MEBT for JHF Linac

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1.Design Targets:

- **Matching the beam from the RFQ to the DTL in 6D phase space.**
  - **Low emittance growth**

- **Chopping the beam into a pulse structure as Fig.1 for injection into the ring.**
  - **Fast rise/fall time**

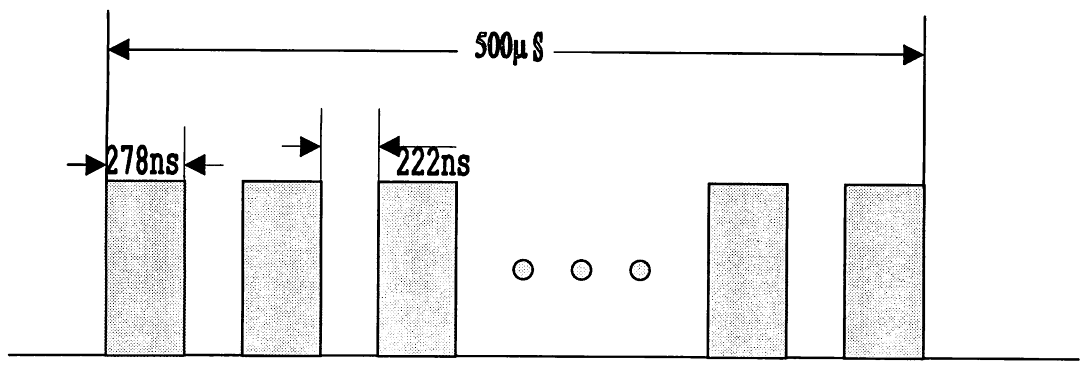


Fig.1 Beam pulse structure after chopping

2. MEBT Design

- **TRACE3-D modifications:**
  - a) **RF-chopper element added;**
  - b) **RF E&B field included;**
  - c) **Fringe field included.**

- **Design Philosophy:**

Separating the matching and chopping sections for an easy tuning in operation.

- **Input Beam:**

I=30 mA

$\varepsilon_{x,y}$=0.187 πmm-mrad (Norm. rms)

ε_z =0.133 πMeV-Deg (rms)

• MEBT Design with TRACE3-D

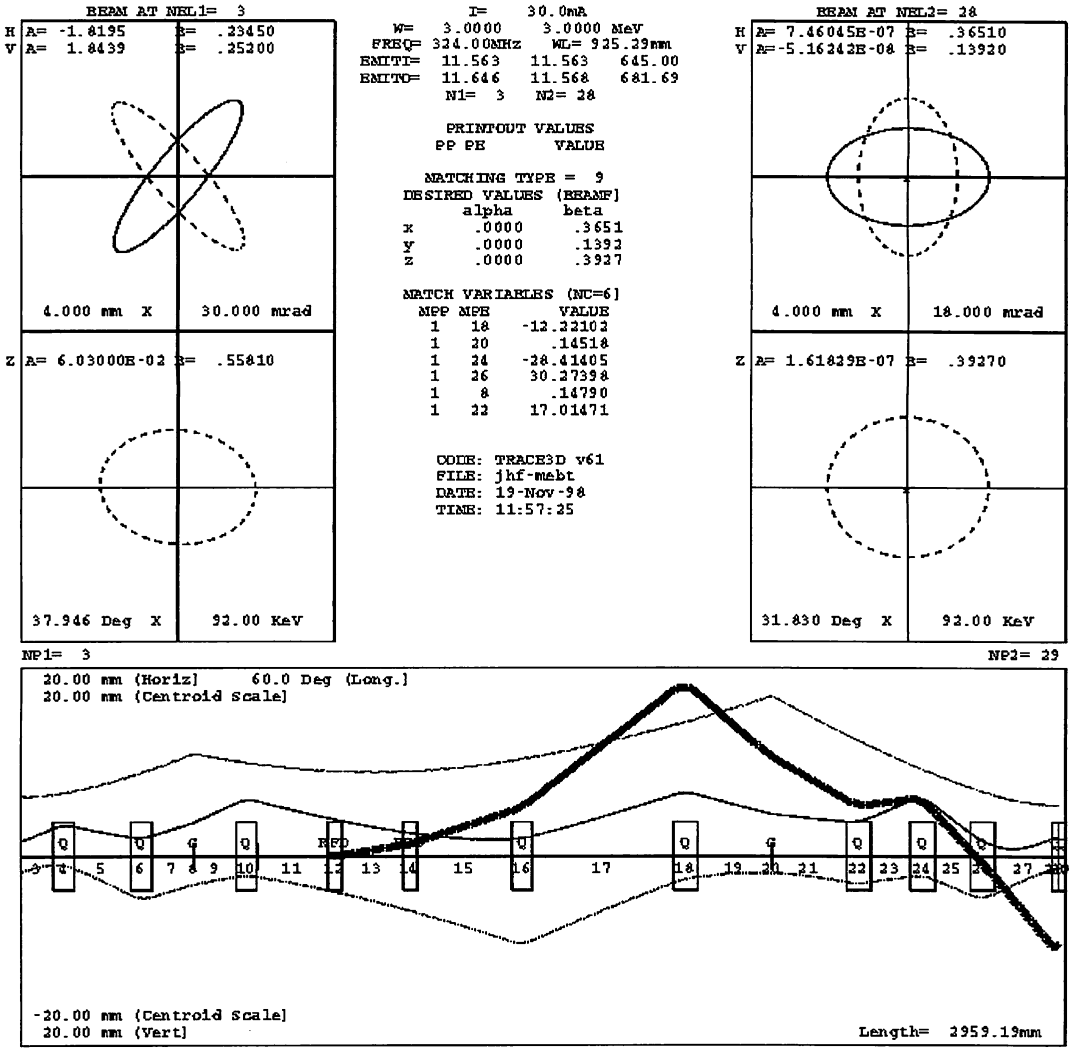


Fig.2 TRACE3-D output of the MEBT. The up-left gives the input beam phase spaces and the up-right gives the matched beam with DTL. The bottom shows the beam profiles in the z, x and y directions respectively. The dark curve traces the beam centroid offset by the two RFDs. The element numbers are denoted under the beam axis.

- **Edge field effect on the deflection**

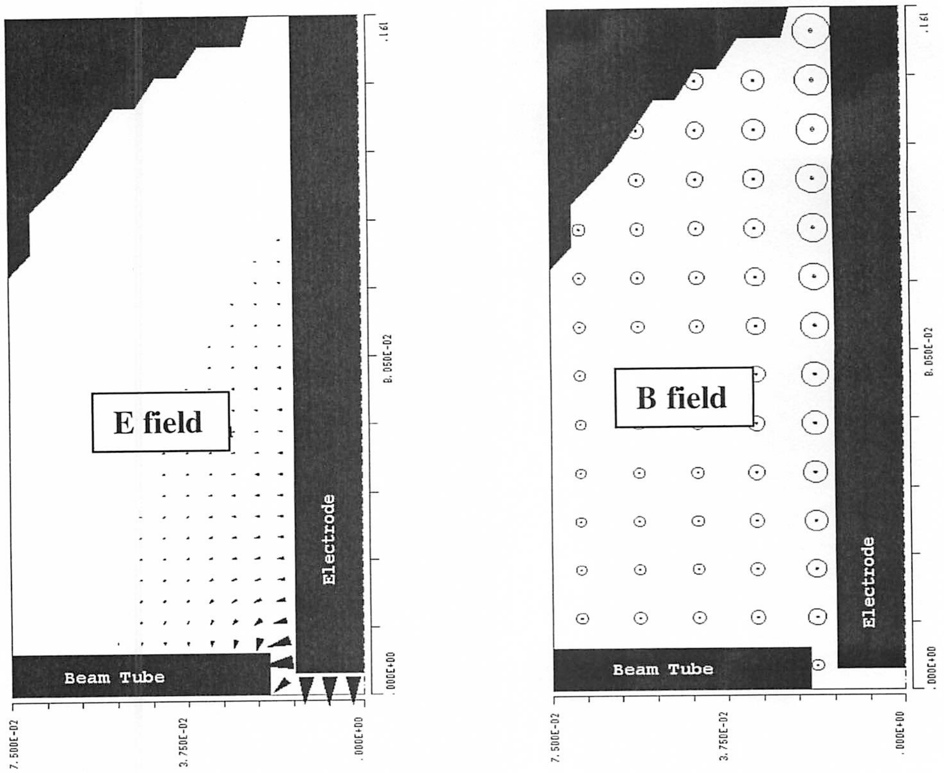


Fig.3 E and B fields are applied in deflection calculation, including their edge fields.

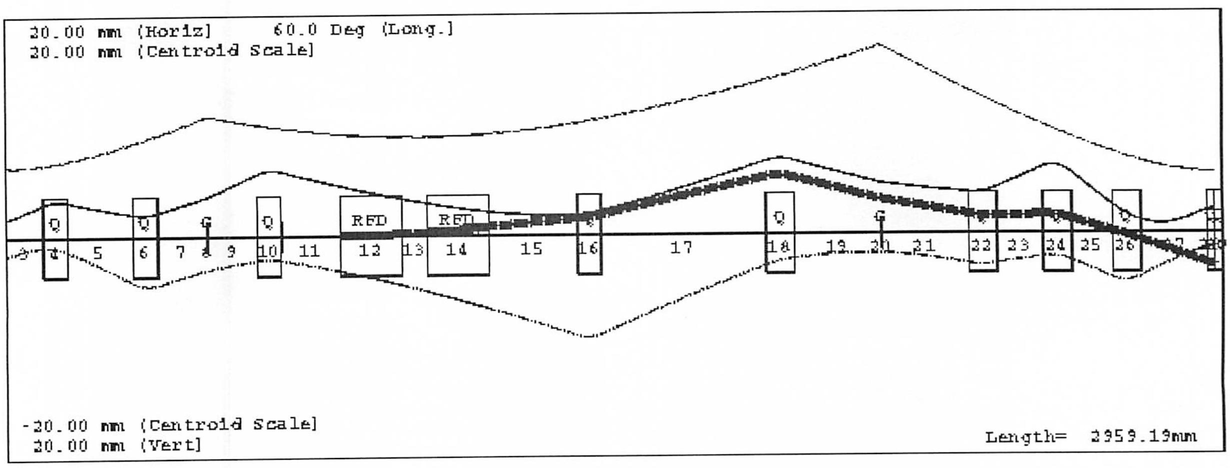
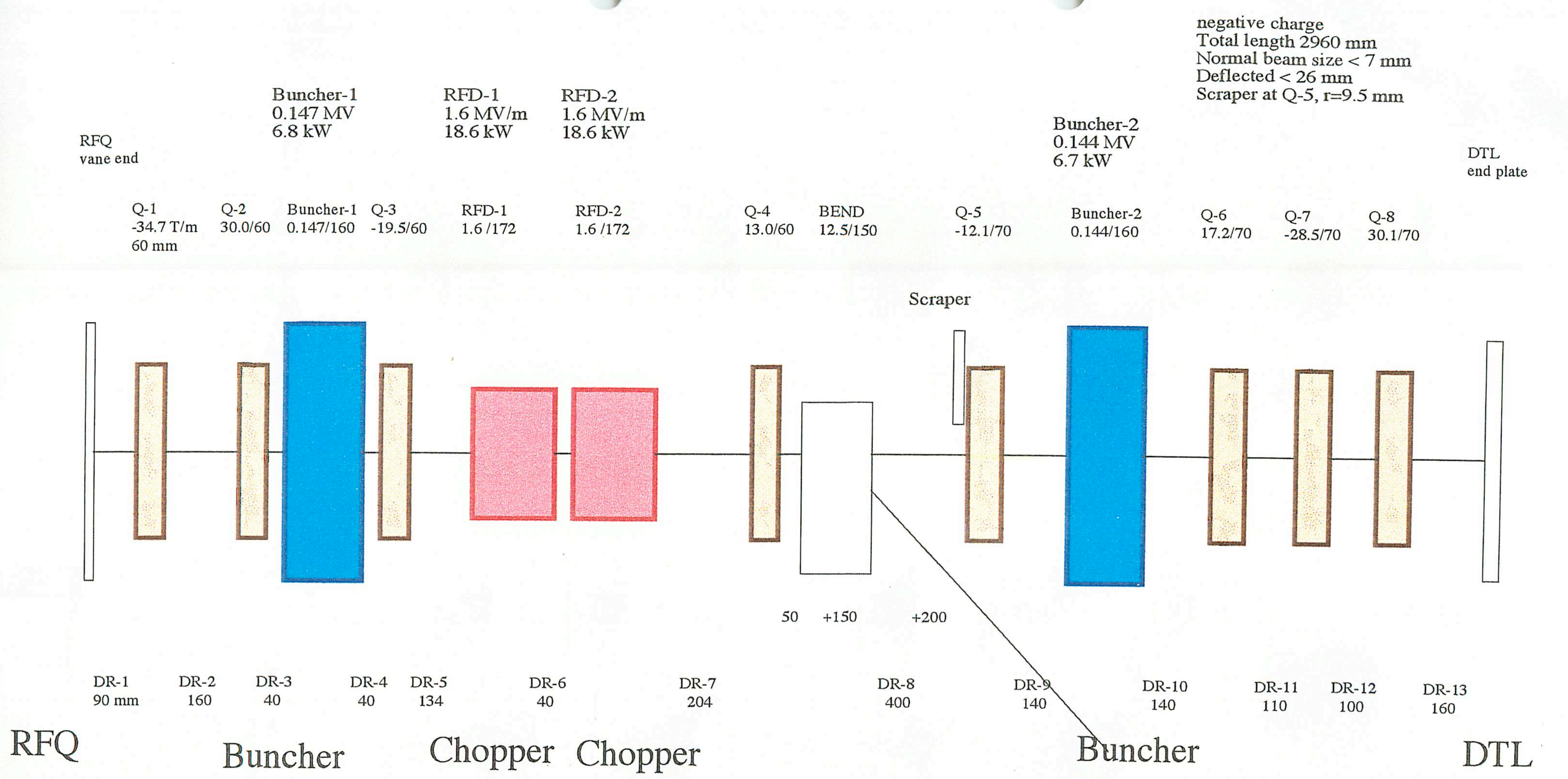


Fig.4 Deflection becomes weak if no beam pipe is used to shield the edge field.



(DR = drift space)

Total length = 2.96 m

• Design Results

Total Length (m)	3
No. of Q magnets	8
No. of RF Deflectors	2
No. of RF Bunchers	2
Chopper frequency (MHz)	324
Chopping field (MV/m)	1.6
Deflection angle (mrad)	6×2
Deflection after Q_{16} (mrad)	29
Beam edge separation (mm)	4.7

◆ The MEBT leaves sufficient space for beam diagnostics and steering magnets.

• Multi-particle simulation (Parmila)

◆ For a scraper with a gap 19mm,
undeflected beam: no losses
deflected beam: no transmission.

◆ RMS emittance growth: $\Delta\varepsilon_x$= 12.8%
$\Delta\varepsilon_y$= 7.8%
$\Delta\varepsilon_z$= 7.2 %

3. RF-Chopper Design and Test

- **Design targets:**

  Fast rise/fall time
  Low power demand

They are related by:

$$P \cong \frac{V^2}{\omega_0 \tau (Z / Q_0)}$$

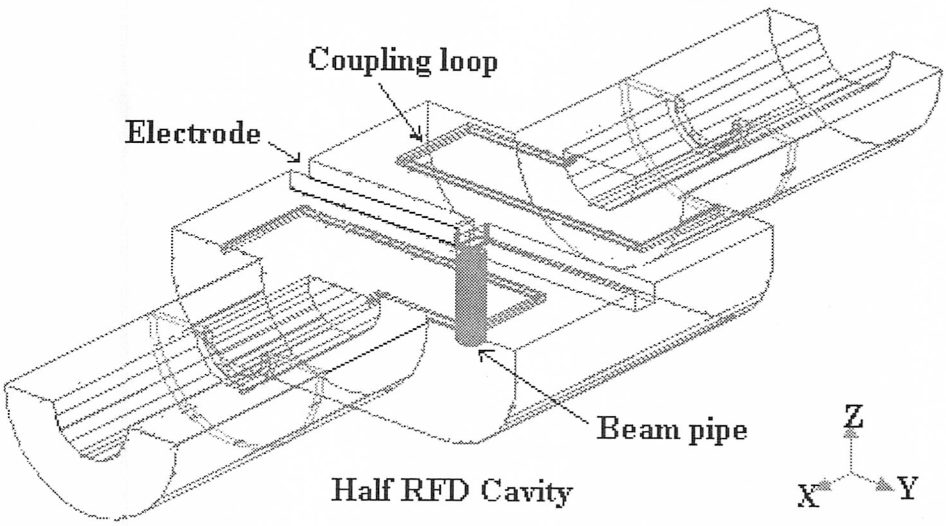


Fig. 5 Half RF Deflector Cavity

• Design with MAFIA

To get a large Z/Q_0, cavity shape optimization with MAFIA:

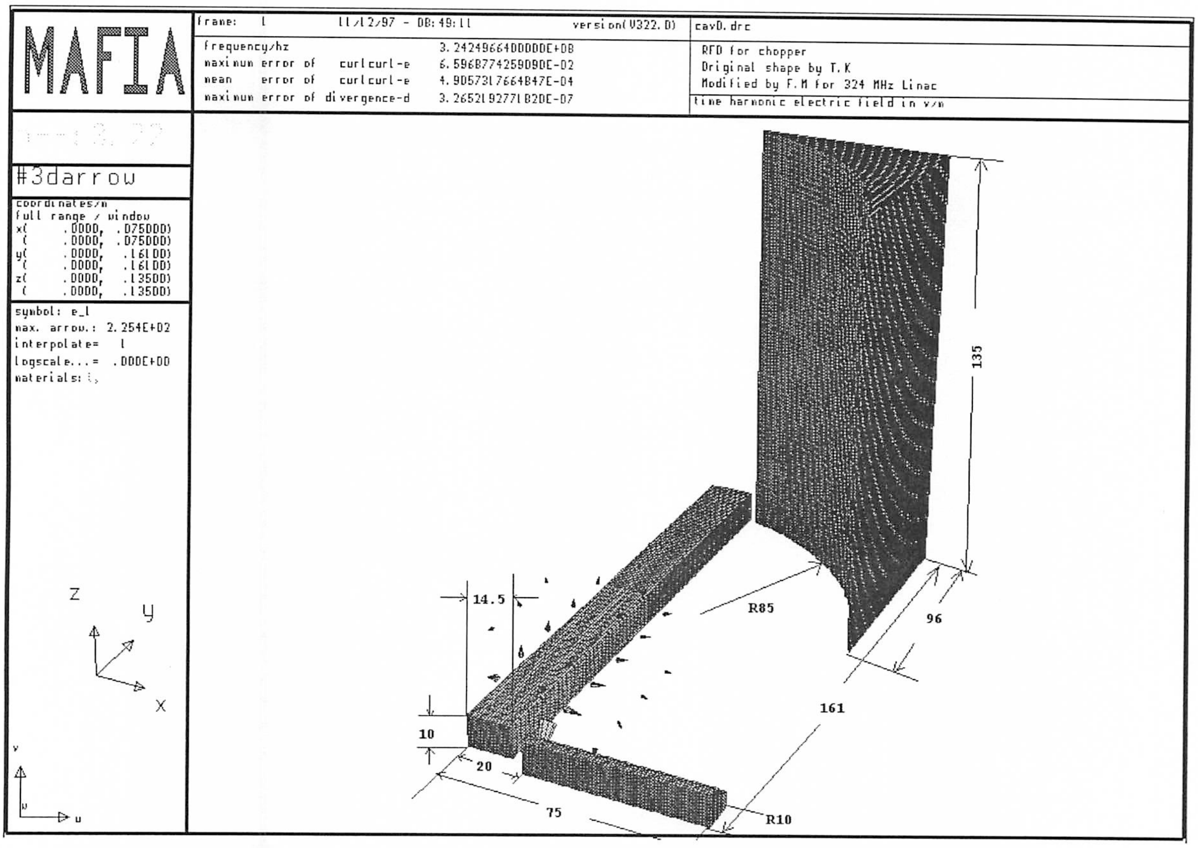


Fig.6 RFD design with Z/Q_0=437Ω

• Design with HFSS

For a low loaded Q, a pair of large coupling loops is used. Loop size = 75×218 mm

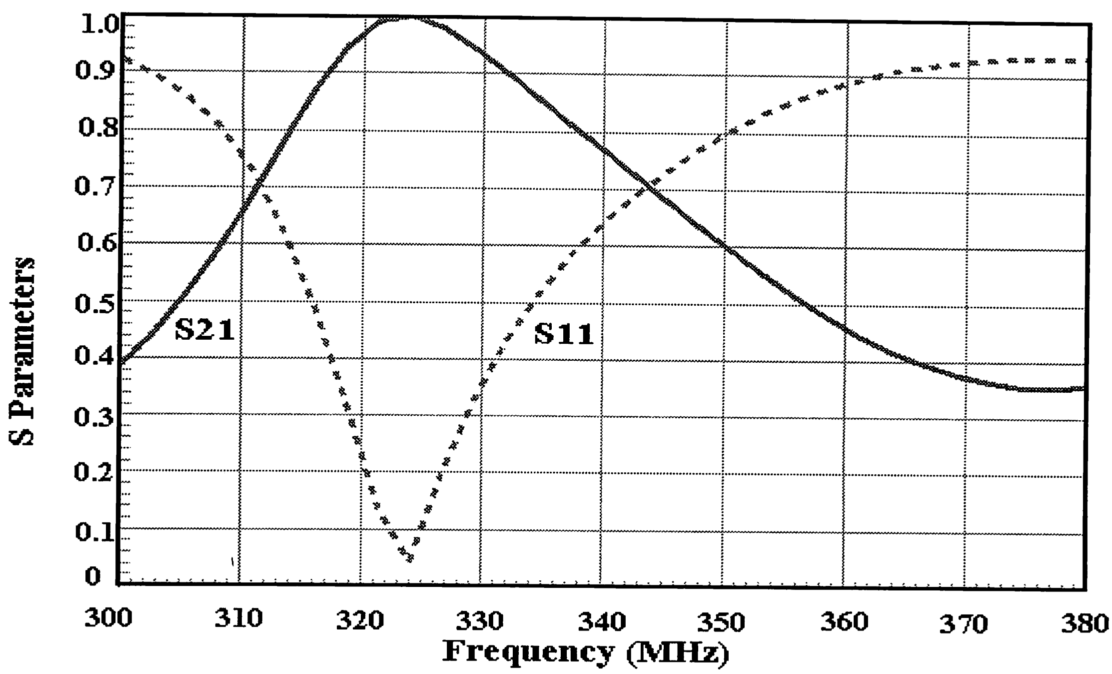


Fig. 7 S-parameters from HFSS

Design results:

f_0= 324MHz, Δf=31MHz
Q_L=10
τ=10nsec
P=27kW for E=1.6MV/m

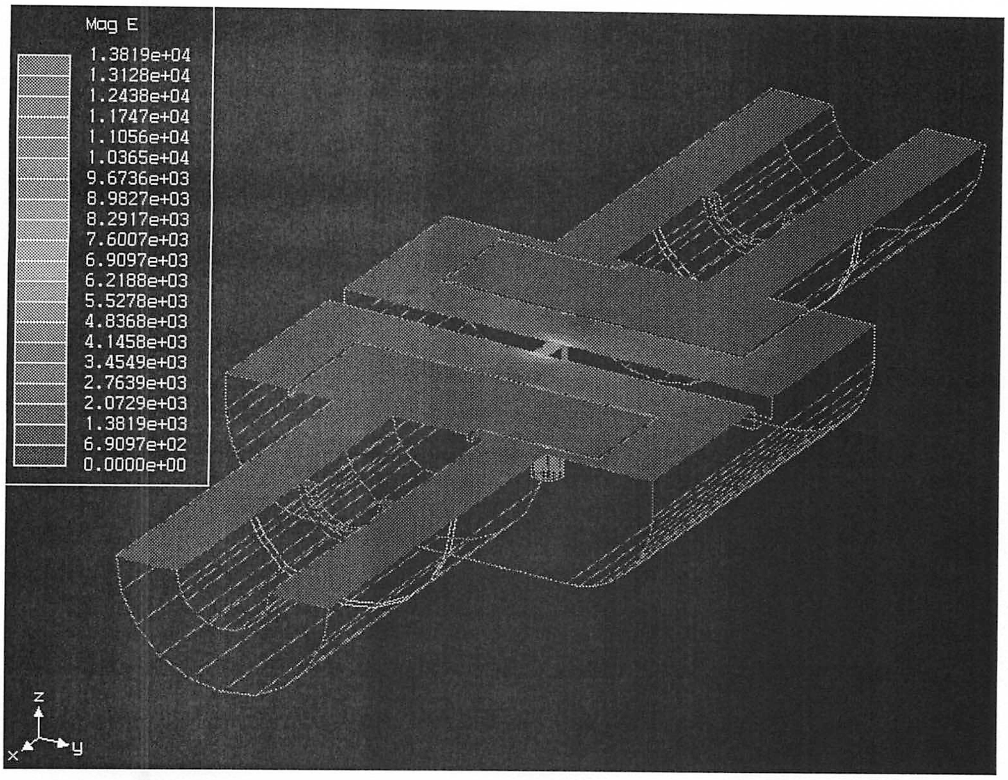


Fig.8 Field pattern in the middle surface, showing a good deflecting mode without significant disturbance due to the insertion of the large coupling loops.

• Test of a cold model

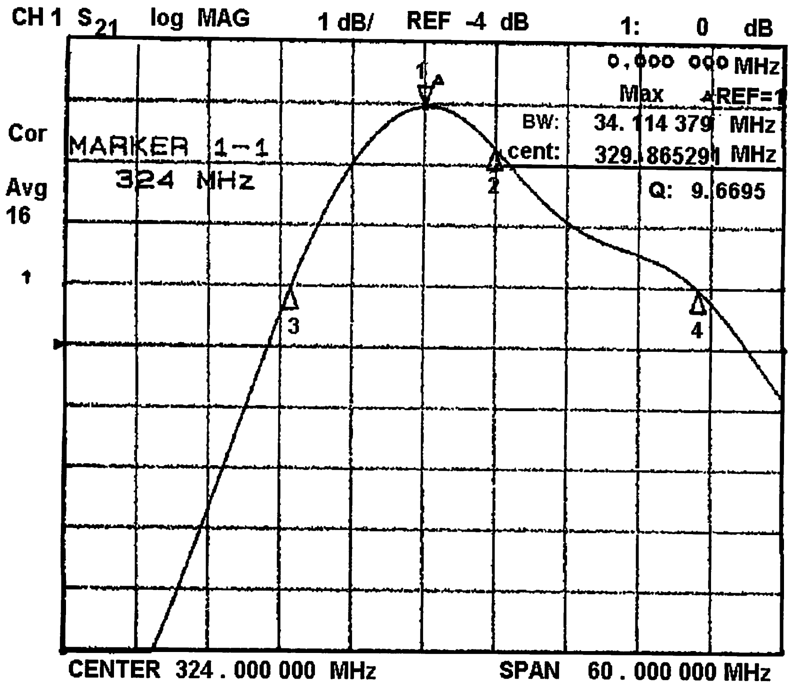


Fig.9 Spectrum of S_{21}, indicating $Q_L = 9.7$

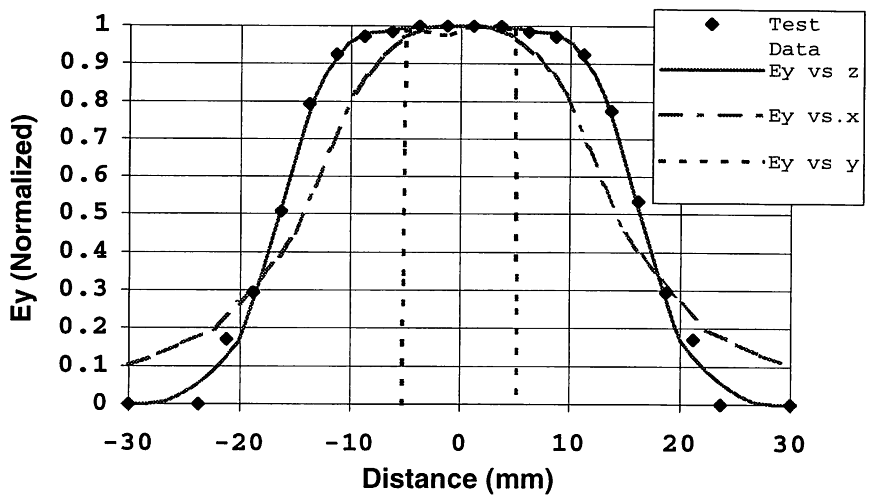
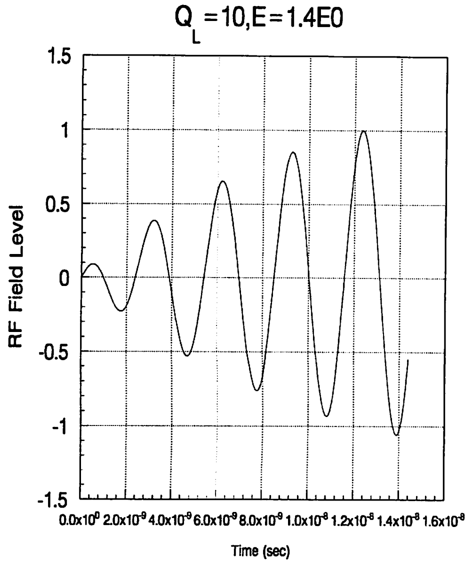


Fig. 10 E_y field distribution in three directions (test data is in z direction)

4. Analysis on unstable particles

During rise/fall time some particles will become unstable due to partial deflection.

- **Improved method for fast rise/fall time**



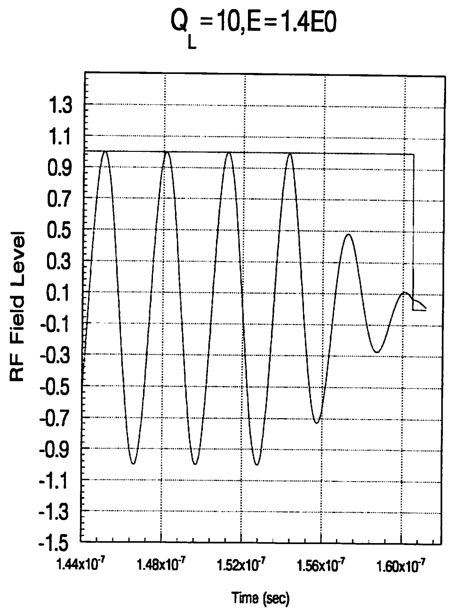


Fig. 11 Double the incident power at pulse head and shift 180° just before the pulse tail

- **Simulations of the partially deflected beam during rise/fall time by PARMILA and LEBT codes**

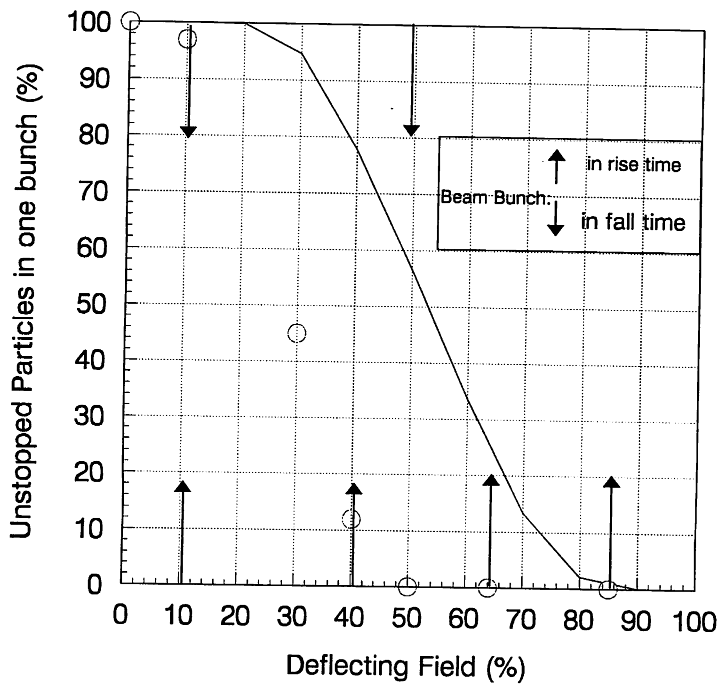


Fig.12 Unstopped particles ratio in one bunch vs the deflecting field variation. The arrows indicate the bunch distribution during the RF rising and falling time. The curve indicates at the entrance of DTL and the circles the exit of DTL. The beam losses are less than 0.08% after the exit of 50-MeV DTL, according to PARMILA and LEBT codes.

- **Preliminary test of the improved method**

180° shift by means of a DBM:

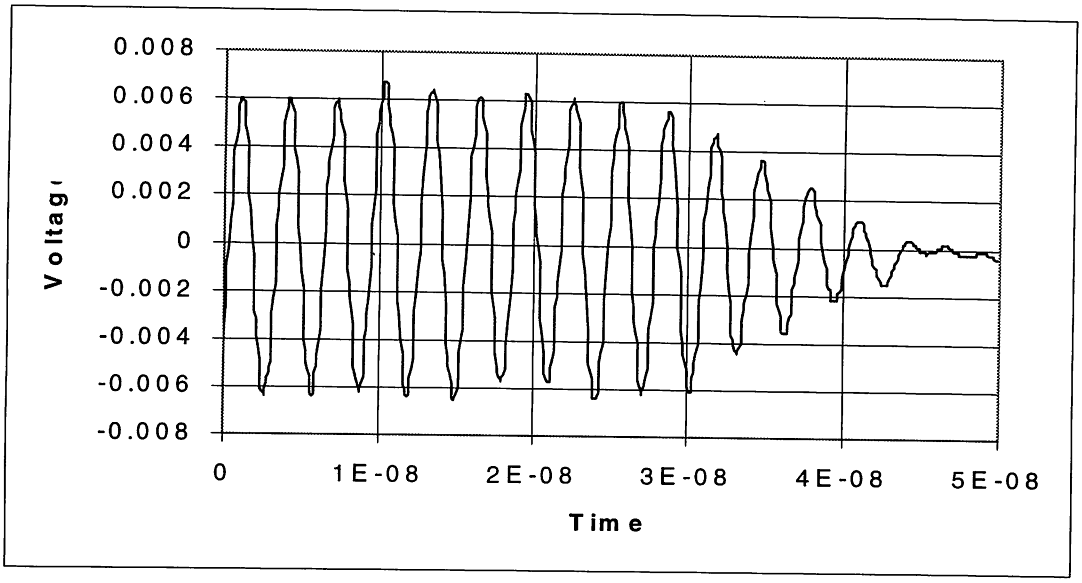


Fig.13 Pulse tail with 180° phase shift

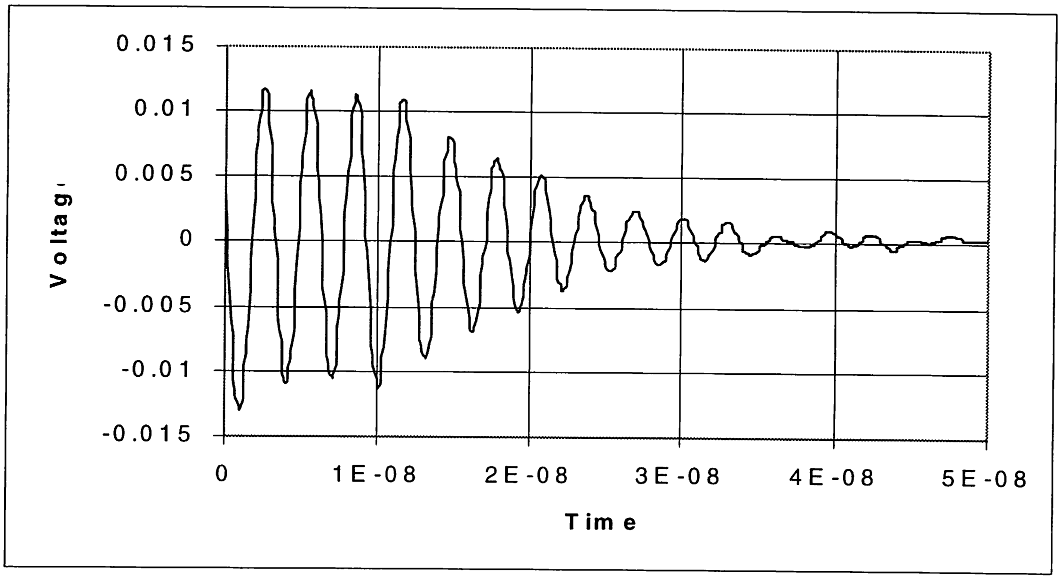


Fig.14 Pulse tail without 180° phase shift

5. Conclusions

1) **3m MEBT**

2) **Two RF Choppers:**

   E=1.6MV/m
   P=27kW(Q_L=10) or P=18kW (Q_L=15)
   Sep.=4.7mm

3) **RFD cavity test: Q_L<10, $\tau \approx$10nsec**

4) **Beam losses < 0.08% at exit of 50MeV DTL**