SPINE: first look at the reconstruction of atmospheric neutrinos

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DEEP UNDERGROUND NEUTRINO EXPERIMENT

CERN

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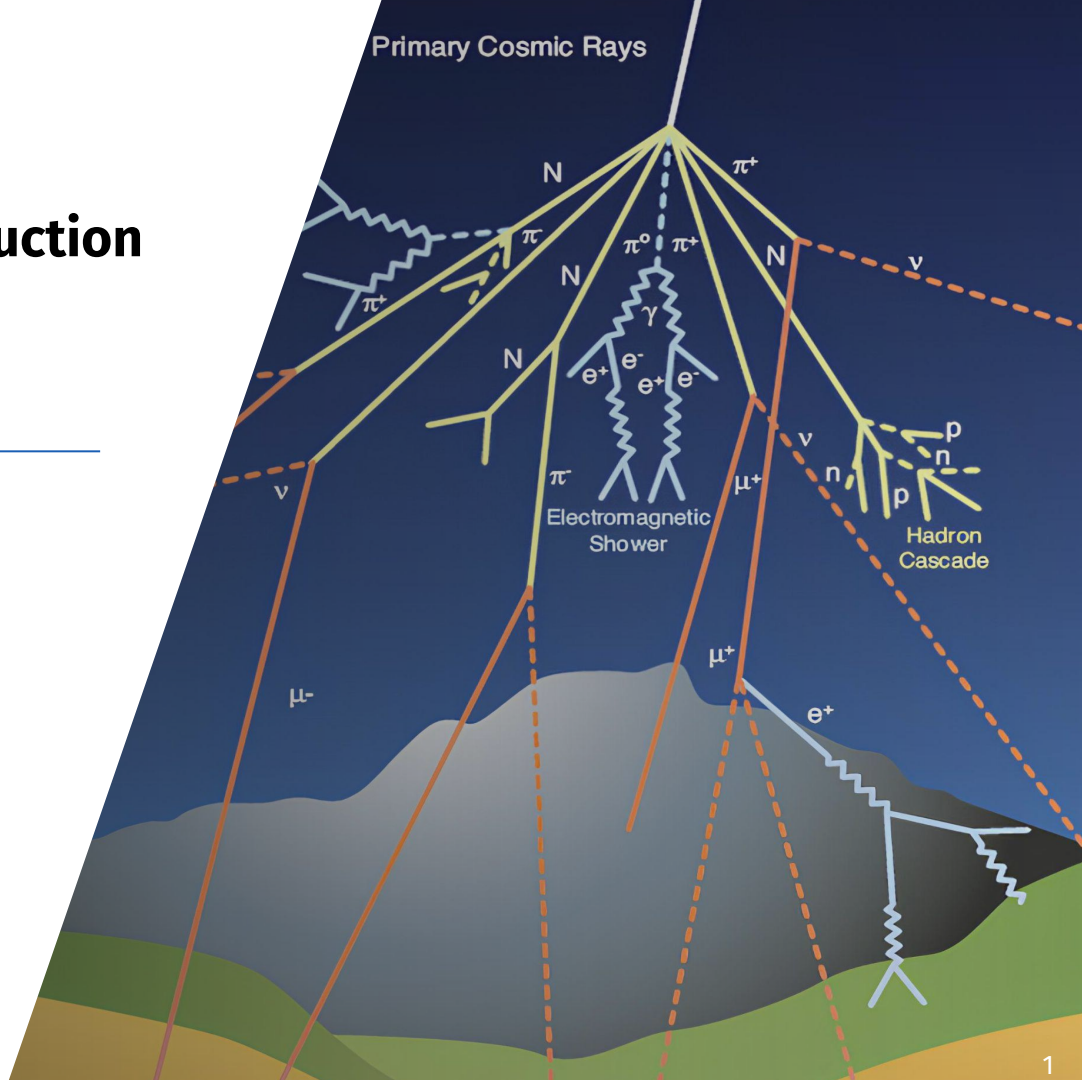
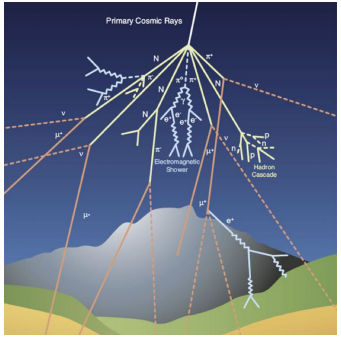
DUNE SPINE meeting

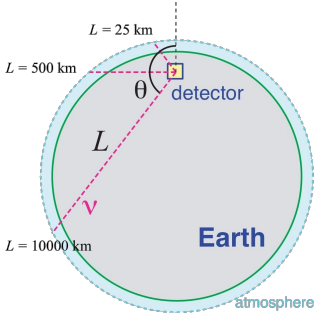


Atmospheric neutrinos

An extra ν source **complementary to beam**:

- Wide energy range: 0.1 GeV to > 100 GeV
- Wide baseline range: few km to ~ 12 800 km
- Multiple flavours: ν_e , ν_μ , $\bar{\nu}_e$, $\bar{\nu}_\mu$



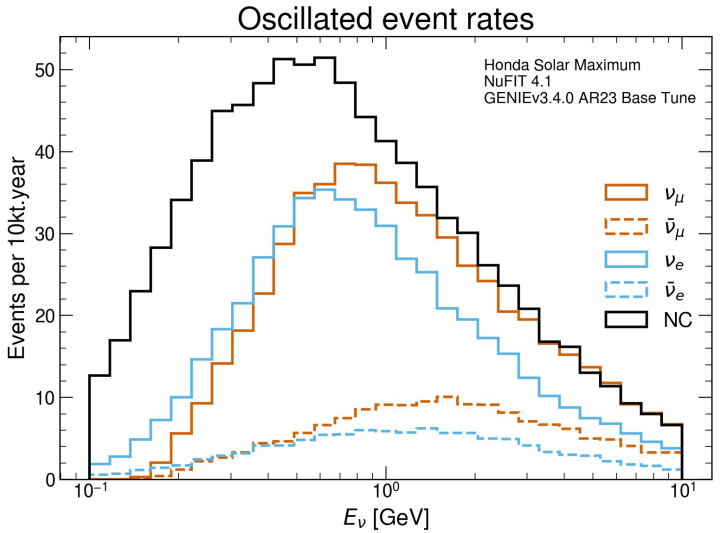


Allow to probe:

- **3 flavour oscillations**
- **matter effects**
- **same L/E with different L**

Challenges:

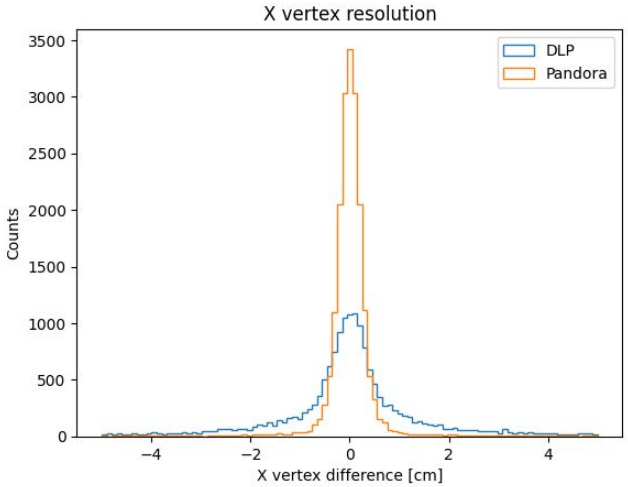
- **Wide range of energies** → multiple processes, reconstruction methods
- Harder to **constrain systematics** (e.g. flux)
- Requires ν **direction reconstruction**

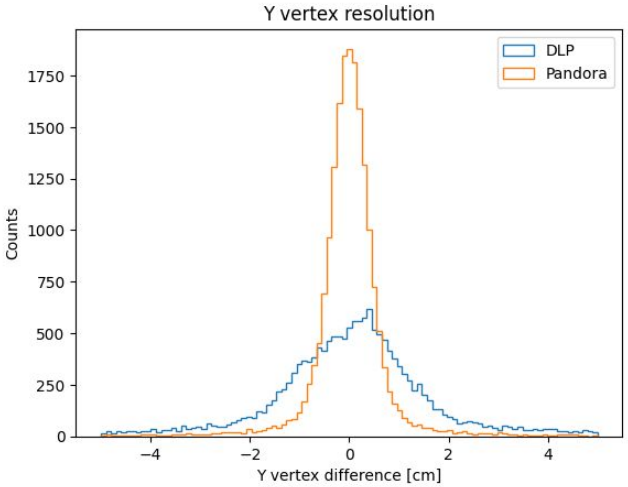


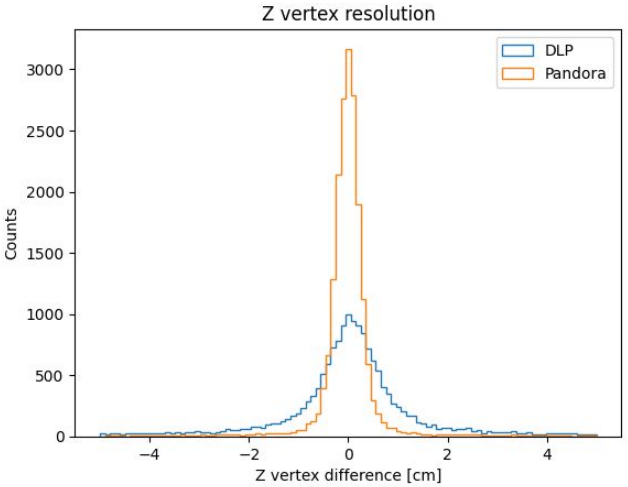
Methodology

- Using the **latest atmospherics sample** (for which a reco performance paper in under publication)
- Used flux is:
  - **Unoscillated** (Flavour ratios derived solely from xsec)
  - **Isotropic**
  - Decaying with a **power-spectrum in energy**
- Geometry: **FD-HD 1x2x6 v5** (only changes in v6 are: splitting of AV definition, small change in CPA thickness and material)
- Running inference with **workshop-era weights** (not using the most recent updates/improvements)
- Running the **full ART -> LARCV -> SPINE/H5 -> CAF pipeline**
- Merging final **reco infos into pre-existing CAFs** (https://github.com/DUNE/dune_ml_cafmaker)

Vertexing performance



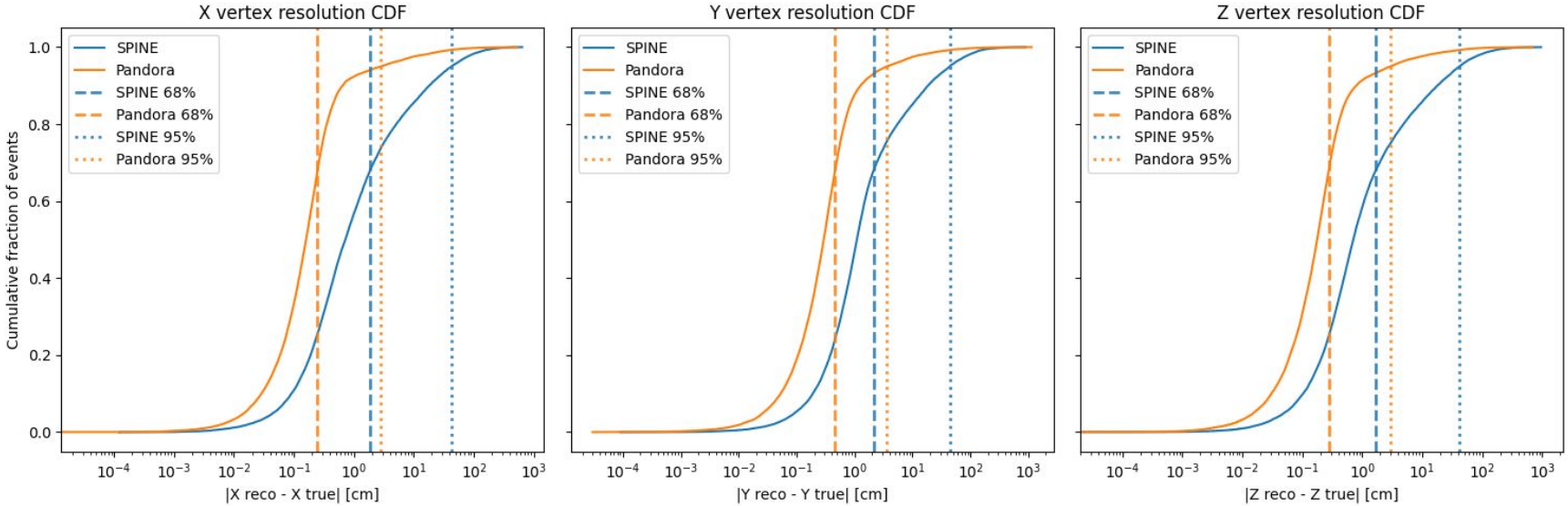




Looking at the **vertex resolution and comparing to pandora** (using some dedicated CNN):

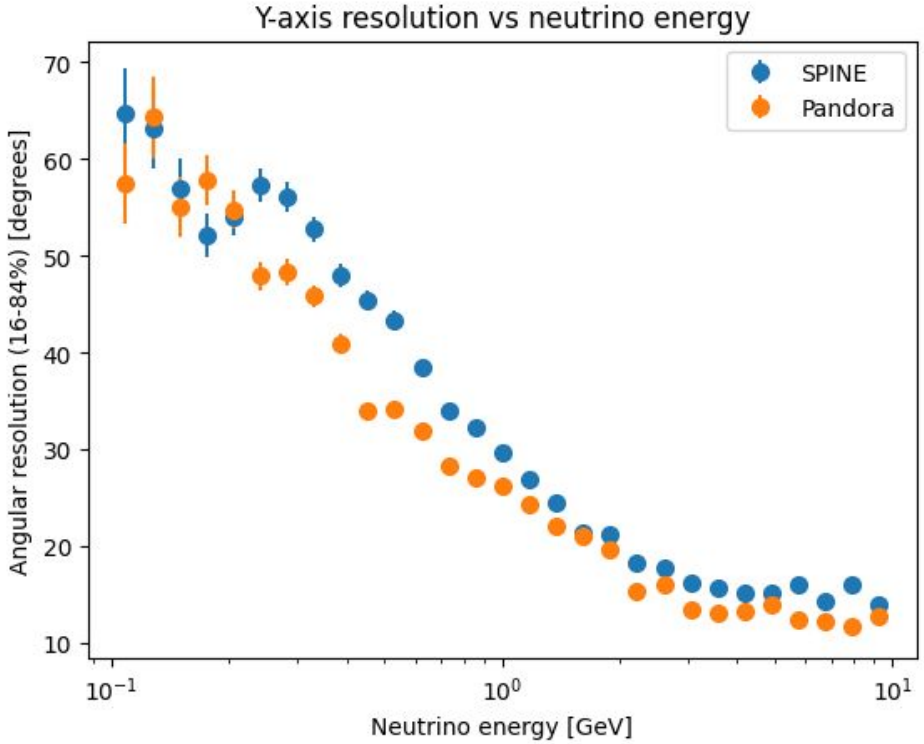
- Whenever multiple interactions are reconstructed by SPINE: taking the closest reco. vertex to the true one (**optimistic treatment**)
- **Overall lower performance** for now
- Specific **asymmetric feature in the Y direction**

Vertexing performance



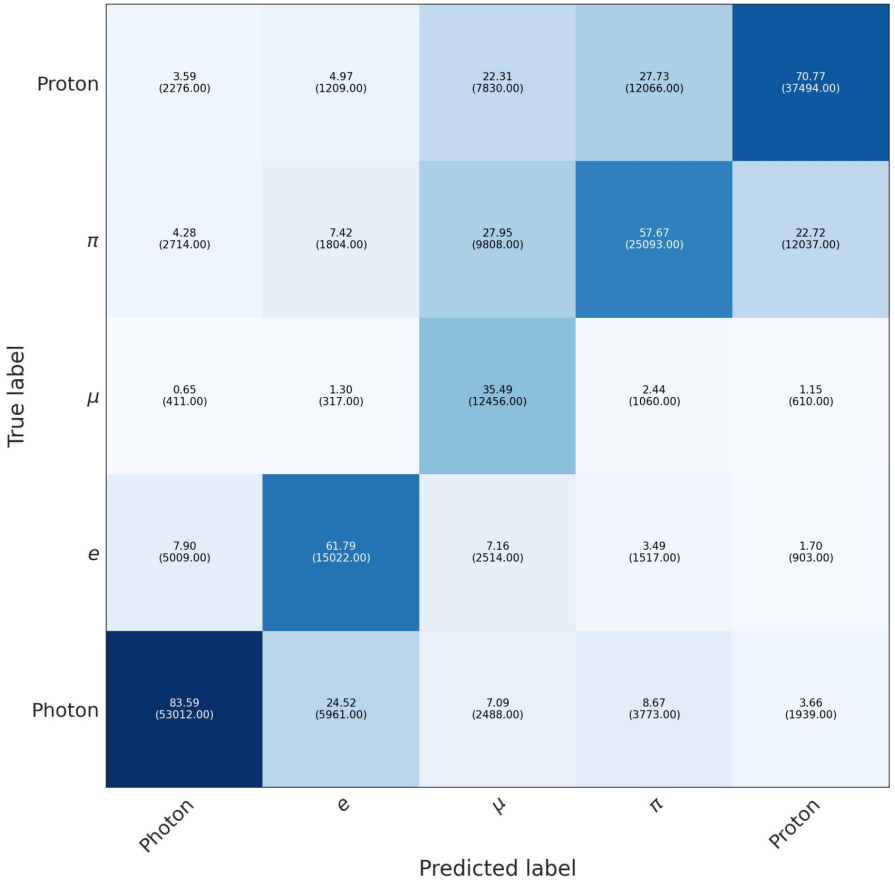
- **68% resolution ~ 2cm** (vs ~ 4mm)
- **95% resolution ~ 40cm** (vs ~ 2cm)
- I didn't look at all at the various failure modes yet (e.g. flipped vertex, secondary vertex, ...)

Neutrino direction reconstruction performance



- Only showing reco. direction along the **Y axis** but X and Z are similar (backup)
- Direction is reconstructed by **summing the momenta of the reconstructed particles** (in theory same method for Pandora and SPINE but would need to check the exact details)
- For now, **worse direction resolution across the whole energy range**
- Seems to witness the same **plateau effect at high-E due to overclustering in Pandora**

PID performance



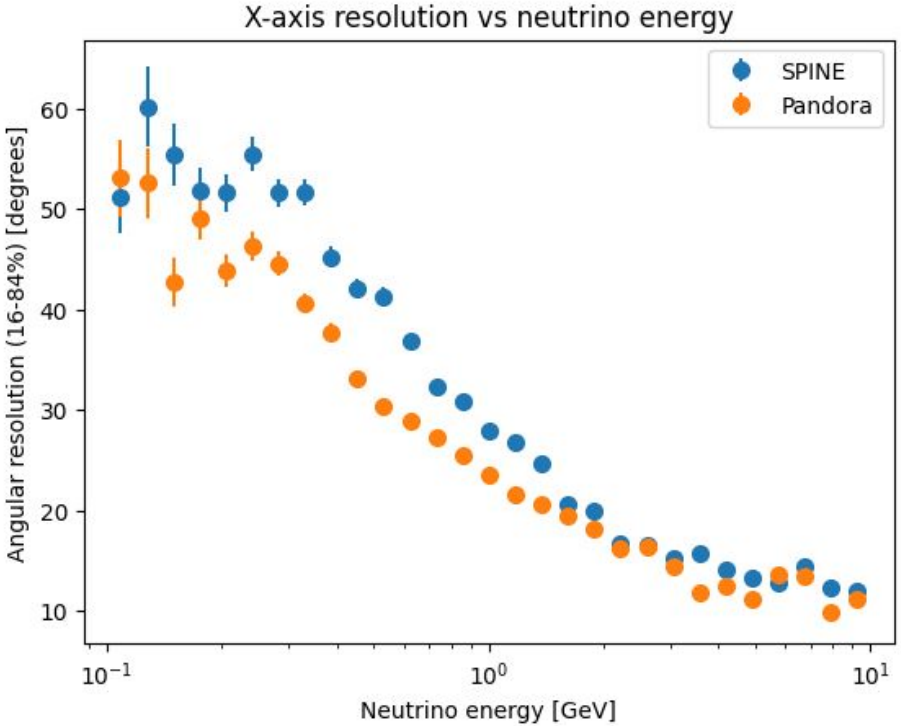
- Precision matrix (**normalized by prediction**) for **primary particles** only
- **e- / γ** seem sensible
- **μ** makes little sense. **Huge confusion** with **pions** (why not) and **protons**!
- Producing the same matrix with the workshop sample (~ 1k events) yields similar results
- Recall matrix in backup

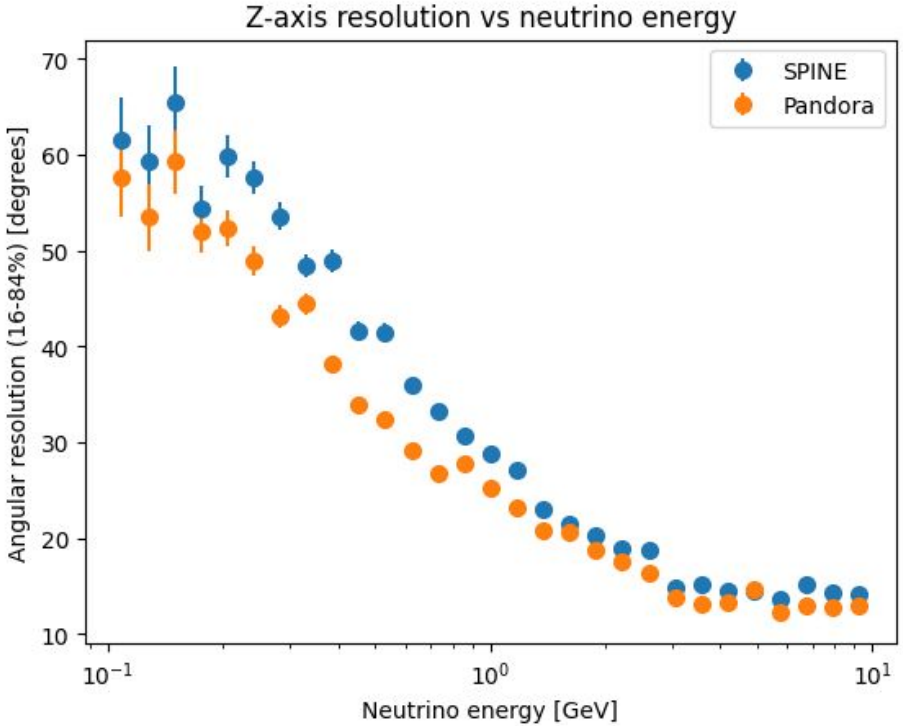
Summary

- Starting to take a **quick look at the performance of SPINE on atmospherics**
- Was a way to **exercise the whole pipeline and machinery** (checking everything could run smoothly, develop the CAF merging, …)
- Performance seem **for now not as good as Pandora**
- Mostly looked at high-level observables. Would now **need to look more in details at what the typical failures/issues are**.
- Possible limitations due to this sample? **Minor mismatch of training/inference geometry. Possible #particles/PID/energy lack of coverage in training?**
- Would be interesting to **compare to beam FD-HD results**

BACKUP

Neutrino direction reconstruction performance





PID recall matrix