LU-115

Discussion of D+W, RFQ and ETC.
A. Schempp

1/26/88

A. SCHEMPP UNIV. FRANKFURT

D+W : STEM PROBLEM

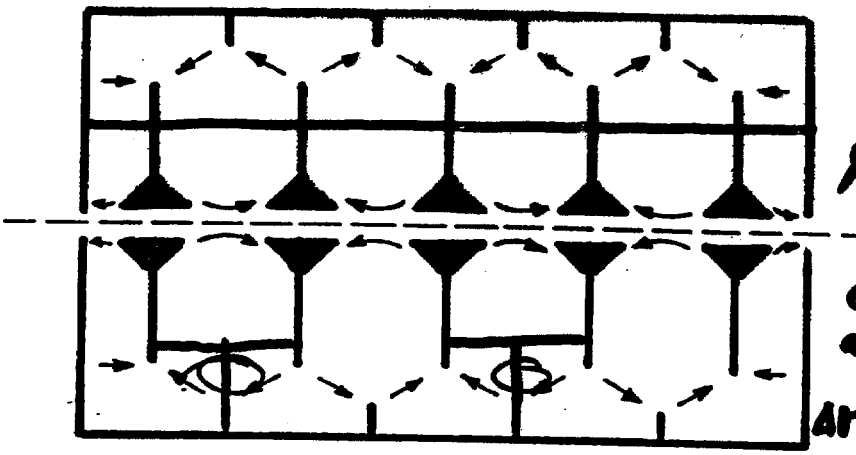
RFQ : New exp. results

Projects

FNAL-RFQ

HE -RFQ

D+W STEMS



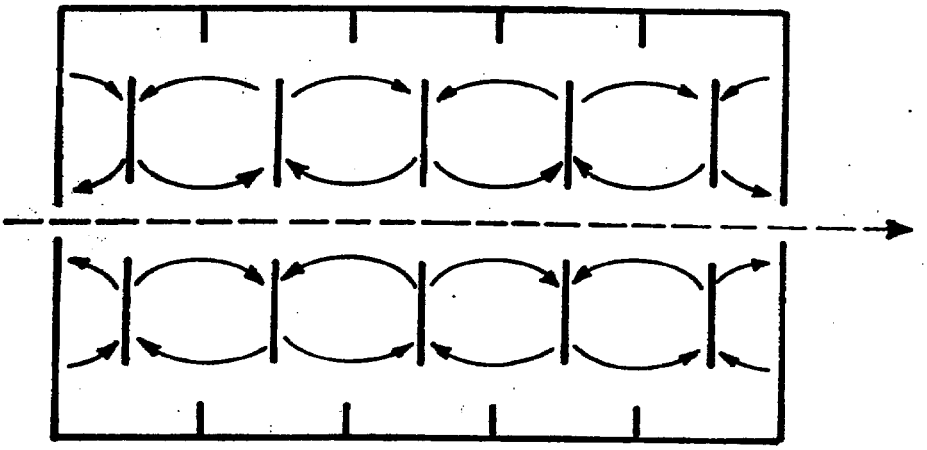
3-4 planes
ϕ 6-10 mm

coupl. mode not affected

$\Delta f < 3 \cdot 10^{-3}$ mm (10)
7.5 (6)

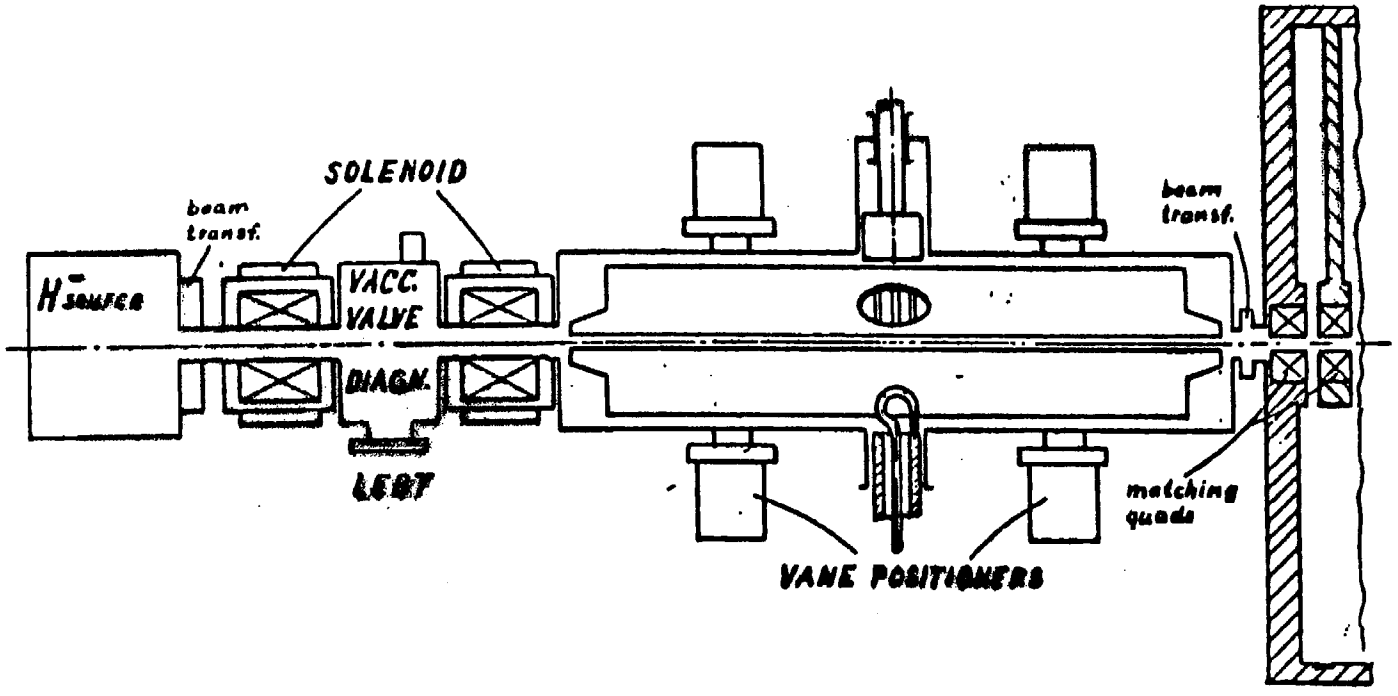
losses, limited mech. stability

perturbation of coupling mode (on-axis beam)



ALIGNMENT OF WASHERS OUTSIDE
LESS WELDING, BRAZING
SMOOTH COPPER PLATED TANK + DISKS

LONG HOMES? ⇒ SINGL RADIAL STEM


SOLENOID
beam transf.
H⁻ SOURCE
VACC. VALVE
DIAGN.
LEBT
beam transf.
matching quads
VANE POSITIONERS

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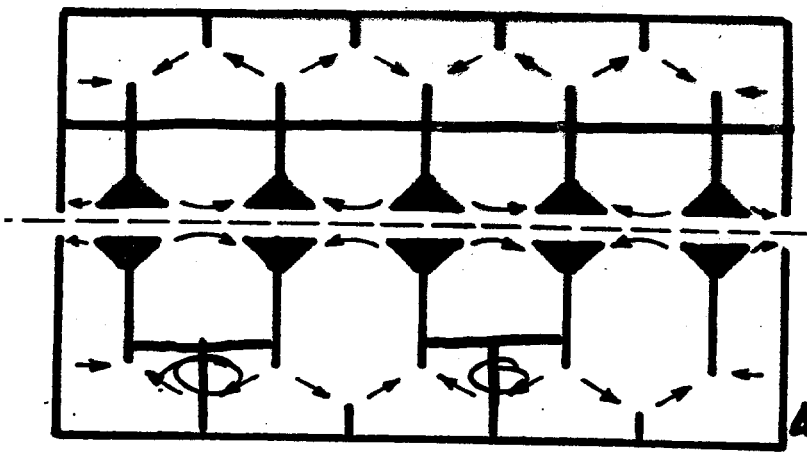
FINAL-RFQ

HE -RFQ

D+W STEMS



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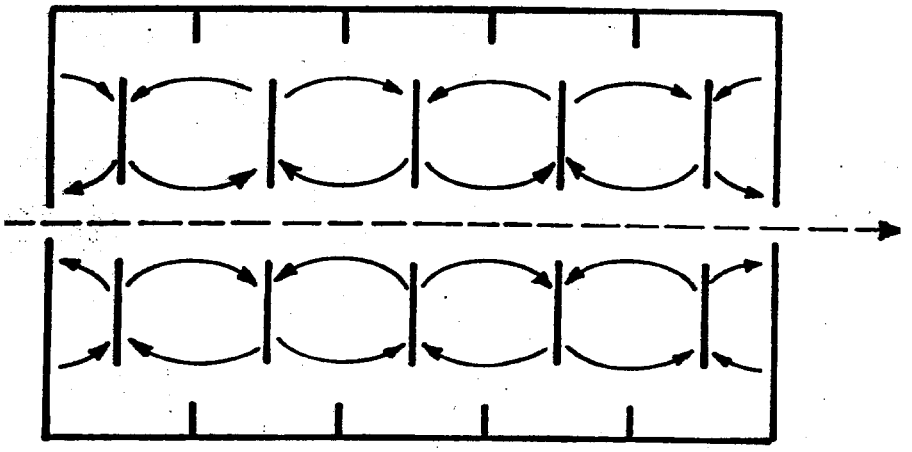
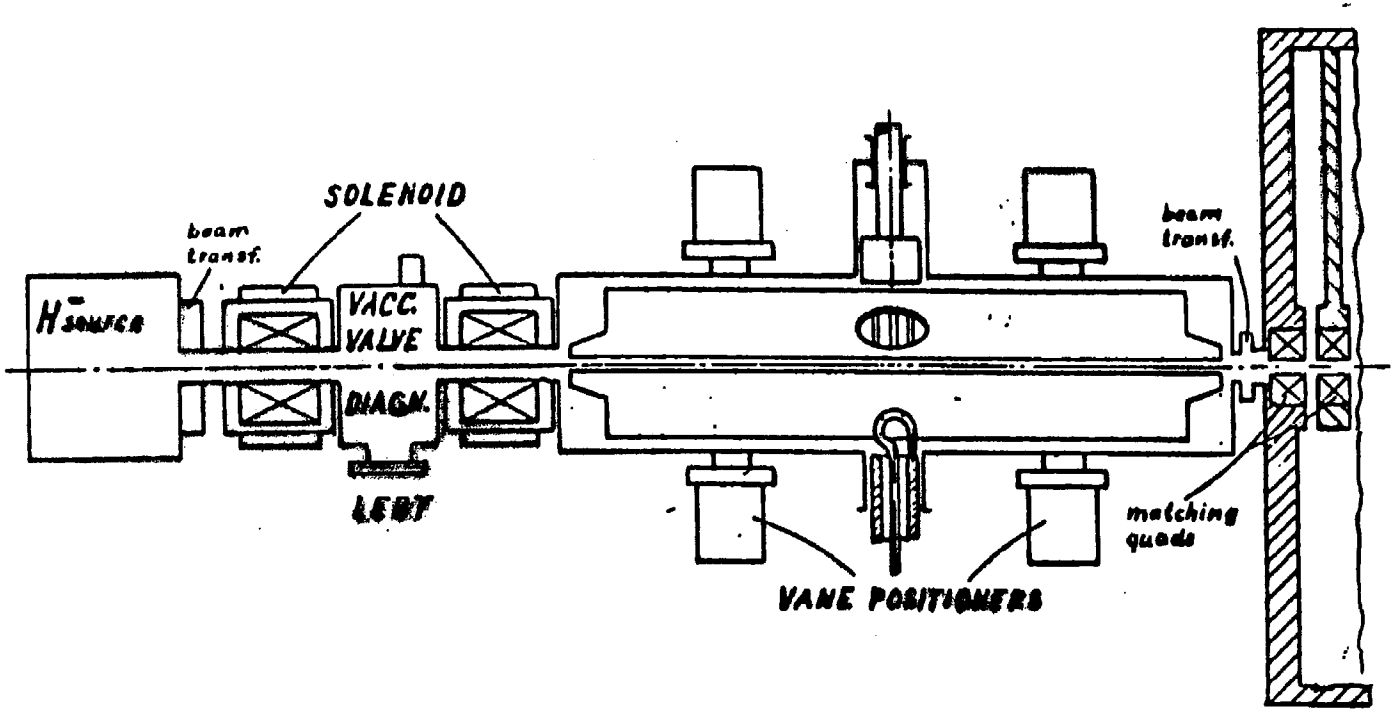
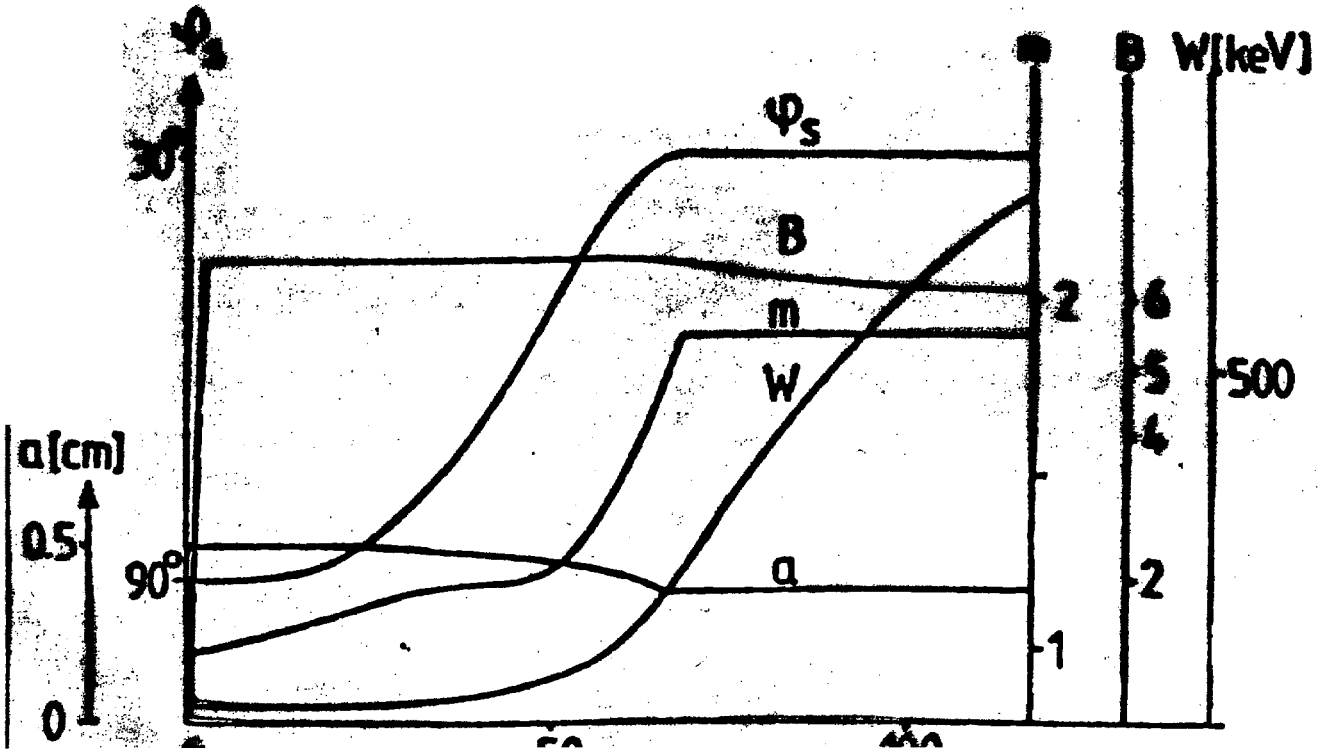


ALIGNMENT OF WASCHERS OUTSIDE
LESS WELDING, BRAZING
SMOOTH COPPER PLATED TANK + DISKS

LONG RODS? ⇒ SINGL RADIAL STEM


SOLENOID
beam transf.
H⁻ SOURCE
VACC. VALVE
DIAGN.
LEBT
beam transf.
matching quads
VANE POSITIONERS

Input energy W_{in}	18	keV
Output energy W_{out}	750	keV
Radio frequency f	202.56	MHz
Beam current I	20	mA
Current limit I_{max}	60	mA
Transmission efficiency η	96	%
Total length L_{tot}	117.7	cm
Total cell number N_o	135	
Intervane voltage V	70.5	kV
Maximum electric field E_{max}	21.9	MV/m
Vane modulation m	1 to 1.88	
Minimum aperture radius a	3.5	mm
Average radius r_o	5.0 - 5.2	mm
Radial focusing strength B	0.4 - 6.5 - 6.14	
Synchronous Phase Angle ϕ_s	90 - 30	degree
Normalized input emittance (90 %) E_{ni}	0.7	π µm rad
Ellipse parameters, input (> 90 %)		
$\alpha_x = \alpha_y$	0.57	
$\beta_x = \beta_y$	20.58	mm
Normalized output emittance (90 %) E_{ne}	1.0	π µm rad
Ellipse parameters, output (90 %)		
α_x	2.41	
β_x	157	mm
α_y	- 1.46	
β_y	- 120	mm
Envelope in x (90 %) x_{max}	2.1	mm
Envelope in y (90 %) y_{max}	1.8	mm
Energy spread (90 %) ΔW_{max}	10.4	keV
Phase spread (90 %) $\Delta\phi_{max}$	22.8	degree

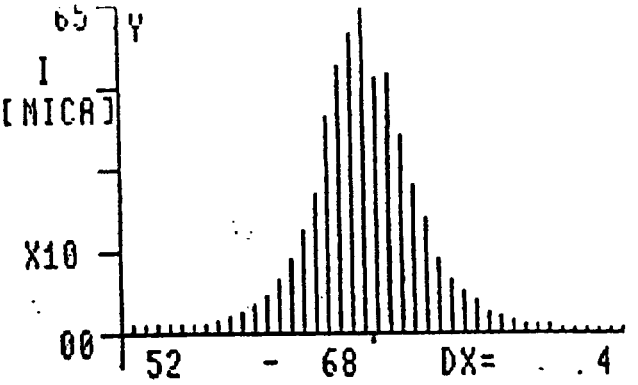


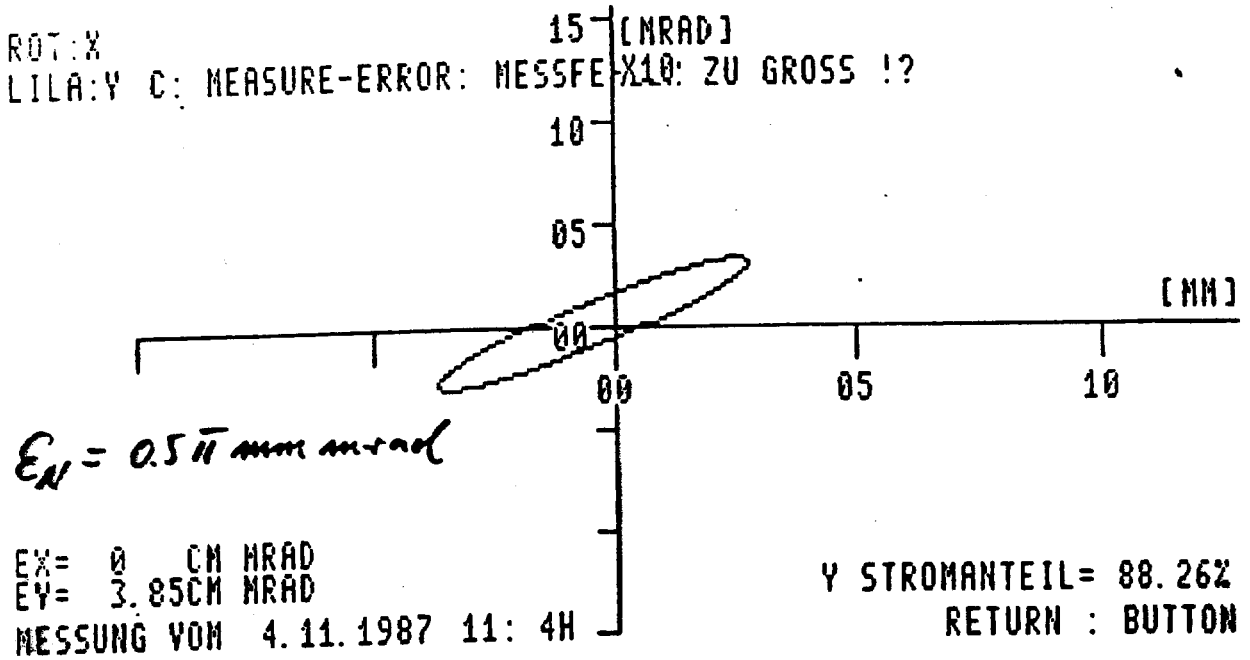
β = 4.03 %

20.5 mA

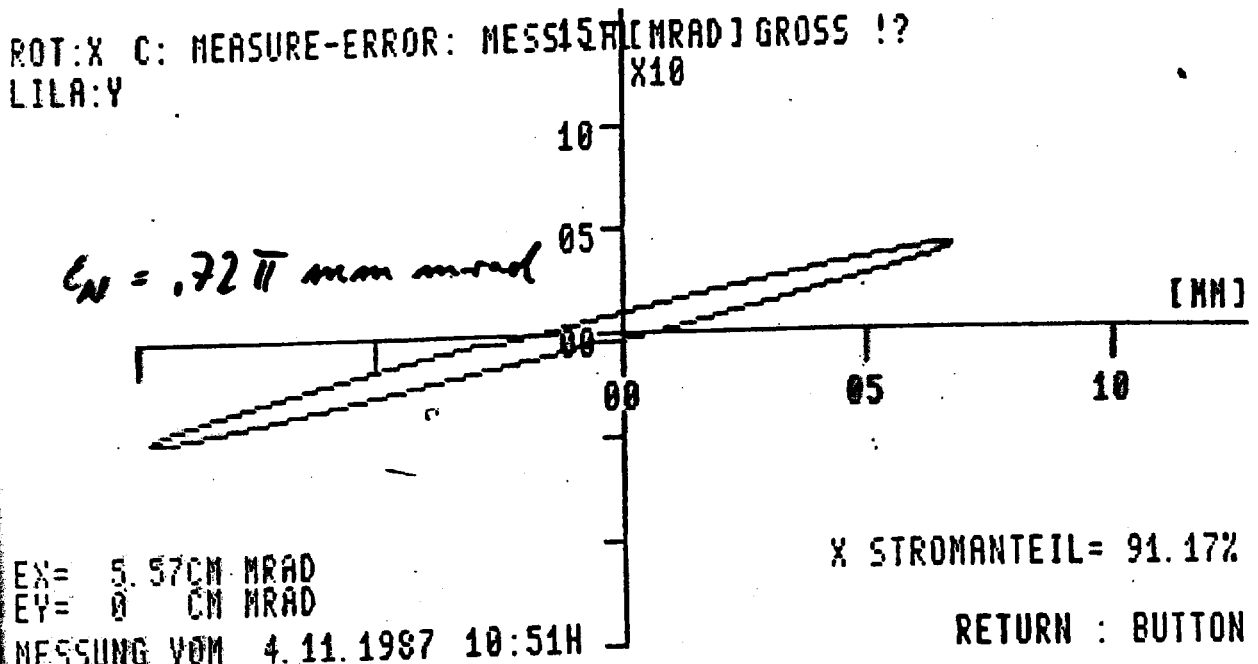
95 kW

$\varepsilon_{n,} = \varepsilon \cdot \beta$

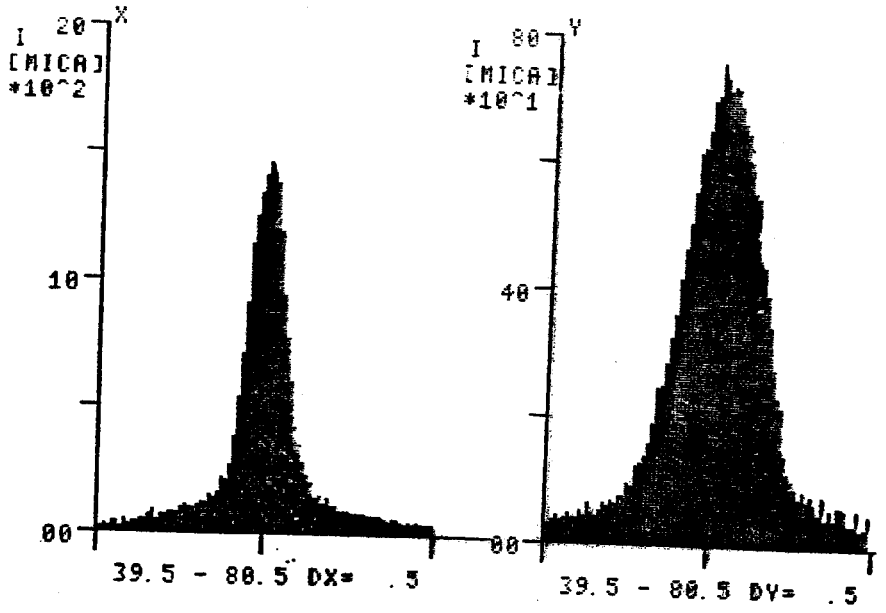




ε_N = 0.5 π mm mrad

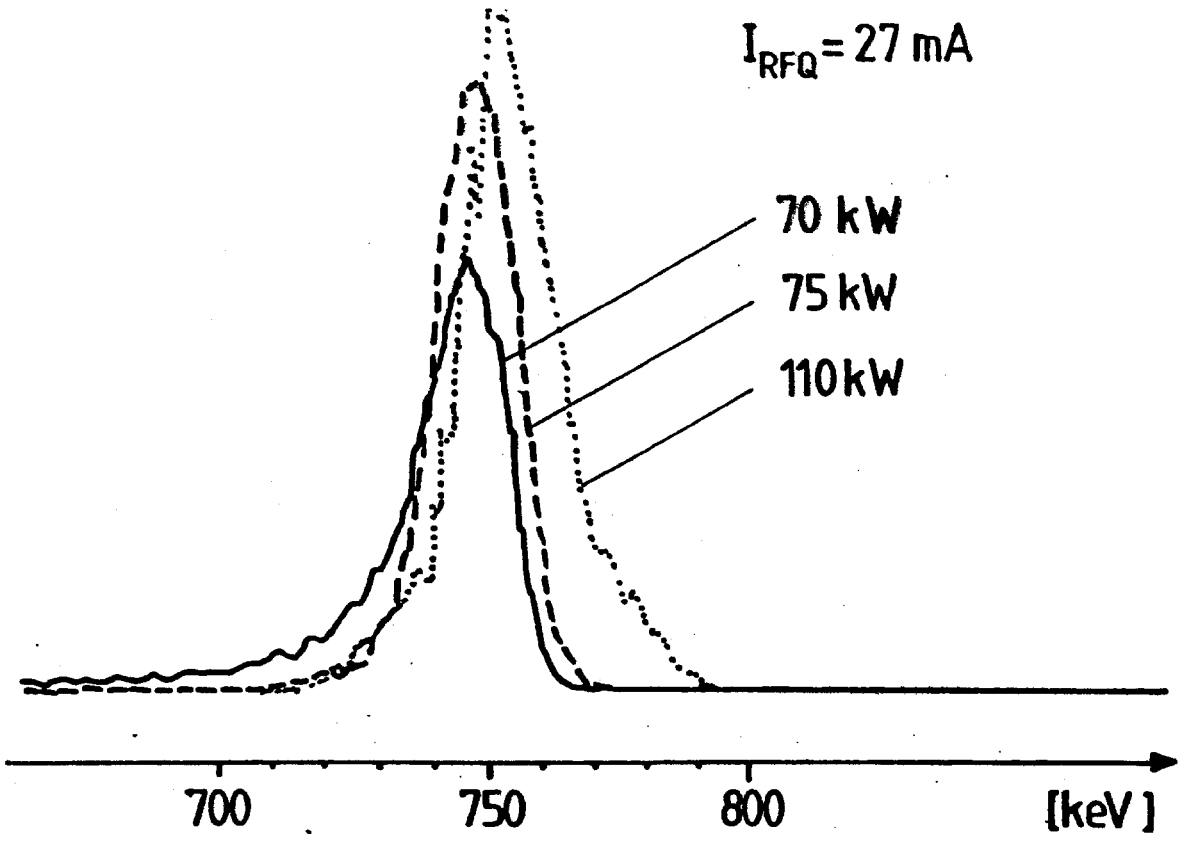


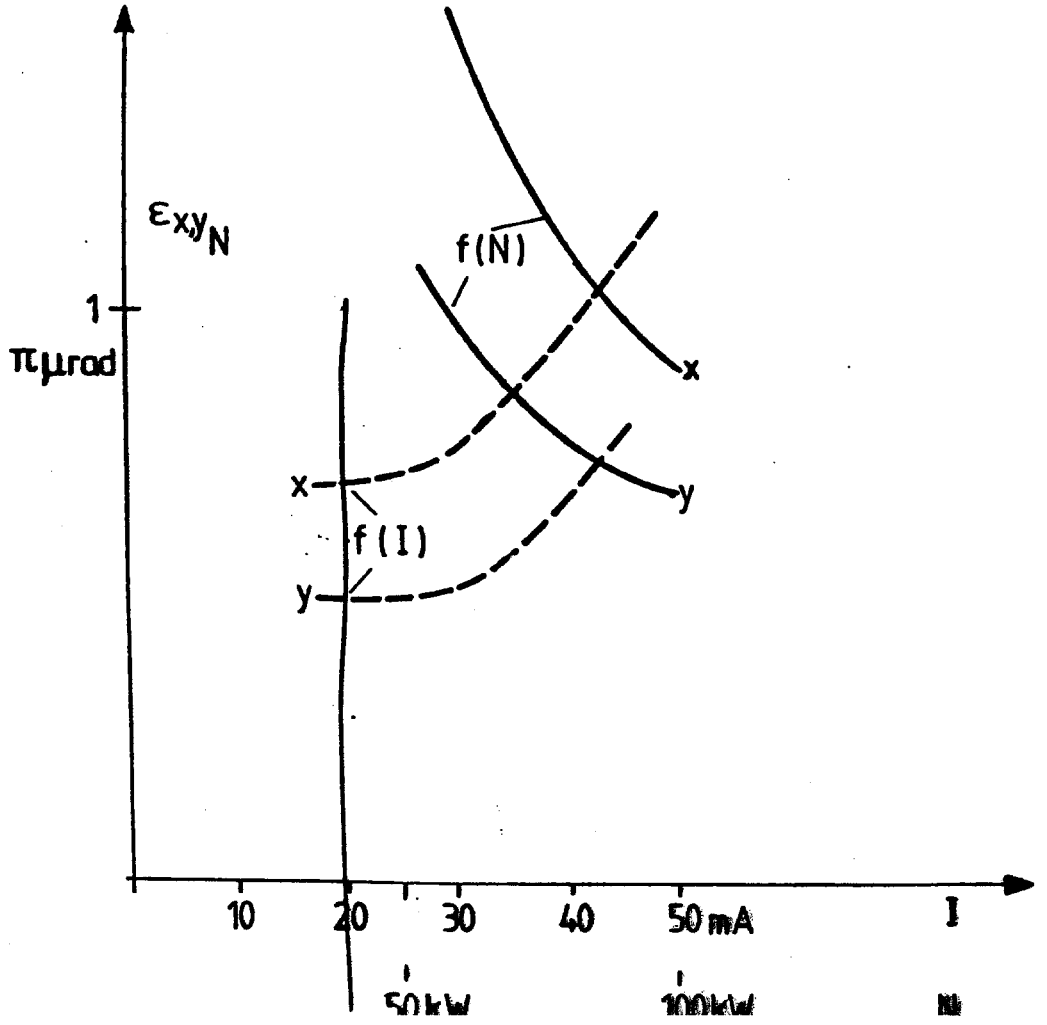
ε_N = .72 π mm mrad



4 ROD-RFQ

I_{IS}= 45mA , $I_i \approx$38mA, I_{RFQ}=30mA


I_{RFQ} = 27 mA
70 kW
75 kW
110 kW
700
750
800
[keV]


ε_{x,y_N}
1
πμrad
f(N)
x
y
x
f(I)
y
10
20
30
40
50 mA
I
50 kW
100 kW

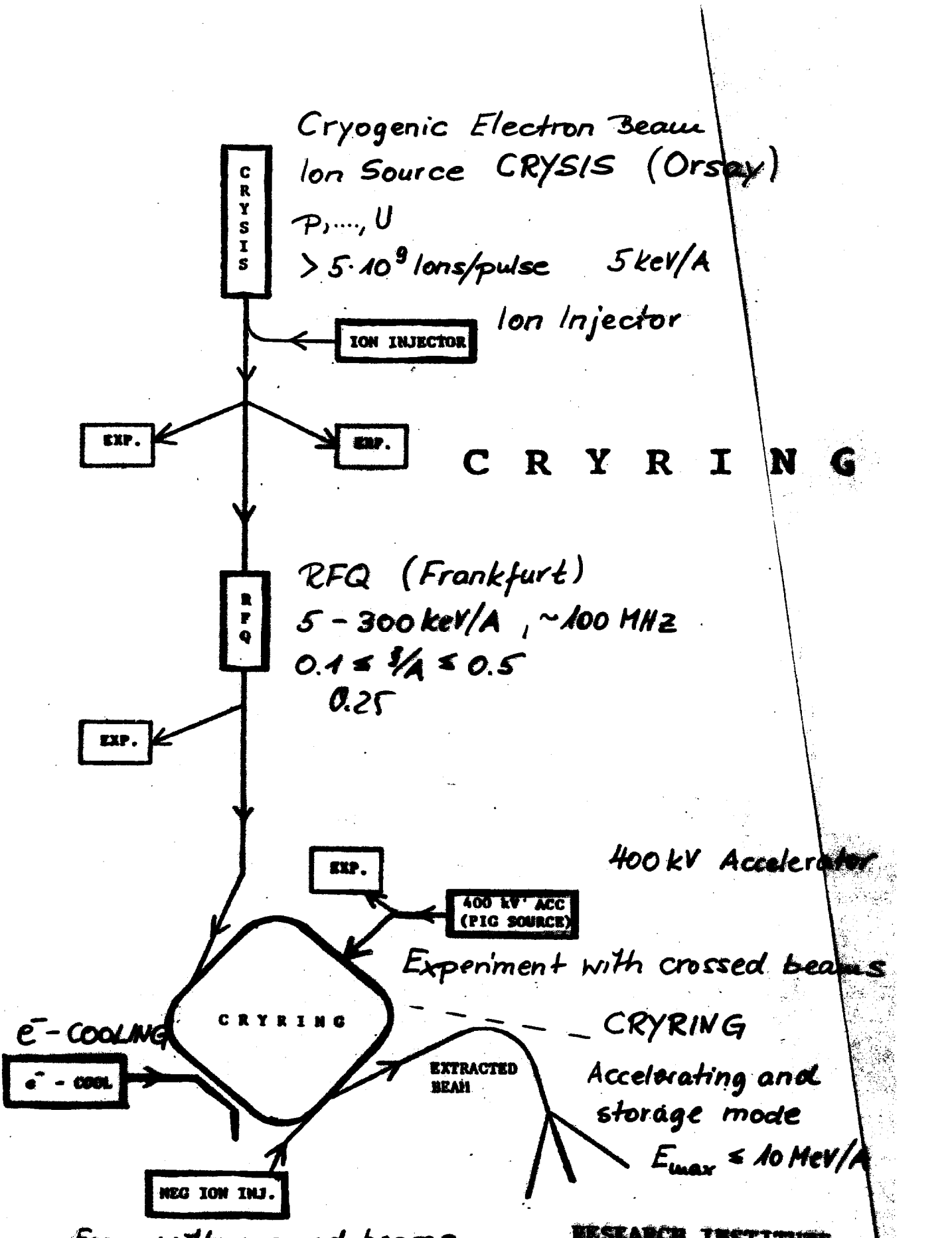
Applications

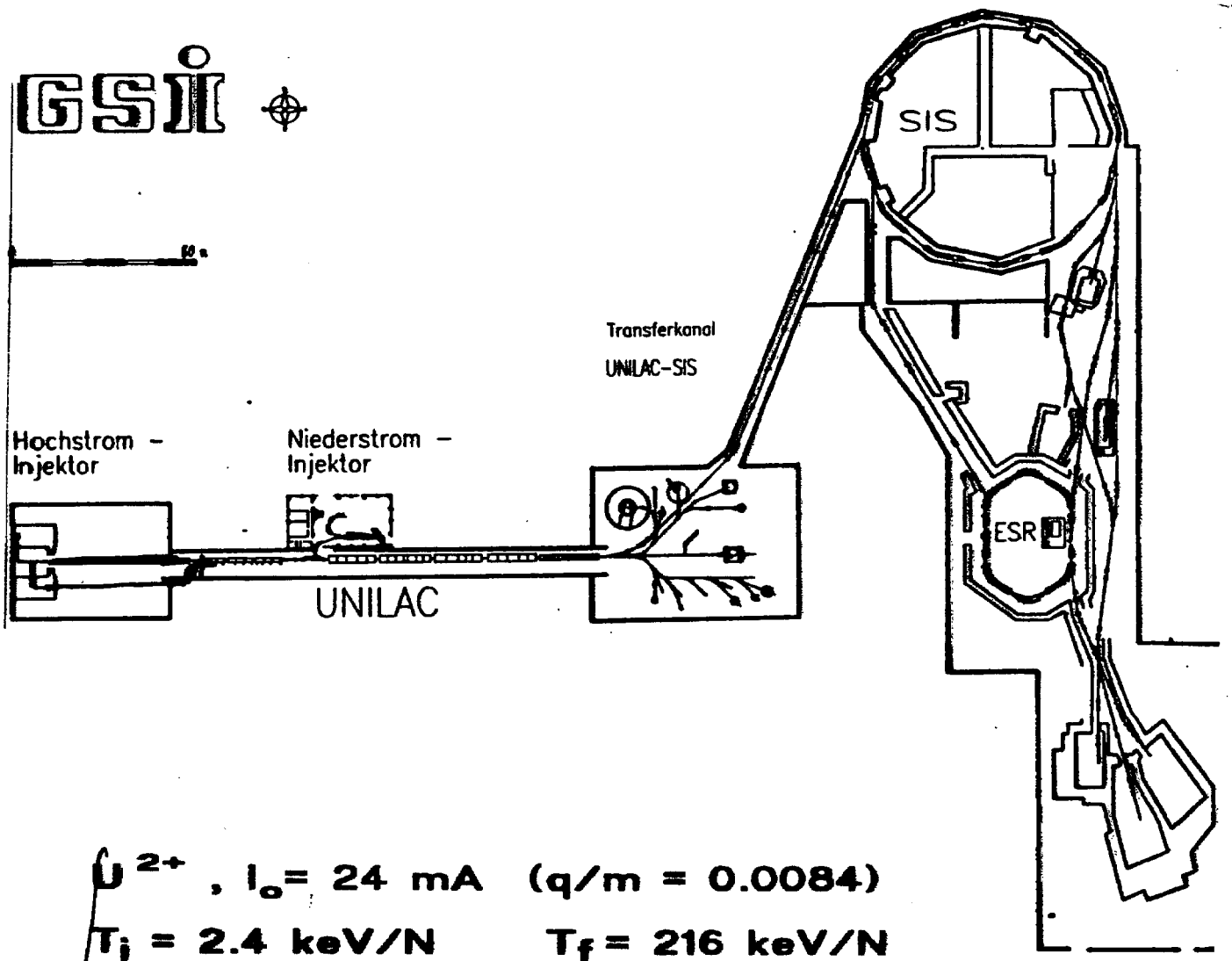
injectors p, H^-, HI
Cluster
decceleration
single pulse
funneling
implanter
ECR/EBIS - RFQ combinations
sc. RFQs

a) T_i low , IS pot. low, high currents

b) higher energies, currents, duty cycles
better emittances ε, $\Delta\varphi$, ΔT

there is a lot outside HEP and GPP !!


Cryogenic Electron Beam
Ion Source CRYSIS (Orsay)
P, ..., U
> 5·10^9 Ions/pulse 5 keV/A
CRYSIS
ION INJECTOR
Ion Injector
EXP.
EXP.
CRYRING
RFQ
RFQ (Frankfurt)
5 - 300 keV/A , ~100 MHz
0.1 ≤ q/A ≤ 0.5
0.25
EXP.
EXP.
400 kV Accelerator
400 kV ACC (PIG SOURCE)
Experiment with crossed beams
CRYRING
e⁻-COOLING
e⁻ - COOL
CRYRING
EXTRACTED BEAM
Accelerating and storage mode
E_max ≤ 10 MeV/A
NEG ION INJ.
Exp. with merged beams
RESEARCH INSTITUTE OF PHYSICS STOCKHOLM

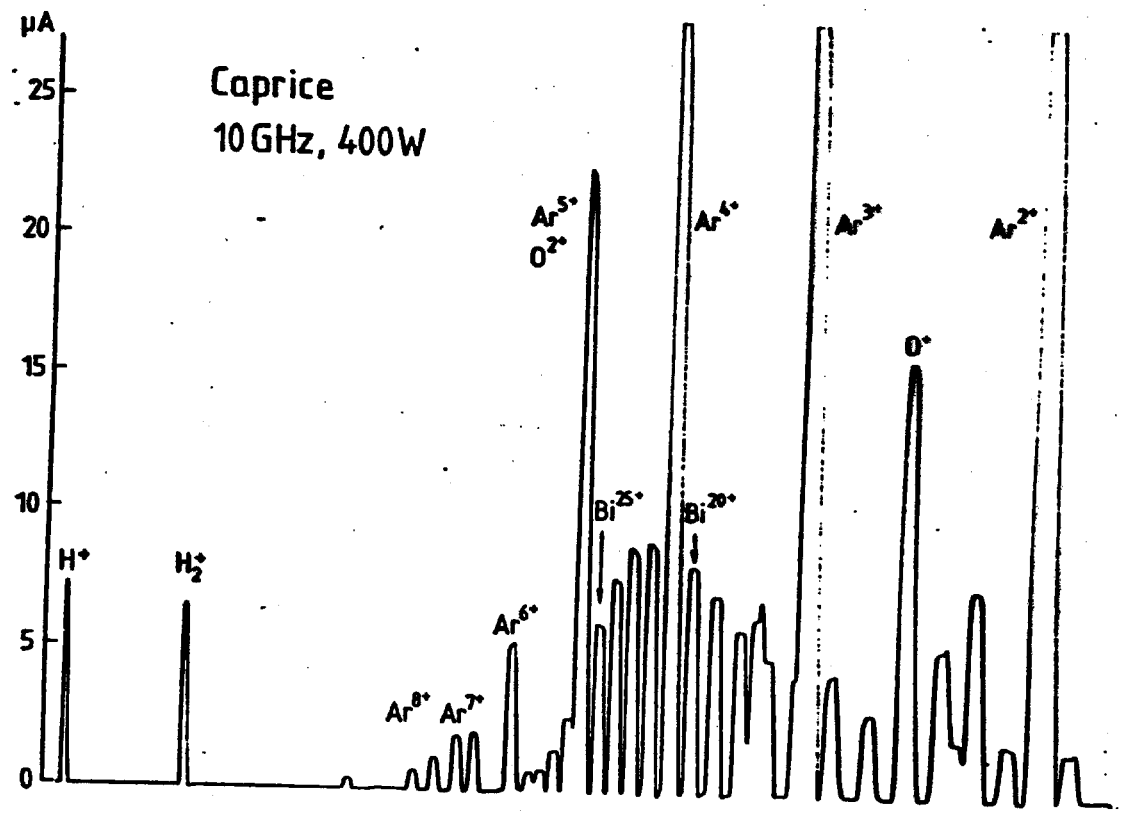


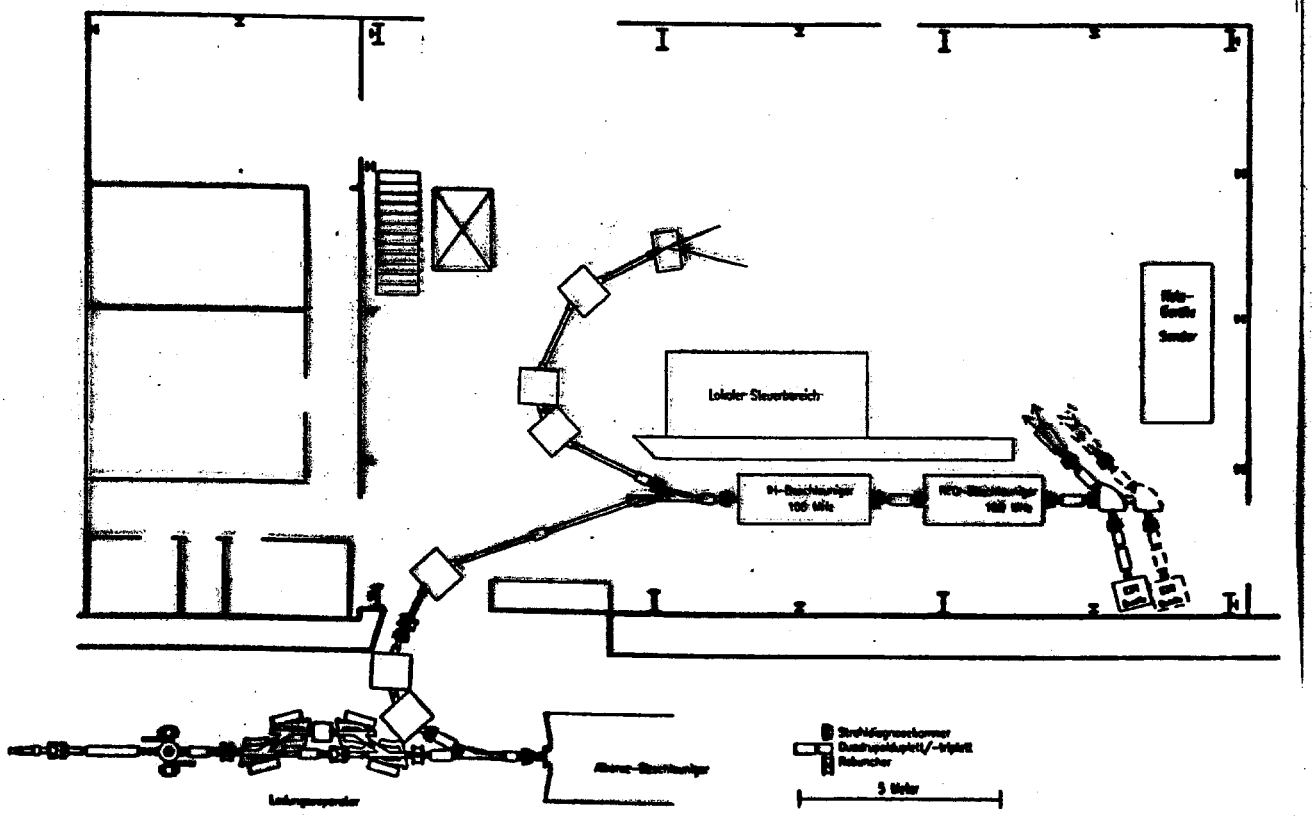
U^{2+} , I_o = 24 mA (q/m = 0.0084)

T_i = 2.4 keV/N T_f = 216 keV/N

ΔU = 12.7 MV L < 40 m

F = 27 MHz , U_Q = 180 kV


µA
25
20
15
10
5
0
Caprice
10 GHz, 400W
H+
H2+
Ar8+
Ar7+
Ar6+
Ar5+
O2+
Bi25+
Ar4+
Bi20+
Ar3+
O+
Ar2+


Lokaler Steuerbereich
5 Meter

FERMILAB-RFQ

4 Rod RFQ 201.5 MHz 90 kV
30-750 keV
Tank L=1.2m, Ø = 25 cm
R_p= 75 kΩm, ED = 1 %

φ_s= 55/35°, a = 4/3.5 mm
m= 1.4/2.0 N = 108
σ_r = 45°
I_{lim} = 120 mA α_n < 2 π μrad

	Transm.	ΔT/T
50. mA	: 90%	1.6 %
100 mA	: 88%	2.%

$\overline{T_F}$ = 1.5 MeV : L = 2.2 m

$\overline{T_F}$ = 2.0 MeV : L = 2.9 m

Separate RFQ 10 MeV (1.5-10) ⌀ 6m

U_Q = 200 kV $\overline{E_{av}}$ ~ 1.4 MV/m

P_f = 450 kW $P_c \approx 530$ kW/m ⇒ 3.2 MW ! $\eta \sim 4.2$ MeV/m

(Alvarez: ≈ 30 MeV/m (P_c ~ .6 MW))

a) Costs of Acceleration } ≈ 3 MW
b.) Cost of rf-focusing

$$\eta = \frac{E^2}{N/L} \quad [MV/m] \qquad \eta_{Alv.} \approx 30\,MV/m \qquad \sim \omega^{\frac{1}{2}}$$

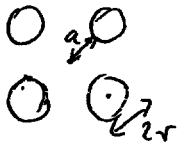
$$\eta_{RFQ} = f(pd)\,, \text{ cross fields} \qquad \sim \omega^{-\frac{3}{2}}$$

(trivial: $\eta \sim$ losses^{-1})

$$\eta \sim \frac{1}{\omega^2 C_a^2} \quad : \text{CHARGING OF ELECTRODES}$$

FACTOR FIVE IN POWER $\Rightarrow$ 2.2 in C_a !

$\approx$ 40 pF/m (Φrod 1:1 $\approx$ 20 pF/m, Φvane 120 pF/m)



$a/r = 1 \Rightarrow$ 88 pF/m

ideal (Septics) $q_r = 9$ $\approx$ min Quad harmonics $h_{6,12,18}$

a average aperture!
> min. aperture

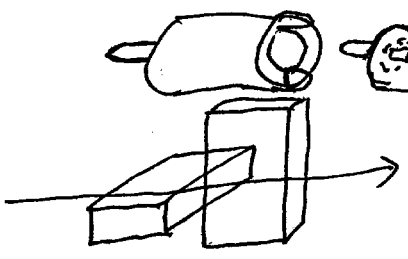
a/r 1.1 (DESY RFQ)
a/r 1.2 CRYRING, GSI
$a/r > 1.2$ (ACC SYS ?)

} higher Quad-harmonics!

Inspection of other electrode schemes:

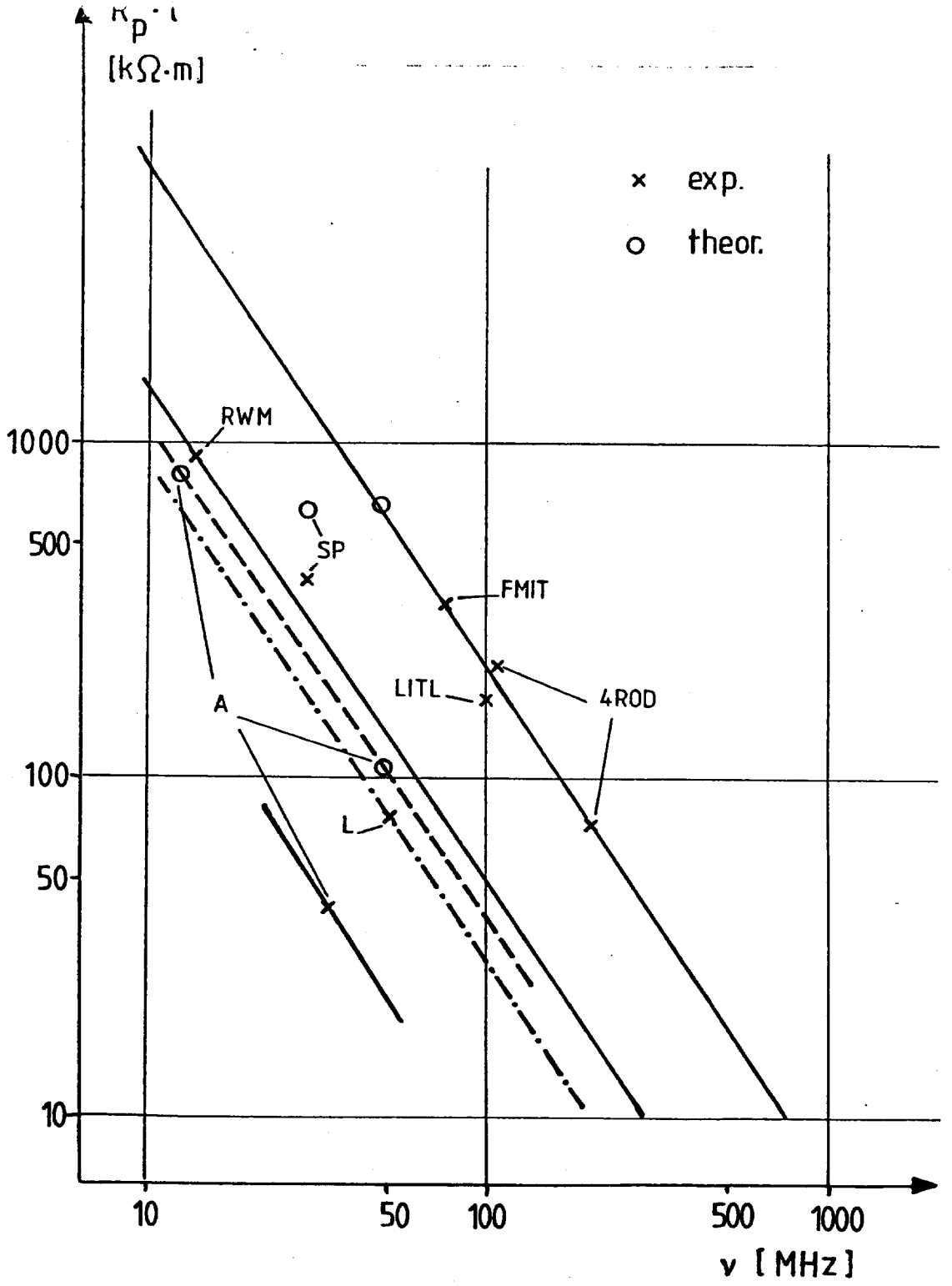
0.) Alvarez : $\approx$ 30-40 pF/m ? no rf focusing

1.) DRIFTUBES WITH FINGERS : BOUSSARD, LAPOSTOLLE, LAPCHINSKI



weak focusing ; $C \sim C_{Alv.}$

weak focusing

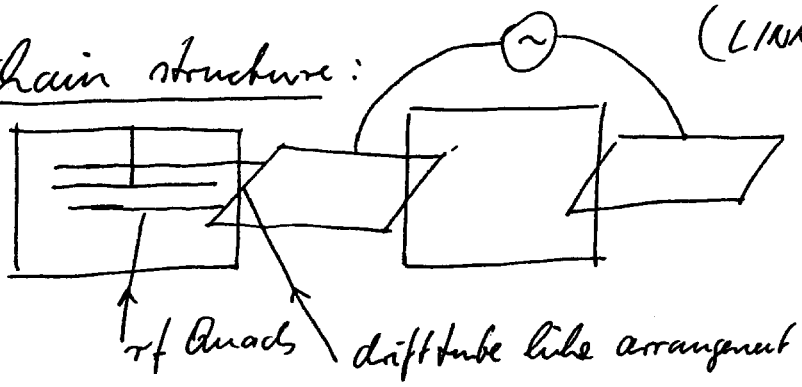


A, RWM : SPLIT COAXIAL RFQs

FMIT, LITL : 4 VANE

SP SPIRAL STEMS - 4 ROD

2) Drift structure: (LINAC 66)



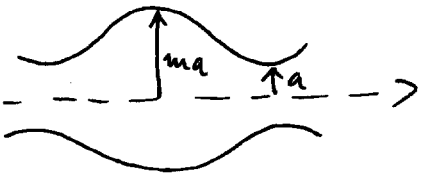
$C > C_{RFQ}$

3) RING LOADED RFQ (WANG B.S.)
ADDED CAPACITY TO INCREASE ACCELERATION

4.) FINGER LOADED RING RFQ (SPLIT COAXIAL TYPE) (GSI)
($\sim$ 140 - 180 pF/m low energie heavy ions

2,3,4 high acc. efficiency

$$A = \frac{m^2 - 1}{m^2 I_0(ka) + I_0(mka)}$$



$m > 1$

$$X = 1 - A\, I_0(ka)$$

$A \simeq$ TT-factor A, X strong correlation

New ideas try to outtrick A, X connection

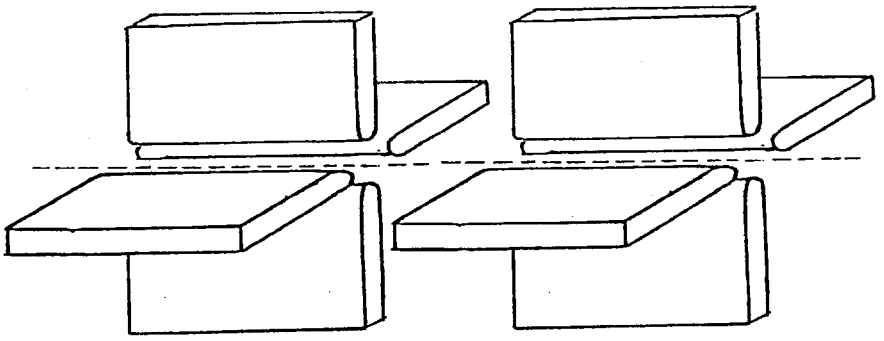
prop.: A increases, $X \hat{=} \text{const}$!

LINAC: $E_z = E_0 I_0(kr)\, e^{i\varphi}$ $E_r \frac{\omega}{v} \frac{r}{2} e^{i\varphi}$ (VLCC)

($E_0 \sim A$) LOOKING FOR A DIFFERENT EFFEKTIV M!

REDUCE CAPACITY

A MAX ACC. A IS NOT SO IMPORTANT,
IT REDUCES FOCUSING



AXIS on ~~ZERO~~-POTENTIAL, NO ACCELERATION

MOVE TWO ELECTRODES TO BIGGER APERTURE

⇒ ACCELERATION