EXPLOITING THE PRISM FEATURE AND PURITY MONITORS OF THE SBND NEUTRINO DETECTOR

Final Term Review

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CONTENTS

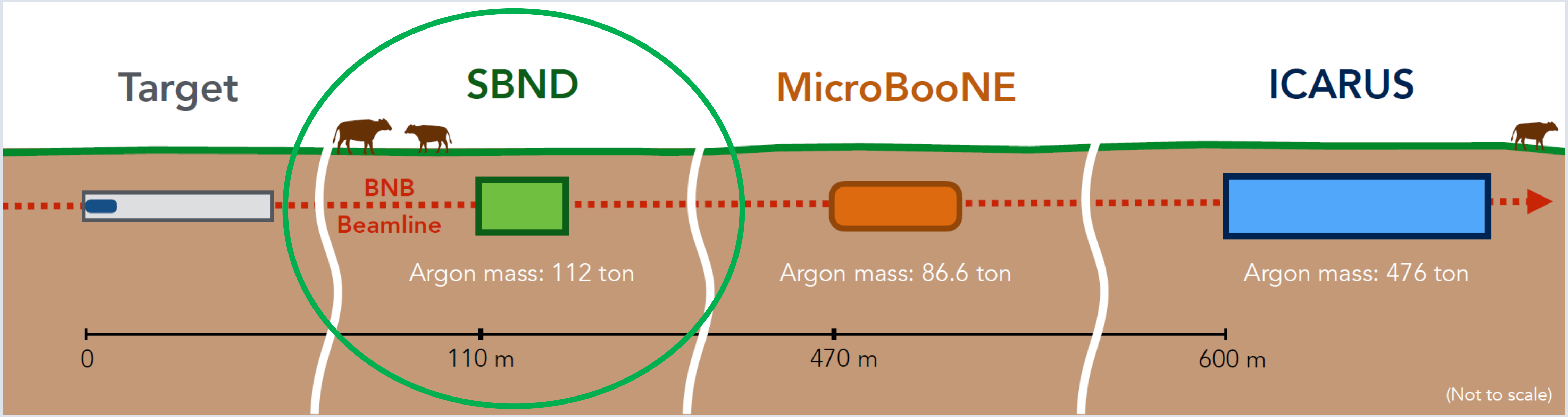
- Software: Exploiting the PRISM Feature
- Hardware: Electrons Drift Studies through Purity Monitors

THE SHORT BASELINE NEUTRINO PROGRAM AT FERMILAB

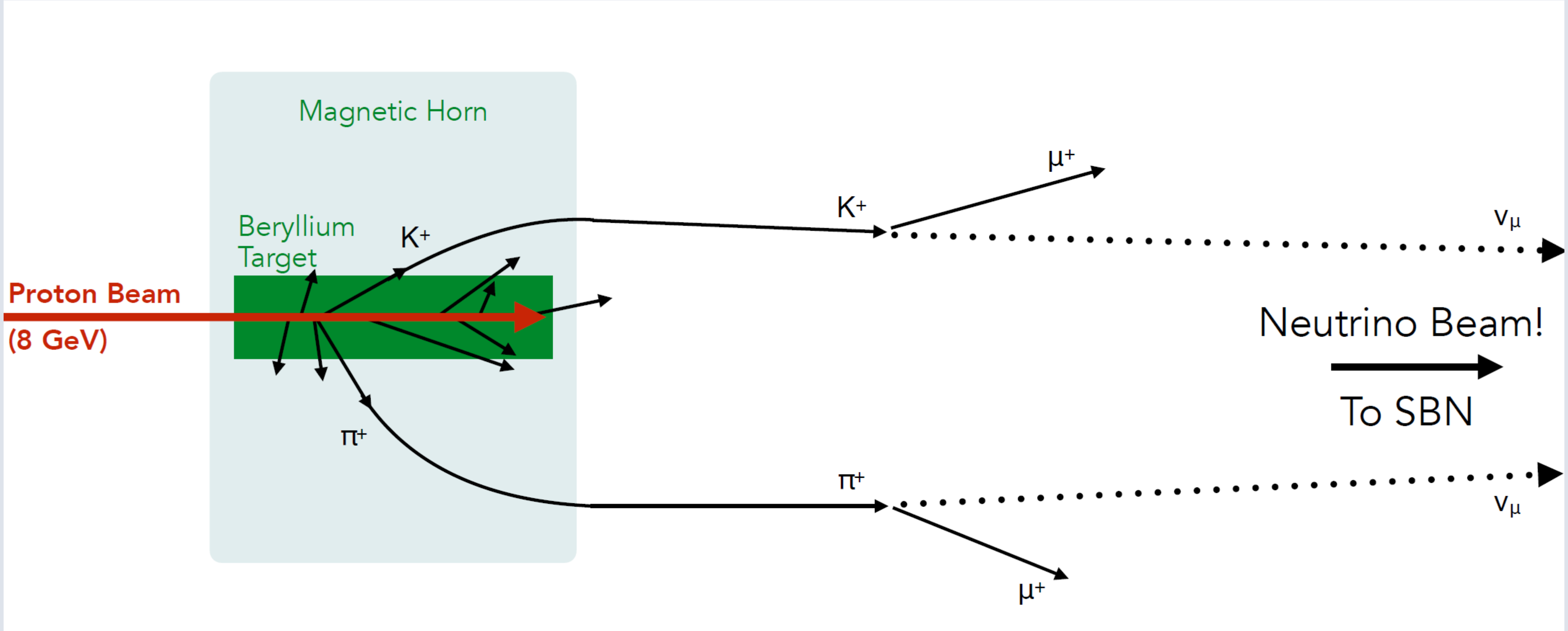
- Three Liquid Argon Time Projection Chamber (**LArTPC**) detectors located along the **Booster Neutrino Beamline** (**BNB**).

Aims:

- Resolving the question of the existence of sterile neutrinos, searching in the eV-mass scale, along with other BSM searches.
- Studying neutrino-Argon interactions at the GeV energy scale, leading cross-section measurements
- Developing LArTPCs technology.



NEUTRINO BEAM: BNB AND FLUX



NEUTRINO BEAM: BNB AND FLUX

ν_μ

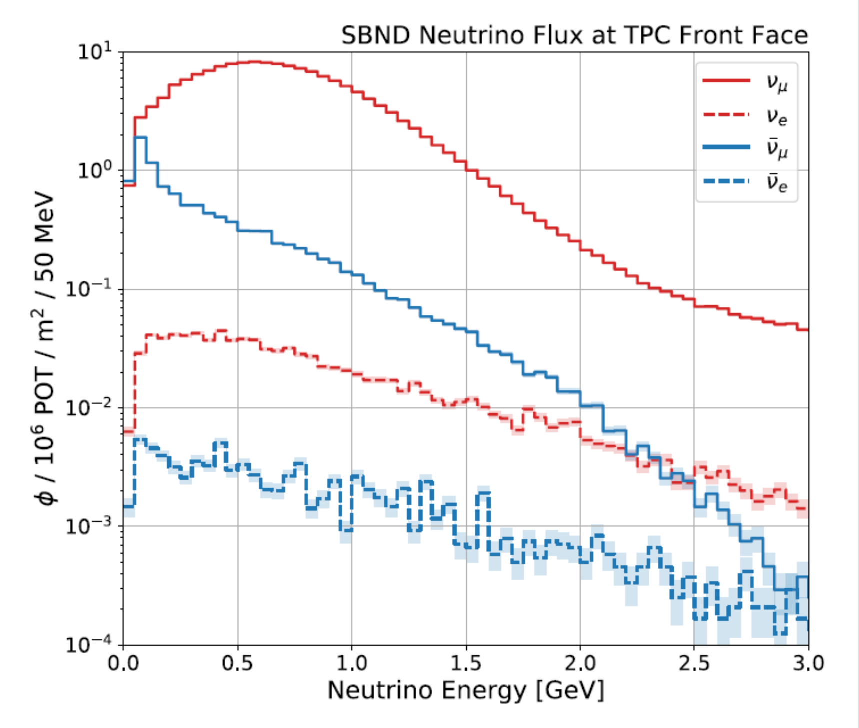
$$\pi^+ \rightarrow \nu_\mu + \mu^+$$
$$K^+ \rightarrow \nu_\mu + \mu^+$$

→ <u>2-bodies decay</u>
'Free' cinematics

ν_e

$$\mu^+ \rightarrow \nu_e + \bar{\nu}_\mu + e^+$$
$$K^+ \rightarrow \nu_e + e^+ + \pi^0$$
$$K_L^0 \rightarrow \nu_e + \pi^- + e^+$$

→ <u>3-bodies decay</u>
More constrained cinematics



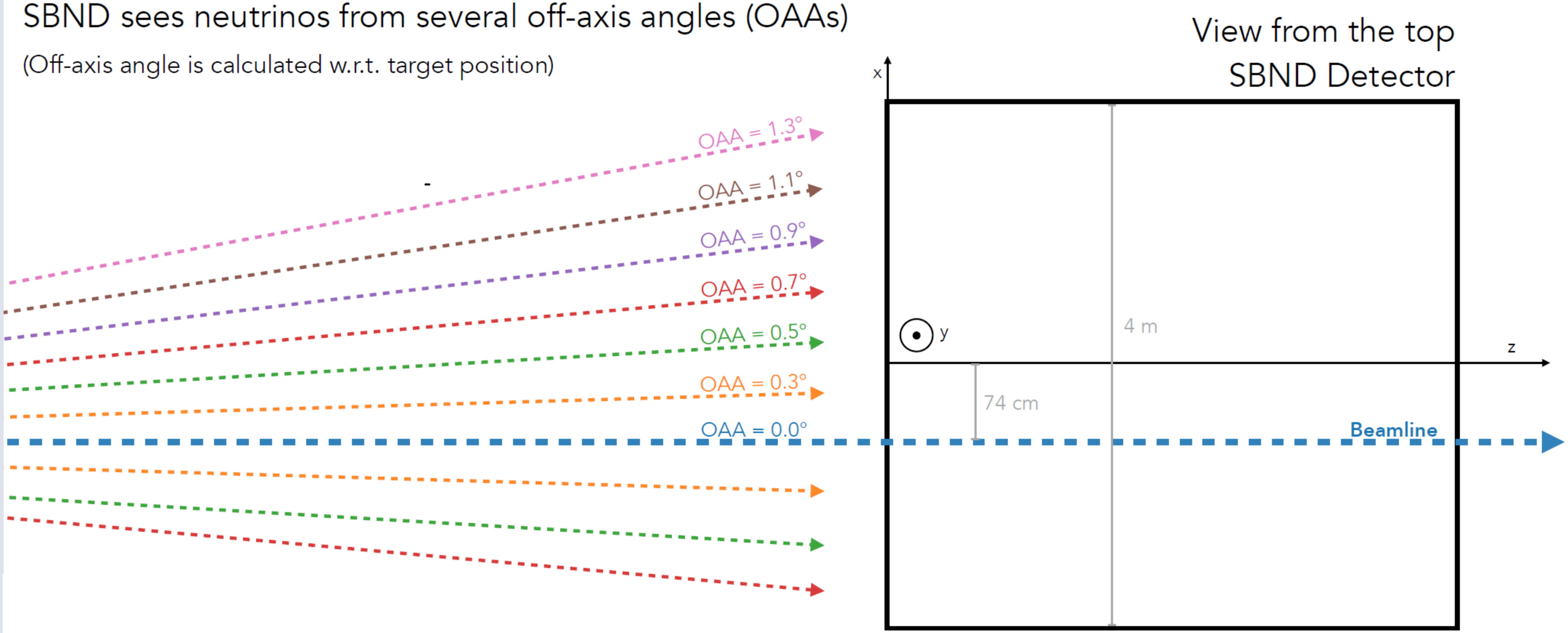
→ Neutrino flux at the SBND front face

ν_μ (93.6%), $\bar{\nu}_\mu$ (5.9%), ν_e+$\bar{\nu}_e$ (0.5%)

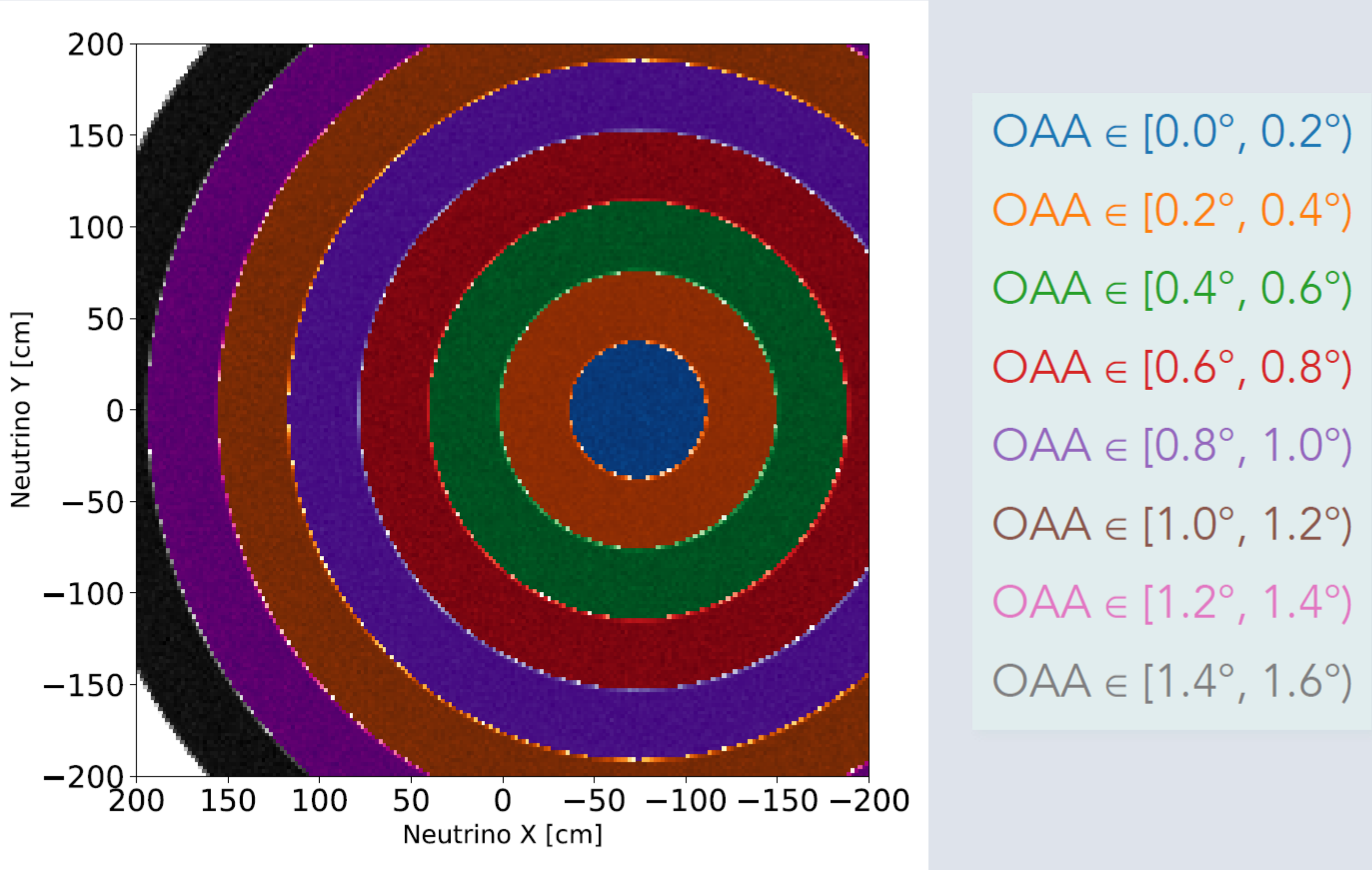
SBND DETECTOR: OFF-AXIS ANGLES

SBND sees neutrinos from several off-axis angles (OAAs)

(Off-axis angle is calculated w.r.t. target position)



SBND DETECTOR: OFF-AXIS ANGLES

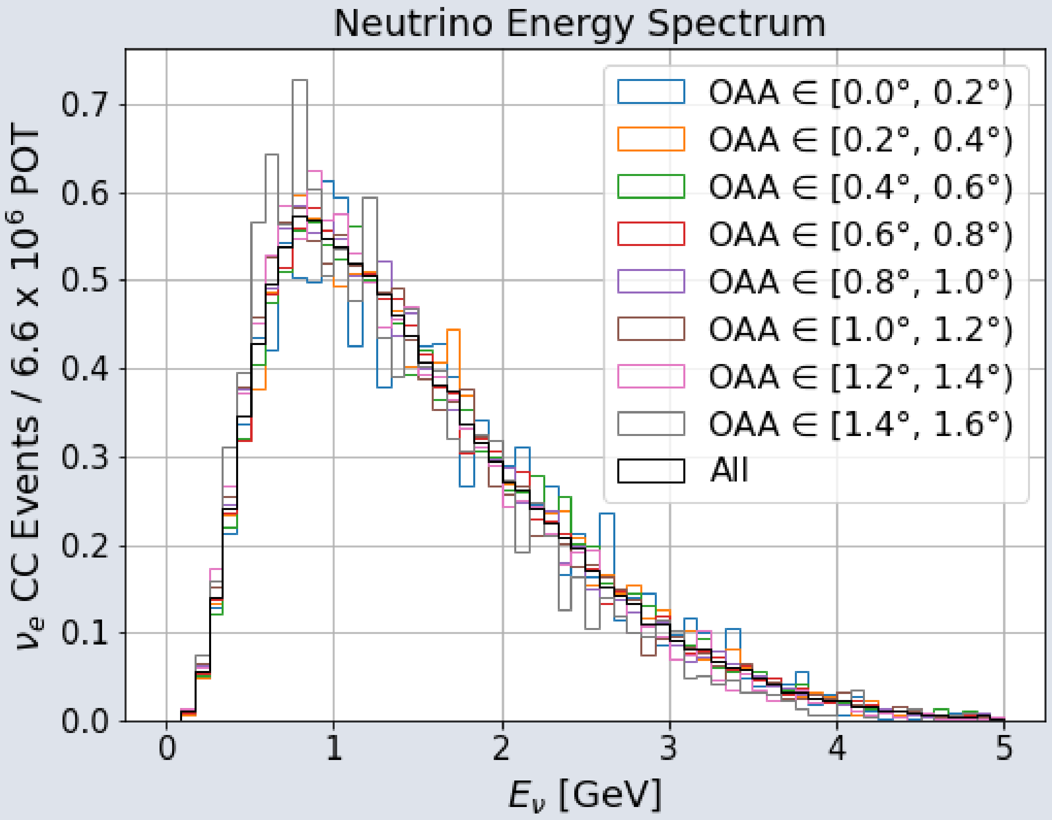


The flux is maximal on axis and then it decreases moving away from the beam center.

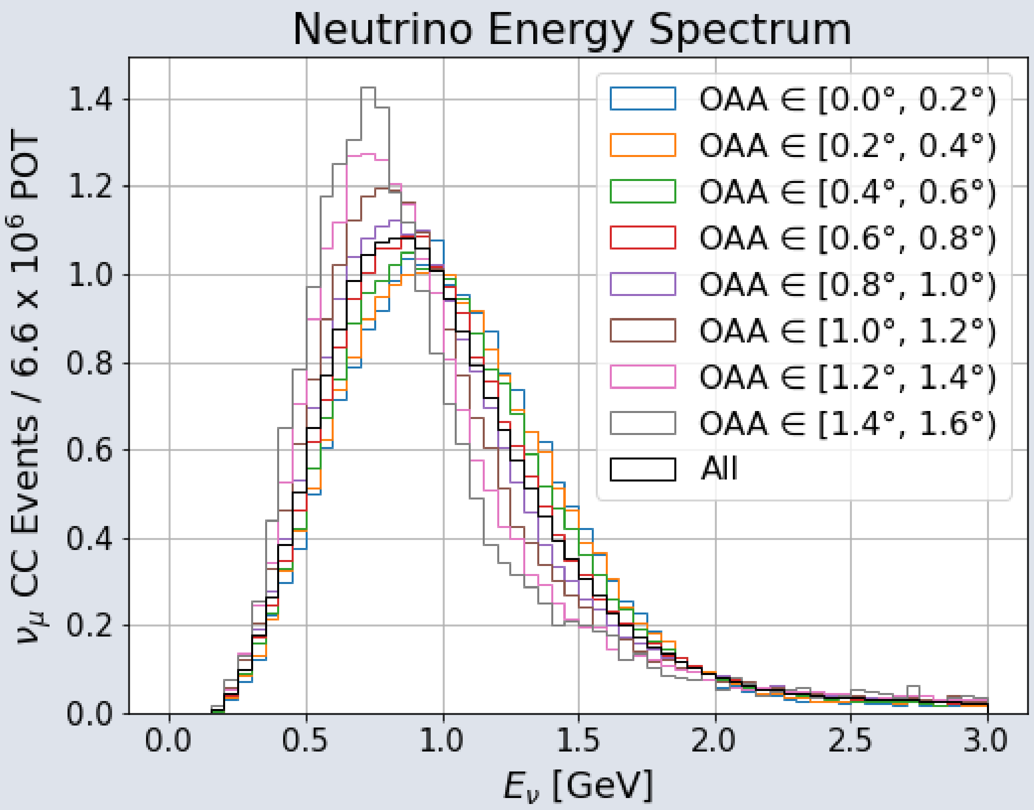
SBND PRISM Precision Reaction Independent Spectrum Measurement

The ν energy distribution is affected by the off-axis position. The neutrino flux was studied in each of the OAA regions, considering neutrinos' energy and associated leptons' momentum and scattering angles.

Electron Neutrinos



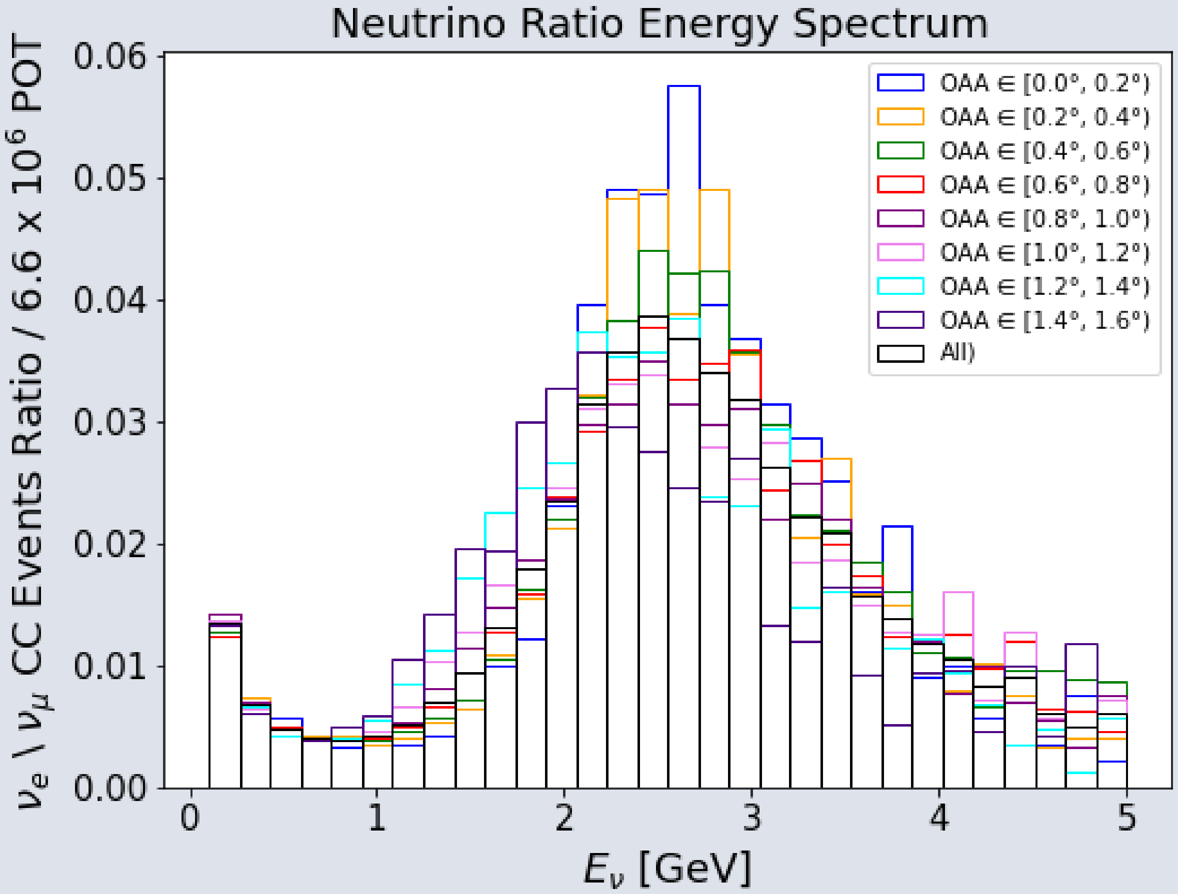
Muon Neutrinos

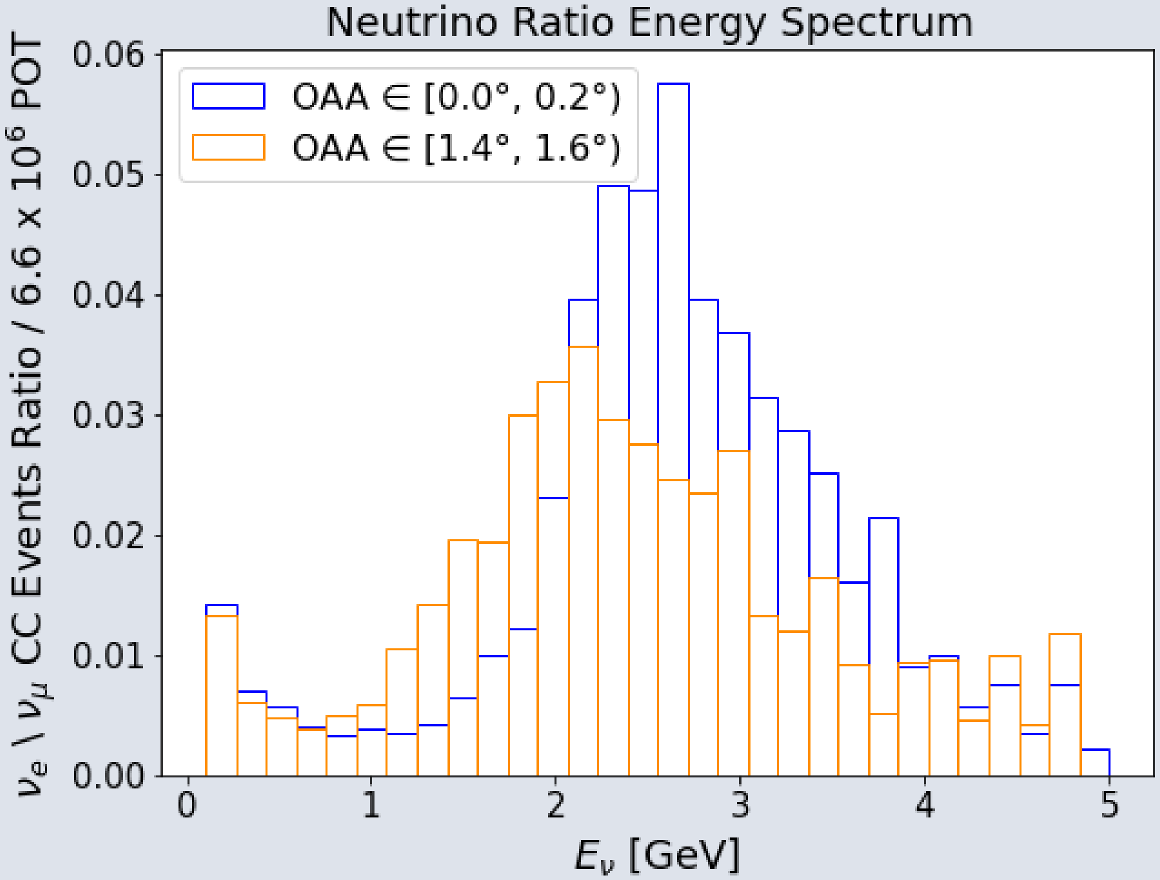


OAA index	N vμ Events	N ve Events
1	155840	1004
2	454059	3075
3	711735	4910
4	753539	5390
5	740447	5469
6	422513	3294
7	286149	2340
8	74061	625
All	3599107	26119

SBND PRISM: NEUTRINO RATIOS

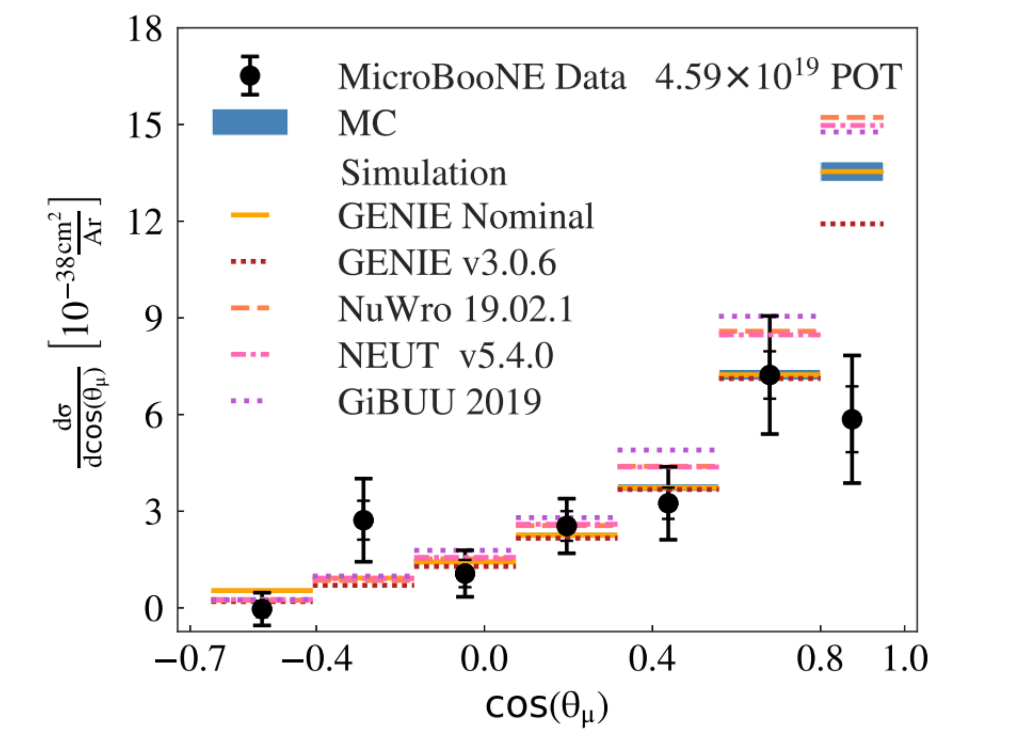
ve / vμ ratios at fixed energy:



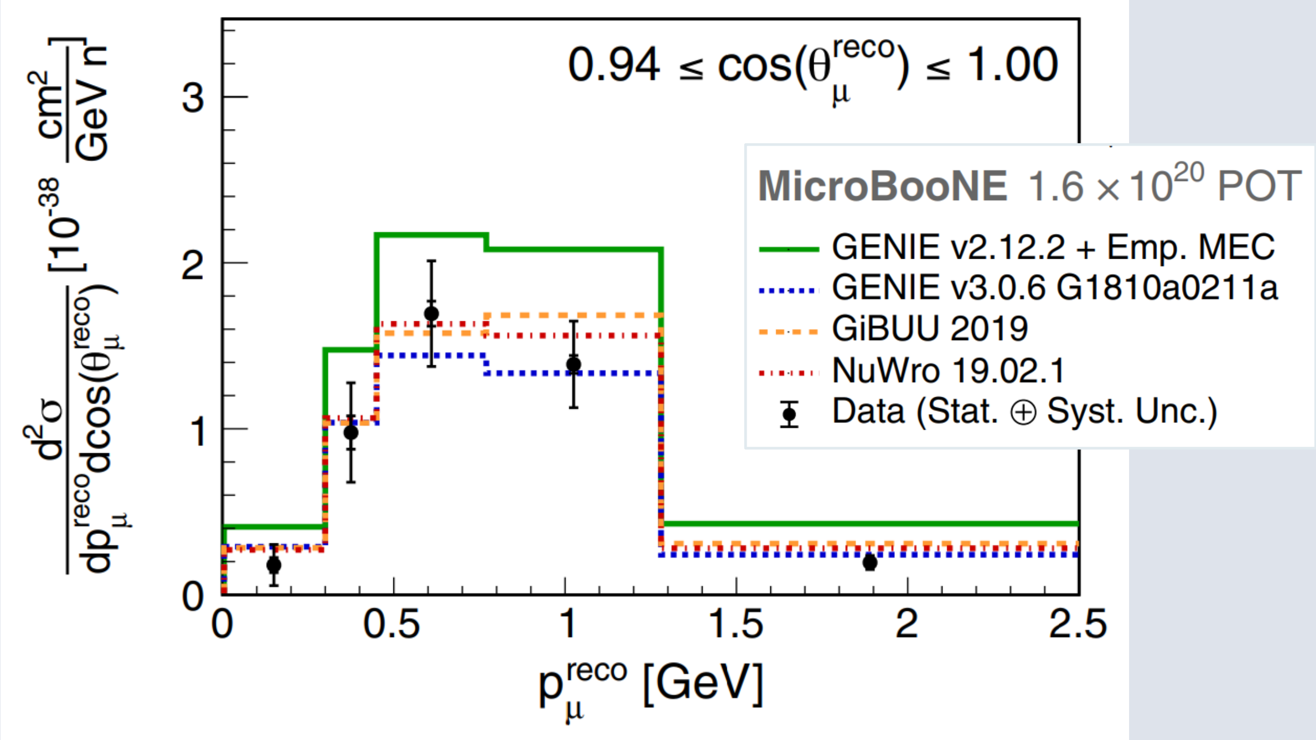


WHAT CAN WE IMPROVE?

(P. Abratenko *et al.* (MicroBooNE Collaboration)
Phys. Rev. Lett. **125**, 201803)



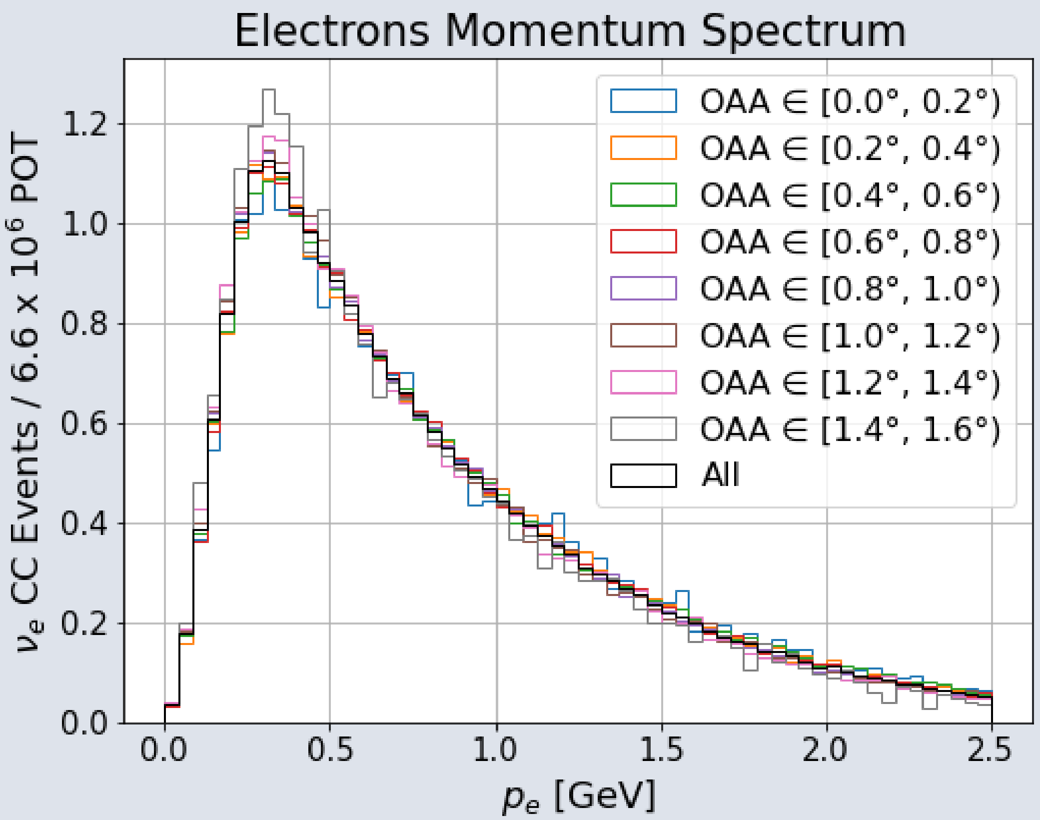
(P. Abratenko *et al.* (MicroBooNE Collaboration)
Phys. Rev. Lett. **123**, 131801)



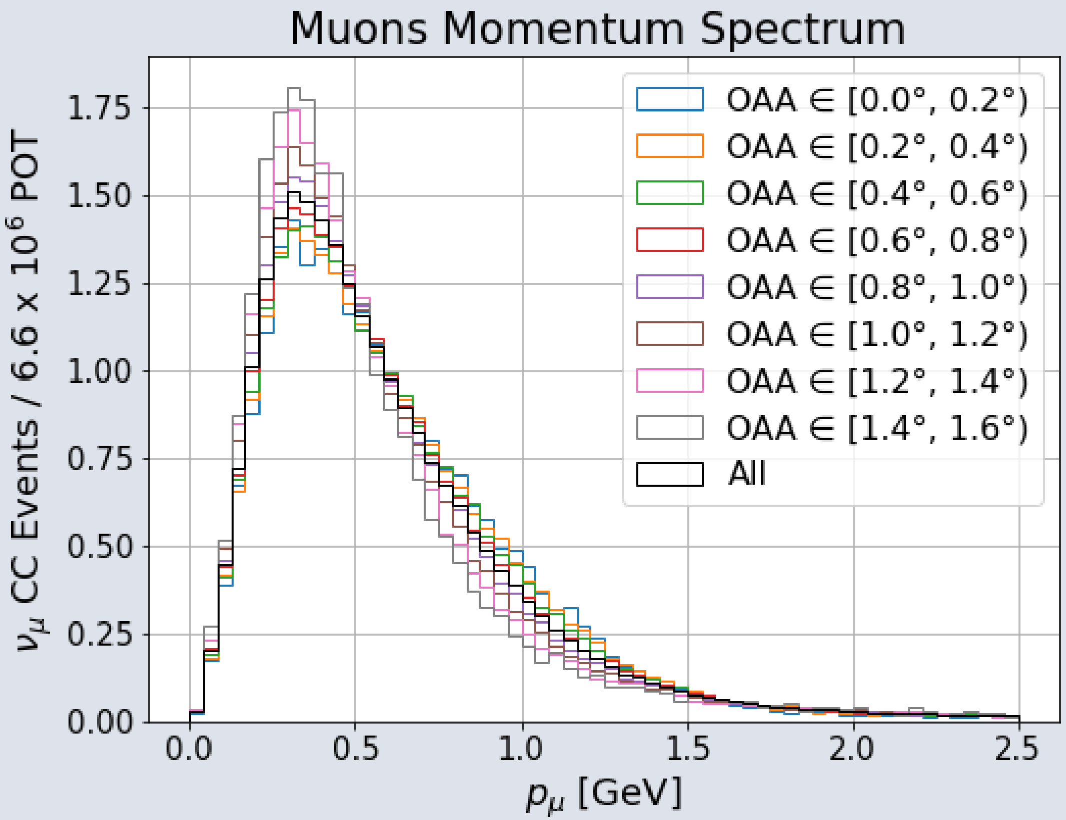
SBND PRISM: MOMENTUM AND SCATTERING ANGLE

Leptons' Momentum Distributions

Electrons



Muons



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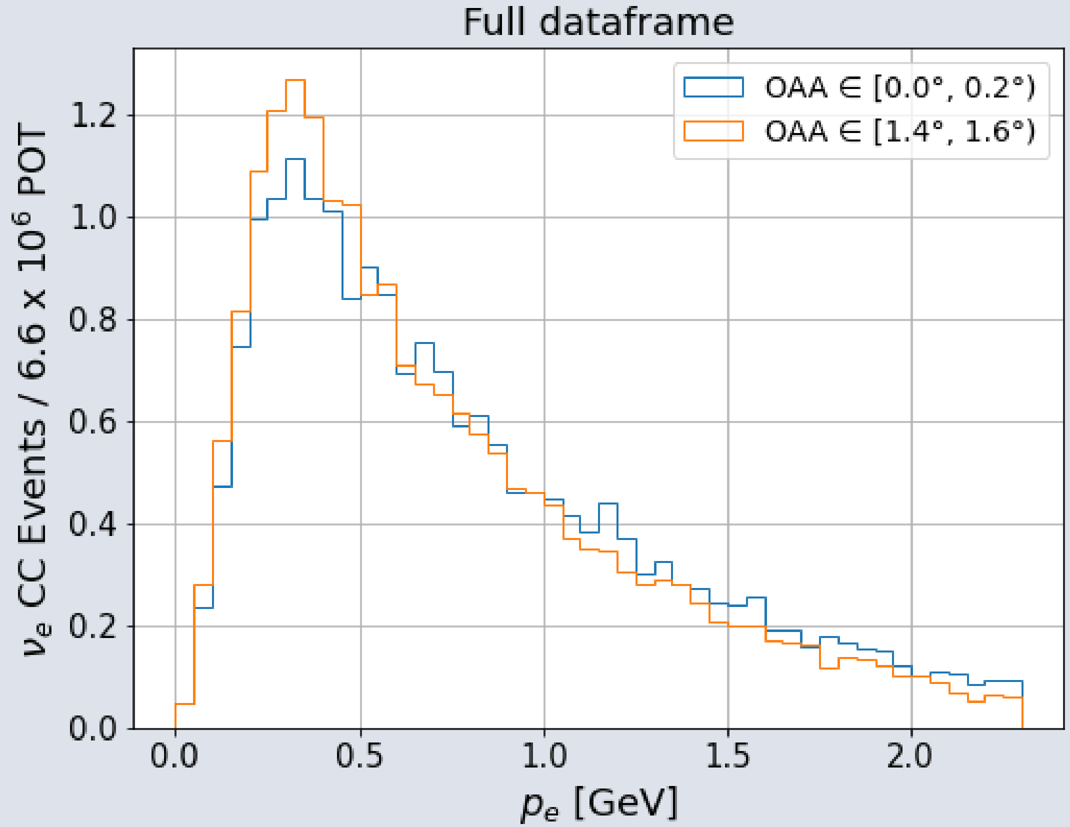
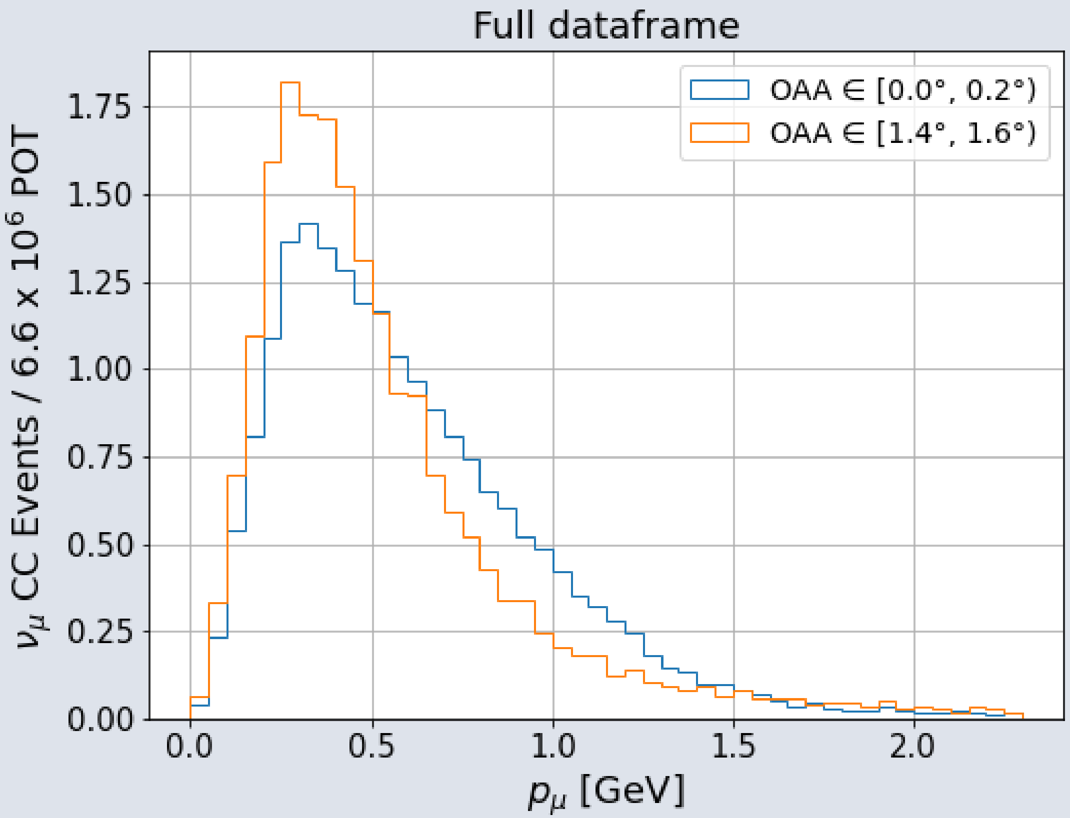
SBND PRISM: MOMENTUM AND SCATTERING ANGLE

Total Distributions (full cosθ range):

Electrons



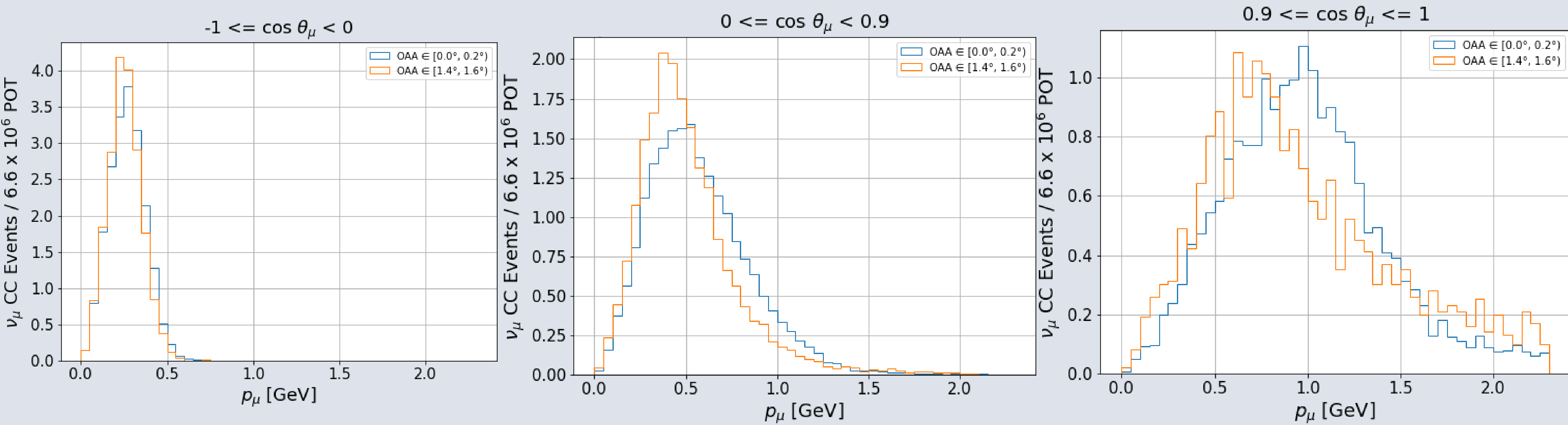
Muons



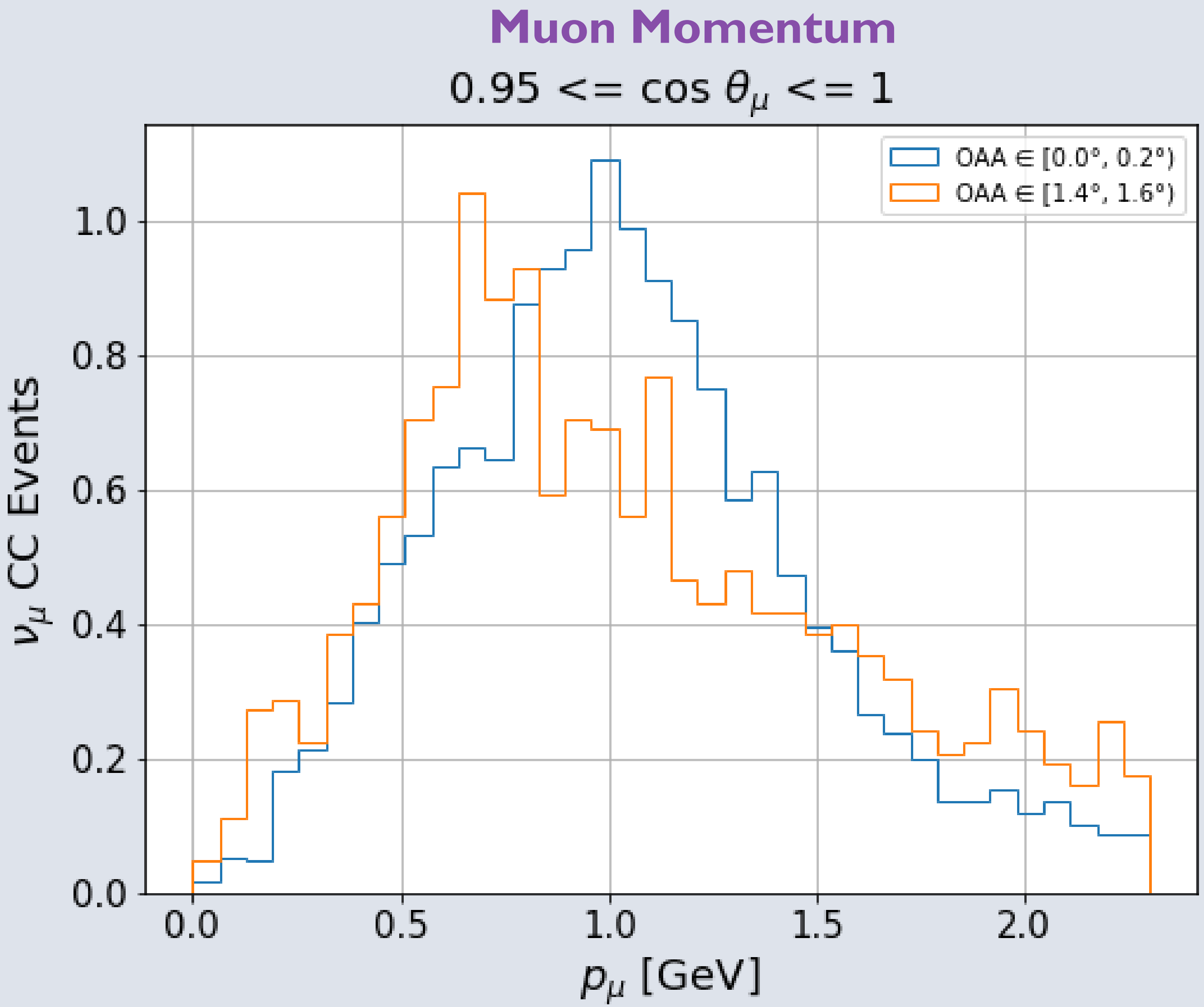
SBND PRISM: MOMENTUM AND SCATTERING ANGLE

Muon Momentum

(cosθ slicing)



SBND PRISM: MOMENTUM AND SCATTERING ANGLE



With leptons going forward, there's a relevant distinction between momentum distributions at different OAAs.

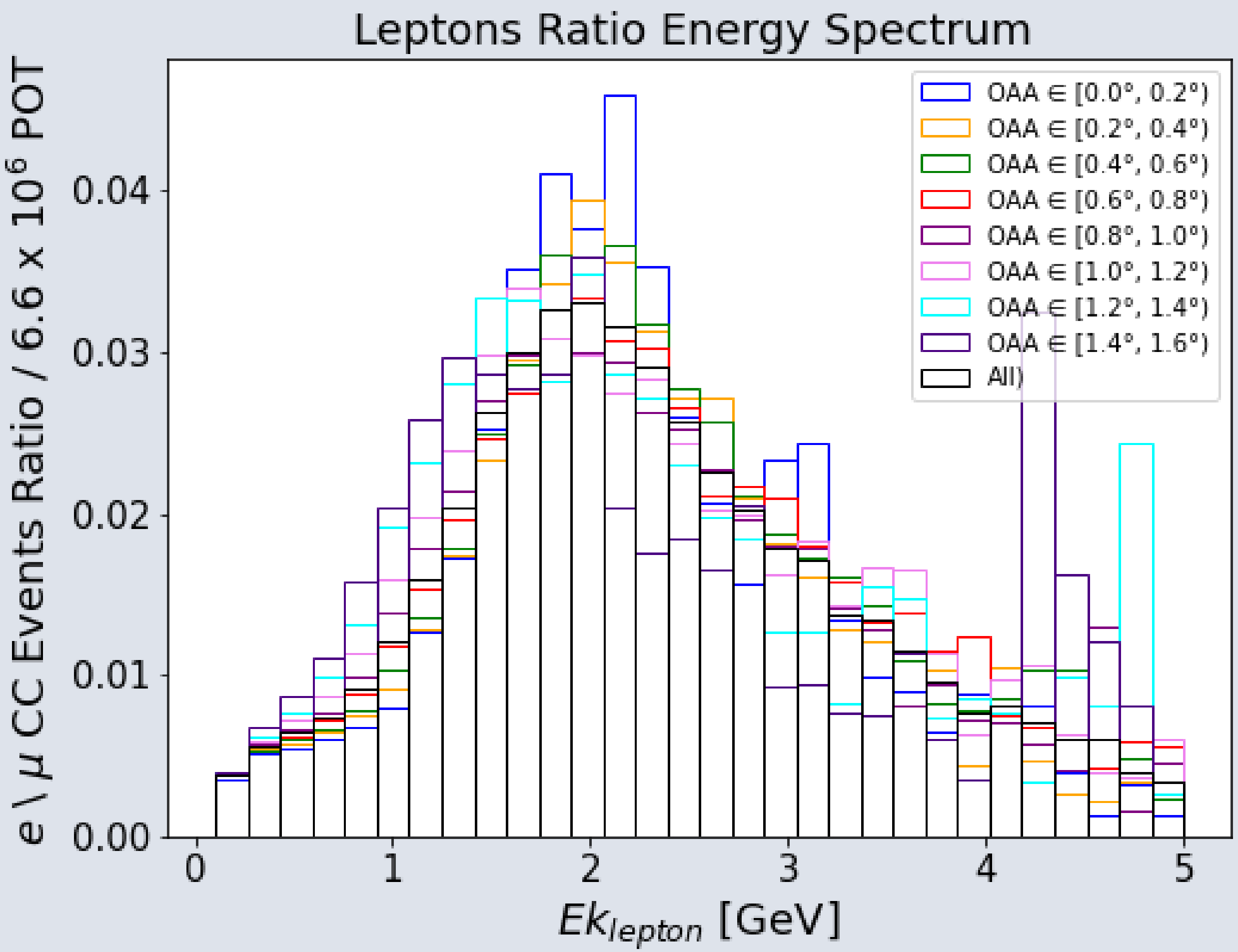
This means that measurement's sensitivity grows in this region, which would remain unexplored without PRISM.

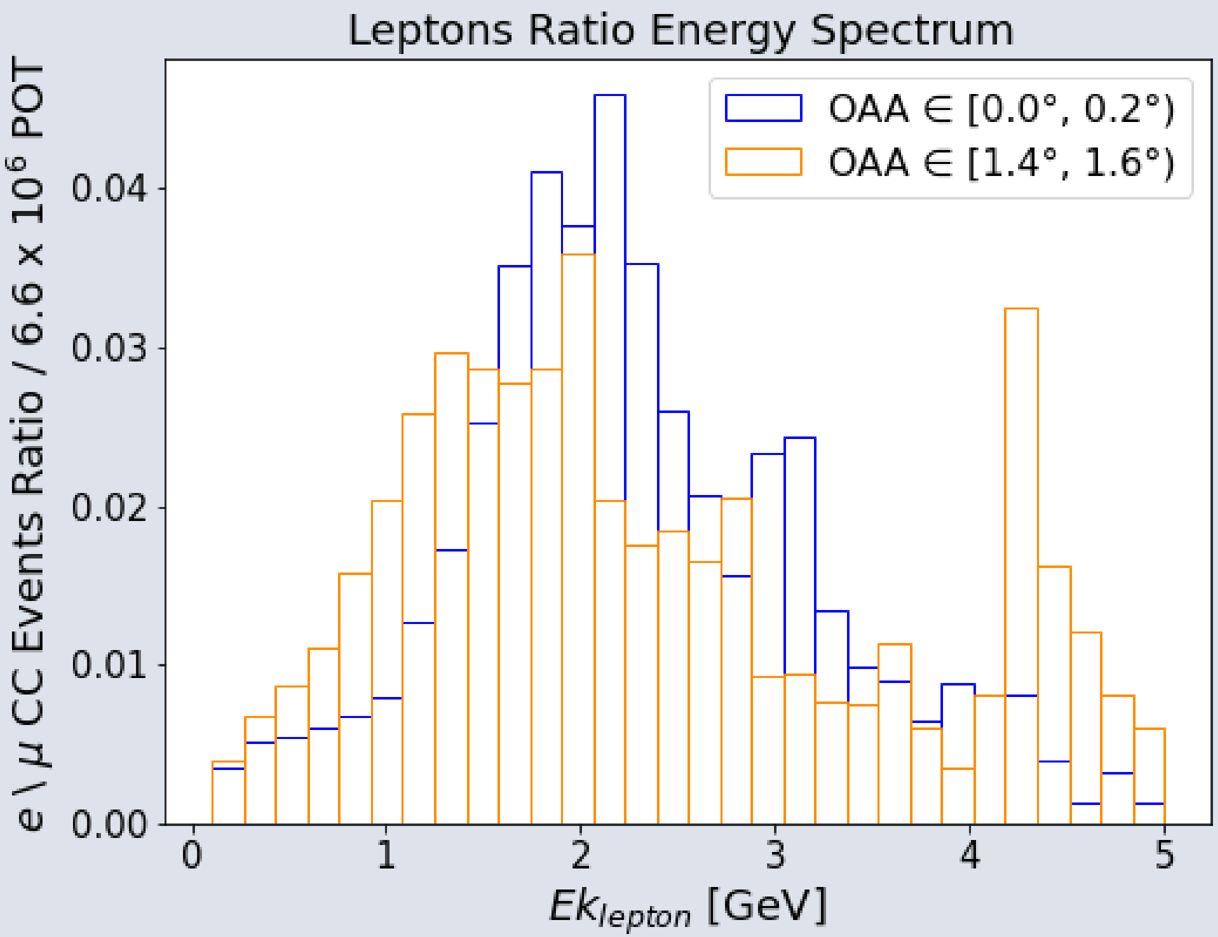
Slicing in OAAs can be important to understand this behavior, which is strictly linked to physics. Measurements in a further OAA slice are tighter and therefore have smaller uncertainties. This can lead to more precise measurements just going more off axis.

N Events	OAA index
18005	1
7269	8

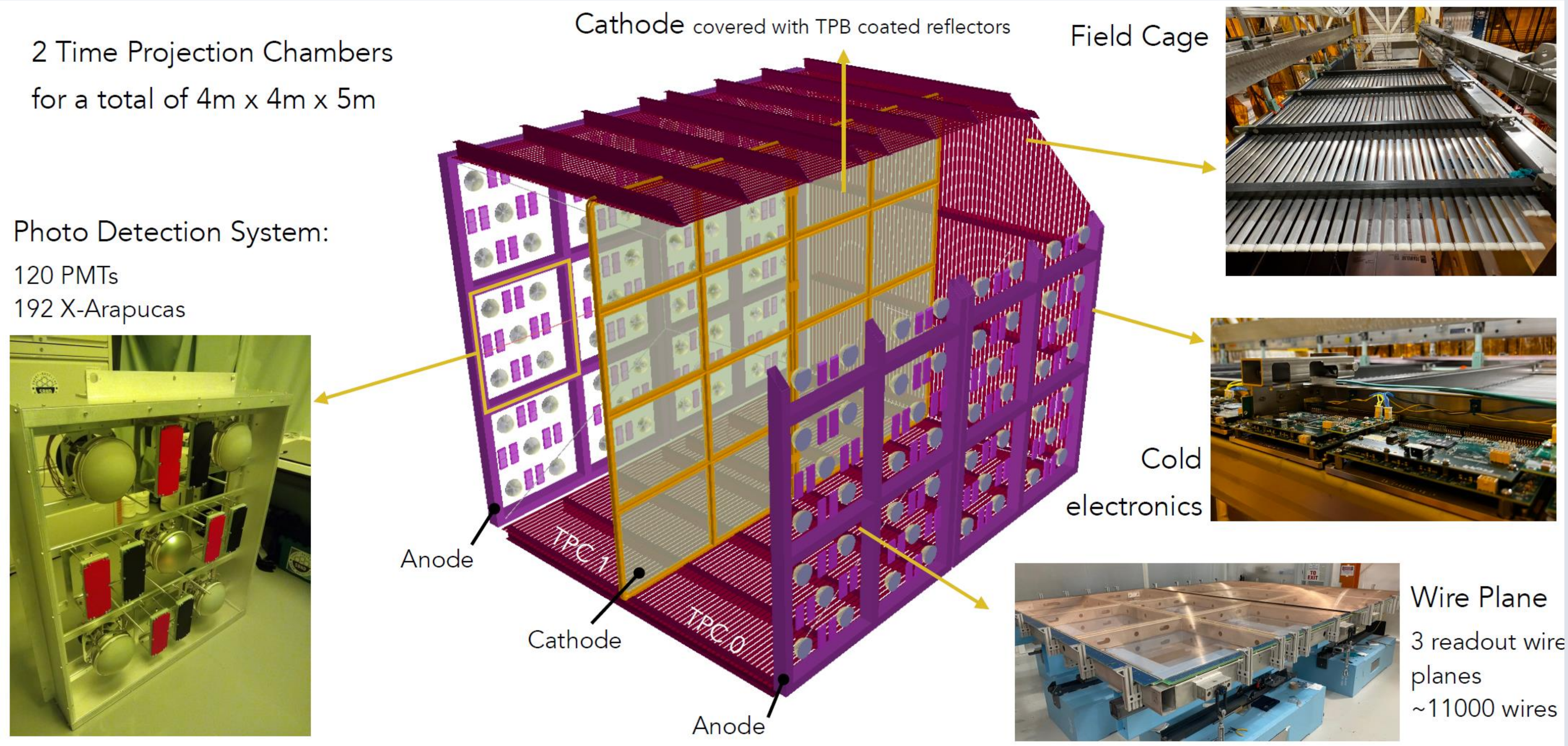
SBND PRISM: LEPTONS RATIOS

e / μ ratios at fixed kinetic energy:

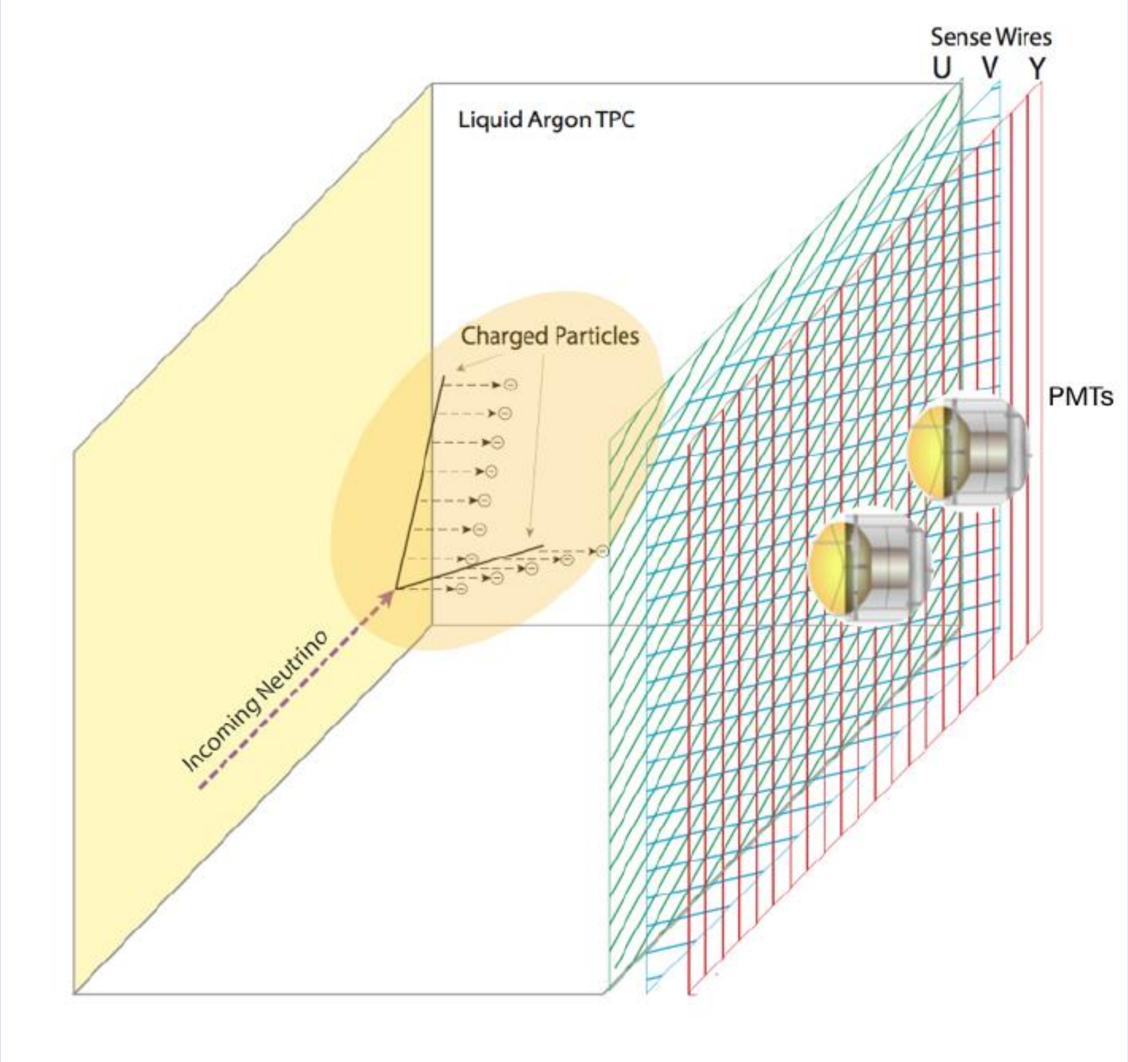




DETECTING NEUTRINOS: LARTPCS



DETECTING NEUTRINOS: LARTPCS



- Uniform Electric Field

$$\nu_\mu + Ar \rightarrow \mu^- + X$$

- $Ar^+ + e^-$ → **Sense Wires**
- $Ar^* \rightarrow Ar + \gamma$ → **Photon Detection System**

Sense Wires

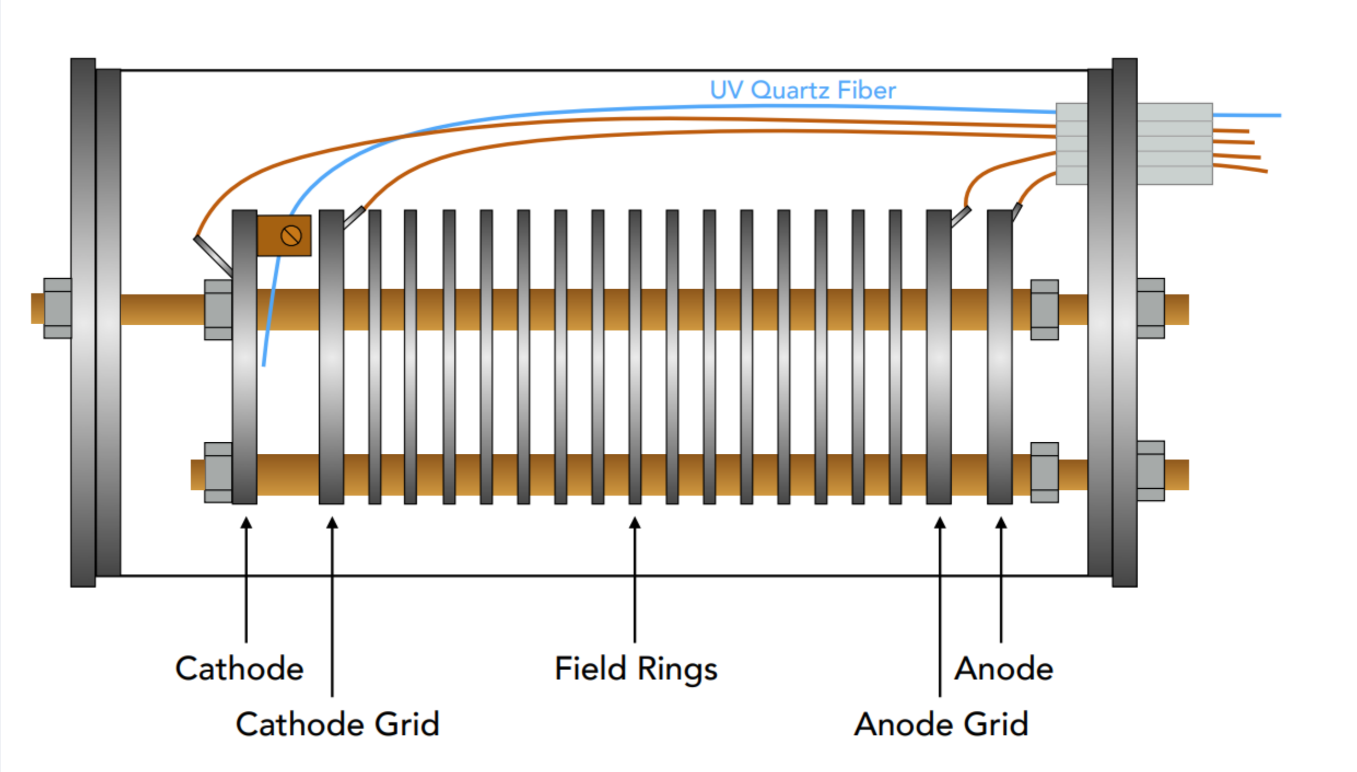
3 wire planes: a vertical one and two rotated by 60° one to another to achieve <u>3D tracks recostruction</u>

PDS

fast response time O(10 ns), which provides signals for <u>triggering</u>

- 3D Imaging
- Geometrical & Calorimetrical Recostruction

PURITY MONITORS



The **purity monitors** are
double-gridded ion chambers

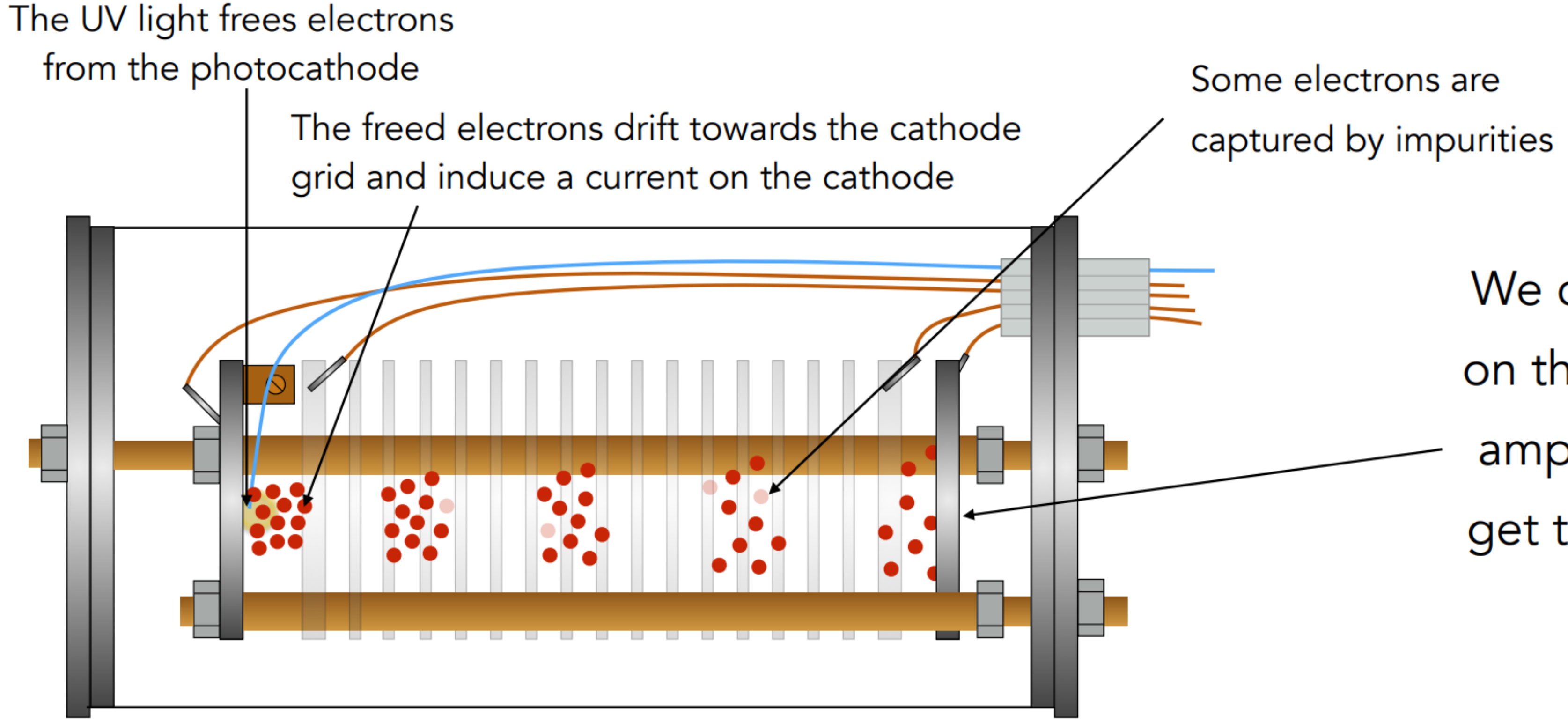
They are composed of four circular electrodes, all parallel to each other:

- a photocathode,
- two open wire grids,

acting as cathodes and anodes respectively,

- an anode.

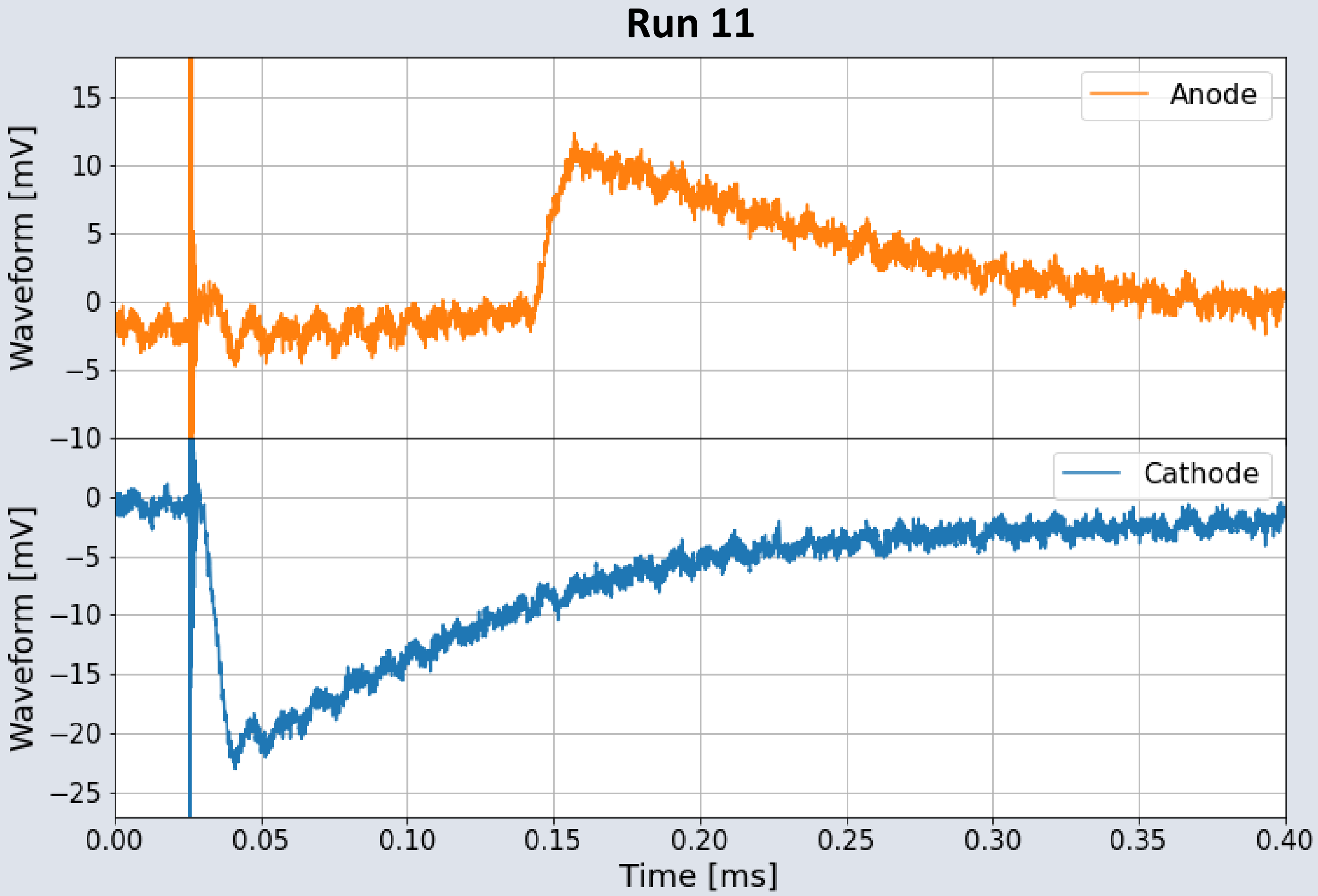
PURITY MONITORS



We can measure the induced signals on the anode and cathode, which are amplified and integrated in order to get the estimated electron lifetime τ:

$$Q_A = Q_C \times e^{-t_{drift}/\tau}$$

PURITY MONITORS: WAVEFORMS



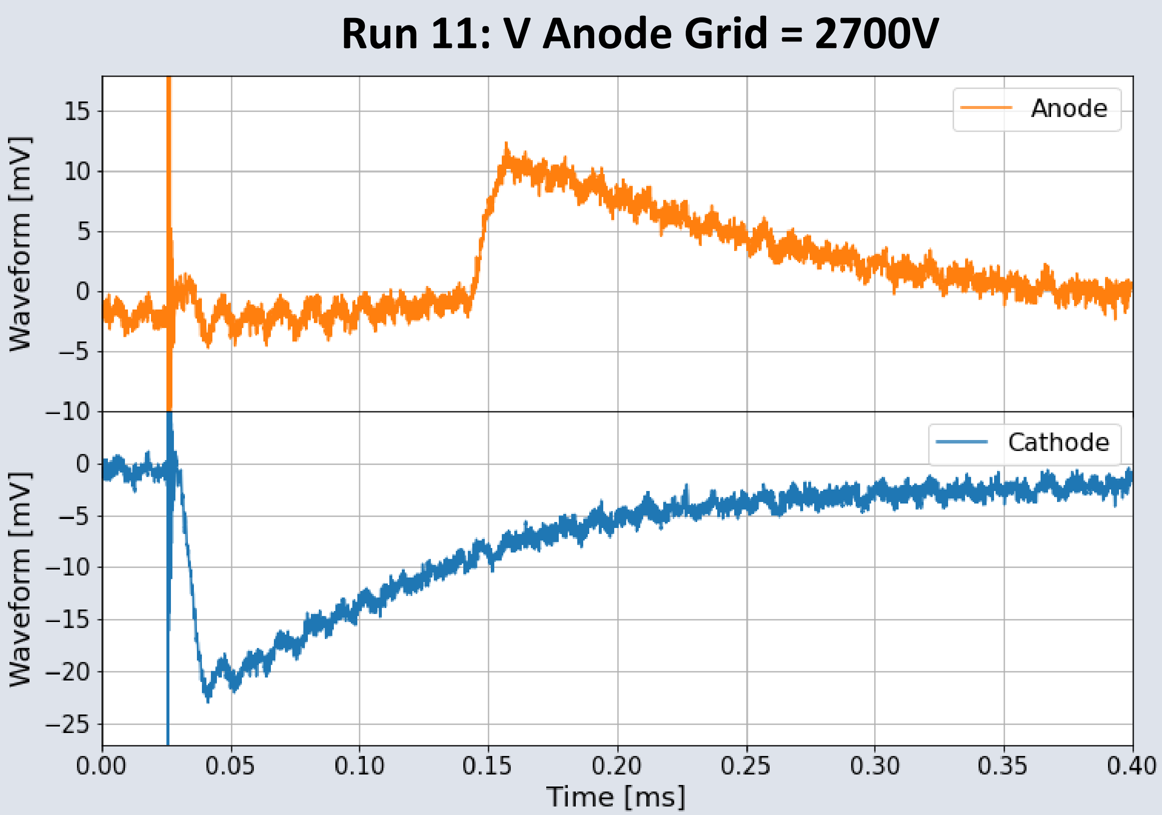
Waveforms obtained from PrM DAQ in GAr.

- Signal looks as expected.
- Amplitude is ~10 mV for the anode signal.
- Spike at ~0.025 ms is caused by flash lamp noise.

V Cathode (V)	V Cathode Grid (V)
-100	0 (Ground)

V Anode Grid (V)	V Anode (V)
2700	3000

PURITY MONITORS: WAVEFORMS

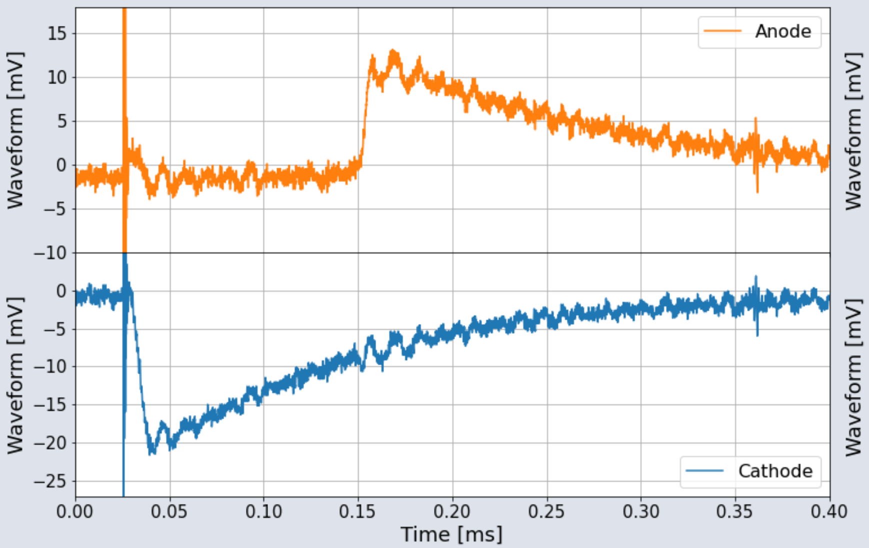


V Anode Grid (V)	**t drift** (ms)	**v drift** (mm/µs)
2500	0,196	2,547
2600	0,133	3,762
2700	0,126	3,959
2800	0,134	3,723
2900	0,133	3,757
2950	0,123	4,075
2970	0,130	3,842

PURITY MONITORS: WAVEFORMS

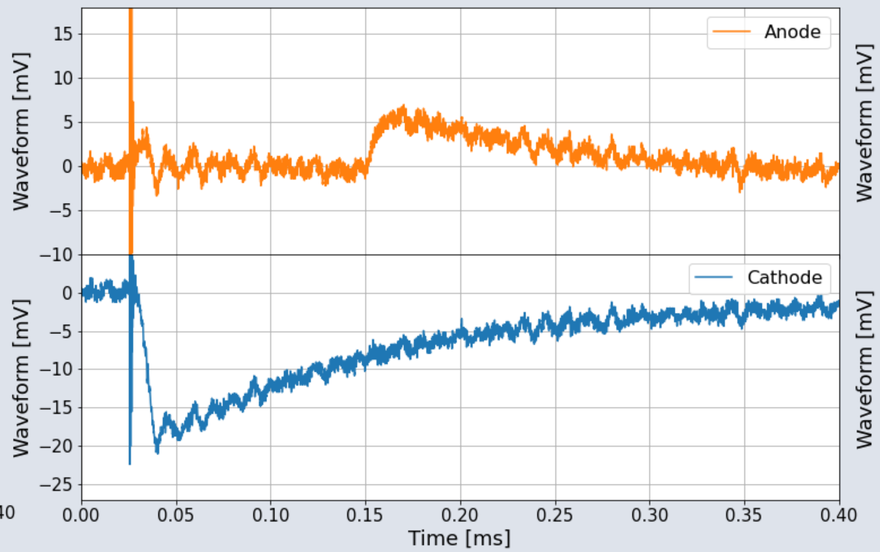
V Cathode (V)	V Cathode Grid (V)
-100	0 (Ground)

Run 23



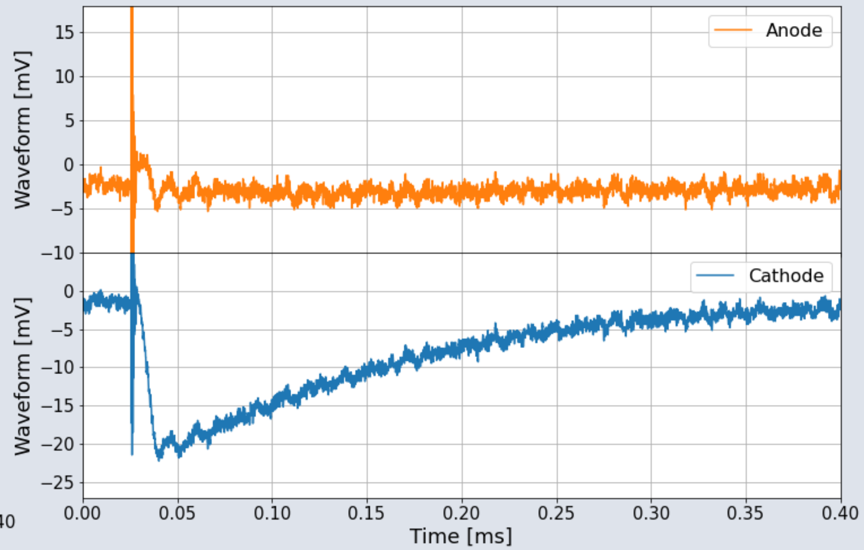
V Anode Grid (V)	V Anode (V)
3000	3000

Run 25



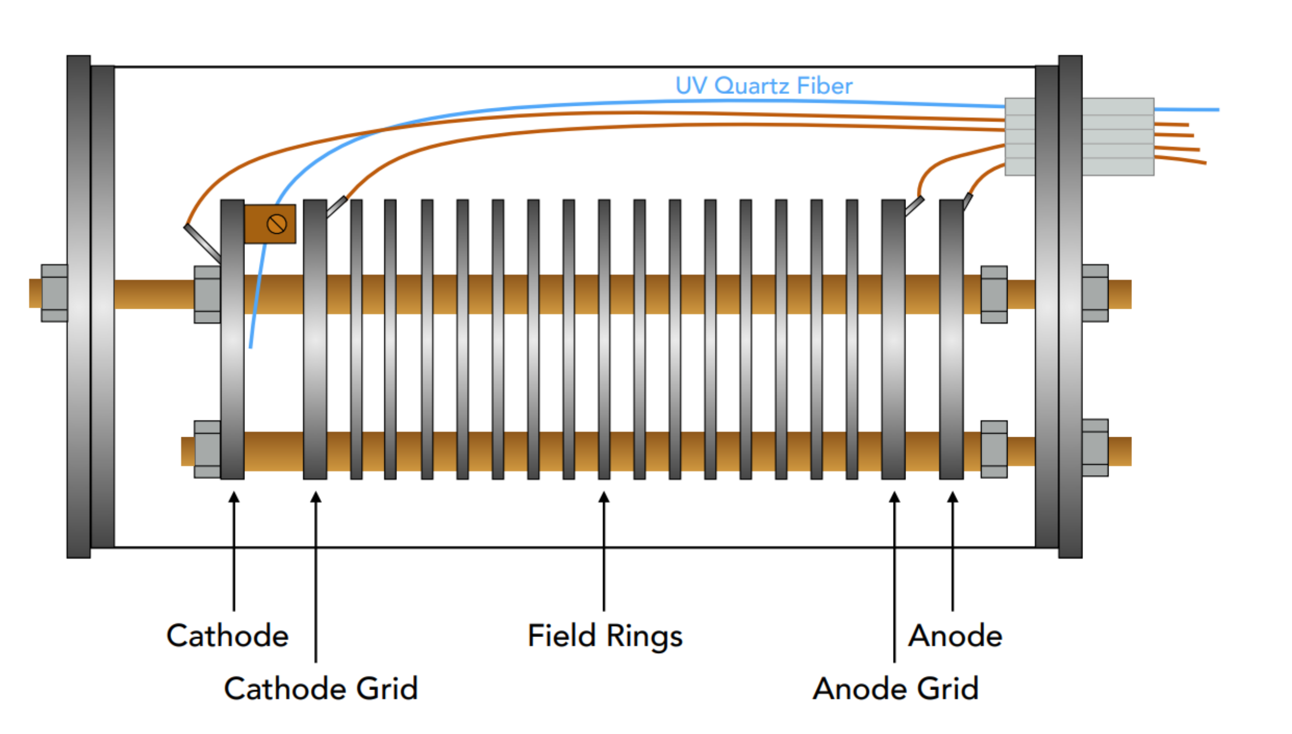
V Anode Grid (V)	V Anode (V)
3175	3000

Run 25

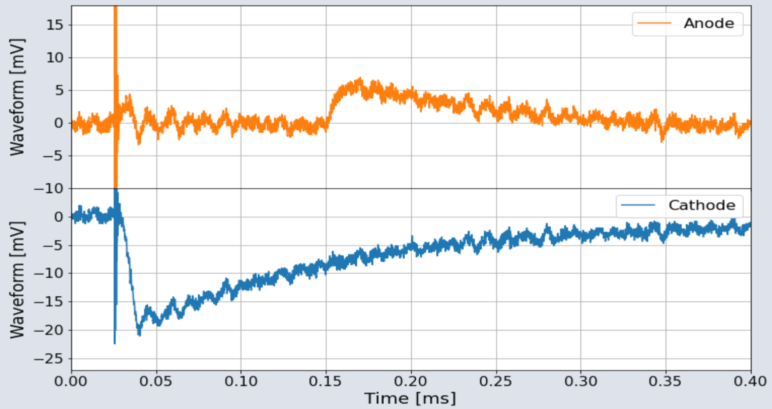


V Anode Grid (V)	V Anode (V)
3200	3000

PURITY MONITORS: WAVEFORMS



Run 25



- One of the possible interpretations is that the electric field is not strong enough to instantly stop electrons or to attract them back once they have passed the grid.
- Since the electrons arrive on the grid with a non-zero momentum, they keep on going forward and they are collected on the anode anyway.
- It is only when the anode grid voltage is greater than the anode one of about **200V** that no signal is observed on the anode.

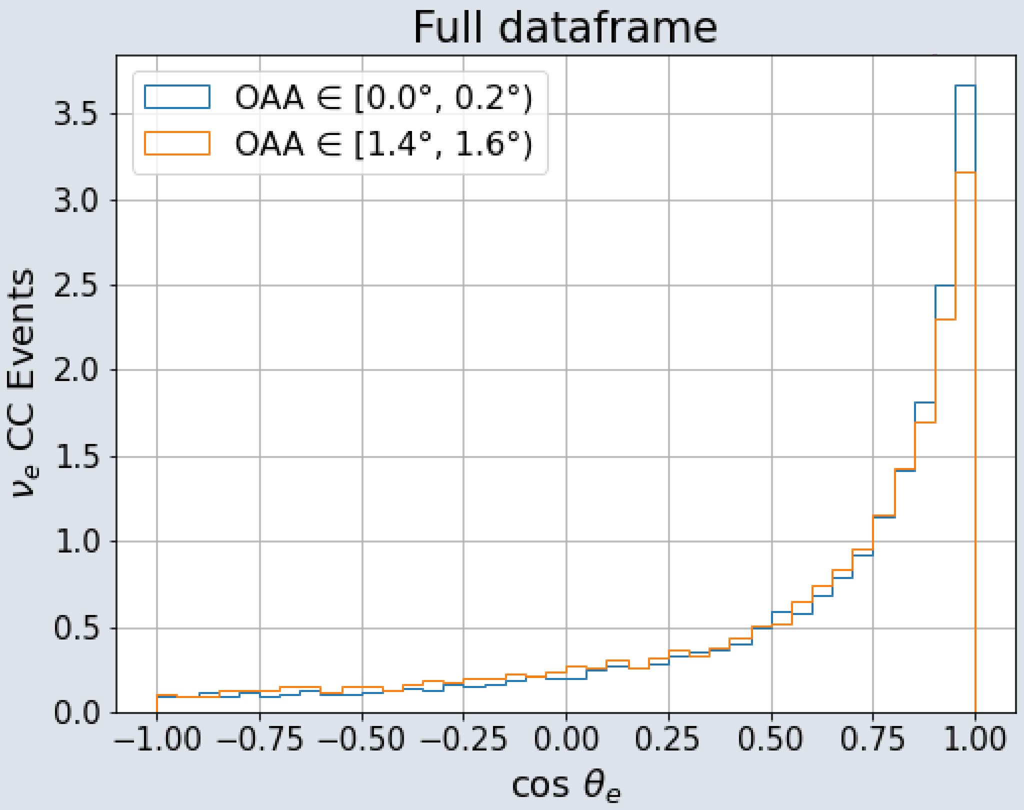
Thank You!

BACKUP

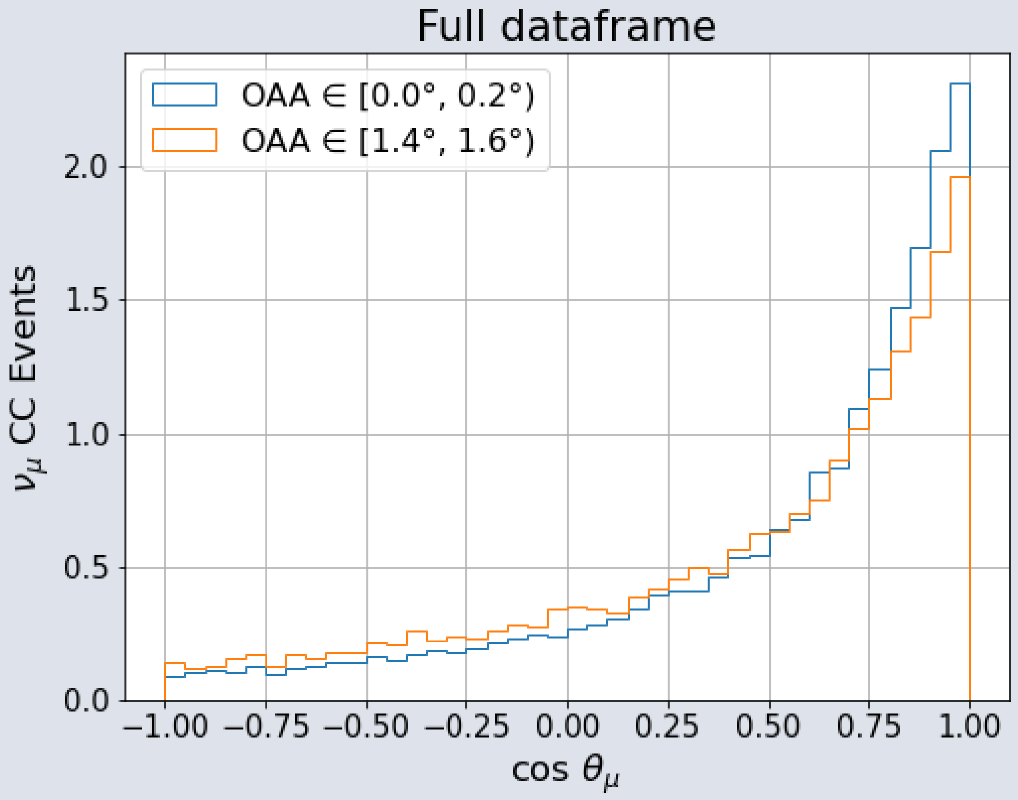
SBND PRISM: MOMENTUM AND SCATTERING ANGLE

Leptons' Scattering Angle Distributions

Electrons



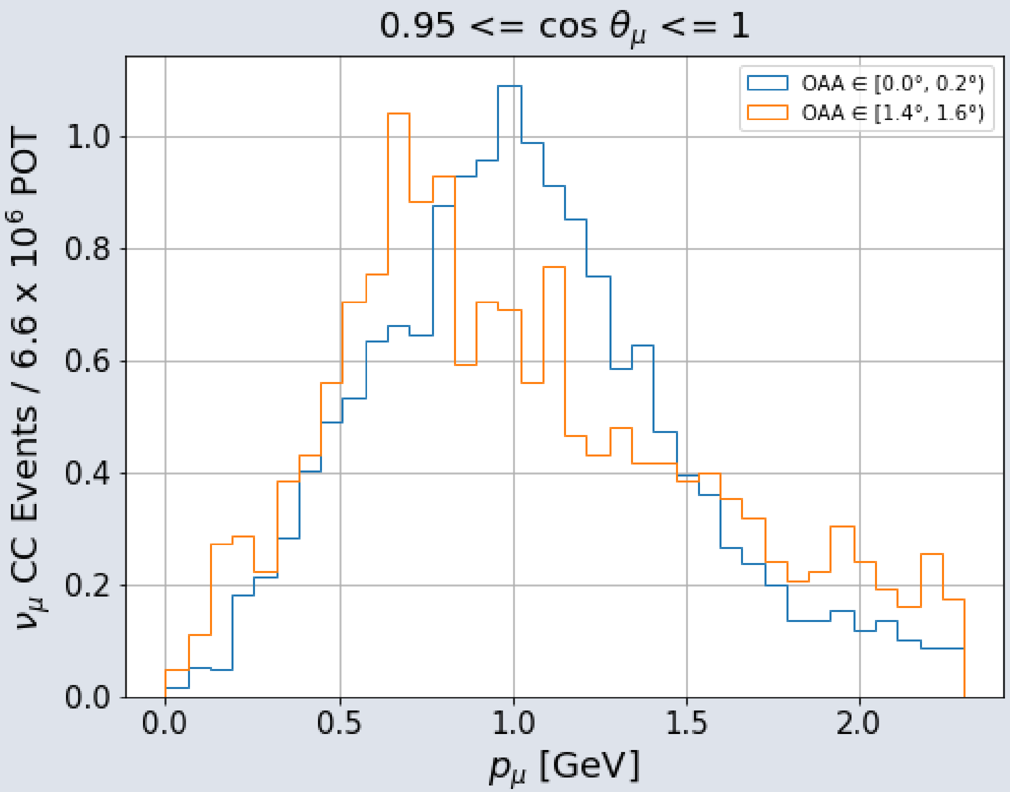
Muons

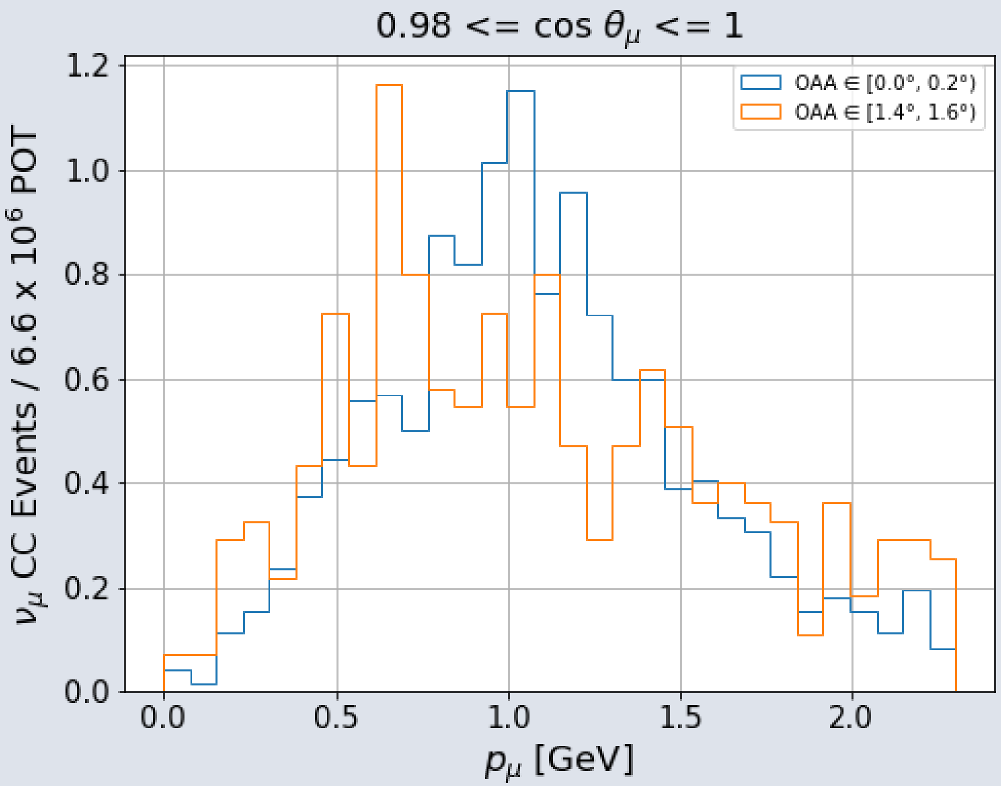


SBND PRISM: MOMENTUM AND SCATTERING ANGLE

Muon Momentum

(cosθ slicing)

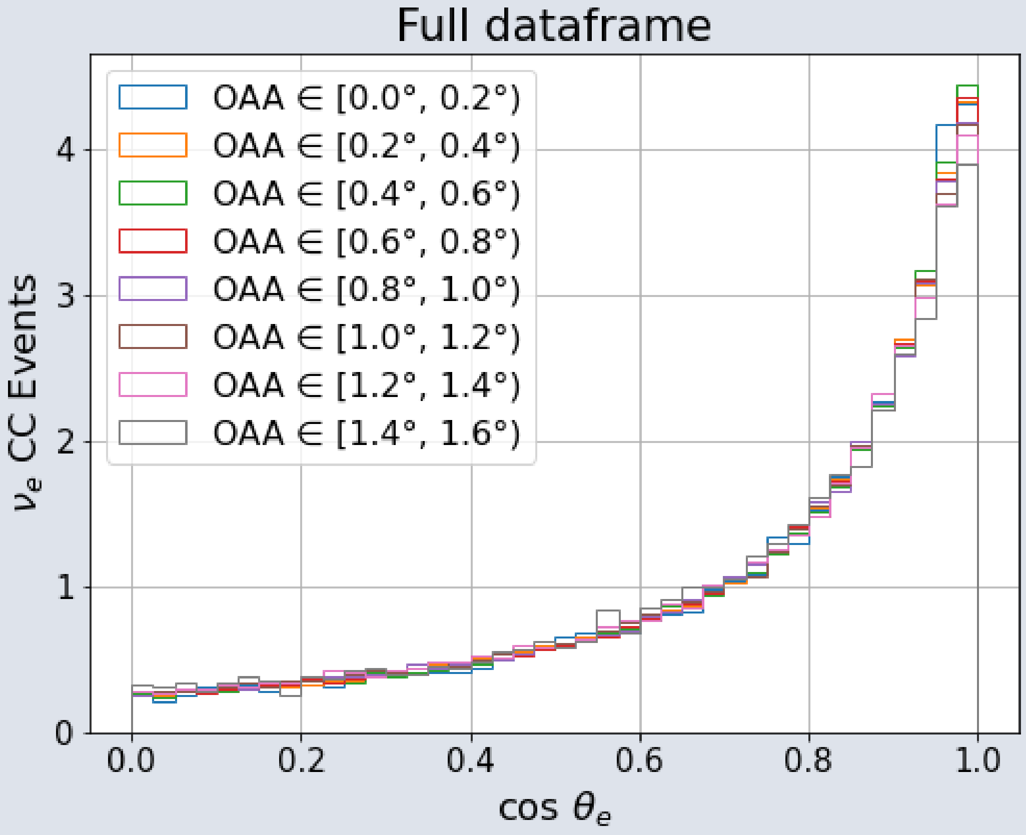




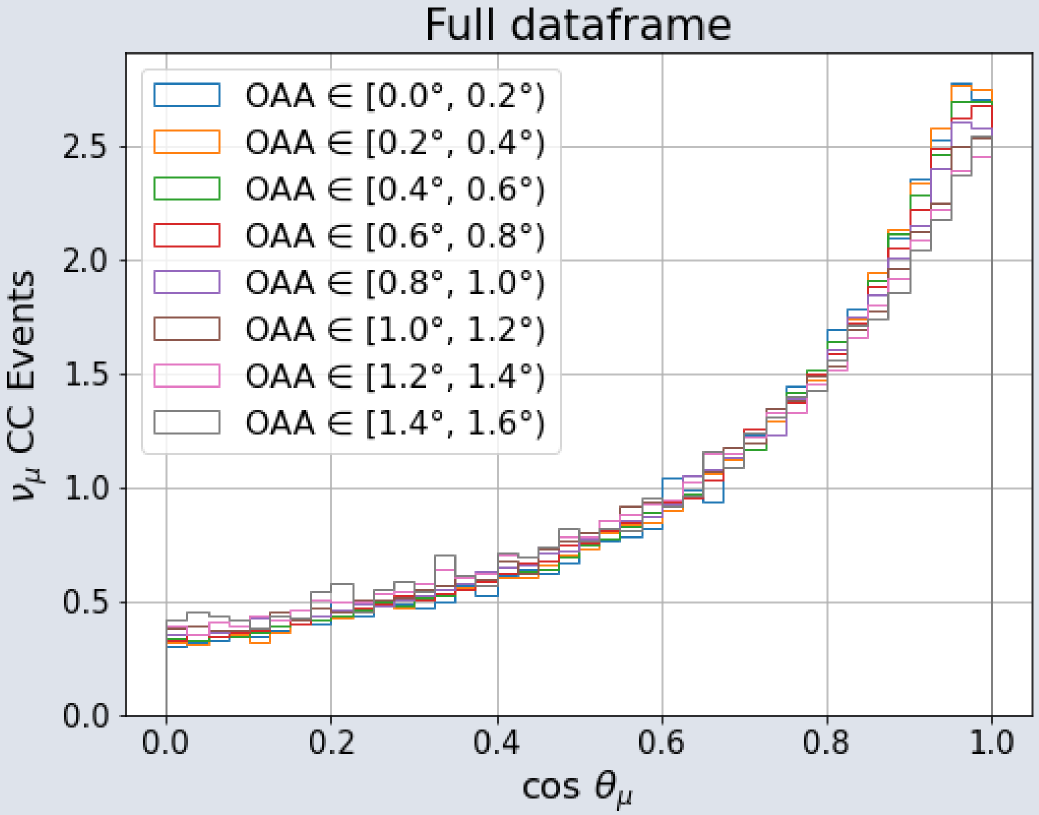
SBND PRISM: MOMENTUM AND SCATTERING ANGLE

Leptons' Scattering Angle Distributions

Electrons

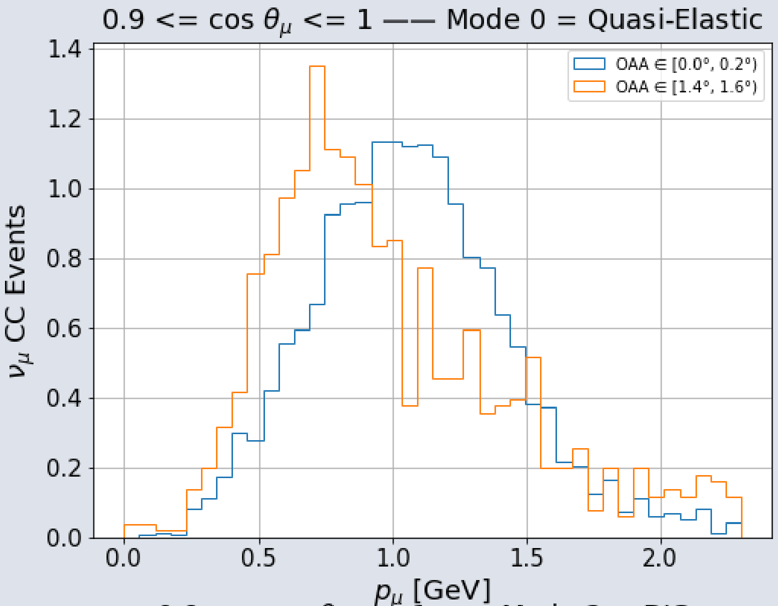


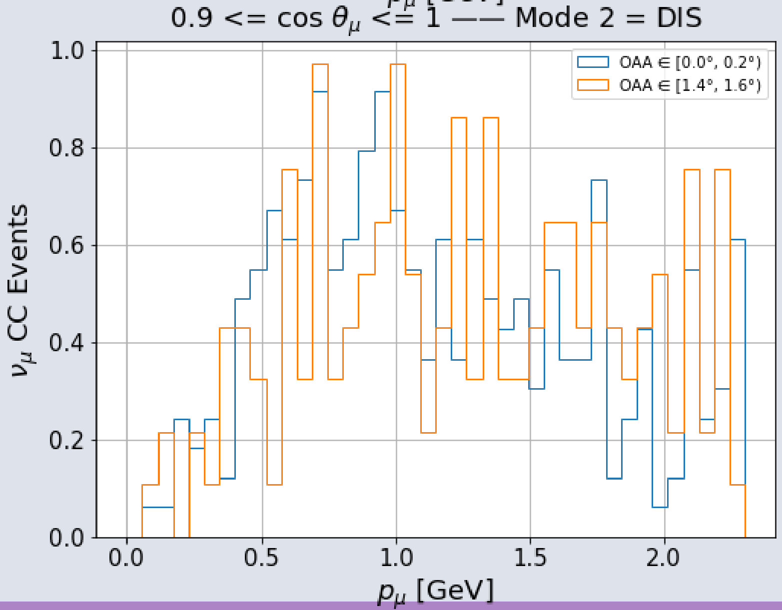
Muons

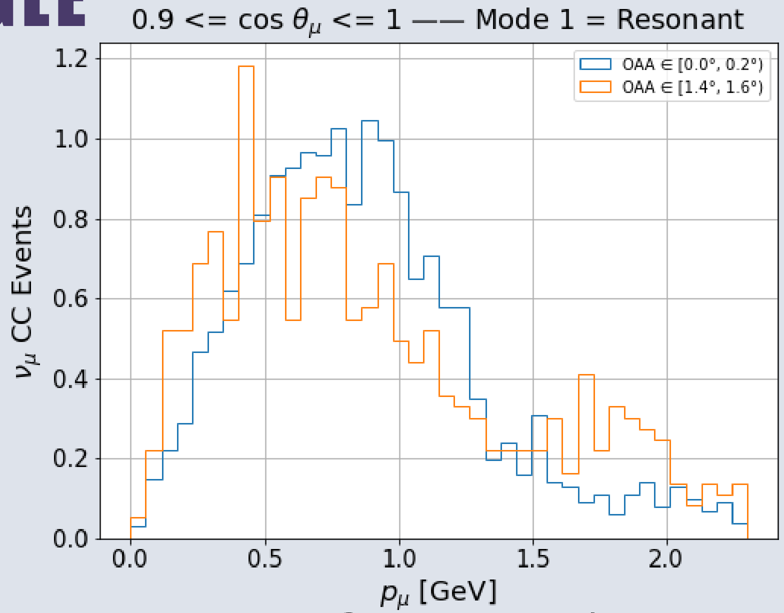


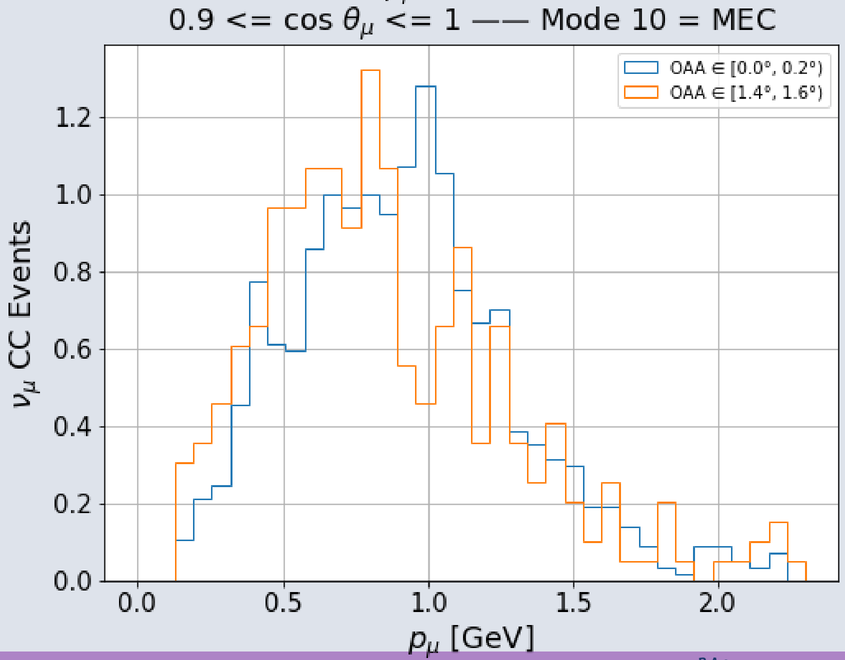
SBND PRISM: MOMENTUM AND SCATTERING ANGLE

Muons Momentum by interaction mode









PURITY MONITORS: ELECTRONICS