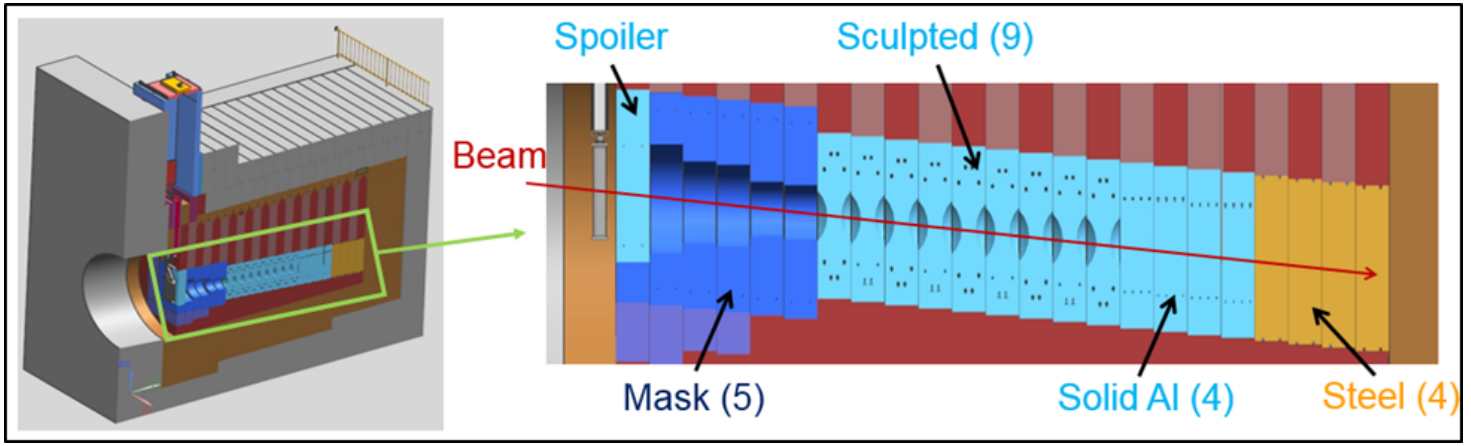
Muon Monitoring Simulations

Jeremy Lopez
University of Colorado
30 June 2016

Beam Geometry

- Recommended optimized beam setup
- 3 Horns, ~300 kA
- 2 m long NuMI-style target (rectangular cross section graphite)
- Baffle ID = 13 mm, target width (thin direction) slightly wider – no space for beam to miss all material
- Beam energies – optimized value is ~62 GeV, also looking at 80, 120 GeV

Absorber Geometry

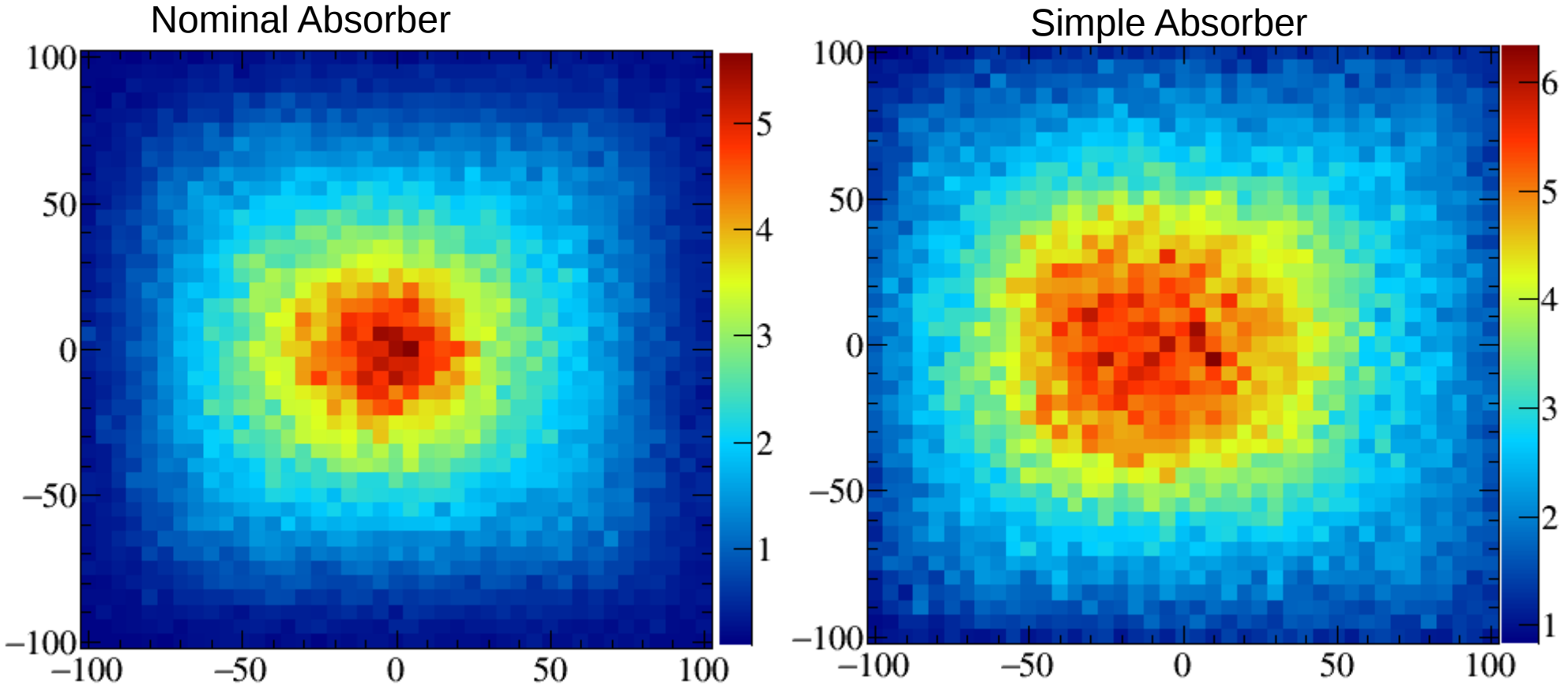


- Nominal Absorber: This design (implemented in G4LBNF by Paul Lebrun
- “Simple Absorber:” Remove spoiler, mask (replace with air volumes), remove sculpting (solid Al blocks), expand core to 2.8 m x 2.8 m.

Reconstructing the Mean X Position

- Raw measurement is 2D distribution of energy loss
- Several options
  - Get mean of full 2D distribution
  - Fit 2D distribution
  - Take 1D projection near y = 0 and get mean
  - Take 1D projection near y = 0 and fit to extract mean
- Note: If values can be guaranteed to be positive, a Gaussian fit (probably 1D or 2D) can be implemented as a matrix operation (I think)

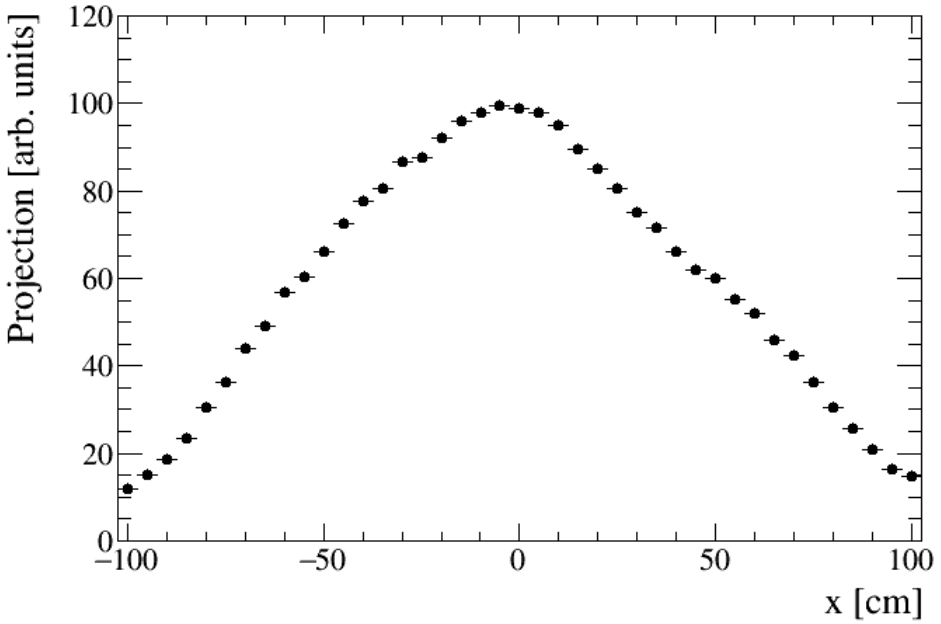
Example: x Shifted 2 mm Off Target



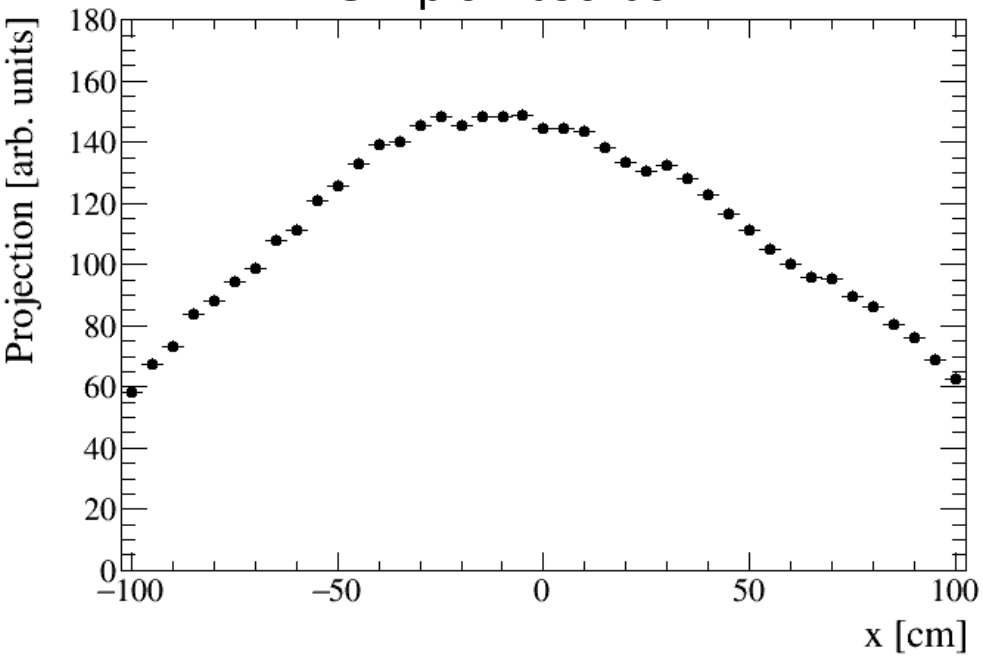
- Shift quite obvious for simple absorber, less clear for nominal

Full Projection of 2D Histograms

Nominal Absorber

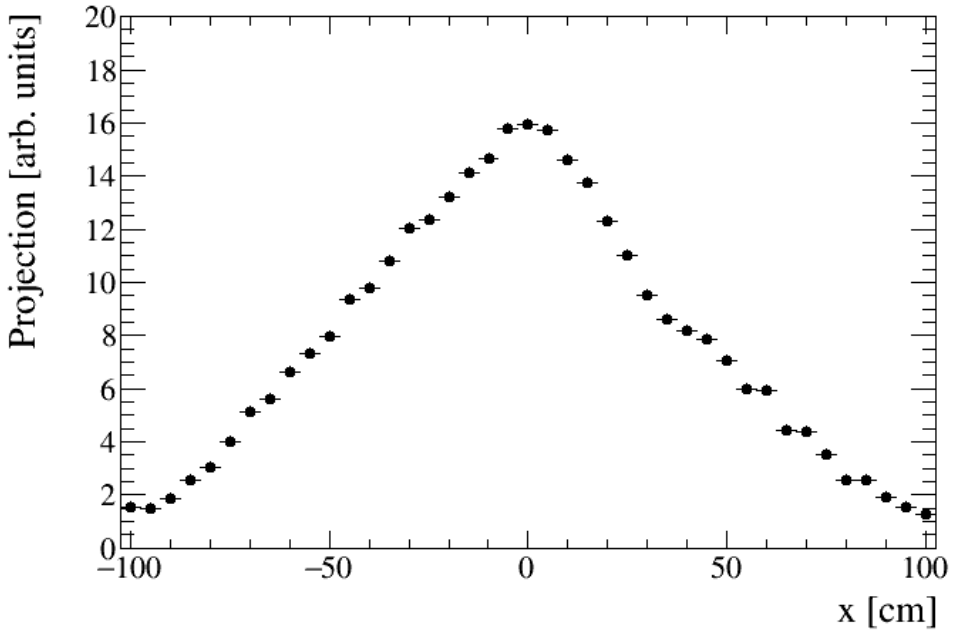


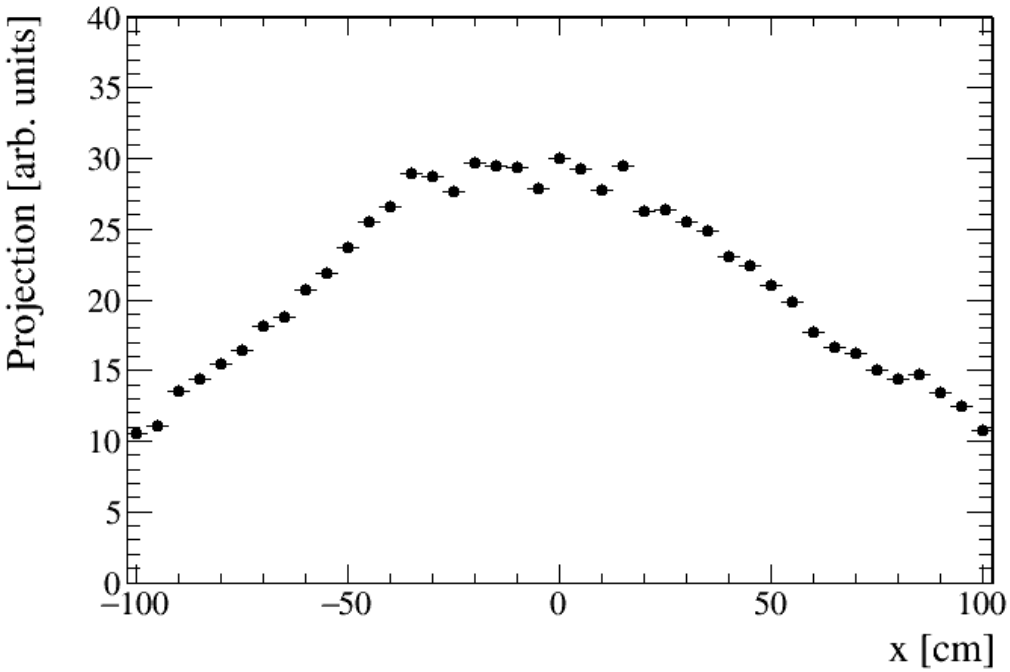
Simple Absorber



- Peak still at/near 0 in nominal case, with asymmetries away from the peak
- Peak clearlly shifted in simple case

Restricted 1D Projection: |y| < 7.5 cm

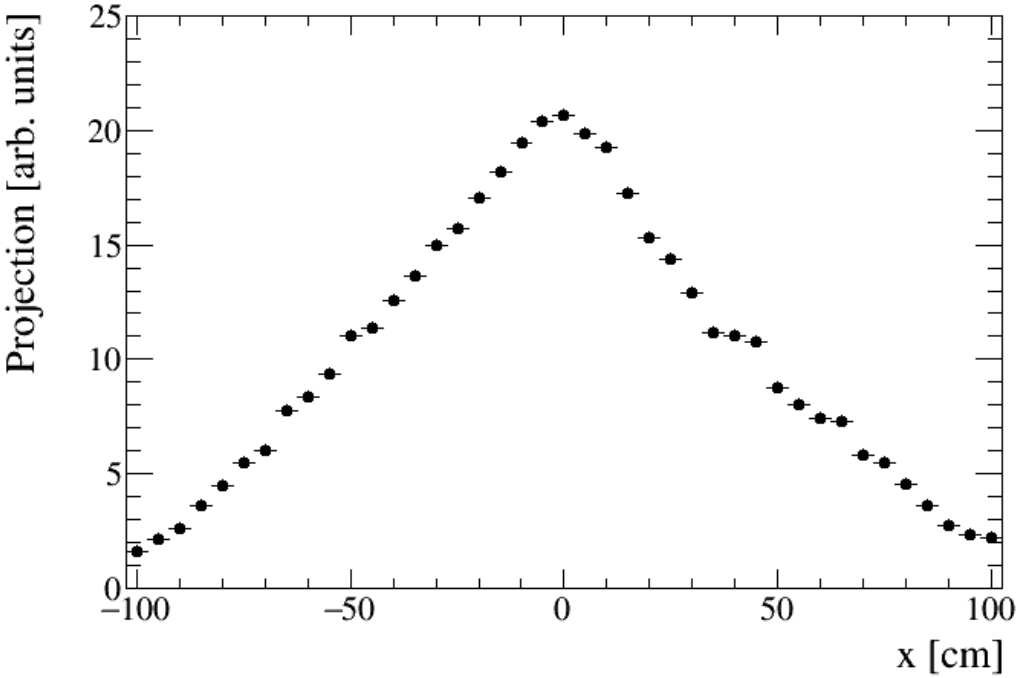




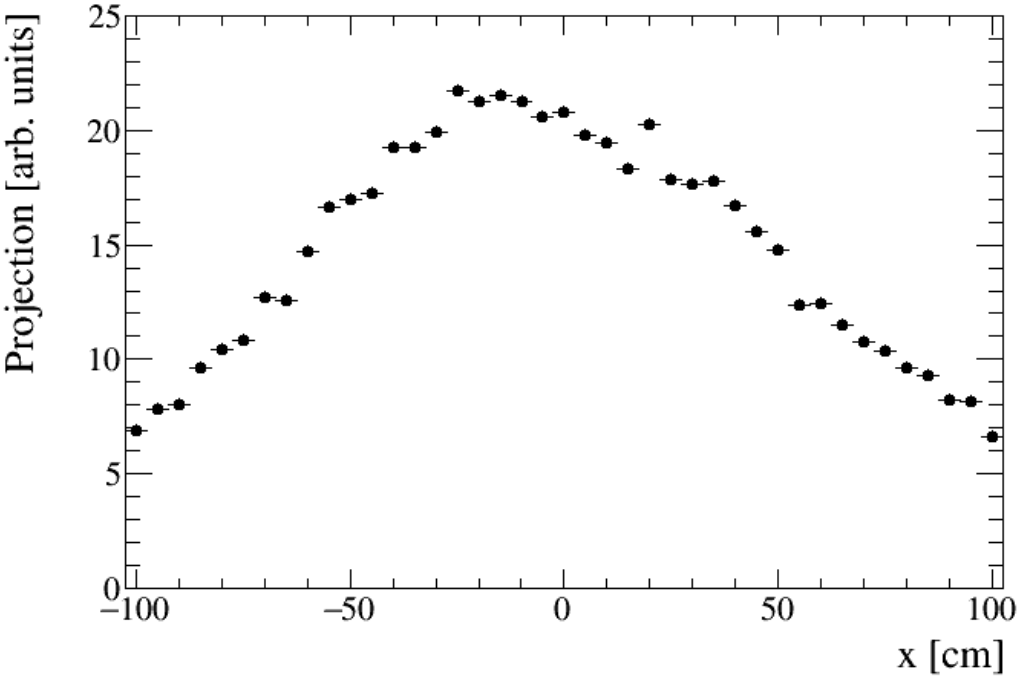
- Peak at 0 for nominal case, complicated shape shows asymmetry
- Much more obvious shift in simple absorber

2 mm Shift in x, 80 GeV

Nominal Absorber

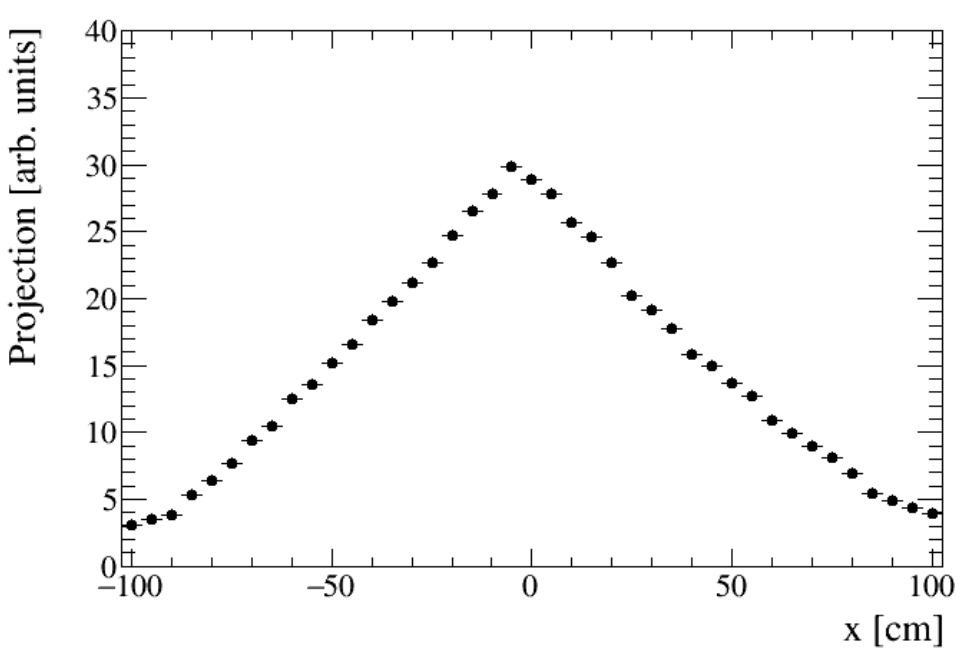


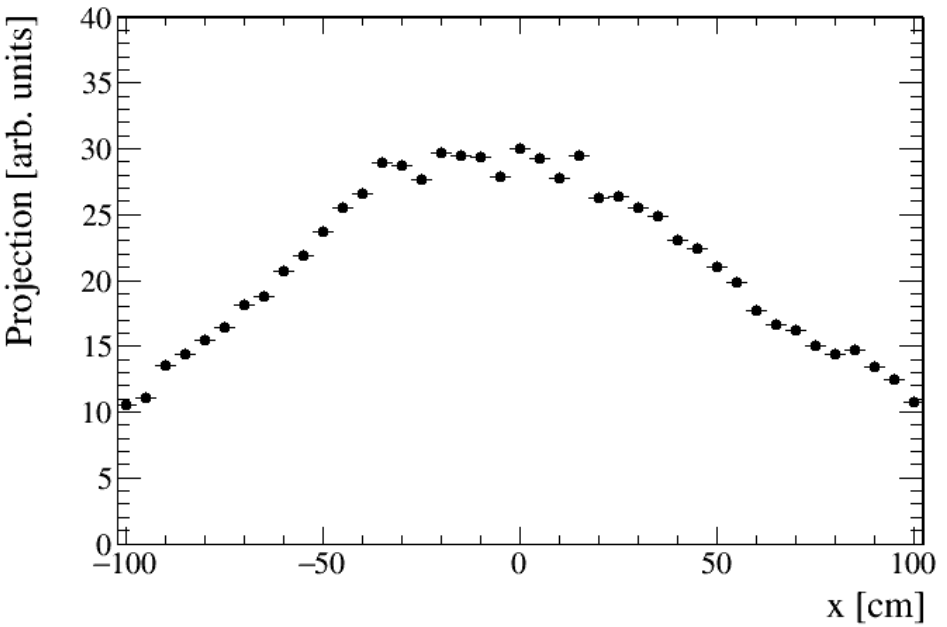
Simple Absorber



- Restricted 1D projection
- Larger overall flux, small shape differences

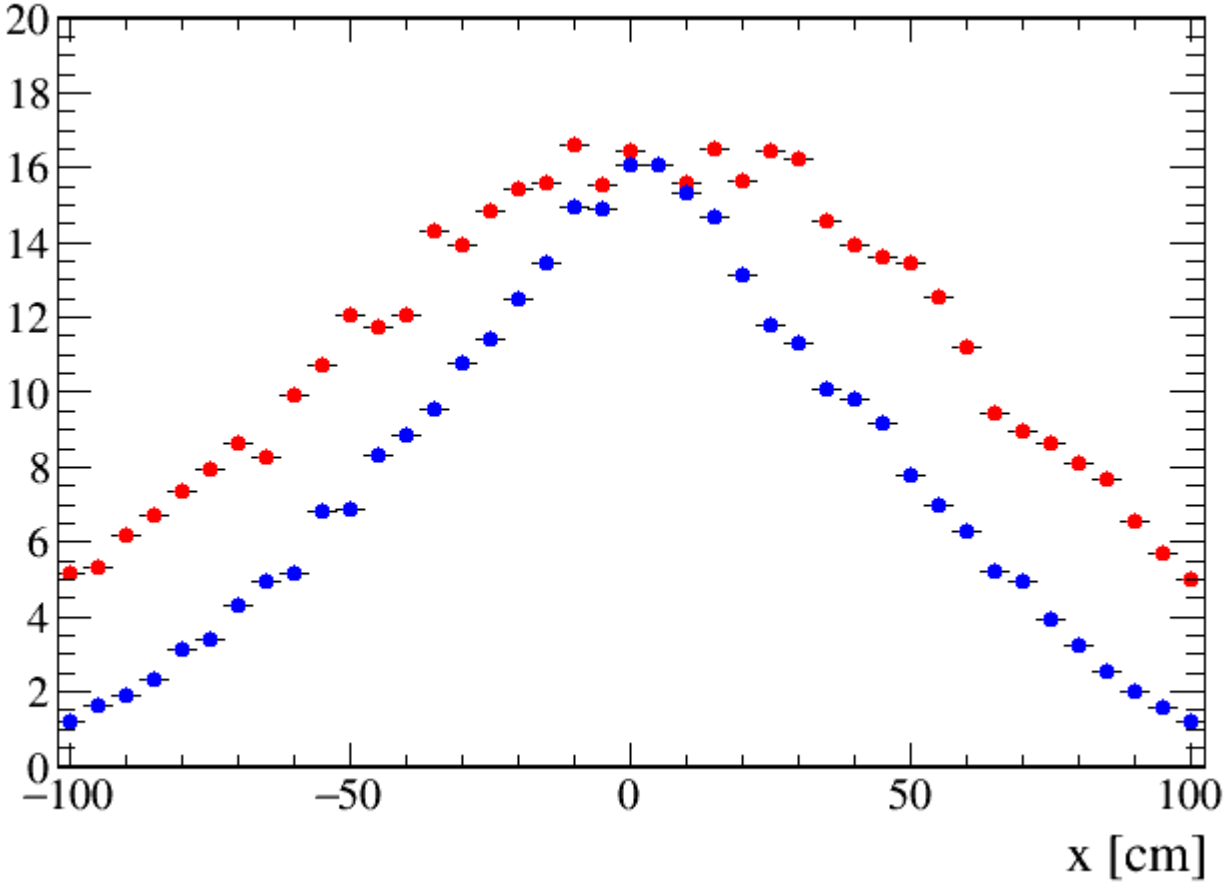
2 mm Shift in x, 120 GeV





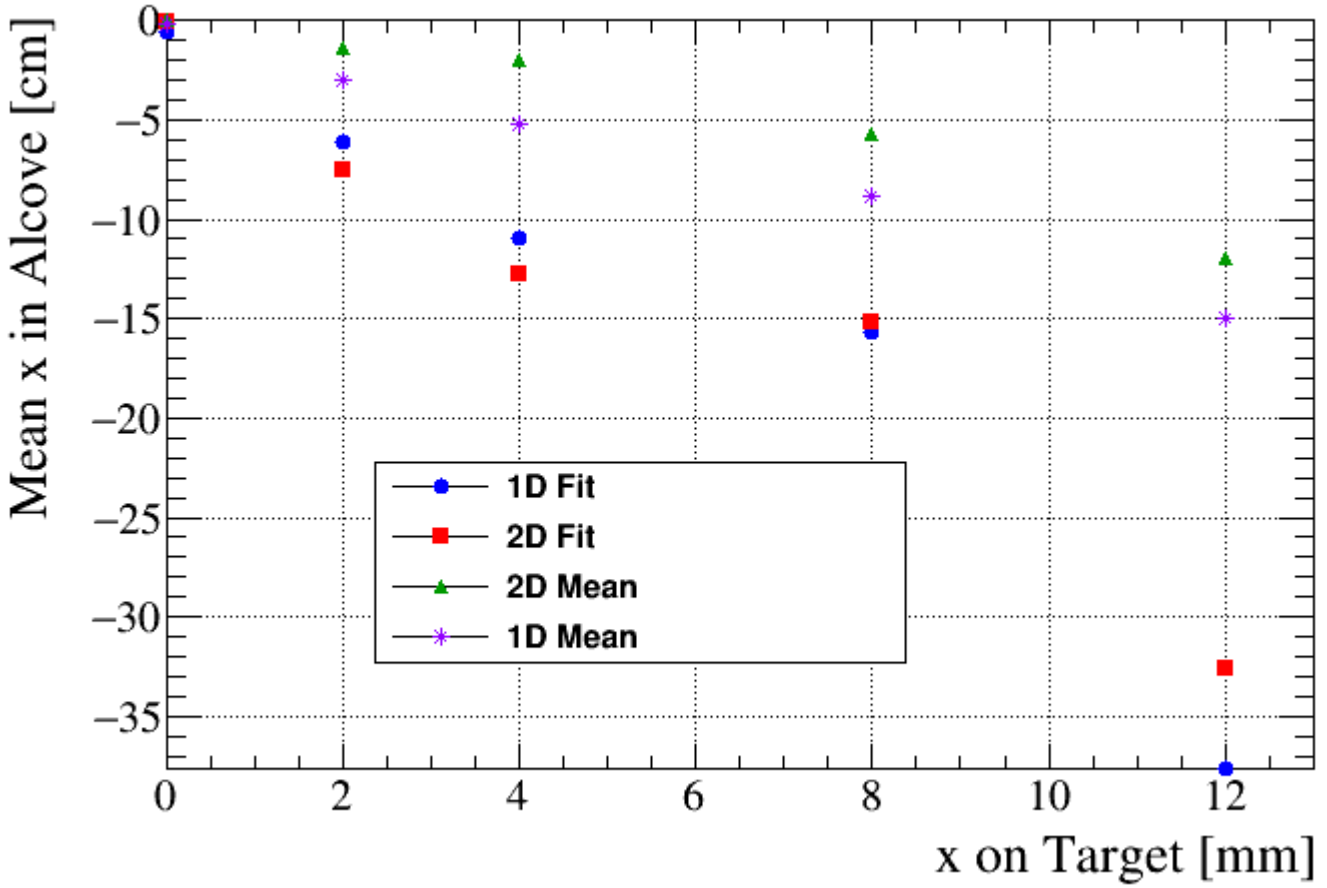
- Current position methods get somewhat less sensitive to position changes as the energy increases

Horn 2 Shift in x by 5 mm



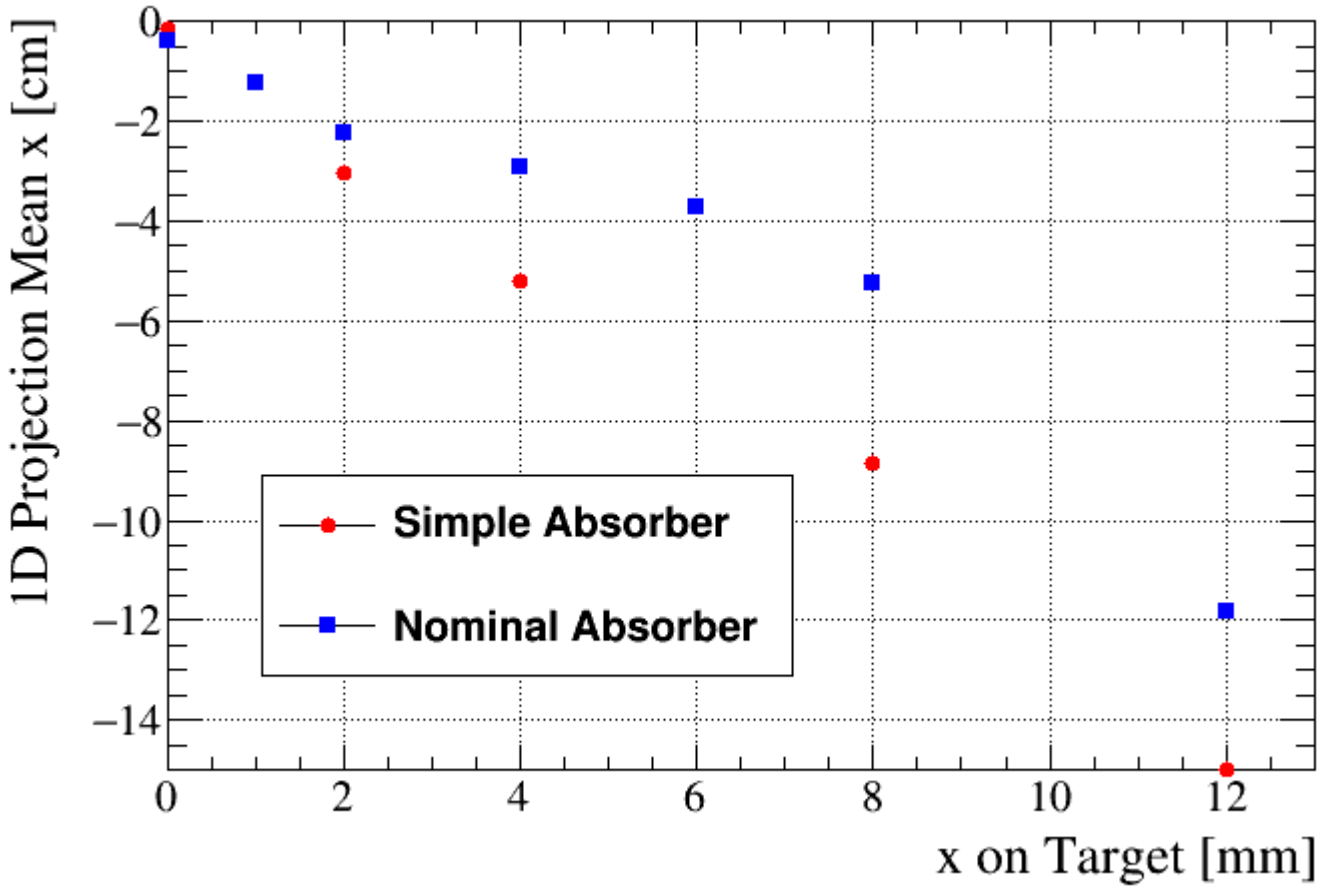
- Small asymmetry present but hard to see. Get ~4 cm in a fit for the simple absorber (red) and ~2 cm for nominal (blue)

Different Mean Reconstruction Options: X Scan on Target



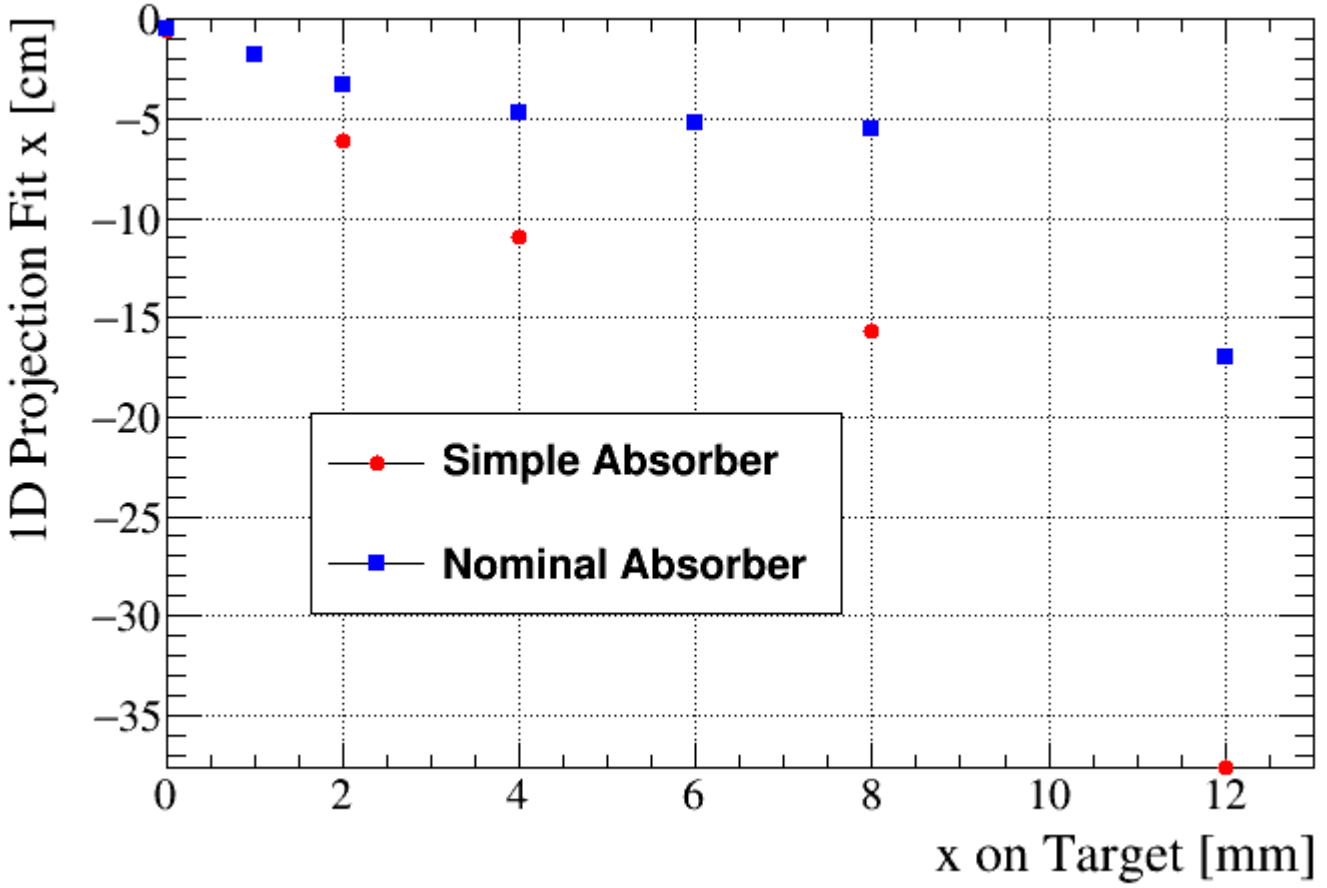
- Gaussian fits look much more sensitive than histogram means
- 2D = full projection, 1D = restricted projection

Absorber Comparison: Restricted Projection Mean x



- Value here highly dependent on array geometry

Absorber Comparison: Restricted Projection Fit X



- Could maybe improve further with a better fit function (lognormal?)

Conclusions

- Pattern generally seems to hold for y scans, horn shifts
- Current absorber design reduces sensitivity to position shifts by roughly a factor of 2 in an idealized case
- Most evident if we try to fit the data, but still clear with basic histogram statistics
- May be worse with a realistic array of detectors due to shape of distribution (peak at 0 with asymmetry away from center vs. clearly shifted center for a simple absorber)