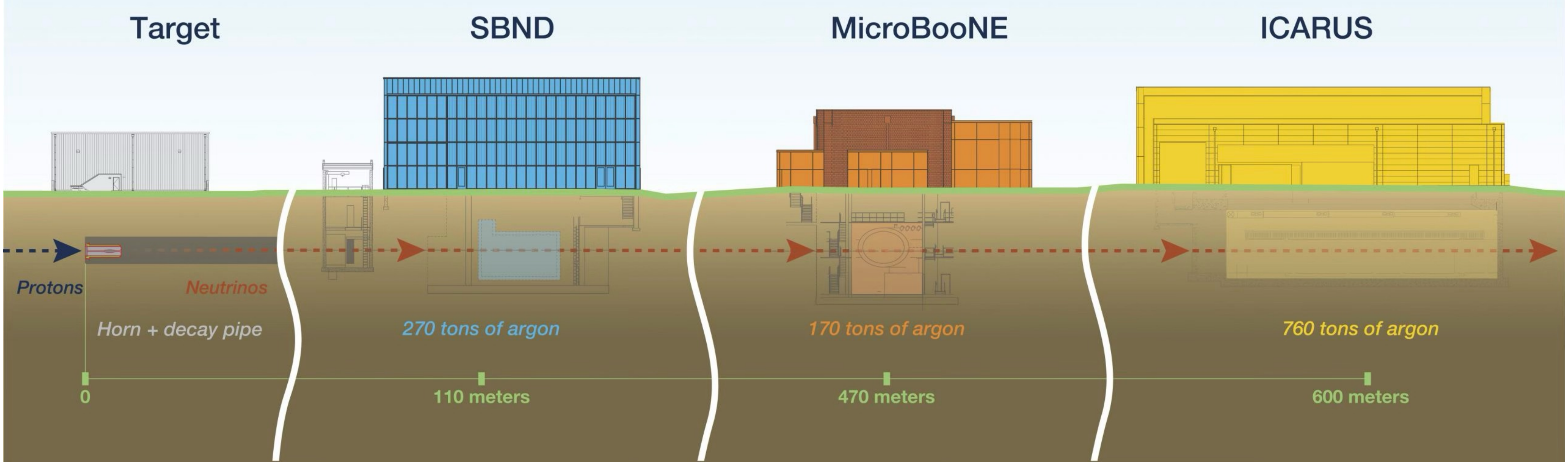
Status of the Short-Baseline Near Detector

Patrick Green, on behalf of the SBND collaboration

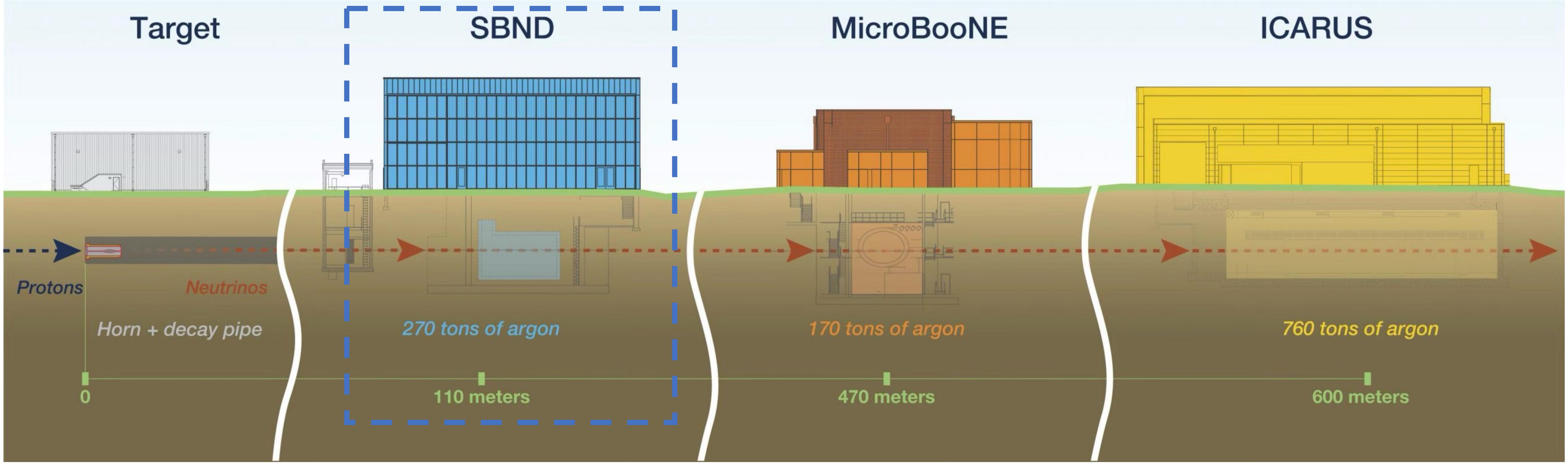
University of Oxford

Short-Baseline Neutrino Program (SBN)



- Three LArTPC detectors in the Booster Neutrino Beam @ Fermilab: SBND, MicroBooNE and ICARUS
- Measure neutrino oscillation over 600m baseline: electron neutrino appearance and muon neutrino disappearance
- Search for eV-scale sterile neutrino oscillations as an explanation for the LSND and MiniBooNE anomalies

Short-Baseline Near Detector (SBND)



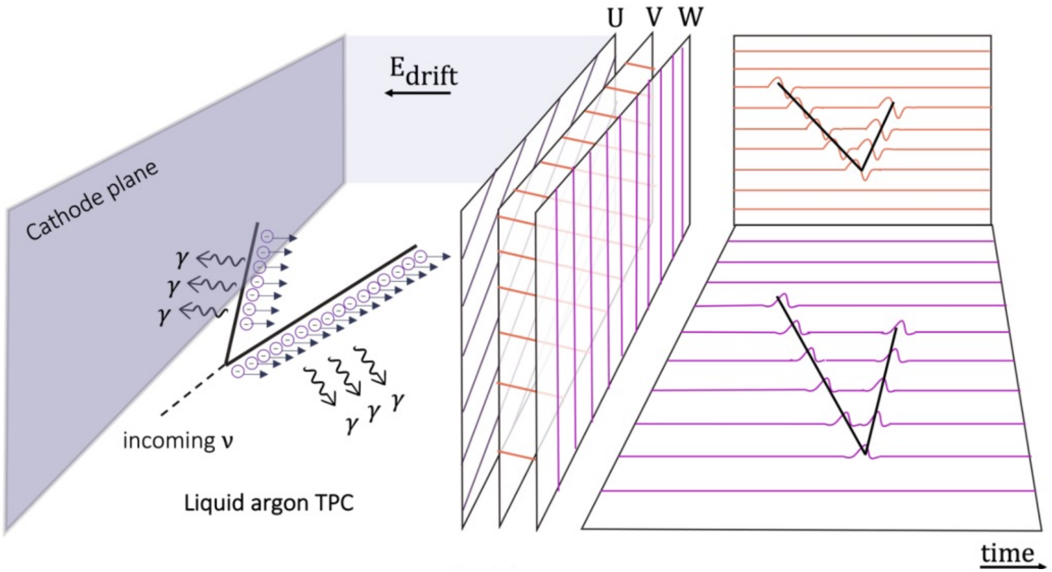
- Near detector for the SBN oscillation measurements: will constrain systematic uncertainties to the %-level
- Precision neutrino interaction cross-section measurements on Argon
- Searches for Beyond the Standard Model physics

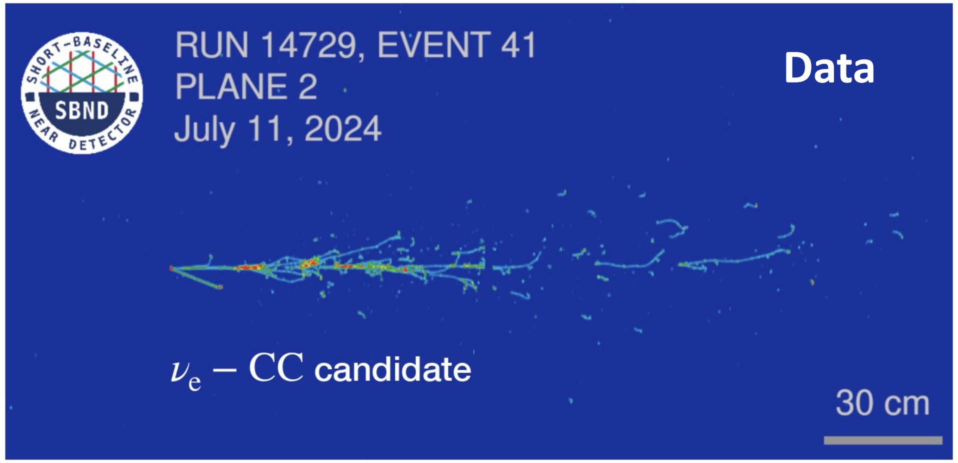
Liquid Argon Time Projection Chambers (LArTPC)

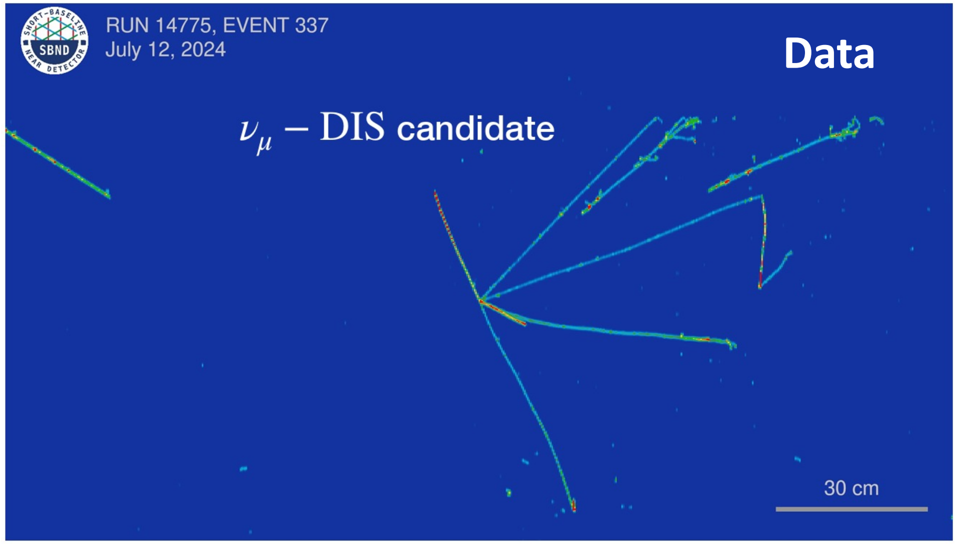
Fully active tracking calorimeter: 3D imaging of neutrinos

Precision neutrino measurements at scale:

- mm-level resolution, ns-scale timing, MeV-scale thresholds
- excellent particle identification capabilities







The SBND Detector

112-ton active argon mass

- two drift volumes
- 500 V/cm
- $4 \times 4 \times 5$ m^3

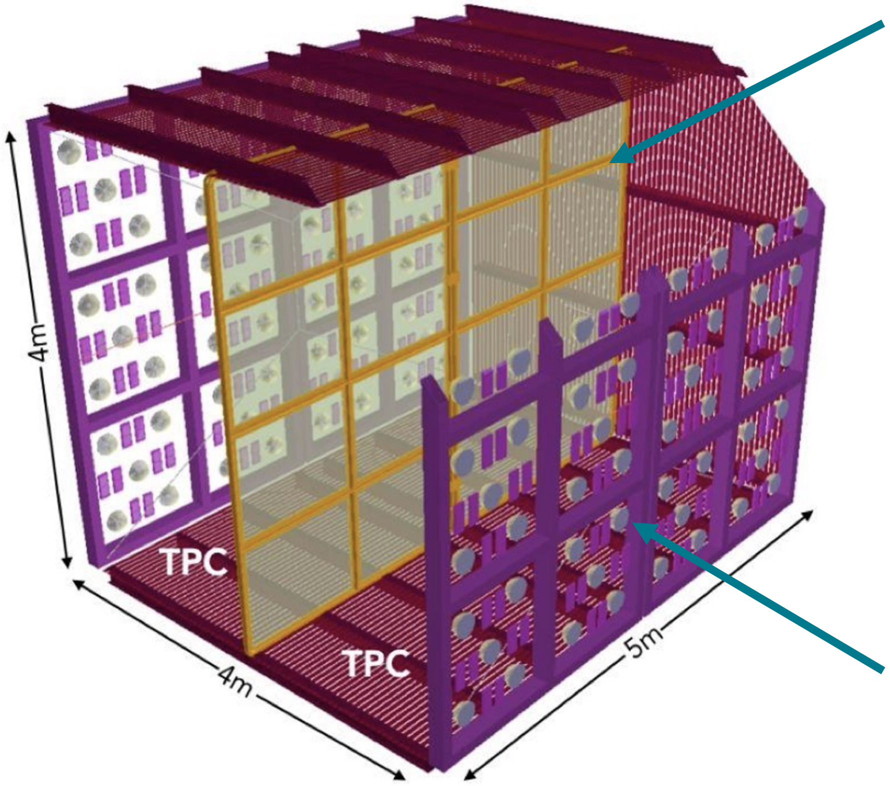
Ionization charge signal:

- three wire planes per anode
- θ = 0°, ±60°, 3mm spacing
- 11,264 total wires

Scintillation light signal:

- 120 PMTs
- 192 X-Arapuca

Cosmic ray taggers on all faces



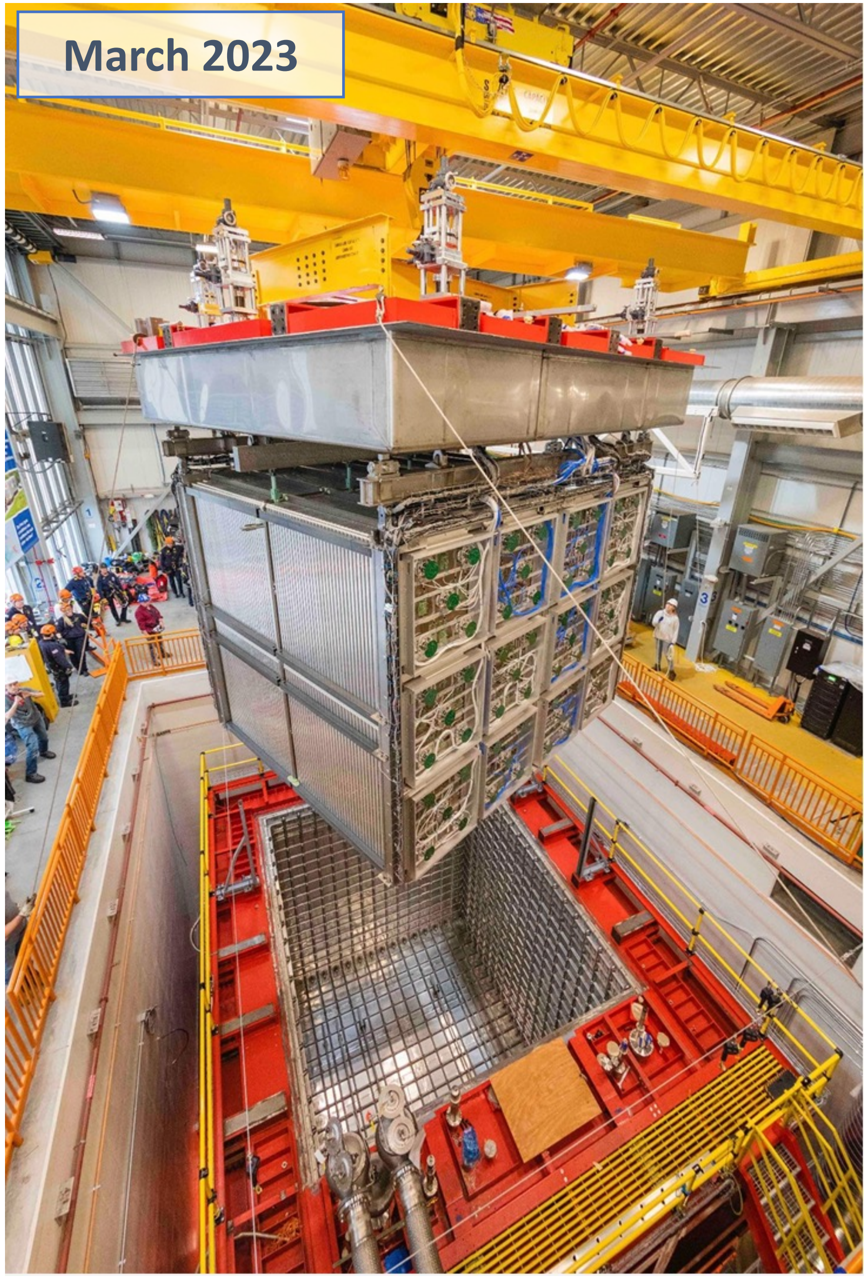
JINST 15 (2020) 06, P06033
Eur. Phys. J. C 84 (2024) 10, 1046

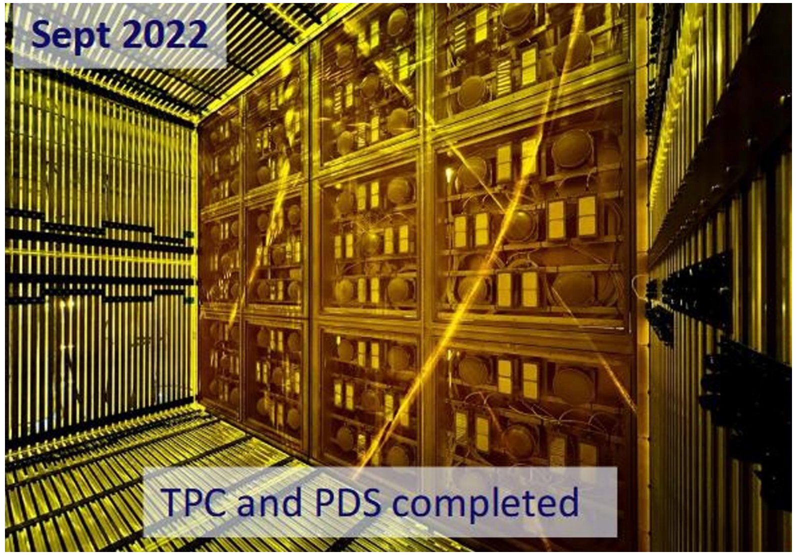
SBND Commissioning

Massive amount of work from many people over several years:

- TPC assembly complete Sep 2022, installed cryostat in Mar 2023
- LAr filling complete Mar 2024, ramped to design drift voltage Jul 2024

First physics run started in December 2024!





SBND Data Collection

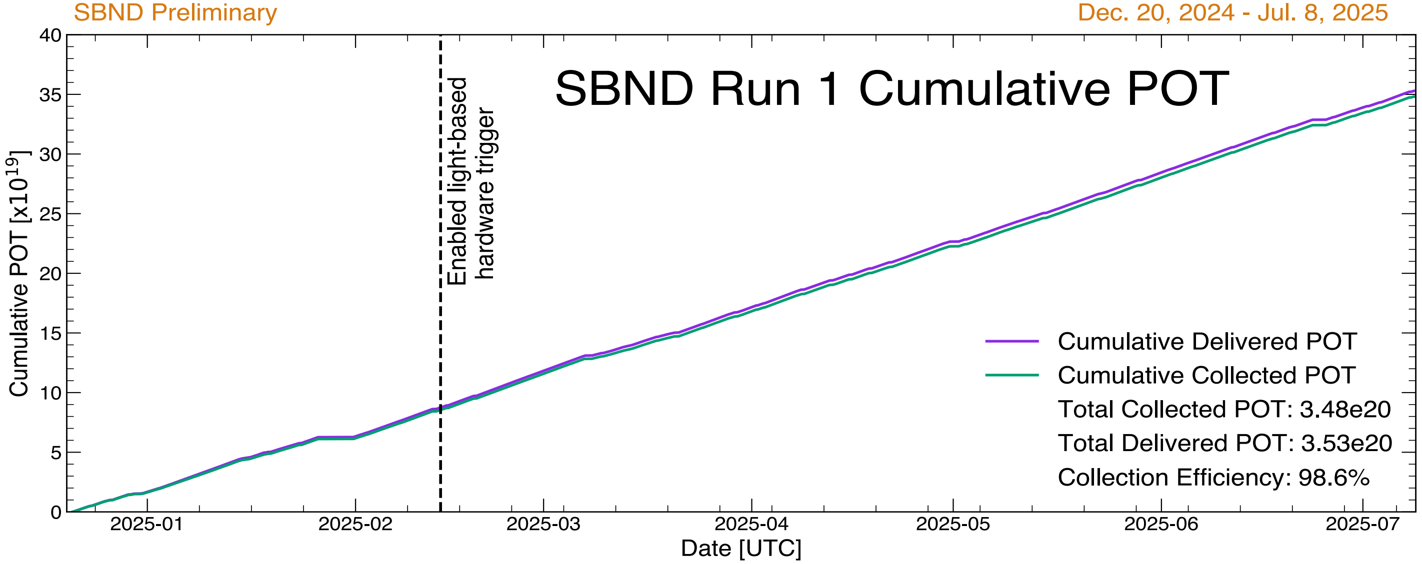
SBND is collecting data in the Booster Neutrino Beam @ Fermilab

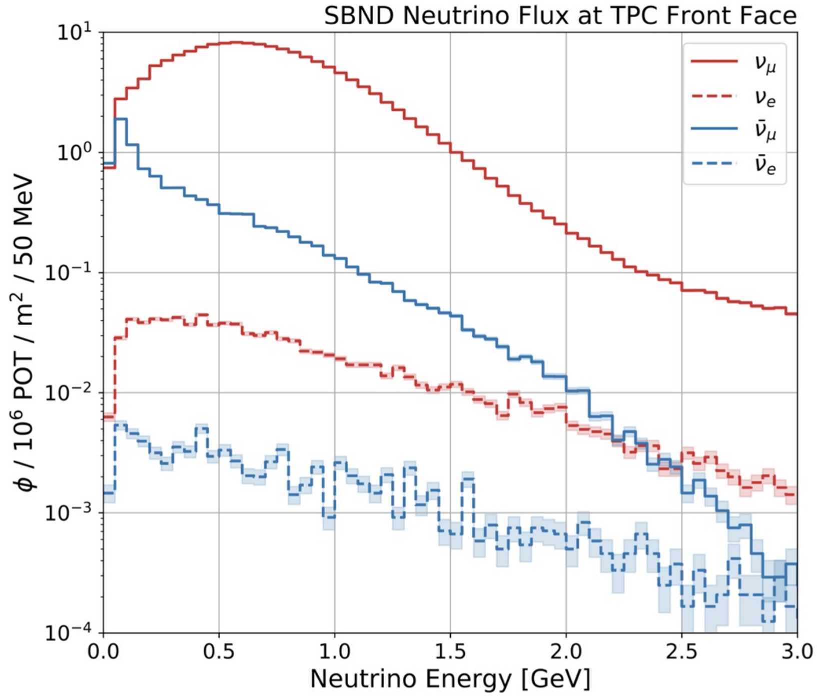
First physics run complete, Dec 2024 – July 2025:

- 3.5×10^{20} POT, 98.6% collection efficiency

BNB flux @ SBND:

- average $E_\nu \sim 800$ MeV
- $\sim$93% ν_μ and $\sim$0.5% ν_e





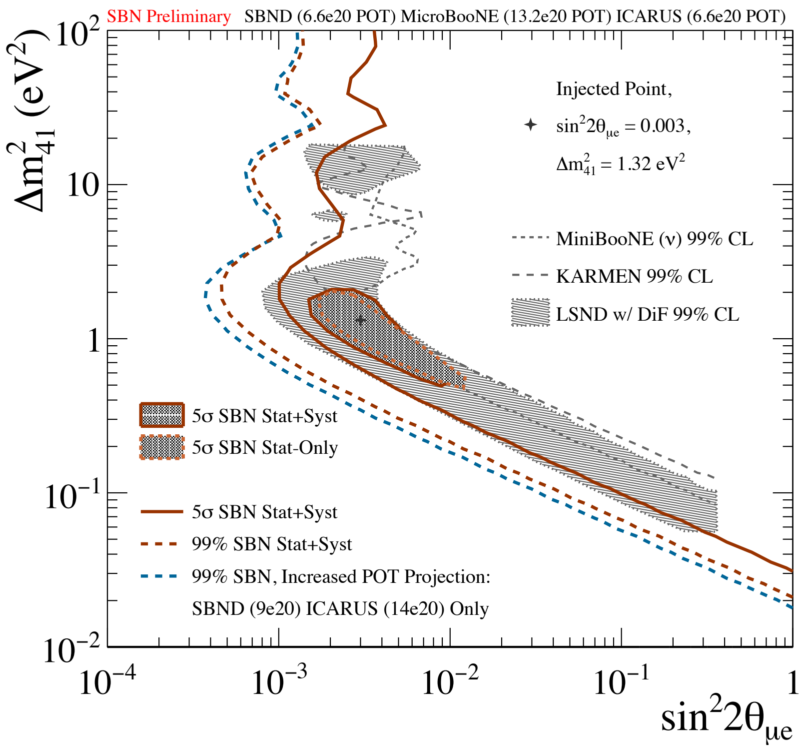
Already collected largest ever data-set of neutrino interactions on argon, > 2 million neutrinos!

SBND Physics: Oscillations

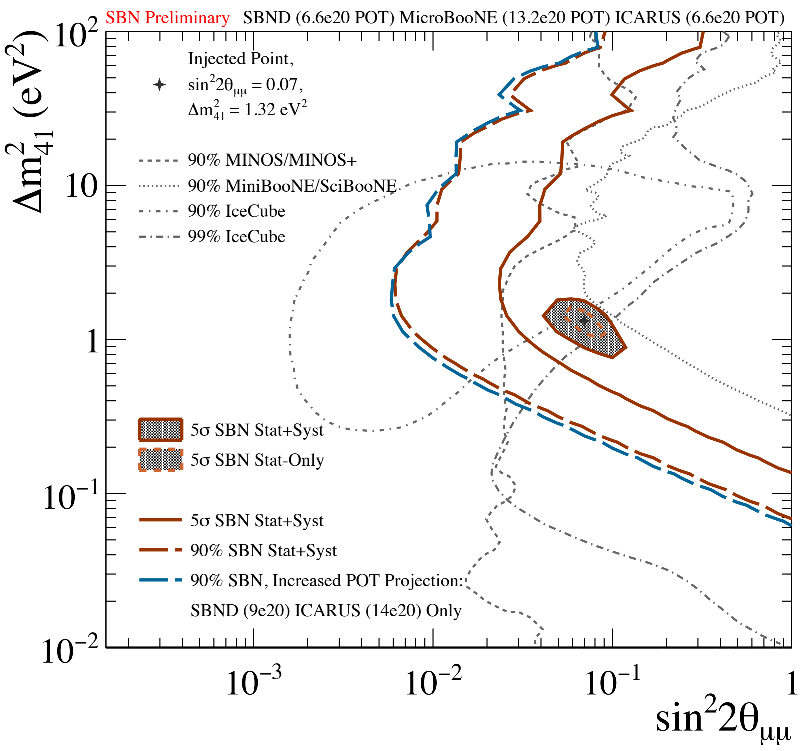
Multiple detectors with same technology, target nucleus, and beamline → constrain uncertainties to %-level

Will conclusively address sterile neutrino hypothesis to the short baseline anomalies (LSND, MiniBooNE)

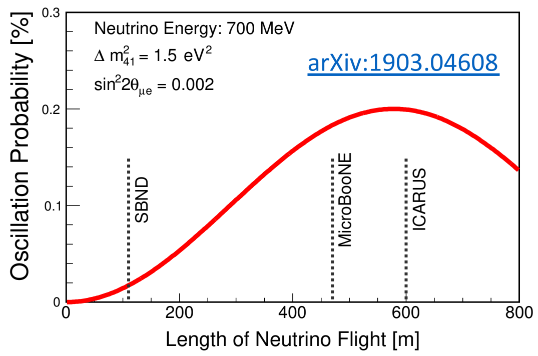
ν_e appearance



ν_μ disappearance



SBND's role is to constrain the un-oscillated prediction



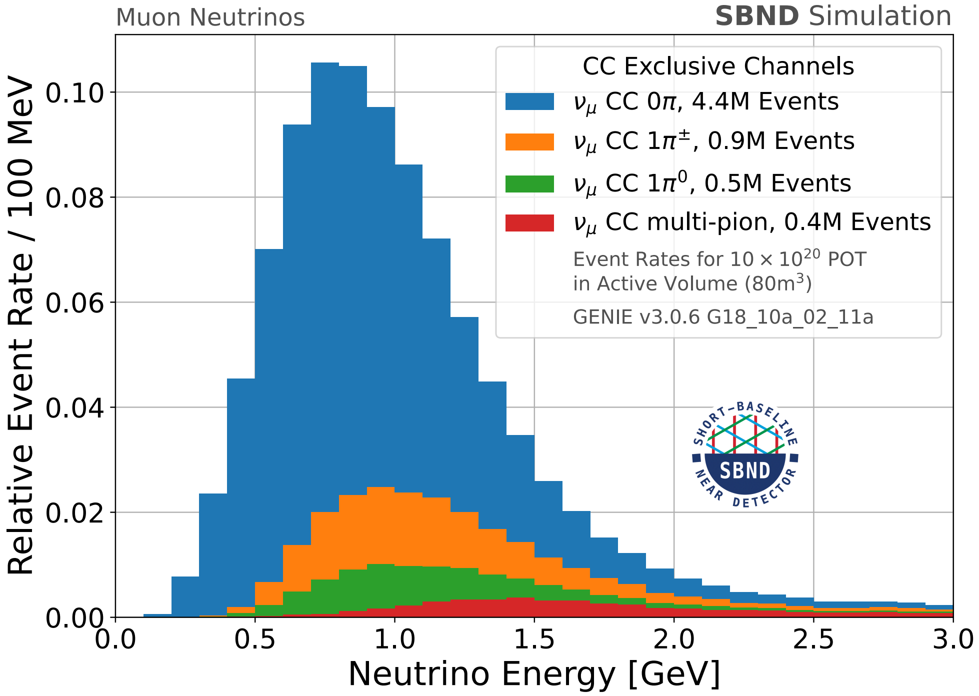
arXiv:1903.04608

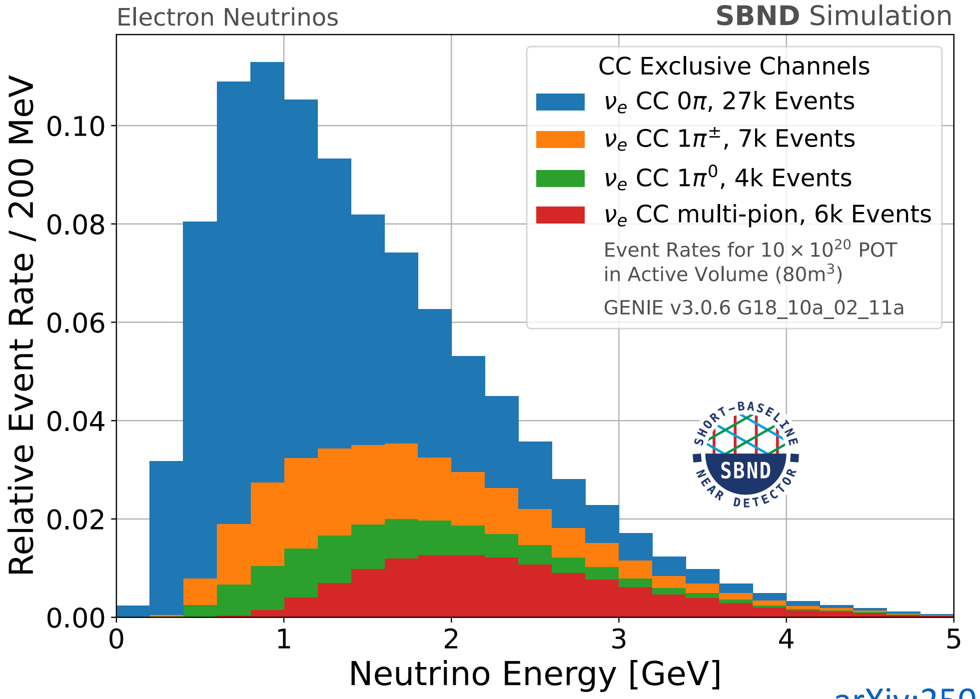
arXiv:2504.00245

SBND Physics: Cross Sections

Unprecedented neutrino interaction statistics: ~7000 interactions / day, ~10 million events in full data-set

Enormous statistics means highly precise, multi-dimensional cross section measurements can be made





arXiv:2504.00245

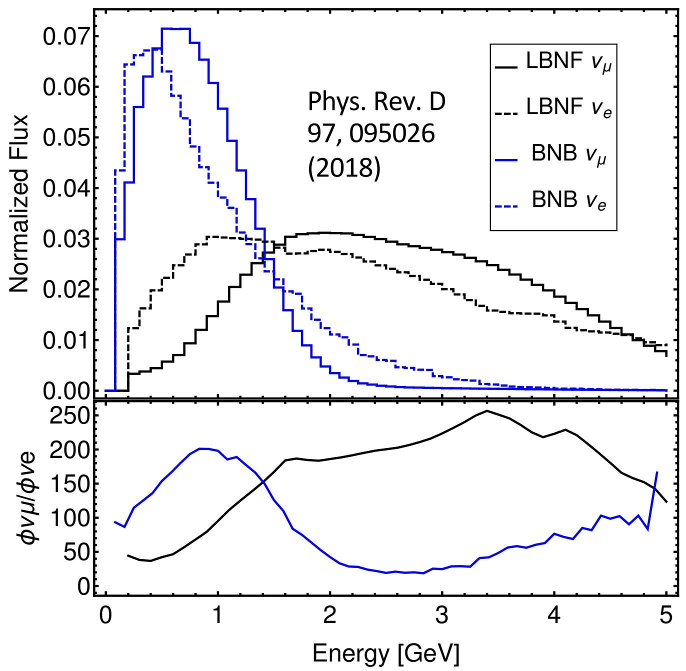
DUNE Phase Space Coverage

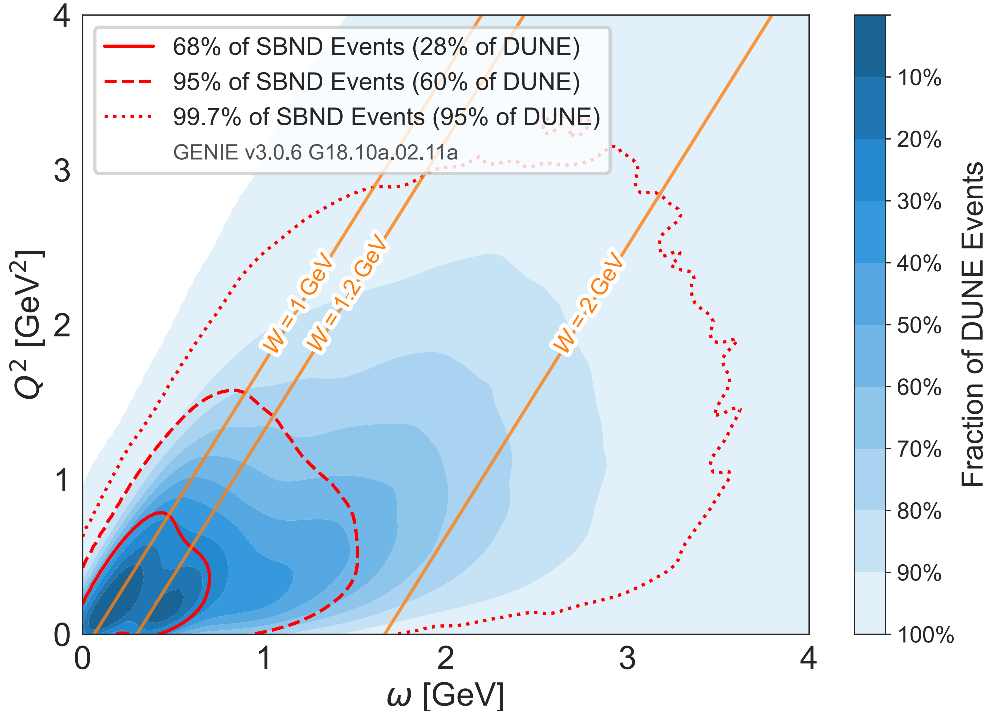
SBND has significant kinematic phase space overlap with DUNE, despite higher energies of LBNF beam:

- unprecedented neutrino statistics: precision measurements even towards tails of neutrino energies

Measurements from SBND will provide crucial input towards improving cross section modeling for DUNE

SBND vs DUNE flux





arXiv:2504.00245

SBND Physics: BSM

Large precision detector close to beam target:

- high intensity neutrino beam, produced by high intensity proton beam

Ideally situated to search for scale Beyond the Standard Model particles produced in the beam:

- competitive sensitives to dark-sector particles
- model-independent searches in development

Advanced technical developments:

- ns-timing: separate particles by time-of-flight
- neutral meson flux modelling overhaul

Actively engaged with the theory community to fully exploit the physics opportunities

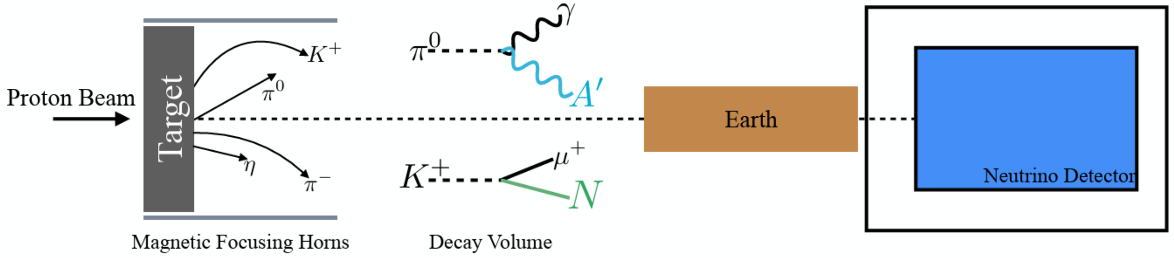


Image credit: Sabrina Brickner, Kevin Kelly

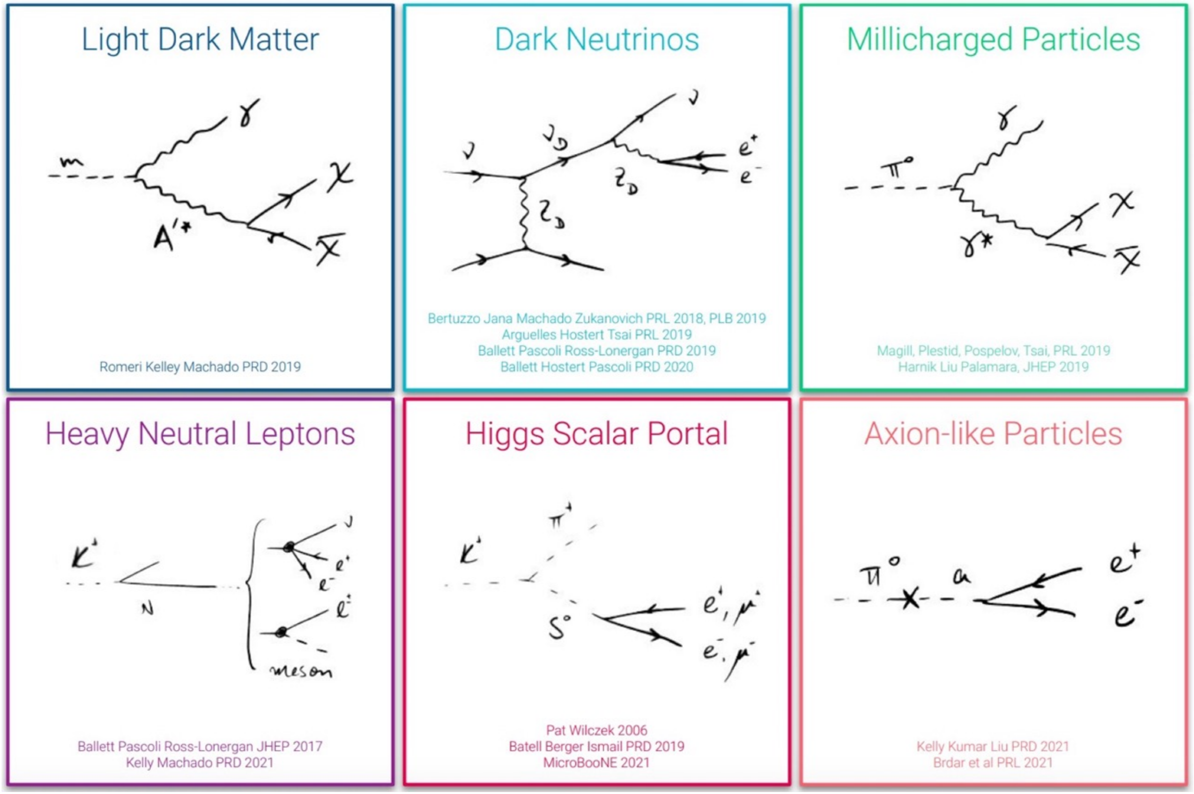
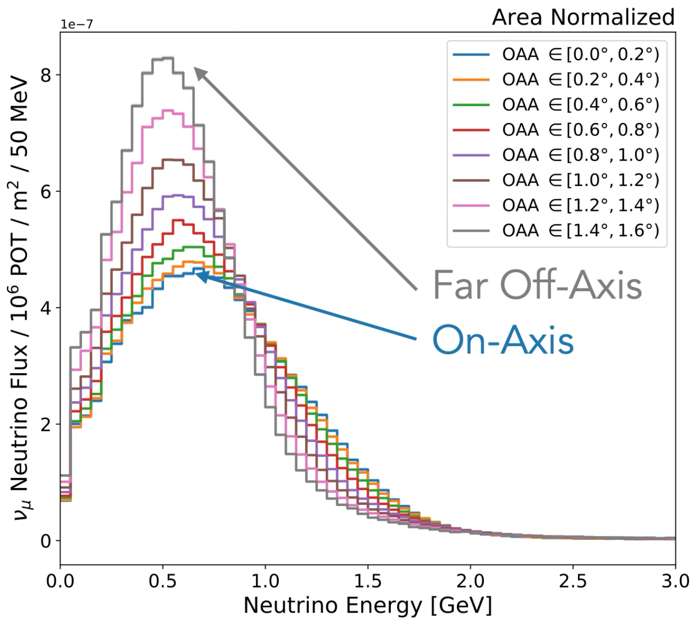


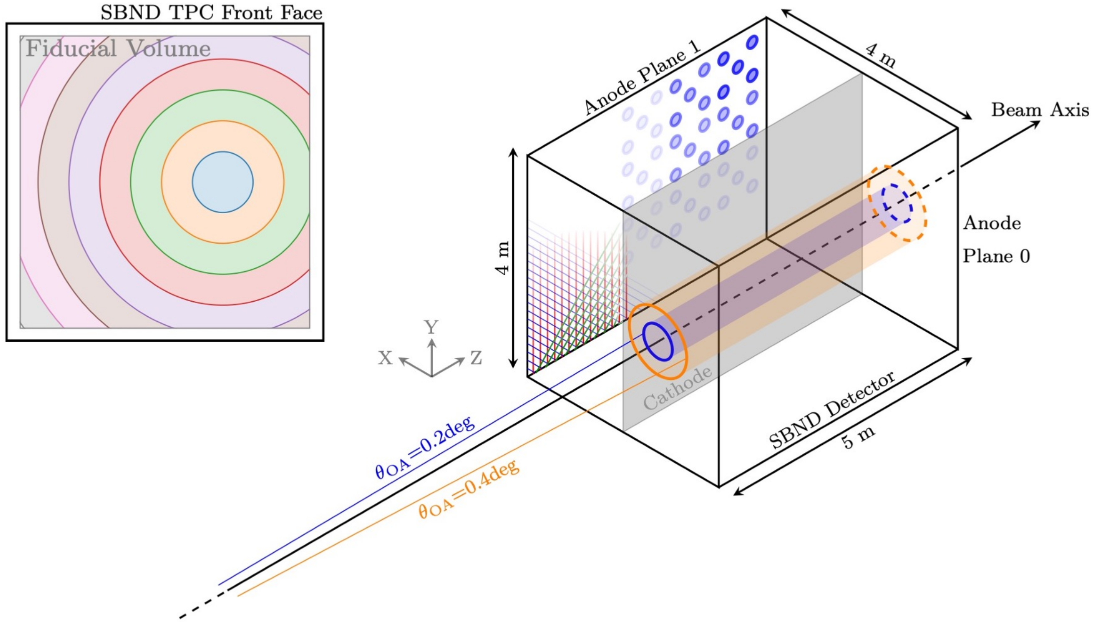
Image credit: Pedro Machado, Marco Del Tutto

SBND PRISM

SBND's proximity to the beam target and 74cm off-set allows it to cover angular range of [0°, 1.6°]

- perform cross section measurements at different neutrino energies, mean energy shift up to 200 MeV
- enhances ability to constrain systematic uncertainties in oscillation measurements
- helps to characterize and mitigate backgrounds in beyond the standard model searches



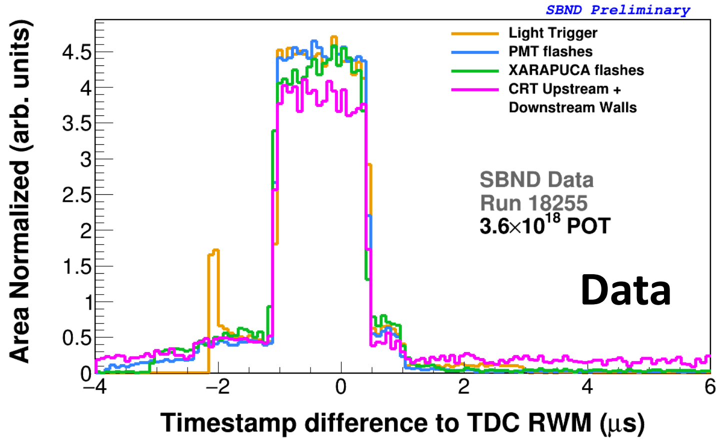


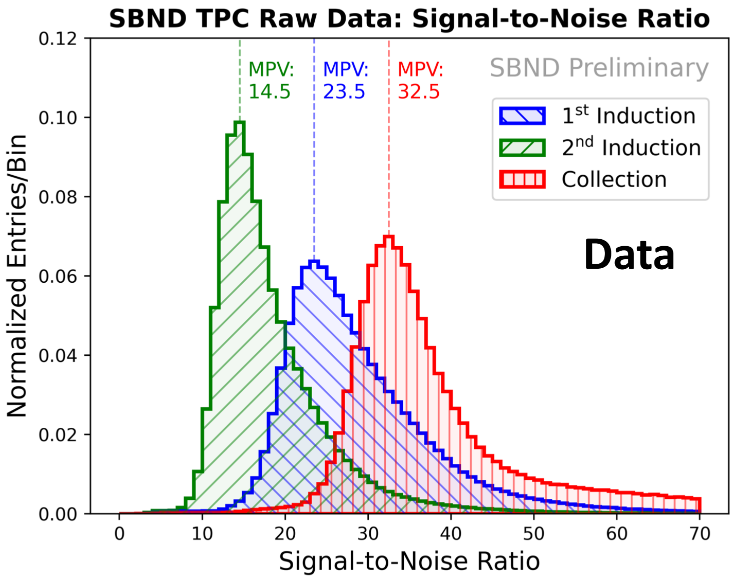
Towards first results: detector performance

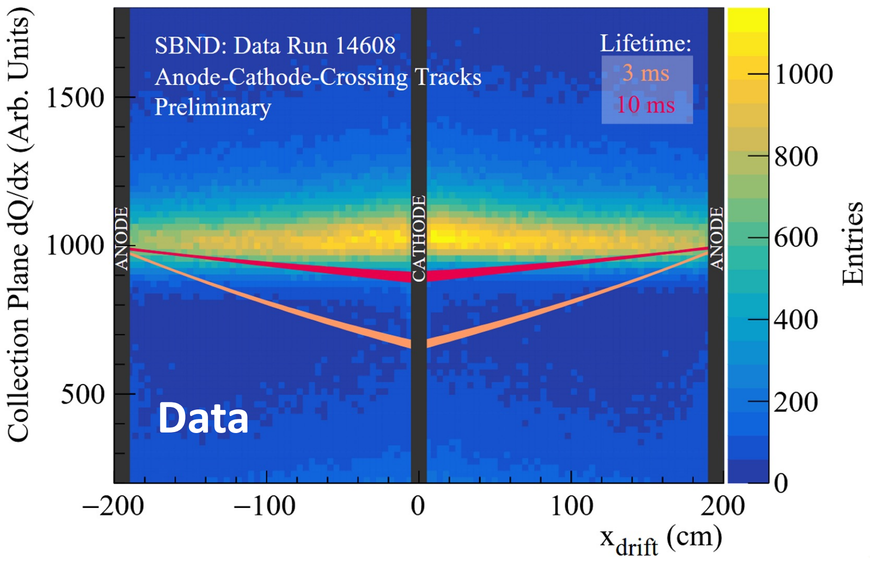
Excellent detector performance seen:

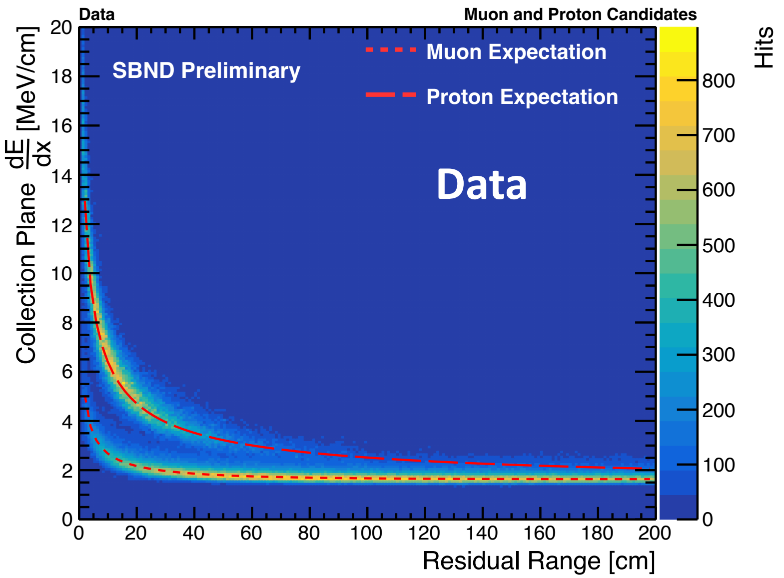
- high signal-to-noise, electron lifetime > 10ms (8 × max drift time)
- all subsystems synchronized: PDS, CRT and trigger see beam concurrently

Mature calibrations: TPC non-uniformities, space charge, dE/dx scale





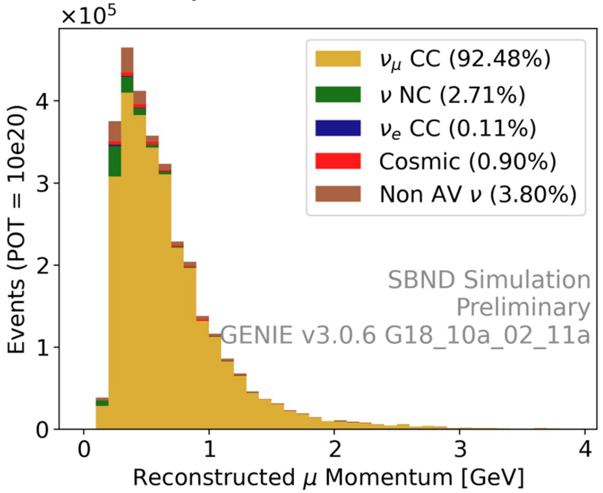




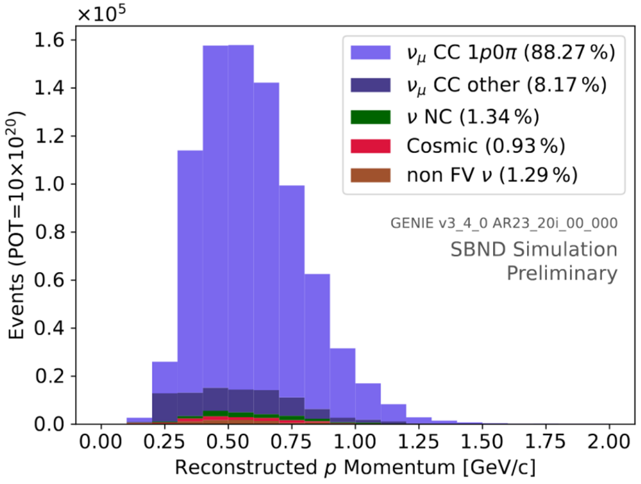
Towards first results: first analyses

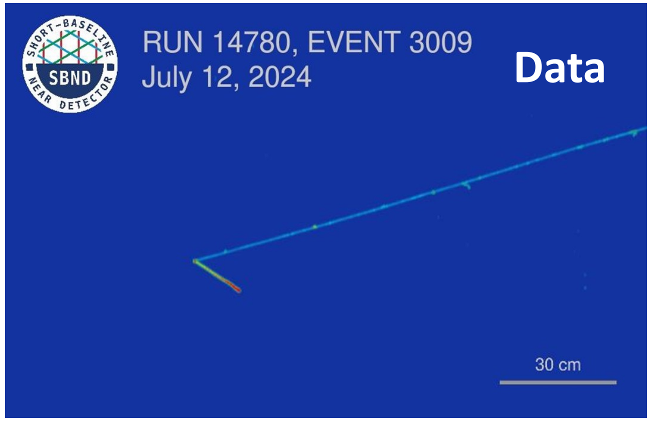
Many more analyses underway!

ν_μ CC Inclusive

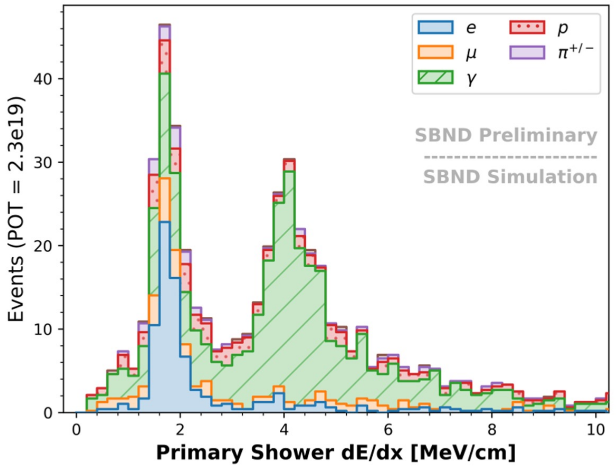


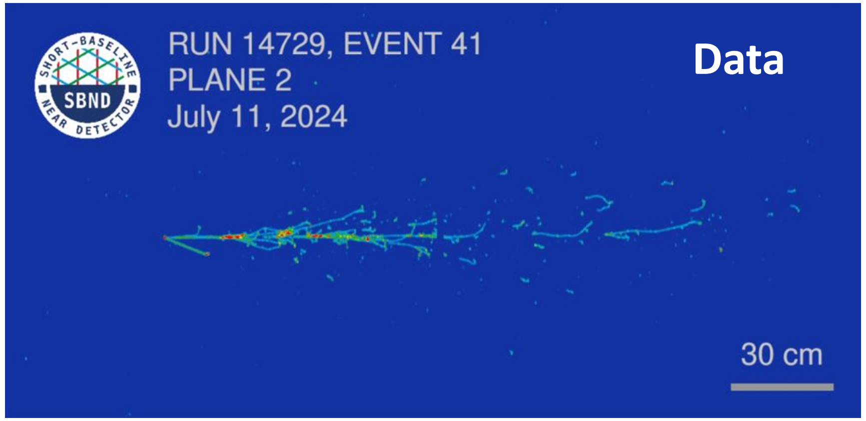
ν_μ CC 0π 1p





ν_e CC Inclusive





Summary

Collecting physics data since Dec 2024:

- largest ever data-set of neutrino interactions on argon already collected, > 2 million interactions

SBND detector performing excellently:

- mature calibrations developed

Broad physics program:

- near detector for SBN oscillations
- neutrino cross-section measurements
- beyond the standard model searches

First physics results coming soon!

SBND June Collaboration Meeting
@ University of Sheffield, UK

Backups