EM shower direction reconstruction with PMA

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Dorota Stefan, CERN/NCBJ

Introduction

1. New approach to the shower direction reconstruction.
2. It has been developed during studies
   - of full neutrino events:
     - far detector parameters optimization,
     - capabilities of e/γ separation,
   - beam window orientation for the protodune detector.
3. Well fits reconstruction chain in the PMA module, so:
   - direction reconstruction implemented in ProjectionMatchingAlg
   - called optionally after track-vertex system reconstruction in PMAlgTrackMaker module.

EM shower direction reconstruction

- **Goal**: as exact direction as possible for any shower orientation, topology and energy.
- **Vertex**: from hadronic system (reconstructed as first), beam direction (e.g. protodune), pattern recognition (isolated showers).

- **Clean track-like starting part** should provide best estimate of the direction, but: it is a topology feature different in each event (examples on the next slide), which does not depend on shower energy:

  → initial reconstruction allows to sort hits in all views by the range from vertex
  → range of hits used for optimization is reduced until fit MSE is acceptable.

- Only rough direction reconstructed from full showers: pattern recognition in various views can give significantly different results:

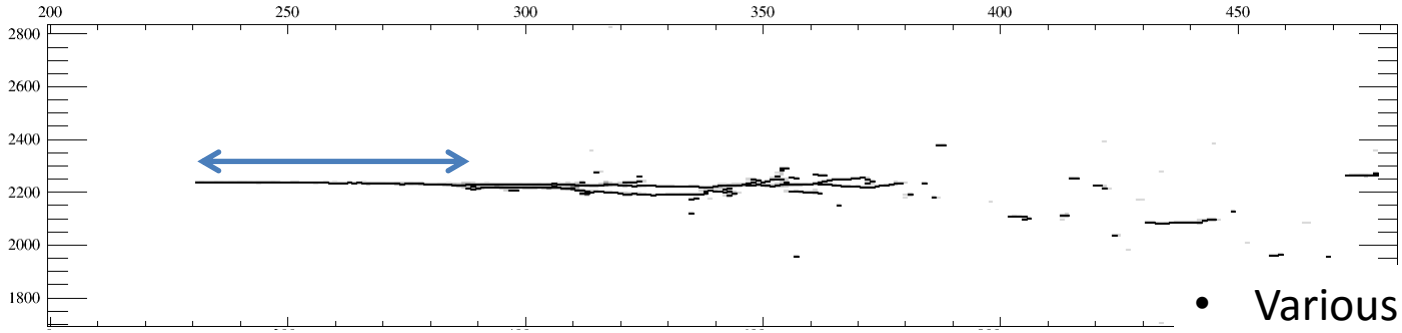
  → use all shower hits only to initialize algorithm.

- **Important**: can tag/reject events where reconstruction did not converge.

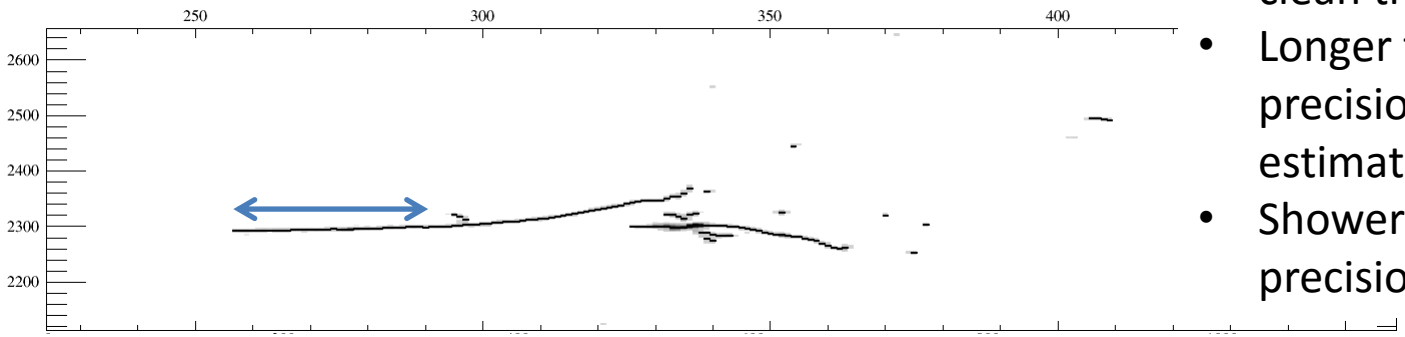
Clean track-like starting - examples

Electrons, the same direction generated

1



2



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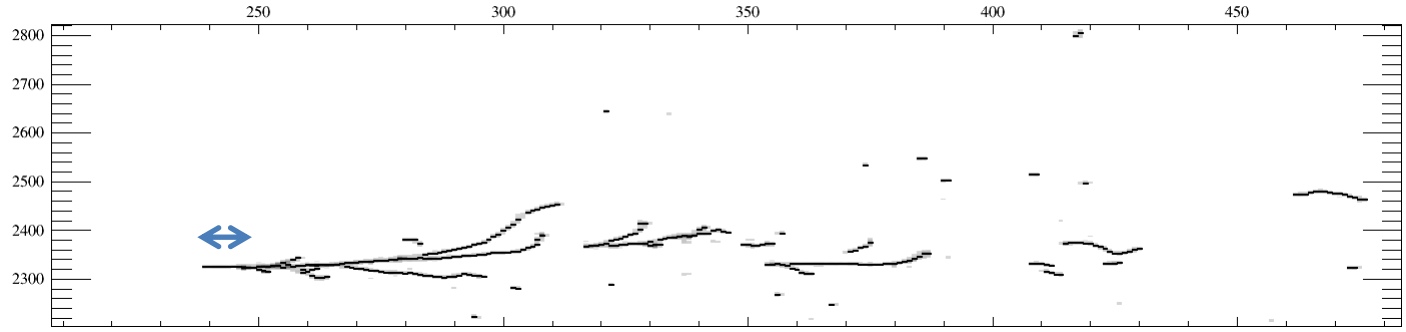
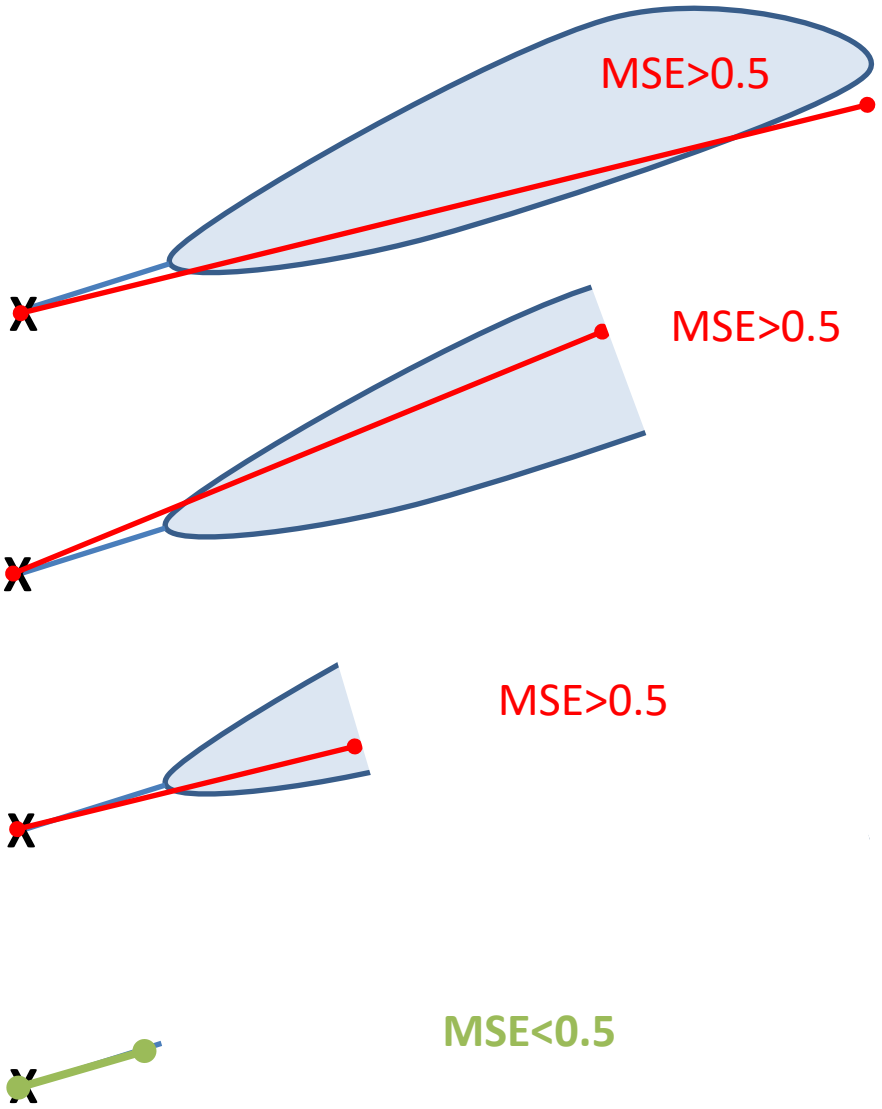


- Various lenght of the clean track.
- Longer track has better precision in direction estimation.
- Showering distorts precision.

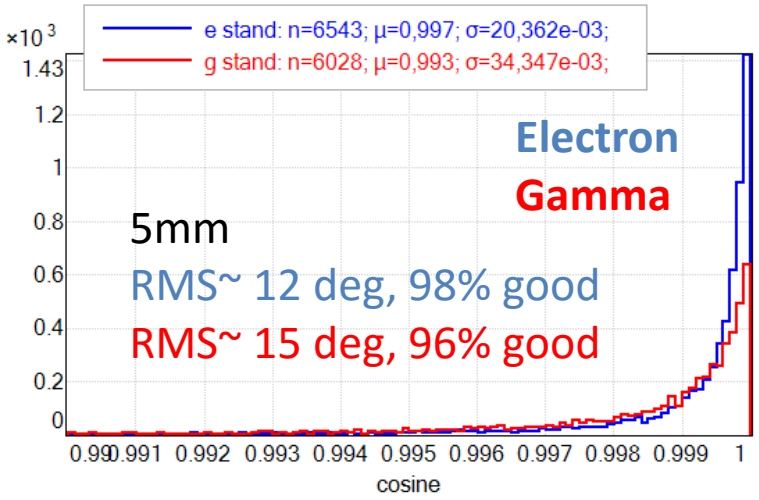
Method description

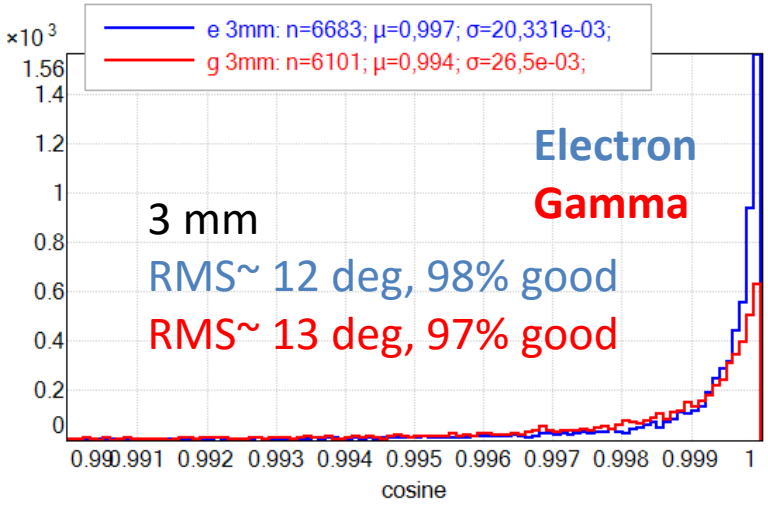
1. Input: pattern recognition provides PFParticle tagged as EM shower, with associated clusters and vertex.
2. Compact group of hits is selected in each view, small & isolated fragments are not used.
3. PMA segment is fitted to all hits from the shower; one endpoint is fixed at the vertex.
4. Hits with high range from vertex are removed, segment is reoptimized until MSE is low enough or min segment length is reached.
5. MSE allows to verify if direction is correctly reconstructed.

Note: Various shower orientation can prevent segment from correct reconstruction (parallel to the wire plane, initial part of the cascade in a shadow of developed cascade).



Results





- Isolated showers with isotropic angular distribution.
- Energy range: 100MeV – 5GeV(electrons), 2GeV(gammas).
- Fiducial cut set to 20cm.

- Direction reconstruction is limited by the properties of EM showers (effects of scattering and showering of electrons, two track from the vertex in case of photons) and orientation of the shower w.r.t. the readout planes.

Technicality

- Input from any pattern recognition that can save results in PFParticles; the following chain was used for tests:
  - Hits →Pandora → fit 3D shower segment to clusters associated with PFP (pdg=11), segment is attached to the vertex associated with this PFP.
- Output (segment from PMA) saved as recob::Track, like for other tracks, using PMA module functionality.

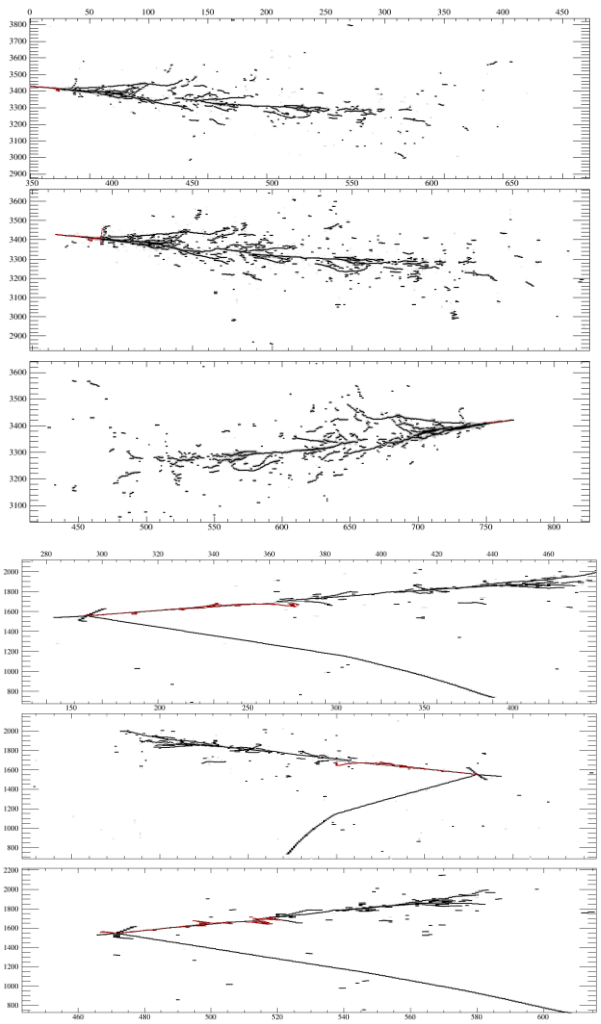
- Methods added to:
  larreco/RecoAlg/ProjectionMatchingAlg.*;
  PMAlgTrackMaker_module.cc, and no more additional files.
- Reconstruction can be enabled/disabled with parameters:

TrackingOnlyPdg OR **TrackingSkipPdg** (standard_pmalgtrackmaker in TrackFinder/trackfindermodules.fcl), e.g.:

`standard_pmalgtrackmaker.TrackingSkipPdg: [13]` will skip all tracks and reconstruct only 3d segments of showers.
`standard_pmalgtrackmaker.TrackingSkipPdg: [11]` will skip all showers and reconstruct only 3d trajectories.

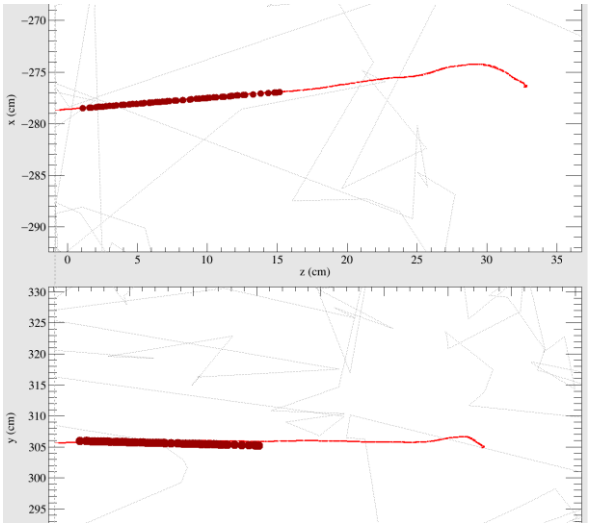
- Huge cascades can make code slow → can be optimized, work is ongoing…

Example of correctly reconstructed shower in ν_e event

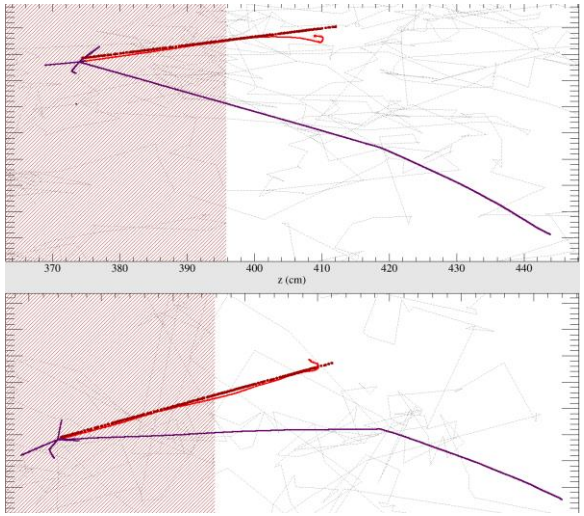


2D

2D

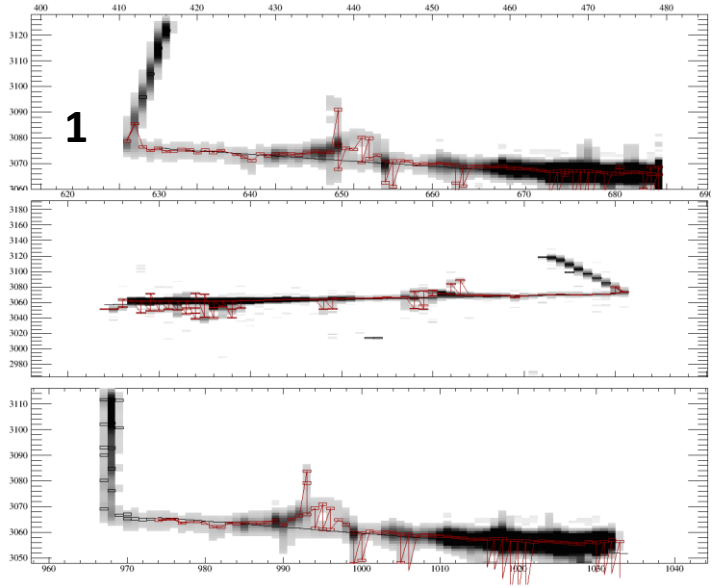


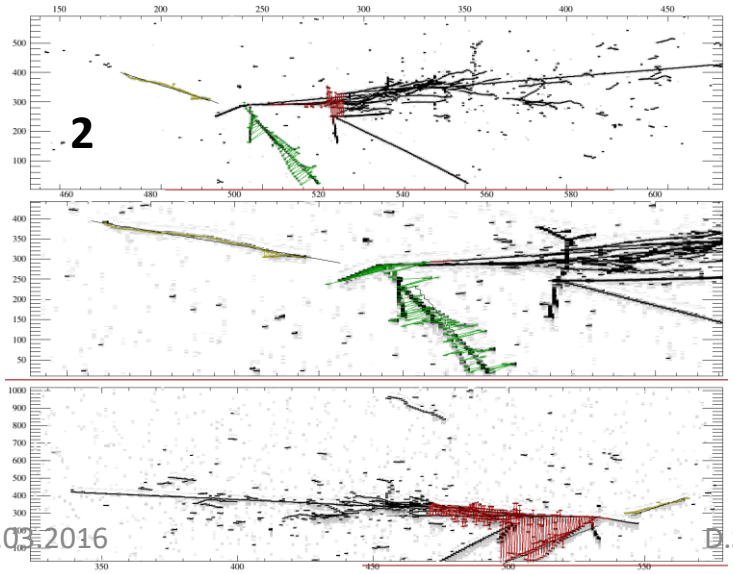
3D

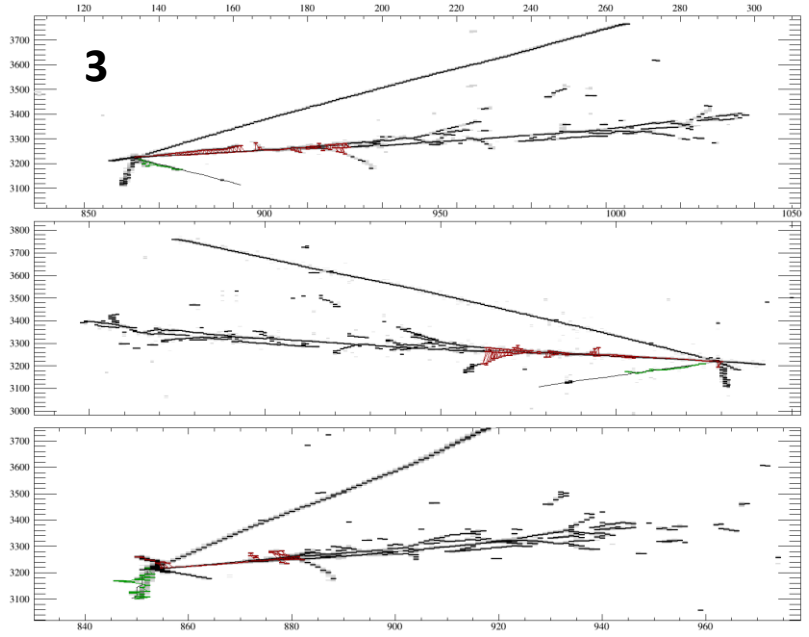


3D

ν_e event (MCC5): shower direction reconstruction depends on the preceding stage of reconstruction







Direction reconstruction is sensitive to:

1. Mistakes of pattern reco in vertex region (small scale, but significant features).
2. Mistakes in selection of shower fragments (large scale features).
3. Wrong clusters association between views.
4. …

Summary

- Developed and implemented shower reconstruction direction, now it is a part of PMA module.
- The code has been committed in larreco, in develop and can be published if approved (can make branch if needed or push directly to develop, no breaking changes, functionality is disabled by default with fcl parameters).
- Need a bit of work to speed up the algorithm. Can be done in relatively short time (known solution).