Recent Progress on Pandora Cosmic Reconstruction

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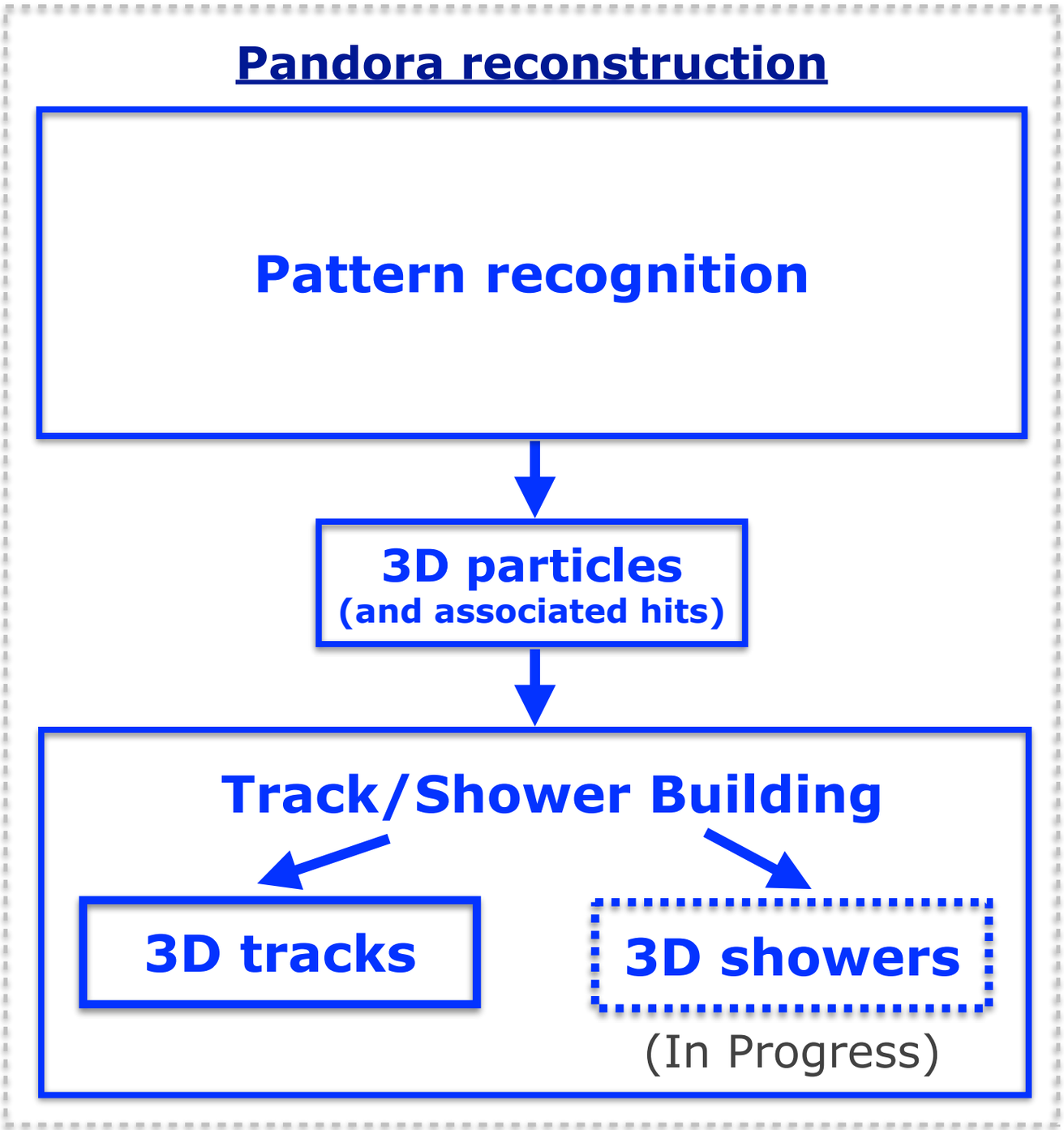
Overview

- **Have returned to development of Pandora reconstruction algorithms over past few weeks.**
  - While mainly preparing to move house and start my new job.
- **Have focused on cosmic-ray reconstruction while John M. works on neutrino reconstruction.**
- **Particular focus on improving efficiency for short tracks.**
  - Efficiency previously dropped away sharply for short tracks.
- **Cosmic reconstruction efficiency is now much-improved! Will show latest performance plots in this talk.**

Pandora Reconstruction



- **Two-step procedure:**

(1) Pattern recognition:

☆ Identify the hits associated with each particle.

☆ Identify parent/daughter relationships between particles

☆ Output reconstructed particles

Aim: one primary Reco particle for each primary True particle.

Pattern recognition is the main application of the Pandora framework.

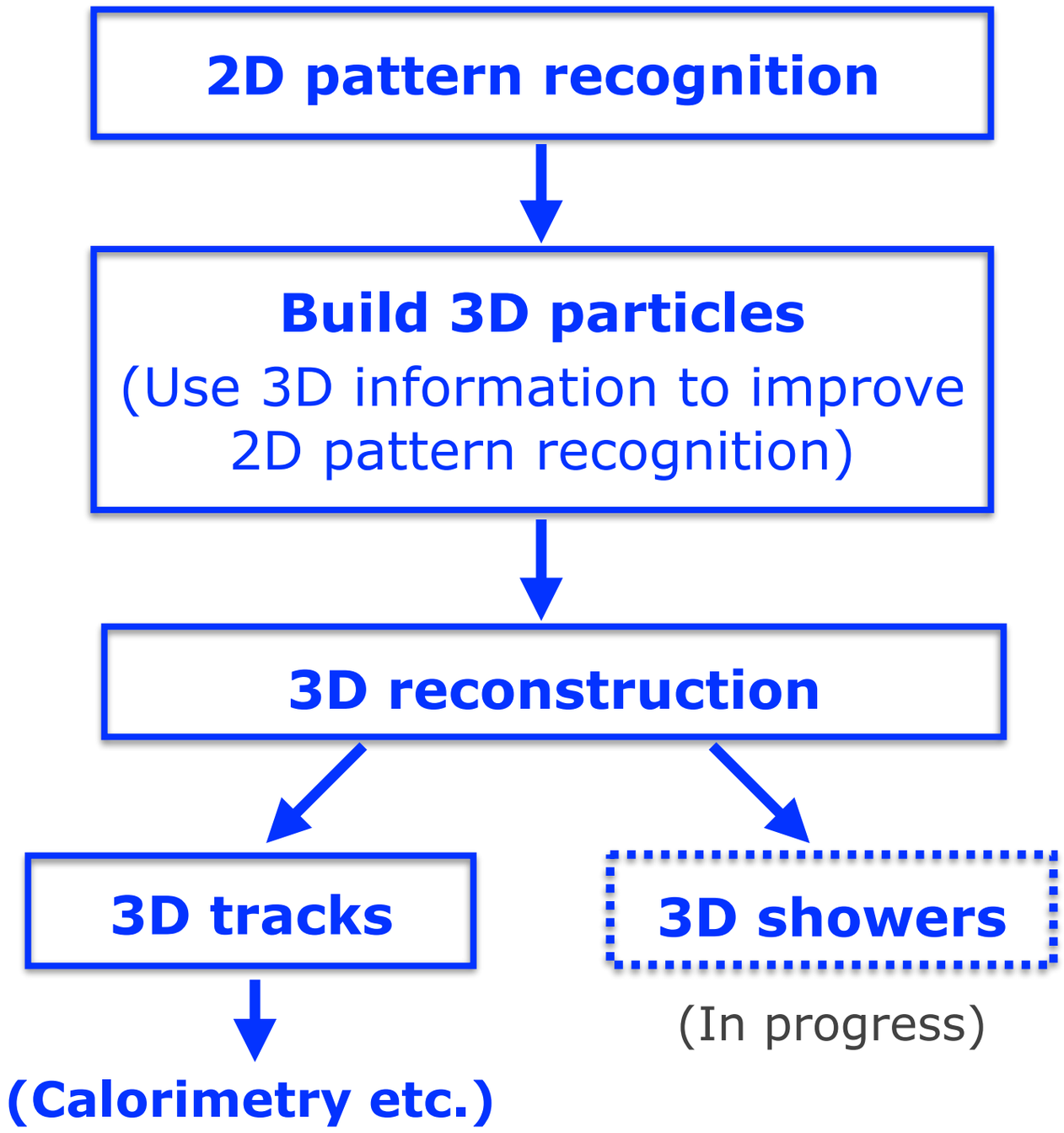
(2) Determine particle properties:

☆ Determine 3D trajectories of track-like particles.

☆ In progress: also determine properties (e.g. direction) of shower-like particles.

Pandora Cosmic Pass

Cosmic pass:



- Start by clustering hits in 2D
  (14 algorithms)

- Match 2D views.
- Form 3D particles.
- Manipulate 2D clusters to improve consistency between views.
- Reconstruct delta rays.
  (12 algorithms)

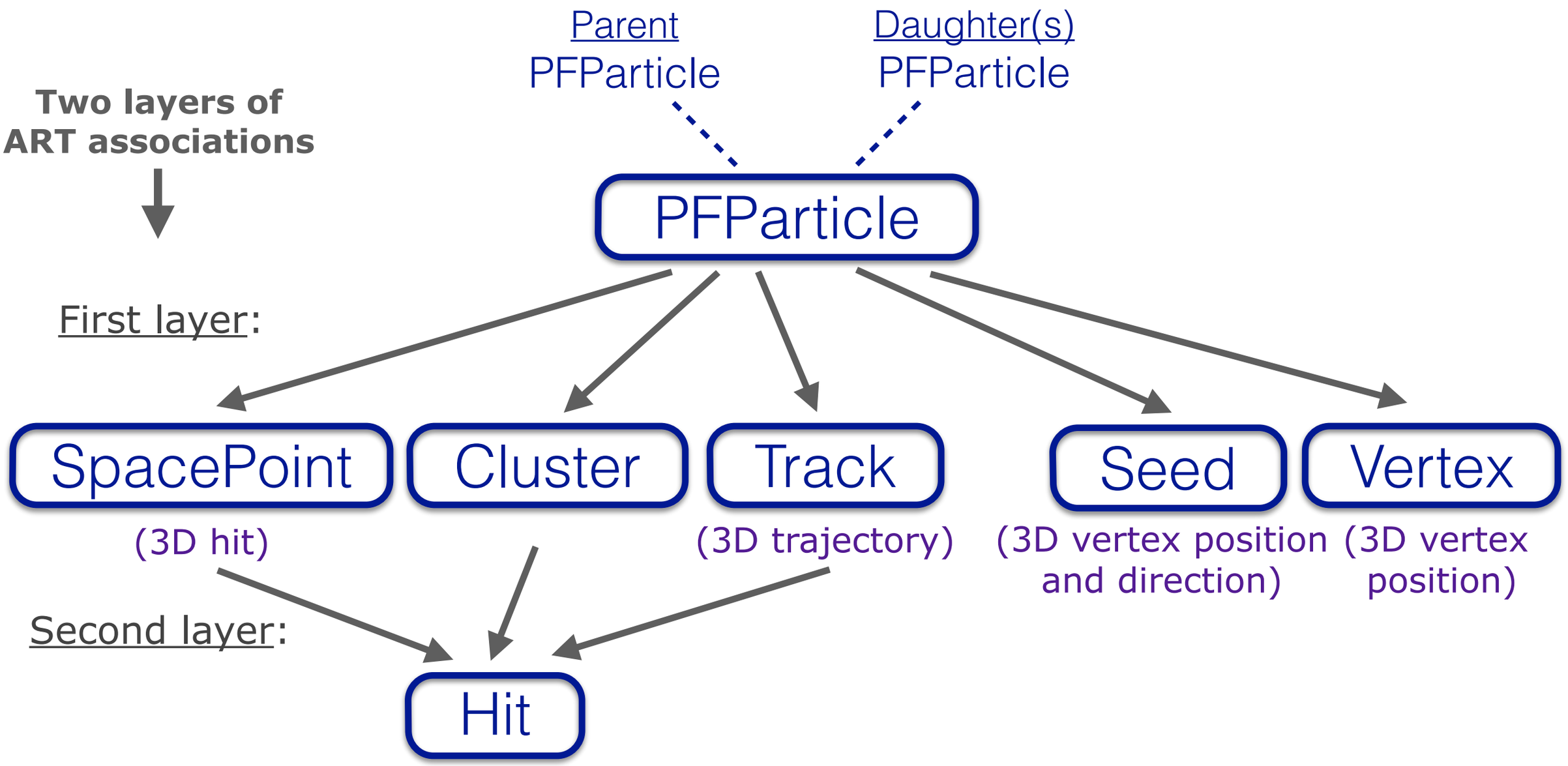
- Build 3D particles: space points, vertex positions, track trajectories, etc.
  (4 algorithms)

- Build 3D tracks from track-like particles.
  (1 algorithm).

Reconstruction Outputs

Output to LArSoft:

Two layers of ART associations



Reconstruction Studies

- **All results (continue to be…) based on 6 GeV single muons simulated in 35t detector.**

  ☆ Use G4 particle gun to inject 6 GeV muons into detector.

  - Injected from disc of radius 2m at top surface of detector.
  - Muons are uniform in azimuthal angle, and distributed as $\rho(\cos\theta) \sim \cos^2\theta$ in zenith angle.
  - Single-window readout ($T_0 = 0$).

- **Continue running cheated hit-finding and disambiguation.**

- **Run Pandora cosmic reconstruction (pattern recognition, track-fitting, stitching, performance metrics).**

- **Aim of this work:**

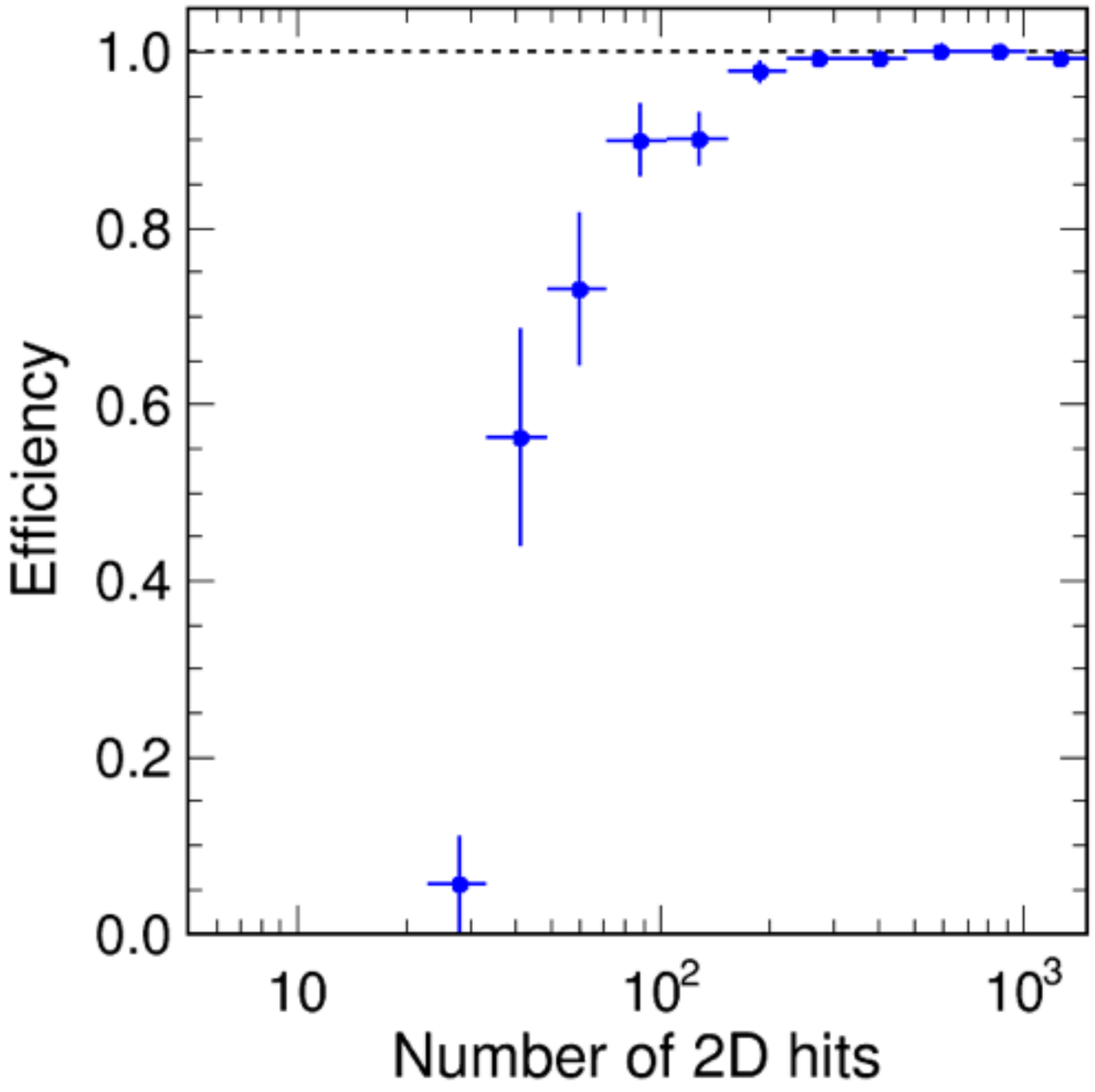
  ◇ Improve reconstruction efficiency for short cosmic events.

  ◇ Use above Sim & Reco to demonstrate improvement.

Previous Performance

Pandora (old)

6GeV muons & cheated hits



- **Left plot: previous performance of cosmic pattern recognition:**
  - Close to 100% above 100 hits.
  - But drops off below 100 hits, crossing 50% at 40 hits.
- **Drop-off in efficiency was mainly due to conservative thresholds used by many algorithms.**
  - Wanted to minimise mistakes, so trod cautiously when developing algorithms.
- **On investigation, most short events look clean and can be recovered "easily" by reducing these thresholds.**
- **So, try reducing thresholds!**

Algorithm Development

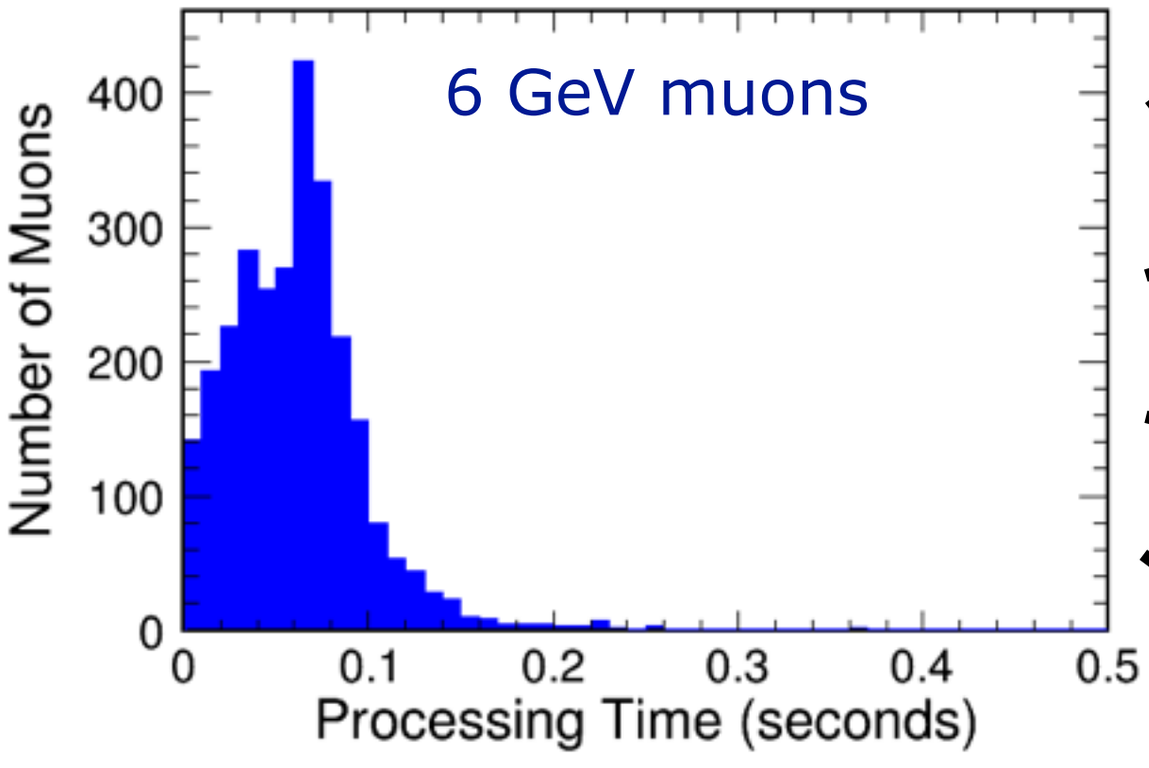
- **Modifications to Pandora cosmic reconstruction:**
  - Loosened selection cuts in existing algorithms.
  - New 3D algorithms designed to use small clusters and/or to run on just two views.
  - Also, now add any "isolated" hits to their nearest particle, which improves the completeness metric.
- **Also tidied up track-fitting and calorimetry algorithms and fully incorporated them in Pandora framework.**

Processing Time

- **Pandora cosmic reconstruction is fast!**
  - Benefitted from recent code review and speed-ups by John M.
  - Most events in my sample now take <0.1s.

INPUT

2D Hits



OUTPUT

PFParticles

2D Clusters

3D Hits

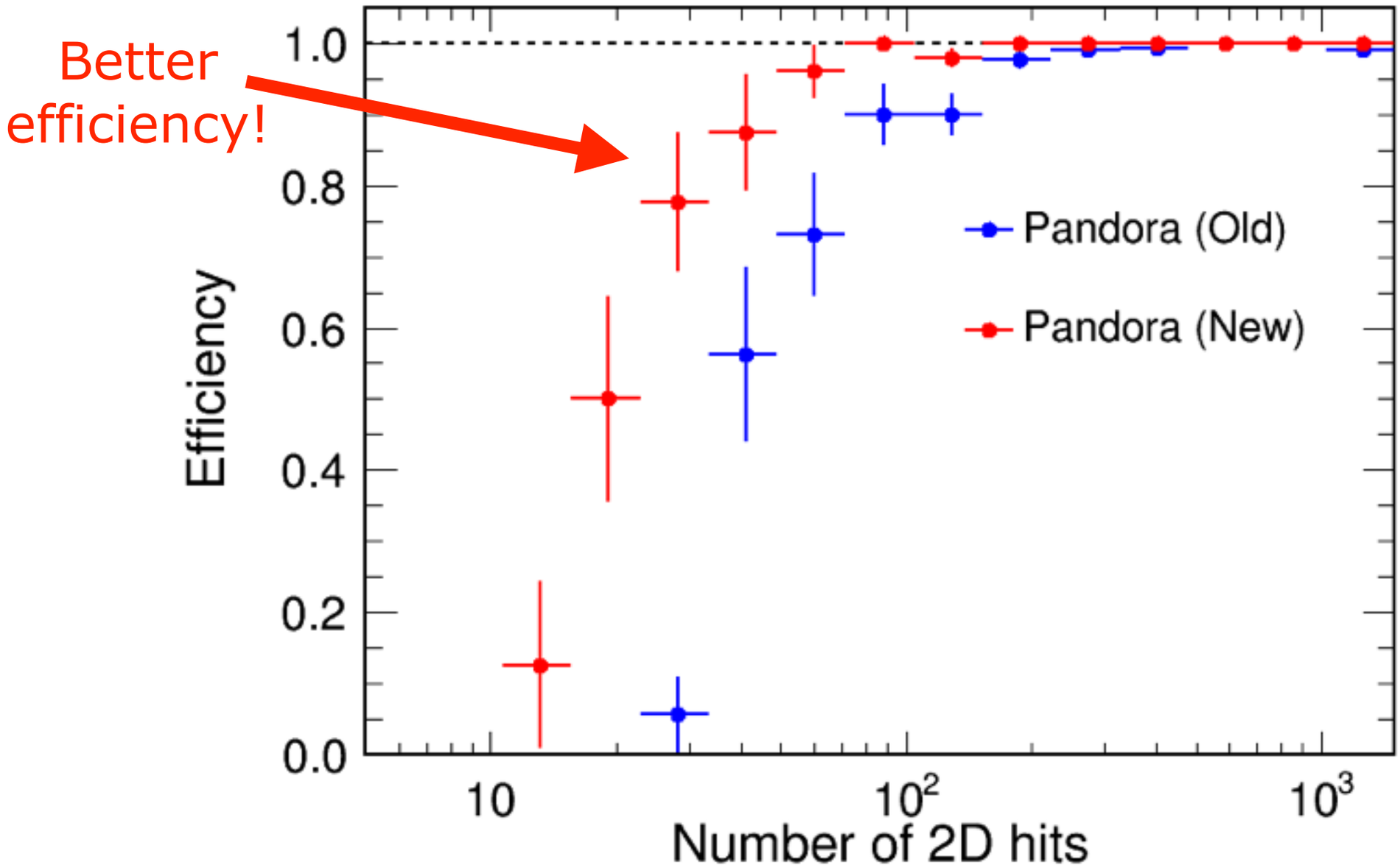
Vertices

Delta-ray showers

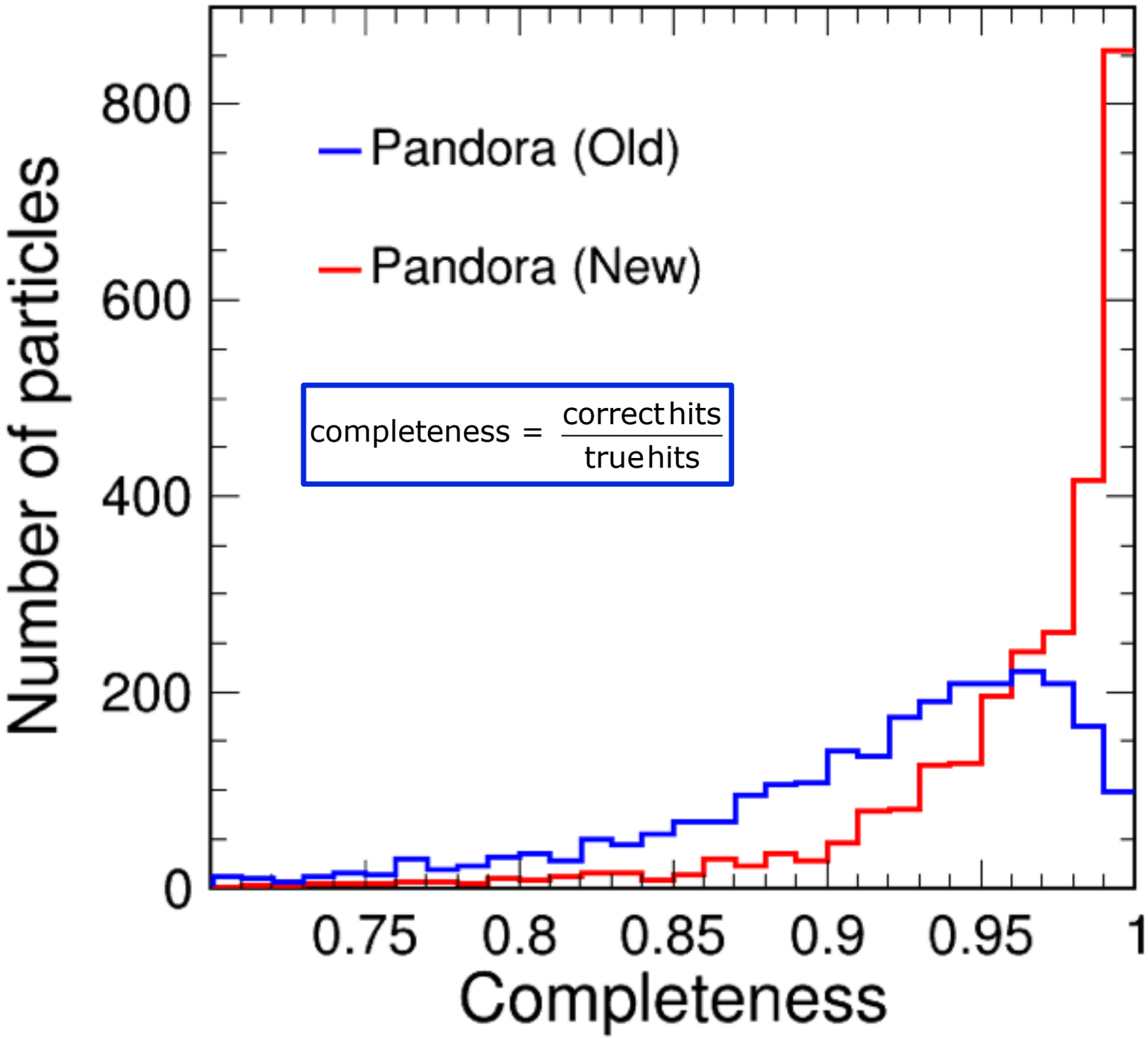
Tracks

Particle Efficiency

- **Efficiency of pattern recognition is now much improved.**

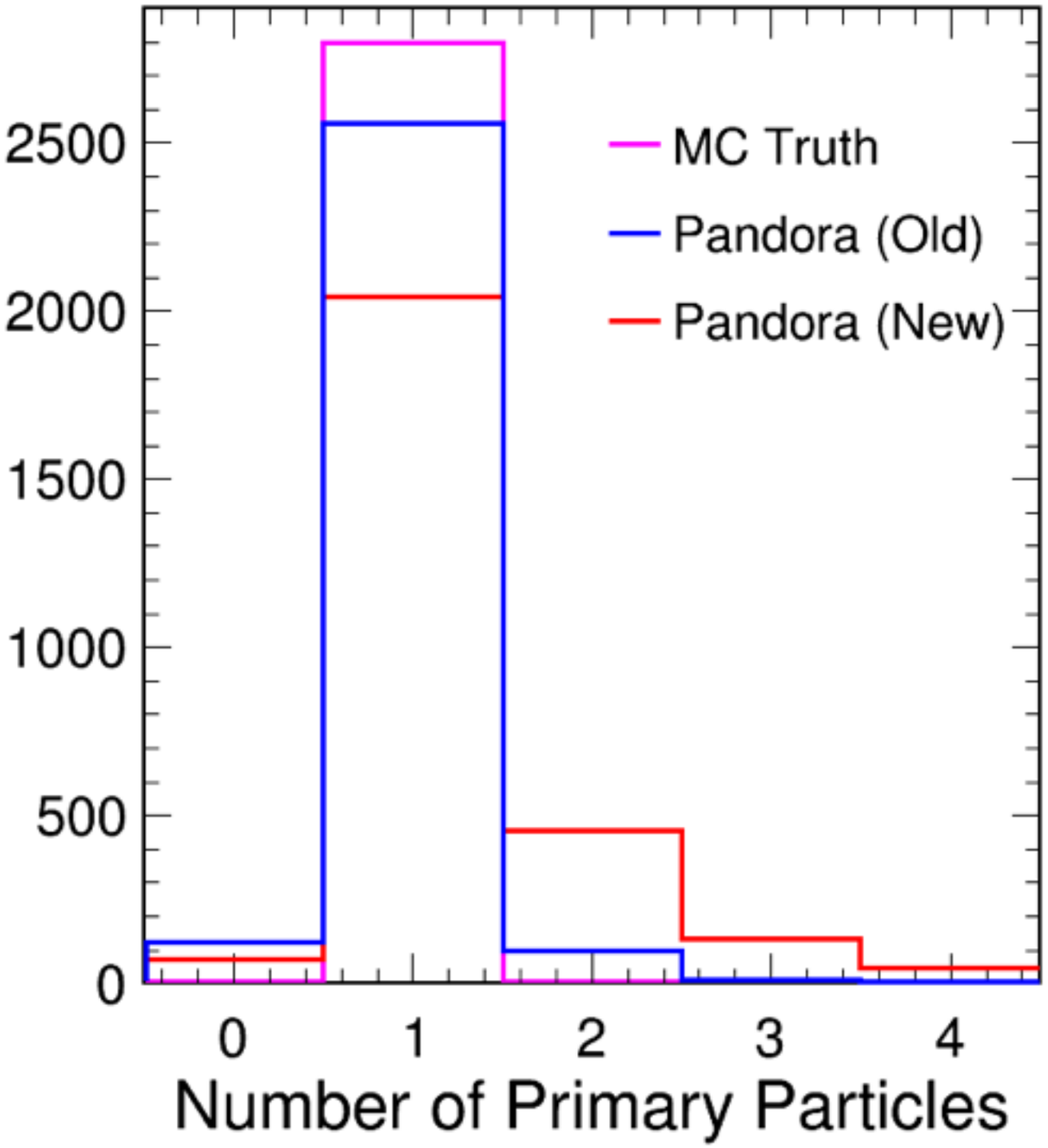


Particle Quality



- **'Completeness' metric is also much-improved.**

Primary Particles



- **One cost of improved efficiency is that we now reconstruct too many primary particles.**
  - Due to halo of small showers around parent tracks.
- **Need to re-optimise reconstruction of particle hierarchy.**
  - Need to associate small showers with their parent tracks.
  - Currently working on this problem.

Track-based Calorimetry

- **Have started filling dQ/dx information in recob::Track. Can use this information do track-based calorimetry.**
- **Values of dQ/dx calculated for each 2D hit on the track:**
  - Determine 'dx' by projecting wire pitch onto track trajectory.
  - Combine with integrated charge of hit to give dQ/dx.
- **Try writing a track-based calorimetry module:**

☆ Convert dQ/dx to dE/dx at each point along the track.

1. Convert charge into numbers of electrons:

   $dN/dx = C \times dQ/dx$ [Using cheated hits in this analysis, so take C from DetectorProperties]

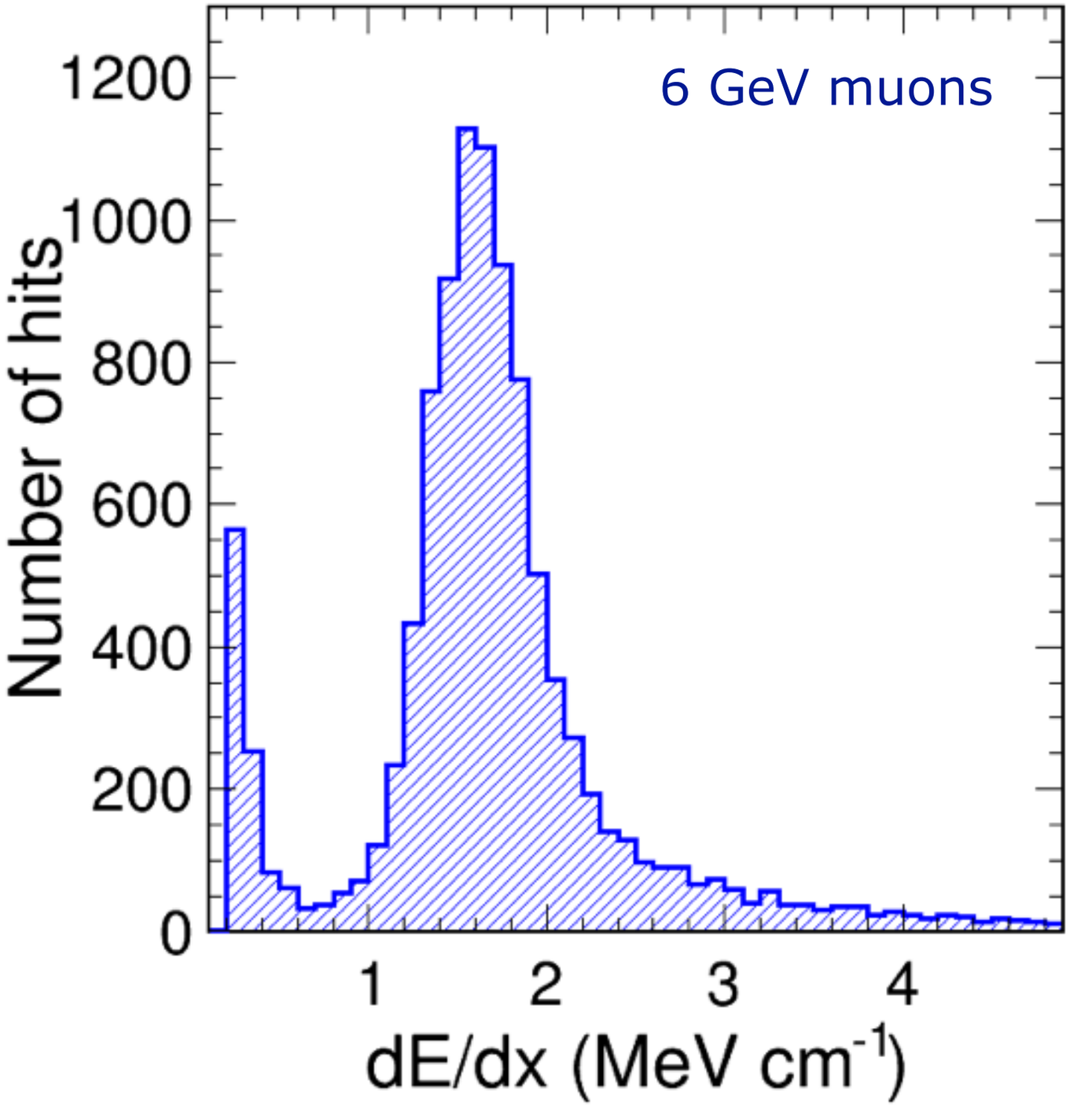
2. Apply lifetime correction:

   $dN_0/dx = dN/dx \times \exp([t-t_0]/\tau)$ [τ = 3 ms]

3. Apply modified box correction:

   $dE/dx = f_{ModBox}\,(dN_0/dx)$

Track-based Calorimetry



- Resulting dE/dx distribution for my 6 GeV muon sample.
- Not bad, but seems a bit low (and also has anomalous peak at low dE/dx).
- Need to try running without cheated hit reconstruction.

Summary

- **After re-tuning existing pattern recognition algorithms, and adding some new ones, reconstruction efficiency is much-improved for short cosmic tracks.**
  - Have also boosted 'completeness' performance metric.
- **One cost of improved efficiency is a greater number of "fake tracks".**
  - Need to re-optimise reconstruction of particle hierarchy in order to fix these events.
- **Pandora track-fitter now stores dQ/dx information in recob::Track object.**
  - Could use this information for track-based calorimetry.
- **Will install latest Pandora software at Fermilab soon (need to finalise code, and coordinate with John M).**