SBN Joint Working Groups Update

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SBN Oversight Board Meeting
September 8, 2023

SBN Joint Working Groups

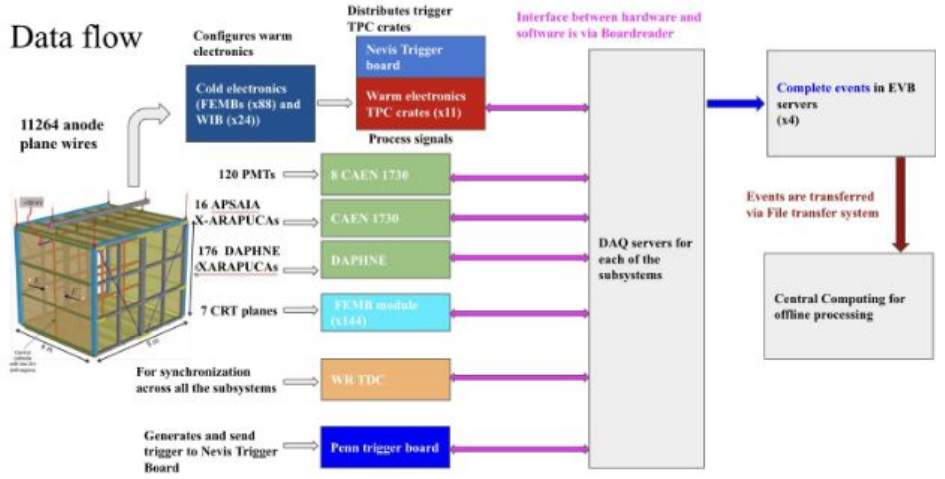
- **SBN DAQ and Data Pre-Processing** [conveners: Bill Badgett, Wes Ketchum]
  - Develop common tools for trigger, data acquisition, and data preprocessing, and coordinate activities in those areas
- **SBN Slow Controls** [conveners: Geoff Savage, Sungbin Oh]
  - Goal: Develop control systems based on hardware and software interfaces as identically as possible for the two detectors
- **SBN Cosmic Ray Tagger** [conveners: Igor Kreslo, Minerba Betancourt]
  - Goal: Review CRT production status and the installation plans for the two detectors, develop common CRT DAQ and monitoring
- **SBN Analysis Trigger** [conveners: Angela Fava, Michelle Stancari]
  - Goal: Share and discuss strategies for cross-checking trigger efficiencies independently measured by the two detectors
- **SBN Analysis Infrastructure** [conveners: Giuseppe Cerati, Steven Gardiner]
  - Coordinate and address data and software infrastructure and computing resource needs across SBN
- **SBN Analysis** [conveners: Daniele Gibin, Georgia Karagiorgi]
  - Goal: Take care of all aspects of multi-detector physics analysis for SBN sterile neutrino oscillation searches

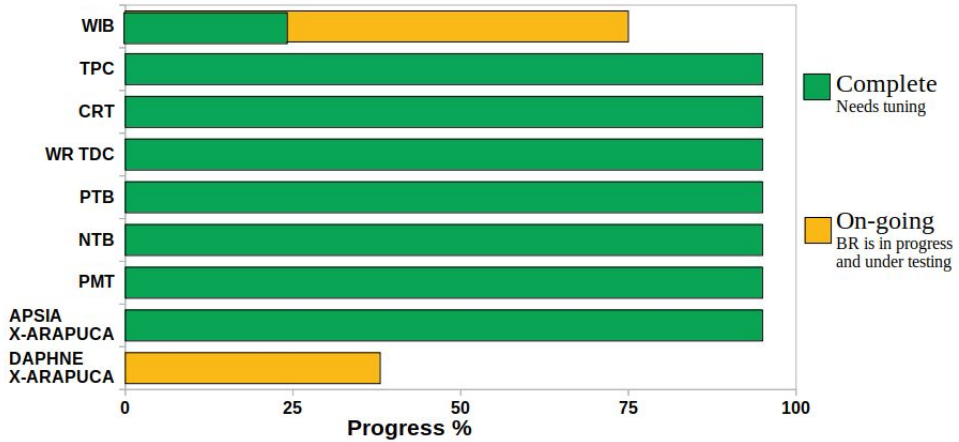
SBN DAQ and Data Pre-Processing

- ICARUS: see C. Montanari's presentation.
- SBND: see next two slides.

SBND DAQ Overview

- List of Subsystems
  - Cold Electronics
  - Warm Electronics (11 Nevis TPC Readout Crates, Nevis Trigger Board (NTB) in TPC Crate-1).
  - Photon Detection System (PDS)-PMTs and X-ARAPUCAs (APSAIA and DAPHNE).
  - Cosmic Ray Tagger (CRT).
  - White Rabbit Time to Digital Converter (WR TDC).
  - Penn Trigger Board (PTB).
- Current progress by subsystem





SBND DAQ Status Update

- Status of DAQ:
  - The group will begin cabling for cold electronics and TPC warm electronics this week, following the finalized TPC channel mapping scheme.
  - DAQ integration tests continue and the group is trying to understand various tunable parameters by looking at the generated files.
  - Network Interface Cards are installed in the CRT servers and CRT-DAQ group will work on configuring the cards and test a DAQ run.
- Status of Slow Controls:
  - Improvements to the Graphical User Interface (GUI) page
  - Scripts that generate alarm server configuration are ready
  - Testing the Drift HV Heinzinger power supply
- Status of DQM:
  - DQM for PMT is fully tested
  - Debugging issues with Online Monitoring tool used for TPC
  - Work on developing and testing Data Quality Monitor (DQM) for CRT and TPC will start soon.

SBN Slow Controls

- ICARUS:
  - No new developments.
  - Niccolo Moggi (architect and point of contact for PMT slow controls) moved to a new position outside physics: a major loss for the experiment.
  - Antonio Gioiosa replacing Niccolo and beginning to learn about the system.
- SBND:
  - See next 3 slides.

SBND Slow Control - Overview

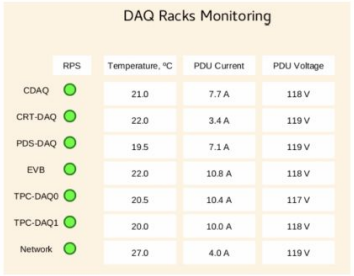
Establish controlling/monitoring system for important devices

- Build input/output controller (IOC) apps
  - Use the EPICS Channel Access protocols to access process variables (PVs)
  - PV : a quantity being monitored or controlled
- Make GUI interface for convenient access to PVs
- Connect to the database servers : archiving history of PVs
- Build monitoring webpage : easy access to history of PVs

Example PVs - TPC Drift HV

Read & Write	Read PV	Write PV
Current limit	sbnd_drift_hv/curr	sbnd_drift_hv/set_curr
Voltage setting	sbnd_drift_hv/meas_volt	sbnd_drift_hv/set_volt
Average number of recording	sbnd_drift_hv/aver	sbnd_drift_hv/set_aver

Example GUI Page



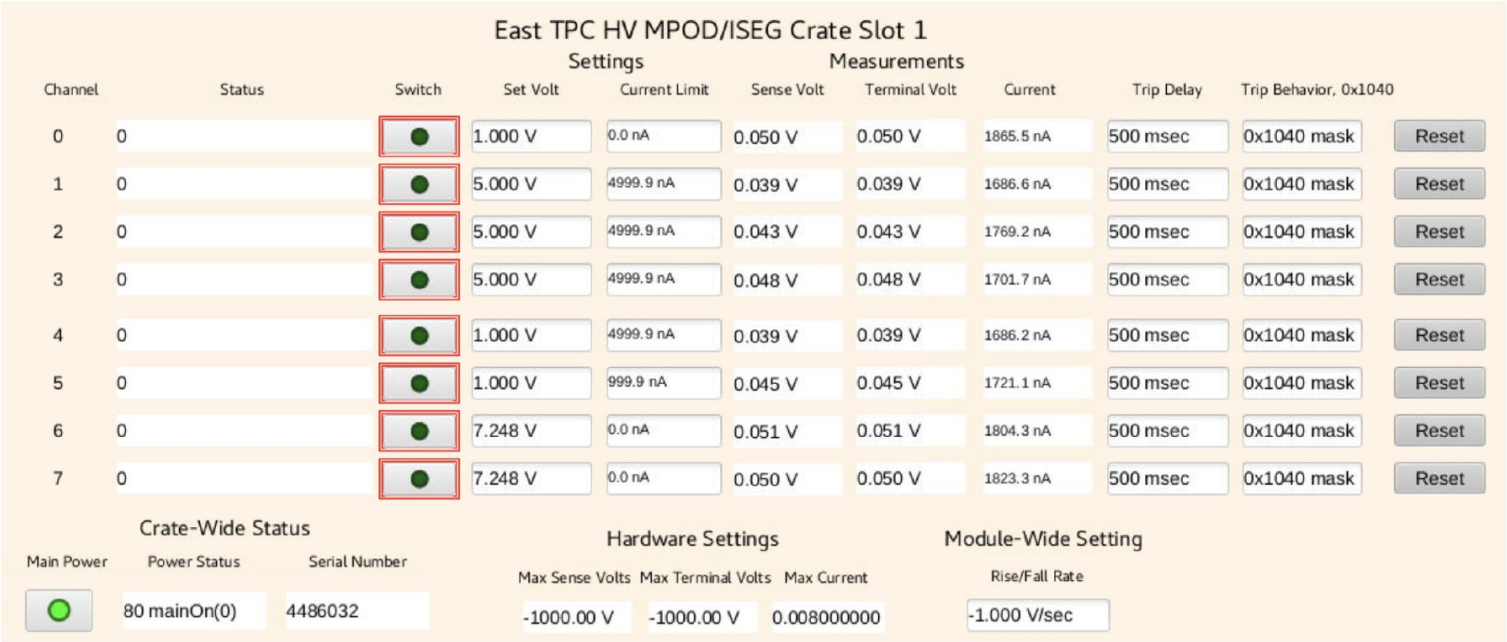
Major updates

- Improvements for TPC powers
- Working on alarm range surveys

1. TPC Power Improvements

Based on feedbacks from sub-system experts

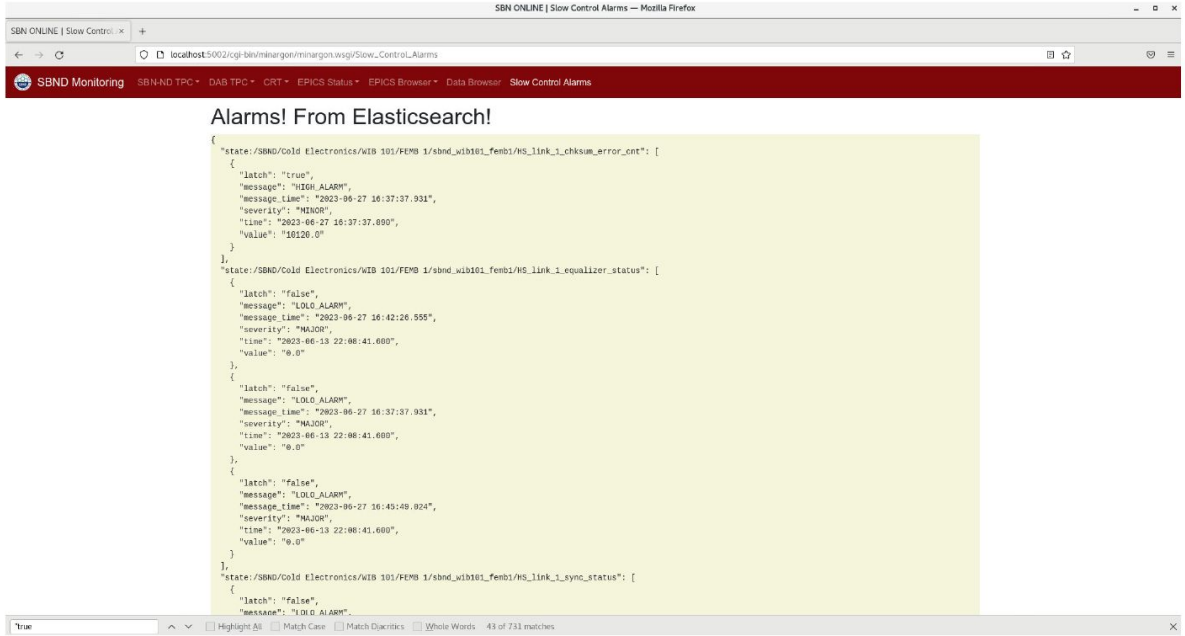
- Current unit : changed to nA from A
- Trip behavior : can be modified now
- Reset button for each channel : no need for power cycle after tripping



2. Alarms

Alarm server and logger

- Alarm range survey is ongoing - done for PL506 and VME8100 (power supply and crate)
- Software packages for the alarm logger are installed and tested well
  - Alarm history is archived into an Elasticsearch DB (database)
  - Can be accessed from the SBN online page : discussing how to visualize it

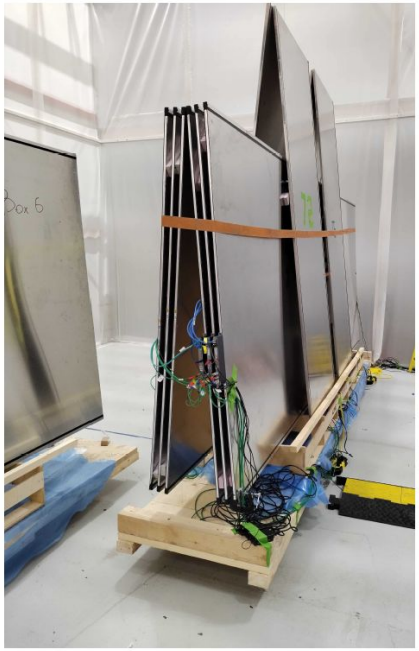


SBN Cosmic Ray Tagger

SBND CRT A-Frame Test Stand

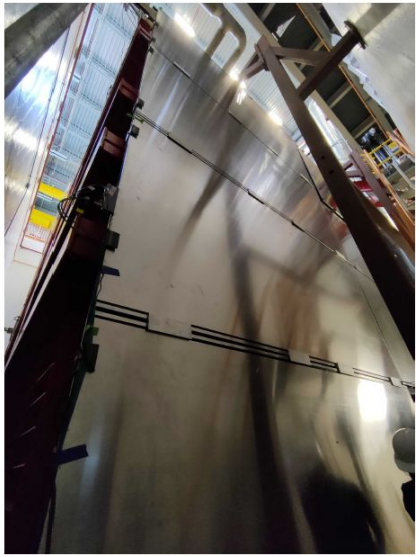
(D0 Assembly Building at Fermilab)

- Test stand at DAB to test and characterize CRT modules prior to installation
  - Light leaks
  - Calibration
  - Tagging efficiency
- Extract initial configuration for later commissioning
- Completion expected end of October



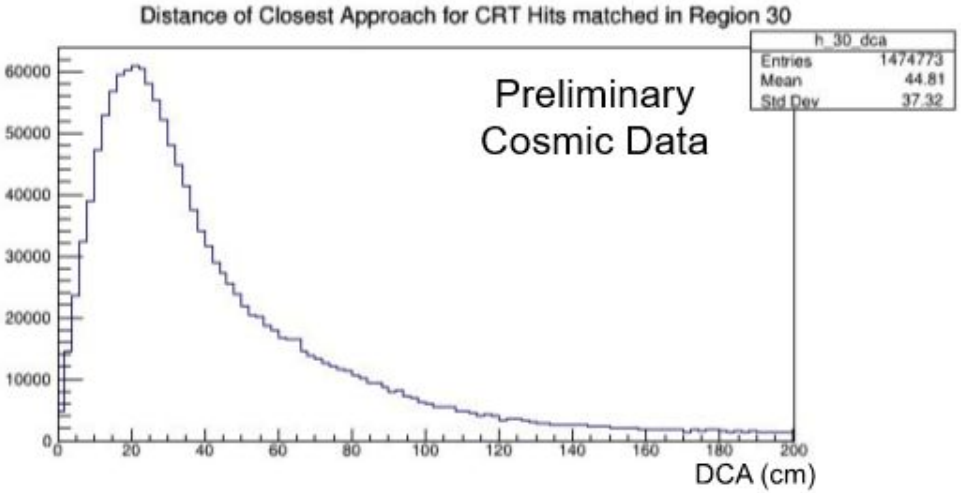
SBND CRT at Near Detector Hall

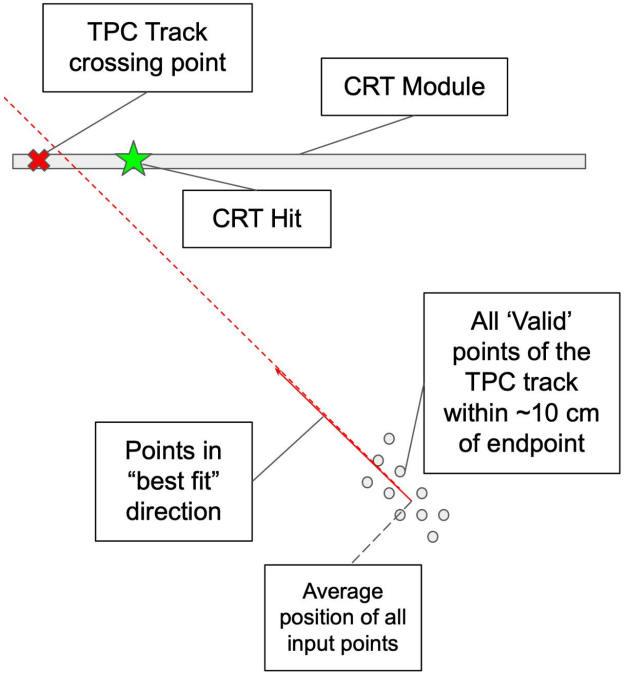
- Bottom CRT
  - Interference with catwalk I-beams resolved
  - Front-end electronics (FEBs) installed + cabling (no power)
- North Wall (Downstream)
  - Mechanical installation last May
  - FEBs + cabling end of July
  - Power for ~1/2 FEBs installed, other half next week
- Remaining power ~ Nov./Dec.



ICARUS CRT – status and updates

- **CRT-TPC matching with data and MC is being evaluated**
  - CRT-TPC matching algorithm takes in TPC tracks and looks for CRT hit candidates
  - The procedure uses principal component analysis (PCA) to find track direction from endpoints of TPC tracks





$$\text{Efficiency} = \frac{\text{N particles detected}}{\text{N total passed through detector}}$$

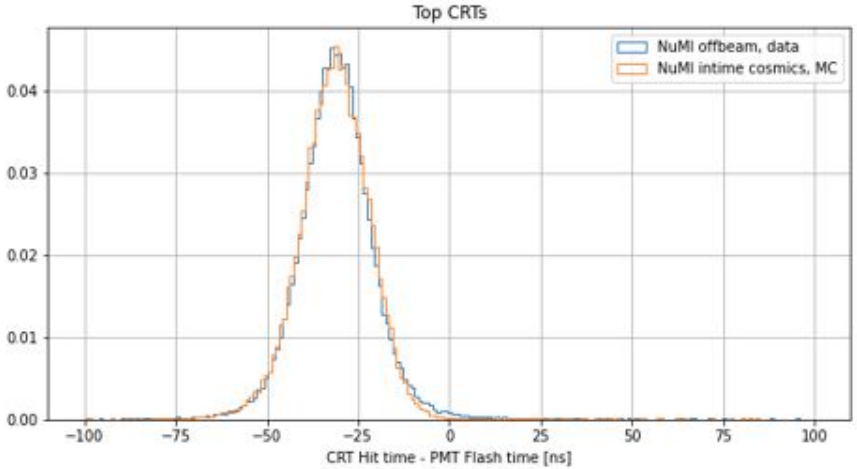
- Preliminary efficiency for top CRT is 97%, where efficiency is defined:

Fermilab

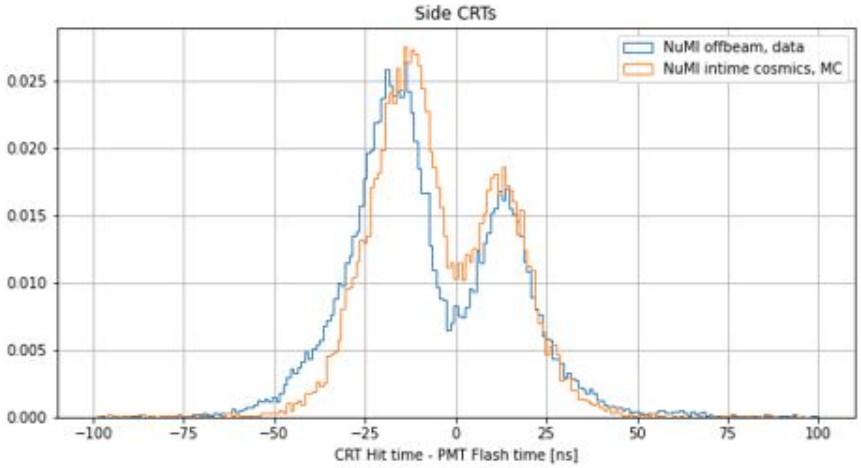
ICARUS CRT – status and updates

- **Data versus MC comparison:**
  - Comparing CRT hit time minus PMT flash time for off beam NuMI data and NuMI intime cosmic MC

Top CRT- PMT matching Data vs MC



Side CRT- PMT matching Data vs MC



Side CRT sees cosmic tracks entering through top and side CRT, and exiting from side CRT

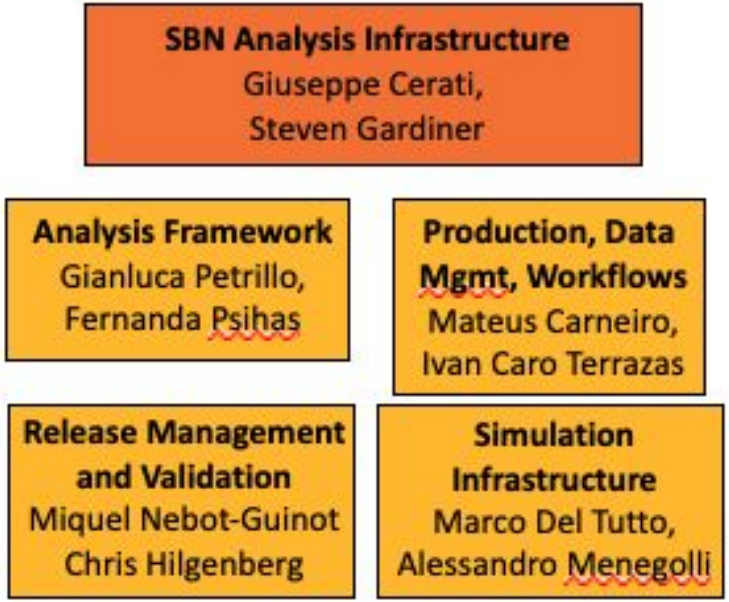
  - Need to follow up with the Data vs MC differences from side CRT

SBN Analysis Trigger

- No updates.

SBN Analysis Infrastructure

- Group charge
  - Oversee computing for the SBN program
  - Coordinate resource requests with Fermilab Computational Science & AI Directory
- Activities include
  - Planning and execution of production campaigns for the SBN program
  - Data storage and data processing
  - Integration of developments and code releases
  - Development of infrastructure for analyses
  - Ensuring consistent simulations and processing between SBND and ICARUS for determining correlated uncertainties etc.



SBN Analysis Infrastructure

- Technical Work

  Various tasks were pursued during the July SBN Analysis Workshop and are ongoing, including:

  - Upgrading icaruscode interface to Geant4 + porting MicroBooNE systematics
  - Updates to neutrino interaction model uncertainties and infrastructure
  - Reconstruction of MeV-scale activity
  - Syncing low-level reconstruction and event displays
  - Defining data-handling strategy (file families, etc.) for SBND
  - Planning for machine-learning-based production workflows
  - Enabling use of overlays: simulated neutrino interactions superimposed on off-beam data

SBN Analysis Infrastructure

- High-level planning

  Detailed plan in development for large production to support 2024 analyses

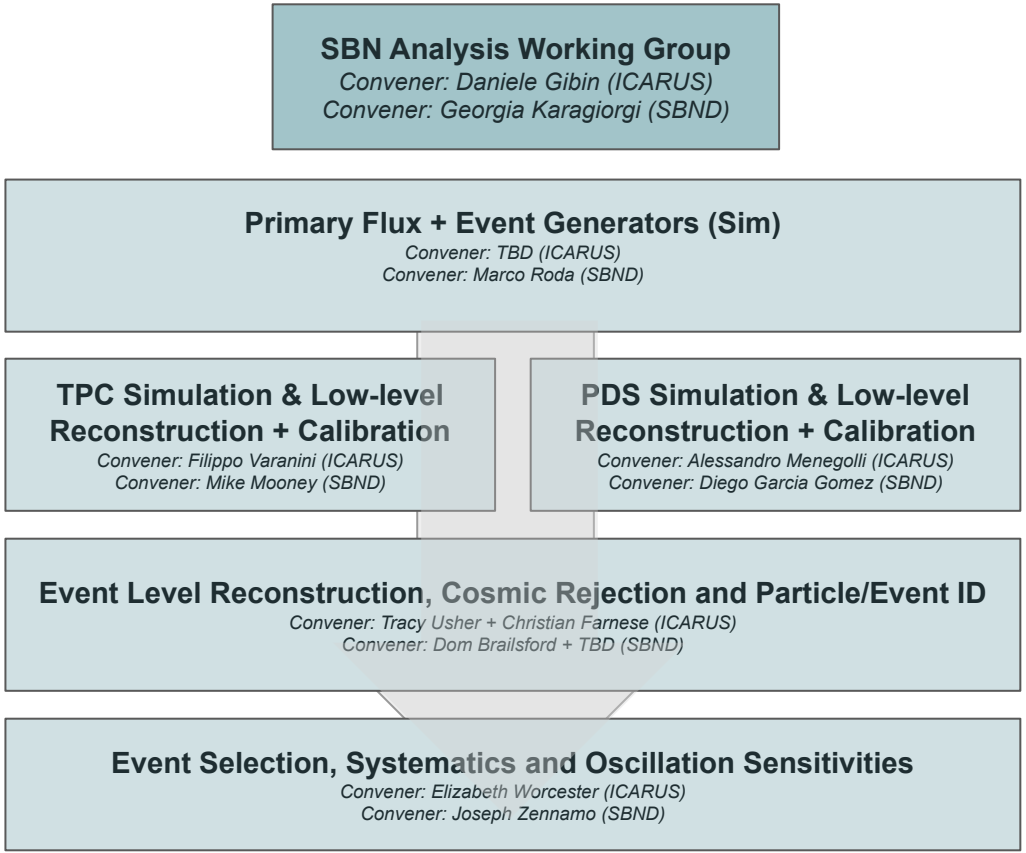
  - Itemized list of requirements
  - Timeline and effort required
  - Procedure for validation and integration of features
  - Data formats and storage strategy
  - Number and size of samples (including det. systematics)
  - Documentation and bookkeeping

- Goals are ambitious, timeline is tight, and resources are limited.
  - Working on optimizing procedures based on past experience and past issues
- Significant increase in group workforce is needed, and essential for success

SBN Analysis

The group was established in 2016 and formally adopted as a SBN Joint Working Group in 2018, in order to:

"Explore how combined SBN physics analysis for sterile neutrino oscillation searches can be most effectively performed. Work focuses on implementing a three detector simulation, building reconstruction and analysis tools within a common framework, and developing an end-to-end common analysis scheme in preparation for real data exploitation."



SBN Analysis

SBN Analysis Infrastructure Working Group

SBND and ICARUS Co-Conveners

The SBN Analysis Working Group also communicates and works closely with the SBN Analysis Infrastructure Working Group in coordinating and addressing data and software infrastructure and computing resource needs across SBN.

SBN Analysis Working Group
Convener: Daniele Gibin (ICARUS)
Convener: Georgia Karagiorgi (SBND)

Primary Flux + Event Generators (Sim)
Convener: TBD (ICARUS)
Convener: Marco Roda (SBND)

TPC Simulation & Low-level Reconstruction + Calibration
Convener: Filippo Varanini (ICARUS)
Convener: Mike Mooney (SBND)

PDS Simulation & Low-level Reconstruction + Calibration
Convener: Alessandro Menegolli (ICARUS)
Convener: Diego Garcia Gomez (SBND)

Event Level Reconstruction, Cosmic Rejection and Particle/Event ID
Convener: Tracy Usher + Christian Farnese (ICARUS)
Convener: Dom Brailsford + TBD (SBND)

Event Selection, Systematics and Oscillation Sensitivities
Convener: Elizabeth Worcester (ICARUS)
Convener: Joseph Zennamo (SBND)

SBN Analysis

Over the past two years, efforts have targeted the following three milestones:

1. **Check:** Reproduce the SBN proposal-era oscillation sensitivities with (three) new oscillation fitting frameworks, using truth-level information ("fake reconstruction") and the same inputs for beam, reconstruction efficiencies, backgrounds, and systematic uncertainties, and check for consistency.
2. **Update:** Update the oscillation sensitivities, still using truth-level information ("fake reconstruction"), and exploiting updated inputs for efficiencies, backgrounds, and systematic effects (accounting for the available/developed SBN event reconstruction and recent results from other LArTPC experiments).
3. **Improve:** Repeat oscillation sensitivity evaluation, this time with full event simulation and reconstruction and detector systematics.

Additionally, we have expanded efforts toward improvements to the oscillation physics assumptions, such as the simultaneous inclusion of appearance and disappearance effects in the fits (multi-channel searches).

SBN Analysis

- Recent major activities:
  - Organized SBN Analysis Workshop in July 2023, at Fermilab

SBN Analysis

- Recent major activities:
  - Organized SBN Analysis Workshop in July 2023, at Fermilab
    - 71 registered attendees, ~40-50 in person, and on zoom
    - 4 topics of high priority: 2D simulation of wire signals and signal processing, SBND/ICARUS simulation and reconstruction convergence, detector systematics, analysis strategy, each organized and led by a set of experts
    - strong support from the production team

- Workshop participants have been presenting at joint WG meetings regularly since workshop

SBN Analysis

- Recent major activities:
  - Held a meeting with SBN Board to discuss our strategy for first joint SBN result: joint SBND+ICARUS muon neutrino disappearance search with SBND statistics collected by summer 2024 accelerator shutdown and ICARUS runs 1+2.
  - Workshop findings: closer coordination will be needed between Analysis Infrastructure and Analysis group (and subgroups) to develop a viable plan for our first result, sync'd with SBND and ICARUS commissioning, operations, data analysis plans, and to plan for needed resources (computing, people, production/software releases, etc.) in order to make this possible.
    - This has started, and we are in the process of developing an organizational chart to first results. The plan, which includes production timelines, resource needs, etc., is to be refined and discussed with SBND and ICARUS leadership, before adopting.
  - To keep SBN Analysis efforts going and further strengthen them over the coming months, we are thinking to have in-person workshops at regular intervals interleaved with ~half a day virtual meetings, which could focus on specific themes.