Vertical drift solution with PCB Anode Readout for DUNE modules: considerations on 2-views vs. 3 views options

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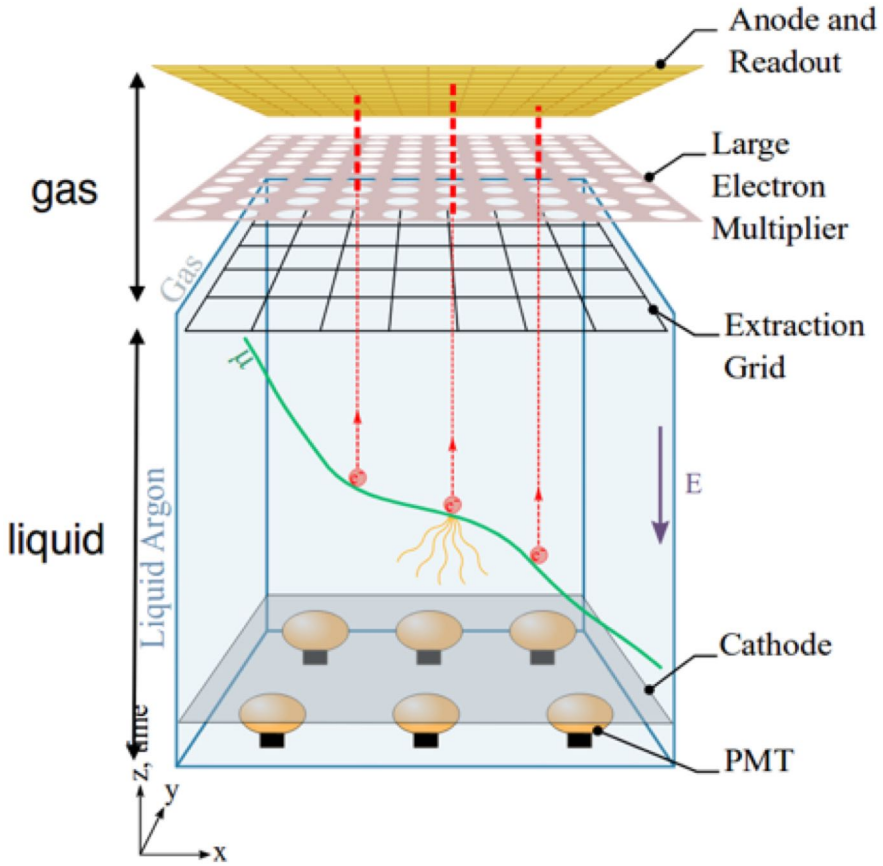
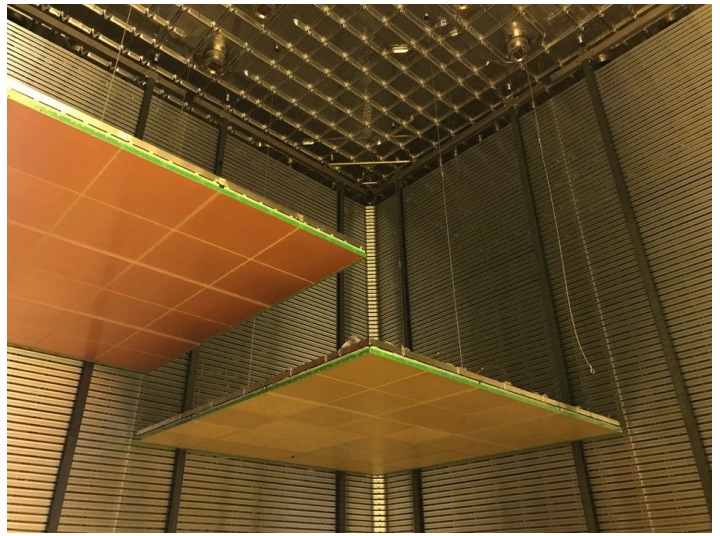
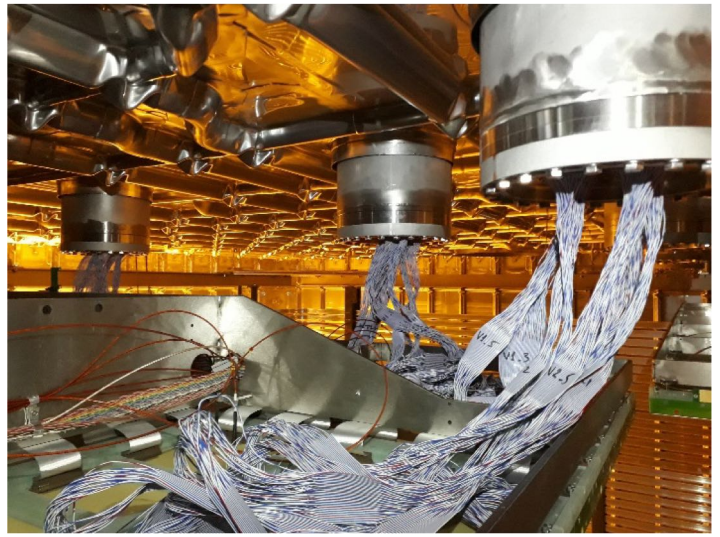
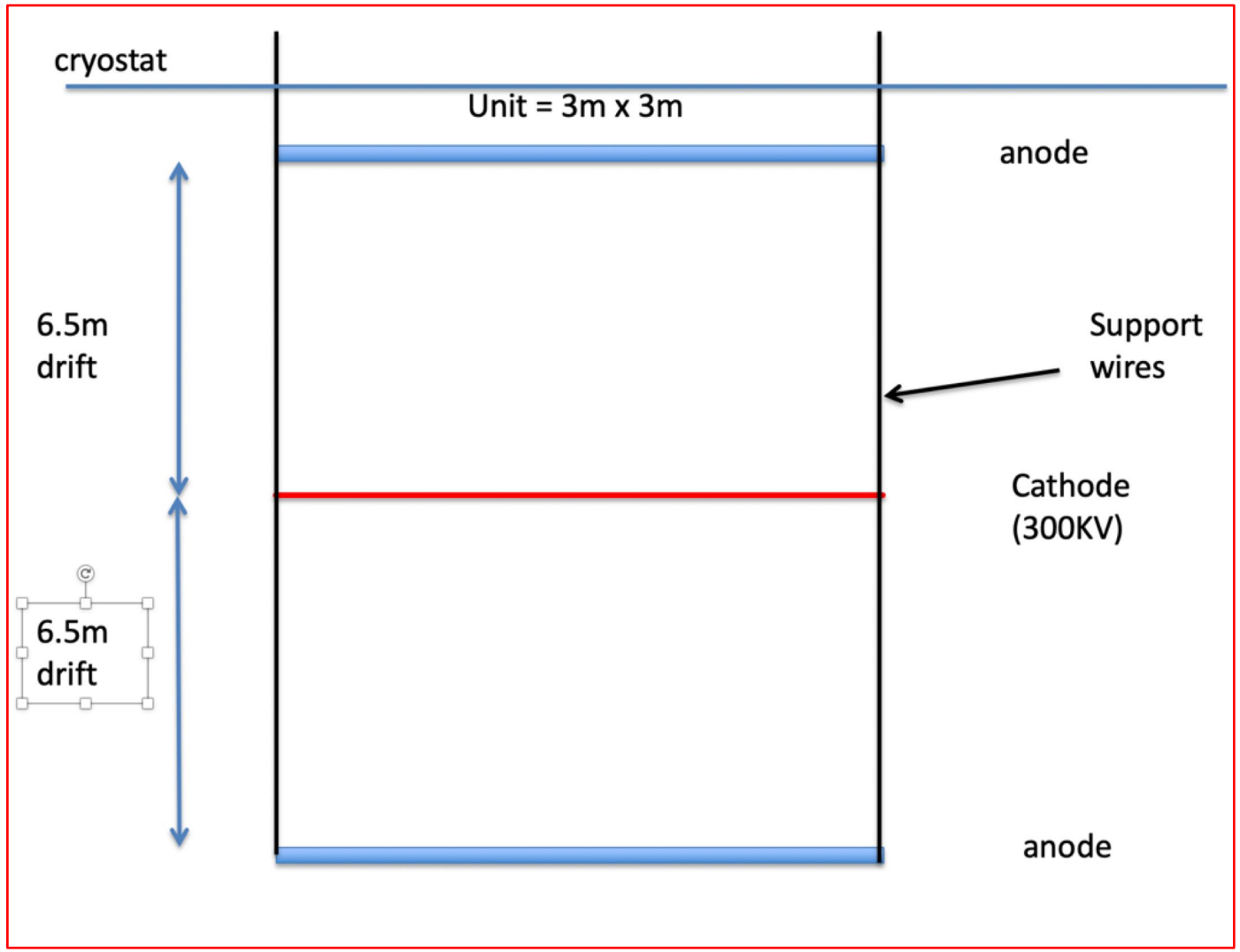


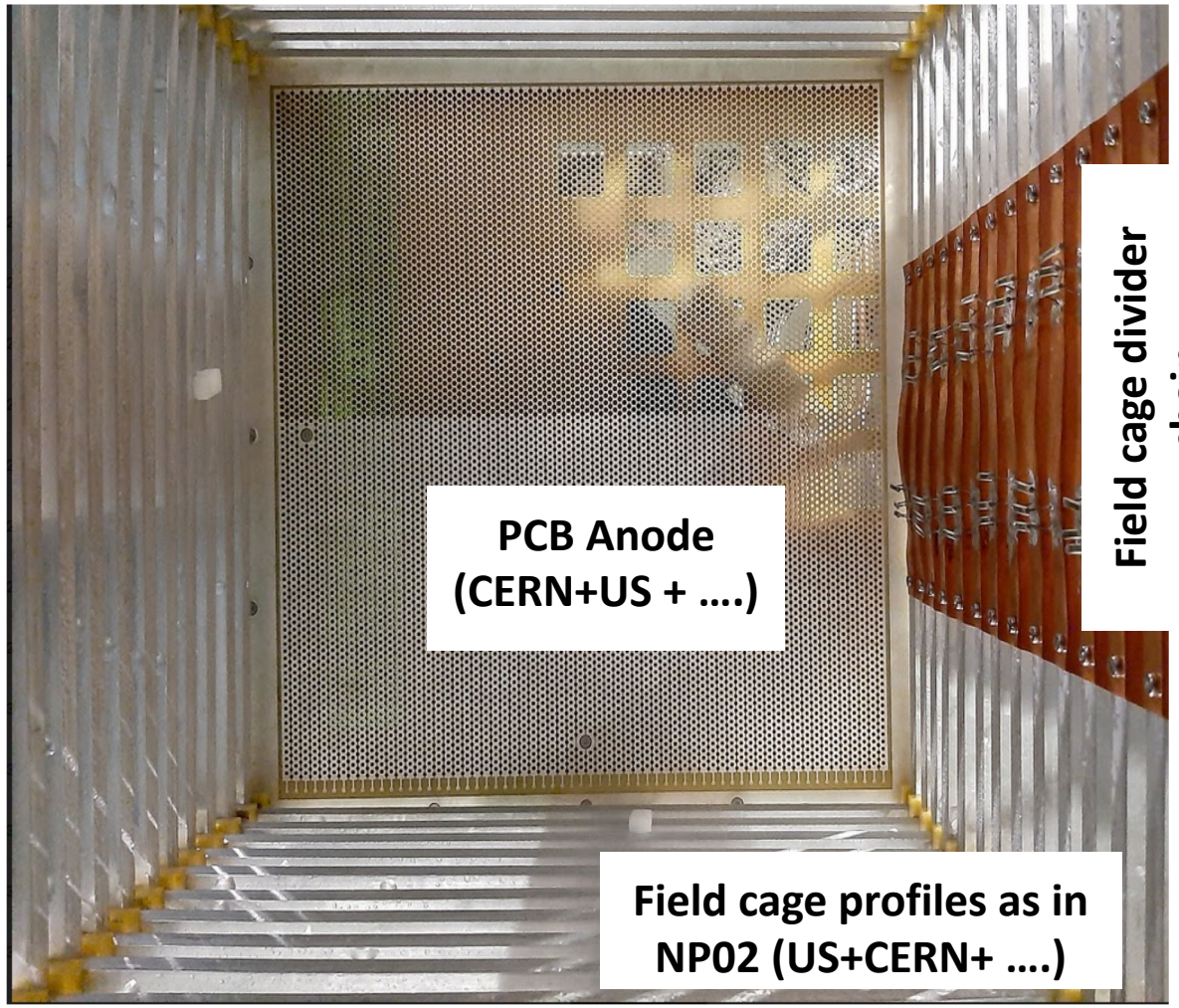




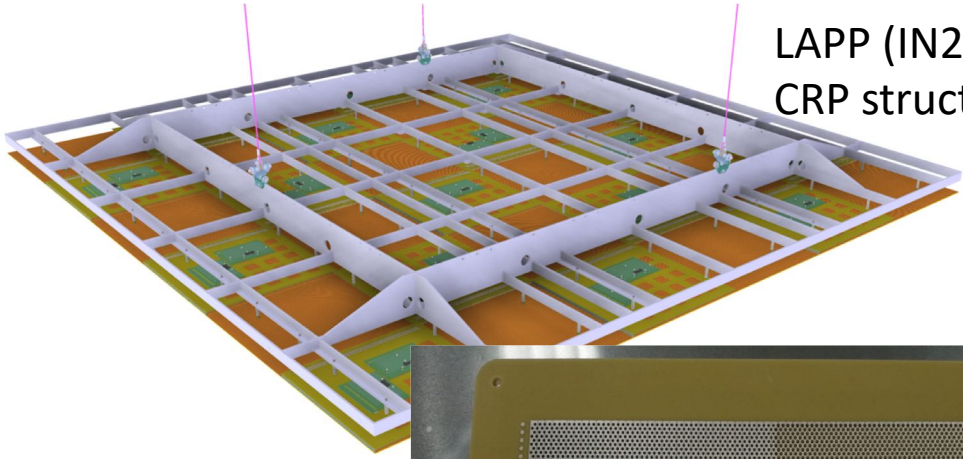
liquid instability ay liquid-vapour interface, close to LEM
Long drift-path, 12 m and 600 kV in DUNE
f.e. electronics in chimneys, short cables

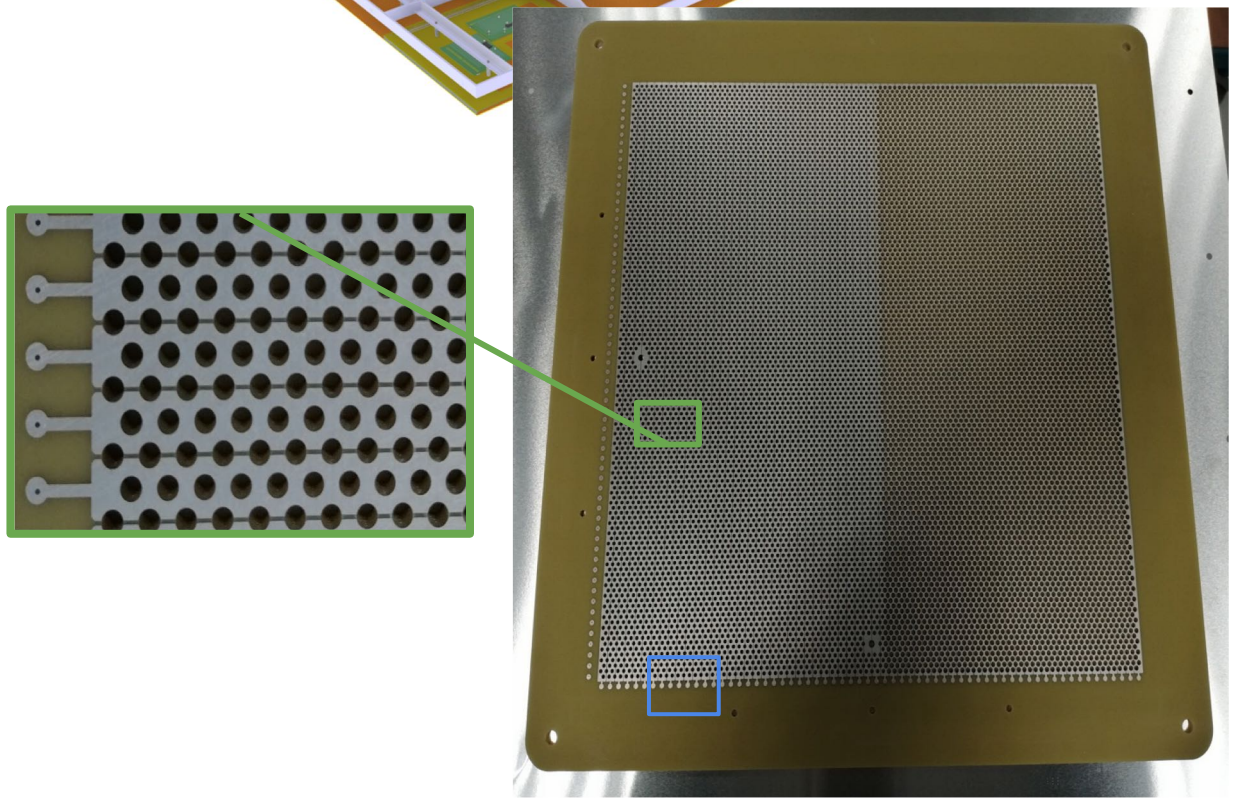

cryostat
Unit = 3m x 3m
anode
6.5m
drift
Support
wires
Cathode
(300KV)
6.5m
drift
anode

ANODE baseline (2 views as in D-P, 3 views possibly)

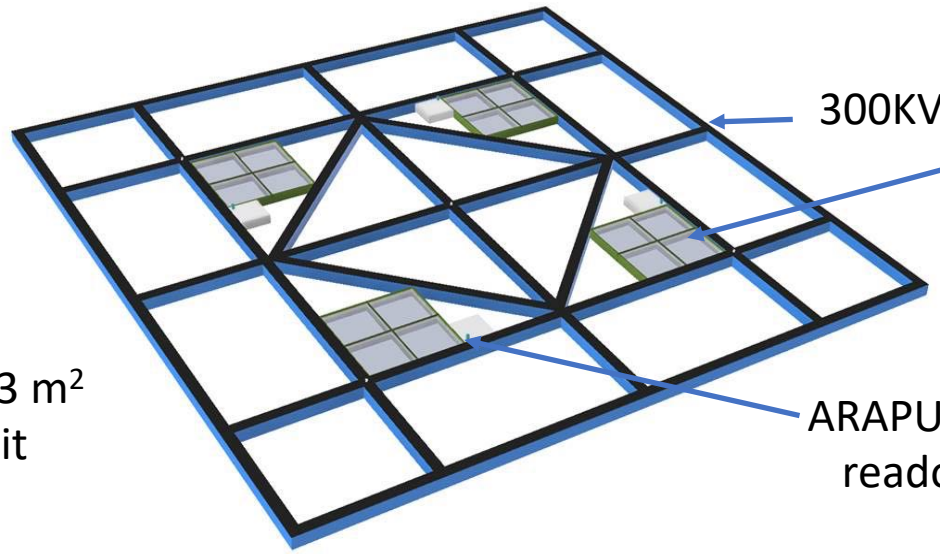


LAPP (IN2P3)
CRP structure

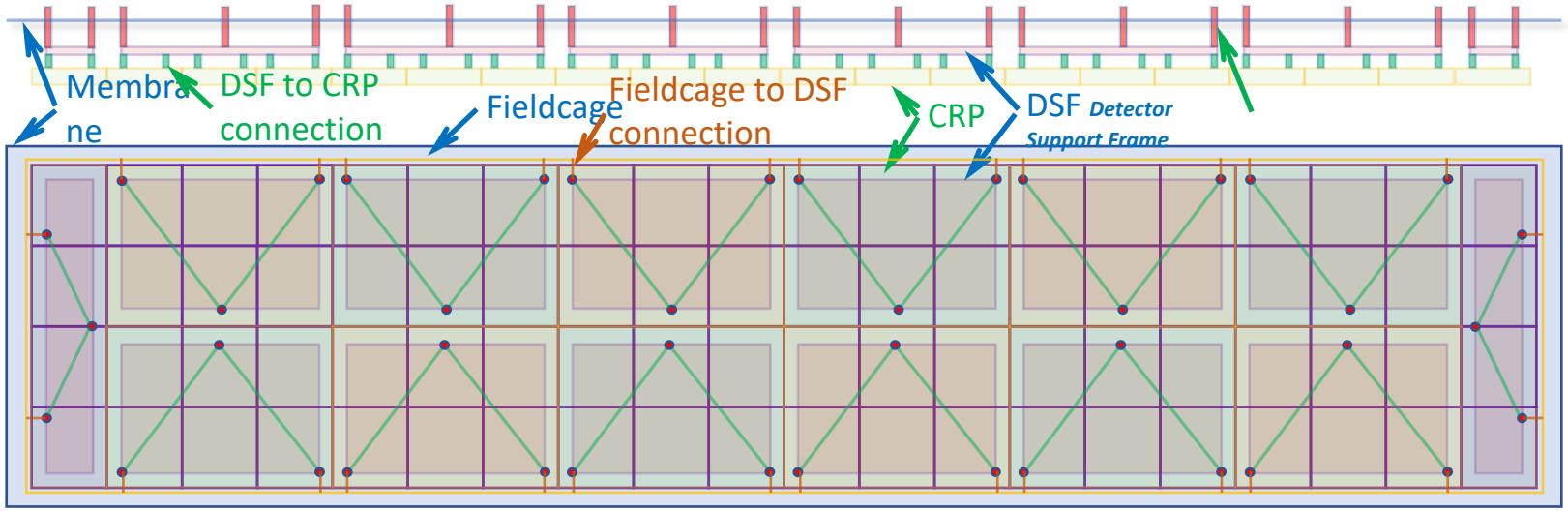




Anode: pcb based (no gain) as tested at CERN



Cathode “transparent”, with light detectors looking on both sides

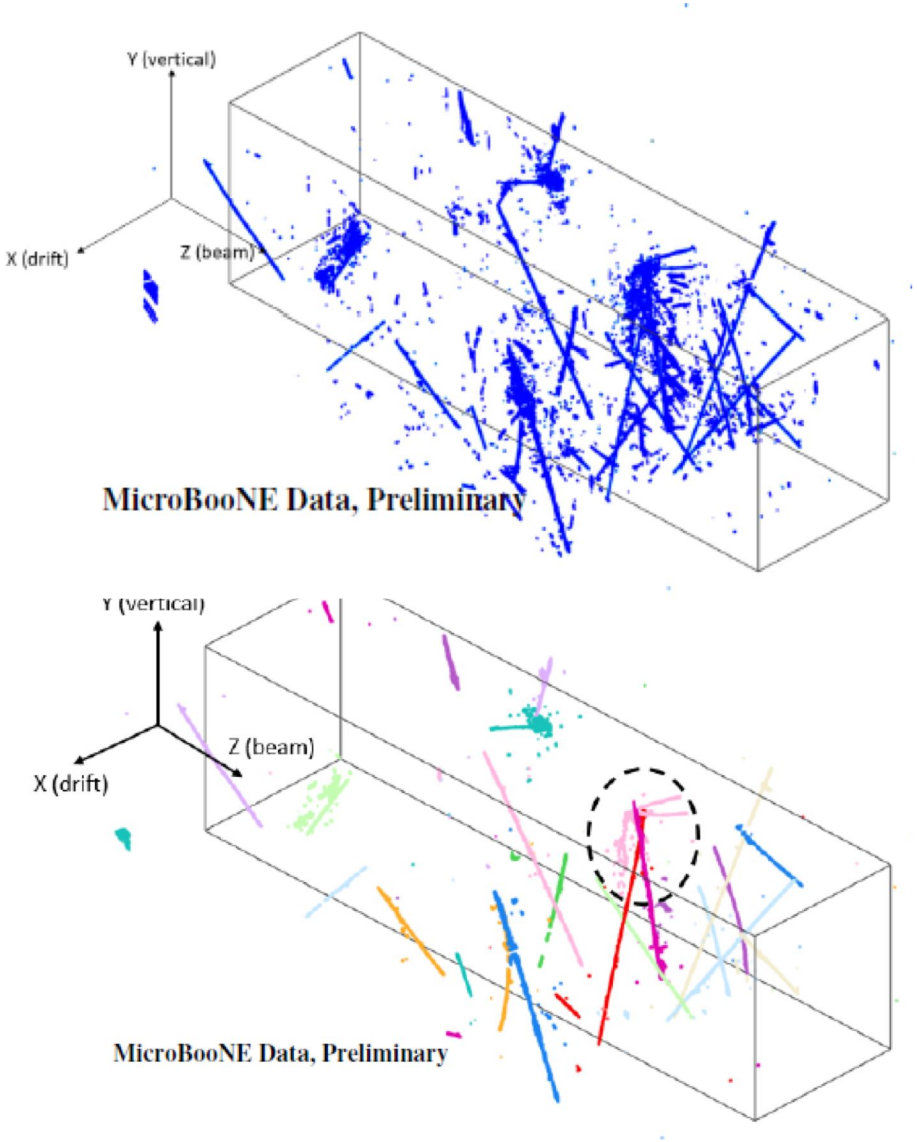


Example of possible layout in DUNE:
80 modules,
14 mechanical units

2-views or 3-views read-out

- ProtoDUNE-DualPhase was built with two views (strips along z and x)
- ArgoNeutT had 2 views
- MicroBooNE has 3 views (nearly)
- ProtoDUNE-SinglePhase, DUNE Module-1 with 3 views (y, and +-35 deg from y)
  - The PC–board anode has been tested with with 2 views.
  - Extension to 3 possible, more complex and expensive of course.
  - 3-view prototypes with LEM (D-P) were not satisfactory.

- “Traditional” event reconstruction is based on 3D matching, 3D reconstruction (Pandora, and also WireCell, PMA, TrajCluster).
- People familiar with these methods seem to believe that 3 views performs better
  - Of course 3-views should not perform less well than 2-views, and 2-views in general provides 3D
  - The point is to identify the eventual loss of performance, quantify it and compare to the gain in detector cost and complexity.
  - The loss of performance may be different among the different physics goals fo DUNE



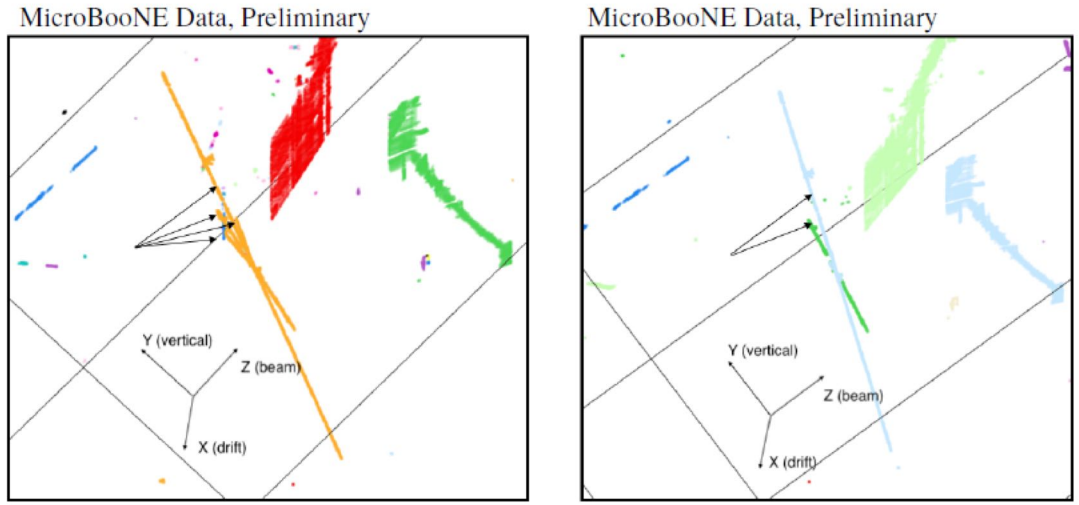
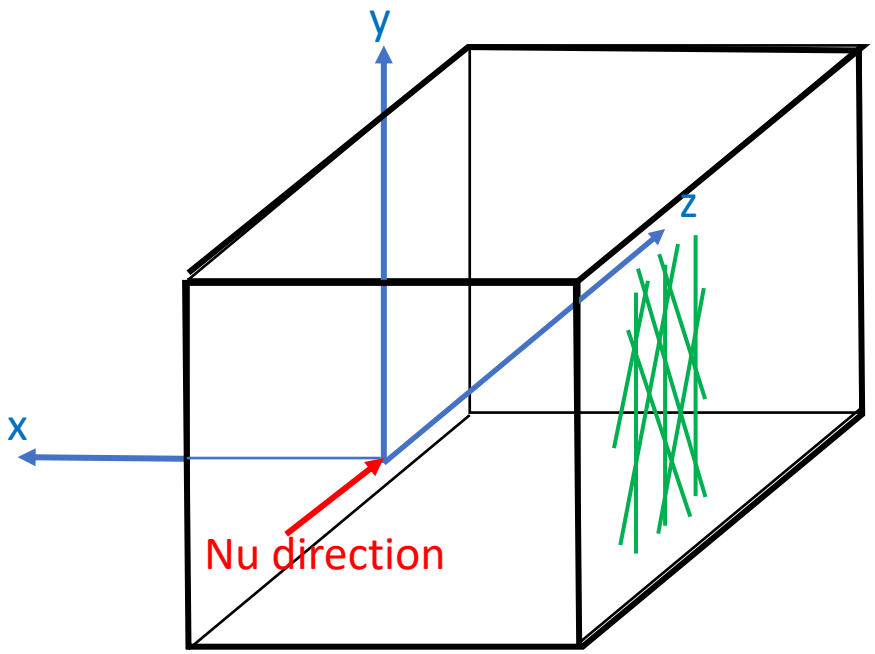


Figure 17: Demonstration of effectiveness of the de-ghosting algorithm with other advanced clustering algorithms applied. The left and right panels show the clusters before and after applying the de-ghosting algorithm following the separation of the "coincidental overlap" cluster. Color indicates cluster membership. The stripy tracks with much worse spatial resolution in Y-Z view correspond to big blobs of isochronous tracks as discussed in section 3.4.

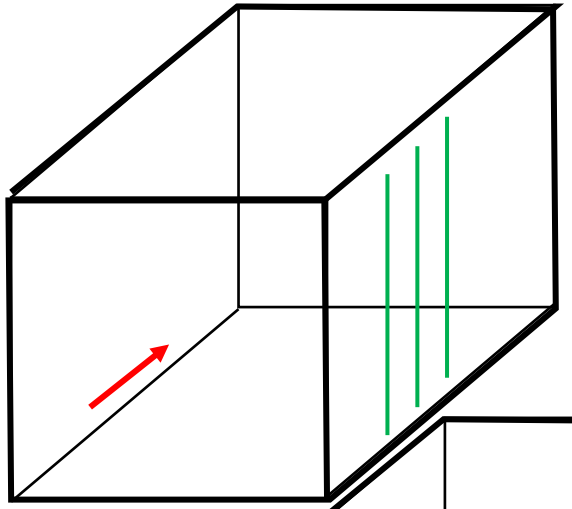
MicroBooNE has 3 views over 70% of the detector.

- The best performance on efficiency and purity for DUNE event classification is obtained with CVN (see https://arxiv.org/abs/2006.15052, *Neutrino interaction classification with a convolutional neural network in the DUNE far detector*), based on simulation.
- Other methods have not achieved the same levels of efficiency and purity in selecting CC nu_e and nu_mu interactions.
- ProtoDUNE data have so far substantially confirmed the limitations of “classic” event reconstruction.
- A test of 2D vs 3D read out has been done (Saul, with Leigh, Tingjun, Wanwei)
  - using existing simulated data of the DUNE far detector,
  - Removing the information form one or two planes, in different tries
  - Training the neural network each time and testing it

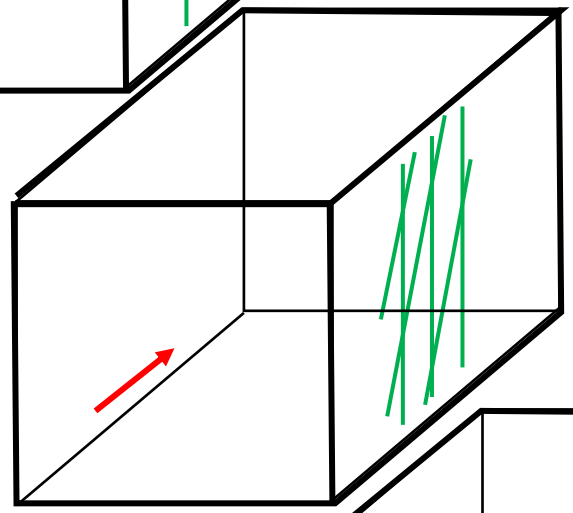
Default DUNE FD-SP (views 0, 1, 2)
Read-out at 90 and +-55 degree from neutrino direction



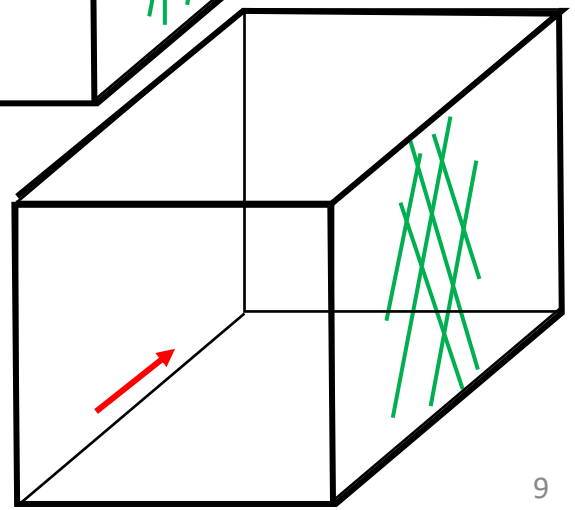
Variation 1D: 2 only



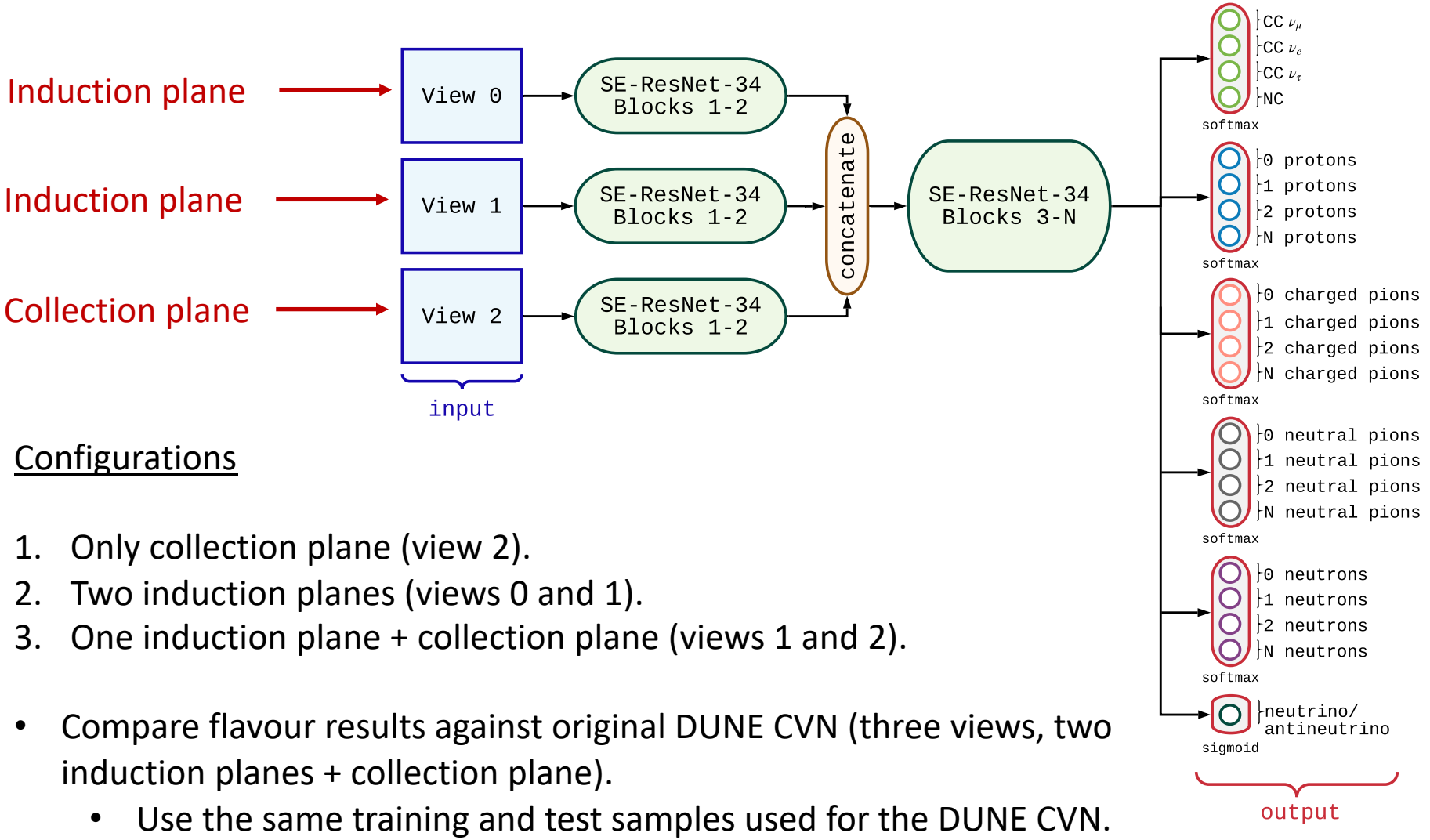
Variation 2d: 1 and 2 only



Variation 2D: 0 and 1 only



CVN trainings



Configurations

1. Only collection plane (view 2).
2. Two induction planes (views 0 and 1).
3. One induction plane + collection plane (views 1 and 2).

- Compare flavour results against original DUNE CVN (three views, two induction planes + collection plane).
  - Use the same training and test samples used for the DUNE CVN.

Results (I)

DUNE CVN (views 0, 1, and 2)

	precision	Recall	F1 score	#events
CC ν_μ	**0.93**	**0.96**	**0.95**	**26108**
CC ν_e	**0.93**	**0.97**	**0.95**	**25665**
CC ν_τ	0.66	0.37	0.47	5813
NC	0.94	0.95	0.94	42382

Collection plane (view 2)

	precision	Recall	F1 score	#events
CC ν_μ	**0.91**	**0.94**	**0.92**	**26108**
CC ν_e	**0.90**	**0.94**	**0.92**	**25665**
CC ν_τ	0.59	0.26	0.36	5813
NC	0.91	0.93	0.92	42382

Induction planes (views 0 and 1)

	precision	Recall	F1 score	#events
CC ν_μ	**0.91**	**0.95**	**0.93**	**26108**
CC ν_e	**0.90**	**0.95**	**0.92**	**25665**
CC ν_τ	0.59	0.27	0.37	5813
NC	0.92	0.93	0.92	42382

Induction plane, collection plane (views 1 and 2).

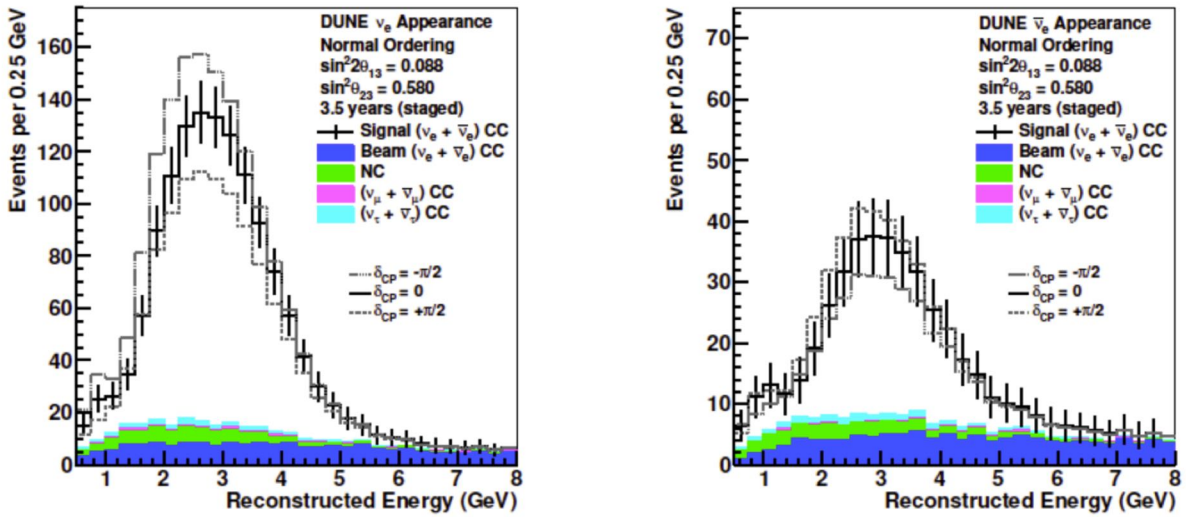
	precision	Recall	F1 score	#events
CC ν_μ	**0.91**	**0.95**	**0.93**	**26108**
CC ν_e	**0.90**	**0.95**	**0.92**	**25665**
CC ν_τ	0.58	0.31	0.40	5813
NC	0.92	0.92	0.92	42382

Results (II)

Due to network parameter initialisation, the results have a ± error of ~0.005

	Overall Purity (CC ν_μ)	Overall Purity (CC ν_e)	Overall Efficiency (CC ν_μ)	Overall Efficiency (CC ν_e)
DUNE CVN (views 0, 1, and 2)	**0.9727**	**0.8705**	**0.9389**	**0.9261**
Collection plane (view 2)	0.9625	**0.7915**	0.8922	0.8846
Induction planes (views 0 and 1)	0.9631	0.7896	**0.9129**	**0.8963**
Induction plane, collection plane (views 1 and 2)	**0.9633**	0.7872	0.9106	0.8924

Loss of performance with 2-views



(a) Neutrino mode.

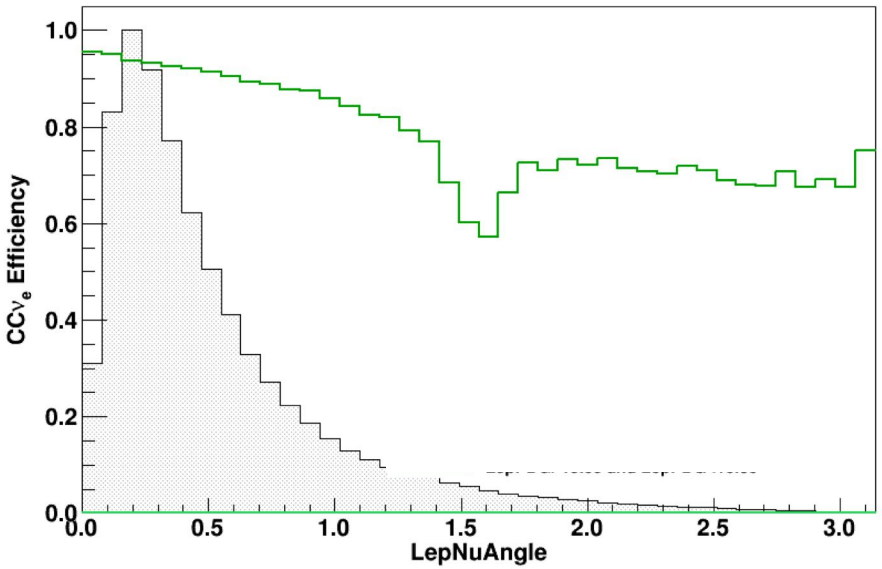
(b) Antineutrino mode.

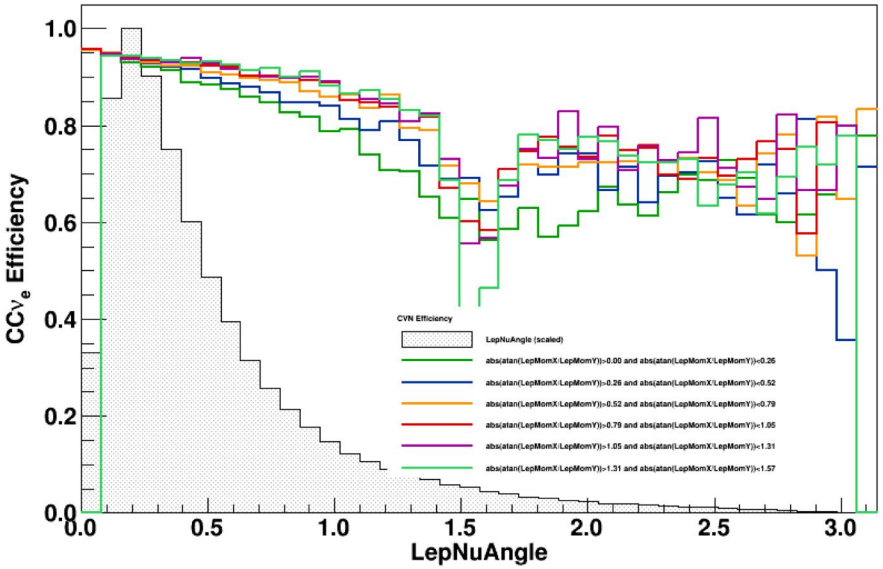
FIG. 1: Reconstructed energy distribution of ν_e and $\bar{\nu}_e$ CC-like events selected by the convolutional neural network algorithm (CVN) assuming 3.5 years (staged) running in the neutrino-beam mode (a) and antineutrino-beam mode (b), for a total of seven years (staged) exposure. The plots assume normal mass ordering and include curves for $\delta_{CP} = -\pi/2$, 0, and $\pi/2$. Background from ν_μ-CC, ν_τ-CC, intrinsic ν_e-CC, and NC interactions are shown as stacked, filled histograms. Figure reproduced from Ref. [14].

Should we worry more about loss of efficiency or loss of purity?

Looking at these plots (published) purity relates to at most half of the background.
If the systematic uncertainty in the background would be < 25%, the loss of purity seen above would not matter much,

If 2-views, orientation is critical?

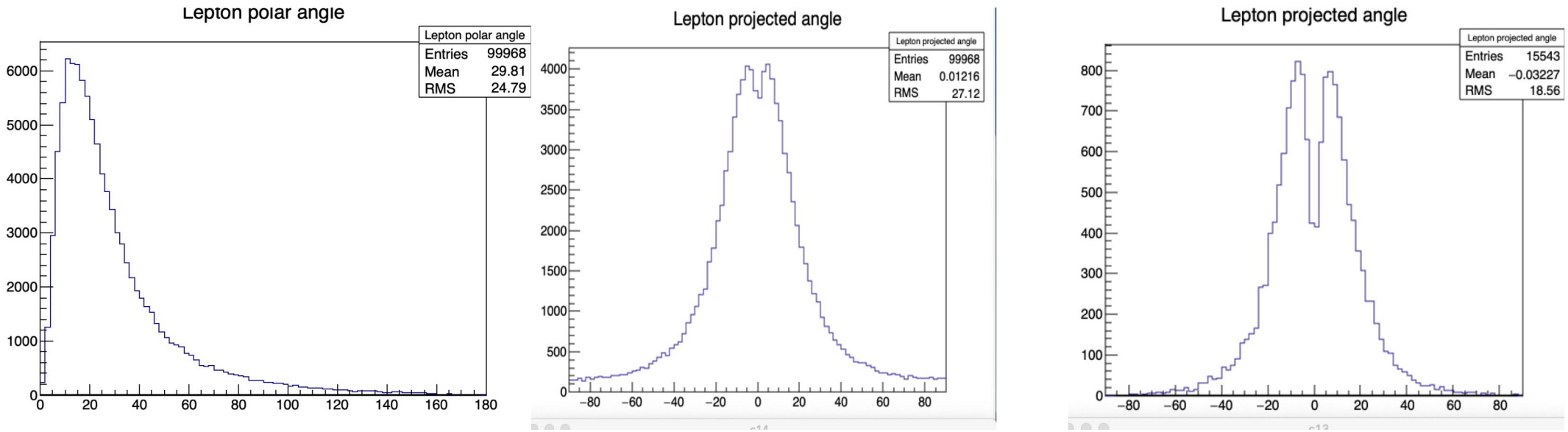




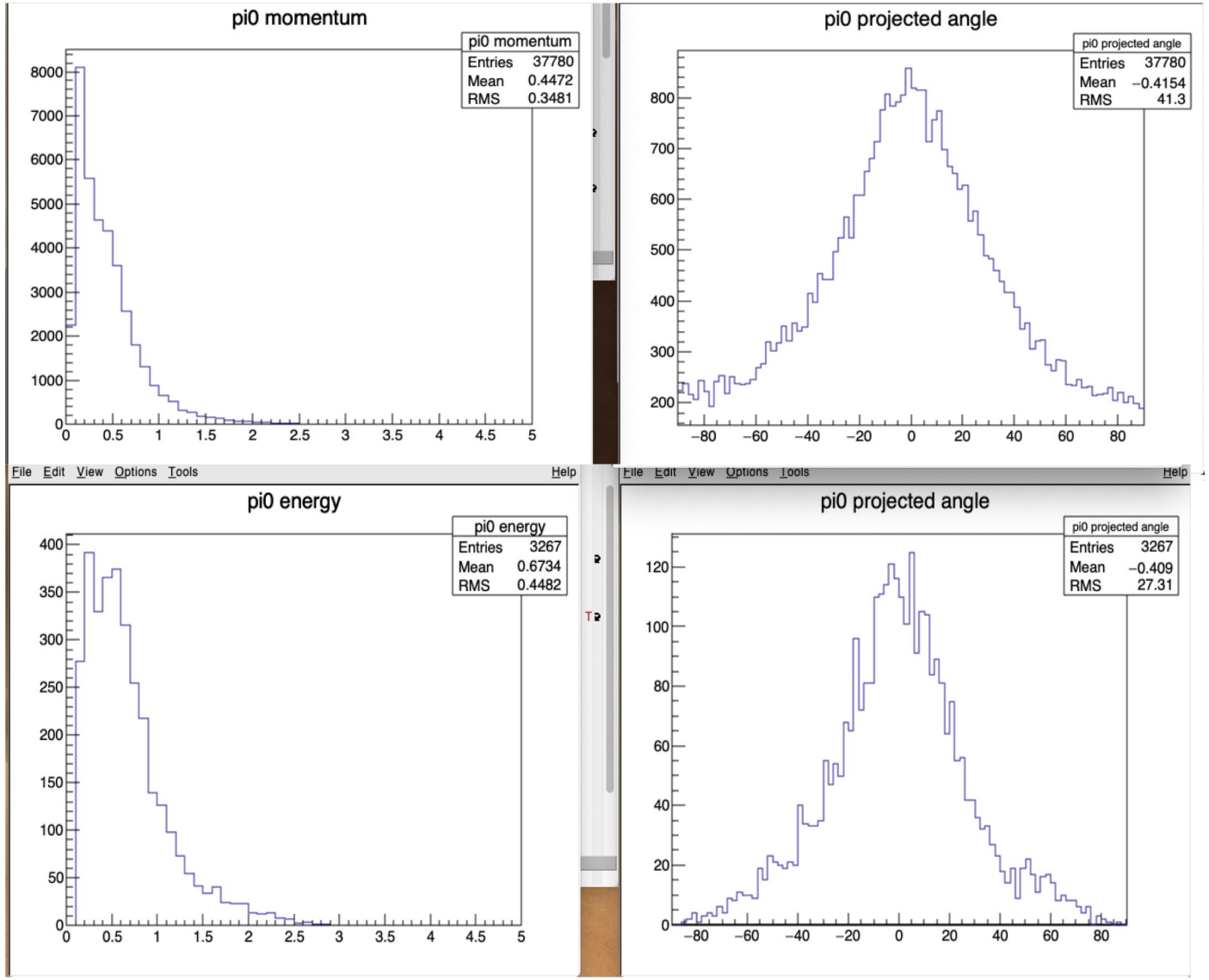
(D. Cherdack, 18/03/19)
The reconstruction efficiency (CVN) depends on the **polar angle** of the electron (shower). (Left plot, published). **Drop at 90 degrees.**
Looking better (right plot, unpublished) we see that the local inefficiency is large for tracks parallel to the drift direction (i.e. orthogonal to the the read-out plane), and small when parallel to the read-out plane. (3 views here.)

Is it less functional to have a read-out strip along the neutrino direction?

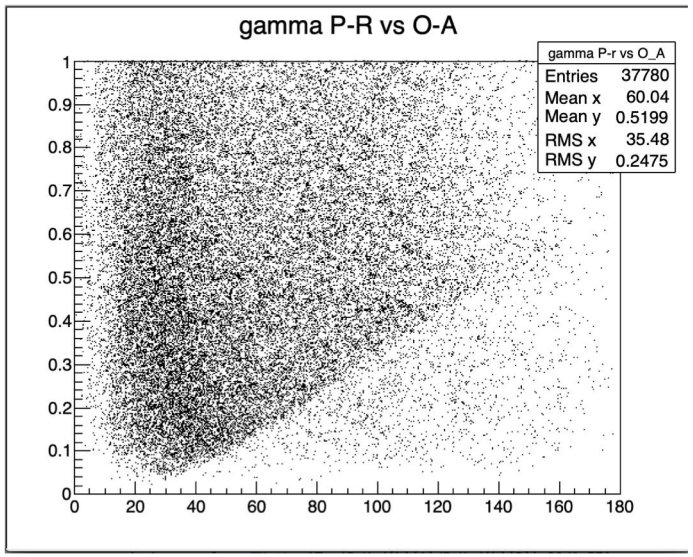
- Difficult to say (experience of ICARUS, but for higher neutrino energies, so far)
- We just started to look at the kinematics of neutrino interactions, using FLUKA (with Paola).



3.5 GeV neutrino CC interactions. From left to right: (1) lepton polar angle to nu direction (compare with previous slide), (2) lepton projected angle on a plane, (3) lepton projected angle when the projection on the orthogonal plane is within 4 degrees of the neutrino direction.



pi0 energy and projected angle, with bottom plots when within +-degree of neutrino axis, in the orthogonal plane.



Gammas' momentum ratio (=LowerP/HigherP) vs opening angle (3D, degrees).

Conclusions today:

- The vertical drift concept to be discussed in December within DUNE
- Going now for preliminary assessment
  - Dedicated simulation, more physics cases afterwards
- Work just started, interesting under different point of views