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Status of the Measurement of Proton Scattering on Carbon Nuclei in EMPHATIC for Neutrino Flux Uncertainty Reduction

Robert Chirco, Illinois Institute of Technology, Chicago, IL, USA[1]
For the EMPHATIC Collaboration

ILLINOIS TECH

Motivation

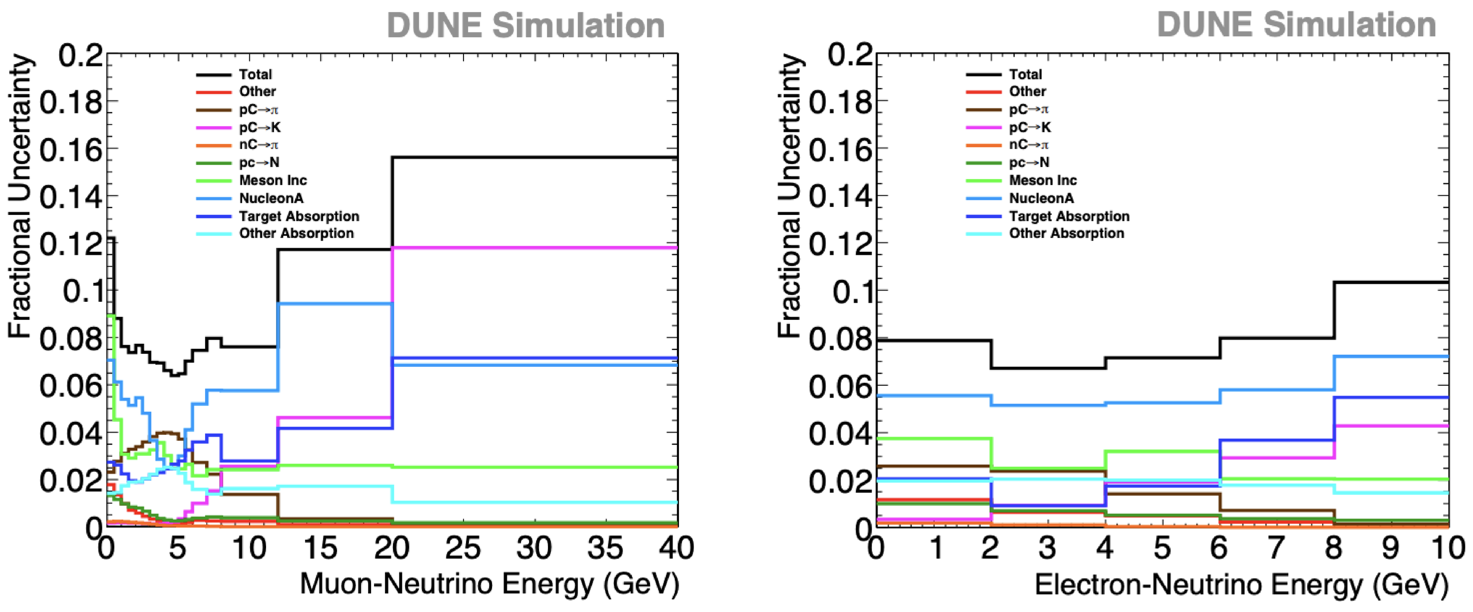

Figure 1: Fractional uncertainties on the DUNE flux calculation due to different hadron production uncertainties (produced independently of DUNE).

Hadron production uncertainties are the dominant systematic uncertainty in neutrino flux predictions. New hadron production data are needed to improve the physics reach of current and future GeV-scale neutrino experiments.

EMPHATIC

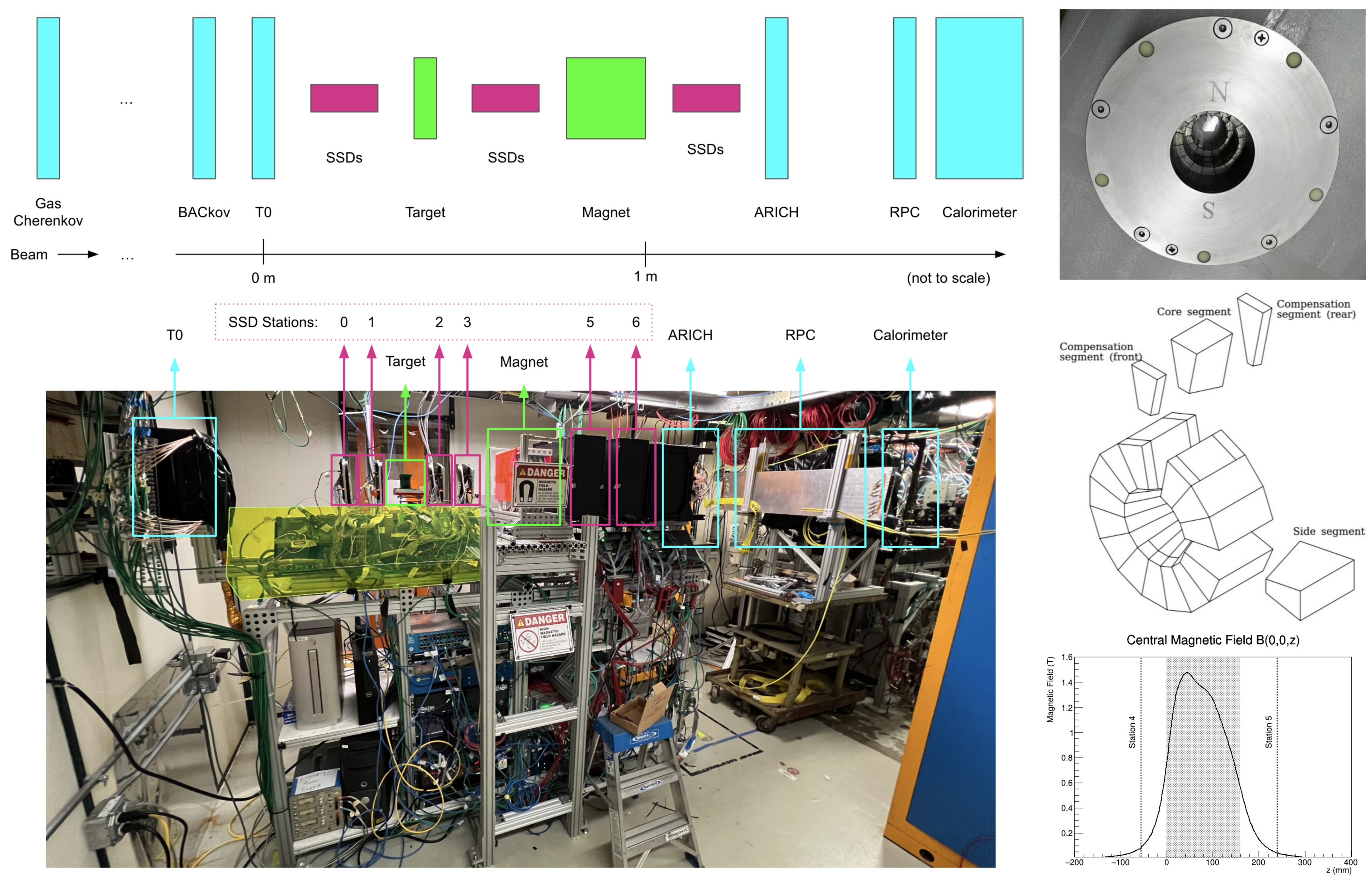

Figure 2: The EMPHATIC spectrometer and magnet details

- Experiment to Measure the Production of Hadrons At a Test-beam In Chicagoland → table-top-sized spectrometer (< 2 m in length)
- Precise measurements of hadron scattering and production cross sections at 2-120 GeV/c and various target species
- Silicon strip detectors (SSDs) for precise tracking with a resolution of $\approx 17.3\ \mu m$ for a 60 μm strip
- Permanent magnet (B_{max} = 1.44 T) provides an asymmetric dipole field
- Upstream PID: gas Cherenkov detectors, beam aerogel Cherenkov (BACkov) detector
- Downstream PID: A compact aerogel ring imaging Cherenkov (ARICH) detector, a time-of-fight (ToF) system, and a lead-glass calorimeter
- The angular acceptance is approximately 100 mrad for Phase 1

3D Space Point Reconstruction

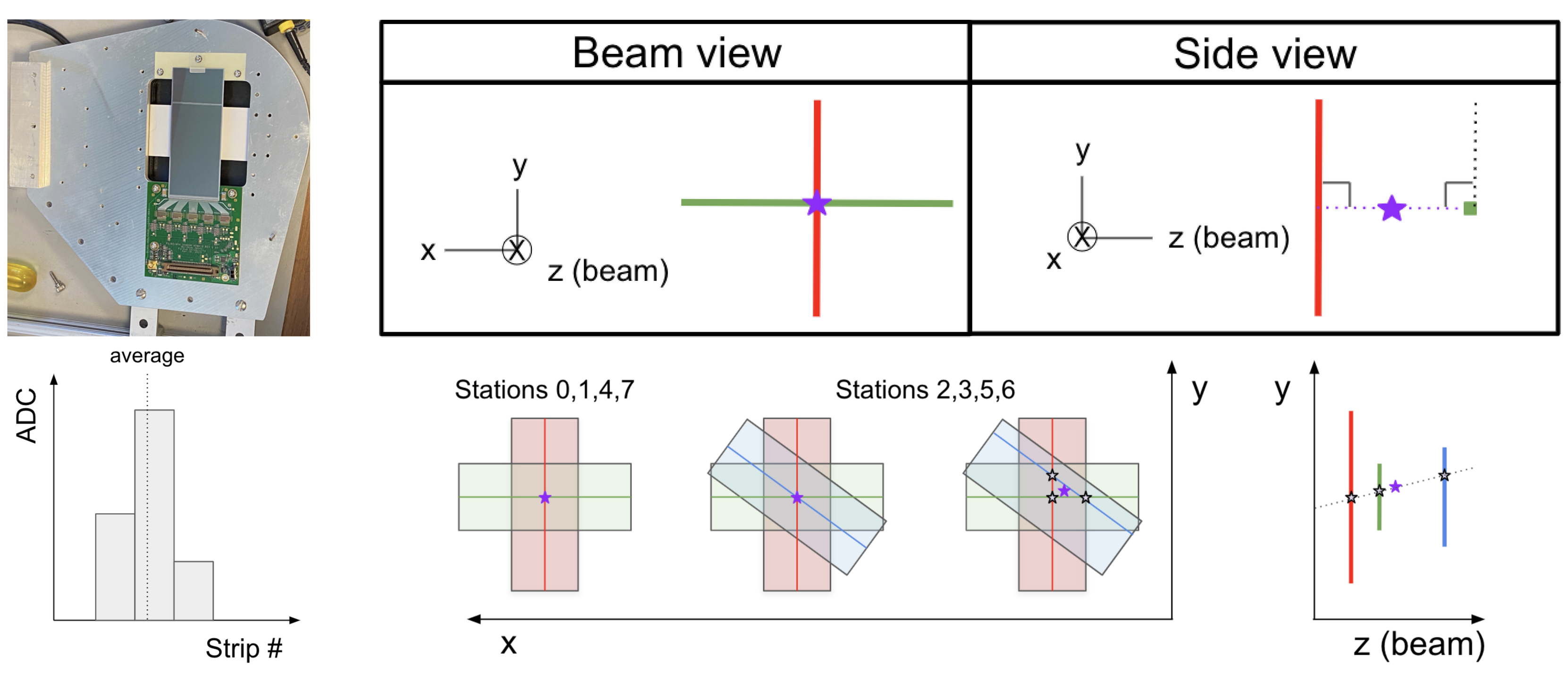

Figure 3: Calculating a 3D space point (shown in purple)

- Create groups of contiguous strips on a sensor that register a signal, find the weighted average position, and form a line segment
- Find the point of closest approach of each line segment to the other segment(s) within a "station" (set of 2 or 3 sensors, shown in Fig. 3)
- Take the average position of the points to create a 3D space point

Momentum and Track Reconstruction

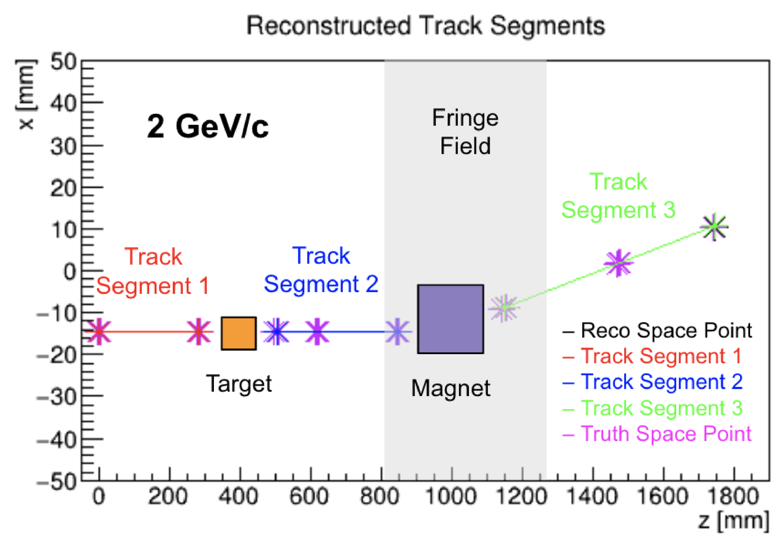

Figure 4: Track segment reconstruction

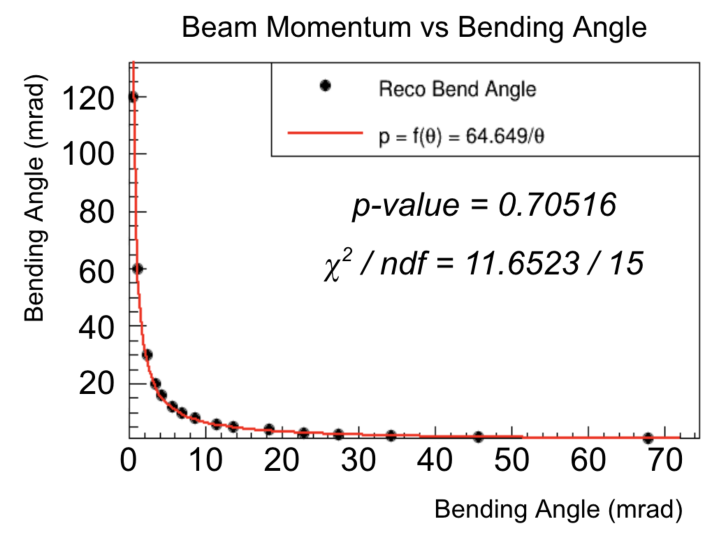

Figure 5: Momentum Reconstruction

- Form straight-line track segments by fitting 3D space points in three regions:
  (1) upstream of the target
  (2) between the target and magnet
  (3) downstream of the magnet
- The angular difference between track segments 1 and 2 gives the scattering angle, while that between track segments 2 and 3 give the bending angle (and therefore reconstructed momentum)
- Studied the bend angle as a function of momentum using a measured magnetic field map → extract momentum $p(\theta_{bend})$ from the curve in Fig. 5 and construct two tracks:
  (1) p_{inc} + vertex from track segment 1
  (2) $p(\theta_{bend})$ + vertex calculated from the intersection of track segments 1 and 2

Bias and Resolution

- Fringe field extends beyond the magnet to stations 4 and 5 → observe some bias in track segments 2 and 3
- At lower momentum, the bias is significant but will be corrected with a more sophisticated function
- Scattering angle resolution is better than 36.5% and bending angle resolution is better than 2.6%

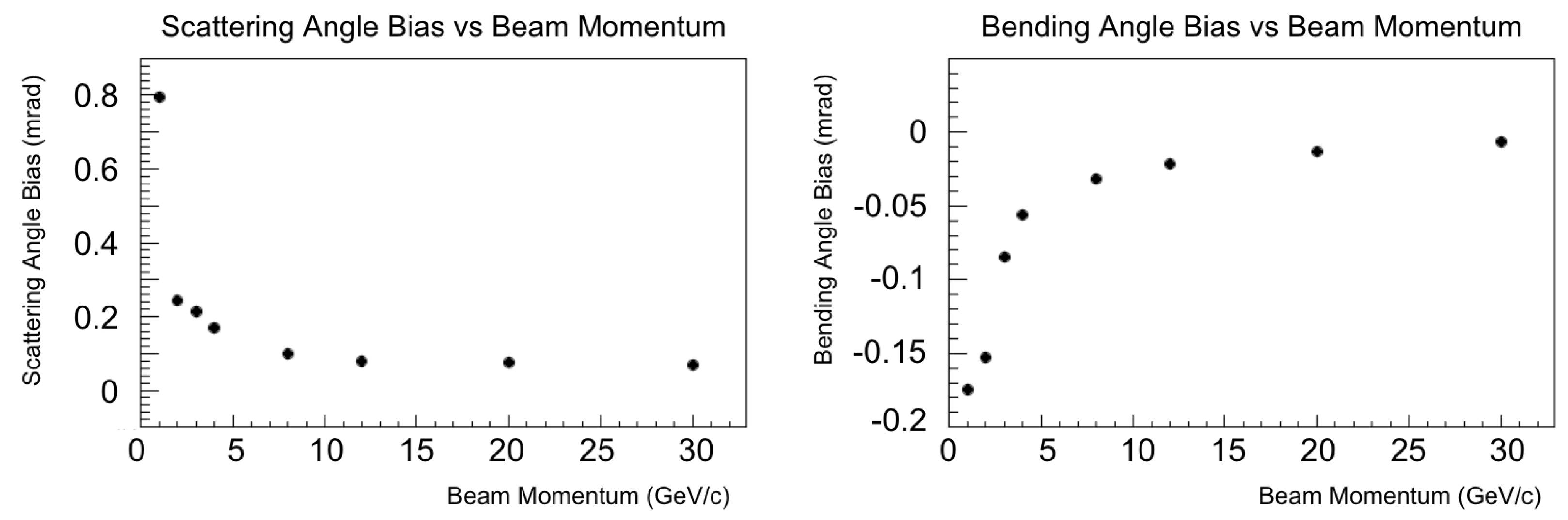

Figure 6: Scattering and bending angle biases

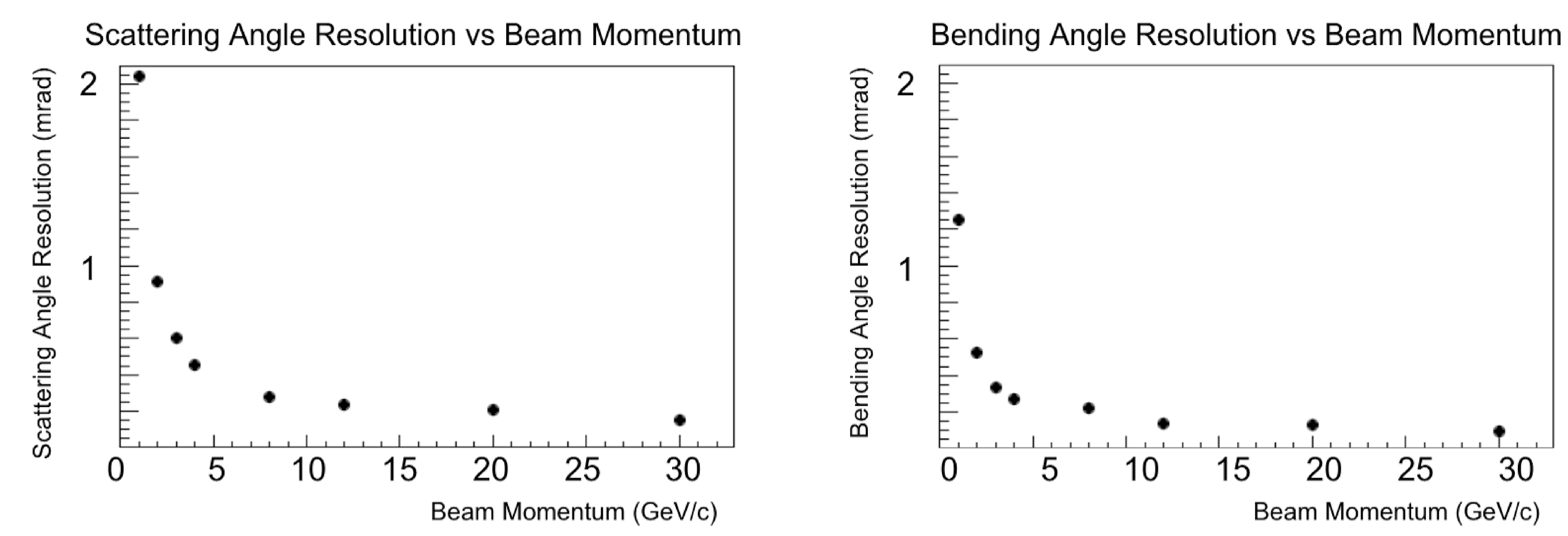

Figure 7: Scattering and bending angle resolutions

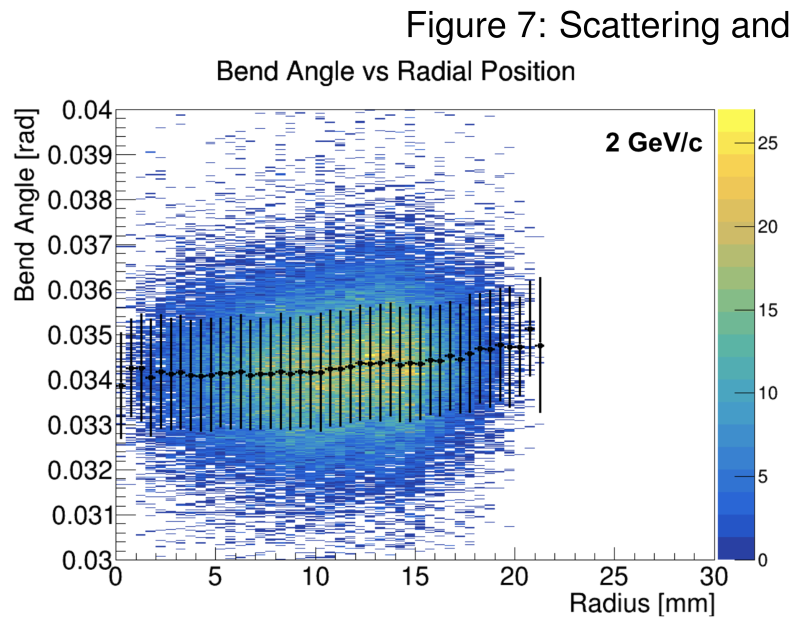

Figure 8: Bend Angle is consistent over radial position

A study was performed to assess the impact of the non-uniformity of the magnetic field on the reconstructed momentum, where the effect was found to be about 3%.

Summary

- Developed an algorithm to reconstruct momentum and scattering angle from particles going through the spectrometer and tested it on simulation
- Need to complete detector alignment and assess systemic uncertainties before looking at data
- Make a new single-track forward scattering measurement (p + C → p + C at several beam momenta)

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