Alternative Tracking Algorithm for the Mu3e Experiment

CHARLIE KINSMAN

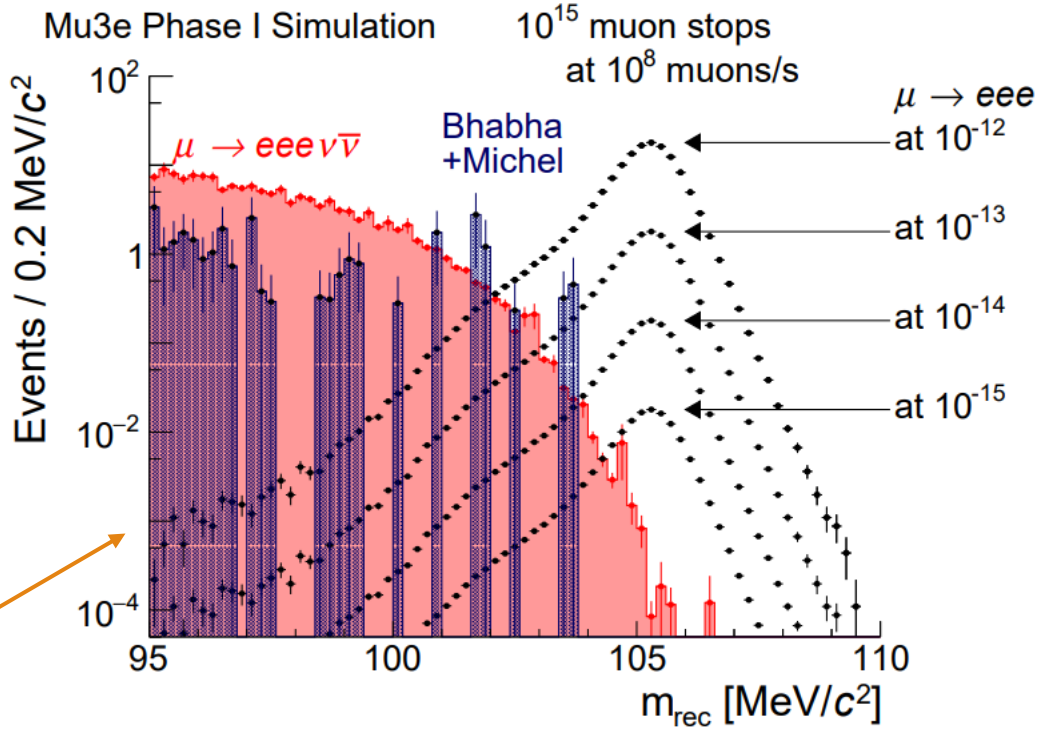
SUPERVISOR: HELEN HAYWARD

Mu3e Physics

- Mu3e aims to observe the decay: $\mu^+ \rightarrow e^+ e^+ e^-$
- If not exclude a branching ratio of $> 10^{-16}$ (Phase II) at a 90% confidence interval.
- Using the fact that the muons are at rest before decay gives the kinematic feature:

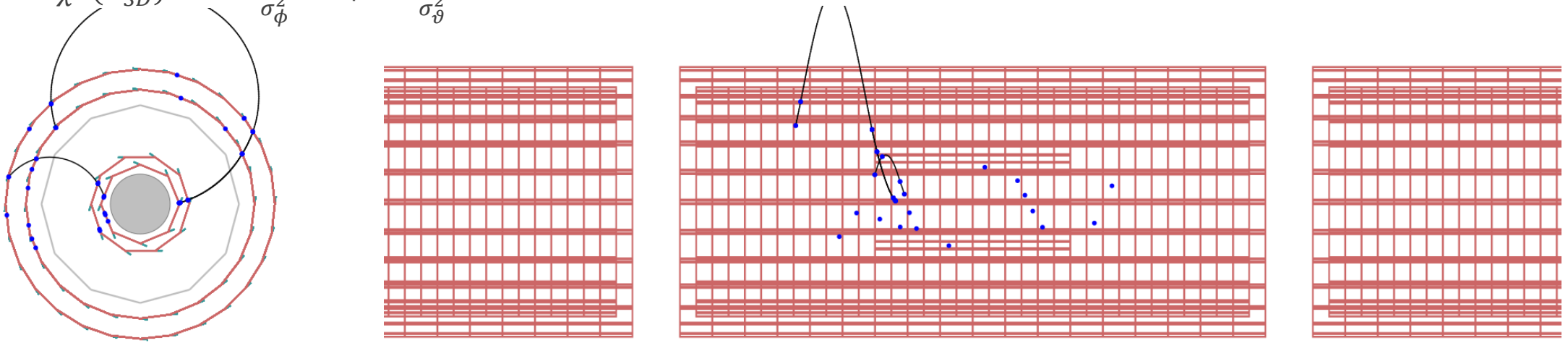
$$\sum p = 0 \quad \text{and} \quad \sum E = m_\mu$$

- By reconstructing the tracks of decay products and deducing their momenta, this feature will be used to identify signal events.
- For this an excellent mass (and therefore momentum) resolution is required to discriminate signal events from background.

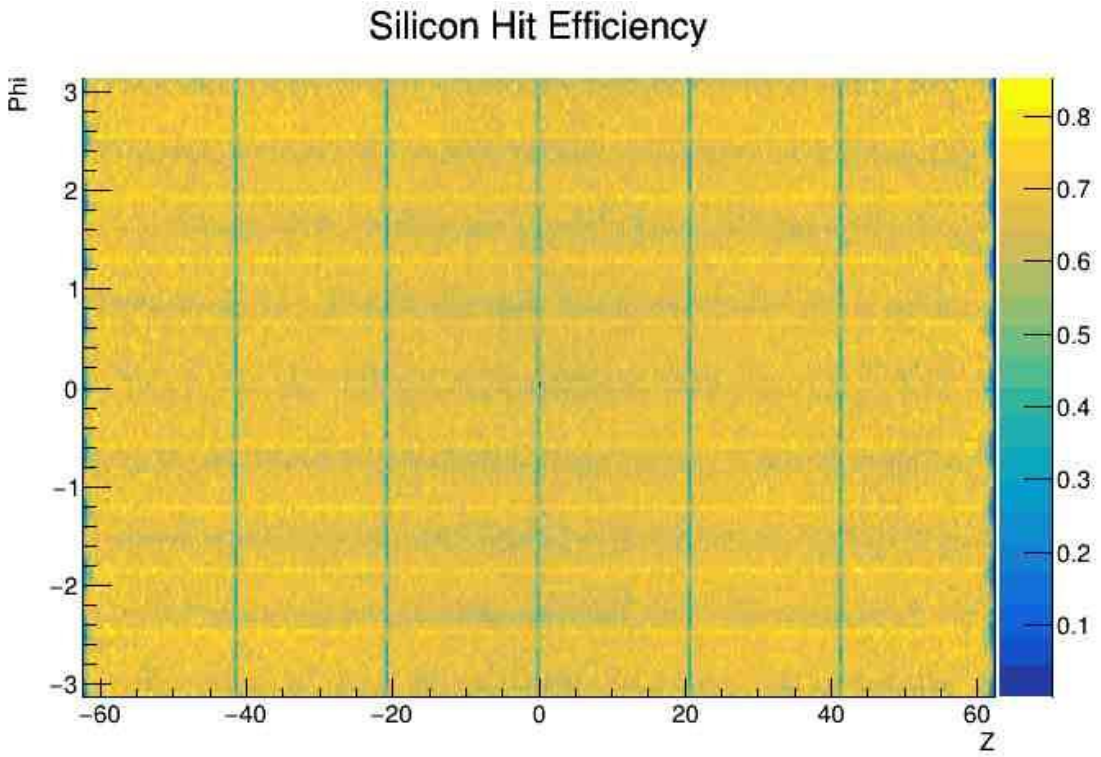


Tracking in the Mu3e Experiment

- The Mu3e experiment is sat in a homogenous magnetic field and therefore the decay products trajectory are described by a helix.
- The base unit for the fitting is a triplet of hits. The fitting is factorised into a circle fit in the plane transverse to the magnetic field and a straight line fit in the longitudinal plane. The scattering angles due to multiple scattering are treated as the only source of uncertainty in the fitting.
- The task is to find a three-dimensional curvature whereby the below equation is minimised:
  - $\chi^2(R_{3D}) = \frac{\Phi_{MS}(R_{3D})^2}{\sigma_\phi^2} + \frac{\Theta_{MS}(R_{3D})^2}{\sigma_\vartheta^2}$



Hit Efficiency

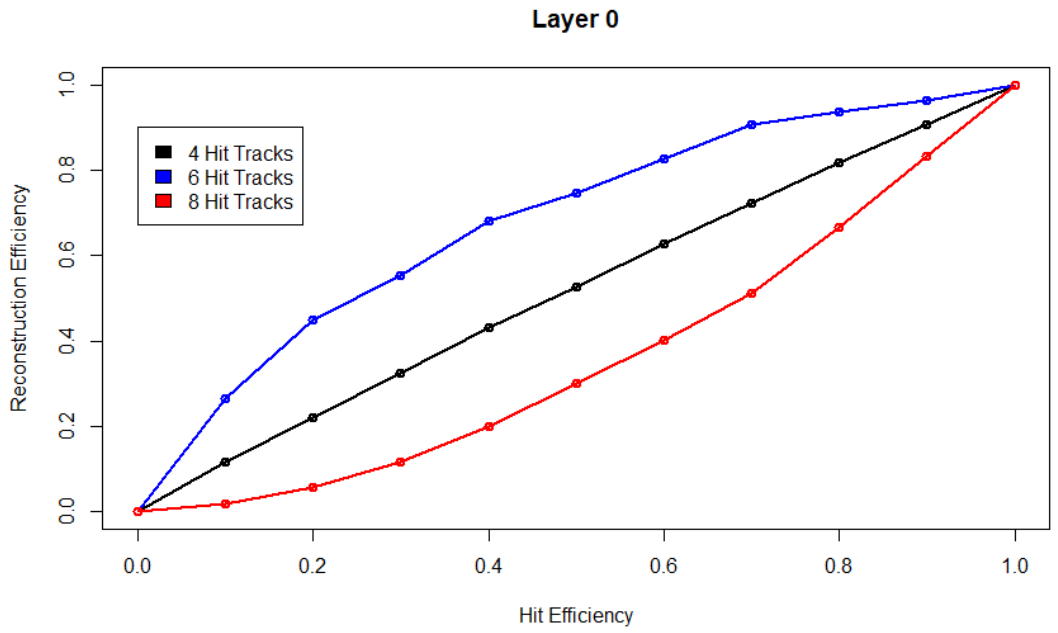


From a 75% efficiency, the total hit efficiency was calculated to be 74.1 +/- 0.84%. (Uncertainty from statistics)

- This tool used tracking to calculate hit efficiencies in the silicon tracking layers.
- By looking at the ratio between tracks that contained a missing hit against complete tracks, hit efficiencies could be calculated across a given test layer to a resolution of 3mm in the z direction and 0.08 rad in the phi.
- On the left is an example of a 75% inefficiency being recorded in the second layer.

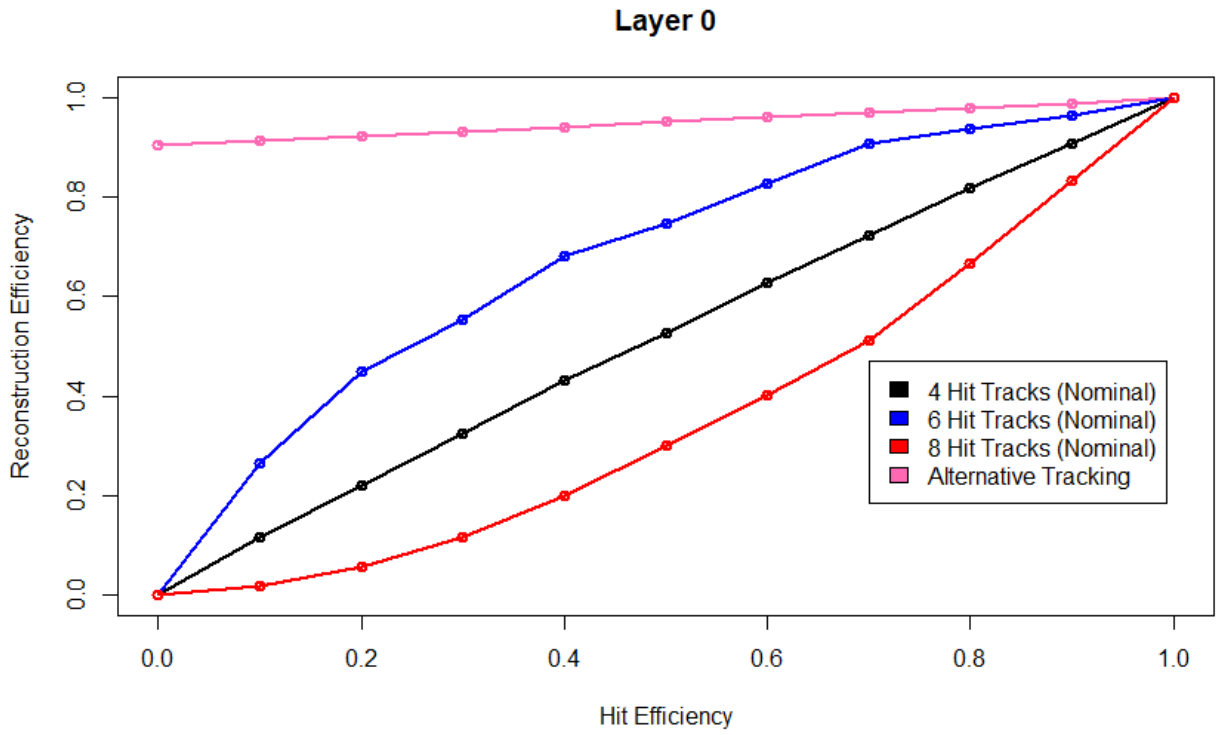
$$Hit\ Efficiency = \frac{Hit\ Found}{Hit\ Found + Hit\ Not\ Found}$$

Track Reconstruction – Efficiency Issues



- The nominal tracking algorithm generates tracks with a series of nested for-loops by moving from layer to layer. This creates an issue when looking at inefficiencies in the detector.
- If a hit is missing in the detector, the track is discarded.
- The reconstruction efficiency of four hit tracks has a directly proportional relationship to the hit efficiency of each layer of the detector.
- Non-linearity comes from reclassification of tracks when a hit is missing.

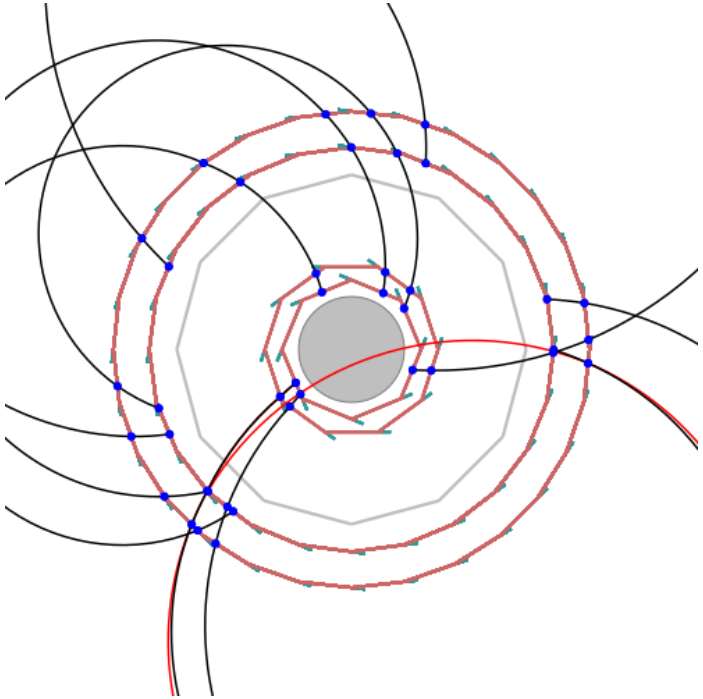
Track Reconstruction – Efficiency Issues



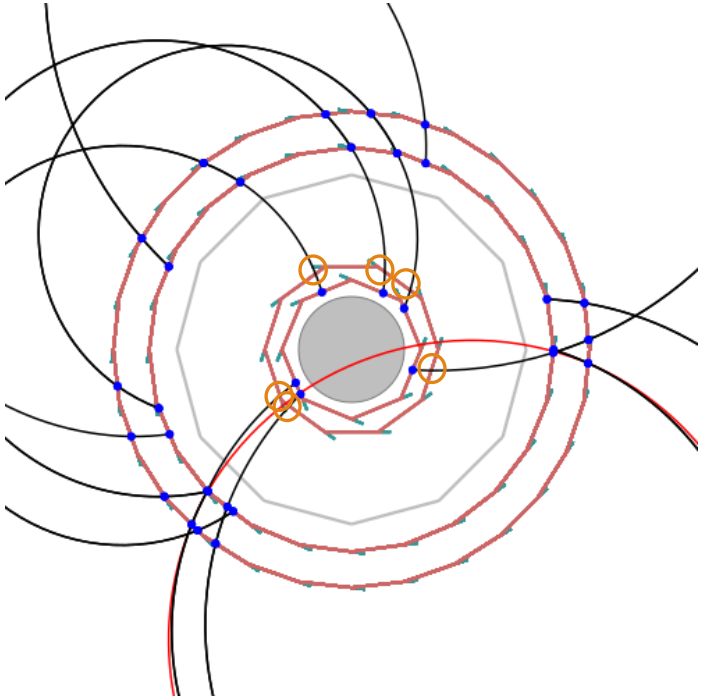
- The nominal tracking algorithm generates tracks with a series of nested for-loops by moving from layer to layer. This creates an issue when looking at inefficiencies in the detector.
- If a hit is missing in the detector, the track is discarded.
- The reconstruction efficiency of four hit tracks has a directly proportional relationship to the hit efficiency of each layer of the detector.
- Non-linearity comes from reclassification of tracks when a hit is missing.

Alternative Tracking Algorithm

- Triplets are used as a starting point instead of individual hits and connecting tracks based on common hits or similar geometrical properties.
- Unique combinations of triplets allow for missing hits in layers to be identified.
- From this missing hits can be skipped over, and N hit tracks that could not be reconstructed, can be partially reconstructed as N-1 hit tracks.



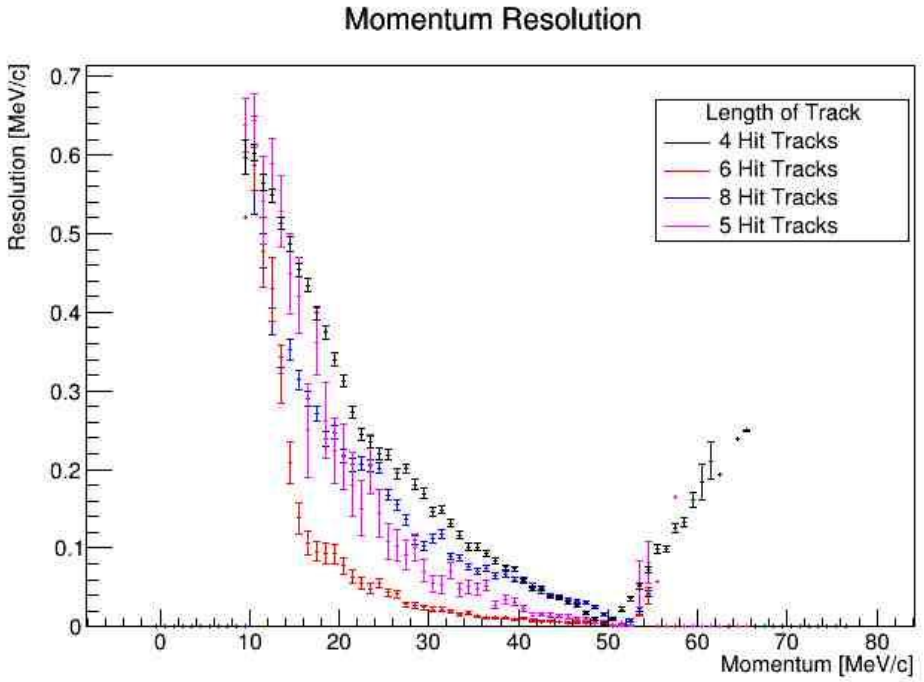
Nominal tracking algorithm – 100% hit efficiency



Alternative tracking algorithm – 10% hit efficiency in layer 2

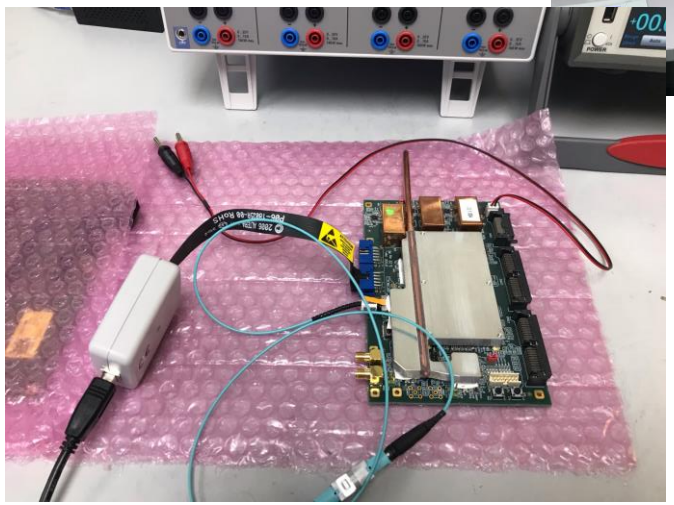
Alternative Tracking Algorithm

- The main assessment of the validity of this algorithm comes with understanding the momentum resolution.
- An excellent resolution is required in order to discriminate from the main physical background (internal conversion).
- To allow the N-1 hit tracks to be used, the tracks must have a momentum resolution < 1MeV.



Hardware Plans

- Liverpool is responsible for the module construction of the outer pixel layers of the tracking detector.
- Over the next few months ladders of pixel detectors will arrive from Oxford. These will be QC tested to understand the yield.
- These will then be constructed into modules (4 ladders sat parallel to one another), to be shipped to PSI.
- Currently the focus has been setting up the test stand and understanding the online software in preparation for the arrival of the ladders.



Next Steps

- Complete the selection cuts for the alternative tracking and reduce computational time for this algorithm.
- Merge this code with the Mu3e tracking code with documentation.
- Prepare for the arrival of ladders to begin QC testing, alongside the construction of modules.