Status of the Short-Baseline Near Detector [SBND] at Fermilab

Supraja Balasubramanian,
on behalf of the
SBND collaboration

28 October 2022 | NuINT 2022

Fermilab

One SBND TPC, with anode wire planes on the left and cathode plane on the right.

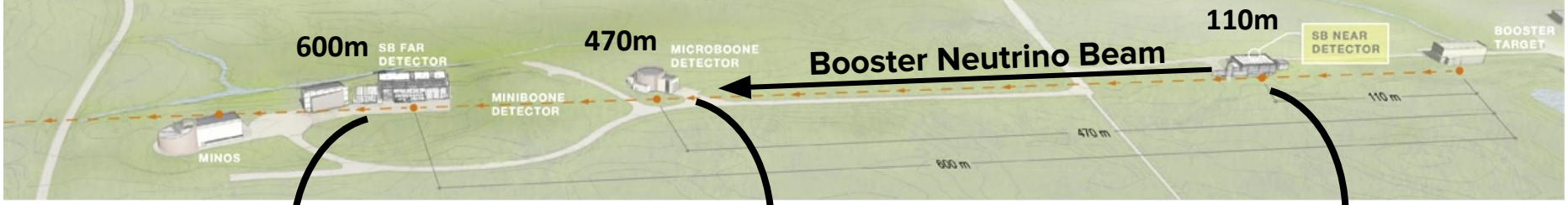
Short Baseline Neutrino Program

arXiv:1503.01520v1

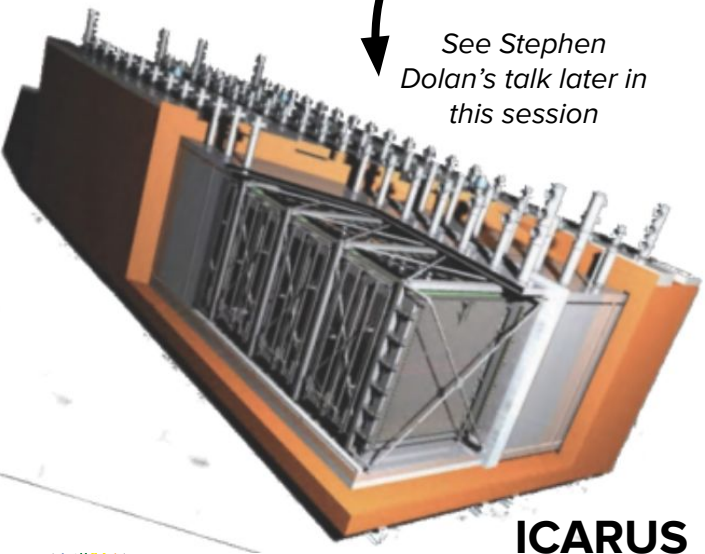
3 detectors with LArTPC technology

Booster Neutrino Beam

Neutrino cross sections, oscillations, BSM new physics



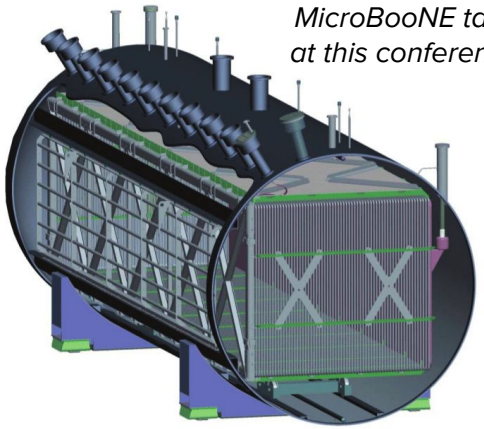
See Stephen Dolan's talk later in this session



ICARUS

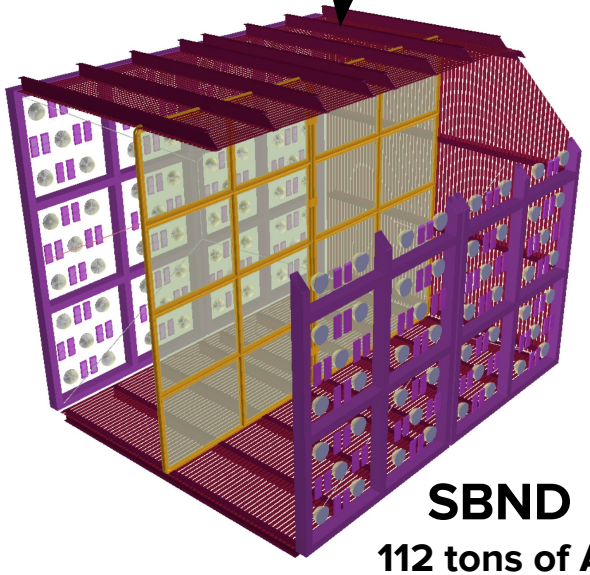
476 tons of Ar

See the seven MicroBooNE talks at this conference!



MicroBooNE

89 tons of Ar



SBND

112 tons of Ar

Short Baseline Neutrino Program

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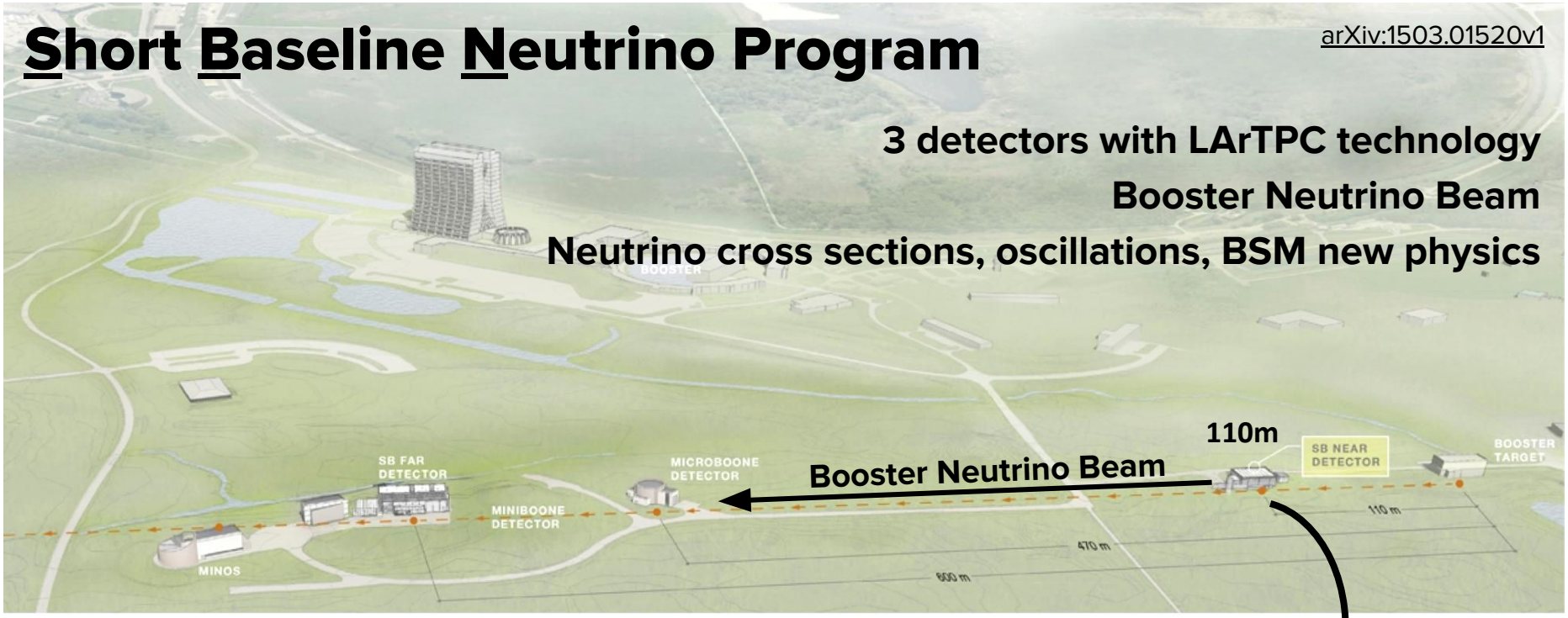


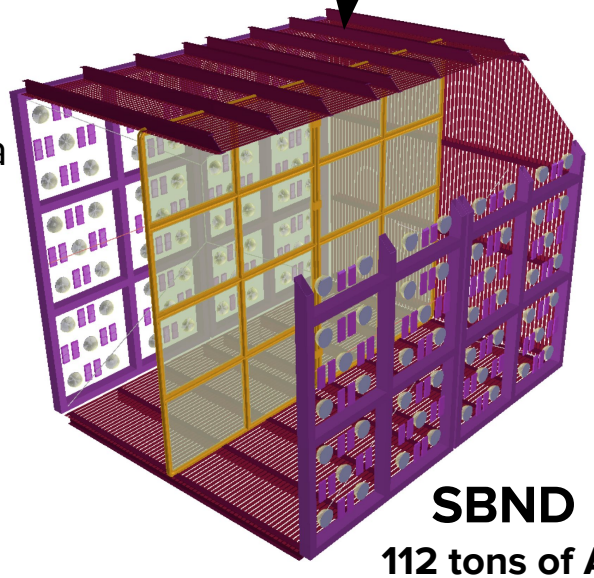
Short Baseline Near Detector

Last LArTPC to begin operating before DUNE
=> last prototype for various design elements, operations, data reconstruction, etc.

The **near detector** of the SBN program [110 m from target].

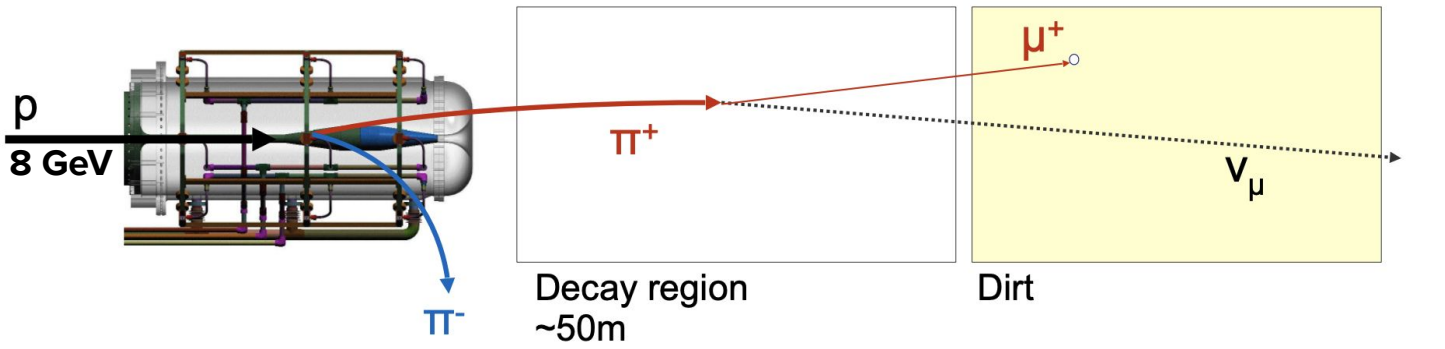
High-intensity neutrino beam + proximity to target
=> **large statistics of neutrino-argon interactions, off axis fluxes**.

Start of operations planned for **2023**.



SBND
112 tons of Ar

The Booster Neutrino Beam @ SBND



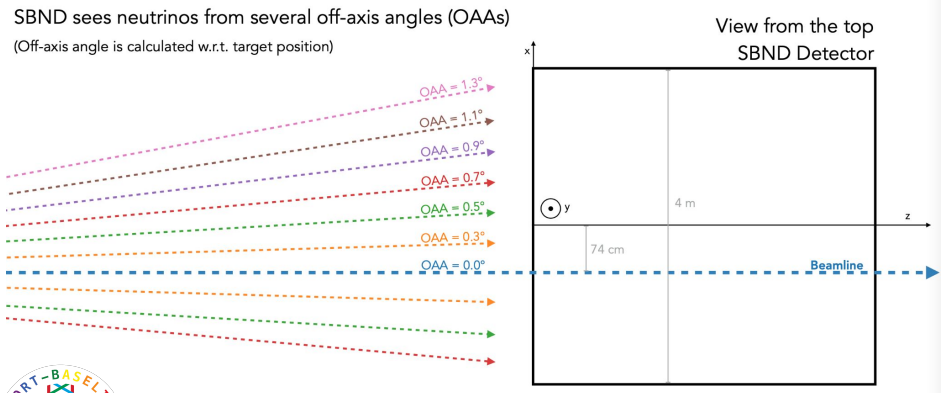
Beam Composition:

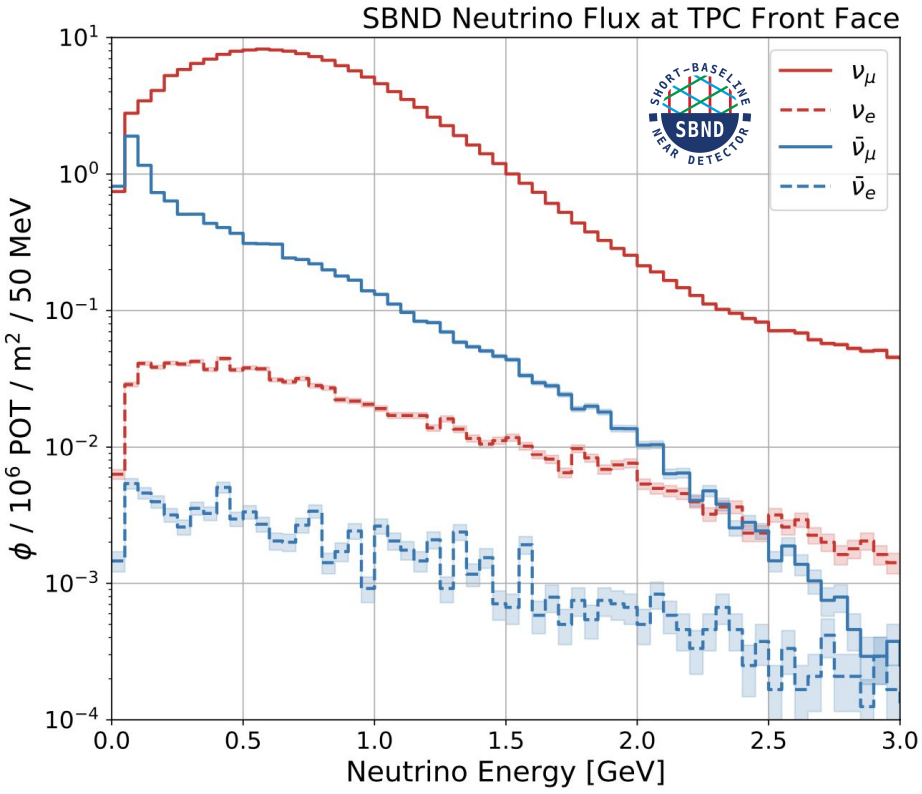
ν_μ = 93.6%

$\bar{\nu}_\mu$ = 5.9%

$\nu_e + \bar{\nu}_e$ = 0.5%

- $\langle E_\nu \rangle$ ~ 800 MeV.
- Projected to take **10-18 X 10^{20} POT** of data in total => large statistics on Argon.
- Close to the target + slightly off-axis => SBND can sample **off-axis fluxes** (hear more about this in the next talk by Lauren Yates).



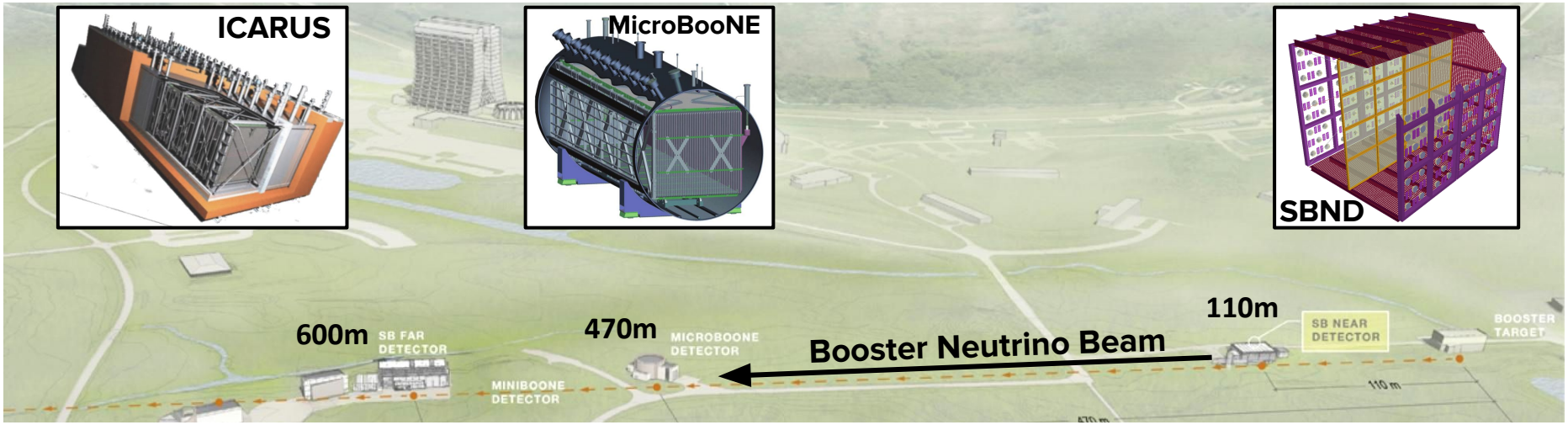


SBND Physics: Neutrino-Argon Cross Sections

See next talk, "Neutrino Interaction Measurement Capabilities of the SBND Experiment" by Dr. Lauren Yates

SBND Physics: Neutrino Oscillations

arXiv:1503.01520v1



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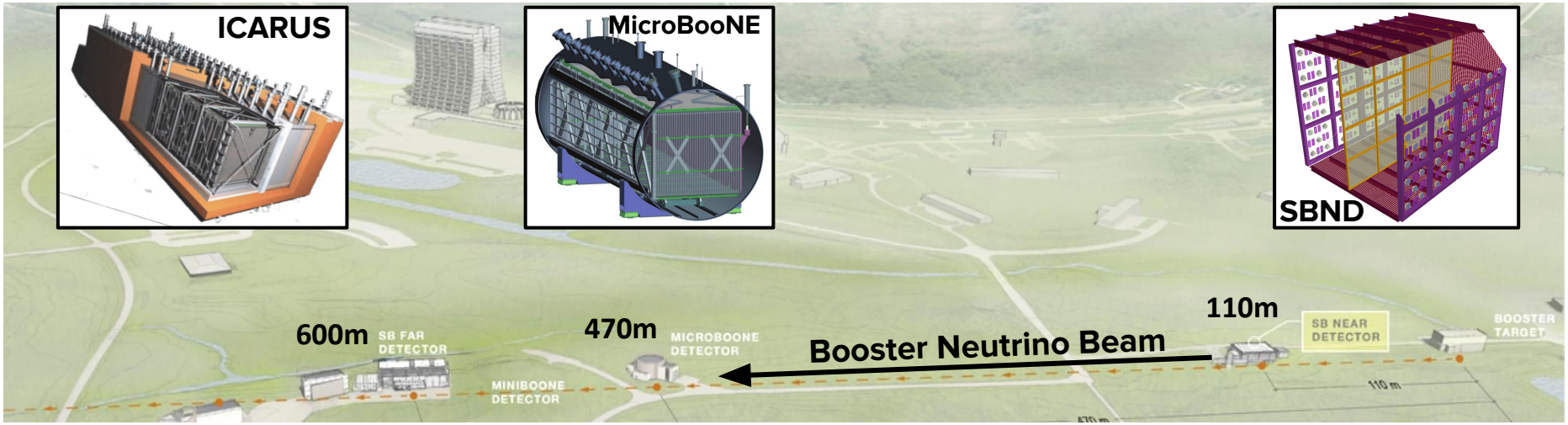
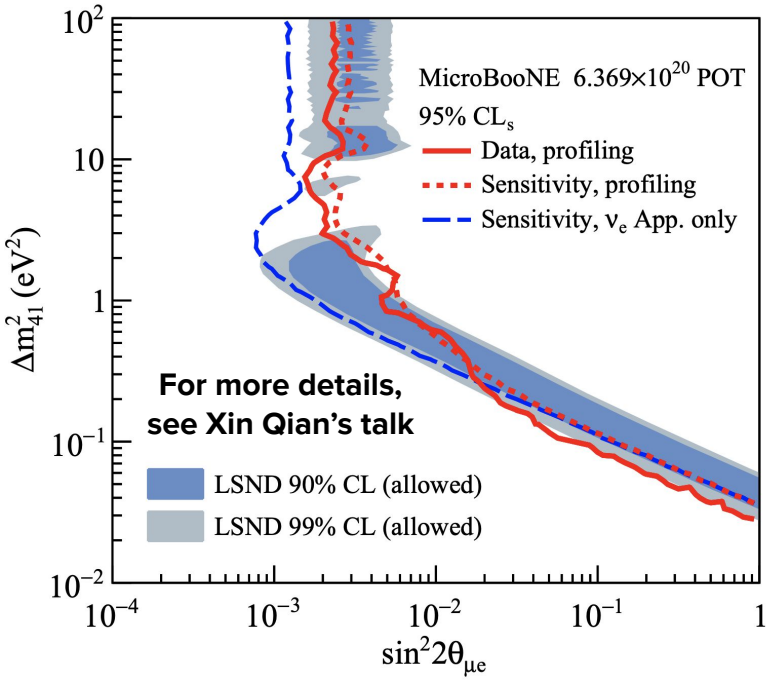


MicroBooNE did not see a “low-energy excess” of electromagnetic events as observed by MiniBooNE, which could have been evidence of sterile neutrino oscillations.

But this does not fully rule out sterile neutrinos.

The MicroBooNE Collaboration, arXiv:2210.10216v2



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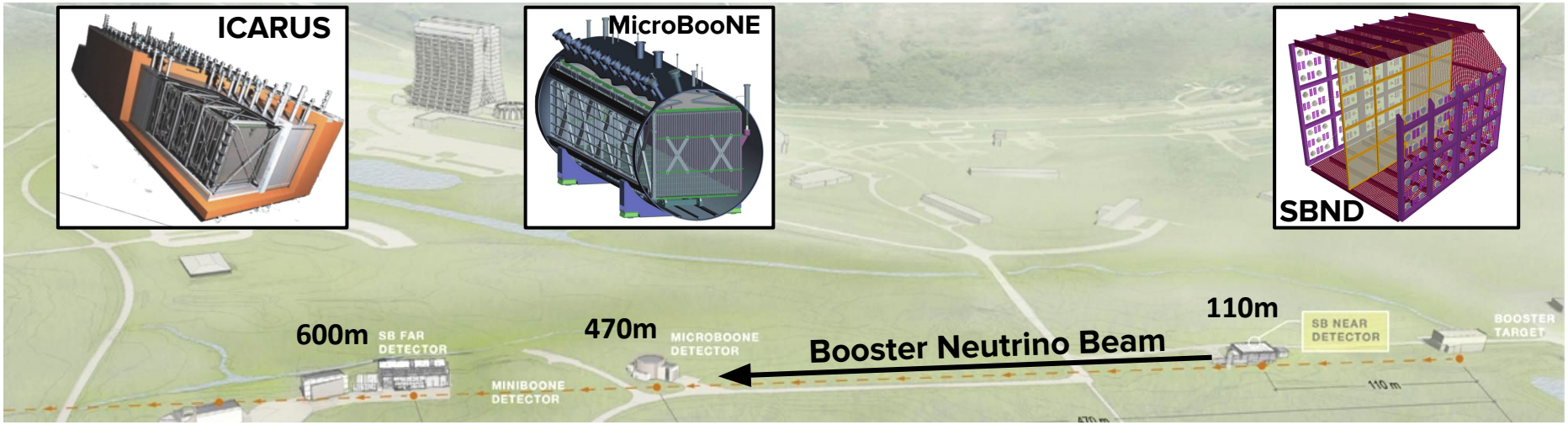

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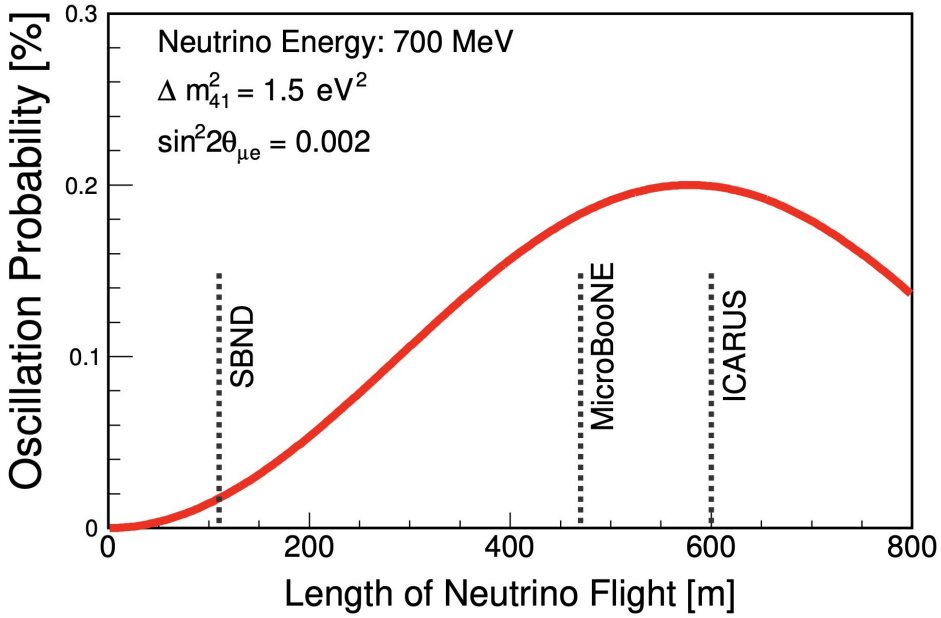
SBN Program:

- **Near Detector (SBND) with large statistics to constrain systematics**.
- Far Detector (ICARUS) with large mass for increased exposure.
- Substantially improve the global dataset regarding sterile neutrinos.

arXiv:1903.04608v1



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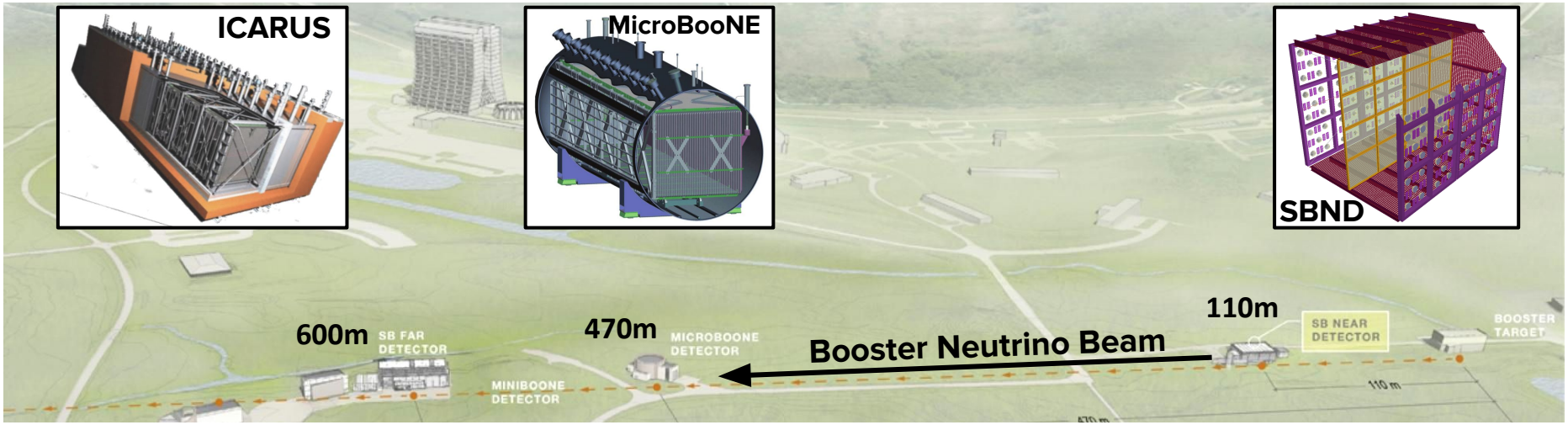
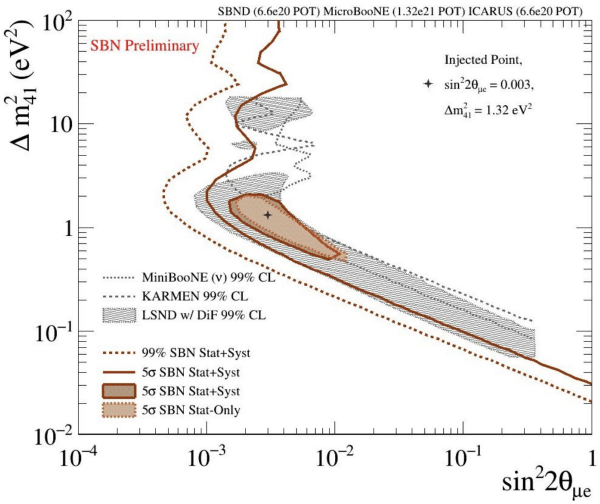
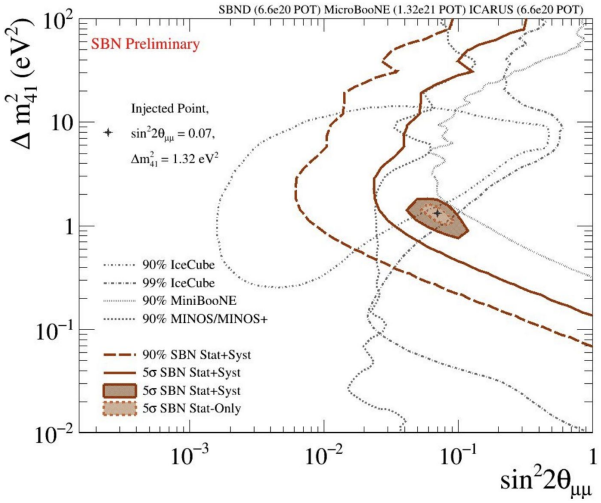


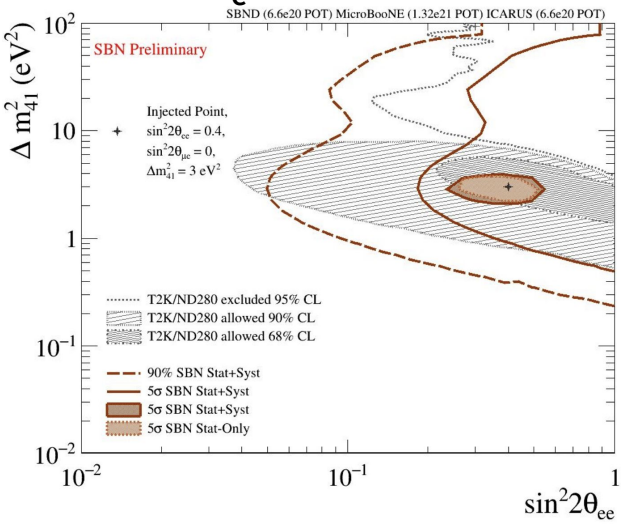
ν_e appearance



ν_μ disappearance



ν_e disappearance



The SBN program will probe all three sterile neutrino oscillation channels: ν_e appearance, ν_μ disappearance, and ν_e disappearance. Expect **5σ sensitivity**.

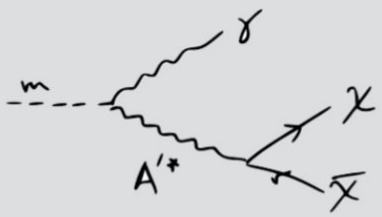
External data: IceCube ν_μ (2020), MINOS ν_μ (2017), T2K ν_e (2014), MiniBooNE ν_e (2013) & ν_μ (2011), KARMEN ν_e (2002), LSND ν_e (2001

SBND Physics: BSM New Physics

- **High-intensity** proton beam
- **Large-mass** LArTPC
- **3 mm resolution** 3D event reconstruction
- Excellent particle identification with **low thresholds**

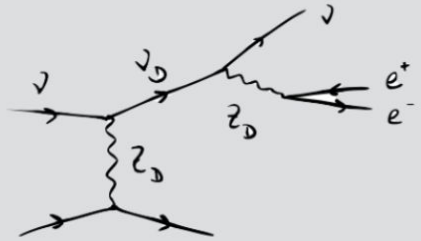
=> SBND can search for a variety of BSM phenomena.

Light Dark Matter



Romeri Kelley Machado PRD 2019

Dark Neutrinos

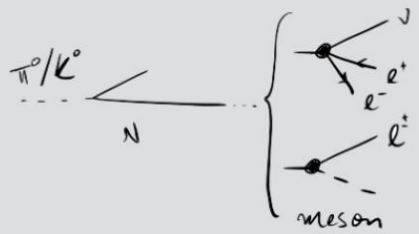


Bertuzzo Jana Machado Zukanovich PRL 2018, PLB 2019
Arguelles Hostert Tsai PRL 2019
Ballett Pascoli Ross-Lonergan PRD 2019
Ballett Hostert Pascoli PRD 2020

Millicharged Particles

Magill, Plestid, Pospelov, Tsai, PRL 2019
Harnik Liu Palamara, JHEP 2019

Heavy Neutral Leptons

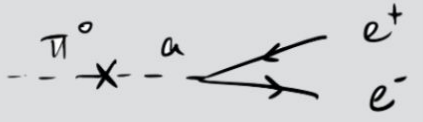


Ballett Pascoli Ross-Lonergan JHEP 2017
Kelly Machado PRD 2021

Higgs Portal Scalar

Pat Wilczek 2006
Batell Berger Ismail PRD 2019
MicroBooNE 2021

Axion-like Particles



Kelly Kumar Liu PRD 2021
Brdar et al PRL 2021

Image credits: Pedro Machado, Marco Del Tutto

SBND Physics: BSM New Physics

We introduce the model into our simulation & run reconstruction.

- **High-intensity** proton beam
- **Large-mass** LArTPC
- **3 mm resolution** 3D event reconstruction
- Excellent particle identification with **low thresholds**

=> SBND can search for a variety of BSM phenomena.

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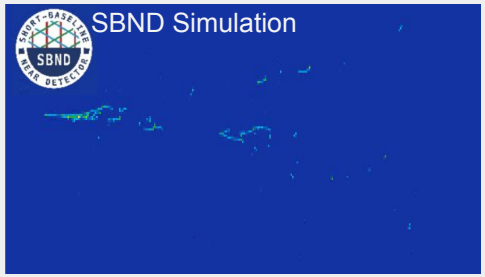
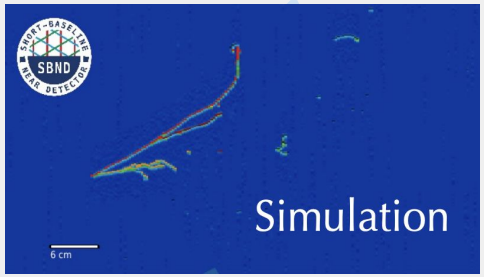


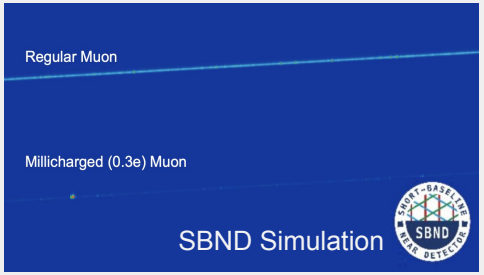
single e^- scattering or e^+e^- pair with no hadronic activity

Dark Neutrinos



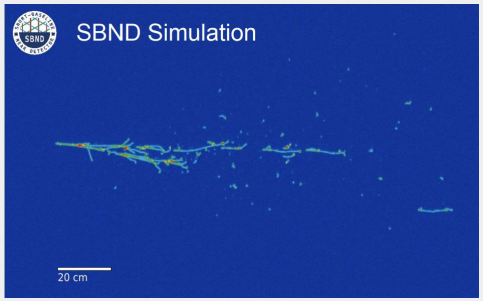
e^+e^- pair with or without hadronic activity

Millicharged Particles



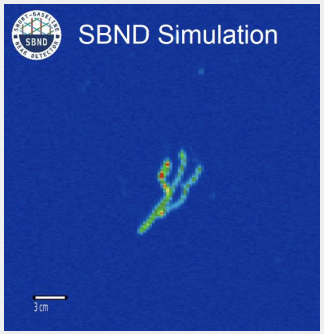
blips or faint tracks

Heavy Neutral Leptons



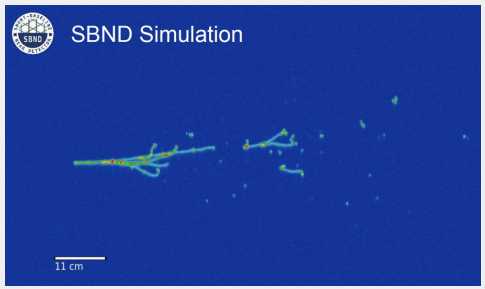
e^+e^-, $\mu^+\mu^-$, or $\mu^\pm\pi^\mp$ pair with no hadronic activity

Higgs Portal Scalar



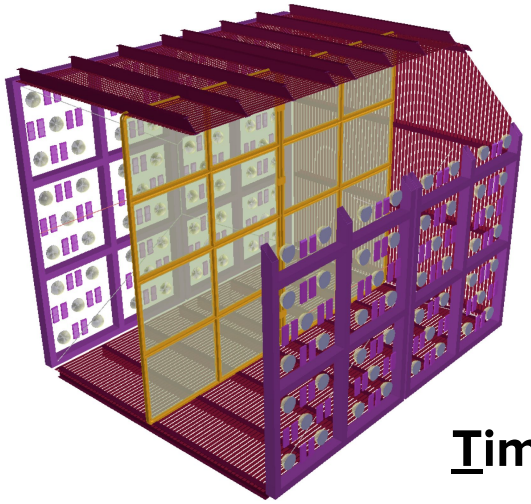
e^+e^- or $\mu^+\mu^-$ pair with no hadronic activity

Axion-Like Particles

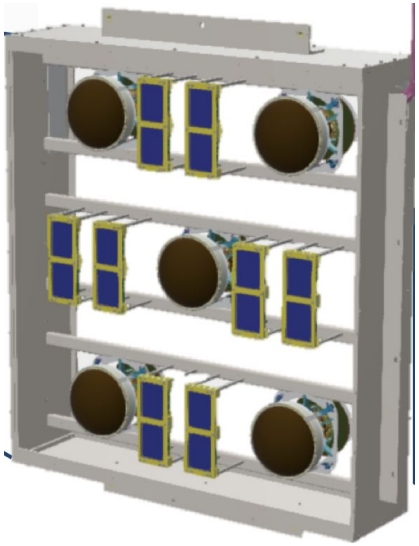


high-energy e^+e^- or $\mu^+\mu^-$ pair

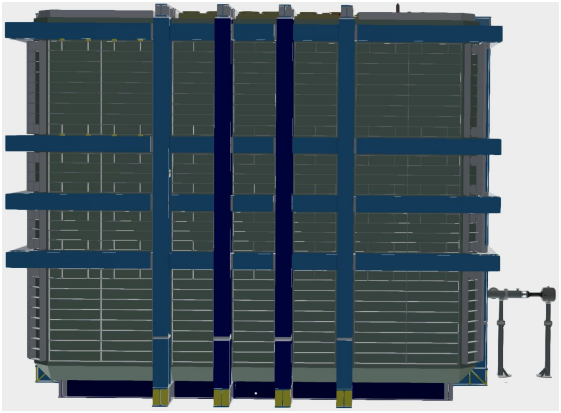
SBND: The Detector Subsystems



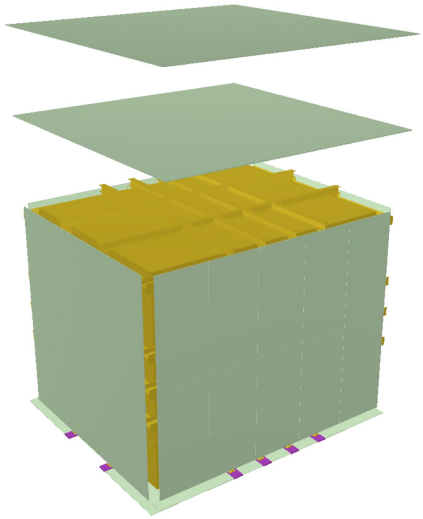
Time Projection Chamber



Photon Detection System

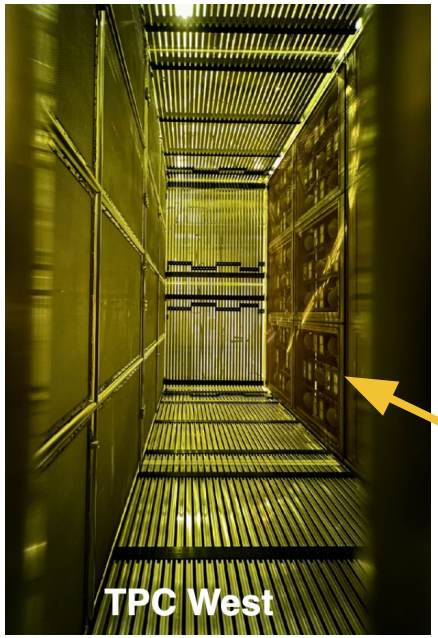


Cryostat

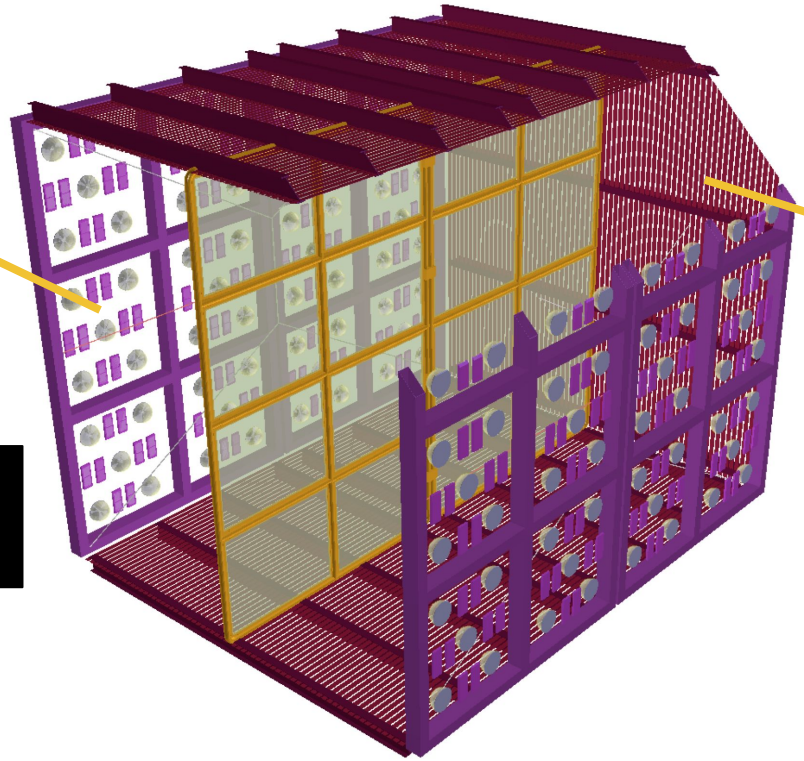


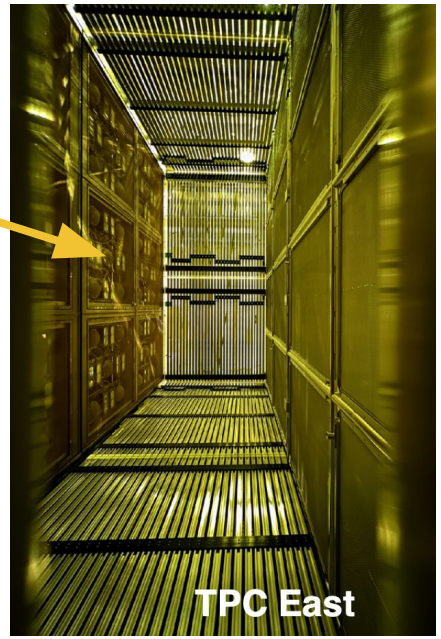
Cosmic Ray Tagger

SBND TPC

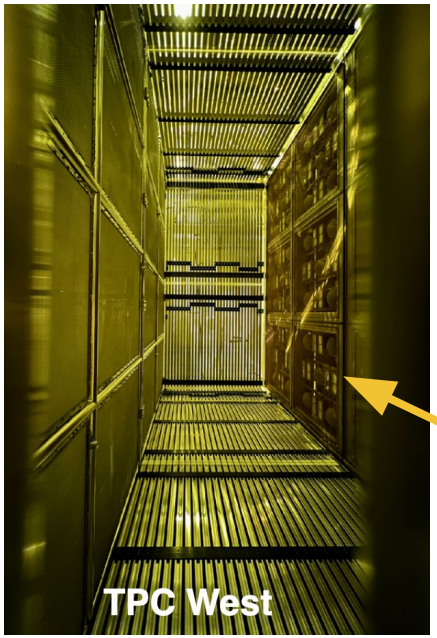


2 Time Projection Chambers
[total 4 X 4 X 5 m]





SBND TPC



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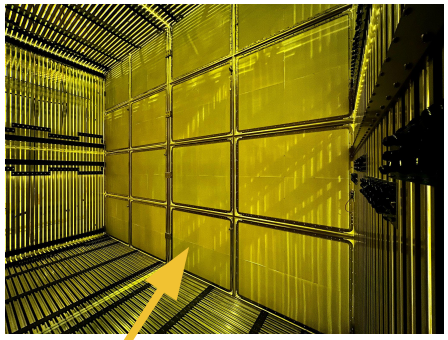
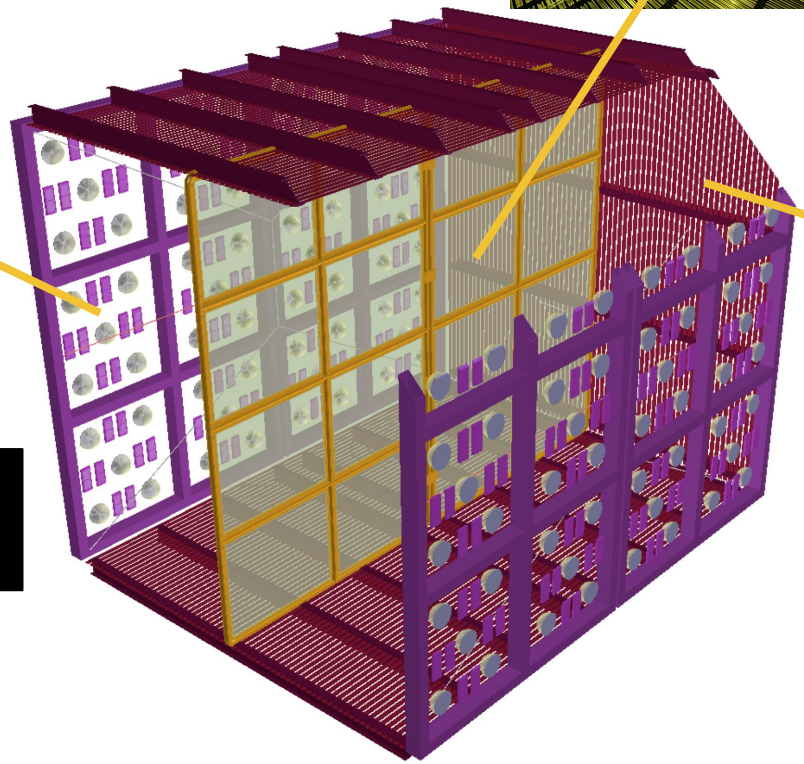
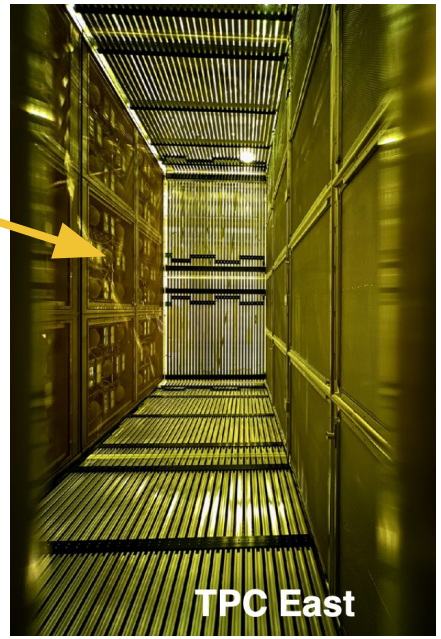


Cathode Plane
in the middle;
divides the detector
into 2 TPCs. Will be
supplied with
-100 kV.





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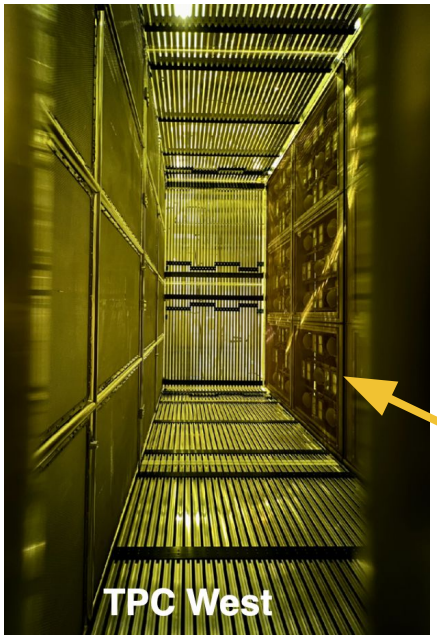

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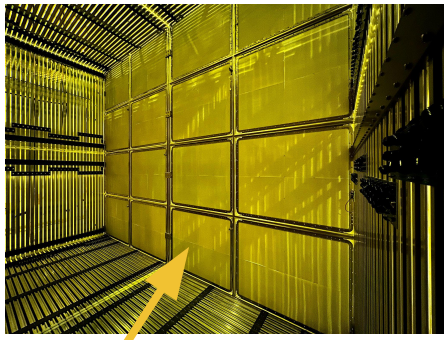

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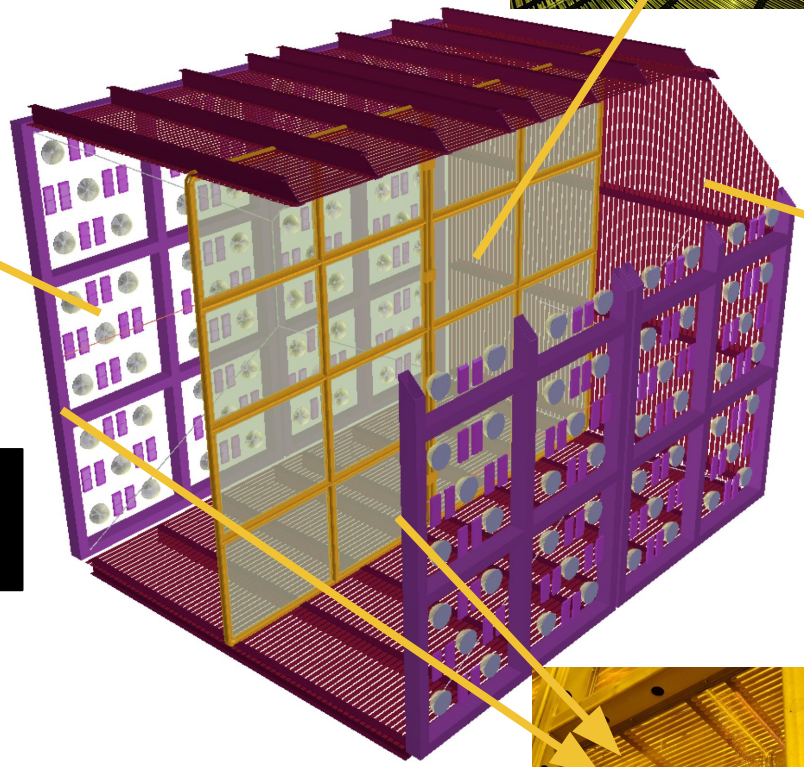
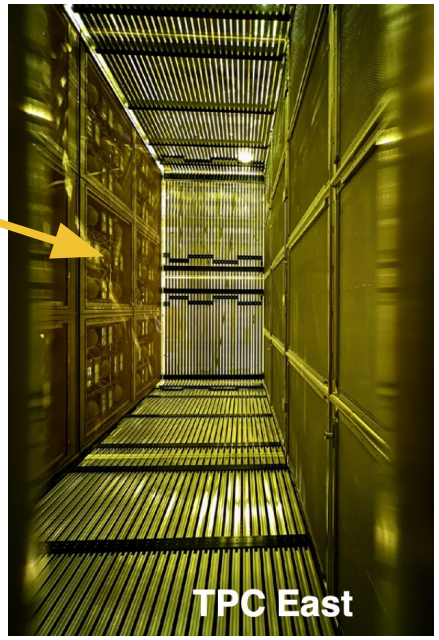
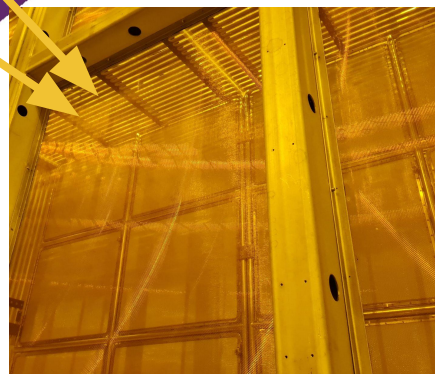
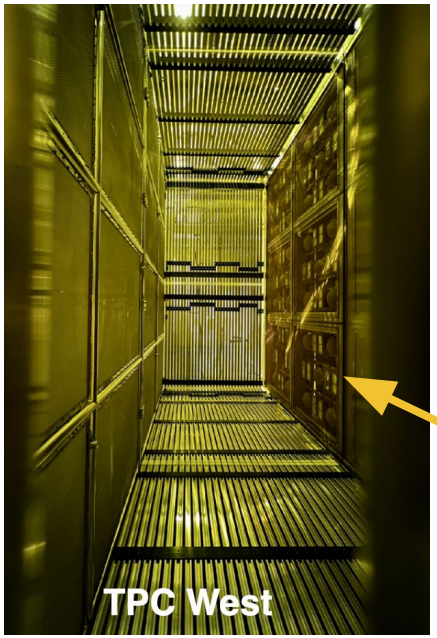


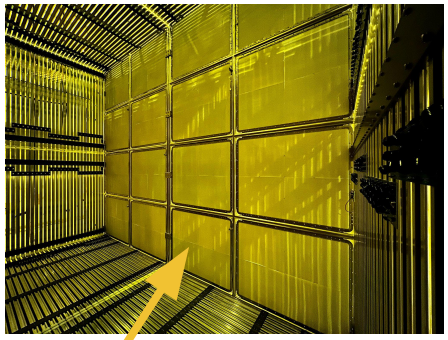




Anode Plane
on either side. Each consists of 3 planes of wires with 3 mm spacing and different angle per plane.

SBND TPC





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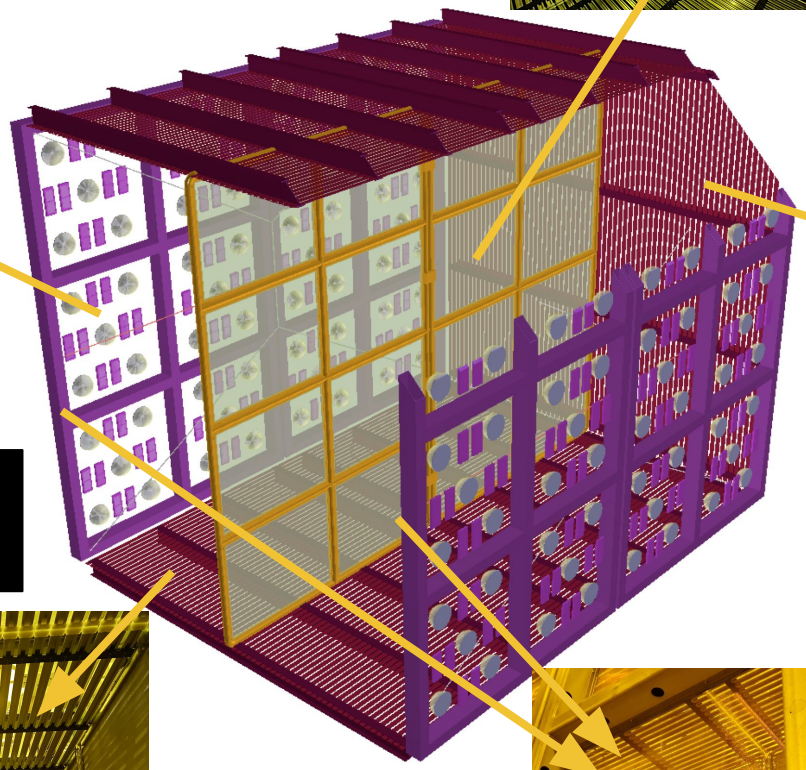
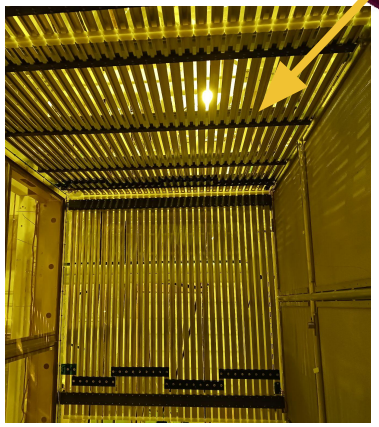
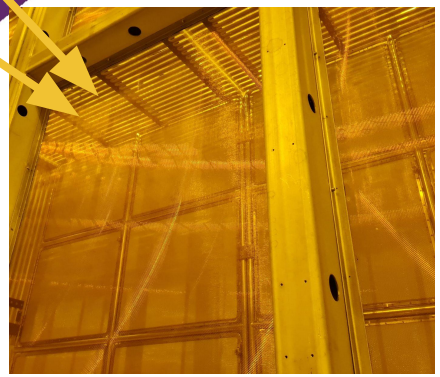


2 Time Projection Chambers
[total 4 X 4 X 5 m]

Field Cage
that wraps around the 2 LArTPCs to step down the voltage & ensure uniform electric field of 500 V/cm.





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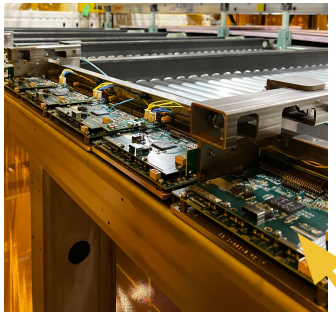
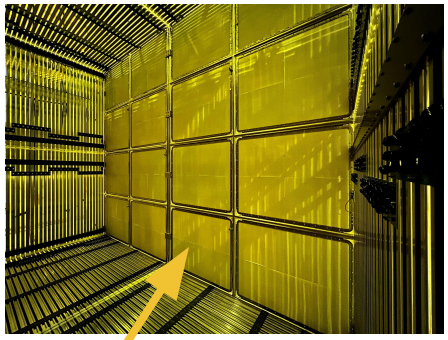
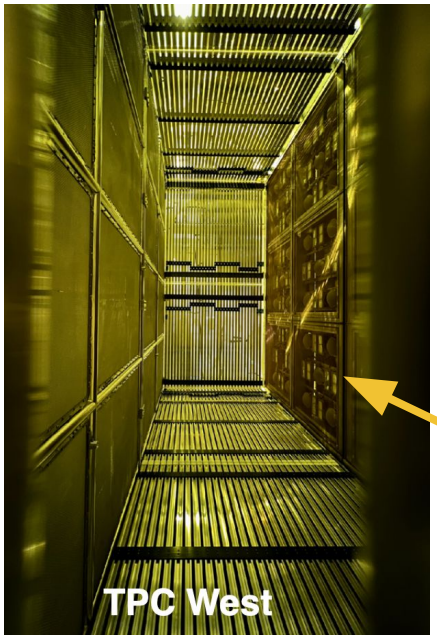
SBND TPC

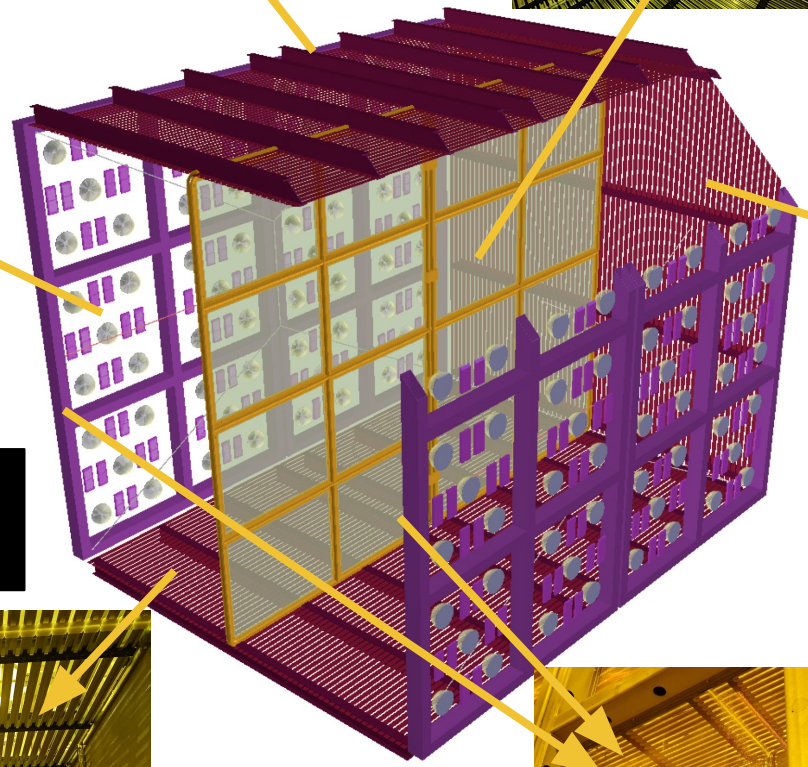


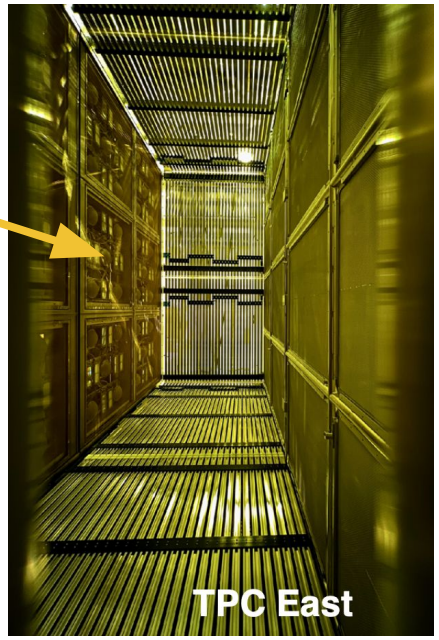
Cold Electronics to pre-amplify & digitize signals in the cold



Cathode Plane in the middle; divides the detector into 2 TPCs. Will be supplied with -100 kV.

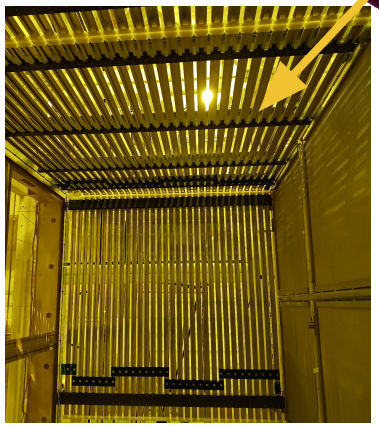


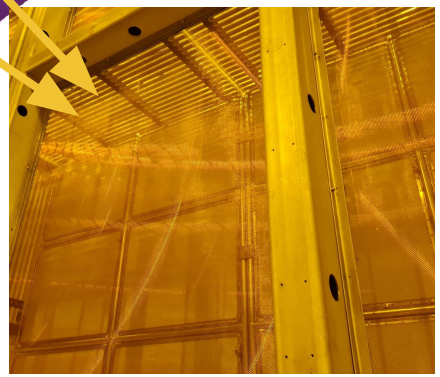




2 Time Projection Chambers
[total 4 X 4 X 5 m]

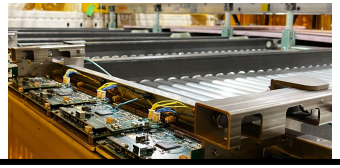
Field Cage that wraps around the 2 LArTPCs to step down the voltage & ensure uniform electric field of 500 V/cm.



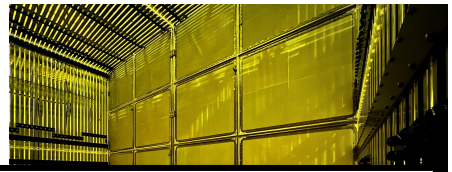


Anode Plane on either side. Each consists of 3 planes of wires with 3 mm spacing and different angle per plane.

SBND TPC



Cold Electronics to pre-amplify &



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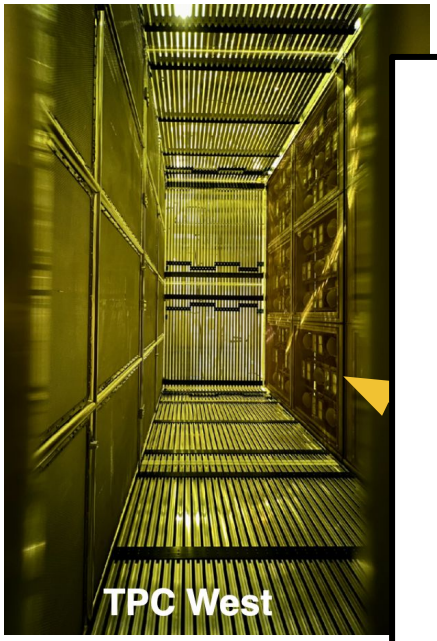


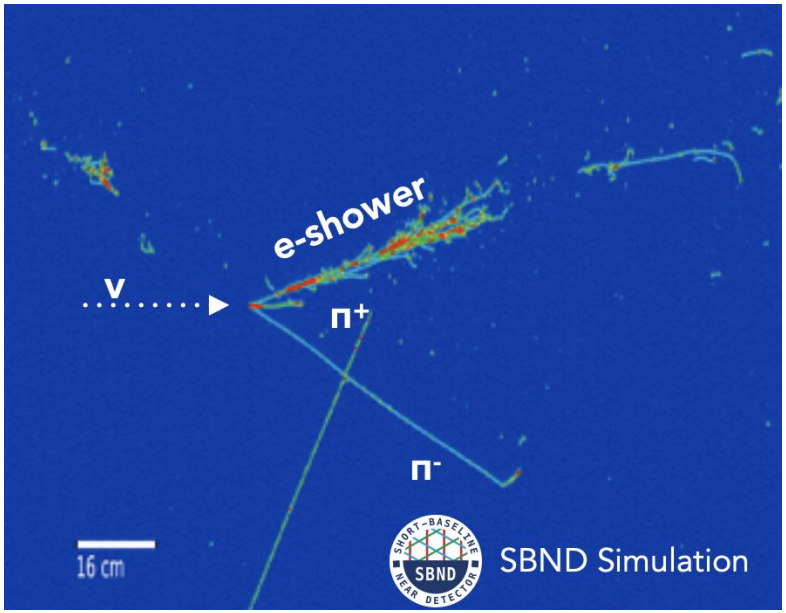
2 Time Projection C
[total 4 X 4 X 5

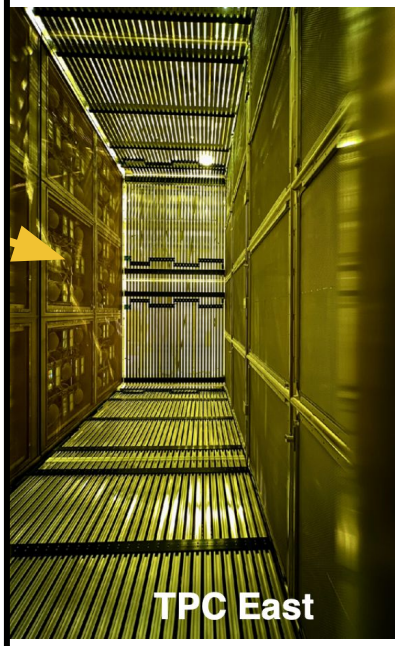
3D event reconstruction.

3 mm position resolution.

Low momentum thresholds.

Particle ID: e/**γ** separation
μ, **π**, p,etc identification.





Field Cage that wraps around the 2 LArTPCs to step down the voltage & ensure uniform electric field of 500 V/cm.

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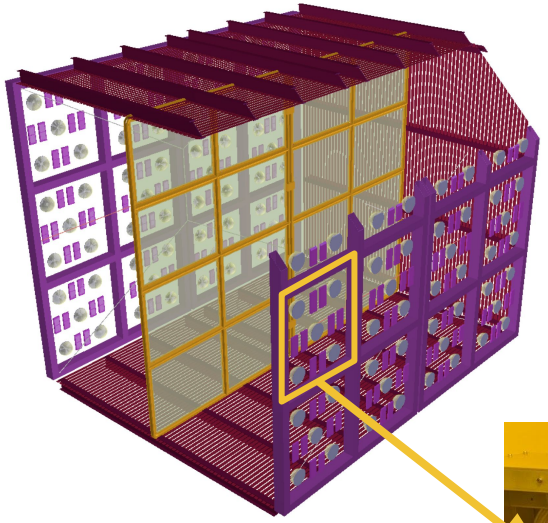
SBND Photon Detection System

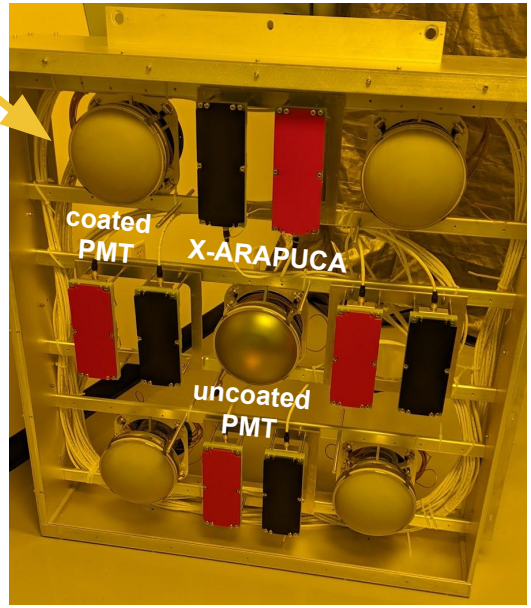


24 Anode Plane boxes

4x24 = 96 **PMTs**
(TPB coated)
1X24 = 24 **PMTs**
(uncoated)

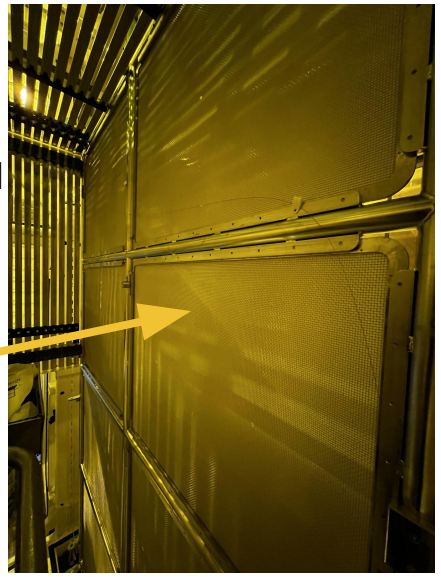
8x24 = 192
X-ARAPUCAs*

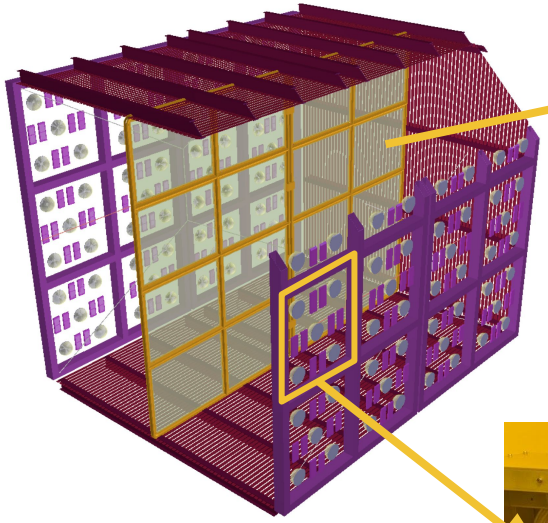
*sensitive to UV
+ visible light



SBND Photon Detection System

Cathode Plane
with TPB coated
reflective foils mounted
between mesh panels.





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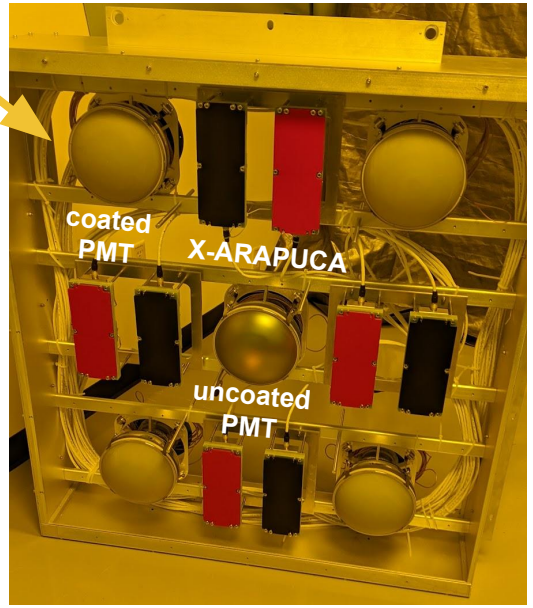
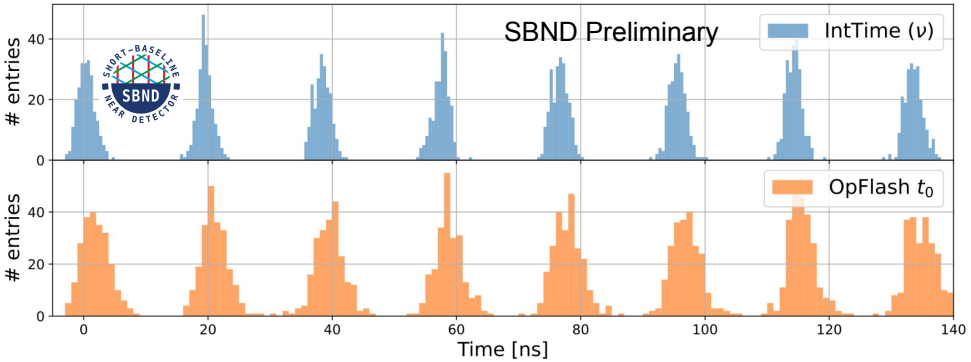


SBND Photon Detection System

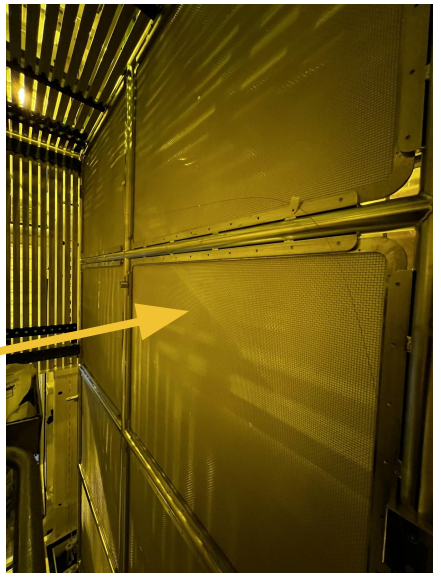
- **Primary scintillation and reflected light:** improved and more uniform total light yield.
- **Triggering :** recent improvements in timing resolution to resolve the beam structure & identify interaction time.
- **Cosmic background tagging**: based on amount of light + 3D position reconstruction.
- **Calorimetry:** light information can supplement TPC information. arXiv:2203.00740

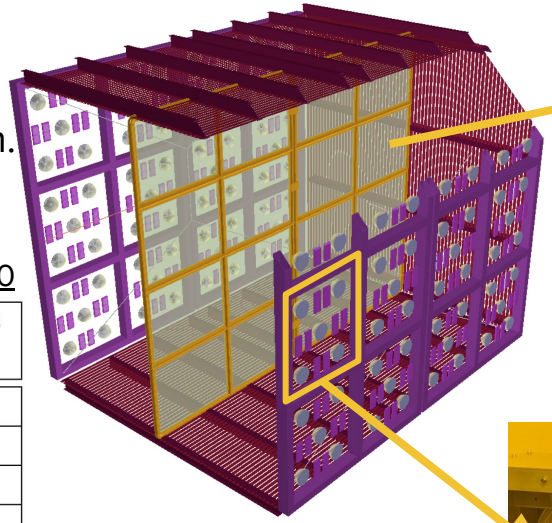
Experiment	Average light yield (PE/MeV)	Uniform light collection?
MicroBooNE	~ 5	no
LArIAT	~ 18	yes
pDUNE-SP	1.9 at 3.3m	no
SBND	~ 80 (> 50 min)	yes
DUNE: Vertical Drift	~ 38 (> 16.5 min)	yes



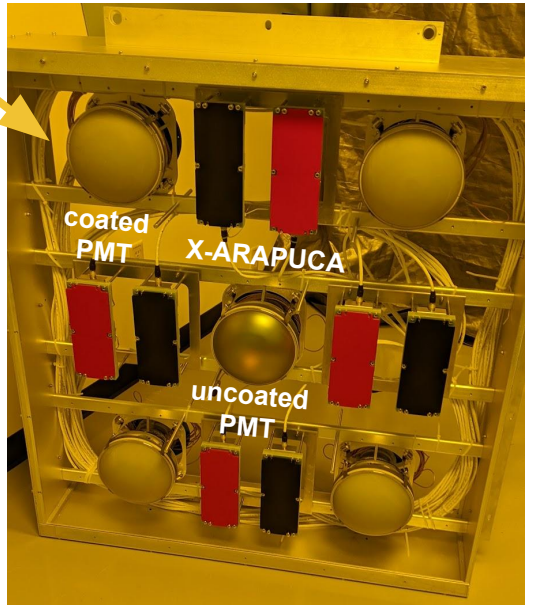
Simulated (top) and reconstructed (bottom) light flashes showing the neutrino beam structure.

Cathode Plane with TPB coated reflective foils mounted between mesh panels.





24 Anode Plane boxes



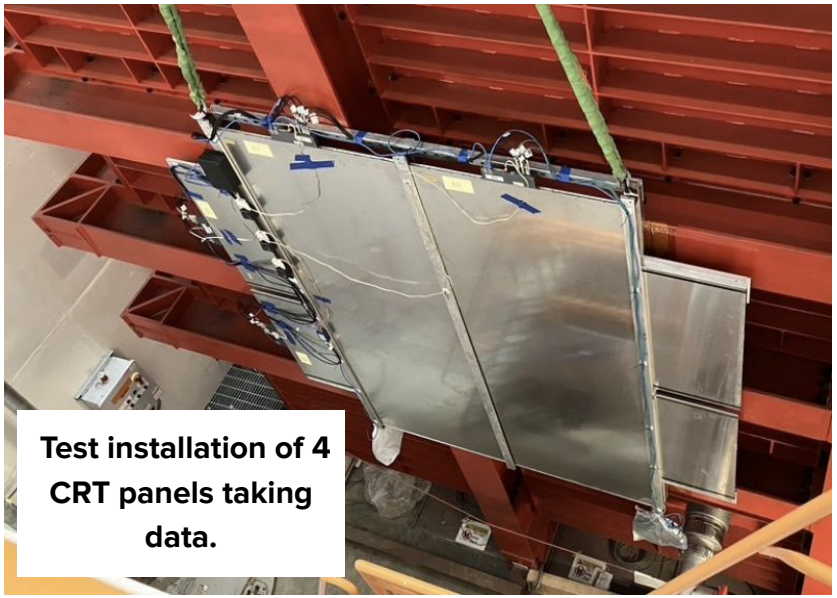
4x24 = 96 **PMTs** (TPB coated)
1X24 = 24 **PMTs** (uncoated)

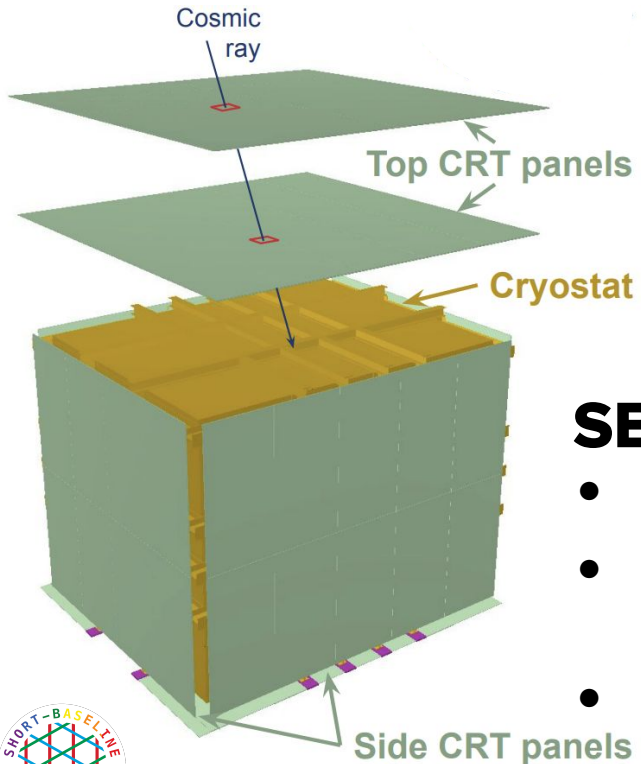
8x24 = 192 **X-ARAPUCAs***

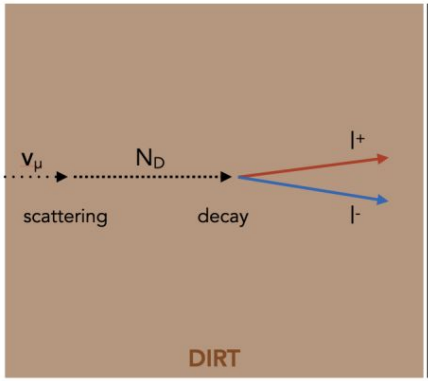
*sensitive to UV + visible light

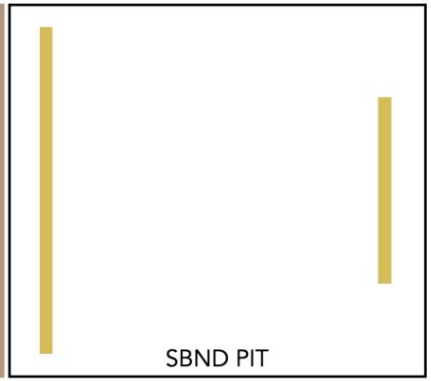
SBND Cosmic Ray Tagger

- 3-4 cosmic muons in TPC per readout window.
- **4π coverage** important for surface detectors
- Can act as a "**beam telescope**," e.g. to look for BSM new physics particles decaying in the dirt around SBND (dark neutrino analysis development underway).





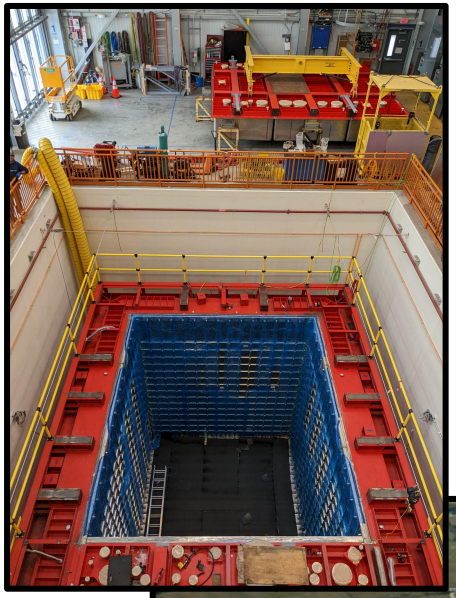


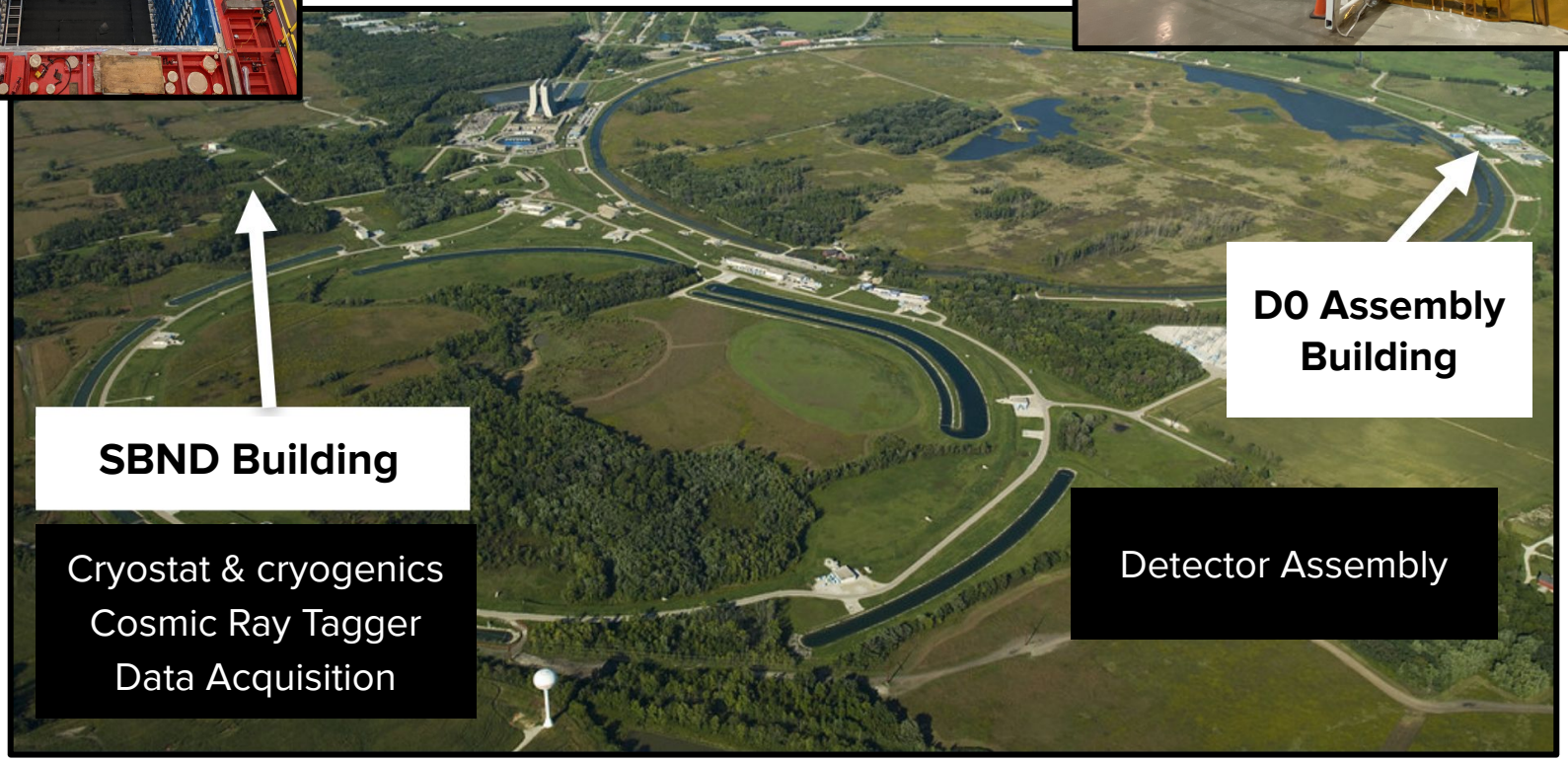


SBND Cryostat

- **Prototype for DUNE** - elements similar to DUNE.
- The detector is suspended from top caps and held inside the cryostat.
- Two top caps through which all cabling and instrumentation will be passed.

Detector Construction at Two Sites





SBND Building

Cryostat & cryogenics
Cosmic Ray Tagger
Data Acquisition

D0 Assembly Building

Detector Assembly

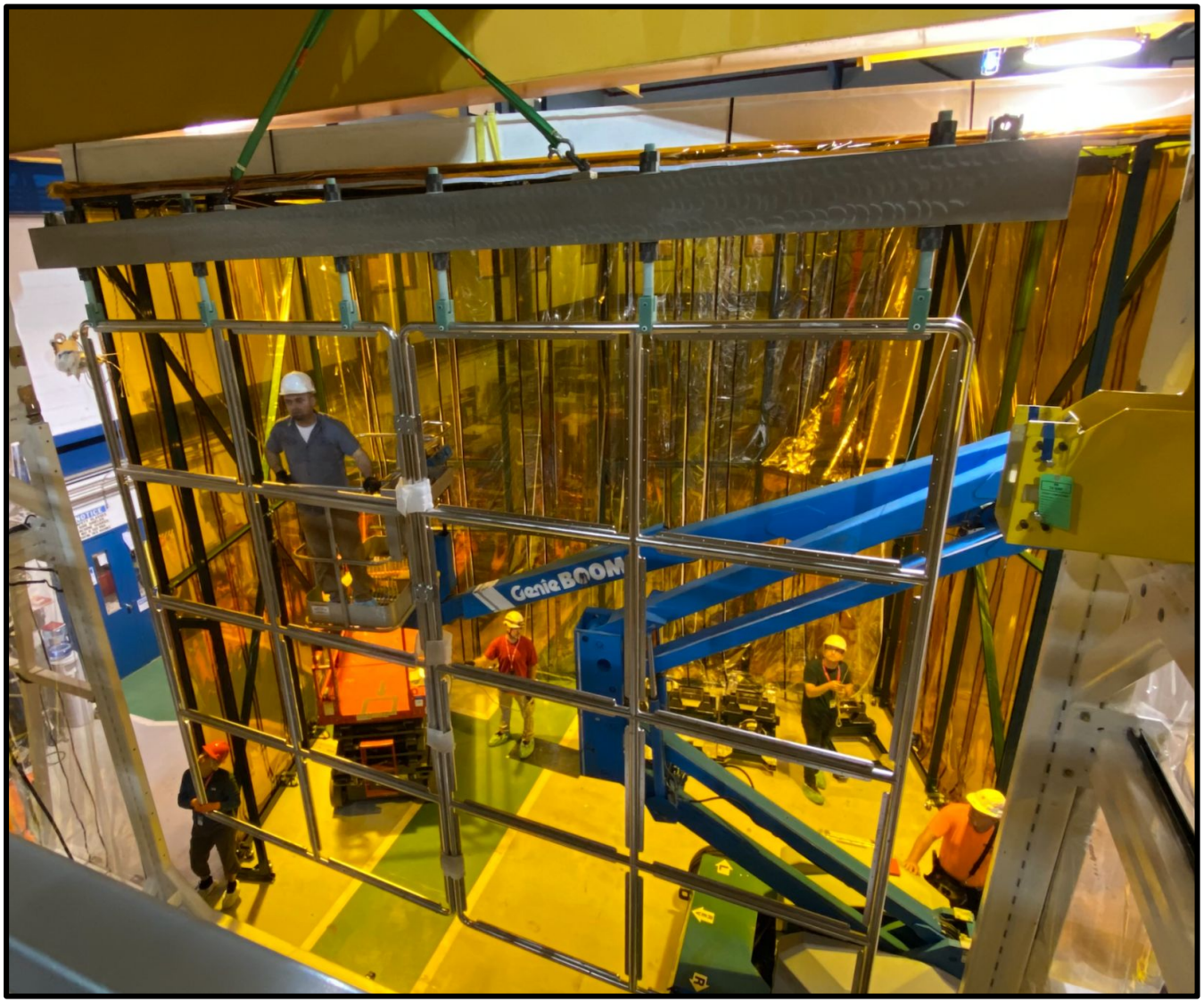
Detector Assembly

Empty Assembly Transport Frame, December 2019

Detector Assembly

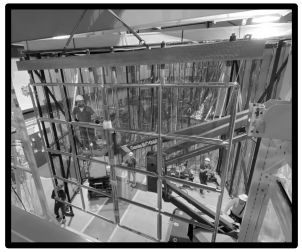
Clean tent with UV filters fully constructed,
April 2021

Detector Assembly



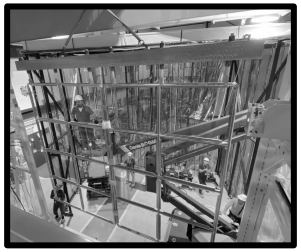
Cathode Plane structure being installed,
July 2021

Detector Assembly



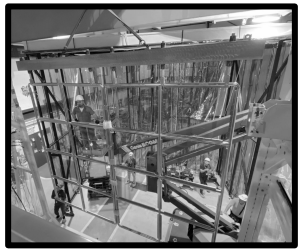
Anode Plane Assembly with wires being brought into place, October 2021

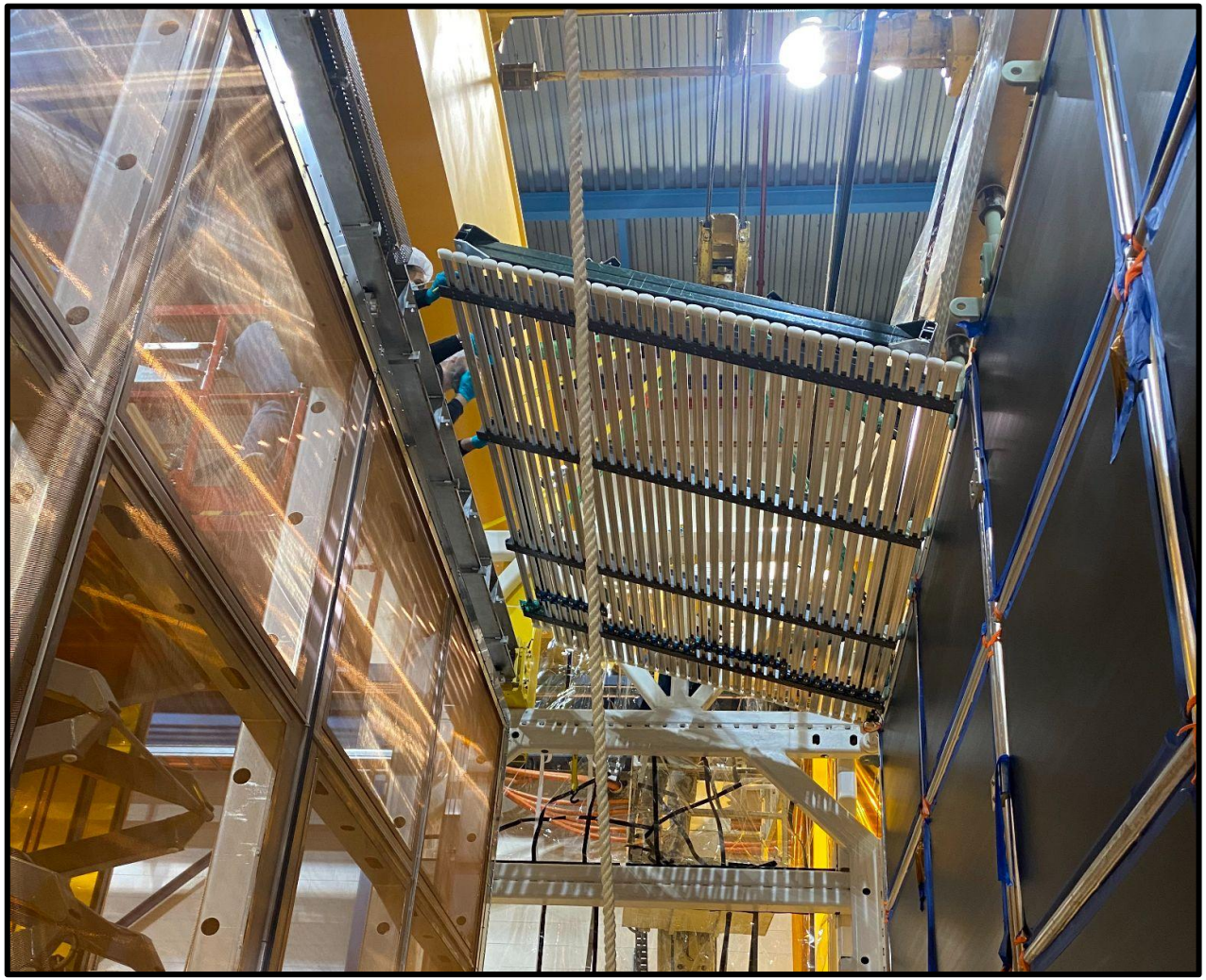
Detector Assembly



Installation of Cold Electronics,
December 2021 & May 2022

Detector Assembly

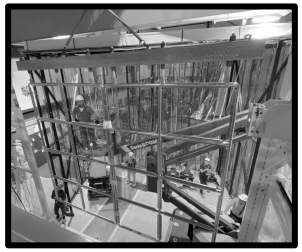


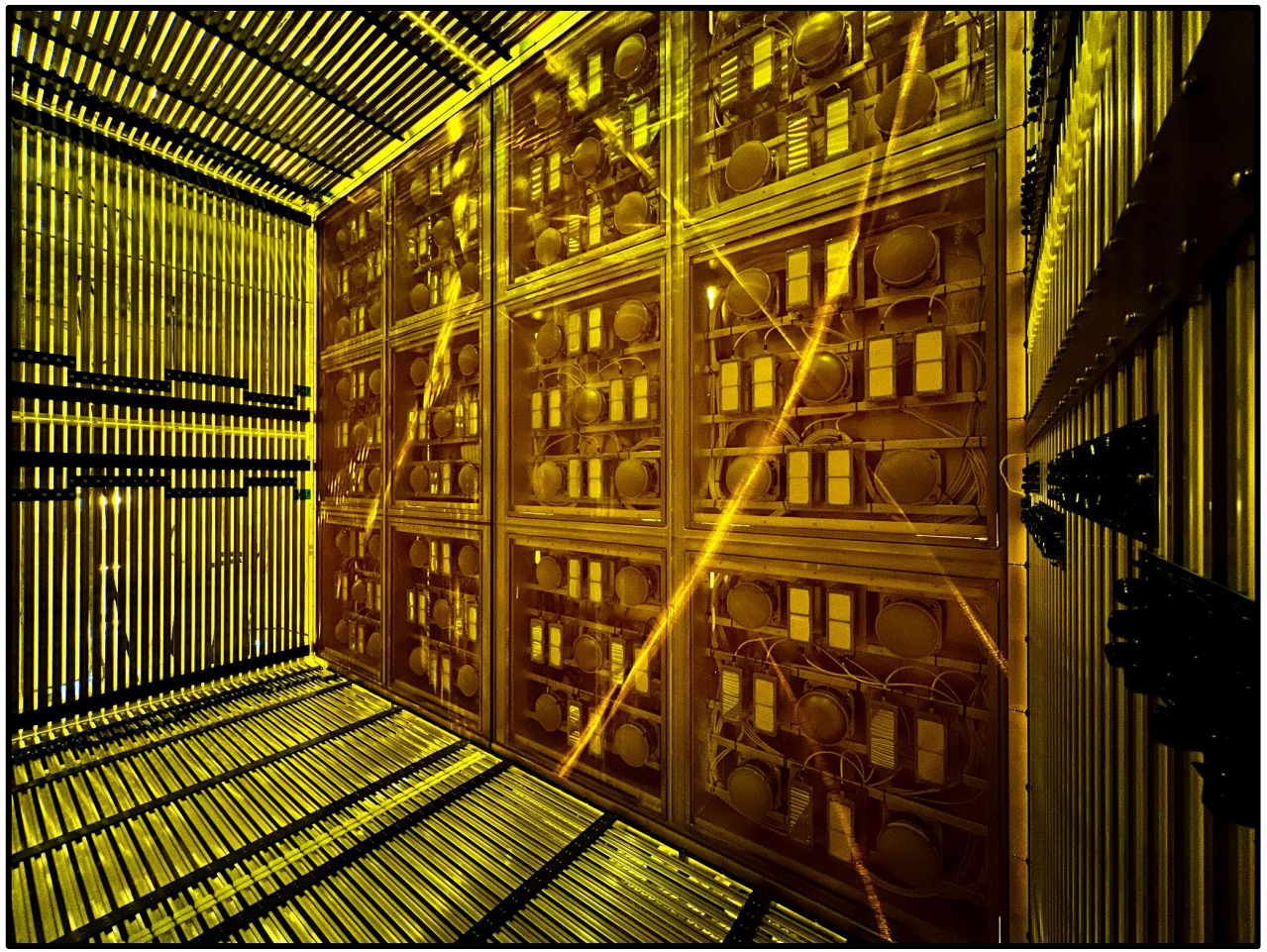


Field Cage top module being lowered,
January 2022

Detector Assembly

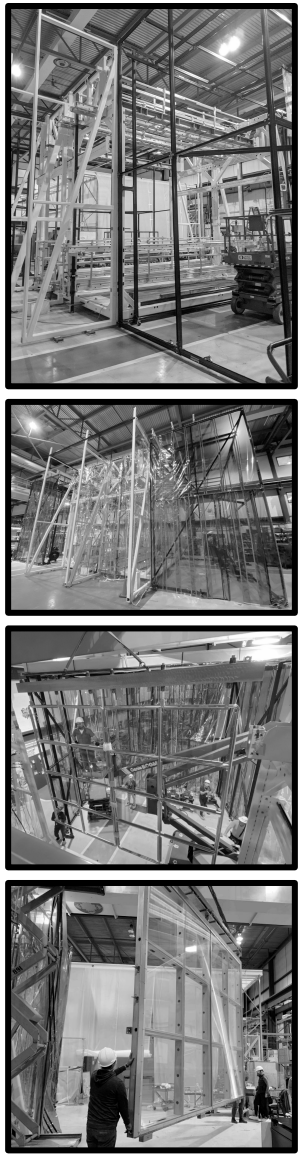




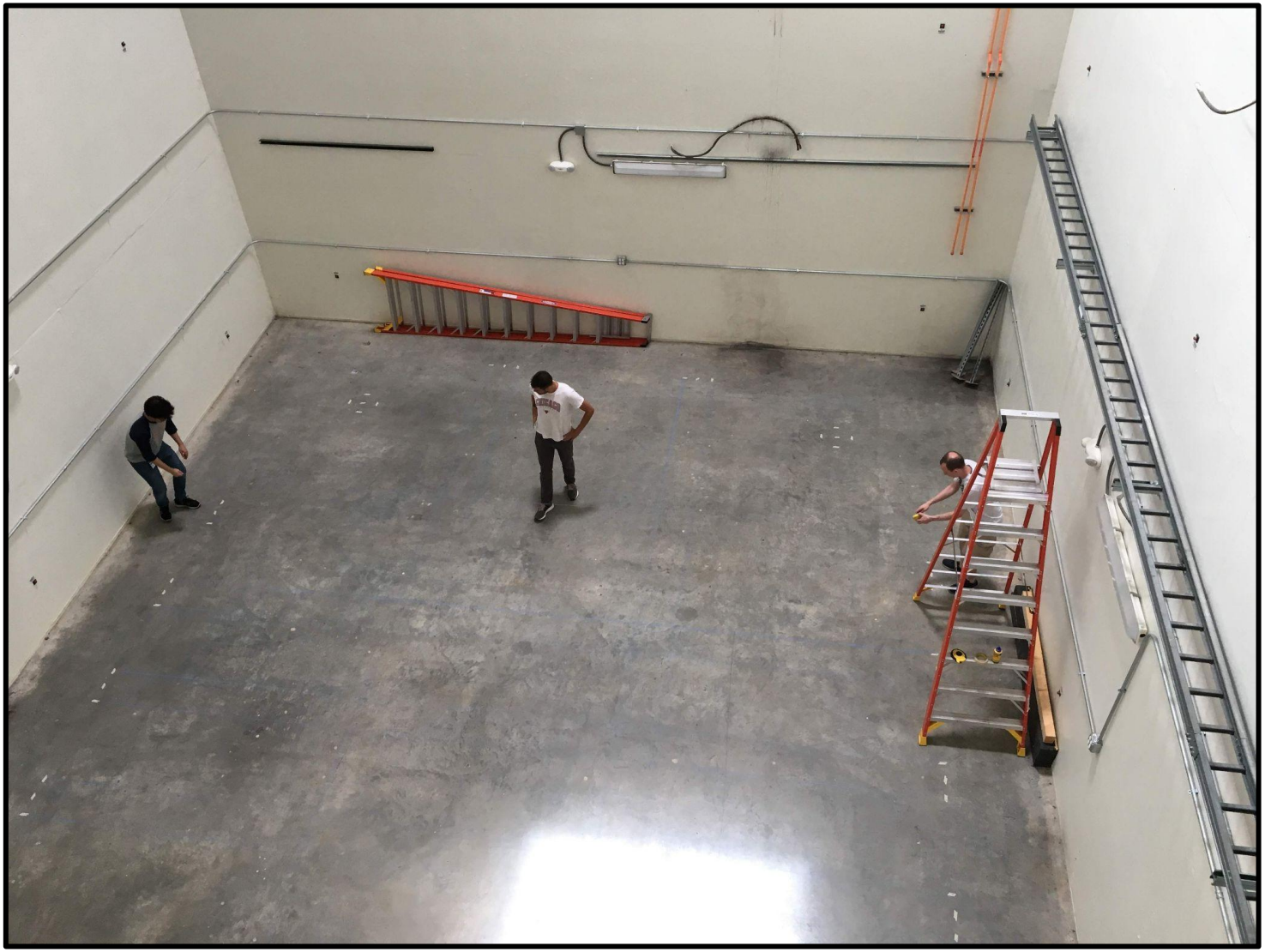
Photon Detection System boxes fully installed behind anode wire planes, September 2022

Detector Assembly



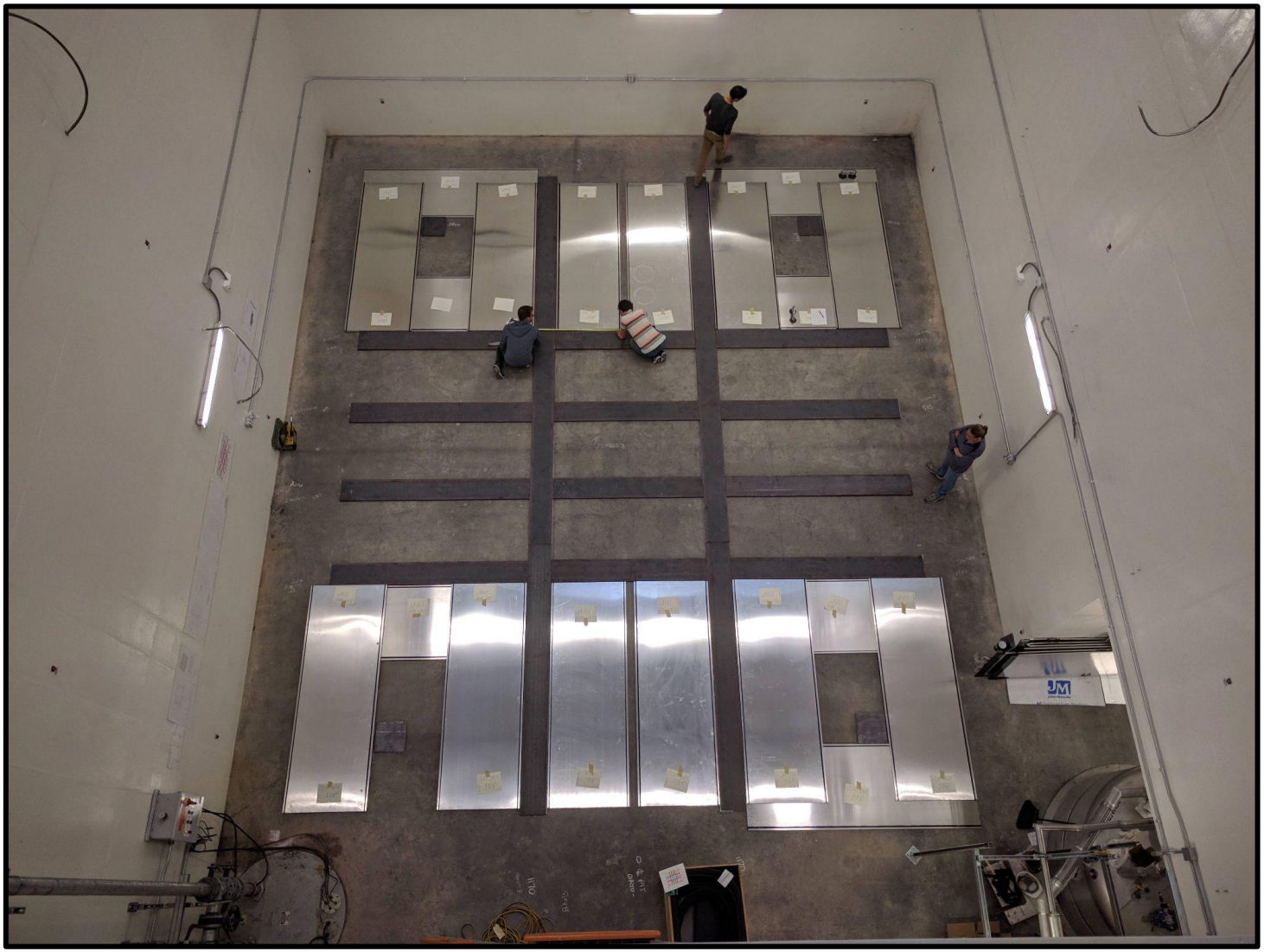
Fully completed assembly of 2 TPCS + Photon Detection System, September 2022

Cryostat + SBN-ND Building Preparation

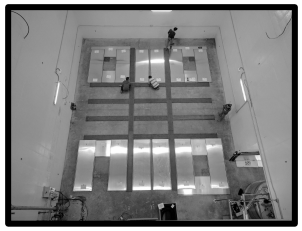


Empty pit where the future detector will go,
July 2019

Cryostat + SBN-ND Building Preparation

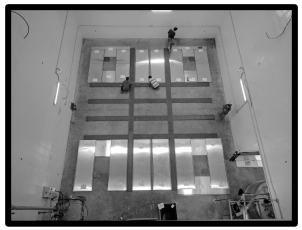


Bottom Cosmic Ray Tagger modules installed,
September 2019



Cryostat + SBN-ND Building Preparation

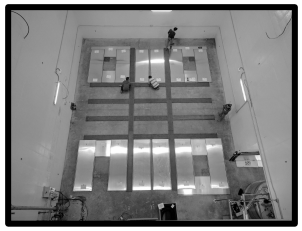
Cryostat outer shell completed, November 2019

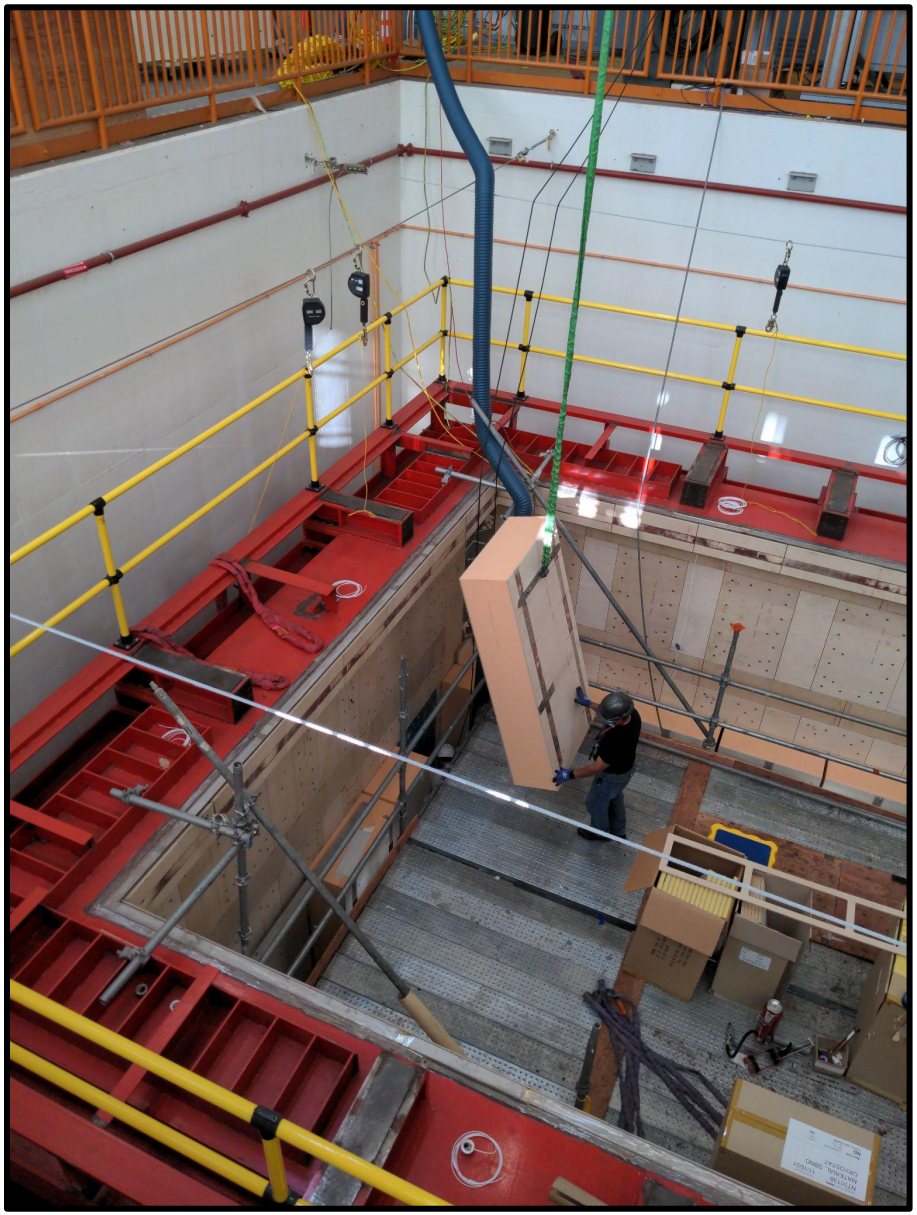


Cryostat + SBN-ND Building Preparation

Data Acquisition System electronic racks installed in the mezzanine level, February 2020

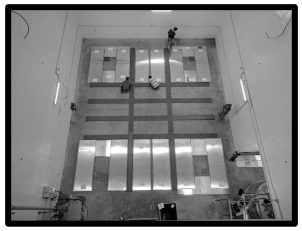
Cryostat + SBN-ND Building Preparation

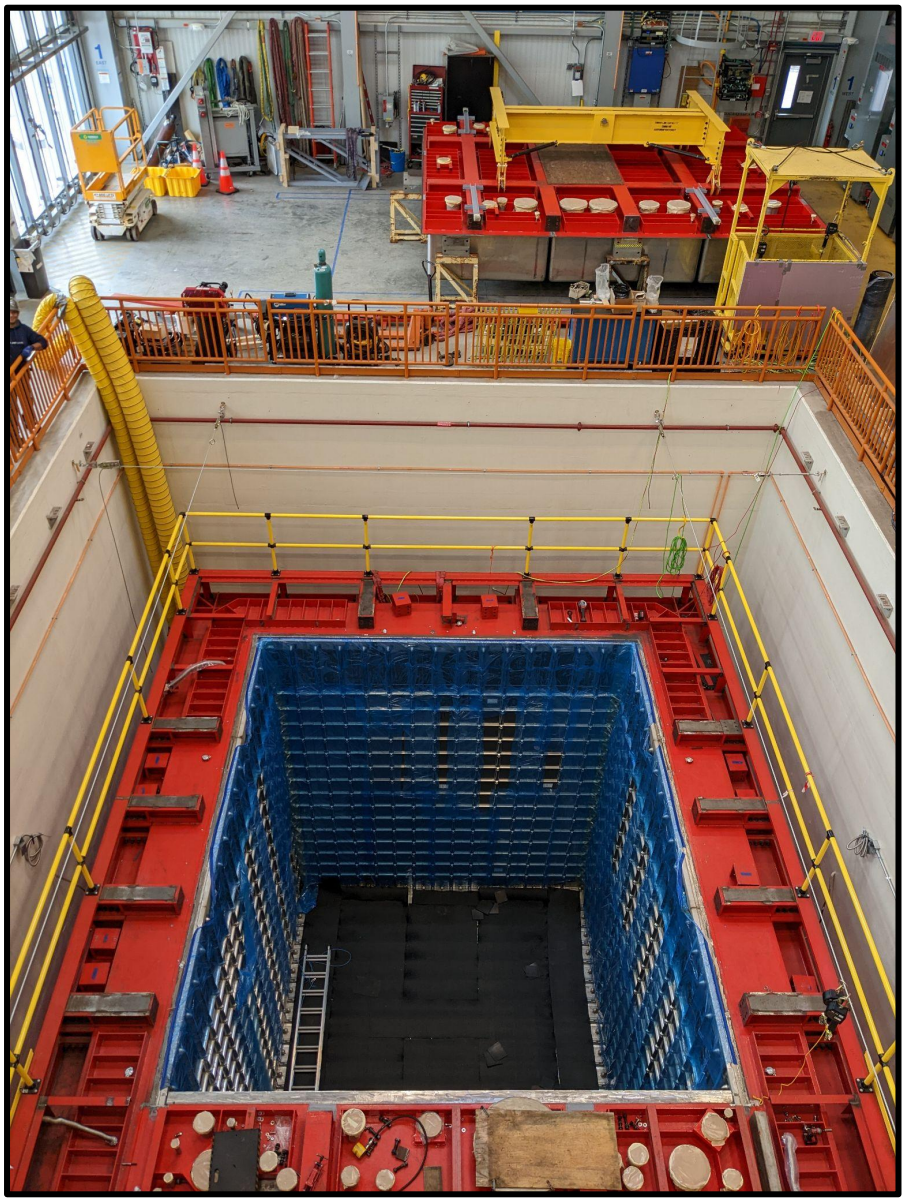




Cryostat insulation installation, July 2022

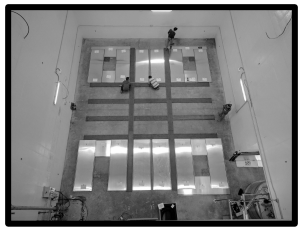
Cryostat + SBN-ND Building Preparation

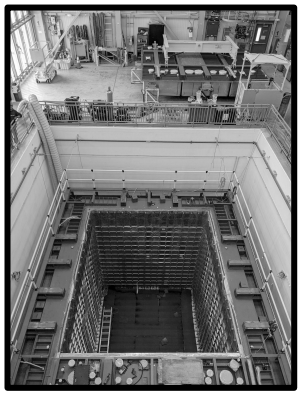



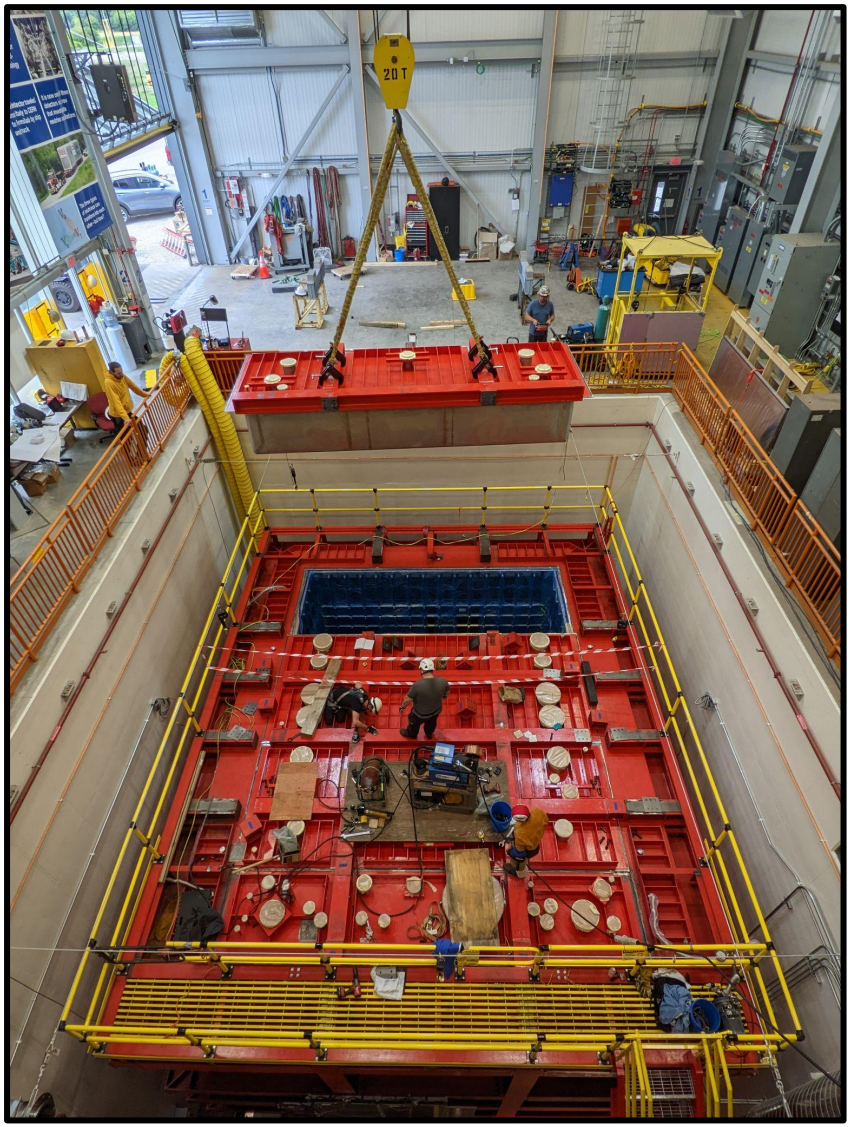



Finished cryostat, September 2022

Cryostat + SBN-ND Building Preparation







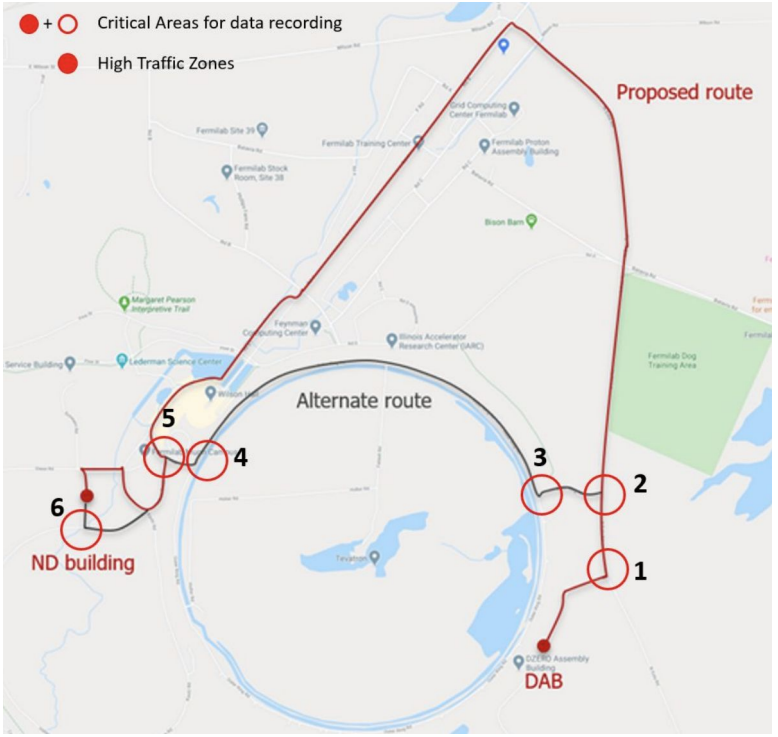
Top caps with ports for cabling & instrumentation test installation, October 2022

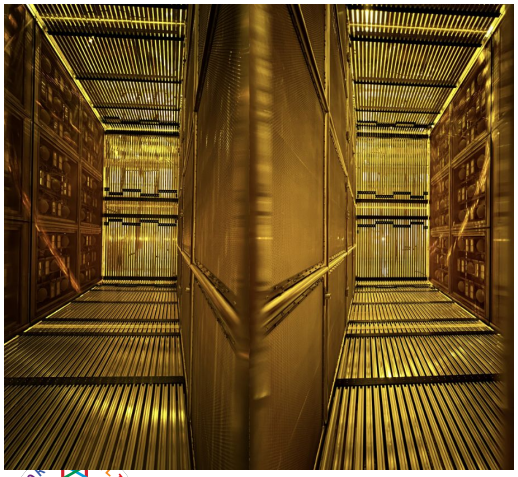
The Road to Physics

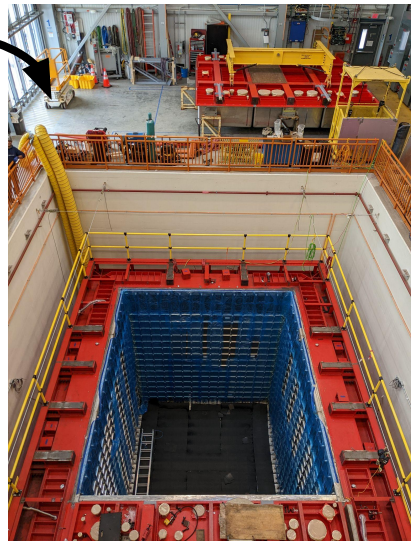
Detector move: We will move the detector in the Assembly Transport Frame from assembly site to SBN-ND Building (permanent location of SBND).
Planned for late November 2022.

Activities at SBN-ND: Quality check of all detector subsystems, installation of instrumentation, finalizing cryogenics, lowering into position inside the cryostat, etc.
December 2022-early Summer 2023.

Filling of liquid argon & cold commissioning
Summer 2023.







SBND physics is coming soon

Backup

SBND Light Collection & Triggering

X-Arapuca technology uses dichroic filters and waveguides to guide photons to SiPM