Full reconstruction chain for DUNE FD detector optimization studies
--status--

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for FD sim/reco group

LArSoft coordination meeting, 11/3/2015

Status of works of the FD sim/reco group for the FD optimization task.

(please, see slides from other meetings for all results and complete descriptions)

- **LArSoft algorithms are used**
- **but there is Pandora, Wire-Cell – each has strong points, which are not used together**
- **can we profit from all these efforts? can this be well organised?**

Single phase FD parameters to be optimized:

- readout plane orientation w.r.t. the beam – avoid reconstruction dificulties
- wire pitch – information versus noise / diffusion / induction effects
- wire angle – reconstruction efficiency / APA sizes / wire wrapping

…in order to maximize efficiencies of:

- **electron / gamma separation, neutrino ID**
- **energy reconstruction**
- **other particles ID**

but these efficiencies are direct input to physics and depend directly on reconstruction

…to calculate finally:

- physics sensitivities from full reconstruction

we are not here, few steps are still missing!

We use simulations:

- wire spacing: 5 mm vs 3 mm
- wire angle: 36 degree vs 45 degree
- different beam angles w.r.t. the wire planes

- neutrino interactions
- single (low / high energy) particles
- test beam simulation (protoDUNE)

- next slides: results for 5 mm / 36 degree

- MCC5 soon: 1-2 weeks, new features can be tested
  - vertex reconstruction
  - dE/dx processing improvements
  - showers with various approaches (and their problems)

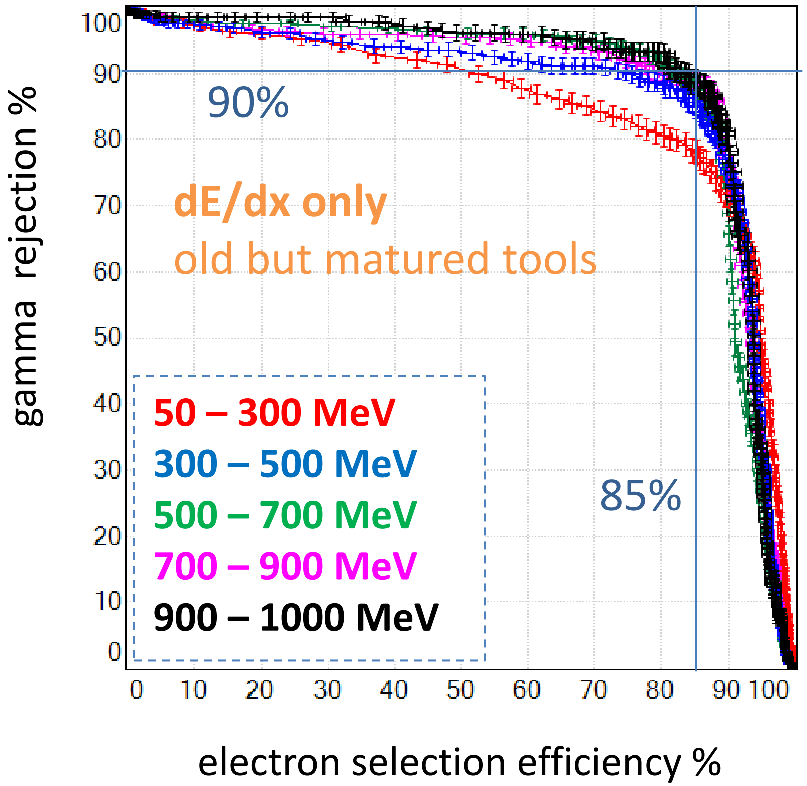
DUNE requirements (from *Requirements Workshop*).

(*my opinions are in italic – for sure can be discussed; blue: OK, orange: not certain, red: bad, black: lack of time to think of*)

1. Vertex position resolution: 2.5cm in all three dimensions. (probably need better than this in order to have e/ separation topology performance) (*but how this is used without track directions, anyway: OK*)
2. Tracking efficiency > 95%
3. Short-sub finding efficiency (10 hits or more, all views together): > 90% (*assume avg., in the interesting vtx's; isolated: OK; not sure if OK in the more crowded region*)
4. e/ separation: 90% efficiency for electrons, 99% rejection of photons from pi0 decays using both dE/dx and topology (*tools ~OK, but full-chain not shown yet – need to include topology*)

- muon detection threhold: 30 MeV (KE) (*track may be not missed, but PID for 30MeV muon…?*)
- muon angular resolution: 1 degree (*at what momentum? not OK for low momenta – scattering*)
- charged pion detection threshold: 100 MeV (KE) (*like muons*)
- charged pion angular resolution: 1 degree (*like muons*)
- stopping track energy resolution: 5% (*energy dependent*)
- showering or exiting energy resolution: 30% (*not tested, energy and geom. dependent, test-beam goal*)
- electron detection threshold: 30 MeV (*not tested*)
- photon detection threshold: 30 MeV (*not tested*)
- EM shower energy resolution: 2% ⊕ 15%/pE where E is in GeV
- EM shower angular resolution: 1 degree (this may be asking a bit much for low-energy showers – *good comment!*)
- EM energy scale uncertainty: < 5%
- proton detection threshold: 50 MeV (KE)
- proton energy resolution: 10% for p<400 MeV, 5% ⊕ 30%/pE for p>400 MeV, where E is in GeV
- proton angular resolution: 5 degrees
- neutron detection threshold: 50 MeV (KE)
- neutron energy resolution: 40%/pE where E is in GeV
- neutron angular resolution: 5 degrees other particles
- detection threshold: 50 MeV (KE)
- energy resolution: 5% ⊕ 30%/pE
- angular resolution: 5 degree

e-gamma seperation: initial, track-like part of cascade at vertex



Discriminative variables:

- **dE/dx** : we have now metadata so dE/dx calculation is easier for recob::track.
- **Distance between vertex and starting point of the *reconstructed* shower.**
- **Gap: visible lack of signal between cascade and tracks in the vertex region.**

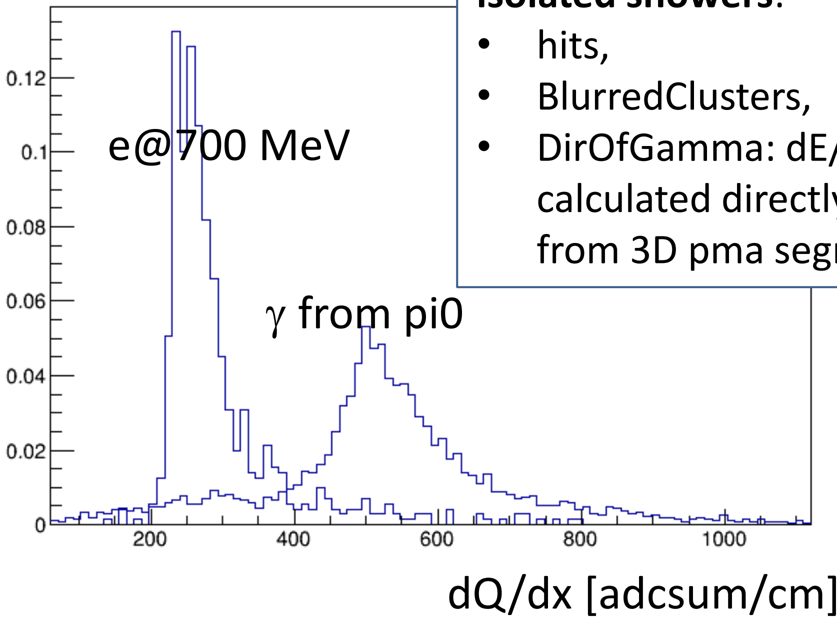
Plot from Collaboration meeting (April):
- isolated electrons/photons
- reco: dE/dx, shower direction
- MC: starting point of the shower

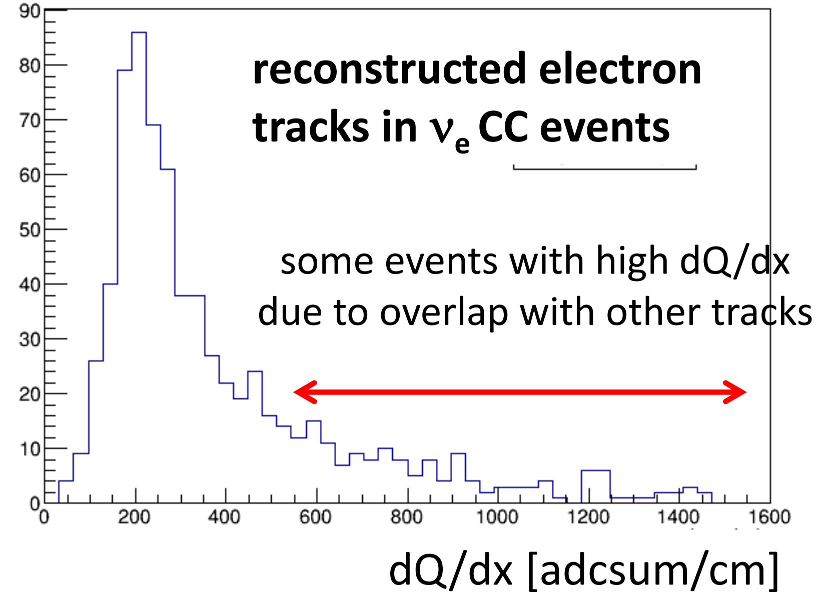
Tools: **FLUKA, non-LArSoft reco**

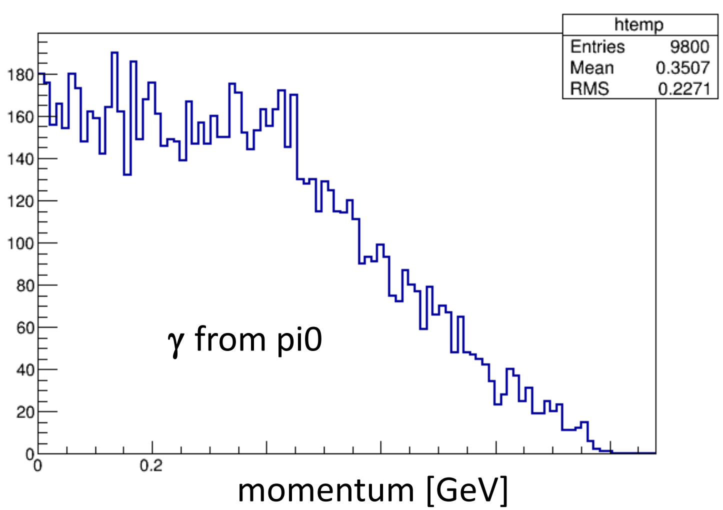
Do this study **in LArSoft**, and:
- ν_eCC / NC (not only isolated e/γ cascades)
- reco: dE/dx, gap, shower direction
- MC to help seletion of primary vertex and direction of shower.

dE/dx studies

isolated showers:
- hits,
- BlurredClusters,
- DirOfGamma: dE/dx calculated directly from 3D pma segment.





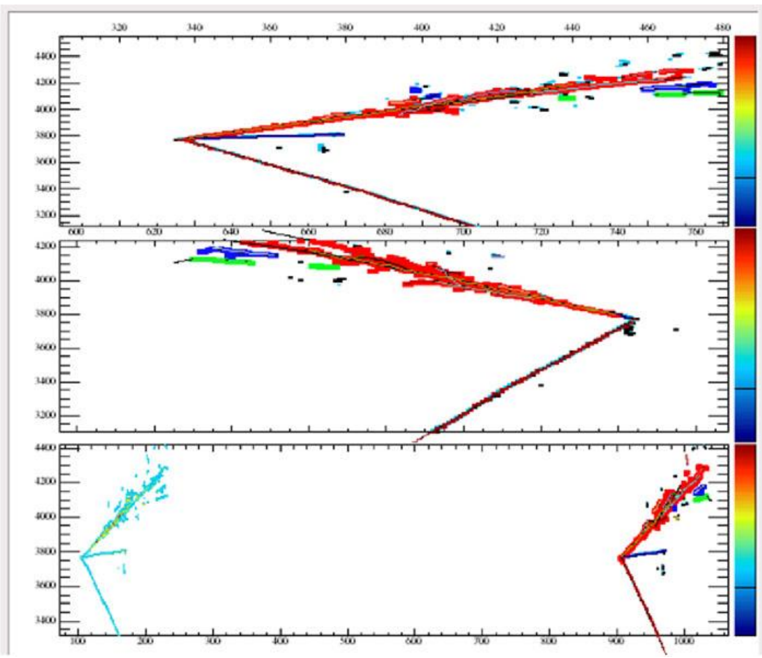


- easier computation of dE/dx with use of metadata, should be more precise.
- low dE/dx for photons due to low energy of generated photons: more reasonable is to do cut > 200 MeV.

EM showers: algs recently merged with develop

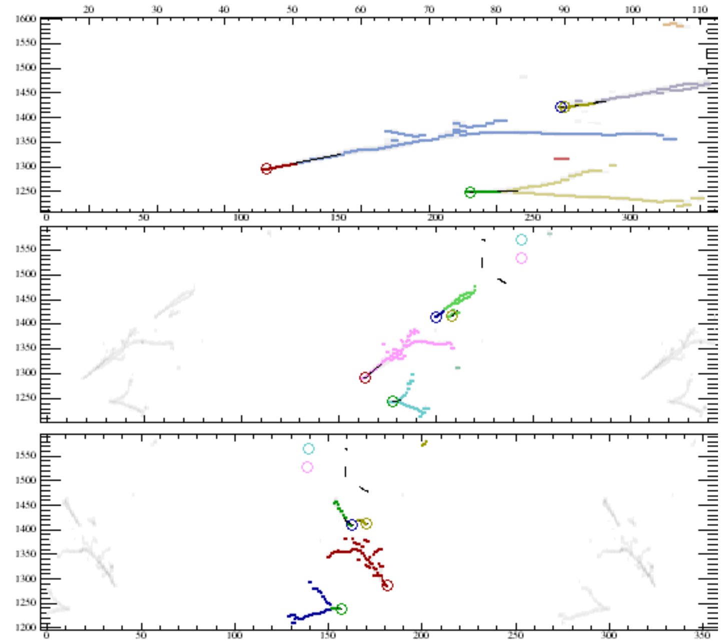
EM Shower 3D from Mike Wallbank
- now testing in nu_e events

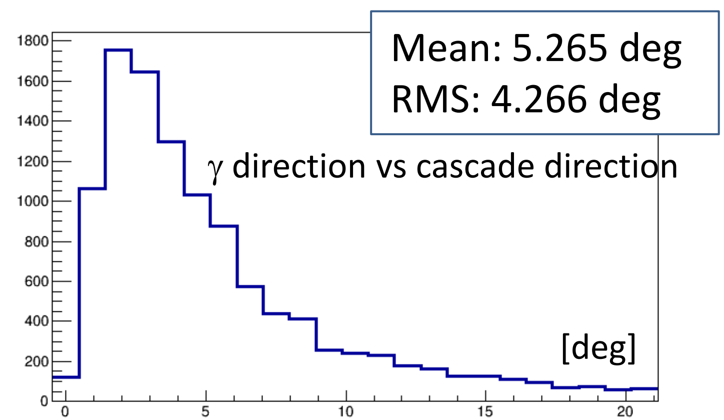
DirOfGamma from Dorota Stefan: deals with low energy, chaotic showes:
- tested in finding 2-shower topologies
- gives resolution of direction reco for low E cascade



FD nueCC

Tingjun Yang





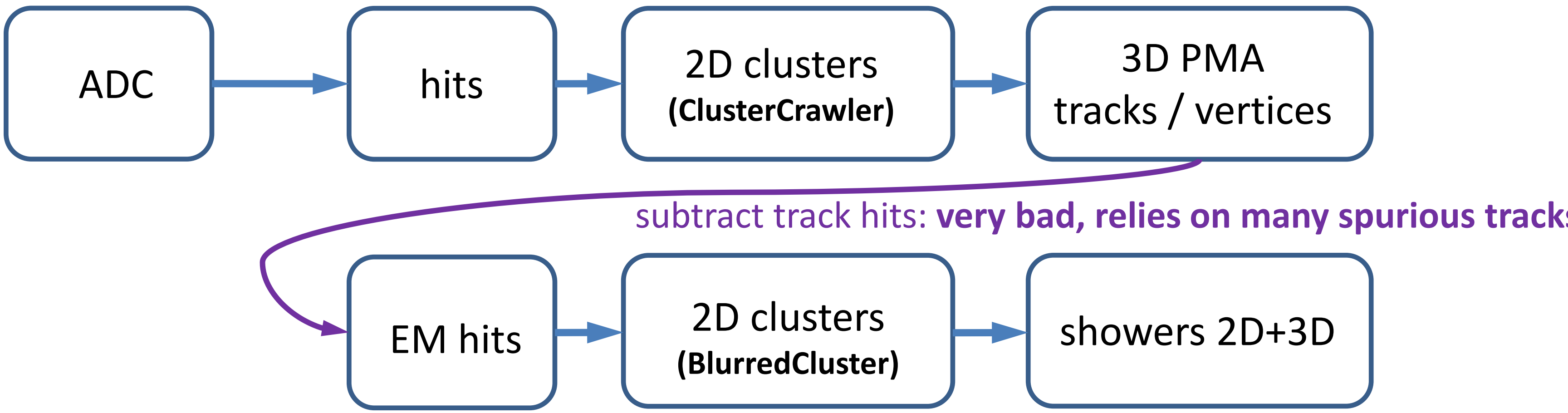
Studies of energy

→ need showers reconstructed inside full event

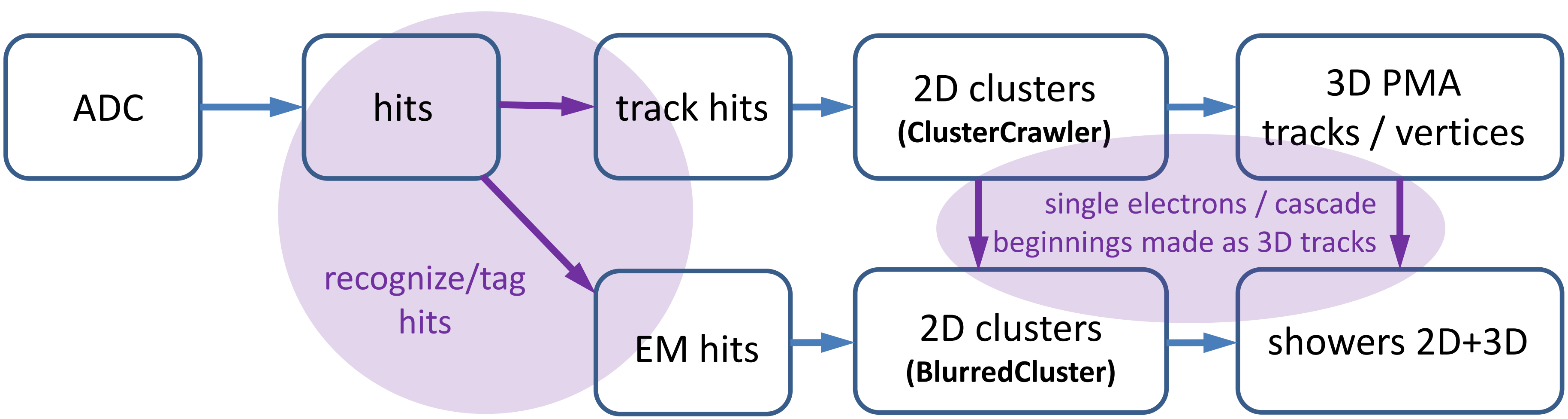
→ **need good EM-like / track-like separation**

Reconstruction chain (just the one that we are using now)

- now we use (due to available set of tools):



- likely more reasonable (work ongoing, the most important to do now):

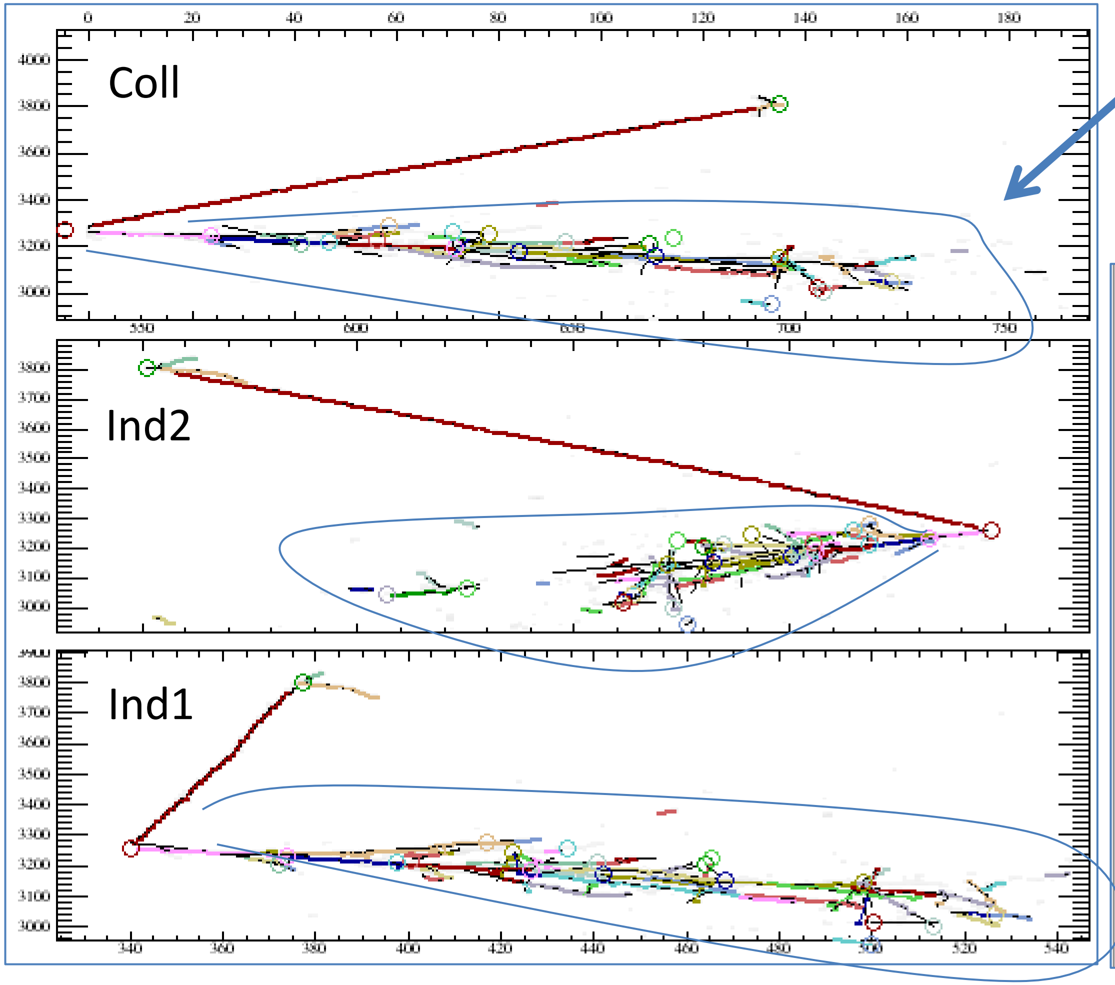


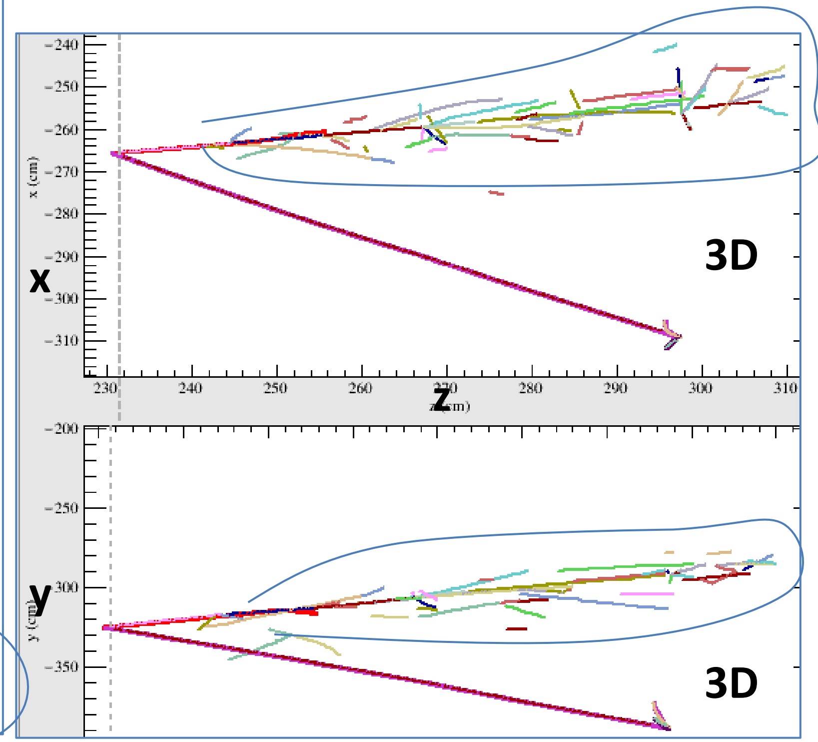
Example of reconstructed ν_e CC in far detector

shower regions:

- chaos of 3D tracks,
- chaos of vertices.

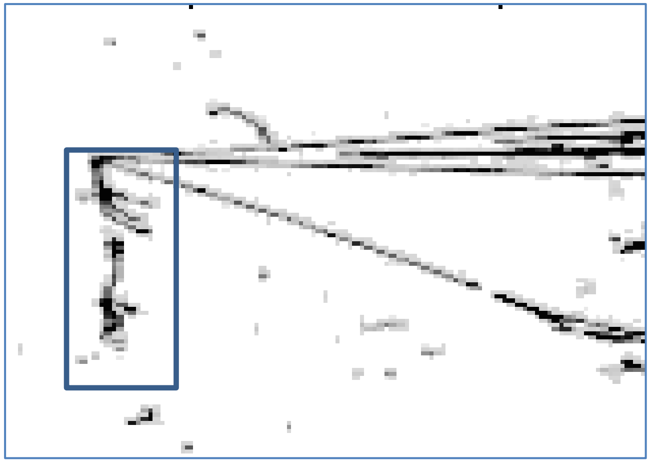
Try to resolve in 2D – work in progress

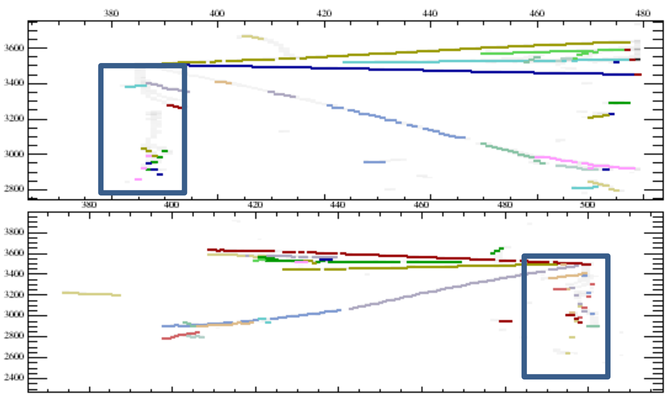


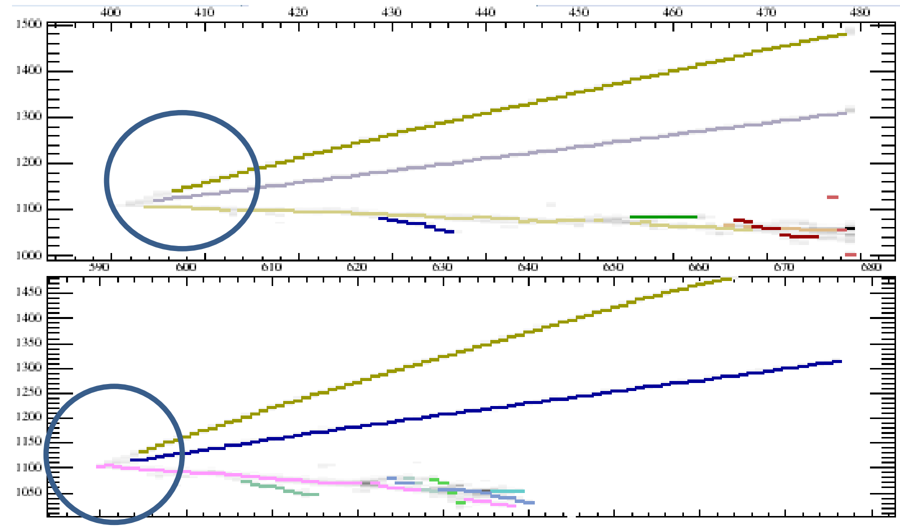


On the 3D level it is also possible to seperate EM-like trajectories or associate single electrons with nearby EM-like parts.

Inefficiencies





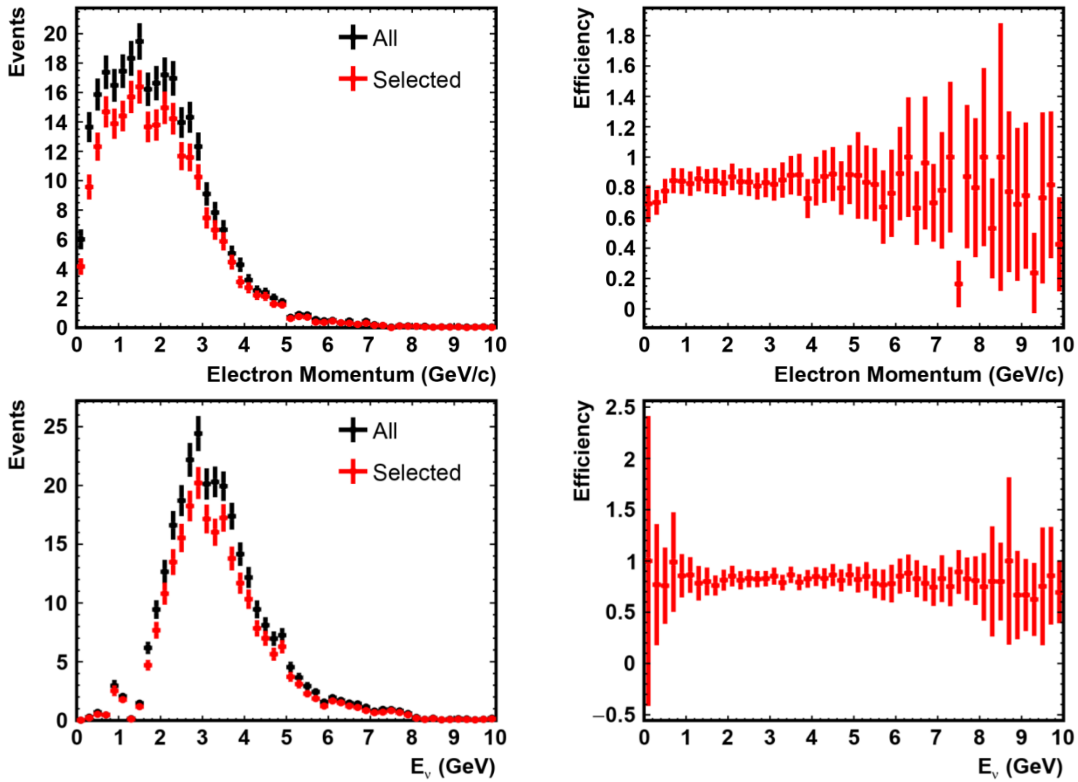


1. Region of vertex is not precisly described with hits and 2D clusters.
2. Poor reco of wire-plane parallel electrons. Can be better now with vertices that bind few tracks in one point.
3. Drift-parallel electrons.

Every inefficiency needs to be addressed, the goal is 90% efficiency / 99% bkg rejection.

Tracking efficiency for electrons 80%

from Tingjun Yang.



Firts attempts, tracks not associated to vertices, so relaxed definition of efficiency:

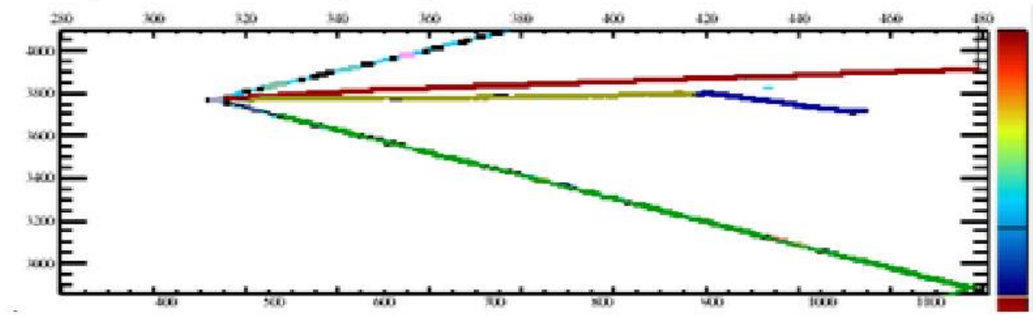
- Electron track reconstructed within 10 cm from the mc truth

Now may be updated with use of vertex reco.

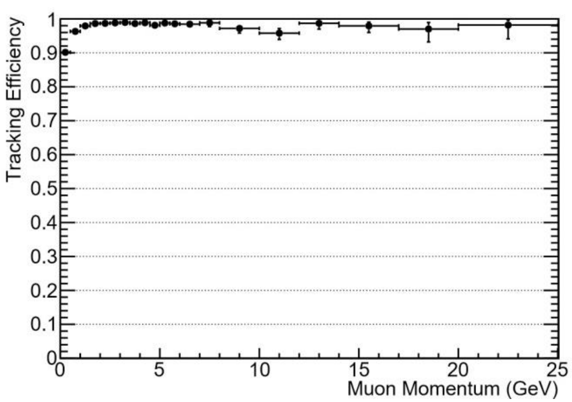
Tracking and vertexing – <u>much easier part</u>

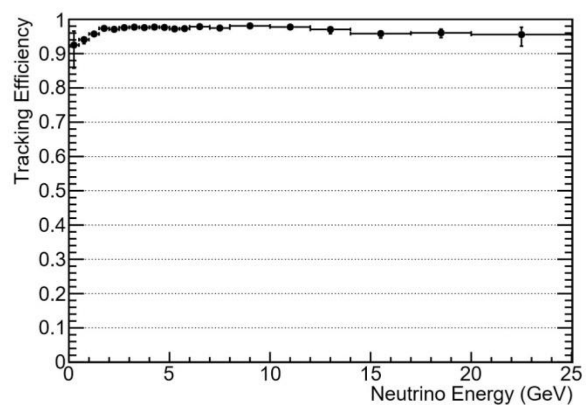
tests done by Aaron Higuera

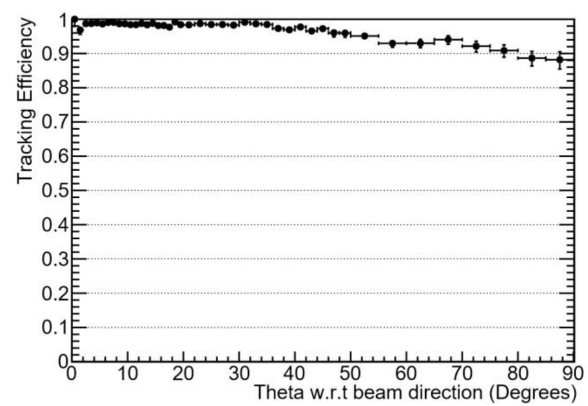
ν_μ + Ar —> μ +p +π +π



Muon tracking efficiency:



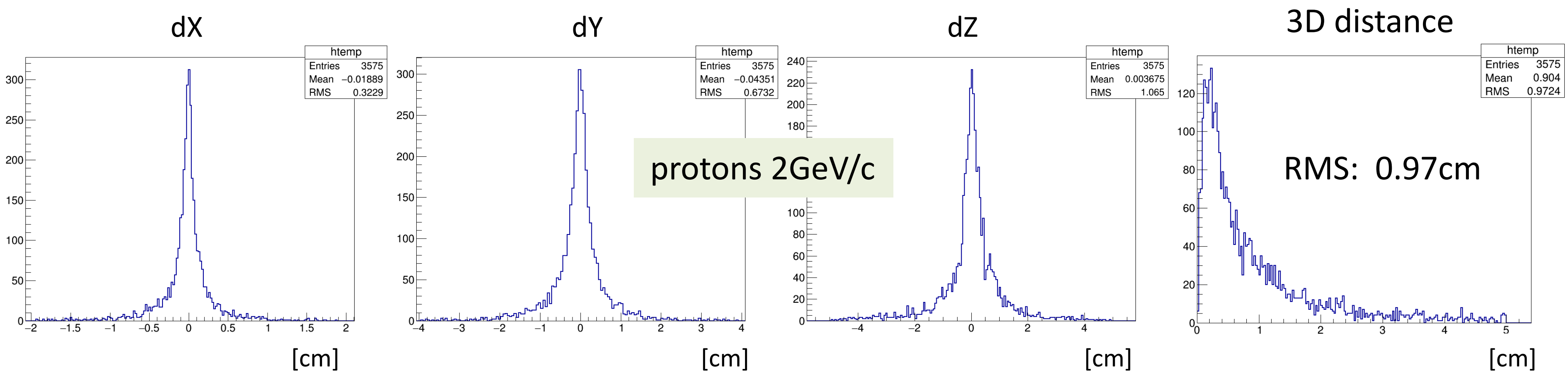




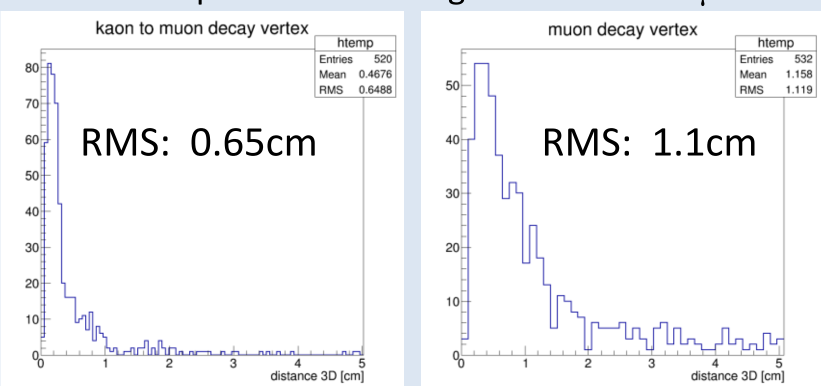
Previous study (different fid.vol cut) showed similar to muons efficiency also for leading π – expect it should be still similar to muon efficiency with the new cut.

Inelastic interaction **vertex position**, angular resolution: tests done in protoDUNE sim/reco

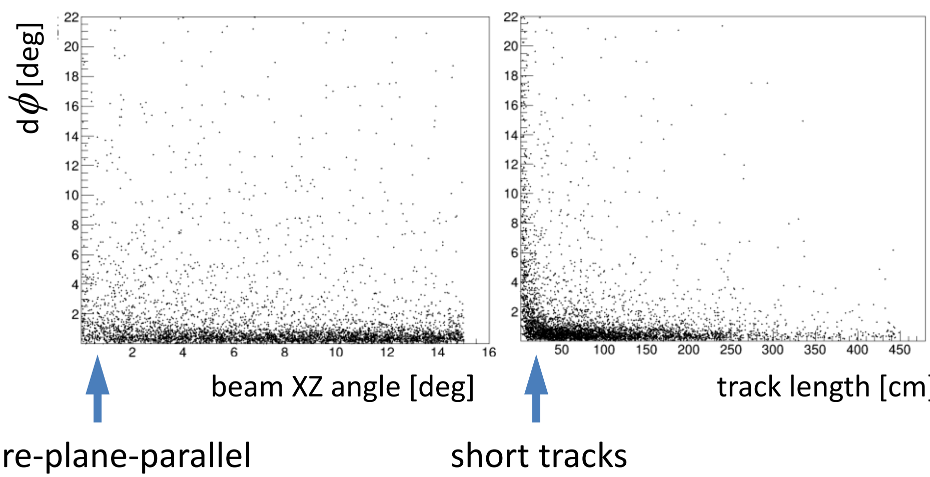
(trying to match MC-reco if > 1 daughter with E_k > 50MeV)



from Sep. collab. meeting: vertices of K→μ→e



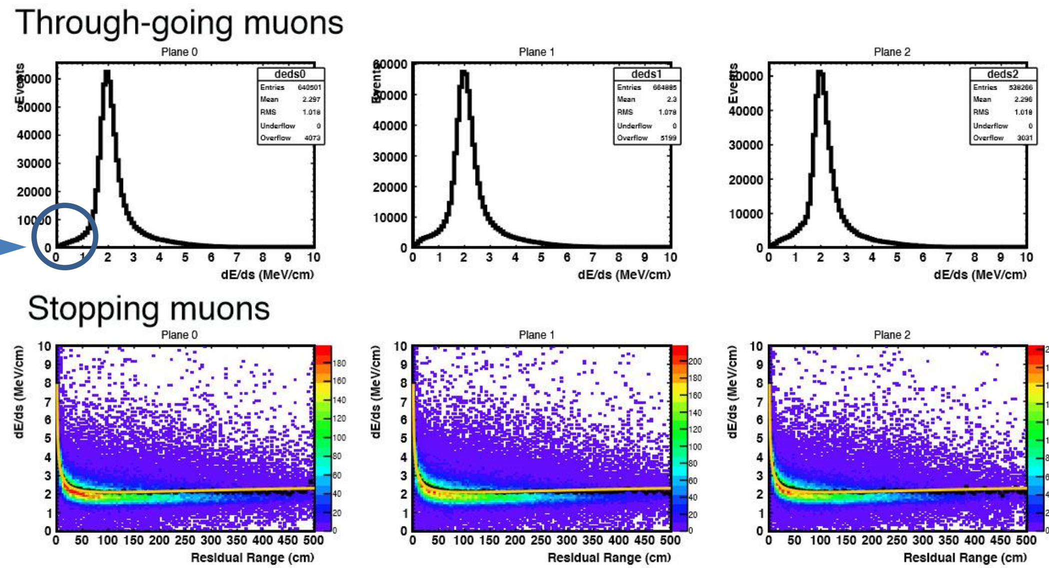
initial direction: primary beam particle



https://indico.cern.ch/event/455067/contribution/2/attachments/1175295/1698776/proto-reco-status-rsulej.pdf

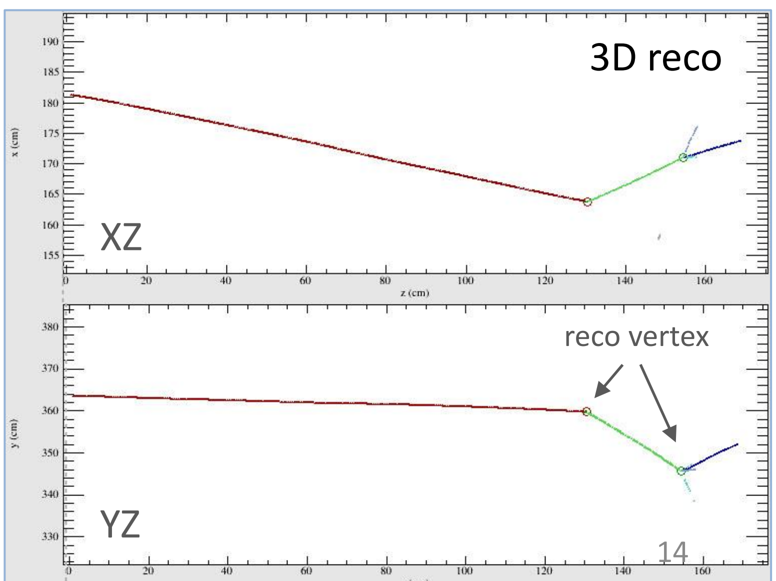
Energy

check if not due to splitted hits in more drift-parllel tracks…



from Tingjun Yang.

2GeV proton in protoDUNE



- **single tracks & stopping tracks calorimetry, dE/dx, … - OK**
- PID & energy of showering particles less exact: this is a nice study to be done and implemented
- energy of EM showers in full event – already talked

- it is possible that present not-yet-optimal algorithms do not feel FD parameters in best way
- there is more information in detector data than present algorithms can find
- optization based on theoretical predictions and simulation should be continued, in this way we can ensure that future reco is not limited by detector design
- and not all available algorithms were used / compared up to now
- however results are teaching us what can be expected and how to define (reasonable) requirements

interesting for this meeting (?)

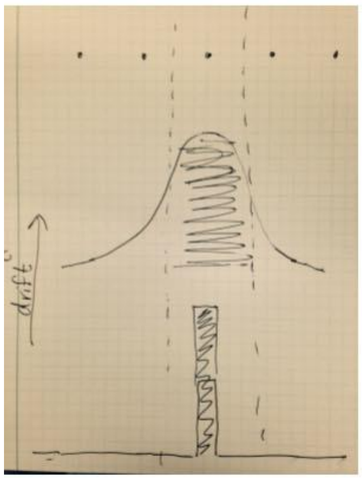
- Separate 2D clustering for tracking (e.g. ClusterCrawler) and for collecting showers (e.g. Blurred Clustering), with respective consecutive reco steps (3D tracks and EM showers reco algorithms) – they are efficient, but expect **tracks and showers separated at input**, but this is mostly missing!
- this is not easy due to very different properties of cascades at different energies, and very smooth transition between these properties
- we are progressing from 2D and 3D side: select very dense cascades in 2D to avoid producing random 3D tracks there –and– tag reconstructed 3D tracks as track-like or EM-like by looking at trajectory smoothness and 3D fit properties; solution is not yet settled but this work has the priority now
- other high-level reconstruction / analysis algorithms are not that challenging in my opinion.

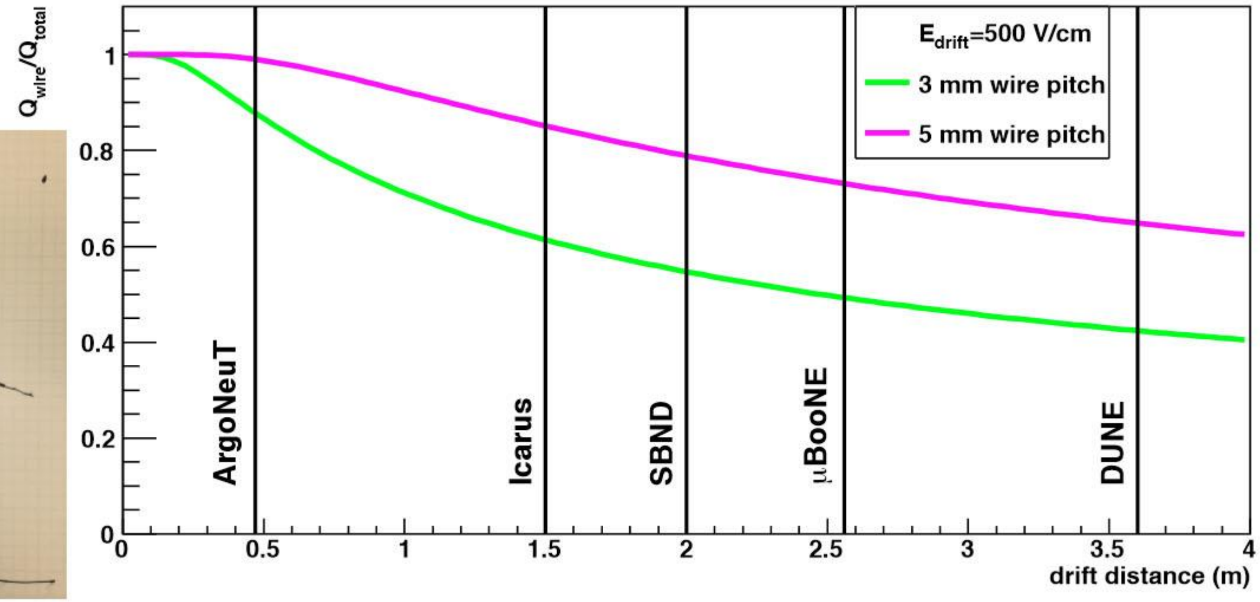
- A lot of **efficiency-testing code** has beed developed, should converge to standard tools for comparisons.

- MUSUN included (Vitaly/Karl) to simulate underground, CRY used for on-surface simulations.

- Also TODO: **neutrino energy** = shower reco + hadronic system + corrections (neutrals at least) backup

How much charge moves from wire to another?





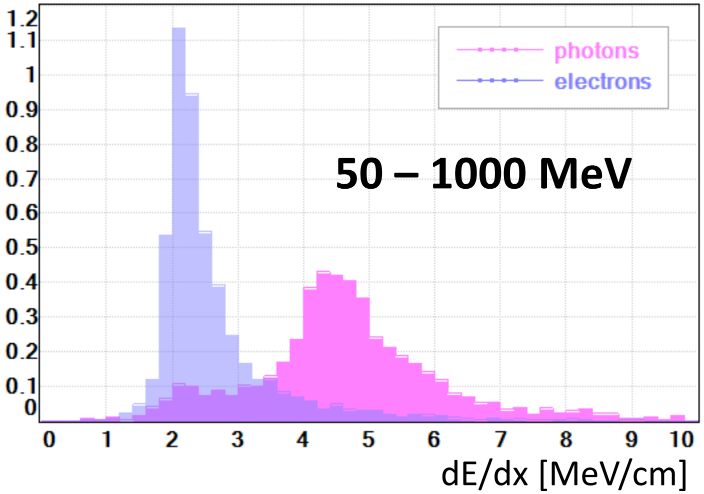
Michelle Stancari: transverse diffusion

Better have this measured, understood, checked noise levels for 3/5 mm:

- oan be just deconvoluted?
- or it makes 3 or 5 mm not reasonable…

dE/dx of the initial part of the cascade

cluster selection +
direction reconstructed



direction known