Analysis of fragments in SRC experiment

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for the SRC collaboration

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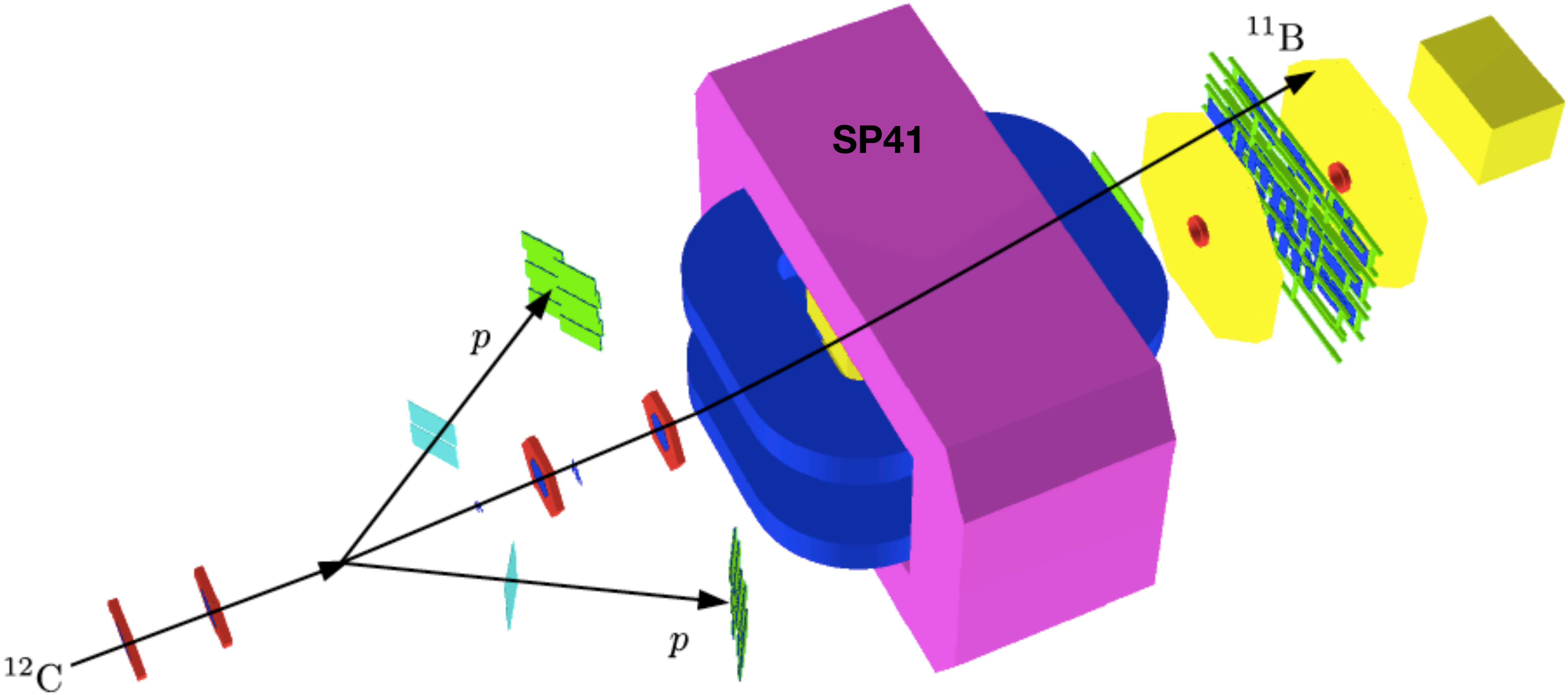
Outline

- Fragment tracking through SP41 magnet
- Multi-Dimensional Fit (MDF) method
- Results from the BMNRoot simulations
- Tracker alignment using experimental data
- Stitching tracks from different detectors before and after SP41
- Global tracks and PID

Overview of SRC setup at BM@N



Extracting momentum information for the reaction fragments by tracking though SP41

Multi-Dimensional Fit (MDF) method

Multi-Dimensional Fit (MDF) method:

- Extracting P/Q information using MDF on simulated data
- ROOT class **TMultiDimFit**: https://root.cern.ch/doc/master/classTMultiDimFit.html

General concept:

- *P* is a known quantity of interest (e.g. P/Q, trajectory length etc.)
- *P* depends on N observables $(x_1, \ldots, x_N)$
- Make a training sample of M tuples (events) of the form *(xj, Pj, Ej)*
    - $x_j = (x_{1,j}, \ldots, x_{N,j})$ - are N observables in the event j
    - P_j - known value in the event j
    - E_j - known error of P_j in the event j
- Class TMultiDimFit tries to find a parameterization:

$$\boxed{P_p(\mathbf{x}) = \sum_{l=1}^{L} c_l \prod_{i=1}^{N} p_{li}(x_i) = \sum_{l=1}^{L} c_l F_l(\mathbf{x})}$$ such that $$S = \sum_{j=1}^{M} (P_j - P_p(\mathbf{x}_j))^2$$ is minimal

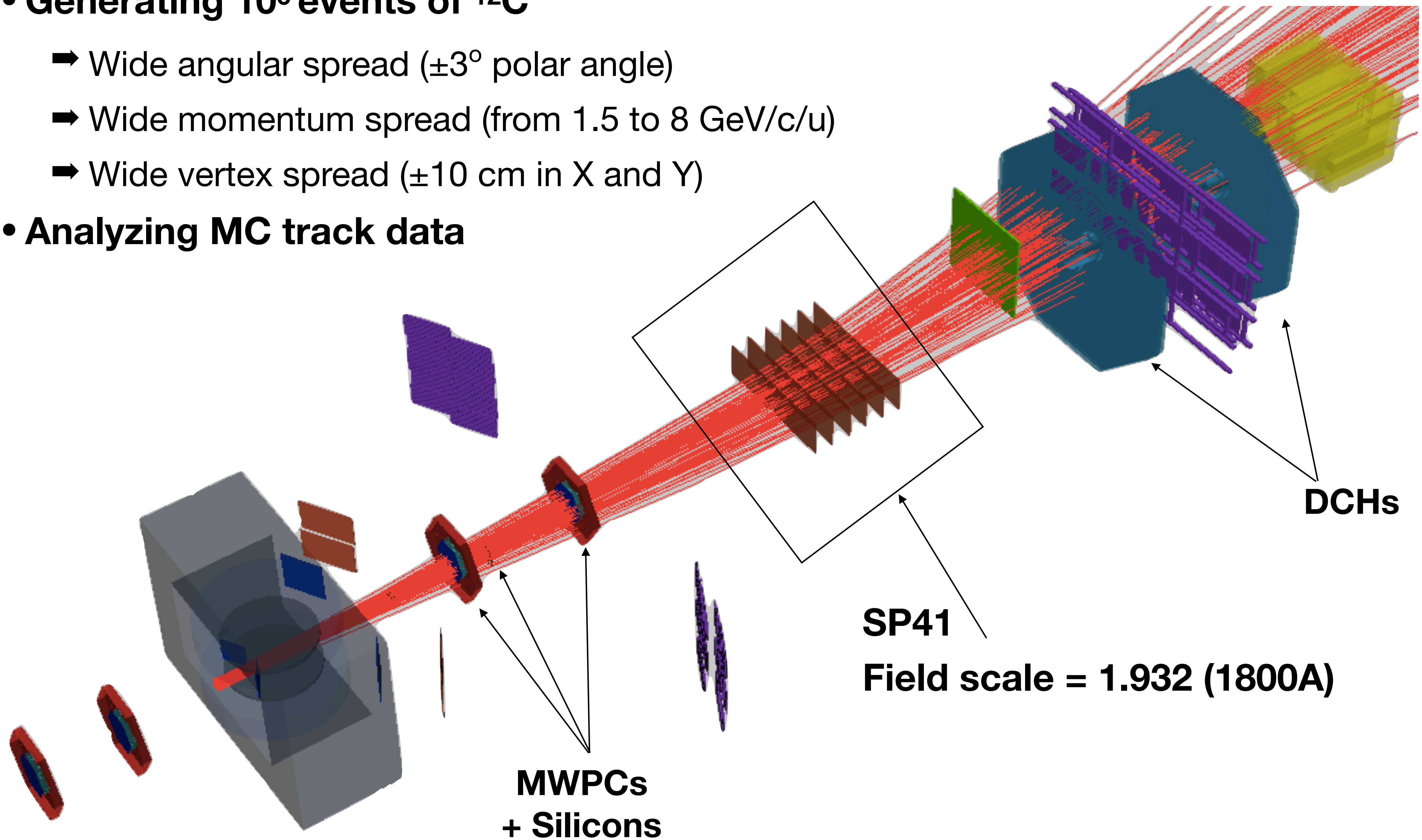
$p_{li}(x_i)$ - Monomials, Legendre or Chebyshev polynomials of x_i

c_l - coefficients determined by the fit

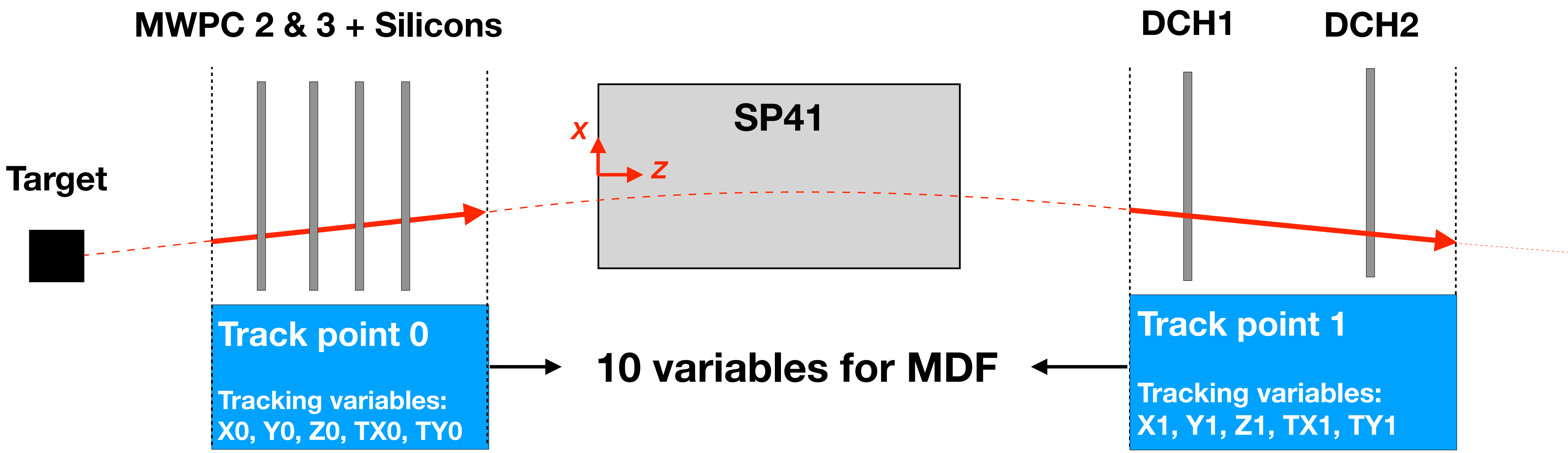
If x_i are linearly dependent, one can use transformation to orthogonal basis e.g. using Principle Component Analysis (PCA)

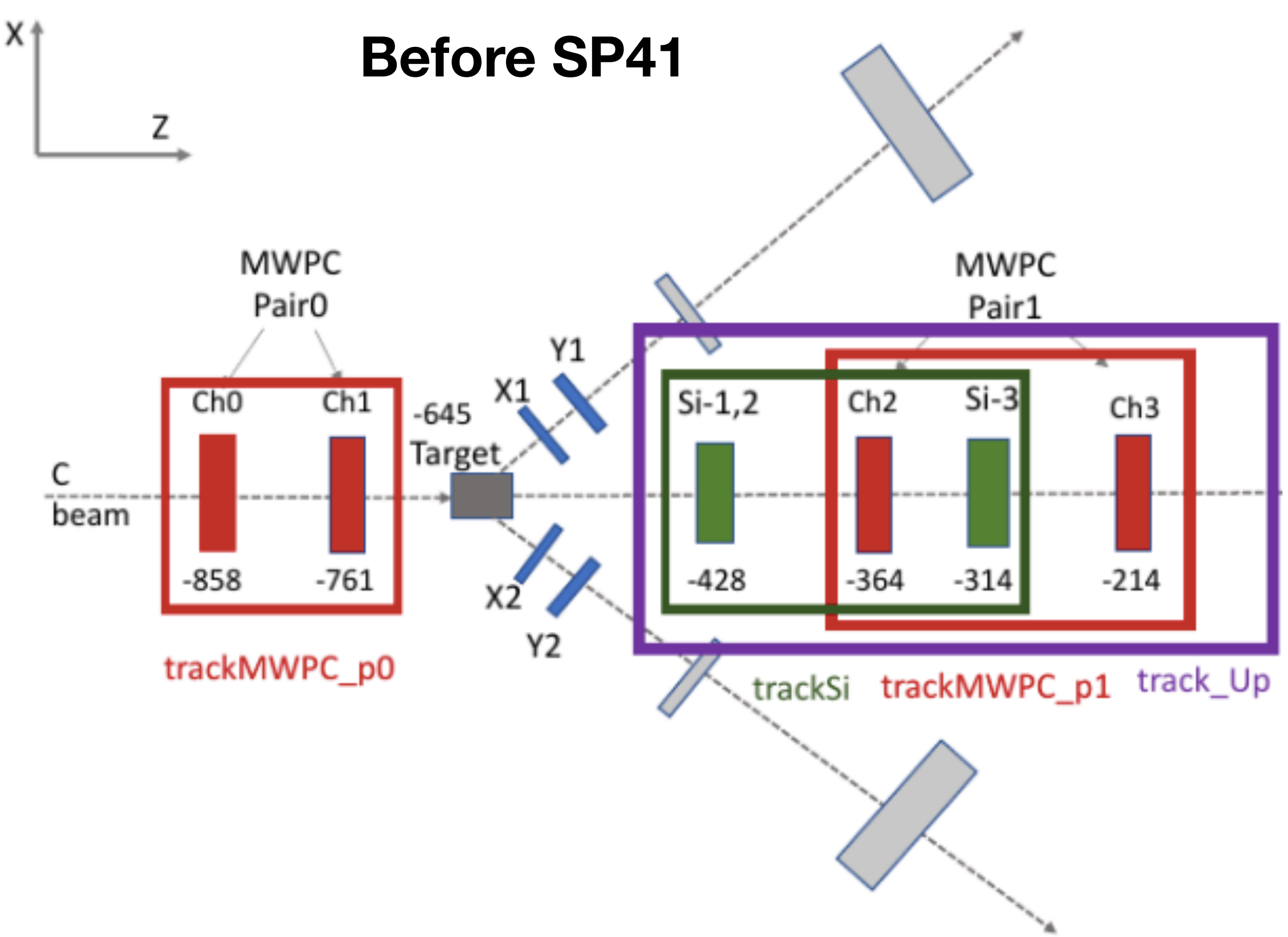
Using BMNRoot simulations to generate a training sample for MDF

- **Generating 10^6 events of ^{12}C**
  - ➡ Wide angular spread (±3° polar angle)
  - ➡ Wide momentum spread (from 1.5 to 8 GeV/c/u)
  - ➡ Wide vertex spread (±10 cm in X and Y)
- **Analyzing MC track data**



Explanation of the tracking variables





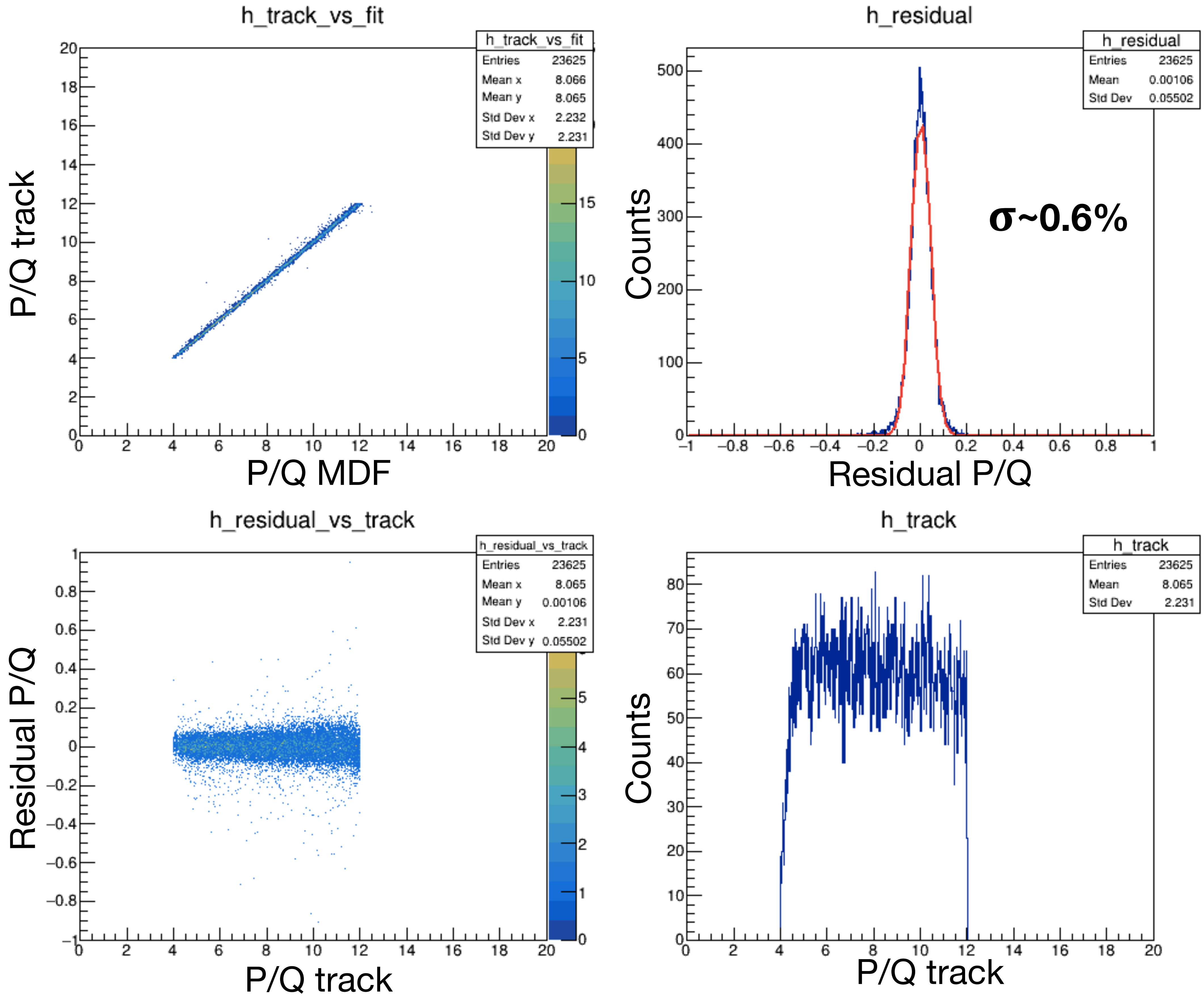
3 choices for upstream tracking:

- trackSi
- trackMWPC_p1
- Up

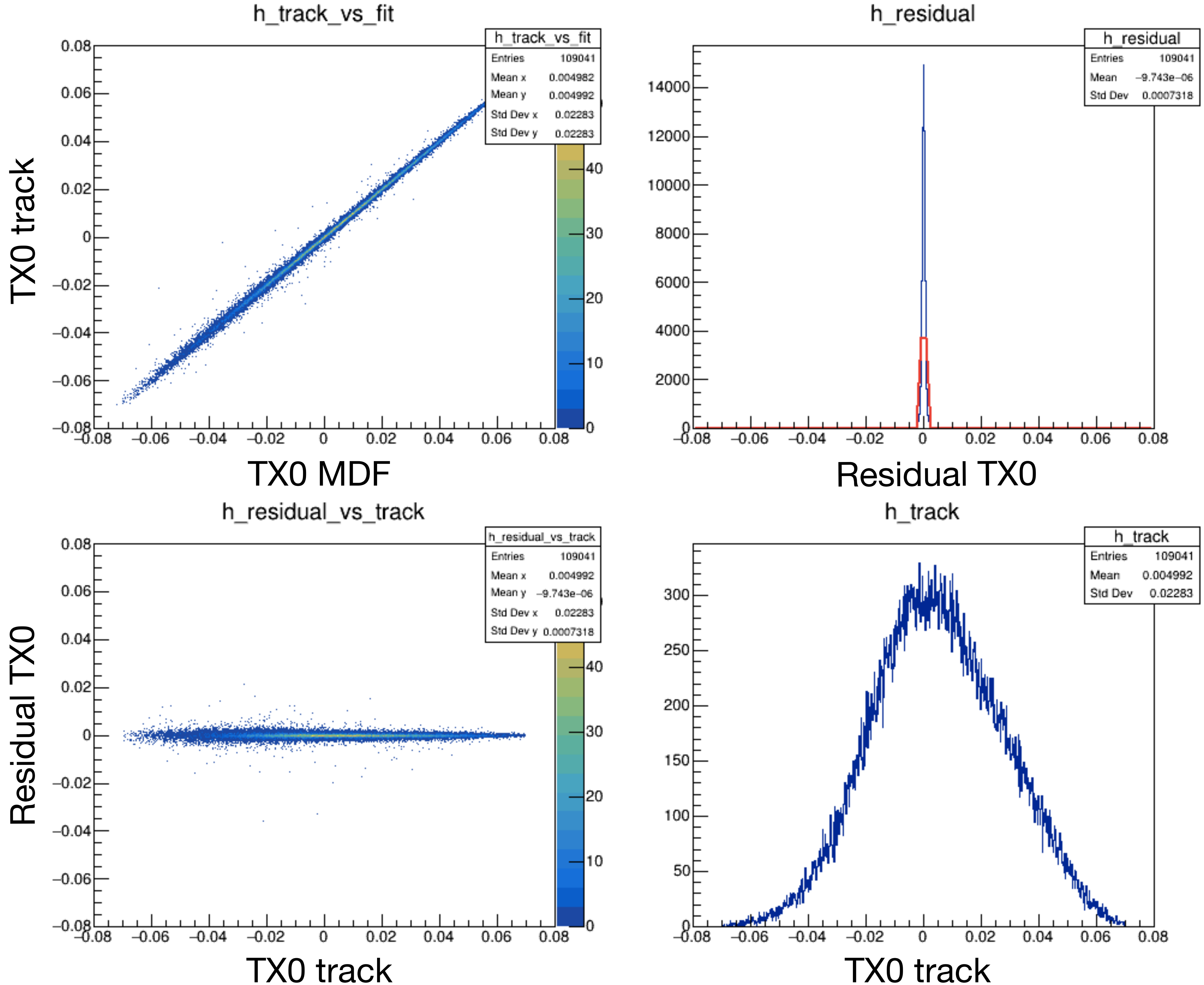
Relative alignment for all upstream detectors

Courtesy of V. Lenivenko

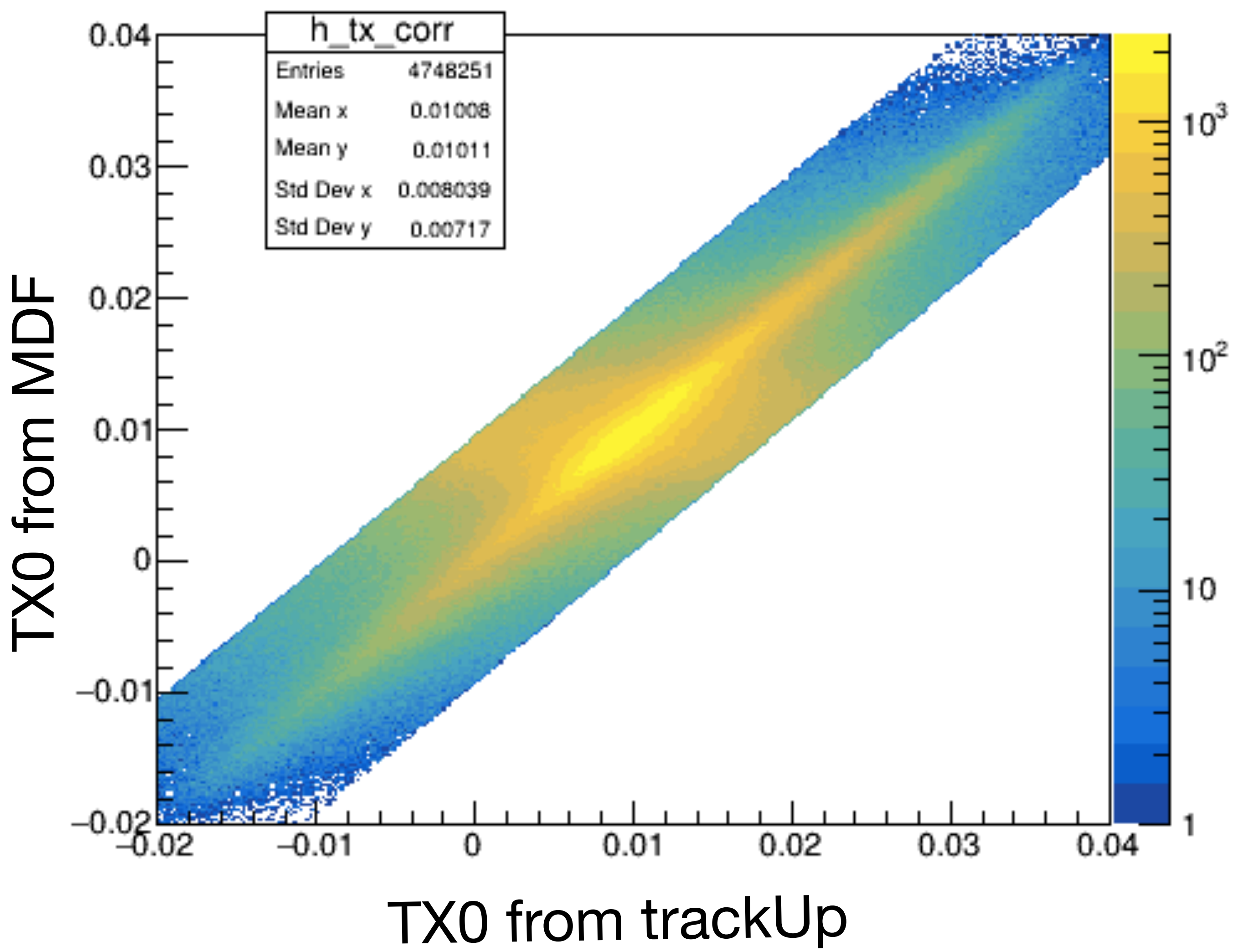
MDF result for P/Q using simulated data

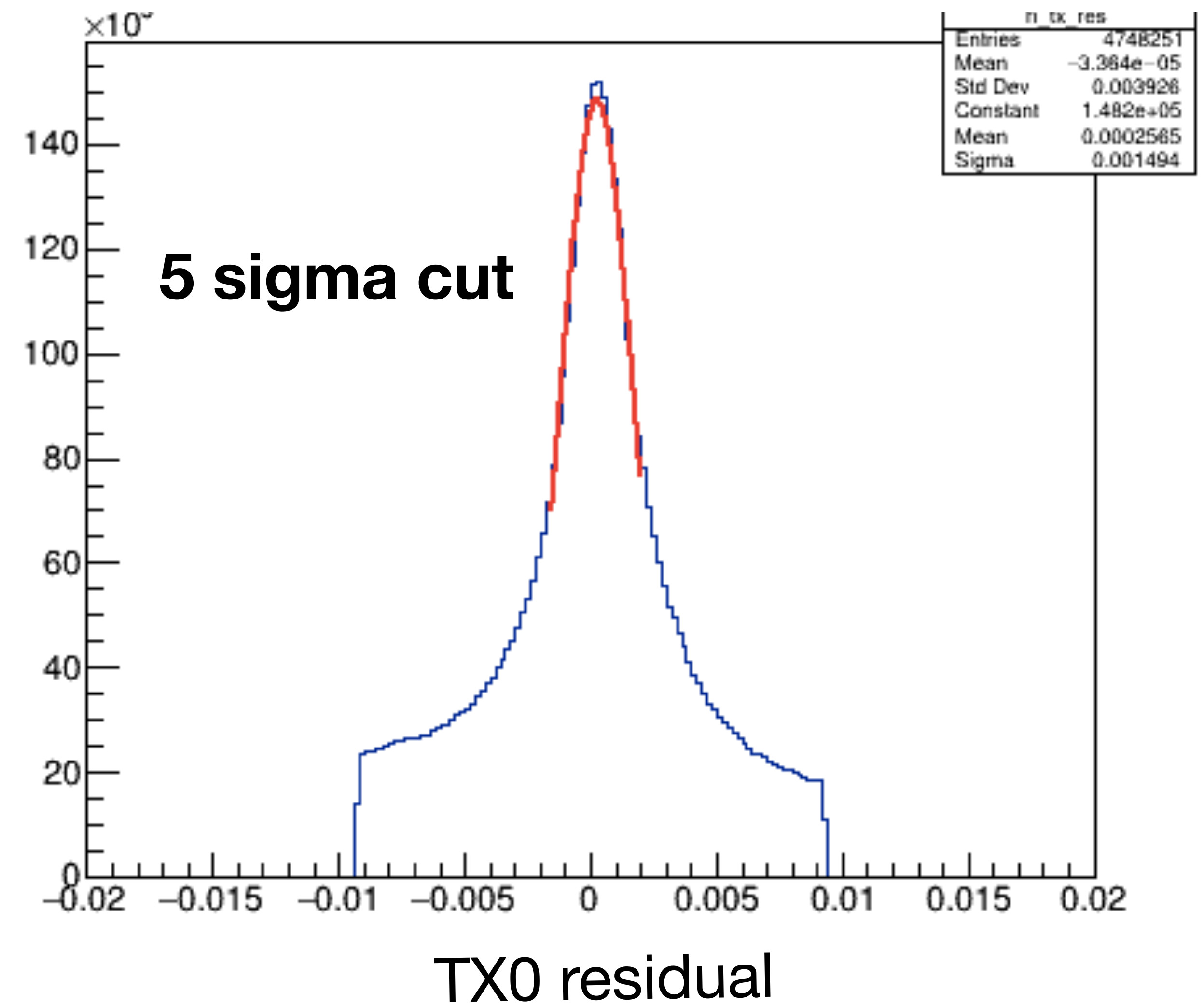


MDF result for TX0 using simulated data



Track selection based on TX0 matching (experimental data for all outgoing fragments)





Tracker alignment

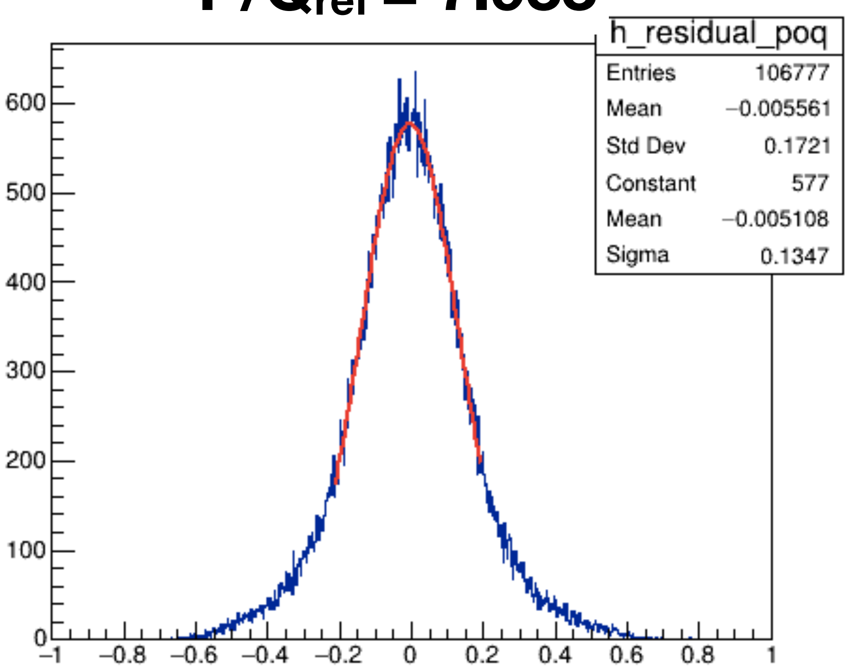
- **Using two MDF functions:**

$P/Q_{mdf} = f_1(X0, Y0, Z0, TX0, TY0, X1, Y1, Z1, TX1, TY1)$ - reconstructing momentum information
$TX0_{mdf} = f_2(X0, Y0, Z0, TY0, X1, Y1, Z1, TX1, TY1)$ - reconstructing TX0 for track matching

- **Tracker alignment using experimental data:**
  - Select outgoing ^{12}C with the reference value $P/Q_{REF} = 7.933$ GeV/C/e (after LH2 target)
  - Simultaneous variation of P/Q_{mdf} and $TX0_{mdf}$:
    - ➡ by variation of the offsets in X0 and TX1
      - ➡ until $(P/Q_{MDF} - P/Q_{REF})^2$ is minimal

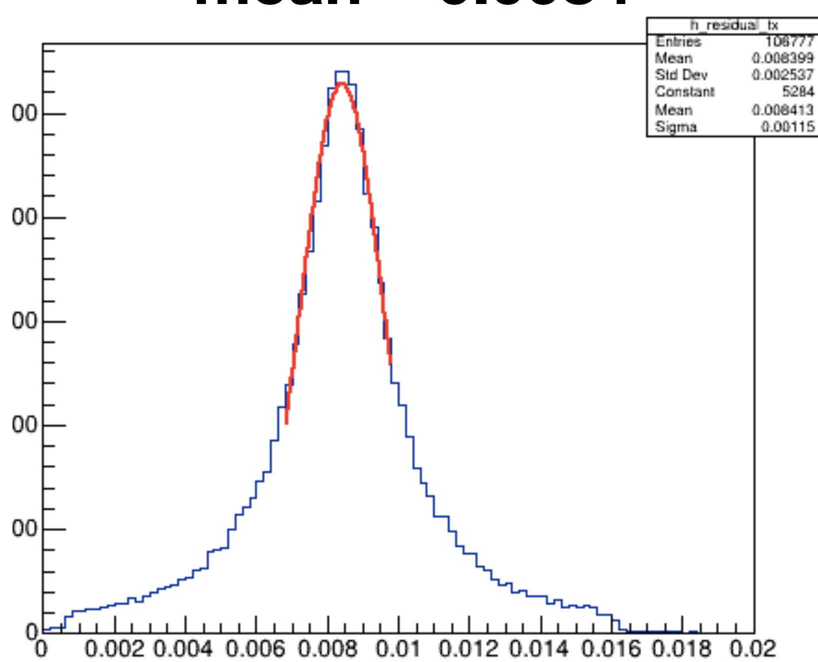
  - Obtaining alignment offsets for X0, TX0 and TX1

P/Q_{ref} = 7.933



P/Q residual

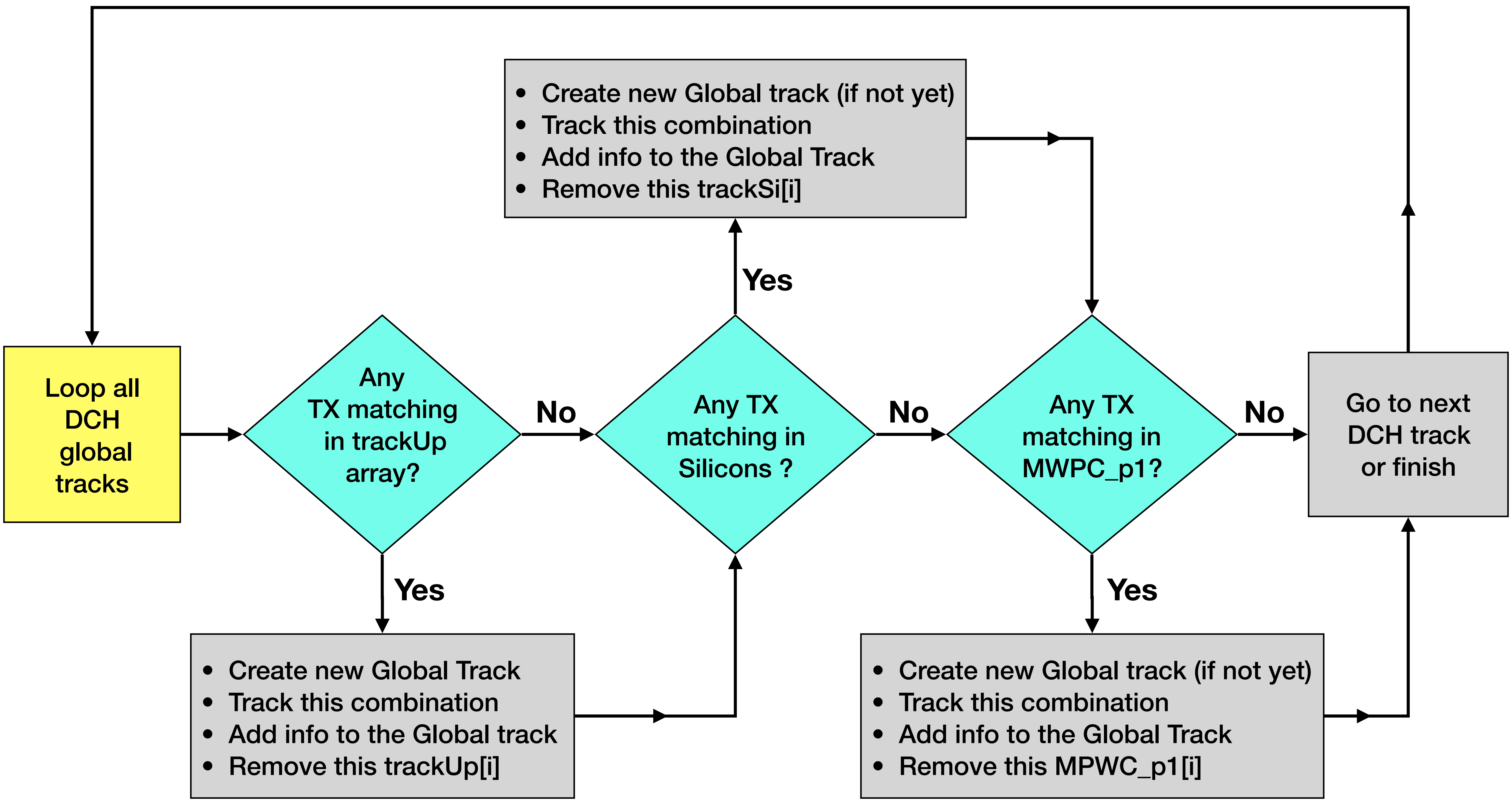
mean = 0.0084



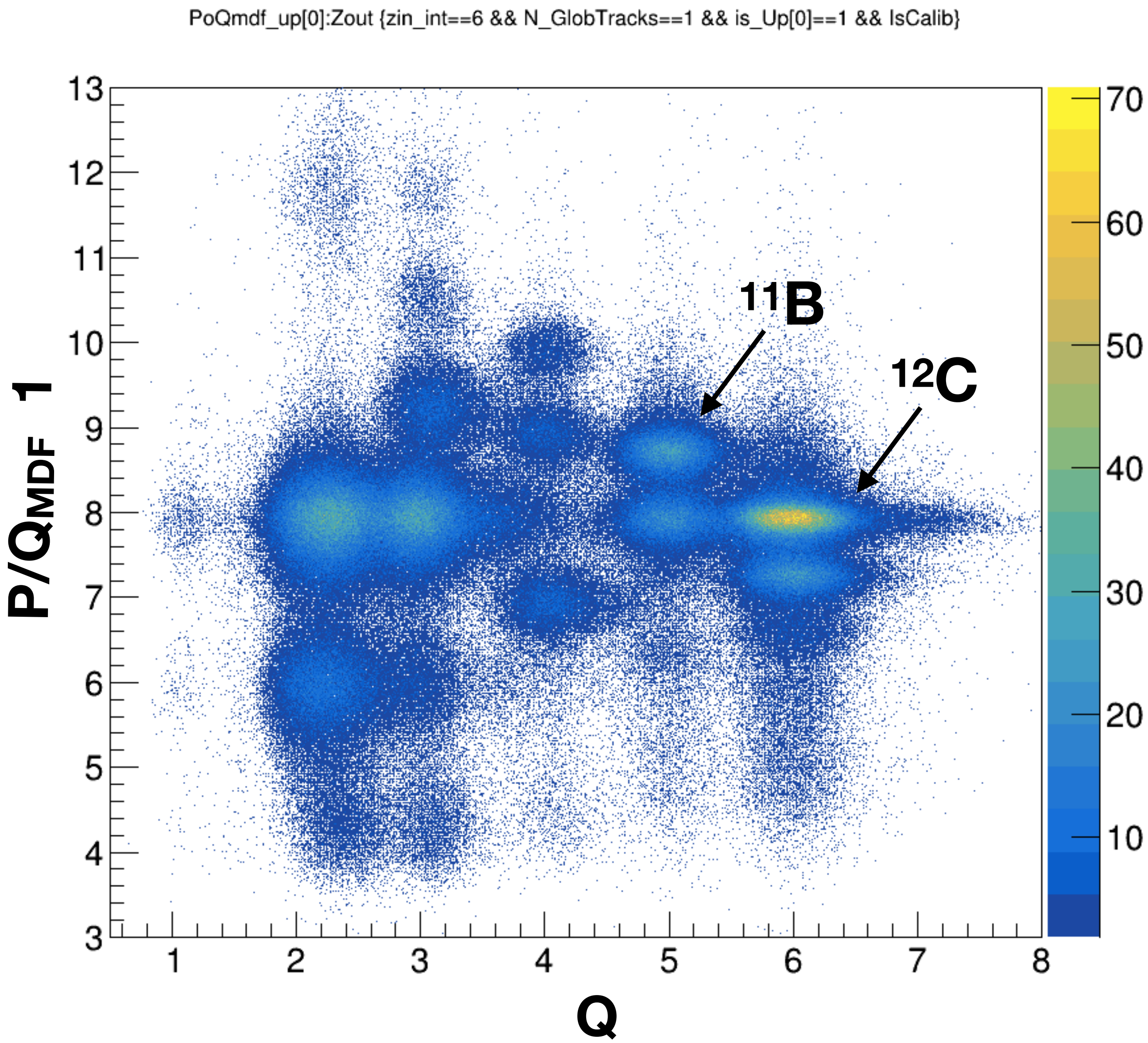
TX0 residual

Resulting offsets in the tracker:
X0 offset = 0.28 cm
TX0 offset = 0.0084
TX1 offset = 0.0092

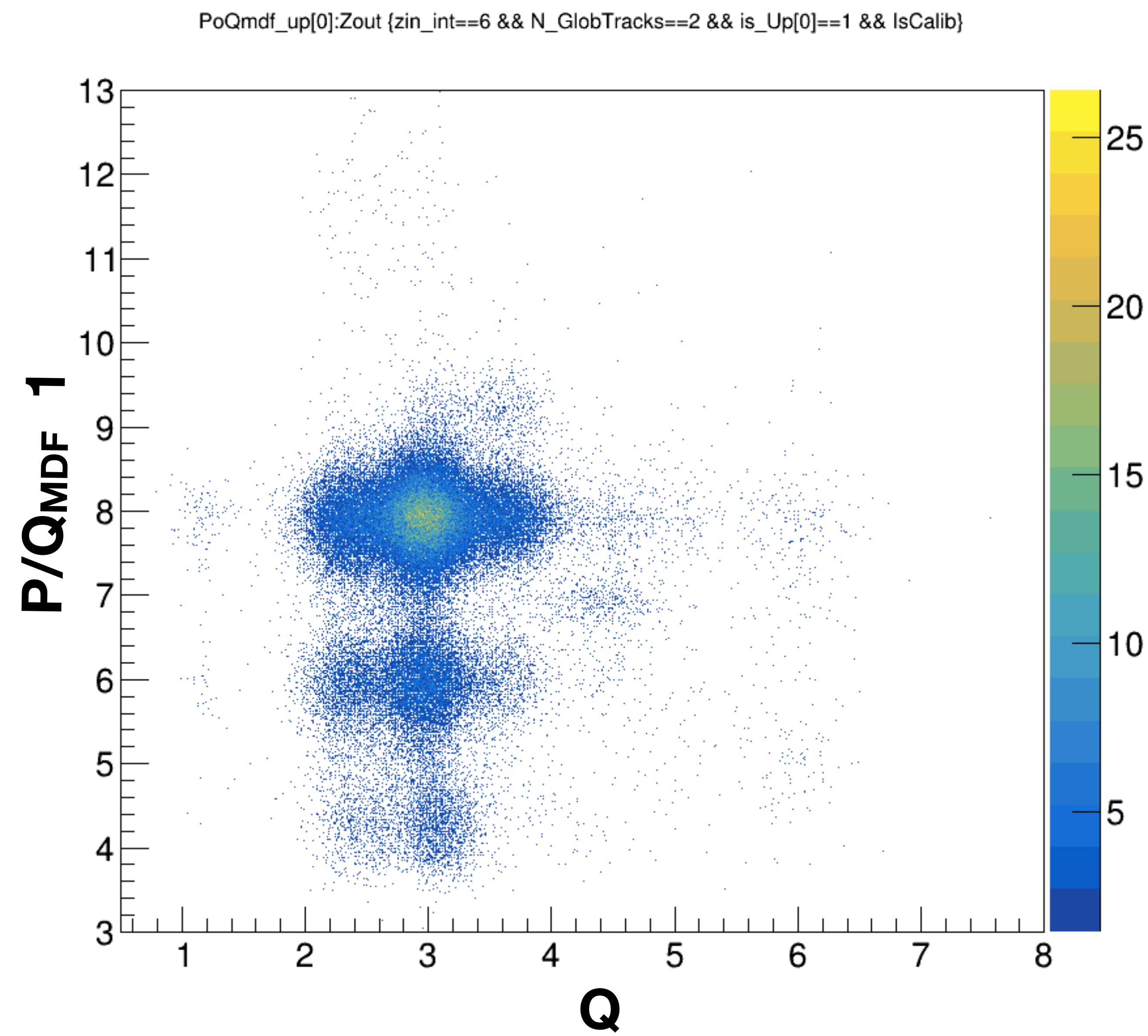
Block diagram for tracking experimental data



PiD for 1 global track

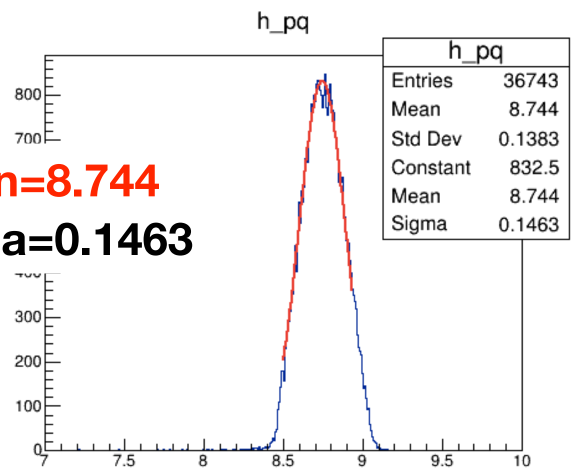


PiD for 2 global tracks



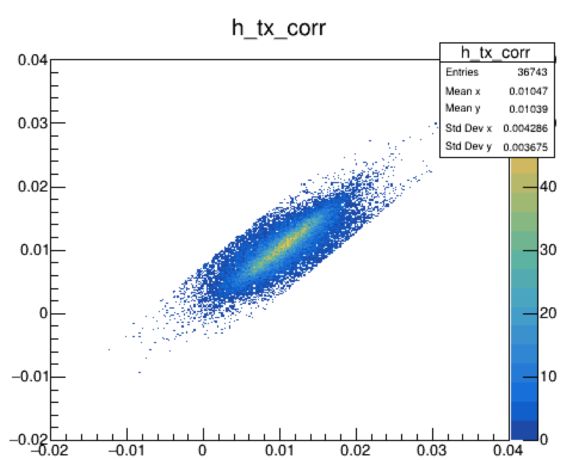
Tracking ^{11}B in different detectors before the magnet

Up



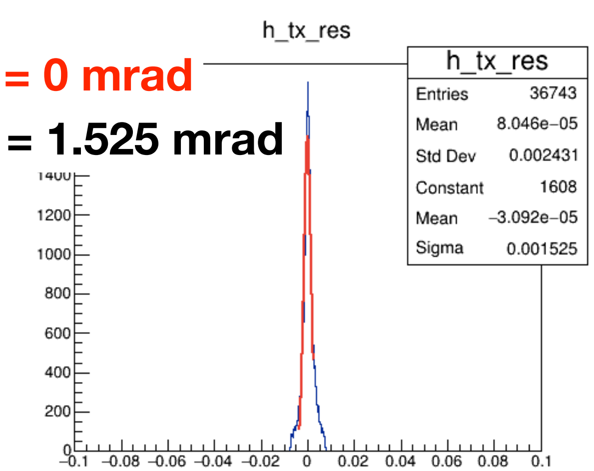
Mean=8.744
sigma=0.1463

P/Q_{MDF}



TX0 MDF

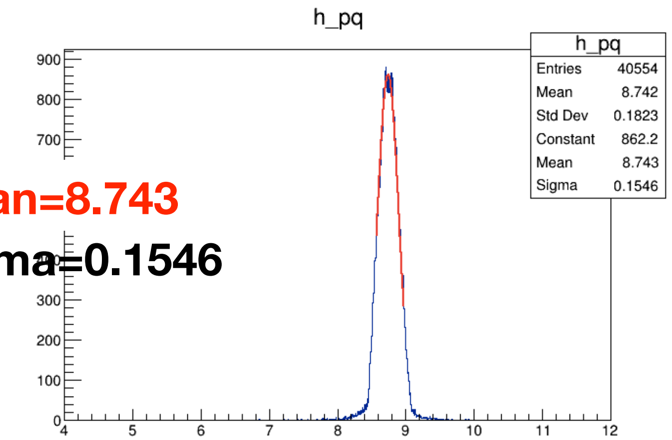
TX0 measured



offset = 0 mrad
sigma = 1.525 mrad

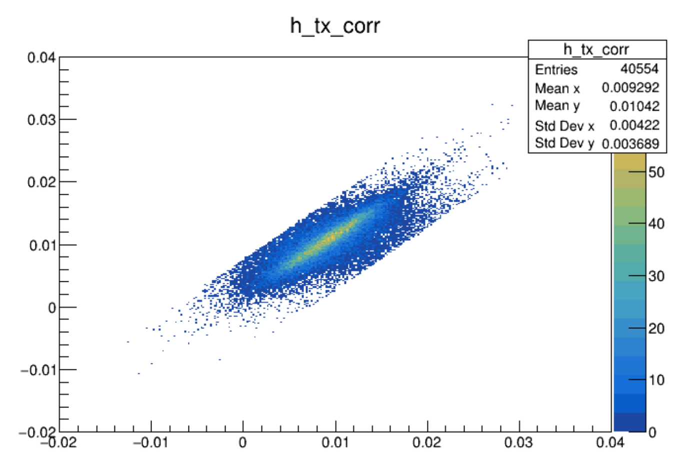
TX0 residual

Silicons



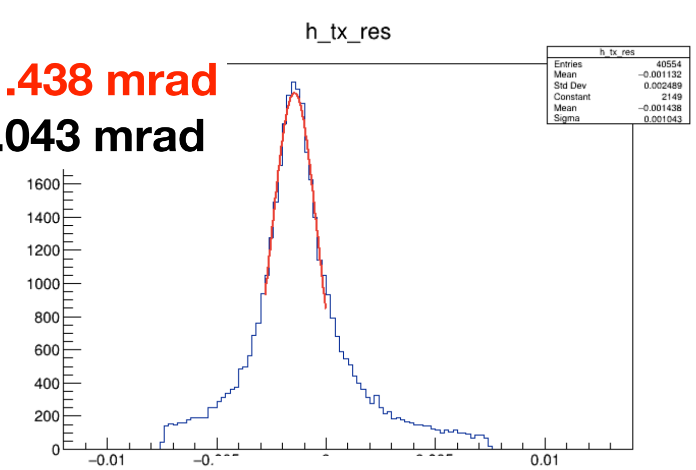
Mean=8.743
sigma=0.1546

P/Q_{MDF}



TX0 MDF

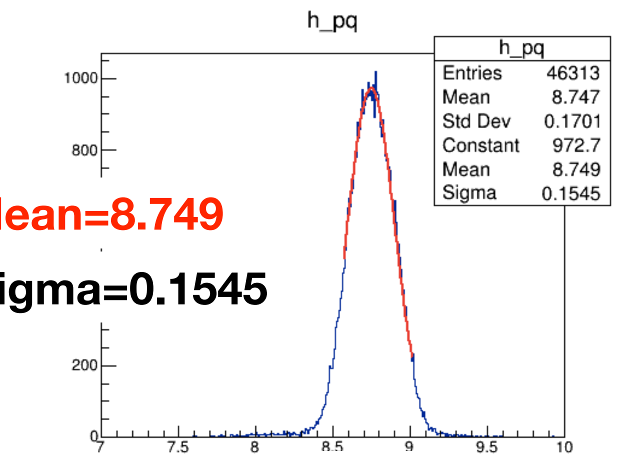
TX0 measured



offset = - 1.438 mrad
sigma = 1.043 mrad

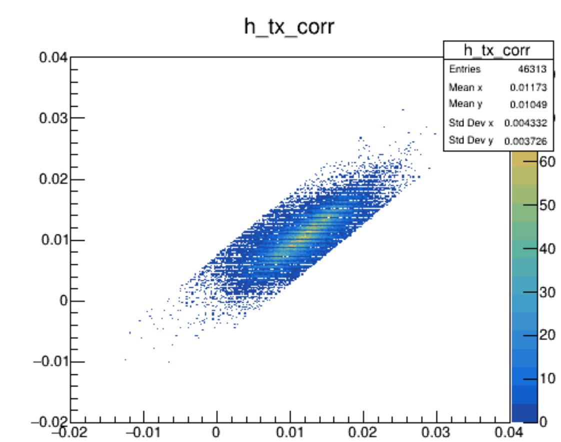
TX0 residual

MWPC_p1



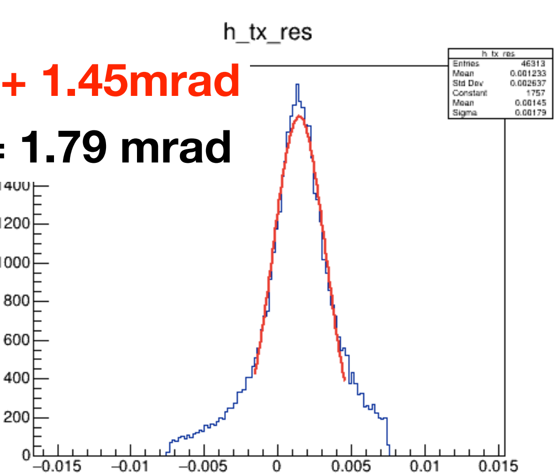
Mean=8.749
sigma=0.1545

P/Q_{MDF}



TX0 MDF

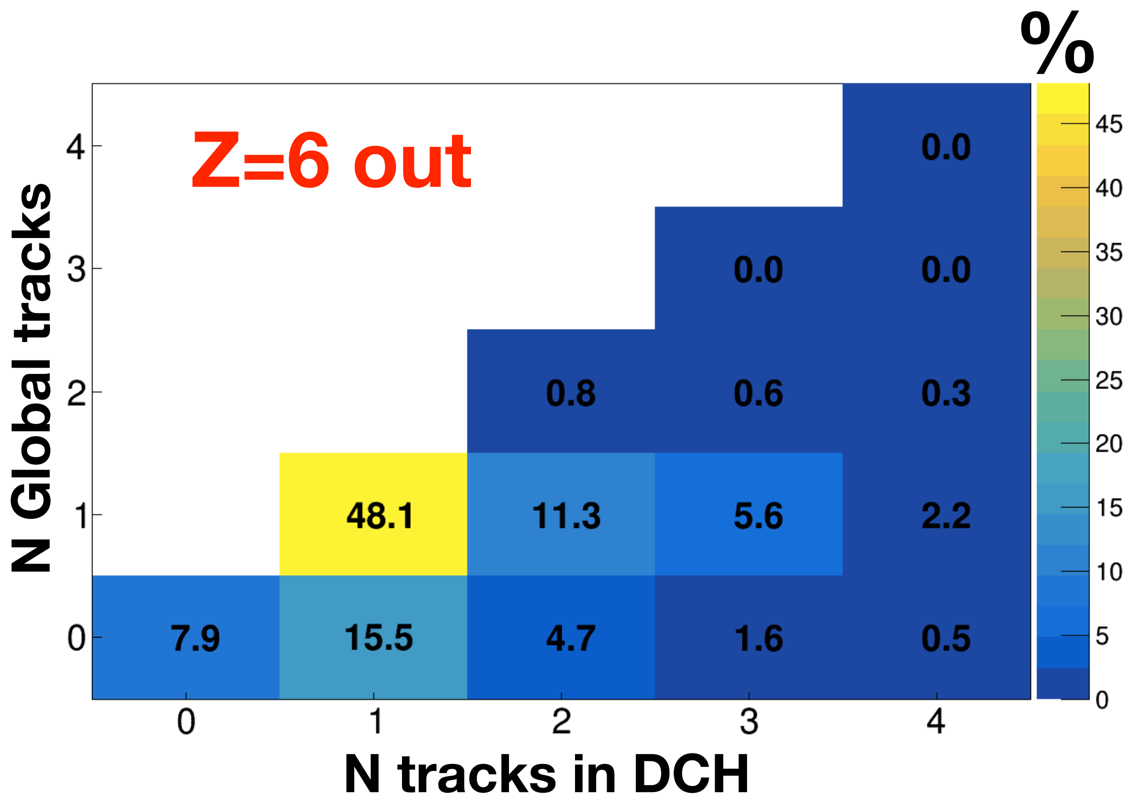
TX0 measured

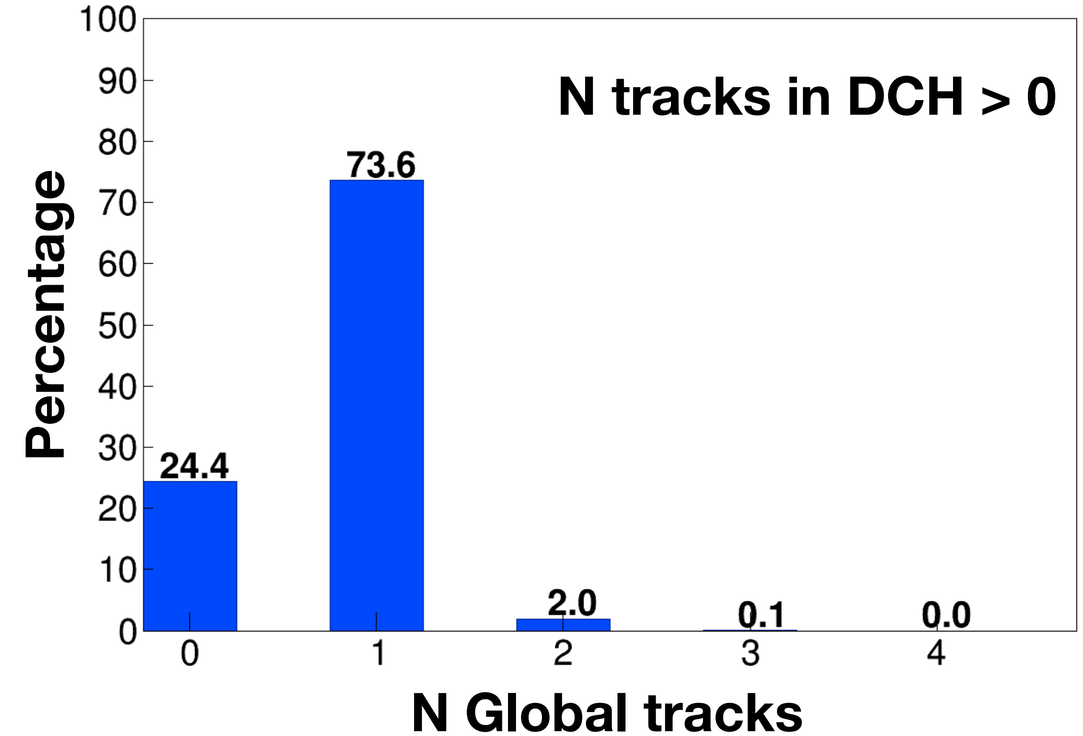


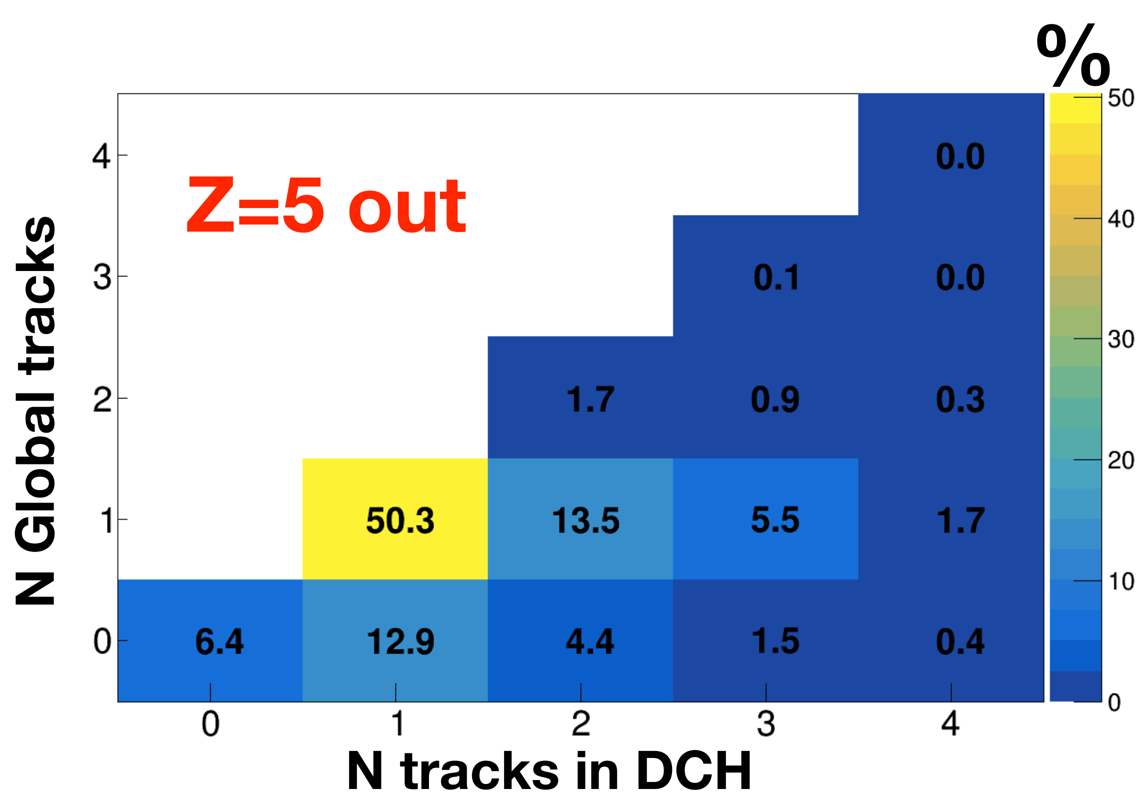
offset = + 1.45mrad
sigma = 1.79 mrad

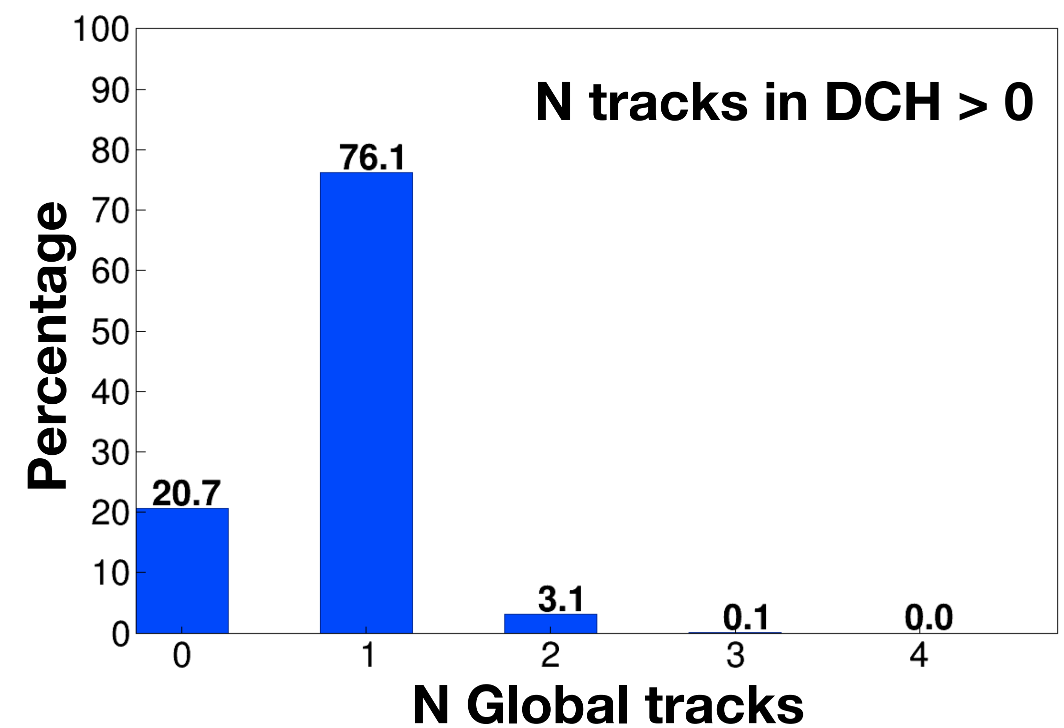
TX0 residual

Tracking efficiency (Zin=6 + at least 1 track upstream)









Summary

- MDF method for fragment tracking in SRC analysis:
  - Based on MC tracks from the simulations with realistic magnetic field
  - Polynomial MDF fit function = fast tracking
  - Reconstruction of experimental P/Q for outgoing fragments
  - Using TX0 fit for the track matching before and after the SP41 magnet

- Momentum resolution ~1.7% - comparable to the field integral method
- Momentum accuracy ~0.1% - consistent between different upstream detectors
- Efficiency of the tracking algorithm > 70%