ALTERNATIVE CAPTURE SOLENOID AND TRANSPORT STUDY FOR THE MUON COLLIDER/NEUTRINO FACTORY TARGET

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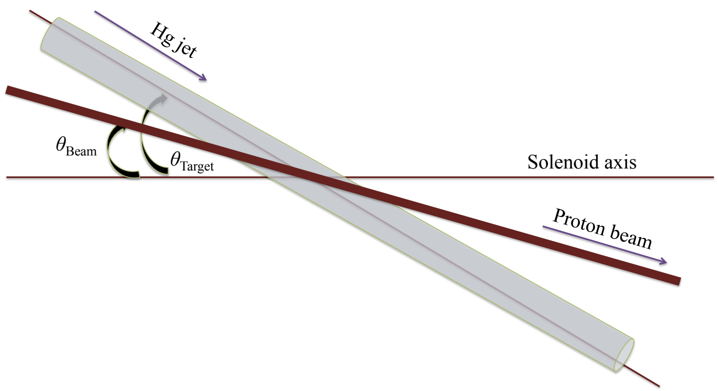
Baseline Optimized Parameters (X. Ding)

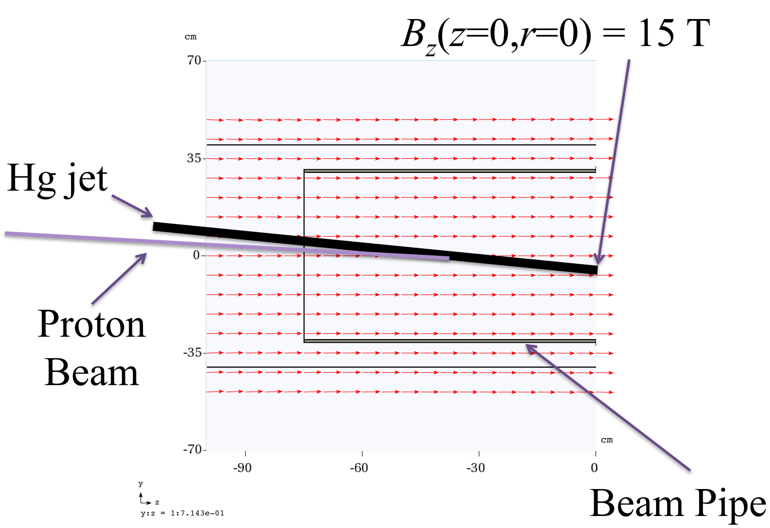
- Hg Target
  - θ_{Target}=0.137 rad
  - R_{Target}=0.404 cm
- Proton Beam
  - E=8 GeV
  - θ_{Beam}=0.117 rad
  - $\sigma_x=\sigma_y$=0.1212 cm (Gaussian Distribution)
  - $\sigma_t=\sigma_z$=0 (Pancake Distribution)
- Solenoid Field
  - IDS120h → 20 T peak field at target position (Z=-37.5)
  - Aperture at Target R=7.5 cm - End aperture R = 30 cm
  - Fixed Field Z = 15 m → Bz=1.5 T

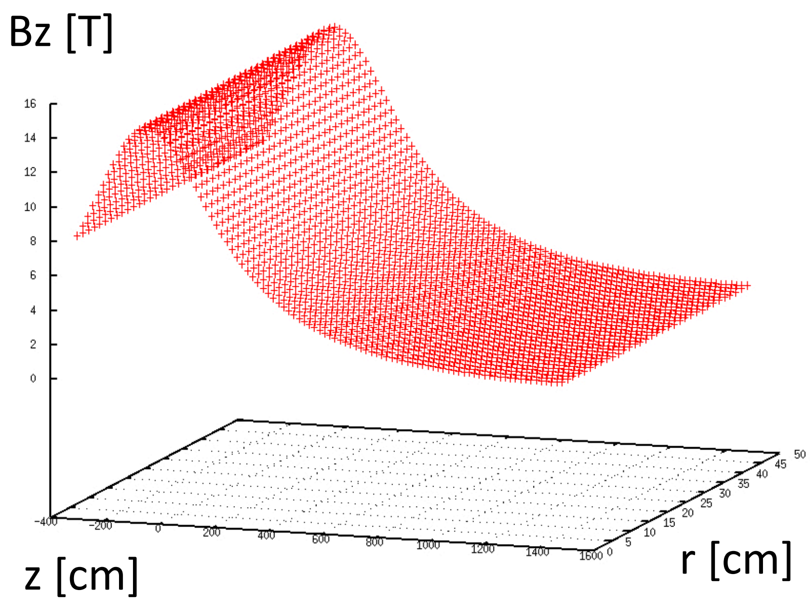


- Production: Muons within energy KE cut 40-180 MeV
  - 3.27 X 10^4 ($N_{ini\ protons}=10^5$)
  - $N_{mesons}/N_{protons}$=0.327

MARS Simulation Setup

- Beam Pipe with constant R=30 cm (eliminate particle loss due to scrapping)
- Beam Pipe material changed to balckhole to speed calculations
- Added subroutine to m1510.f (FIELD) to calculate the field using inverse cubic equations





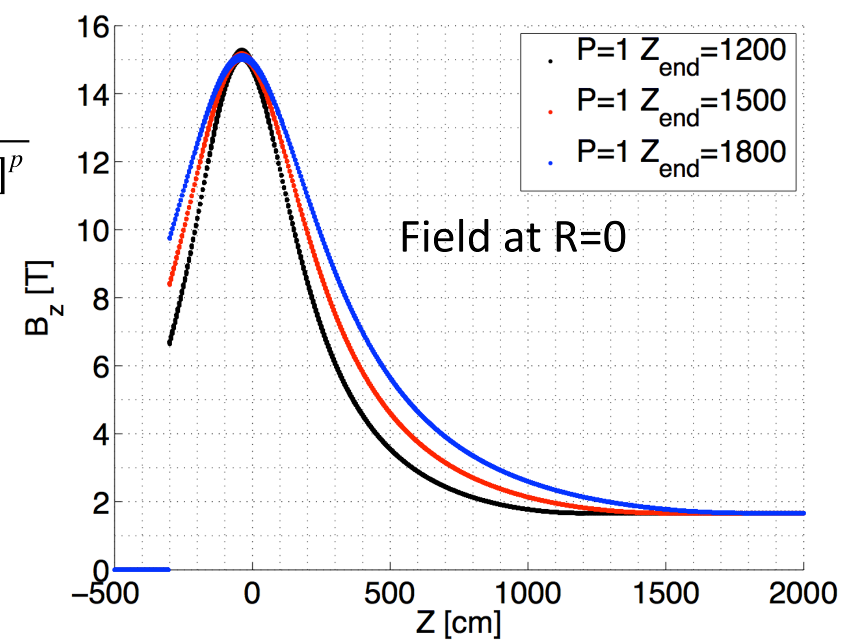
Analytic form for Tapered Solenoid

Inverse-Cubic Taper

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

$$a1 = -\frac{B_1'}{pB_1} \qquad a_2 = 3\frac{(B_1/B_2)^{1/p} - 1}{(z_2 - z_1)^2} - \frac{2a_1}{z_2 - z_1}$$

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



Off-axis field approximation

$$B_z(r,z) = \sum_n (-1)^n \frac{a_0^{(2n)}(z)}{(n!)^2}\left(\frac{r}{2}\right)^{2n}$$

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

$$a_0^{(n)} = \frac{d^n a_0}{dz^n} = \frac{d^n B_z(0,z)}{dz^n}$$

```
! First Order
BZ = B1 / CUBIC**POW
BR = -R / 2. * DBZ1
! Second Order
BZ = BZ - R**2 / 4. * DBZ2
BR = BR + R**3 / 16. * DBZ3
! Third Order
BZ = BZ + R**4 / 64.0 * DBZ4
BR = BR - R**5 / 384.0 * DBZ5
! Fourth Order
BZ = BZ - R**6 / 2304.0 * DBZ6
BR = BR + R**7 / 18432.0 * DBZ7
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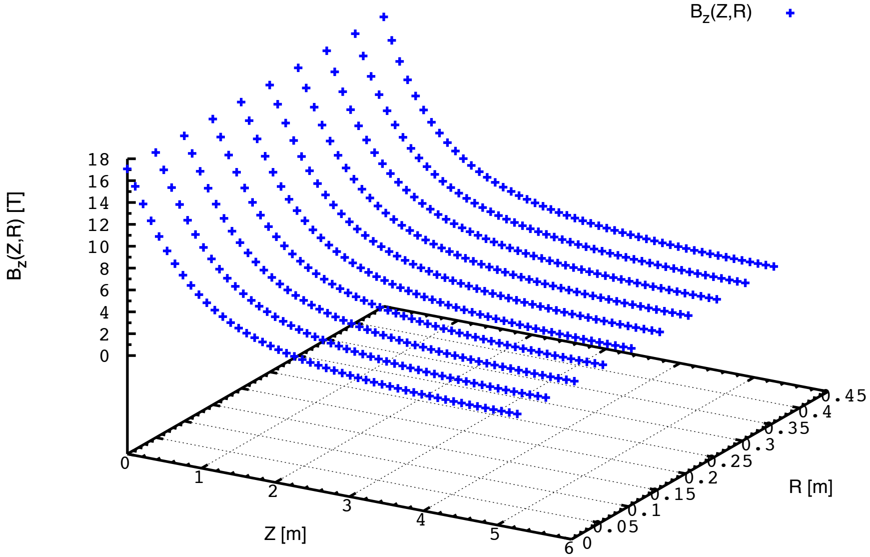
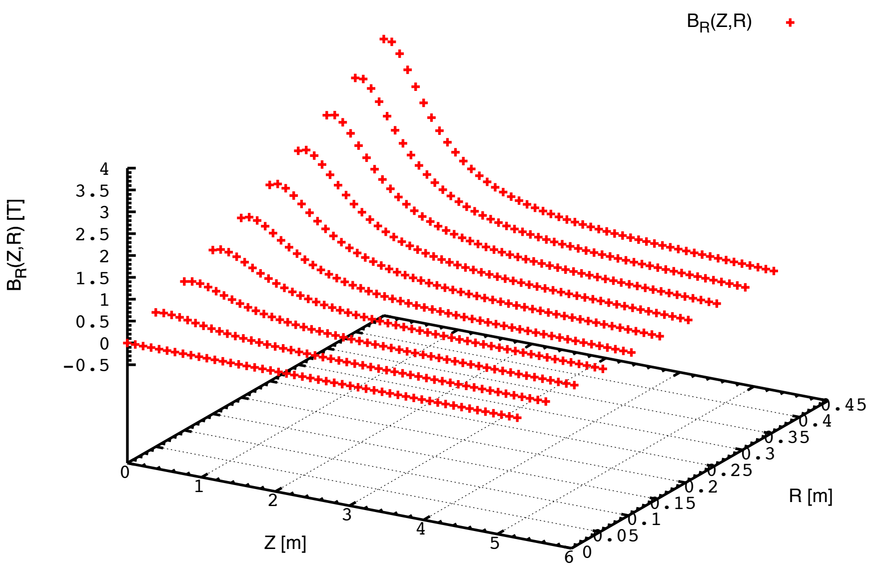
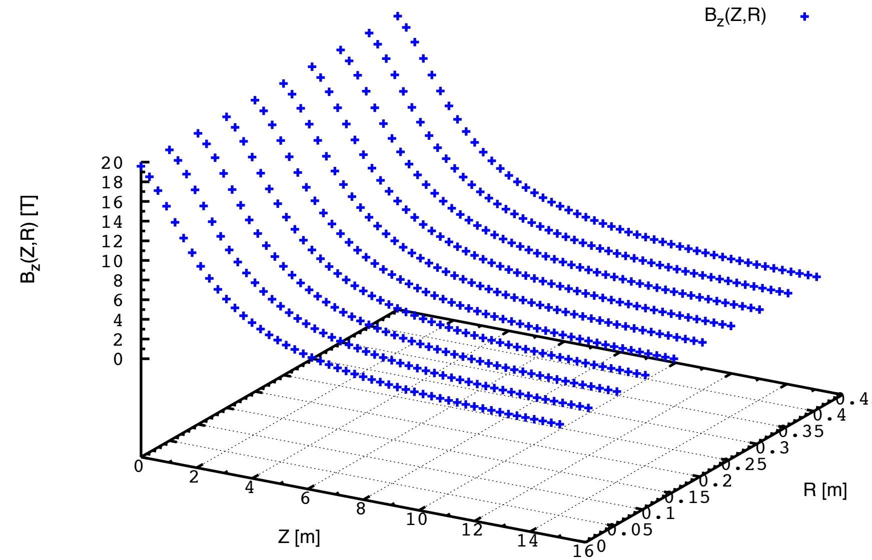
Solenoid Tapered Field

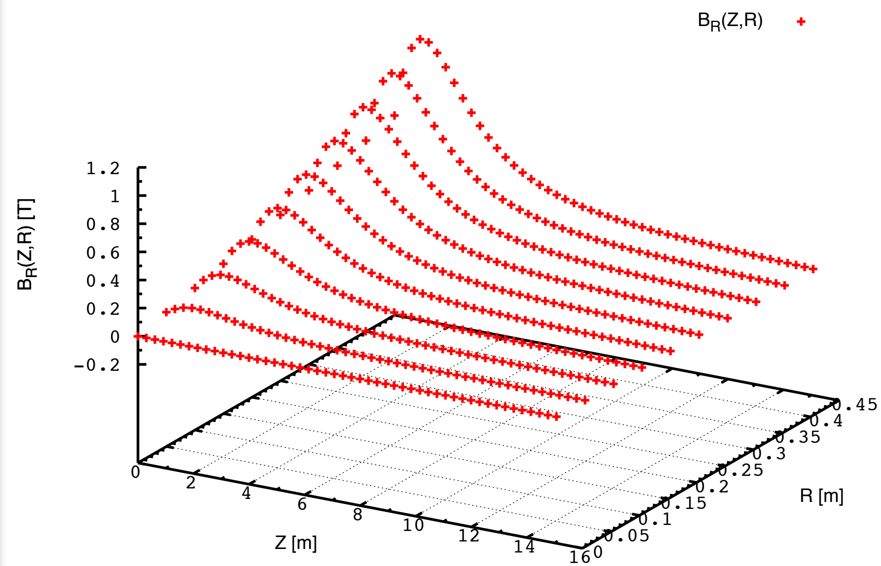
Bz=20-1.5T Ltaper=4 m





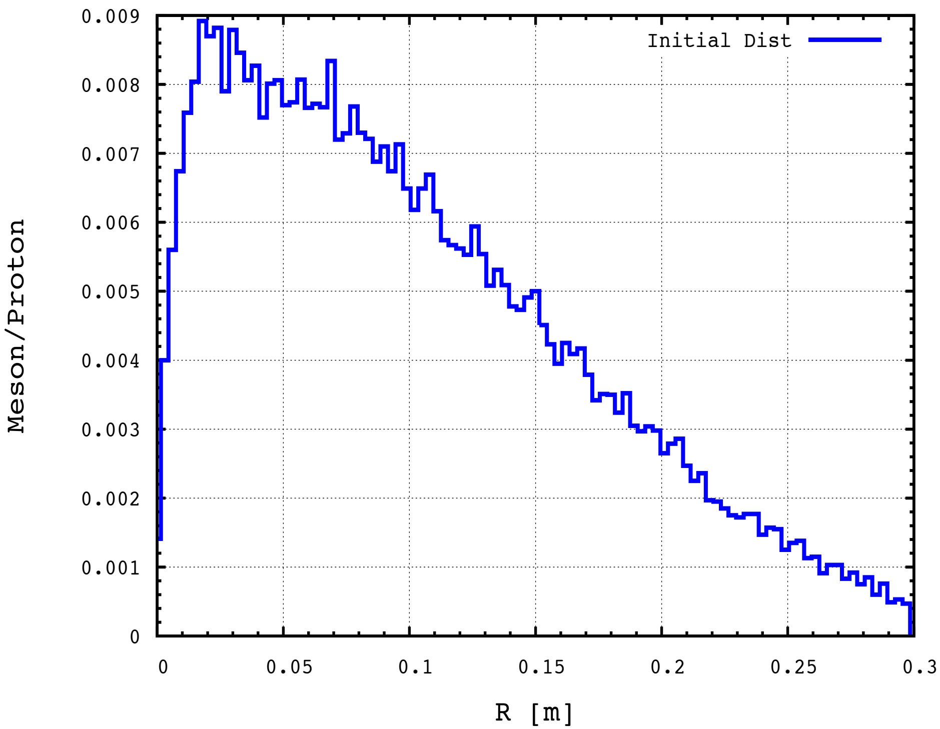
Bz=20-1.5T Ltaper=14 m



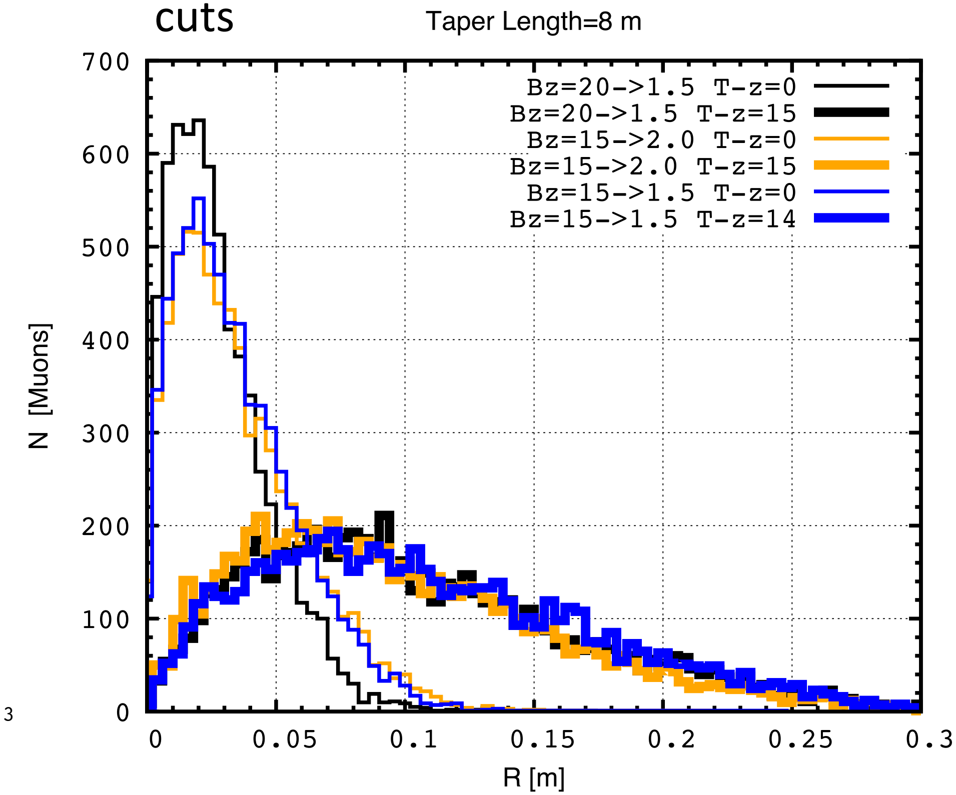


Initial Particle Distributions

Distribution of all Mesons at z=0

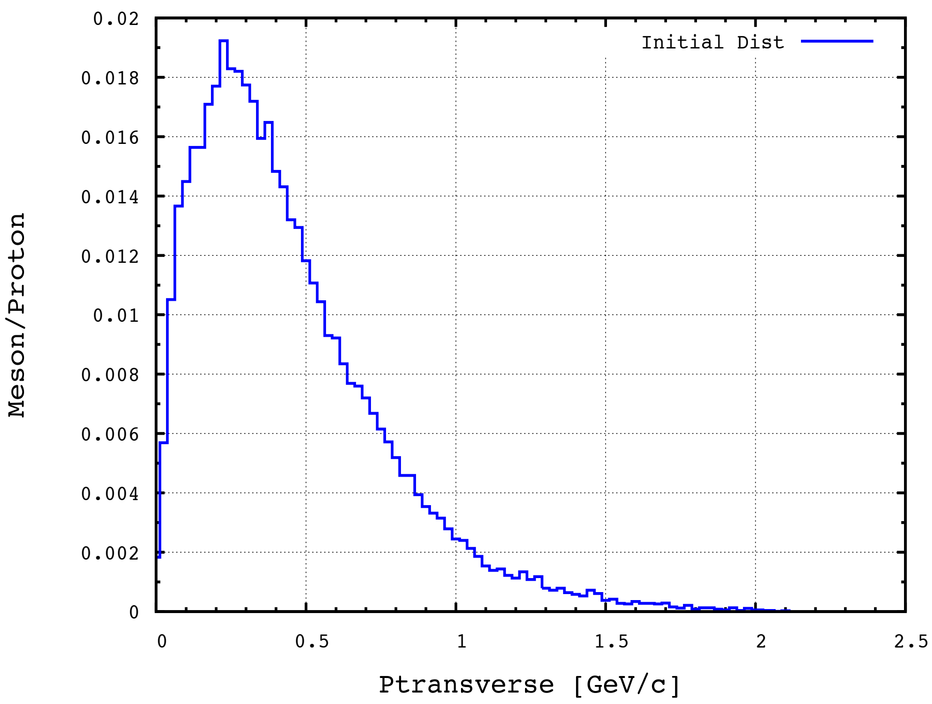


Distribution of Muons which made it to the end of cooling section and satisfied acceleration acceptance cuts



Good Muons Particle Distributions

Distribution of all Mesons at z=0



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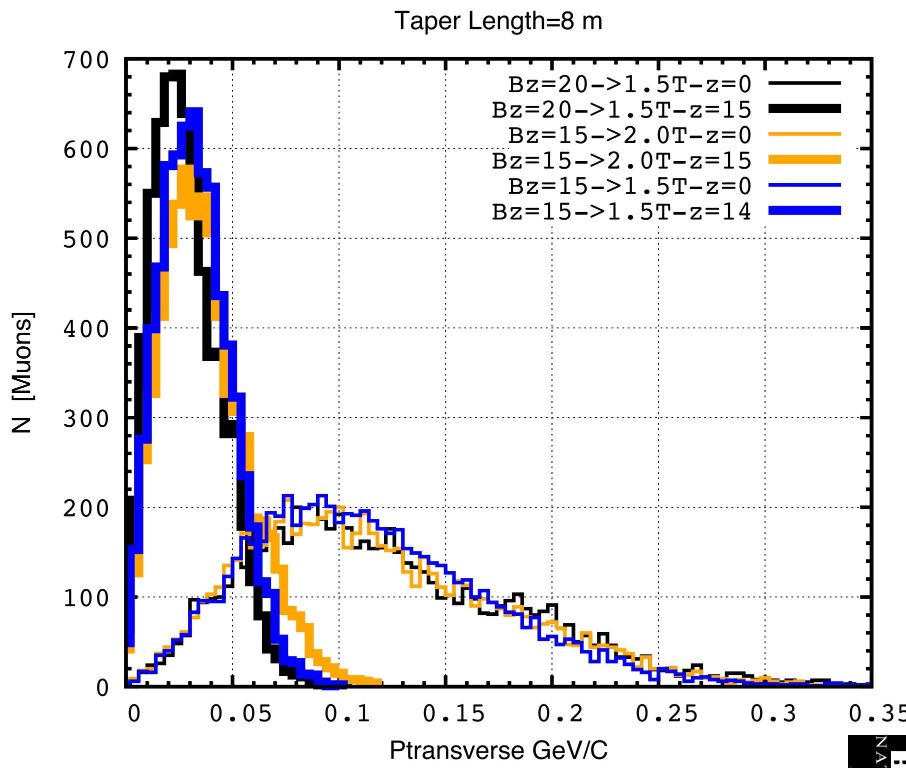
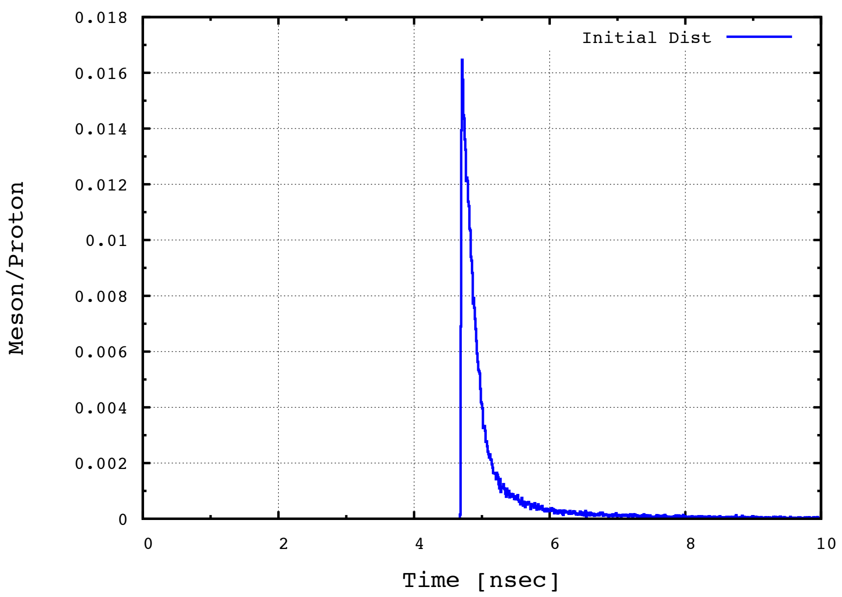
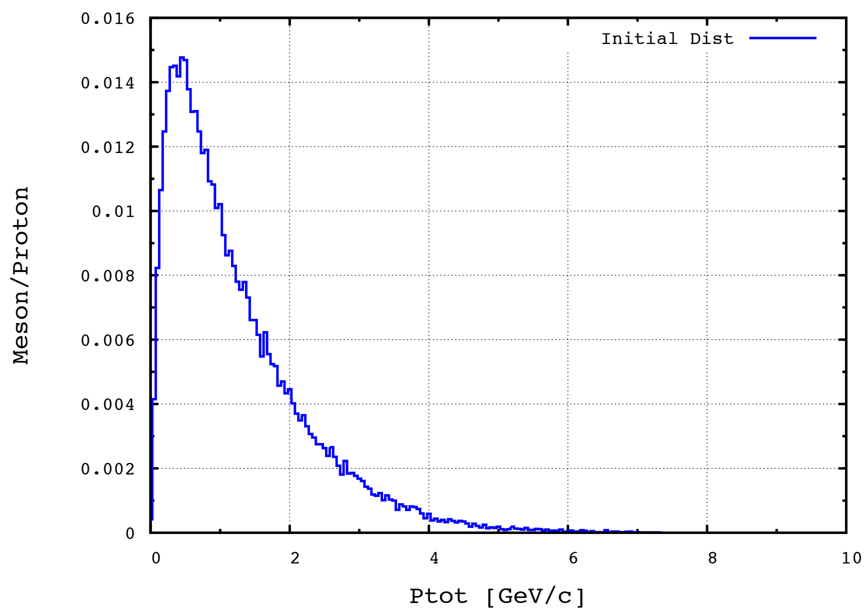


Mesons Initial Distribiution

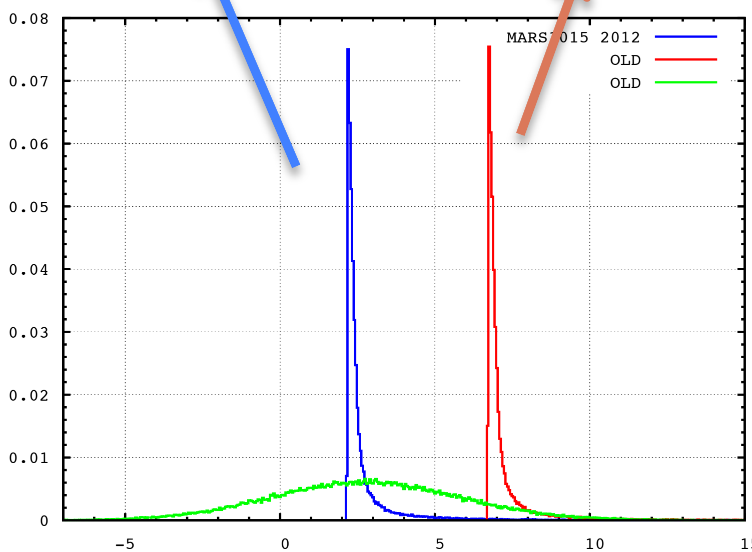


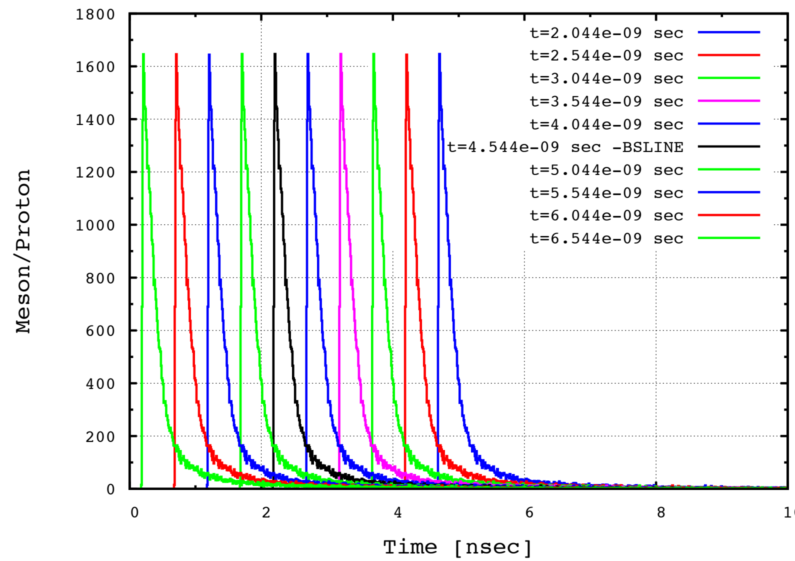


Fixing time of arrival

TOA Protons
at z=-75 cm

TOA Protons
at z=-200 cm

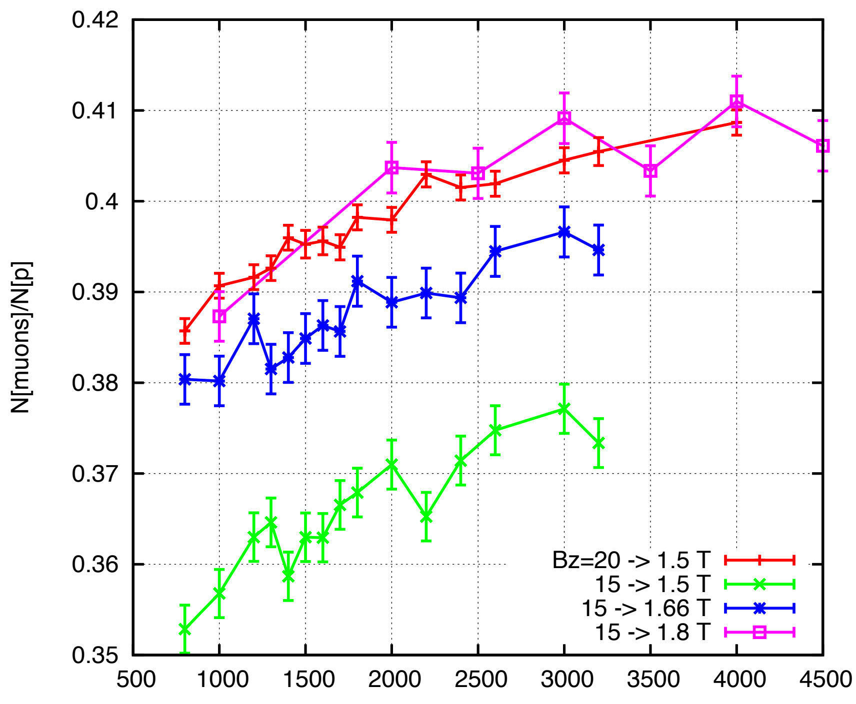




MARS simulation was performed with a “pancake” shaped proton beam, lunched at t=0 from a specified z<0.
The Gaussian time distribution is “usually” produced by using a random Gaussian generator on the meson distribution at z=0.

TRANSMISSION

MARS simulation results:
Counting muons at 50 m with K.E. 80-140 MeV



Solenoid Taper Length [cm]

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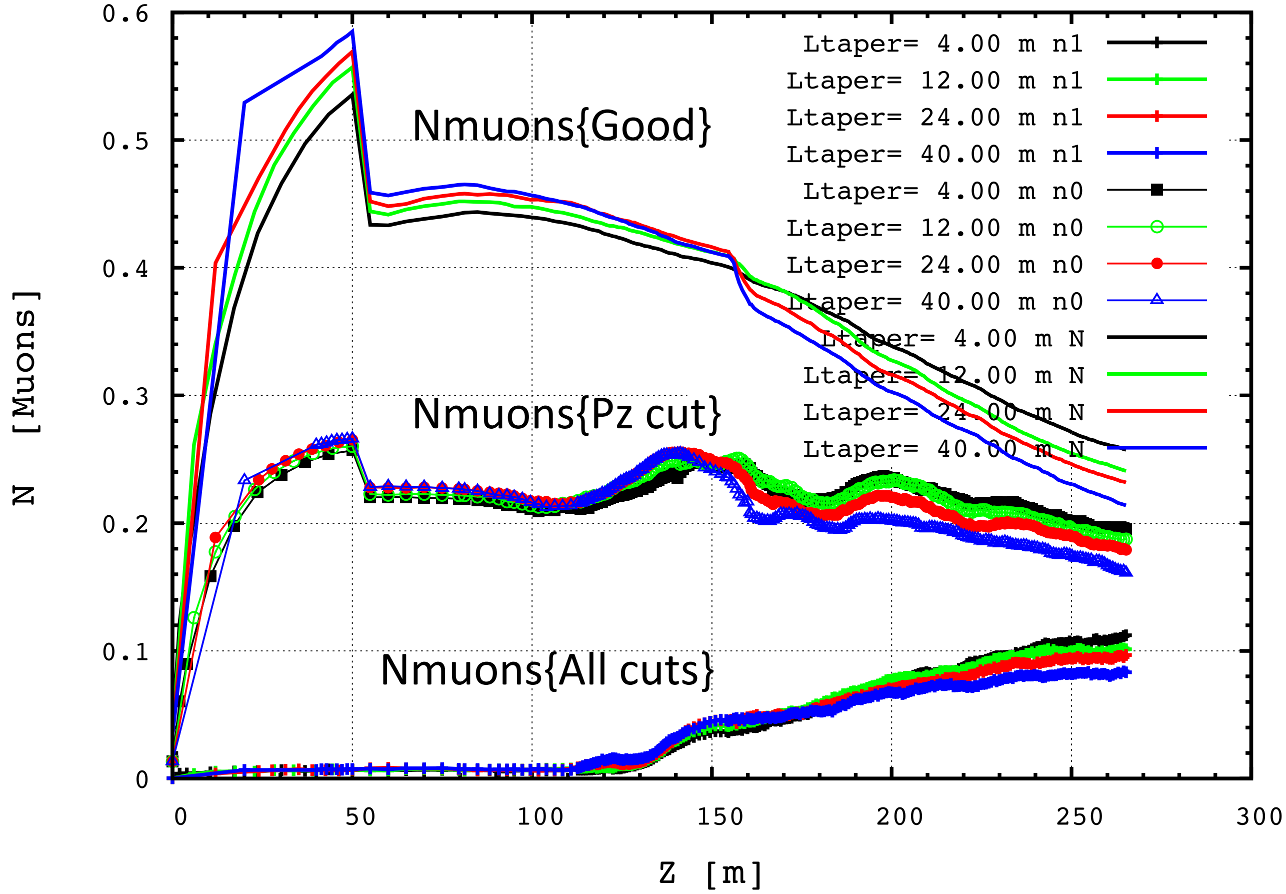
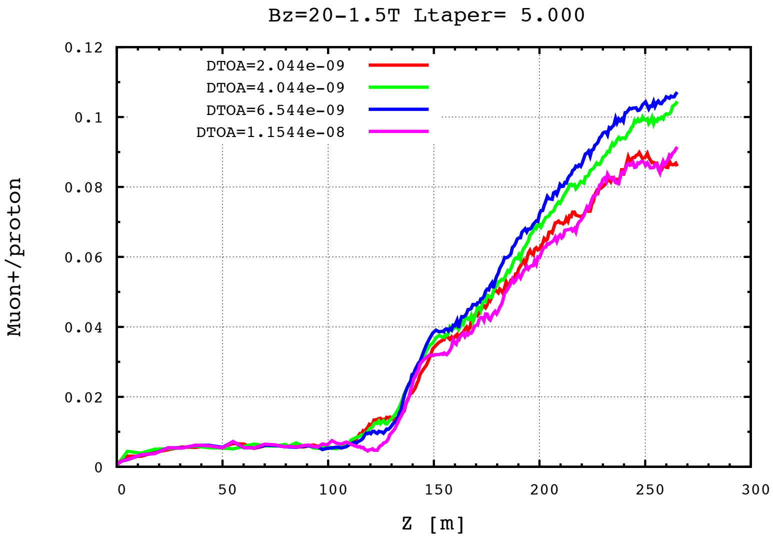
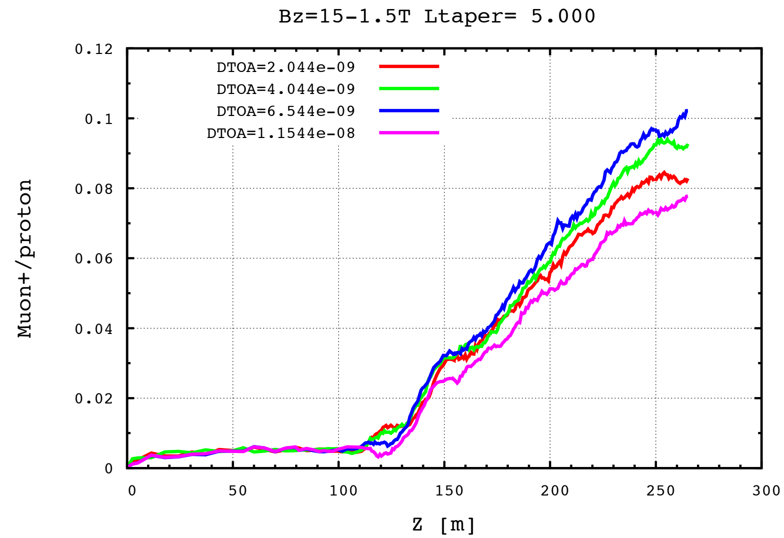
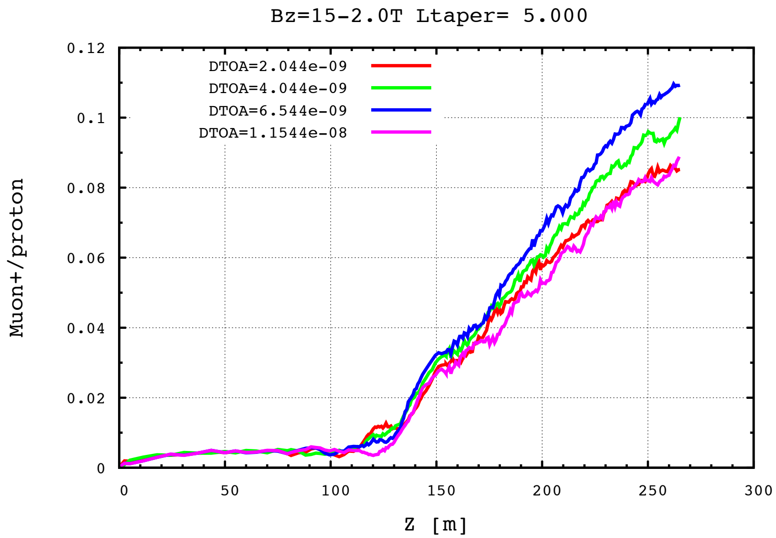
TRANSMISSION



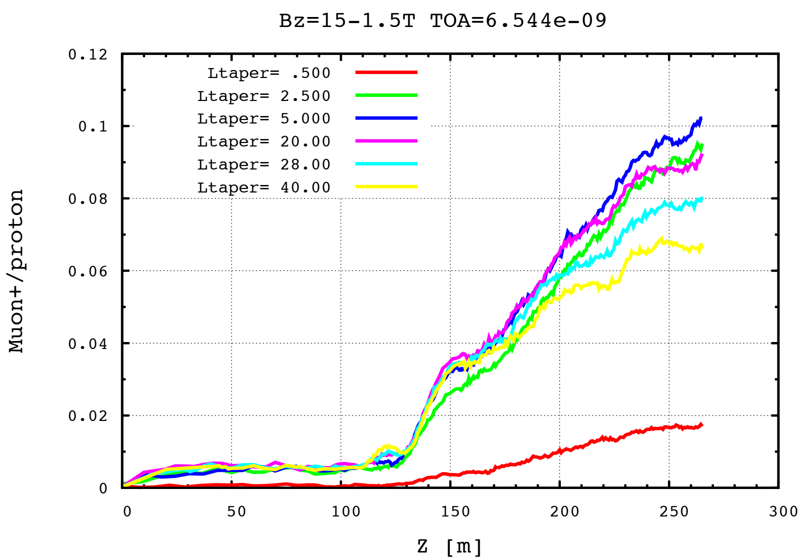
TIME OF ARRIVAL SCAN

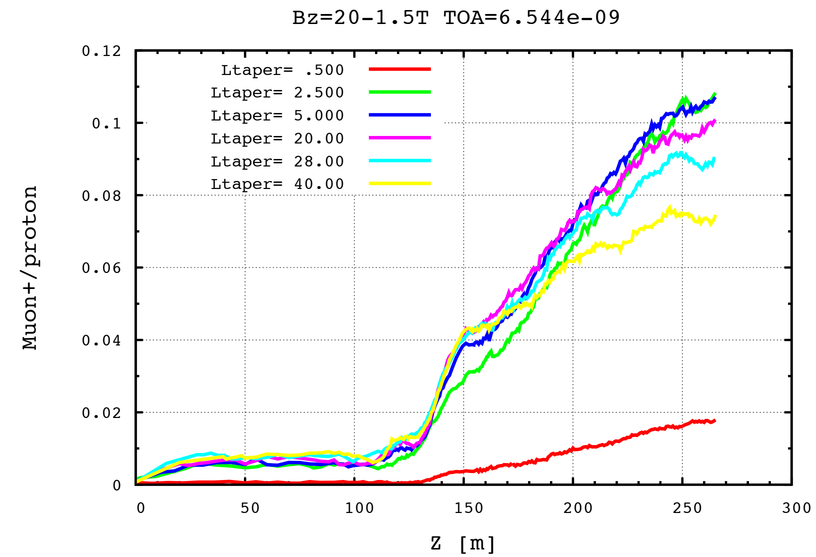


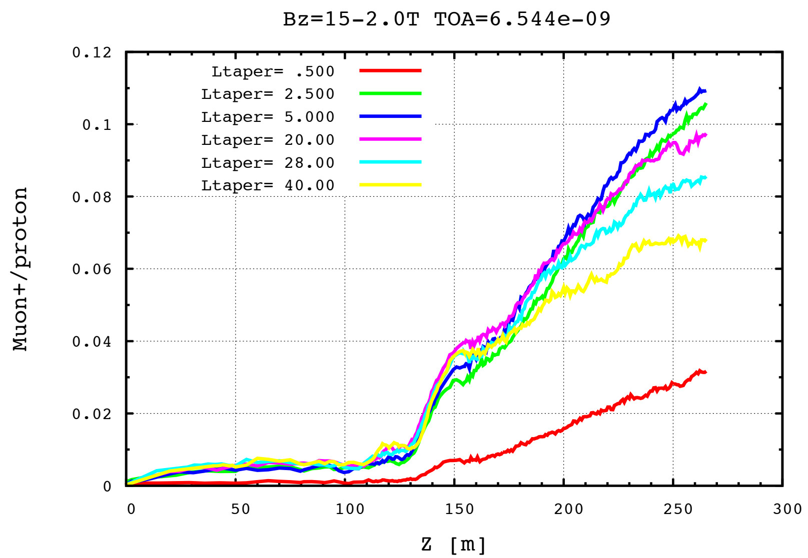




TAPER SCAN







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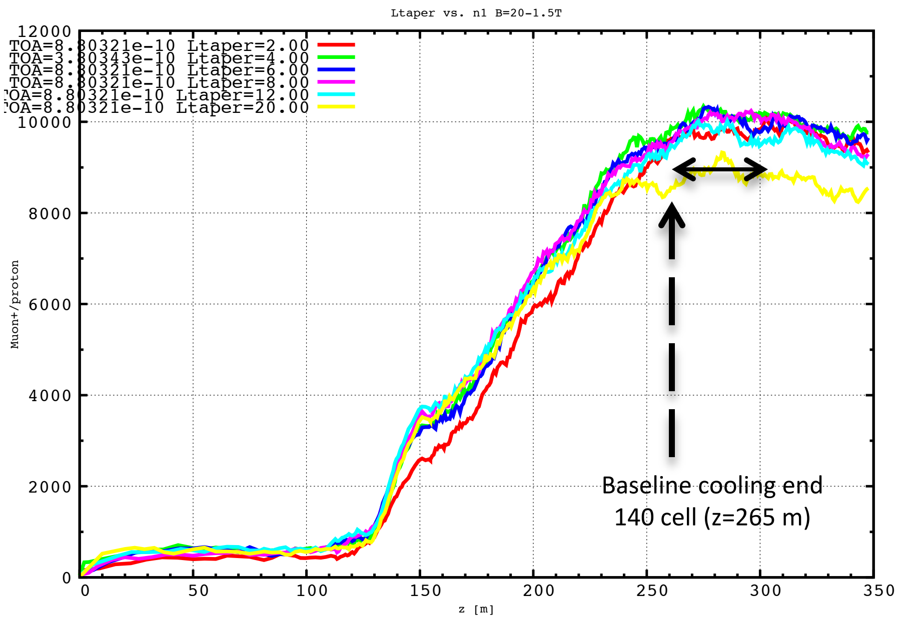
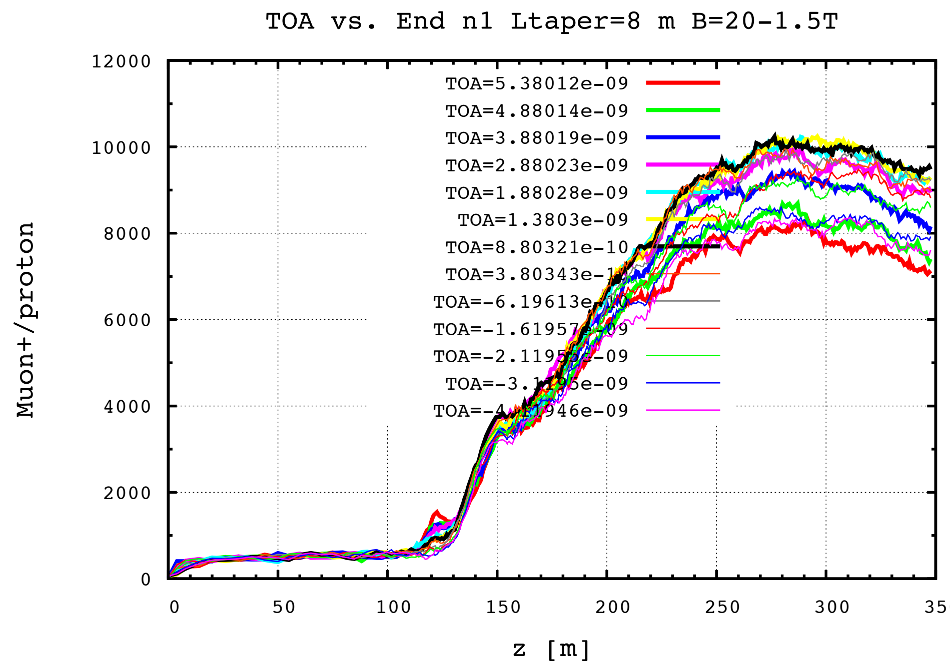
More Cooling

For every taper length optimized TOA

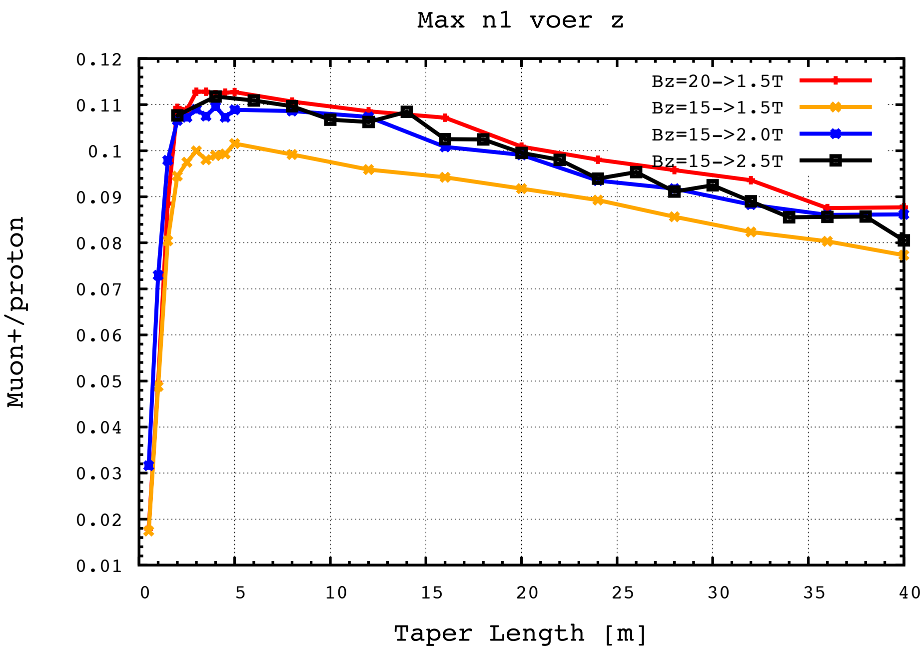


For 8 m taper length TOA scan

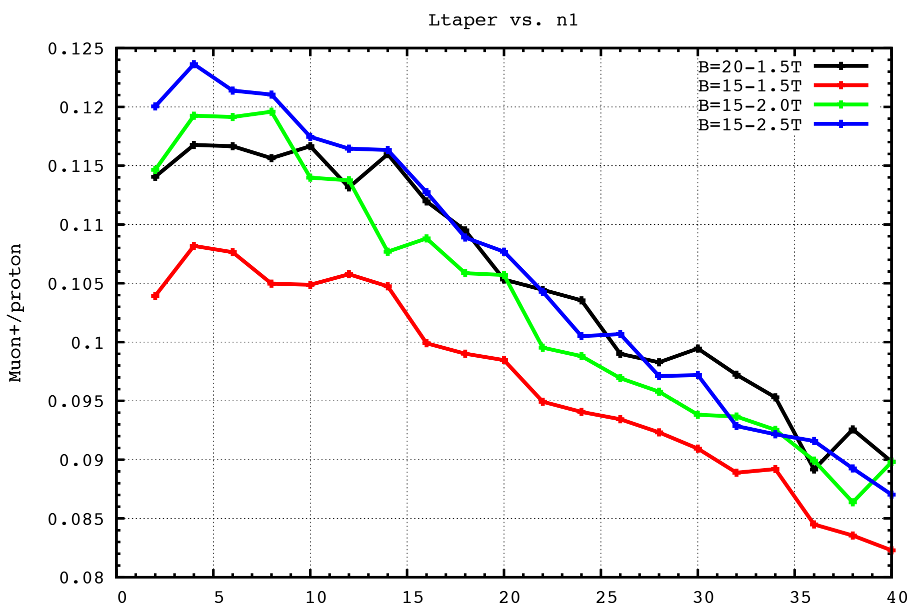


TIME & TAPER LENGTH SCAN

Using baseline cooling section (140 cooling cell)

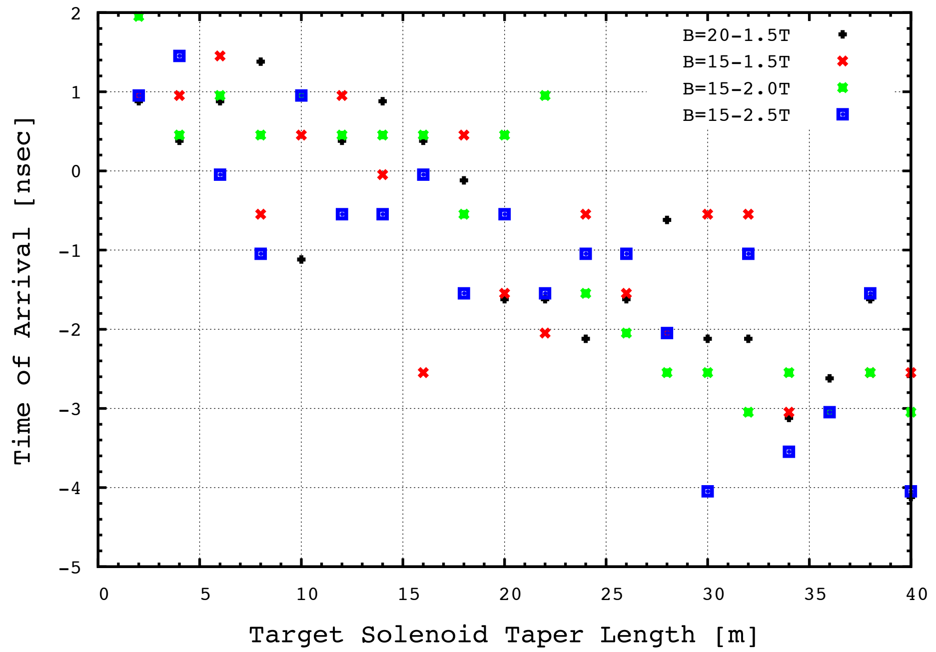


Using longer cooling section (200 Cooling cell)



Time & Taper Length scan

TOA for optimum throughput at end of cooling for each capture solenoid case



Conclusion & Summary

- Varying the capture solenoid settings requires optimizing the time of arrival (re-phasing) .
- Longer tapers have more meson yield at the decay channel (z=50).
- Shorter tapers produce “more good” muons which could be bunched & cooled.
- The maximum yield requires tapers with z=4-6 m.
- Particle loss at z=150 m needs more detailed study.
- Adding longer cooling channel is required to reach maximum cooling.

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