



Kalman Filter Tracking

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Overview

- Wrote a module for tracking based off of a Kalman filter
 - Currently in the repository under TrackFit package
- Successfully verified the tracking algorithm using the Event Display
- Currently optimizing the track fitting parameters

Kalman Filter Basics

- Process and Measurement equations:

$$\begin{aligned}\mathbf{x}_k &= A\mathbf{x}_{k-1} + \mathbf{w}_{k-1} \\ \mathbf{z}_k &= \mathbf{x}_k + \mathbf{v}_k\end{aligned}\quad A = \begin{pmatrix} 1 & \Delta z \\ 0 & 1 \end{pmatrix} \quad \mathbf{x}_k = \begin{pmatrix} position \\ slope \end{pmatrix}$$

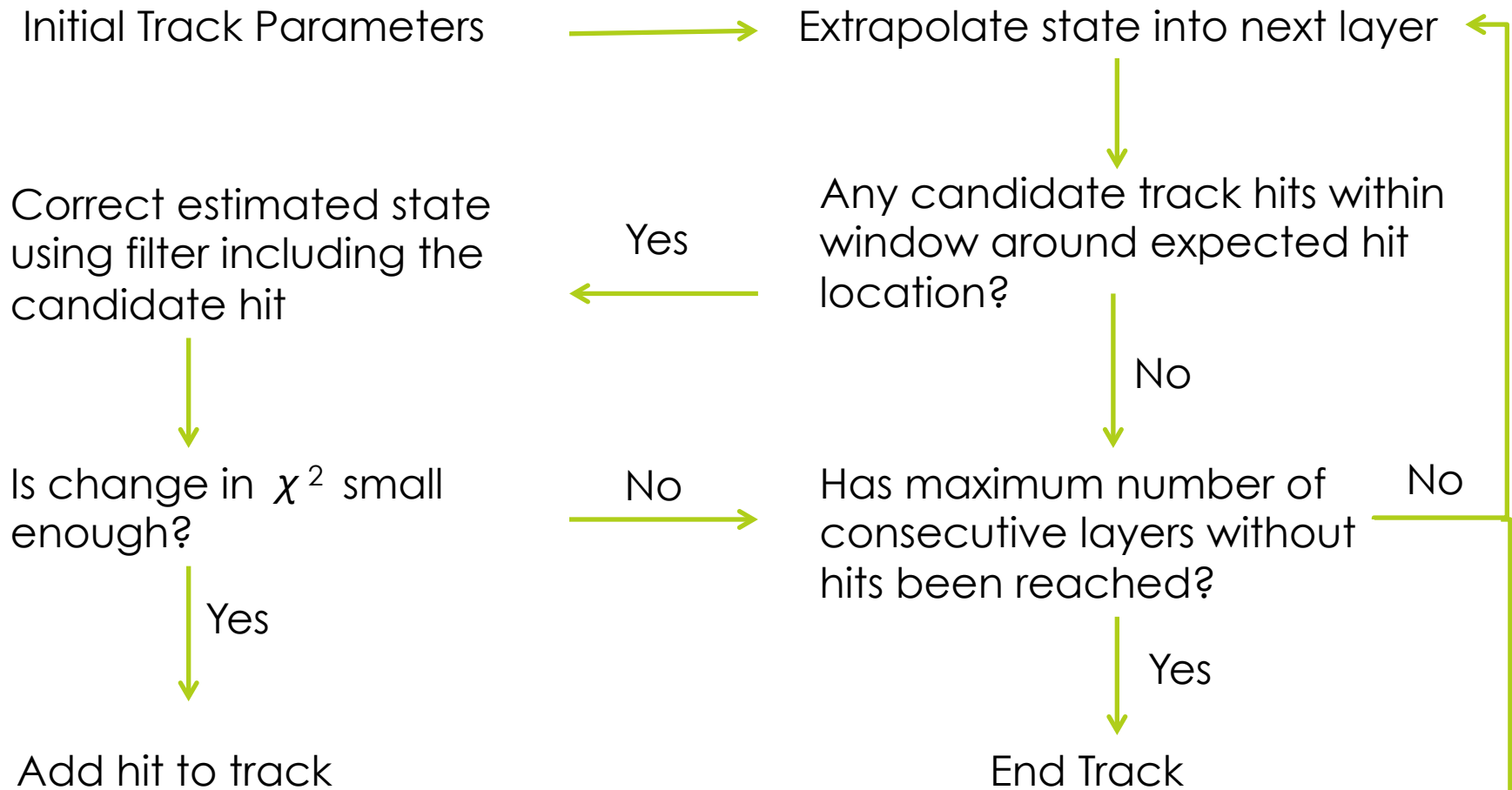
Where the process noise w has variance Q and the measurement noise has variance R

- Filter provides best estimate of the state based on projection of earlier measurements and current measurement

$$\hat{\mathbf{x}}_k = A\hat{\mathbf{x}}_{k-1} + K_k(\mathbf{z}_k - \hat{\mathbf{x}}_{k-1})$$

Where the filter K is chosen to minimize the error in the estimated state

Track Following Procedure



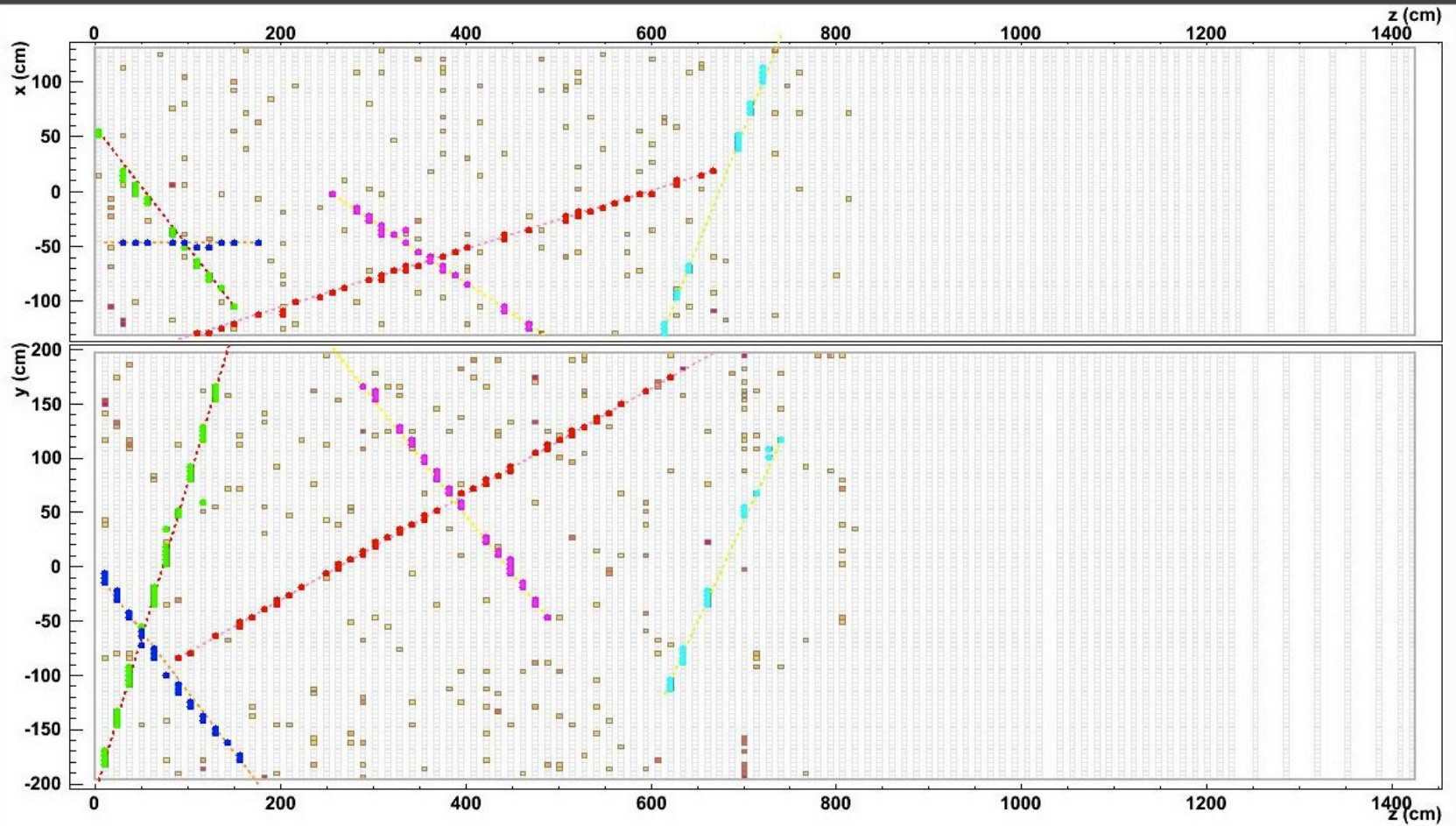
Algorithm

- Group cell hits into time clusters using Slicer. For each slice in both the x and y views determine a list of all possible tracks by grouping two hits together separated by less than a maximum number of planes
- Use the initial hits to determine tracks initial slope and position and approximate error covariance of the track
- Follow tracks starting from back of the detector forward
- Use same track following procedure follow tracks from the front of the detector backward using the tracks found to form the initial track parameters
- Iterate the backward/ forward track following procedure until track parameters vary by less than 1%
- Cut tracks that are short in the z direction or are fully contained in longer track
- Remove track with lowest chi squared value and iterate until no more tracks are found
- For each slice match xz and yz tracks found

Track Parameters

- Configurable:
 - Minimum track length (50 cm)
 - Maximum change to chi squared by the addition of one hit
 - Maximum distance between hits forming track start (50 cm)
 - Minimum number of hits in each view (4)
 - Hit Window Size
- Non configurable, but not optimized yet
 - Measurement noise variance (100 cm²)
 - Process noise variance
 - Expected to be dominated by multiple scattering
 - Based on : $\langle \theta_{rms} \rangle$ for a 2 GeV muon
 - Future implementation based on iterations over reconstructed track energy

Event Displays



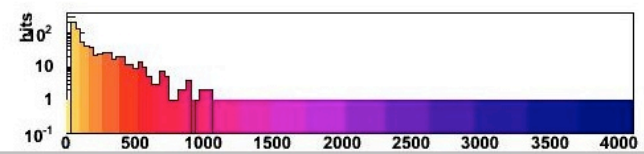
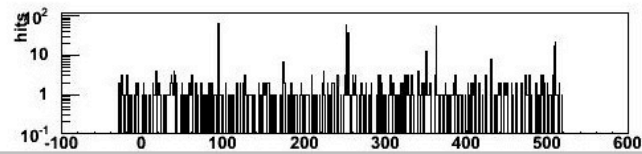
NOvA - FNAL E929

Run: 11810/16

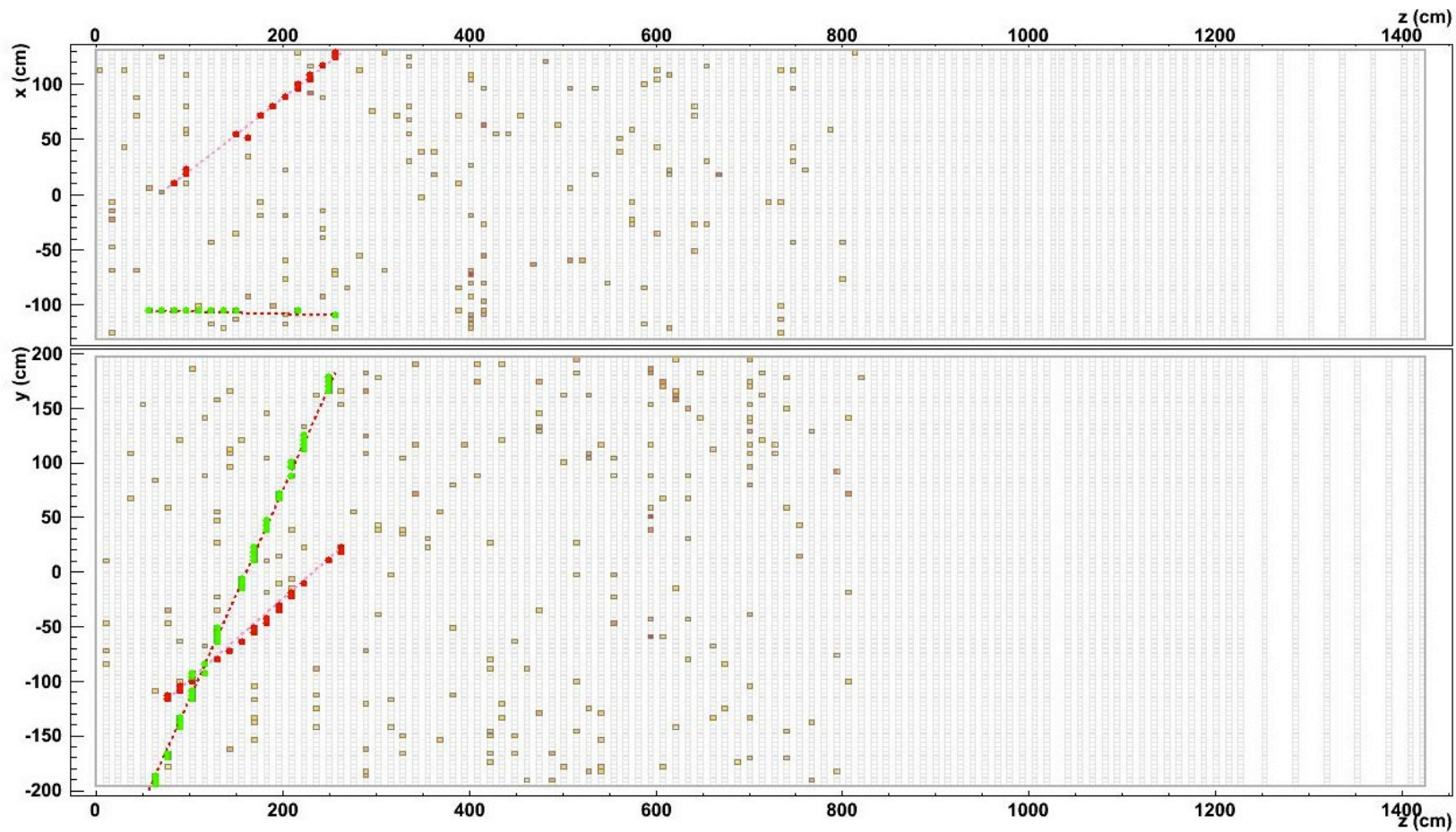
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UTC Thu Mar 24, 2011

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More Event Displays



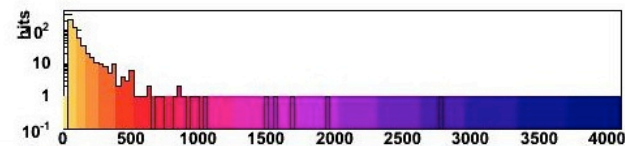
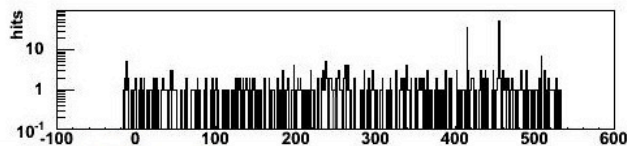
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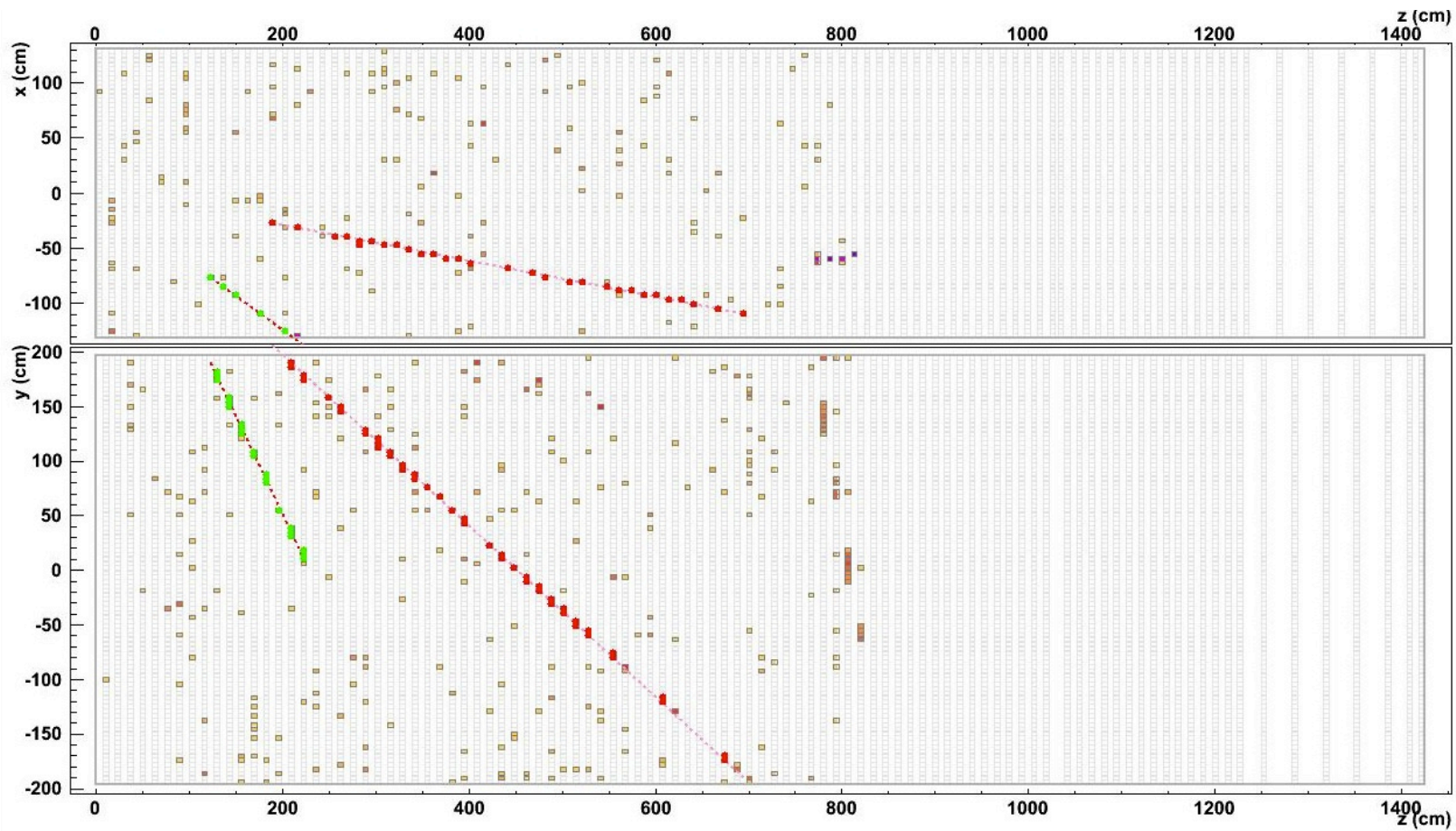
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UTC Thu Mar 24, 2011

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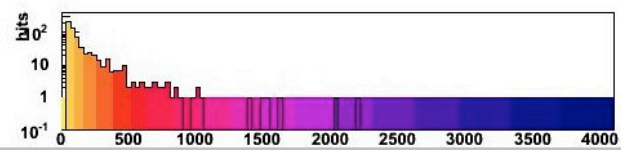
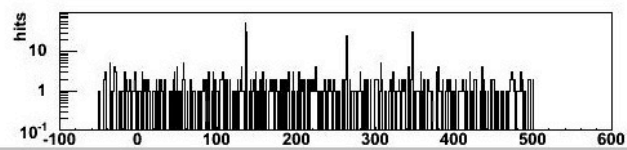
NOvA - FNAL E929

Run: 11810/16

Event: 4319

UTC Thu Mar 24, 2011

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Future Work

- Continue optimizing track parameters, especially multiple scattering uncertainties
- Verify tracking procedure using Monte Carlo and determine tracking efficiencies
- Implement optimized procedure on large scale data sets
- Potentially work on hybrid implementations with other tracking modules