MARS Target Yield Studies

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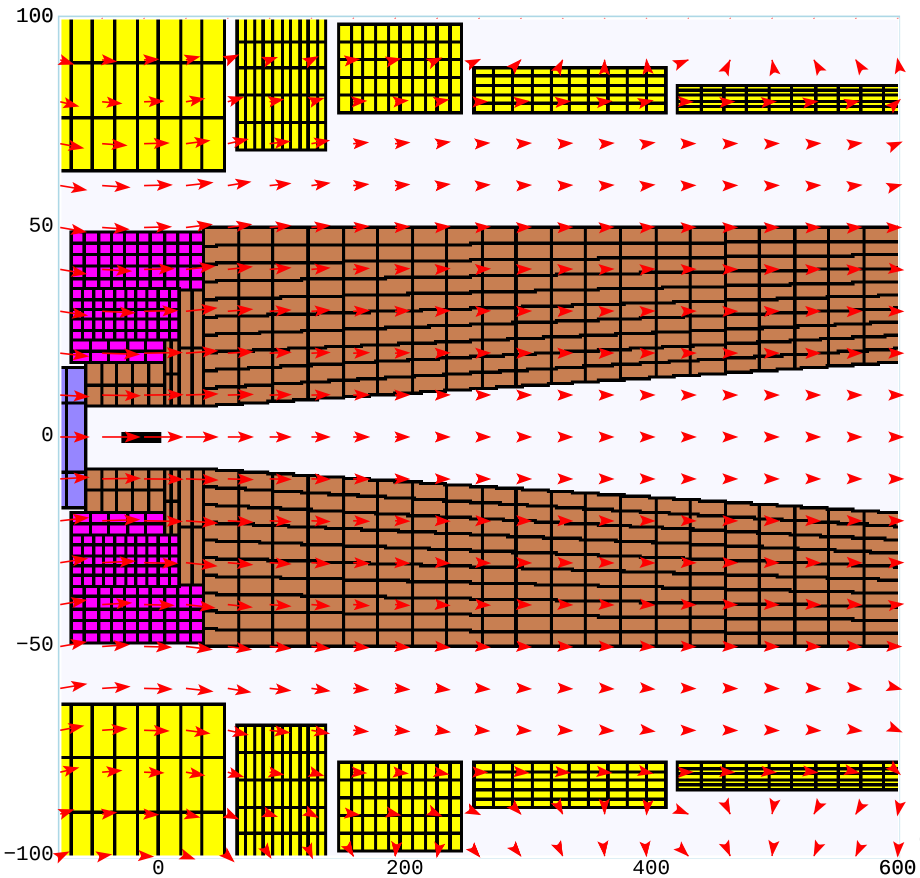
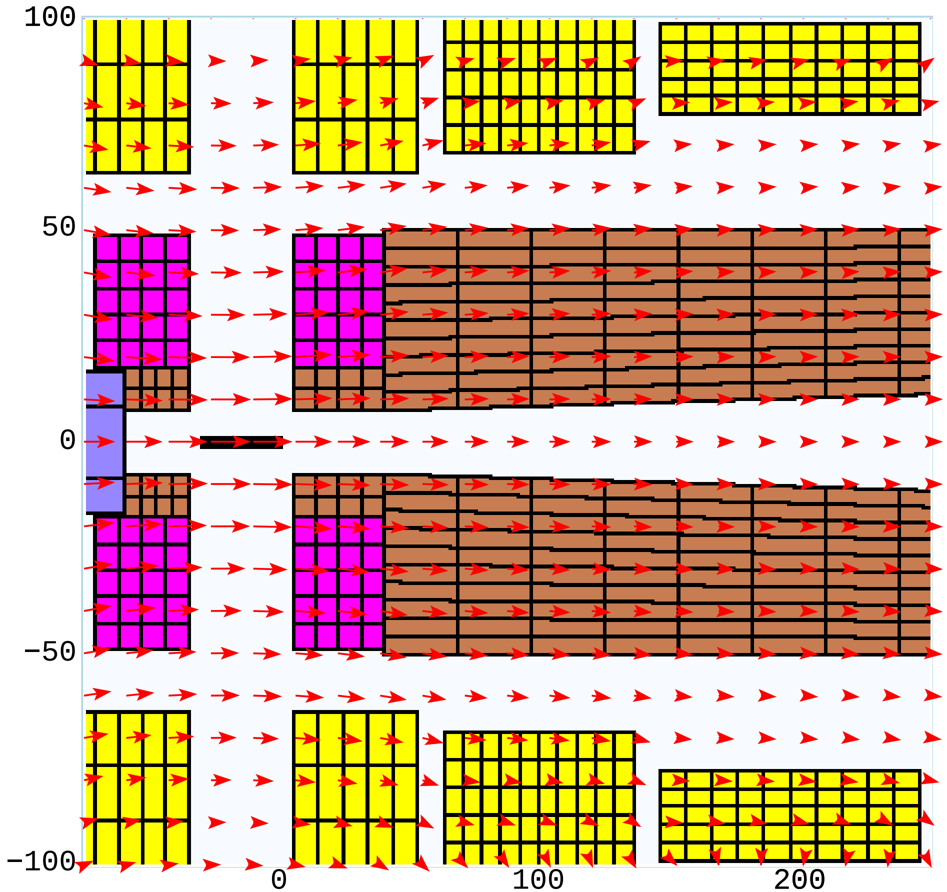
Introduction

- Using MARS (v15.07) and Study-II geometry to find pion & muon yields
- 10 GeV parabolic proton beam hitting cylindrical tungsten rod in 20 T field
  - Rod lengths: 15, 20, 25 and 30 cm
  - Rod radii: 0.25, 0.50, 0.75, 1.0, 1.5 cm; $r_{\rm beam} = r_{\rm rod}$
  - Rod tilt (θ): 0, 20, 50, 100, 150, 200, 250, 300 mr; $\theta_{\rm beam} = \theta_{\rm rod}$
- Counting number of π and μ (per proton) along different z planes within target aperture ($z \leq 6$ m) directly from MARS output
- Applying simple kinetic energy cuts to estimate particle acceptance in cooling channel: K.E. < 0.35 GeV (used for Hg yields in ISS analysis)
- Hg jet yield per proton is $17.3 \pm 0.1\%$ ($\theta_{\rm beam} = 67$ mr, $\theta_{\rm Hg} = 100$ mr). Hg jet: cylinder with L=30 cm, r=0.5 cm. Parabolic beam: r=0.15 cm.

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



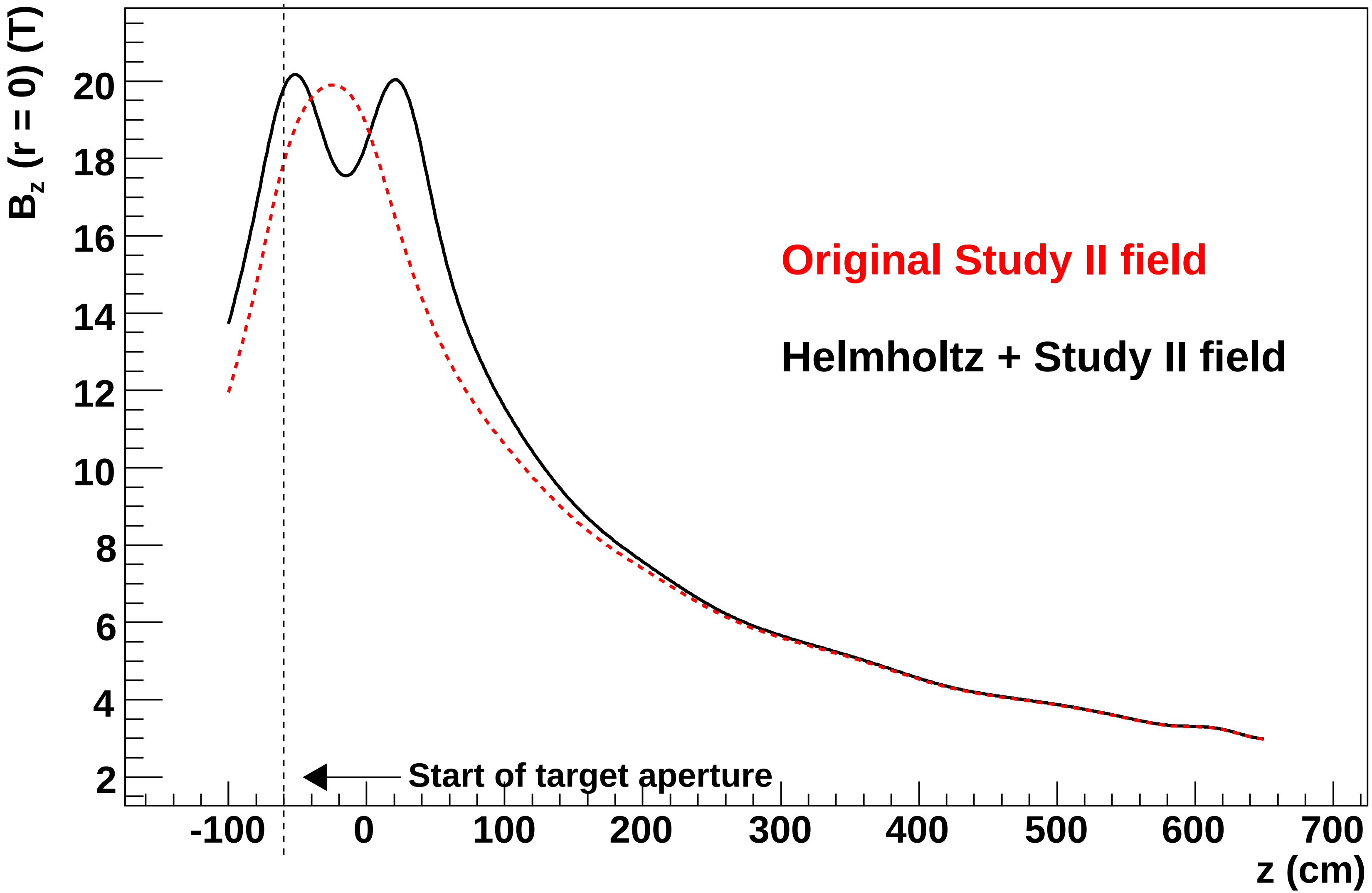
StudyII



Helmholtz (close up)

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

On-axis B_z field

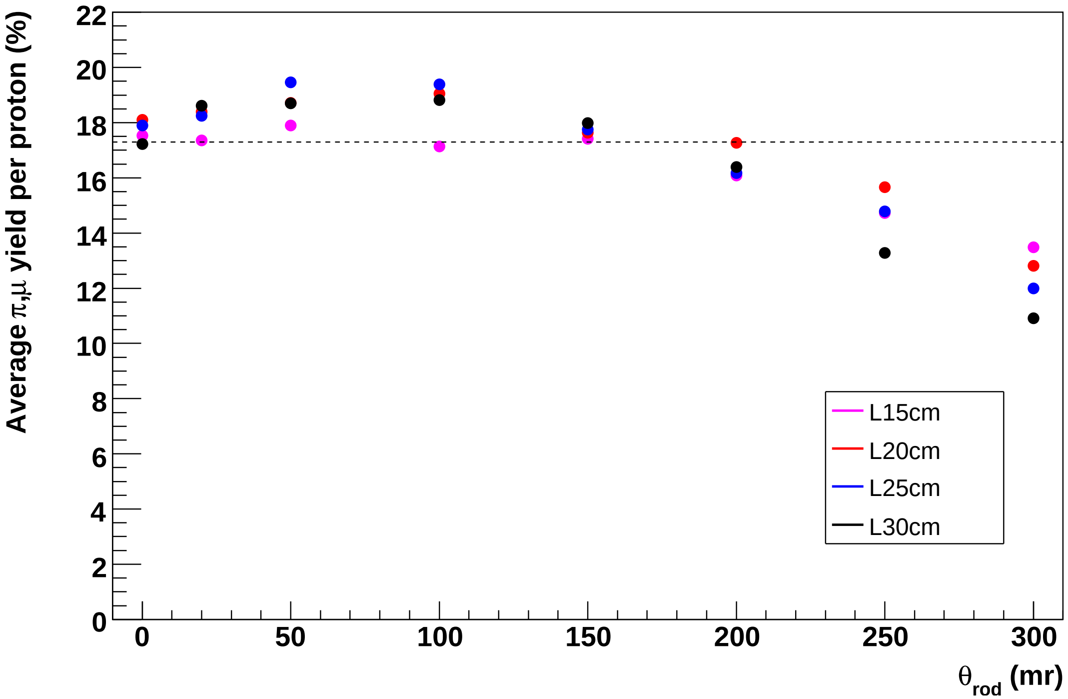


Current density in Cu coils: <Study II> $= 20\,\mathrm{A\,mm^{-2}}$, Helmholtz $= 30\,\mathrm{A\,mm^{-2}}$

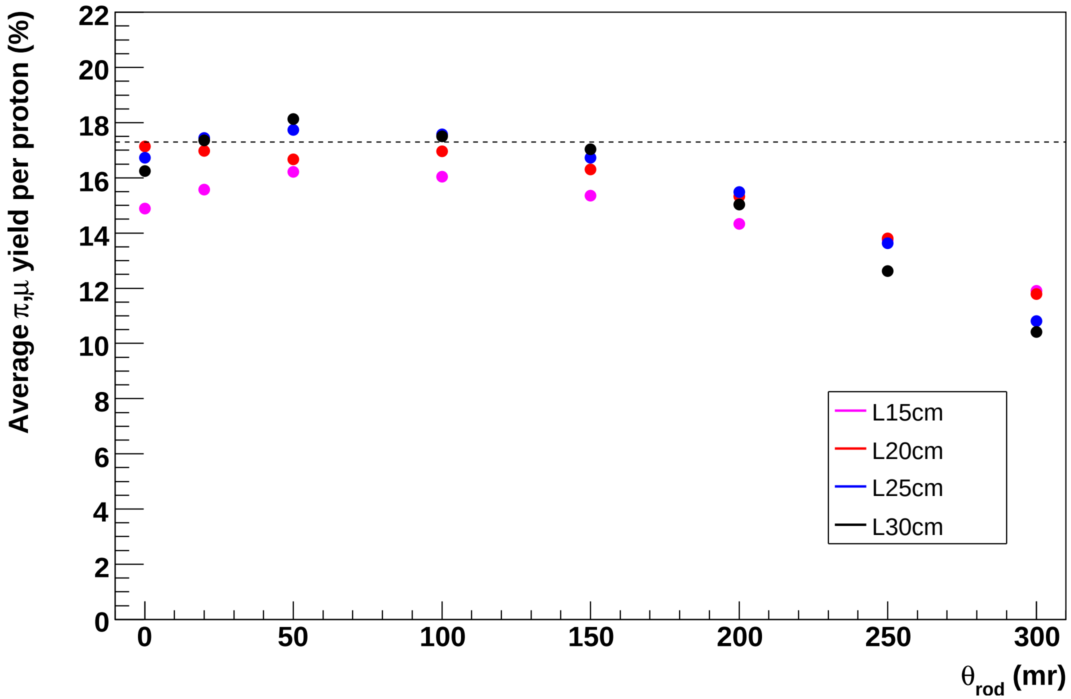
Solid target yields

- Following plots show the yield for solid W cylindrical rods as a function of
  - rod length
  - rod radius = proton beam radius
  - rod tilt = beam tilt (w.r.t z axis)
- Comparing original Study 2 geometry and magnetic field with the Helmholtz arrangement
  - gap between the magnets so the solid target can pass through (via a chain system)
- Also comparing the yields from the solid target with the yield from the optimal Hg jet case.

Charge averaged π, μ yield per proton at $z = 6\,\mathrm{m}$ for $r_{\mathrm{beam}} = 0.25\,\mathrm{cm}$



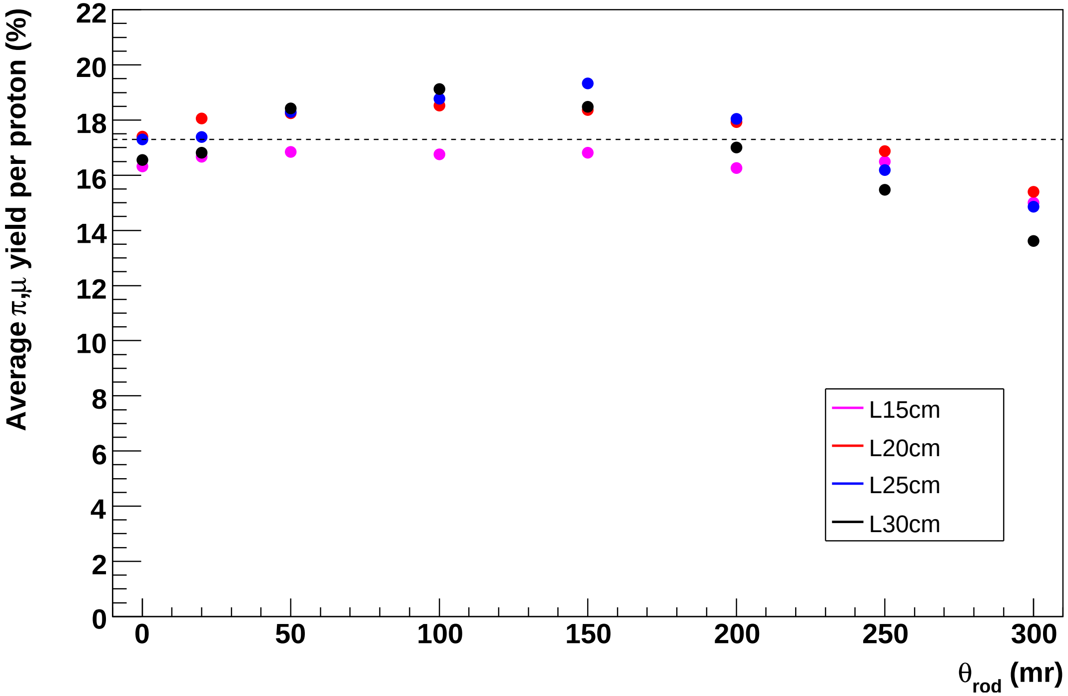
Original field



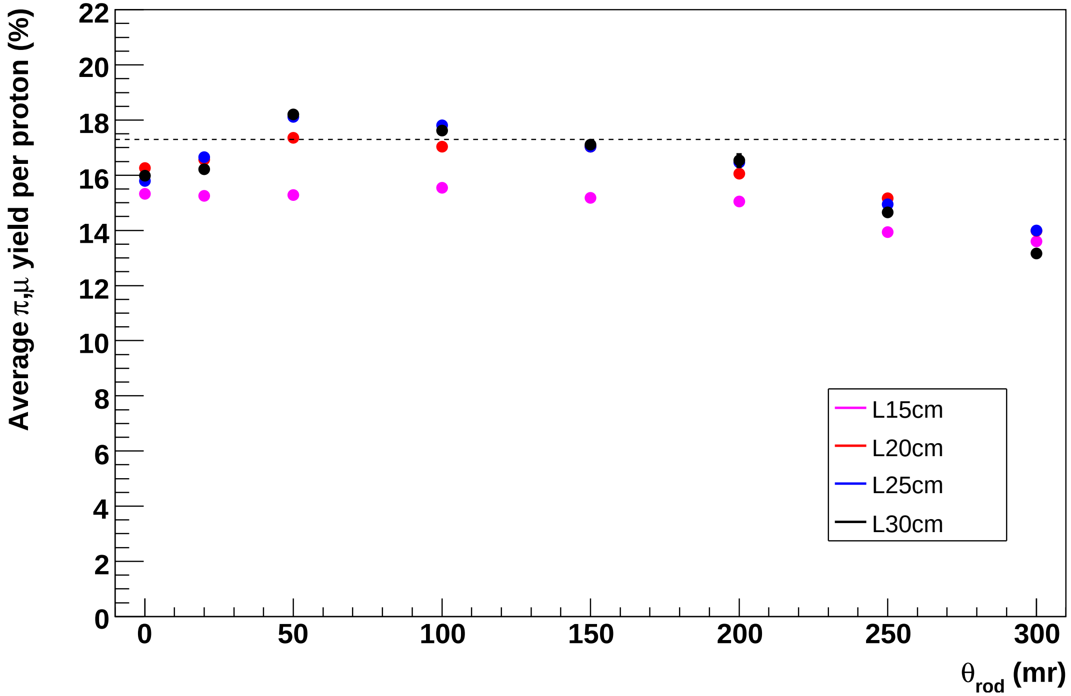
Helmholtz + StudyII field

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

Charge averaged π, μ yield per proton at $z = 6\,\text{m}$ for $r_{\text{beam}} = 0.50\,\text{cm}$



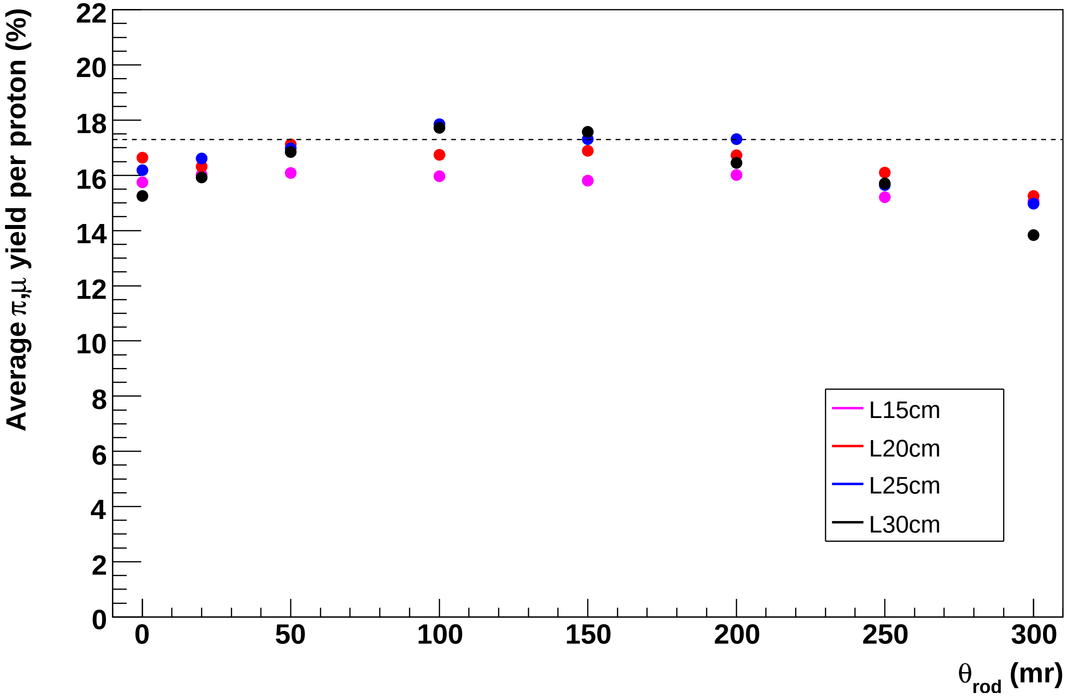
Original field



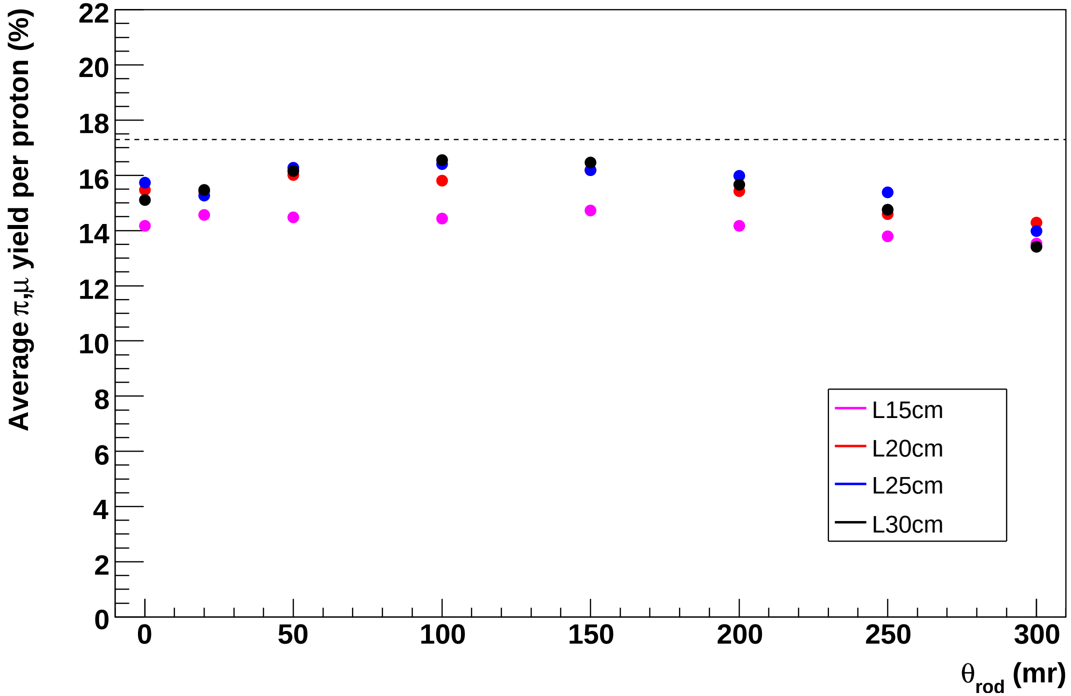
Helmholtz + StudyII field

Dotted line is Hg jet yield for $10\,\text{GeV}$ beam (using StudyII optimal tilt, radii)

Charge averaged π, μ yield per proton at $z = 6\,\text{m}$ for $r_{\text{beam}} = 0.75\,\text{cm}$



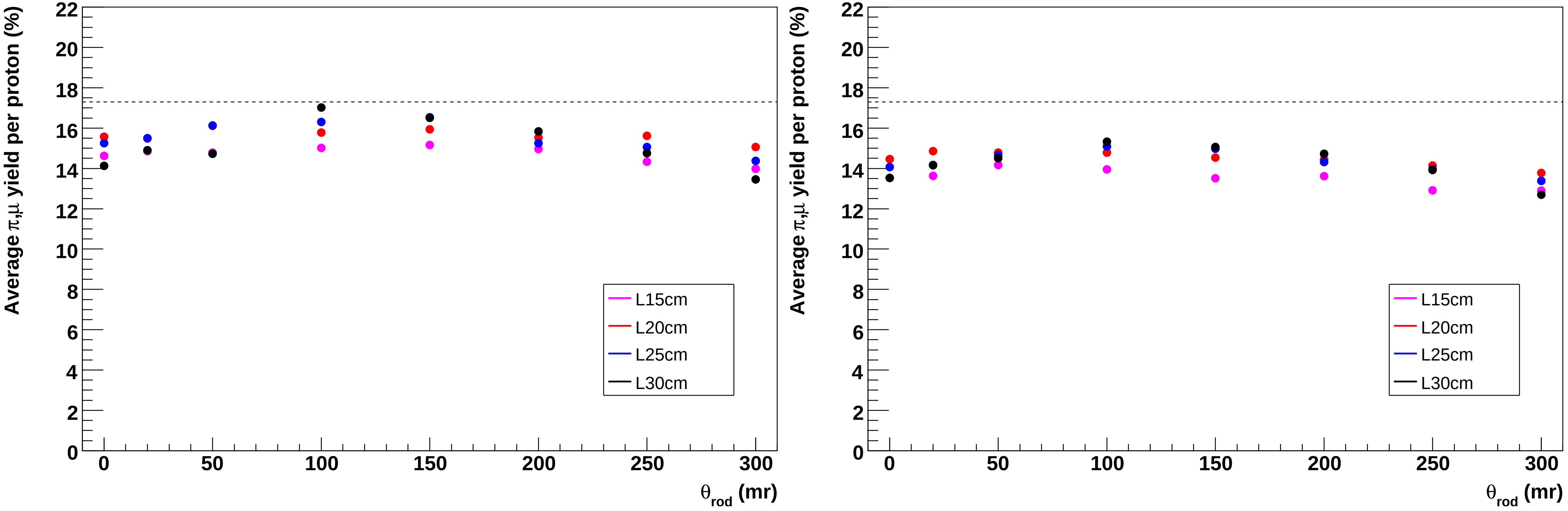
Original field



Helmholtz + StudyII field

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

Charge averaged π, μ yield per proton at $z = 6\,\mathrm{m}$ for $r_{\mathrm{beam}} = 1\,\mathrm{cm}$

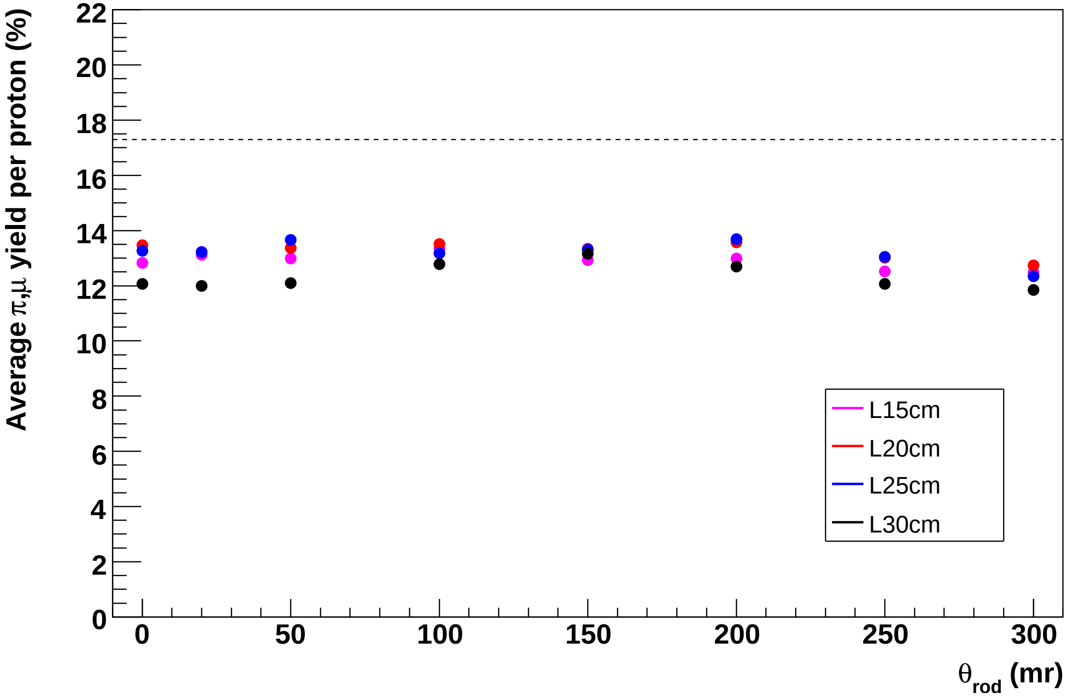


Original field

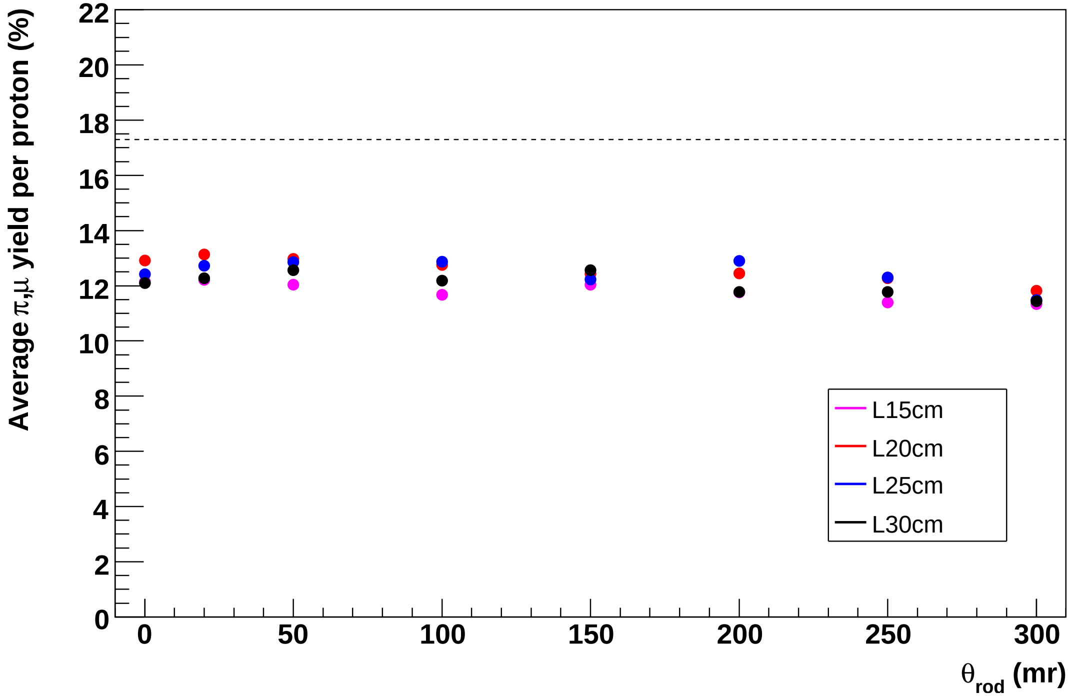
Helmholtz + StudyII field

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

Charge averaged π, μ yield per proton at $z = 6\,\mathrm{m}$ for $r_{\mathrm{beam}} = 1.5\,\mathrm{cm}$



Original field



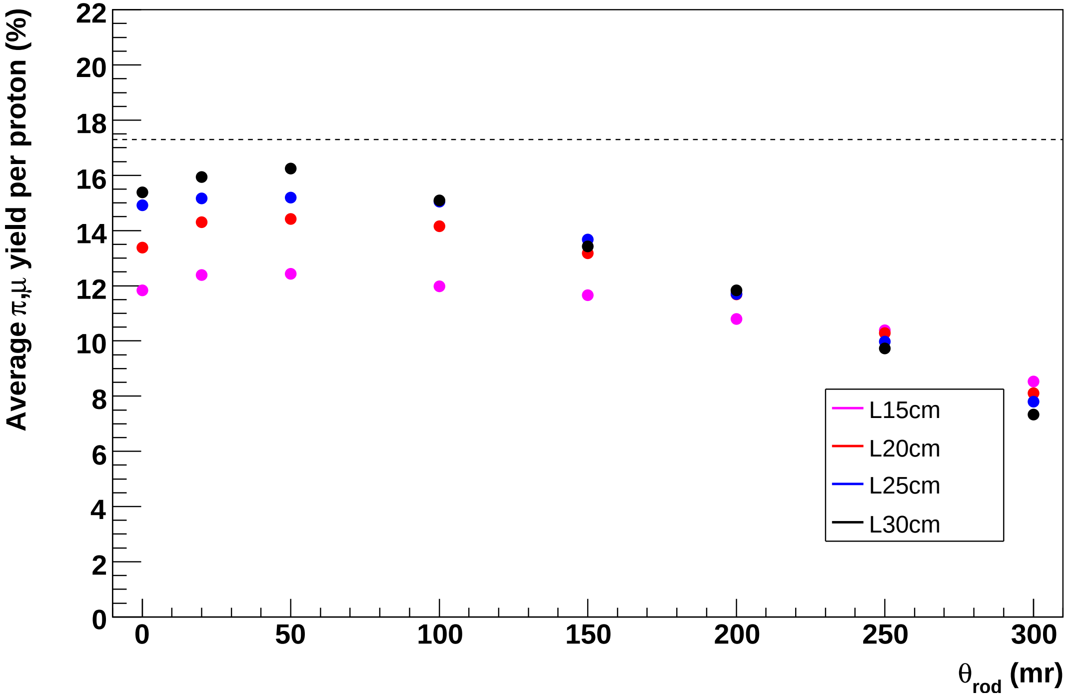
Helmholtz + StudyII field

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

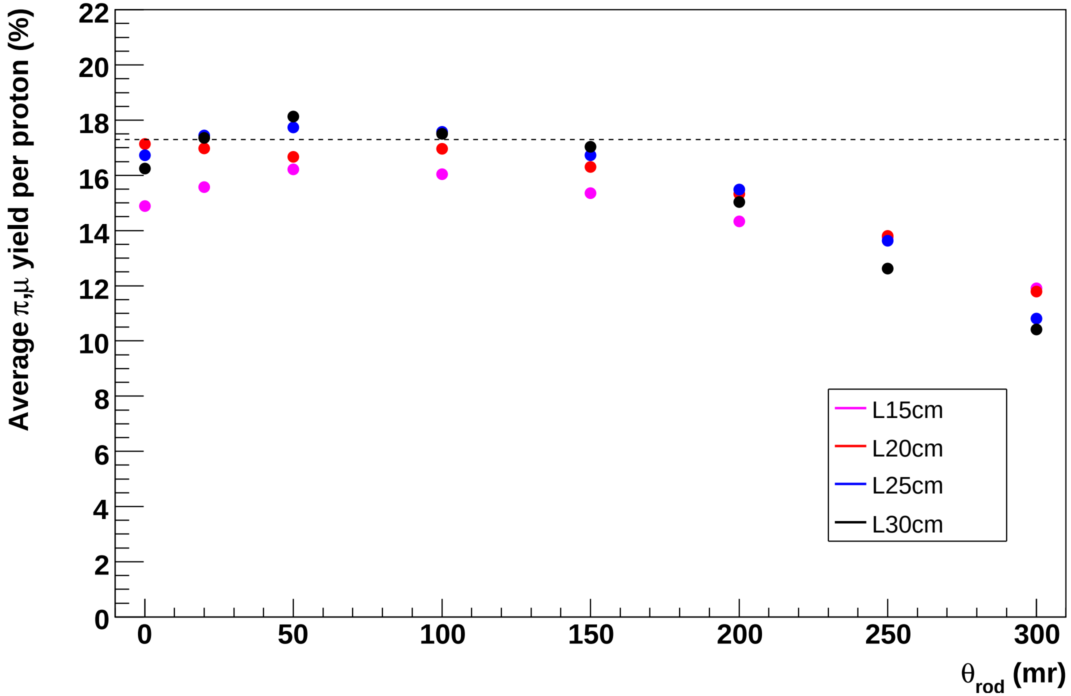
Powder jet target yields

- Following plots show the yield for a W powder particle jet:
  - Jet simulated as a simple cylinder, with $\rho = 0.5\rho_W$
  - Jet parameters: useable length, radius and tilt
  - Assuming $r_{\rm beam} = r_{\rm jet}$, $\theta_{\rm beam} = \theta_{\rm jet}$, unlike Hg jet case
- Use Study 2 geometry for the powdered jet (not Helmholtz arrangement)
- Comparing yields against those from the solid W target Helmholtz arrangement
- Also comparing the yields from the powdered jet with the yield from the optimal Hg jet case.

Charge averaged π, μ yield per proton at $z = 6\,\mathrm{m}$ for $r_{\mathrm{beam}} = 0.25\,\mathrm{cm}$



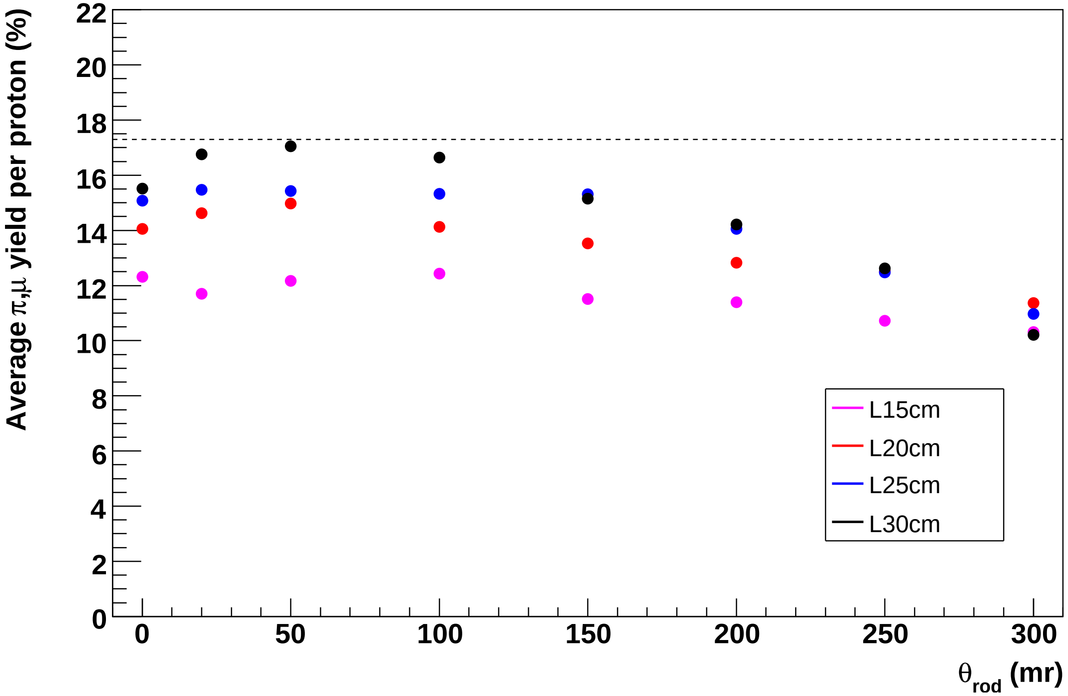
Powdered jet



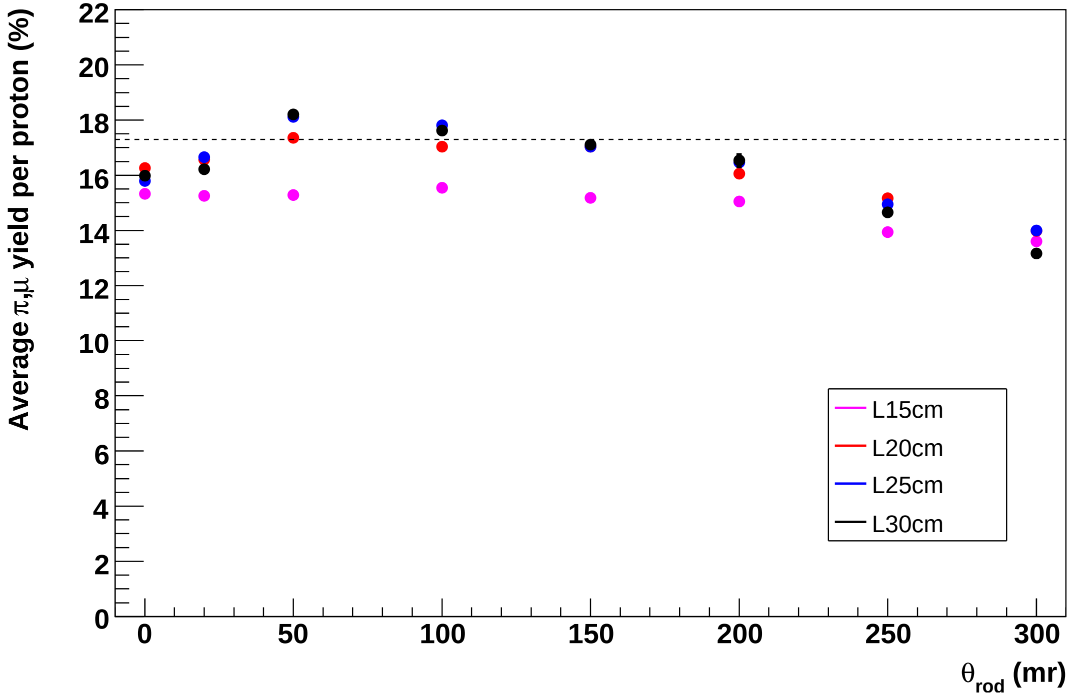
Solid (Helmholtz)

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

Charge averaged π, μ yield per proton at $z = 6\,\mathrm{m}$ for $r_{\mathrm{beam}} = 0.50\,\mathrm{cm}$



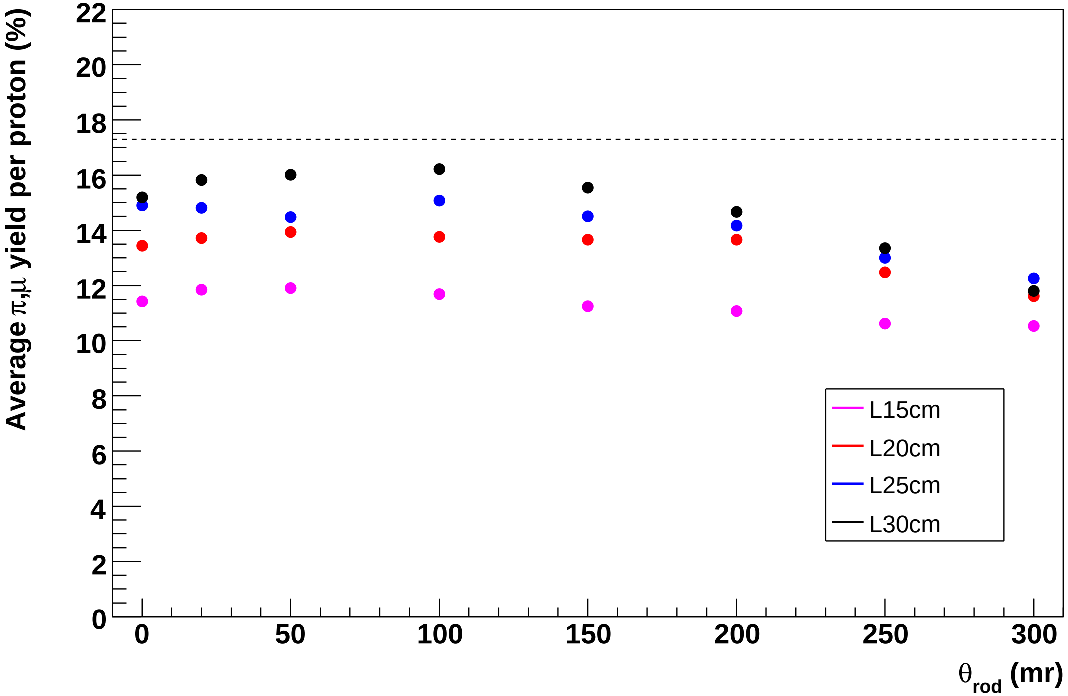
Powdered jet



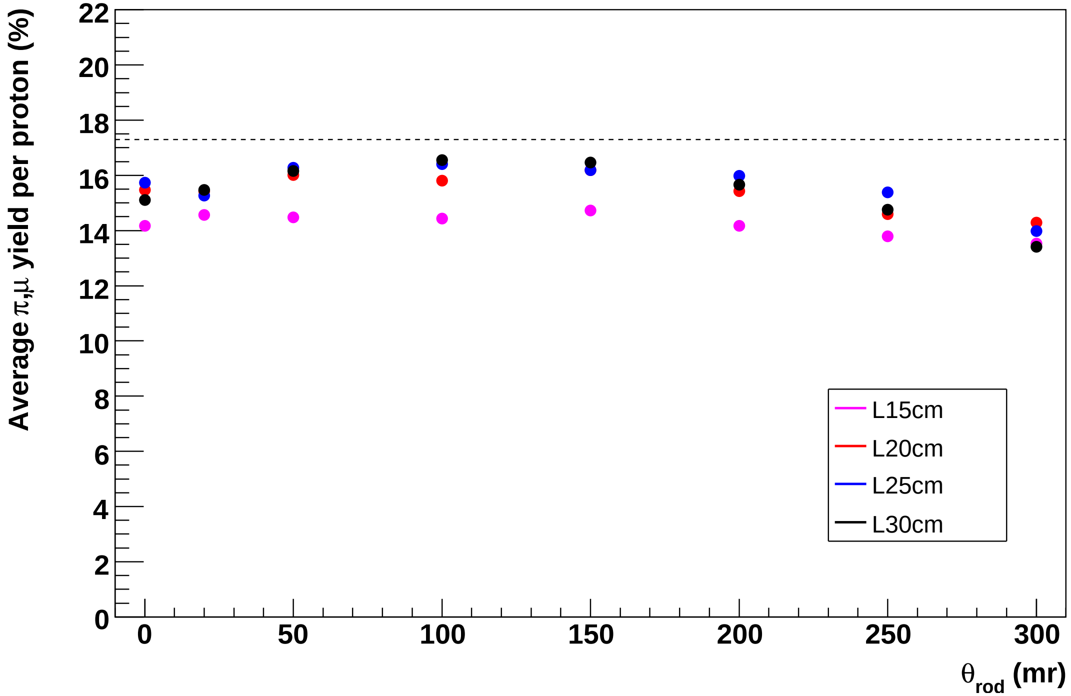
Solid (Helmholtz)

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

Charge averaged π, μ yield per proton at $z = 6\,\mathrm{m}$ for $r_{\mathrm{beam}} = 0.75\,\mathrm{cm}$



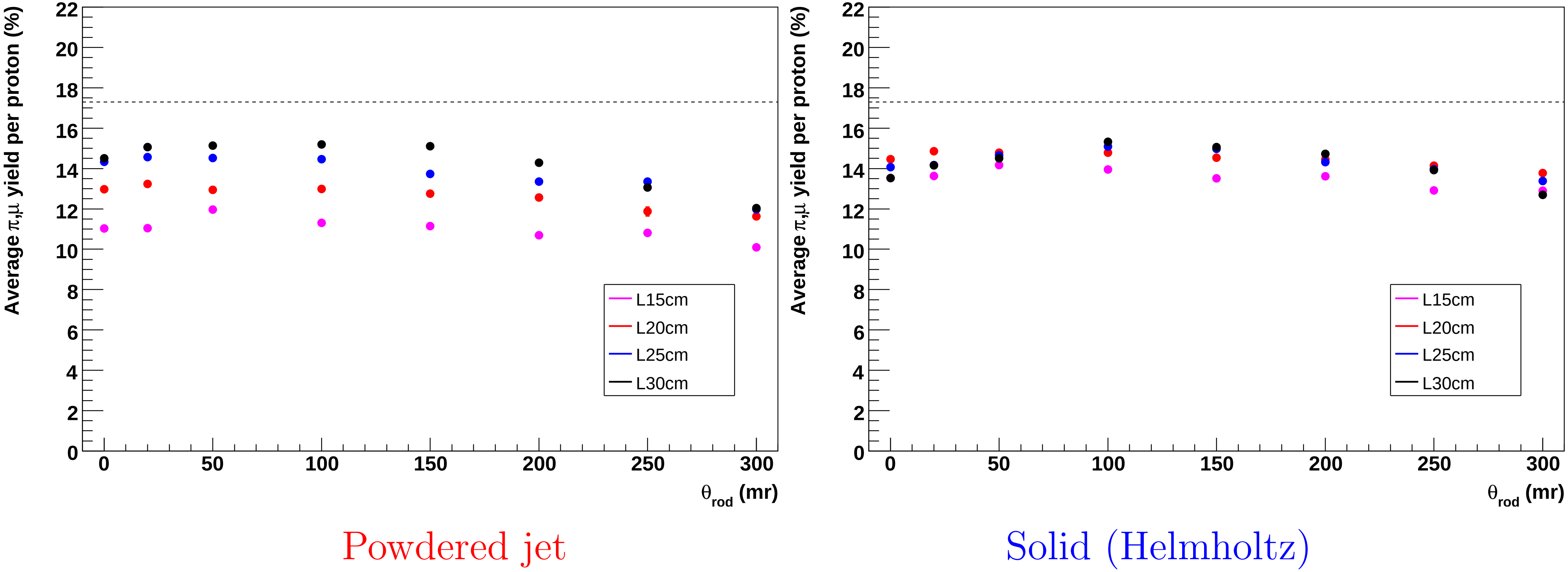
Powdered jet



Solid (Helmholtz)

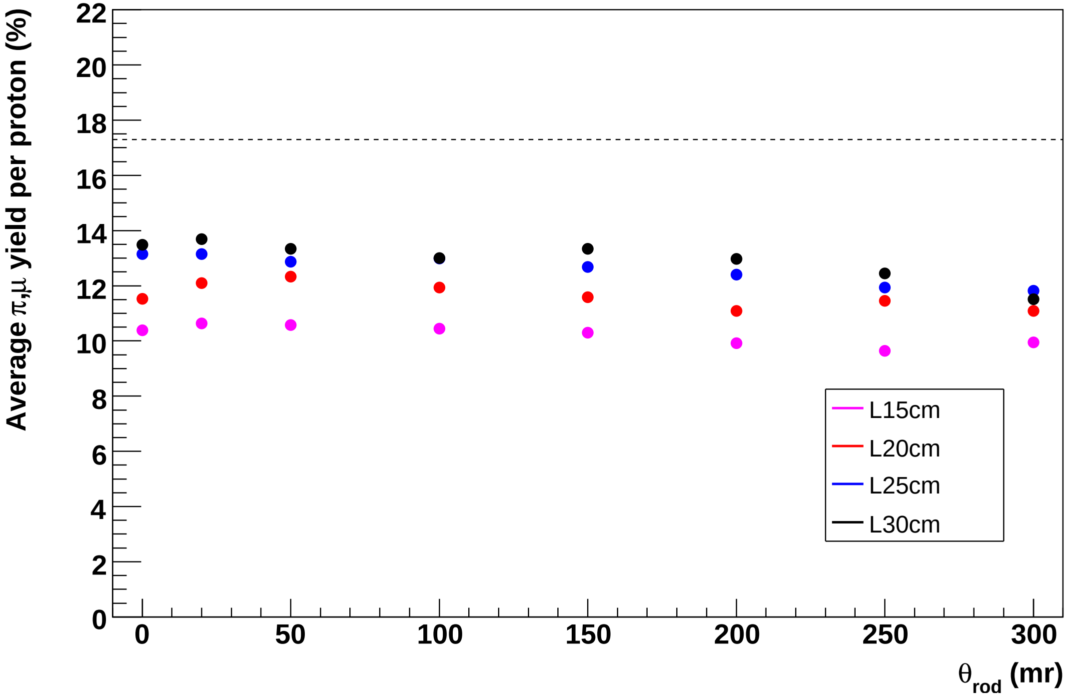
Dotted line is Hg jet yield for 10 GeV beam (using StudyII optimal tilt, radii)

Charge averaged π, μ yield per proton at $z = 6\,\mathrm{m}$ for $r_{\mathrm{beam}} = 1\,\mathrm{cm}$

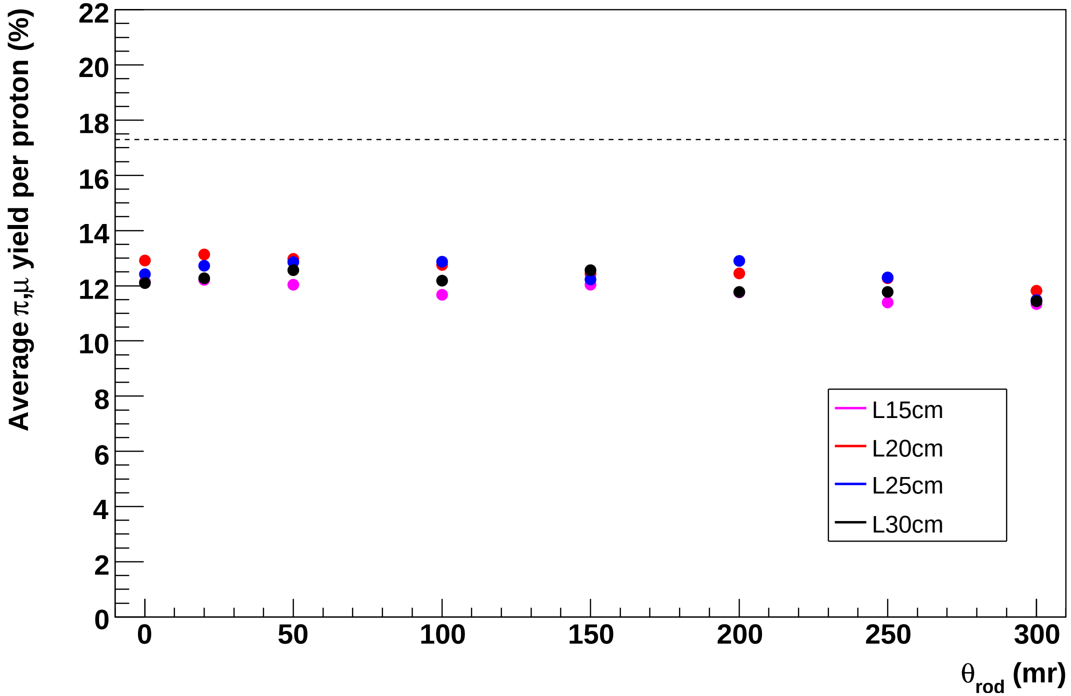


Dotted line is Hg jet yield for 10 GeV beam (using StudyII optimal tilt, radii)

Charge averaged π, μ yield per proton at $z = 6\,\mathrm{m}$ for $r_{\mathrm{beam}} = 1.5\,\mathrm{cm}$



Powdered jet



Solid (Helmholtz)

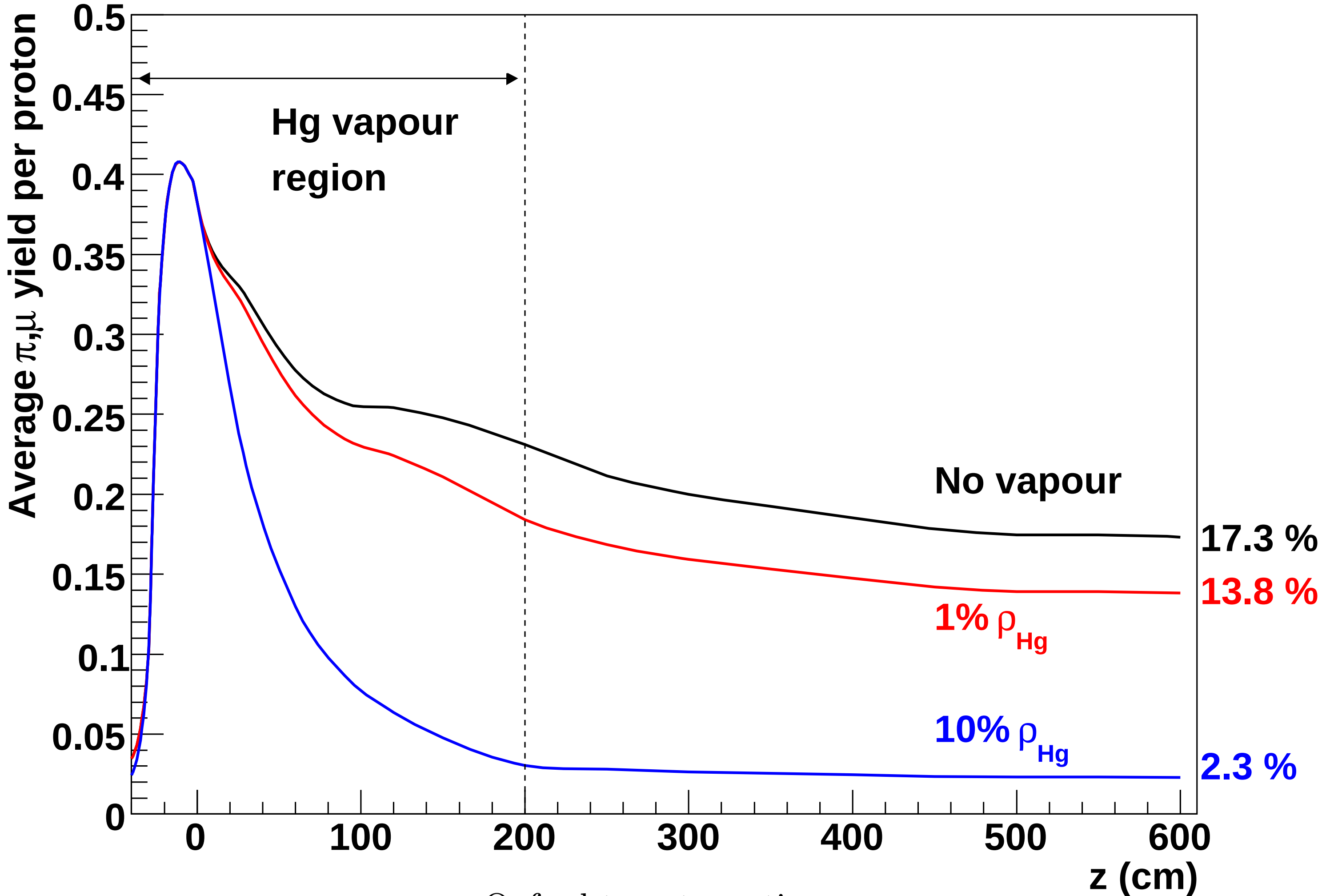
Dotted line is Hg jet yield for 10 GeV beam (using StudyII optimal tilt, radii)

Hg jet re-absorption

π, μ re-absorption due to Hg vapour (up to Be window at z=2 m).

Hg jet: simple cylinder, Study 2 parameters.

$\rho_{\text{vapour}} = \rho_{\text{He}} \times (0.1\text{bar}/1\text{atm}) + w \times \rho_{\text{Hg}}; \quad w = 0, 1\%, 10\%.$



Summary

- Presented π, μ yields for solid and powder W targets; $E_p = 10\,\text{GeV}$
- Helmholtz geometry yields are $> 90\%$ of original geometry yields
- Solid W yields higher (lower) than optimal Hg yield for $r_{\text{target}} < 0.75\,\text{cm}$ ($r_{\text{target}} > 0.75\,\text{cm}$)
- Powdered jet yields comparable to Helmholtz solid target yields
- 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).
- Hg vapour re-absorption significant effect: yield $\approx Y_0\, e^{-(\Delta z/L_{\text{int}})}$
  - effective interaction length $L_{\text{int}} \approx 10\text{cm}/w$, where w = density fraction
  - Y_0 is the yield for the no vapour case.