Fermilab

SBND-PRISM
and a
Magnetized LArTPC

Marco Del Tutto

URA Tollestrup Award Ceremony - Fermilab Users Meeting
29th June 2023

The Short-Baseline Neutrino Program

My research has been mostly focused on the **Short-Baseline Near Detector** (**SBND**) at Fermilab

Together with MicroBooNE and ICARUS, it forms the Short-Baseline Neutrino (SBN) program

SBN: Three Liquid Argon Time Projection Chamber (LArTPC) detectors located along the Booster Neutrino Beamline (BNB) at Fermilab

Marco Del Tutto
1st March 2023

SBND/SBN Goals

MiniBooNE found a ν_e-like event excess in the BNB beam

SBND and SBN will try to understand the origin of this excess:

- Sterile neutrinos?
- Alternative explanations?
  - Dark neutrinos?
  - Transition magnetic moment?
  - Others?

Additionally, many other **beyond standard model** (BSM) models can be explored with the SBND detector

→ axions, heavy neutral leptons, light dark matter, millicharged particles, …

SBND/SBN Goals

The proliferation of models that need to be tested calls for **new analysis techniques** and **hardware improvements**!

Analysis: **SBND-PRISM**

Hardware: **Magnetized LArTPC**

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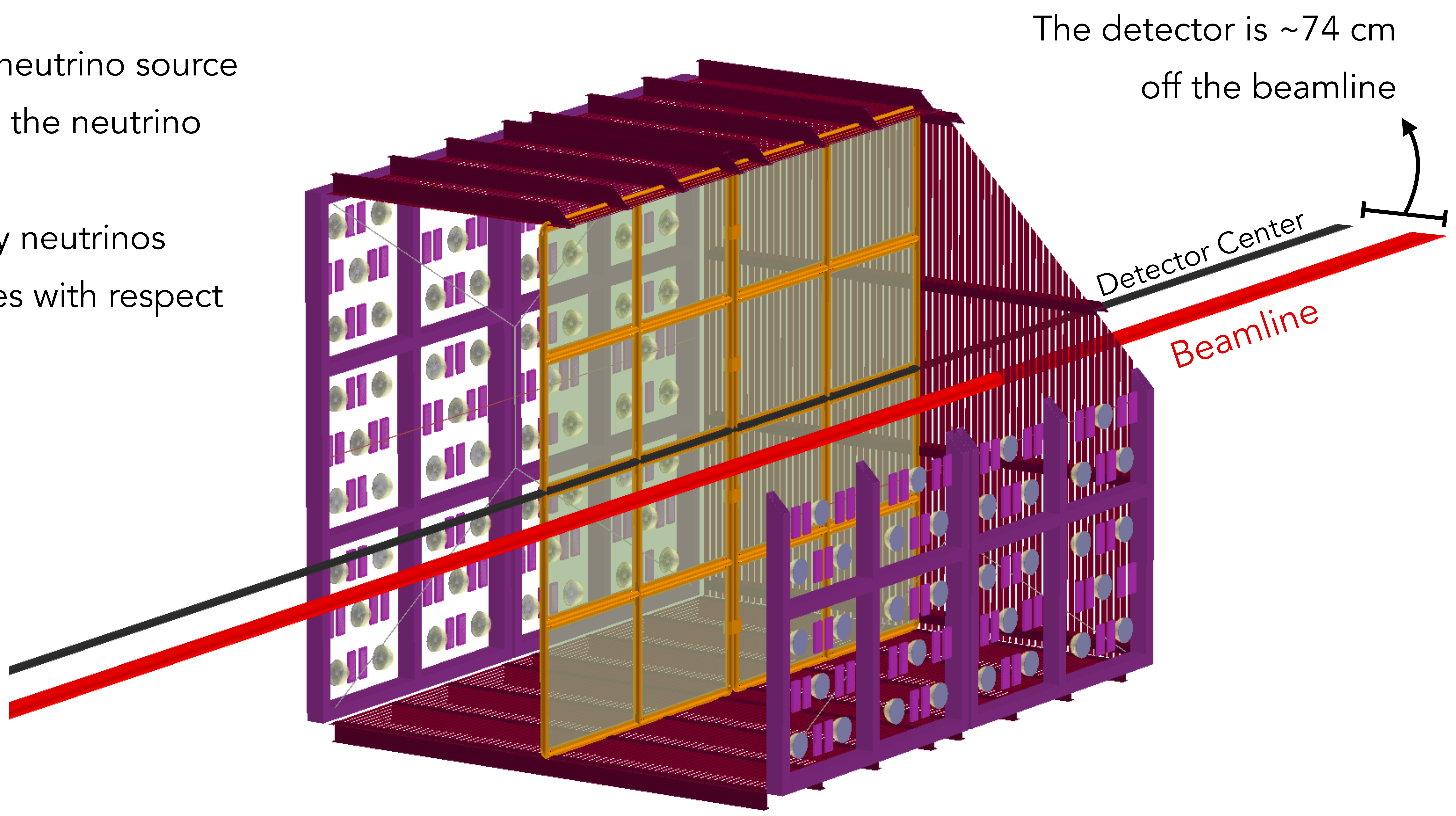
SBND-PRISM

SBND is:

- very close (110 m) to the neutrino source
- not perfectly aligned with the neutrino beamline

The detector is traversed by neutrinos coming from different angles with respect to the beam axis.



SBND-PRISM

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

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

View from the top

SBND Detector

DUNE/SBND Comparison:

DUNE: 1° ≈ 10 m

SBND: 1° ≈ 2 m

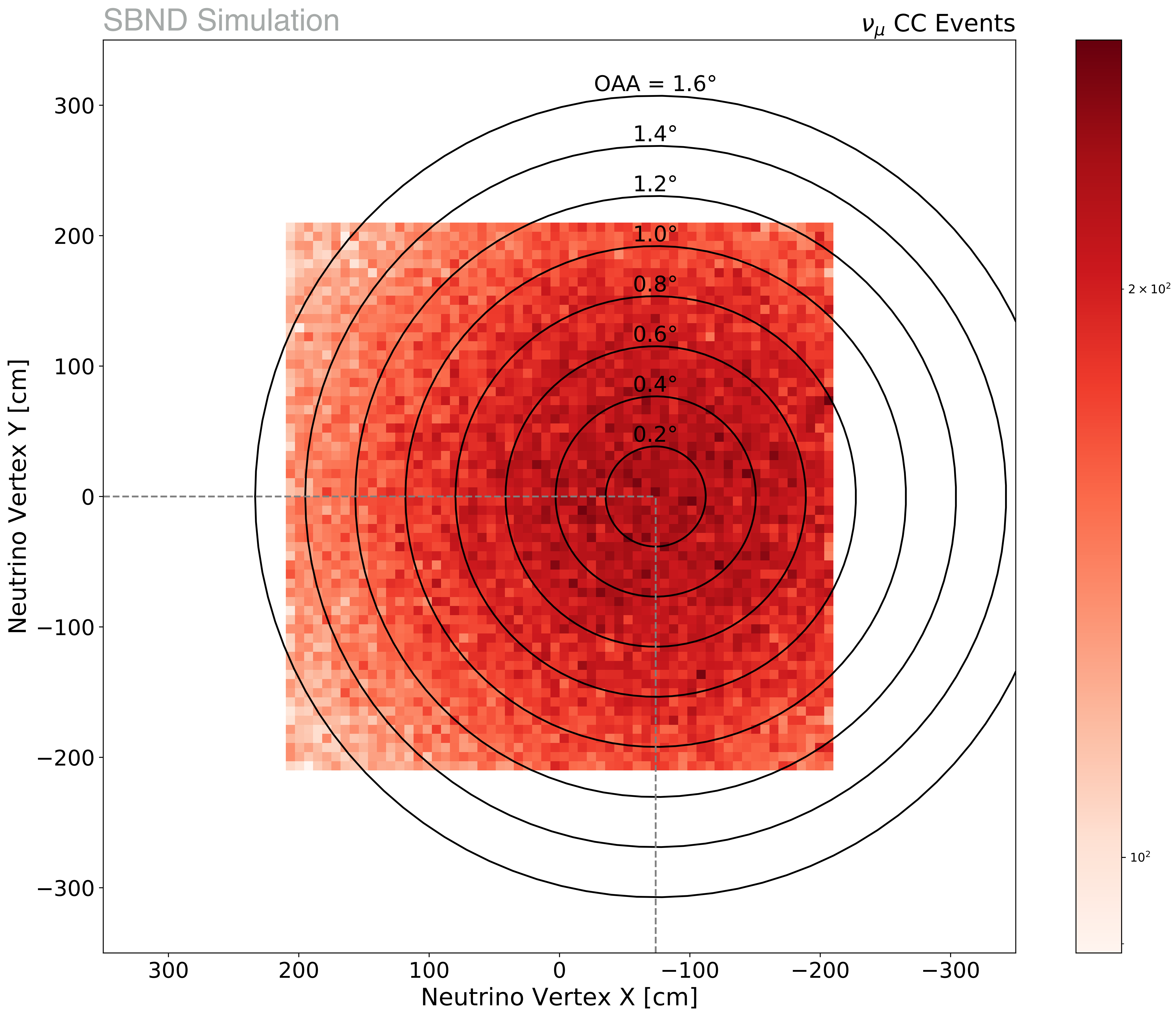
SBND-PRISM

Neutrinos come from charged mesons, focused by the magnetic horns in the beamline.

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

Muon-neutrinos CC Events

peak coincident with the on-axis position



SBND-PRISM

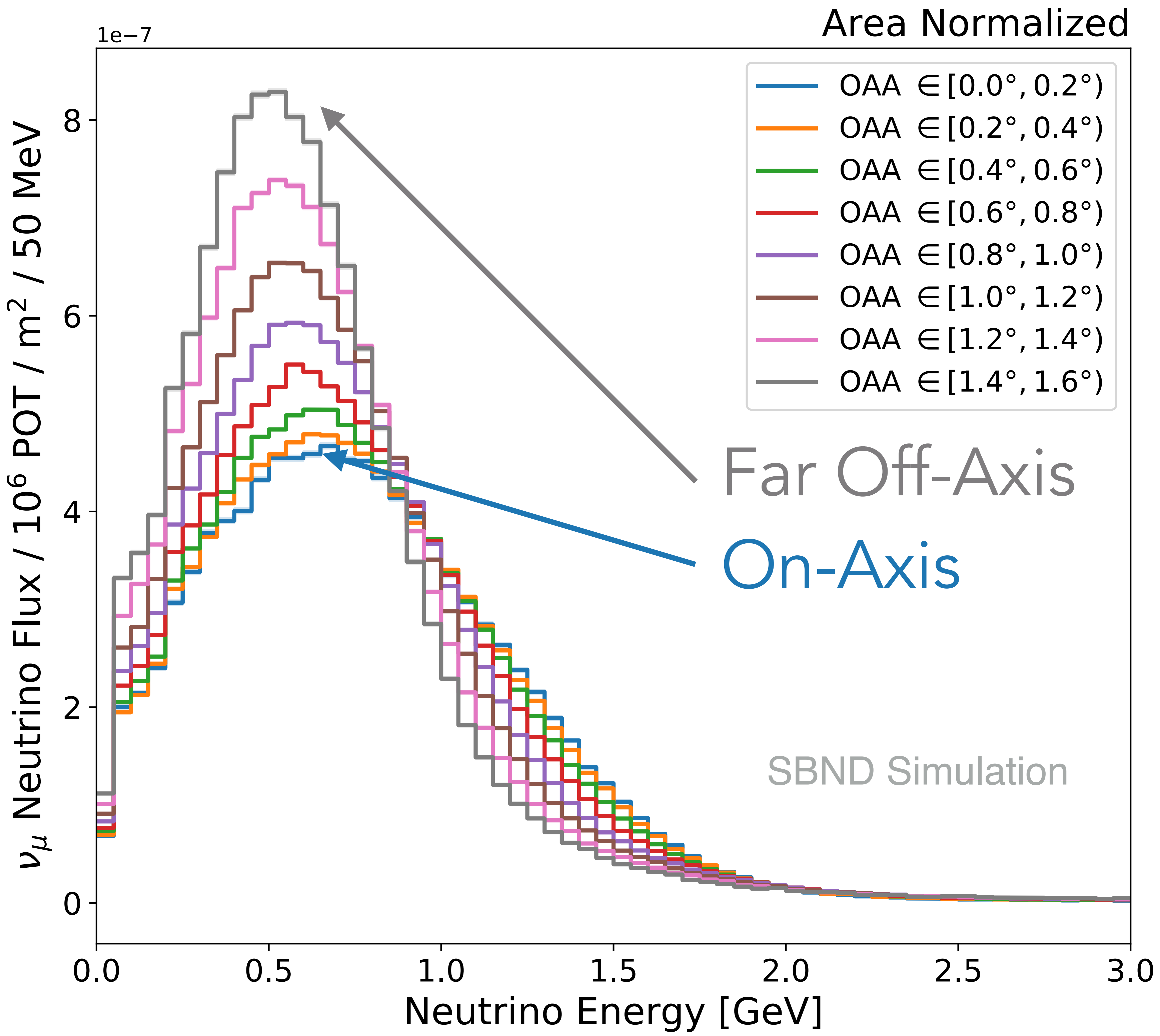
Precision **R**eaction **I**ndependent **S**pectrum **M**easurement (*)

Neutrino events are divided based on the off-axis angle (OAA) region they fall in:

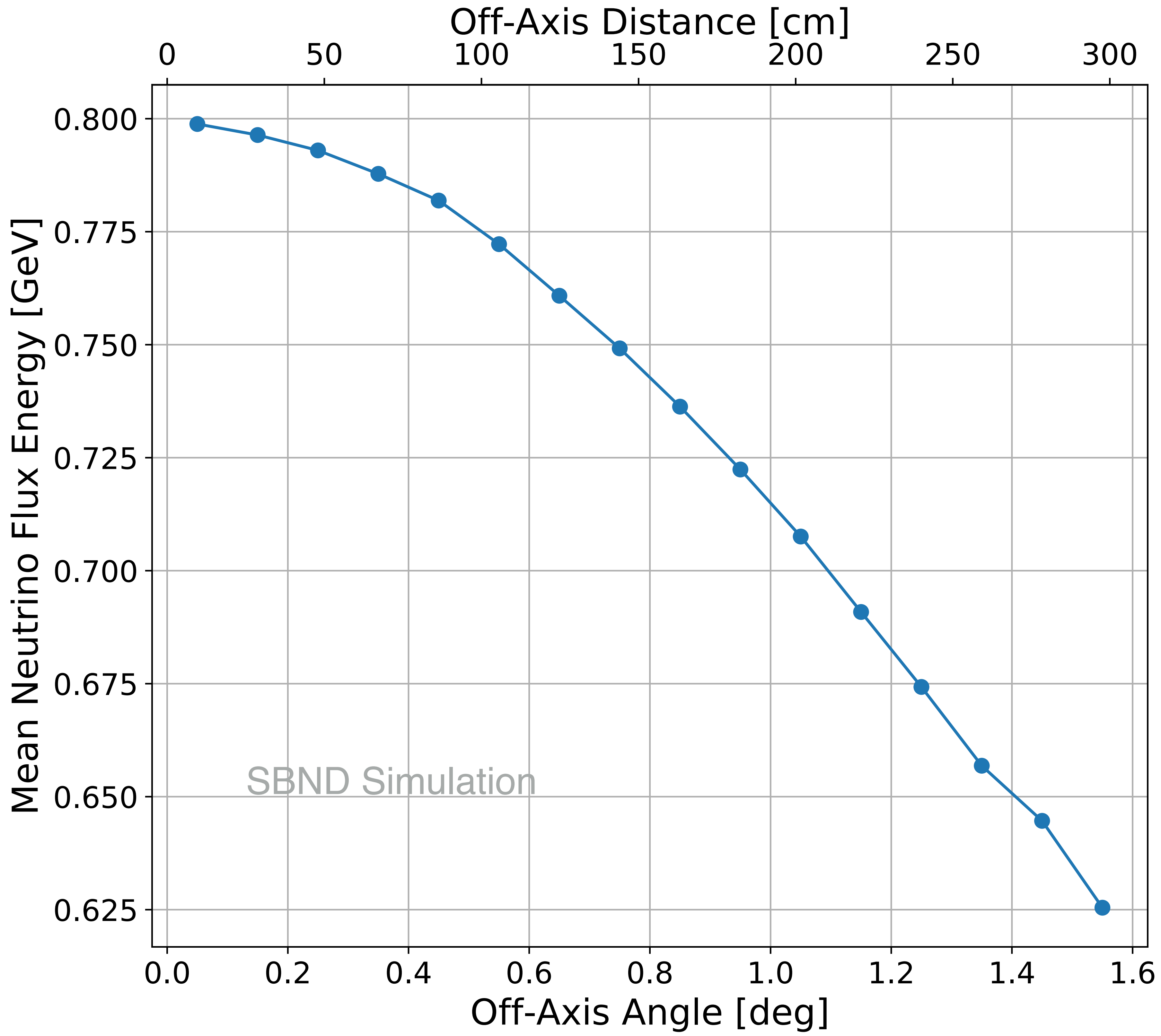
- OAA ∈ [0.0°, 0.2°)
- OAA ∈ [0.2°, 0.4°)
- OAA ∈ [0.4°, 0.6°)
- OAA ∈ [0.6°, 0.8°)
- OAA ∈ [0.8°, 1.0°)
- OAA ∈ [1.0°, 1.2°)
- OAA ∈ [1.2°, 1.4°)
- OAA ∈ [1.4°, 1.6°)

The ν_μ energy distribution is affected by the off-axis position

Muon neutrino flux in each of the OAA regions

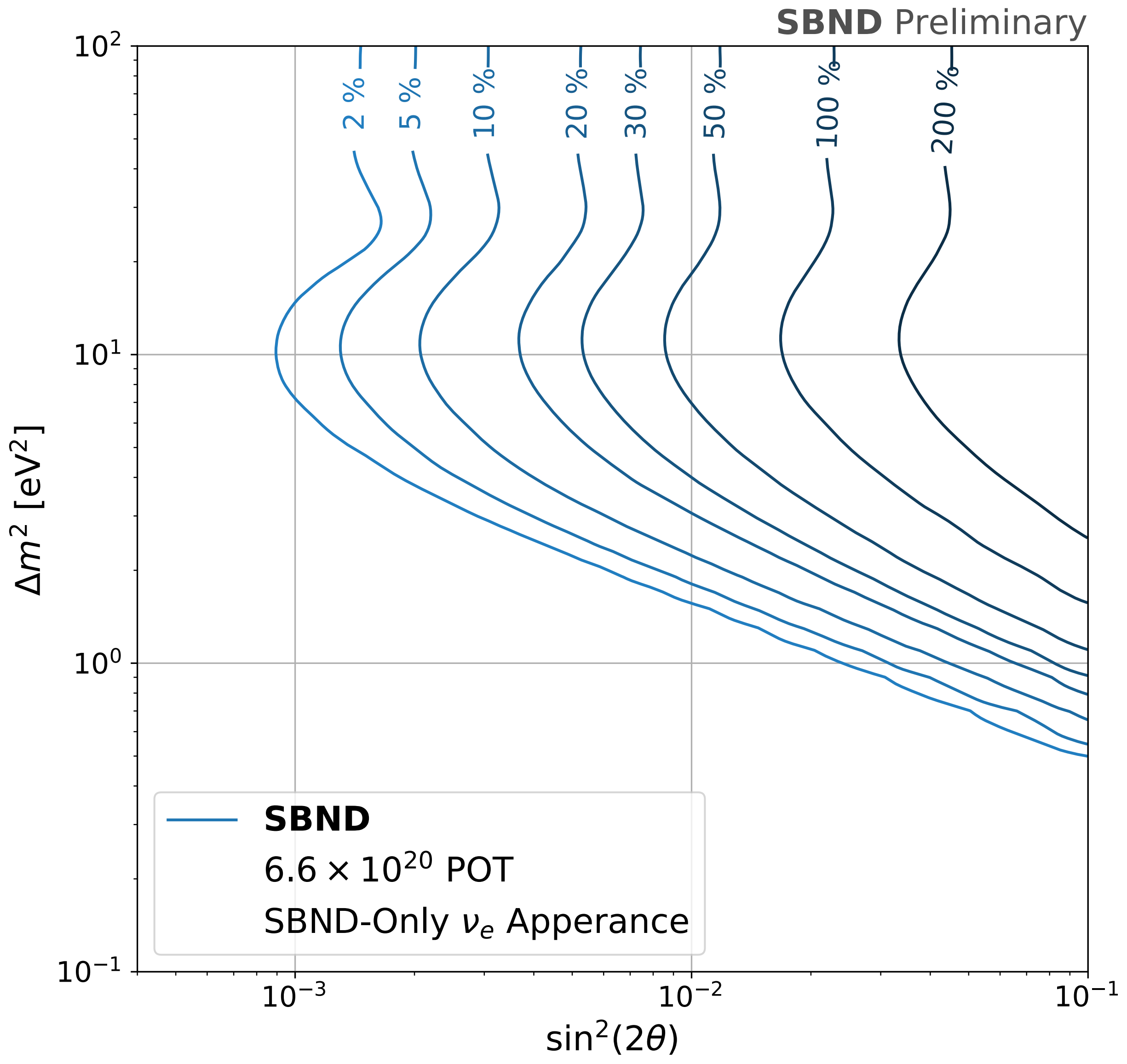


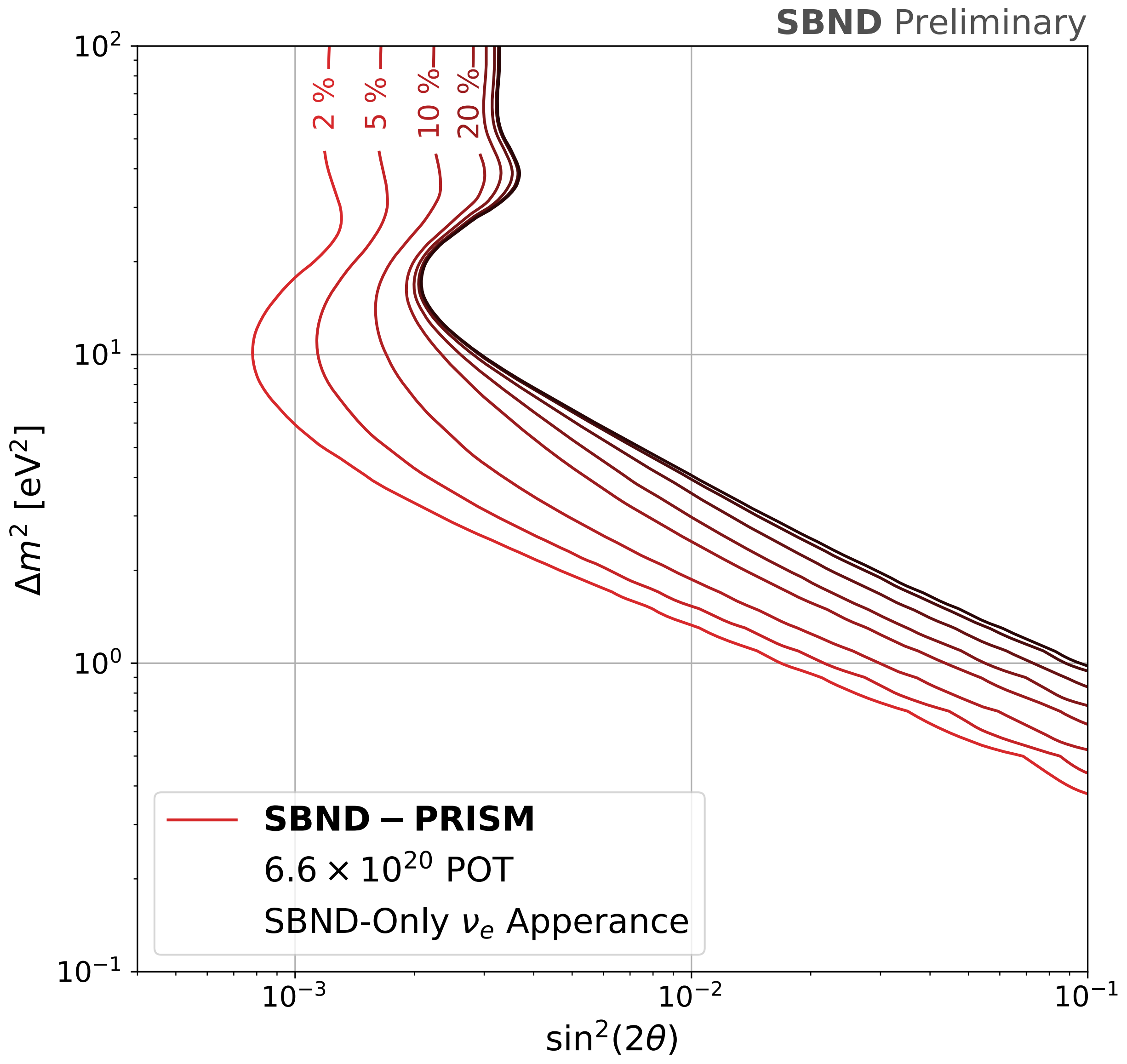
Mean neutrino energy



(*) nuPRISM https://arxiv.org/abs/1412.3086

SBND-PRISM

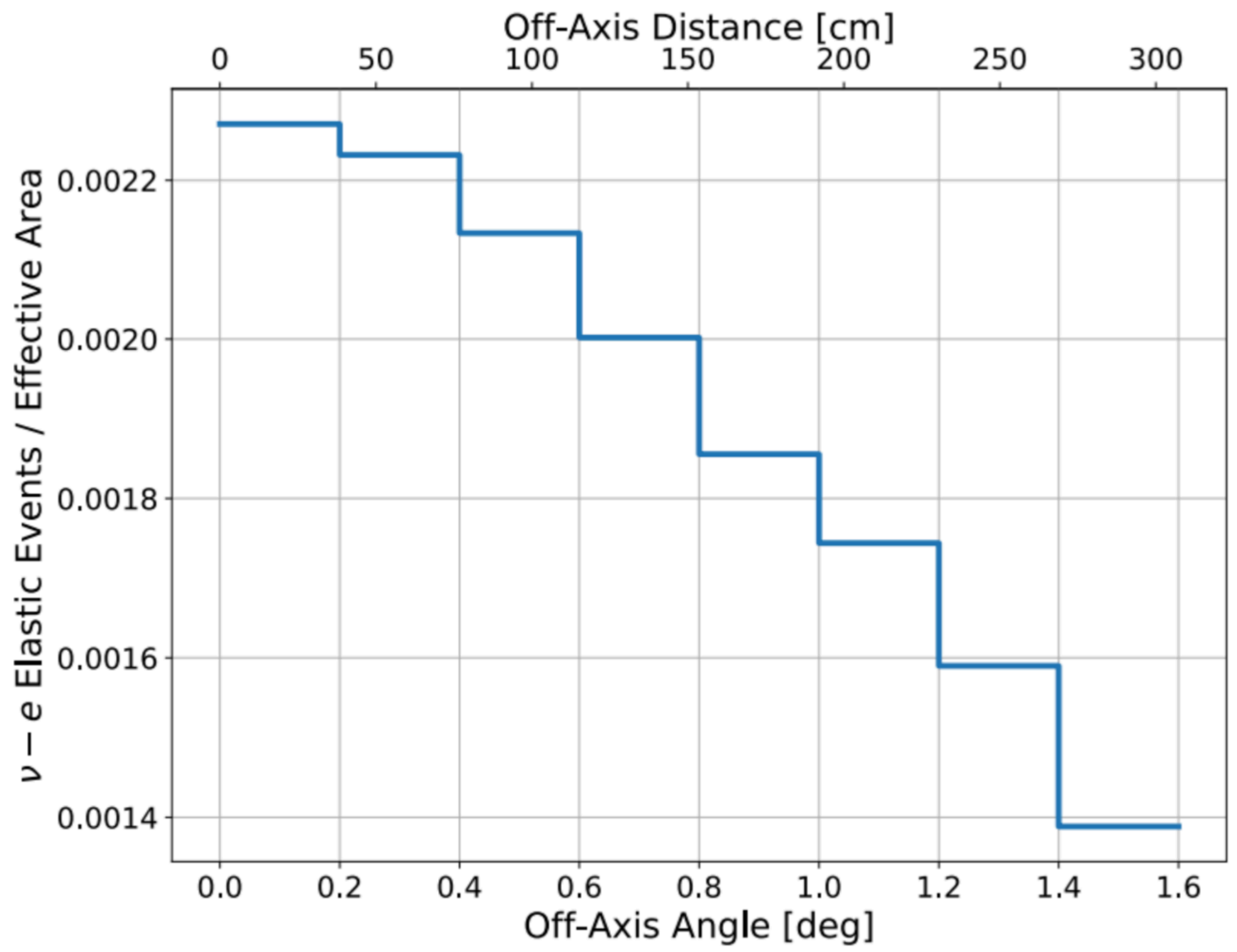


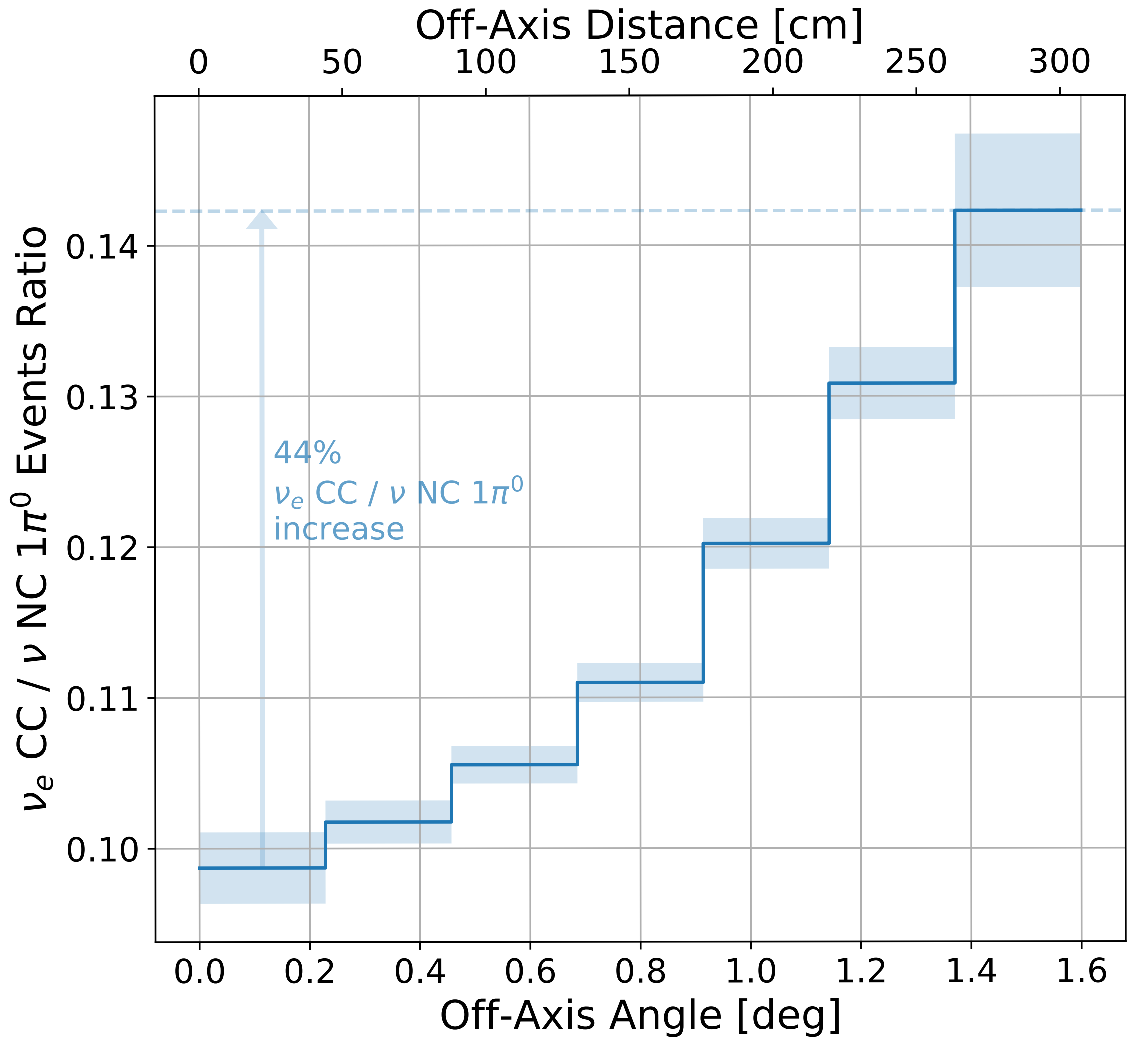


Sterile Neutrinos

Initial SBND-Only ν_e Appearance Oscillation Study

- Comparing two cases: SBND as a single detector vs SBND-PRISM (8 sub-detectors at different off-axis angles)
- Includes flux systematics, plus an uncorrelated 2-to-200% total cross-section uncertainty





Background Reduction

- Neutrino-electron elastic scattering events decrease with the off-axis angle
- $NC\pi^0$ events decrease with the off-axis angle

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explored with the SBND detector

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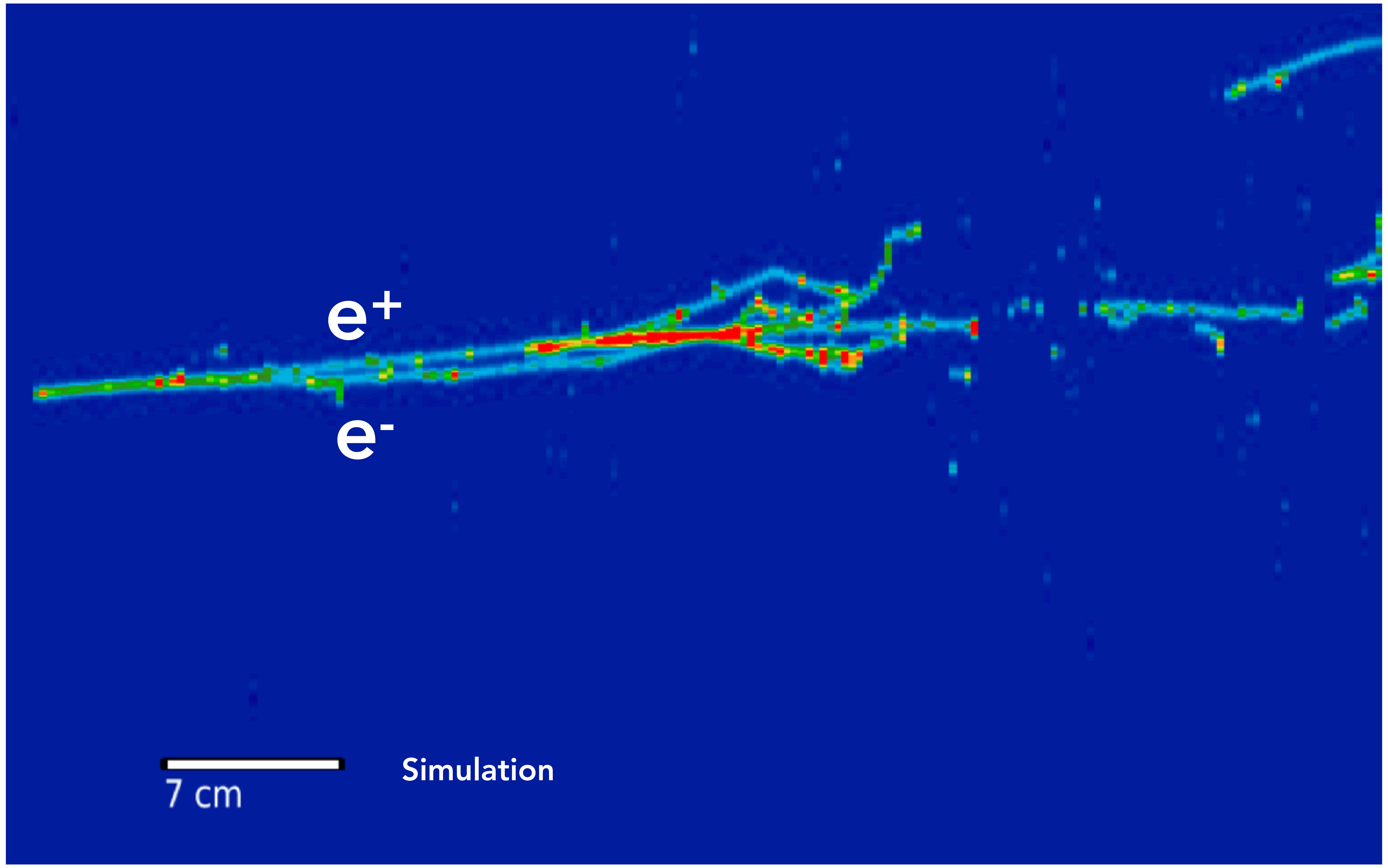
Magnetized LArTPC

Many BSM models produce two **very-collinear** particles in the final state



Example of Dark Neutrino simulation in SBND

Two particles with

opposite charge

Hard to separate

and reconstruct properly

Magnetized LArTPC

A **magnetic field** will solve this problem

It separates two oppositely charged particles

Simulation of a magnetized LArTPC detector:

Magnetized LArTPC

Benefits of a magnetized LArTPC:

- open up collinear pairs
- determination of particle charge sign (currently impossible in LArTPCs)
- enables to run on an anti-neutrino beam
- better electron/photon discrimination
- particle momentum measurement from curvature

Magnetized LArTPC

***Ar*CS**

***Ar*gon detector**

with Charge Separation

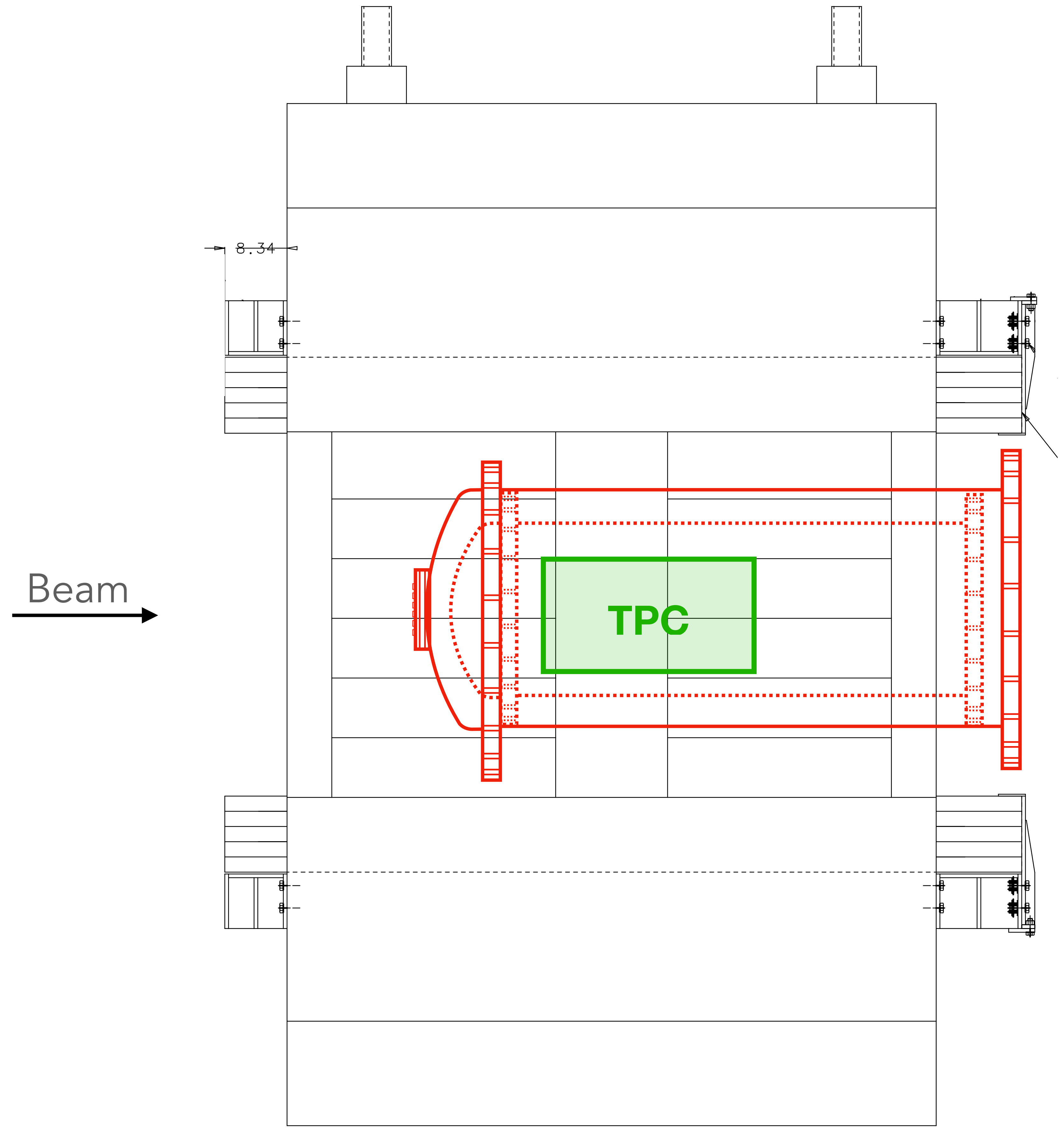
FNAL-LDRD-2022-001

"A Liquid Argon Time Projection Chamber in a Magnetic Field"

This project's scope is to demonstrate that a LArTPC detector can operate in a magnetic field and provide measurements of **particle charge sign** and **momentum** for particles of 100s of MeV

Magnetized LArTPC

We will re-use the LArIAT TPC and insert it inside the Jolly Green Giant Magnet at the Fermilab Test Beam Facility

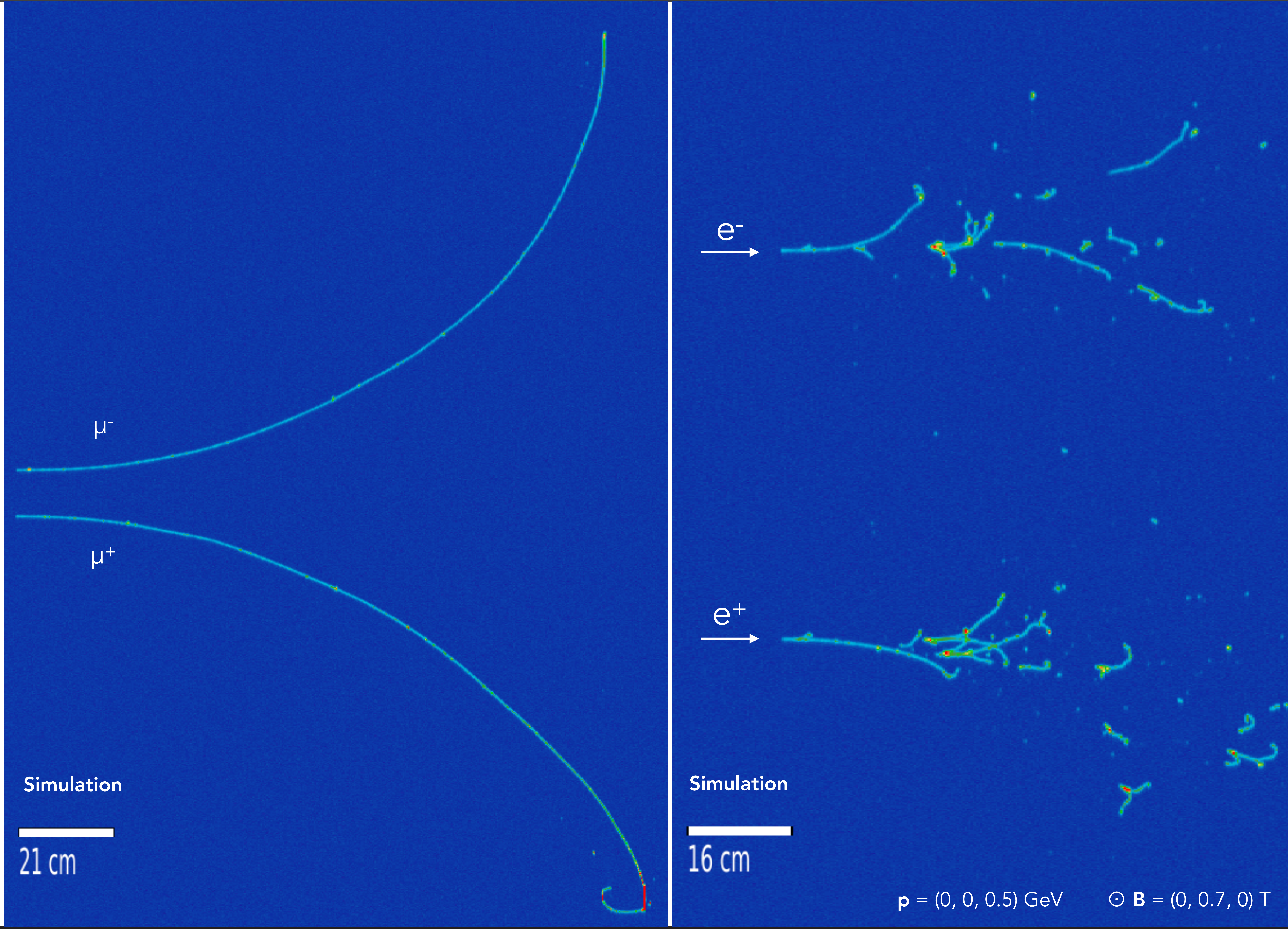


250-ton magnet, 0.7 T field

Magnetized LArTPC

We are getting ready to take data

Stay tuned for the results!



Thank You!