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EXPLOITING THE PRISM FEATURE OF THE SHORT BASELINE NEAR DETECTOR

MIDTERM REPORT

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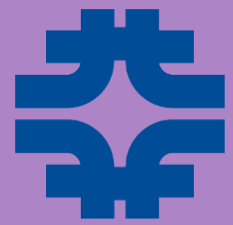
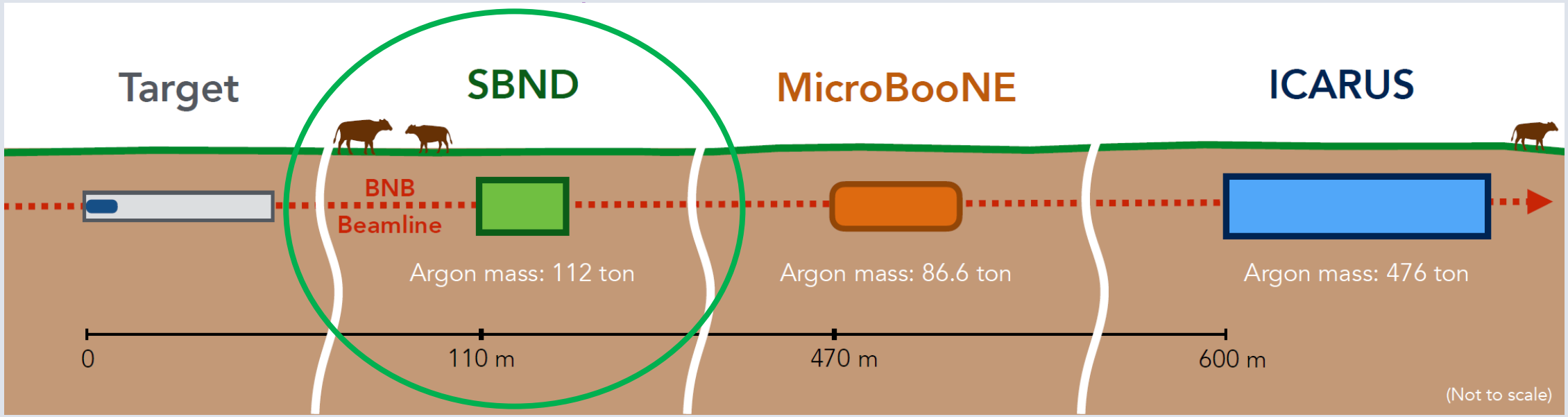


THE SHORT BASELINE NEUTRINO PROGRAM AT FERMILAB

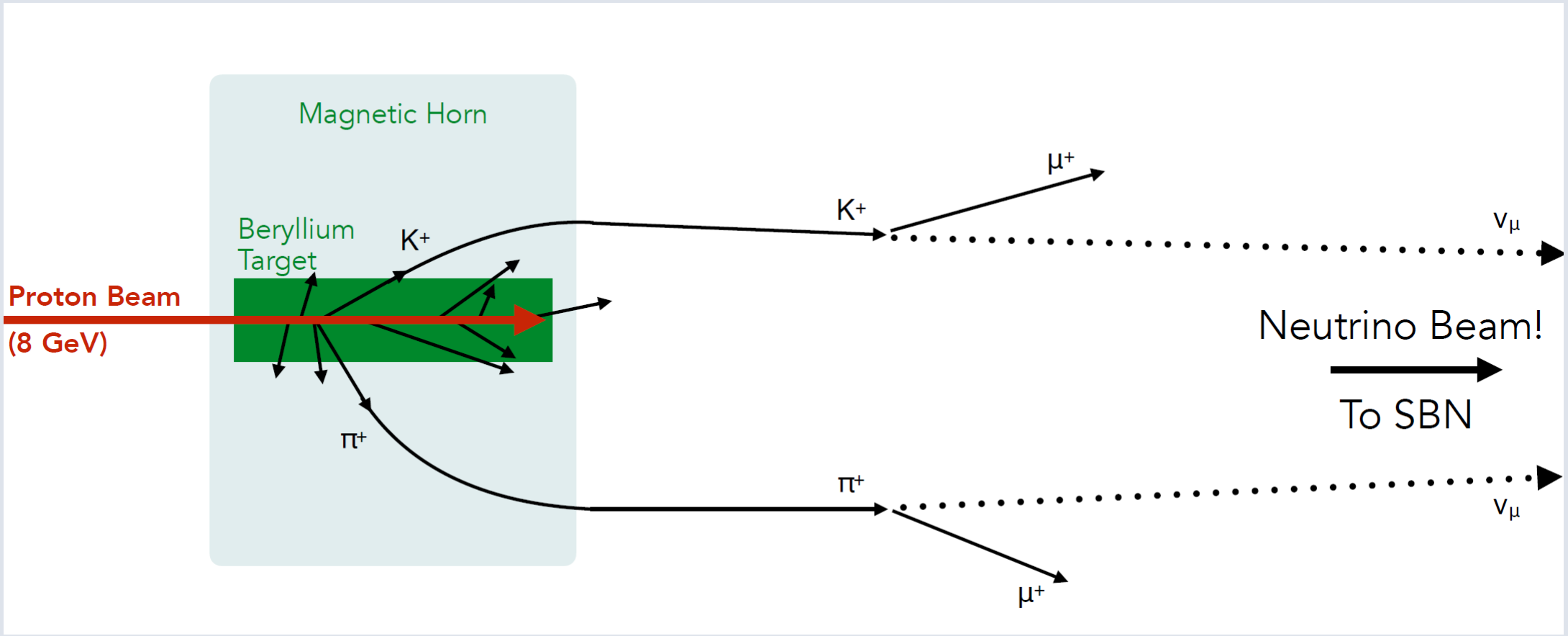
- Three Liquid Argon Time Projection Chamber (**LArTPC**) detectors located along the **Booster Neutrino Beamline** (**BNB**).

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

νμ

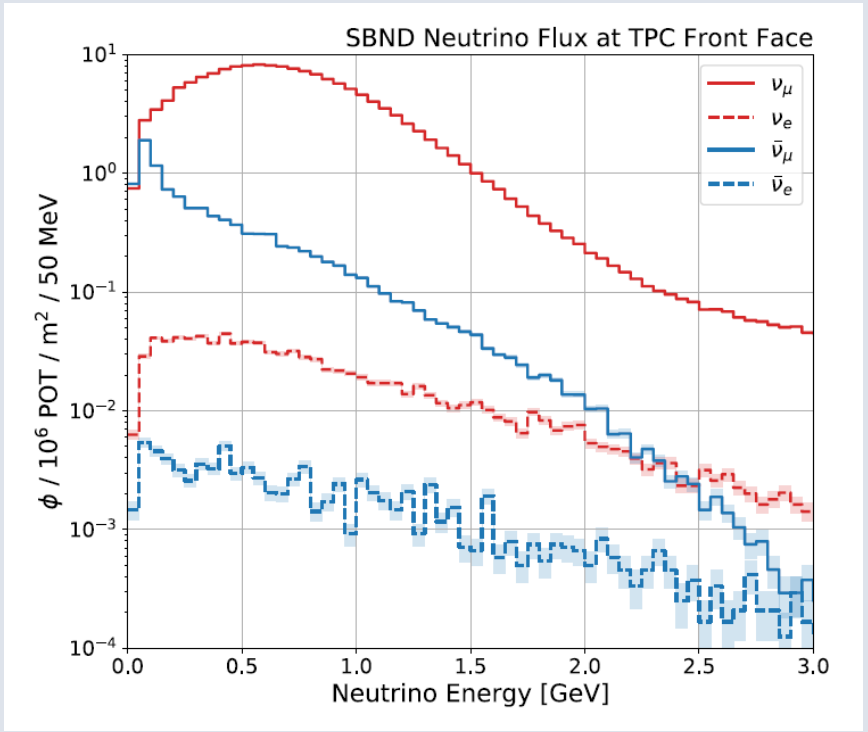
$$\pi^+ \rightarrow \nu_\mu + \mu^+$$
$$K^+ \rightarrow \nu_\mu + \mu^+$$

2-bodies decay
'Free' cinematics

νe

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

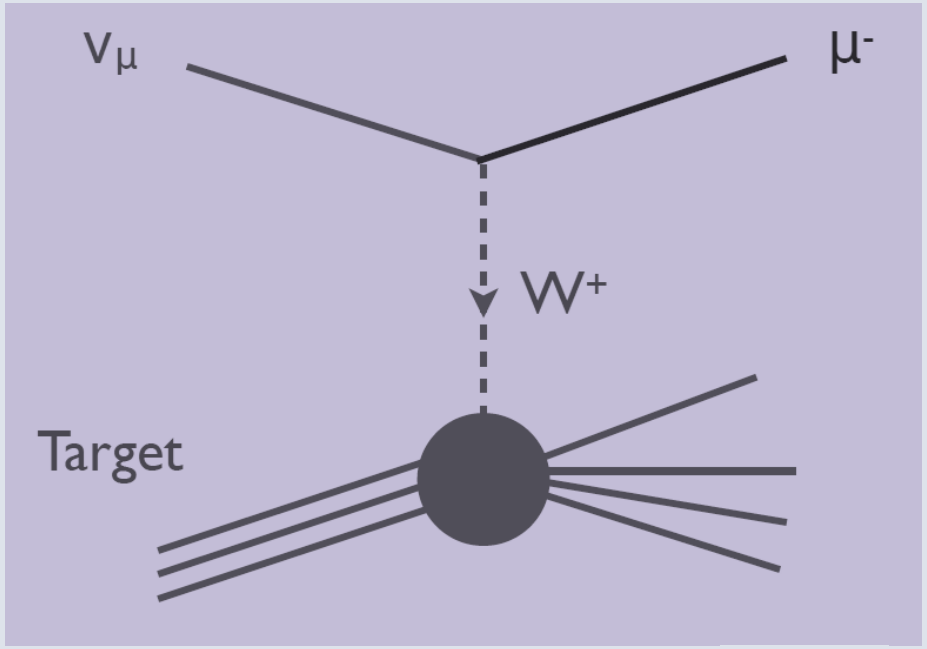
3-bodies decay
More constrained cinematics



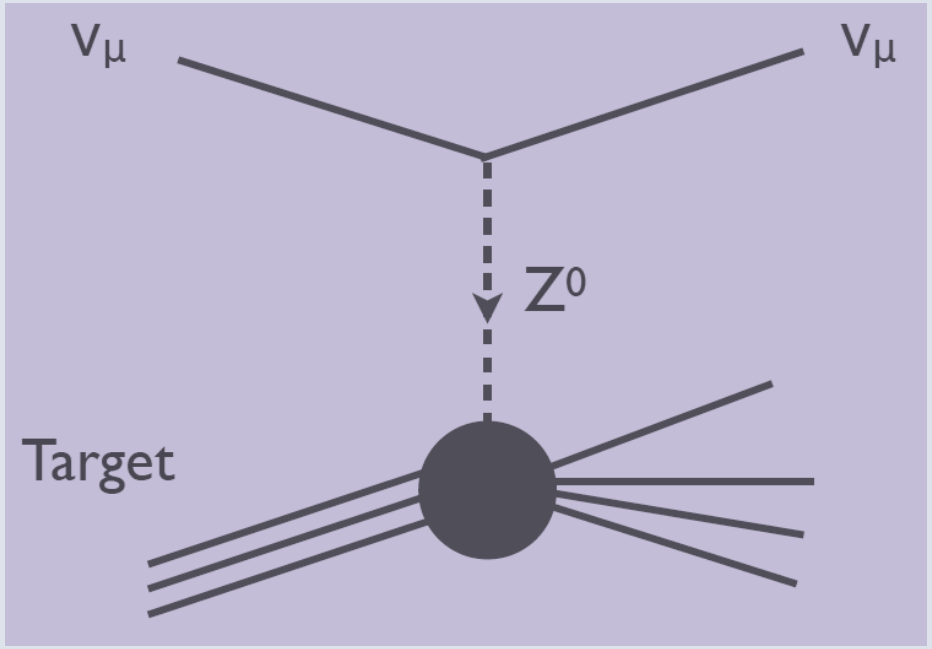
Neutrino flux at the SBND front face

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

NEUTRINO INTERACTIONS

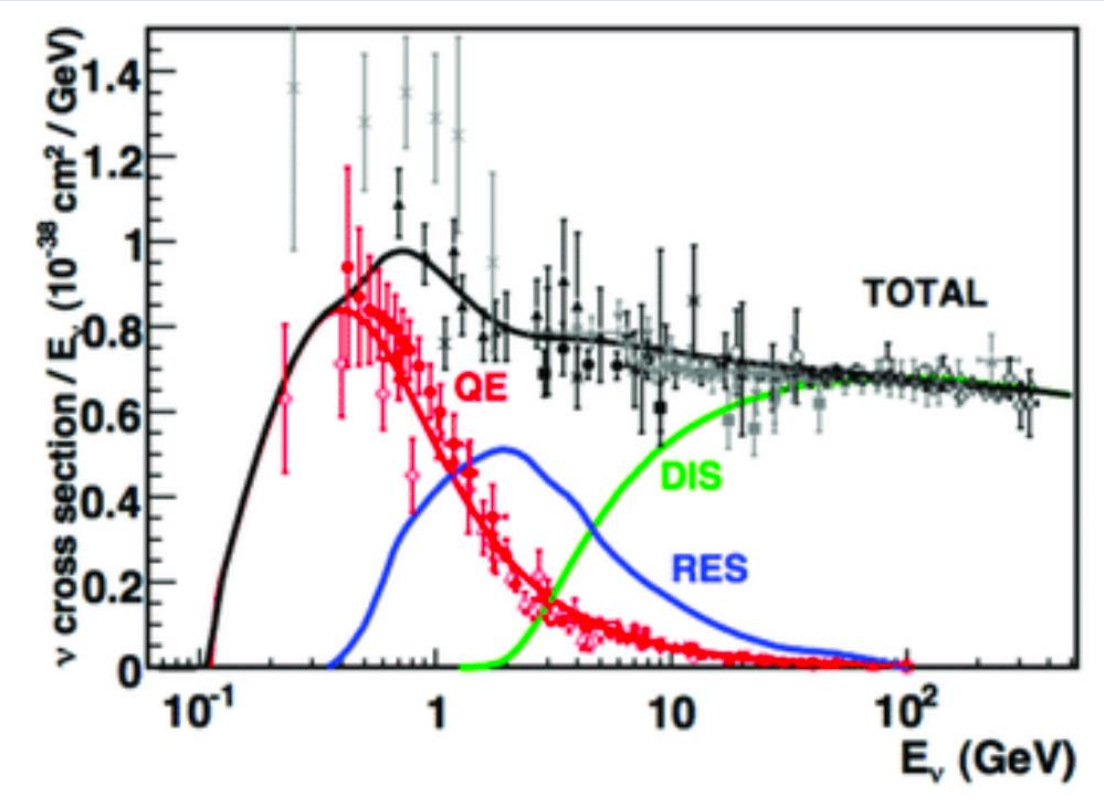


Charged Current

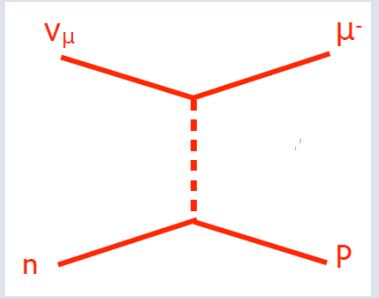


Neutral Current

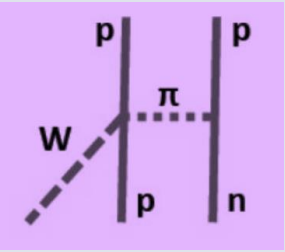
NEUTRINO INTERACTION MODES



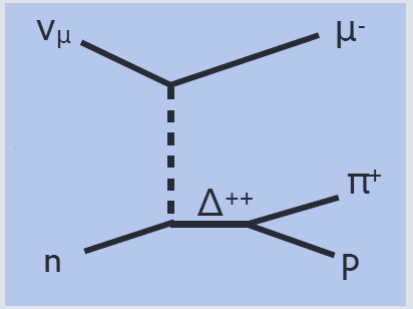
1. Quasi Elastic Interaction



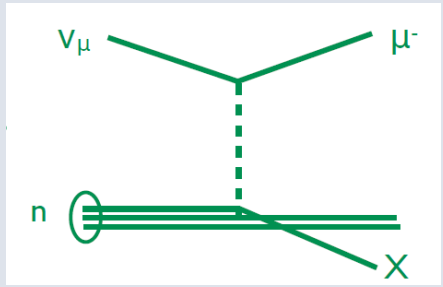
2. Meson Exchange Current



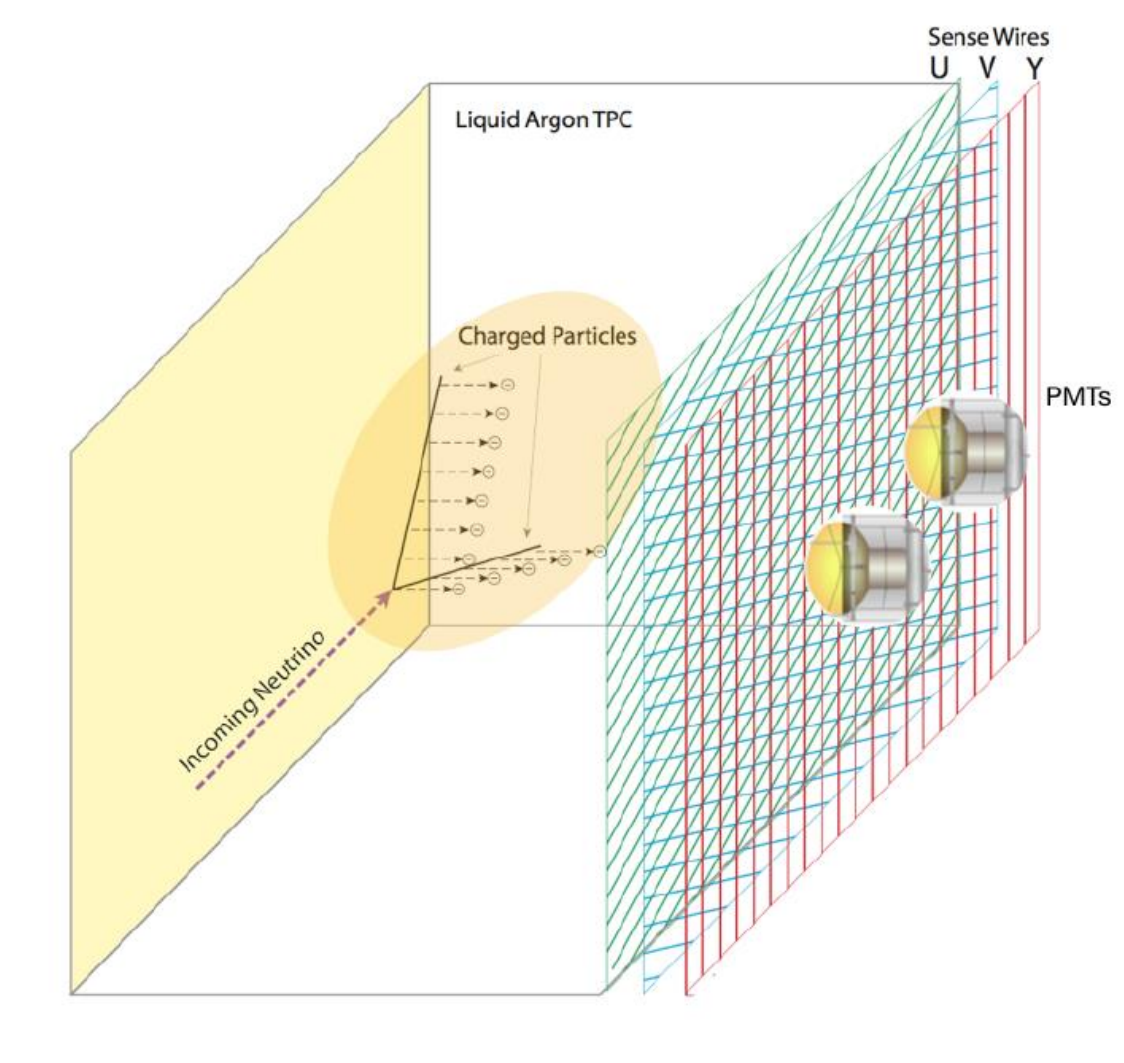
3. Resonant Interaction



4. Deep Inelastic Scattering



DETECTING NEUTRINOS: LARTPCS



- Uniform Electric Field

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

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

Sense Wires

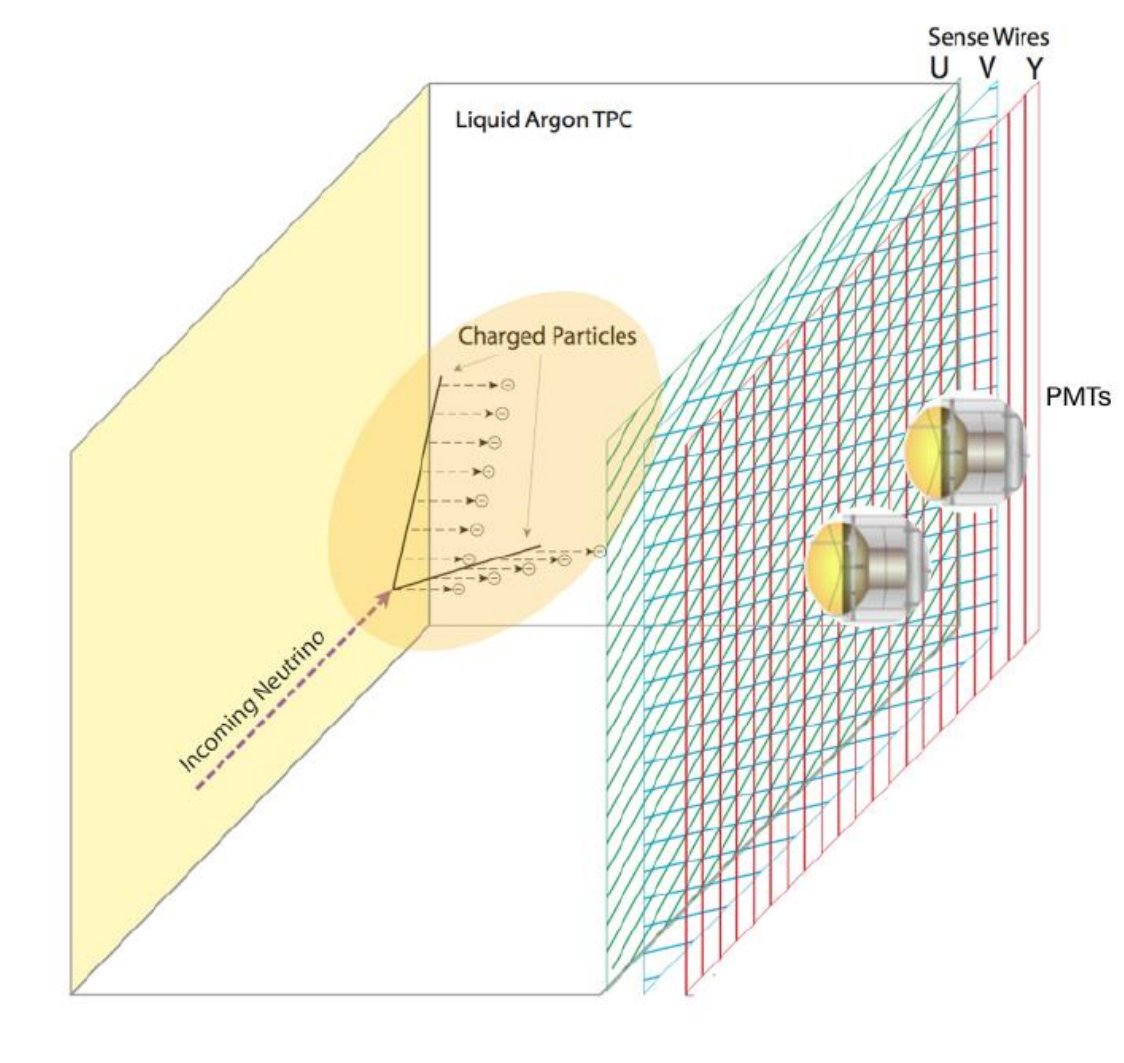
3 wire planes: a vertical one and two rotated by 60° one to another to achieve 3D tracks recostruction

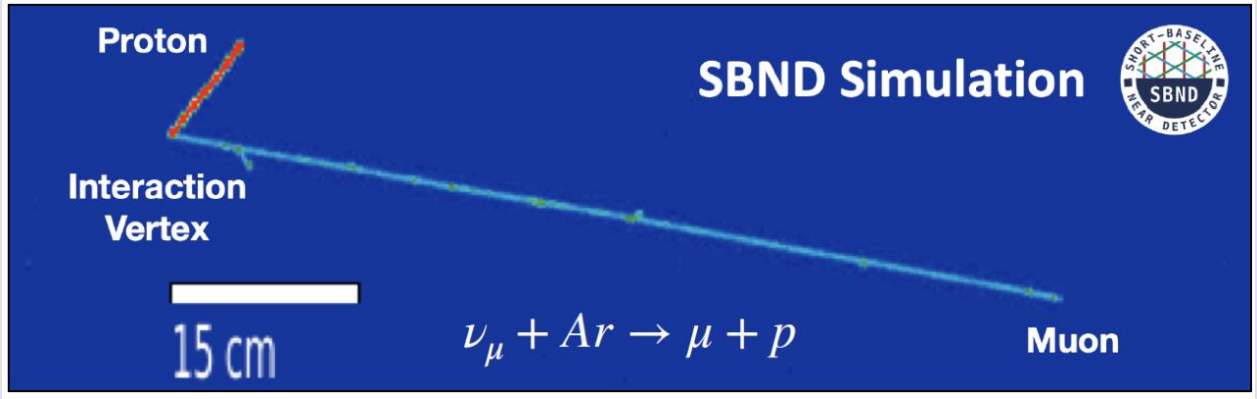
PDS

fast response time O(10 ns), which provides signals for triggering

- 3D Imaging
- Geometrical & Calorimetrical Recostruction

DETECTING NEUTRINOS: LARTPCS





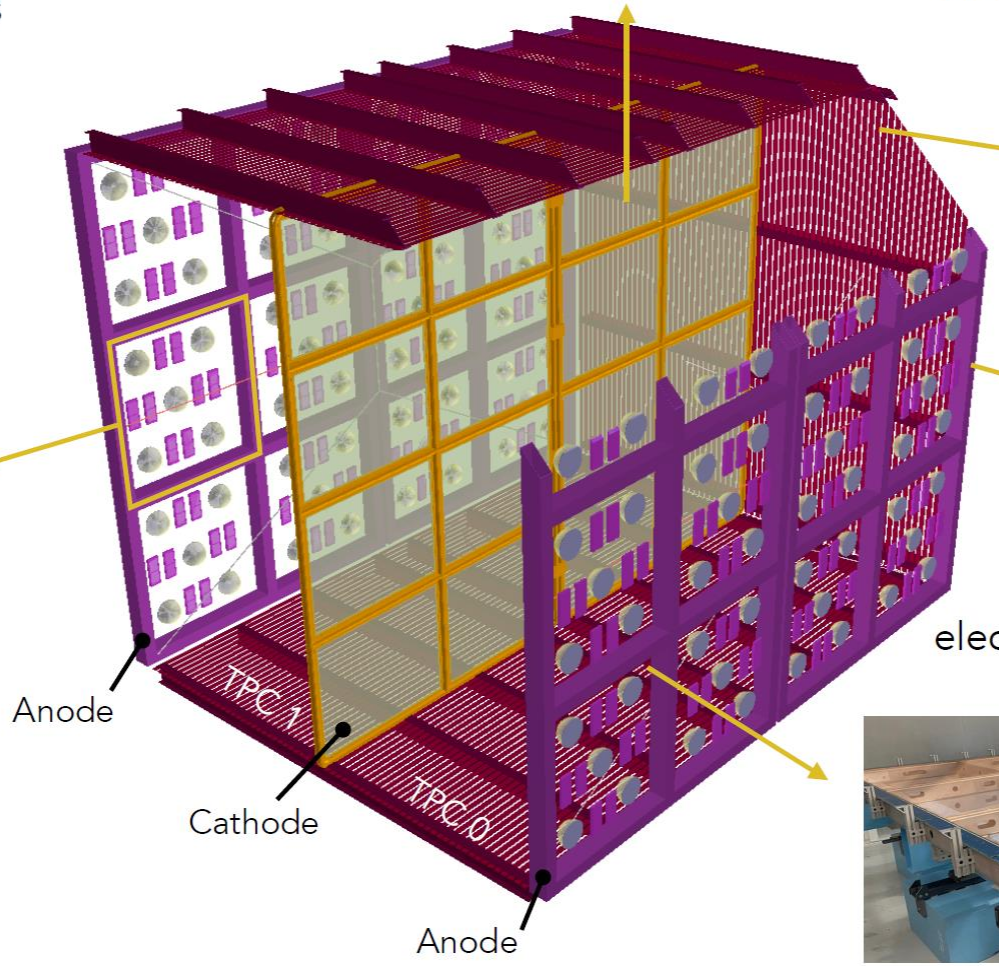
- 3D Imaging
- Geometrical & Calorimetrical Recostruction

DETECTING NEUTRINOS: LARTPCS

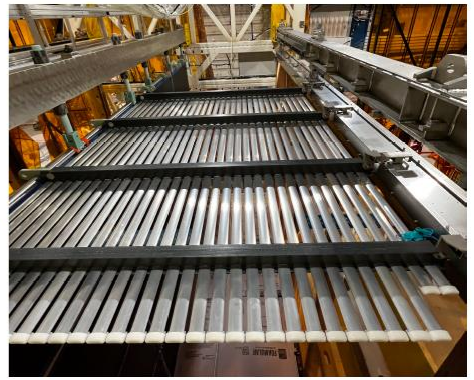
2 Time Projection Chambers
for a total of 4m x 4m x 5m

Photo Detection System:
120 PMTs
192 X-Arapucas

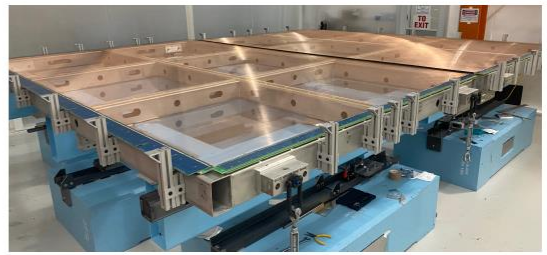
Cathode covered with TPB coated reflectors



Field Cage



Cold electronics

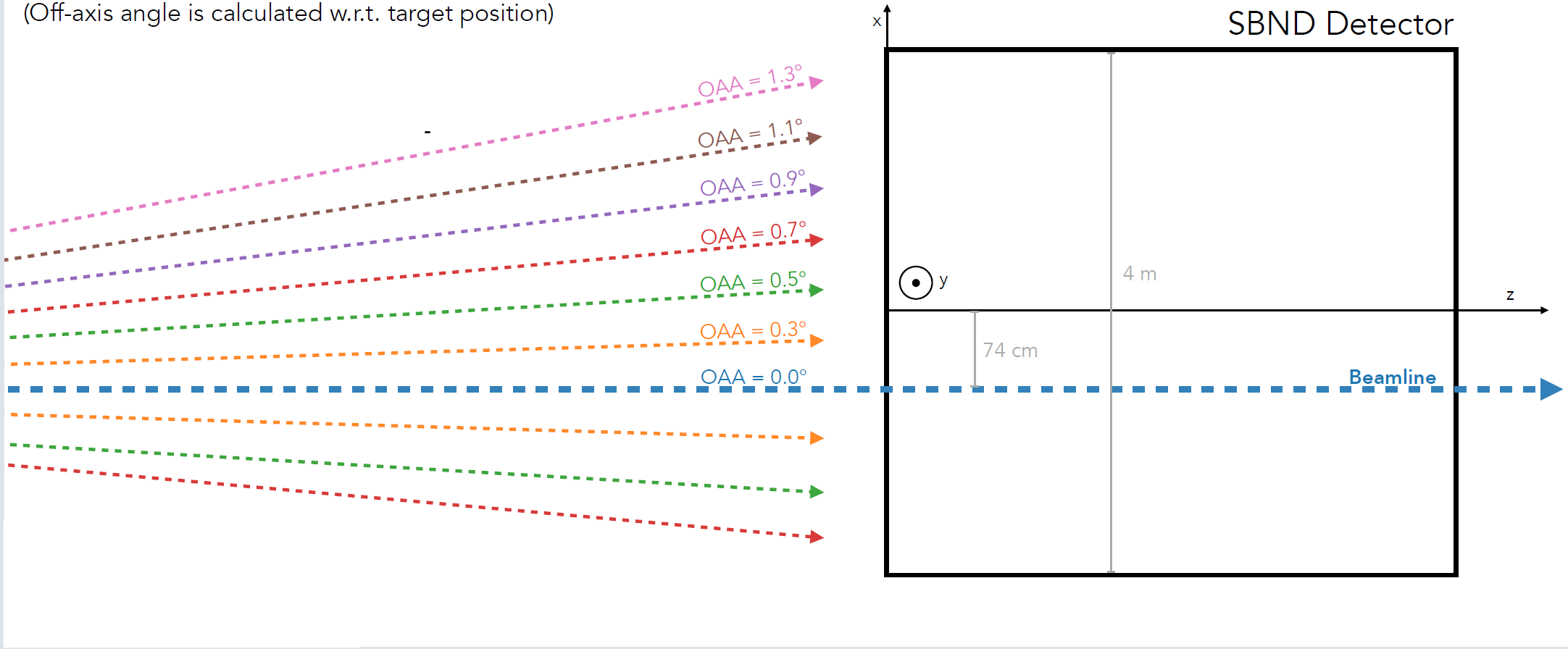


Wire Plane
3 readout wire planes
~11000 wires

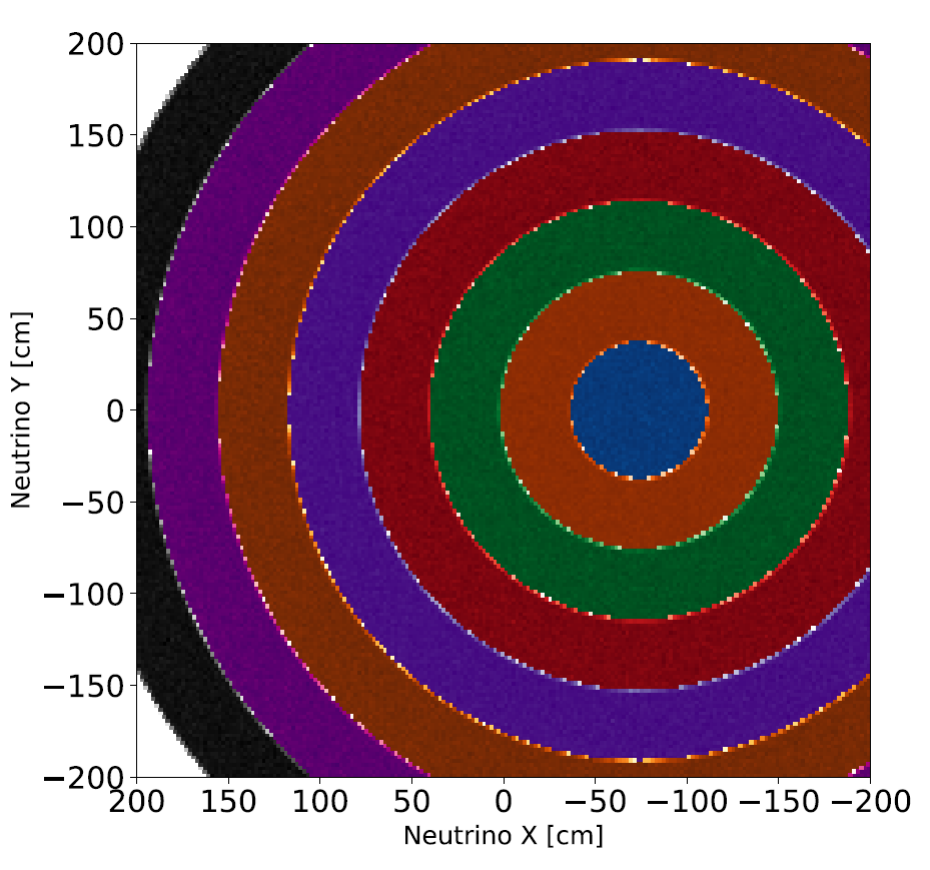
SBND DETECTOR: OFF-AXIS ANGLES

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

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



SBND DETECTOR: OFF-AXIS ANGLES



OAA ∈ [0.0°, 0.2°)

OAA ∈ [0.2°, 0.4°)

OAA ∈ [0.4°, 0.6°)

OAA ∈ [0.6°, 0.8°)

OAA ∈ [0.8°, 1.0°)

OAA ∈ [1.0°, 1.2°)

OAA ∈ [1.2°, 1.4°)

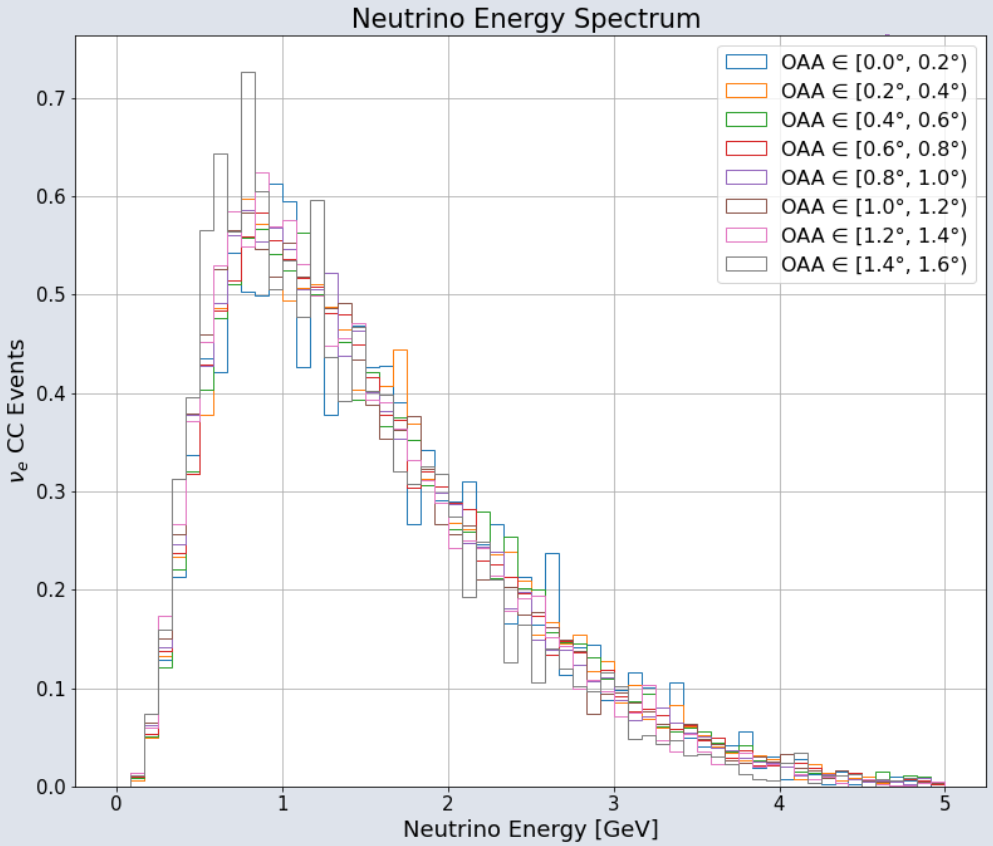
OAA ∈ [1.4°, 1.6°)

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

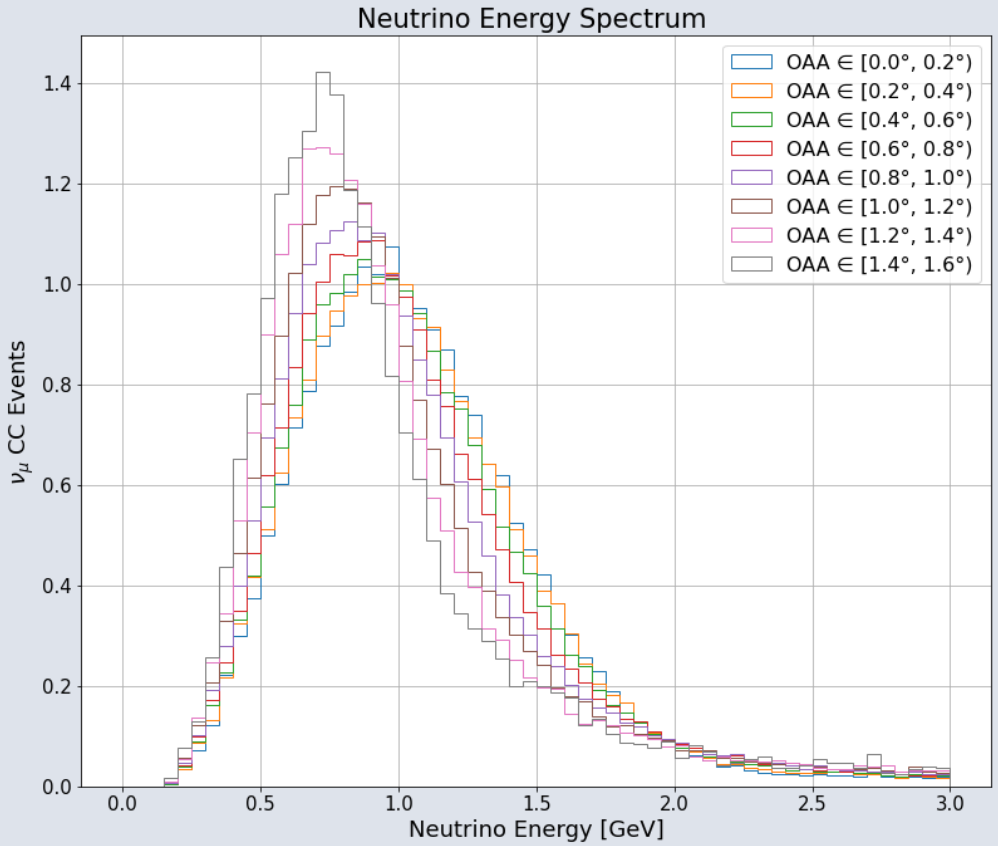
SBND PRISM Precision Reaction Independent Spectrum Measurement

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 Neutrino

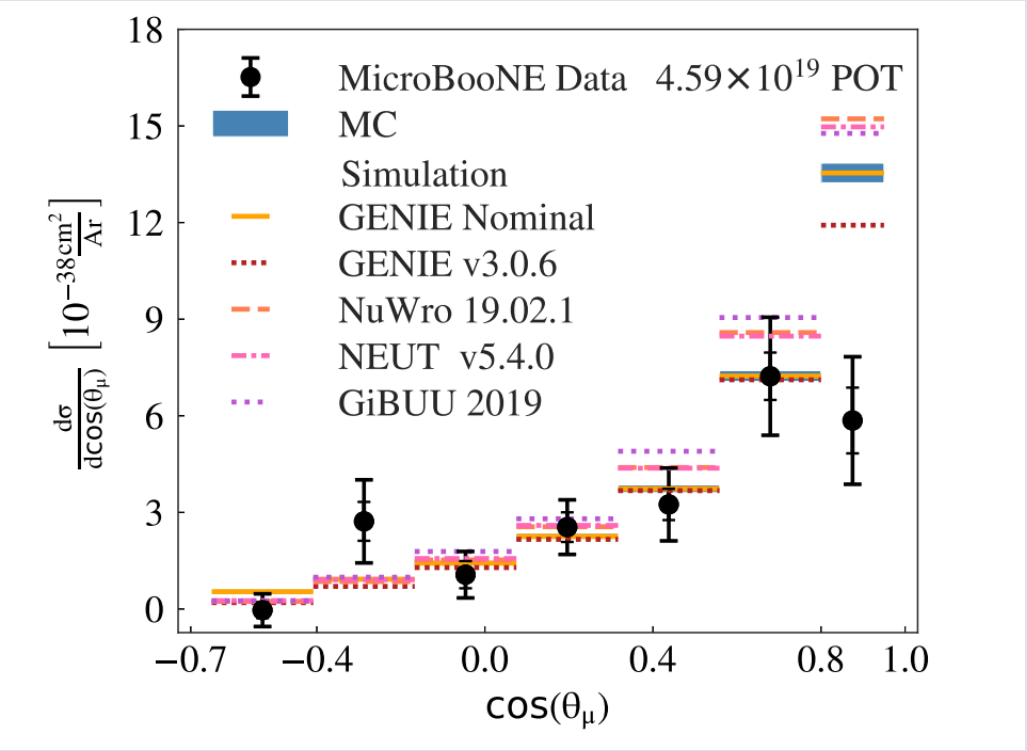


Muon Neutrino

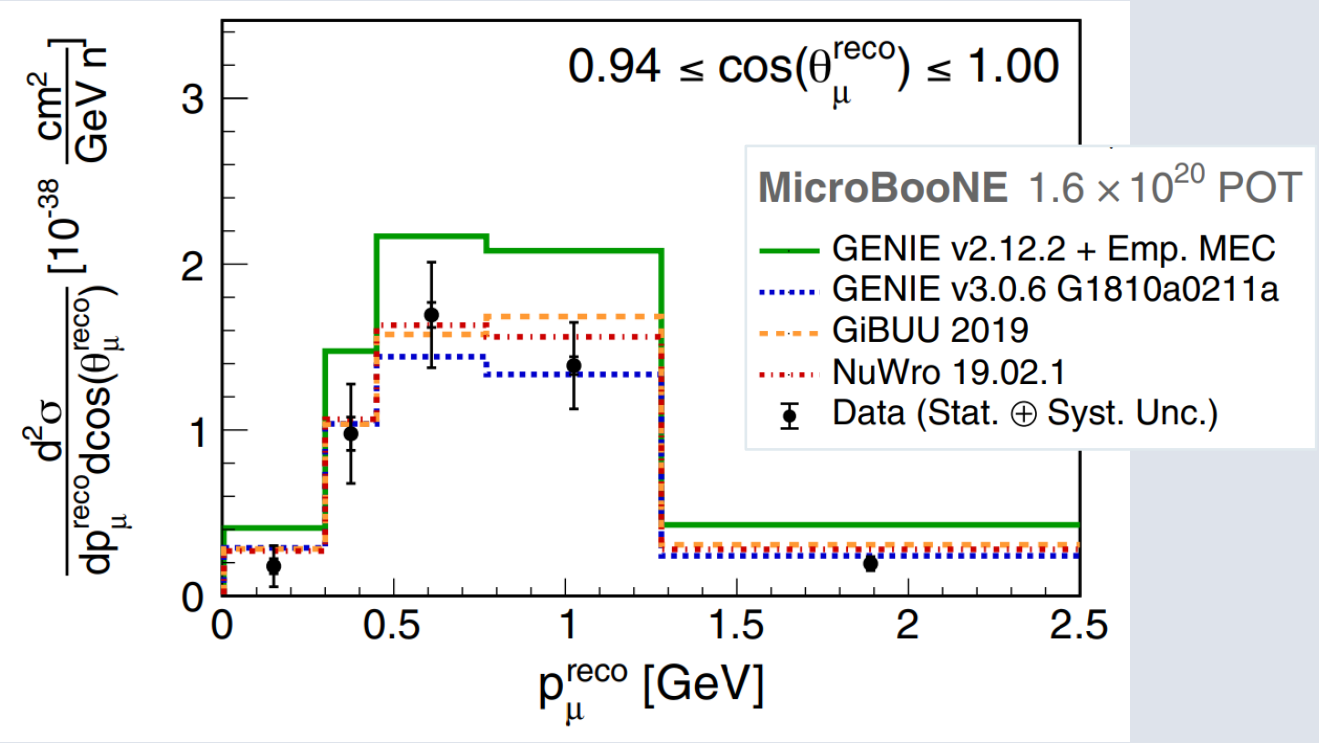


WHAT CAN WE IMPROVE?

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



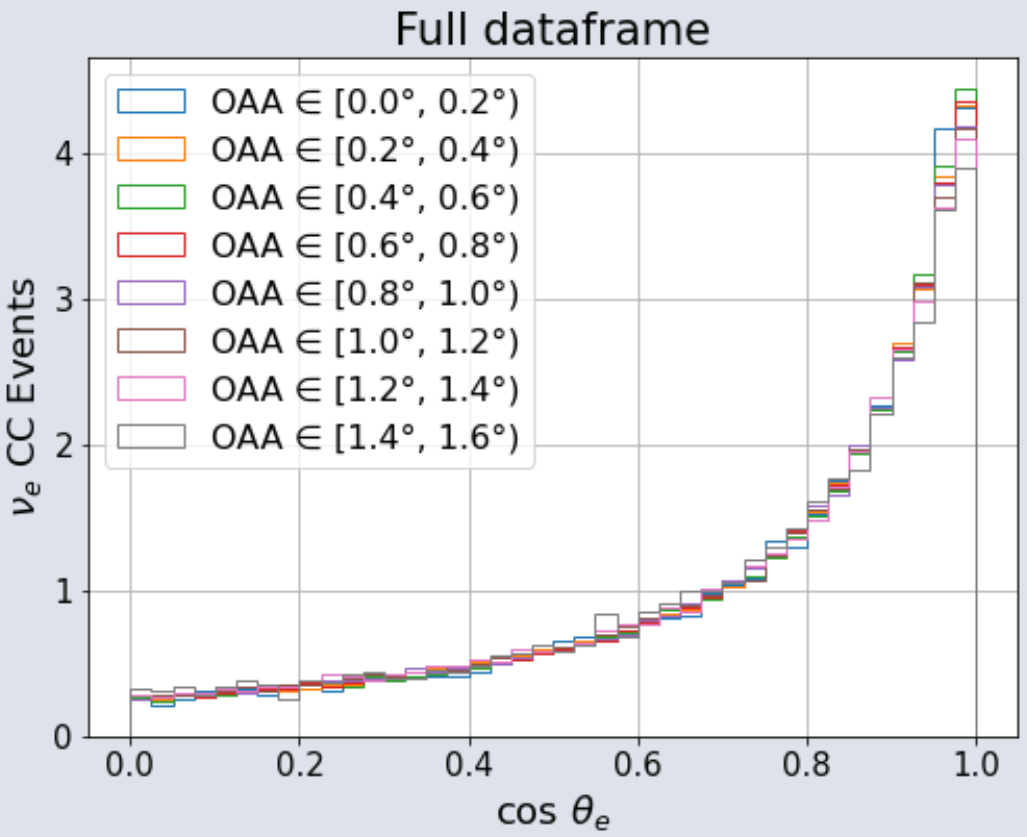
(P. Abratenko *et al.* (MicroBooNE Collaboration) Phys. Rev. Lett. **123**, 131801)



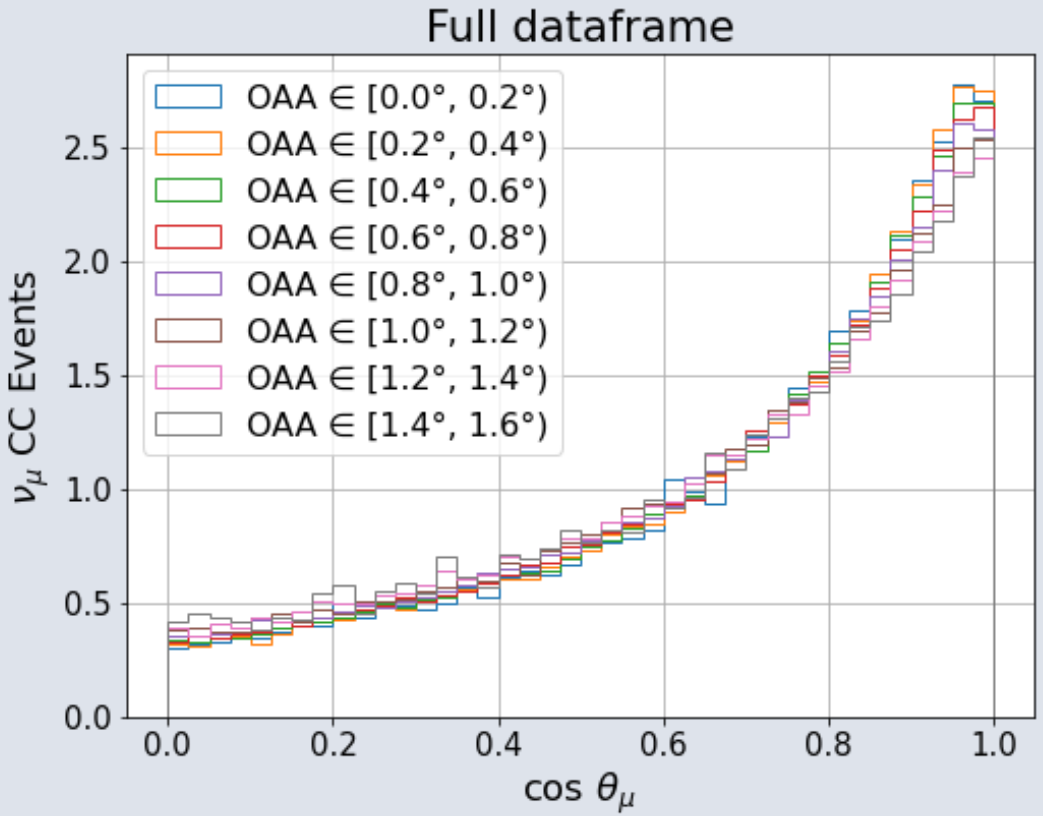
SBND PRISM: MOMENTUM AND SCATTERING ANGLE

Leptons' Scattering Angle Distributions

Electrons



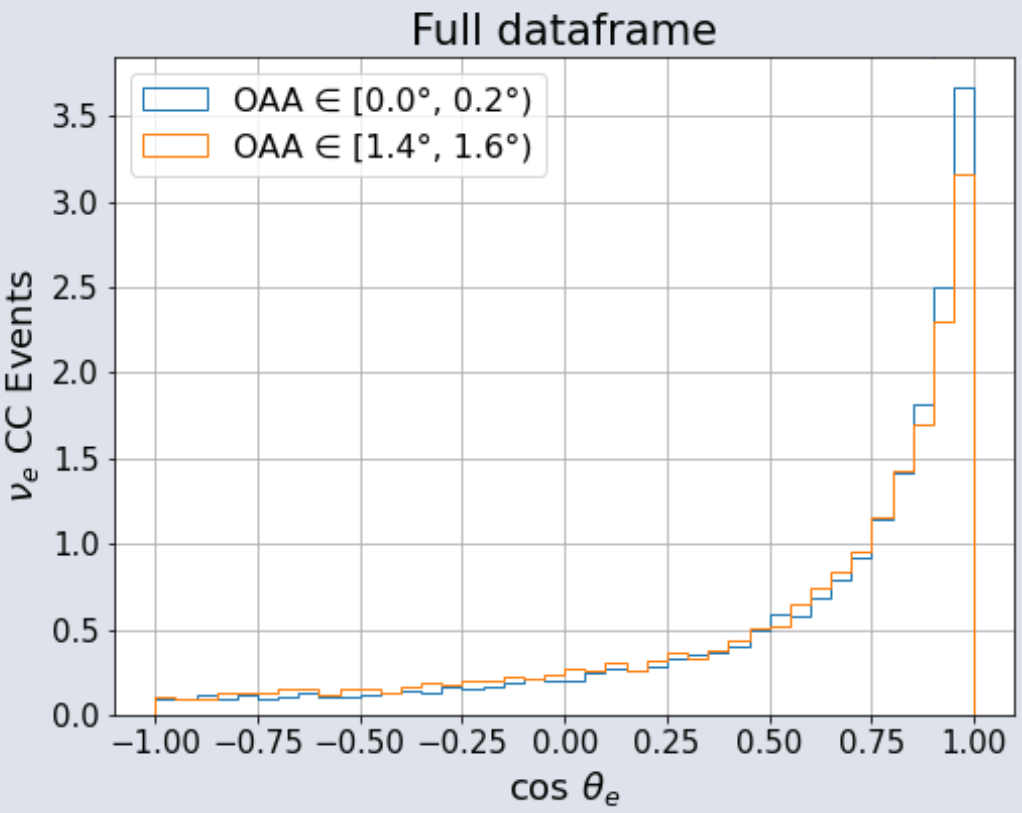
Muons



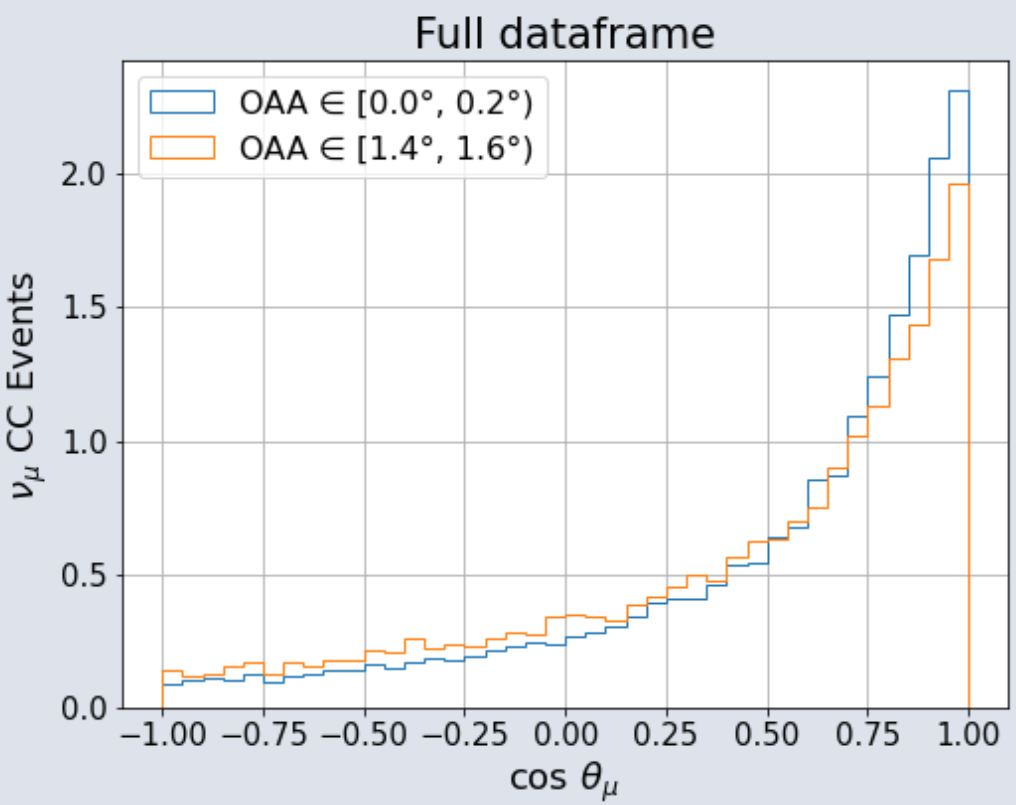
SBND PRISM: MOMENTUM AND SCATTERING ANGLE

Leptons' Scattering Angle Distributions

Electrons



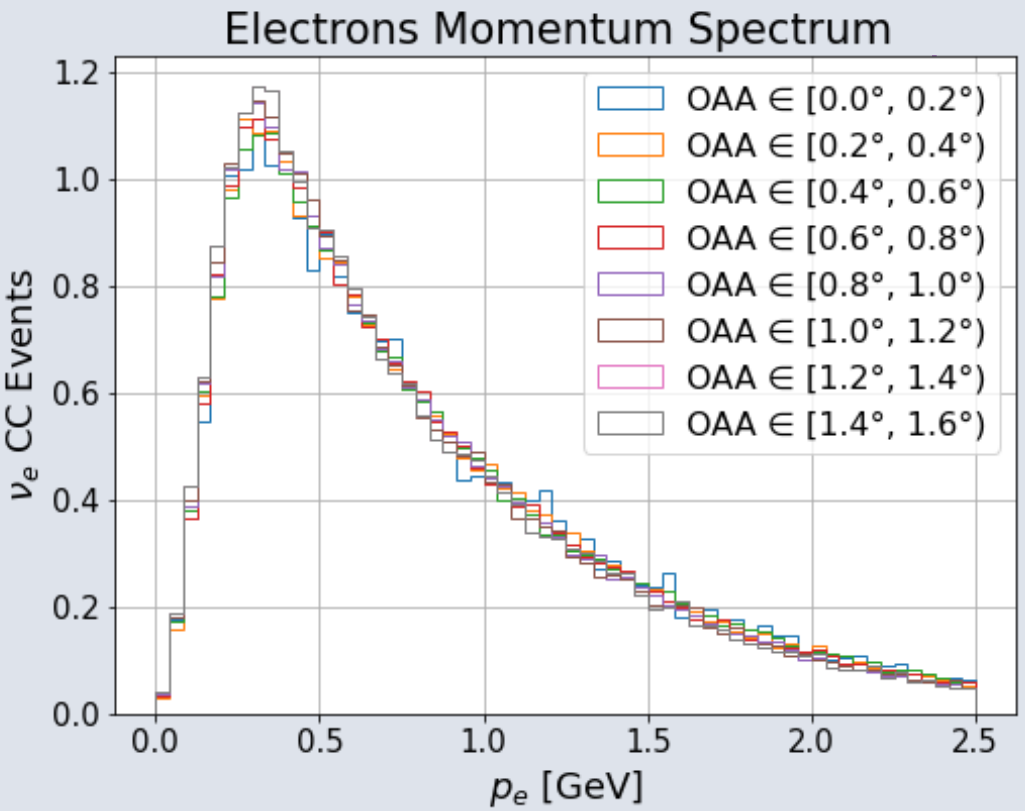
Muons



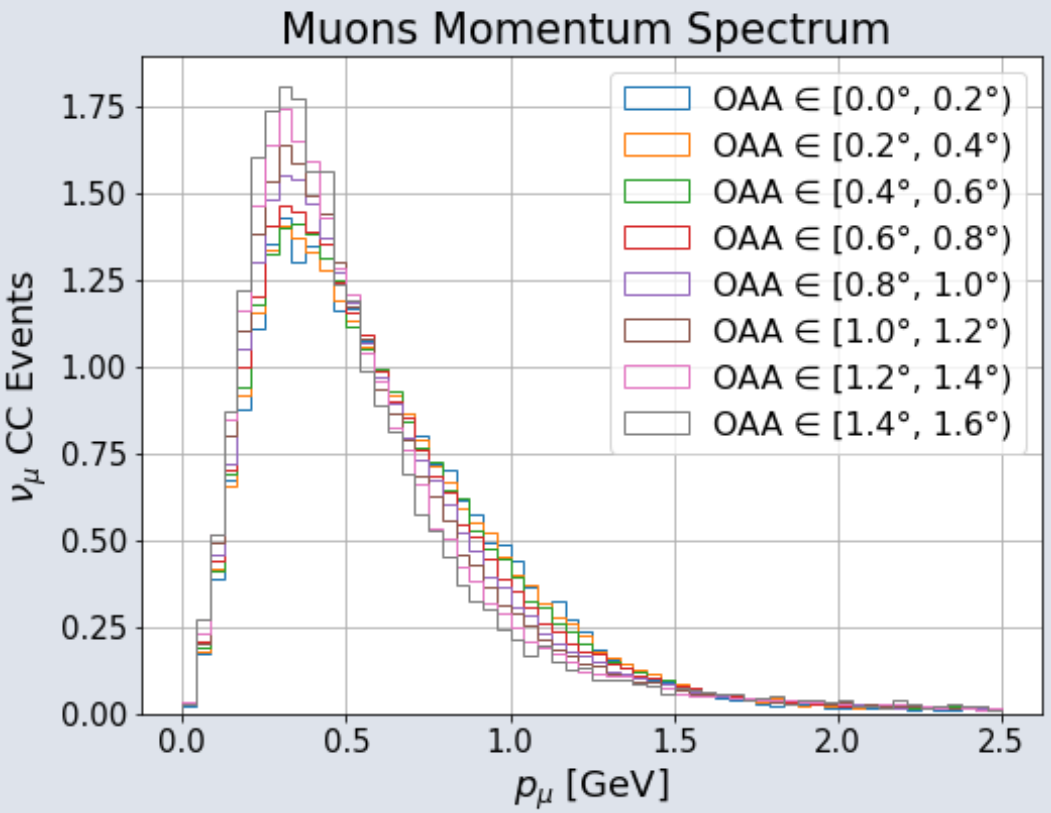
SBND PRISM: MOMENTUM AND SCATTERING ANGLE

Leptons' Momentum Distributions

Electrons



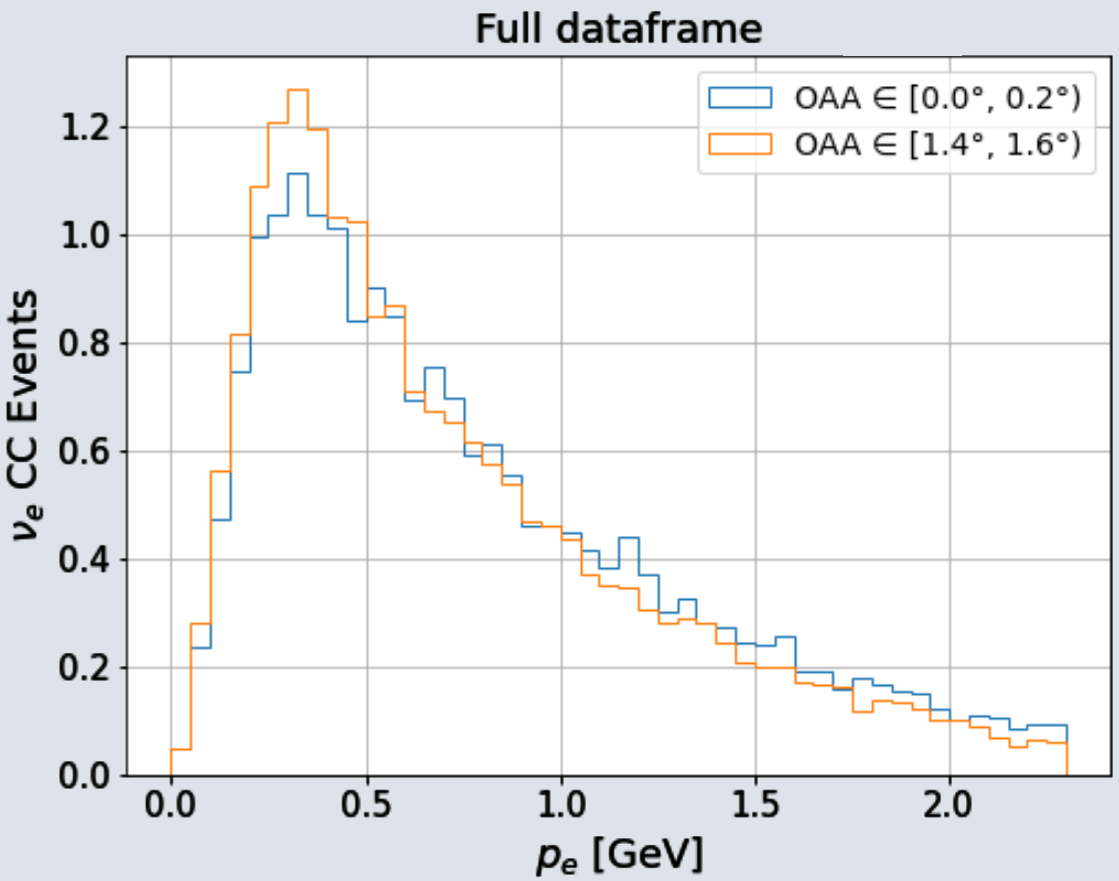
Muons



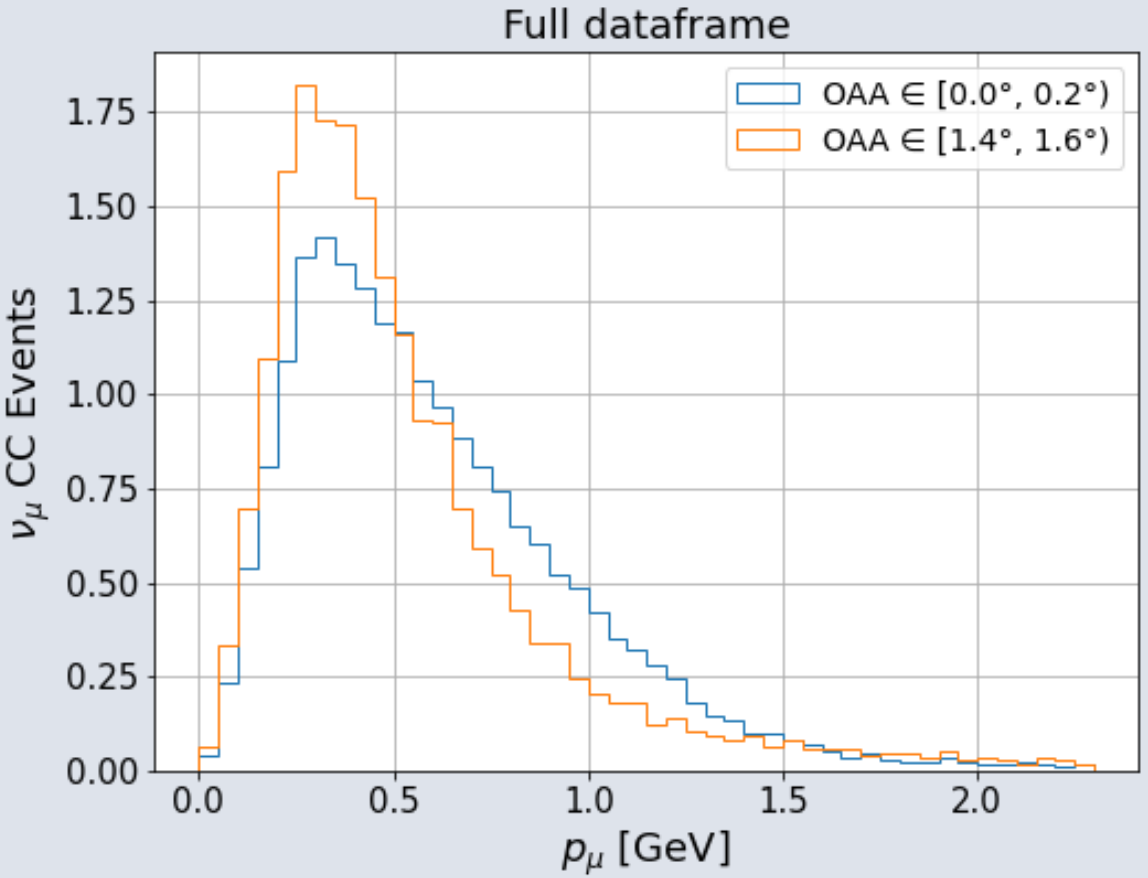
SBND PRISM: MOMENTUM AND SCATTERING ANGLE

Total Distributions (full cosθ range):

Electrons

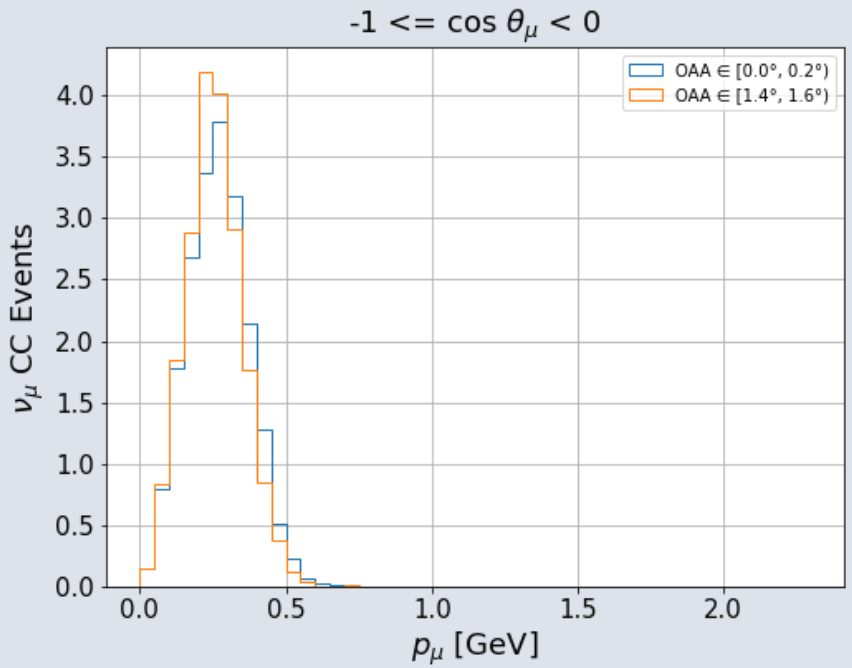


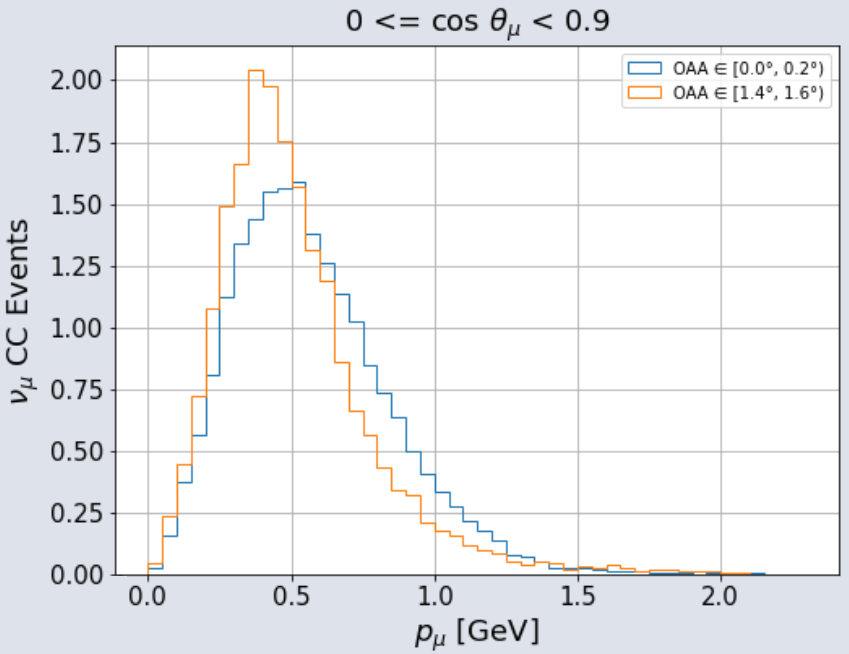
Muons

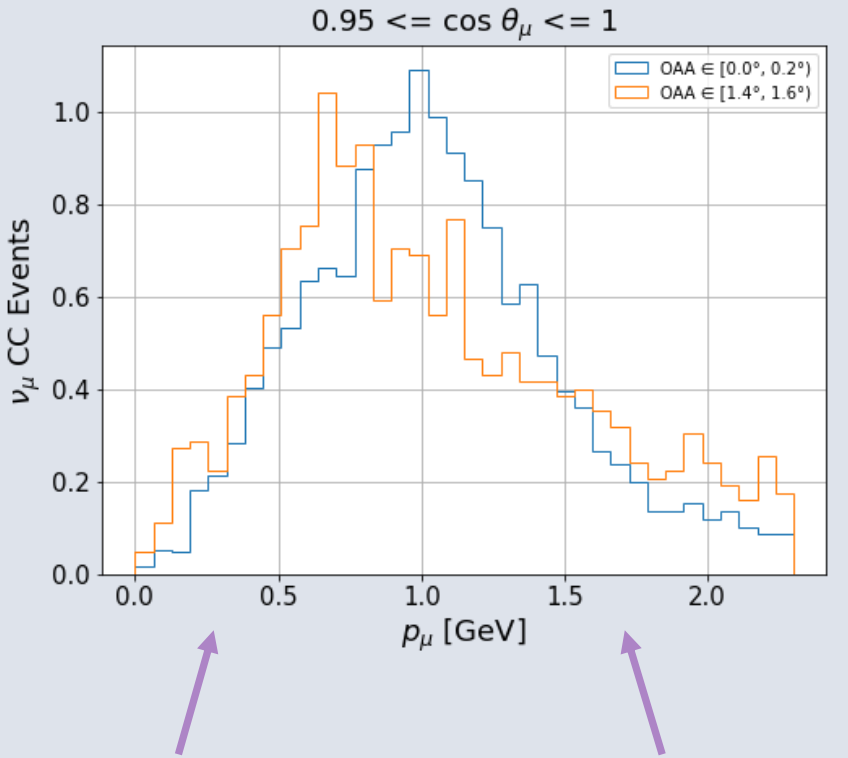


SBND PRISM: MOMENTUM AND SCATTERING ANGLE

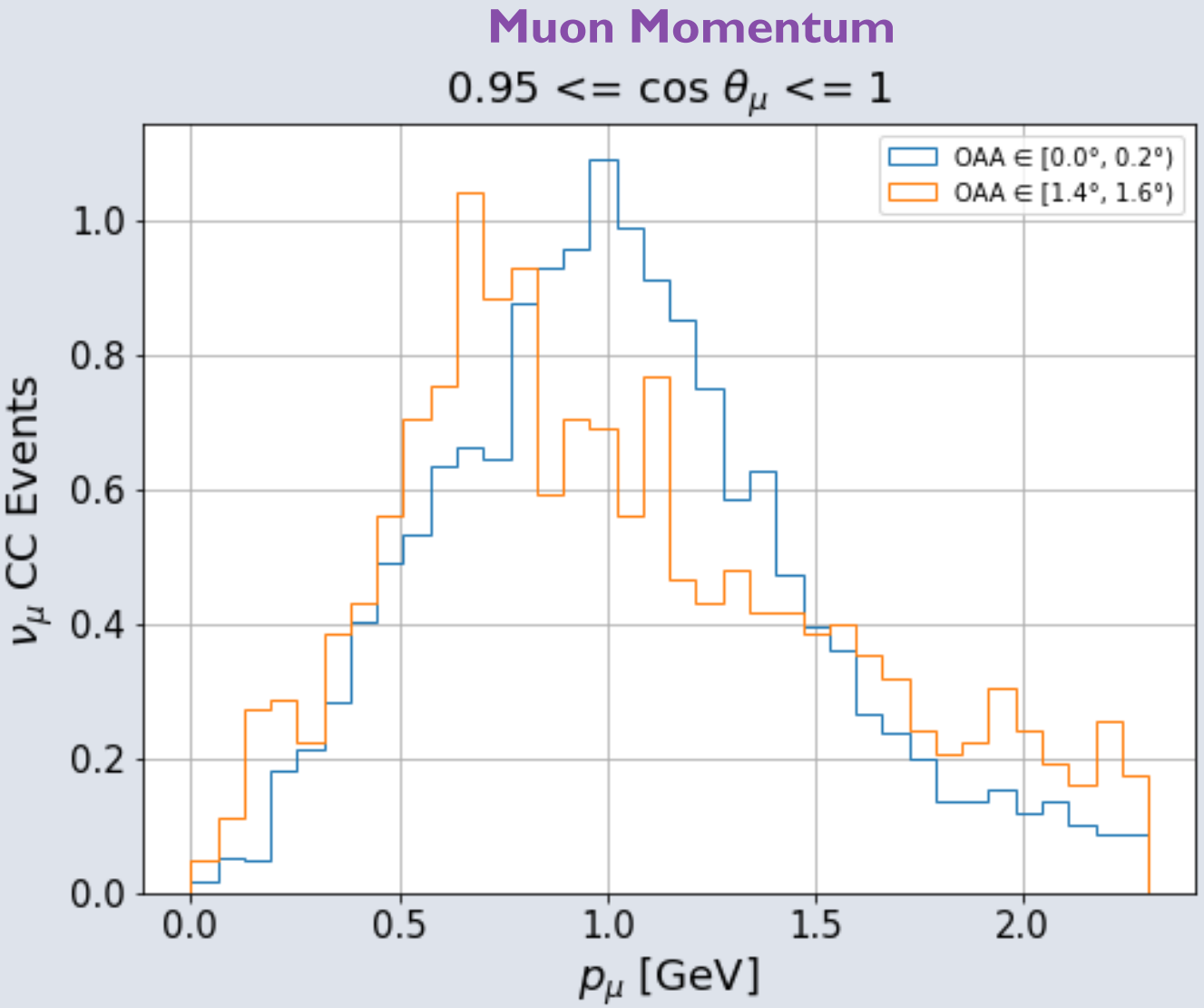
Muon Momentum
(cosθ slicing)







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.

Thank You!

BACKUP

SBND PRISM: MOMENTUM AND SCATTERING ANGLE

Muons Momentum by interaction mode