TESLA - COLLABORATION

Transparencies from the

TESLA Input Coupler Workshop, LAL Orsay, January 17 - 18, 2000

March 20000, TESLA 2000-06

TESLA Reports are available from:

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

Phone: (+49/40) 8998 3339
Fax: (+49/40) 8998 4302
e-mail: katrin.lando@desy.de

TESLA Input Coupler Workshop at LAL Orsay, January 17 - 18, 2000

Programme

3rd Joint DESY-LAL Saclay Workshop on High Power Couplers for TESLA

Monday 17th - Salle Bleue (Bât. 200)

09:30		**Introduction**
9:45 - 10:00	J. Sekutowicz	Update on coupler specification for the T Superstructure
10:00 - 10:25	B. Dwersteg	Coaxial input coupler design for the TTF Superstructure
10:25 - 10:55		Coffee Break
10:55 - 11:20	M. Dohlus	Design of waveguide couplers for the TESLA Superstructure
11:20 - 11:45	A. Zavadtsev	A rectangular waveguide input coupler for the Superstructure
11:45 - 12:15	P. Lepercq	Low level measurements of reduced height waveguide transition
12:15 - 13:45		Lunch
13:45 - 14:15	L. Grandsire	The Orsay - Saclay coupler design
14:15 - 14:45		**General discussion on new coupler designs**
14:45 - 15:10	D. Kostine	TTF linac ACC1 (module 3) input coupler performance
15:10 - 15:30	C. Martens	Experience with manufacturing coaxial input couplers for TESLA
15:30 - 16:00		Coffee Break
16:00 - 16:45	C. Travier	Results from the TW window tests (titanium version)
16:45		**General discussion**

Tuesday 18th - Salle Bleue (Bât. 200)

9:30 - 9:50	M. Lalayan	Argon discharge treatment of TTF input
9:50 - 10:15	S. Iariguine	Conditioning of TTF input couplers
10:15 - 10:45		Coffee Break
10:45 - 11:15	C. Travier	Results of the tests on the second $\lambda/2$ window
11:15 - 11:35	N. Rouvière	Conditioning couplers and preventive measures
11:35 - 12:05		**Open discussion on conditioning**
12:05 - 12:30	G. Devanz	Multipactor simulations
12:30 - 14:00		Lunch
14:00 - 14:20	D. Proch	Multipacting measurement with a TiZrV coated Cu sample
14:20 - 14:45	A. Zavadtsev	RF losses in a Cu surface with TiZrV coating
14:45 - 15:10	J. Lorkiewicv	Recent activities in TiN coating of ceramic RF power elements at DESY
15:10 - 15:40		Coffee Break
15:40		**AOB** **Future developments** **Conclusions**

25th February, 2000.

Summary of the TESLA Input Coupler Workshop,

Laboratoire de l'Accelerateur Lineaire, Orsay 17th and 18th January, 2000.

This meeting was the third in a series of joint Orsay - Saclay - DESY workshops on the input coupler. The aims of these meetings are to exchange ideas and to share information obtained on the respective coupler test stands at DESY and Saclay. The specification of the TESLA coupler is continuously changing in response to the changing parameters of the machine. Calculations (Sekutowicz) show that, if the cavity stiffening cannot be increased, the superstructure would need to transmit 2.6 MW for the parameters of TESLA 800 ! Clearly increased stiffening is absolutely necessary.
Various new coupler designs were presented. ;

- an upgraded version of the DESY co-axial coupler intended for the superstructure (Proch),
- Computational studies of waveguide couplers (Dohlus, Zavadtsev) ,
- The co-axial design from the French collaboration (Grandsire).

The Orsay-Saclay coupler proposal provoked little criticism from the meeting participants implying that the principle of the design is considered reasonable. It employs a reduced height waveguide transition for which some low level measurements were presented. A high power test is foreseen in March. The choice of cold window for the French design is still undecided. The existing candidates are (i) the $\lambda/2$ window, (ii) the travelling wave window, and (iii) a DESY-like cold window. A rather new topic of discussion was a comparison of the degree of RF « kick » transmitted to the beam by the co-axial and waveguide options. This has still to be assessed.

The DESY group have now obtained considerable experience with coupler manufacturing (Martens), conditioning (Iariguine) and testing on modules with the TESLA Test Facility (Kostine). The talk by Martens illustrated the numerous procedures necessary to produce the finished object – machining, cleaning, welding, brazing, copper plating, metallisation, TiN deposition etc.. The French group still have the pleasure of this work ahead of them.
The results of the first tests of a TW wave window were shown (Travier). The relative merits and disadvantages of such a window were outlined. The window was tested both in SW and TW operation and illustrated a rather fast conditioning time to 1 MW. Nevertheless some multipactor barriers persist although these are thought to be due to the co-axial line.
Conditioning couplers remains a subject of great importance as experience to date shows that it takes far too long. Tests on TTF couplers at DESY seem to indicate that an argon discharge treatment can reduce the conditioning period (Lalayan). Many of the conditioning issues in the coupler have similarities with conditioning of vacuum systems for electron storage rings. Studies at the ESRF have demonstrated hysteresis effects after conditioning with RF power and baking (Rouvière). The importance of cleanliness and venting under dry nitrogen was noted if one wishes to preserve, at least partially, the effects of conditioning.

Vacuum pumping might be improved by Non-Evaporable Getter (NEG) pumps. Work at CERN, by Ch. Benvenutti, is in progress on thin film NEG coatings (D. Proch). However, the question of RF losses in the coating and creation of « dust » particles has to be answered. There are indications that such a coating might be useful in the struggle against multipactor. A new 2-D code was described for the calculation of multipactor. The code has been written to study multipacting in proton linac cavities but will be useful also for window studies. It would be nice to have a comparison between this code and the Helsinki code for a given problem. A likely candidate for an NEG coating would be compounds of TiZr. Calculations and measurements of RF losses for a coating of TiZrV are being performed at DESY (Zavadtsev). Preliminary results show that the increased RF losses might be acceptable in view of the advantages gained for conditioning and multipactor. TiN coating of ceramics is essential to avoid multipactor. The French group have established a coating procedure along with an industrial partner, as discussed in an earlier meeting. In contrast, DESY perform their own TiN coating. Experience with coating waveguide windows and cylindrical coupler windows with Ti in the vapour phase was discussed and the apparatus described (Lorkiewicz).

Action points

It was agree that by the next meeting we would attempt to ;

- Establish a data base for ceramics (All institiutes).
- Find a way to validate multipactor codes (Travier, Proch).
- Evaluate the transverse kick given to the beam (M. Dohlus).
- Set up a measurement of ε and tan δ (DESY).
- Learn as much as we can about conditioning from experience on e+e- storage rings.

The next meeting should take place at DESY in September 2000.

T. Garvey, Orsay 25-02-2000

Workshop Participants

M. Dohlus	DESY
S. Iariguine	
D. Kostine	
M. Lalayan	
J. Lorkiewicz	
C. Martens	
W.D. Möller	
D. Proch	
J. Sekutowicz	
A. Zavadtsev	
J.C. Bourdon	LAL-Orsay
T. Garvey	
L. Grandsire	
P. Lepercq	
J. Le Duff	
G. Mace	
J. Marini	
R. Panvier	
F. Richard	
B. Aune	CEA-Saclay
P. Boachon	
S. Chel	
N. Colombel	
M. Desmons	
G. Devanz	
C. Travier	
T. Junquera	IPN-Orsay
N. Rouvière	

UPDATE ON INPUT COUPLER SPECIFICATION FOR THE TESLA SUPERSTRUCTURE

J. Sekutowicz, DESY

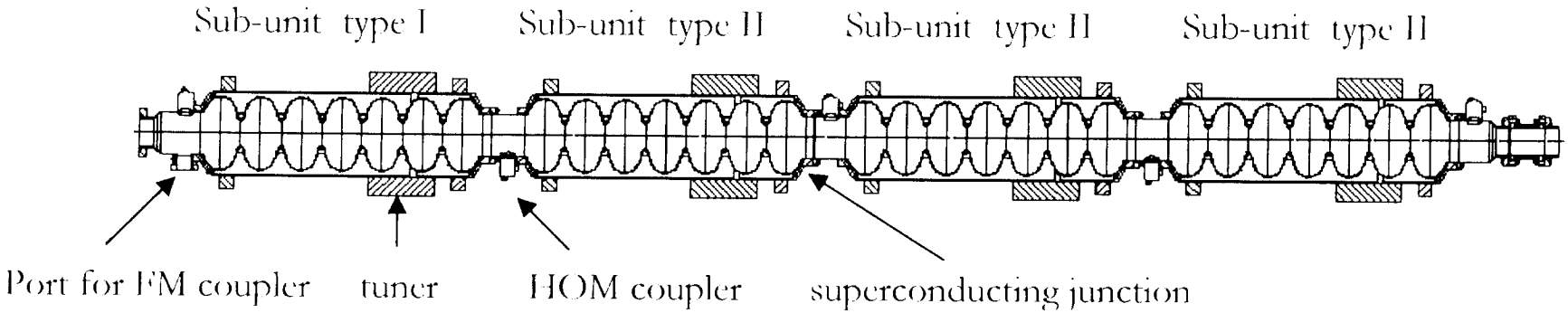
4

I Schedule for the first Nb prototype and specification for the FM coupler

II FM coupler for the TESLA 500 and TESLA 800: Specification

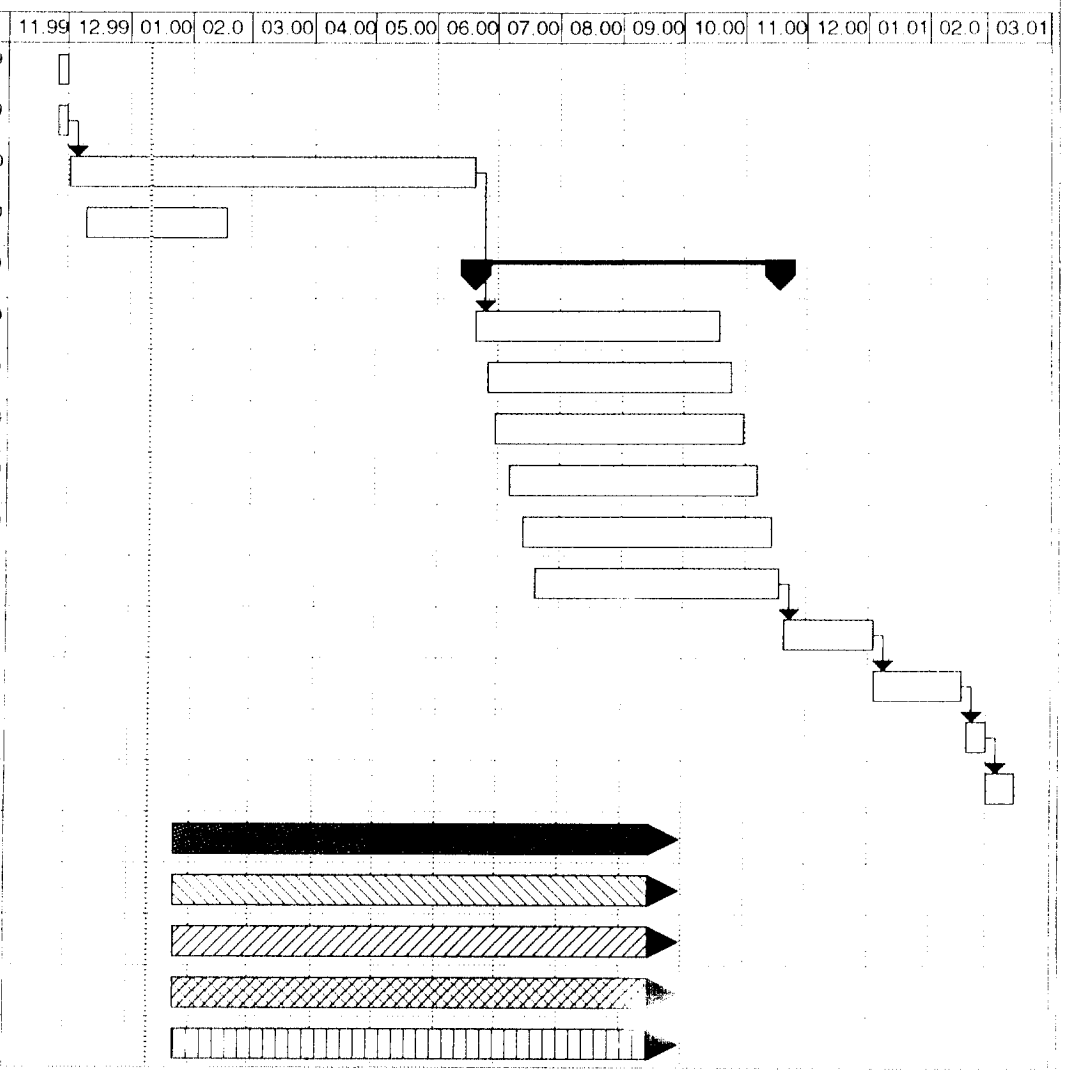
I Schedule for the first Nb prototype and the specification for FM coupler

5



13:23 Di 11.01.00

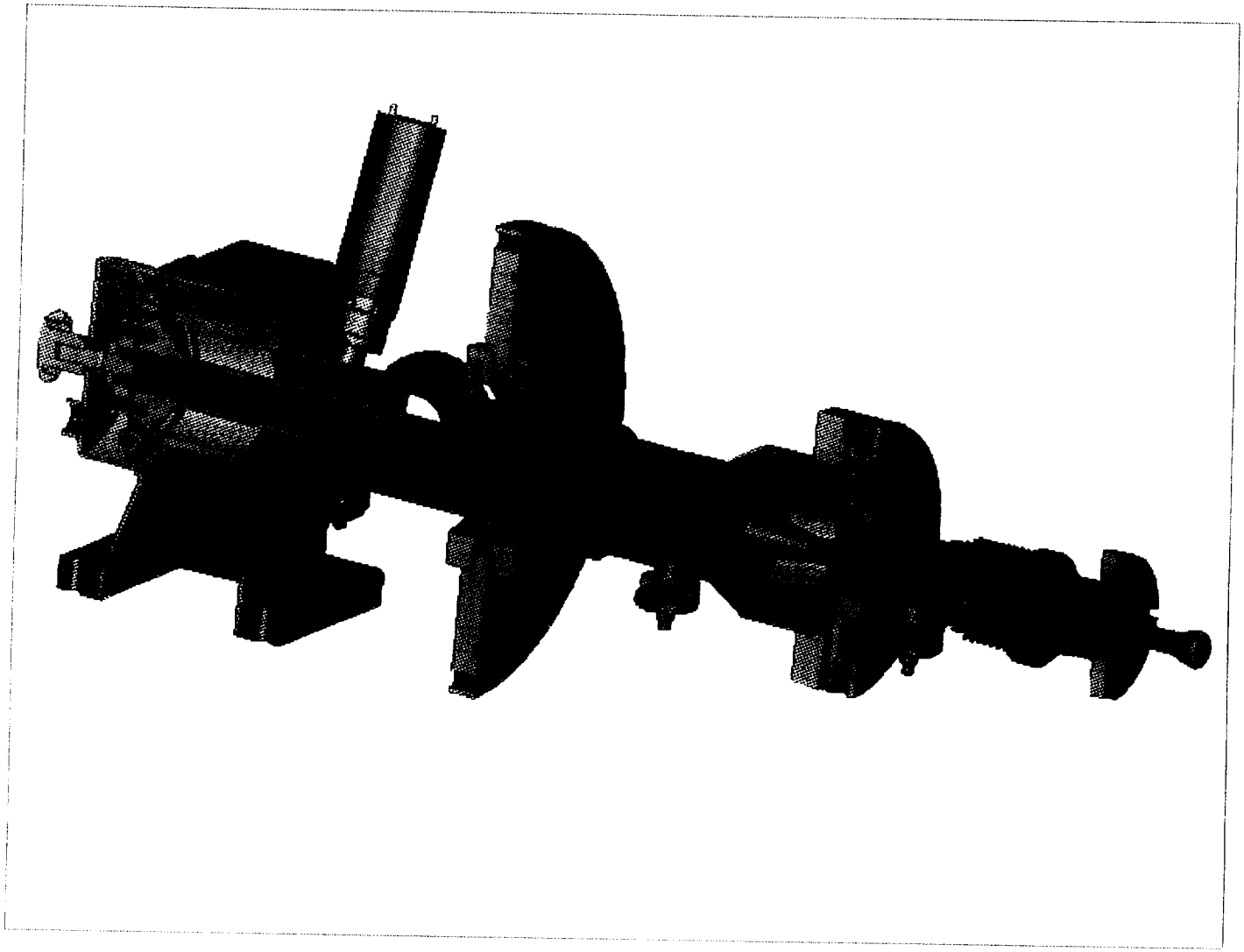
Nr.	Vorgangsname	Dauer	Anfang	Ende
1	62 Nb sheets + Nb Tubes+NbTi to Zanon	3 Tage	Fr 26.11.99	Di 30.11.99
2	30 Nb sheets to Soltan Institut	3 Tage	Fr 26.11.99	Di 30.11.99
3	Cavity Production by Zanon ->Deliv.DESY	143 Tage	Do 02.12.99	Mo 19.06.00
4	End -cups deep drawing at Soltan Inst.	50 Tage	Fr 10.12.99	Do 17.02.00
5	Preparation and test of 6 sub-units	112 Tage	Di 20.06.00	Fr 17.11.00
6	Cavity #1: Prepar/Test/Lhe vessel welding	90 Tage	Di 20.06.00	Mi 18.10.00
7	Cavity #2: Prepar/Test/Lhe vessel welding	90 Tage	Mo 26.06.00	Di 24.10.00
8	Cavity #3: Prepar/Test/Lhe vessel welding	90 Tage	Fr 30.06.00	Mo 30.10.00
9	Cavity #4: Prepar/Test/Lhe vessel welding	90 Tage	Fr 07.07.00	Mo 06.11.00
10	Cavity #5: Prepar/Test/Lhe vessel welding	90 Tage	Fr 14.07.00	Mo 13.11.00
11	Cavity #6: Prepar/Test/Lhe vessel welding	90 Tage	Do 20.07.00	Fr 17.11.00
12	Cryomodul Assembly	33 Tage	Mo 20.11.00	Mi 03.01.01
13	Installation in Linac	32 Tage	Do 04.01.01	Fr 16.02.01
14	cooldown/Low RF measurements, Callibration,...	8 Tage	Mo 19.02.01	Mi 28.02.01
15	Beam test	10 Tage	Do 01.03.01	Mi 14.03.01
16	1 Quadrupole/Feedthroughs/Pickups/Cables/...	180 Tage	Mo 24.01.00	Fr 29.09.00
17	5 Tuner	180 Tage	Mo 24.01.00	Fr 29.09.00
18	4 Lhe Vessels	180 Tage	Mo 24.01.00	Fr 29.09.00
19	1 Cryostat	180 Tage	Mo 24.01.00	Fr 29.09.00
20	Input Coupler DESY TTF III	180 Tage	Mo 24.01.00	Fr 29.09.00



Projekt: &[Nb prototype of the superst
Datum: &[ab 29.11.1999]

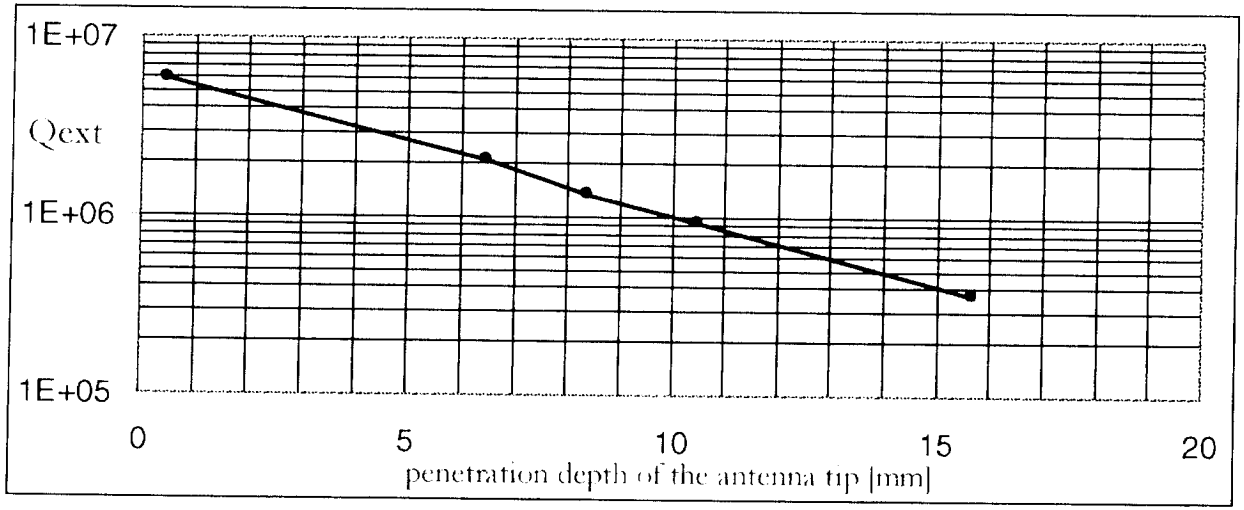
Vorgang		Sammelvorgang		Rollup in Arbeit	
Unterbrechung		Rollup-Vorgang		Externe Vorgänge	
In Arbeit		Rollup-Unterbrechung		Projekt-Sammelvorgang	
Meilenstein		Rollup-Meilenstein			

- the superstructure will be fed by one coaxial coupler of the DESY TTF III type,



- the coupler will be placed 45 mm apart from the end cell (axial position), the radial position is changed because new beam tube has bigger radius by 18 mm,

- penetration depth of the antenna tip for **Q_L=2.5·10^6 is 5÷6 mm** (similar to 9-cell cavities),



- the only modification is a new shape of the flange used for assembly in the cryostat (C. Martens).

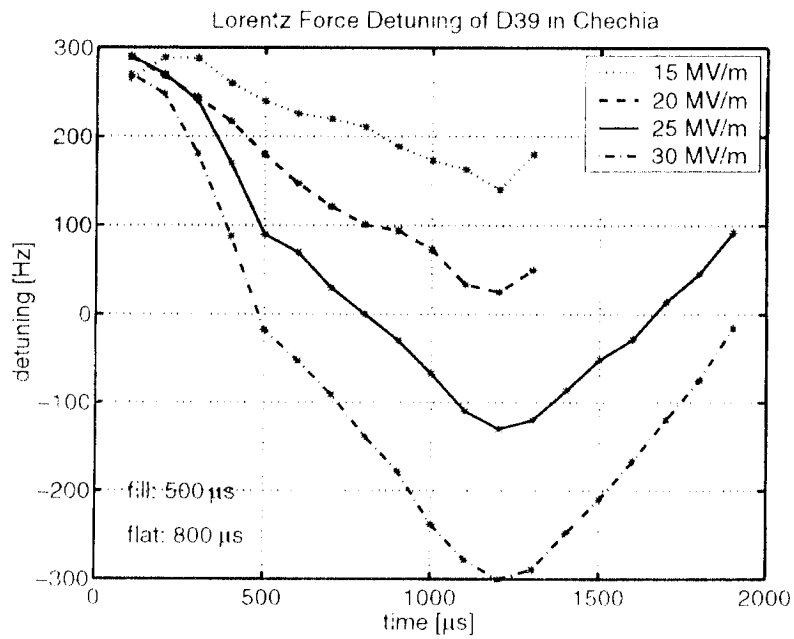
The FM coupler specification for the beam test of Nb prototype (February / March 2001)

$\mathbf{I_b}$ max = **8mA**, $\mathbf{Q_L = 2.5 \cdot 10^6}$ (nominal value for TESLA 500),

thus the operating voltage V (gradient E) and the beam power P_b are:

$$\mathbf{V} = (R/Q)\cdot Q_L \cdot I_b = 2928\ \Omega \cdot 2.5 \cdot 10^6 \cdot I_b = \mathbf{58.6\ MV},$$
$$\mathbf{E} = V/L = 58.6\ MV/(3.228m) = \mathbf{18.2\ MV/m},$$
$$\mathbf{P_b} = V \cdot I_b = \mathbf{468.8\ kW}.$$

Expected total Lorentz detuning after 1300 μs at 18.2 MV/m will be about 200 Hz



The total input power including power needed to compensate for the Lorentz detuning will be :

$$\mathbf{P_{in}} = P_b \cdot [\,1+0.25\cdot(200\mathrm{Hz}\cdot Q_L/f)^2] = 468.8\ \mathrm{kW}\cdot[1+0.037] = \mathbf{486\ kW}$$

II FM coupler for TESLA 500 and TESLA 800: Specification

TESLA 500, based on 4x7cell superstructure :

I_b max = 9.5 mA, V = 70.1 MV/superstructure, E= 21.7 MV/m

$\mathbf{Q_L = 2.52 \cdot 10^6}$, $\Delta f = f/Q_L = 516$ Hz,

$P_b = 9.5\ \text{mA} \cdot 70.1\ \text{MV} = 666$ kW.

Expected Lorentz detuning ($k=1\text{Hz}/(\text{MV/m})^2$) will be 300 Hz

$$\mathbf{P_{in}} = P_b \cdot |\, 1+0.25\cdot(300\text{Hz}\cdot/\Delta f\ )^2| = 666\ \text{kW} \cdot |1+0.085| = \mathbf{723\ kW}$$

TESLA 800, based on 4x7cell superstructure:

I_b max = 11.9 mA, V = 112.2 MV/superstructure, E= 34.7 MV/m

$\mathbf{Q_L = 3.2 \cdot 10^6}$, $\Delta f = f/Q_L = 406$ Hz,

$P_b = 11.9$ mA $\cdot$ 112,2 MV = 1335 kW.

Expected Lorentz detuning ($k=1\,\mathrm{Hz}/(\mathrm{MV/m})^2$) will be 768 Hz

$$\mathbf{P_{in}} = P_b \cdot [\,1+0.25\cdot(768\ \mathrm{Hz}/\Delta f)^2] = 1335\ \mathrm{kW} \cdot [1+0.89] = \boxed{\mathbf{2529\ kW}}$$

LABORATOIRE
DE L'ACCÉLÉRATEUR
LINÉAIRE

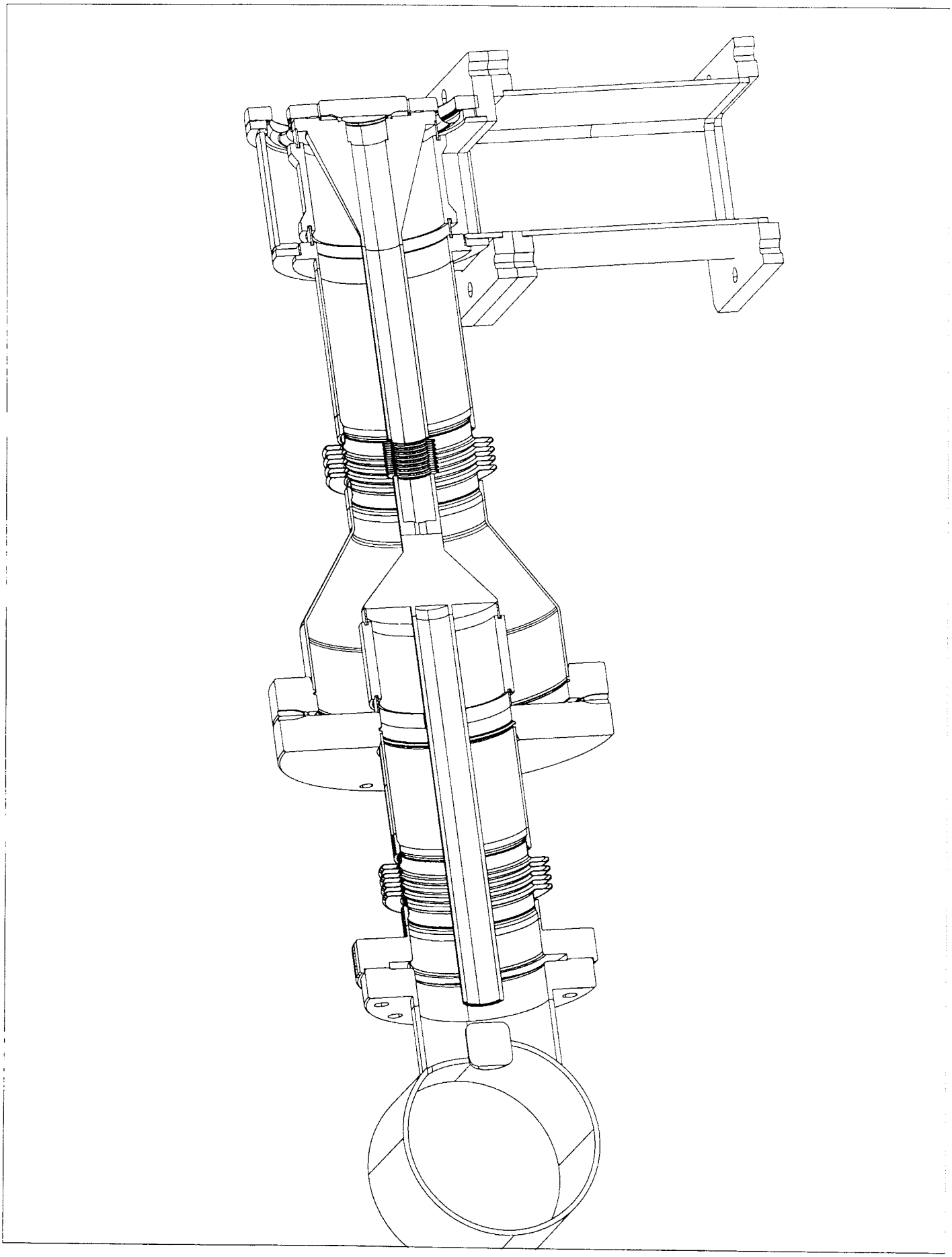
3rd Joint DESY – LAL – Saclay Workshop on High Power Couplers for TESLA

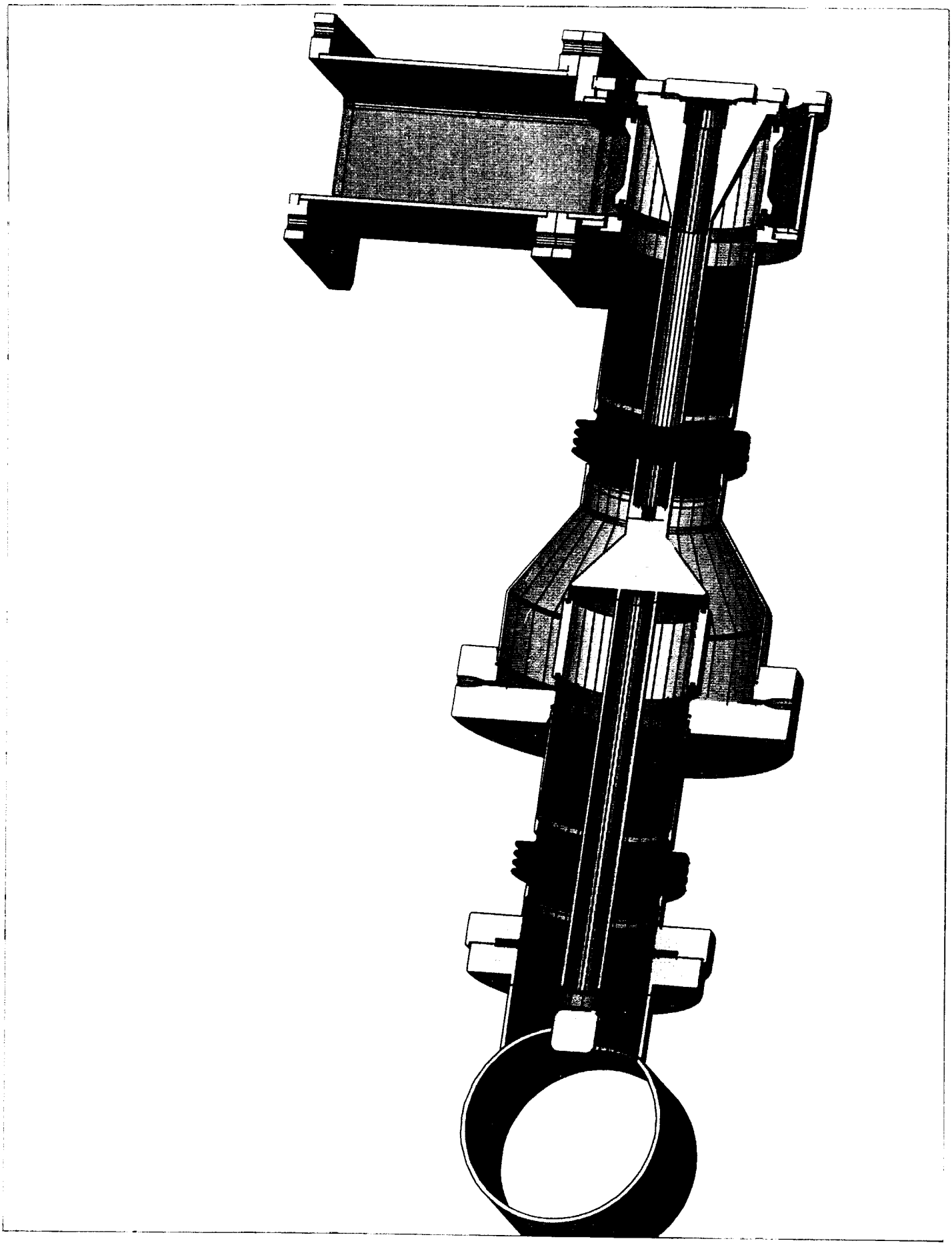
LAL – Orsay, 17th and 18th January 2000

D. PROCH

(B. Dwersteg)

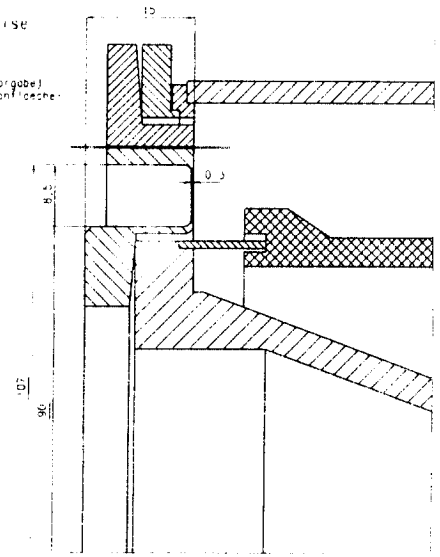
13





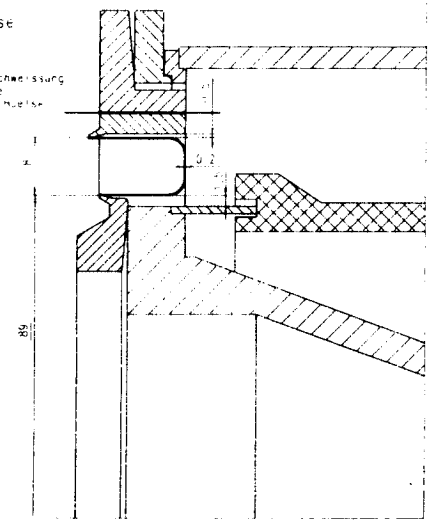
Membrane,
Integralbauweise

V: Anzahl Teile,
Montage
(HF-Sollform, Vorgabe)
N: Drehen d. Membranflaeche

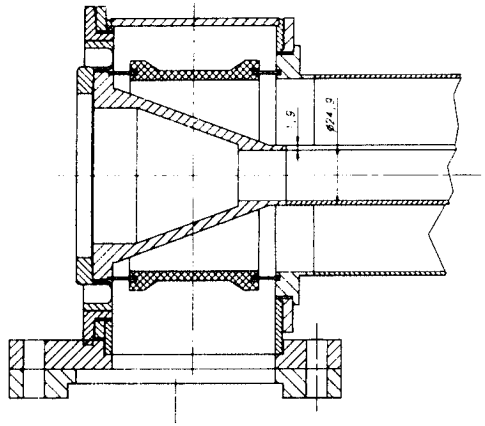


Membranhülse
geschweißt

V: einfache Schweissung
N: Abdeckringe
zentriegung Huelse

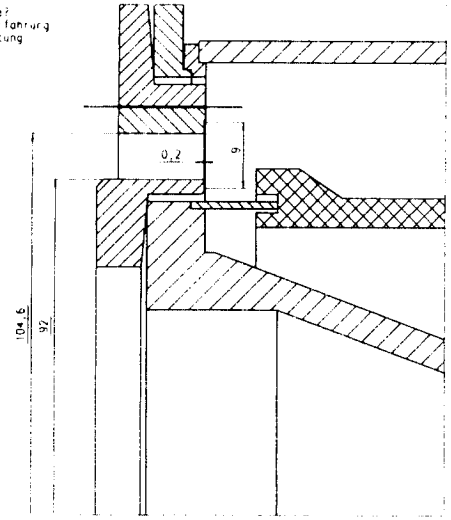


M 1 1

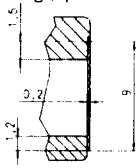


Membrane,
eben gelötet

VT: Arbeitsschritte?
NT: bisher keine Erfahrung
bei Membranloetung

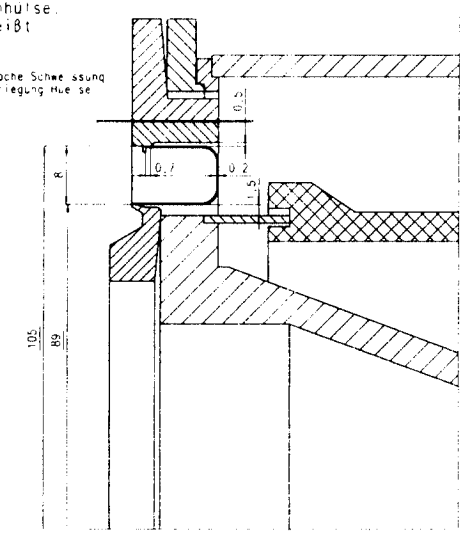


5:1



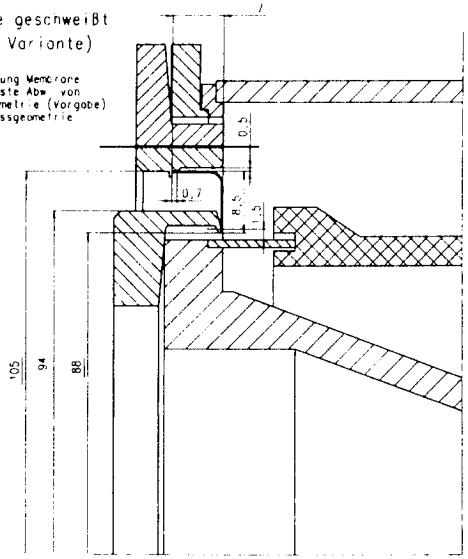
Membranhülse
geschweißt

VT: einfache Schweissung
NT: zentriegung Huelse



Membrane geschweißt
(erste Variante)

V: Fertigung Membrane
geringste Abw. von
HF-Geometrie (Vorgabe)
N: Schweissgeometrie



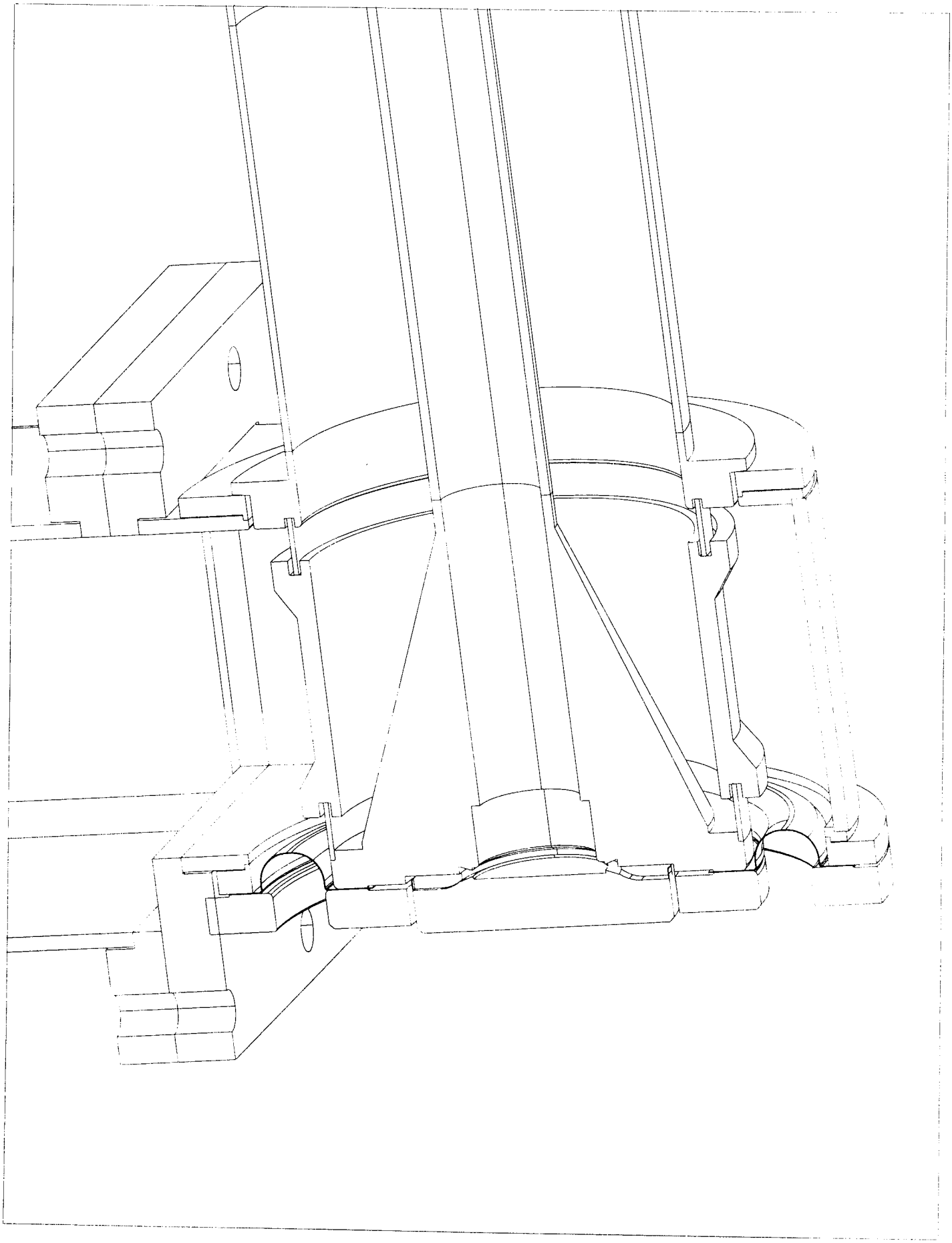
Maßstab 3:1 (1:1, 5:1)

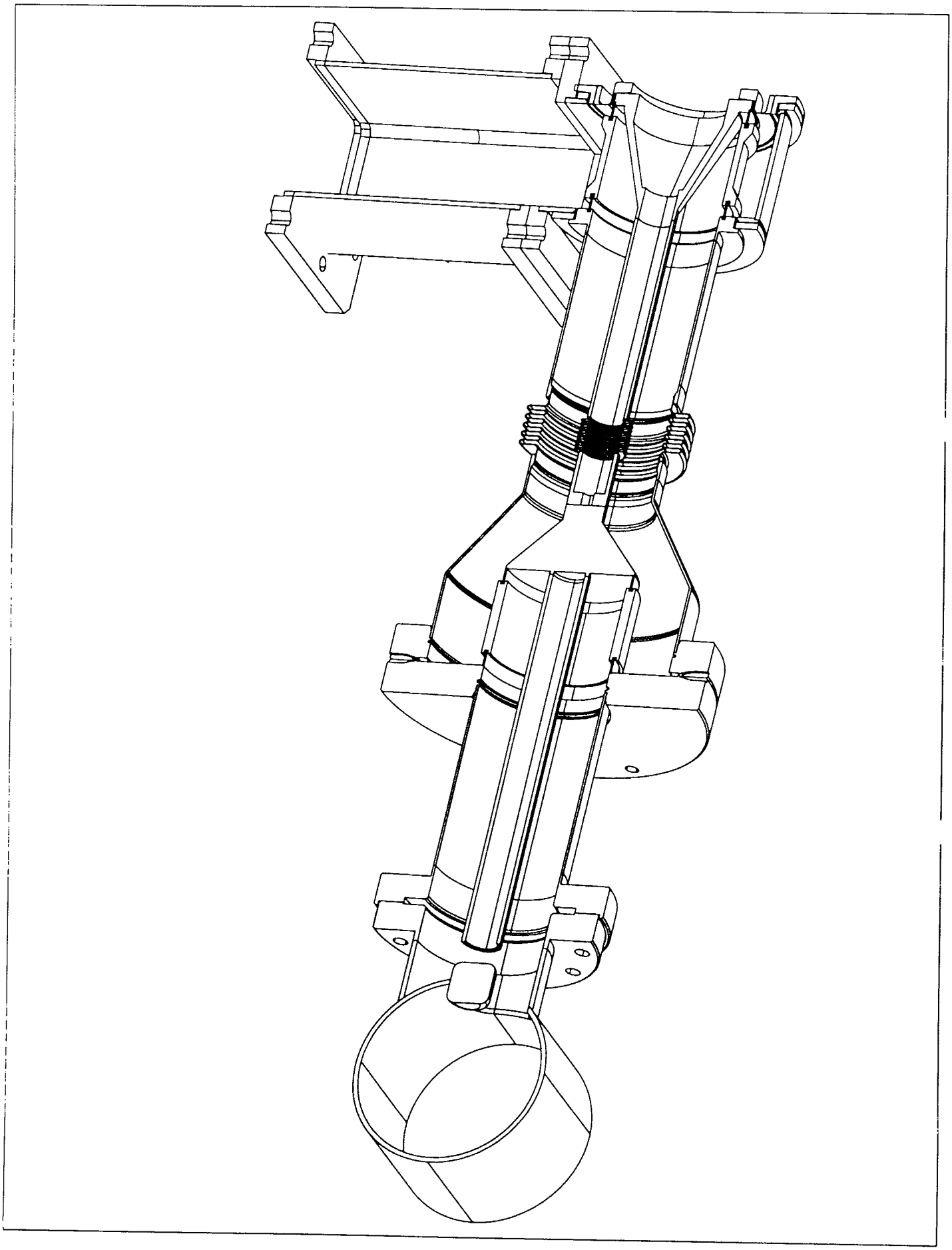
Datum Name

DESY-MHF

Membranevarianten
TTF-Einkoppler IV

Skizze



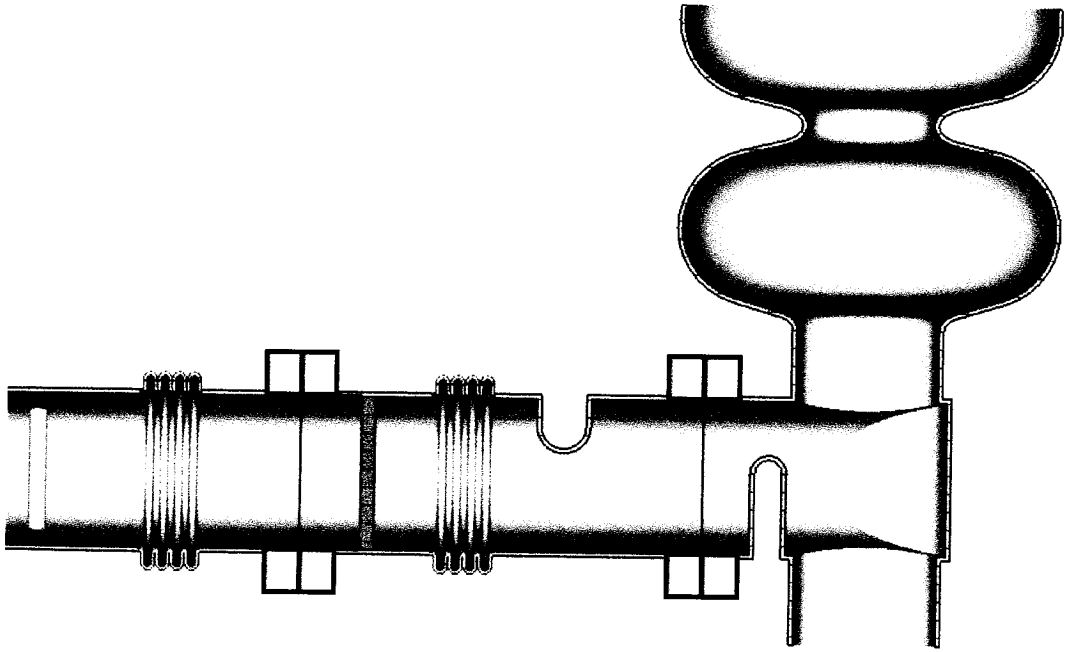


TESLA Waveguide Coupler

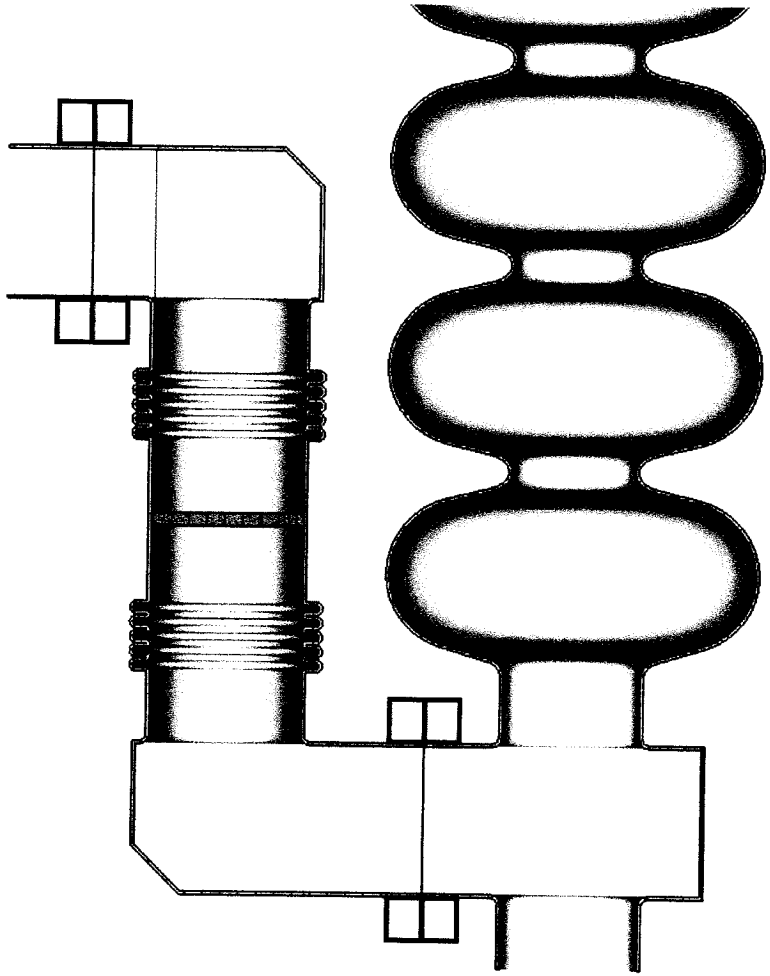
M.Dohlus, H. Hartwig, J.Boster, C.Martens, M.Seidel, A.Zavadsev

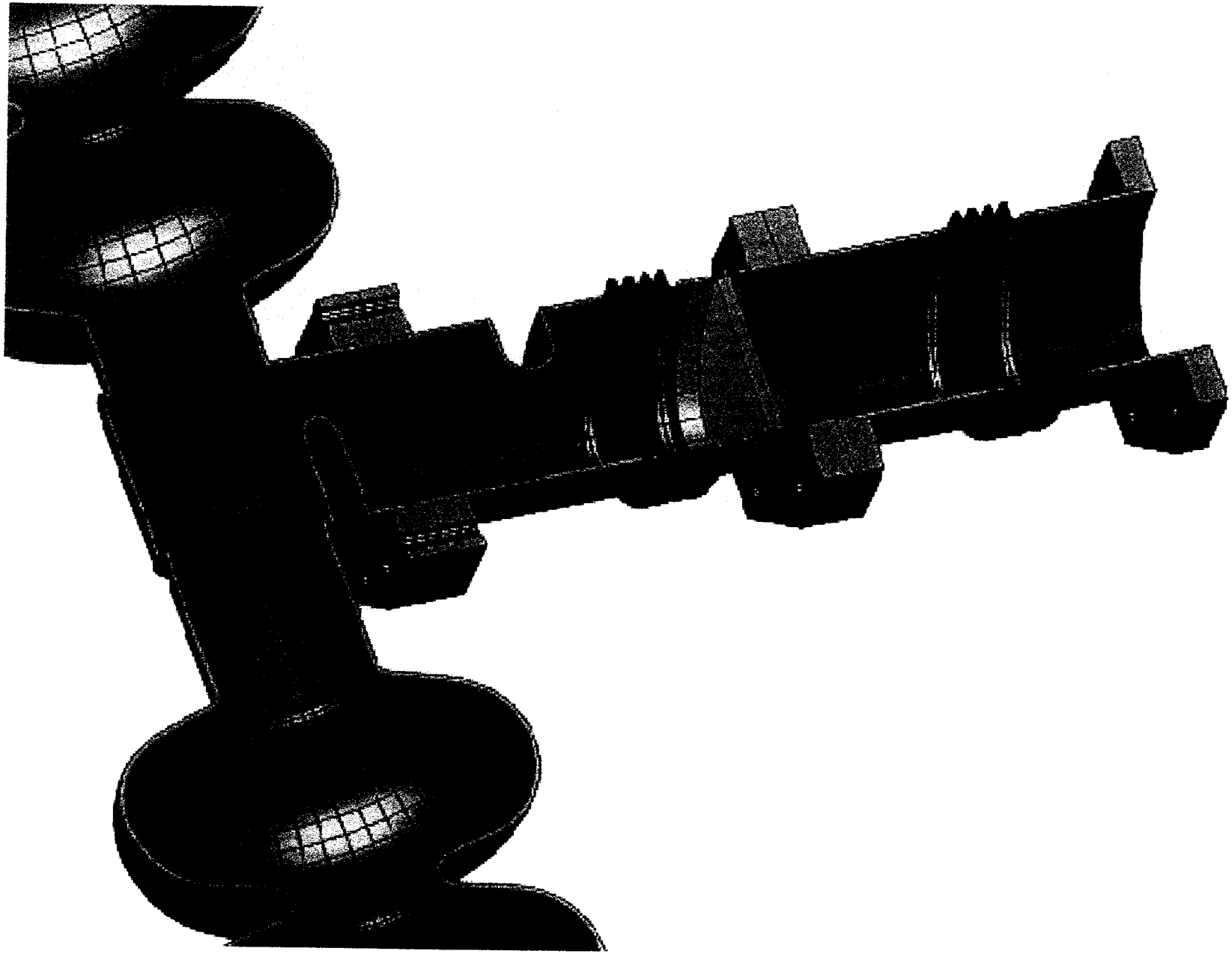
1. Versions, Geometrical Problems
2. Peak Field
3. Kick
4. Losses
5. Summary

S-Coupler

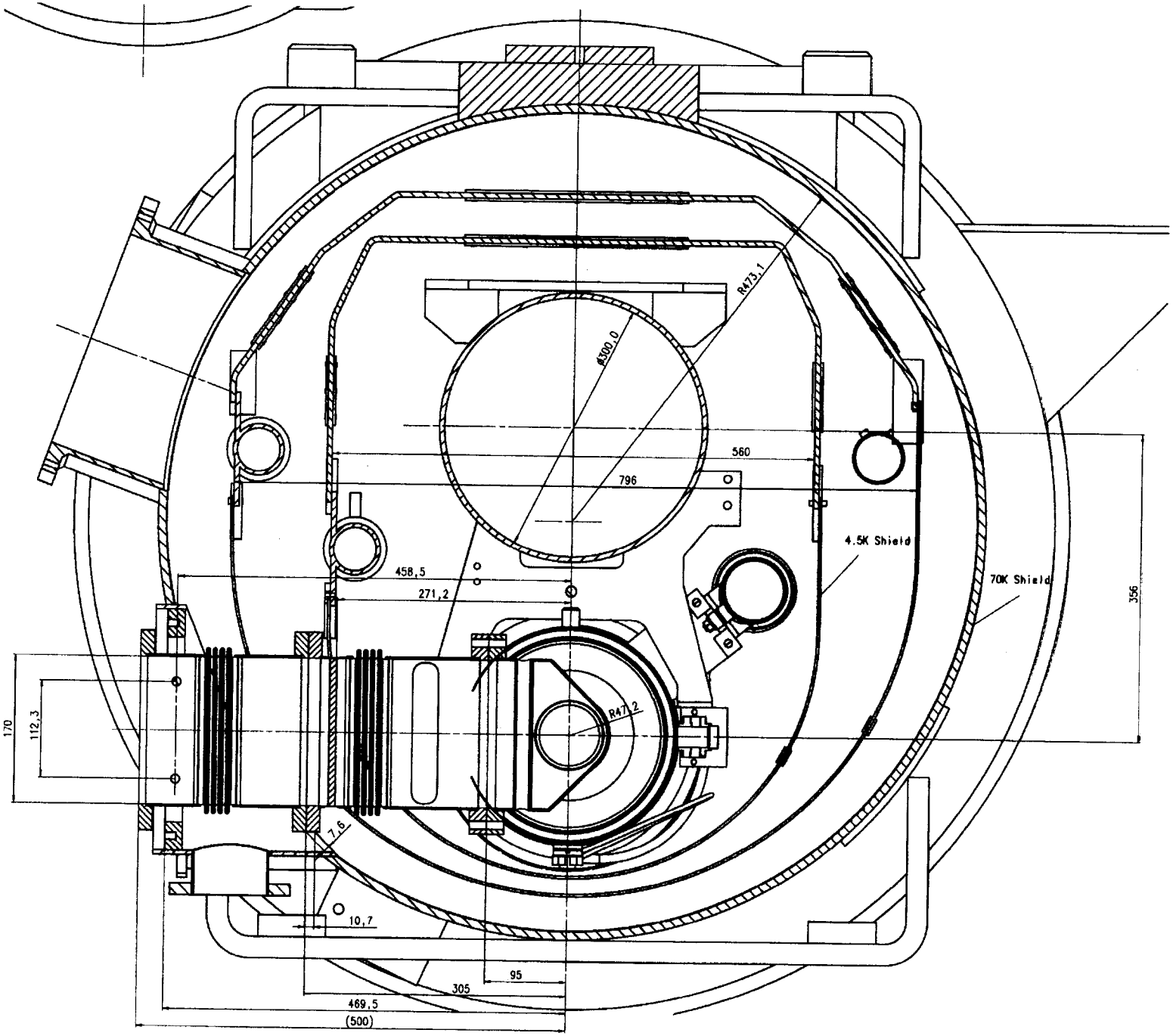


2L-Coupler

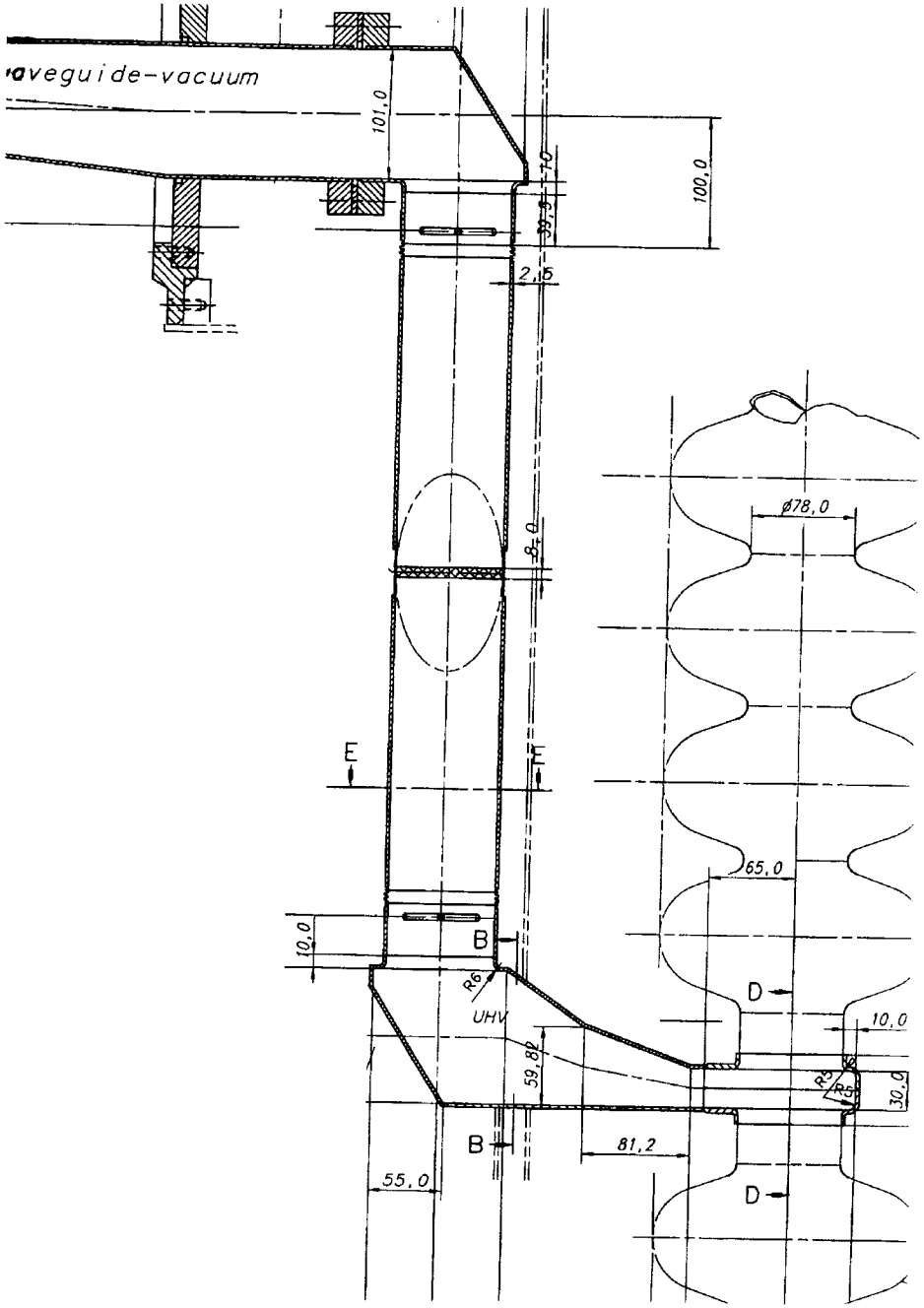


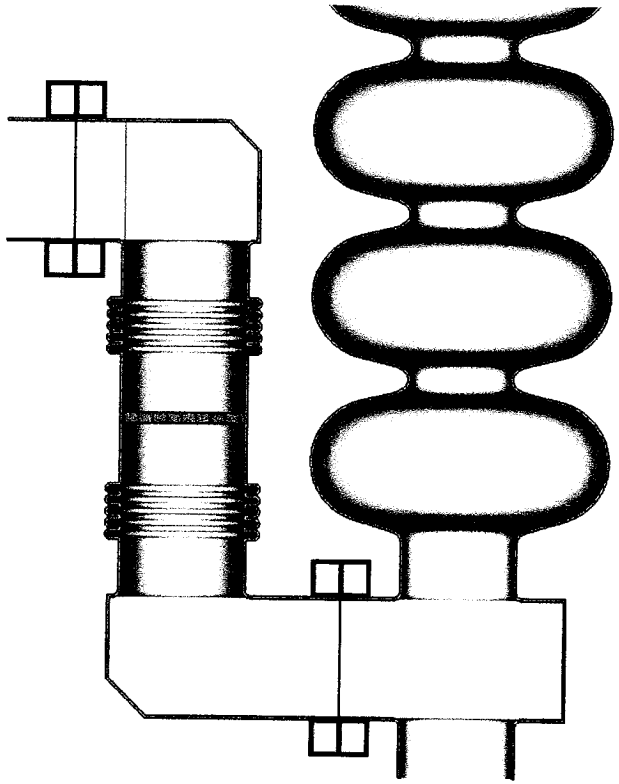


Martin Dohlus Deutsches Elektronen Synchrotron Jan.2000



Martin Dohlus Deutsches Elektronen Synchrotron Jan.2000


waveguide-vacuum
101,0
100,0
1,0
39,5
2,5
8,0
E
E
ø78,0
65,0
10,0
B
R6
UHV
59,82
D
10,0
R3
R3
30,0
B
81,2
55,0
D

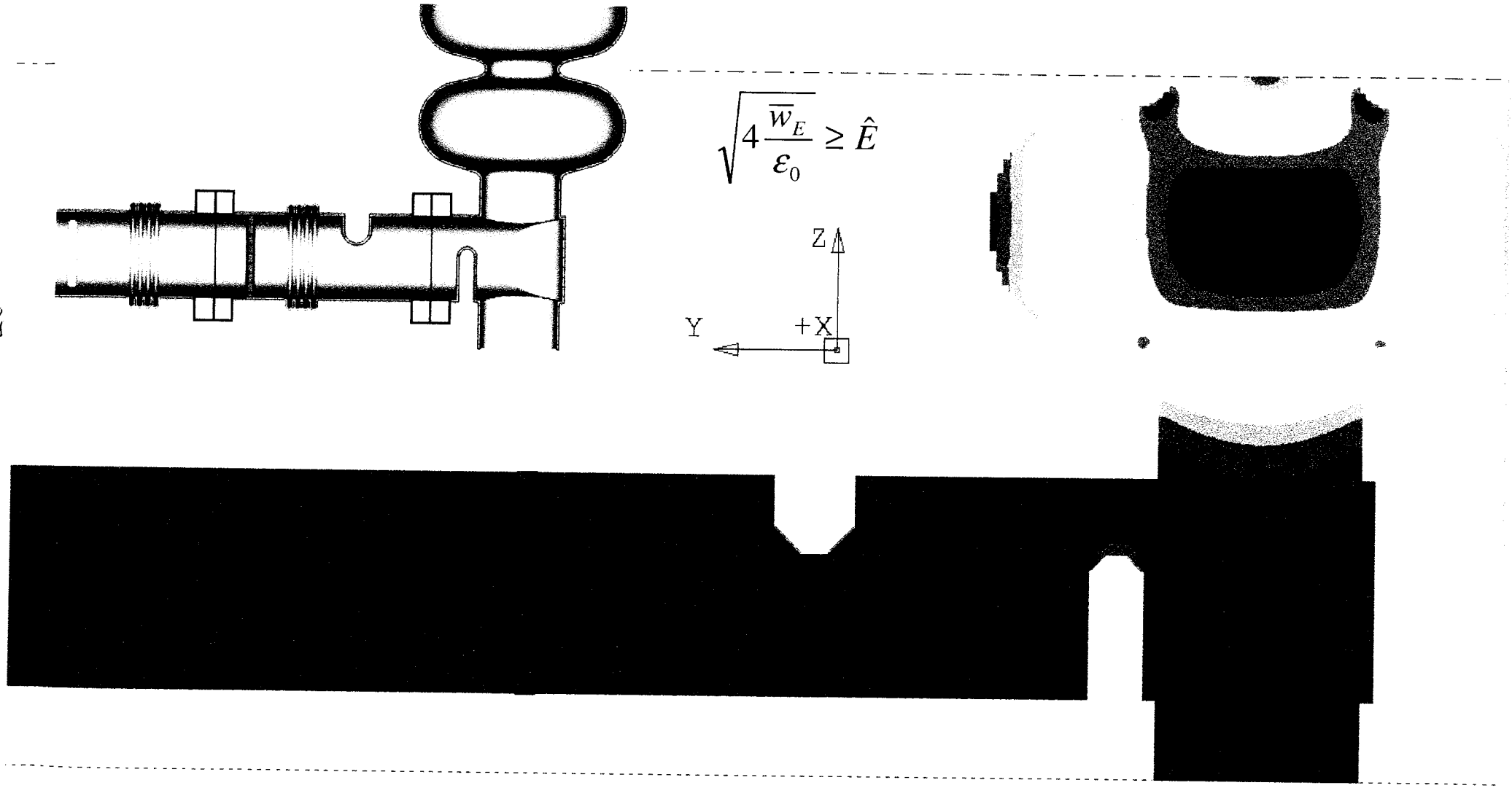


2L-Coupler

Peak Field

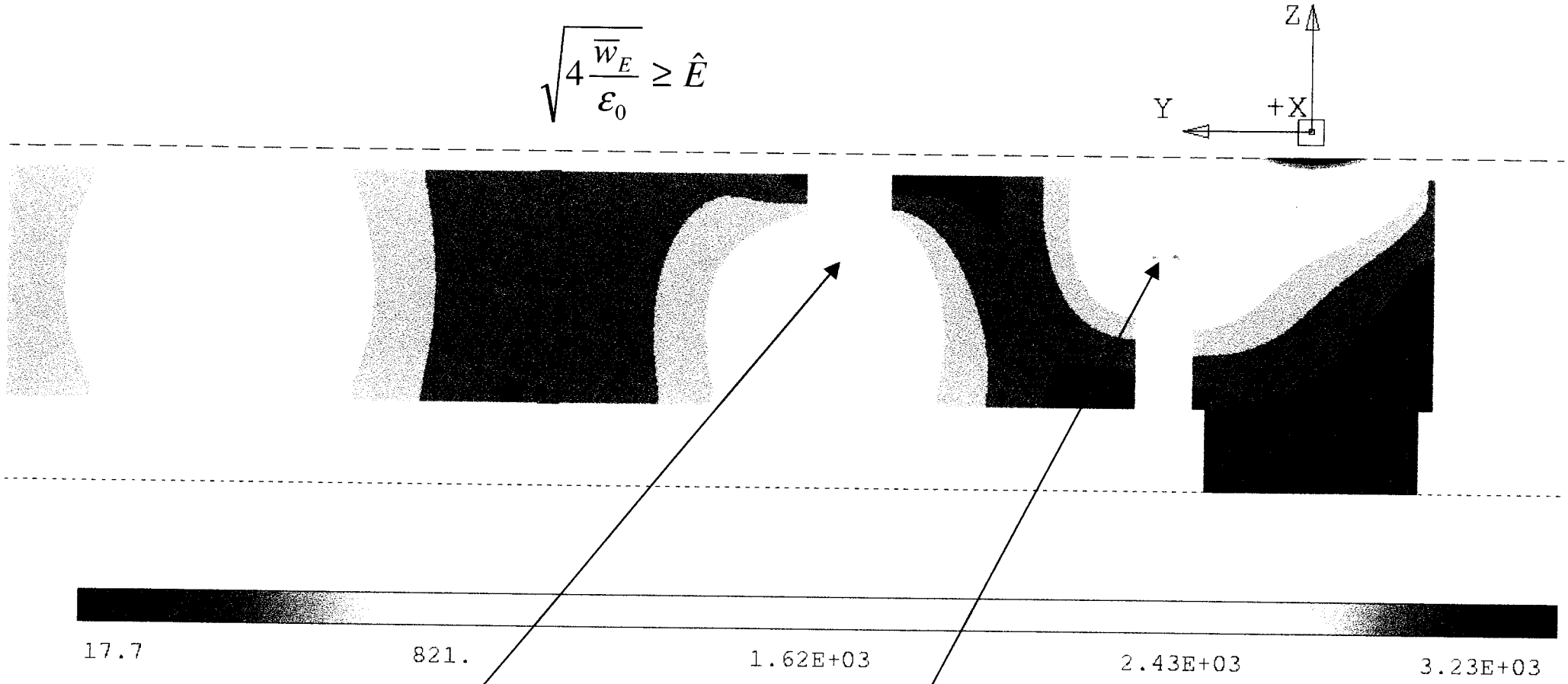
Martin Dohlus Deutsches Elektronen Synchrotron Jan.2000

S-Coupler



S-Coupler

$$\sqrt{4\frac{\overline{w}_E}{\varepsilon_0}} \geq \hat{E}$$

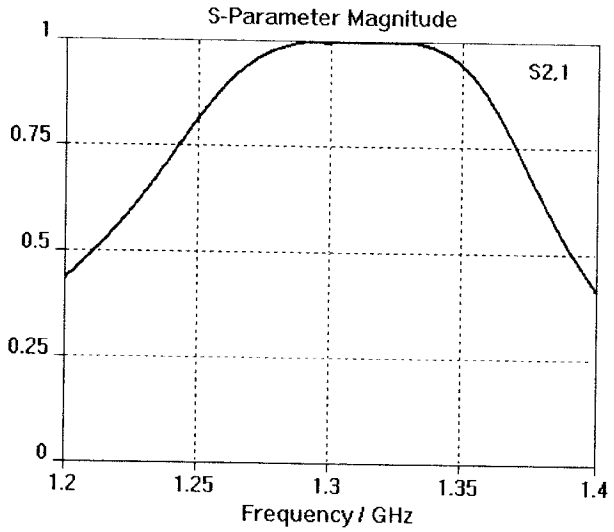


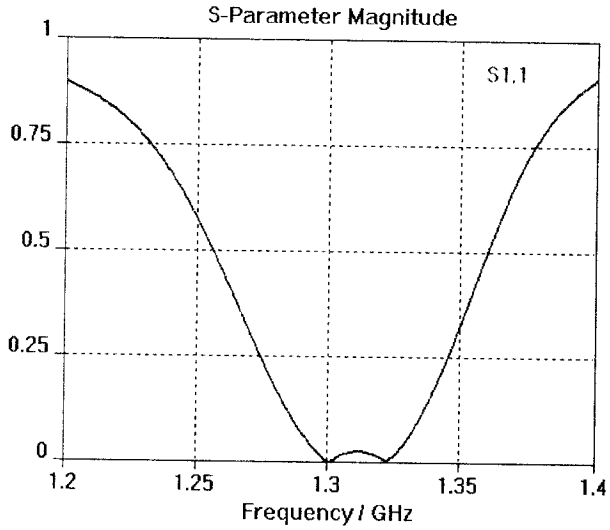
(scale: V/m @ 1W input power)

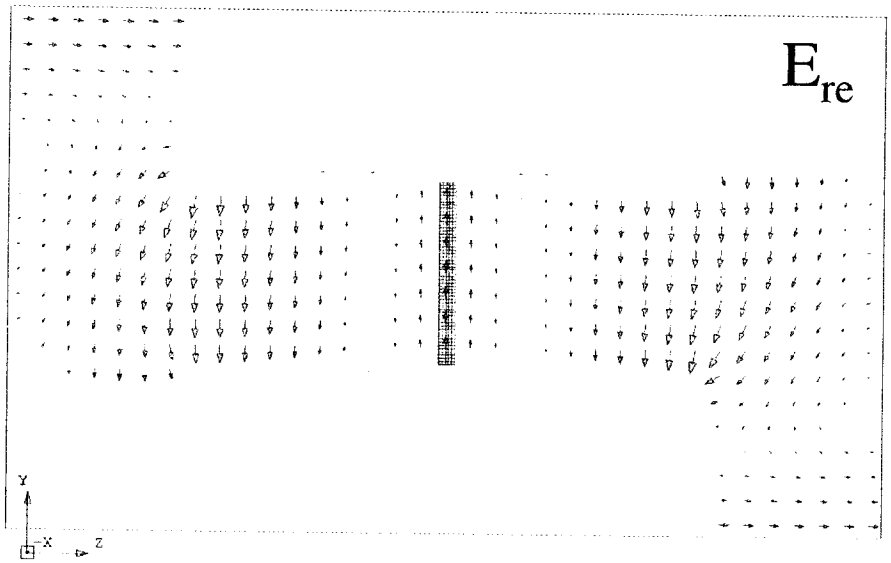
1.97 MV/m @ 1 MW input 2.78 MV/m @ 1 MW input

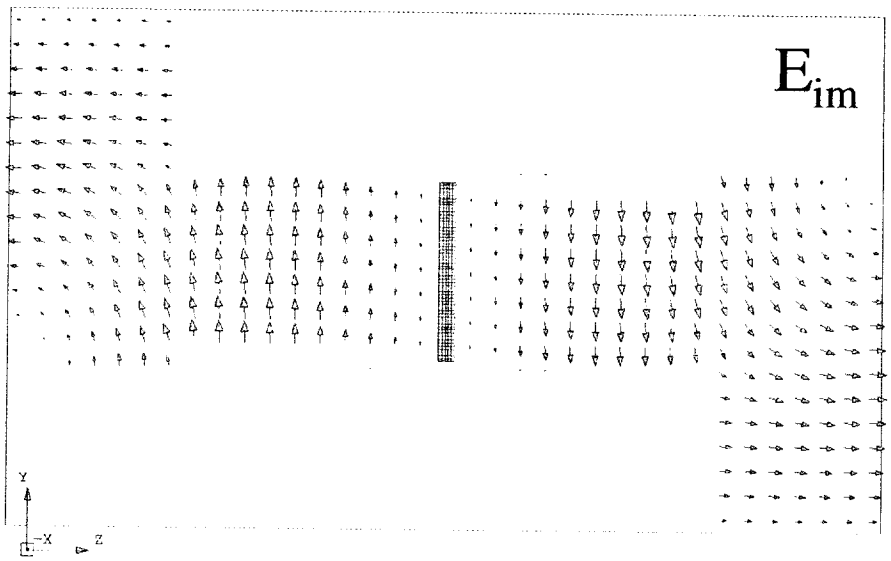
Martin Dohlus Deutsches Elektronen Synchrotron Jan.2000

2L-Coupler

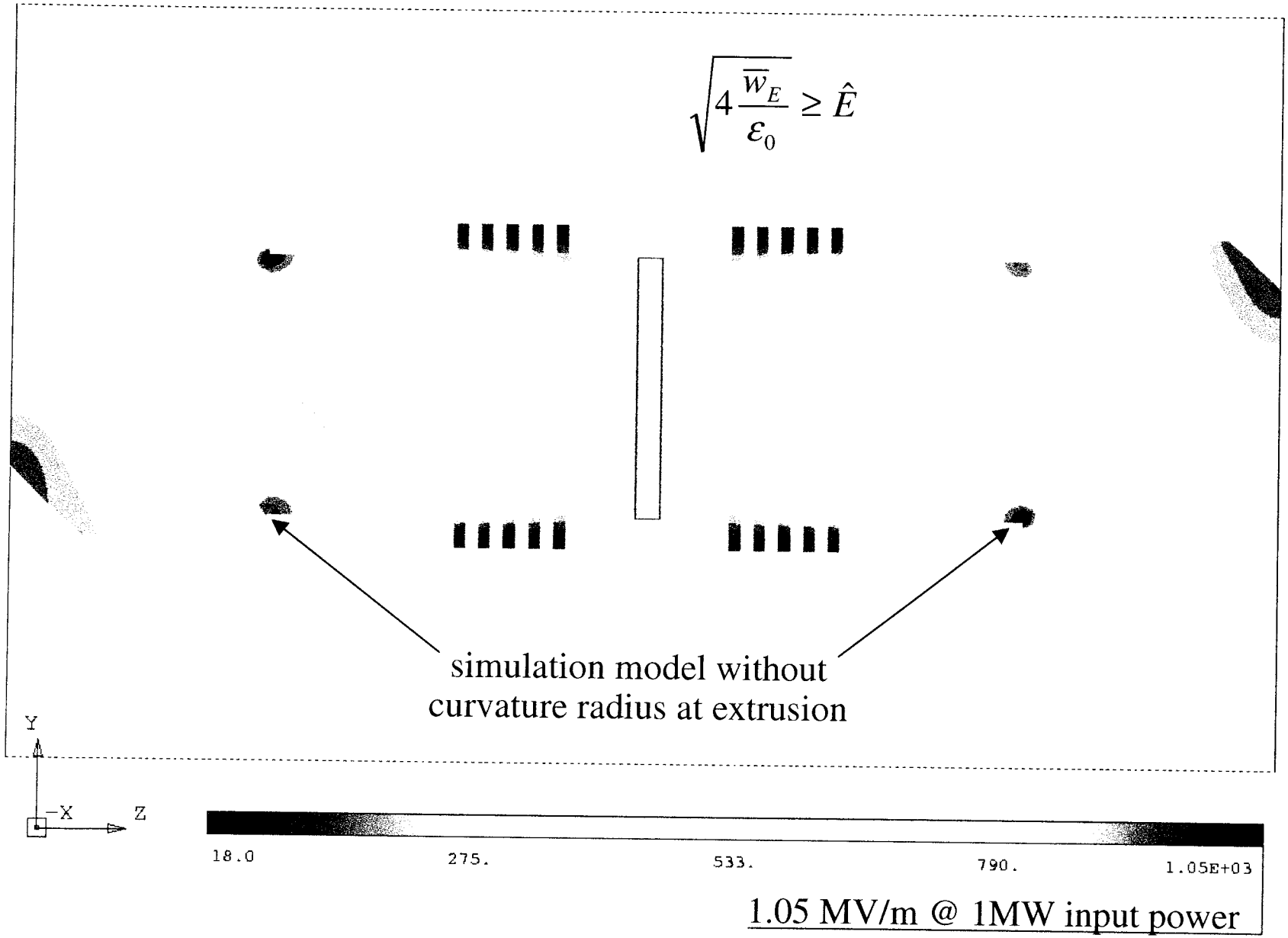








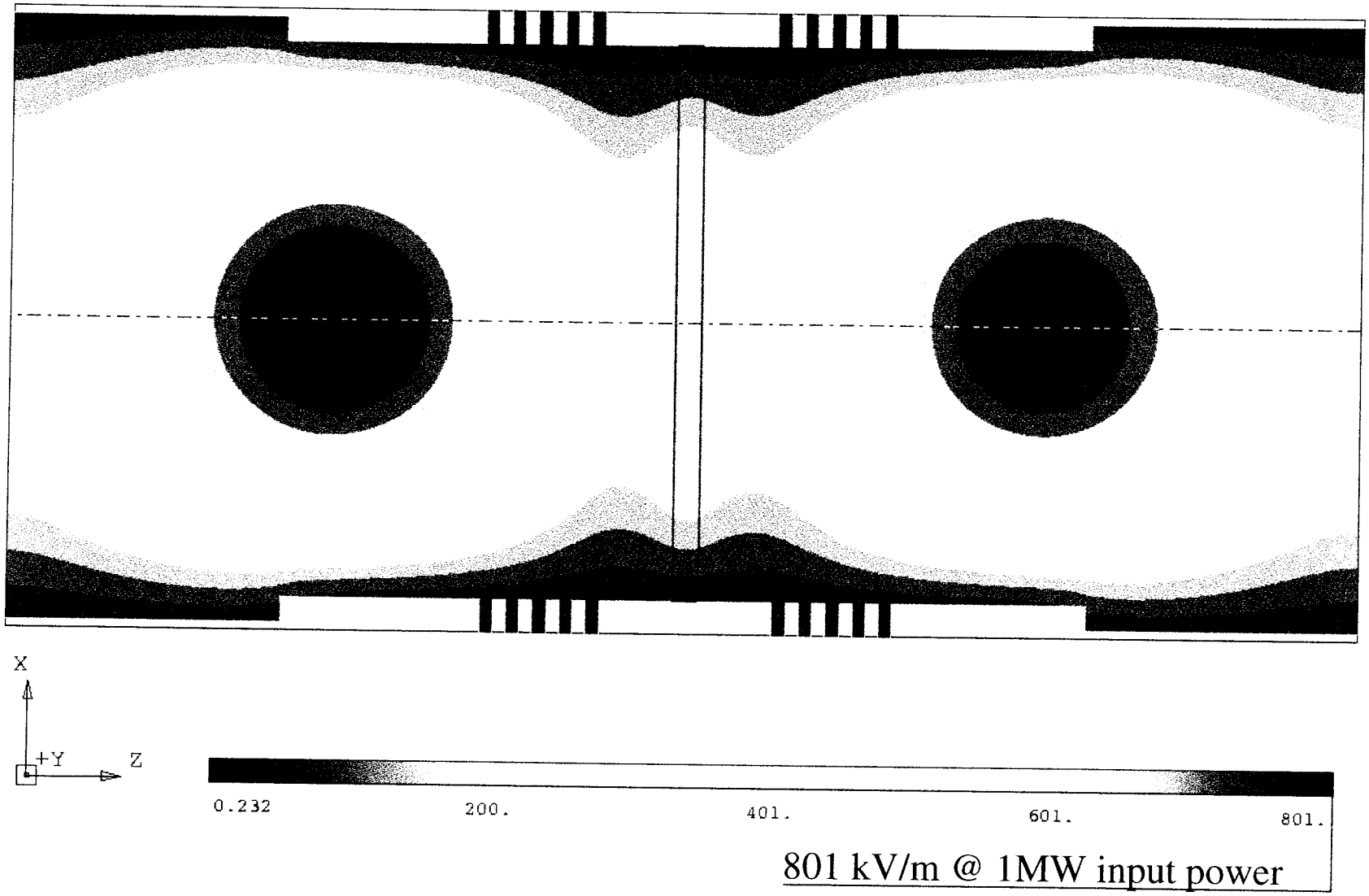
2L-Coupler



1.05 MV/m @ 1MW input power

2L-Coupler

$$\sqrt{4\frac{\overline{w}_E}{\varepsilon_0}} \geq \hat{E}$$



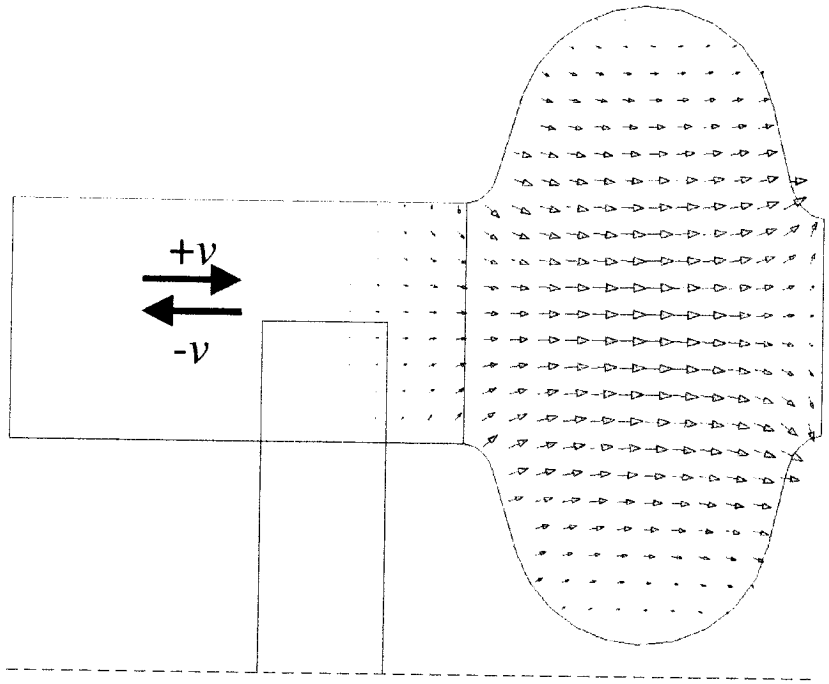
801 kV/m @ 1MW input power

Kick

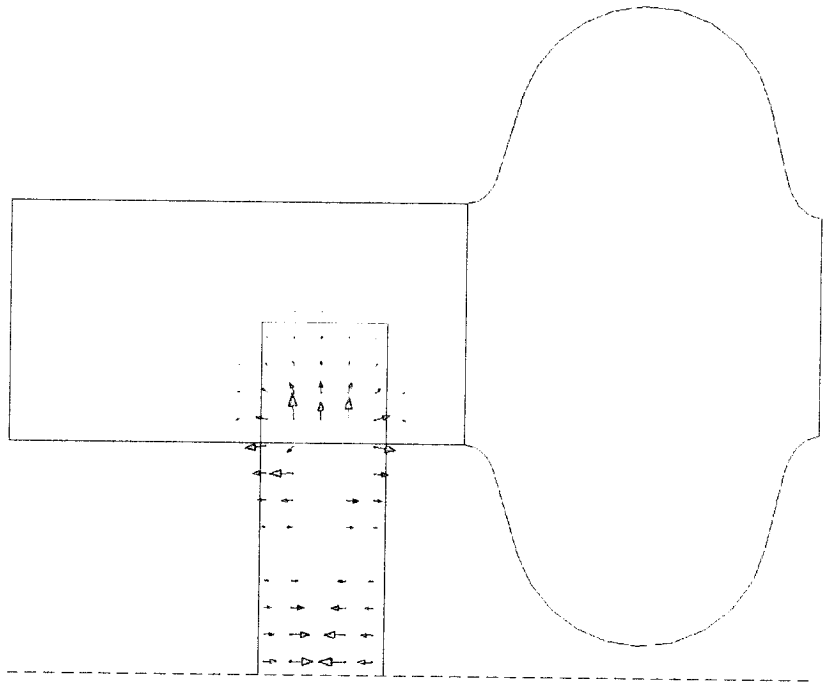
Martin Dohlus Deutsches Elektronen Synchrotron Jan.2000

Coax-Coupler (9 cells, $Q_{ext} = 2.56 \cdot 10^6$)

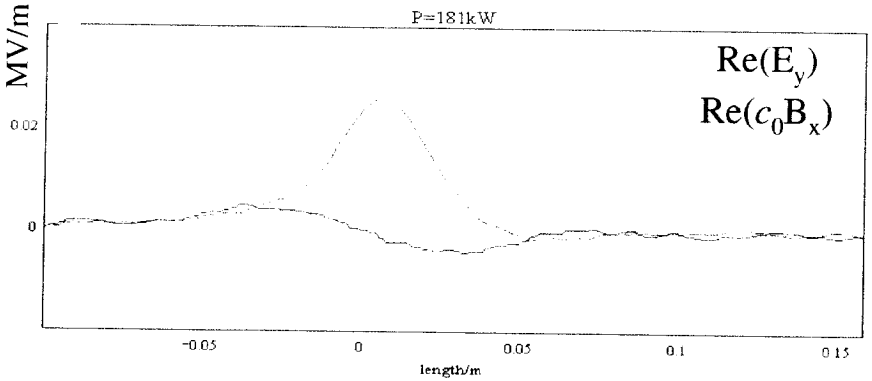
E_{re} max arrow = 39.9 MV/m @ 181 kW

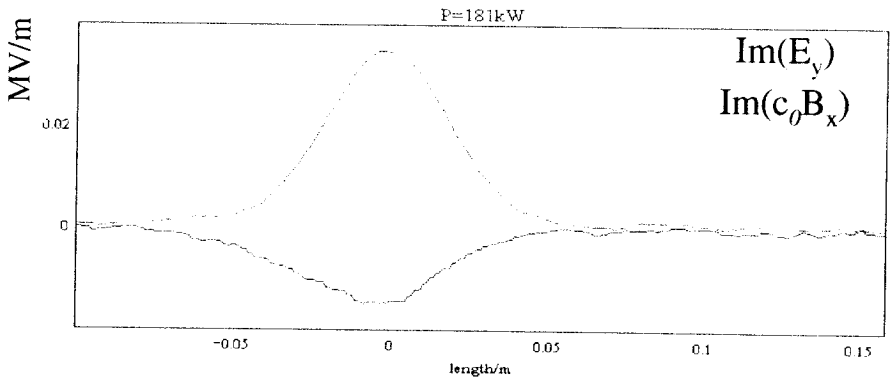


E_{im} max arrow = 0.44 MV/m @ 181 kW



transverse fields (on axis)

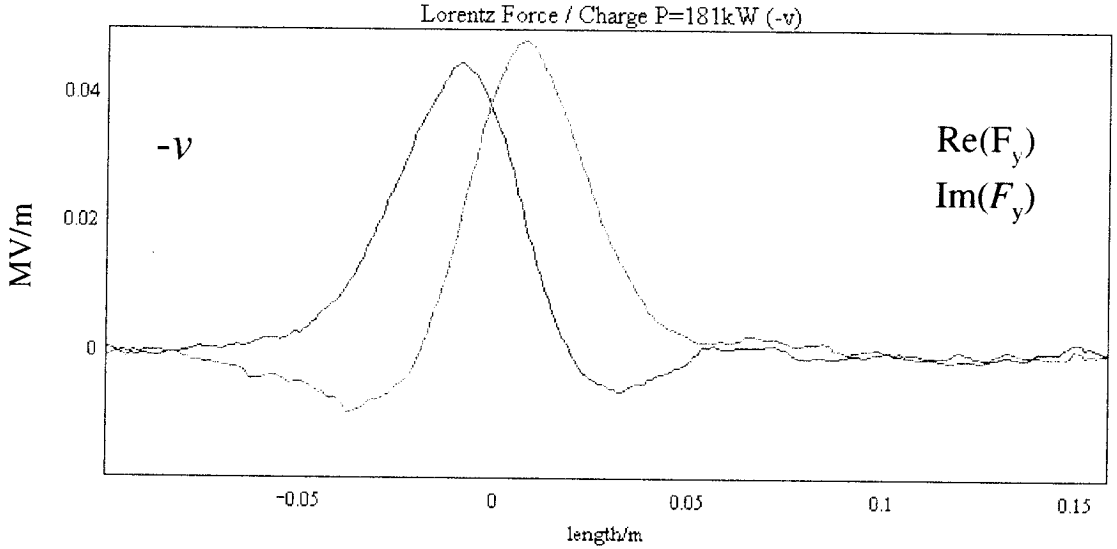




Lorentz Force Coax-Coupler

(9 cells, $Q_{\text{ext}} = 2.56 \cdot 10^6$)

$$F_y(z) = \pm q\left(E_y(z) \pm c_0 B_x(z)\right)\exp\left(\pm \frac{j\omega}{c_0}(z - z_{\text{cavity}})\right)$$



Integrated Kick

$$\int F_y(z)dz = q\,(-0.57 - j\,0.77)\ \text{kV} \quad +v \qquad /20\text{MV} = (-28\text{-j}38)\ \mu\text{rad}$$

$$\int F_y(z)(-dz) = q\,(1.30 + j\,1.43)\ \text{kV} \quad -v \qquad /20\text{MV} = (65\text{+j}72)\ \mu\text{rad}$$

$$@\ P_{\text{in}} = 181\ \text{kW}$$

TESLA - COLLABORATION

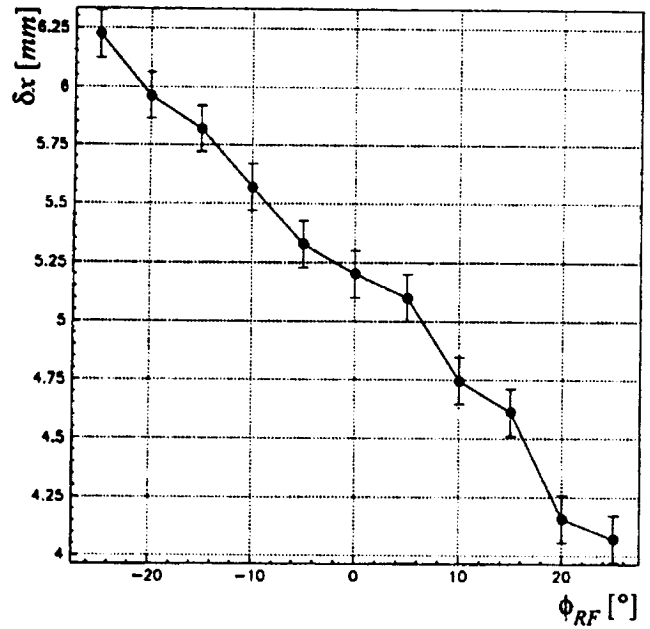
RF Kick Measurement on TTF and Comparison with the TESLA Specifications

S. Fartoukh, M. Jablonka, O. Napoly, T. Garvey*, M. Hüning+, H. Weise+

CEA Saclay, *LAL, +DESY

September 1998, TESLA 98-25

horizontal displacement vs. RF phase



(a)

anti. symm. part of kick
or
imag. part of kick voltage

$$\mathrm{Im}\left\{\frac{V_{\mathrm{kick}}}{V_{\mathrm{acc}}}\right\} = T_x \sin\varphi_0 = 0.32\ \mathrm{mrad}\ \sin(157.7)$$

$$= 1.21 \cdot 10^{-4}\ \mathrm{rad}$$

measured value

$Q_{\mathrm{ext}} = 1.8 \cdot 10^6$

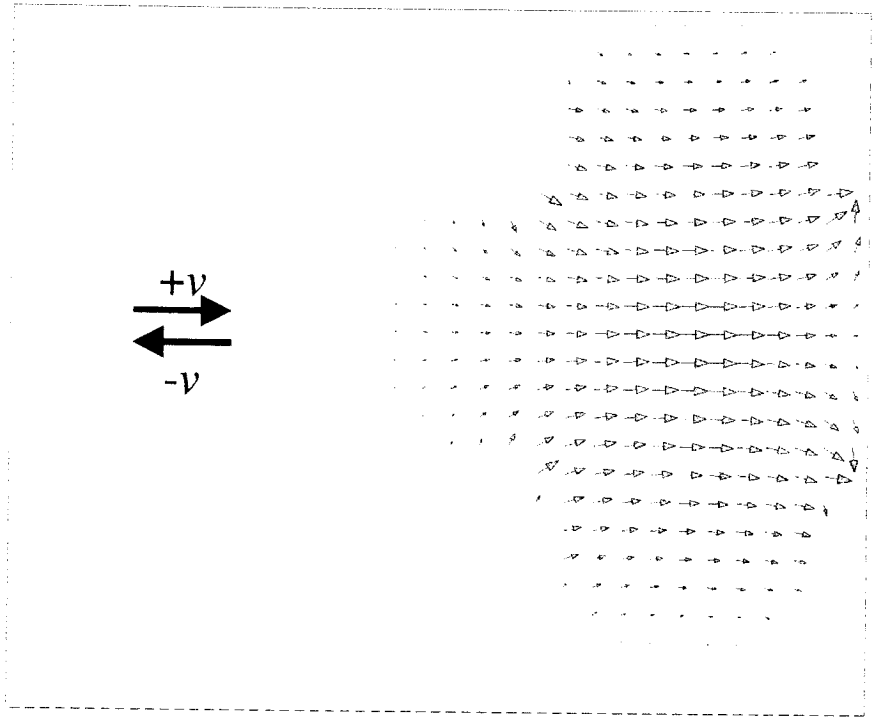
calculated value (Q_{ext}=2.6 · 10^6)

$$\mathrm{Im}\left\{\frac{V_{\mathrm{kick}}}{V_{\mathrm{acc}}}\right\} = \mathrm{Im}\left\{\frac{(1.3 + j1.4)\ \mathrm{kV}}{20\ \mathrm{MV}}\right\} = 0.72 \cdot 10^{-5}$$

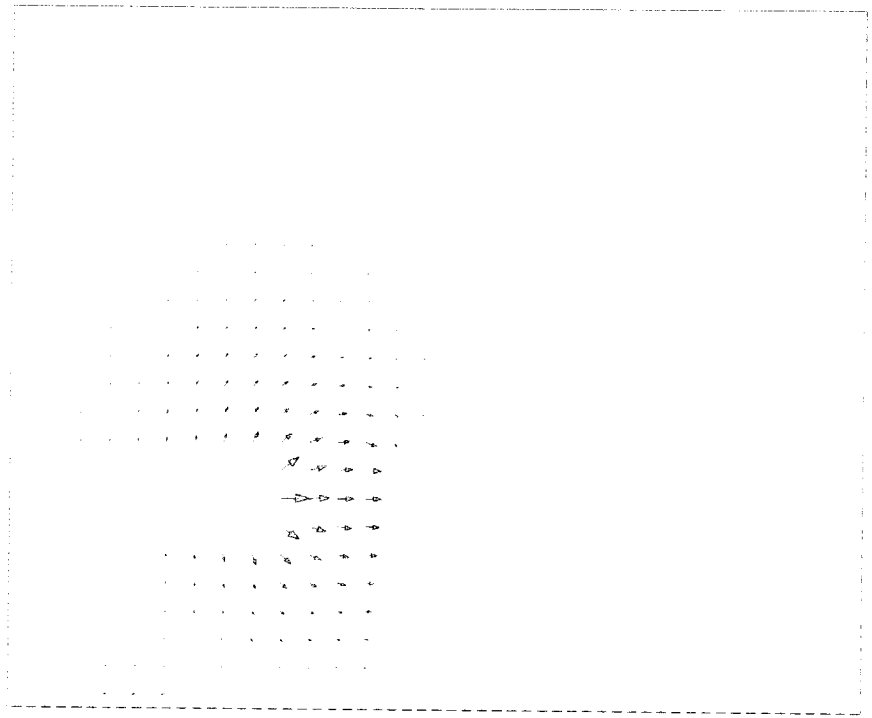
extrapolation $Q_{\mathrm{ext}} \rightarrow 1.8 \cdot 10^6$: $0.86 \cdot 10^{-5}$

S-Coupler $Q_{ext} = 1.1 \cdot 10^6$

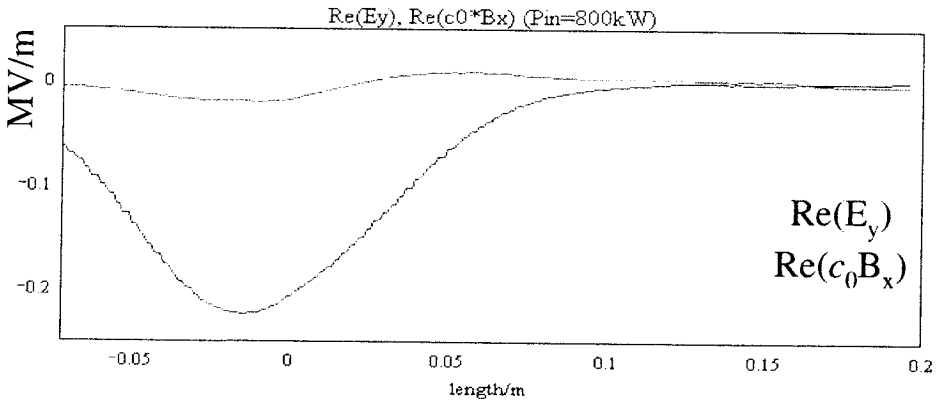
E_{re} max arrow = 31.4 MV/m @ 800 kW

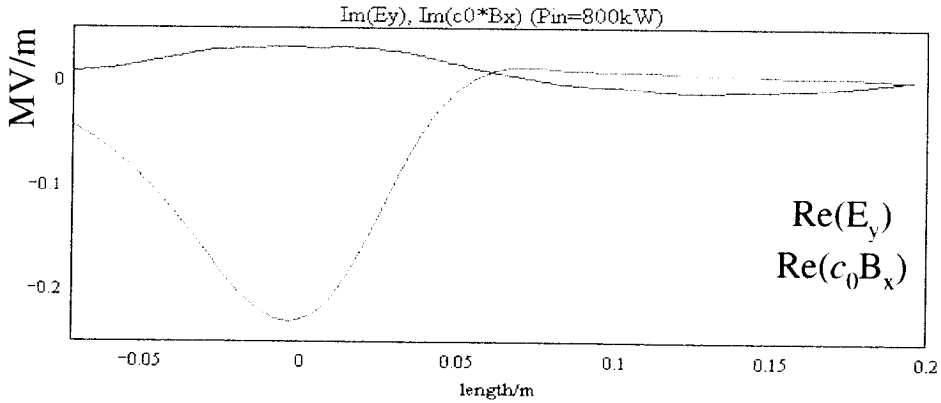


E_{im} max arrow = 2.21 MV/m @ 800 kW



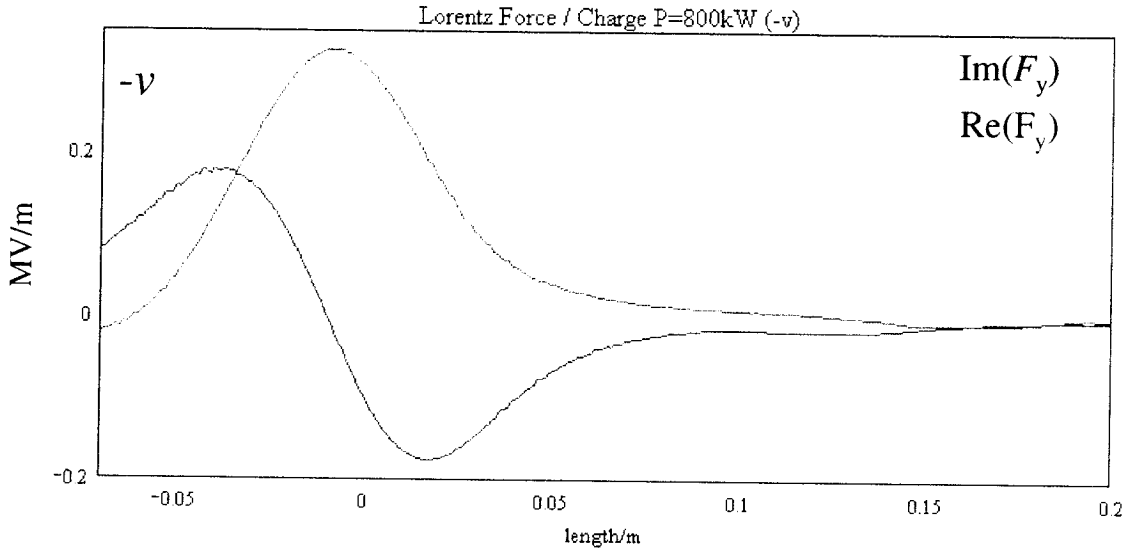
transverse fields (on axis)





Lorentz Force S-Coupler ($Q_{\text{ext}} = 1.1 \cdot 10^6$)

$$F_y(z) = \pm q\left(E_y(z) \pm c_0 B_x(z)\right)\exp\left(\pm \frac{j\omega}{c_0}(z - z_{\text{cavity}})\right)$$



Integrated Kick

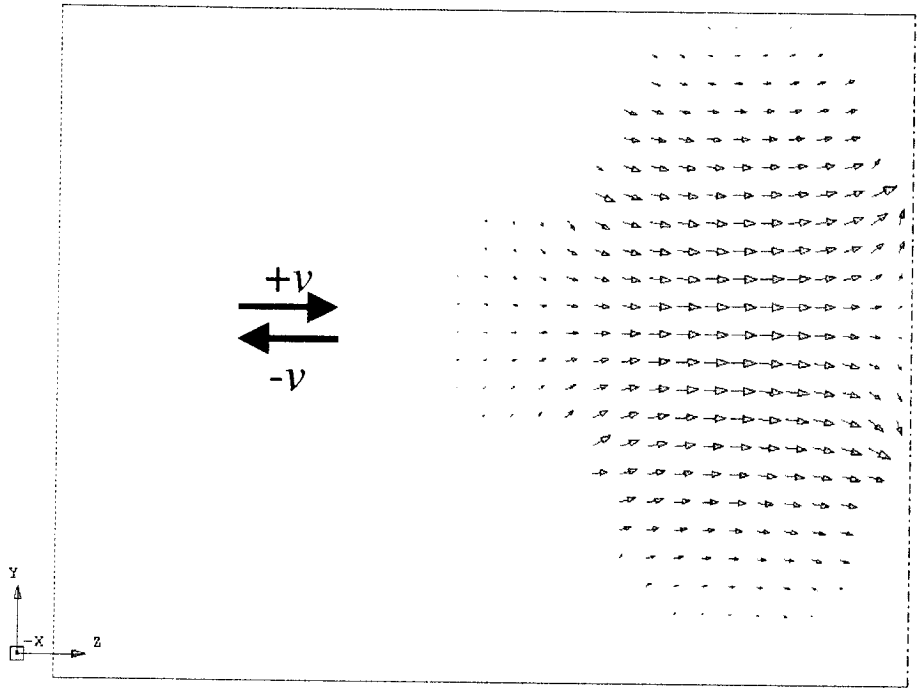
$$\int F_y(z)dz = q\,(16.0 - j\,6.1)\,\text{kV} \qquad +v \qquad /67.6\text{MV} = (236\text{-j}90)\ \mu\text{rad}$$

$$\int F_y(z)(-dz) = q\,(18.5 - j\,1.1)\,\text{kV} \qquad -v \qquad /67.6\text{MV} = (273\text{-j}16)\ \mu\text{rad}$$

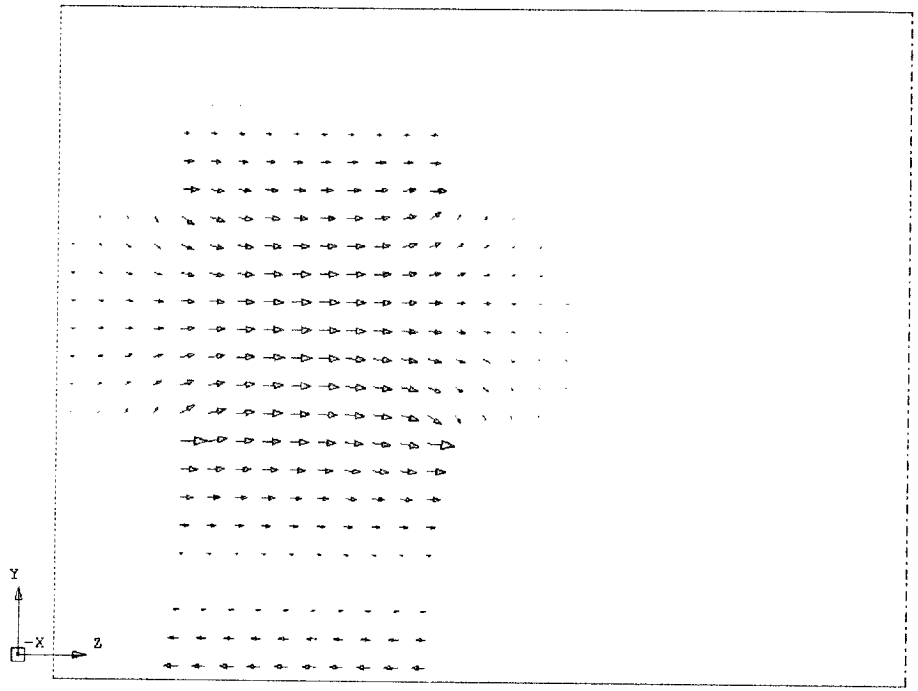
$$@\ P_{\text{in}} = 800\,\text{kW}$$

2L-Coupler $Q_{ext} = 2.2 \cdot 10^6$

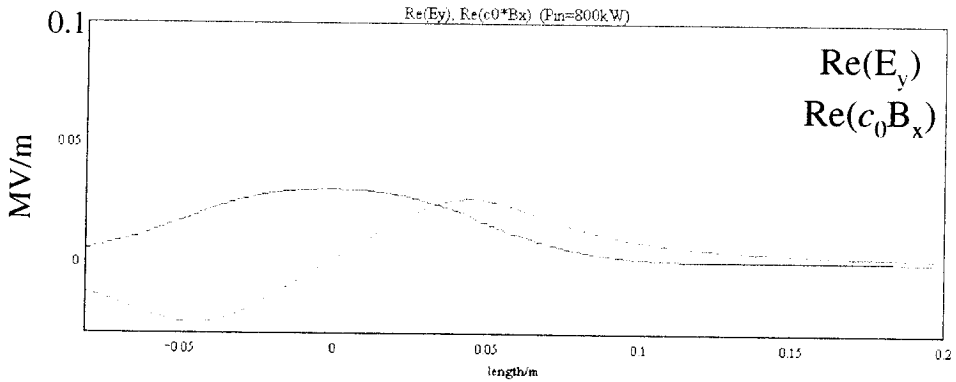
E_{re} max arrow = 47.6 MV/m @ 800 kW

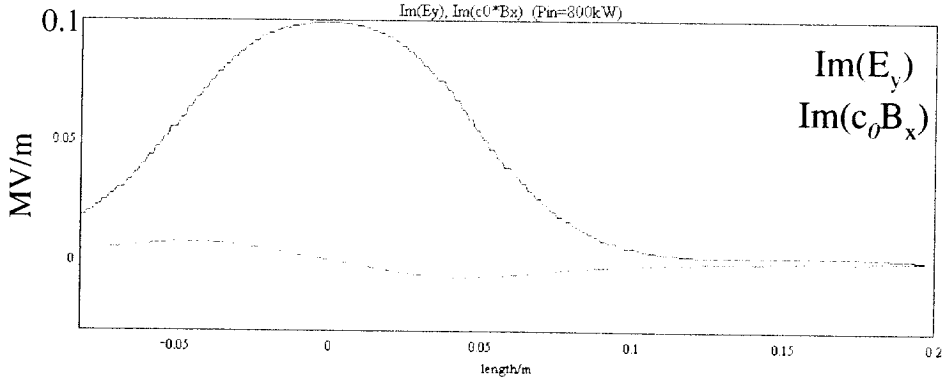


E_{im} max arrow = 0.36 MV/m @ 800 kW



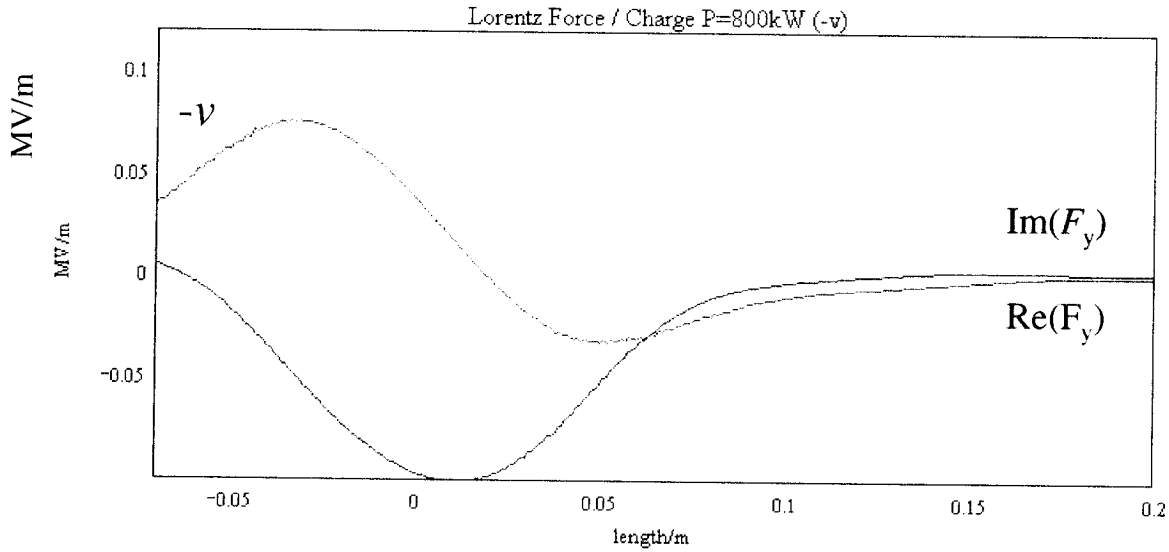
transverse fields (on axis)





Lorentz Force 2L-Coupler

$$F_y(z) = \pm q\left(E_y(z) \pm c_0 B_x(z)\right)\exp\left(\pm \frac{j\omega}{c_0}(z - z_{\text{cavity}})\right)$$



Integrated Kick

$$\int F_y(z)dz = q\,(-7.08 - j\,4.69)\ \text{kV} \quad +v \qquad /67.6\text{MV} = (-105\text{-j}70)\ \mu\text{rad}$$

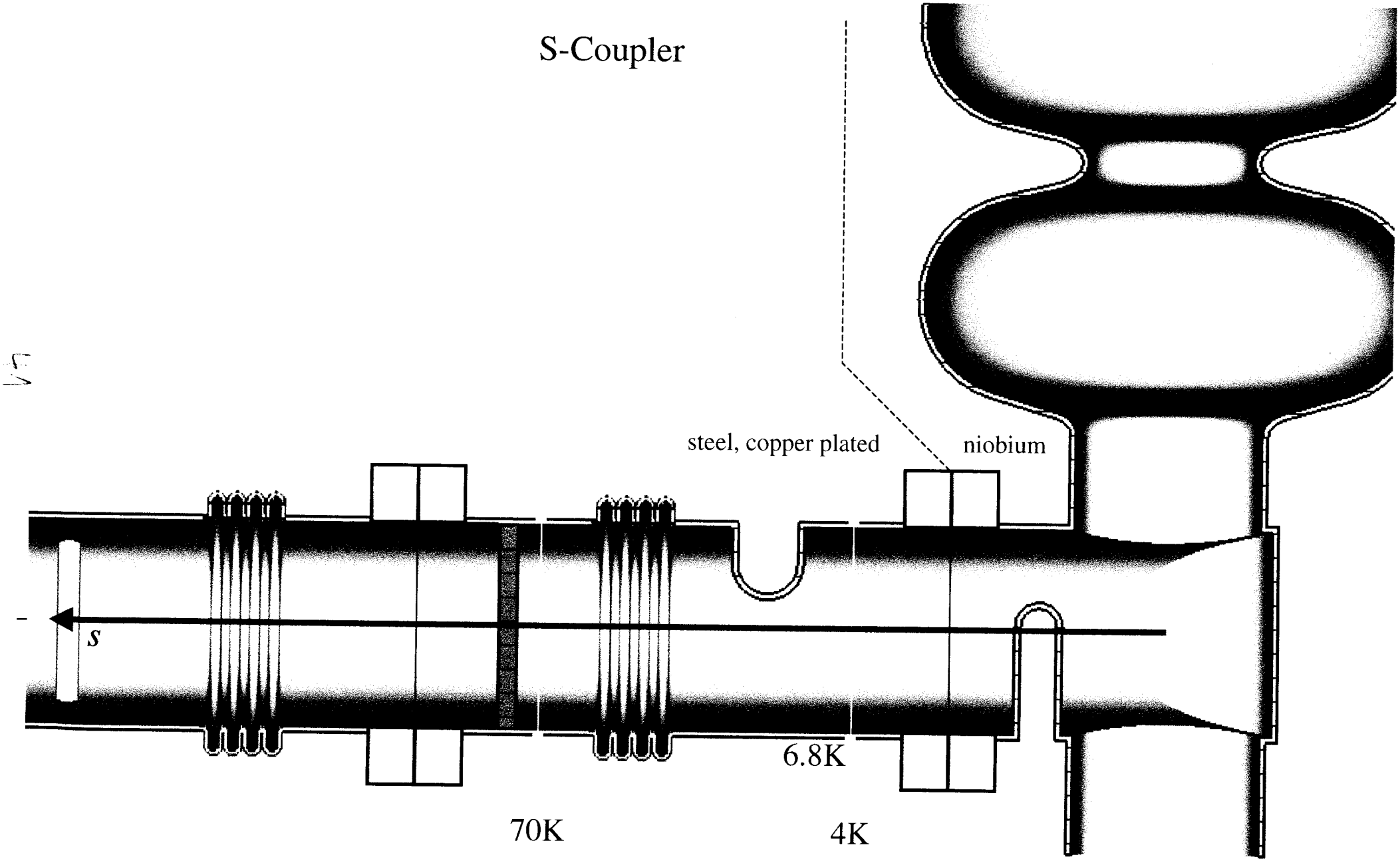
$$\int F_y(z)(-dz) = q\,(3.33 - j\,7.81)\ \text{kV} \quad -v \qquad /67.6\text{MV} = (49\text{-j}115)\ \mu\text{rad}$$

$$@\ P_{\text{in}} = 800\,\text{kW}$$

5

Losses

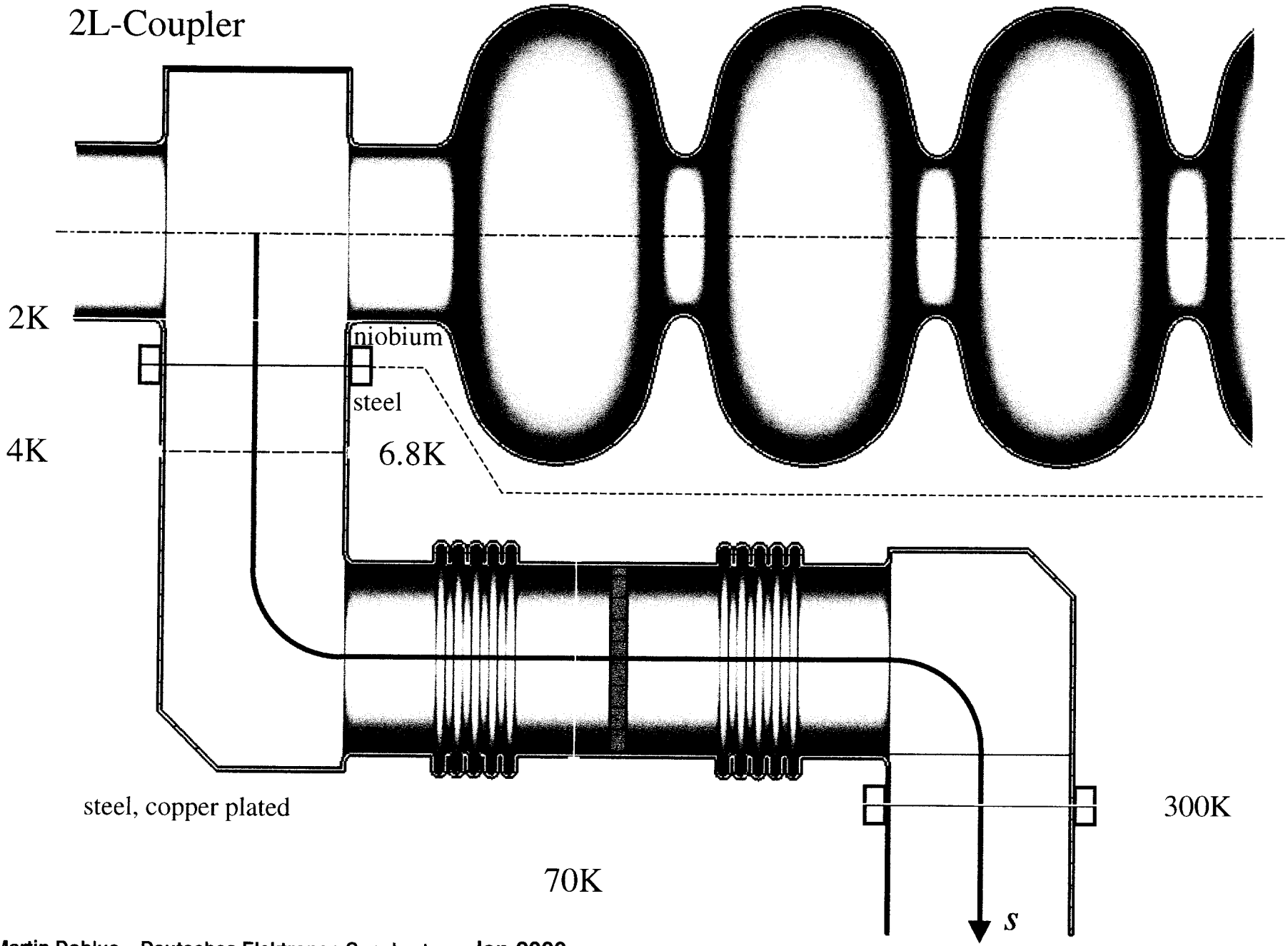
S-Coupler



S Coupler

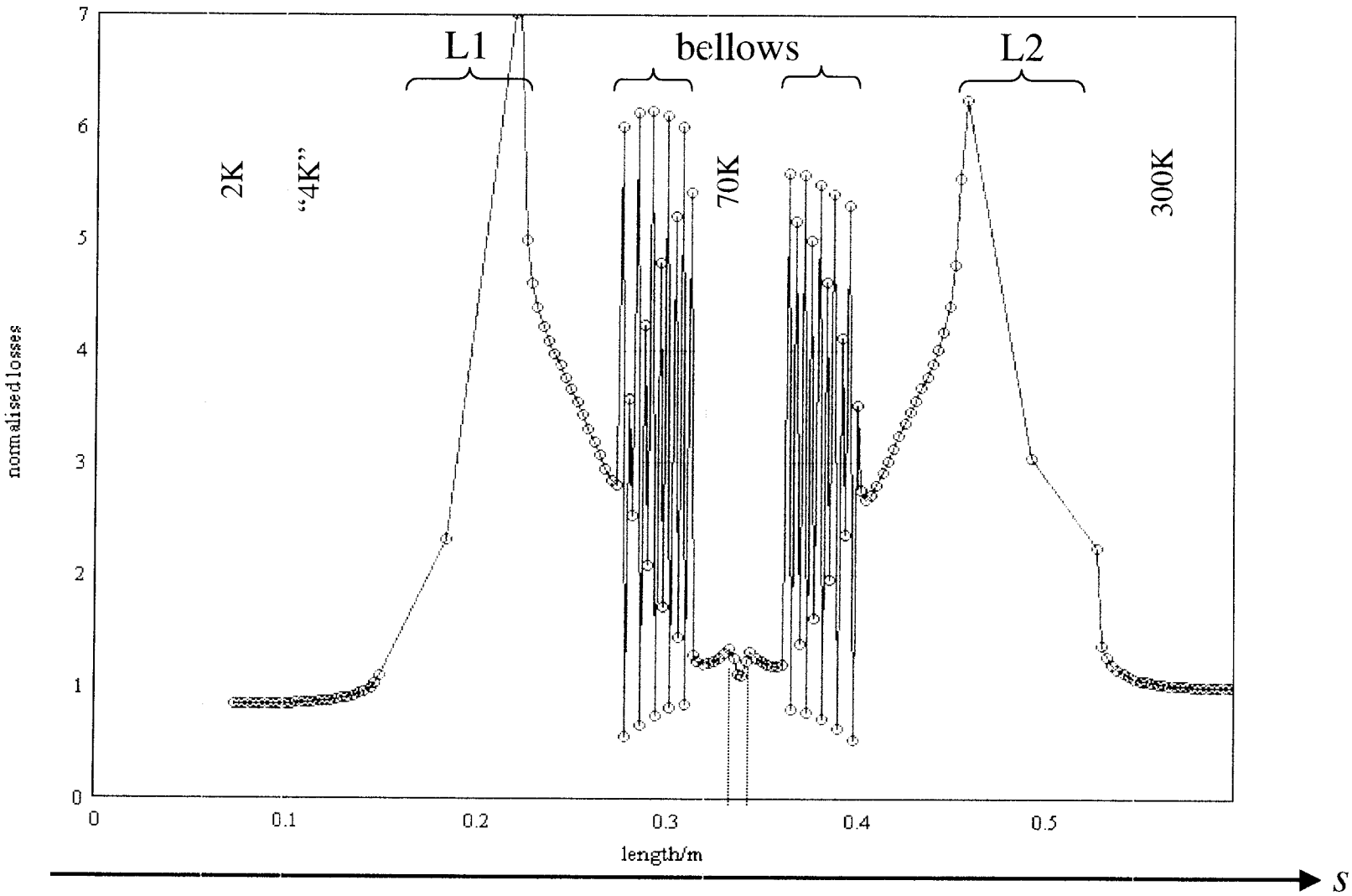
Klystron Operation	Configuration: steel: 2 mm @waveguides 0.2 mm @ bellows copper: 5 µm (RRR=10)	Configuration: steel: 2 mm @waveguides 0.2 mm @ bellows copper: 10 µm (RRR=10)
$P = 0$ W ($P_{av} = 0$ W)	$P_{2K} = 0.071$ W $P_{4K} = 0.53$ W $P_{70K} = 2.29$ W $P_{300K} = -2.9$ W	$P_{2K} = 0.093$ W $P_{4K} = 0.86$ W $P_{70K} = 2.89$ W $P_{300K} = -3.8$ W
$P = 800$ kW $t_{klystron} = 1.4$ ms $f_{rep} = 5$ Hz ($P_{av} = 5.6$ kW)	$P_{2K} = 0.149$ W $P_{4K} = 1.48$ W $P_{70K} = 4.09$ W + 2.96 W(1) $P_{300K} = -0.02$ W	$P_{2K} = 0.165$ W $P_{4K} = 1.79$ W $P_{70K} = 4.73$ W + 2.96 W(1) $P_{300K} = -1.0$ W
$P = 1.4$ MW $t_{klystron} = 1.4$ ms $f_{rep} = 5$ Hz ($P_{av} = 9.8$ kW)	$P_{2K} = 0.208$ W $P_{4K} = 2.26$ W $P_{70K} = 5.58$ W + 5.20 W(1) $P_{300K} = 2.25$ W	$P_{2K} = 0.219$ W $P_{4K} = 2.53$ W $P_{70K} = 6.26$ W + 5.20 W(1) $P_{300K} = 1.24$ W

(1) dielectric losses (ceramic $\tan\delta = 0.0003$)


2L-Coupler
2K
4K
niobium
steel
6.8K
steel, copper plated
70K
300K
s

2L-Coupler Normalized RF-Losses for T = const, κ = const

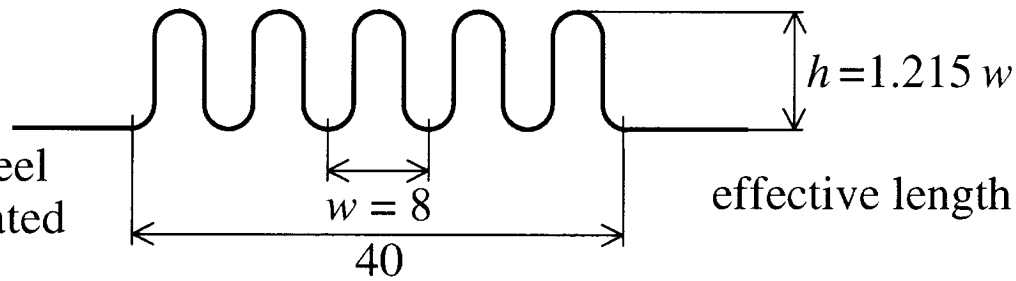
(without dielectric losses)



material: 2 mm steel
copper plated

copper: **conventional copper** or RRR=10 copper
5 µm or 10 µm plating

bellows:



0.2 mm steel
copper plated

effective length = 3 x real length

ceramic:

1996 International Accelerator School in Japan

DEVELOPMENT OF A HIGH POWER RF-WINDOW AT S-BAND

H. Matsumoto
KEK, High Energy Accelerator Research Organization
1-1 Oho, Tsukuba, Ibaraki 305, Japan

Table 3: Physical properties of high-purity alumina ceramic.

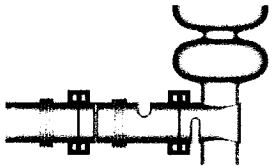
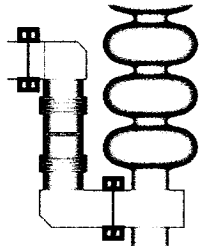
	99.5%	99.9%	99.9% (no MgO)
Thermal conductivity: cal/cm·h·°C	0.060	0.070	0.075
tan δ (× 10^{-4}): (at 2853 MHz)	13.0	3.0	0.27 (at 10 GHz)

2L Coupler

Klystron Operation	Configuration: steel: 2 mm @waveguides 0.2 mm @ bellows copper: 5 µm (conventional)	Configuration: steel: 2 mm @waveguides 0.2 mm @ bellows copper: 10 µm (RRR=10)
$P = 0$ W ($P_{av} = 0$ W)	$P_{2K} = 0.139$ W $P_{4K} = 0.78$ W $P_{70K} = 1.78$ W $P_{300K} = -2.7$ W	$P_{2K} = 0.093$ W $P_{4K} = 0.83$ W $P_{70K} = 2.79$ W $P_{300K} = -3.7$ W
$P = 800$ kW $t_{klystron} = 1.4$ ms $f_{rep} = 5$ Hz ($P_{av} = 5.6$ kW)	$P_{2K} = 0.154$ W $P_{4K} = 1.27$ W $P_{70K} = 2.87$ W + 2.96 W(1) $P_{300K} = 0.6$ W	$P_{2K} = 0.127$ W $P_{4K} = 1.81$ W $P_{70K} = 4.04$ W + 2.96 W(1) $P_{300K} = -0.5$ W
$P = 1.4$ MW $t_{klystron} = 1.4$ ms $f_{rep} = 5$ Hz ($P_{av} = 9.8$ kW)	$P_{2K} = 0.165$ W $P_{4K} = 1.74$ W $P_{70K} = 3.77$ W + 5.20 W(1) $P_{300K} = 8.9$ W	$P_{2K} = 0.153$ W $P_{4K} = 2.67$ W $P_{70K} = 5.08$ W + 5.20 W(1) $P_{300K} = 2.1$ W

(1) dielectric losses (ceramic $\tan\delta = 0.0003$)

Summary

	S-Coupler 	 2L-Coupler
geometry	length to flunge critical	position of elliptical waveguide critical
peak field (@ 1 MW)	2.8 MV/m at first chicane	≈ 1 MV/m
kick ($-\nu$) (@ 0.8 MW)	(**18.5** - j 1.1) kV /67.6MV = (**273**-j16) µrad	(3.3 - j 7.8) kV /67.6MV = (49-j115) µrad
Losses (@ 4K)	1.5 W @ 0.8 MW 2.3 W @ 1.4 MW	1.3 W @ 0.8 MW 1.7 W @ 1.4 MW

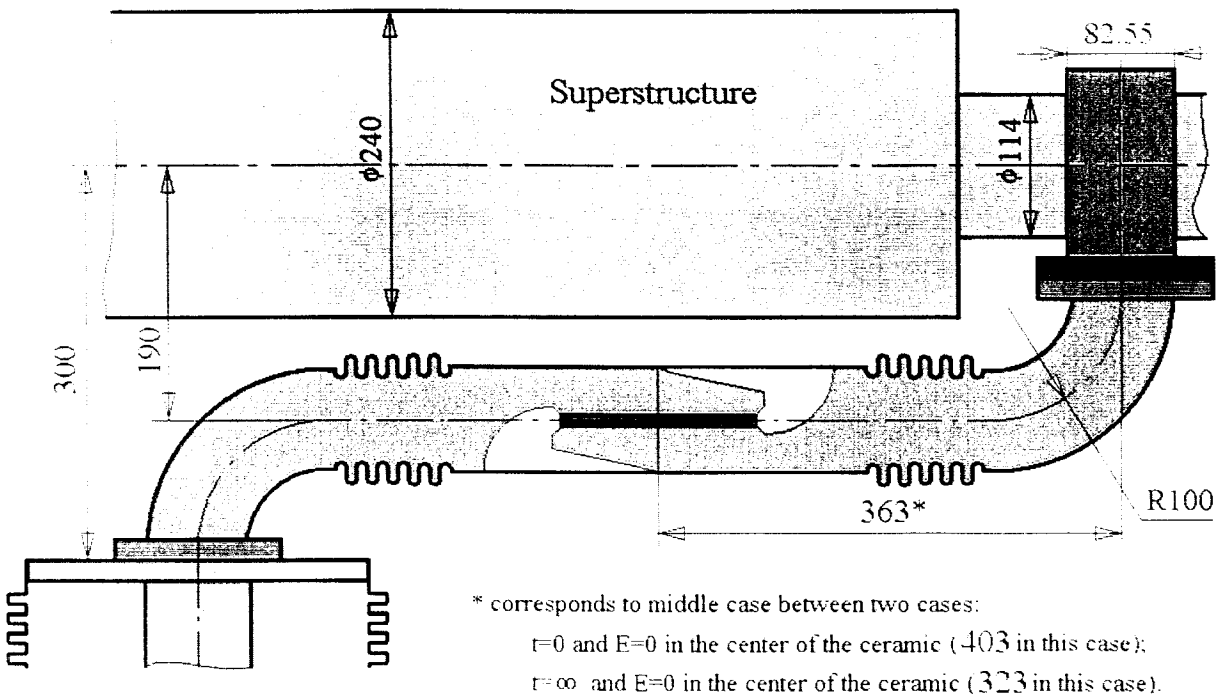
Rectangular Waveguide Input Coupler for Superstructure

A.Zavadtsev
DESY

Main parameters of the input coupler for superstructure

1. The input coupler consists of
   - the coupling element disposed in the cryomodule at 2K temperature,
   - the cold ceramic window at 70K temperature,
   - the warm ceramic window disposed out the cryomodule at room temperature
   - connecting line pieces with two bellows.
2. The input coupler is connected to the gas filled waveguide from the klystron.
3. The ceramic of the cold window should not be seen from the beam axis to minimize additional possibility of the electron emission from the ceramic.
4. There are two rectangular waveguide bellows both sides the cold window. Two rectangular waveguide bellow manufacturers are known at least:
   - Senior Flexonics Division Calorstat, France;
   - American Boa Cummings, USA.
5. The needed 21.7 MV/m gradient in 28-cell superstructure and 11.3 mA pulse beam current lead to the values: Qext=$2.12*10^6$ and RF power 792 kW.
6. Operating frequency 1.3 MHz.
7. 165.1x82.55 mm waveguide cross-section

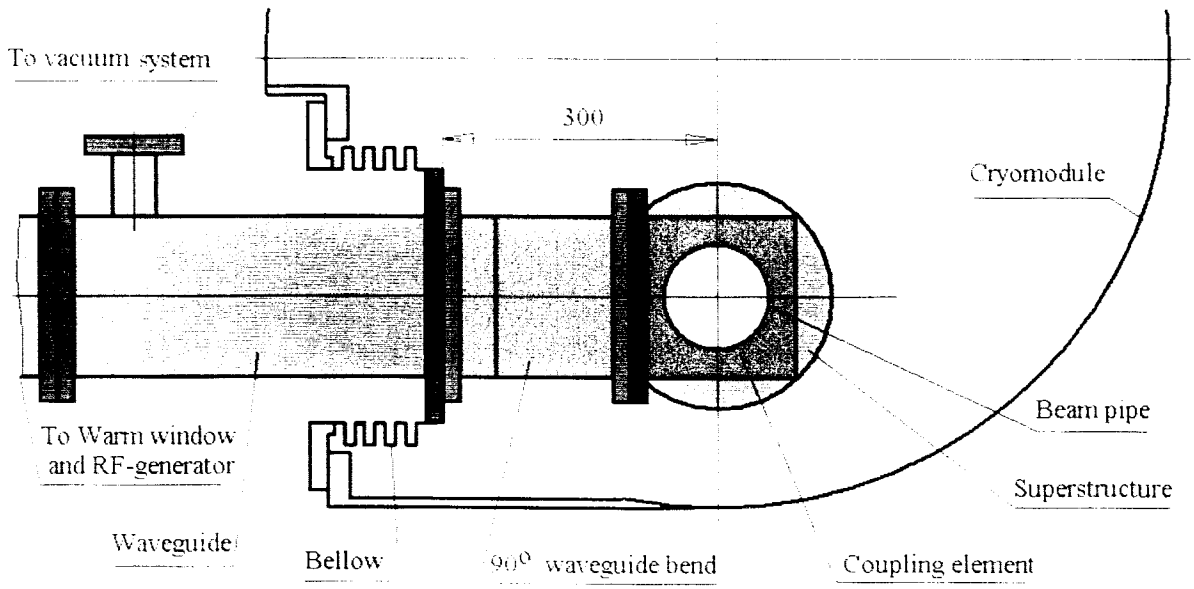
Coupler scheme



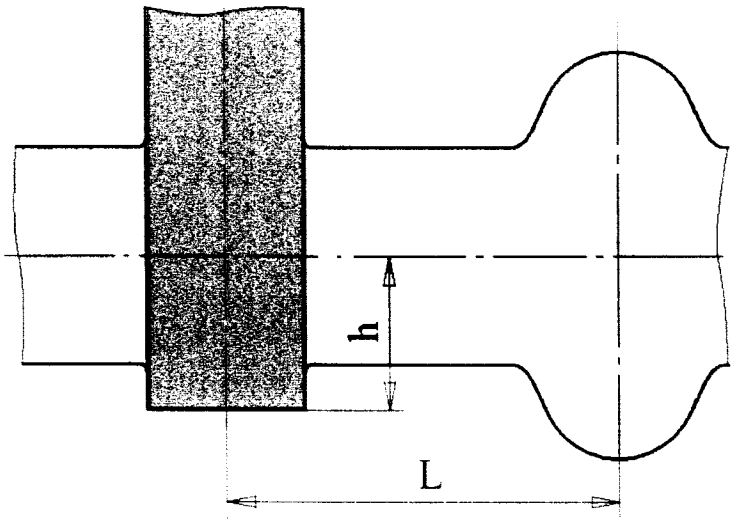
* corresponds to middle case between two cases:

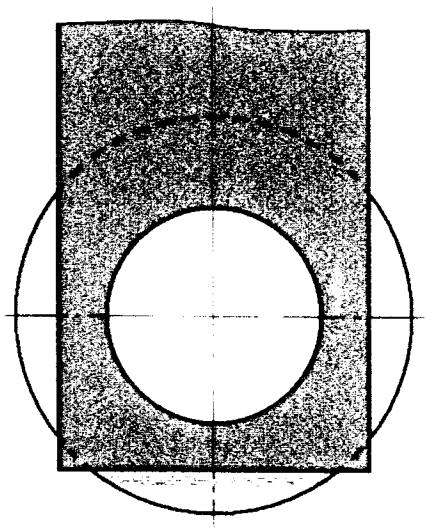
t=0 and E=0 in the center of the ceramic (403 in this case);

t=∞ and E=0 in the center of the ceramic (323 in this case).



Coupling element





L=204 mm

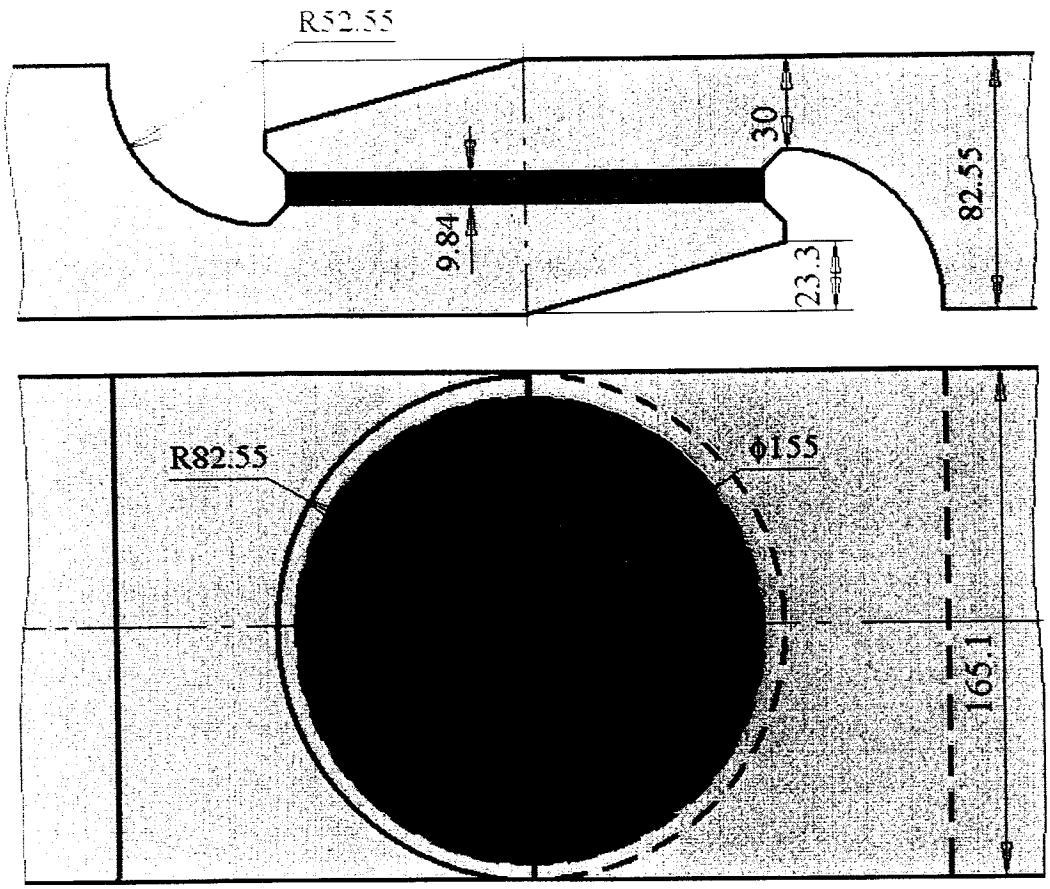
H=80 mm

$Q_{ext}=2*10^6$

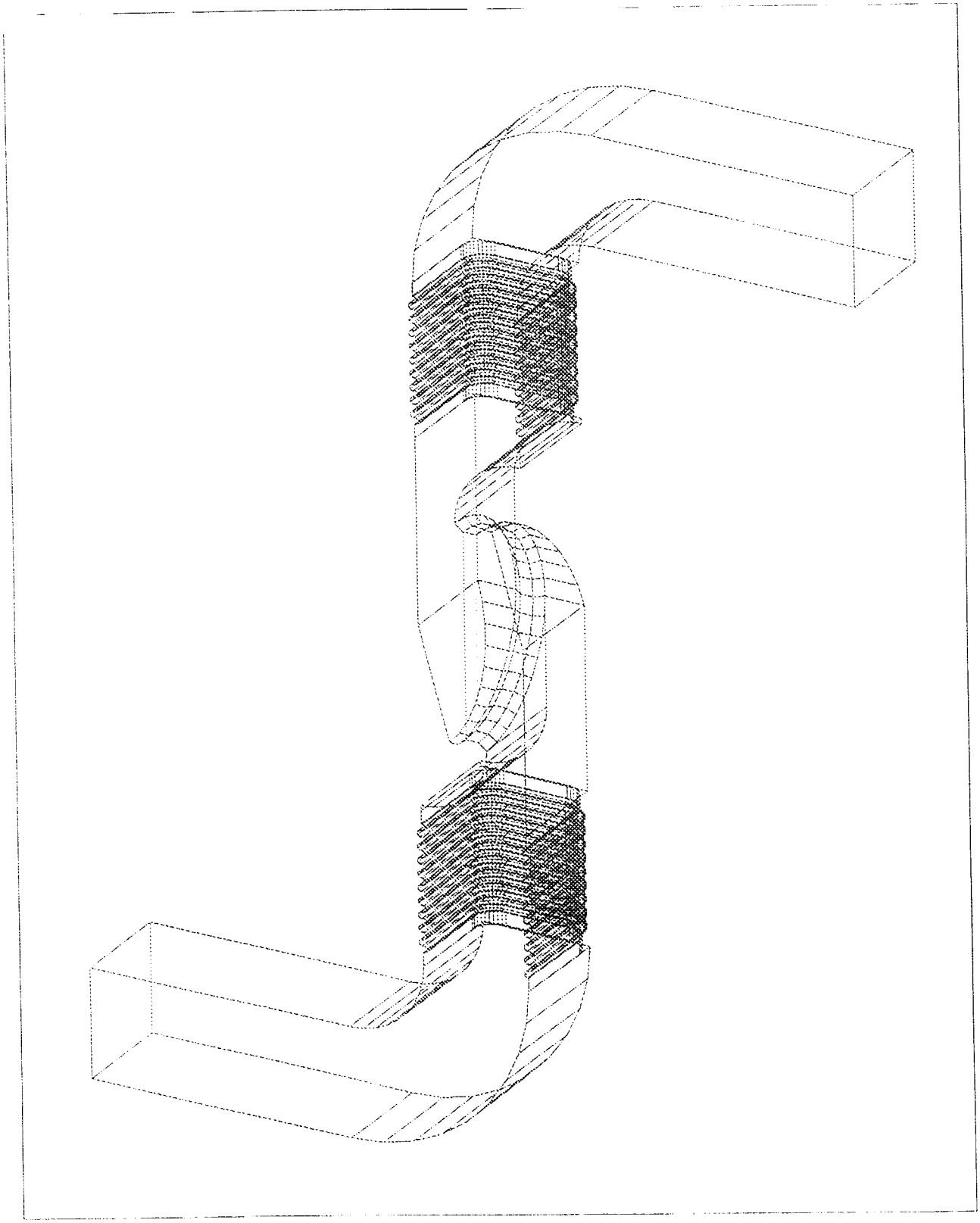
$dQ_{ext}/dL=1*10^5\ mm^{-1}$

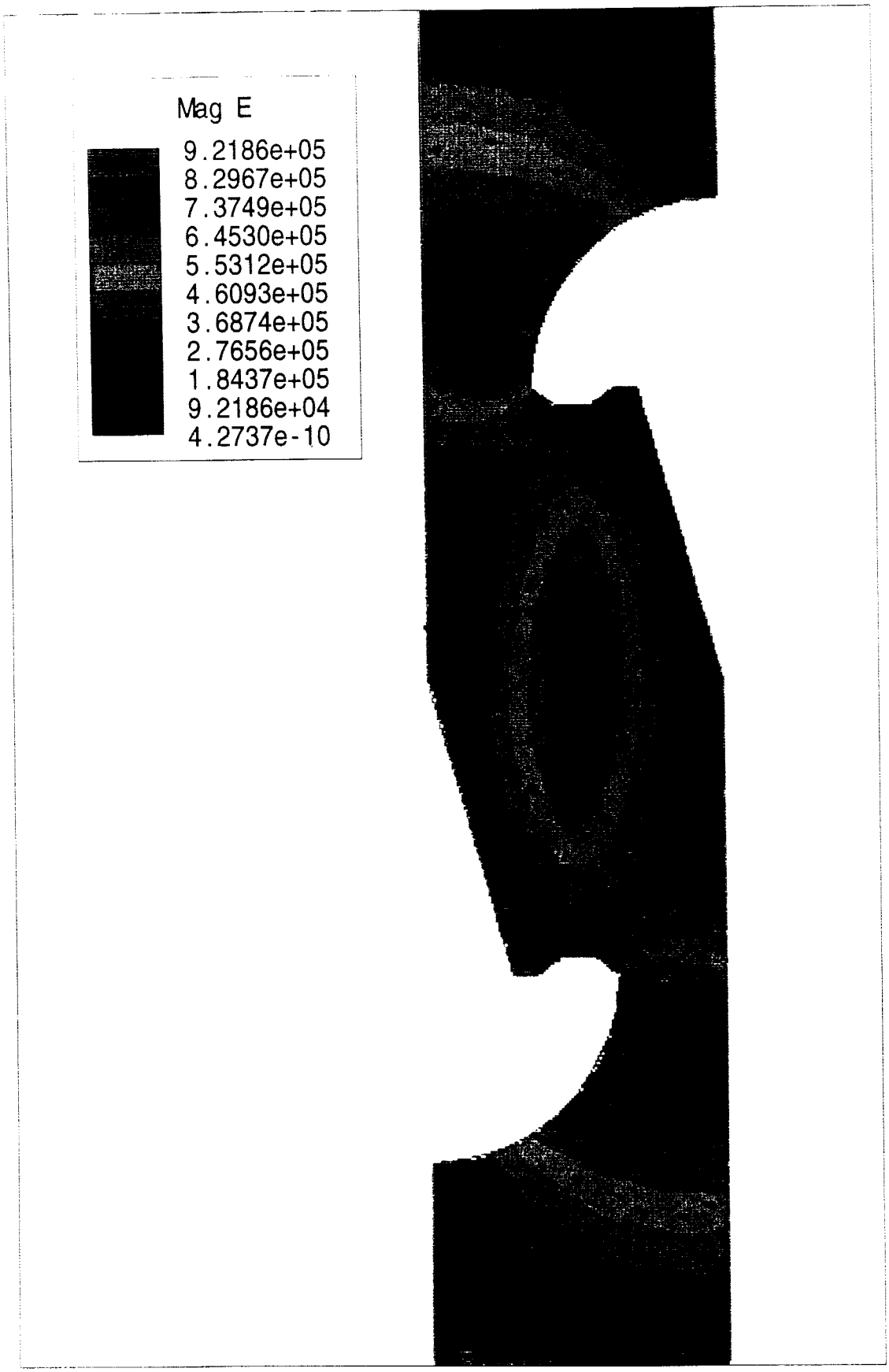
$dQ/dh=2*10^4\ mm^{-1}$

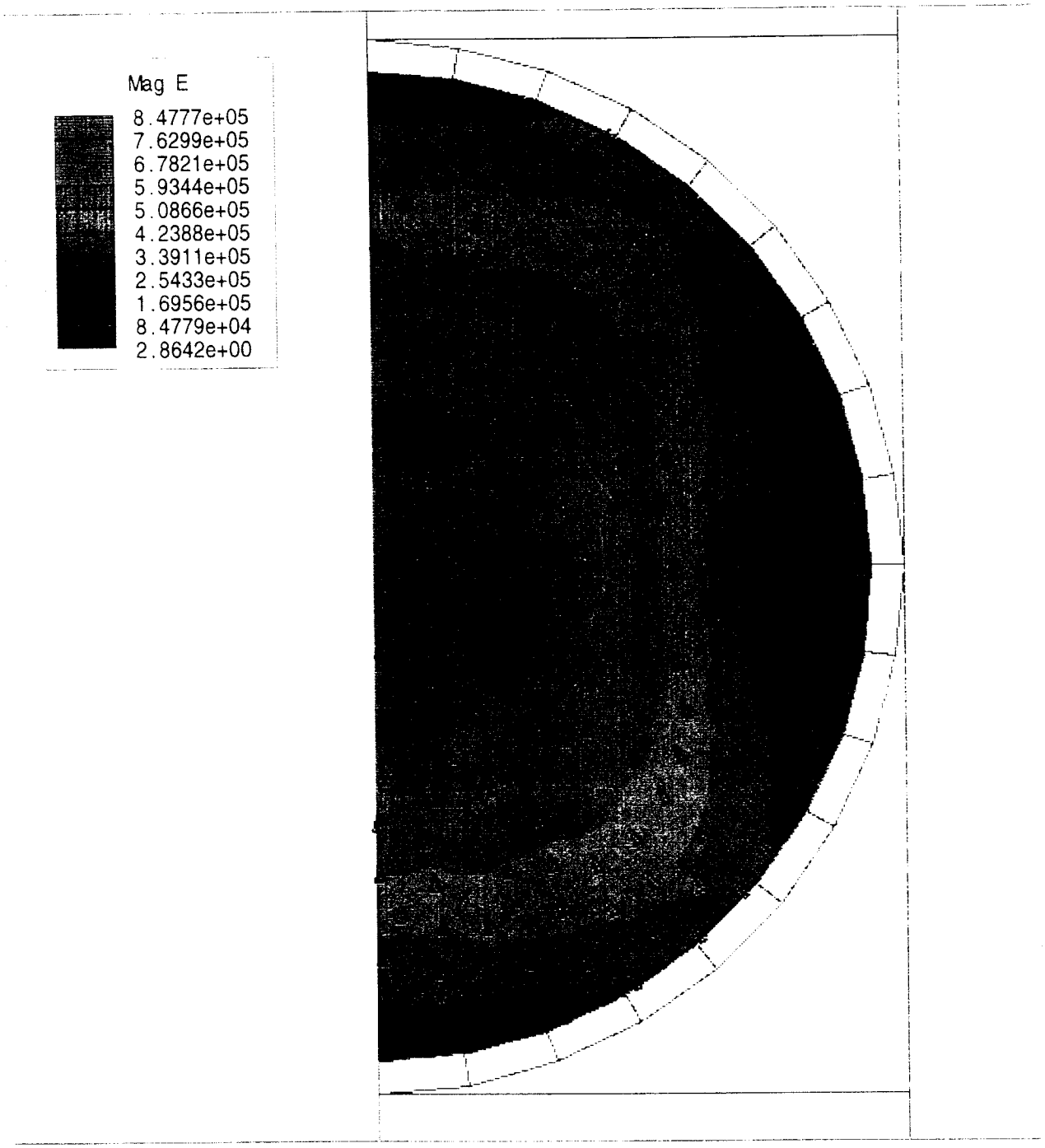
Cold structure

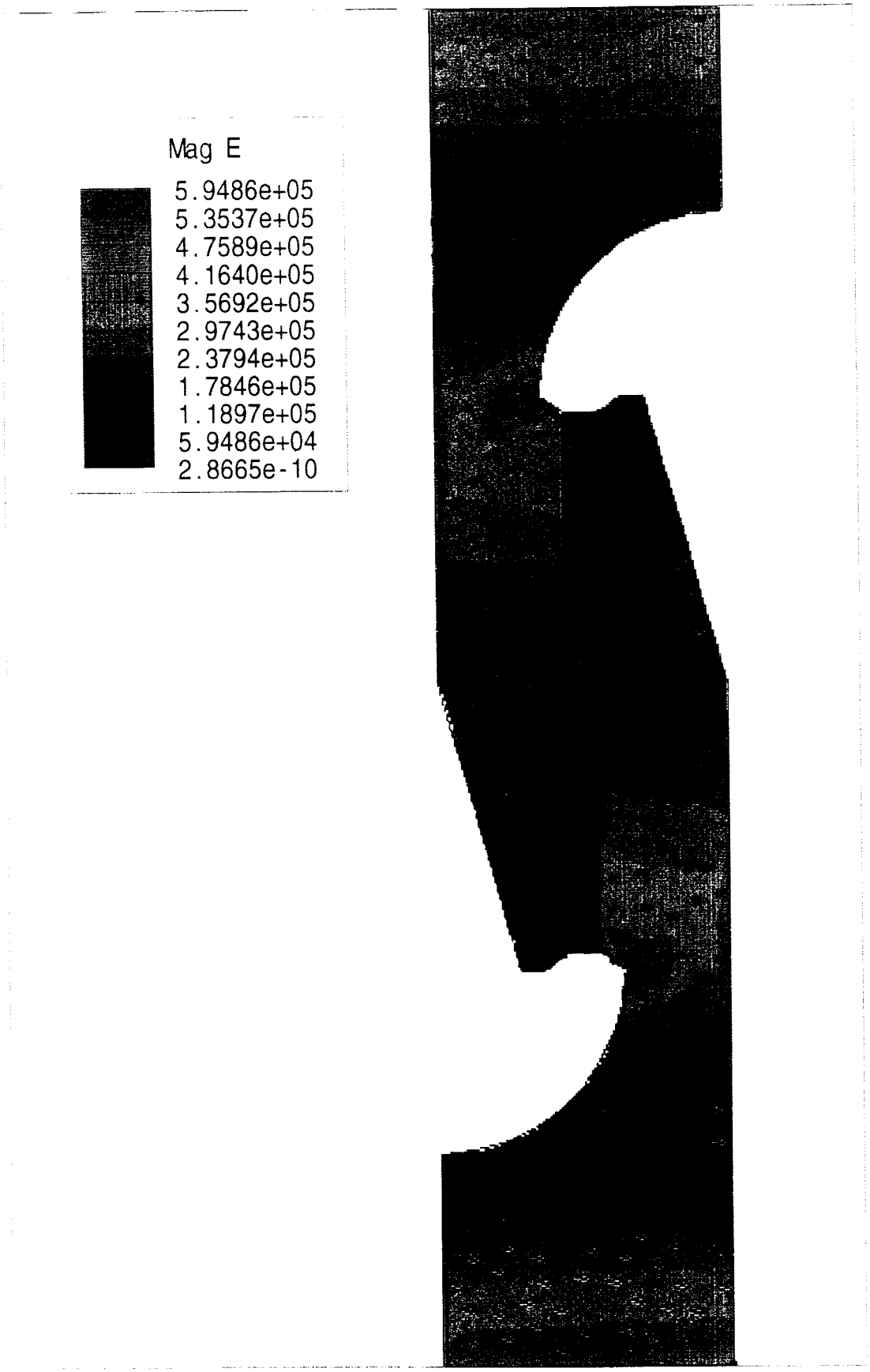


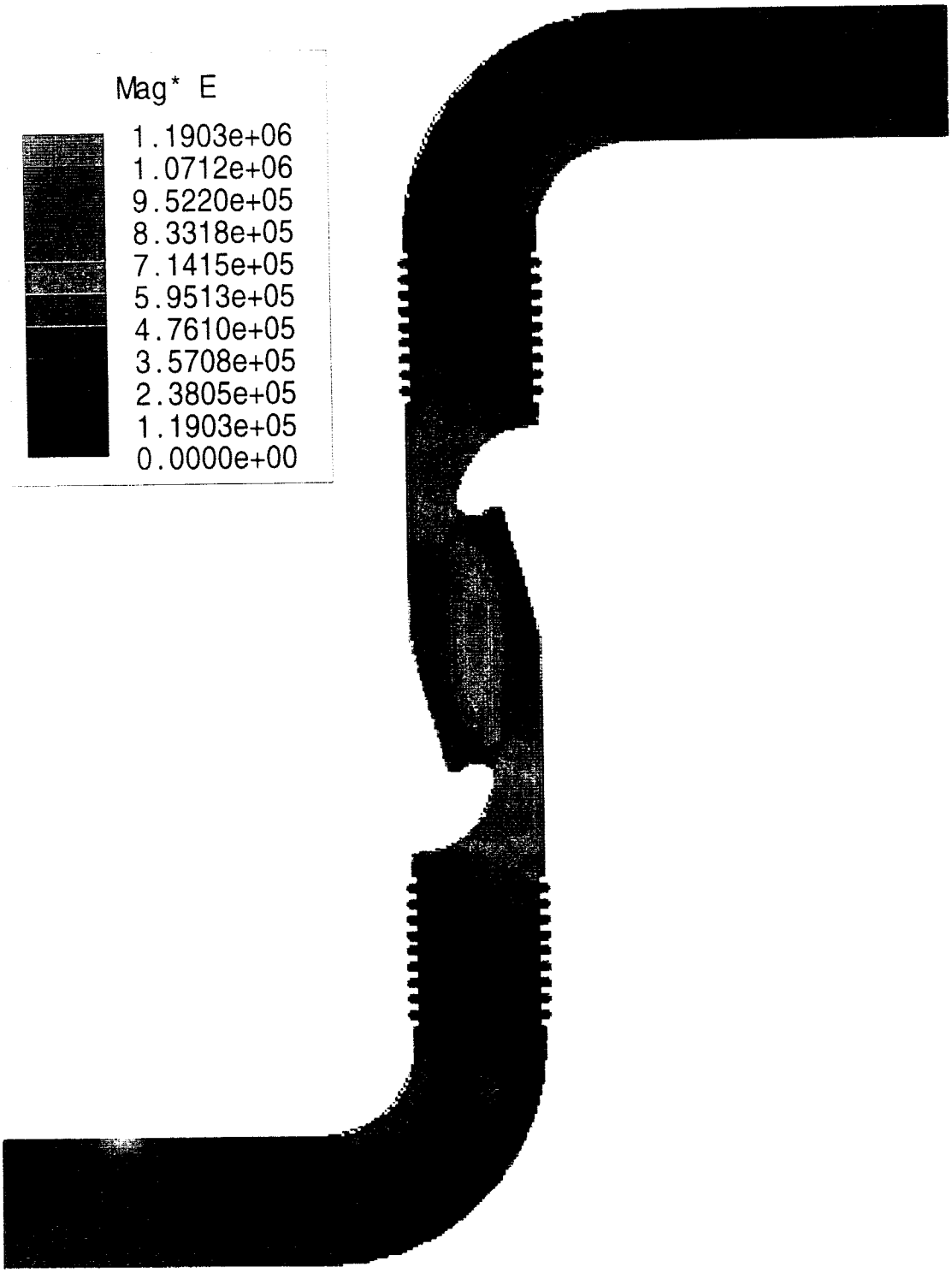
- Frequency f=1.3 GHz.
- Ceramic: ε=9, thickness t=9.84 mm.
- Main mode TE_{111} (in cylindrical cavity)
- Main component of electric field on the ceramic surface is tangential.
- $|S_{11}|<0.05$ at t=9.84 mm in range f=1286-1313 MHz.
- $|S_{11}|<0.1$ at t=9.84 mm in range f=1264-1323 MHz.
- $|S_{11}|<0.05$ at the f=1.3 GHz in range t= 9.4-10.1 mm.
- $|S_{11}|<0.1$ at the f=1.3 GHz in range t=9.1-10.3 mm.
- Maximum electric field on the ceramic is 1.7 of maximum electric field in the waveguide.

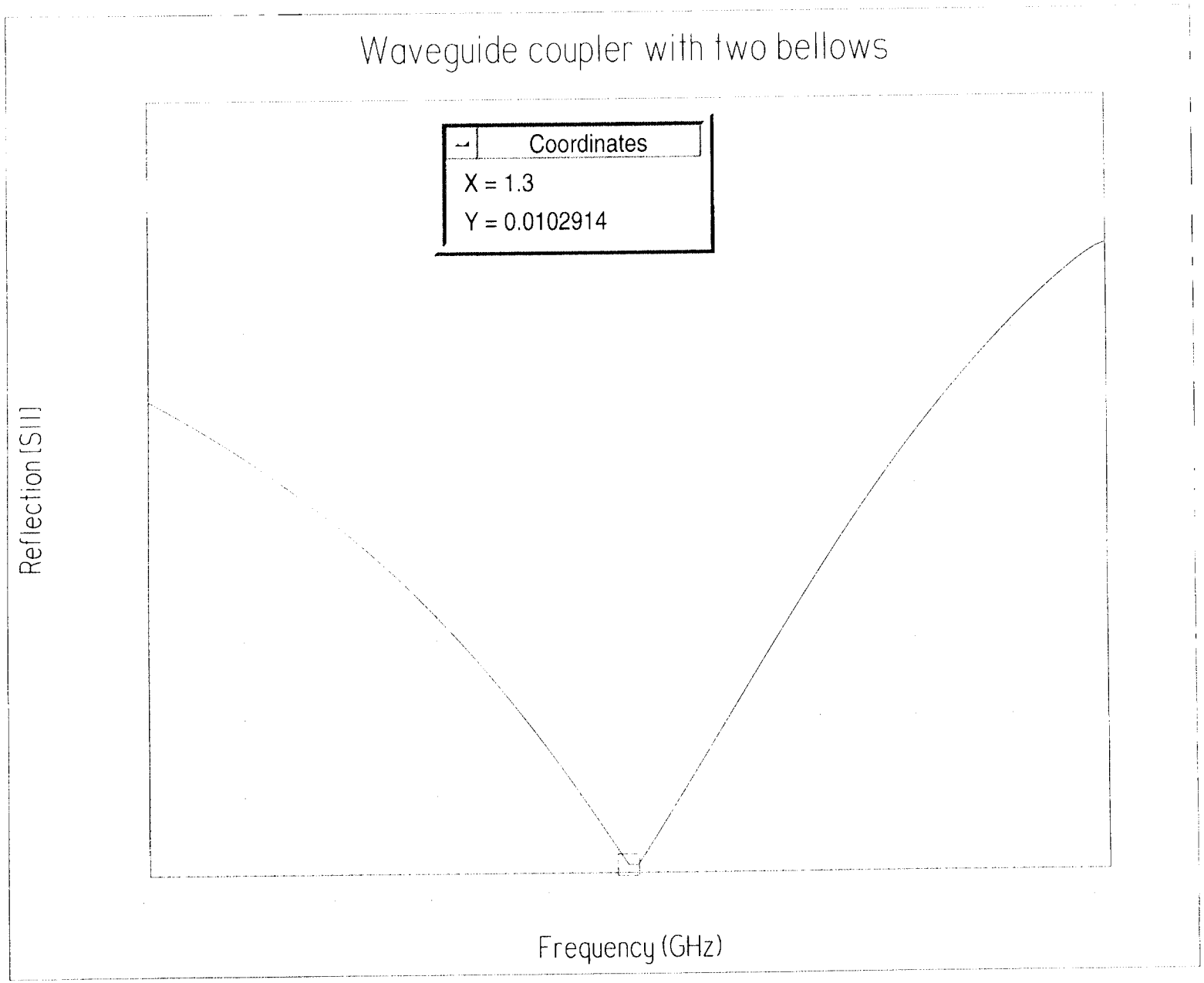



Mag E
9.2186e+05
8.2967e+05
7.3749e+05
6.4530e+05
5.5312e+05
4.6093e+05
3.6874e+05
2.7656e+05
1.8437e+05
9.2186e+04
4.2737e-10


Mag E
8.4777e+05
7.6299e+05
6.7821e+05
5.9344e+05
5.0866e+05
4.2388e+05
3.3911e+05
2.5433e+05
1.6956e+05
8.4779e+04
2.8642e+00


Mag E
5.9486e+05
5.3537e+05
4.7589e+05
4.1640e+05
3.5692e+05
2.9743e+05
2.3794e+05
1.7846e+05
1.1897e+05
5.9486e+04
2.8665e-10


Mag* E
1.1903e+06
1.0712e+06
9.5220e+05
8.3318e+05
7.1415e+05
5.9513e+05
4.7610e+05
3.5708e+05
2.3805e+05
1.1903e+05
0.0000e+00


Waveguide coupler with two bellows
1
Coordinates
X = 1.3
Y = 0.0102914
Reflection [S11]
Frequency (GHz)

LOW LEVEL MEASUREMENTS ON REDUCED HEIGHT WAVEGUIDE TRANSITION

P.Lepercq, T.Garvey, R.Panvier

CNRS, IN2P3, LAL Orsay (France)

C.Travier, S.Chel, M.Desmons

CEA Saclay (France)

DESIGN OF THE NEW RF TRANSITION

GOAL :

-transition working under neutral gaz pressure

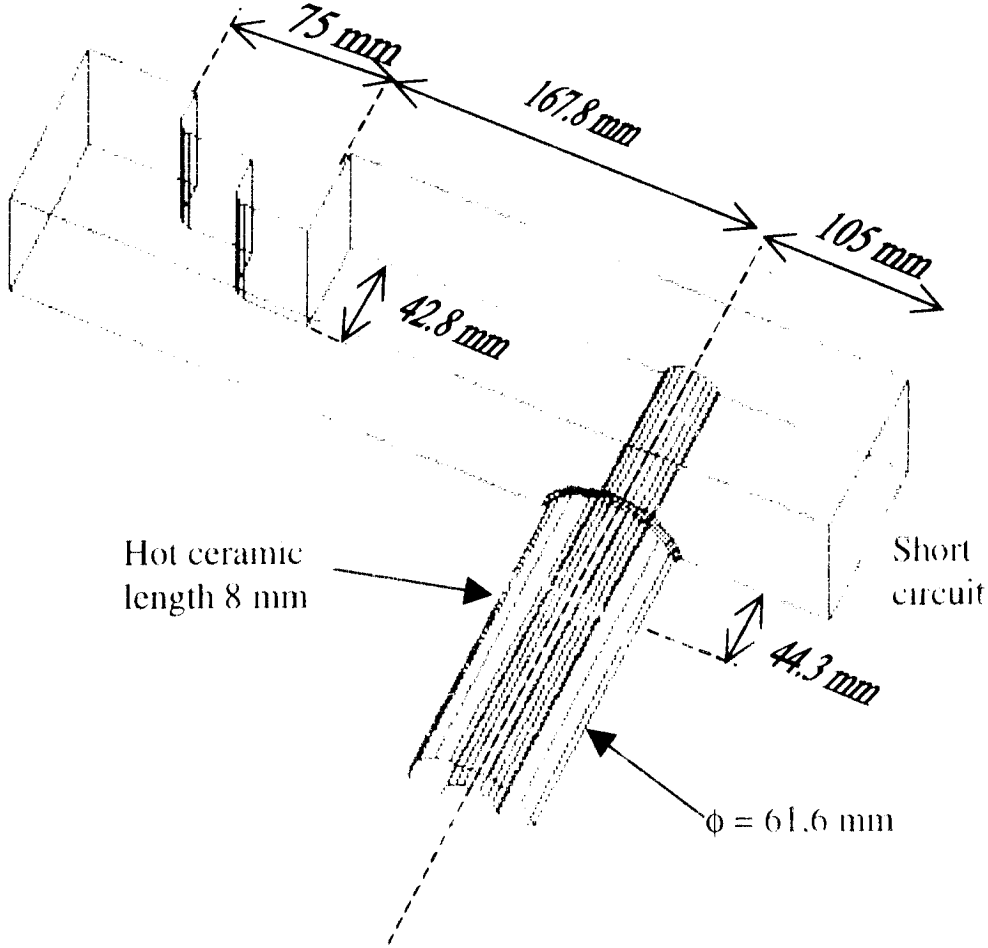
-integration of the « hot » ceramic window in the design of the transition

-low electric field in the transition and the ceramic window

-large mechanical tolerances

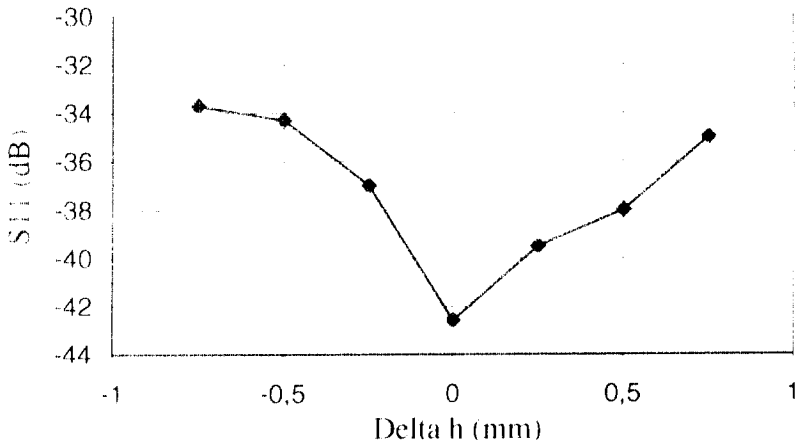
-realisation easy

Straight transition

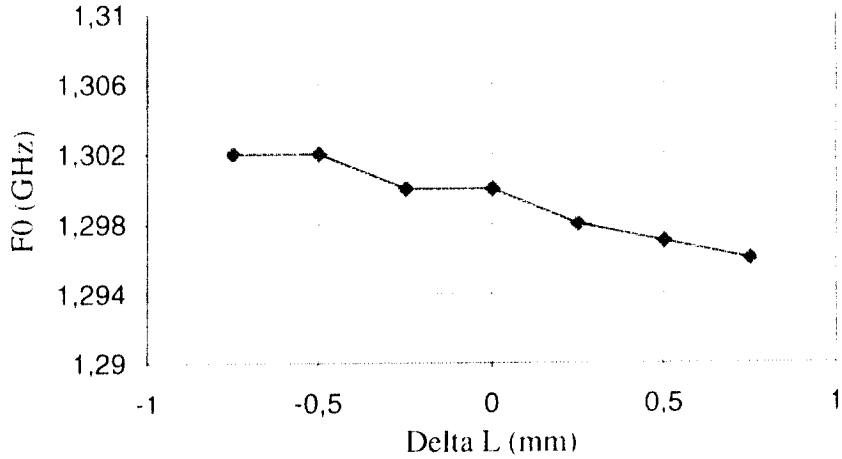


EFFECT OF SHIFT IN DIMENSIONS

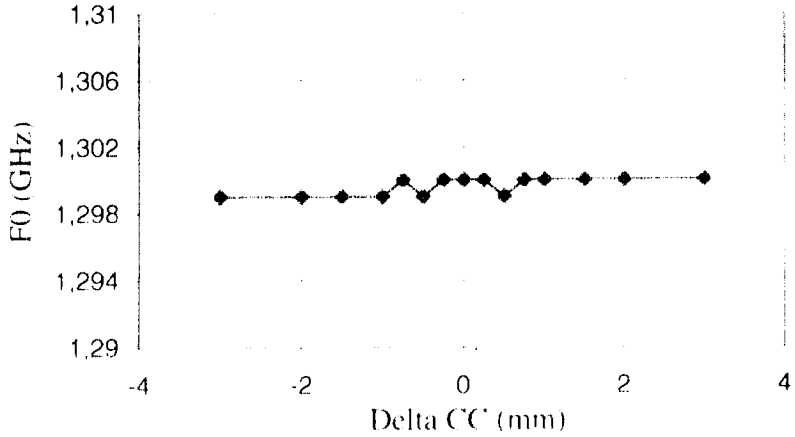
Penetration of the reduced waveguide

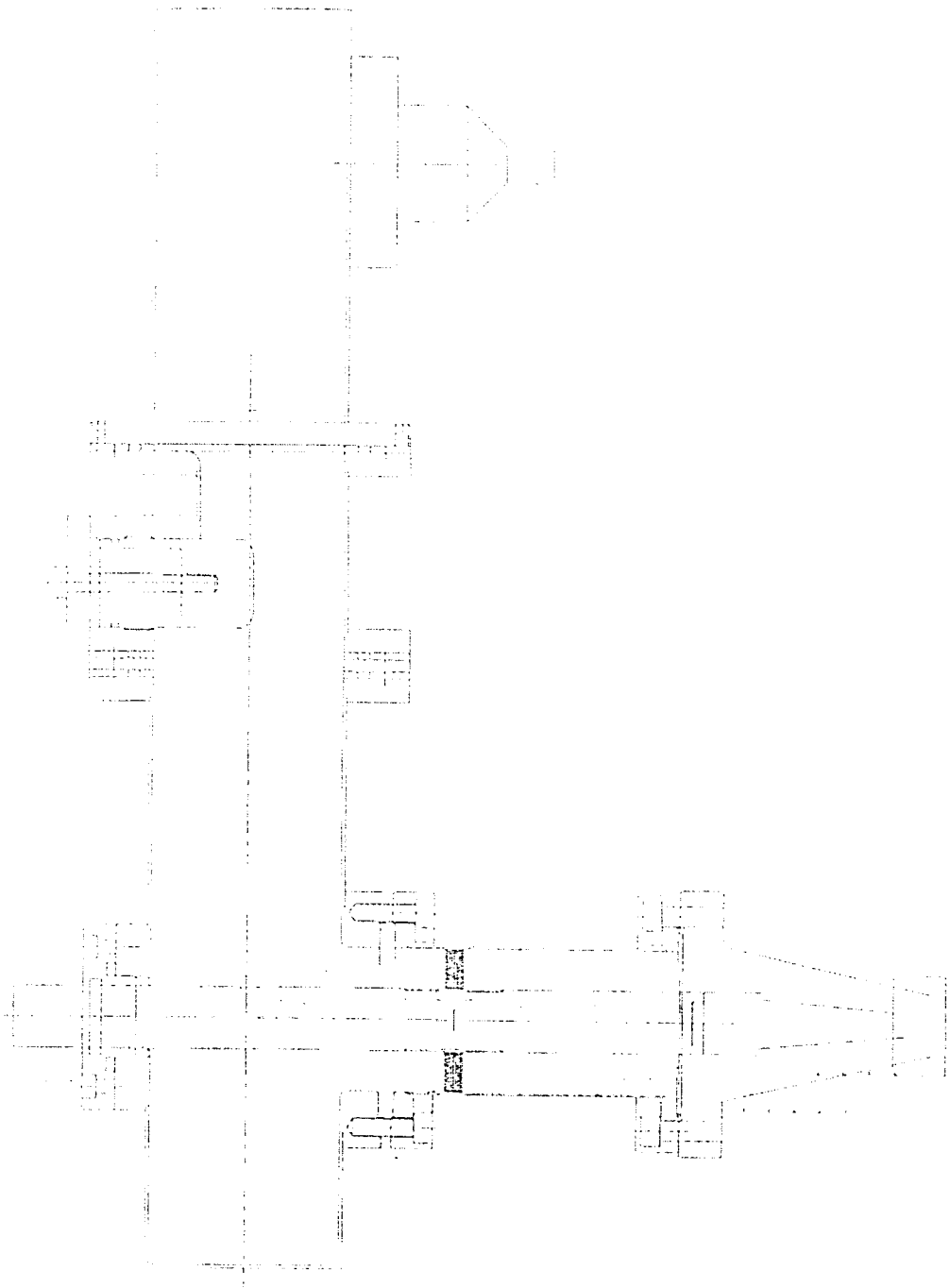


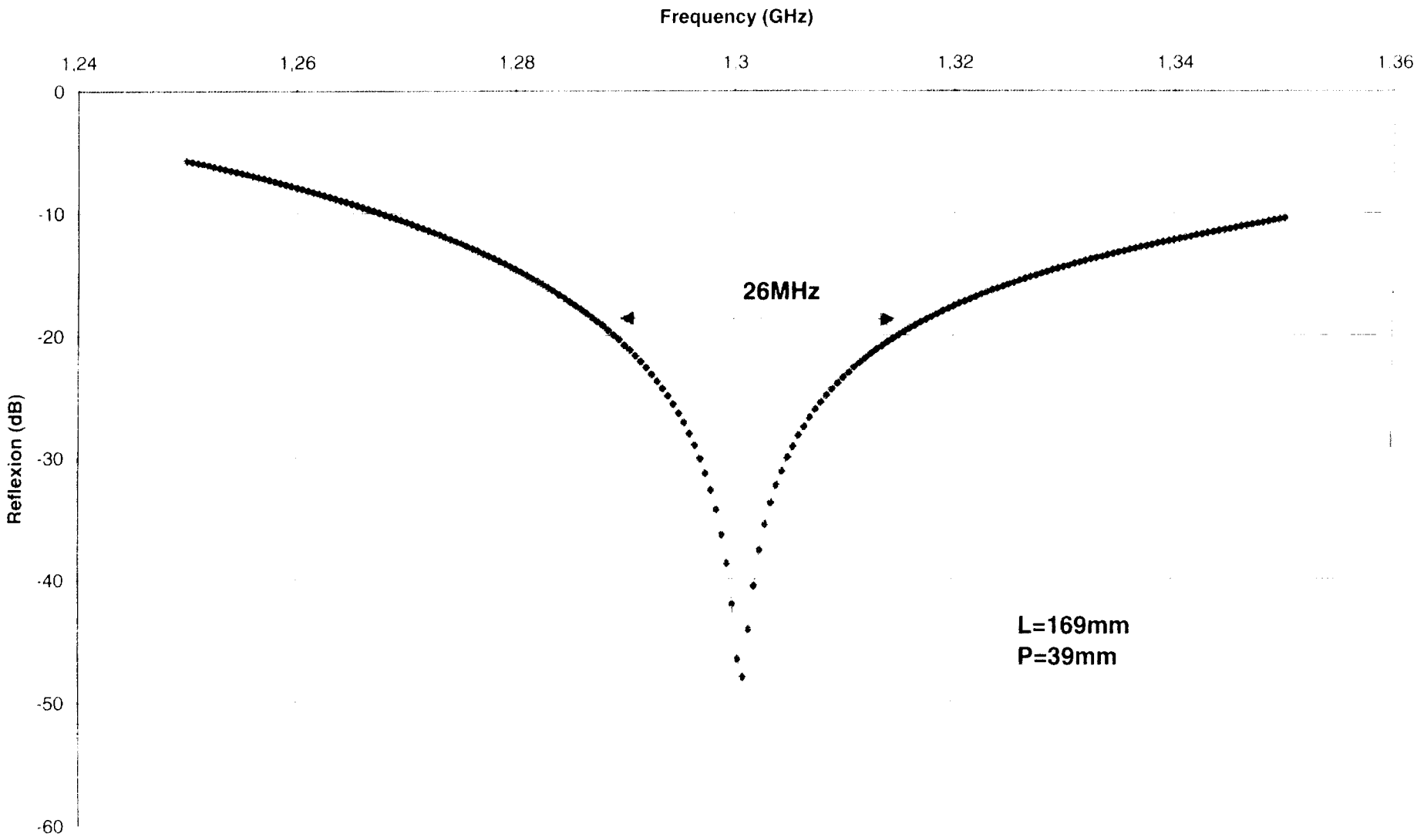
Localisation of the reduced waveguide

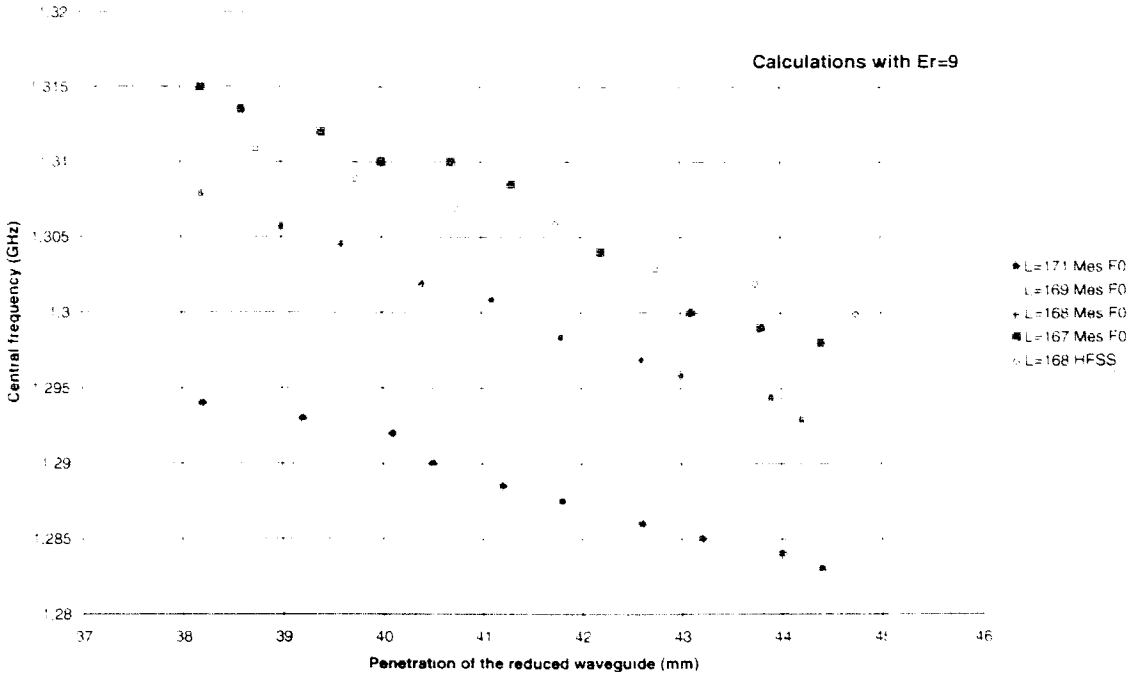


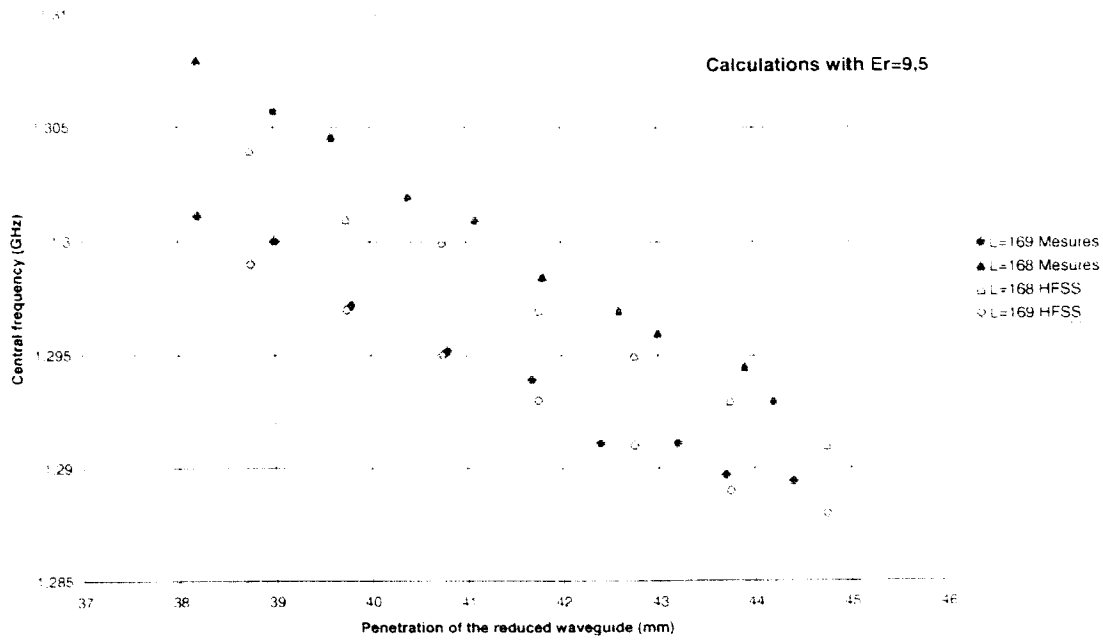
Variation of the localisation of the short-circuit






Frequency (GHz)
1,24
1,26
1,28
1,3
1,32
1,34
1,36
0
-10
-20
-30
-40
-50
-60
Reflexion (dB)
26MHz
L=169mm
P=39mm

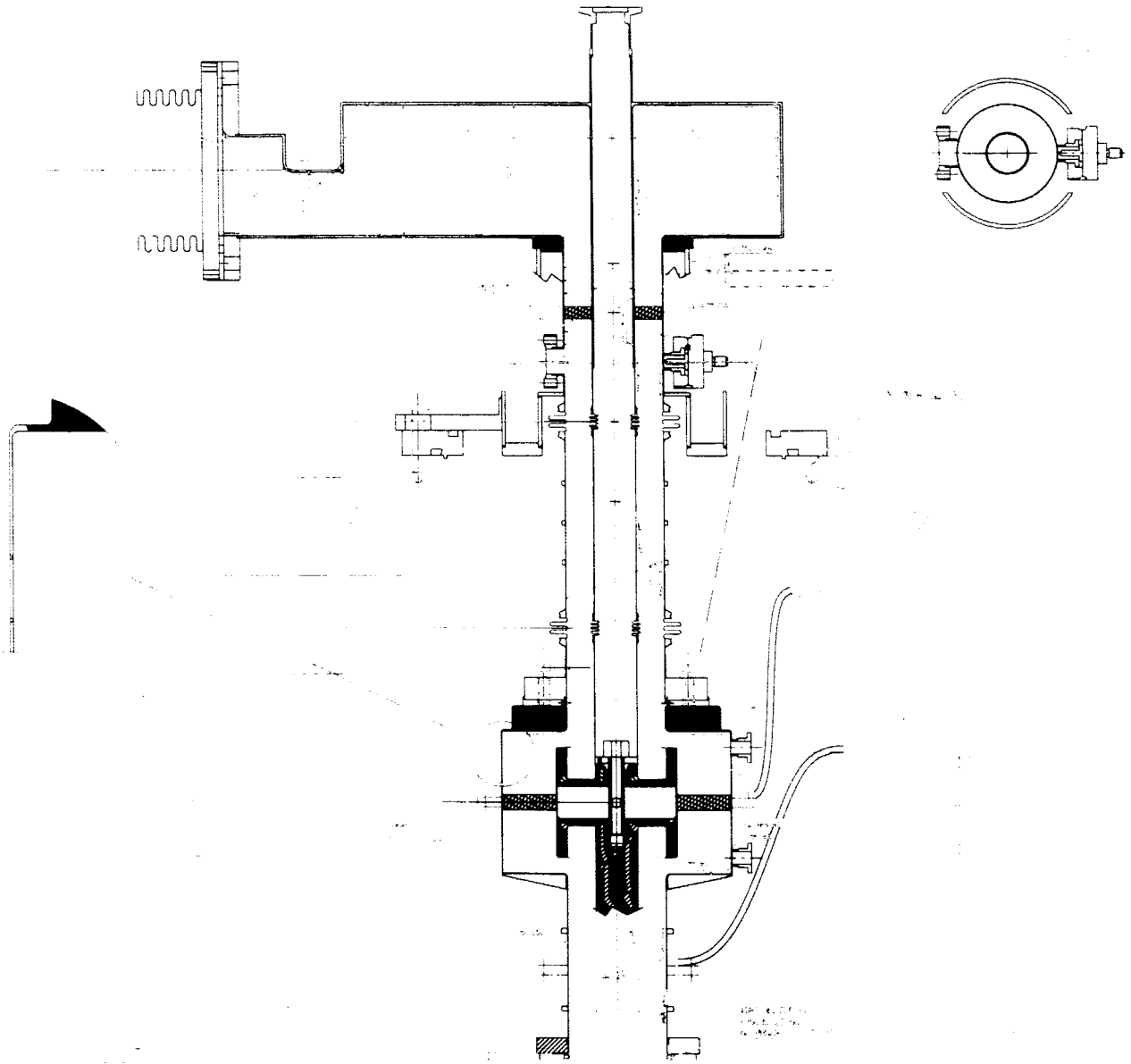

Calculations with Er=9
Central frequency (GHz)
Penetration of the reduced waveguide (mm)
L=171 Mes F0
L=169 Mes F0
L=168 Mes F0
L=167 Mes F0
L=168 HFSS


Calculations with Er=9,5
Central frequency (GHz)
Penetration of the reduced waveguide (mm)
L=169 Mesures
L=168 Mesures
L=168 HFSS
L=169 HFSS

LAL General Mechanical Design for TTF/TESLA Couplers

- to be first mounted in the 7th and 8th cryomodule ?
- we need the confirmation of some tests (transition)
- Assumptions:
  - 3rd generation cryostat (± 2 mm)
  - stub tuner on the wave guide before the coupler (no adjustable antenna)

66

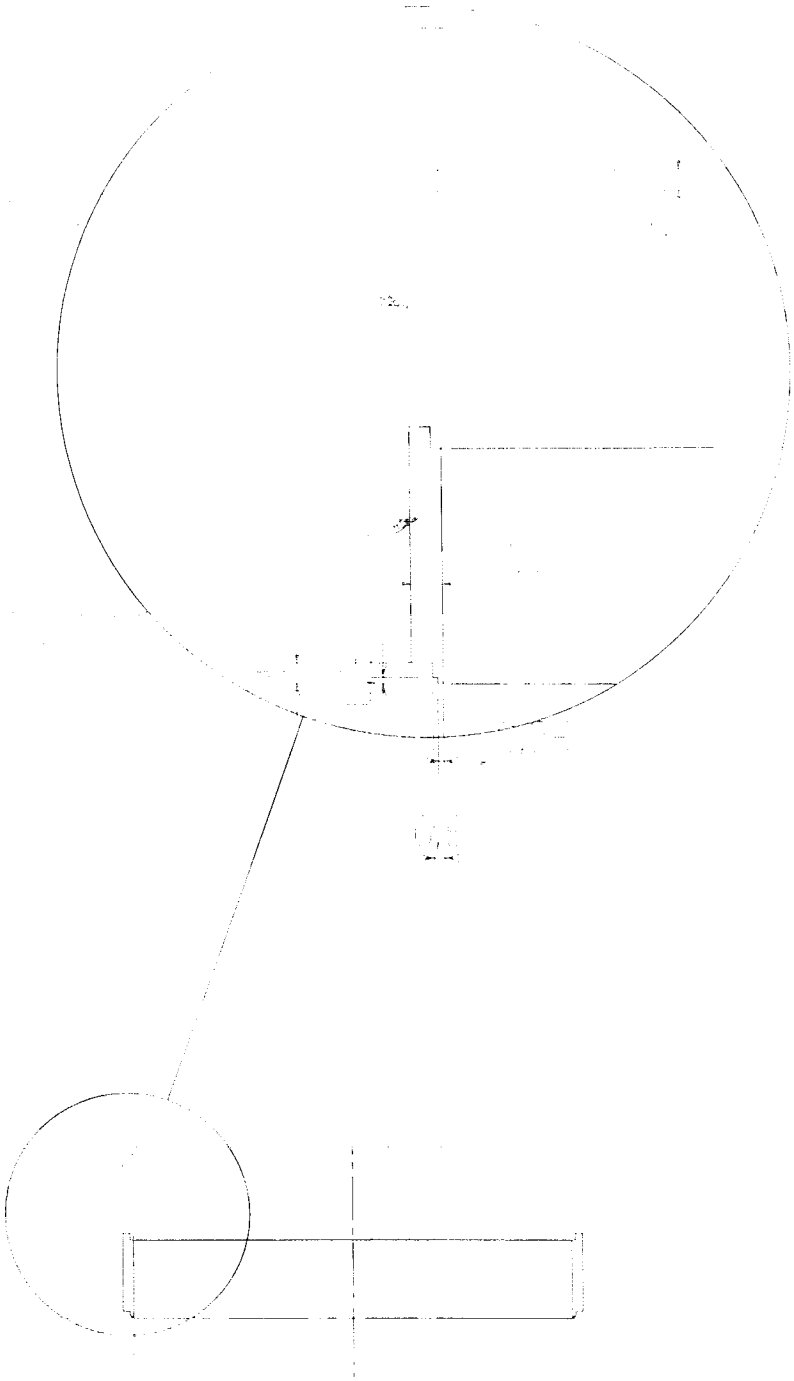


LAL General Mechanical Design for TTF/TESLA Couplers

- « Reduced Height Waveguide » transition (P. Lepercq)
  - SF6 / AIR
    - no vacuum, cost less money
  - welded core and guide
  - cost reduction (2500 $ with ceramic)
  - to be tested !

LAL General Mechanical Design for TTF/TESLA Couplers

- Ceramics brazed on titanium collar
  - easiest way to be made
  - less dielectric losses expected
  - Ti/SS transitions made by brazing
  - transitions welded (Ti/Ti & SS/SS)
  - exception: inner collar of cold ceramic: Copper



LAL General Mechanical Design for TTF/TESLA Couplers

- Coax
  - optimised thickness
    - 0.2/0.5/0.2/0.1 mm + stiffening collars
    - made by grinding
  - rigid couplers
    - ± 2 mm in each direction
    - just 2 very small bellows
  - copper coating
    - 5 microns everywhere except for:
      - bellows (probably tolerable)
      - titanium (very difficult coating)
  - length
    - a little bit longer than current coupler ?

LAL General Mechanical Design for TTF/TESLA Couplers

- Static losses (w)

	LAL	Ferm.	DESY
2 K	0.035	0.03	0.051
4.2 K	0.42	0.32	0.39
77 K	0.48	2.2	1.65
RT	140	135	160

- RT = 800*L2 + 250*L4 +14*L77

LAL General Mechanical Design for TTF/TESLA Couplers

- Coax (II)
  - rigid connection between cryostat and waveguide
    - to protect the warm ceramic
  - closing
    - compensation of clearance by welded flanges

LAL General Mechanical Design for TTF/TESLA Couplers

- Cold ceramic
  - 3 options
    - TW
    - Cylindrical type (Desy type)
    - $\lambda/2$ (or twin-disk)
- Connection to cavity
  - 61.6 mm diameter ?

Discussion of the Proposed Orsay-Saclay Coupler Design

T. Garvey (LAL, Orsay)

The French design is based on the following two assumptions (already discussed at the previous meeting) ;

(a) No variation is required on the antenna depth of penetration (Qext variations are assumed to be done with a 3-stub tuner in the upstream waveguide).
(b) The longitudinal motion due to thermal shrinkage is $< \pm 1$ mm.

These assumptions were accepted.

The following comments were made ;

· the stainless bellows must be coated,

· the overall coupler length is not necessarily fixed by the case of TTF,

· some mechanical flexibility is needed between the warm window and the WG transition,

· calculations are needed to check what we gain in going to 0.1 mm co-ax tube width,

· welding the warm part of the coupler to the cryostat is acceptable,

· we need to look seriously at how the coupler is mounted to the module,

· it was pointed out that the superstructure flange is intende to be $\phi = 80$ mm and not 60 mm.

→ Options for the French group ;

(i) Design ϕ 80 version of existing proposal,

(ii) Stay with ϕ 60 and employ a « taper »,

(iii) Propose 60 mm flange for Superstructure and design 'intermediate' stage coupler (480 kW coupler, see transparencies of Sekutowicz).

TTF Linac ACC1 (Module 3) Input Couplers Performance.

D.V.Kostin, M.V.Lalayan, W.-D.Moeller, D.Proch, S.N.Yarigin. DESY, Hamburg.

1. Couplers Conditioning. 07.10 -25.10.1999

Total test time: 342hr.
RF ON time: 245hr. (72% of total time).
RF OFF time: 97hr. (Open tunnel time 24hr.)

Performance:

Test conditions: TW regime, On Resonance (with tuned cavities).

- Power was limited by Klystron (~380kW max. per coupler).
  Power rise time limited by coupler vacuum (2.5×10^{-7}mbar max.),
  also e^- at long pulses (≥300μs) and several minor problems.
- Electron pick-ups (e^- sensors) signal was in range of 0.5÷1.5V,
  (1.5V corresponds ~300μA).
- Rise time (only RF ON) for rectangular pulses at 1Hz rep.rate:

Pulse	20μs	20μs	50μs	100μs	200μs
$P_{for.max}$,kW	250	380	380	380	380
time, hr	11	3	2	3	5

Pulse	300μs	300μs	400μs	500μs
$P_{for.max}$,kW	250	350	300	260
time, hr	2	1	2	1

- Rise time (only RF ON) for rectangular pulses at 10Hz rep.rate:

Pulse	20μs	50μs	100μs	200μs	200μs
$P_{for.max}$,kW	360	360	360	300	340
time, hr	1	1	1	0.5	0.5

- Rise time (only RF ON) for FT pulses at 10Hz rep.rate:

Pulse	240μs	440μs	440μs	640μs	1040μs	1200μs
$P_{for.max}$,kW	350	250	350	350	340	350
time, hr	3	1	2	0.5	2	2*

* with bias voltage 2.5kV on.

Main Problems:

a. 1 Hz repetition rate.
   - Klystron IL events.
   - VAC.Cpl and e^- IL events.
   - Spark, PM, WG Spark IL events caused by X-Rays.

b. 10Hz Repetition rate.
   - Klystron and Modulator IL events.
   - Klystron Gun Voltage jumps.
   - VAC.Cpl IL events.
   - Cavity 8 Quench (3 times, at FT 240+800μs,10dB,350kW)
   - Coupler 2 behavior at high gradient. Knob heated up (Δt_{max}=+30K).
     It looks like thermal flow goes from center of coaxial part.

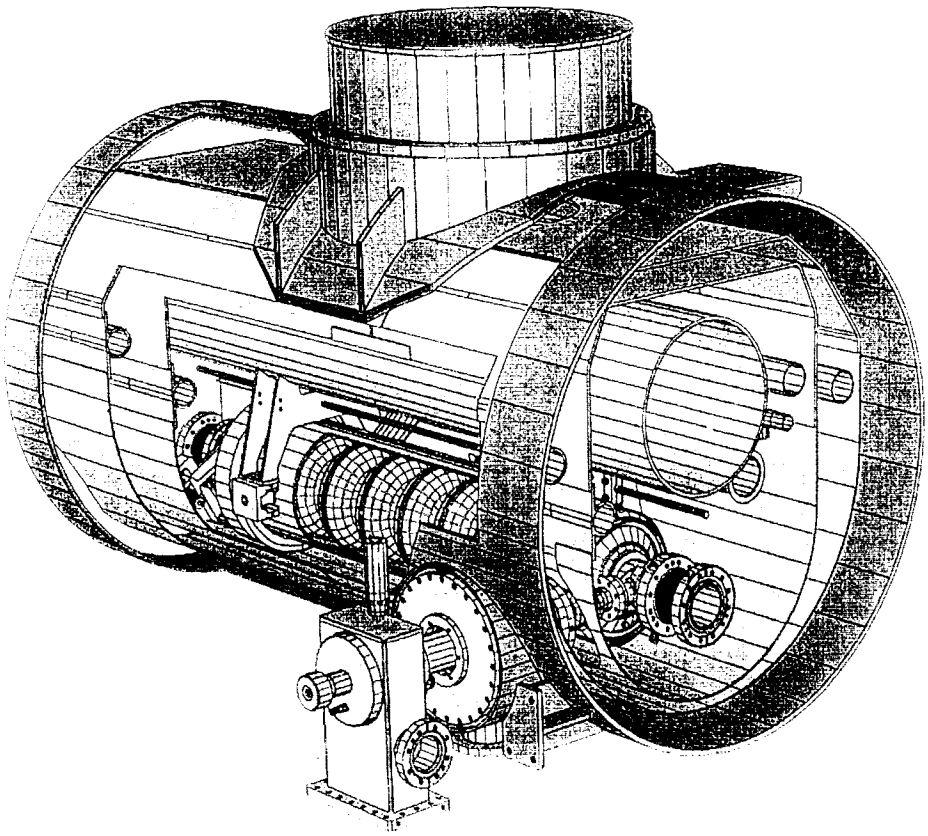


Fig.1. TTF Module layout.

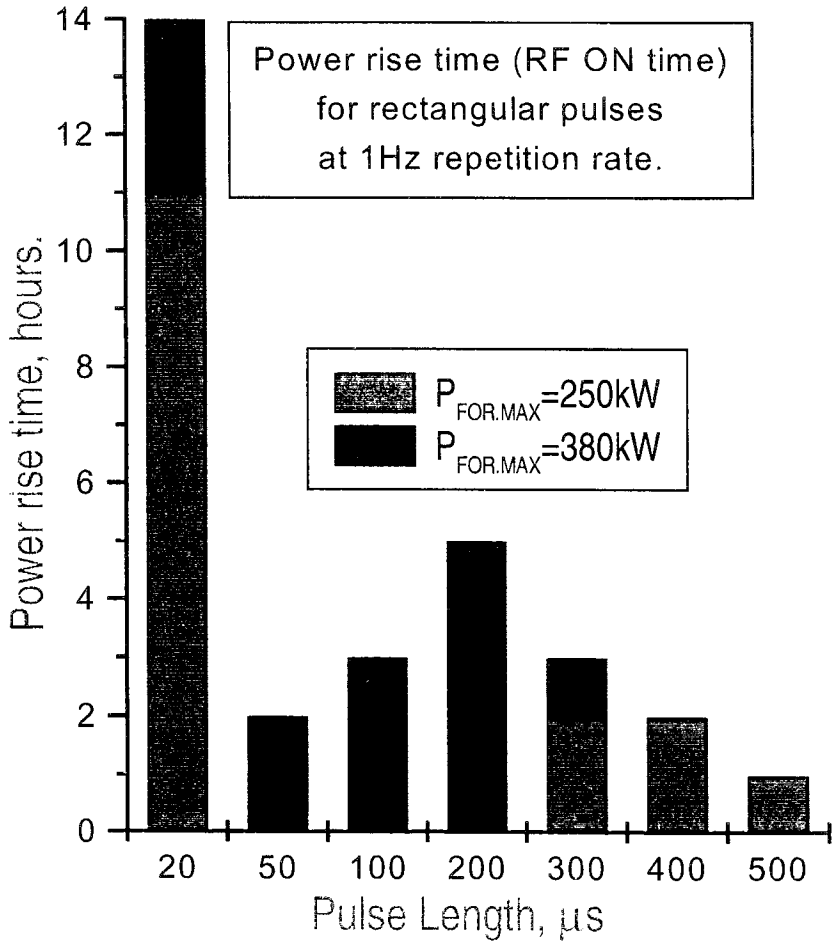


Fig.2. TTF Module Input couplers performance.

2. Single Cavities tests. 25.10 -09.11.1999

TESLA resonators were tested. Maximum E_{ACC} was determined for each cavity. Cryo losses measurements were done. Maximum accelerating gradient was obtained in region of 18÷30MV/m limited by thermal breakdown in cavities, no limitation from couplers performance was present.

Main Problems:

- Klystron Gun Voltage jumps.
- RF Loop operation is too noisy.
- Coupler 2 behavior at high gradient. VAC.Cpl IL events.
- Klystron IL events.

3. Module test. 09.10 -14.11.1999

Power was connected to all cavities normal way save cavities 1 and 8, because they have lower maximum E_{ACC} values.
Cavity 1 has 1.1dB and Cavity 8 has 3.0dB attenuation in WG.

Operating at FT pulse, 1300μs, $P_{for.max.}$=185kW
Maximum non-stop time: 11hr.
Maximum time without the Quench: 22hr.

Electron sensors still registering some activity (0.2÷1.5V)
On coupler #3 e^- pick-up voltage holds on 1.0V (~200μA) level.
Coupler #2 knob Δt_{max}=+7K.
Couplers Vacuum level dropped from 2×10^{-7} to 2×10^{-9}mbar within 72hr.

Main Problems:

- Klystron Gun Voltage jumps (with 3.0÷6.5kV amplitude).
- Klystron Modulator IL events (12.11-14.11 →17 events)

4. Module test (continuation). 18.11.1999

E_{ACC}=22±1 MV/m reached with beam.

Main Problem:
Coupler #3 Q_{EXT} dropped drastically, no operation was possible.
Coupler Vacuum jumped up to IL level, 3 e^- pick-up filters were destroyed.
HV input impedance measured was 18MΩ (must be infinite).
Probably, that was caused by plasma discharge in warm coaxial part.
After disconnecting HV and shortening of HV input problem disappeared.
Exact cause of this can by discovered by disassembling.

5. Conclusion.

TTF Linac module #3 operation allowed its multiplicity of different systems and parts to be tested in order to determine the performance of superconducting linac module as a whole. As a primary goal of this test superconductive TESLA cavities performance investigation should be named, but many other systems must be put under test as well. TESLA main couplers are one of such parts. Performed test operation showed that TESLA couplers apt to meet needed requirements for linac operation and the main limitation of accelerating gradient increasing are resonators themselves. Minor problems accounted with TESLA couplers are nevertheless important to be investigated and could be solved by gaining more experience on this way.

TTF-Coupler-Workshop
Saclay, 17./18.01.2000

Experiences and problems in designing and manufacturing coaxial couplers

by Cornelius Martens, DESY

Introduction

- the coaxial concept, warm window
- prefer welding instead of brazing (so copper-plating is necessary)

Machining and cleaning cylindrical Parts

- machining cylindical parts
- cleaning and transport

Welding and Brazing

- welding
- heat procedure
- brazing copper-rings and 4.5K-connector

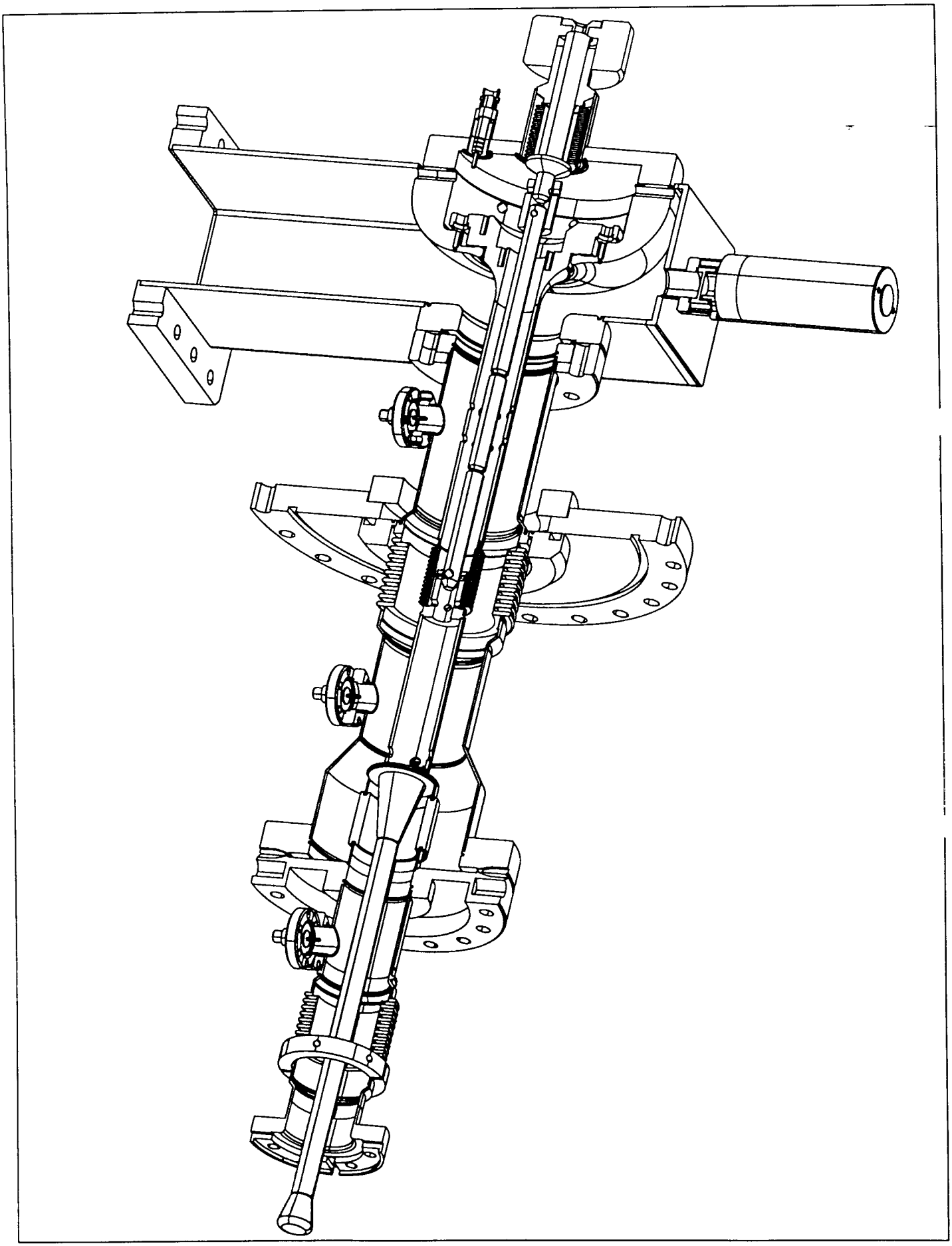
Copper-plating

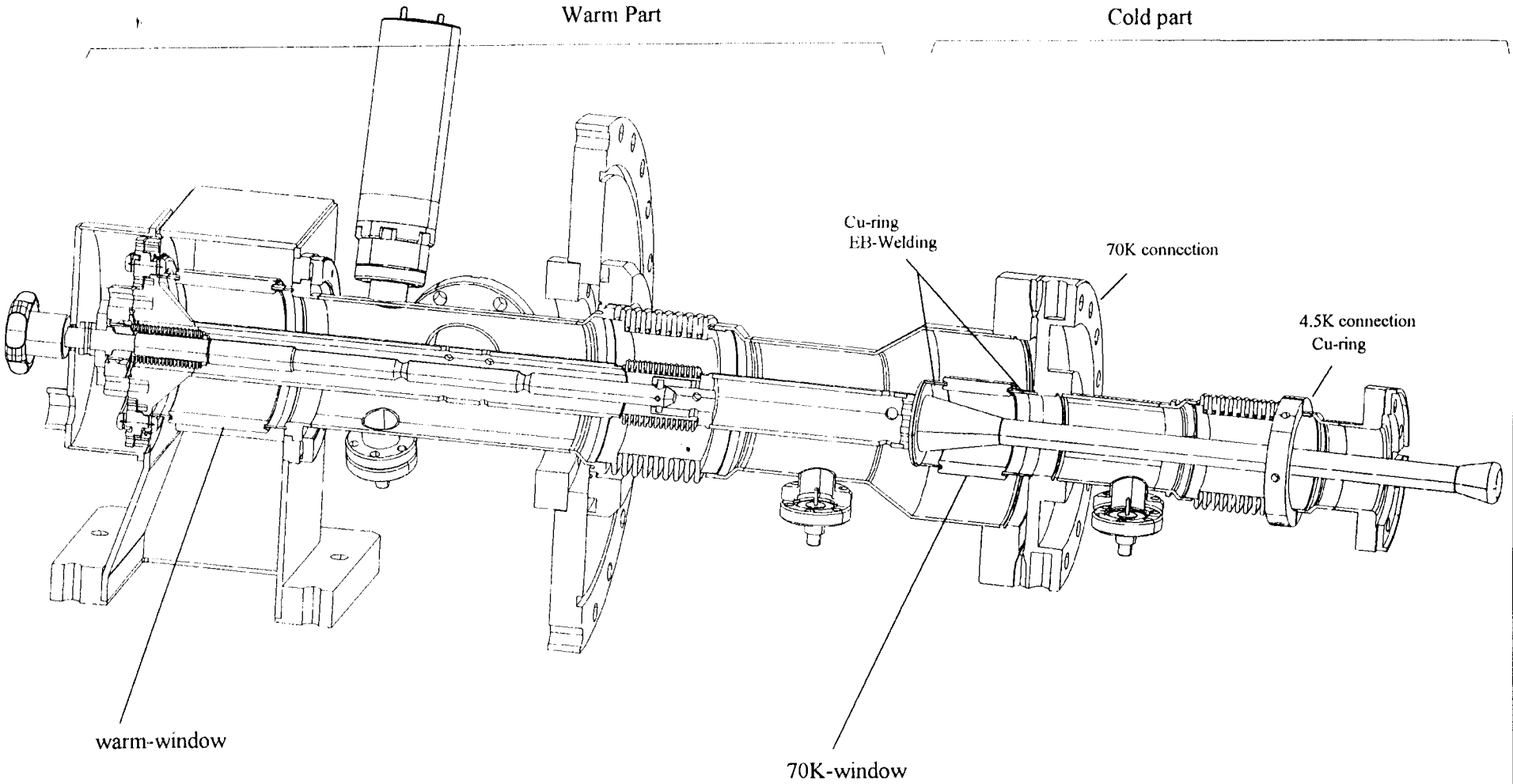
- inner and outer conductors
- cleaning and package
- What´s not to cover?
- Standard-procedure for copper-plating

Manufacturing ceramic windows

- manufacturing and accuracy
- material
- metallisation
- brazing
- TiN-coating
- EB-Welding
- Standard-procedure for ceramic-handling

- Some points for handling and mounting UHV-components




Warm Part
Cold part
Cu-ring
EB-Welding
70K connection
4.5K connection
Cu-ring
warm-window
70K-window

Introduction

- all manufactured couplers for TTF are coaxial.
- difference between copplerII and III is the warm window under atmospheric conditions (two instead of three vacuum components).
- coaxial line is welded and copper coated

Machining and cleaning

- machining without problems
- cleaning (washing-machine) and washing in clean, destilled water.
- natural surfaces prepared with a special liqiuidity to avoid oxidates („Passivierung").

Example: Waveguide windows after acid-procedure. Spots or dirt is visible after acid procedure and heating. Reason is not clear at time.

Welding and brazing

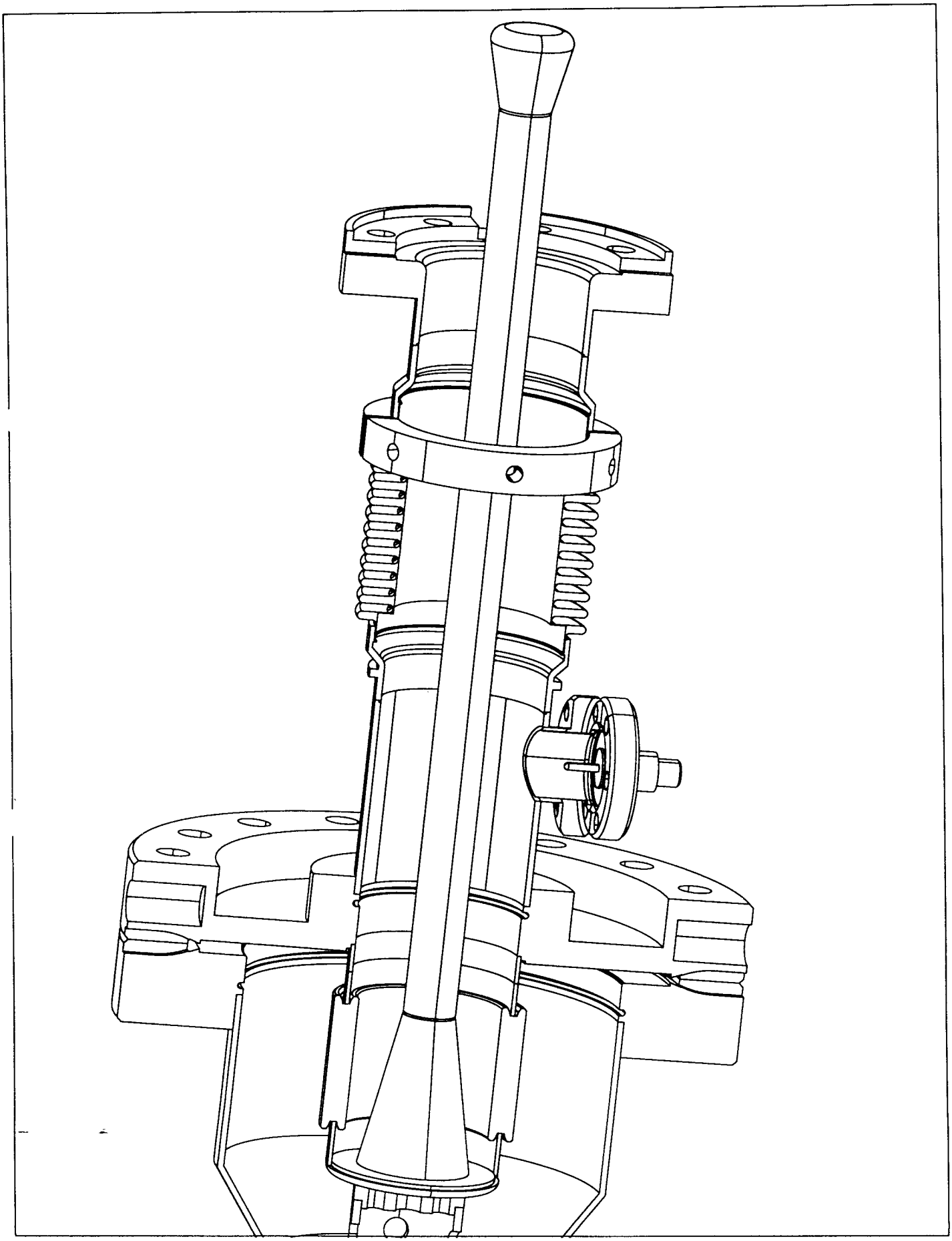
- no problems with welding cylindrical parts.
- leack-test after every step.
- cleaning with destillated water (washing-machine) and next
- heatet-procedure at 800°C for 1h for stainless-steel (before coating!)
- transport and rest in transport-vessels for each assembly or in special paper (no dust or fluff-paper). Avoid polymere-packages!

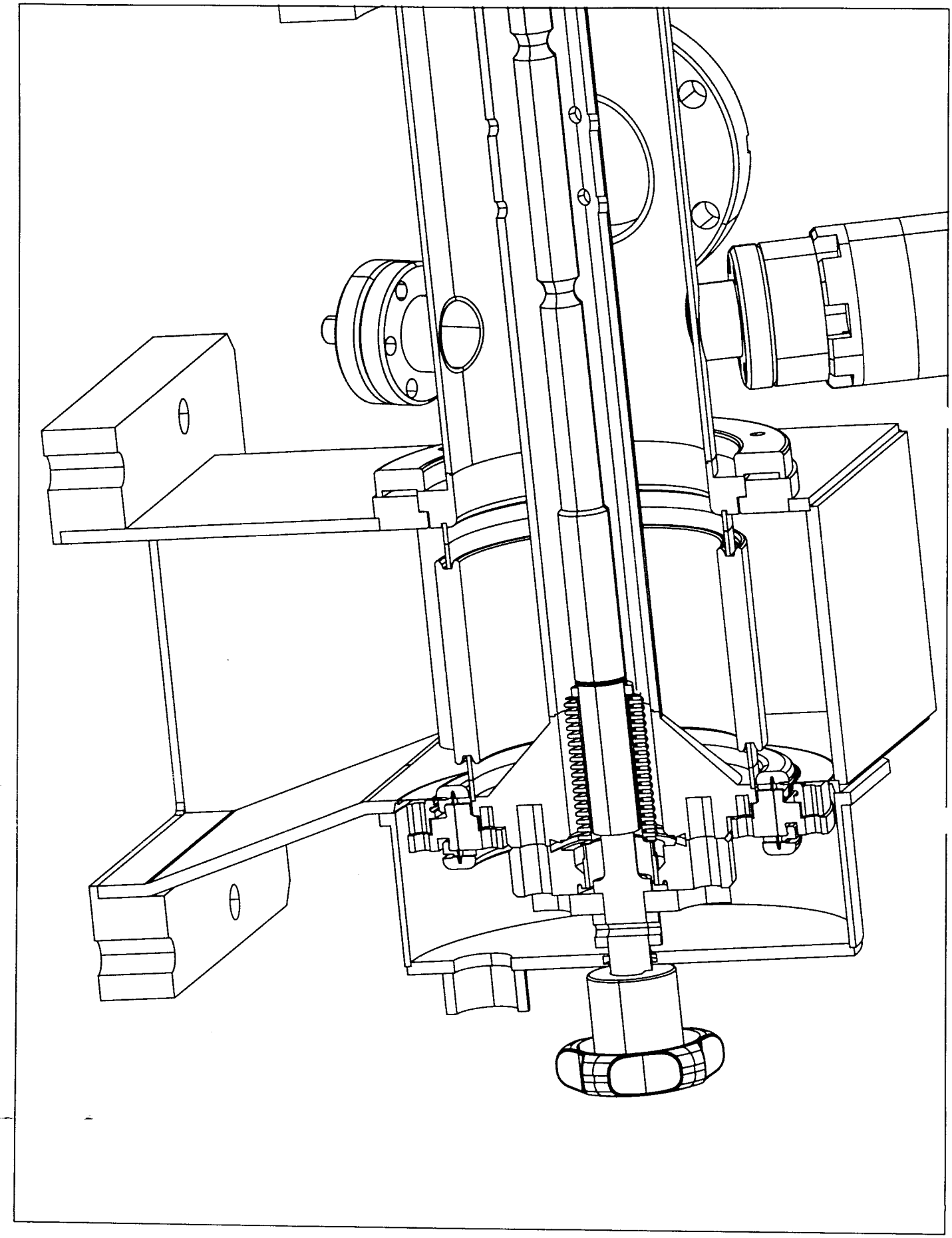
  Example 1: Inner and outer conductor

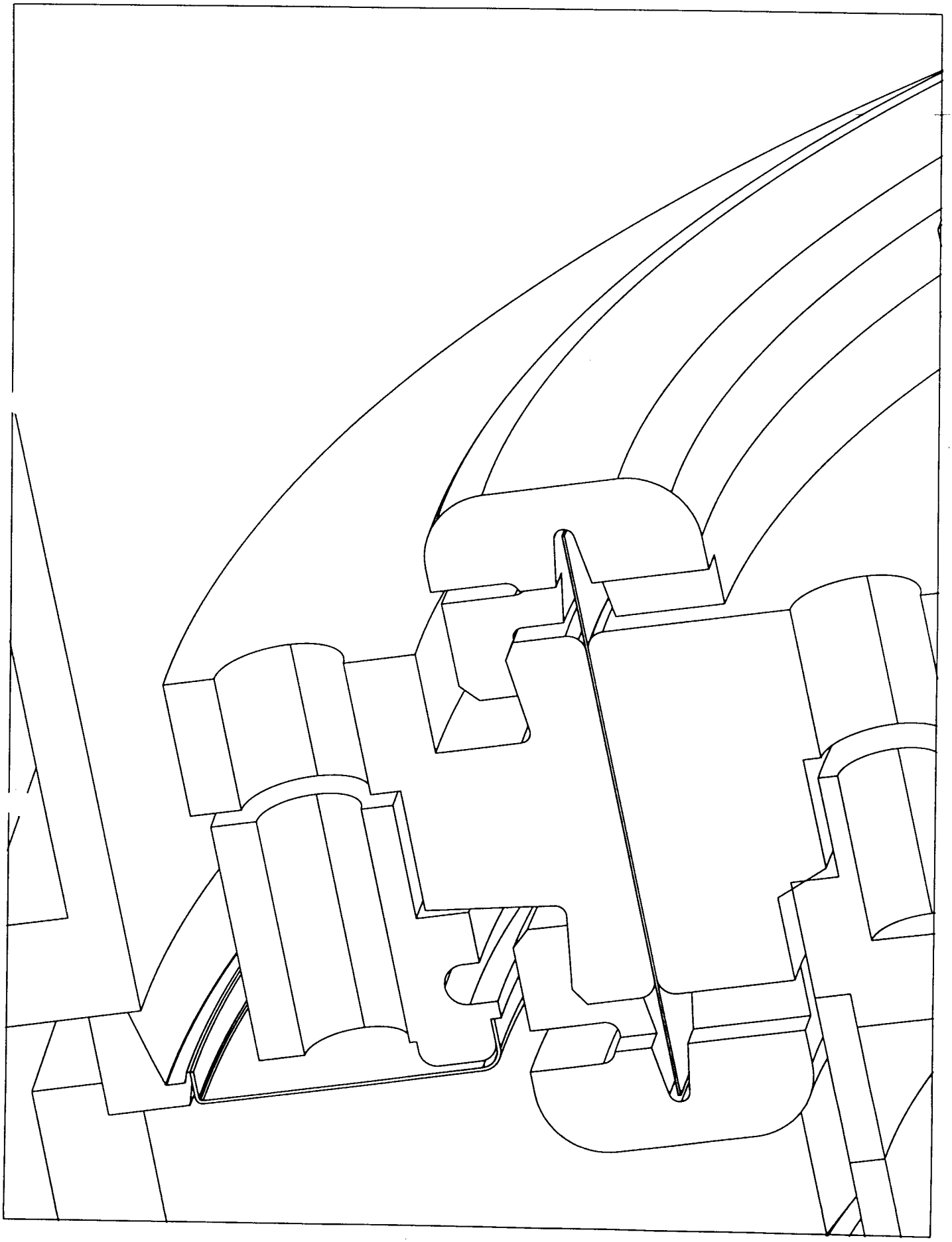
  Example 2: welding waveguide for coupler.
- solder-Part: copper-ring at cold side flange without coating.

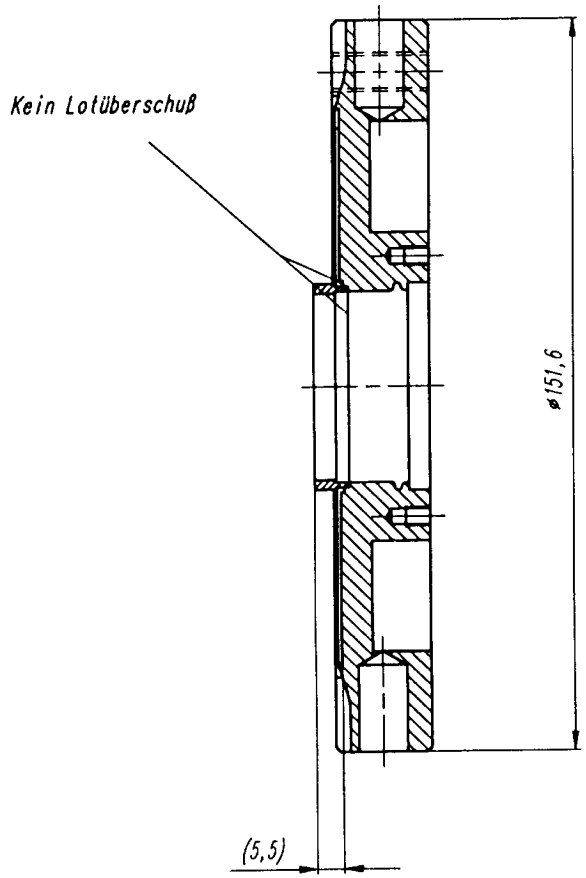
Example 3: problem gap: use of solder-ring instead of foil. Secound problem: deformation of copper-ring.

Example 4: 4.5K connector. Cu-ring was not correctly positioned at brazing.









Löten des Cu-Kragens mit Cu-Sn-Folie bei 1020°C im Vakuum

Spaltfrei löten. Eindrehung frei von Lot

Richtlinien fuer UHV-Bauteile Z.-Nr.3 73 0100/B.020 beachten.	
Ausheiztemperatur max.....	
Desorptionsrate	$\leq 5 \cdot 10^{-12}$ $\left[\frac{mbar \cdot l}{s \cdot cm^2}\right]$
Leckrate	$\leq 1 \cdot 10^{-9}$ $\left[\frac{mbar \cdot l}{s}\right]$

ghdrthfgjh

DIN ISO 8015

DESY-Norm	▽▽▽▽					▽▽▽		▽▽		▽		~
Ra (mikro m)	0.025	0.05	0.1	0.2	0.4	0.8	1.6	3.2	6.3	12.5	25	50	e.B.
ISO Rauhigkeits-Kennzahl	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11	N12	✓

Allg.-toleranzen n. DIN ISO 2768 T1 u. T2 Toleranzkl. m

Oberfl. Angb. n. DIN 3142 oder ISO-1302

Abmasse in micro m

					Datum	Name
				Gez.	7.11.96	Deppe
				Gepr.		
				Gen.		
d	Bemerkungen	13.01.00	Mar	Erzeug.		
c	(5,5), bildl.	13.03.98	Mar			
b	geaendert	25.3.97	De			
a	Bohrung hinzu	12.2.97	De			
Zust.	Aenderung	Datum	Name			

DESY-MHF

Ident.: DE129,28

Fuer Rueckfragen wenden Sie sich bitte an DESY Abteilung TT

Massstab: 1:1

Werkstoff:

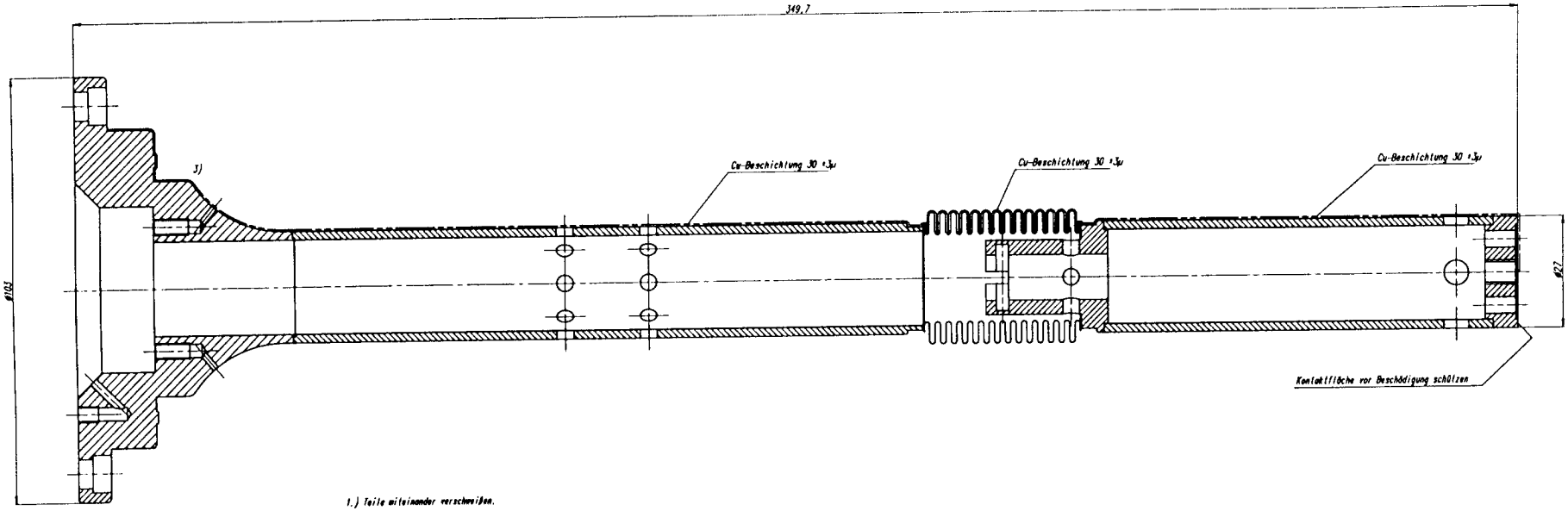
Grosser Flansch mit Cu-Kragen

3 96 4328/A.300

Blatt von Blättern

Ers. f.

Ers. d.



1.) Teile miteinander verschweißen.

(Schweißnähte außen glatt, keine Spitzen oder Kanten)

2.) Schweißgruppe im sauberen Vakuum ($p<10^{-6}$ mbar)

bei 950°C 2 Std. Wasserstoff-frei-glühen.

3.) Schweißgruppe außen 30µ verkupfern (wasserstoffarm verkupfern)

4.) Innen darf verkupfert werden. Wellbalg innen und Gewinde frei von Cu!

5.) Bei 400°C 2 Std. tempern.

6.) Baugruppe in vorgesehenen Behälter verpackt,

danach Handhabung nur noch mit Latex-Handschuhen (UHV-Richtlinien beachten)

Richtlinien fuer UHV-Bauteile Z.-Nr. 3 73 0100/B.020 beachten.
Ausheiztemperatur max. ....
Desorptionsrate ≤ 5·10⁻¹¹ [[illegible]]
Leckrate ≤ [[illegible]]

Maßstab: 2:1

Werkstoff: 1.4435

Innenleiter warm

DESY-MHF

1 96 4328/B.000

Standard procedure for Coppler-plating

- All parts and welded assemblies have to be be clean. There shouldn´t be lubricants on the surface.
- The last cleaning should be done with destilled water.
- Heat the parts at 950°C for two hours (stainless steel, the material for flanges can be 1.4429)
- The tripel R should be defined by the customer.
- Tolerances for copper plated komplex parts should be equal or higher than ±30% (for a tickness between 10 and 40μ). For example inner conductor with bellow: 10μ±3μ. Higher accuracy is not reachable.
- The regions of seals (Cy-Flange) shouldn´t be coated.
- Edges of CF-flanges shouldn´t be coated.
- Threads (for screws) shoudn´t be coatet,
- No interesting surfaces (outer surface of an outer conductor) needn´t be coated but they can! This minimizes costs.
- These points should be remarked in the drawings.

Manufacturing ceramic windows

- manufacturing is done by WESGO Ceramics GmbH/Germany
- cold pressing of material and heating under melting-point (1700°C).
- material is Al300 (not pure Al_2O_3, bad quality of metallisation ⇒share of glas-matrix).
- surfaces are smoothed.
- accuracy of ceramic procedure: ±1% is reachable.
- ceramics are metallised in the ground of the left- and rightside gaps. (Mo-Mn-film, then Ni-coatet). This metallisation has to be soldable.
- The metallized ceramic is heated at 800°C (or higher) for one hour.

Problem: grey spots on ceramik-surface

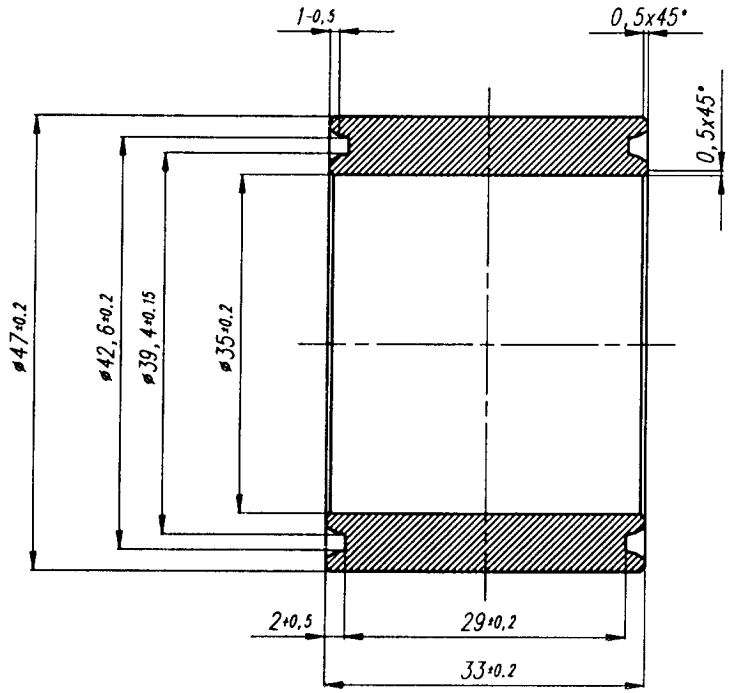
- brazing copper-rings at 780°C with Silver-Copper Alloy (AgCu28). Ceramic should be covered.

  Example 1: in the past: dirty stove at desy (DESY bought a new one).

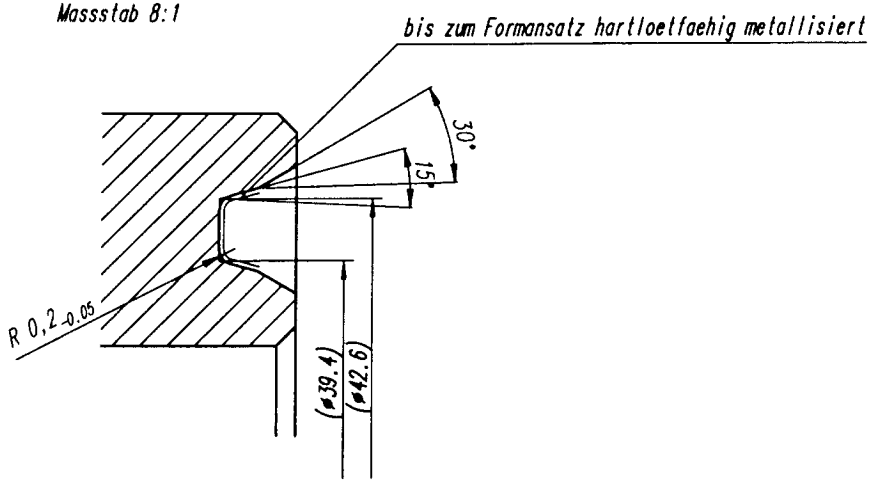
  Example 2: bellows with less inner dimension.(EB-welding) (+)

- titanisation in two steps (thickness of 100A). The welding area should be covered.

- Standard procedure for ceramic-handling.



Massstab 8:1



Durchmessermasse beziehen sich auf den Schnitt der Geraden

UHV-gerecht verpackt. Keine Polymerverpackung verwenden

Handhabung nur mit Batist-Handschuhen und fusselfreien Batist-Tuechern

N7

DIN ISO 8015

DESY-Norm	▽▽▽▽					▽▽▽		▽▽		▽		~	DESY behaelt sich fuer diese Zeichnung alle Rechte gem. DIN 34 vor / DESY reserves for this drawing all rights according to DIN 34
Ra (mikro m)	0.025	0.05	0.1	0.2	0.4	0.8	1.6	3.2	6.3	12.5	25	50	o.B.
ISO Rauhigkeits-Kennzahl	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11	N12	▽

Fuer Rueckfragen wenden Sie sich bitte an DESY Abteilung TT

Allg.-toleranzen n. DIN ISO 2768 T1 u. T2 Toleranzkl. m

Oberfl. Angb. n. DIN 3142 oder ISO-1302

Abmasse in micro m

Massstab: 2:1 (8:1)

Werkstoff: Al 300 (Fa. Wesgo)

	Datum	Name
Gez.	18.10.96	Deppe
Gepr.		
Gen.		
Erzeug.		

70 K-Fenster

fuer TTF-Koppler II

DESY- MHF

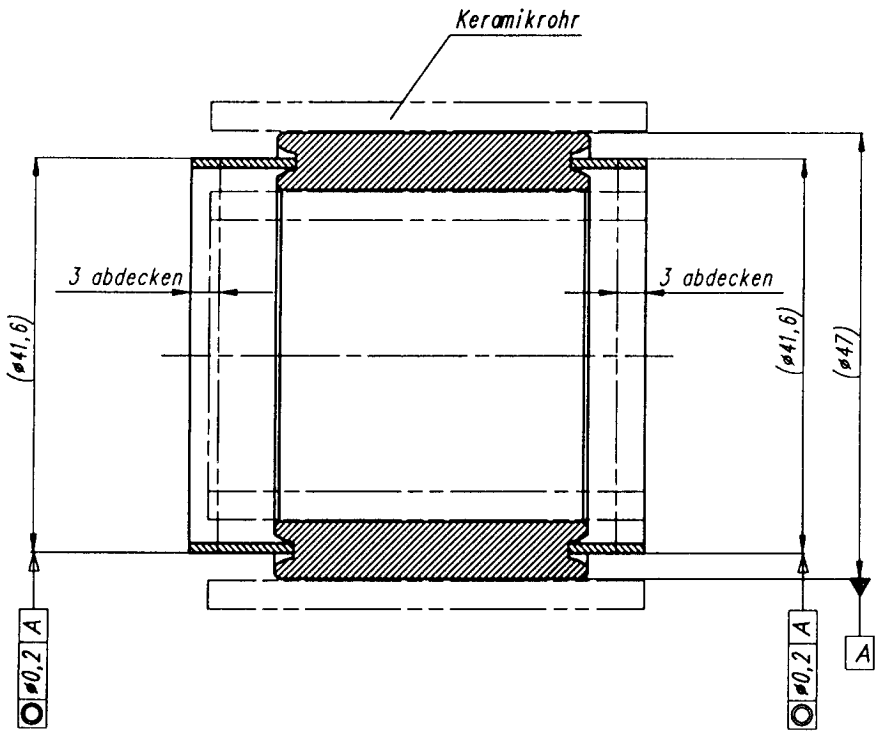
Ident.: DE129,48

3 96 4328/A.201

Blatt von Blattern

Zust.	Aenderung	Datum	Name
b	Toleranzen, Text	09.07.96	Mar
a	Darstellung	12.10.97	Mar

Ers. f. Ers. d.



1.) Keramik hartloetfaehig metallisiert bestellen.

2.) Keramik bei 800°C 1 Std in sauberem Vakuum ($p<10^{-5}$mbar) entgasen, danach Handhabung nur noch mit Handschuhen und fusselfreien Batist-Tuechern. (UHV-Richtlinien beachten)

3.) Loeten der Keramik bei 780°C mit Cu-Ag-Eut. im Vakuum, dabei Keramikoberflaechen innen und aussen mit Keramikrohren abgedeckt. (Lotueberschuss darf nicht Cu-Kragen ausserhalb der Keramik netzen)

4.) Aufdampfen einer TiN-Beschichtung aussen und innen von 100 Angstroem, (sollte sichtbar ein wenig gelblich sein) (Schweisskante 3mm abdecken) danach bei 350°C 1 Std tempern, mit trockenem N_2 fluten.

5.) Baugruppe in hartes nicht fusselndes Papier oder Batist-Tuecher einwickeln.

Richtlinien fuer UHV-Bauteile Z.-Nr.3 73 0100/B.020 beachten.	
Ausheiztemperatur max.....	siehe Text
Desorptionsrate	$\leq 5 \cdot 10^{-12}$ $\left[\frac{mbar \cdot l}{s \cdot cm^2}\right]$
Leckrate	$\leq 1 \cdot 10^{-9}$ $\left[\frac{mbar \cdot l}{s}\right]$

DIN ISO 8015

DESY-Norm	▽▽▽▽					▽▽▽		▽▽		▽			~
Ra (mikro m)	0.025	0.05	0.1	0.2	0.4	0.8	1.6	3.2	6.3	12.5	25	50	e.B.
ISO Rauhigkeits-Kennzahl	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11	N12	√

Abmasse in micro m

Allg.-toleranzen n. DIN ISO 2768 T1 u. T2 Toleranzkl. m

Oberfl. Angb. n. DIN 3142 oder ISO-1302

	Datum	Name
Gez.	23.10.96	Deppe
Gepr.		
Gen.		
Erzeug.		

Zust.	Aenderung	Datum	Name
c	Lagetloeranzen	09.07.96	Mar
b	"Latex" entf.	19.3.97	De.
a	Text geaendert	9.1.97	De.

DESY-MHF

Idenl.: DE129,11

Fuer Rueckfragen wenden Sie sich bitte an DESY Abteilung TT

Massstab: 2:1

Werkstoff:

70 K-Fenster
mit Cu-Kragen

3 96 4328/A.200

Blatt von Blaettern

Ers. f.

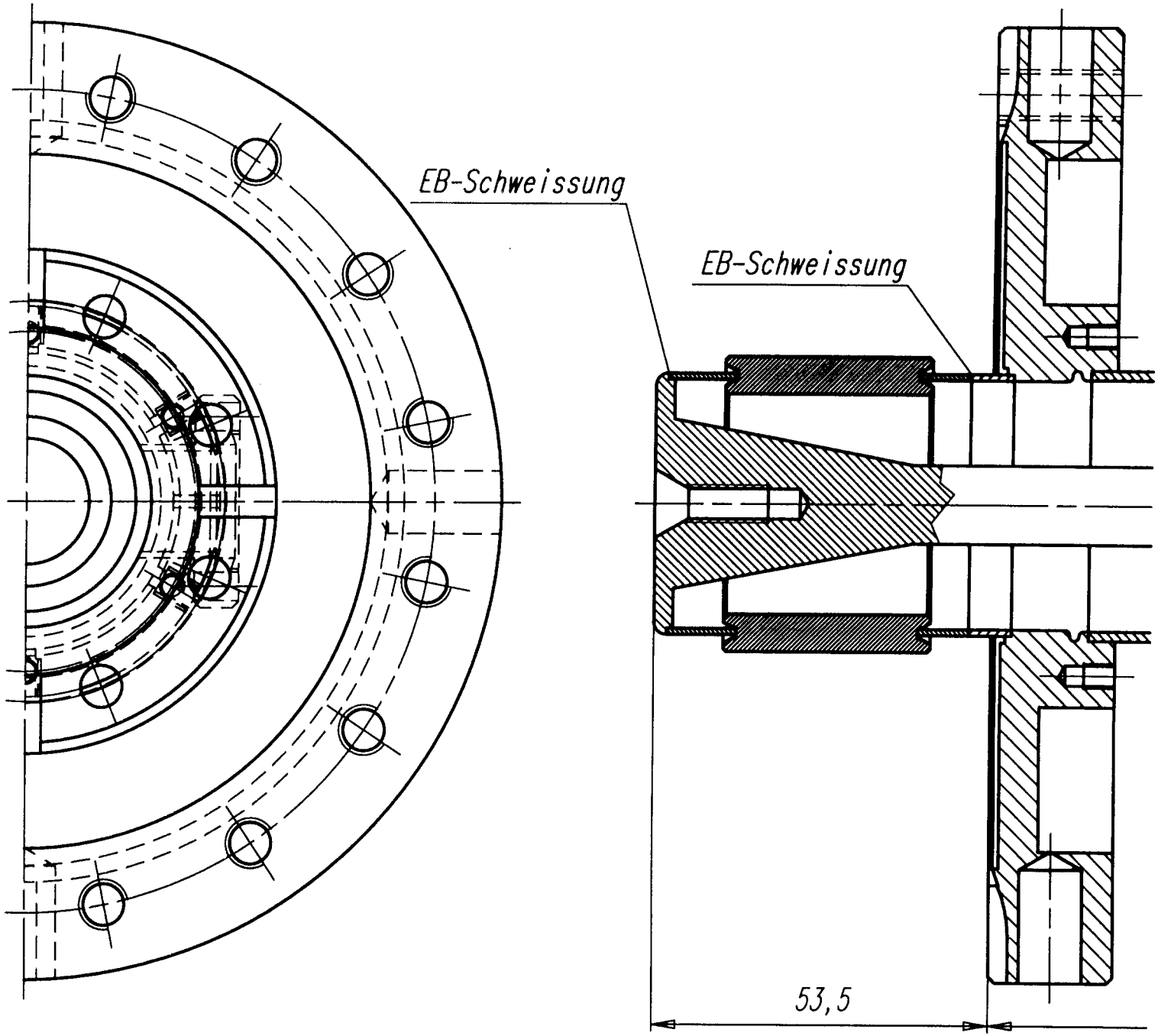
Ers. d.

Standard procedure for ceramic-handling

- Not every ceramic material is usable for metallisation. A shared glas-component in the matrix is needed (e.g. Al300 WESGO).
- All ceramic parts should be clean. Ceramics shouldn´t be touched. Or if necessary only with clean gloves. Never touch the surface with fingers.
- Don´t wash or wipe the surface.
- The metallized ceramic will be heated at 800°C for one hour. The heat-procedure should be the last cleaning-step.
- Cover the ceramic-surface if brazing.
- After brazing (Ag-Cu-Alloy, 780°) heat the ceramic at 350°C for one hour.
- Transport and rest only in vessels or packed in special paper (no fluff/dust paper). Rest in Nitrogen is usual.
-

EB-welding

- EB-welding is done by ACCEL/Germany
- antenne is covered with titanium-sheets
- shriking between 0.2 and 0.4mm for each ring


EB-Schweissung
EB-Schweissung
53,5

Copper-plating

- coating is done by Collini-Flühmann AG/Switzeland.
- vacuum-assemblies cleaned and heated in vacuum at 950°C for 2 hours
- reachable accuracy of tickness: ±30% for complex structre (e.g. bellows)
- thickness of inner conductor from 27 to 45μ
- thickness of outer conductor from 7 to 13μ (current is lower).
- cleaning with destilled water, drying in Nitrogen-atmosphere

  Example 1: bellow with leack after Copper-plating
- transport in vessels for each assembly (avoid damages!)

  Example 2: holder of Cu-antenna.
- no directly touch is allowed! handling only with gloves
- defining the metallized surfaces is important.

Examples: regions of seals (Cy-flange), edges for CF-flanges, threads. Outer surfaces needn´t be coated but they can!

- Standard-procedure for Copper-plating.

TESLA coupler Workshop
Orsay, January 17-18, 2000

Results from the Travelling Wave Window tests

C. Travier (CEA Saclay)

Outline

- Travelling wave window design
- Low level RF measurements
- Power test stand
- RF conditioning
- First power cycling
- Steady state TW operation

This talk is based on the publication « Design and test of a 1.3 GHz Travelling Wave Window » made at the Santa Fe SRF workshop.

Travelling Wave window design

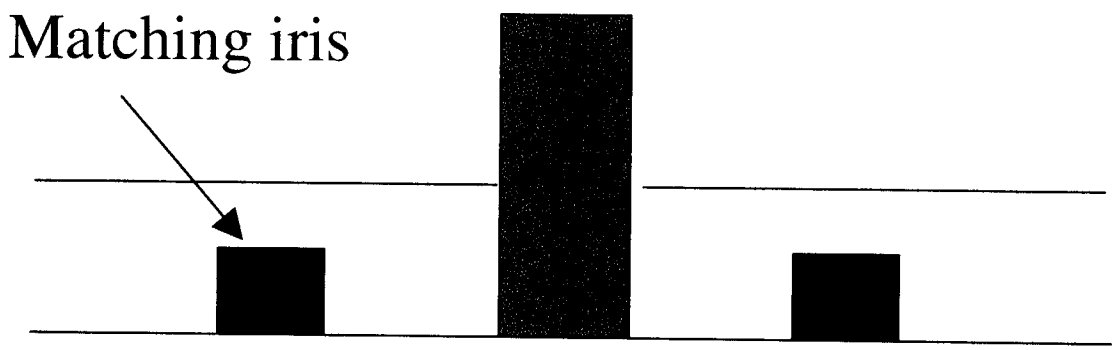
- Concept first proposed by Kasakov (1992)
- First application to coaxial window for Tesla coupler by Mosnier & Hanus (1995)

Principle

Establish a pure travelling wave inside the ceramic

How to achieve it

Use matching inductive or capacitive components on both side

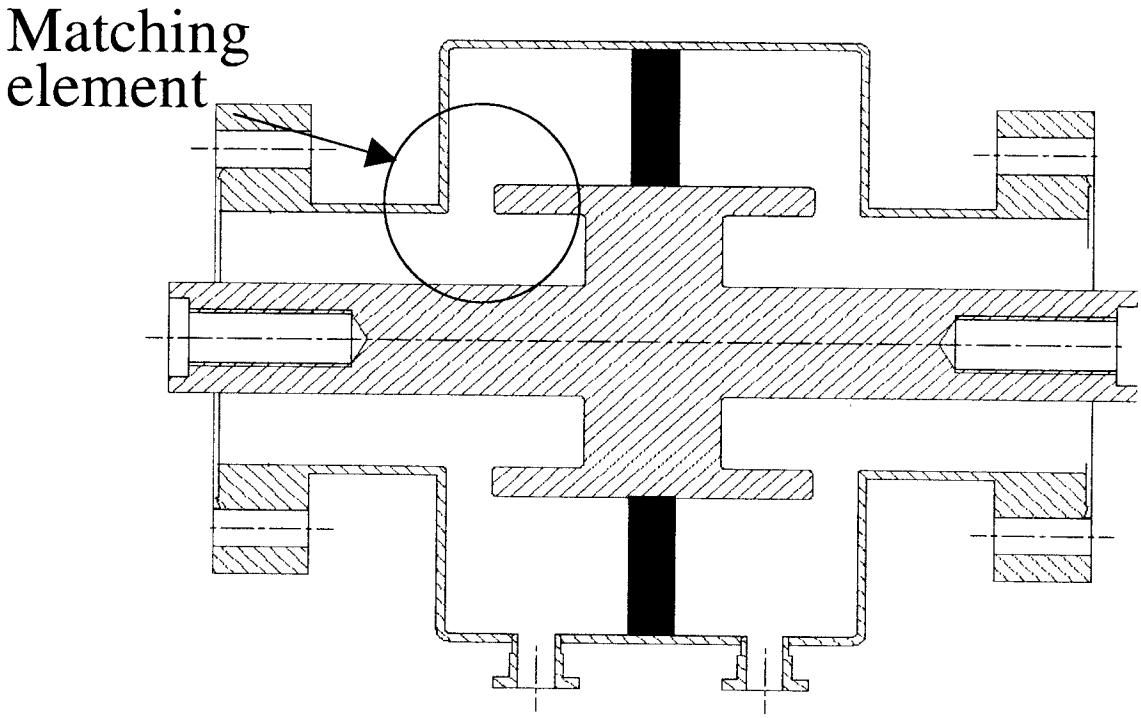


Mosnier & Hanus design

Avantage

- Reduces Electric field inside the ceramic
- Allow to use a thin ceramic (reduces dielectric losses)

Present Travelling Wave window design



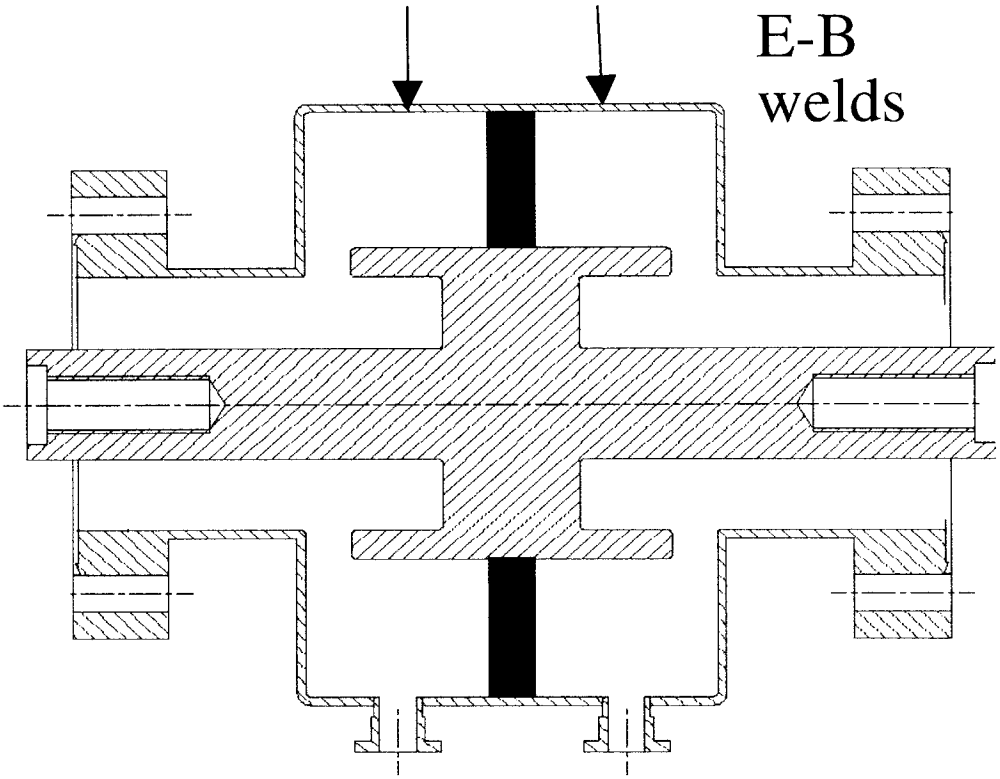
Advantages

- low field at brazing point (25% of coax inner conductor field)
- low dielectric loss (17 W @ 1 MW-1% duty cycle)
- great flexibility in parameters choice
- potentially moderate cost for large number
- no multipactor
- no direct view of cavity electrons

Drawbacks

- large diameter (150 mm)
- high field on noses (2 times coax inner conductor field)
- difficult to clean
- narrow bandwidth (60 MHz @ 20 dB)

Mechanical design



2 windows were fabricated by SICN

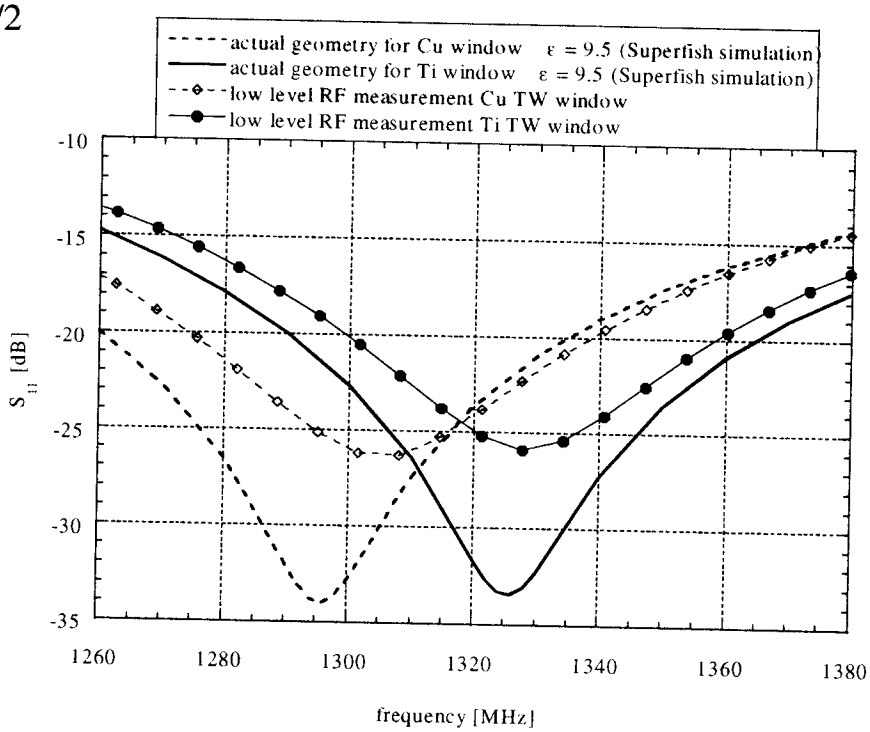
- **both, with copper inner conductor**
- **one with copper outer conductor**
- **one with titanium outer conductor**

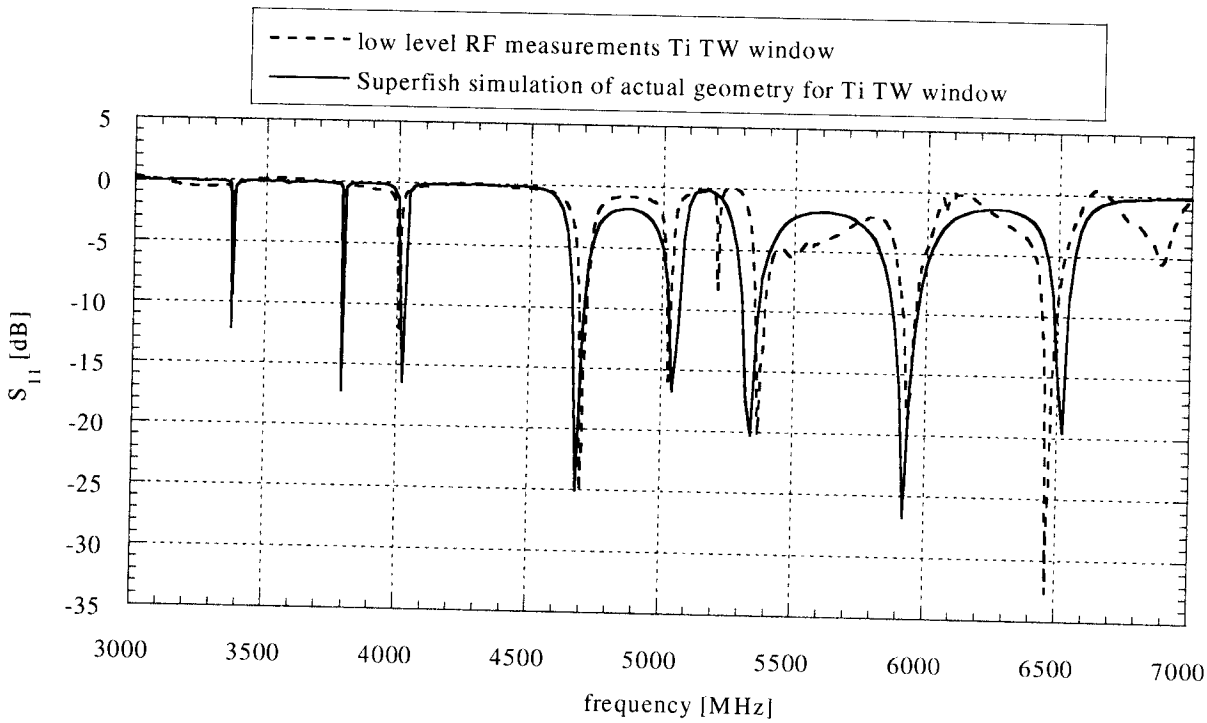
- Al300 (97.5 %) from WESGO was used

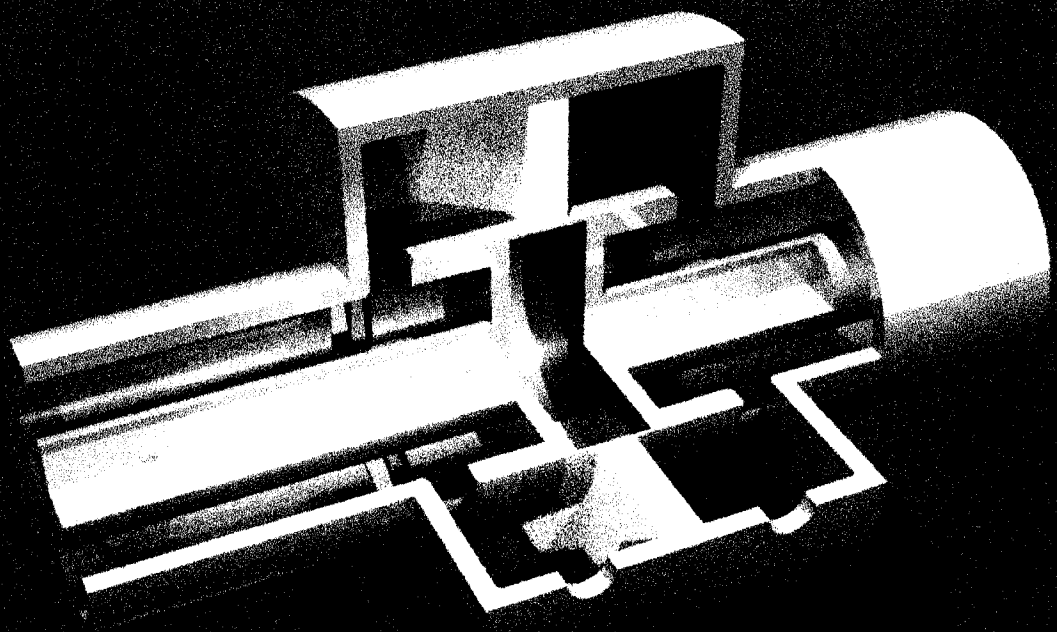
Low level RF measurements

$\varepsilon = 9.5$ is deduced from $\lambda/2$ window measurements

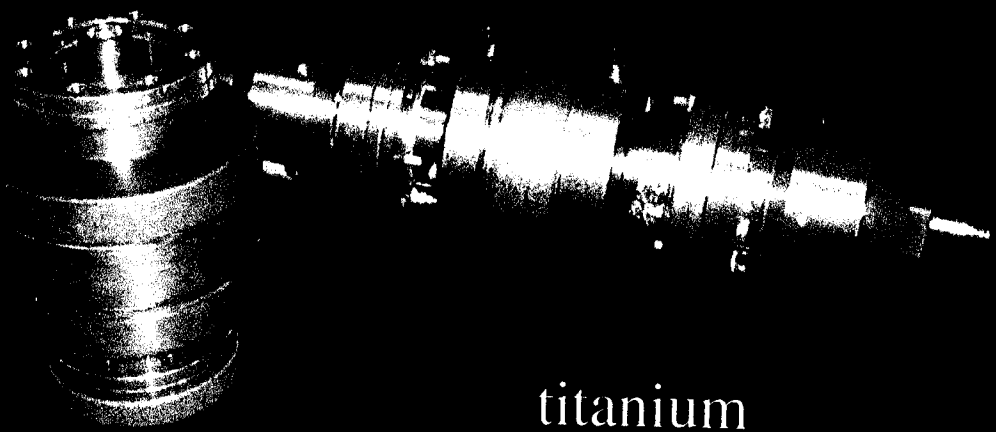
Larger discrepancy between measured and computed curve for copper window is due to less precise dimensions mesurement







Travelling wave window

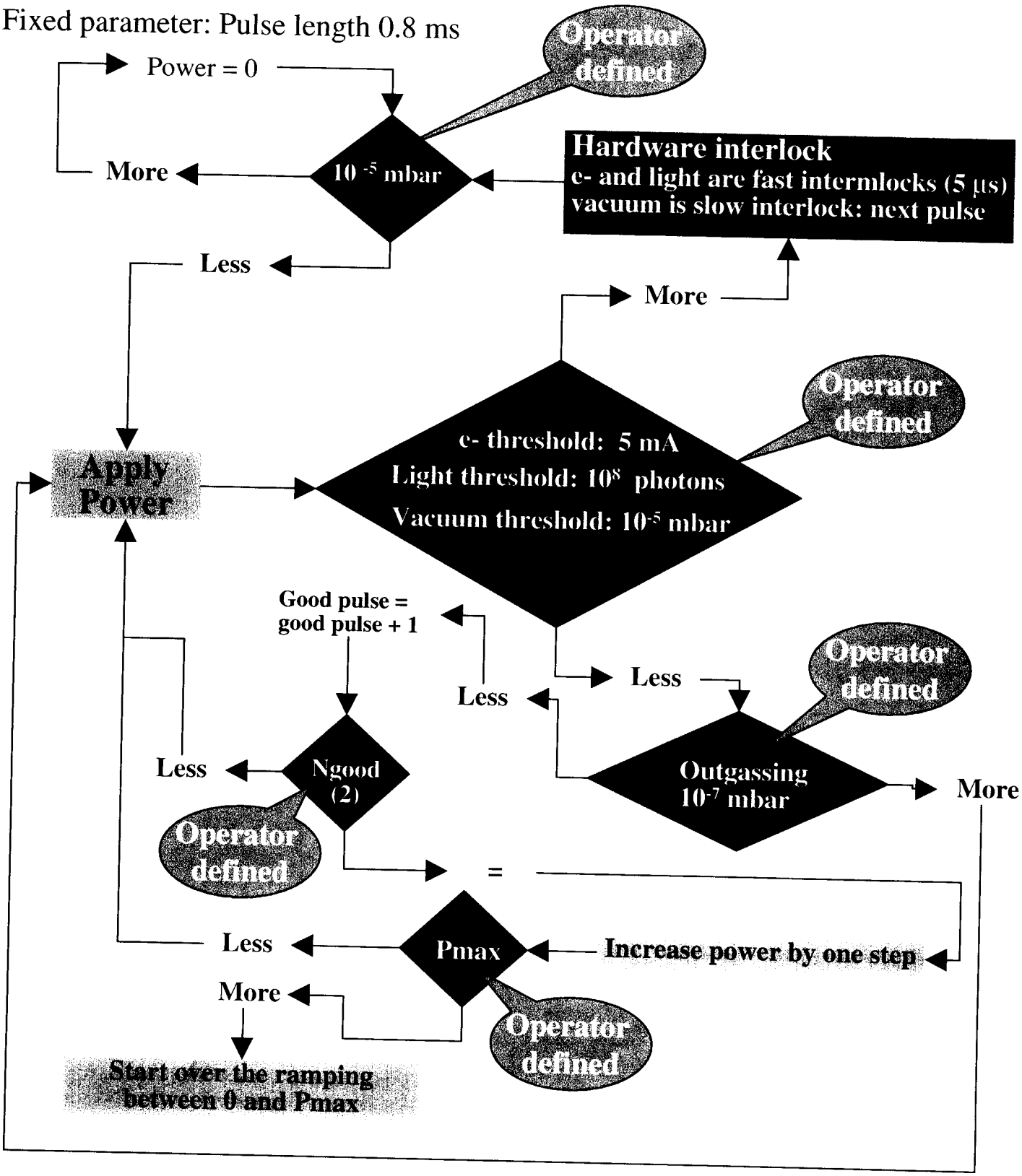


titanium

copper

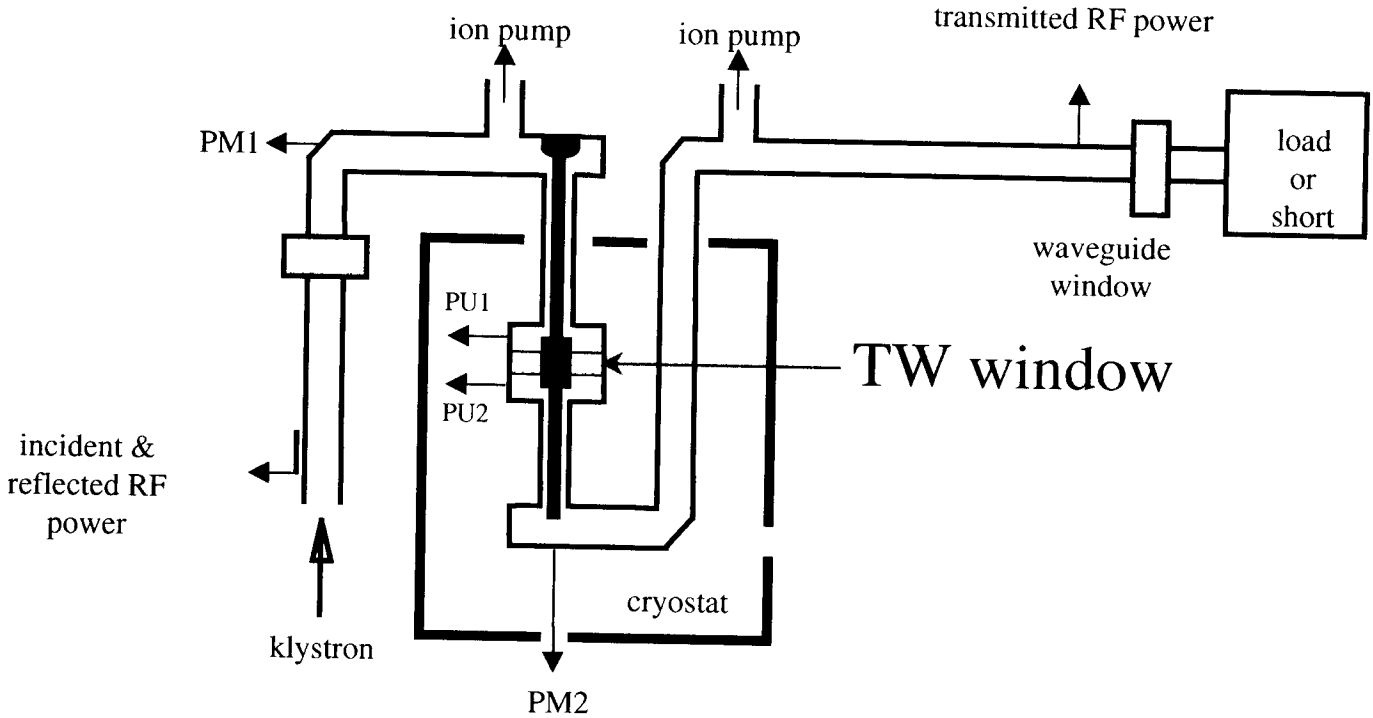
Conditioning procedure

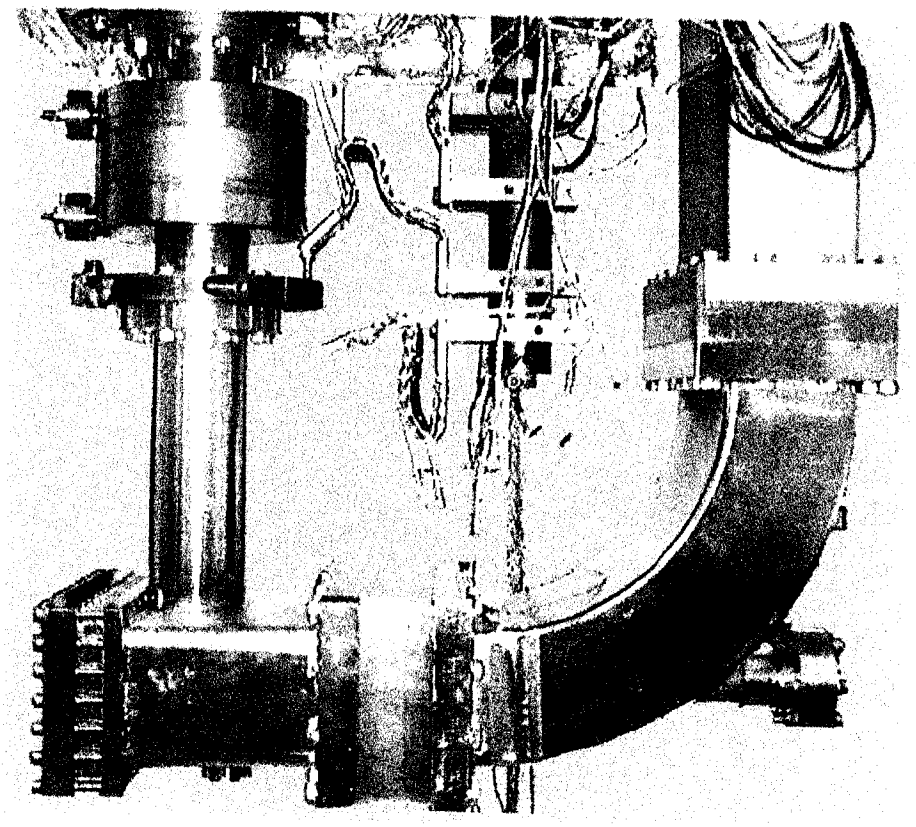
Fixed parameter: Pulse length 0.8 ms

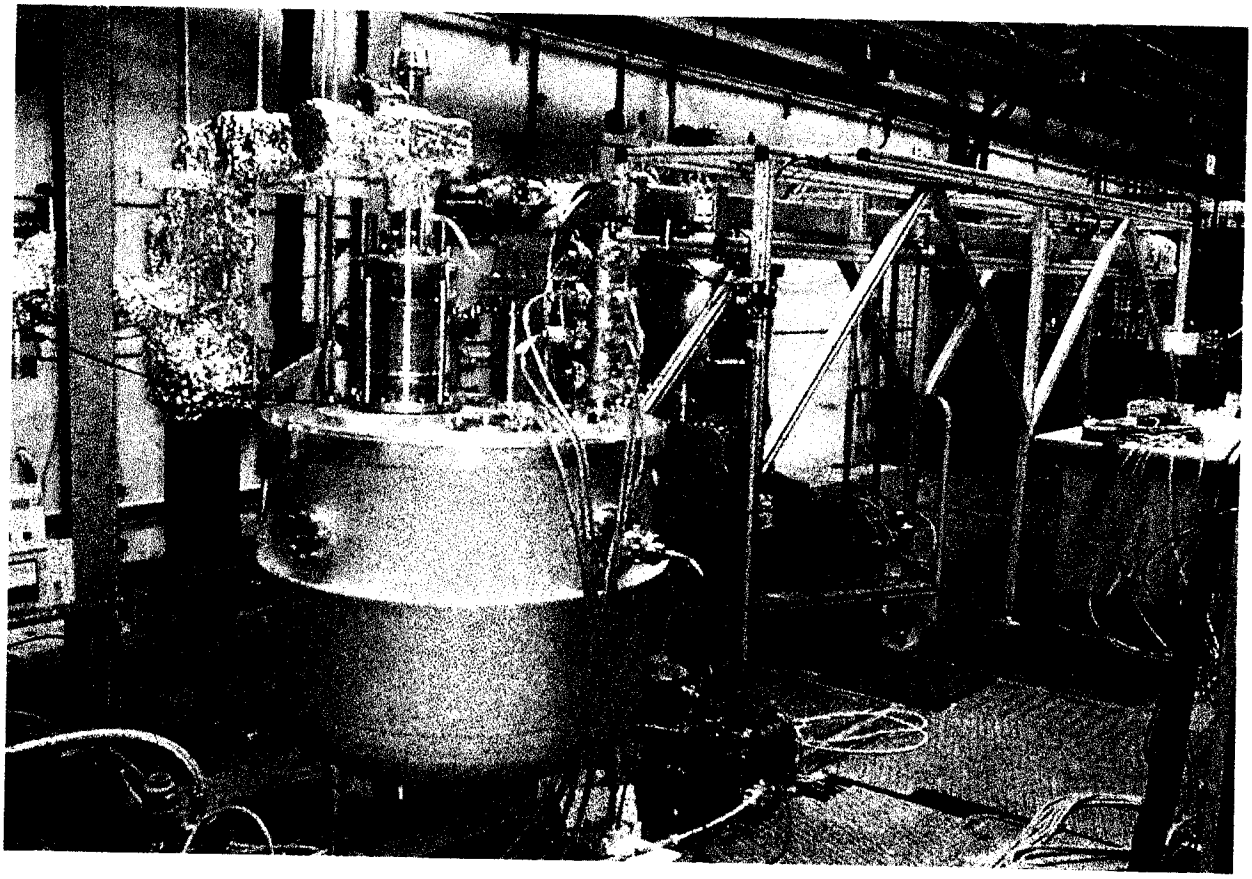


After a few ramping, Pmax is increased, until one reaches 1 MW

Test stand


ion pump
ion pump
transmitted RF power
PM1
load
or
short
waveguide
window
PU1
TW window
PU2
incident &
reflected RF
power
cryostat
klystron
PM2

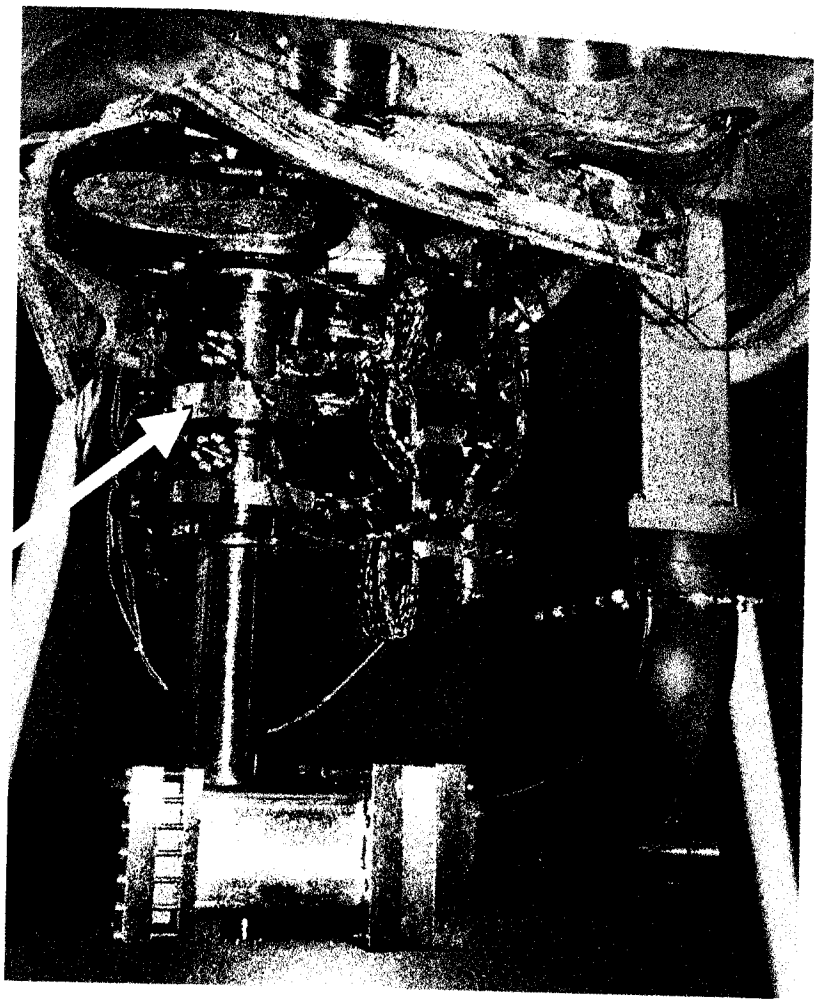




general view

Cryostat

window to test



inside view

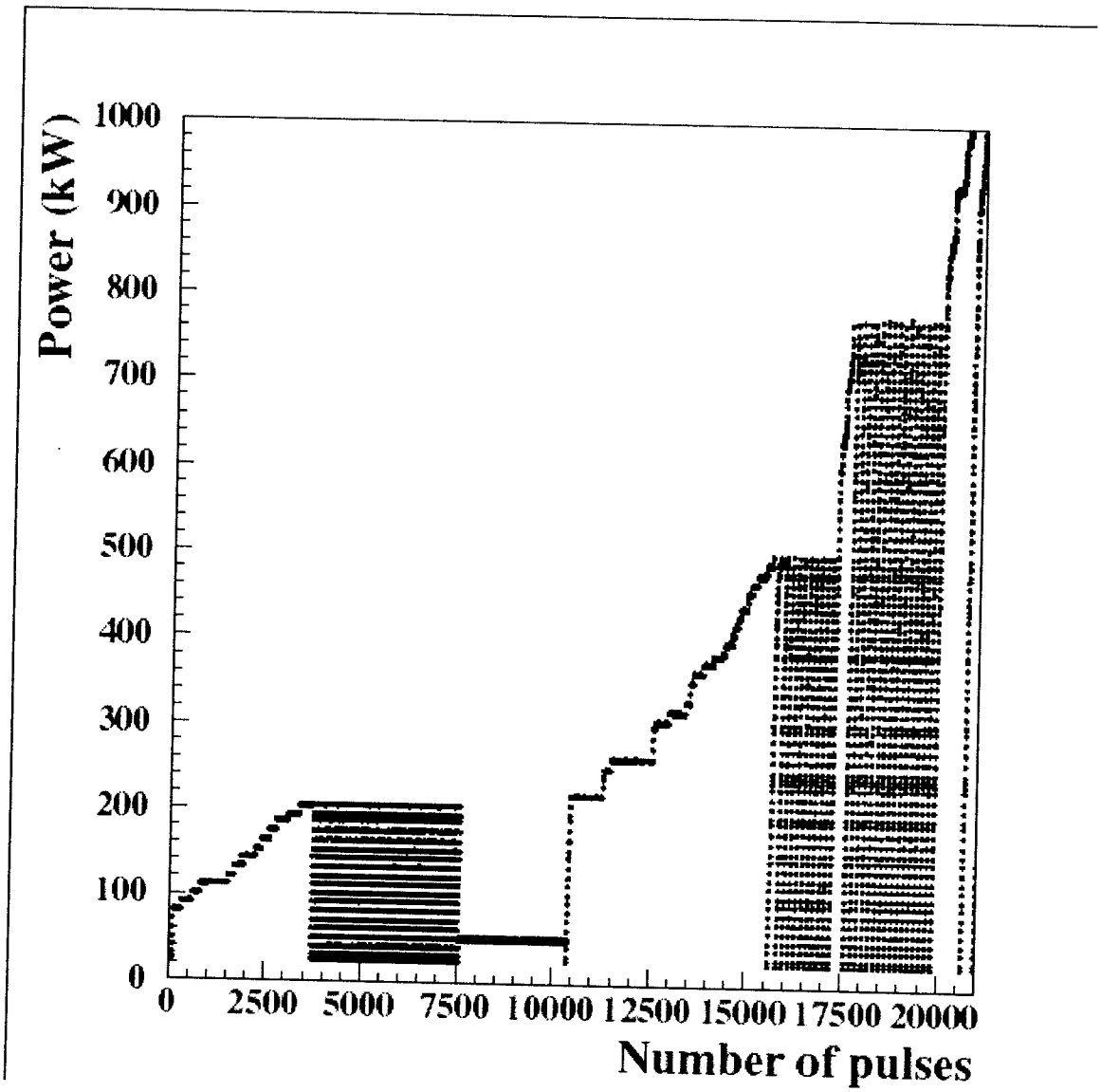
Operating sequence 483,000 pulses

Number of pulses	Power level (kW)	Tempera-ture (K)	Comment
Travelling wave operation			
25,500	0-1000	230	conditioning
1,700	0-400	250	
8,800	400-650	250	
25,000	300-1000	250	
26,600	500-1000	250	
Standing wave operation			
44,400	0-1000	230	
8,000	0-1000	230 →105	cooling
7,000	1000	105	
26,000	0-1000	105	
12,000	1000	105	
Travelling wave operation			
15,000	0-1000	105	
4,000	100	175	Window baking
21,000	0-1000	105	
9,000	1000	105	Losses measurement
13,000	0-1000	105	
27,000	0-1000	250	
18,000	1000	250 →300	
42,000	0-1000	300	
33,000	500-1000	105	
74,000	0-1000	300	
8,000	1000	300	
28,000	700-800	300	
9,000	1000	300	

Conditioning

1 MW was reached after 21,000 pulses

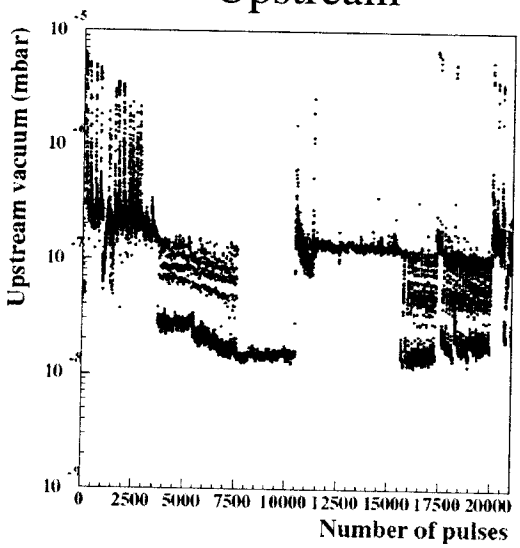
This corresponds to 58 hours @ 0.1 Hz and 6 hours @ 1 Hz

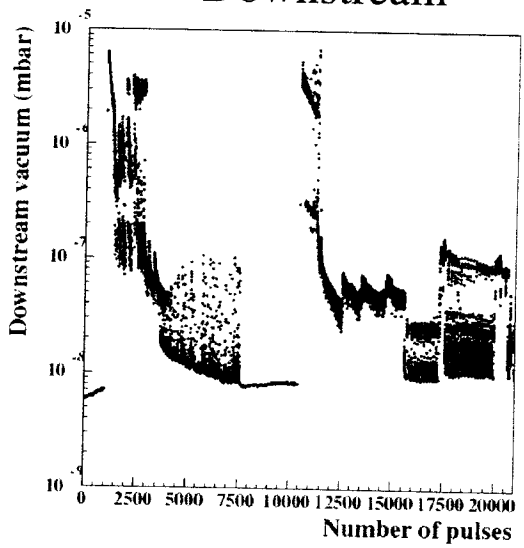


Signals during conditioning

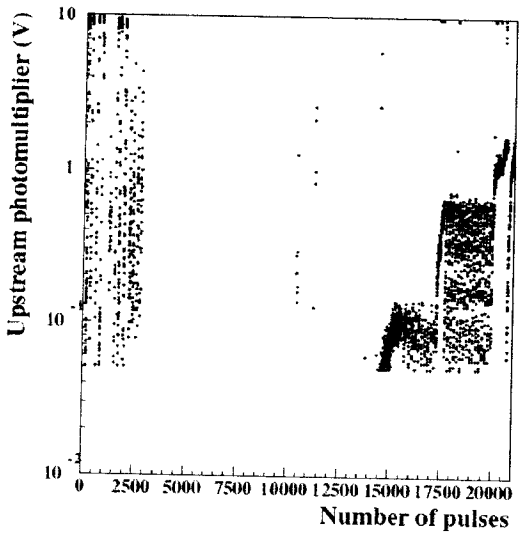
Upstream | Downstream

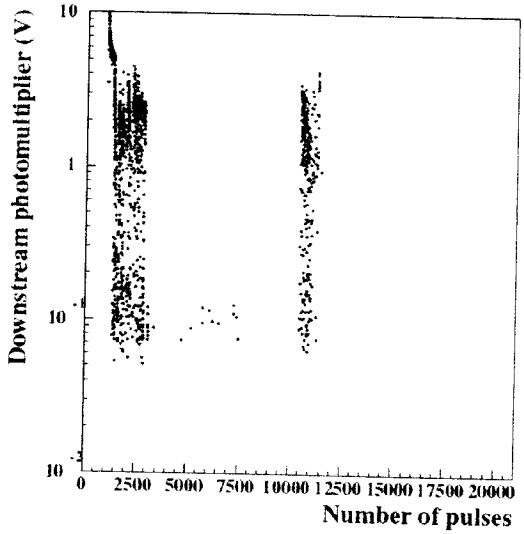
Vacuum



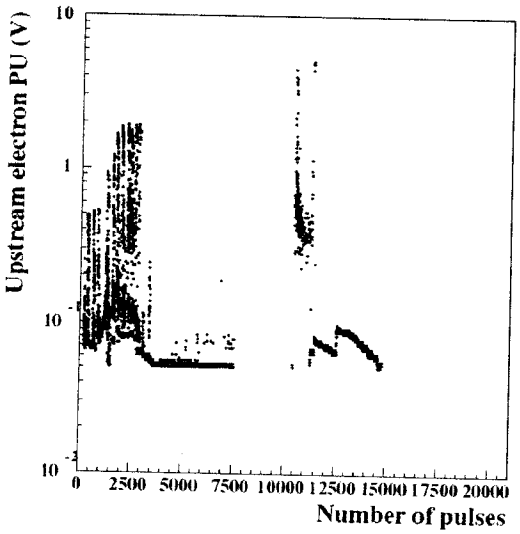


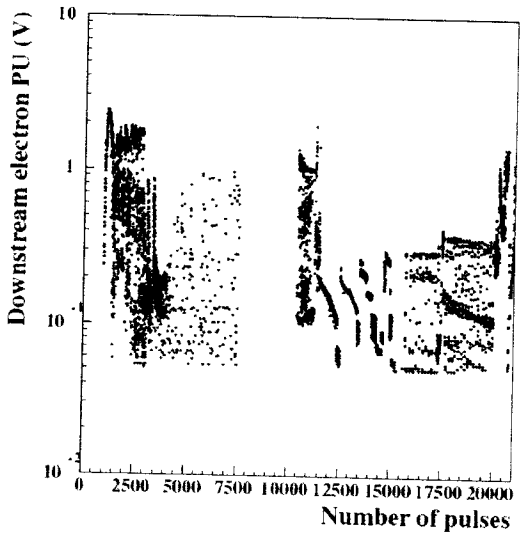
Light





Electrons



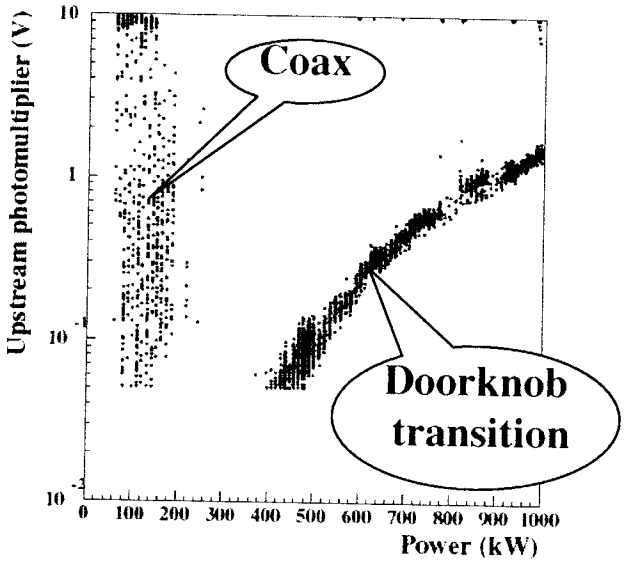


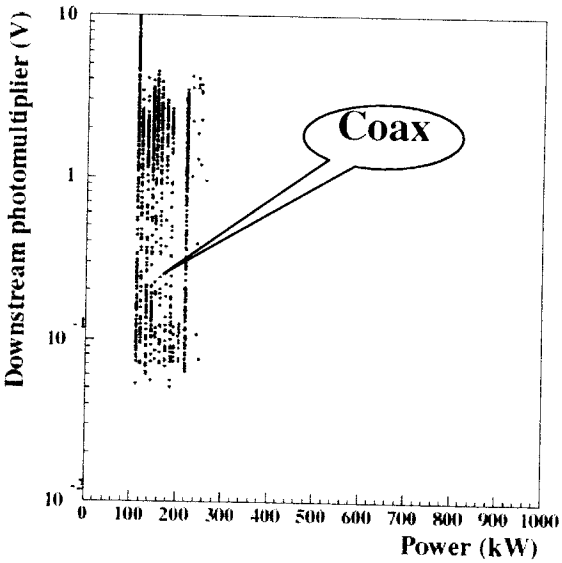
Signals during conditioning (vs. Power)

Upstream

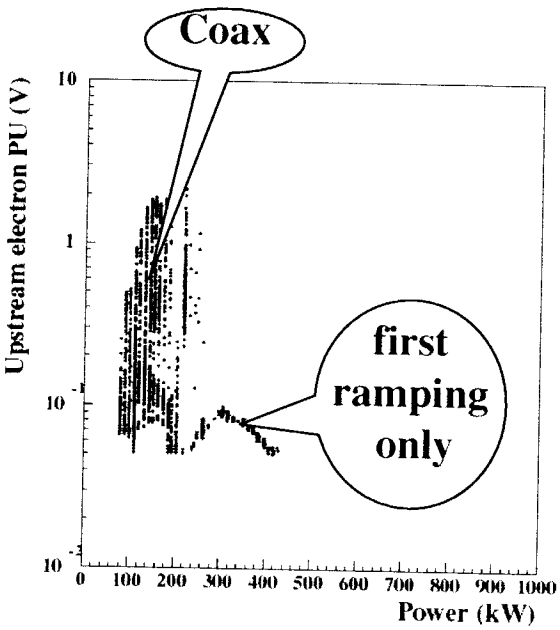
Downstream

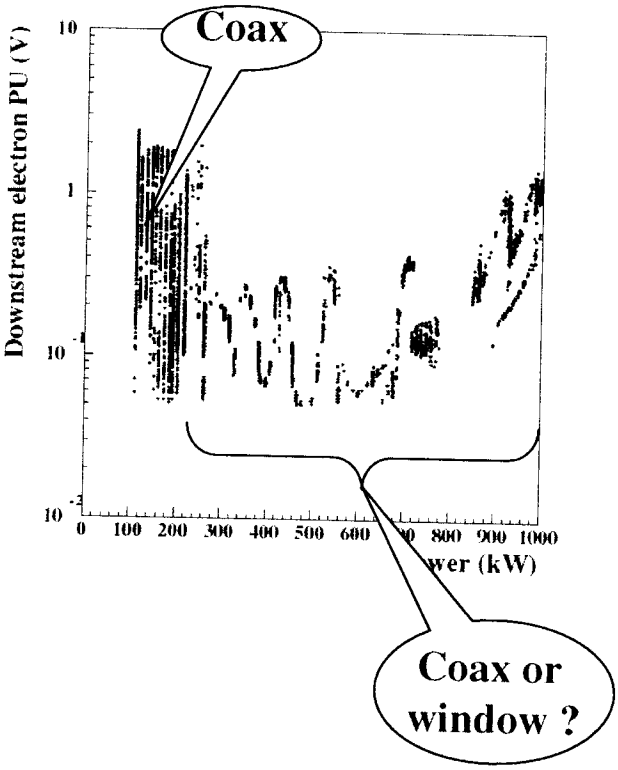
Light





Electrons



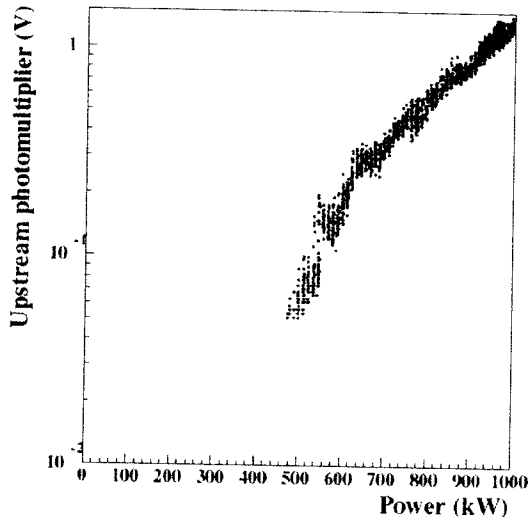


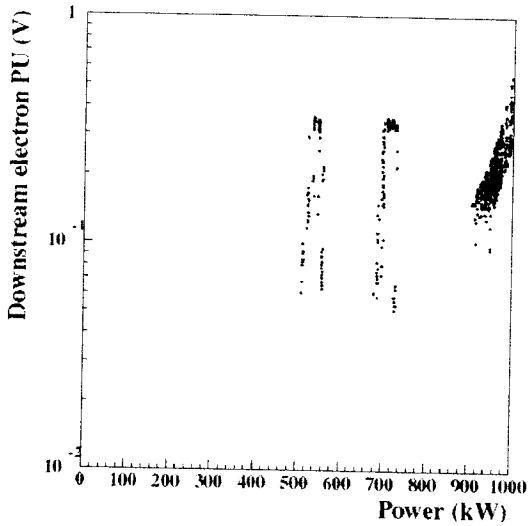
Signals during first complete power ramping (vs. Power)

Upstream

Downstream

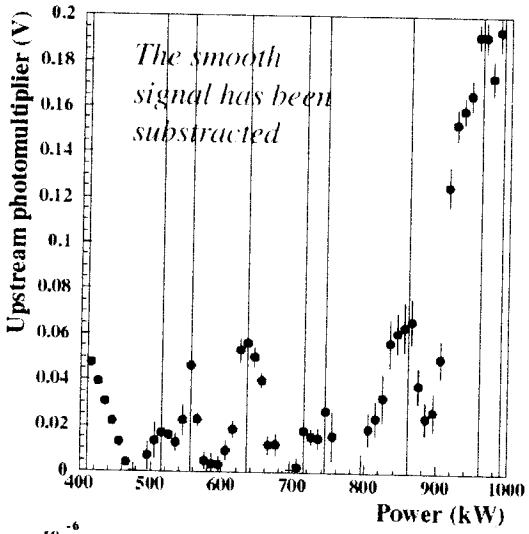
Light





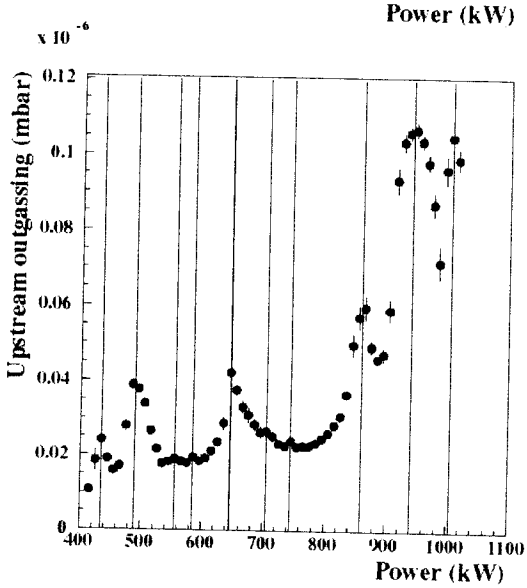
Electrons

Light



Downstream light = 0
Upstream e- = 0

Vacuum

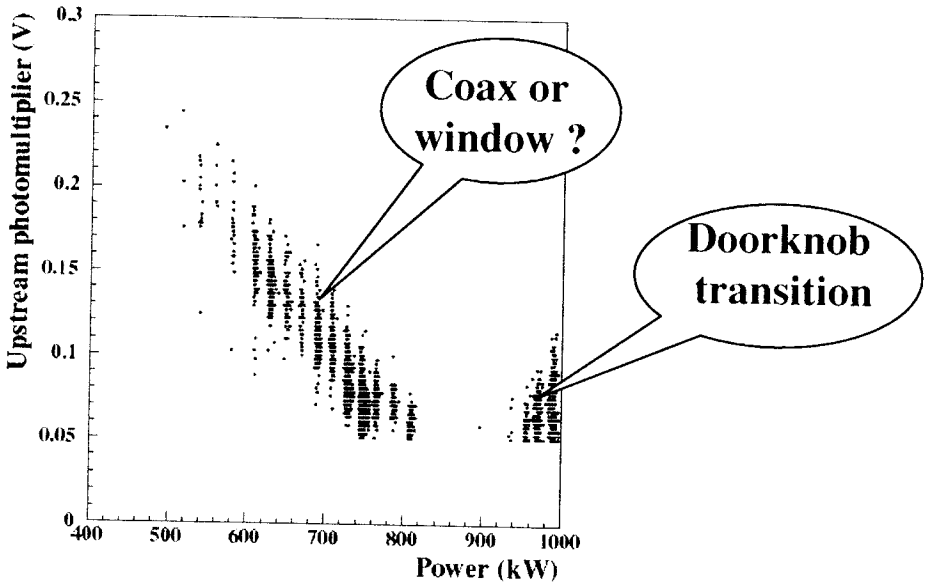


Barriers found on vacuum signals	Barriers found on PM signals (kW)
435	410
490	515
555	555
585	-
645	635
705	715
745	745
860	860
940	960
1005	990

Steady state operation: conclusions

- operation in standing wave regime at high power helped the processing of the doorknob transition

- at the end, back to TW operation, only remains a very low upstream light signal



- on downstream side, the 700 kW coax multipactor barrier is still visible, but the corresponding outgassing is only 3 10^{-9} mbar

- we didn't observe any difference between operation at 100 and 300 K

- dielectric losses inside the ceramic are not measurable (20 mW with our duty cycle)

Argon Discharge Treatment of Input Couplers

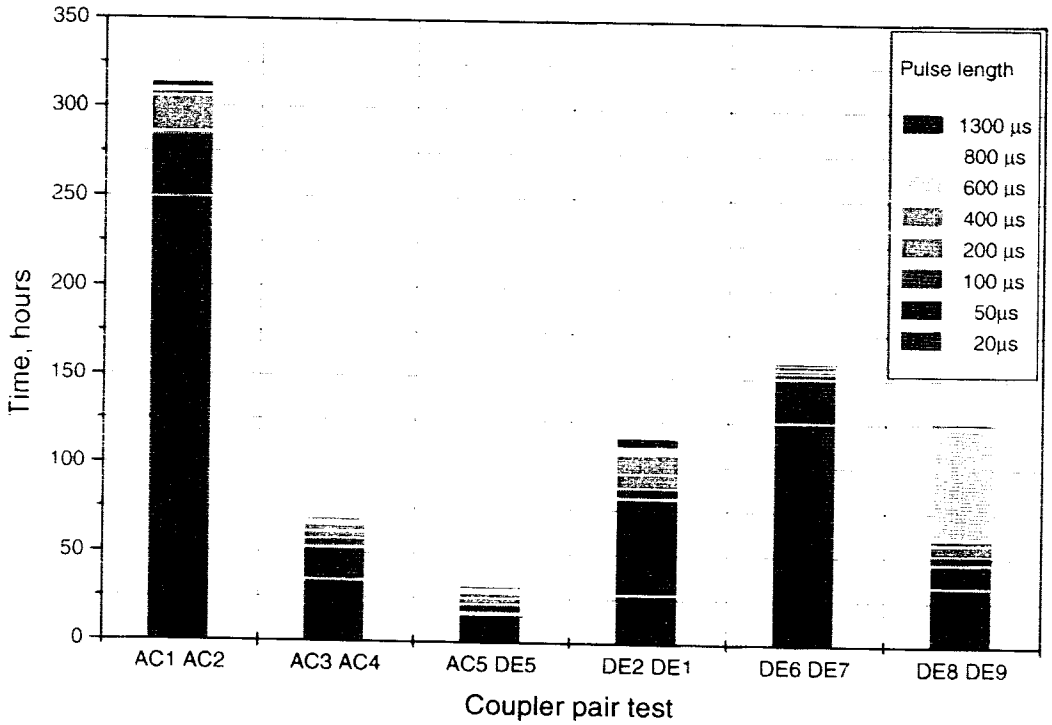
D. Kostin, M. Lalayan, W.-D. Moeller, D. Proch, S. Yarigin, A.Zavadtsev

DESY

1. Present state of TTF 2 – type couplers

RF processing rate for different coupler pairs tests

(time needed for RF power reached target value on each pulse length)



Problem: Processing is too time-consuming.

Proposal: Use RF-driven discharge in Argon under controlled conditions to clean-up surface

2. Argon discharge treatment procedure

2.1. Ar-treatment place in the Main scheme

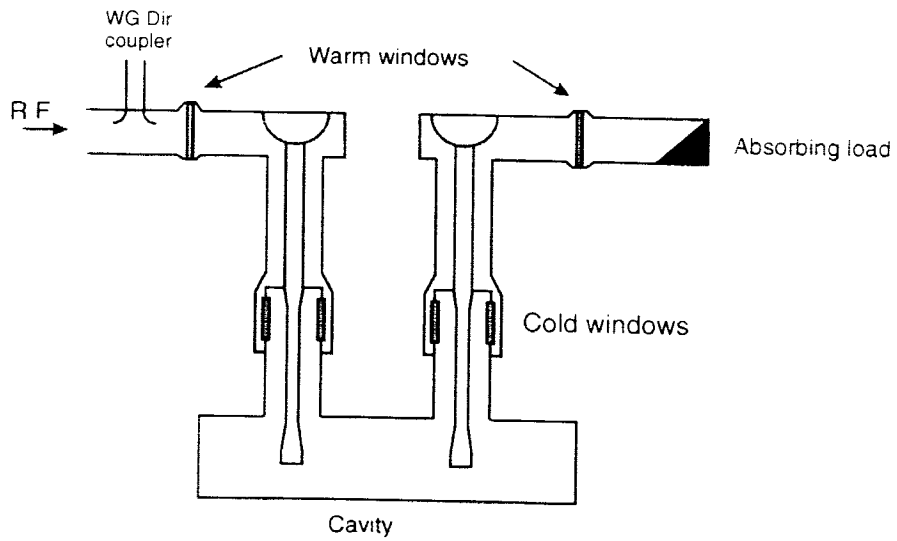
Vacuum pumping + baking at 200 °C
Ar – process
Pumping
RF procedure on 20μs, 50μs ...

2.2. Modification of RF scheme for Ar-processing

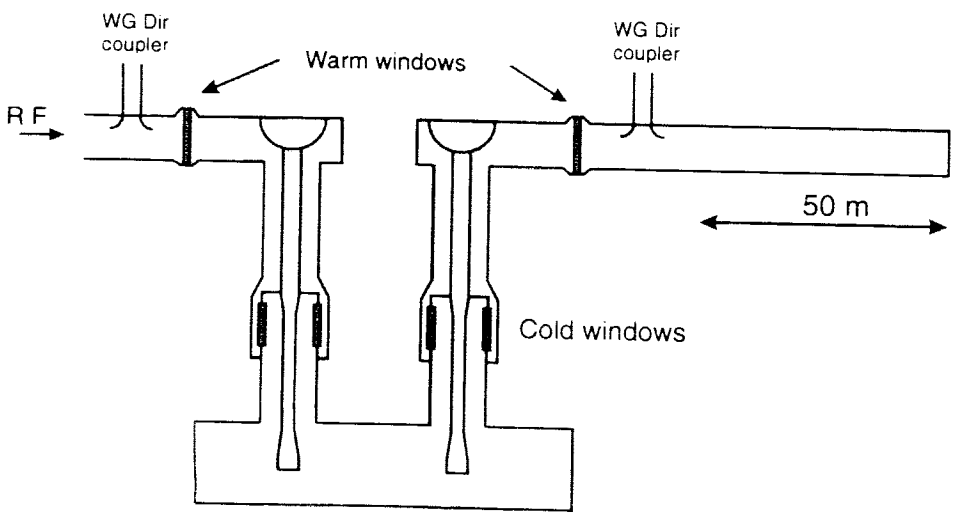
To obtain uniform treatment of RF surfaces we made standing wave phase shift using:

a. Long RWG is connected to output coupler
b. Frequency sweeping 1.95 MHz
=> Standing wave phase within test stand shifted on $\lambda/2$

RF–scheme for RF–conditioning



Modified RF–scheme for Ar processing



2.3. Algorithm

A. Only input coupler filled with Ar at 10 mbar (slightly higher than Paschen curve minimum)

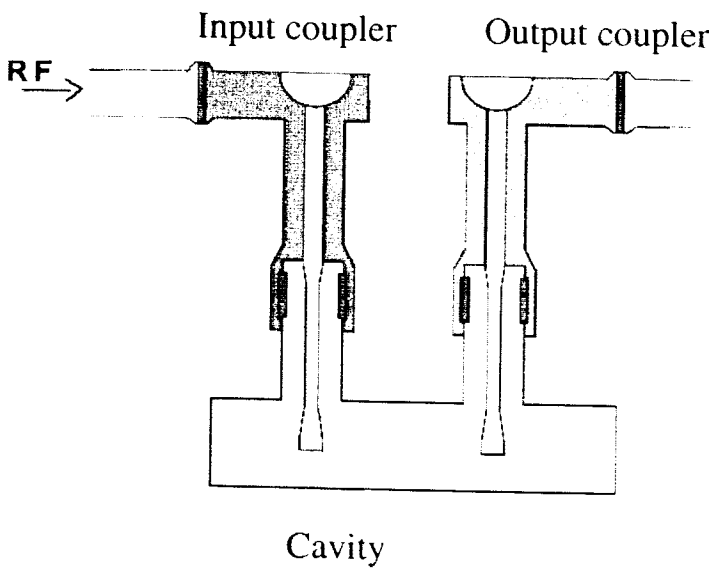
- RF is on for ~1 hour
- Exchange Ar with fresh one
- RF is on for ~1 hour
- Pump Ar out of input coupler

B. Only cavity filled with Ar at 10 mbar,

- Procedure is the same

C. Only output coupler filled with Ar at 10 mbar,

- Procedure is the same



2.4. Diagnostics and handling soft discharge during Ar-process

RF power control:

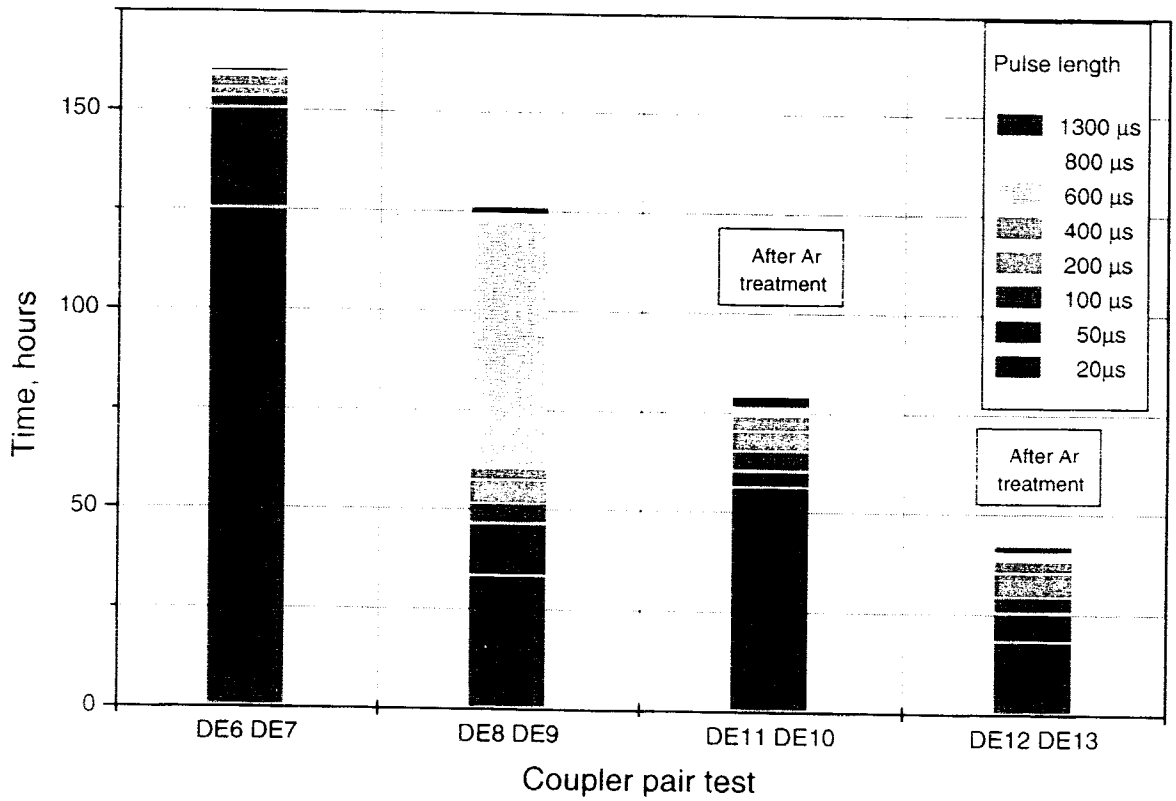
Pulse length	20 μs
Repetition rate	2 Hz
RF power level	up to reflected power appeared

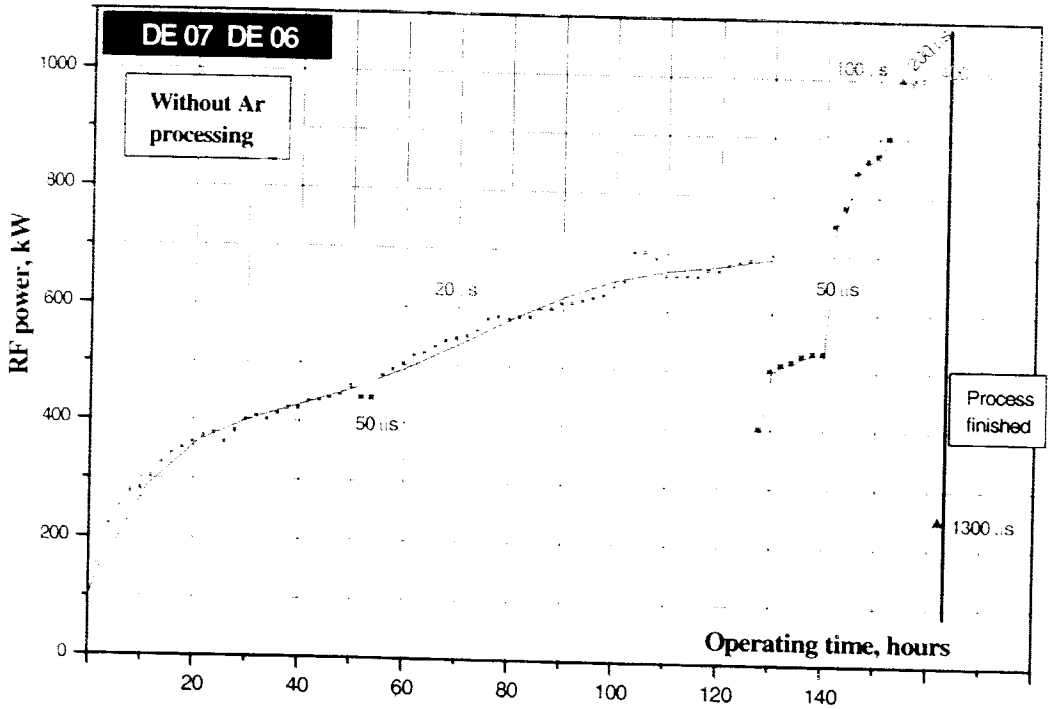
Sensors

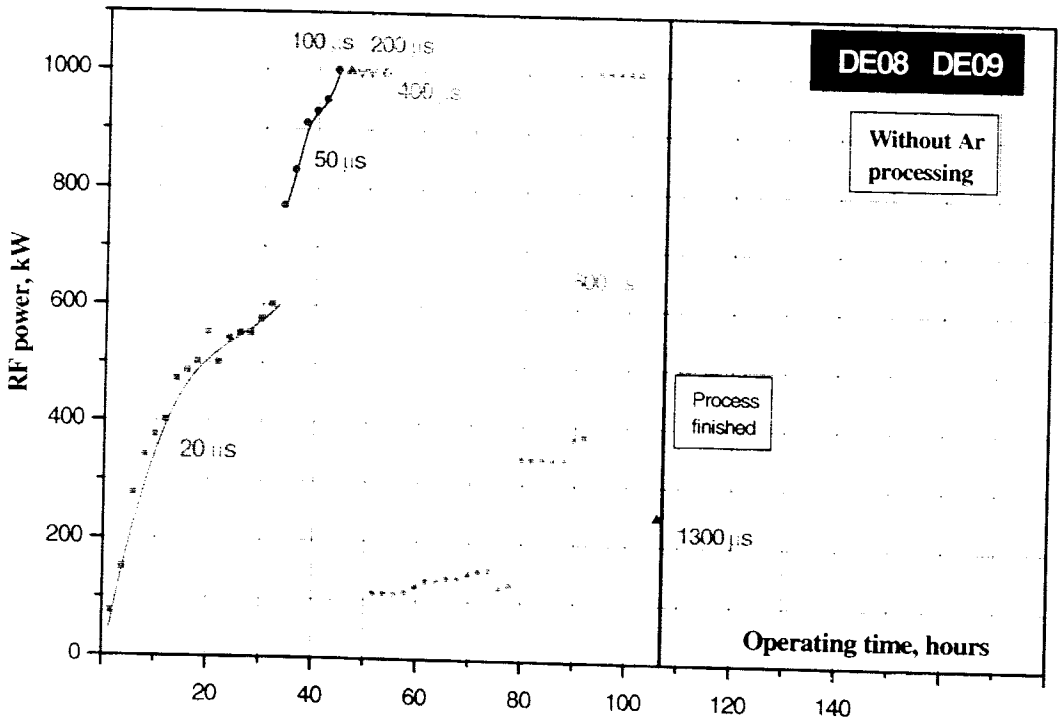
Light	– switched off
electron pickups	
pressure	– Ar pressure is controlled manually
P reflected	
P forward	
P transmitted	

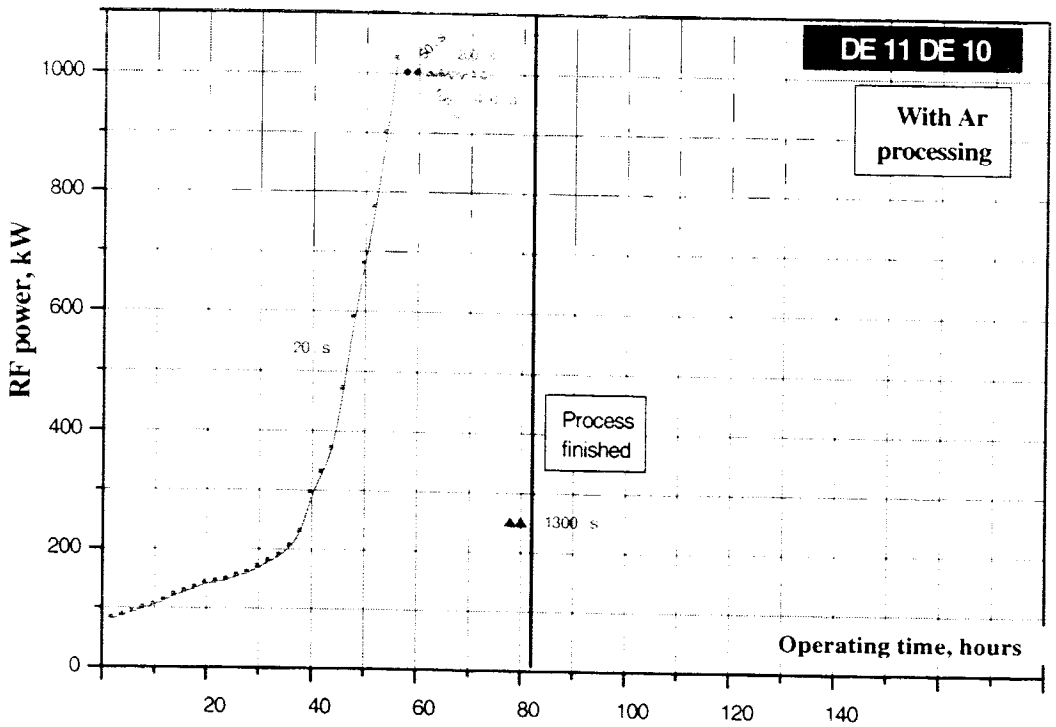
Comparison of typical input coupler test and test after Ar treatment

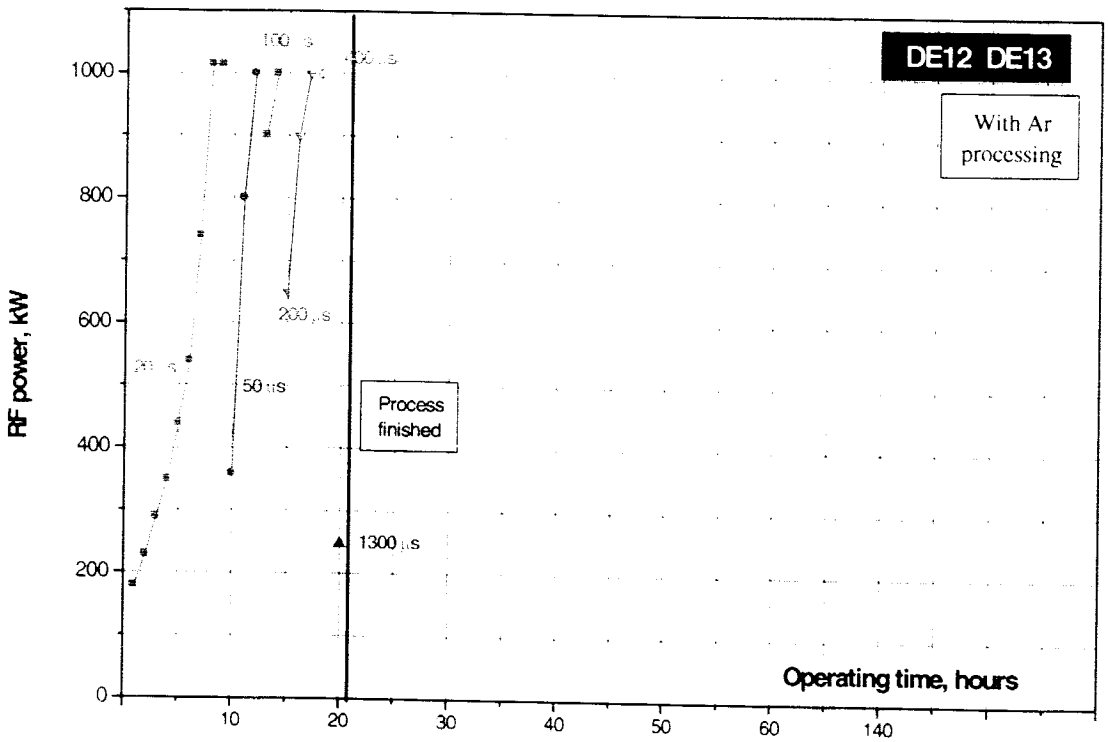
Forward power vs. time




DE 07 DE 06
Without Ar processing
RF power, kW
Operating time, hours
20 µs
50 µs
50 µs
100 µs
200 µs
1300 µs
Process finished
0
200
400
600
800
1000
20
40
60
80
100
120
140


DE08 DE09
Without Ar processing
RF power, kW
Operating time, hours
100 µs
200 µs
400 µs
50 µs
20 µs
1300 µs
Process finished
0
200
400
600
800
1000
20
40
60
80
100
120
140


DE 11 DE 10
With Ar processing
RF power, kW
Process finished
1300 s
Operating time, hours
0
200
400
600
800
1000
20
40
60
80
100
120
140

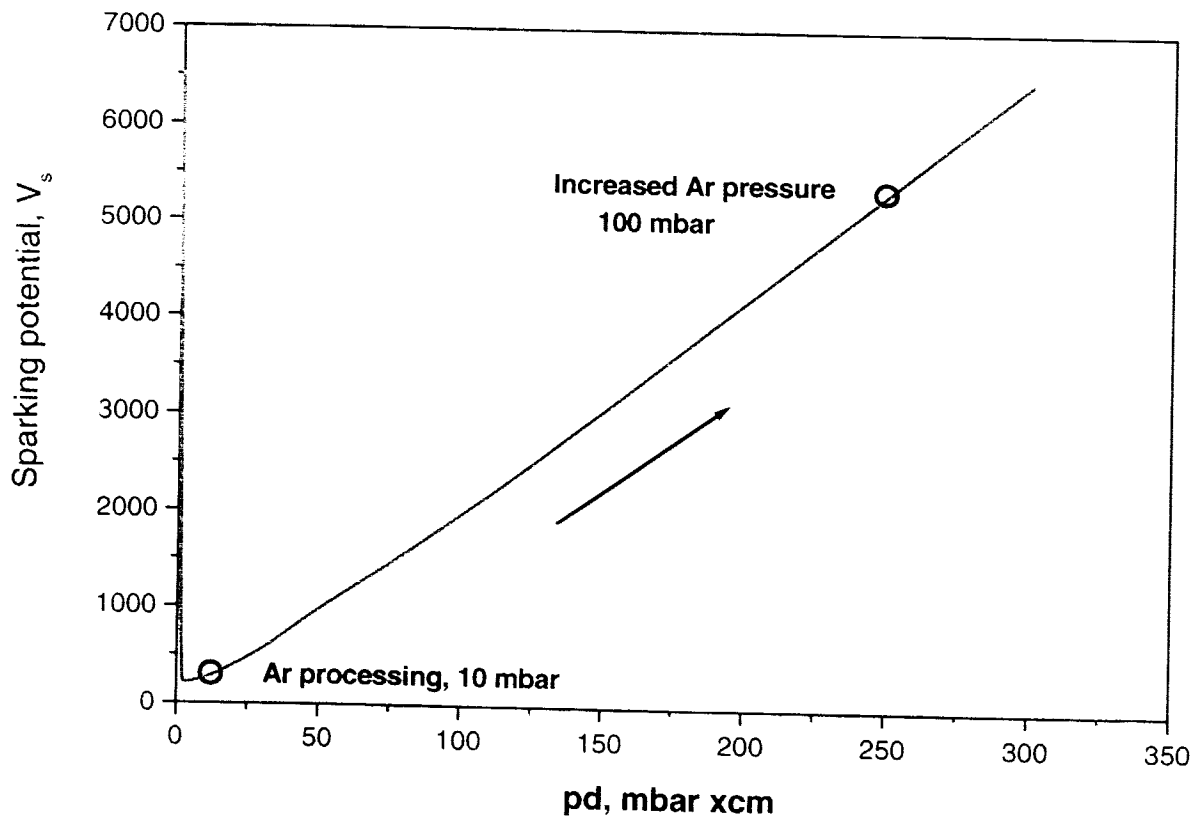

DE12 DE13
With Ar processing
RF power, kW
50 µs
200 µs
Process finished
1300 µs
Operating time, hours
0
200
400
600
800
1000
10
20
30
40
50
60
140

3. Modification of Argon Processing Algorithm

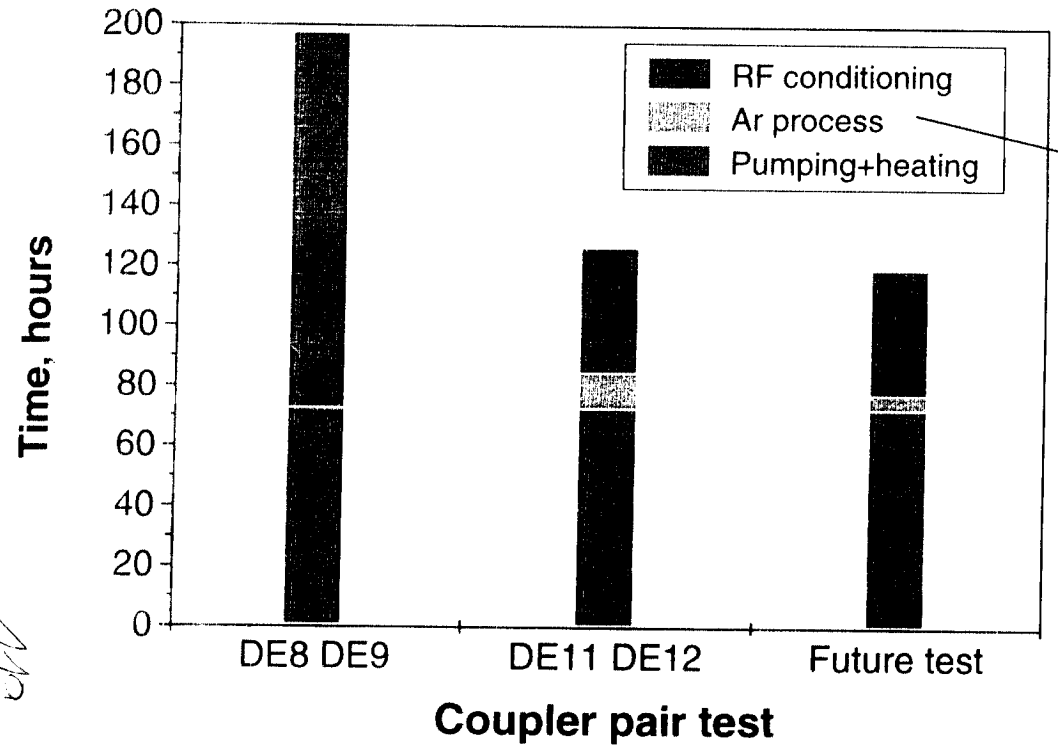
A. Sequence changing

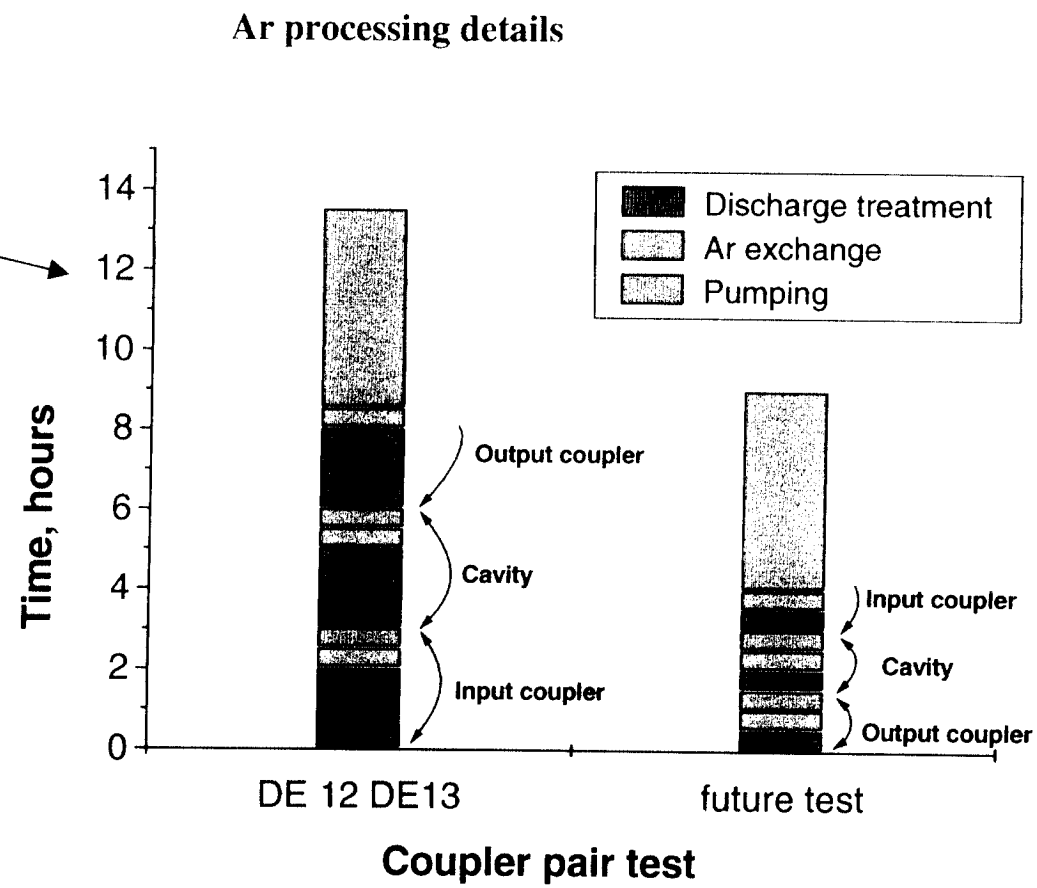
1. Vacuum pumping of **all volumes**
2. Fill with Ar at 10 mbar **output coupler** volume and do RF process
3. Ar pressure increasing in output coupler to 100 mbar
   Fill with Ar at 10 mbar **cavity** volume and do RF process
4. Ar pressure increasing in cavity to 100 mbar
   Fill with Ar at 10 mbar **input coupler** volume and do RF process
5. Final pumping out

Paschen curve for Ar



B. Ar processing at higher repetition rate (10-20 Hz)

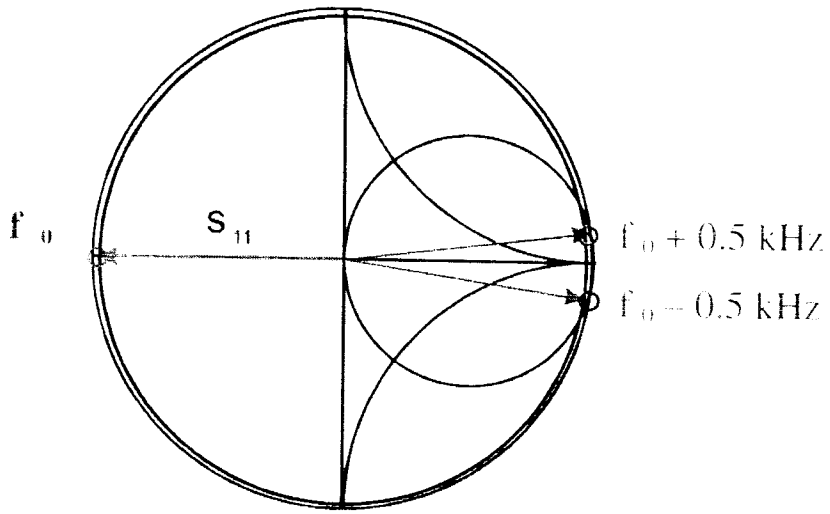




Improvement of Coupler Processing in Chechia and in Cryomodule

Frequency sweep during Ar and RF conditioning

Smith chart



- $Q_0 = 5*10^9$
- $Q_{ext} = 3*10^6$
- $f_0 = 1.3$ GHz
- Frequency sweep 1 kHz

- Electric field maximum displacement in coupler is equal to $\lambda / 2$

(115 mm in coaxial line)

LABORATOIRE
DE L'ACCÉLÉRATEUR
LINÉAIRE

3rd Joint DESY – LAL – Saclay Workshop on High Power Couplers for TESLA

LAL – Orsay, 17th and 18th January 2000

S. IARIGUINE

121

Control signals limits determination.

a. Vacuum

It is measured by current of ion-pumps.

IL value is 1×10^{-5}.

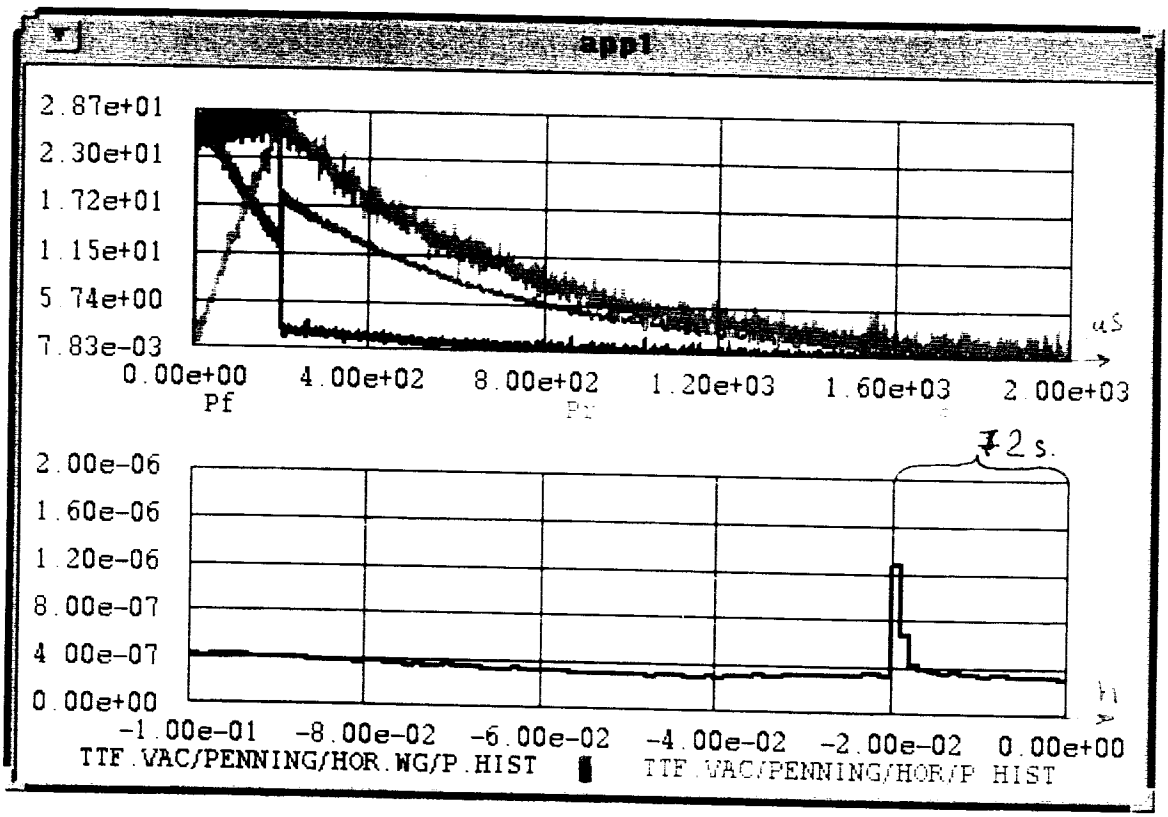
Soft limit is 2×10^{-7}.

This corresponds to the highest safe stable value, at higher values the probability of discharge increases rapidly (as of our experience with TTF couplers). It is possible to maintain power increasing if the vacuum is about this value (with our speed vacuum measurements and response in power). Probably it is possible to work at higher values, but only with faster response and measurements.

Currently response in power take 20-30s, it is a program cycle. At 2Hz repetition rate it means 40-60 pulses.

It is necessary to work at highest value as possible to achieve the highest speed of RF-cleaning.

Vacuum now is the main parameter of processing and clean state indicator.


appl
2.87e+01
2.30e+01
1.72e+01
1.15e+01
5.74e+00
7.83e-03
0.00e+00
4.00e+02
8.00e+02
1.20e+03
1.60e+03
2.00e+03
Pf
uS
2.00e-06
1.60e-06
1.20e-06
8.00e-07
4.00e-07
0.00e+00
-1.00e-01
-8.00e-02
-6.00e-02
-4.00e-02
-2.00e-02
0.00e+00
TTF.VAC/PENNING/HOR.WG/P.HIST
TTF.VAC/PENNING/HOR/P HIST
72 s.

b. Electron current

The pick-up antennas on the outer coax wall are used for DESYII coupler.

There are three places:
warm part top (e-3),
warm part bottom (e-2),
could part (e-1).

All earlier tests were done with cards, which give 1V output at 500mkA, and have a saturation at about 1.8V.

The 30V voltage is applied to each pick-up.

Last measurements shows, that at ~135kW pressure 2×10^{-7} we have a current about 2mA. (card saturation at 1.56 ~ 2 mA)

IL limit is at 3v. It corresponds to the 170mkA CW (180kOm). Card has some integration circuit, so it allow more amplitude at short pulses.

These old e- monitor card can not work with pulses less then 100mks, it makes unreliable output in this case and should be calibrated in a way, different from long pulses or CW.

At the last week new fast cards was tested, they have limit of 2mA at 1V scope output. IL integration constant was not yet calibrated. That cards can measure pulses shorter then 15mks.

It is possible to use whole inner-coaxial as e- pick-up, in this case the integral current will be seen, but it is difficult to apply at the same time HV.

During the process the next parameters are monitored:

Vacuum in each part of test-stand.

Electron current through e- pick-ups.

Light in RWG box of couplers.

Temperature of warm window (by IR).

Temperature of could window (by touch-thermometer at 80k flange).

Spark detector to indicate a brake-down on the air part of warm window.

There are two kinds of limitation for this parameters: program soft limits and hardware IL limits.

If IL limit is overcome for some of them then hardware will switch the power off completely.

If soft limit is overcome then control program will decrease the input power in some rate (typically 0.1..0.3 dB).

c. ML investigation procedure.

First clean coupler without HV and with 600mks pulse up to 1000kW, like in previous steps.

"Clean"-means that all control signals are below the soft limits, so there is no probability to receive problems in power region up to 1000kW.

Then at each HV value power goes from 10 to 1000kW and down two times (2 times sweep).

After all the signals are analyzed in order to obtain the ML regions for each HV value.

The Main processing sequence.

a. Baking

Normally backing is carried out after the assembly of coupler at test-stand and vacuum leak check.

Main purpose of it is to remove water and oil from surfaces.

The procedure is next:

1) increasing of temperature in 20C steps up to 200C.
1) Stay at 200C until the pressure in couplers start to goes down.
1) Step decreasing of temperature back.

Total time required is about 2 or 3 days. During the backing pumping is carried out by ion-pumps.

Pressure is maintained below 10^{-5}mbar in order to avoid Cu oxidation.

b. Pulse RF cleaning at travelling wave.

Purpose: Remove residual dirt and field emission sources.

The main sequence looks like it shown below.

All process goes at 2Hz repetition rate.

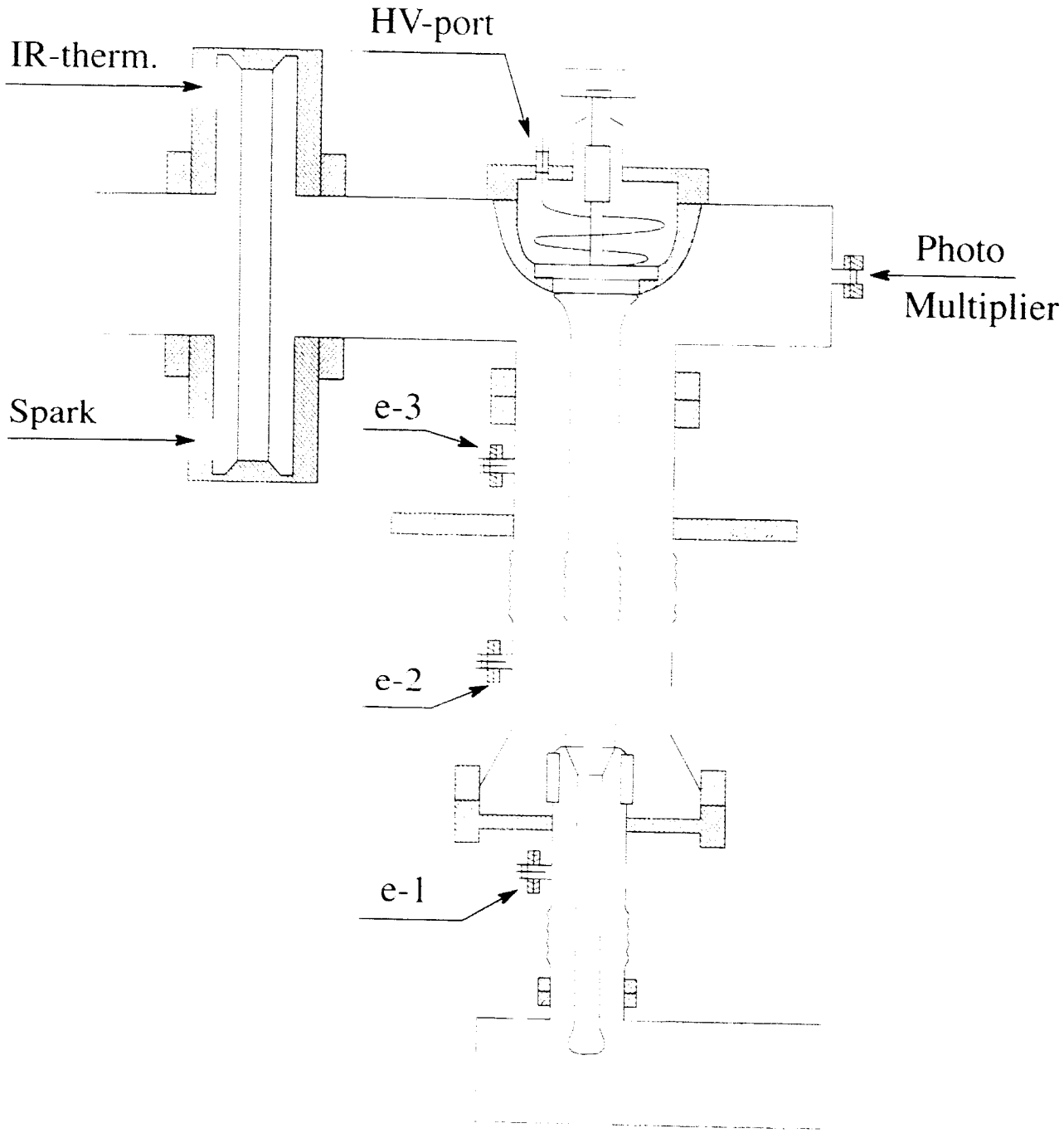
Procedure for each pulse length from 20, 50, 100, 200, 400 mks:

1) Power rise up to 1000kW.
1) Maintain power at 1000kW for some time (typically about 20min to 1h).
1) Power decreasing to about 10kW and switch to the higher pulse length.

Procedure for each pulse length from 800,1000,1300 mks:

1) Power rise up to 250kW.
1) Maintain power at 250kW for some time (about 20min to 1h).
1) Power decreasing to about 10kW and switch to the higher pulse length.

This sequence was applied as initial step for most of couplers in the last time.



Picture 1: Coupler diagnostic.

Test processing of TTF input couplers.

1. Preface

At TTF we treat the coupler at 3 different places:

1) 2 couplers test
1) Horizontal test
1) Module

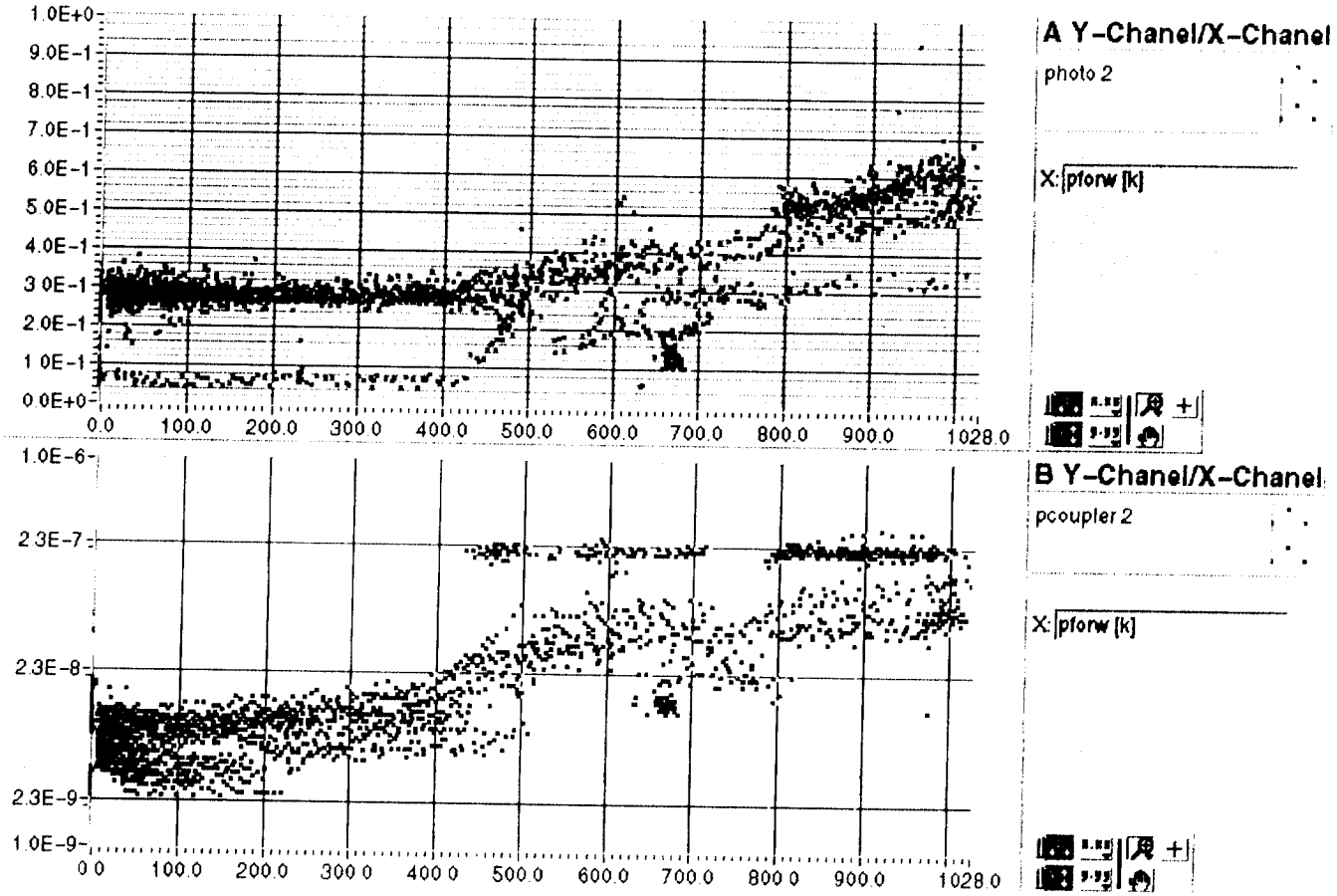
Here the first one will be observed[1].

2. Couplers conditioning at 2-couplers test-stand.

Goals in rough priority order.

1) Check functionality of each coupler.
1) Make the first high temperature and RF cleaning of each coupler.
1) Investigation of multipucting with HV and without HV.
1) Investigation of different control signals (e-,vacuum, light) during RF operation.

1. Not all couplers/cavities go through the horizontal test, the main points are the same for all tests, horizontal test is similar to modul operation


A Y-Chanel/X-Chanel
photo 2
X: pforw [k]
1.0E+0
9.0E-1
8.0E-1
7.0E-1
6.0E-1
5.0E-1
4.0E-1
3.0E-1
2.0E-1
1.0E-1
0.0E+0
0.0
100.0
200.0
300.0
400.0
500.0
600.0
700.0
800.0
900.0
1028.0
B Y-Chanel/X-Chanel
pcoupler 2
X: pforw [k]
1.0E-6
2.3E-7
2.3E-8
2.3E-9
1.0E-9
0.0
100.0
200.0
300.0
400.0
500.0
600.0
700.0
800.0
900.0
1028.0

c. Light

Light is measured at the RWB box of DESYII coupler.

Card and photomultipliers are calibrated to see up to 1 lux light.

IL limit is currently set to 0.5 lux.

Soft limit is about 0.4 lux.

At some conditions it should be adjusted lower, in order to receive stable operation without IL's. These values roughly correspond to the vacuum ones. That is: if light is constantly at 0.4 lux, the vacuum should be in a region around 2×10^{-7}.

Light measurements are fast enough to see 10mks pulses. Because of glossy Cu surface, it is possible to detect light in whole warm part, but probably with different absolute value.

d. Temperature of windows.

Warm window temperature can be detected by IR sensor.

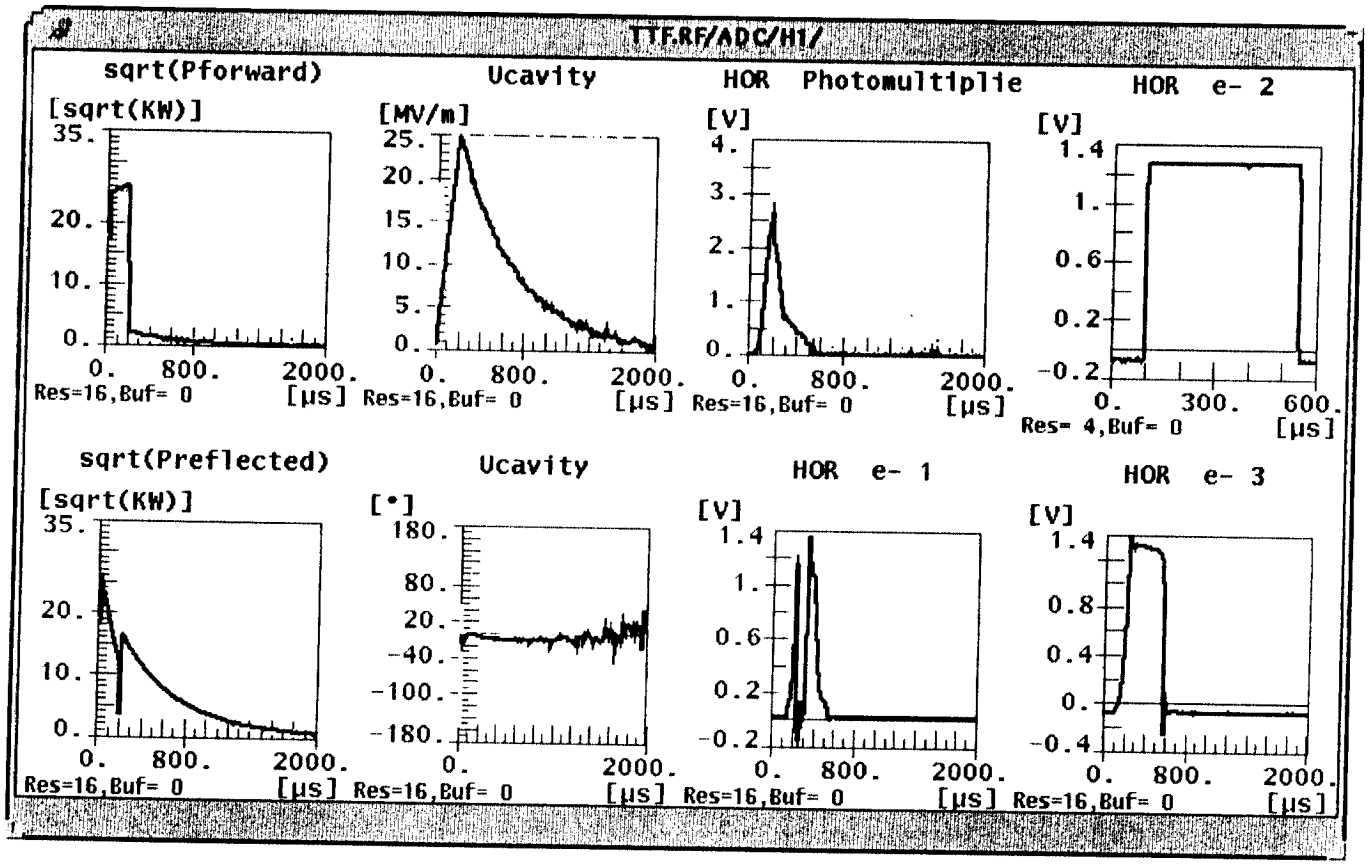
Could window temperature is detected by temperature of outer conductor near the 80K flange. Which is not so precise.

The IL value is set to 40C.

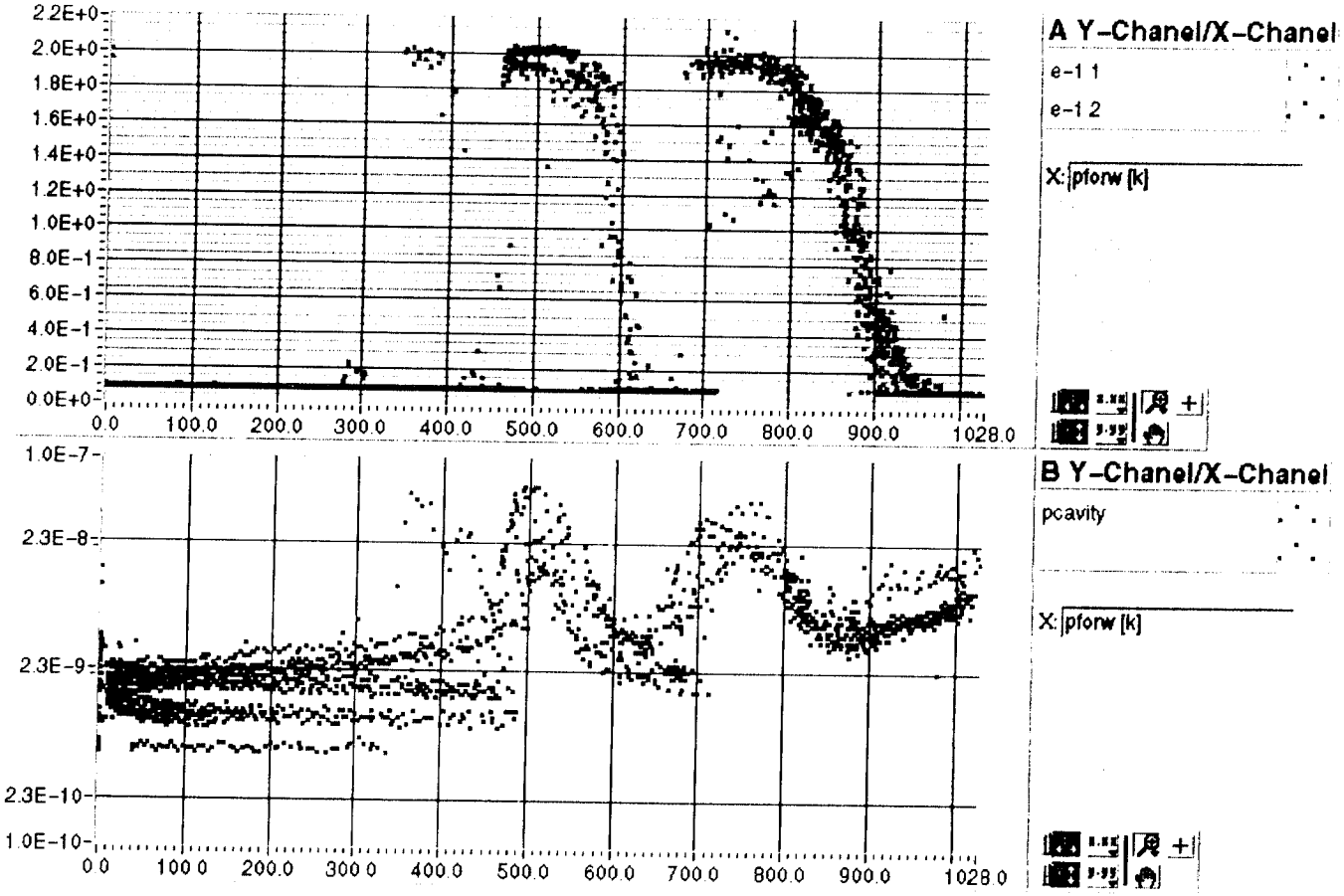
No any troubles were encountered with DESYII windows temperature. Because temperature measurements are very slow, they can not be effectively used for rapid power control during conditioning.

3. Some Conclusion.

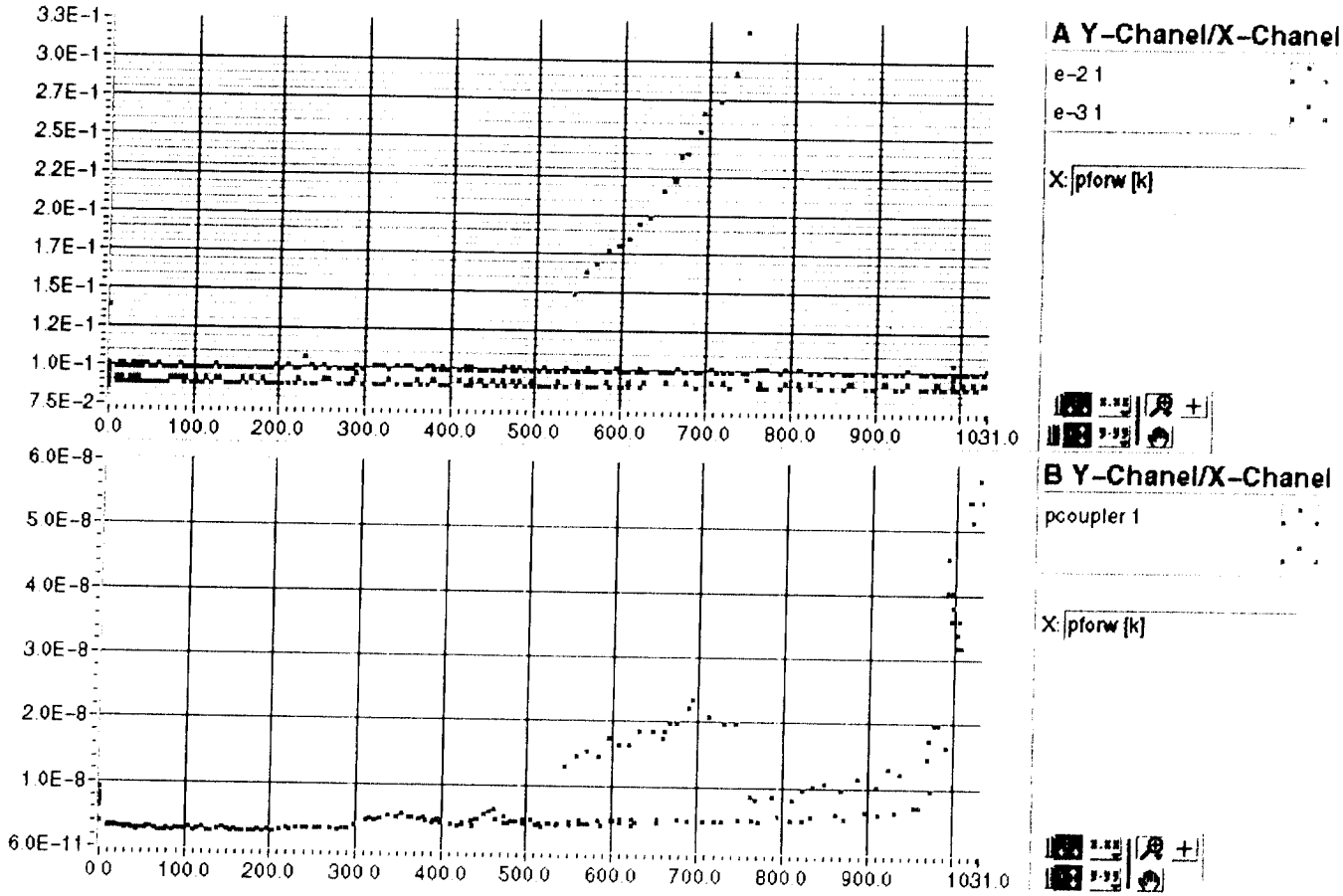
1) We are not pleased with time of processing.
2) Our diagnostic is not perfect, only vacuum is more or less reliable.
3) Limitations for e- have improper settings now
4) Pressure limits can be set a little higher, 4×10^{-7}mbar.
5) May be it will be good to implement some experience of CERN couplers processing to our side.


TTF.RF/ADC/H1/
sqrt(Pforward)
[sqrt(KW)]
35.
20.
10.
0.
0. 800. 2000.
Res=16,Buf= 0
[µs]
Ucavity
[MV/m]
25.
20.
15.
10.
5.
0.
0. 800. 2000.
Res=16,Buf= 0
[µs]
HOR Photomultiplie
[V]
4.
3.
2.
1.
0.
0. 800. 2000.
Res=16,Buf= 0
[µs]
HOR e- 2
[V]
1.4
1.
0.6
0.2
-0.2
0. 300. 600.
Res= 4,Buf= 0
[µs]
sqrt(Preflected)
[sqrt(KW)]
35.
20.
10.
0.
0. 800. 2000.
Res=16,Buf= 0
[µs]
Ucavity
[°]
180.
80.
20.
-40.
-100.
-180.
0. 2000.
Res=16,Buf= 0
[µs]
HOR e- 1
[V]
1.4
1.
0.6
0.2
-0.2
0. 800. 2000.
Res=16,Buf= 0
[µs]
HOR e- 3
[V]
1.4
0.8
0.4
0.
-0.4
0. 800. 2000.
Res=16,Buf= 0
[µs]

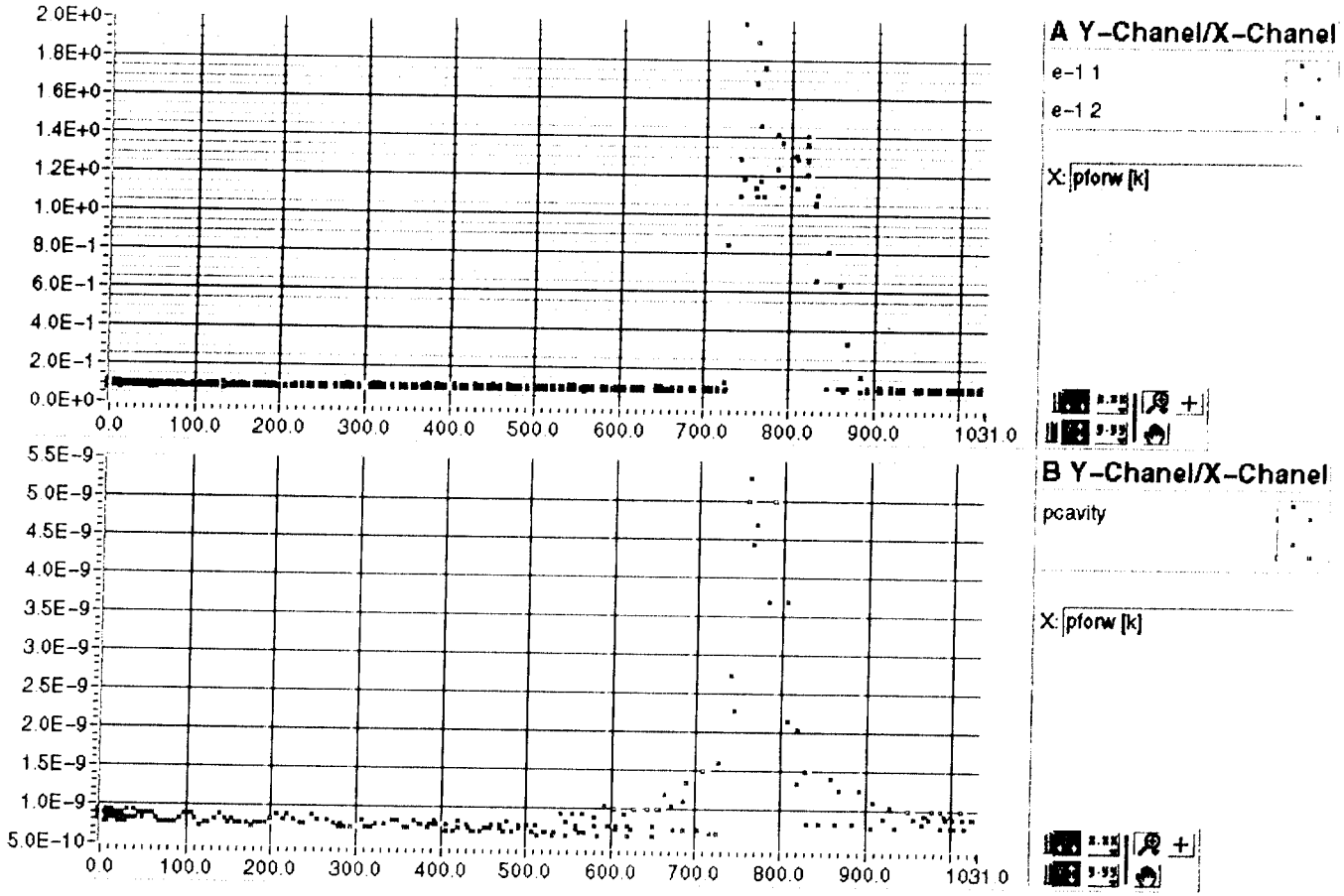
131


A Y-Chanel/X-Chanel
e-1 1
e-1 2
X: pforw [k]
2.2E+0
2.0E+0
1.8E+0
1.6E+0
1.4E+0
1.2E+0
1.0E+0
8.0E-1
6.0E-1
4.0E-1
2.0E-1
0.0E+0
0.0
100.0
200.0
300.0
400.0
500.0
600.0
700.0
800.0
900.0
1028.0
B Y-Chanel/X-Chanel
pcavity
X: pforw [k]
1.0E-7
2.3E-8
2.3E-9
2.3E-10
1.0E-10

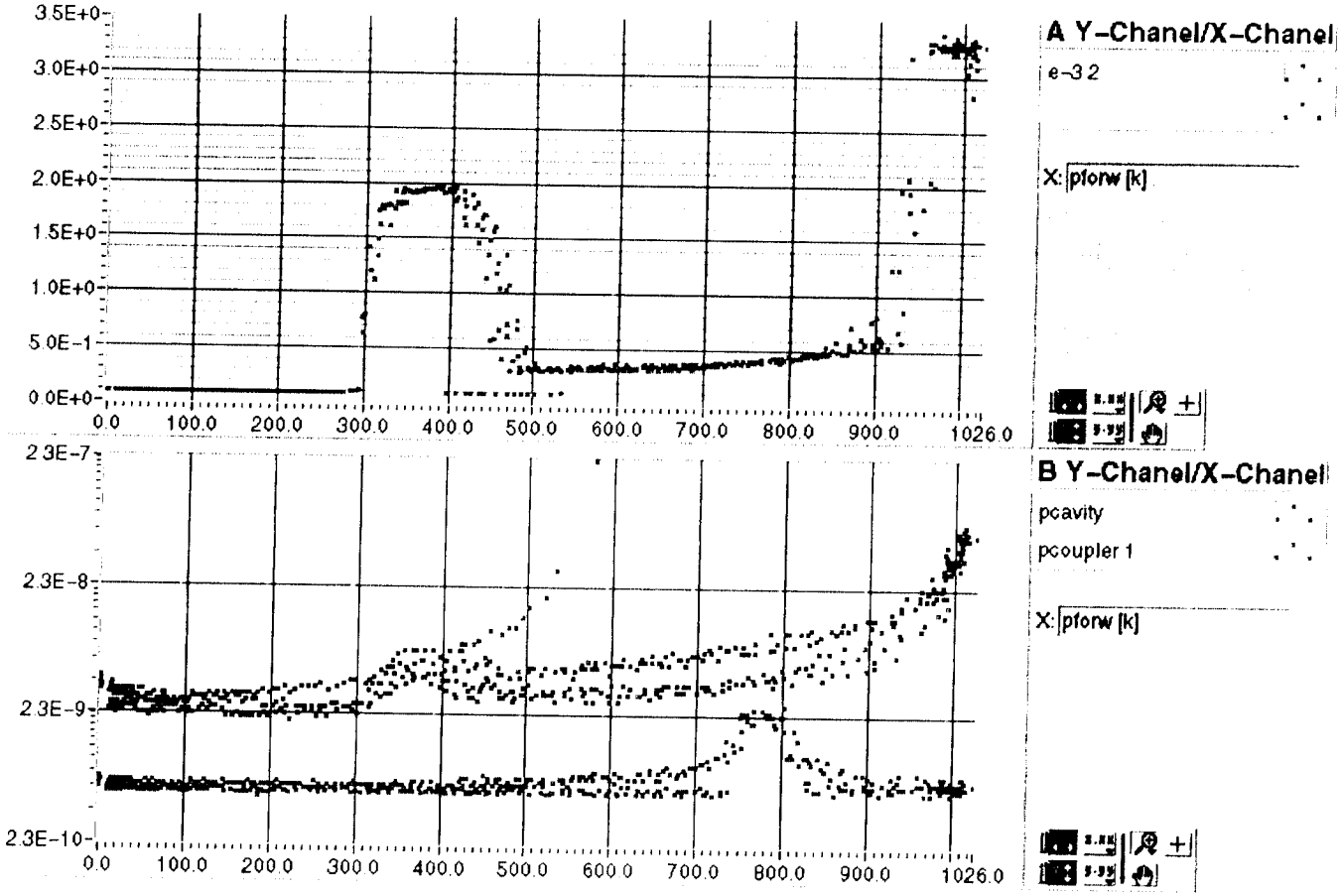
132

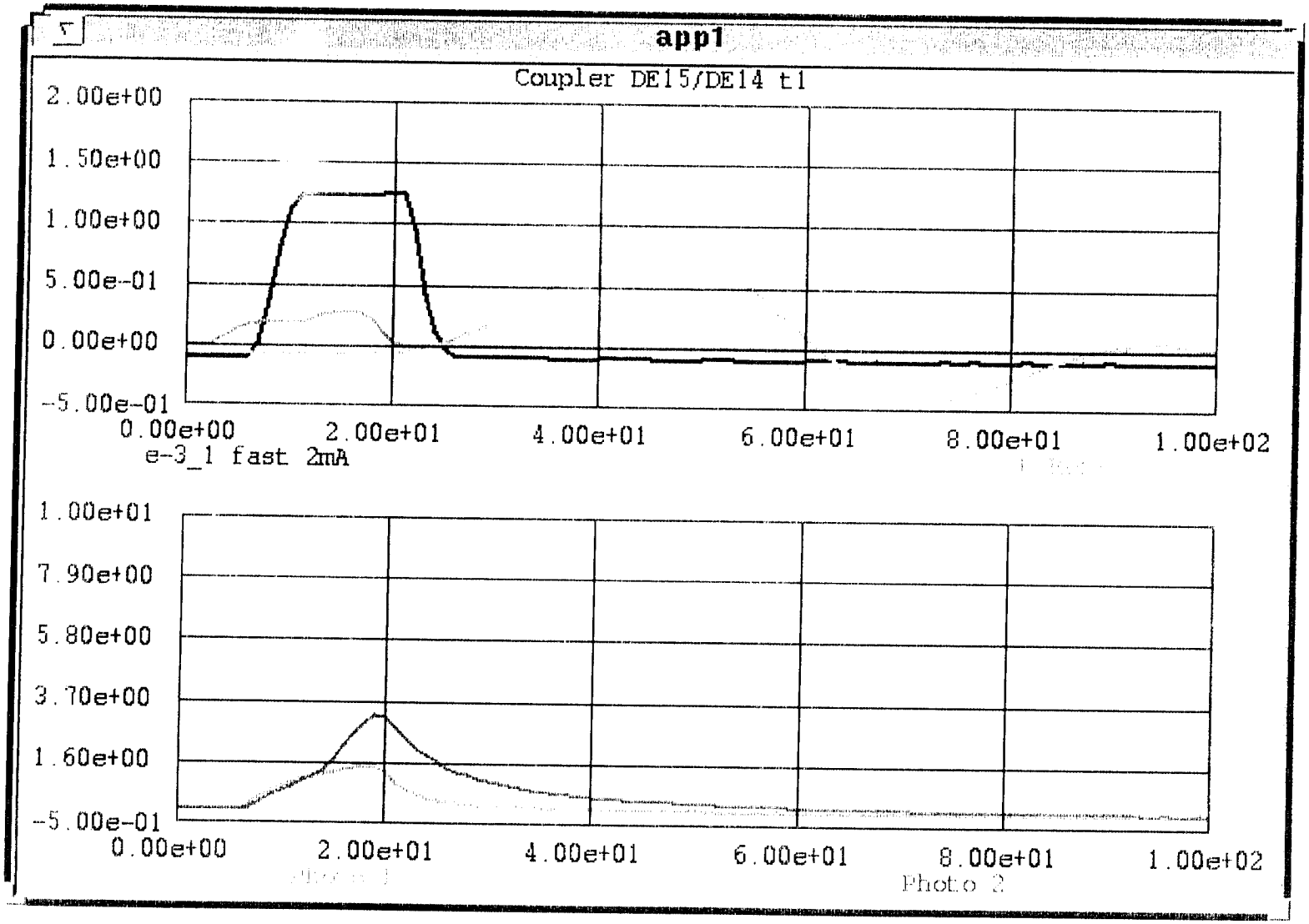

3.3E-1
3.0E-1
2.7E-1
2.5E-1
2.2E-1
2.0E-1
1.7E-1
1.5E-1
1.2E-1
1.0E-1
7.5E-2
0.0
100.0
200.0
300.0
400.0
500.0
600.0
700.0
800.0
900.0
1031.0
A Y-Chanel/X-Chanel
e-2 1
e-3 1
X: pforw [k]
6.0E-8
5.0E-8
4.0E-8
3.0E-8
2.0E-8
1.0E-8
6.0E-11
B Y-Chanel/X-Chanel
pcoupler 1
X: pforw [k]

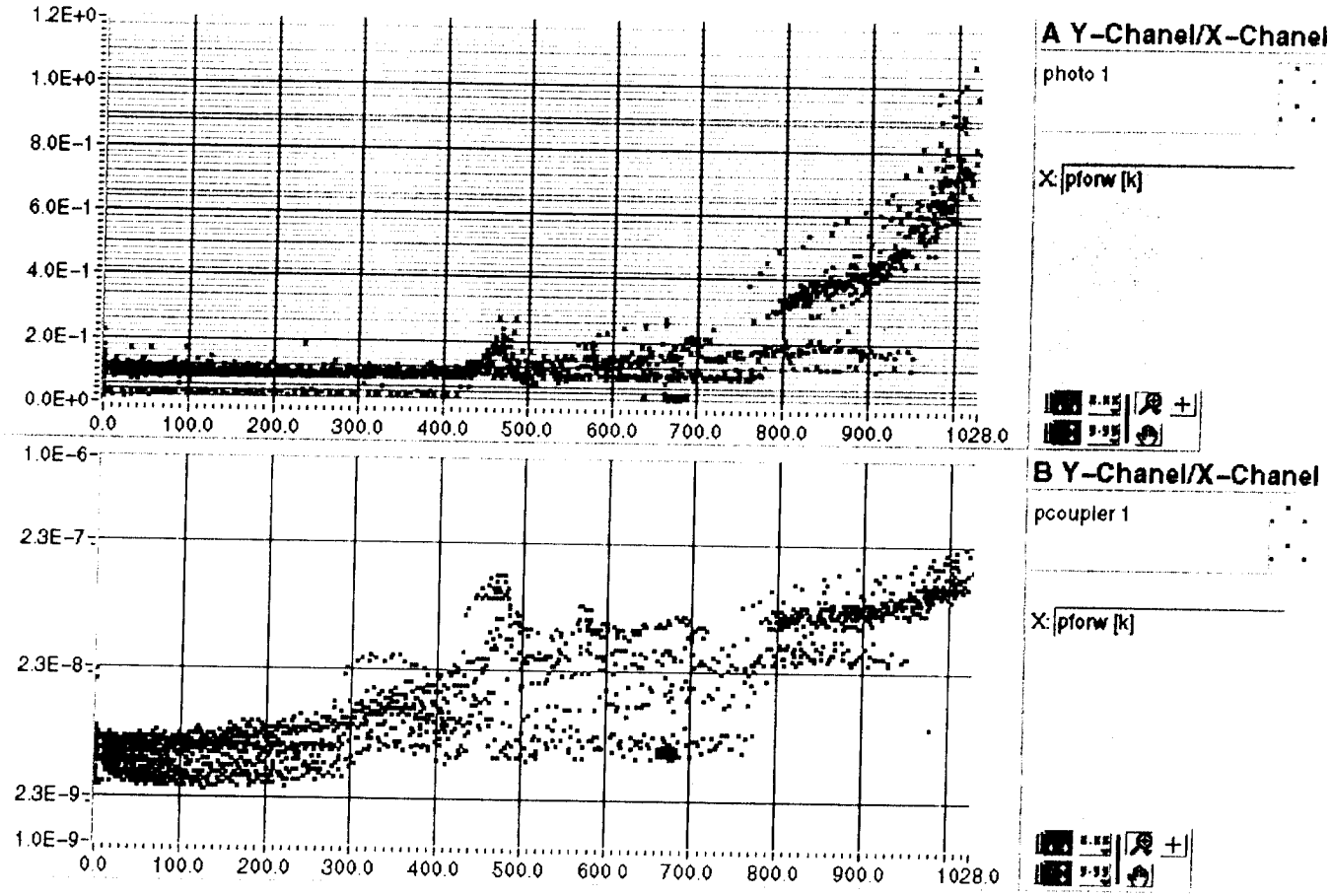
133

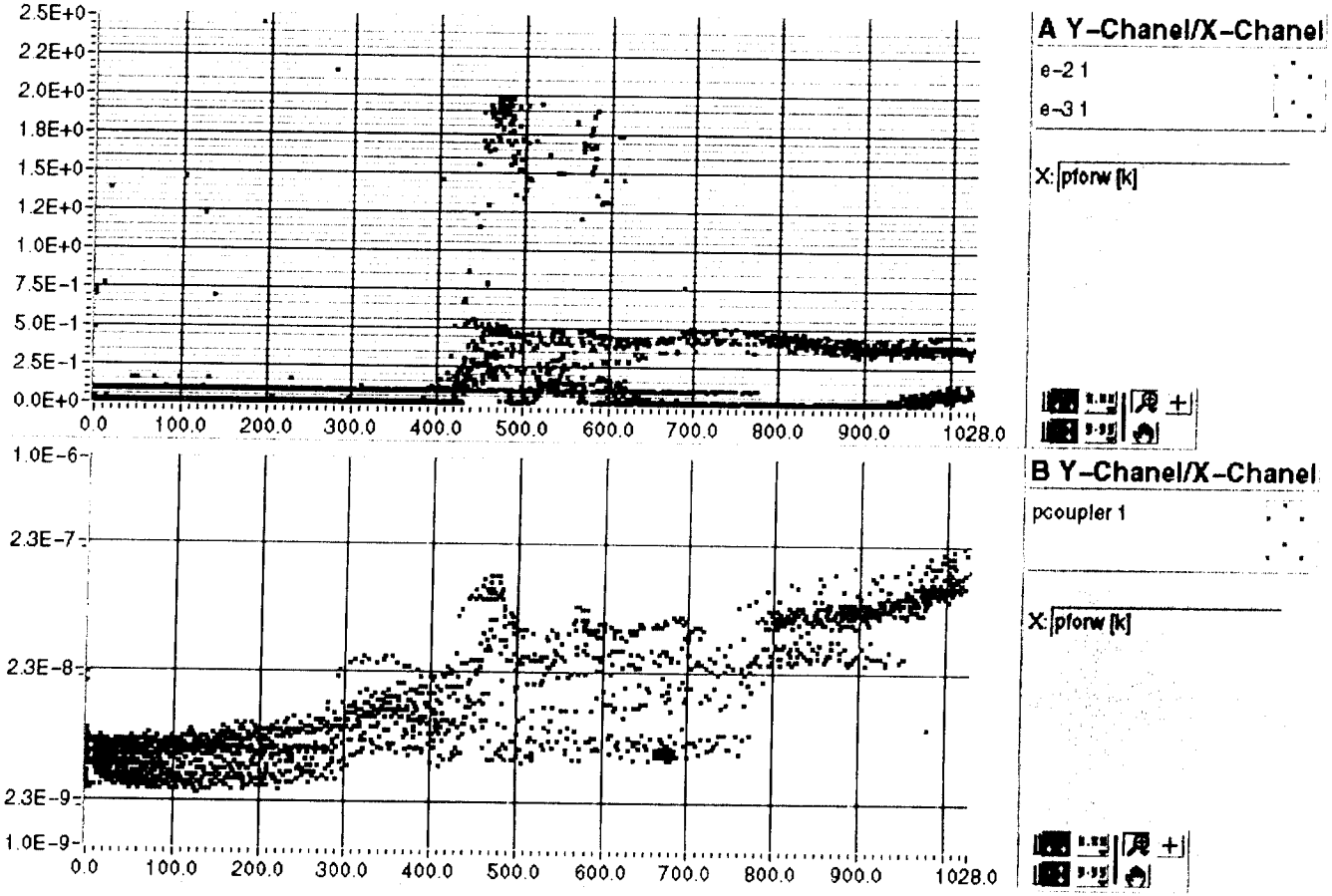

A Y-Chanel/X-Chanel
e-1 1
e-1 2
X: pforw [k]
B Y-Chanel/X-Chanel
pcavity
X: pforw [k]
2.0E+0
1.8E+0
1.6E+0
1.4E+0
1.2E+0
1.0E+0
8.0E-1
6.0E-1
4.0E-1
2.0E-1
0.0E+0
5.5E-9
5.0E-9
4.5E-9
4.0E-9
3.5E-9
3.0E-9
2.5E-9
2.0E-9
1.5E-9
1.0E-9
5.0E-10
0.0
100.0
200.0
300.0
400.0
500.0
600.0
700.0
800.0
900.0
1031.0

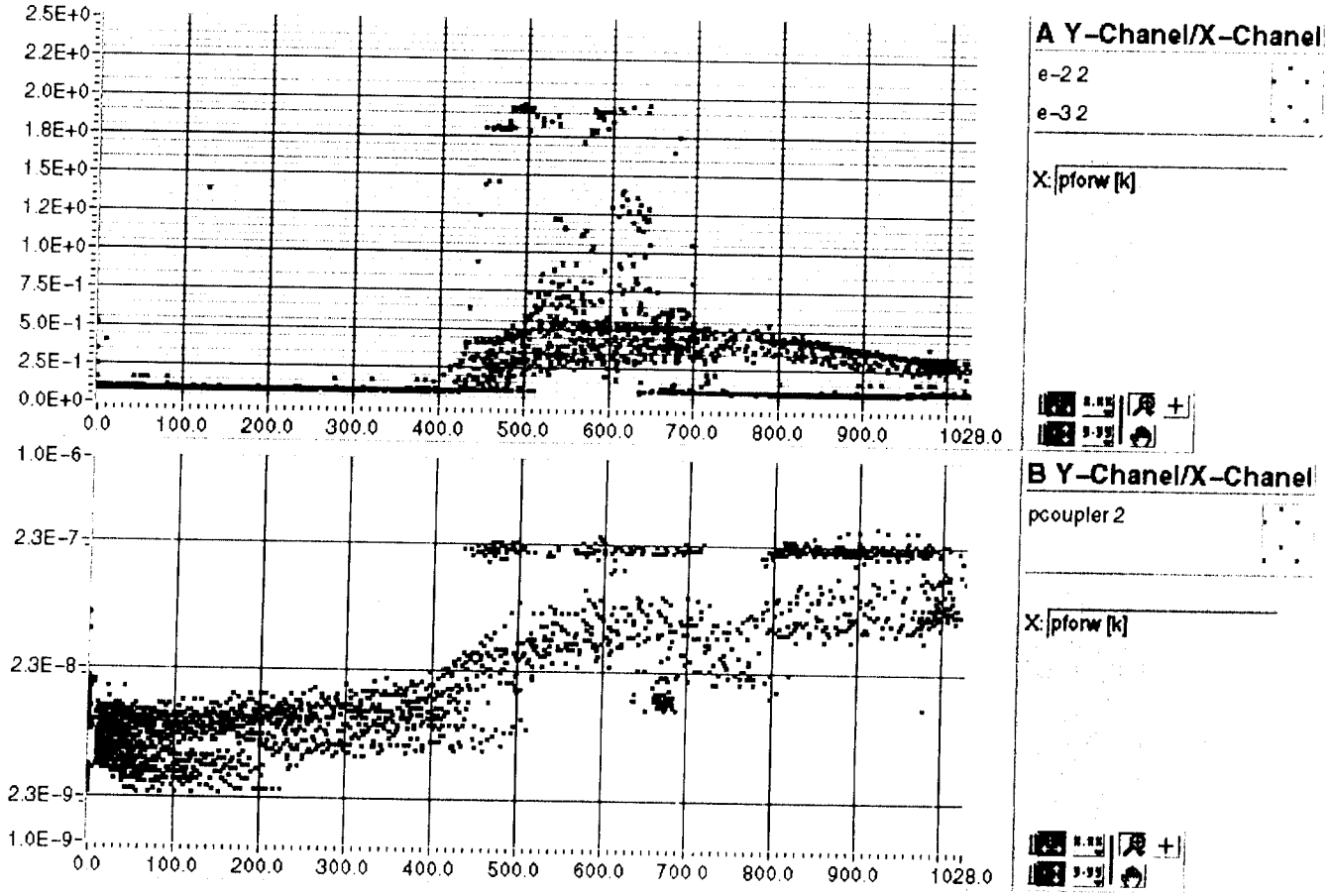
A24


A Y-Chanel/X-Chanel
e-3 2
X: pforw [k]
3.5E+0
3.0E+0
2.5E+0
2.0E+0
1.5E+0
1.0E+0
5.0E-1
0.0E+0
0.0
100.0
200.0
300.0
400.0
500.0
600.0
700.0
800.0
900.0
1026.0
B Y-Chanel/X-Chanel
pcavity
pcoupler 1
X: pforw [k]
2.3E-7
2.3E-8
2.3E-9
2.3E-10


app1
Coupler DE15/DE14 t1
2.00e+00
1.50e+00
1.00e+00
5.00e-01
0.00e+00
-5.00e-01
0.00e+00
2.00e+01
4.00e+01
6.00e+01
8.00e+01
1.00e+02
e-3_1 fast 2mA
1.00e+01
7.90e+00
5.80e+00
3.70e+00
1.60e+00
-5.00e-01
0.00e+00
2.00e+01
4.00e+01
6.00e+01
8.00e+01
1.00e+02
Photo 2


A Y-Chanel/X-Chanel
photo 1
X: pforw [k]
1.2E+0
1.0E+0
8.0E-1
6.0E-1
4.0E-1
2.0E-1
0.0E+0
0.0
100.0
200.0
300.0
400.0
500.0
600.0
700.0
800.0
900.0
1028.0
B Y-Chanel/X-Chanel
pcoupler 1
X: pforw [k]
1.0E-6
2.3E-7
2.3E-8
2.3E-9
1.0E-9


2.5E+0
2.2E+0
2.0E+0
1.8E+0
1.5E+0
1.2E+0
1.0E+0
7.5E-1
5.0E-1
2.5E-1
0.0E+0
0.0 100.0 200.0 300.0 400.0 500.0 600.0 700.0 800.0 900.0 1028.0
A Y-Chanel/X-Chanel
e-2 1
e-3 1
X: pforw [k]
1.0E-6
2.3E-7
2.3E-8
2.3E-9
1.0E-9
0.0 100.0 200.0 300.0 400.0 500.0 600.0 700.0 800.0 900.0 1028.0
B Y-Chanel/X-Chanel
pcoupler 1
X: pforw [k]


2.5E+0
2.2E+0
2.0E+0
1.8E+0
1.5E+0
1.2E+0
1.0E+0
7.5E-1
5.0E-1
2.5E-1
0.0E+0
0.0 100.0 200.0 300.0 400.0 500.0 600.0 700.0 800.0 900.0 1028.0
A Y-Chanel/X-Chanel
e-2 2
e-3 2
X: pforw [k]
1.0E-6
2.3E-7
2.3E-8
2.3E-9
1.0E-9
0.0 100.0 200.0 300.0 400.0 500.0 600.0 700.0 800.0 900.0 1028.0
B Y-Chanel/X-Chanel
pcoupler 2
X: pforw [k]

DESY LAL/CEA Coupler Workshop
Orsay, January 17-18/2000

SECOND LAMBDA/2 WINDOW PRELIMINARY RESULTS

C. Travier (CEA Saclay)

Lambda/2 windows

1) Differences between the 2 windows during fabrication

First Window:

- ceramic brazed onto Cu and Kovar collars
- TiN coating
- E-B welding of flanges

Second Window:

- TiN coating
- ceramic brazed onto Cu and Kovar collars
- E-B welding of flanges

2) Differences during conditioning

First Window:

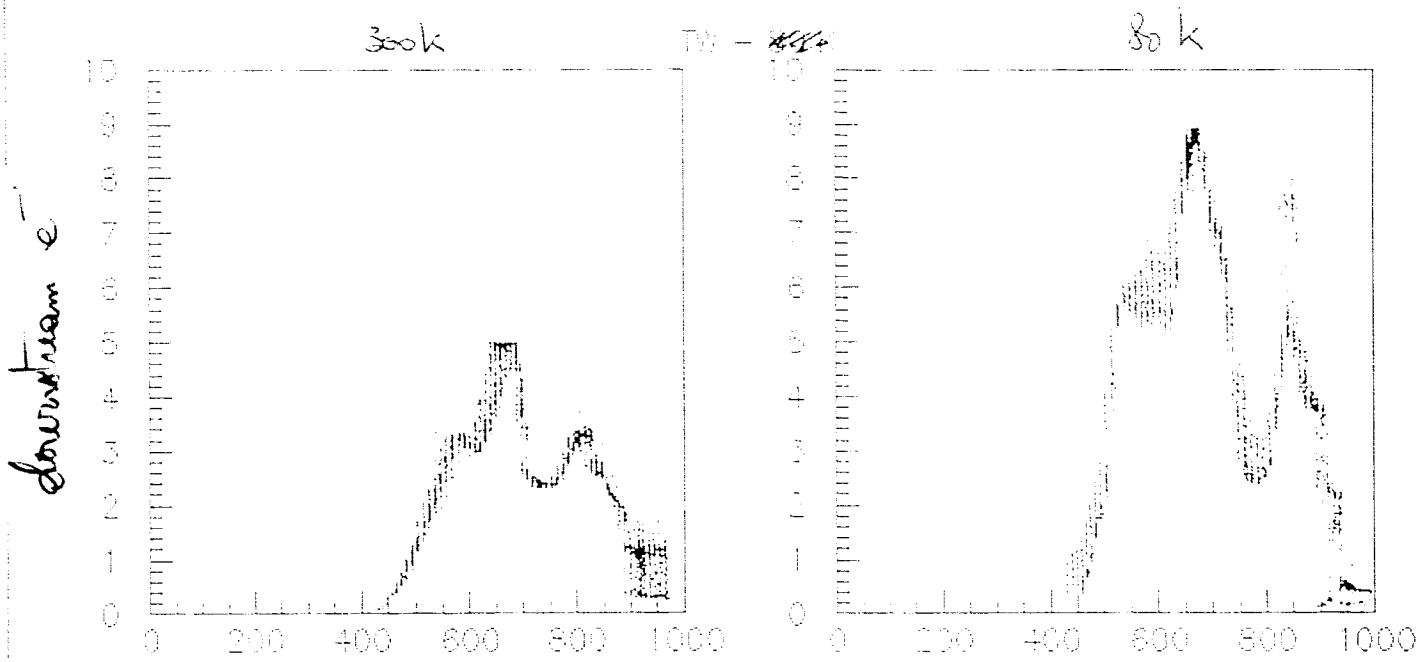
- conditioning @ room temperature
- conditioning under SW regime
  - 30'000 pulses to reach 1 MW
  - than "dramatic event" that induces ceramic coating with copper
- 300'000 pulses to recondition to 1 MW

Second Window:

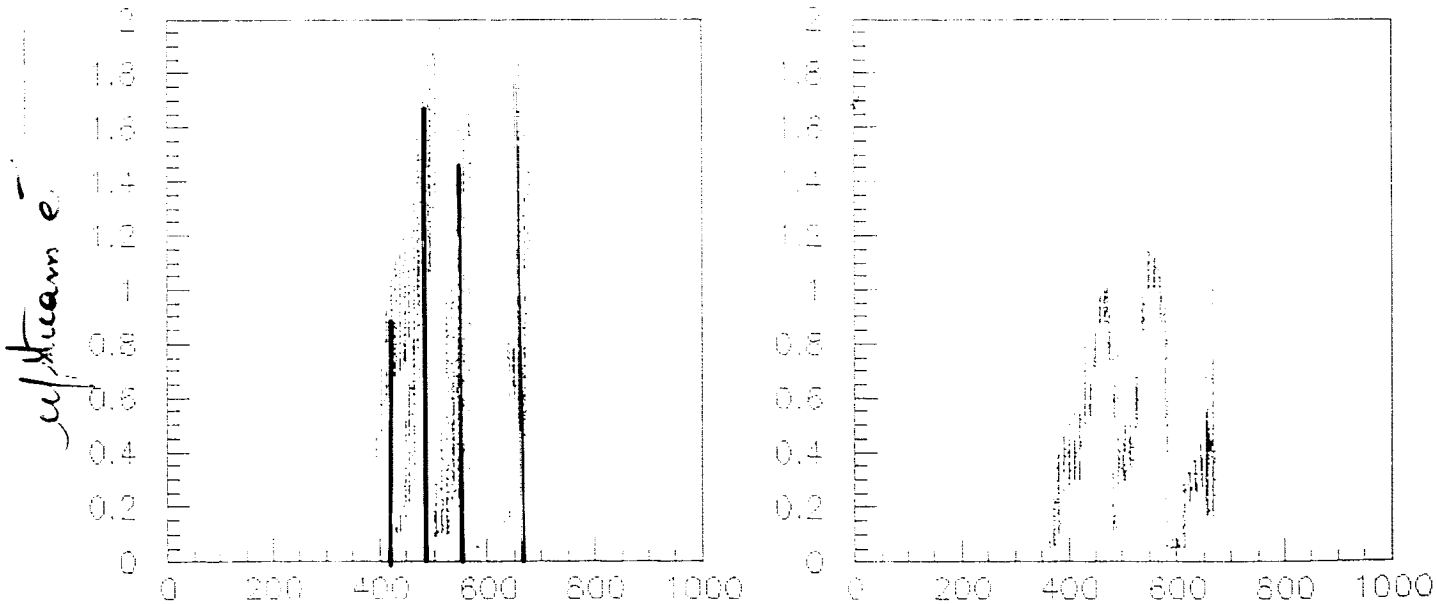
- conditioning @ 100 K
- conditioning under TW regime
  - 180'000 pulses to reach 1 MW

FIRST ½ WINDOW after 400000 pulses

Damaged side



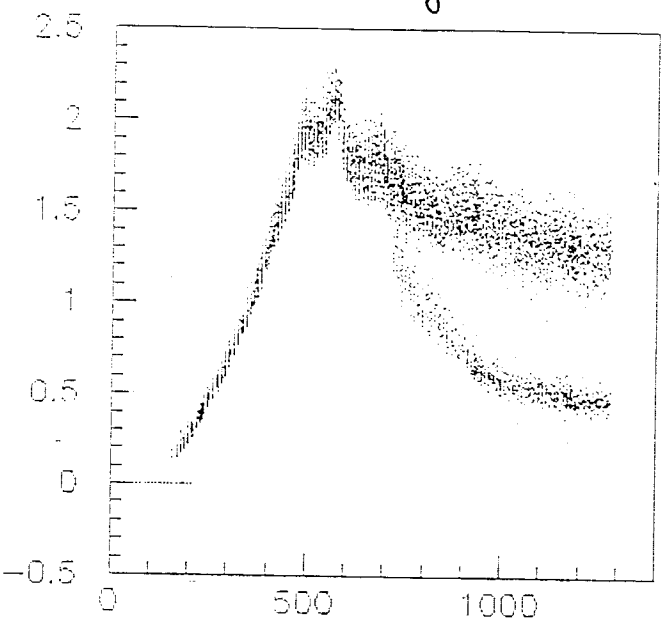
Normal side



~ 420 kW
~ 480 kW
~ 550 kW
~ 660 kW

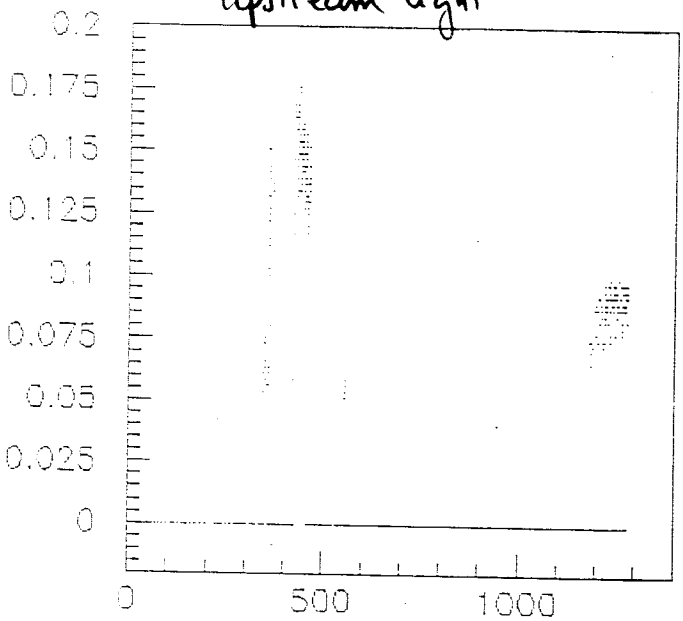
SECOND λ/2 WINDOW: after ~400'000 pulses

downstream light



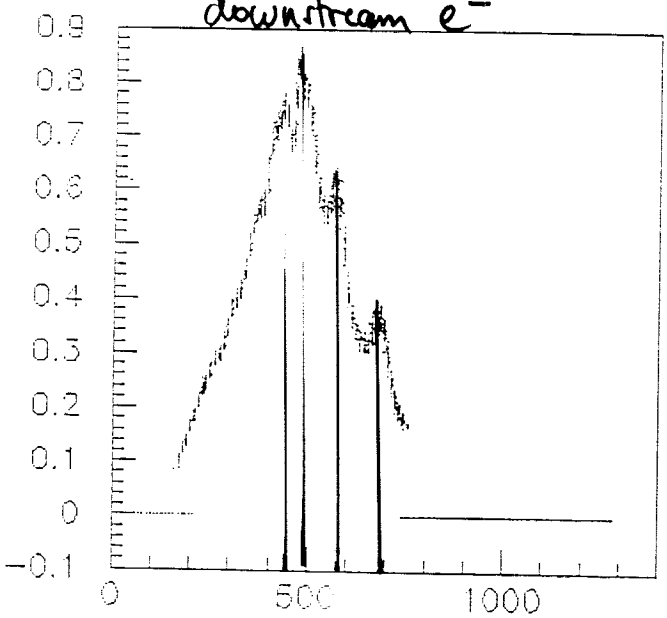
pm2max VS. pdirmax

upstream light



pmmax VS. pdirmax

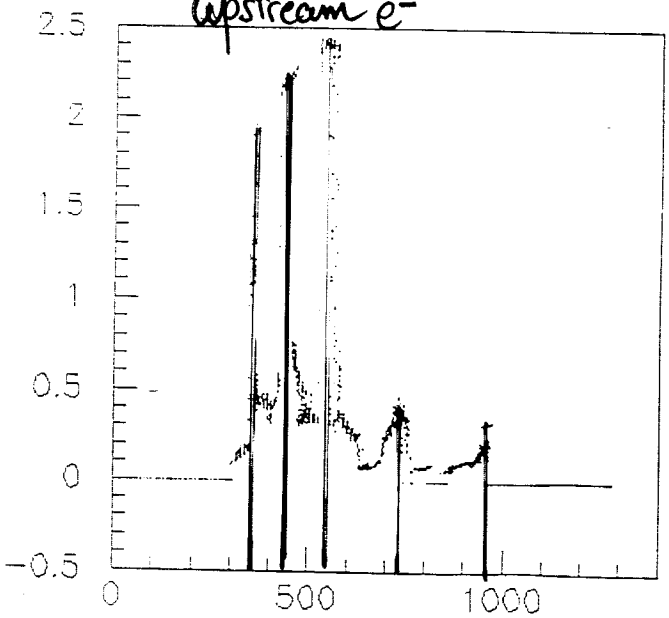
downstream e^-



pue2max VS. pdirmax

~ 450 keV
~ 580 keV
~ 590 keV
~ 700 keV

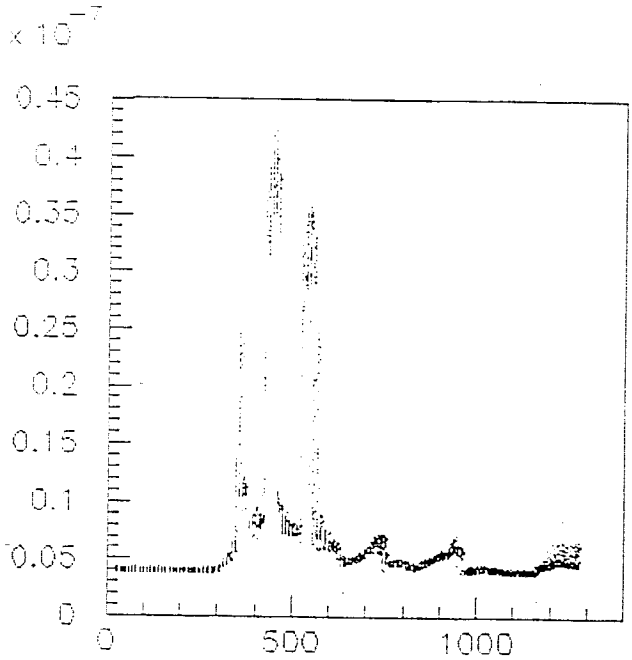
upstream e^-



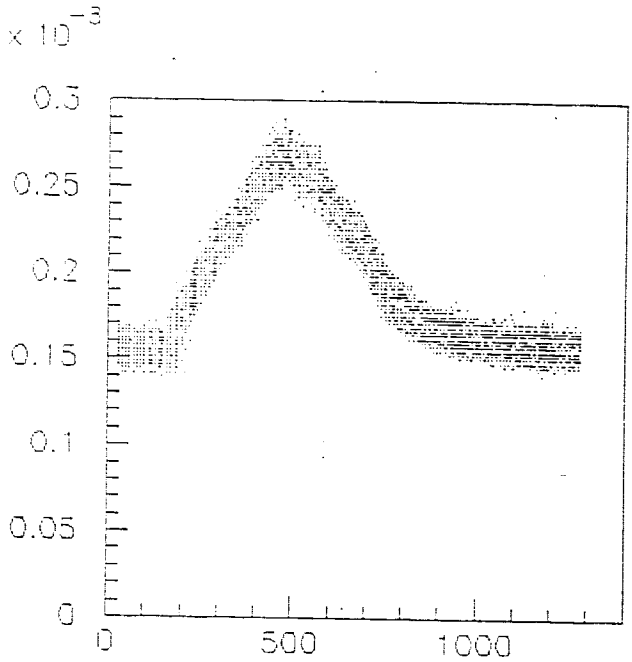
puemax VS. pdirmax

~ 350 keV
~ 430 keV
~ 550 keV
~ 720 keV
~ 950 keV

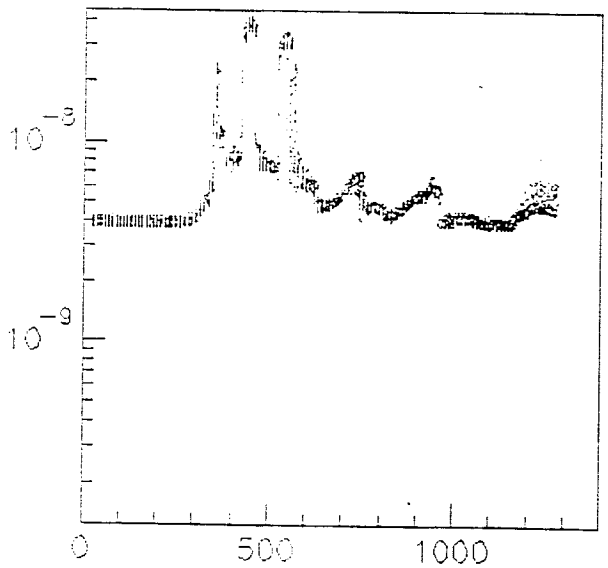
SECOND $\lambda/2$ WINDOW after ~ 600'000 pulses



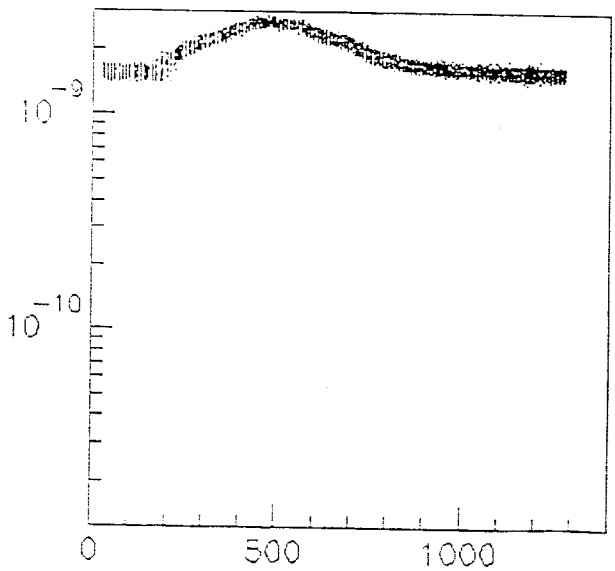
v1max VS. pdirmax



v3max VS. pdirmax



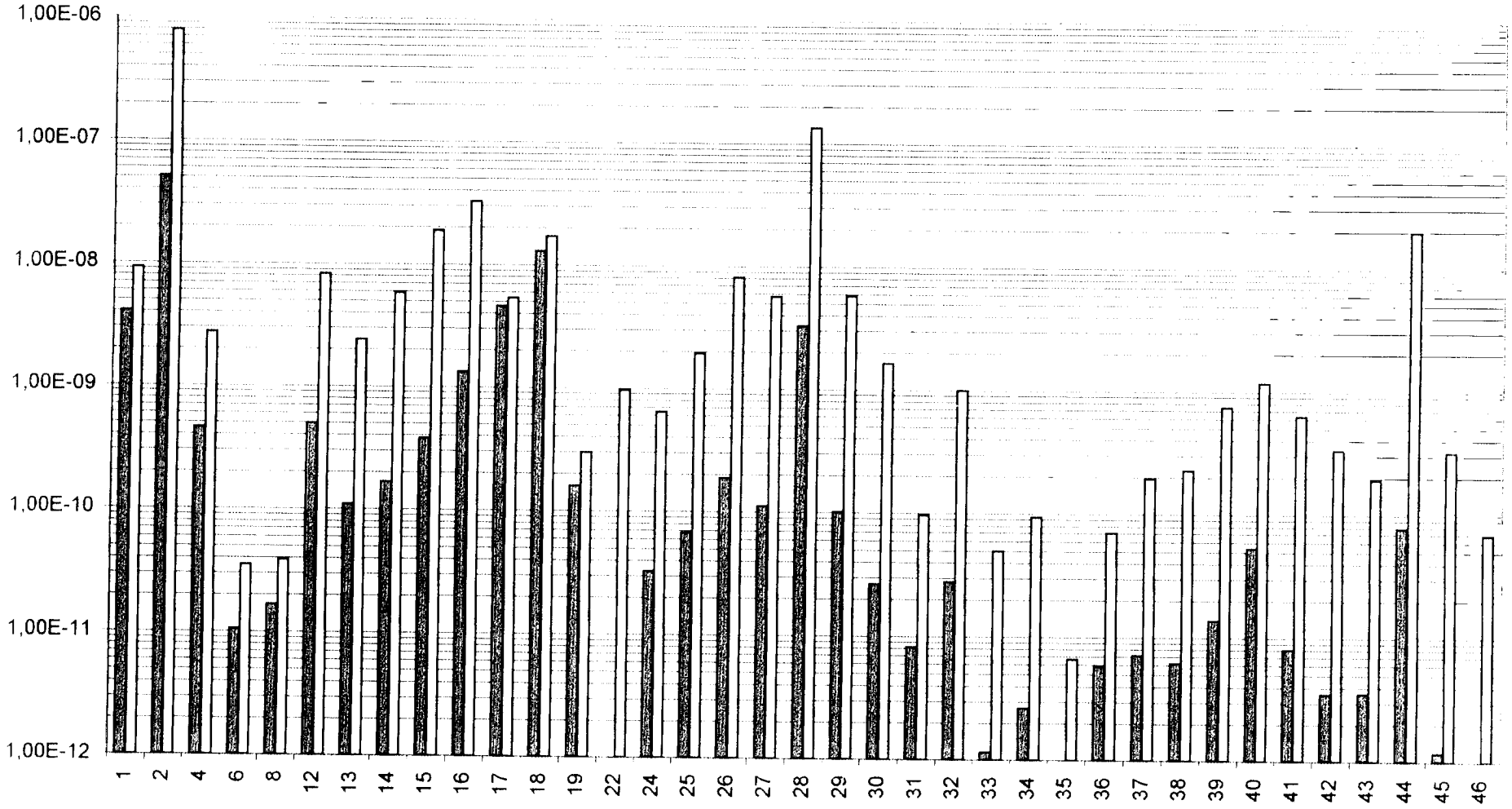
v1max VS. pdirmax



v3max VS. pdirmax

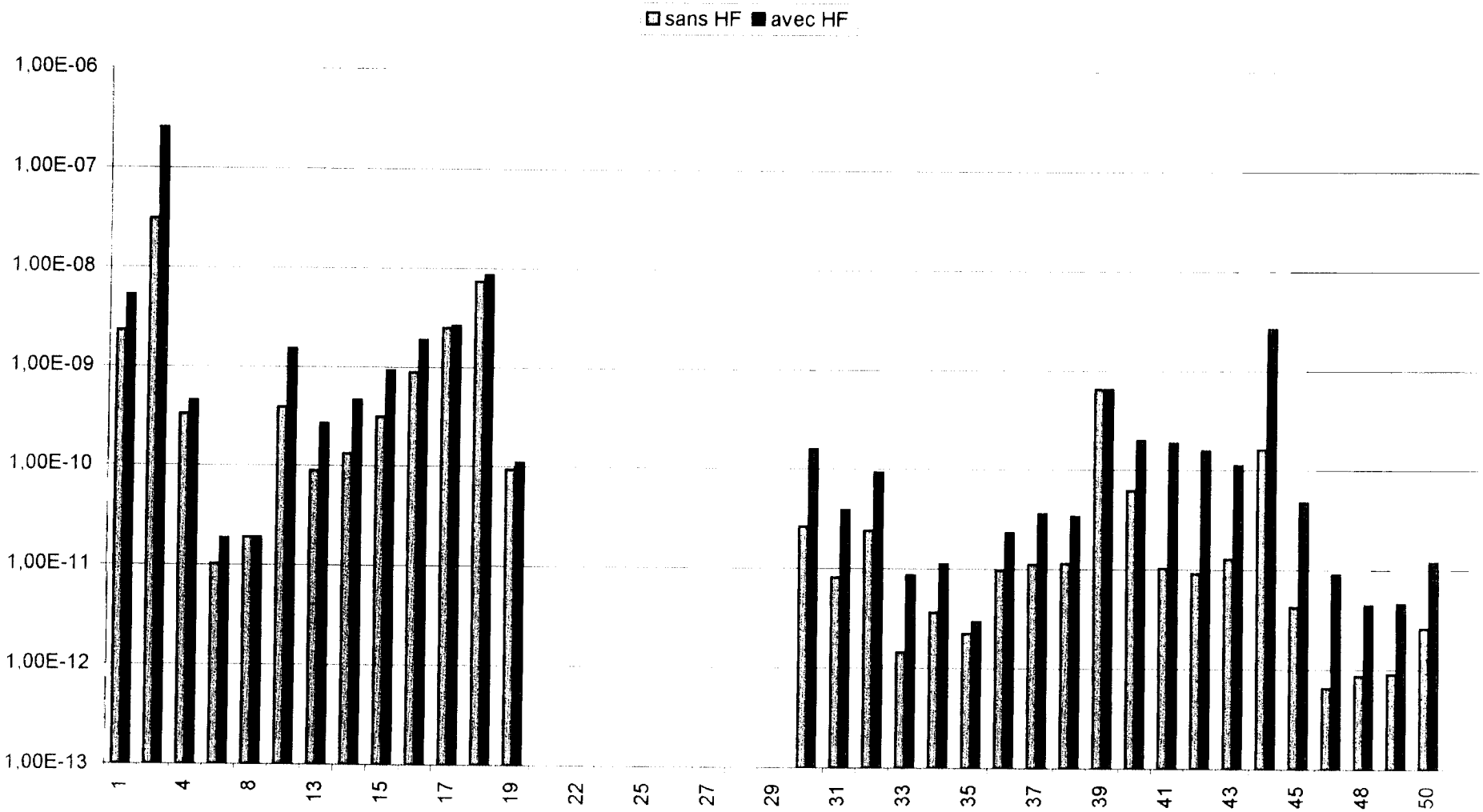
LIGNE2 24/09/1999

PRF = 1200kW 800us avec et sans lumière sur la fenêtre Thomson aval



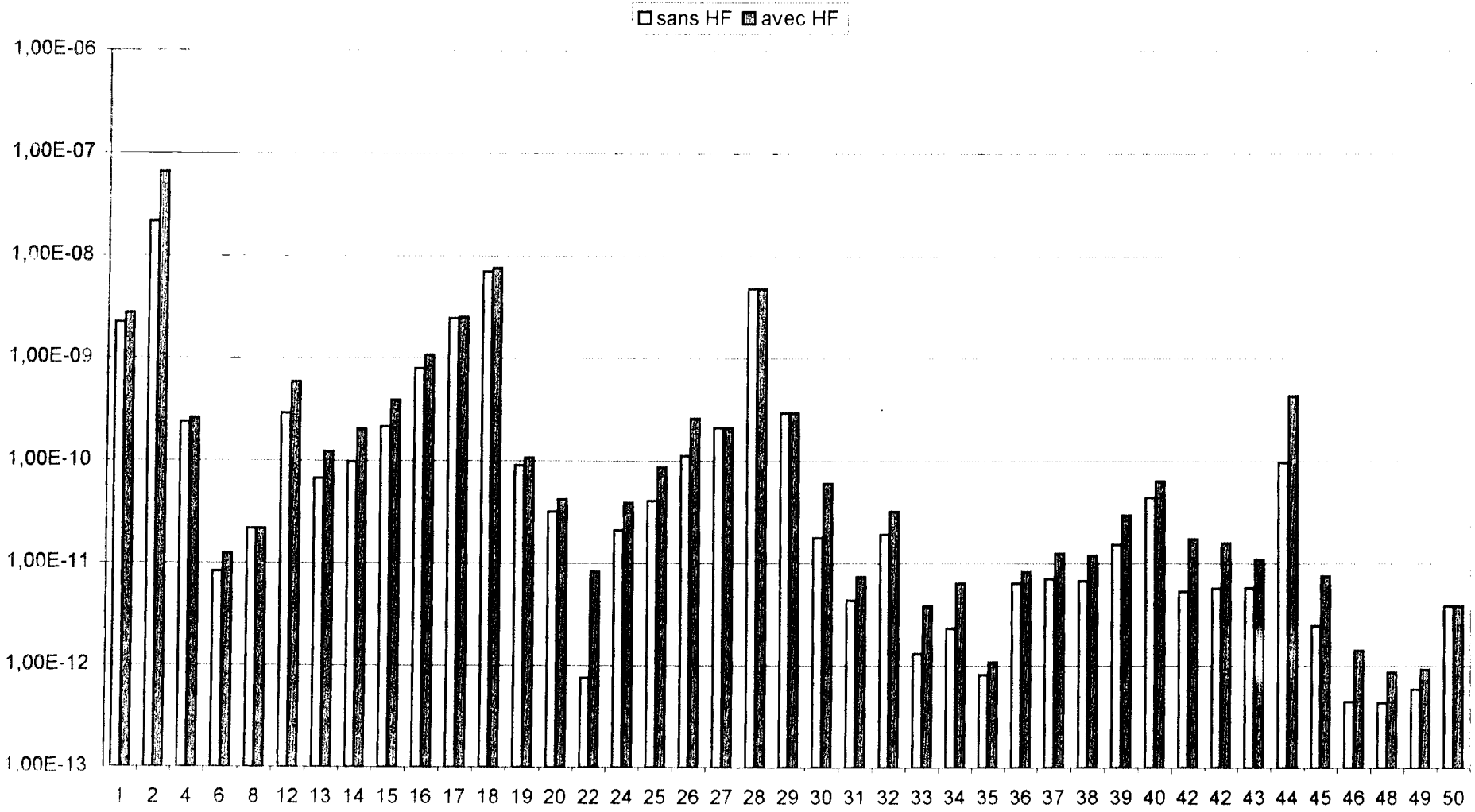
145

27/09/1999 Ligne2
analyse de gaz sans electrons Pick-Up (1200kW 800us)

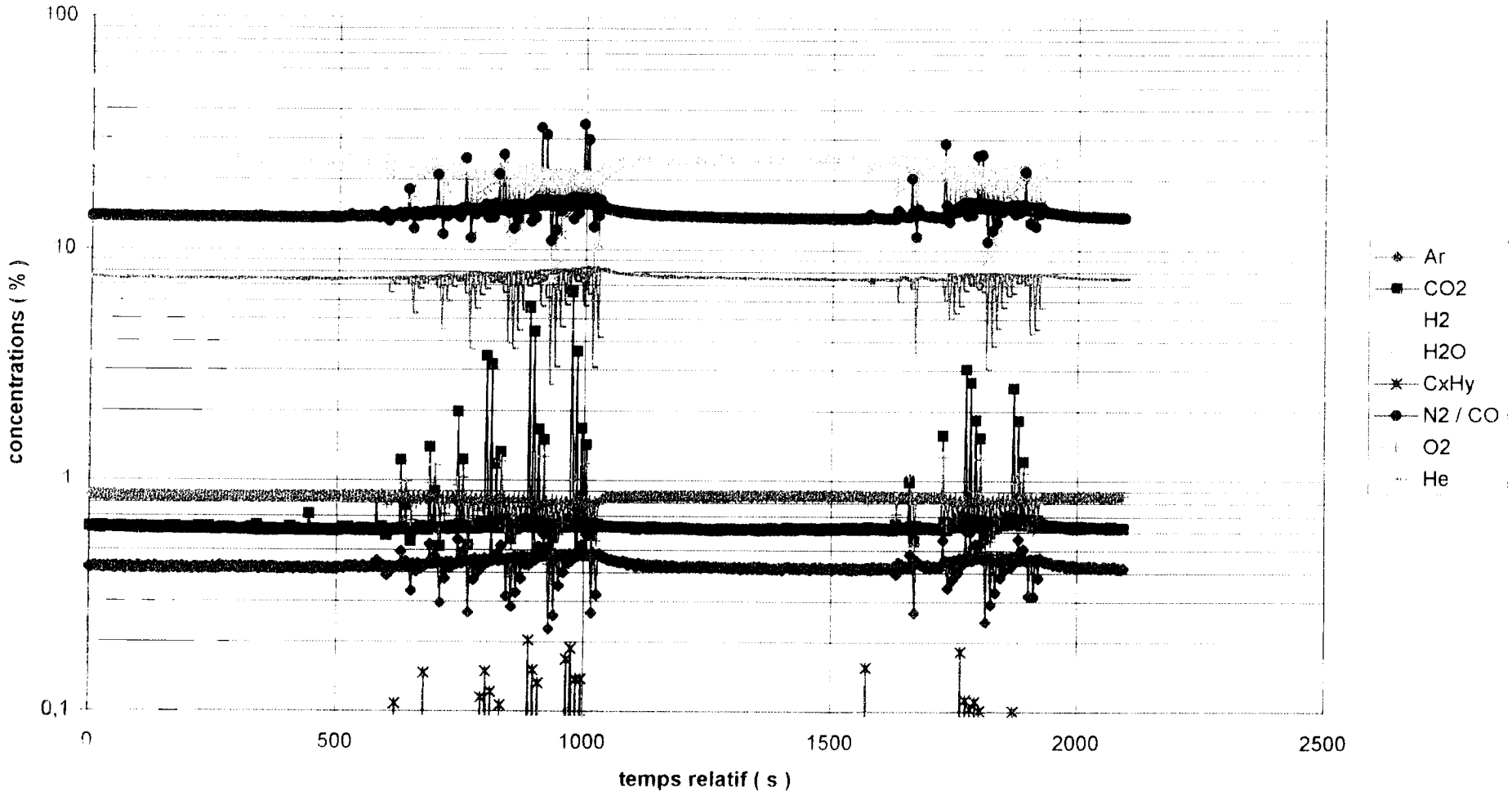


27/09/1999 Ligne2

analyse de gaz avec electrons Pick-Up (PRF = 500kW 800us)



Ligne2 7/10/1999
Traveling Wave 100kW à 1300kW



3rd Joint DESY – LAL – Saclay Workshop on High Power Couplers for TESLA

LAL – Orsay January 18th, 2000

Conditioning the couplers

- avoid the volumes difficult to pump,
- condition at high temperature (300°C), following the indications of the RGA,
- ventil at atmospheric pressure under dry nitrogen
- condition in situ with a bakeout at 120°C, following the RGA (H2O decreases)
- condition with the RF power on, under vacuum with a turbomolecular pump with a high compression rate,
- when the satisfactory pressure is obtained (1. 10-8 mbar) , strart the ion pumps

Preventive measures

- use a fast vacuum interlock (VAT) with a reponse time of a few ms (threshold at 1.10-7 mbar or less)
- use a visual detection of the emission light by camera.

Remarks

- there is a memory effect after a conditioning with bakeout and RF power
- ventilating under dry nitrogen and good conditions of cleanliness, allow to lose only 30% of the conditioning,
- at the ESRF, the vacuum interlock threshold is now at 5.10-8 mbar.

N. Rouvière

Multipactor calculations

G. Devanz, CEA/Saclay

TESLA Power Coupler Workshop
LAL – Orsay, 18th January, 2000.

2D multipactor code

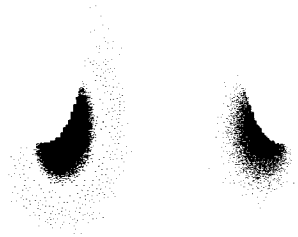
- Based on CAD-like geometry description
- Uses fish/cfish EM-fields
- Adaptative RK (4-5th order) integration

General purpose

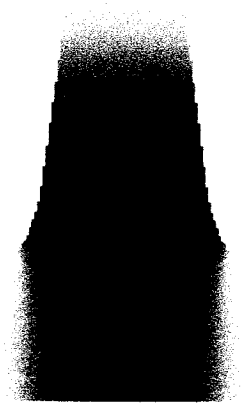
- Accelerating cavities
- RF windows, both in TW & SW
- Other «2D » coupler parts (tapers, coaxial lines)

Milan 704 MHz a103

E_r field



E_z field



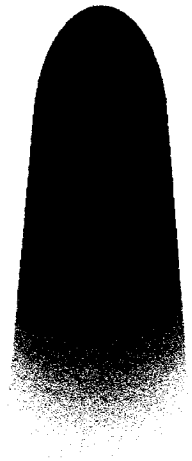
H_θ field

Saclay 704 MHz a102

E_r field

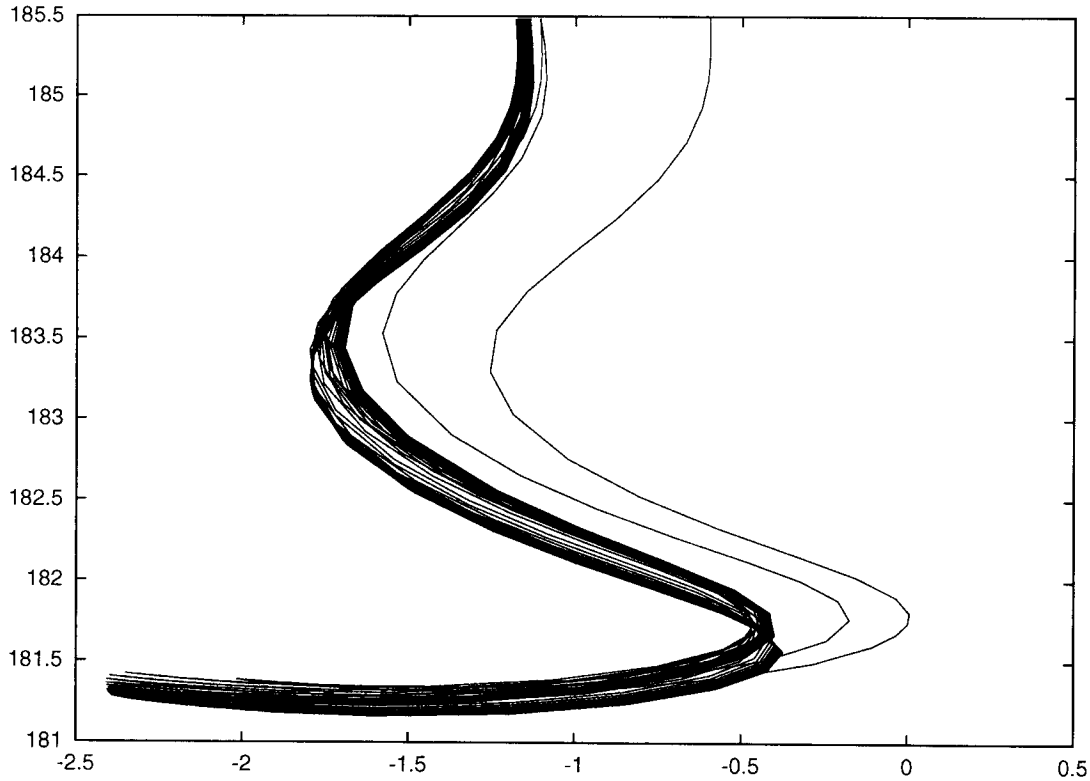
E_z field

H_θ field

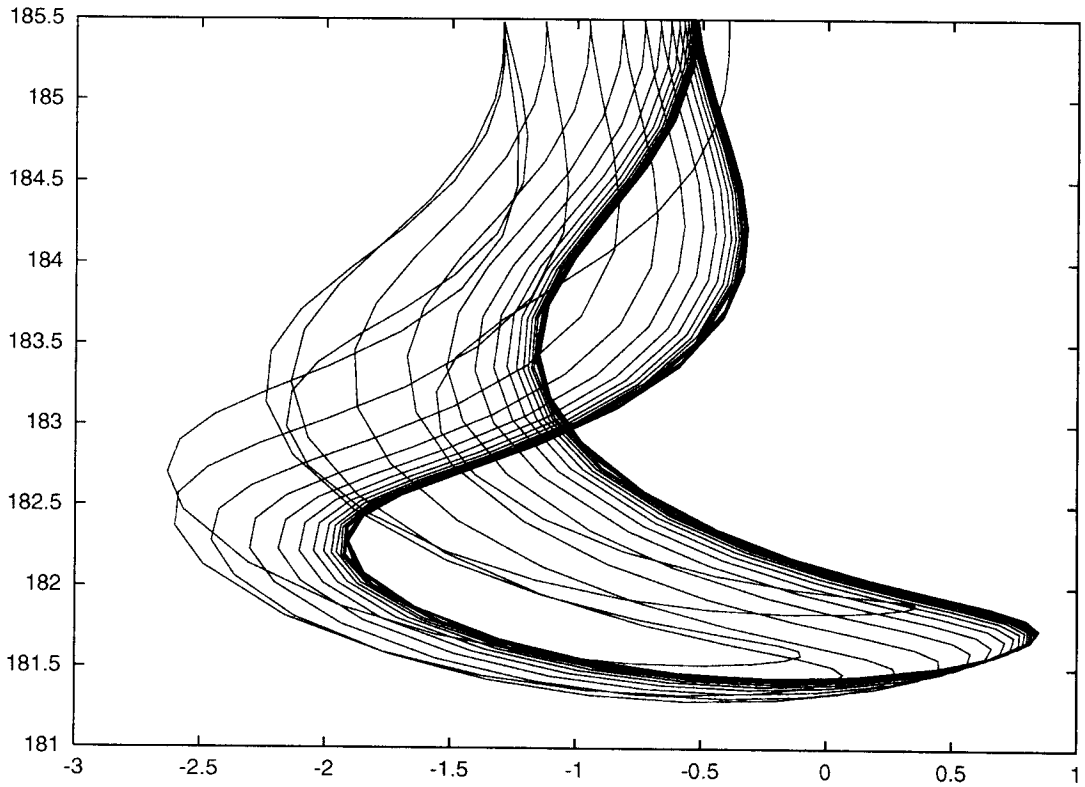


A 102 Cavity (circular)

2 MV/m

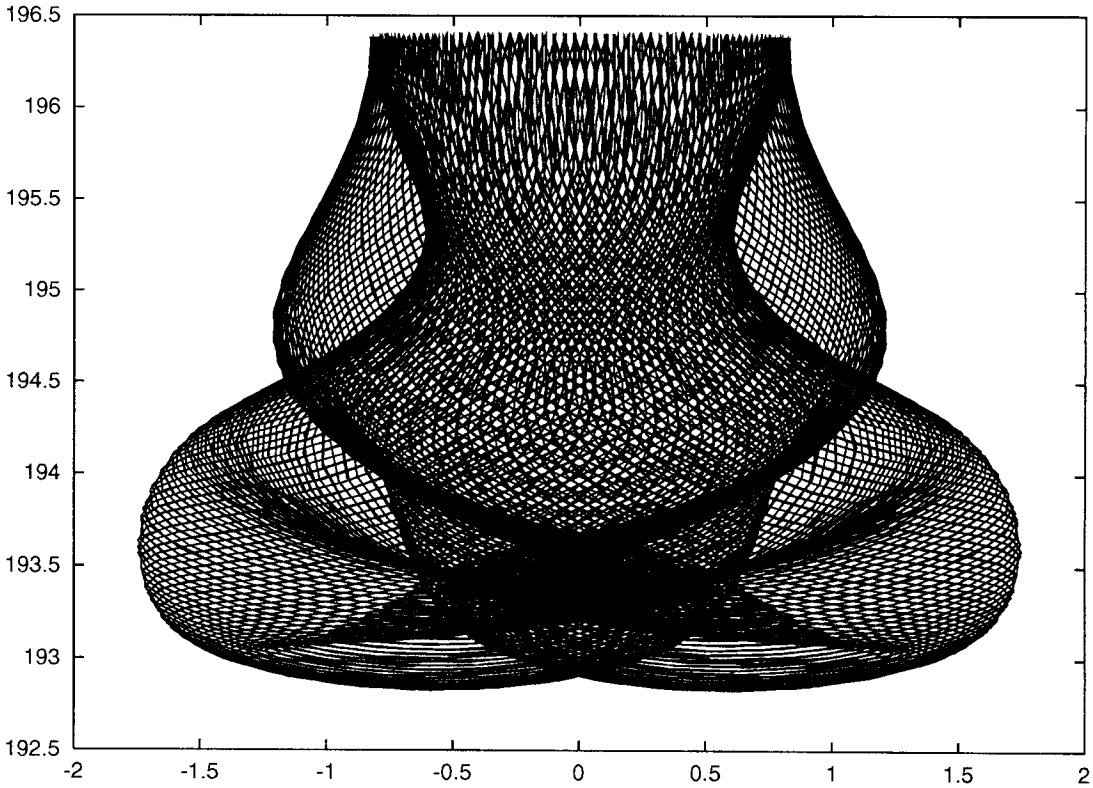


3 MV/m

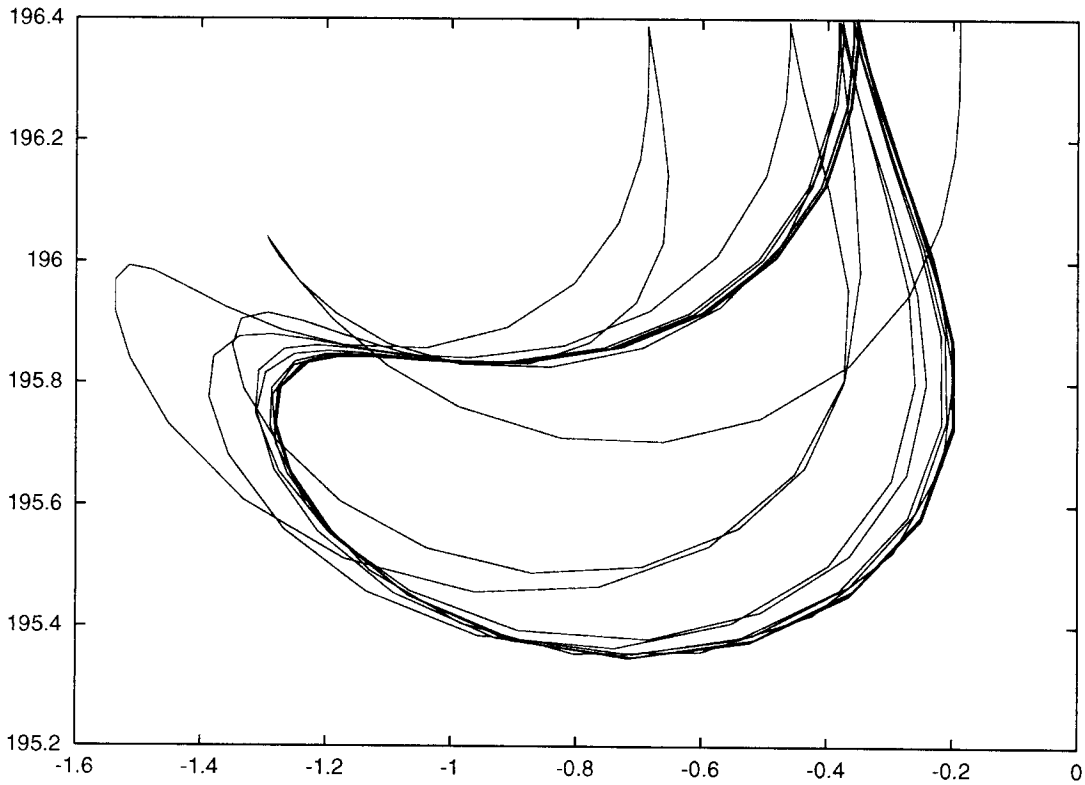


A 103 Cavity (elliptical)

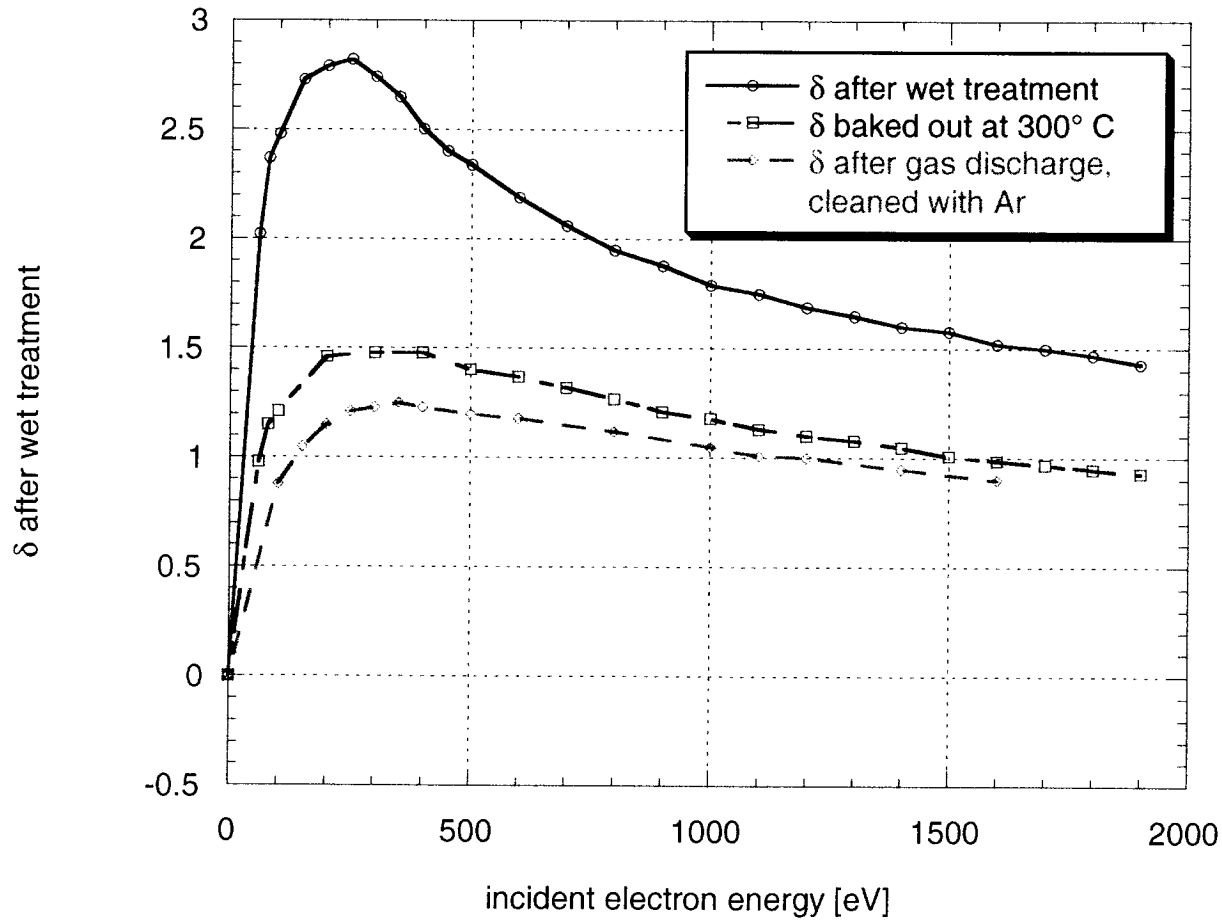
2 MV/m

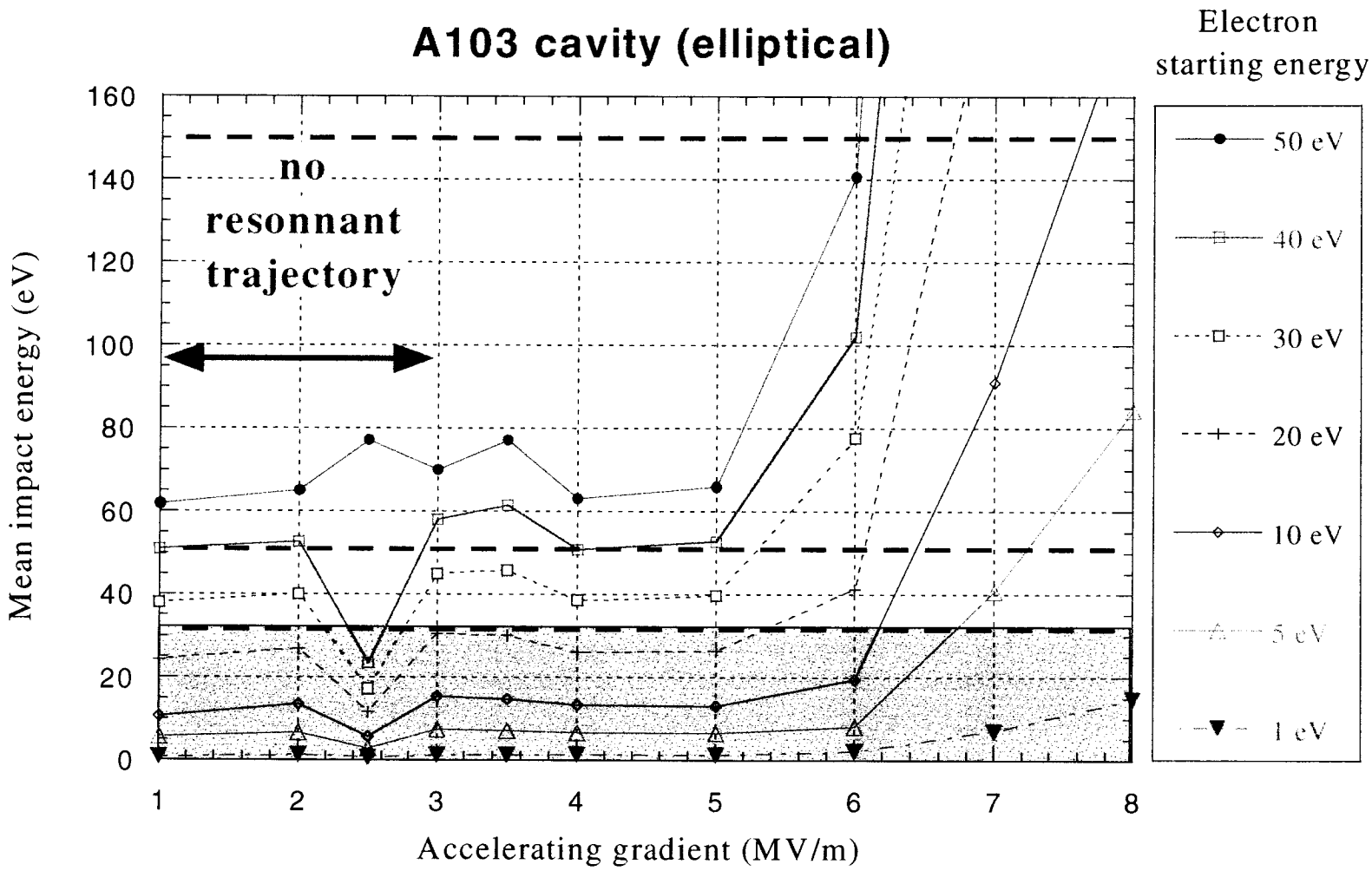


5 MV/m



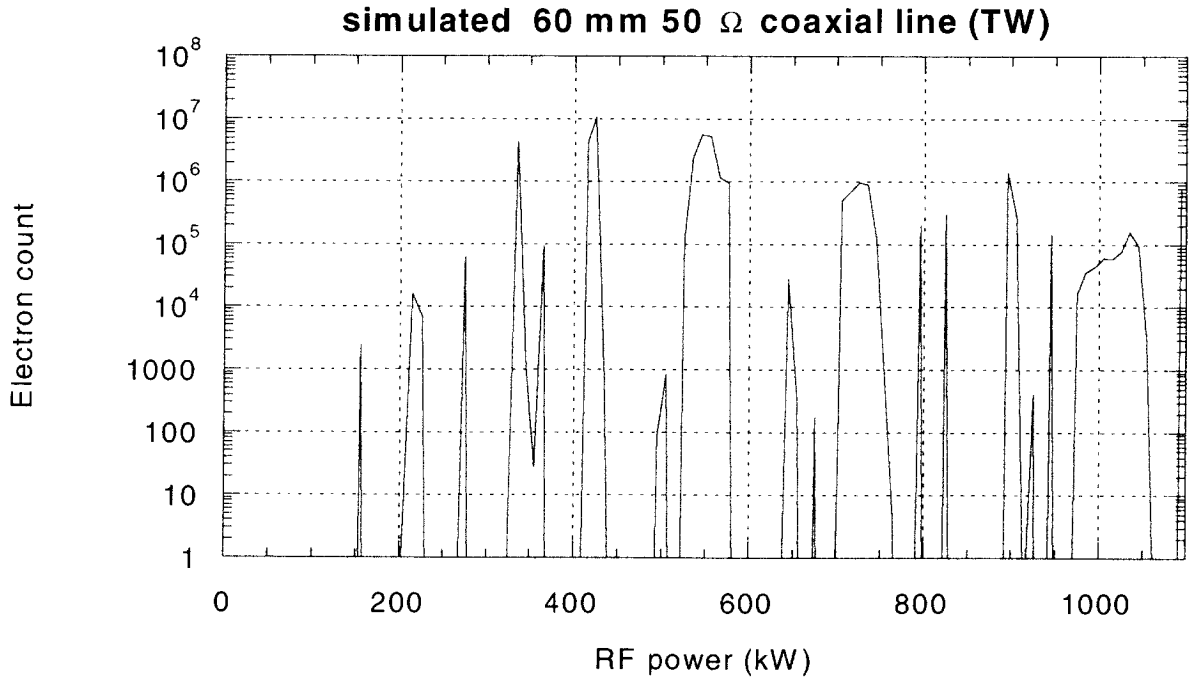
Secondary emission coefficient for Nb



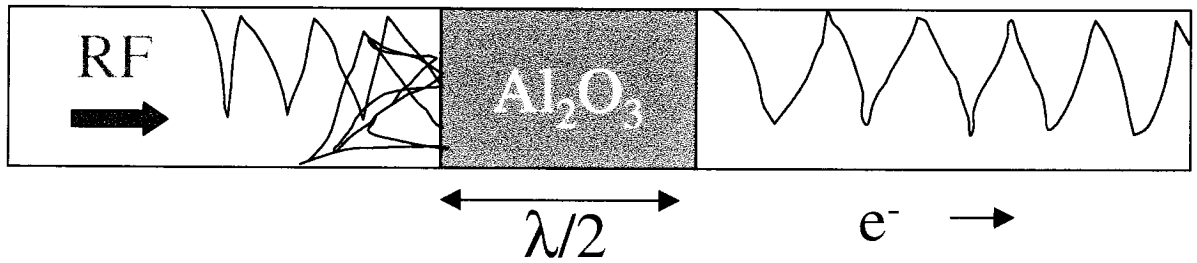

A103 cavity (elliptical)
Electron starting energy
50 eV
40 eV
30 eV
20 eV
10 eV
5 eV
1 eV
no resonnant trajectory
Mean impact energy (eV)
Accelerating gradient (MV/m)
0
20
40
60
80
100
120
140
160
1
2
3
4
5
6
7
8

Code testing

- Influence of δ_{max} of surface materials :
  changed from 1.5 to 1.1 → almost no multipactor left
- SEE δ parameters need to be tuned for every material of the problem
- Slight discrepancy observed when using Superfish fields or analytical expression in the case of a coax line in TW mode : 10 % error on power levels (relative field errors in Superfish can be kept as low as 10^{-4}).
- Simple case of the 60 mm 50 Ω coaxial line

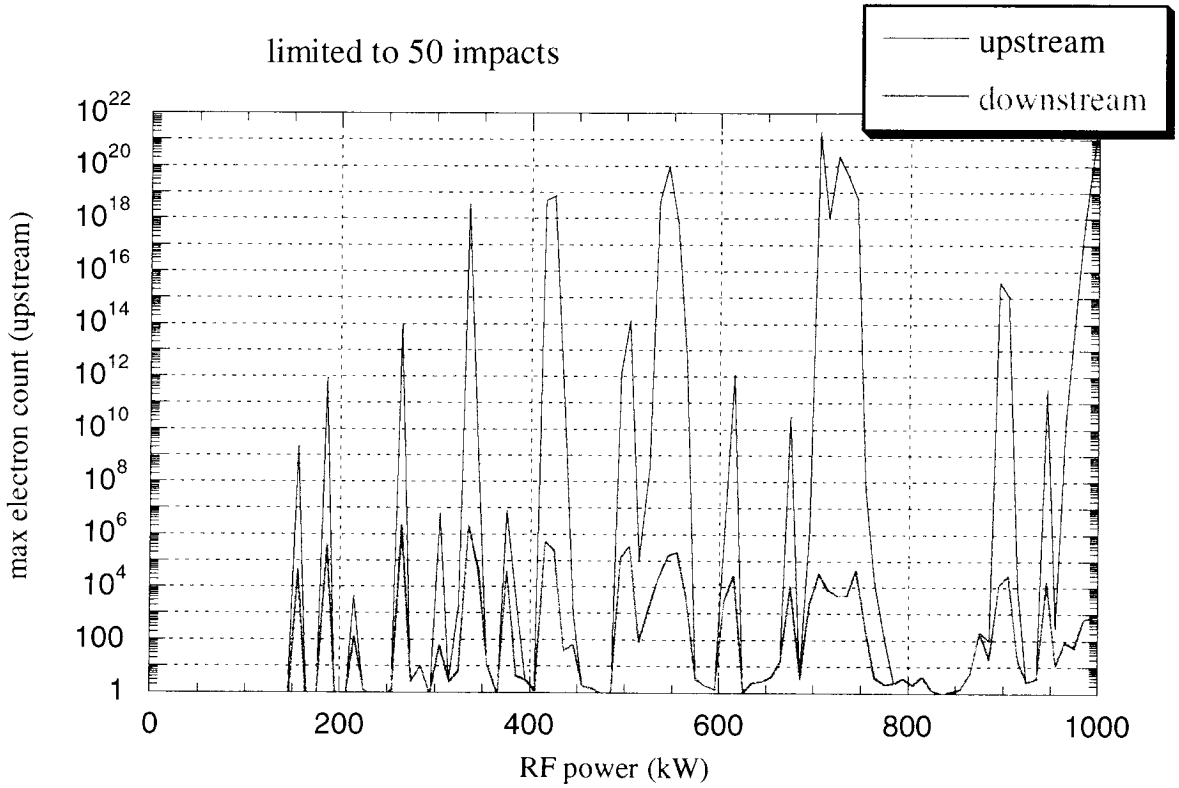


Test with the λ/2 geometry



TW mode : electrons follow the EM wave

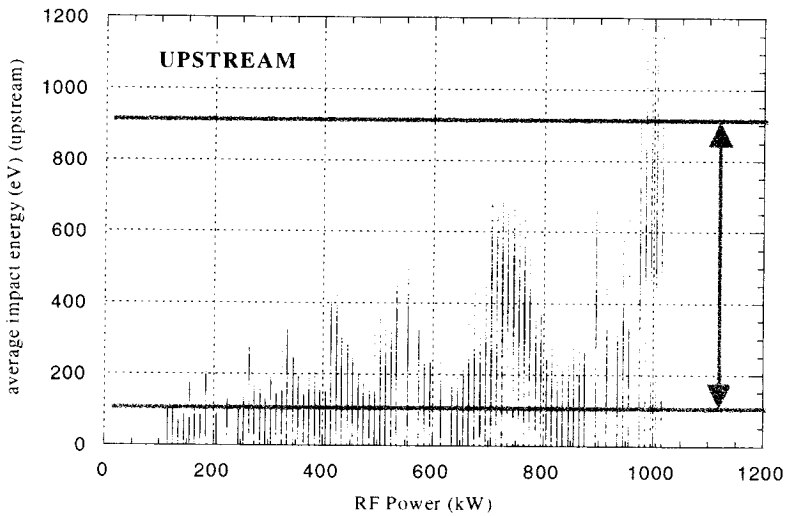
greater e⁻ activity expected on the upstream side in the vicinity of the ceramic



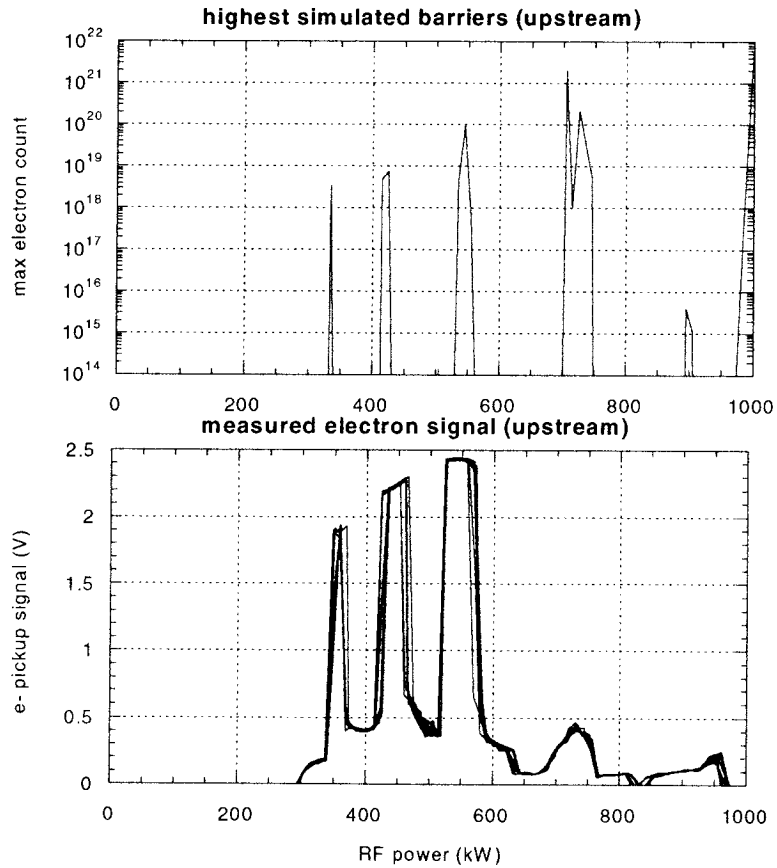
Comparison with experimental results

- Power levels OK for the highest e^- yield barriers

MP barriers can be predicted with the average impact energy



$\delta > 1$



- δ values need some tuning...

Status & perspectives

- Parallelization (in progress)
  - On Networked workstations
  - PVM library (almost a standard now). Several architectures can be used in a single Parallel Virtual Machine
  - Computation parameters distributed over N_{ws} machines, with load balancing. Speedup by a factor of N_{ws}
- Simulation of the measurements (in progress)
  - Define detector elements in the geometry (e.g. pickups)
  - Use Poisson static field map
- Better description of the $e^- \rightarrow$ solid interaction

Conclusion

- Need a better knowledge of surface condition
  - Simulations are VERY sensitive to E_1 , $\delta(E1) = 1$ (SC cavities)
  - SEE δ measurements ?
  - Influence of the RF conditioning on δ ?

- Is there any influence of
  - the position of the pickups on the experimental results (what do they actually "see") ?
  - the geometry and bias voltage of the PU ?

Thin Film NEG Coating for RF-Couplers

Ch.Benvenutti, CERN; D.Proch, DESY

NEG: **N**on **E**vaporable **G**etter pumps

Basic advantage:

- NEG coating can be placed inside the vacuum chamber, pumping at the spot
- low secondary electron yield
- in situ activation at moderate temperatures

Open questions:

RF loss?, dust free quality?, how many activation cycles needed/possible?

Idea: Use NEG coating for RF couplers

- -will suppress multipacting by low secondary yield
- -provides pumping at the RF surface, thus
  - might eliminate RF discharge
  - might reduce conditioning time

Best NEG candidate: Ti-HF-Zr compound

activation starts at 200°C

can easily be sputtered on RF surfaces

only 1.5 um thick film needed

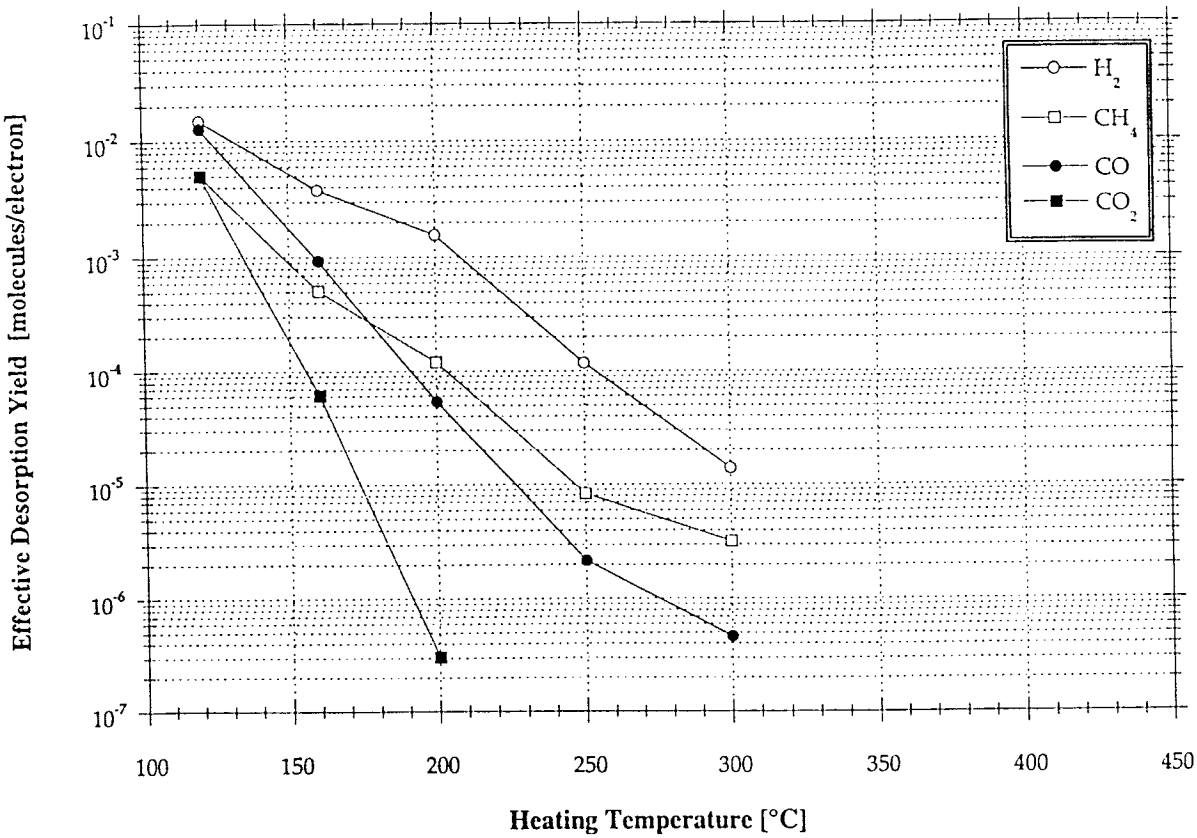


Figure 5. Effective desorption yield of H_2,CO, CO_2 and CH_4 for an equiatomic TiZr coating. The measuring conditions are the same as indicated for Fig. 2. "Effective" here indicates the net desorption per impinging electron, as resulting from the competing action of surface degassing and pumping. Since CH_4 is not pumped, the measurements represent a real desorption yield for this gas.

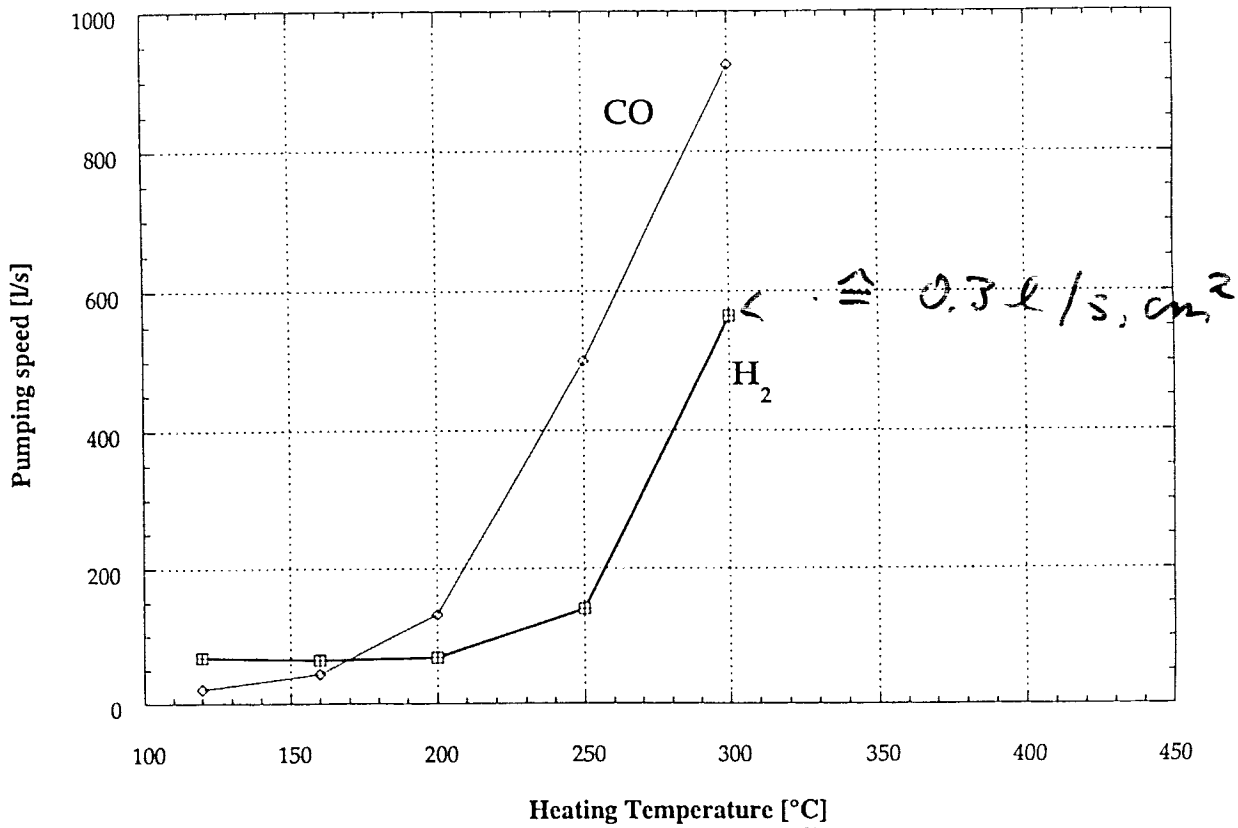


Figure 6. Pumping speed variation as a function of the heating temperature for H_2 and CO of a TiZr coated sample. The measurements are carried out at 20°C after 2 h heating at the indicated temperature.

165

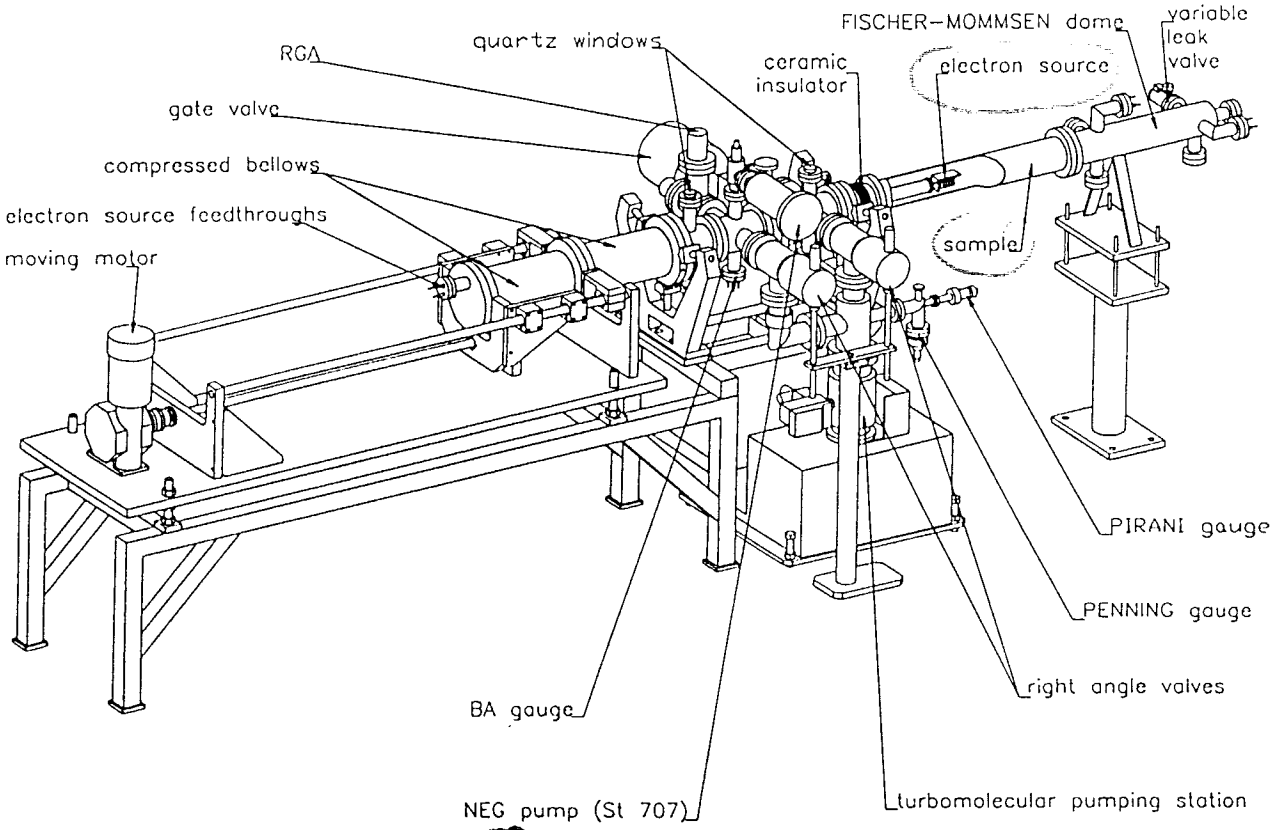


Figure 1. Schematic view of the vacuum system used for ESD and Pumping Speed measurements.

ESD

closed. During all measurements the system is pumped by a turbomolecular pump providing an effective pumping speed of about 75 l s^{-1} for H_2.

For ultimate pressure measurements, two chambers 1 m long, 16 cm diameter, providing a total coated surface area of about 1 m^2, are linked together and connected to a pumping system via an orifice of 25 l s^{-1} conductance for H_2. The pumping system, equipped with turbomolecular, sputter-ion and titanium sublimation (nitrogen cooled) pumps, is capable of an ultimate pressure lower than 10^{-12} Torr. At the free extremity of the coated chambers the pressure is monitored by means of an improved Helmer type gauge, able to measure pressures down to the 10^{-14} Torr range.[5]

Results

Pumping speed and ESD measurements have been carried out on chambers coated with Ti, Zr, Hf and some of their alloys. The results obtained on elemental coatings are shown in Fig. 2 together with those relative to a stainless steel vacuum chamber vacuum fired at 950°C.[4]

Titanium follows closely the stainless steel reference curve up to 300°C, and then quickly drops by two orders of magnitude at 400°C. Hafnium and zirconium are slightly worse at the beginning, but activation starts at lower temperatures (about 200°C) and sets in more progressively, to reach the same value as titanium at 400°C. The results of Fig 2 are a clear indication that these elements are adequate for use on stainless steel chambers made of copper or aluminium alloys.

The results obtained on equiatomic binary Ti, Zr, Hf alloys (produced by means of composite cathodes made by intertwinsting two wires of different materials) are show in Fig. 3. The alloys display a lower activation temperature compared to elemental coatings, and the lowest activation temperature corresponds to TiZr. In this case activation starts below 150°C and is practically completed at 300°C. Two hours at 250°C are sufficient for an almost complete activation.

Since Ti and Zr mixing provides the lowest activation temperature, the composition of the TiZr alloy has been varied by using cathodes obtained by intertwinsting two wires of one element and one of the other. The results, shown in Fig. 4, indicating that the equiatomic TiZr alloy still provides the lowest activation temperature,[4] and that consequently it is the most adequate for applications where the heating temperature must be reduced to a minimum. This conclusion agrees with results, reported in literature,[6,7] obtained by measuring the weight increase while heating samples of different Ti and Zr content in air at 700°C. In this case, the weight increase presents a maximum corresponding to equal atomic concentrations of these two elements, showing that this composition provides the highest oxygen diffusion coefficient.

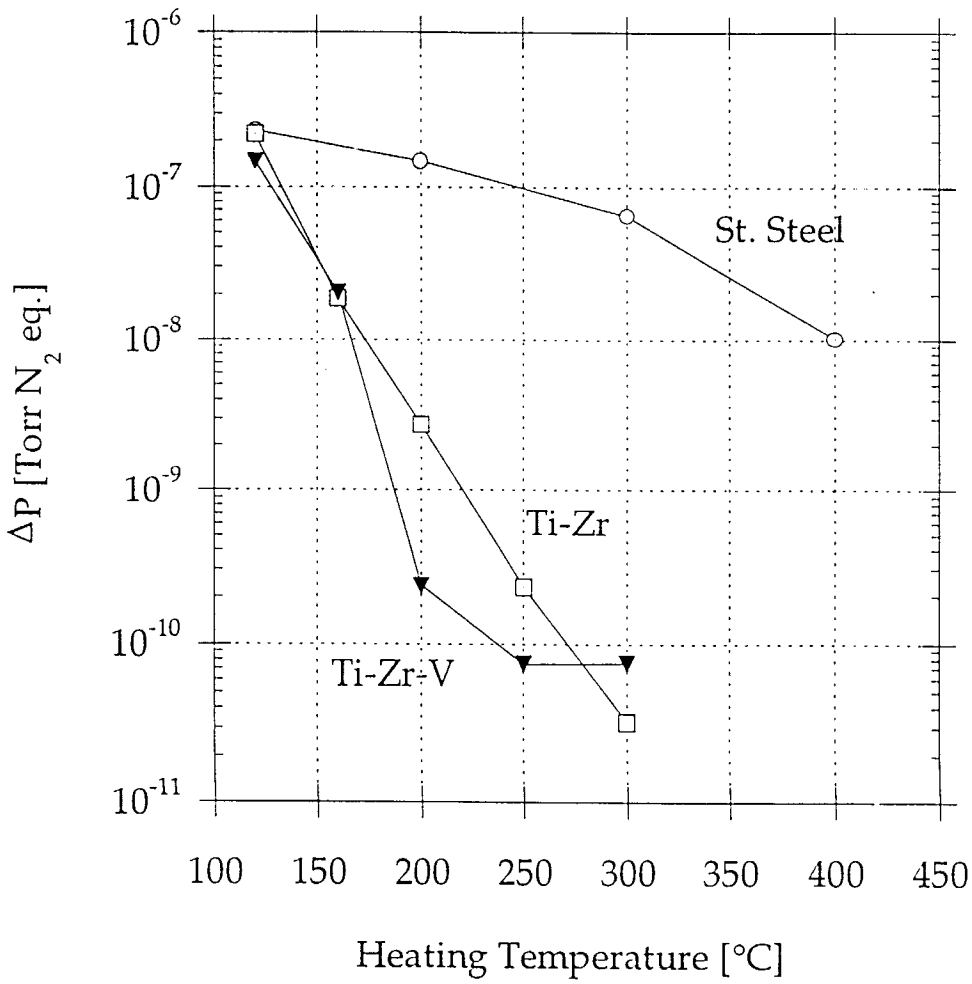
The "effective" desorption yields (desorbed molecules par incident electron) for H_2, CO, CO_2 and the real CH_4 desorption yield for the equiatomic TiZr alloy are shown in Fig. 5.[4] Note the very fast decease of CO_2 and the leading presence of H_2 at all temperatures. All the other samples with different composition also display a similar behaviour.

The variation of pumping speed as a function of the heating

166

Figure 4

ESD desorption



Experimental program

- measure multipacting with RF test resonator (reentrant Cu-cavity, 500MHz, at 300°K)

  -NEG coating of Cu-electrodes

  -measure multipacting after various conditions of NEG film

- Prepare NEG coating at inner surface of outer coax-conductor of TTF input coupler

  -test conditioning and operational behavior at coupler test stand

cl e. This electron current might result in of the stored energy in microwave ıl y ignite a breakdown. To suppress these o.ıant condition can be avoided by proper '. Resonant conditions for a parallel plate ectric fields can be easily predicted and thus ıe right gap distance. In the case of lc s, however, multipacting is simulated by s. In the case of complicated three components a simulation of electron es very demanding. Furthermore the RF low to change the geometry by the needed

pts are undertaken to suppress multipacting f critical surfaces. A material for coating is secondary yield of smaller than or at least ferent coating materials are known, for CrO_2, etc. [1] . Those materials have been measuring the secondary yield in DC nple surfaces. RF components might have

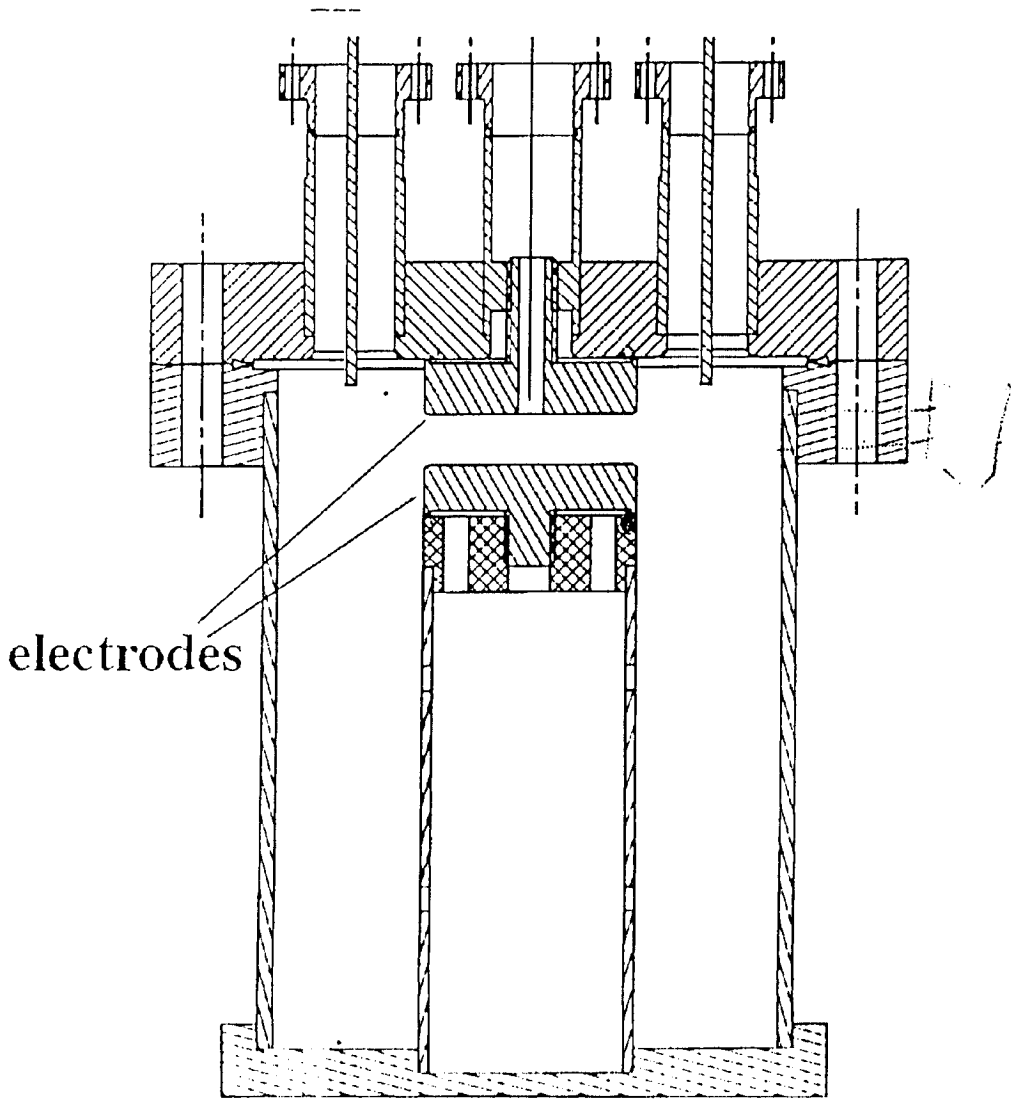


Figure 1: Test resonator

169

e lower horizontal axis is (in $(\mathrm{GHz}\times\mathrm{mm})^4\times\mathrm{Ohm}^2$), cting. By computing this vith the band marked with rs. Note that there is only e picture; the higer order nore prominent two–point of the band indicates where Vith typical design param- o large kinetic energy for s in the picture correspond

behavior of the multipacting standing wave to the trav- vanishes. We repeated the vith no reflected wave, and hift according to the simple

SW,

each multipacting level ap- rf power. There is a simple nomenon: The peak voltage the peak voltage of the trav- jectories show, however that since the multipacting elec-

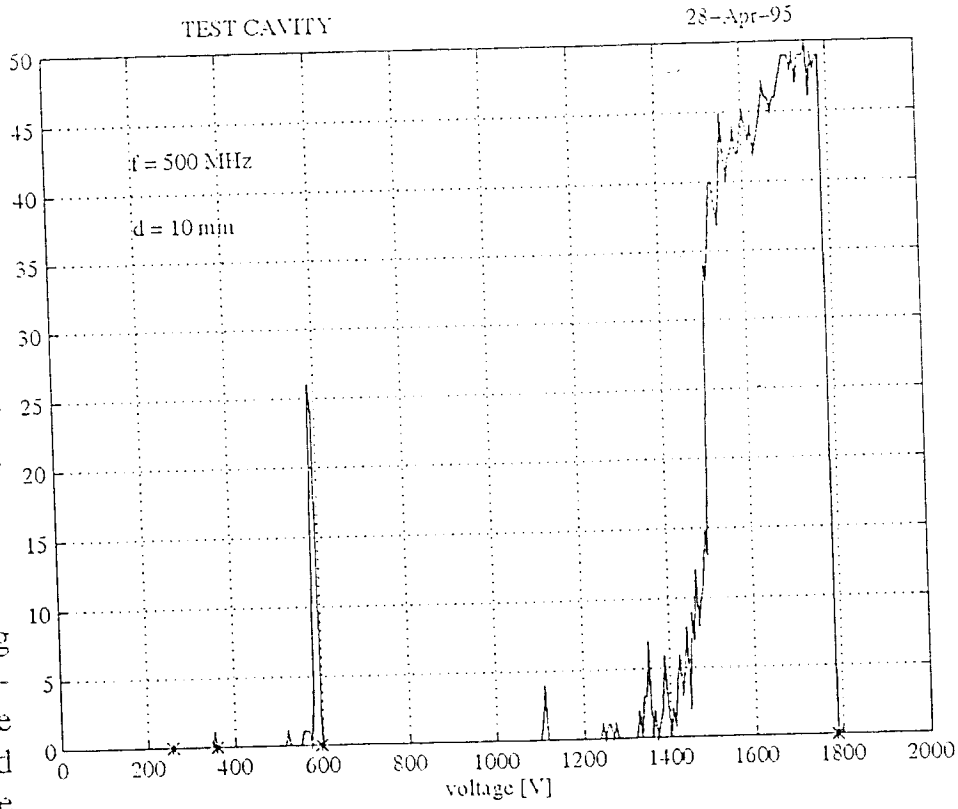


Figure. 2. Multipacting counter function for the test cavity

curve in Figure 3 in [2]. Let us mention that the computed kinetic energy for the second order process is typically too low to appear with secondary electron yields characteristic e.g. to Niobium surfaces.

References

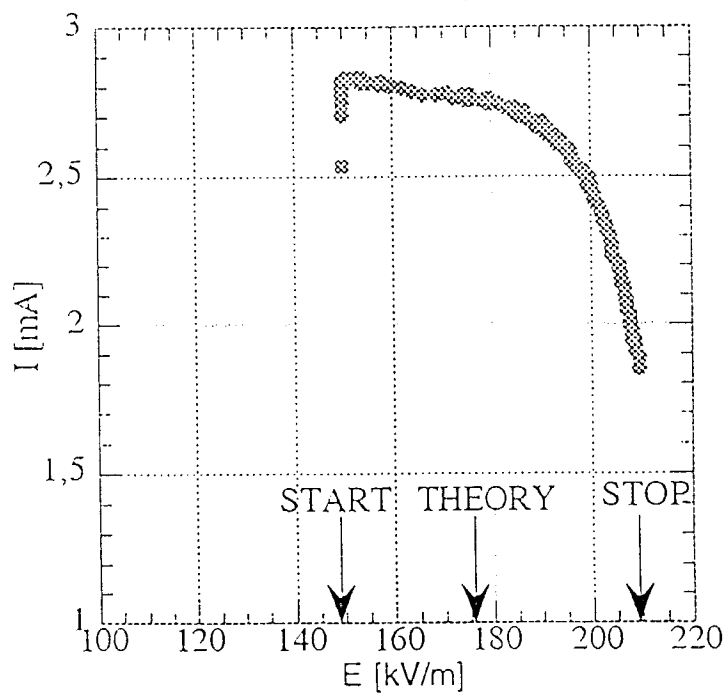
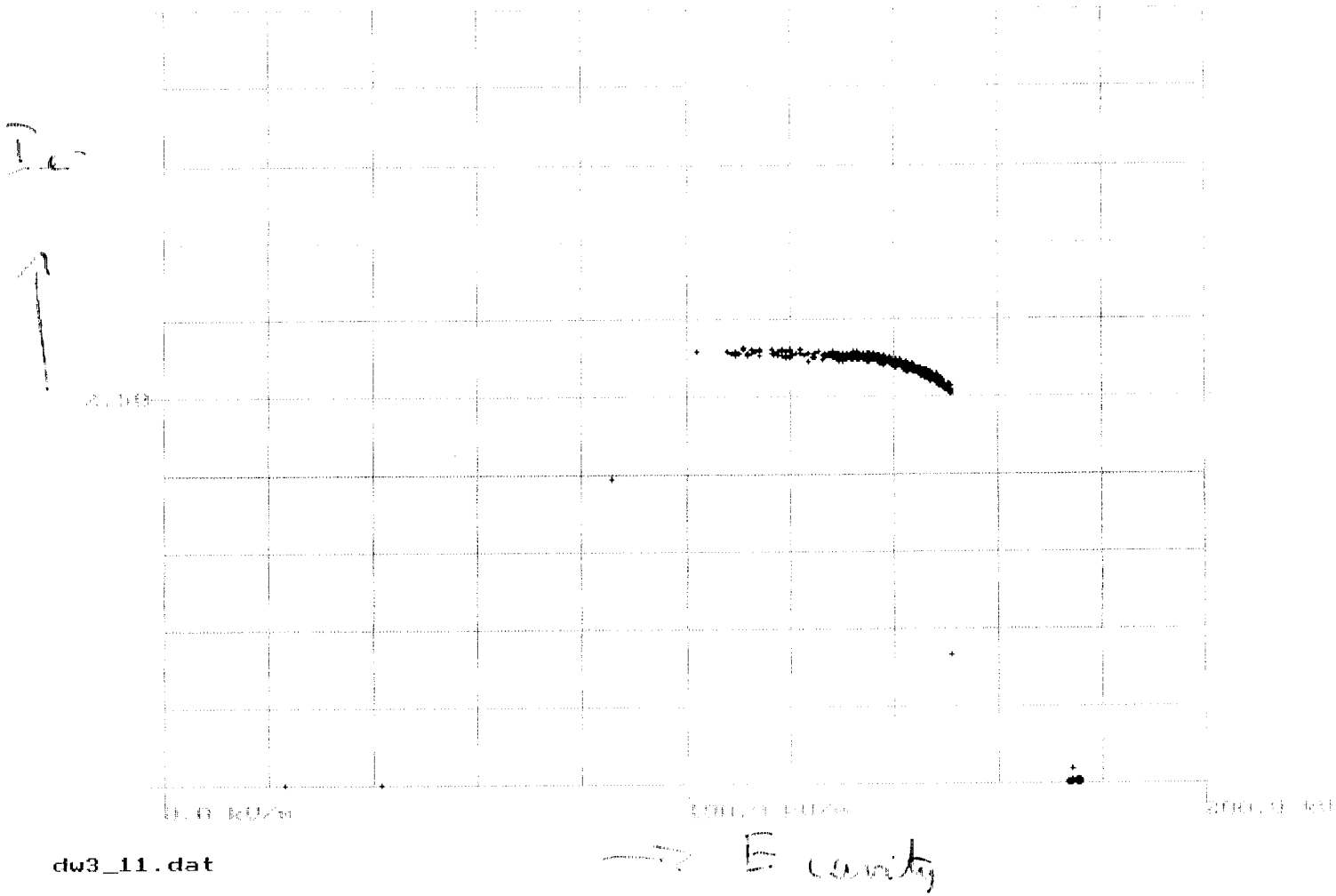
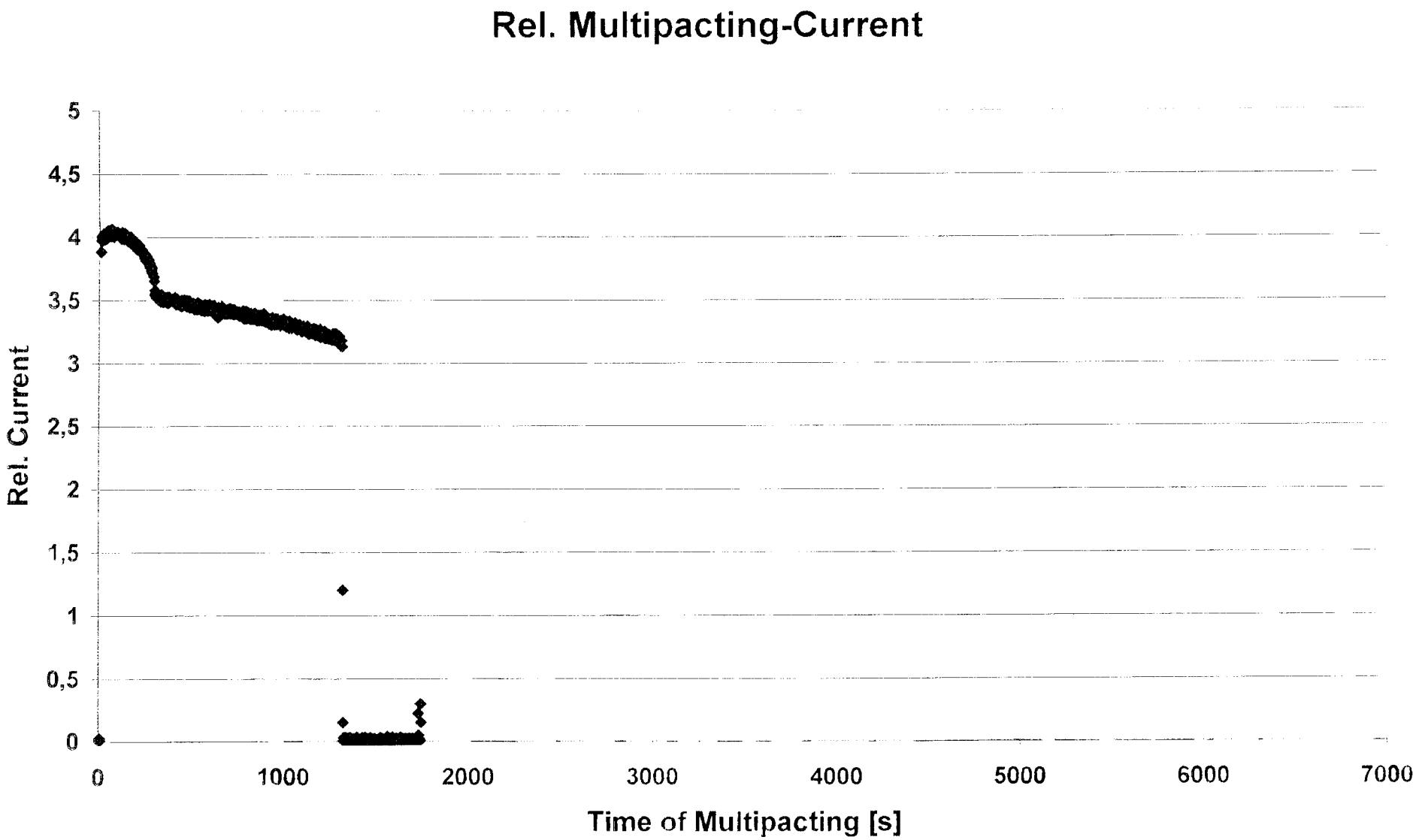


Figure 3: Multipacting current vs. electric field gradient for Titanium on Copper

Rel. Multipacting-Current vs. E-Field [kV/m]



dw3_11.dat


Rel. Multipacting-Current
Rel. Current
5
4,5
4
3,5
3
2,5
2
1,5
1
0,5
0
0
1000
2000
3000
4000
5000
6000
7000
Time of Multipacting [s]

mbar. The generator is locked to the cavity resonance and the antennas are calibrated at low RF feld level. Then the RF power is modulated up to 20 watts with a saw-tooth generator of 0.1 Hz. The onset of multipacting current is measured and the order of multipacting is determined from the calibrated gap electric field gradient. The magnitude and the processing behavior of the mutipacting current are measured the following way:

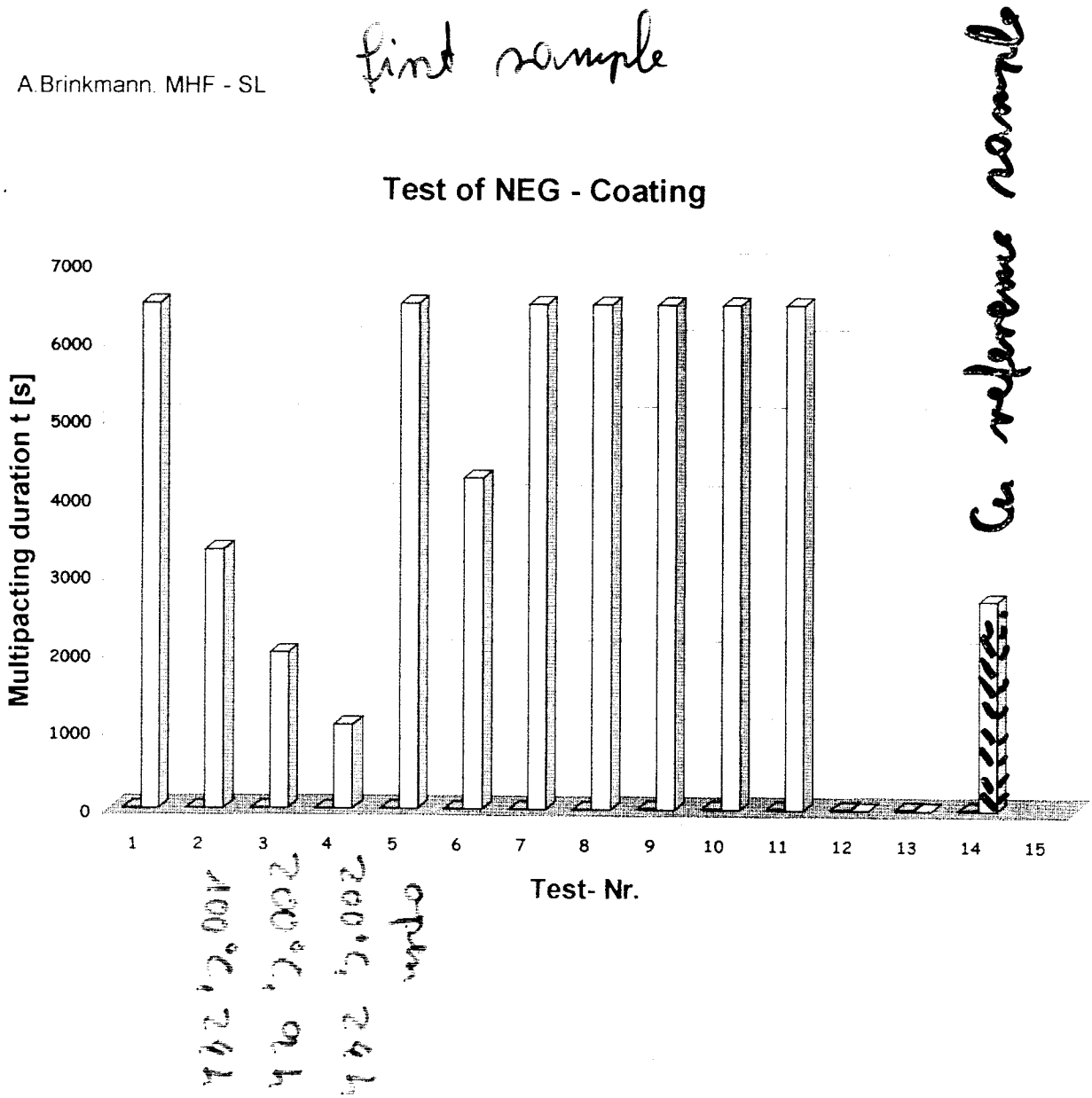
evaporation) [3]. Four stainless steel samples have electroplated with 20 μm of Cu. Four samples (2 Cu, 2 Cu) have been stored in a plastic (PE) bag (filled with dr for one week. Table 2 summarizes the measured results numbers of the multipacting current and of the processing are mean values of the individual measurements. They typically from measurement to measurement by 12 % (cu and 40 % (time). The value of the electric field at the on multipacting varies only by

MATERIAL	N	I [mA]	E1 [kV/m]	E2 [kV/m]	n	t [s]
Copper	18	2.92	132.1	188.4	1	2080
Copper (heated at 400°C)	2	3.52	145.8	231.4	1	1223
Cu, stored one week in PE bag	2	3.30	82.5; 139.0	108.9; 192.8	2 ; 1	>6500
Titanium on Copper	5	3.03	139.9	184.5	1	933,1
TiN on Copper	1	3.00	129.3	170.7	1	552
Titanium on Aluminum	2	2.88	141.8	183.4	1	885,5
Cu Ti, stored one week in PE bag	2	3.21	51.1; 123.6	68.1; 190.0	3 ; 1	>6500
Aluminium	7	4.30	54.7	69.4	3	>6500
Stainless Steel	18	3.37	69.3; 128.8	87.7; 147.6	2 ; 1	2781
Copper electrochemically plated on S.S.	7	3.33	132.7	183.8	1	2571

Table 2: Results of the multipacting measurements (N: number of measurements; I: multipacting current; E1, E2: electric gradient at onset, stop of multipacting current; n: order of multipacting; t: processing time)

A.Brinkmann, MHF - SL

first sample

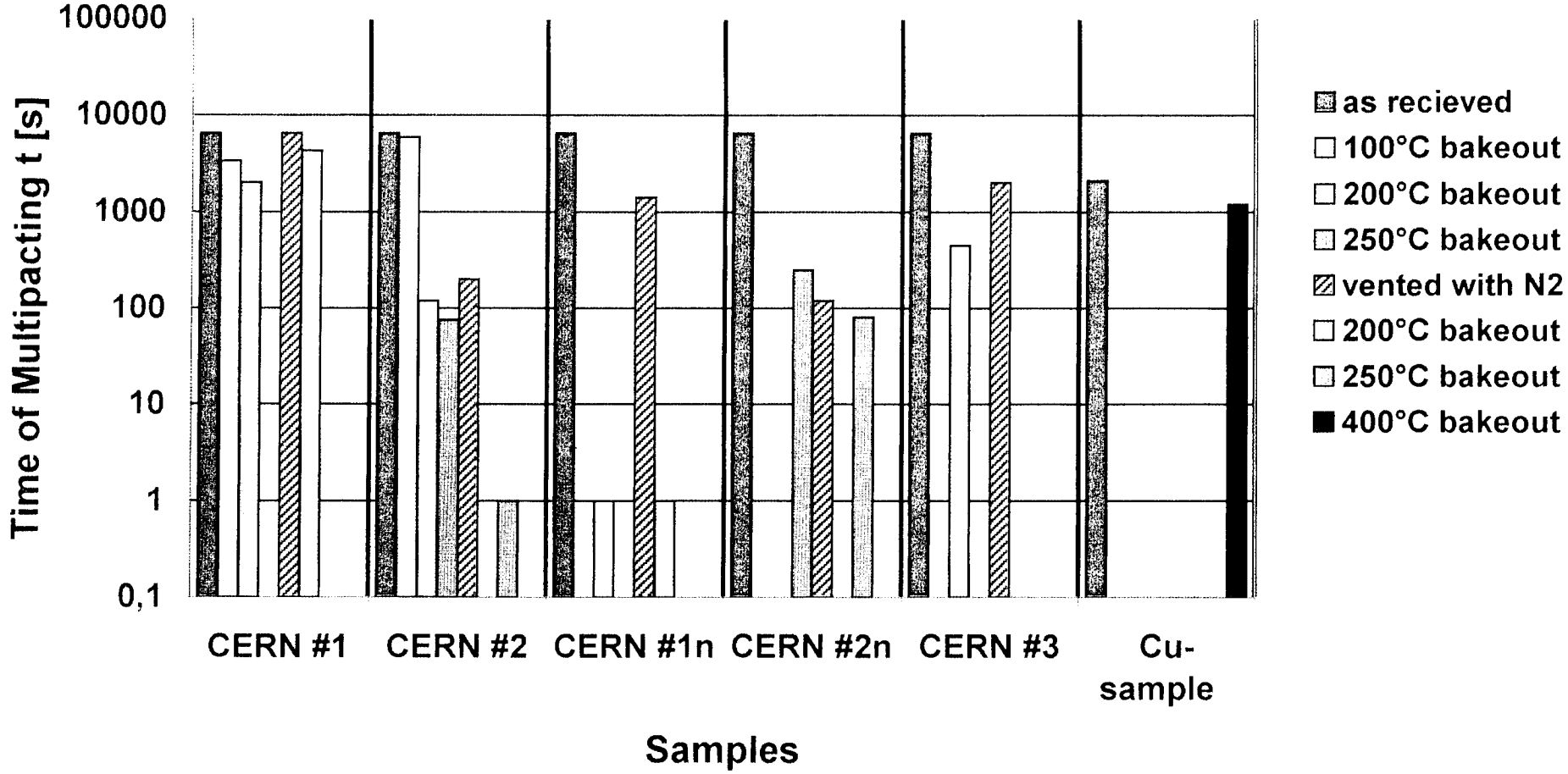


TEST 1:	as recieved
TEST 2:	after 24 h at 100°C
TEST 3:	after 09 h at 200°C
TEST 4:	after 24 h 200° C
TEST 5:	flooded with dry N_2,Probes put out and in
TEST 6:	after 24 h at 200°C
TEST 7:	after 5 days of pumping, not heated
TEST 8:	flooded with dry N_2 up to 1 mbar for 1 h
TEST 9:	after 24 h at 250°C
TEST 10:	after 24 h at 100° C, MP-Test starts at 50°C, during cooldown
TEST 11:	after 20 h at 250° C
TEST 14:	Cu-Probe as Reference

Arne Brinkmann DESY -MHF-SL-

NEG coating: Benvenuti, CERN
multipacting measurement: A. Brinkmann, DESY

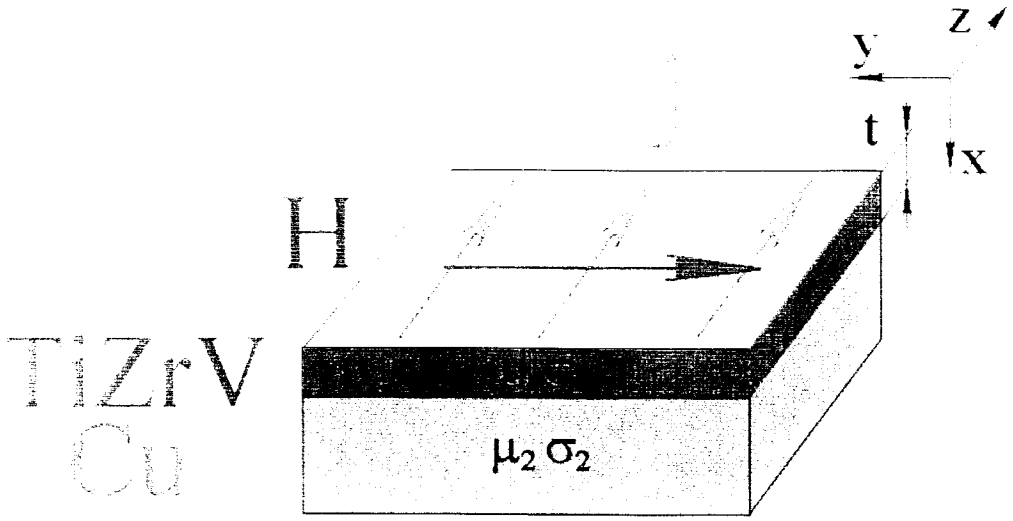
Multipacting-Investigations of NEG-coated CERN-Samples



RF Losses in Cu Surface with TiZrV Coating

D.Proch, A.Zavadtsev
DESY

Copper surface of the fundamental mode input coupler may be coated by some material (for example TiZrV) to decrease secondary yield and thereby to decrease multipacting.



- Operating frequency — $f = 1.3$ GHz
- Conductivity of TiZrV — $\sigma_1 = 0.0286*10^7\ (\mathrm{Ohm*m})^{-1}$
- Conductivity of Cu — $\sigma_2 = 5.8*10^7\ (\mathrm{Ohm*m})^{-1}$
- Coating thickness — $t = 1\ \mu m$

[illegible] of penetration depth, current density and surface impedance

The current density in the wall is

$$j_z = A\sinh\tau_1 x + B\cosh\tau_1 x$$

$$\tau_1 = \frac{1+i}{\delta_1}$$

Penetration depth in the coating material is

$$\delta_1 = \frac{1}{\sqrt{\pi f \mu_1 \sigma_1}}$$

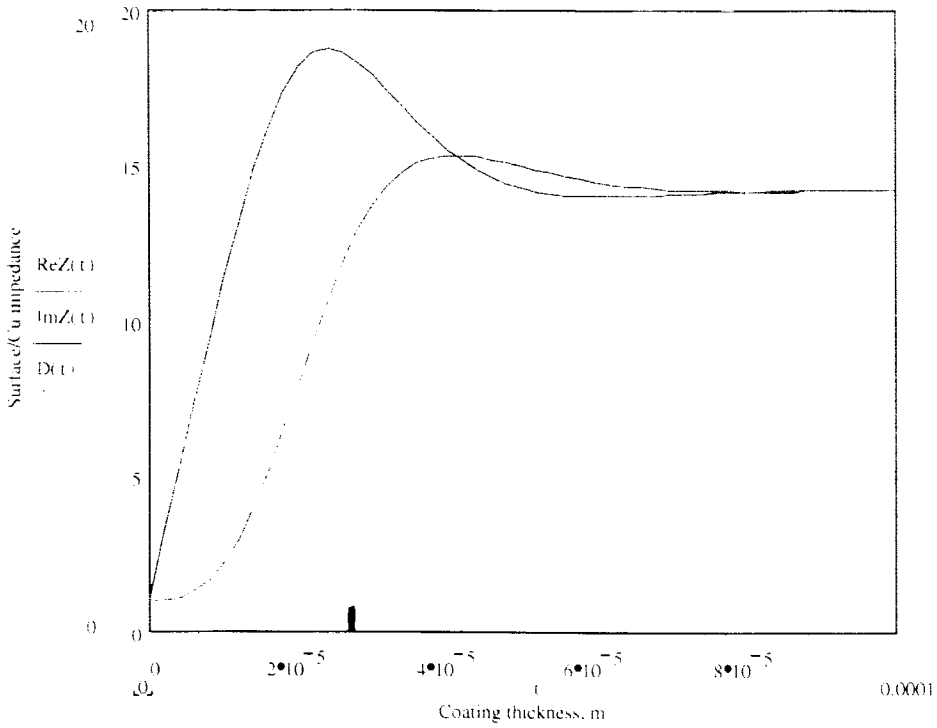
$$\frac{B}{A} = -\frac{\sinh\tau_1 t + \dfrac{\tau_2\sigma_1}{\tau_1\sigma_2}\cosh\tau_1 t}{\cosh\tau_1 t + \dfrac{\tau_2\sigma_1}{\tau_1\sigma_2}\sinh\tau_1 t}$$

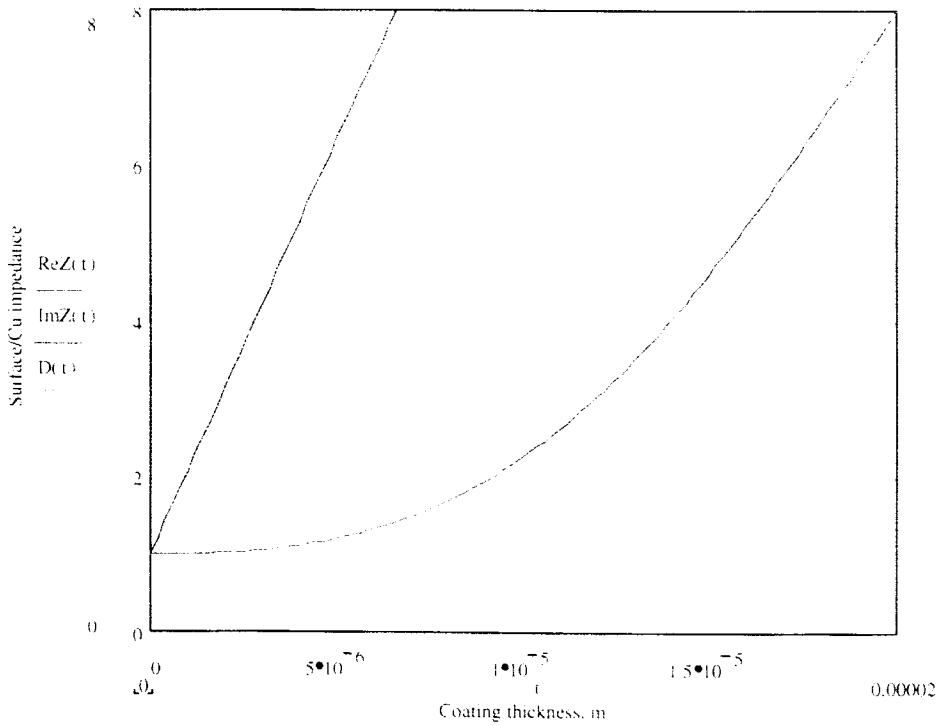
Surface impedance is

$$Z = -\frac{E_z}{H_y}\Big|_{x=0} = (1+i)R_{Co}\,\frac{\sinh\tau_1 t + \dfrac{R_{Cu}}{R_{Co}}\cosh\tau_1 t}{\cosh\tau_1 t + \dfrac{R_{Cu}}{R_{Co}}\sinh\tau_1 t}$$

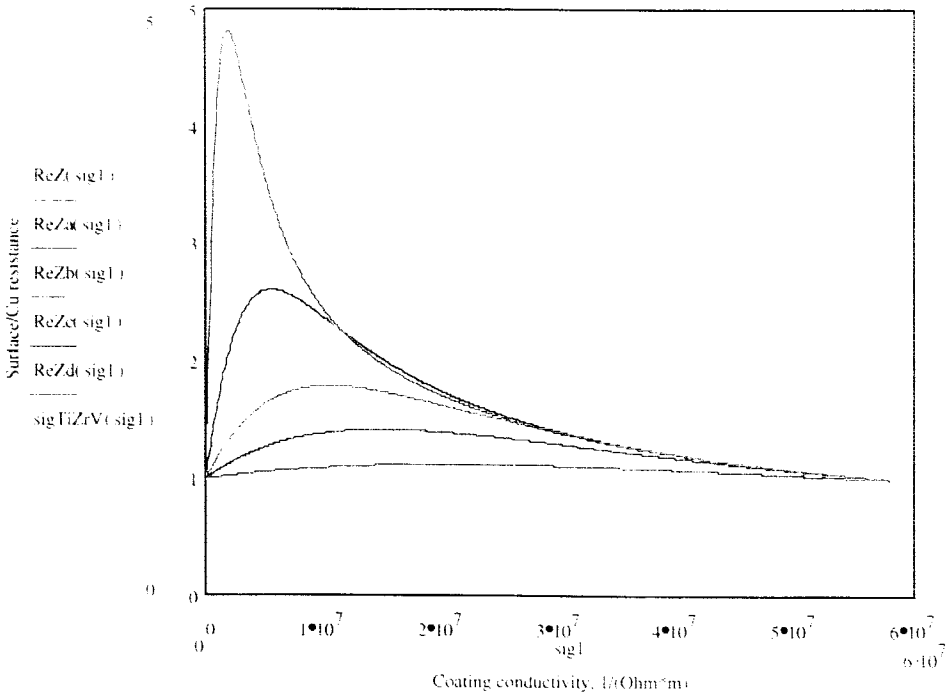
R_{Co} and R_{Cu} are the surface resistance of the coating material (TiZrV) and Cu.

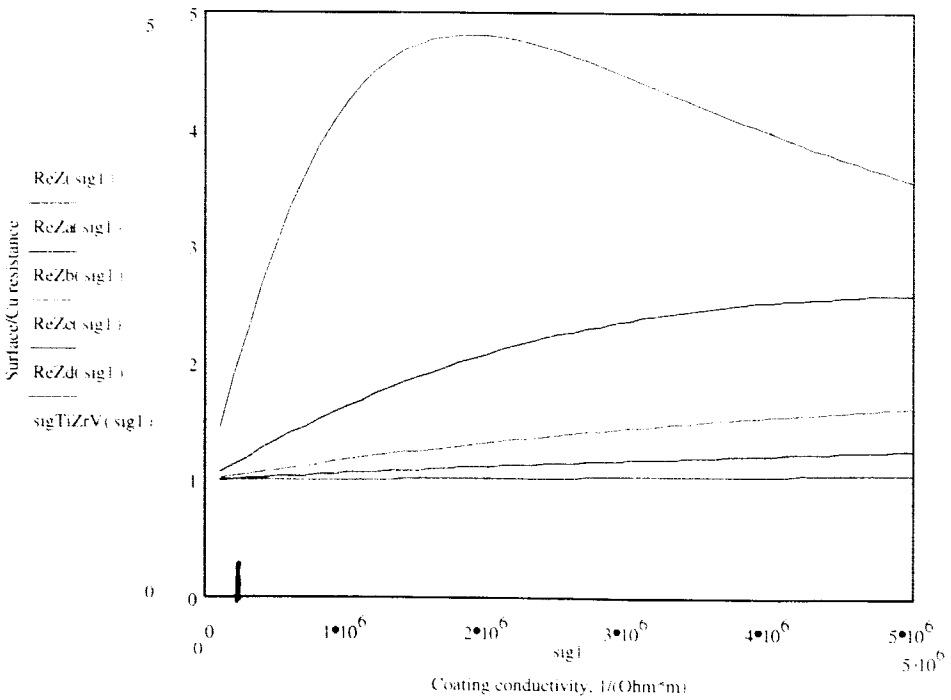
The real and imaginary parts of the surface impedance depending on the coating thickness at 1.3 GHz and $\sigma_{coat}=0.0268*10^{7}\ (Ohm*m)^{-1}$.





Surface resistance depending on coating conductivity at 1.3 GHz and coating thickness 1, 2, 3, 5 and 10μm.





t=1mcm
t=2mcm
t=3mcm
t=5mcm
t=10mcm
TiZrV conductivity

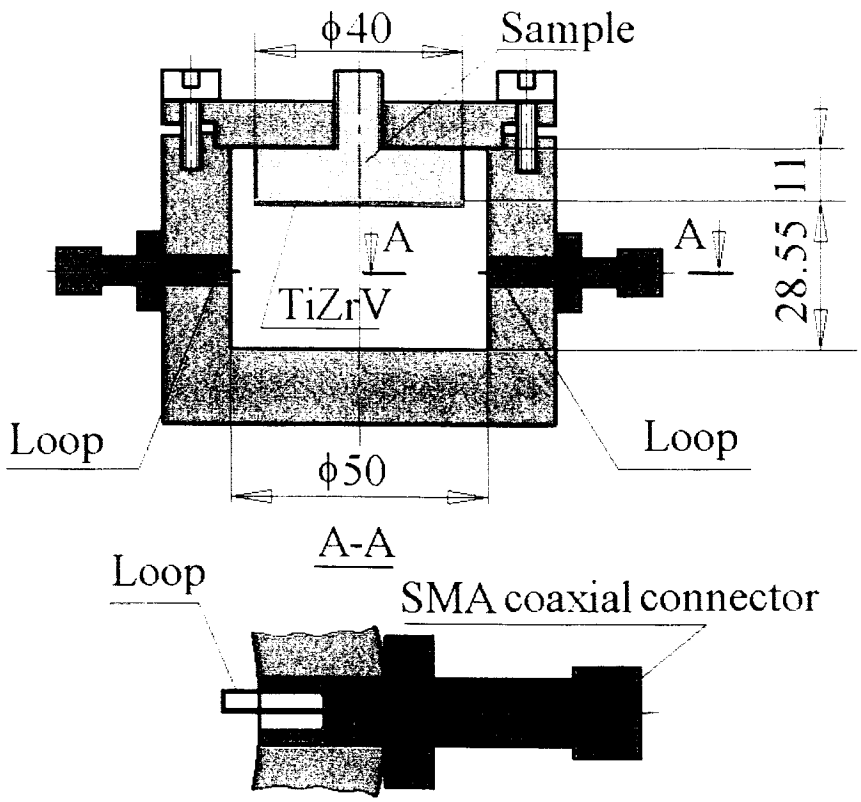
Test cavity

1. The test cavity is destined for the measurement of the surface resistance in the Cu-surface coated by TiZrV.

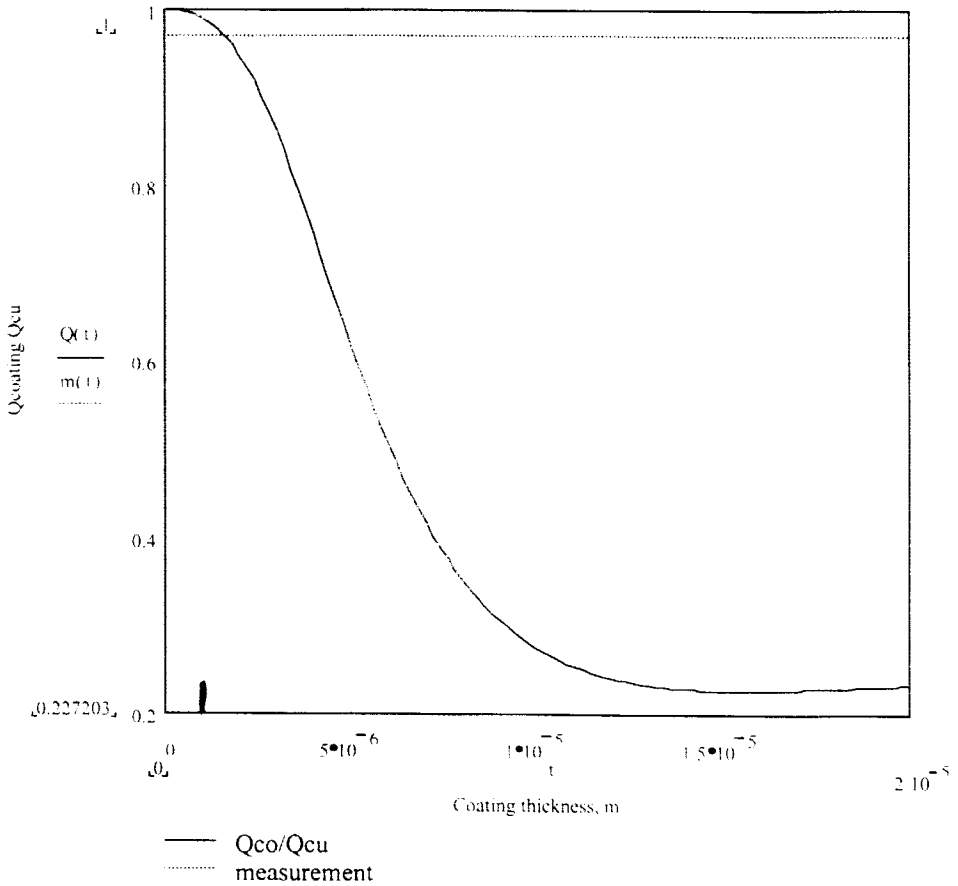
2. The existing Cu-samples coated by TiZrV should be used. These samples used for multipacting investigation in DESY earlier.

3. TE_{011}-mode is preferential because it has highest Q-factor and there is φ-component of the surface current only, i.e. there is no contact problem in the cavity.

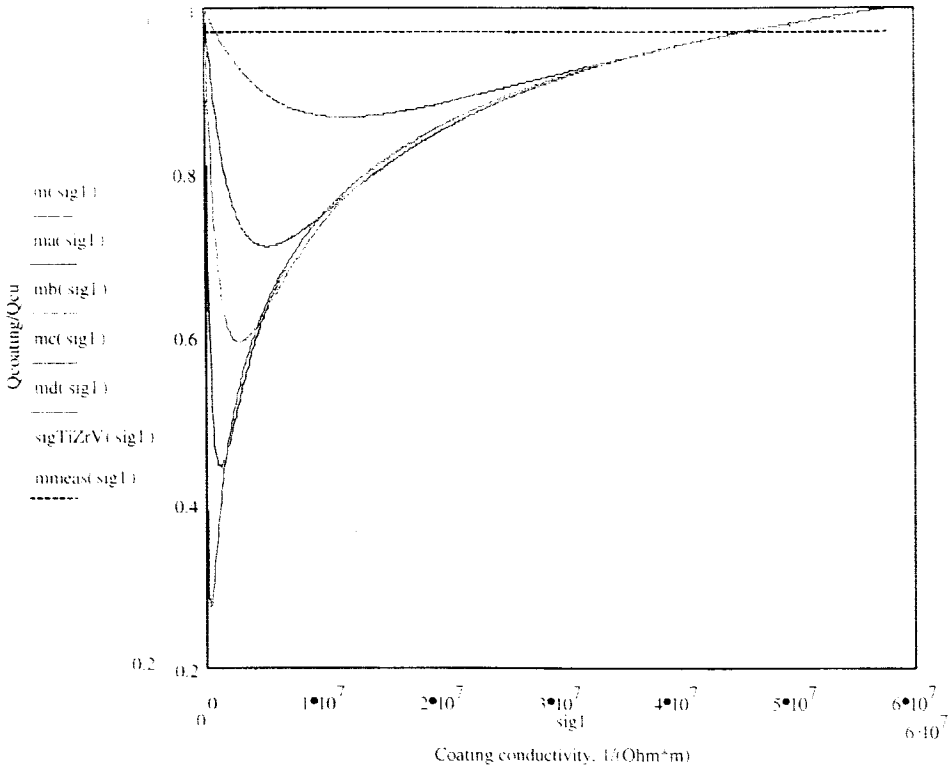
4. Operating frequency 9 GHz was chosen because:
   - the surface resistance of the coated surface increases with the increasing of the frequency, and therefore the measurement accuracy increases also;
   - sample size corresponds to the size of the TE_{011}-cavity approximately at 9 GHz.

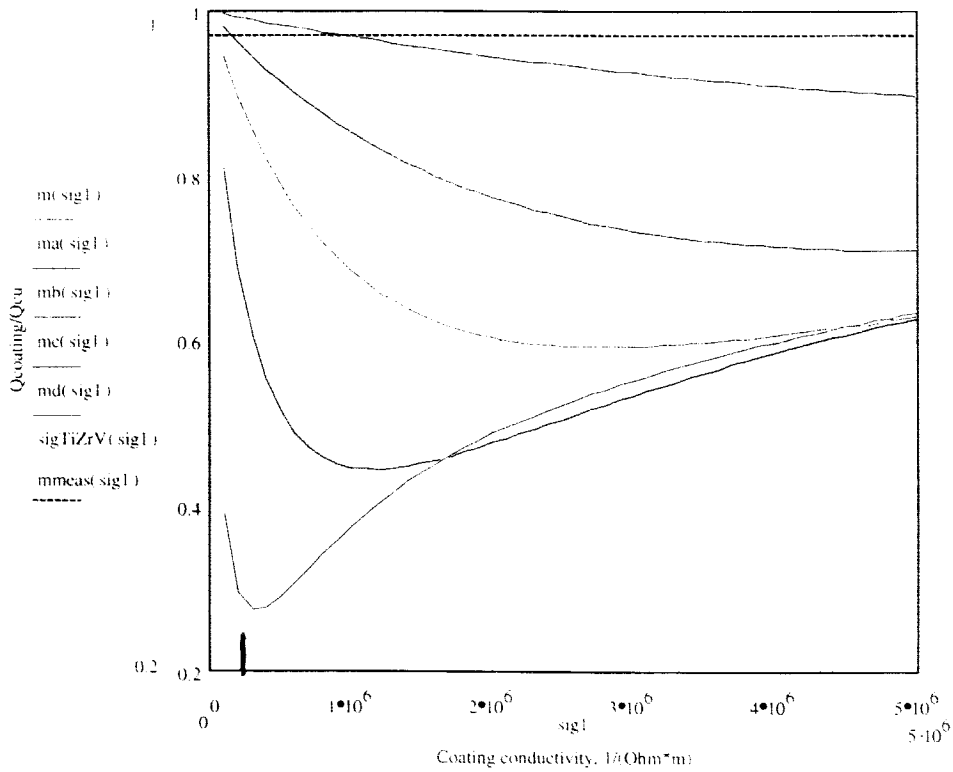


Q-factor of test cavity vs. coating thickness for coating conductivity $0.0268*10^{7}$ $(Ohm*m)^{-1}$



Q-factor of test cavity vs. coating conductivity for 1, 2, 3, 5 and 10 μm coating thickness.





t=1mcm
t=2mcm
t=3mcm
t=5mcm
t=10mcm
TiZrV conductivity
measurement

Test cavity parameters and resistance measurement

Cavity material	Cu	Cu + TiZrV coating	
Calculated parameters			
Frequency, GHz	9	9	
Coat. thickness, μm		1	
Coat. conductivity, $(Ohm*m)^{-1}$		$2.86*10^5$	
Relative surface resistance of the sample R_{sample}/R_{Cu}	1	1.039	
Q	28610	28350	
k	0.237		
Measured parameters			
Frequency, GHz	[illegible]	[illegible]	
Quality factor measured assembling #1	[illegible]	[illegible]	
assembling #2	[illegible]	[illegible]	
assembling #3	[illegible]	[illegible]	
average	[illegible]	[illegible]	
Analyzed parameters			
Relative surface resistance of the sample at 9 GHz R_{sample}/R_{Cu}	**1**	**1.133**	
Coating parameters:			
• conductivity, $(Ohm*m)^{-1}$		**$2.86*10^5$**	**$10*10^5$**
• thickness, μm		**1.61**	**1**
Relative surface resistance of the sample at 13 GHz R_{sample}/R_{Cu}	**1**	**1.013**	**1.012**

$$\frac{R_{sample}}{R_{Cu}} = 1 + \frac{1}{k}\left(\frac{Q_{Cu}}{Q_{sample}} - 1\right)$$

k is the power loss in the Cu sample divided by the whole power loss in the cavity without coating.

Conclusion.

1. RF power loss increasing because the coating is 0.4% for 1μm coating thickness and $0.0286*10^7$ $(Ohm*m)^{-1}$ coating conductivity.

2. RF power loss increasing because the coating is 2.5% for 1μm coating thickness and $0.2*10^7$ $(Ohm*m)^{-1}$ coating conductivity.

3. RF power loss increasing because the coating is 2 times for 10μm coating thickness and $0.0286*10^7$ $(Ohm*m)^{-1}$ coating conductivity.

4. RF power loss increasing because the coating is 4.8 times for 10μm coating thickness and $0.2*10^7$ $(Ohm*m)^{-1}$ coating conductivity.

5. The result of the measurement of test cavity is surface resistance at 9 GHz. There are two indefinite parameters for the coating: thickness and conductivity. We can assume that one of them is equal to designed value and fine the second one. The difference of the surface resistance of described coating at 1.3 GHz for these two cases is 0.1%.

6. The test cavity measurement is sufficiently sensitive to the loss value. 1.3% RF loss increasing because the coating was successfully measured on the Cu sample coated by TiZrV.

Current activities in TiN coating at DESY

J. Lorkiewicz, B. Dwersteg
DESY

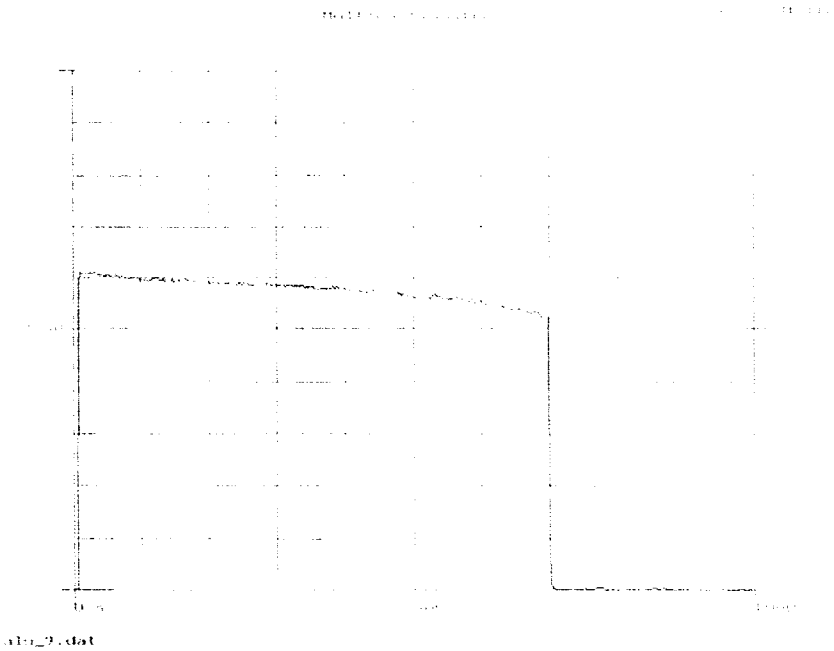
Technique used: Ti evaporation in NH_3 atmosphere.

- Selection of coating procedure,
- Coating of flat WG windows for main TTF coupler,
- Coating of cylindrical windows for DESY – TTF- III coupler.

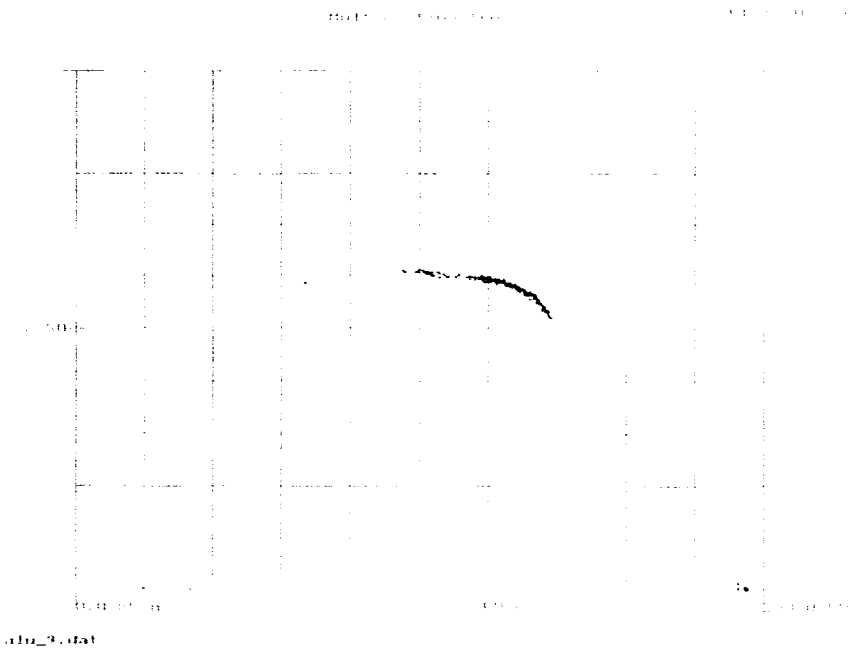
A.Brinkmann 09.11.99

Alu-sample #14, Ti coating test No. 23, Date of coating 04.11.99
Heating current 17 A, deposition time 48 s, Chamber heating off

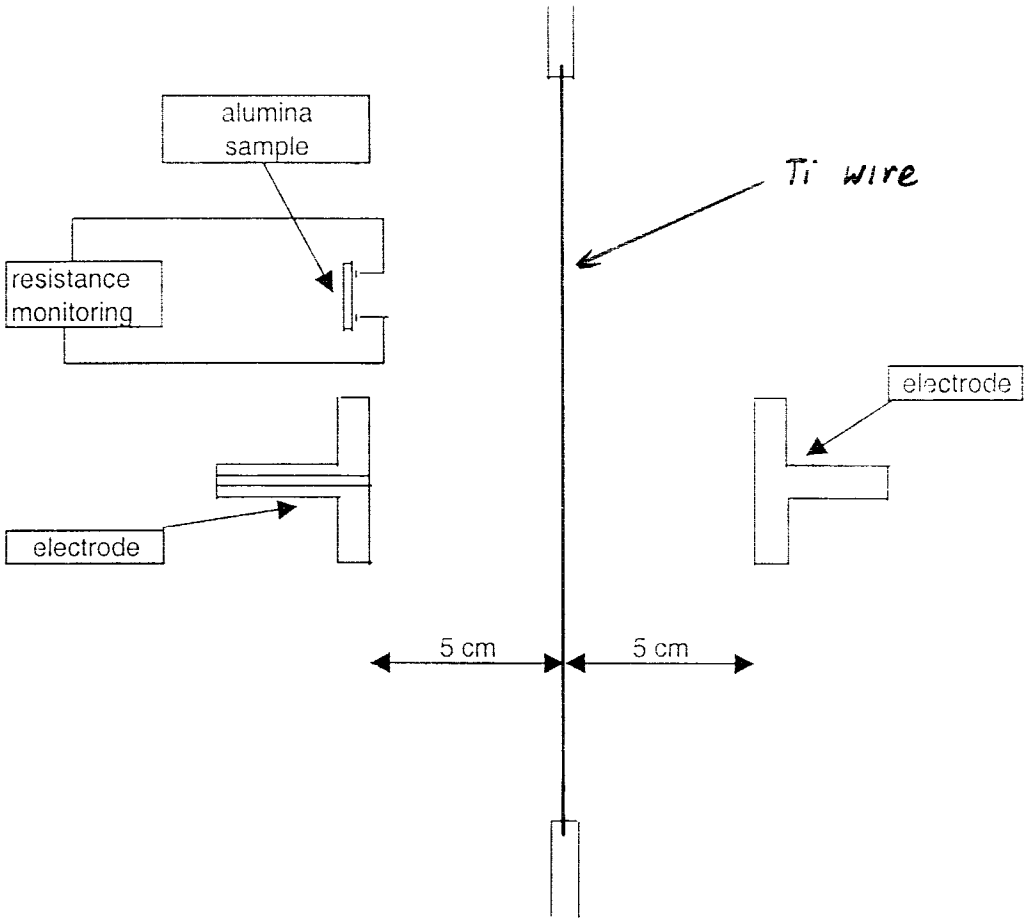
Multipactingstrom-Verlauf



Feldstärkenverlauf



Coating of electrodes for RF test resonator



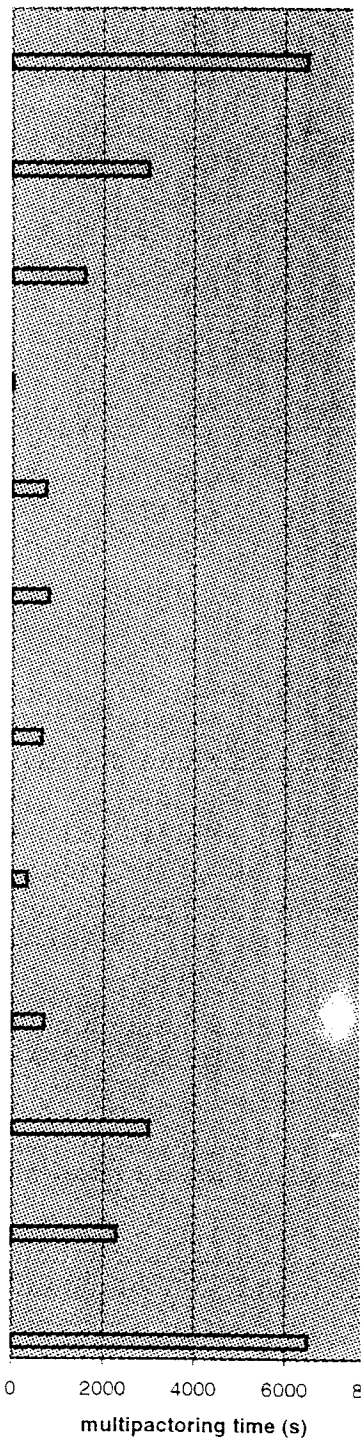
Coating parameters:

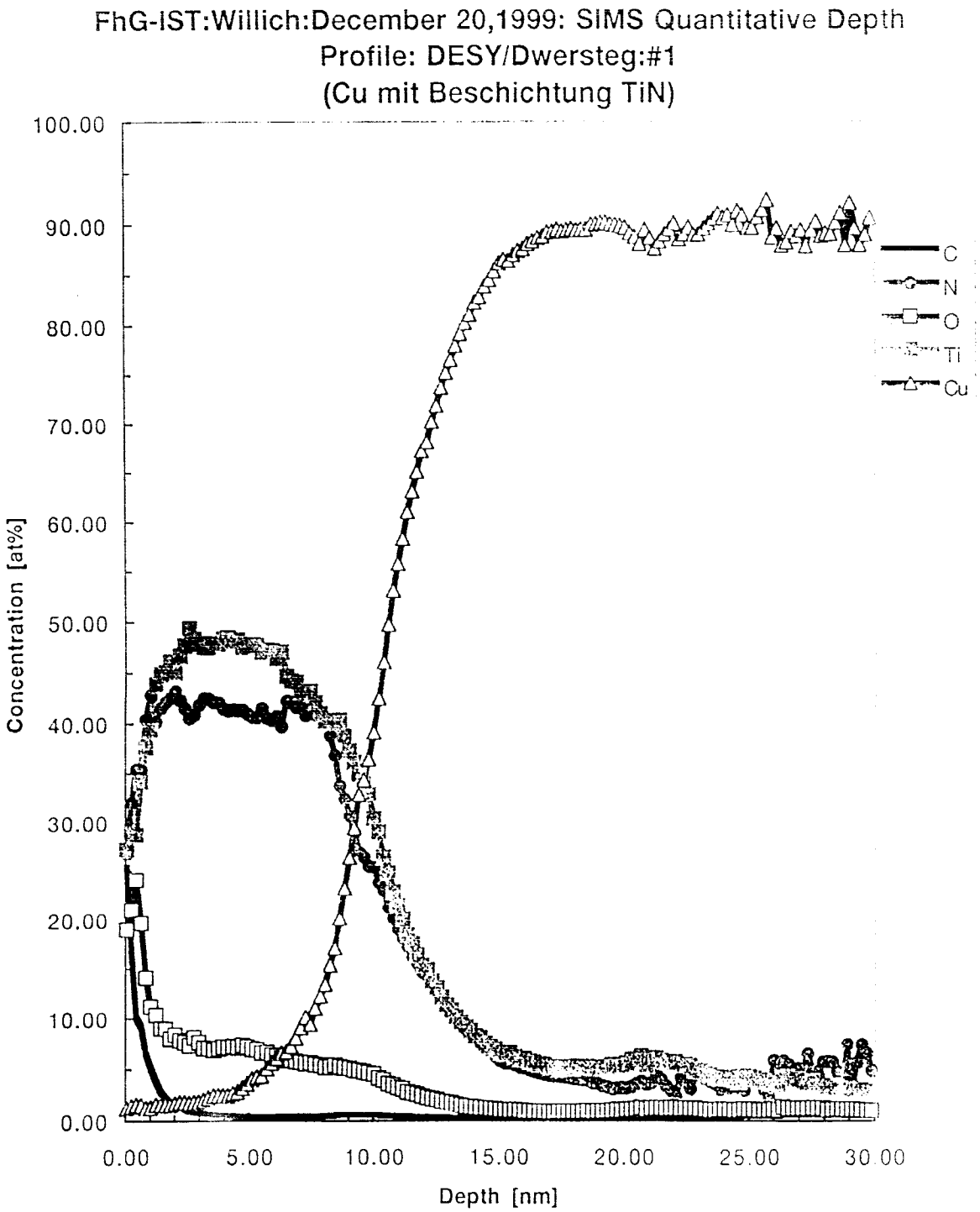
- deposition rate: 9nm/min, 20 nm/min,
- final layer thickness: 4 - 40 nm,
- NH_3 pressure during deposition: 10^{-3} mbar,
- substrate temperature: 25°C, 150°C,
- postprocessing: NH_3 pressure 150 - 750 mbar, duration time 20 hours - 1 week.

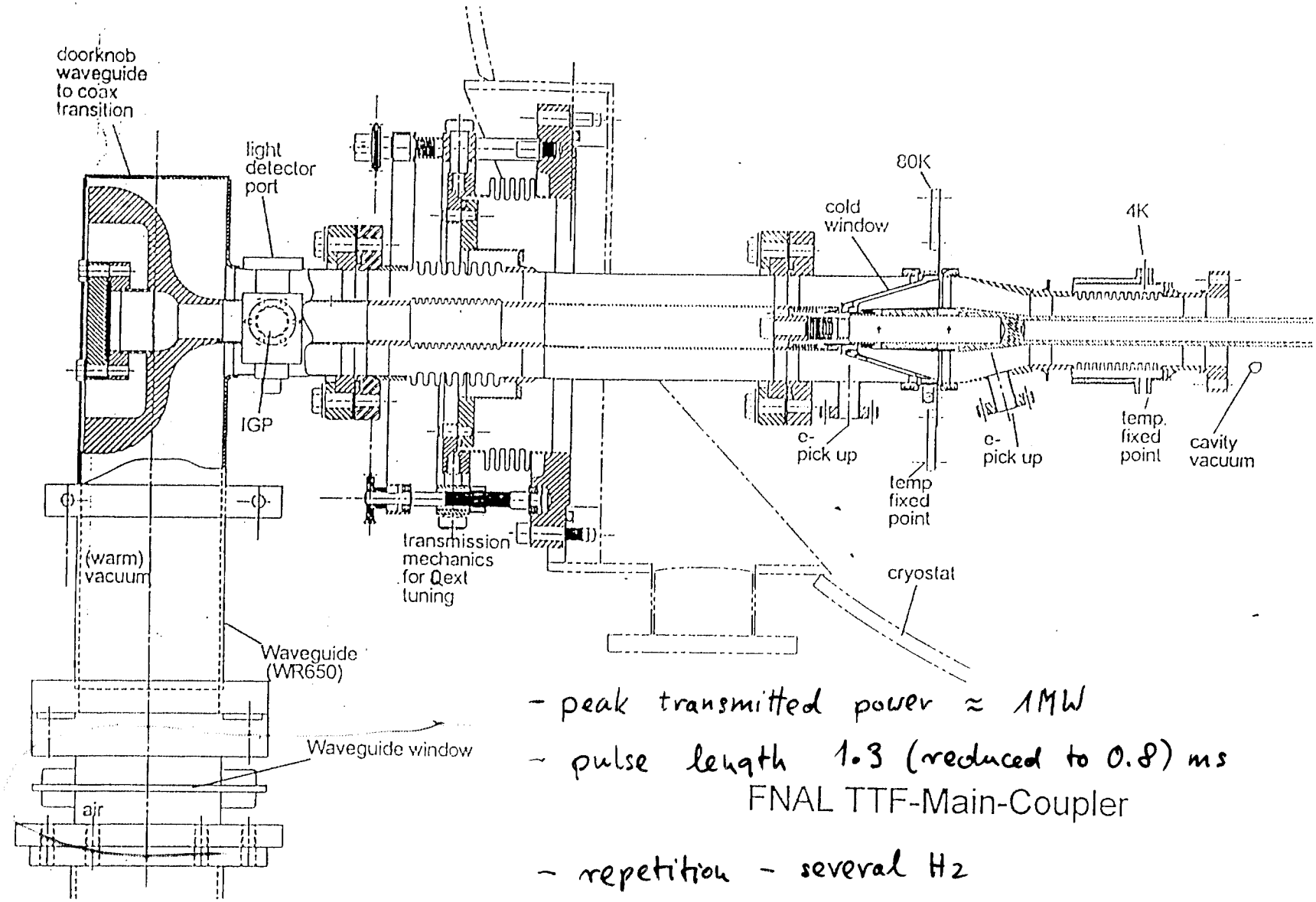
Test results from DESY coaxial resonator

Sample	Substrat temperature	Deposition rate (atmosphere)	Layer thickness	Further processing	Layer resistivity (Mohm/sq.) at 3000 K	Layer resistivity (Mohm/sq.) at 70 K
1. Al		before processing				
2. Cu		before processing				
3. Cu	25° C	20 nm/min (res. gas)	ca. 40 nm	no		
4. Cu	25° C	20 nm/min (NH_3)	ca. 40 nm	no		
5. Cu *	150° C	9 nm/min (10^{-3} mbar NH_3)	13 nm	150 mbar NH_3 3 days	960	14600
6. Al	150° C	9 nm/min. (10^{-3} mbar NH_3)	15 nm	300 mbar NH_3 2 days	55	960
7. Al	150° C	9 nm/min. (10^{-3} mbar NH_3	ca. 7 nm	250 mbar NH3 3 days	2900	195000
8. Al *	25° C	9 nm/min. 10^{-3} mbar NH_3	7 nm	700 mbar NH_3 20 hours	11700	195000
9. Al *	25° C	9 nm/min 10^{-3} mbar NH_3	7 nm	700 mbar NH_3 23 hours	24300	290000
10. Al *	150° C	9 nm/min. 10^{-3} mbar NH_3	ca. 4 nm	200 mbar NH_3 24 hours		
11. Al	150° C	9 nm/min. 10^{-3} mb[illegible] NH_3	7 nm	750 mbar NH_3 21 hours	0.6	4.5
12. Al	150° C	9 nm/nim. 10^{-3} mbar NH_3	7 - 8 nm	400 mbar NH_3 1 week		

Multipactoring time



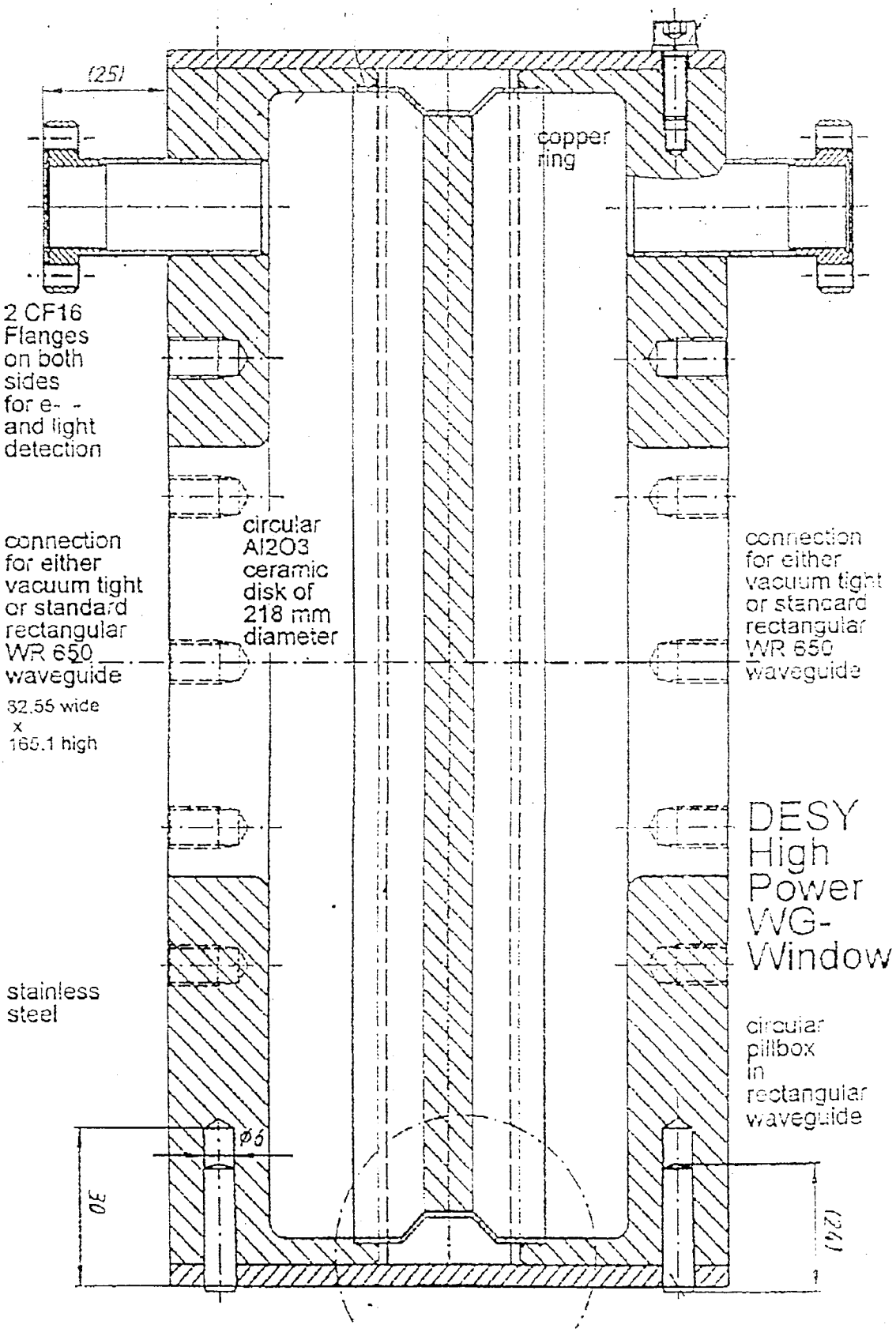

FhG-IST:Willich:December 20,1999: SIMS Quantitative Depth
Profile: DESY/Dwersteg:#1
(Cu mit Beschichtung TiN)
Concentration [at%]
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0.00
5.00
10.00
15.00
20.00
25.00
30.00
Depth [nm]
C
N
O
Ti
Cu



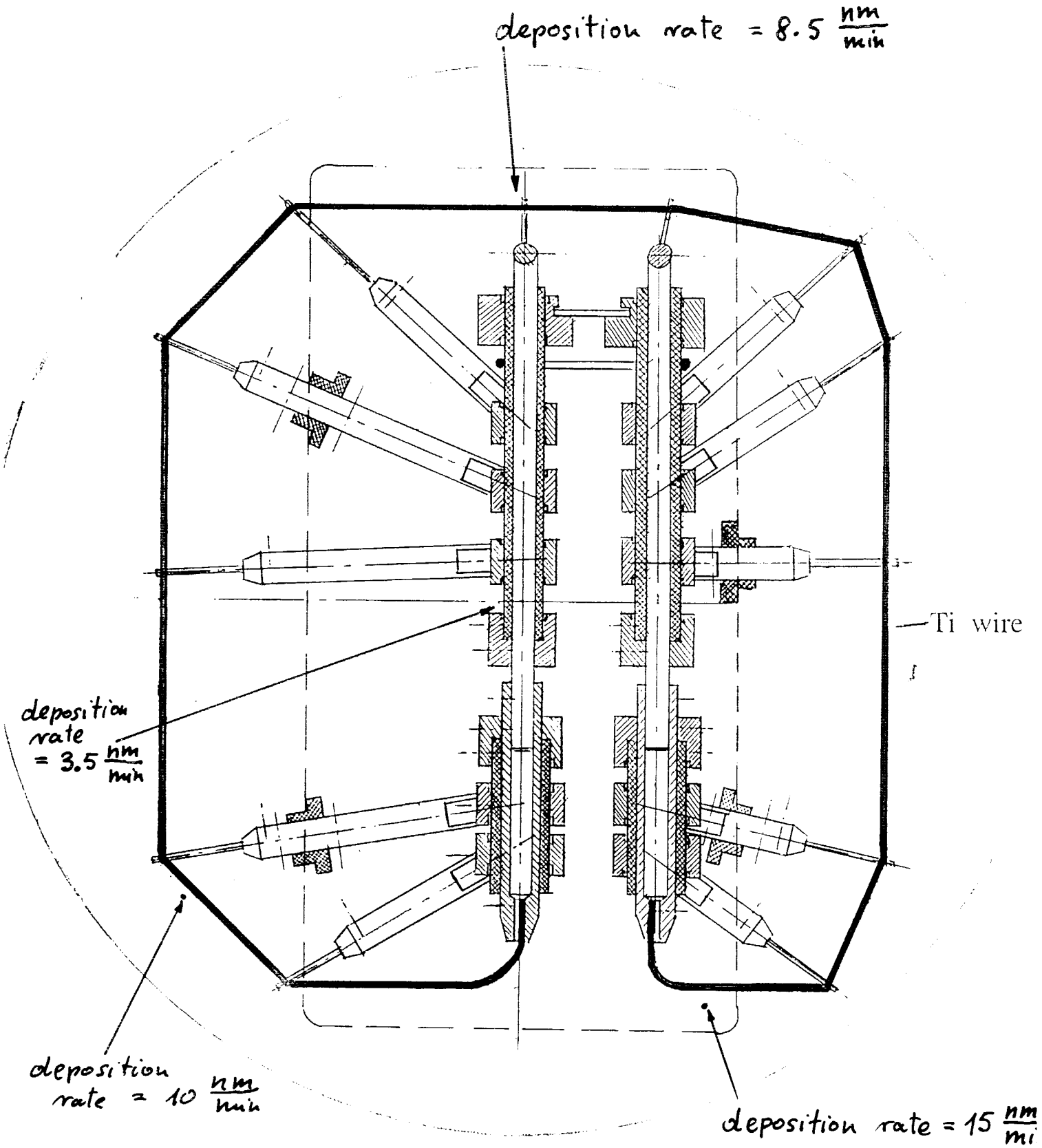
- peak transmitted power ≈ 1MW
- pulse length 1.3 (reduced to 0.8) ms

FNAL TTF-Main-Coupler

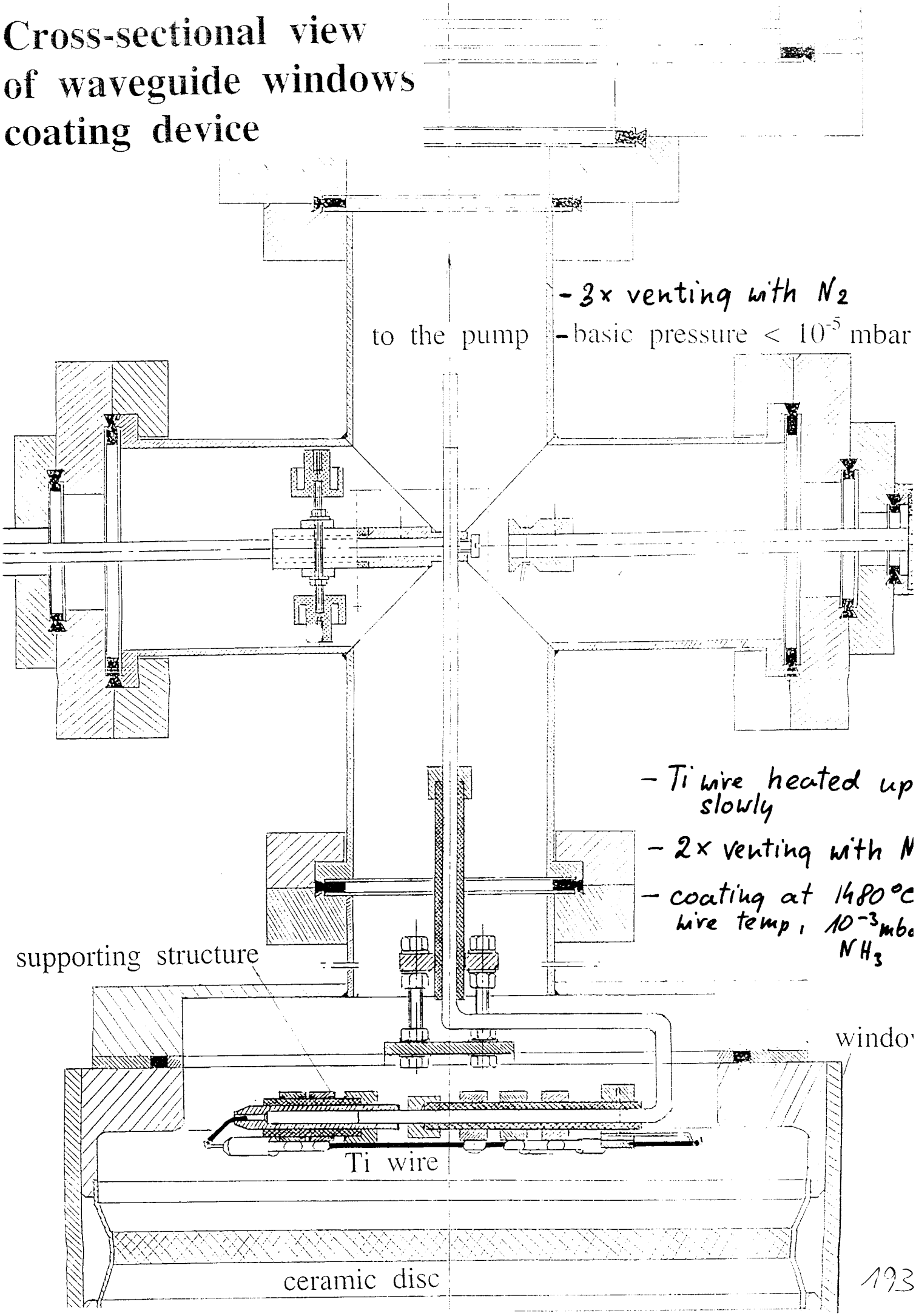
- repetition - several Hz


(25)
copper ring
2 CF16 Flanges on both sides for e- - and light detection
circular Al2O3 ceramic disk of 218 mm diameter
connection for either vacuum tight or standard rectangular WR 650 waveguide
32.55 wide x 165.1 high
connection for either vacuum tight or standard rectangular WR 650 waveguide
DESY High Power WG-Window
stainless steel
circular pillbox in rectangular waveguide
ϕ6
30
(24)

Ti wire loop with supporting structure



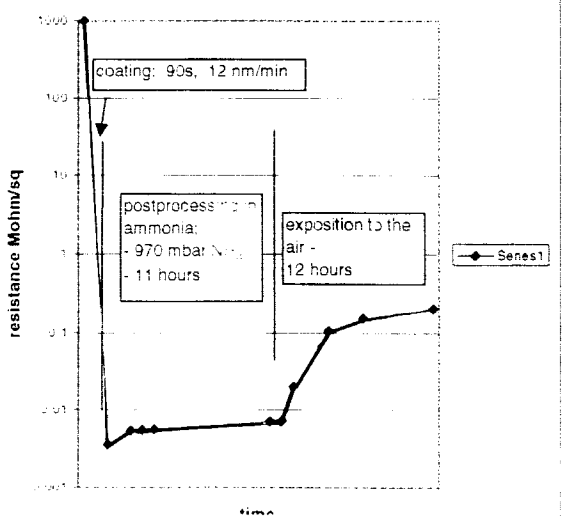
Cross-sectional view of waveguide windows coating device



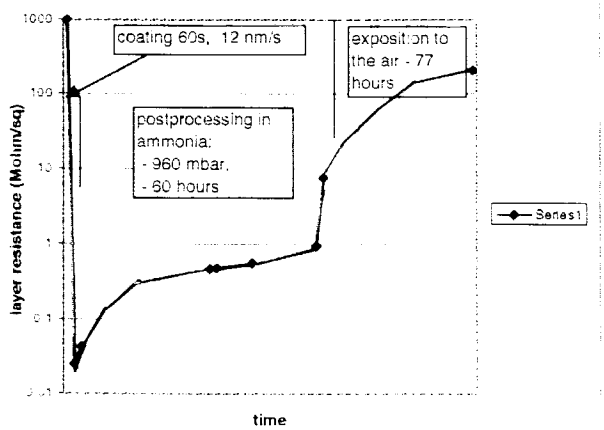
"G"-series waveguide windows coating - processing parameters

of WG window coated	Maximum deposition rate on the disc	Ammonia pressure during coating	Estimated layer thickness range	Postprocessing NH_3 pressure, duration time	Layer resistance after coating / after postprocessing	Colour the disc surface
G-16	12 nm/min	2E-3 mbar	5 - 22 nm	940 mbar (41 hours)		metallic grey, pale in the centre
G-17	12 nm/min	2E-3 mbar	5 - 22 nm	970 mbar (11 hours)	3.3 Kohm/sq. / 7.3 Kohm/sq.	metallic grey, pale in the centre
G-18	12 nm/min	2E-3 mbar	3 - 12 nm	860 mbar (40 hours)	90 Kohm/sq. / 161 Kohm/sq.	metallic grey, grey-yellowish, pale
G-20	12 nm/min	2E-3 mbar	3 - 12 nm	850 mbar (18 hours)	16 Kohm/sq. / 54 Kohm/sq.	metallic grey, grey-yellowish, pale
G-21	12 nm/min	2E-3 mbar	3 - 12 nm	700 mbar (17 hours)	6.7 Kohm/sq. / 28 Kohm/sq.	metallic grey, grey-yellowish, pale
G-22	12 nm/min	2E-3 mbar	3 - 12 nm	650 mbar (38 hours)	12 Kohm/sq. / 223 Kohm/sq.	metallic grey, grey-yellowish, pale
G-23	12 nm/min	2E-3 mbar	3 - 12 nm	ca.900 mbar (60 hours)	25 Kohm/sq. / 949 Kohm/sq.	metallic grey, grey-yellowish, pale
G-24	5 nm/min	2E-3 mbar	3 - 12 nm	780 mbar (88 hours)	32 Kohm/sq. / 1277 Kohm/sq.	grey-yellowish, pale
G-25	5 nm/min	2E-3 mbar	3 - 12 nm	ca.700 mbar (63 hours)	18 Kohm/sq. / 330 Kohm/sq.	grey-yellowish, pale
G-26	5 nm/min	2E-3 mbar	3 - 12 nm	ca.620 mbar (2 weeks)	12 Kohm/sq. / 1500 Kohm/sq.	grey-yellowish, pale

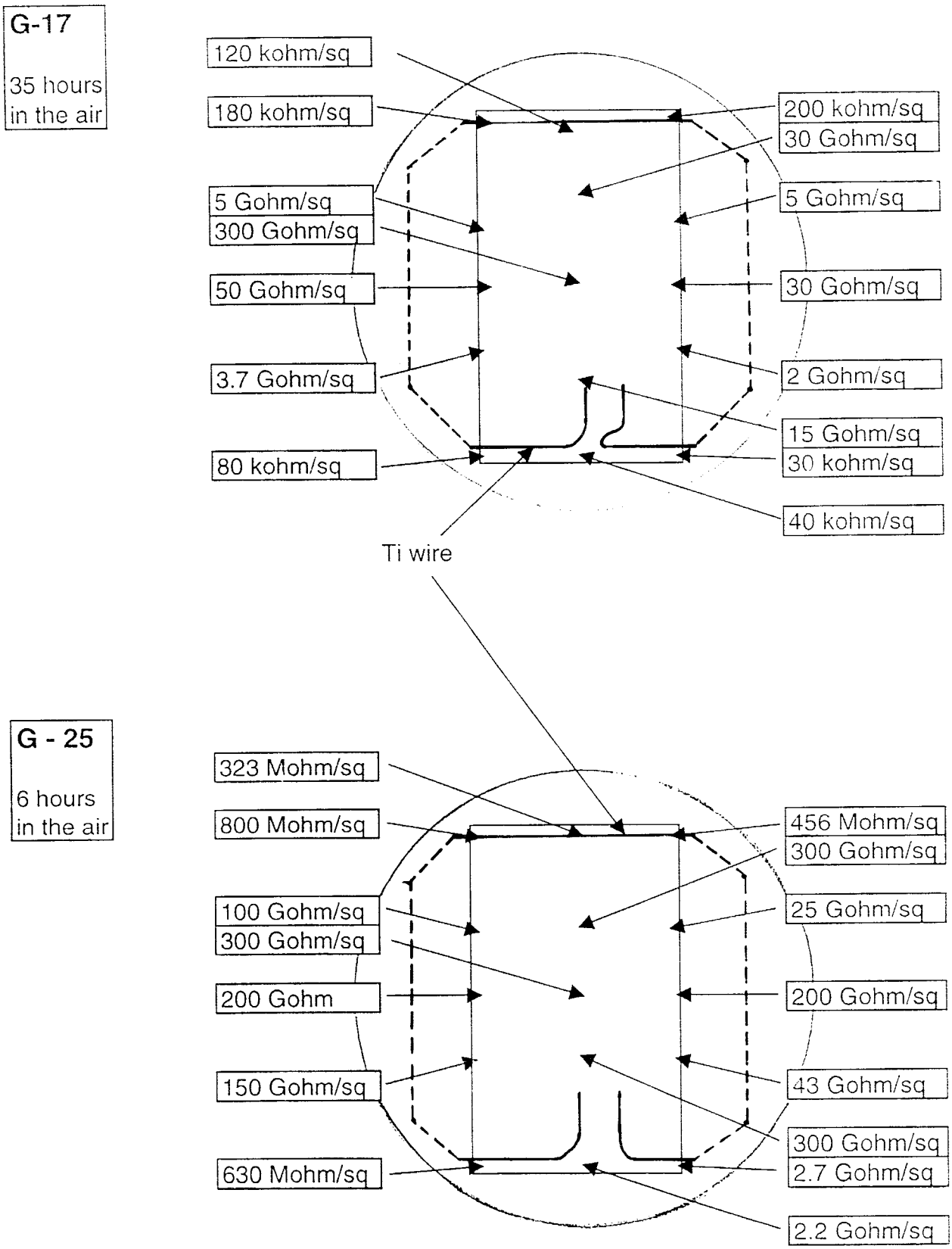
RF window G-17, Ti-layer resistance/sq vs time



G-23 window coating, Ti-layer resitance/sq vs time



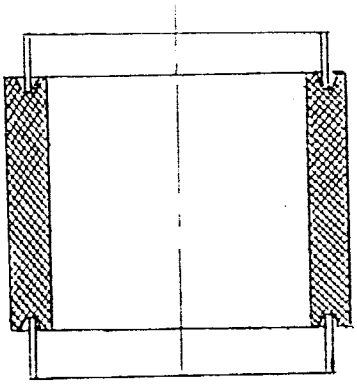
Layer resitivity distribution on the disc



TiN coating of cylindrical windows for DESY-TTF-III coupler

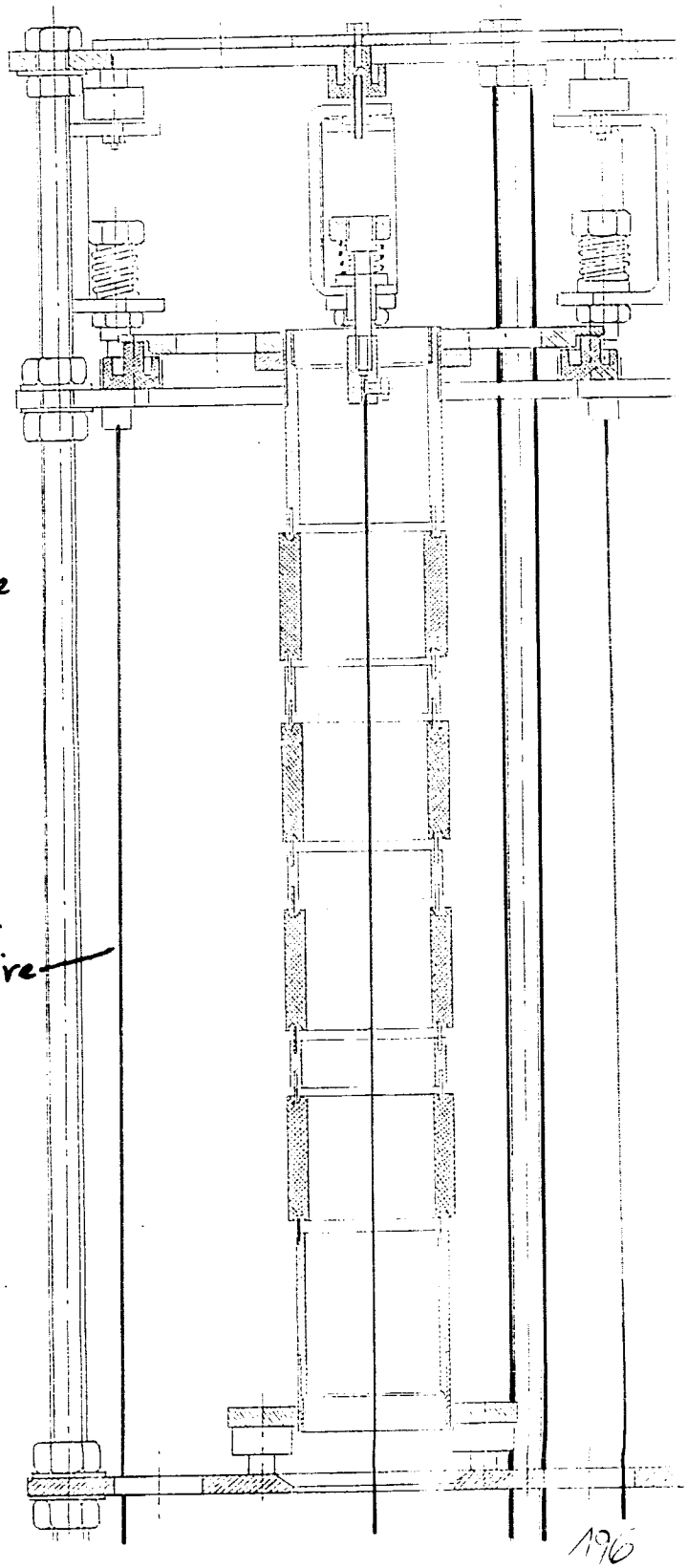
70 K windows - 20 pcs

"warm" windows - 20 pcs

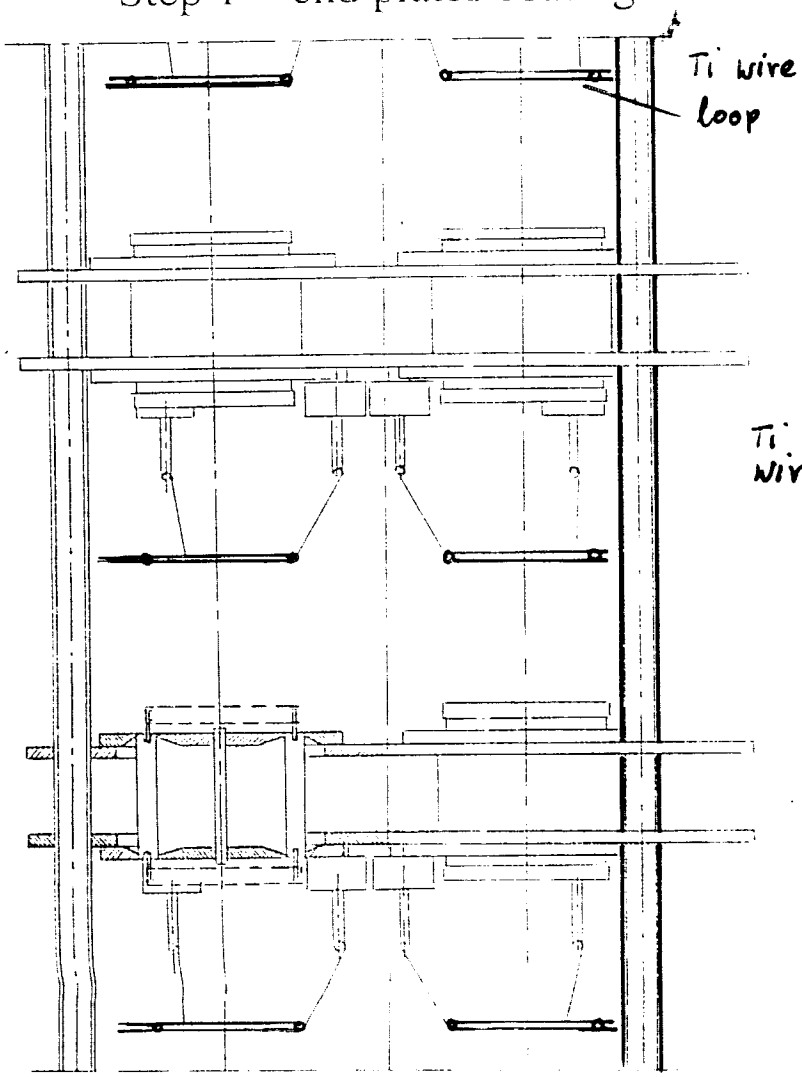


copper collar

Step 2 - coating of cylindrical surfaces



Step 1 - end plates coating



Summary

Experience with Ti deposition from vapour phase:

- ADVANTAGES:

- Can be used for surfaces with difficult access,

- The layer thickness distribution is calculable and well predictable,

- The process is relatively slow and easy to control,

- There is no need of substrate movement (rotation) under vacuum to reach good layer homogeneity.

DRAWBACKS:

- Slow Ti-TiN conversion,

- Possible problems with high residual conductivity,

- Using a chemically active atmosphere (NH_3) in a vacuum system (corrosion, no possibility of using cold traps).

Plans for the future

A new multipurpose device for antimultipactor surface processing:

- large number of RF components coated simultaneously,
- possible adaptation for other techniques (e.g. sputtering),
- monitoring and control system.