EHF - 87 - 56

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EFFICIENCY OF A SIDE COUPLED LINAC

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6.10.87

EFFICIENCY OF A LINAC $\equiv$ SHUNT IMPEDANCE

$$\rightarrow ZT^2 = \frac{(\text{Energy gained by a part.})^2}{\text{Power dissipated}}$$

$$\text{Cost} \propto \frac{1}{\sqrt{ZT^2}}$$

$\Rightarrow$ AIM OF A LINAC DESIGN IS TO MAXIMIZE THE SHUNT IMPEDANCE

$$\boxed{Z \propto \sqrt{f}}$$

EFFICIENCY OF A LINAC AS A FUNCTION OF FREQUENCY

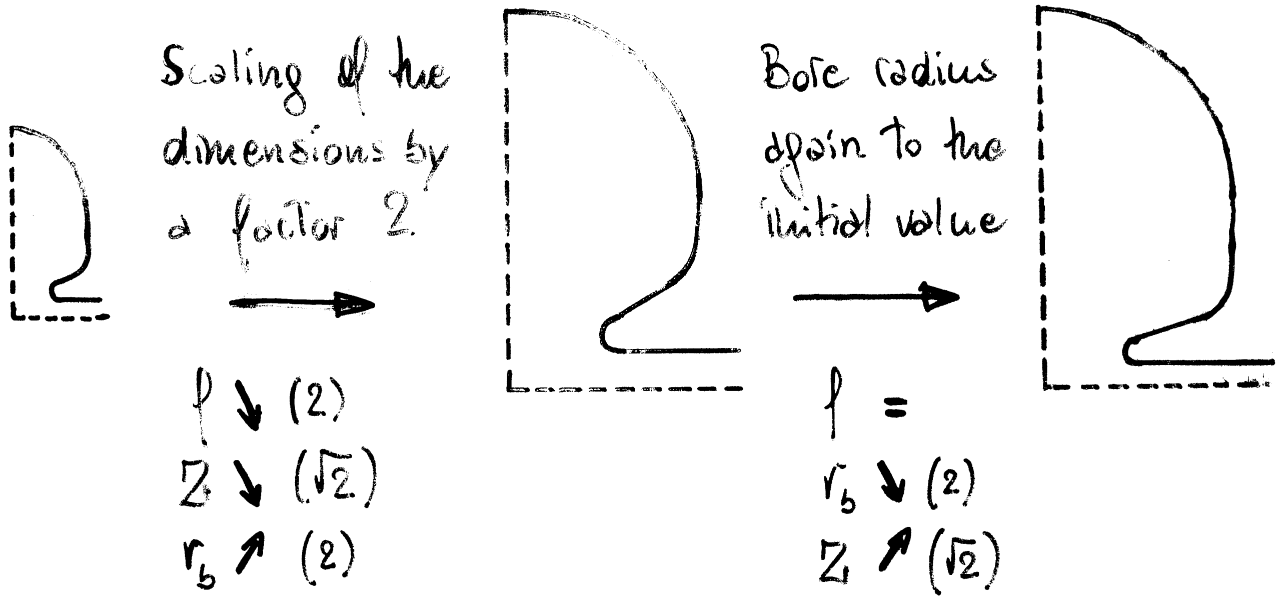
- CAVITY DIMENSIONS $\propto 1/f$
- SKIN DEPTH $\propto 1/\sqrt{f}$

$\Rightarrow$

$$\Rightarrow Z \propto \frac{1}{R_s} \propto \frac{\delta}{D} \propto \sqrt{f}$$

(1) FIRST CORRECTION - BORE RADIUS

$$Z \propto \frac{1}{\sqrt{r_{bore} + 2 r_{nose}}}$$



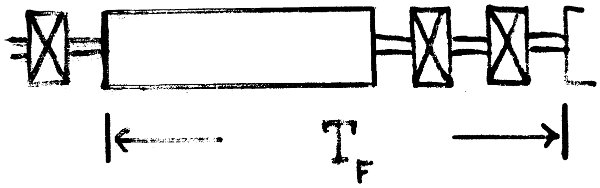
- ⇒ FOR A COSTANT BORE, THE EFFICIENCY OF A SIDE COUPLED STRUCTURE IS <u>INDIPENDENT</u> FROM THE FREQUENCY

<u>BUT</u> :

$$r_{bore} \propto r_{beam} \propto \sqrt{\frac{\varepsilon_t}{f}} \Rightarrow \boxed{Z \propto f^{1/4}}$$

THE BORE HAS TO BE INCREASED TO TAKE INTO ACCOUNT THE INCREASED BEAM DIMENSIONS

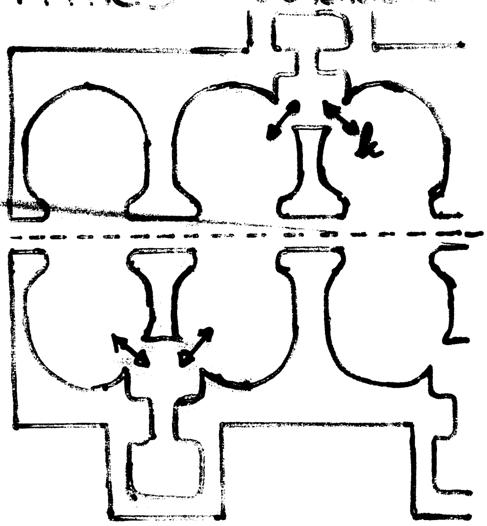
② SECOND CORRECTION – FOCUSING PERIOD



$$r_{beam} \propto T_F$$

REDUCING THE FOCUSING PERIOD IT IS POSSIBLE TO REDUCE THE BEAM SIZE ($\Rightarrow$ THE BORE RADIUS)

③ THIRD CORRECTION – COUPLING



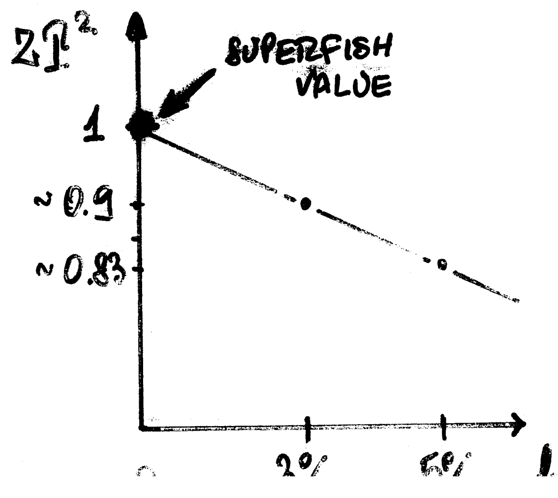
- GROUP VELOCITY
- STABILITY
- POWER FLOW DROOP

$\propto \frac{k}{N}$

N = number of cells in a tank

$\Rightarrow$ A REDUCED FREQUENCY ($\Rightarrow N \downarrow$) CAN ALLOW THE SAME TANK BEHAVIOUR WITH A REDUCED COUPLING

BUT:



$$Z \propto \frac{1}{\text{slot dimensions}} \propto \frac{1}{k}$$

A REDUCED COUPLING ALLOWS A HIGHER EFFICIENCY

EFFICIENCY OF A 600 MHZ SIDE COUPLED LINAC COMPARED TO THE 1200 MHZ SCL

A. SHUNT IMPEDANCE OF THE 1200 MHZ SCL → ZT^2: 57.7 MΩ/m

B. SCALING THE CAVITIES DIMENSIONS BY A FACTOR 2 (TO GO TO 600 MHZ) → ZT^2: 40.8 MΩ/m

C. NEW BORE RADIUS :

$r_{beam} \propto \sqrt{\varepsilon_t / p}$ ↑
tanks length ↓
} ⇒ r_{bore} ↑ (1 cm → 1.2 cm)

D. REDUCTION OF THE COUPLING FACTOR BETWEEN CELLS

5% → 3%

⇒ THE SAME SHUNT IMPEDANCE AS AT 1200 MHZ

EVERYTHING OK ?

PEAK FIELD :

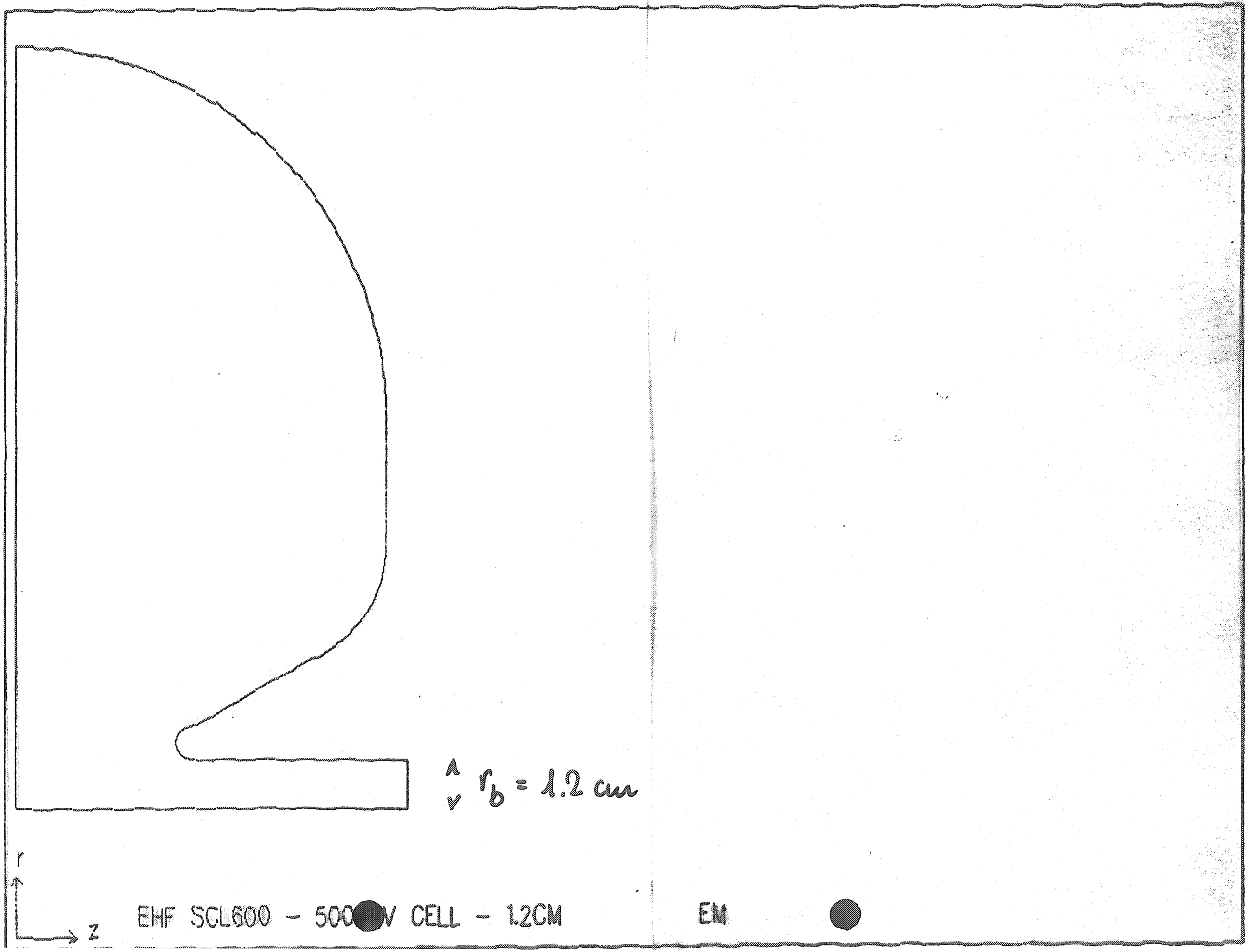
$\frac{r_{bore}}{L_t}$ ↓ ⇒ $\frac{g}{L_t}$ ↓ ⇒ $\frac{E_p}{E_0}$ ↑ ⇒ E_p ↑ (E_0 is kept the same)

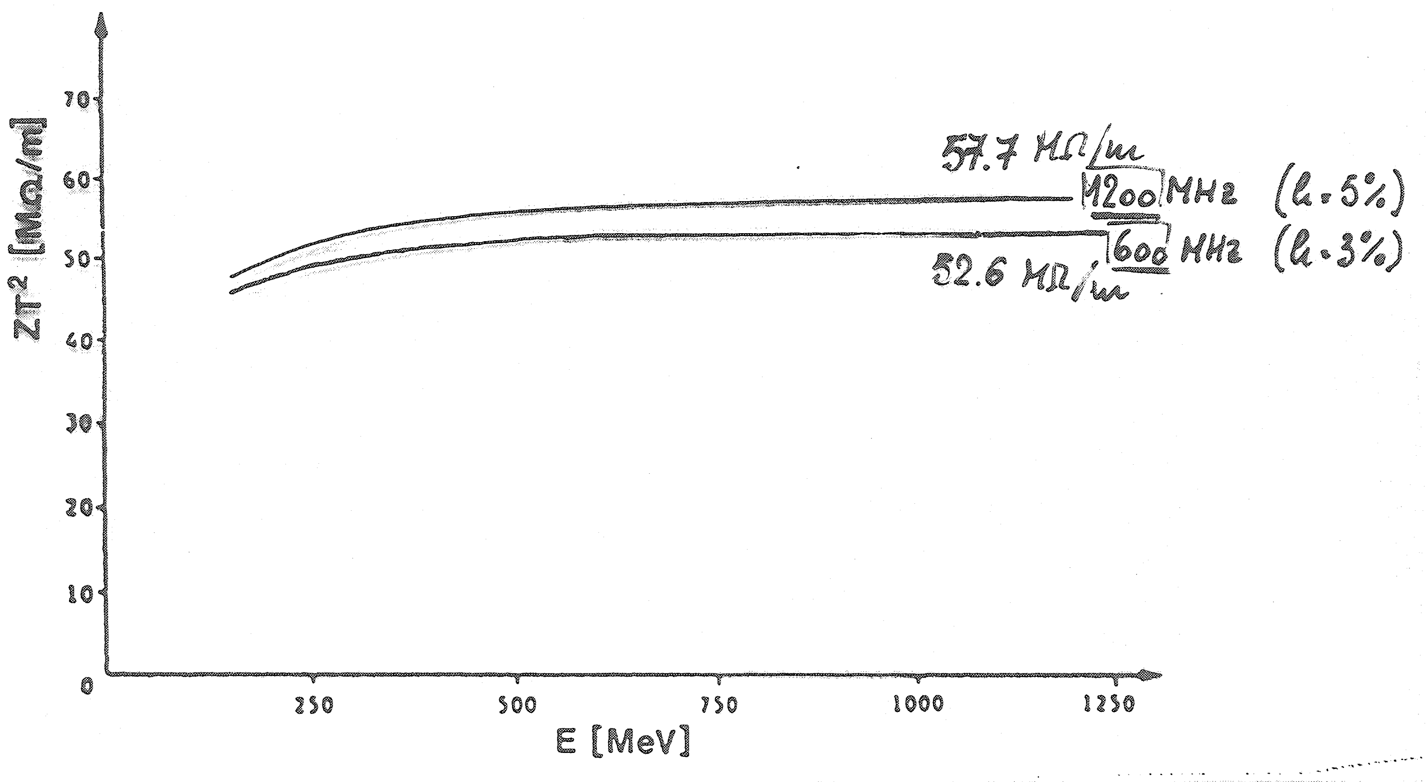
Kilpatrik field E_k ↓ (22 MV/m at 600 MHz)

} ⇒

⇒ A RELEASED DESIGN OF THE NOSES IS NEEDED

THIS REDUCES AGAIN THE ZT^2 TO 52.6 MΩ/m


r_b = 1.2 cm
r
z
EHF SCL600 - 500[illegible]V CELL - 1.2CM
EM



ZT^2 [MΩ/m]
0
10
20
30
40
50
60
70
250
500
750
1000
1250
E [MeV]
57.7 MΩ/m
1200 MHz (h = 5%)
600 MHz (h = 3%)
52.6 MΩ/m

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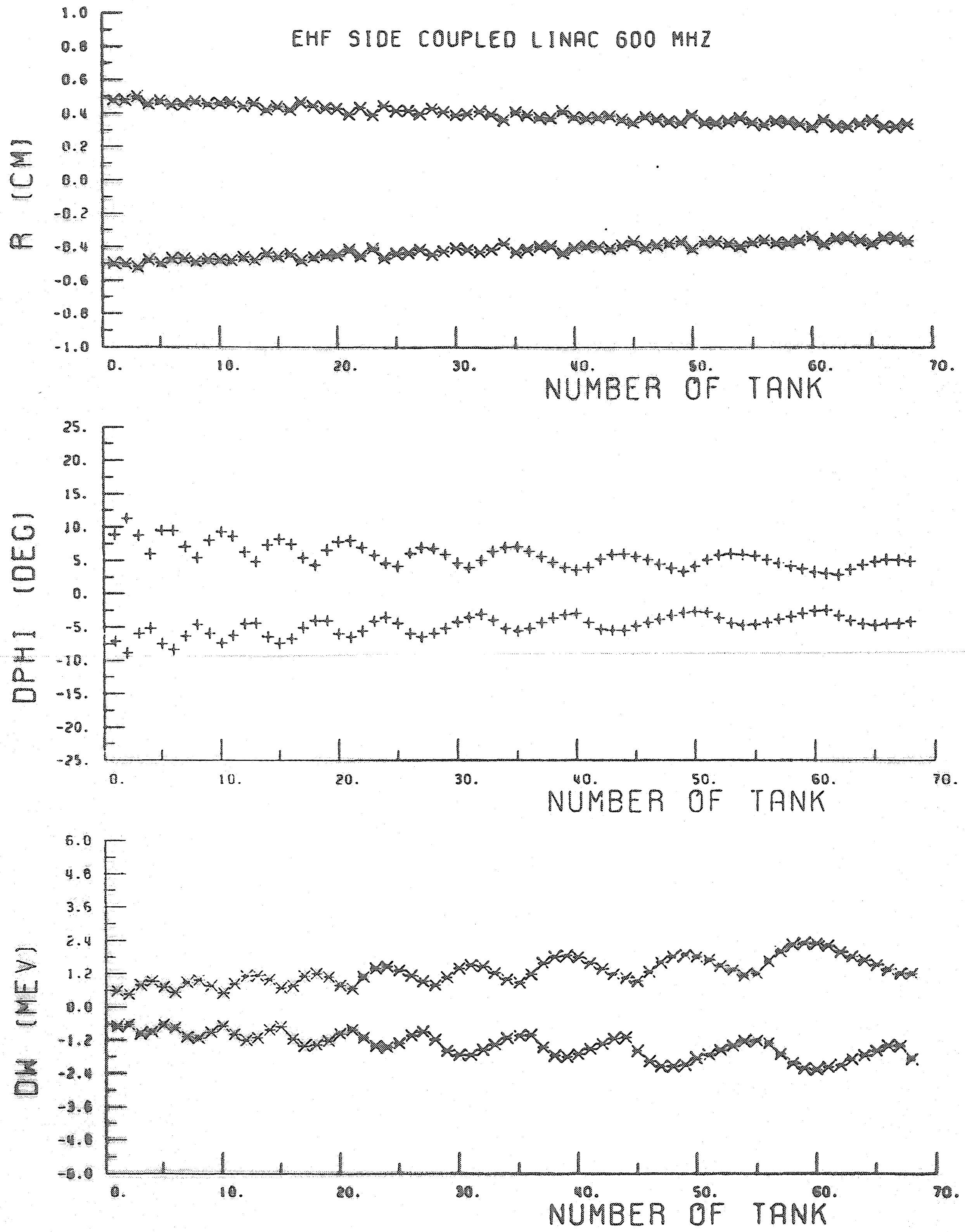
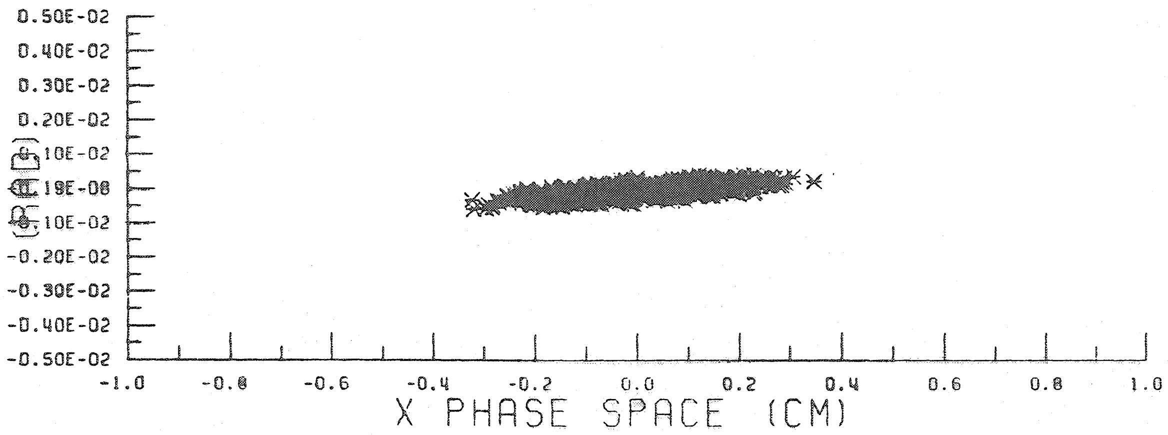
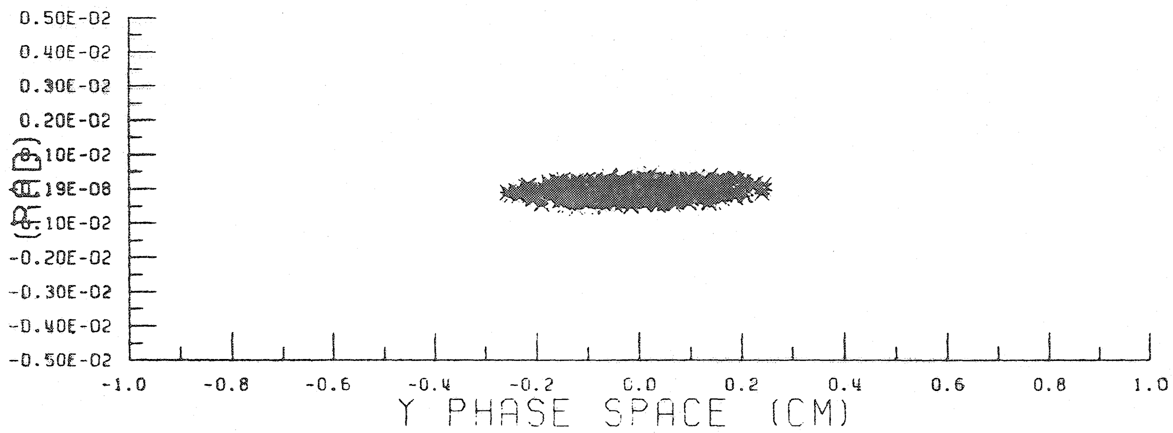
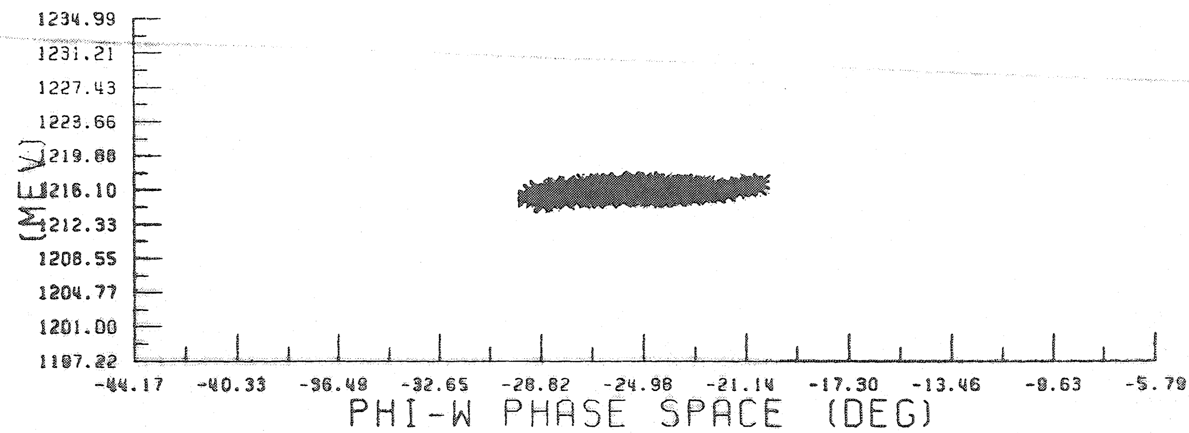
Table 13.6: SCL - Table of Parameters

Input Energy	150	MeV	
Output Energy	1200	MeV	
Frequency	1200	MHz	600
Number of Modules	16		17
Number of Tanks	64		68
Number of Acc. Cells per Tank	38		18
Accelerating Field E_oT	5.6-4.7	MV/m	
Peak Power	117	MW	125
Average Power	1.2	MW	1.25
Duty Cycle	1%		
Total Length	294.2	m	302.8
Synchronous Phase	-25°		
Beam Radius	0.4-0.25	cm	0.5-0.3
Norm. Transv. Emittance (RMS)	$\sim 0.6\pi$	mm.mrad	
Norm. Long. Emittance (RMS)	$\sim 4\pi$	deg.MeV	
Output Phase Spread	8°		5°
Output Energy Spread	2.7	MeV	1.8
Bore Hole Radius	1	cm	1.2
Ratio of gap/cell length	0.3-0.5		0.35-0.40
Accelerating Cell Radius	8.8-9.4	cm	~ 18.3
Real Eff. Shunt Impedance	47-58	MΩ/m	46.0-52.6
Transit Time Factor	0.89-0.85		0.93-0.88
Quality Factor	19-25	$\times 10^3$	≈ 30
Peak Surface Electric Field	38-32	MV/m	40-33 (= 1.8-1.5 E_K)
Quadrupole Gradients	35-55	T/m	30-46
TANKS LENGTH	2.5-4.5	m	2.3-4.0
COST	70	MUM	74.5


EHF SIDE COUPLED LINAC 600 MHZ
R (CM)
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
0.
10.
20.
30.
40.
50.
60.
70.
NUMBER OF TANK
DPHI (DEG)
25.
20.
15.
10.
5.
0.
-5.
-10.
-15.
-20.
-25.
0.
10.
20.
30.
40.
50.
60.
70.
NUMBER OF TANK
DW (MEV)
6.0
4.8
3.6
2.4
1.2
0.0
-1.2
-2.4
-3.6
-4.8
-6.0
0.
10.
20.
30.
40.
50.
60.
70.
NUMBER OF TANK


0.50E-02
0.40E-02
0.30E-02
0.20E-02
0.10E-02
0.19E-08
-0.10E-02
-0.20E-02
-0.30E-02
-0.40E-02
-0.50E-02
(RAD)
-1.0
-0.8
-0.6
-0.4
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
X PHASE SPACE (CM)


0.50E-02
0.40E-02
0.30E-02
0.20E-02
0.10E-02
0.19E-08
-0.10E-02
-0.20E-02
-0.30E-02
-0.40E-02
-0.50E-02
(RAD)
-1.0
-0.8
-0.6
-0.4
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
Y PHASE SPACE (CM)


1234.99
1231.21
1227.43
1223.66
1219.88
1216.10
1212.33
1208.55
1204.77
1201.00
1197.22
(MEV)
-44.17
-40.33
-36.49
-32.65
-28.82
-24.98
-21.14
-17.30
-13.46
-9.63
-5.79
PHI-W PHASE SPACE (DEG)