Magnetic Configuration of the Muon Collider/ Neutrino Factory Target System

Hisham Kamal Sayed,*[1] H.G Kirk,[1] K.T. McDonald[2]

[1] Brookhaven National Laboratory, Upton, NY 11953

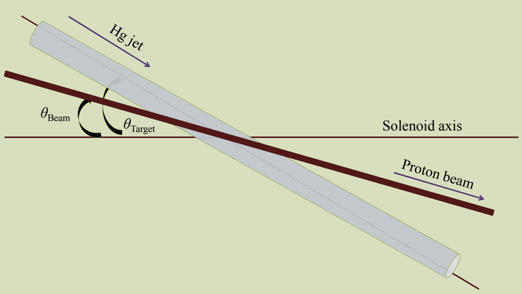
[2] Joseph Henry Laboratories, Princeton University, Princeton, NJ 08544

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)

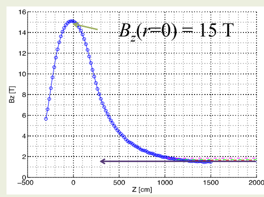
- **Mercury-Target Parameters**
  - Angle of target to solenoid axis θ_{target}= 0.137 rad
  - Target radius r_{target} = 0.404 cm
- **Proton Beam Parameters**
  - E = 8 GeV
  - θ_{beam} = 0.117 rad
  - $\sigma_x = \sigma_y$ = 0.1212 cm (Gaussian distribution)
- **Solenoid Field**
  - 20 T peak field at target position (z = -37.5 cm)
  - Aperture at Target, r = 7.5 cm,
  - Aperture at Front End, r = 30 cm
  - z_{end} = 1500 cm, where B_z=1.5 T
- Muons within kinetic-energy cut of 40-180 MeV
  - $N_{\text{muons at } z = 50\text{ m}} = 3.27 \times 10^4$ ($N_{\text{initial protons}} = 10^5$)

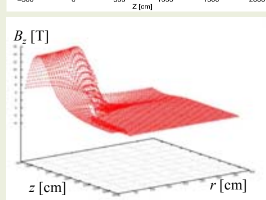


Muon Production IDS120h 15 T

- Particle-capture requirement ($P_t \leq 0.225$ GeV/c)
  - $B \times r$ = 20 T × 7.5 cm = 150 T-cm
  - $B \times r$ = 15 T × 10 cm = 150 T-cm
- Fixed-flux requirement (Aperture requirement)
  - $B \times r^2$ = 20 × 7.5^2 = 1125 T-cm^2
  - $B \times r^2$ = 15 × 10^2 = 1500 T-cm^2
- MARS simulations with 15-T peak field & new aperture settings (taper radius r = 30 cm at all z)

IDS120h (R. Weggel)





Analytic Form for Tapered Solenoid

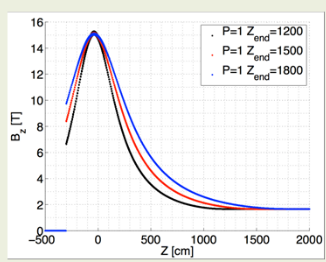
Inverse-Cubic Taper, defined by initial & final axial fields (B_1 & B_2), their derivatives, and position of end of taper (z_{end}):

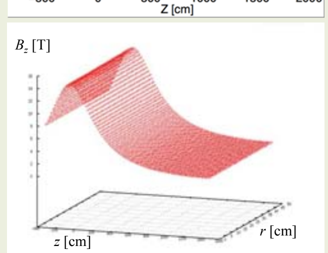
$$B_z(0, z_i < z < z_{end}) = \frac{B_1}{[1 + a_1(z-z_1) + a_2(z-z_1)^2 + a_3(z-z_1)^3]^p}$$

$$a_1 = -\frac{B_1'}{pB_1}, \qquad a_2 = 3\frac{(B_1/B_2)^{1/p} - 1}{(z_2 - z_1)^2} - \frac{2a_1}{z_2 - z_1}, \qquad a_3 = -2\frac{(B_1/B_2)^{1/p} - 1}{(z_2 - z_1)^3} + \frac{a_1}{(z_2 - z_1)^2}$$

Off-axis field approximation:

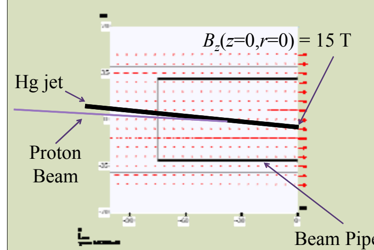
$$B_z(r,z) = \sum_n (-1)^n \frac{a_0^{(2n)}(z)}{(n!)^2}\left(\frac{r}{2}\right)^{2n}, \quad B_r(r,z) = \sum_n (-1)^{n+1} \frac{a_0^{(2n+1)}(z)}{(n+1)(n!)^2}\left(\frac{r}{2}\right)^{2n+1}, \quad a_0^{(n)} = \frac{d^n a_0}{dz^n} = \frac{d^n B_z(0,z)}{dz^n}$$





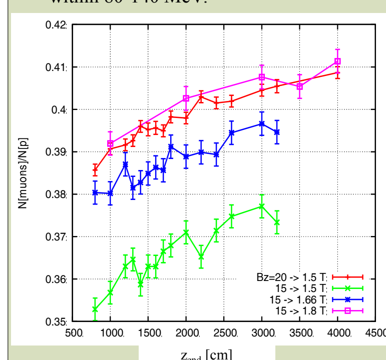
MARS 1510 Simulation Setup

- Beam Pipe with constant r = 30 cm.
- Beam Pipe material changed to "MARS-Blackhole" to speed calculation.
- Added subroutine to m1510.f (FIELD) to calculate the field an using inverse-cubic fit.



RESULTS

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



Tapered field using inverse-cubic field (P = 1)

Conclusion

- Promising results for 15-T peak field at the target, particularly if increase z_{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.

*Email: hsayed@bnl.gov

Work supported in part by US DOE Contract No. DE-AC02-98CH10886.