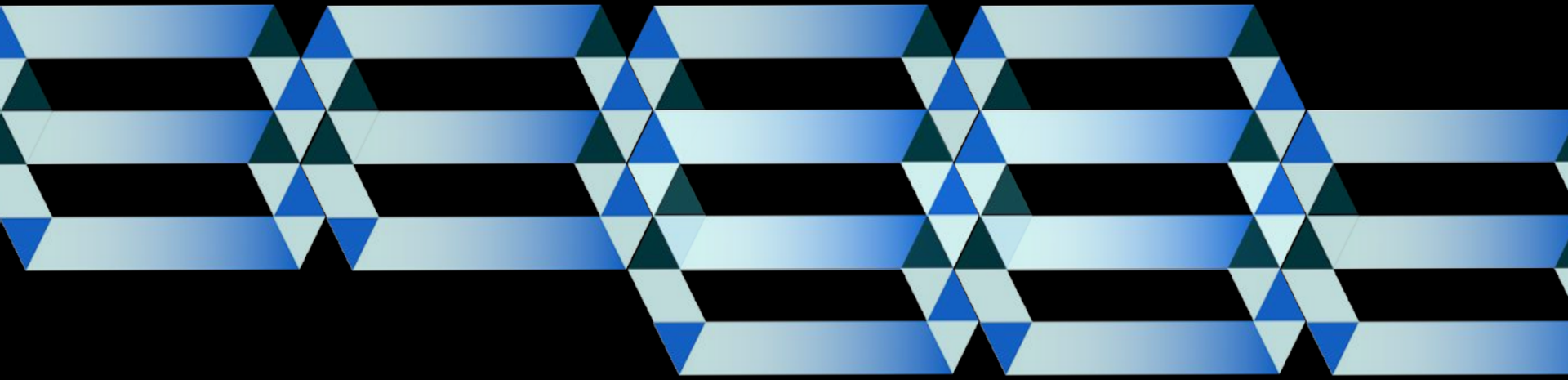
BROOKHAVEN NATIONAL LABORATORY

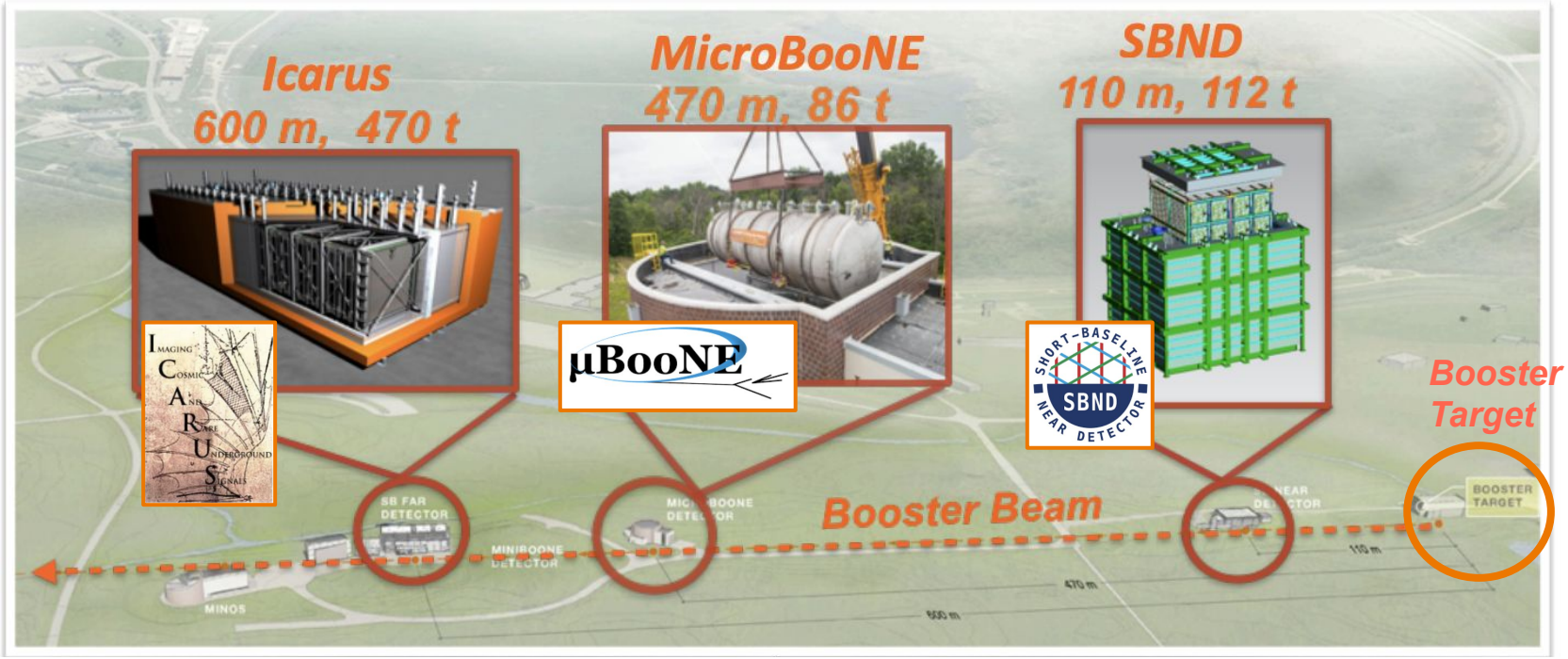


Status of the SBN Program

Mateus F. Carneiro on behalf of the SBN Collaboration

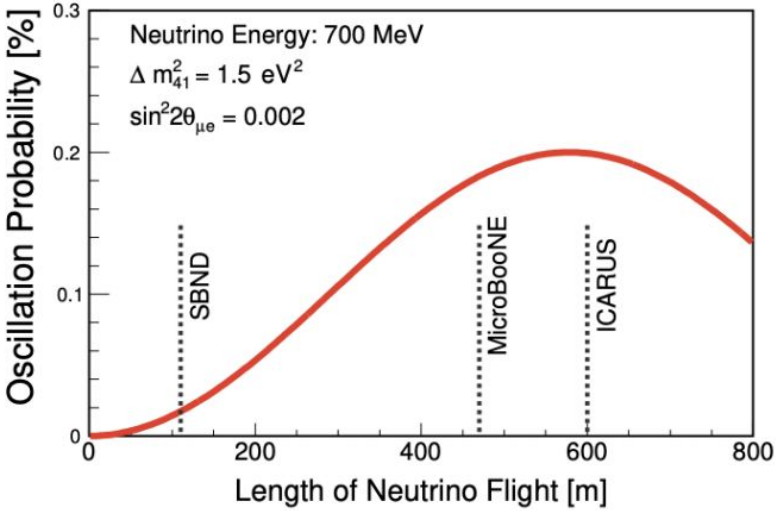
Short Baseline Neutrino Program at Fermilab

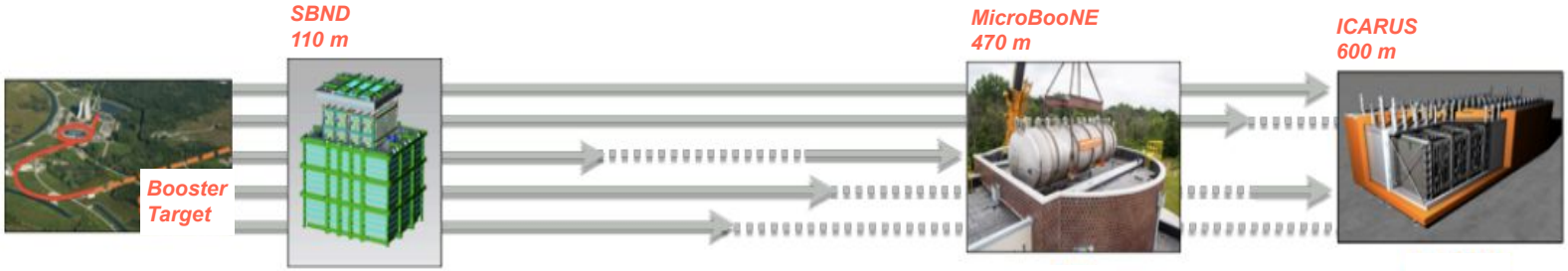
- Search for eV-scale **sterile neutrinos** by looking for muon neutrinos **disappearance** and electron neutrinos **appearance** oscillations
- Perform detailed study of **neutrino-argon interactions** at the GeV energy scale
- Pursuit advancement of the liquid argon **detector technology**
- Search for **new/rare physics** processes in the neutrino sector and beyond



Neutrino Oscillation at the SBN Program

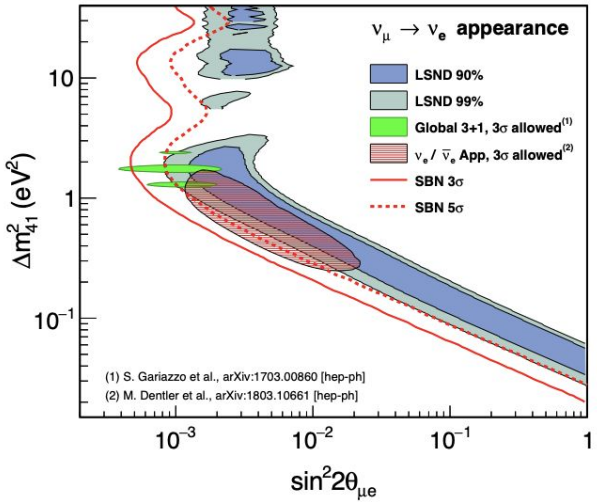
- Three functionally identical LArTPC detectors:
  - Same **nuclear target**
  - Same **detector technology**
  - Same **neutrino beam**
  - **different** distances from the source

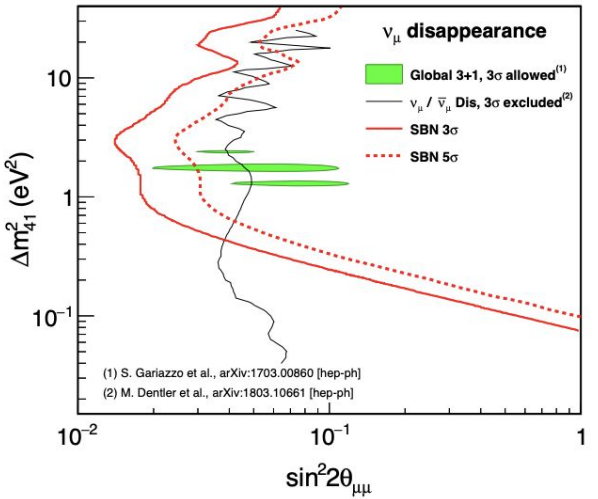




Sterile Neutrino Sensitivity

- Unique capability to study appearance and disappearance channels **simultaneously**
- **5σ coverage** of the parameter region relevant to the **LSND/MiniBooNE anomaly** in 3 years (6.6 x 10^{20} pot).
- **Statistics 1 order of magnitude beyond** SciBooNE + MiniBooNE limits in 3 years (6.6 x 10^{20} pot), probing the parameter region relevant to **reactor and gallium anomalies**.



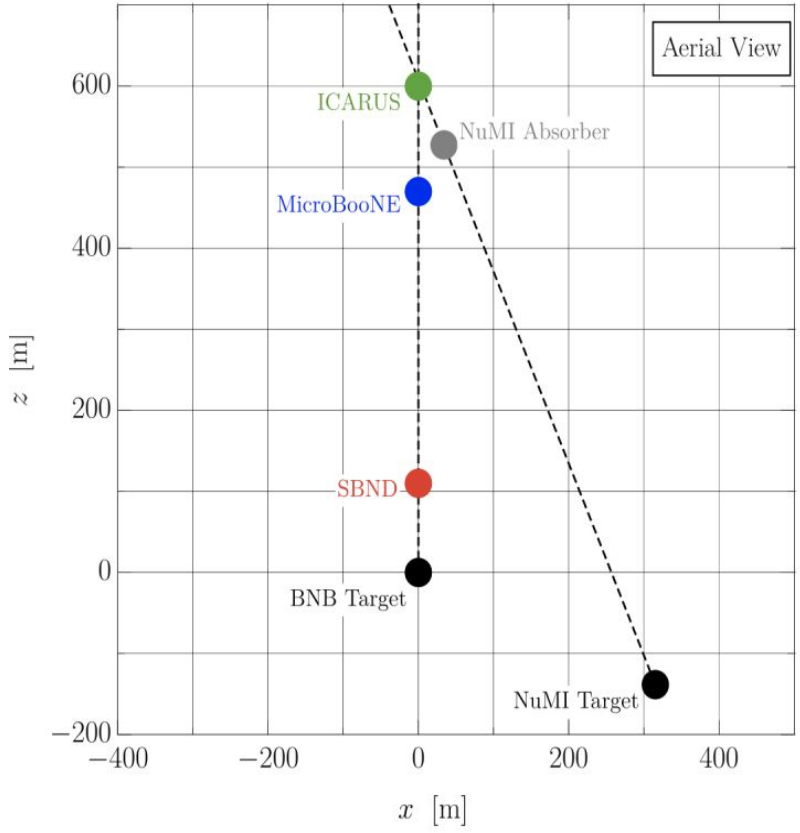


Annual Rev. Nucl. Part. Sci. 2019.69:363-387
Sensitivity curves produced with the 3 detectors

Neutrino Interaction on SBN

- **High statistics** precision measurements of neutrino argon cross sections in the **DUNE energy range**.
- **ICARUS** high statistics **neutrino cross section** measurement using the **NuMI beam off axis**
  - ~ 10^4 nue events/year
  - ~ 300k numu events/year

arXiv:1909.11670 [hep-ph]



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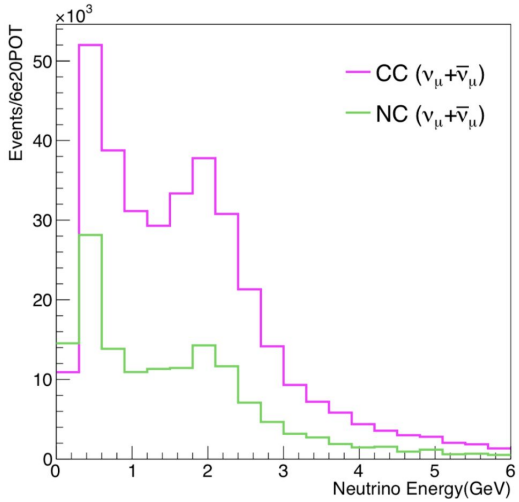
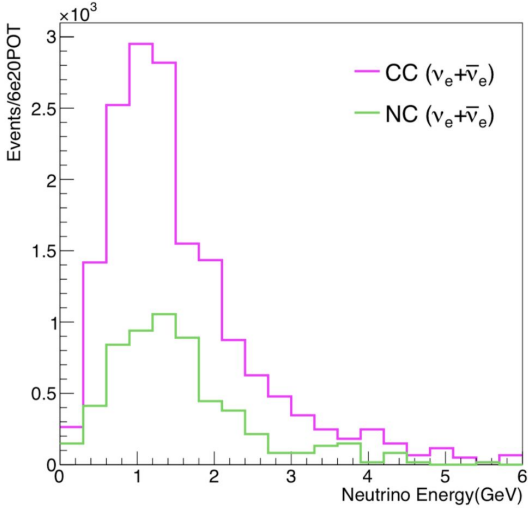


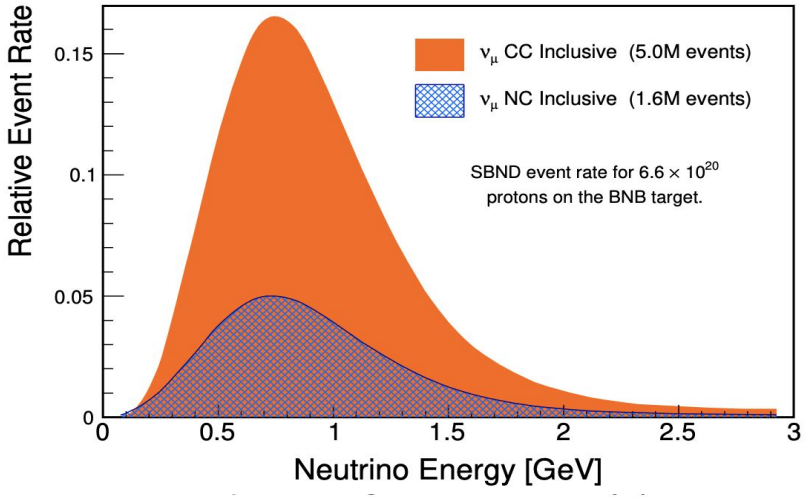
Numi off-axis muon neutrinos

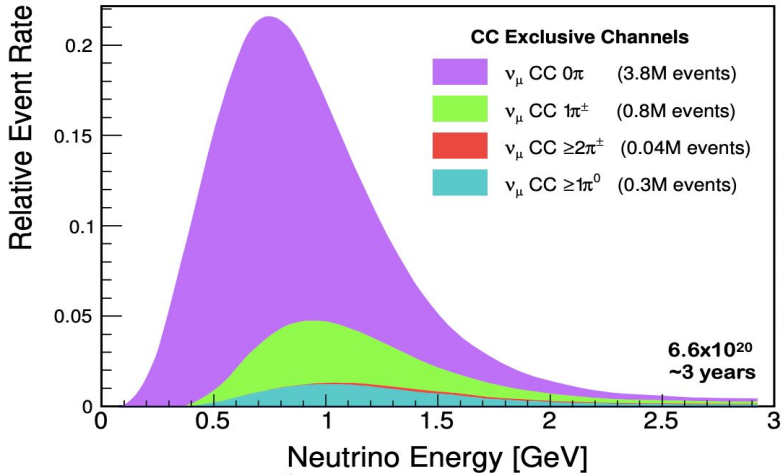


Numi off-axis electron neutrinos

Neutrino interactions at SBN

- **High statistics** precision measurements of neutrino argon cross sections in the **DUNE energy range**.
- **SBND**: world's **highest statistics** cross section measurements **on argon**
  - ~ 7 million numu and
  - ~ 50,000 nue in 3 years



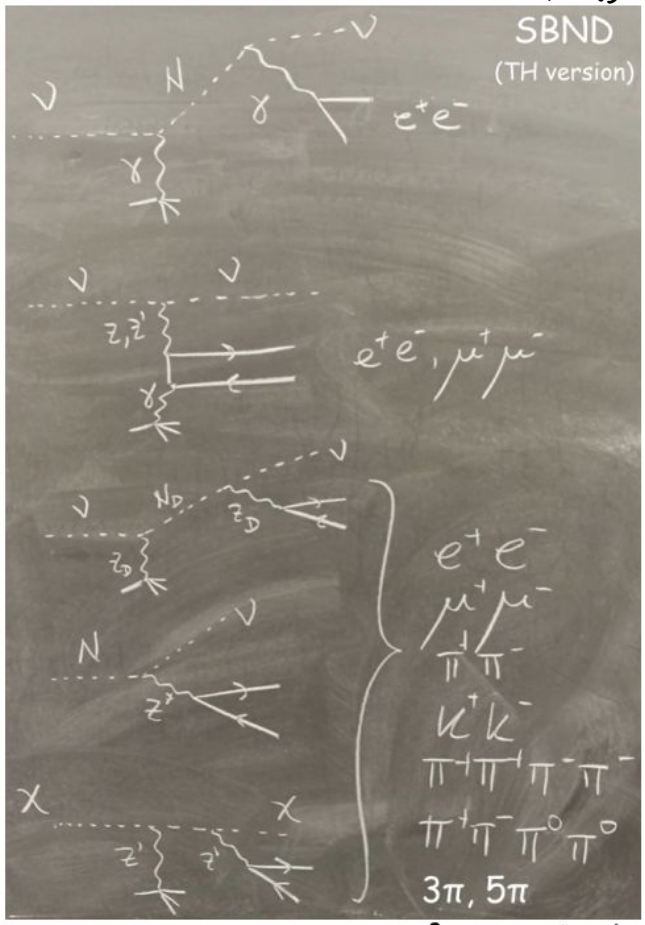


BSM

- Conditions create great potential to probe a vast range of **BSM physics** at SBN:
  - **Sterile neutrinos**
  - **Neutrino tridents**
  - **Light dark matter**
  - **Millicharged particles**
  - **Heavy Neutral Leptons …**

For more details, check Iker de Icaza
***Dark Neutrino Simulations with GENIE on SBND* talk later today**

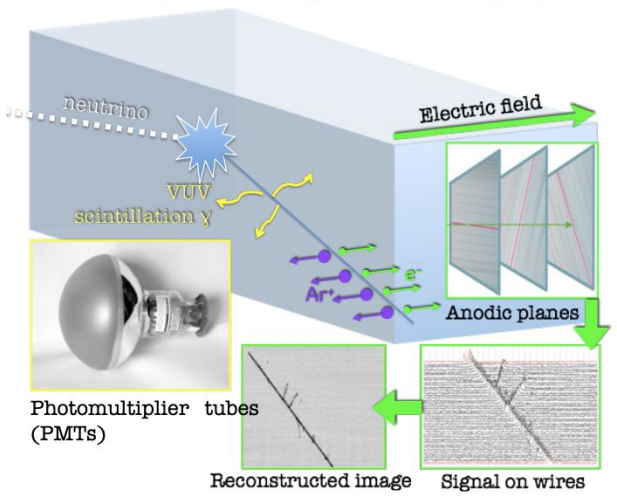
Neutrino tridents *(topology)*

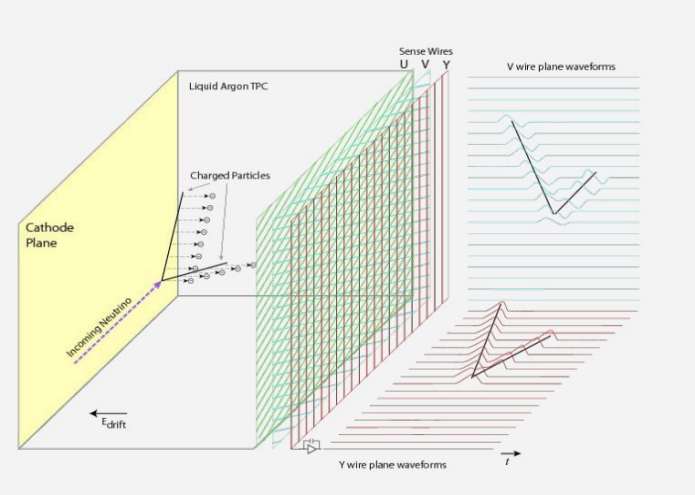


Courtesy of P. Machado

Liquid Argon TPC detection technique

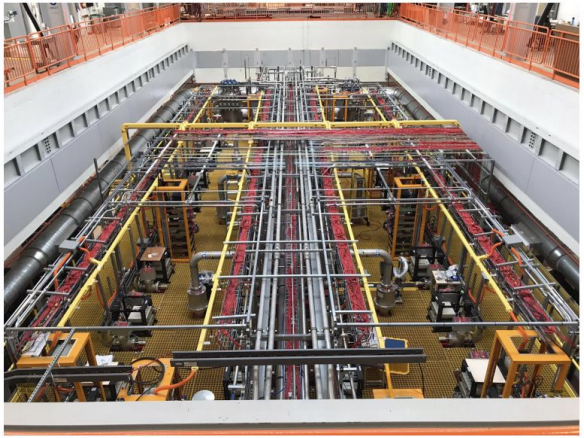
- Massive and **homogeneous target**, excellent **tracking** & **calorimetric** capabilities:
  - **Ionisation electrons**:
    - 42000 e^- /MeV
    - Drift toward wire planes inducing a signal.
    - Response time = drift time (~ms)
  - **3D image reconstruction** by combining coordinates on different wire planes at the same drift time
  - **Light** component
    - λ = 128 nm scintillation light:
    - 40000 g/MeV wo electric field.
    - Response time ~ 6 ns ÷ 1.6 μs

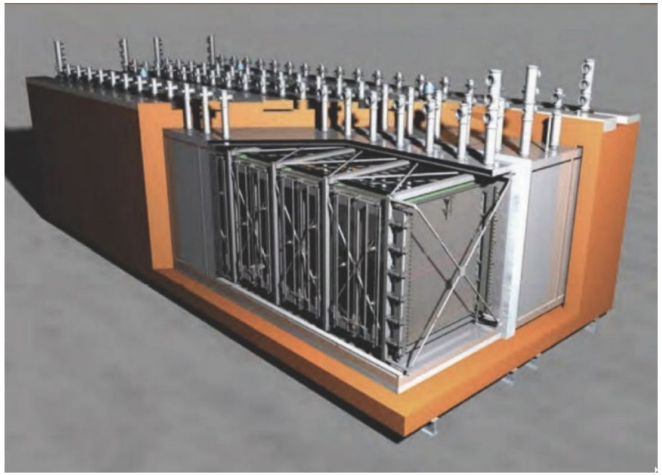




ICARUS Detector

- **LArTPC**
  - **600 m** from ν beam production
  - **476 ton active volume** (760 t total)
  - **4 TPCs** with **1.5 m drift** length
  - **75kV** high voltage
  - **0.95 ms drift time** at 500V/cm
  - **3 wire planes**:
    - horizontal, ∓30 deg,
    - 3mm wire pitch,
    - 53246 wires
  - Warm analog and digital **electronics**
  - **360 8” PMTs** coated with **TPB** (wavelength shifter for better scintillation photons sensitivity)
- CRT (**cosmic ray tagger**) coverage

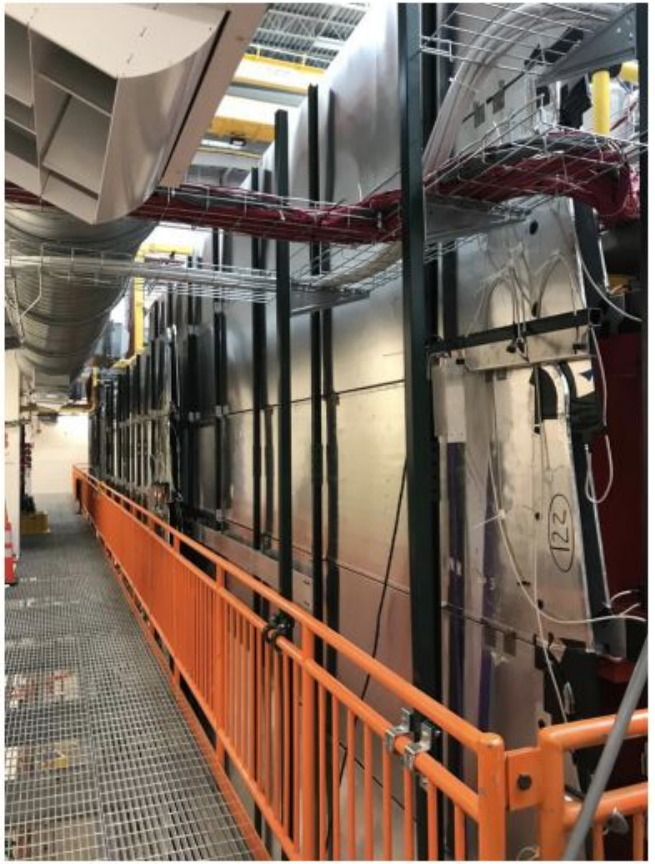




Comissioning

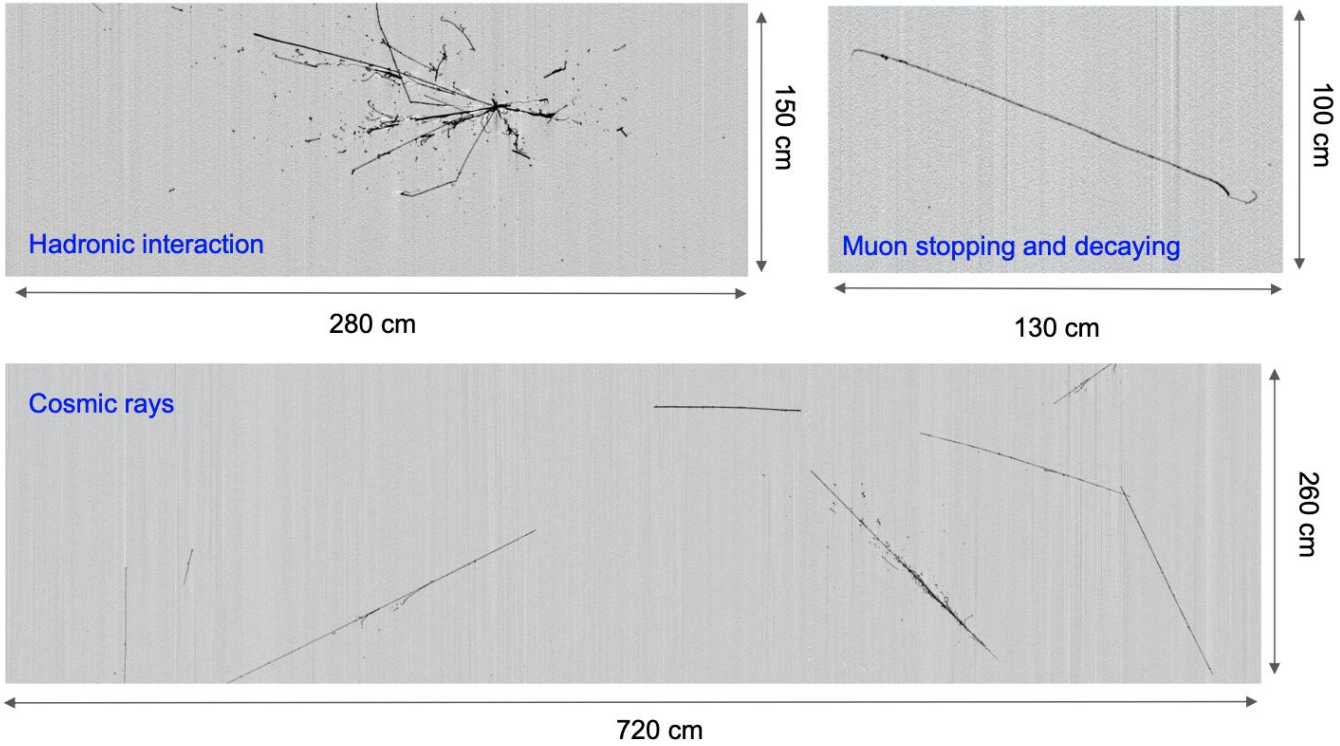
- **TPC, PMT, trigger and DAQ** installation activities complete
- Commissioning in progress and **activities ongoing** despite of **restricted operations** due to COVID-19:
  - Bottom CRT and **7 out of 8 walls** of side **CRT installation** complete.
  - **24/7 shifts** since February 14th 2020 shortly before the TPCs were filled.
  - **Remote only shifts** since March 17th 2020.

CRT East walls complete



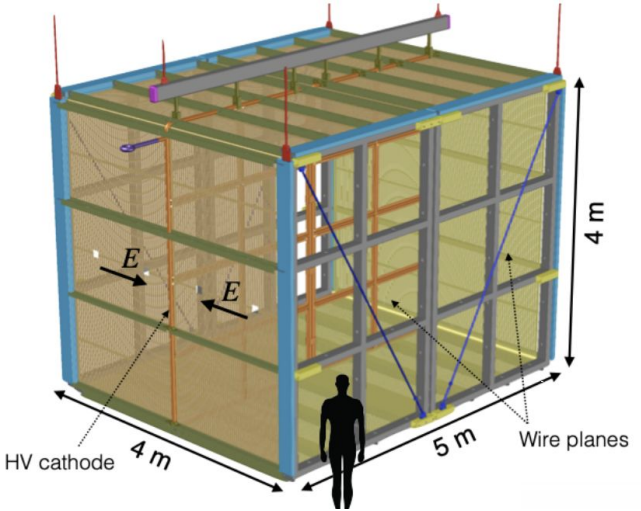
Comissioning

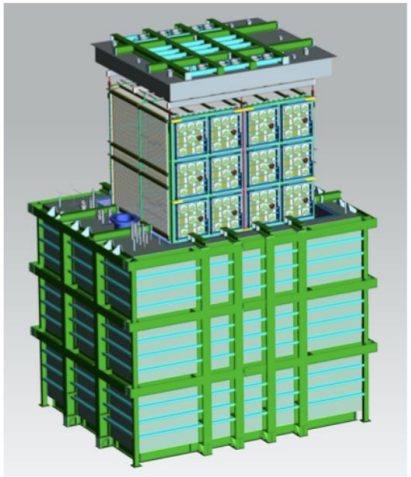
- ICARUS detector expected to **initiate physics data** taking **early in the Fall** with Booster and NUMI off-axis higher energy beam.
- After the first year, it will be operated **jointly with SBND** to address the **sterile neutrino puzzle** within the SBN program.



SBND Detector

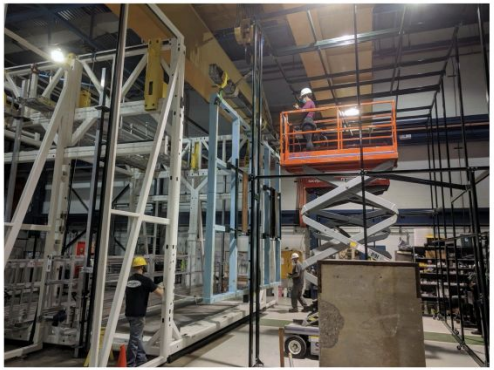
- **LArTPC**
  - **110 m** from ν beam production
  - **112 ton active volume** (260 total)
  - **2 TPCs** with **2.0 m drift** length
  - **100 kV** high voltage
  - **1.28 ms drift time** at 500V/cm
  - **3 wire planes:**
    - 0, ∓60 deg,
    - 3mm wire pitch,
    - 11264 wires
  - **Cold** analog and digital **electronics**
  - **Photon Detection System (PDS)**
    - **120 8” PMTs** (**96** coated with **TPB**)
    - **192 X-ARAPUCA** modules
    - **TPB** coated **reflector foils** on the cathode
- CRT (**cosmic ray tagger**) coverage





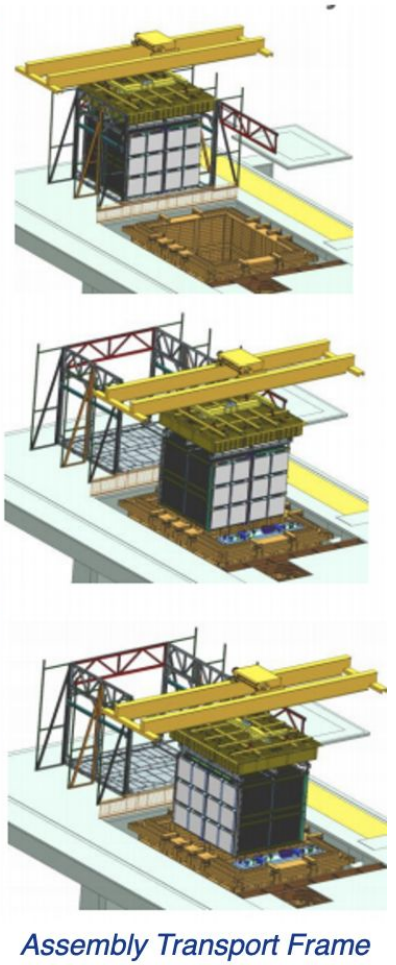
Construction/Installation

- Detector **assembly**
  - All TPC components **constructed**
  - **Assembly ongoing** at Fermilab in clean room at Dzero
  - Readout **electronics tested** and **ready for installation**
- **CRT** system:
  - Panels **constructed**
  - Bottom panels **installed**
  - Beam **measurements in pit**
- **Cryostat/cryogenics**
  - Warm outer vessel **installed**
  - Cryostat material **at FNAL**
  - Top cap fabrication finalizing **at CERN**
  - Cryogenics **installation ongoing**



Test of mock APA hanging

APA



Assembly Transport Frame

Construction/Installation

- Detector **assembly**
  - All TPC components **constructed**
  - **Assembly ongoing** at Fermilab in clean room at Dzero
  - Readout **electronics tested** and **ready for installation**
- **CRT** system:
  - Panels **constructed**
  - Bottom panels **installed**
  - Beam **measurements in pit**
- **Cryostat/cryogenics**
  - Warm outer vessel **installed**
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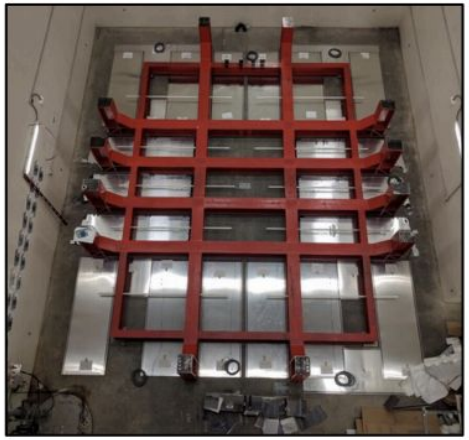
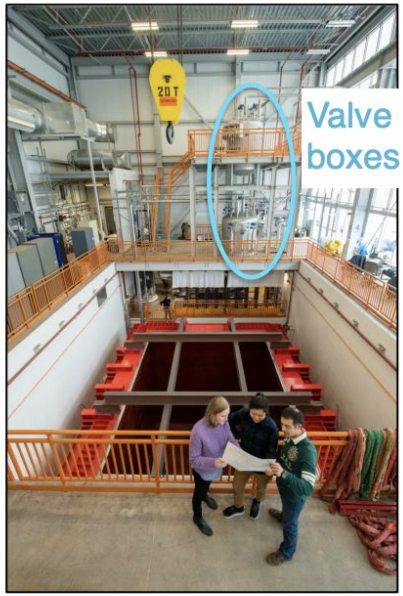
  - Top cap fabrication finalizing **at CERN**
  - Cryogenics **installation ongoing**

BNB measurement with CRT



Bottom CRT



Warm outer vessel in the pit

Top cap _ part 1

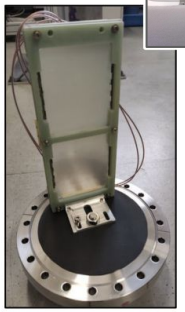
Photo Detection System

- **PMTs**:
  - **tested** at LANL in the Coherent Captain Mills experiment
  - all **120 PMTs, mounted in the 24 PDS boxes**, are now delivered **at FNAL**
- **X-ARAPUCA**s:
  - **assembly** of the **modules** ongoing
  - **cold tests** in Brazil with different light guides
  - **test stands at FNAL** for mass testing of silicon photomultipliers (**SiPMs**) and readout development/test
- **TPB** coated **reflector foils** on the cathode:
  - At FNAL, to be installed when CPA ready

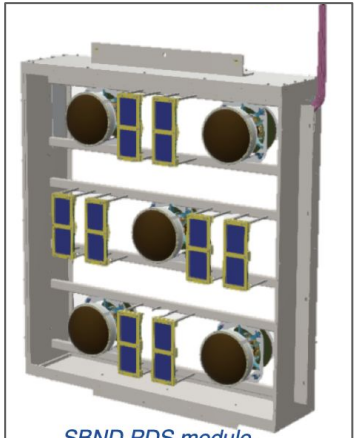
PMTs being tested at LANL

PMTs mounted in PDS boxes at Fermilab

SiPM cold test



X-ARAPUCA

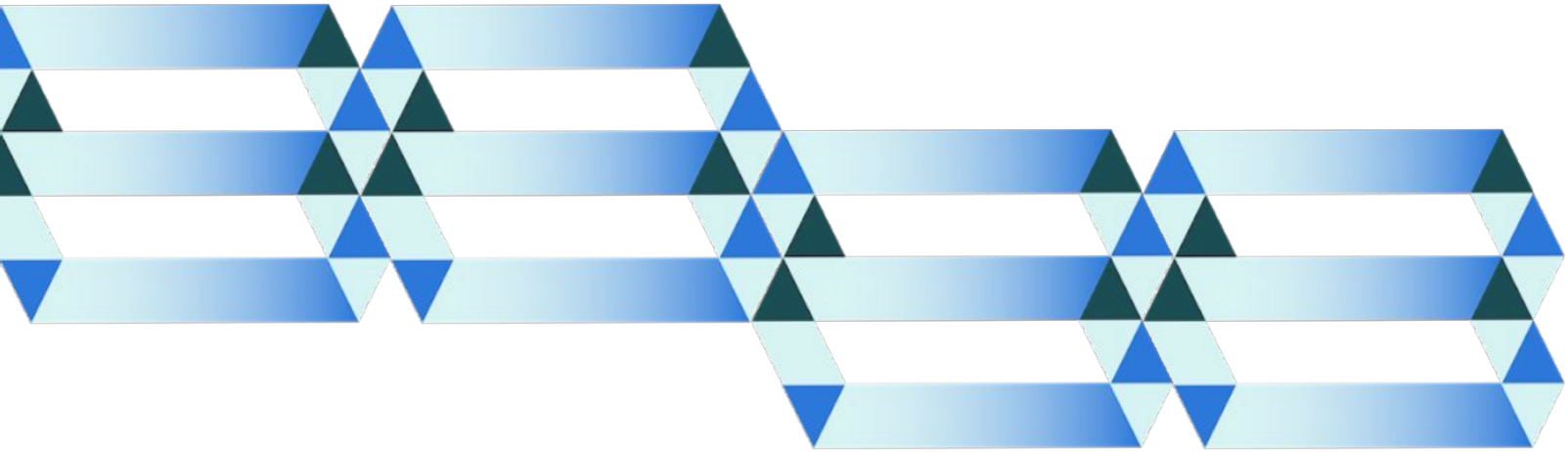


SBND PDS module

Status of SBN

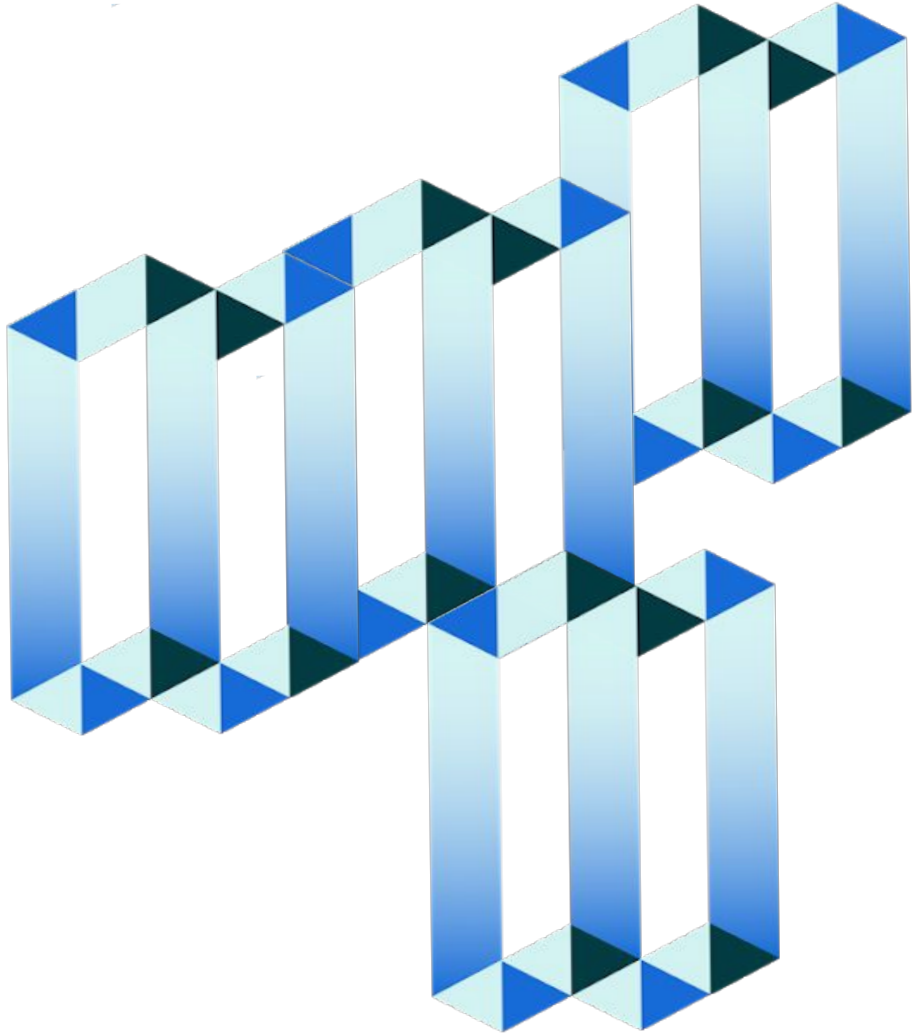
- The **SBN Program at Fermilab** is well on its way to:
  - an exciting **search for neutrino oscillations** over short baseline addressing the **sterile neutrino puzzle**;
  - make **high precision** measurements of **neutrino-Ar cross sections**;
  - develop **LAr-TPC technology & expertise**
    - Working together in between **collaborations sharing systems, tools and resources**

- **Despite the challenges** posed by the Covid-19 pandemic:
  - the **ICARUS** detector was **activated** in August 2020 and is now in commissioning phase, expected to be completed **early in the Fall 2021**;
  - **assembly and installation** of the **SBND** detector are progressing, with projected activation in **2022**.

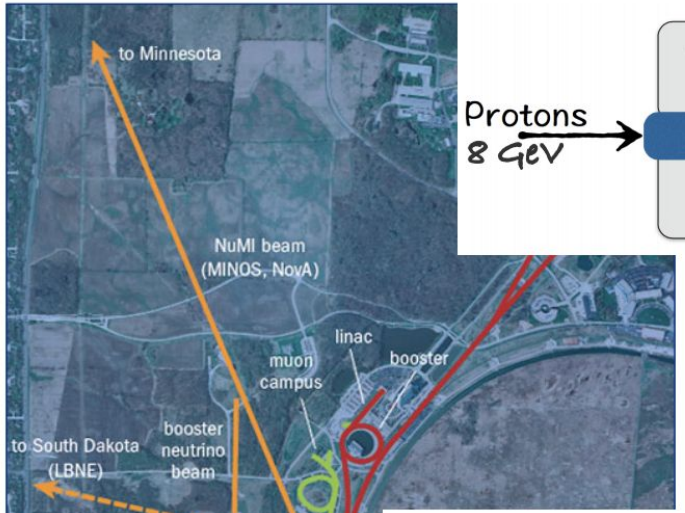


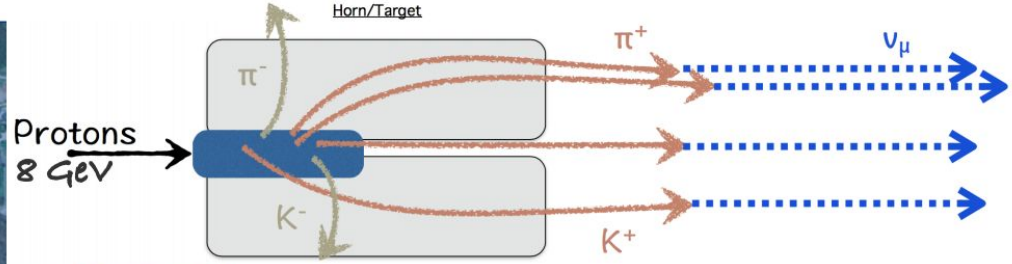
Thank you!

Backup



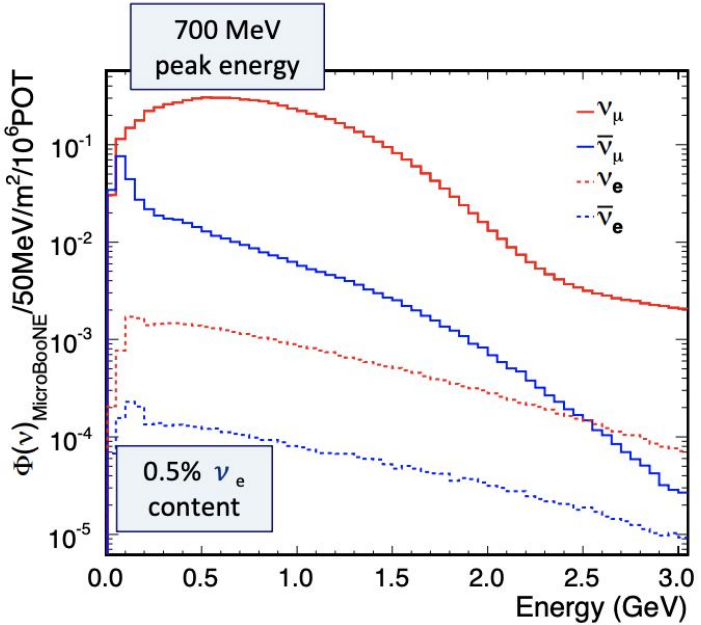
The Booster Neutrino Beam





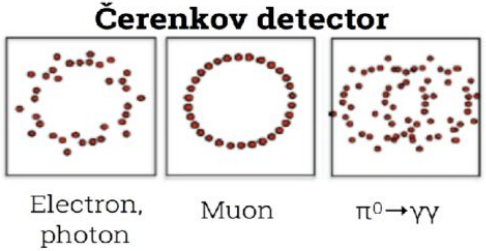
@ SBND:
- BNB: 0.25 Hz ν, 0.03 Hz cosmic

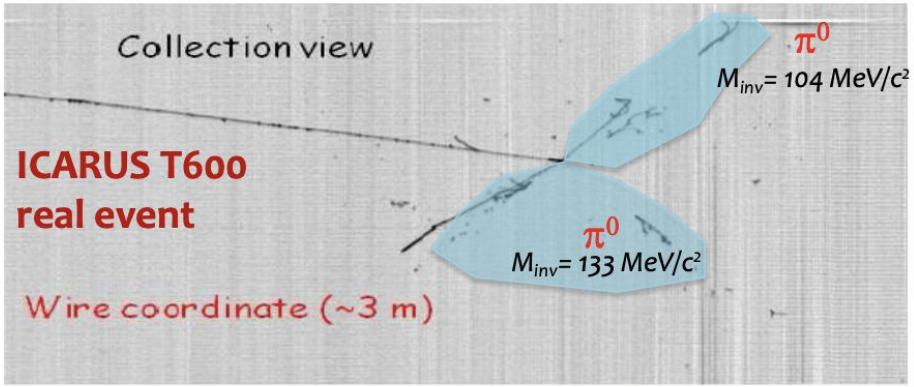
@ ICARUS:
- BNB 0.03 Hz ν, 0.14 Hz cosmic
- NuMI: 0.014 Hz ν, 0.08 Hz cosmic



Electron neutrinos in LAr-TPC

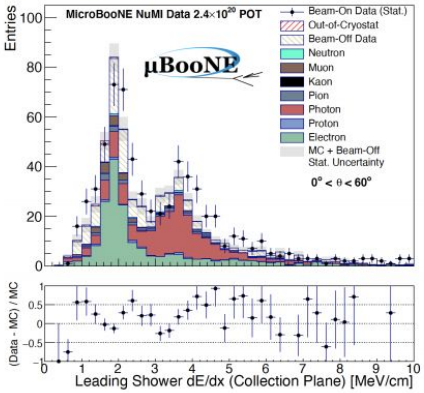
Fine tracking & calorimetry essential for e/γ separation and π^0 reconstruction



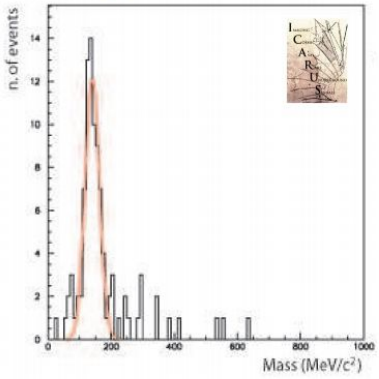


CNGS ν beam direction

arXiv: 2101.04228



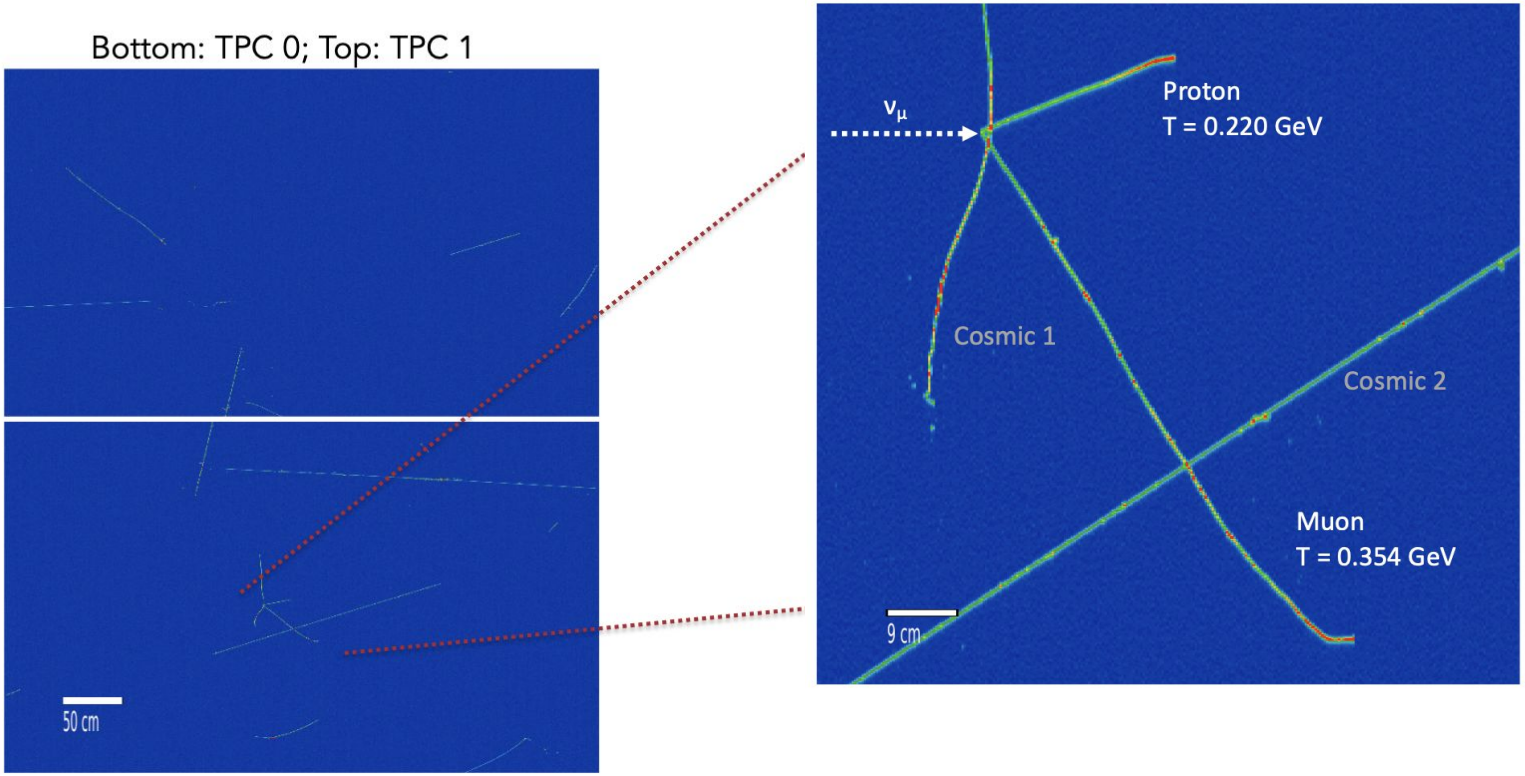
Acta Phys.Polon.B41:103-125



- Gap between vertex and shower.
- Ionization in the first segment of showers (1 mip or 2 mips).
- π^0 invariant mass.

Liquid Argon TPC detection technique

- **Simulated BNB Neutrino event in SBND**
  - Muon neutrino charge current interaction
    - Energy = 0.697 GeV



SBN vs DUNE: kinematic range

Even though DUNE is at higher energy, SBND covers peaks of area relevant for DUNE