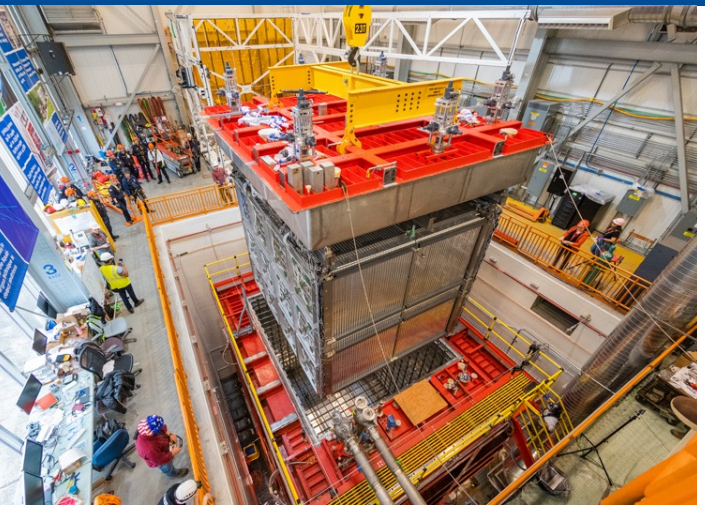

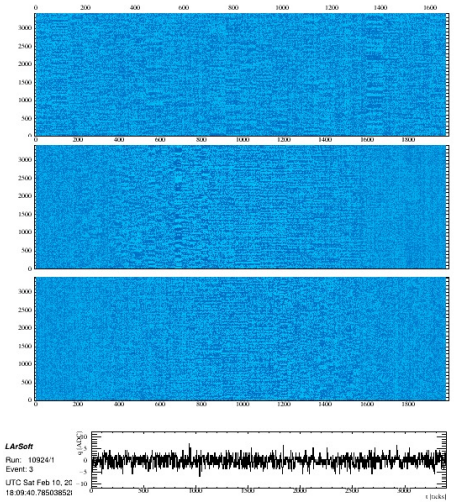

SBND Data Acquisition

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SBND Operations Readiness Review

February 21-22, 2024

Overview

- SBND DAQ is responsible for many operations:
  - Readout of detector electronics from detector subsystems (TPC, photon detectors, CRT, trigger and timing, etc.)
  - Configuration and control of readout electronics systems
  - Interfaces between systems for synchronization and online event-building
  - Monitoring of DAQ health using grafana
  - Transfer of data to permanent storage
- Development activities are largely shared with ICARUS through the common DAQ and Data Pre-processing working Group

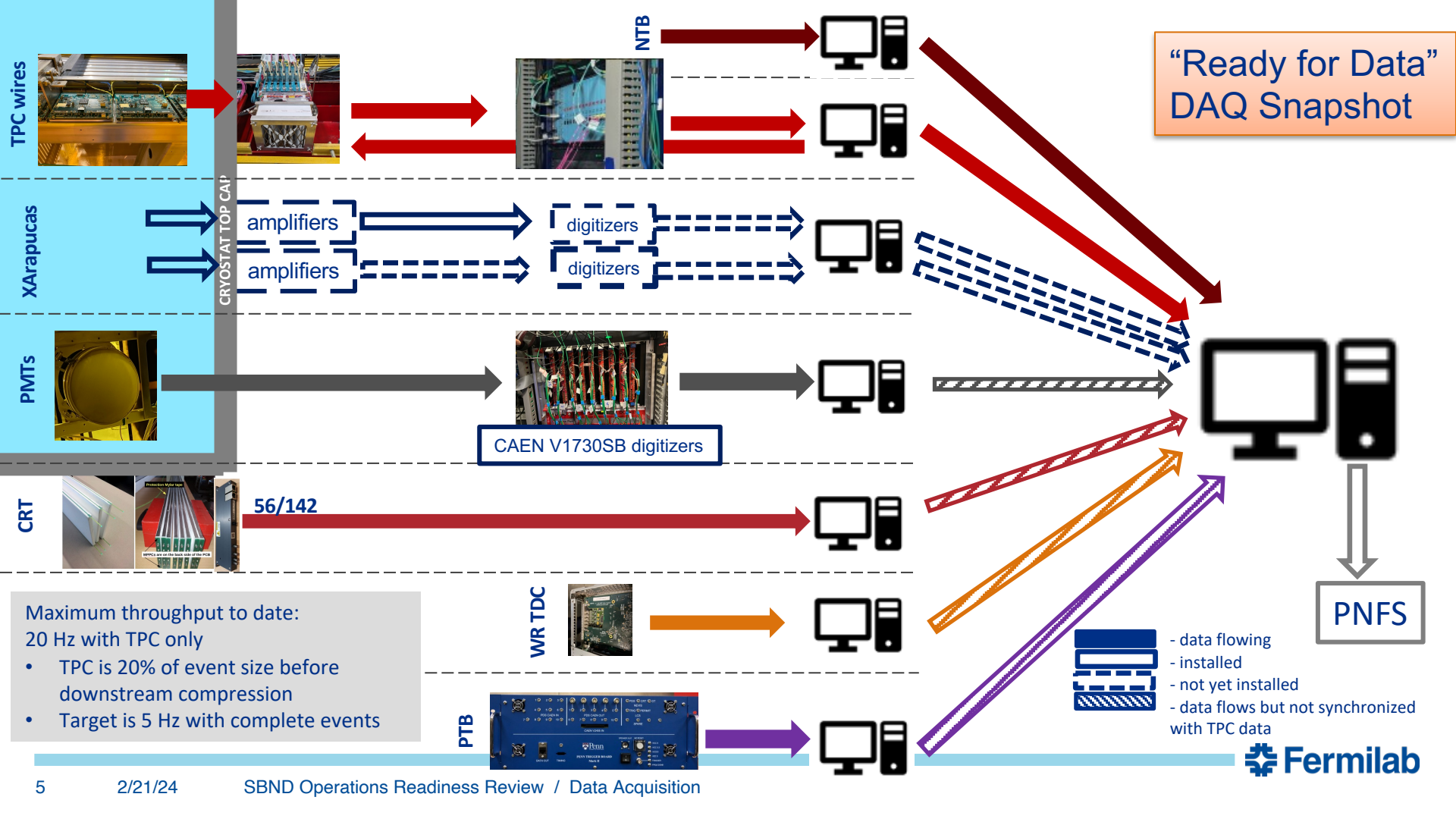
DAQ Software Framework

- SBND DAQ uses the *artdaq* software framework
  - **BoardReader** applications interact with detector electronics and produce data fragments
  - **EventBuilder** applications request, receive and combine data fragments corresponding to the same event or common time window
  - **DataLogger** applications write the data to local disks in the SBND detector hall, where they can later be sent to offline storage
  - **Dispatcher** applications receive stream of data for online monitoring
- ArtDaq makes use of the *art* event-processing framework. The raw data can be converted to larsoft analyzable format.
- The board readers are developed and supported by the SBND collaboration.

Support from Fermilab

- The *artdaq* software framework is developed and supported by Fermilab CSAID.
- The *artdaq* experts from CSAID provide technical support to debug DAQ code and maintain code releases.
- The ND Operations Support Group (OSG) provides technical support for various online and DAQ systems both as primary experts and through general online system expertise.
- **Continued support from Fermilab is critical to the SBND commissioning and operations.**

"Ready for Data" DAQ Snapshot



Maximum throughput to date:
20 Hz with TPC only

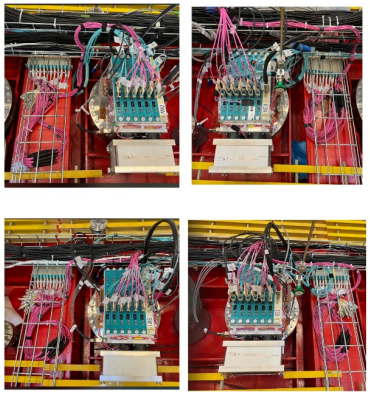
- TPC is 20% of event size before downstream compression
- Target is 5 Hz with complete events

Fermilab

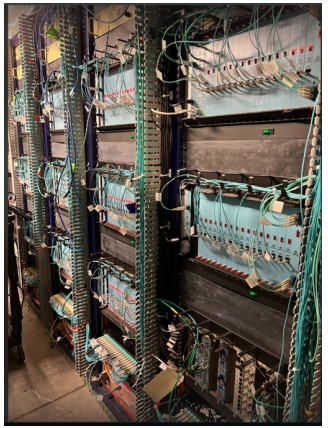
TPC Readout

- Cold FEMBs read out through warm readout and buffering electronics
- 88 cold FEMBs
  - Each FEMB is connected to 128 channels: 11264 channels in total
- 24 Warm Interface Boards (WIBs) in 4 crates mounted to cryostat flanges
- 11 Nevis TPC crates on the mezzanine
  - Each Nevis TPC crate consists of 16 readout boards.
  - Two Nevis readout boards read out one FEMB.
- One board reader for one WIB.
  - Only configures WIB.
- One board reader for one Nevis crate.
- Both board readers are finished and tested.

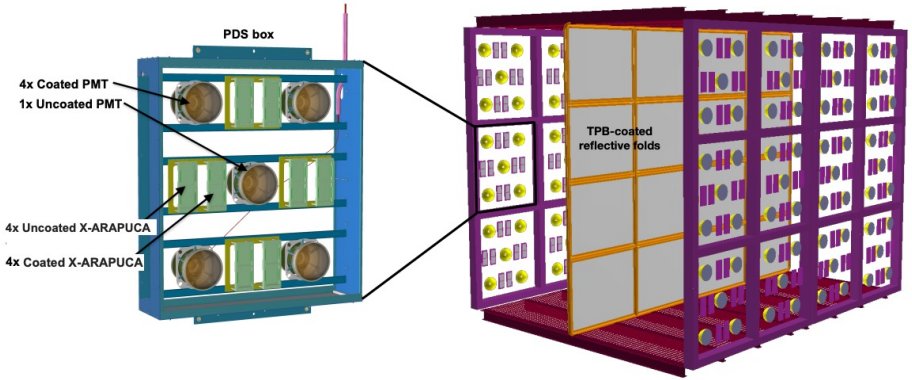
WIBs



Nevis TPC crates



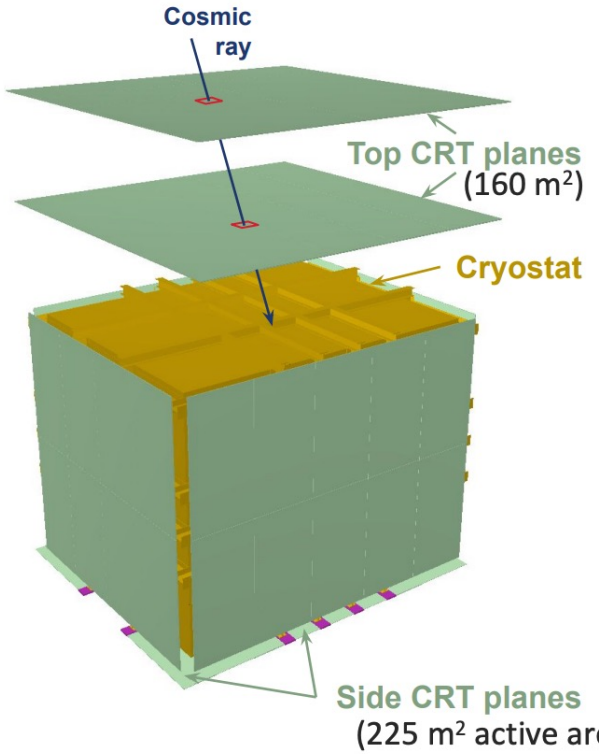
Photon Detector System (PDS) Readout



- SBND uses both PMTs and X-ARAPUCAs to record scintillation light signals.
- Analog signals from PMTs go to the digitizer CAEN 1730 commercial VME module. The digitized waveforms are sent to the event builder computer through a PCIe card over a fiber optical link.
- X-ARAPUCA uses a different flavor of the same digitizer, CAEN 1740, with a lower sampling frequency and the same PCIe card.
- The board reader for CAEN 1730 module is complete.
  - Shared with ICARUS and has also been tested extensively as part of pre-LAr commissioning at SBND.
- The board reader for CAEN 1740 module does not exist yet, but it should be a small perturbation from the one for CAEN 1730. LArIAT also uses CAEN 1740 digitizers. Expertise in code is shared between the two experiments.

CRT Readout

- CRT is designed to tag muons to veto the cosmic ray backgrounds.
- The CRT system is made of scintillator strips (1 cm thick) read out by two fibers and two Silicon photomultipliers (SiPMs).
- There is a process running on the CRT server that communicates with the FEBs
  - Configures FEBs and gathers data out of their memory buffers
  - 8-10 FEBs per process.
- A total of 142 FEBs.
- The CRT board reader is complete.
  - Shared with ICARUS and has been tested at SBND as part of the CRT commissioning.



SBND Trigger

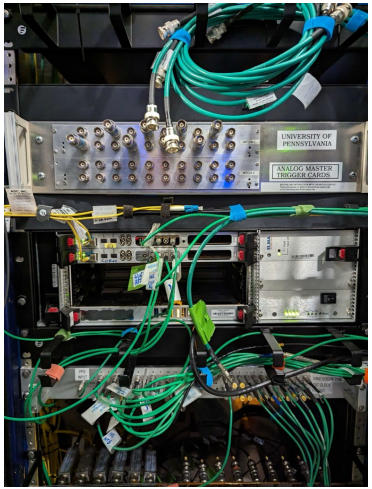
- The Penn Trigger Board (PTB) receives logic inputs listed below and issues triggers to TPC and PDS readout.
  - Beam signals from accelerator complex
  - PMT multiplicity above threshold
  - CRT activity – one input for each plane
- The CAEN 1730 digitizers and the MTC-A card combine the discriminated PMT waveforms to evaluate multiplicity
- We expect 7-25 PMT readouts (10 μs each) per event and 1 TPC readout (1.5 ms) per event
- The MicroZED Xilinx ZYNQ7020 inside the PTB contains a processing core and an FPGA. In addition to trigger outputs, the PTB produces a continuous data stream containing timestamps of low level and high level triggers
- The Nevis Trigger Board (NTB) distributes the PTB trigger signal to all 11 Nevis TPC crates

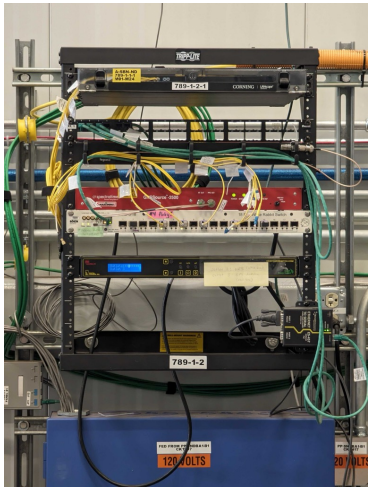
The Penn/Photon Trigger Board (PTB)

Analog Master Trigger Cards (MTC/A)

Timing

- White Rabbit timing system provides synchronization across all the subsystems
  - 10MHz clock for the PTB and PDS to phase lock their internal clocks to the common WR/GPS clock.
  - A pulse per second (PPS) signal to reset internal clock counters for PDS, CRT.
  - A PPS time stamp is recorded by PTB and NTB.
  - The PPS information is used to create the fragment time stamps used for event building.





DAQ Integration

- The goal is to run all the subsystems and make sure that we get signals in each of them, and the readout windows are consistent.
- We have successfully run the simple strobe trigger with NTB, 1 TPC crate of 11 total, PTB, WR TDC, 8 CAEN digitizers for PMTs and CRT bottom and north walls at 1, 2 and 5 Hz.
- We are able to take noise data from the TPCs using all 11 TPC crates and 24 WIBs at a rate of 1 Hz.
- We'll move to running with the beam structure where there are short bursts of beam followed by longer gaps

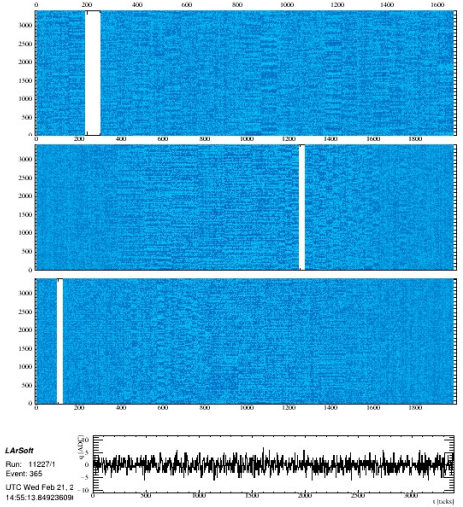
Prepare for offline analysis

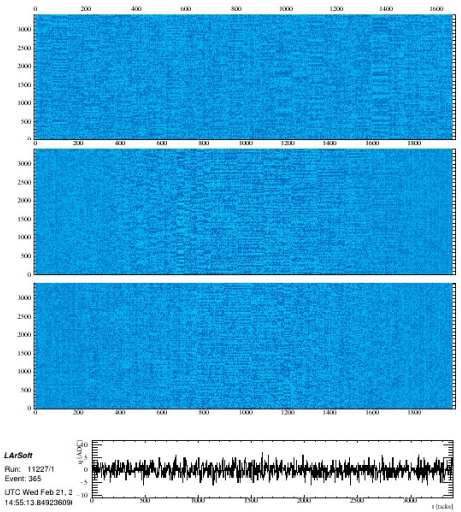
- Raw data are in the *artdaq* format.
- We have written code to convert the raw data to the format that can be reconstructed and analyzed in the *larsoft* framework.
  - This has been done for TPC, photon detectors, CRT, SPEC TDC, NTB, PTB.

East side TPC

West side TPC

White stripes: 128 channels from a shorted FEMB.





Collection

Induction V

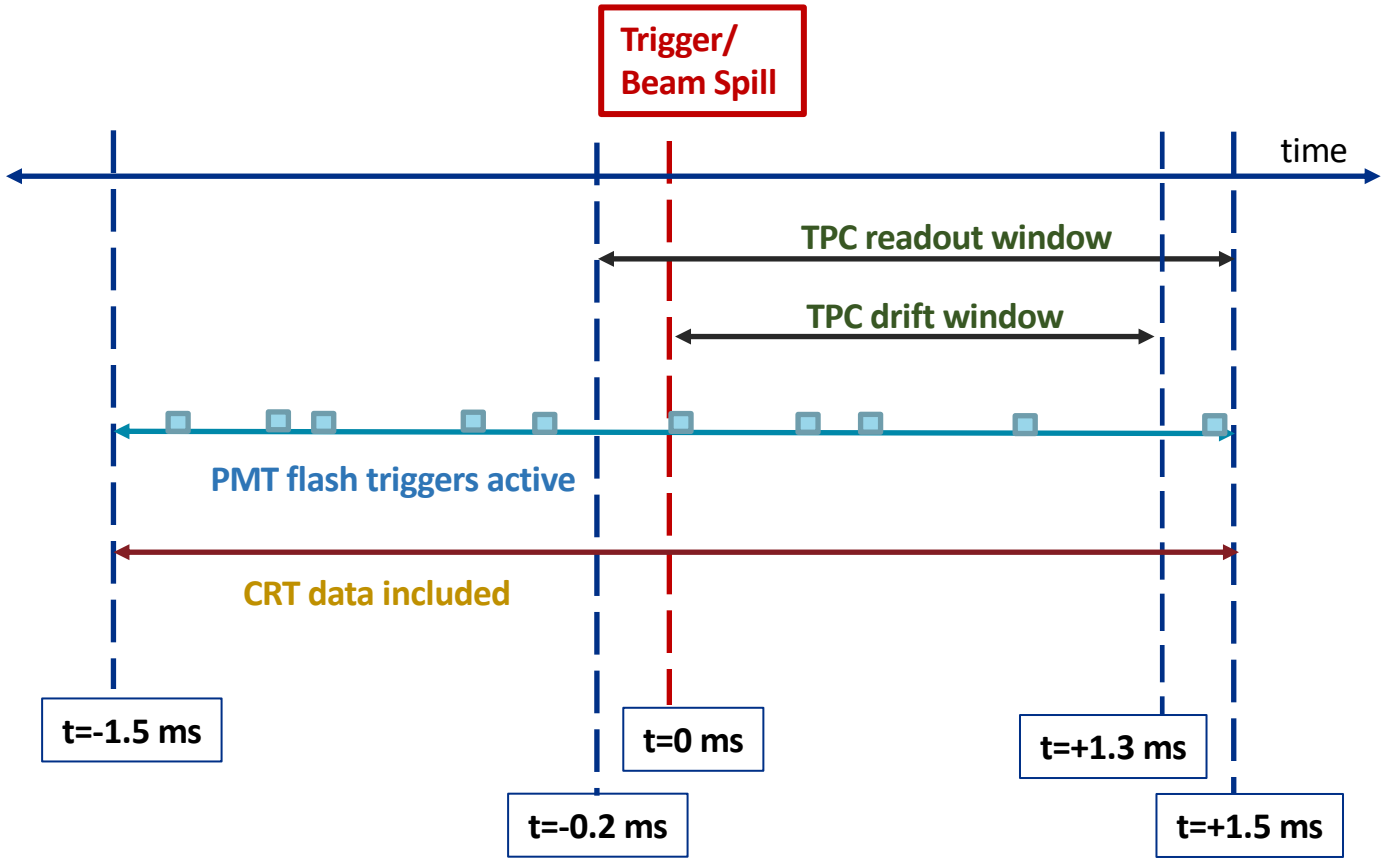
Induction U

Data taken at 9 am this morning.

Summary

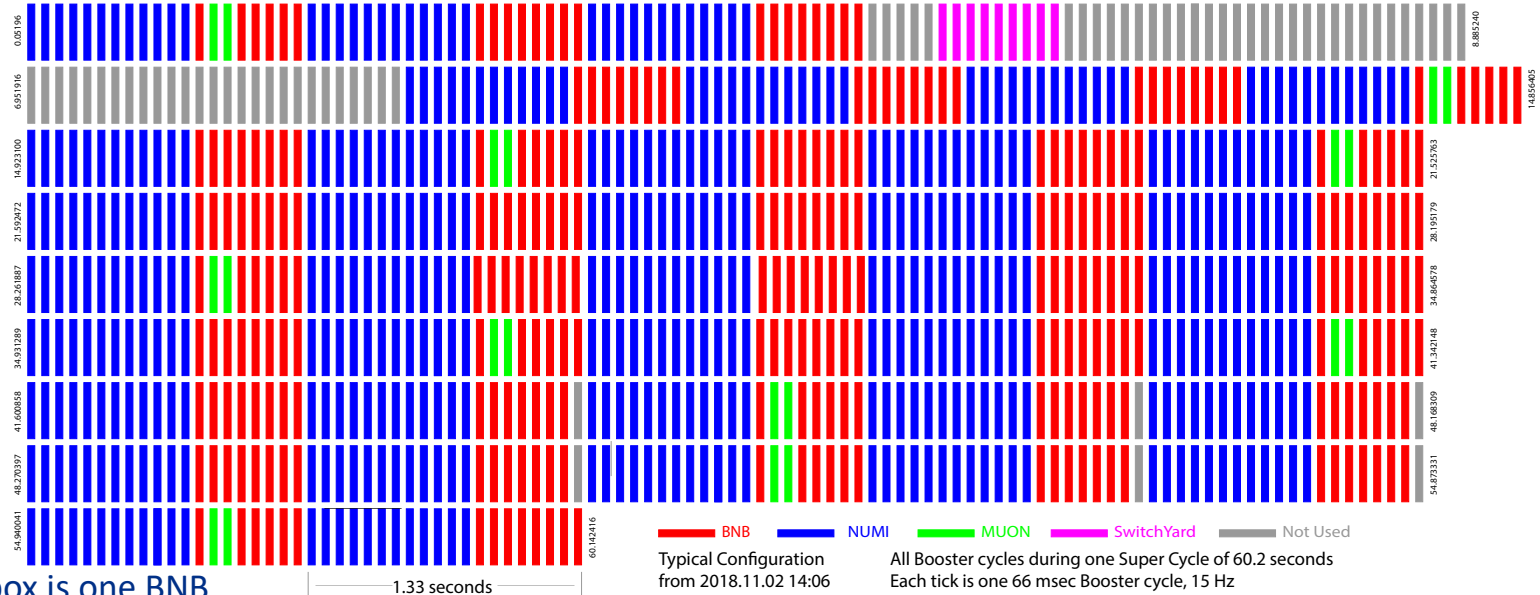
- Readout of individual subsystems have all been tested and will continue to be as we are able to turn on more components with liquid argon and beam
- Integration tests are underway and will continue to increase in complexity of included elements, rate of data taking and throughput
- TPC noise is regularly being read out during filling
- The SBND DAQ is designed to accommodate a 15 Hz instantaneous rate with a 5 Hz average rate, consistent with the maximum BNB beam delivery rate

Backup slides


Trigger/
Beam Spill
time
TPC readout window
TPC drift window
PMT flash triggers active
CRT data included
t=-1.5 ms
t=-0.2 ms
t=0 ms
t=+1.3 ms
t=+1.5 ms

Introduction to the Accelerator Complex *Super Cycle*

- The basic repeating unit is the 60.2 second *Super Cycle*
  - Example program below



Each box is one BNB extraction cycle, $1F and can be directed to four locations

One NUMI sub-cycle

Caveat: Muons running with lower cycles than normal in this example

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