Design and optimization of a particle selection system for muon based applications

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Abstract: In muon accelerators, muons are produced by impacting high energy protons onto a target to produce pions. The pions decay to muons which are eventually accelerated. A significant background of protons and electrons are generated that deposit heat in superconducting materials and activate the machine. In this study we describe a two-step particle selection scheme: a chicane to remove the high momentum particles from the beam and a beryllium absorber that reduces the momentum of all particles in the beam, resulting in the loss of low momentum protons. We review the design and numerically examine its impact on the performance of the muon front end.

Beam Manipulation: FE manipulates the beam phase-space so that it can be cooled and accelerated downstream:
- Pion capture in a 20 T solenoid
- 20 T field on target drops to 2.0 T in the rest of Front-End over ~ 5 m
- Drift and Pion → Muons
- Chicane to remove energetic protons
- Increase progressively rf voltage and bunch the beam
- Rotate bunches and align to equal energy

CHICANE AND ABSORBER SYSTEM

- High energy particles could activate the entire FE channel
- Bend solenoid chicane induces vertical dispersion in beam. Axial field is 2 T.
- Beryllium proton absorber to remove low momentum protons
- With the chicane on, there is a drop in performance
- Goal: Optimize chicane angle, length and absorber thickness for best performance.

CHICANE OPTIMIZATION

Chicane Optimization
- First, looked at chicane without absorber
- Scanned chicane length and angle
- Defined performance in terms of
  - Muon transmission from 80 to 260 MeV KE
  - Maximum energy of transmitted protons (cut-off).
- For a given proton energy cutoff, we selected the point with best transmission and fitted results to a mathematical expression (yellow line)

Absorber Optimization
- Picked four cutoff points
- Then, varied absorber thickness and looked at muons vs. proton power at two absorber positions:
  - End of chicane
  - 30 m from chicane start
- Favor a low proton energy cut-off
  - Unless you allow a lot of power downstream

Summary
- We have a solution for chicane parameters for a given proton kinetic energy cutoff
- Significant tradeoff between muon transmission and downstream proton power
- Low proton energy cutoff in chicane is generally preferred
- Next steps:
  - Add chicane apertures that track muon beam size
  - Design a new buncher and phase-rotator matching system for different chicane solutions
  - Pick solution with best transmission for permitted proton energy downstream. This will require detailed energy deposition studies
  - Repeat process for different magnetic fields

CHICANE/ABSORBER MODELING

- Good agreement when simulating the chicane with a toroidal field model or a field map generated from actual coils
- Absorber was found to stop pions before they decay to muons
- Therefore, it was moved downstream by 30 m to avoid this