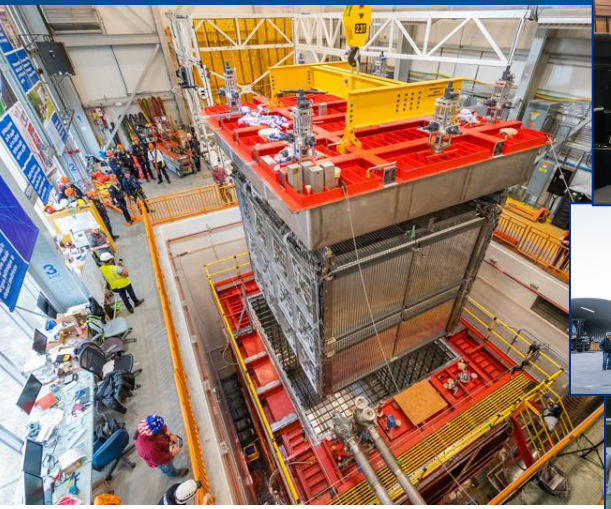


Introduction to SBND and Operations Planning Overview

David Schmitz (U. of Chicago), Ornella Palamara (FNAL)

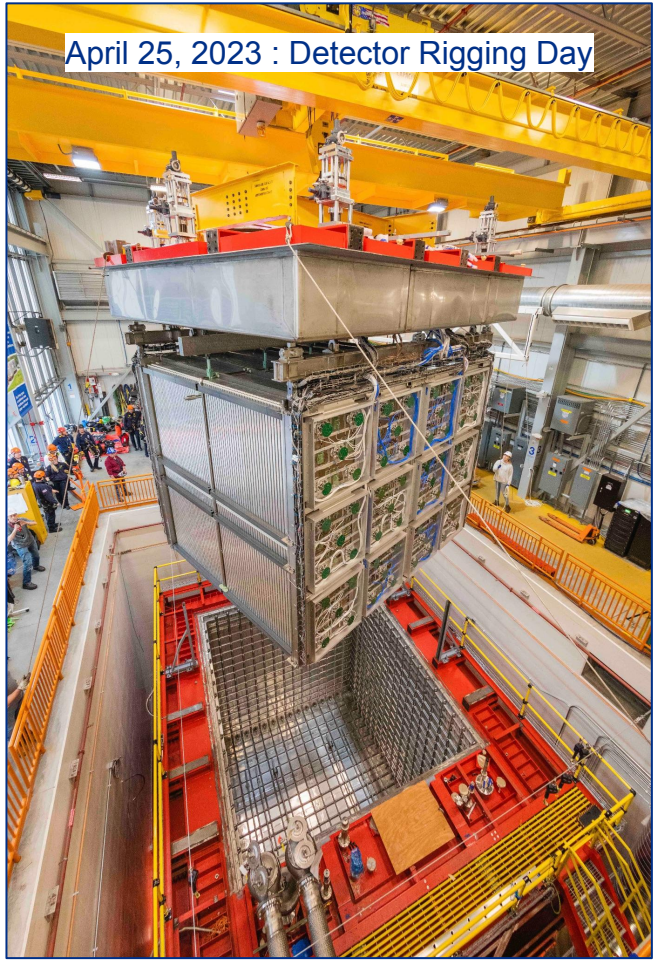
SBND Operations Readiness Review

February 21-22, 2024

SBND and the Fermilab Short-Baseline Neutrino Program

Outline

- Science Goals of SBND and SBN : Why Operate?
- Experiment Overview : What to Operate?
  - TPC
  - Photon Detectors
  - Cosmic Ray Tagger
  - Booster Neutrino Beam
- Collaboration Organization : Who will Operate?
- Operations Planning Process
- Review Agenda and Introduction of Presenters
- Summary of Fermilab Roles and Resources
- Charge Questions and Where to Expect Answers
- Outline of SBND's Early Run Plan Goals



Science Goals of SBND and SBN

SBND's large detector mass, proximity to the source, and high-performance detector design enables a broad, exciting physics program:

Precision neutrino-nucleus interaction measurements:

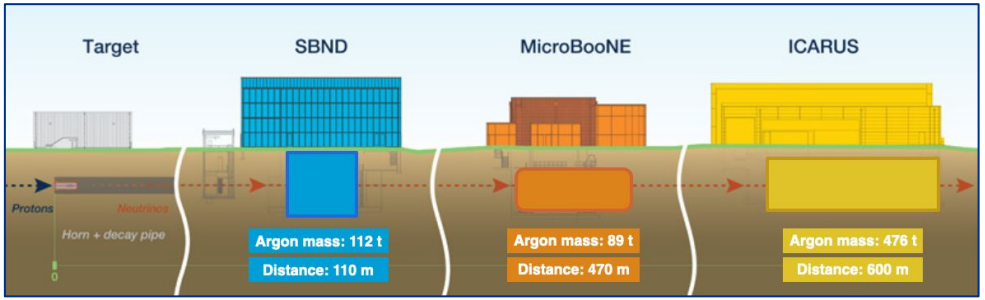
- Differential measurements of high-rate channels (inclusive, single and multi-proton, charged/neutral mesons, etc.) with more than an order of magnitude more ν-Ar data than is currently available.
- High rates of both muon AND electron neutrinos.
- Exploration of low-rate interaction channels not easily studied in smaller data sets (hyperon production, ν-e scattering, etc.)

Tests of Beyond Standard Model scenarios:

- Tests of various models (heavy neutral leptons, Higgs portal scalar models, etc.) in multiple final-states.
- Strong collaboration with theory community and many on-going sensitivity studies.

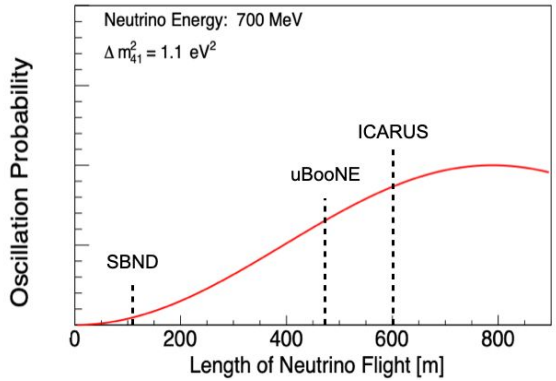
Sensitive searches for sterile neutrino oscillations:

- As the Near Detector in the SBN Program, SBND is the key to mitigating large neutrino flux and cross-section uncertainties.
- Multiple detectors also enables searches in BOTH appearance and disappearance.



Relative Neutrino Interaction Rates (BNB)	23	1	3.3
ν_μ-CC interactions per 1x10^{20} POT (BNB)	625k	27k	90k
ν_e-CC interactions per 1x10^{20} POT (BNB)	4k	0.2k	0.6k

Rates shown for full active TPC masses and integrated over all energies.

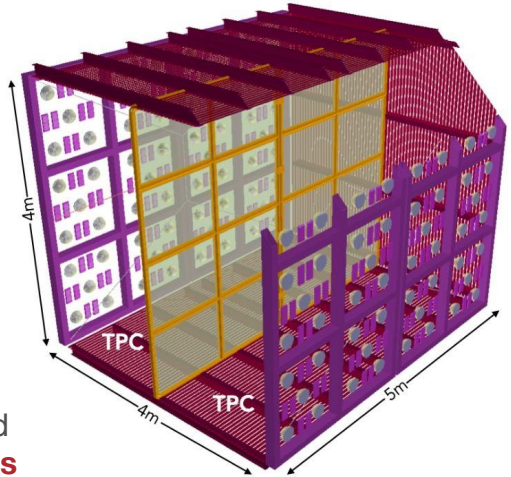


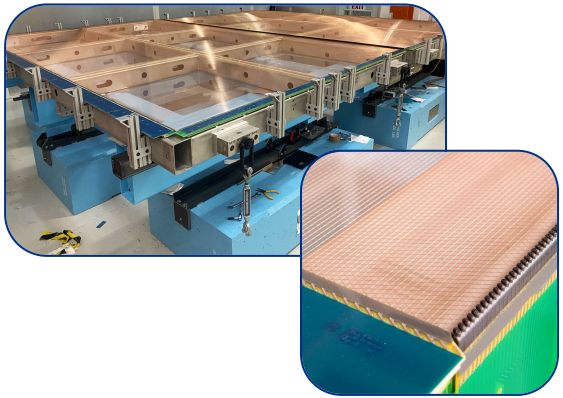
Example sterile neutrino oscillation probability evolution over the SBN baseline

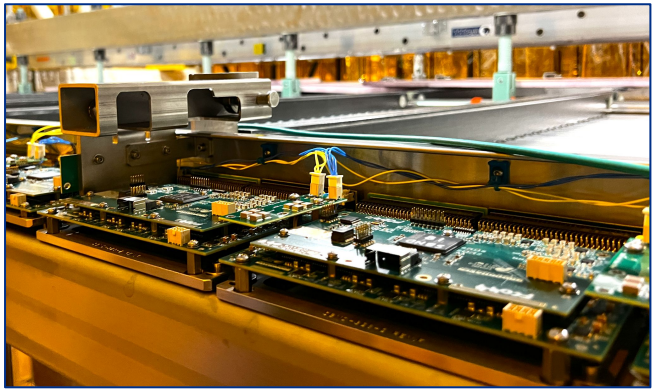
(probability shown near the peak neutrino energy)

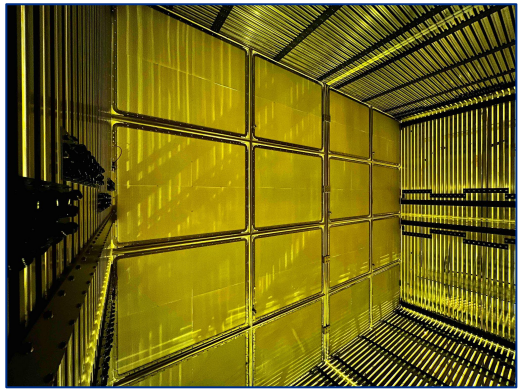
Time Projection Chamber (TPC)

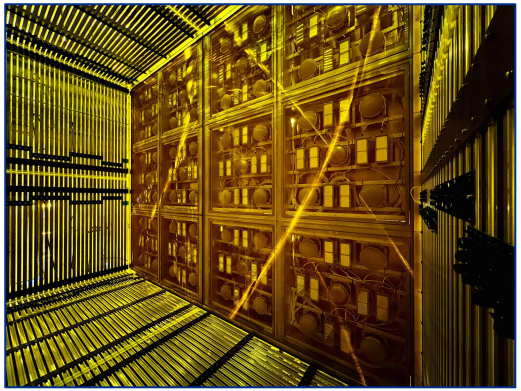
- Two TPC regions that share a central HV cathode
  - 5m (L) x 4m (H) x 2m (drift) (x2)
  - 112 ton total active argon mass
- Drift HV = -100 kV
- 3 wire planes
  - 1 collection (vertical)
  - 2 induction (±60°)
- TPC cold electronics
  - shaping, amplification, and digitization in cold
  - **11,264 wire channels read out by 88 FEMBs** mounted directly to the wire plane frames





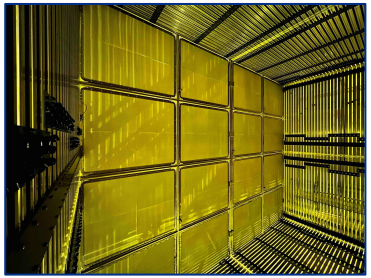


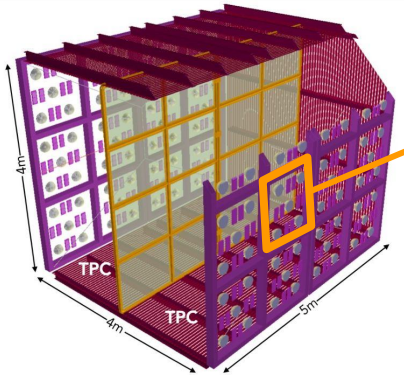




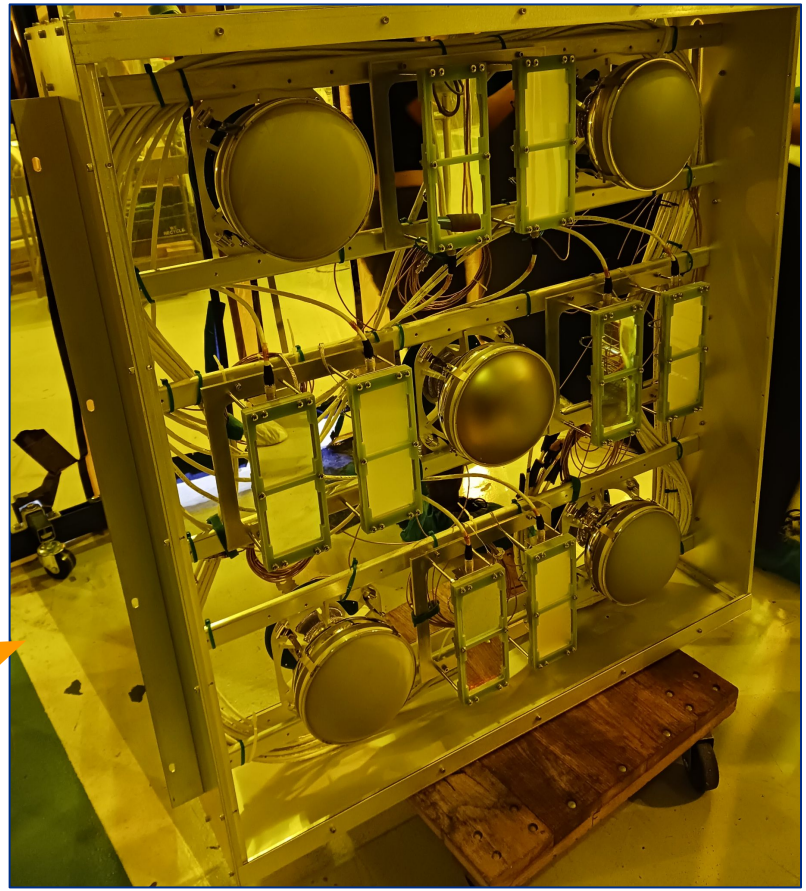
Photon Detection Systems (PDS)

- Argon scintillation light is 128 nm (VUV) - requires wavelength shifting for detection
- **120 PMTs** - Hamamatsu R5912-mod 8”
- **192 X-ARAPUCA** devices composed of a dichroic filter window on a highly internally reflective box instrumented with SiMPs
- Reflective foil panels coated with wavelength shifter are embedded into the cathode plane
- Substantial light-yield increase over previous LAr neutrino detectors: ≥100 pe/MeV



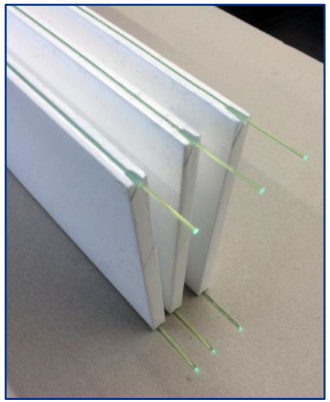


24 Photon Detection Boxes mounted beyond anode wires

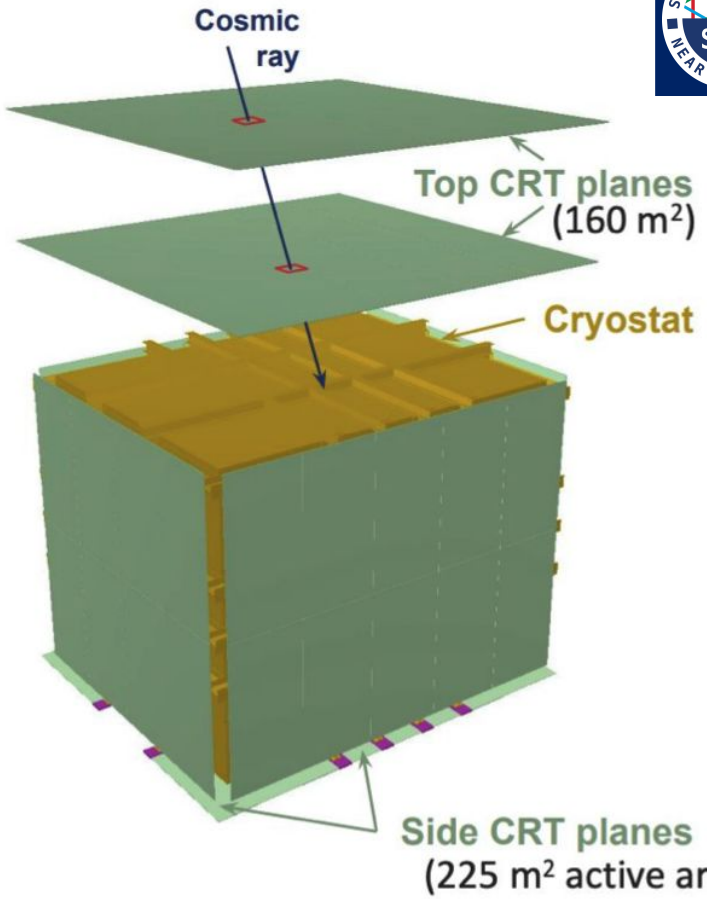


Cosmic Ray Tagger (CRT)

- CRT system will surround the SBND cryostat on all 6 sides.
  - double layer telescope on top
- **142 CRT modules** built from sixteen 10mm x 112mm wide scintillator strips. Two WLS fibers per strip read out at the end with MPPC photo-diodes (32 per module).
- CRT not yet completely installed - in next talk, Peter will present the schedule for completing installation.



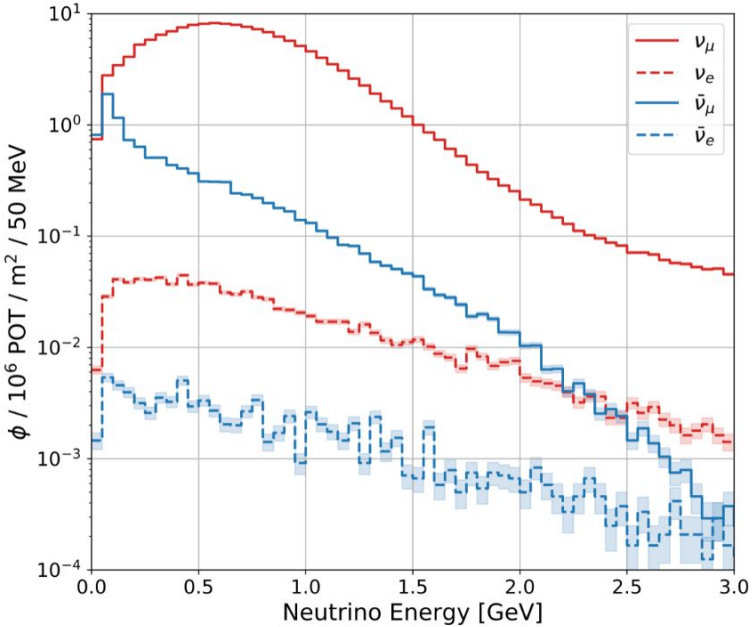
Installation of CRT North Wall, May 2023



Booster Neutrino Beam (BNB) and Collecting Neutrino Events

- **Some BNB technical specs:**
  - 8 GeV protons from the Booster impinged on a 1.7 interaction length beryllium target. Focusing horn around target bends charged secondaries into a 50 m long decay pipe. SBND sits ~60 m past the end of decay region.
  - Proton bunches are extracted from the Booster at an **average rate of 2.5–5 Hz**, depending on the configuration of the complex.
  - Each BNB spill is **1.6 μs in total length** (81 buckets, 2ns wide, 19 ns between [53 MHz]).
  - Typical spill intensity is **4.5e12 protons**.
- **Given SBND's mass and proximity to the beam, ~1:20 spills will produce a neutrino interaction in the active volume of the TPC.**
  - For comparison, ICARUS sees a neutrino ~1:180 spills; MicroBooNE ~1:600.
  - SBND uses a scintillation light-based trigger to identify beam spills with a neutrino and instruct the DAQ to record.
  - Not critical for online bandwidth (DAQ can run at 5 Hz), but the trigger improves the efficiency of offline data storage and processing.
  - SBND trigger system can implement many other types of triggers as well: unbiased, off-beam, different light criteria, use CRT inputs to collect efficient calibration samples, pre-scales.

Booster Neutrino Beam Fluxes



Neutrino flux at the SBND front face

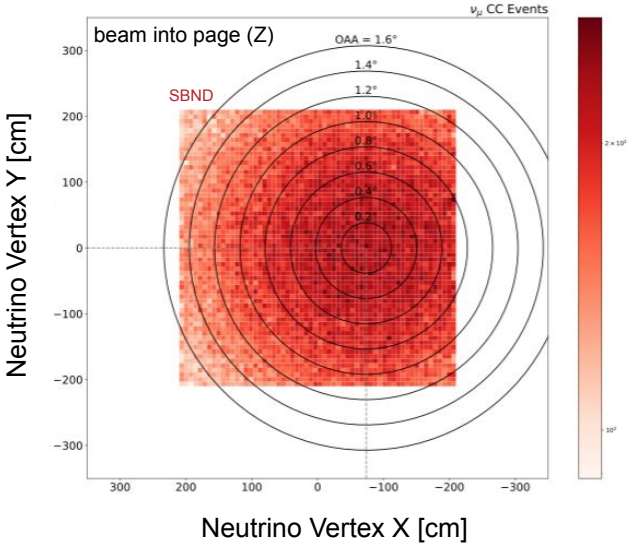
Mean muon-neutrino energy: ~0.8 GeV

Beam composition:

ν_μ (93.6%)

$\bar{\nu}_\mu$ (5.9%)

ν_e+$\bar{\nu}_e$ (0.5%)



SBND is close enough to the source to easily see the shape of the neutrino beam across the face of the detector.
This “SBND-PRISM” effect can be exploited for physics!

SBND Collaboration

250 Total Collaborators

211 Scientific Collaborators
(faculty/scientists, postdocs, PhD students)

38 Institutions

4 Brazilian Universities

CERN

1 Spanish University, 1 National Laboratory

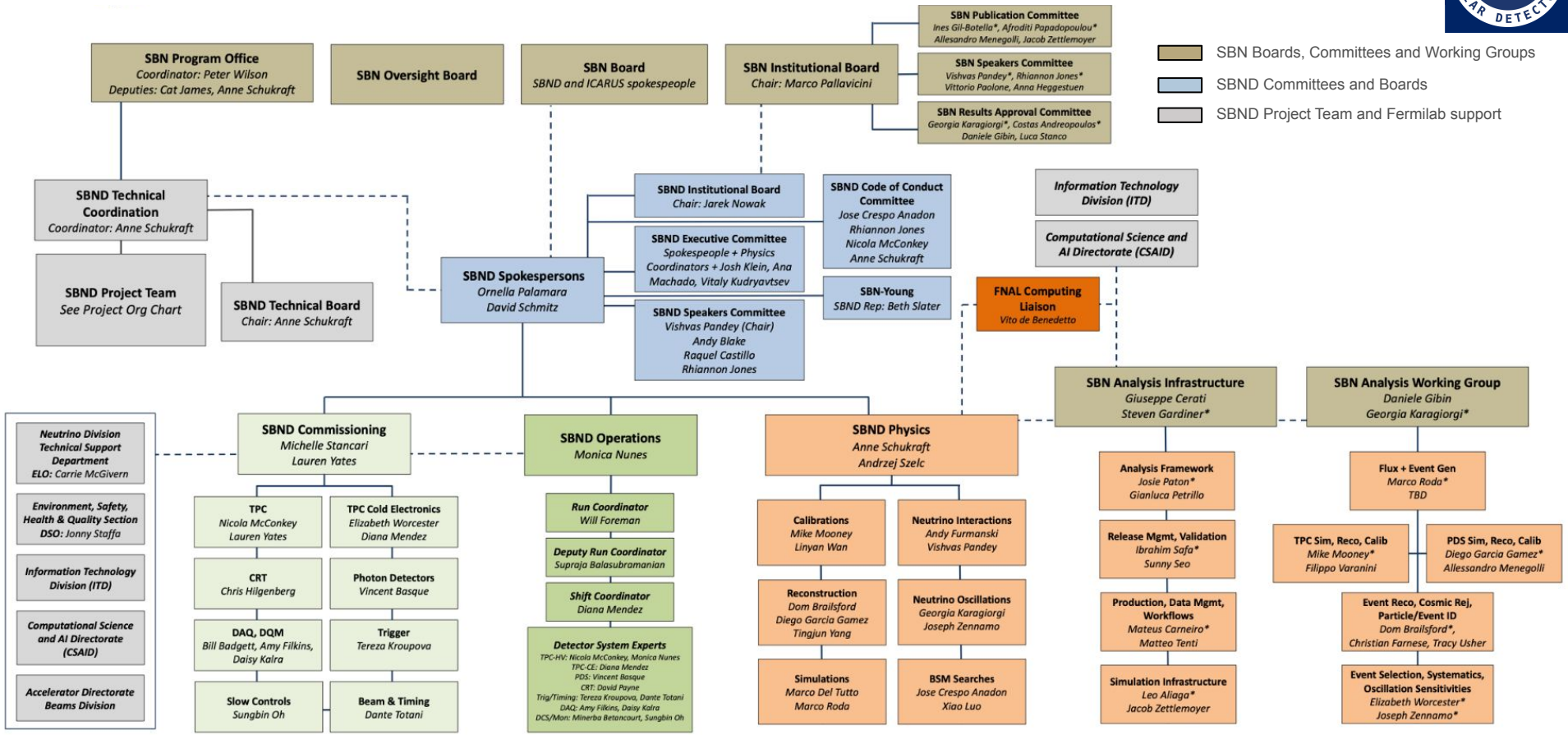
1 Swiss University

10 UK Universities

16 US Universities, 4 National Laboratories

Argonne National Laboratory	USA
Universität Bern	Switzerland
Brookhaven National Laboratory	USA
University of California, Santa Barbara	USA
Universidade Estadual de Campinas	Brazil
CERN	CERN
University of Chicago	USA
CIEMAT	Spain
Colorado State University	USA
Columbia University	USA
University of Edinburgh	UK
Universidade Federal do ABC	Brazil
Universidade Federal de Alfenas	Brazil
Fermi National Accelerator Laboratory	USA
University of Florida	USA
Universidad de Granada	Spain
Illinois Institute of Technology	USA
Imperial College London	UK
Lancaster University	UK
University of Liverpool	UK
Los Alamos National Laboratory	USA
Louisiana State University	USA
University of Manchester	UK
University of Michigan	USA
University of Minnesota	USA
University of Oxford	UK
University of Pennsylvania	USA
Queen Mary University of London	UK
Rutgers University	USA
São José dos Campos	Brazil
University of Sheffield	UK
University of Sussex	UK
Syracuse University	USA
Texas A&M University	USA
University of Texas at Arlington	USA
Tufts University	USA
University College London	UK
Virginia Tech	USA

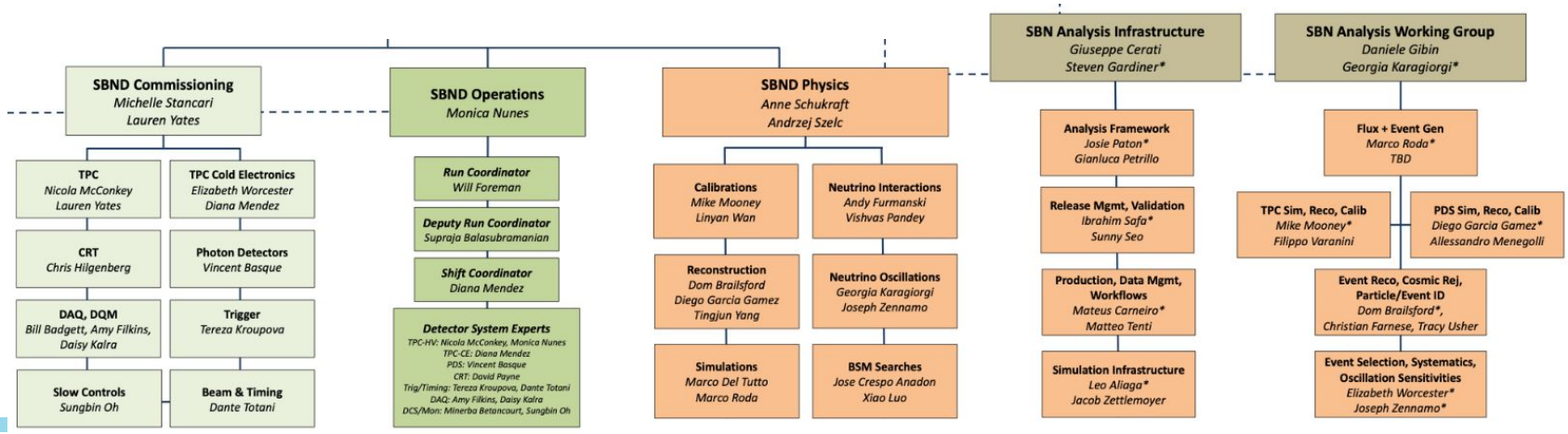
Collaboration Organization



Collaboration Organization

SBND is currently organized into three main groups:

- **Commissioning Group**, in charge of commissioning the detector; the process of activating all components and validating that the systems are configured to produce physics-quality data and are capable of stable running.
- **Operations Group**, in charge of ensuring smooth operations and the collection of physics-quality data over the duration of data taking.
- **Physics Group**, in charge of coordinating the different physics analyses and preparing the tools needed to perform detector calibrations, simulate the experiment, reconstruct events, and produce physics results.
  - The Physics Group is directly linked to the **SBN Analysis** working group (in charge of SBN joint-detector analyses) and to the **SBN Analysis Infrastructure** working group (in charge of data and software management and processing in SBN).



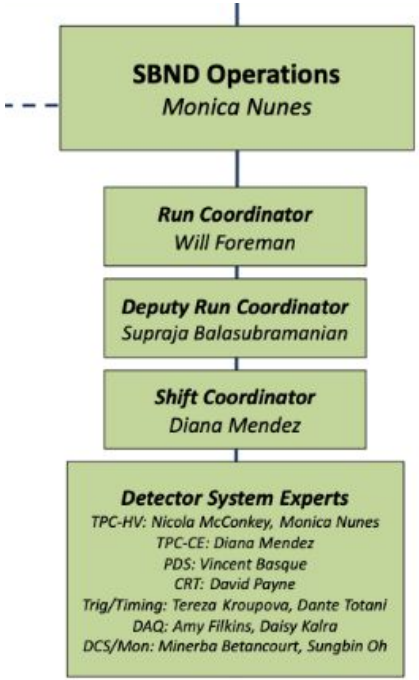
Operations Planning Process

- An **Operations Planning Task Force** (OPTF) was formed in May 2023 to prepare systems, procedures, policies, and documentation needed for the operations phase of the experiment - including this review.
- A key purpose of the OPTF has been to **facilitate communication across different activities** (from shift-taking to physics analysis).
- The task force is composed of representatives from efforts ranging from commissioning, to detector monitoring, to data management, to reconstruction, calibration, and analysis.
  - 15 members in total
  - Spokepersons chaired the Task Force

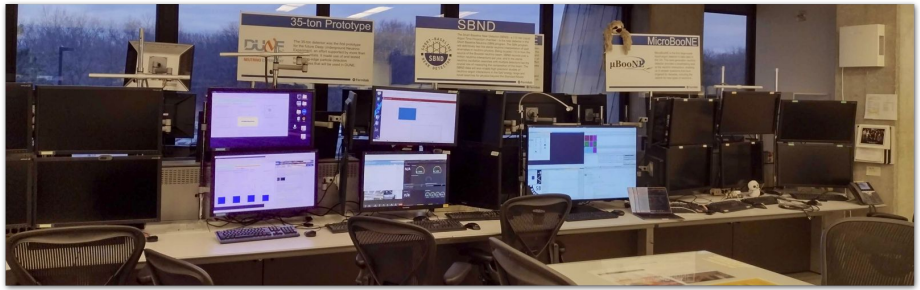
- **The charge for the OPTF included:**
  - Establish an SBND control room station at FNAL and ensure it is ready for shift-taking
  - Establish remote shifting capabilities
  - Generate documentation needed for shifters to safely operate the detector
  - Ensure ability to control and monitor all detector systems as needed for operations
  - Ensure ability to monitor and QC the data being collected during operations
  - Ensure trigger system capable of recording data needed for calibration and physics goals in early running
  - Ensure readiness to handle and process data as required for operations
  - Ensure availability of all beam information required for offline analysis of data
  - Ensure ability to process and analyze data offline as needed for calibration and physics goals in early running.

Minerba Betancourt, Andrew Brandt, Marco Del Tutto, Steven Gardiner, Bruce Howard, Moon Jung, Tom Junk, Mike Mooney, Sungbin Oh, Andrzej Szelc, Tingjun Yang, Lauren Yates, Joseph Zennamo, OP, DS

Operations Group and Start of Shifts



SBND shift station in ROC-West, Wilson Hall



- SBND Operations Team in place since the beginning of the year.
- 24/7 Detector Monitoring Shifts by collaborators started on **January 29, 2024** - during cryostat piston purge and cooling.
  - Going very well! Successfully transferred many technical solutions for shifting from experience in ICARUS.
  - Advancements in shift processes and documentation continuously made thanks to Ops Team and feedback from shifters.
  - Shifts scheduled through June 30 (we schedule in 6 month blocks).
- Detector System Expert teams are building up; Lead Experts identified for all systems; 24/7 on-call Expert Shifts have started

Review Agenda & Introduction of Presenters

- **Introduction to SBND and Operations Planning Overview**
  - Ornella Palamara (FNAL) & David Schmitz (U. of Chicago) - SBND co-Spokespersons, OPTF chairs
- **Cryo Commissioning Status and Completing the SBND Project**
  - Peter Wilson (FNAL) - SBN Program Coordinator
- **Detector Commissioning**
  - Lauren Yates (FNAL) - SBND Commissioning co-Coordinator, OPTF member
- **Data Acquisition**
  - Tingjun Yang (FNAL) - SBND DAQ commissioning team, OPTF member, SBND Reconstruction co-Convener
- **Detector Control and Monitoring Infrastructure**
  - Sungbin Oh (FNAL) - SBND Slow Controls Commissioning Convener, OPTF member
- **Operations Group and Ops Overview**
  - Monica Nunes (FNAL) - SBND Operations Coordinator
- **Shift Procedures and Status**
  - Will Foreman (IIT) - SBND Run Coordinator
- **Data Management and Computing**
  - Steven Gardiner (FNAL) - SBN Analysis Infrastructure Group co-Coordinator, OPTF member
- **Run Plan and Analysis Outlook**
  - Andrzej Szelc (U. of Edinburgh) - SBND Physics co-Coordinator, OPTF member
- **Detector Calibrations**
  - Mike Mooney (Colorate State U.) - SBND Calibrations co-Convener, SBN TPC Sim/Reco/Cal co-Convener, OPTF member

Fermilab Roles and Resources - ND Technical Support

Neutrino Division (ND) - primary source of technical assistance to the SBND collaboration and oversight of experiment operations. ND provides funds for the operation and maintenance needs of the SBND detector and the SBN Near Detector (SBN-ND) facility, including cryogenics systems.

- The **Technical Support Department** (TSD) provides key operations support:
  - **Experiment Liaison Officer** (ELO), currently **Carrie McGivern**, works with the SBND Operations Coordinator to identify necessary resources to support the experiment and to ensure all work in the SBN-ND facility is coordinated with required work planning, scheduling, and safety procedures.
  - **Operations Support Group** (OSG) provides technical support for **online** and **DAQ** systems.
  - **Electrical Group** provides support for electronics infrastructure such as detector AC power distribution, rack protection systems, the ground impedance monitor, and the cryogenics controls system.
  - **Cryogenics group** has primary responsibility for operation of the cryogenics systems. The group provides 24/7 emergency response through on-call expert engineers, performs daily monitoring checks of the cryogenic system performance and arranges for scheduled maintenance.
  - **Electrical and mechanical technician support** on an as-needed basis. The leaders of the groups work with the ELO to identify additional technician resources from other divisions if needed.

More details on the critical FNAL Roles and Resources are in the EOP and will be throughout today's presentations.

Fermilab Roles and Resources - Safety

Environment, Safety, Health & Quality Section (ESHQ) - Safe operation of SBND is a top priority

- The SBND **Operations Coordinator** is responsible, in consultation with the **Division Safety Officer** (DSO), currently **Jonny Staffa**, with making sure that all work on the detector is conducted according to Fermilab safety rules.
- Hazard Awareness Training, ODH training, two person rules are required for access and working in the SBN-ND building.
- All work occurring in the SBN-ND building must be discussed in toolbox meetings and work that is considered high risk requires written hazard analyses and work plans.
- The DSO oversees any SBN activities where there are safety concerns.
- Any new equipment installed in the SBN-ND building must undergo Operational Readiness Clearance (ORC) review prior to being put into full operation.

More details on the critical FNAL Roles and Resources are in the EOP and will be throughout today's presentations.

Fermilab Roles and Resources - Beam

Accelerator Directorate (AD) - beam operations and monitoring

- The Beams Division within the AD is responsible for the **commissioning, operation**, and **maintenance** of the **BNB proton beam line**, **target**, **horn**, and **decay pipe**.
- AD is responsible for the maintenance of all existing standard **beamline elements**, **instrumentation**, **controls**, and **power supplies**.
- AD also provides the **online monitoring** of the intensity and beam quality of the primary proton beam.
- The External Beam Delivery Department provides the necessary **beam timing signals** and provides support in delivering the beam signals, via the AD network, from the sending locations (MI-12) to the experiment hall.
  - The setting up of timing signals at the experiment hall is up to the experiment, but the External Beam Delivery experts are available for consultation and help.
  - The replacement of broken modules (at the experiment's site) will be done by the AD Controls Department, contacted by the External Beam Delivery Department upon the experiment's notification.

More details on the critical FNAL Roles and Resources are in the EOP and will be throughout today's presentations.

Fermilab Roles and Resources - Computing

Fermilab's computing organizations, including the **Information Technology Division** (ITD) and the **Computational Science and Artificial Intelligence Directorate** (CSAID), support the needs of the SBN program, including SBND-specific needs, through provision, maintenance and support of common, and in some cases experiment-specific, core and scientific services and software.

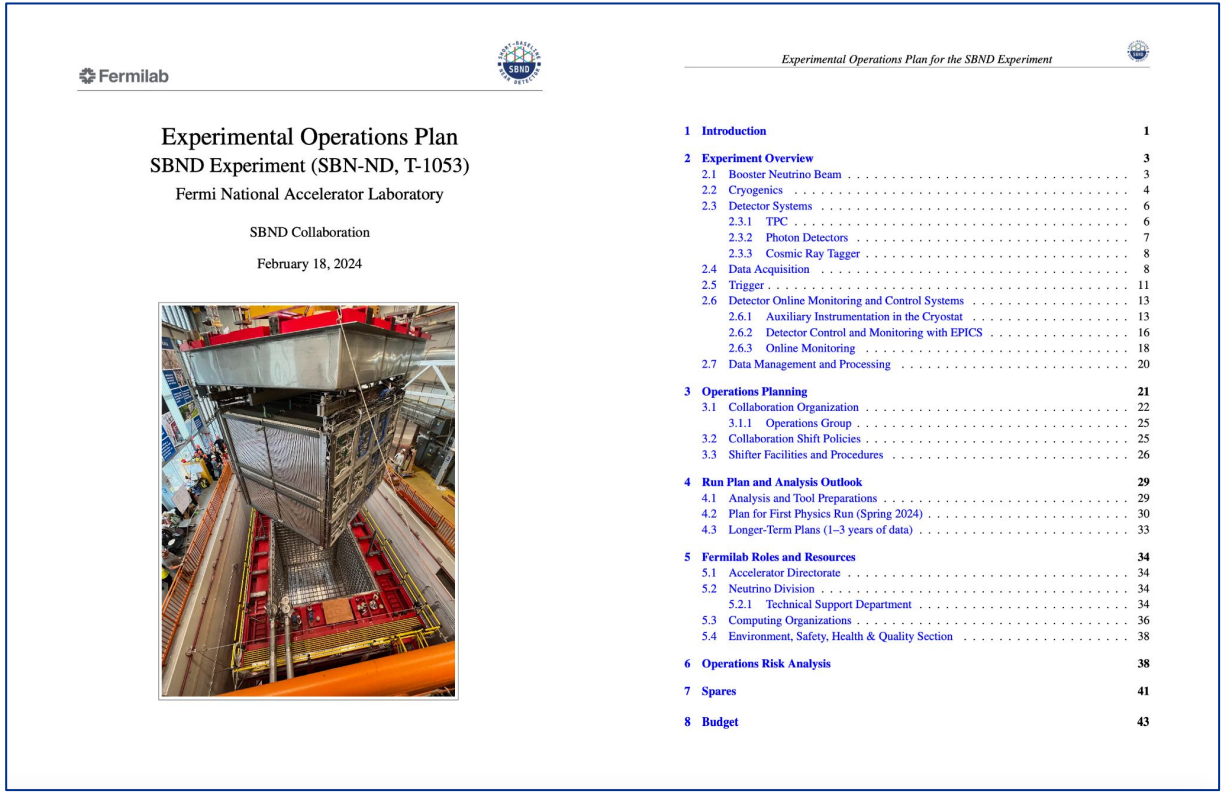
- CSAID assigns a **Liaison to the SBND experiment**, currently **Vito Di Benedetto**, whose responsibilities include maintaining **communication between the experiment and the computing organizations**, as well as ensuring that the computing needs, agreements, issues and any other relevant items between the experiment and Fermilab are addressed in a timely and mutually agreed upon manner.
- CSAID provides user support for the common `artdaq` software framework, and also system administrative support of SBND's **DAQ** and **control room computers**.

More details on the critical FNAL Roles and Resources are in the EOP and will be throughout today's presentations.

Review Charge Questions

Charge Question #1:

Has the experiment written a completed **Experiment Operations Plan (EOP)**? The document should include: (a) an outline of the Science goals (b) a description of operations tasks and how they will be covered, (c) ES&H activities and how they will be managed, (d) organization charts showing the management structure for the experiment and how it interfaces with the laboratory, (e) Fermilab resources and roles as they pertain to each Directorate, (f) the model for data processing and analysis including the computing budget and effort required, (g) a list of the identified resources available, and (h) a description of the roles and responsibilities of each institution together with a list of support required by each institution from funding agencies.



Fermilab

Experimental Operations Plan
SBND Experiment (SBN-ND, T-1053)
Fermi National Accelerator Laboratory

SBND Collaboration

February 18, 2024

Experimental Operations Plan for the SBND Experiment

Fermilab

Review Charge Questions

Charge Questions	Where to look for answers
2. What work remains to prepare the experiment to begin physics data-taking?	
a. The installation of the CRT is not expected to be complete at the start of the commissioning period. Is any other work required to complete the assembly of the detector? When will assembly of the full detector be complete? How will this impact the first physics run?	Peter: Completing the SBND Project Andrzej: Run Plan and Analysis Outlook
b. Is there a plan for commissioning the detector in preparation for an initial physics run in FY24? Are the roles and responsibilities of members of the collaboration and Fermilab staff clearly defined for this commissioning period?	Lauren: Detector Commissioning Tingjun: Data Acquisition throughout for FNAL roles and responsibilities
c. Is there a plan for monitoring the beam and the data quality and has the infrastructure been tested? If not, what actions are required to complete the data quality monitoring system before physics data-taking?	Sungbin: Detector Control and Monitoring Infrastructure Will: Shift Procedures and Status

Review Charge Questions

Charge Questions	Where to look for answers
3. Is there a well-understood run plan for the remainder of FY24, consistent with the planned accelerator schedule and performance? Have adequate resources from the laboratory and the collaboration been identified for an efficient and safe running of the experiment and for maintenance of the detector, and have the responsibilities of the collaboration and Fermilab staff been clearly defined?	Lauren: Detector Commissioning Andrzej: Run Plan and Analysis Outlook Mike: Detector Calibrations Monica: Operations Group and Ops Overview
4. Are there well-developed plans for data processing and analysis? Have sufficient resources from the laboratory and collaboration been identified to execute these plans?	Steven: Data Management and Computing Andrzej: Run Plan and Analysis Outlook Mike: Detector Calibrations
5. Are there clear goals set for reporting and publishing the results from the experiment in a timely fashion?	Andrzej: Run Plan and Analysis Outlook Mike: Detector Calibrations
6. Are the ES&H (Environment, Safety, and Health) aspects of all anticipated work properly assessed and managed, with clear roles and responsibilities?	Peter: Cryo Commissioning Status Lauren: Detector Commissioning Monica: Operations Group and Ops Overview

SBND's Early Run Plan Goals

- **Achieve stable operation within a few months from detector filling.**
  - Commissioning team has a detailed plan and is working very hard toward this goal.
  - Detector system configurations must be ~stable and appropriate for the physics goals of an initial data set.
  - The CRT will not yet be complete, but this is acceptable for many physics analyses.

- **Collect a first substantial physics-quality dataset before the 2024 summer shutdown.**
  - Depending on the configuration of the accelerator complex, the BNB can delivery **between 3.5e19 and 5.2e19 protons on target (POT) per month** (a main difference being whether NuMI is running or not).
  - Note that a 6-7e19 POT exposure is already comparable to the entire MicroBooNE neutrino data set.
  - Potential dataset of hundreds of thousands of ν_μ CC and several thousand ν_e CC interactions.

- **Further optimize detector operating configuration during summer 2024.**
  - Come out of the summer shutdown (October 2024) fully optimized for physics data taking.
  - Including a fully integrated CRT system.
  - Data taking will continue over the summer to collect cosmic ray data for studying cosmic background and performing more accurate calibrations.

Summary

- The SBND Collaboration is excited to be preparing for the operations and physics phase of the experiment!
- Today our team will present the work going on throughout the collaboration in preparation for transition to operations.
- Following successful commissioning, underway now, **SBND aims to collect a substantial first dataset of neutrino interactions before the summer shutdown.**
- In the longer run, SBND intends to operate until at least the long-shutdown scheduled for 2027. SBND stands to collect 6-12e20 POT (depending on beam delivery and schedule), **resulting in the largest sample of neutrino interactions on argon by a factor of 10–20.**

February 9, 2024 : Chilly Checkout Day - detector at 130K

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  - Monica Nunes (FNAL) - SBND Operations Coordinator
- **Shift Procedures and Status**
  - Will Foreman (IIT) - SBND Run Coordinator
- **Data Management and Computing**
  - Steven Gardiner (FNAL) - SBN Analysis Infrastructure Group co-Coordinator, OPTF member
- **Run Plan and Analysis Outlook**
  - Andrzej Szelc (U. of Edinburgh) - SBND Physics co-Coordinator, OPTF member
- **Detector Calibrations**
  - Mike Mooney (Colorate State U.) - SBND Calibrations co-Convener, SBN TPC Sim/Reco/Cal co-Convener, OPTF member

Backup

Operations Budget

M&S projected annual cost of steady operations
[informed by MicroBooNE and ICARUS operations]

Cryogenic system maintenance	$ 43K
Liquid Nitrogen	$ 112K
Misc. Operations Expenses	$ 50K
Replacements for end-of-life DAQ servers	$ 70K

Projected annual technical personnel support from Particle Physics Directorate
[informed by ICARUS operations]

Cryo Engineering support	0.30 FTE
Electrical Engineering support	0.15 FTE
Technician support (electrical and mechanical)	0.40 FTE
Online computing support	0.50 FTE
Experiment Liaison Officer	0.20 FTE

Currently most of the technical support comes from personnel in the Neutrino Division Technical Support Department.

The online computing support from the Particle Physics Directorate does not include ARTDAQ support and SLAM team support, which are provided by CSAID. It does include coordinating OS upgrades and end-of-life server replacements, as well as general support for online infrastructure such as databases, slow controls, networking, etc.

Managed by Michelle Stancari as Head of SBN Department. Details in the SBND EOP.