Muon Acceleration to 750 GeV in the TevatronTunnel

D. J. Summers, R. Godang, B. R. Kipapa
University of Mississippi-Oxford

R. B. Palmer
Brookhaven

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Muon Acceleration to 400 GeV in the Tevatron Tunnel

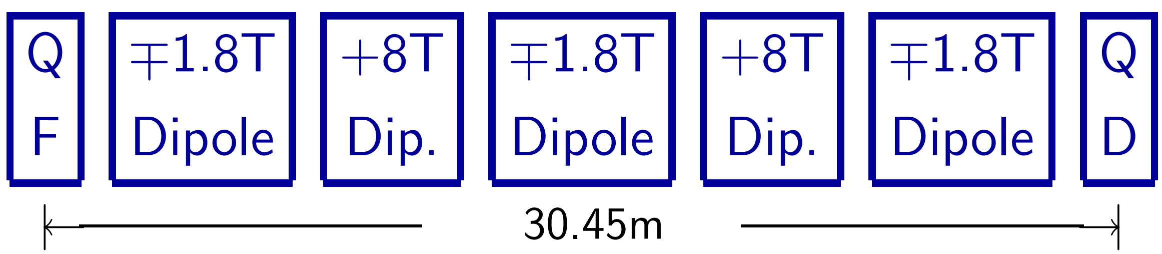
- **30 $\rightarrow$ 400 GeV in 28 orbits (0.59 ms)**
  14 GV Superconducting RF (1.3 GHz, 31 MV/m)
  Muon Survival = 80%   Radius = 1000m

- **Duplicate the Fermilab Main Ring FODO Lattice**
- **1.7m, 30T/m Quadrupoles, $f = 400$Hz**
- **6.3m, 1.8T Dipoles (8/60.9m cell), $f = 400$Hz**
  Muon transverse emittance = 25 μm, γ(30 GeV) = 284
  h = $6\sigma = 6\sqrt{25\mu\mathrm{m}\ 99\mathrm{m}/[6\pi\beta\gamma]}$ = 6mm
  6×30mm bore, N=4; $I = B\,h/\mu_0 N$ = 2200A
  W = $\int \frac{B^2}{2\mu_0} d\tau = .5\,LI^2 = .5\,CV^2$, $f = 1/2\pi\sqrt{LC}$; V = 3400V
  .28mm grain oriented 3% Silicon steel laminations
  Core Loss = $4.38 \times 10^{-4} f^{1.67} B^{1.87}$ = 29 w/kg
  550 Tons @ 13Hz Duty Cycle $\rightarrow$ 520kw/ring

- **β(30 $\rightarrow$ 400 GeV) = .99999380 $\rightarrow$ .99999996**
  Adjust radius; 1000 $\rightarrow$ 1000.006 m

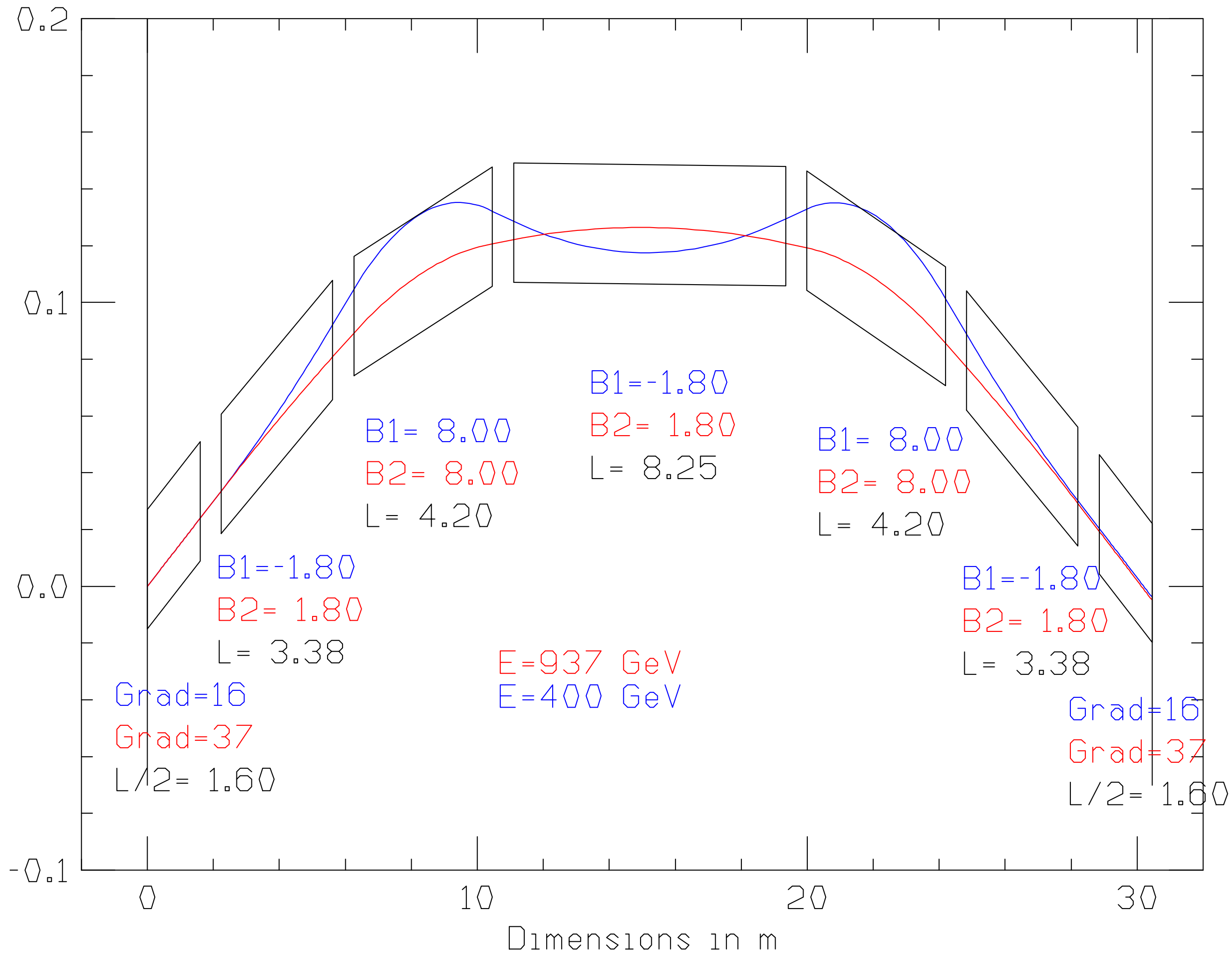
400 $\longrightarrow$ 750 GeV Hybrid Ring

- 400 $\longrightarrow$ 750 GeV in 44 orbits (0.92 ms)   Radius = 1000m
  8 GV, 1.3 GHz Superconducting RF; Muon Survival = 92%
- Approximate the Fermilab Main Ring FODO Lattice
- 3.2m, 30T/m Quadrupoles, f = 150Hz
- 4.2m, 8T Fixed Superconducting Dipoles
- 3.4/8.2/3.4m, -1.8 $\longrightarrow$ +1.8T Dipoles, f = 550Hz
  5mm$\times$50mm$\times$8.2m bore, N=2; $I = B\,h/\mu_0 N$ = 3600A
  W = $\int \frac{B^2}{2\mu_0} d\tau = .5\,LI^2 = .5\,CV^2, f = 1/2\pi\sqrt{LC}$; V = 5100V
  Core Loss = $4.38 \times 10^{-4} f^{1.67} B^{1.87}$ = 50 w/kg
  780 Tons @ 13Hz Duty Cycle $\longrightarrow$ 910kw/ring



- Dipoles oppose, then act in unison
- 1/50000 Path Length Difference during an acceleration cycle
  Adjust radius; 1000 $\longrightarrow$ 1000.02 m

Palmer Particle Paths in a Hybrid Half Cell



1.3 GHz, 10 MW Klystrons

- 66 10MW Klystrons, 3 Cells/RF Coupler
  72 orbits, $4\times10^{12}\mu$, 13 Hz
  3 cell superconducting cavities $\sim$kept full
  22 MW AC to modulators, 3 MW AC to cryogenic pumps
- Head/Tail, Wakefield, and HOM issues for 1.3 GHz cavities:
  2×10^{12} μ/bunch on crest $\longrightarrow$ 8% beam loading
- Eddy Currents controlled with 2mm copper wire and
  .28mm grain oriented 3% Silicon steel laminations.
  Lamination losses dominate copper losses.
- Minimal $W = \int \frac{B^2}{2\mu} d\tau$ in 3% Silicon steel at 1.8T
  $\mu(\|) = 3000\mu_0 \longrightarrow$ lower magnet voltages
- ν Radiation Safety: km$\left(\frac{2\text{ bananas}}{\text{week}} = \frac{\text{mrem}}{\text{year}}\right) \propto \sqrt{\mu/\text{yr}}\, E^{1.5}$
  Elevations: Fermilab 227m, Batavia 218m, Aurora 198m
  Distance: 2.7km for 30$\longrightarrow$750 GeV; Tevatron OK @ 220m

Synchrotron Oscillations per Orbit

$$d\tau/\tau = (1/\gamma_t^2 - 1/\gamma^2)(dp/p) = \eta(dp/p)$$

$$\gamma(30\,\mathrm{GeV}) = 284$$

$$h = 2\pi \times 1000m \times 1.3\,\mathrm{GHz}/c = 27200$$

$$\nu_s = \sqrt{-\frac{h\eta}{2\pi\beta^2 E_s}\,\mathrm{eV}\cos\phi_s}$$

$$\nu_s = \sqrt{-\frac{27200\times 1/18^2}{2\pi(30\times 10^9)}\,(14\,\mathrm{GeV})(-0.1)} = 0.8$$

To Do List

- Head/Tail, Wakefields, and HOM vs. beam loading
- Lattice momentum acceptance (both rings)
- Lattice momentum compaction (both rings)
- Design complete lattices (both rings)
- Ramping Magnet Power Supplies: LC, “White” ...
- Multipole B fields from eddy currents in the pole faces
- Forces on fast ramping magnet pole faces
- Build a short prototype fast ramping dipole