High-Level Analysis and *lp* Cross Sections
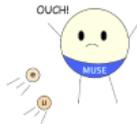
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BVR Subcommittee Meeting for MUSE

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# Blinding

- Blind at track level using blinding scheme presented by J. C. Bernauer at BVR 52, EWC at BVR 54, arxiv:2310.11469, submitted to PRC
- Blind tracks with angular dependence, determined by STT angle
- Unique blinding for species, momentum, polarity, and data vs sim
- Recall we will extract ratios of blinded quantities
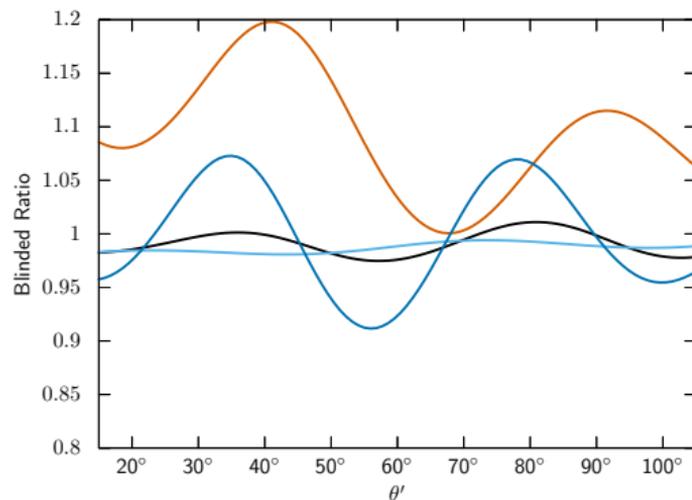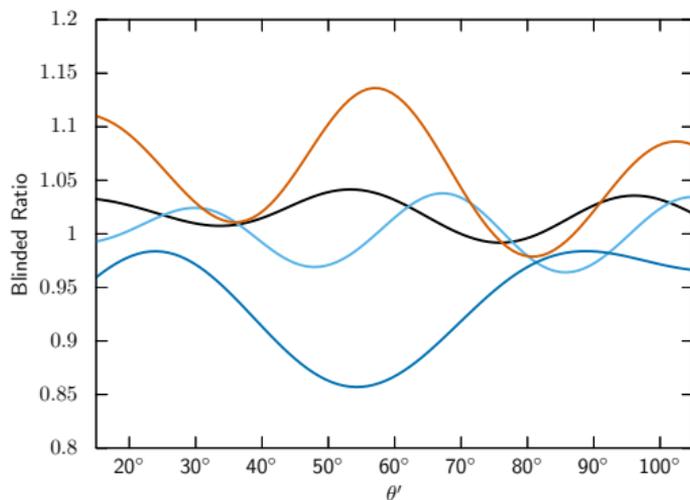
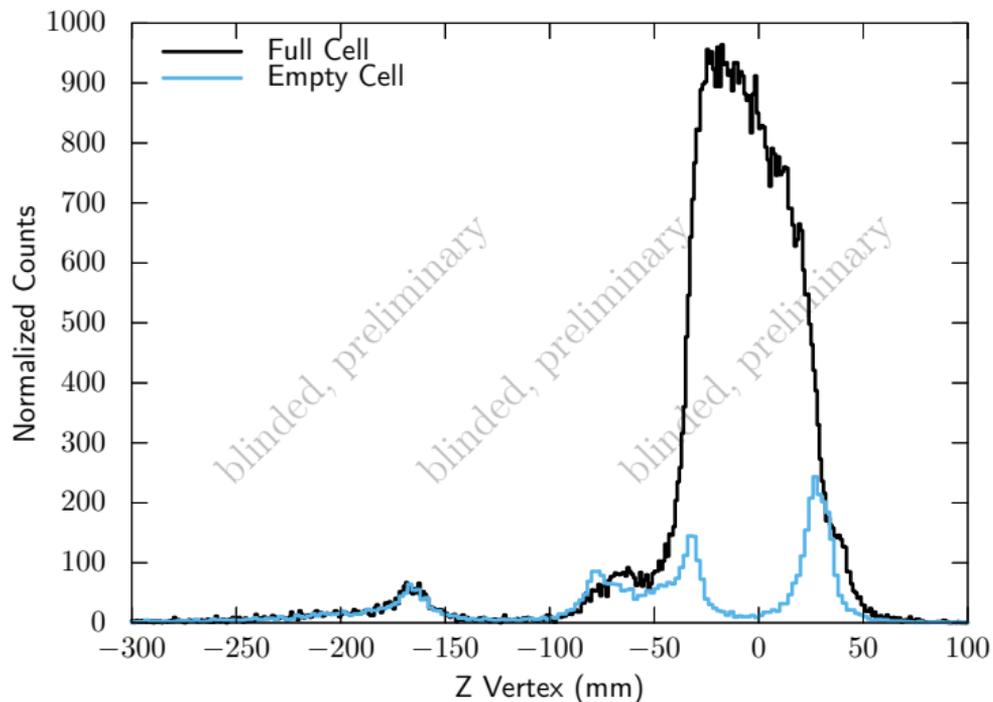
Example of eight blinded ratios. True ratio assumed to be 1. Blinding can introduce angular dependent structures in data, up to ± 20 % in ratios.
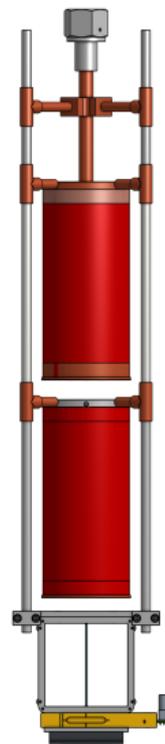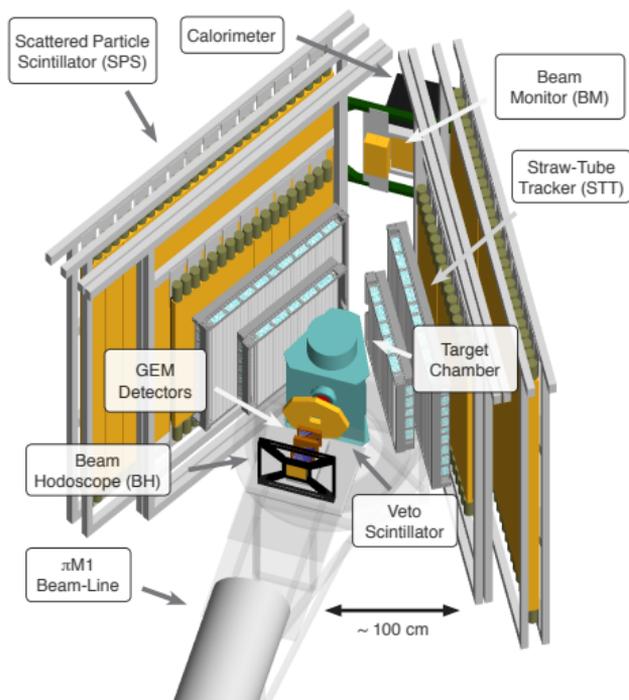
Addition of target aluminized mylar, run-by-run parameterization of beam profile in simulation.
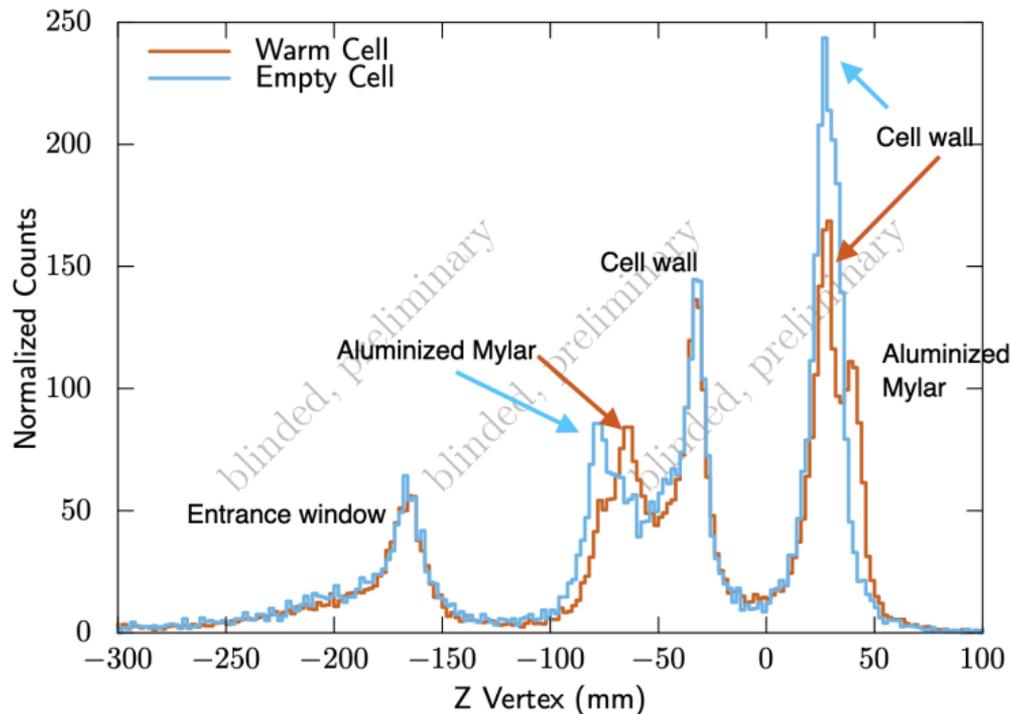
Comparison between luminosity-normalized full and empty cells for $+210$ MeV/c π beam. Note slight disagreements of aluminized mylar between full and empty cell near $z = -75$ mm. Clearly see cell walls in empty cell. Excellent agreement in entrance window distribution, $z = -175$ mm.

Aluminized Mylar in Target Cell
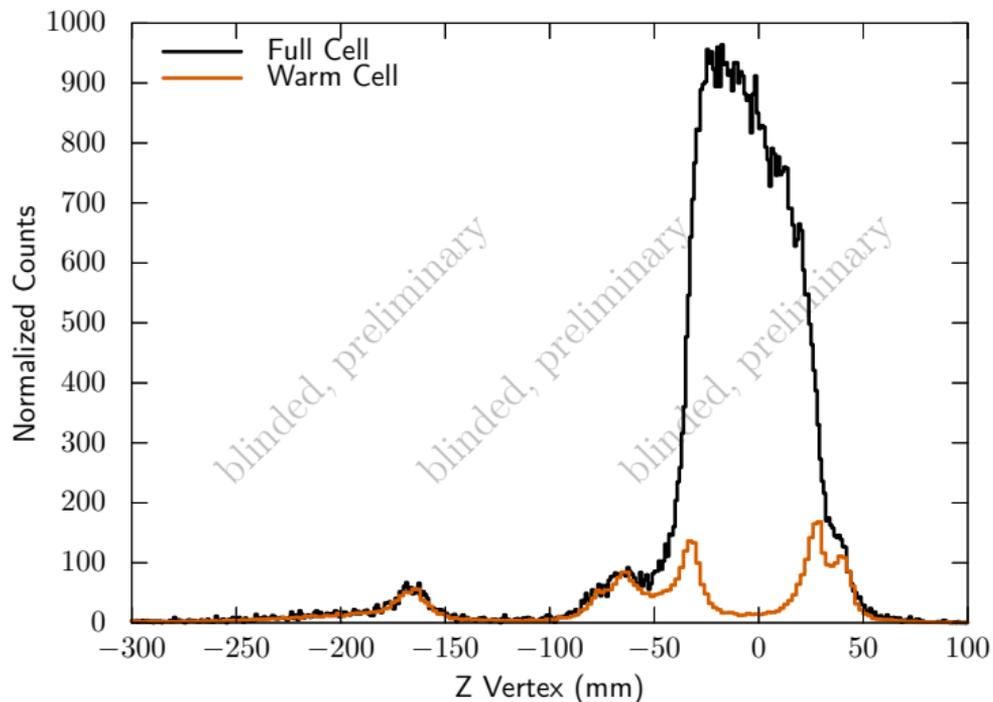
Comparison between luminosity-normalized full and warm cells for $+210$ MeV/c π beam. "Full" cell and "warm" cell are the same cell, "full" is filled with LH_2, "warm" is not. Note agreement in aluminized mylar peak. Clearly see cell walls in warm cell.

Aluminized Mylar Wrapping Differences
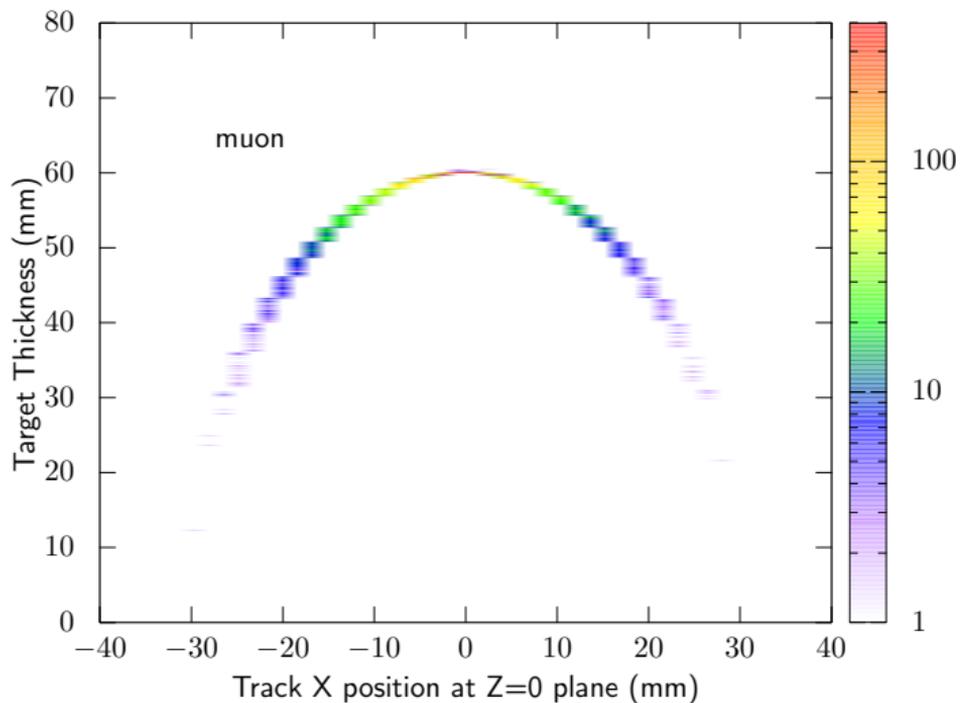

Comparison between luminosity-normalized warm and empty cells for $+210$ MeV/c π beam. Clearly see difference in aluminized mylar wrapping in both cells. Note that *cell walls* are in almost identical positions, $z = \pm30$ mm.
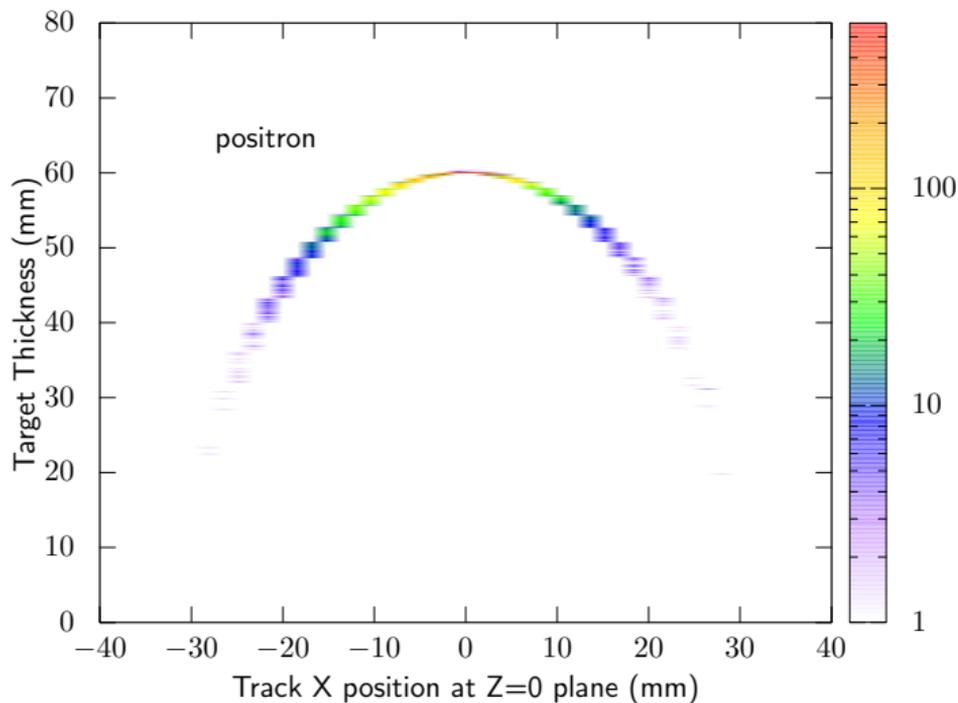
Target thickness as seen by e^+. Trajectory through the target cell is calculated using GEM tracks. Note subtle differences between species.

Target thickness as seen by μ^+. Trajectory through the target cell is calculated using GEM tracks. Note subtle differences between species.
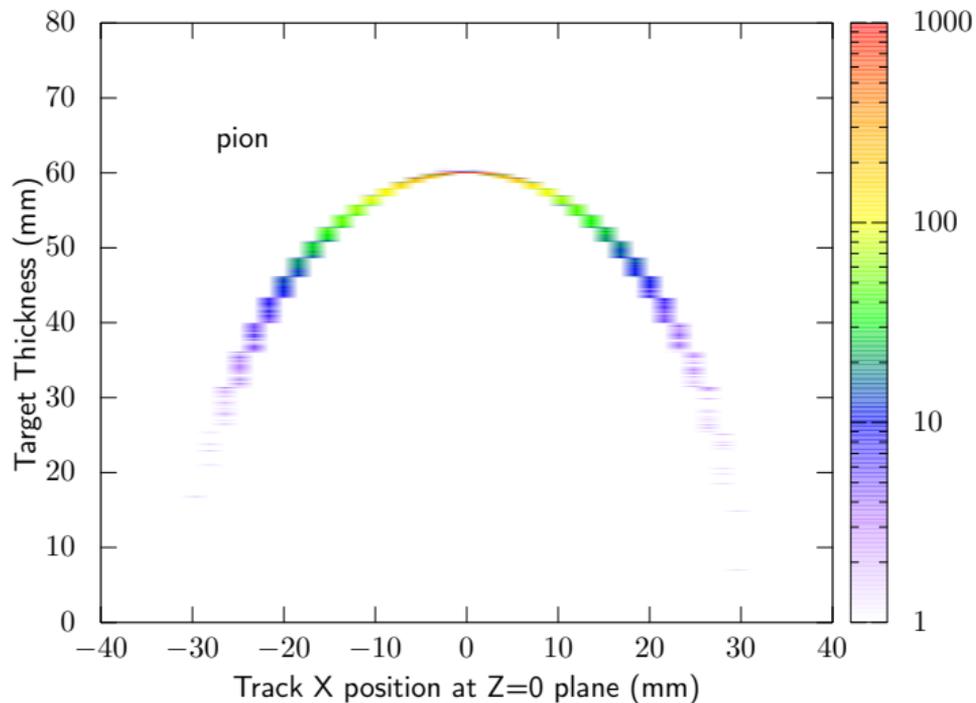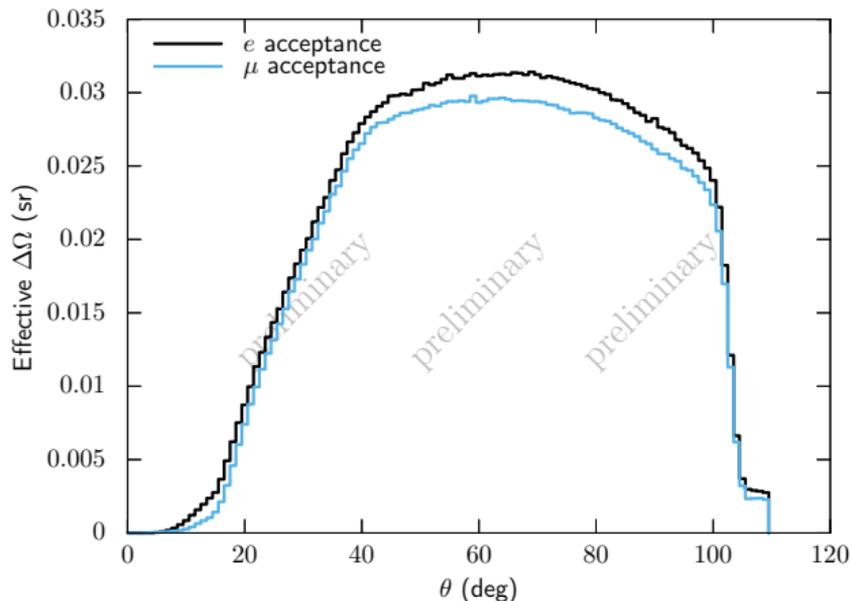
Target thickness as seen by π^+. Trajectory through the target cell is calculated using GEM tracks. Note subtle differences between species.
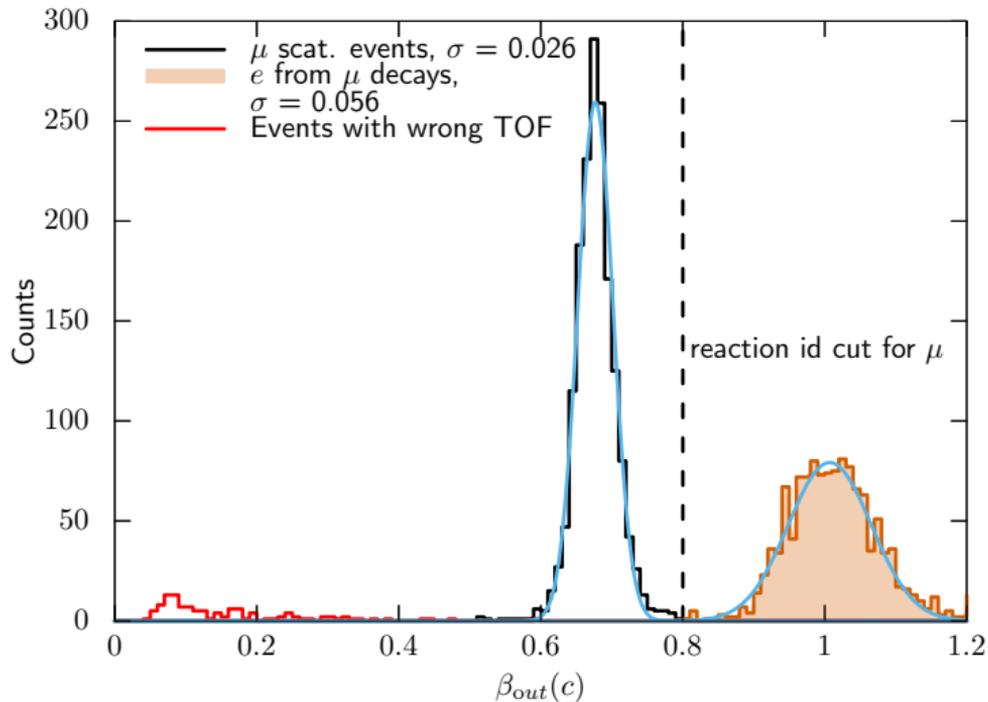
Effective Acceptance

Simulation-driven acceptance calculation for *ep* and *μp* scattering at 115 MeV/*c*
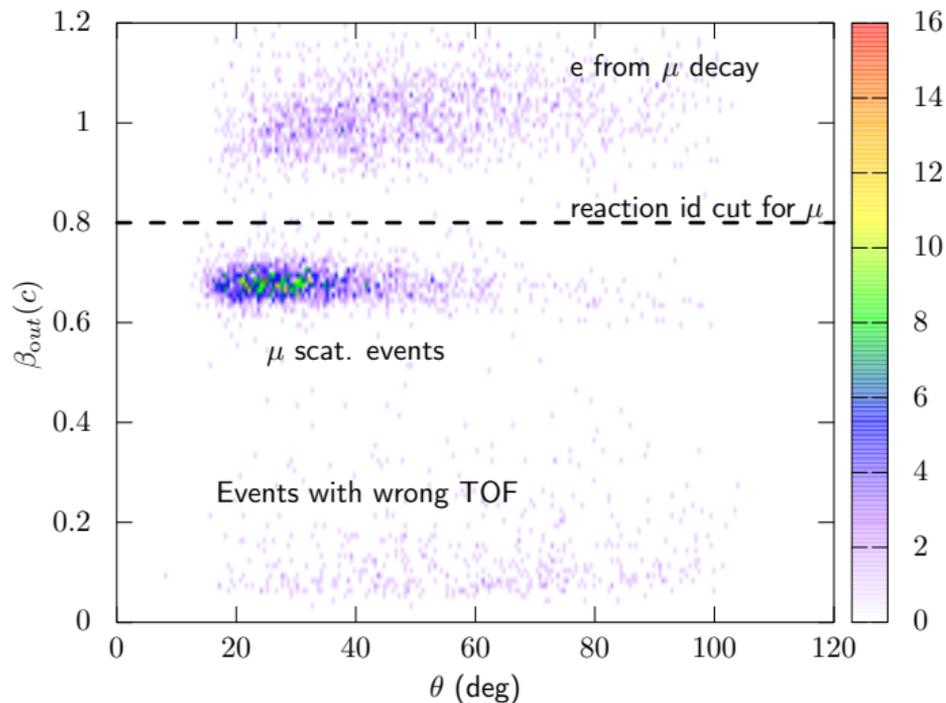
- Particles fired uniformly from target
- Must deposit energy in STT
- Must deposit energy in both SPS planes

- *μ* multiple scattering is larger than *e*
- Does not include all physics
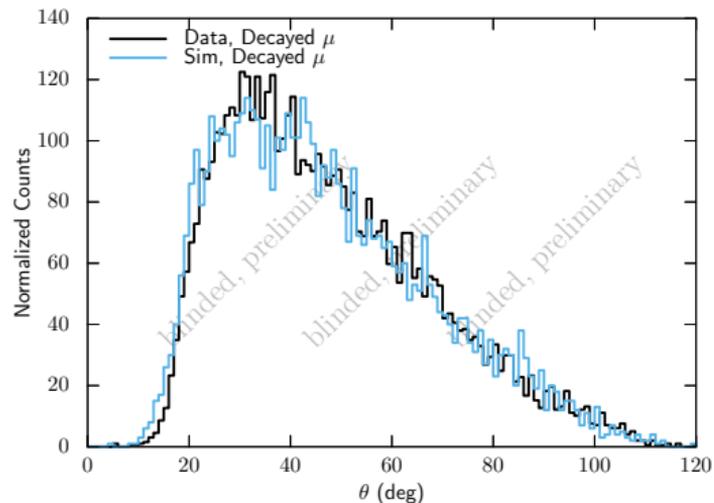
Reaction ID

β_{out}, the β between the reaction vertex and the SPS. The β_{out} cut separates μp scattering events from μ decay-in-flight events. Shown for -115 MeV/c.

Note that the β_{out} distributions are roughly independent of angle. Scattering and decay events are well-separated. Shown for -115 MeV/c.
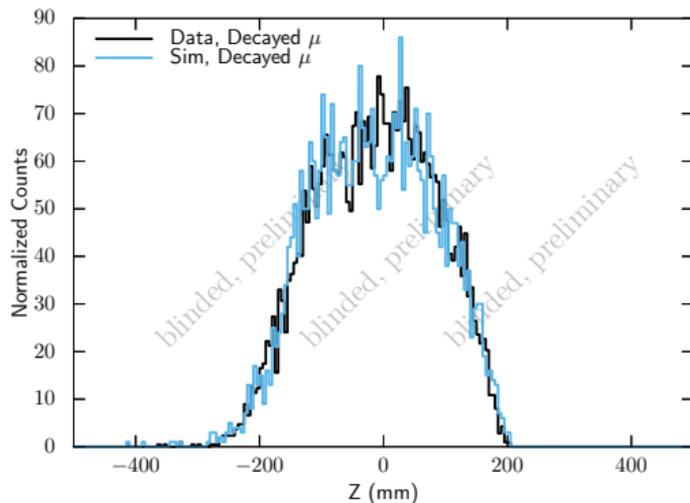
Comparison of μ decay events as identified by reaction ID in simulation and data at 115 MeV/c. Good agreement between single run of data and simulation. **Left:** Reconstructed Z vertex. **Right:** Reconstructed θ.

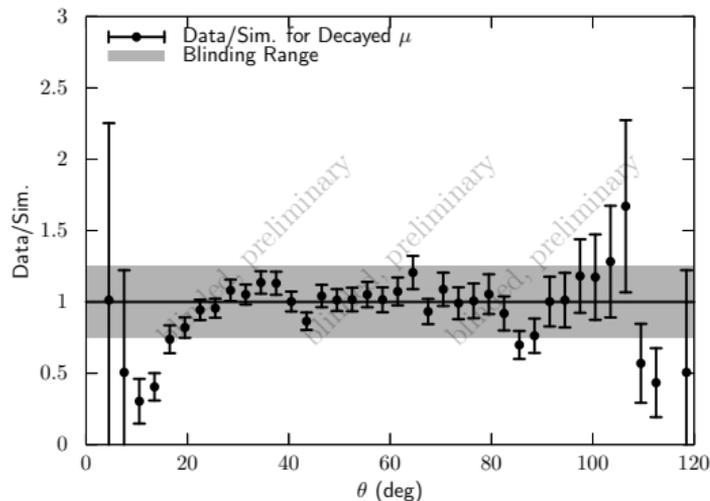Data/Sim. ratio of μ decay events as identified by reaction ID at 115 MeV/c. Good agreement between single run of data and simulation within blinding except at extremes. Recall MUSE target is located within $z = \pm 30$ mm. **Left:** Reconstructed Z vertex. **Right:** Reconstructed θ.
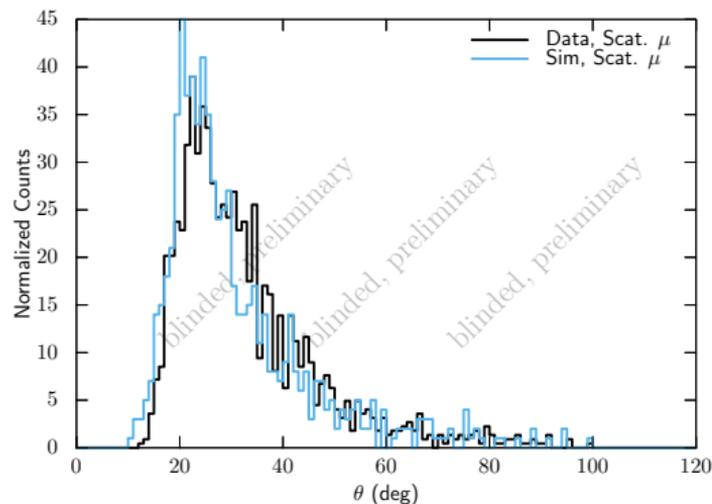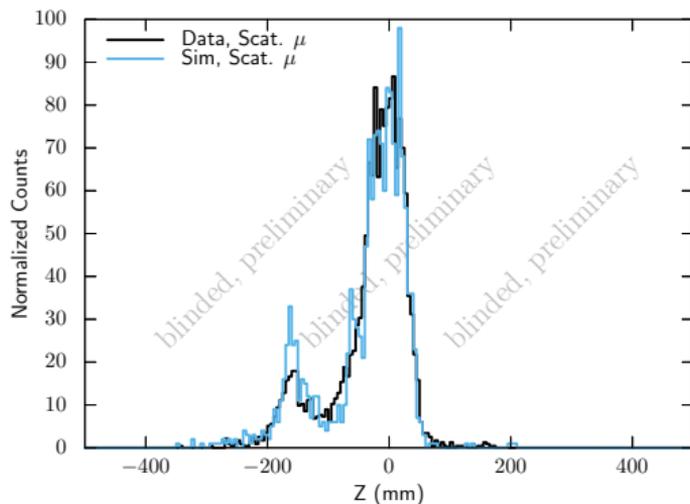
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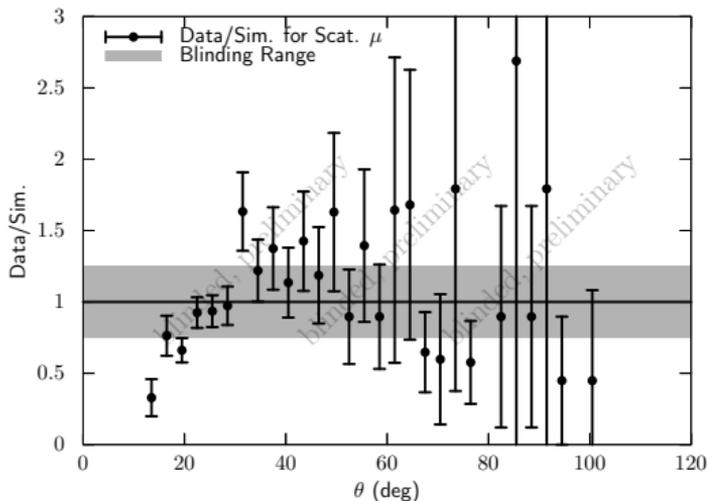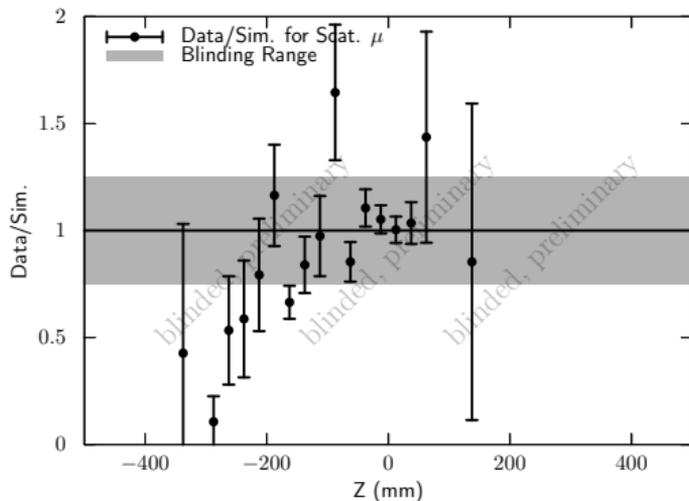
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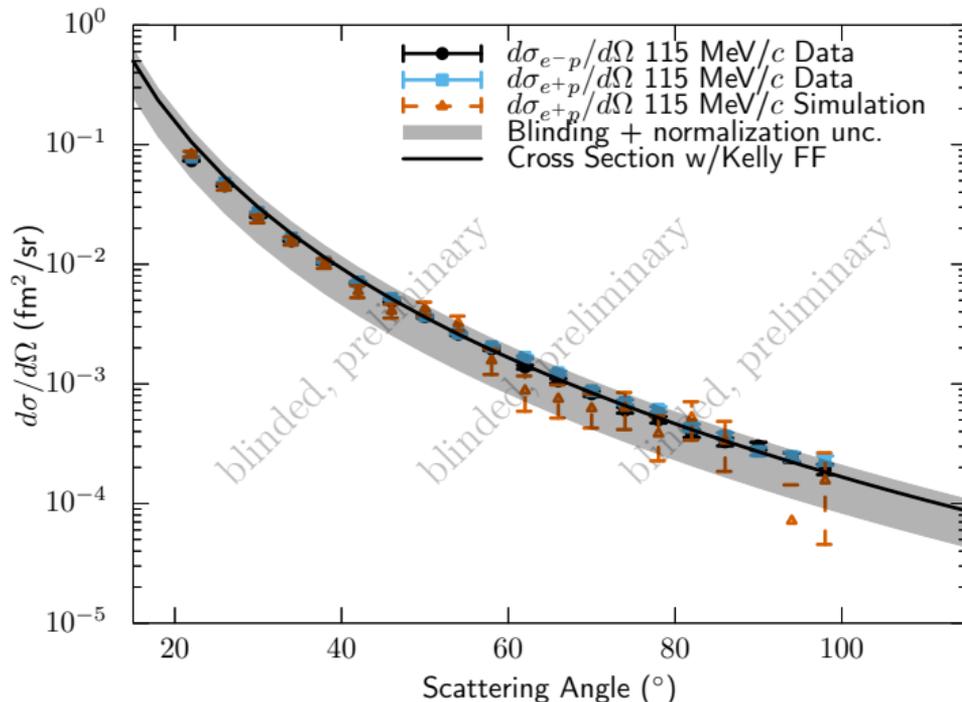
"Traditional" Cross Section Extraction

- Measured cross section for $e^{\pm}, \mu^{\pm}, \pi^{\pm}$-$p$
- Presenting results for $e^{\pm}p$ and $\mu^{\pm}p$ at 115 and 160 MeV/c scattering

$$\frac{d\sigma}{d\Omega}_i = \frac{\text{counts}_i}{x\rho N_{beam}\Delta\Omega_i\epsilon_{DAQ}\epsilon_{fiducial}\epsilon_{rad}}, \tag{1}$$

- counts$_i$ given from reconstructed vertices binned in angle
- N_{beam} calculated from BH trigger rates
- $x\rho$ target areal density
- $\Delta\Omega_i$ simulation-driven estimate of acceptance
- ϵ_{DAQ} (reconstruction efficiency, detector efficiency, live time, etc.) known from analysis
- $\epsilon_{fiducial}$ imposed in analysis of sim and data
- ϵ_{rad} radiative corrections, taken to be 1 for this analysis

Absolute, blinded cross section, data and simulation compared to OPE with Kelly FF. Gray band indicates blinding and normalization uncertainty – data should generally fall within band.

- 33 % (85 %) of + (−) data from 2023 dataset

Blinded cross section compared to cross section with OPE with Kelly FF. Gray band indicates blinding and normalization uncertainty – data should generally fall within band. Recall blinding can introduce varying slopes in the data and simulation.

Ratio of e^+p/e^-p cross sections. Gray band indicates blinding and normalization uncertainty – data should generally fall within band. Recall blinding can introduce varying slopes in the data and simulation.
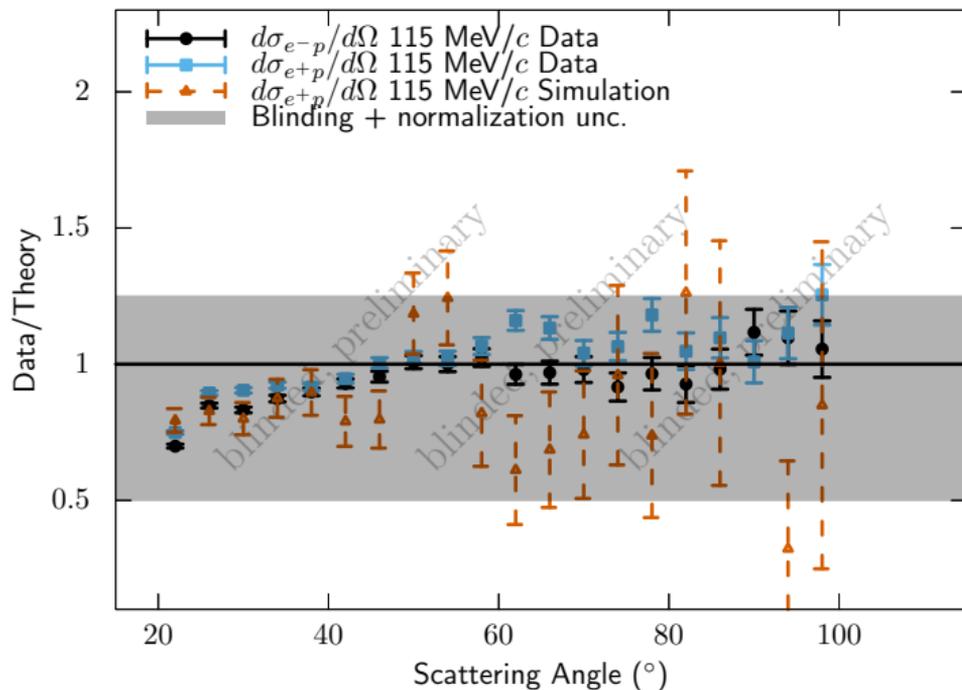
$\mu^{\pm}p$ 115 MeV/c Scattering

Absolute, blinded cross section, data and simulation compared to OPE with Kelly FF. Gray band indicates blinding and normalization uncertainty – data should generally fall within band.
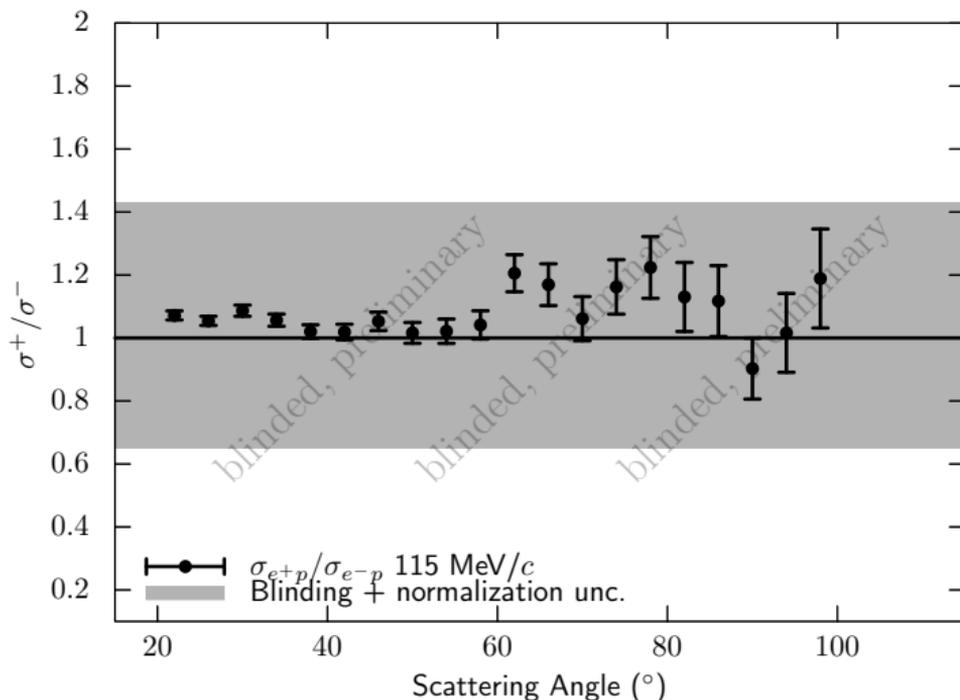
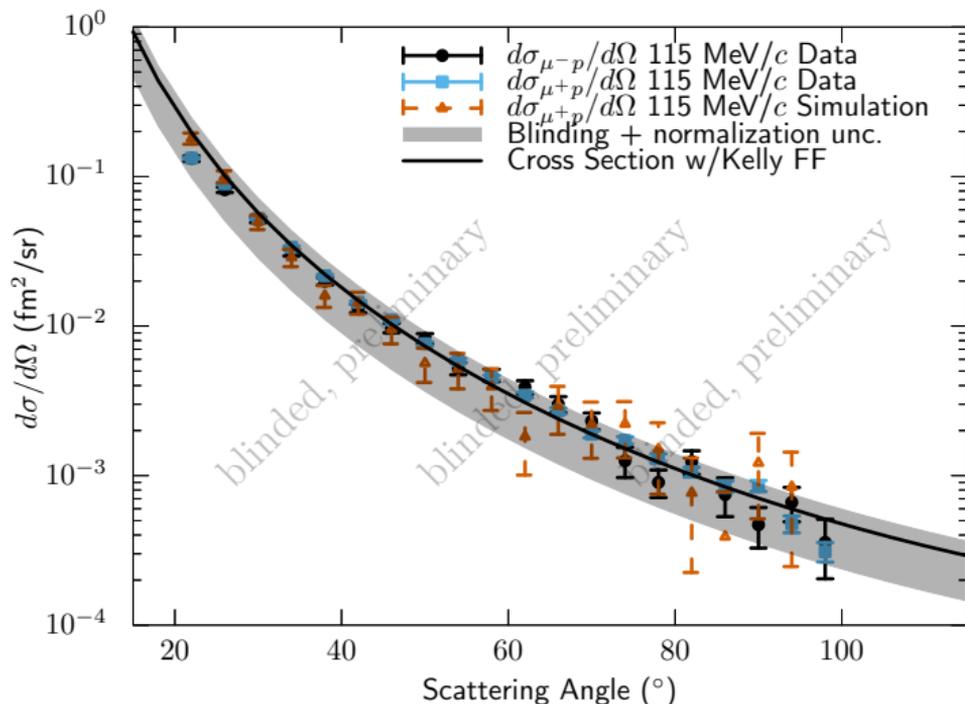- 33 % (85 %) of $+$ ($-$) data from 2023 dataset

Blinded cross section compared to cross section with OPE with Kelly FF. Gray band indicates blinding and normalization uncertainty – data should generally fall within band. Recall blinding can introduce varying slopes in the data and simulation.

Ratio of $\mu^+ p / \mu^- p$ cross sections. Gray band indicates blinding and normalization uncertainty – data should generally fall within band. Recall blinding can introduce varying slopes in the data and simulation.
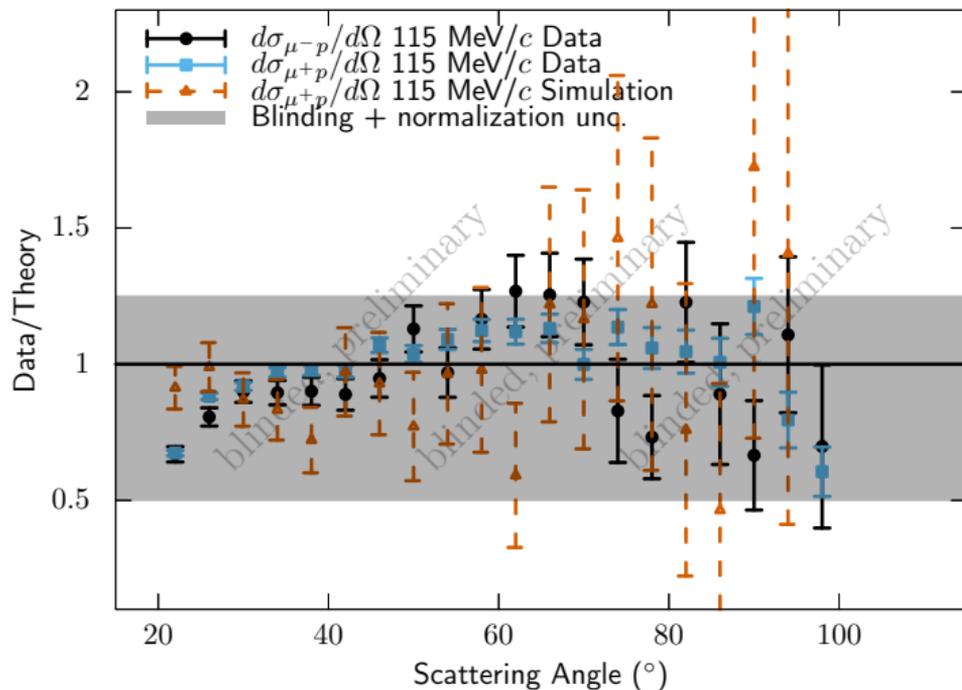
$e^{\pm}p$ 160 MeV/c Scattering

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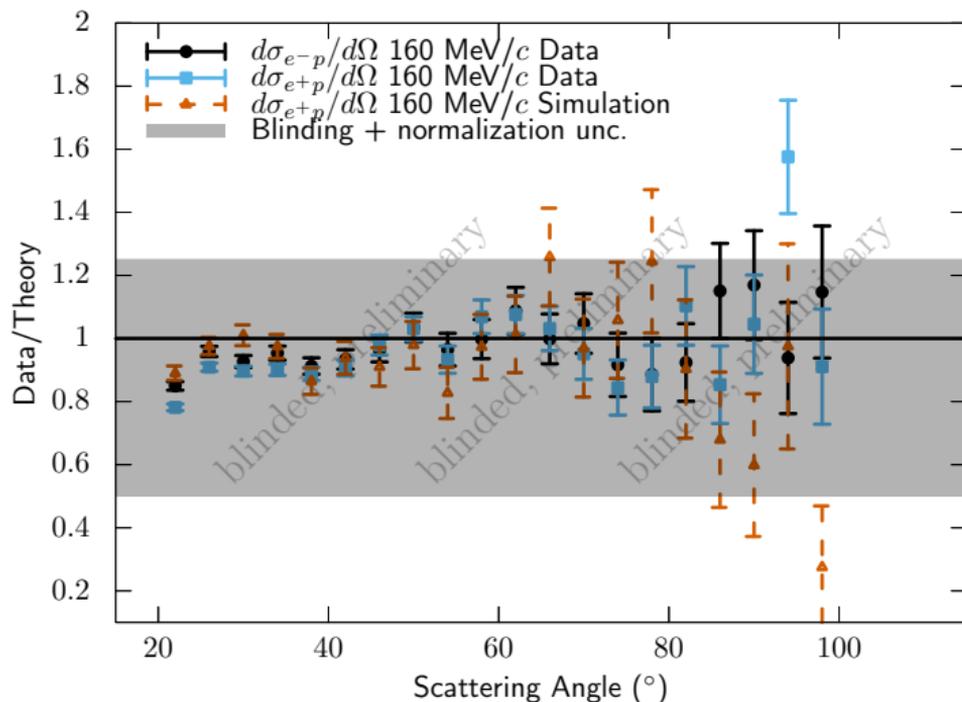
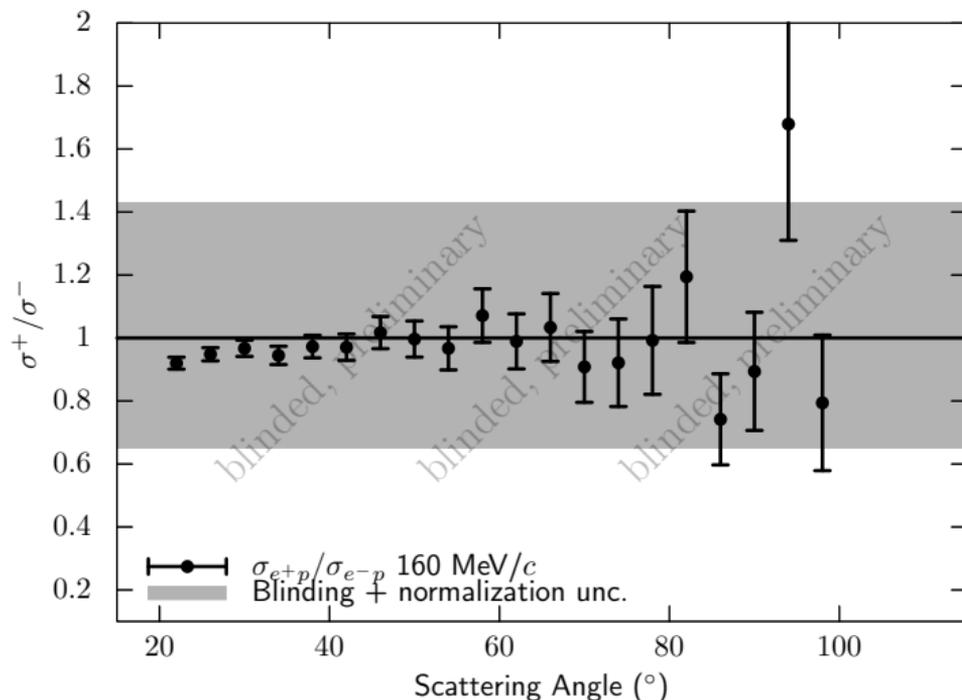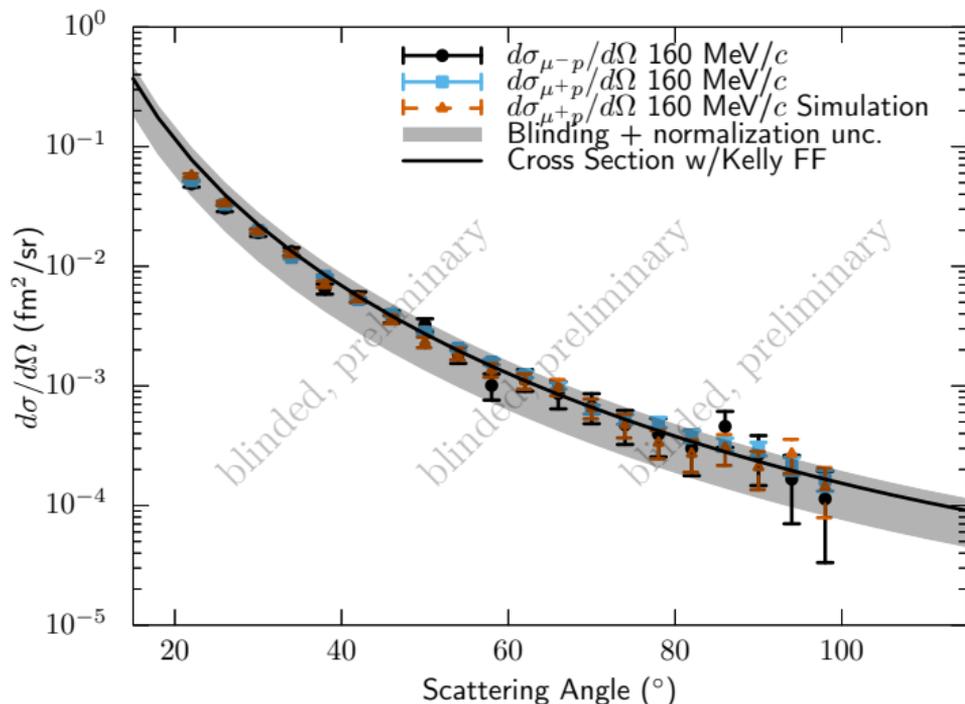- 19 % (25 %) of $+$ ($-$) data from 2023 dataset

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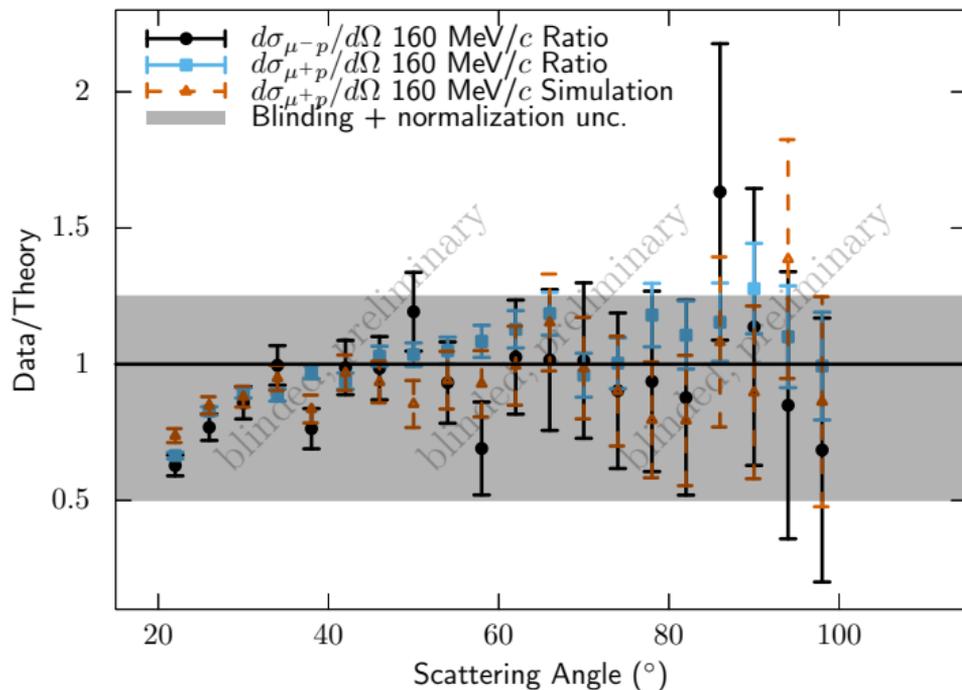
$\mu^{\pm}p$ 160 MeV/c Scattering

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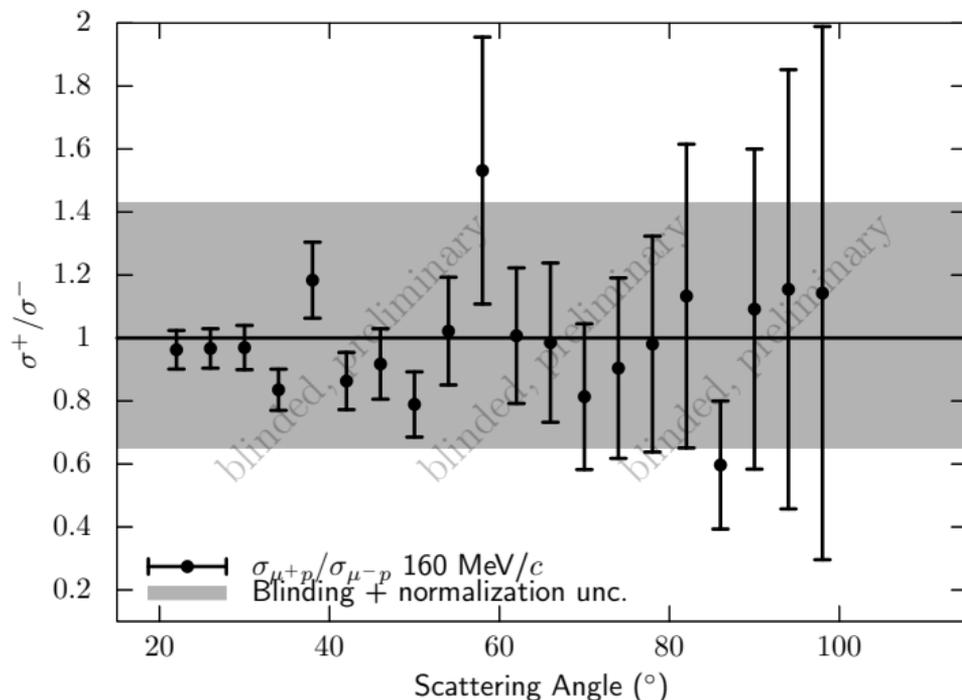
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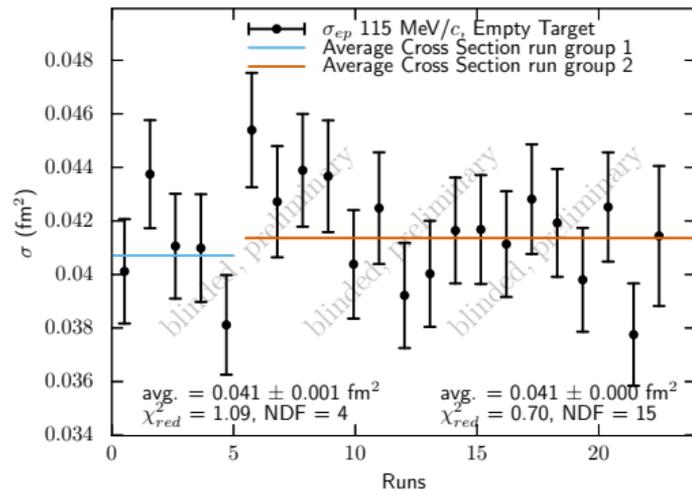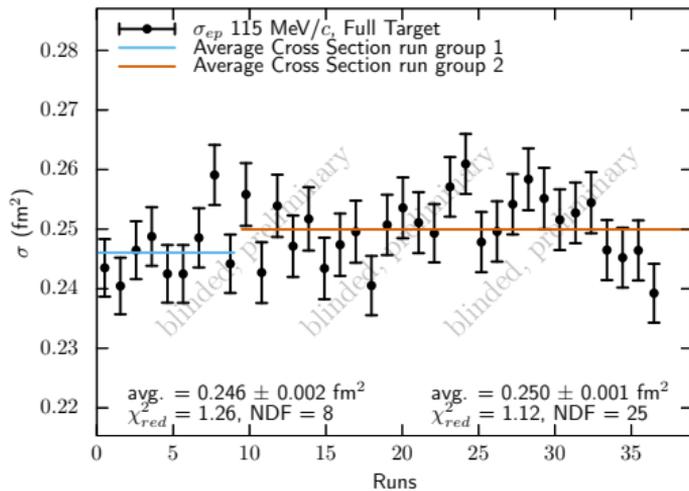
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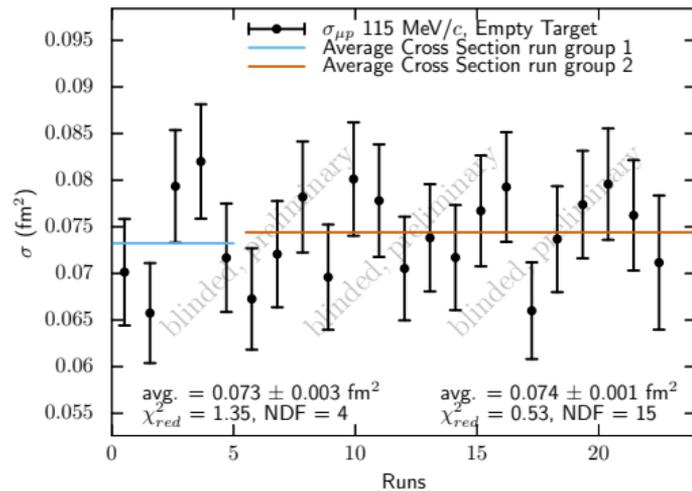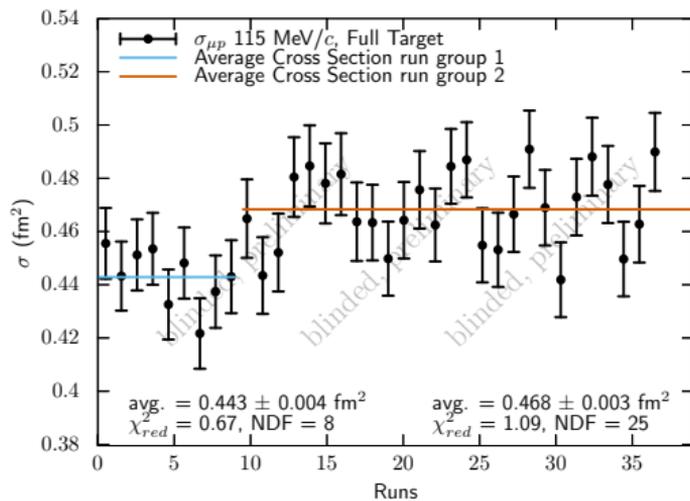
Integrated cross section vs run number used in analysis. **Left:** Full target *ep* 115 MeV/*c*. **Right:** Empty target *ep* 115 MeV/*c*

- 39 % of Full Target data from 2023 dataset

- 27 % of Empty Target data from 2023 dataset

Integrated cross section vs run number used in analysis. **Left:** Full target μp 115 MeV/c. **Right:** Empty target μp 115 MeV/c

- 39 % of Full Target data from 2023 dataset

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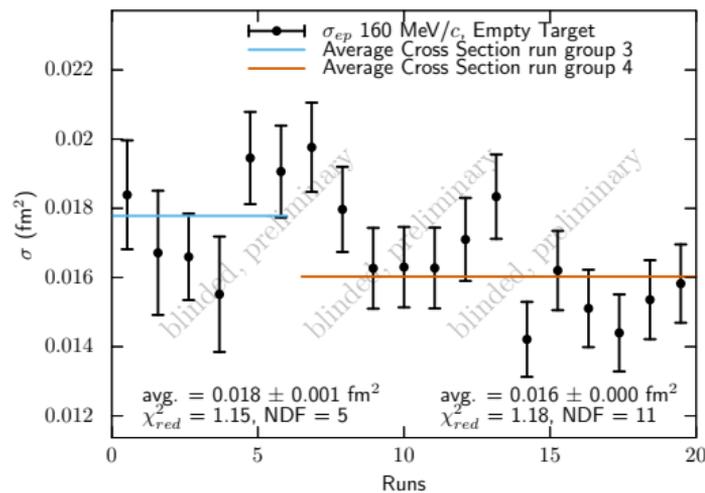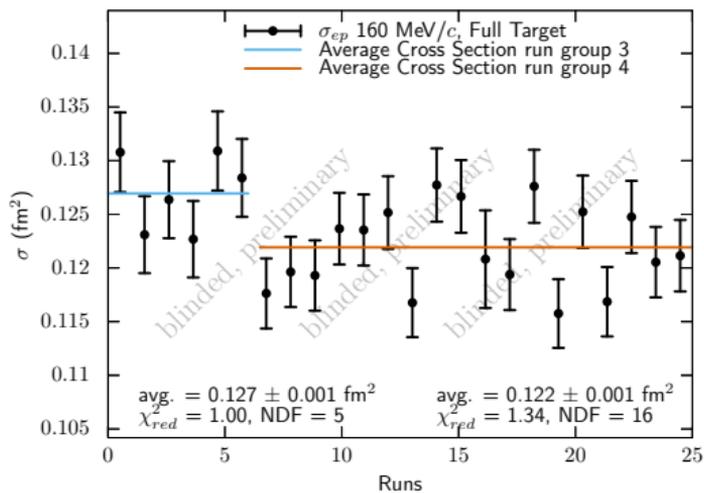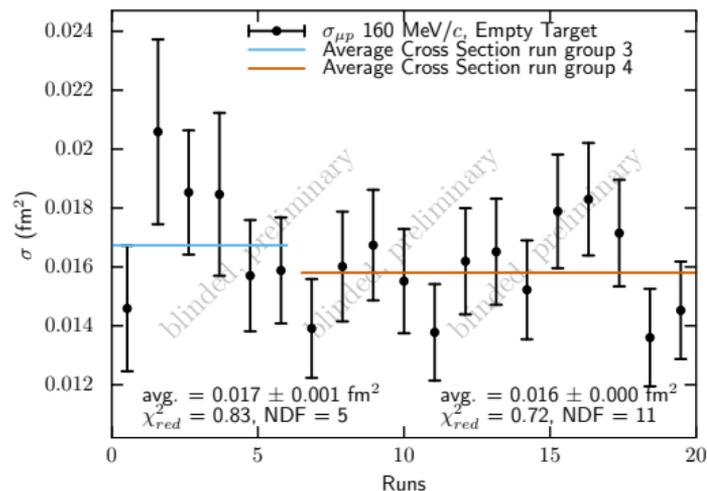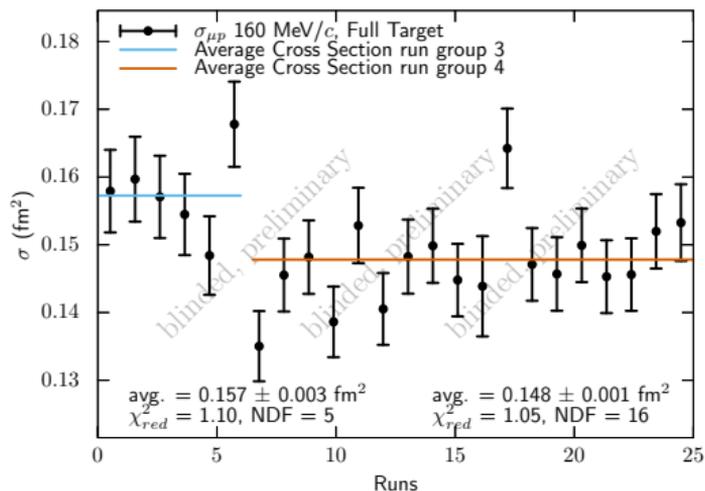# ep 160 MeV/c Total Cross Sections - New Analysis

Integrated cross section vs run number used in analysis. **Left:** Full target ep 160 MeV/c. **Right:** Empty target ep 160 MeV/c

- 19 % of Full Target data from 2023 dataset

- 18 % of Empty Target data from 2023 dataset

Integrated cross section vs run number used in analysis. **Left:** Full target μp 160 MeV/c. **Right:** Empty target μp 160 MeV/c

- 19 % of Full Target data from 2023 dataset

- 18 % of Empty Target data from 2023 dataset

Summary

- Have extracted blinded "traditional" cross sections from $e^{\pm}p$ and $\mu^{\pm}p$ scattering at 115 and 160 MeV/c

- Good agreement between data and simulation, comparison limited by blinding and normalization uncertainties

- Initial look at point-to-point systematic uncertainties
  - Appears purely statistical within a run group
  - Average offset between run groups 3-4 % – needs study

- TCPV, fiducial, β_{out}, and TOF cuts suppress background
  - Exact background subtraction requires MC, agreement in good shape at this stage

- Analysis work and development ongoing