Pandora ND future plans and validation

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Future Plans for ND Reco.

- My laptop broke yesterday, so these slides have been hastily recreated.
  - Apologies if they're not the finest design you've ever seen.

- The DUNE ND complex is, uh, complex.
  - Lots of new challenges for reconstruction.

- Pandora is extremely well developed and validated for 3x2D readout LArTPCs.
  - But the ND doesn't have one of those.
  - Although right now we pretend.

- Need new development for additional subsystems.
  - And matching between them.

- Everything everywhere all at once.

DUNE ND Complex

Phase I:
ND-LAr (movable)
TMS (movable)
SAND (on-axis)
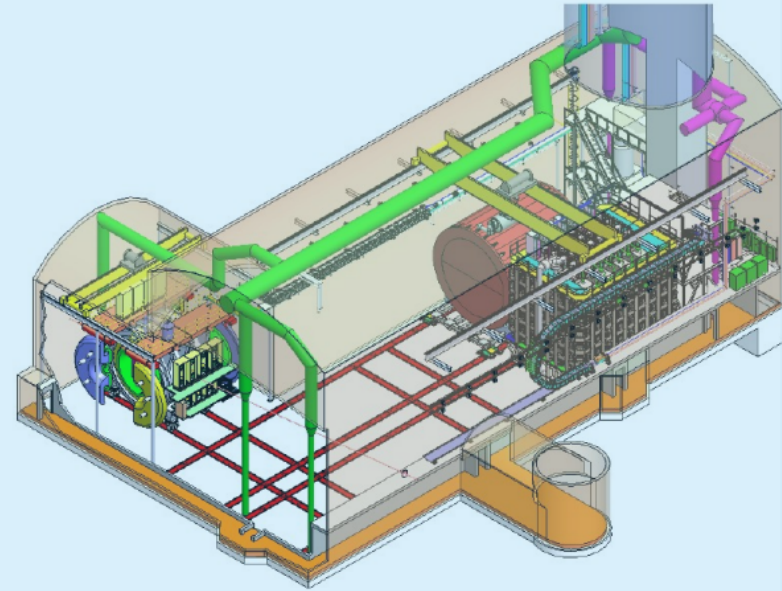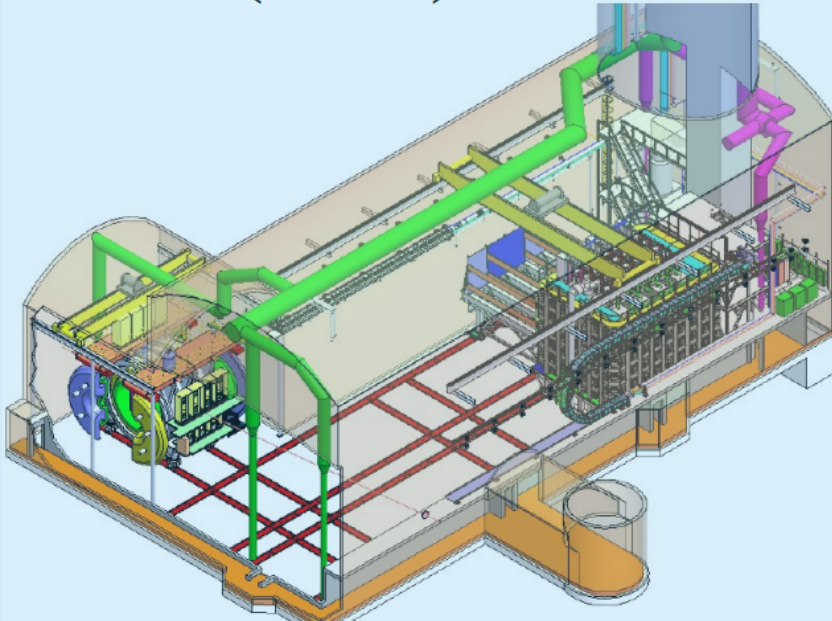
Phase II:
ND-LAr (movable)
MCND / ND-GAr
SAND (on-axis)

ND-LAr

- **Pixel Readout** LArTPC

    – Native 3D readout rather than 3x2D.

    – Short drift, good timing.

- **Unprecedented multiplicity**.

    – A FD event might have one neutrino.

    – An ND event will have 50.

- Current Pandora reconstruction projects 3D hits in 3x2D planes to leverage the work that has gone into 3x2D, and maintain similarity to the FD reco.
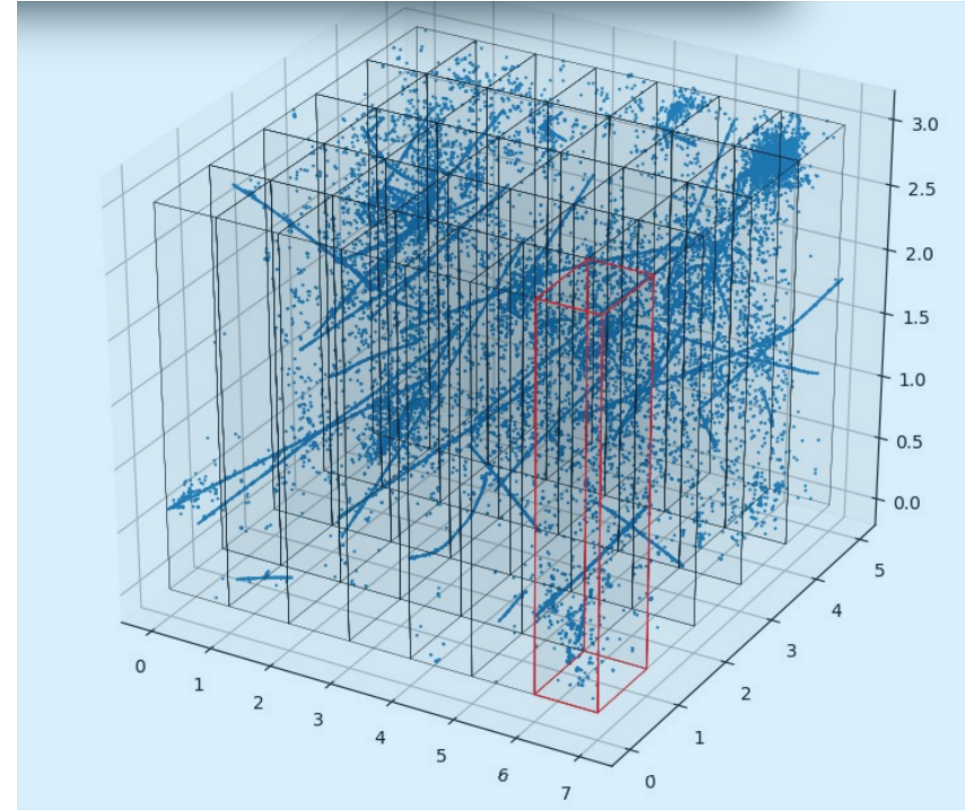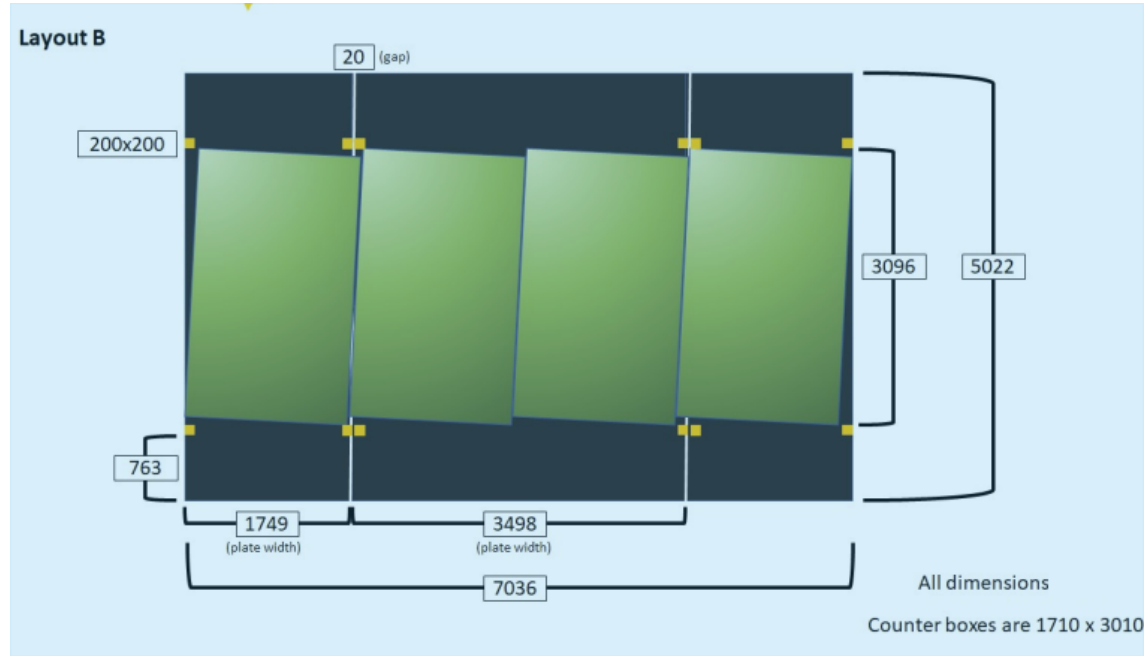
Future of ND-LAr

- Critical path forward: native 3D reconstruction.

  - Utilise power of the 3D technology, especially for slicing.

  - Buy in from the detector team to consider Pandora as their primary reconstruction requires this to be considered the highest priority.

  - Required per NDLAr prototype use case.

- But of course 2D projections are still the natural choice for many algorithms.

  - Eg Deep Learning.

  - For now, sticking with the U,V,W projections but in future alternatives could be chosen (eg X,Y,Z).

- Requires many new Pandora algorithms, will be led UK-led with Bern team in place for development manpower.

  - Staged approach to maintain compatibility with existing Pandora chain.

TMS

- TMS is a weird detector.

  - 1x2D view with "stereo".

- Significant work required to implement into Pandora.

  - Existing infrastructure reusable.

  - Unclear how many actual algorithms will be reused.

- In discussion with existing TMS team to merge existing efforts into Pandora's infrastructure.

- Distant future: using TMS tracks to seed ND-LAr reco.

Layout B
20 (gap)
200x200
3096 5022
763
1749 (plate width)
3498 (plate width)
7036
All dimensions
Counter boxes are 1710 x 3010

ArgonCube 2x2 (ProtoDUNE-ND)

- ProtoDUNE ND is being worked on right now.

    - Expect first data ~January.

    - Evaluation of physics performance in 2023/2024.

    - Strict deadline for Pandora to be selected as the reconstruction of choice.

- All the same challenges as ND-LAr.

- But a different spectrometer:

    - MINErVA planes.

    - 2x2D scintillator readout, with novel triangular design.

- Argon work led by UK, searching for manpower for MINErVA matching.
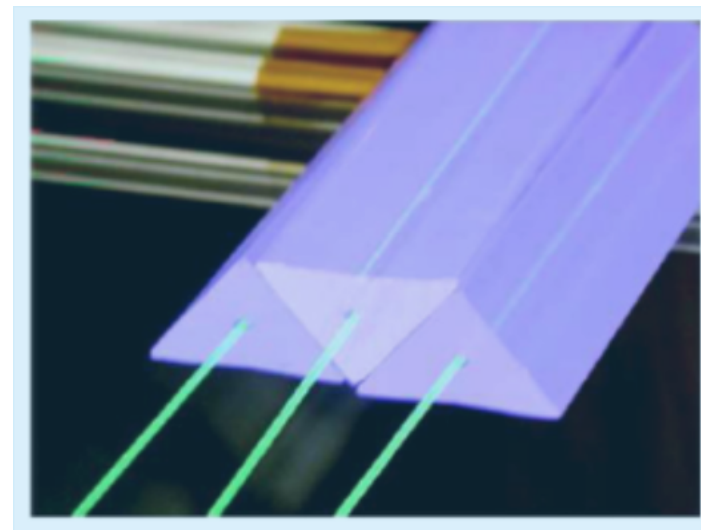
Other Detectors

- There is an Italian SAND team in place to implement Pandora reconstruction.

  – To be combined with UK expertise.

- MCND? Still up in the air, but if it's ND-GAr our extremely powerful 3x2D performance should place us in a great position as soon as any work begins.

  – ND-GAr group currently operating their own reco using a Kalman filter on toy MC.

  – Expect that Pandora can ramp up fast given properly simulated MC.

  – Already a team working on ND-GAr using Pandora for ILC.

- Global reco plans still in development.

  – 2x2 -> MINErVA planes matching ASAP due to time constraints.

  – ND-LAr –> TMS matching.

  – MCND?

Summary (of Steve's bit)

- The Pandora ND Reco Team has prioritised LAr-ND up until now.

- Now attracting significant interest from other detector groups.

- Many new tasks and challenges.

- And they sort of all have to be done at once.

- An exciting time for the reco.

- Are you interested in getting involved? Reach out to me (or have your supervisor do it).

- Now, please welcome Jing to present the validation work so far.

Validation

- Uses edep-sim with a Pandora interface.
  - Currently projects native hits into 3x2D views to utilise existing Pandora algorithms.
  - Interface by Alex Moor and John Back.
- Utilising existing algorithms benefits ND to FD comparisons.
- Studies performed with single particle and single GENIE neutrino events.
  - Full spill validation samples underway.

Stages of validation

Single particle (0.1 to 4 GeV)

Muon: A. Moor
Photon: T. Yang
Pion: M. Alrashed
Electron: J. Shi
Proton: J.Shi

ν events

ν_μ: J. Back
ν_e: J. Shi

Full spill sample

Ongoing...

ν_μ event: J. Back

CCQE μ + 1p: **10,479** events, correct reco'd eff = **75.6%**

# Matched particles	0	1	2	3+
μ	0.2%	**91.8%**	7.8%	0.3%
p	9.7%	**81.3%**	7.9%	1.0%

CCDIS μ + 1p + 1π⁺ : **1,042** events, correct reco'd eff = **43.6%**

# Matched particles	0	1	2	3+
μ	2.6%	**89.6%**	7.4%	0.4%
p	22.0%	**63.8%**	12.8%	1.4%
π⁺	9.3%	**71.6%**	17.1%	2.0%

CCDIS μ + 1p + 1π⁰ : **1,459** events, correct reco'd eff = **24.8%**

# Matched particles	0	1	2	3+
μ	3.2%	**88.5%**	8.2%	0.2%
p	20.6%	**66.8%**	11.0%	1.6%
γ₁	8.4%	**86.2%**	5.1%	0.3%
γ₂	55.9%	**41.1%**	2.8%	0.2%

π⁰ → γ₁, γ₂

Jingyuan Shi

ν_e CCQE event: J. Shi

- CCQE e + 1p: 9884 events, correct: **69.1%**

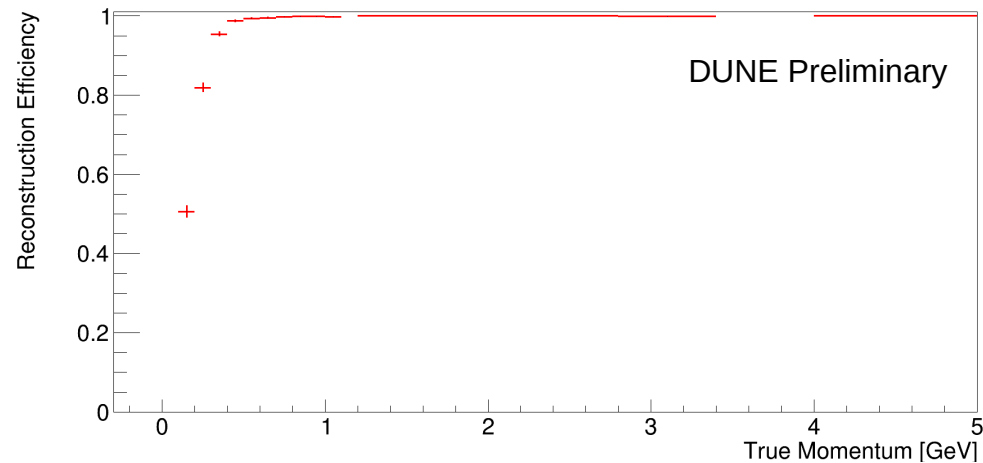| Matched particles	0	**1**	2	3+
e	0.1%	**91.2%**	8.5%	0.2%
p	15.6%	**75.4%**	8.0%	1.0%

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μ⁻: A. Moor

- Ideal performance in completeness.

- Large ΔR (distance between true and reco vertices).

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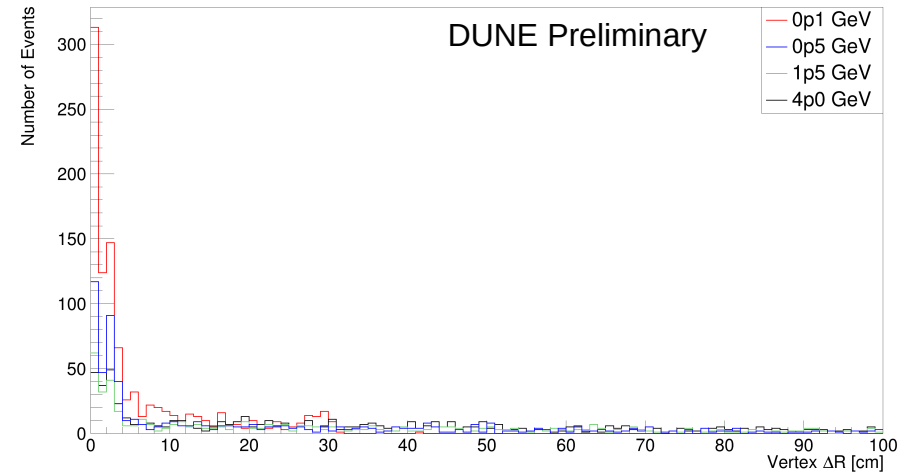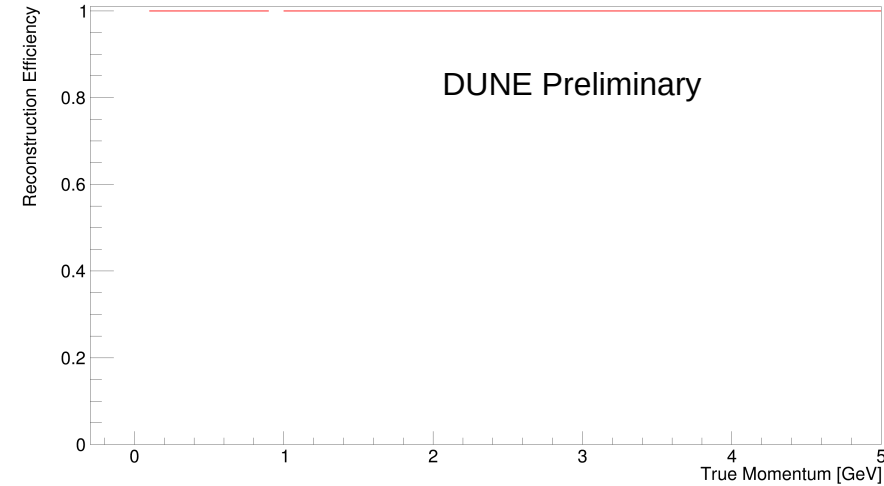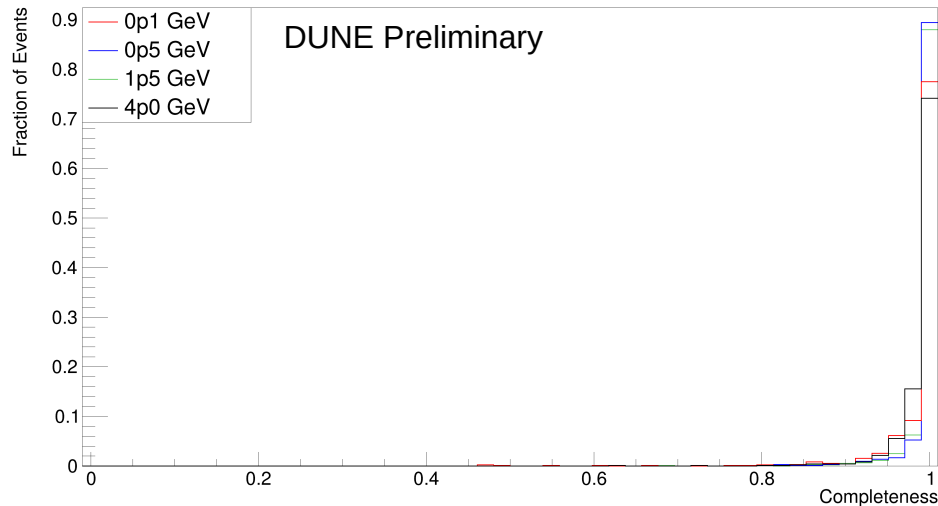
e⁻: J. Shi
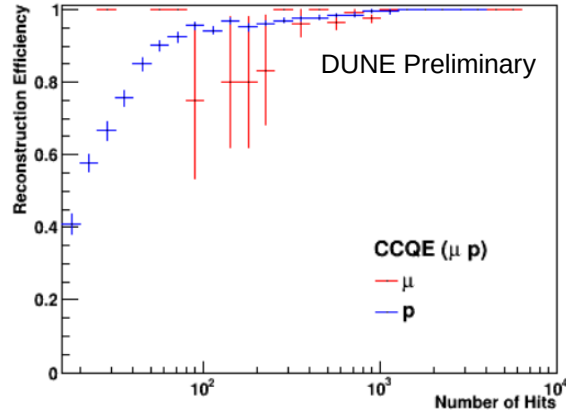
- Worse completeness compared with μ⁻.

- Smaller ΔR (still large).
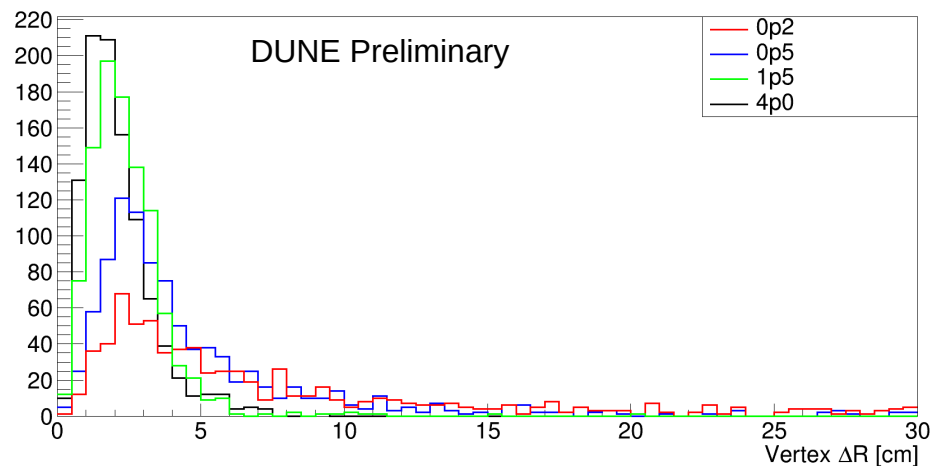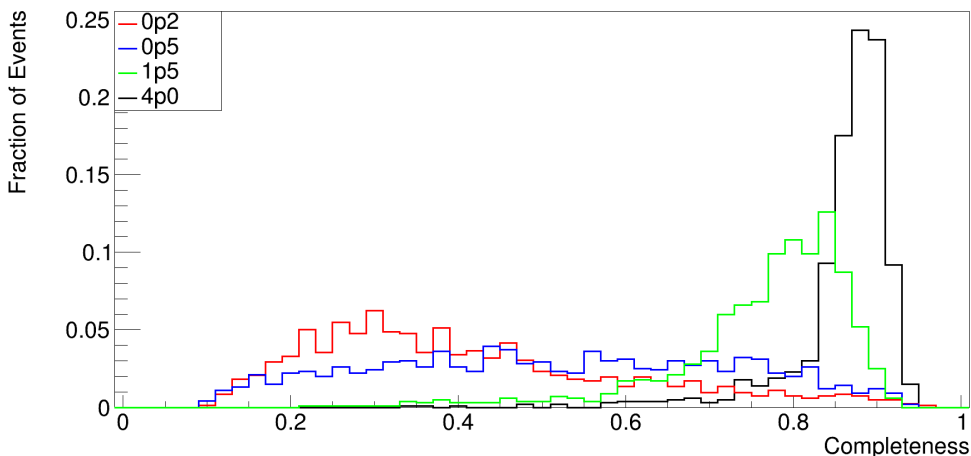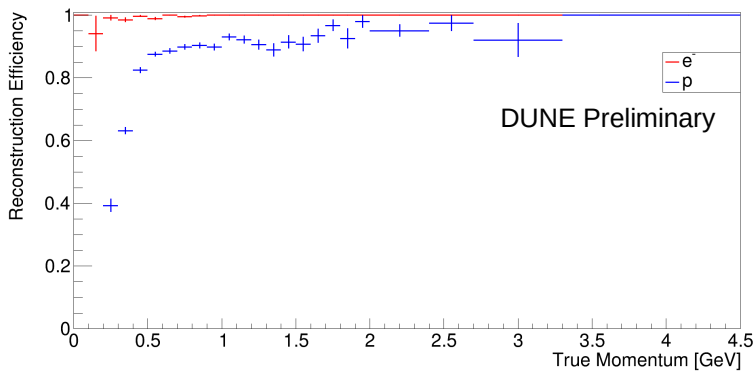
ν$_\mu$ CCQE event: J. Back

CC QE
$\nu_\mu + Ar \rightarrow \mu + p$

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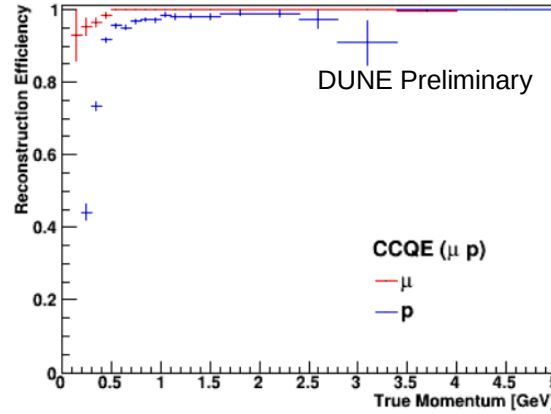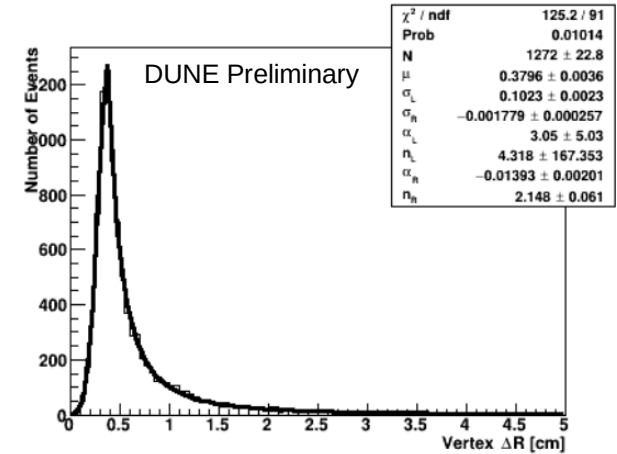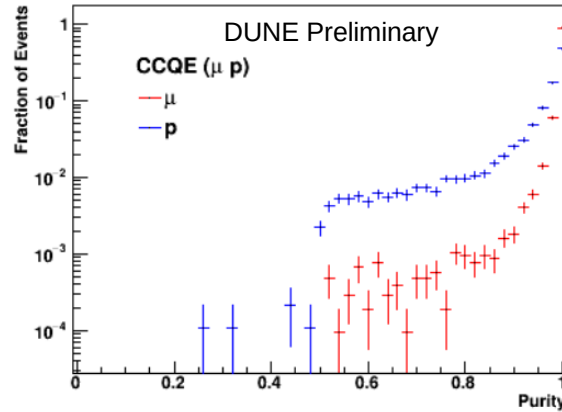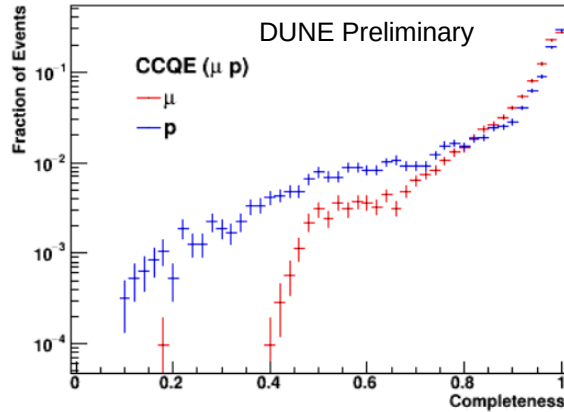
ν_e CCQE event: J. Shi
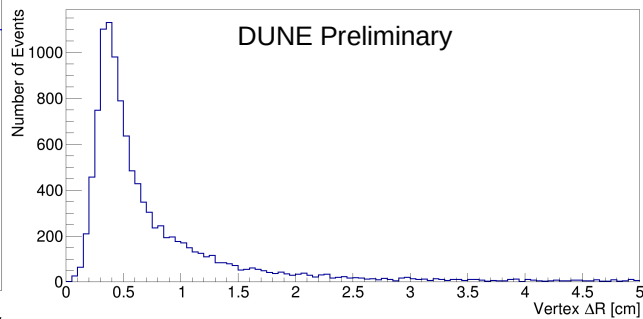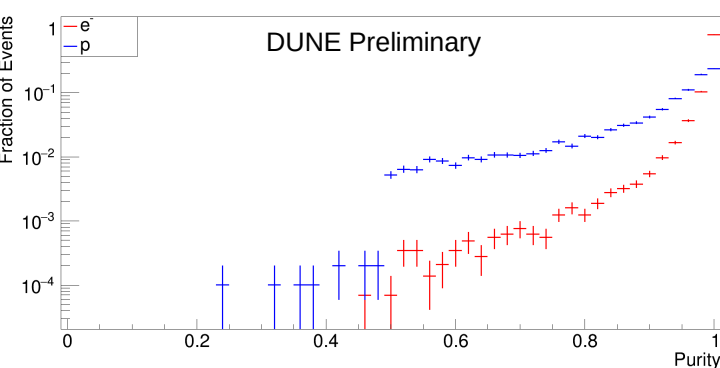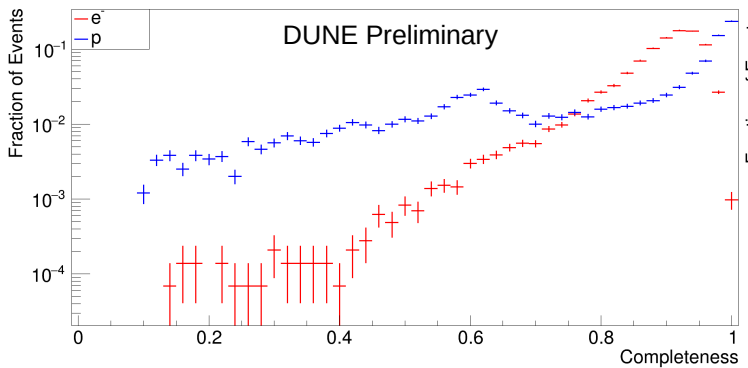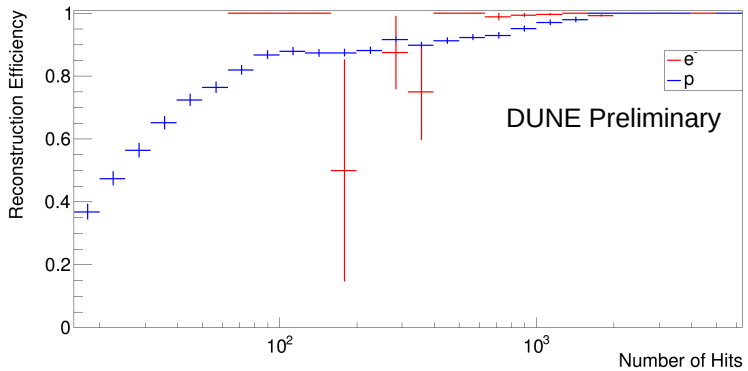
Full-spill sample

- Full-spill samples have been generated by Jeffrey Kleykamp.

- Testing on the way by John Back.

- Tingjun has been generating GENIE events.

Summary

- Pandora shows great flexibility.

  -Strong performance pre-tuning.

  -In future, parameters will be tuned for ND LAr.

- Ongoing full-spill sample validation.

- Exploring algorithms to reconstruct based on native 3D hits.

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