Pion and Muon Yields

John Back

University of Warwick, UK

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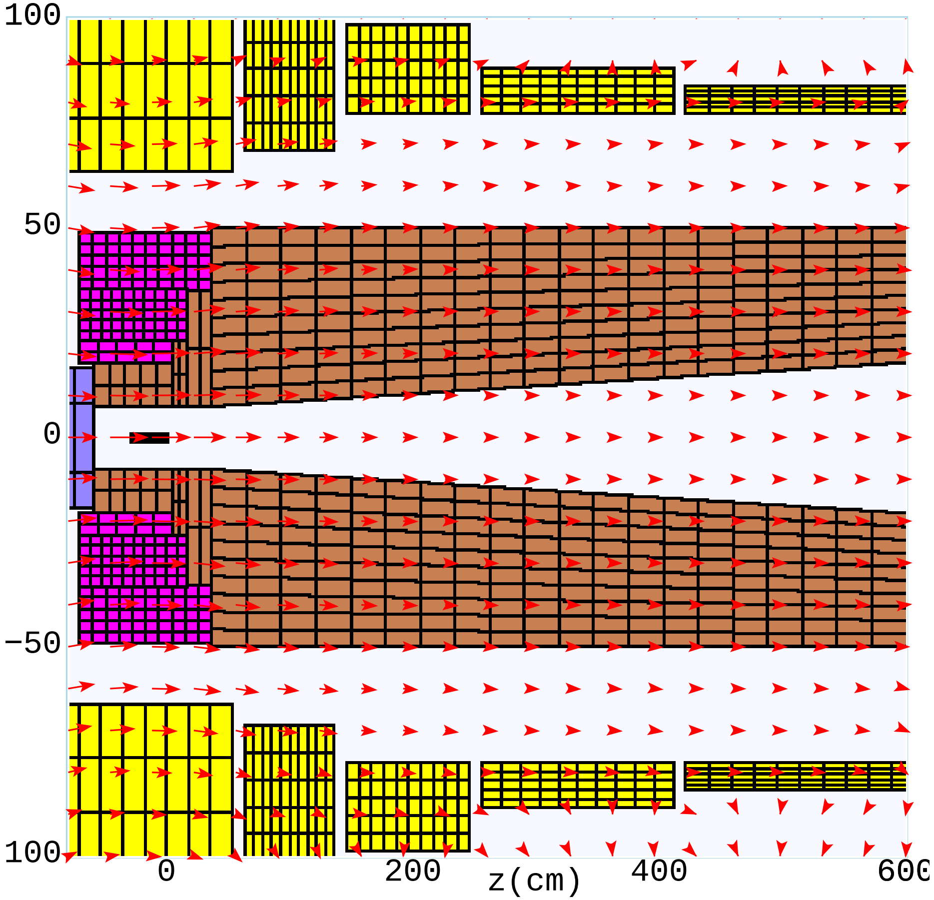
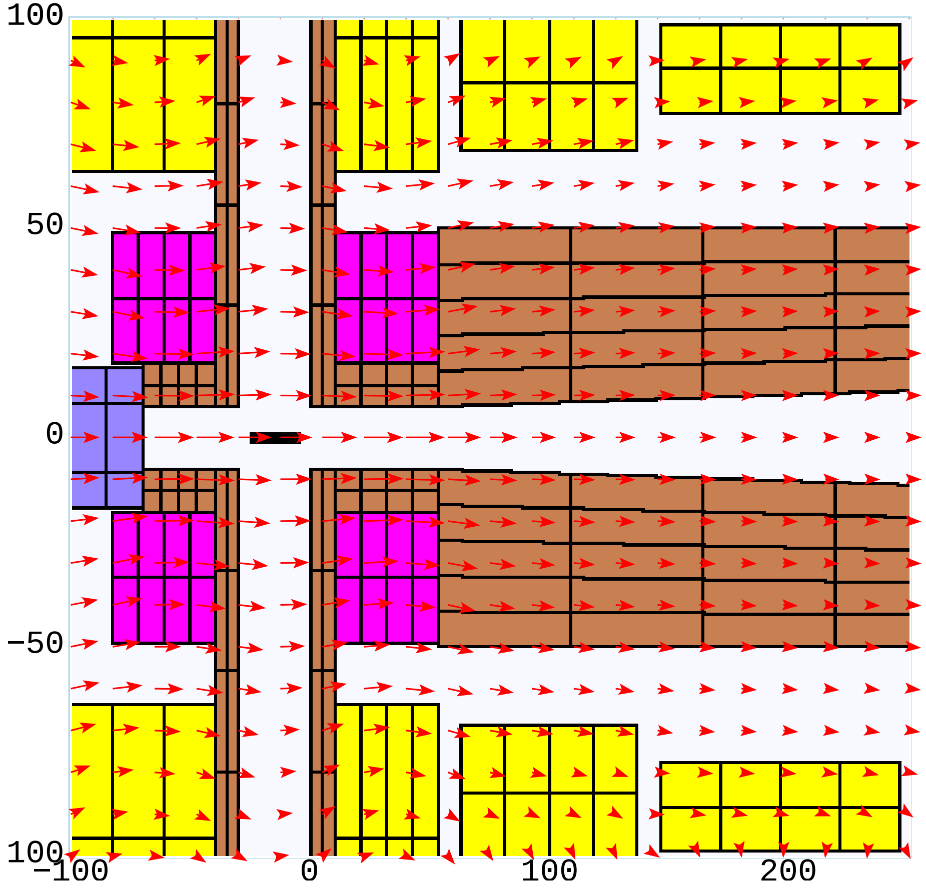
Introduction

- Using MARS (v15.07) and Study-II geometry to find pion & muon yields for solid tungsten target and tungsten powder jet (50% ρ)
- 10 GeV parabolic proton beam in 20 T field region
- Solid target is a cylindrical rod. Vary:
  - Rod length: 15, 20, 25 and 30 cm
  - Rod radius: 0.25, 0.50, 0.75, 1.00, 1.50 cm; $r_{\rm beam} = r_{\rm rod}$
  - Rod tilt (θ): 0, 20, 50, 100, 150, 200, 250, 300 mr; $\theta_{\rm beam} = \theta_{\rm rod}$
- Use ICOOL (v3.10) to calculate final muon acceptance
- Comparing solid target with Hg jet: $\theta_{\rm beam} = 67$ mr, $\theta_{\rm Hg} = 100$ mr, $r_{\rm beam} = 0.15$ cm, $r_{\rm Hg} = 0.50$ cm (input files courtesy H. Kirk)

Target Geometry: $(\boldsymbol{z},\boldsymbol{x})$ plane



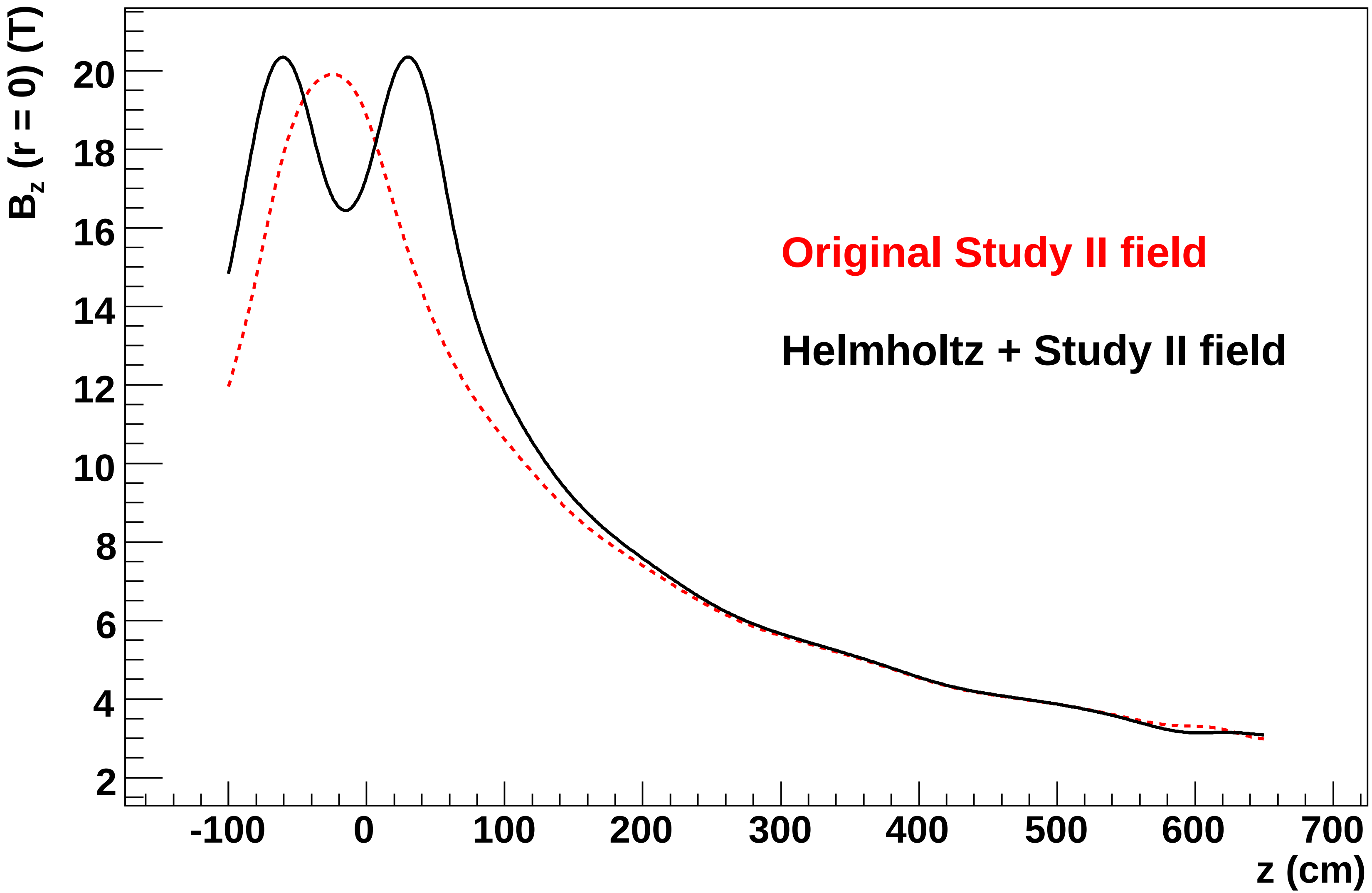
StudyII



Helmholtz (zoom in); 10 cm shielding on both sides of gap

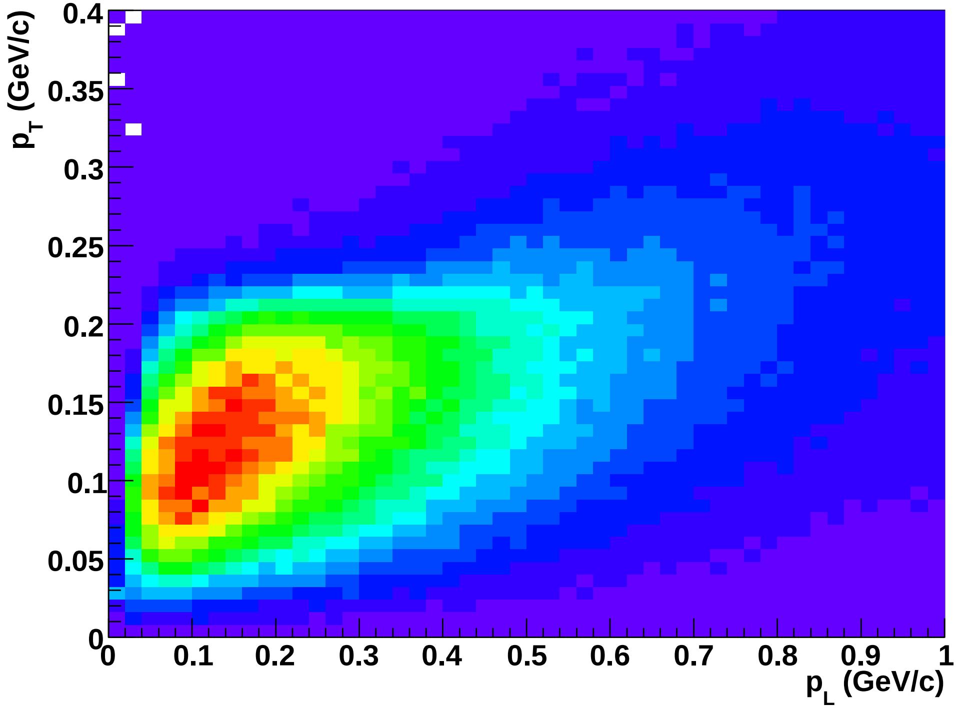
Colour scheme: Target rod (black), $\underline{B}$ field lines (red), Cu coils (magenta), SC magnets (yellow), shielding (brown), iron plug (purple).

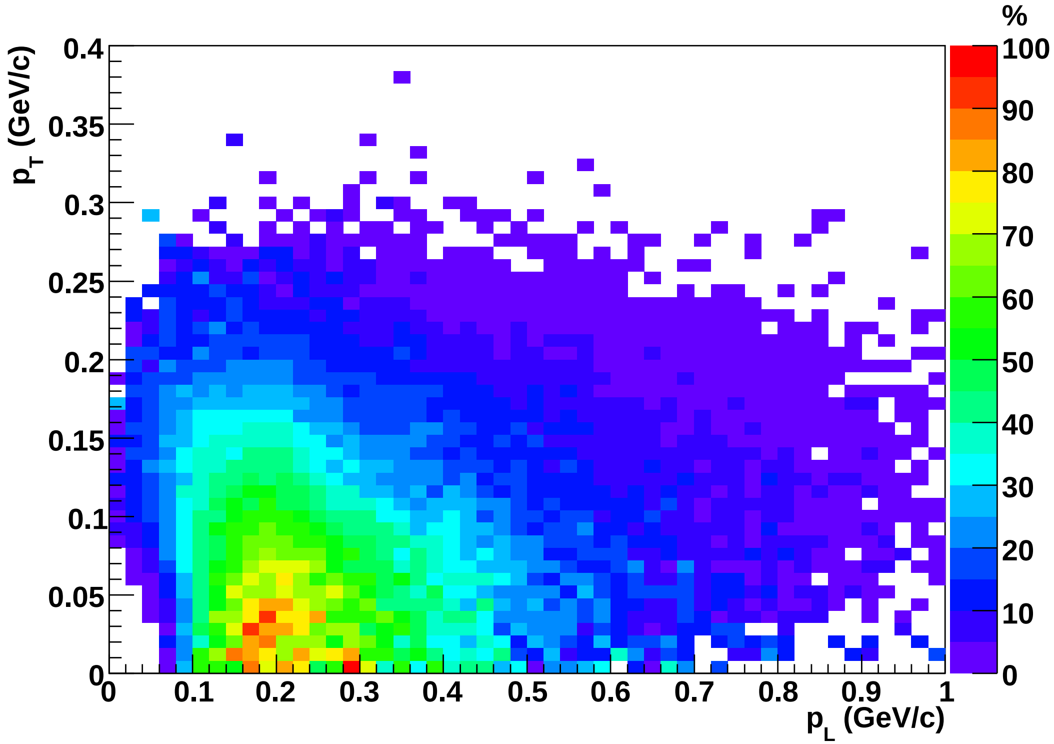
On-axis $\boldsymbol{B_z}$ field



Current density in Cu coils: <Study II> $= 20\,\mathrm{A\,mm^{-2}}$, Helmholtz $= 30\,\mathrm{A\,mm^{-2}}$

Probability acceptance map





Initial π momentum distribution

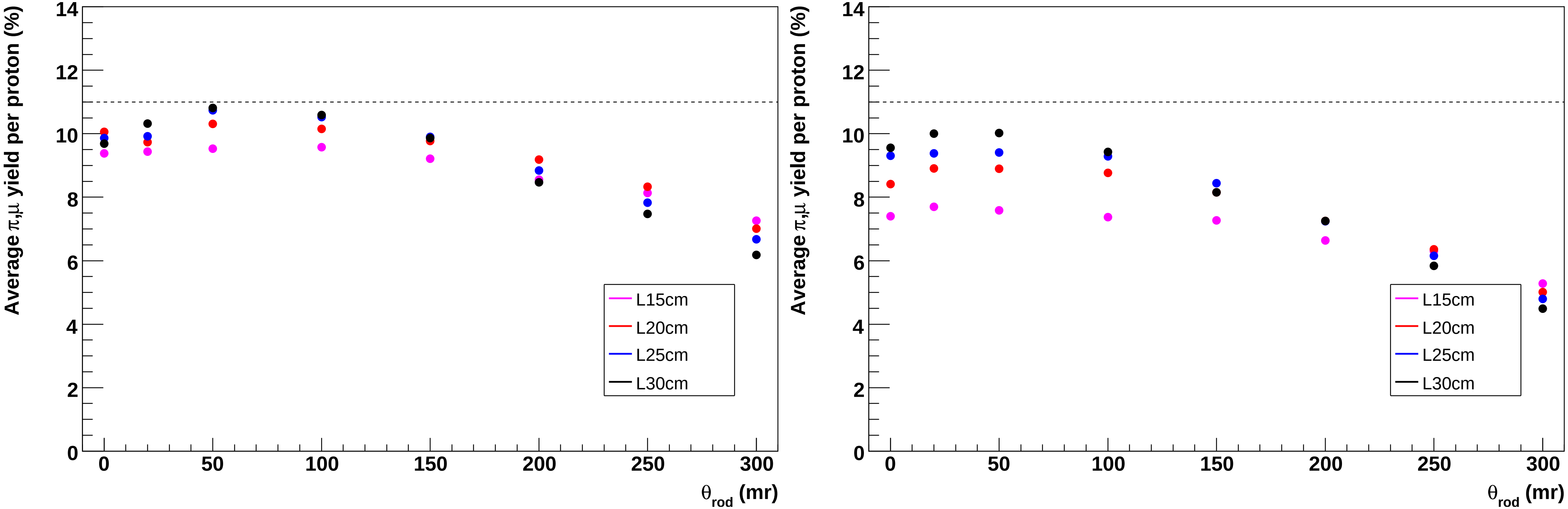
from MARS ($z = 0\,\mathrm{m}$)

Probability of π from target going through cooling channel:

$$\mathcal{P} = \frac{\Sigma_i w_i(\mathrm{pass})}{\Sigma_i w_i}, \;\; w_i = \mathrm{weight}$$

ICOOL files: ISS machine working group website

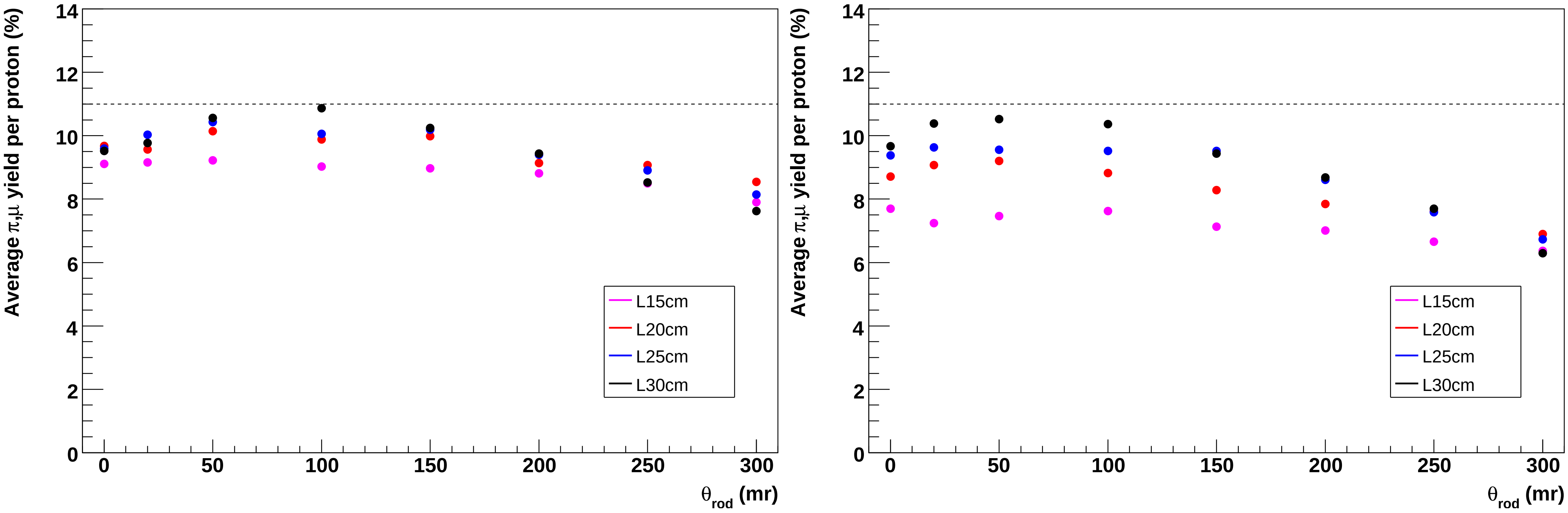
Charge averaged π, μ accepted yield per proton for $r_{\mathrm{beam}} = 0.25\,\mathrm{cm}$



Solid target (Helmholtz) Powder jet 50%ρ (Original geom)

Dotted line is Hg jet yield for 10 GeV beam (using StudyII optimal tilt, radii)

Charge averaged π, μ accepted yield per proton for $r_{\text{beam}} = 0.50\,\text{cm}$

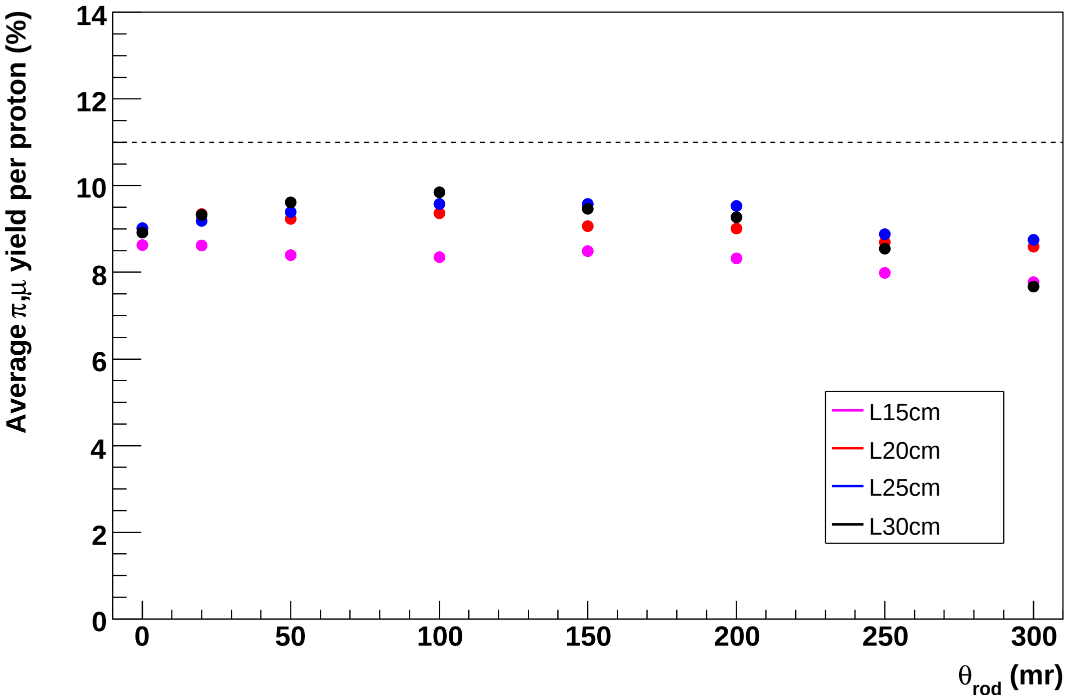


Solid target (Helmholtz)

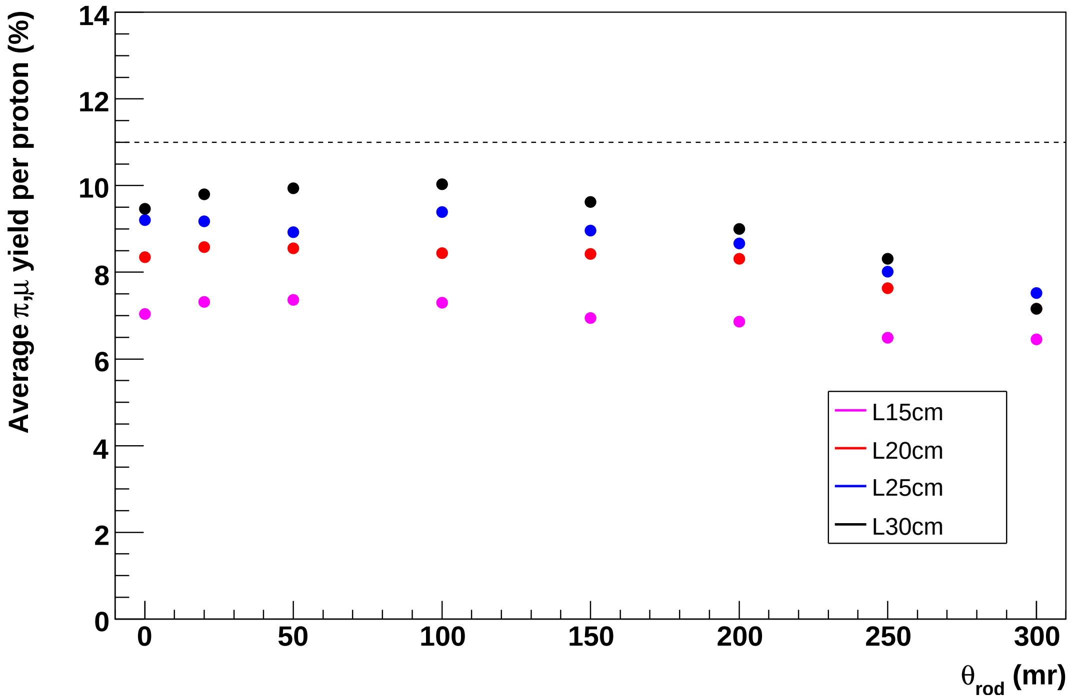
Powder jet 50%ρ (Original geom)

Dotted line is Hg jet yield for 10 GeV beam (using StudyII optimal tilt, radii)

Charge averaged π, μ accepted yield per proton for $r_{\text{beam}} = 0.75\,\text{cm}$



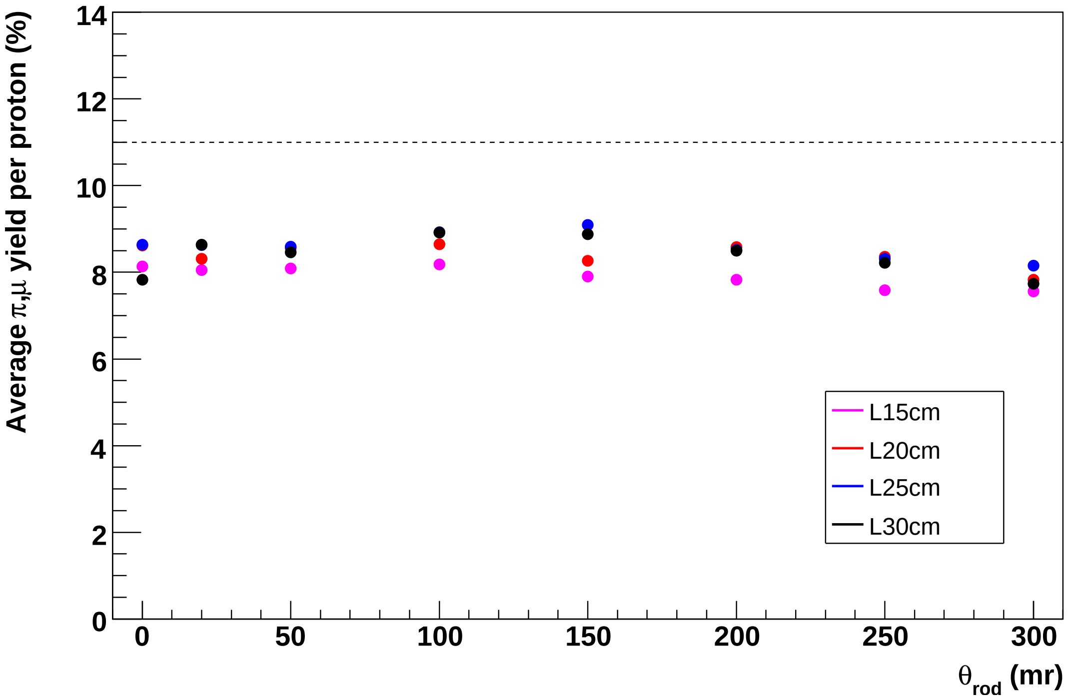
Solid target (Helmholtz)



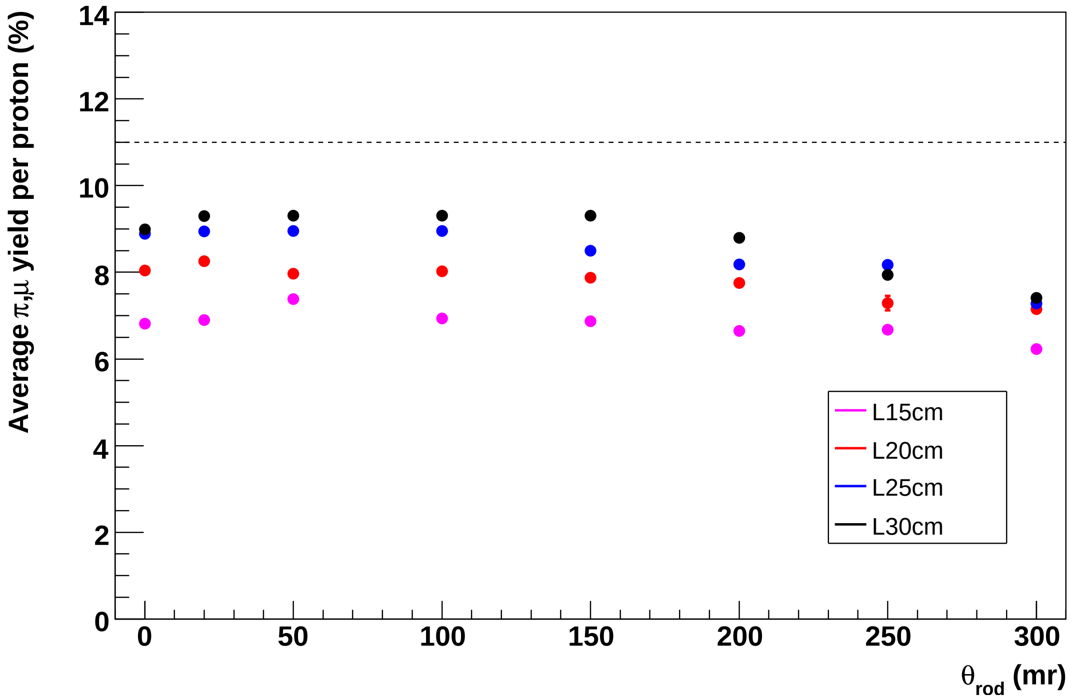
Powder jet 50%ρ (Original geom)

Dotted line is Hg jet yield for 10 GeV beam (using StudyII optimal tilt, radii)

Charge averaged π, μ accepted yield per proton for $r_{\rm beam} = 1\,{\rm cm}$



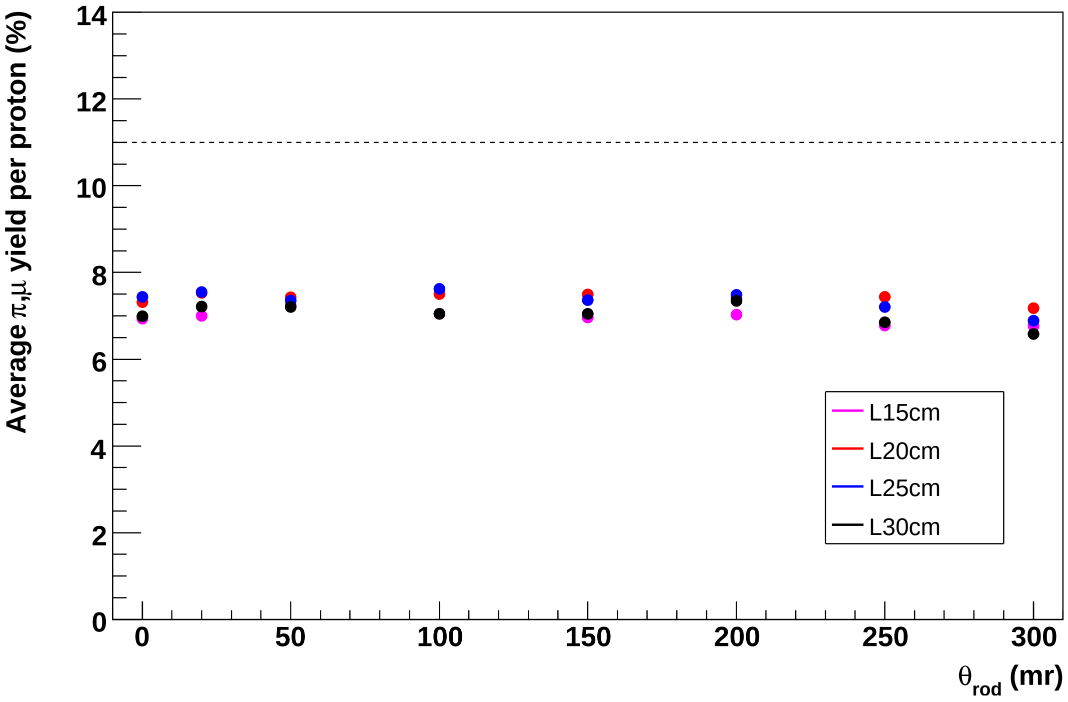
Solid target (Helmholtz)



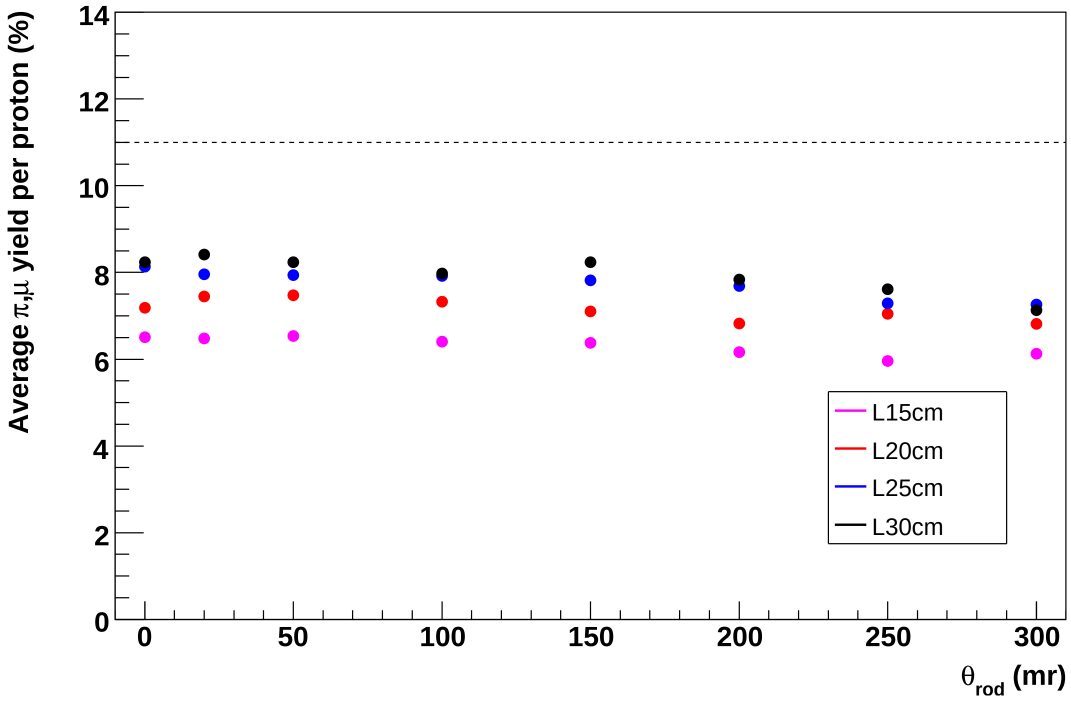
Powder jet 50%ρ (Original geom)

Dotted line is Hg jet yield for 10 GeV beam (using StudyII optimal tilt, radii)

Charge averaged π, μ accepted yield per proton for $r_{\mathrm{beam}} = 1.5\,\mathrm{cm}$



Solid target (Helmholtz)



Powder jet 50%ρ (Original geom)

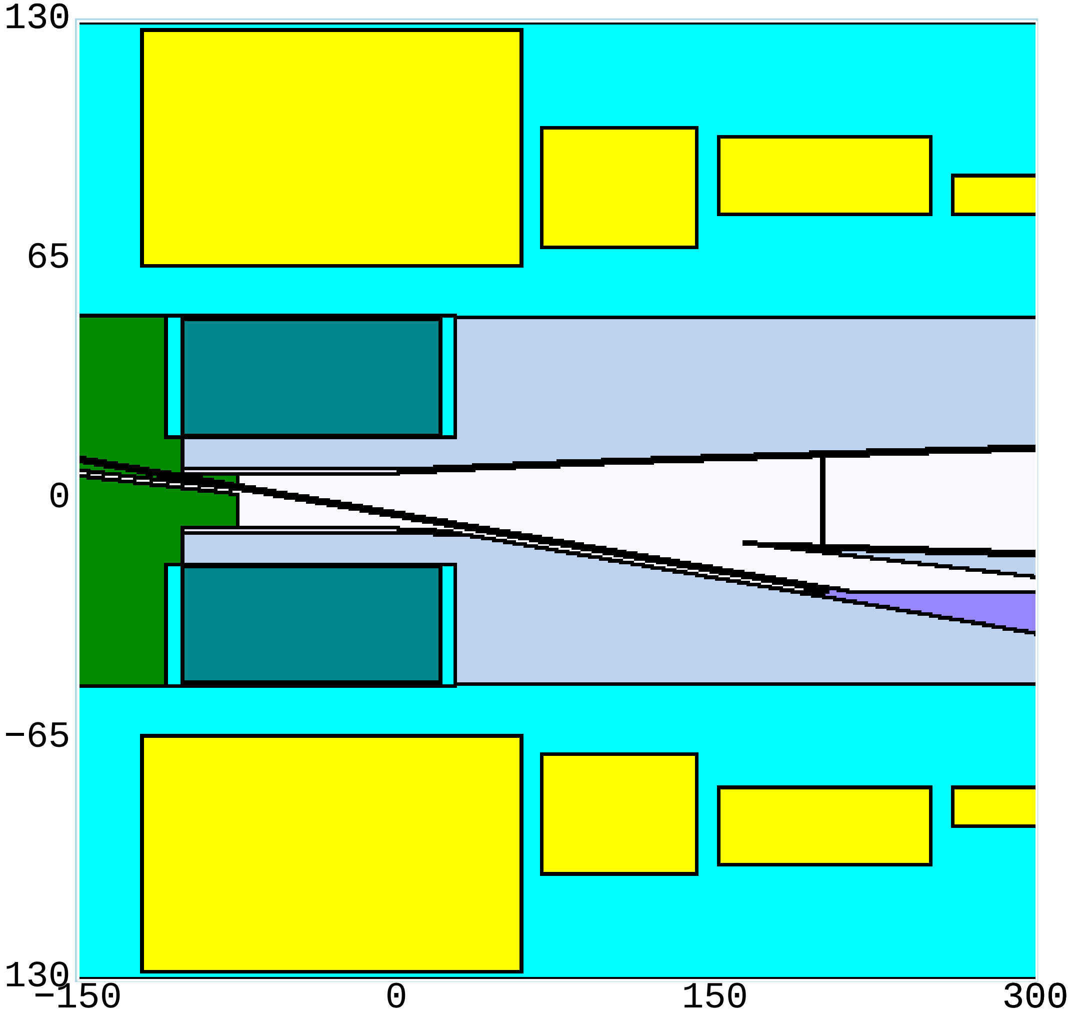
Dotted line is Hg jet yield for 10 GeV beam (using StudyII optimal tilt, radii)

Pion absorption - solid target

- Compare π yields from one rod (Y_0) with yields (Y) from 3 rods or a toroid to estimate target re-absorption: lost fraction, $f_{\rm lost} = (Y_0 - Y)/Y_0$
  - Solid tungsten target rod length $L = 30\,{\rm cm}$ ($\theta_{\rm rod} = \theta_1$)
  - 3 rod case: $L = 30\,{\rm cm}$, gap between rods $= 10\,{\rm cm}$ ($\theta_{\rm rod} = \theta_3$)
  - Horizontal toroid: radius of curvature $= 5\,{\rm m}$. Effective length $L_z \approx 1\,{\rm m}$
  - 10 GeV parabolic proton beam, $\theta_{\rm beam} = 67\,{\rm mr}$

$r_{\rm rod}$	$r_{\rm beam}$	3 rods $f_{\rm lost}$ ($\theta_1 = \theta_3 = 0$)	toroid $f_{\rm lost}$ ($\theta_1 = 0$)	3 rods $f_{\rm lost}$ ($\theta_1 = \theta_3 = 100\,{\rm mr}$)
0.5 cm	0.5 cm	39%	23%	7%
1 cm	1 cm	57%	47%	15%
1 cm	1.5 cm	53%	53%	11%

Pion absorption - Hg jet



Consider Hg jet vapour inside target aperture up to $z = 2\,\mathrm{m}$ (Be window)

$$\rho_{\mathrm{vapour}} = \rho_{\mathrm{He}} \times (0.1\mathrm{bar}/1\mathrm{atm}) + w \times \rho_{\mathrm{Hg}}$$

$$w = V_1/V_2$$

V_1 = volume of Hg jet
V_2 = volume inside aperture ($z \leq 2\,\mathrm{m}$)

Consider two jet volumes:
Whole jet $z < 2\,\mathrm{m}$ (A) and effective jet-beam overlap length of $30\,\mathrm{cm}$ (B)

Jet volume	w	f_{lost}
Case A: $z < 2\,\mathrm{m}$	0.3%	5%
Case B: $L = 30\,\mathrm{cm}$	0.03%	1%

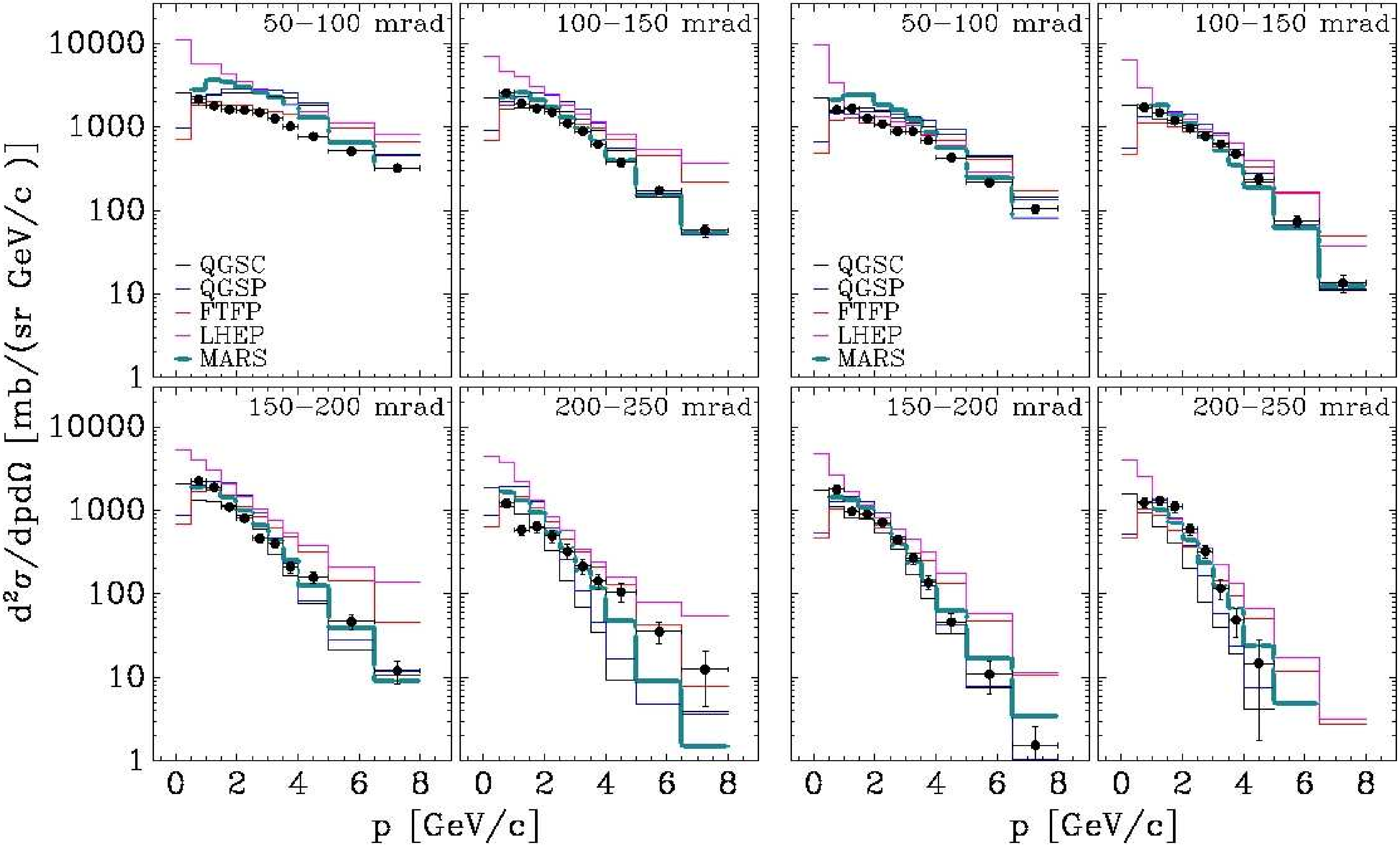
Summary

- Presented π, μ yields for solid and powder (50% ρ) W targets; $E_p = 10\,\text{GeV}$
- Solid W yields comparable (lower) than optimal Hg yield for $r_{\text{rod}} < 0.75\,\text{cm}$ ($r_{\text{rod}} > 0.75\,\text{cm}$)
- Powdered jet yields comparable to solid target yields
  - Reduced π production, but also reduced re-absorption in the target
- Overall optimal W target tilt (= beam tilt) is approximately 100 mr
- Overall optimal solid target length is $\geq 25\,\text{cm}$ (≥ 2.6 interaction lengths)
- Cross-checking results with Geant 4
  - MARS pion production calculations agree rather well with experimental data
  - Need to check that MARS absorption calculations also agree with data

Extra material

- Pages 15-17 show comparison of Monte Carlo simulation models with HARP data
  - Plots courtesy of G. Skoro (University of Sheffield, UK)
- Pages 18-22 show comparison of the solid target yields between the standard Study-II geometry and the Helmholtz gap geometry (shown earlier)

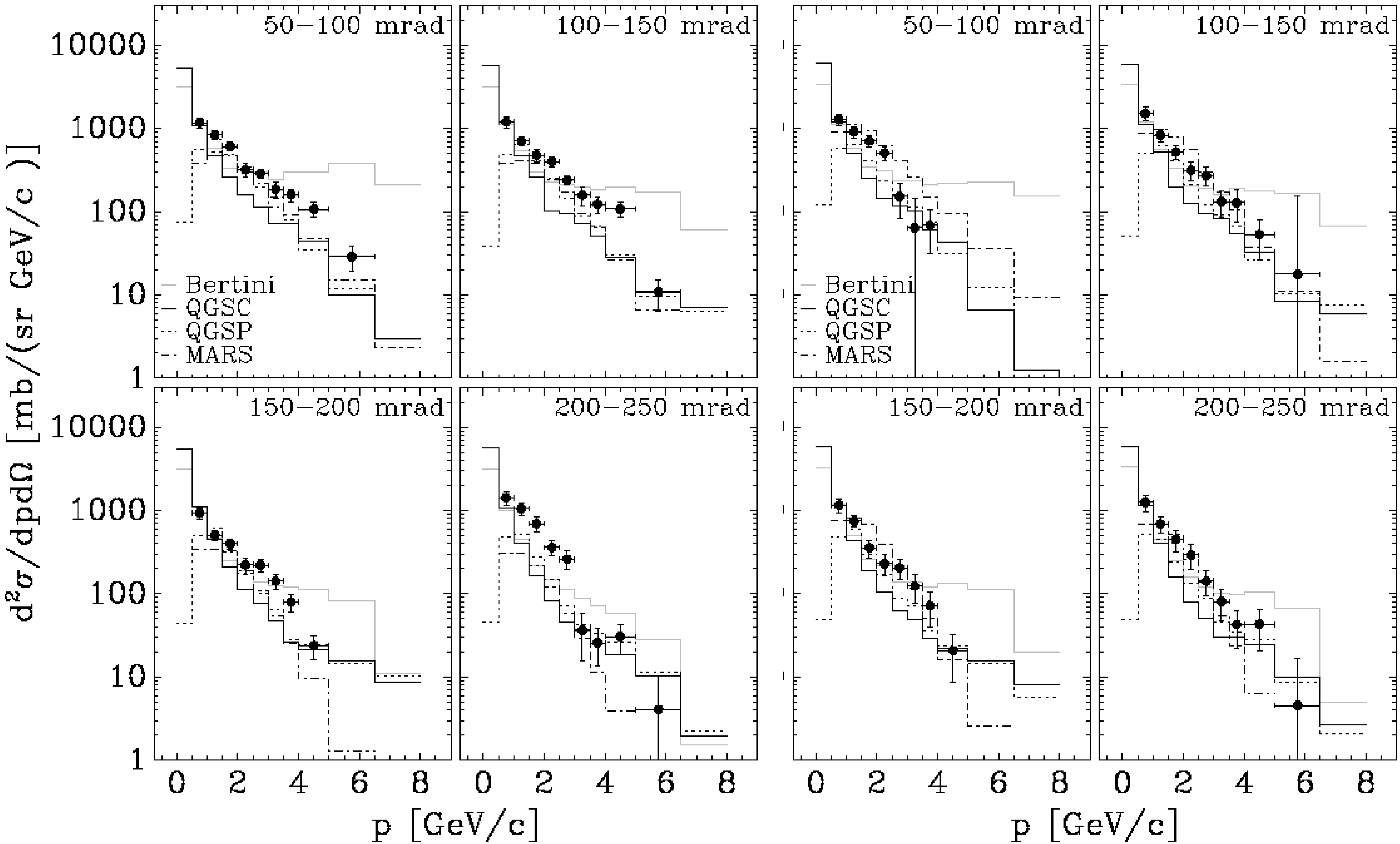
HARP data for 12 GeV/c $\pi^{\pm}$ beam producing secondary $\pi^{\pm}$ in Ta target (5%λ_I)



π^- beam

π^+ beam

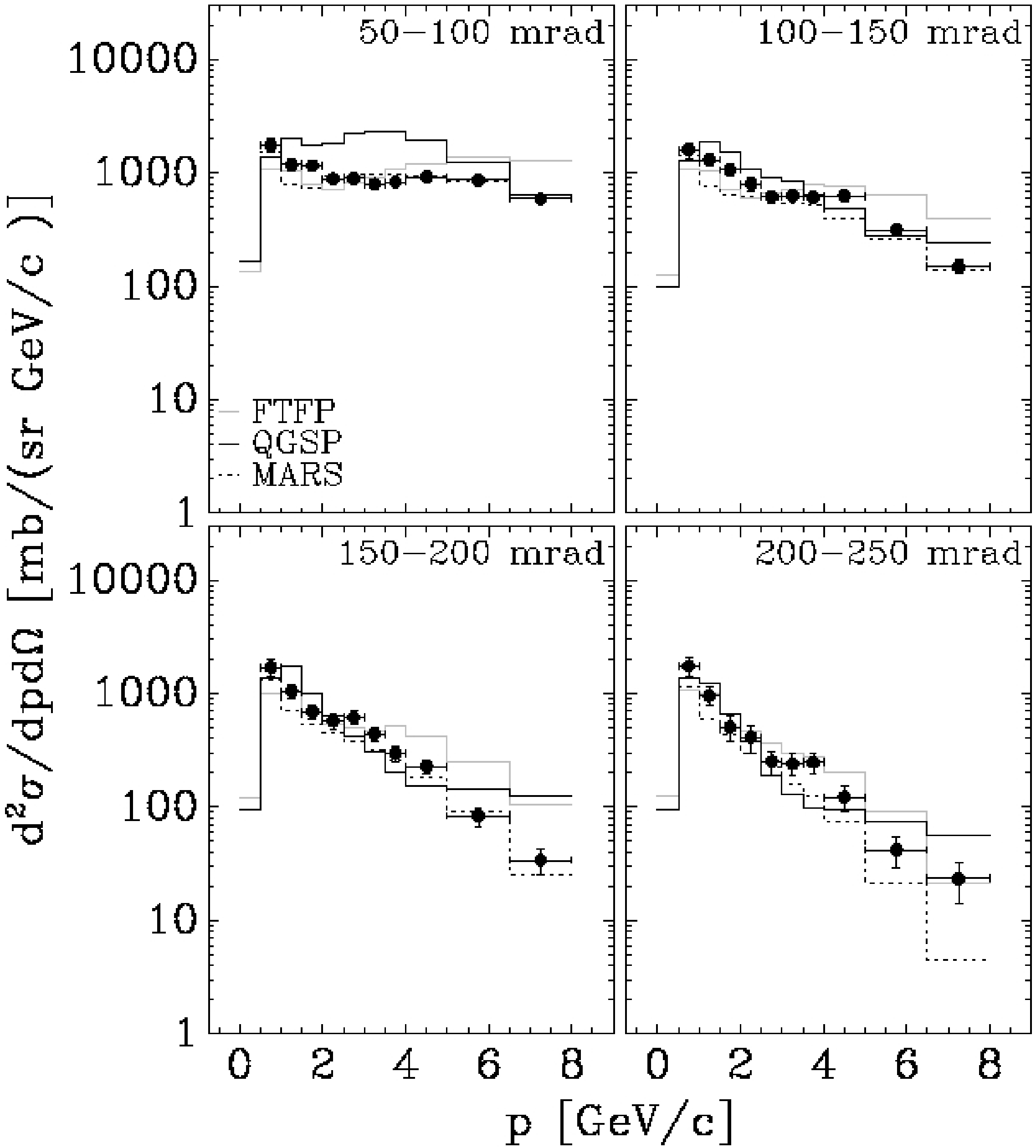
HARP data for 8 GeV/c $\pi^{\pm}$ beam producing secondary p in Ta target (5%λ_I)



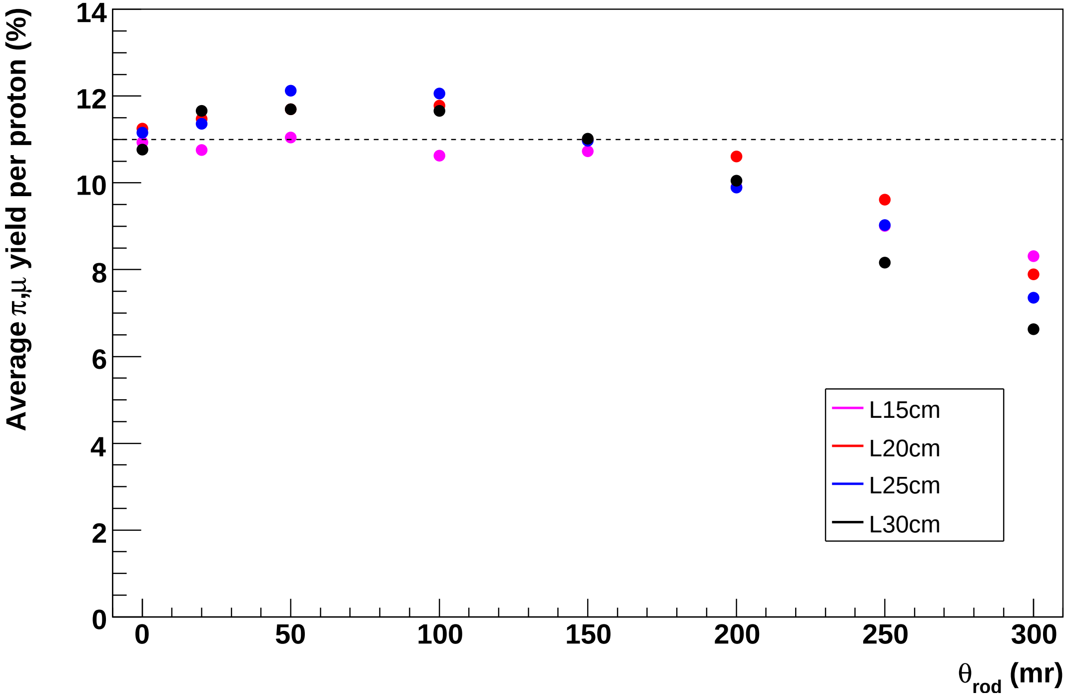
π^- beam

π^+ beam

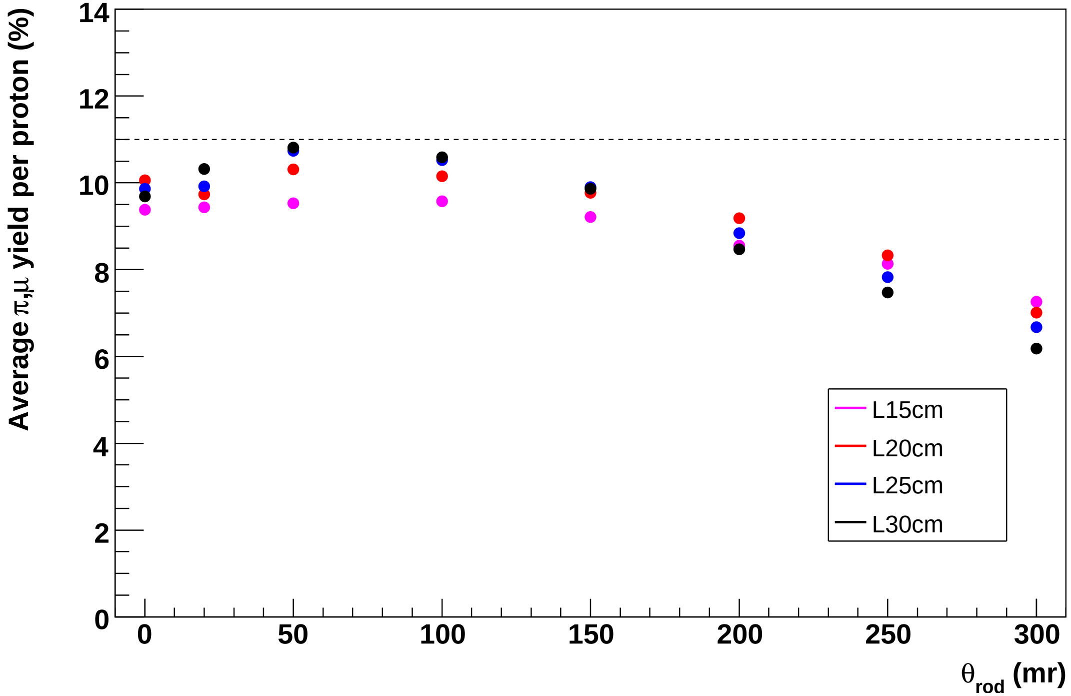
HARP data for 12 GeV/c p beam producing secondary p in Ta target (5%λ_I)



Charge averaged π, μ accepted yield per proton for $r_{\text{beam}} = 0.25\,\text{cm}$



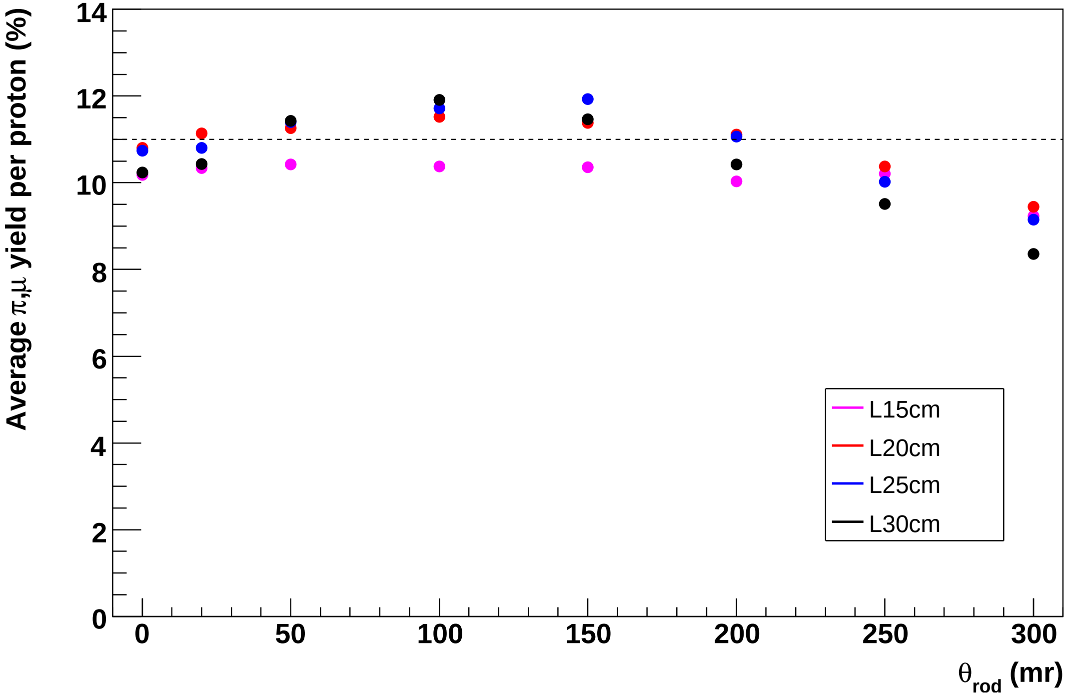
Solid target (Original geom)



Solid target (Helmholtz geom)

Dotted line is Hg jet yield for 10 GeV beam (using StudyII optimal tilt, radii)

Charge averaged π, μ accepted yield per proton for $r_{\text{beam}} = 0.50\,\text{cm}$



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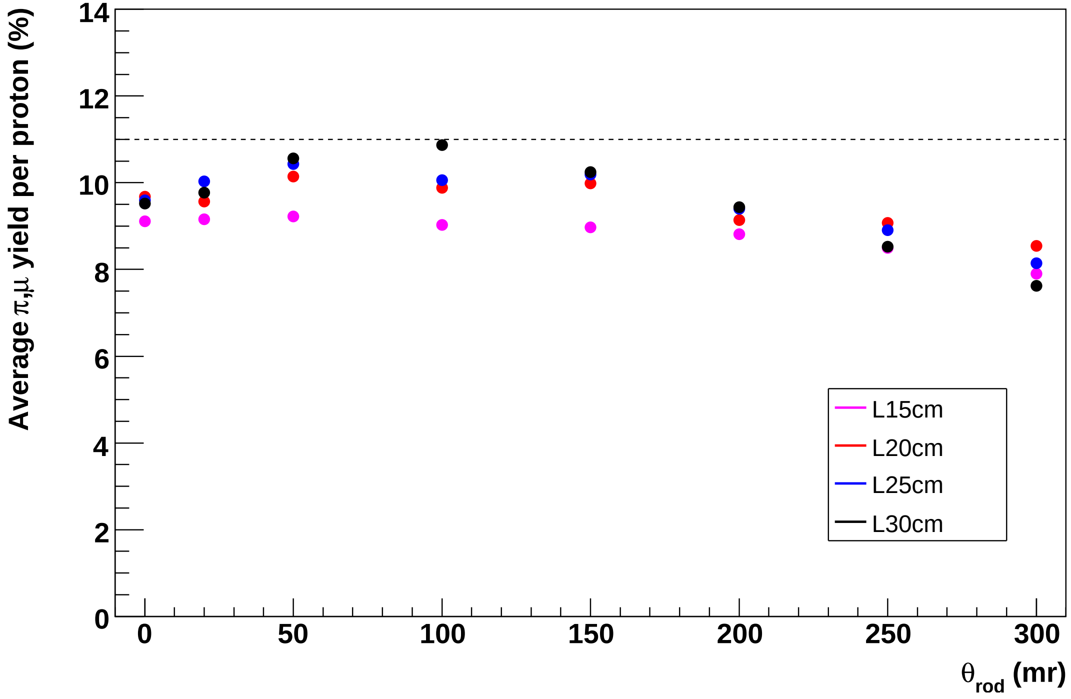

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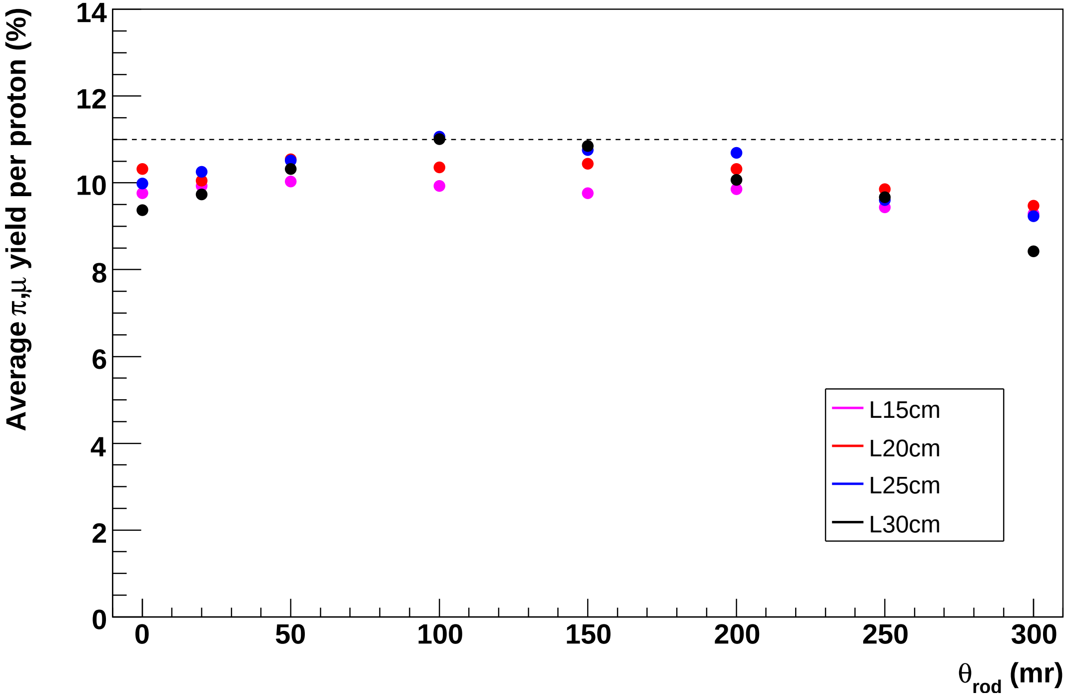
Charge averaged π, μ accepted yield per proton for $r_{\text{beam}} = 0.75\,\text{cm}$



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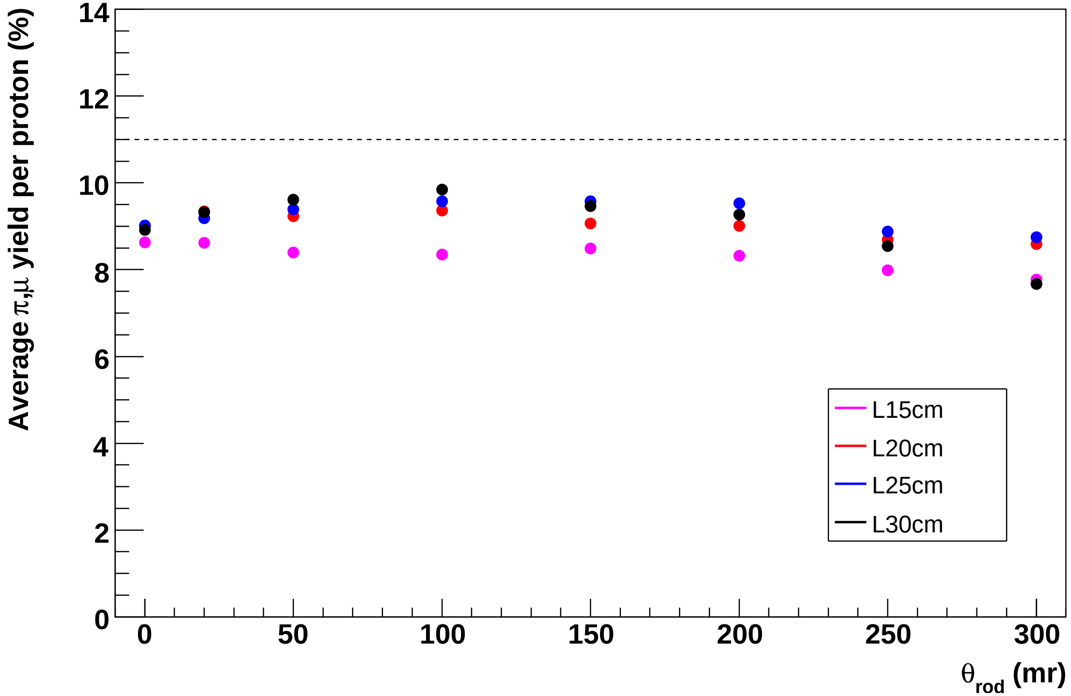

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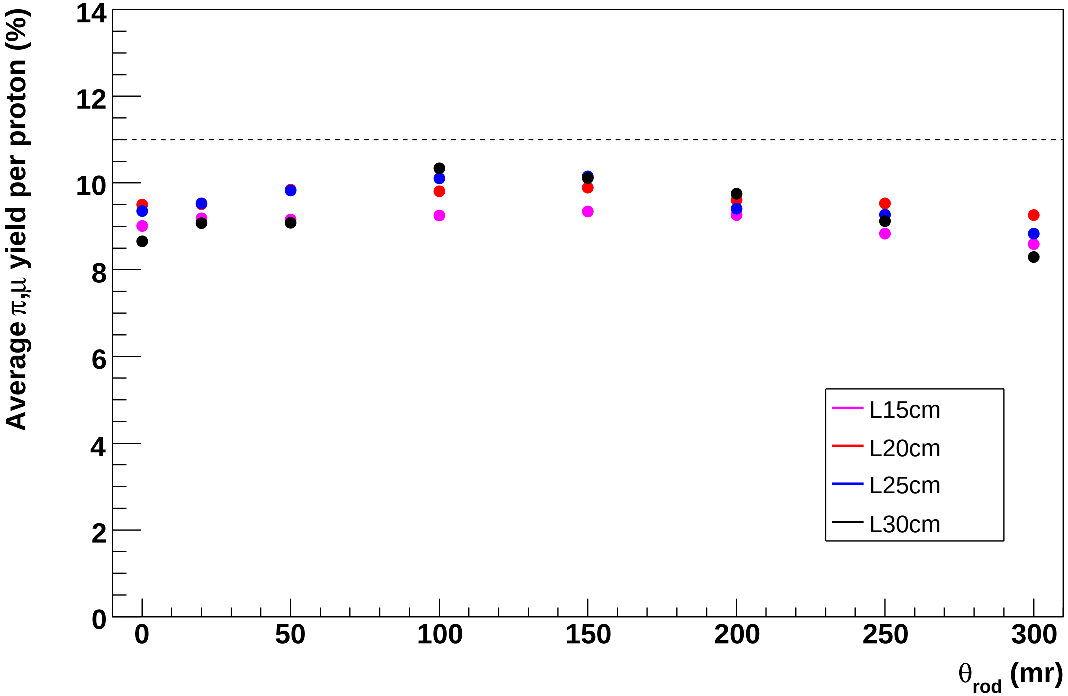
Charge averaged π, μ accepted yield per proton for $r_{\mathrm{beam}} = 1\,\mathrm{cm}$



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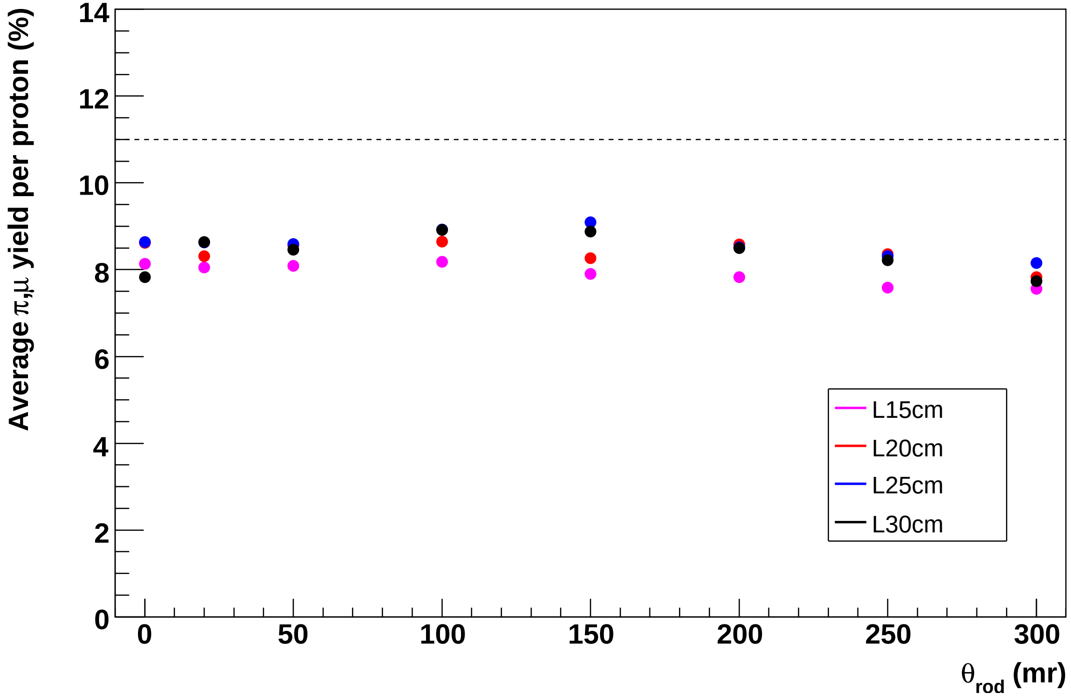

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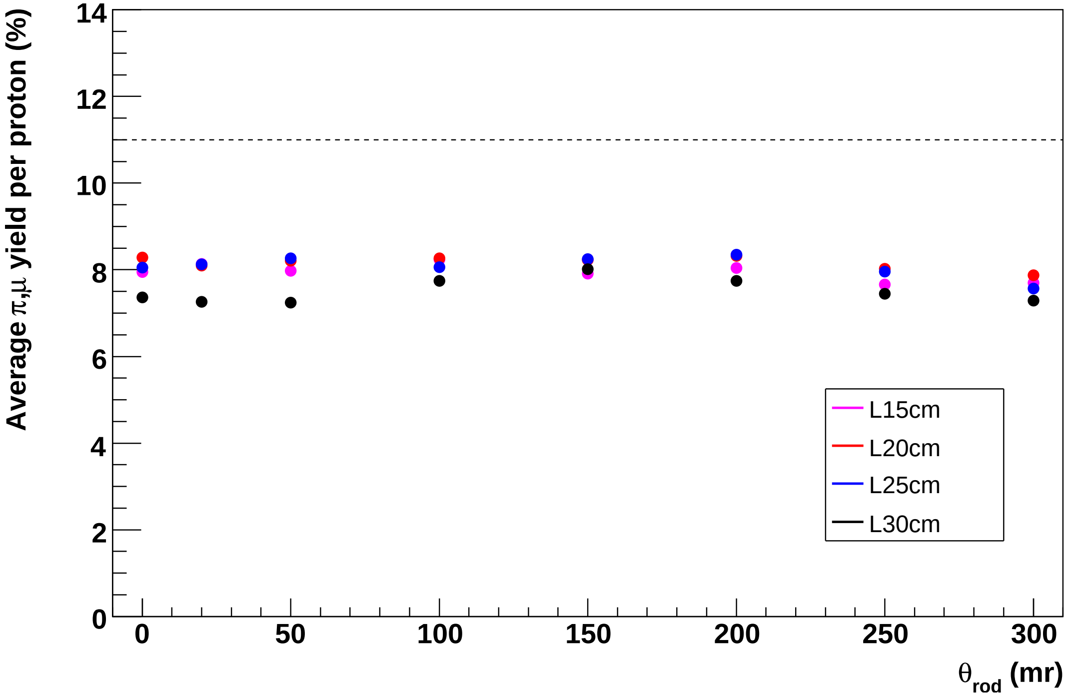

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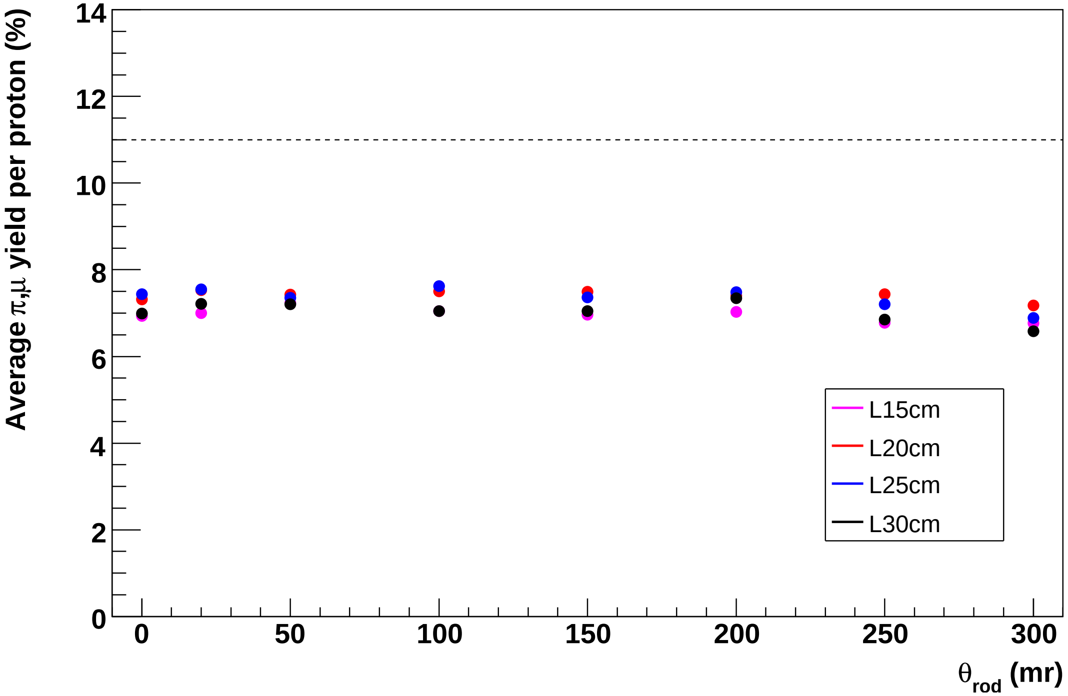

Solid target (Helmholtz geom)

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