Muon Acceleration to 750 GeV in the Fermilab Tevatron Tunnel

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Modify the 400 GeV Main Ring

- **70 → 750 GeV in 68 orbits (1.4 ms).**
  10 GeV of 1.3 GHz, 30 MV/m SRF.
  Muon Survival = 79%. r = 1000 m.
- **FODO Lattice 30.45 m Long Half Cell.**
  3.3 m, 160 Hz, 30 T/m Quadrupoles.
  3.2 m, 8 Tesla Superconducting Dipoles.
  5.7 m, 360 Hz, ∓1.8 Tesla Dipoles.
  Dipoles oppose, then act in unison.
  Eddy Currents: Thin copper wire and .28mm grain oriented Si steel laminations.

Q F	∓1.8T Dipole	+8T Dip.	∓1.8T Dipole	+8T Dip.	∓1.8T Dipole	Q D

- **1.5 TeV $\mu^+\mu^-$ Collisions in the MI Tunnel.**
  Little civil construction. Existing tunnels.

Horizontal Magnet Apertures and Longitudinal Dynamics

- **Horizontal Dipole Aperture Required.**

  200 half cells/ring.

  1.8° per half cell.

  5.7m, 1.8T dipole bends 0.4° at 400 GeV.

  5.7m, -1.8T dipole bends 2.3° at 70 GeV.

  Use the single bend point approximation.

  5.7/2 sin(2.3°) = 12 cm bore width.

- **Longitudinal Dynamics.**

  Path length difference during acceleration.

  Use Pythagorus.

  $[\sqrt{2.85^2 + 0.12^2} - 2.85]/2.85 = 1/400$

  4 dipoles/half cell → 58% real estate

  So a 1/700 SRF frequency shift is needed.

Two Ring Option to Reduce Path Length Difference

- **20 → 400 GeV in 38 orbits (0.8 ms).**
  No superconducting magnets, just Si-iron.
  10 GeV of 1.3 GHz, 30 MV/m SRF.
  Muon Survival = 74%. r = 1000 m.
  No Path Length Difference.

- **400 → 900 GeV in 50 orbits (1.1 ms).**
  Hybrid magnet system with larger superconducting magnet fraction.
  10 GeV of 1.3 GHz, 30 MV/m SRF.
  Muon Survival = 92%. r = 1000 m.
  1/4000 Path Length Difference.

Enabling Technology: Grain Oriented Silicon Steel

- **Much less $E = B^2/2\mu$ in steel at 1.8T.**

Material (μ/μ_0)	1.0T	1.5T	1.8T
1008 Steel	3000	2000	200
Grain Oriented ($\parallel$)	40000	30000	3000
Grain Oriented ($\perp$)	4000	1000	

Transverse Beam Size with Cold Muons

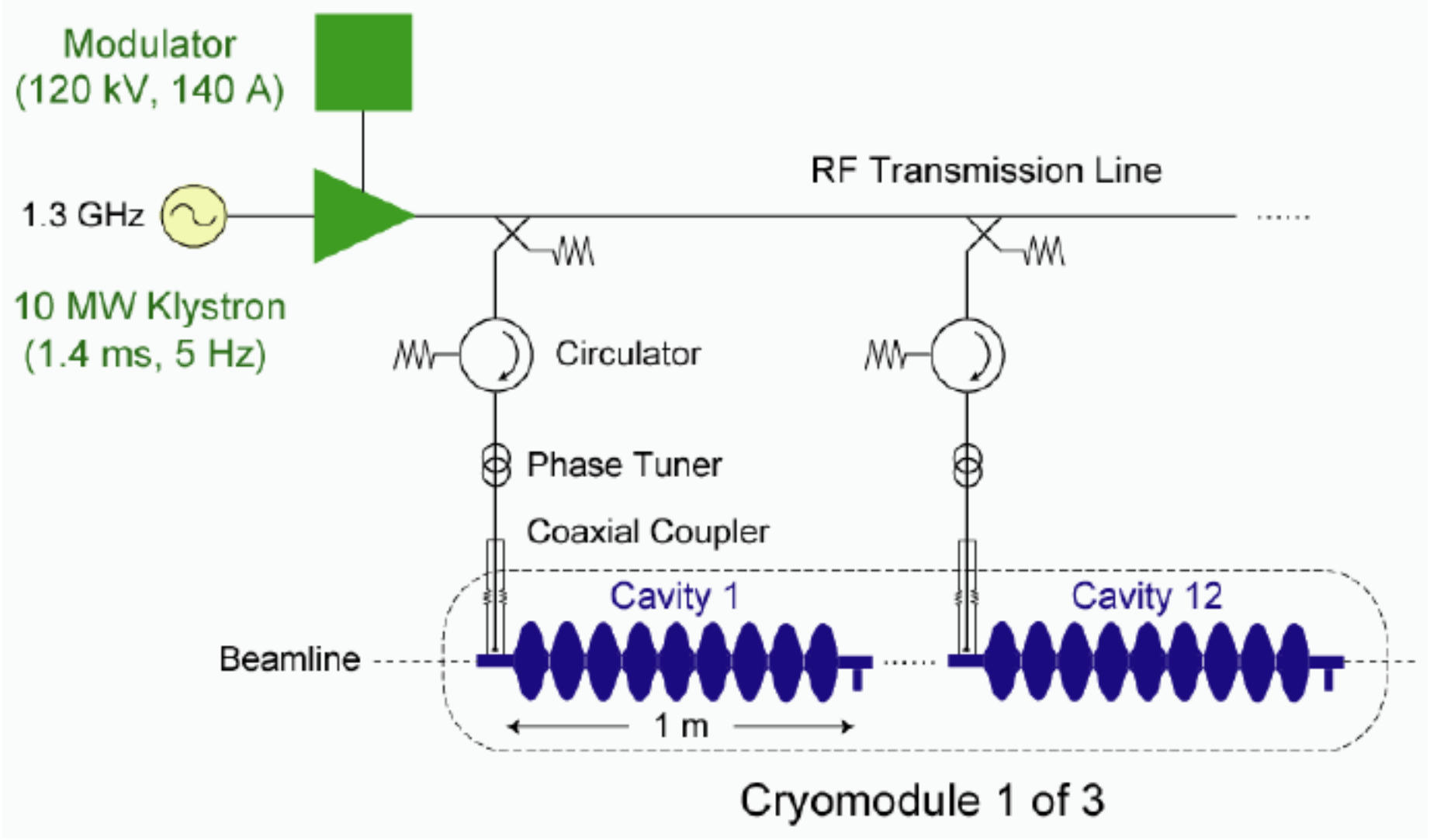
- $\epsilon =$ **25 mm-mrad,** $\beta =$ **99 meters.**
  $\mathbf{6}\sigma = 6\sqrt{\epsilon\beta/[6\pi(v/c)\gamma]}$
- **20 GeV/c,** $\gamma =$ **190** $\rightarrow$ $\mathbf{6}\sigma =$ **9.0mm**
- **70 GeV/c,** $\gamma =$ **660** $\rightarrow$ $\mathbf{6}\sigma =$ **4.7mm**
- **Apertures and magnets are small.**

1.3 GHz Superconducting RF

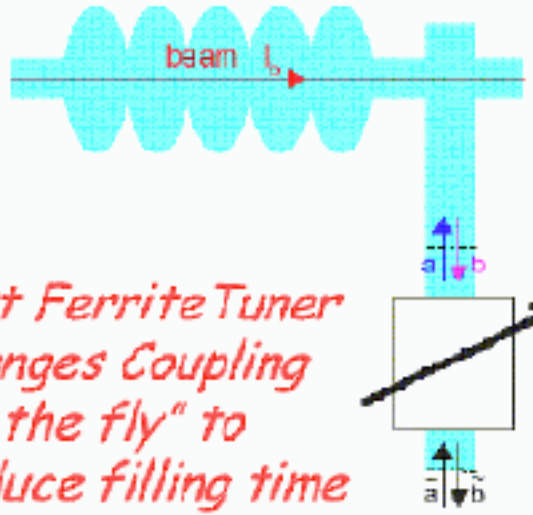
- **Costs from the TESLA TDR.**
  0.9 M Euro / 12m acceleration module
  1.8 M Euro / 10 MW RF station
- **Stored Energy with 30 MV/m and**
  Thirty 12m acceleration modules.
  41000 Joules
- **Energy of 4×10^{12} 750 GeV Muons.**
  480 000 Joules
- **Energy of Ten 10MW Klystrons in 1.4ms.**
  140 000 Joules.
- **Options.**
  Twenty Klystrons, Two couplers per cavity.
  Let MV sag, high γ muons decay slowly.
  Longer pulse, more caps in the modulator.
  15 GeV of SRF rather than 10 GeV.

International Linear Collider (ILC) RF Unit

(1 of 600, TESLA TDR Layout)



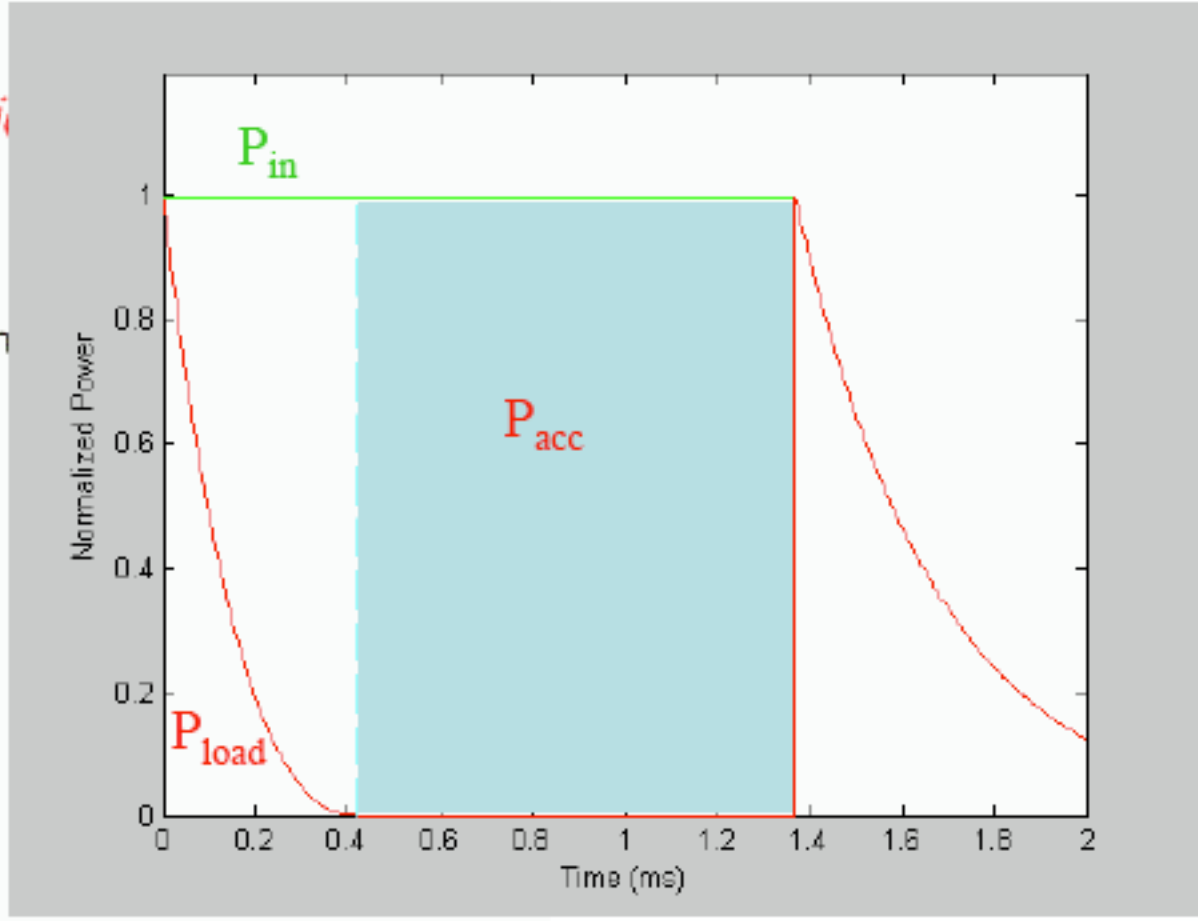
external tuner



Fixed Waveguide Coupler Possible

Fast Ferrite Tuner Changes Coupling "on the fly" to Reduce filling time & save power

e.g. tran

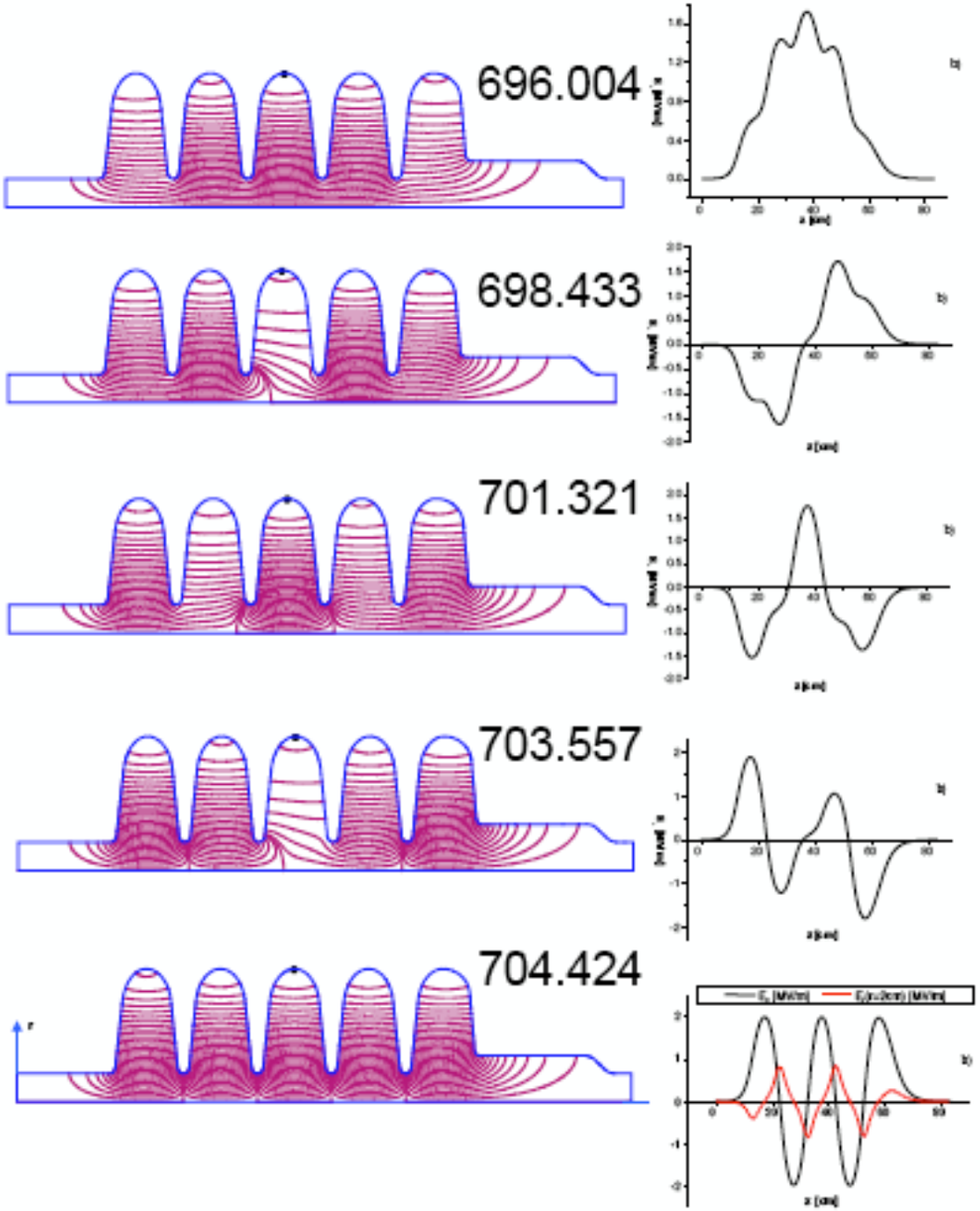


$$\mathrm{SWVR}_{\tilde{b}=0} = \frac{|a|-|b|}{|a|+|b|} = \max\left\{r, r^{-1}\right\}$$

Martin Dohlus Deutsches Elektronen Synchrotron Feb.2004

Chris Nantista

Modes of the multicell cavity



A coupled system of N resonant oscillators at ω_0 can oscillate in N normal modes, "fist band" with eigenfrequencies close to ω_0

$$\omega_n = \omega_0 \sqrt{1 + k\left[1 - \cos\left(\frac{n\pi}{N}\right)\right]}$$

Where k is the coupling coefficient