Abstract

An alternative capture-solenoid field is presented for the mercury jet target for a neutrino factory or muon collider. A peak solenoid field of 15 T at the mercury-target location is studied in comparison to the current baseline value of 20 T. The magnetic-field profile tapers down to 1.5 T in the Front End, nominally beginning 15 m downstream of the target. This field profile is optimized to maximize the "useful" muons 50 m downstream from the target within a kinetic-energy window of 80-140 MeV. Two parameters are considered for the optimization study: the length z_end of the tapered field and the field strength in the front end. The axial-magnetic-field profile is specified analytically using an inverse-cubic equation and the off-axis field is computed from a series expansion based on derivatives of the axial field. The simulation is performed using the MARS15 code.

Mercury Target – Proton Jet Baseline Parameters (from optimization by X. Ding using MARS15)

- Mercury-Target Parameters
  - Angle of target to solenoid axis $\theta_{\text{target}} = 0.137$ rad
  - Target radius $r_{\text{target}} = 0.404$ cm

- Proton Beam Parameters
  - $E = 8$ GeV
  - $\theta_{\text{beam}} = 0.117$ rad
  - $\sigma_p = \sigma_{\text{up}} = 0.1212$ cm (Gaussian distribution)

- Solenoid Field
  - 20 T peak field at target position ($z = -37.5$ cm)
  - Aperture at Target, $r = 7.5$ cm,
  - Aperture at Front End, $r = 30$ cm
  - $z_{\text{end}} = 1500$ cm, where $B_z = 1.5$ T

- Muons within kinetic-energy cut of 40-180 MeV
  - $N_{\mu\text{ons}}$ at $z = 50$ m = $3.27 \times 10^4$ ($N_{\text{initial protons}} = 10^9$)

Muon Production IDS120h 15 T

- Particle-capture requirement ($P \leq 0.225$ GeV/c)
- $B \times r = 200 \times 7.5 \text{ cm} = 150$ T-cm
- $B \times r = 15 \times 10 \text{ cm} = 150$ T-cm
- Fixed-flux requirement (Aperture requirement)
- $B \times r^2 = 20 \times 7.5^2 = 1125$ T-cm$^2$
- $B \times r^2 = 15 \times 10^2 = 15000$ T-cm$^2$
- MARS simulations with 15-T peak field & new aperture settings (taper radius $r = 30$ cm at all $z$)

Analytic Form for Tapered Solenoid

Inverse-Cubic Taper, defined by initial & final axial fields ($B_i$ & $B_f$), their derivatives, and position of end of taper ($z_{\text{end}}$):

$$ B_i(z)(z < z_{\text{end}}) = \frac{B_f(z_{\text{end}})}{B_f(z_{\text{end}})} = 1 + a_i(z-z_i) + a_i^2(z-z_i)^2 + a_i^3(z-z_i)^3 $$

Off-axis field approximation:

$$ B_o(z) = B_i^3(z) \sum_{i=0}^{n} \frac{a_i^i e^{\frac{i}{a_i^i z-z_i}}}{1-e^{\frac{i}{a_i^i z-z_i}}} $$.  $B_o(z) = a_i^3 e^{\frac{i}{a_i^i z-z_i}} + a_i^2 e^{\frac{i^2}{a_i^i z-z_i}} + a_i e^{\frac{i^3}{a_i^i z-z_i}}$  $a_i^i e^{\frac{i}{a_i^i z-z_i}}$  

Results

Muon count at 50 m for kinetic energy within 80-140 MeV.

Conclusion

- Promising results for 15-T peak field at the target, particularly if increase $z_{\text{end}}$ beyond 15 m and the Front-End magnetic field above the 1.5-T baseline.
- To be done:
  - Investigate transmission through the downstream phase rotator & cooling sections, using ICOOL.

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