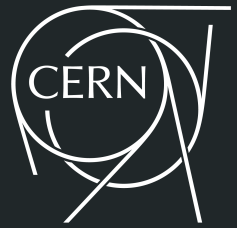
Atmospherics events in the VD geometry

P. Granger - CERN



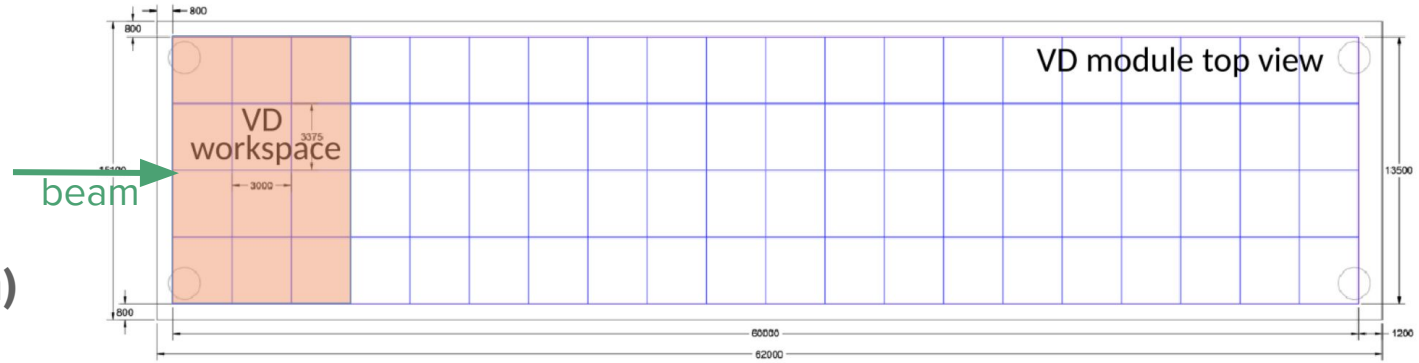
Generation

```
prodgenie_atmnu_max_weighted_randompolicy_dunevd10kt_1x8x6_3view_30deg.fcl
```

- Same config as for the latest atm. HD production
- Reweightable power spectrum flux
- All flavours generated according to their xsec ratios

<u>1x8x6 geometry</u>

- Full width (13m)
- 15% length (9m)
- **Half height (6.5m)**



Not ideal for up-going atmospherics

Reconstruction

```
standard_reco2_atmos_dunevd10kt_1x8x6_3view_30deg.fcl
```

- HD atmospherics Pandora config (including vertex CNN)
- VD beam flavour CVN
- Energy reconstruction
- Direction reconstruction (same algos as HD)

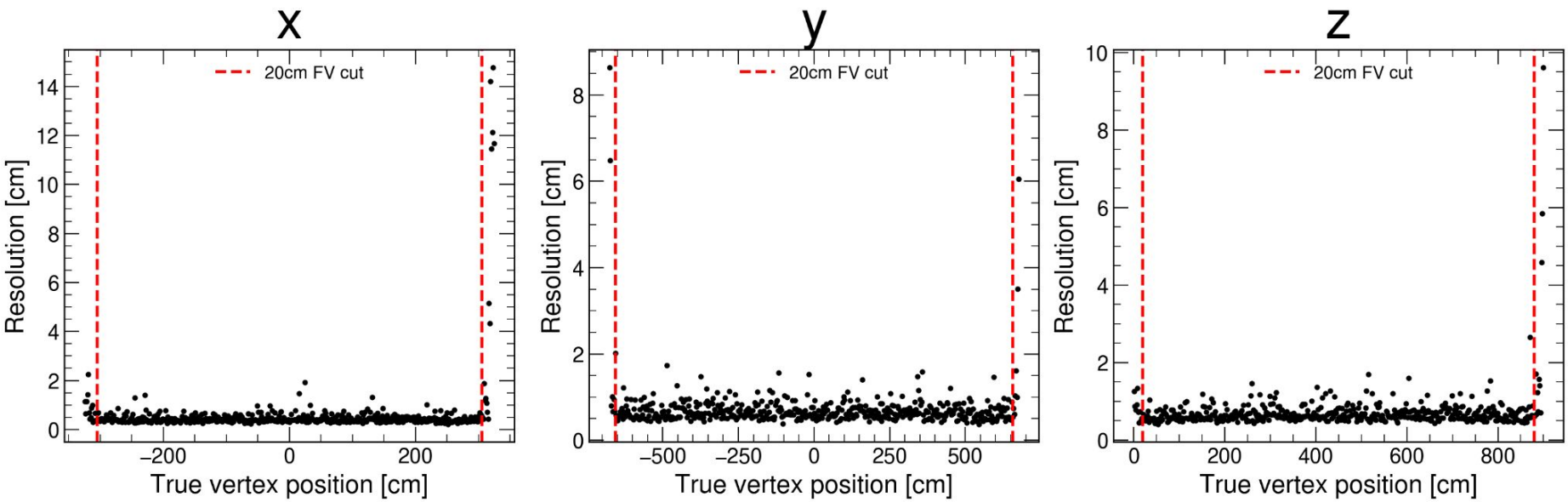
Available test sample (~250k events) at:

```
/pnfs/dune/persistent/users/pgranger/atm_VD_test/reco2/
```

Analysis file used for all later plots (from `atmoAnalysis` module):

```
/pnfs/dune/persistent/users/pgranger/atm_VD_test/reco2/ana_sum.root
```

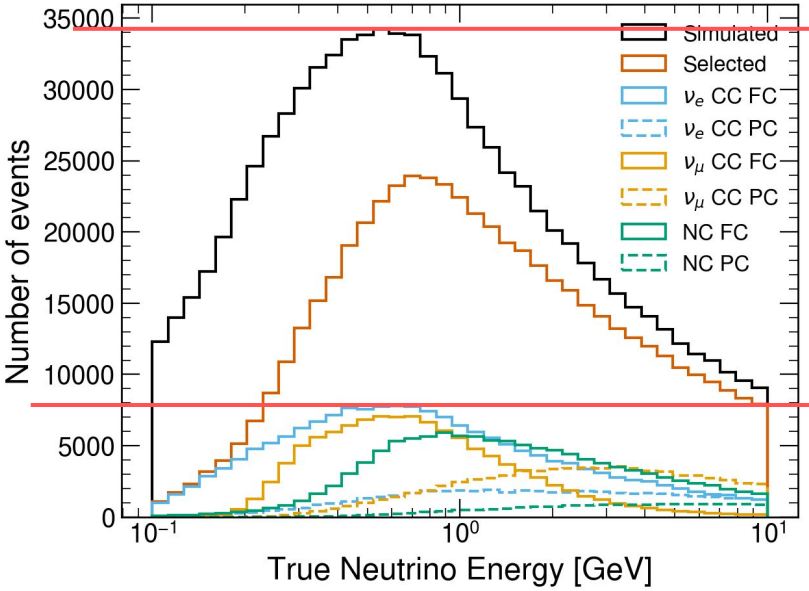
Containment



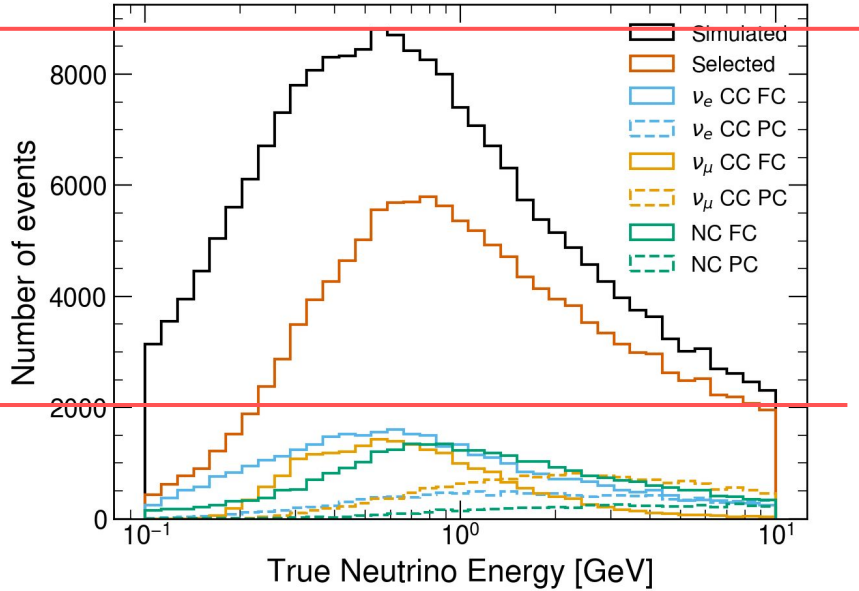
- 20cm fiducialization on all borders
- ⚠️ Up direction is x in VD

Containment

HD



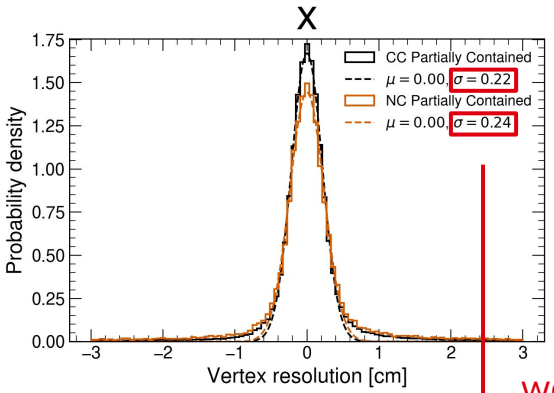
VD

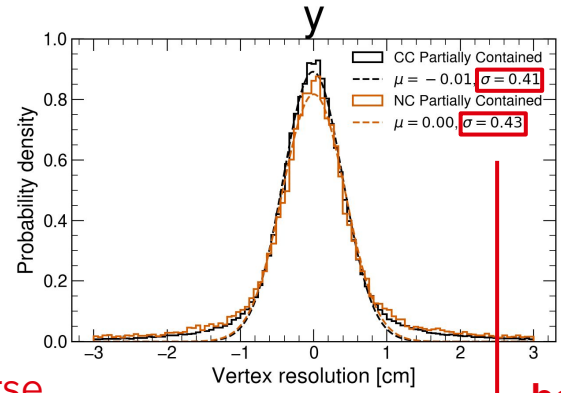


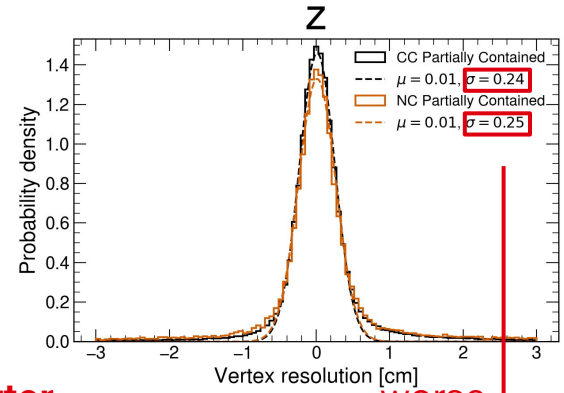
Lower containment in the simulated VD geometry (as expected) by smaller size

Vertex reconstruction

HD





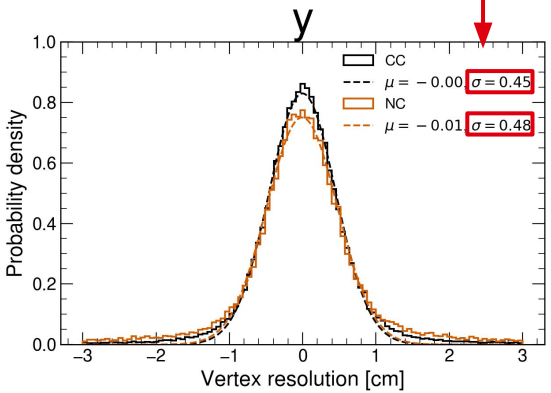


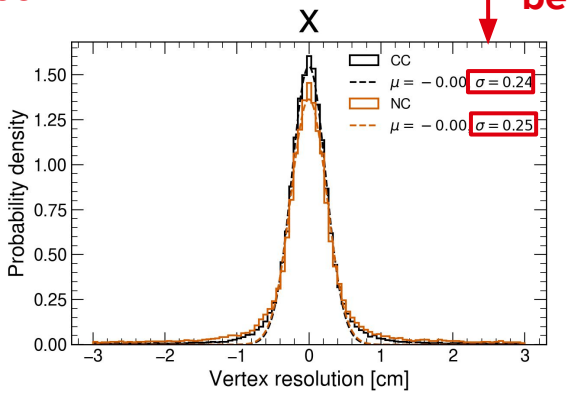
worse

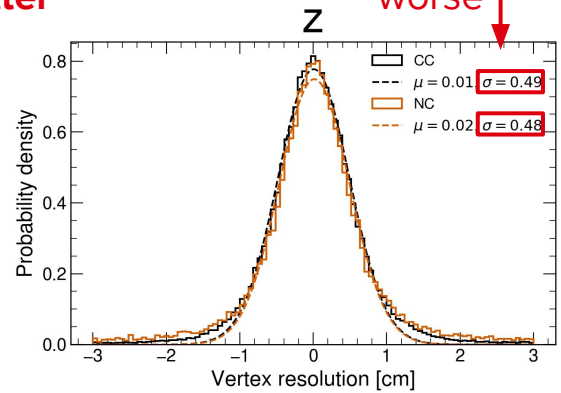
better

worse

VD

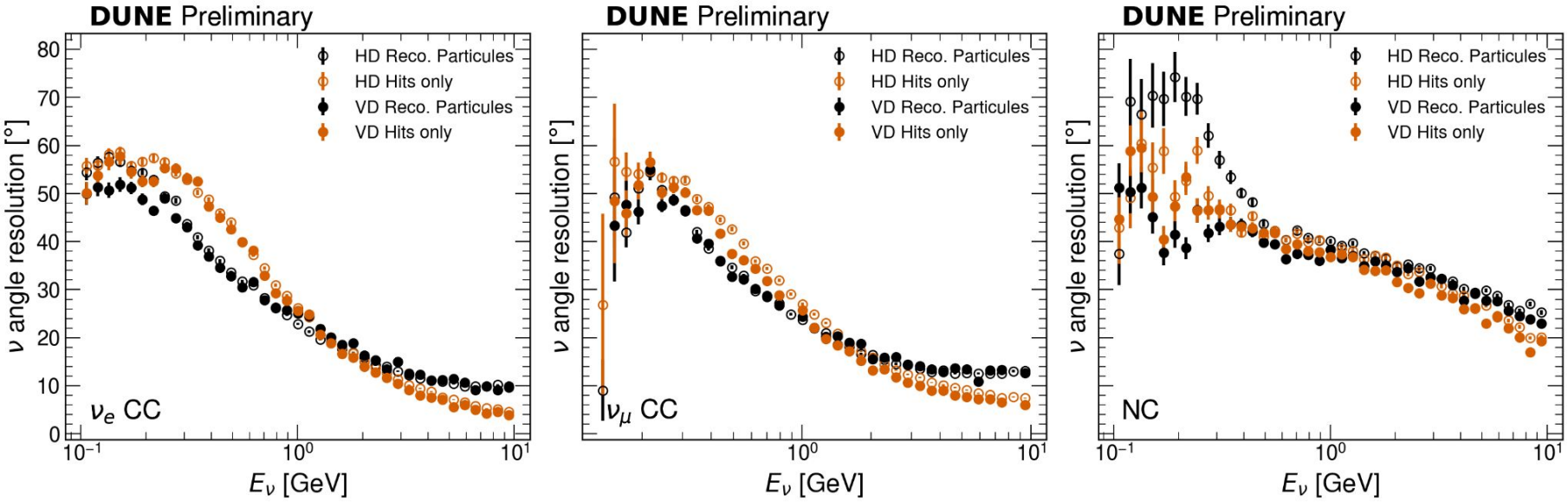






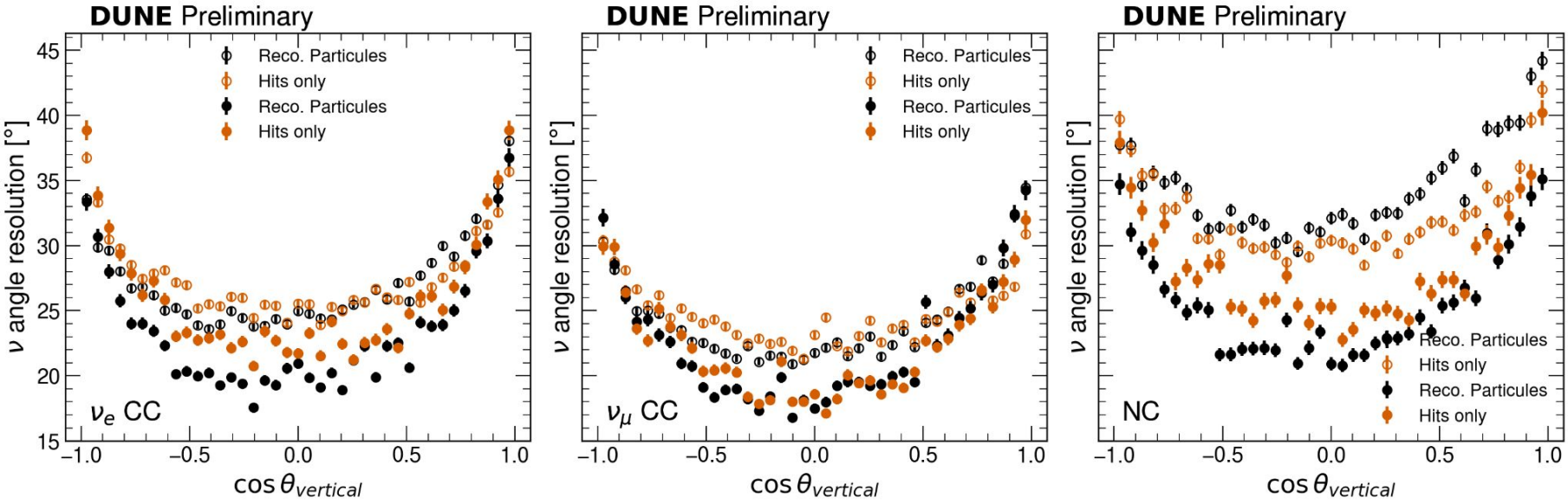
Very good perfs. (**HD** atm. CNN, no VD retraining) — **Improved resolution in vert. dir.**

Direction reconstruction



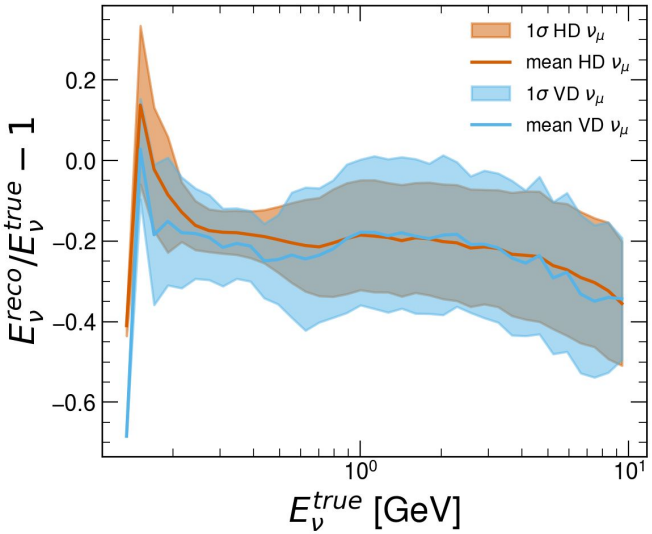
- Slightly better VD direction reconstruction performance (despite lower containment)
- Significant VD gain at low-E using reco. particles.
- VD gain at high-E using the calorimetric method

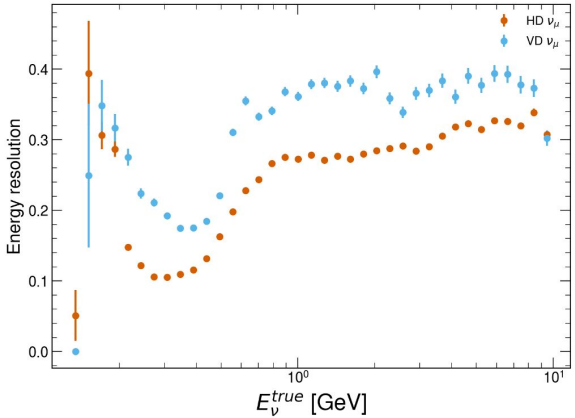
Direction reconstruction

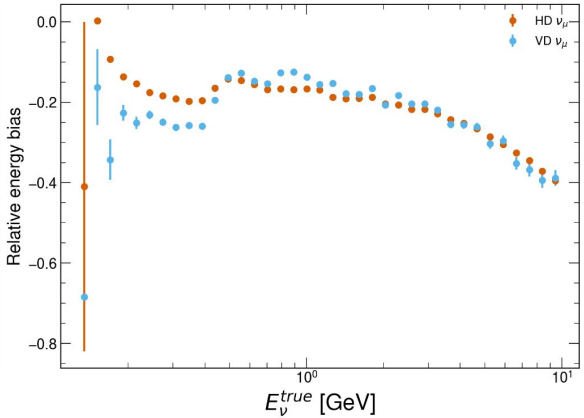


- Worse VD performance for vertically aligned tracks (along drift)
- Better performance for other tracks
- Higher dependency of the performance on the neutrino direction

Energy reconstruction (numu)

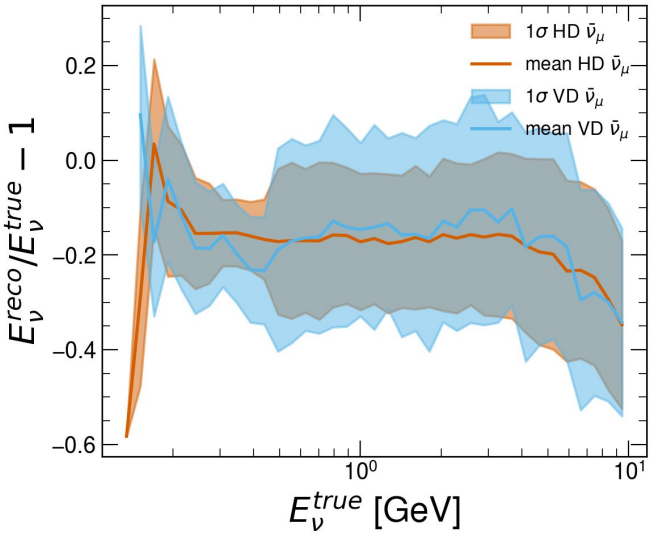


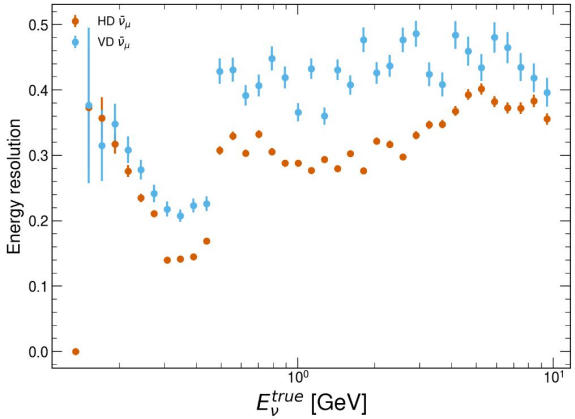


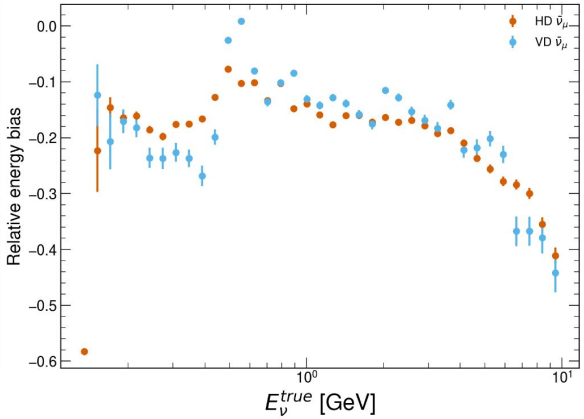


- Just using the reconstructed hadronic + leptonic sum => **no scaling correction**
- Currently better performance of HD => can be due to containment, no retuning of the MCS method (different pitch and resolution)

Energy reconstruction (numubar)







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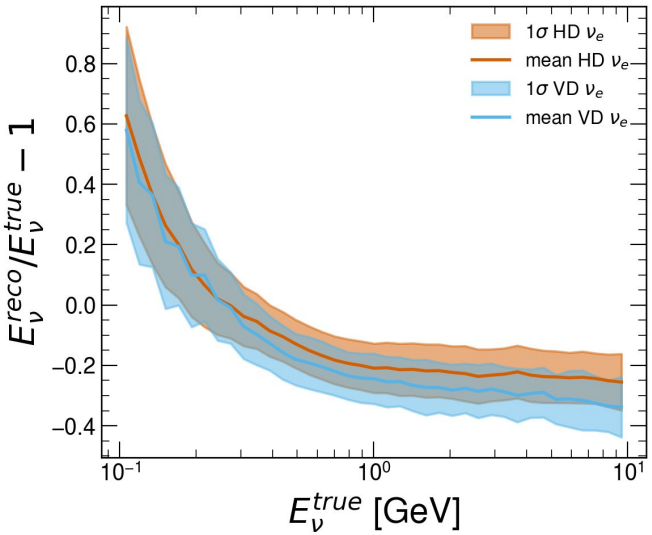
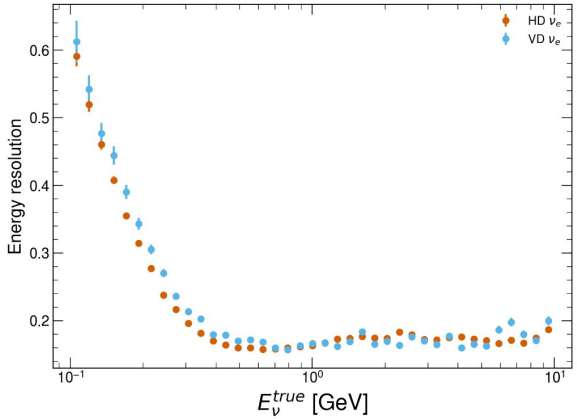
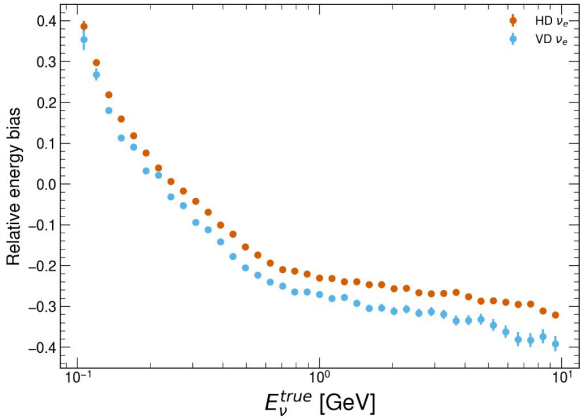
Energy reconstruction (nue)







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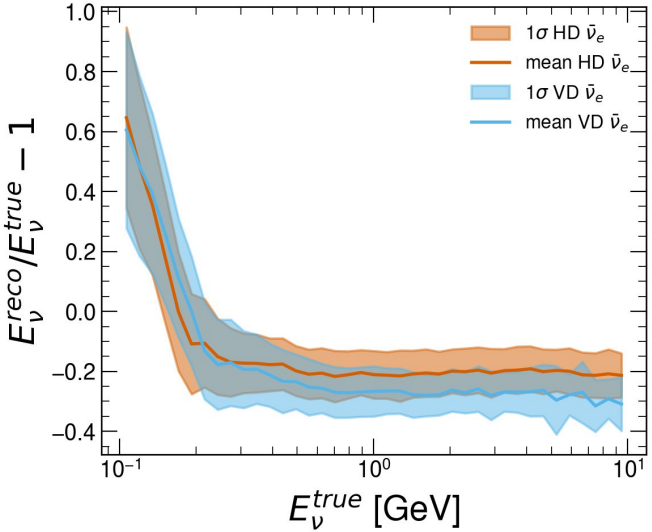
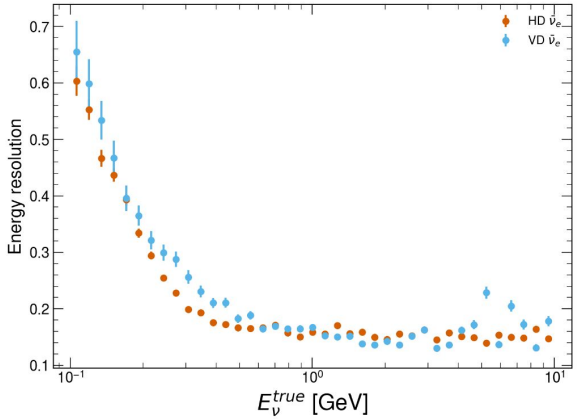
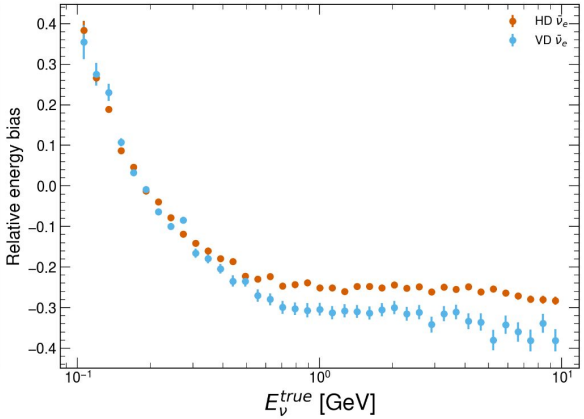
- More similar resolution but stronger bias => probably different scalings required for HD and VD

Energy reconstruction (nuebar)







- Just using the reconstructed hadronic + leptonic sum => **no scaling correction**
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Conclusion

Just a quick presentation to say that:

- Atmospherics events can be simulated and reconstructed in VD 1x8x6 geometry with relevant fcls in dunesw
- **Without requiring any further work**:
  - Good performance of HD vertexing CNN on VD sample. Better vertex resolution in vertical direction => good for atmospherics
  - Better vertical direction resolution performance in VD thanks to the different orientation
- **Several things to investigate**:
  - Degraded energy resolution => Possibly due to lower containment, no adjustment of reco methods (MCS), ...
  - Flavour CVN => Can the HD atm. one be used directly?

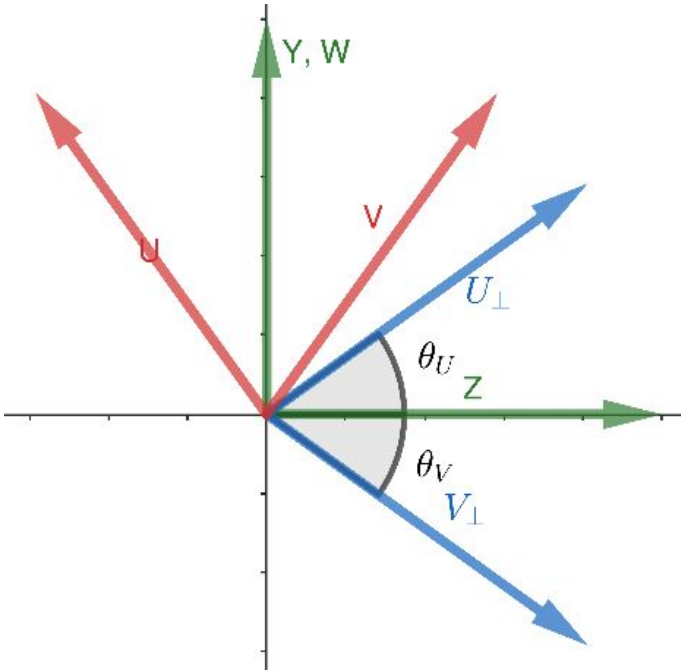
Relevant topic as VD will be the first installed detector => many things to look at for whoever is interested

Backup

Using the recob::Hit objects

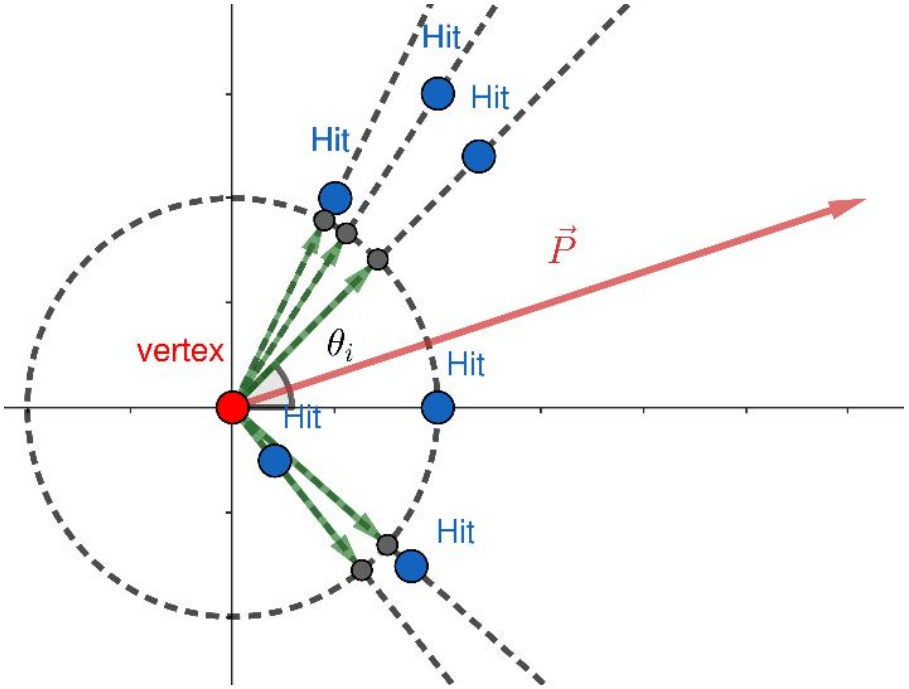
- All the recob::Hit objects are sorted in the 3 views (U, V, W) and put back in the view coordinate system
  (with V- = U+ and U- = V+)

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



- 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

Method:

- 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 $\vec{P}_{\text{view}} = P_{\text{view}} e^{i\theta_{\text{view}}}$ for each view.
- We only use the θ_{view} information, which should be the only relevant for the direction (and allows to not care about views calibration)

- We have an excess of measurements with respect to what we want to reconstruct. We make a fit in spherical coordinates to use all of them:

$$\chi^2 = \sum_{\text{view}} \left(\theta^{obs}_{\text{view}} - \theta^{fit}_{\text{view}} \right)$$

$$\vec{P}_{\text{fit}} = \begin{pmatrix} \sin\theta\cos\phi \\ \sin\theta\sin\phi \\ \cos\theta \end{pmatrix}$$

e.g. $\theta^{\text{fit}}_{W} = \arctan 2(\cos\theta, \sin\theta\cos\phi)$

Calorimetric direction reconstruction: demo