MANCHESTER 1824

The University of Manchester

The Short Baseline Near Detector

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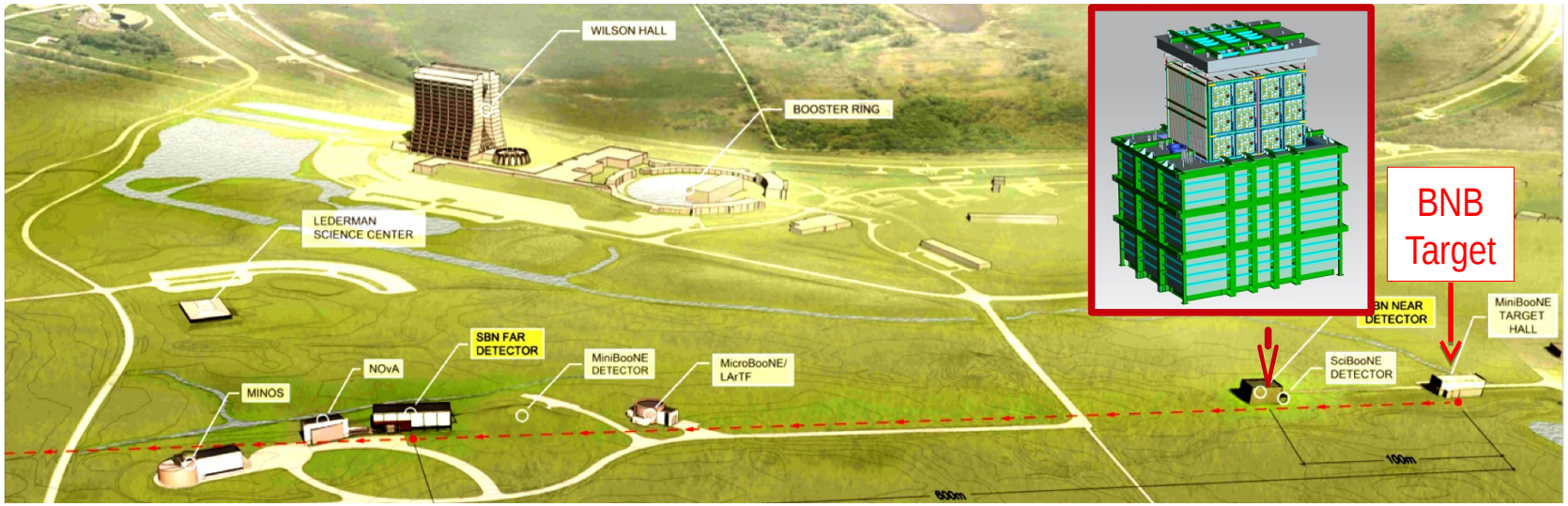
(University of Manchester)

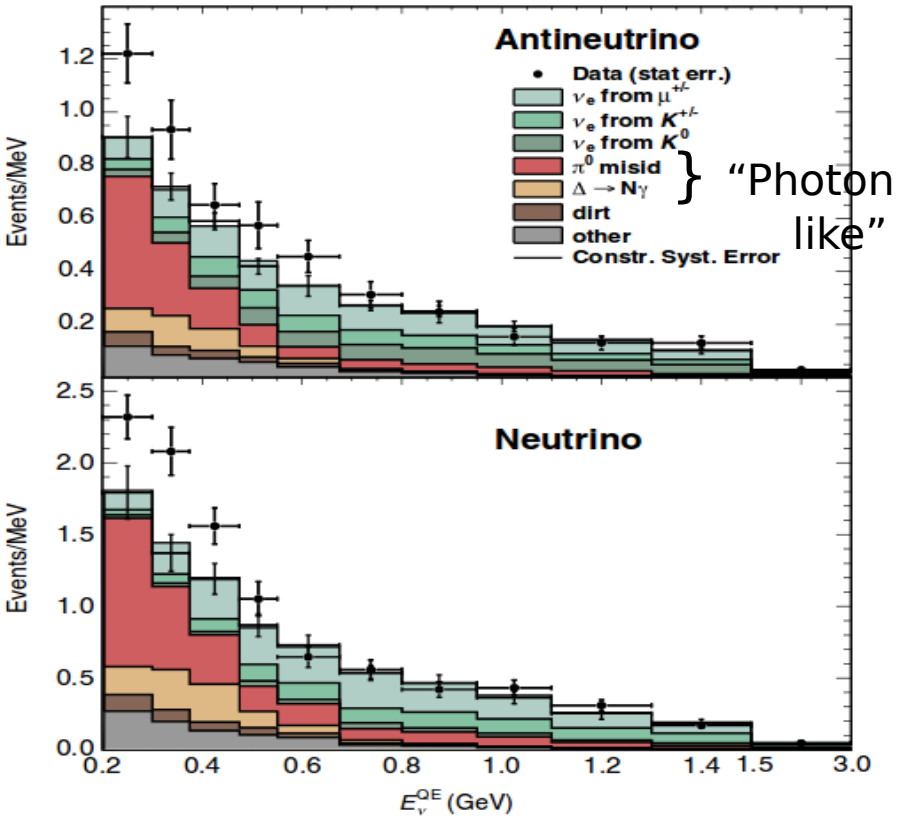


Outline

- Short Baseline Physics
- Detecting neutrinos with the SBND LArTPCs
- Cross Section measurements in SBND
- Current Status
- Conclusions

Sterile Neutrino Hints

- Recalculation of reactor neutrino fluxes and analysis of sources in gallium experiments (still) shows a disappearance effect.

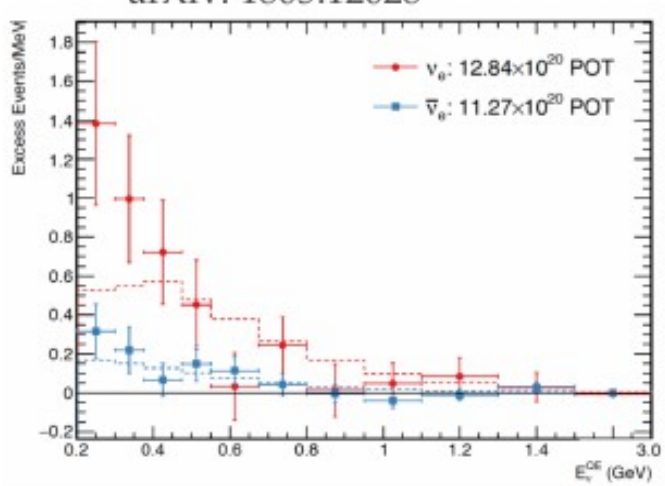


Phys. Rev. Lett. 110, 161801 (2013)

MiniBooNE

Baseline 540 m
E=[0 - 2] GeV
L/E ≈ 1 m/MeV

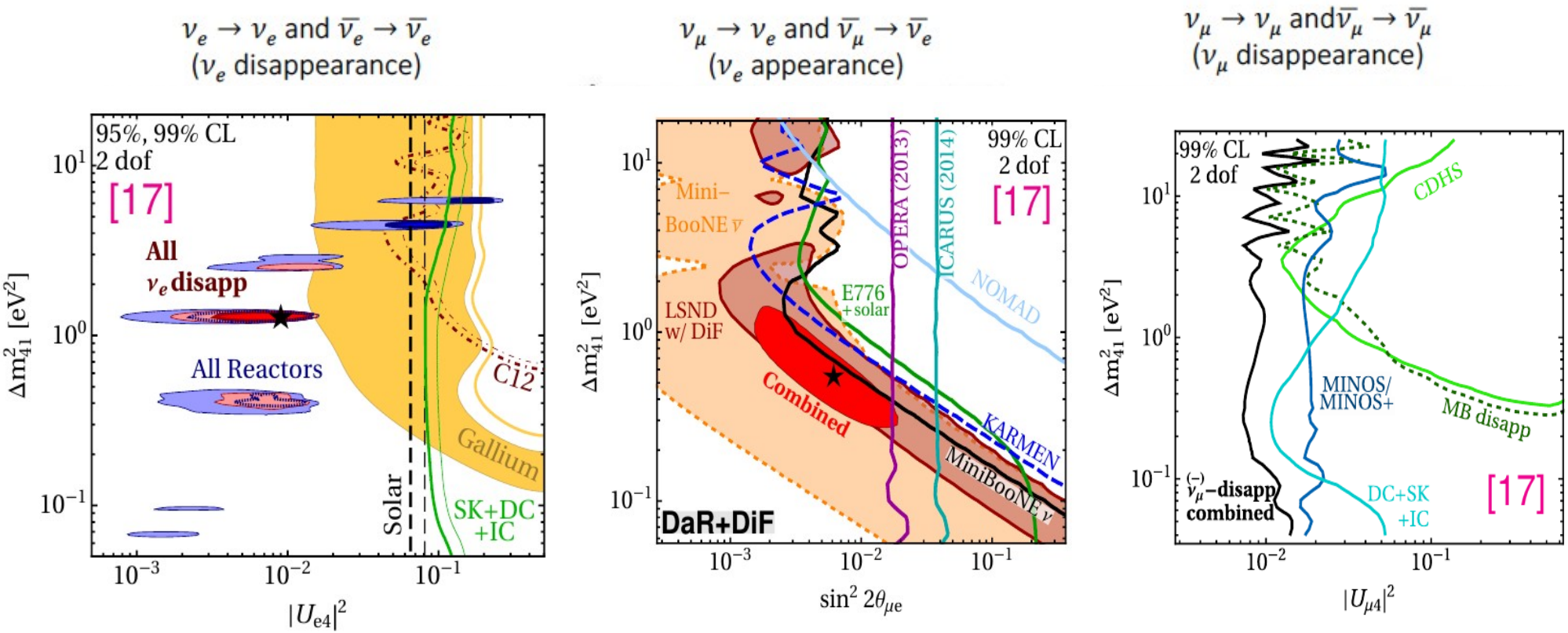
arXiv: 1805.12028



excess appearance of $\bar{\nu}_e$ and ν_e:
So called low energy excess.
evidence for $\nu_\mu \to \nu_e$ oscillation
at $\Delta m^2 \simeq 1$ eV^2 ?

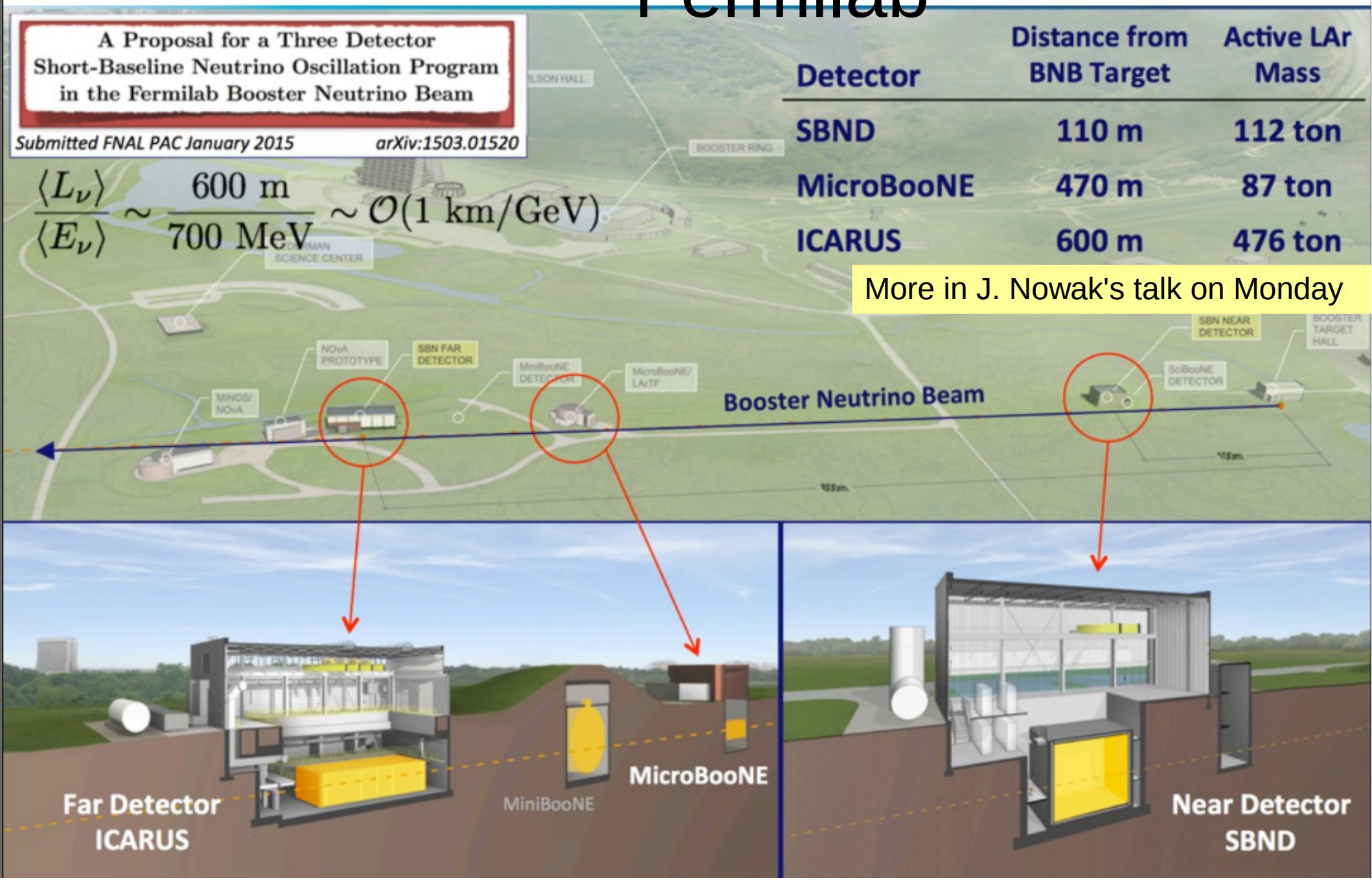
Global Fits

Dentler, Hernández-Cabezudo, Kopp, Machado, Maltoni, Martinez-Soler, Schwetz, arXiv:1803.10661.



Tension with experiments that observe no signal, especially recent measurements by **IceCube and MINOS+** leads to significant constraints on possible sterile neutrino parameters.

Enter SBN Programme at Fermilab



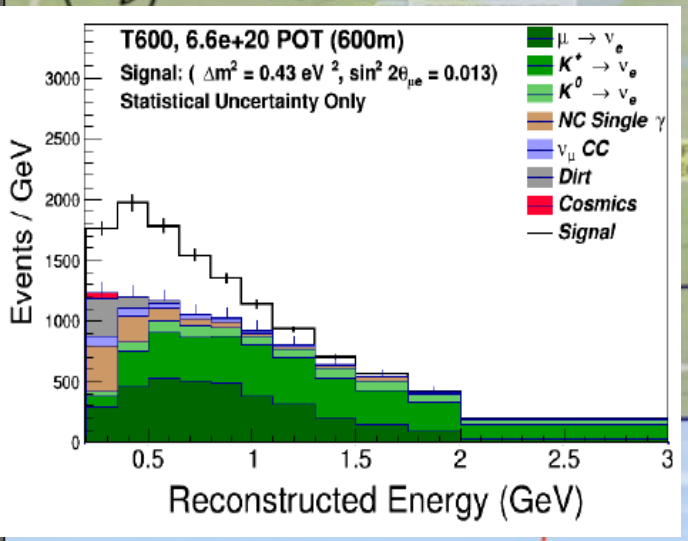
Full SBN running

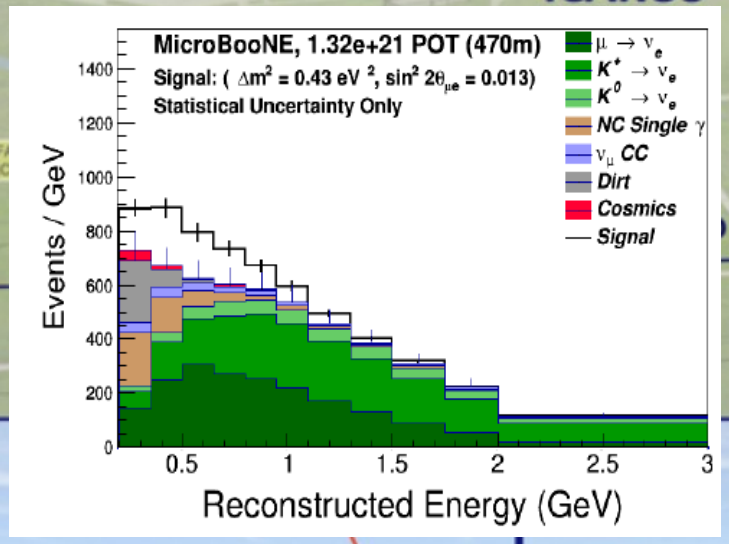
A Proposal for a Three Detector Short-Baseline Neutrino Oscillation Program in the Fermilab Booster Neutrino Beam

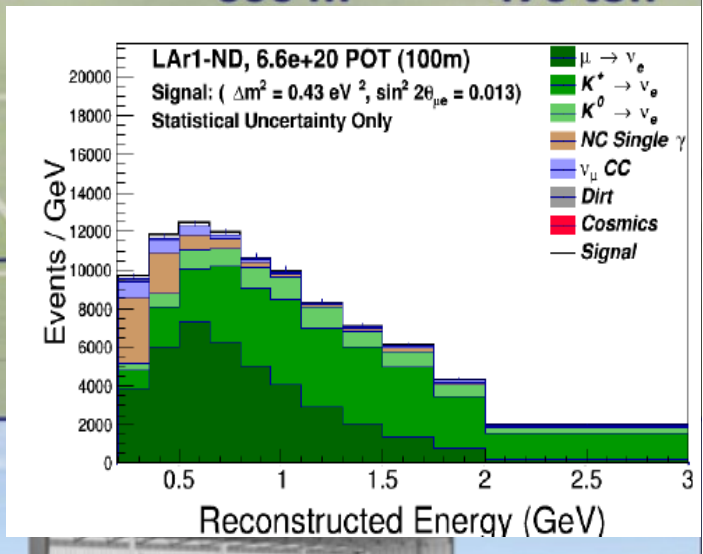
Submitted FNAL PAC January 2015 *arXiv:1503.01520*

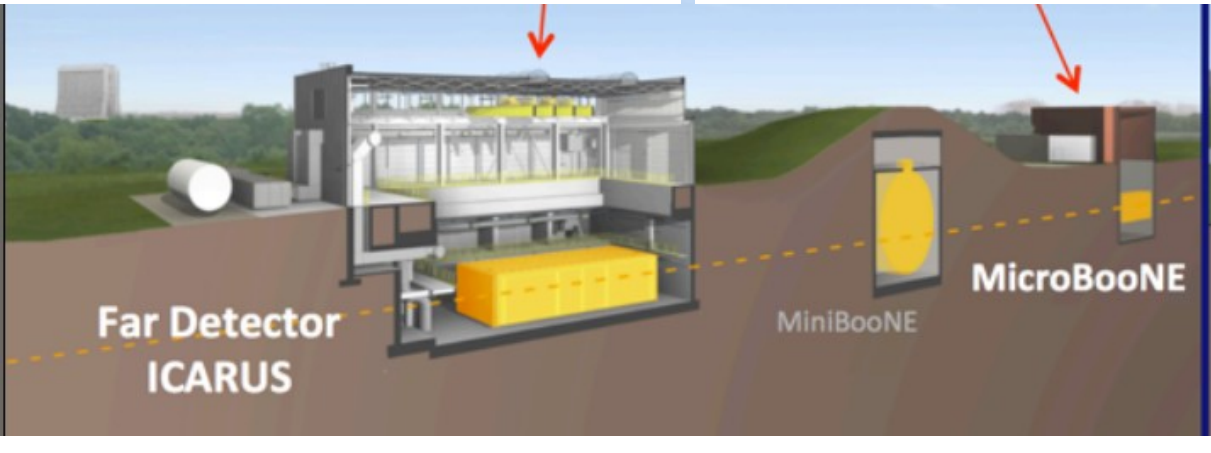
$$\frac{\langle L_\nu \rangle}{\langle E_\nu \rangle} \sim \frac{600\ \mathrm{m}}{700\ \mathrm{MeV}} \sim \mathcal{O}(1\ \mathrm{km/GeV})$$

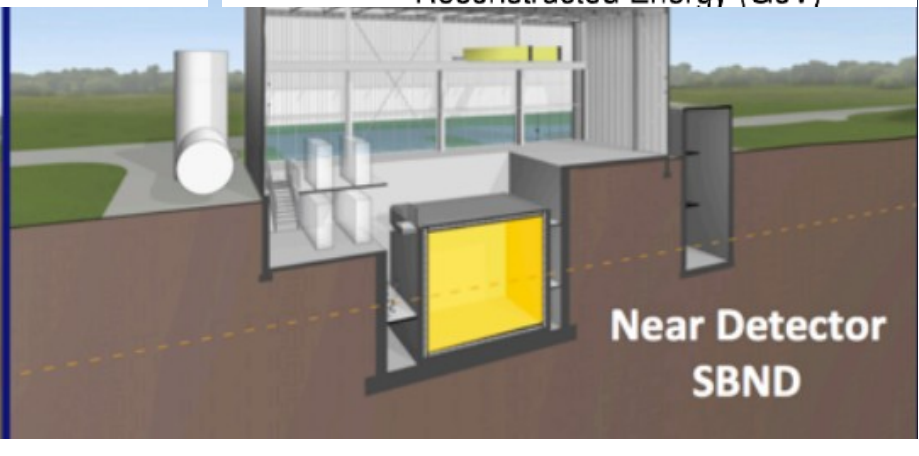
Detector	Distance from BNB Target	Active LAr Mass
SBND	110 m	112 ton
MicroBooNE	470 m	87 ton
ICARUS	600 m	476 ton



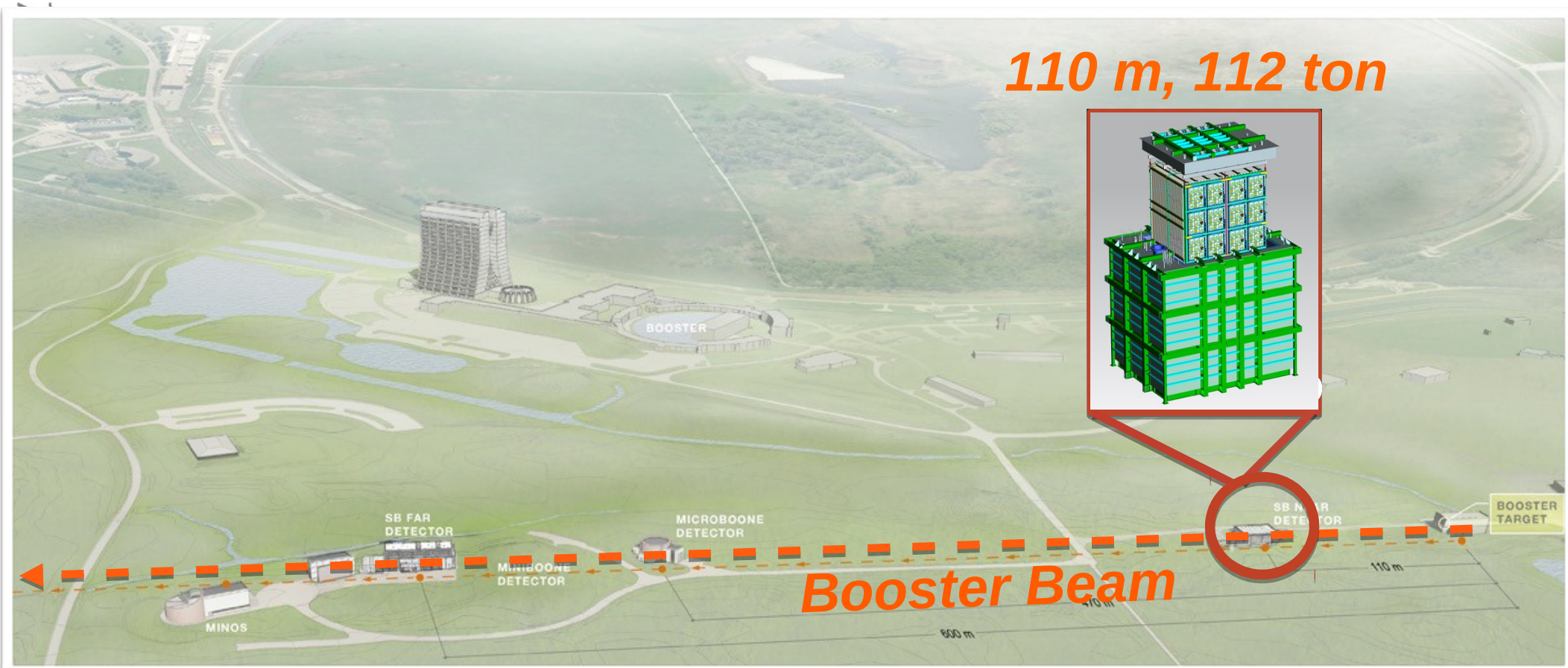








SBND – the near detector



The Short-Baseline Near Detector (SBND), will be located closest to the source of neutrinos.

It will characterize the beam before oscillations occur and address one of the dominant systematic uncertainties.

Planned start of operation 2020.

SBND at a glance

112-ton (active volume) in two Liquid Argon Time Projection Chambers.

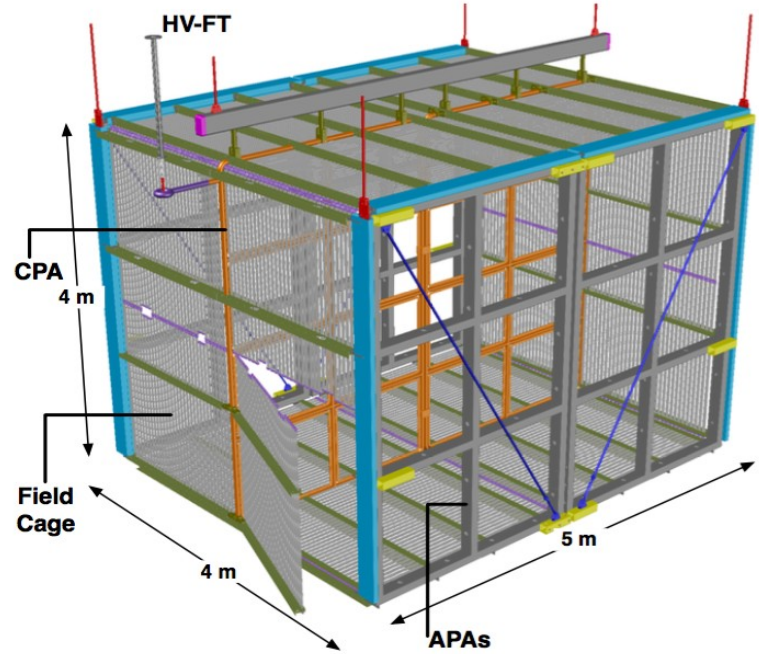
Four Anode Plane Assemblies and 2 Cathode Plane Assemblies.

4x4x5m Active Volume.

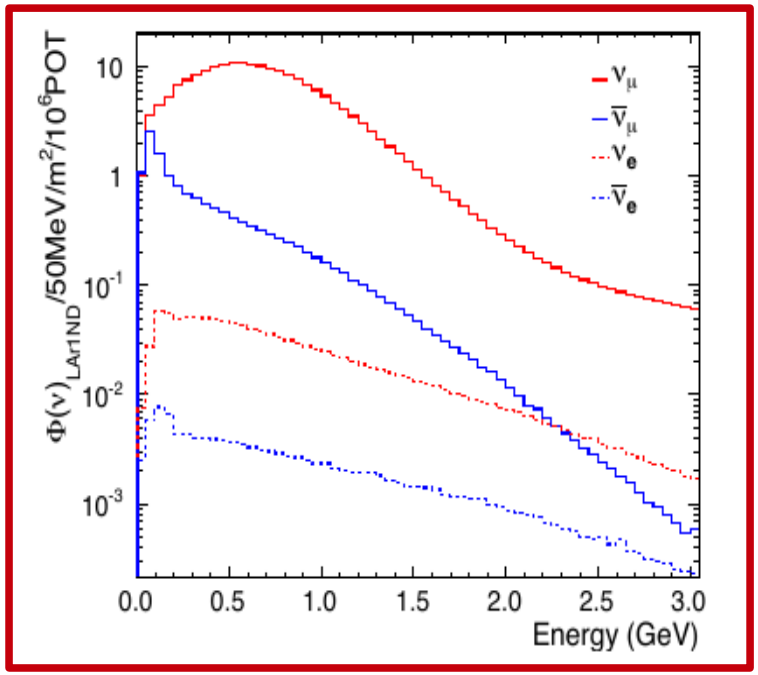
Cold readout electronics.

Membrane Cryostat.

Cosmic Ray Tagger

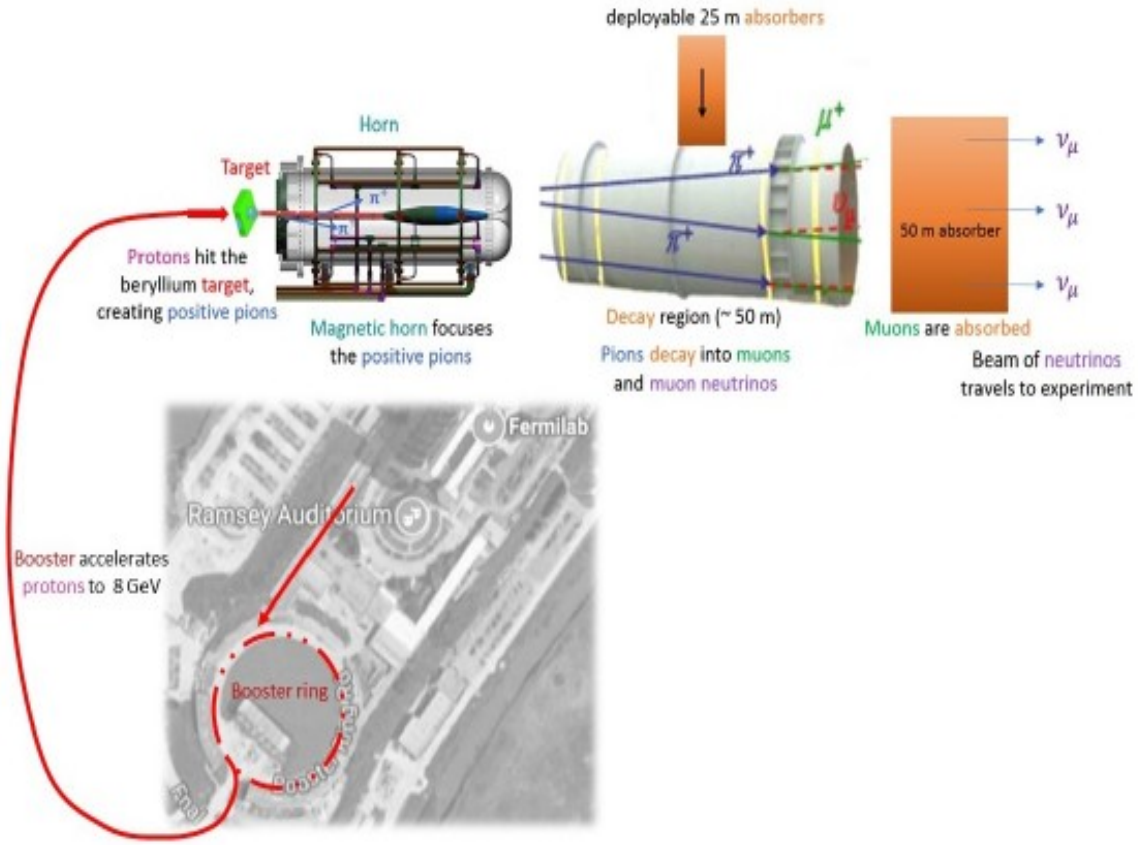


Booster Neutrino Beamline



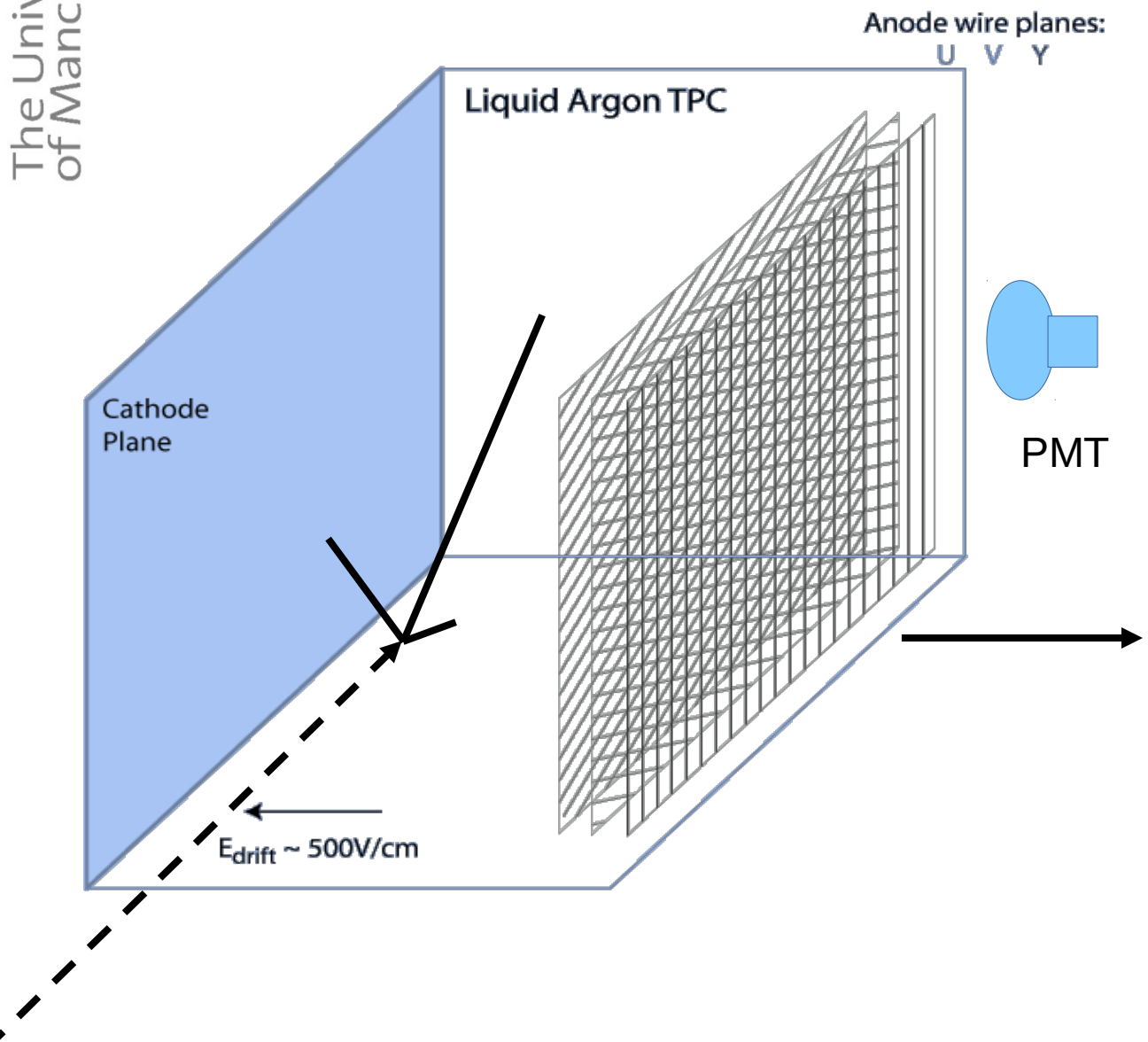
at SBND

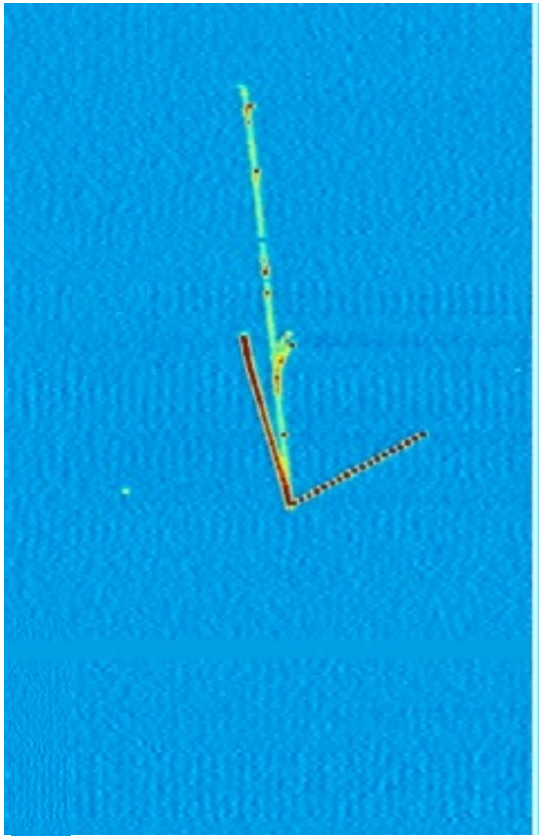
0.5 % ν_e contamination



- A well known and understood system.
- Running stably for +10 years

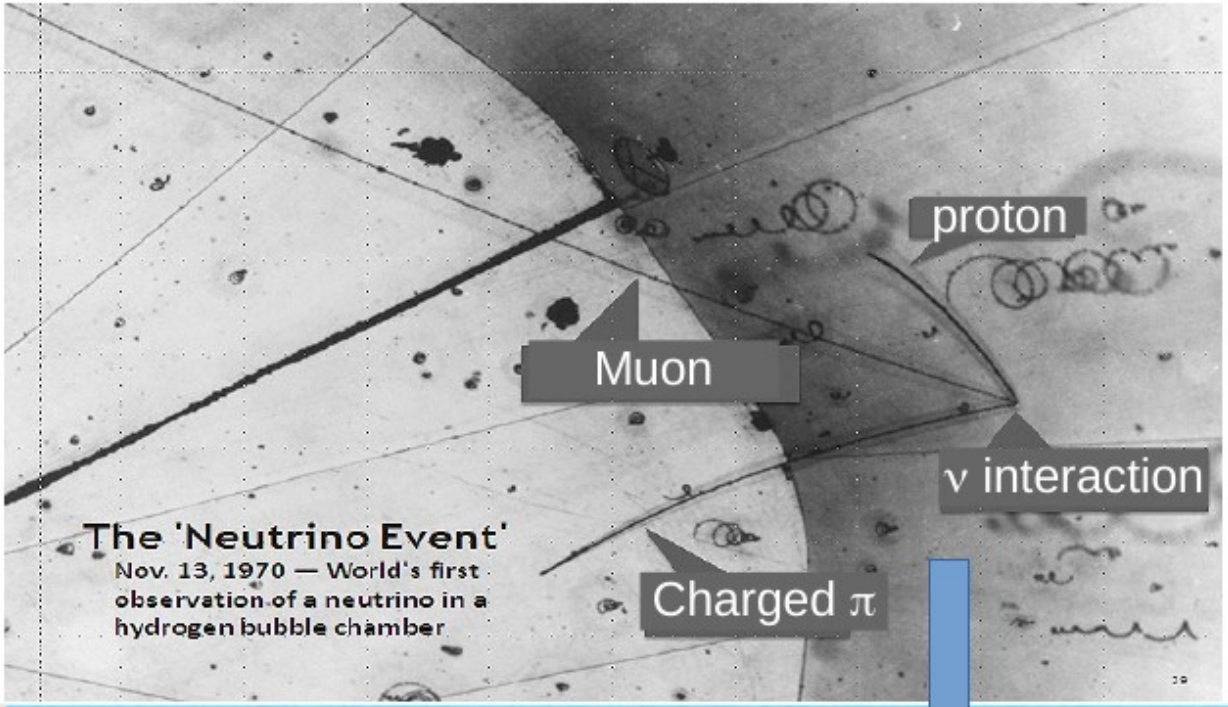
LArTPC Operation

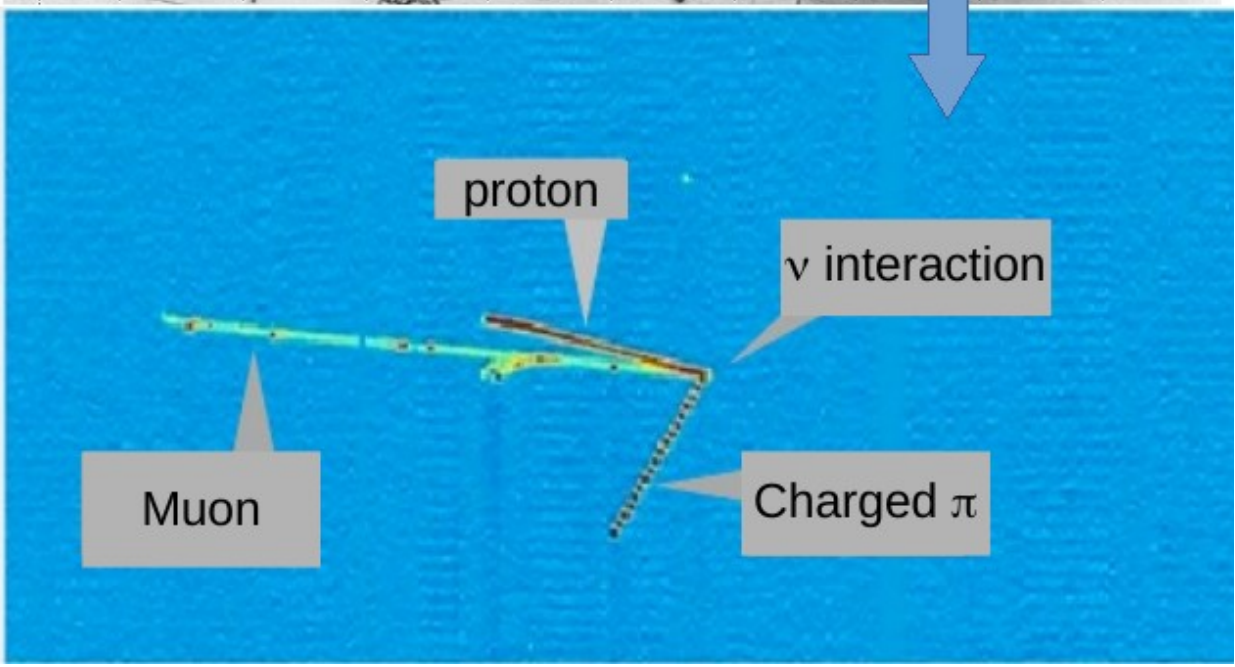




Detecting neutrinos in a LArTPC

- The golden channel in the SBN is ν_e appearance ($\nu_\mu \rightarrow \nu_e$)
- Photon backgrounds make ν_e appearance a particularly challenging game.
- The LArTPC and its bubble chamber-like data gives us strong background rejection tools.
- But it is also an excellent tool for precision cross-section measurements.





SBND cross-section physics

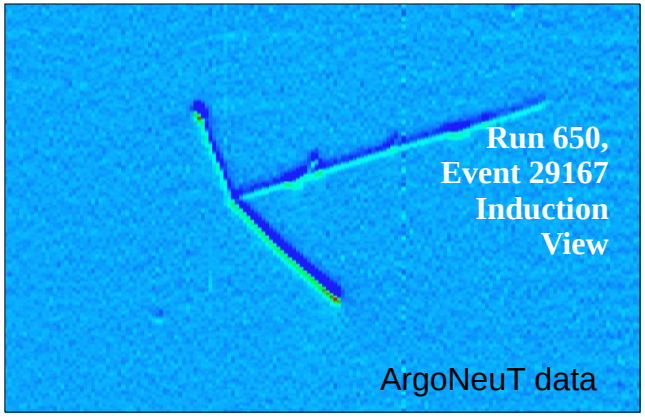
Charged Current	
ν_μ Inclusive	5,389,168
$\rightarrow 0\pi$	3,814,198
$\longrightarrow 0p$	27,269
$\longrightarrow 1p$	1,261,730
$\longrightarrow 2p$	1,075,803
$\longrightarrow \geq 3p$	1,449,394
$\rightarrow 1\pi^+ + X$	942,555
$\rightarrow 1\pi^- + X$	38,012
$\rightarrow 1\pi^0 + X$	406,555
$\rightarrow 2\pi + X$	145,336
$\rightarrow \geq 3\pi + X$	42,510
$\rightarrow K^+K^- + X$	521
$\rightarrow K^0\bar{K}^0 + X$	582
$\rightarrow \Sigma_c^{++} + X$	294
$\rightarrow \Sigma_c^{+} + X$	98
$\rightarrow \Lambda_c^{+} + X$	672
ν_e Inclusive	**$\approx$ 12,000**
Neutral Current	
Inclusive	2,170,990
$\rightarrow 0\pi$	1,595,488
$\rightarrow 1\pi^\pm + X$	231,741
$\rightarrow \geqslant 2\pi^\pm + X$	343,760
$\rightarrow e(^-)$	374

SBND will see a huge event rate.

Enables precision measurements of neutrino cross-sections and nuclear effects.

Crucial for energy reconstruction in oscillation measurements.

A multitude of exclusive channels



SBND Cross-Sections

Charged C

ν_μ Inclusive
$\rightarrow 0\pi$
$\longrightarrow 0p$
$\longrightarrow 1p$
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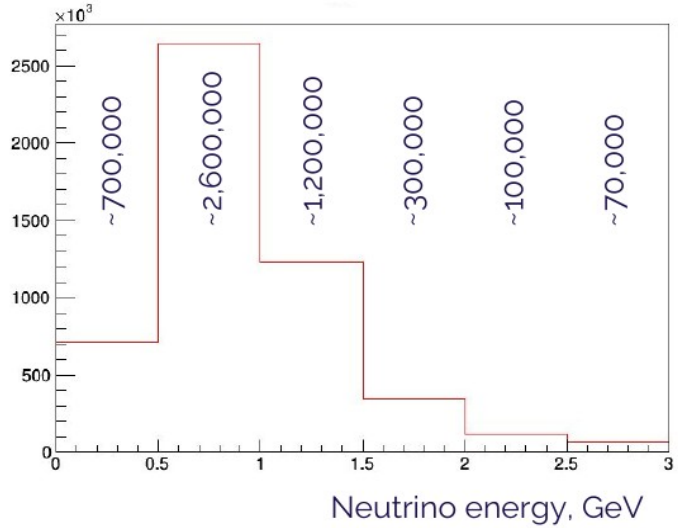
$\rightarrow K^0\bar{K}^0 + X$
$\rightarrow \Sigma_c^{++} + X$
$\rightarrow \Sigma_c^{+} + X$
$\rightarrow \Lambda_c^{+} + X$
ν_e **Inclusive**

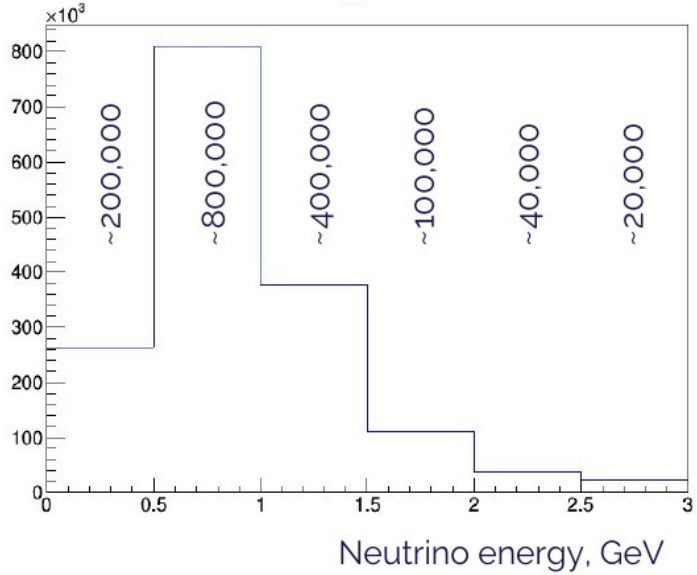
Neutral C

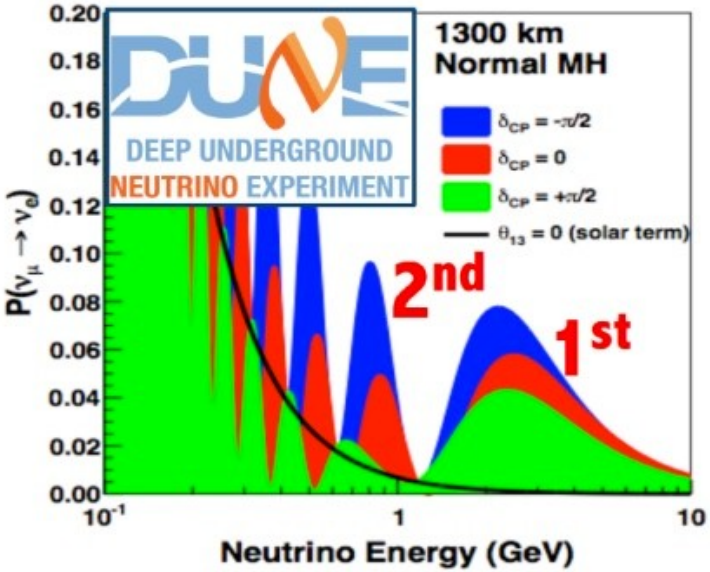
Inclusive
$\rightarrow 0\pi$
$\rightarrow 1\pi^\pm + X$
$\rightarrow \geqslant 2\pi^\pm + X$
$\rightarrow e(^-)$

Discrete event rate energy distributions CC



Discrete event rate energy distributions NC





SBND First planned Cross-Section measurements

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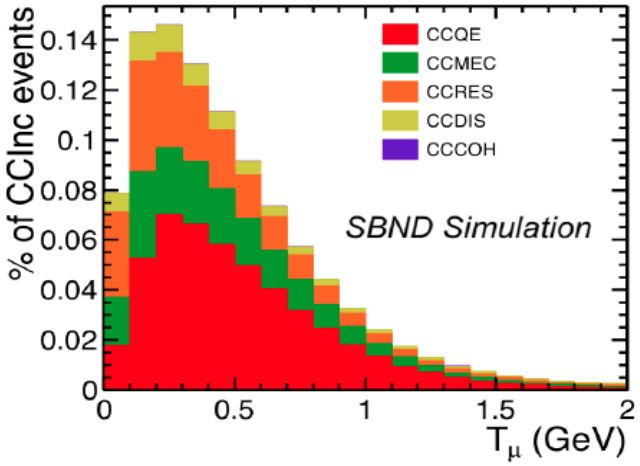

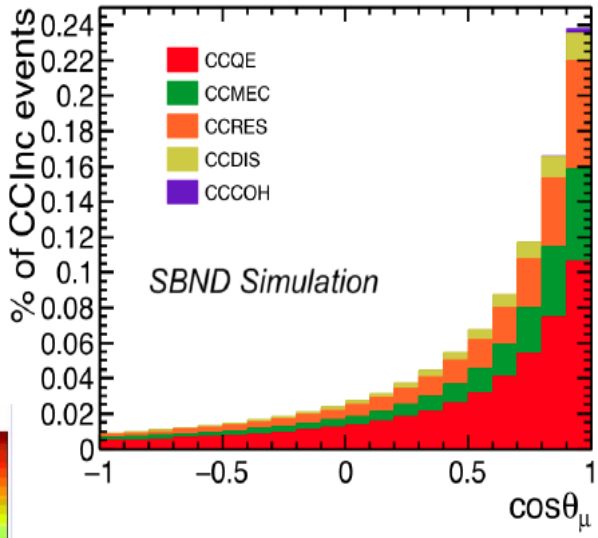

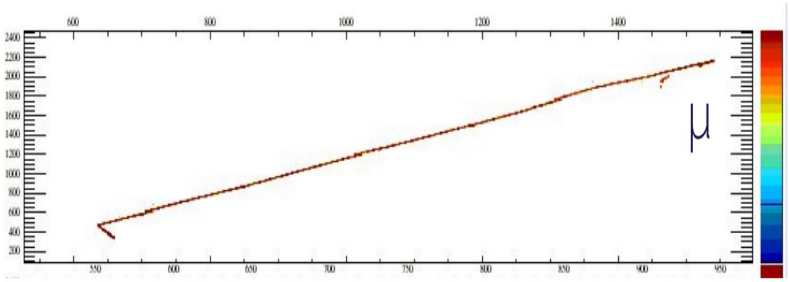

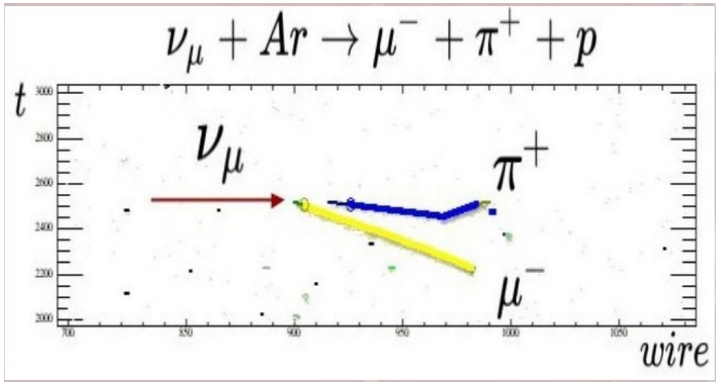

SBND event rates for rare event searches

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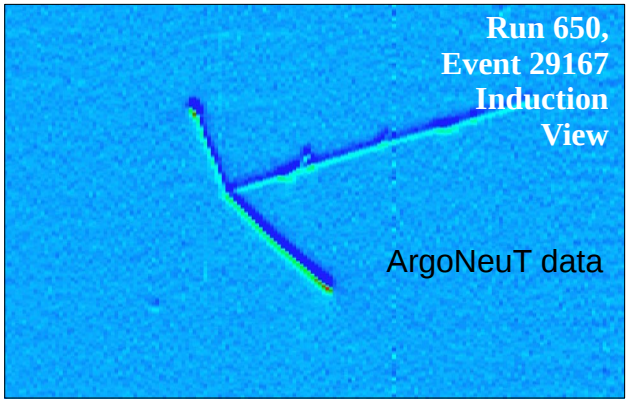
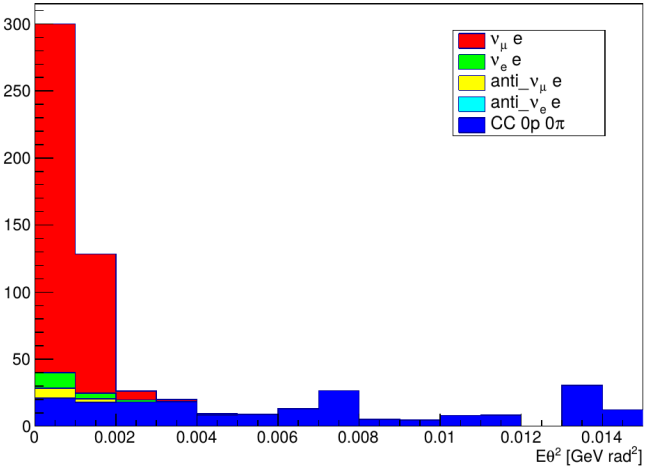
$\rightarrow e(^-)$	374

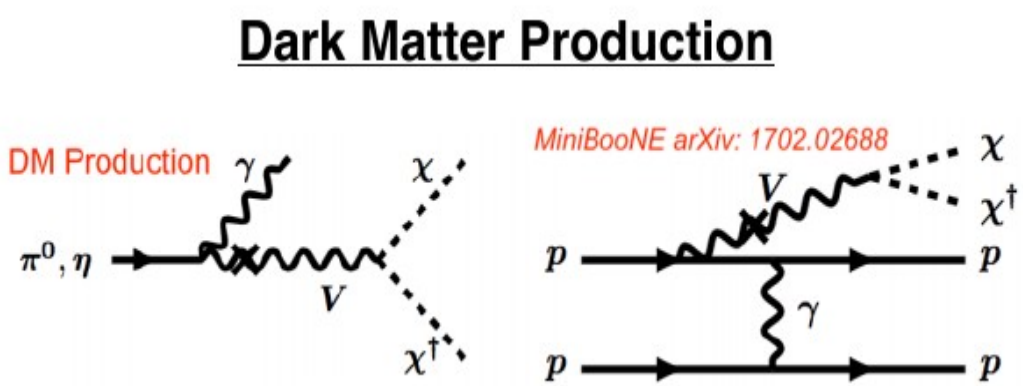
- Two proton events will no longer be “rare” (as seen in Raquel's talk).
- v. large sample of electron neutrinos.
- significant number of hyperons produced.
- Electron scattering measurements also possible.

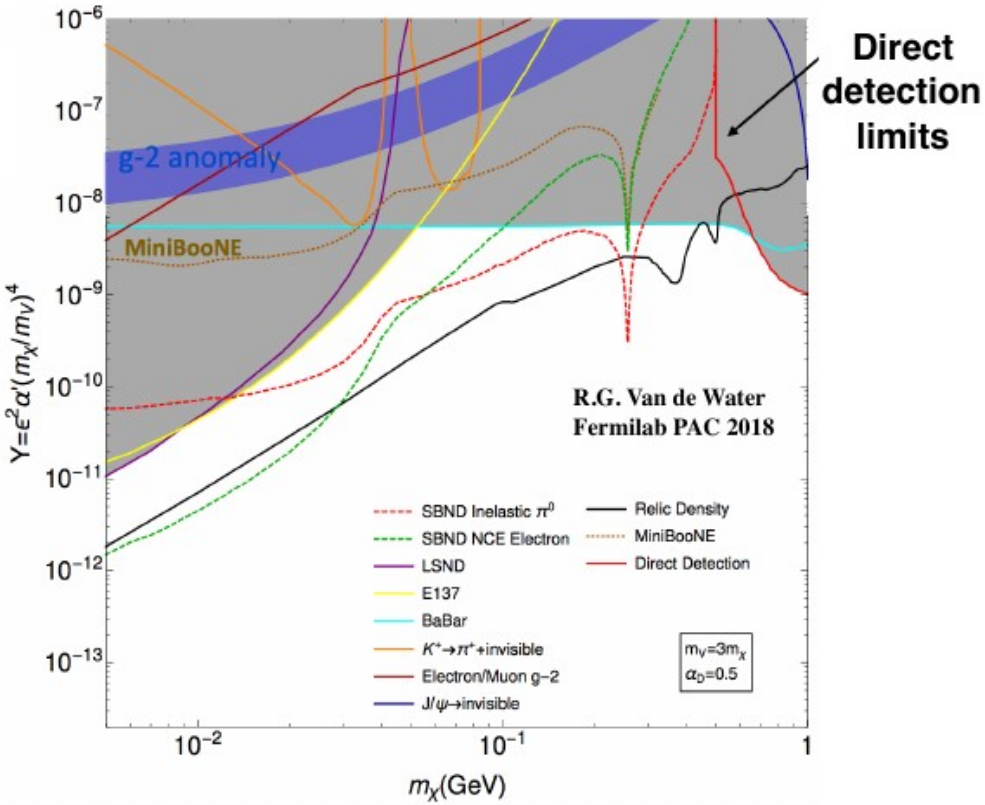




Beyond SM Searches

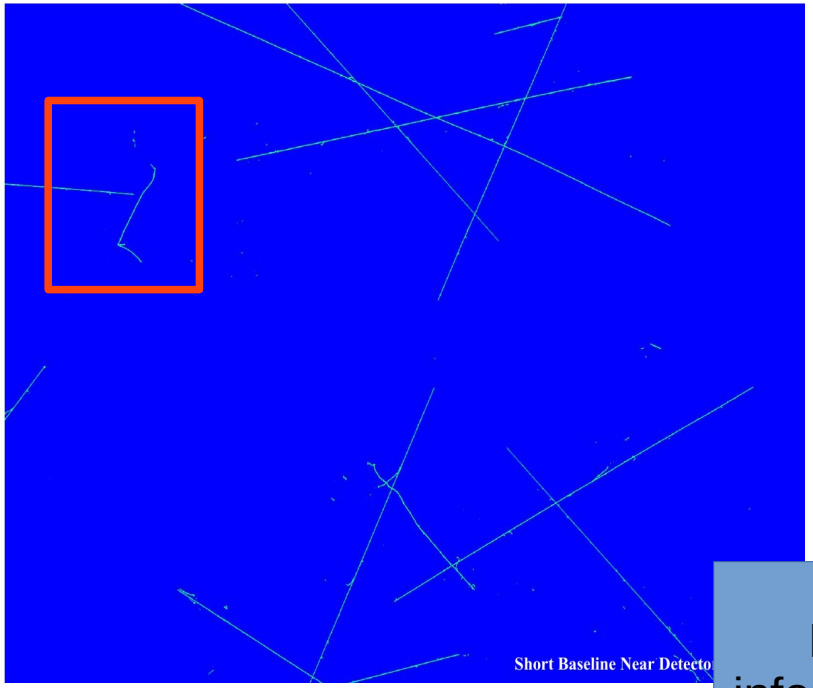
- There is a rising interest in potential detection of unconventional neutrino-sector and dark-sector physics signals in large-volume neutrino experiments
- The proximity to the beam target, large detector mass and relative detection isotropy makes the LAr TPC SBN detectors well suited for beyond the standard model searches.
  - Sub-GeV dark matter (with proton beam dump)
  - Hidden-sector particles
  - Exotic signatures

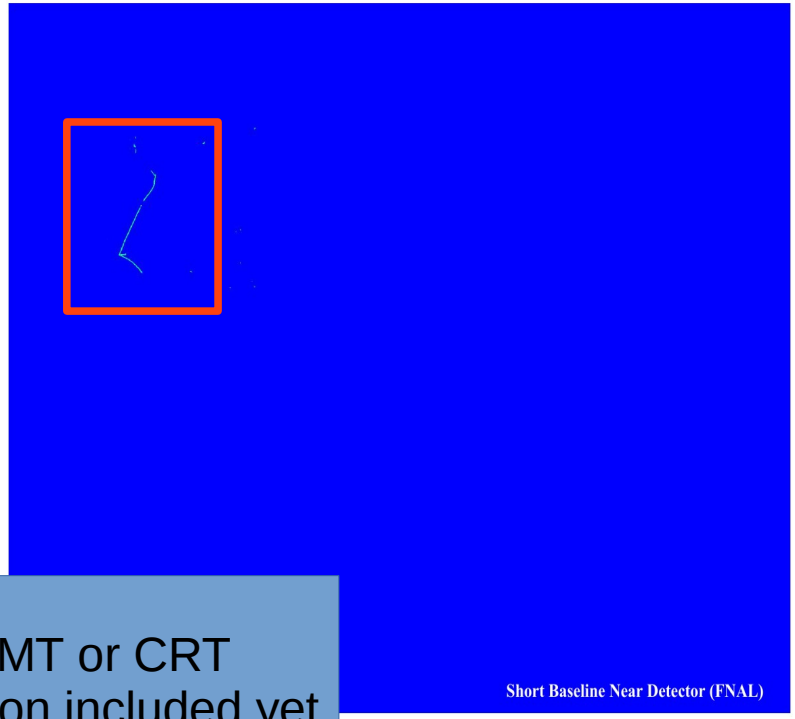




Removing Cosmic Backgrounds with Machine Learning

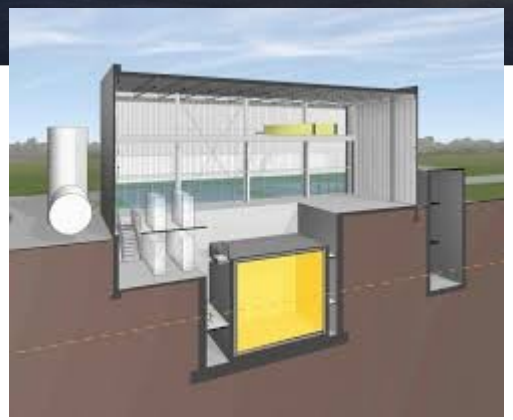
- Liquid argon detectors provide image-like quality event displays.
- Can use tools for “image-recognition” to remove cosmic ray background events.
- Crucial tool in identifying neutrino interactions.
- Using Multiplane URes-Net





No PMT or CRT information included yet

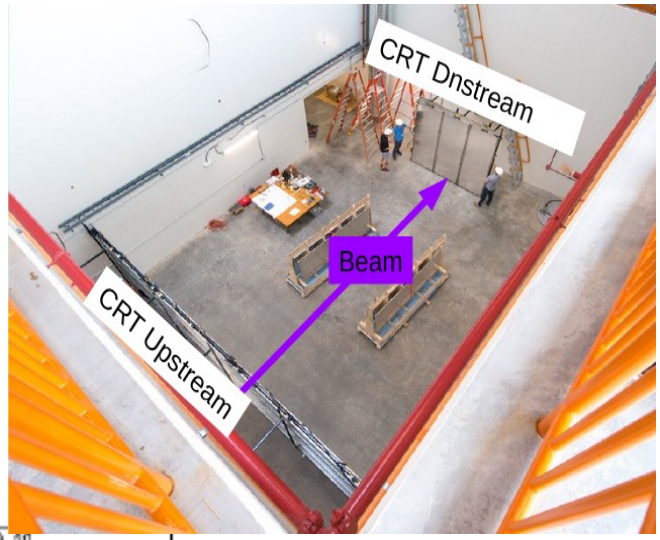
SBND Status: Building

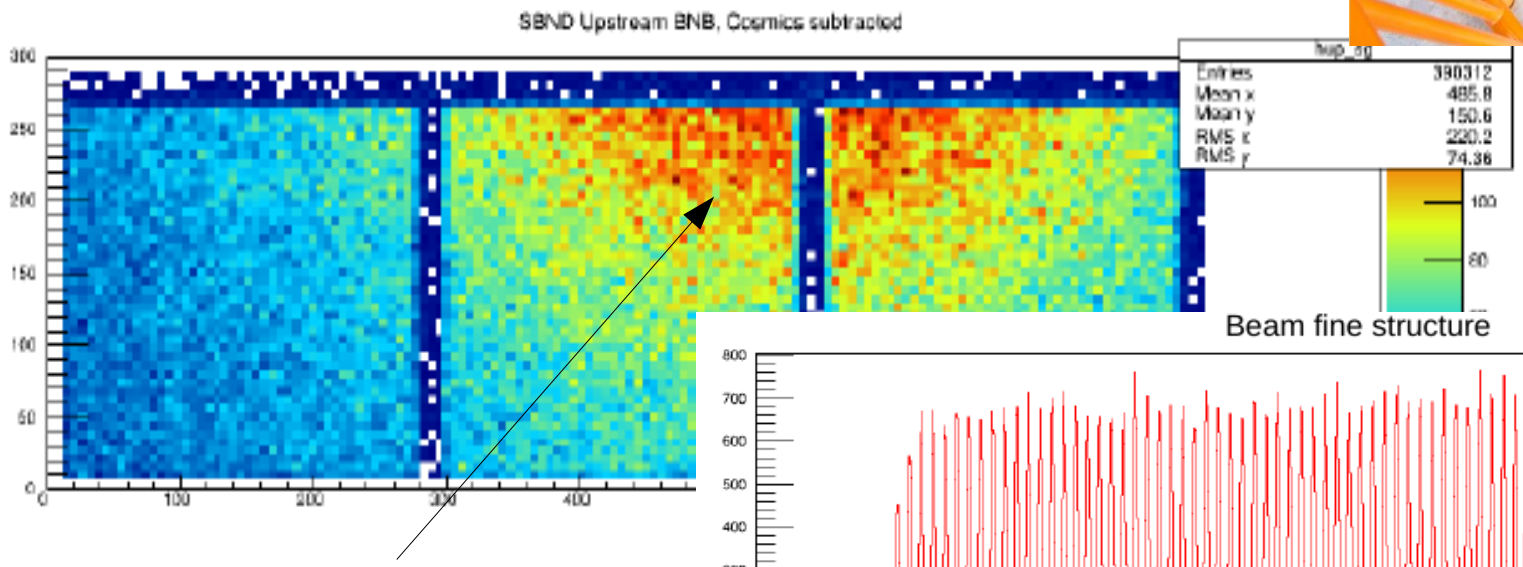


- Building is ready and first detector components are being installed.

SBND Status: CRT

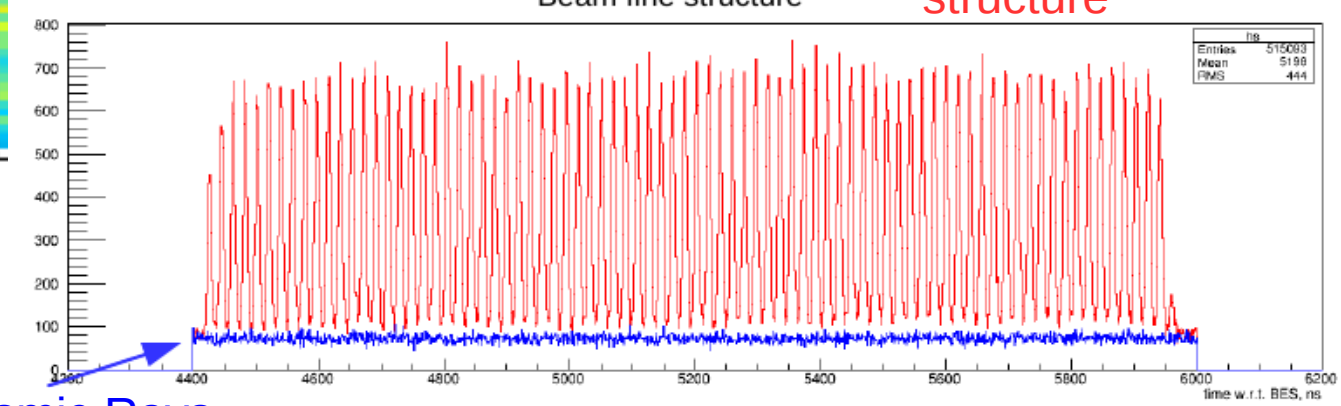
- Cosmic Ray Tagger will ensure cosmic and dirst background suppression.
- First modules already at Fermilab and taking data.





Beam fine structure

BNB bucket structure

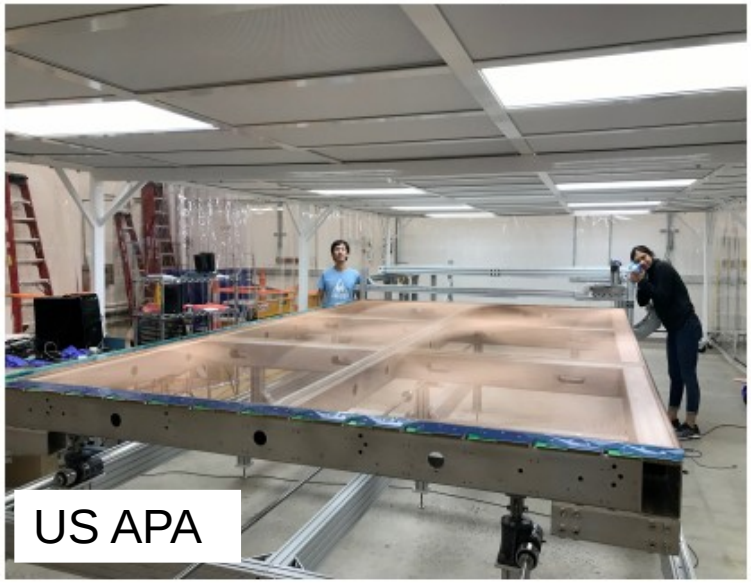


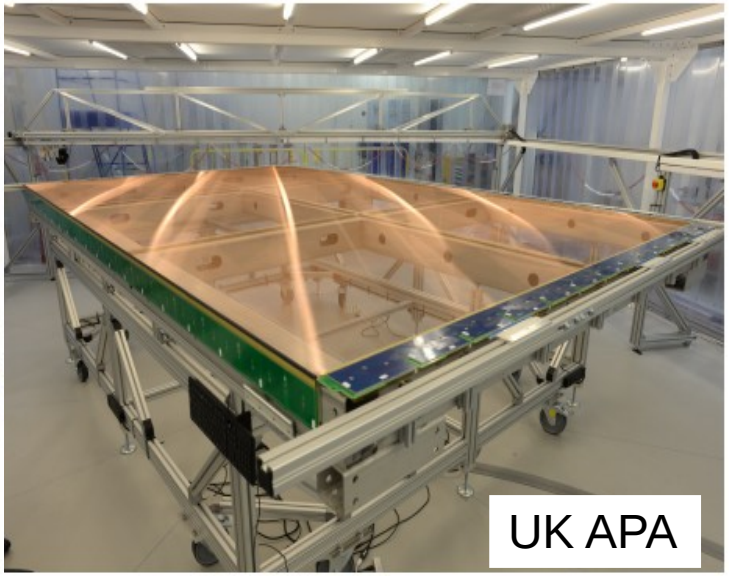
Beam Centre where expected

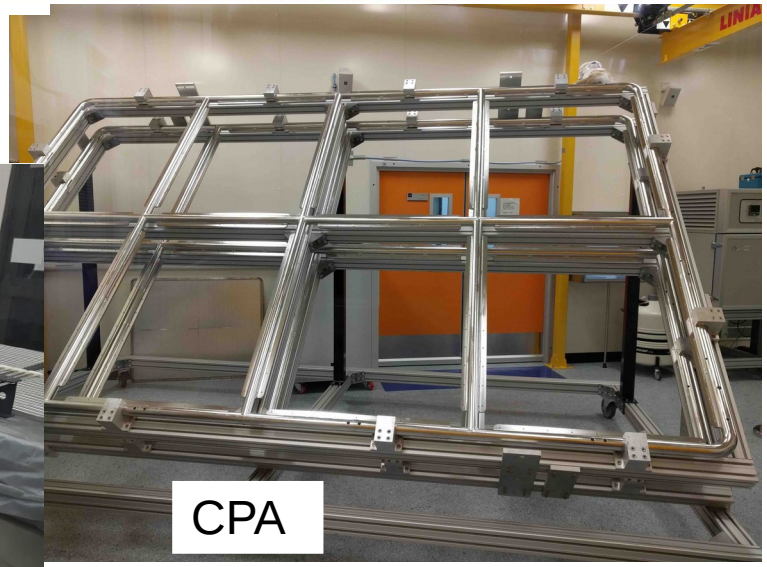
Cosmic Rays

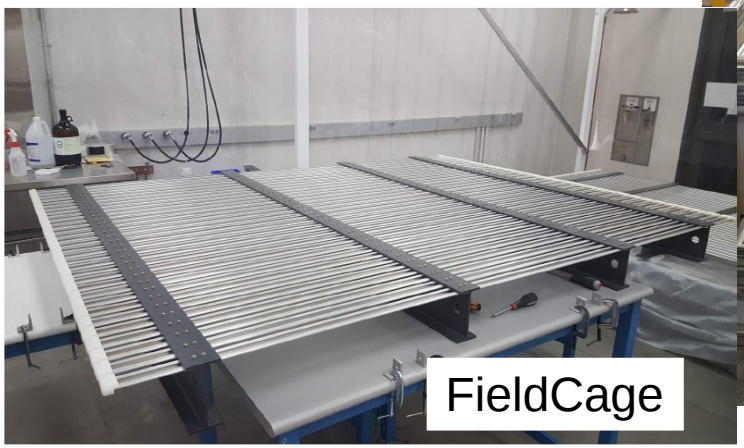
SBND Status: APA, CPA & Fieldcage

- Two Anode Plane Assemblies have been finalized and shipped to Fermilab.
- The CPA has arrived in Fermilab.
- Field cage has been assembled and is ready to ship.



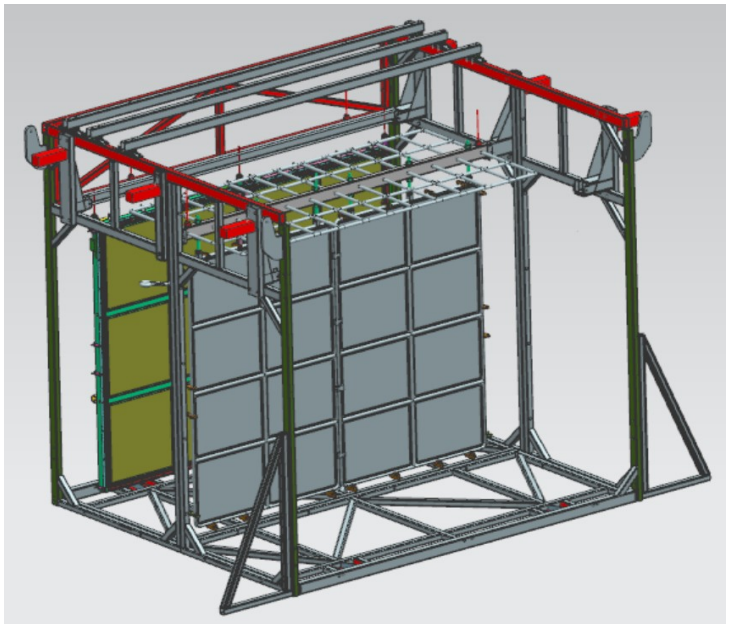






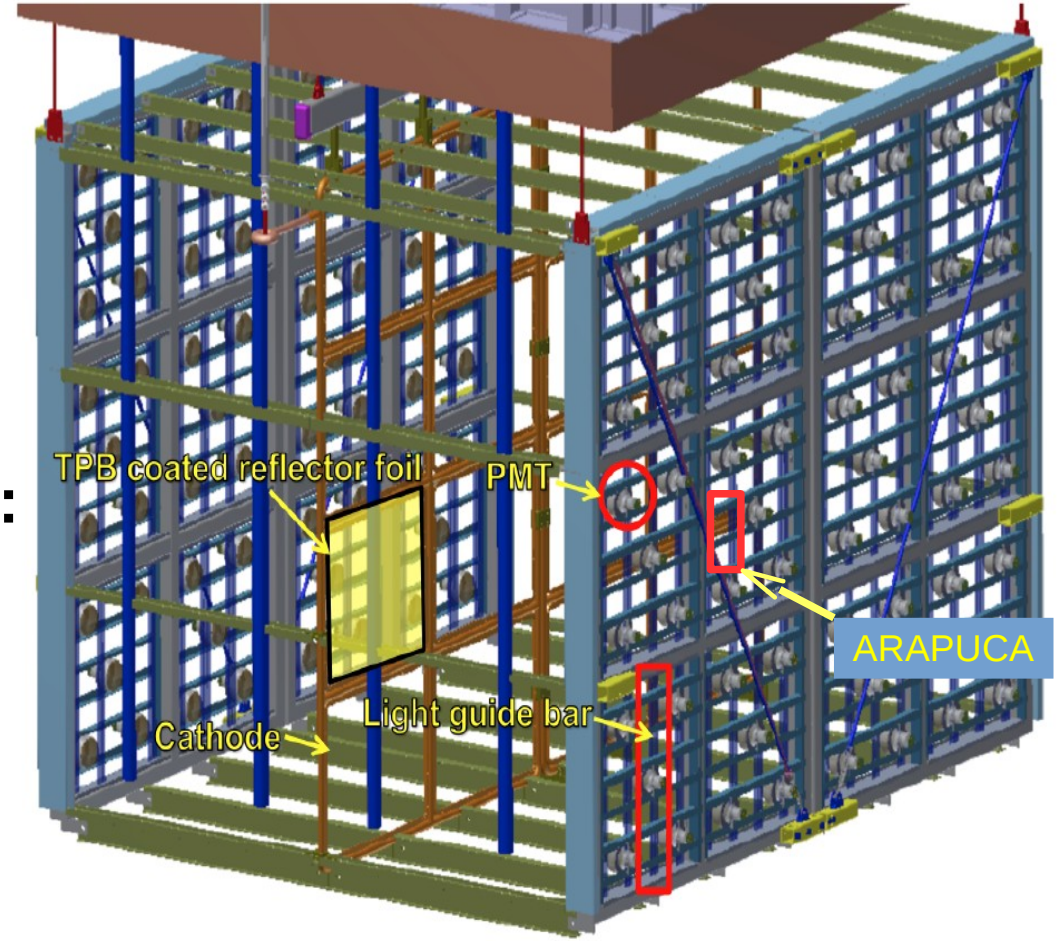
SBND Status: Assembly & Construction

- Assembly Site in the DAB building is ready.
- First order is testing APA alignment with mock-frames.
- The whole fieldcage will be assembled at DAB and transported to the detector building once the cryostat is ready.

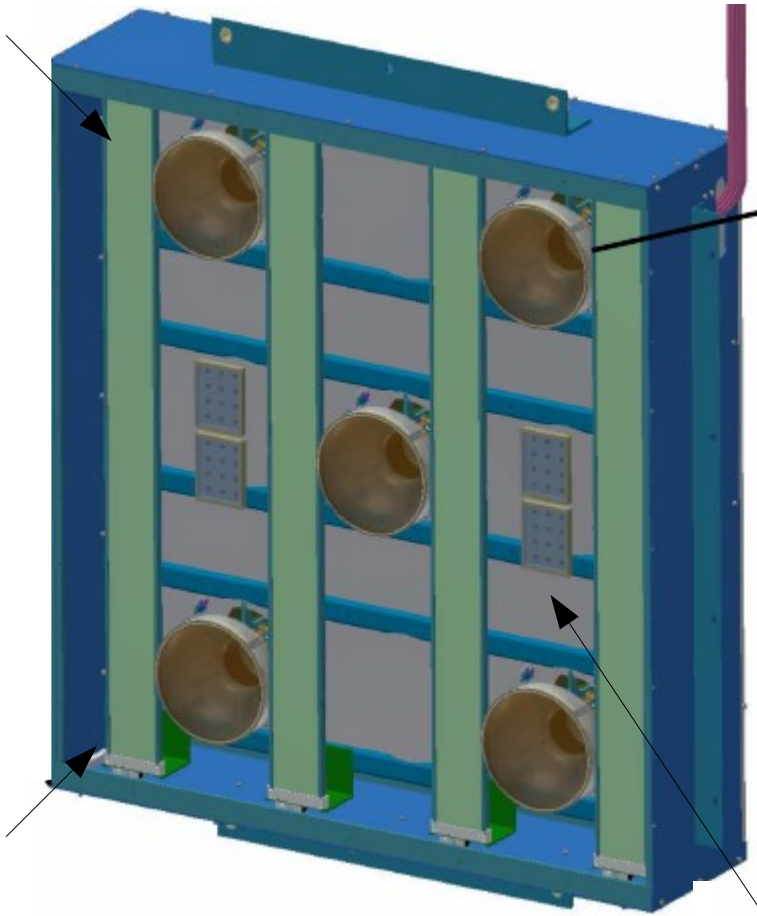


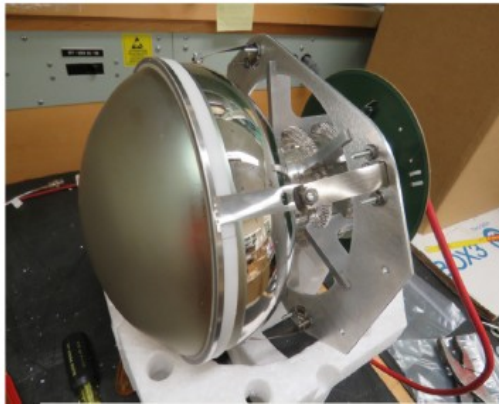
Scintillation Light Detection in SBND

- Important R&D aspect
- Scintillation light applications:
  - trigger, t_0
  - background rejection
  - calorimetry, particle ID
- **Mounted on anode planes:**
  - PhotoMultiplier Tubes
  - Waveguide bars
  - ARAPUCA light traps
- **Mounted on cathode planes:**
  - WLS covered reflector foils

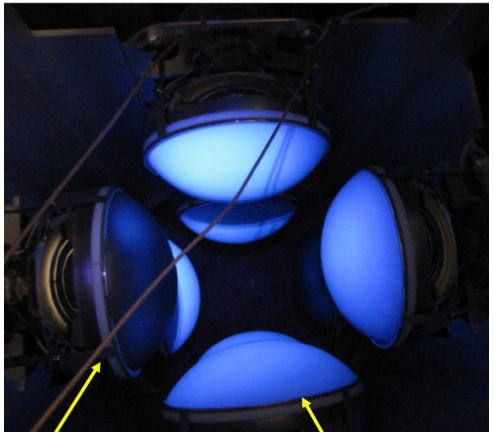


Light Collectors





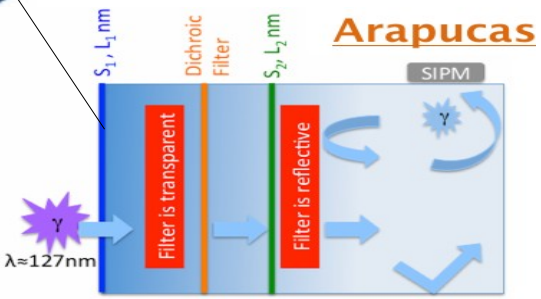
Primary System:
8" PMTs read out at 2ns sampling.



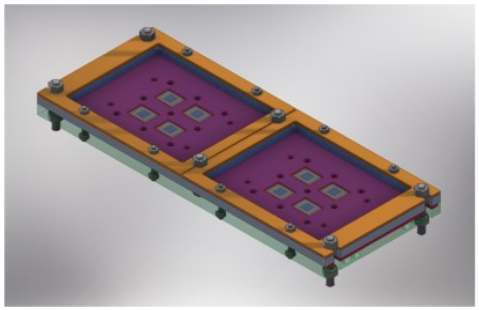
Sandblasted and coated with TPB to enable VUV light detection.

Secondary System(s):
- Dip-coated light guide bars

- ARAPUCA light traps

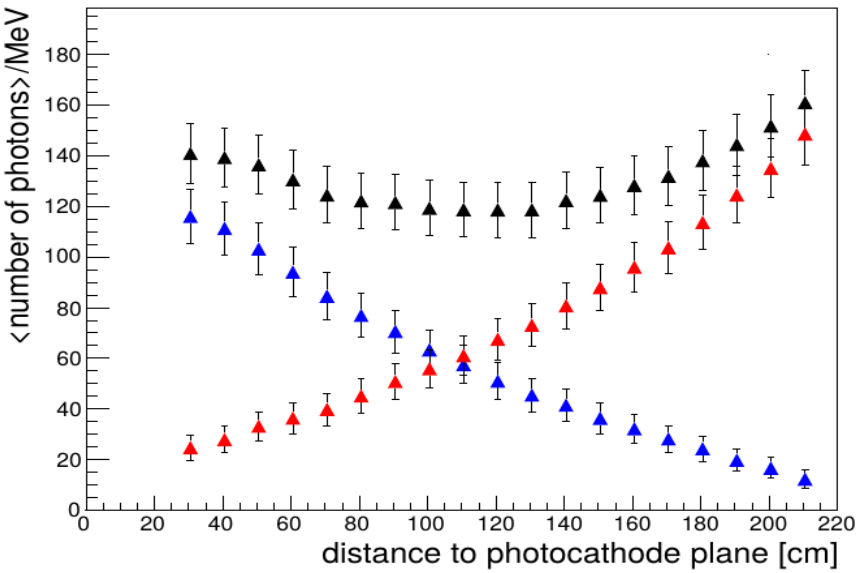


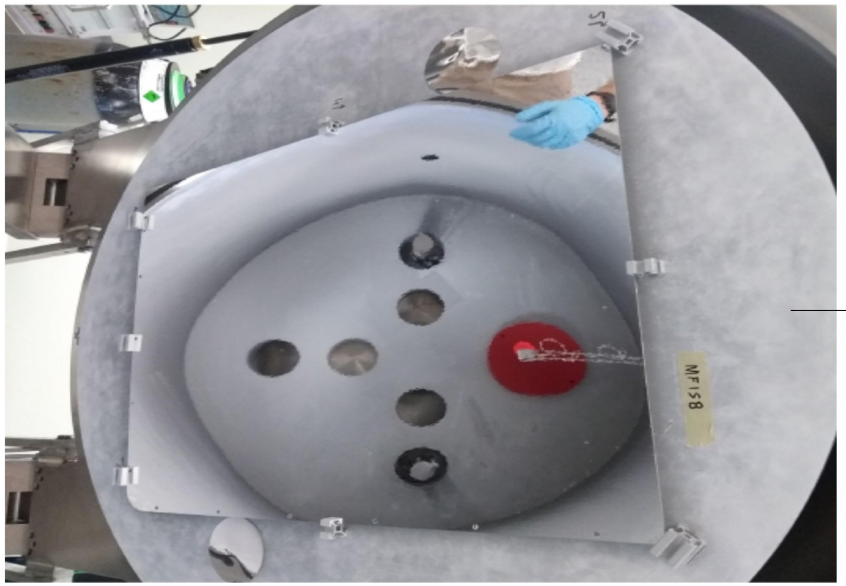
A. A Machado and E. Segreto, JINST 11 2016



Boosting Light Collection

- Adding wavelength-shifting surface at the cathode recovers a large fraction of light that would normally be lost.
- The SBND LDS enables new applications of argon scintillation light – calorimetry, timing, drift position reconstruction.
- Enhancement expected especially at low energies.





The SBND Collaboration

Updated September 2018

Including both scientific and technical personnel

*Spokespeople

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The SBND Collaboration

196 Total Collaborators

166 Scientific Collaborators (faculty/scientists, postdocs, students)

36 Institutions

23 US Institutions

- 5 DOE national laboratories
- 18 US universities
- University of Puerto Rico

13 International Institutions

- CERN
- 6 UK universities
- 1 Swiss university
- 5 Brazilian universities





Summary

- SBND construction is well on its way and the detector will come online in early 2020.
- As the SBN near detector it plays a key role in enabling the full scale SBN oscillation analysis.
- But more importantly it will provide a wealth of cross-section data on argon.
- Stay tuned!

MANCHESTER 1824

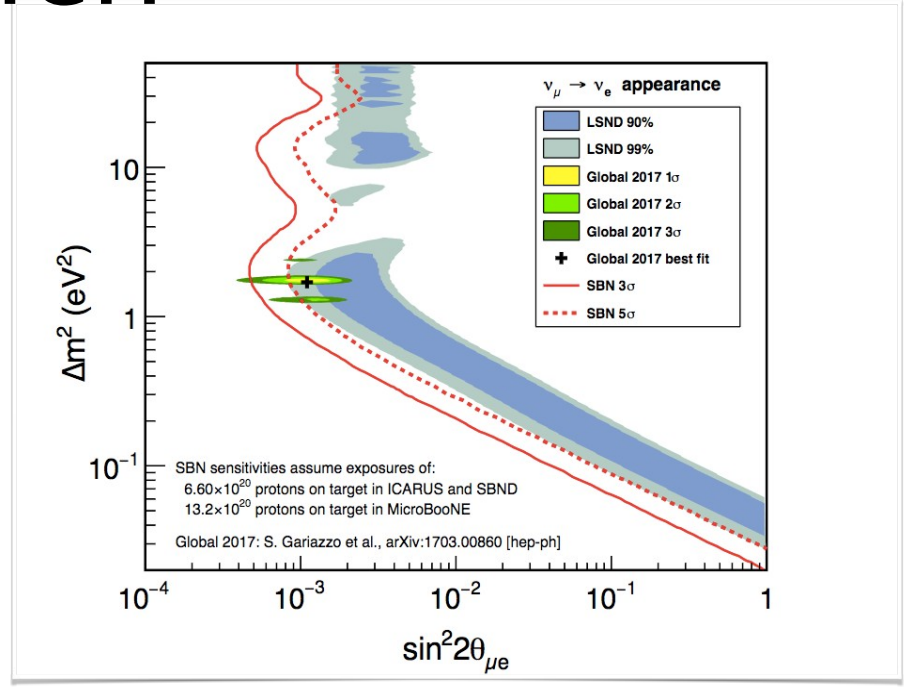
The University of Manchester

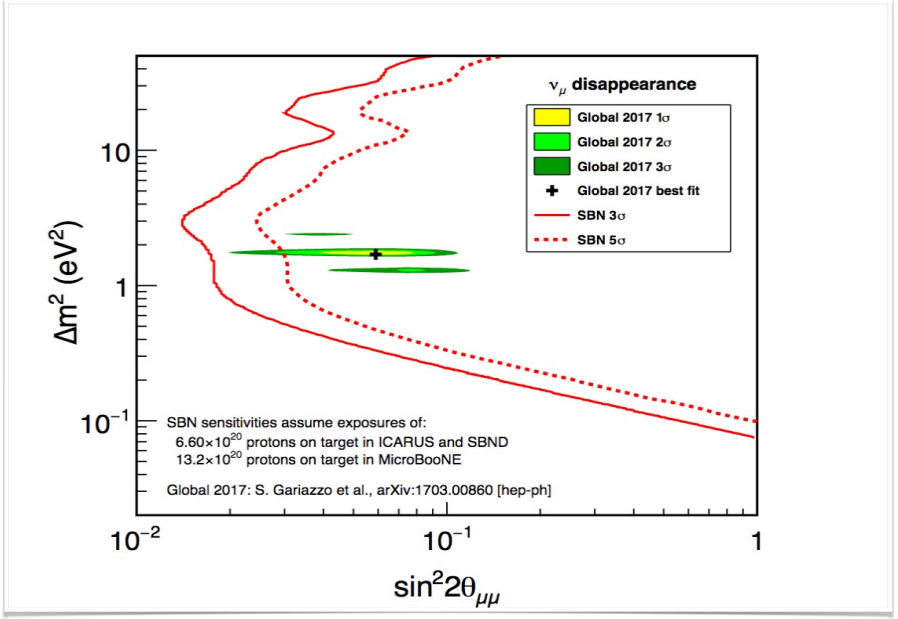
Physics reach

Constraints on the flux and cross-sections from the near detector lead to a powerful combined exclusion region.

LSND parameter space excluded at 5σ.

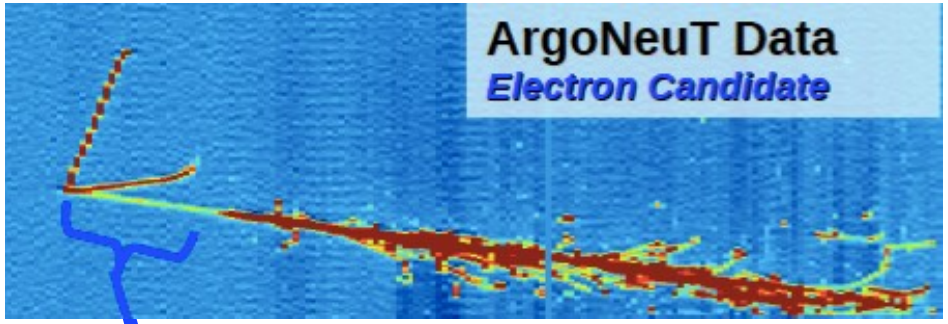
In addition, SBN can also perform ν_μ disappearance searches. Would confirm an oscillation interpretation of any observed ν_e appearance signal.

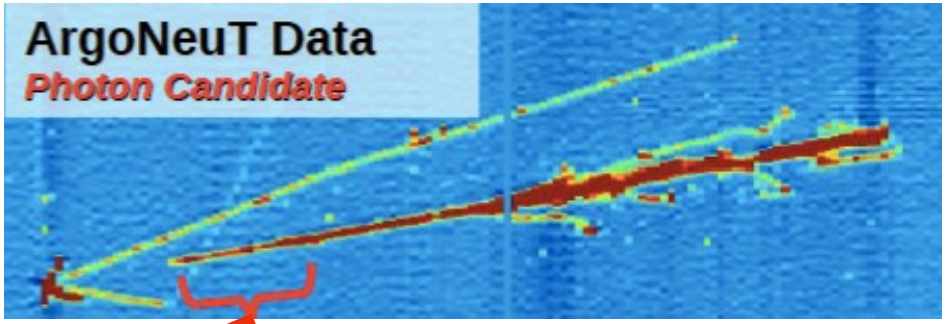


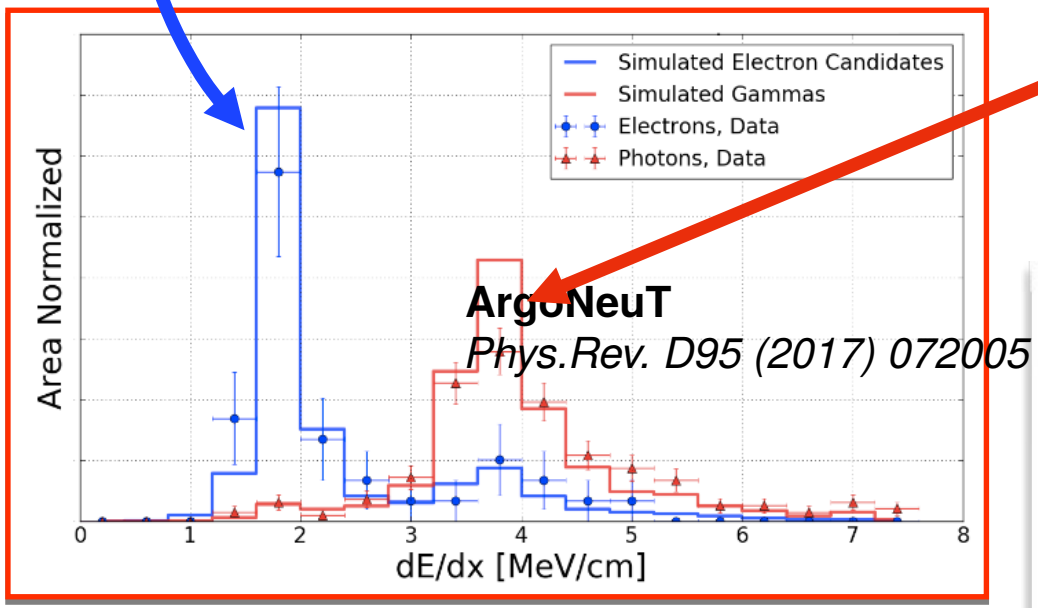


Fit from S. Gariazzo et al., arXiv:1703.00860

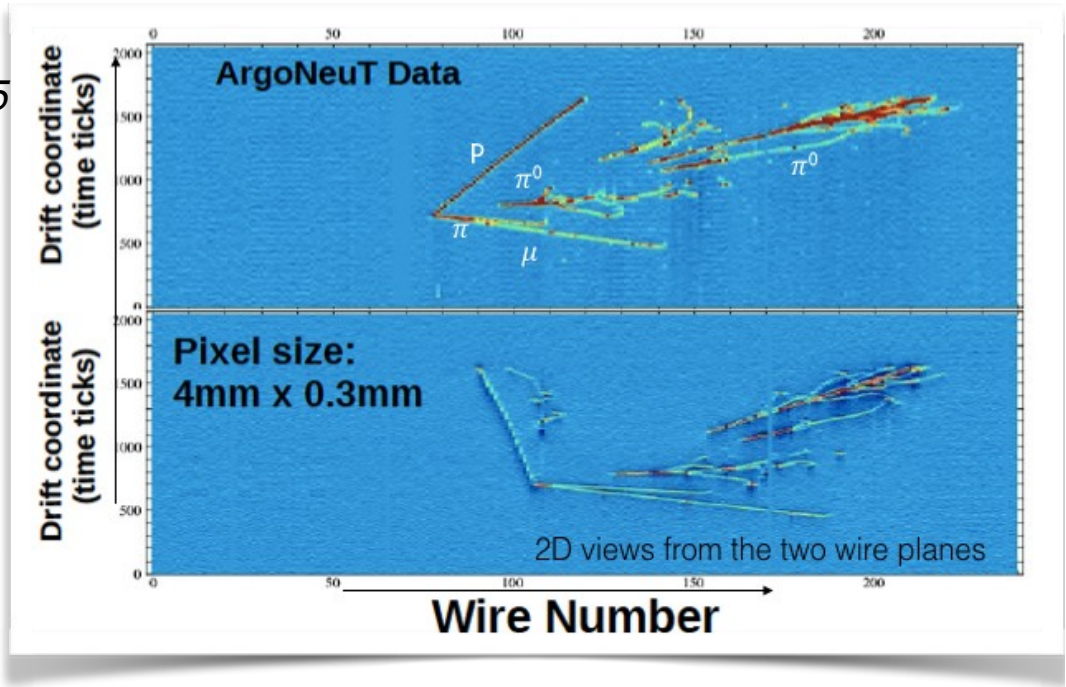
Electron-γ separation in LAr







Double handle: topology and dE/dx



The LArTPC is an excellent tool for electron/photon separation

Neutrino interactions in LArTPCs