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π^0 studies with ArgonCube 2x2 in NuMI

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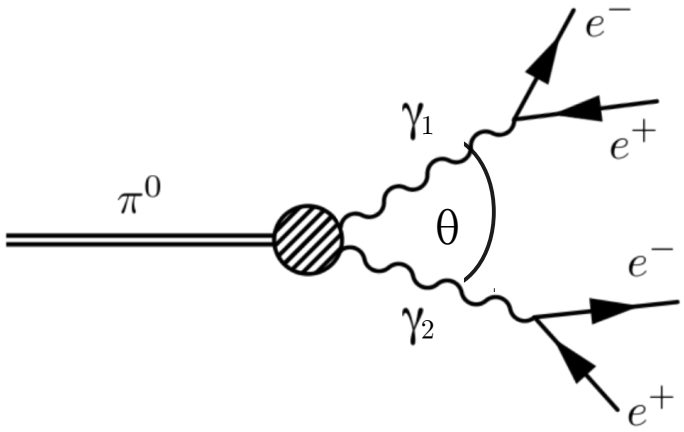
Motivation

Total π^0 energy goes into showers (back-to-back γ's in CM frame)

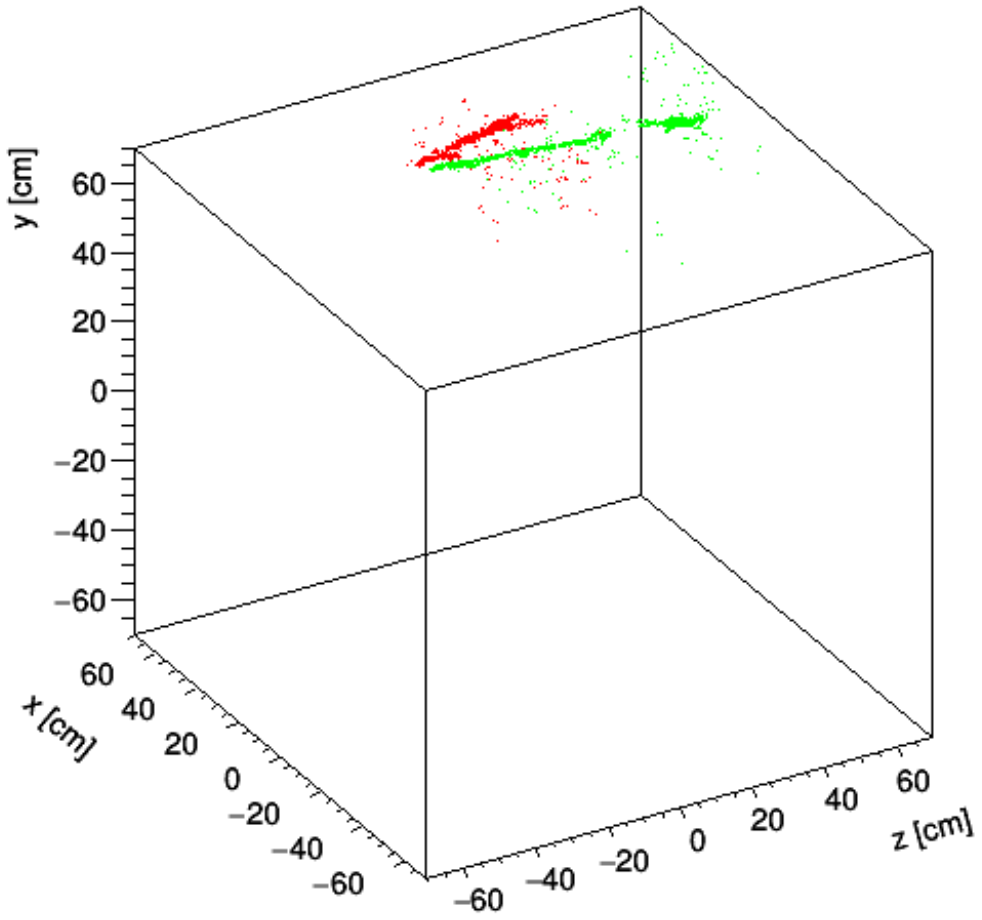


→ Angle between γ's and the energy deposits allow for π^0 mass reconstruction

→ **Calibrating electron energy scale**

$BR(\pi^0 \to \gamma + \gamma) \approx 0.988$

Simulated π^0 decay in LAr



Needs

For this study: Need software for event reconstruction

(or at least something to identify EM showers / π^0 induced showers)

→ What's the status of ML based pattern recognition?

→ What code does already exist for event reconstruction, what do we need to develop?

→ How can I integrate with the group of reconstruction?

What I (don't) have at this moment

- Geant4 simulation of NuMI ν_μ interactions in Argon (using Dan's ArgonBox)
- Voxelisation
- Clusterisation (density based spacial clustering)
- Cluster merging / track matching for a modular environment
- Cluster separation (e.g. for muon crossing EM shower
- Track-/shower- identification
- Vertex-finding, shower's start position detection
- Principal components analysis (no outlier detection yet)
- 2D Hough-Transform

All my code: Python

Voxelisation

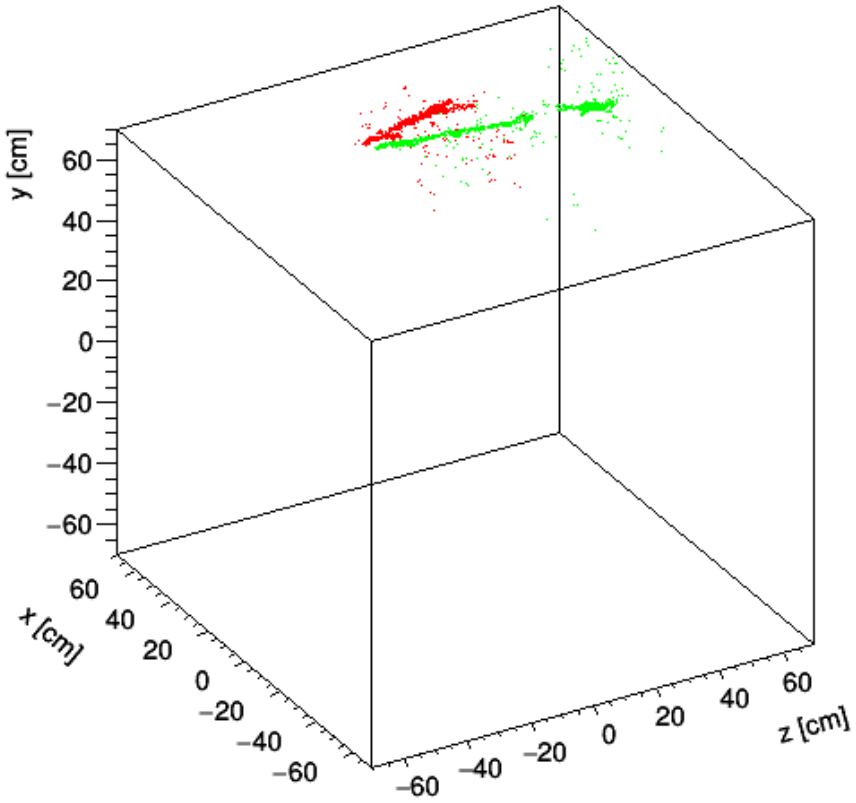
- Voxelised $(1.4\ \mathrm{m})^3$ box with $350 \cdot 350 \cdot 700$ voxels corresponding to 4 mm pixel pitch (x,y) and 2 mm in drift direction (z)

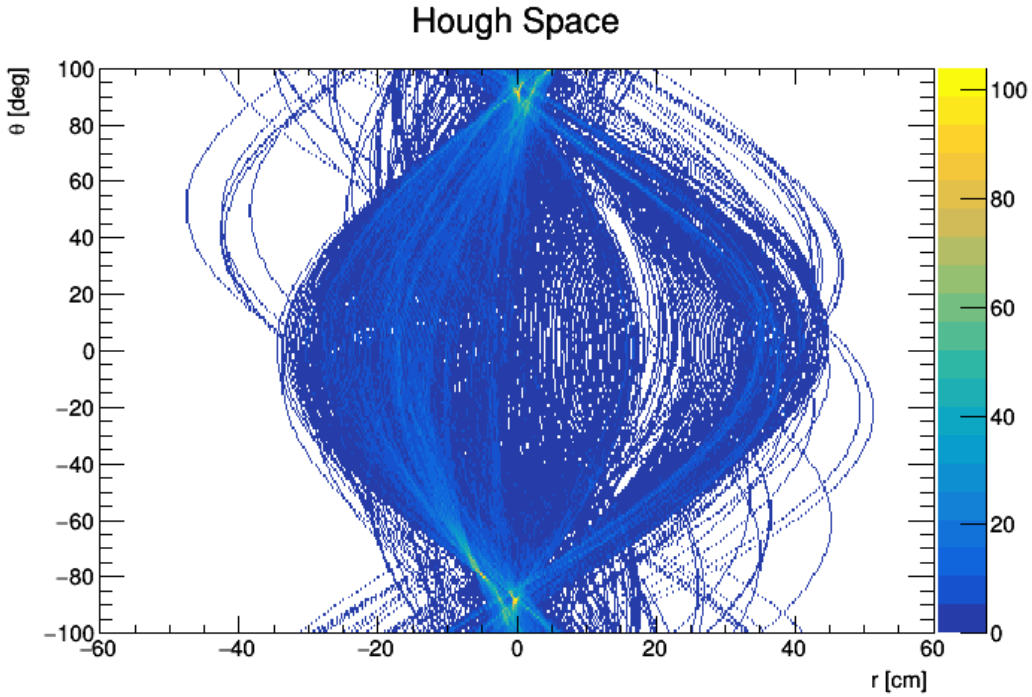
  [2 mm: 1 μs timing and an electric field intensity of ~0.75 kV/cm]

- General voxel index: $n_x + n_y \cdot 10^3 + n_z \cdot 10^6 \quad (n_i \in N)$ (simplifies integration to machine learning algorithms)

2D Hough Transform

Projected all energy deposits onto plane produced by first two principal components





Generalised Hough Transform (using Laguerre-Planes)

Could be interesting:

Surface recognition with principal component analysis on the Blaschke image [https://www.geometrie.tuwien.ac.at/peternell/hough_lag1.pdf]

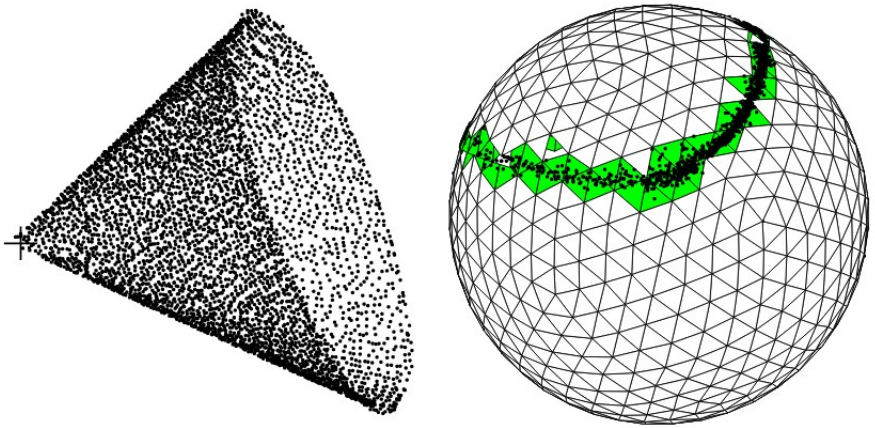


Figure 4: Left: Data points of a general quadratic cone and estimated vertex, indicated by a cross. Right: Blaschke image, orthogonally projected onto S^2.

Backup

Hough Transformation (2D)

- For each 2D-hit in (x,y)-space: Sampling theta in 1° angles from -100° to +100°

$$\theta_i \in \{-100, -99, \dots, 99, 100\} \quad \text{(angle w.r.t. x-axis)}$$
$$r_i = x \cdot \cos(\theta_i) + y \cdot \sin(\theta_i)$$

  → Each point in (x,y)-space yields 200 points in (r,θ)-space (Hough-space, HS)
- Straight tracks in (x,y)-plane produce local maxima in HS
- Example: Two tracks in (x,y)-space (red and blue stars):