TRANSPORT STUDY FOR THE MUON COLLIDER/NEUTRINO FACTORY FRONTEND

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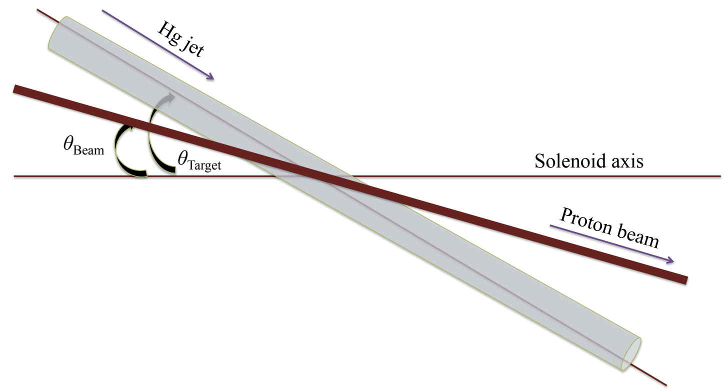
BASELINE OPTIMIZED PARAMETERS (X. DING)

- **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



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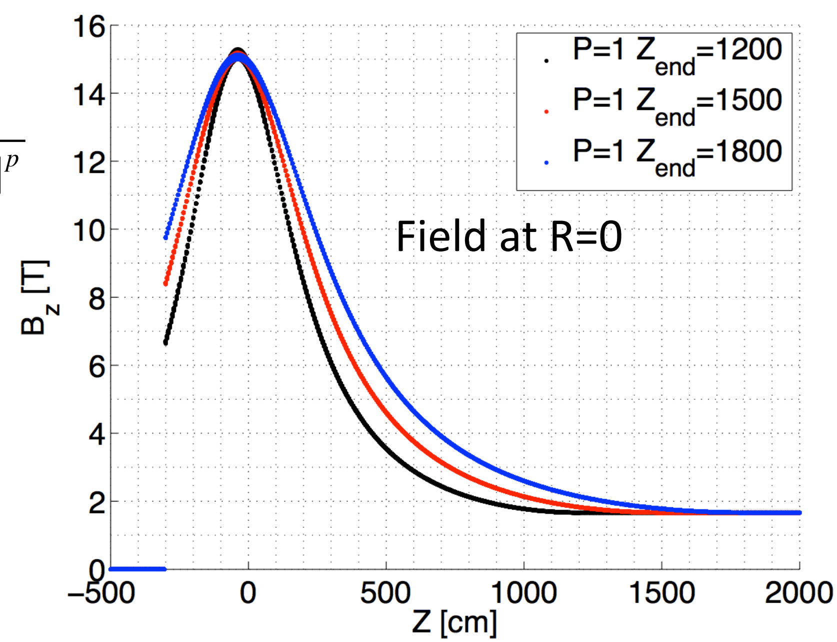
Analytic form for Tapered Solenoid

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

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

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

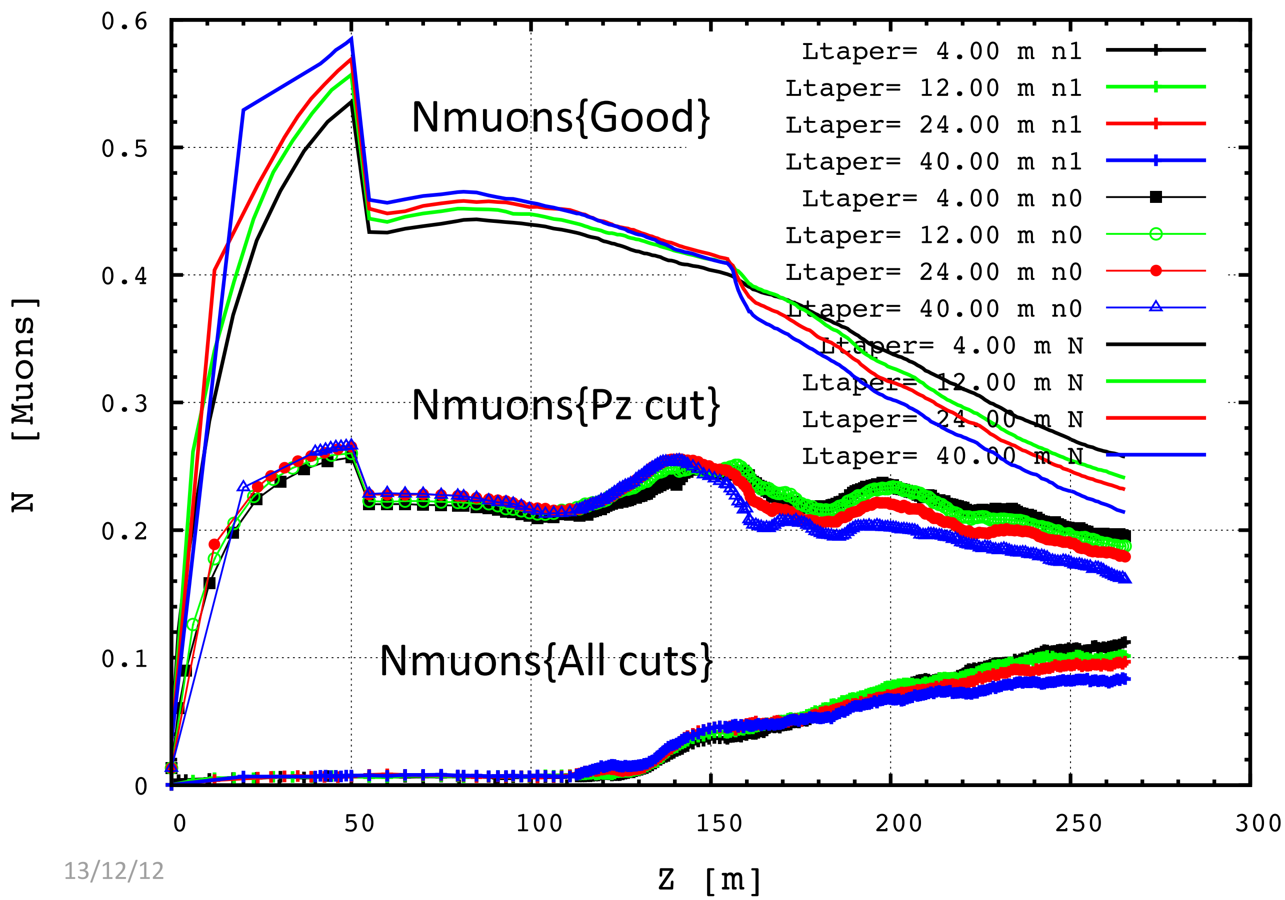
$$a_0^{(n)} = \frac{d^n a_0}{dz^n} = \frac{d^n B_z(0,z)}{dz^n}$$

```
! 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
```

TRANSMISSION

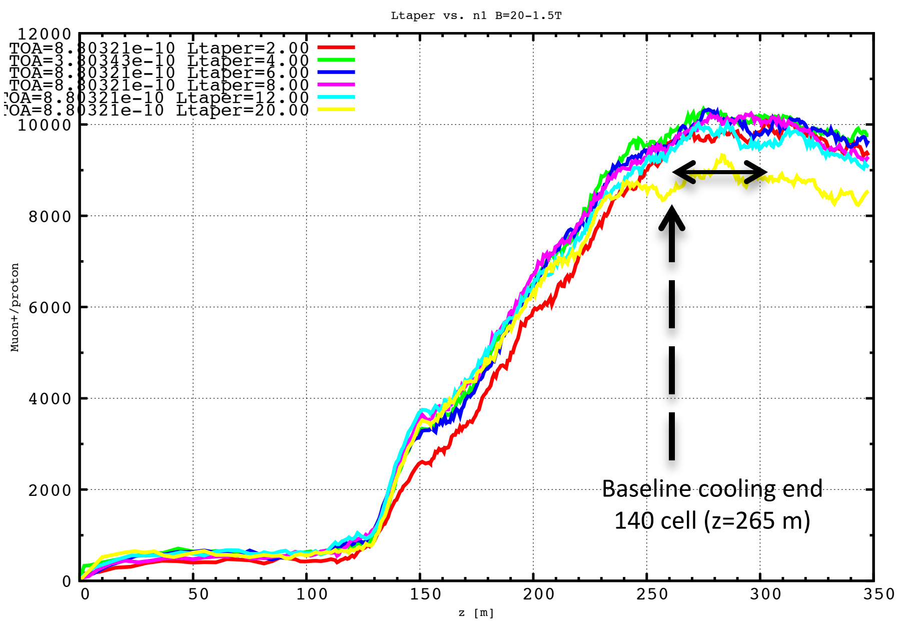
Good particles are those who satisfy the following conditions/cuts

- Survived the phase rotator and cooling sections
- Acceleration acceptance cuts
  - 0.1 <Pz< 0.3 GeV
  - Transverse cut R < 0.3 m
  - Longitudinal cut < 0.15 m

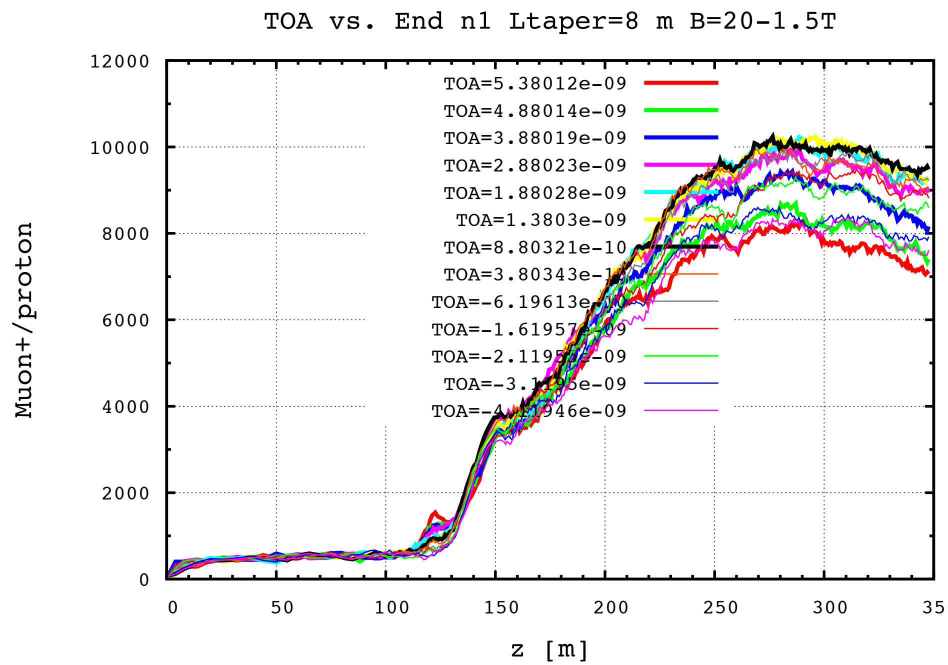


More Cooling

For every taper length optimized TOA

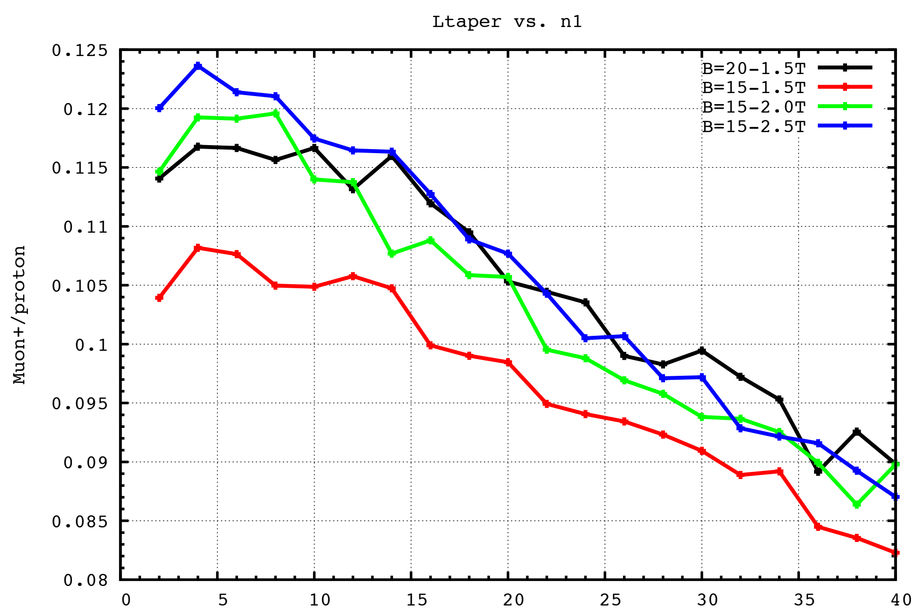


For 8 m taper length TOA scan



Time & Taper Length scan

Using longer cooling section
(200 Cooling cell)



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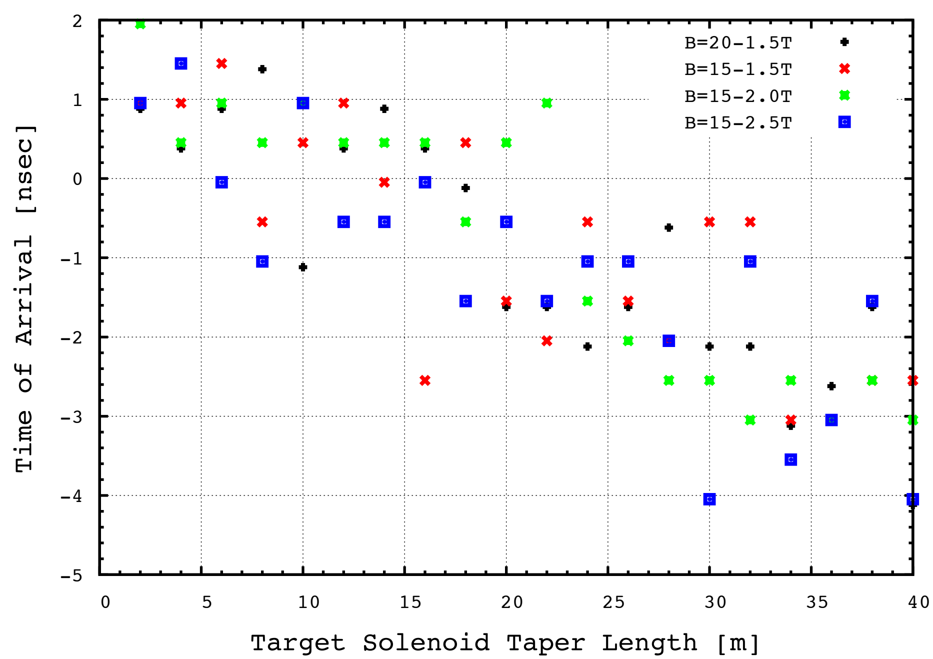
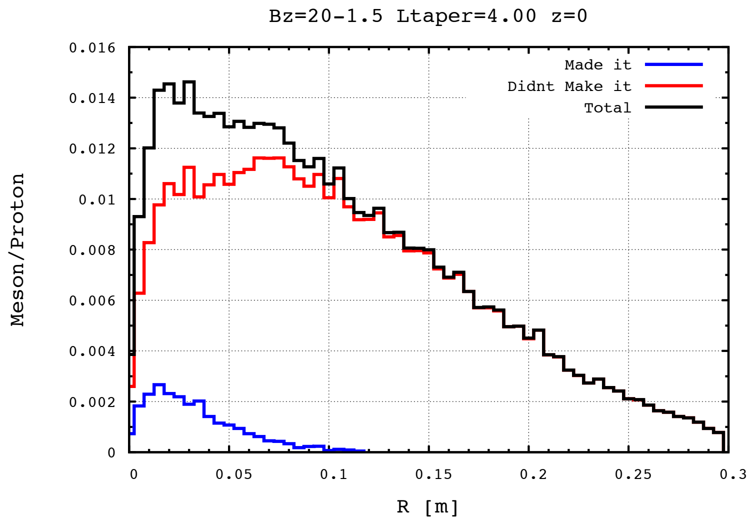
TIME & TAPER LENGTH SCAN

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

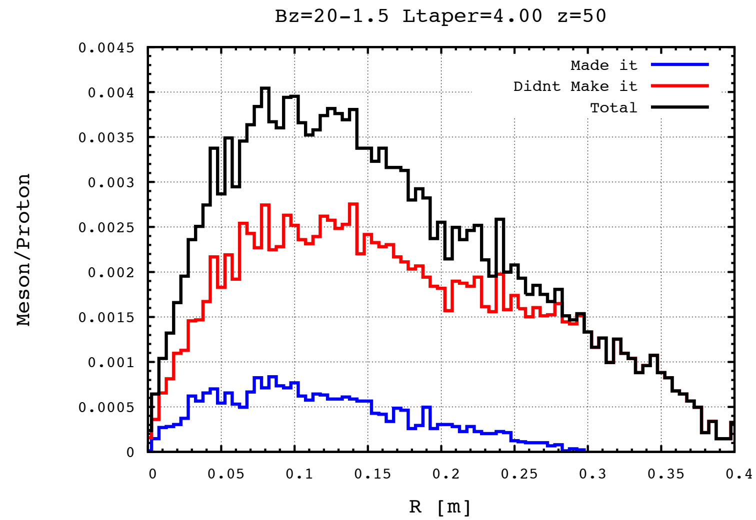


PHASE SPACE DISTRIBUTIONS

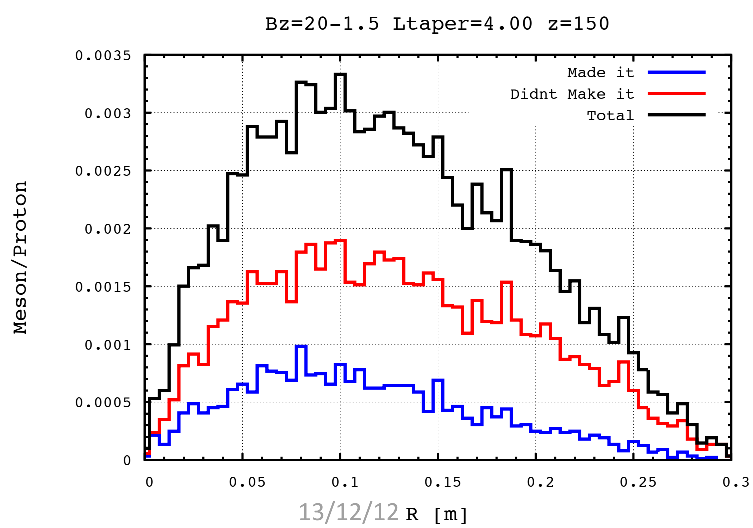
INITIAL



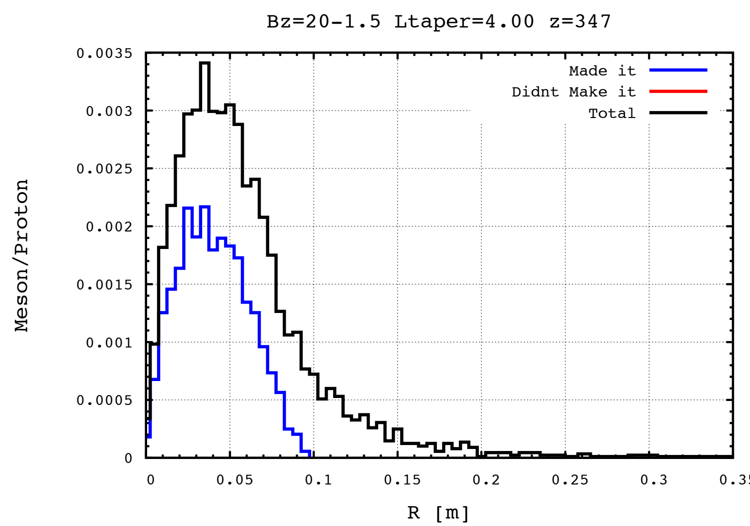
END DECAY CHANNEL



END PHASE ROTATOR



END COOLING



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Phase Space Distributions

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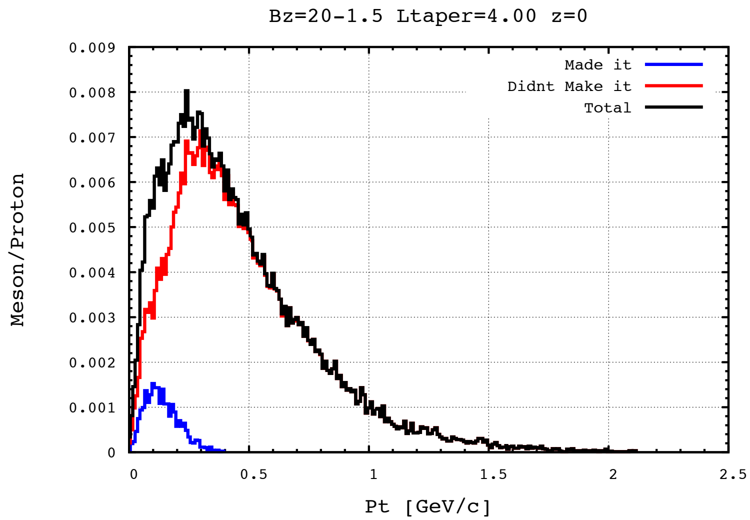

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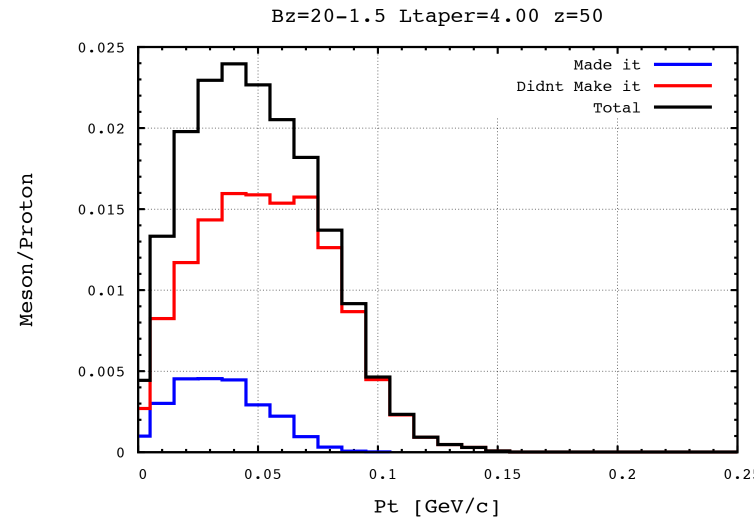

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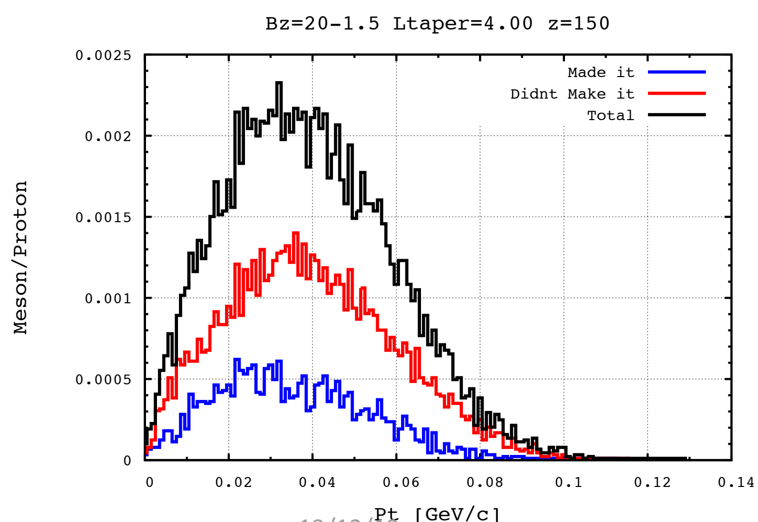

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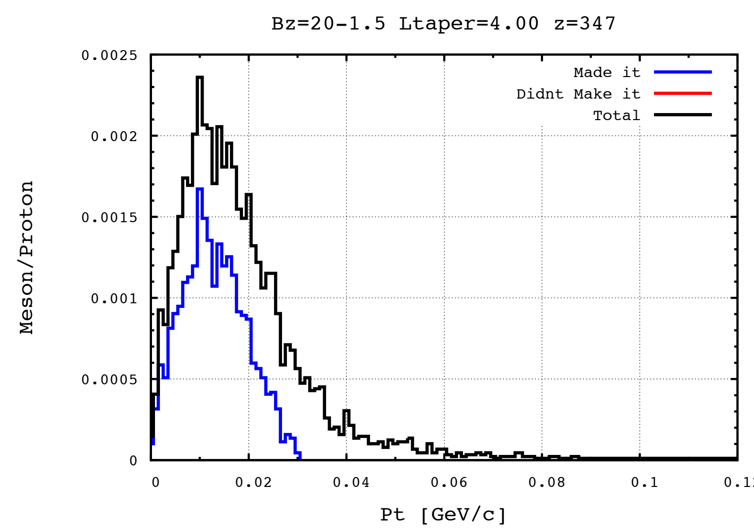

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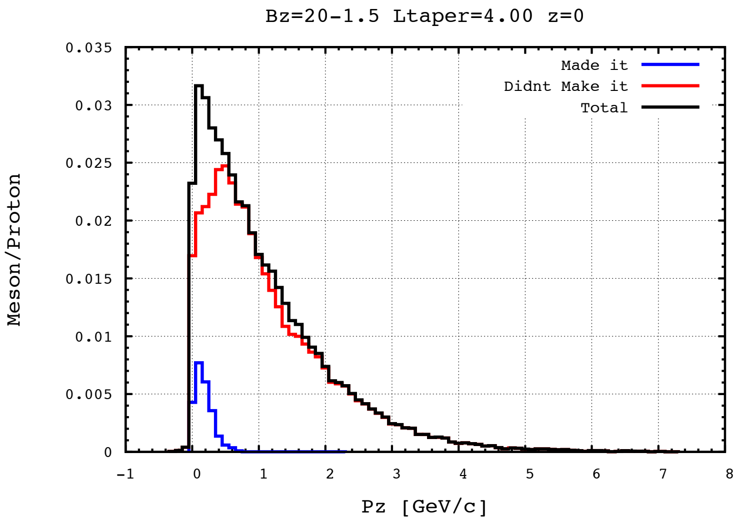

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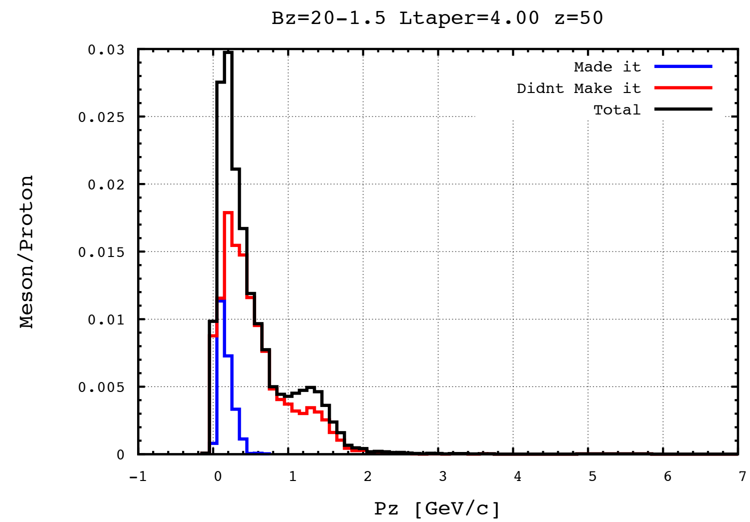

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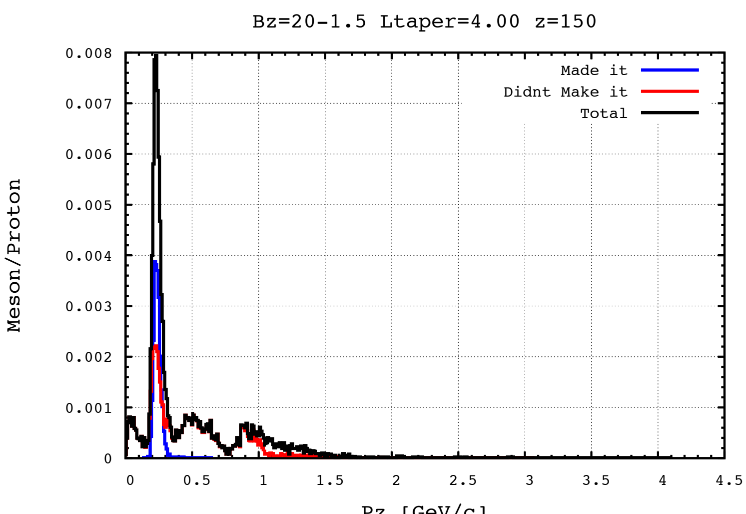

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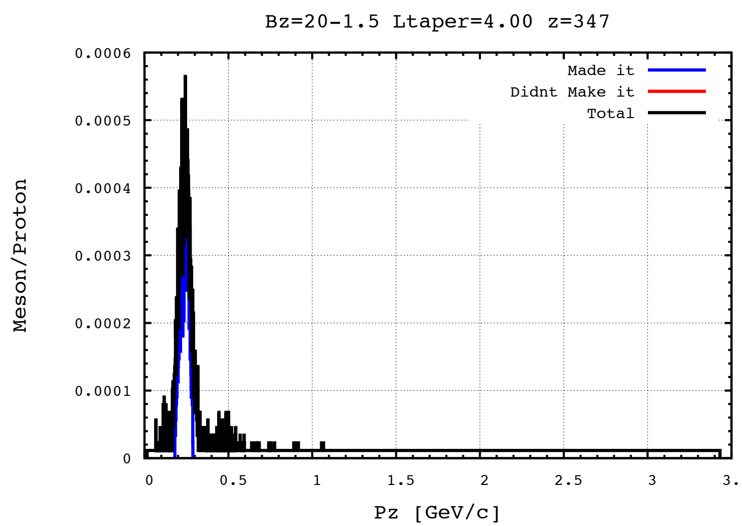

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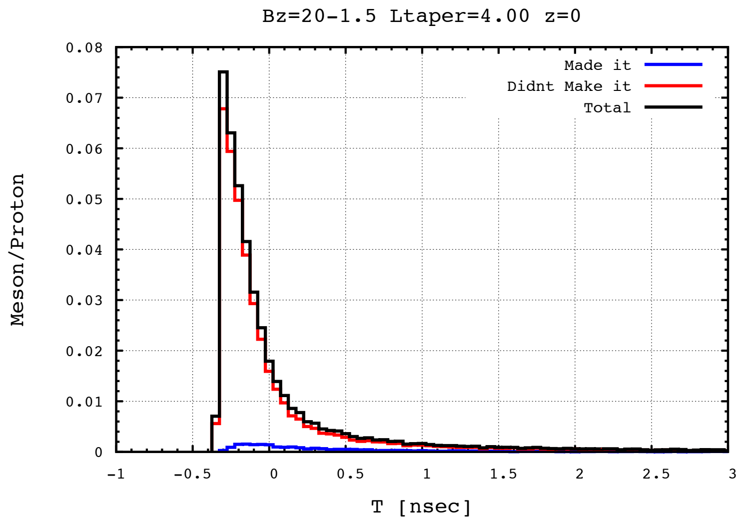

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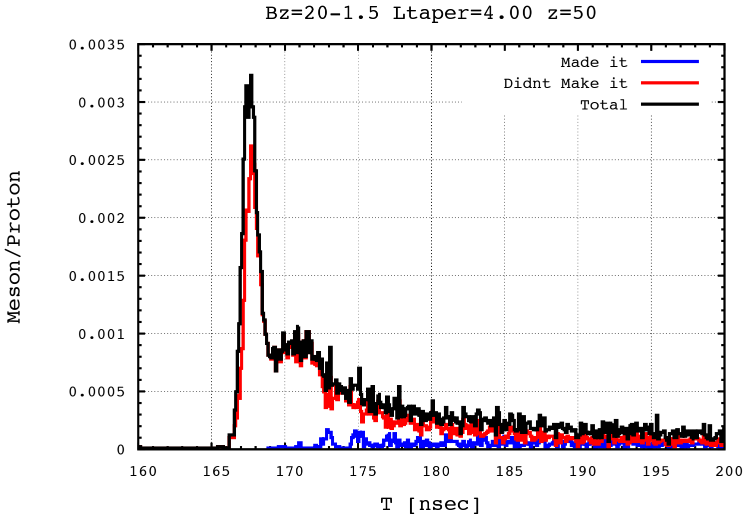

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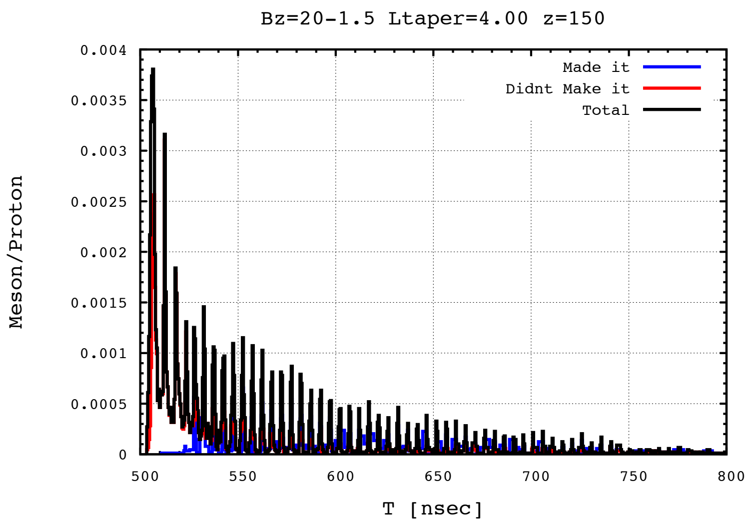

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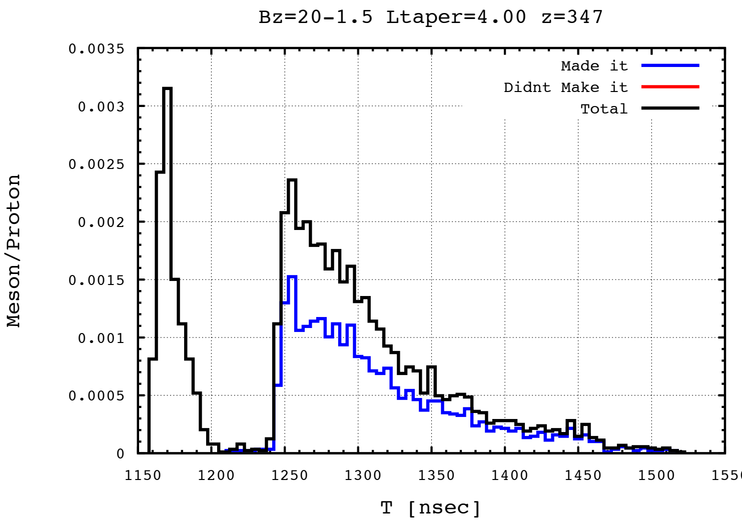

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Phase Space Distributions

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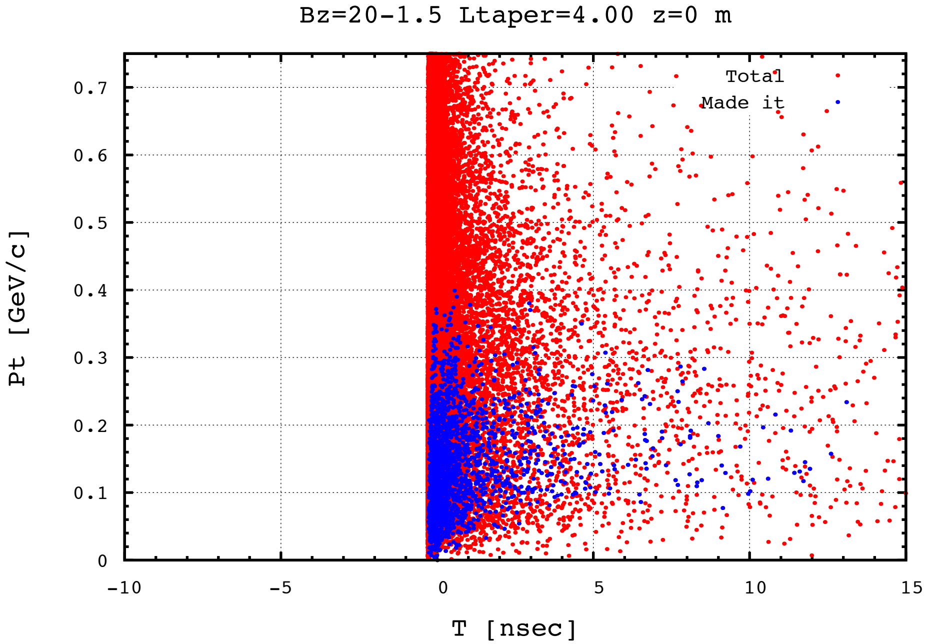

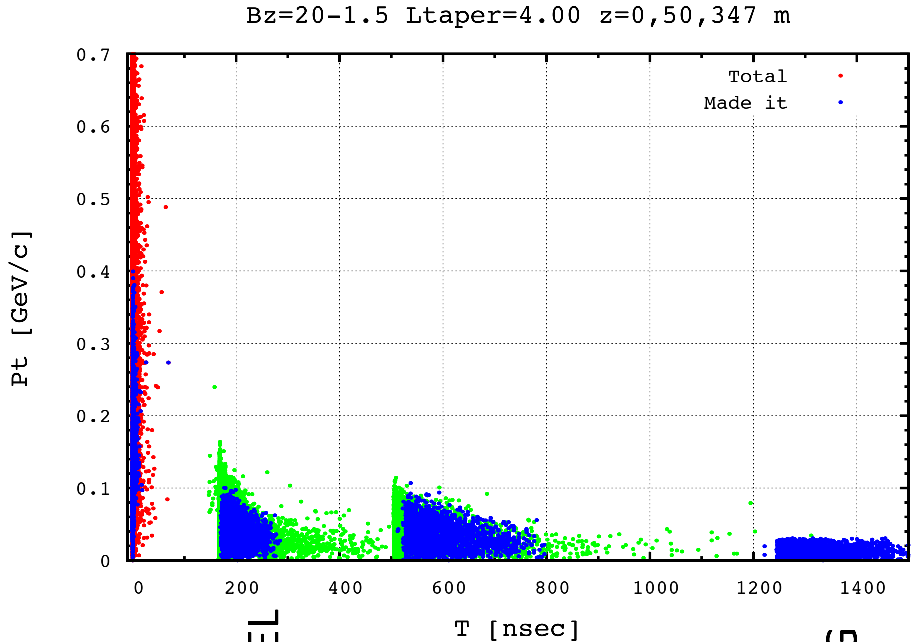

INITIAL

END DECAY CHANNEL

END PHASE ROTATOR

END COOLING

PHASE SPACE DISTRIBUTIONS

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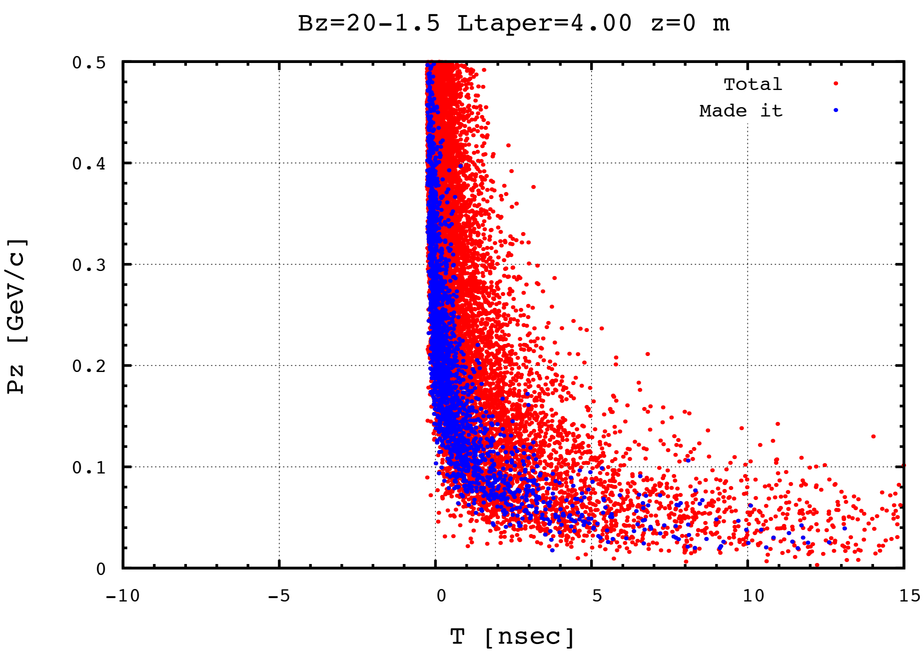

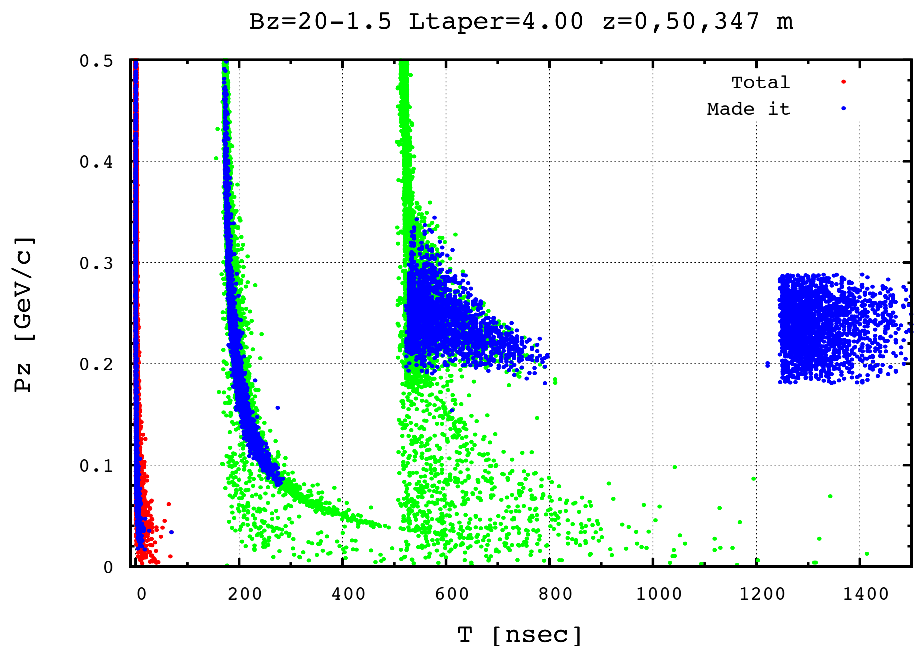

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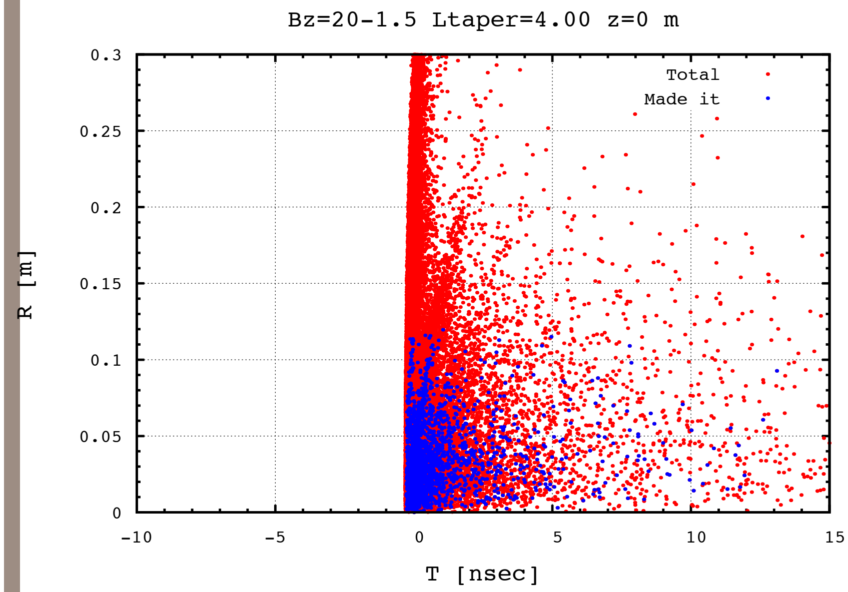
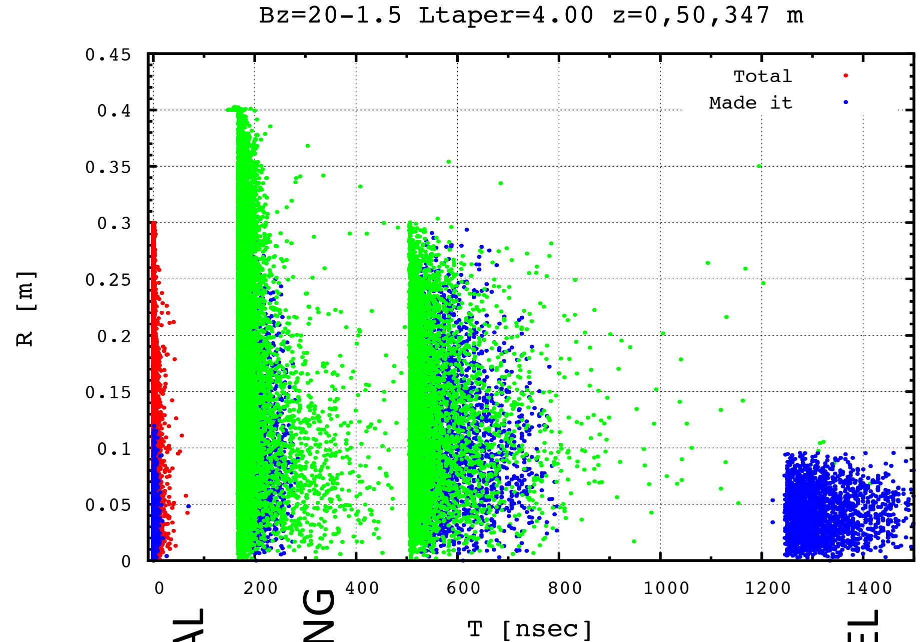




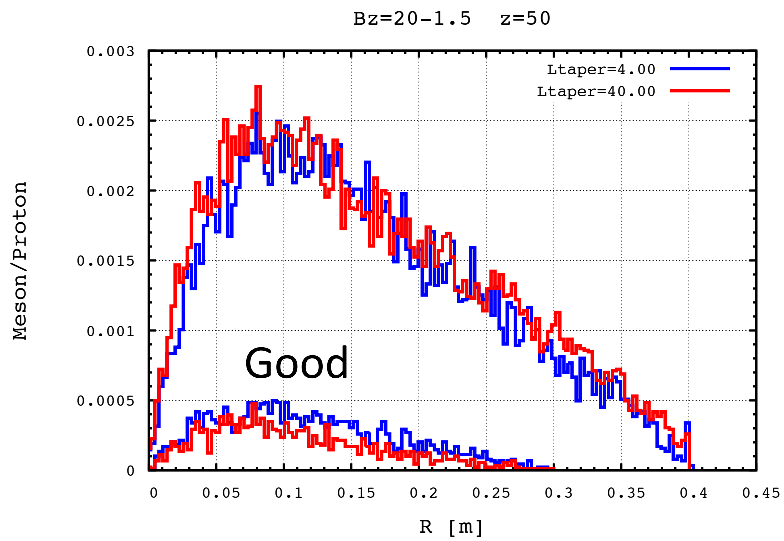
INITIAL

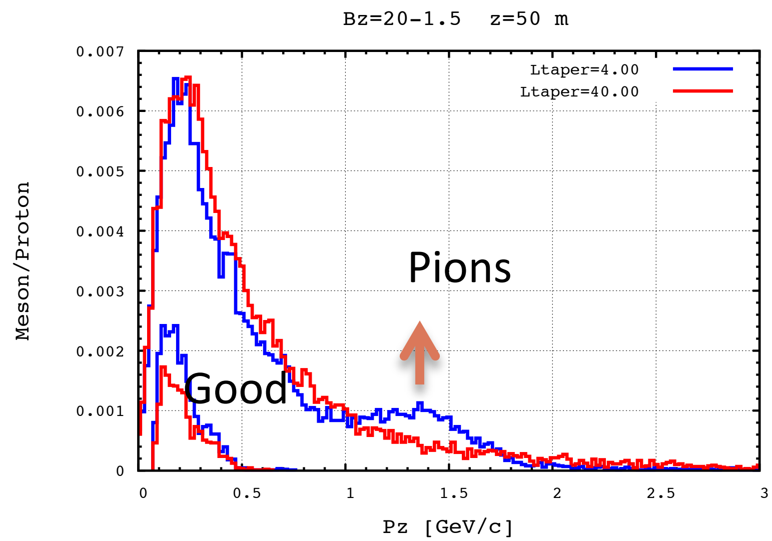
END COOLING

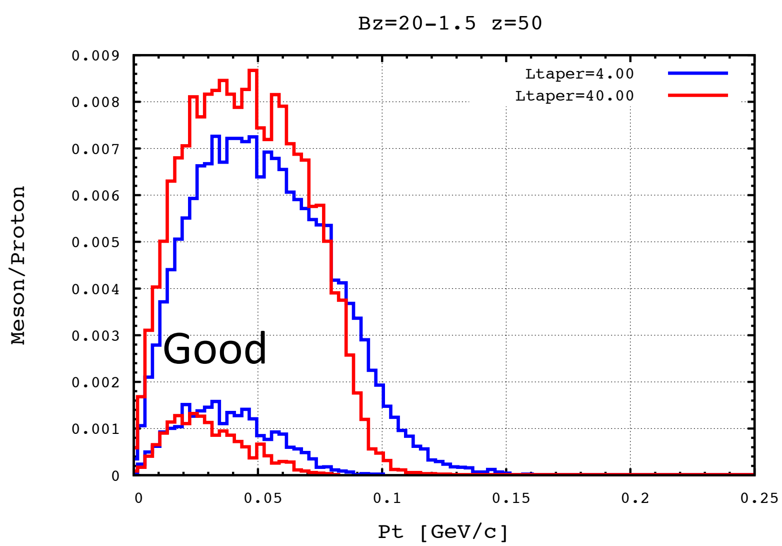
END PHASE ROTATOR

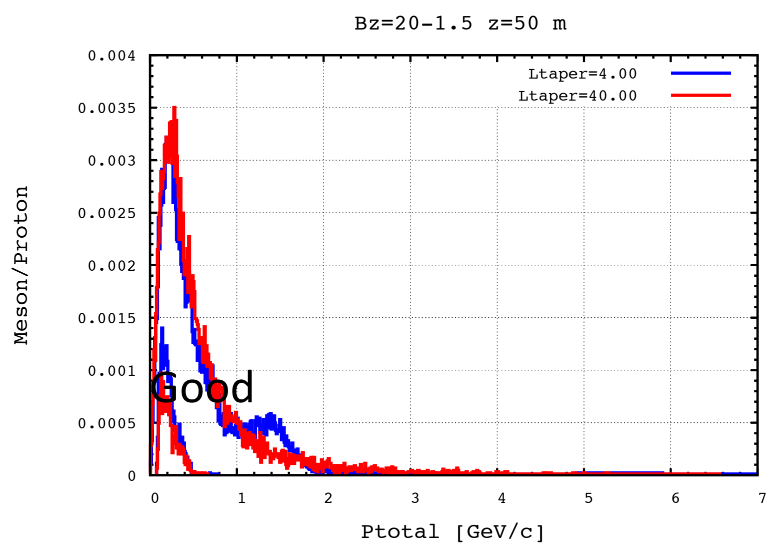
END DECAY CHANNEL

Phase Space Distributions (Short versus long taper)

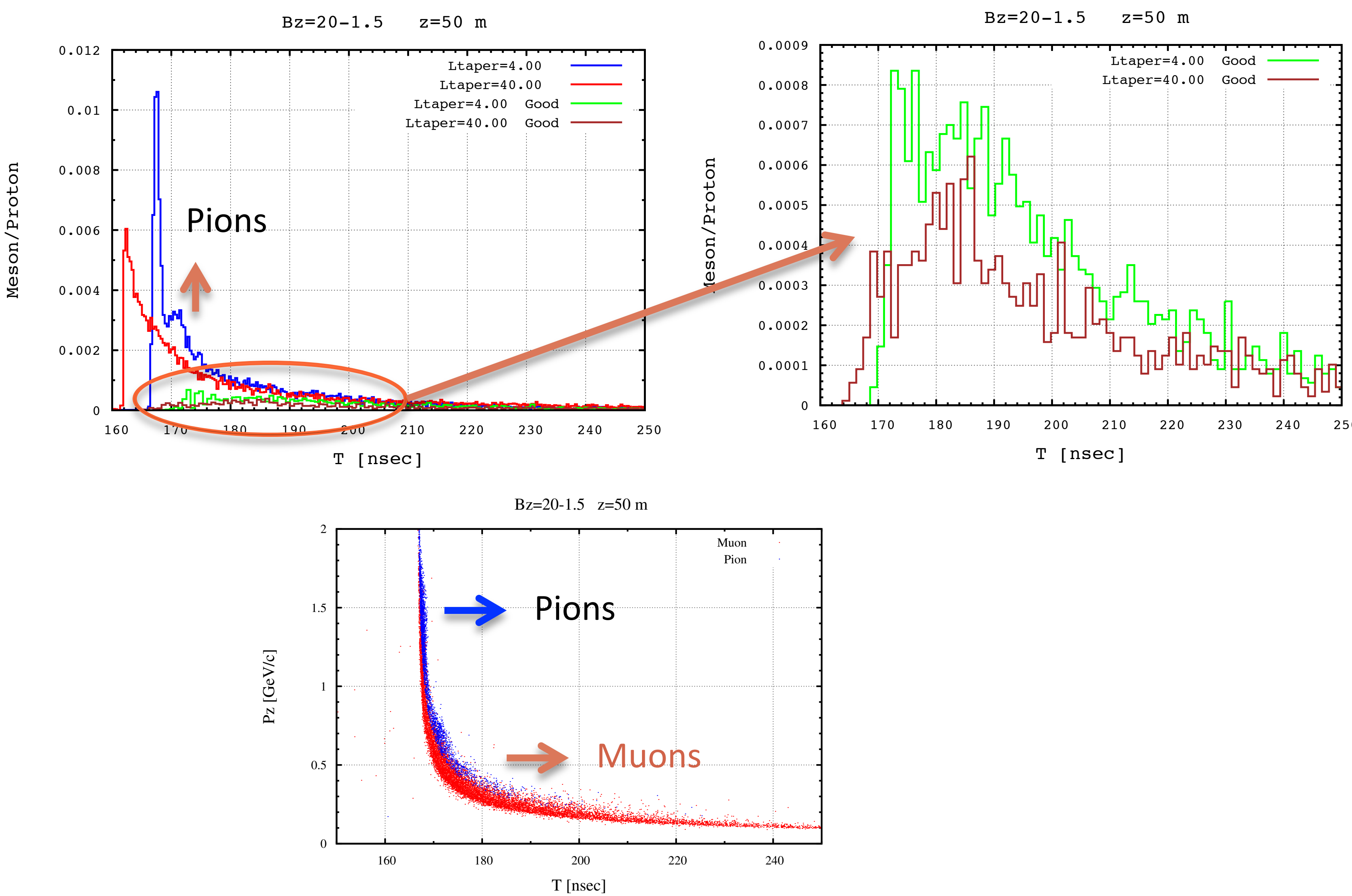








PHASE SPACE DISTRIBUTIONS (SHORT VERSUS LONG TAPER)



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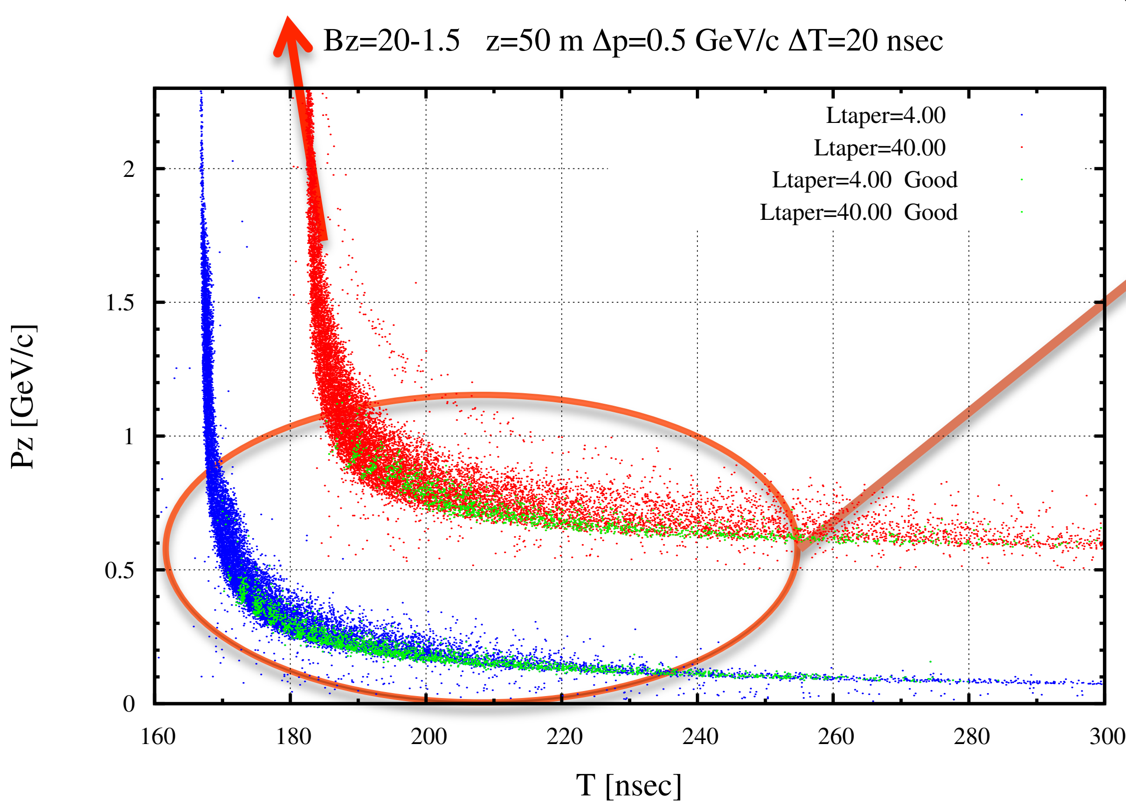
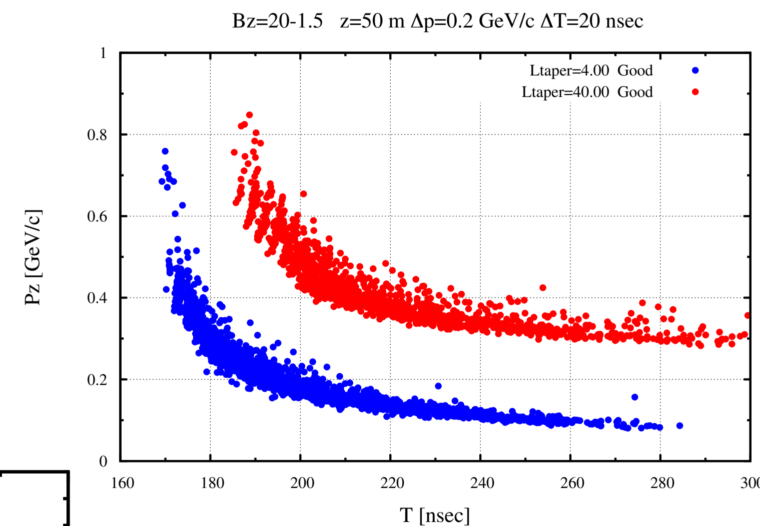
Phase Space Distributions (Short versus long taper)

- Shorter taper produces "dense-slim" Pz-T distribution that fits more muons within the "Good particle" windows

- ΔT=20 nsec
  ΔPz=0.5 GeV/c





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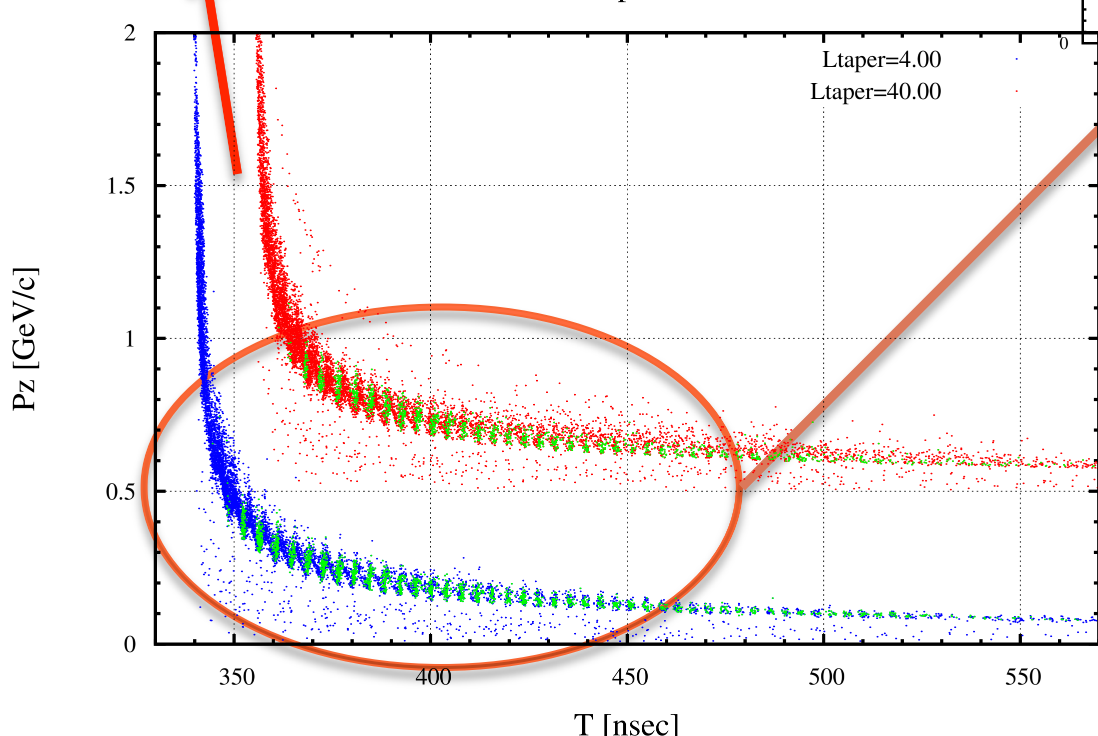

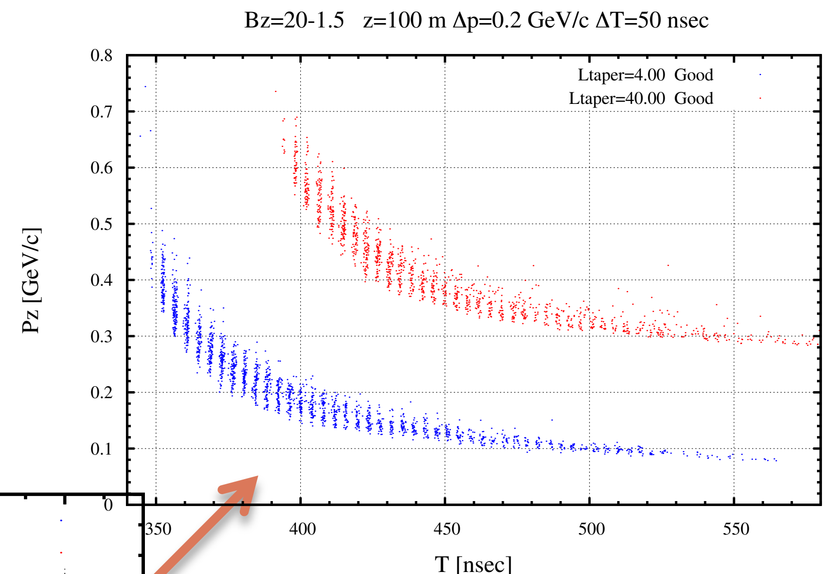

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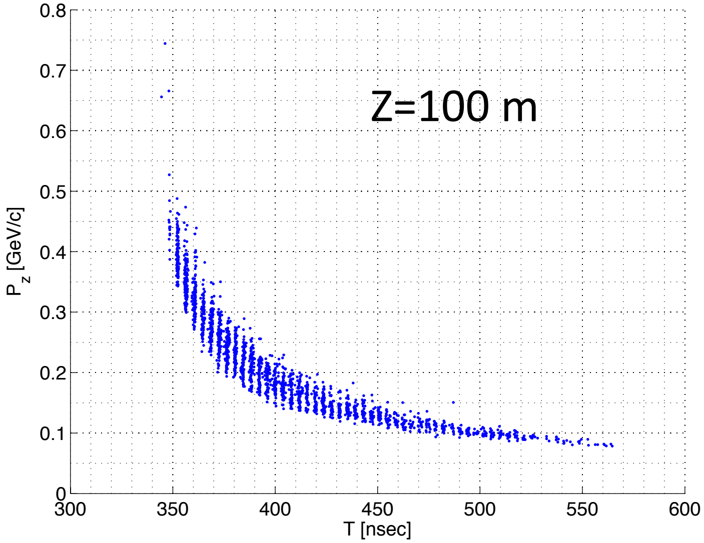

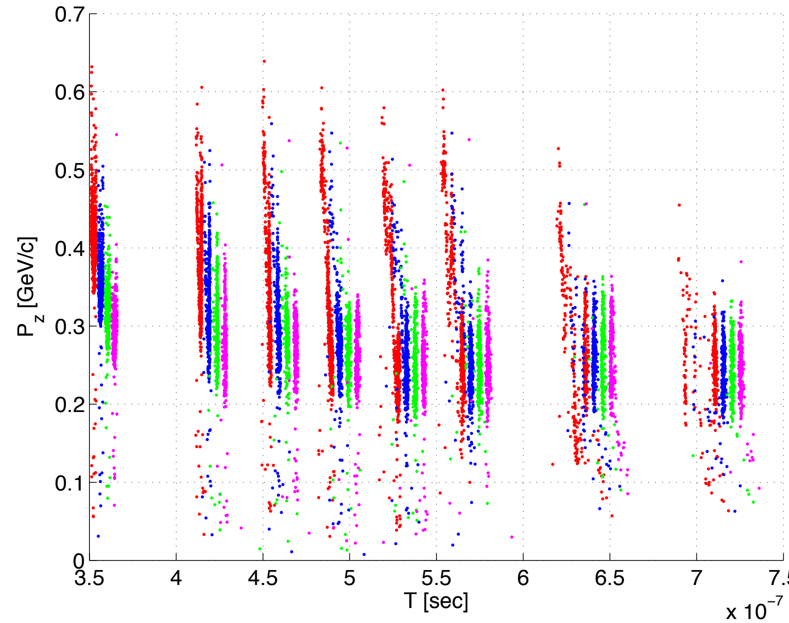

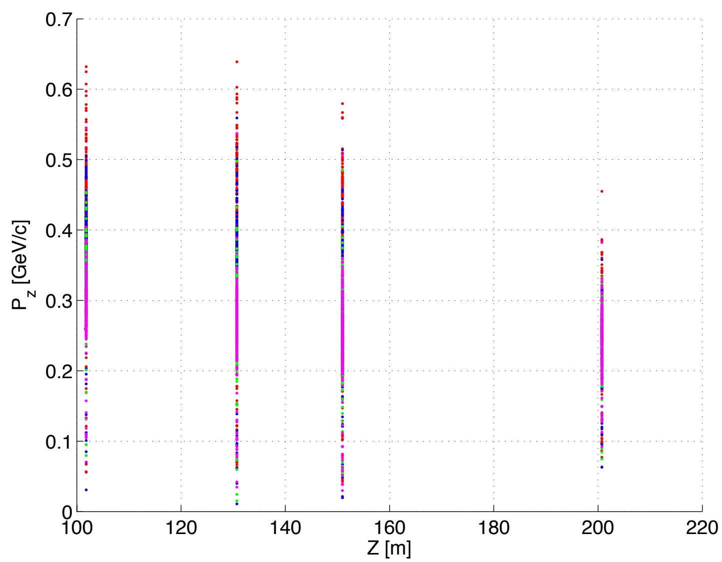

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Conclusion & Summary

- 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.
- Longer cooling channel is required to reach maximum cooling.
- Pz-T correlation influence the efficiency of front end performance.
- Shorter taper produces "dense-slim" Pz-T distribution that fits more muons within the "Good particle" windows