

TESLA - COLLABORATION

Transparencies from the
R & D Meeting at DESY, March 12 - 13, 1997



March 1997, TESLA 97-05

R & D Meeting at DESY, March 12 - 13, 1997

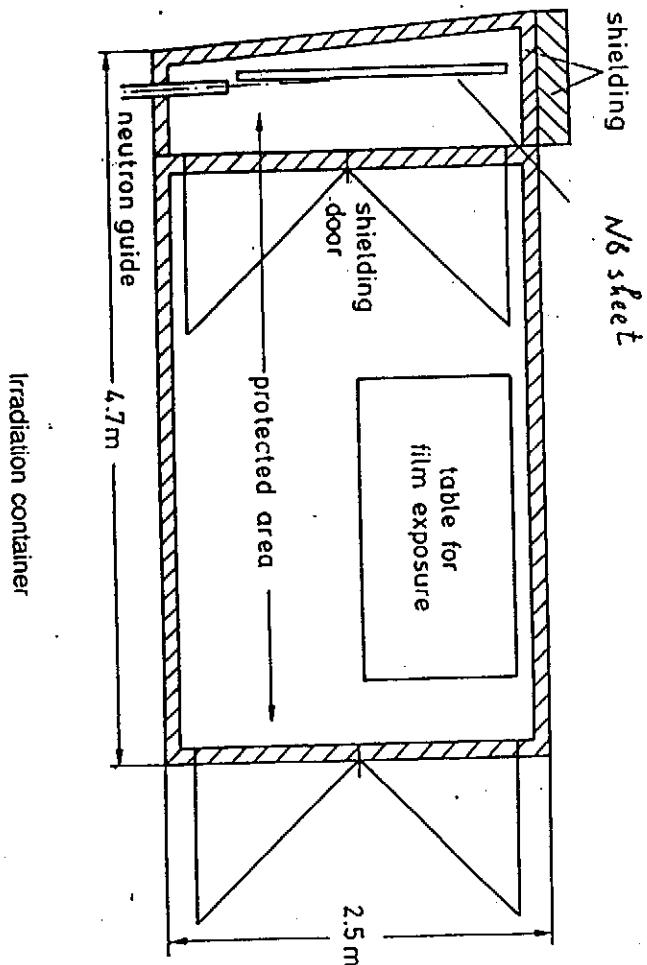
Contents of TESLA Report 97-05	I
<i>D. Proch</i> , Progress in Quality Control of Nb Sheets & Welds.....	1
<i>D. Gawlik, D. Proch, W. Singer</i> , Neutron Activation Analysis	14
<i>I. Campisi</i> , RF Losses in Nb/Cu Cavities	20
<i>H. Safa</i> , Heat Treatment	41
<i>H. Safa</i> , Q-Degradation.....	44
<i>P. Kneisel</i> , Q-Degradation without Field Emission.....	48
List of Participants	50

Progress in quality control of Nb sheets & welds

Why should we check the material?

- after "good" cleaning the max Eacc is not limited by field emission but by thermal instabilities (quench)
 - it is caused by a "defect" in the material, most likely a normal conducting spot
 - sometimes the limitation is unchanged after chemical etching (D6)
 - often the max Eacc is improved after successive chemical etching
- defect is a "bulk" property, not a pure surface effect
- all ACCEL cavities were limited at the weld

1



How can we check the material?

I Eddy current

fast scanning technique, sensitive to change of conductivity,
sensitive penetration can be adjusted by choice of frequency
(here: .3 mm)

IIa Roentgen Fluorescence

very sensitive surface technique, but slow, small area

IIb X-ray absorption

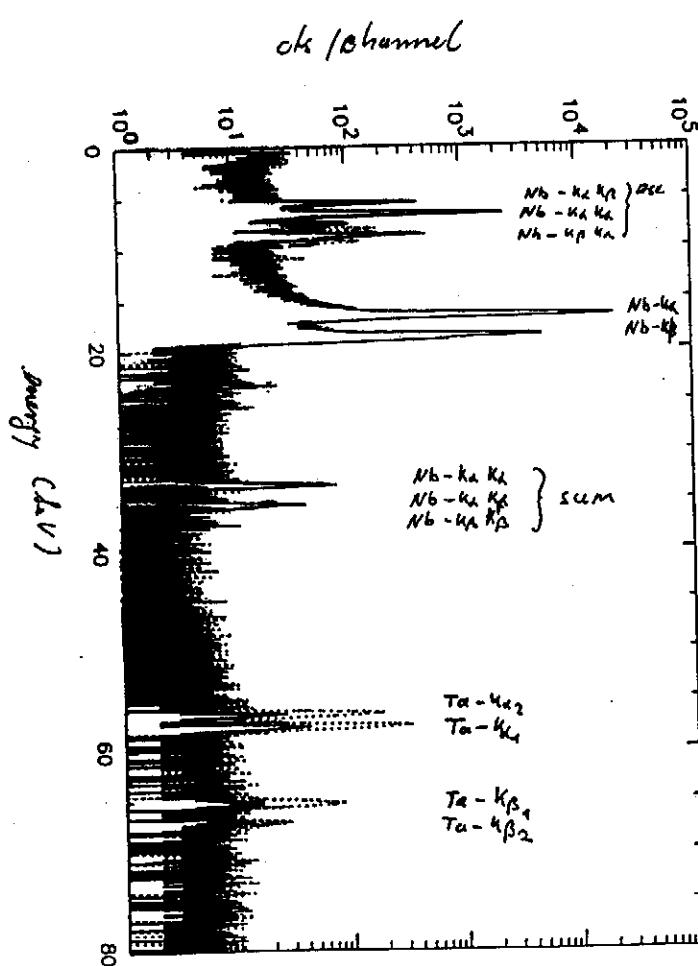
measures bulk properties,
but high sensitivity only for small surfaces

IIc Neutron activation

very sensitive bulk measure for Ta,
large area, but slow

2

LEITZ 4734
Made in Germany



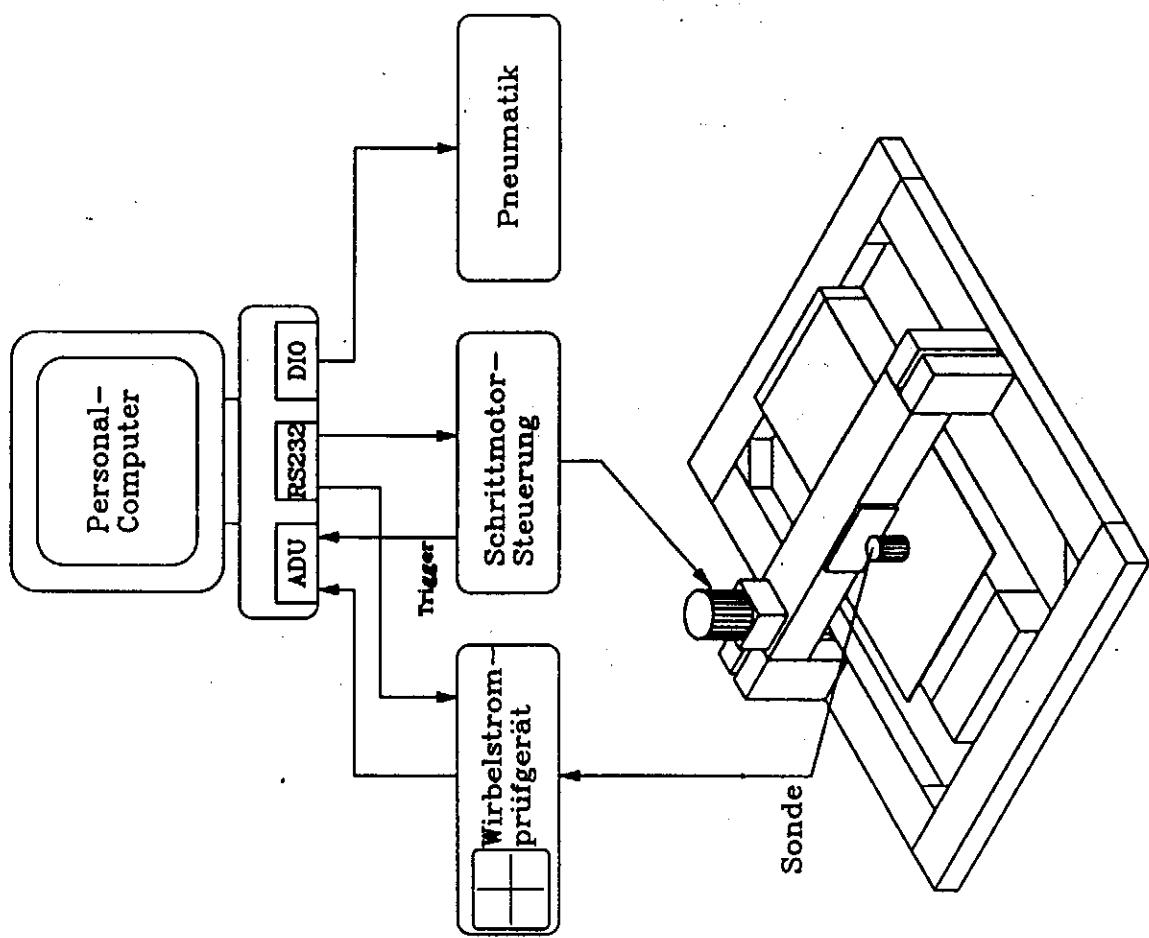
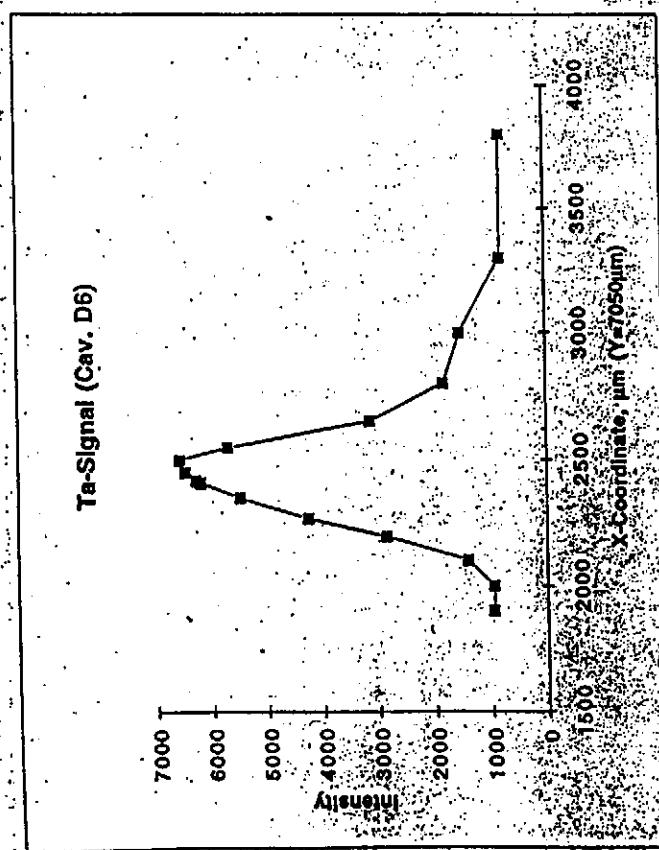
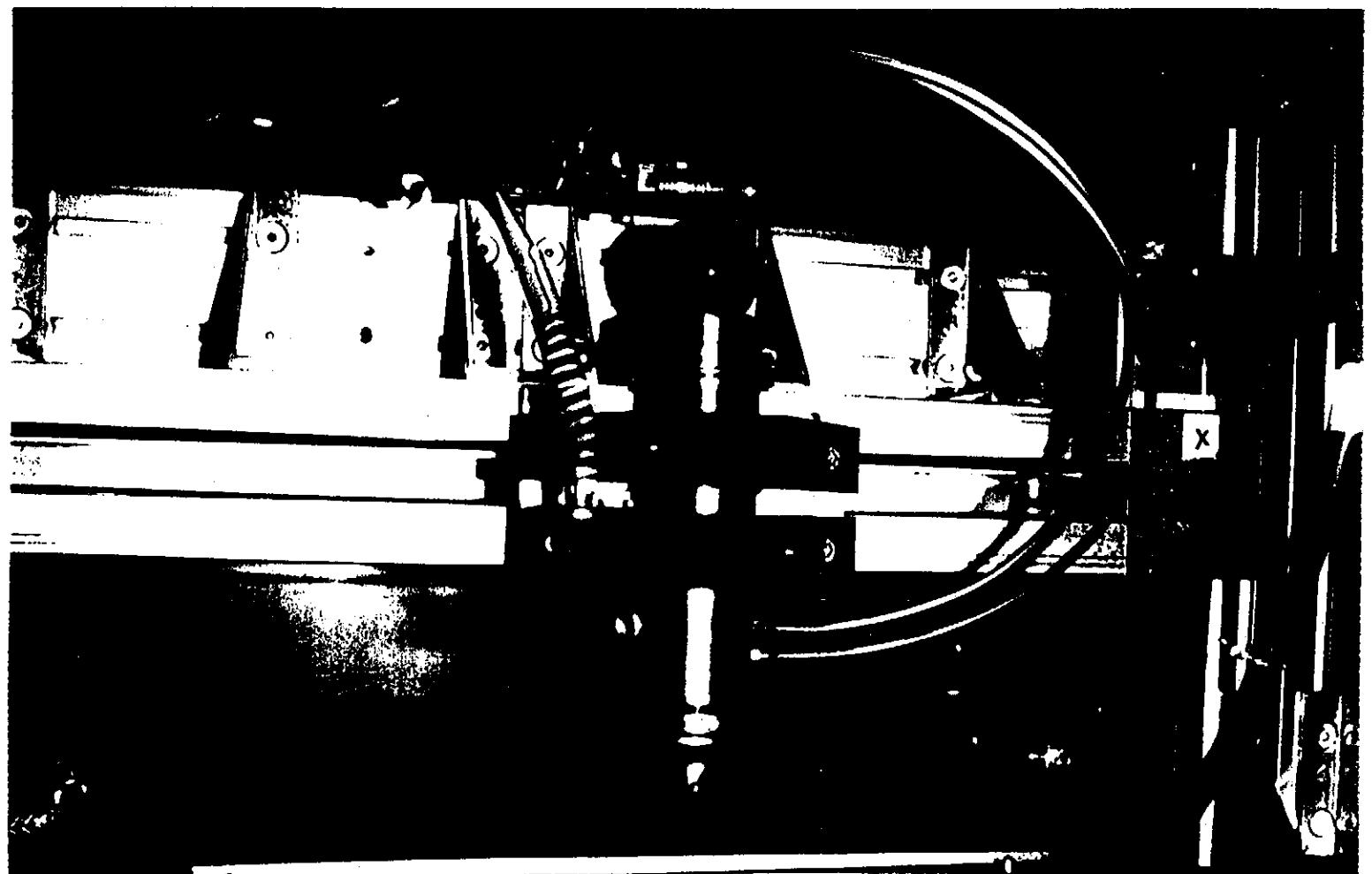
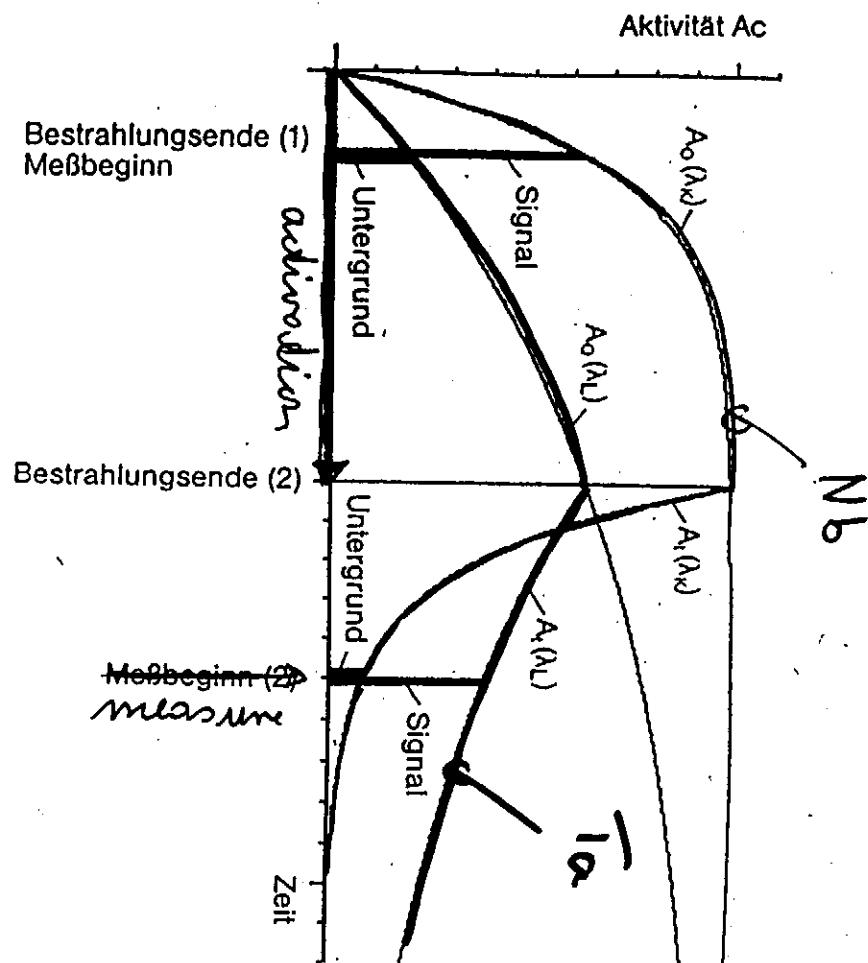


Abb. 1:
Schematische Ansicht des Prüfsystems für Niob-Bleche







What is our strategy?

- Fast scan of all sheets and welds by class I technique
- detailed analysis by class II technique on defects found by class I

What did we check so far?

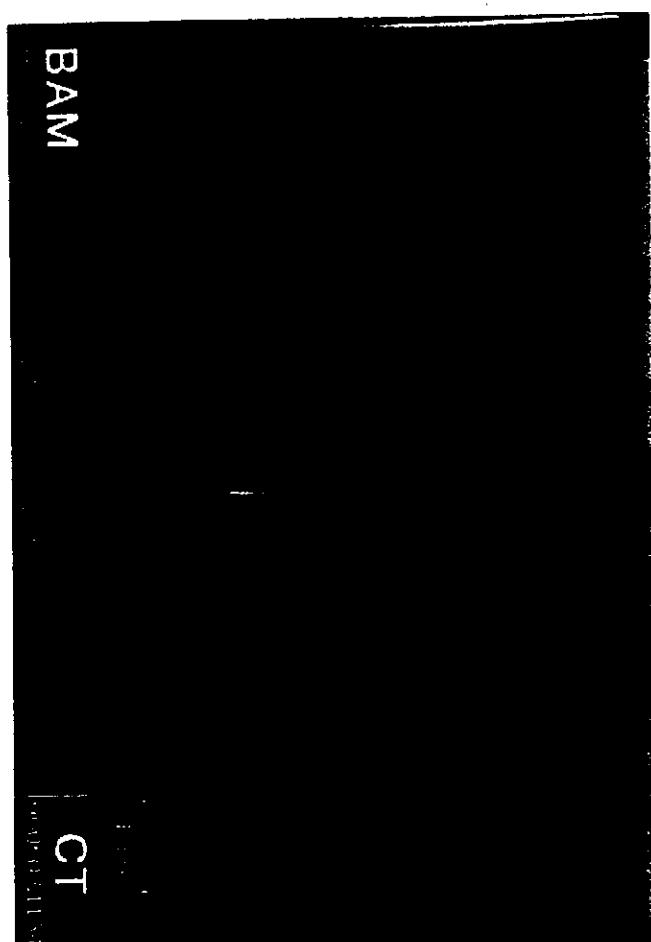
- 150 sheets by eddy current
- 40 welds by eddy current (S9, Dx, Cx, test welds on cells)
- all other: a few Nb defects (not more than 5)

What did we find in Nb sheets?

item	eddy current	röntg. fluor.	x-ray	neutron activat.
D6, defect cell	<u>X</u> , yes	<u>X</u> , Ta	<u>X</u> , heavy Z	
Cabot sheet	<u>X</u> , yes	X, no	<u>X</u> , heavy Z	X, (Ta) -----
Wah Chang sheet	<u>X</u> , yes	X, no	<u>X</u> , low Z	X, no
Heraeus sheet	X, yes	X, no		
Tokyo D. sheet	X, yes			
Ta defect test sheet	<u>X</u> , yes X , yes			<u>X</u> , (Ta) X , (Ta)

X, yes (no) : measurement, (no) finding
 — : correlation

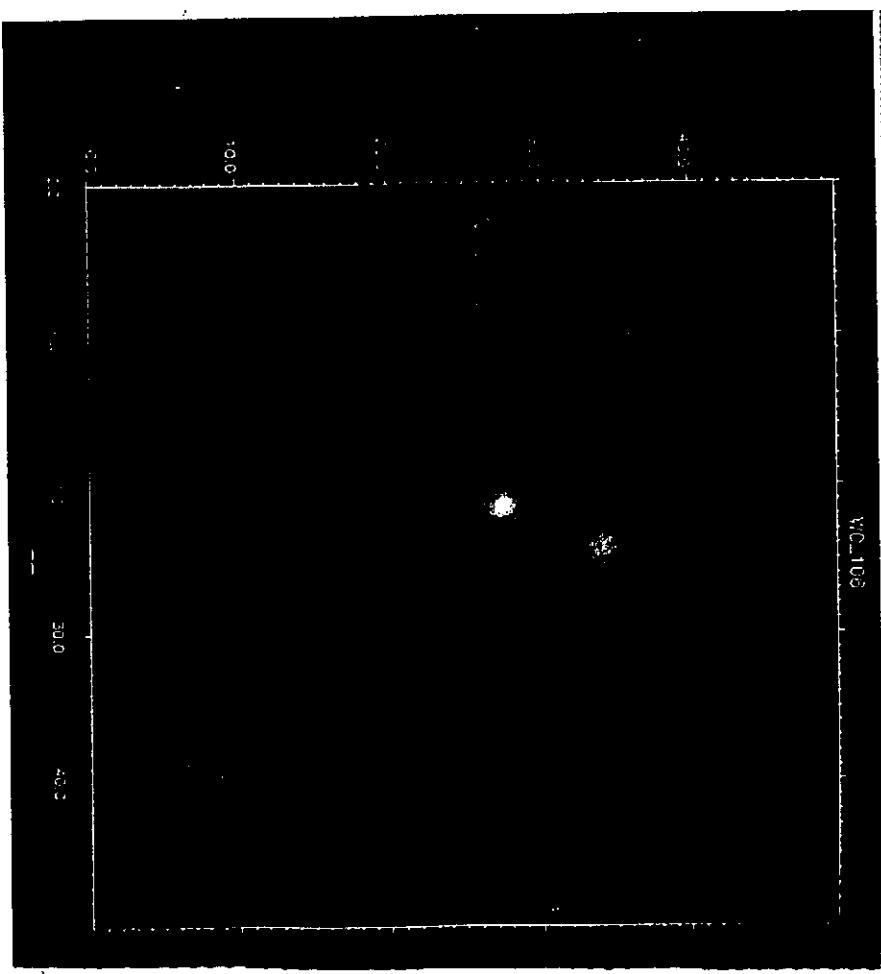
4



Bundesanstalt für Materialforschung und -prüfung (BAM)
Labor VIII.43

Unsere neuesten Meßergebnisse am Blech & Wah Chang 166>;

WC-108



Vorderseite

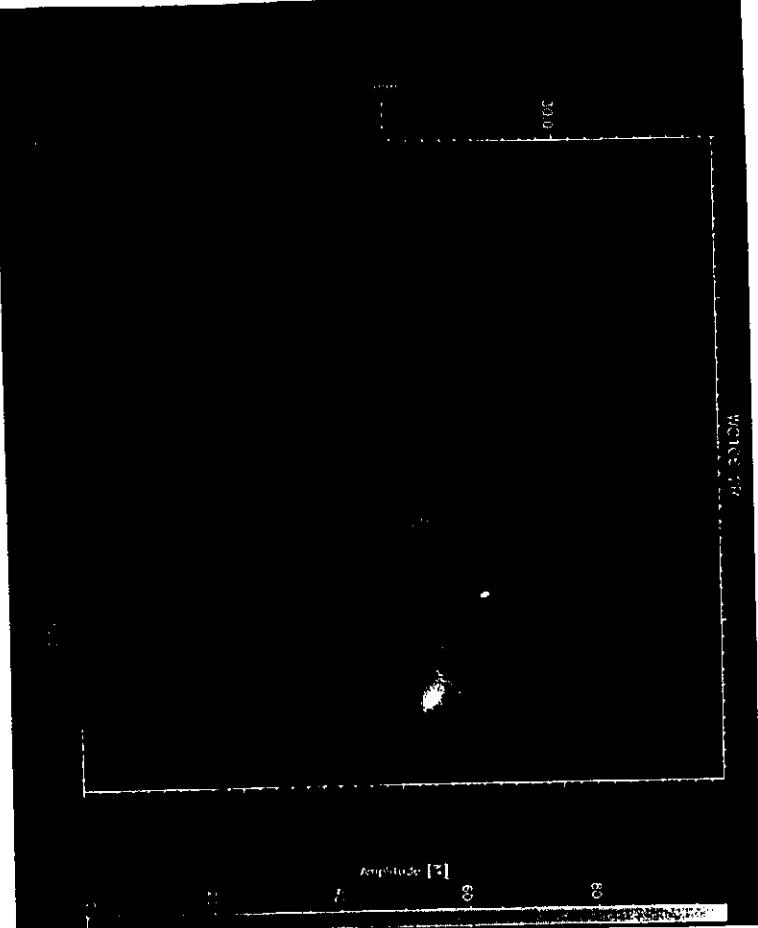
/usr/pdt/images/BAS1000/image/Detector/Detector2.tif
Wed Feb 5 11:58:53 1997 200
lakot 54

41

WOCHE 17/97

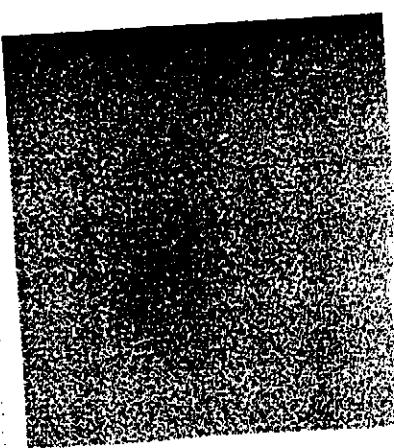
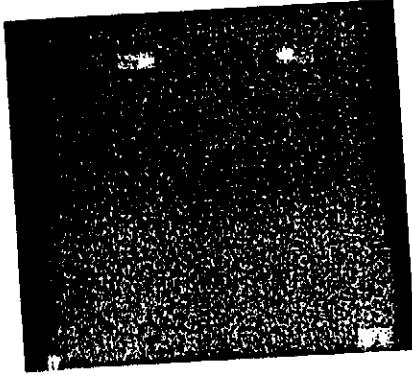
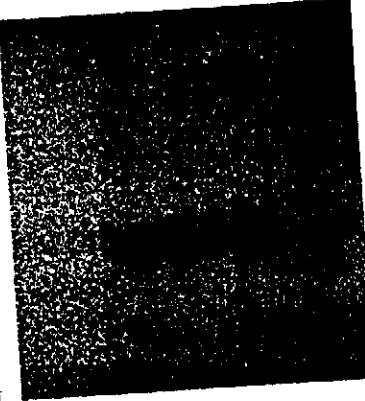
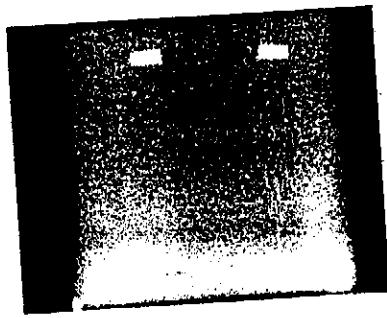
33.0

Rückseite

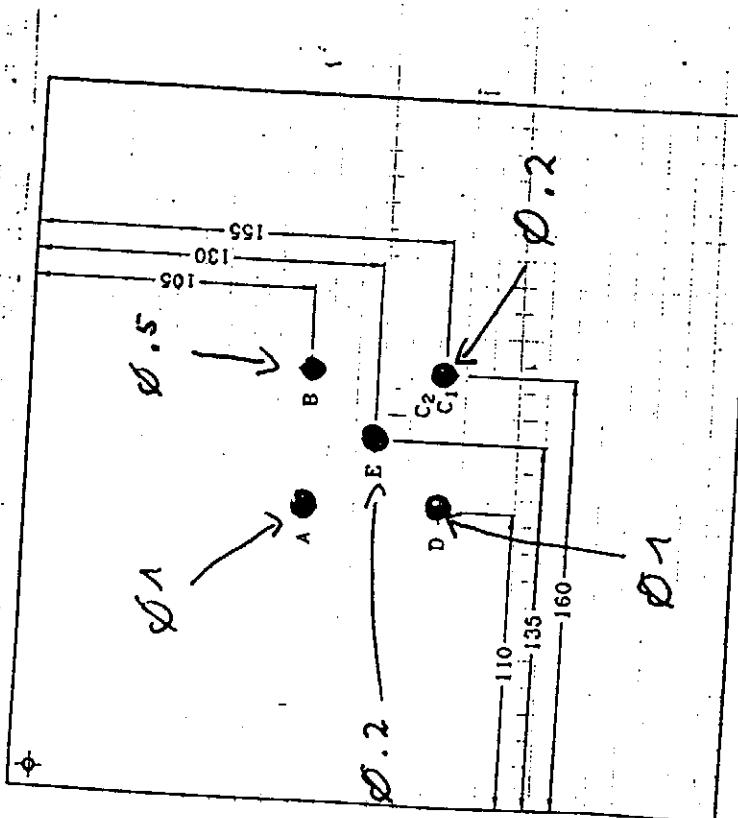


LEITZ 4734
Made in Germany

real thinnig



Testblech mit Ta-Einlagen



Fehler	σ	Tiefe
A	1	0.5
B	0.5	0.5
C ₁	0.2	0.3/0.2
C ₂	0.2	0.1
D	1	1
E	0.2	0.3

Positionenangaben = ungefähre Maße
die Bohrungen wurden mit Tantal-Draht gefüllt

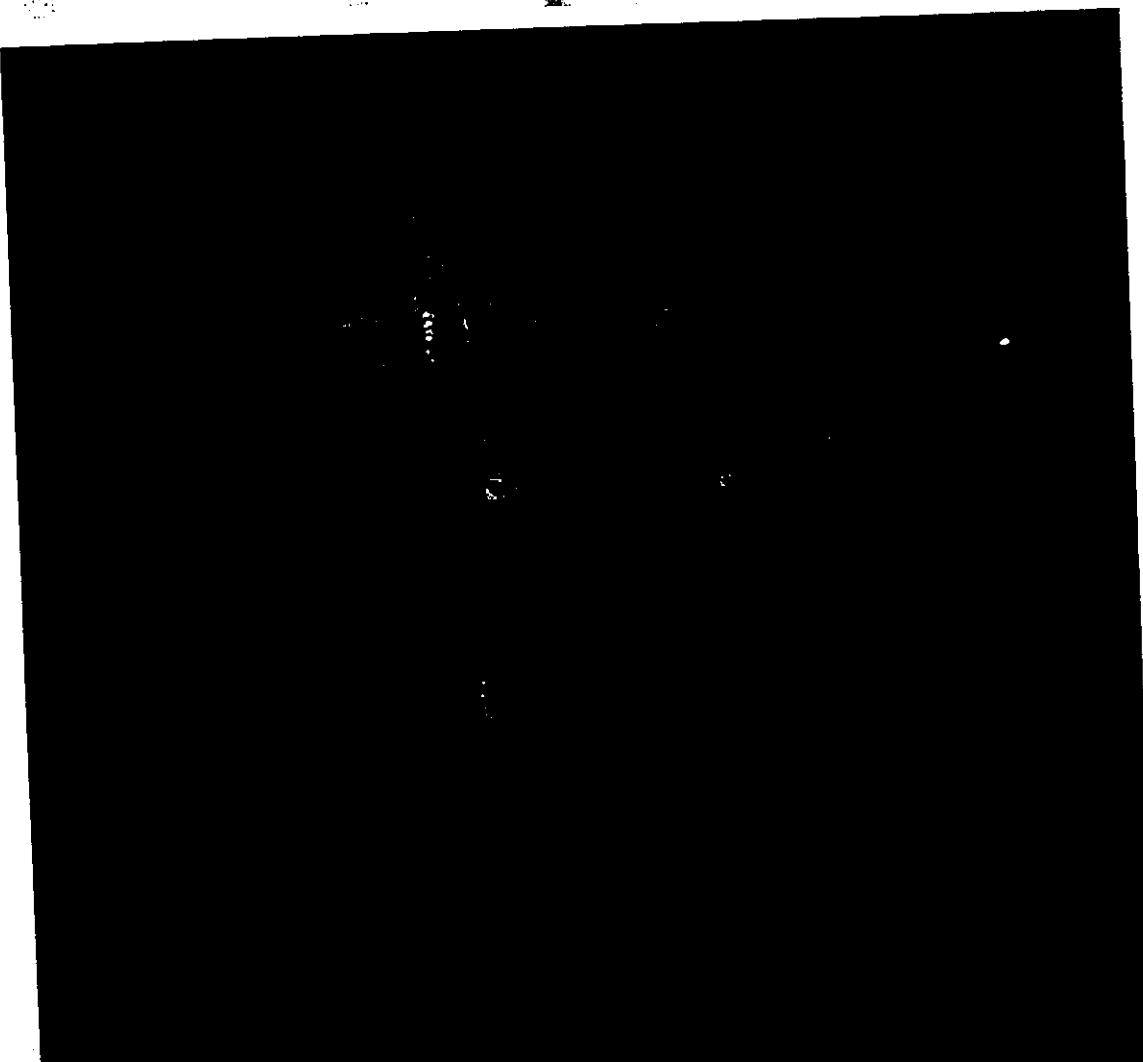
Blech Ca. 60 x 39

Techn. Zeichnung Nr. 17, 50 mm x 50 mm

HERAU MUSEZ : EXHIBITION ZEIT 27 IT0.
/usr/pdi/images/BAS1000/image/Dictor/Dieter11.img

FAX 0701
Thu Mar 6 15:09:45 1997 200

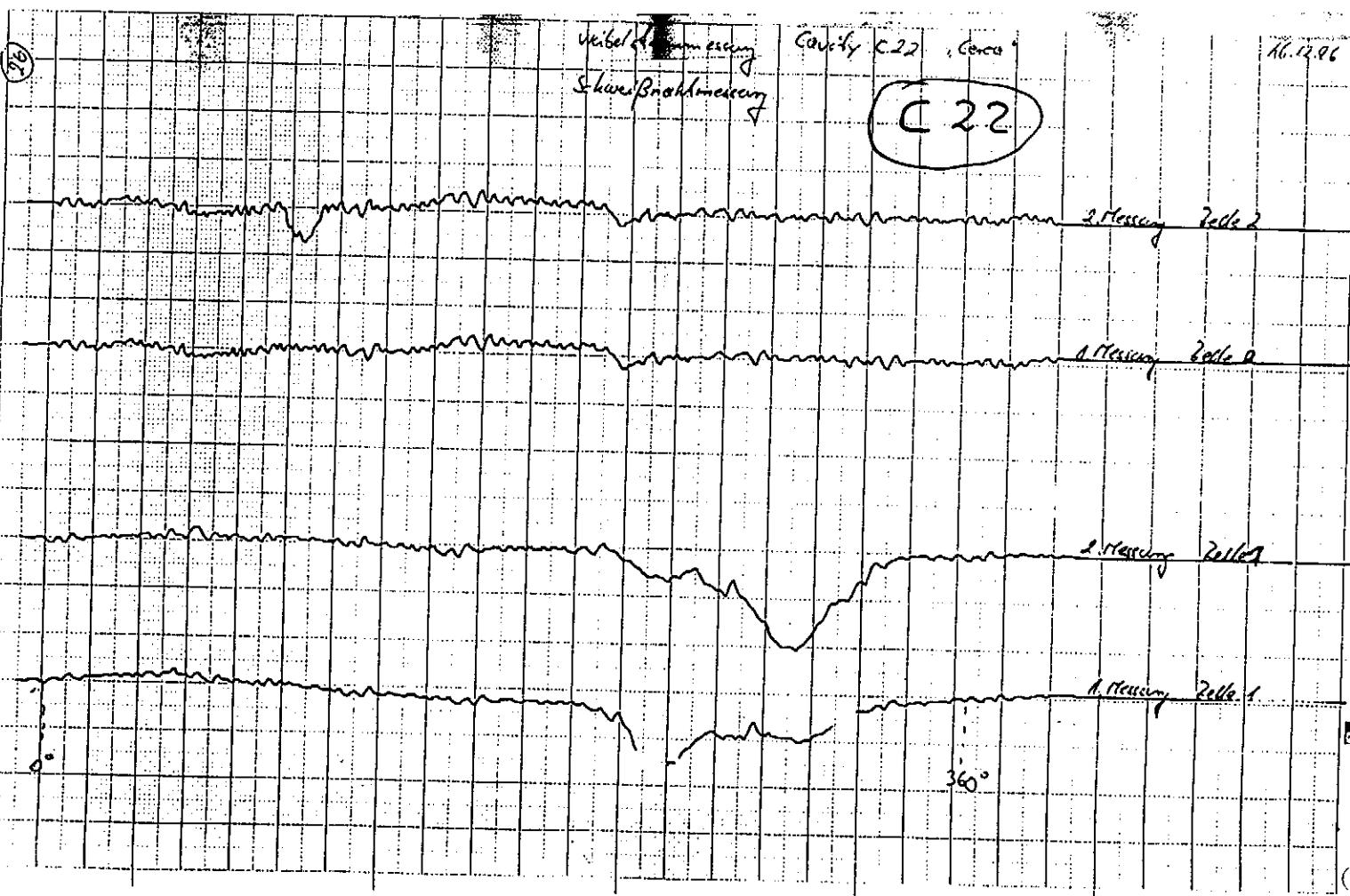
Qualitative increasing poly. Gmp, zw 27

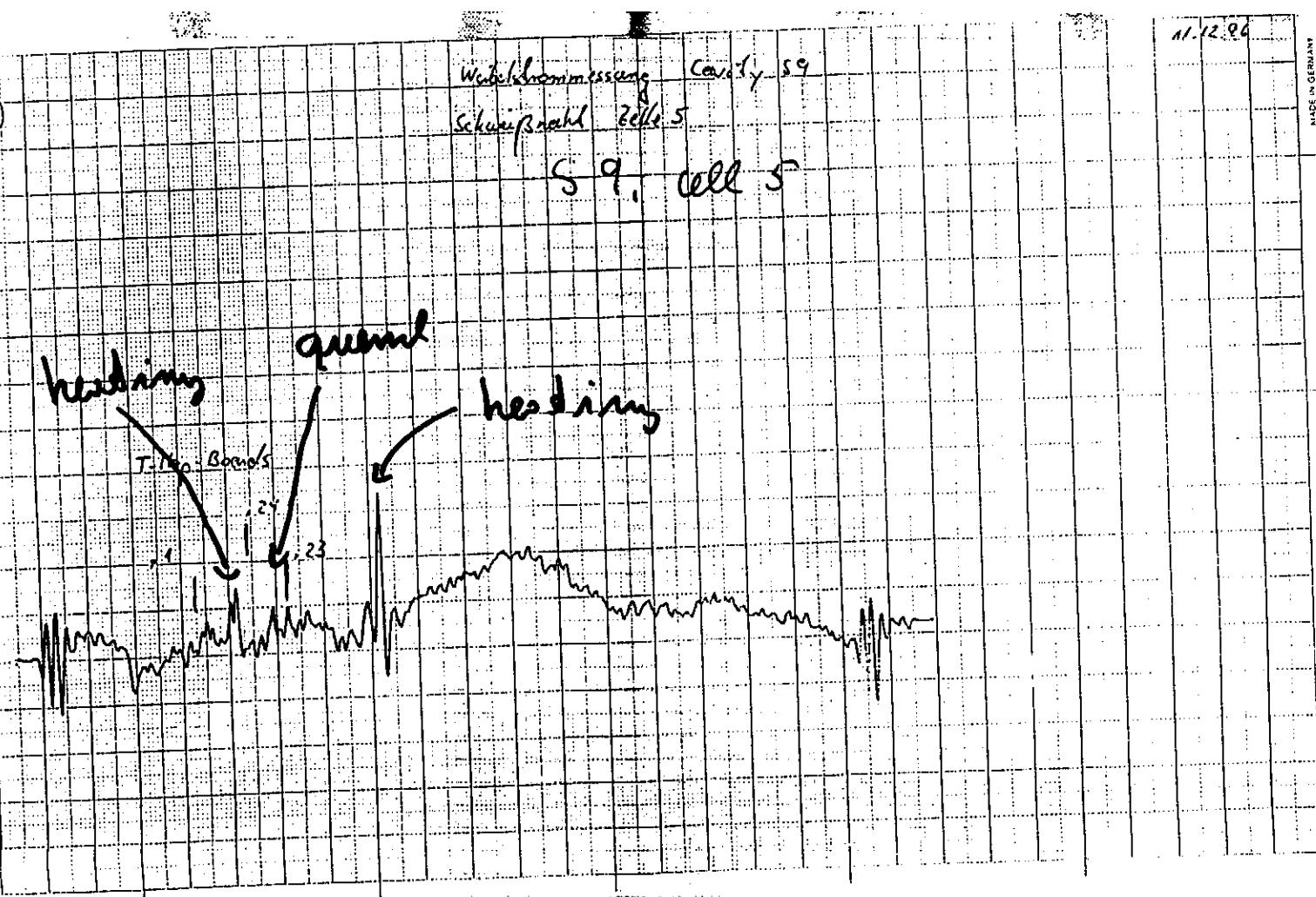
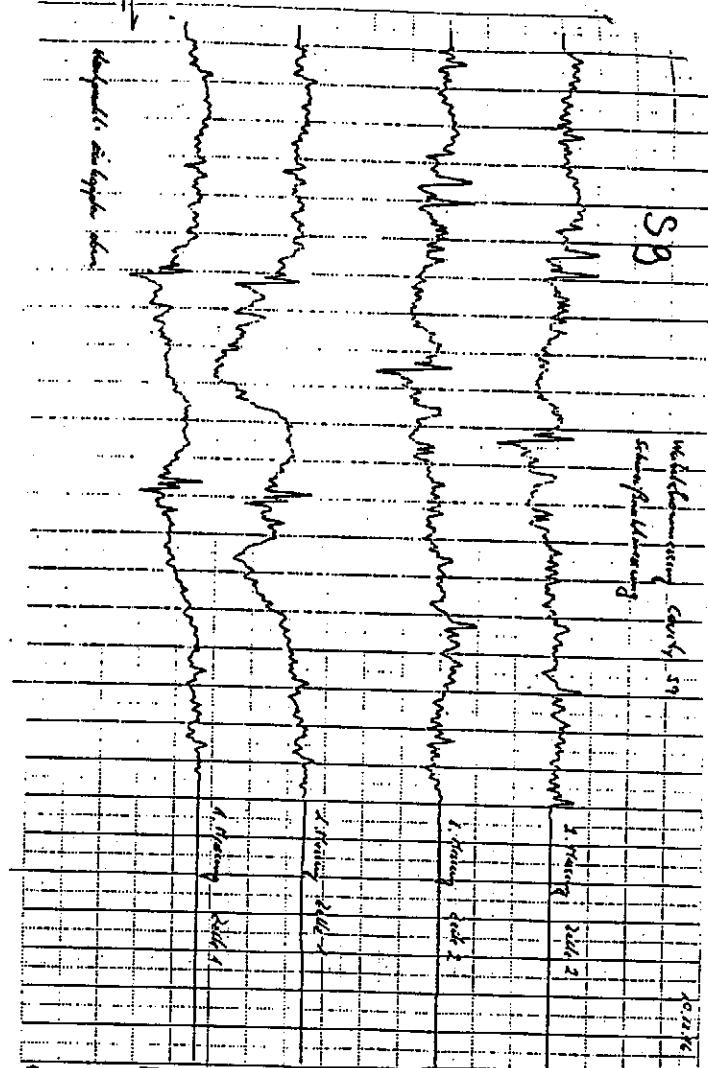
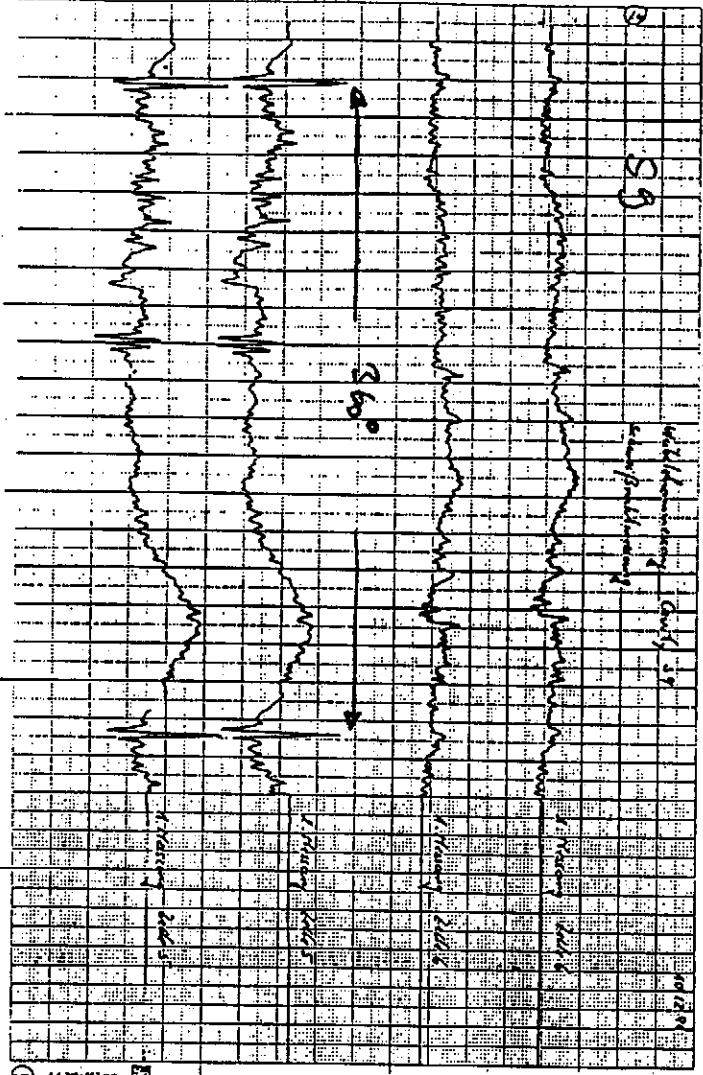


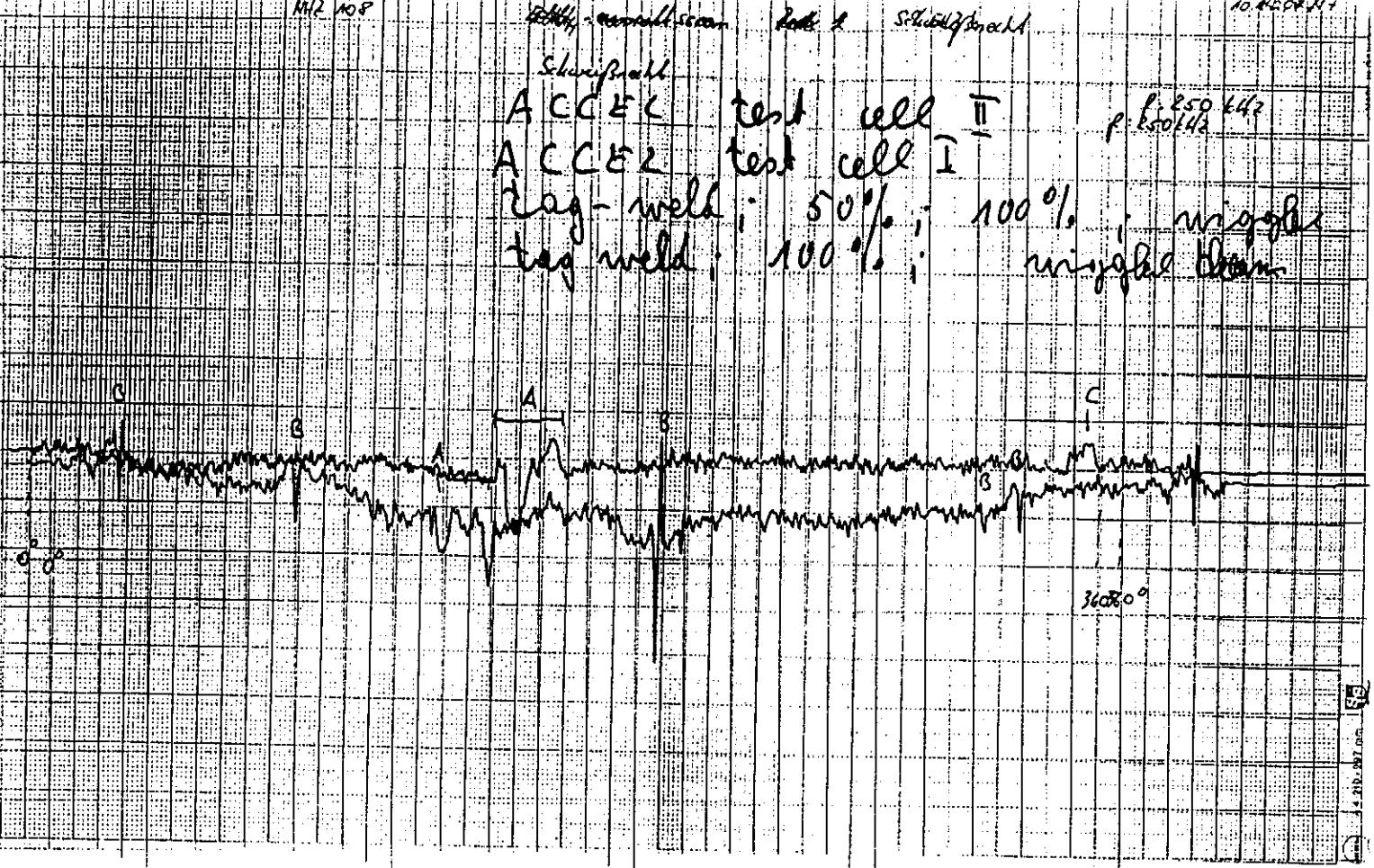
What did we learn from eddy current check of welds?

- eddy current signals of "good" welds (Dornier and CERCA cavities) and "bad" welds (ACCEL) were compared
- there is a clear difference in the signature of the eddy current signals:
 - a smooth signal in the first case
 - a noisy signal with sharp spikes in the second case
- there is correlation between the location of quench or excessive heating (RF measurement & temperature mapping) and the spikes in eddy current measurement
- the eddy current test is used now to optimize welding parameters (ACCEL, Zanon, SICN)

5







Conclusion

- clusters of foreign material have been found in Nb sheets
- at present (low statistic!):
 - this is true for all investigated vendors
 - it is rare (4 identified findings in about 150 sheets)
- Ta has been identified, but there is more
- welds:
 - it seems, there is a quality control of Nb cavity welds by eddy current

D. Gawlik, D. Proch, W. Singer

Neutron Activation Analysis (NAA)

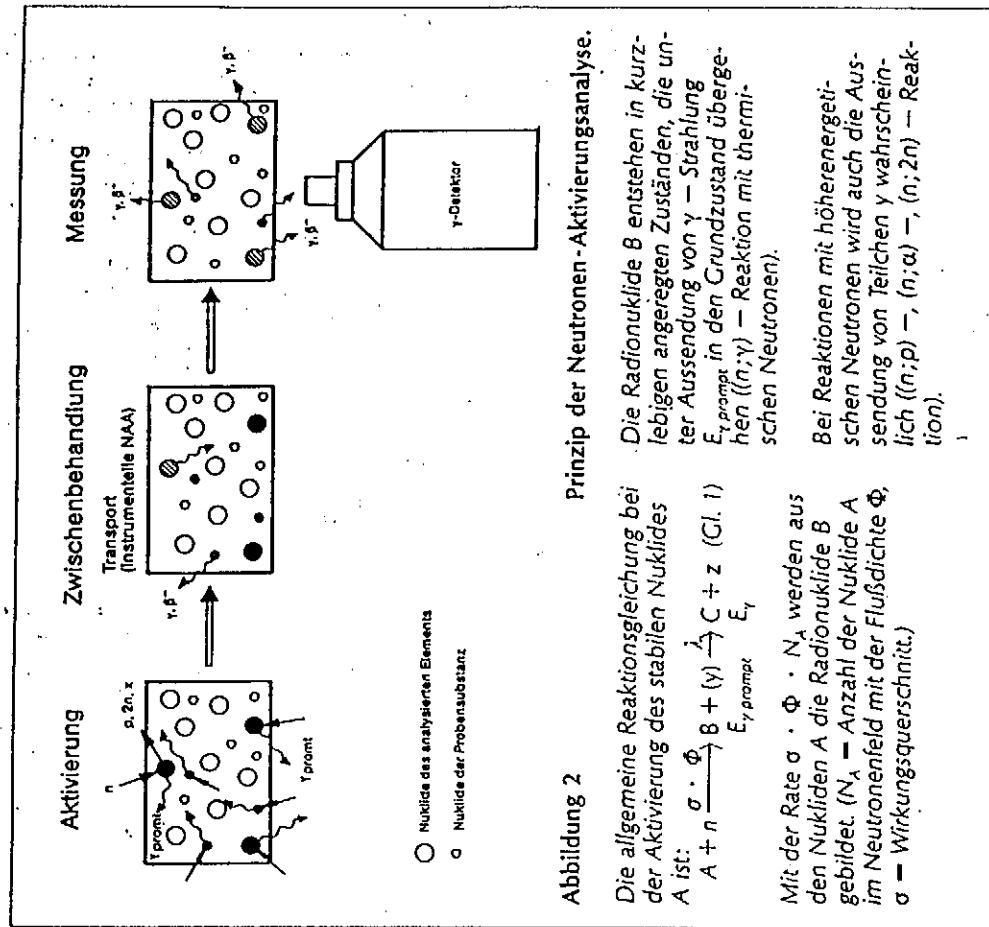
Hahn-Meitner-Institute Berlin GmbH

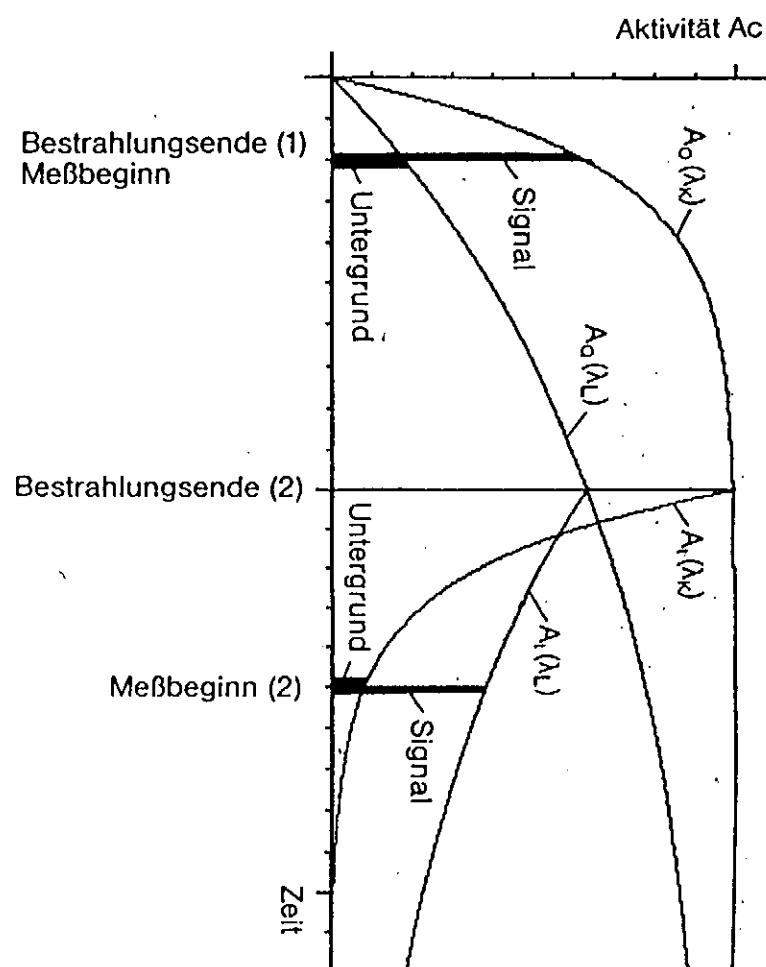
Contact person: Dr. Dieter Gawlik

Irradiation Devices at the Research Reactor BER II
High detection sensitivity, limits of detection
may be as low as a several ppm.

Very efficient for detection of Ta cluster in Nb.
Tantalum creates a long lived isotope with half
lives time $\Delta t(Ta) = 115$ days, that is bigger as of a
most another elements. For instance $\Delta t(Nb) = 6,2$
min.

- First step: Nb sheet is placed in a beam of thermal neutrons (flux density about $10^9 \text{ cm}^{-2} \text{s}^{-1}$) for about 5 hours. Radioactive isotopes with characteristic half-life time are formed.
- Second step: The total radiation of the Nb sheet is measured after a half hour with a pure germanium detector at a distance of 50 cm. The Nb sheet is slightly radioactive and emits gamma rays, the count rates of selected photo-peaks in the gamma spectrum are measured. Comparing the count rates of sample with those of standard sample the content of the element can be calculated.
- Third step: The highly sensitive image plates be in contact with activated Nb sheets for two-three days. Ta clusters can be localized due to black spots on the image plates.

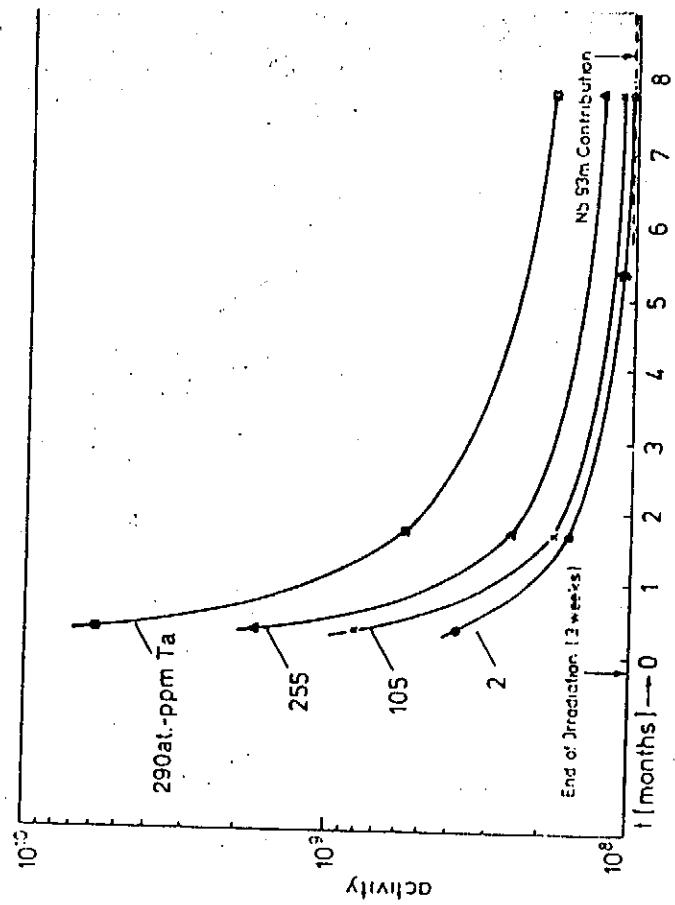
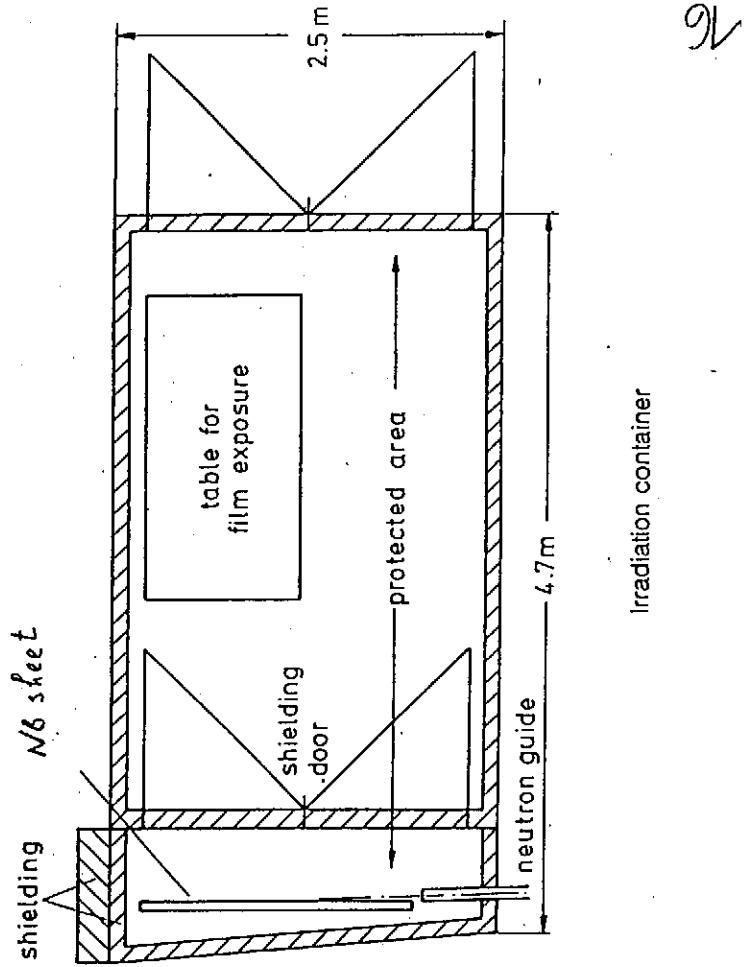




Bestrahlungszeit (T_{irr}) < 10 min

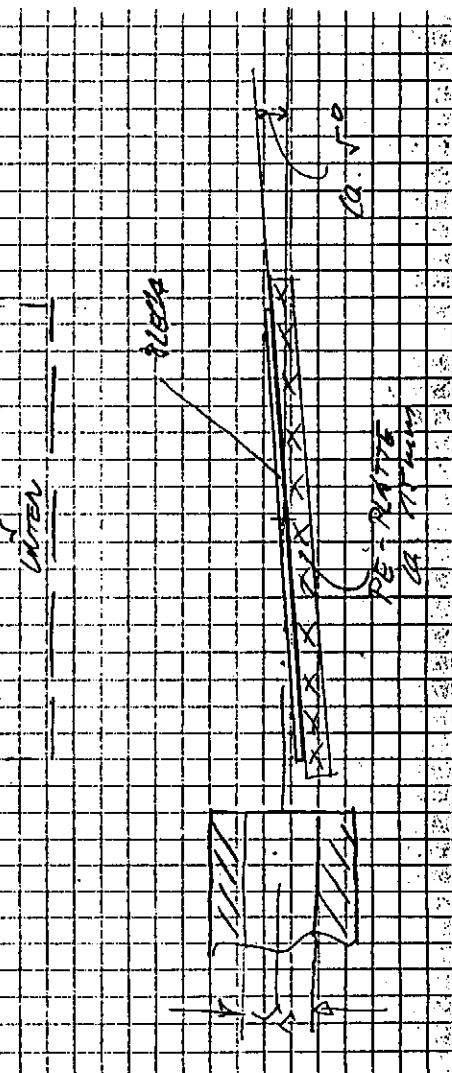
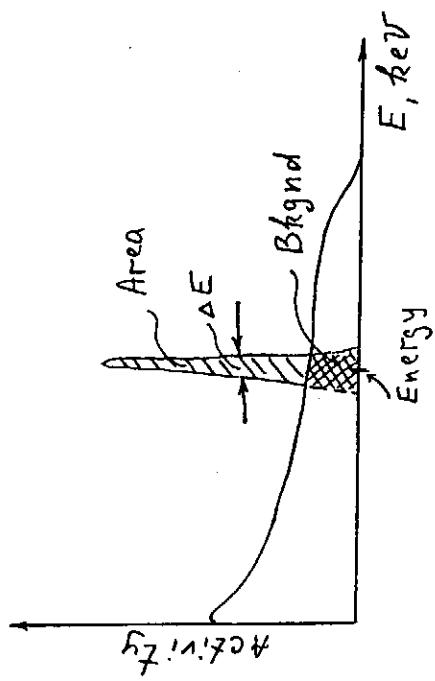
Kein Nachweis möglich

Li	Be	Mg	Na	Al	Si	P	S	Cl	Ar	Ge	Zn	Cu	Ru	Tc	Zr	Y	Sc	V	Cr	Mn	Fe	Ga	As	Se	Br	Kr	Xe	Pt	Au	Hg	Tl	Pb	Bi	159	Re	Ds	Ir	45	0,6	23	5	5x10 ⁻⁴	W																																	
noY	noY	noY	noY	0,02	0,02	0,02	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01																									

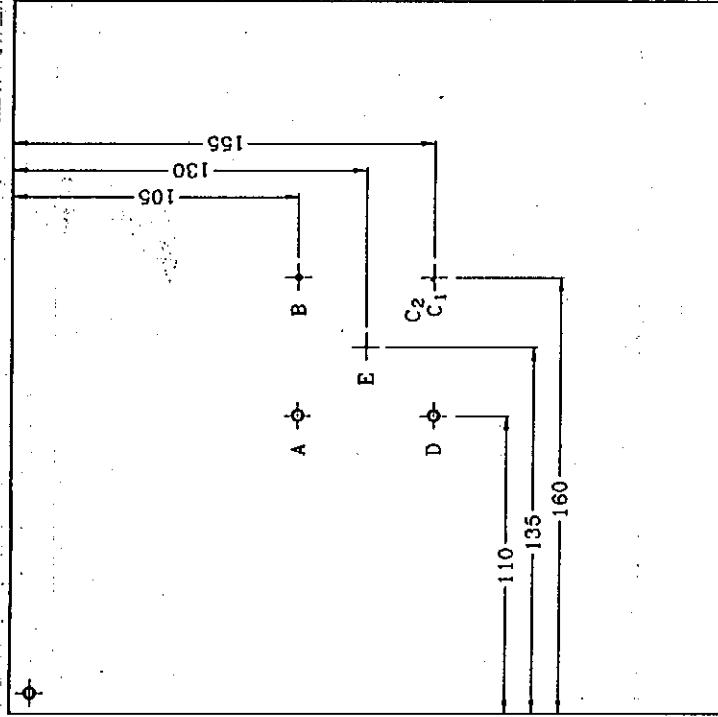


Nuclide Identification in the Nb Sheet (Cabot 34)
Irradiation time 5 hours, start of measurement after 30 min.

Energy, keV	Area	Bkgnd	ΔE , keV	Error, %	Nuclide	Ta theor. line, keV
99.95	329	1165	0.79	20.2	Ta-182	100.1
134.28	168	796	0.93	30.2	W-187	
152.63	313	716	1.09	15.9	Ta-182	152.4
156.57	200	654	0.84	23.3	Ta-182	156.4
179.75	145	592	1.18	30.2	Ta-182	179.4
222.18	367	519	1.02	12.30	Ta-182	222.1
229.3	176	420	1.03	21.5	Ta-182	229.3
238.75	124	385	0.97	29.1	Th-232	
264.04	174	343	1	20.7	Ta-182	264.07
294.79	67	291	1.16	47.4	Ra-226	
352.15	138	174	1.24	19.3	Ra-226	
479.46	298	181	1.22	10.8	W-187	
551.65	108	75	1.13	18.2	W-187	
583.67	119	106	1.67	20.4	Th-232	
609.54	112	113	0.98	20.3	Xe-135	
618.68	97	122	1.23	26.3	W-187	
685.79	308	104	1.58	9	Mo-93	
772.94	58	65	1.66	29.1	Th-232	
911.27	84	78	1.44	23.7	Th-232	
1121.56	608	46	1.80	4.6	Ta-182	
1189.23	251	45	1.57	8.6	Ta-182	
1221.88	394	60	1.63	6.3	Ta-182	1121.3
1231.48	162	56	1.91	13	Ta-182	1189.05
1290.87	29	25	4.68	43.8	Fe-59	1221.42
1461.31	507	18	2.03	4.8	K-40	1230.97
1765	35	5	1.18	20.7	Ra-226	



Testblech mit Ta-Einlagen



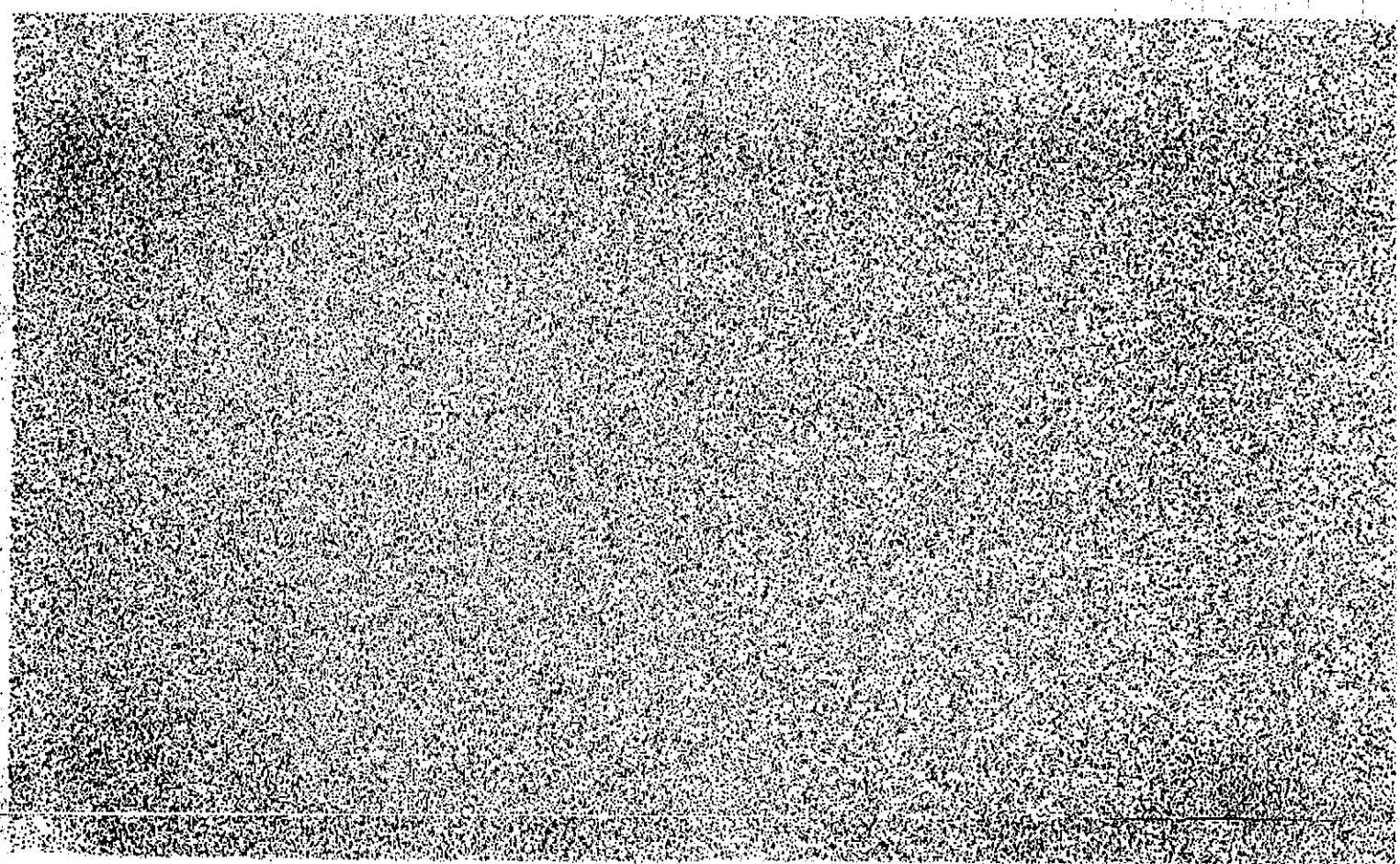
Fehler	ϕ	Tiefe
A	1	0.5
B	0.5	0.5
C1	0.2	0.3/0.2
C2	0.2	0.1
D	1	1
E	0.2	0.3

Positionsangaben = ungefähre Maße
Alle Bohrungen wurden mit Tantal-Draht gefüllt

Blech Ca. 60 + 39

TWE 106 4h belichtet

/usr/pdi/images/BAS1000/image/Dieter/wahchan2.img linke Platte Fri Feb 28 14:06:48 1997



RF LOSSES IN

Nb/Cu CAVITIES

A progress report

C. BENVENTU

S. CALATRONI

E. CAMPISI

C. DARRIULAT

C. DURAND

M. PECK

R. RUSSO

Also

S. Marsh

S. Sgobba

N. Renning

The motivation is to improve our understanding of the physics mechanisms responsible for RF losses in Nb/Cu cavities such as those in use at LEP

The method consists in a systematic study of the dependence of the surface resistance of Nb/Cu films on various parameters of relevance

For convenience we use 1.5 GHz monostatic models of the LEP cavities operated in the fundamental ($\pi^{\text{M}010}$) mode

$$Z_s = R_s + iX_s$$

$$R_s = \frac{2.95 \Omega}{Q} \quad 10 \Omega \Rightarrow Q \approx 310'$$

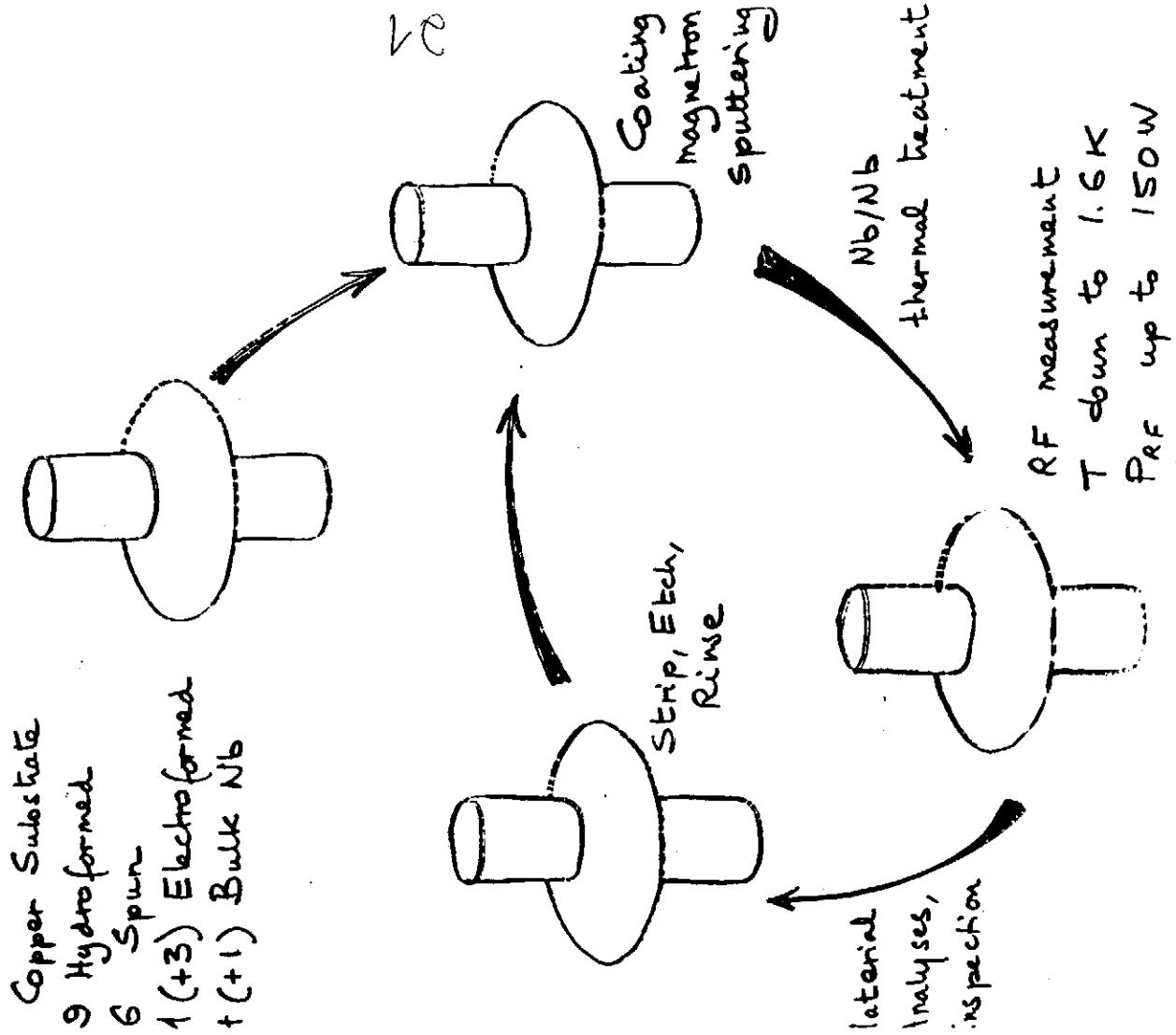
$$\frac{H_{RF}}{E_{acc}} \approx \frac{4 \text{ mT}}{1 \text{ MV/m}}$$

$$\text{RF Losses} \propto \frac{1}{2} \int R_s H_{RF}^2 ds$$

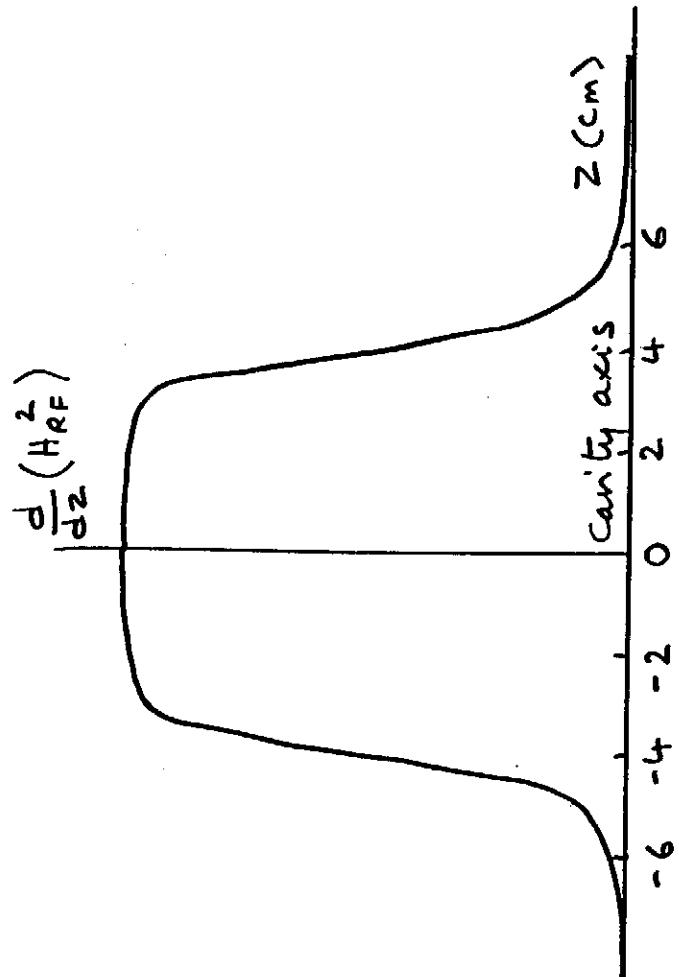
Aim and Method

SL Seminar
27/02/97

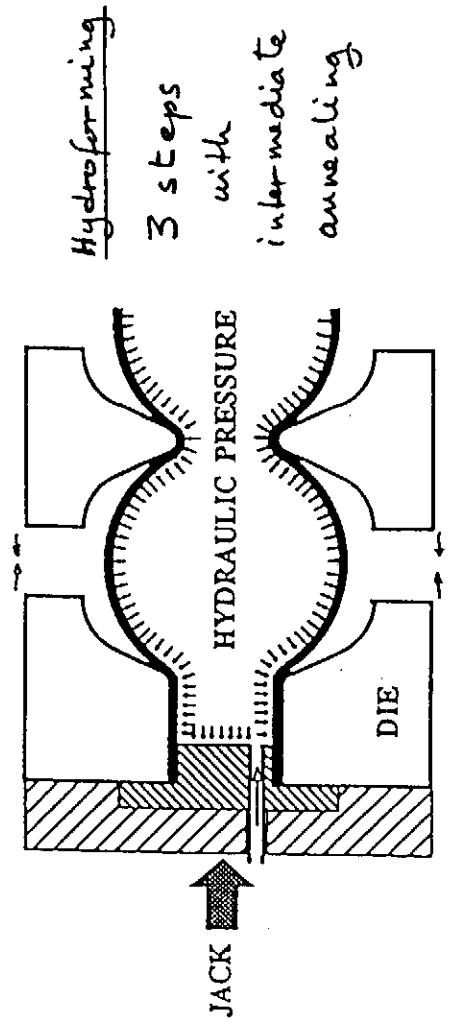
Standard Procedure



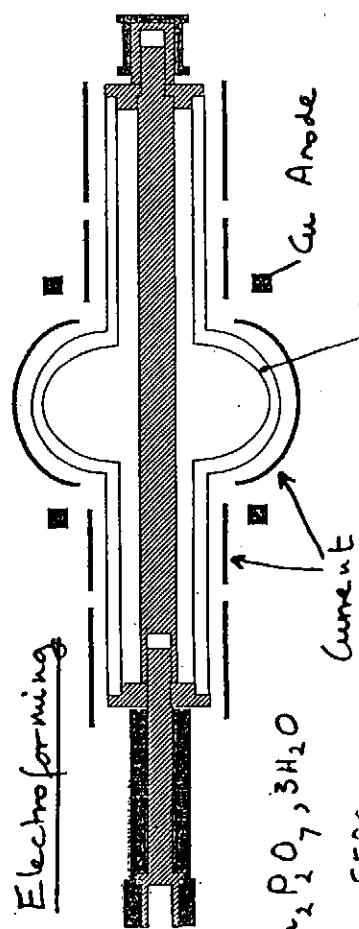
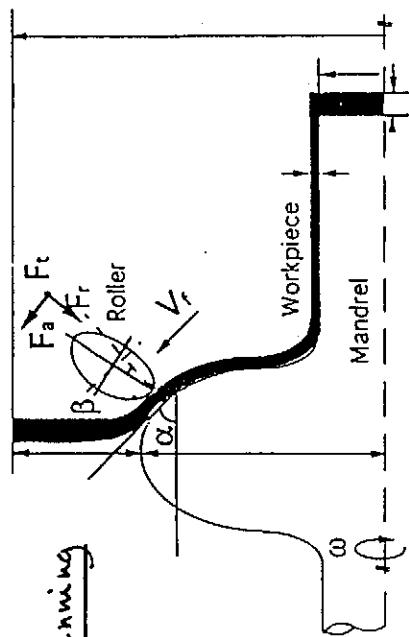
Variation of the RF field along the cavity wall



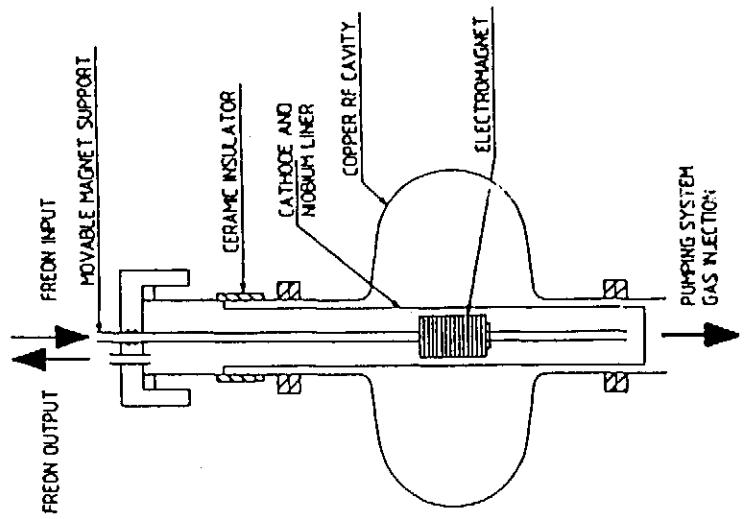
The Copper Substrate



Lathe Spinning



Film Sputtering

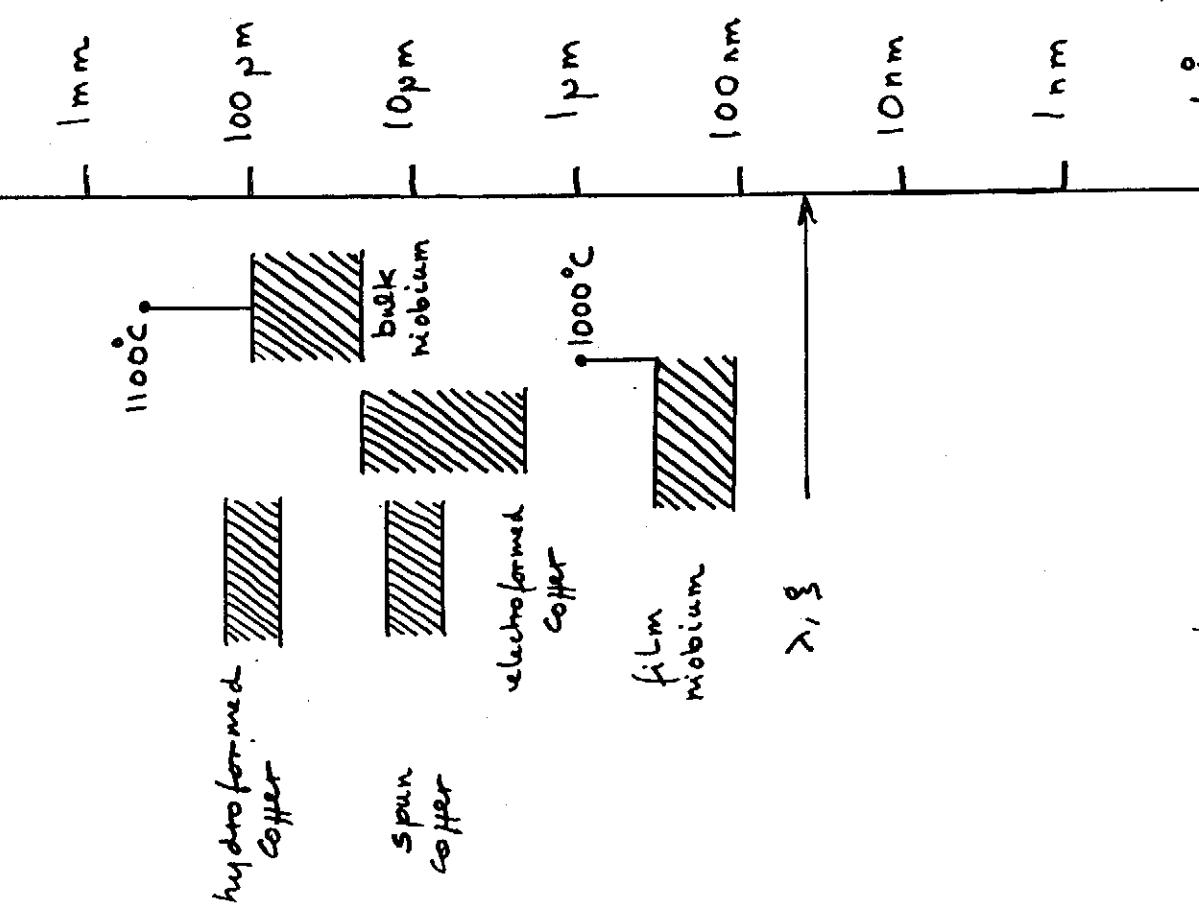


Discharge Parameters

Argon Pressure	$1.5 \cdot 10^{-3}$ mbar
Argon Contamination	$\approx 0.4\%$
R.R.R.	$= 20 - 30$
Grain Size	$\approx 200 \pm 100$ nm

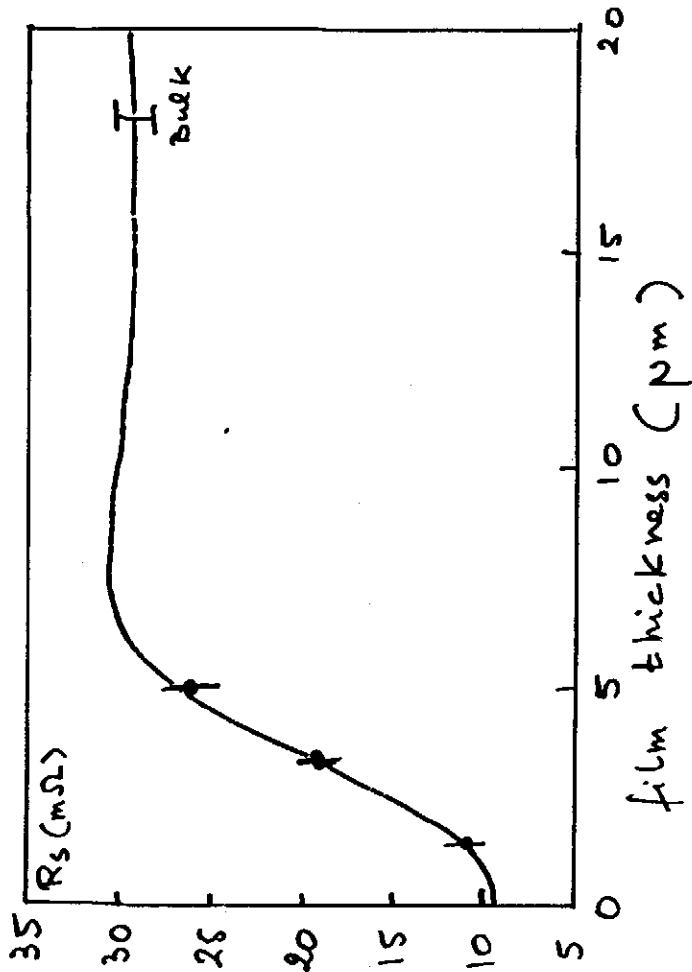
TEMPERATURE: $150 - 160^\circ C$

Grain sizes



Film thickness

Checking the average film thickness at room temperature



sensitive for thicknesses

↙ skin depth

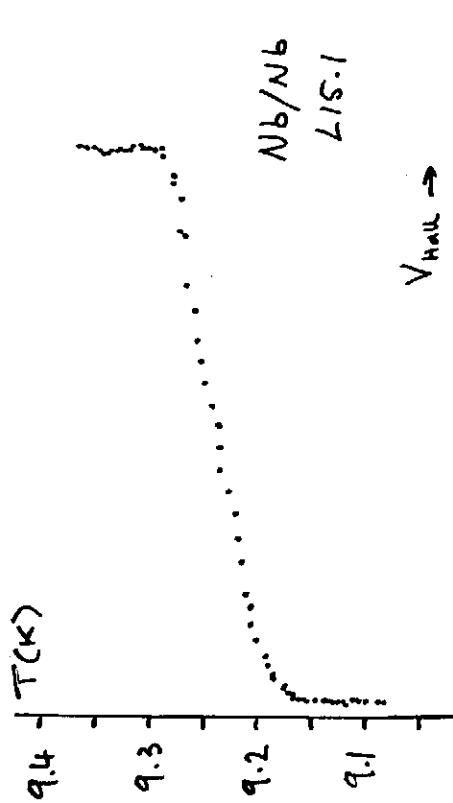
We observe no significant dependence
of R_s on film thickness

Critical temperature

Measuring up to T_c :

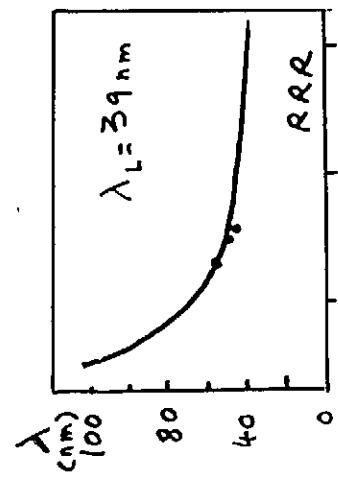
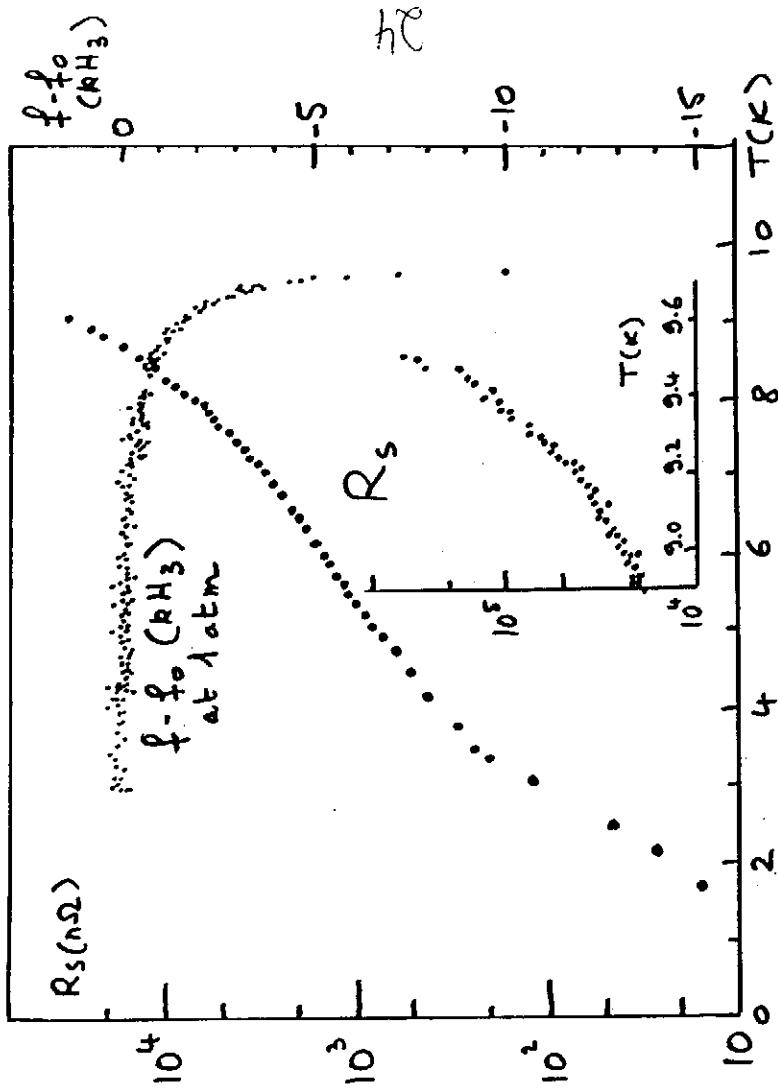
the surface reactance
and the penetration depth

Measured by watching the
dependence on temperature of
the magnetic field in the vicinity
of the cavity wall when warming
up slowly from a "the He II" state



Typically $T_c \approx 9.2$ K for bulk Nb
and Nb/Nb_x ≈ 9.5 to 9.7 K for Nb/Cu

This result is consistent with
the expectation from the stresses
in the film (due to the different



Theory

Barddeen Cooper Schrieffer / Eliashberg

$$(H - E) | \psi \rangle = 0$$

$$H = H_0 + H_{\text{pert}}$$

$$\frac{p^2}{2m} \rightarrow \frac{(p - \frac{e}{c} A)^2}{2m}$$

$$H = \nabla_A A \quad \nabla \cdot A = 0$$

$$H_{\text{pert}} = -\frac{e}{2mc} (p \cdot A + A \cdot p)$$

No second order

calculation available

$$|\psi_{CS}\rangle = \int \pi_k \left\{ \cos \theta_k |k\uparrow, -k\downarrow\rangle + \sin \theta_k |0\rangle \right\} |q\rangle$$

Bloch + impurities \int
Meissner effect \bigcirc

$$\Delta \approx \hbar \omega_D / \sin \left\{ \frac{1}{e \tau v} \right\}$$

$$g = \mu_B / \Delta$$

Motis Bardeen / Abrikosov Gor'kov Khaletnikov

$$(H - i \hbar \frac{\partial}{\partial t}) |q\rangle = 0$$

Using the same approximations \rightarrow result not
expressible in analytic form but

$$R_s \approx \frac{\omega^2}{T} \exp \left(-\frac{\Delta}{T} \right) \left(\ln \frac{4T}{\omega} \right)$$

In simpler words...

Alt variance with DC superconductivity
RF superconductivity includes RF losses
essentially due to the scattering of
unpaired electrons

$$R_{BCS} \propto \frac{\omega^2}{T} \exp \left(-\frac{\Delta}{T} \right)$$

$$\text{For Nb } T_c \approx 9.2 \text{ K}, \Delta \approx 1.8 \text{ to } 2.0 \text{ T}_c$$

$$\lambda \text{ (penetration depth)} \approx 3 \text{ (coherence length)}$$

$$\approx 40 \text{ nm at } 0 \text{ K}$$

$$\text{For a real (non-ideal) superconductor}$$

$$R_s = R_{BCS} + R_{\text{res}}, \text{ where } R_{\text{res}}$$

$$\text{induced by the presence of } \text{defects. Data show that } R_{\text{res}}$$

$$\text{has no strong temperature dependence}$$

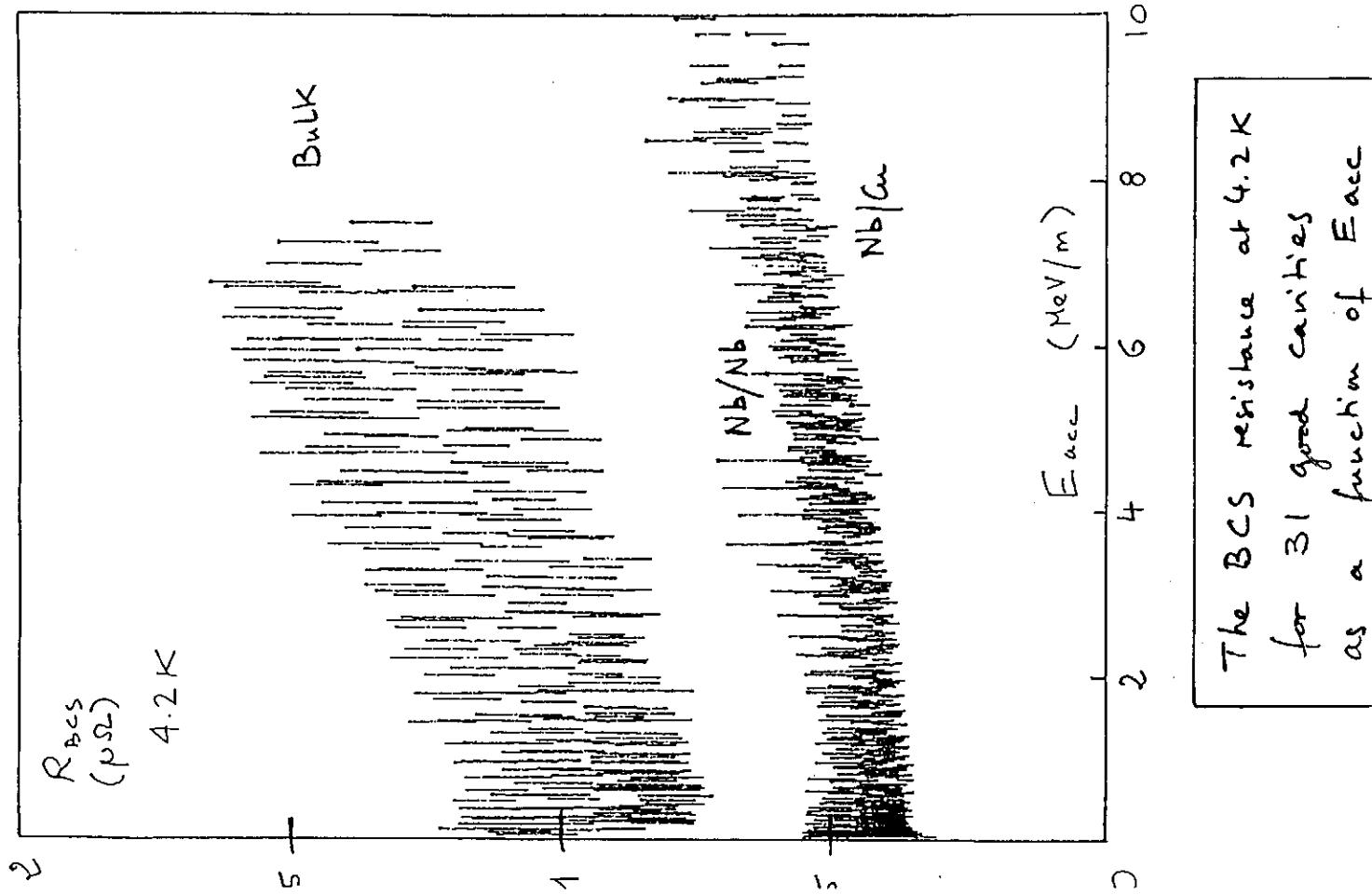
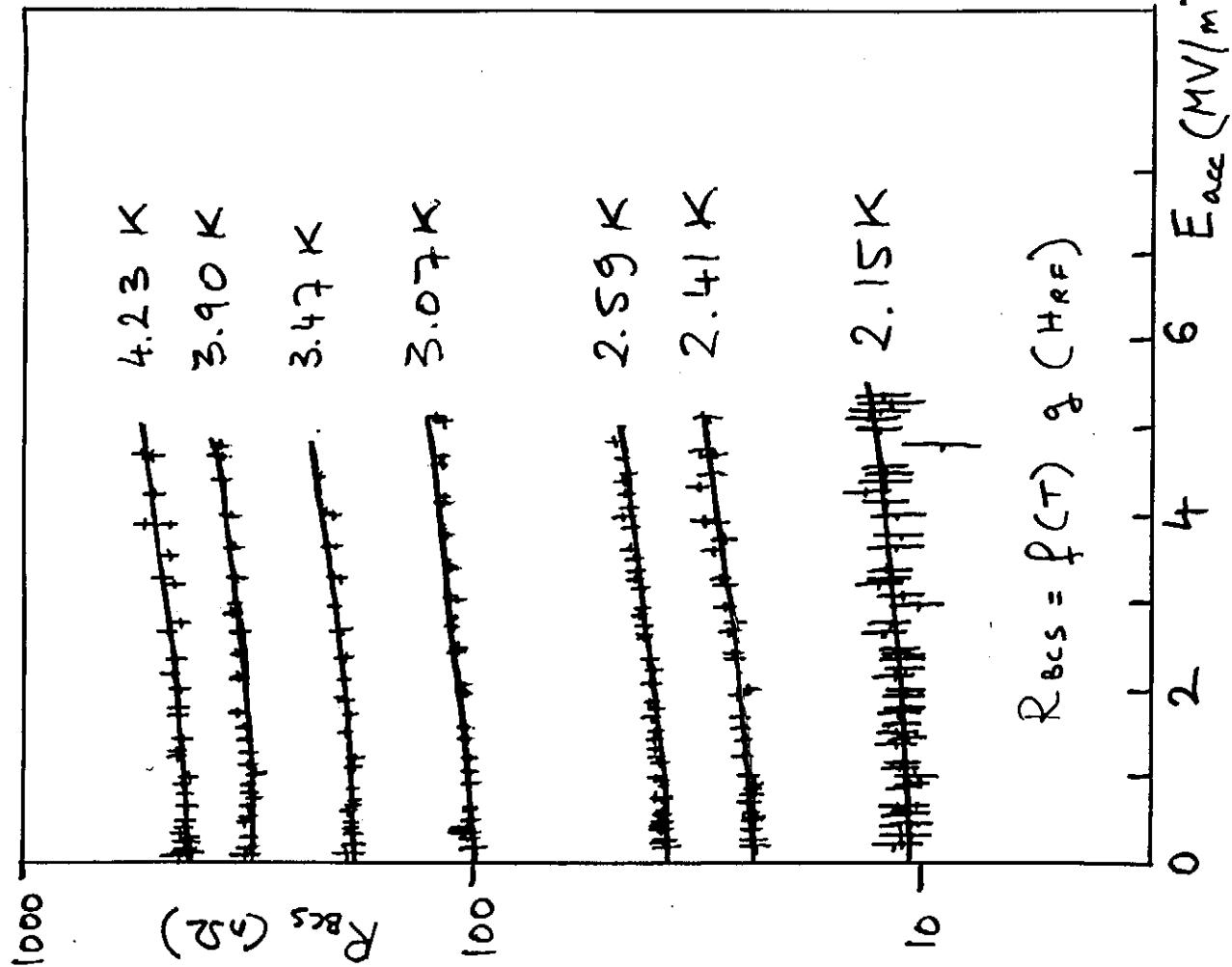
$$\text{At } 1.5 \text{ GHz for a "good" cavity}$$

$$R_{\text{res}} \leftarrow 30 \text{ n} \Omega, R_{BCS}(4.2 \text{ K}) \approx 400 \text{ n} \Omega$$

$$4.2 \text{ K} \rightarrow R_{\text{res}}$$

As there is no second order calculation available, there exists no prediction for the HRF dependence of R_{BCS} -

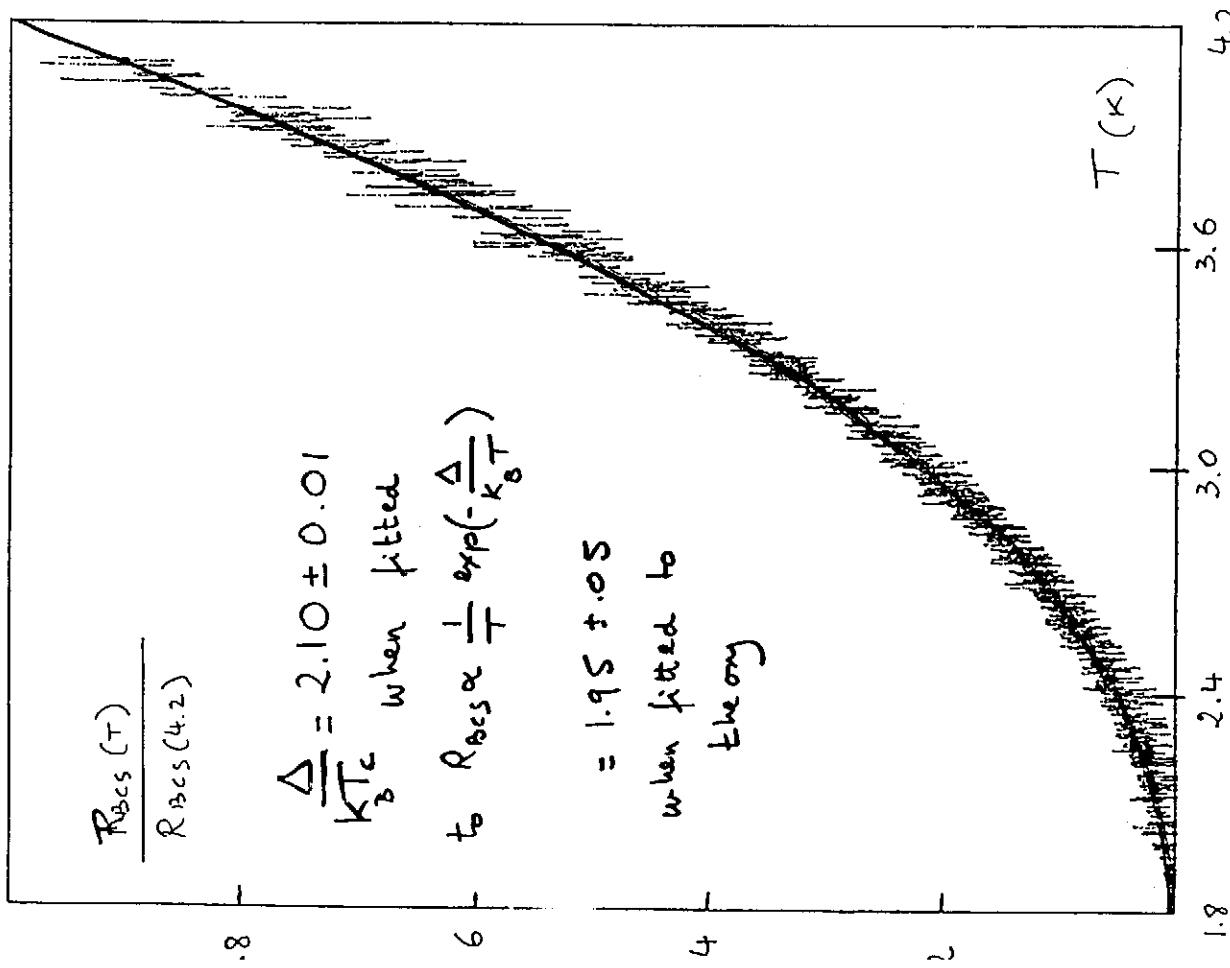
The T and H_{RF} dependences of
 R_{BCS} factorize -



The BCS resistance Temperature dependence

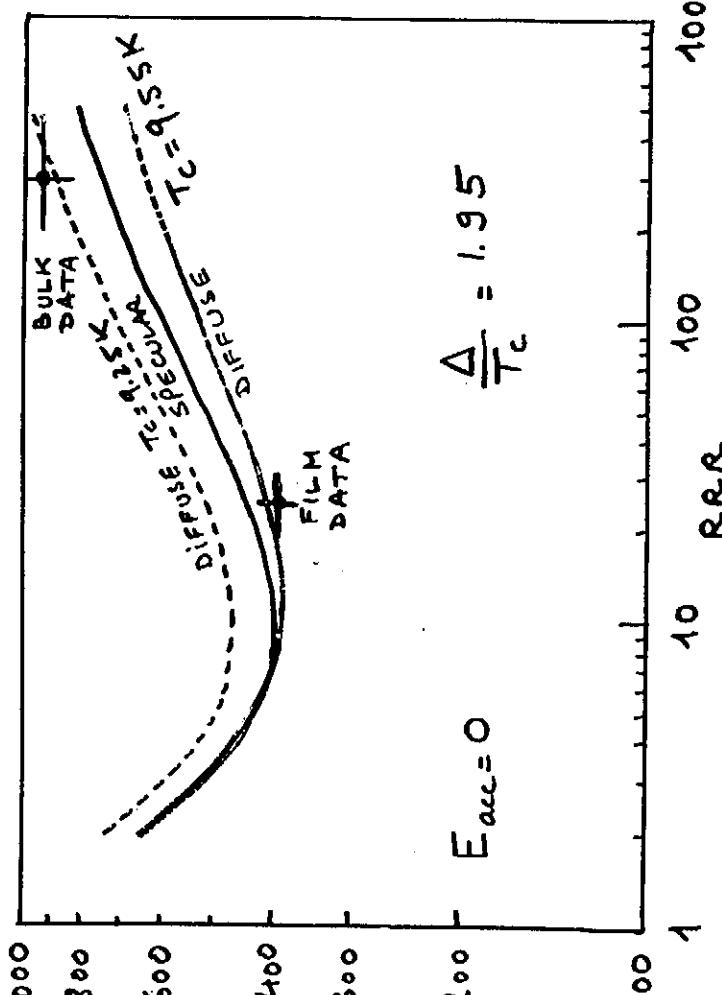
$$\frac{R_{BCS}(\tau)}{R_{BCS}(4.2)}$$

$$\begin{aligned} \frac{\Delta}{k_B T_c} &= 2.10 \pm 0.01 \\ &\text{when fitted} \\ &\text{to } R_{BCS} \propto \frac{1}{T} \exp\left(-\frac{\Delta}{k_B T}\right) \\ &= 1.95 \pm 0.05 \\ &\text{when fitted to} \\ &\text{theory} \end{aligned}$$



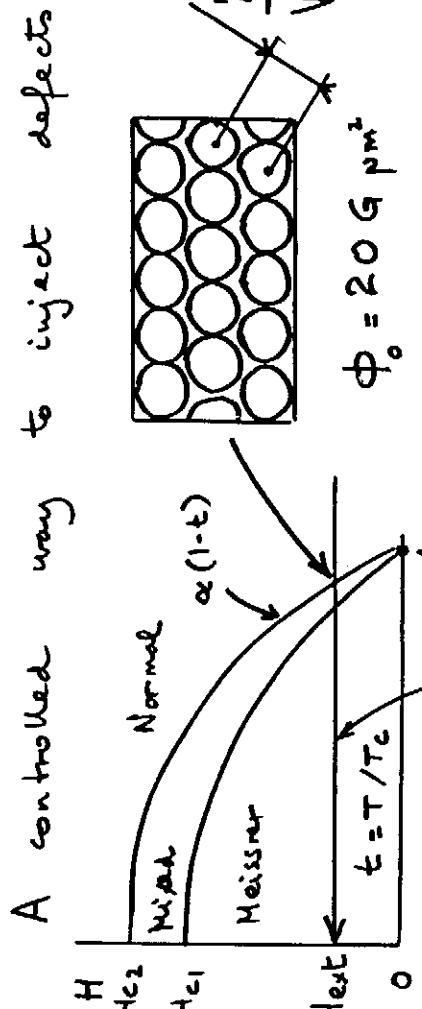
Comparison with theory

Numerical calculation using Halbritter's code
(Abrikosov, Gorkov, Khalatnikov treatment
of the time dependent BCS
Schrödinger equation).



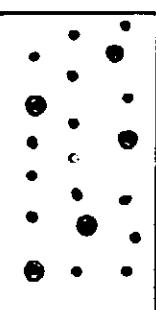
Note that $\frac{\Delta}{T_c} = 2.1$ is obtained
from a fit to the approximate
formula $R_s \propto \frac{\Omega^2}{T} \exp(-\Delta/T)$. This
only neglects the imperfection of

Trapped Fluxions



$$\Phi_0 = 20 \text{ G } \mu\text{m}^2$$

$$\rightarrow H_{ext} \text{ fluxions} / 20 \mu\text{m}^2$$



Relative area covered by fluxon
comes $\frac{H_{ext} \pi S^2}{20 \mu\text{m}^2} \approx 2.5 H_{ext} 10^{-4}$



$$H_{ext} = 1 \text{ G} \rightarrow 400 \text{ n}\Omega \times 10^2 \times 2.5 10^{-4} \frac{\lambda_{eff}}{\lambda}$$

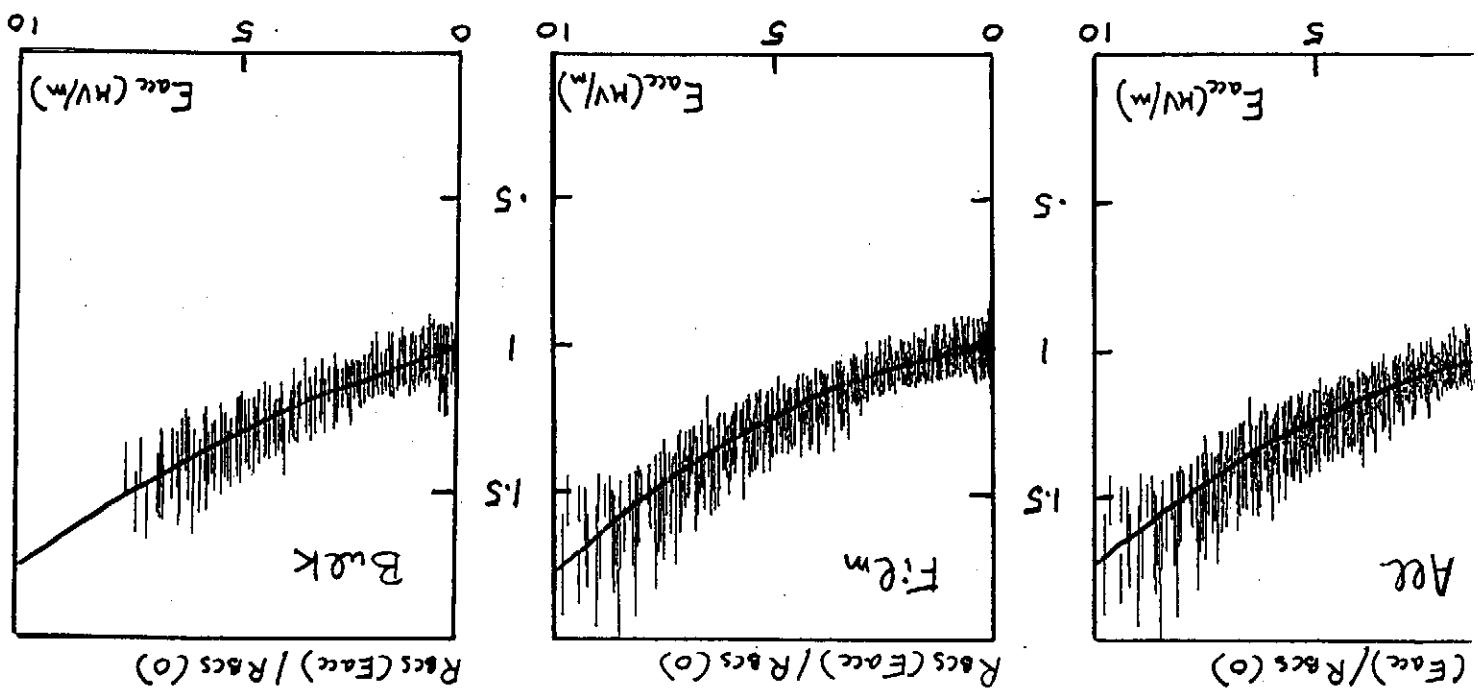
$$\approx 1 \text{ to } 50$$

88

$$R_s = R_s(H=0) + R_H$$

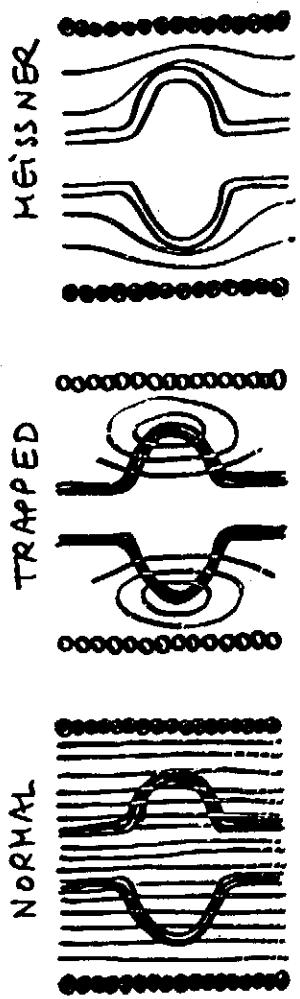
$$R_H \propto H_{ext}$$

(i.e. 0 and 30 mT)
 R_{Bcs} increases by $\approx 50\%$ between 0 and 7.5 HeV/m
 Bulk samples 52 ± 4%
 Film samples 43 ± 1%
 Al samples 47 ± 1%



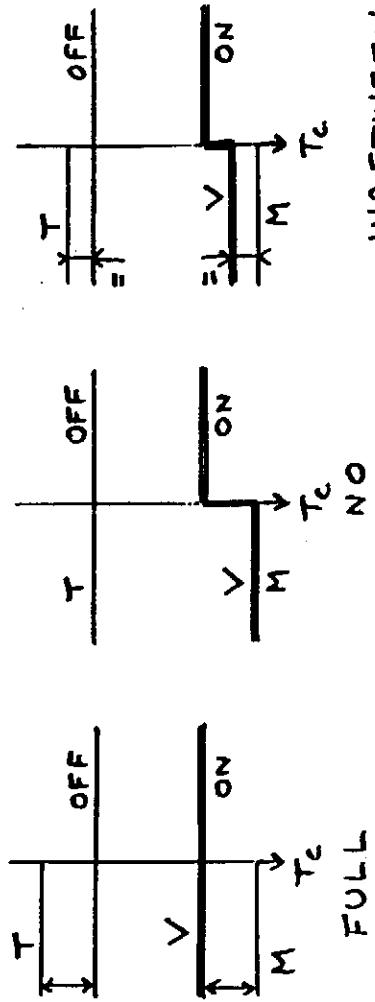
| BCS resistance = dependence on RF field |

Field Configurations



Linearity of Maxwell equations
+ boundary conditions

NORMAL - TRAPPED = MEISSNER
→ Q unaffected → Full Meissner effect

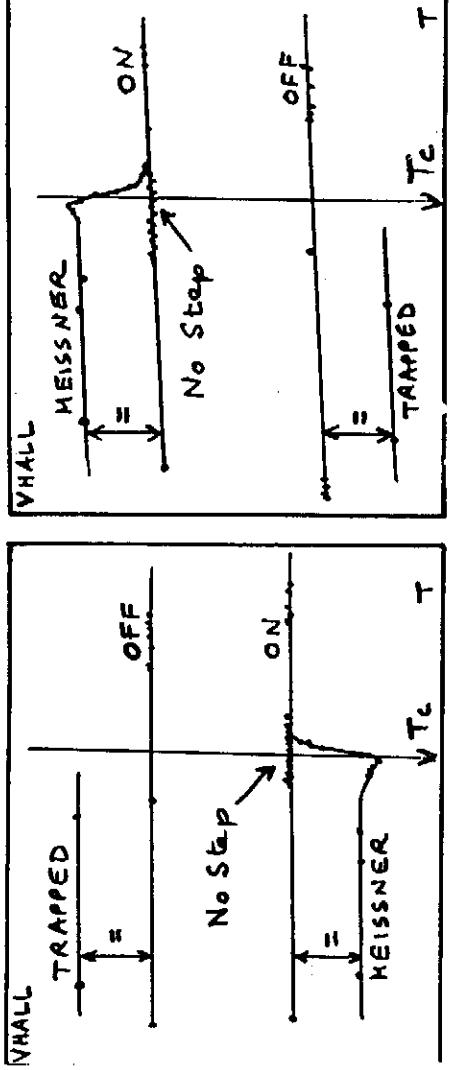


TRAPPING TRAPPING

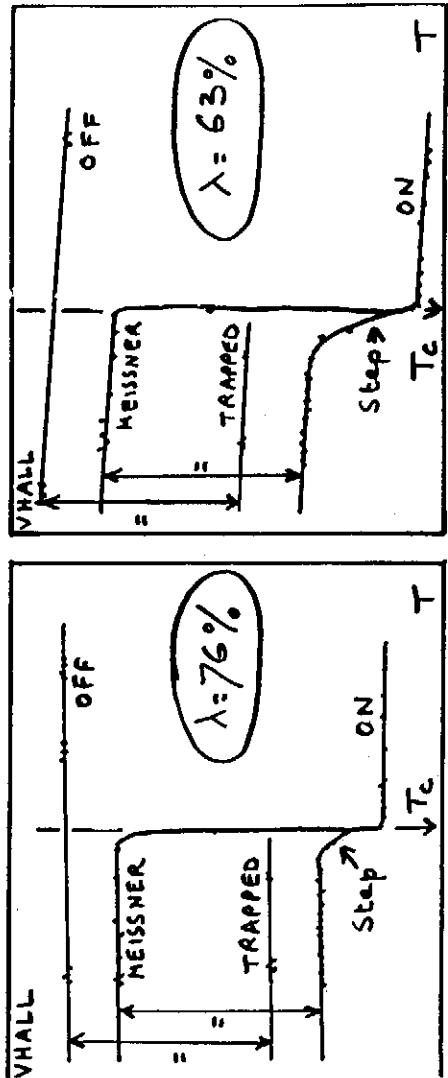
Fraction of flux trapped

$$\lambda = \frac{V - V_H}{V}$$

Is the flux fully trapped?

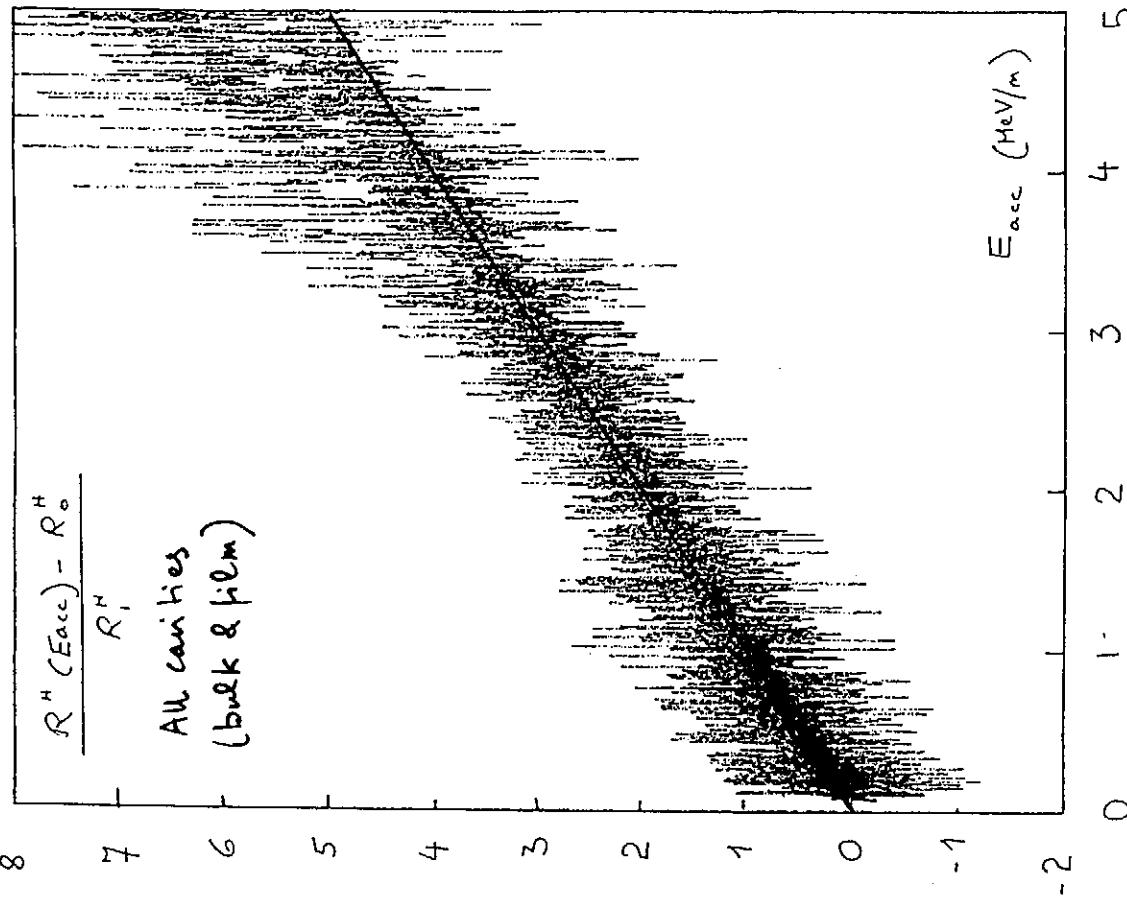


In film cavities the flux is fully trapped

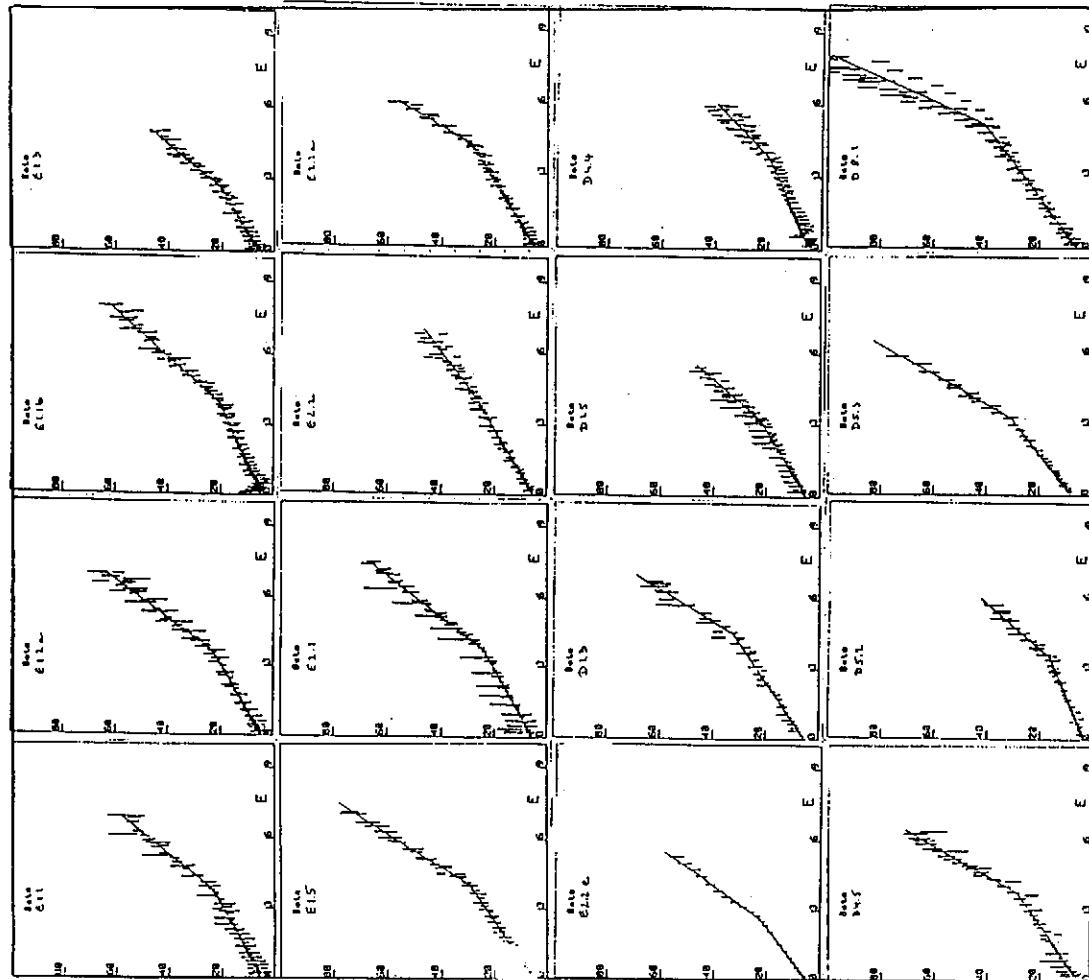


In bulk cavities (particularly after thermal treatment) it is not. This makes it very difficult to perform reliable measurements of the flux - induced losses.

$$R^H(E_{acc}) = R_o^H + R_i^H E_{acc}$$



The dependence of R_H on E_{acc}
for 16 film cavities



A kink is often visible, apparently
correlated with field emission
 $E_{acc} \approx 1$ F (1 nA electron current)

Fluxon-induced losses
Linearity in the low E_{acc}
region

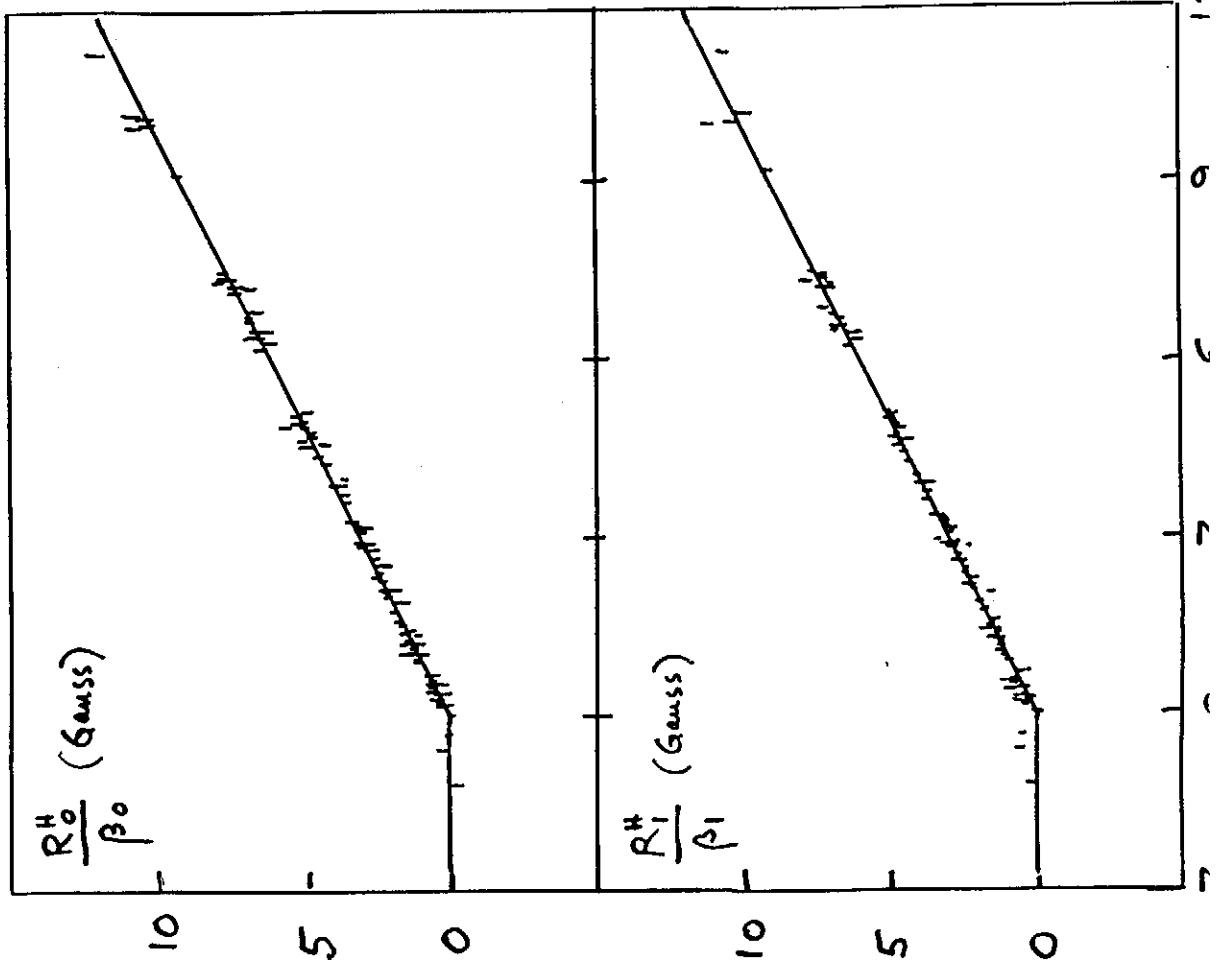
$$T = 1.8 \text{ K}$$

$$R_H(E_{\text{acc}}) = R_o^H + R_i^H E_{\text{acc}}$$

$$R_i^H = \beta_i (H - H_{\text{th}})$$

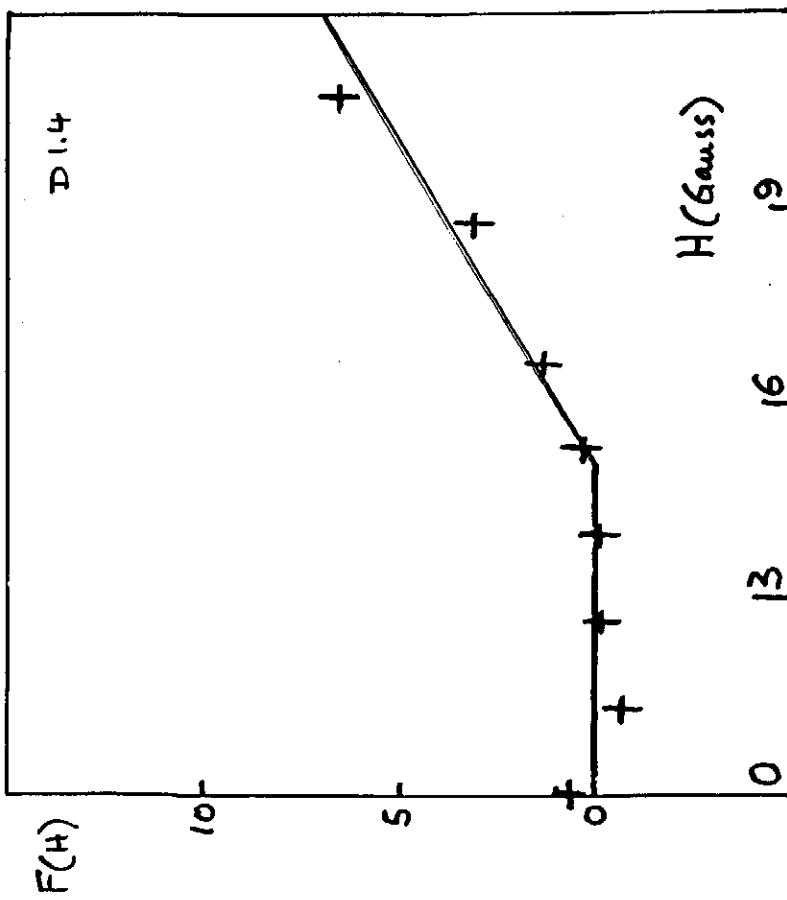
$$= 0 \quad H > H_{\text{th}}$$

$$= \infty \quad H \leq H_{\text{th}}$$



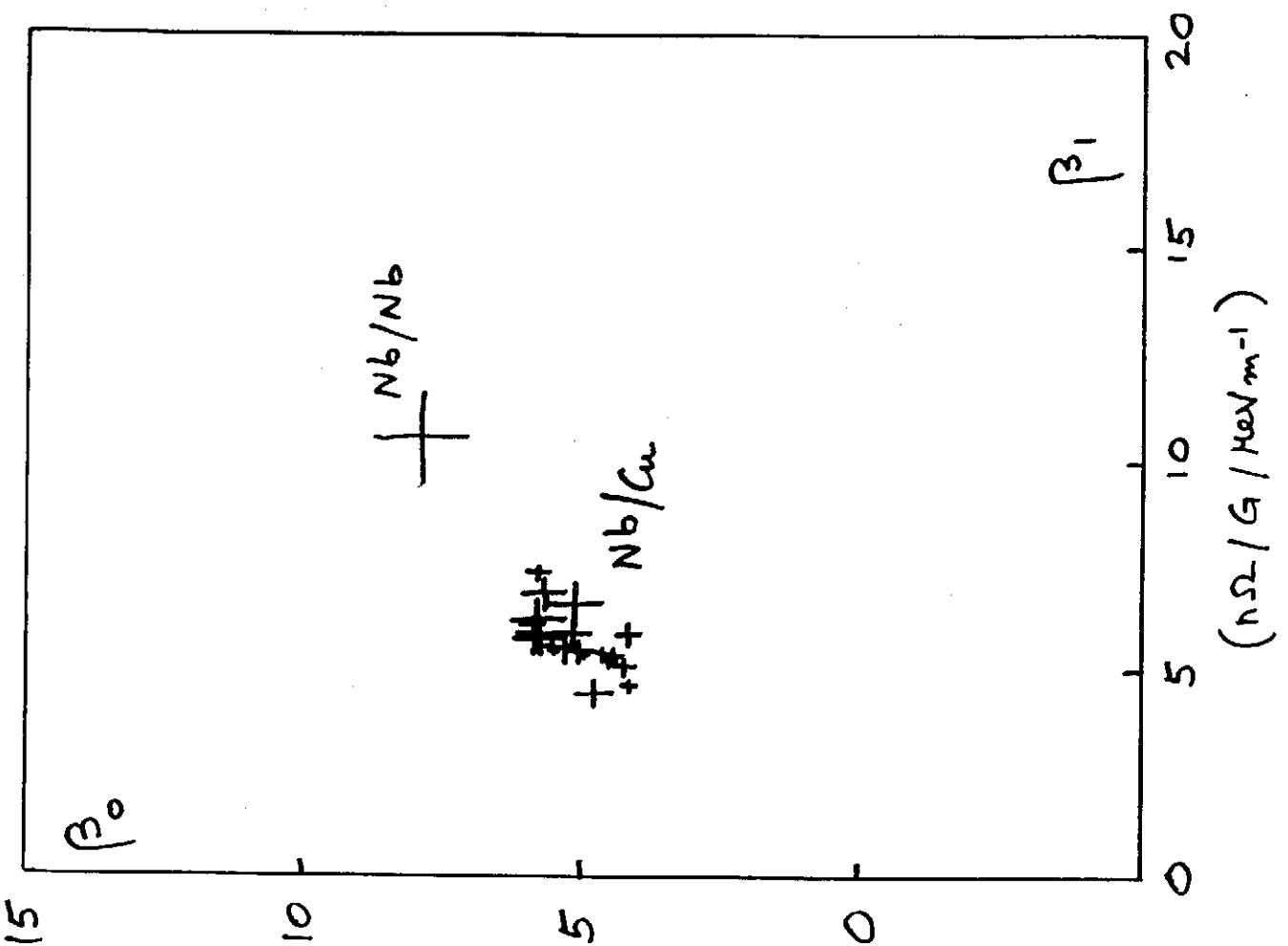
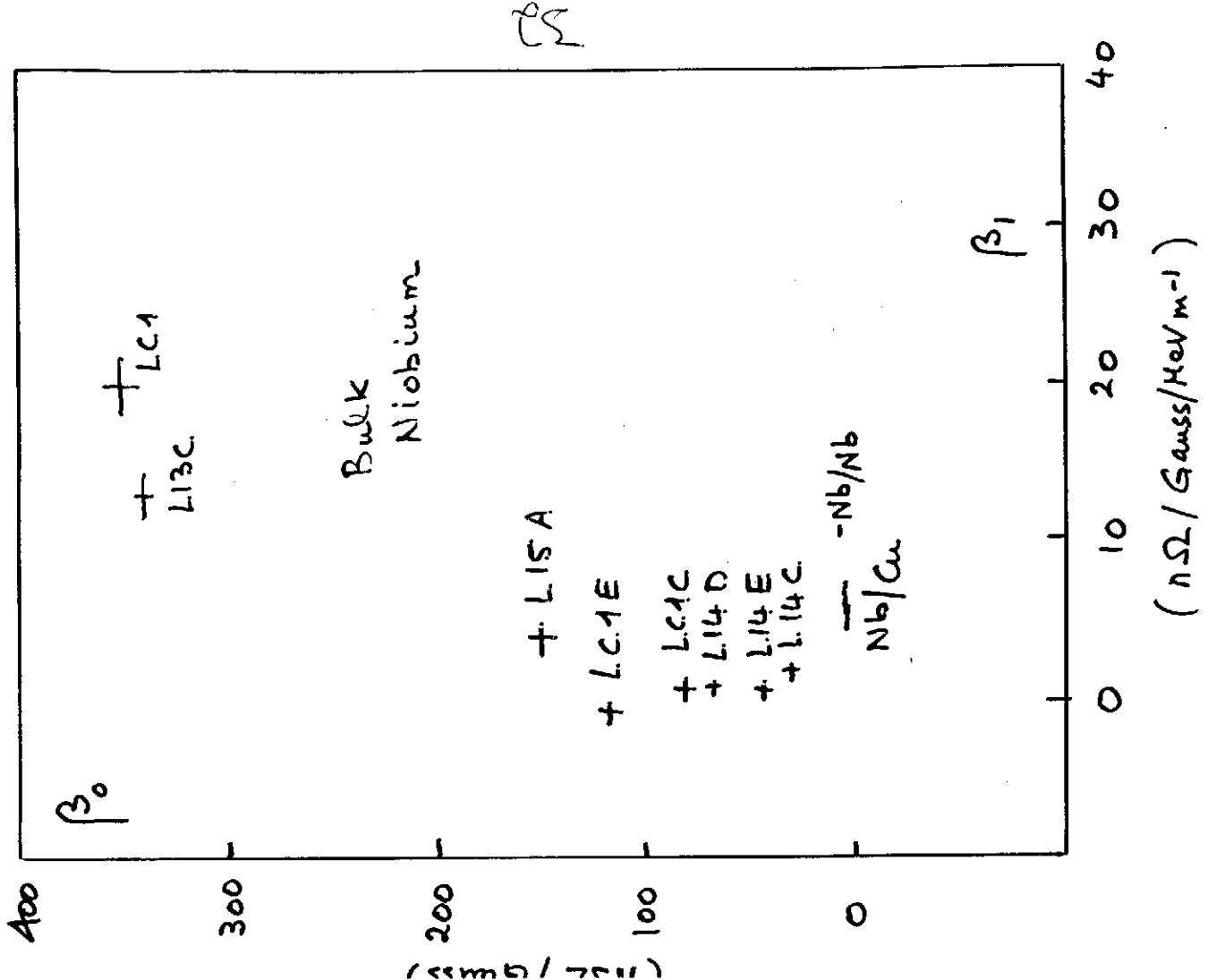
Fluxon-induced losses
Dependence on the trapped
magnetic flux

Bar cavities show a threshold (up to
saturation of defects having $R \gg \Omega$)

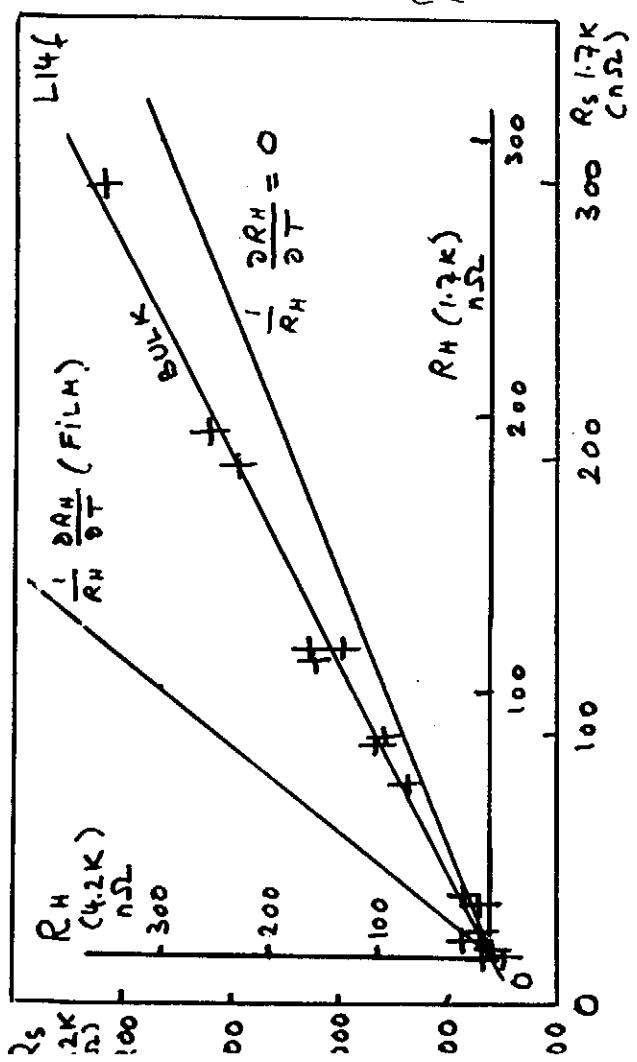


$$H_{\text{threshold}} \approx H_c \propto \sigma_r$$

$$\sigma_r = \int_0^\infty \frac{dn}{dr} \pi r^2 dr$$

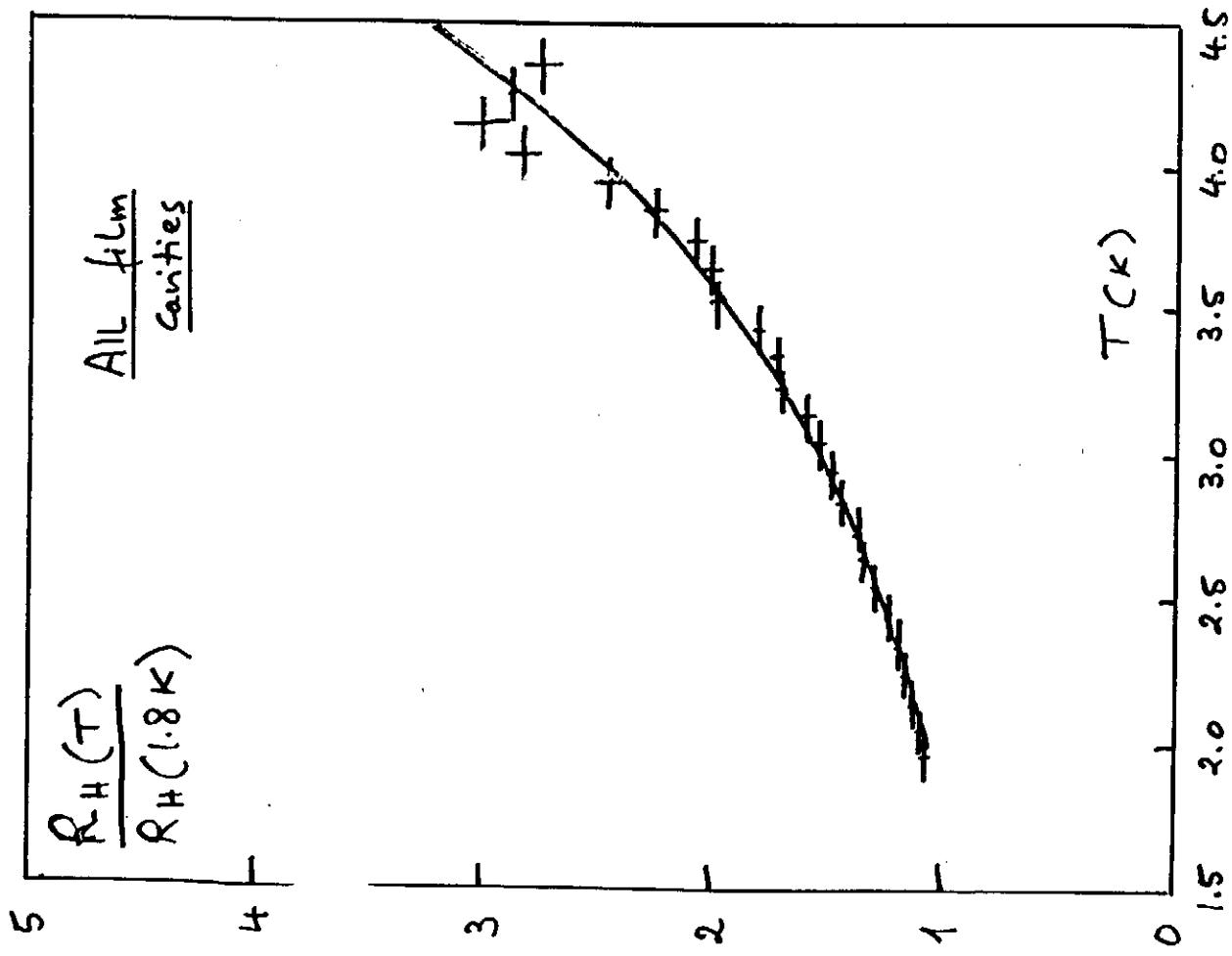


Fluxon-induced losses
Temperature dependence
Bulk case

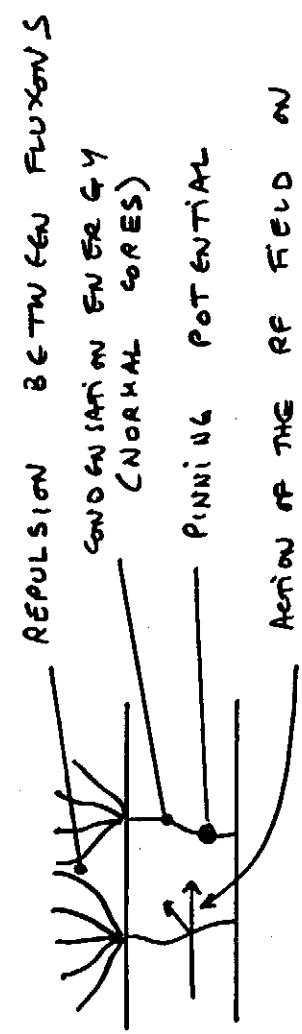


Bulk cavities exhibit a much lower temperature dependence than film cavities - In particular after thermal treatment we observe weak pinning, a small H_{RF} dependence (low p_f) and a small T dependence

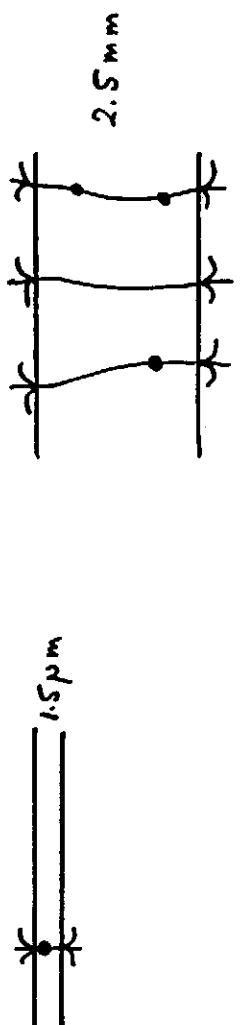
Fluxon-induced losses
Temperature dependence



Loss mechanisms with trapped fluxons

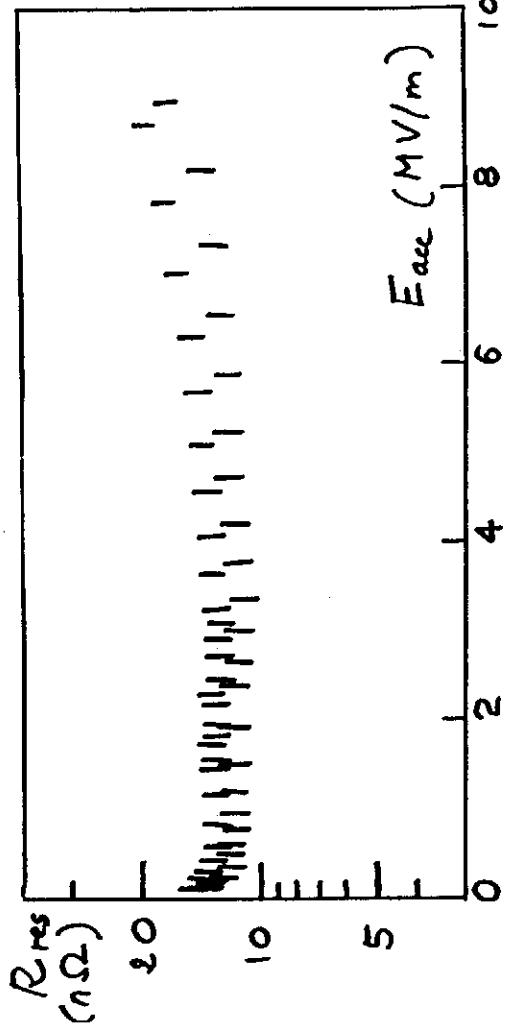


... DATA SUGGEST A MUCH STRONGER
PINNING IN THE FILM THAN IN THE
BULK. ARSENIC PURITIES OR
STRUCTURAL / GEOMETRY EFFECTS ?
ALSO β^2 (film) $< \beta^2$ (bulk)



QUANTITATIVE UNDERSTANDING OF
 β_0 AND EVEN QUALITATIVE UNDERSTANDING
OF $\frac{\partial R_H}{\partial H_{RF}} (\beta_0)$ AND $\frac{\partial R_H}{\partial T}$ ARE STILL
LACKING

THE RESIDUAL RESISTANCE

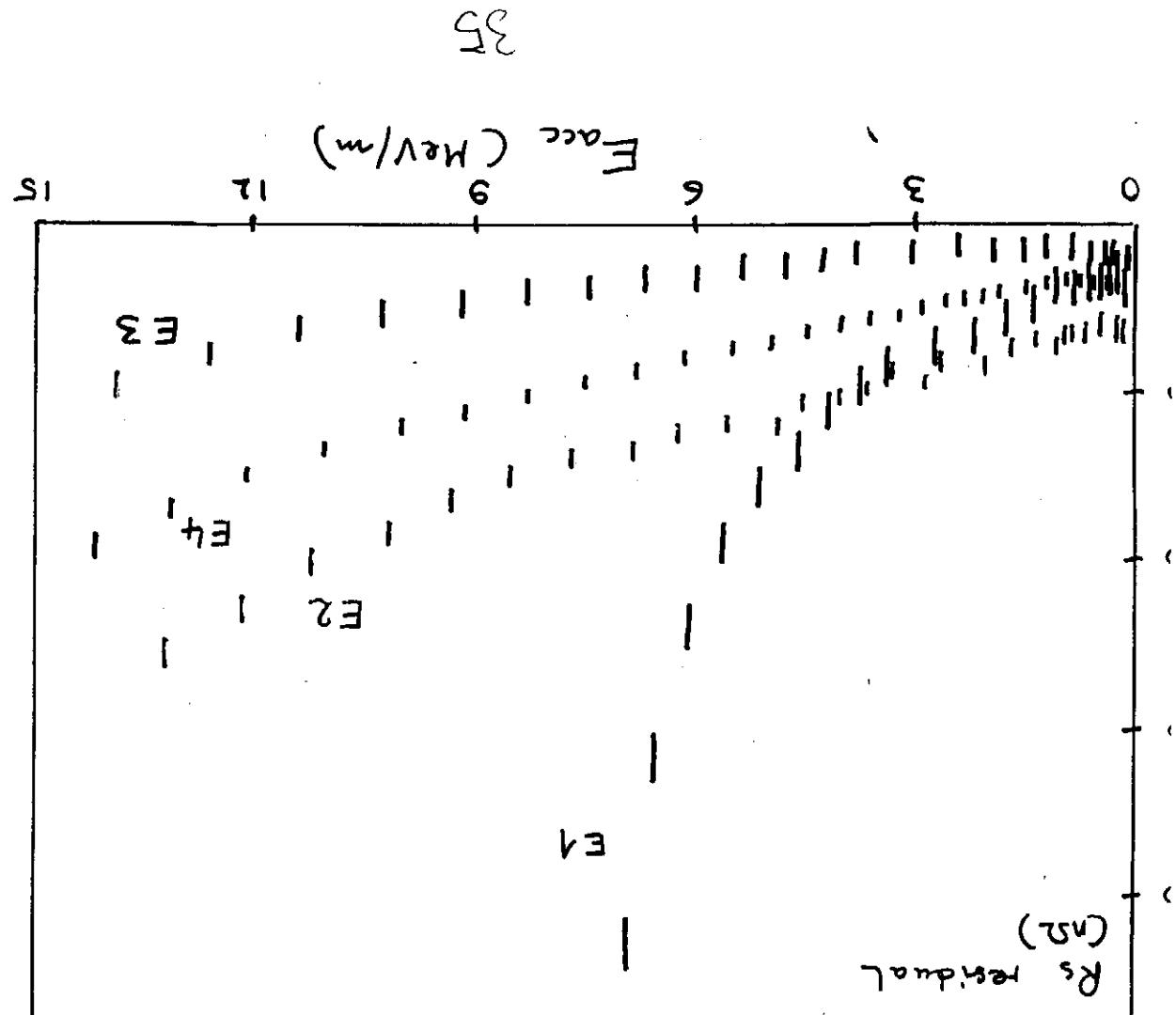


LOW RUGOSITY SUBSTRATES
(LATHE SPUN CAVITIES) ALLOW FOR
SMALL RESIDUAL RESISTANCES WITH
VIRTUALLY NO HRF DEPENDENCE

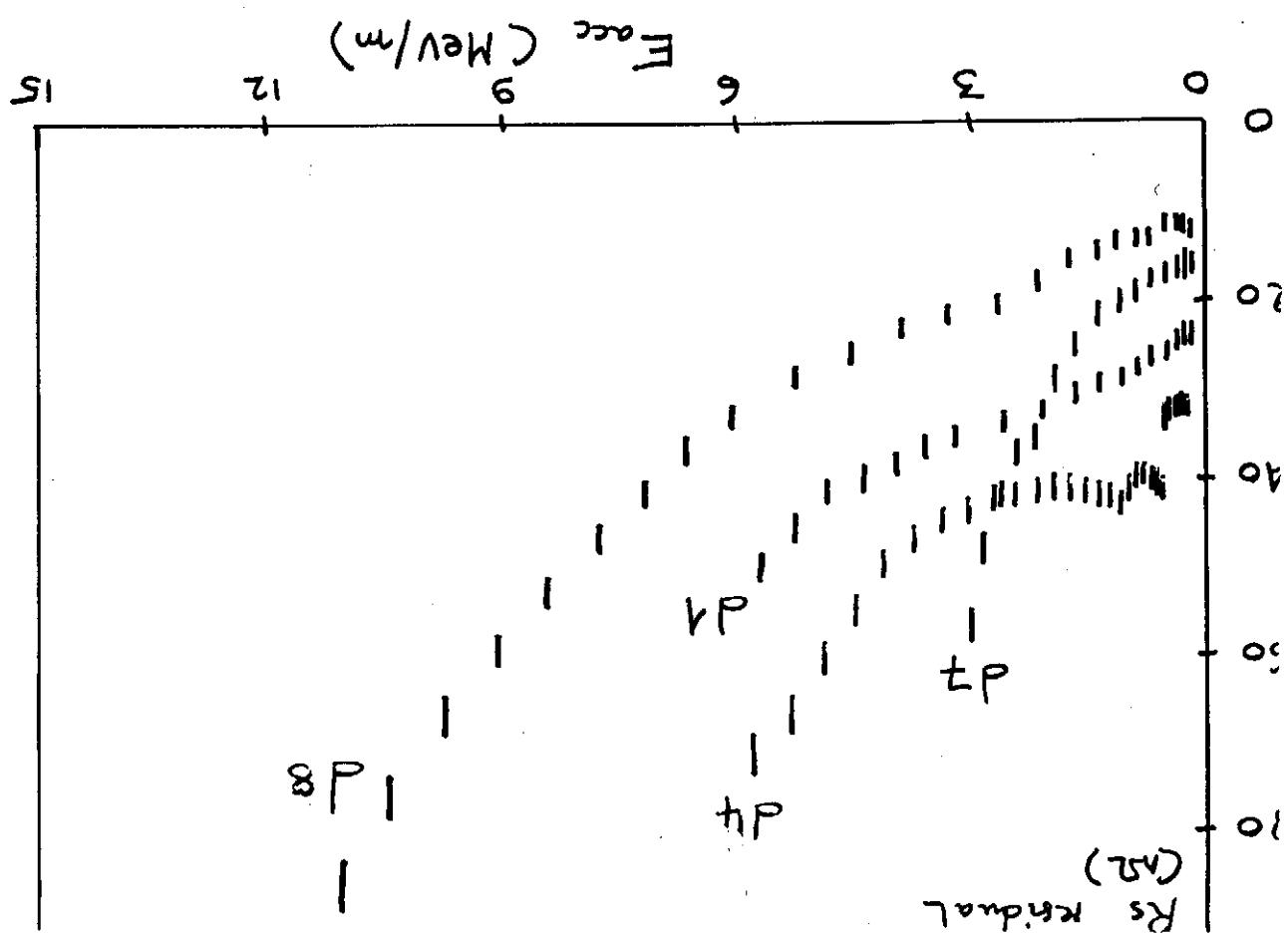
WE FIND NO EVIDENCE THAT
FILMS IMPLY INTRINSIC LIMITATIONS
ON THE VALUES OF R_{res} & R_{HRF}
(IN COMPARISON TO BULK (because,
for example, of the much smaller grain size)).

WE PLACE GREAT HOPES IN
ELECTROFORMED SUBSTRATES UNDER
CURRENT PRODUCTION (VIRTUALLY STRESSLESS)

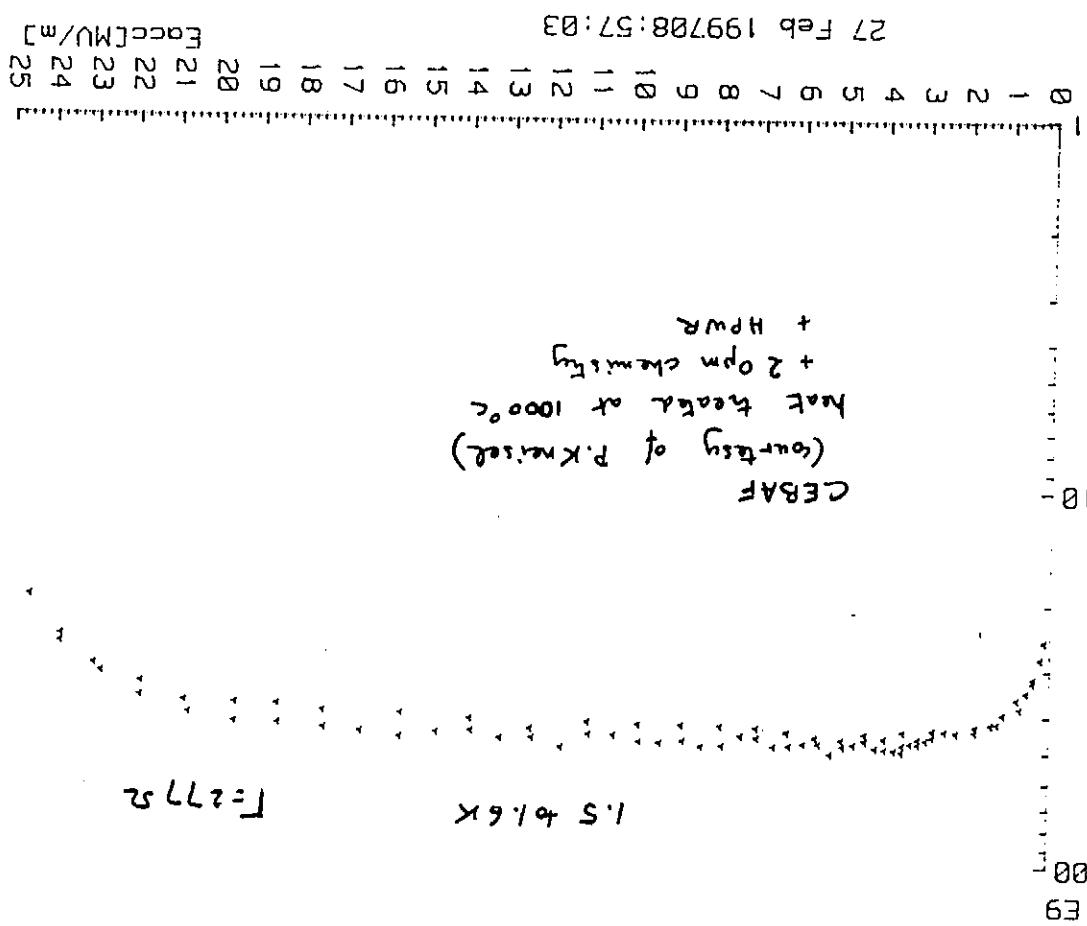
The best spun cavities



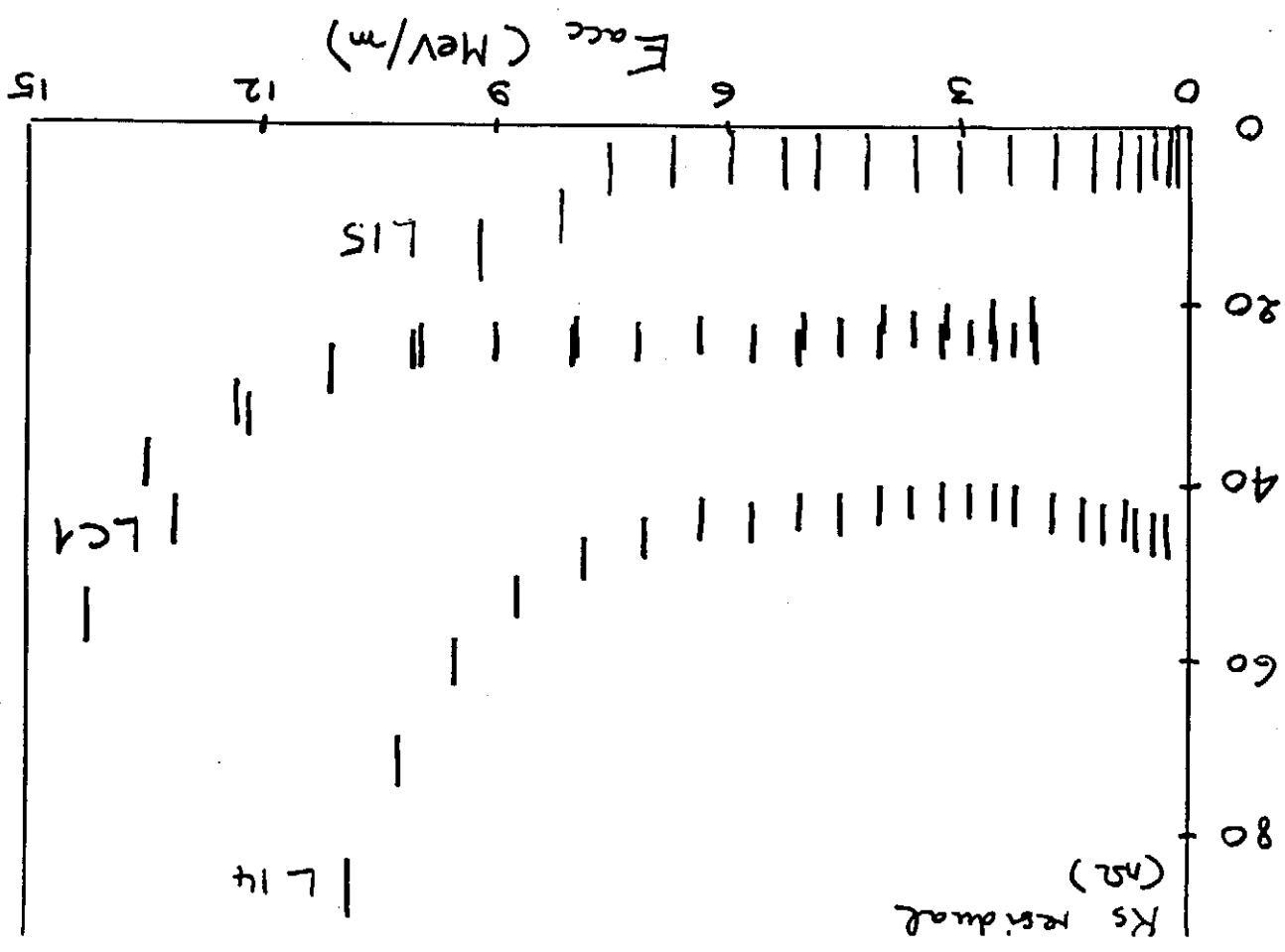
The best hydroformed cavities



36

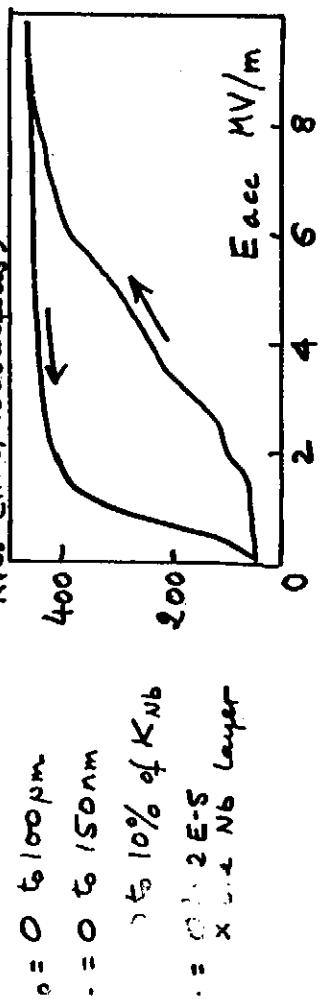


Some bulk niobium data



Simulating film defects

Q -switches are usually described as local "blister" defects causing a small area to switch from Sc to ns . It is easy to simulate large values of R_{ns} and $\partial R_{ns} / \partial H_{RF}$ with a large number of mini- Q -switches



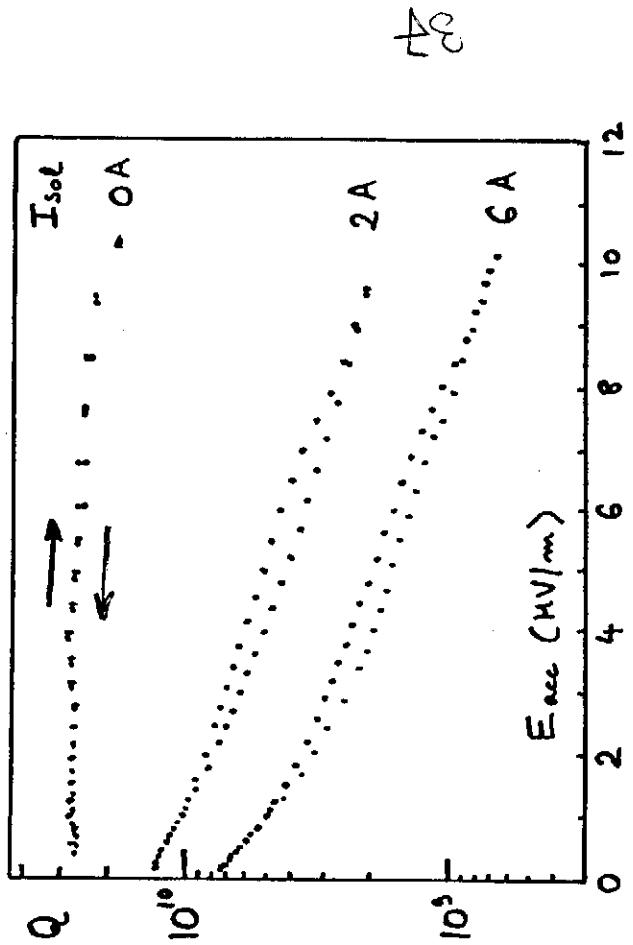
HOWEVER SUCH MODELS FAIL TO RE PRODUCE THE HYSTERETIC BEHAVIOUR. REAL Q -SWITCHES RECOVER MUCH FASTER THAN THOSE SIMULATED

$$R \left(\frac{H_{RF}}{H_{RFy}} \right)^2 \approx \frac{R_{high}}{R_{low}}$$

→ IN NEED FOR ANOTHER MECHANISM?
FIELD EMISSION?

Hysteresis

Never observed on bulk cavities but usually observed on film cavities.



WHEN HYSTERESIS IS PRESENT IT IS OBSERVED TO BE ENHANCED BY FLUX TRAPPING
EVEN MORE SURPRISING: HYSTERESIS MAY BE ABSENT AT $H_{ext} = 0$ AND APPEAR IN THE PRESENCE OF TRAPPED MAGNETIC FLUX (see above)

Lack of time...

... prevented me to discuss a number of important topics among which

- the Nb/Nb programme currently underway. Originally meant to elucidate the dependence of R_s on grain size, turns out to be a powerful tool to discriminate between different hypotheses.
- the possible role of the oxygen layer at the Cu-Nb interface in the film case
- the current limitation at large E_{ac} ($\sim 18 \text{ MV/m}$) due to field emission

Film vs Bulk

Parameter	Film	Bulk	Comments
T_c	$\sim 9.5 \text{ K}$	$\sim 9.2 \text{ K}$	lattice
R_{RR}	~ 30	~ 300	Argon
Grain size	$\sim 2.00 \text{ nm}$	Tens of μm	
$R_{RR}(4.2 \text{ K})$	$\sim 4000 \text{ nS}$	$\sim 900 \text{ nS}$	RRR
$\frac{\Delta R_{RR}}{R_{RR}}$	$\Delta \sim 1.95 \text{ %}$	$\Delta \sim 1.95 \text{ %}$	no 2nd order calc.
$H_{threshold}$	Yes but $\lesssim 2 \text{ G}$ for good films	no evidence	larger defects $r \gtrsim 3$
$R_H/H_{ext} \text{ at } H_{RF} = 0$	$\sim 5 \text{ nS/G}$	a few 100 nS/G	S^2 effect strong pinning?
λ (trapping)	100%	may be much lower	Who are the pins? Argon? Geometry?
$\frac{dR_H}{H_{ext} \text{ at } H_{RF}}$	$\sim 1.2 \text{ nS/G mT}$	similar/ may be lower	?
R_{res}	$\times 3 \text{ in } 2.5 \text{ K}$	much lower	
		sensitivity to contamination and polarizing	
		sensitivity to film (substrate) quality	
		usually hysteretic no hysteresis Fluxon enhanced	?

Conclusions

Improving our understanding of RF losses in Nb/Cu cavities is a very time consuming effort. In now nearly two years we have been able to clarify a number of issues

- the behaviour of R_{es} is well understood - Note that its dominates LEP - R_{es} and its "slope" are twice as large in the bulk than in the film case.
- evidence for a much stronger pinning in the film than in the bulk has been presented
- evidence that the residual resistance and its "slope" are similar for bulk and film as long as the film is of good macroscopic quality (at the level of a few nΩ)

At the same time we have raised a number of new questions such as

- which is the pinning mechanism at play in the film? what causes the HRF and T dependence of the

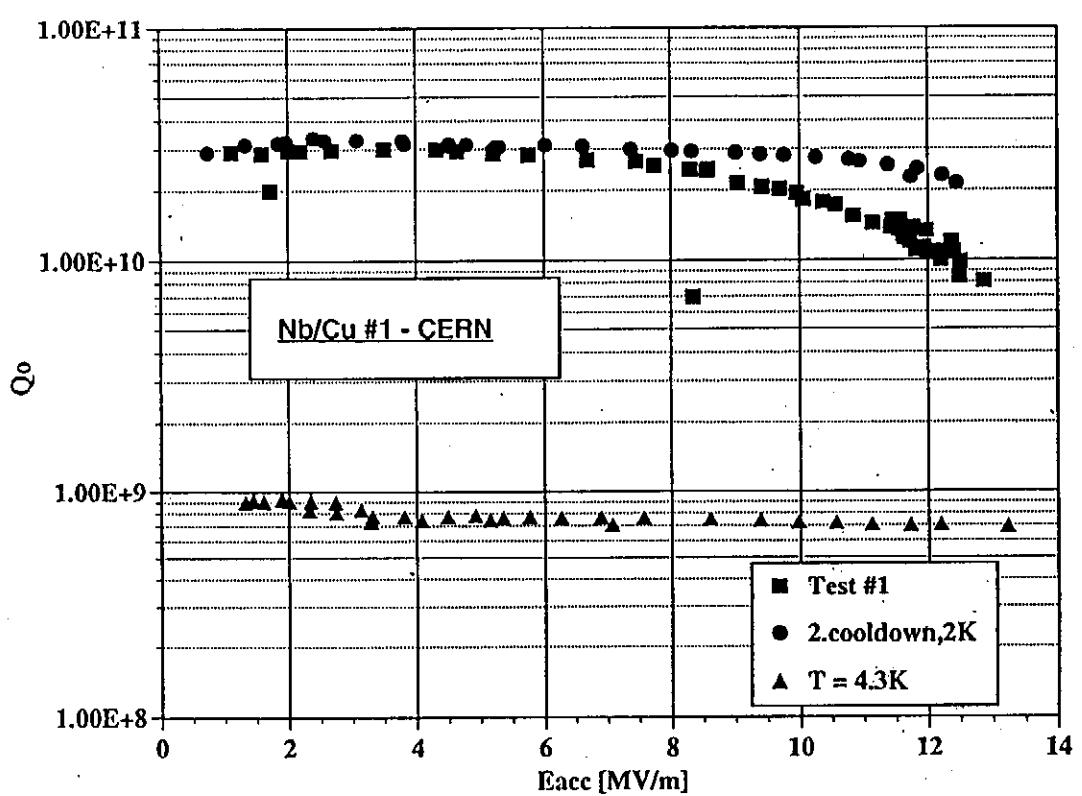
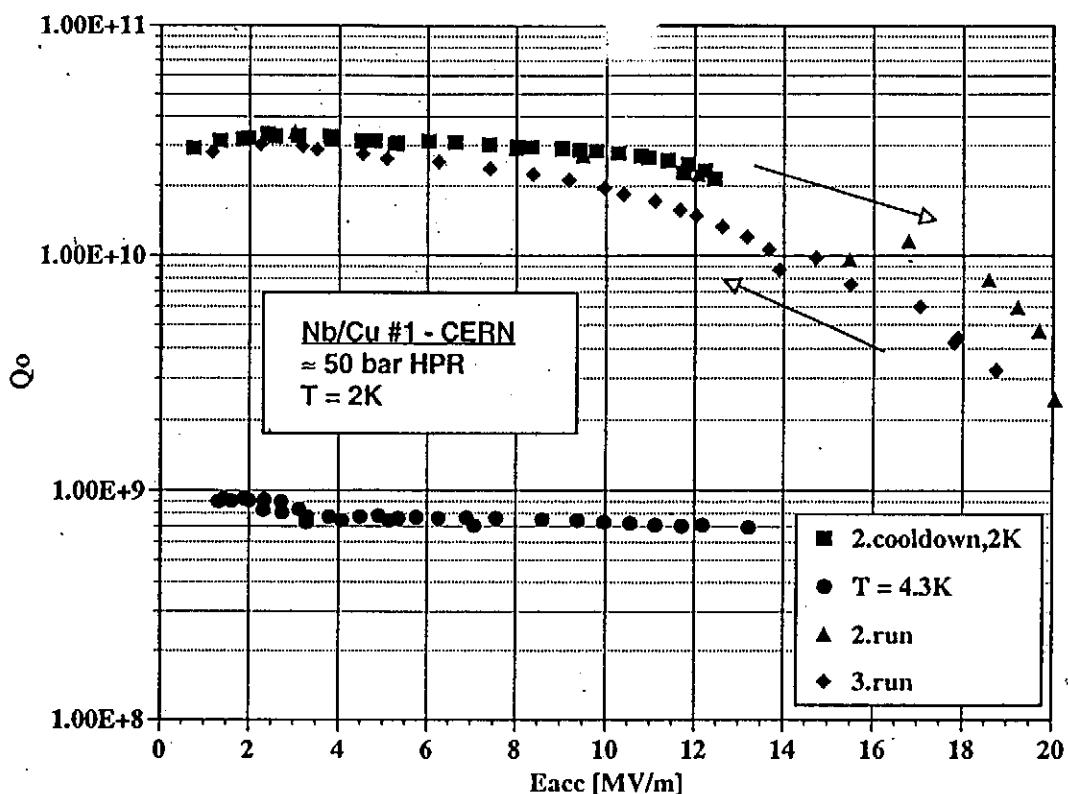
- which is the role of field emission in R_{es} - which is the mechanism responsible for it to enhancement by trapped fluxons?

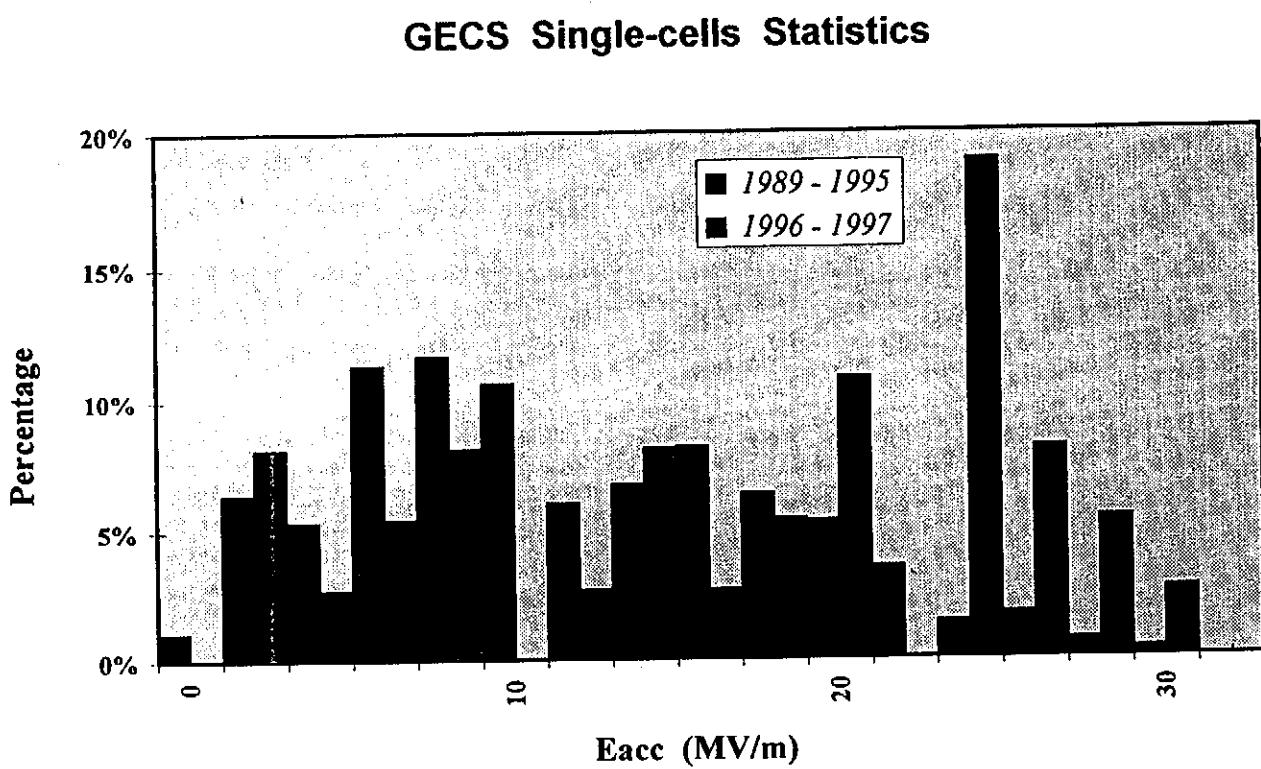
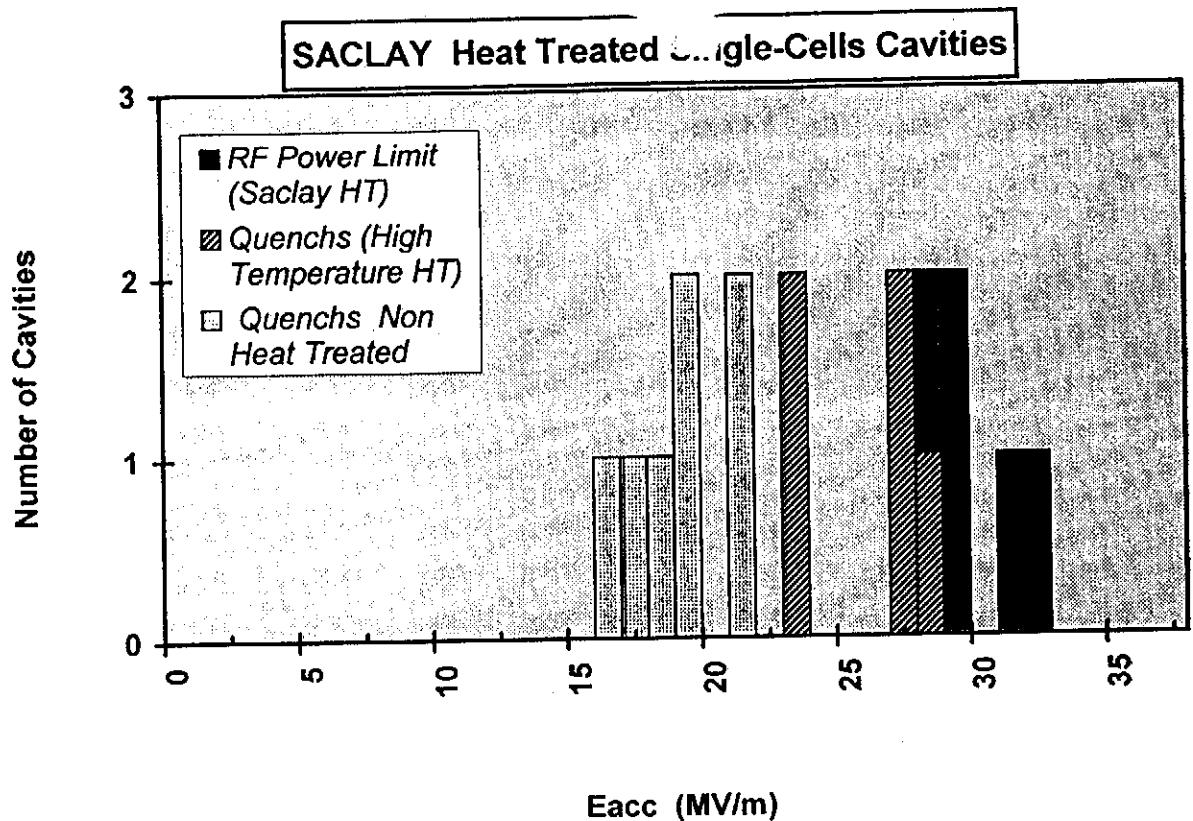
Our ongoing programme is addressing these questions. It includes

- Kr & Xe
- a study of Nb/Nb₃ films (with thermal treatment)
- electroformed substrates
- the role of the Nb/Cu interface
- measuring light emission inside the cavity
- pushing the field emission limit to higher values of E_{ac}

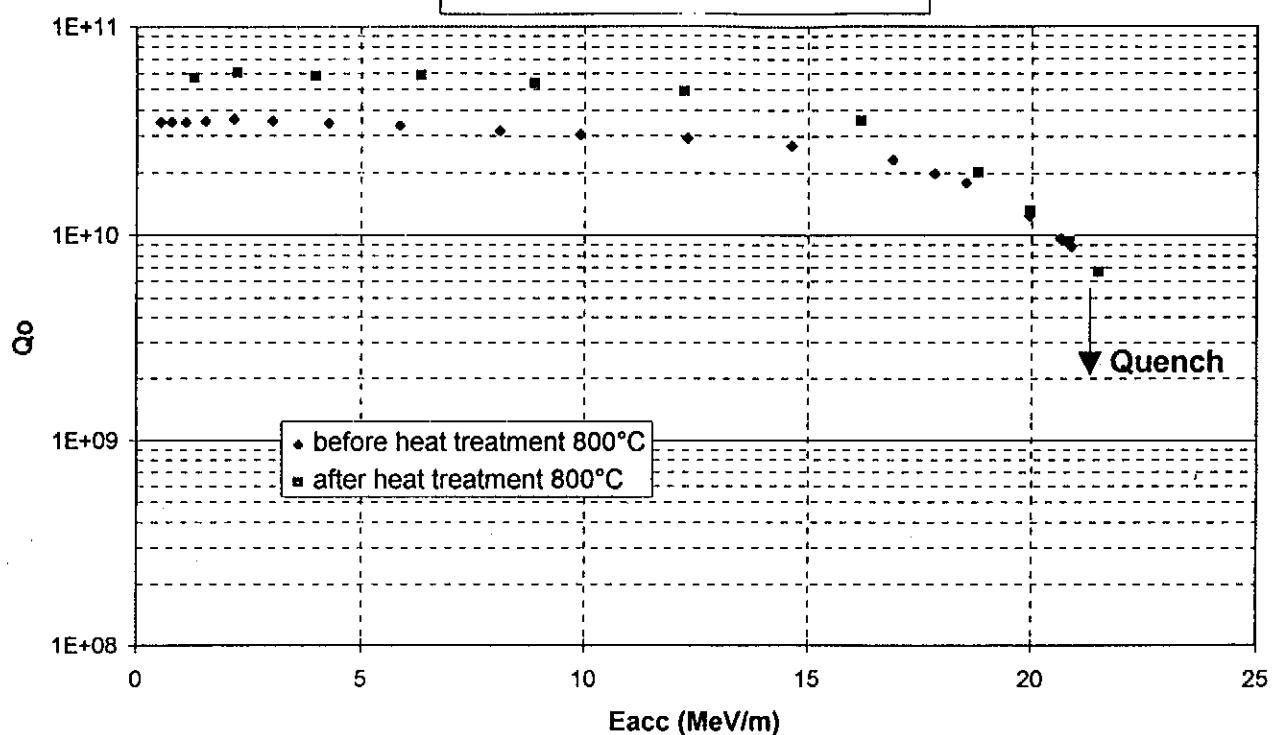
In addition some understanding of the frequency dependence of the various loss components should be obtained

Thank you to all those who are helping us, and to E. Haibel, E. Maher and W. Weingarten for useful discussions.

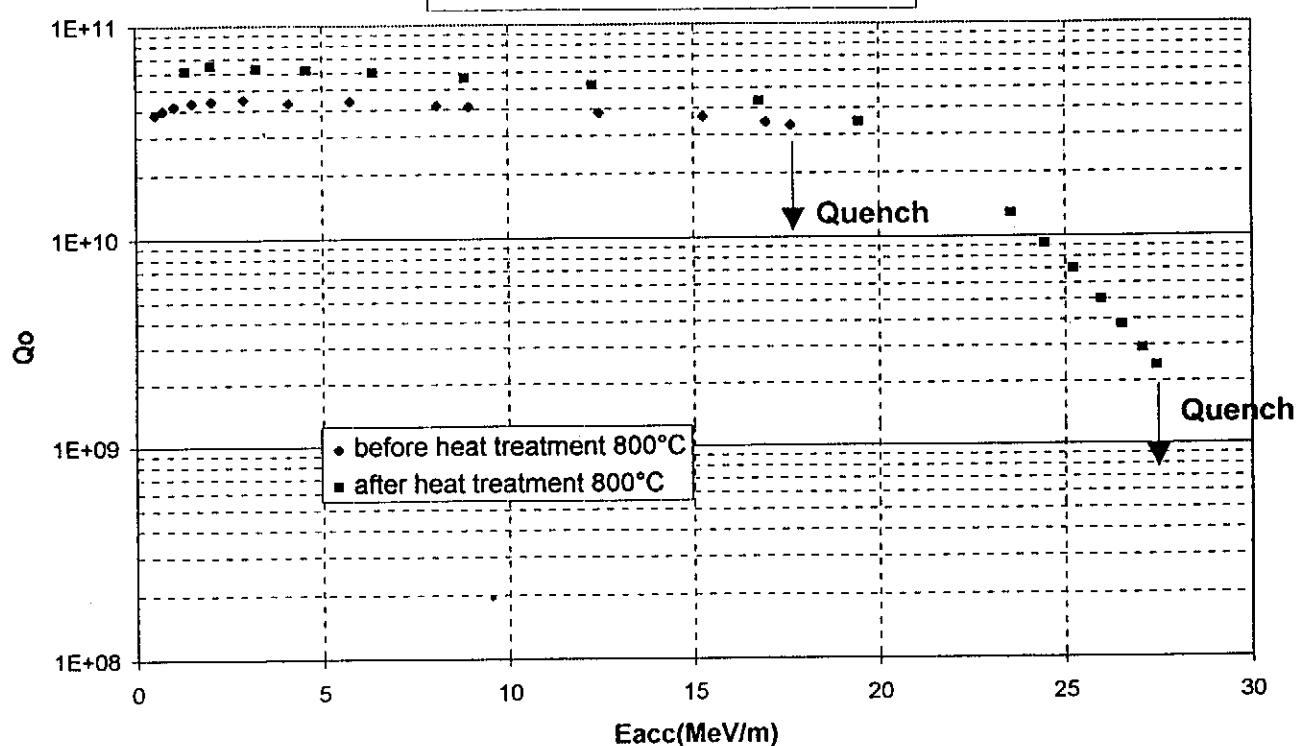




C1 09 F=1300MHz T=1.7K



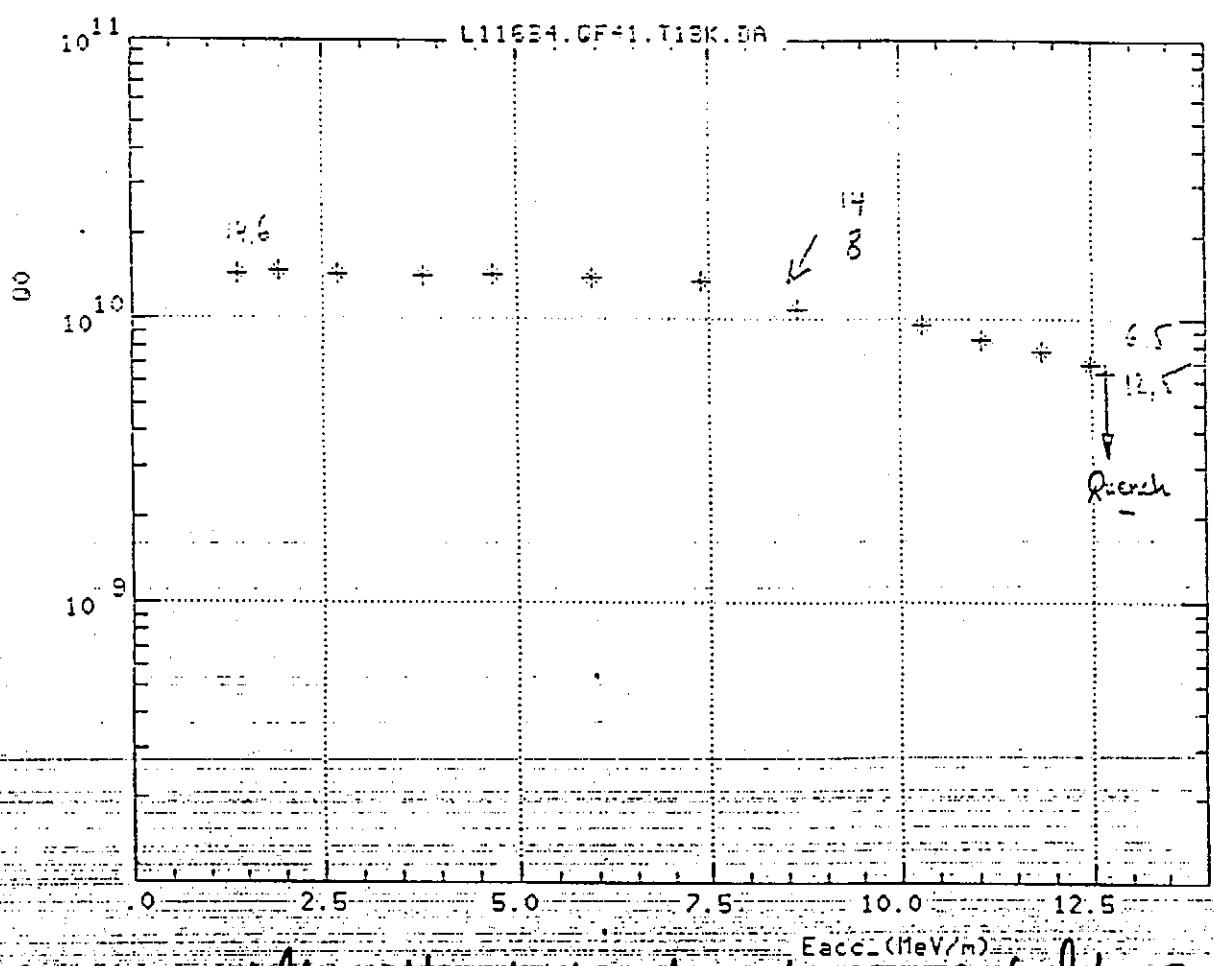
C1 10 F=1300MHz T=1.7K



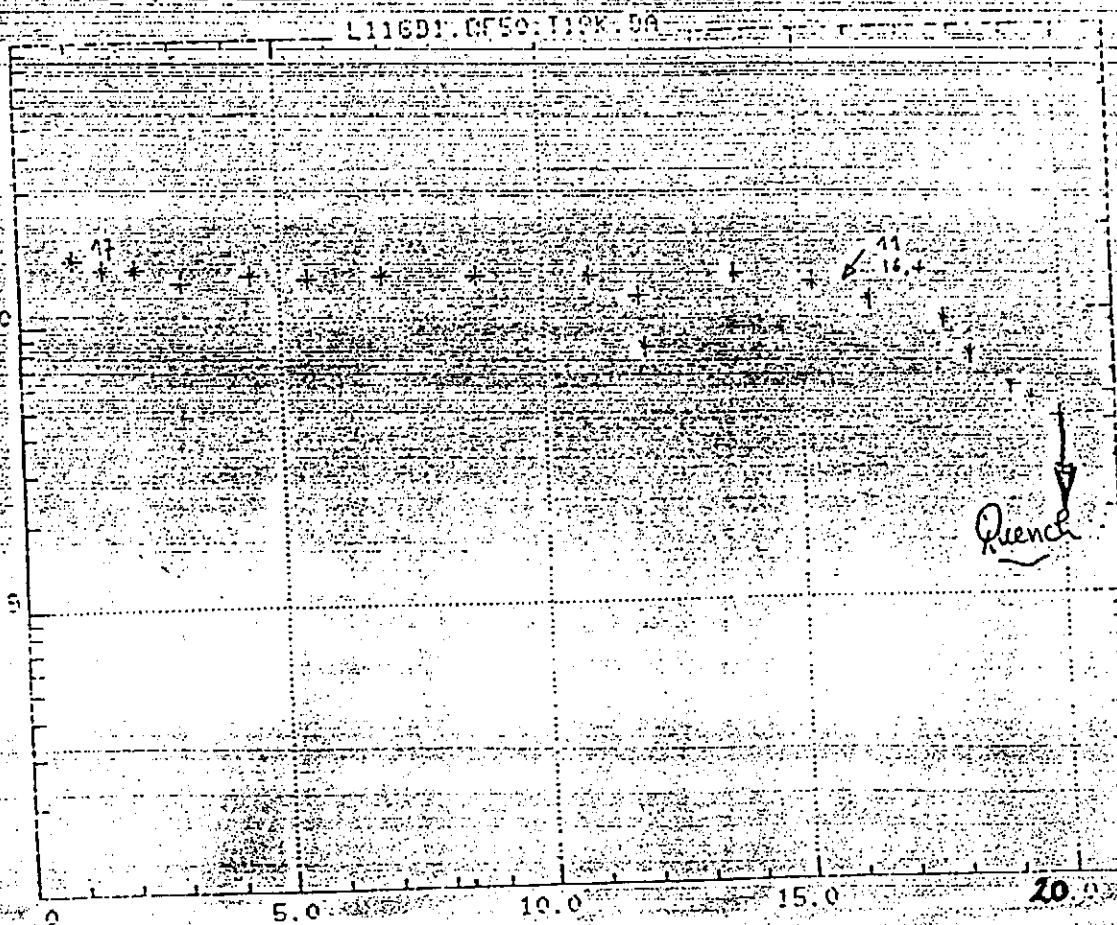
CAVITY L1-16

RRR ≈ 275

63



After heat treatment 750°C(2h) + 3 min etch



43

Q -Degradation without electrons neither X-Ray Detected

Appear on all cavities since February 1996.

Before 1996	Electrons Field level Quench Field level	10 - 20 MV/m 18 - 22 MV/m	No HPR, No Valve in clean room No Heat treatment
After Feb. 1996	Electrons Field level Quench Field level	> 20 - 30 MV/m > 30 MV/m	HPR (100 bars) + Valve mounted in clean room NO Quenches for SACLAY Heat Treatment

RF Processing levels between 17 and 22 MV/m (Multipactoring ?)

Q degradation above 20 MV/m

Depends on Insert II:

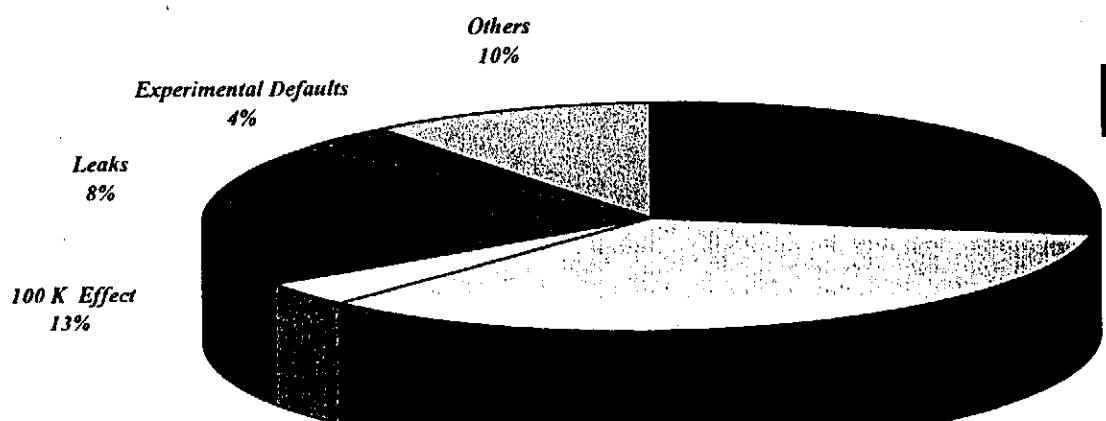
CV2A	Slight degradation above 30 MV/m
CV2B	Strong degradation at 25 MV/m

Differences	CV2 A	CV2 B
Pumping	$\Phi = 16$ mm	$\Phi = 35$ mm
Input Coupler	Bottom	Top
Antenna length	Long	Short

Questions
Magnetic Field ?
Adsorbed Gases ?
Connectors Losses ?

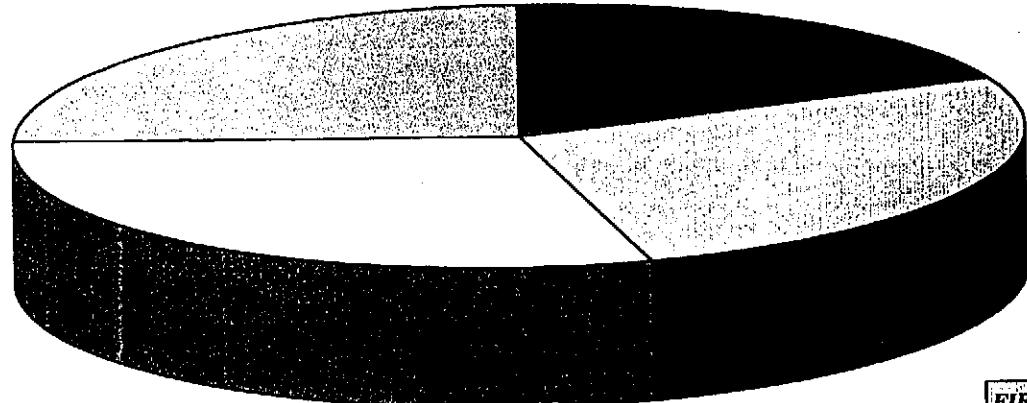
GECS Group - SEA / C. E. SACLAY
Total of 320 tests [1989- Feb. 1997]

SACLAY SINGLE-CELLS STATISTICS



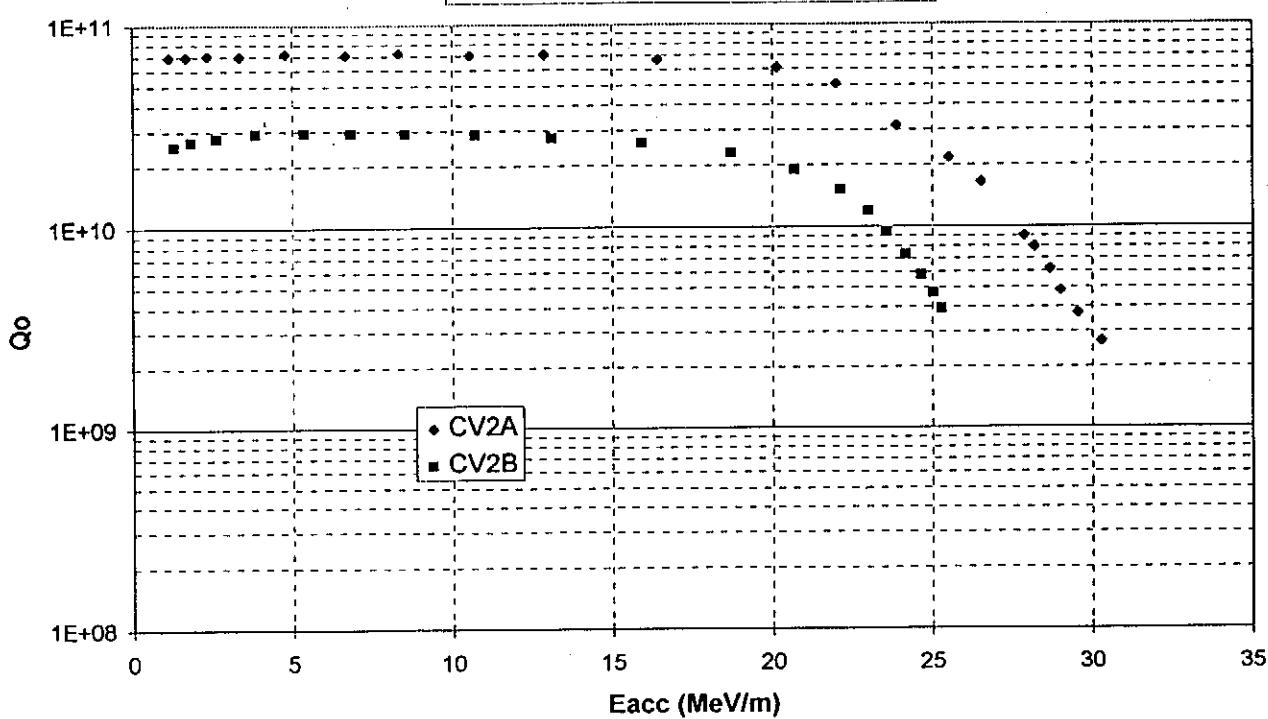
SACLAY SINGLE-CELLS STATISTICS

Others
24%

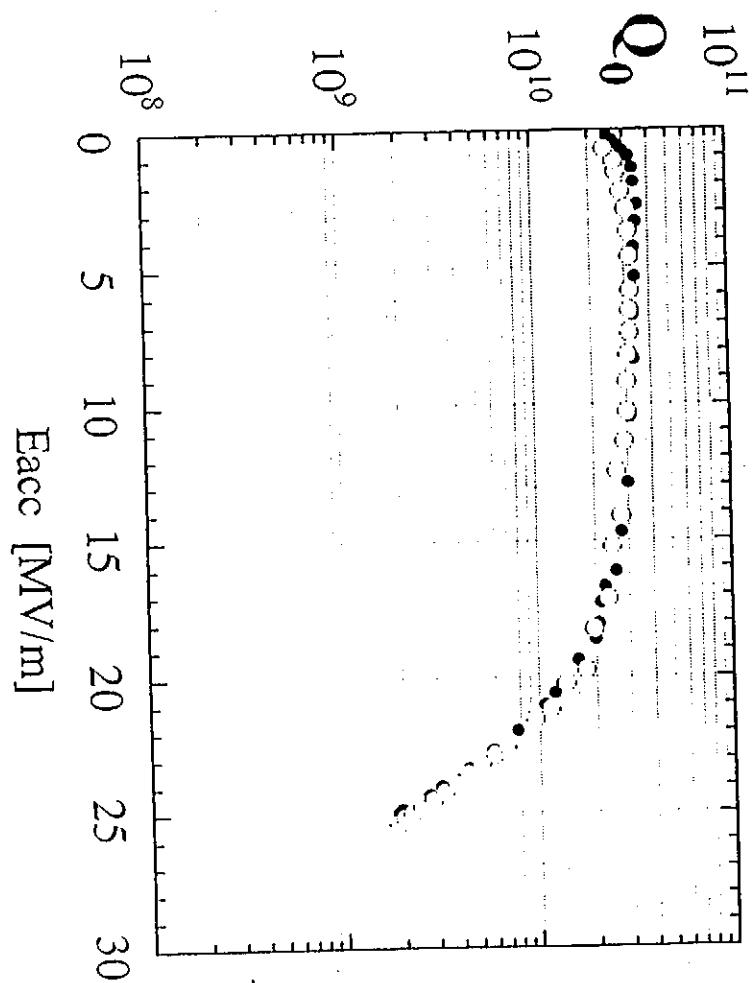
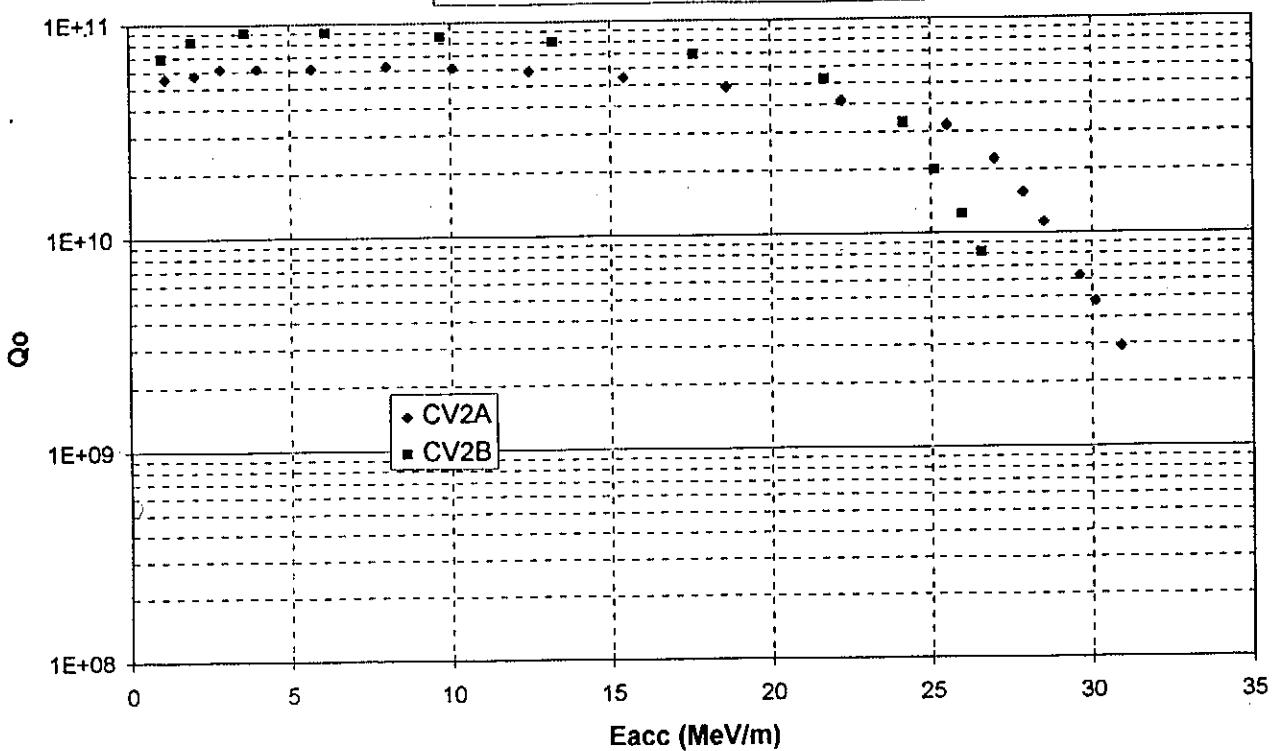


FIELD EMISSION
27%

Q-DEGRADATION
30%

C1 05 F=1300MHz T=1.7K

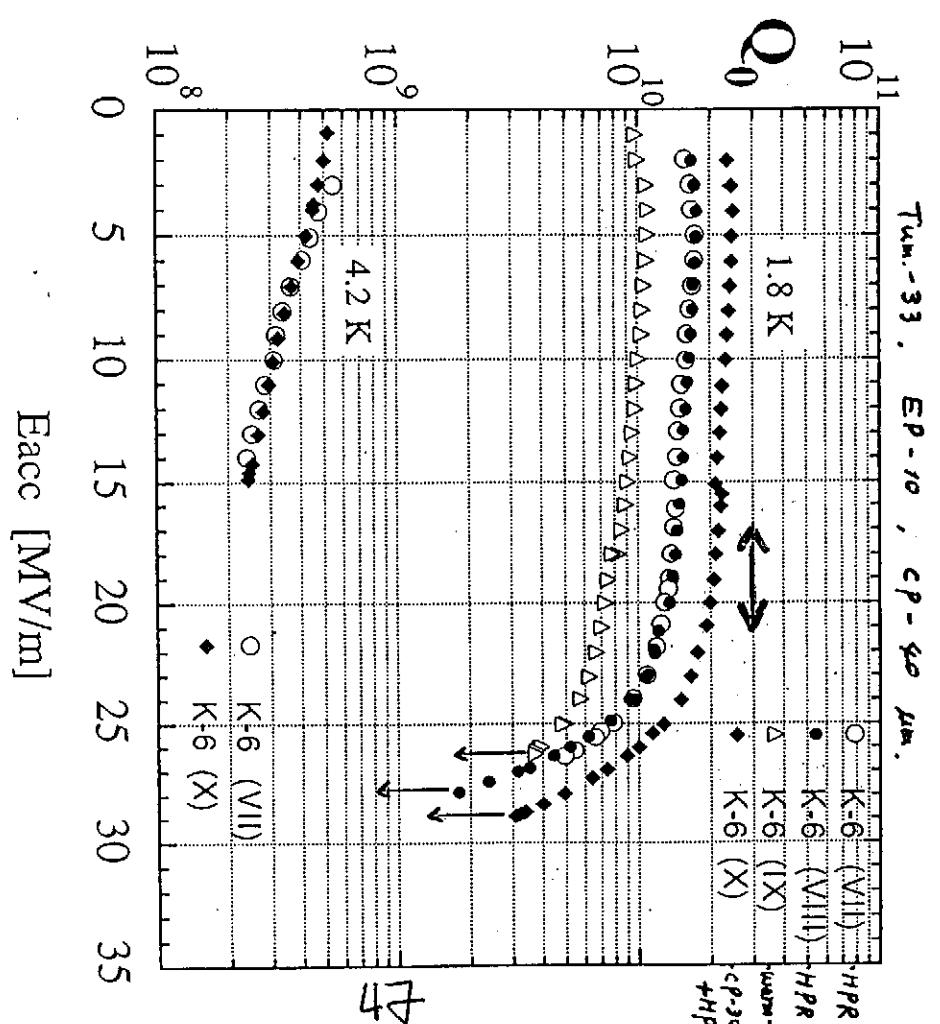
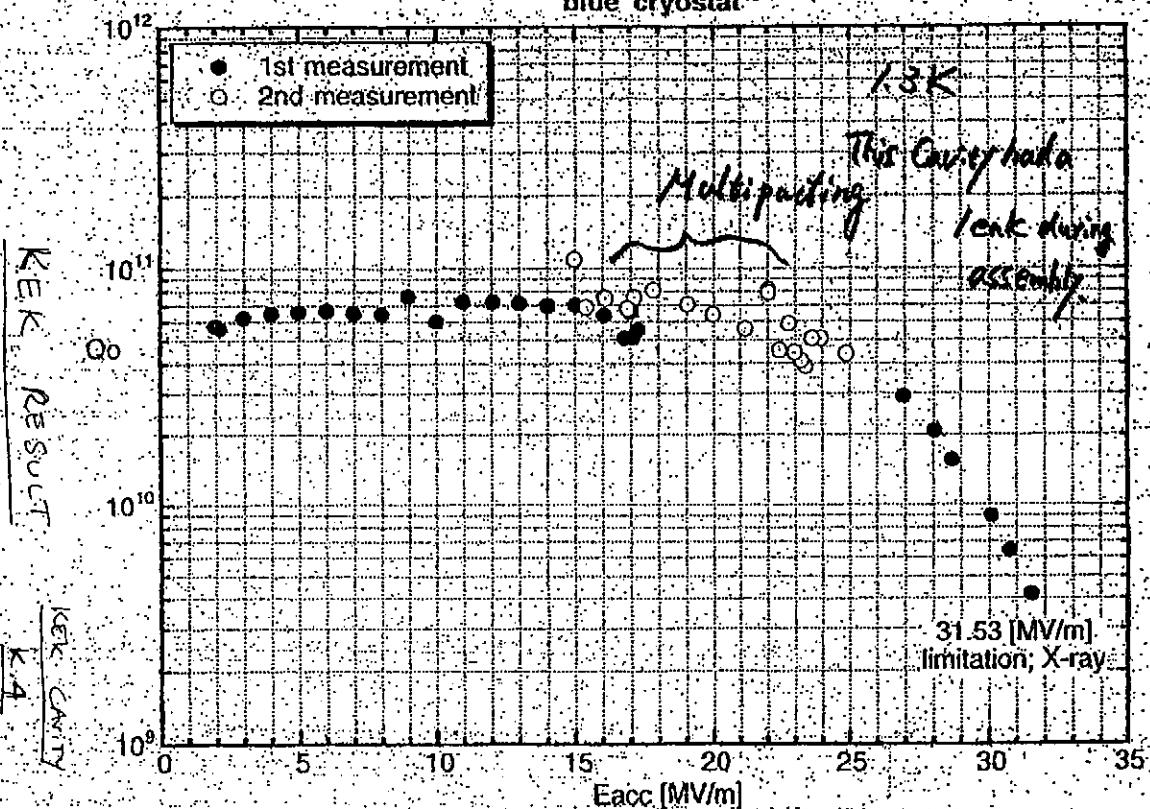
C101 F=1300MHz T=1.7K



K1-01d, 97'01/14
K1-01e, 97'02/06
KEK Cavity measured at SACLAC
 $H_T: 100^\circ C, 6h$
 $CP + H_{PN} + \text{Valve in clean room}$
Insert CN2B

- K1-01d, 97'01/14 [with no Field Emission]
- K1-01e, 97'02/06 [with strong elec. & x-ray emission]

K-4 7th measurement '95.12.14(Thu)
 CP(20μm), HPR(1hr, p.w.), shower rinsing(0.1μm filtered p.w.)
 blue cryostat



- KEK result
- K-4
- $E_{\text{acc}} = 18 \sim 22 \text{ MV/m} : \text{Processing level}$
 Quenched with e^- & x-ray
 - $E_{\text{acc}} > 25 \text{ MV/m} : Q_0\text{-drop}$
 without e^- & x-ray (no F.E.)

Q-Degradation without Field Emission

P. Kneisel

Laboratory	Cavity # of cells	onset of Q-degradation E _{acc} [MV/m]	Treatment of cavity	Treatment on cavity outside	Observations	H _p /E _{acc}	Comments
Saclay	1 [L-Band]	20 - 25	Ti, 1100 °C > 20 h	bcp	4 cavities effect dependent on insert T-map: heating at equator	40 - 42	exponential decrease power limited very sensitive e ⁻ -probe
DESY I	D1 9 [L-Band]	≥ 20	Ti, 1350 - 1400 °C 4 h	bcp	π-mode only	42	
DESY II	C21 9 [L-Band]	20 - 25	800 °C 2 h	bcp	several modes, 1-cell?	42	
KEK	1 [L-Band]	~ 25	800 °C, no Ti	bcp?	2 cavities	~ 42	
CERN/ CEBAF	1 [L-Band]	~ 20	Ti, 1000 °C, 20 μm, bcp	no bcp?		~ 45	
CEBAF	5 [L-Band]	16 - 19	Ti, 1350 °C 4 h, 2 sides	bcp	2 K	~ 45	quadratic decrease
Wuppertal I	1 [S-Band]	~ 10 - 27	Ti - single sided 20 μm bcp	no bcp		~ 42	
Wuppertal II	1 [S-Band]	~ 20	Ti, 1350 °C ~ hrs 20 μm bcp	bcp		42	e ⁻ -probe very sensitive photo diodes exponential decrease

Explanations

- a) Statistical distribution of "weak" areas (Ta, Ti ..)
- b) Multipacting

Proposed Experiments/Activities

- a) Neutron irradiation of Saclay cavity(ies)
- b) Model calculations of H vs Q for
 - statistical distribution of "weak" SC spots
 - statistical distribution of normal conducting spots
- c) Neutron irradiation of several Nb-sheets from different vendors to look for Ta-distribution
(Tokyo Denkai, Wah Chang, Cabot, ...)
- d) More diagnostic measurements at Saclay on Saclay cavities
(T-mapping, different bath temperatures, application of radiation diodes, etc.)
- e) Multipacting simulation calculations

List of Participants

Aune, Bernard - DESY/FDET, e-mail: aune@aune.desy.de
Bathe, Mirko - DESY/FDET
Bloess, Dieter - CERN, e-mail: dietrich.bloess@cern.ch
Bousson, Sebastien - IPN Orsay
Campisi, Isodoro - CERN EST/EM - CEBAF, e-mail: campisi@cebaf.gov
Diete, W. - ACCEL, e-mail: diete@accel.de
Garvey, Terry - LAL Orsay, e-mail: garvey@lalcls.in2p3.fr
Grandsire, Laurent - LAL Orsay
Habermann, Thomas - Univ. Wuppertal,
e-mail: habermann@wpos4.physik.uni-wuppertal.de
Junquera, Thomas - IPN Orsay, e-mail: junquera@ipno.in2p3.fr
Kaugerts, Juris - FZ Karlsruhe, e-mail: juri.kaugerts@itp.fzk.de
Kneisel, Peter - Jefferson Lab, e-mail: kneisel@micro1.cebaf.gov
Lesrel, Jean - IPN Orsay
Lierl, H. - DESY/MKS
Maccioni, Pierre, CERCA
Magne, Christian - Saclay
Matheisen, Axel - DESY/MHF-SL, e-mail: math@vxdesy.desy.de
Möller, Wolf-Dietrich - DESY/MHF-SL, e-mail: wolf-dietrich.moeller@desy.de
Müller, Günter - Univ. Wuppertal e-mail: mueller@wpos4.physik.uni-wuppertal.de
Pekeler, Michael - DESY/FDET, e-mail: michael@pekeler.desy.de
Proch, Dieter - DESY/MHF-SL, e-mail: proch@proch.desy.de
Reschke, Detlef - DESY/MHF-SL, e-mail: reschke@vxdesy.desy.de
Safa, Henri - Saclay
Schmüser, Peter- DESY/FDET, e-mail: peter.schmueser@desy.de
Singer, Waldemar - DESY/MHF-SL, e-mail: singer@singer.desy.de
vom Stein, Peter - FZ Rossendorf, e-mail: steinp@fz-rossendorf.de