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T2K

Measuring charged current neutrino interactions in the T2K near detector ECals

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IOP HEPP & APP Meeting

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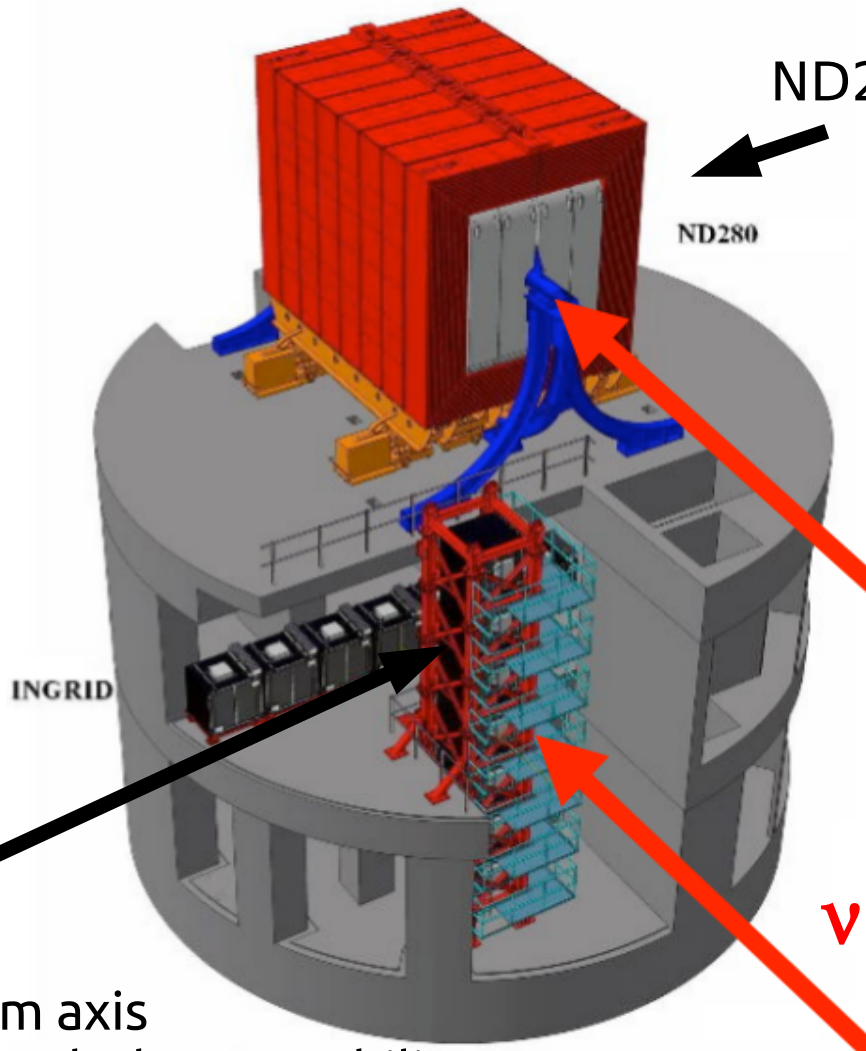
T2K near detector complex



ND280

2.5º off-axis to beam pointing

Used for variety of measurements

2.5º

ν_μ beam this way

0º

INGRID

On the beam axis

Primarily checks beam stability

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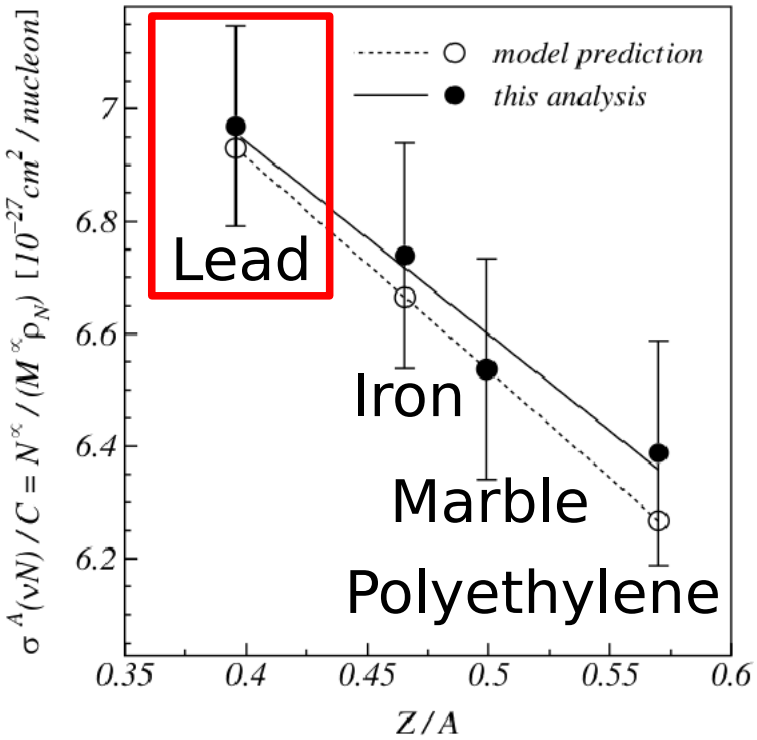
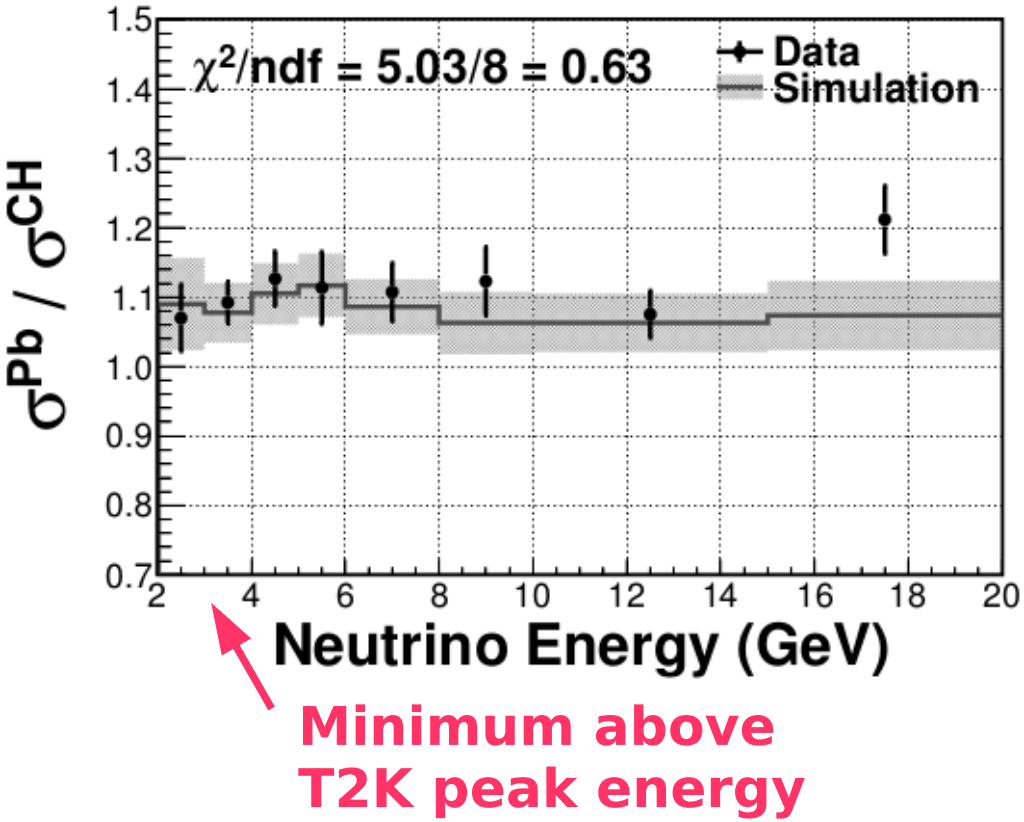
T2K

ν interactions on lead

CHORUS Collaboration 2003



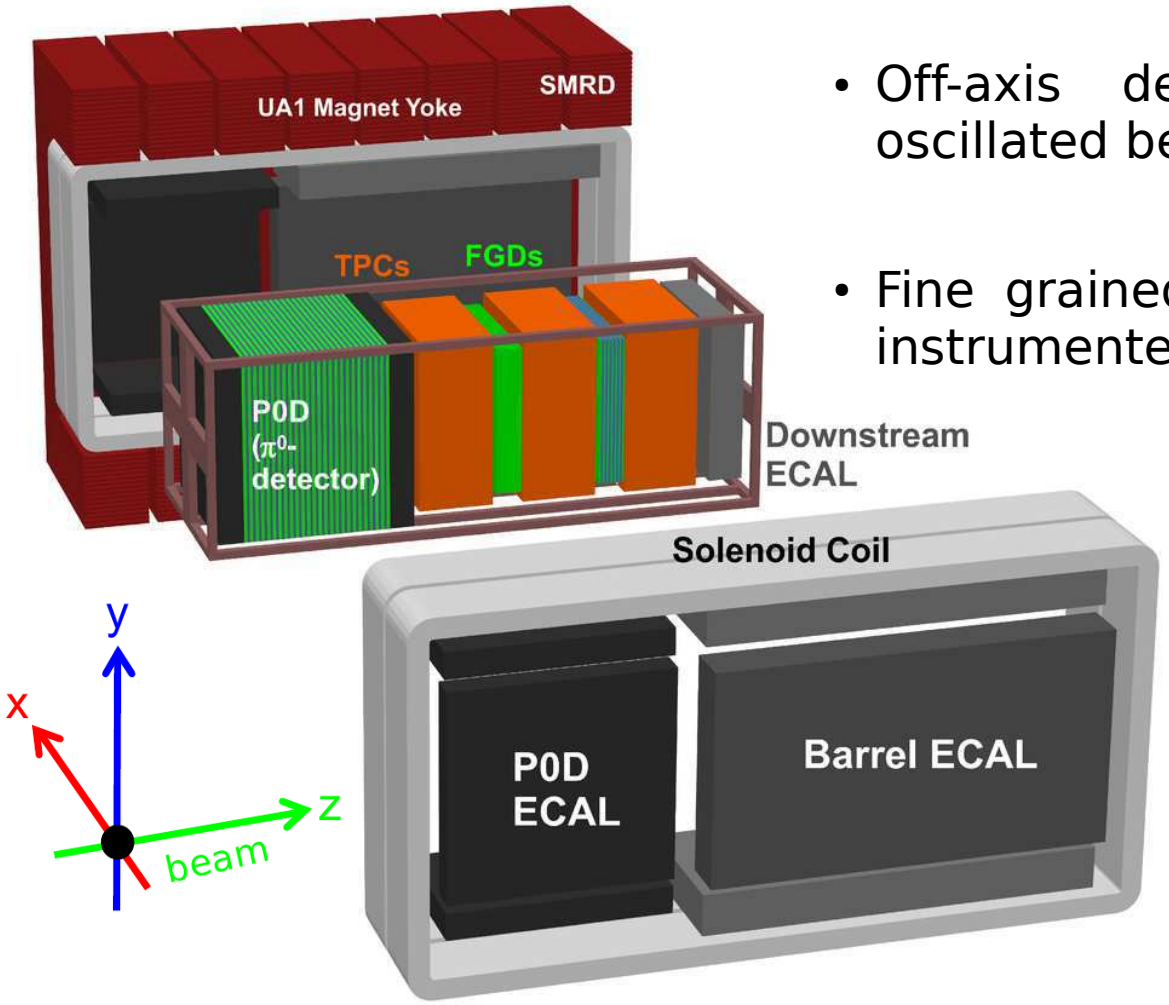
MINERνA Collaboration 2014



Minimum above T2K peak energy

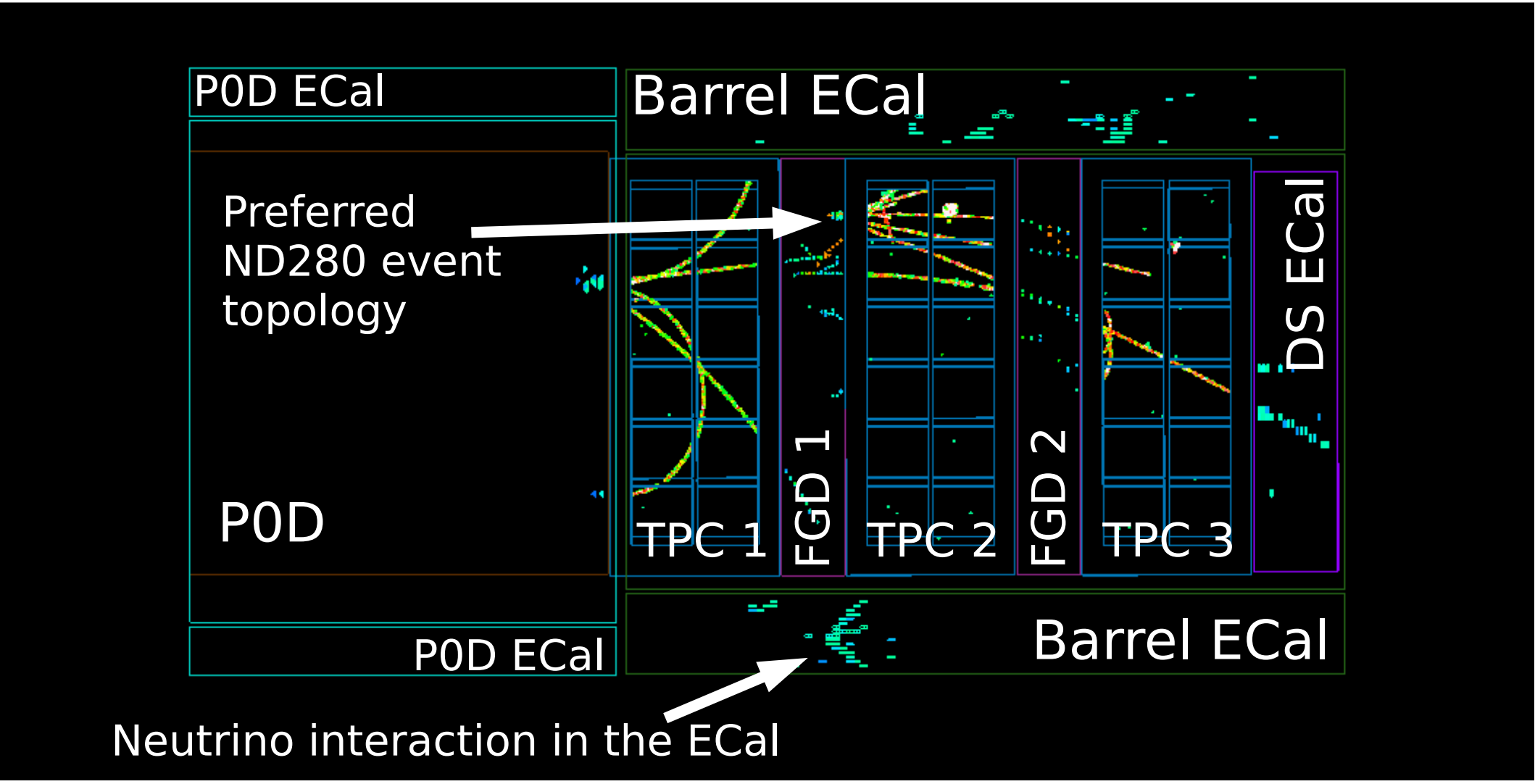
World's knowledge on neutrino interactions on lead

ND280

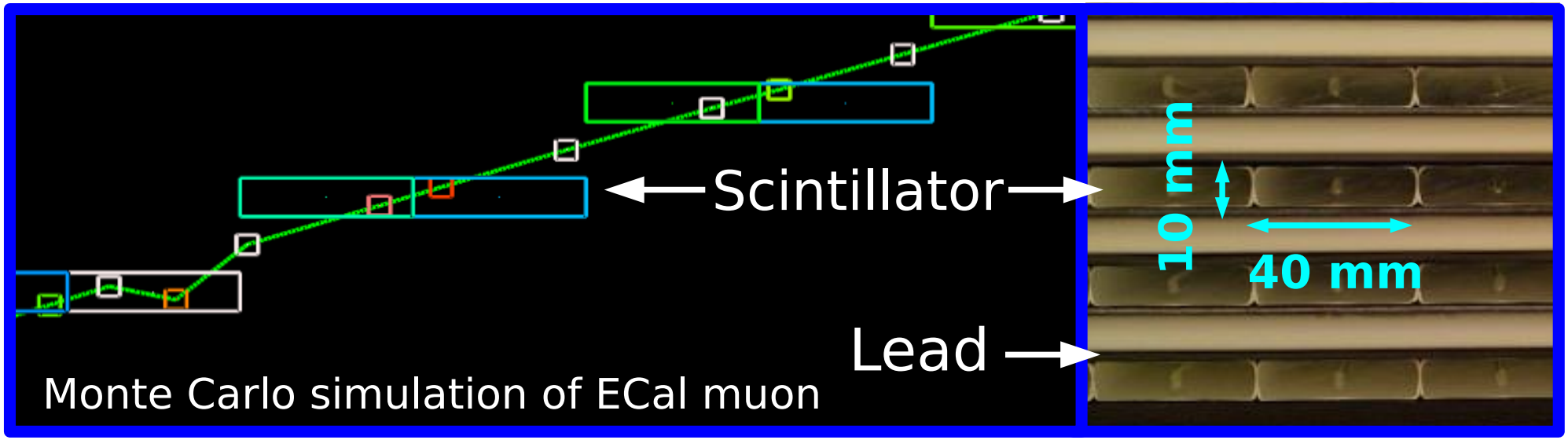


- Off-axis detector which measures pre-oscillated beam characteristics
- Fine grained detectors consist of layers of instrumented scintillator
- TPCs used for particle Identification
- ECals provide coverage for outbound energy

ND280 event topology

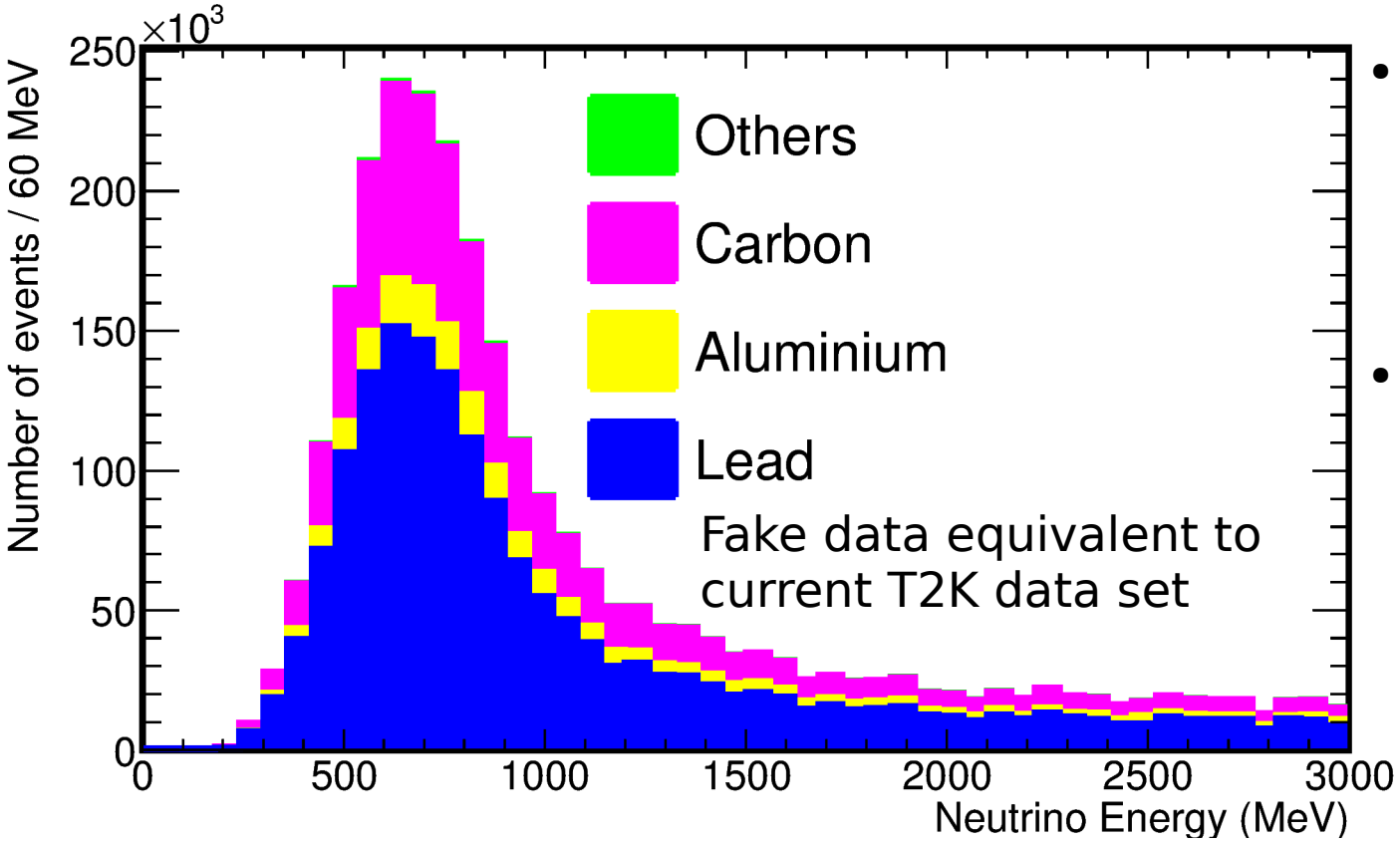


ND280 ECal



- Designed and constructed by T2KUK group
- Lead-scintillator sampling calorimeter
- Highest-mass detector in ND280
- Approximately 50% of neutrino beam simulated ECal events come from neutrino-ECal interactions

Neutrino-ECal interaction rates



- ECal sees a large number of neutrino interactions
- In the fake data example:
  - 3,000,000 neutrino-ECal interactions
  - Roughly 67% are lead interactions

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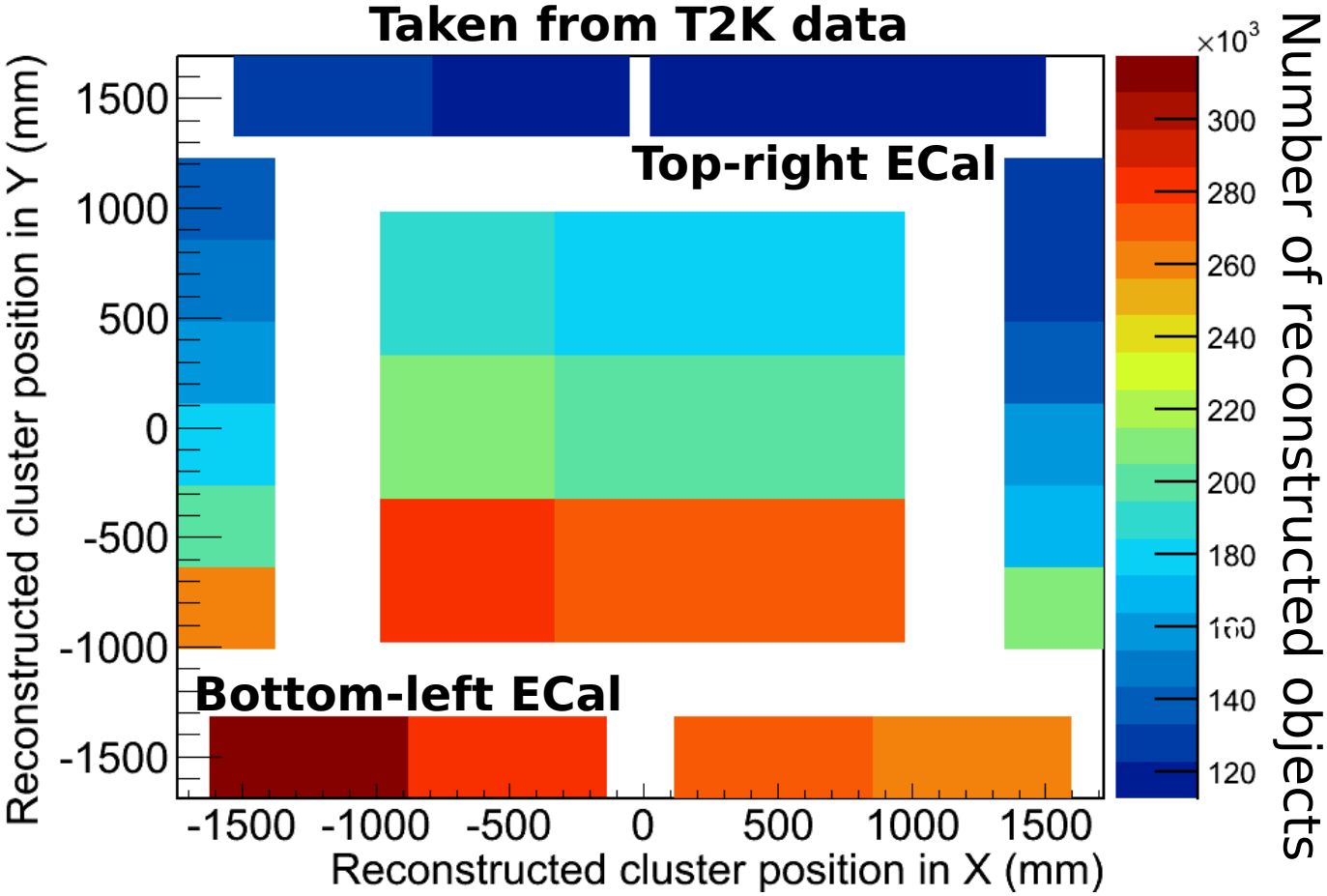
ND280 ECal and the off-axis effect

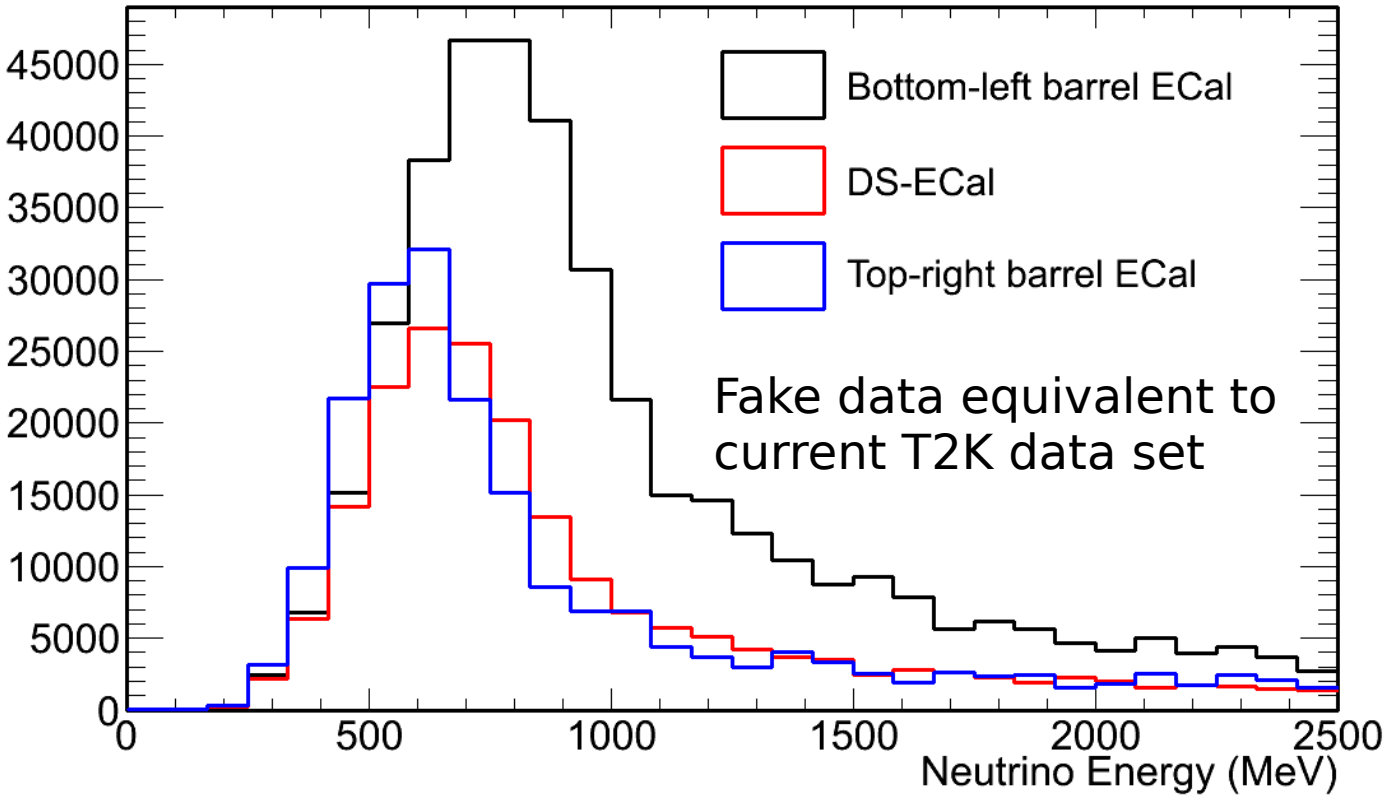
- ECal capable of seeing off-axis effect
- Example here taken from T2K data
  - Number of reconstructed objects per unit mass in each bin
- The barrel modules reveal the effect due to their position



Beam axis 2.5° from ND280 centre

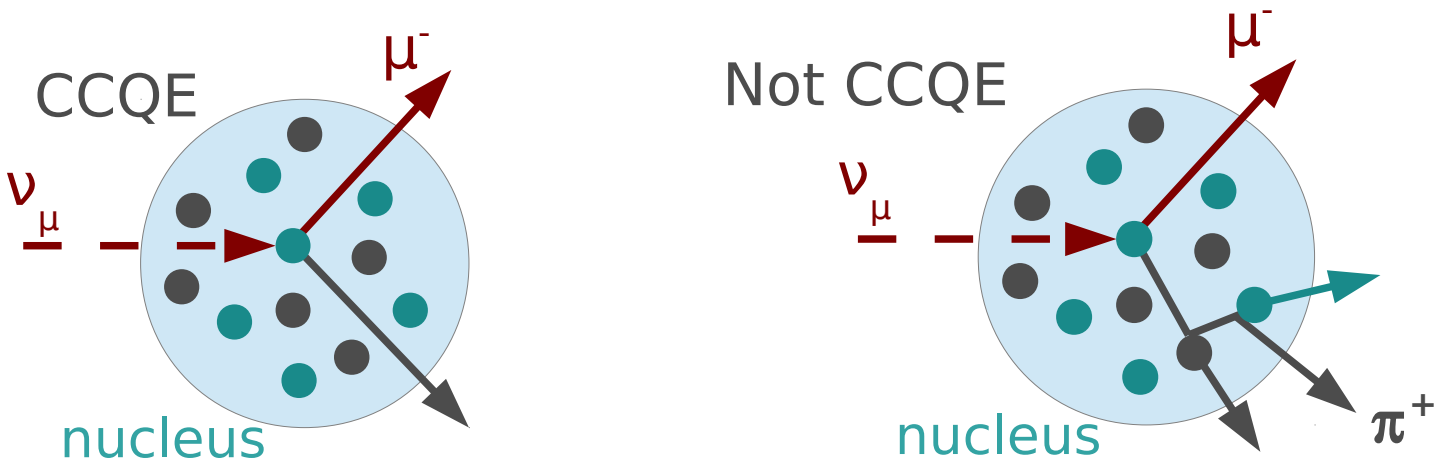
ND280 ECal and the off-axis effect

The number of ECal neutrino interactions



- Simulation which uses the off-axis effect reveal flux features
- Peak value of neutrino energy distribution different for each ECal module
- Extra information for studying T2K neutrino flux

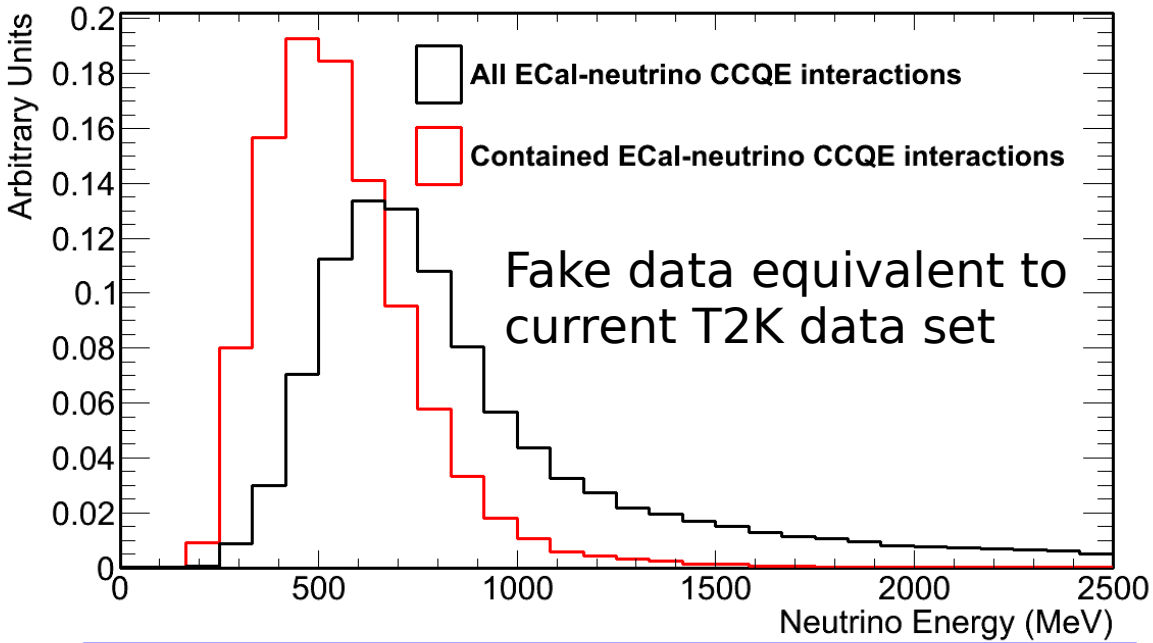
Aside – Interaction types

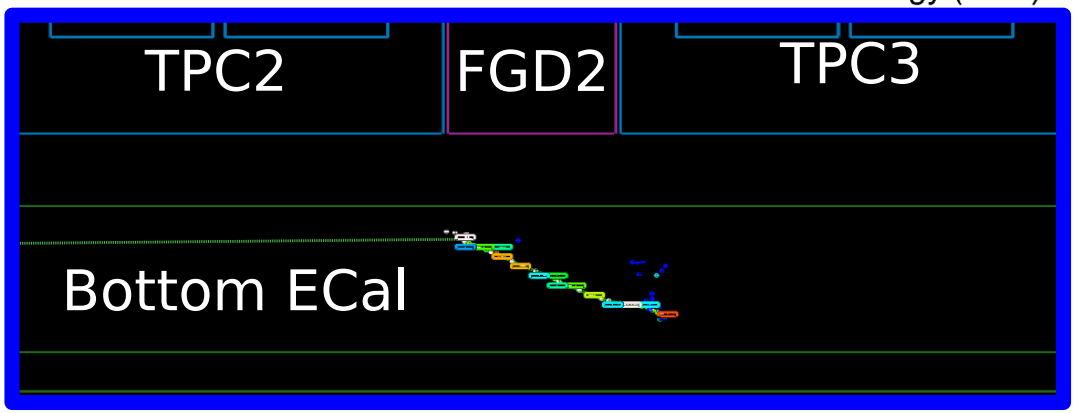


- Neutrino interactions can be broken down into sub categories
- The dominant type at T2K energies is the charged current quasi-elastic (CCQE) interactions
- Typical final states are the converted lepton and an ejected nucleon
- You can calculate neutrino energy from charged lepton kinematics in CCQE interactions

ND280 ECal and CCQE containment

- ECal capable of seeing fully contained CCQE interactions
- In simulation of data set
  - 3,000,000 ECal-neutrino interactions
  - **60,000 fully contained ECal-neutrino CCQE interactions**
- In same simulation, there are 75,000 CCQE interactions in the FGDs (total)
- If the final state particles are fully contained, you can estimate the kinematics → infer neutrino energy

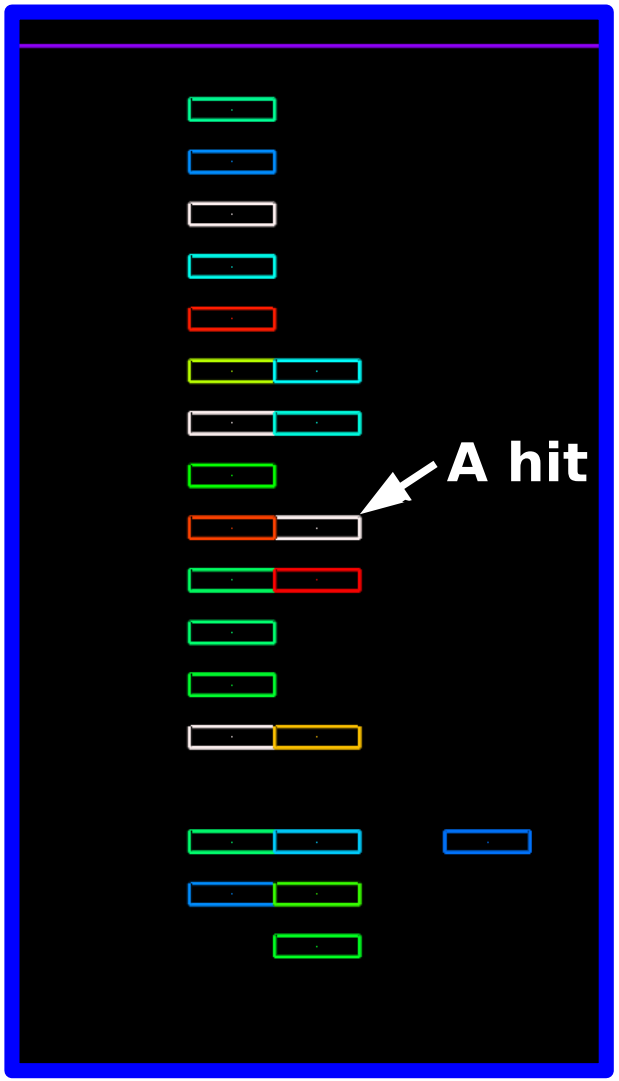




ECal reconstruction

- ECal reconstruction algorithms optimised for tracker energy containment

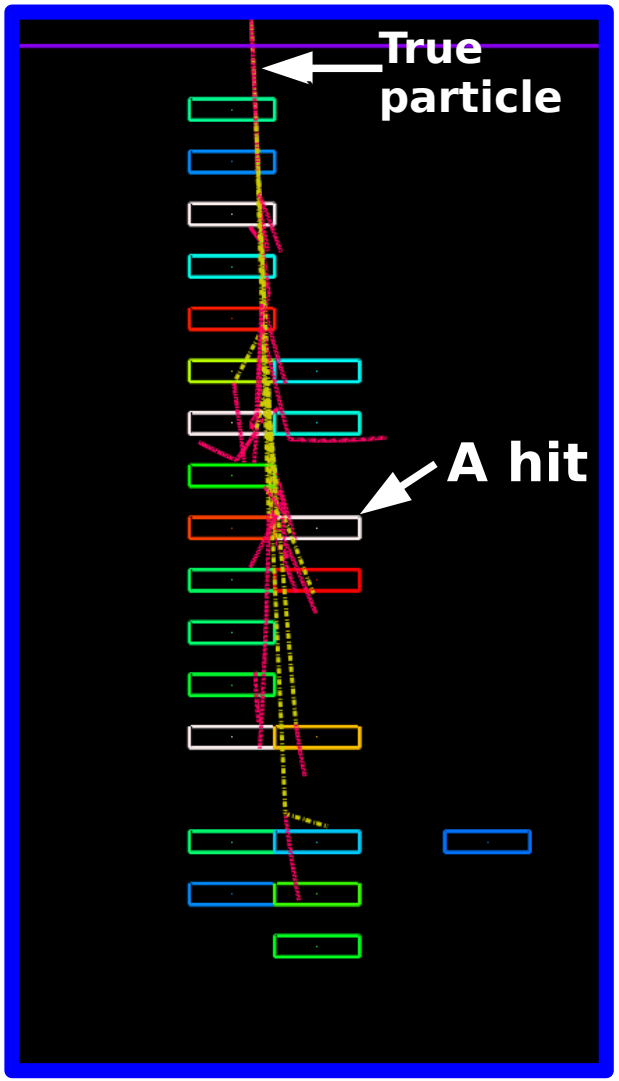
1) Start with set of scintillator deposits (hits)



ECal reconstruction

- ECal reconstruction algorithms optimised for tracker energy containment

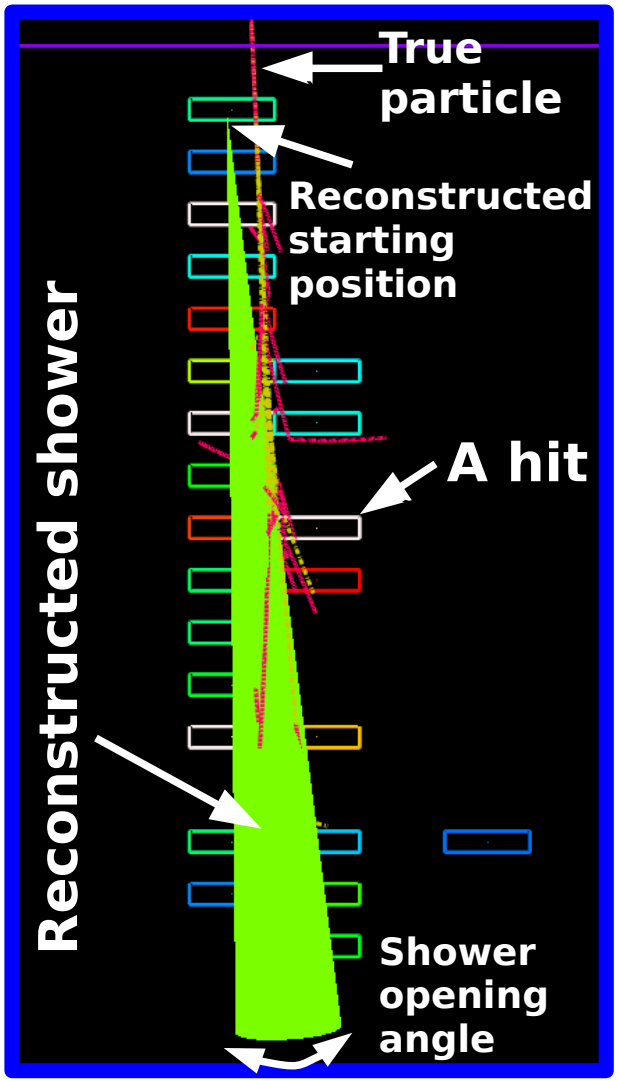
1) Start with set of scintillator deposits (hits)
2) These correspond to charged particles depositing charge



ECal reconstruction

- ECal reconstruction algorithms optimised for tracker energy containment

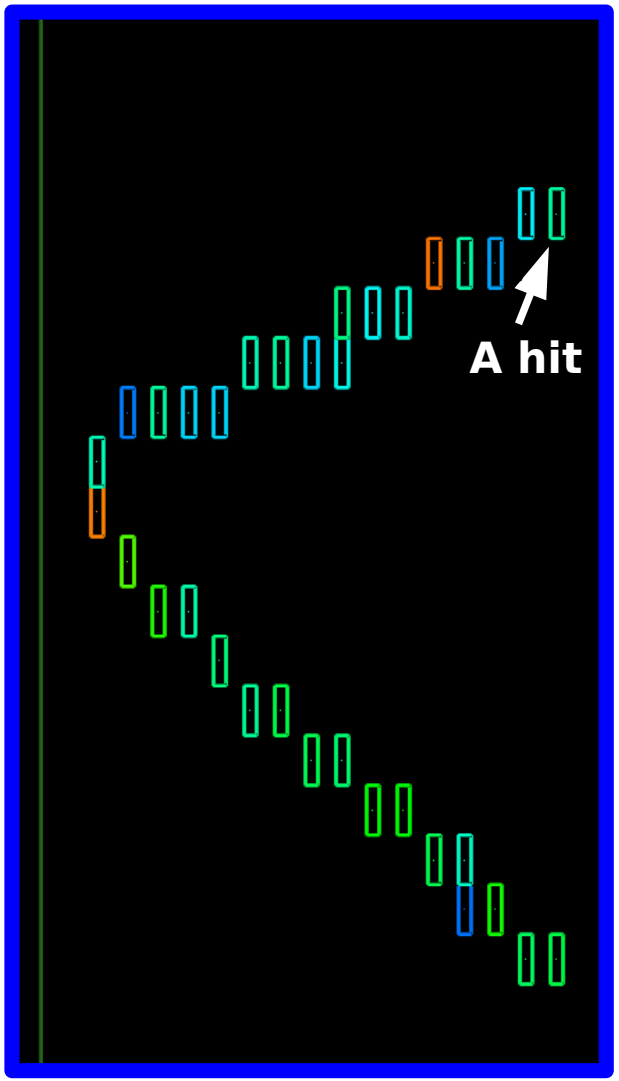
1) Start with set of scintillator deposits (hits)
2) These correspond to charged particles depositing charge
3) Apply tracking and showering algorithms
   - This decides whether cluster is track-like or shower-like (in this case, it is shower-like)



ECal reconstruction

- This method of reconstruction is problematic for vertex reconstruction

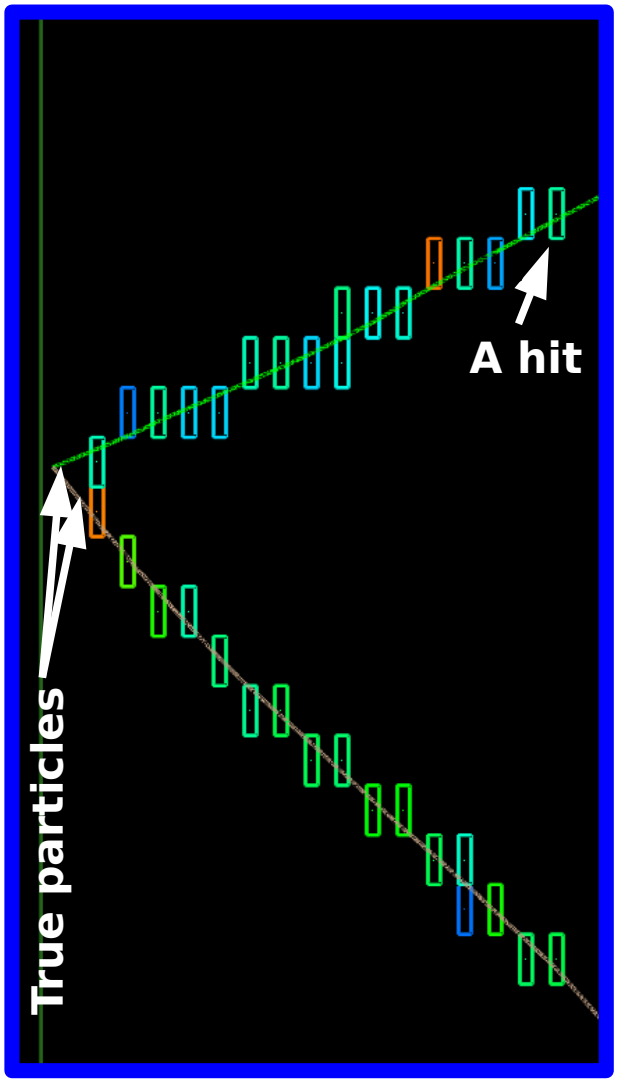
1) Again, start with a set of scintillator deposits (hits)



ECal reconstruction

- This method of reconstruction is problematic for vertex reconstruction

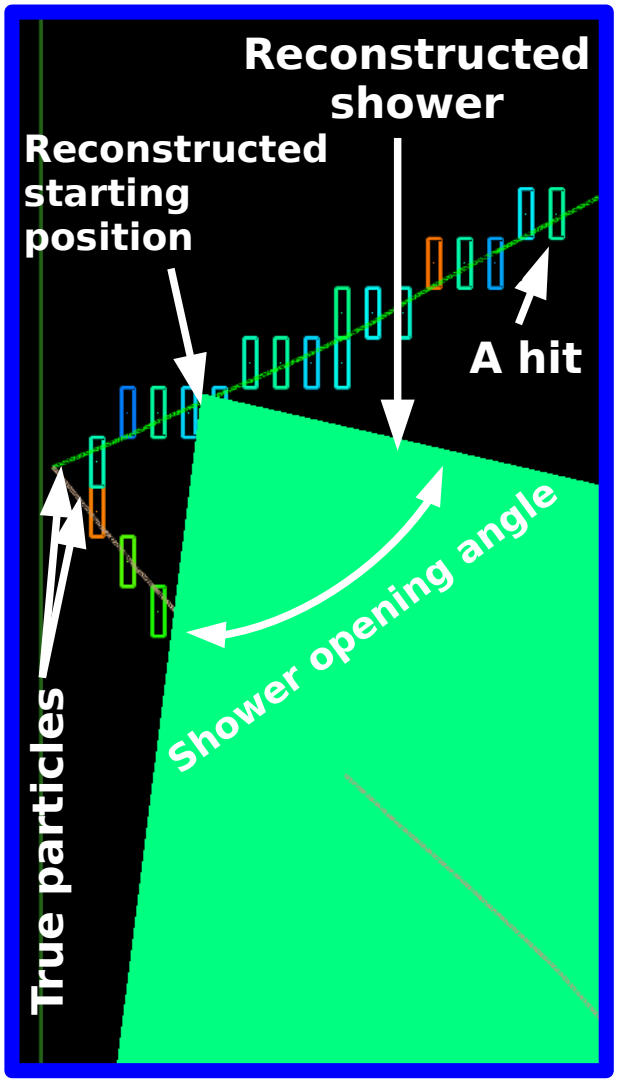
1) Again, start with a set of scintillator deposits (hits)
2) This time, the hits come from a π^+ and a μ^- fired from a vertex



ECal reconstruction

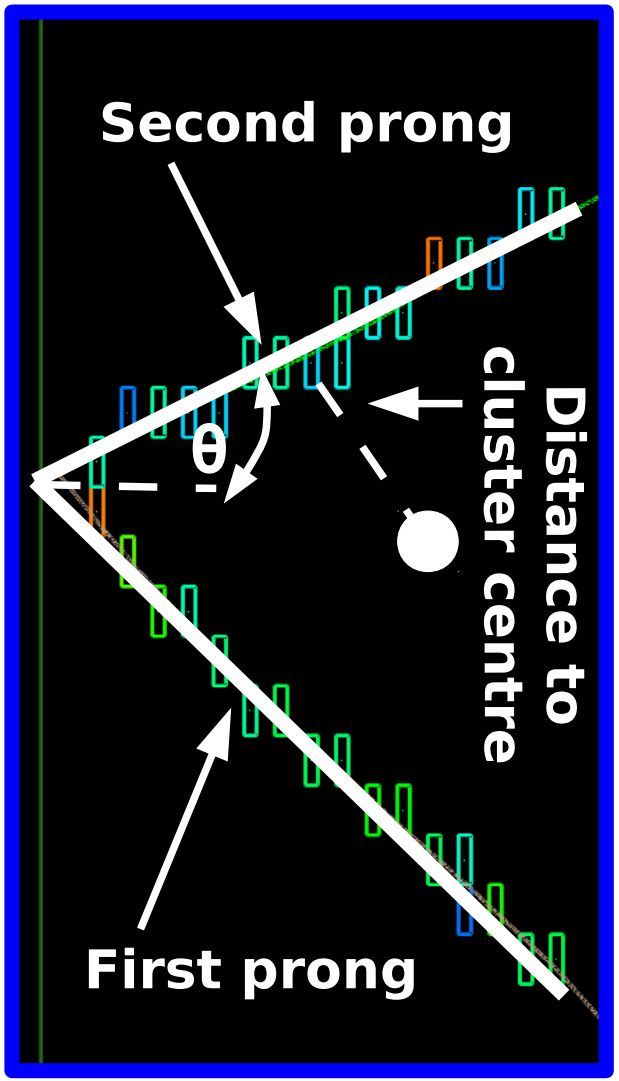
- This method of reconstruction is problematic for vertex reconstruction

1) Again, start with a set of scintillator deposits (hits)
2) This time, the hits come from a π^+ and a μ^- fired from a vertex
3) Applying the tracking and showering algorithms will give you **one** track or **one** shower
   - It often reconstructs a vertex as a shower



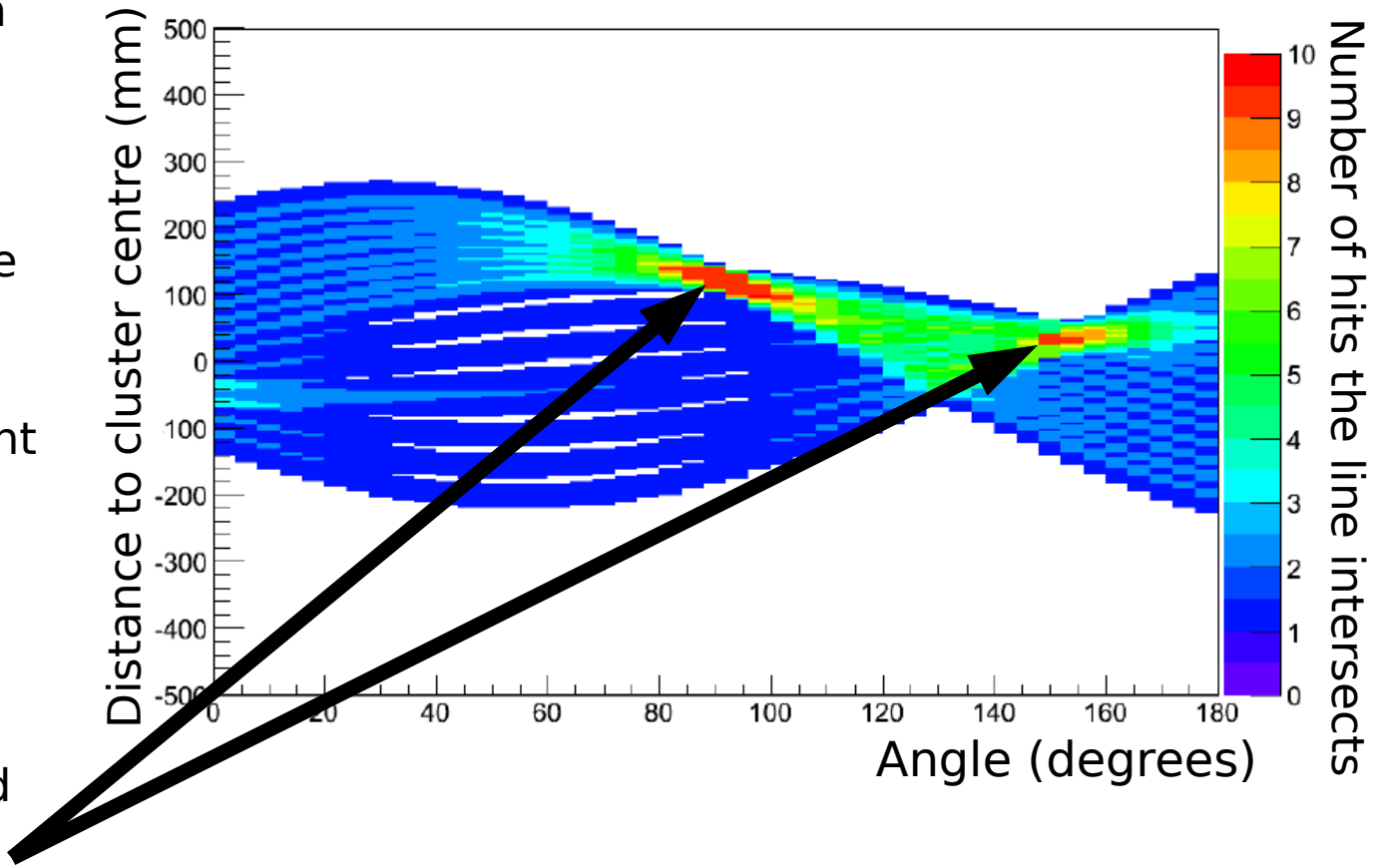
New ECal reconstruction

- Instead, take it back a step
- Try and pick out the multiple 'prongs' which make up the hit collection
- Example: draw many straight lines and see which fit the hits the best



The Radon transform

- I am currently developing a new reconstruction algorithm
- Draws many **straight** lines over the hit collection
  - Spans huge amount of line parameter space
- Each test line becomes a point in radon space
  - Height of point is number of hits the line intersects
- Local maxima of the radon space distribution correspond to reconstructed track parameters



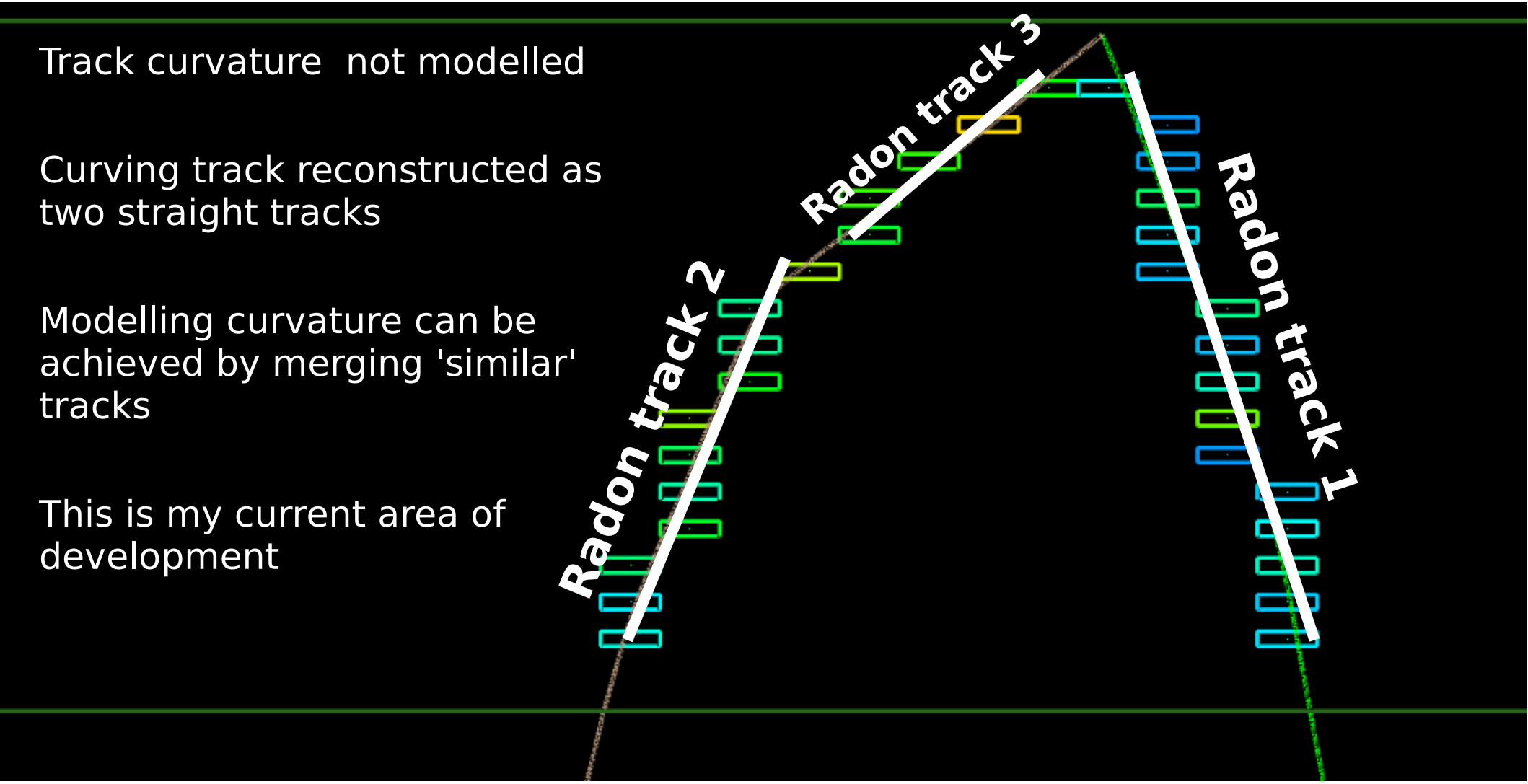
Track curvature in the Radon transform

Track curvature not modelled

Curving track reconstructed as two straight tracks

Modelling curvature can be achieved by merging 'similar' tracks

This is my current area of development

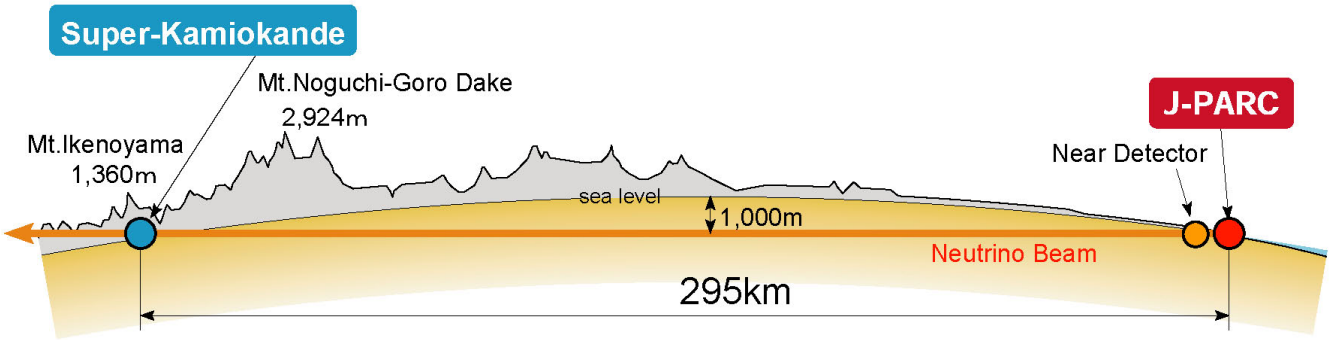


Summary

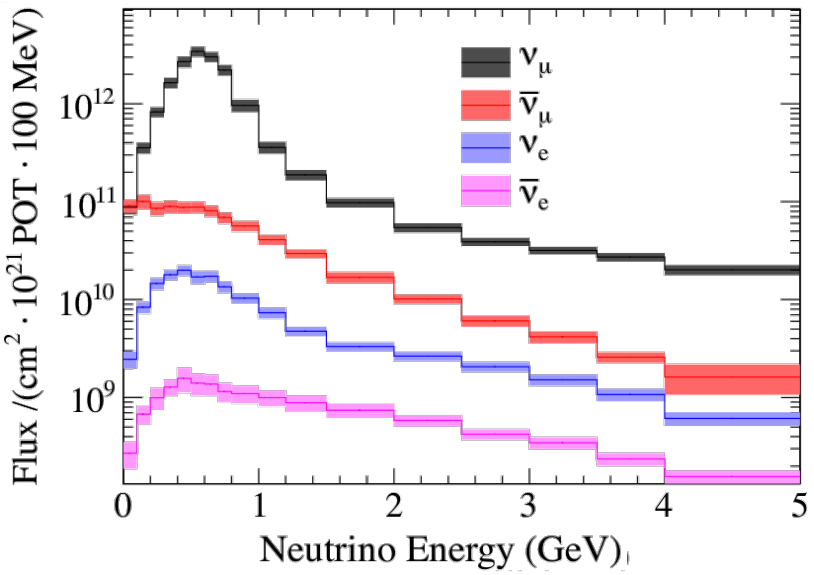
- Part of T2K's near detector consists of 7 high mass ECal modules
- With current data set, we expect 3,000,000 neutrino interactions in the ECal
  - 67% of these interact on ECal's lead sheets
- Geometry and mass of the ECals allows for a unique study of the T2K neutrino flux
- I am developing a new ECal reconstruction algorithm
  - Based on a popular method of pattern recognition (Radon transform)
  - Can pick out multiple particles in one reconstructed cluster
  - Unlocks a completely new event category (neutrino-ECal interaction vertex)
- After Radon transform development, I will focus on making the world's first absolute measurement of the ν_μ charged current cross-section on lead

Backups

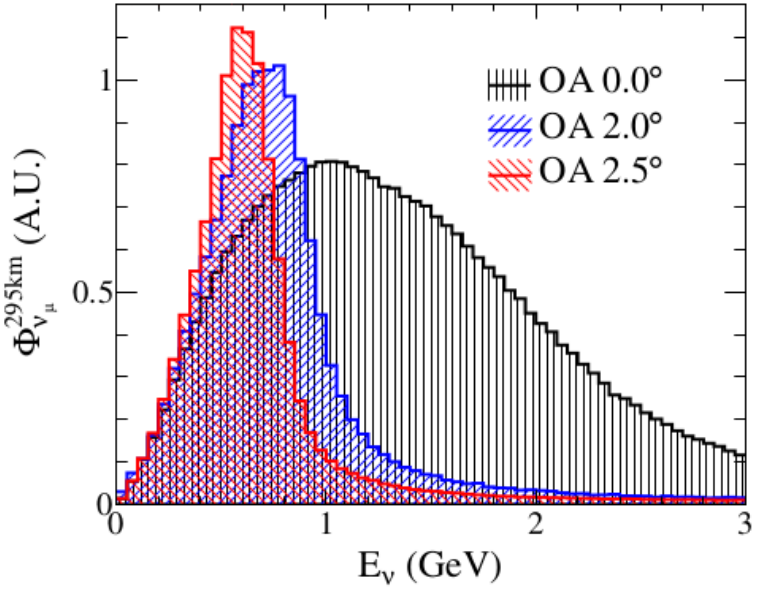
The T2K experiment



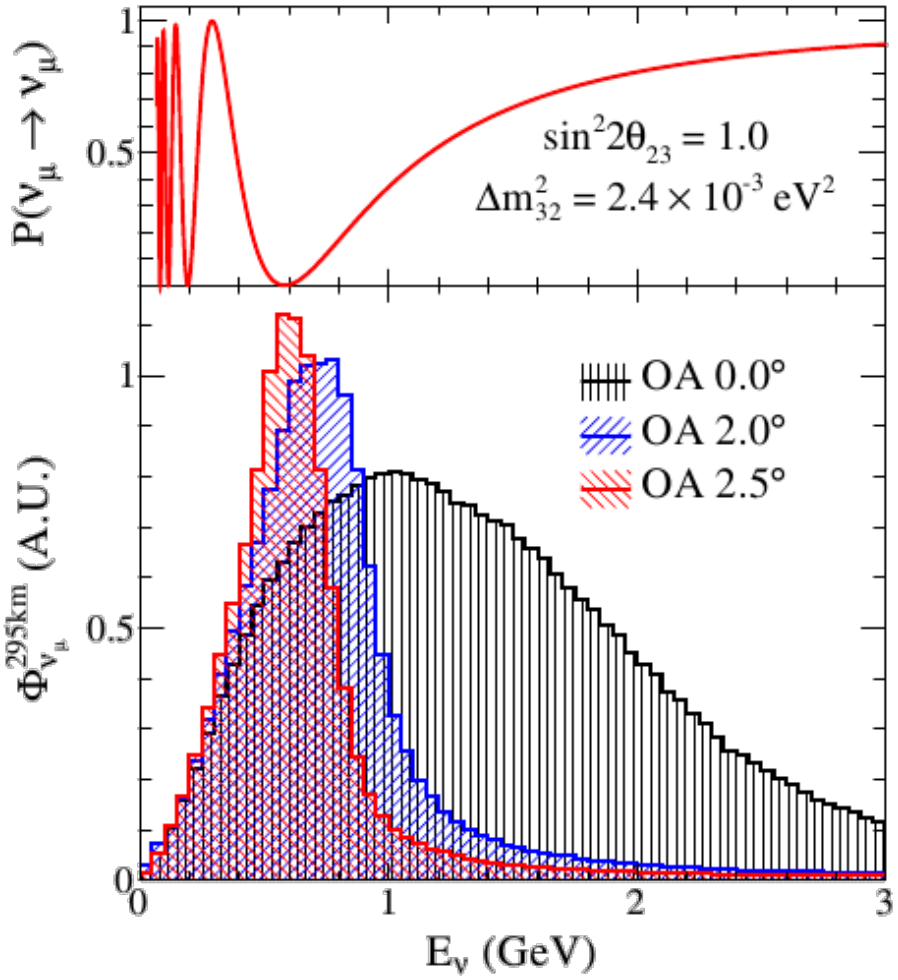
Generates ν_μ beam with high purity



Uses "off-axis" ν_μ beam



The off-axis beam



- ND280 and SK sit 2.5° off-axis to axis of beam
  - Suppresses high energy tail
  - Narrows energy peak
- The magnitude of the effect carefully selected
  - The energy peak chosen to align with oscillation probability max/min