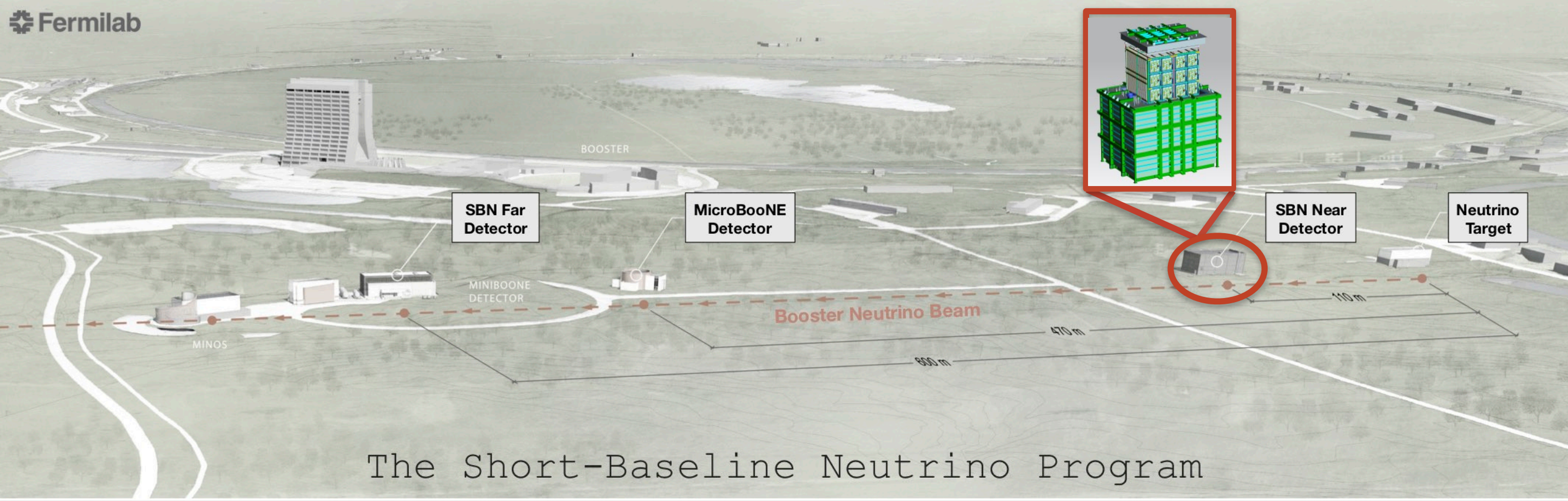

Status of the Short-Baseline Near Detector [SBND]

Fermilab PAC
November 16, 2021

David Schmitz (U. of Chicago) & Ornella Palamara (fermilab)

SBND COLLABORATION

- 265 collaborators (220 physicists) from 40 institutions in 6 countries

Argonne National Lab: C. Adams, Z. Djurcic, M. Goodman
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University of Edinburgh: L. Jiaoyang, M. Nebot, A. Szelc
Federal University of ABC – UFABC: C. Moura, L. Paulucci, L. Quintino
Federal University of Alfenas – UFAL: G. Valdiviesso
Federal University of Rio de Janeiro: C. Bonifazi
Federal University of Sao Carlos – UFSCAR: F. Marinho
Fermilab: R. Acciarri, W. Badgett, L. Bagby, S. Balasubramanian, M. Betancourt, D. Caratelli, F. Cavanna, M. Del Tutto, V. Di Benedetto, S. Dixon, J. Estrada, M. Chávez Estrada, M. Geynisman, H. Greenlee, S. M. Kancharla, B. Howard, C. James, W. Ketchum, M.J. Kim, D. Montanari, T. Nichols, B. Norris, O. Palamara*, Z. Pavlovic, F. Psihas, R. Rameika, A. Schukraft, S. Shetty, M. Stancari, A. Stefanik, T. Strauss, D. Torretta, M. Toups, P. Wilson, W. Wu, G.P. Zeller, J. Zennamo
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Harvard University: R. Guenette
Illinois Institute of Technology: W. Foreman, B. Littlejohn
Kansas State University: G. Horton-Smith
Lancaster University: A. Blake, D. Brailsford, H. Lay, J. Nowak, P.N. Ratoff
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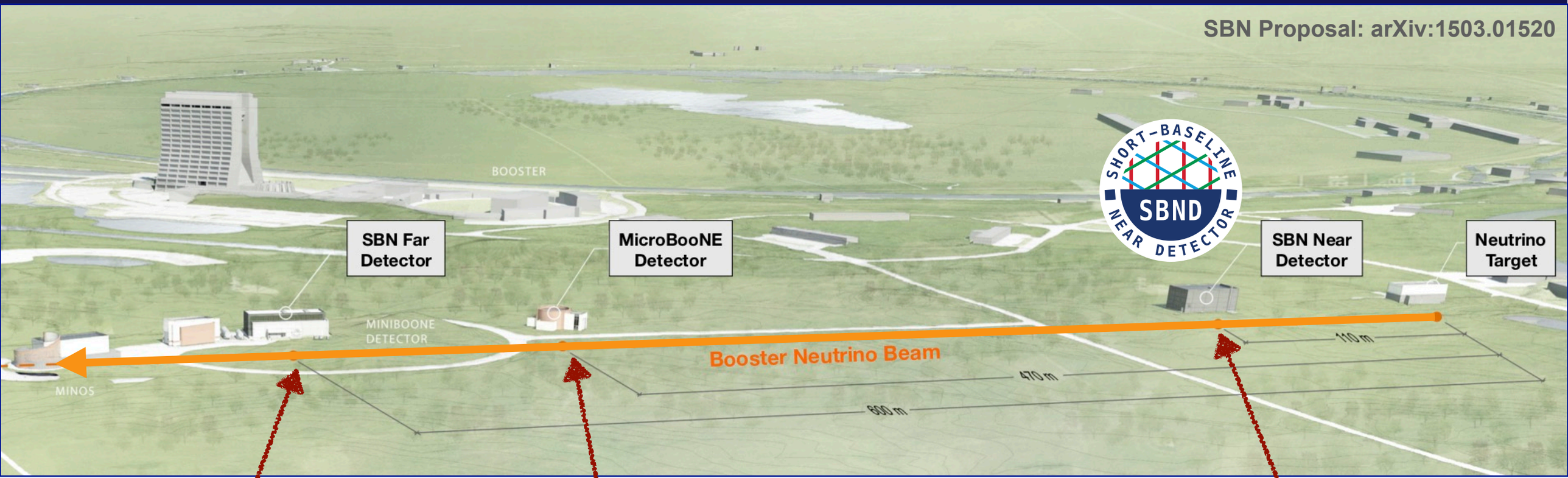
National University of Asuncion: E. Cristaldo, J. Molina
University of Pennsylvania: J. Klein, T. Kroupova, D. Rivera, R. Van Berg
Rutgers University: I. Lepetic, K. Lin, A. Mastbaum, A. Schwartz
Rutherford Appleton Laboratory: C. Andreopoulos
University of Sheffield: A. Ezeribe, T. Gamble, V.A. Kudryavtsev, L. Nguyen, A. Scarff, H. Scott, N. Spooner, E. Tyley, M. Wright, A. Zeglam
University of Sussex: G. Chisnall, R. Darby, I. de Icaza Astiz, C. Griffith
Syracuse University: O. Benevides Rodrigues, A. Bhat, K. Manivannan, M. Nunes, M. Soderberg
University of Tennessee, Knoxville: S. Gollapinni, A. Mogan, W. Tang, G. Yarbrough
University of Texas, Arlington: J. Asaadi, A. Brandt, R. Castillo, A. Chatterjee, Z. Williams, J. Yu
Tufts University: P. Abratenko, K. Mason, J. Mills, R. Sharankoca, T. Wongjirad
University College London: C. Backhouse, A. Basharina-Freshville, R. Nichol
Virginia Tech: C. Mariani
Yale University: L. Cooper-Troendle, B.T. Fleming, D. Franco, L. Hagaman, J. H. Jo, K. Li, G. Scanavini, A. White

Outline

- SBND Collaboration
- Quick overview of the experiment
- Construction status
- Schedule to completion
- POT and event estimates before Long Shutdown in 2027
- SBND physics

The SBN Program

SBN Proposal: arXiv:1503.01520

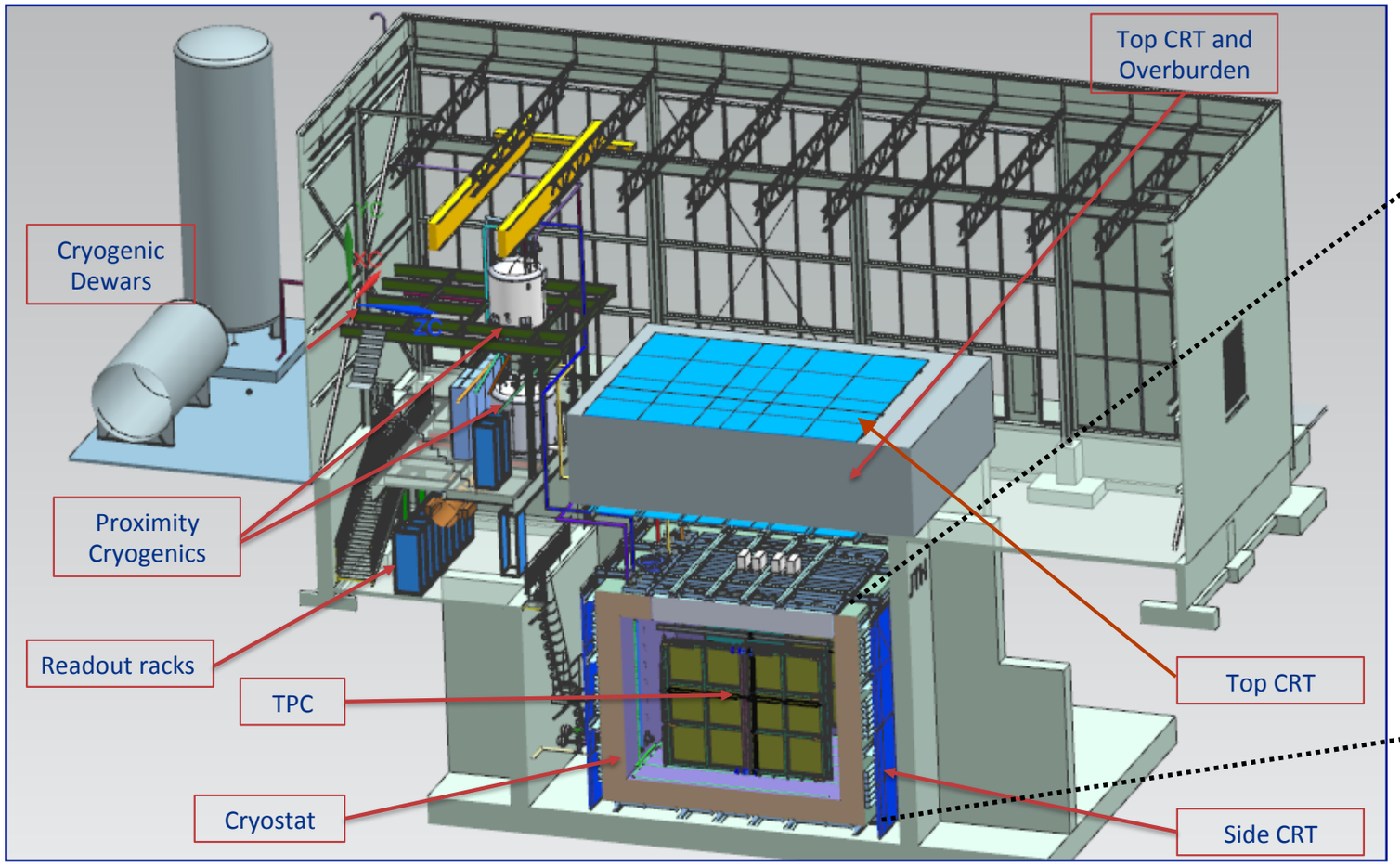


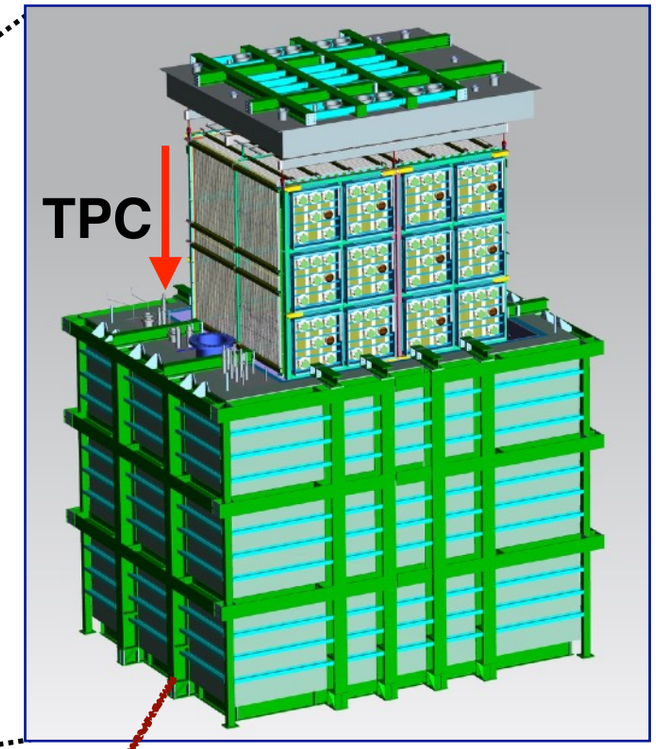
470t LArTPC, 600m from target

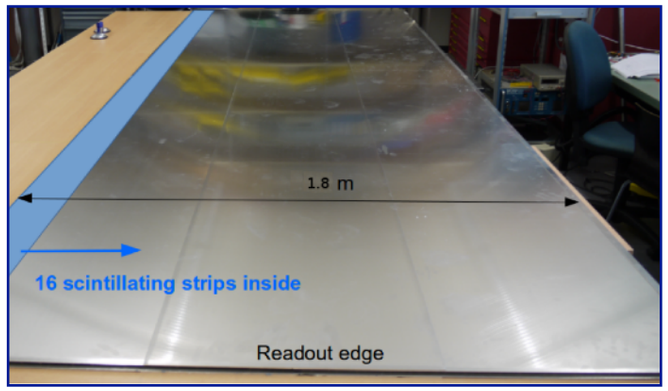
89t LArTPC
470m from target

112t LArTPC, 110m from target

SBND Design Overview



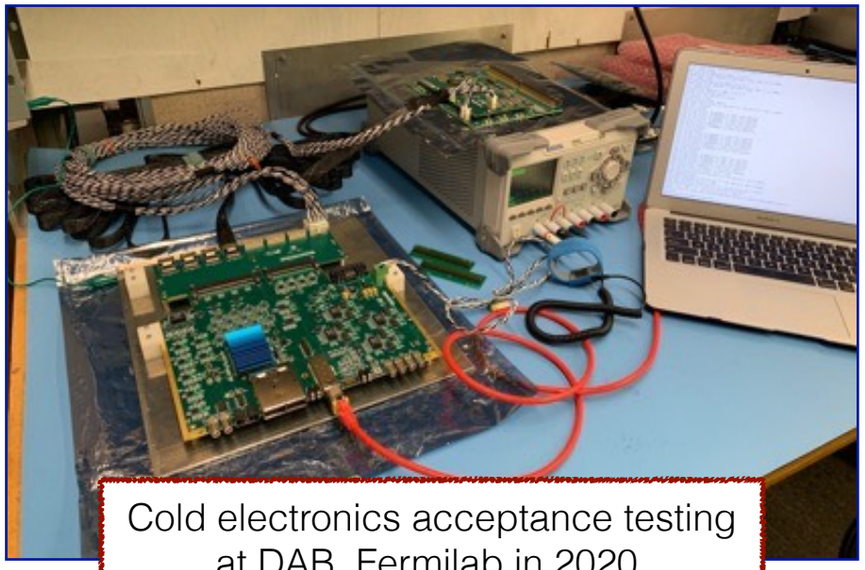




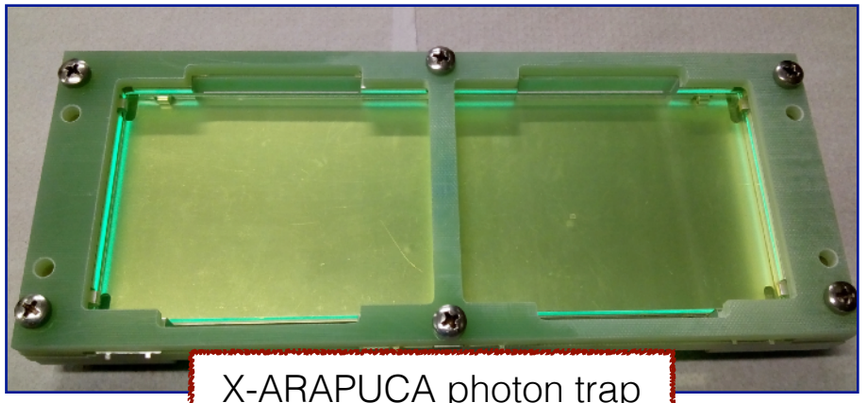
Cosmic Ray Tagger (CRT) system surrounds the cryostat on all six sides (double layer on top)

SBND Design Overview

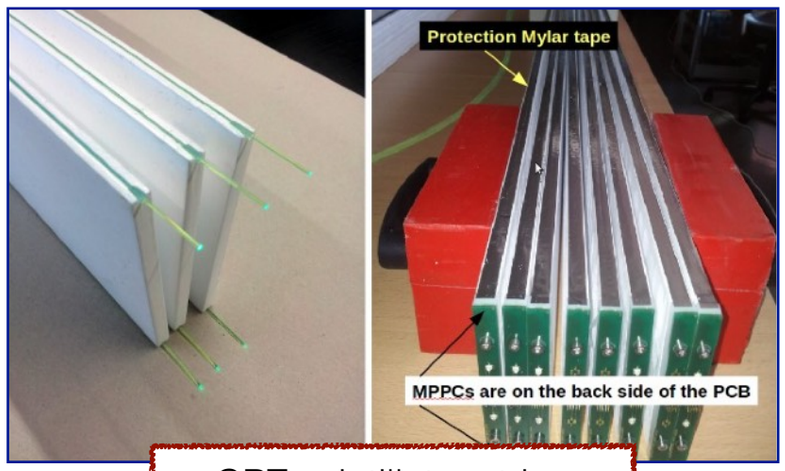
- **112 ton active volume LAr TPC**
  - Central cathode with two 2.0m drift regions.
  - 11,263 TPC channels read out with amplification (ASIC) and digitization (commercial AD7274) in the cold.
- **Photon detection system (PDS)**
  - 120 8” Hamamatsu PMTs: 96 coated with wavelength-shifting Tetraphenyl Butadiene (TPB) + 24 uncoated for seeing visible light
  - 192 X-ARAPUCA channels
  - TPB coated reflective foils embedded in cathode
- **Cosmic Ray Tagger (CRT) system**
  - Extruded scintillator strips read out by SiPMs
  - >130 modules enable nearly 4π coverage with double layer above the cryostat



Cold electronics acceptance testing at DAB, Fermilab in 2020.

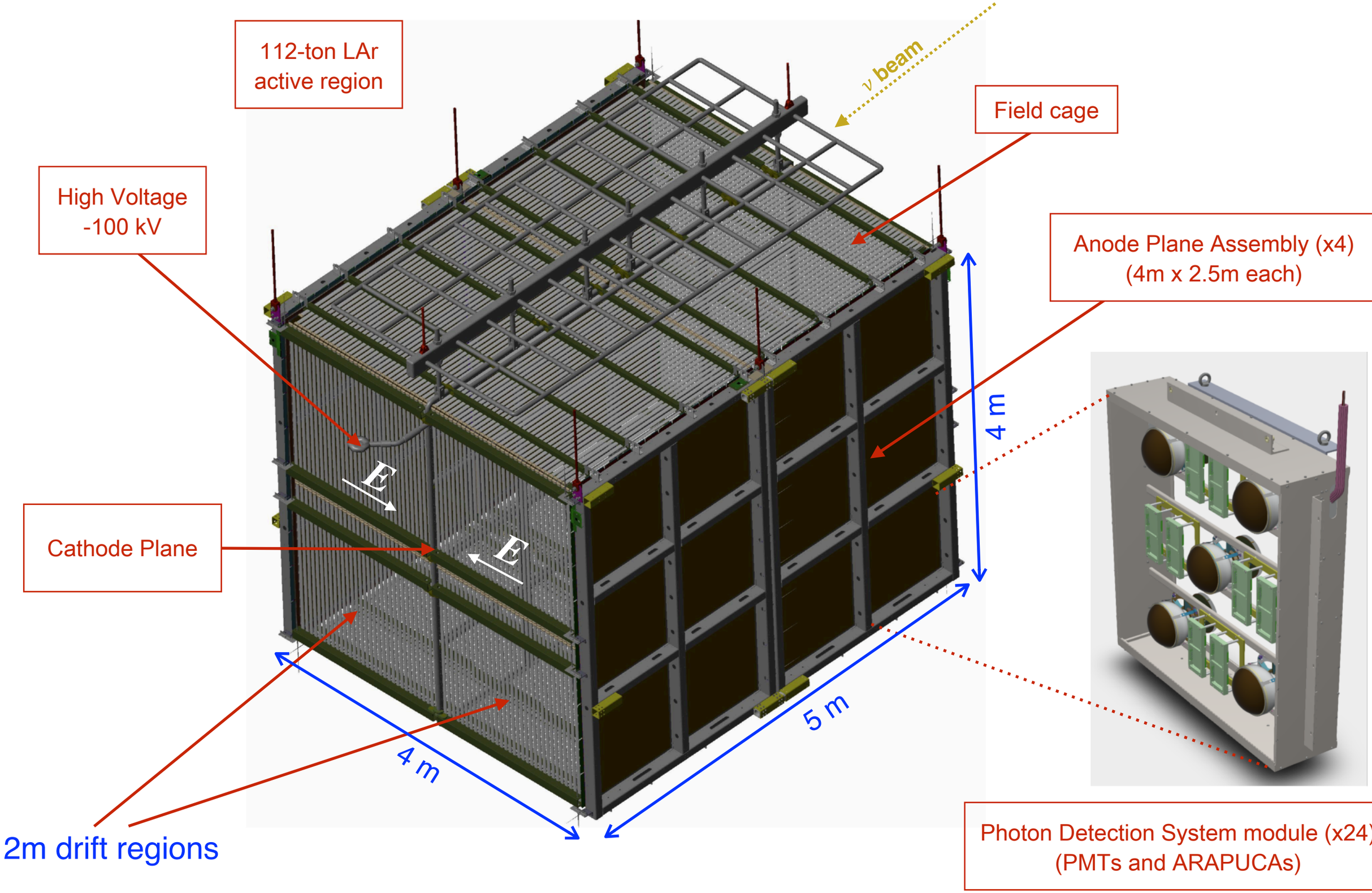


X-ARAPUCA photon trap



CRT scintillator strips

THE SBND TPC

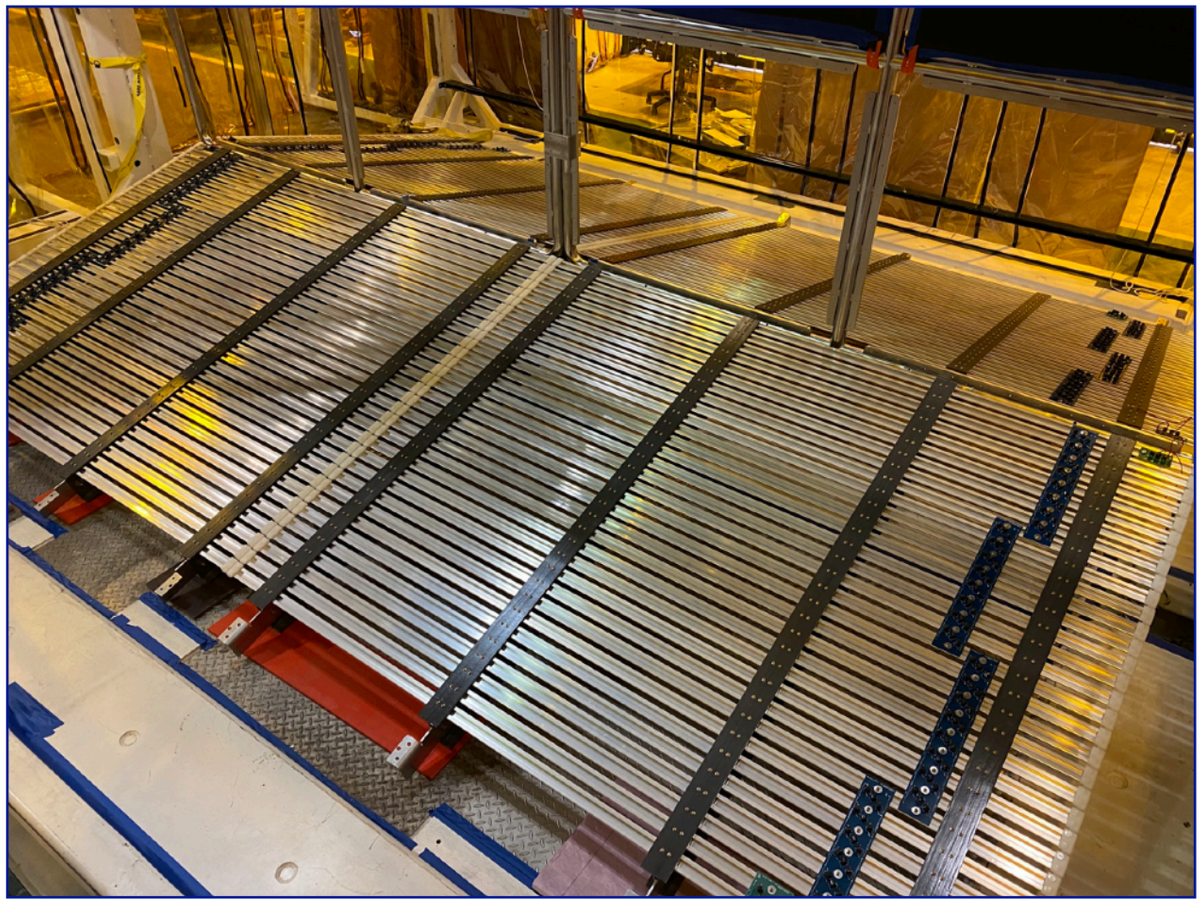

112-ton LAr active region
High Voltage -100 kV
Cathode Plane
2m drift regions
Field cage
Anode Plane Assembly (x4) (4m x 2.5m each)
Photon Detection System module (x24) (PMTs and ARAPUCAs)
ν beam
E
E
4 m
4 m
5 m

TPC + PDS Assembly

- TPC and PDS (photon detection system) subsystems were built at collaborating institutions and delivered to FNAL for assembly and integration.
- The TPC is being assembled outside of the cryostat at DAB (D0 Assembly Building) and will be transported across site to the SBND Hall when the cryostat is ready.
- Assembly at FNAL is a joint effort by Fermilab technical team and subsystem experts from collaboration institutions.
- Major effort in 2020/early 2021 was to complete the atf (assembly and transport fixture)

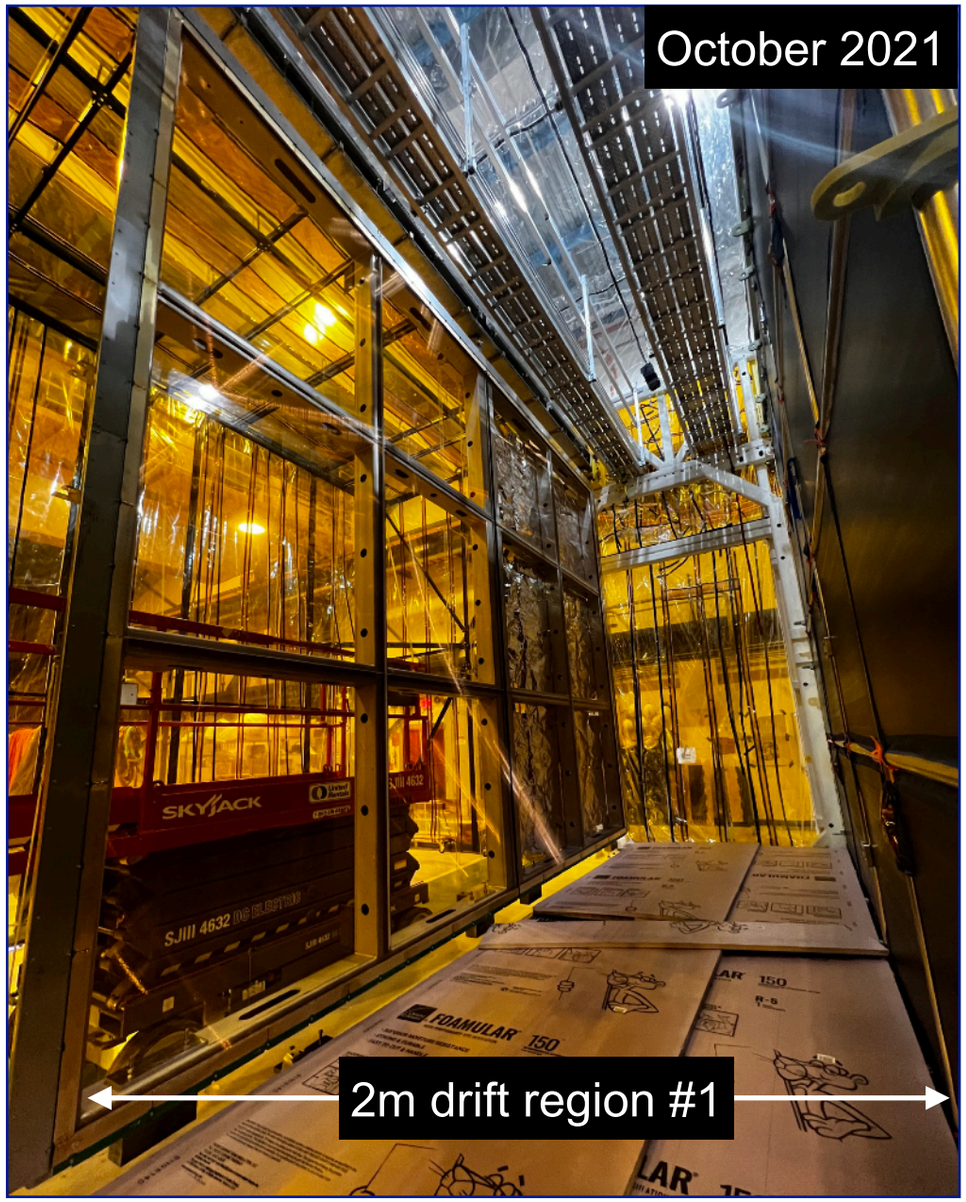
TPC Assembly

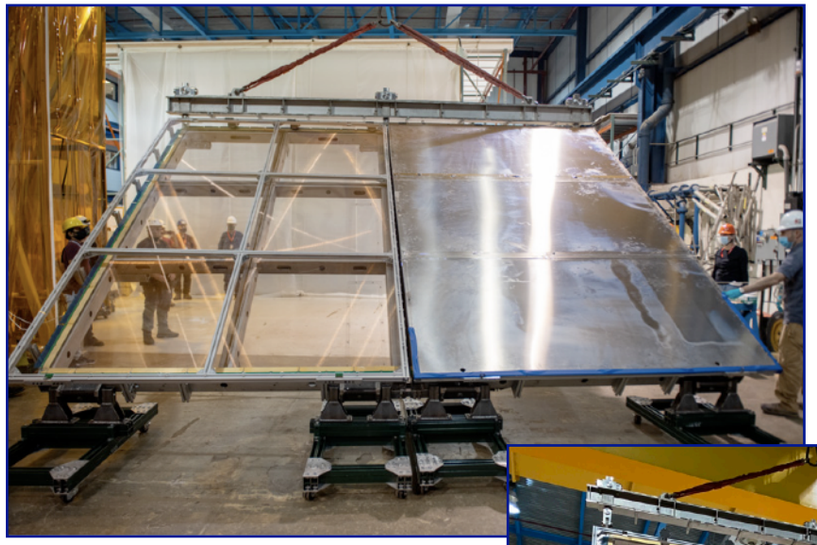
- First TPC components installed in July 2021
  - Cathode plane, including mesh panels with reflector foils mounted inside and calibration system for photon detectors (diffusers)
  - Field cage bottom panels



TPC Assembly

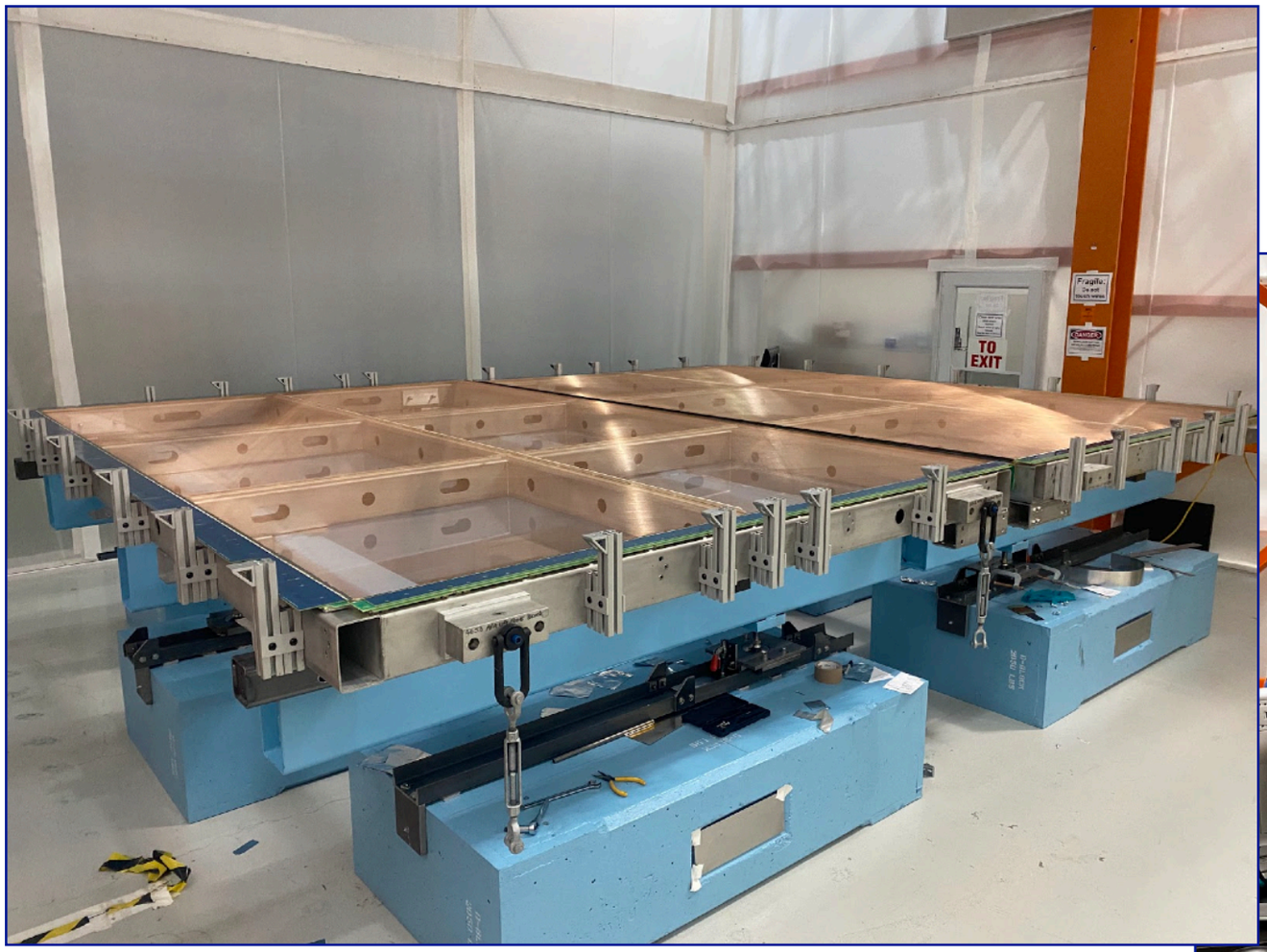
- First Anode plane successfully installed in October 2021 - this is a big milestone in the detector construction!





TPC Assembly

- 2nd APA pair is currently being aligned, tested, and prepared for installation before the end of the year.
- 2nd pair progressing very well because of the experience from the first time, excellent technical support at Fermilab, and an excellent team of local students & postdocs.

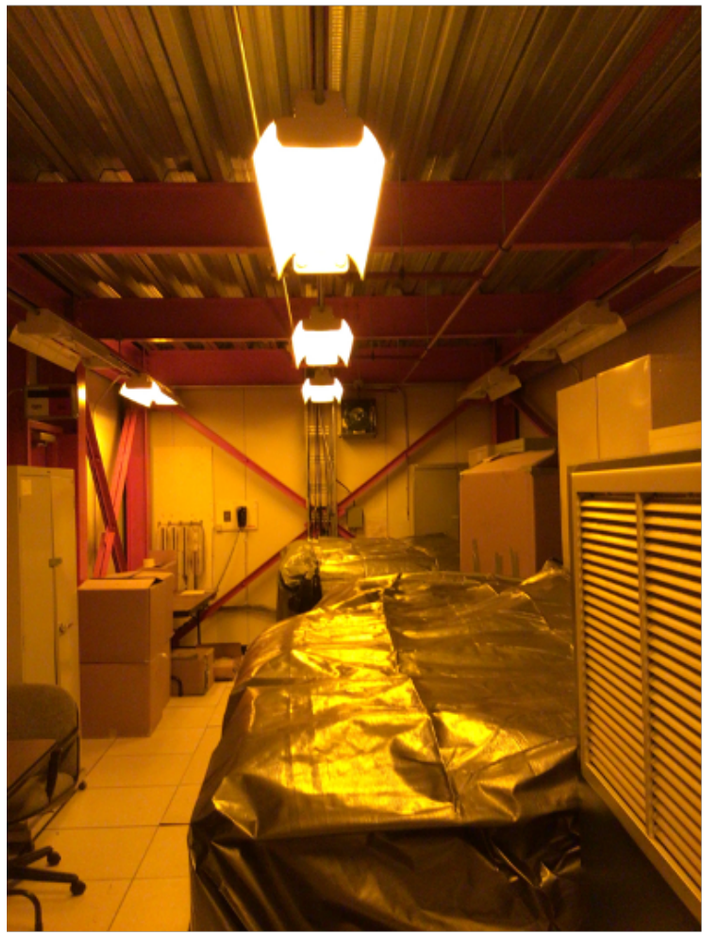


PHOTON DETECTORS

- All PMTs, mounted in PDS boxes, delivered to FNAL. Stored in light-protected room at DAB. Post-shipment reception tests completed.

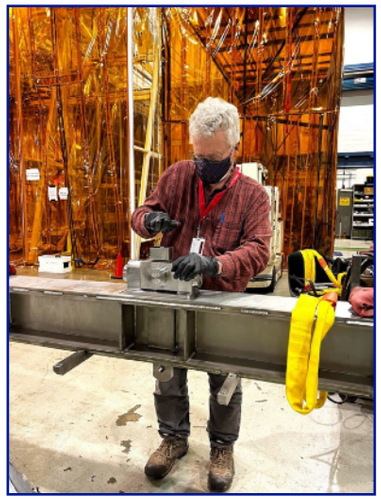
- All X-ARAPUCA modules also delivered to FNAL. Clean tent ready at DAB for final assembly.

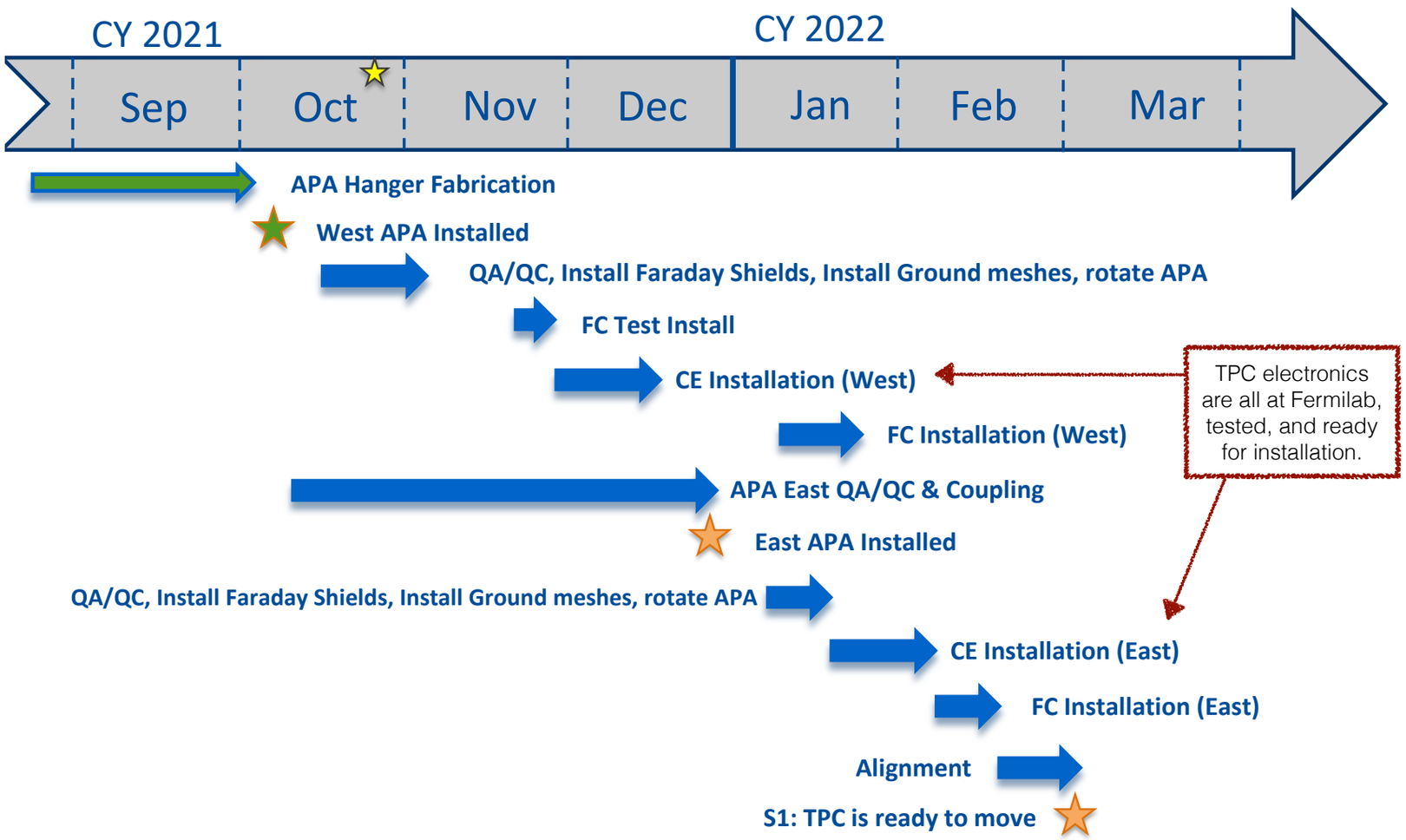
- Photon detector calibration diffusers successfully installed on cathode plane.



Detector Assembly Schedule

- Delays in 2020-21 mostly attributed to the TPC hanger system (CPA & APA support beams and hangers).
  - COVID was an underlying cause of many of those delays: backlogs in machining, difficulty sourcing stainless steel, difficult communications with shops and vendors.

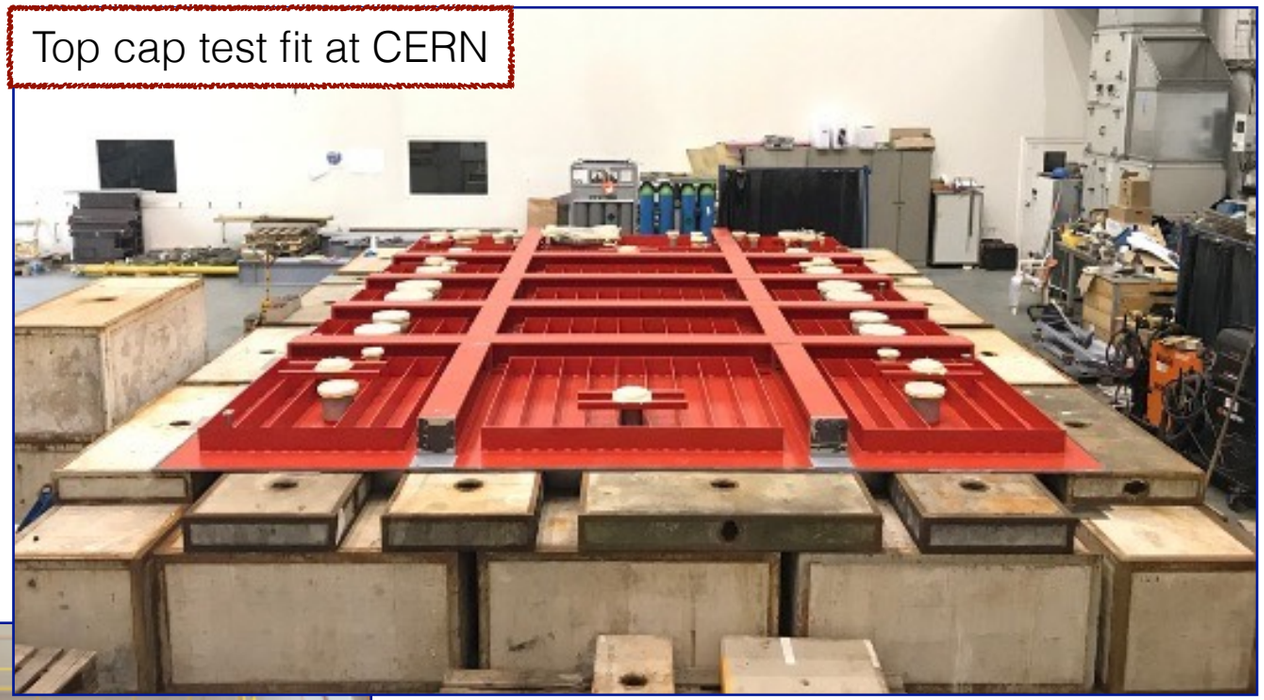




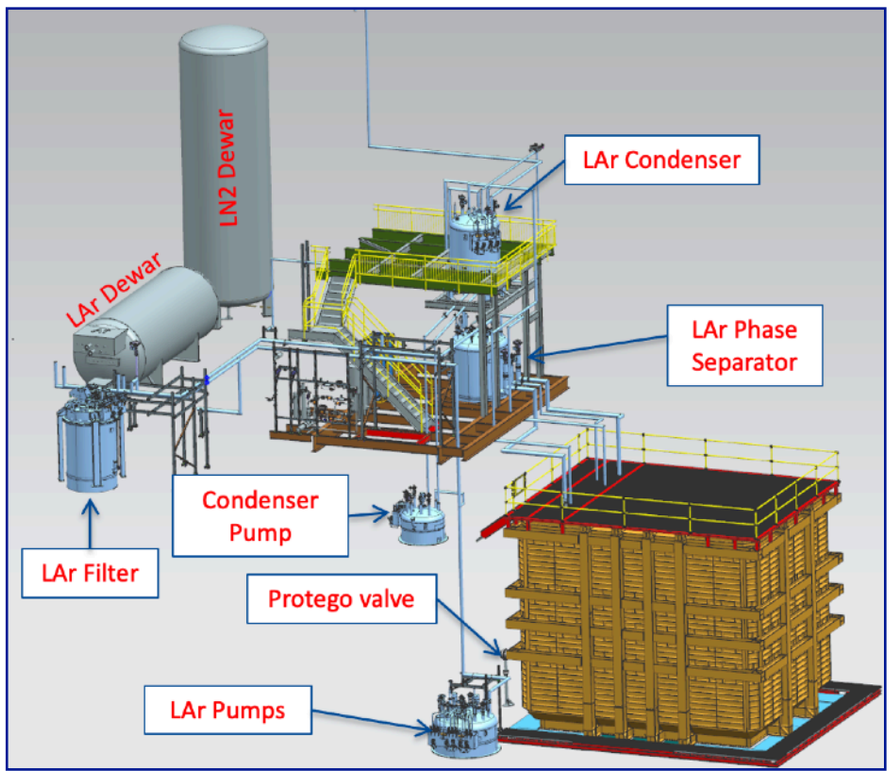
- Technical Coordination team proactively reordered the installation sequence to make up for some of the delay.
- Assembly work on schedule since completing hangers.
- TPC expected “ready to move” in March 2022.

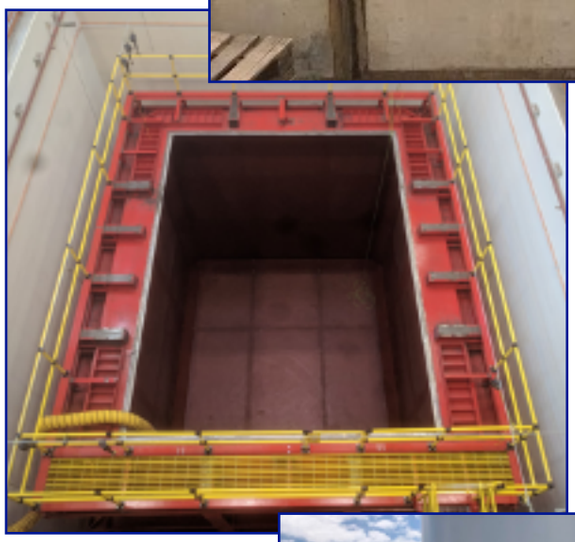
CRYOSTAT AND CRYOGENICS

- Membrane cryostat materials arrived at Fermilab April 2021
- Cryostat top cap construction and test fit completed at CERN in May 2021.
- External cryogenics installation progressing well at Fermilab.

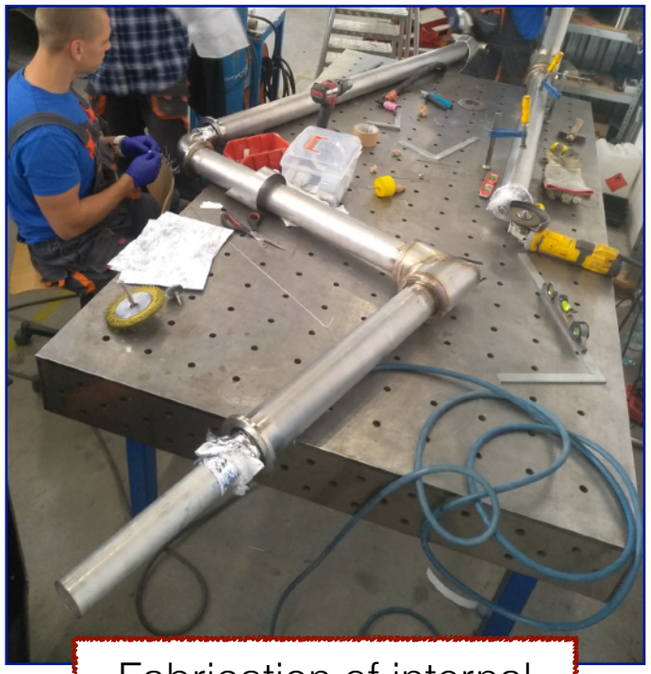


Top cap test fit at CERN





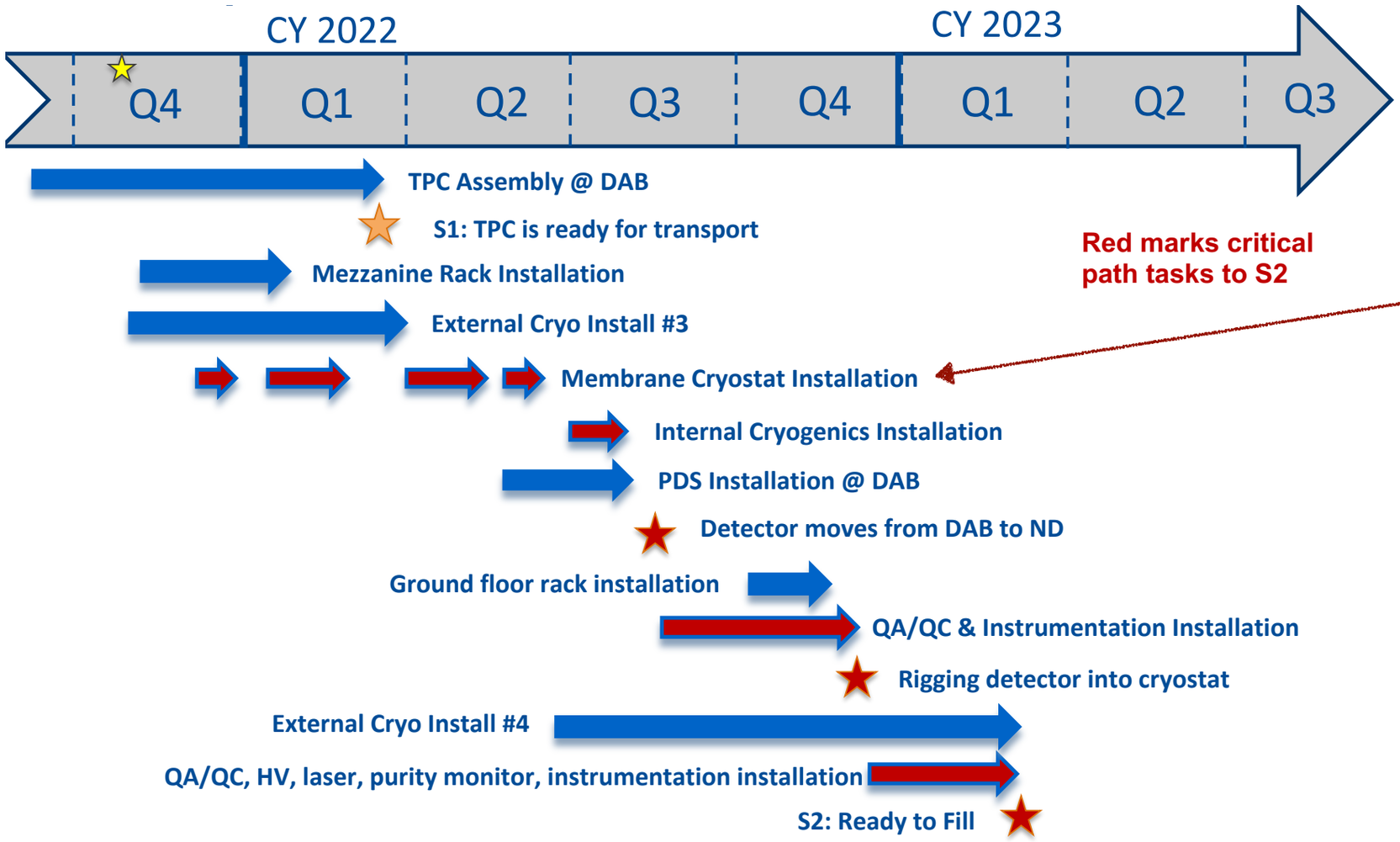
External cryogenics dewars at FNAL



Fabrication of internal cryogenics in Poland

CRYOSTAT/CRYOGENICS SCHEDULE

- Installation of the cryostat has suffered significant delays in the past year.
  - Delays in delivery of membrane materials from manufacturer in Korea; also in securing installation contract between Gabadi and CERN.
  - Installation requires travel from Gabadi (Spain), CERN, GTT (France), which took significant effort to arrange.



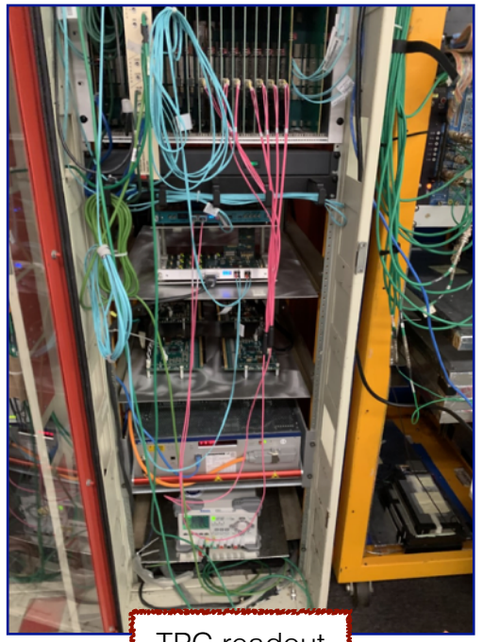
- Cryostat installation is the critical path in the project.
- Cryostat installation planned in four phases
  - studs welding - 2 weeks
  - insulation installation - 6 weeks
  - membrane insulation - 6 weeks
  - tests and checks - 2 weeks
- The good news: Phase I set to begin on Dec 6, 2021.

DAQ, Electronics Installation

- Includes DAQ, detector control systems, detector monitoring, readout, and trigger
  - Both hardware and software
  - Test stand important for development
- Installation of electronics components for detector readout and monitoring at the SBND experimental hall is well underway.
  - Racks, readout electronics, power supplies, ground impedance monitor, cabling, etc.
  - All detector readout racks expected completed in early 2022.
- On track to be complete well before systems needed.
- SBND and ICARUS have both benefited from combined efforts.

Test Stand at DAB

PMTs, Trigger



TPC readout

SBND Experimental Hall

TPC readout

DAQ servers

Trigger components

DIRECTOR'S REVIEW

SBND Director's Review

Slide from SBN Program Coordinator Peter Wilson, summarizing the review.

- Annual progress review on Oct 26-28 chaired by Gina Rameika
- Focus on cost, schedule and progress for main remaining activities: cryogenics, TPC assembly, installation and commissioning plans
- Excerpts from the *draft* executive summary:

  Overall the Review Committee was very impressed with the progress presented by the SBN team, in particular, in light of the challenging situations experienced by the team with regard to the pandemic.

  Nevertheless, the Committee remains concerned with the schedule for completion of the SBND. The critical path activity is the installation of the cold elements of the SBND cryostat.

  Given the current state of progress with the TPC construction, the Review Committee is confident that the SBND team will meet the S1 milestone: TPC ready to move to SBND building, at the required time.

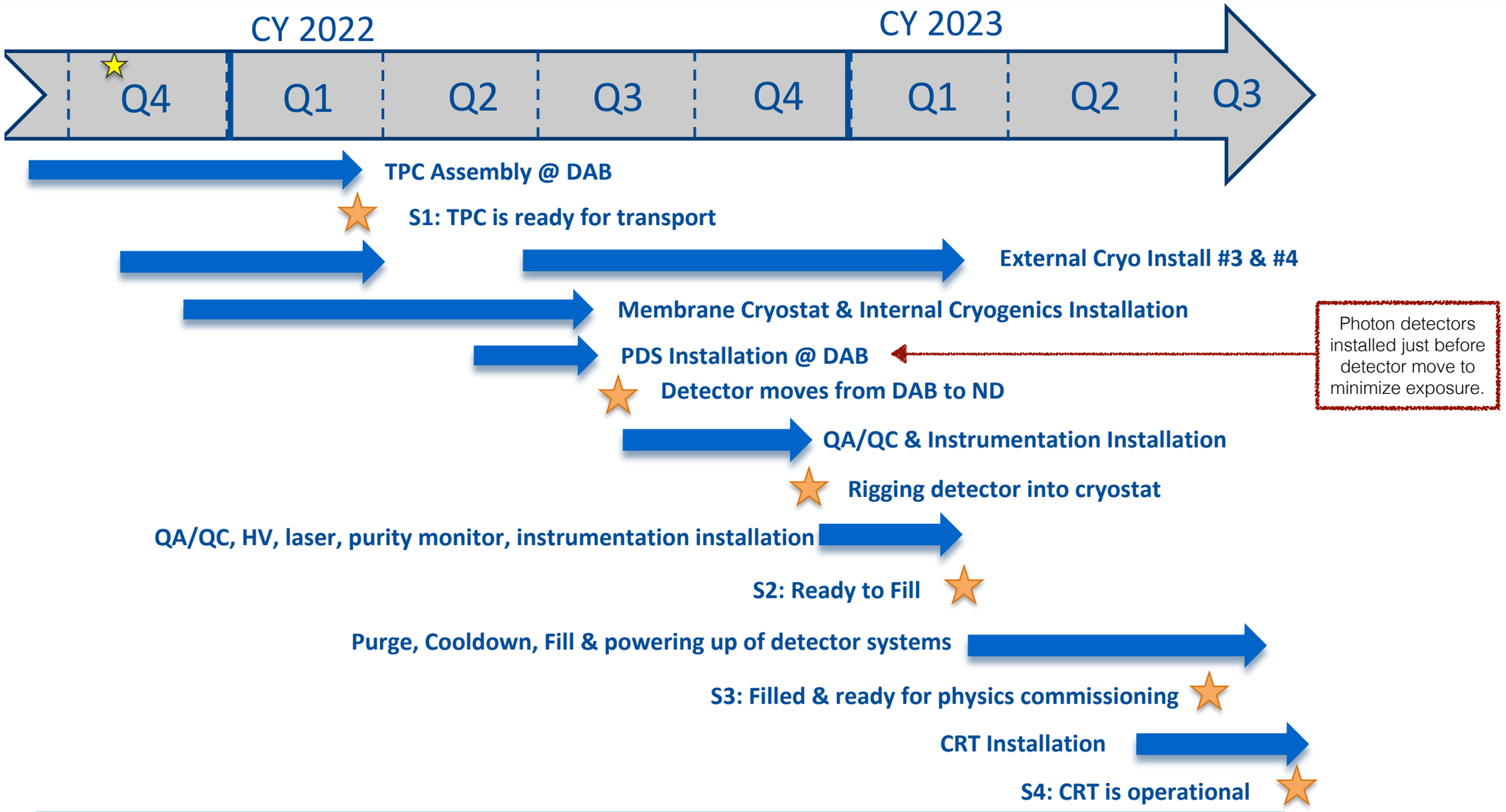
  The Committee notes that the cost estimate to complete is not converging (reducing) as quickly as would be desired. This is a consequence of the extended schedule.

- No comments or recommendations that were unexpected by the SBND team

Second slide with a few more details in backup. Review report will soon be availble on review web page.

OPSS web page for SBND Review

Overall Schedule



S1: TPC ready for transport	March 2022
S2: Ready to fill	March 2023
S3: Filled and ready for commissioning	Summer 2023

The collaboration is developing a commissioning plan and work has started preparing analysis tools for commissioning. We aim to be taking physics quality data before the end of the summer shutdown in 2023.

POT and Event Estimates

- Assuming a start in summer 2023 and running until the FNAL long-shutdown in January 2027, we can estimate the potential exposure and event statistics for SBND over this **3.25 year period**.
- Beam delivery projections from Accelerator Division predict **3-5e20 (base-design) protons on target per year** to the BNB during this period.

Scenario	Run time	POT/y	POT total	nm CC events	ne CC events	NC events
proposal	3 years	2.2E+20	6.6E+20	5.2M	36k	2M
2023-2027 base	3.25 years	3E+20	9.75E+20	**7.7M**	**53k**	**3M**
2023-2027 design	3.25 years	5E+20	16.25E+20	**12.8M**	**88k**	**5M**

SBND is poised to collect a very large neutrino-argon data set for physics.
(current largest is MicroBooNE at ~0.5M)

SBND Physics Program

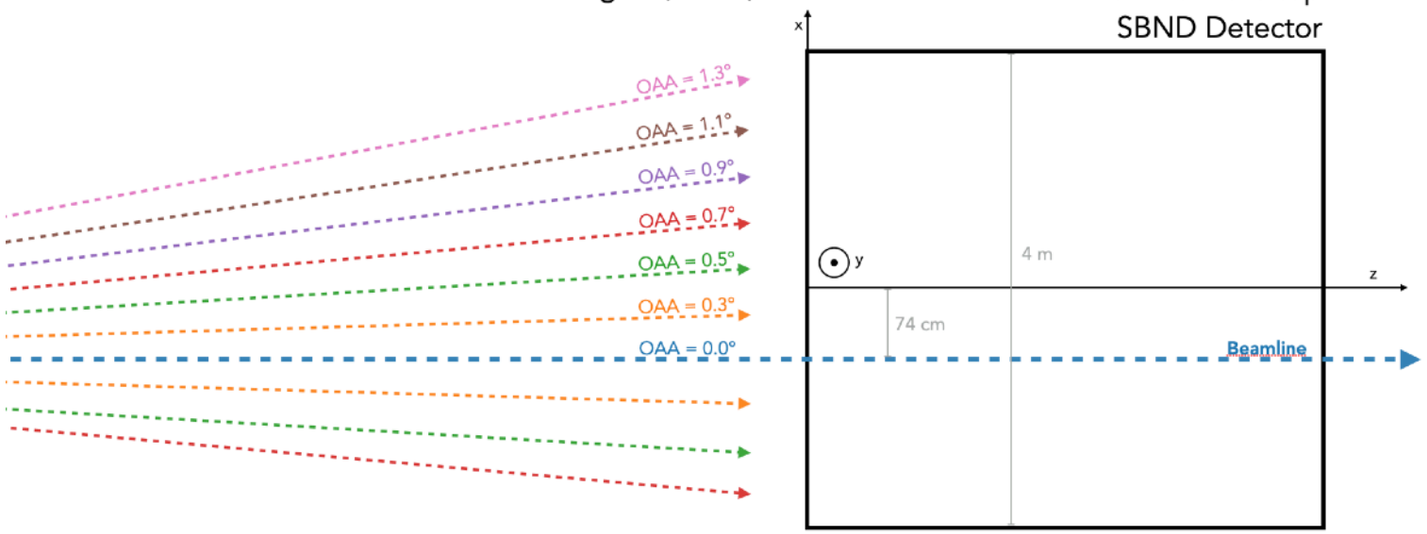
- **Neutrino cross sections** *
  - SBND will have the largest neutrino-argon dataset at the GeV-scale prior to DUNE, enabing detailed studies of ν+Ar interactions to improve understanding of both signal and background channels in future neutrino experiments (SBN & DUNE).
- **Sterile Neutrino searches** *
  - To go from MicroBooNE's check of the MiniBooNE LEE to a general test of the sterile neutrino hypothesis (or other new physics possibilities), must have a near detector constraint!! (and more statistics) [see Pedro Machado's presentation]
    - Note: MicroBooNE results with 3 yrs data ≈ 600 total ν_e events (inclusive analysis, fully+partially contained) at 46% efficiency, or ≈1300 true ν_e interactions. SBND collects 1300 ν_e interactions in order 1 month. SBND running will quickly produce >10x more data than the recent MicroBooNE results for making near detector constrained predictions at both the MicroBooNE and ICARUS locations.
- **BSM searches** *
  - Many opportunities to explore BSM physics in SBN and especially in SBND [again, see Pedro Machado's presentation]

*There is a huge amount of development work ongoing in **simulation, reconstruction, calibration, and analysis** directed toward all areas of the physics program that we don't take the time to cover here, focusing instead on the status of the detector construction.

SBND-PRISM*

- One analysis idea we've been studying recently that leverages the near location, detector geometry, and large neutrino rate of SBND to enhance the sensitivity in multiple areas of the SBN physics program.

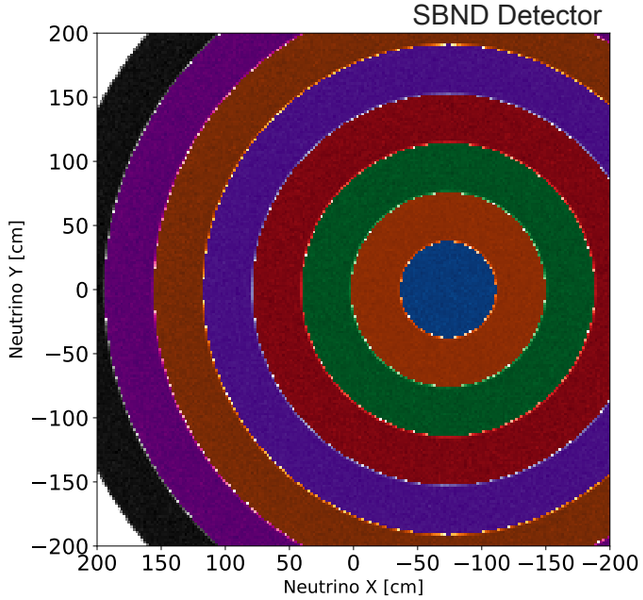
SBND sees neutrinos from several off-axis angles (OAAs)



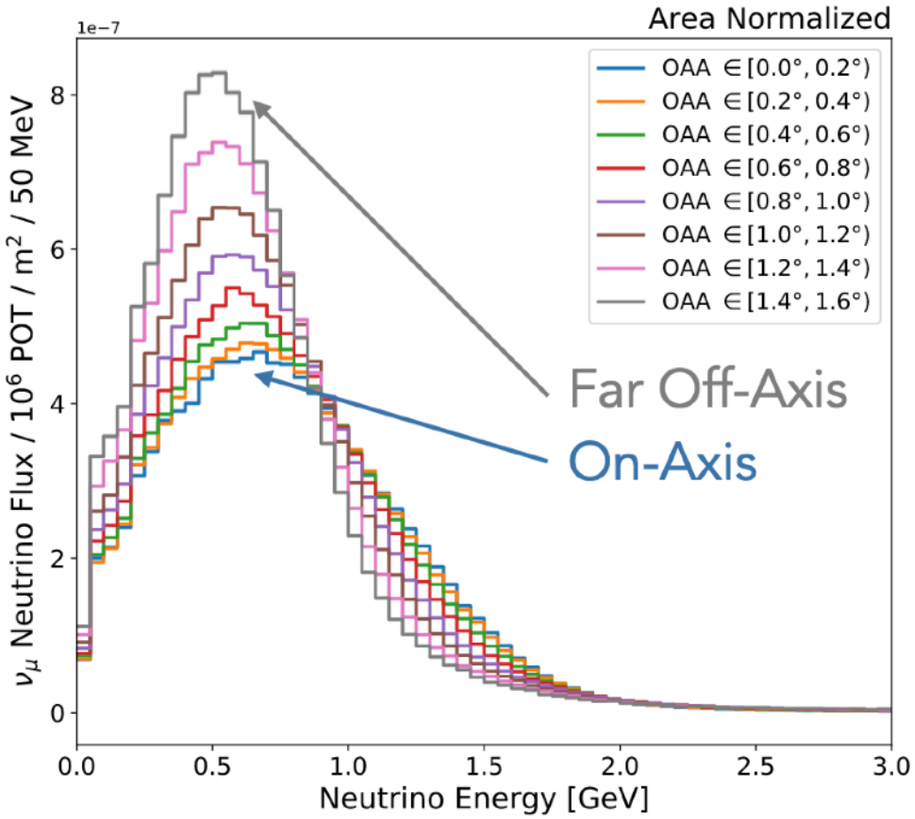
View from the top
SBND Detector

The detector can be divided into annular rings to sample multiple off-axis fluxes in the same detector.

View from the front
SBND Detector



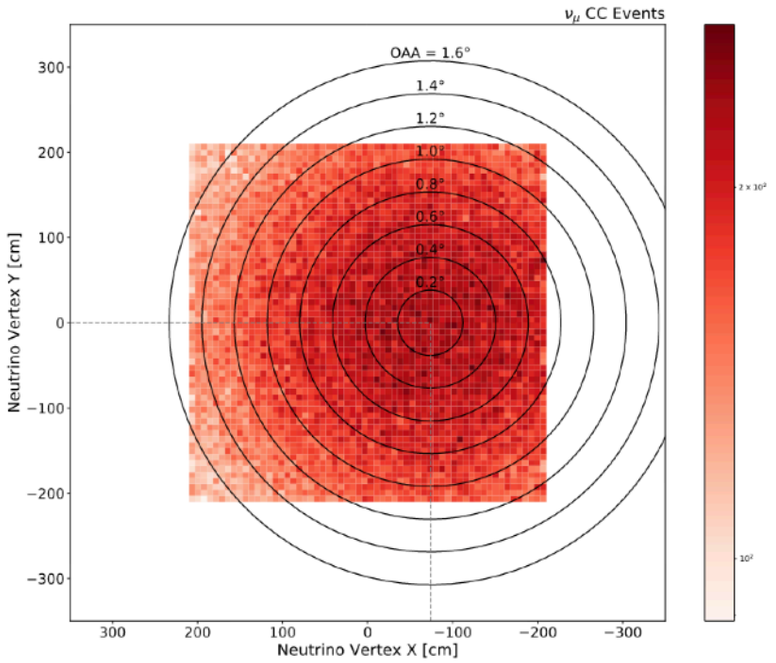
Muon neutrino flux in each of the OAA regions



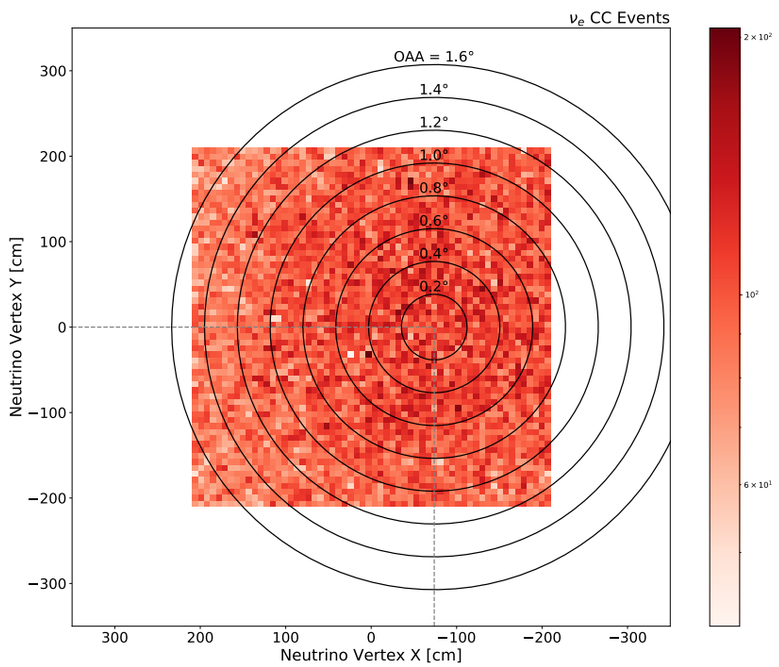
*Precision Reaction Independent Spectrum Measurement
[nuPRISM https://arxiv.org/abs/1412.3086]

SBND-PRISM

Muon-neutrino Charged Current Events



Electron-neutrino Charged Current Events



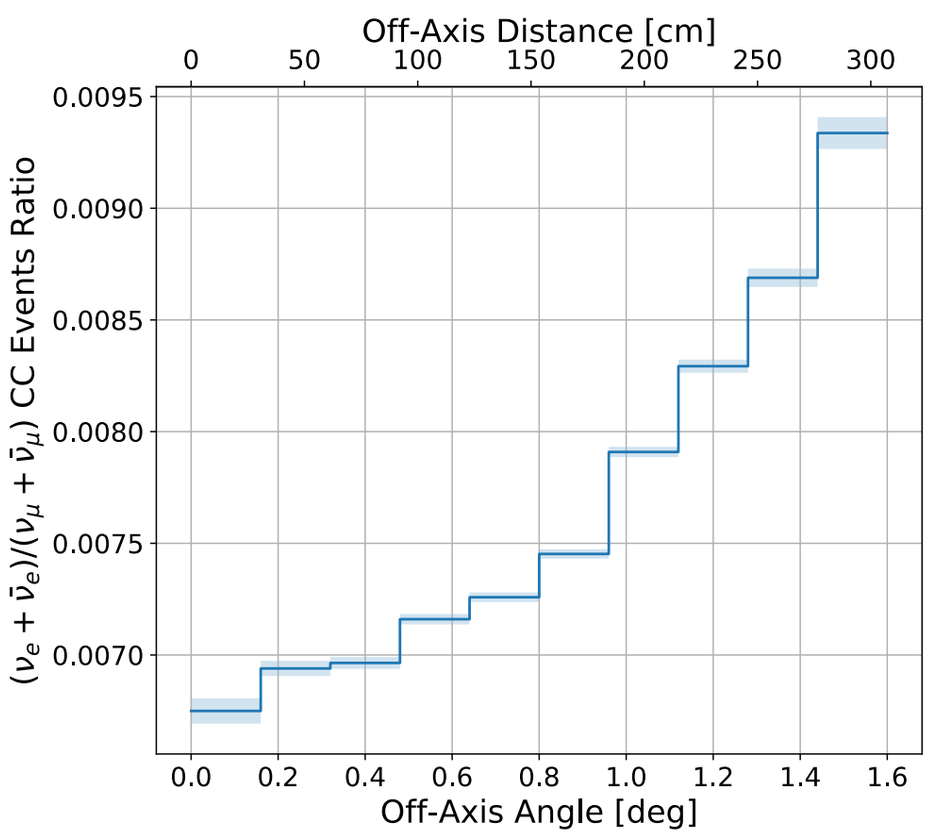
Large statistics in all off-axis slices.

>200,000 ν_μ events in each slice

>1000 ν_e events in each slice

for 6.6 x 10^{20} POT

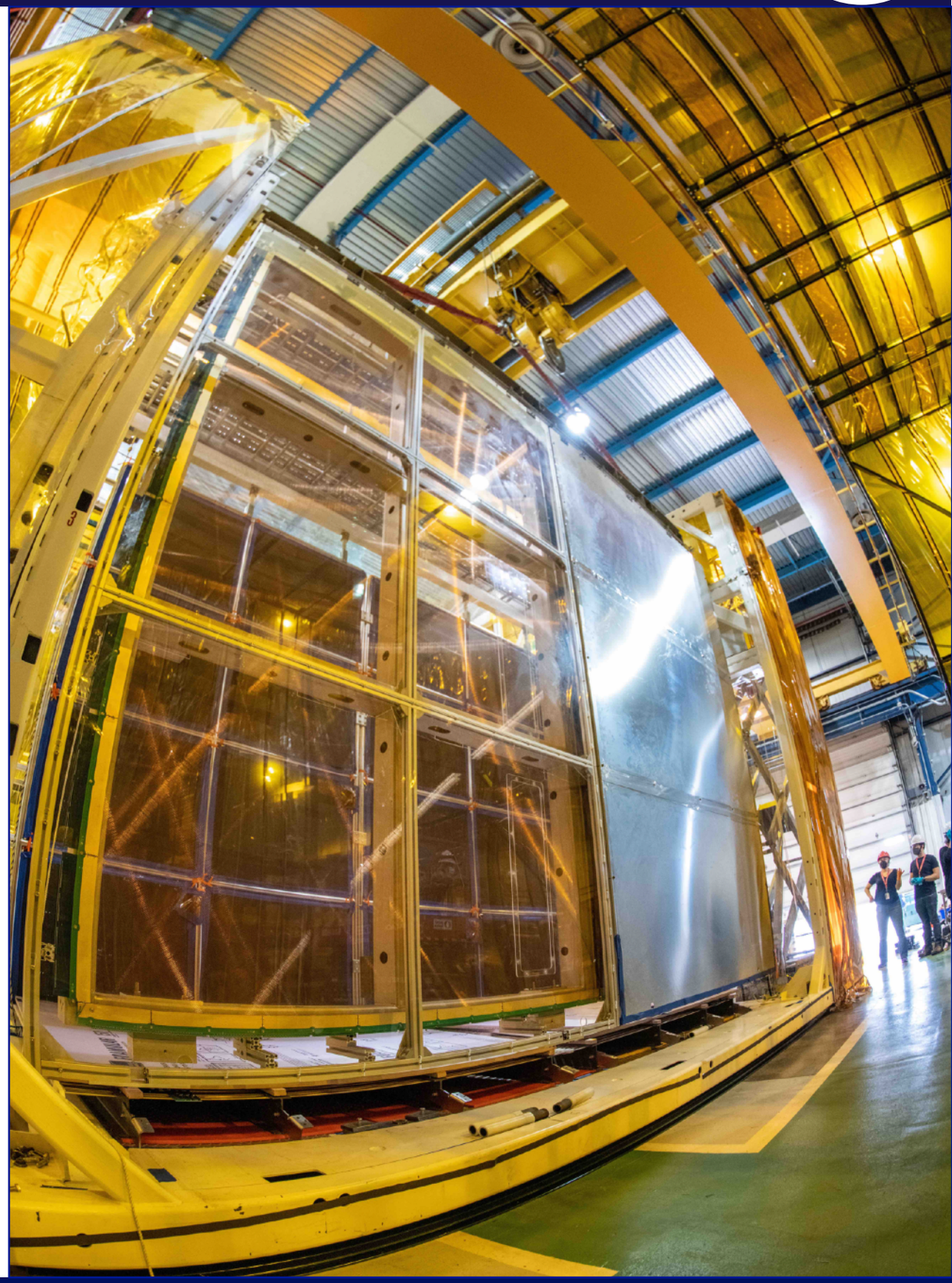
ν_e to ν_μ ratio changes moving off-axis



- Investigating the impact of the SBND-PRISM concept throughout the physics program:
  - Neutrino cross section measurements
  - SBN neutrino ocillations
  - SBND-only neutrino oscillations
  - Dark Matter/BSM searches
  - …

SUMMARY

- **Despite continuing COVID impact, significant progress has been made in SBND construction thanks to a tremendous effort by a fantastic team.**
  - Detector assembly is now in full swing with the cathode and first anode planes installed in the past 2 months.
  - Membrane cryostat installation gets underway December 6. External cryogenics installation continues apace at Fermilab.
  - Electronics, readout, DAQ, controls all in good shape.
- **SBND, starting in 1.5 years, will transform the physics we can do in the Short-Baseline Neutrino program:**
  1. Near detector data is essential for performing a broad, definitive test of the light sterile neutrino hypothesis - both appearance and disappearance.
  2. SBND will provide us with 20-30 times more data than we have now, enabling a detailed investigation of neutrino-argon interactions around 1GeV and many new searches for signatures of physics beyond the standard model.



EXTRAS

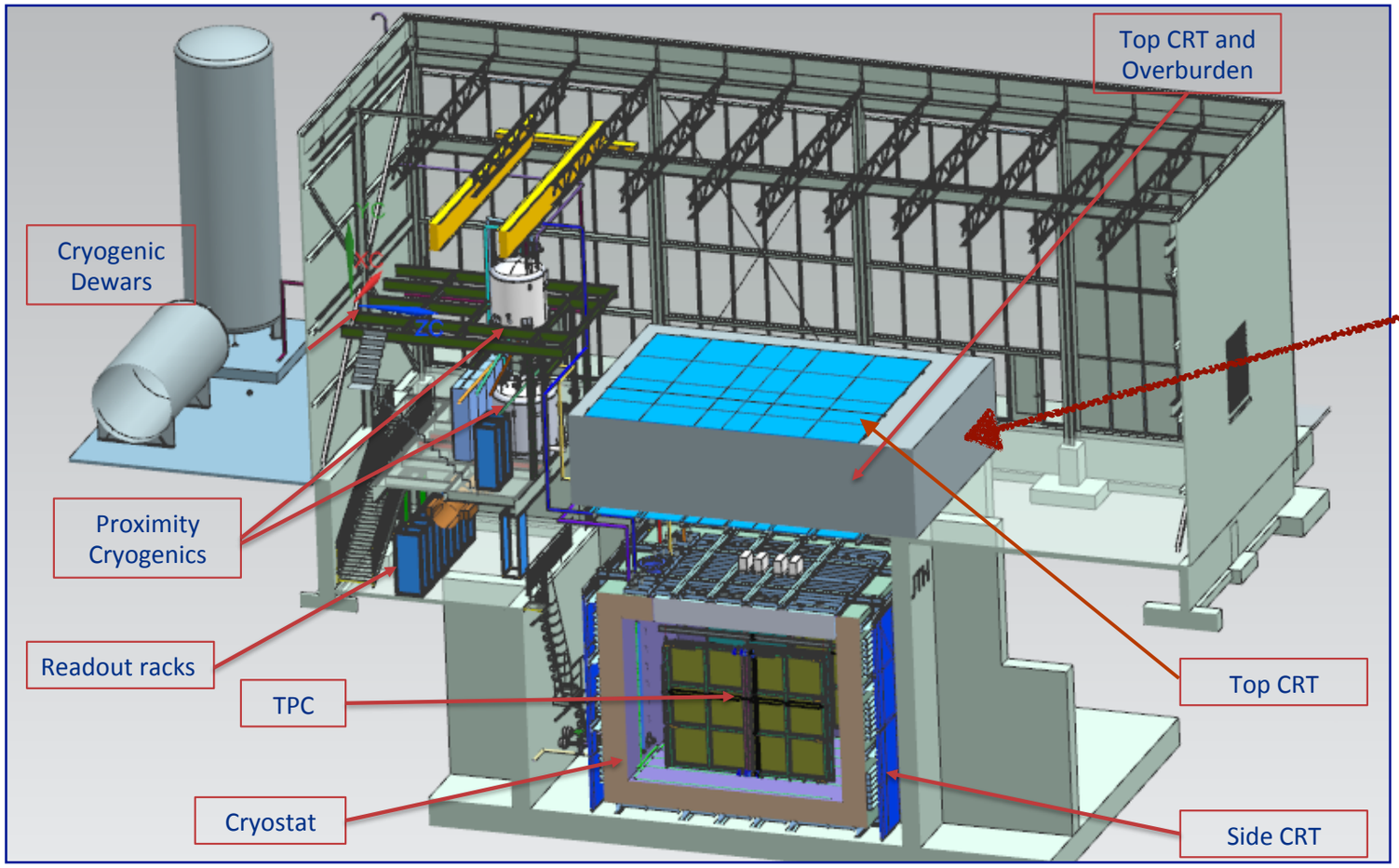
DIRECTOR'S REVIEW

SBND Director's Review - cont

Slide from SBN Program Coordinator Peter Wilson, summarizing the review.

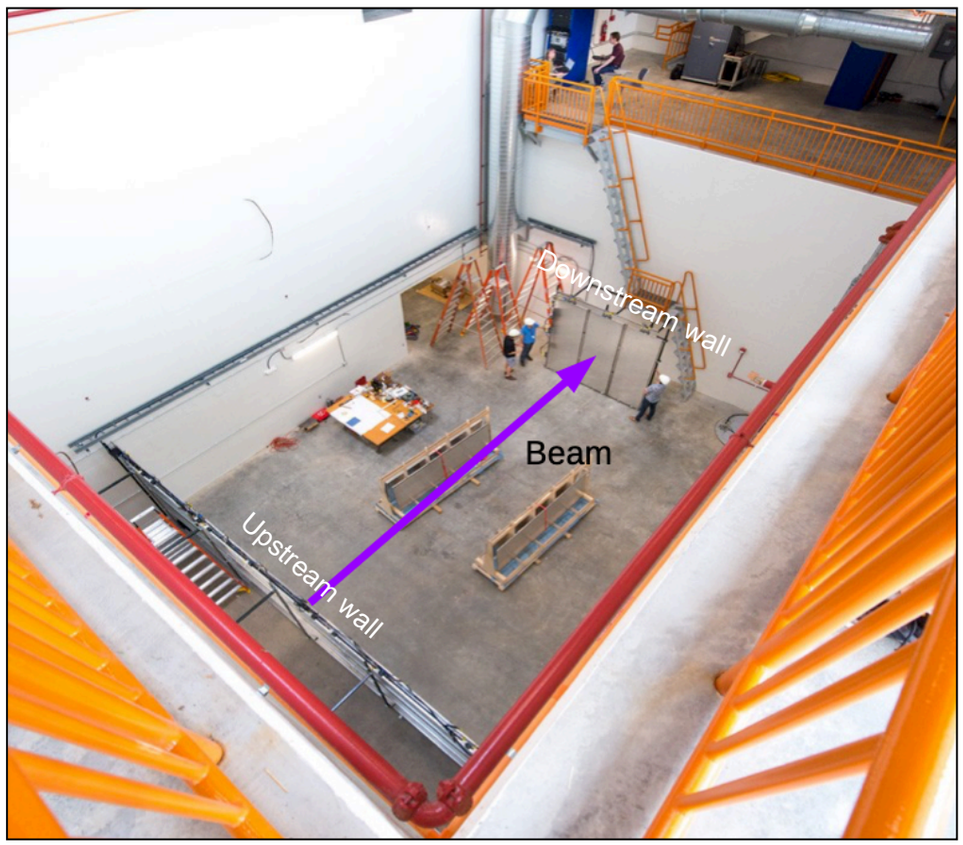
- At Oct 2020 review: significant concern about availability of technician resources.
  - Alleviated by additional personnel in Neutrino Division and reduction in peak need
  - Some concern about competition from other projects
- At Oct 2020 review: concern that FY21 plan was $1.5M over budget
  - Adjustments in plan resulted in completing FY21 on budget w/o impacting critical path
  - FY22 plan is within expected budget w/o impacting critical path
- Concerns remain about impact of COVID particularly for international travel until cryostat installation is complete
  - Program continues working with CERN to minimize future delays to installation
- Committee provided 10 recommendations to ensure the schedule is maintained:
  - No significant technical recommendations
  - Ensure cryostat and cryostat top-cap installation stay on schedule
  - Focus on improvements in tracking of costs and milestones
  - **Briefing on milestones, total cost, and schedule with a subset of the committee in 6 months - assess cryostat progress**
- SBN Program will present a response plan at the SBN PMG on Nov 18

SBND Design Overview



Based on the studies presented at the last PAC meeting and the input of the committee, the collaboration has approved a plan to **remove the concrete overburden** from the SBND project.

Cosmic Ray Tagger (CRT) Data



Part of the SBND CRT system was temporary installed in the detector hall and took BNB data in 2017-2018

CRT data: **muons from neutrinos** that interacted in the material upstream of the SBND detector hall. The beam intensity decreases moving away from the beam center.