MUON TARGET PARTICLE PRODUCTION STUDY: TAPERED FIELD PROFILE

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Ding’s Optimized Parameters

- **Hg Target**
  - $\theta_{\text{Target}} = 0.137 \text{ rad}$
  - $R_{\text{Target}} = 0.404 \text{ cm}$

- **Proton Beam**
  - $E = 8 \text{ GeV}$
  - $\theta_{\text{Beam}} = 0.117 \text{ rad}$
  - $\sigma_x = \sigma_y = 0.1212 \text{ cm (Gaussian Distribution)}$

- **Solenoid Field**
  - IDS120h $\rightarrow$ 20 T peak field at target position ($Z=0$)
  - Aperture at Target $R = 7.5 \text{ cm}$ - End aperture $R = 30 \text{ cm}$
  - Fixed Field $Z = 1862.0 \rightarrow B_z = 1.5 \text{ T}$

- **Production**: Muons within energy KE cut 40-180 MeV
  - $3.27 \times 10^4 \ (N_{\text{ini}} = 10^5)$
Target Particle Production with 15 T Peak Solenoid Field

- Particle Capture requirement ($P_+ \sim 0.225$ GeV/c)
- $B r = 20 \times 7.5$ cm $= 150$ T cm ------ $B r = 15 \times 10$ cm $= 150$ T cm
- Fixed flux requirement (Aperture Requirement)
- $B r^2 = 20 \times 7.5^2 = 1125$ T cm$^2$ ------ $B r^2 = 15 \times 10^2 = 1500$ T cm$^2$
- MARS simulations with 15 T peak field & new aperture settings
  (Taper R = 10-30 cm)
Muon Production IDS120h 15 T

- Muons within 40–180 MeV cut

- $B_z = 2.5\, T$
- $B_z = 2.12\, T$
- $B_z = 1.7\, T$
- $B_z = 1.667\, T$
- $B_z = 1.667\, T$
- $B_z = 1.5\, T$

- $B_{z,\text{peak}} = 20\, T$
- $Z_{\text{end}} = 1862$
- $B_{z,\text{end}} = 1.5\, T$
Analytic form for Tapered Solenoid (K. McDonald)

- Inverse-Cubic Taper

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

Field at \( R = 0 \)

\[ a_1 = -\frac{B_1}{pB_1} \quad a_2 = \frac{3(B_1 / B_2)^{1/p} - 1}{(z_2 - z_1)^2} - \frac{2a_1}{z_2 - z_1} \]

\[ a_3 = -2 \frac{(B_1 / B_2)^{1/p} - 1}{(z_2 - z_1)^3} + \frac{a_1}{(z_2 - z_1)^2} \]
In case MARS reads field map up to $R = 50$ [cm]
INVERSE CUBIC Fit (ICP1) FIELD MAP

ICP1 Input Field Map

ICP1 MARS FIT2D Output Field Map
- Beam Pipe with constant $R = 30$ cm
- Added subroutine to m1510.f (FIELD) to calculate the field using inverse cubic equations

\[ \sqrt[3]{xyz} = 1.2200 \times 10^{1} \]
Inverse Cubic Field (P=1)

$B_z$ (end of taper) = 1.6667 T
Initial $N_P = 10^5$

<table>
<thead>
<tr>
<th>Z (end of Taper) [cm]</th>
<th>Muons ($10^4$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1200</td>
<td>0.48</td>
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<td>1700</td>
<td>2.48</td>
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<tr>
<td>1800</td>
<td>1.08</td>
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</table>
Inverse Cubic Field (P=1)

$B_z(\text{end of taper}) = 1.5 \, \text{T}$
Initial $N_P = 10^5$

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<thead>
<tr>
<th>$Z$ (end of Taper) [cm]</th>
<th>Muons ($10^4$)</th>
</tr>
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<td>1200</td>
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<tr>
<td>1800</td>
<td>2.39</td>
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</tbody>
</table>
MUON COUNT Z = 50 [m]
CONCLUSIONS

- Tapered field profile proved to have an impact on Muon production.

- Bz(R>0) & B_R(R>0) how realistic & how can they effect the particle production.

[This study changed the field around the target, but did not insure that the beam overlapped well with the target => Apparent production falloff for long tapers.]