The Fermilab Short-Baseline Neutrino (SBN) Program

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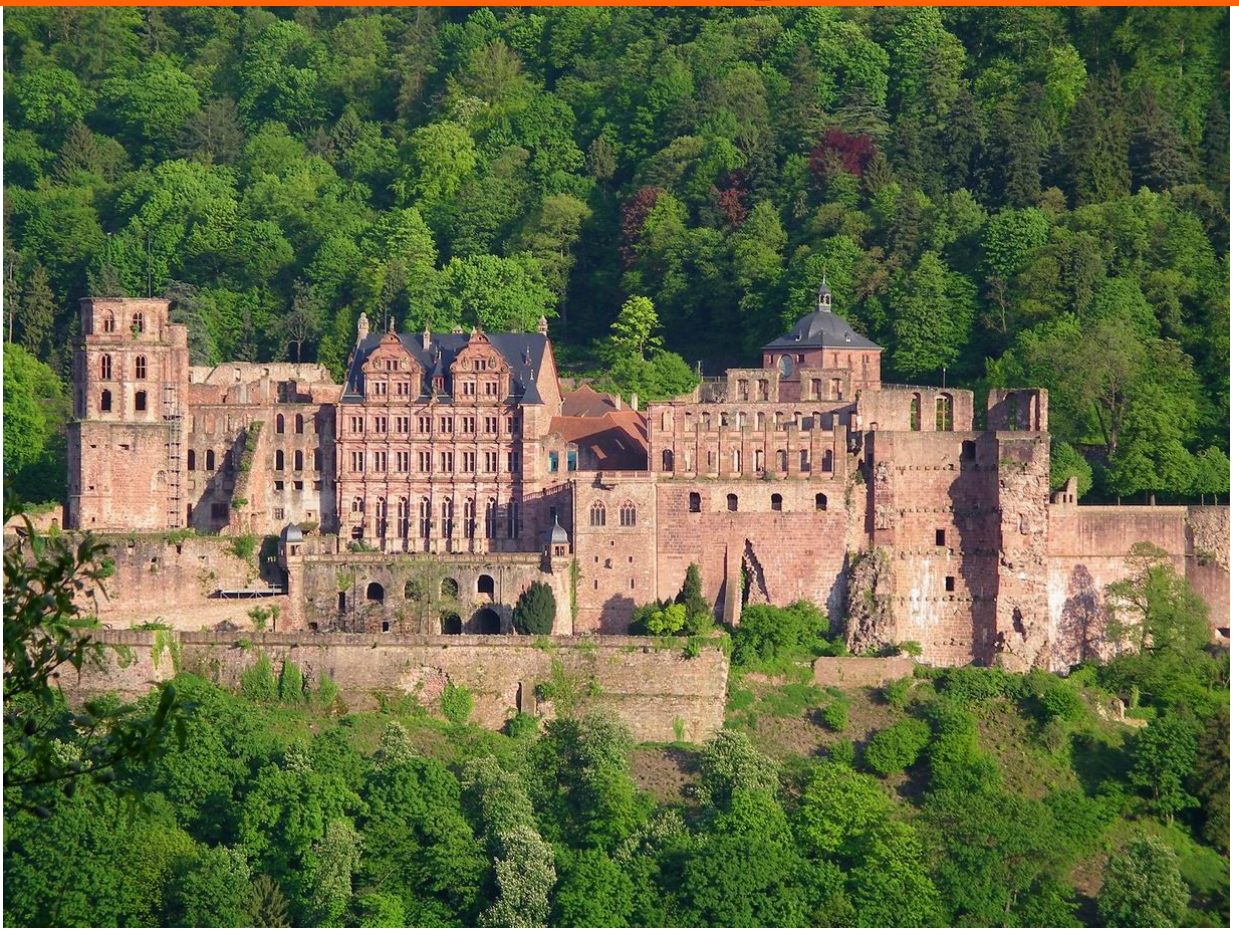
The SBN Program and Heidelberg

- **Built up over time in different phases**
- **Utilized by many different users**
- **Long history of physics**

Where I hope we ultimately differ



Kurtze
Beſchreibung
Der uralten/Chur-Pfältziſchen Reſidentz-Stadt
Heydelberg/
Deren Urſprung/und was in derſelben beſonderliches und denckwürdiges geſchehen und allda zu ſehen geweſen/auch wie jüngſthin dieſelbe und deren Innwohner/durch des ſo genannten Chriſtlichen Königs von Franckreich/Ludwig des XIV. Unchriſtliche und mehr als barbariſche Behandelung und Tractament reſpectivè verſtöret/zernichtet und zerſtreuet/So dann anbey/wie der/durch deſſen Veranlaß all dieſes Unglück geſchehen/zur Straffe gezogen worden.

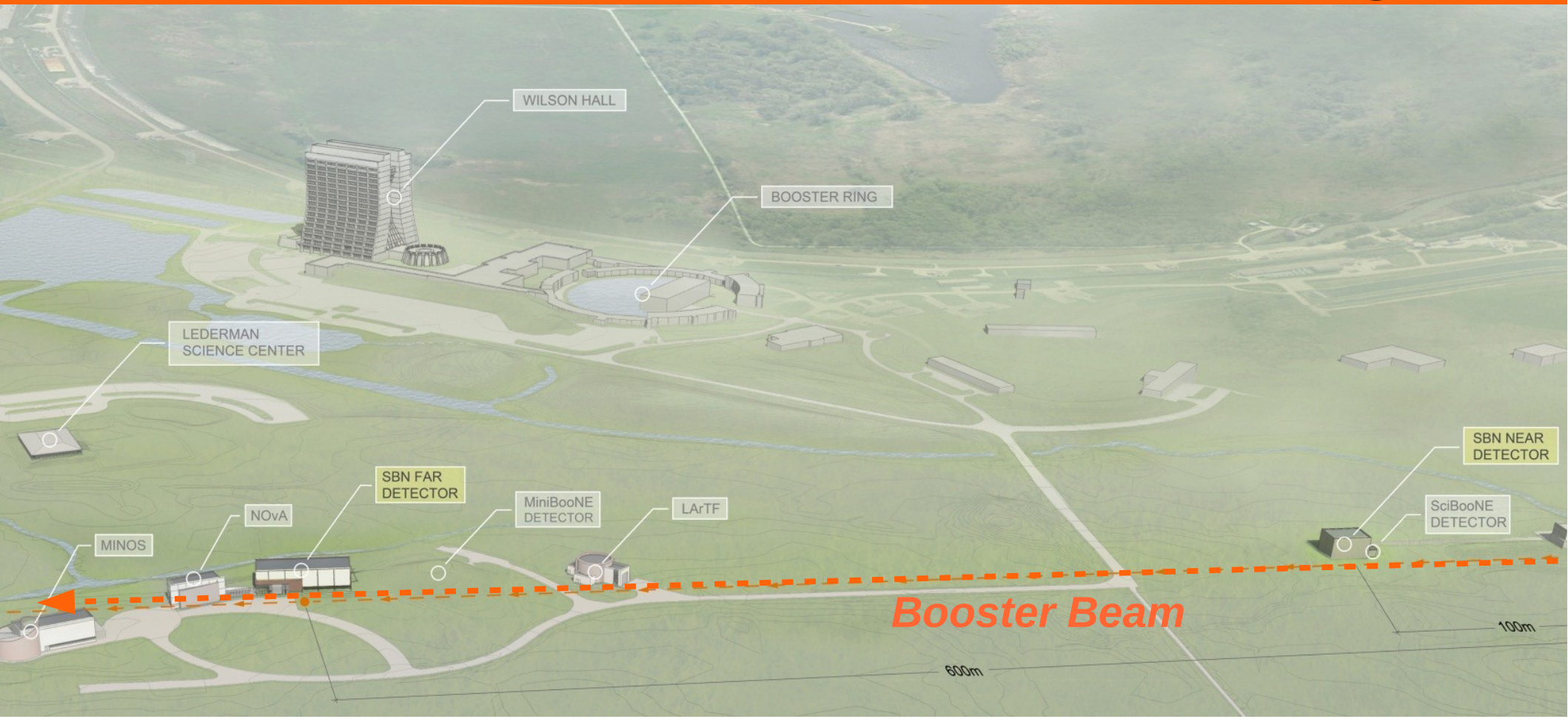
HEIDELBERG.

Neccar flu:

Gedruckt im Jahr 1693.

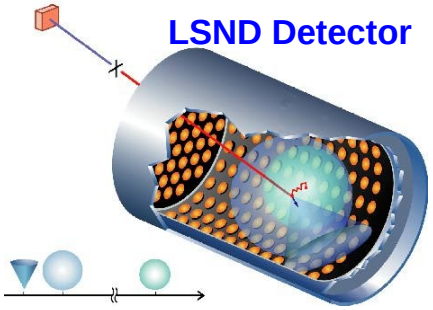
- Hopefully SBN will be destroyed fewer times by the French
- Hopefully SBN will be struck by lightning fewer times
- Hopefully more neutrino interactions will be seen at the SBN

The Short-Baseline Neutrino Program

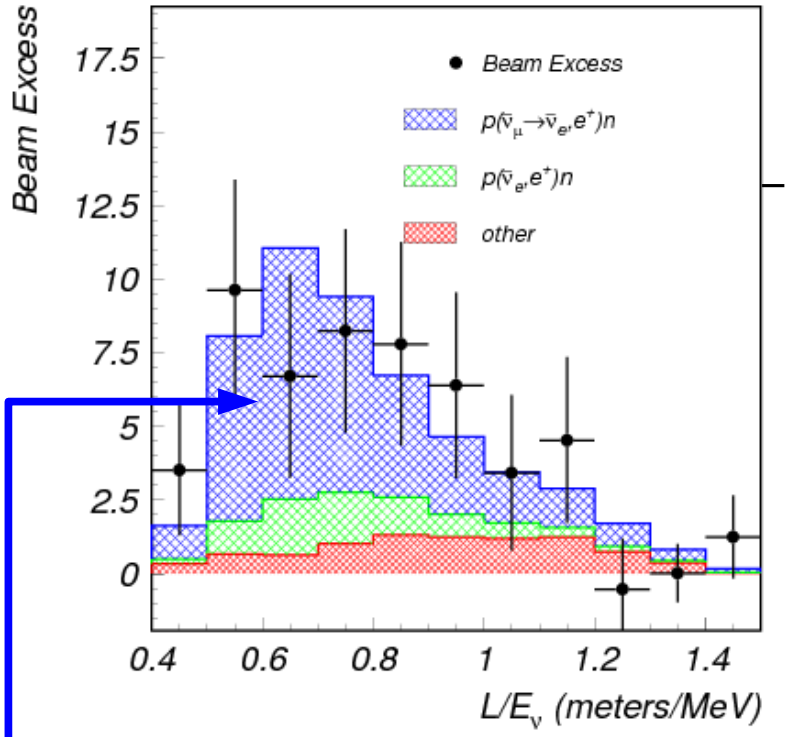


The story of the Short-Baseline Neutrino Program can best be understood through the history of the physics that we've been following

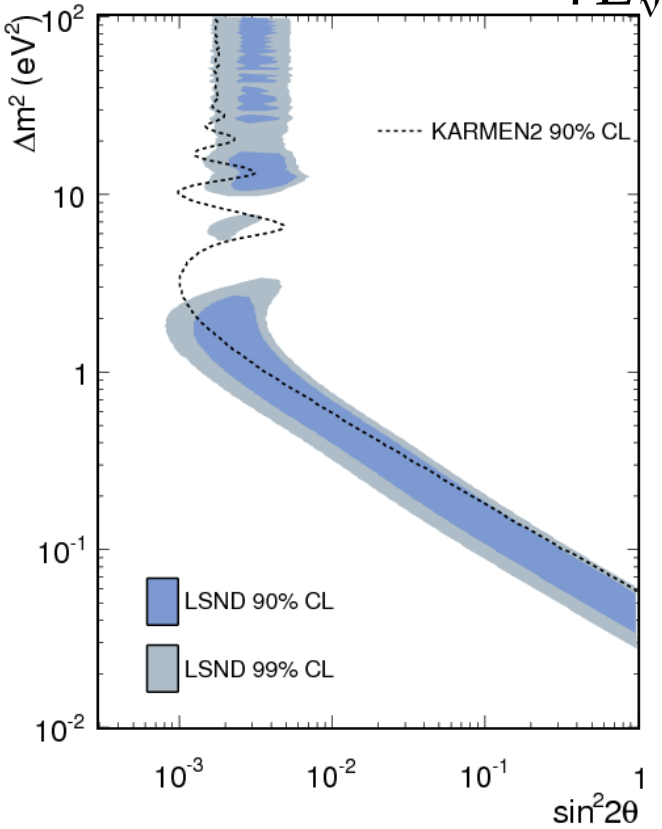
Hints of new physics?



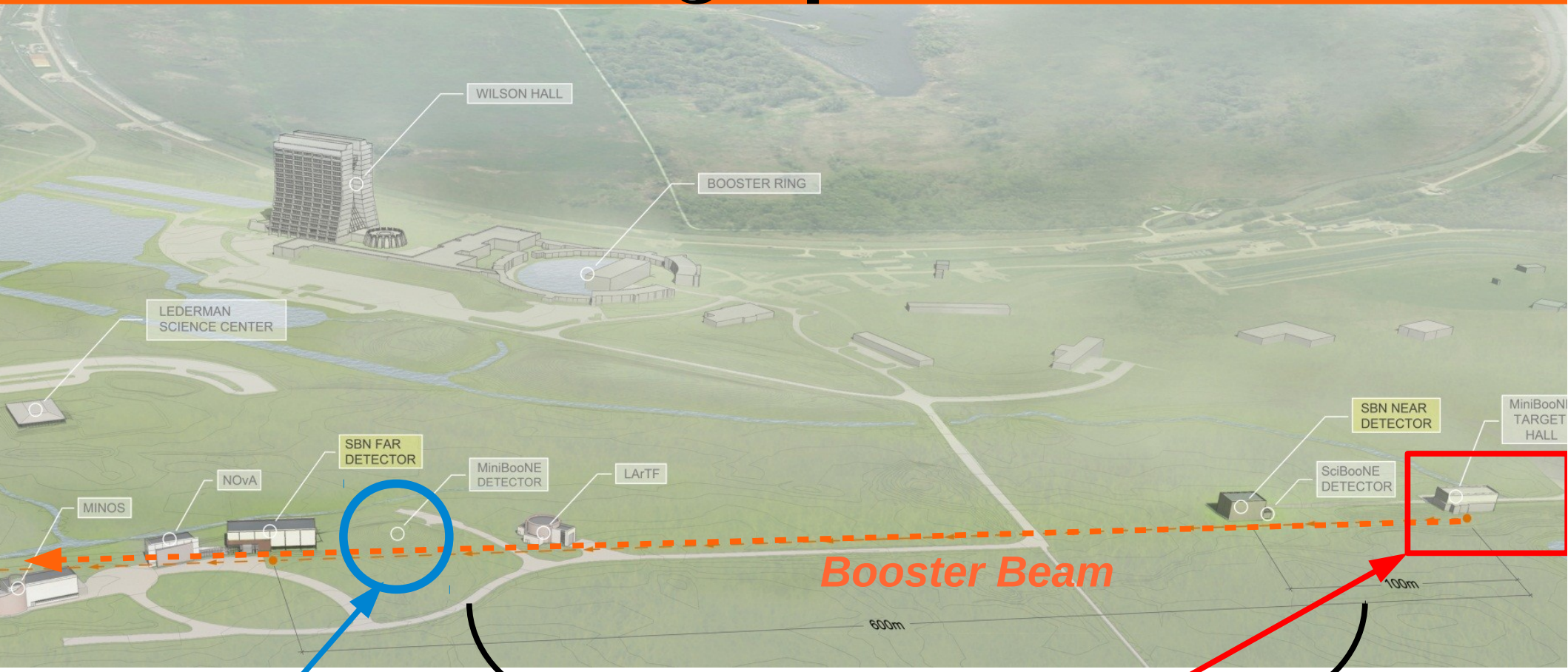
- LSND ran in a low energy $\bar{\nu}_\mu$ beam from a decay-at-rest source
- Detected a 3.8σ excess in the appearance of $\bar{\nu}_e$
  - The result was interpreted from within the neutrino oscillation model as an additional mixing
  - $P(\nu_\beta \rightarrow \nu_\alpha) = \sin^2(2\theta)\sin^2\left(\frac{\Delta m^2 L}{4E_\nu}\right)$

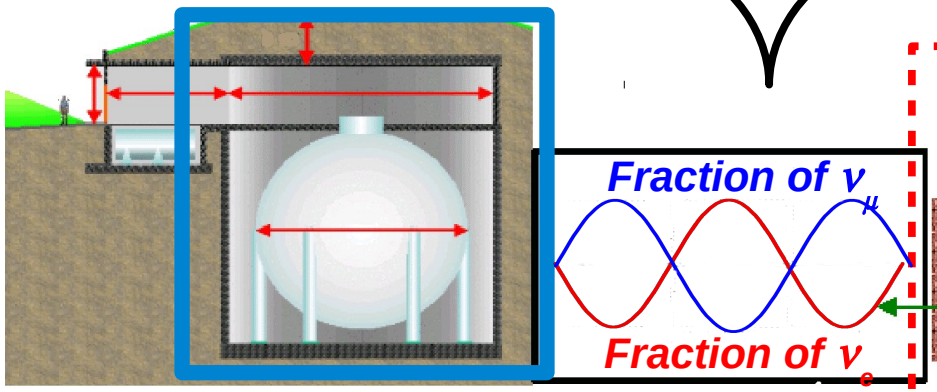


Could this excess be evidence for sterile neutrinos?

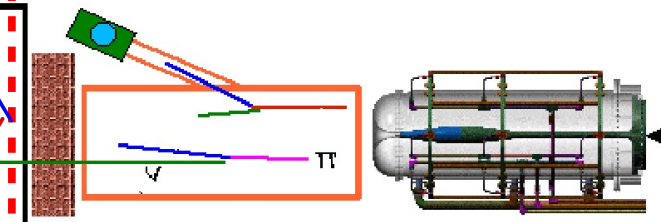


Following up on LSND



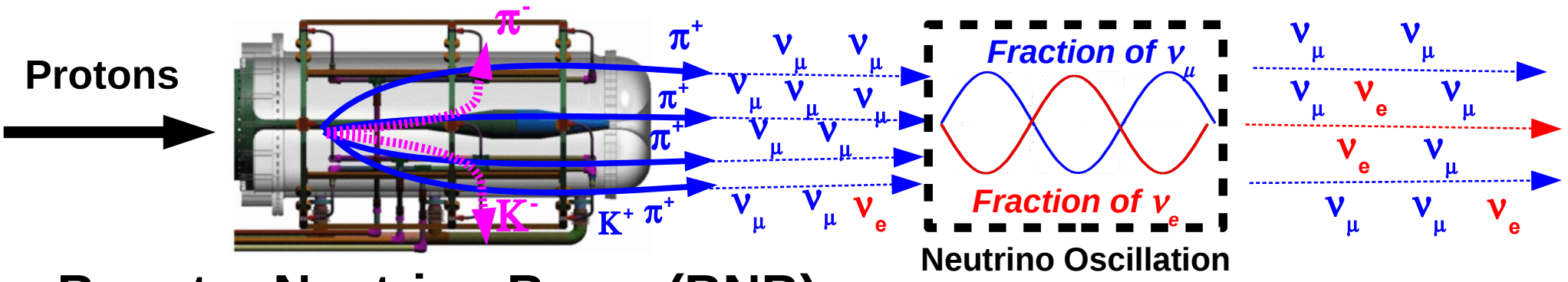


MiniBooNE Detector

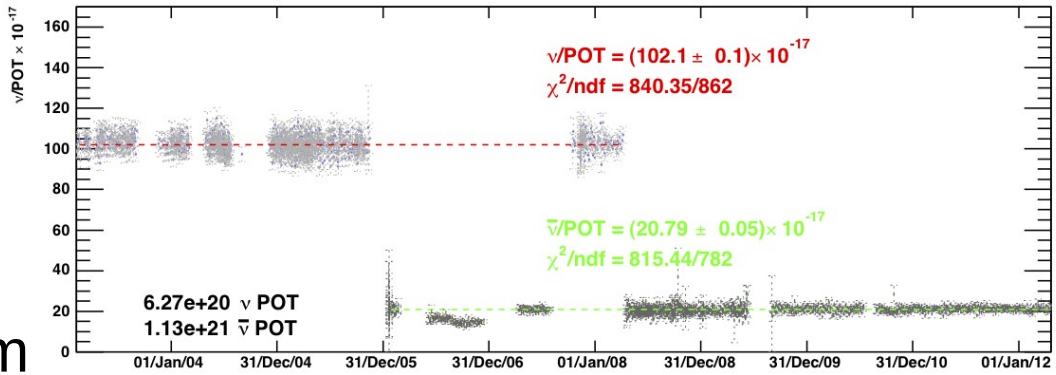


Booster

Booster Neutrino Beam

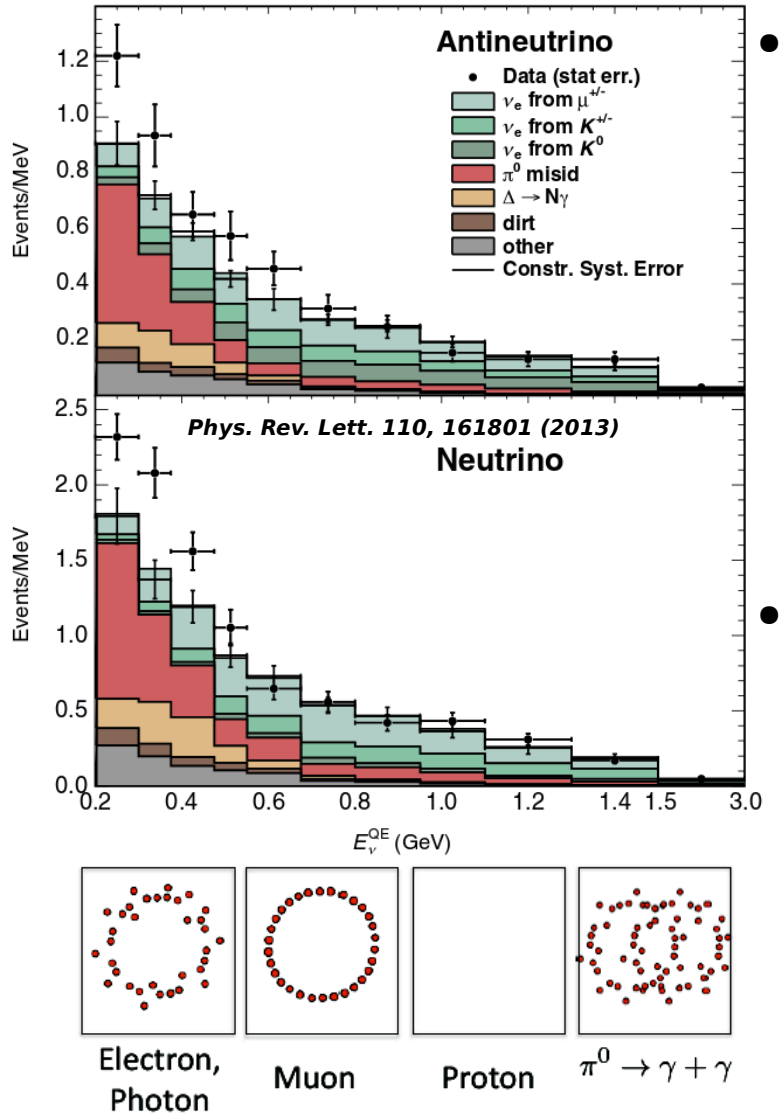


- **Booster Neutrino Beam (BNB) has been operating for a decade!**
  - A very well understood and characterized beam
  - Low (< 0.5%) contamination from intrinsic ν_e



- **Neutrino beam created from 8 GeV protons colliding on a beryllium target and having sign selected pions focused by a magnetic horn**

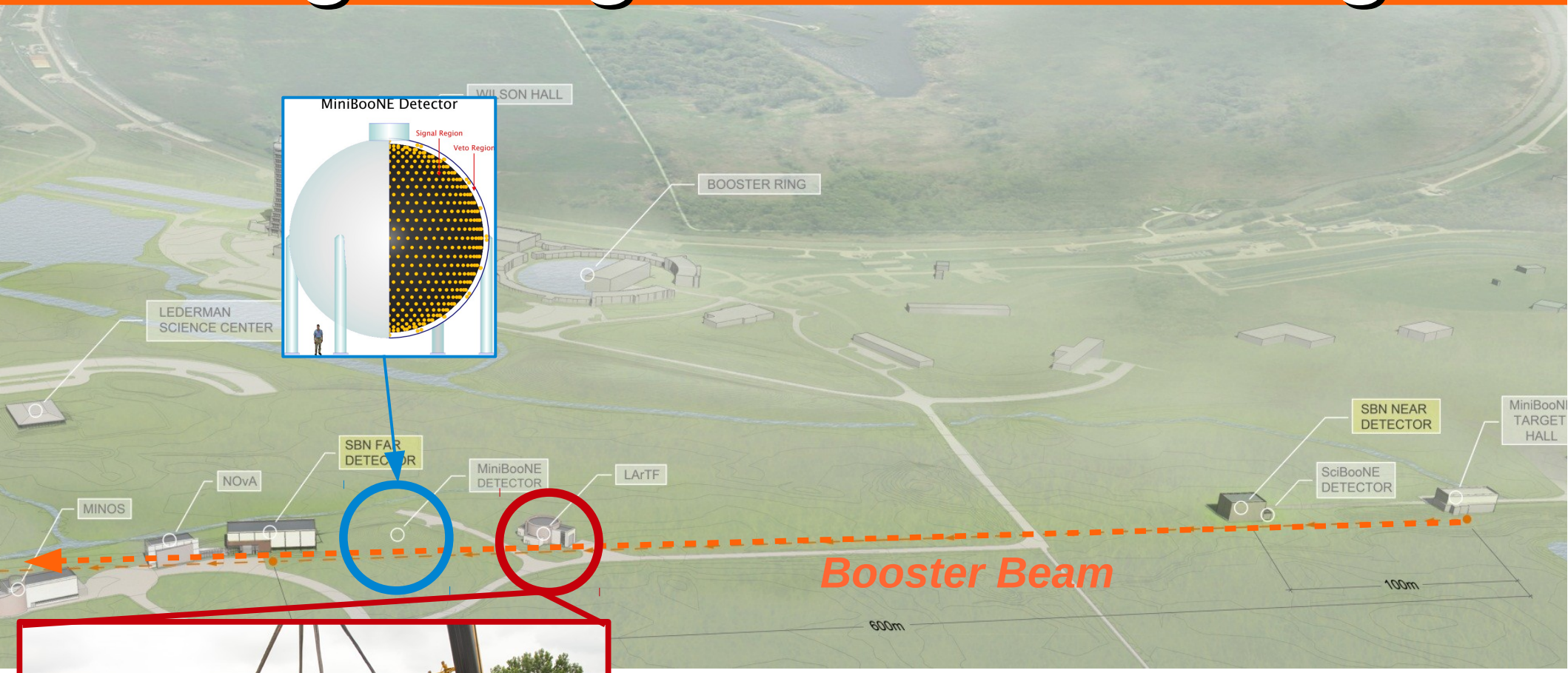
More hints of new physics?



- **MiniBooNE ran at a similar L/E (utilizing decay in flight neutrino source) and sees a low energy excess in $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ and $\nu_\mu \rightarrow \nu_e$ appearance search**
  - Excess can also be interpreted as an additional mixing
- **However, MiniBooNE (Cherenkov detector) has a difficult time determining the composition of the excess**
  - **Electron like?**
  - **Photon like?**

What you would like is an experiment that sees the same beam as MiniBooNE, at (nearly) the same distance as MiniBooNE but with superior electron/photon separation ability

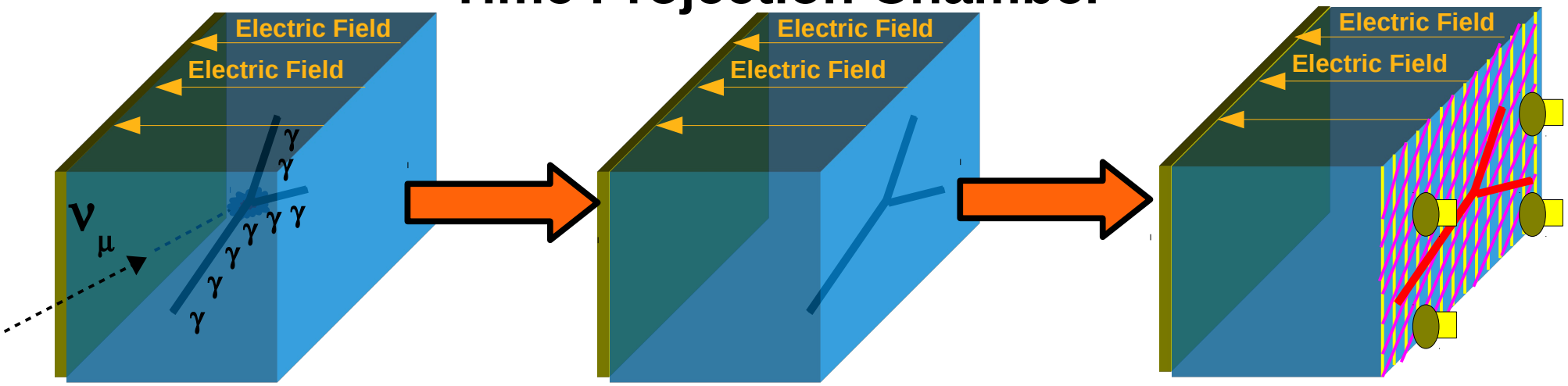
The beginning of the SBN Program



MicroBooNE is the first LArTPC detector on the short-baseline and kicks off the SBN program

LArTPC's

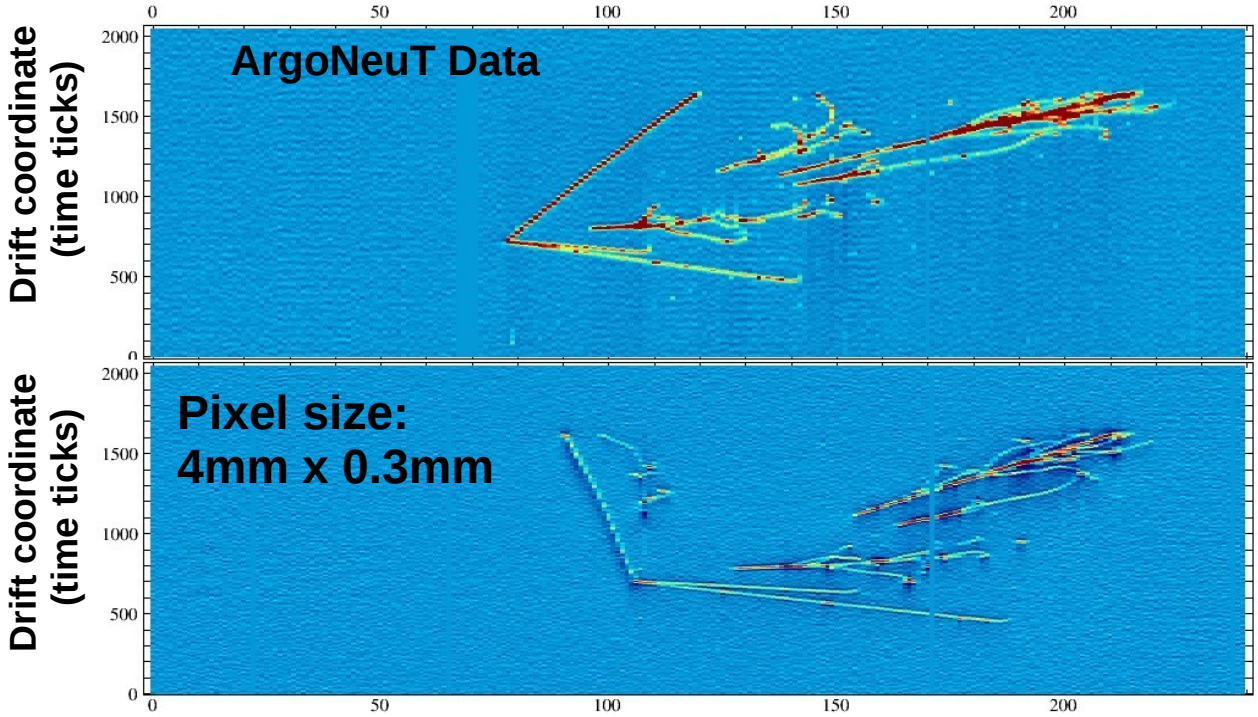
Time Projection Chamber



Neutrino interaction in LAr produces ionization and scintillation light

Drift the ionization charge in a uniform electric field

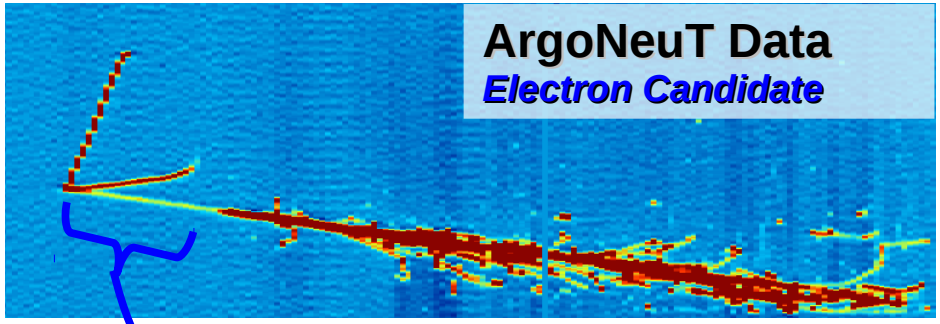
Read out charge and light produced using precision wires and PMT's

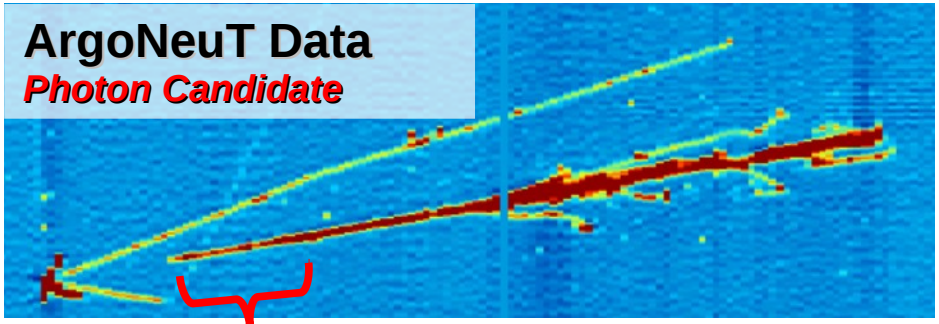


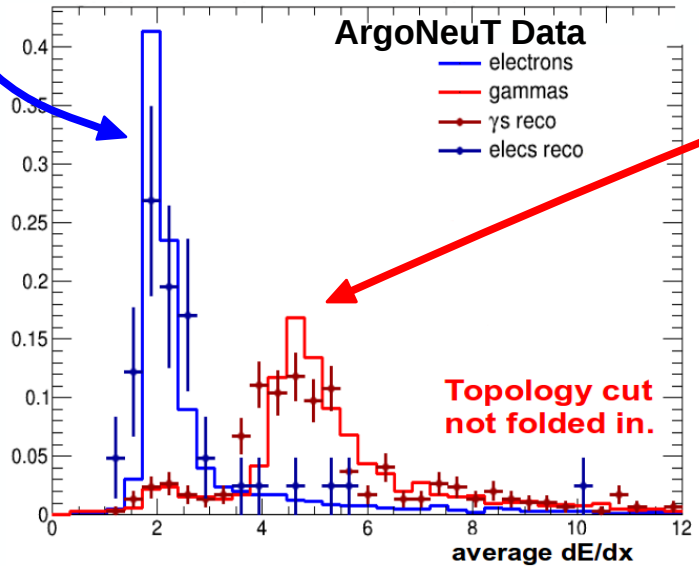
LArTPC's offer incredible fine grain tracking along with electron/photon separation

MicroBooNE

- **MicroBooNE will utilize the electron / photon discrimination power of LArTPC's to determine if the MiniBooNE excess is electron like** *(from ν_e appearance)* **or photon like** *(unaccounted for background)*

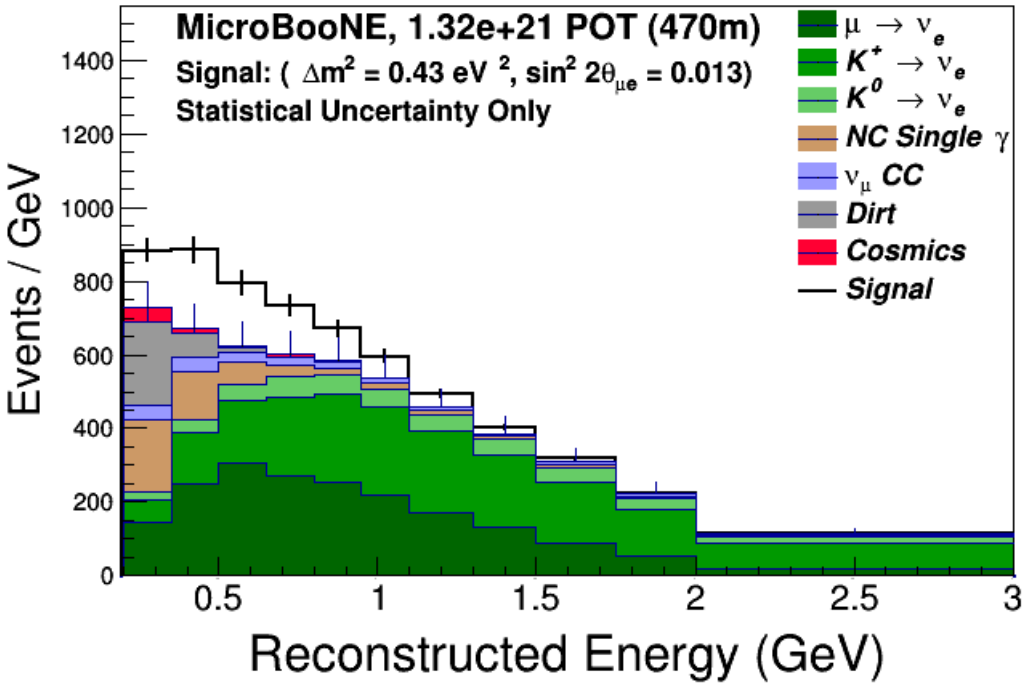


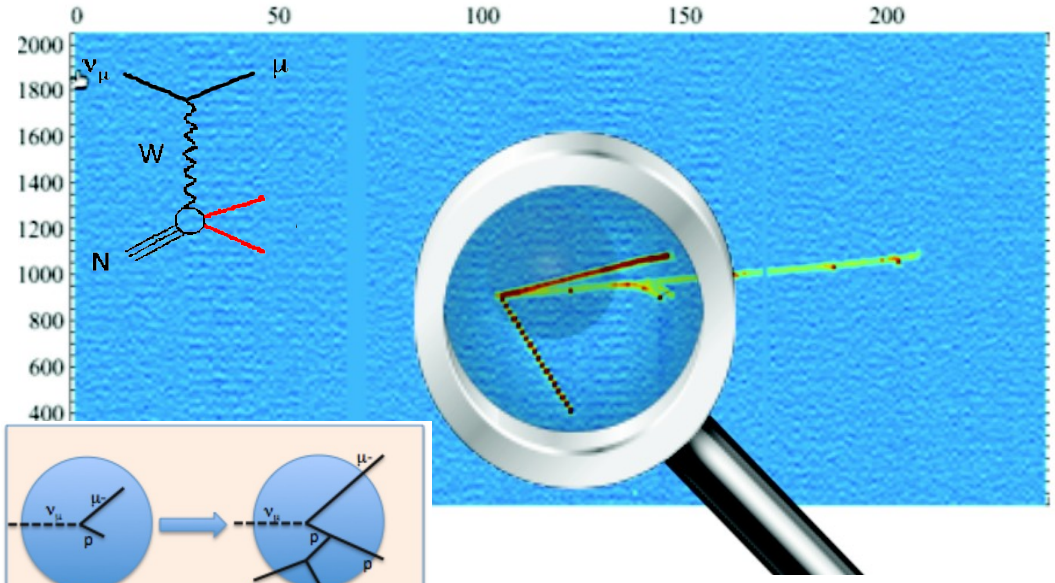




By analyzing the topology and the dE/dX of the electromagnetic shower, disentangling the MiniBooNE low energy excess becomes possible

MicroBooNE





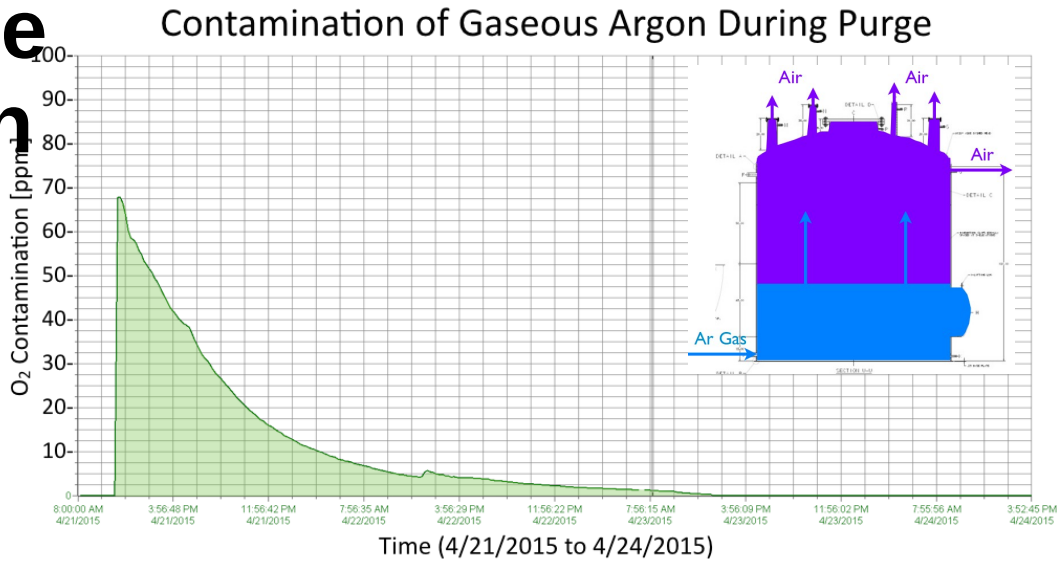
- **MicroBooNE is the largest LArTPC ever built in the U.S.**
  - 89 Tons of active mass

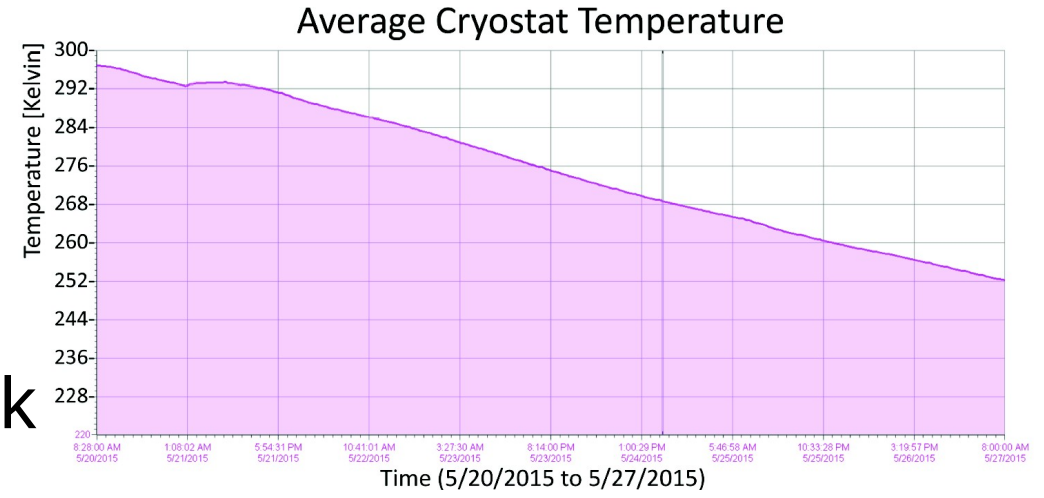
about this big

- **MicroBooNE also has a rich physics program planned**
  - Determining the nature of the MiniBooNE low energy excess
  - Neutrino cross-sections
  - Studying nuclear final state interactions
  - Exploring the capabilities for LArTPC to look at astroparticle and exotic phenomenon

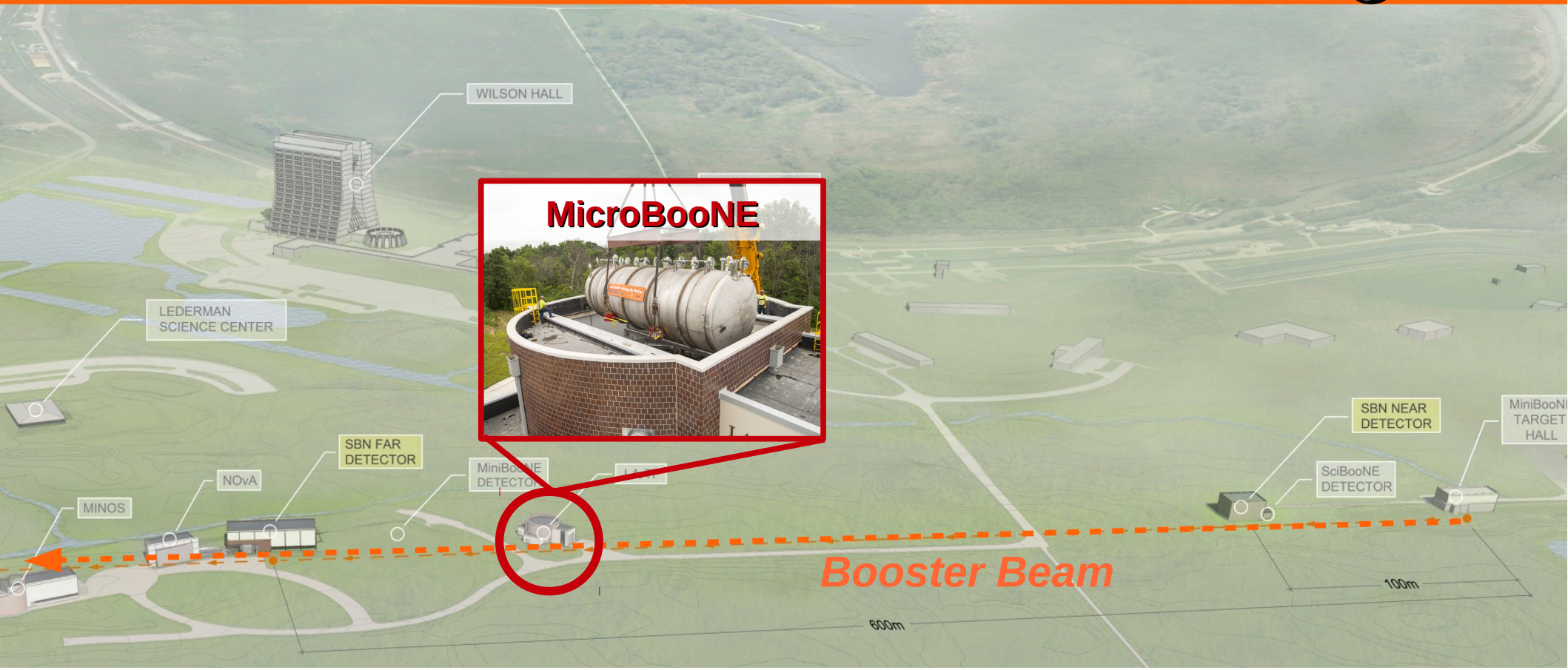
MicroBooNE: Current Status

- **MicroBooNE is fully installed and starting the O2 purge and cool down process**
- **24 hour commissioning shifts have begun**
  - Exercising our full readout and monitoring systems
- **We expect to be full of LAr and taking data this summer**
  - Neutrino data run to start when the beam comes back this fall





The Short-Baseline Neutrino Program



What do I need to add to the existing program (top notch neutrino beam + world class neutrino detectors) to make a definitive search eV scale for sterile neutrinos?

→ Normalization of the unoscillated neutrino beam **(Near detector)**

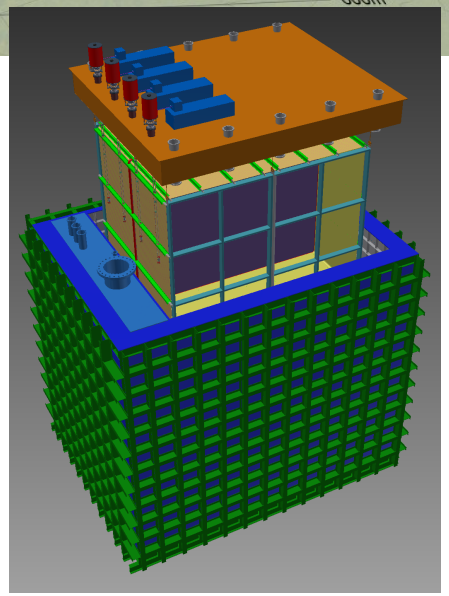
→ High statistics in the appearance channel **(large mass far detector)**

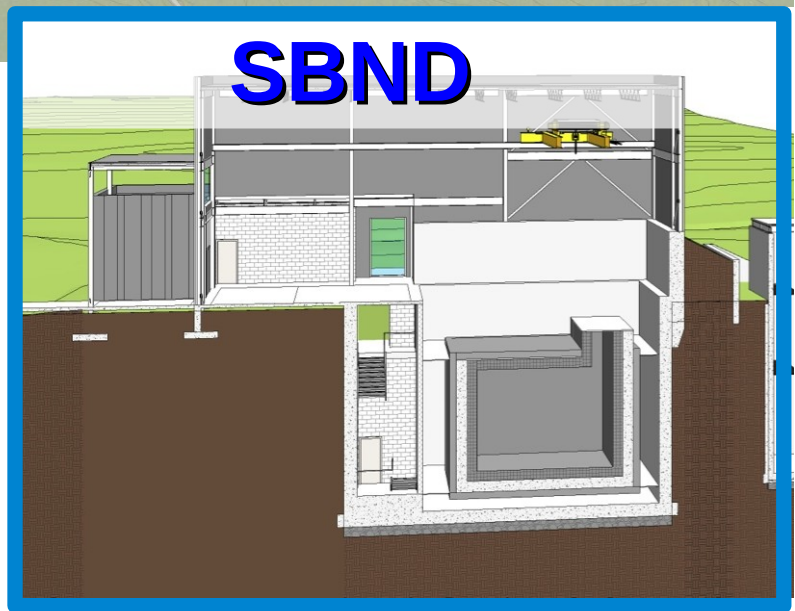
→ Look for complimentary muon disappearance **(near/far comparison)**

The Short-Baseline Neutrino Program

The Short-Baseline Near Detector (SBND) will be a 112 ton LArTPC located 110 meters from the target

- Characterize the beam before oscillation
- Cancel many dominant systematic



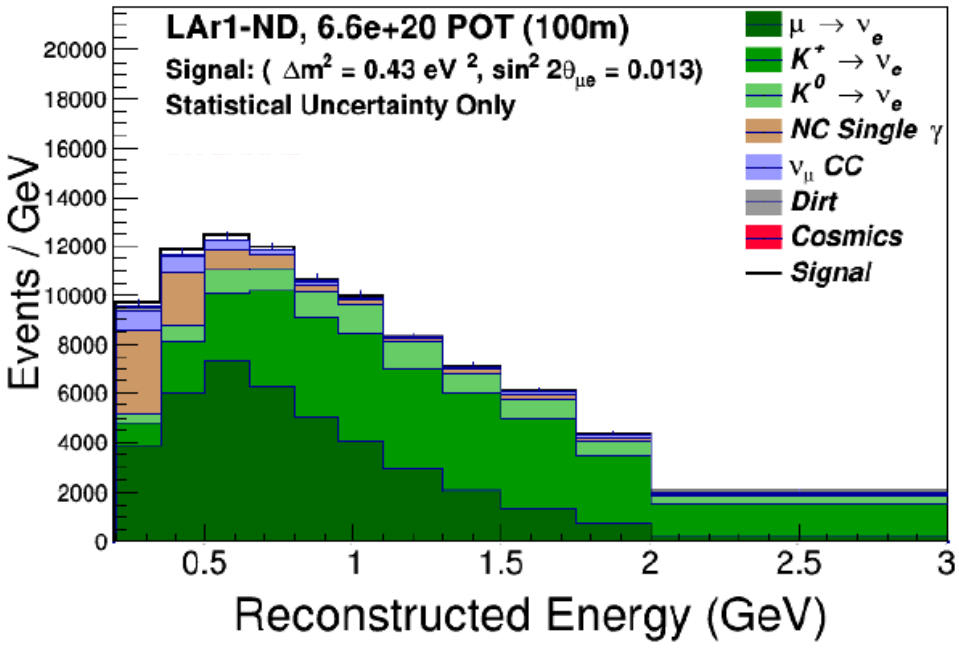


Short Baseline Near Detector (SBND)

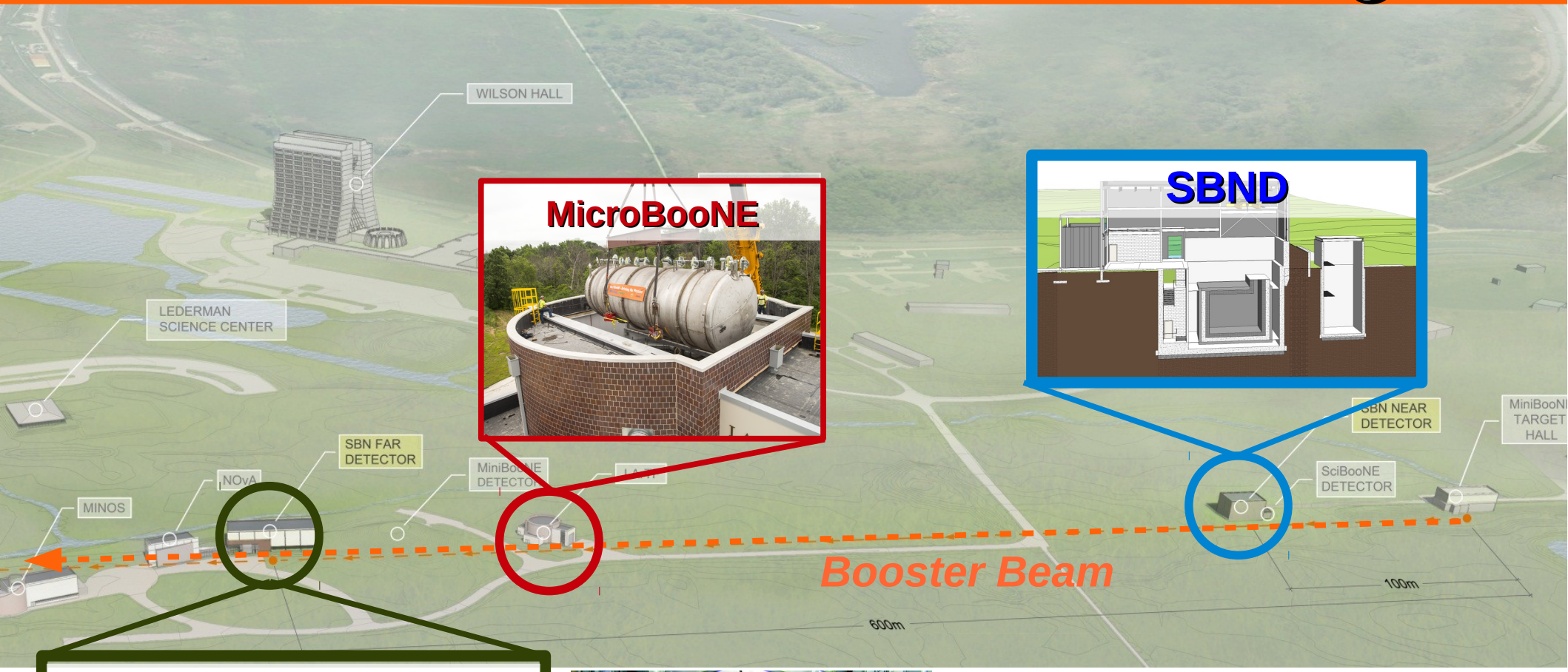
Process		No. Events
	ν_μ *Events (By Final State Topology)*	
CC Inclusive		5,212,690
CC 0 π	$\nu_\mu N \to \mu + Np$	3,551,830
	$\cdot\ \nu_\mu N \to \mu + 0p$	793,153
	$\cdot\ \nu_\mu N \to \mu + 1p$	2,027,830
	$\cdot\ \nu_\mu N \to \mu + 2p$	359,496
	$\cdot\ \nu_\mu N \to \mu + \geq 3p$	371,347
CC 1 $\pi^\pm$	$\nu_\mu N \to \mu + \text{nucleons} + 1\pi^\pm$	1,161,610
CC $\geq 2\pi^\pm$	$\nu_\mu N \to \mu + \text{nucleons} + \geq 2\pi^\pm$	97,929
CC $\geq 1\pi^0$	$\nu_\mu N \to \mu + \text{nucleons} + \geq 1\pi^0$	497,963
NC Inclusive		1,988,110
NC 0 π	$\nu_\mu N \to \text{nucleons}$	1,371,070
NC 1 $\pi^\pm$	$\nu_\mu N \to \text{nucleons} + 1\pi^\pm$	260,924
NC $\geq 2\pi^\pm$	$\nu_\mu N \to \text{nucleons} + \geq 2\pi^\pm$	31,940
NC $\geq 1\pi^0$	$\nu_\mu N \to \text{nucleons} + \geq 1\pi^0$	358,443
	ν_e *Events*	
CC Inclusive		36798
NC Inclusive		14351
Total ν_μ and ν_e Events		7,251,948

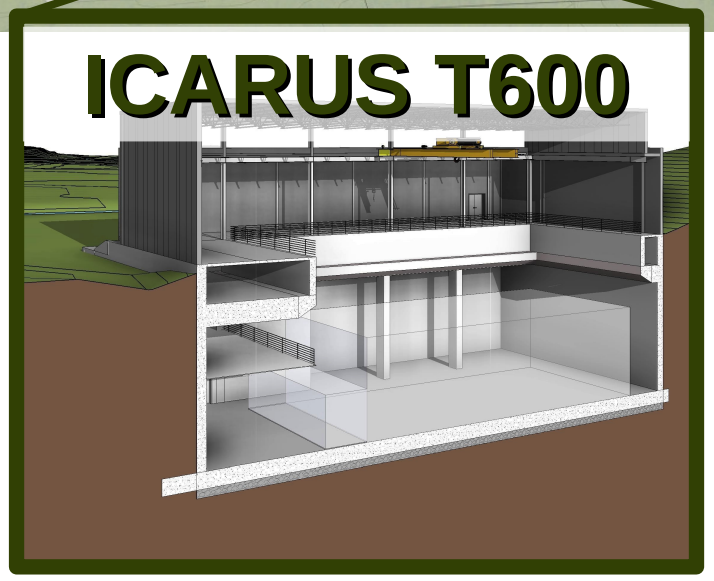
- **Provides an un-oscillated spectrum for the electron neutrino appearance search**

- **SBND will collect millions of neutrino interactions**
  - High statistics, precision neutrino cross-sections measurements



The Short-Baseline Neutrino Program

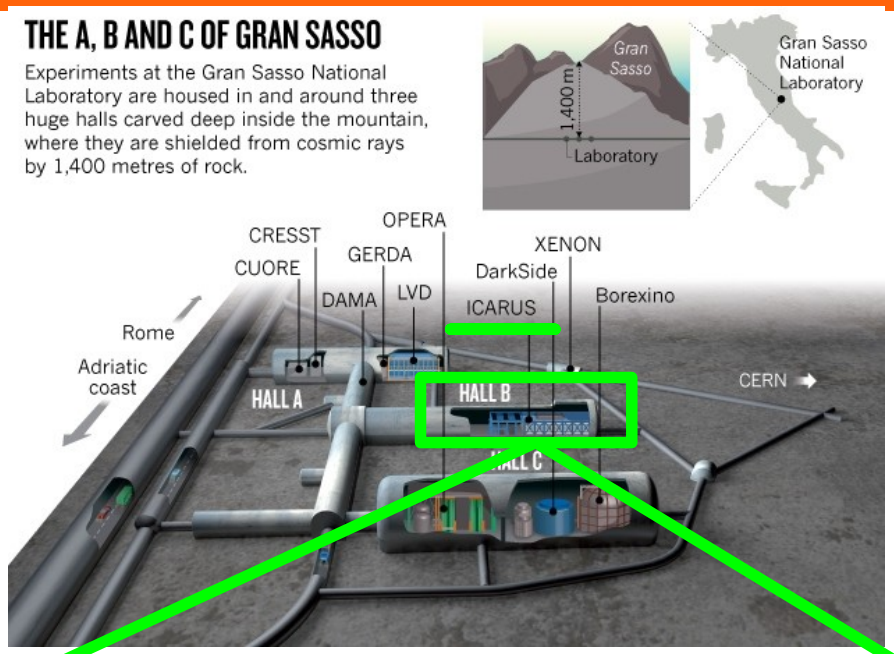




The ICARUS detector is the largest LArTPC ever built

- Adding the large mass allows for precision oscillation search

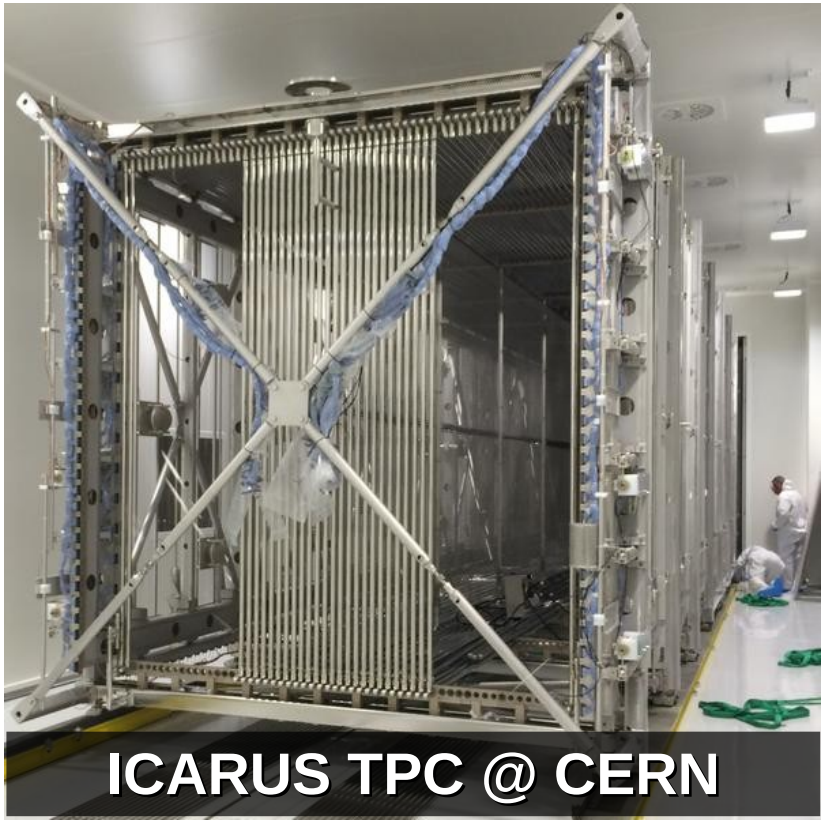
ICARUS T600



ICARUS Detector @ Gran Sasso

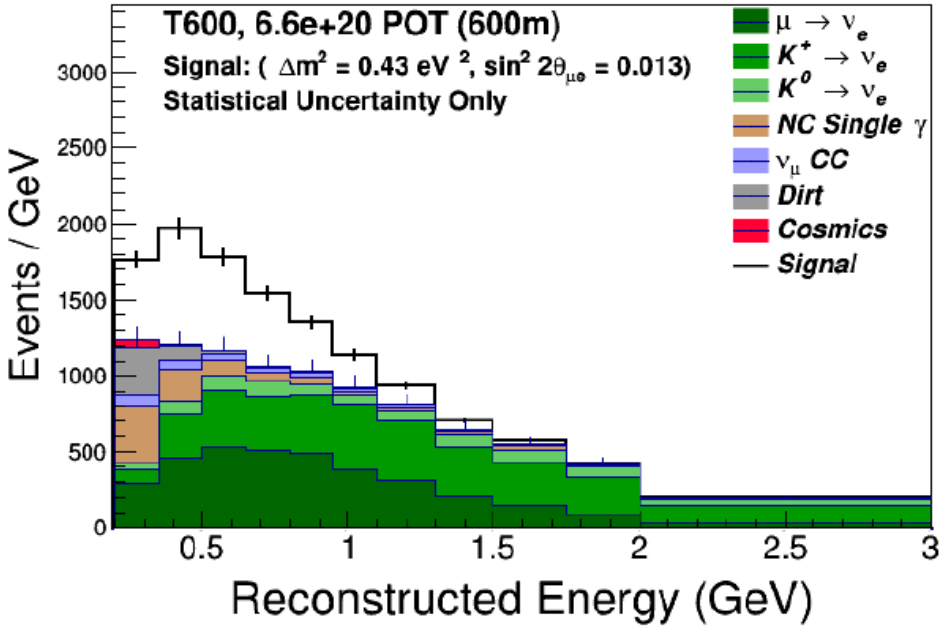
- **ICARUS was the first large scale LArTPC to run in a neutrino beam line**
  - Ran in the CNGS beam from CERN to Gran Sasso Labrotory from 2010 – 2013
- **After completing a successful neutrino run demonstrating the power of the LArTPC technology in an underground laboratory the detector has been moved from Gran Sasso to CERN**

ICARUS T600

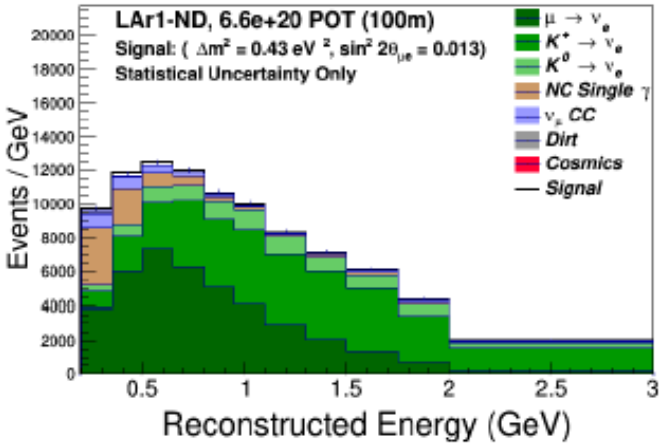

ICARUS TPC @ CERN

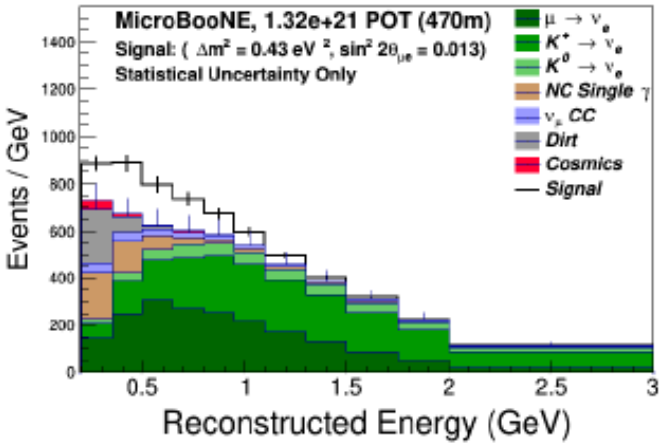
- **The ICARUS detector is at CERN for refurbishment before it is shipped to Fermilab**
  - The first module is expected to be finished in 2015
- **This large mass detector will provide increased sensitivity to the electron neutrino appearance search**

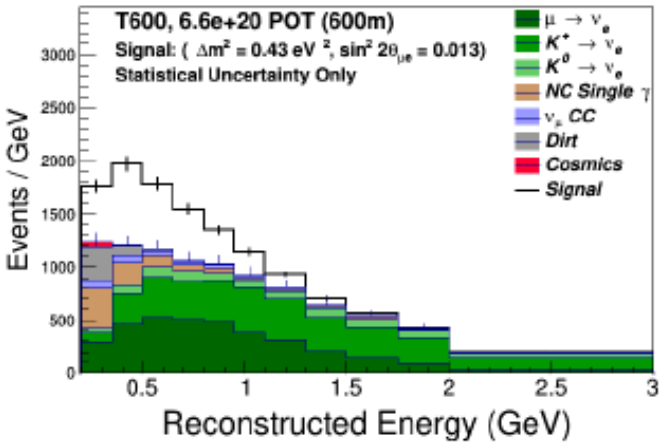
Far Detector Building Design



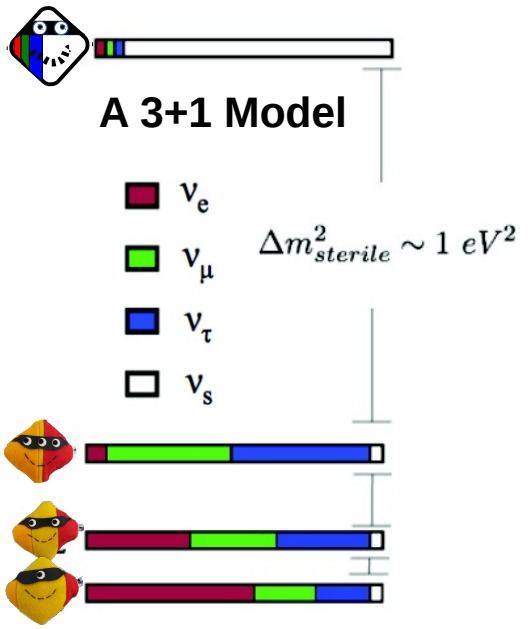
The SBN Program

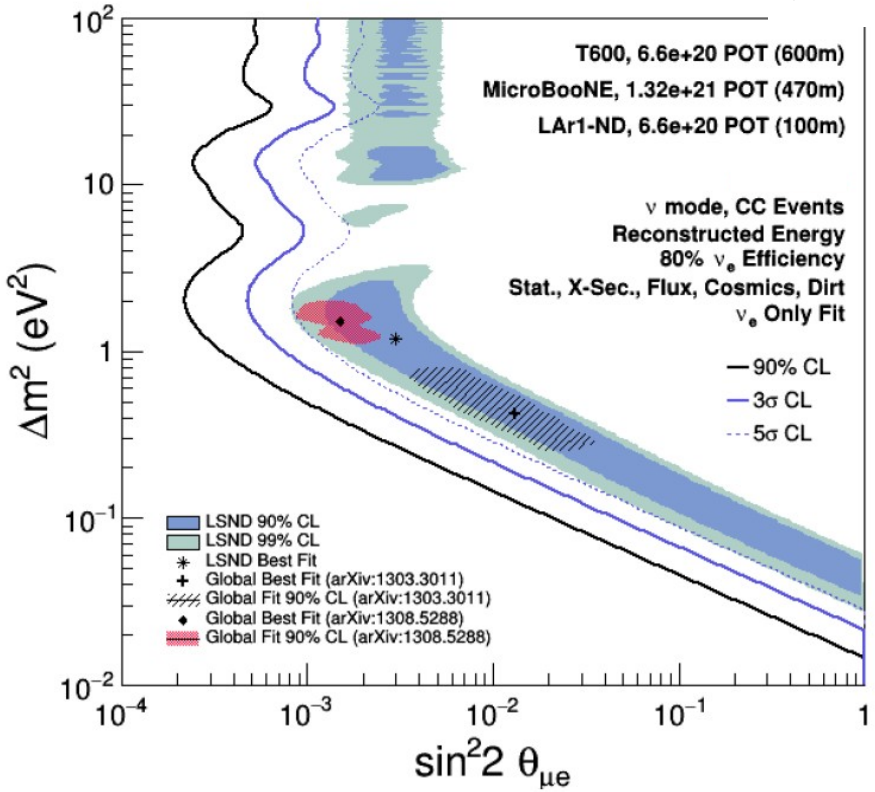




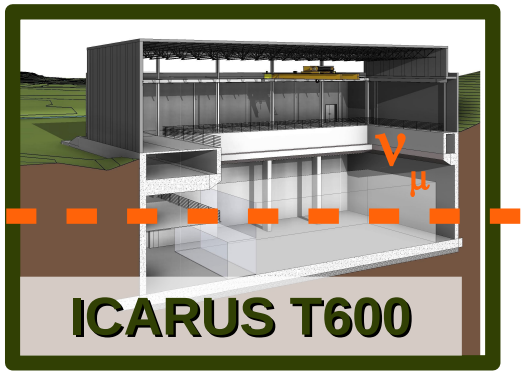


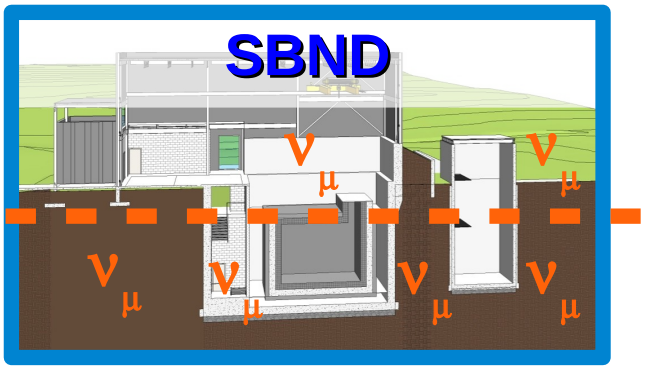
Utilizing three similar detectors at three different distances along the same neutrino beam allows for a **definitive measurement** of the allowed sterile neutrino parameter space

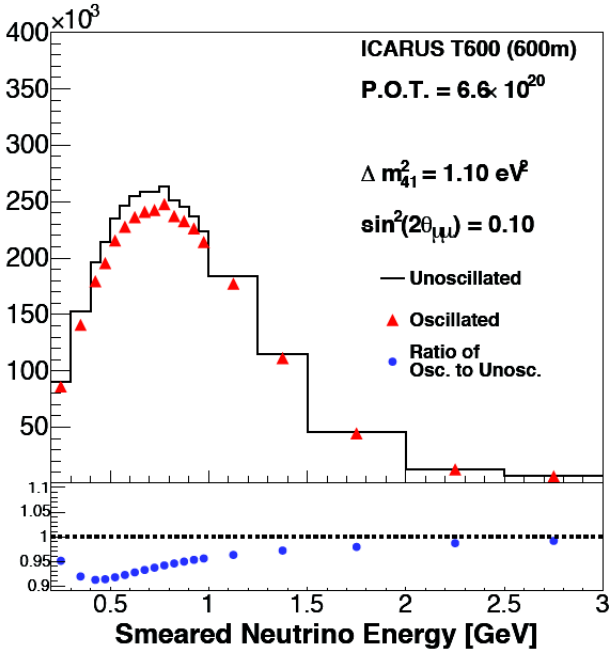


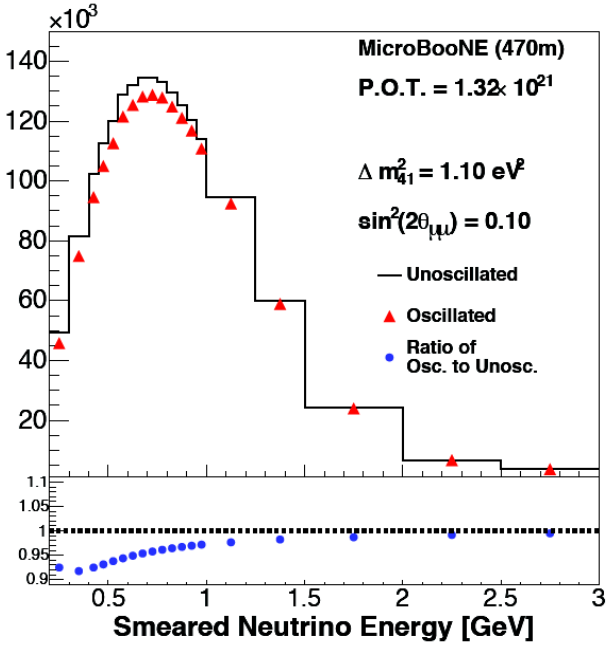


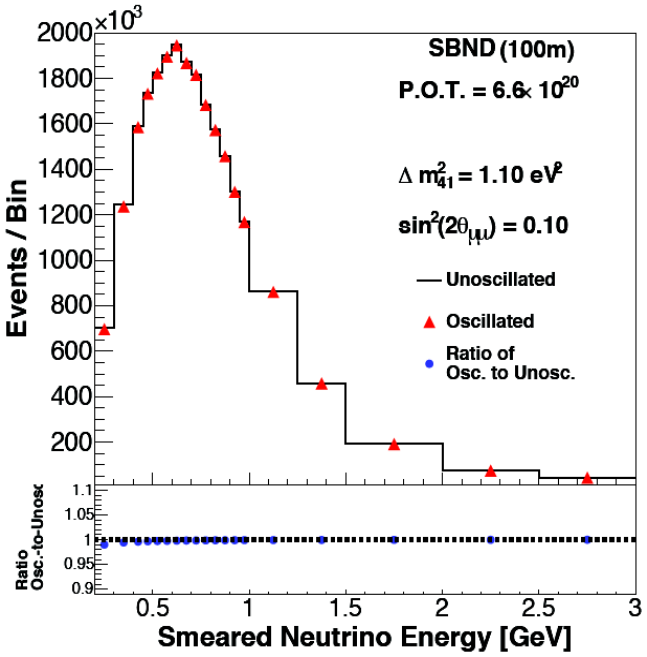
The SBN Program











- **The three detector configuration also allows you to search for the muon neutrino disappearance channel as well**
  - Complimentary to the electron neutrino appearance search

Conclusions

- **Fermilab stands at the dawn of the next generation of precision neutrino experiments**
- **The MicroBooNE experiment will begin to take data this summer**
  - This turns the key on the launch of the short-baseline experiment at Fermilab
- **Ground breaking on the buildings for the near and far detector will occur this summer**
  - Planning and design work on the near detector is moving ahead at full speed
  - The refurbishment of the ICARUS detector is ongoing at CERN and is expected to be complete in 2016

Thank you for your attention

The ICARUS-WA104 Collaboration

M. Antonello[16], B. Baibussinov[31], V. Bellini[3], P. Benetti[32], S. Bertolucci[6], H. Bilokon[15], F. Boffelli[32], M. Bonesini[17], J. Bremer[6], E. Calligarich[32], S. Centro[31], A.G. Cocco[19], A. Dermenev[20], A. Falcone[32], C. Farnese[31], A. Fava[31], A. Ferrari[6], D. Gibin[31], S. Gninenko[20], N. Golubev[20], A. Guglielmi[31], A. Ivashkin[20], M. Kirsanov[20], J. Kisiel[38], U. Kose[6], F. Mammoliti[3], G. Mannocchi[15], A. Menegolli[32], G. Meng[31], D. Mladenov[6], C. Montanari[32], M. Nessi[6], M. Nicoletto[31], F. Noto[6], P. Picchi[15], F. Pietropaolo[31], P.Płoński[42], R. Potenza[3], A. Rappoldi[32], G. L. Raselli[32], M. Rossella[32], C. Rubbia[*,6,11,16], P. Sala[18], A. Scaramelli[18], J. Sobczyk[44], M. Spanu[32], D. Stefan[18], R. Sulej[43], C.M. Sutera[3], M. Torti[32], F. Tortorici[3], F. Varanini[31], S. Ventura[31], C. Vignoli[16], T. Wachala[12], and A. Zani[32]

The SBND Collaboration

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The MicroBooNE Collaboration

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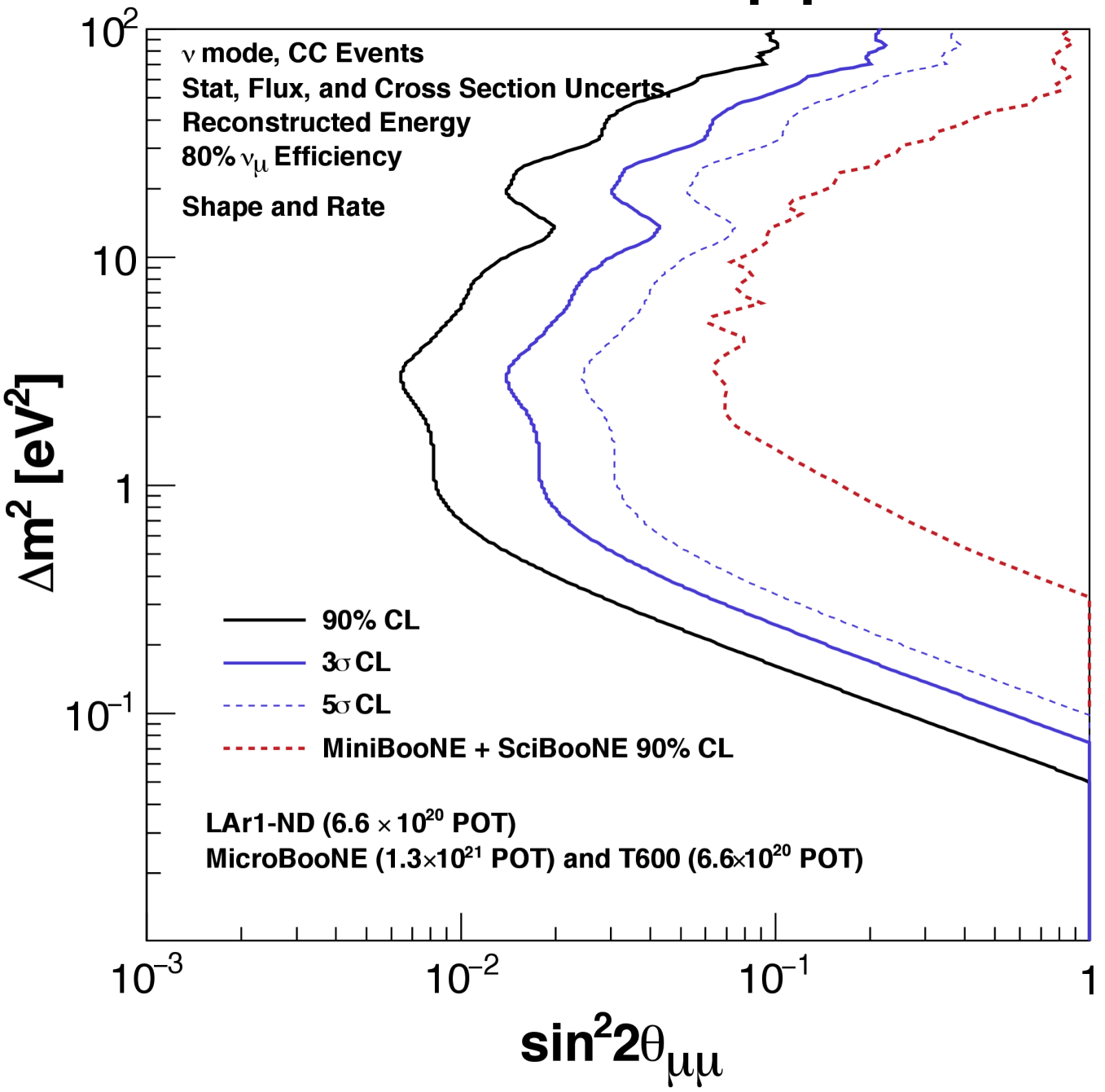
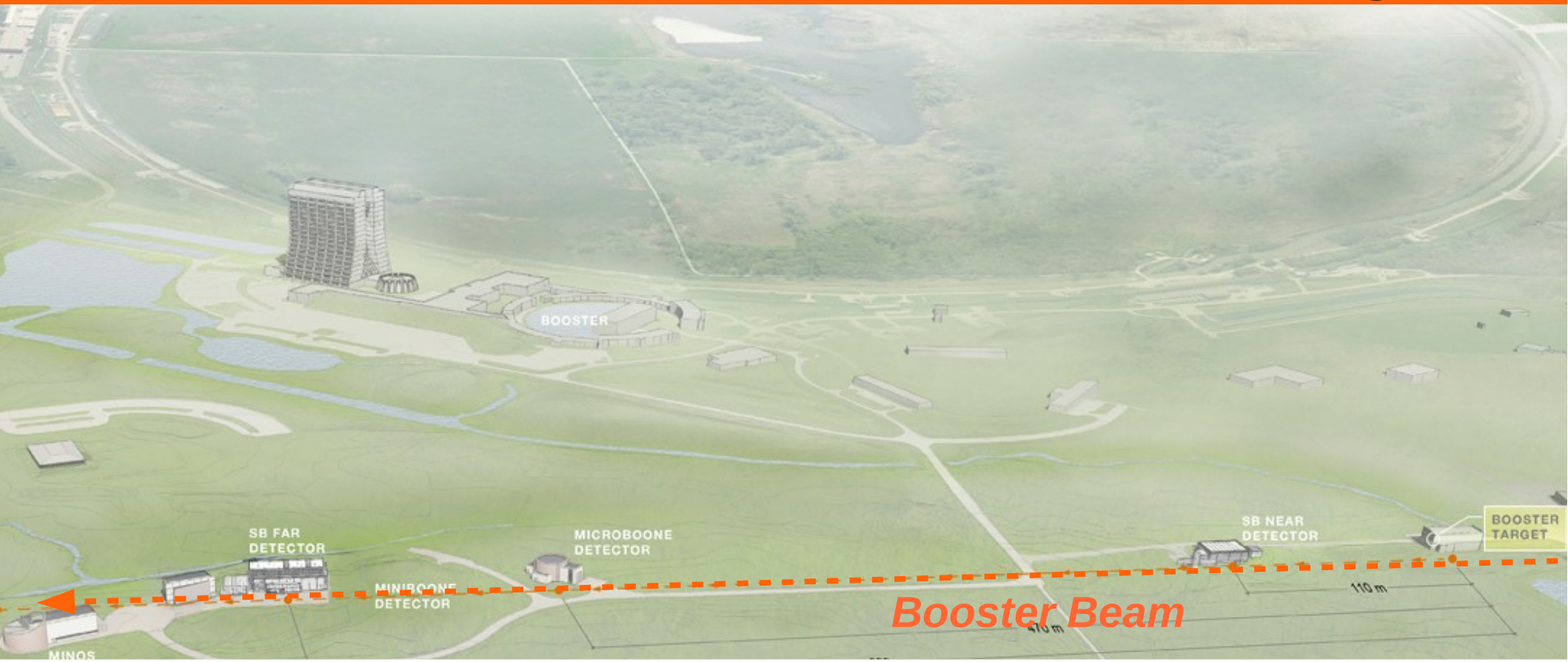
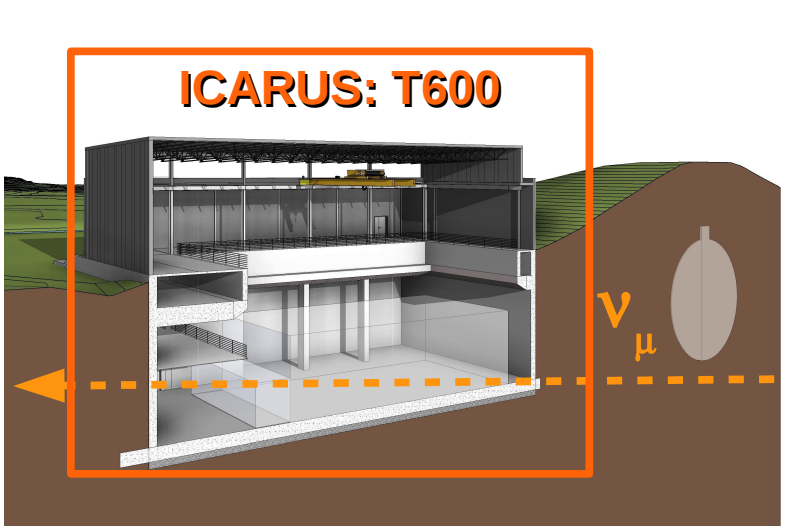
Backups

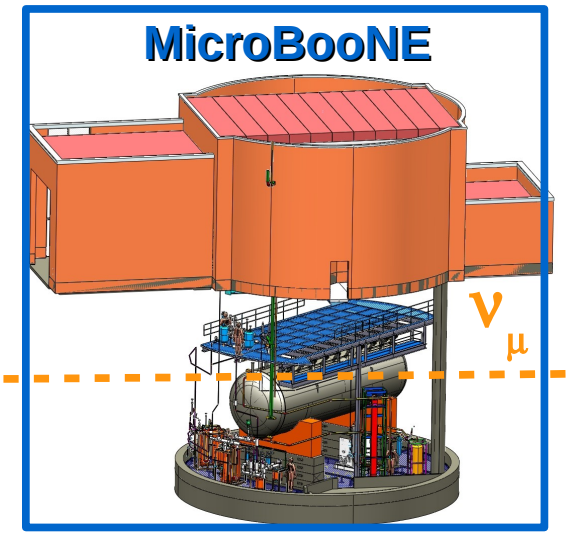
Muon Neutrino Disappearance

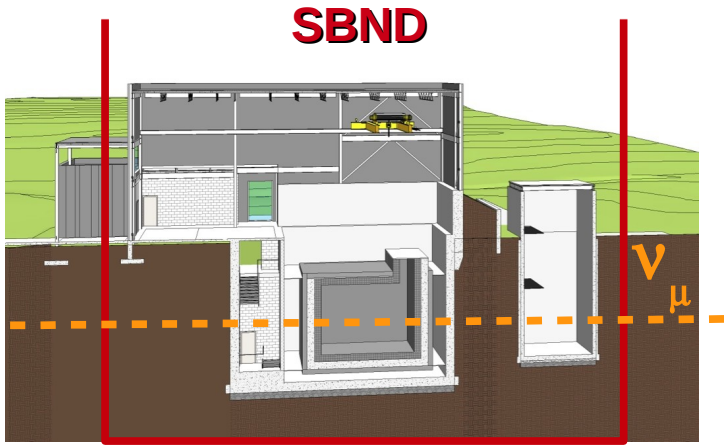


The Short-Baseline Neutrino Program



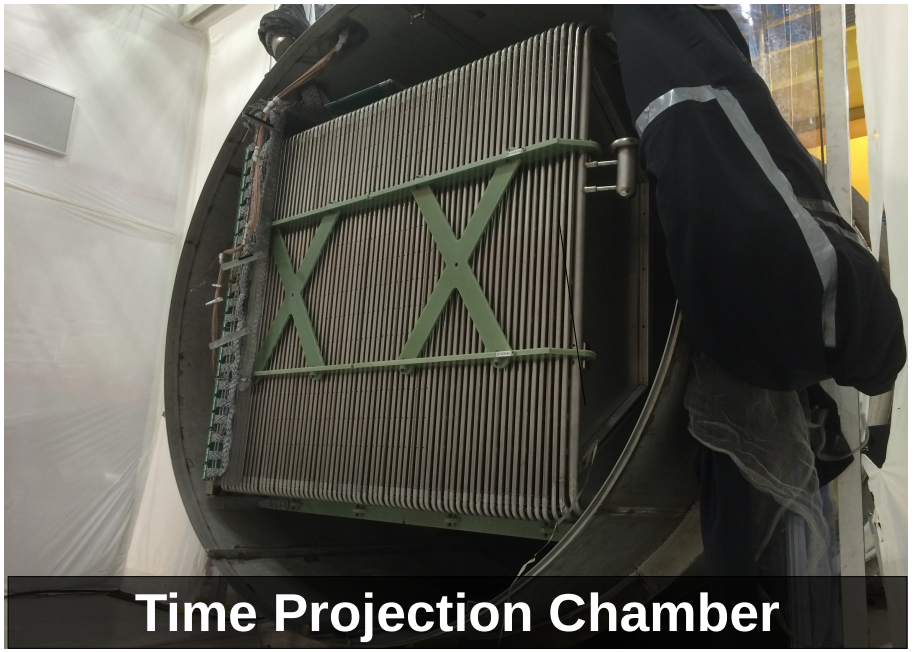


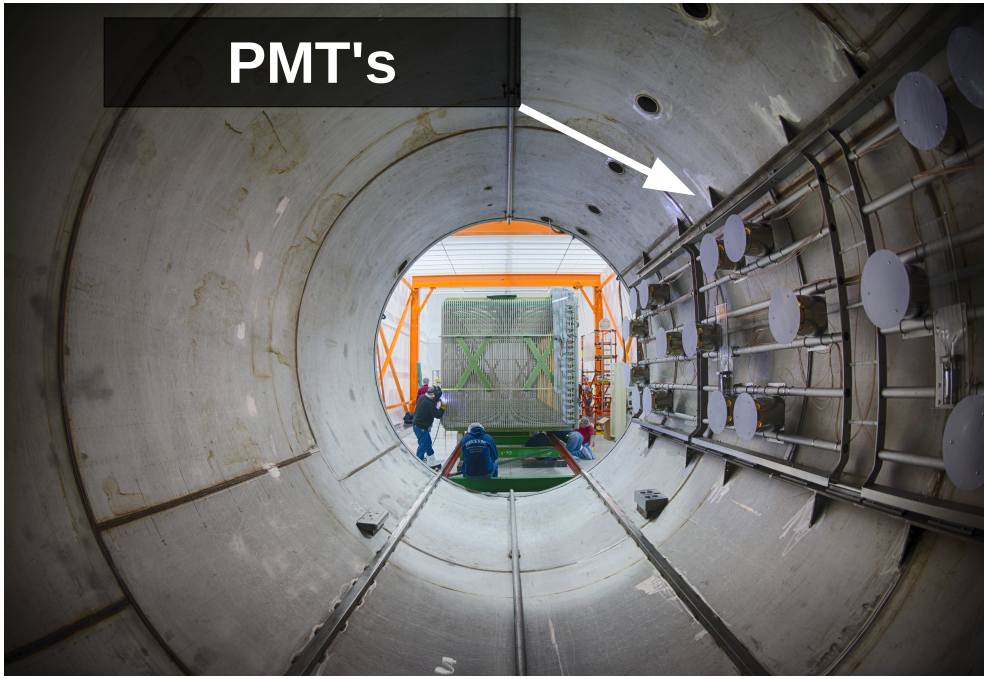




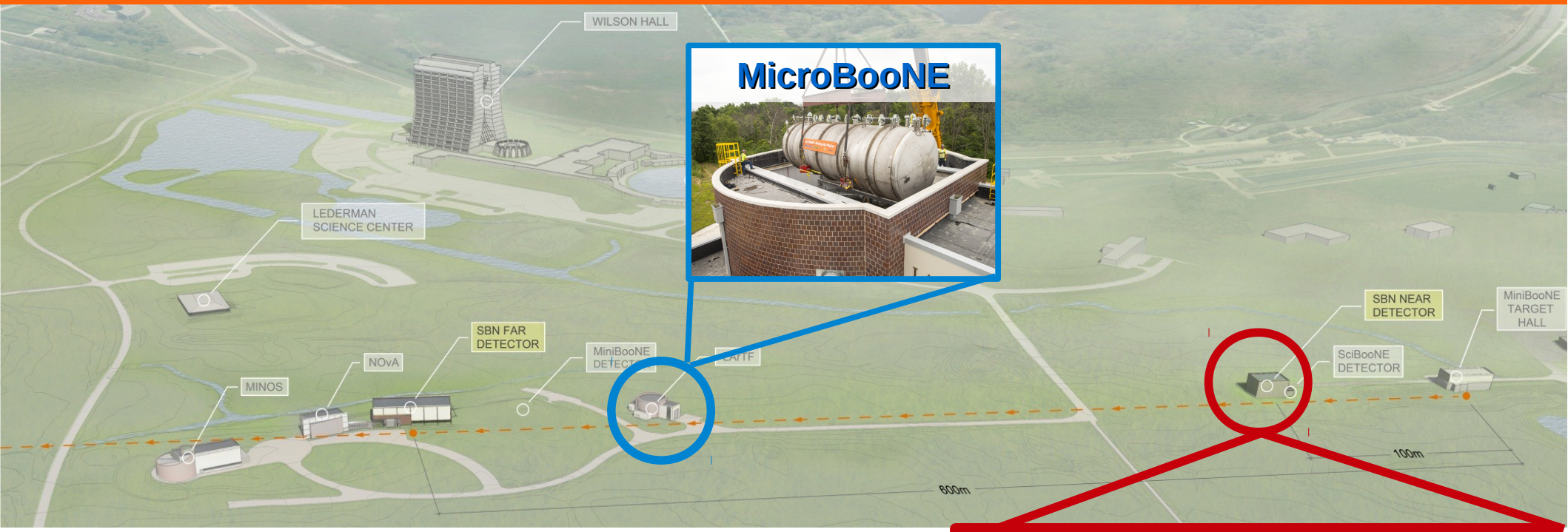
MicroBooNE

- **MicroBooNE is a 170 ton (total volume) LArTPC**
- **TPC Dimensions:**
  - 10.3 m long x 2.3 m tall x 2.5 m wide (drift distance)
  - 89 ton active mass
- **8256 wire channels**
  - 3456 Collection channels
    - Wires oriented w.r.t. the vertical
  - 4800 Induction channels
    - Wires oriented +/- 60^{o}
- **32 8” cryogenic PMT's**
  - Provides event t_0 as well as cosmic ray removal
- **UV Laser Calibration System**

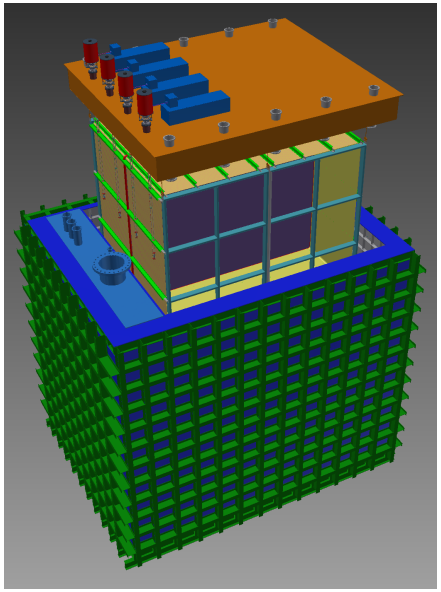


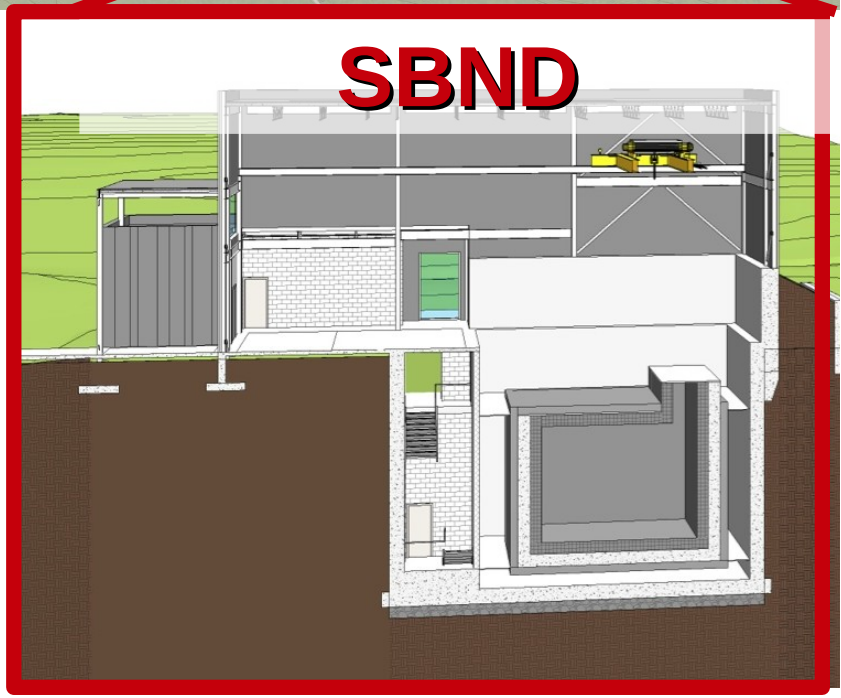


Current Status of SBN



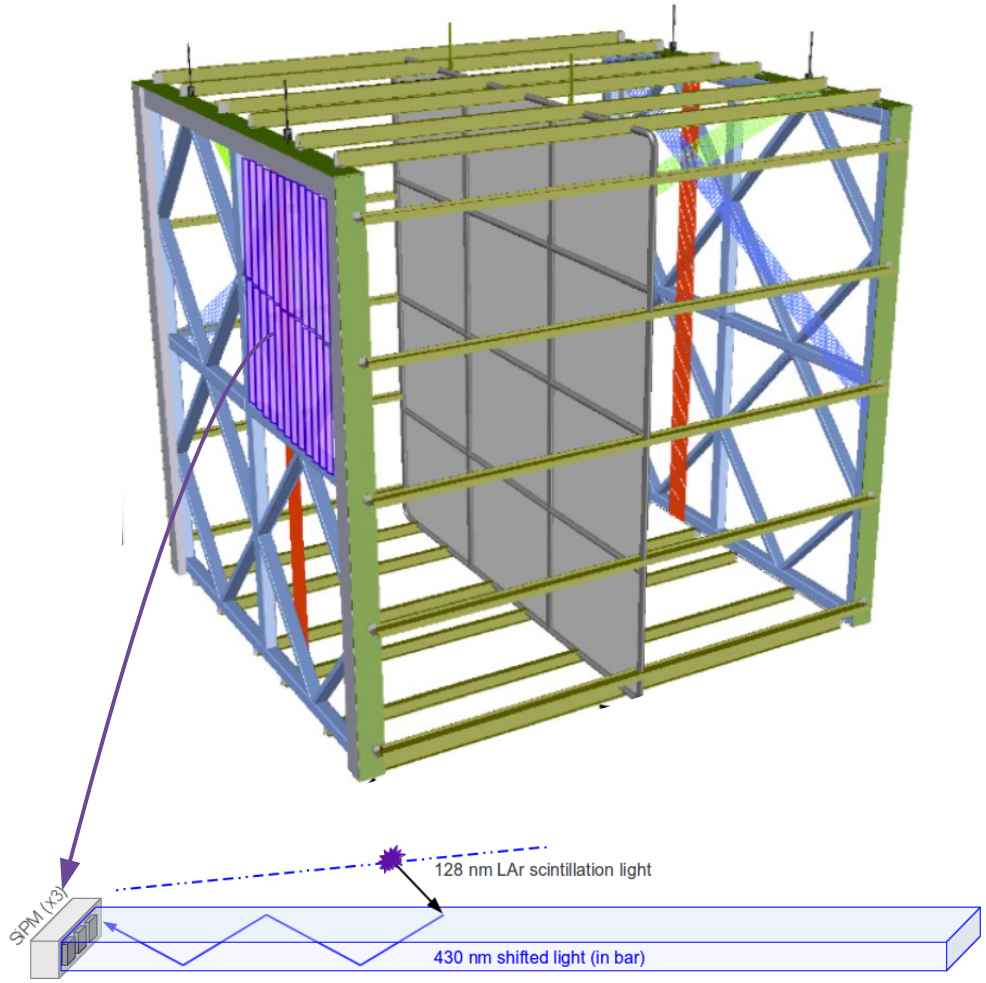
SBND will serve as the near detector and

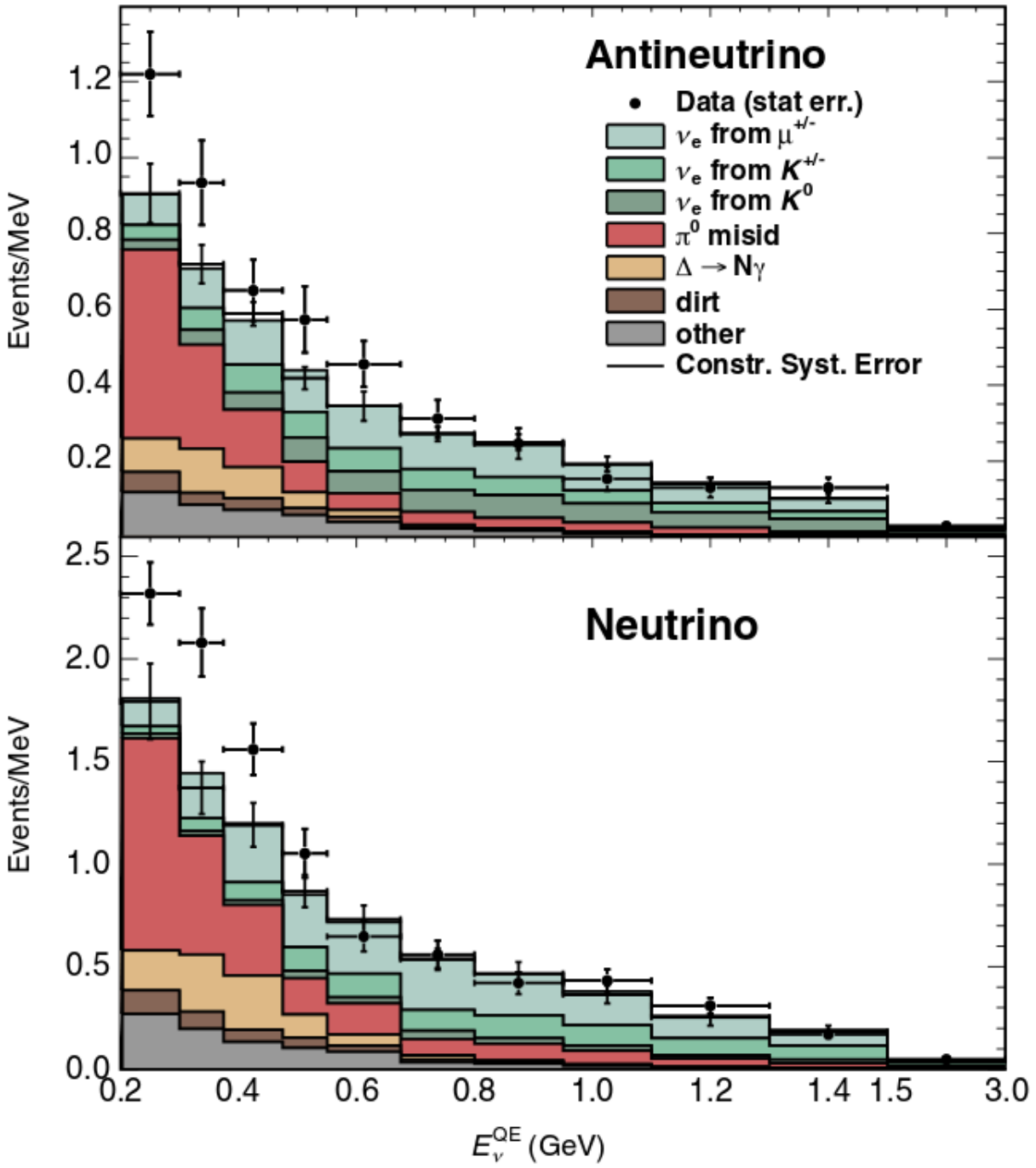




Short Baseline Near Detector (SBND)

- **SBND is a 210 ton (total volume) LArTPC**
- **TPC Dimensions:**
  - 5 m long x 4 m tall x 4 m wide (drift distance)
  - 112 ton active mass
- **11,264 wire channels**
  - ???? Collection channels
    - Wires oriented w.r.t. the vertical
  - ???? Induction channels
    - Wires oriented +/- 60^{o}
- **Finalizing the Light Detection System Desing**
  - Provides event t_0 as well as cosmic ray removal
- **UV Laser Calibration System**




Antineutrino
Data (stat err.)
ν_e from $\mu^{+/-}$
ν_e from $K^{+/-}$
ν_e from K^0
π^0 misid
$\Delta \rightarrow N\gamma$
dirt
other
Constr. Syst. Error
Neutrino
Events/MeV
Events/MeV
E_ν^{QE} (GeV)

Opening windows on new areas

Opening windows on new areas