

Pandora optimisation with respect to the search for CP-symmetry violation at the DUNE FD

A Pandora CP-violation Analysis

The application of a Pandora-based nue/numu selection procedure* to study CP-violation at DUNE

*nue/numu selection procedure and utilised electron/muon-like BDTs created by Dom Brailsford

Pandora pattern
recognition

Particle
characterisation

Nue/numu
selection

Neutrino energy
estimation

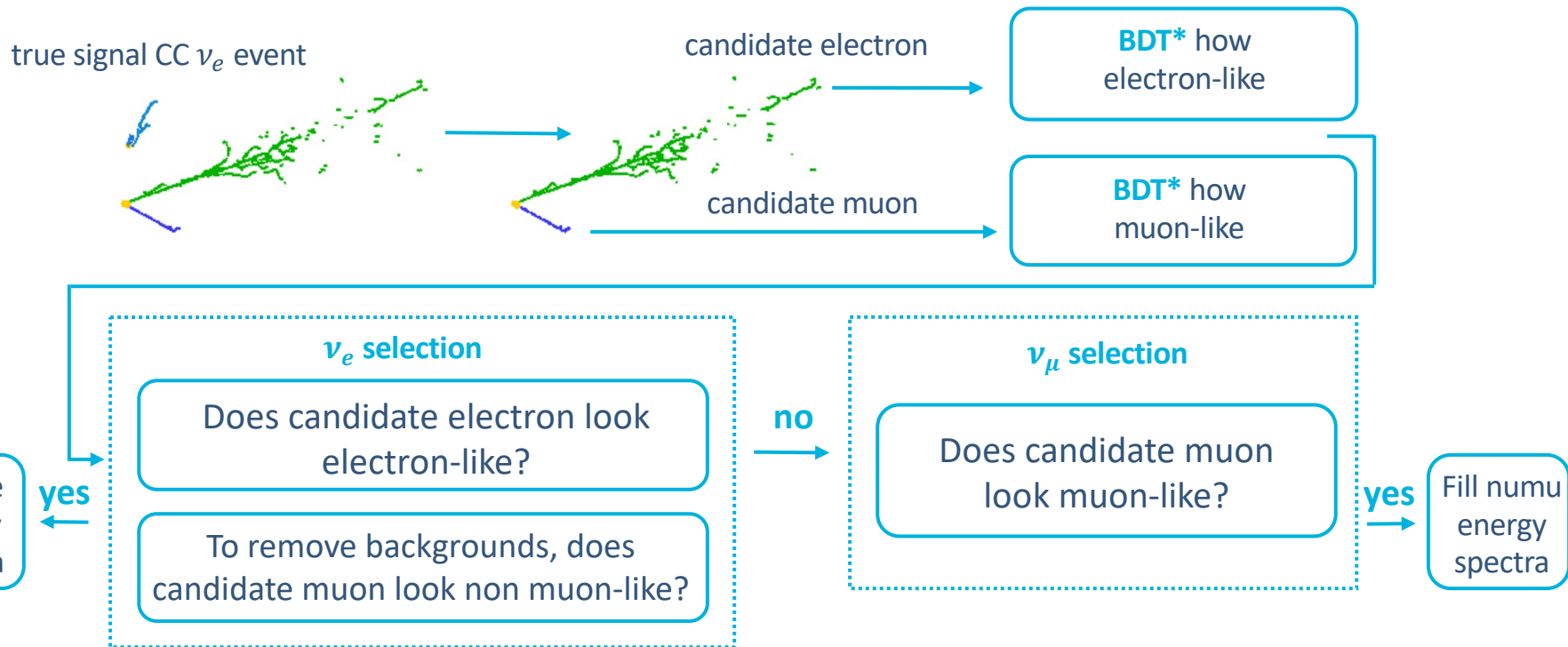
CP-violation
metrics



nue/numu Selection

Events are selected as a result of the determined identity of the **candidate leading leptons** in the event (should they exist)

* Credit to **Dom Brailsford** for initial development and continued support

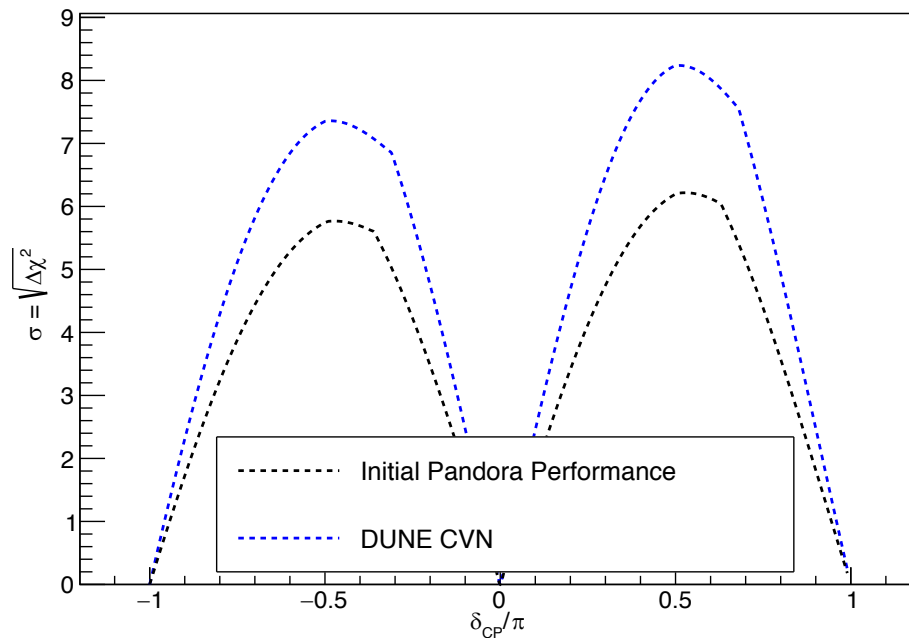


Initial Performance

Nue Efficiency	Nue Purity	Nue BG Rejection
60.0%	67.1%	98.6%

Numu Efficiency	Numu Purity	Numu BG Rejection
88.3%	87.2%	94.4%

Pandora CP Violation Sensitivity (no systematics, no stat fluctuations)



Searching for Reconstruction Improvements

Pandora pattern
recognition

Particle
characterisation

Nue/numu
selection

Neutrino energy
estimation

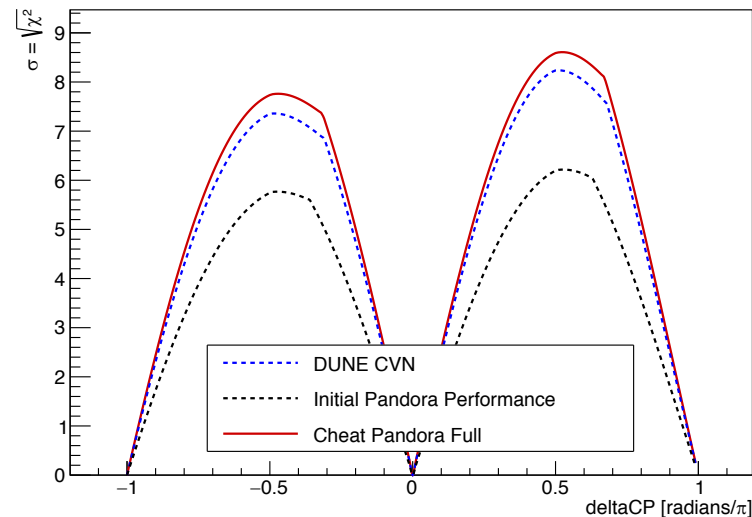
CP-violation
metrics

the Pandora reconstruction is the foundation of the workflow

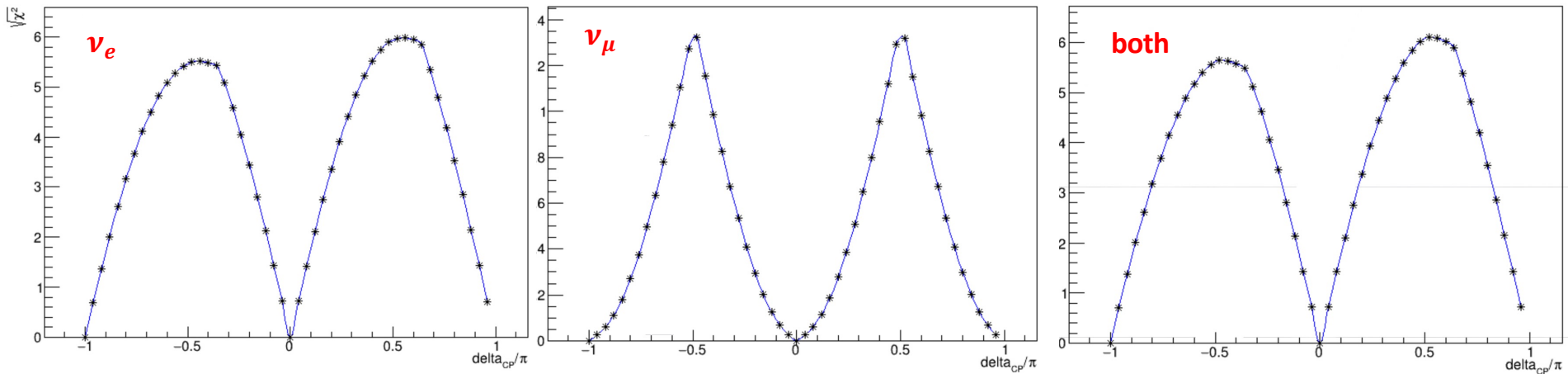
what if the pandora reconstruction was perfect?

→ *large sensitivity gains*

Pandora CP Violation Sensitivity (no stats/systematics)



Searching for Reconstruction Improvements



the ν_e selection dominates the sensitivity

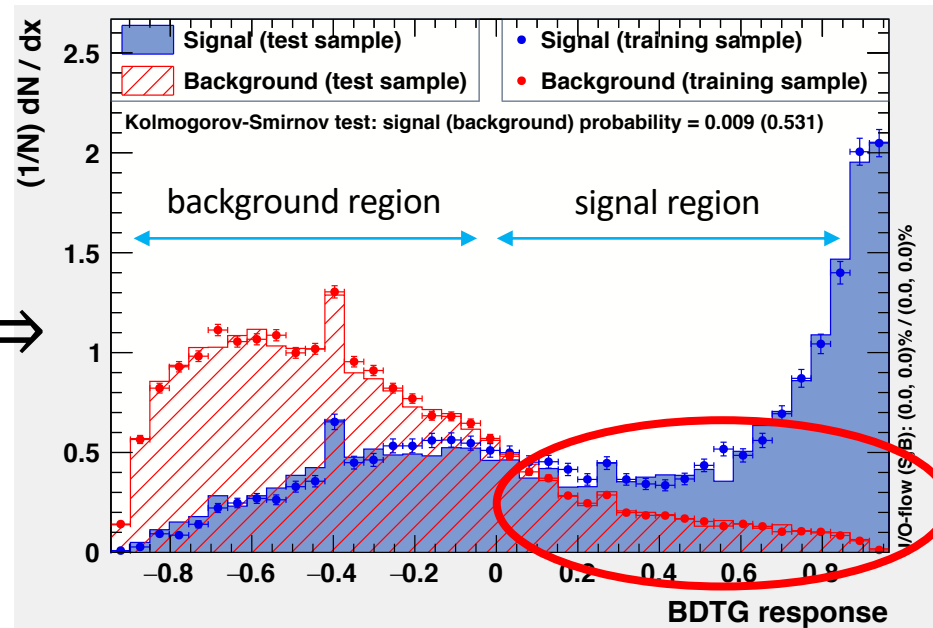
what if the shower reconstruction was perfect?

→ *more pure and efficient selection*

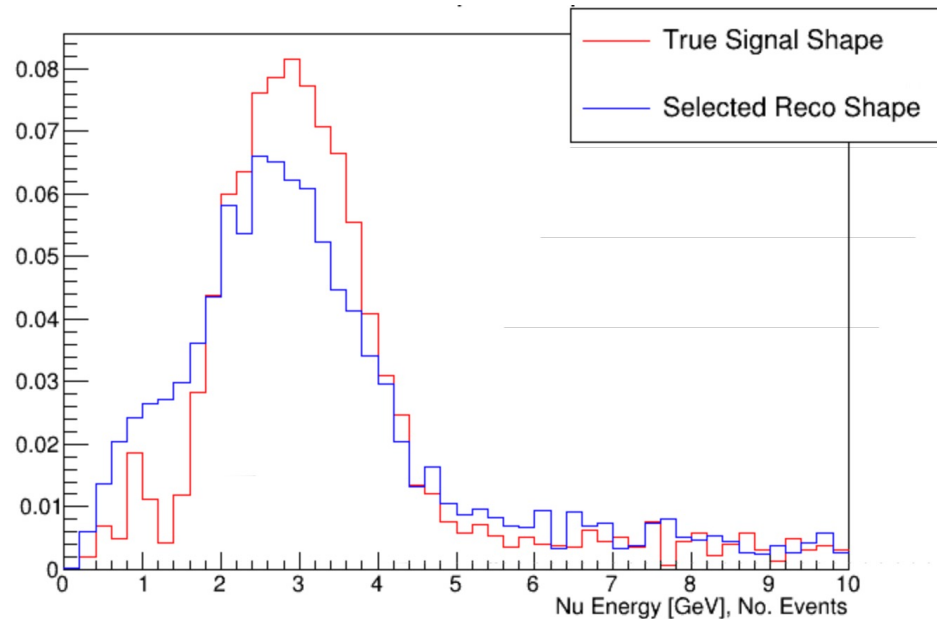
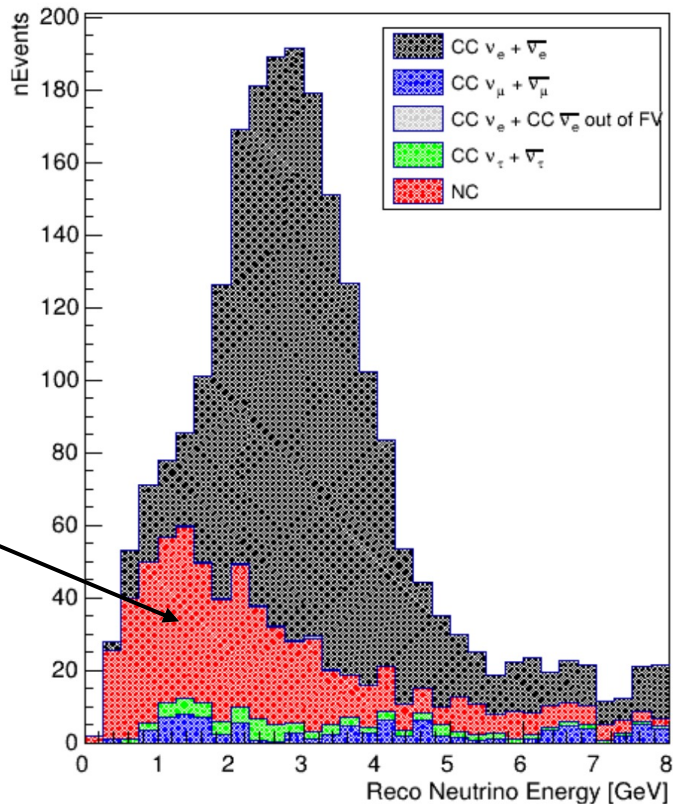
→ *large sensitivity gains*

Searching for Reconstruction Improvements

what should we focus on?

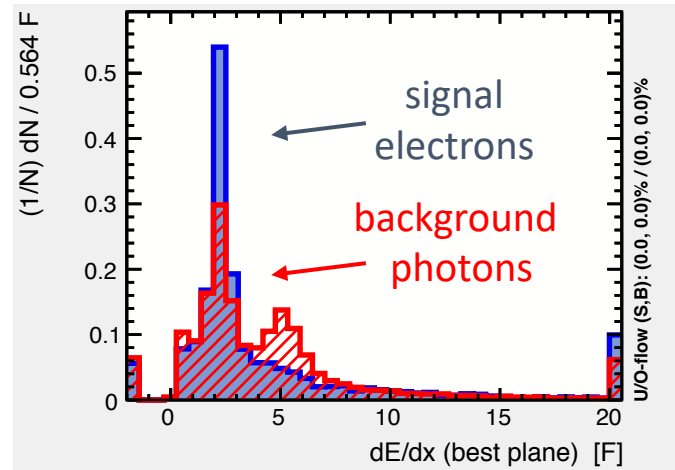
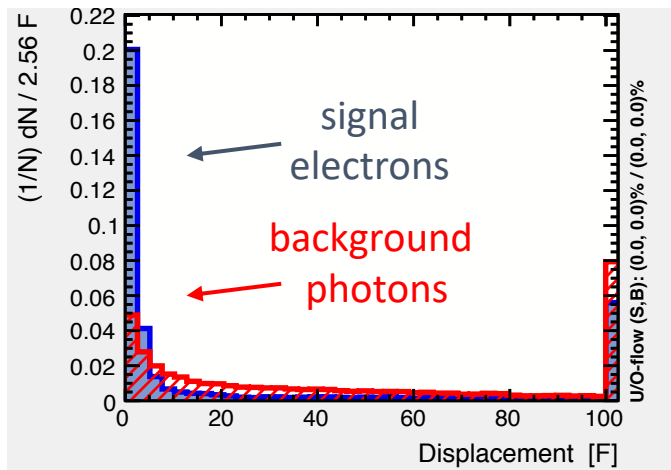
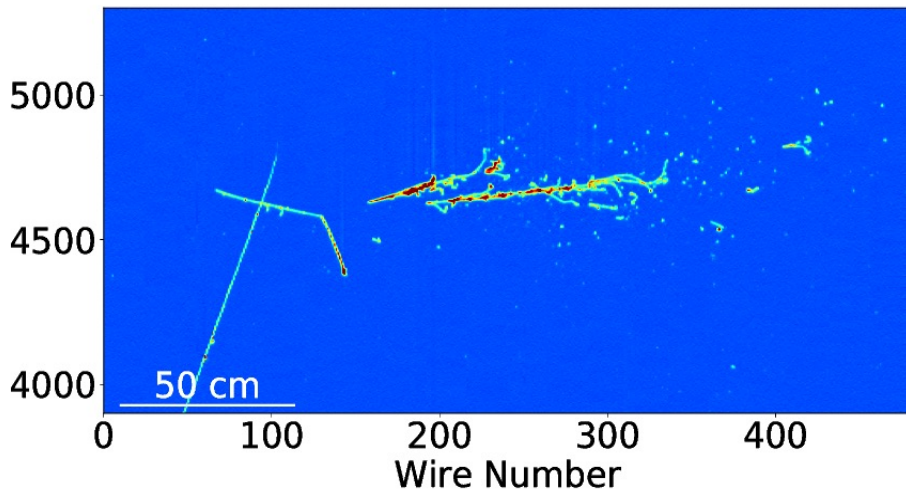
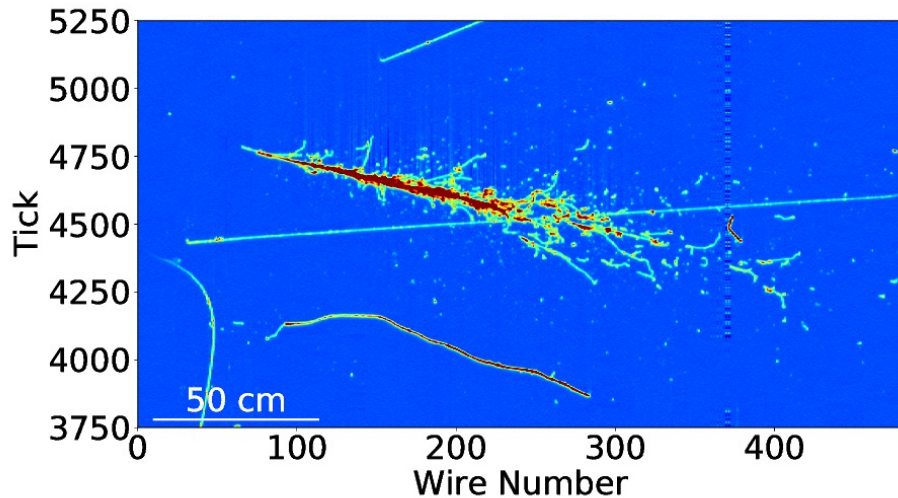


Searching for Reconstruction Improvements



⇒ need to make our BDT signal profile more defined

1. Correct the reconstruction errors
2. Add more information to the BDT



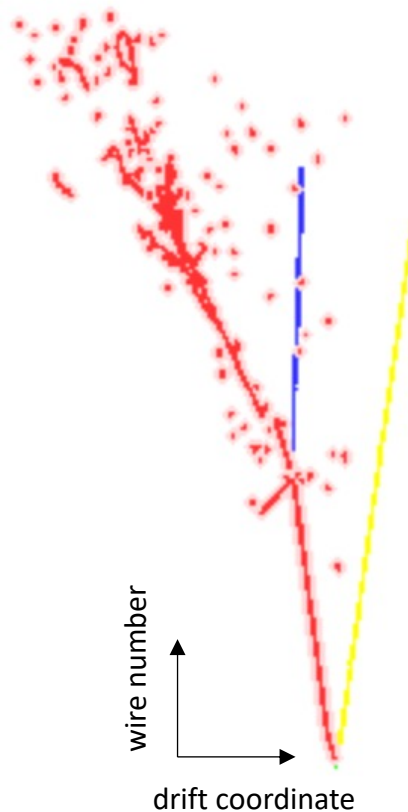
Searching for Reconstruction Improvements



broken electron shower:

⇒ high $dEdx$

⇒ photon-like gap



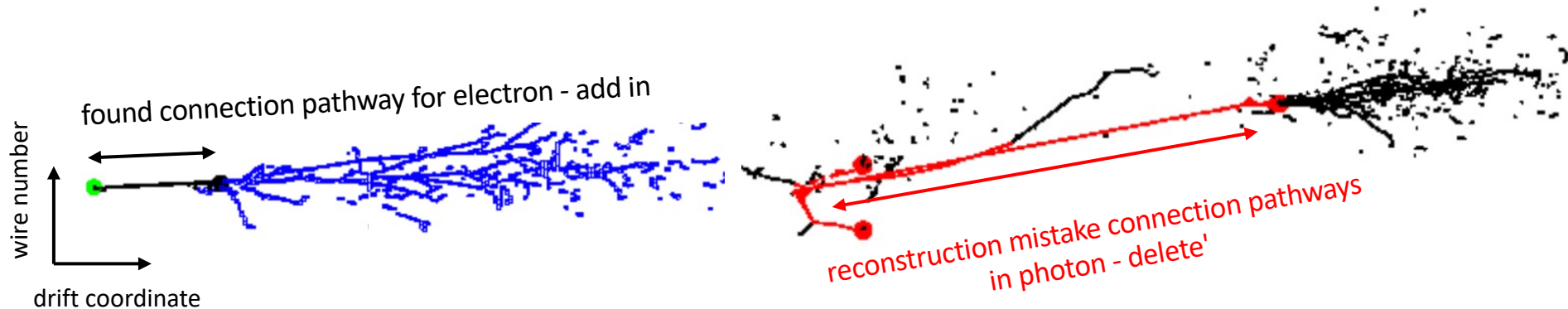
merged photon shower:

⇒ incorrect $dEdx$

⇒ electron-like 'gap'

Creating a Reconstruction Algorithm

1. **Find the connection pathways** that the electron (photon) should have (has) followed to get back to the neutrino vertex
2. **Decide** whether the connection should be there or not
3. **Add or remove** the connection pathway



Decide

Track Stub

Is it straight?

Is it short?

Does it connect to the neutrino vertex?

Has the shower has existed since the neutrino vertex?

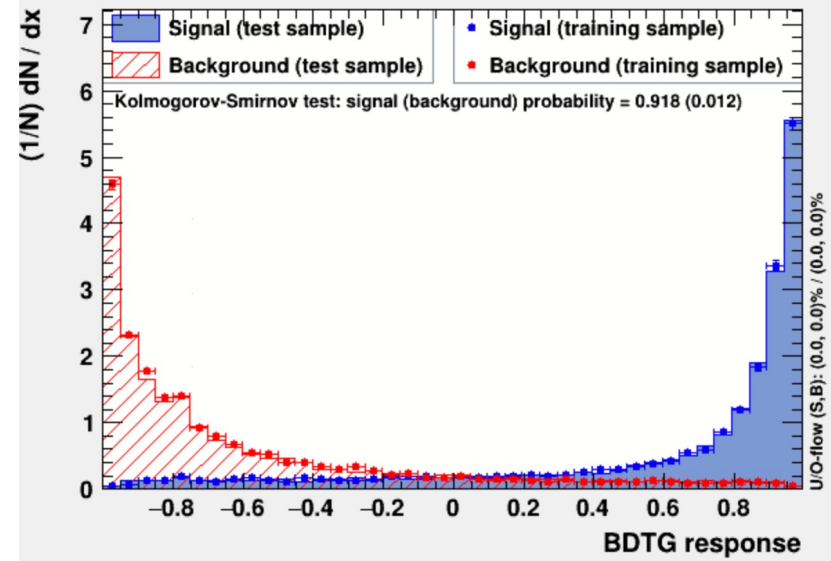
Shower Region

Is the Moliere radius well-defined?

Is the energy distributed uniformly around the connecting pathway?

Does the shower align with the connecting pathway?

Is the energy distributed uniformly around the shower core?

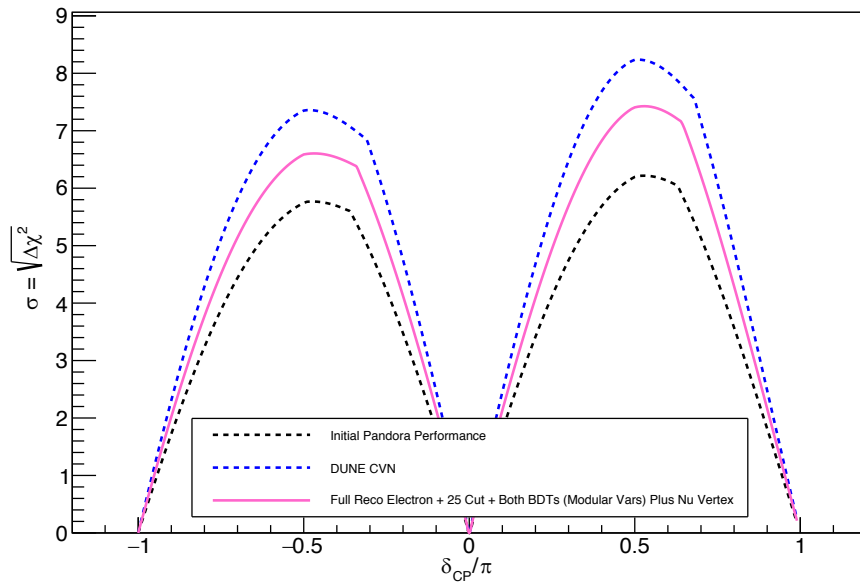


Enhancing the electron-like BDT

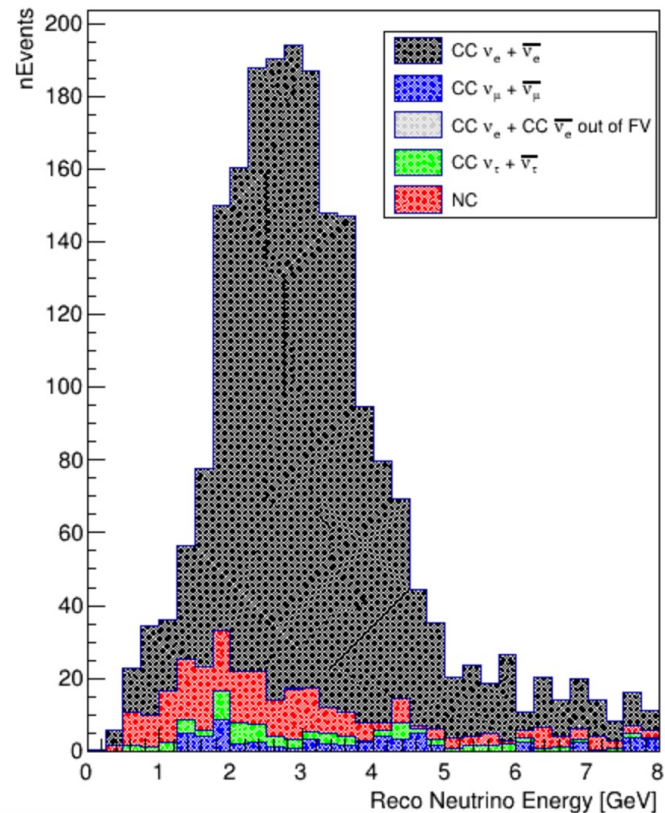
⇒ need to make our BDT signal profile more defined

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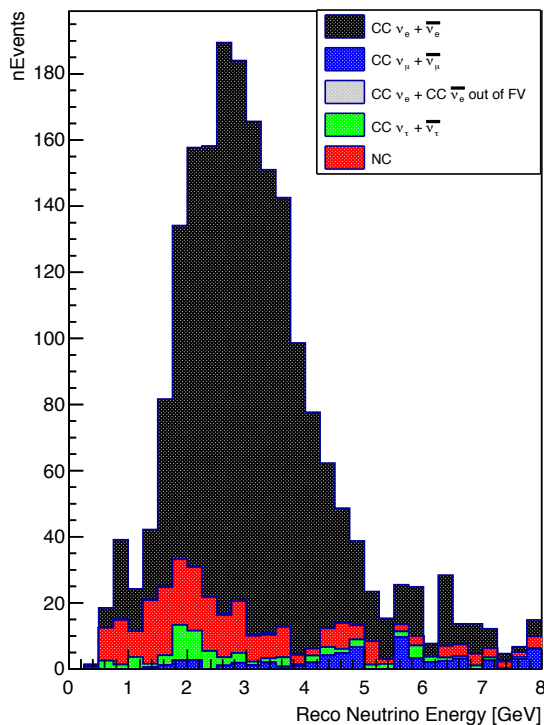
Pandora CP Violation Sensitivity (no systematics, no stat fluctuations)



* the neutrino vertex is cheated here

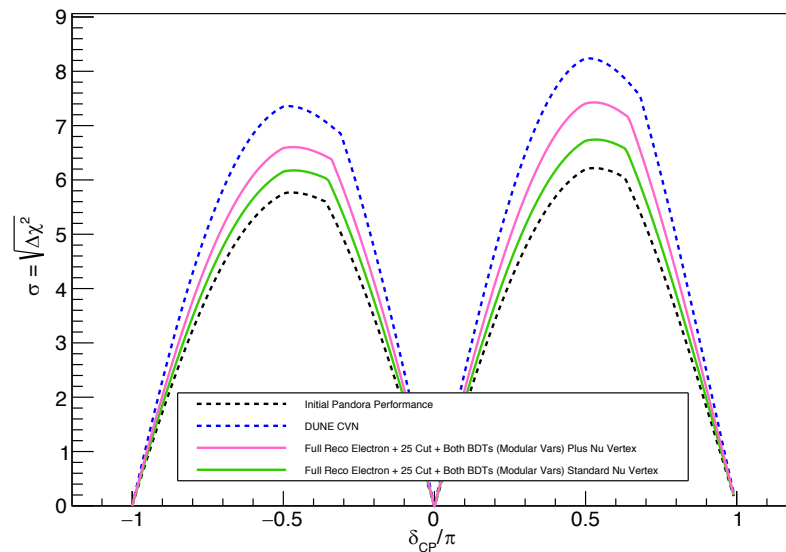


Removing the Vertex Cheat



Vertex improvements ongoing (A. Chappell)

Pandora CP Violation Sensitivity (no systematics, no stat fluctuations)



	Nue Efficiency	Nue Purity
Standard	60.0%	67.1%
Cheat Vertex	66.7%	82.0%
Standard Vertex	62.9%	79.2%

Robustness

MC/data study

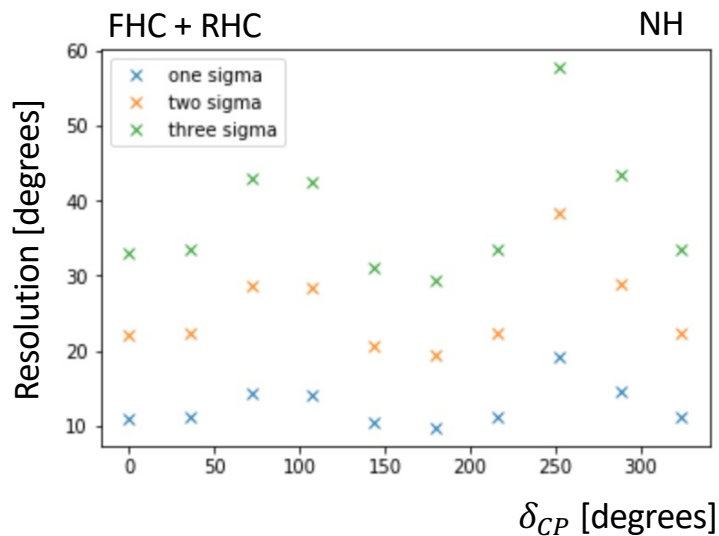
- How is this analysis likely to perform on data?
- Use ProtoDUNE data where electron showers are frequent

Systematic study

- How sensitive is the Pandora analysis to the MC model?
- How does this compare to the CVN

Systematic Study

- CP-violation metrics have been implemented in CAFAna



- 500 universes
- Statistical fluctuations
- Thrown $\sin^2 \theta_{23}$, Δm_{32}^2
- Fit $\sin^2 \theta_{23}$, Δm_{32}^2 , δ_{CP}

- what parameters to throw? to fit?

Systematic Study

Thorough but not exhaustive...

- Advice – what systematics are most interesting?
- Help – how are these systematics are implemented?

Conclusions

- Illustrated the use of the Pandora-based selection procedure to study CP-violation at DUNE
- Initial shower reconstruction was found to limit the achieved sensitivity
- In line with the multi-algorithm approach, a shower refinement algorithm was created
- Significant gains to the nue selection performance and sensitivity have been achieved
- Focus is now on making this more robust with a MC/data comparison and sensitivity study