Muon Bunching for a Muon Collider

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Outline

- **Motivation**
  - $\mu^+-\mu^-$ Collider
    - Multi-TeV high-energy collider

- **Produce, collect and cool as many muons as possible**
  - Start with $\nu$-Factory IDS design study
  - Reoptimize for Collider
    - Shorter bunch train
      - Higher energy capture, shorter front-end
    - Larger gradients

- $\nu$-Factory $\rightarrow \mu^+-\mu^-$ Collider

- Discussion
Need ~4MW pulsed proton source from Project X

Initial Project X is (currently) cw 3GeV linac
<1G$
will need upgrade

• Beamstrahlung in any $e^+e^-$ collider
  • $\delta E/E \propto \gamma^2$
Baseline Muon Collider beam preparation system identical to that for Neutrino Factory

- downstream portions (6D cooling, acceleration, collider) are distinct
  - much more cooling and acceleration needed for collider
Muon Collider front end optimum is somewhat different

- Short bunch train preferred
  - Bunches are recombined later ...
- Maximum μ/bunch wanted
- Longitudinal cooling included; may accept larger $\delta p$
- Larger rf gradient can be used (?)
  - NF will debug gradient limits
  - Cost is less constrained

For variant, we will have shorter BR system, more gradient, and capture at higher momentum

- $230 \rightarrow 270$ MeV/c
- $150m \rightarrow 120m$
- $9/12/15$ MV/m $\rightarrow 15/16/18$ or $15/18/20$ MV/m
- $1.5T \rightarrow 2T$
High-frequency Buncher and \( \phi \)-E Rotator

- Drift \((\pi \rightarrow \mu)\)
- “Adiabatically” bunch beam first (weak 350 to 232 MHz rf)
- \( \Phi \)-E rotate bunches - align bunches to \( \sim \)equal energies
  - 232 to 202 MHz, 12MV/m
- Cool beam 201.25MHz
End up with fewer, denser bunches

- More $\mu/p$
- Larger $\delta p$

15 bunches
Neutrino Factory version

- **NF baseline version**

![Diagram of Neutrino Factory]

- Proton (p) enters and produces pions (π) which decay into muons (μ) after a drift.
- The process occurs over different sections:
  - Target
  - Solenoid
  - Drift
  - Buncher
  - Rotator
  - Cooler

Dimensions:
- Target: 18.9 m
- Drift: ~60.7 m
- Buncher: ~33 m
- Rotator: 42 m
- Cooler: ~80 m

- COOLING LATTICE:
  - SC coll
  - RF cavity: 201.25 MHz
  - 15.25 MV/m

- Particle distributions:
  - Region 455: 6333 particles
  - Region 1000: 4472 particles
  - 23 bunches
Collider version

- Has ~30% shorter train
- More $\mu/p$
  - ~0.12 $\mu/p$ (from ~0.09)
- Captures more of the "core" of the initial $\pi/\mu$
  - Rather than lower half of the core...

All at target 8GeV p
Muon Collider version is an incremental change from IDS

- ~25% shorter
- Higher gradients
  - 9/12/15 → 15/16/18
  - →16/18/20?
- Capture at ~275MeV/c rather than 230MeV/c

Collider optimum might be a further increment along ... ?

Optimization should include initial cooling with 6-D

- Used only transverse in present study, LiH absorbers (~1.2cm)
Thoughts for IDS/NF

- Shoud central capture momentum be increased
  - 210 → 230 → 270?

- Would start cooling at higher momentum
  - Longer channel for cooling

- Might want to increase acceptance