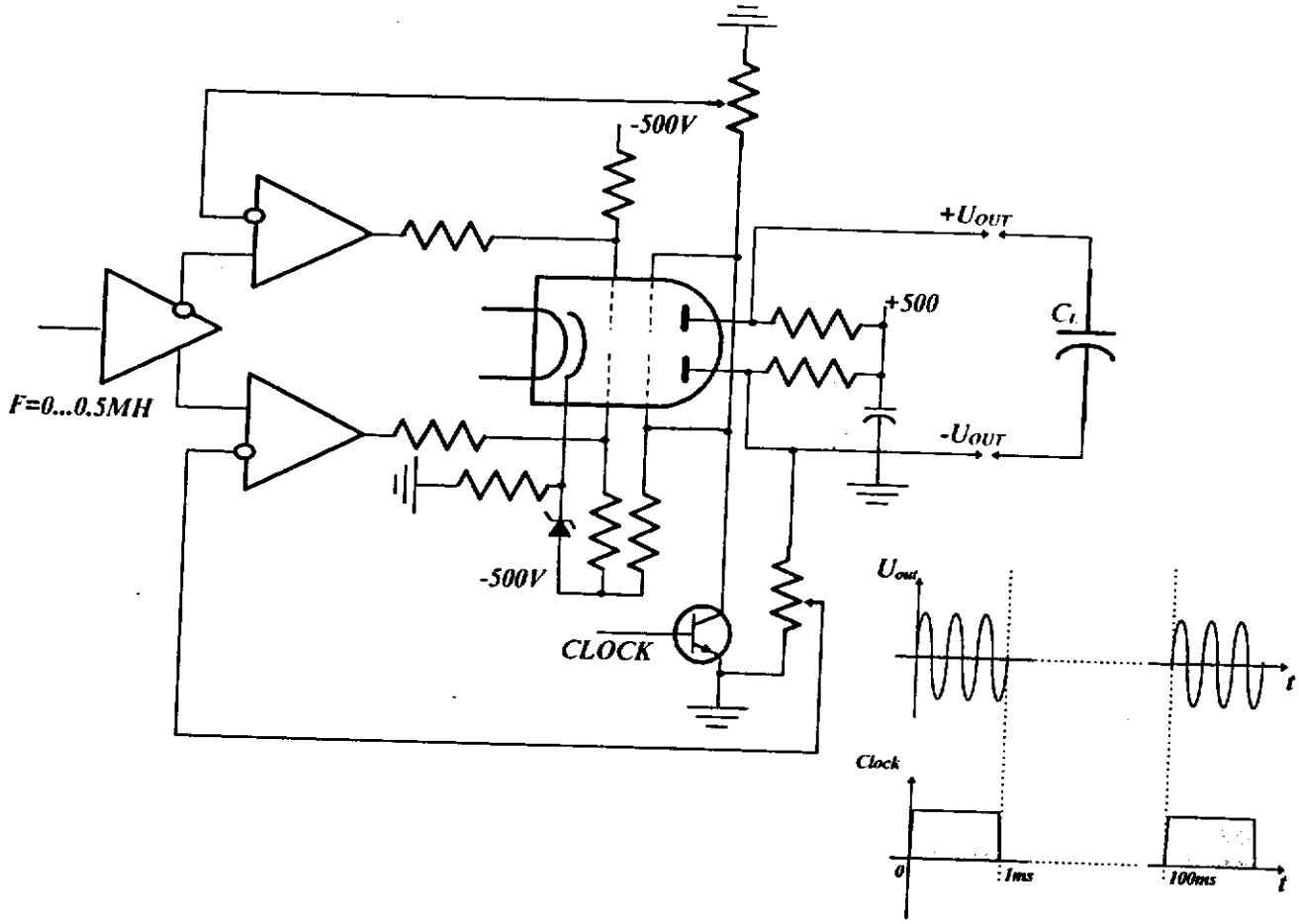


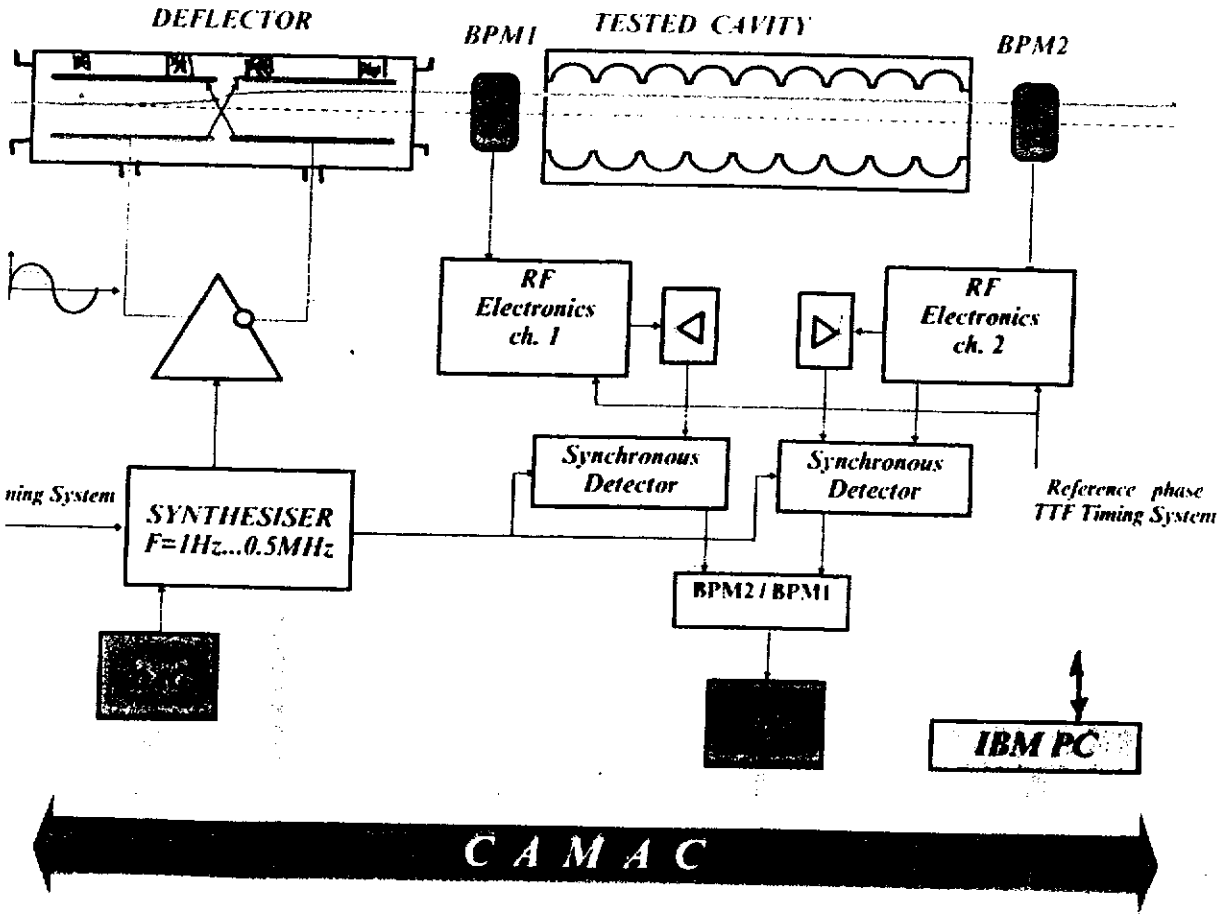
FEL - Precooler - Box

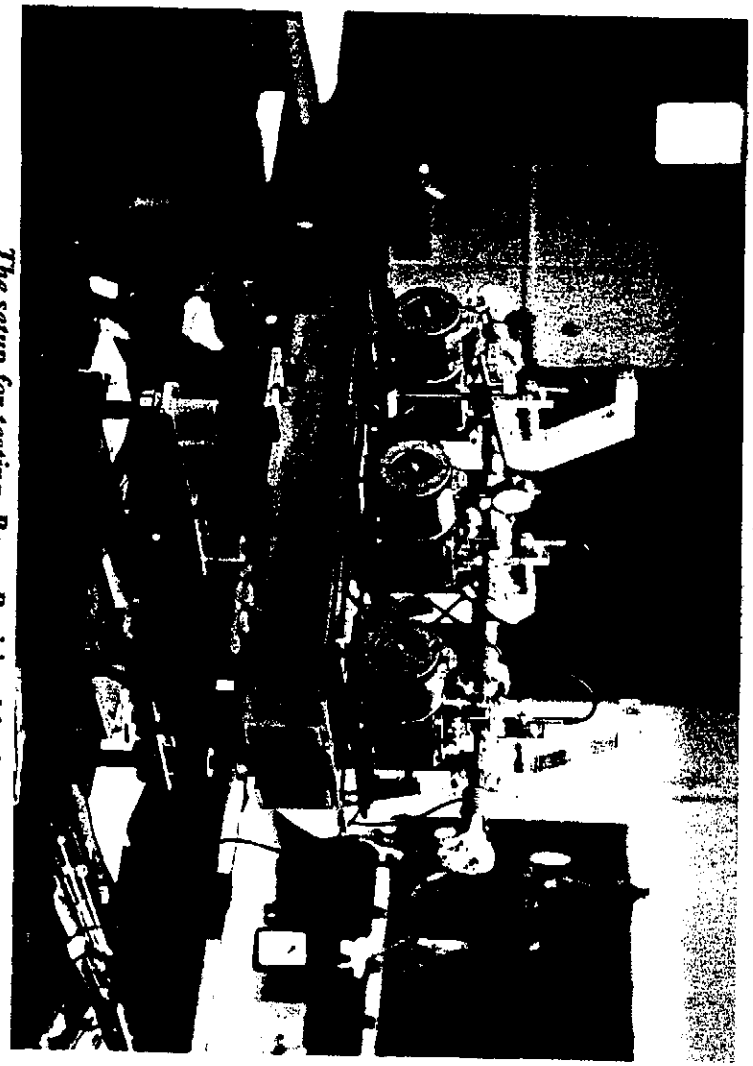


FEL-Vorkühlerbox
Status: 02.03.1998
B.Petersen -DESY MKS1-

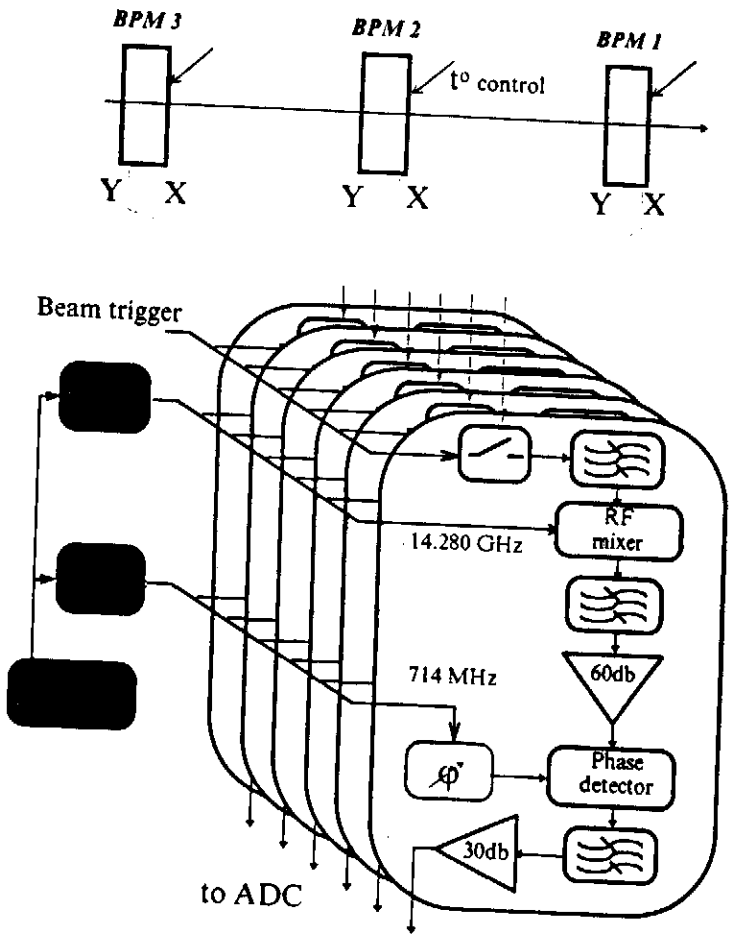



-500V
+UOUT
+500
CL
F=0...0.5MH
-UOUT
-500V
CLOCK
Uout
t
Clock
0
1ms
100ms
t


DEFLECTOR
BPM1
TESTED CAVITY
BPM2
RF Electronics ch. 1
RF Electronics ch. 2
Synchronous Detector
Synchronous Detector
ning System
SYNTHESISER F=1Hz...0.5MHz
Reference phase TTF Timing System
BPM2 / BPM1
IBM PC
CAMAC



The setup for testing Beam Position Monitor



RF circuit of experiment

S. Schreiber
TTF Meeting
9-Mar-1998
DESY

Injector Modifications

- Chicane Section
- Dispersive Section
- Matching Section

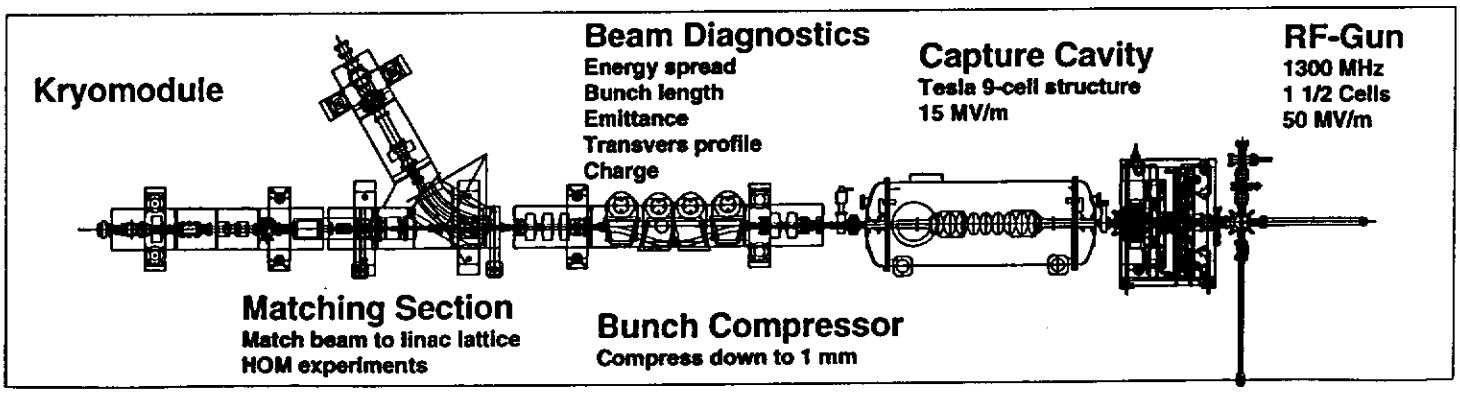
Aim:

- To prepare for Injector II
- Remember:
  we have to be able to run any of the three injector types if required (Inj I, II, FEL)
- The main change is to include a bunch compressor and adding diagnostics (OTR, Slits, Pepperpot etc.)
- Space for HOM experiments is available in Sector 600

Parameter	TTFL	Inj I	Inj II
Linac Energy	500 MeV	10 MeV	20 MeV
RF frequency	1.3 GHz	$\approx 5\mu m$	$\approx 20\mu m$
Accel Gradient	15 MV/m	$250\mu m$	$500\mu m$
Q_0	3×10^9	1.7 mm	2.5 mm
# Cryo modules	4	217 MHz	1MHz
$\Delta E/E$ single bunch rms	$\approx 10^{-3}$	4.6 ns	$1\mu sec$
$\Delta E/E$ bunch to bunch rms	$\approx 2 \times 10^{-3}$	2.3×10^8	5×10^{10}
Bunch length rms	1 mm		
Beam current	8 mA		
Beam macro pulse length	0.8 ms		
Lattice β typical	12 m max		
Injection Energy			
Emittances (x/y), $\gamma\sigma^2/\beta$			
Beam size σ, end of linac			
Beam size σ, injection			
Bunch frequency			
Bunch separation			
Particles per bunch			

TTF Injector II

Train of 800 electron bunches, train length = 0.8 ms
Repetition rate 10 Hz
Bunch charge = 8 nC
Bunch length = 1 mm
Energy = 20 MeV
Emittance (x,y) = 20 π mm mrad



Laser
262 nm (UV)
~5 μJ/pulse → 8 nC/bunch
800 pulses/train (1 MHz)
10 Hz rep. rate

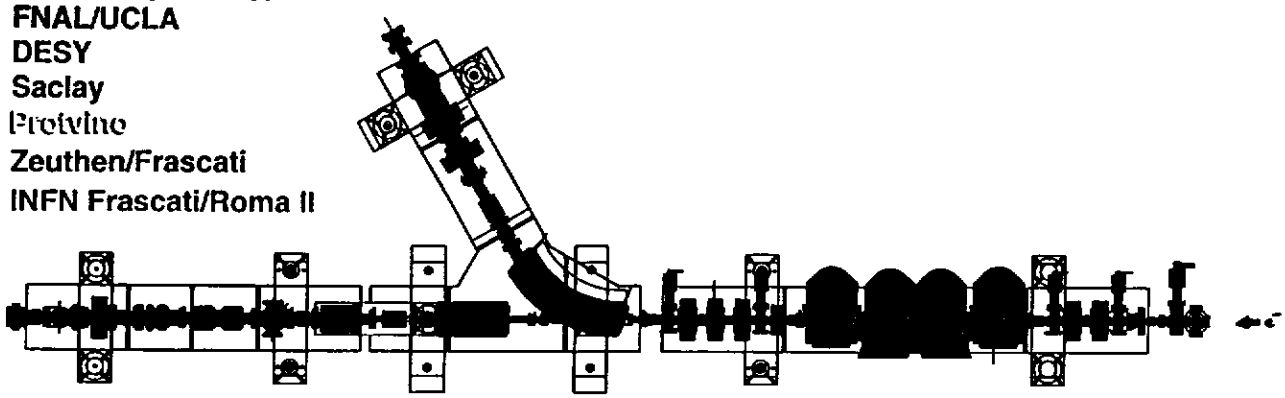
Cathode System
Material: Cs2Te
QE > 1 %

S. Schreiber
8.Nov.1997

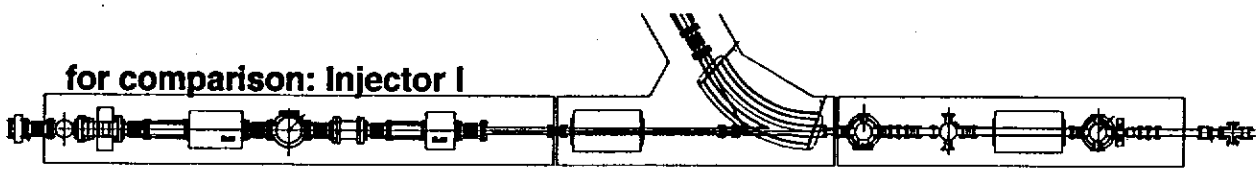
Injector II
Sectors 400, 500, and 600

S. Schreiber
8-Mar-1998

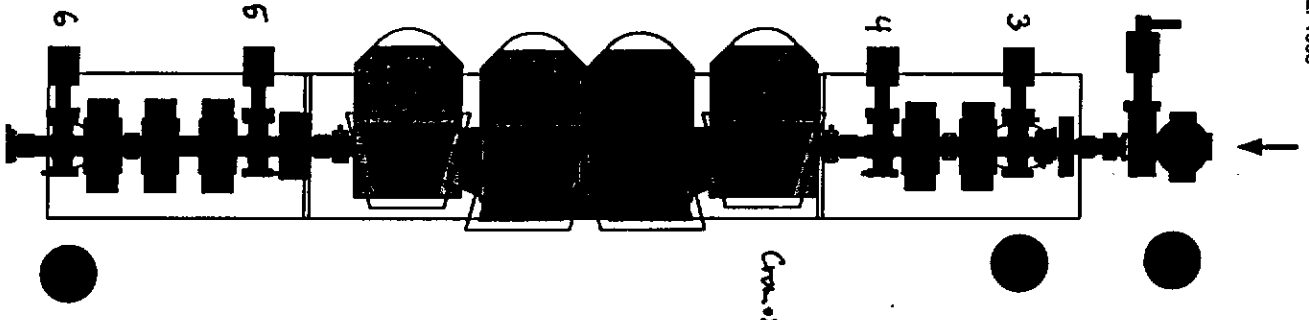
Inj I (Orsay/Saclay)
FNAL/UCLA
DESY
Saclay
Protvino
Zeuthen/Frascati
INFN Frascati/Roma II



for comparison: Injector I



S. Schreiber
8-Mar-1998



(Side View)

Chicane Section

Pump-out cross
Gate Valve

Toroid (BIS) or **ICT**
2 Quads + power supplies + vacuum chamber
Magnetic chicane ⇨ magnets being tested
4 Bend magnets + power supplies + vacuum chamber

Cross 3
Screen + OTR + slits/ppot + adj. actuator (normal actuator)
Glass window/video camera (v)
Ion pump + Ti sub + controls

Cross 4
Screen + OTR + slits + actuator (pneumatic)
Glass window/video camera

Cross 5
Screen + OTR + slits + actuator ⇨ has Cherenkov radiator
Glass window/video or intensified or streak camera (v)
Ion pump + Ti sub + controls

Cross 6
Screen + OTR + slits + actuator (pneumatic)
Quartz or glass window/video camera
Interferometer (bunch length) (v)

ICT + read out
4 H/V **Steerers** + power supplies
2 **BPM** (buttons) + read out
Triplet + power supplies

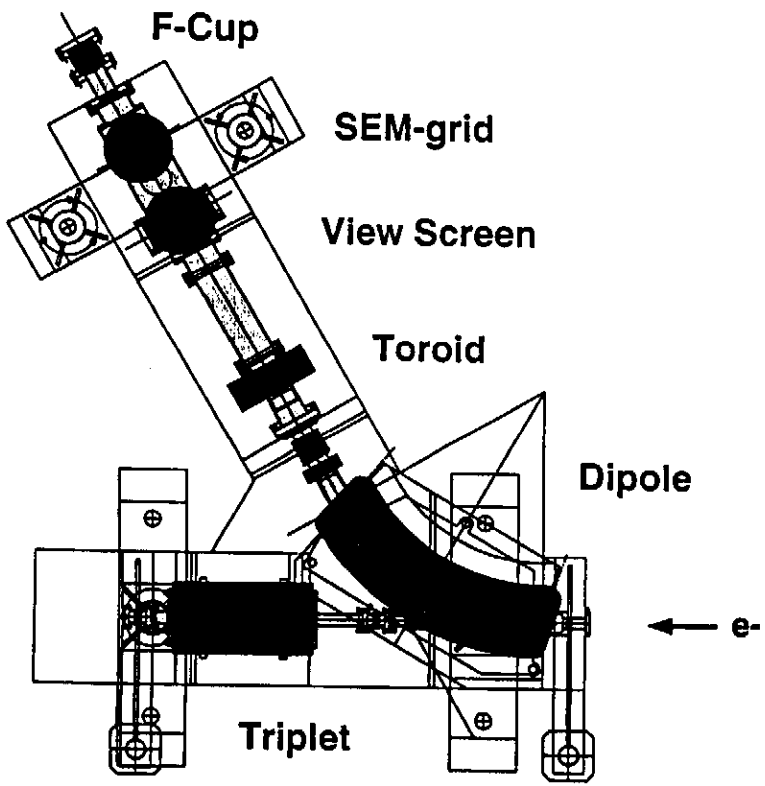
Girder

FNAL
UCLA
(Magnets)
DESY
INJ I
INFN

Dispersive Section

- completely taken from Injector I
- recent modifications:

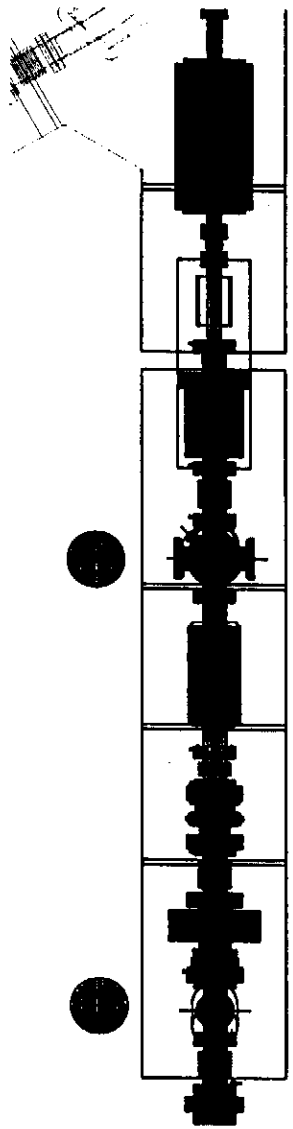
1. to reduce background for SEM grid:
   - SEM grid protection
   - toroid moved closer to dipole
2. new ceramic screen with less persistance



S. Schreiber
8-Mar-1998

Matching Section

INJ I
Saclay
Protvino
DESY
Zeuthen/
Frascati



- To match the beam to the linac lattice
- gives room for experiments:

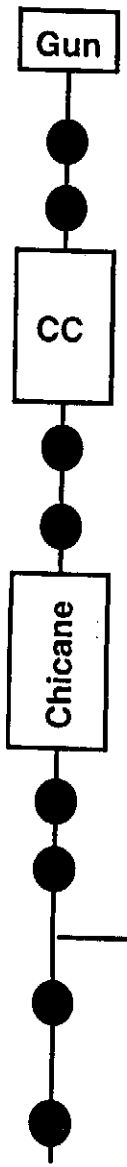
- Kicker and High Resolution BPM (Protvino)
  the modulated beam excites a broad spectrum of higher order modes in the cavities
- Dogleg Steerer (Saclay)
  HOM experiments with a horiz. displaced beam (0 ... 10 mm)
- Reentrant Cavity BPM (Saclay) ✓
  expected resolution: 100 nm

Triplet + Steerers H/V ✓
View Screen (Ceramic ✓ or OTR (✓))
Toroid ✓
F-Cup ✓

S. Schreiber
8-Mar-1998

Diagnostics

✓ installed

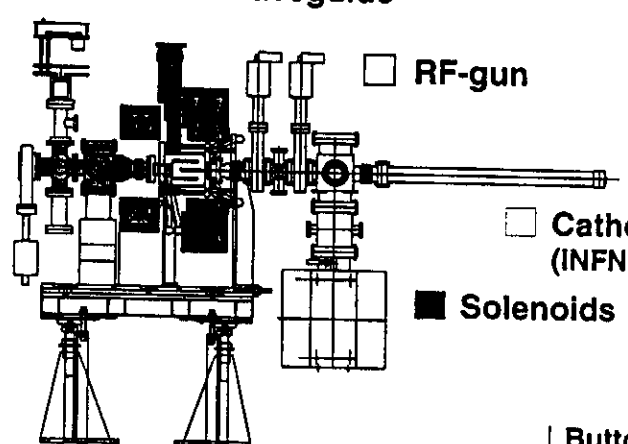


x,y	I,Q	$\sigma_{x,y}$	$\varepsilon_{x,y}$	$\delta E/E$	σ_z
buttons	ICT Fcup	Screen OCR	Slits or PepperPot		
buttons (✓)	Toroid ✓ or ICT	Screen ✓ OTR	Slits (v)		
		Screen ✓ OTR	Slits (h)		
buttons (✓)	ICT (✓)	Čerenkov Screen ✓ OTR	Slits (h)	Interfero- meter Intensified or Streak Camera	
		Screen ✓ OTR	Slits (v)		
	Fcup ✓ Toroid ✓			SEM grid ✓ screen or OCR ✓	
		Screen ✓ OTR			
Stripline ✓ Reentrant BPM ✓					
	Fcup ✓ Toroid ✓				

TTF RF-Gun

Fermilab
(E. Colby, H. Edwards et al)

- 1 1/2 cell rf gun, 1.3 GHz
- Laser driven with a Cs_2Te cathode
- High bunch charge: Q = 8 nC
  Long bunch train: 800 bunches within 0.8 ms
  High peak current: I = 1 kA
  Repetition rate: 10 Hz
  Mean RF power: 50 kW
- Emittance compensation (with solenoids):
  - transverse emittance: 15 mm mrad
  - long. emittance: 100 deg keV



■ RF Waveguide

□ RF-gun

□ Cathode System (INFN LASA)

■ Solenoids

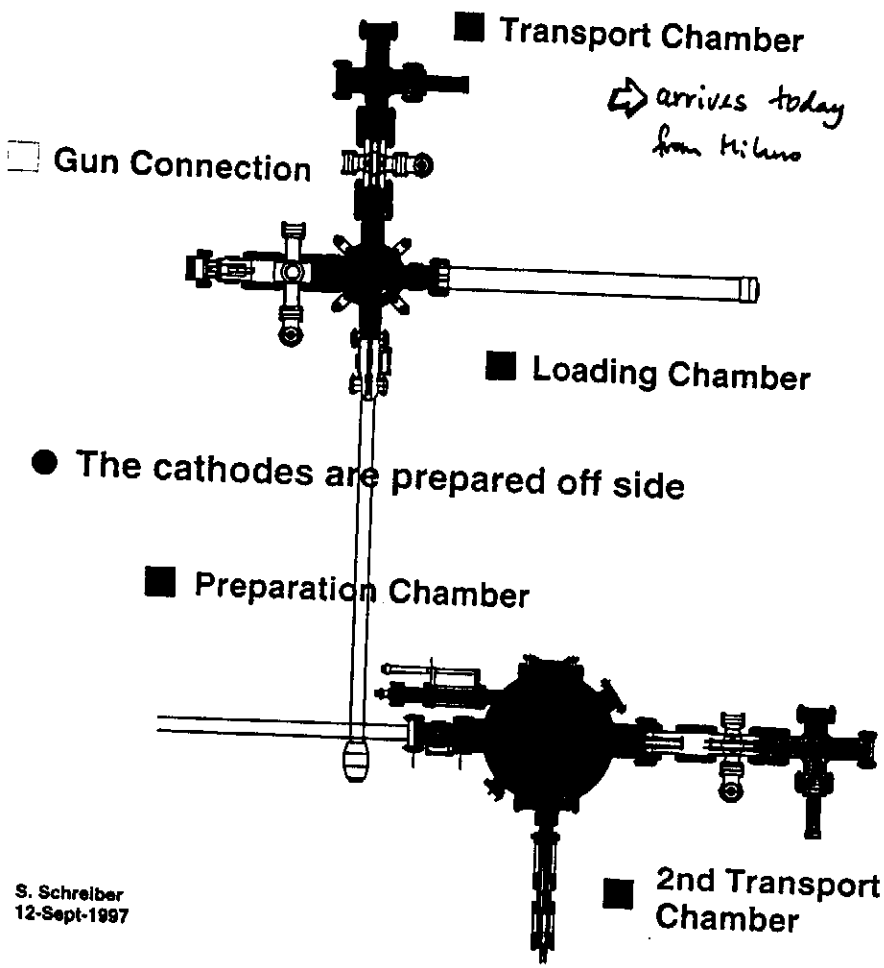
■ Laser Port and Diagnostics:
- Buttons
- ICT
- Faraday Cup
- Screen or OCR
- Slits or Pepper Pot

S. Schreiber
6-Nov-1997

Cathode System

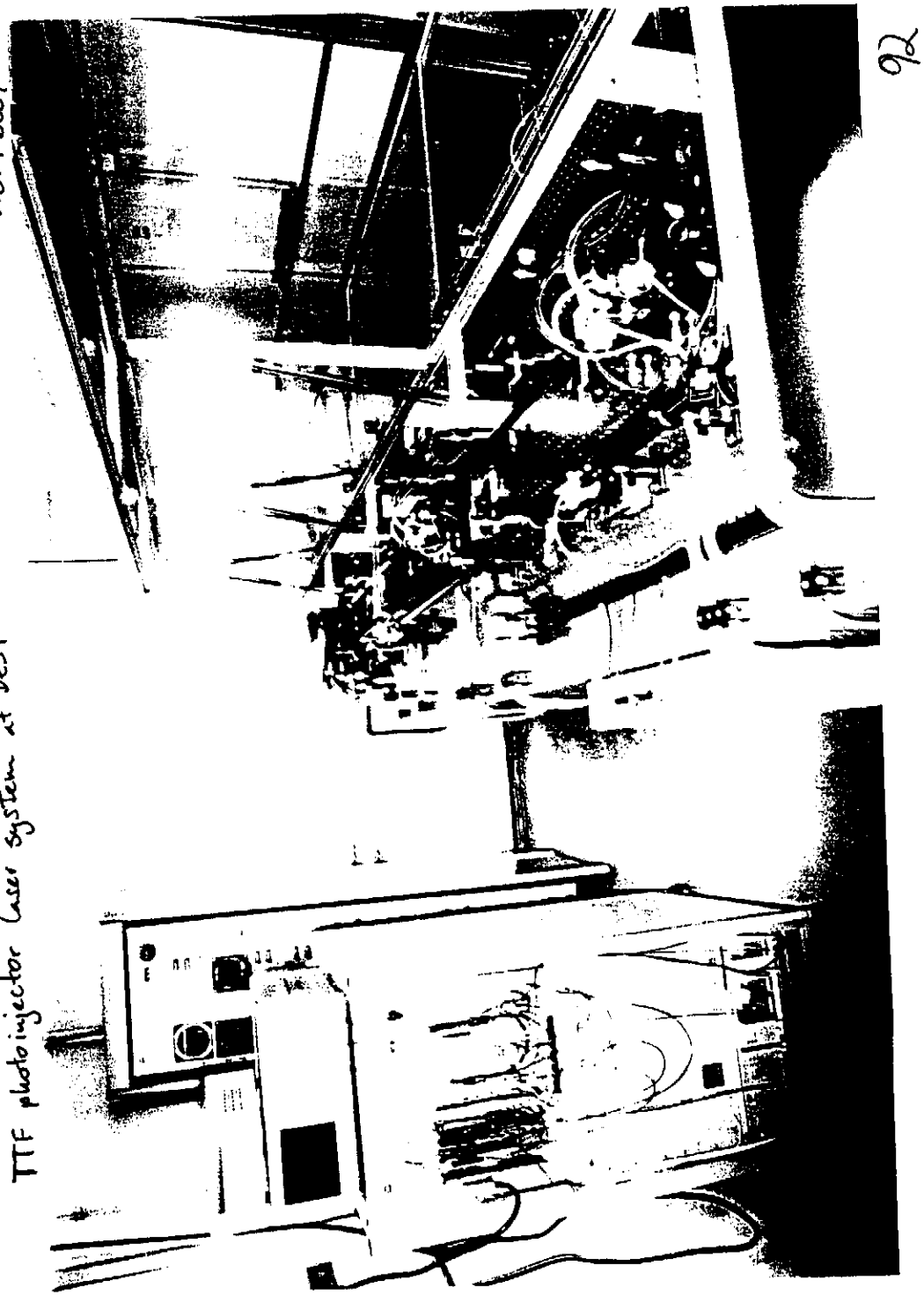
INFN Milano LASA
DESY (Vacuum equ.)

- Cs_2Te cathode: high QE (>1 % over months)
- The cathode system allows to change the cathode without breaking the vacuum
  This is essential to maintain the high quantum efficiency of the Cs_2Te cathode



- The cathodes are prepared off side

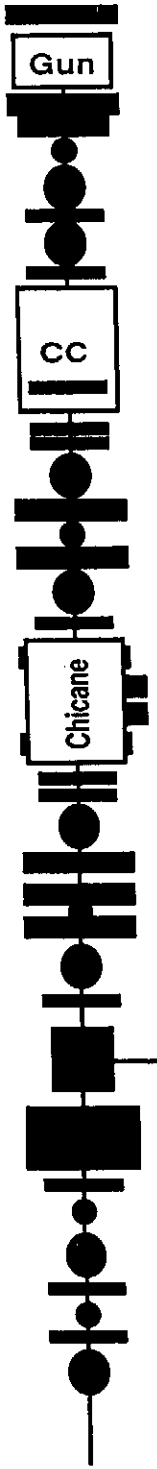
S. Schreiber
12-Sept-1997



MBI / DESY

TTF photoinjector laser system at DESY

TTF Injll Beamline Elements



Magnets	Instrum.	Diagnostic Crosses
Solenoid 1 Solenoid 2 Trim Coil Steerer H/V	BPM ICT/Toroid Buttons ICT	Pneum. Actuator F-Cup 2 TV Screen/Slits
Steerer H/V Steerer H/V	Toroid	3-Stepper-Actuator TV Screen/PP
2 Quads Steerer H/V	Buttons	Stepper-Actuator TV Screen/Slits
4 Dipoles Steerer H/V	ICT	Stepper-Actuator TV Screen/Slits
3 Quads as Triplet Steerer H/V	Buttons	Stepper-Actuator TV Screen/Slits/F-Cup
Dipole Steerer H/V	Toroid	Pneum. Actuator SEM grid screen TV F-Cup
Triplet + Steerer H/V		
Steerer H/V (Protvino Kicker)	Stripline	Pneum. Actuator Screen TV
Steerer H/V (Dogleg Steerer)	Reentrant BPM Toroid	Pneum. Actuator F-Cup

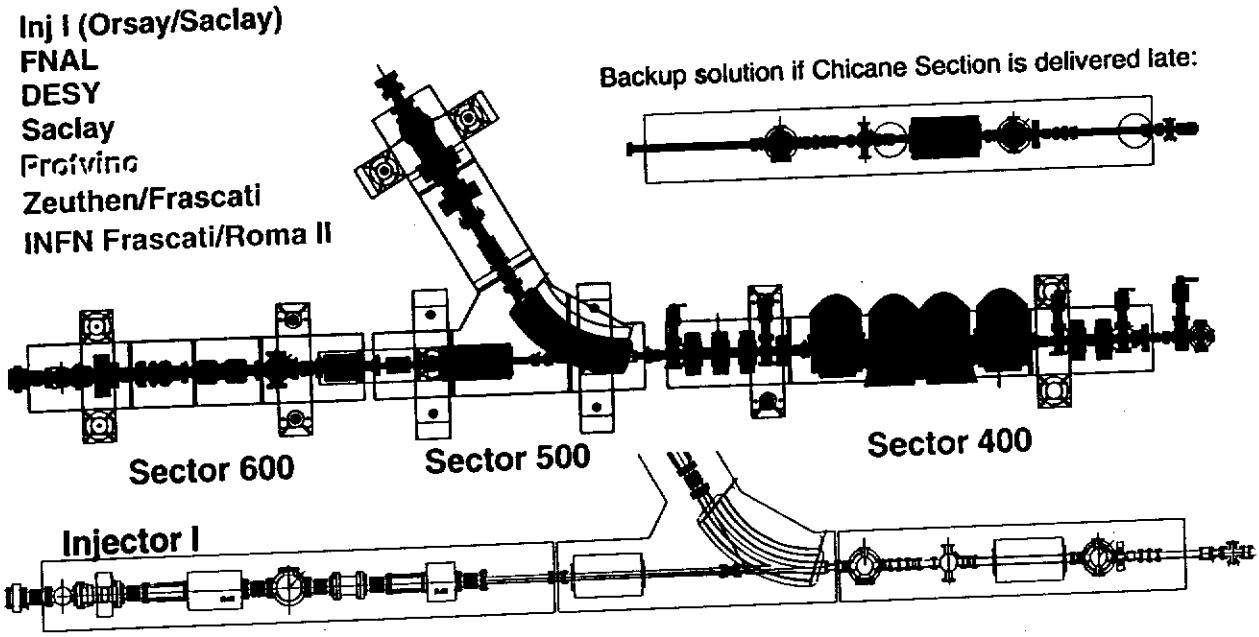
S. Schreiber
8-Nov-1997

Summary

- Installation of Sectors 400, 500, and 600 successfully completed
  - ➪ thanks to the enormous effort of the Fermilab colleagues and the DESY MVP group
  - ➪ all "old" Inj I items have been tested and debugged by Saclay
  - ➪ partly installation of the INFN actuators
  - ➪ improvement of Sector 500 diagnostics by Orsay

S. Schreiber
28-Oct-1997

Installation Injector II
Sector 400, 500, and 600



Outlook

- Installing chicane magnets and completing diagnostics during the next months
- Installation of dogleg and Protvino experiments and
- Installation of the gun section forseen for this summer
- Laser and cathode system will be tested together with the FEL rf gun in the test beamline

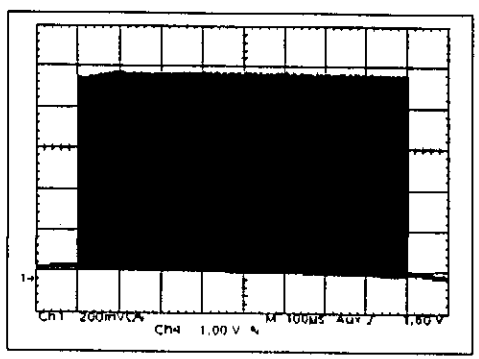
Status of the photocathode laser

March ´98

A.Liero, I.Will, W.Sandner

Summary of status in Nov. 1997:

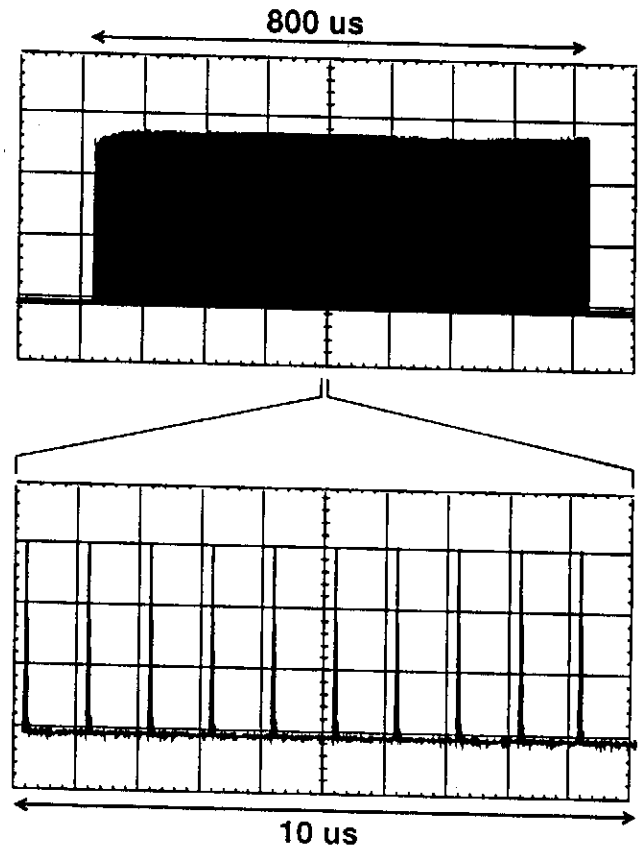
- Pulse trains of the desired energy and stability have been produced at the output of the laser amplifier stage (Infrared (IR) radiation, $\lambda = 1.05\mu m$)
- Envelope is freely programmable.



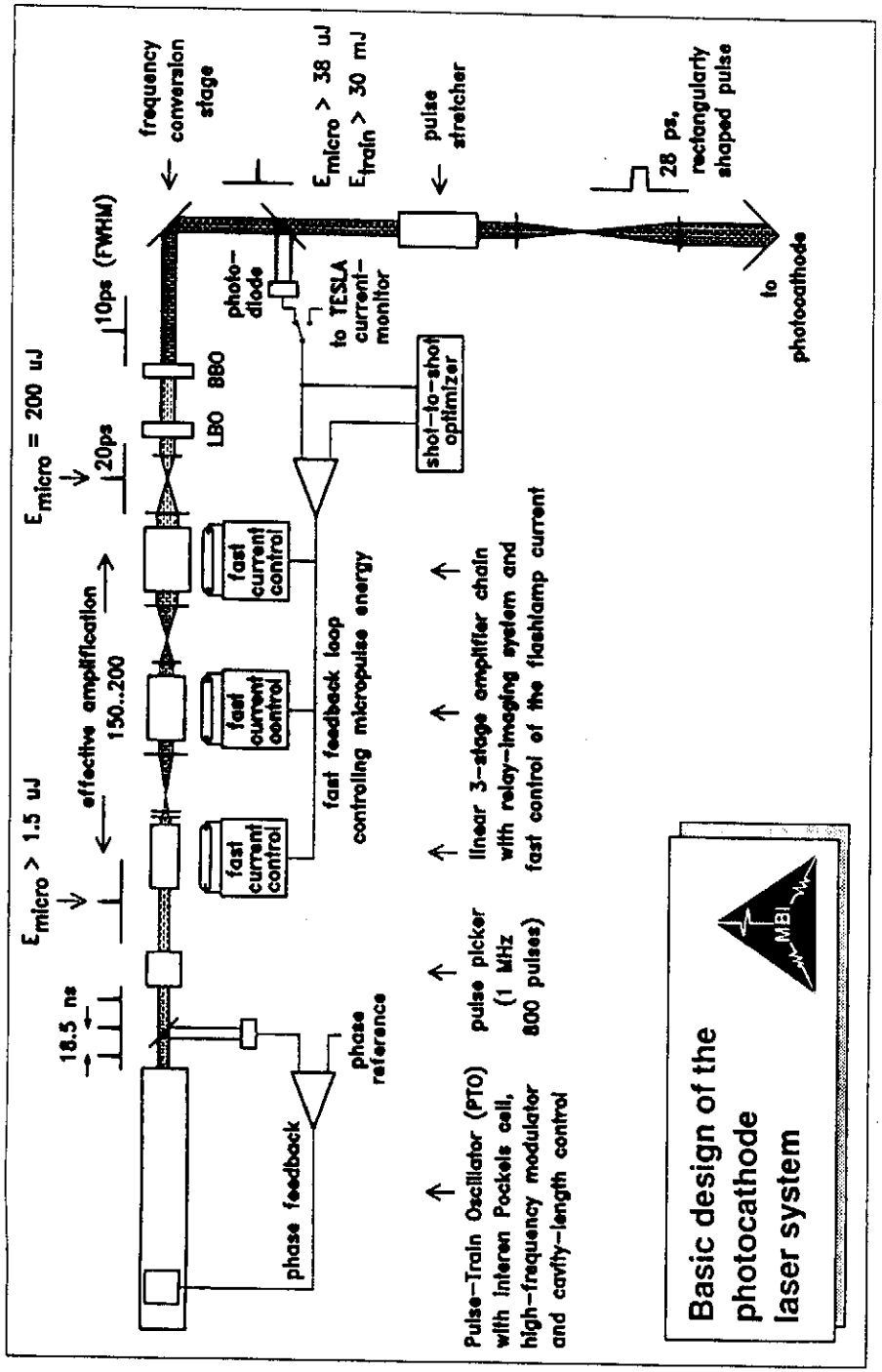
But:
Photocathode is not sensitive to IR radiation
-> conversion into the Ultraviolet (UV) required ($\lambda = 0.26\mu m$)

Main effort of the last months:
Wavelength conversion stage

Pulse train (SHG) measured at the output of the laser system

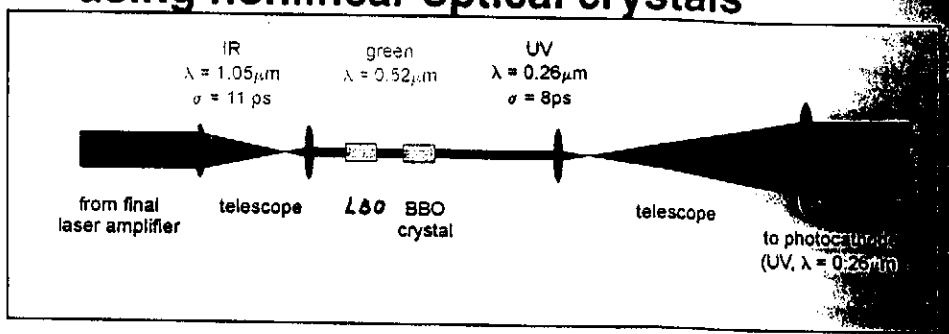


- Energy per micropulse at 1.06 um: E = 200 uJ
- Accuracy of synchronization: dt = 1 ps
- Pulse width (FWHM) at 1.06 um: t = 25 ps
  at 0.26 um: t = 12 ps
- Energy stability from shot to shot
  at 1.05 um: ± 1 %
  at 0.53 um: ± 2 %



Basic design of the photocathode laser system

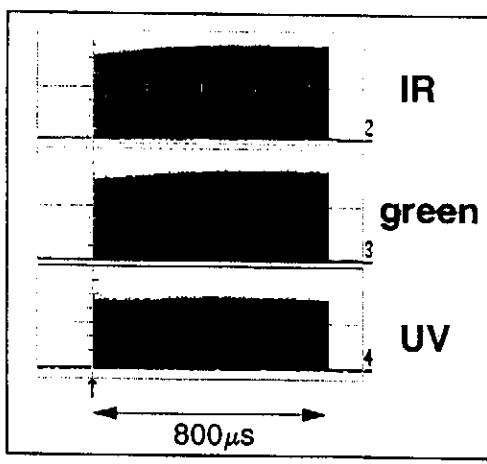
Conversion of the wavelength using nonlinear optical crystals



1. LBO: Lithium Triborate (LiB_3O_5)
2. BBO: Beta-Barium Borate (β-BaB_2O_4)

- Total energy of a micropulse in the UV: 25μJ (at 5Hz repetition rate)
  (5μJ required at the photocathode for 8nQ bunch charge)
- Total conversion efficiency from IR to UV: 10-12%
  (at 5Hz repetition rate)

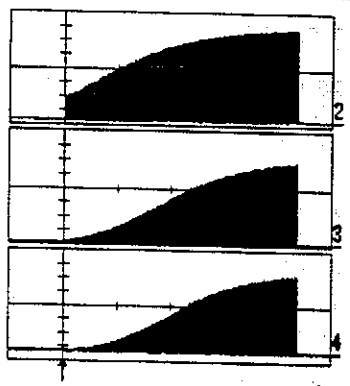
Measurement:



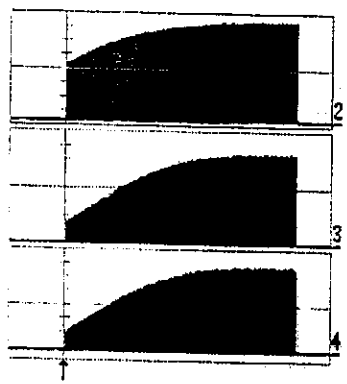
1. Small changes in the laser power cause large changes in the UV (4-th order nonlinear effect)
2. Envelopes are different in the IR, Green and UV
3. Conversion efficiency lower at 10Hz rep. rate

Measurement of the relationship between laser input in the IR and output radiation in the UV

Method:
Production of a pulse train of slowly rising energy of the micropulses.



1/8 of the nominal output intensity reached at the end of the train (UV)

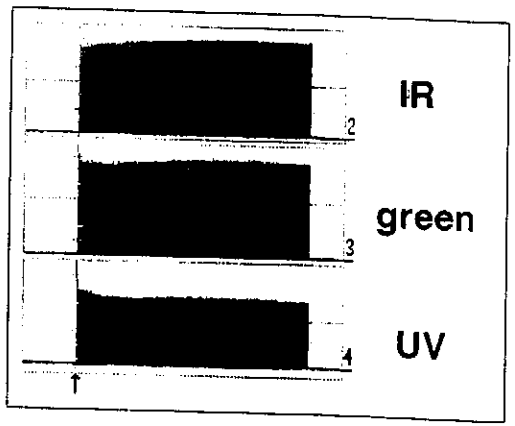


nominal output intensity at the end of the train (UV)

Conclusion:

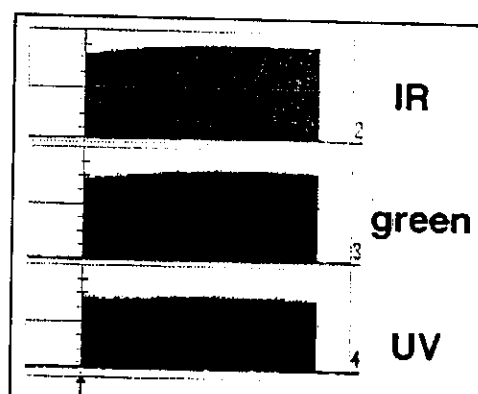
At the actual working point:
1% deviation in the IR = 2% deviation in the UV

Conversion efficiency is slightly higher during the first 200us than during the main part of the train.



Reason:

- Small changes in the beam profile at the beginning of the train due to spatial holeburning in the laser amplifiers.
- Amplifier chain reaches steady-state after approx. 200μs.



We can compensate for changes of the conversion efficiency during the first 200μs by appropriately shaping the IR input pulse (programmable-pulse-shape mode)

Reduction of the conversion efficiency at 10Hz rep rate in comparison to 5Hz

Conversion efficiencies reached:

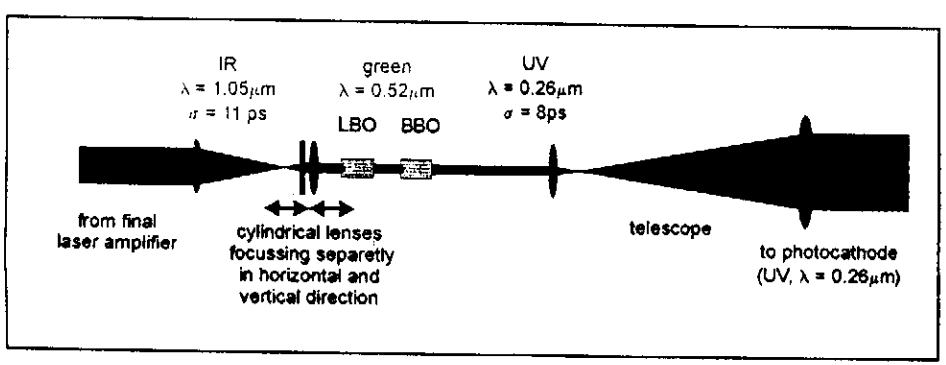
- at 5Hz: >10%
- at 10Hz: approx. 7%, in addition: bad beam profile

Reason:

- thermal lenses in the laser rod, stronger at 10Hz than at 5Hz rep. rate
- thermal lensing is different in horizontal and vertical direction (specific to Nd:YLF)
- unfavorable defocussing effect is enlarged in the spatial filter between amplifier chain and nonlinear crystals

Solution: "adaptive optics"

Two cylindrical lenses for separate focus control in horizontal and vertical direction.



Summary

We have demonstrated a conversion efficiency IR->UV of better 10% at 5Hz rep rate.
The energy **in the UV is 25μJ per micropulse** (i.e. 20mJ per macropulse) (5uJ per micropulse is required on the photocathode for 8nQ bunch charge)

Next steps:

- Adaptive spatial filter for compensation of thermal lensing which should allow to produce 25μJ UV per micropulse (20mJ per pulse train) at 10Hz repetition rate.
- Remote alignment system of the nonlinear crystals and feedback control is required for stable long-term operation.

Conclusion:

The wavelength conversion from IR to UV has shown to be a major difficulty in the development of the photocathode laser system.

We have to spend significantly more time and somewhat more money than initially planned to fully solve this problem.

Status of Controls

Kay Rehlich
DESY MVP2

- New Components and Improvements
- Injector 1 & 2
- Next Steps

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Interlock

Beam Inhibit System (BIS) ➠ new channels

"Fast OFF" box ➠ new

Personal interlock ➠ new

KnobBox

Knobs to control parameters of the linac ➠ improved

Wire Alignment (INFN)

User interface ➠ improved

Timing

Problems with long cables ➠ improved

RF

DSP programs and server ➠ improved

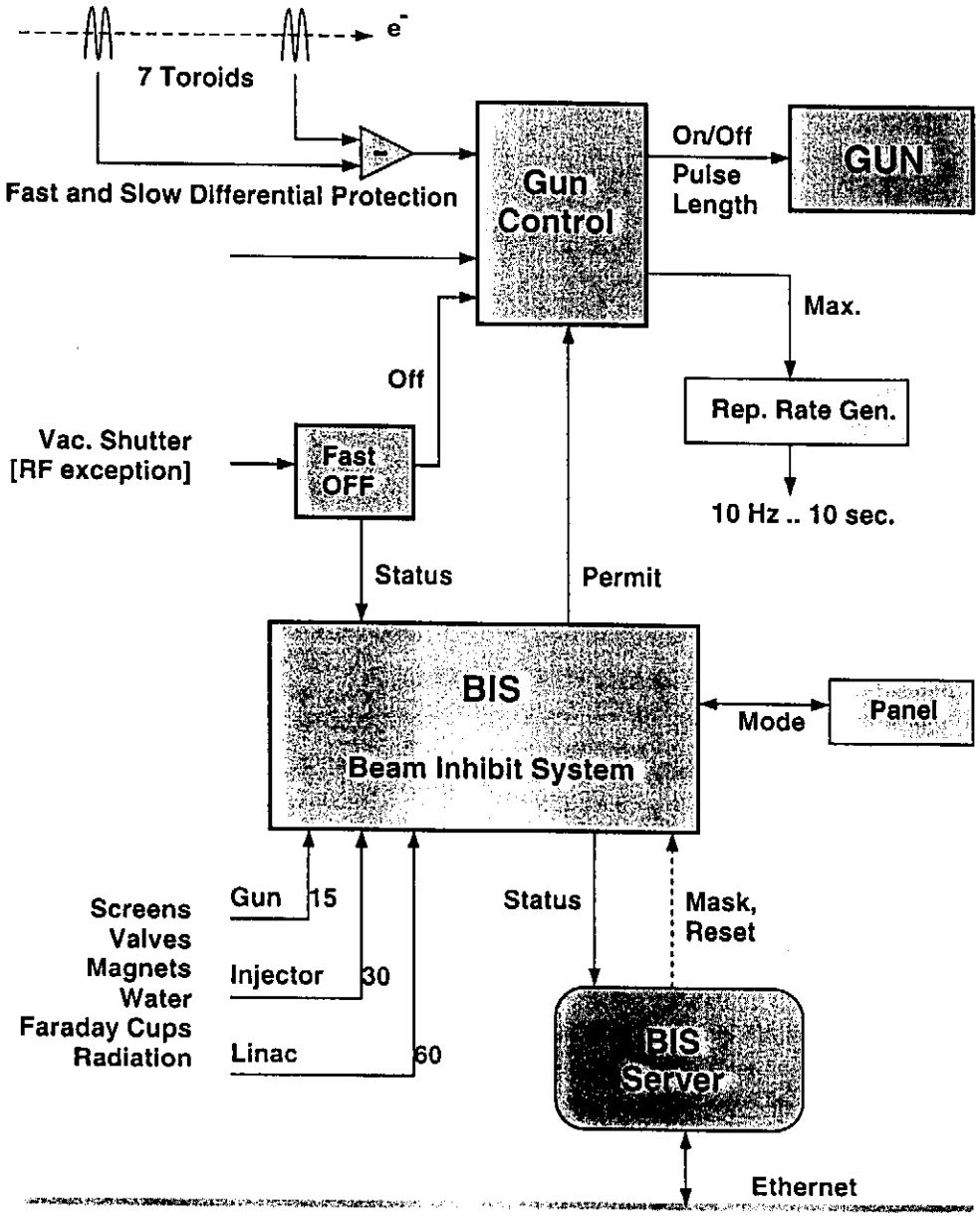
Klystron 2 (FNAL) ➠ new

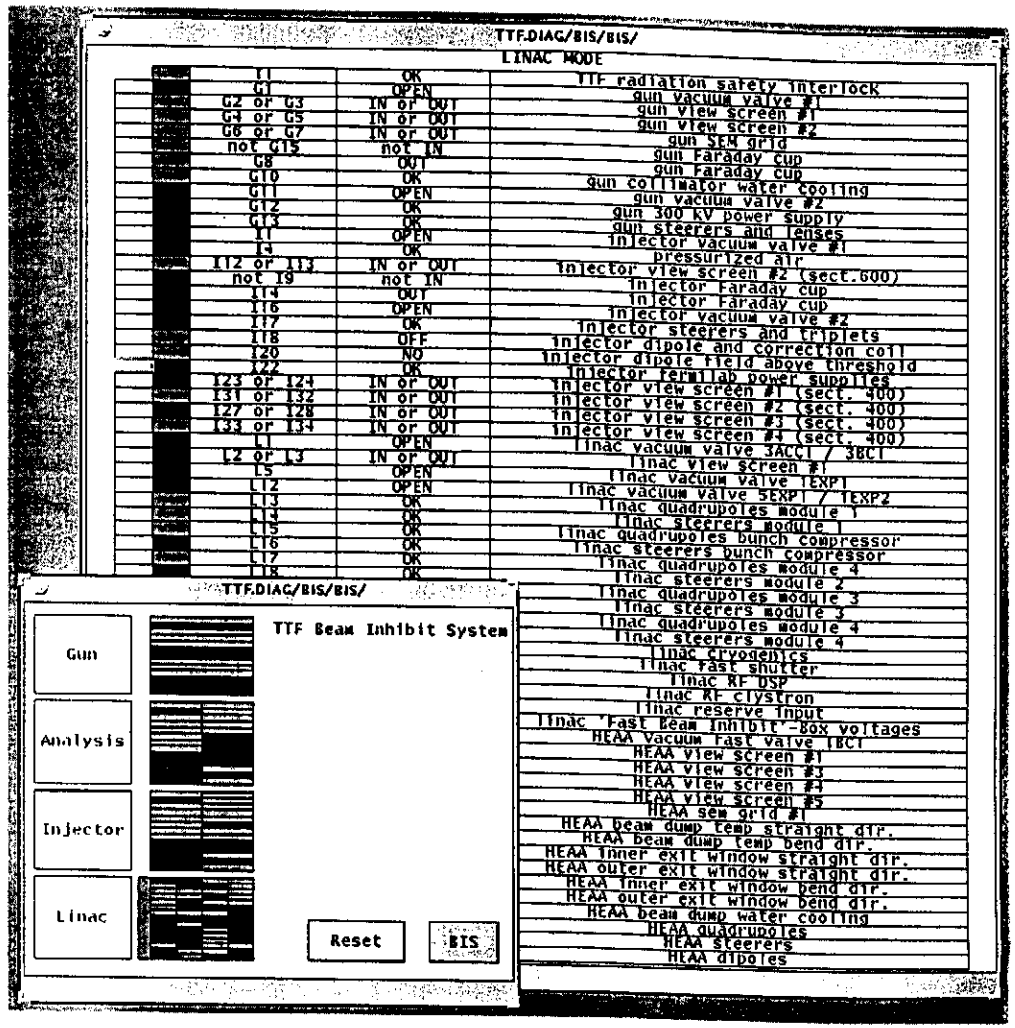
DSP hardware (ADC, DAC, Exception, Transmitter, IQdriver) ➠ new boards

DSP user interface ➠ improved

Stepper motors for three stub tuners ➠ new

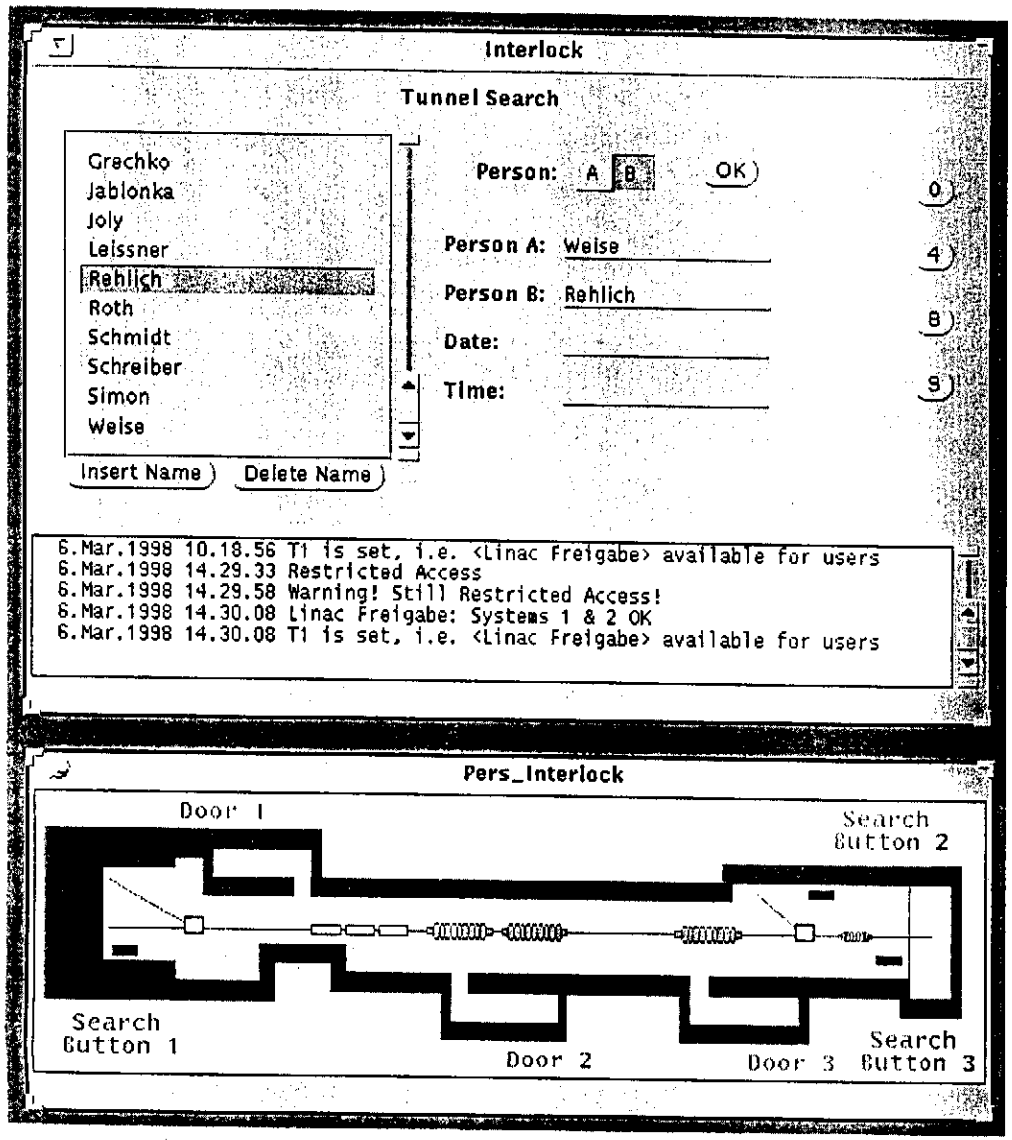
Diagnostics (Pforw/refl, Probe, Transients, Coupler Interlocks) ➠ improved



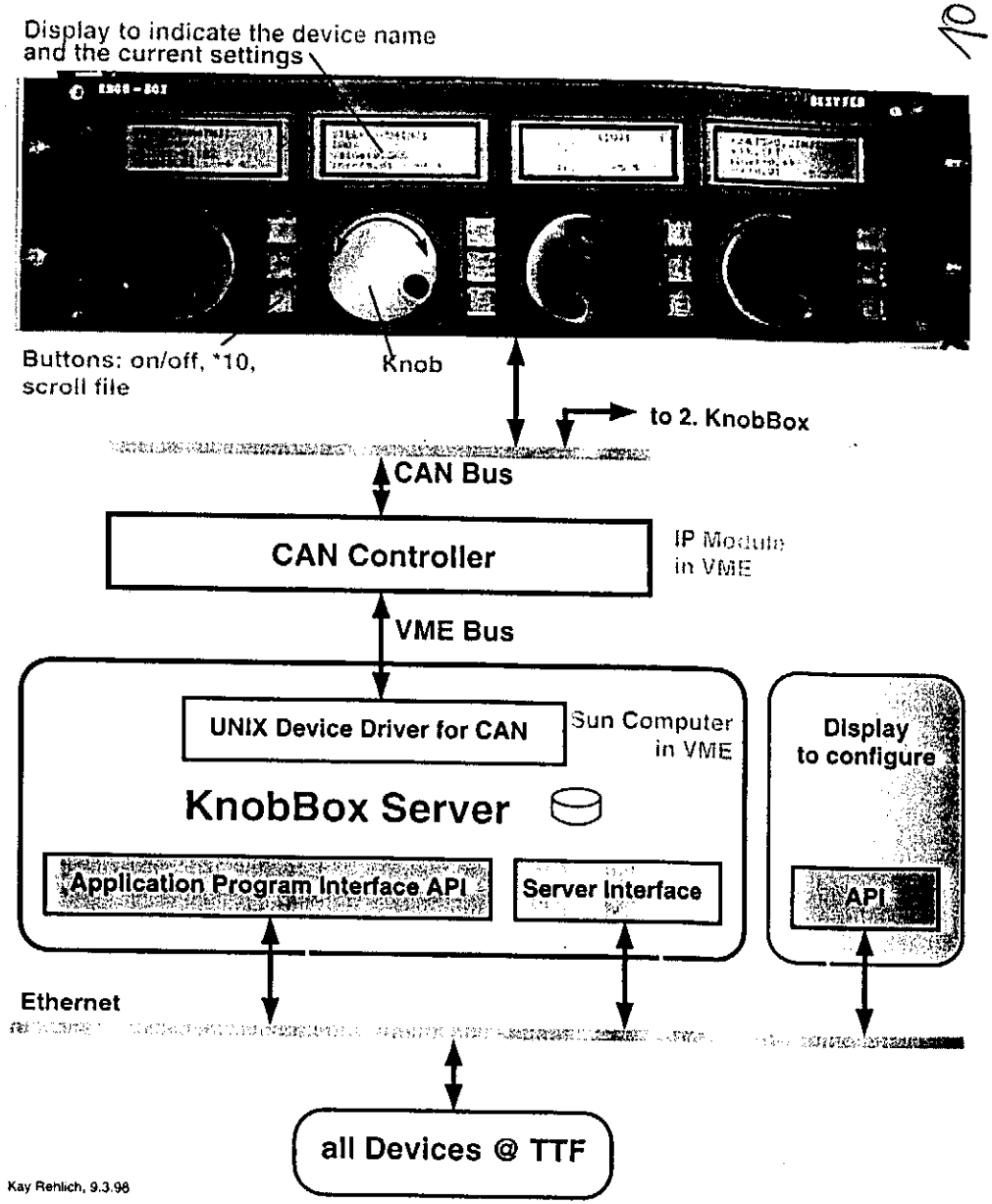


Kay Rehlich, 9.3.98

TTF-Linac Protection System



The TTF KnobBox



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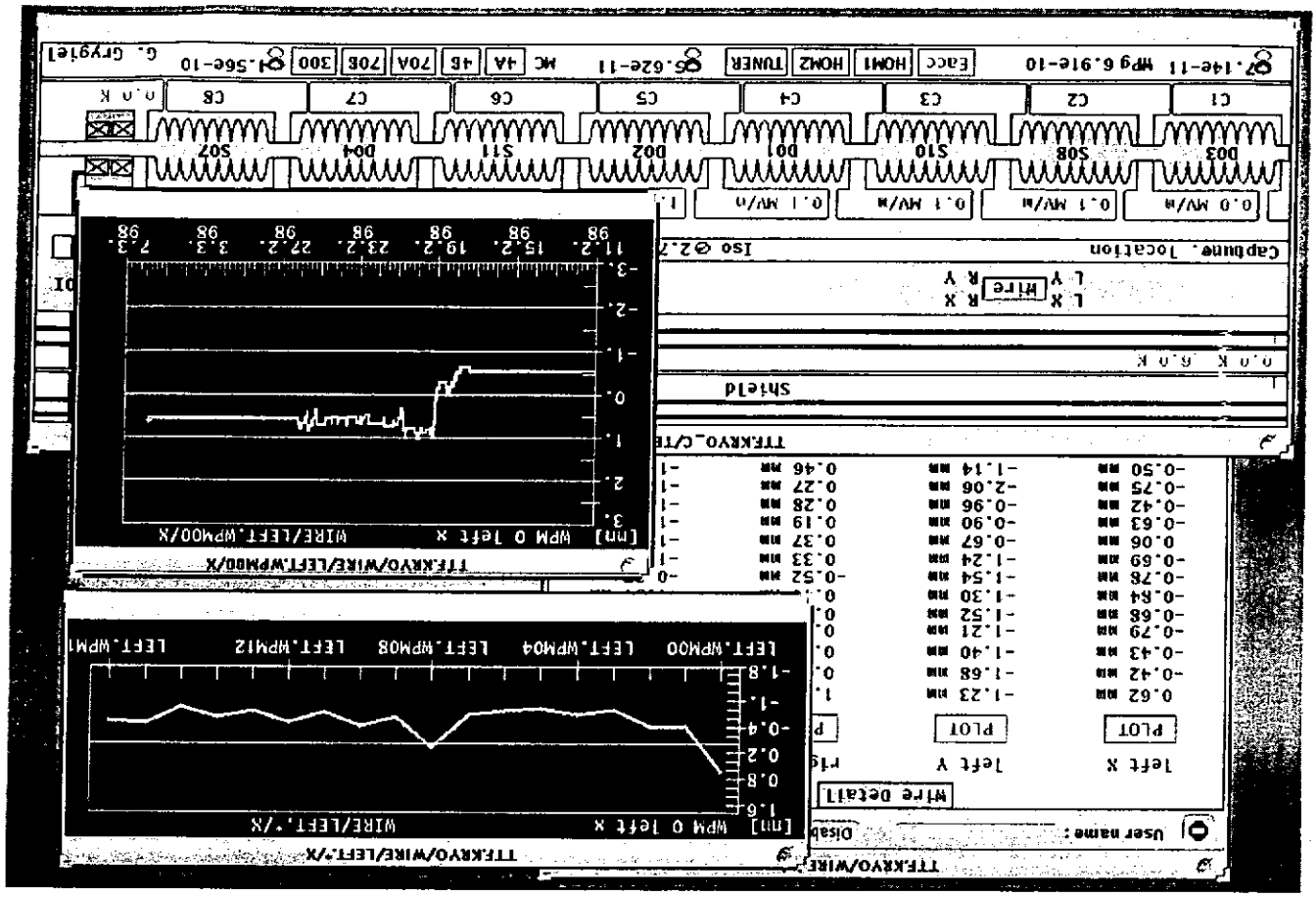
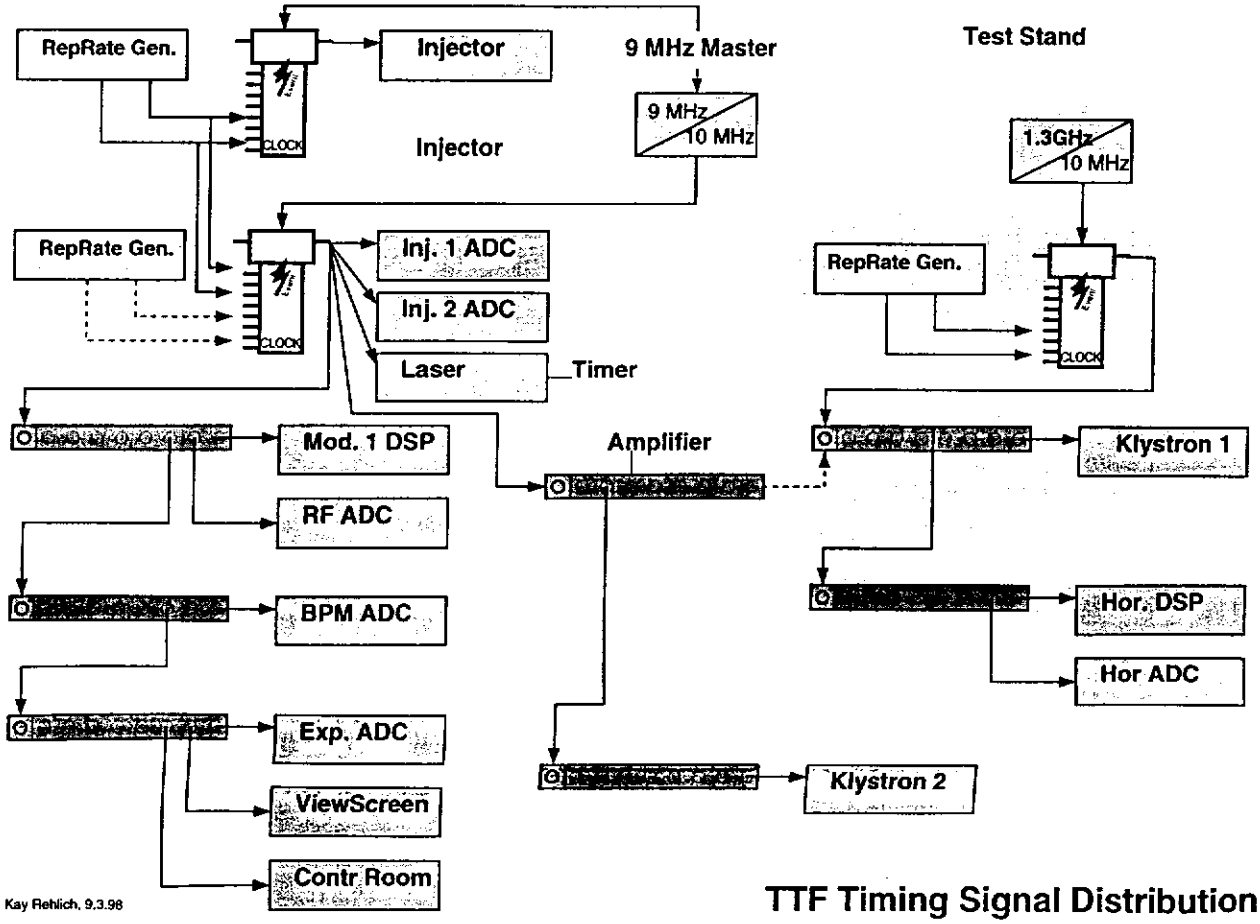
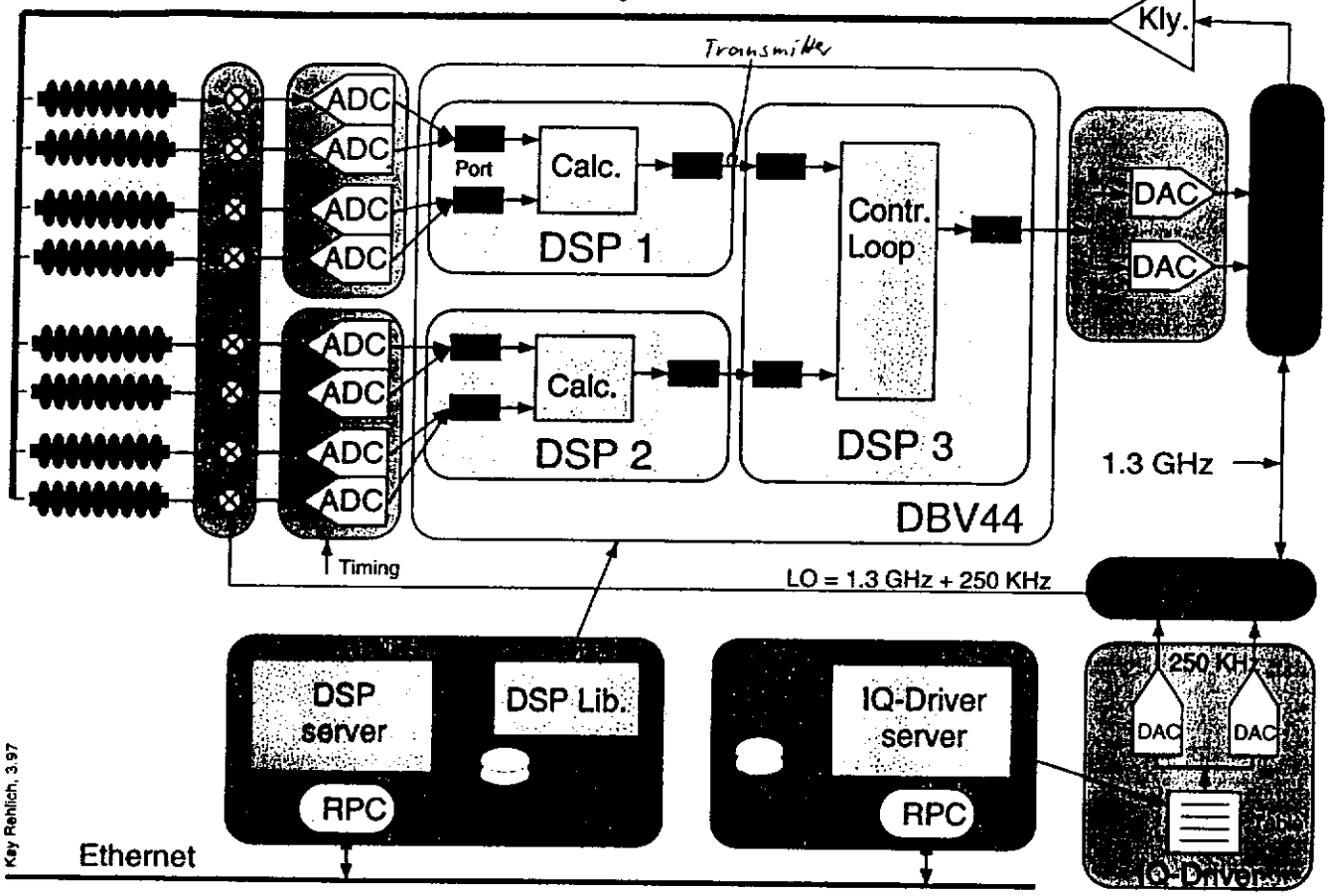
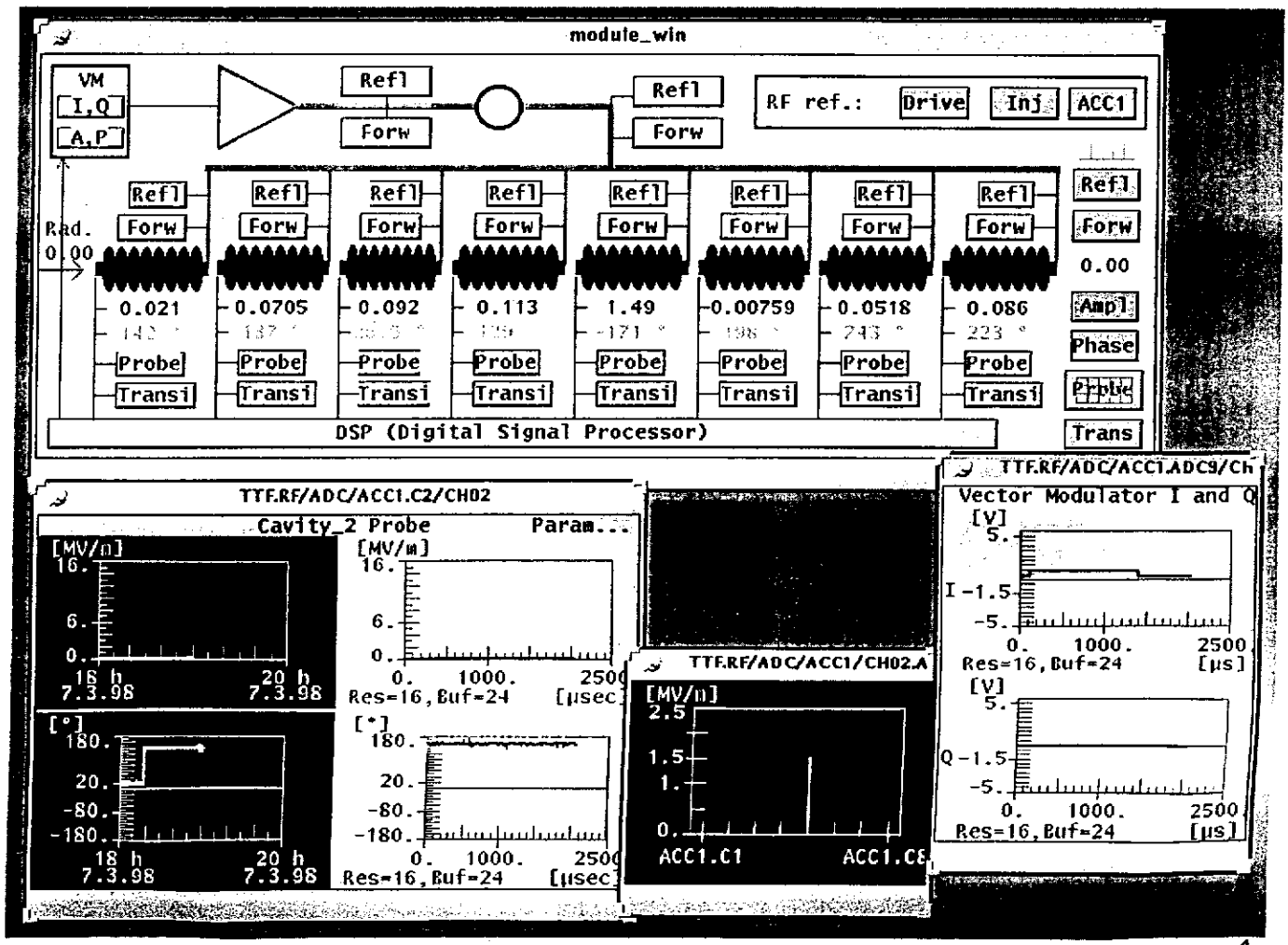




TTF Timing Signal Distribution

Digital Signal Processor System for the RF Control





Watchdog

System performance monitor and auto restart ➠ new

Computer Infrastructure

(together with SBand:
>70 SUNs, 10 LINUX PCs, 5 NT PCs)

Sun ULTRA for HFSS or coupler processing ➠ new

Sun ULTRA for cavity optimization,
2*300MHz CPUs, 1 GByte memory ➠ new

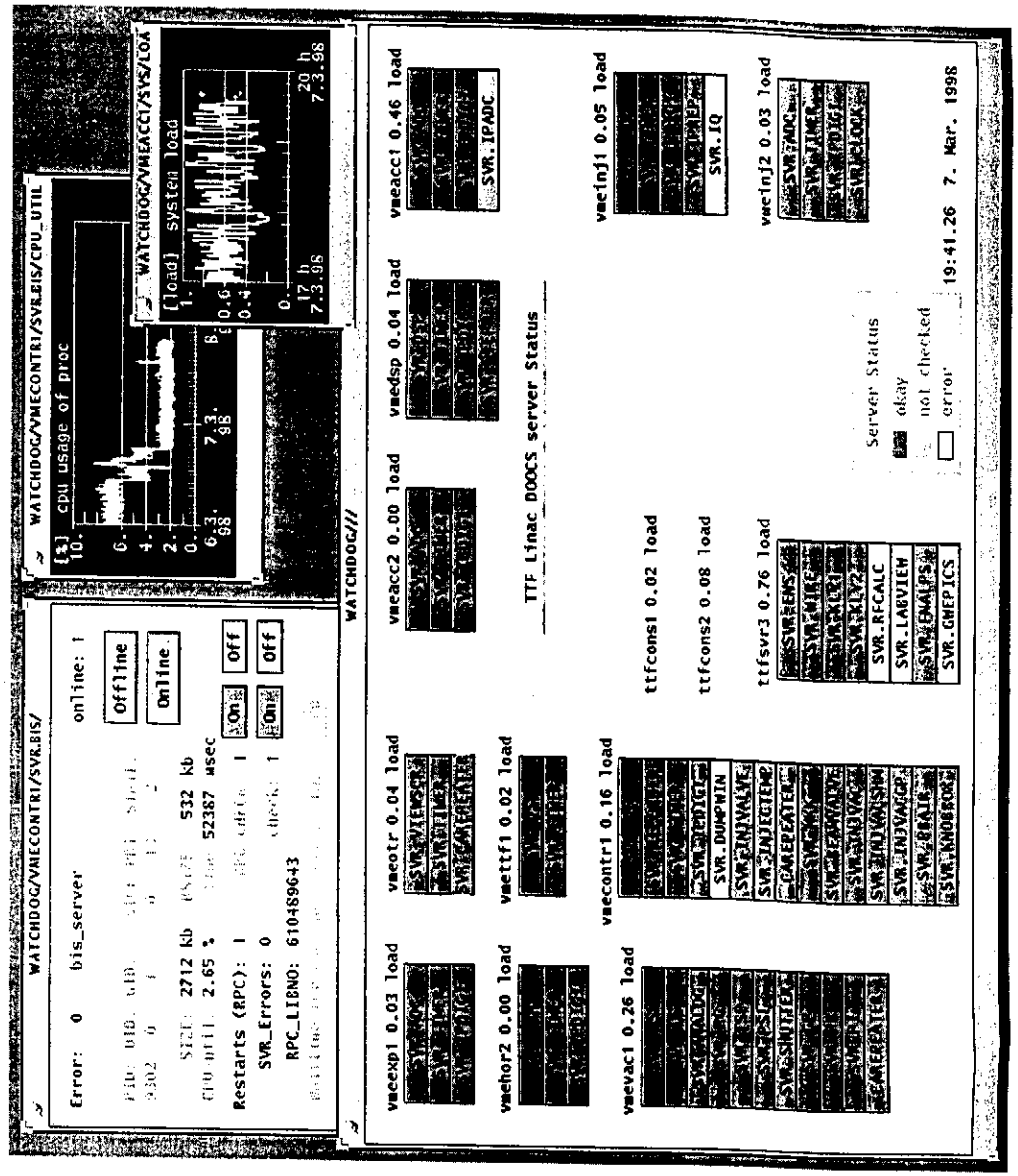
Exp. Area

Wire scanner (with Zeuthen) ➠ new

SEMgrid and laser port ➠ new

BPM

2 cavity monitors with 4 ADC and
4 digital channels each ➠ improved



Injector 1

Orsay/Saclay: more memory, timing improved, displays improved, new channels for SHB ..

Vacuum pumps (ion + titan sublimation pumps) ➠ new

Vacuum valve controller (PLC) ➠ adapted

Recorder for magnets, gun .. ➠ new

Injector 2

Magnet power supplies (FNAL) ➠ integrated

View screens (INFN) ➠ 5 new devices

Actuators for screens ➠ new

Diagnostics (ADC) ➠ new

Laser ➠ integrated

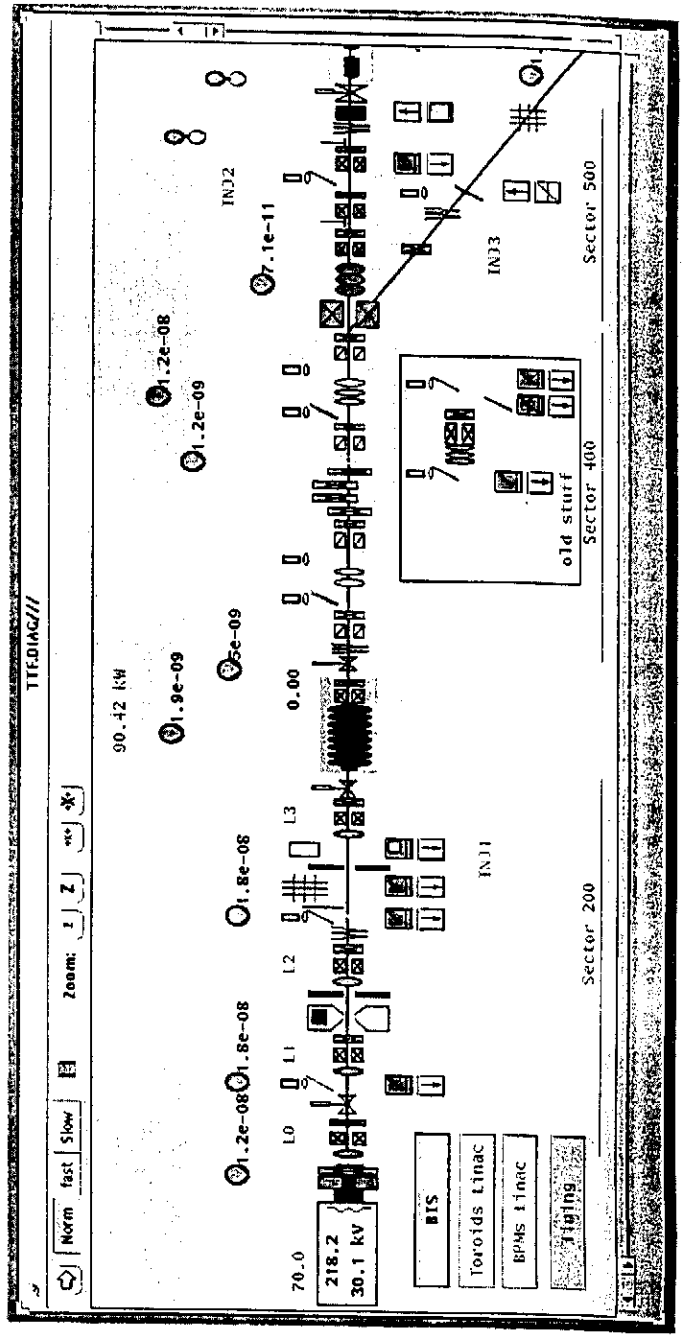
FEL gun: temperature, pumps, valves ➠ new

Next Steps

Modules 2 & 3 ..

New ADC board design
for diagnostics and feedback systems:
- cheaper diagnostics
- faster feedback
  - C40 = 25 instructions / µs
  - C60 < 1600 instructions / µs

Automated procedures

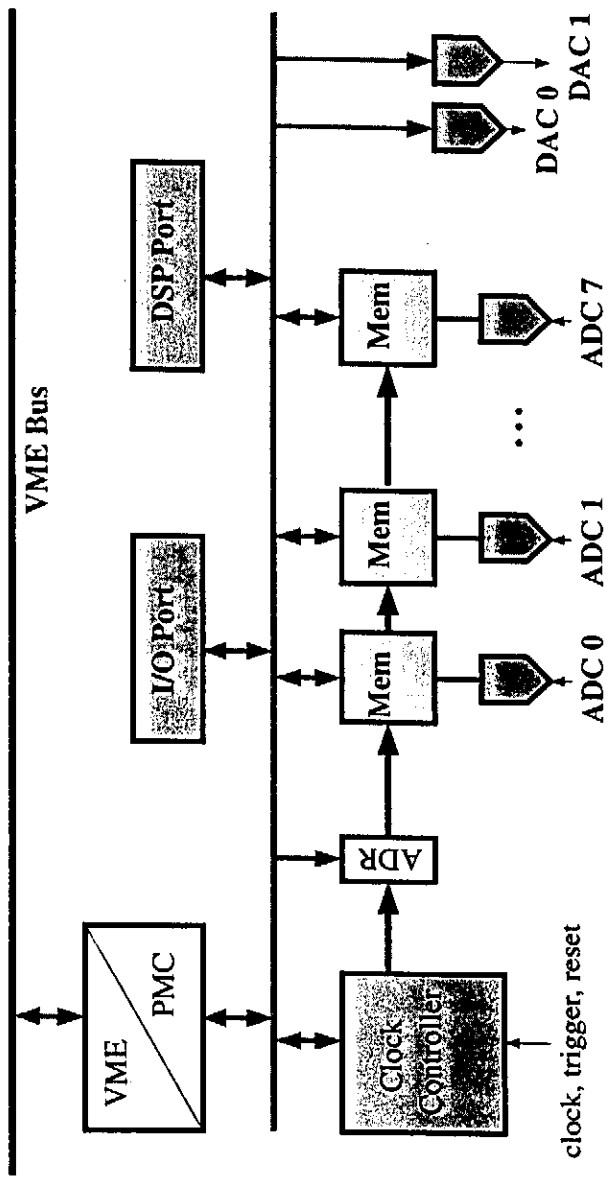


Diagnostics for INJ II: FastADC Channels

Ch Number	Type	Signal Description
0	Scope	Faraday Cup 1 FEL_GUN or FNAL_GUN
1	Scope	Faraday Cup 2 FEL_GUN or FNAL_GUN
2	Scope	Faraday Cup 3 FEL_GUN
3	Scope	Button BPM Sum FEL_GUN or FNAL_GUN
4	Scope	Button BPM X FEL_GUN or FNAL_GUN
5	Scope	Button BPM Y FEL_GUN or FNAL_GUN
6	Scope	RF Window IR or e- FEL_GUN or FNAL_GUN
7		Spare (RF ref, Capture P for, Laser UV ..)
8	RF 216	SHB Probe
9	RF 216	Gun Grid Voltage
10	RF 216	Beam Pickup Inj 1
11	RF	Capture Cavity Probe
12	RF	Klystron 1 P forward
13	RF	Klystron 1 P reflected
14	RF	Klystron 2 P forward
15	RF	Klystron 2 P reflected
16	RF	Klystron 3 P forward
17	RF	Klystron 3 P reflected
18	RF	Gun P forward FEL_GUN or FNAL_GUN
19	RF	Gun P reflected FEL_GUN or FNAL_GUN
20	RF	Gun Probe FEL_GUN or FNAL_GUN
21	Scope	ICT 1 Inj 1 + 2
22	Scope	ICT 2 Inj 1 + 2
23	Scope	ICT 3 Inj 1 + 2
24	Scope	Button BPM X FNAL_GUN
25	Scope	Button BPM Y FNAL_GUN
26	Scope	Button BPM Sum FNAL_GUN
27		
28		

Ch. 0 .. 15 are installed
Ch 16 .. 27 will be installed later

Kay Rehlich, 3.98



8 Channels of fast ADCs: up to 1 or 10 MHz sampling, 14 bit resolution, 128k word of memory
2 DAC channels: 16 bit resolution, 35 ns settling time
1 DSP port: for a standard Ti C60 processor on a PMC module
1 I/O port for communication links or a second DSP

Kay Rehlich, 3.98

New ADC Board Design for Diagnostics and Feedback Systems

106

RF Gun for FEL operation

K. Flöttmann

9.3.98

Status of Gun Components:

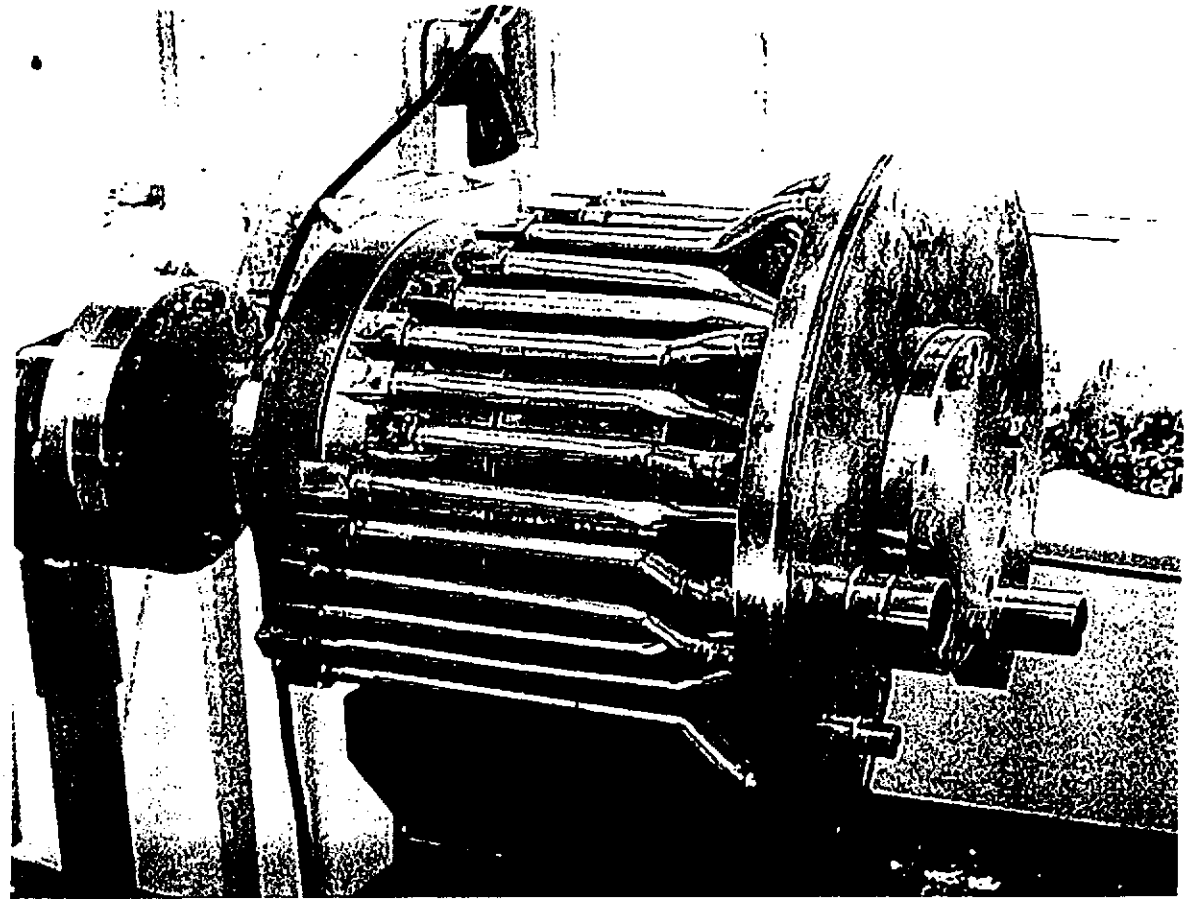
- Solenoids are in House
- Input Coupler is fabricated
- Gun Cavity is ready

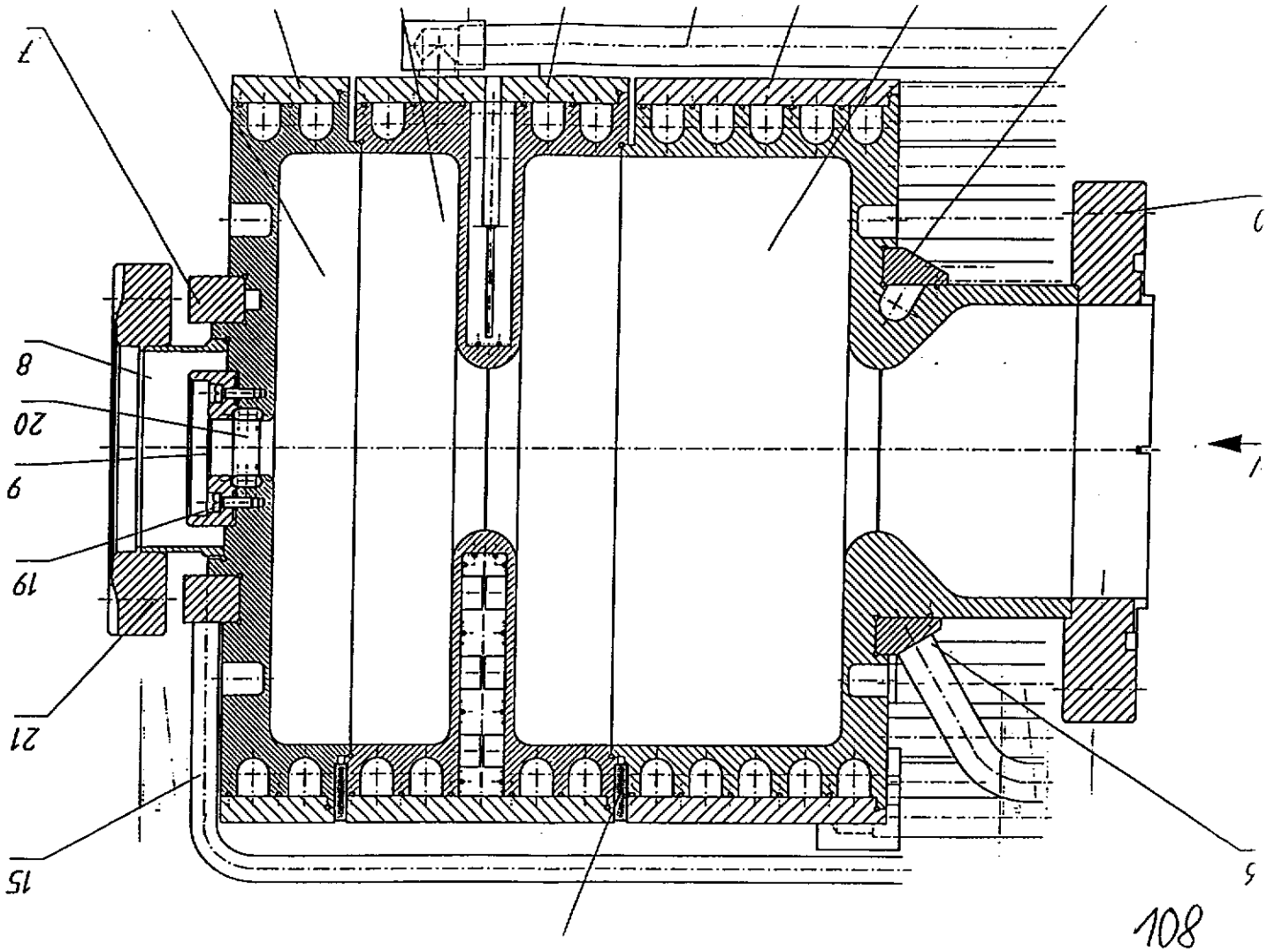
Problems during Cavity production:

Due to porous copper:
- vacuum problems
- spots of brazing alloy on the inner surface.

---

copper quality: 1. Grade OFHC, forged to increase density.
new material ordered: NA-BE
same electrical properties as OFHC, but better mechanical properties.

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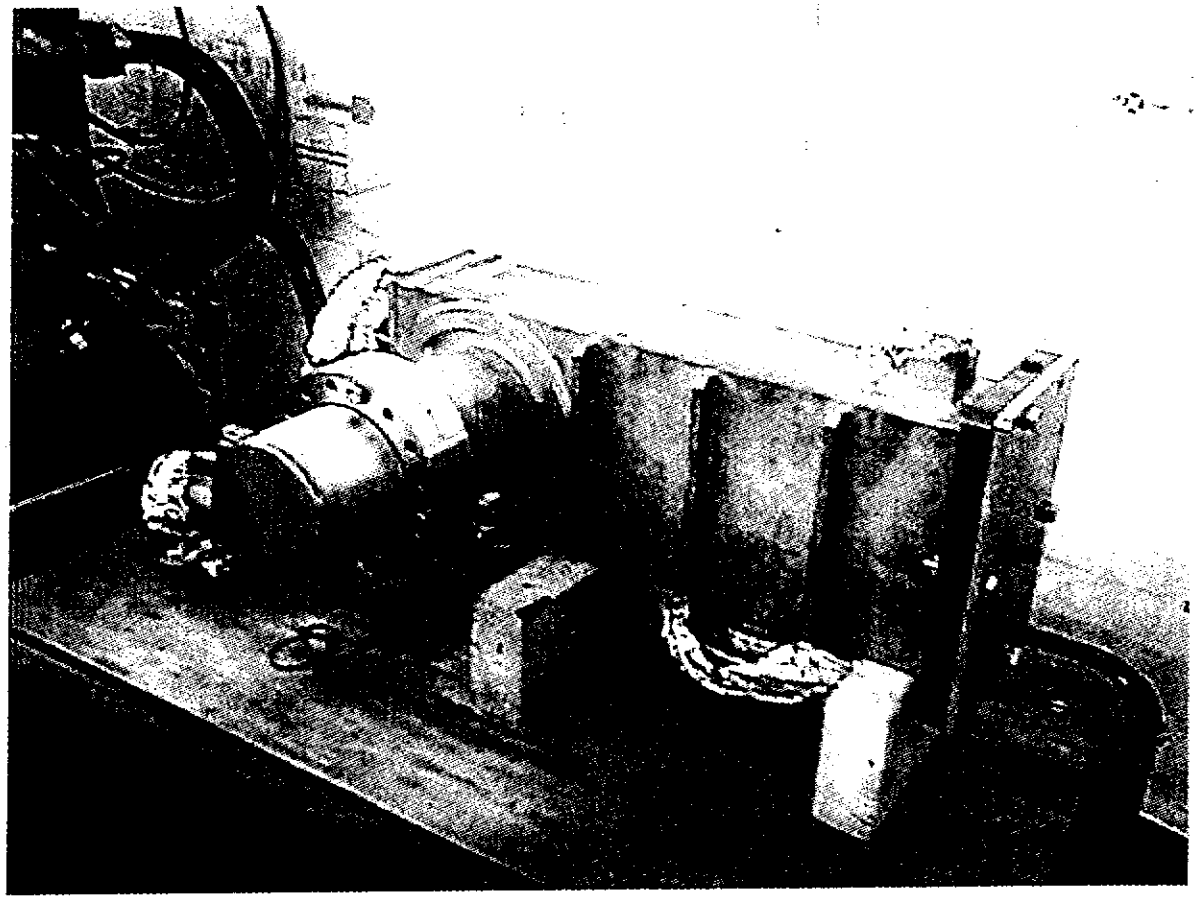

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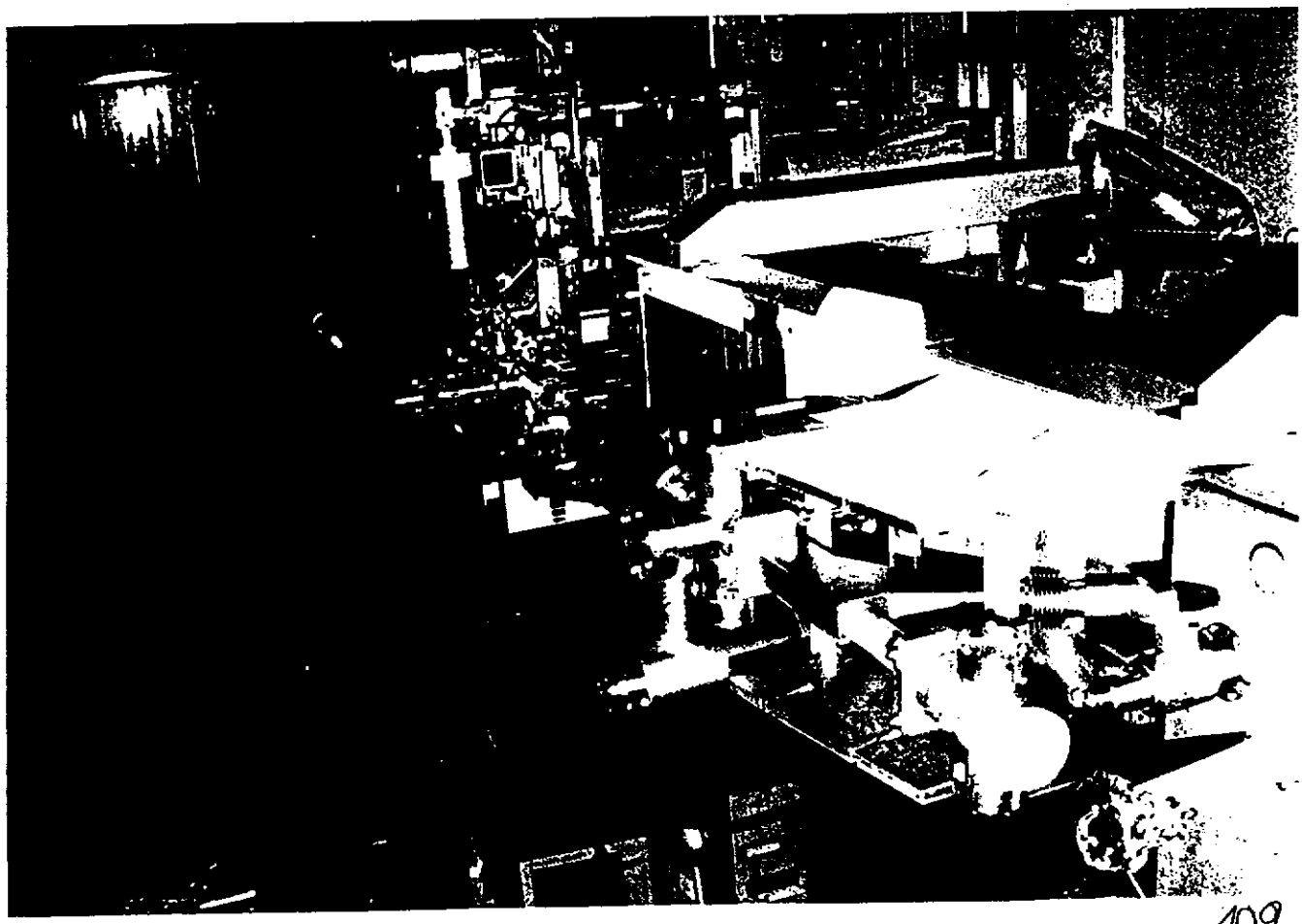
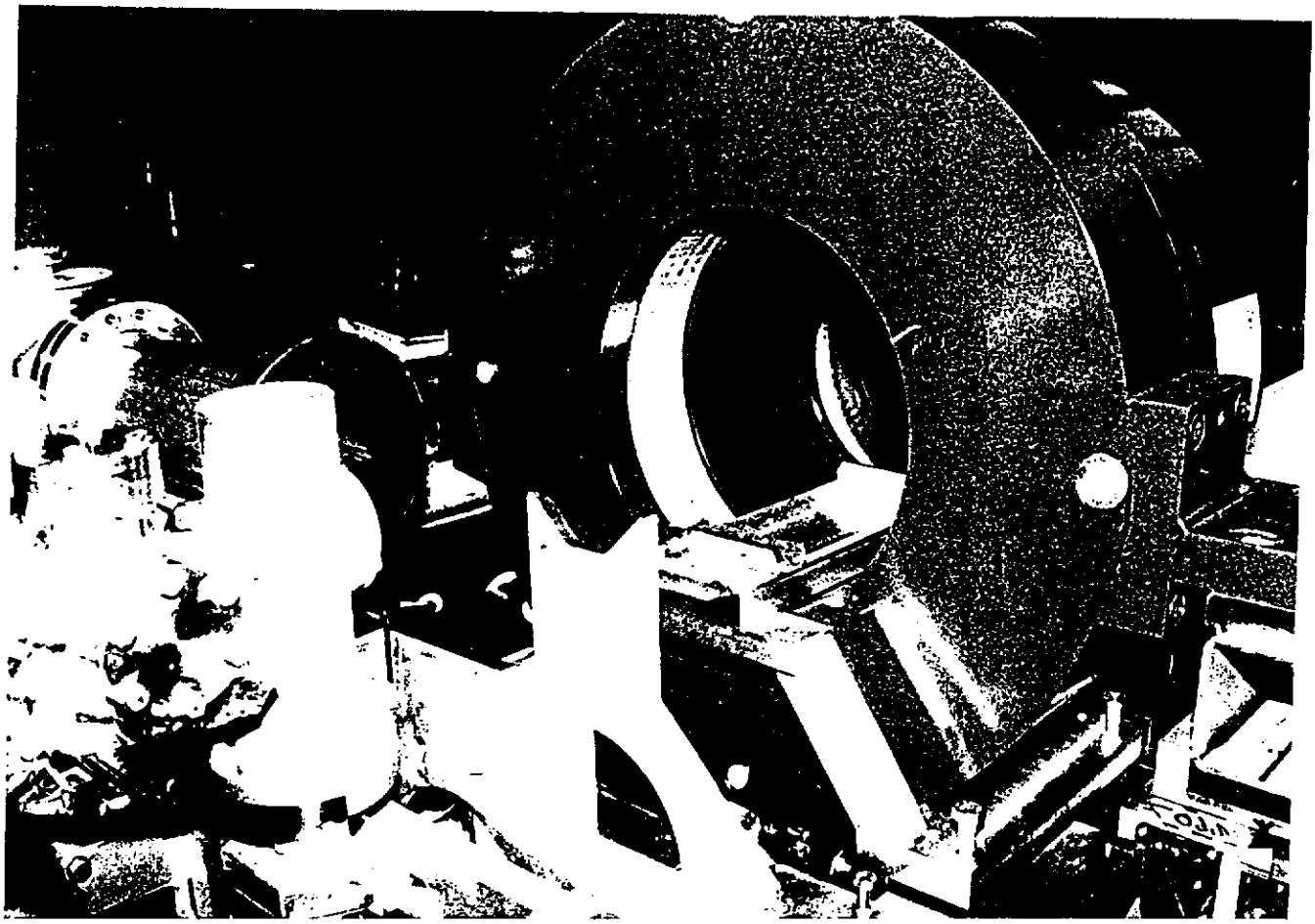
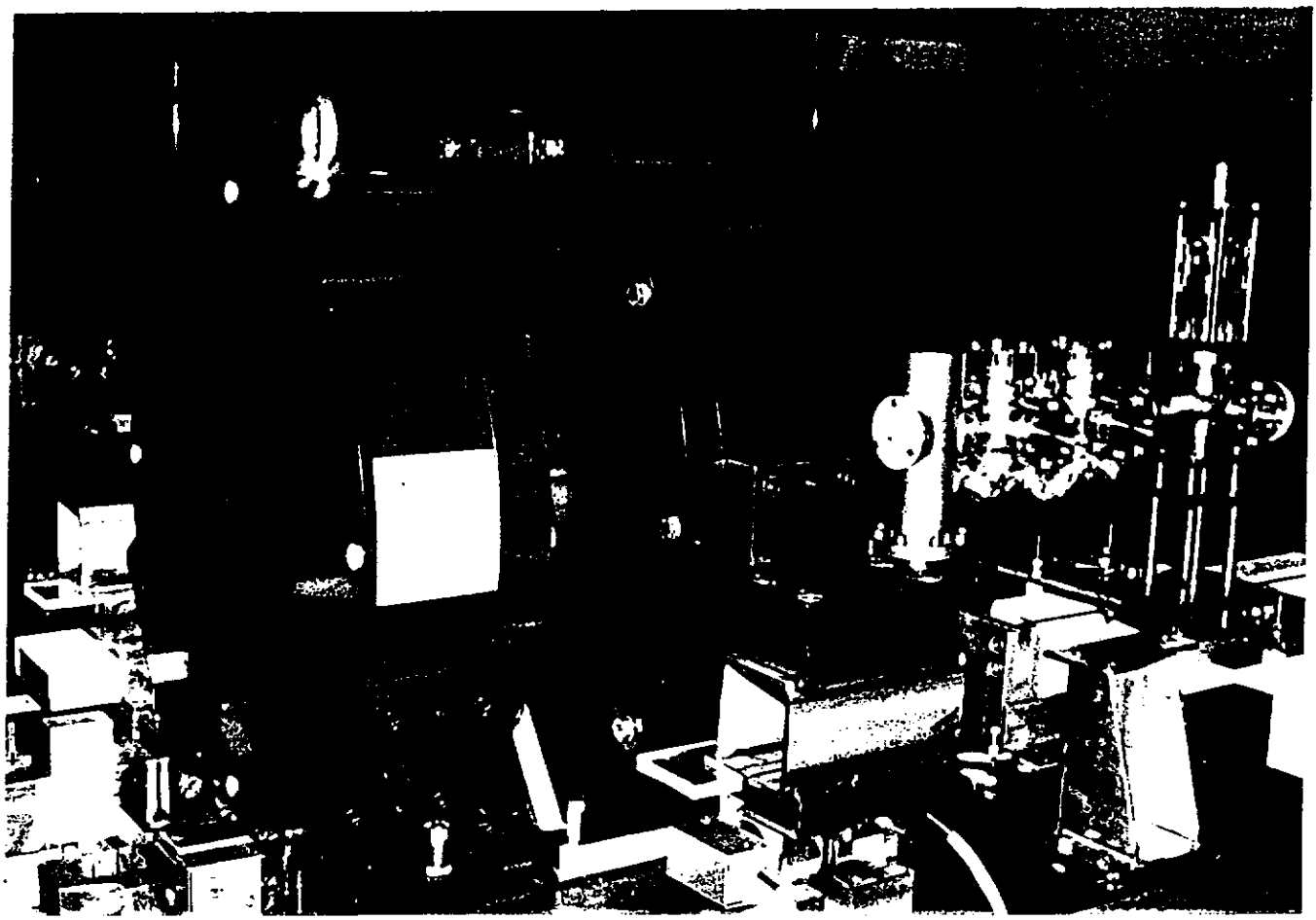
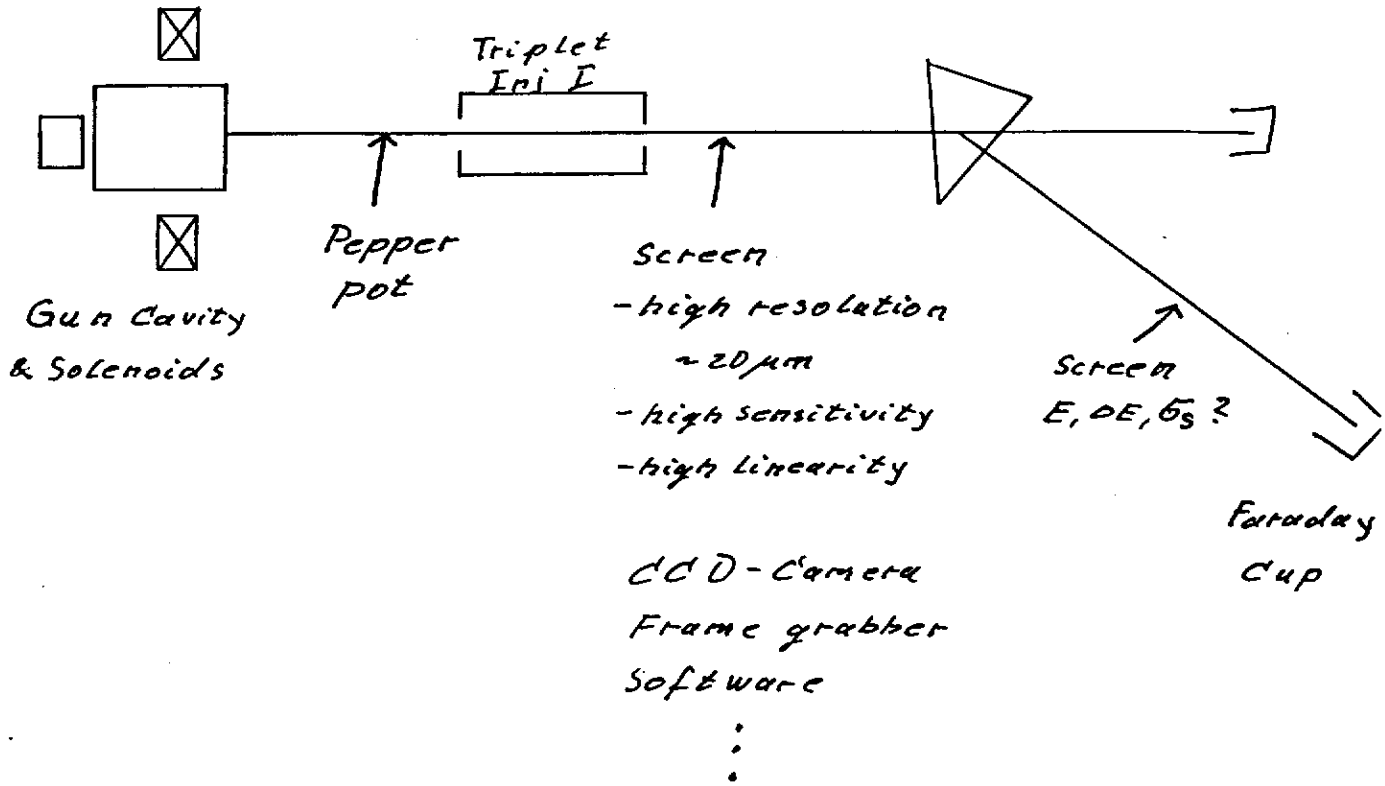
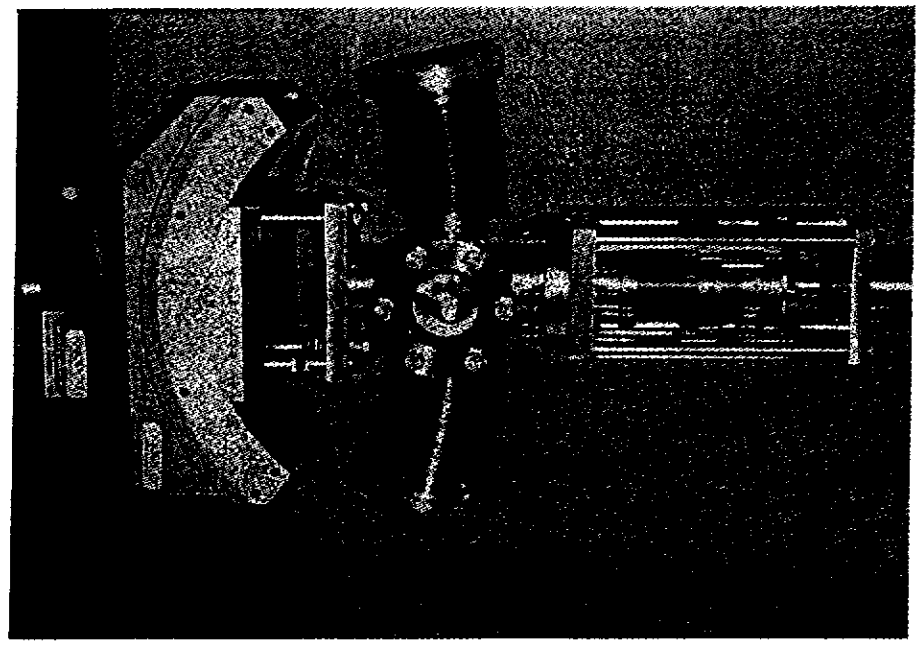






Test Beam Line





High resolution screen for Pepper Pot measurement:

- New screen based on YAG powder, grain size ≤ 3 µm, fabricated at DESY.

- Resolution measurement with a scanning fluorescent microscope at HASYLAB ≤ 10 µm

- Beam test at S-Band Test Facility, very bright spot, absorbers were required to prevent cameras from saturation.

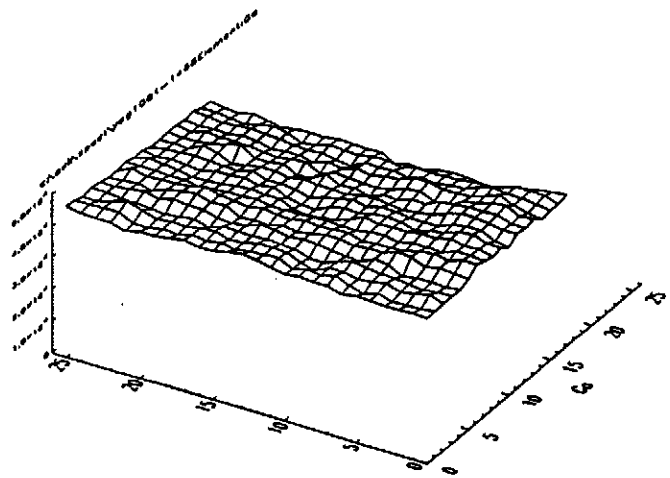


Abb. 4 Zweidimensionaler Scan über YAG-Leuchtschirm mit Schrittweiten von 4 µm. Aufgetragen ist die normierte Fluoreszenzintensität für Ga. Größe des untersuchten Gebiets: 100 µm x 68 µm.

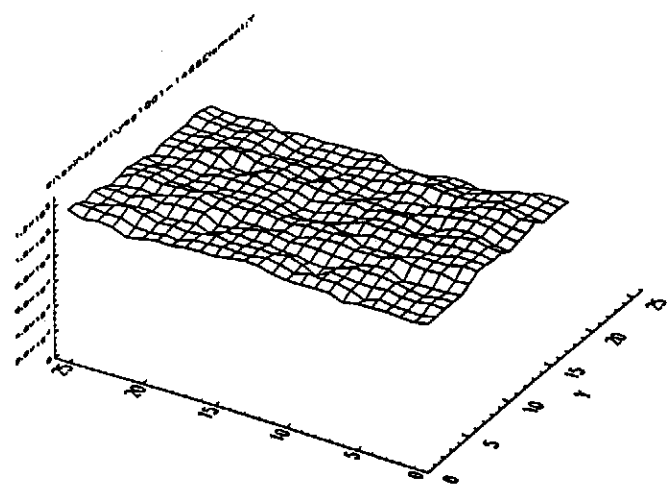


Abb. 5 Zweidimensionaler Scan über YAG-Leuchtschirm mit Schrittweiten von 4 µm. Aufgetragen ist die normierte Fluoreszenzintensität für Y. Größe des untersuchten Gebiets: 100 µm x 68 µm.

The Next Steps:

- low level rf measurements of cavity and coupler
- assembly of photocathode transfer system at DESY
- cleaning and cleanroom assembly of gun test stand
- move into vault

Bunch Compressor II Status

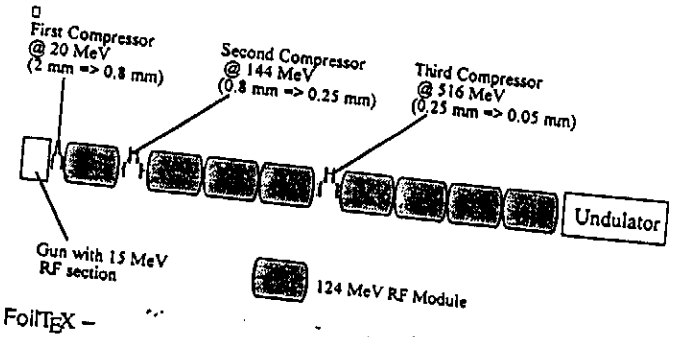
A. Kabel

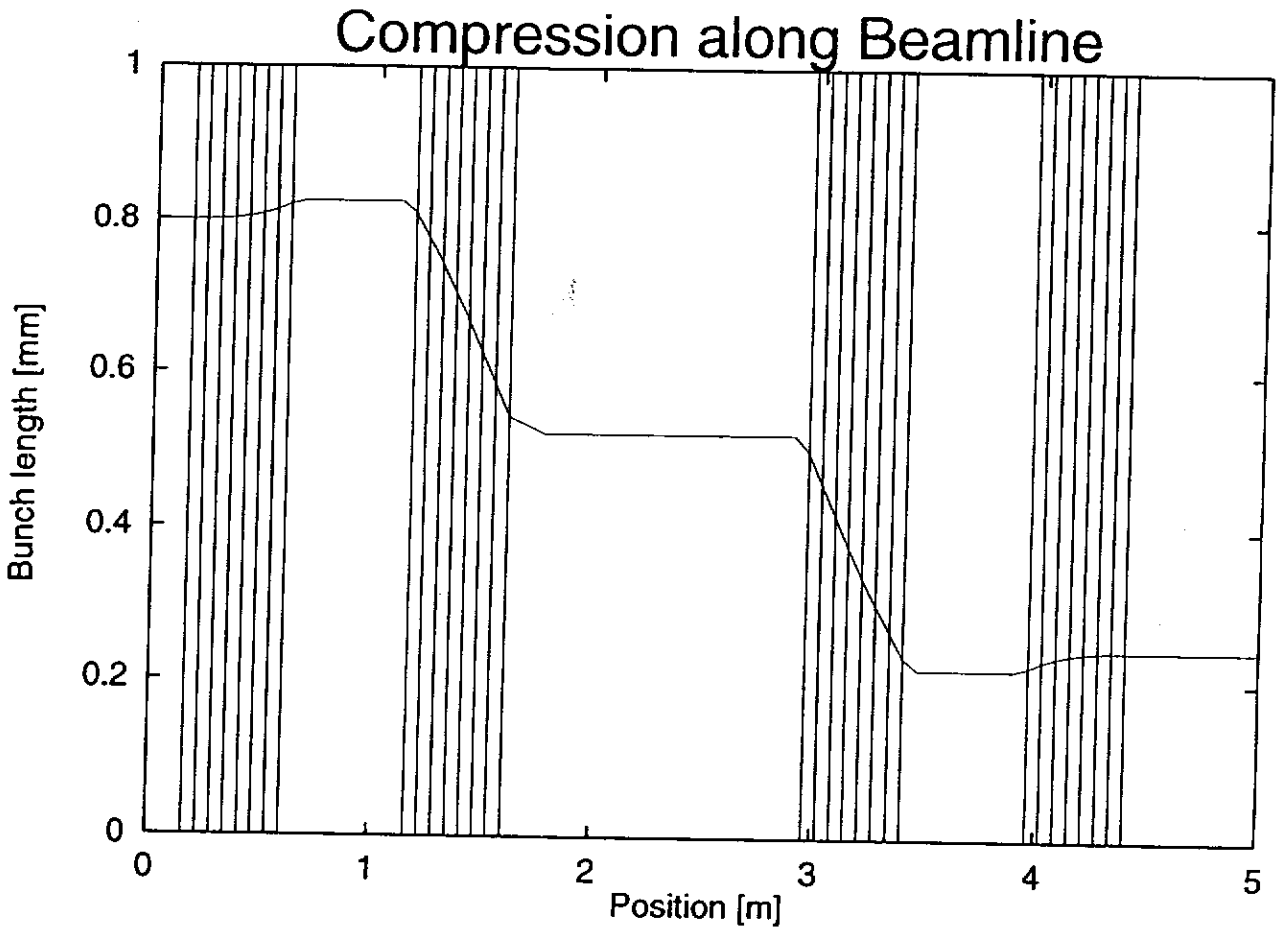
March 9, 1998

- Overall Design & Beamline
- Instrumentation
- Component Status: Beamline
- Component Status: Instrumentation

Overall Design

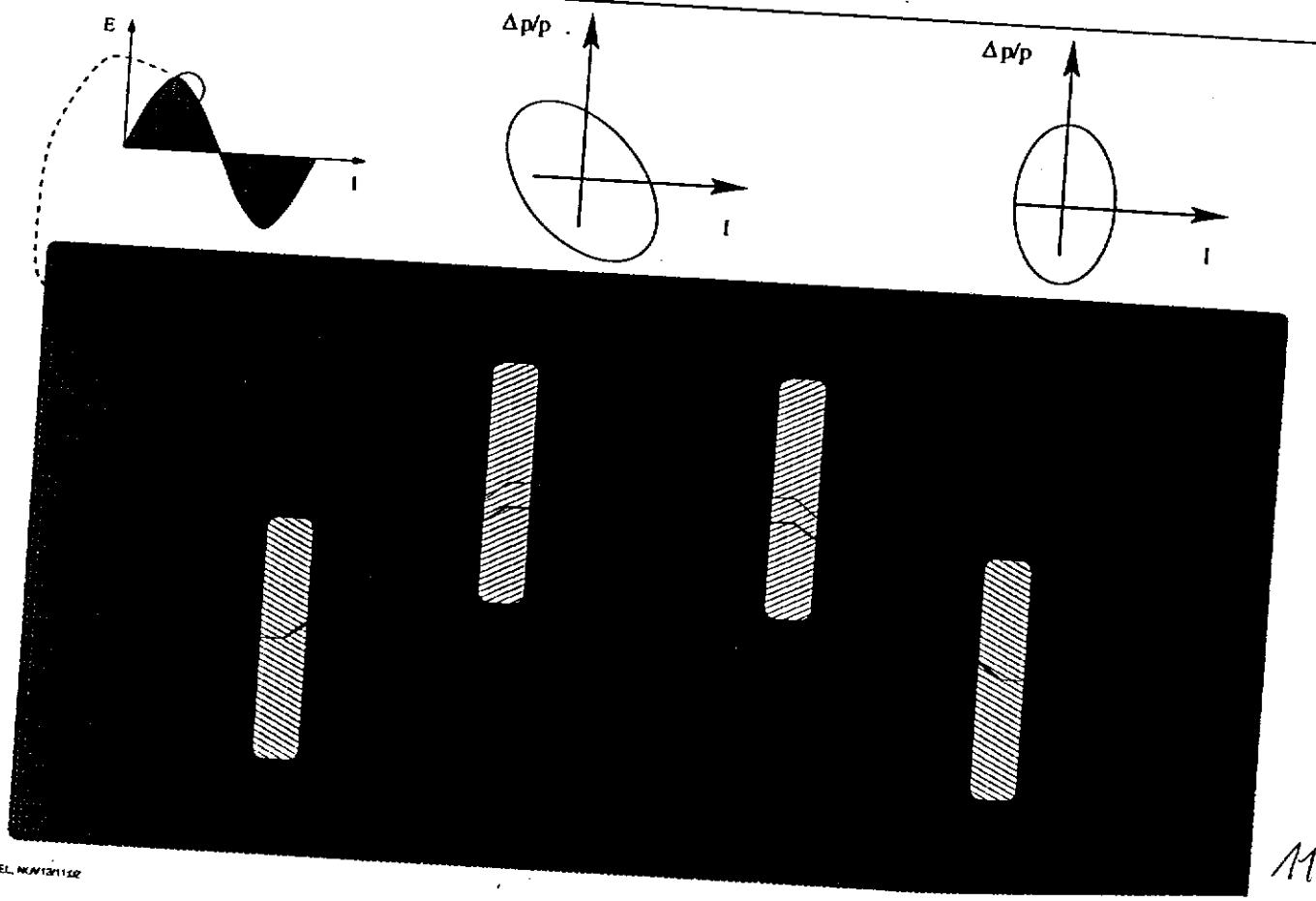
- Magnetic chicane
- Inserted downstream module #1
- E=144 MeV
- $800\mu m \rightarrow 250\mu m$



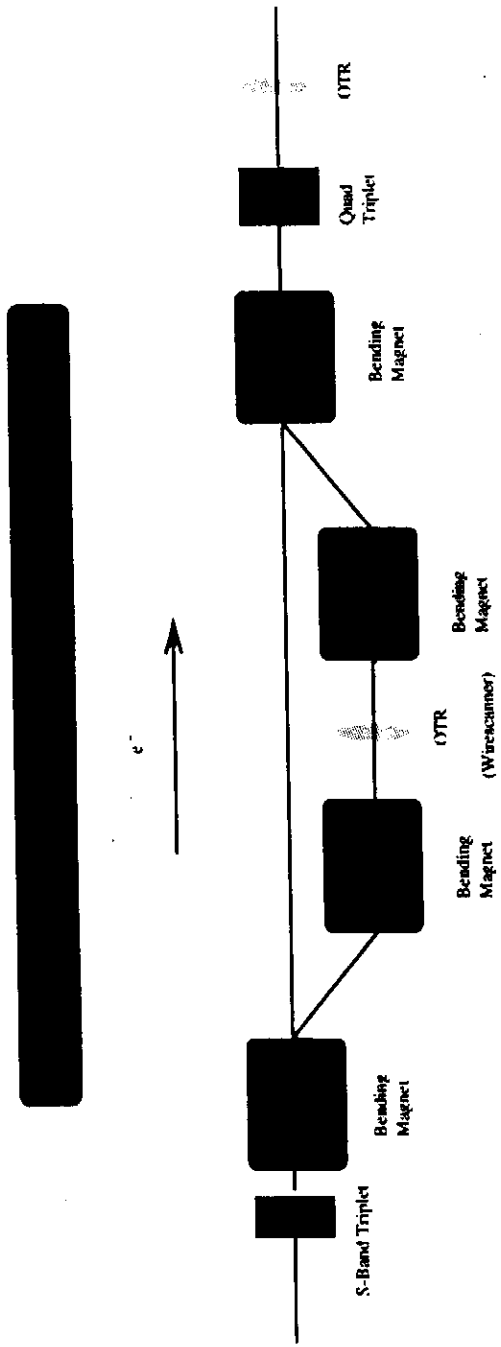


\KABEL@SOLAR02, OCT31/15:40

Magnetic Chicane

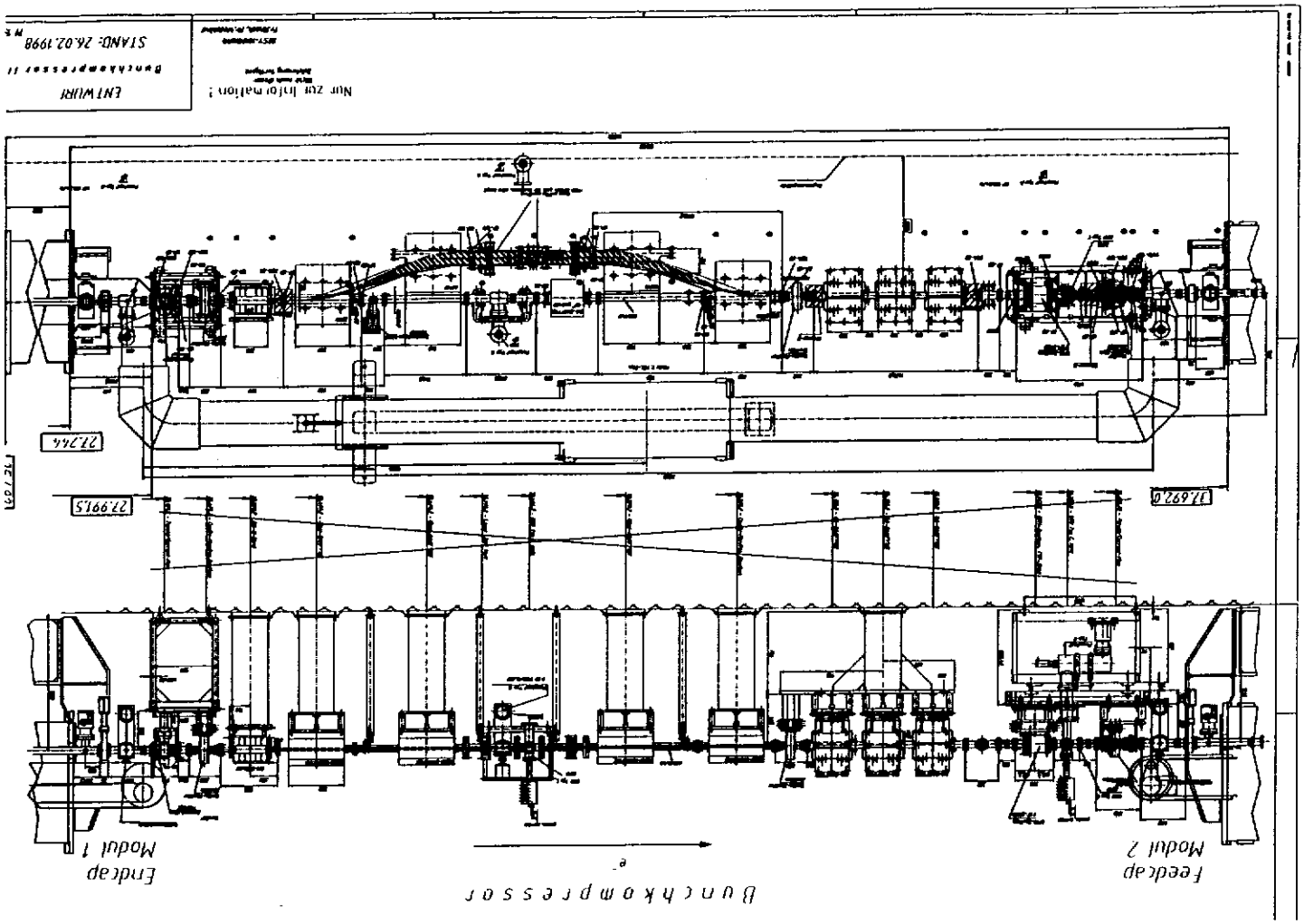


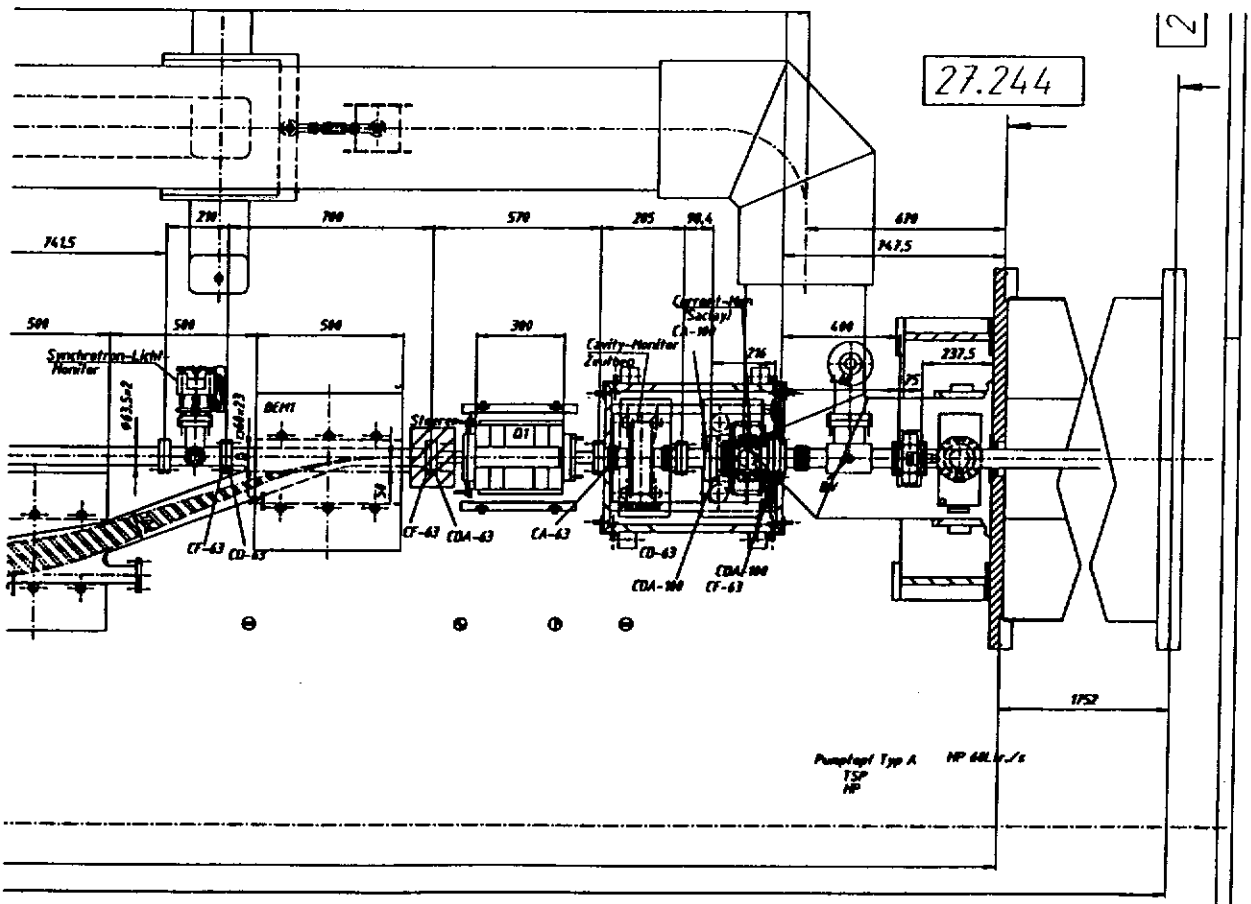
AHF | @MPY1,TKABEL, NUM/13/11:02



Instrumentation & Diagnosis

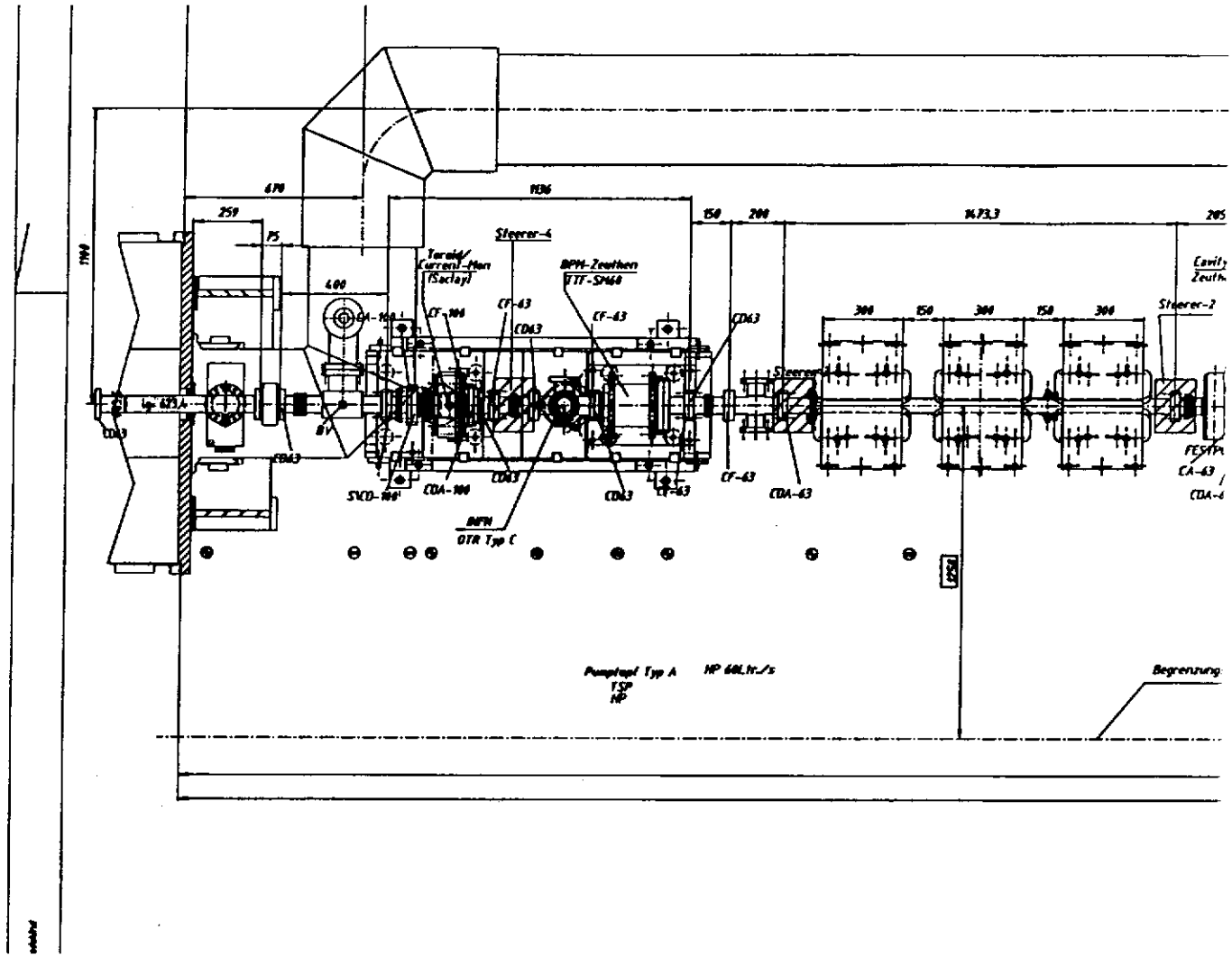
- Transversal beam tomography: quad triplet, OTR
- Longitudinal beam tomography: RF phase variation & OTR inside of dispersive section
- Synchrotron light inside of chicane
- Beam position: cavity & stripline BPMs
- Current measurement: toroids

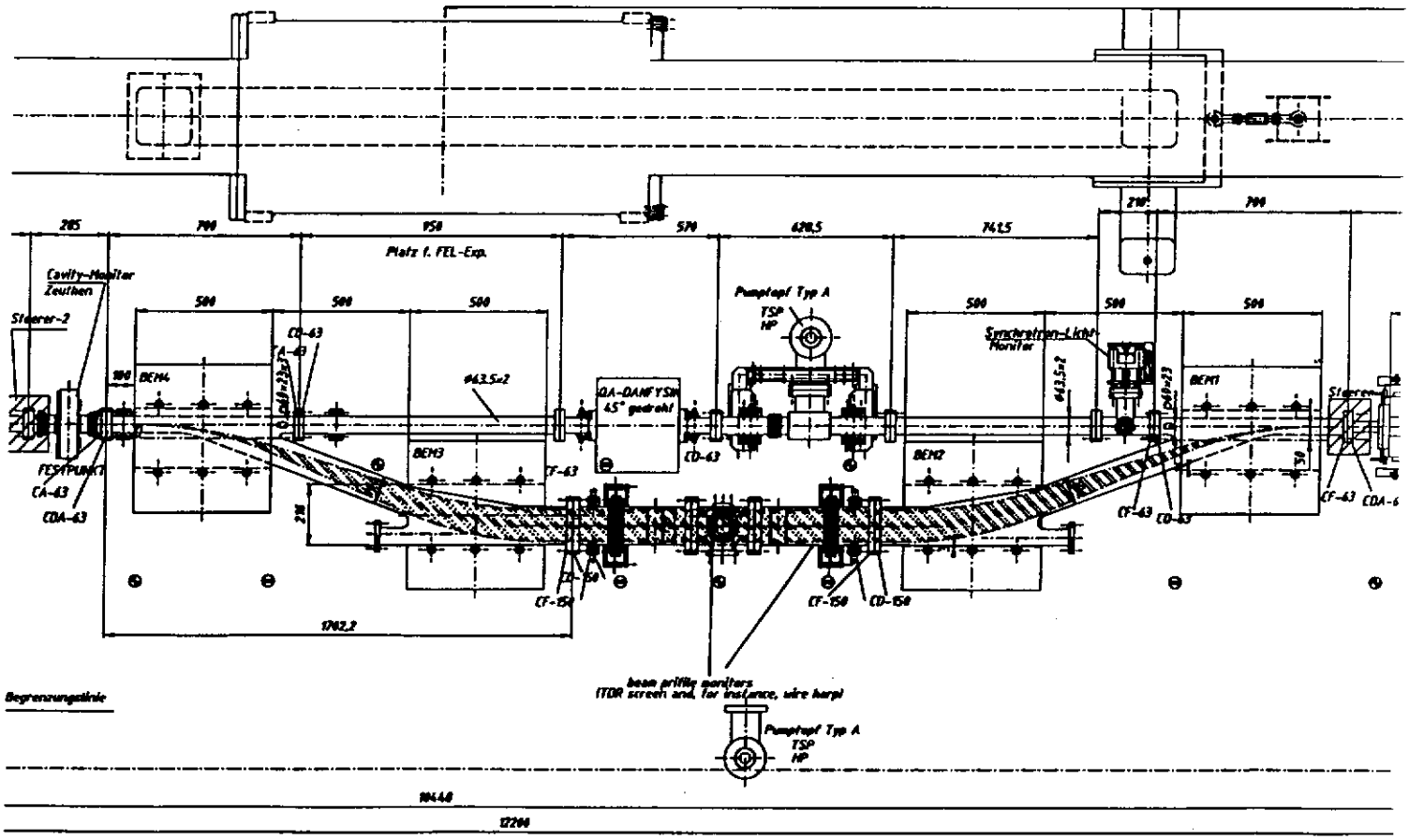




Nur zur Information !
Nicht nach dieser

ENTWURF





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Nur zur Infor
Nicht nach die

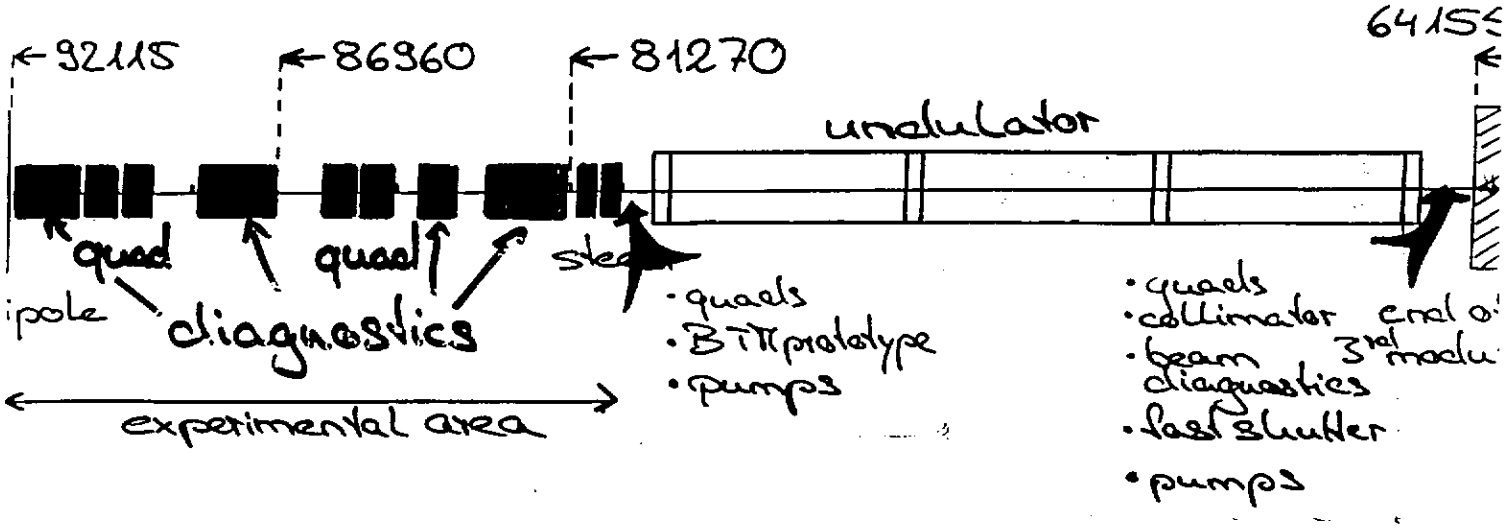
Component Status: Instrumentation

- Stripline BPM: exists
- Cavity monitors (Zeuthen): vacuum firing at DESY finished; welding & alignment. Supports are being constructed
- Toroid (Saclay): no final date fixed yet, but up to schedule
- OTR dispersive section (Frascati): no final date fixed yet, but up to schedule

Component Status: Beamline

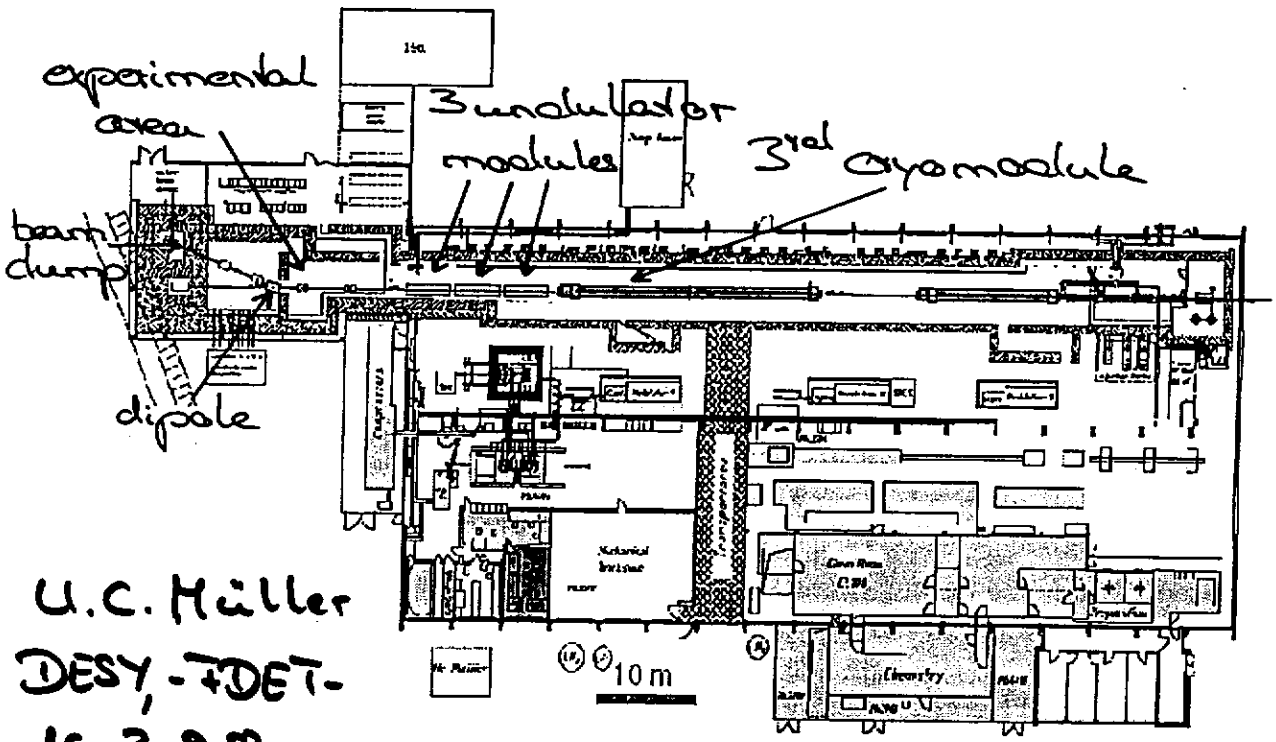
- Beampipes dispersive section: manufacturing started, finished end of April, 1998
- Special bellows dispersive section: $\approx$ mid of April, 1998
- Standard beampipes: in-house fabrication, finished within schedule
- power supplies: been/being delivered
- Dipole magnets: delivered; measurements underway
- 1st quad triplet: exists
- 2nd quad triplet & skew quad: available when module #2 is built in
- Supports: design being finished; Manufacturing (Cracow) $\approx$ end of April, 1998

Beam Line



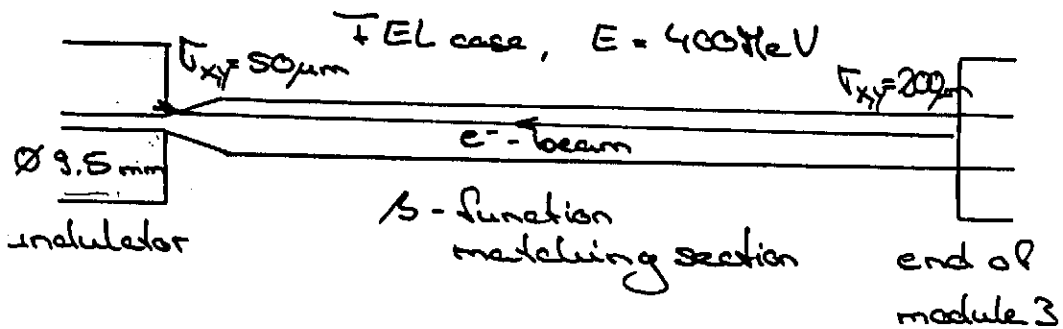
- diagnostic equipment for TTF and FEL
- matching of β-function
- safety for undulator (collimator, fast interlock
- safety for cryomodules (fast shutter, pumps...)

Layout of Undulator Beam Line



U.C. Müller
DESY, -TDET-
10.3.98

Safety Protection



temperature rise at the core of the bunch at the entrance of the undulator

number of electrons $6 \cdot 10^{11} e^-$ $4 \cdot 10^{12} e^-$

time 0.9 μs 8.9 μs 10 μs 35 μs 70 μs

Cu	92°C	843°C	material heavier than Al cracked	current interlock system	–
Al	59°C	532°C			–
C	73°C	475°C			2529°C

[redacted]

→ speed up interlock system

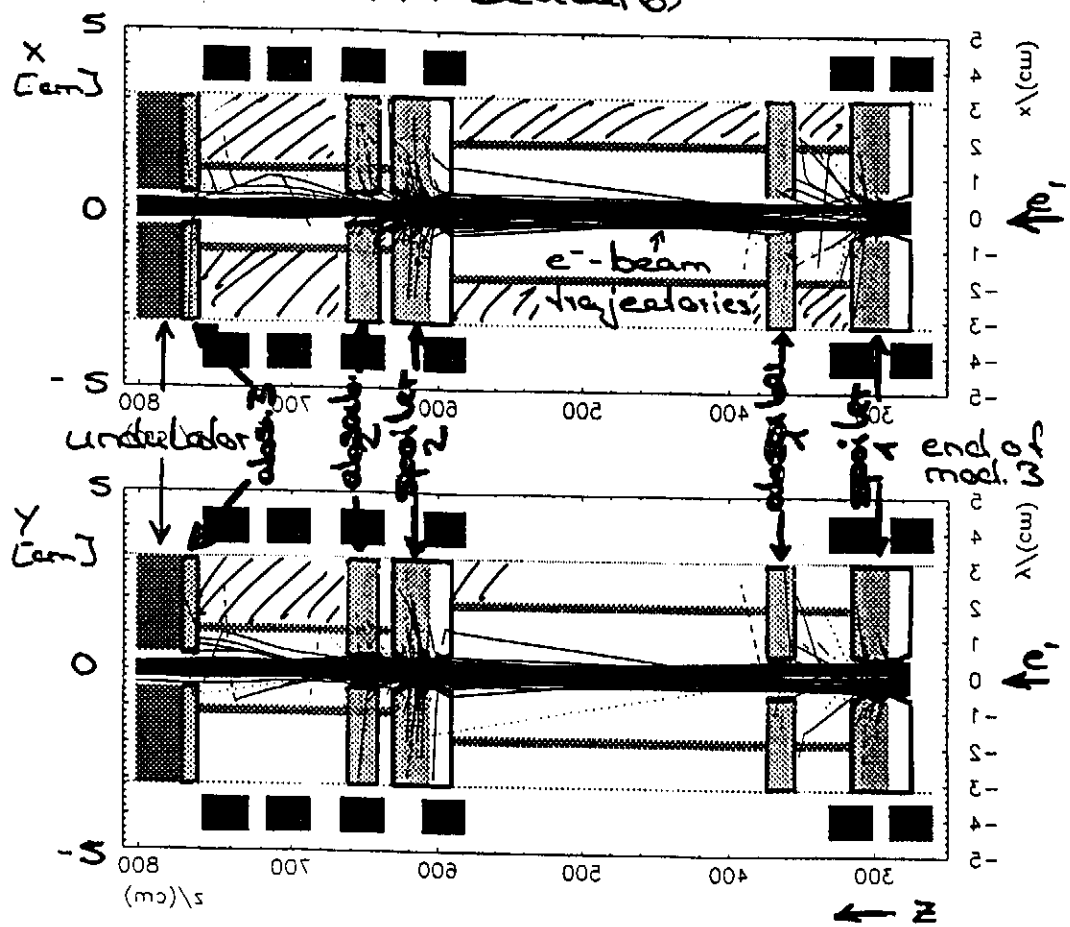
→ collimator system

Collimator System

- Large energy range (200 MeV – 500 MeV)
- $\varepsilon_\perp$: 2π mm mrad (FEL) – 20π mm mrad (TT
- fit between 3rd cryomodule and undulator

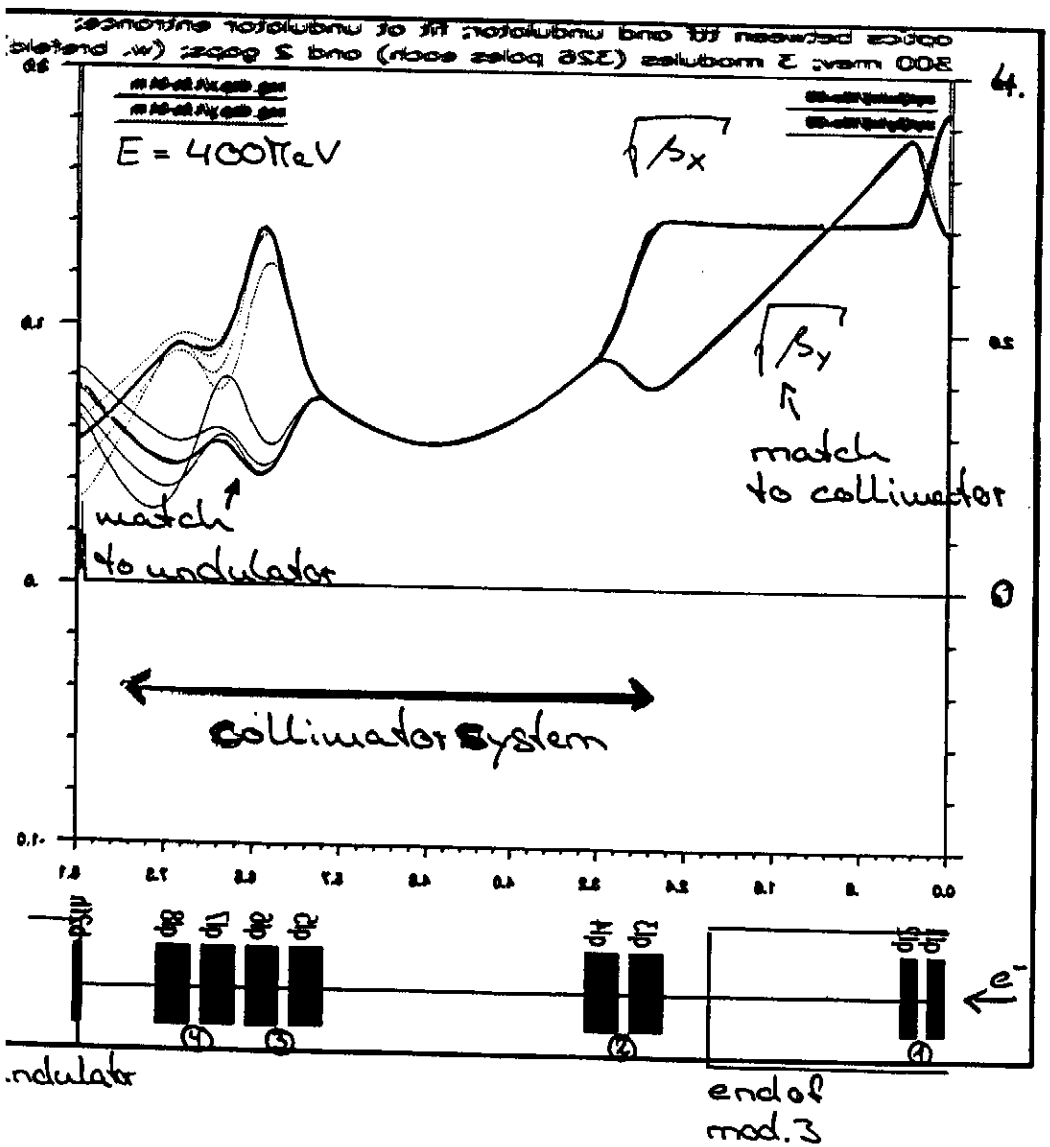
Collimator Layout

(H. Schlarb)



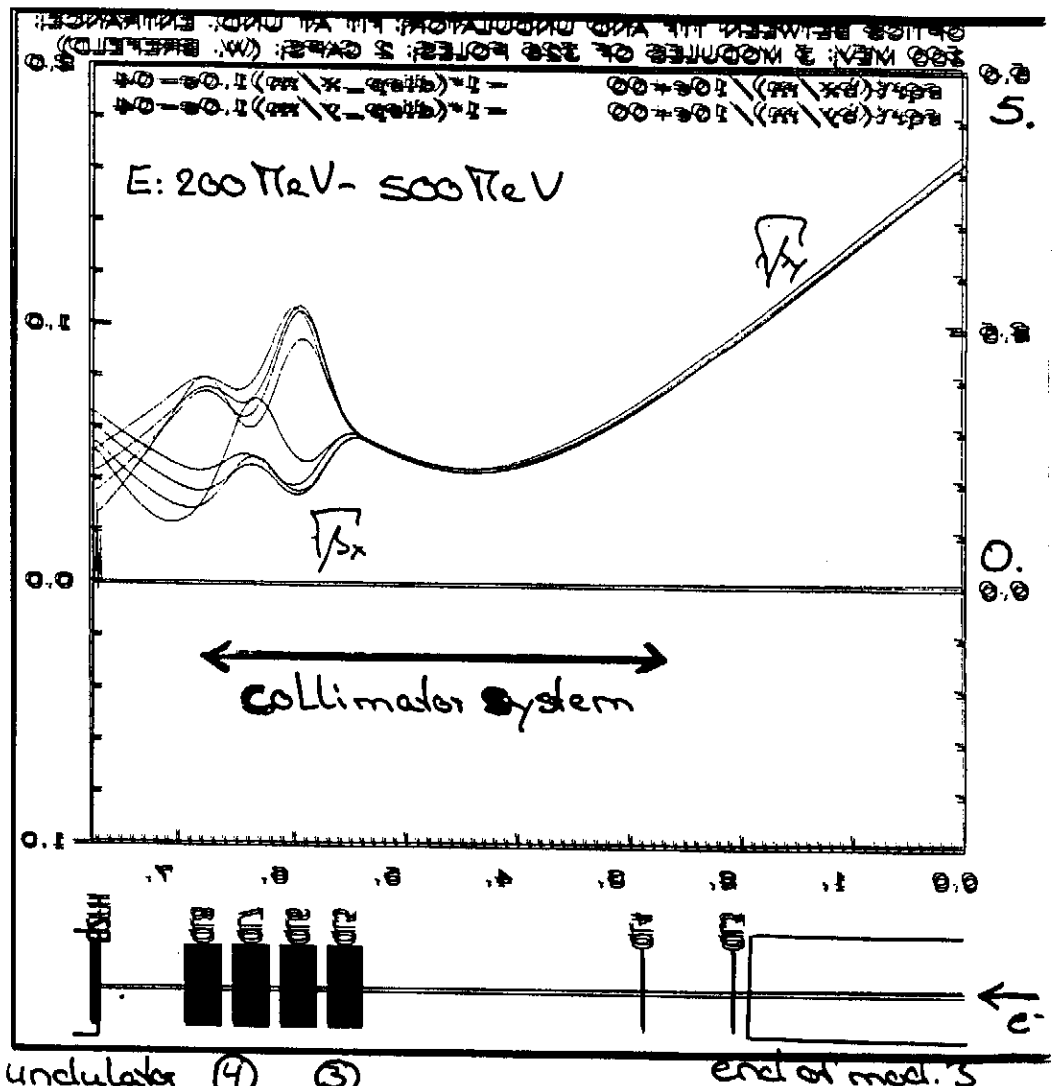
energy independent solution → 4 quad pairs necessary

Optics (W. Brefeld)



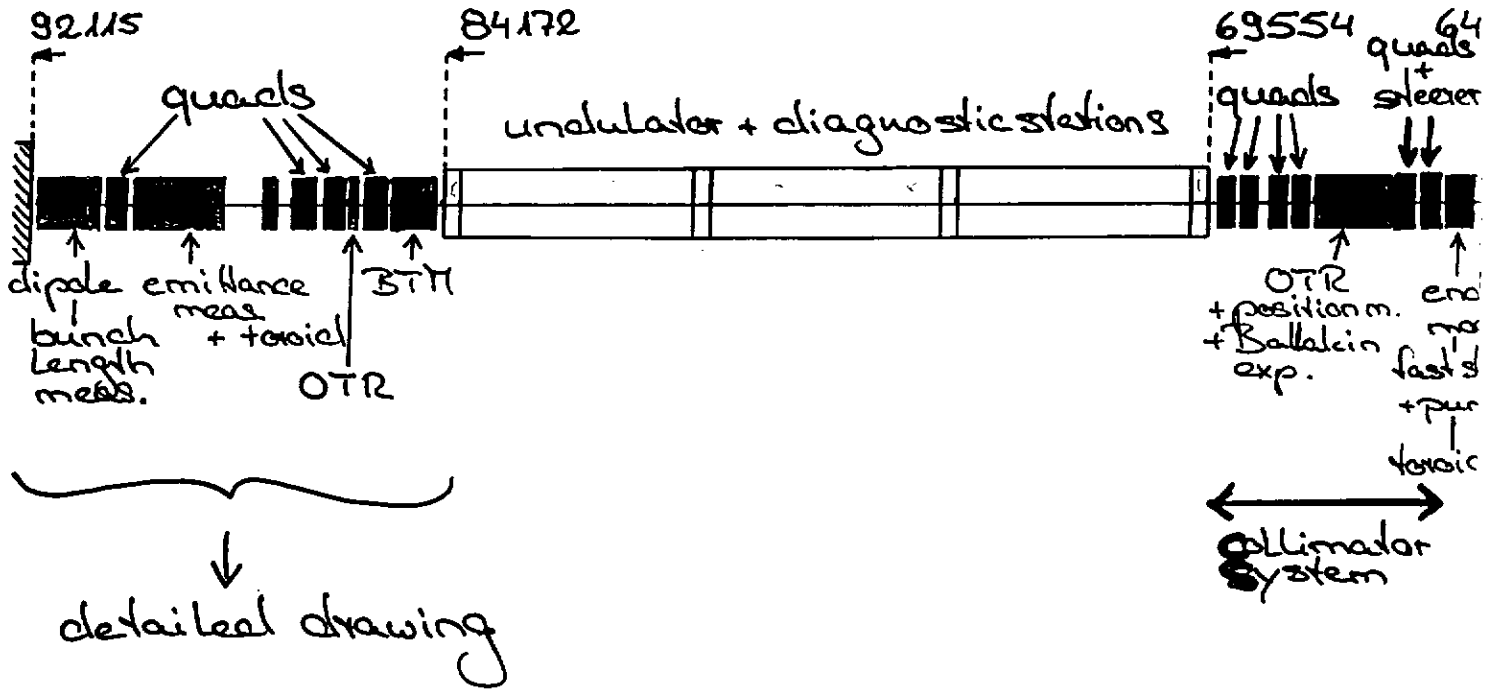
energy independent solution

but: use SC quads in modules 2+3

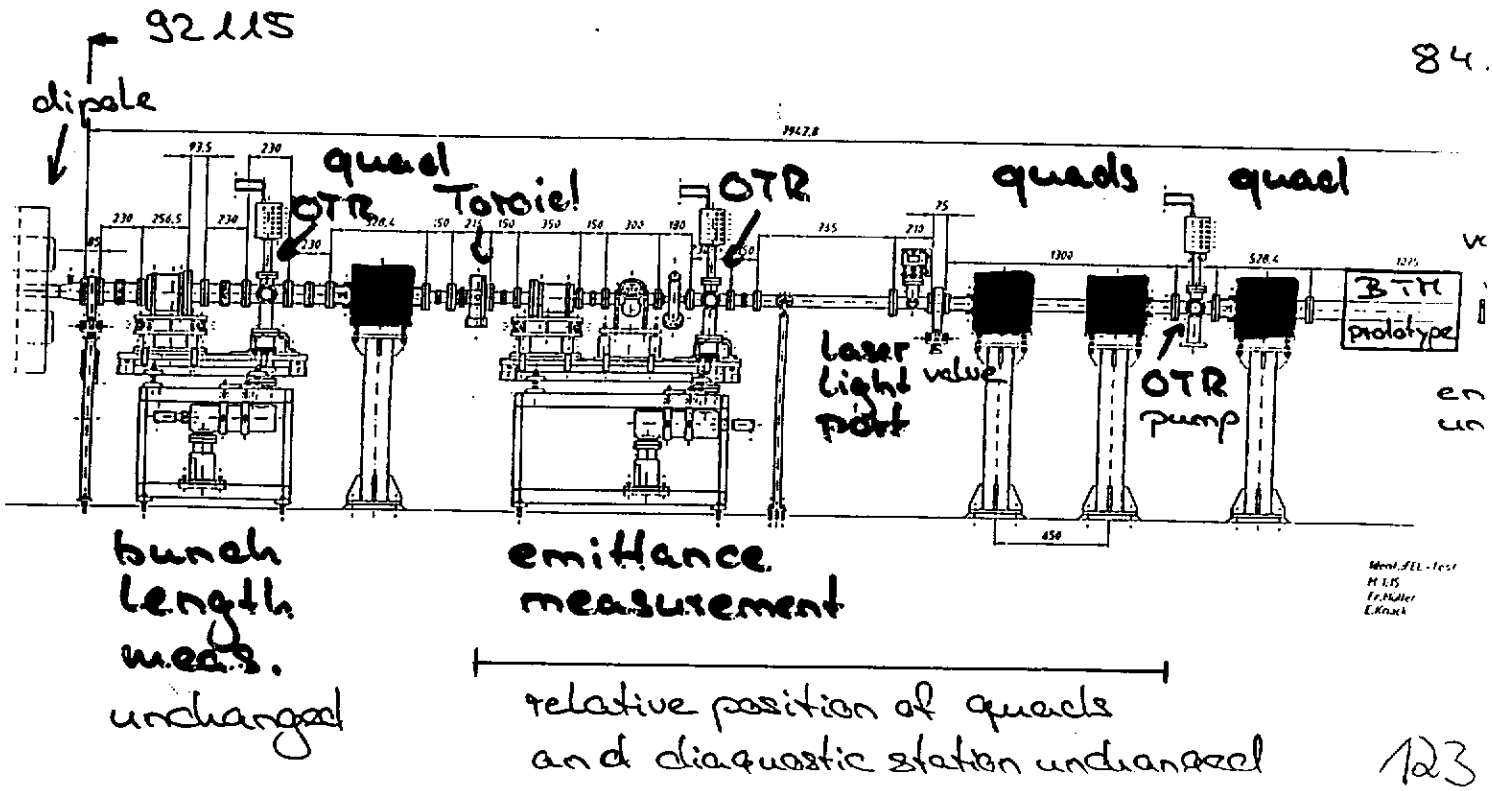


quad pair ①: module 2
quad pair ②: module 3

New Beamline Proposal

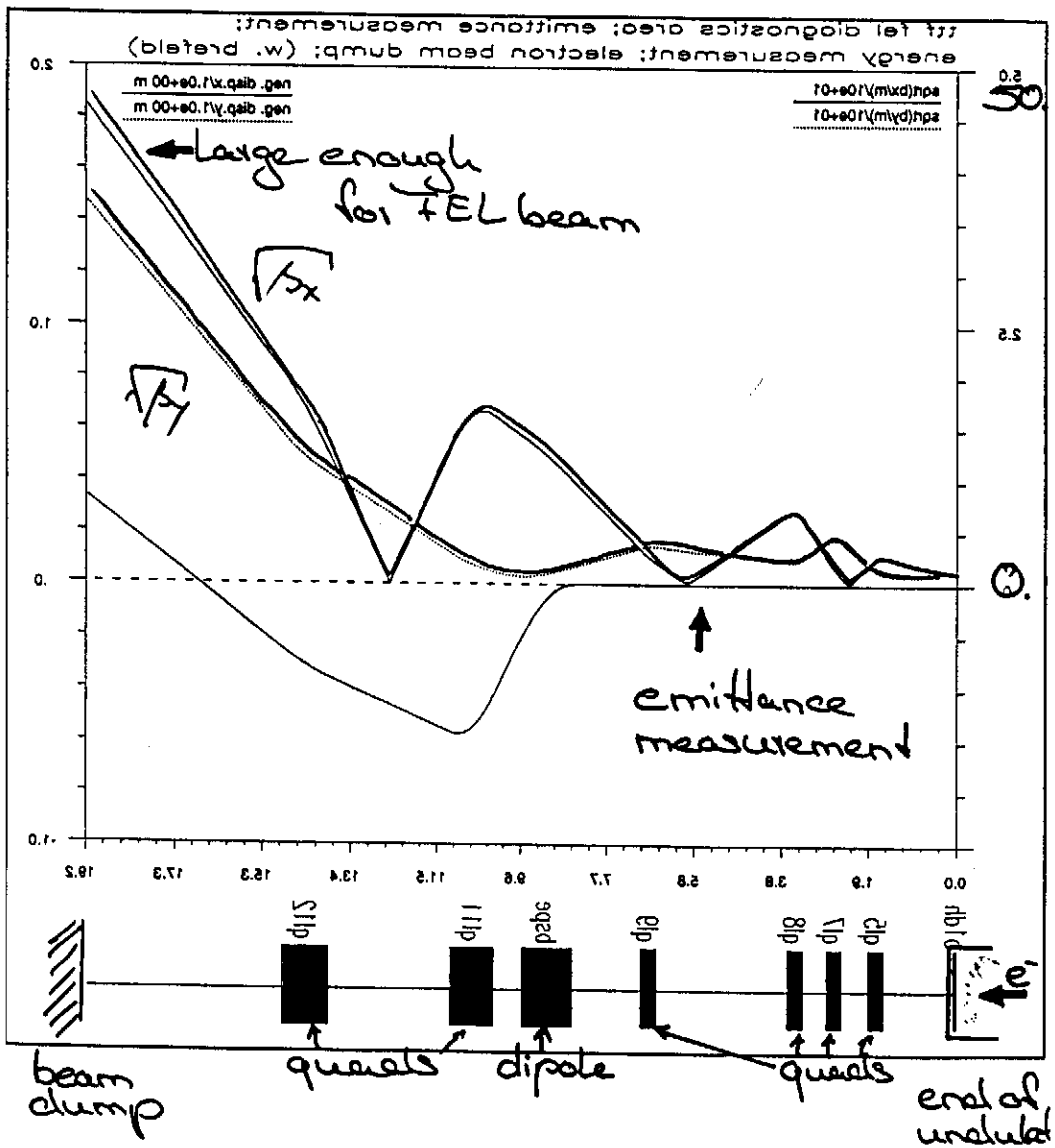


Beam line behind Undulator

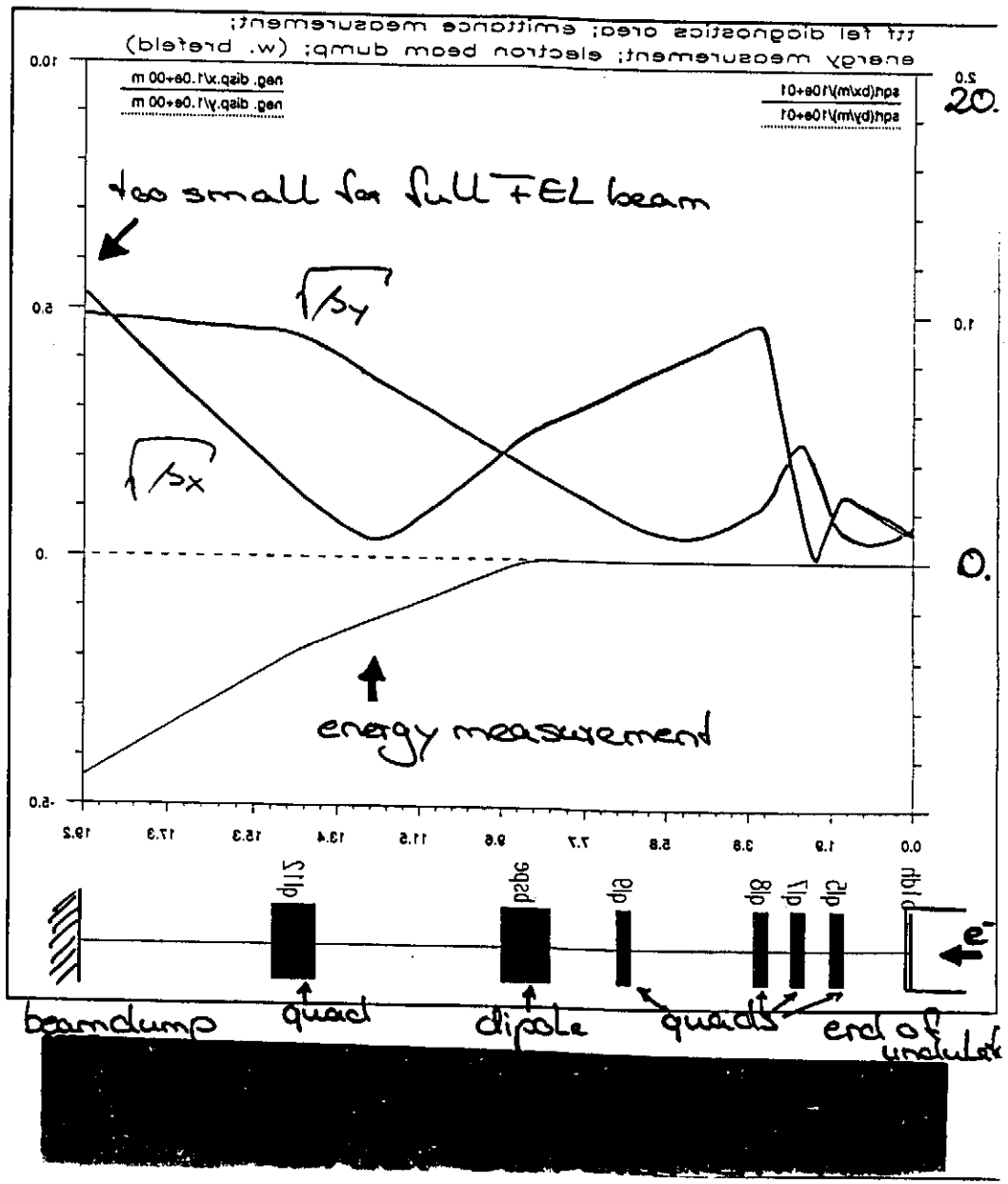


Optics behind the Undulator

(W. Brefeld)



Optics behind the Undulator - energy measurement



For [redacted] operation of TTF-FEL

changes are necessary

adapt interlock system

collimator system

Discussion tomorrow in the LINAC operation WG!

Diagnostics for the Undulator

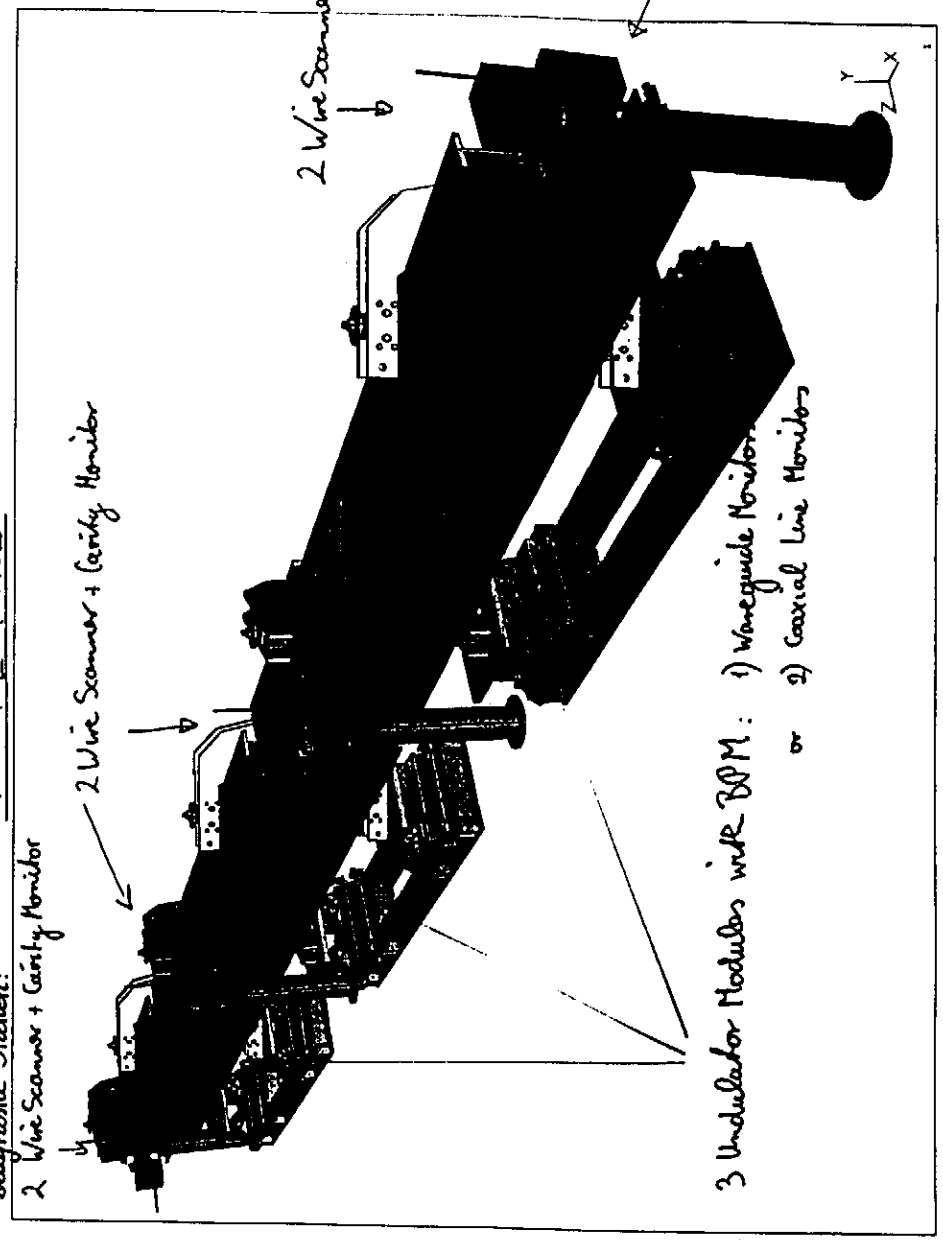
R. Lorenz/G. Schmidt

1) Introduction

2) Diagnostic Block: Cavity Monitor and Wire Scanner

3) BPM's in the undulator chamber

4) Summary



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1) Introduction: Diagnostic for the Undulator

4 times 2 Wire Scanner (horizontal, vertical direction)
-> for absolut position and beam size measurement

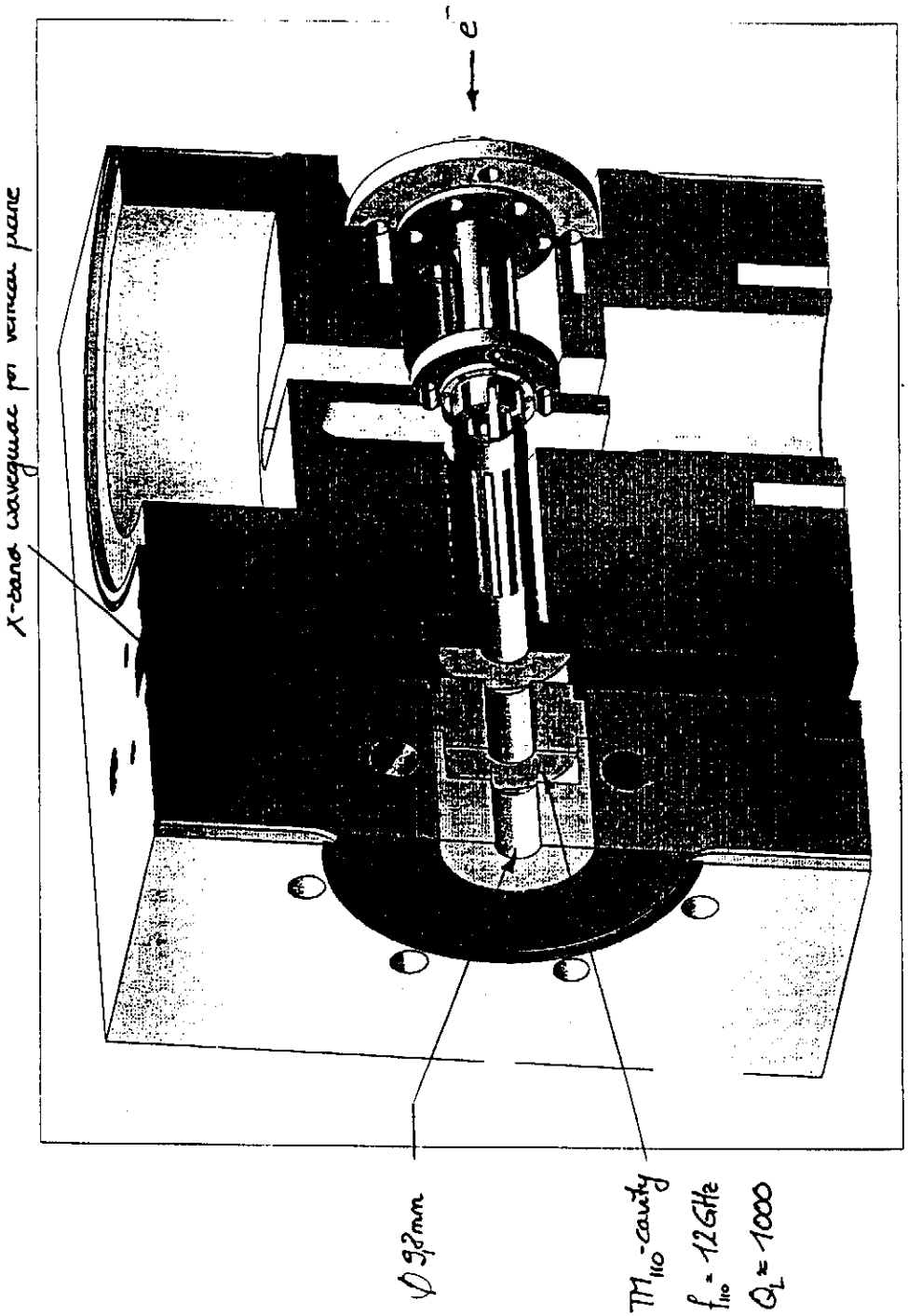
4 Cavity Monitors
-> for BPM
26 BPM in the undulator chamber
-> for BPM

BTM = Beam Trajectory Monitor (after the last module)
-> for BPM (Protoype not standard diagnostic)

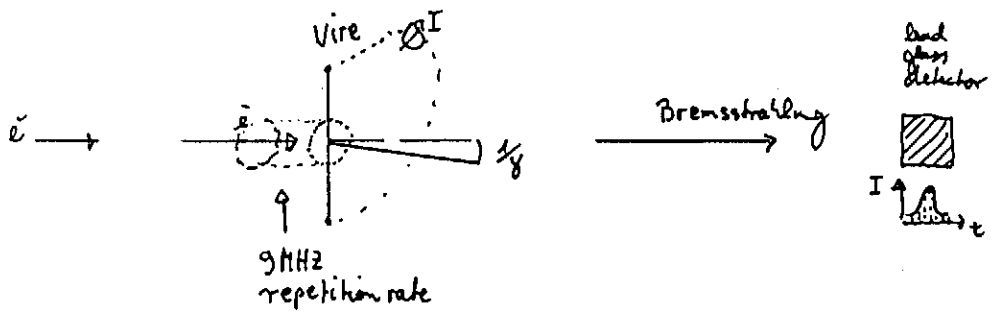
DIAGNOSTIC STATIONS (BPM)

Requirements:

- Resolution
  - less than 1 micron
  - even for single bunches
- Mechanics
  - longitudinal space-300mm max.
  - probably for absolute alignment
- Others
  - also current measurement



Basic Working Principle of the Wire Scanner



Main effects used for diagnostics

Bremsstrahlung and secondary electron emission detected with lead glass detector (plastic scintillator) and current on the wire

Values which can be measured

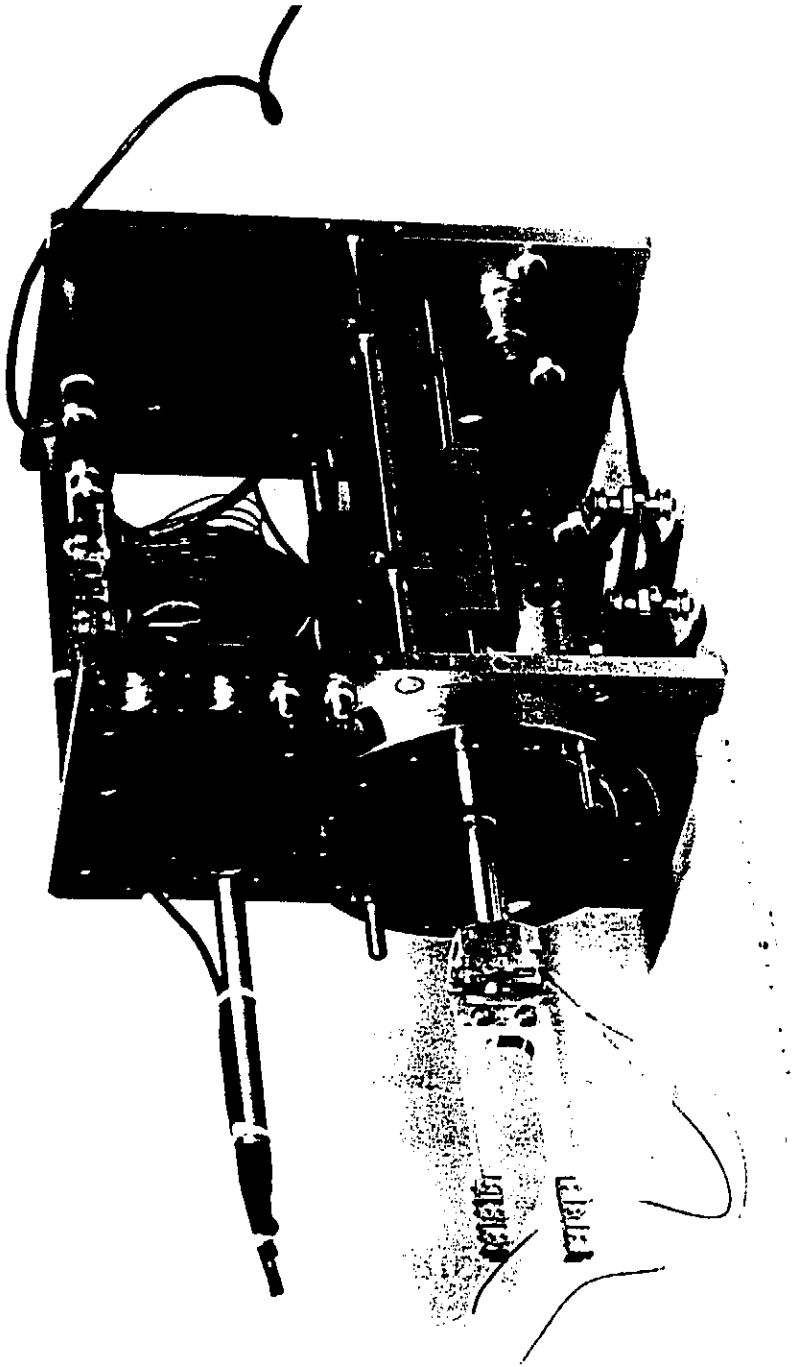
1) Position of the beam (absolute and relative). To get an absolute value a calibration will be done before installtion of the scanner.
2) Beam Profile

More or less non destructive if the wire size is small compared to the beam size

INSIDE EACH MODULE (BPM)

Requirements:

- Resolution
  - less than 5 microns
  - averaged over the bunch train
- Mechanics
  - transverse space 12 mm .
  - only horizontal acces; 4.5 m long
- Others
  - minimized effect on the impedance



Prototype TTF Undulator Wire Scanner

G. Schmidt, MPI, 3/98

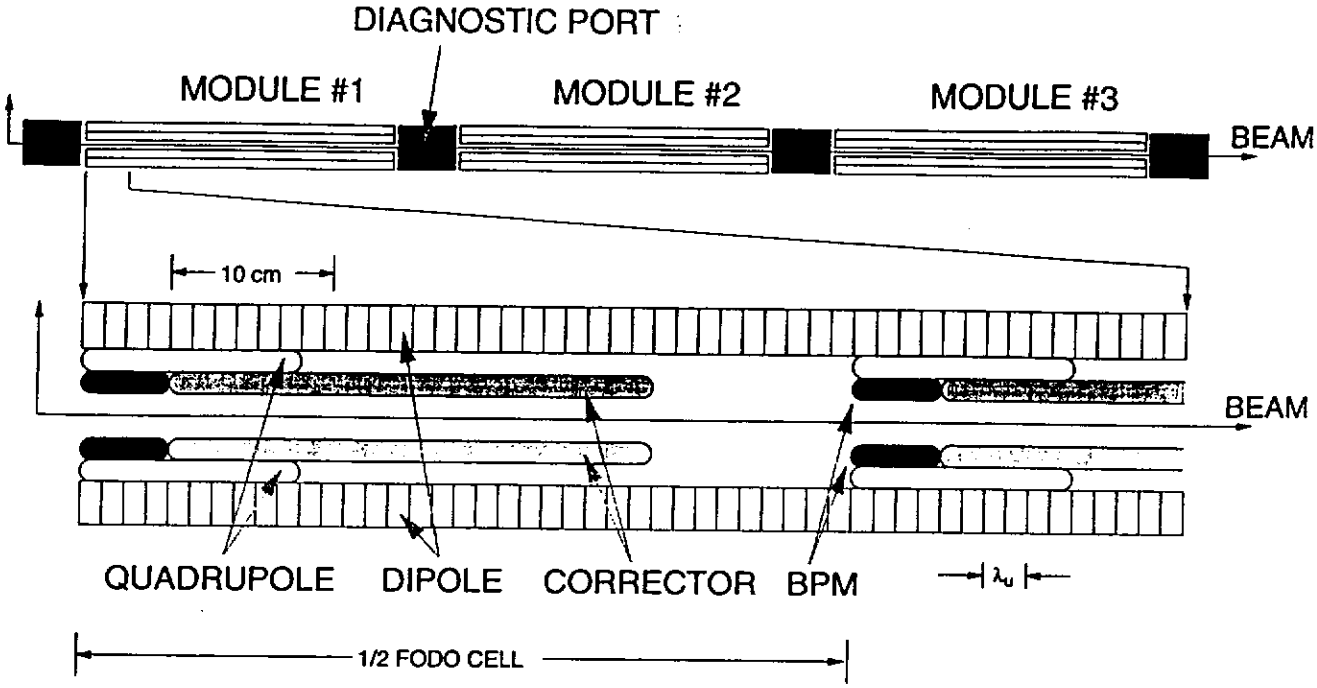


Fig.: Sideview of the FEL-undulator for phase I (top) and zoom into one FODO-cell (bottom)

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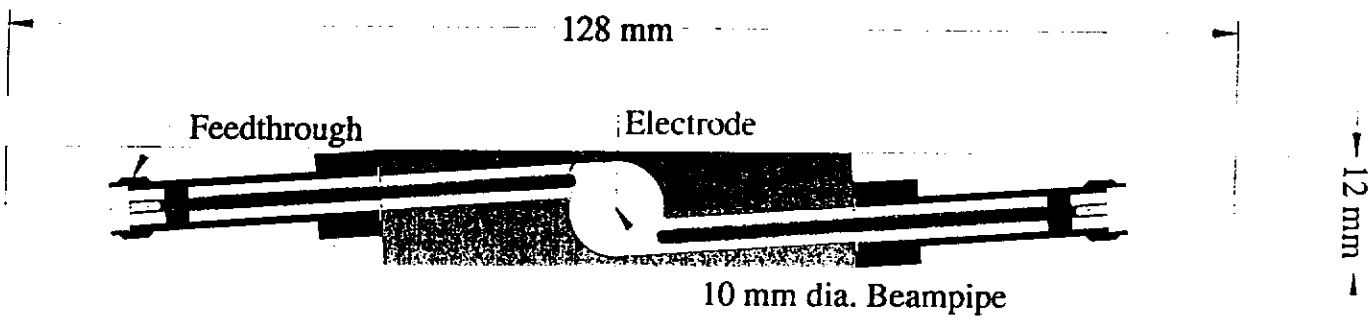
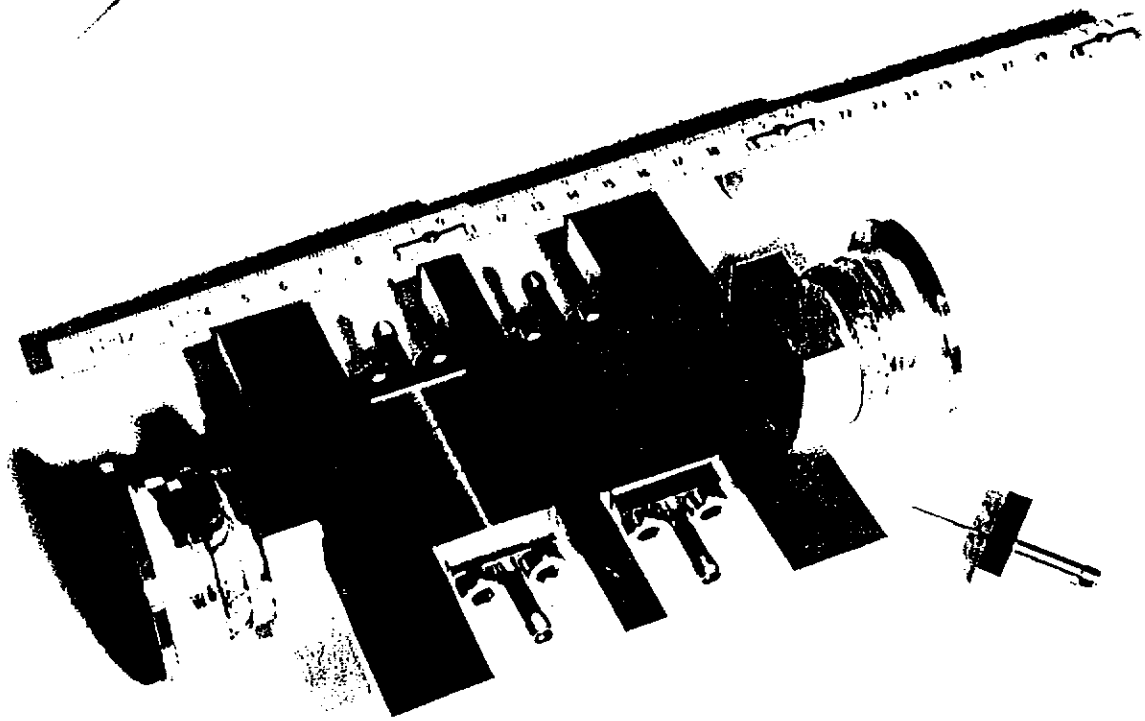
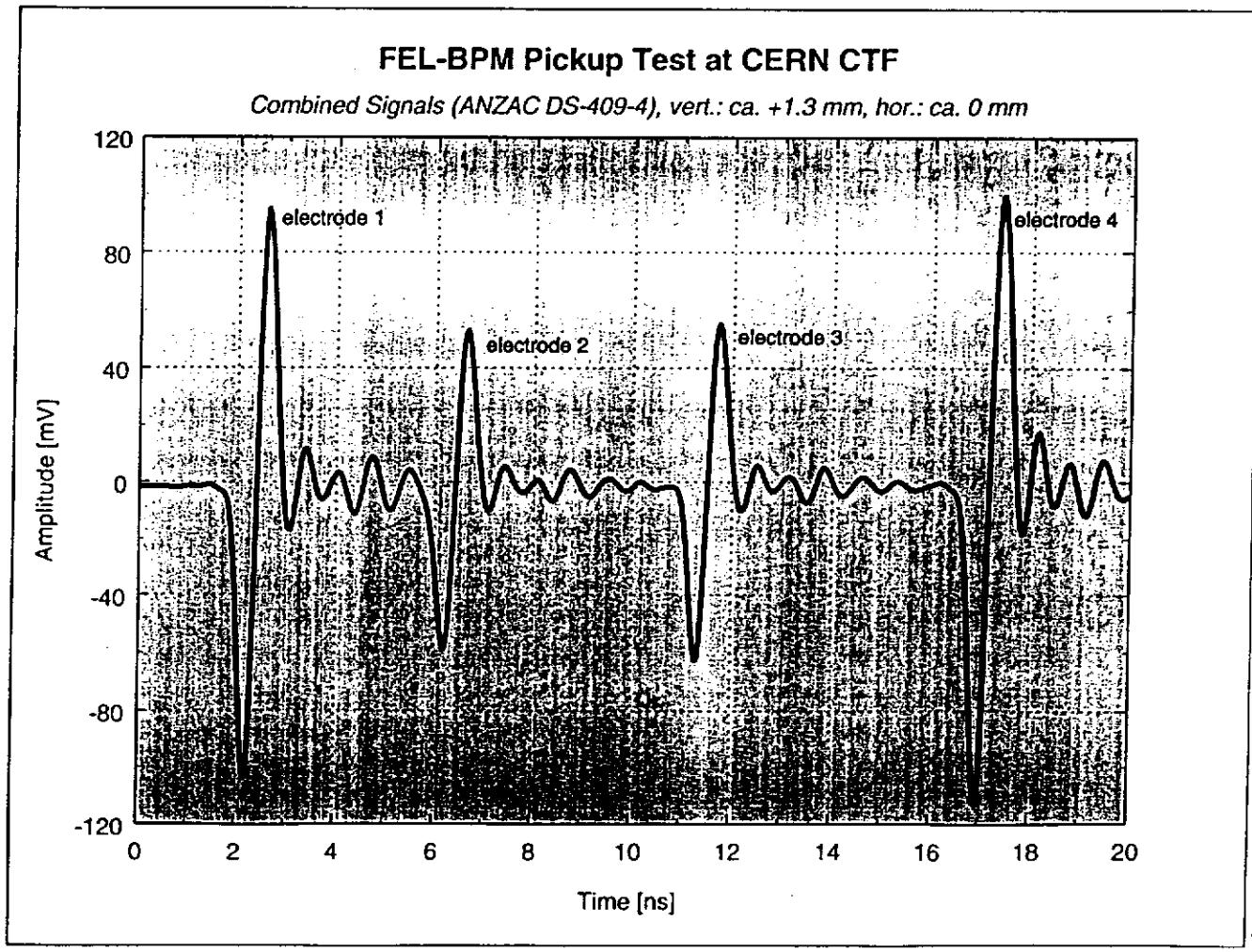
Manfred Wendt,

TTFL-FEL: Electrostatic BPM Pickup

Cross-section of a couple of opposide electrodes

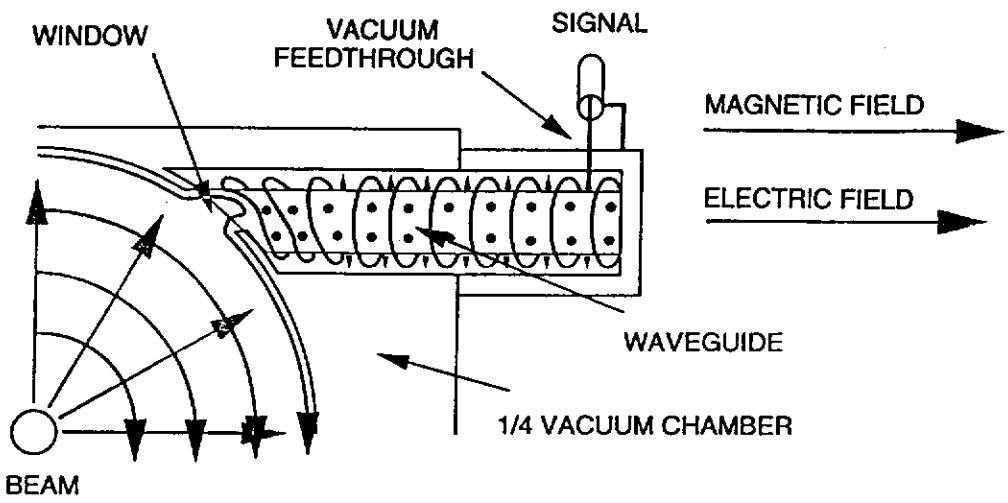




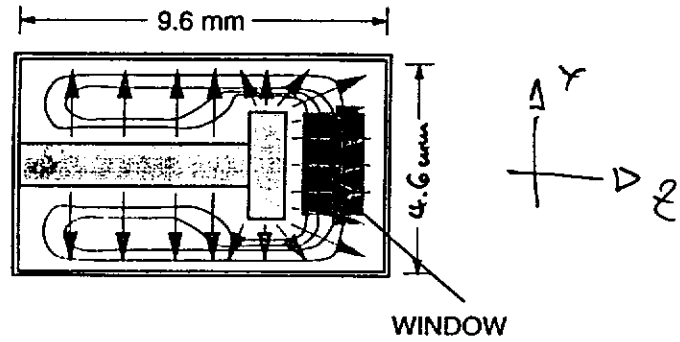

FEL-BPM Pickup Test at CERN CTF
Combined Signals (ANZAC DS-409-4), vert.: ca. +1.3 mm, hor.: ca. 0 mm
electrode 1
electrode 2
electrode 3
electrode 4
Amplitude [mV]
120
80
40
0
-40
-80
-120
0
2
4
6
8
10
12
14
16
18
20
Time [ns]

Waveguide - Monitor (Scheme)

- Idea: Coupling to magnetic field of electron beam via coupling windows in beam pipe



- Ridged waveguide with cut off at 9 GHz, common mode at 12 GHz



TKAMPS@CERES, FEB03/18:06

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View in beam direction | Top view | Waveguide-T and flange

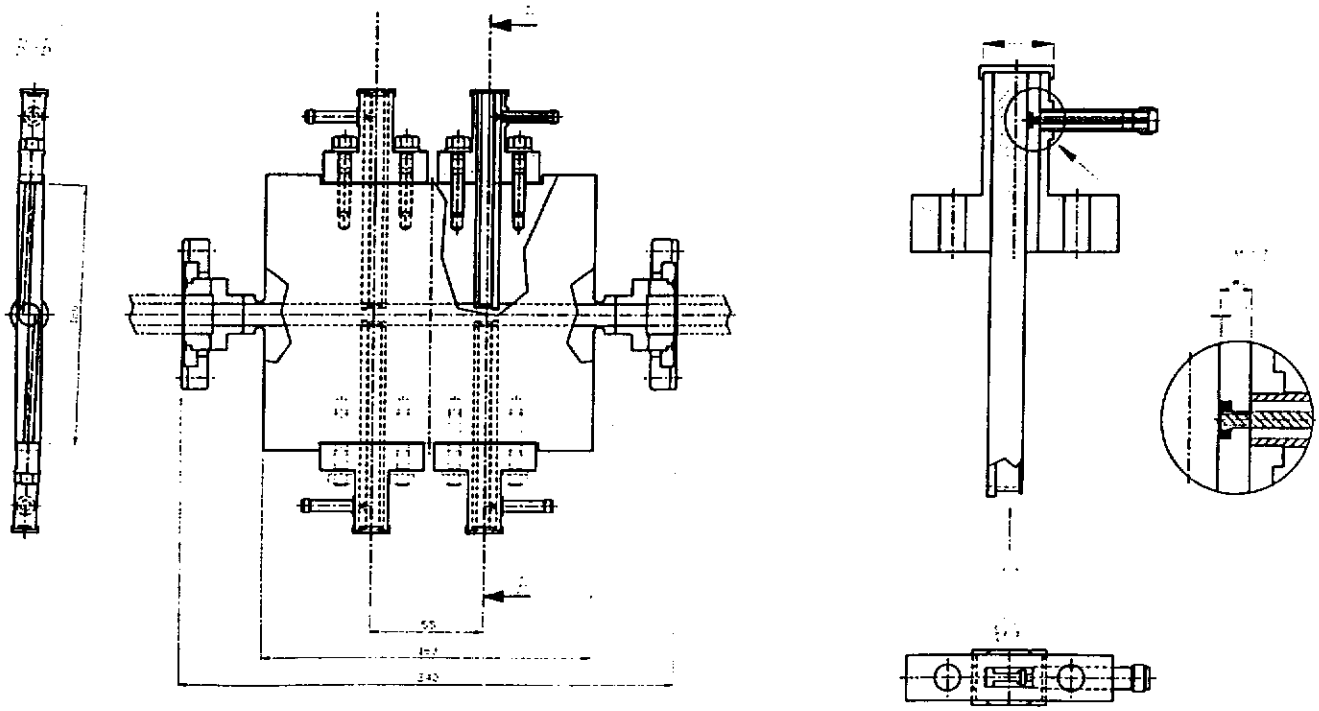
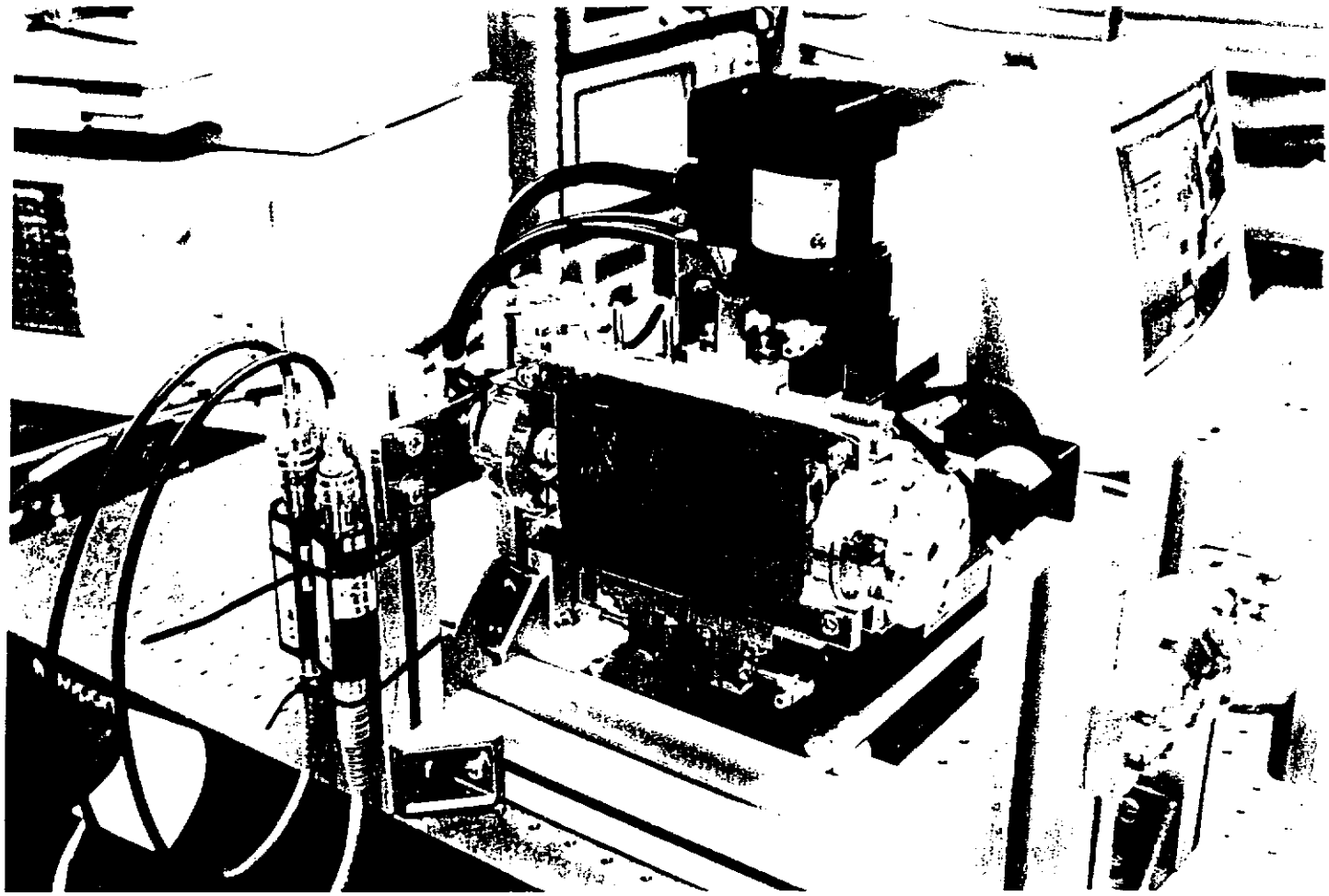
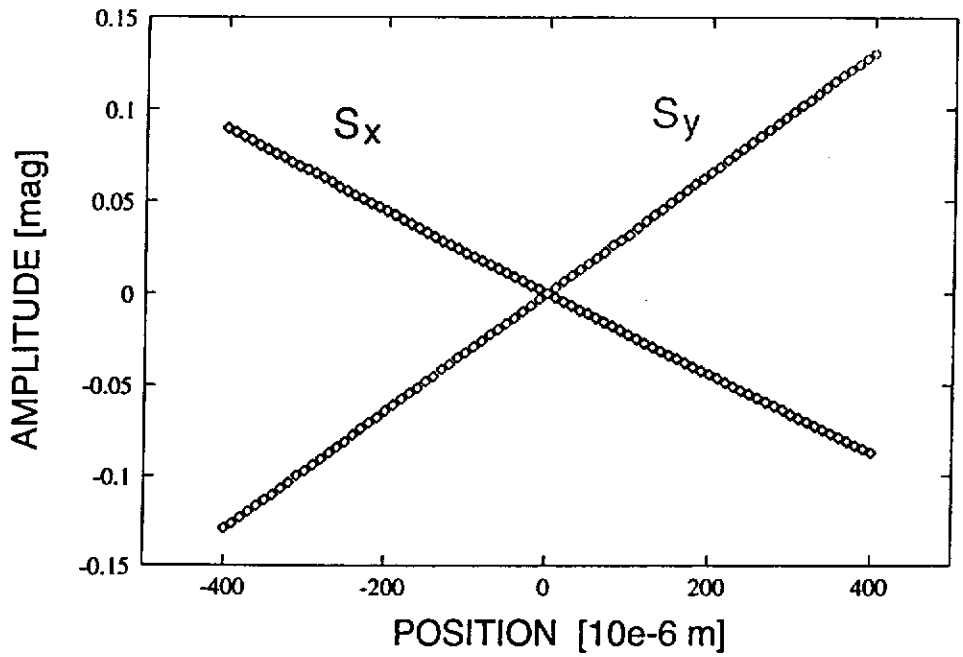


Fig.: Drawing of prototype waveguide beam position monitor



I. Kamps, DESY Zeuthen

- Linearity of measured signals in the center of the BPM



Signals:
q = 1nC, single bunches
$V_{pp} \approx 500mV$ (12 GHz)

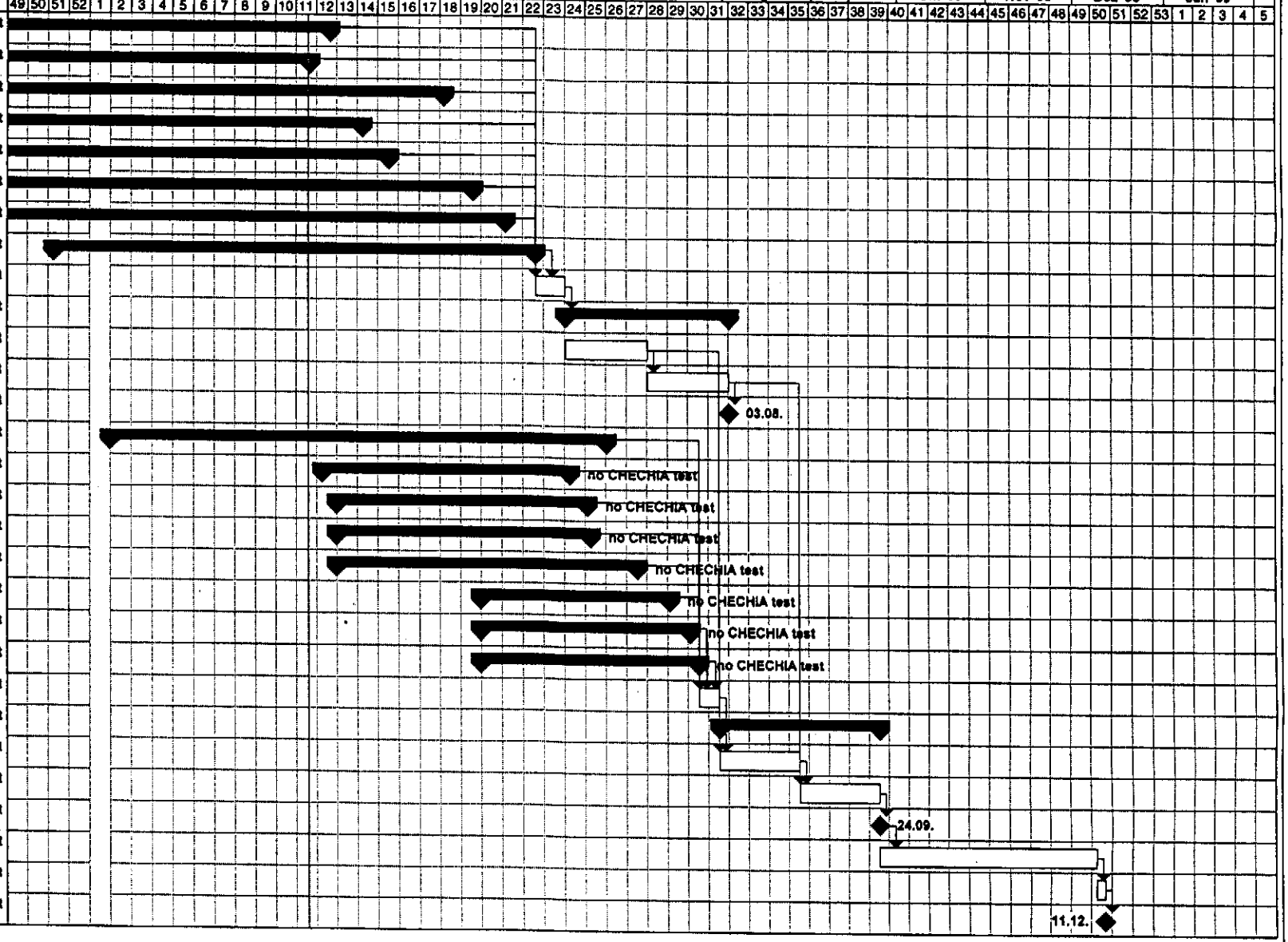
Fig.: From measurements derived electrical signalfunctions using Δ / Σ-method

- Measured sensitivity: 5.60 dB/mm hor., 3.83 dB/mm ver.

Module 2
800°C + 1400°C treatment

S. Wolff, C:\WINPROJ\TESLA\XZ100398.MPP

Nr.	Vorgangsname	Dauer
1	C22 cavity preparation, 20.2	176t
63	C21 cavity preparation, 29.3	174t
100	C24 cavity preparation, 18.9	204.5t
167	C25 cavity preparation, 28.4	186t
221	C23 cavity preparation, 23.0	136t
282	C26 cavity preparation, 21.4	153.5t
340	C27 cavity preparation, 23.9	133.5t
401	A15 cavity preparation, 23.0	105.5t
440	remaining string assy in cl. roon	5t
441	module assy	40t
442	assy on 4-post system	20t
443	assy on cantilever system	20t
444	module 2 ready for installation	0t
445	S29 cavity preparation	115.5t
503	D38 cavity preparation	55t
535	S30 cavity preparation	56t
567	S31 cavity preparation	57t
599	S32 cavity preparation	69t
631	S33 cavity preparation	44t
663	S34 cavity preparation	49t
695	S35 cavity preparation	52t
727	remain. string assy in cl. room	5t
728	module assy	40t
729	assy on 4-post system	20t
730	assy on cantilever system	20t
731	module 3 ready for installation	0t
732	assembly of modules into linac	53t
733	cool down of modules	3t
734	modules cold	0t



poject end Fre 11.12.98

Fre 13.03.98

Summary of TESLA-500 Working Group, DESY, March 10, 1998

Introduction

The purpose of the working group was to discuss new developments in the overall design of the TESLA Linear Collider. A major part of the studies presented at the meeting was related to investigations of the luminosity potential of TESLA. Further subjects concerned the positron source, wakefields in a vacuum chamber with "rough" surface and the layout of the collider site and conventional facilities. In total, 11 contributions were given during the session. Transparency copies of the talks can be obtained upon request (please contact Katrin Lando or Reinhard Brinkmann).

The high-luminosity parameter sets under study are those proposed in TESLA-97-13. The derivation of these (preliminary) parameters was not discussed in detail in the working group. For convenience, an overview of the parameter sets is given below.

	ref. design	Stage-I	Stage-II	Stage-III
General Parameters				
acc. Gradient [MV/m]	25	21.7	21.7	21.7
unloaded Q_0	$5\cdot10^9$	10^{10}	10^{10}	10^{10}
total AC-power [MW]	95	95	95	95
# of bunches p.p.	1130	1410	2820	4028
pulse length [μs]	800	950	950	950
bunch spacing Δt_b [ns]	708	674	337	236
bunch charge N_e [10^{10}]	3.63	4.0	2.0	1.4
pulse current [mA]	8.2	9.5	9.5	9.5
av. beam power [MW]	8.3	11.3	11.3	11.3
emittance at IP $\varepsilon_{x,y}$ [10^{-6} m]	14, 0.25	14, 0.25	10, 0.03	8, 0.0075
$\beta_{x,y}$ at IP [mm]	25, 0.7	25, 0.7	15, 0.4	12.7, 0.3
spot size at IP $\sigma_{x,y}$ [nm]	845, 19	845, 19	558, 5	459, 2.1
bunch length at IP σ_z [mm]	0.7	0.7	0.4	0.3
beamstrahlung δ_B [%]	2.5	3.0	3.0	3.0
vert. Disruption D_y	18	20	33	50
luminosity [10^{34} cm^{-2} s^{-1}]	0.6	0.9	2.6	5.2

Preliminary high-luminosity parameter sets for TESLA in comparison with the CDR reference design (see R. Brinkmann, TESLA-97-13).

Positron Source

R. Glantz gave an update on the design for the spent electron beam capture system after the IP. By optimising the chromatic correction, the capture efficiency for the CDR parameters could be increased from 85% to 89%. With the new stage-III parameters an efficiency of 93% is obtained. The amount of beam which must be collimated can thus be reduced by up to a factor of two. Optimisation of the system is done by adjusting sextupole strengths, no lattice modification is necessary when changing the beam parameters. Variations of the positron production yield due to mis-steering of the beams at the IP will be rapidly damped within a few machine cycles, but the loss rates at some of the collimators can increase significantly.

E. Merker reported on preliminary results for the spent beam collimation system. A combined Al/Cu collimator could stand up to 1.5% of beam loss, reaching a temperature rise of 200K. Since a somewhat higher beam loss at most critical collimator positions can not be excluded (especially in case of mis-steering), it is suggested to open the apertures to allow a larger fraction of beam to pass through the system. Further studies will be done.

An alternative concept for the positron source was discussed by R. Chehab. It is based on the channeling effect in crystals, which causes high energy (few GeV) electrons to radiate hard (10s of MeV) photons in the strong electric fields between layers in the crystal. The benefit of the concept is a higher e+ yield for given heat load in the target compared to amorphous materials. Questions concerning the lifetime of a crystal under continous electron bombardment and dynamic heating during a single beam pulse still need to be resolved.

Damping Ring

R. Brinkmann discussed constraints on the dogbone damping ring parameters. A serious problem when aiming for a reduction of emittance and bunch length for higher luminosity is caused by the incoherent space charge tune shift, which reaches already 0.18 for the CDR design. A shorter ring and a higher energy would help, but result in reduced bunch spacing (faster kickers!) and stronger arc focusing (dynamic aperture!). N. Walker proposed to introduce dispersion in the long straight sections to reduce the space charge by increasing the beam size. This very promising idea will be studied in the near future.

The question of single bunch longitudinal stability in the damping ring was addressed by C. Burnton. Simulation studies were done with realistic models for the impedance of cavities, kickers and purely inductive contributions. For up to 3 times the nominal bunch charge ($3.6\cdot10^{10}$) no signs of instability (such as in the SLC damping ring) were found, the only effect being a potential well distortion bunch lengthening as predicted by the Haissinski equation. The conclusion was that a reduction of bunch length well below the present design value is not a problem from the instability point of view.

Beam Dynamics

A. Mosnier discussed beam dynamics in the main linac for the low-emittance parameter sets. For the (most ambitious) stage-III, single bunch effects lead to an emittance growth of 57% (12% and 24% for stage-I and II, respectively). Since this is obtained with unchanged conservative assumptions on the alignment (0.5mm for quads and cavities, 0.1mm for BPM's and 0.01mm BPM resolution) and without advanced beam-based methods except for the "shunt-technique" (BPM-to-quad alignment), preservation of single bunch emittance appears sufficiently safe even for stage-III. As for multi-bunch effects, the simulations show an increase of emittance growth from 4% for stage-I to 72% for stage-III. Improvements could be possible by using fast kickers to remove the "static" (or: "reproducible") part of the multi-bunch orbit deviations. A careful analysis of the actual cause of the emittance growth is necessary before this point can be settled.

M. Dohlus gave a theoretical analysis of the "surface impedance" due to the roughness of vacuum chamber. One important result is that the impedance which the beam sees (and which causes coherent energy spread, especially for very short bunches such as foreseen for the X-ray FEL) can be significantly reduced if the typical wavelength of roughness is large compared to the size of the imperfections (measurements of the undulator chamber show a roughness amplitude of a few 100nm, whereas the wavelength is tens of μm).

M. Timm reported on a 2-D analysis of short range wakefields from surface roughness done together with A. Novokhatsky and T. Weiland. An estimate of the transverse wake was derived, showing the potential danger of instability if a bunch travels over a long distance in a

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transfer channel with transverse offset. In 3-D calculation, the effect appears to be somewhat smaller.

Beam Delivery System

The impact of high luminosity scenarios for the TESLA beam delivery system was studied by **O. Napoly** and **N. Walker**. They showed that from the point of view of beam optics the existing system layout can be used without drastic modifications. However, with the foreseen small emittance and spot size at the IP of 2nm, instrumentation for beam size measurement becomes very demanding. Keeping beams in collision with the fast feedback is still possible, but requires a BPM resolution of 1μm instead of 10μm. The main reason is a strongly enhanced sensitivity of the luminosity due to the kink instability driven by a very high disruption parameter (~50 for stage-III). Fast luminosity tuning (e.g. a full waist scan within one beam pulse) is possible by means of a fast bremsstrahlung electron (Bhabha) detector behind the final doublet. One potential problem addressed in the discussion is due to the increased heat load at the collimators in case of accidental beam loss because of the smaller beam cross section. Wake fields at the collimators do not seem to be a problem. Dilution of the 2nm spot size was studied with the newly developed MERLIN code. With an orbit feedback operating with a 0.25Hz bandwidth the beam size could be stabilised.

Conventional Facilities

W. Bialowons presented progress on the overall layout of the Linear Collider site at DESY. Drawings of the layout for the tunnel, external halls forcryo plants and modulators, the experimental hall and the beam dump were shown (many of these pictures, prepared byT. Stoye, are available on the internet: www.desy.de/~stoye/tesla.htm).

Hamburg, March 13, 1998

R. Brinkmann

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TESLA-500 WG Schedule

Tuesday March 10th, 9.00h - 18.00h,
Bldg. 25b, Room 109 (HASYLAB)

Optimization of Spent Beam Capture for e+ Source	R. Glantz
Spent Beam Collimation	E. Merker
e+ Source With Channeling Concept	R. Chehab

10.30 - 10.50h Coffee Break

Damping Ring Constraints	R. Brinkmann
Single Bunch Long. Collective Effects	C. Burnton
Main Linac Beam Dynamics (high lumi case)	A. Mosnier

12.30 - 13.30h Lunch Break

Short Bunch Wakefields from Surface Roughness	M. Dohlus, M. Timm
Update on Beam Delivery System	O. Napoly
Luminosity Stabilisation and Diagnostic Requirements	N. Walker
Site Layout and Conventional Facilities	W. Bialowons

16.00h Coffee Break

16.30 - 18.00 Reserve for Discussion

	ref. design	Stage-I	Stage-II	Stage-III
General Parameters				
# of bunches p.p.	1130	1410	2820	4028
pulse length [μs]	800	950	950	950
bunch spacing Δt_b [ns]	708	674	337	236
bunch charge N_e [10^{10}]	3.63	4.0	2.0	1.4
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bunch length at IP σ_z [mm]	0.7	0.7	0.4	0.3
beamstrahlung δ_B [%]	2.5	3.0	3.0	3.0
vert. Disruption D_y	18	20	33	50
luminosity [10^{34} cm^{-2} s^{-1}]	0.6	0.9	2.6	5.2
Damping Ring				
energy E_{DR} [GeV]	3.2	3.9	3.9	4.3
circumference C_{DR} [km]	17	8.5	8.5	8.5
arc radius [m]	60	85	85	85
arc FODO cell phase advance Φ_c [deg.]	90	60	75	108
wiggler length [m]	388	350	350	350
wiggler field B_W [T]	1.5	1.06	1.06	1.06
transverse damping time [ms]	33.8	31	31	28
RF voltage [MV]	25	16	16	19
emittance at extraction $\varepsilon_{x,y,DR}$ [10^{-6} m]	12, 0.2	12, 0.2	8, 0.02	6, 0.005
energy spread $\sigma_{E,DR}$ [10^{-3}]	1.0	0.93	0.93	0.97
bunch length $\sigma_{z,DR}$ [mm]	9.5	9	6	6
incoh. space charge ΔQ_{incoh}	0.18	0.07	0.20	0.27
bunch compression ratio	13.3	12.7	15	20
compressor RF voltage [MV] (at 1.3 GHz)	200	220	400	600

Table 4: Proposed modified TESLA-500 parameters for higher luminosity in comparison with the reference design. The values for the beamstrahlung and for the luminosity quoted are scaled numbers, which need to be confirmed by beam-beam simulations (a constant pinch enhancement factor has been assumed for all versions). Some of the damping ring parameters have been obtained from scaling of basic lattice properties. More precise values must be determined from a detailed design study.

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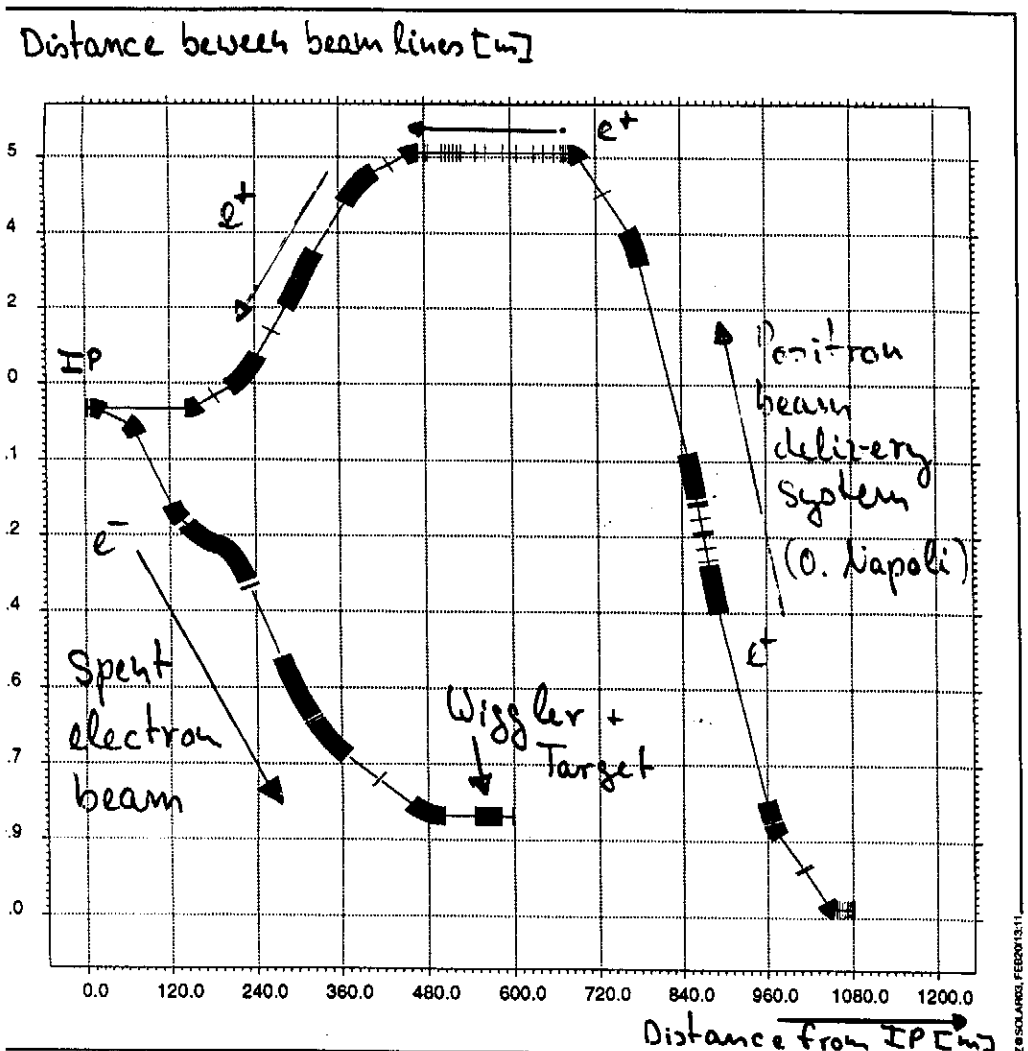
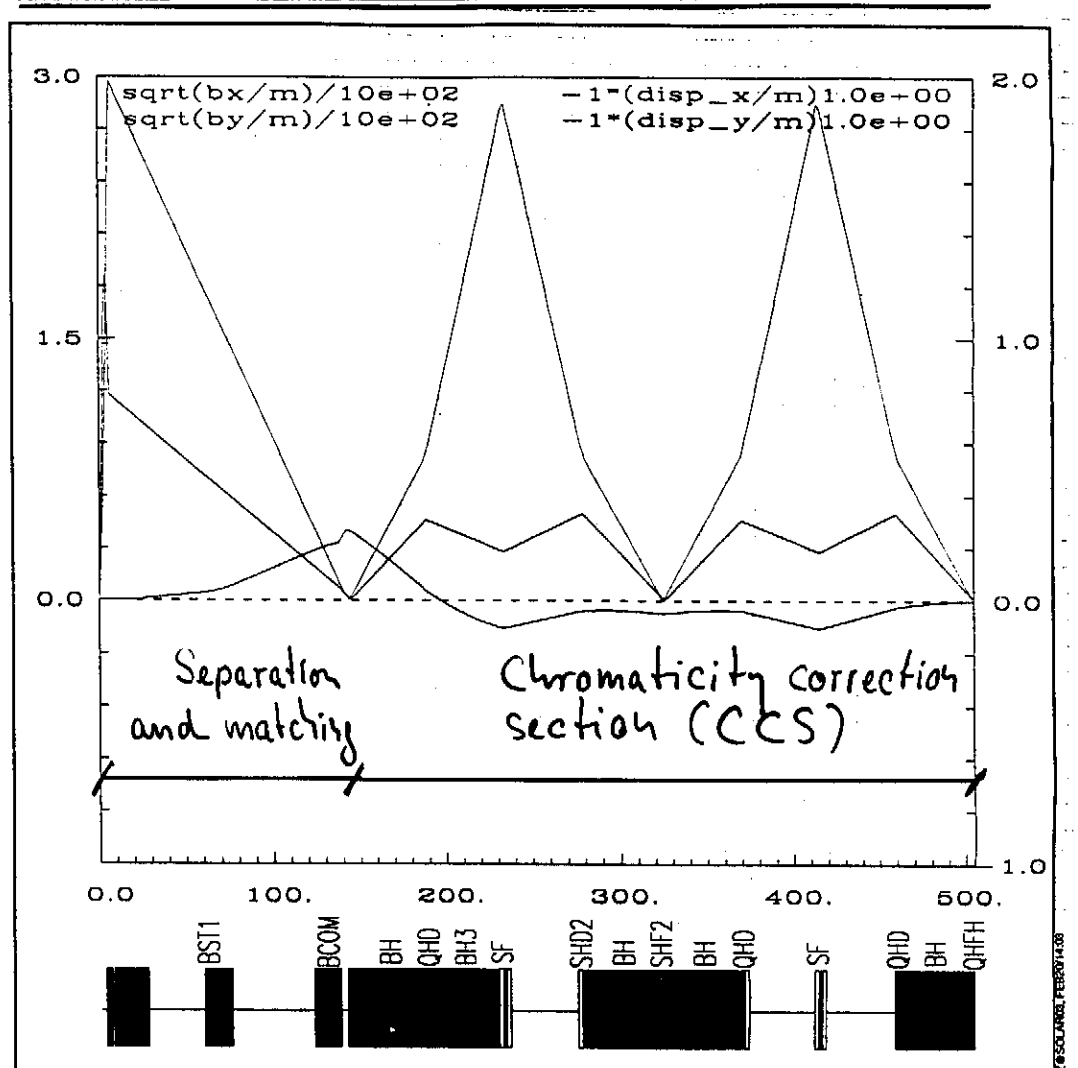
Spent beam capture system and oncoming positron beamline [unpolarized source]



Optics functions from the IP to the end of the achromatic section



Efficiencies of the capture systems:

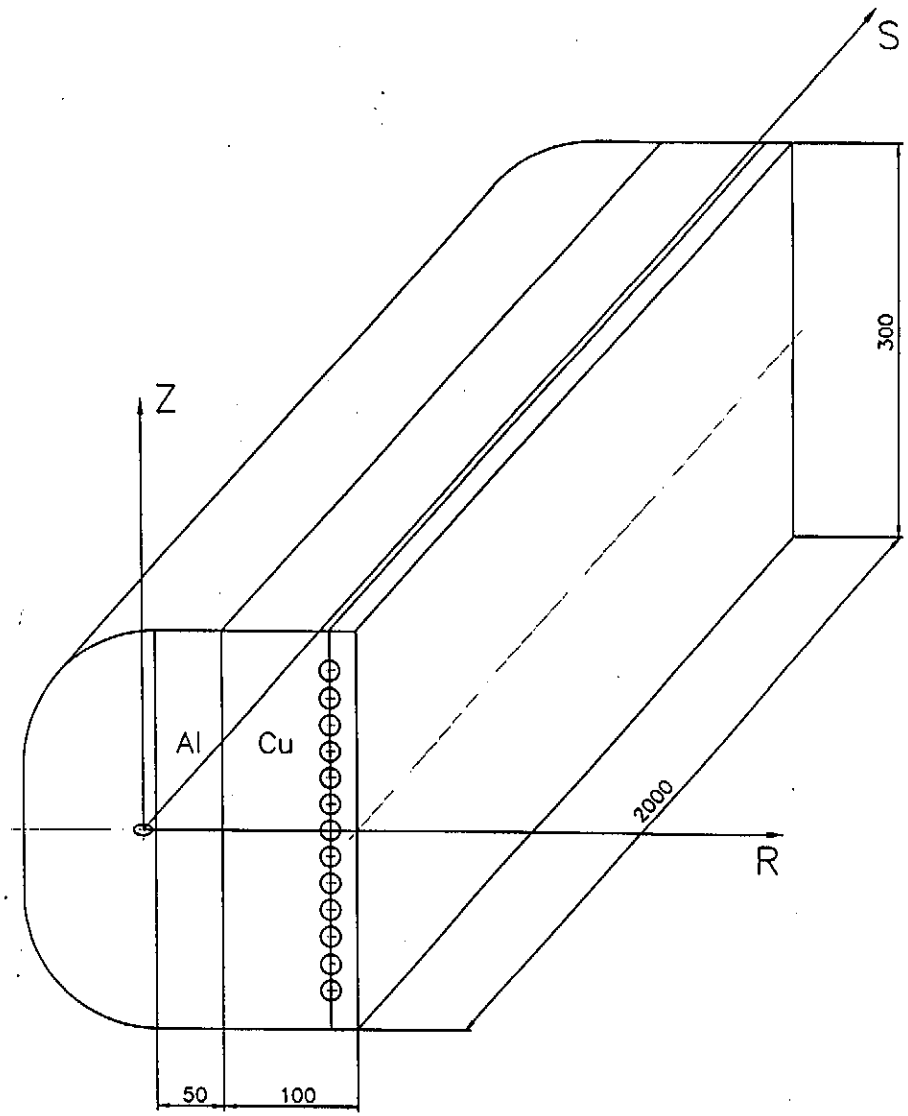
Unpolarized source:

89% (+4%) for the ref. design and 93% for the Stage III upgrade!

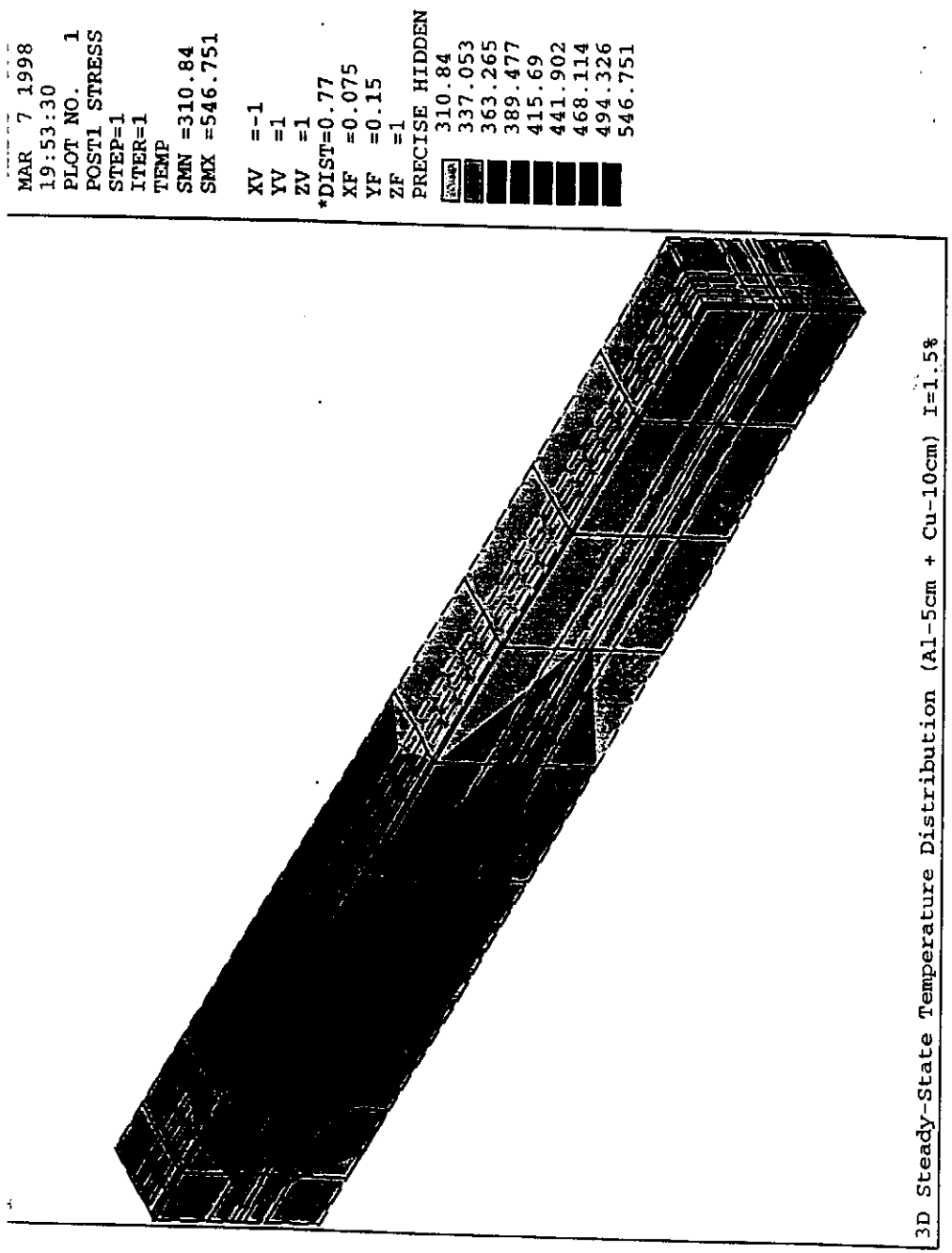
Polarized source:

65% for the reference design and 76% for the Stage III upgrade!

Higher efficiencies and better distributed collimators
▸ higher operational stability



R. Chehab.



POSITRON SOURCES USING CRYSTALS

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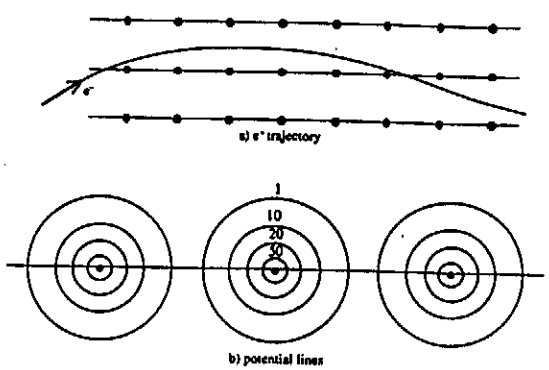
CRYSTAL EFFECTS

* CHANNELING
* COHERENT BREMSSTRAHLUNG
* COHERENT PAIR PRODUCTION
* PAIR CREATION IN STRONG FIELDS

CHANNELING



: *Axial channeling on a Si < 111 > crystal.*

critical angle for channeling

$$\Psi_c = \sqrt{\frac{2U_0}{E}}$$

U_0, potential well

E, particle energy

frequency of the radiated photon

$$w = 2\gamma^2 \Delta E_T$$

ΔE_T, transverse energy loss between channeled states

$\Delta E_T \sim$ some eV ; with $E = 1$ GeV => $\omega \sim 40$ MeV

TESLA Damping Ring (E= 3.2 GeV)

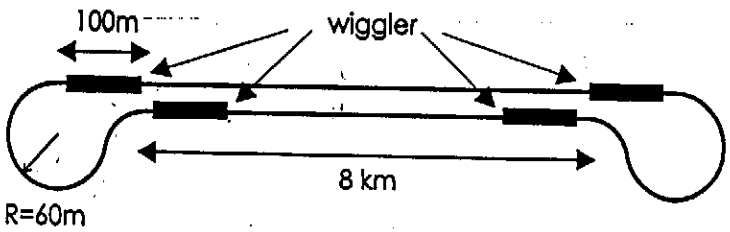


Figure 3.1: General layout of the "dogbone"-shaped damping ring

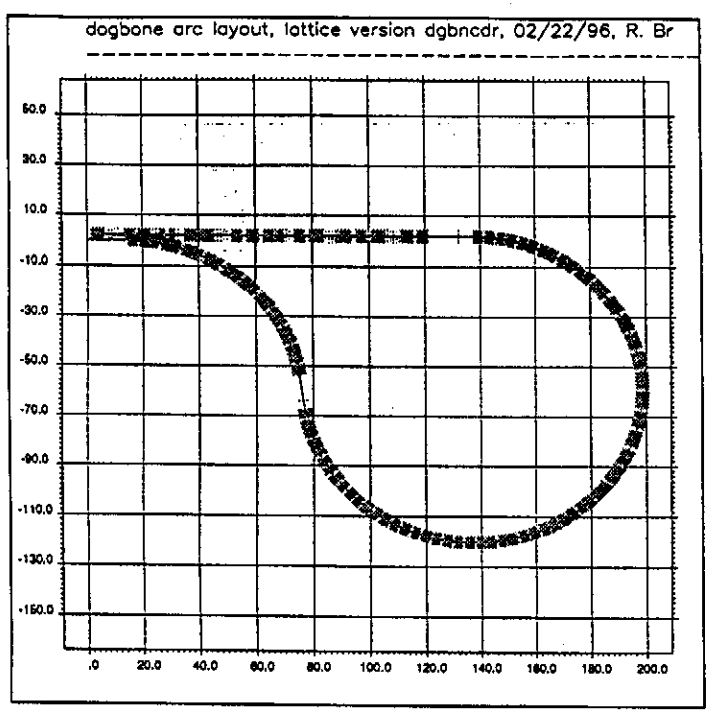


Figure 3.2: Geometry of the "dogbone" damping ring arcs

serious limitation due to large ratio circumference/energy: **space charge**

$$\Delta Q_{incoh} \approx C_{DR} \cdot \frac{N_e r_e}{(2\pi)^{3/2} \gamma_{DR}^2 \sigma_z (\varepsilon_x \varepsilon_y)^{1/2}} \approx -0.2 (ref.design)$$

how to scale D.R. parameters to keep space charge constant with smaller ε_y ?

case (a): $$\frac{N_e}{\sigma_z \sqrt{\varepsilon_x}} \propto \delta_B^{1/2} \sqrt{\frac{\beta_x^*}{\sigma_z}}$$

(reduction of bunch charge doesn't help !)

[reduction of $\beta_x^* \sim \sigma_z$ and $\varepsilon_x \sim 1/\sigma_z^2$ ruled out because divergence at IP $\sigma_{x'}^* \sim \sigma_z^{-3/2}$!]

$$\Rightarrow \qquad \Delta Q_y \propto \varepsilon_y^{-3/4} \frac{C_{DR}}{\gamma_{DR}^2} \qquad \text{(a)}$$

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	ref. design	high lumi (II)	high lumi (III)
C_{DR} [km]	17	8.5	8.5
# of bunches	1130	2820	4028
Δt_B [ns]	50	10	7
Ne/bunch [10^{10}]	3.6	2.0	1.4
energy [GeV]	3.2	3.9	4.3
arc radius [m]	60	85	85
Φ_β/FODO cell [°]	90	75	108
wiggler length [m]	388	350	350
wiggler field [T]	1.5	1.06	1.06
$\varepsilon_{x,y}$ at extr. [10^{-6} m]	12, 0.2	8, 0.02	6, 0.005
σ_E/E [%]	0.1	0.093*)	0.097*)
σ_z [mm]	9.5	6	6
ΔQ_{incoh}	0.18	0.20	0.27
bunch comp. ratio	13.3	15	20

Suggested dogbone ring modifications for high luminosity parameters

*) typing error in TESLA-report, sorry…

All simulation thresholds were far greater than those predicted by analytical estimations and also do not seem to relate as $\sim \alpha^{3/2}$.

- All Wakes

npar=200 000 (nrf=1), npar=100 000 (nrf=2)
$\alpha = 5 \cdot 10^{-4}$; QGF: IN+RW:1 mm, CV+FK:2 mm
bin: 0.15 mm, nturn: 3000, nrms= 500

	nrf=1		nrf=2		Haiss.
I	$\bar{\sigma}_\tau$	$\bar{\sigma}_\epsilon$	$\bar{\sigma}_\tau$	$\bar{\sigma}_\epsilon$	$\bar{\sigma}_\tau$
[mA]	[cm]	[MeV]	[cm]	[MeV]	[cm]
0.09	0.56	3.47	0.56	3.45	0.56
0.18	0.65	3.49	0.65	3.46	0.64
0.27	0.74	3.79	0.71	3.47	0.71
0.36	0.84	4.36	0.78	3.48	0.77

Very similar result for $\alpha = 7 \cdot 10^{-5}$.

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Multi-bunch Dynamics.

for long-range wakefields only:
and for constant pulse lengths

$$\frac{\Delta\varepsilon}{\varepsilon} \sim \frac{Q_b}{\varepsilon} \approx \frac{1}{\varepsilon^{3/4}}$$

For simulations, bunch-to-bunch energy spread (10^{-3}) has been added.

stage	I	II	III
$\frac{\Delta\varepsilon}{\varepsilon}$	4%	17%	72%.

$\sim \frac{1}{\varepsilon^{0.8}}$

→ not tolerable $\frac{\Delta\varepsilon}{\varepsilon}$ multi must be a few %. !

Further studies:

- dependence on b. to b. energy spread
- Add Fast kickers but also <u>dynamic</u> errors (jitter). along the linac. (work well with static errors).

remark. larger frequency detuning will likely not be useful because $\sigma_\omega T_b$ is already > 1.

Single-Bunch ε. growth.

- Cavity misalignment

$$\frac{\Delta\varepsilon}{\varepsilon} \sim \frac{N^2 W_\perp^2}{\varepsilon} \times \langle d^2 \rangle \times F(f_{oc})$$

for $W_\perp \sim \sqrt{\sigma_z}$ → $\frac{\Delta\varepsilon}{\varepsilon} \sim \frac{1}{\sqrt{\varepsilon_y}}$

- quad. misalignment

$$\frac{\Delta\varepsilon}{\varepsilon} \sim \frac{\delta^2}{\varepsilon} \langle d^2 \rangle \times F(f_{oc})$$ δ = energy spread

for correlated energy spread $\delta_c \approx \sigma_z$

→ $\frac{\Delta\varepsilon}{\varepsilon} \sim \frac{1}{\sqrt{\varepsilon_y}}$

Stage	I	II	III
$\frac{\Delta\varepsilon}{\varepsilon}$ (%)	12.3	23.8	57.5

for $\sigma_{cav} = \sigma_{quad} = 500\ \mu m$
$\sigma_{bpm} = 100\ \mu m$ resolution $= 10\ \mu m$
shunt correction technique.

Jitter

- slow quad motion

  ex. ATL model relative displacement $\sigma^2 = A \cdot T \cdot L$

  → to keep $\frac{\Delta\epsilon}{\epsilon}$ constant
  the time scale needed for correction
  are proportional to ϵ_y.

  for the most demanding case (stage III)

  { orbit correction → every few minutes
  { BBA procedure → every few weeks.

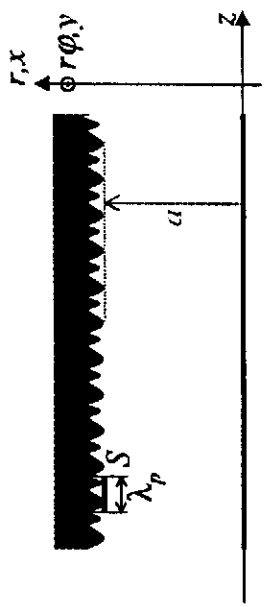
- fast quad motion :

  Fast kickers must be installed not only at the exit
  but also along the linac for preventing
  from beam filamentation.
  tolerating max. jitter of 1 μm rms :

	stage I	stage II	stage III
w/o fast kickers	20	55	138 %.
w/ fast kickers*	1.5	5	15 %.

* results for 6 kicker-pairs
BPMs follow the quad motion
but the orbit is bounded (see fig.)

Wakes of Periodic Surfaces



stimulation by current

$$\bar{J} = J_z(\bar{r}_t)\exp\left(-\frac{j\omega}{c_0}z\right)\bar{e}_z$$

fields:

$$\tilde{\bar{E}}(\bar{r}) = \bar{E}(\bar{r})\exp\left(-\frac{j\omega}{c_0}z\right) \text{ with } \bar{E}(\bar{r}+\lambda_p\bar{e}_z) = \bar{E}(\bar{r})$$

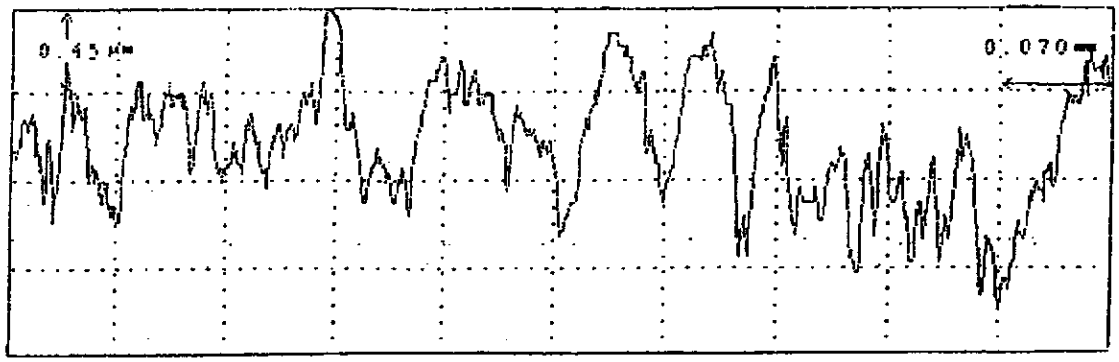
$$\tilde{\bar{H}}(\bar{r}) = \bar{H}(\bar{r})\exp\left(-\frac{j\omega}{c_0}z\right) \text{ with } \bar{H}(\bar{r}+\lambda_p\bar{e}_z) = \bar{H}(\bar{r})$$

concept of surface impedance (~independent on beam pipe geometry) :

$$Z_s = -\frac{\langle E_z(S)\rangle}{\langle H_\varphi(S)\rangle}$$

$$\boxed{Z(j\omega) = -\frac{1}{2\pi a}\frac{Z_s(j\omega)}{1+\alpha a\frac{j\omega}{c_0}\frac{Z_s(j\omega)}{Z_0}}}$$

measured surface roughness of a piece of the undulator pipe



$\sigma_{RMS}=0.35\mu m$

$\lambda_{RMS}=10\mu m$?
MIN

$\frac{\sigma_{RMS}}{\lambda_{RMS}} \approx 0.035$?

skineffect: $\sigma_{bunch}=50\mu m \rightarrow f_{RMS}=950GHz$

$\kappa_{alu}=3.7\cdot 10^7$ S/m

$\delta_{skin}=0.084\,\mu m$

Martin Dohlus Deutsches Elektronen Synchrotron

DOHLUS@MPYNTDOHLUS, MAR05/12:47

TUD

The Shortrange Dipole Wake Fields in a Transport Line Due to a Rough Surface

A. Novokhatski, M. Timm, T. Weiland

Martin Timm Technische Universität Darmstadt

Summary of the 2D-Calculations

- **The transverse wake function is given by**

$$W_{\perp}(s) = 2\left(\frac{r_0}{a}\right)\frac{Z_0 c}{\pi a^3 k_1}\sin(k_1 s)$$

- **Gradient of the wake function**

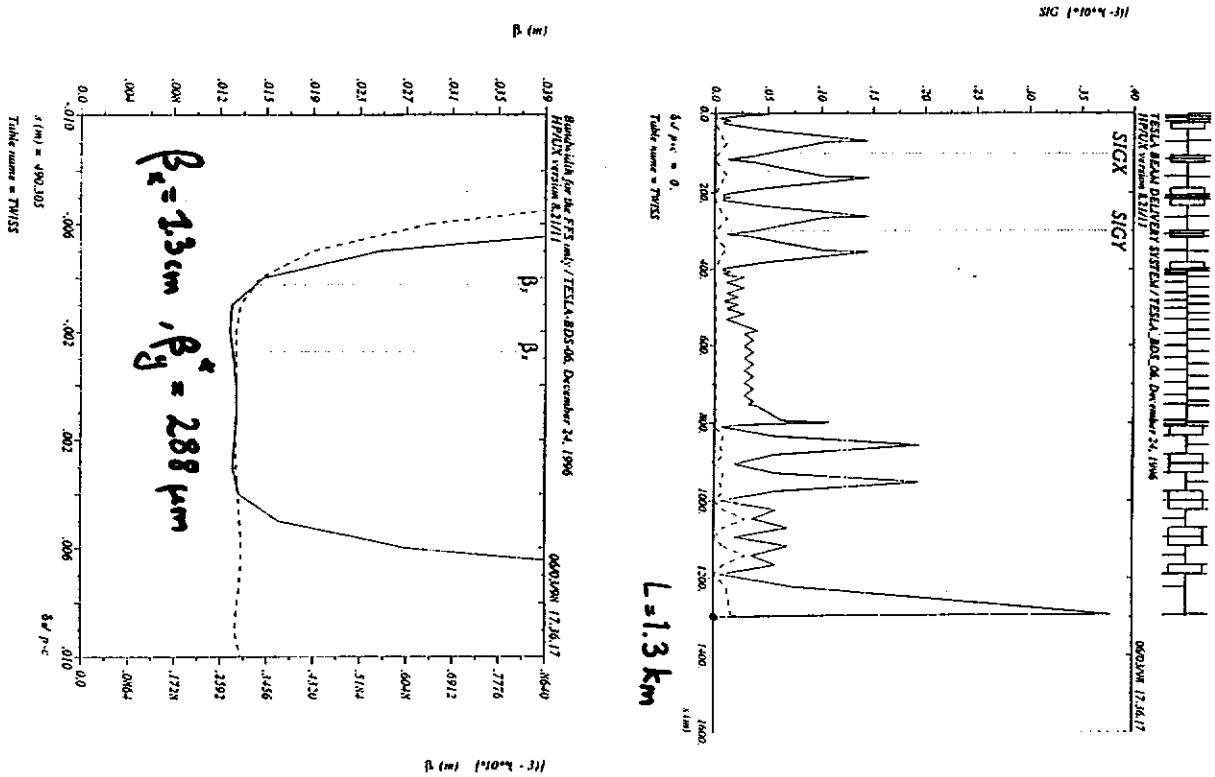
$$G(s) = \frac{W_{\perp}(s)}{r_0} = 2\frac{Z_0 c}{\pi a^4 k_1}\sin(k_1 s) \quad \sim a^{3.5}$$

- **The instability length**

$$Z_{inst} = \sqrt{\frac{E}{G}} = 1m \quad \sim a^{1.75}$$

Martin Timm

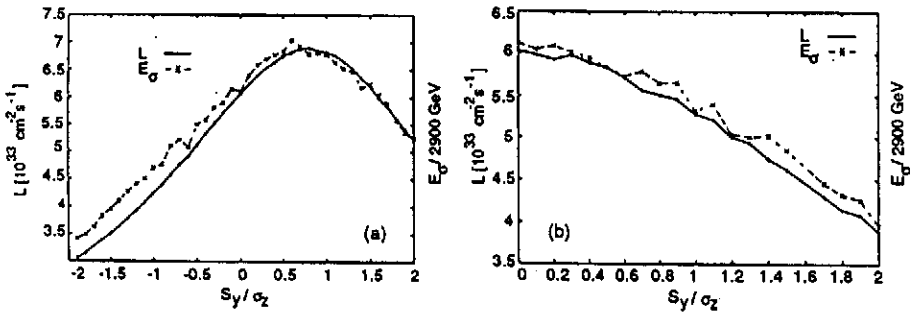
Technische Universität Darmstadt



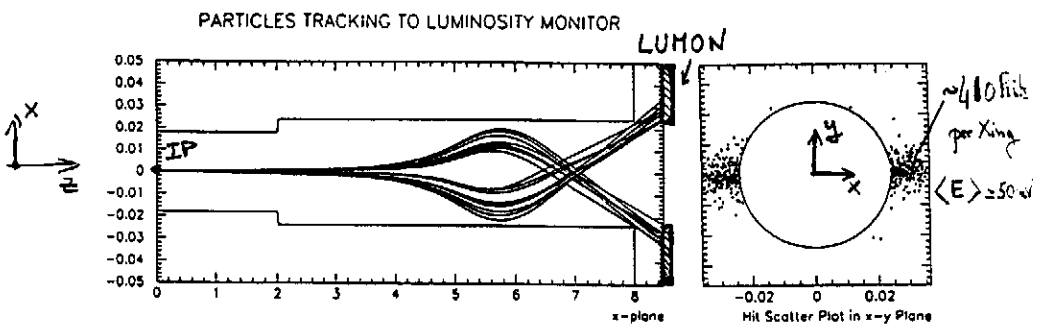
Beam Delivery System

IP Tuning example: Vertical waist-shift scan

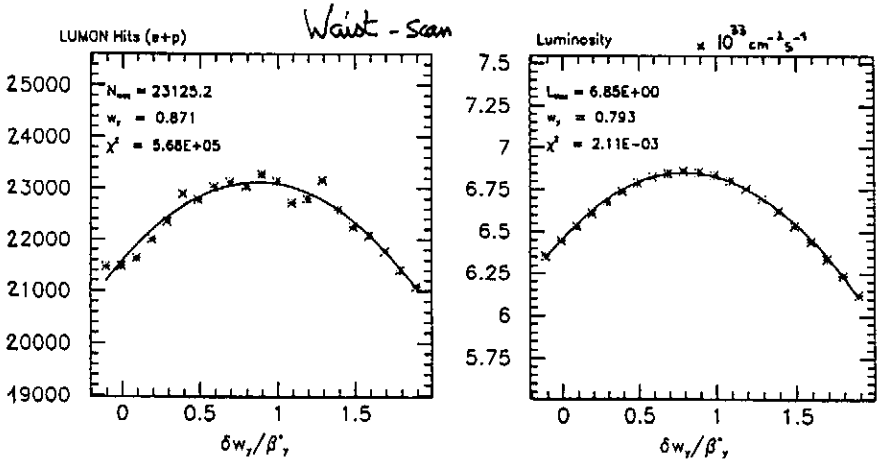
Energy deposited by e^+-e^- pairs in the mask

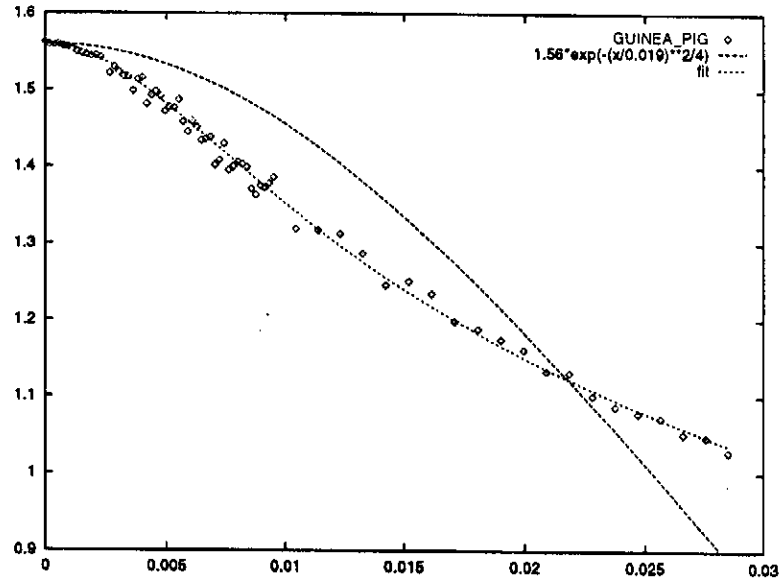


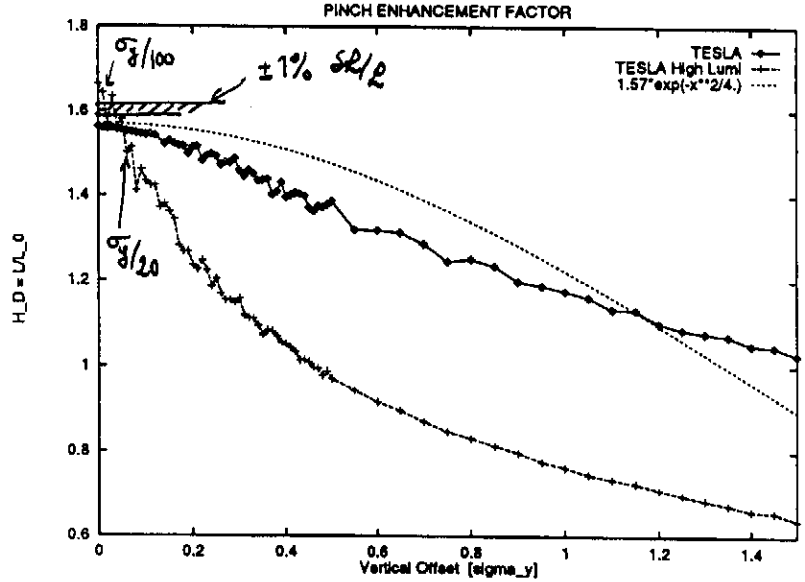
Number of low energy (~ 50 GeV) radiative Bhabha $e^{\pm}$ particles hitting the luminosity monitor (O.N. WG5)



Waist - Scan







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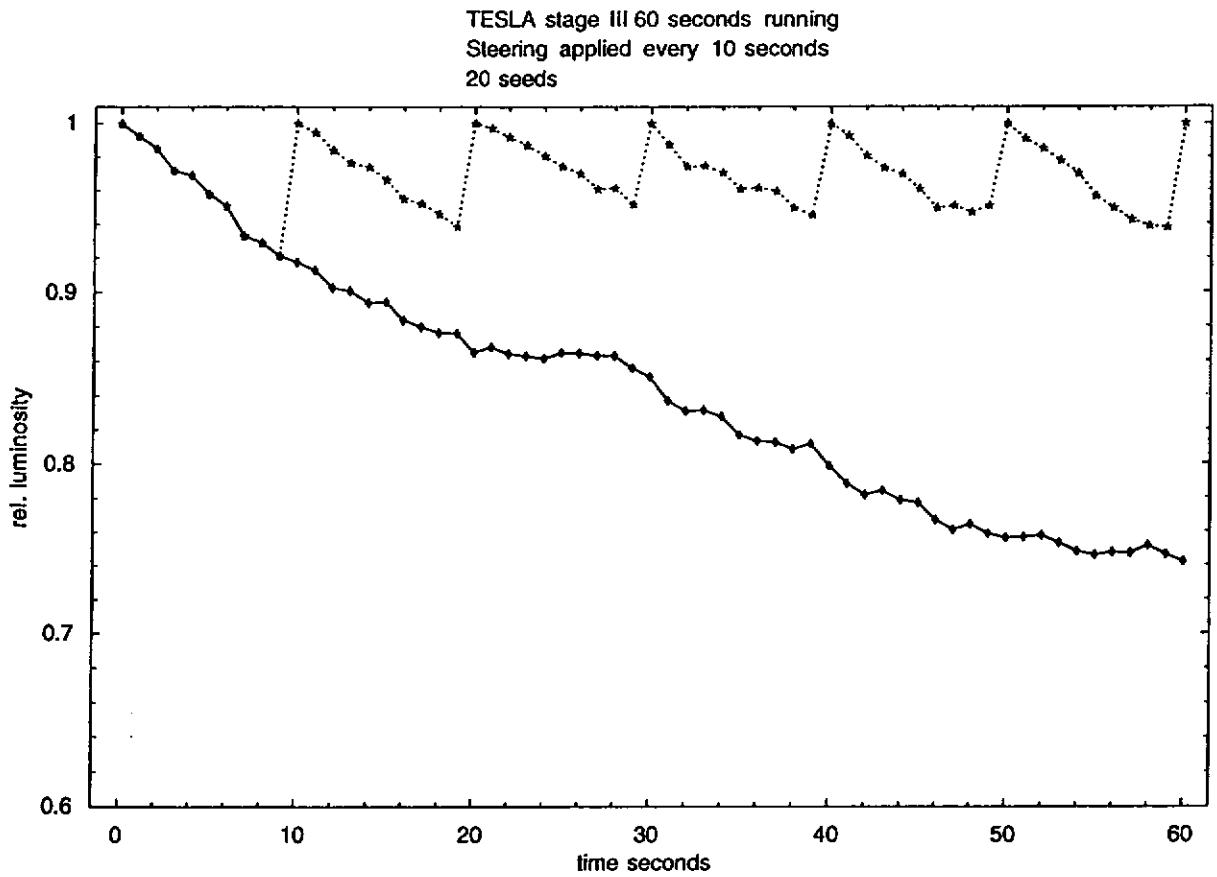
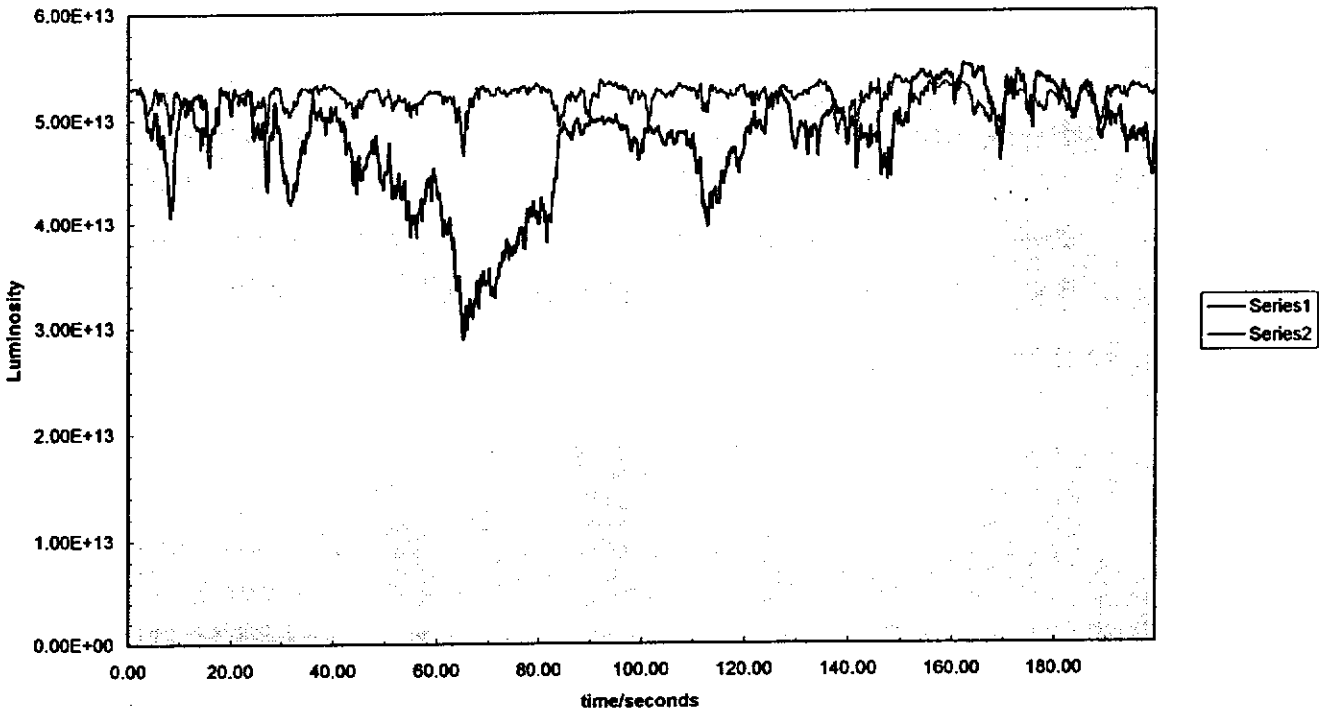


Chart1

freq /20 bandwidth

= 4s response time

One-to-One feedback



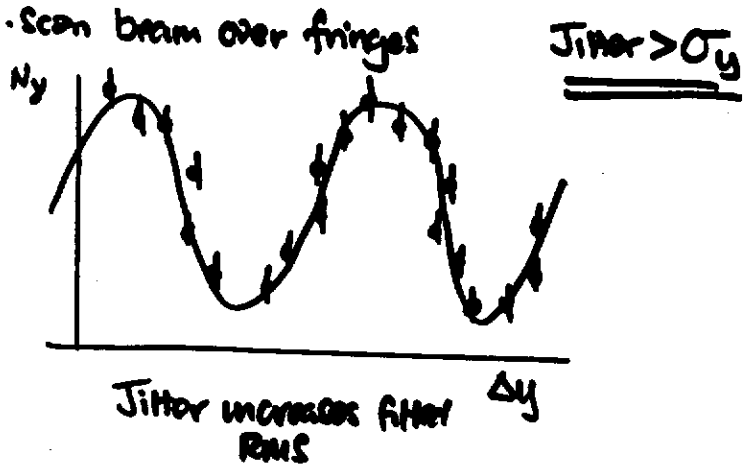
Emittance Measurement Section

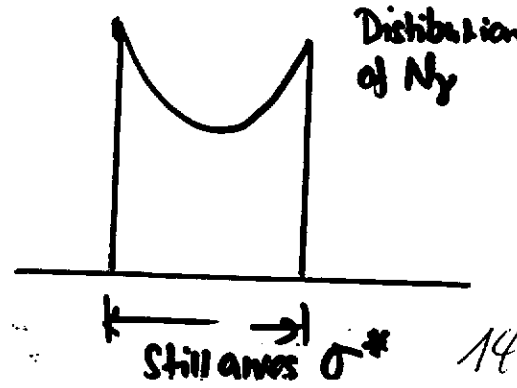
- Current Ref. Design achieves 1% Emittance measurement error.
- For stage III, beam size at "wire" scanners reduces from 6.4μm to 0.9μm
- "Wire" resolution goes from 1μm to 120 nm (laser interferometry)
- systematic errors (magnet errors) still need to be looked at (specify quad tolerances for stage-III)

IP beam size measurement

What do we tune on?

- Luminosity operation: luminosity / beam-beam scans
- Single beam operation (NB. Doublet motion)
  a) >100 bunches: single shot Shintake monitor (long laser pulse)
  b) <100 or 1 bunch: *PROBLEM*?





CONCLUSIONS

- Impact of high L parameters on:
  - Optics, ℓ^*, Bandwidth — OK
  - Collimation Section — (OK!) fast T-rise in Ti-spoiler!
  - Beam size measurement → Luminosity meas.
  - Luminosity vs. jitter — worrying
  - Fast orbit feedback — OK
  - e^+e^- pair masking — ?

Linear Collider

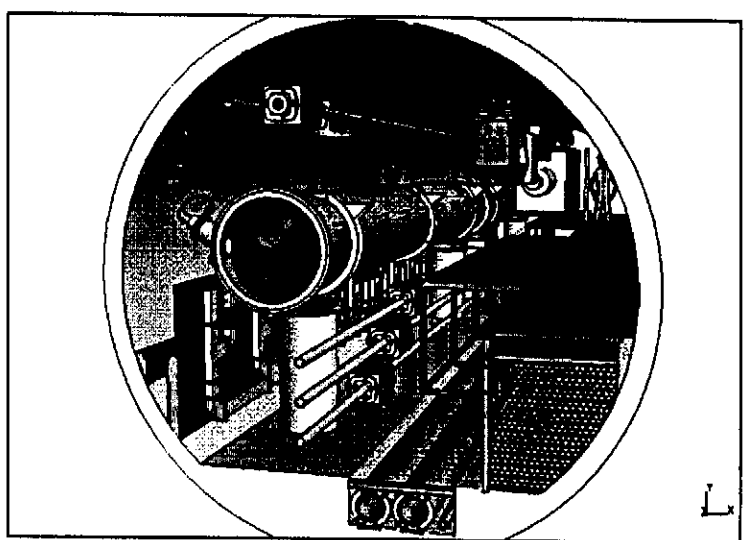
TTF Collaboration Meeting, DESY, March 9-11, 1998, Working Group: TESLA 500

Site Layout and Conventional Facilities for the TESLA Superconducting Linear Collider at DESY

Wilhelm Bialowons

Deutsches Elektronen-Synchrotron DESY
Hamburg

March 10, 1998

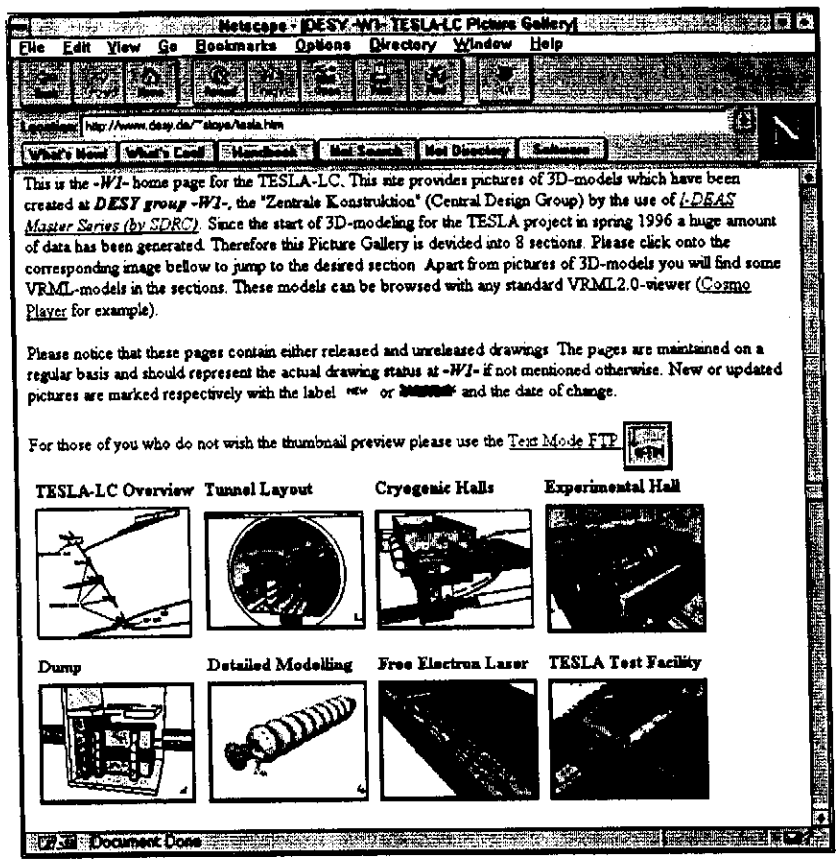


Source: http://www.desy.de/ftp/pub/wl/linac/tesla04b.gif

View into the TESLA Linear Collider tunnel.

Linear Collider

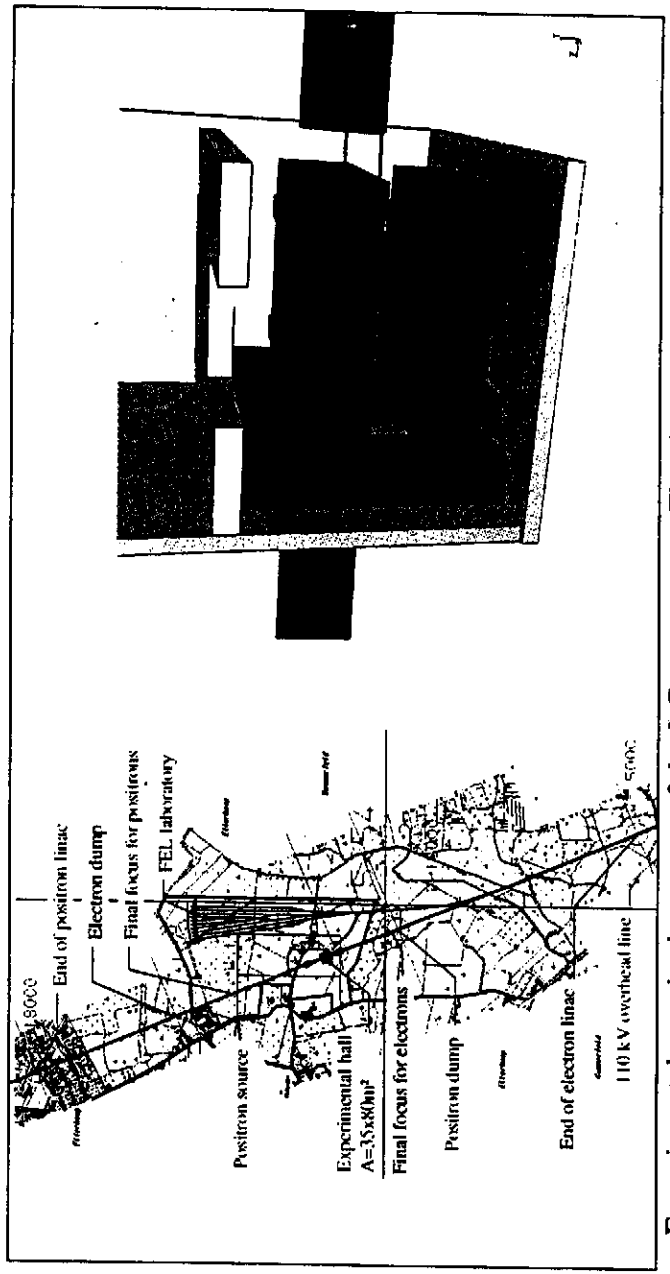
TTF Collaboration Meeting, DESY, March 9-11, 1998, Working Group: TESLA 500



The TESLA Linear Collider in the WorldWideWeb.

Linear Collider

TTF Collaboration Meeting, DESY, March 9-11, 1998, Working Group: TESLA 500



Experimental area in the center of the LC.

First layout of a dump hall.

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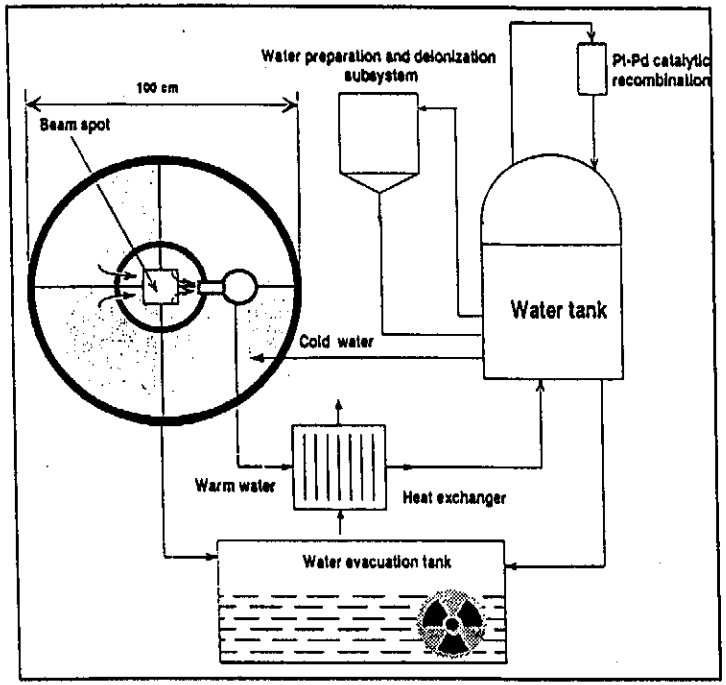
BRALOWICHS @ AXDESY.C, MARCH 18.22



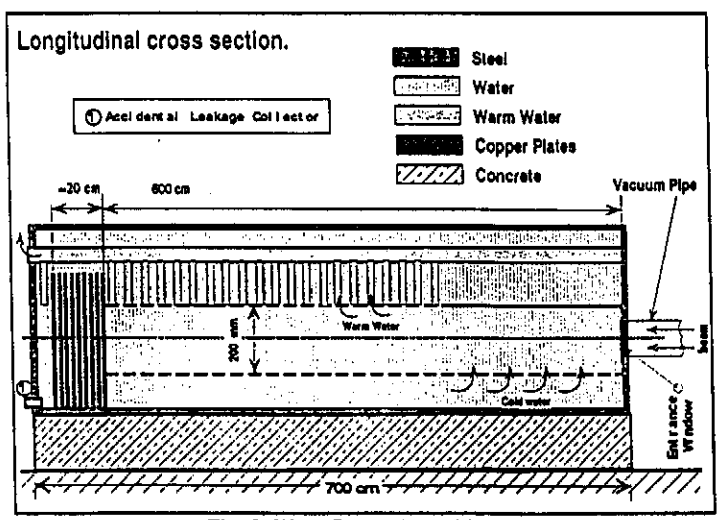
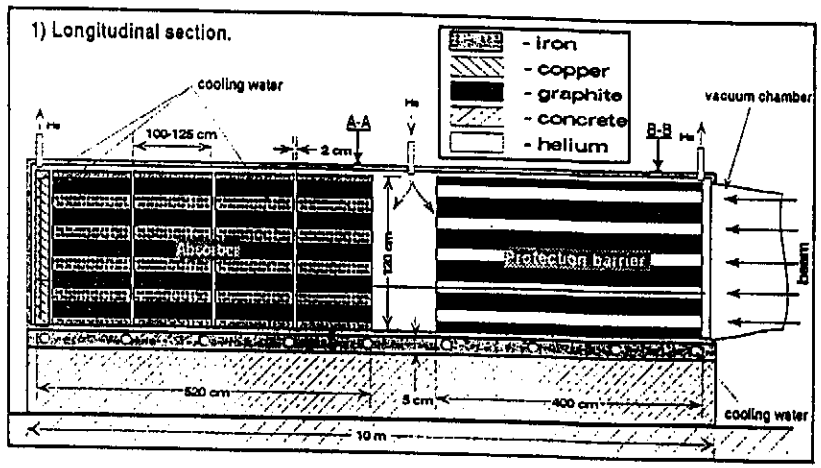
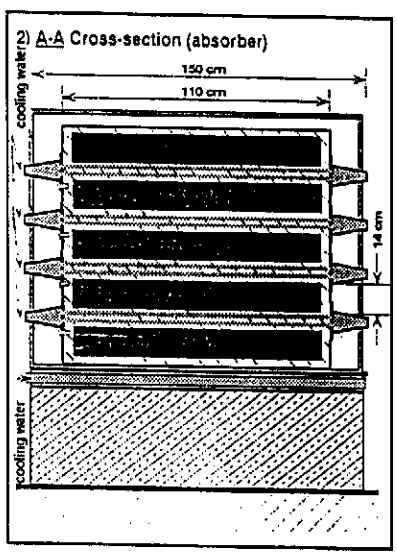


Fig. 8 Water Dump Assembly





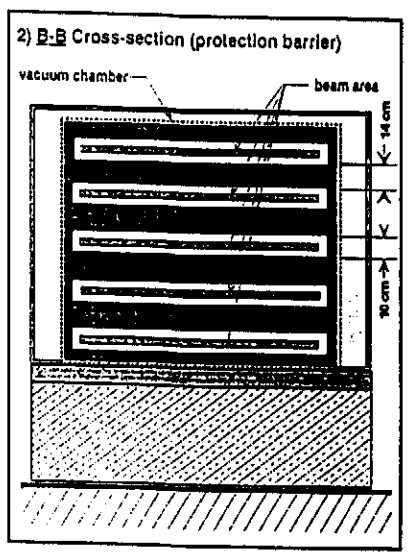
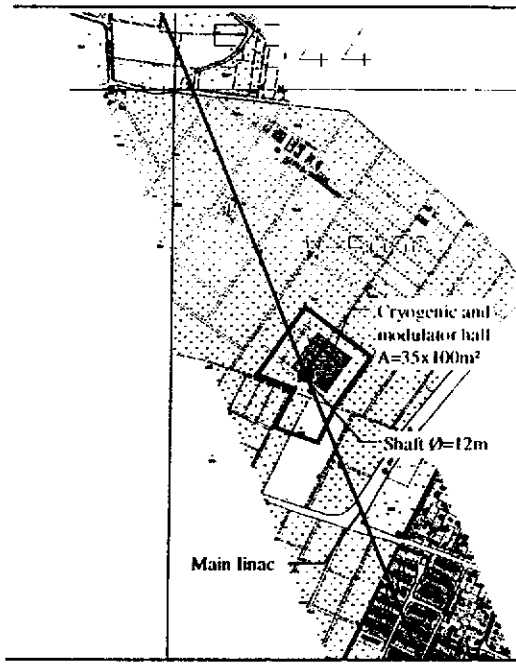
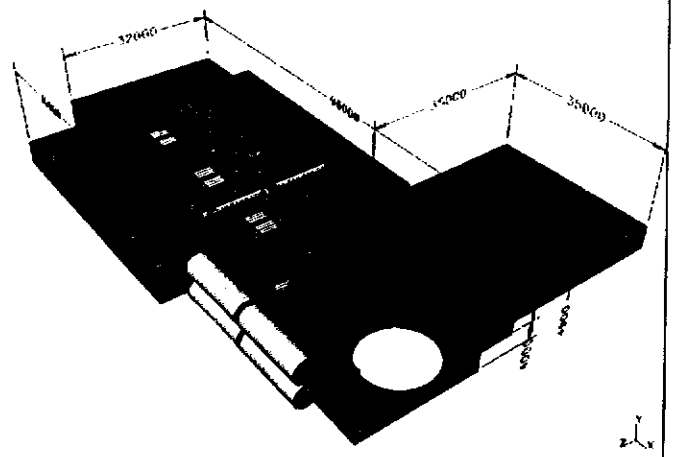


Fig.2 Solid dump scheme.

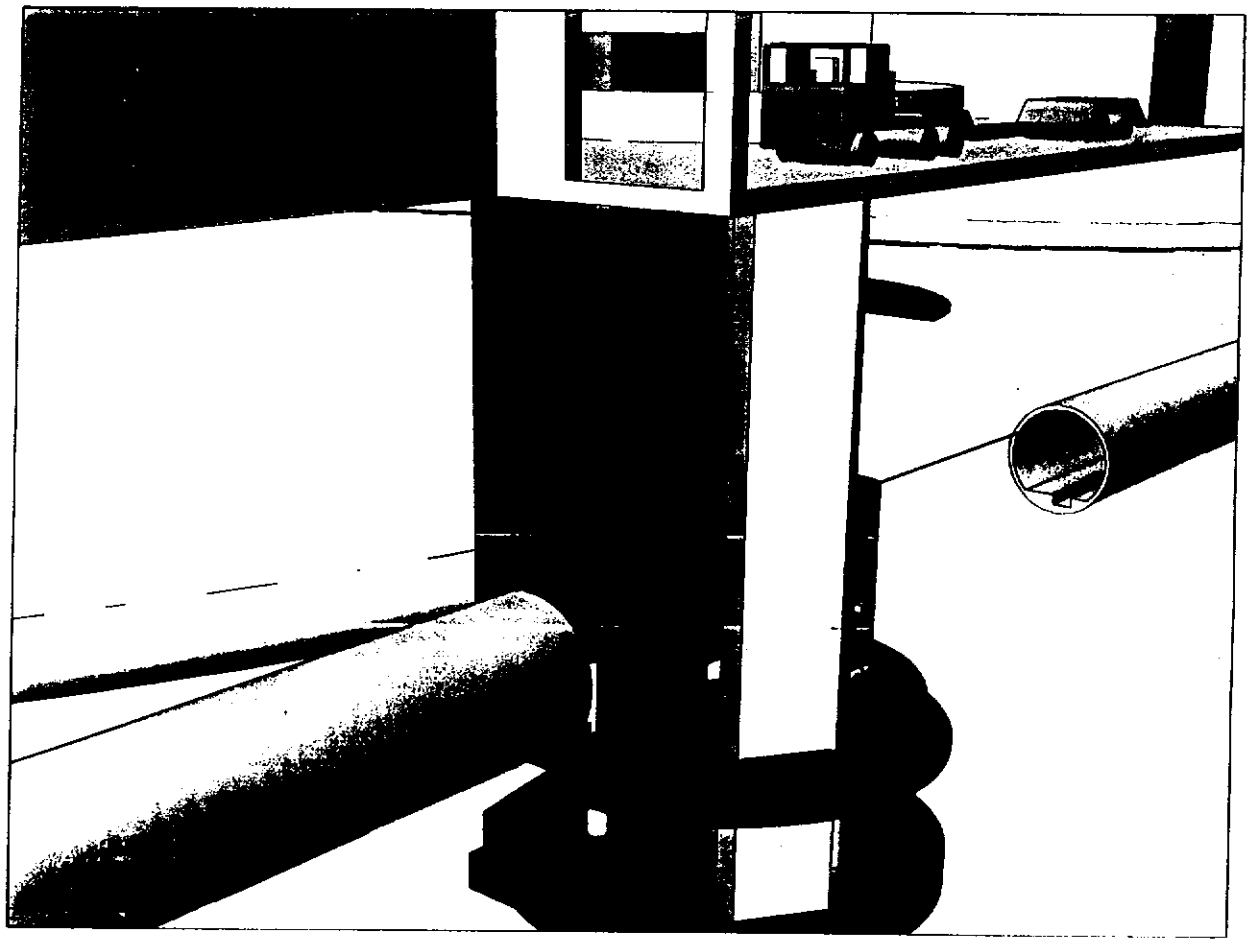


Area for a cryogenic plant.



First layout of a cryogenic hall.

BIALOWONS@AXIDSYC, MAR09/15:08



Working Group Cavities

Tuesday, 9:00, Room 4b, Bldg. 1b

I : Cavity fabrication & treatment (Bloess)

field emission scan on samples	(Haberman)
quality control in the clean-room	(Reschke)
activities at Saclay/Orsay	(Fouaidy)
hydroforming of cavities	(Singer)
material investigations	(Singer)

II : Cavity measurements (Schmüser)

single cell program at Saclay/Orsay	(Bousson)
multipacting calculations for cavities	(Proch)
Q-drop but no x-rays in welded cavities	(Pekeler)
Q-drop in cavities made by spinning	(Haebel)
cavity R&D for Eacc > 30 MV/m	(Lilie,Liepe)

TTF - specifications reached

and now:

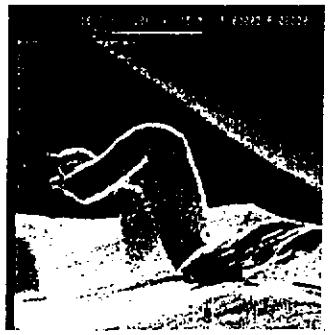
1) higher reliability of production process
2) higher fields - higher Q_0
3) faster
4) cheaper

Analysis of single emitters on sample B

E(0.5nA) = 35 MV/m
$\beta = 86$
$S = 7 \cdot 10^{-11}$ cm²

particle, slanted view:

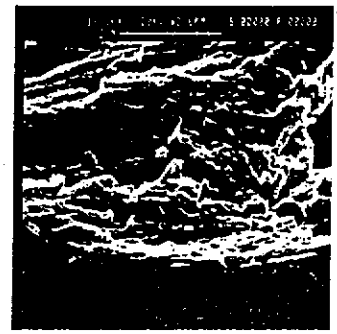
view from the side:



E(0.5nA) = 40 MV/m
$\beta = 88$
$S = 2 \cdot 10^{-12}$ cm²

defect, slanted view:

slanted view:



E(0.5nA) = 47 MV/m
$\beta = 103$
$S = 2 \cdot 10^{-14}$ cm²

defect/scratch, slanted view:

view from the side:

Analysis of single emitters on sample A

E(0.5nA) = 19 MV/m
$\beta = 83$
$S = 2 \cdot 10^{-4}$ cm²

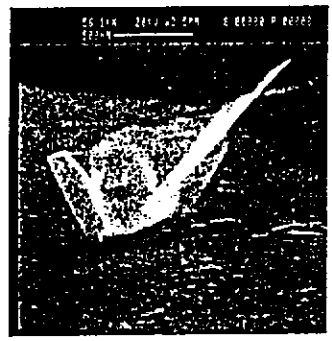
particle, slanted view:

view from the side:

E(0.5nA) = 28 MV/m
$\beta = 107$
$S = 1 \cdot 10^{-9}$ cm²

particle, view from above:

view from the side:

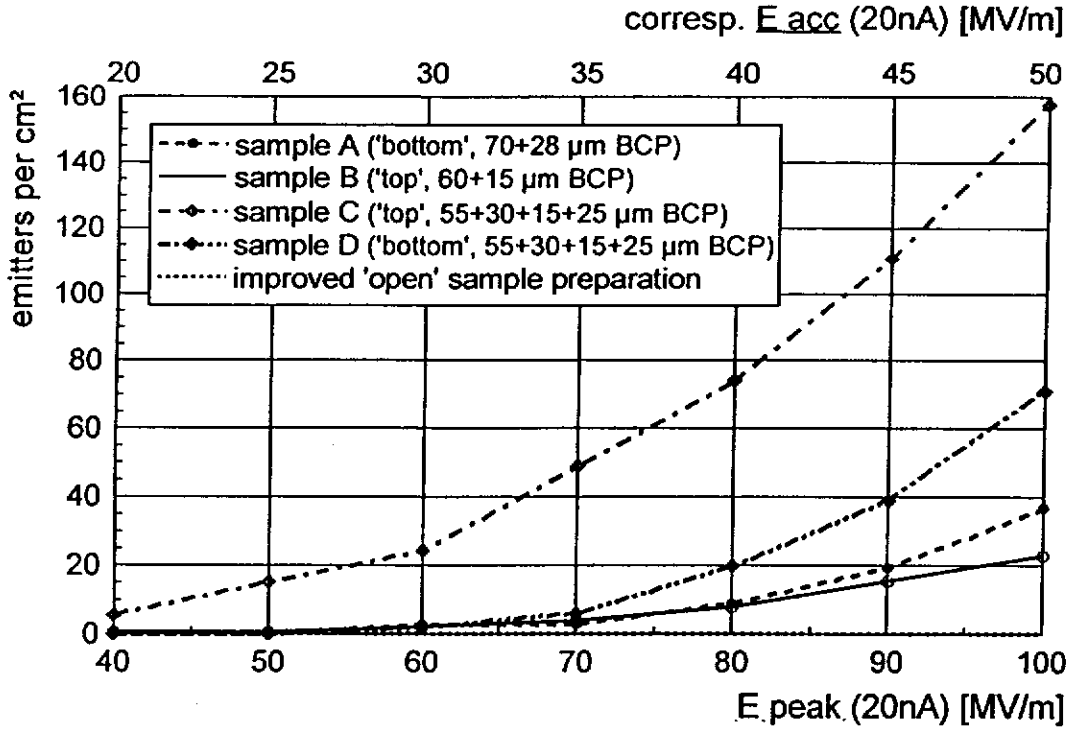


E(0.5nA) = 28 MV/m
$\beta = 310$
$S = 4 \cdot 10^{-16}$ cm²

particle, view from above:

view from the side:

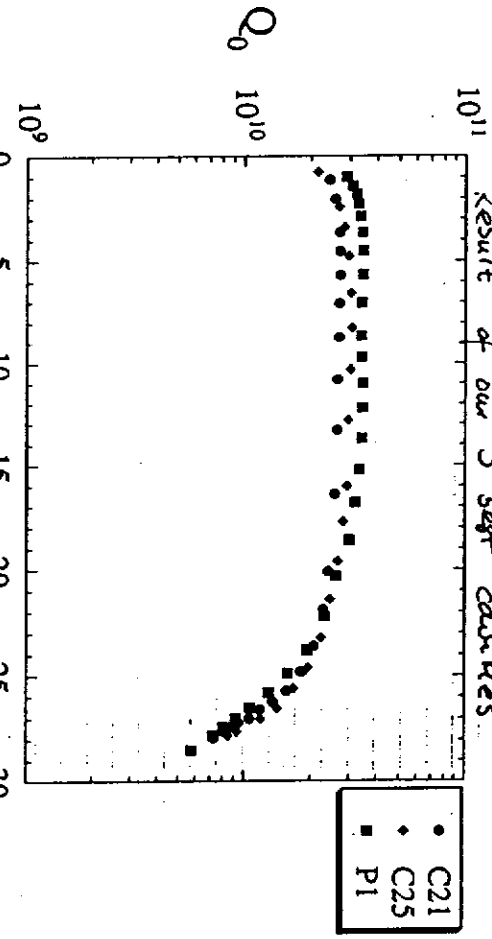
DC FE-Samples Prepared in TESLA-Cavities



Q-drop at high gradients

1. We always have x-rays in TE-mode at high gradients

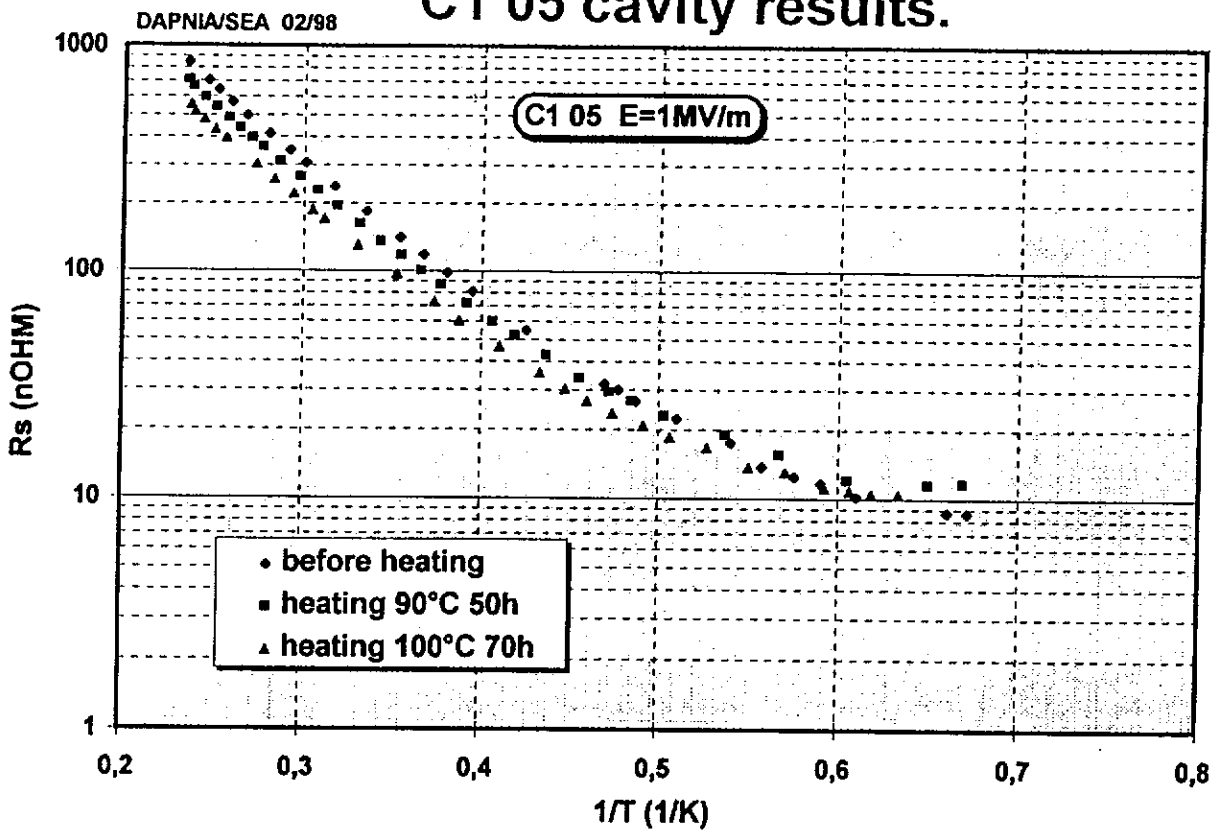
2. We have observed Q-drop without x-rays in other modes.



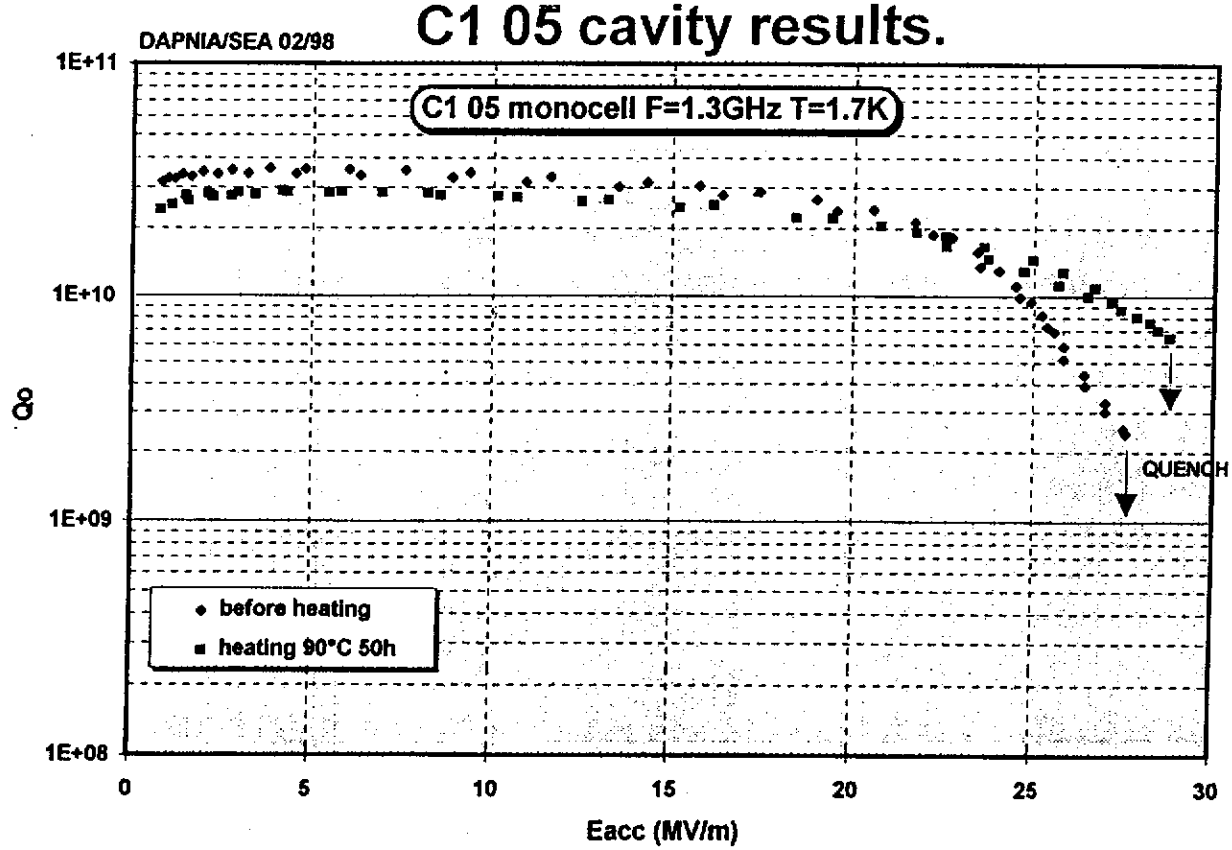
always x-rays, but in case of C25 very low

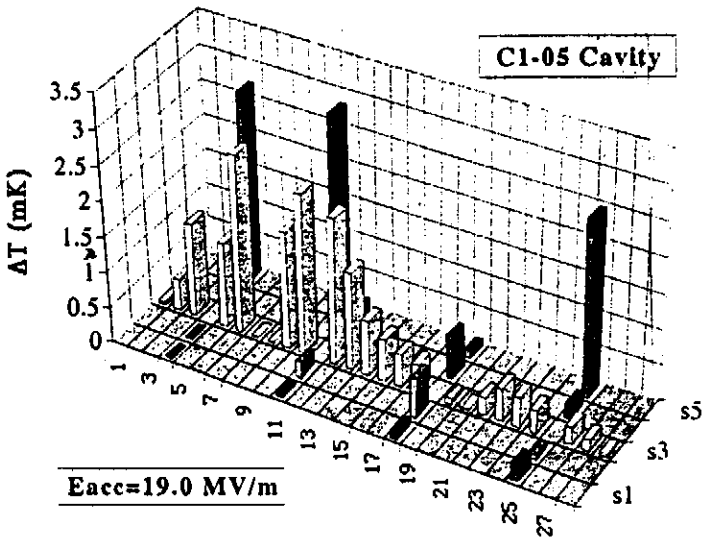
Why are the 3 curves almost identical?

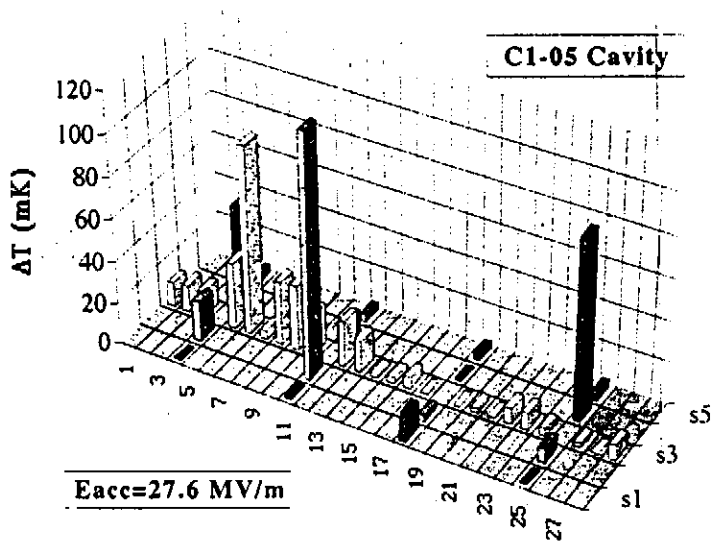
C1 05 cavity results.



C1 05 cavity results.

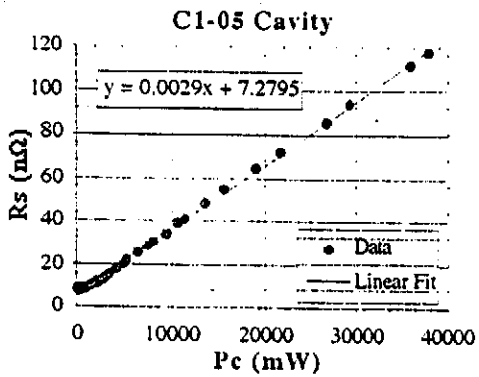


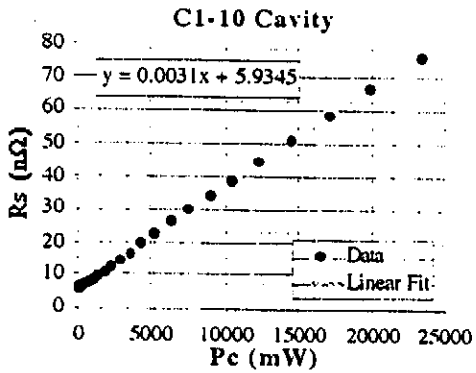




Variation of Rs versus the dissipated power

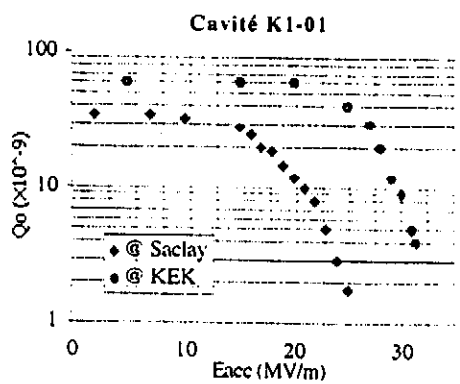
Assuming an increase of the global surface resistance Rs with Eacc

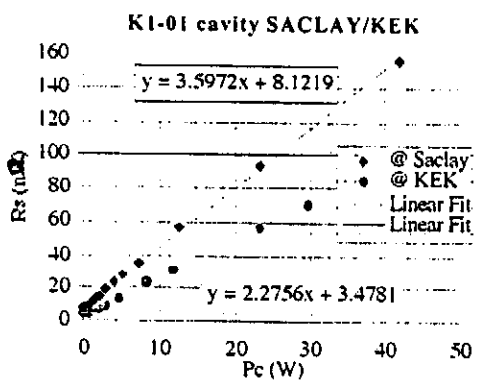




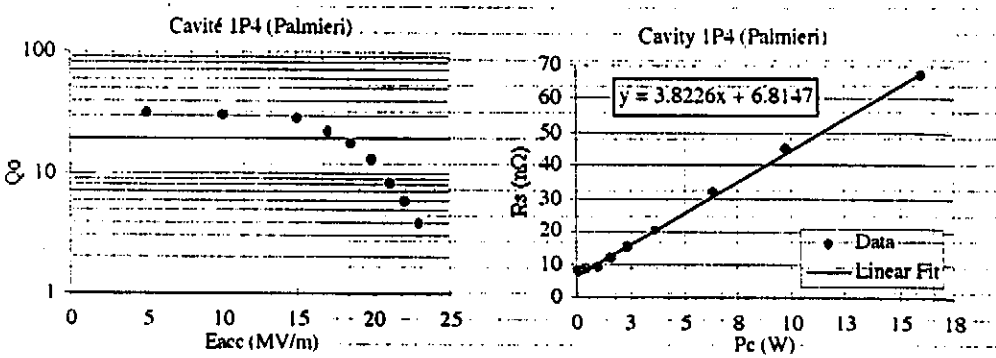
The linear dependency of Rs vs Pc seems to be a constant:

KEK Cavities:



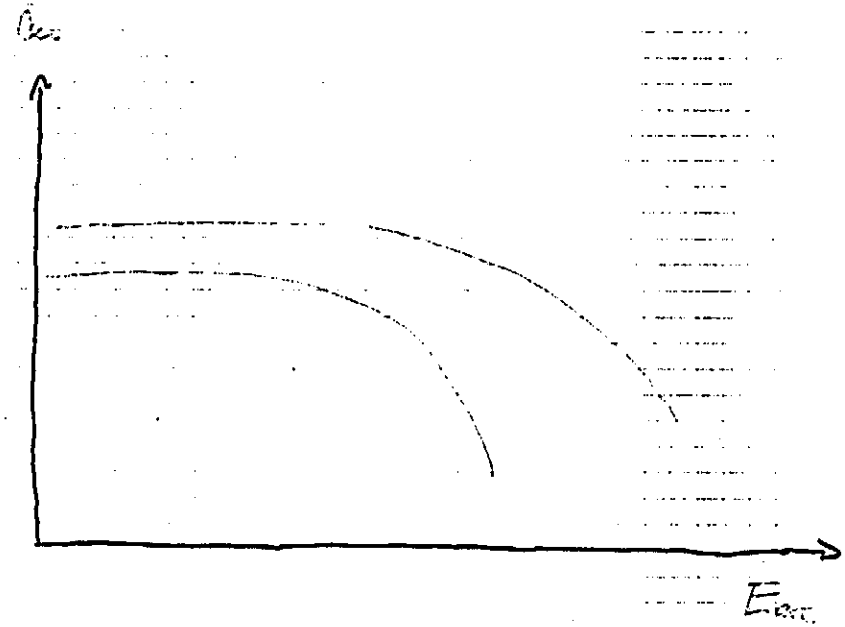


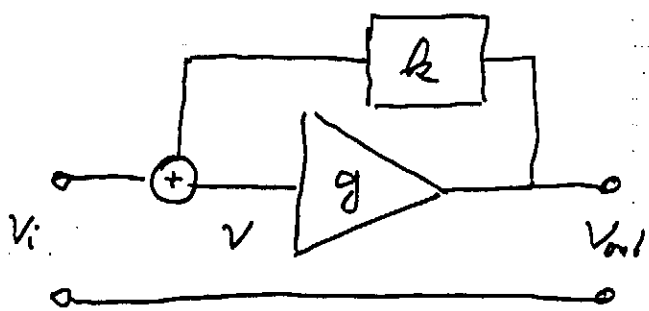
ALSO for the non-welded cavities (Palmieri):



- This behaviour is not seen on thin films cavities.

- BUT cavities having strong FE also have a linear dependancy of the "equivalent" surface resistance with the dissipated power.

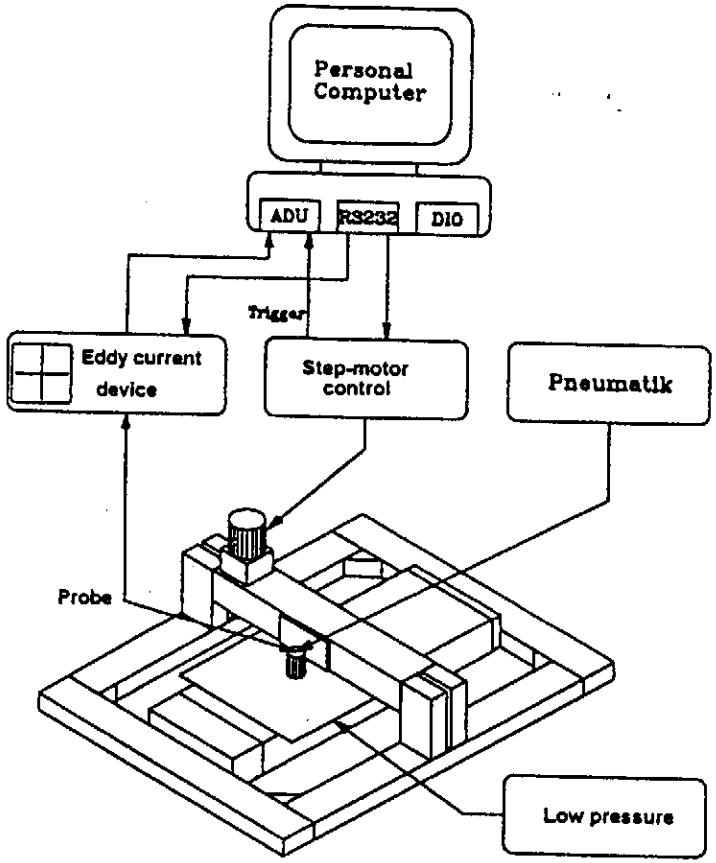




$$V_{out} = gV = g(V_i + k V_{out})$$

$$V_{out}(1 - gk) = g V_i$$

$$V_{out} = \frac{g V_i}{1 - gk}$$



The depth of signal penetration
(Skin Effect)

$$\delta = A\sqrt{\frac{\rho}{\mu f}}$$

BAM: Two frequency set up

160

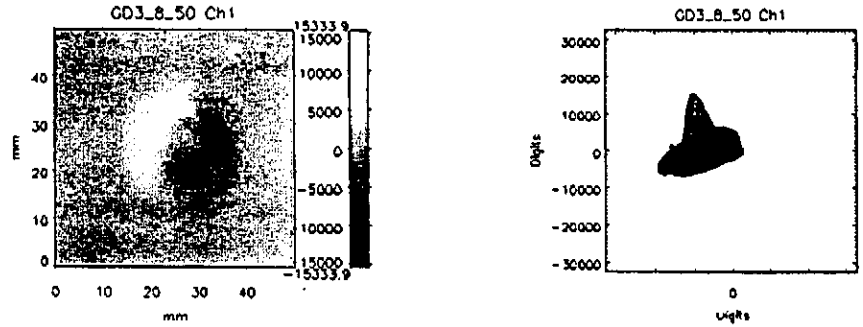


Bild 13a: Mulde mit verdeckten Bohrungen Kanal 1
(80 kHz)

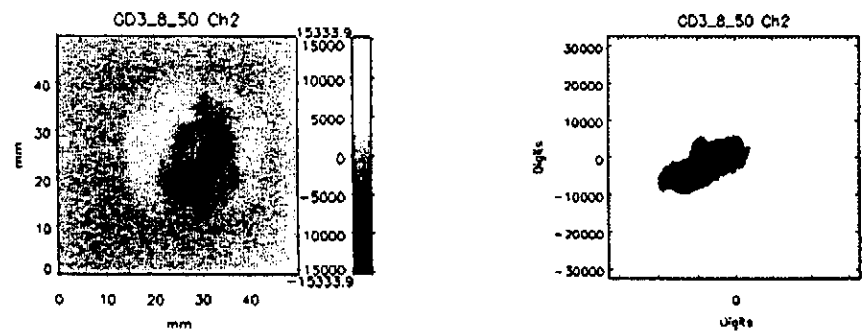


Bild 13b: Mulde mit vedeckten Bohrungen Kanal 2
(500 kHz)

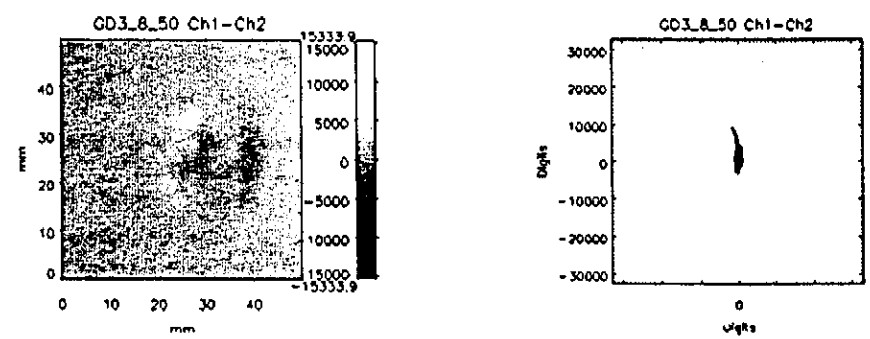
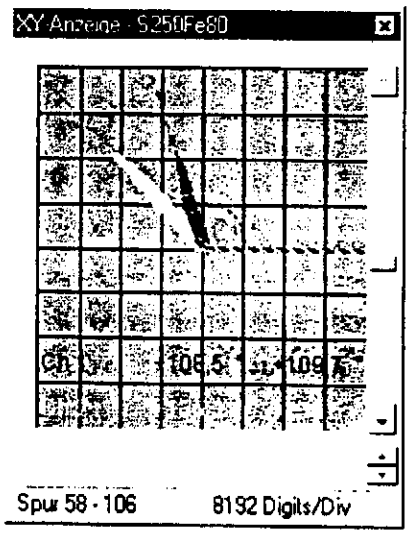
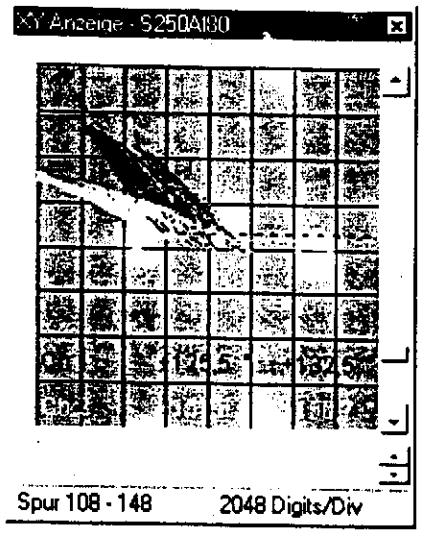


Bild 13c: Mulde mit verdeckten Bohrungen Verknüpfung beider Kanäle
($f_1 - f_2$)

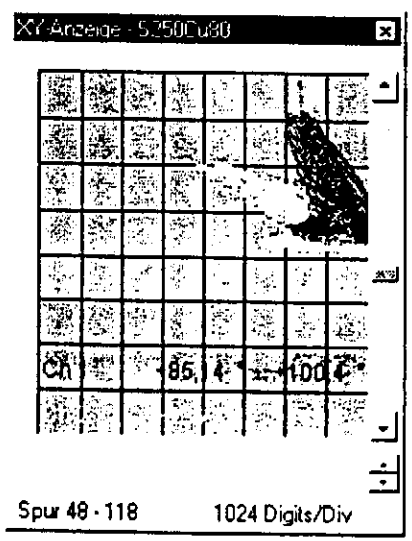
161



a) Fe



b) Al



c) Cu

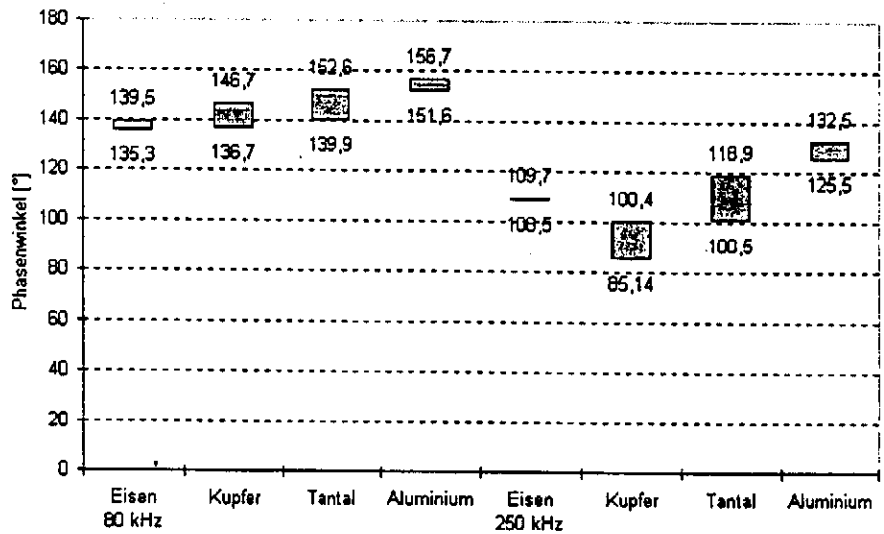
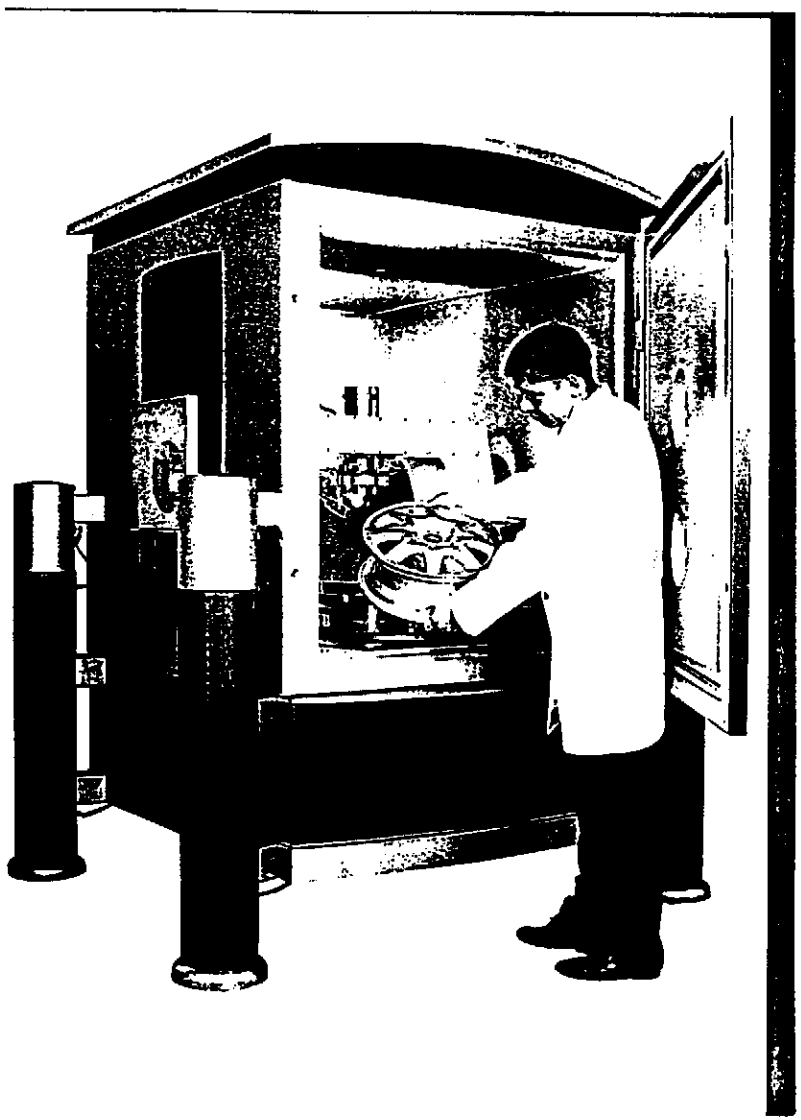
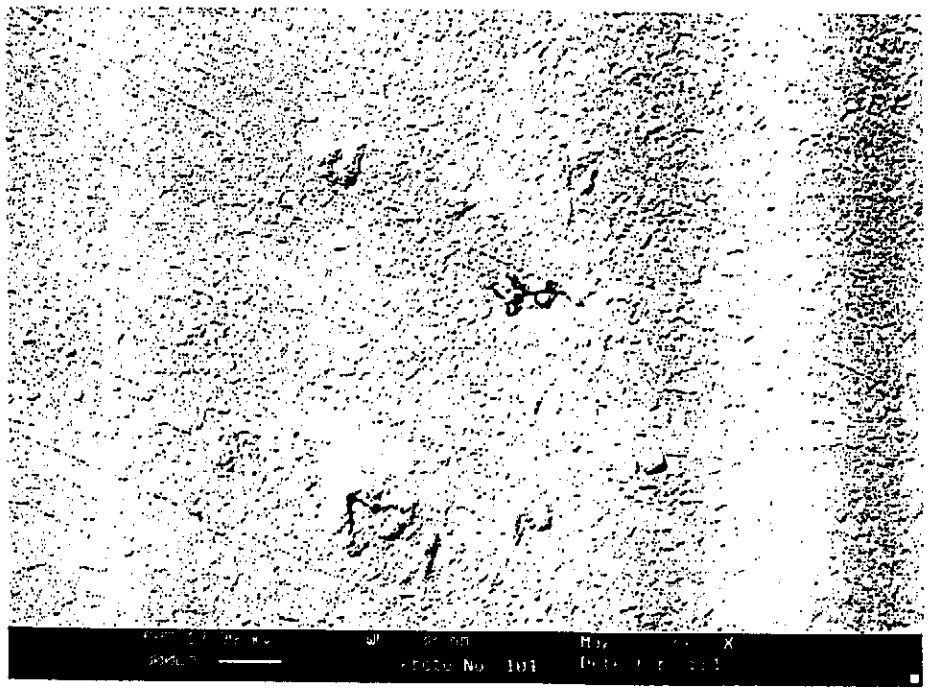
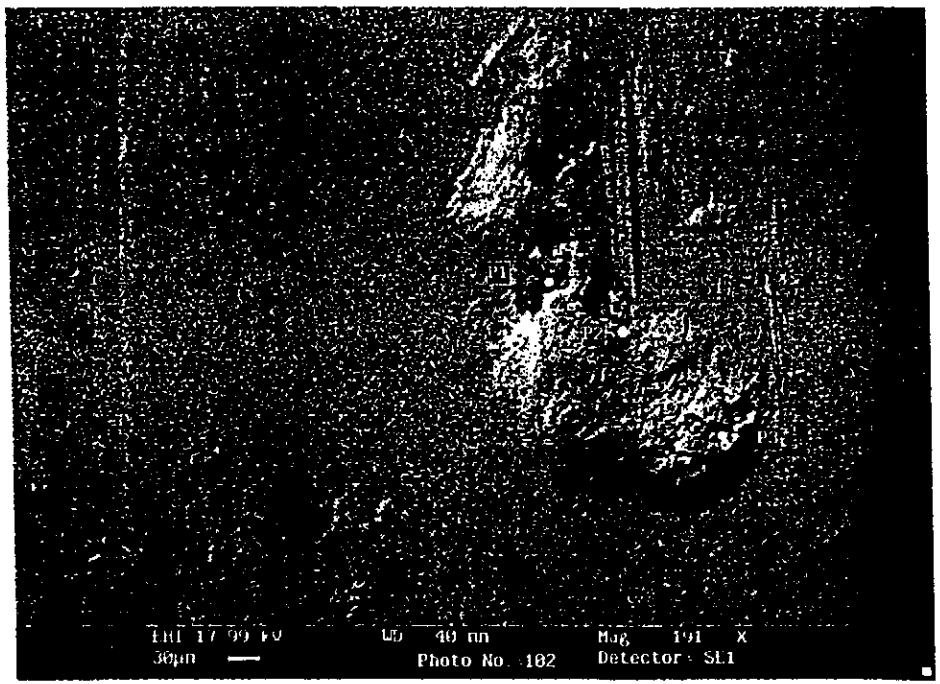


Bild 16: Phasenverhalten bei verdeckten Materialeinschlüssen für die Prüffrequenzen 80 kHz und 250 kHz

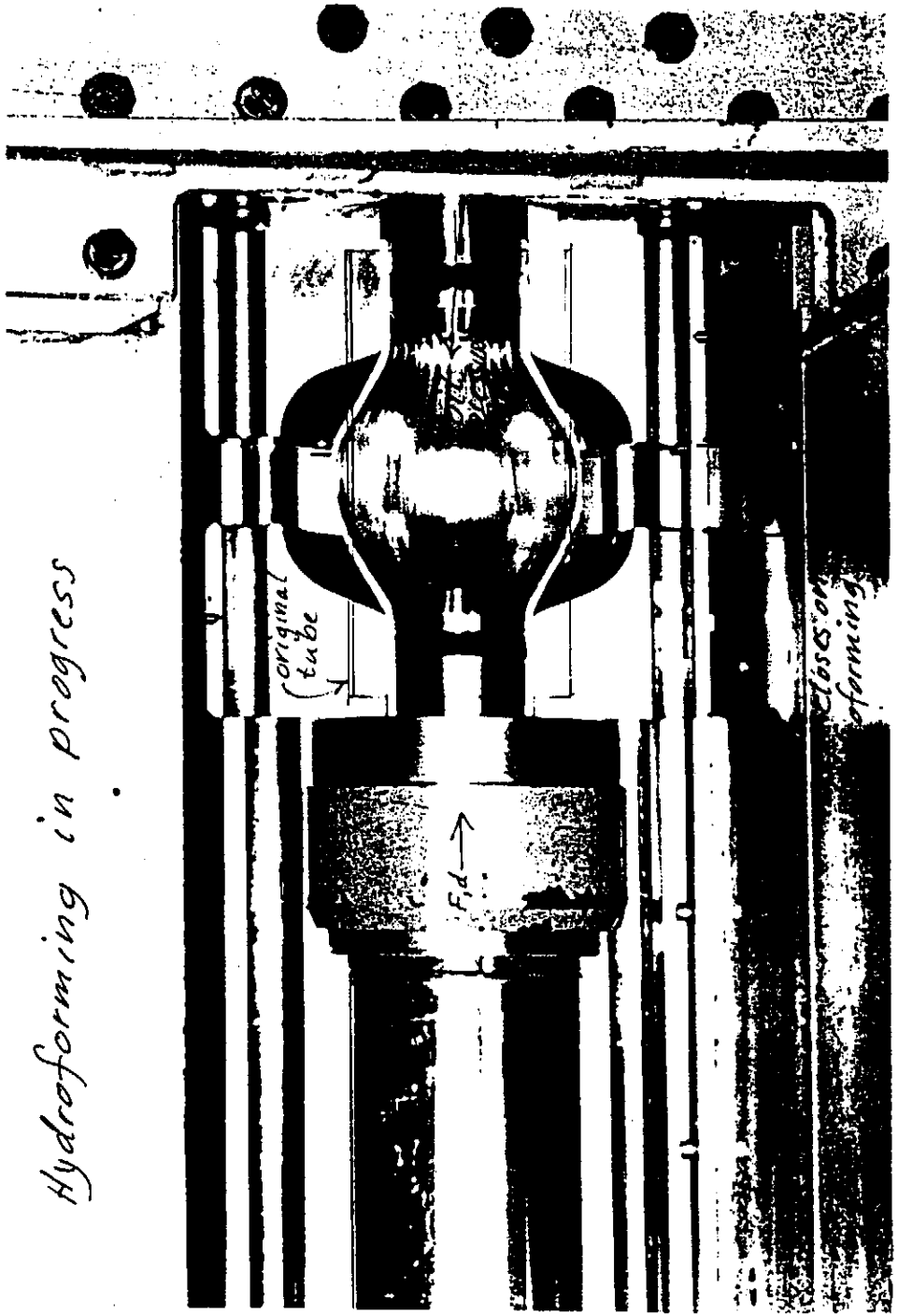




T 44
after etching 30 µm



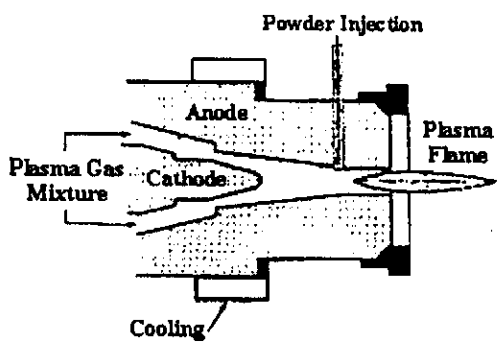
Position	Element	Atom%	Wt %
P 1	Nb	50,3	64,9
	Fe	46,5	34,7
P 2	Nb	90,1	93,9
	Fe	8,75	5,48
P 3	Nb	59,7	71,13
	Fe	40,2	28,8



Hydroforming in progress

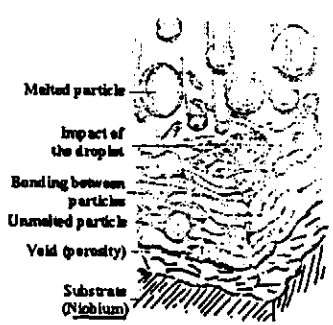
A R&D program concerning new fabrication techniques of SRF cavities has started in a close collaboration with CEA and LAL(CNRS-Orsay).

The technique is based on **copper plasma sprayed onto thin wall** (~1 mm) Niobium cavities. The ultimate goal is to produce 1.3 GHz hydroformed (or deep drawed and EB welded) multicell niobium cavities stiffened by the copper layer.



Current: 500 A
Voltage: 50 V
Powder size: 50 µm
Particle velocity: Mach 1-2
Plasma gas : mixture of Argon (or Nitrogen) with Hydrogen.

Plasma Spray Gun

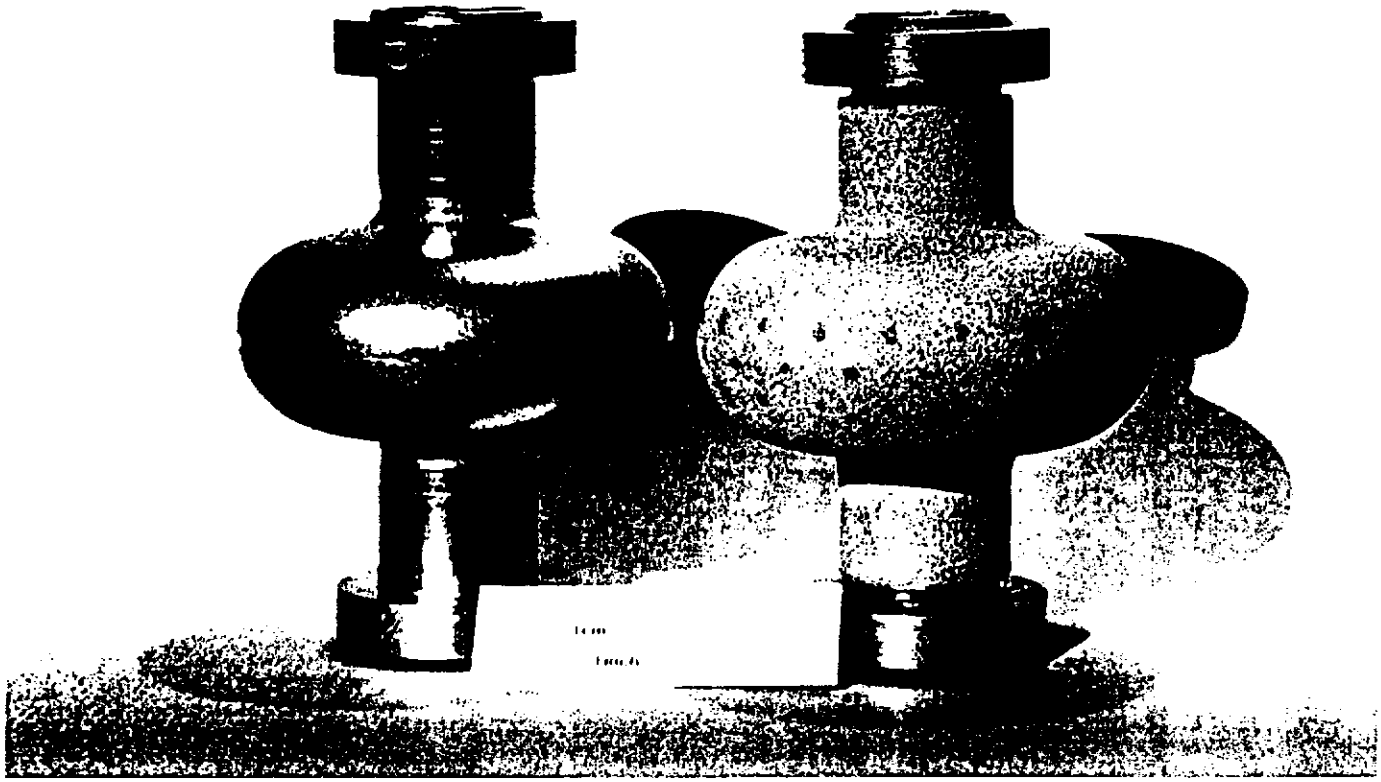


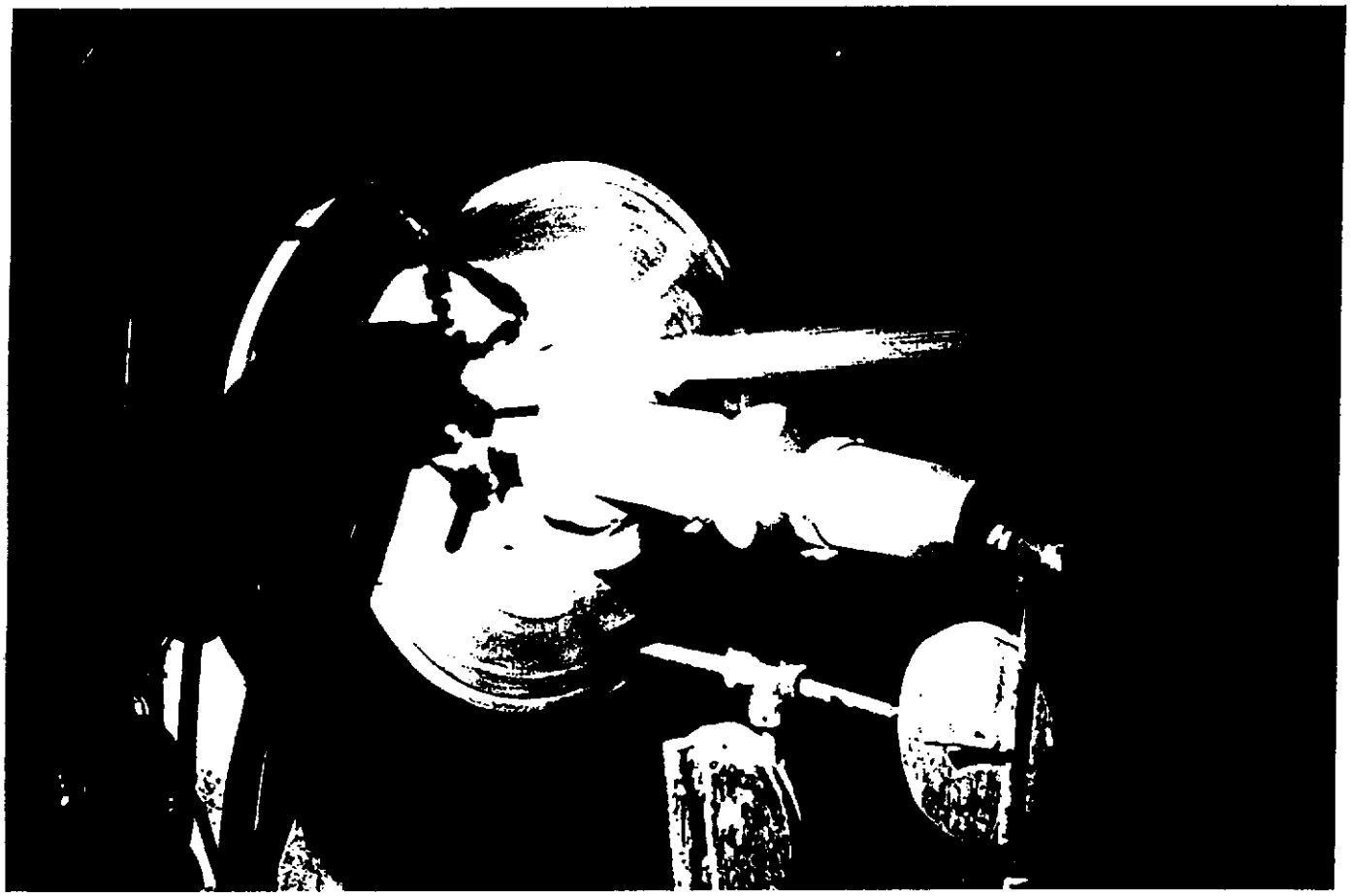
First hydroformed Nb. TESLA-monocell

Fabrication details:
- from seamless tube 138 x 4 mm (Heräus)
- ends reduced with conical rings
- no intermediate anneals
- Nb tube-wall hydro-forming stabilized with 1 mm thick stainless steel jacket
- wall thickness 2 mm
- 1.2997 GHz

Test status:
- being fitted with endtubes for RF-testing

ZUNDIS





Standard surface preparation

- remove damage layer (50 - 100 µm BCP)
- 800 degrees firing
- 20 µm BCP
- Test
- 1400 degrees firing
- 100 µm BCP
- Test
- always 1:1:2 BCP
- always drying by pumping

New preparation ideas

- BCP with dilution at the end (reduced heating of surface)
- BCP 1:1:1 ...
- BCP and rinsing with H_2O_2, O_3
- HPR with hot water and/or higher pressure
- Electropolishing
- Tumbling and EP or BCP
- hardening of niobium surface

M. Liepe & L. Lilje 9.3.98

Standard deep drawing and welding	Spinning	Hydroforming	TE011-Resonator
test of standard preparation and of alternative preparation at Cornell	test of manufacturing procedure	test of manufacturing procedure	test of critical field
many tests	many tests	few tests	few tests
in collaboration with Cornell	in collaboration with INFN Legnaro	DESY	DESY
build and test EP at Cornell (learn technology)	EP at Legnaro (or CERN)	EP at CERN (or Legnaro)	?
Cornell: build 1-cell cavities build EP build T-map for 1.3 GHz	DESY: cleanroom (Hall NO) infrastructure (pumps, antennas, 2nd T-mapping, own insert...)	DESY: cleanroom	new design special insert DESY: cleanroom SACLAY, ORSAY

EP of [illegible]

M. Liepe & L. Lilje 9.3.98

Research issues

1. How to avoid field emission safely?
2. Best surface preparation
3. Q-drop at high field without X-rays and new physics
4. New cavity production line (spun +hydroformed)
5. Quench origins

⇒ Single cell program

because of
- fast turnaround time
- T-mapping possible
- good diagnostics
- cutting of cavities possible (Cornell)

+ probes for H_{C2}, etching parameters, FE,HPR, etc.

at DESY, CORNELL, CERN (EP), INFN Legnaro (EP)

Many things to do, a joint effort is needed!

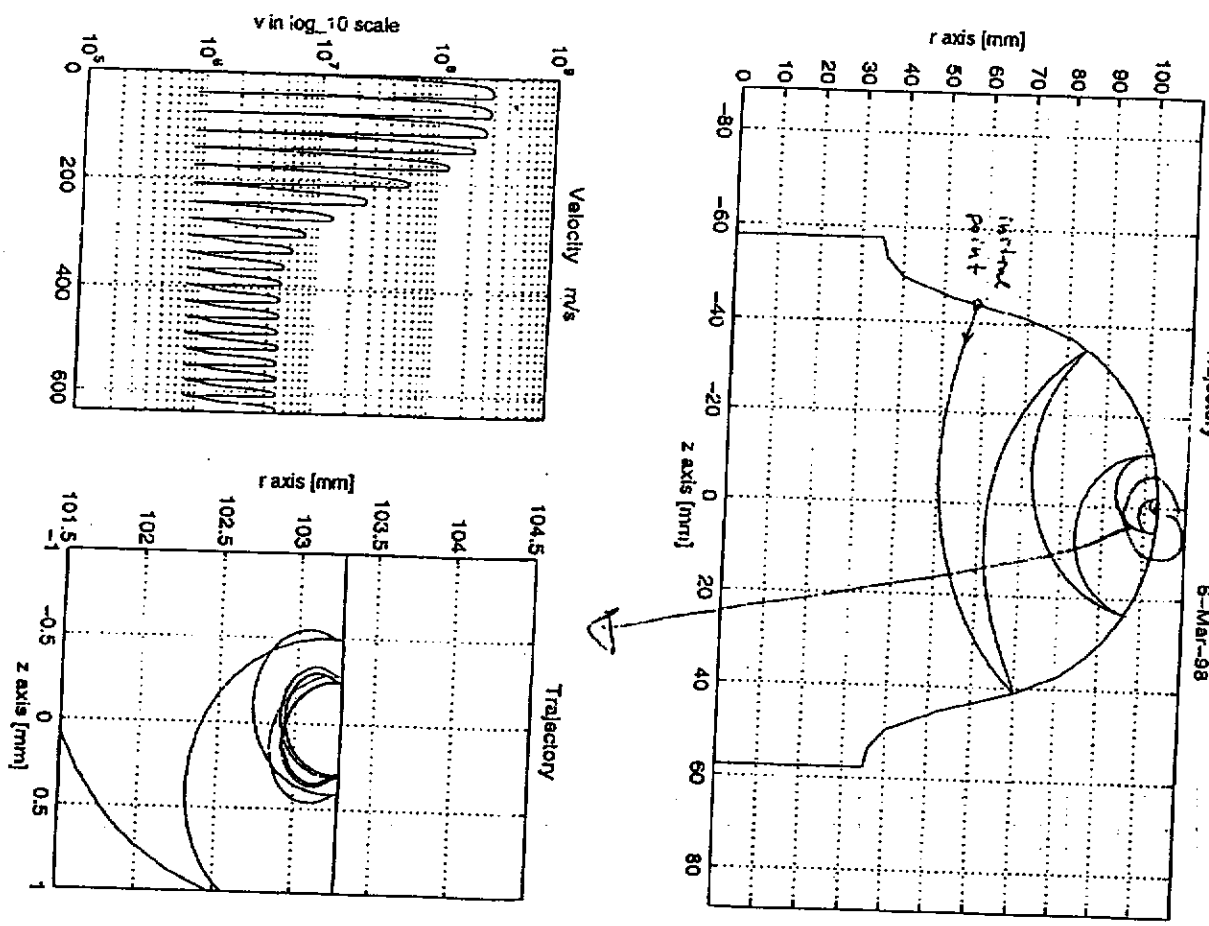
M. Liepe & L. Lilje 9.3.98

III : Couplers (Haebel)

coupler development at Saclay (Travier)
status of couplers TTF II, TTF III (Proch)
rectangular coupler for TTF (Yarigin)

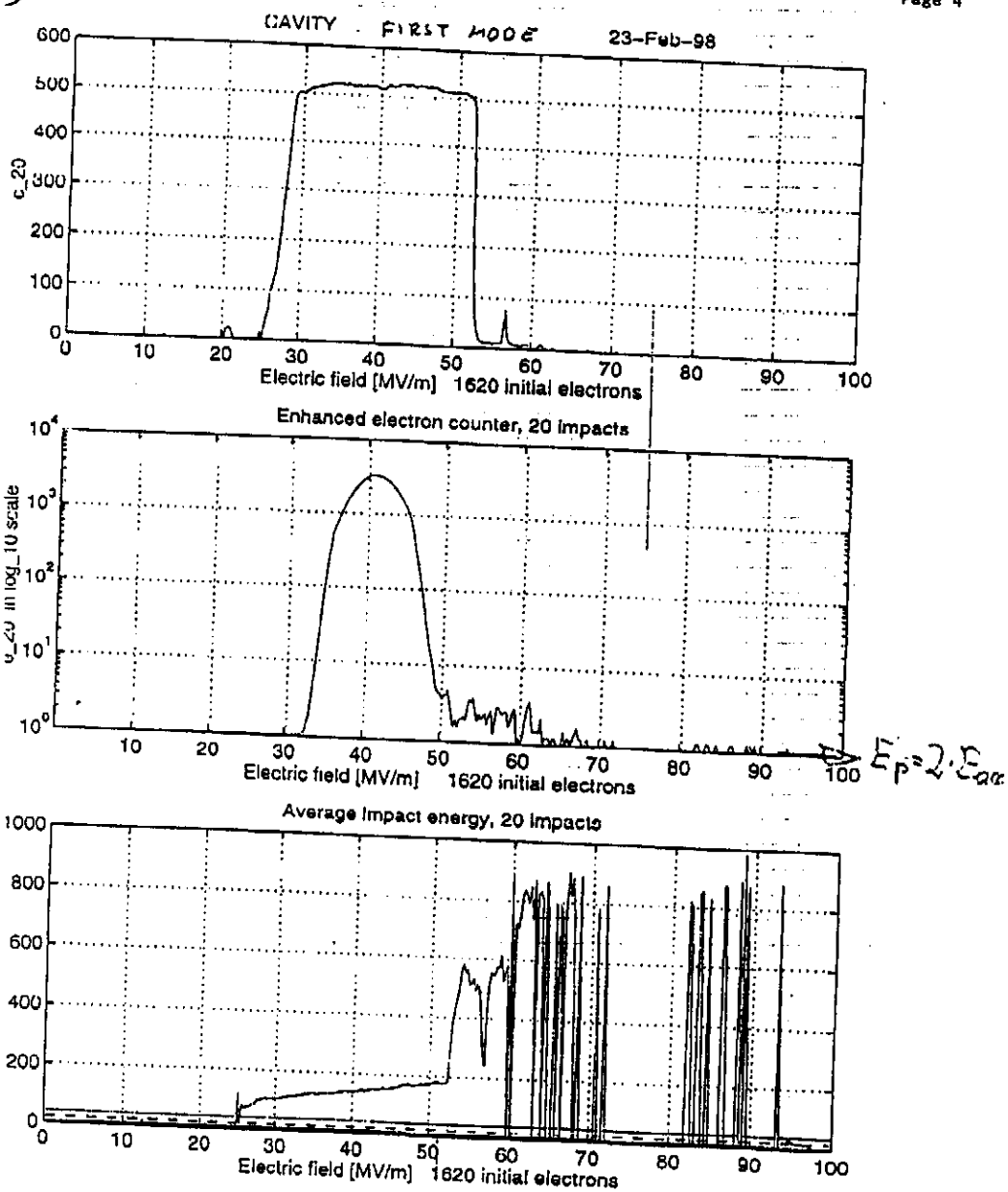
IV : new cavities & components(Proch)

first rf-meas. of the superstructure (Tang), Ferronis)
calc. of trans. kick by the input coupler (Zhang)
meas. of the electric cavity axis (Deibele)
calc. of a broad band HOM absorber (Joestingm.)

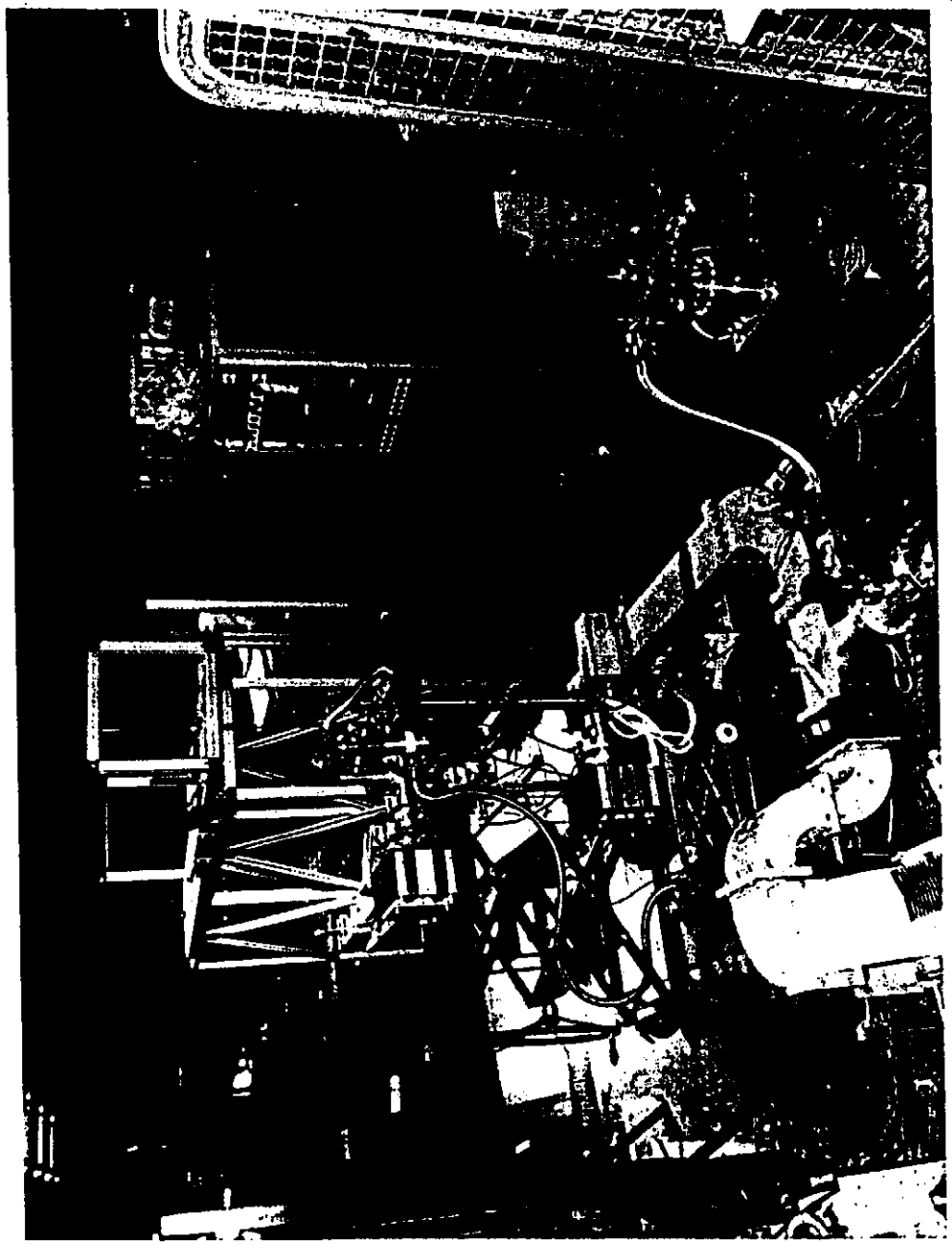


169

2)



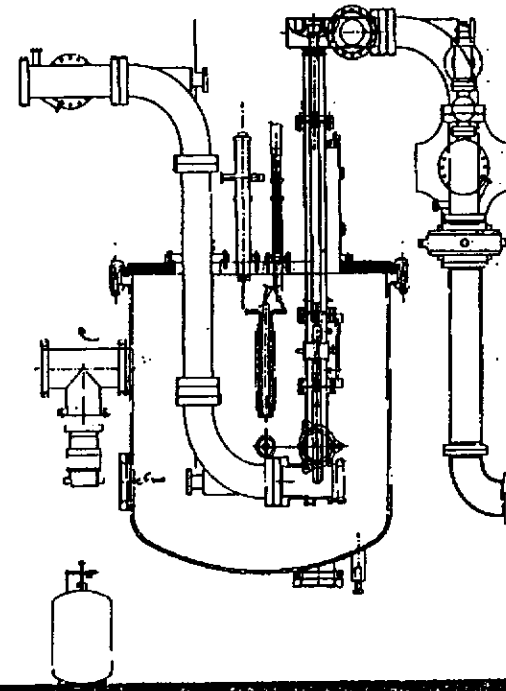
$E_p = 2 \cdot E_{acc}$



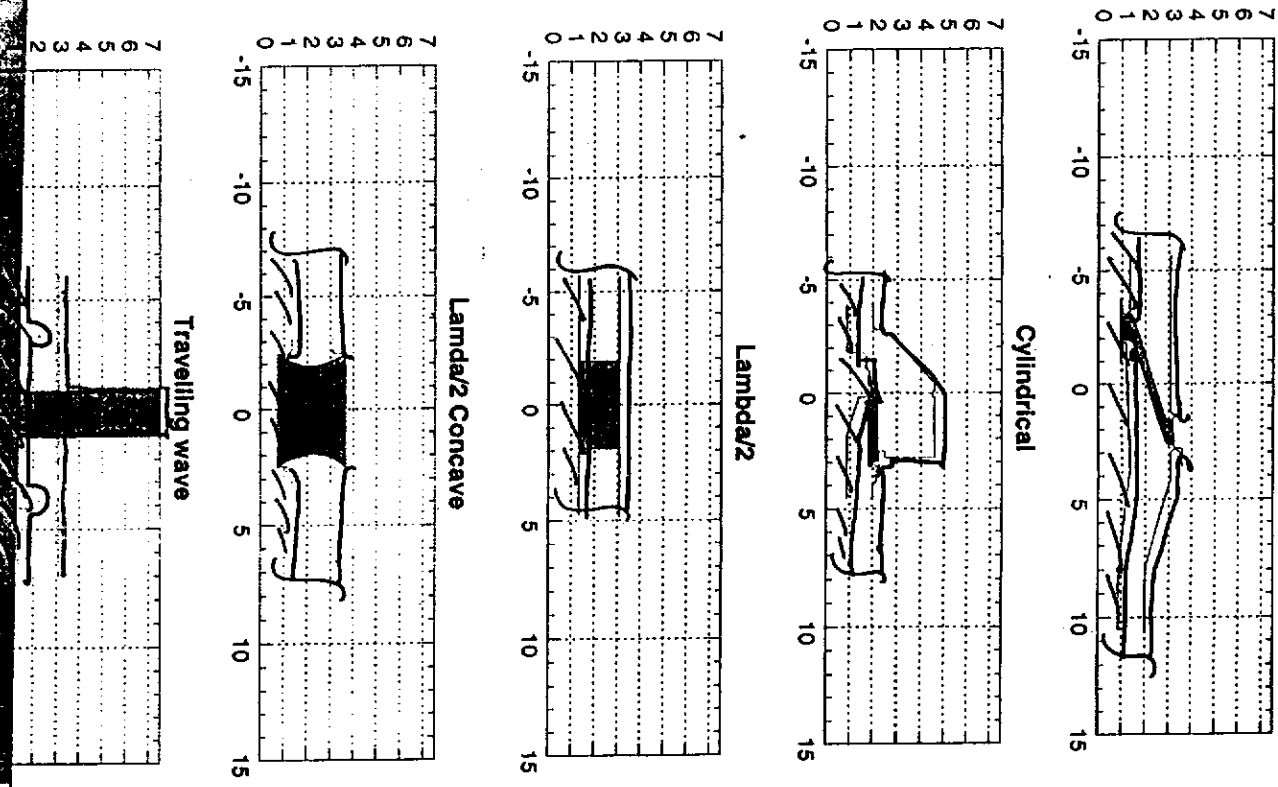
Cryostat

- temperature 70 K
- allow bakeout 150 C
- local heating of window during cool down to avoid cryogenic adsorbtion

ready to start test: avril 98

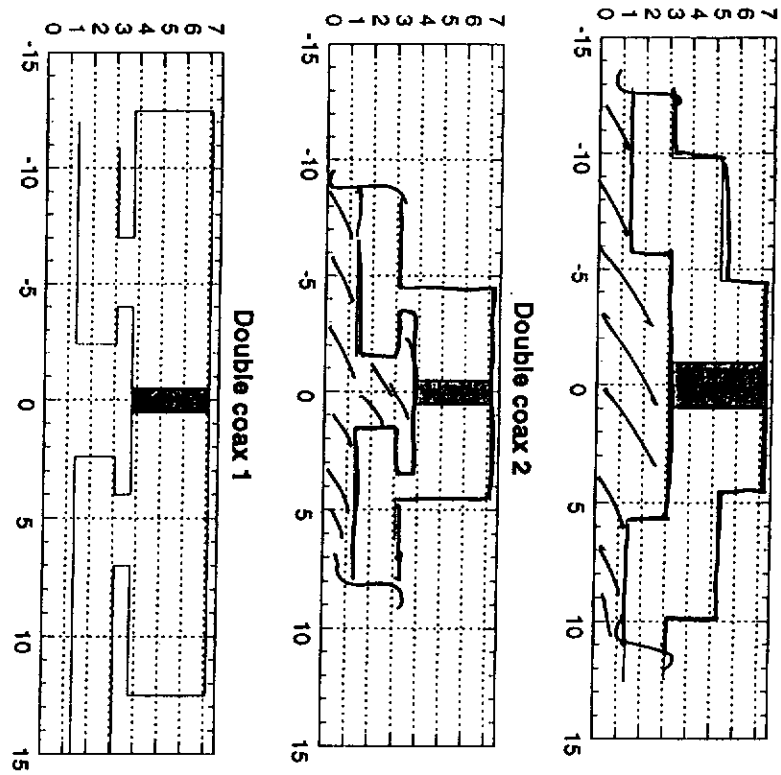


Window comparaison



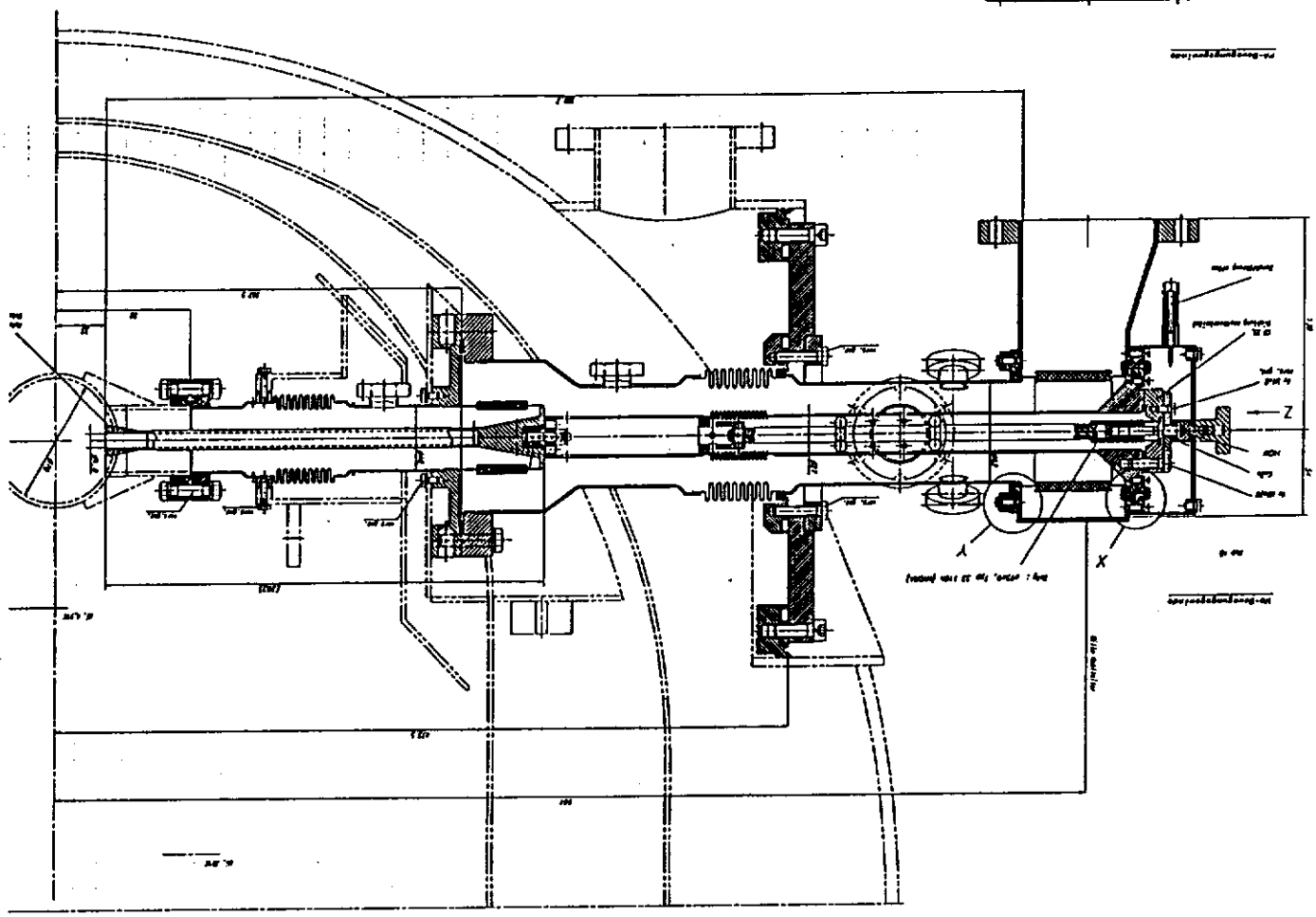
17K

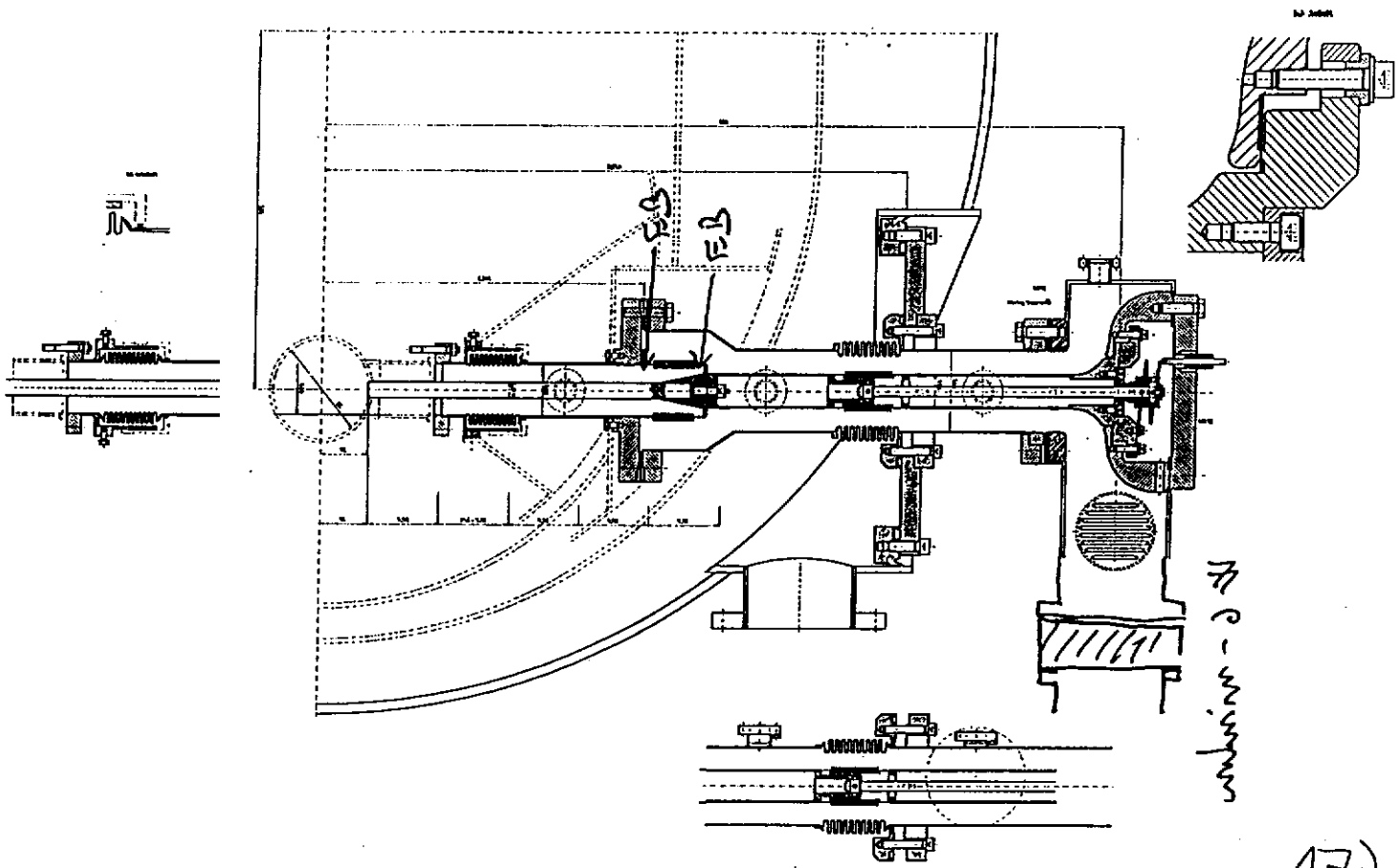
Window comparaison



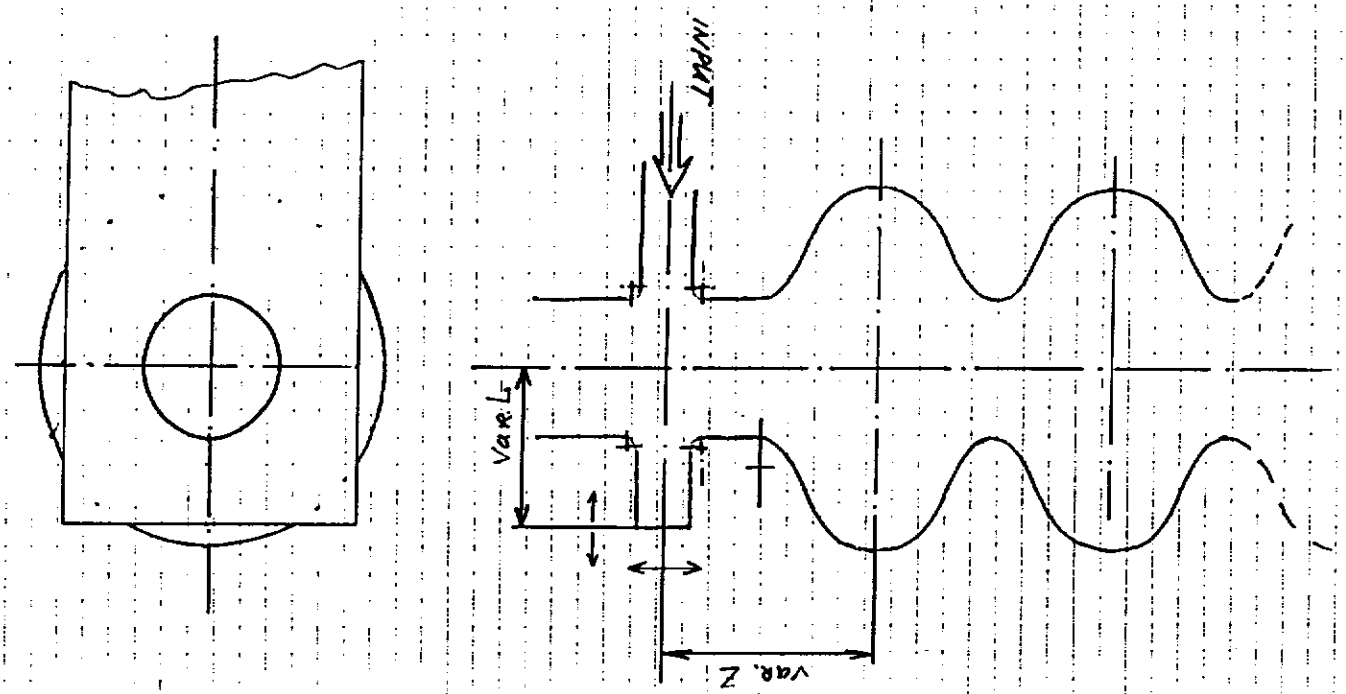
Planning

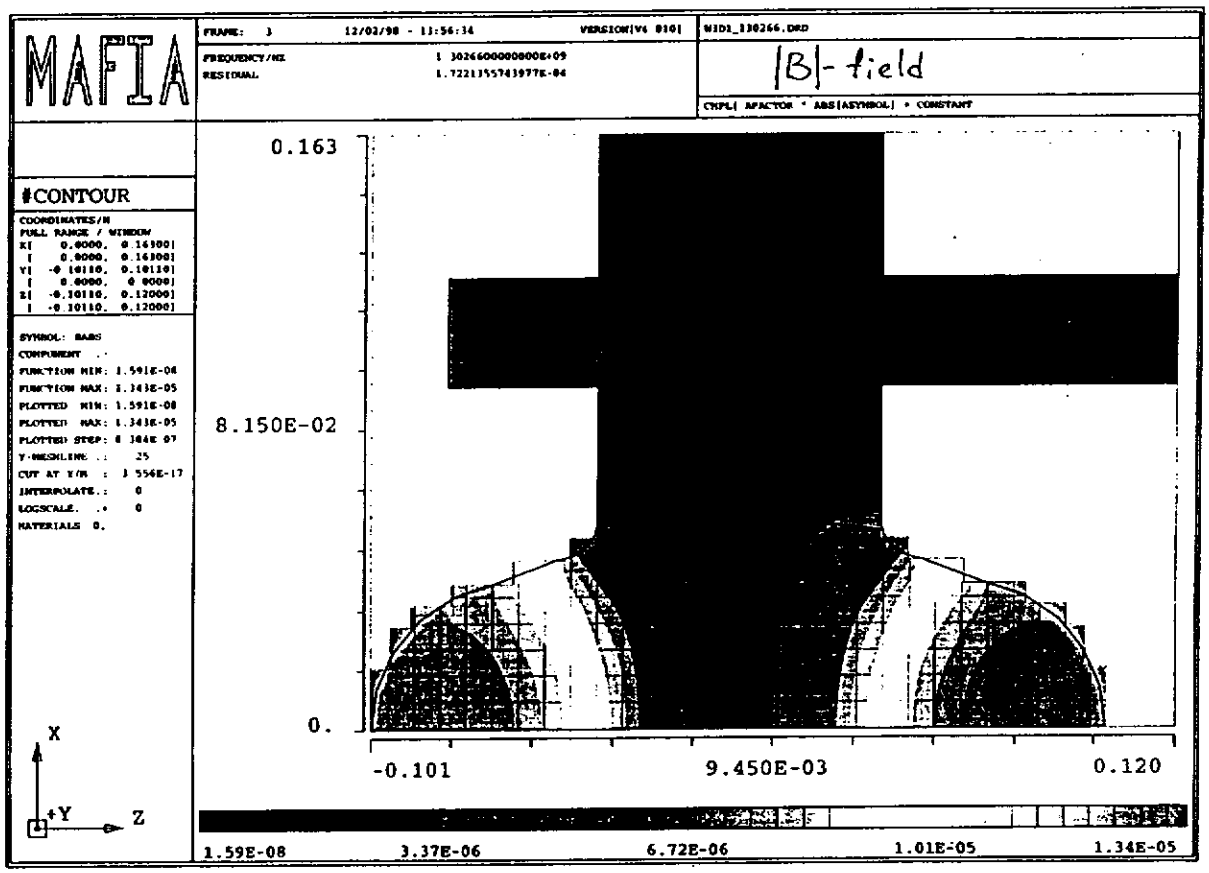
- march-april:
- - assembly and test new cryostat
- - start overall study of prototype coupler
- - continue TiN coating analysis
- may-june:
- - test Lambda/2 window
- - fabrication TW window
- july-october:
- - continue test windows (TW)
- - test polarized transition
- - start fabrication of first coupler prototype
- end of 1998
- - installation of new modulator (10 Hz)
- beginning of 1999
- - test first prototype coupler





172


INPUT
VAR. L
VAR. Z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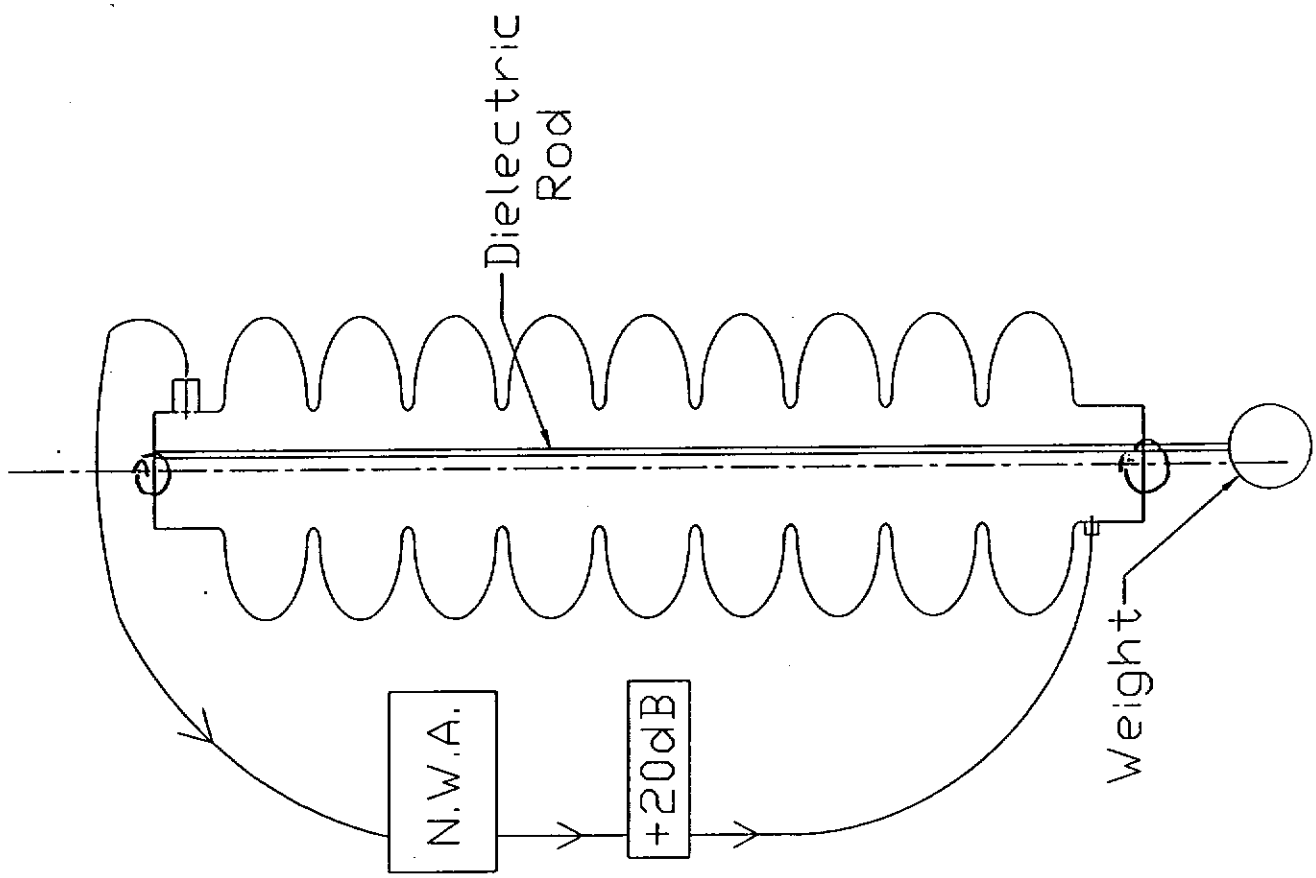
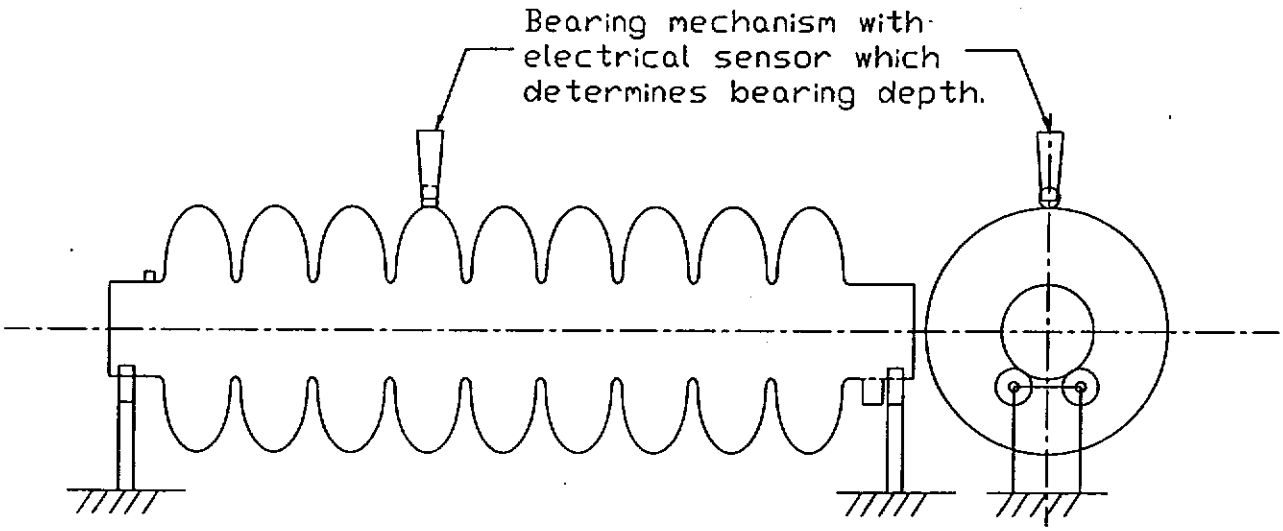
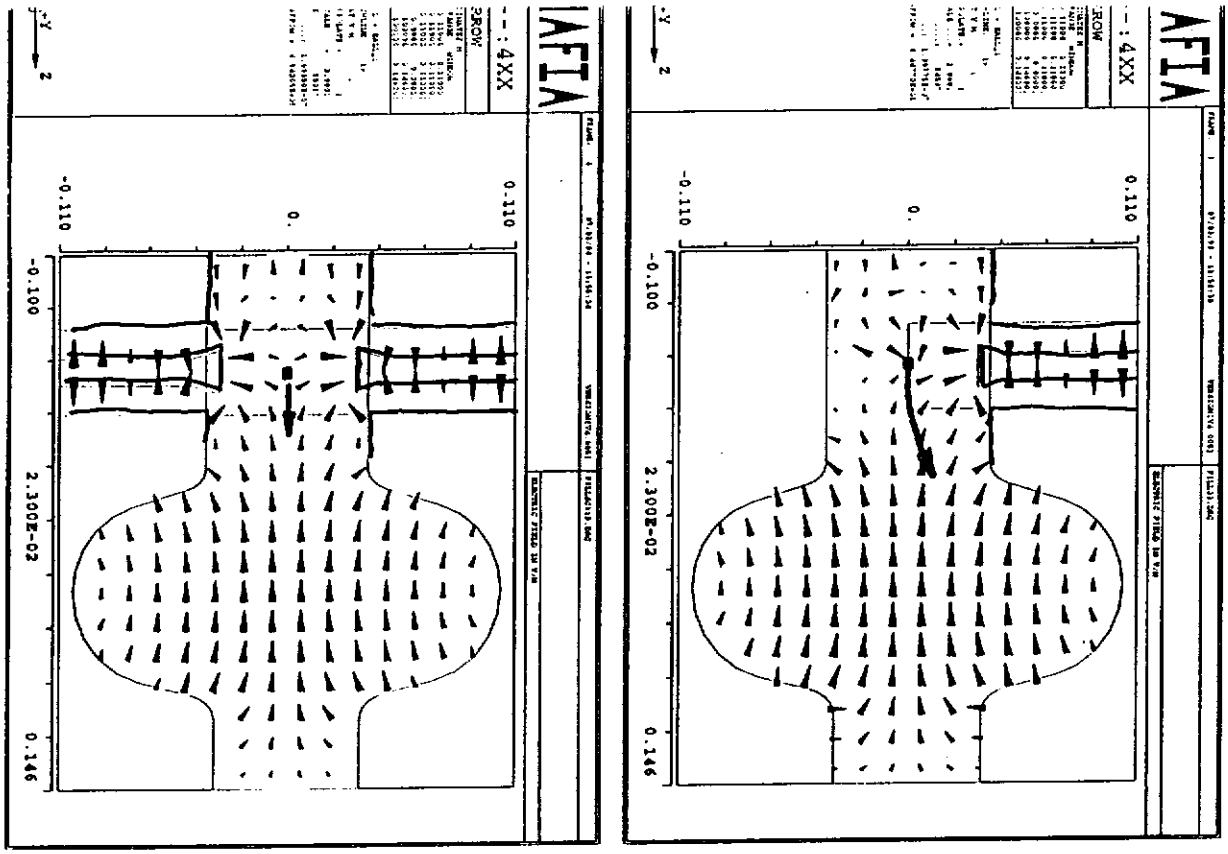
FRAME: 3
12/02/98 - 11:56:34
VERSION(V4 010)
WID1_130266.DRD
FREQUENCY/HZ 1.3026000000000E+09
RESIDUAL 1.7221355743977E-04
|B|- field
CMPL(AFACTOR * ABS(ASYMBOL) + CONSTANT
#CONTOUR
COORDINATES/M
FULL RANGE / WINDOW
X[0.0000, 0.16300]
[0.0000, 0.16300]
Y[-0.10110, 0.10110]
[0.0000, 0.0000]
Z[-0.10110, 0.12000]
[-0.10110, 0.12000]
SYMBOL: BABS
COMPONENT ..
FUNCTION MIN: 1.591E-08
FUNCTION MAX: 1.343E-05
PLOTTED MIN: 1.591E-08
PLOTTED MAX: 1.343E-05
PLOTTED STEP: 8.384E-07
Y-MESHLINE ..: 25
CUT AT Y/M : 3.556E-17
INTERPOLATE..: 0
LOGSCALE. .+ 0
MATERIALS 0.
0.163
8.150E-02
0.
-0.101
9.450E-03
0.120
X
+Y
Z
1.59E-08
3.37E-06
6.72E-06
1.01E-05
1.34E-05

173


Dielectric Rod
N.W.A.
+20dB
Weight


Bearing mechanism with electrical sensor which determines bearing depth.



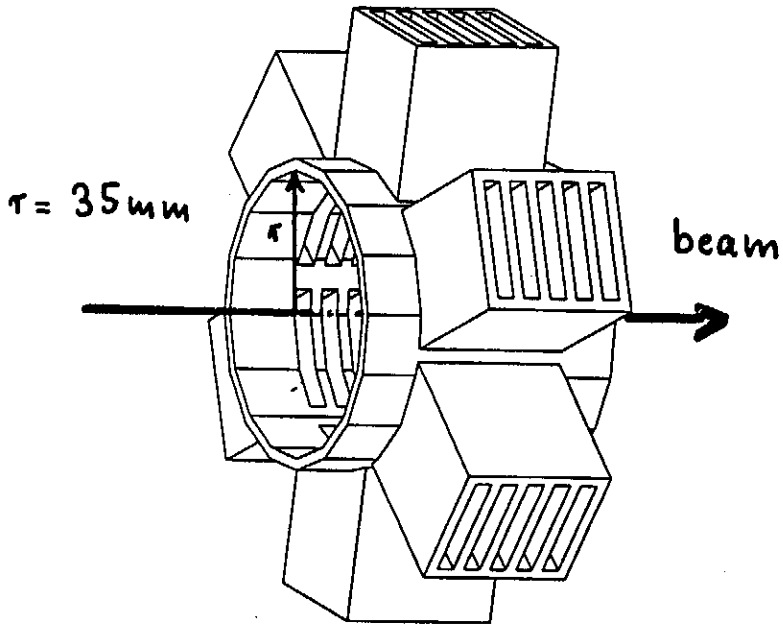
ZHANGM@SOLAR03, MAR07/14:00

The Transverse Kick

- $\text{Kick}_{\text{coupler-rf}}$ is equivalent to the kick experienced by a 1nC σ_s=1mm bunch traversing the TESLA 9cell cavity with a *1.2cm* off-axis due to wakefield

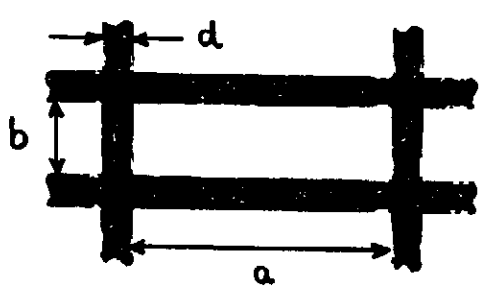
- This number depends only on the cavity Q_{ext}

- The higher the Q_{ext}, the smaller the $\text{kick}_{\text{coupler-rf}}$ (when E_{acc} fixed)



Schematic drawing of the absorber.

Typical waveguide dimensions:



$a = 1.5\,mm$

$b = 0.3\,mm$

$d = 0.1\,mm$

$\Rightarrow \approx 140$ packages of waveg.

4. MATIA computations for a modified absorber

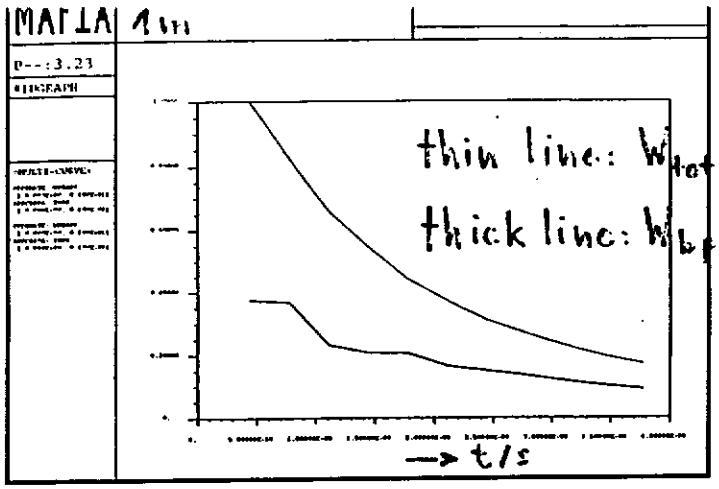
- Why do we need a modified absorber?
  - vacuum problems
  - difficult to manufacture

- Concept of the new absorber:
  - no cutoff frequency

  $\Rightarrow$ an additional absorber is required for $f < 100$ GHz (long range wake)

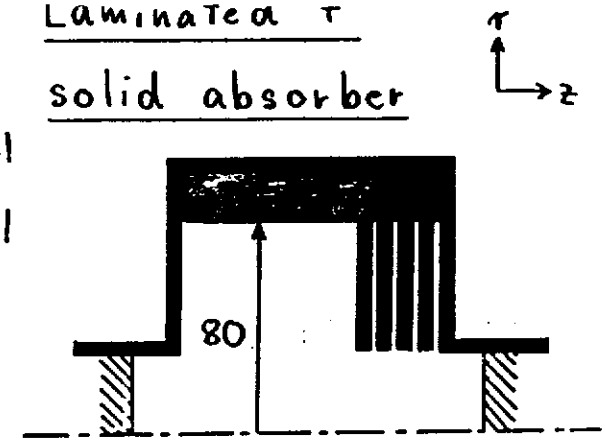
- Why MATIA computations:
  - $L_{crit} \approx r_{iris}^2 / \sigma$

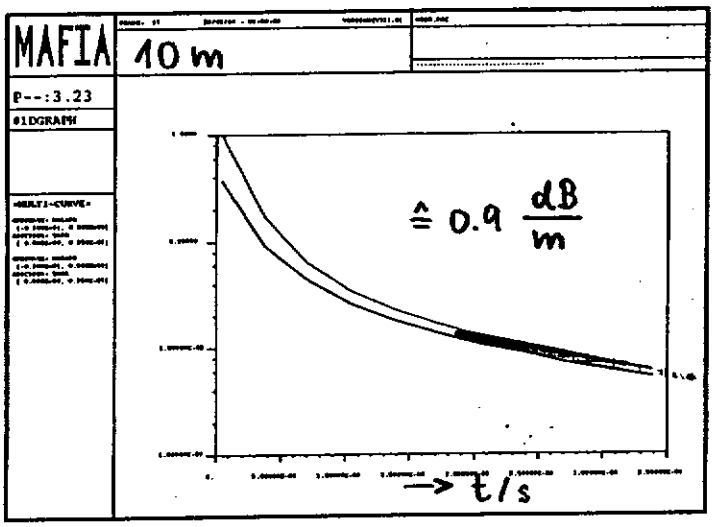
    especially for small σ

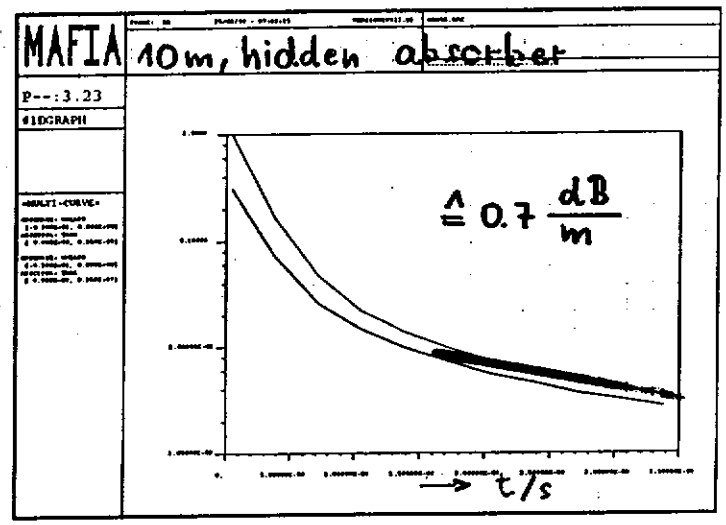


Laminated τ

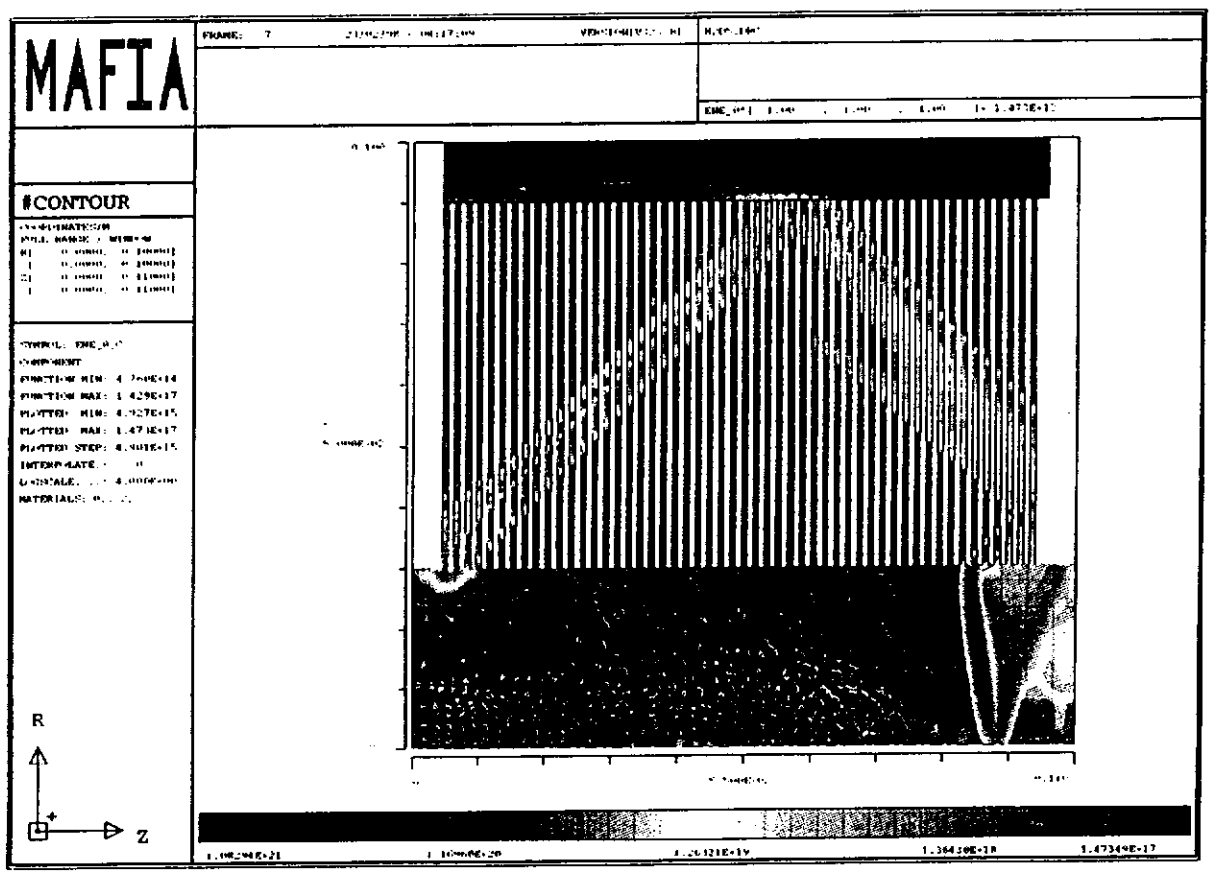
solid absorber





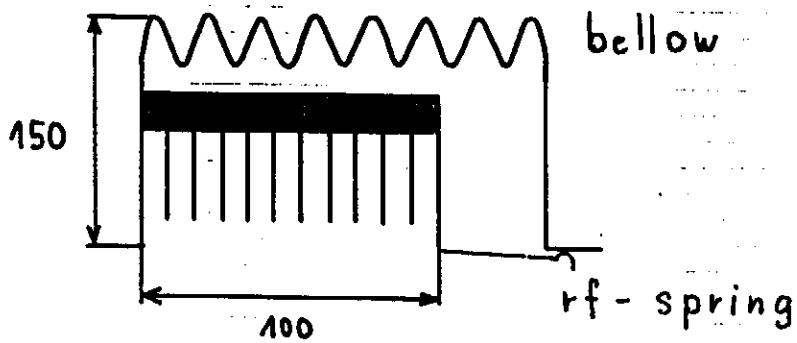


Energy density in a cell which contains the combined absorber

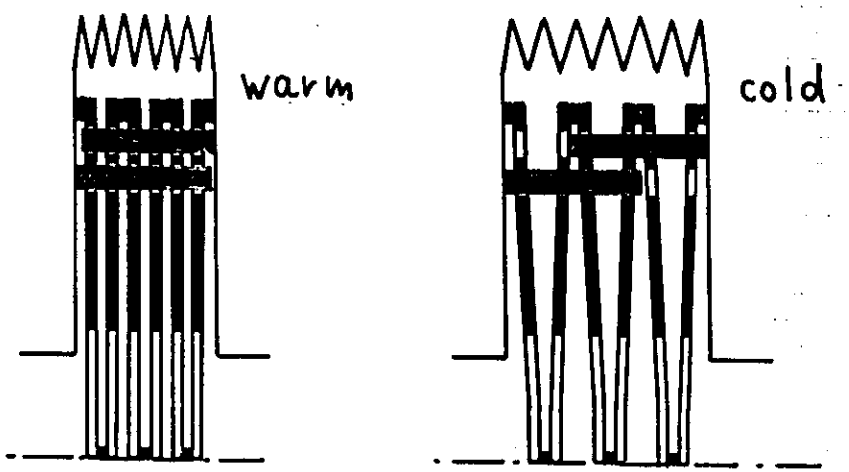


5. Installation

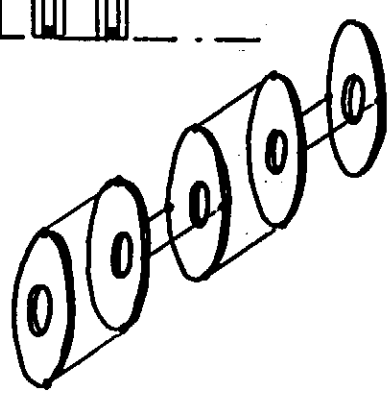
Straightforward solution:



Flexible absorber:



Connection scheme:



6. Conclusions + outlook

- 2d grating analysis
- 1d periodic structure with beam
- Modification of the absorber
  - Low frequencies → SiC
  - High frequencies → Metallization
  - Reasonable attenuation properties
  - Small short range wake
- Further work
  - Material properties of SiC at 70 K
  - Realization

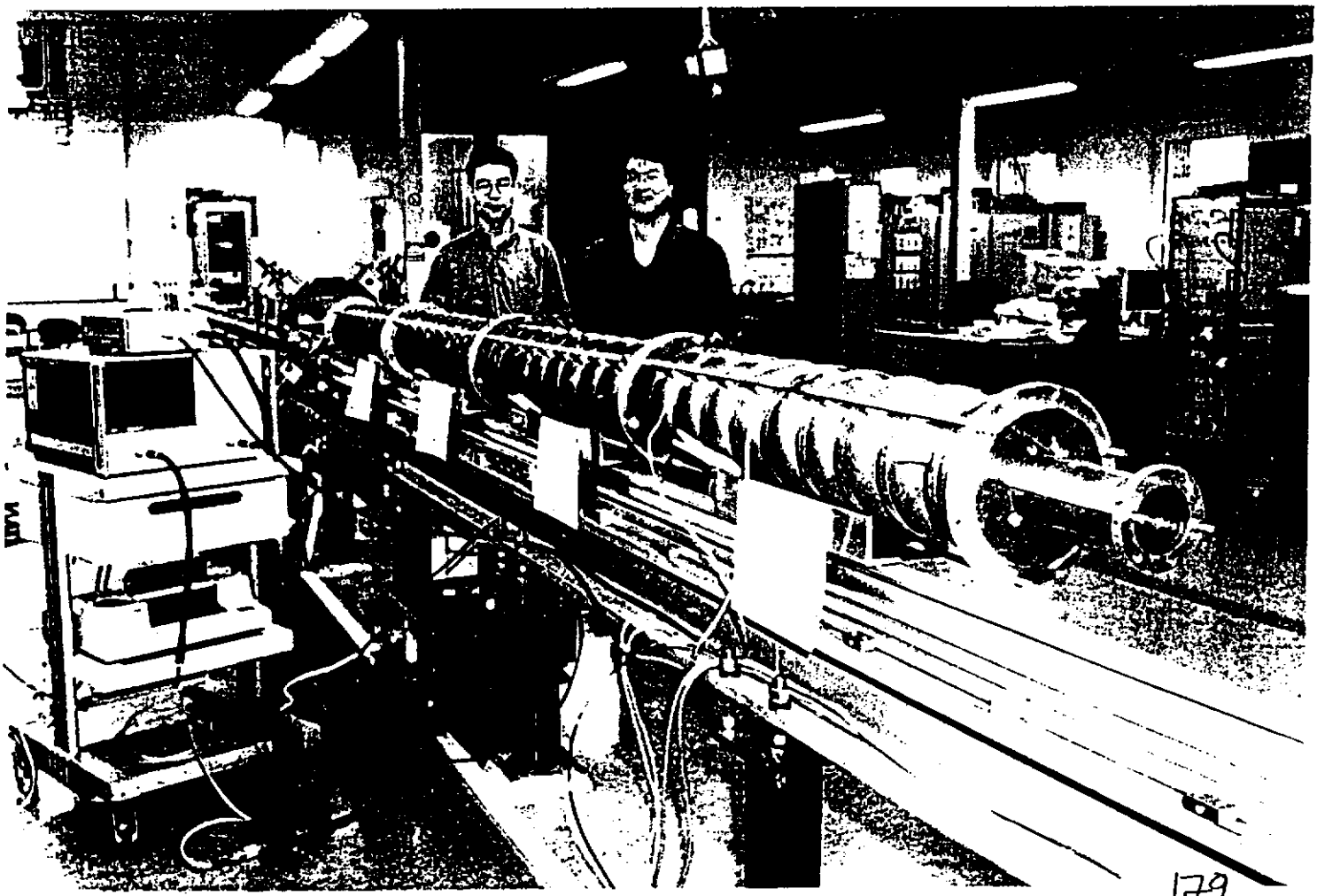
Measurement of A Super-Structure

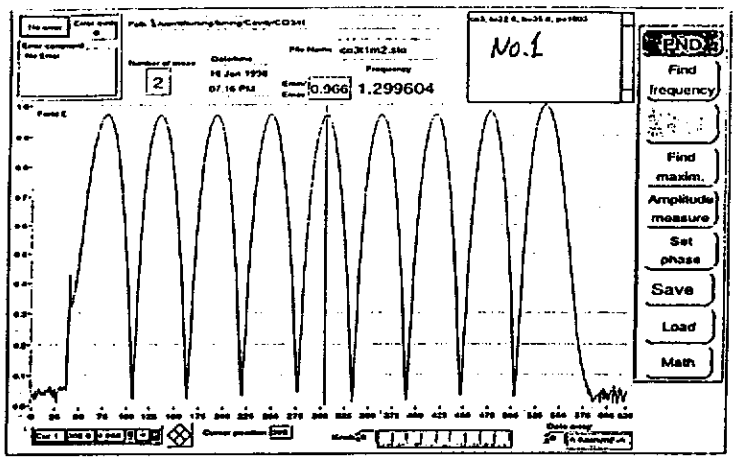
J. Sekutowicz . M. Ferrario . Ch. Tang*

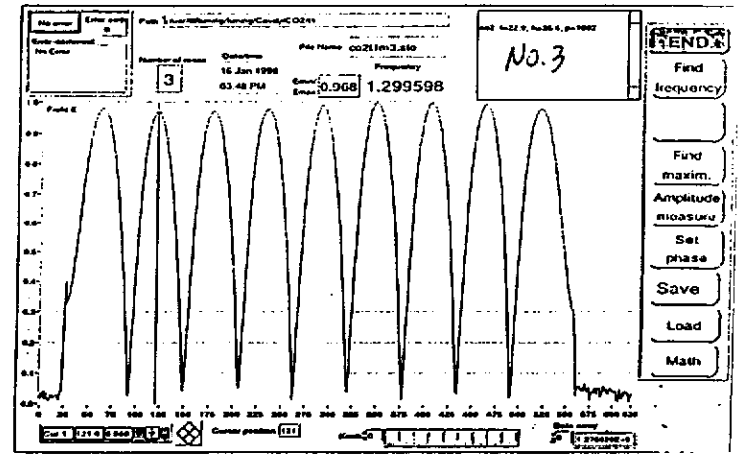
(10/3/98)

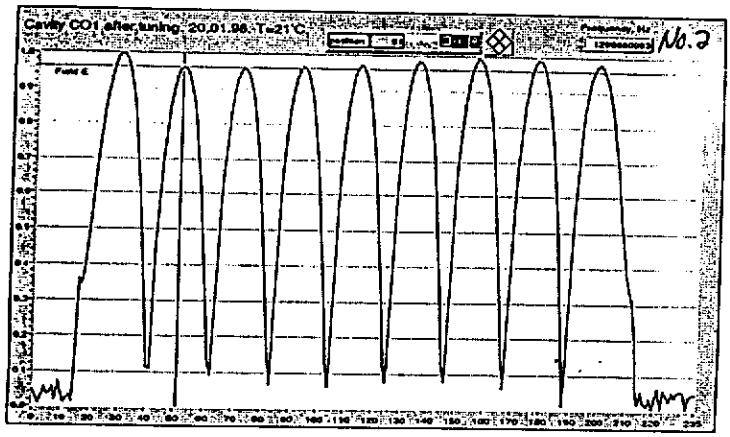
4 TTF Copper Cavities:

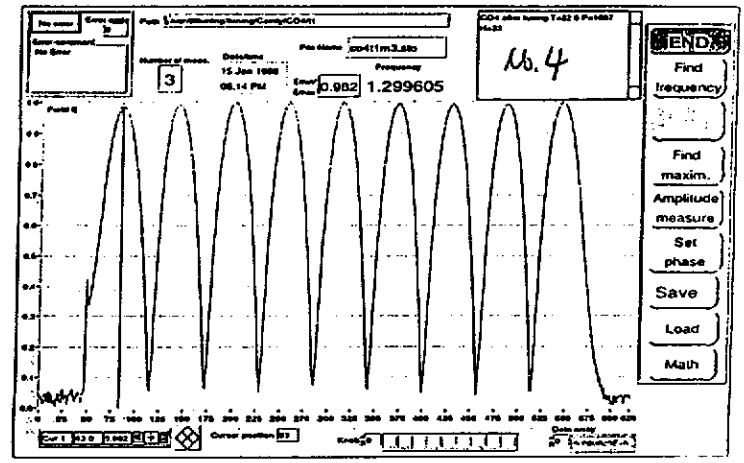
- Tuning : Field Flattness $\gtrsim 95\%$
- Steady State Properties. Field Profiles
  Dispersion Property ...
- Transient Responses .

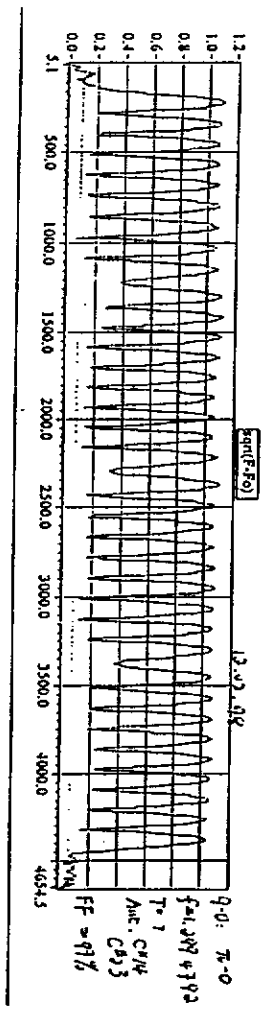


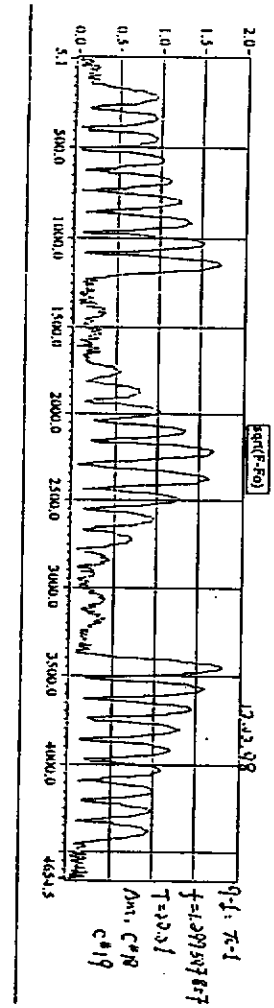


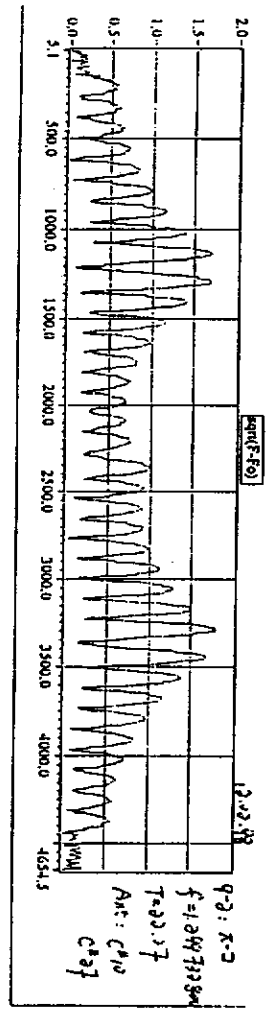


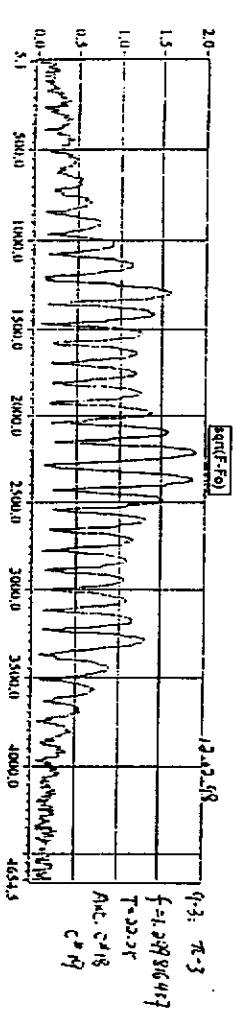








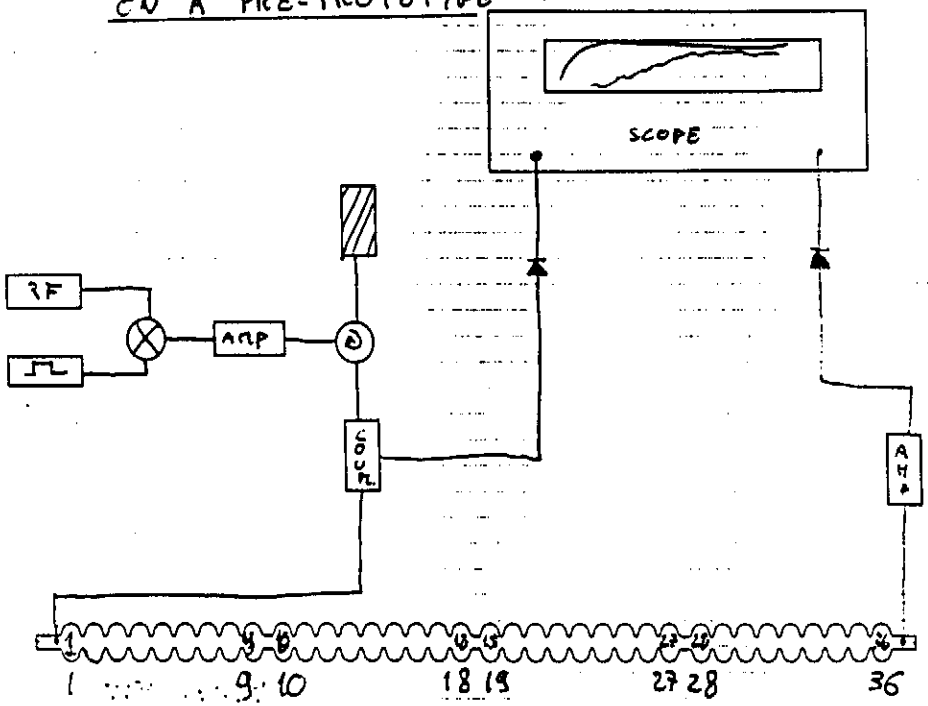


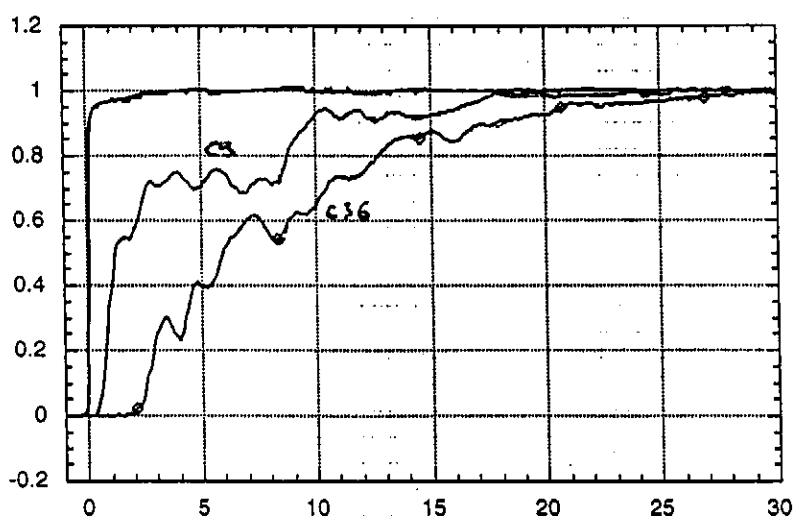


$$\left|\frac{f_{\pi-1}-f_{\pi-0}}{f_{\pi}}\right| \sim 2.19\cdot 10^{-4}$$

180

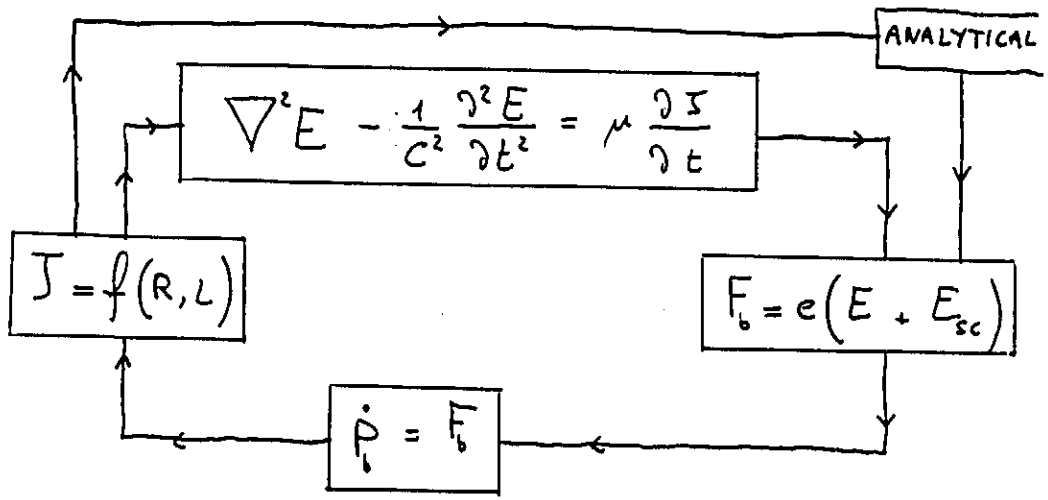
TRANSIENTS MEASUREMENTS ON A PRE-PROTOTYPE





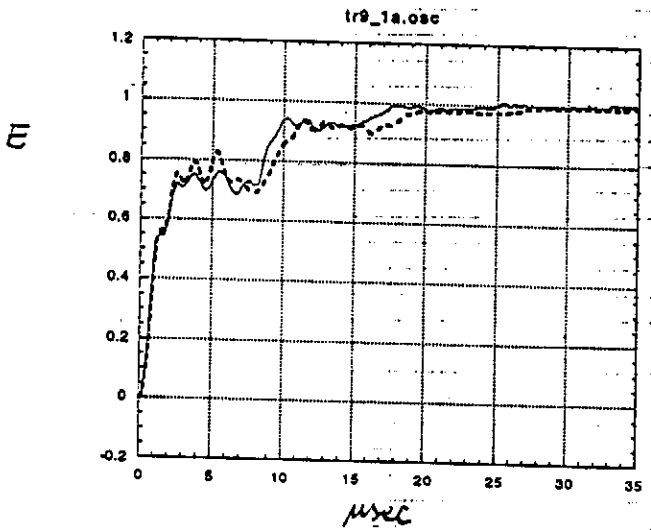
~ SELF CONSISTENT MODEL

LONG TERM (MULTI BUNCH) BEAM-CAVITY INTERACTION

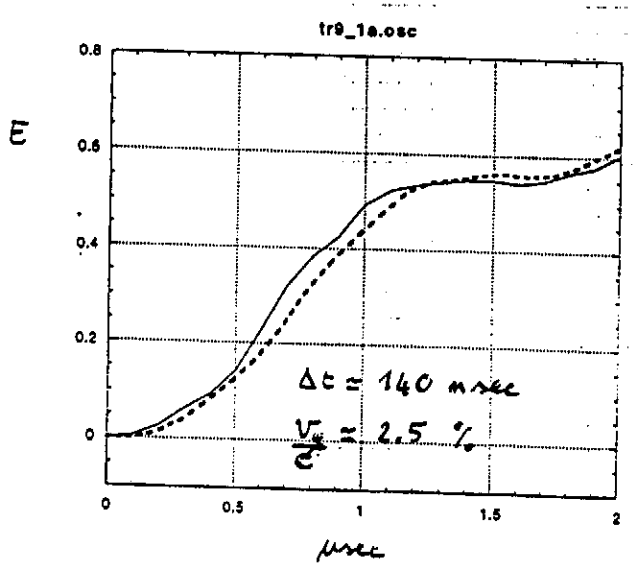


- NORMAL MODES EXPANSION OF CAVITY FIELD
- CURRENT DENSITY DESCRIPTION OF BUNCHES (UNIFORM CHARGED CYLINDER) J_b
- ANALYTICAL COMPUTATION OF SPACE CHARGE FIELD
- $J = J_h + J_g (1 - e^{-t/\tau_g})$
- ANALYTICAL COMPUTATION OF FIELDS FROM BUNCH TO BUNCH
- HOMAYN ⇝ [PART. ACC, VOL 52, 1996]

NORMALIZED FIELD IN CELL N° 9

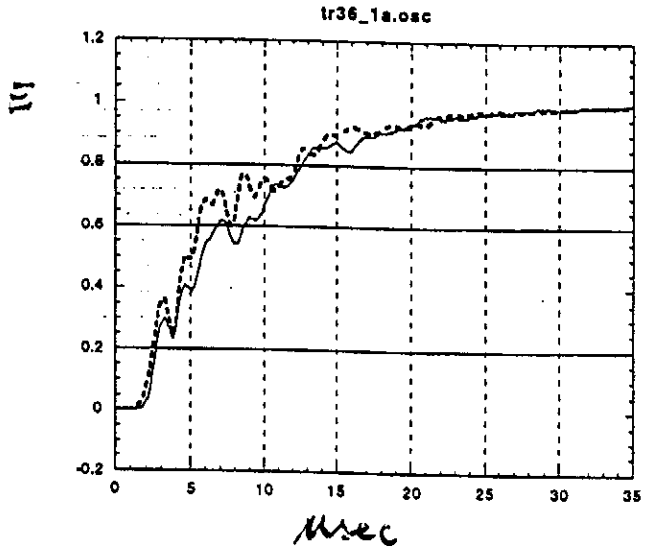


--- COMPUTED
—— MEASURED



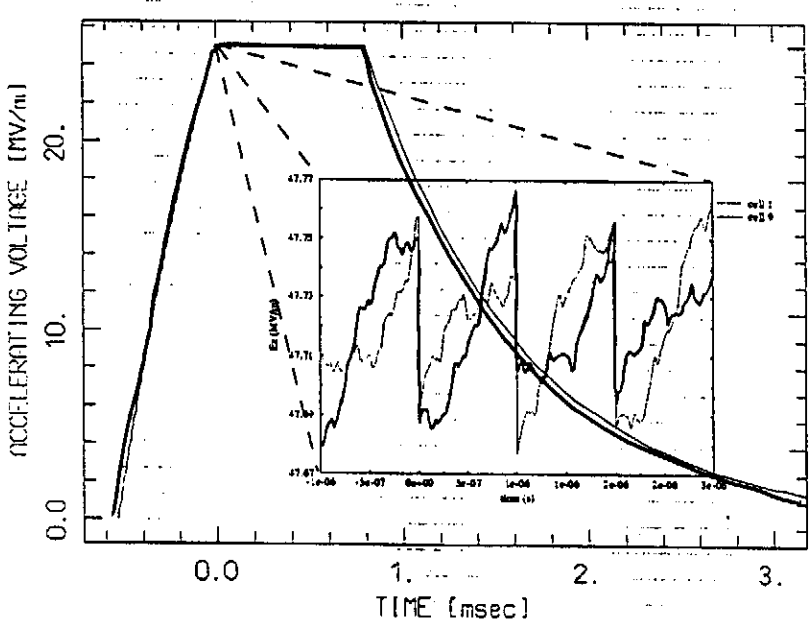
182

CELL 36

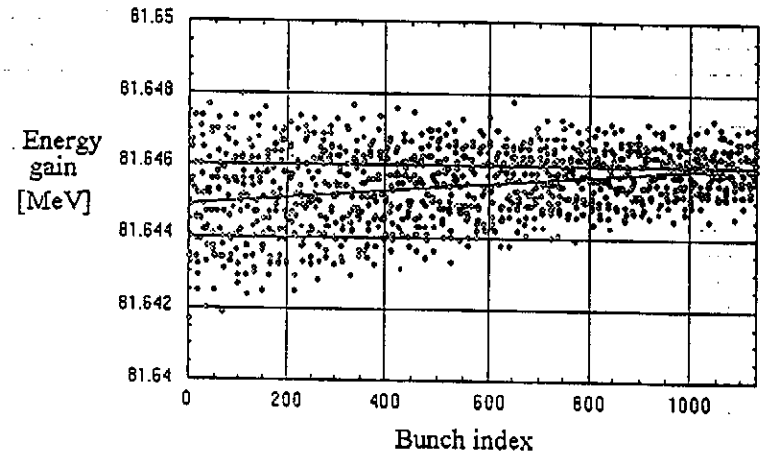


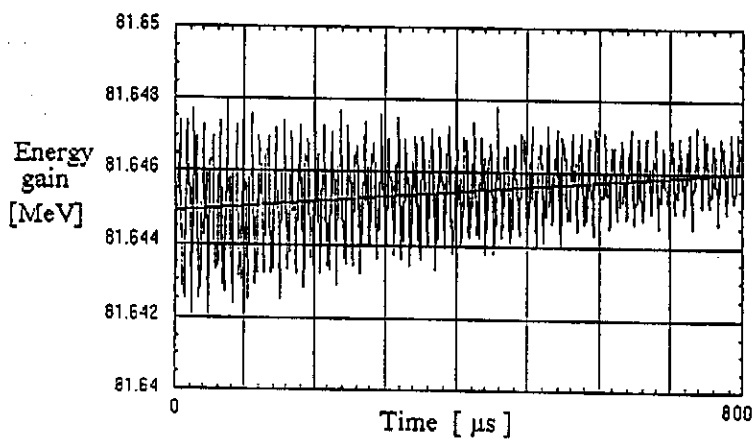
$\frac{v_g}{c} = 0.7\ \%$

CAVITY REFILLING



Energy gain of 1130 bunches accelerated by the small iris superstructure (N=7, N_s =4) as computed by **HOMDYN**:





The oscillation seen on the diagram has the frequency:

$$\boxed{80\ \text{kHz} = f_{\pi-\pi/4} - f_{\pi-0}}$$

$$\frac{\Delta\lambda}{\lambda} = 7\ 10^{-5}$$

Linac Operation

I. Injector issues

- the actual recommissioning (M.Jablonka, T.Garvey et al.)
- Modifications Sector 200 --> RF gun (S.Schreiber et al.)
- Test Beamline (K.Floettmann) ≥ 11:00 a.m.
- vacuum issues (K.Zapfe-Dueren)

II. The actual run

- schedule until June 98 (H.Weise et al.)
- discussions of experiments (S.Fartoukh and others...)
- new bunch length measurement (M.Geitz, B.Leissner)
- diagnostics (M.Castellano?)

chair: Terry Garvey

III. Bunch Compressor

- LLRF modifications for bunch compression (S.Simrock)
- Diagnostics bunch compressor II (G.Schmidt)
- Bunch length measurement (M.Geitz)
- Other diagnostics (M.Castellano?)

IV. Undulator

- Layout of Undulator Beam Line - discussion (U.Mueller)
- Collimator (H.Schlarb)
- Vacuum chamber (U.Hahn)
- Impedance budget (R.Wanzenberg)
- Diagnostics in/around the undulator (G.Schmidt)
- Regenerative amplifier scheme (J.Krzywinski)
- Air conditioning for undulator ??? (J.Pflueger)

chair: Hans Weise

short talks & long discussions

LINAC OPERATION WKG. GROUP

- **INJECTOR START UP**
  - Needs one more week of "fine tuning".
  - additional signals required in Ctrl Rm, Beam Dump, SHB Cavity power.....
  - Problem to make transverse phase space measurement @ 10 MeV + 12 MeV (needed to match beam to module #1)
    OTR's missing from Sector 400. 1 month delay
    Reluctance to break vacuum while modules is cold.
  - Request to install electronic allowing 1 MHz operation of gun. → Tests in April ?

- **Modify Sector 200 → RF Gun(s)**
  - Support required for e.s column + valve
  - Need to dismount all components if we cut girder !
  - Cabling

- **FEL Gun Test Beamline**

  Transport of laser light to cathode. Do we have to protect mirrors ?

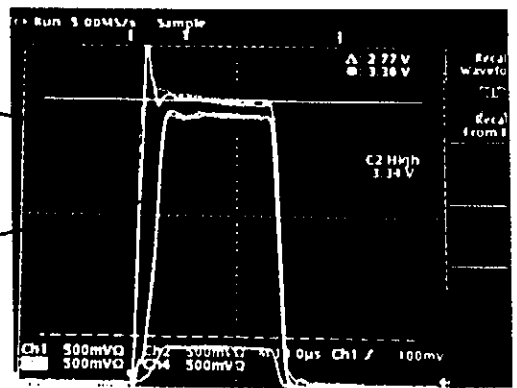
  Personnel security when laser "ON".

J.M. Joly
B. Anne
M. Desmons
J. Fusellier
T. Garvey
M. Jablonka
S. Schreiber

Injector Start-up

Since last meeting - (i) cathode changed
(ii) FNAL/UCLA sector 400 installed.

"Teething" problems - control of flags
- magnet settings



Toroids #1, #2

Toroid #3

Rise-time difference due to beam loading
→ Corrected using "phase-jump".

Beam dump signal! → adjust optic to make it equal to toroid #3 signal.

- Transition toroid #1 → toroid #3 ~ 97%
- 100% transmission to VS4
- Nice spectra obtained on SEM-grid.
- Less persistance on VS of analysing line
- Reliable computer control of SHB
- More operator friendly system for CAPCAV.

↳ Still some "fine-tuning" needed!

⇒ Encouraging re-start given modifications

- **SCHEDULE UP TO JUNE 98.**

Schedule prepared at beginning of year has slipped by 2~3 wk (iso one leak)

Difficult to fix dates for given experiments.

2 week stoppage required for modifications to He tubing

But when? INSTALLATION OF RF GUN?

[install OTR's during this "shutdown"]

H. Weise to re-do schedule end of March.

- **Experiments**

- Comparison of Mosnier and Balakin proposals to investigate HOM's. (S. Fartouk, SEA 98-04)

- **BUNCH LENGTH MEASUREMENTS**

- Cross check various techniques for "long" (2ps) bunches
  - Streak camera → No good for 250 μm bunches
  - Coherent Radiation (OTR, Synch..)
  - Autocorrelation with interferometer
  - Josephson Junction Detector

- Brief description of interferometer (B. Larsson)
- Coherent Radiation (M. Geitz)
- Josephson Junction (M. Geitz)
  - characteristic I-V curve when impinged by e.m. radiation
    ⇒ power spectrum gives gaussian fit to σ_z.
- Longitudinal Phase Space Tomography (M. Geitz)

Changing ϕ (or Amp) in last cav of module 1
→ "shear" long phase space
Can reconstruct phase space profile from beam image in BC2.

→ Increasingly Sophisticated expts to get
(i) Transverse Phase Space
(ii) Transverse Coupling (using skew quad)
(iii) Transverse / Longitudinal Coupling

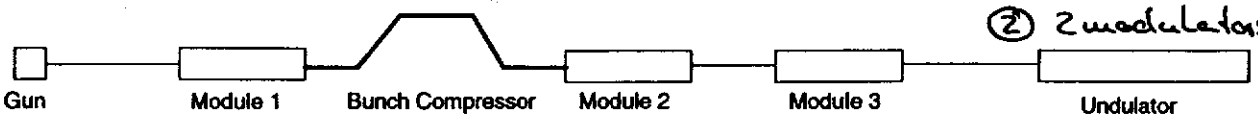
LLRF + modifications (S. Simrock)

TTF

Bunch Compressor Issues

① 1 modulator for modules 1-3 → pro

② 2 modulators for mod. → pro



Experiment	Module 1	Modules 2+3	Remark
Tomographie (Bunch Compression)	V_{acc} = 50-100 MV stability 1% settability 1% ϕ_{cav} -45 deg. to +45 deg. stability 1 deg. settability 1 deg.	unregulated or not powered	30 µs beam pulses control vectorsum of module 1 only
Undulator test	Vacc = 50 MV , stability +-5 % ϕ_{cav} -10 deg. , stability 1 deg.	80 + 100 MV +-5 %	30 µs beam pulses vectorsum 1-3 regulated better than 1 % phase of vectorsum stable +- 1 deg.
TTF operation	120 MV +-5%	160 + 200 MV +-5%	800 µs beam pulses vectorsum 1-3 regulated better than 1 % phase of vectorsum stable +- 1 deg. V_{acc} up to 500 MV

S.Simrock

/usr/ttfsvr2/simrock/doc/frame/ttf_meeting/ttf_meet_mar_98/bunch_comp_2.doc 10 March 1998 1:07 pm

Summary of WG I (part 2)

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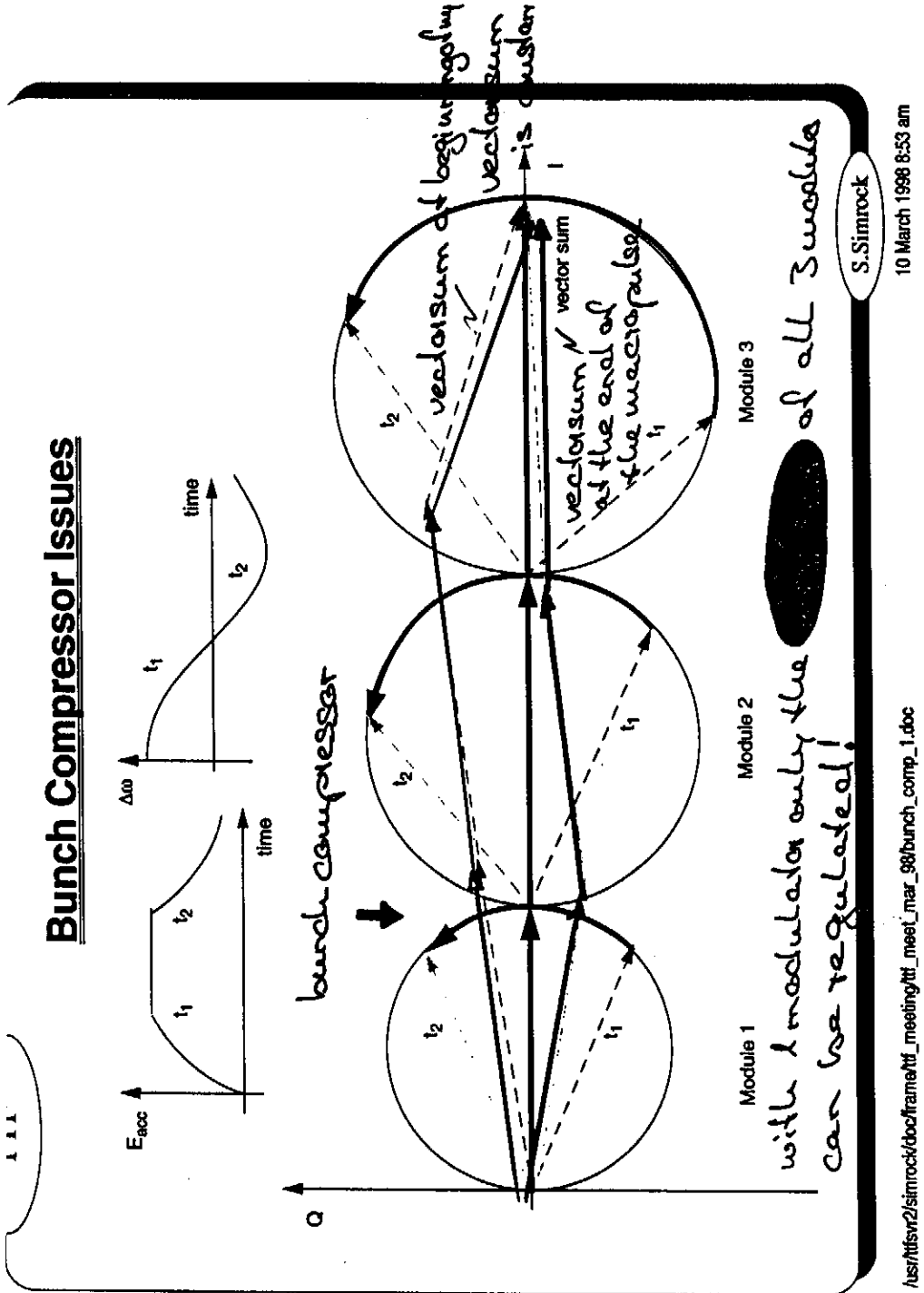
11.3.98
J. C. Zieller



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Bunch Compressor Diagnostic and orbit Correction

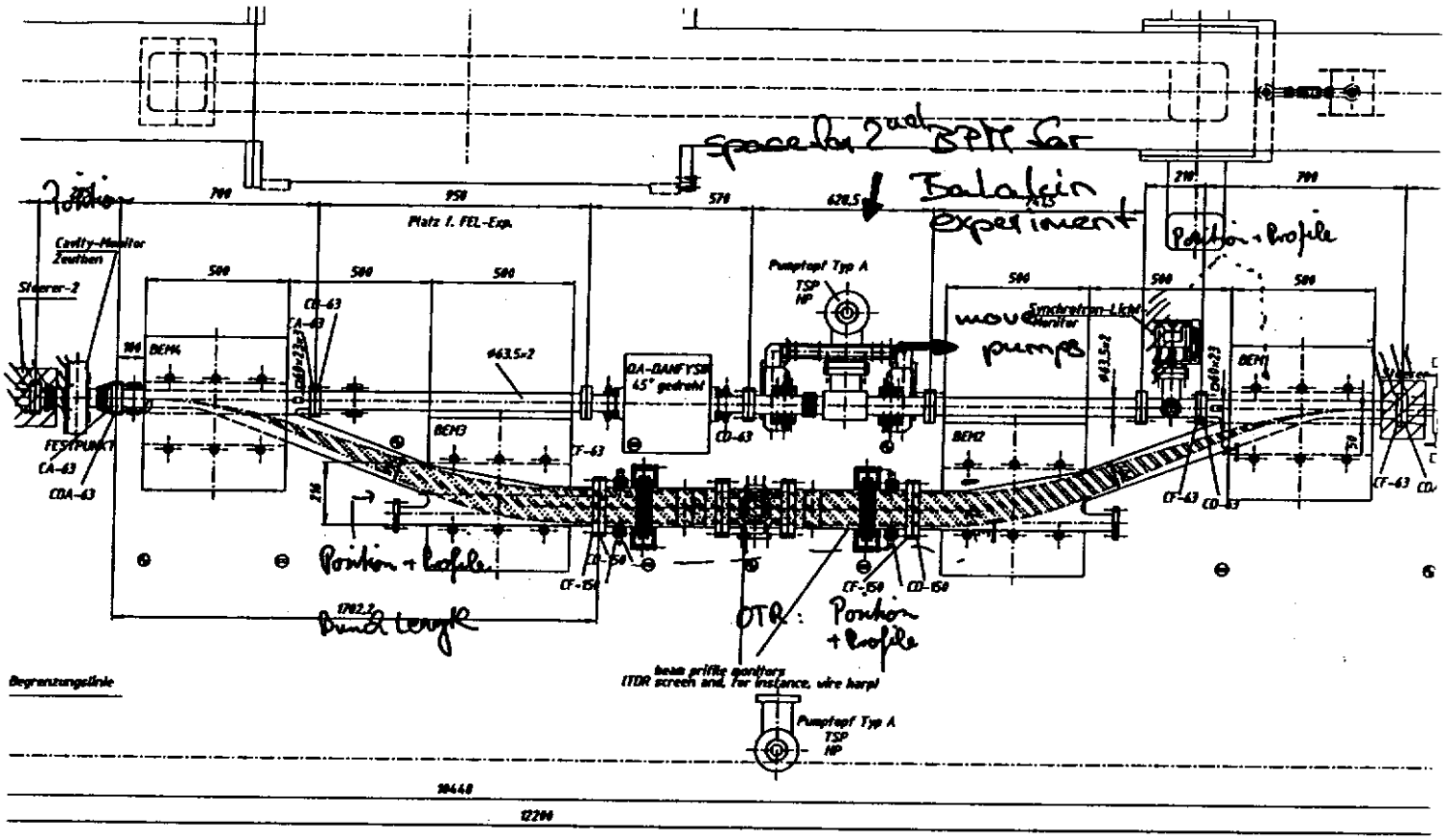
Measurement of:

- Beam position → at each Quad for fast correction
- Beam profile → phase space tomography
  - → energy spread if in the dispersive region
- Bunch length

Correction of orbit should allow to correct:

- displacement and angles at the entrance and end of the section
- steering through the chicane
- center the beam into the quads.

Synchrotron Light → non destructiv
→ permanent beam size measurement
→ " orbit control
→ possibility to use it for a fast interlock system if orbit displacements occure.
→ Works at <u>full macropulse length</u>

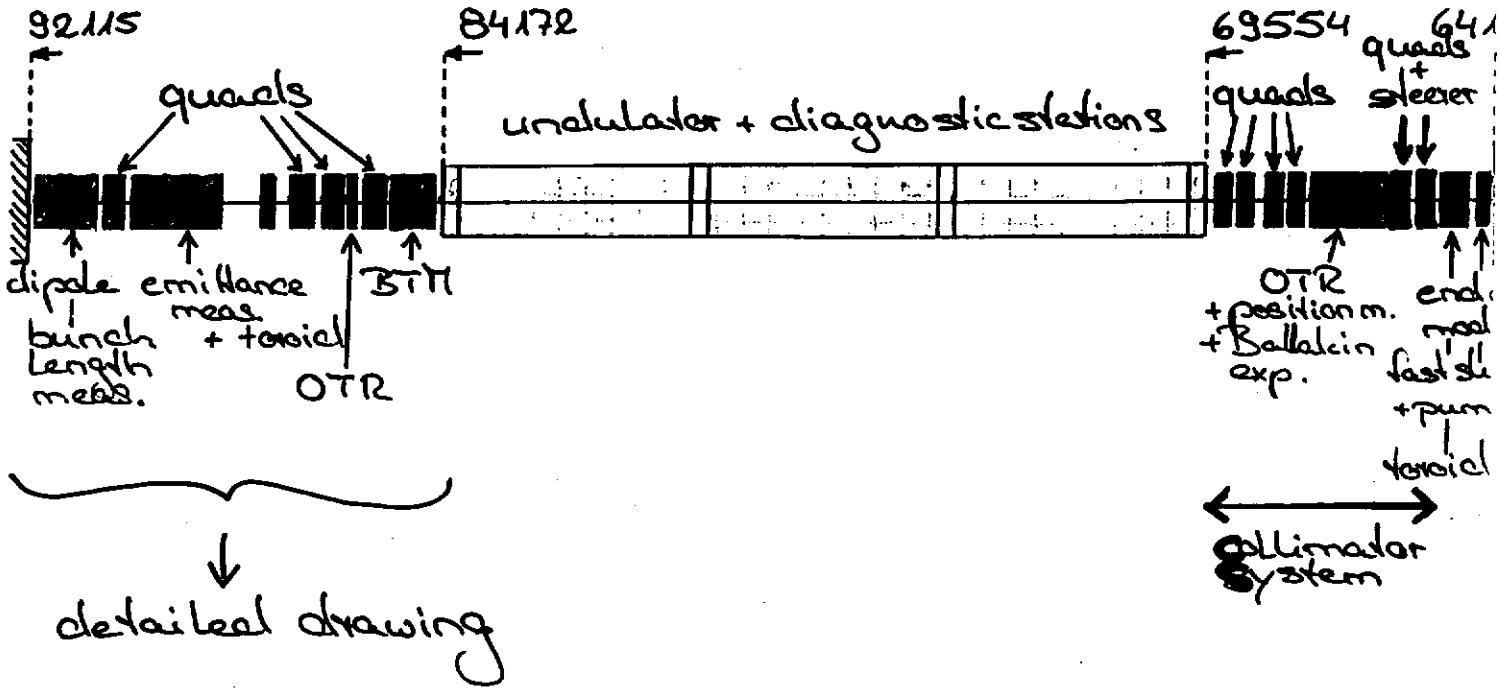


Bunch Compressor

Nur zur Info
Nicht nach di
Zeichnung fe

AKABEL ©MPYLIXKABEL, MAR08/12:53

New Beamline Proposal

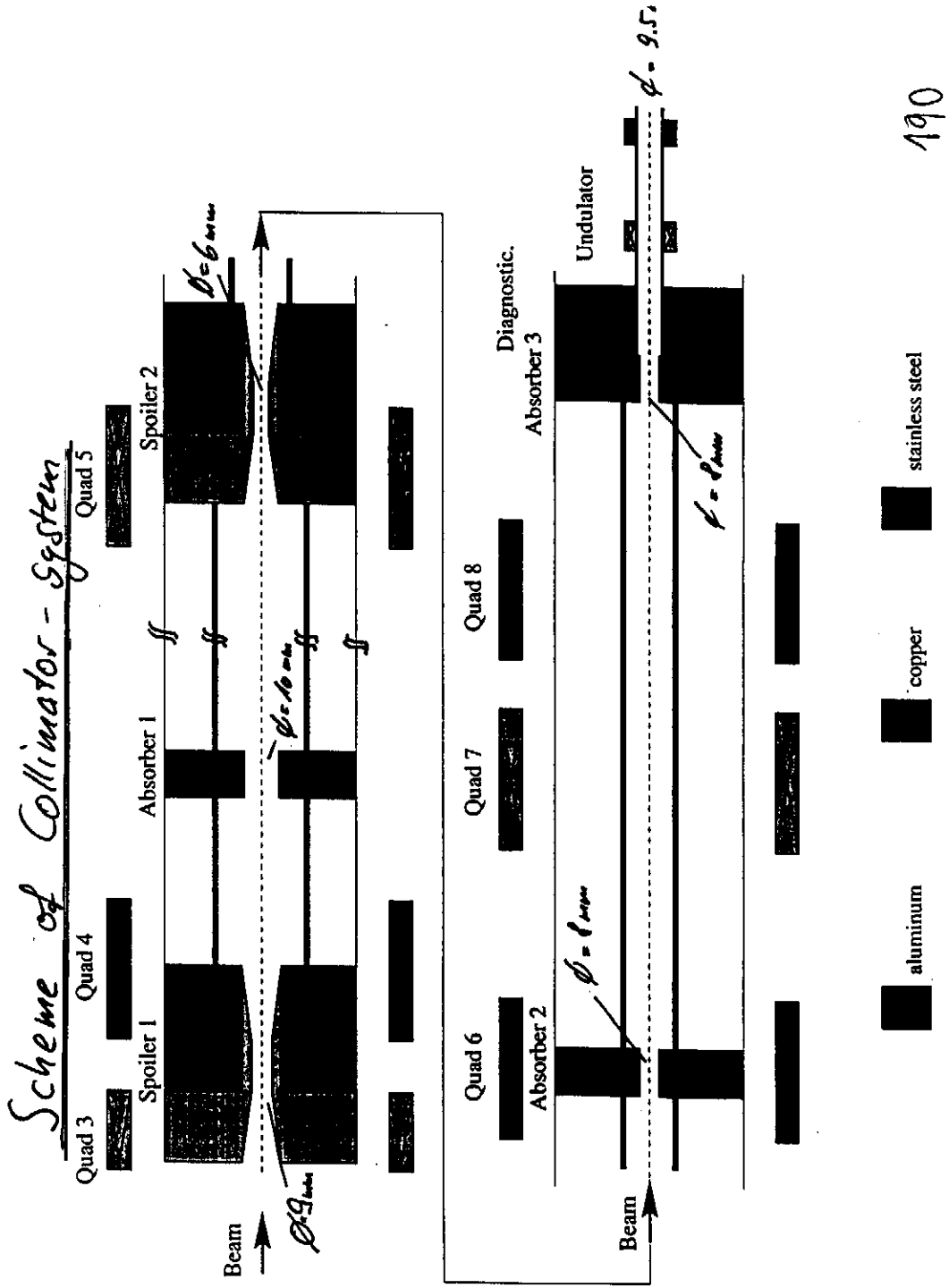


Requirements for the Collimator

- avoid irradiation of the permanent magnets
- collimate the TTF beam (ϵ^N = 20 mm mrad) and the FEL beam (ϵ^N = 2 mm mrad)
- machine operation between 200 - 500 MeV beam energy
- safety for all beam line elements at low β-function
- fit into the beam line
- simple mechanical construction
- small contribution to the wake field budget

Construction of the Collimator

- collimation of beam offsets and beam angulars
- reduction of the edge effect



Result of Tracking Calculations

- **Acceptance of the collimator system:**
  - 100 % for the TTF-beam between 200 and 500 MeV beam energy
  - At 150 MeV the aperture of spoiler 1 & 2 are $8.25\,\sigma_\perp$ and $7.02\,\sigma_\perp$
- **Efficiency of the collimator system:**
  Particle distribution used for numerical simulation:
  - Emittance $\epsilon_\perp = 100 \times \epsilon_\perp^{TTF}$
  - Energy spread $\epsilon_E = 5\,\mathrm{MeV}$
  - Number of particles at each run N = 50000
  - Cutoff charged particle: 1.5 MeV; cutoff photons 0.1 MeV

Primary particles:

Energy	Transmission no coll.	Interception no coll.	Transmission with coll.	Interception with coll.
MeV	%	%	%	%
200	54.0	32.8	10.7	0.0
300	64.6	26.2	20.1	0.0
400	68.6	23.6	30.0	0.0
500	71.1	21.9	39.6	0.002

Table 1: Result tracking of primary particles

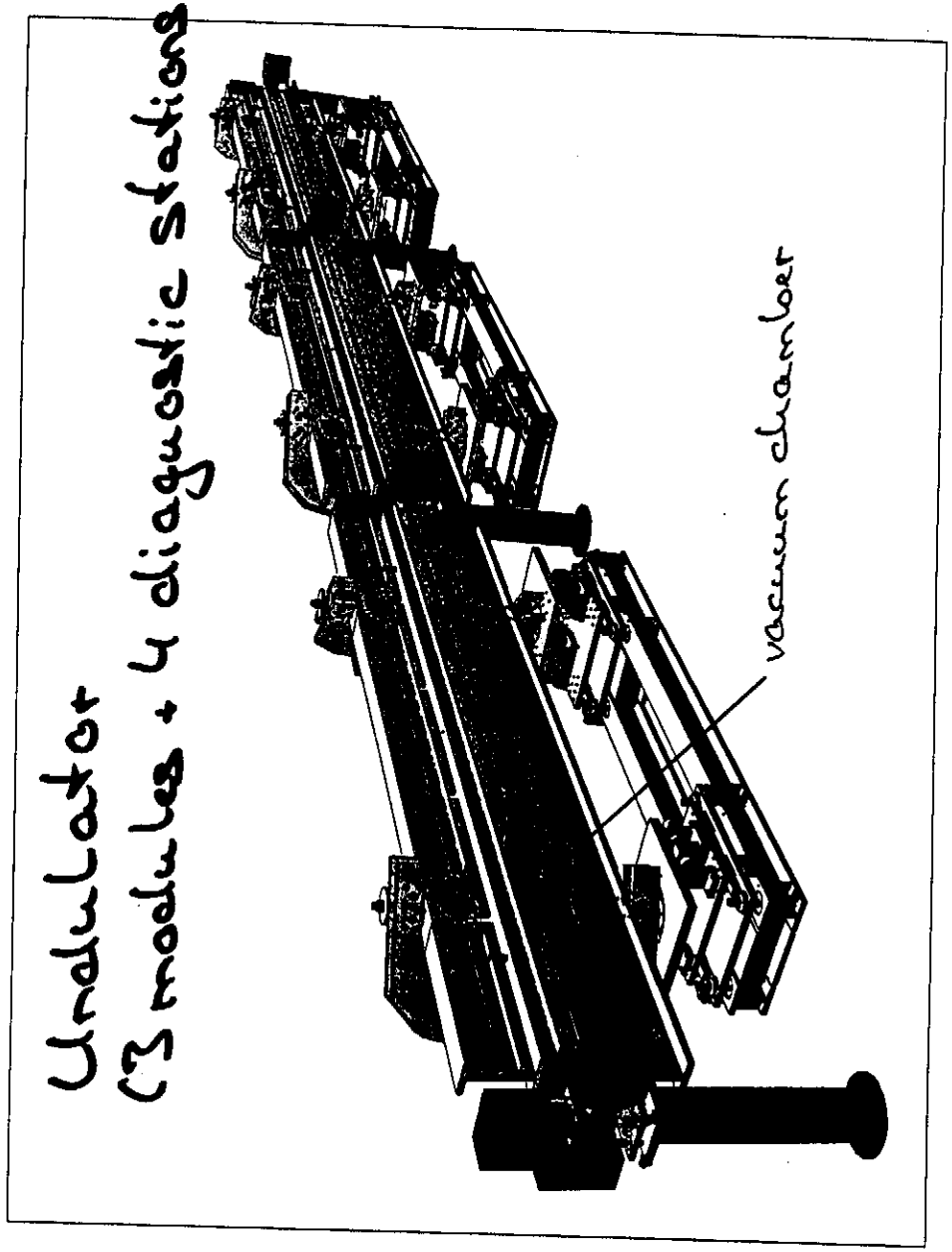
no primary particles hit the undulator when collimator is installed

Secondary particles:

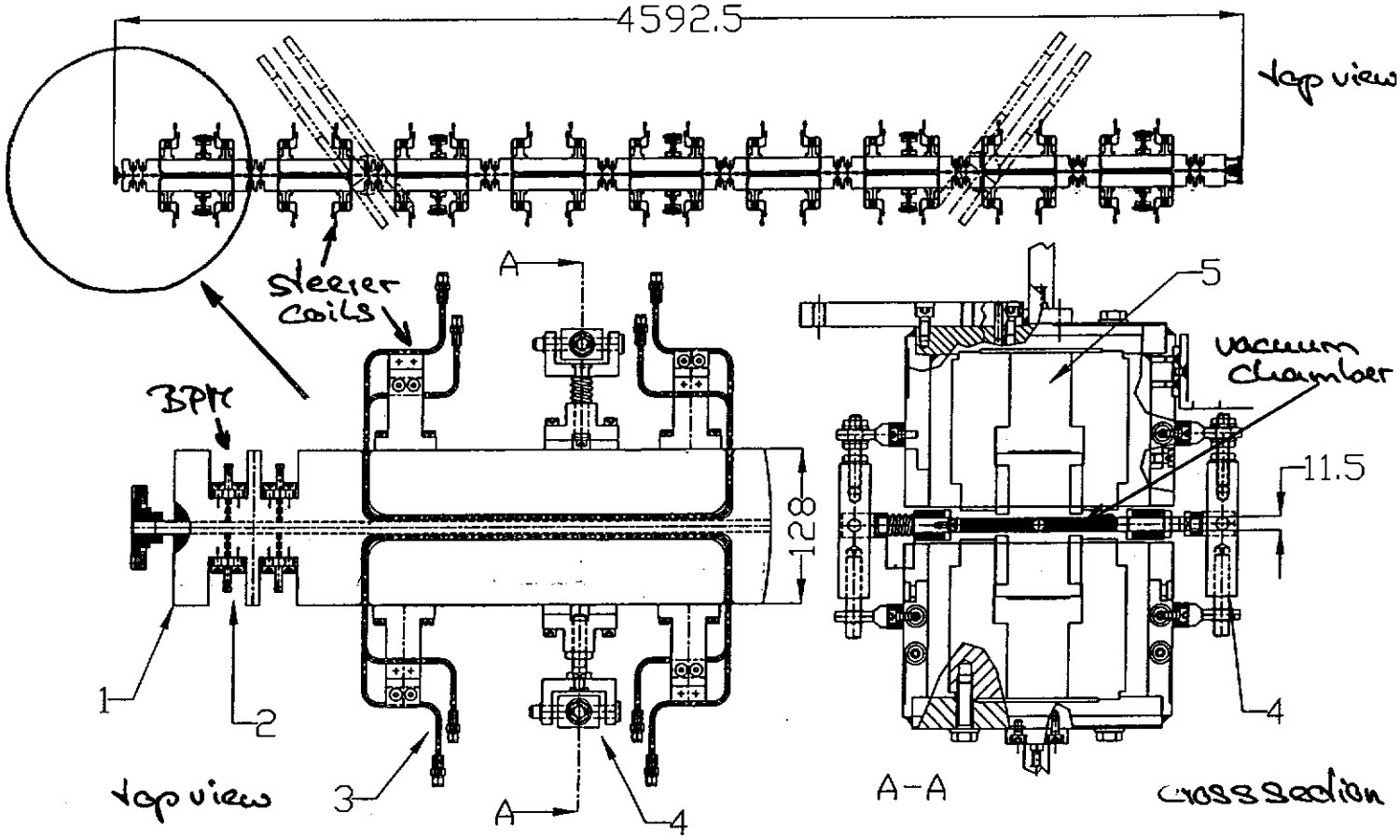
Energy	Deposition total	Deposition module 1	Deposition first 50 cm
MeV	%	%	%
200	0.036	0.036	0.025
300	0.096	0.092	0.053
400	0.192	0.188	0.120
500	0.275	0.265	0.151

Table 2: Result tracking or secondary particles

⇒ with collimator energy deposition in the undulator is reduced by factor: **80-1000!**



Undulator vacuum chamber



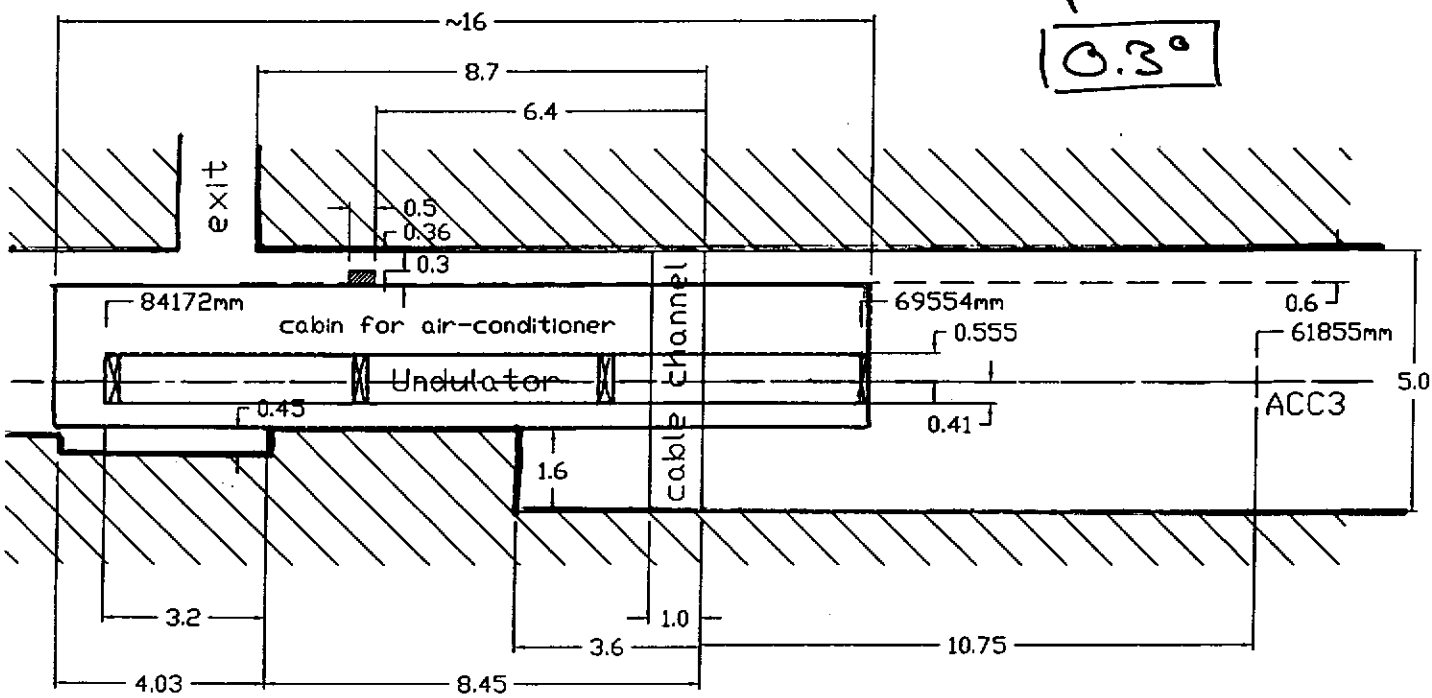
top view

scale 1:100 (unit:M)

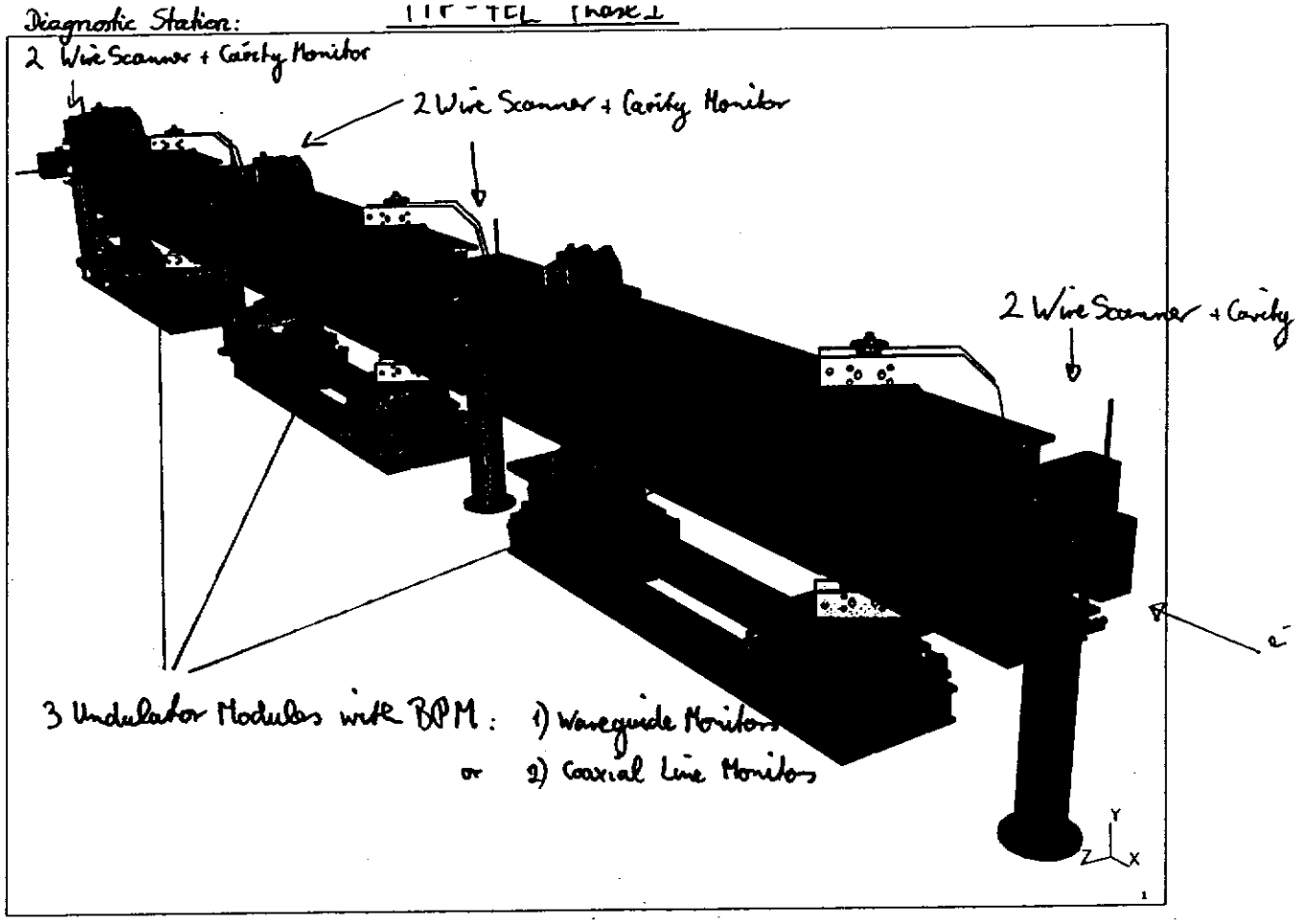
Climatic Chamber for the Undulator

temperature stability

$\boxed{0.3°}$



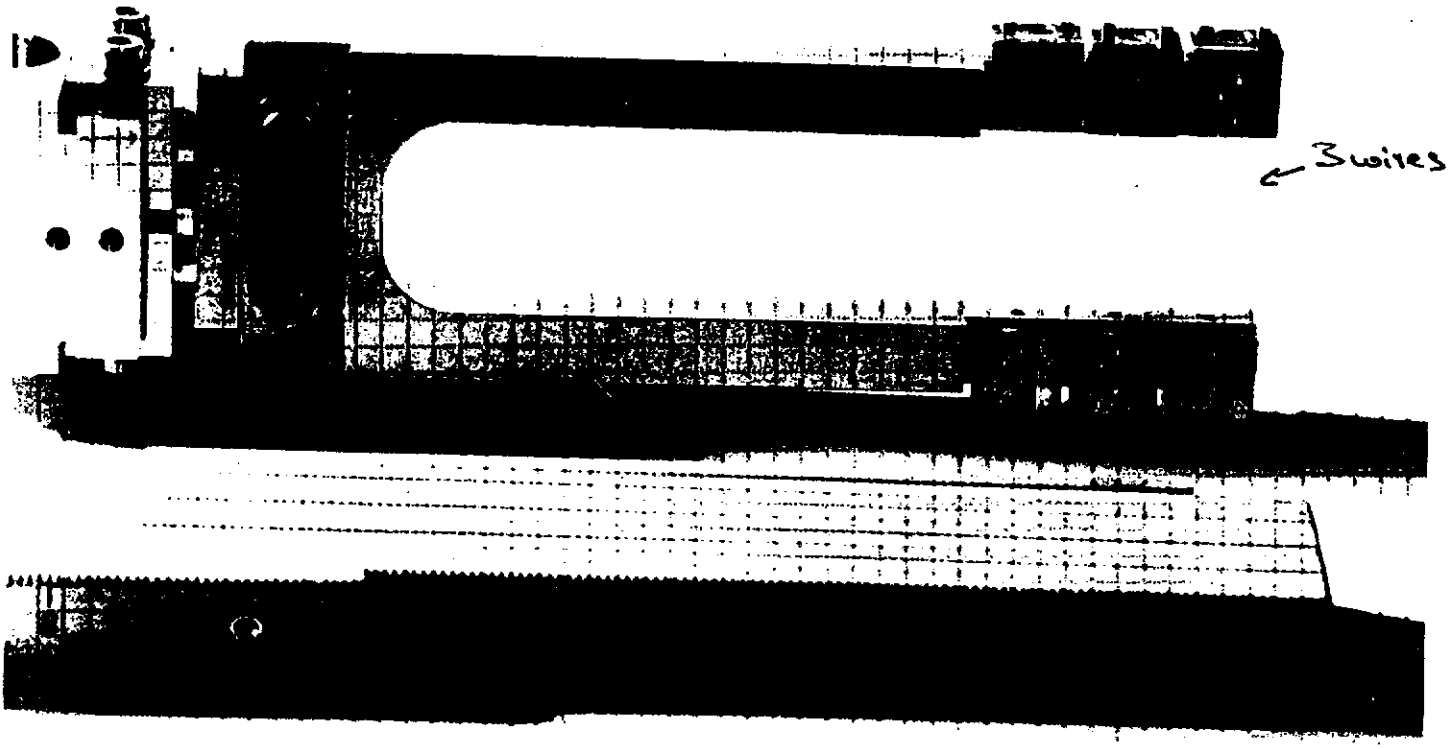
Diagnostic Station: TTF-FEL Phase 2



G. Schmidt, MPY, 3/98

Wire Holder Prototype

absolute alignment precision: ≈ 20 μm



Status of Wakefield Calculations

(R. Wanzenberg)

Important for FEL process:
compare initial energy spread (0.1 %)
to changing correlated energy spread
in the undulator.

Summary:

- no problem for TTF-FEL phase 1
  $\left(\frac{\Delta E}{E}\right)_{corr} < 0.1\ \%$
- critical for TTF-FEL phase 2
  $\left(\frac{\Delta E}{E}\right)_{corr} > 0.1\ \%$
  (surface roughness!)

paper in preparation

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Regenerative FEL Amplifier at the DESY TESLA Test Facility as a Fully Coherent VUV Laser

B. Faatz, J. Feldhaus, J. Krzywinski*, E.L. Saldin+, E.A. Schneidmiller+, M.V. Yurkov°

HASYLAB-DESY, *Institute of Physics, Warszawa, +ASC Samara, °JINR Dubna

300 MW peak power
30 W average

possible interferences
with the main stream
project

November 1997, TESLA-FEL 97-07

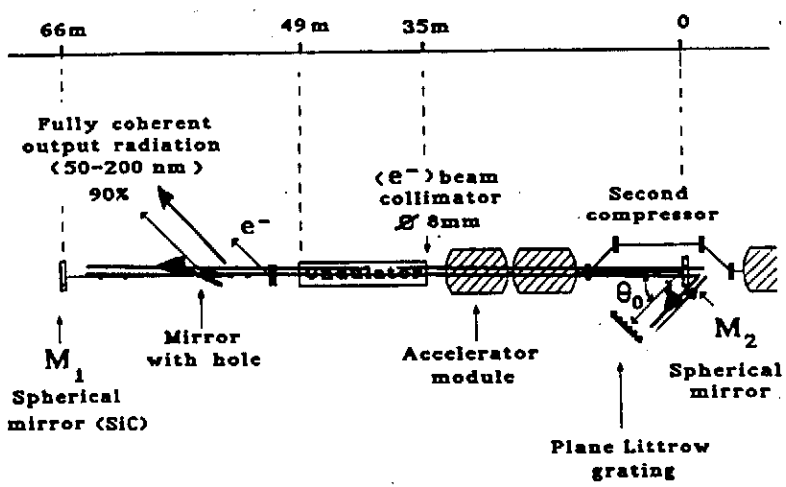


Fig. 1. Schematic layout of the UV-VUV regenerative FEL amplifier at the TESLA Test Facility.

compatibility has to be checked:
- apertures
- time structure
- energy spread

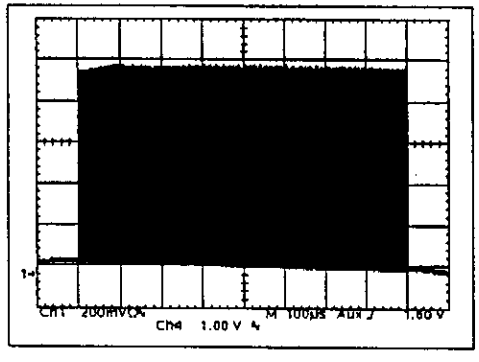
Status of the photocathode laser

March ´98

A.Liero, I.Will, W.Sandner

Summary of status in Nov. 1997:

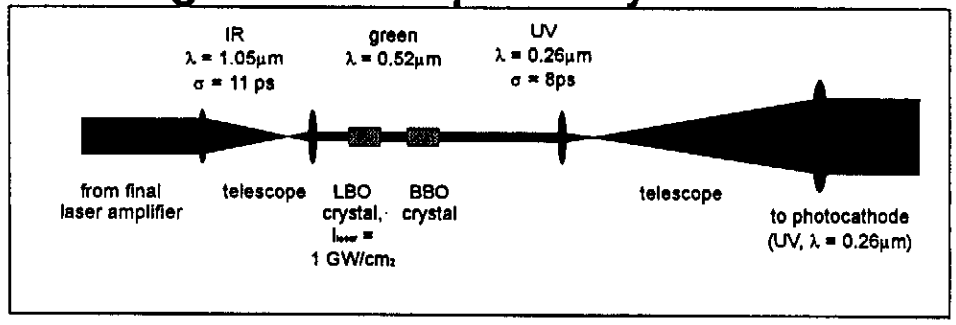
- Pulse trains of the desired energy and stability have been produced at the output of the laser amplifier stage (Infrared (IR) radiation, $\lambda = 1.05\mu m$)
- Envelope is freely programmable.



But:
Photocathode is not sensitive to IR radiation
-> conversion into the Ultraviolet (UV) required ($\lambda = 0.26\mu m$)

Main effort of the last months:
Wavelength conversion stage

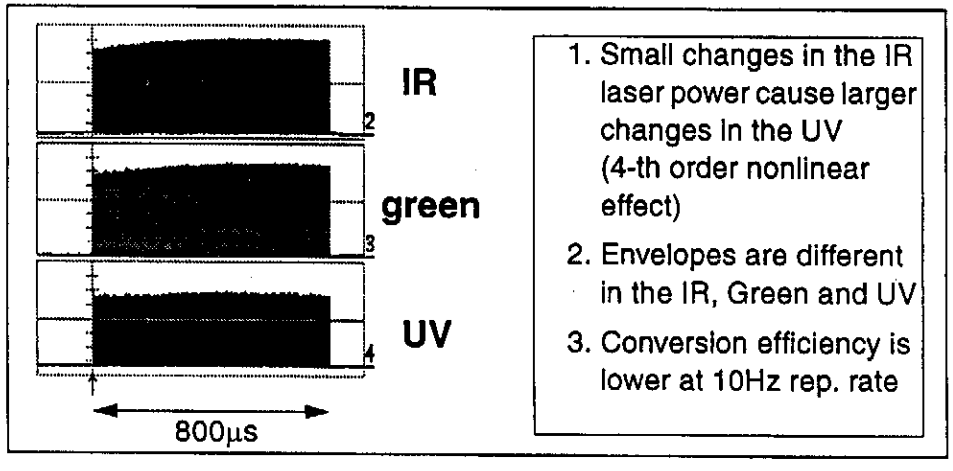
Conversion of the wavelength using nonlinear optical crystals



1. LBO: Lithium Triborate (LiB_3O_5)
2. BBO: Beta-Barium Borate (β-BaB_2O_4)

- Total energy of a micropulse in the UV: 25μJ (at 5Hz repetition rate) (5μJ required at the photocathode for 8nQ bunch charge)
- Total conversion efficiency from IR to UV: 10-12% (at 5Hz repetition rate)

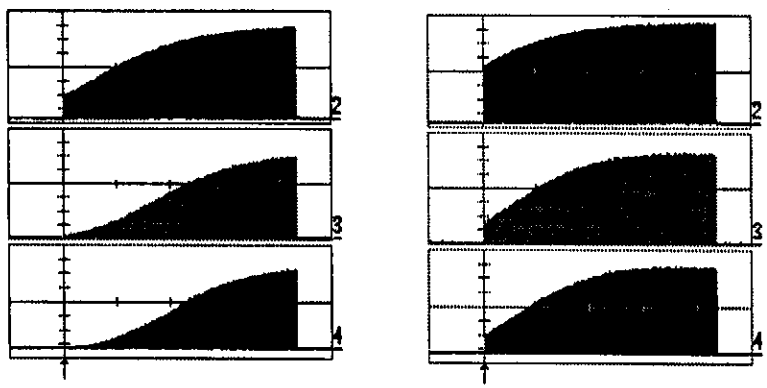
Measurement:



1. Small changes in the IR laser power cause larger changes in the UV (4-th order nonlinear effect)
2. Envelopes are different in the IR, Green and UV
3. Conversion efficiency is lower at 10Hz rep. rate

Measurement of the relationship between laser input in the IR and output radiation in the UV

Method:
Production of a pulse train of slowly rising energy of the micropulses.



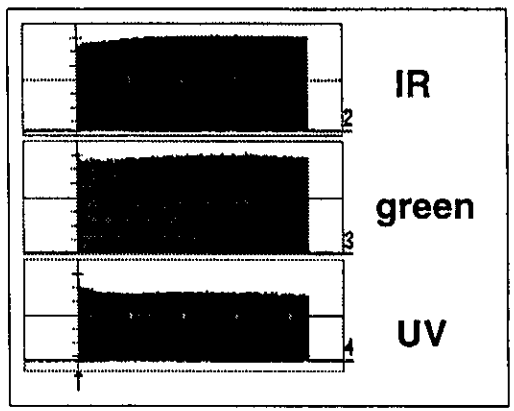
1/8 of the nominal output intensity reached at the end of the train (UV)

nominal output intensity at the end of the train (UV)

Conclusion:

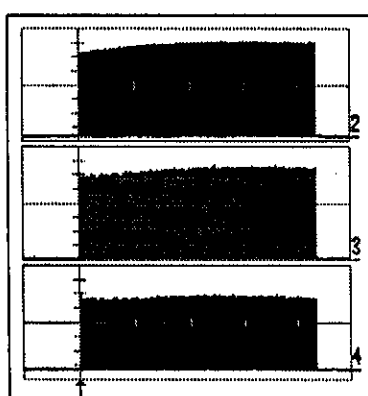
At the actual working point:
1% deviation in the IR = 2% deviation in the UV

Conversion efficiency is slightly higher during the first 200us than during the main part of the train.



Reason:

- Small changes in the beam profile at the beginning of the train due to spatial holeburning in the laser amplifiers.
- Amplifier chain reaches steady-state after approx. 200µs.



We can compensate for changes of the conversion efficiency during the first 200µs by appropriately shaping the IR input pulse (programmable-pulse-shape mode)

Reduction of the conversion efficiency at 10Hz rep rate in comparison to 5Hz

Conversion efficiencies reached:

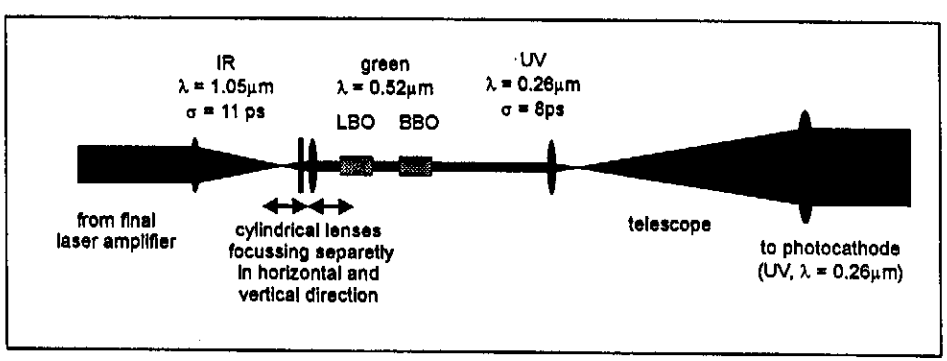
- at 5Hz: >10%
- at 10Hz: approx. 7%, in addition: bad beam profile

Reason:

- thermal lenses in the laser rod, stronger at 10Hz than at 5Hz rep. rate
- thermal lensing is different in horizontal and vertical direction (specific to Nd:YLF)
- unfavorable defocussing effect is enlarged in the spatial filter between amplifier chain and nonlinear crystals

Solution: "adaptive optics"

Two cylindrical lenses for separate focus control in horizontal and vertical direction.



Summary

We have demonstrated a conversion efficiency IR->UV of better 10% at 5Hz rep rate.

The energy **in the UV is 25μJ per micropulse** (i.e. 20mJ per macropulse) (5uJ per micropulse is required on the photocathode for 8nQ bunch charge)

Next steps:

- Adaptive spatial filter for compensation of thermal lensing which should allow to produce 25μJ UV per micropulse (20mJ per pulse train) at 10Hz repetition rate.
- Remote alignment system of the nonlinear crystals and feedback control is required for stable long-term operation.

Conclusion:

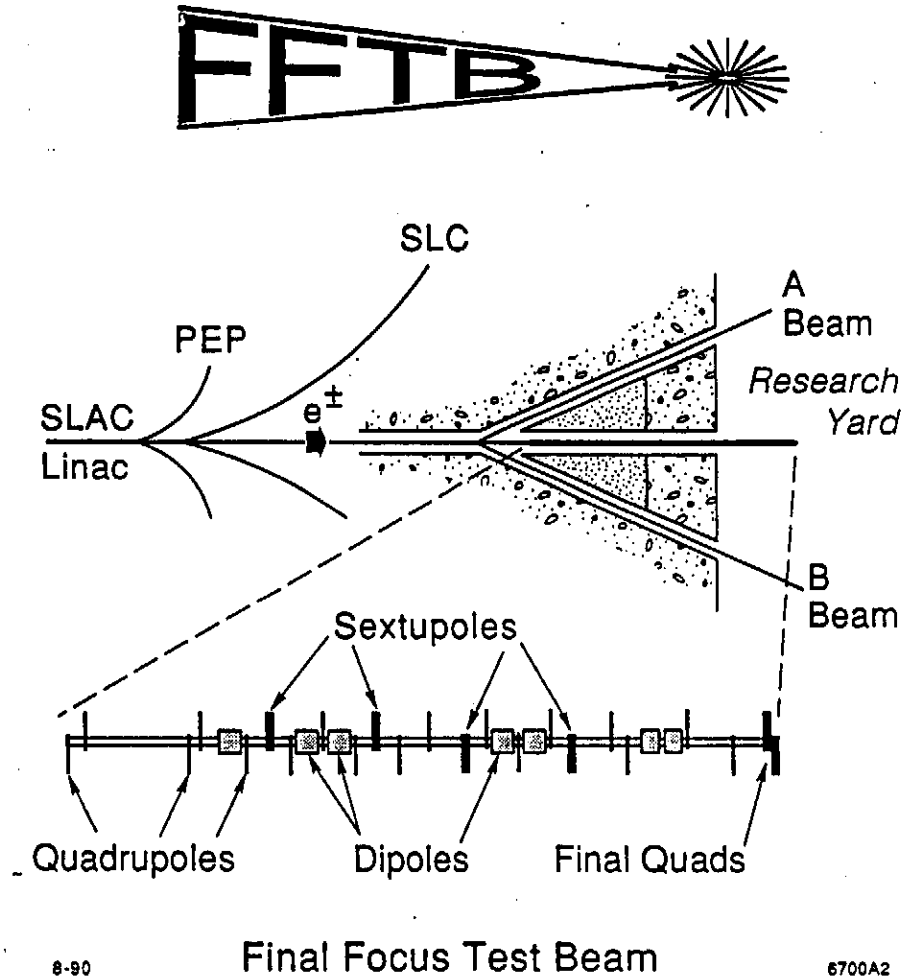
The wavelength conversion from IR to UV has shown to be a major difficulty in the development of the photocathode laser system.

We have to spend significantly more time and somewhat more money than initially planned to fully solve this problem.

Results from the Final Focus Test Beam

D. L. Burke
SLAC

DESY
March 1998



Complete prototype of final focus.

FFTB Collaborating Institutions

BINP (Novosibirsk/Protvino)

DESY

Fermilab

IBM

Kawasaki

KEK

LAL(Orsay)

MPI(Munich)

Rochester

SLAC

FFTB BIBLIOGRAPHY

Journal Publications

A Beamsize Monitor for the FFTB	J. Buon et al	Nucl.Inst.&Meth. A306, 93-111 (1991)
High Resolution BPM for FFTB	H. Hayano	Nucl.Inst.&Meth. A320, 47-52 (1992)
Proposal of a Nanometer Beam Size Monitor for e^+e^- Linear Colliders	T. Shintake	Nucl.Inst.&Meth. A311, 453-464 (1992)
Quadrupole Magnets for the Final Focus of the FFTB at SLAC	H. Nakayama et al	Particle Accelerators 46, 225 (1994)
New Stanford Facility Squeezes High-Energy Electron Beams	B.Schwarzschild	Physics Today Pg. 22 (1994)
Focusing of Submicron Beams for TeV-Scale e^+e^- Linear Colliders	V. Balakin et al	Physical Rev. Letters 74, 2479 (1995)
The Wire Scanner System of the FFTB	C. Field	Nucl.Inst.&Meth. A360, 467-475(1995)
Precision Magnet Movers for the FFTB	G. Bowden et al	Nucl. Inst.&Meth. A368, 579-592(1996)
Radiation Protection System for the FFTB	S. Rokni et al	Health Physics 71, 786-94 (1996)

Advanced Degree Thesis

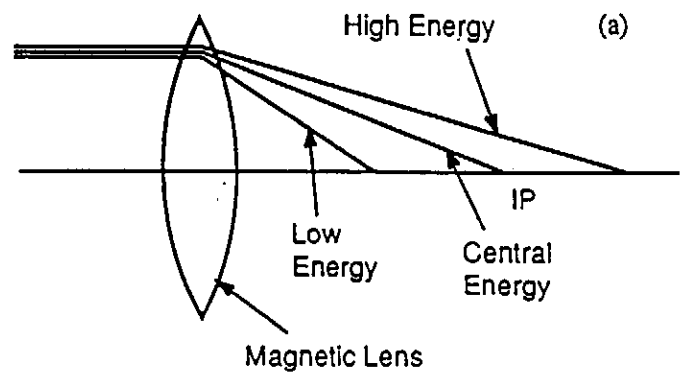
The Measurement of Submicron Beam size with the ORSAY Beam Monitor in the FFTB. (In French)	P. Puzo	PhD Thesis (ORSAY,LAL) LAL-94-09
Analysis of the FFTB Optics Using Lie Algebra Based Techniques	G. Roy	PhD Thesis SLAC-397
Investigation on Precision Mechanics for Future 500-GEV e^+e^- Linear Colliders (In German)	G. Heimlinger	Diplomarbeit (Max Planck) MPI-PhE-93-13
Expanded Studies of Linear Collider Final Focus Systems at the FFTB	P. Tenenbaum	PhD Thesis SLAC-R-95-475
Calculations and Measurements of Neutron Arrival Time Dist. for Neutron Detectors at SLAC	R. Kaur	MS Thesis SLAC-R-96-490

Conference and Laboratory Publications

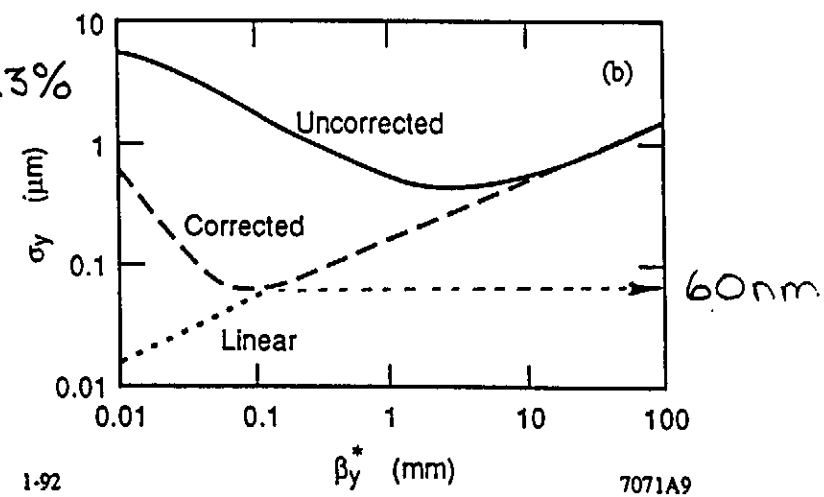
Design of Optics for the FFTB at SLAC	K. Oide	SLAC-PUB-4953 (1989)
FFTB Alignment A Draft Proposal	G. Fischer R. Ruland	Proceedings of the 1st Int'l Workshop on Accel Alignment Stanford 296 (1989)
The Proposal Alignment System for the FFTB at SLAC	R. Ruland G. Fischer	Proceedings of the 2nd Int'l Workshop on Accel Alignment Hamburg 419-452 (1990)

• • • 30 Conference Presentations

FFTB Chromatic Correction

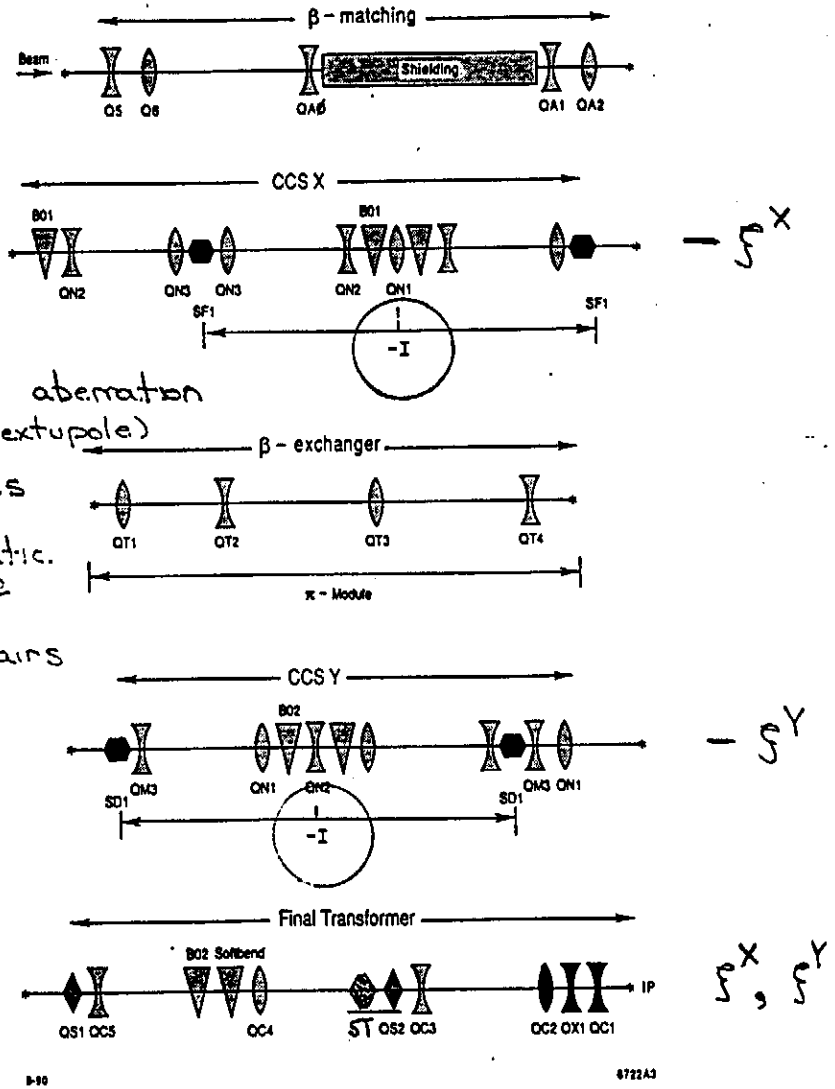


$\delta p/p = 0.3\%$



$(\gamma\epsilon_y = 3 \times 10^{-6}$ rad-m$)$

FFTB Optics



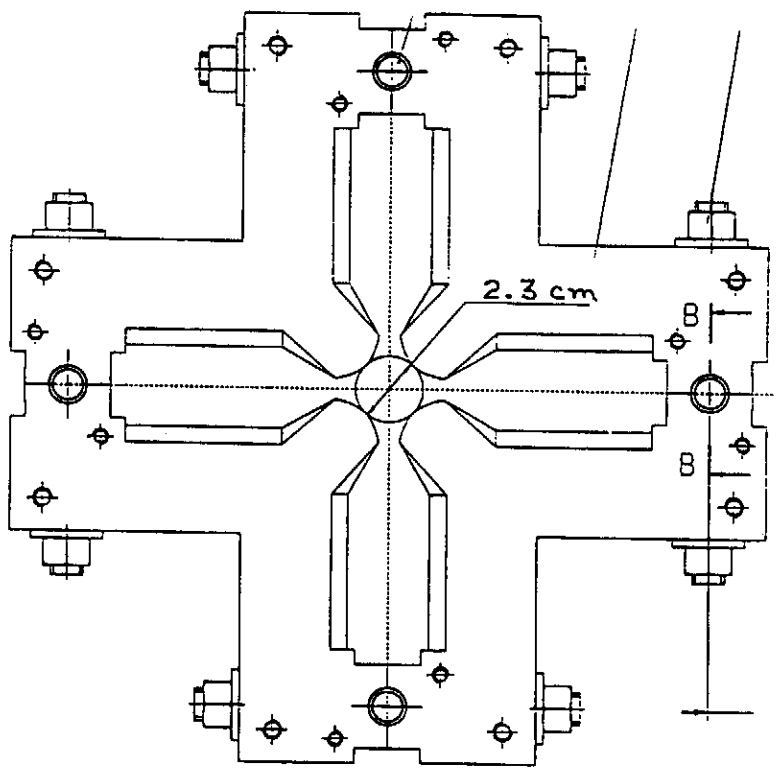
Geometric aberration (per sextupole) ≈ 40 times monochromatic size

⇒ -I pairs

Uncorrected chromatic aberration ≈ 30 times monochromatic size.

FFTB "Standard" Quadrupole

BINP (Protvino/Novosibirsk.)

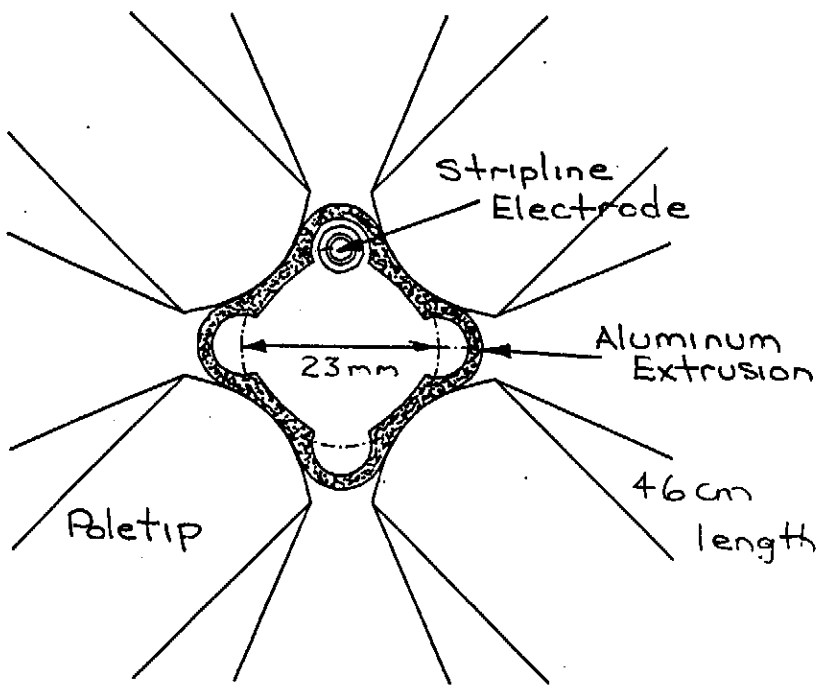


Harmonic tolerance: $\frac{B_6}{B_4} < 10^{-3}$

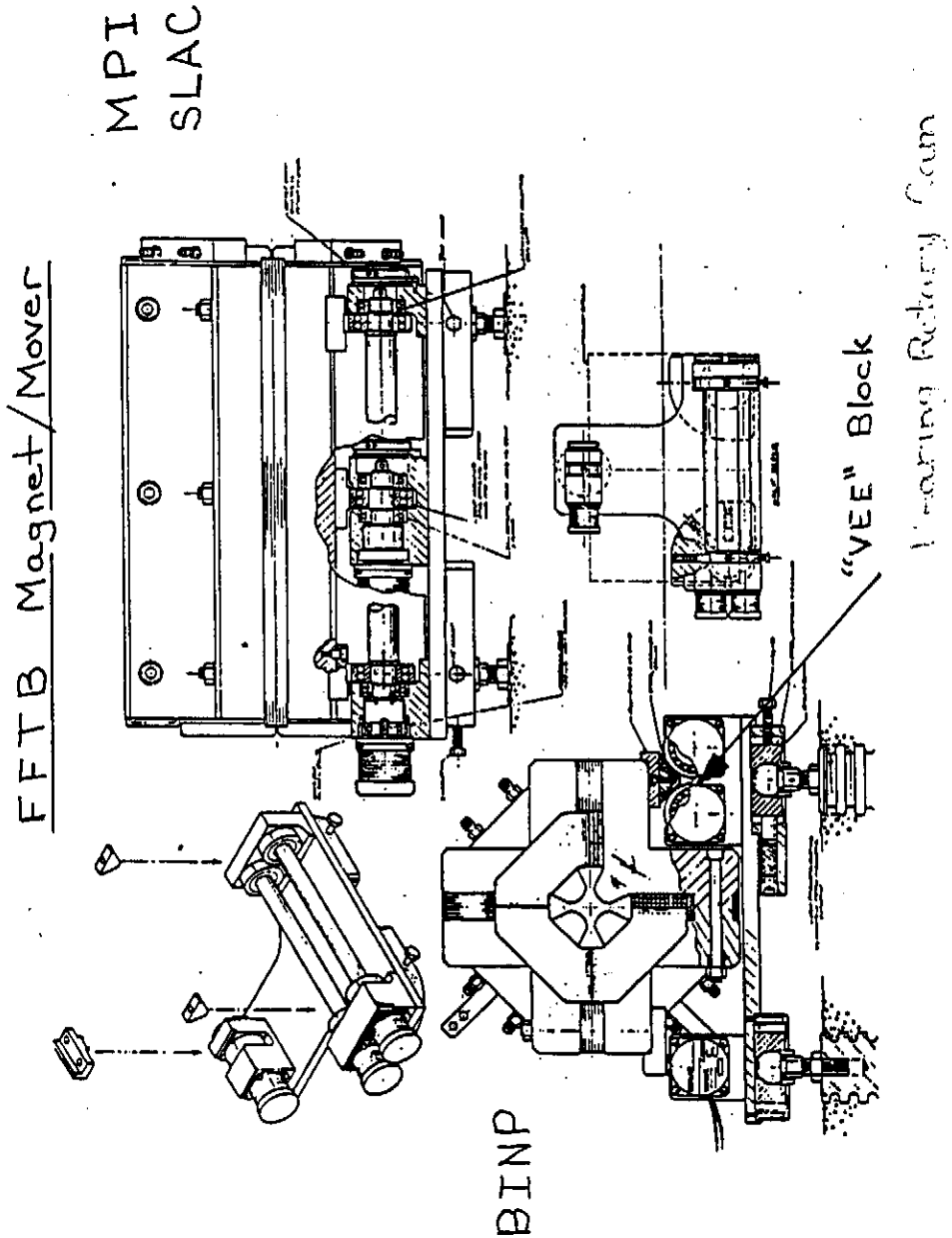
(70% aperture)

FFTB Beam Position Monitors

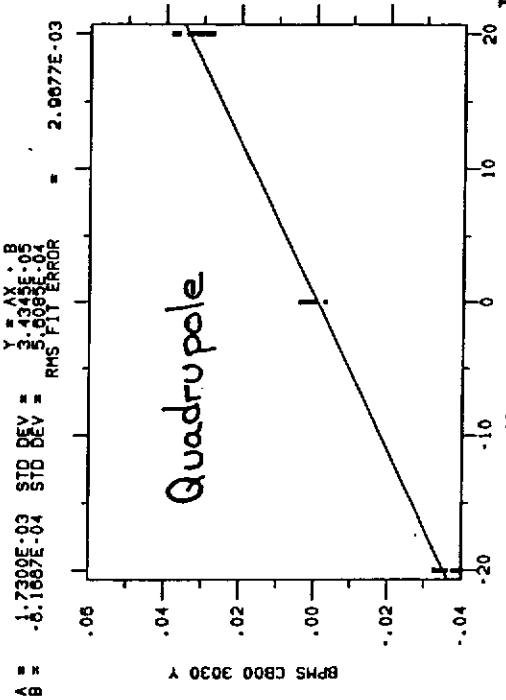
SLAC/Orsay/KEK



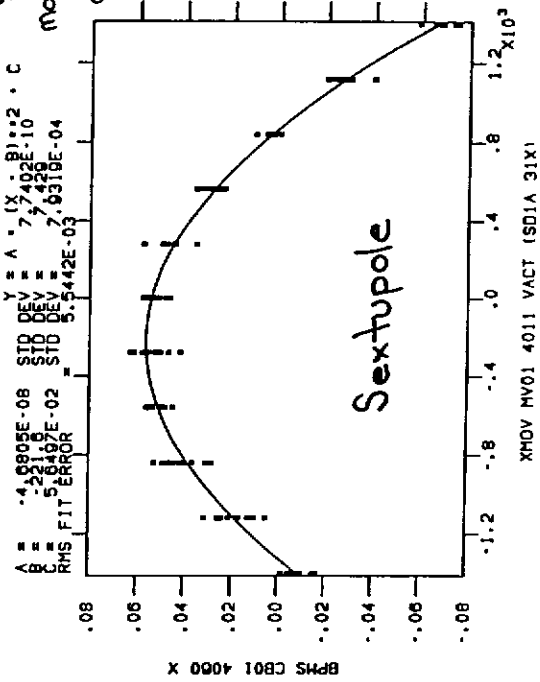
Resolution = 1 micron
with 10^{10} e^- per pulse.

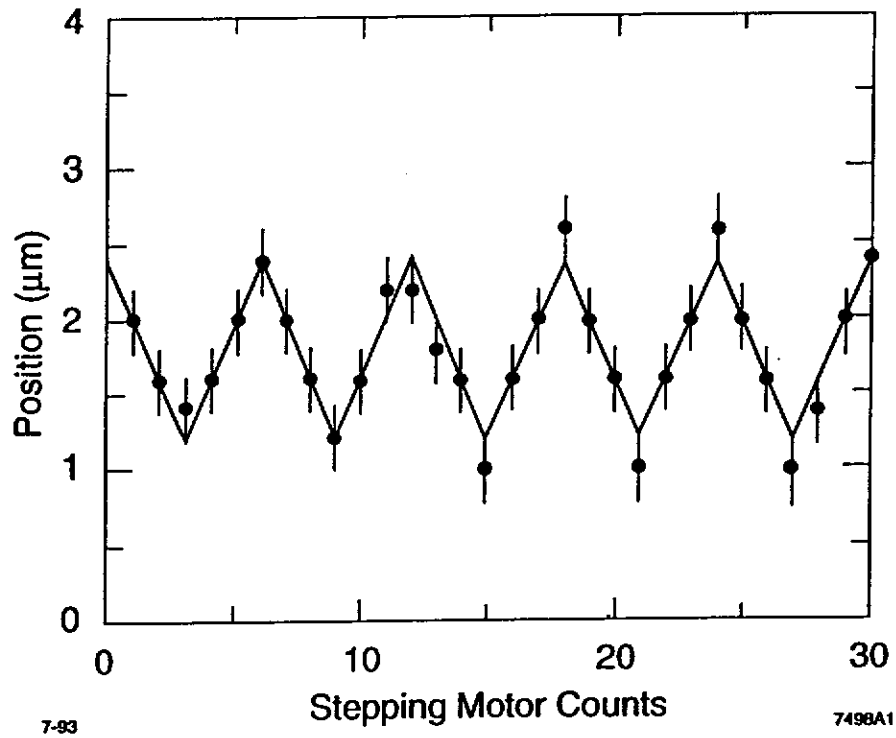


Beam - Based Alignment



Fit beamline sections to match dispersion and establish proper launch.

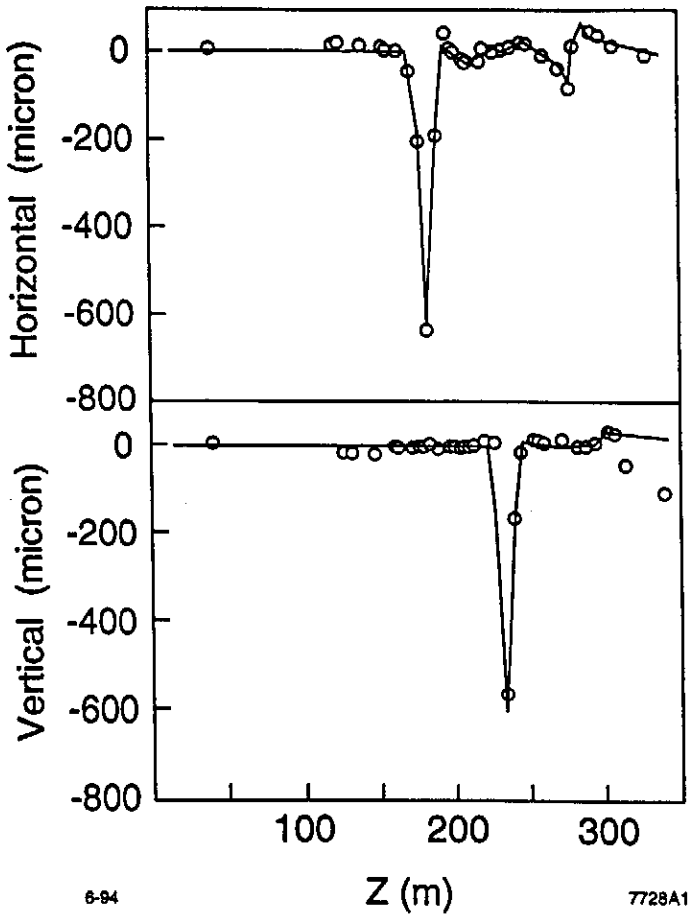




FNAL

Lattice Diagnostics

Orbit bumps with movers at sextupoles.



CCX (-I)

CCY (-I)

Complete Sets of Orbit Bumps → { Quads, BPMs, Energy }

Beamline stability measurements

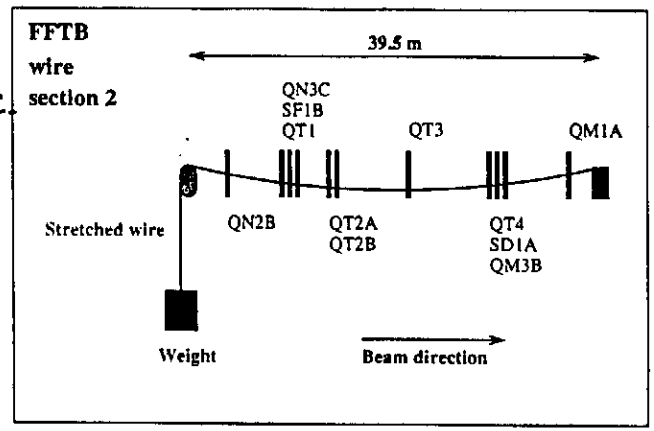
(FFTB Tunnel)

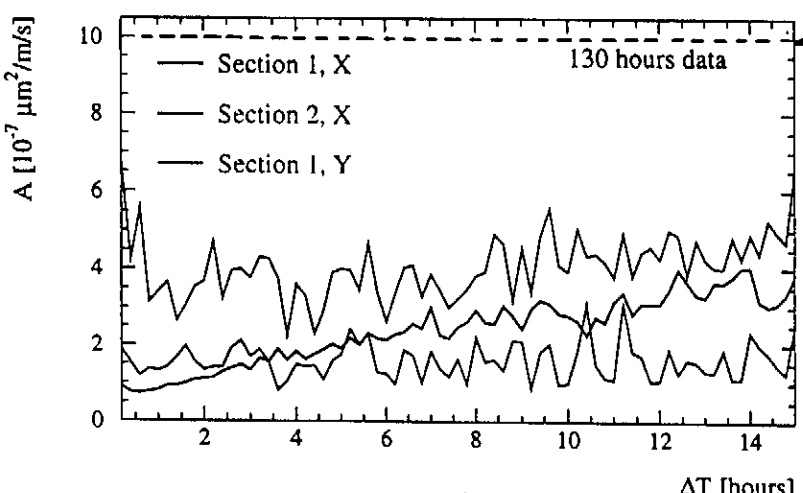
DESY/ SLAC

Tunnel sealed to air intrusion and stable to $\Delta T \leq 0.1°C$.

"ATL Law"

$\langle \Delta^2 \rangle = A \cdot \Delta T \cdot \Delta L$





← NLC design spec

→ Measurements around globe depend on site and civil construction.

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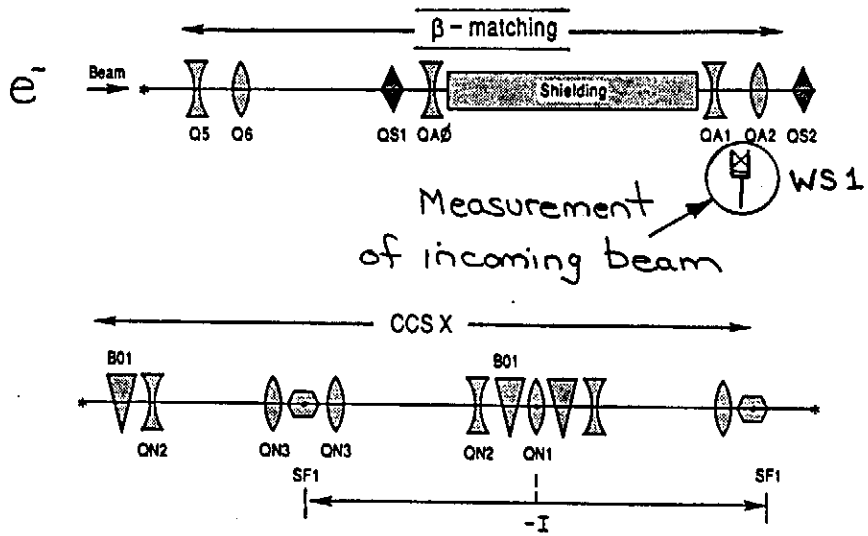
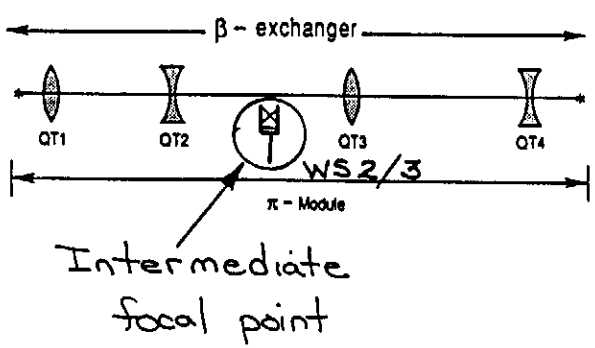
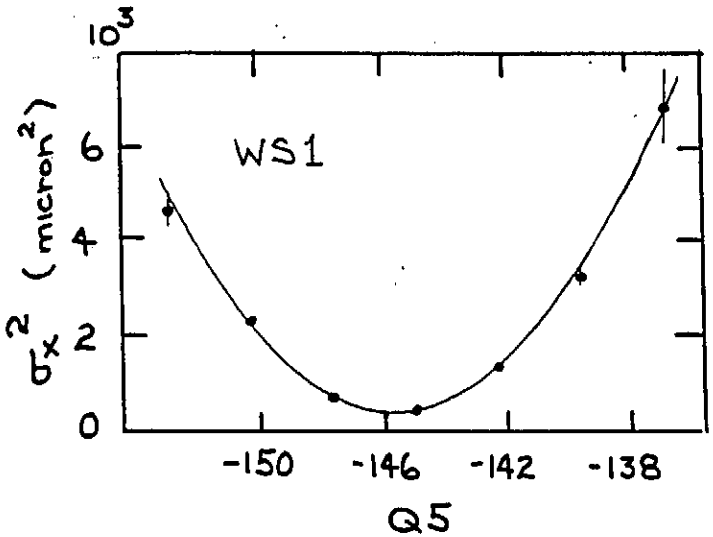
Beta Match



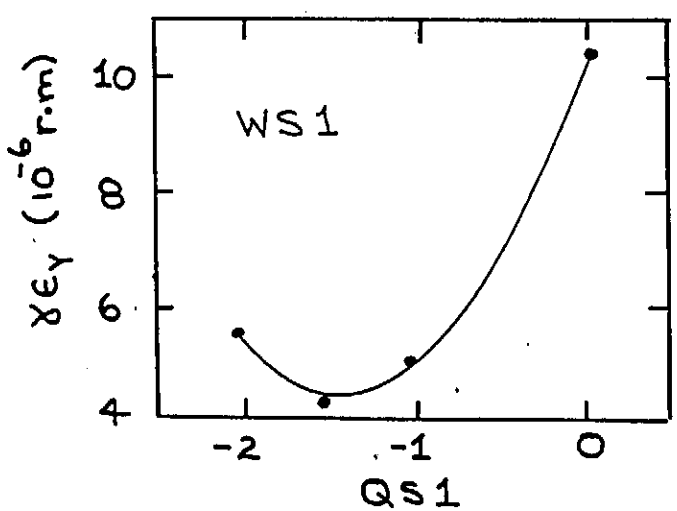


FFTB Incoming Beam



Quadrupole Scans

TWISS

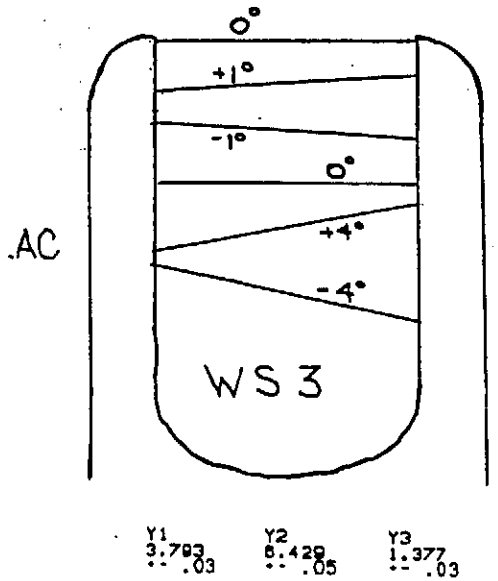


Coupling Correction

$\gamma\epsilon_x = 2.5 \times 10^{-5}$ rad·m

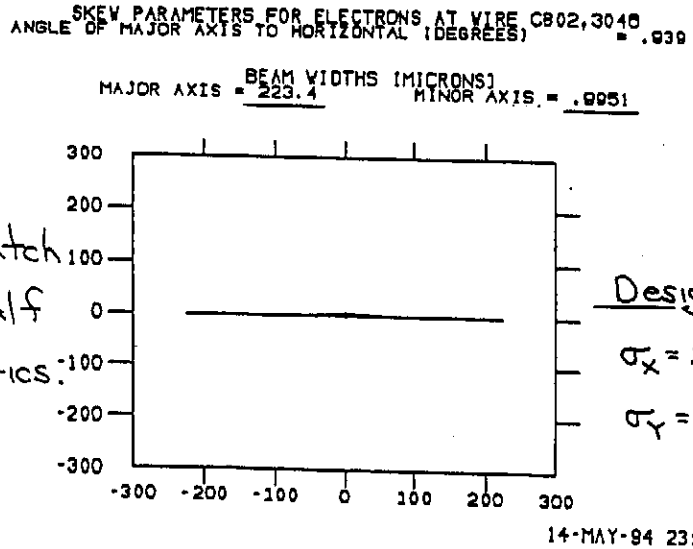
$\gamma\epsilon_y = 2.5 \times 10^{-6}$ rad·m

$\delta E/E \approx 0.05 - 0.1\%$



Intermediate Focal Point

Horizontal (WS2) and vertical (WS3) focal points approximately meter apart.



confirm β-match and first half of FFTB optics.

Design:

$\sigma_x = 210\mu m$

$\sigma_Y = 1.1\mu m$

Emittance Propagation to FFTB

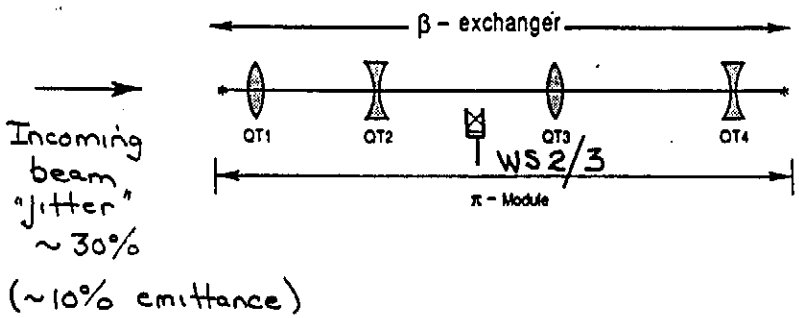
Zimmermann, Usher, et al.

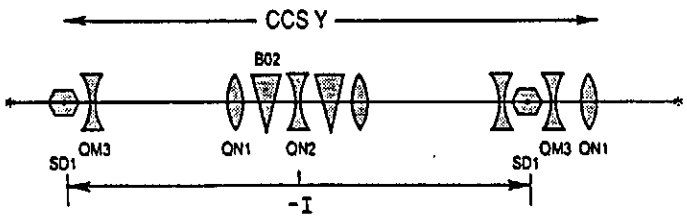
$I^- = 0.6 \times 10^{10}$

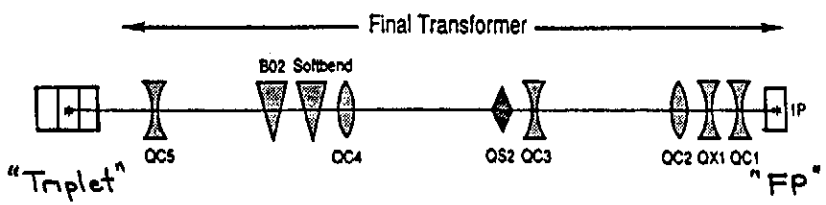
$\gamma\epsilon_y$ (μm) Li28	$\gamma\epsilon_y$ (μm) FFTB	comment
2.34	3.05±0.1	all collimators open
—	2.81±0.1	coll. 28-9, 400 μm gap, centered
2.66	2.62±0.3	coll. 28-9, 400 μm gap, 150 μm, off-center
—	2.47±0.1	coll. 29-9, 730 μm gap, centered
—	2.91±0.2	coll. 29-9, 730 μm gap, 100 μm, off-center
2.37	2.33±0.1	all collimators closed

No sign of emittance growth.

RFBPMs



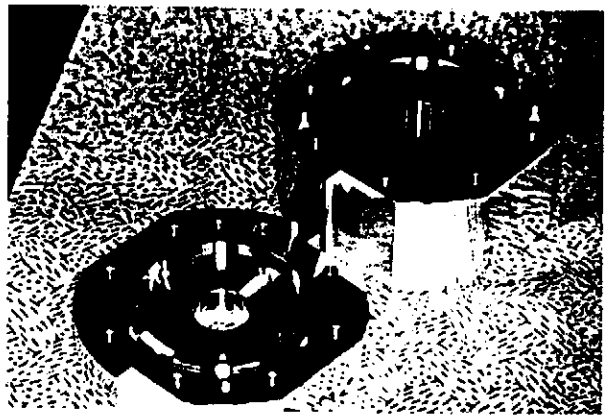


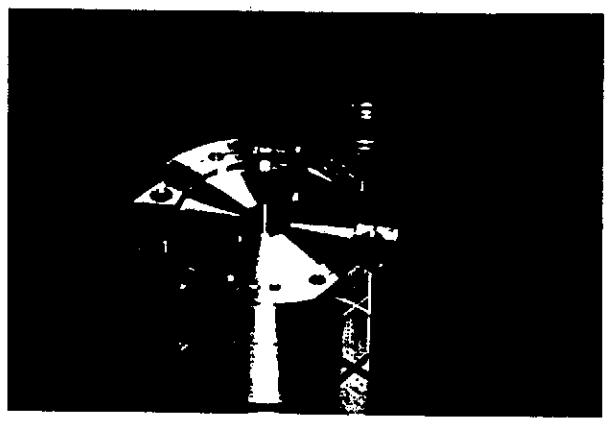


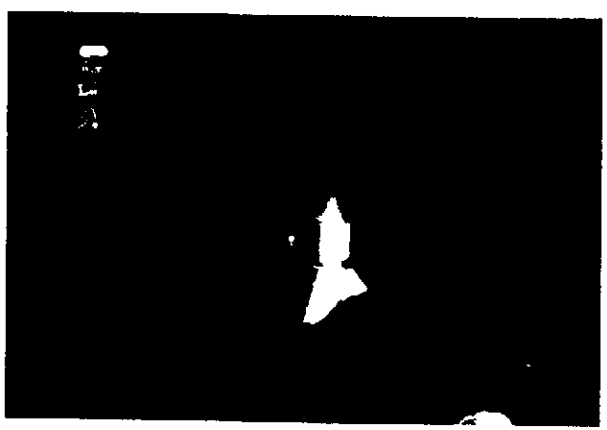
400 nm —— geometric demagnification ⟶ 50 nm

C-BAND RF-BPM for FFTB

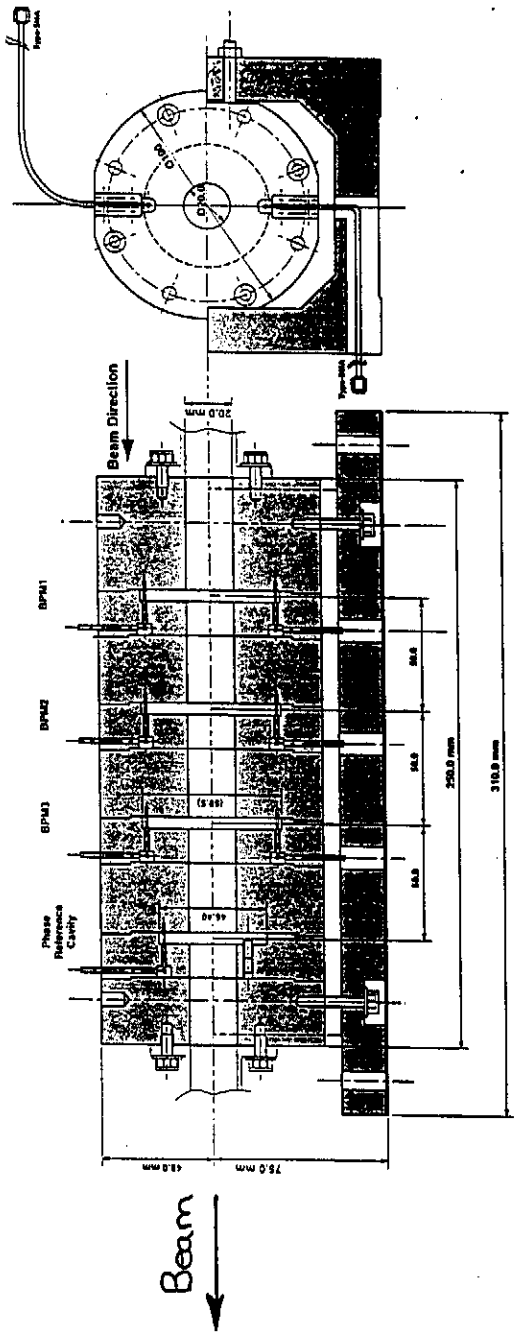
KEK-SLAC







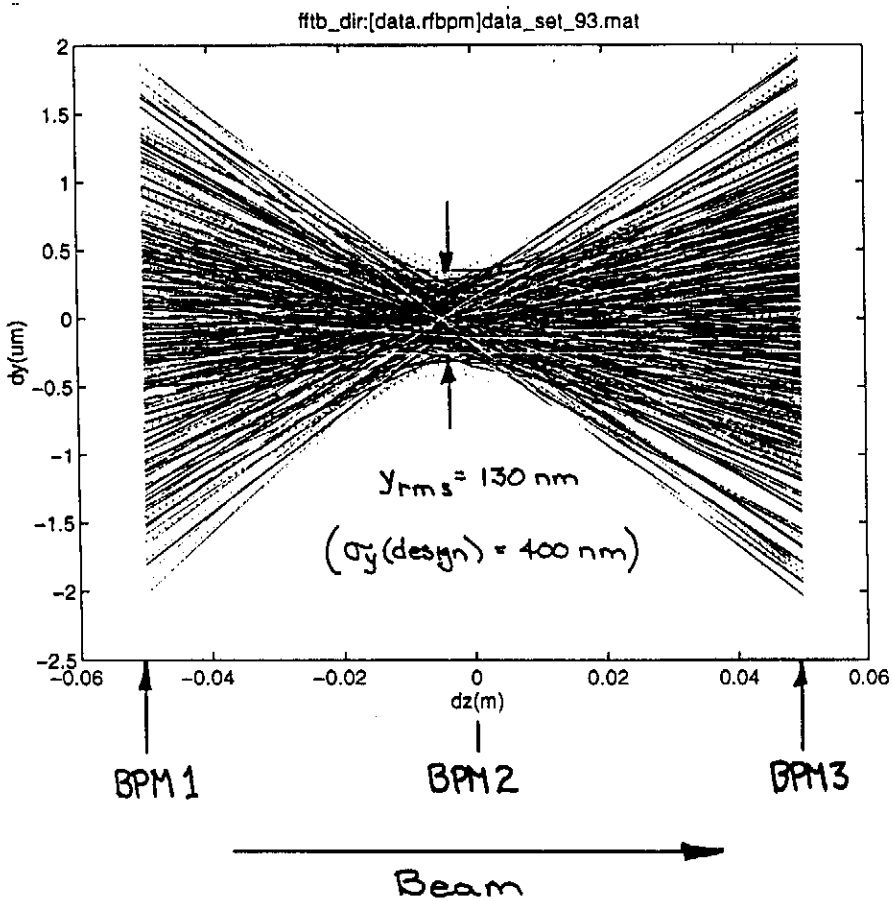
C-Band RFBPM



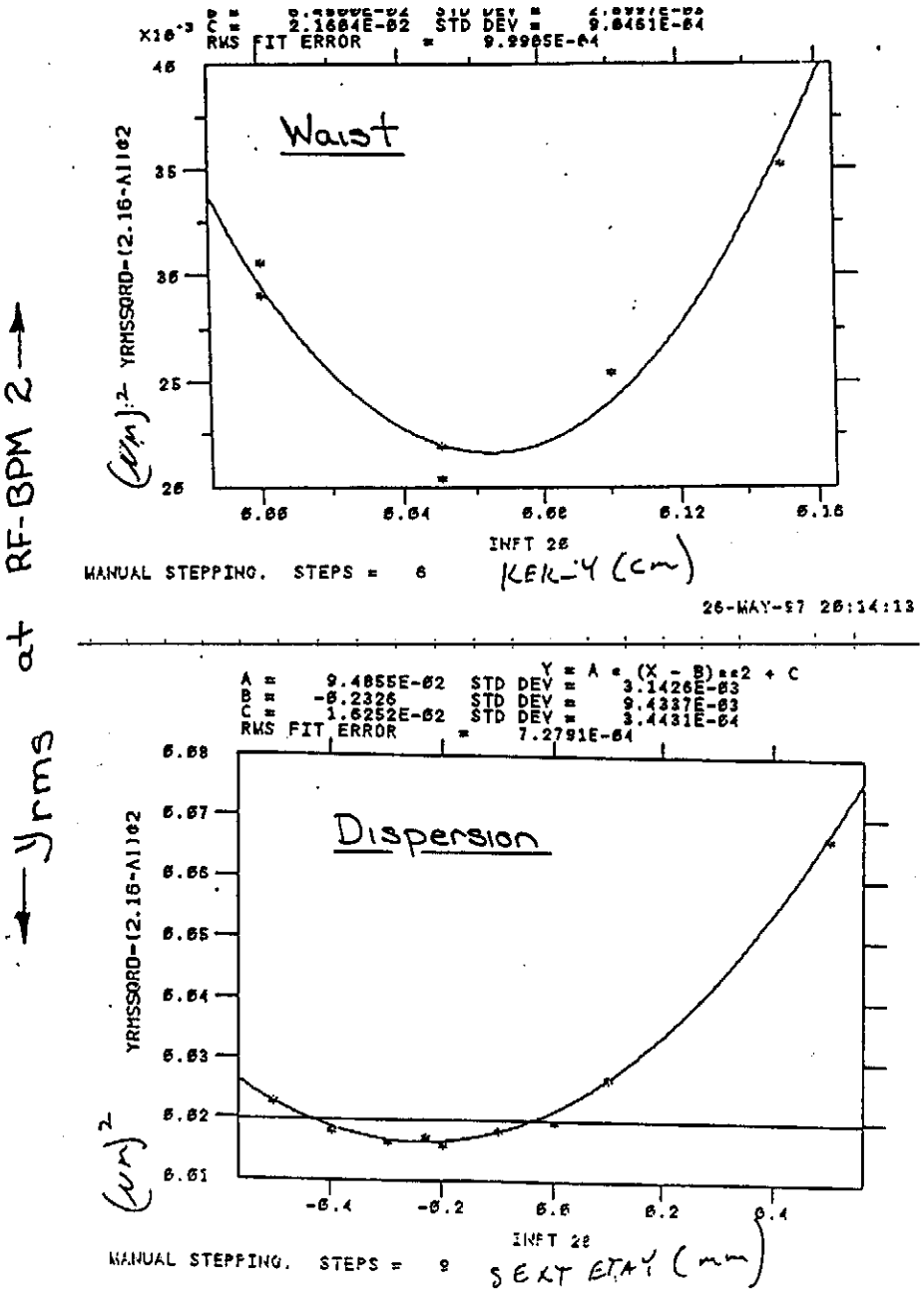
RF-BPM Resolution Test

Fig. 1. Newly developed RF-BPM. Three BPM cavities and one phase reference cavity are assembled in one block.

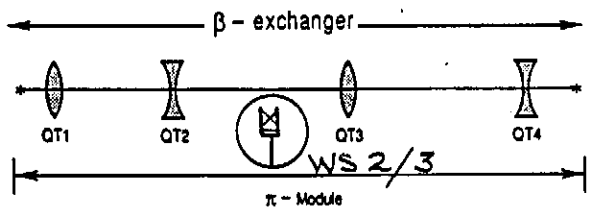
Track Reconstruction in RF-BPM "Triplet"

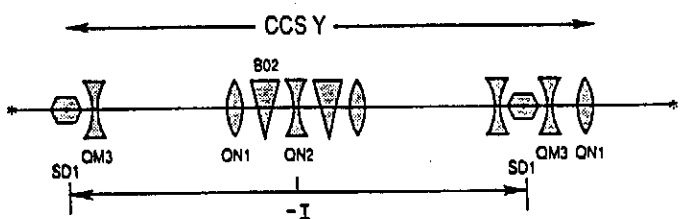


Measured resolution of 25 nm per BPM per pulse.

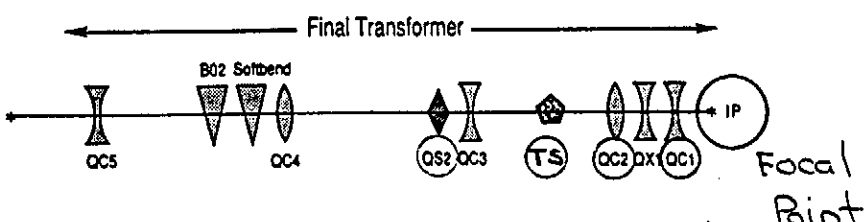


Final Spot





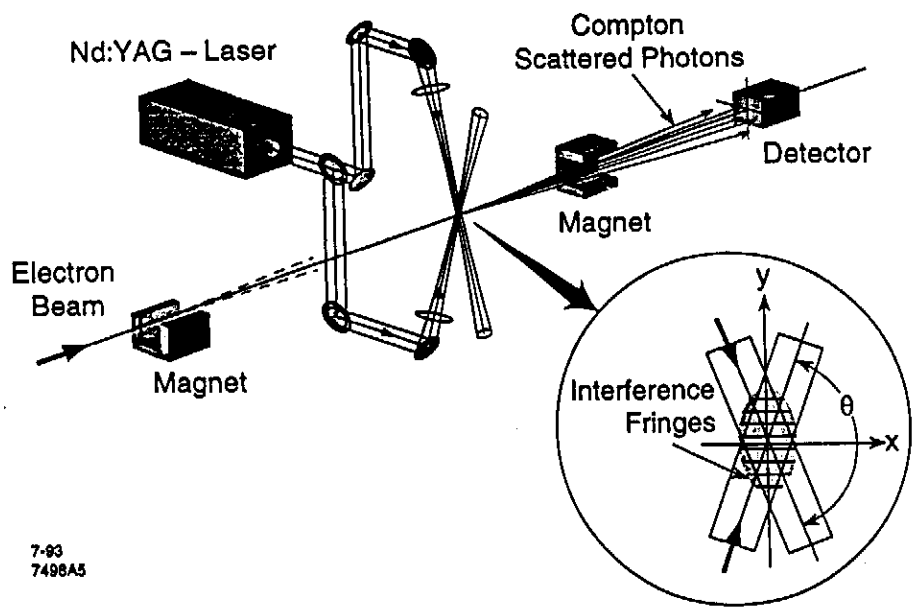
Odd/Even movements of SF and SD to trim coupling and dispersion.

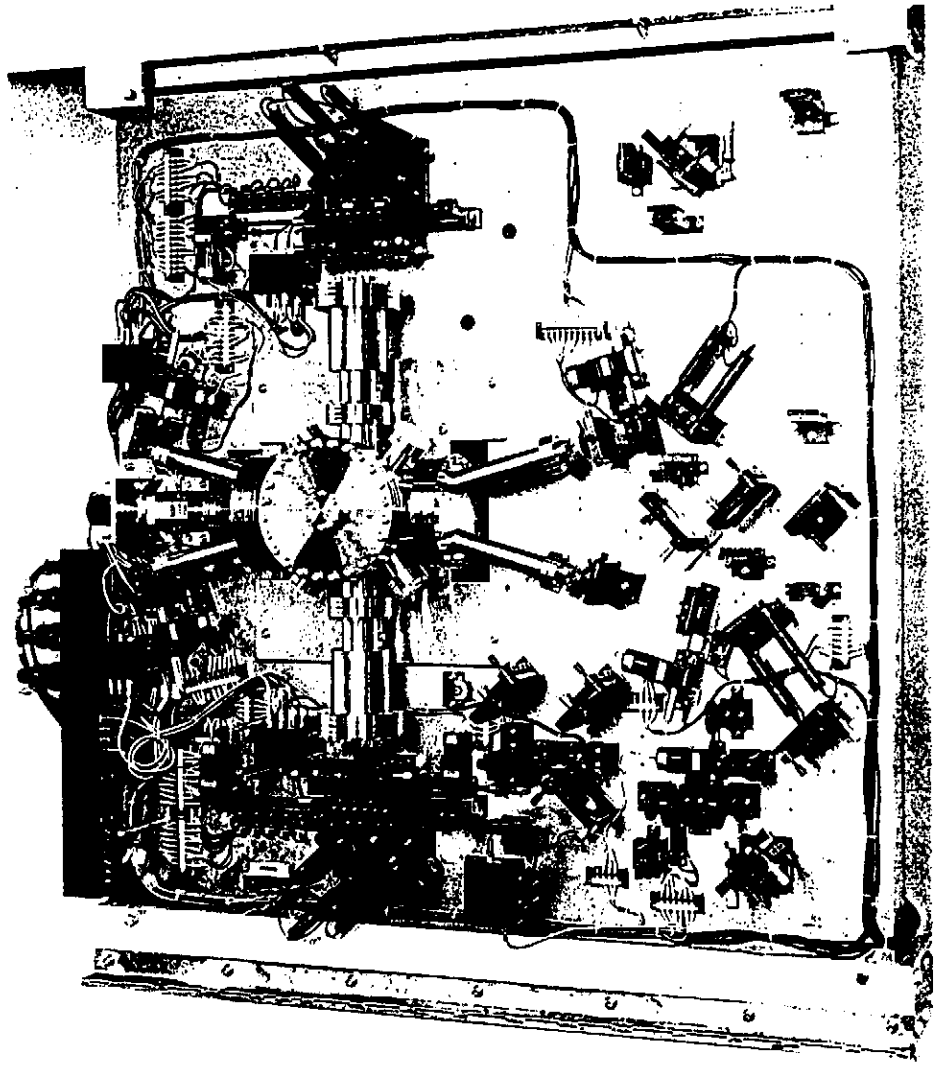


Final doublet corrections
waist
coupling
sextupole

Final Spot Size Measurement

KEK
Kawasaki

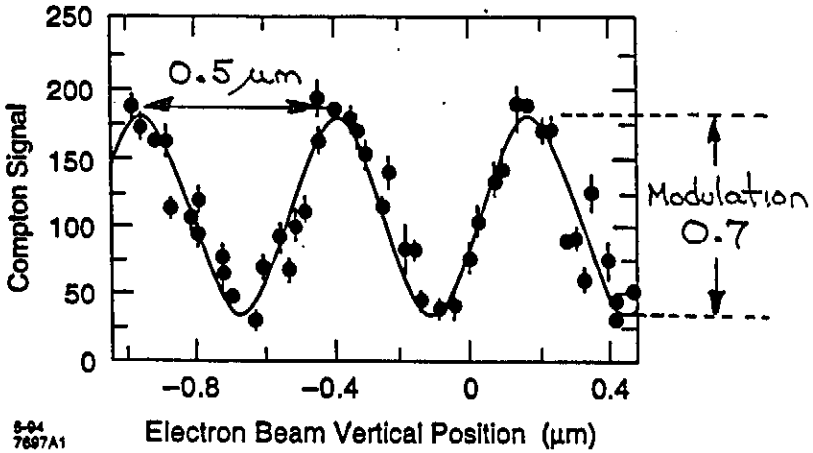


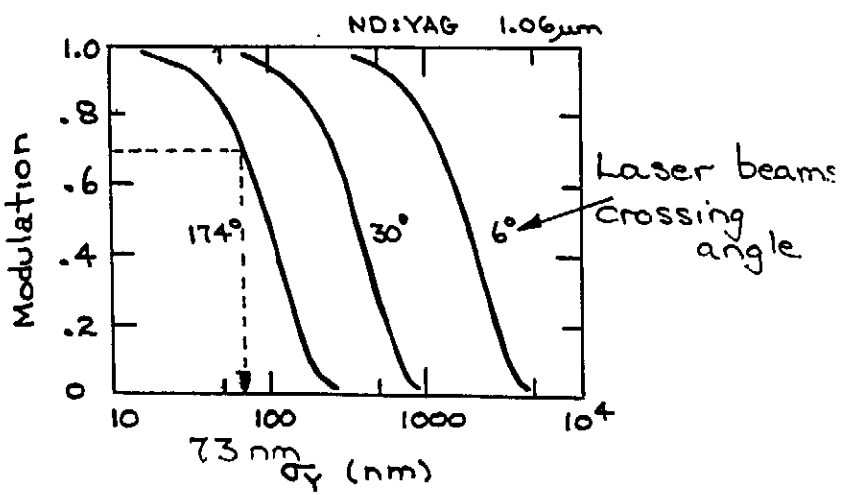


KEK Laser Spot Size Monitor
for
Nanometer Electron Beam Size

Assembled in KAWASAKI Heavy Ind. Japan
Installed in SLAC FFTB

FFTB Laser-Compton



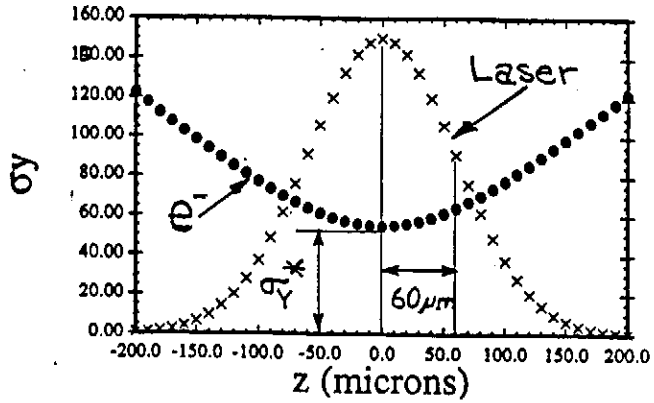


Bunch-Length Correction

$\beta^* = 100\ \mu m$

$\sigma_z = 500\ \mu m$

$\sigma_Y^m \approx 1.1\ \sigma_Y^*$



Error Sources	Error of Spot Size
• Electron Beam Position Jitters (Estimated from size of error bar at slope) $\sigma_{y,jitter} = 25$ nm	+ 5.0 nm
• Laser Beam Position Jitters (Observed on CCD camera) $\sigma_{L,jitter} = \frac{1}{2}\sigma_{L,spotSize} = 30\ \mu m$	
x-direction jitters does not produce substantial error.	~ zero
z-direction jitters results in waist jitters: $\sigma_y^2 = \sigma_{y0}^2 [1 + (\sigma_{L,jitter} / \beta)^2]$	+ 2.6 nm
• Laser Beam Misalignment z-axis : suppose $dz = 30\ \mu m$ Fringe contrast = 98.5 %	+ 2.0 nm
x-axis : suppose laser field intensity imbalance at the electron beam path : $p_2 / p_1 = 1.5$ Fringe contrast = 97.9 %	+ 2.8 nm
• Background Subtraction Error - 2 zero-level error (average γ-ray count = 100)	- 2.5 nm

Uncorrected Systematic Errors

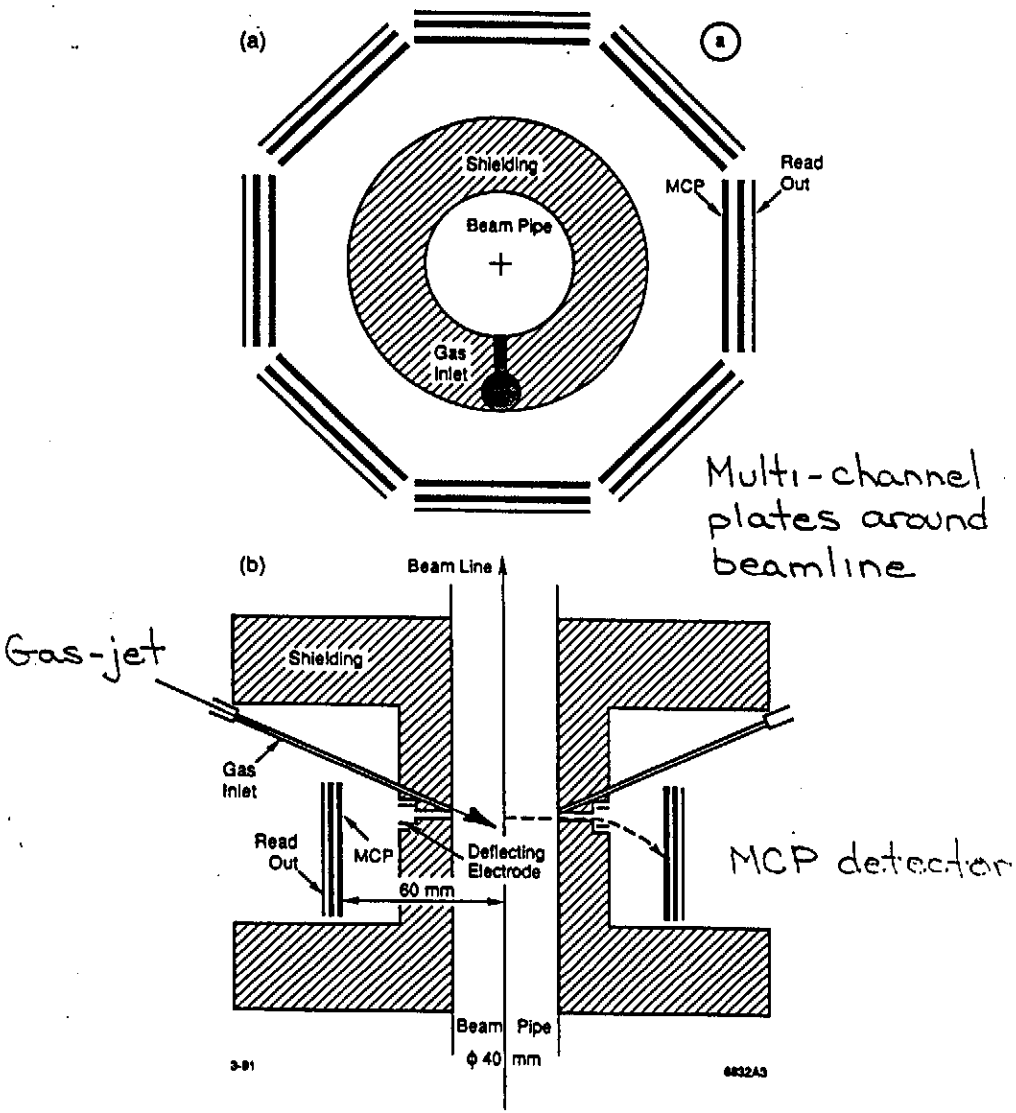
Quadrature:

+ 6.6 nm

- 2.5 nm

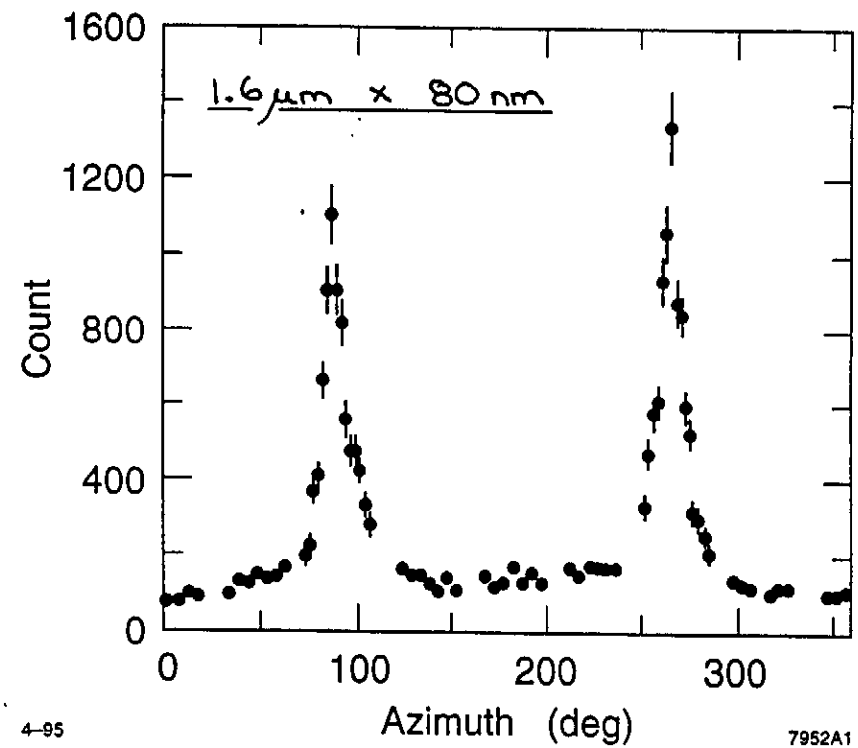
LAL (Orsay)

Spot Size Detector



LAL (Orsay)

Gas-Jet Spot Monitor



Initial Runs

(1994- 1995)

Phys. Rev. Lett. 74, 2479 (1995).

Measured,

$$\sigma_y = 70 \pm 7 \; {}^{+2}_{-7} \text{ nm}$$

(statistical) (systematic)

where ≈ 50 nm spots were expected.

$$\gamma\varepsilon_y \approx 1.5\text{-}2 \times 10^{-6} \text{ rad}\cdot\text{m}$$

In 1995 -1997 we continued to look more carefully at the properties of the beamline ...

Focal Point Chromaticity

$\beta^* = 100\,\mu m$

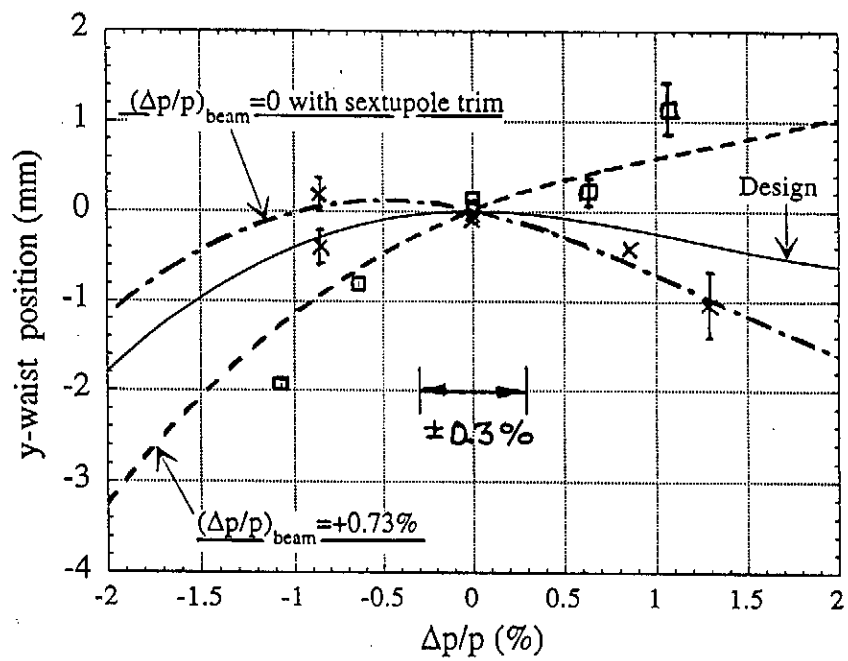
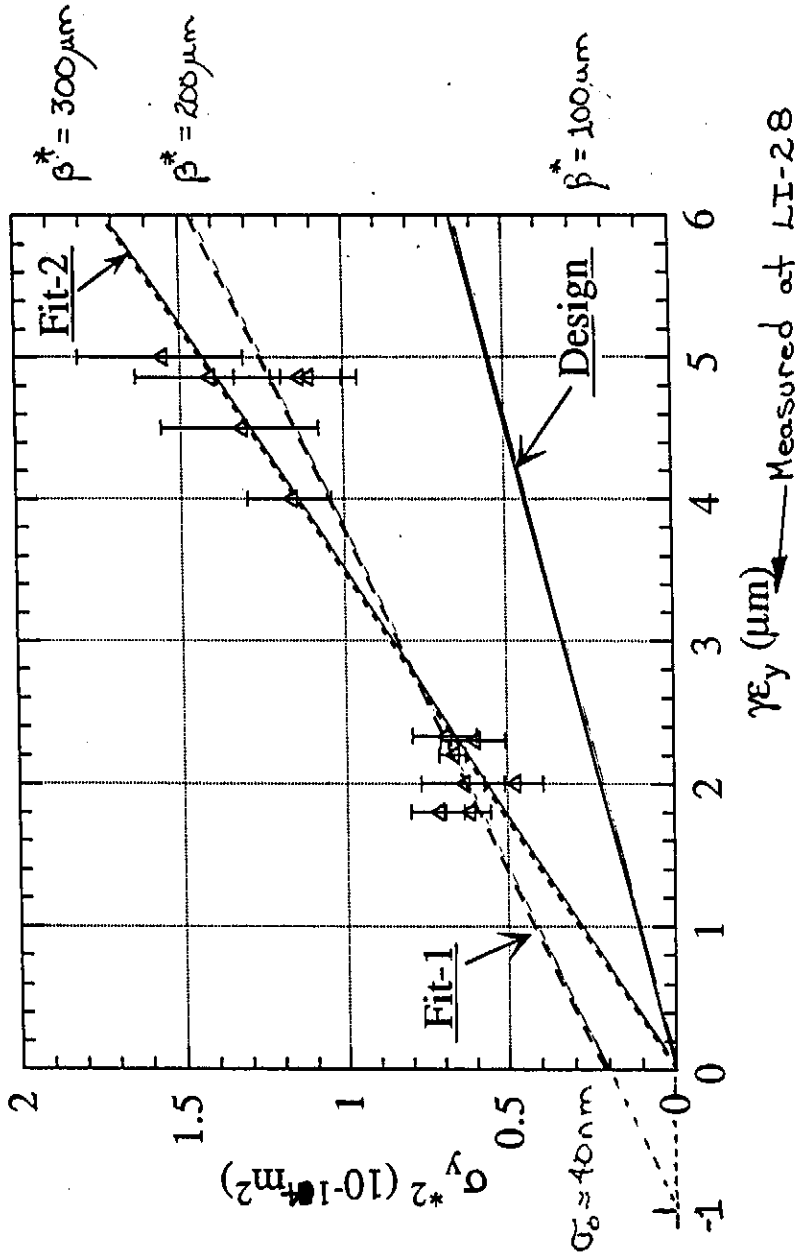


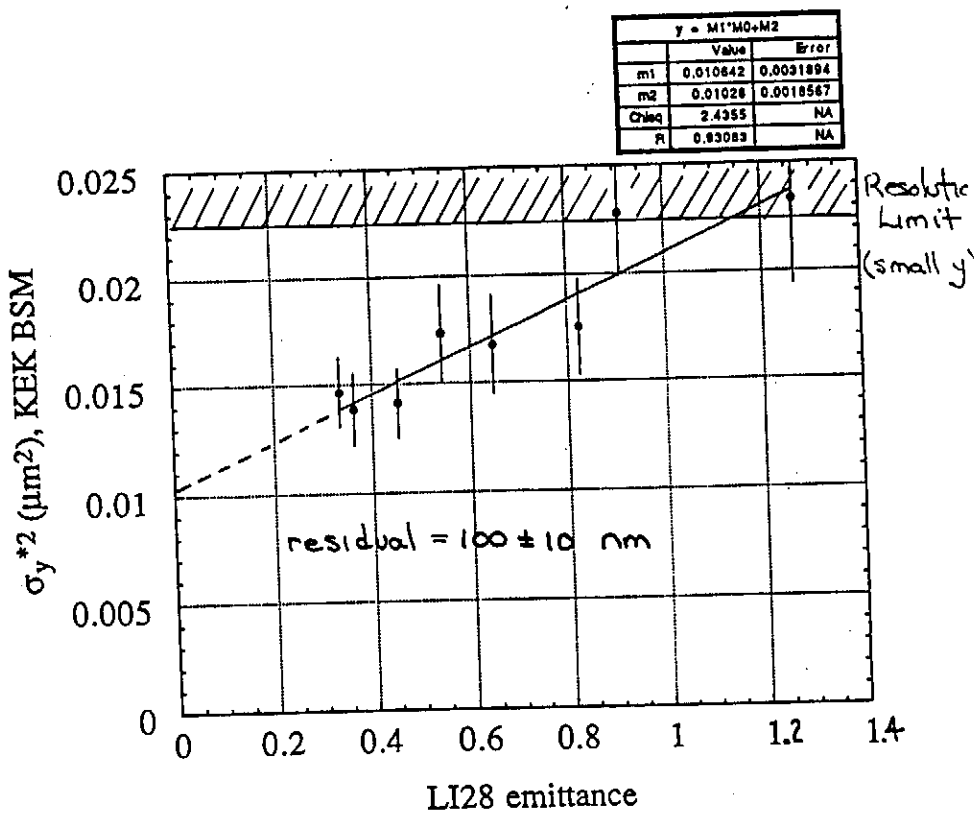
Figure. 5. Shift of the vertical waist position as a function of the momentum offset of the incoming beam, measured at the Laser-Compton monitor. Squares are measured before the correction of the beam-energy offset. Dashed line is expected from the energy offset of +0.73%. The crosses are measured after the correction. The dot-dashed is expected from the trimmed values then applied to the sextupoles. The design is shown by the solid line.

EFTB Geometric Optics (1995)



Final Focal Point — KEKBSM

(May 1997)



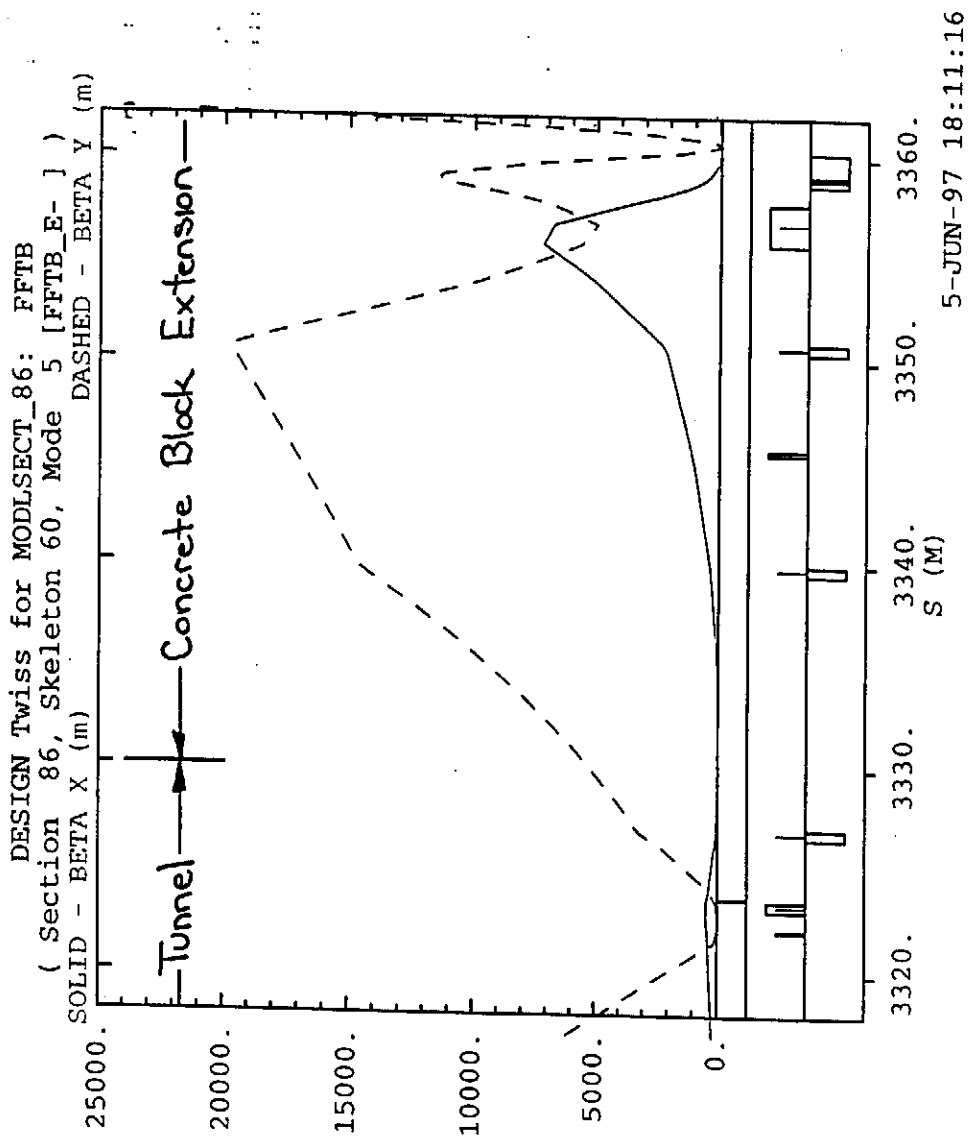
Hypothesis:

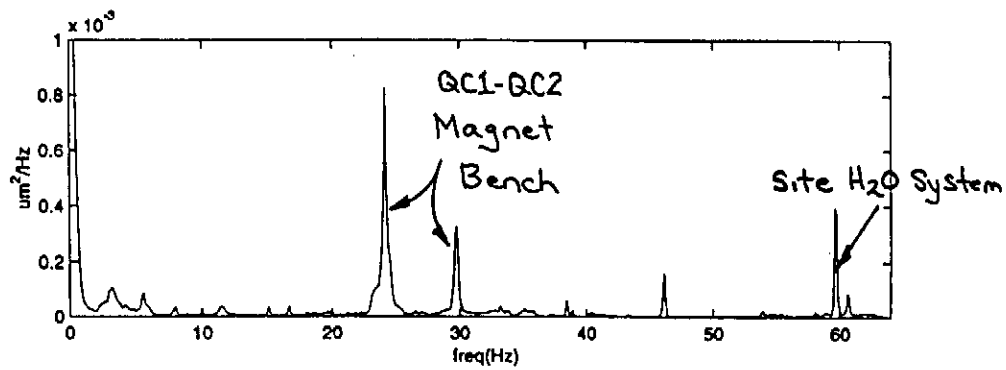
$$\text{Spot} = \underbrace{(\varepsilon_y \beta_y^*) \oplus \mathcal{O}(\delta^3)}_{\text{"ideal"}} \oplus \underbrace{(50\text{nm})}_{\text{"jitter"}} \oplus \underbrace{(60\text{nm})}_{\text{"sextupole aberration"}}$$

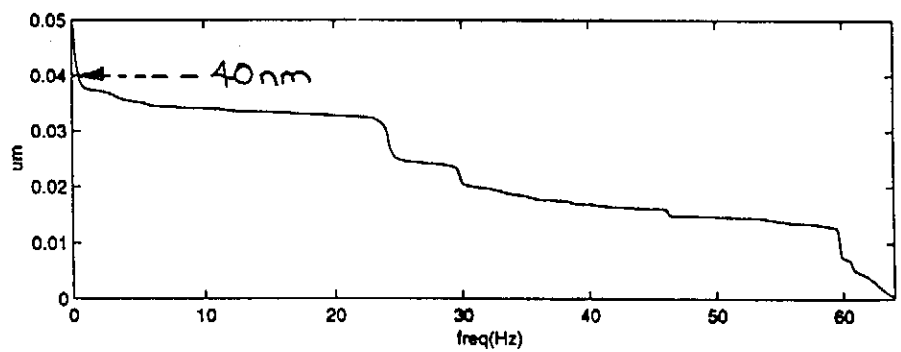
T. Slaton
G. Magaheri

Seismic Survey

RFBPM / Laser Monitor Housing

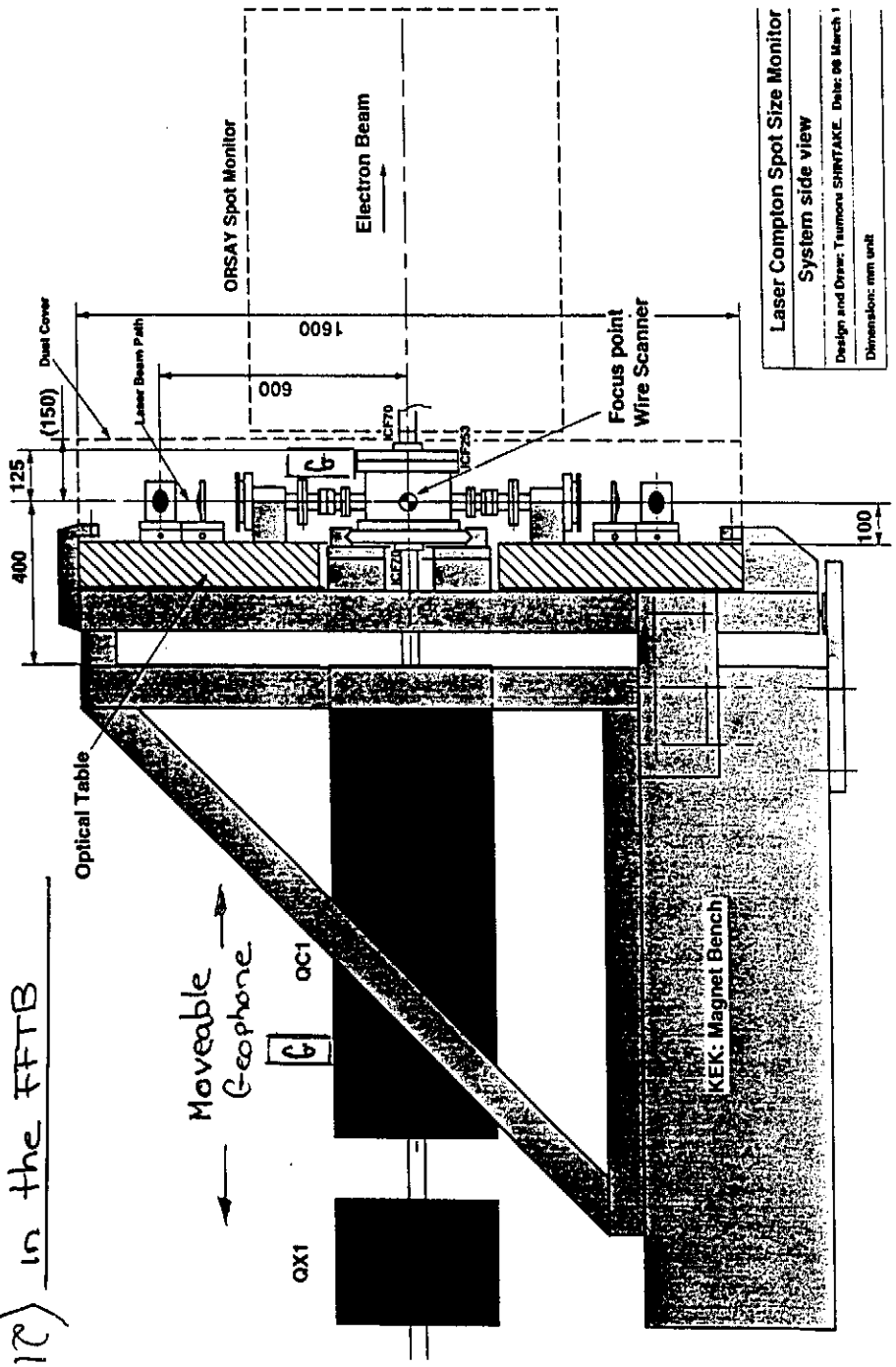






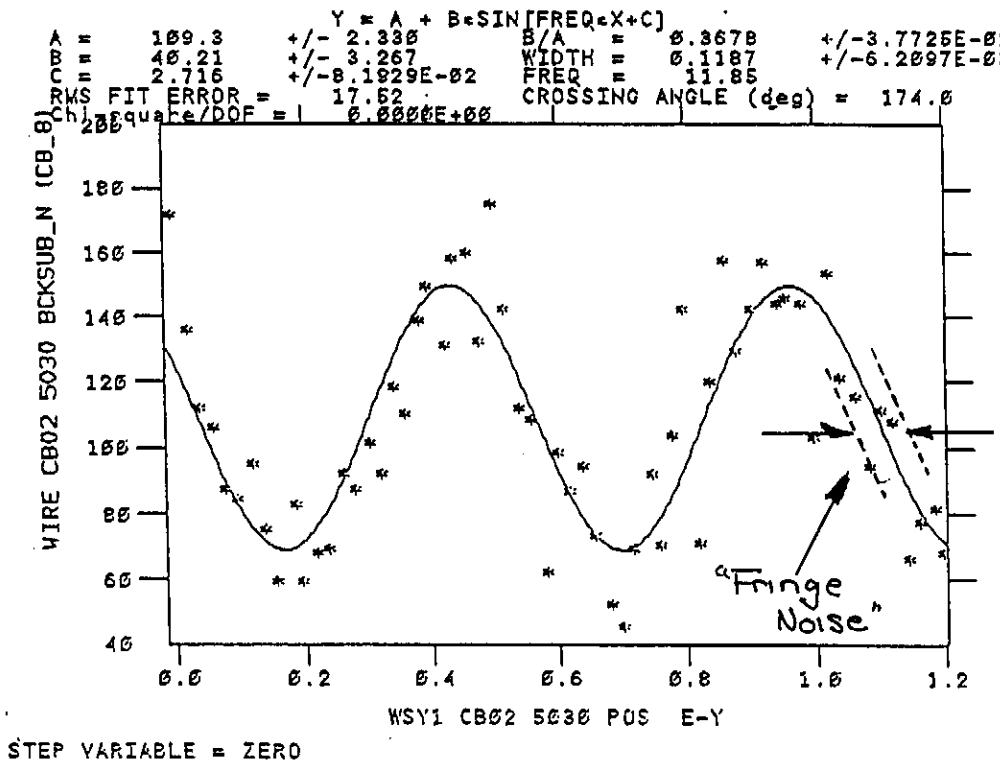
... consistent with "geometric residual".

Seismic Measurements in the FFTB

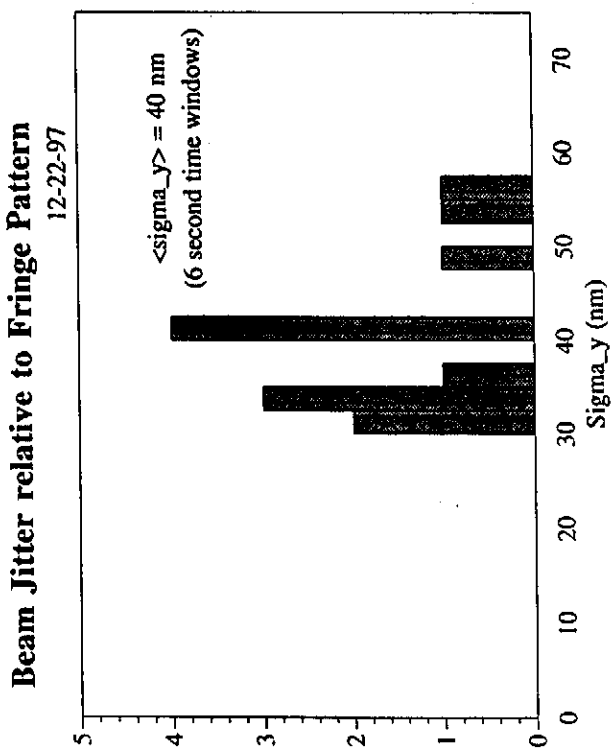


Focal Point – "Fringe Noise"

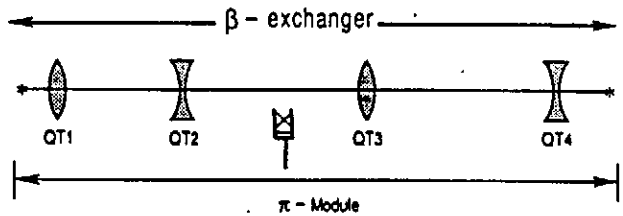
Oide
Raimondi
Woods

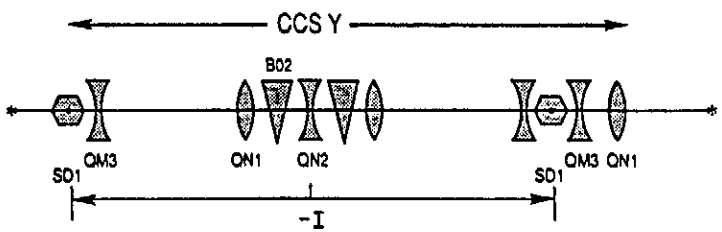


Estimate 30-60 nm of "jitter" (pulse-to-pulse) between fringe pattern and beam (vertical) position.

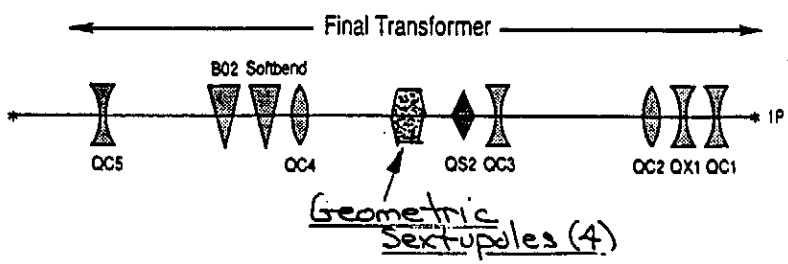


Problem in 1997 Run (May)





→ Unable to tune geometric sextupoles due to misalignment (no movers) !!

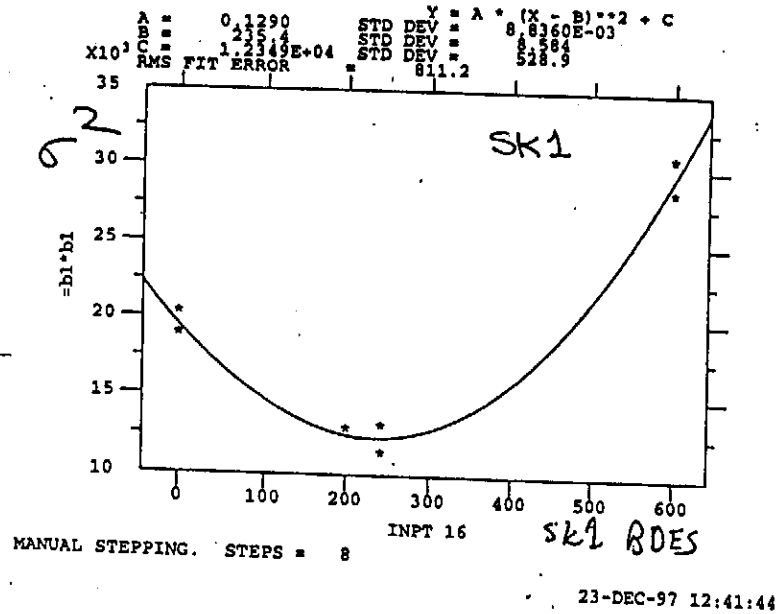


Note: In 1996 Runs these were used to cancel 50-60 nm of aberrations

FTB

December 1997

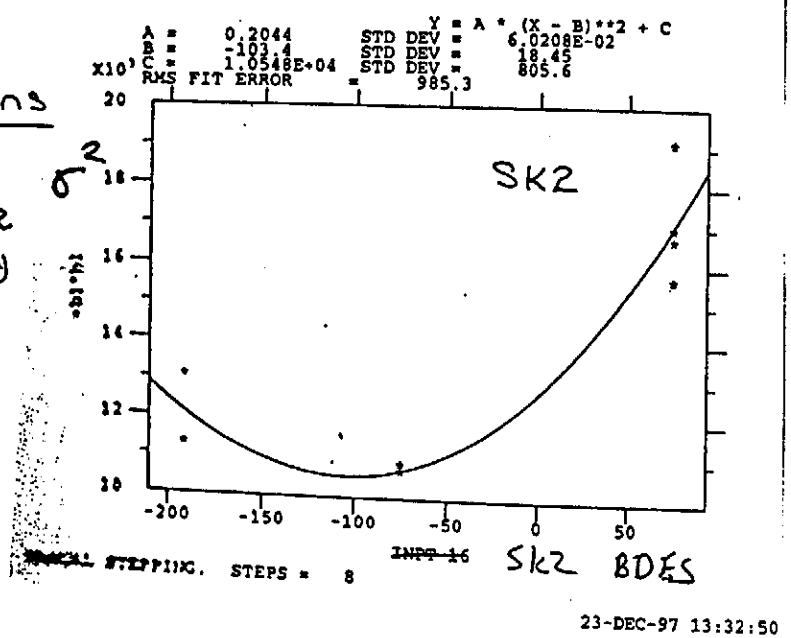
Geometric Sextupole Tuning



Sextupole Aberrations

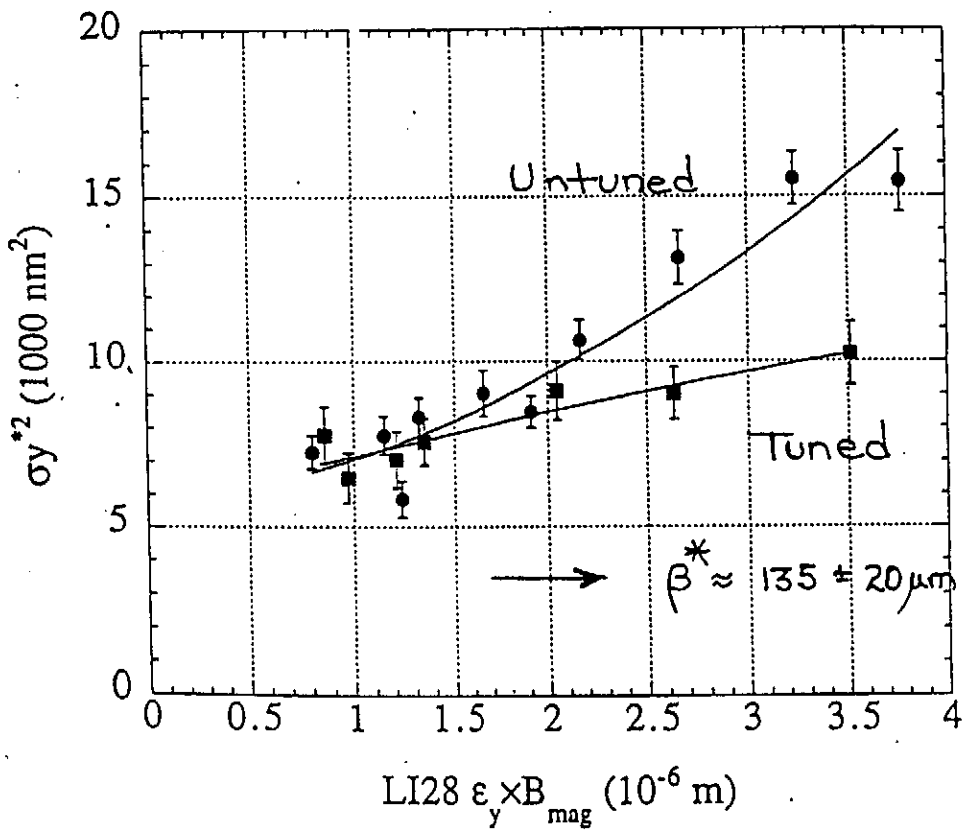
, $\varepsilon_x\varepsilon_y$, ε_y^2

$- \sigma_y^2$).



FFTB Geometric Sextupoles

December 1997



FFTB

December 1997

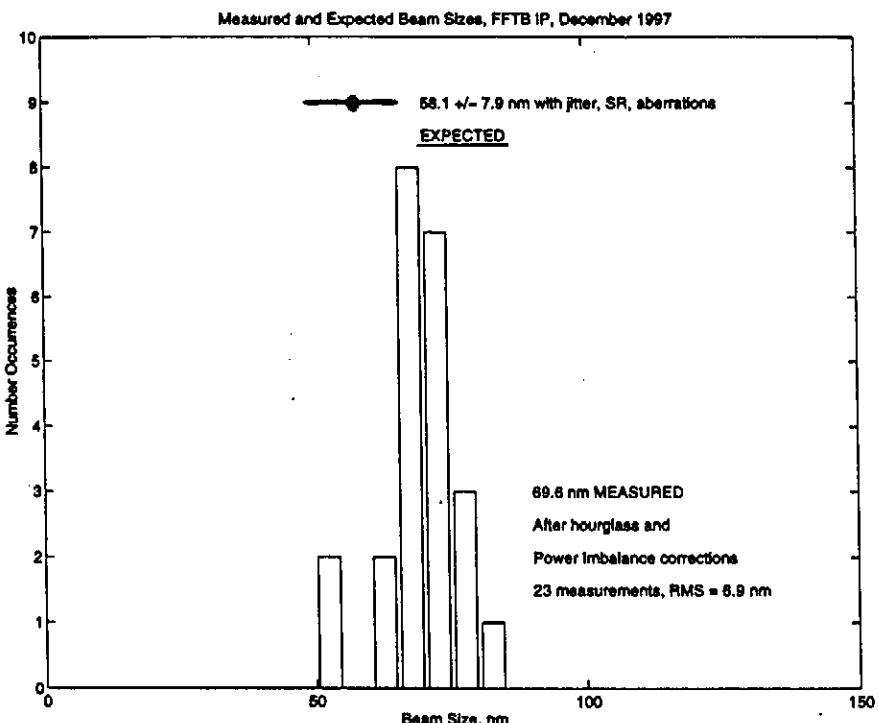


Figure 1: Comparison of measured and expected FFTB beam sizes.

σ_y^* (nm)

→ Successfully demagnified SLC beam by a factor ≈ 350.

Conclusion

The FFTB Collaboration has done what we set out to do.

- Beamline fabrication and operation.
- Instrumentation.
- Optics and tuning techniques.

To go further:

- Rebuild final quadrupoles and supports.
- New final spot monitor.
- Extended periods of running.

→ Spot sizes ~30-40 nm might be possible.

Interactions of Real and Virtual Photons

$\gamma e \rightarrow e^+ e^- e$ — Incoherent pair production (Bethe - Heitler)

$\gamma\ \mathcal{E}m_{coherent} \rightarrow e^+ e^-$ — Coherent pair production (Schwinger)

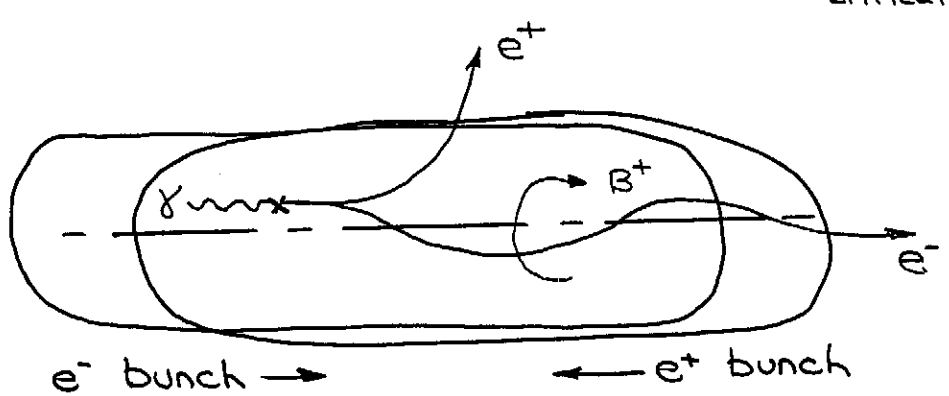
Chen - Telnov

$\gamma\gamma \rightarrow \ell^+ \ell^-$ — (Landau - Lifshitz)

$\rightarrow$ hadrons — Drees

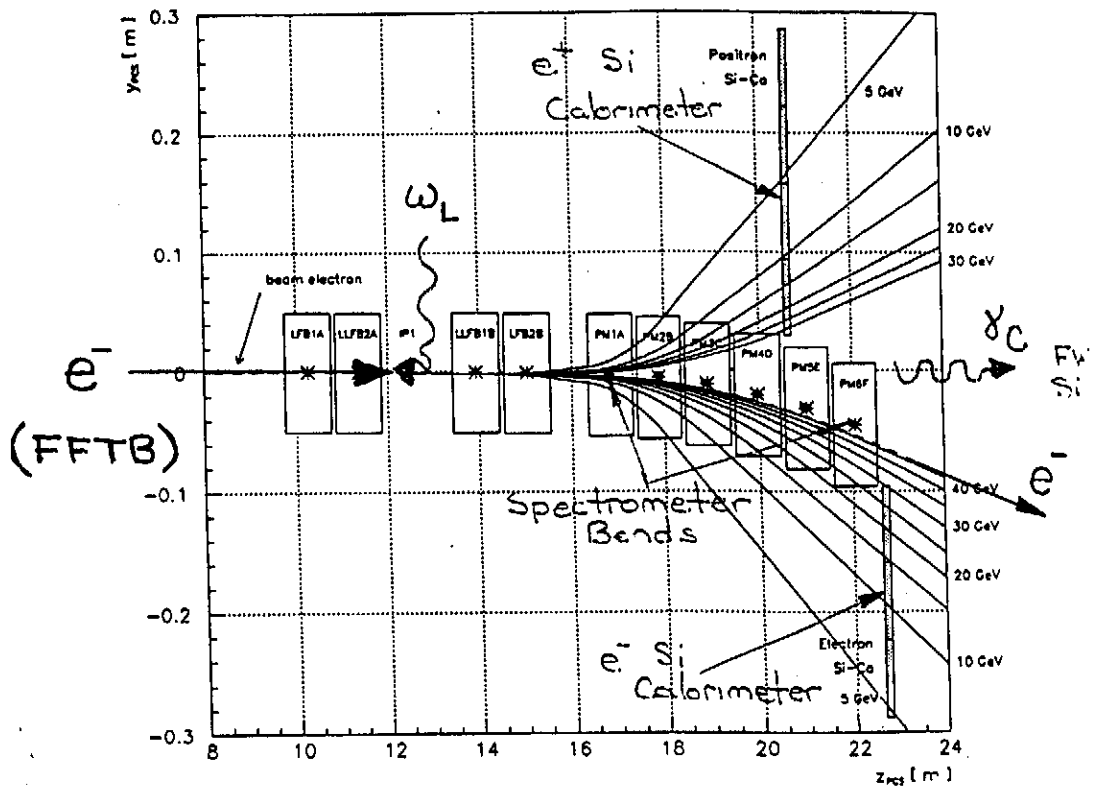
Secondary Trajectories

$$\Upsilon \equiv \frac{\mathcal{E}_{bunch}}{\mathcal{E}_{critical}}$$



E144 Experimental Layout

Princeton / Rochester / SLAC / Tennessee



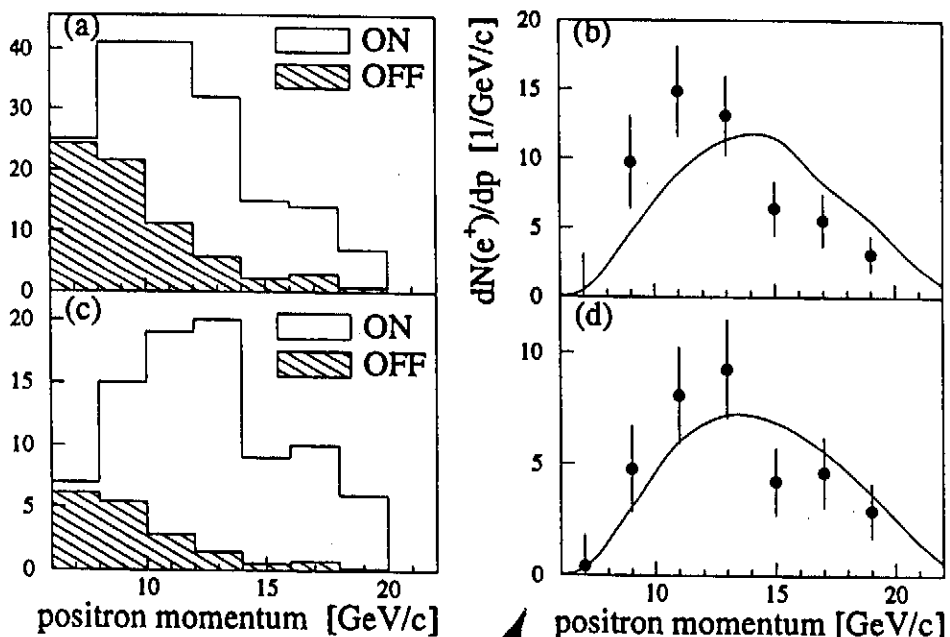
45 GeV electrons collide with Tera-Watt laser pulse → non-linear QED

E144 Non-Linear QED

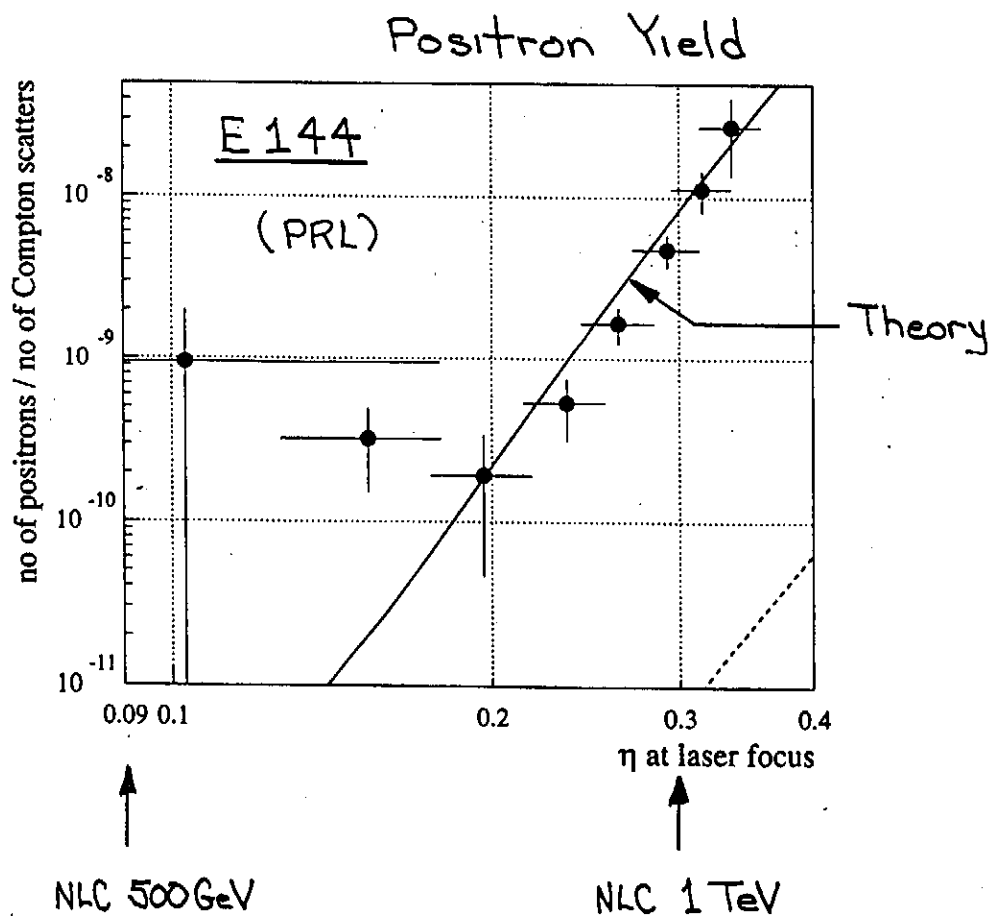
Positron Production

(Uncorrected Data)

August 1997



Curves are expected shape normalized to observed events.



NLC beam-beam environment experimentally achieved.

22