Global Reconstruction Update

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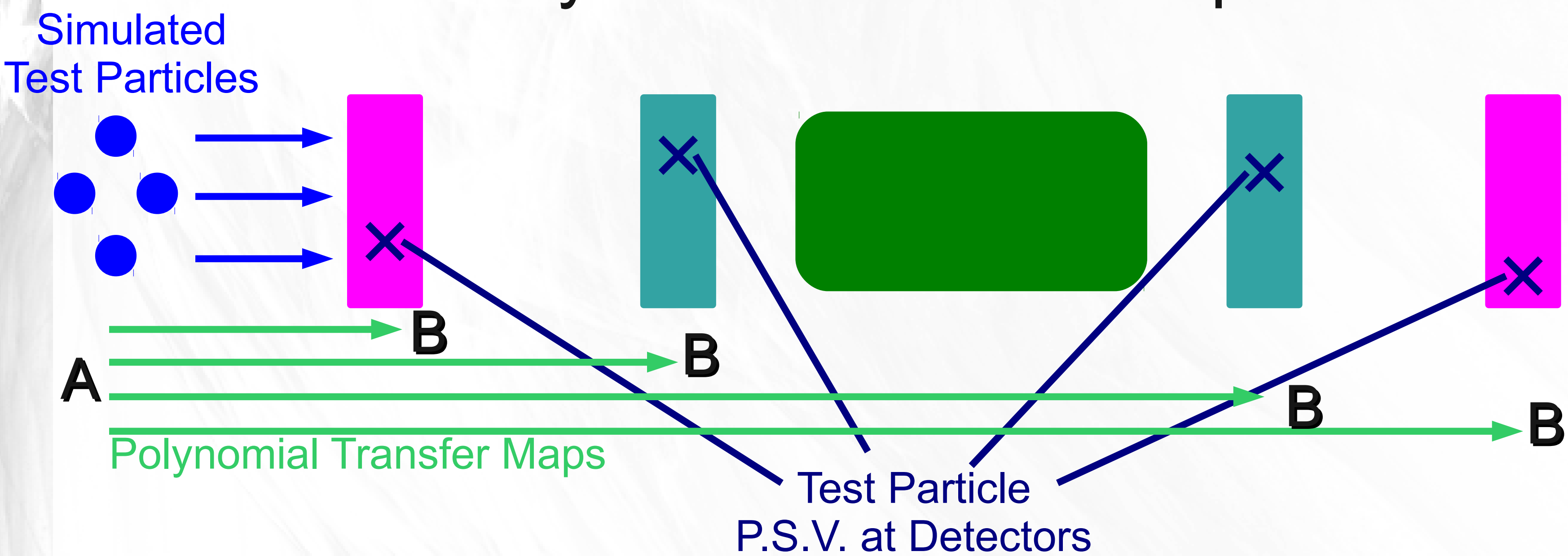
MICE Collaboration Meeting 36

Outline

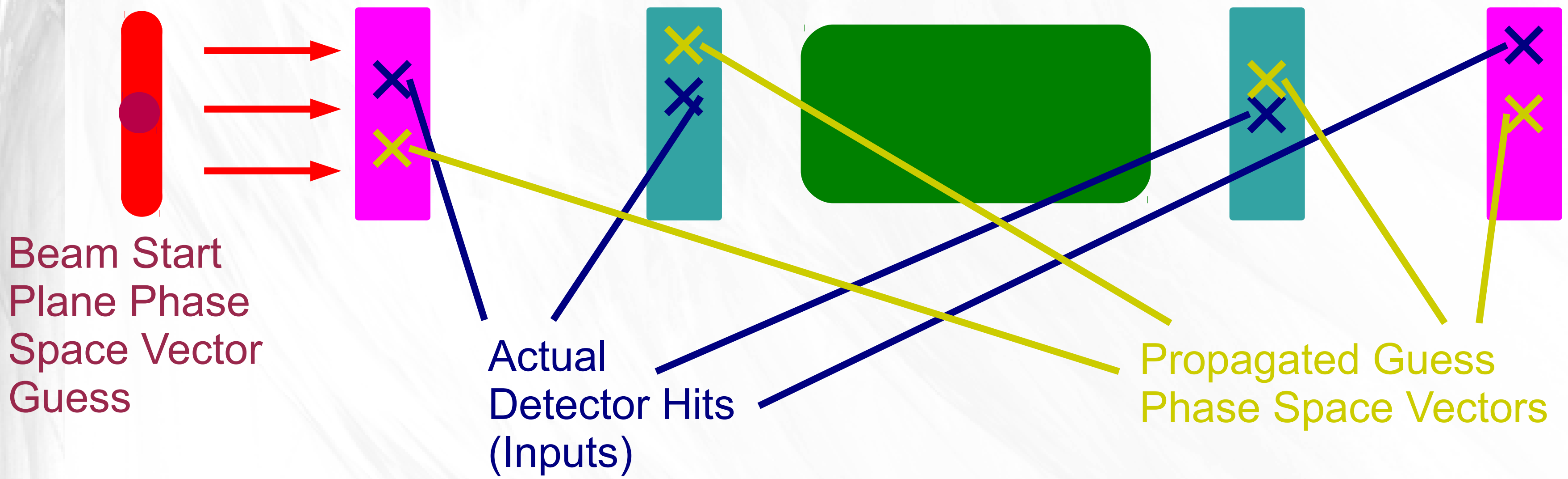
- Background/Prior Progress
- Current Progress
- Drift Reconstruction Results
- Conclusions
- Next Steps

Background:
Polynomial Transfer Maps



- Expand initial P.S.V. (t, E, x, Px, y, Py) of test particles into terms of a polynomial: $\mathbf{A}_i$ = (1, t, ..., t^2, tE, ..., py^2)$_i$
- **B** are the matrices formed from the P.S.V. at detector centers
- Solve the matrix equation $\mathbf{B} = \mathbf{A}\, C^T \rightarrow C^T = (\mathbf{A}^T \mathbf{A})^{-1} \mathbf{A}^T \mathbf{B}$
  - For N linearly independent inputs, N = # polynomial terms
- C is a coefficient matrix for polynomials that describe the evolution of the phase space coordinates
  - Transport phase space vectors with $\mathbf{b} = C\, \mathbf{a}$

Background:
Track Fitting Algorithm



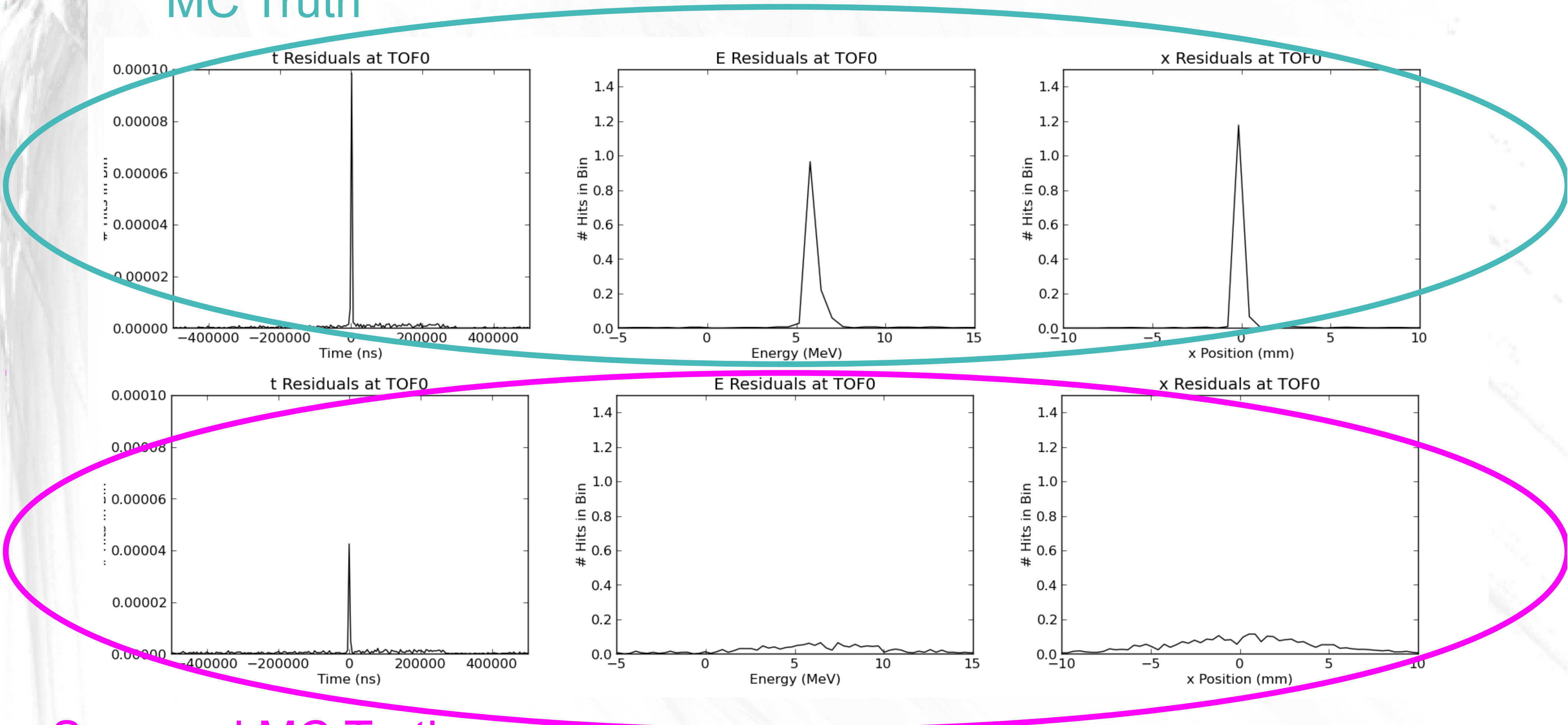
- Find initial phase space vector that minimizes χ^2 -- the sum of the squares of the differences between the propagated guesses (Outputs) and the detector hits (Inputs).
    - weighted by the detectors' measurement uncertainties

Progress Prior to CM36:
Initial Fitting Tests

- Tested with moderate success on MC truth and smeared MC inputs
    - MC truth was a check on the fitting algorithm
    - Smeared MC simulated detector resolutions
    - Drift and single quad configurations
    - Verified the linear order transfer maps using COSY INFINITY transfer matrices
    - *CM34 track fitting output residuals plots*

Progress Prior to CM36:
Excerpt of CM34 Track Fitting Residual Plots

MC Truth



Smeared MC Truth

Progress Prior to CM36:
Framework and Data Structure

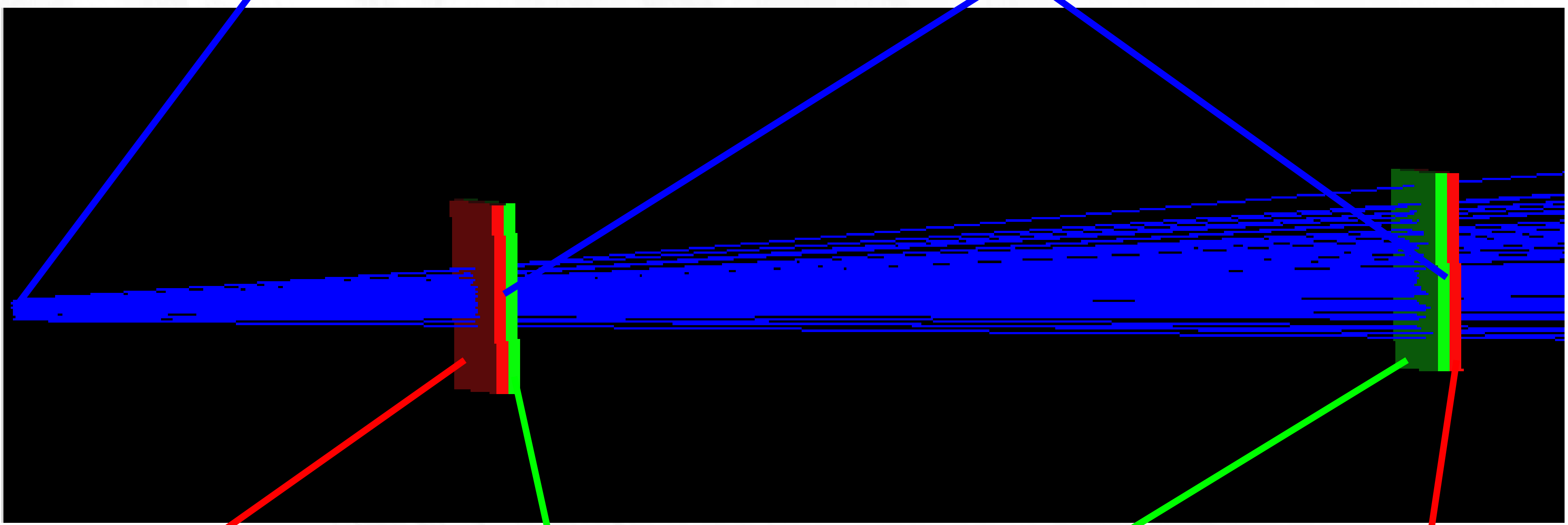
- Developed software framework for plugging in different optics models and fitting algorithms
  - *Optics models:* models used for generating transfer maps
    - Polynomial Approx., Runge-Kutta
  - *Fitting Algorithms:* χ^2 minimization, Kalman Filter
- Created flexible, simple to use data structure capable of storing complicated triggers and event topologies if needed.

Current Progress

- Using reconstructed detector data

  (“space points”) instead of smeared MC for track fitting inputs
- Using the new global recon data structure
- Verified track fitting inputs using a drift configuration of TOF0 and TOF1
- Improved/fixed track fitting algorithm
- *Compared track fit input (space points) residuals with output (reconstruction) residuals for a 1,000 particle run*

2 m Drift: TOF0 to TOF1



Initial distribution chosen to light up all TOF1 slabs.

Geometry and Longitudinal Beam Definition

- Fire 1000 muons 1m upstream of TOF0
  - No decays. Mean energy loss only. Air.
- 2m drift between centers of TOF0 and TOF1
  - 1.950 m of air in between two 25 mm thick TOF scintillator planes
- Longitudinal Parameters:
  - Gaussian distribution in Energy and Pz
  - Mean Pz: 200. MeV/c (Mean E: ~226. MeV)
  - σ_p: 25 MeV/c (MAUS default)

Transverse Beam Definition

- Transverse Parameters:
  - Gaussian x, Px, y, Py with means = 0
  - RMS Emittance (x & y): 0.1 π mm·rad
  - β_0 (x & y): 1000. mm / rad
  - α_0 (x & y): 2.

Initial dist. chosen to light up all TOF1 slabs

- σ_x = 10mm (arbitrary) and
- $3 \cdot \sigma_{x'}$ (99.73% of the particles) = $x'_{max} = \Delta x / \Delta z$

Caveats for Residuals

- Residuals: difference of p.s.v. and MC truth
- MC hits are registered by Geant4 when they enter the scintillating slab volume (upstream edge of TOF plane)
  - Use only plane 1 hit since z is at the center of the detector (same as space point z)
- Uncalibrated MC time stamps
  - MC t_0 is beam creation
  - Space point t_0 is calibrated trigger time
  - Slight offset in the mean of the input time residuals

Muon Drift Track Fitting Input

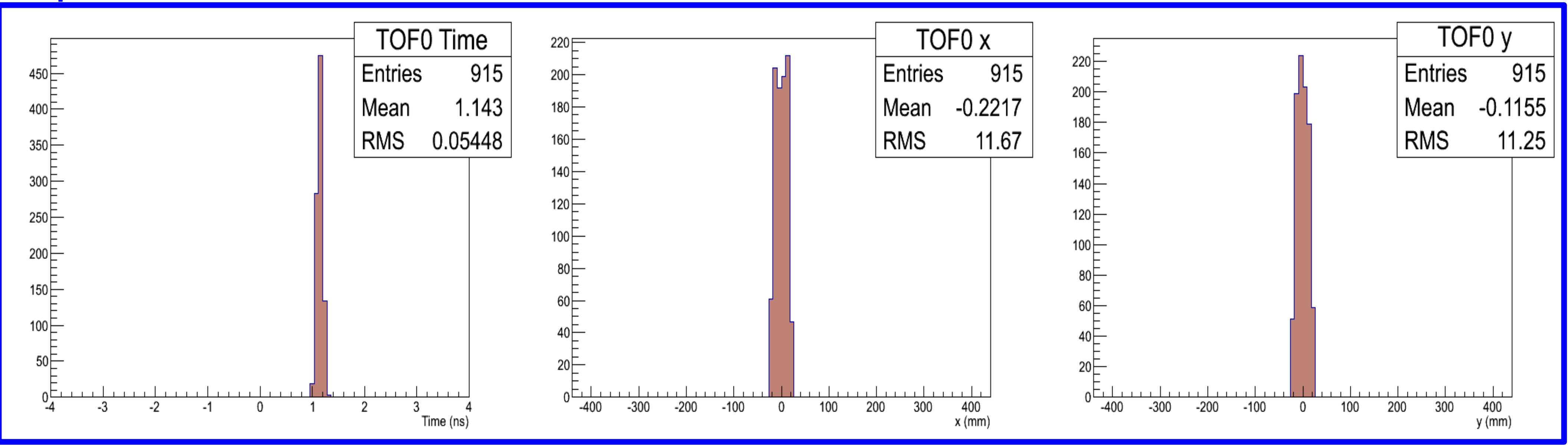
- TOF reconstruction gives time and pixel (ID of horiz. & vert. slabs that were hit)
  - pixel gives rough x & y
- Note: 8.5% reduction in particles from
  - Rejection of events with multiple plane hits (3.2%)
  - Hits on TOF pixels without valid trigger calibration (5.3%)
- Energy & momenta set to reference particle's since they are unknown
- *Generate residuals with MC truth to verify inputs are sane*

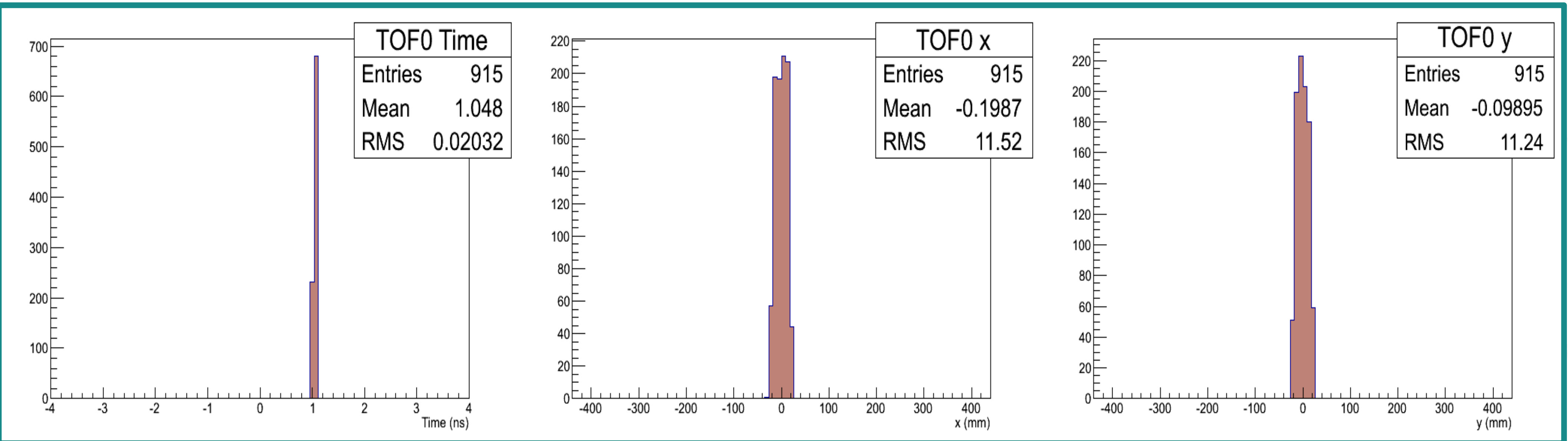
Muon Drift Track Fitting Output

- Using linear order polynomial transfer maps
- *Generate best fit track points with MC truth*

TOF 0 Input/Output Residuals 1

Input





Output

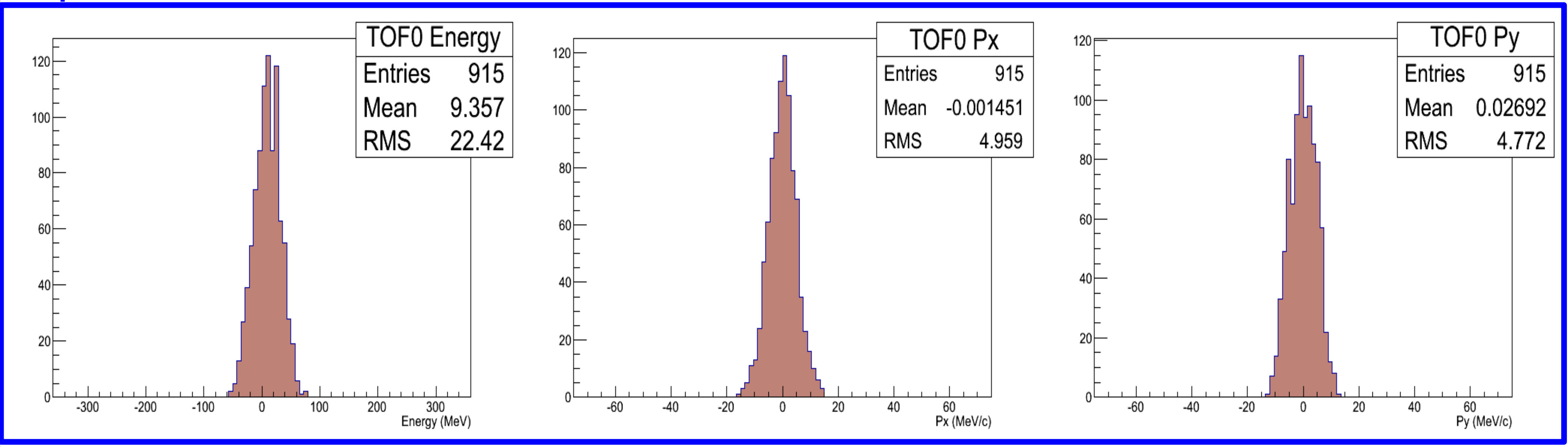
t res. = 55ps

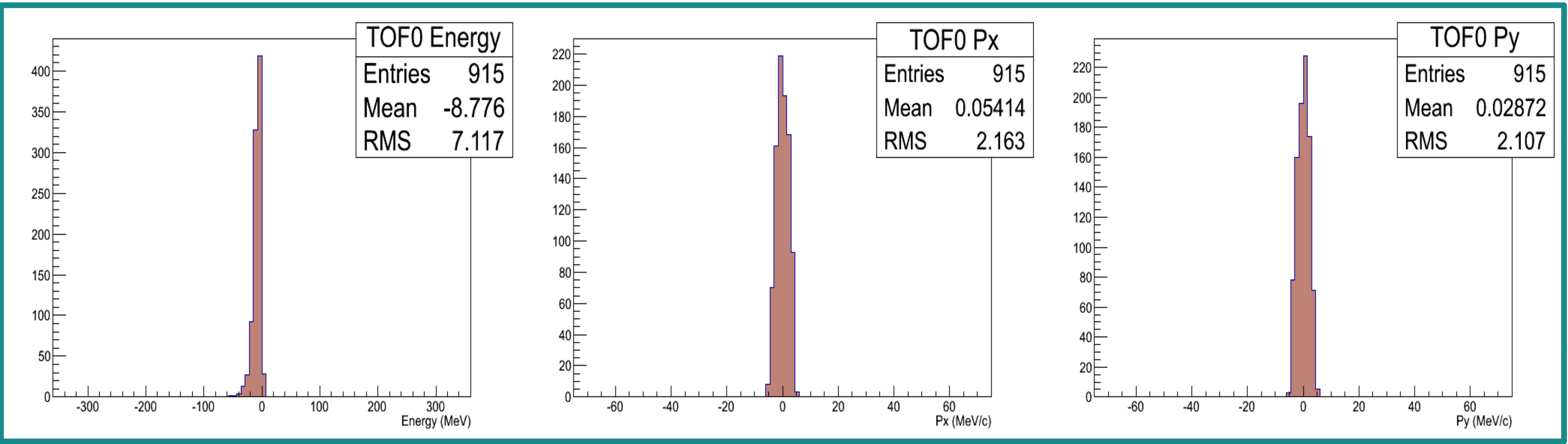
x res. = 11.55 mm

y res. = 11.55 mm

TOF 0 Input/Output Residuals 2

Input





Output

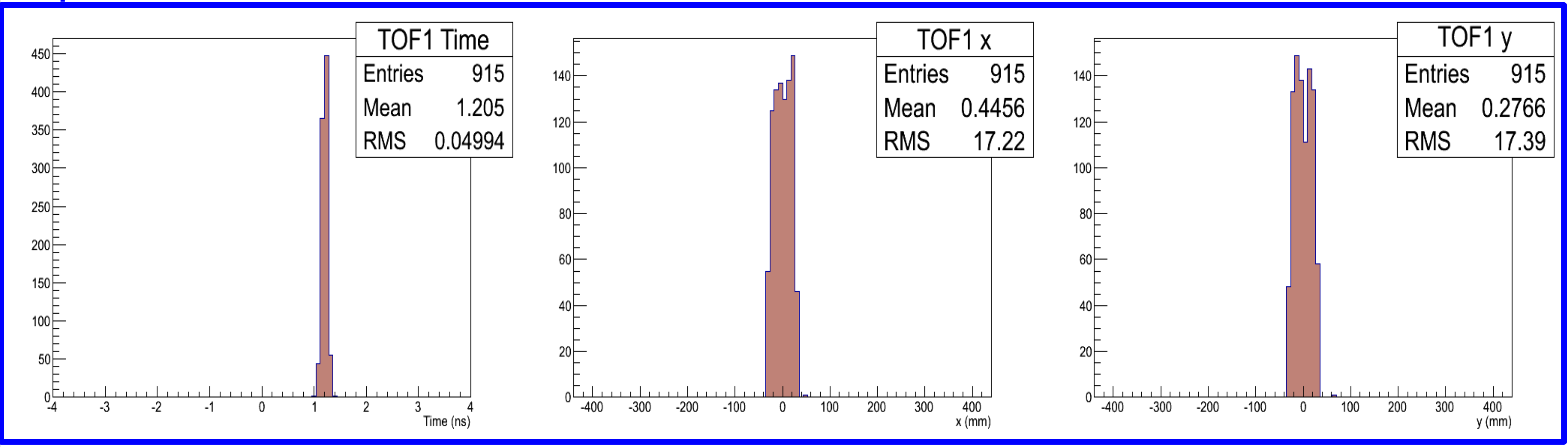
E res. ≈ 8 MeV

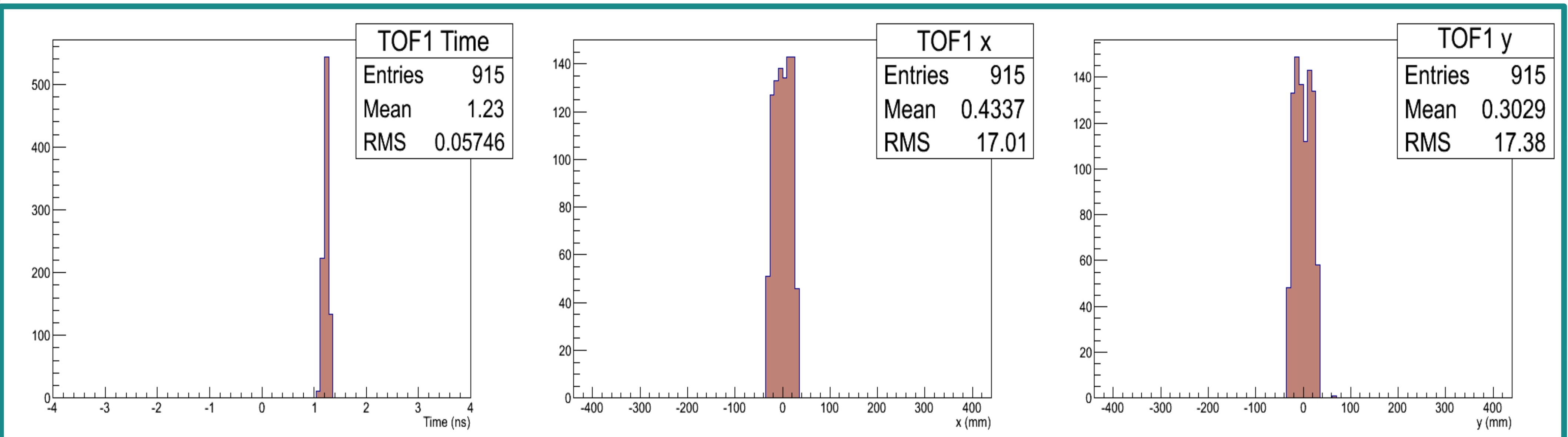
Px res. ≈ 1 MeV/c

Py res. ≈ 1 MeV/c

TOF 1 Input/Output Residuals 1

Input





Output

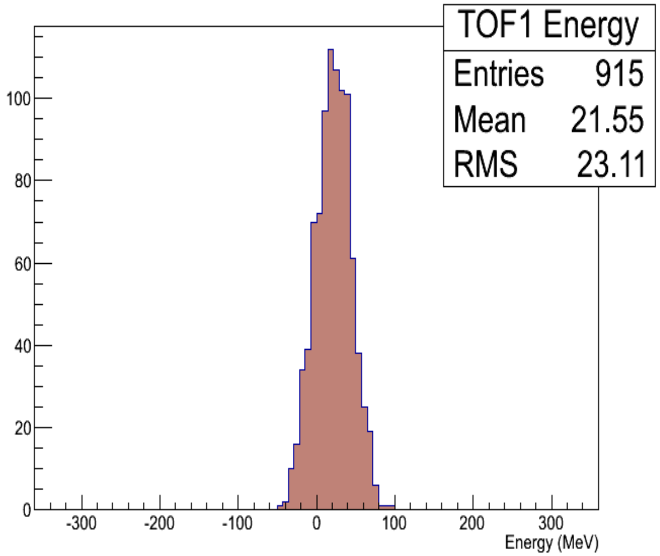
t res. = 53ps

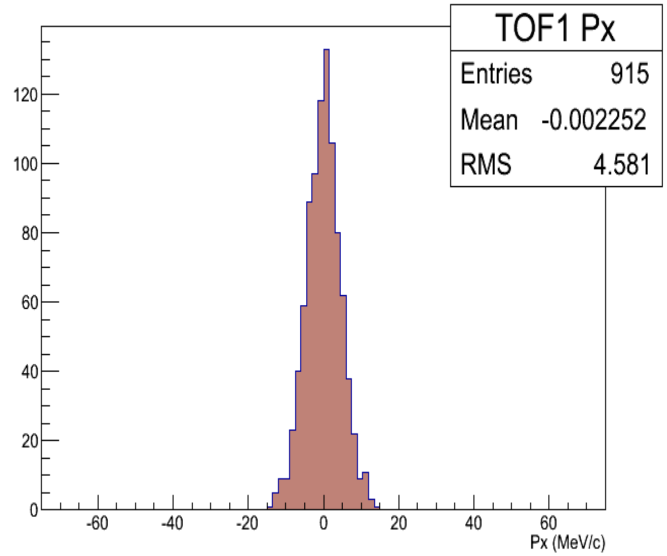
x res. = 17.32 mm

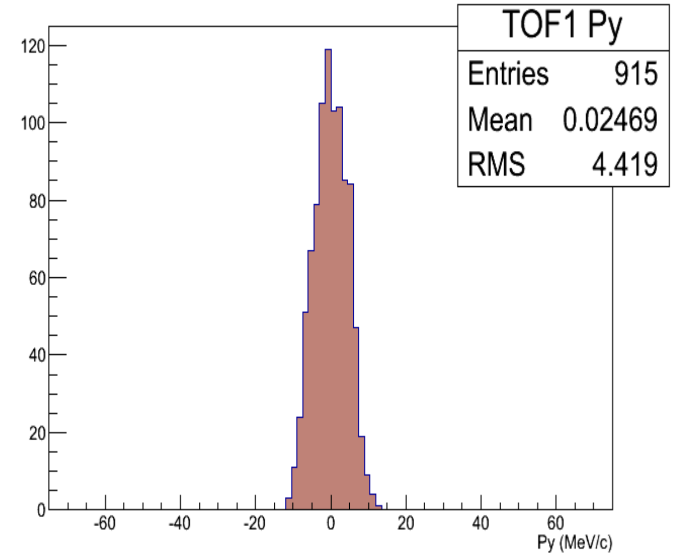
y res. = 17.32 mm

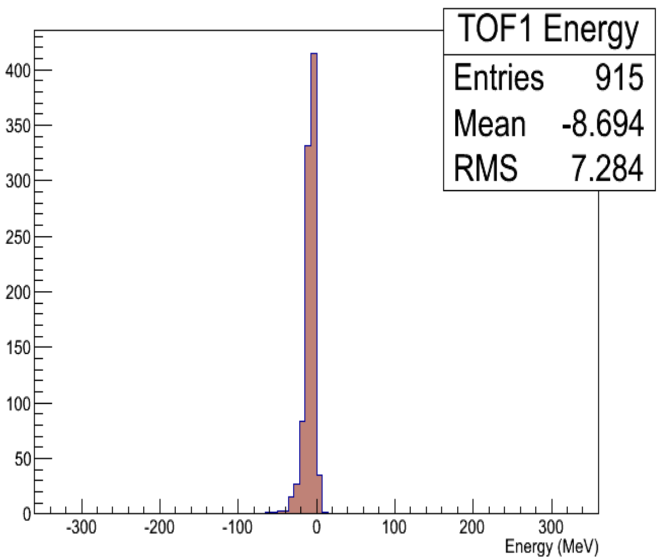
TOF 1 Input/Output Residuals 2

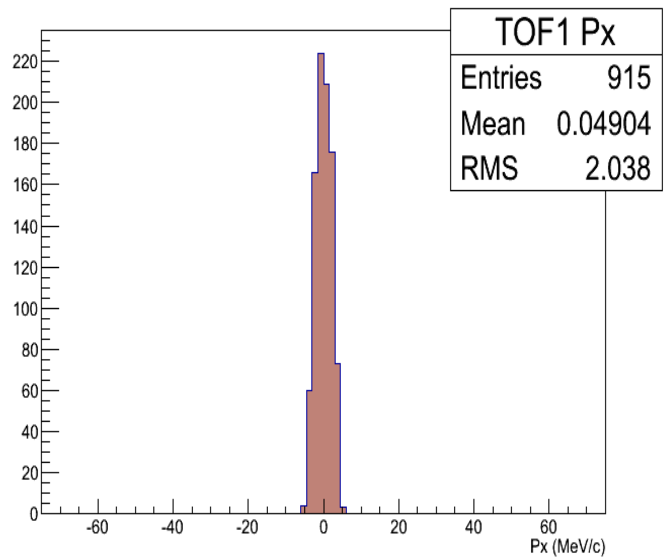
Input

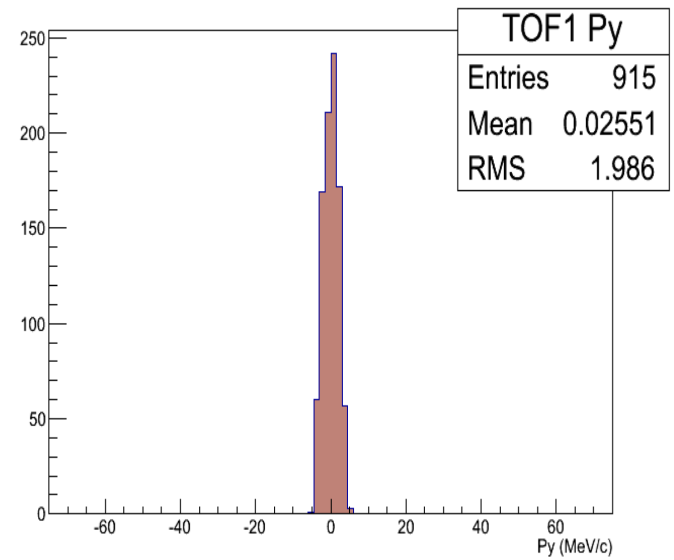












Output

E res. ≈ 8 MeV

Px res. ≈ 1 MeV/c

Py res. ≈ 1 MeV/c

Conclusions

- TOF inputs verified
  - Time residual RMS are within TOF resolution
  - Time residual mean offset is understood
  - x/y residual RMS are close to transverse spacial resolution of TOF0/TOF1 slabs
- Drift track fitting working well
  - RMS are improved overall
    - E & P RMS are close to estimated resolutions
  - Energy mean is much better, but still significantly different from zero
    - t_0 compensation seems to help

Next Steps

- Add TOF2
- Add magnets
    - quads (focusing)
    - solenoid (transverse momentum)
    - dipole (longitudinal momentum)
- Add tracker stations
    - PID possible once reconstruction available
- Add other materials (Ckov, absorber, etc...)

End

Extra Slides

Transfer Map Generation

- Calculate C from matrix of polynomial vector inputs (A) and a matrix of p.s.v. outputs (B)
  - Solve the matrix equation $B = A C^T$
- The Moore-Penrose Pseudoinverse of A is the least squares solution
- The MPP takes the simple form $(A^T A)^{-1} A^T$ if there are N linearly independent inputs
  - N = number of polynomial terms