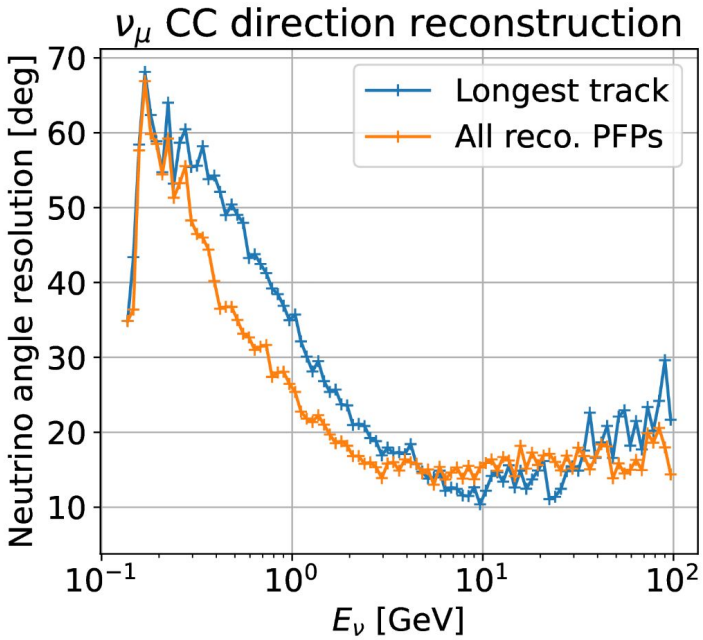
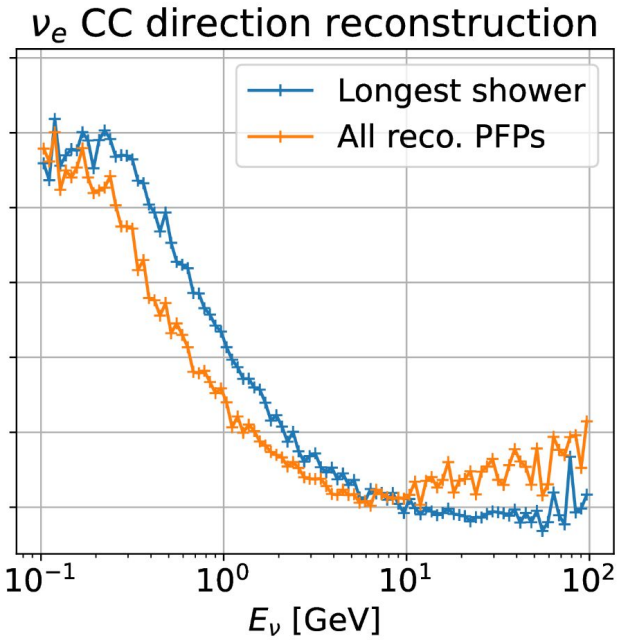
Direction reconstruction for atmospheric neutrinos

P. Granger - APC/CNRS

Recap of previous studies

- Relying on the Pandora reconstructed PFPs
- Different methods available





- Low-Energy performance are not great (mostly due to Fermi motion)
- Loss of resolution $\gtrsim$ 4GeV because of reconstruction issues

Trying an additional method

Trying out an additional naive method:

- Calorimetric only: using only the 2d hits information
- Also using the reconstructed vertex

Idea:

- Fit individually each of the 2D reco planes (U, V, W) to get an average projected 2D direction and merge the information to obtain a reconstructed 3D direction

Hopes:

- Does not depend on particle reconstruction at High-Energy -> should improve
- At Low-Energy all the reconstructed hits might provide some info -> could improve

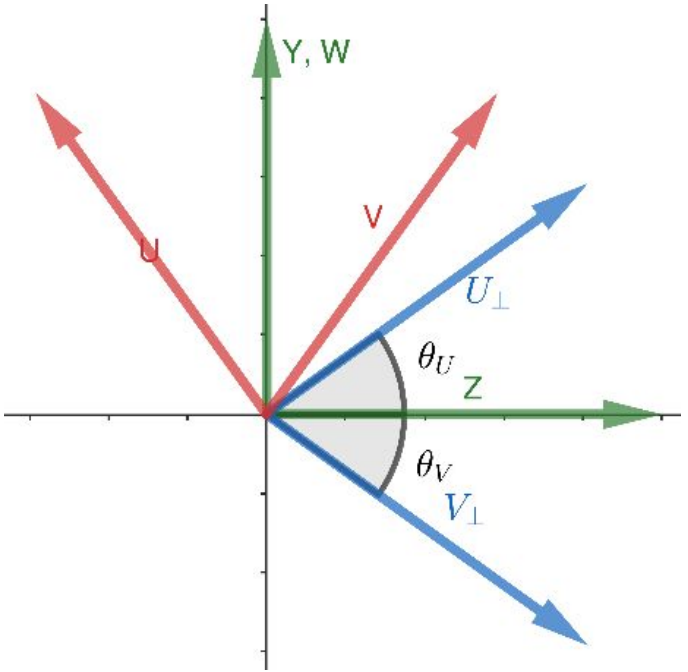
Cons:

- We approximate KE to momentum and don’t use any PID info

Using the recob::Hit objects

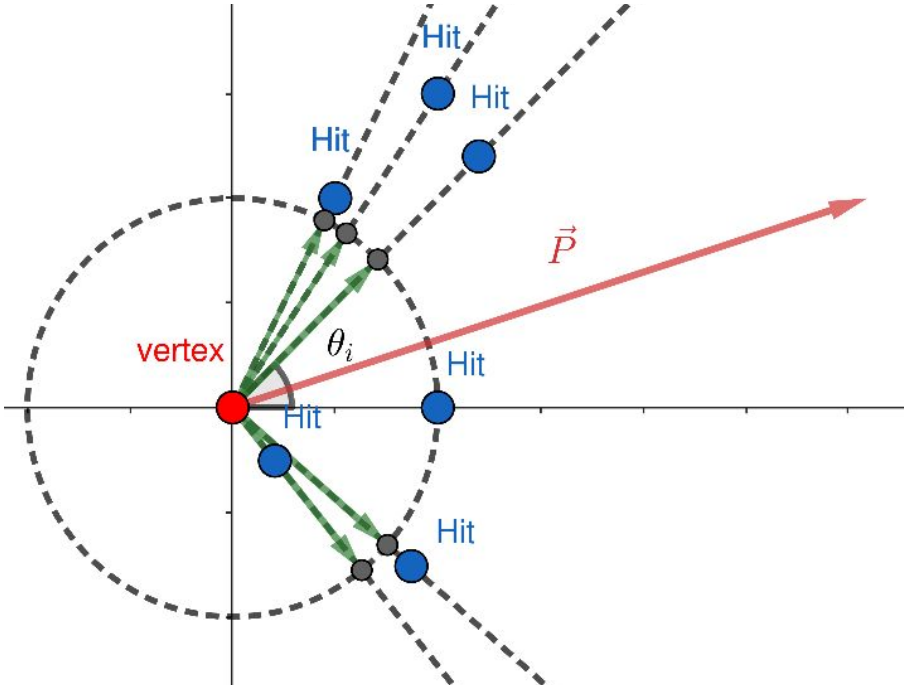
- All the recob::Hit objects are sorted in the 3 views (U, V, W) and put back in the view coordinate system

$$\begin{pmatrix} \vec{e_{U_\perp}} \\ \vec{e_{V_\perp}} \end{pmatrix} = \begin{pmatrix} -\sin\theta_U & \cos\theta_U \\ -\sin\theta_V & \cos\theta_V \end{pmatrix} \begin{pmatrix} \vec{e_y} \\ \vec{e_z} \end{pmatrix}$$



- The coordinates are shifted so that the vertex lies at (0, 0) in all the views.

Method itself



$$\vec{P} = \sum_i \left(w_i \frac{x_i \vec{e_x} + y_i \vec{e_y}}{\sqrt{x_i^2 + y_i^2}} \right) = \sum_i w_i e^{j\theta_i}$$

'y' here is the view direction, not the real 'y'

Hits (x_i, y_i, w_i):

- x_i is the time position
- y_i is the view we consider
- w_i is the number of ADCs of the hit

<u>Method:</u>

- We get the direction of all the hits with respect to the vertex. We sum all of them weighted by the number of ADCs.
- Should give the average KE vector in this view

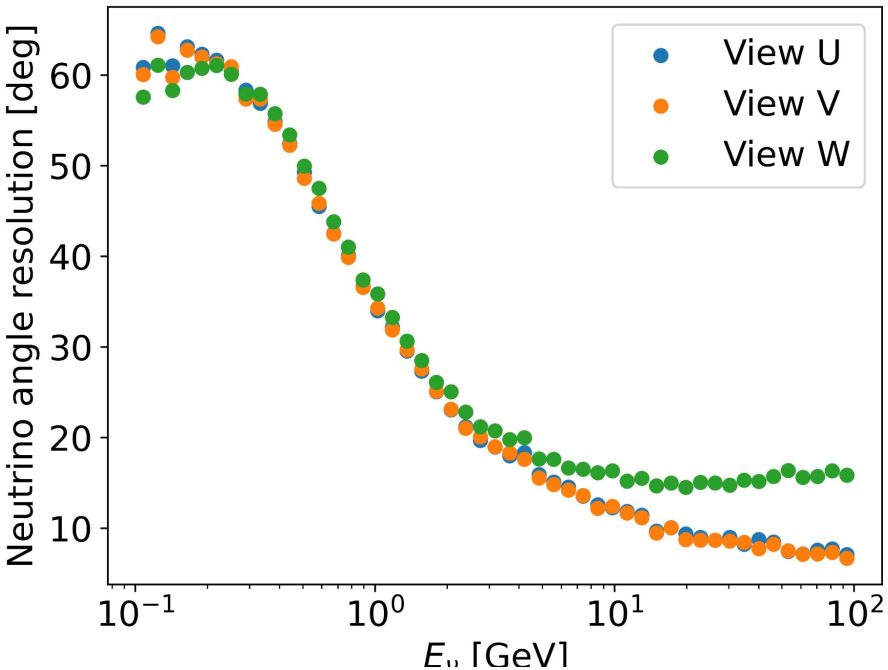
Combining the 2D infos back to 3D

- We measure (P_x, P_{view}) for each view.
- We invert back (U, V) coordinates to (y, z)

$$\begin{pmatrix} \vec{e_y} \\ \vec{e_z} \end{pmatrix} = \frac{1}{\sin\theta_V \cos\theta_U - \cos\theta_V \sin\theta_U} \begin{pmatrix} \cos\theta_V & -\cos\theta_U \\ \sin\theta_V & -\sin\theta_U \end{pmatrix} \begin{pmatrix} \vec{e_{U_\perp}} \\ \vec{e_{V_\perp}} \end{pmatrix}$$

- We have an excess of measurements with respect to what we want to reconstruct. Only using one value of Px and the values of Py, Pz are coming from the linear combination of Pu, Pv.

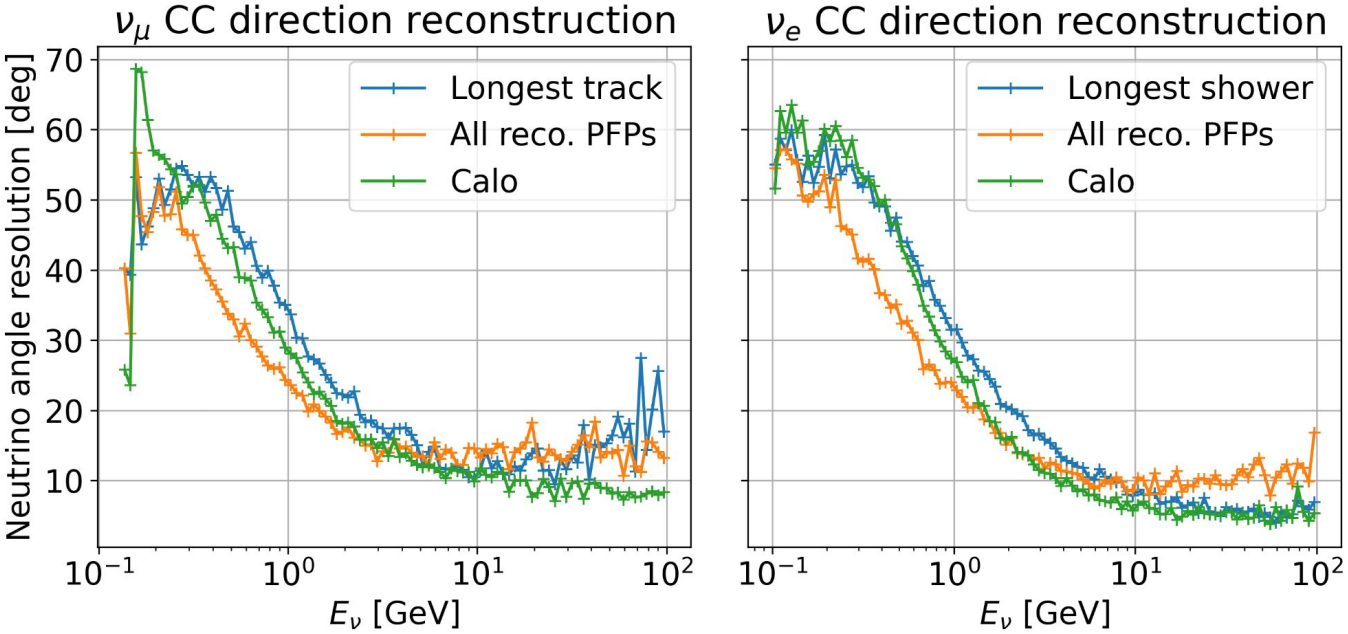
Reconstruction of direction along x



- The neutrino direction along x is similar for the 3 views up to 3GeV. Then only U and V show the best resolutions.
- Not sure why...
- Trying to combine 2 or 3 measurements by averaging them shows no improvement.

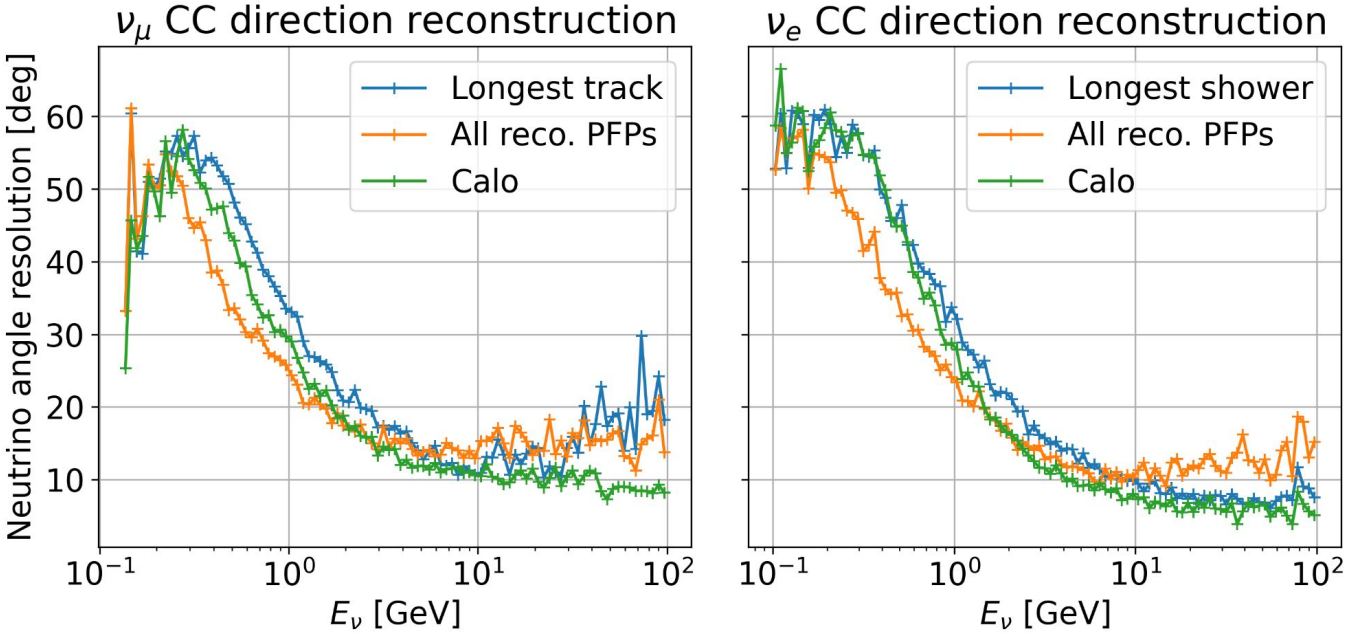
-> Using P_x from the U view.

Reconstruction of direction along x



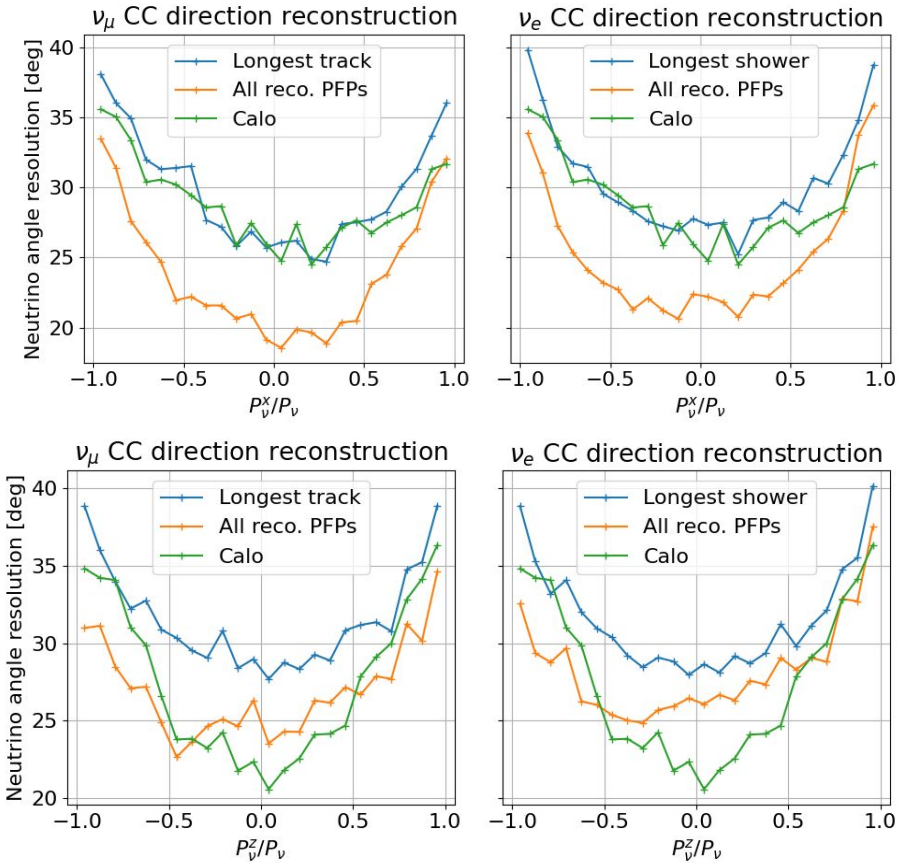
- Slight improvement at high-energy as hoped.
- Performs worse than the PFP method for all other energies

Reconstruction of direction along z



- Identical results along the z axis (using the combination of U+V views here, not W)

Angular dependence of the resolution



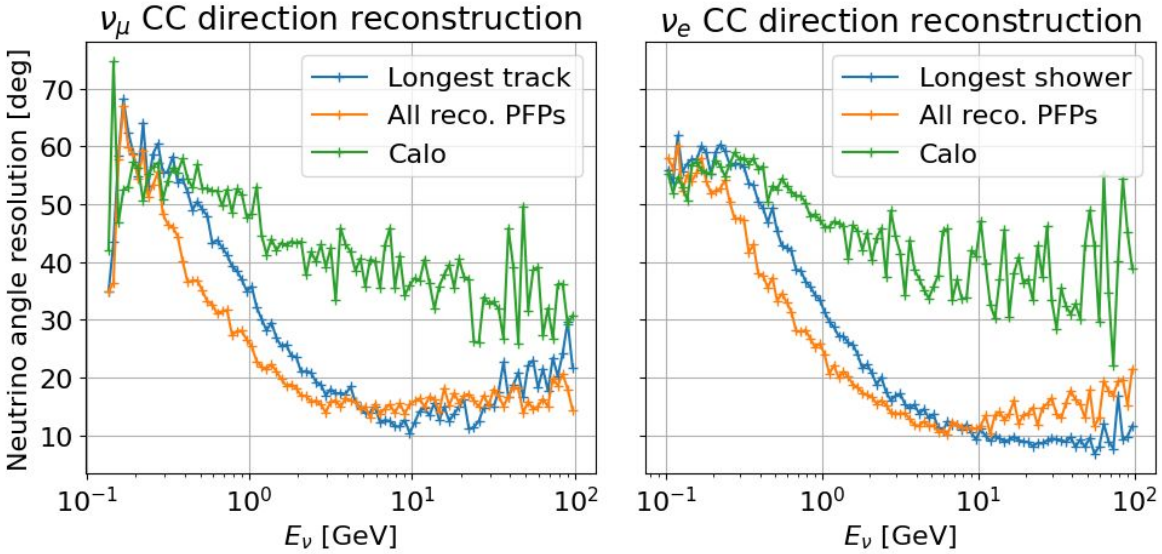
Along X:

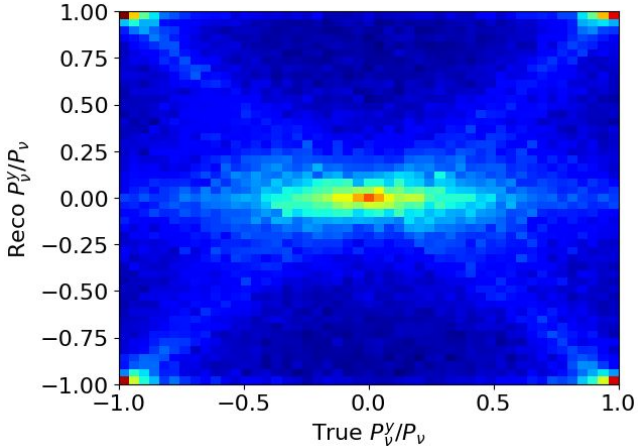
- Performs rather poorly for all neutrino angles

Along Z:

- Performs better at low angles => tracks orthogonal to the beam direction

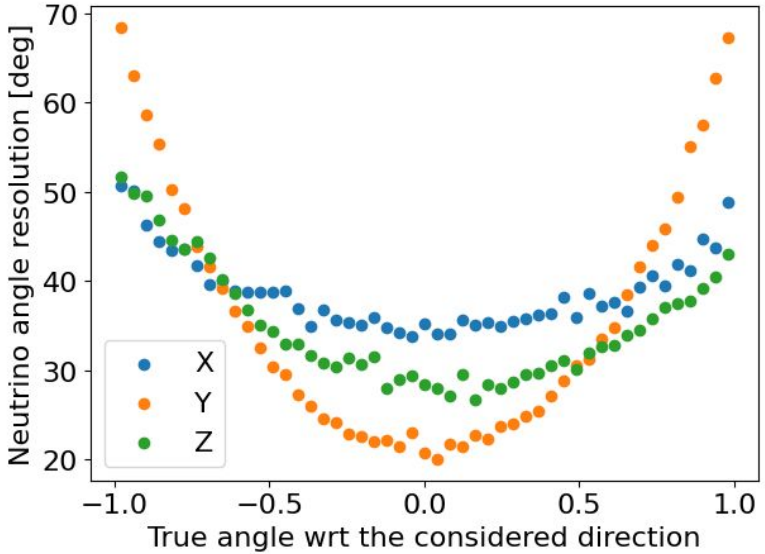
What about y?





- Performs awfully in the y direction
- Looks like there is some degeneracy that is not lifted properly
- Need to find out why as it is the most relevant axis for osc. studies...

What about y?



- Seems to perform correctly for the Y direction when most of the momentum is not along Y.
- Gets terrible for track along Y (up-going / down-going muons)

Summary

- The first basic implementation of a calorimetric direction estimate for atmospheric neutrinos seem encouraging to tackle the current HE inefficiencies of the reco along X and Z.
- However, there is currently some big issue in the use of such method for the Y direction (that actually matters the most for osc studies...).
- Need to understand where this comes from! All the methods using the reco particles yielded similar results for all directions.

Possible improvements:

- Find a method to combine all the available information.
- Directly use the 3D reconstructed spacepoints.
- Apply some filtering on the hits themselves (not checking anything for now)

If you have any comment/idea, I would be pleased to here them!