

# Global Reconstruction Update

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# Status Summary

- Polynomial Least Squares reconstruction functioning with first-order transfer matrices
  - *Details Shortly*
- Transfer matrix of drifts verified against COSY INFINITY
- Transfer matrix of no-fringe quads verified against COSY INFINITY
- Post-CM34 task is to clean up, write unit tests, and merge code with the MAUS trunk

# Technical Background

- Polynomial least squares algorithm
- What polynomial transfer maps are
- Generation of polynomial transfer maps
- Example drift and quad transfer matrices

# Polynomial Least Squares Fitting

- Simulate test particles through MICE geometry
- Use simulated hits to determine transfer maps between start plane and detector
  - *Polynomial Transfer Map*
- Perform least squares fit of data using transfer maps to create predictions

# Polynomial Transfer Map

- Arbitrary order, multivariate polynomial approximation of a transfer map
- Represented as a matrix of coefficients ( $C$ )
  - $v$  Rows: output variables
  - $N$  Columns: polynomial terms
- Phase space vector  $(t, E, x, px, y, py)$  to be transported is expanded into a vector of polynomial term variable products
  - $a = (1, t, \dots, t^2, tE, \dots, py^2)$
- Transported vector  $b = C a = (t', E', \dots, py')$

# 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

# Drift Matrix

- 2.0001m drift matrix in  $x, x', y, y', l, \delta$
- Elements  $< 1e-4$  made zero for readability
- Minor deviations of  $2e-5$  likely due to higher order effects

|          |          |          |          |          |          |
|----------|----------|----------|----------|----------|----------|
| 1.000000 | 2.000120 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| 0.000000 | 1.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| 0.000000 | 0.000000 | 1.000000 | 2.000120 | 0.000000 | 0.000000 |
| 0.000000 | 0.000000 | 0.000000 | 1.000000 | 0.000000 | 0.000000 |
| 0.000000 | 0.000000 | 0.000000 | 0.000000 | 1.000000 | 0.201053 |
| 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 1.000000 |

# Quad Matrix

- 2m quad at 0.1 T/m (x, x', y, x', I, delta)
- Deviations from textbook thin lens quad matrix verified with COSY INFINITY

```
0.714888 1.806134 0.000000 0.000000 0.000000 0.000000
-0.270720 0.714860 0.000000 0.000000 0.000000 0.000000
0.000000 0.000000 1.315080 2.206100 0.000000 0.000000
0.000000 0.000000 0.330663 1.315110 0.000000 0.000000
0.000000 0.000000 0.000000 0.000000 1.000000 0.196009
0.000000 0.000000 0.000000 0.000000 0.000000 1.000000
```



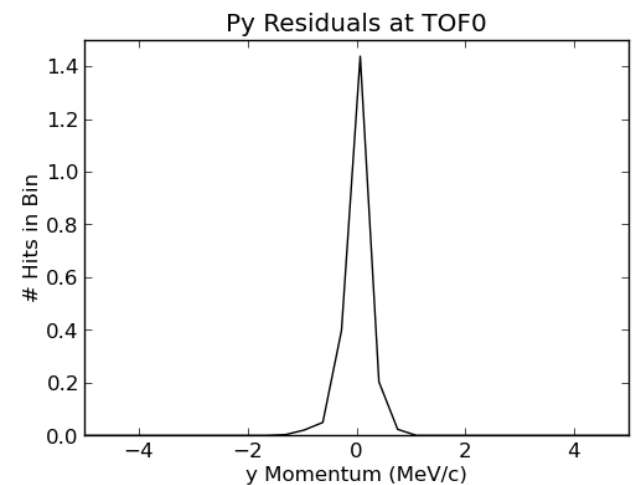
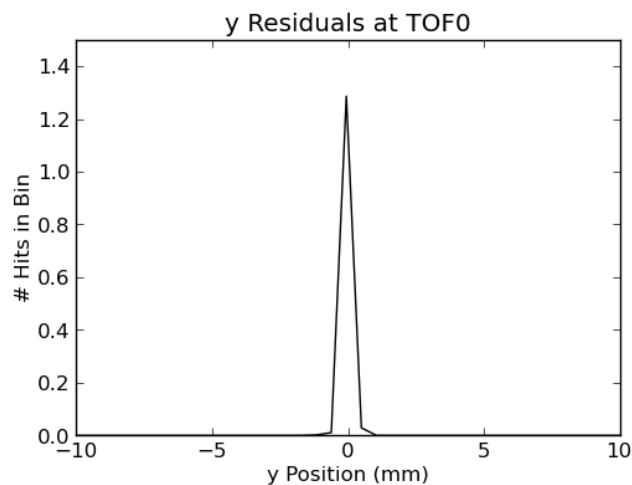
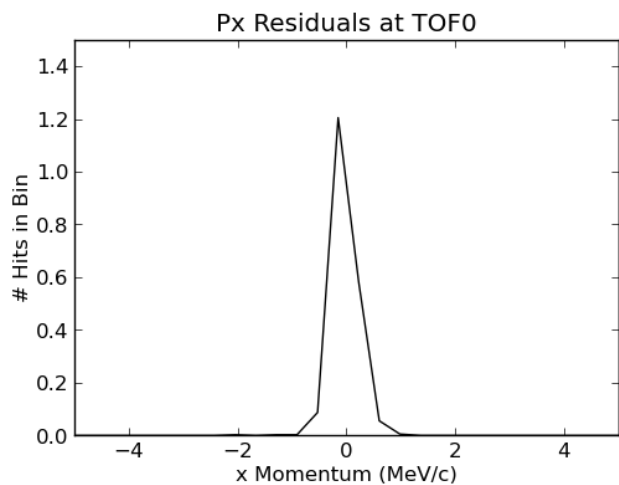
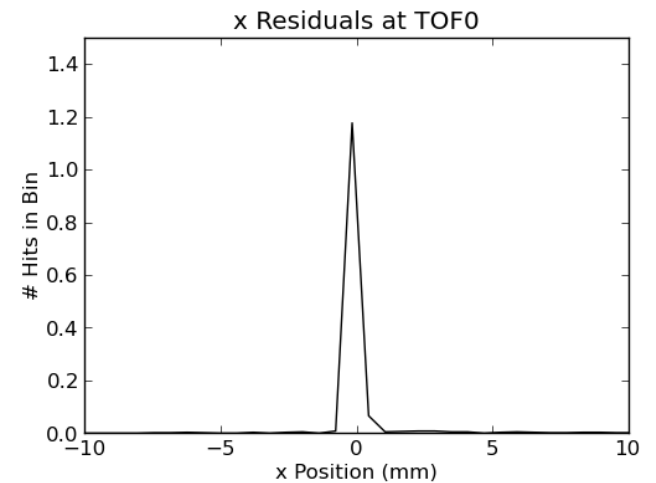
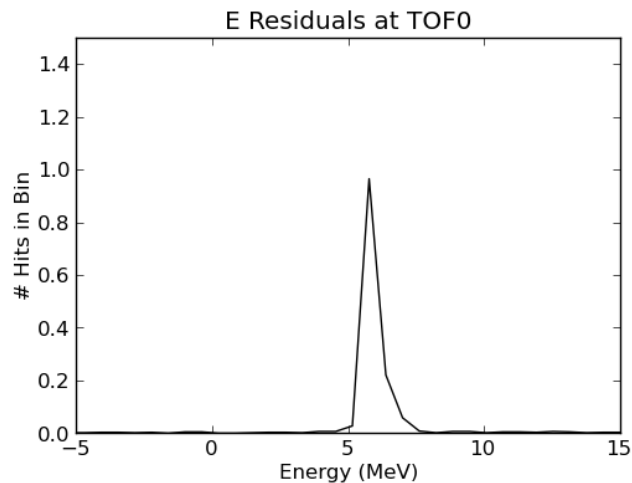
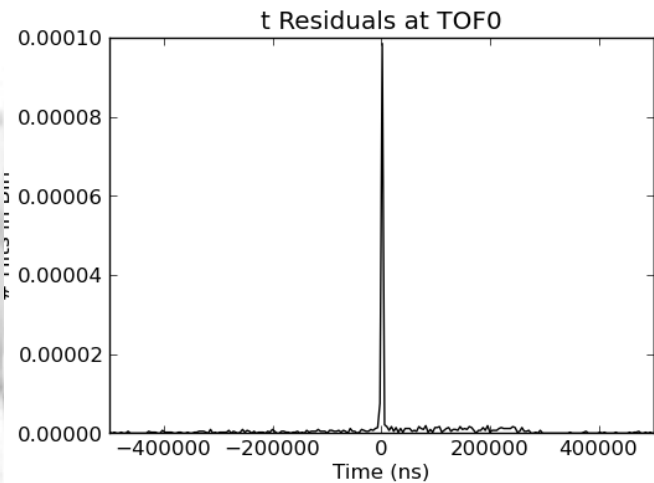
# Reconstruction Analysis

- Comparison of reconstruction results of
  - Monte Carlo truth data
  - Smearred Monte Carlo data
    - Add random values from normal distribution with width equal to the TOF resolution
      - t smear set to 0.06 ns
      - E, P<sub>x</sub>, P<sub>y</sub> smear set to 2 MeV[*c*]
      - x, y smear set to 10 mm
- Did this for two simple lattice elements:
  - A single 2m drift
  - A single 2m quadrupole magnet

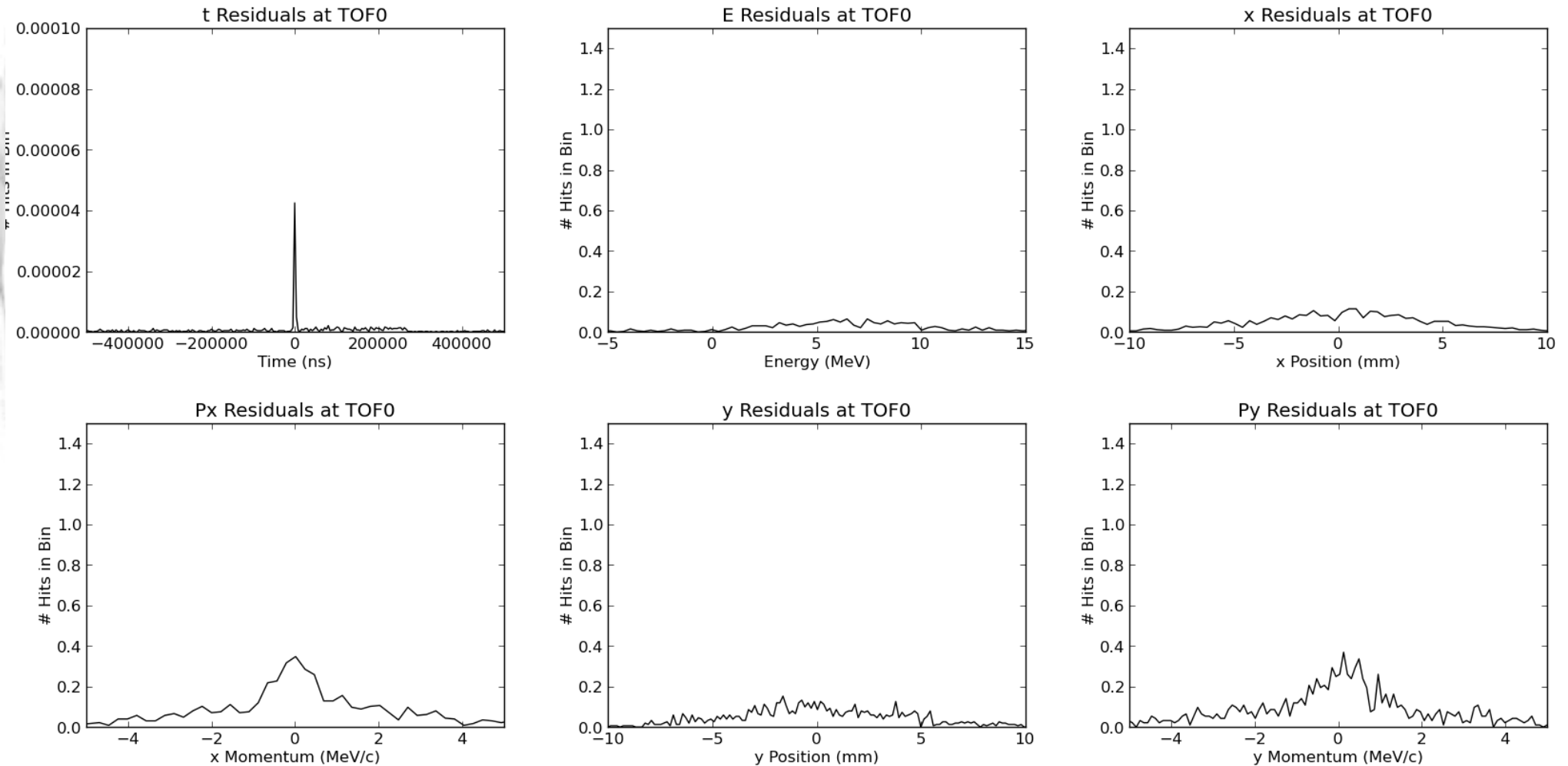
# Drift Monte Carlo Residuals TOF0

- Reconstruct 2.0m drift in vacuum between TOF0 and TOF1
  - TOF hit  $z$  is taken at the entry point of the slab volume
  - Fired particles from .1mm upstream of downstream TOF0 slab so hit will register
    - This means drift length is actually 2.0001m
  - Virtual detectors at -1 m and +1 m used to reconstruct
- Generate residual plots for  $t$ ,  $E$ ,  $x$ ,  $P_x$ ,  $y$ ,  $P_y$ 
  - With respect to Monte Carlo truth

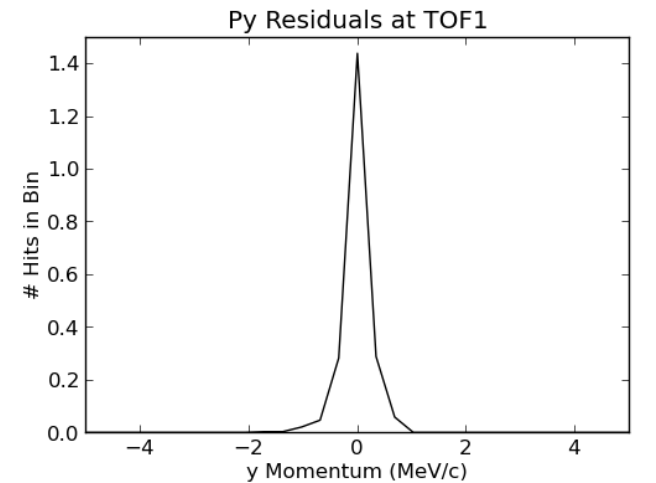
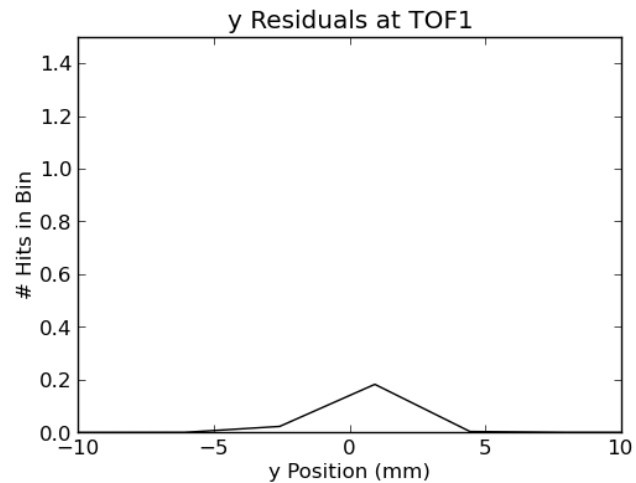
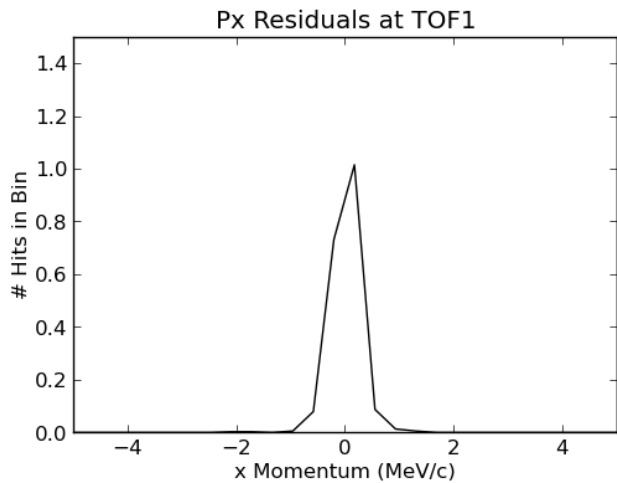
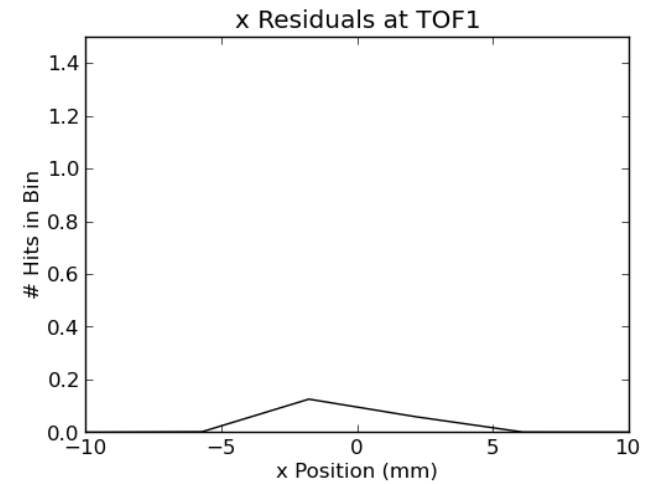
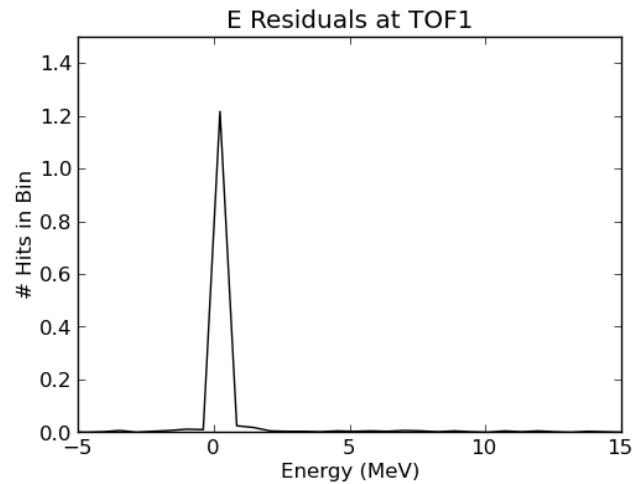
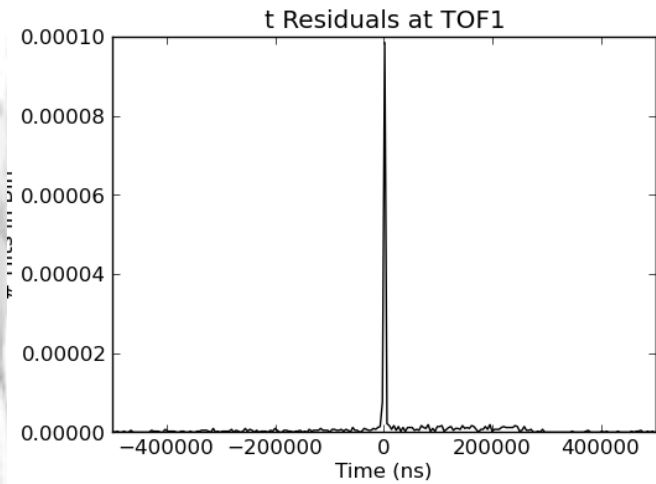
# TOF0 Drift Residuals: Reconstructed Monte Carlo Truth



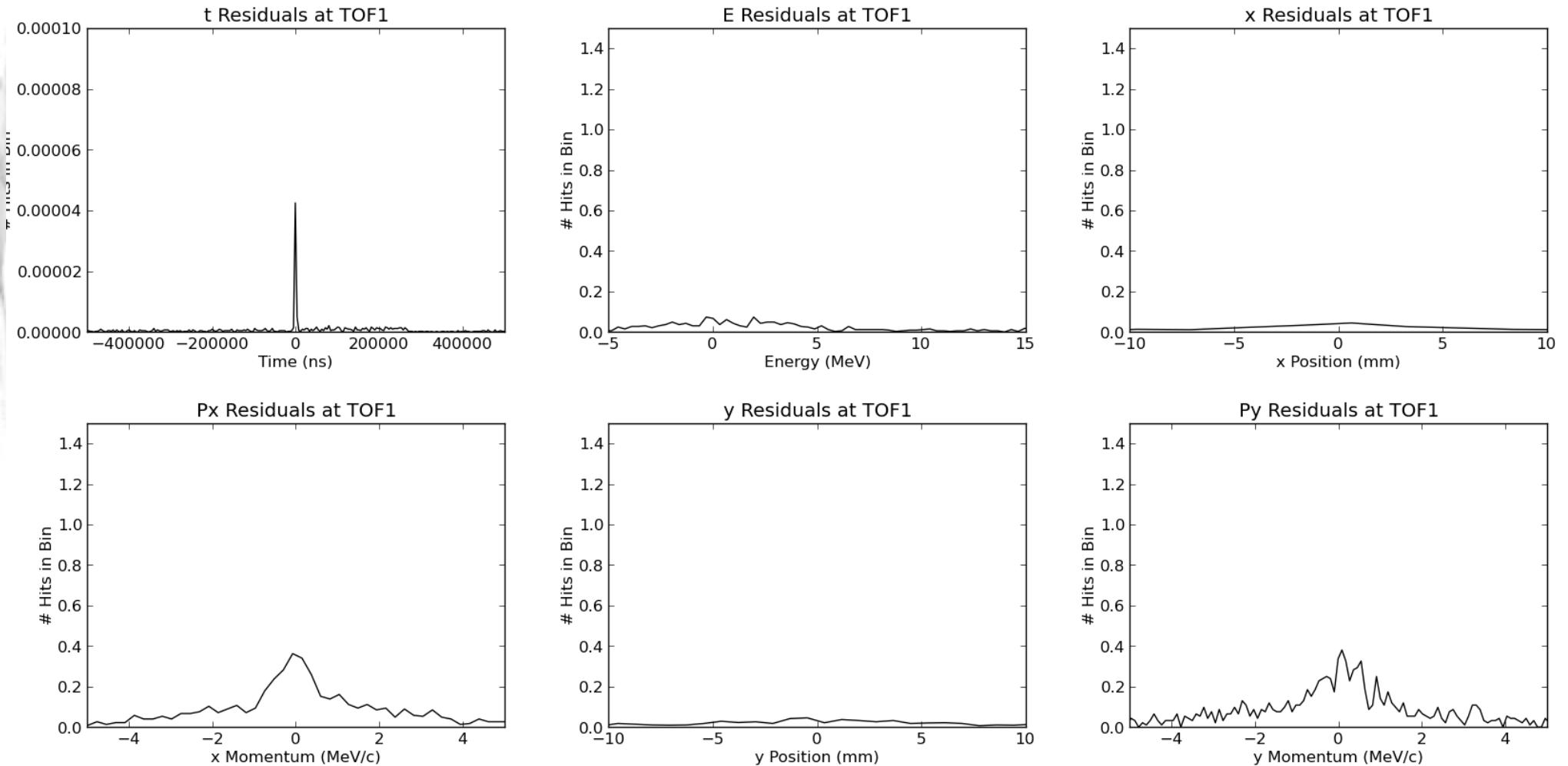
# TOF0 Drift Residuals: Reconstructed Smeared MC



# TOF1 Drift Residuals: Reconstructed Monte Carlo Truth



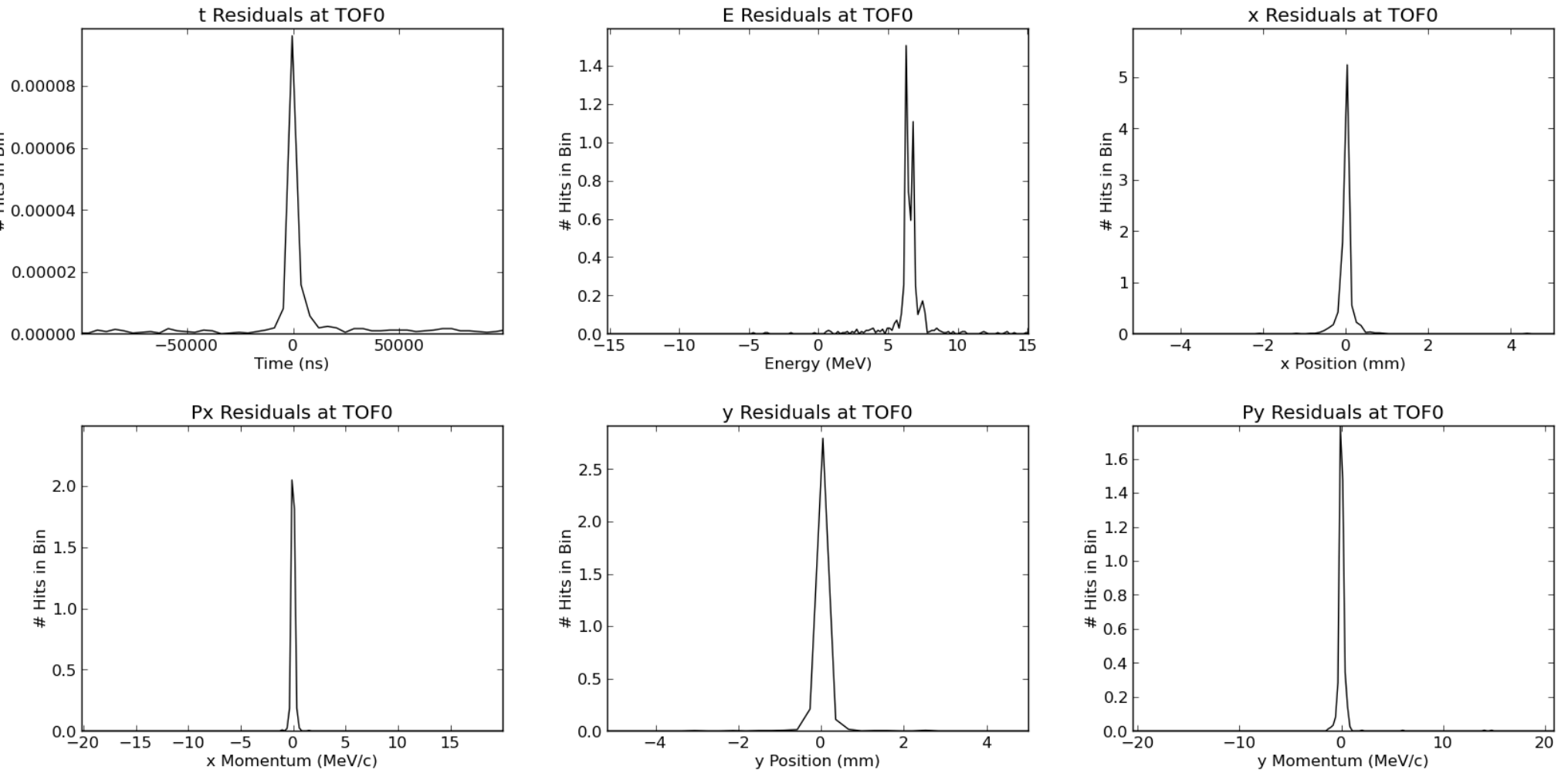
# TOF1 Drift Residuals: Reconstructed Smearred MC



# Quad Reconstruction

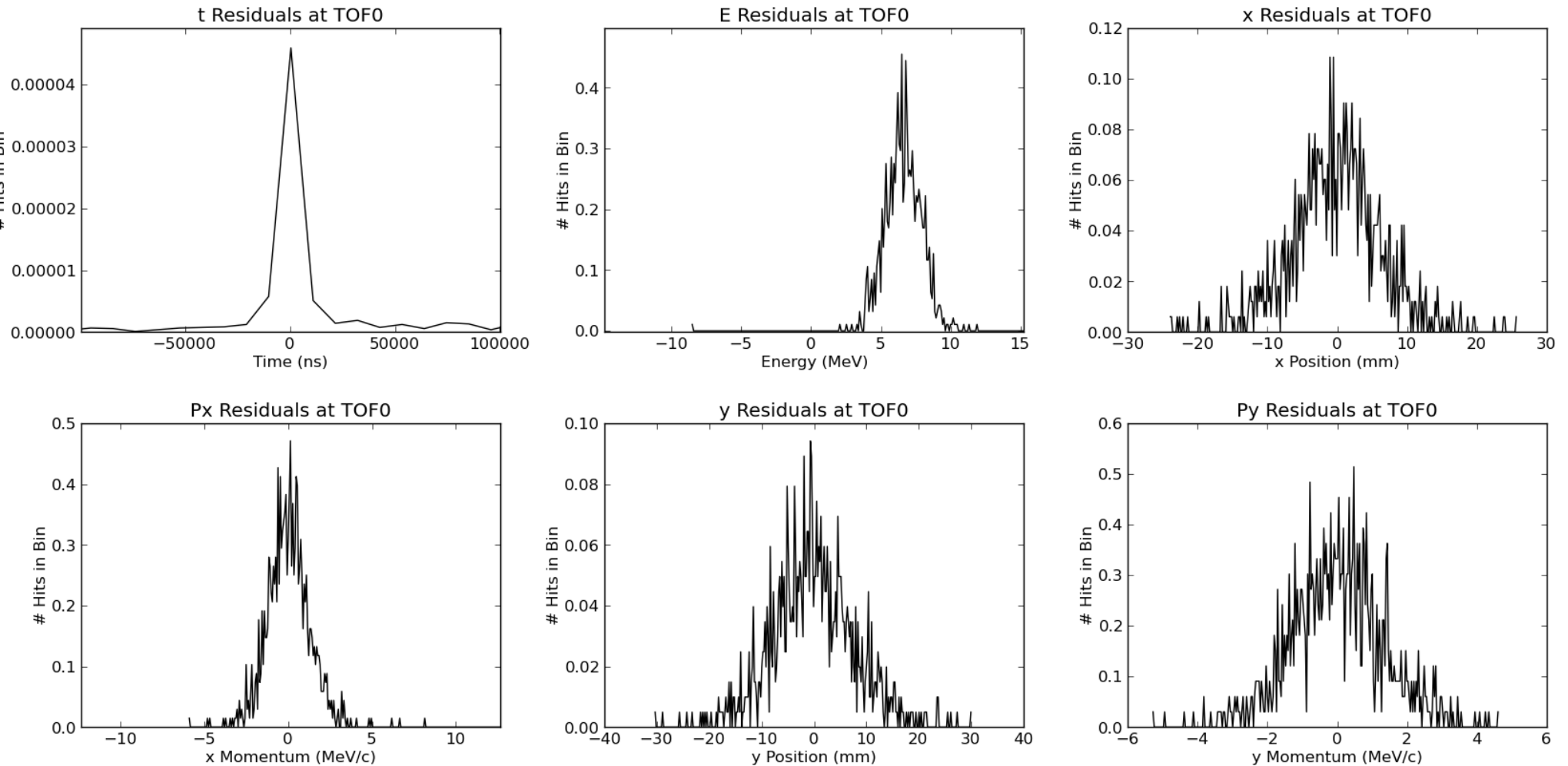
- A single 2m long quad at 0.1 T/m with no fringe fields between TOF0 and TOF1
  - Particles fired .1 mm into downstream end of TOF0 like drift
  - Virtual detectors again at -1 m and +1 m used to reconstruct
- Generate residual plots for  $t$ ,  $E$ ,  $x$ ,  $P_x$ ,  $y$ ,  $P_y$

# Quad Monte Carlo Residuals TOF0

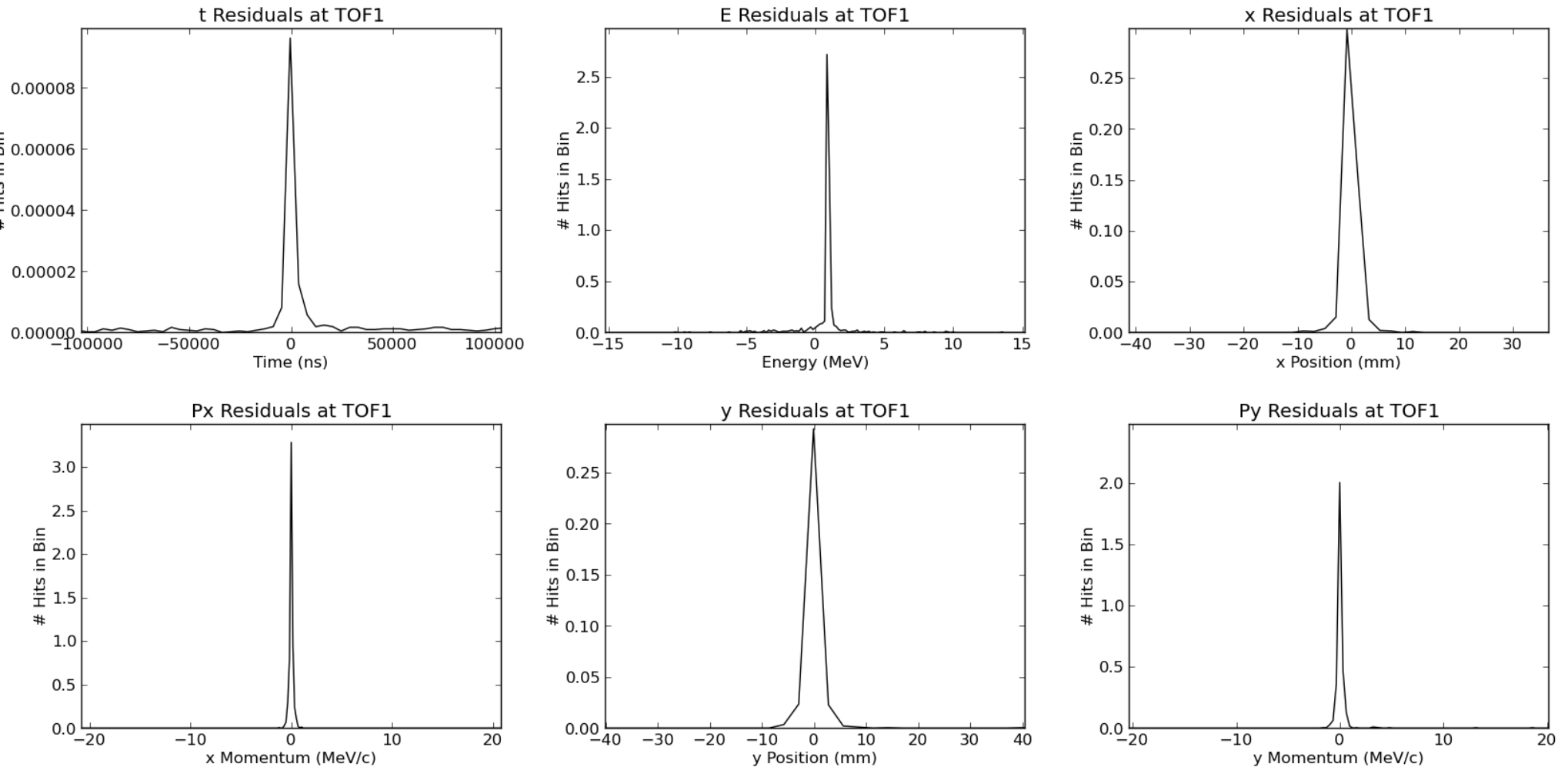




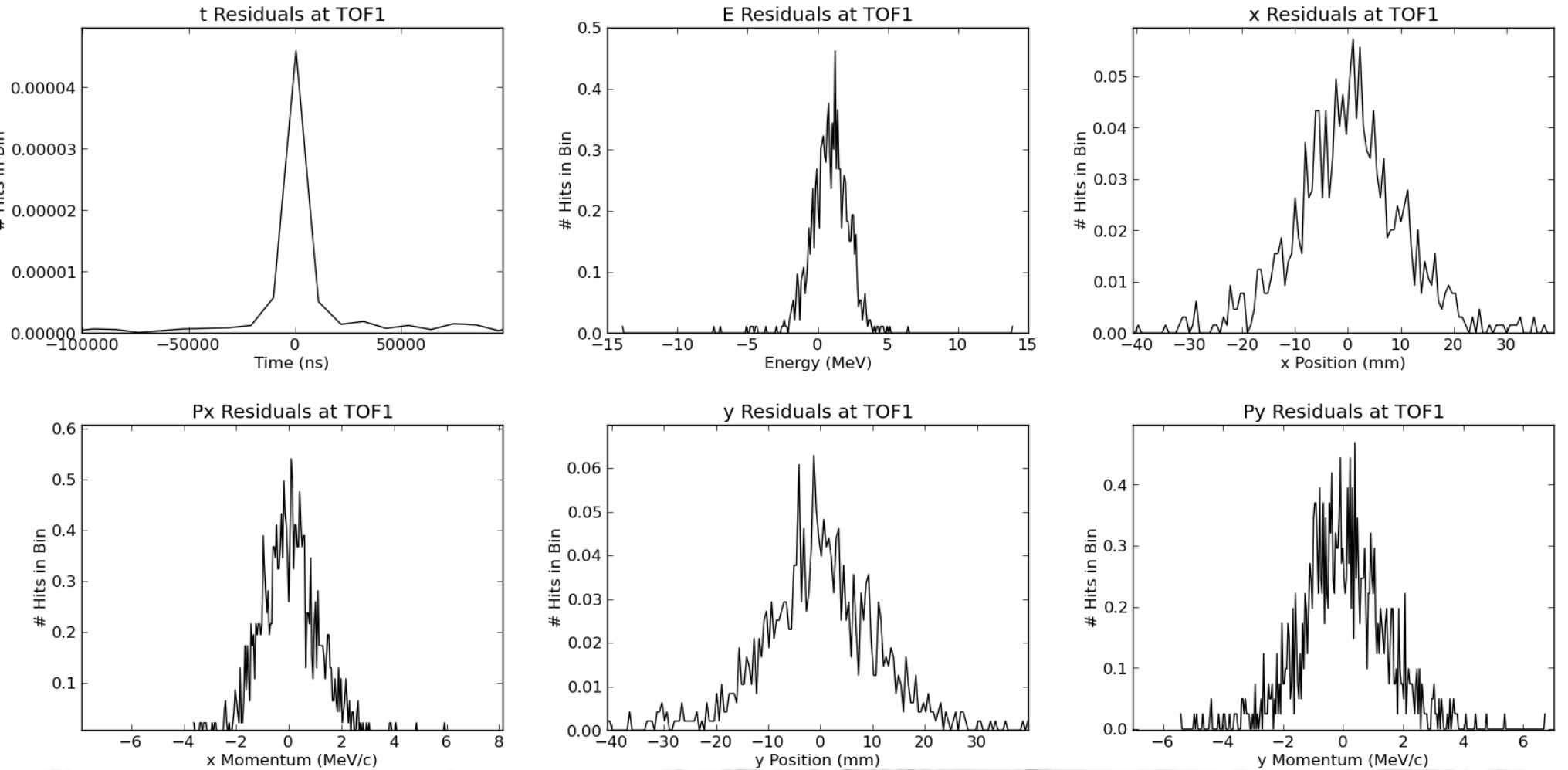
# Quad Smearred MC Residuals TOF0



# Quad Monte Carlo Residuals TOF1



# Quad Smearred MC Residuals TOF1



# Reconstruction Summary

- Drift energy shift in TOF0 due to energy loss in TOF0
  - Drift space seems to cancel the effects (TOF1)
- Quad has very large energy shift in both TOF0 and TOF1.
  - Quad seems to exacerbate the effects of energy loss in TOF0.
- Current method is extremely sensitive to material stochastics. Need way to handle materials separately.
- Oh my, look at the time...

# Time Reconstruction Summary

- Time reconstruction is suspicious
- Did not have time to look into this
- It may be that the histogram resolution simply is not sufficient
- Need to do some statistics

**End**