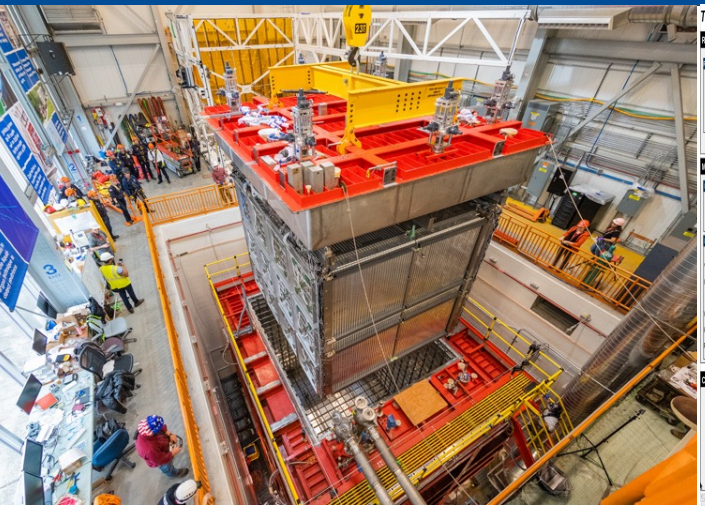
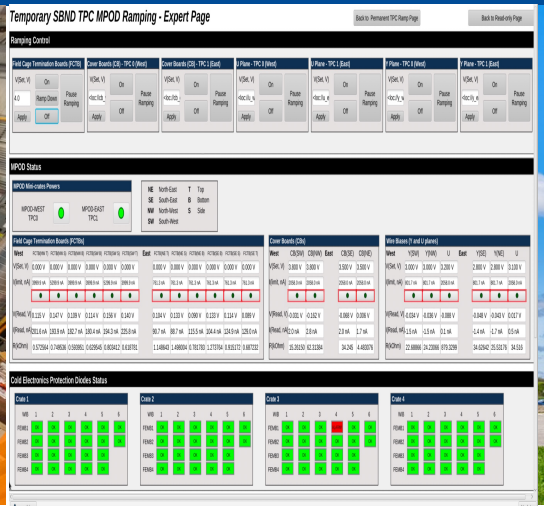




Detector Control and Monitoring Infrastructure

Sungbin Oh, Minerba Betancourt, and Mun Jung Jung

SBND Operations Readiness Review

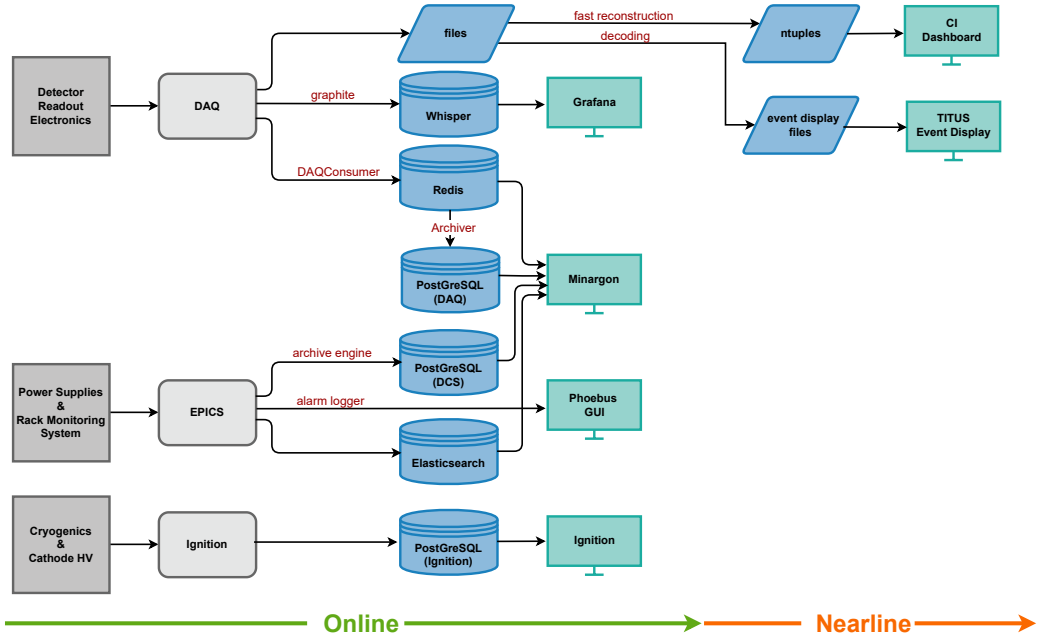
February 21-22, 2024

Main Focus

- Answering the charge question 2-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?”
- From detector control system and monitoring side
  - Including data quality monitoring system!

Detector Control and Monitoring System Overview

It comprises multiple tools for the various components of the experiment



Detector Control and Monitoring System Overview

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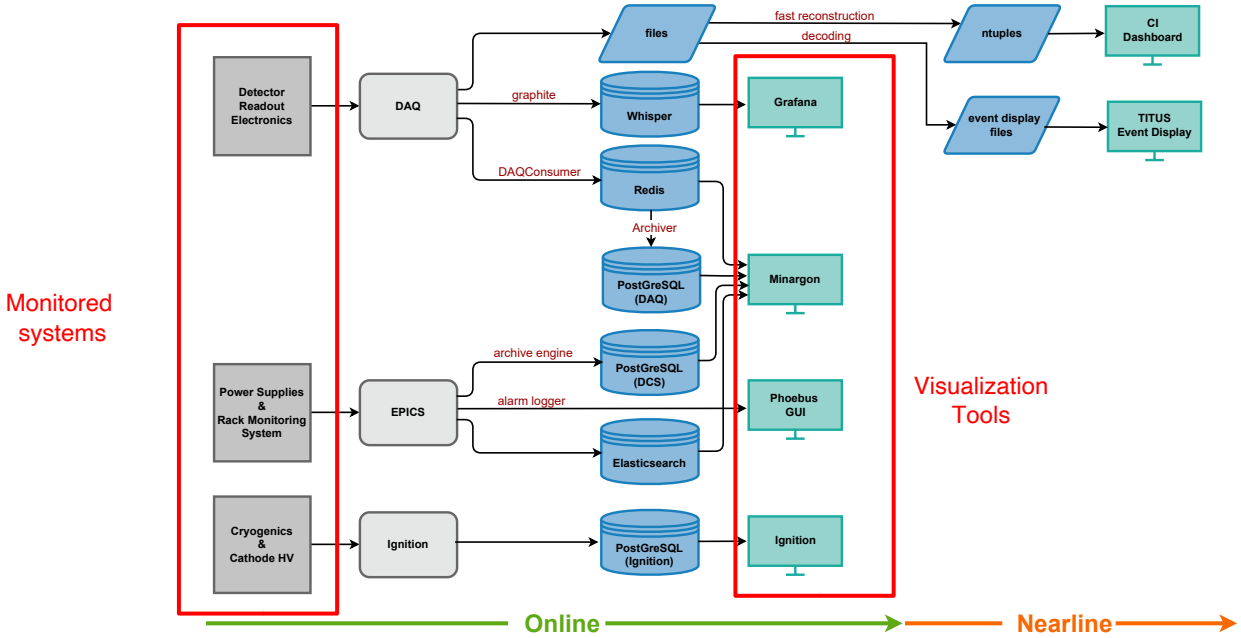
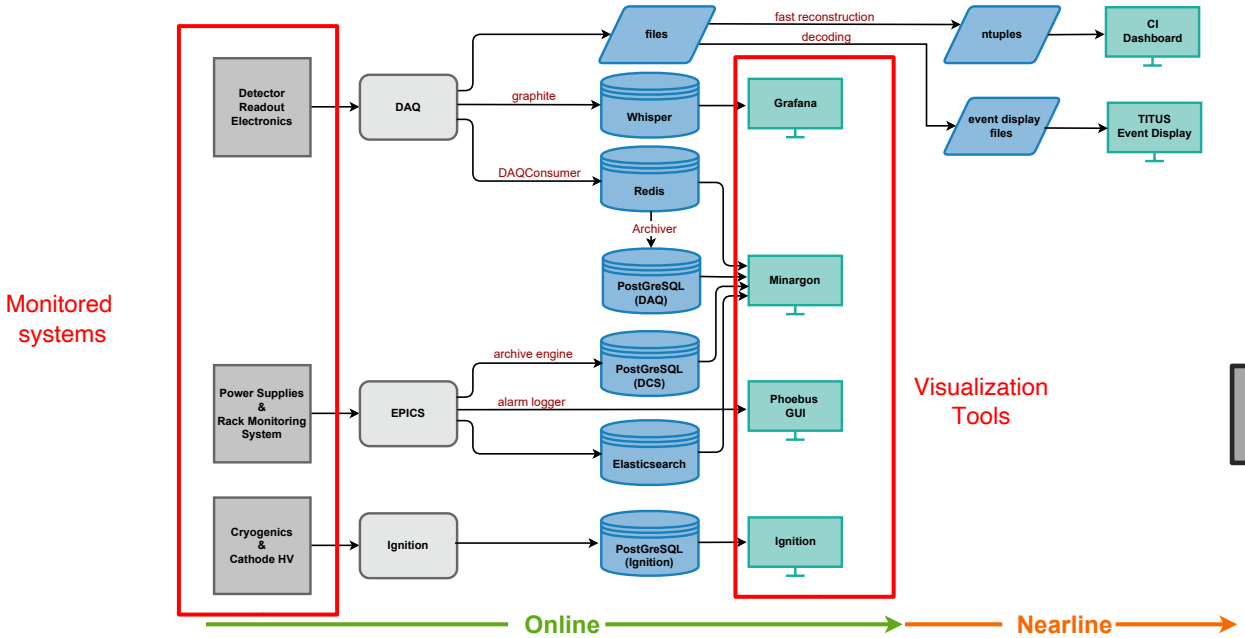


Detector Control and Monitoring System Overview

It comprises multiple tools for the various components of the experiment



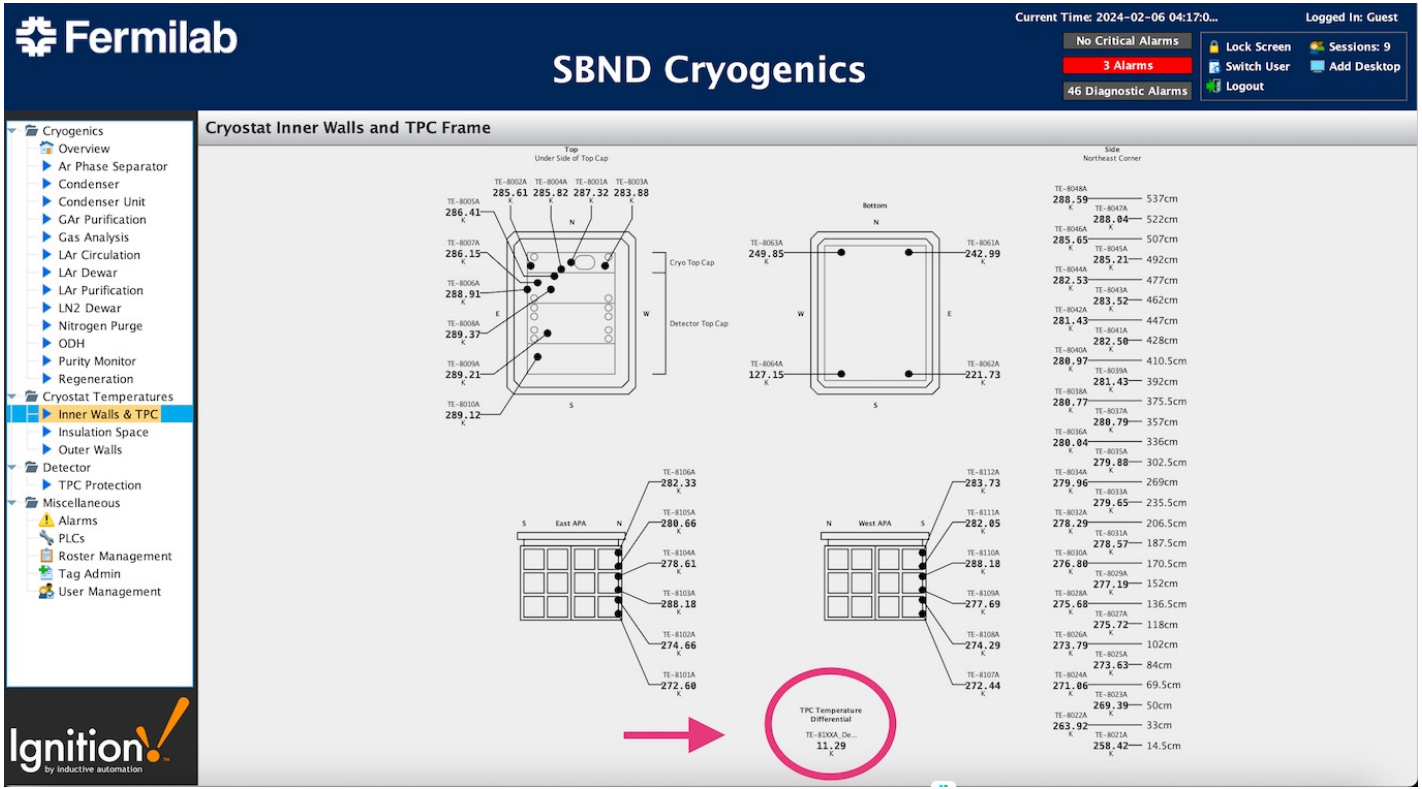
Auxiliary Instrumentations in the Cryostat

Auxiliary Instrumentations in the Cryostat

Resistance temperature detectors (RTDs)

- They are 4-wire PT100 Class A devices from Omega with 0.55 K precision
- 79 RTDs
  - 36 on the cryostat walls
  - 18 on the TPCs
  - 25 outside the cryostat
- Measured temperatures are archived in the Ignition DB
  - Visualized in the Ignition (next page)

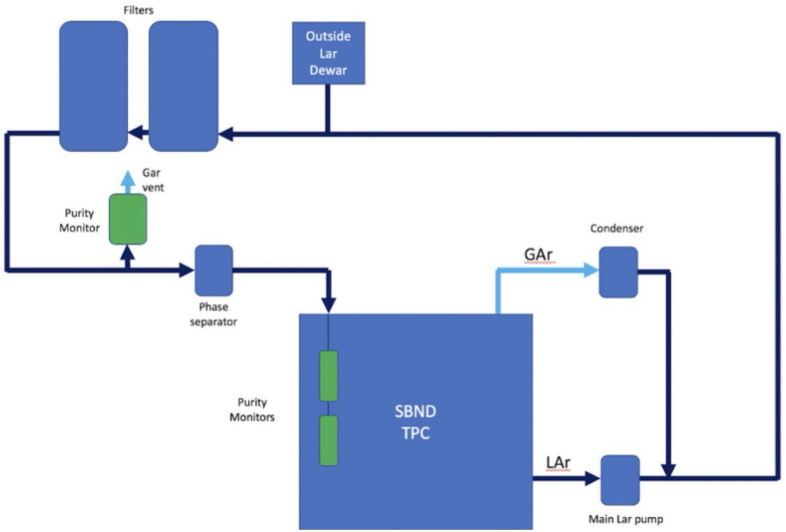
Resistance temperature detectors (RTDs)

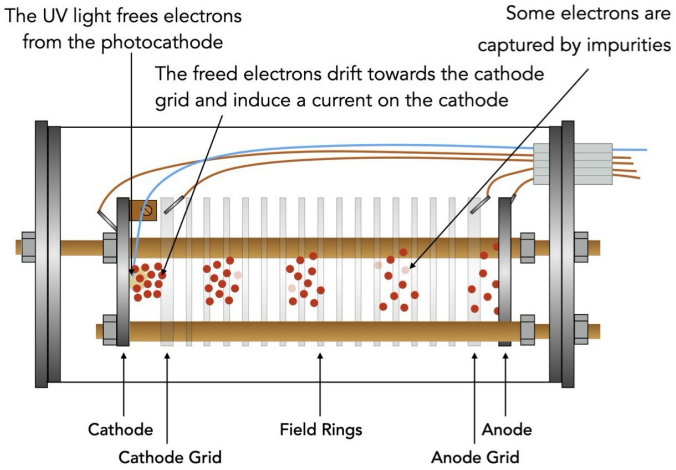


One of RTD pages

- RTDs at inner walls and inside TPC are presented

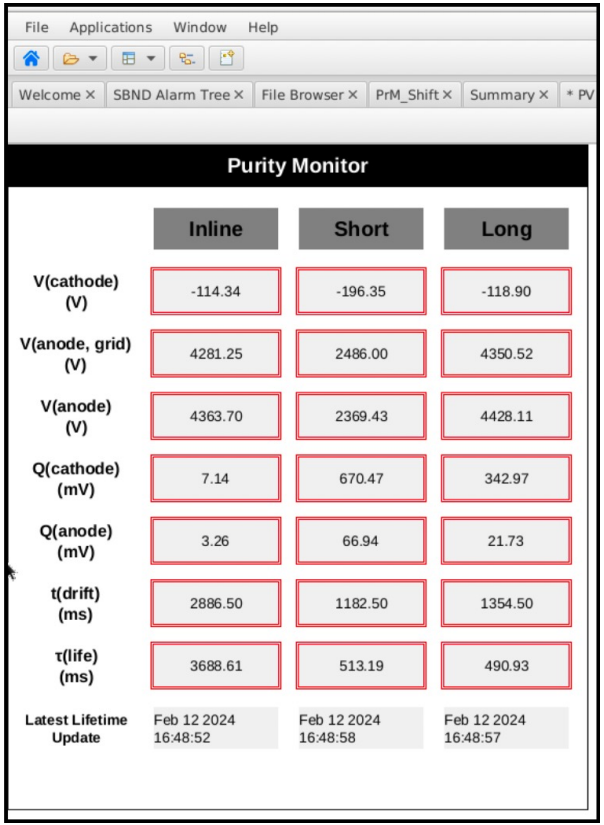
Liquid Argon (LAr) Purity Monitors





- Measures electronegative contamination, especially O_2 and H_2O molecules, in LAr
- Three monitors (green) : one long inline after filters, two inside TPC (one long and one short)
  - Electron cloud generated at the cathode drifts toward the anode : amplitude of charge signals are compared
- Have independent control & DAQ system : variables are reported to EPICS for monitoring

Liquid Argon (LAr) Purity Monitors

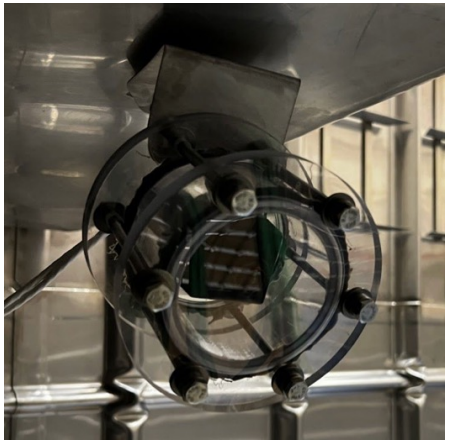


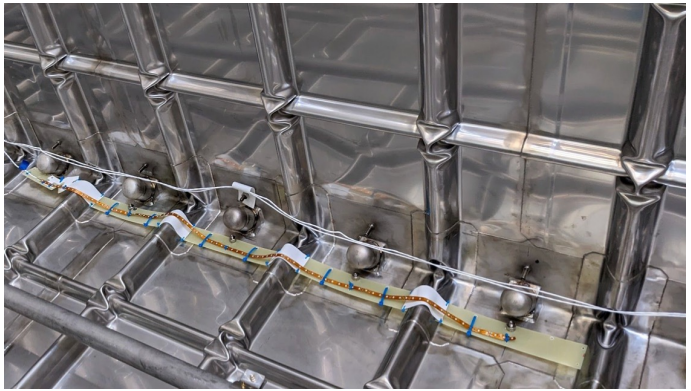
- Purity monitor variables are visualized in the Phoebus
- Please ignore red borders
  - Working on defining alarm ranges
- All voltages, charge signals, and times are presented
  - They are also archived into the EPICS PostgreSQL DB

Cameras

Five cameras are installed inside the cryostat

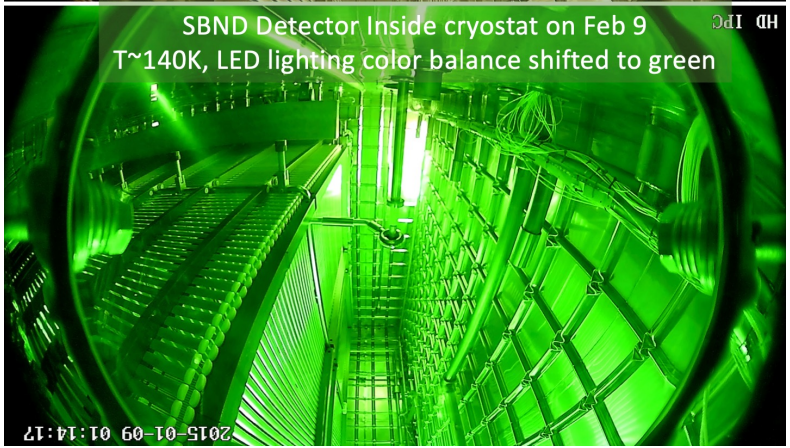
- 3.0 Megapixel - 2304 x 1296P
- Installed inside enclosures together with heaters
- Can see only visible light
  - Five 5 ft long yellow LED strips are installed in strategic places of the cryostat walls
  - Interlock to protect photon detectors
  - Color balance shifts to green in lower temperature





- Cameras have independent control/monitoring system

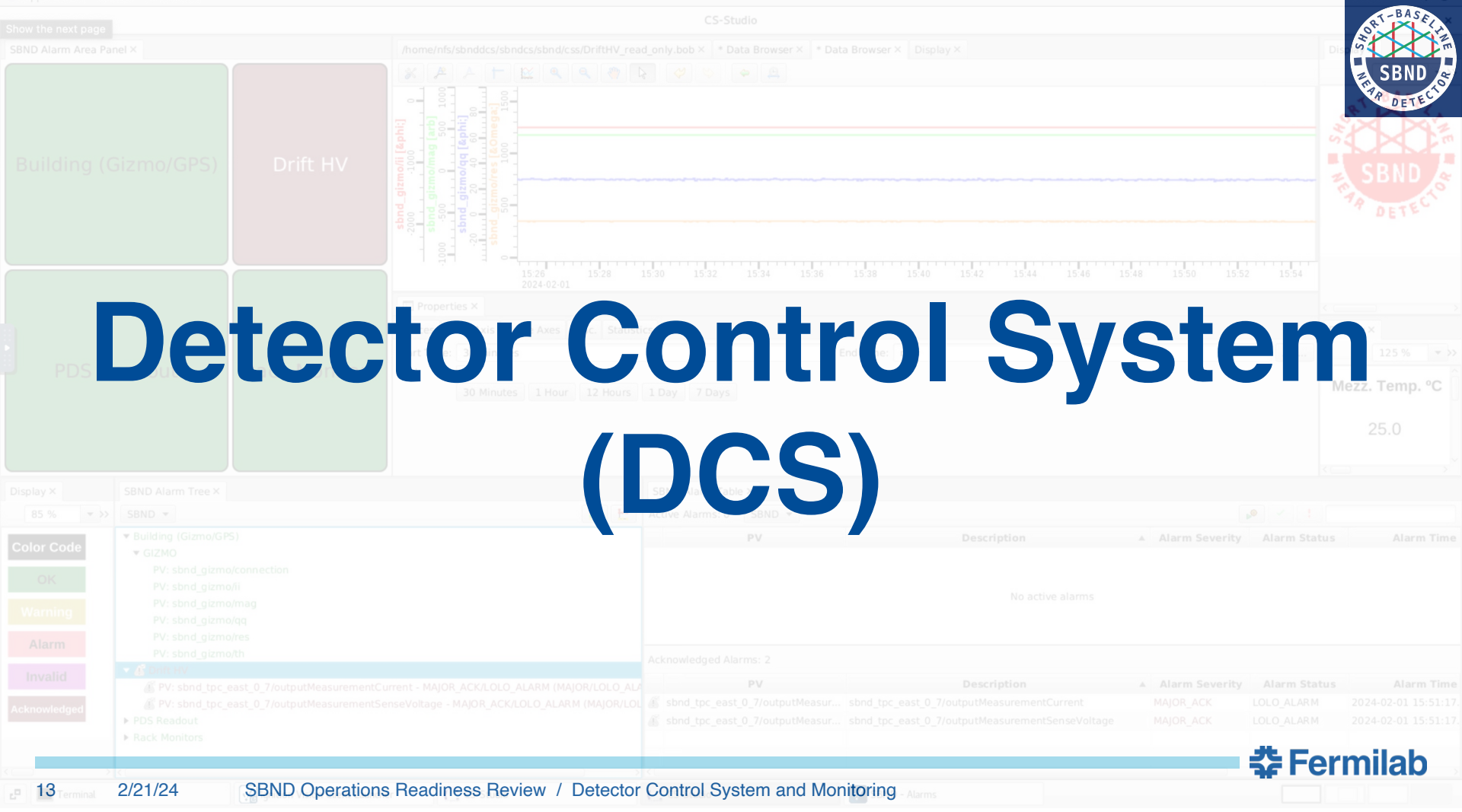
Cameras



Pictures from detector cooling down process

- HV feedthrough view
- Top
  - LEDs have yellow color balance at ~ 240 K
- Bottom
  - LEDs have green color balance at ~ 140 K

Detector Control System (DCS)



Detector Control System (DCS) – Overview

The DCS monitors

- Power supplies
  - Voltages for photon detection system, TPC planes, and readout electronics
- Rack monitoring system
  - Device temperatures, power distribution units, cooling fans, and rack protection system
- Things will be described later in this presentation
  - DAQ, cryo-control, and main cathode plane power supply

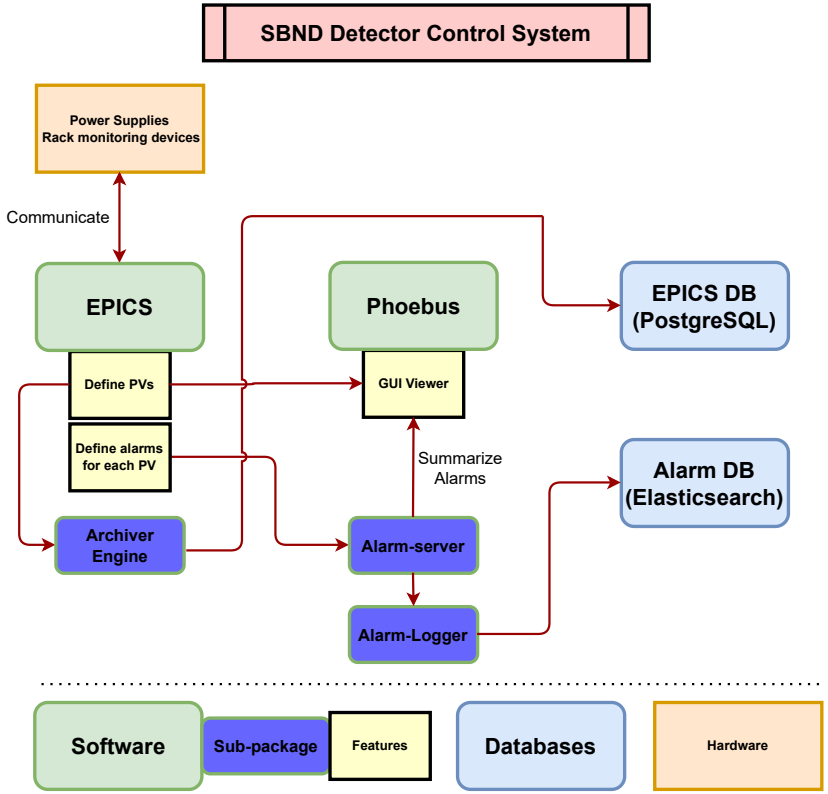
Purpose

- Control/monitor hardware, archive important variables, and present alarm status

Detector Control System (DCS) – Structure

The EPICS (**E**xperimental **P**hysics and **I**ndustrial **C**ontrol **S**ystem)	• Direct communication with hardware ○Provides a single simple protocol to users for various devices ○A controlled or monitored variable is called as a process variable (PV) • An Open Source software for detector control/monitor systems • PIP-II, ICARUS, Mu2e,,, we have growing expertise on it in Fermilab
The Phoebus (CS-Studio)	• Provides GUI views for PVs • Its sub-package, “Alarm-server” and “Alarm-logger”, are used for alarm feature
The Archiver engine and PostgreSQL DB	• The archiver engine of the EPICS archives PVs into a dedicated PostgreSQL DB (“EPICS DB”)
The Elasticsearch DB	• Alarm histories are archived in a separate DB with the Elasticsearch

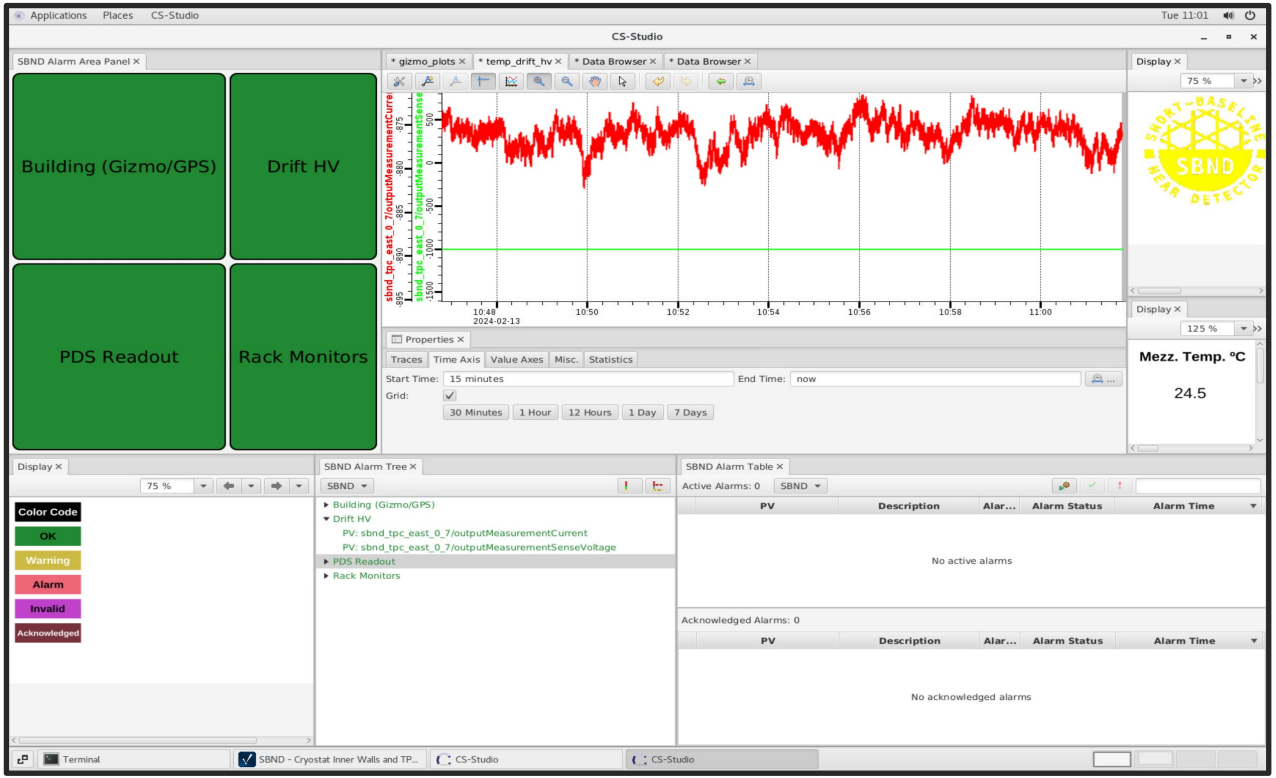
Detector Control System (DCS) – Structure



Detector Control System (DCS) – Shifter's Window

The Phoebus is used to provide shifter window for the DCS

- Alarms for sub-systems are summarized
- SBND symbol changes its color to indicate if shifter's connection is alive
  - Every 0.2 sec with 5 colors
- Shifters and experts can add plots for any variable in time series
- Being used for shift these days

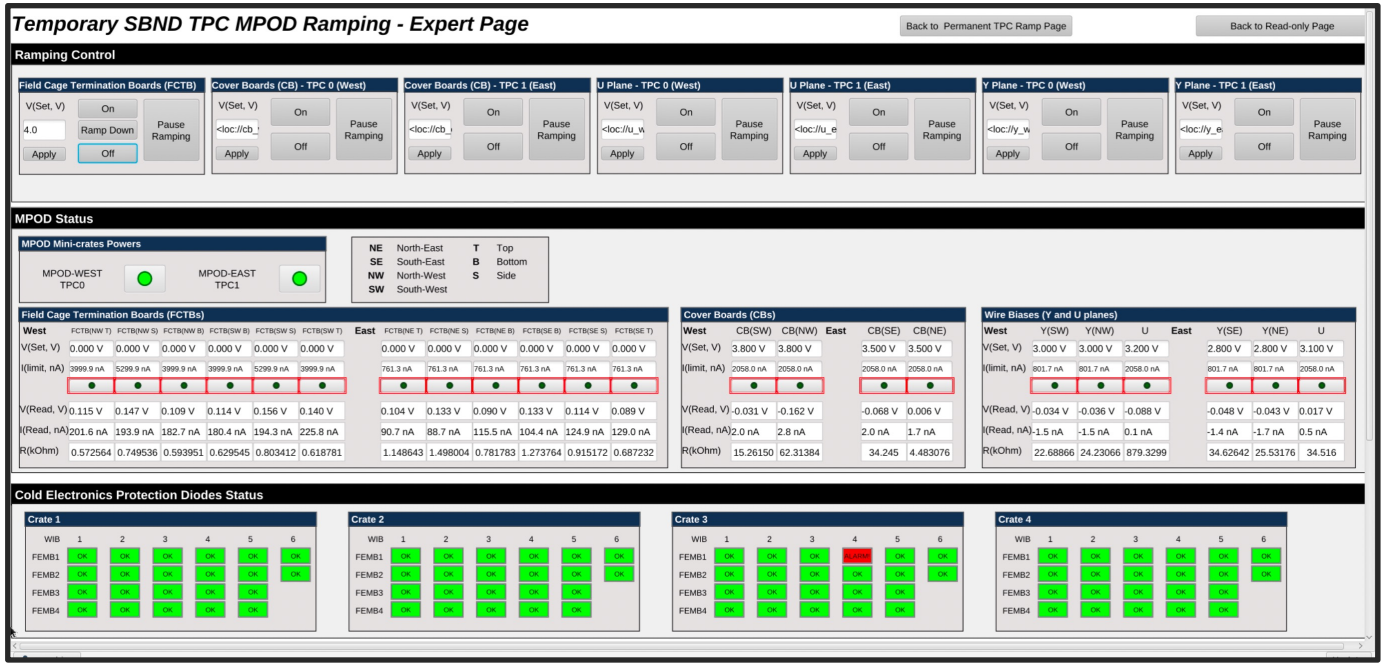


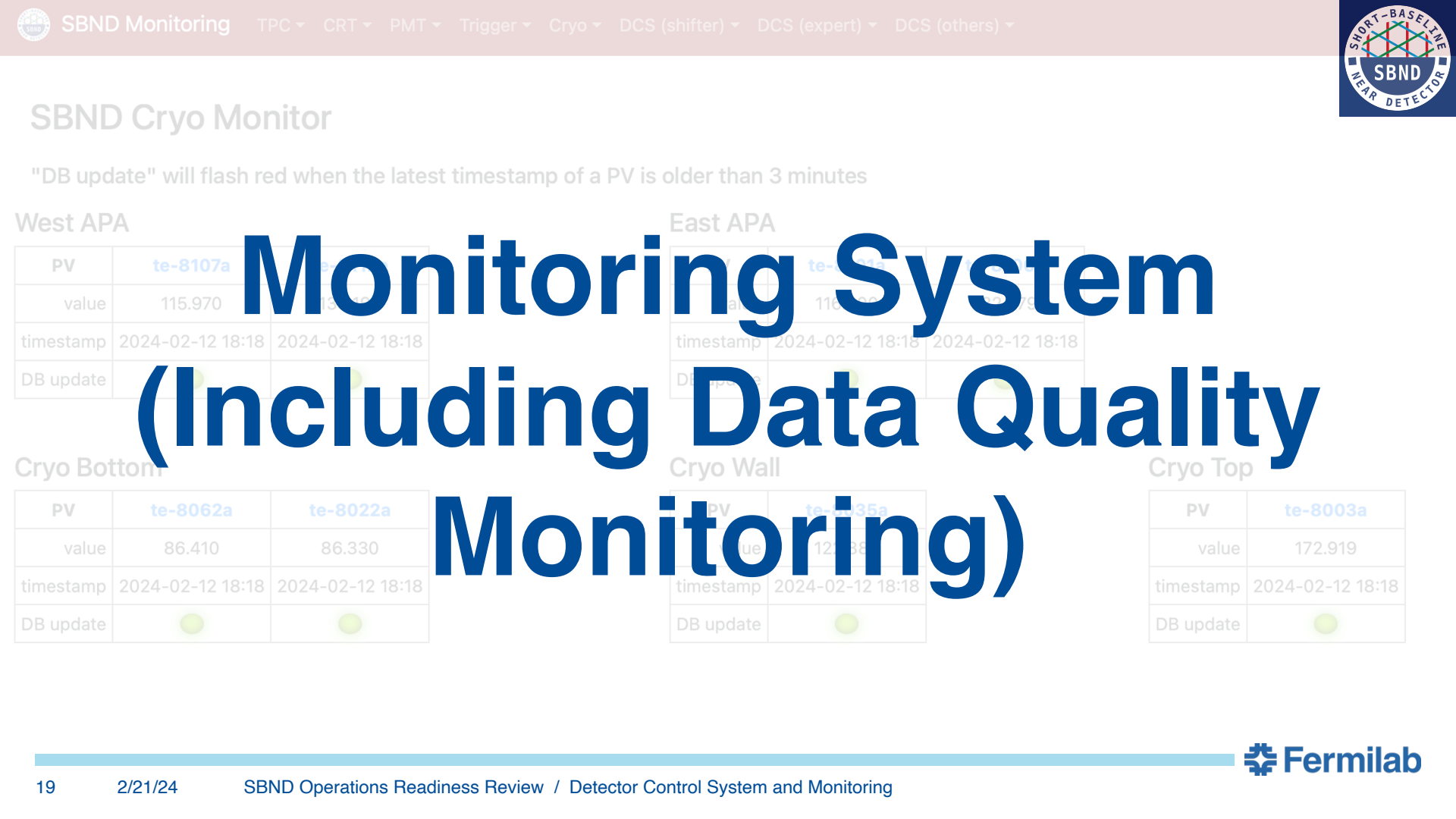
Detector Control System (DCS) – Experts Pages

Power supply control and monitoring pages are provided with the Phoebus

- All power supplies for CRT/TPC readout, PDS HV, and TPC planes have dedicated windows

(Example)
TPC bias voltage control/monitoring page for experts

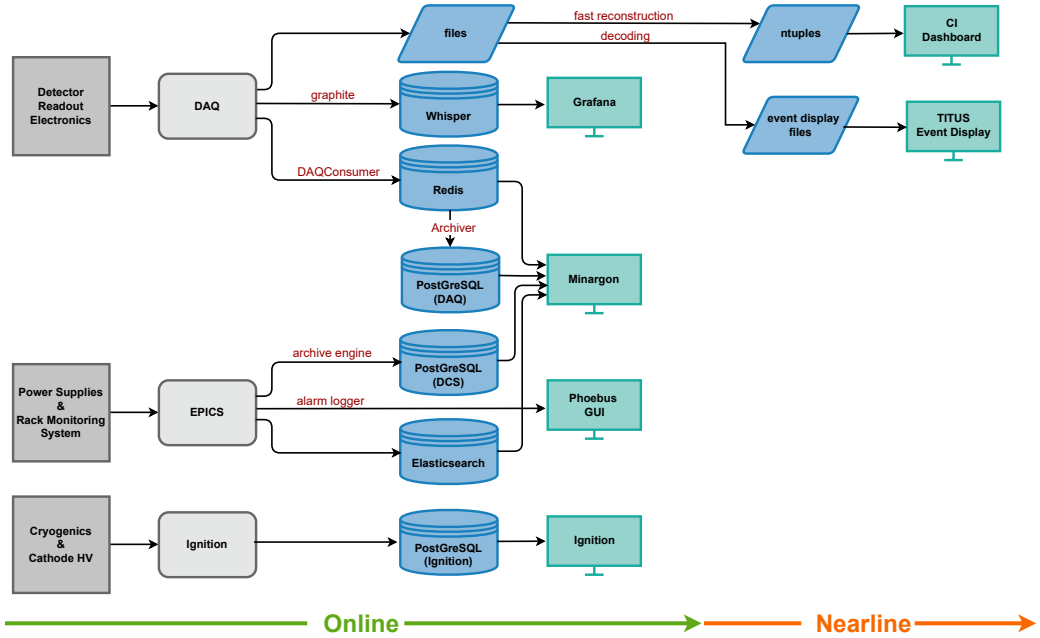




Monitoring System (Including Data Quality Monitoring)

Detector Control and Monitoring System Overview

Reminder for overall structure



DAQ Monitoring

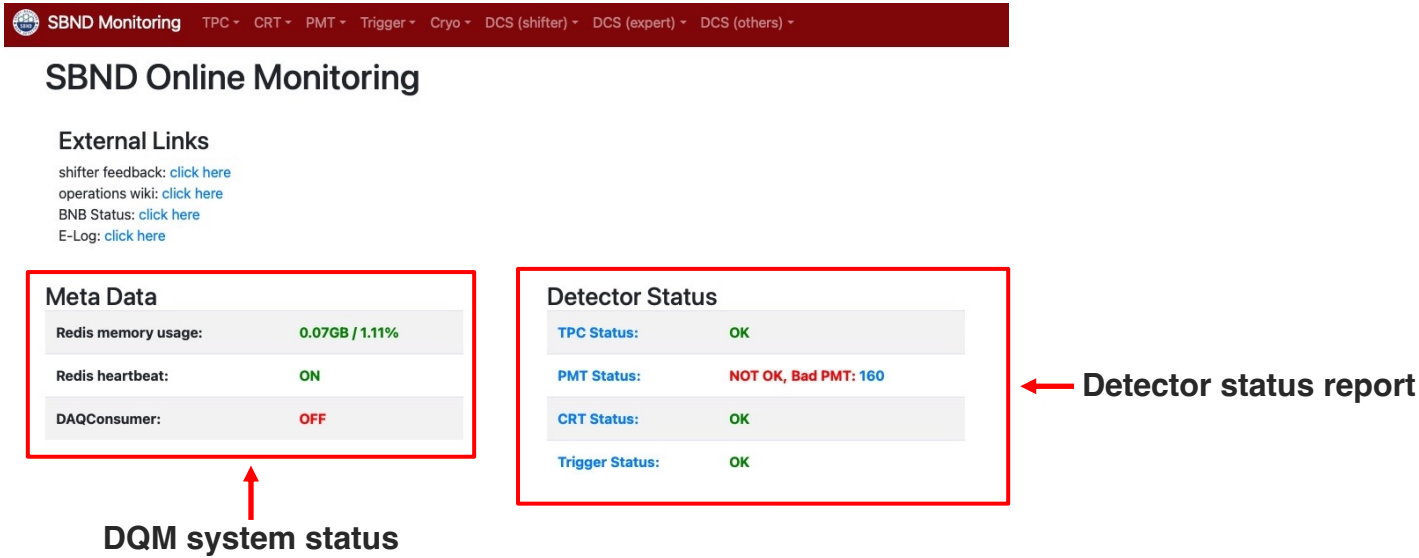
- DAQ health is monitored through the Grafana monitoring system
- 24 to 48 hours of live DAQ data can be monitored in different formats of tables and plots
- **Various DAQ metrics** including system metrics, event-building metrics, board-reader metrics, memory buffer status, and trigger and event rate metrics **are monitored**

Online Data Quality Monitoring (DQM)

- DQM system calculates and displays detector metrics in real-time
  - Raw data is dispatched from the DAQ to the DQM system
  - DQM analyzer calculates metrics and saves to the in-memory Redis database
  - Minargon website displays the data in multiple formats
- The same infrastructure is in routine use for operations at the ICARUS experiment
- Data can be organized in multiple tiers for subsystem experts and shifters
  - Time-series metrics and waveforms for detector components
  - Higher-level summary of metrics
  - Detector status reports for shifters from alarm levels defined by experts
- **Tools for monitoring the TPC, CRT, PDS, trigger system and the timing system are in place**

Online Data Quality Monitoring (DQM)

Shifter DQM overview page



Online Data Quality Monitoring (DQM)

Shifter DQM overview page

SBND Monitoring | TPC | CRT | PMT | Trigger | Cryo | DCS (shifter) | DCS (expert) | DCS (others)

SBND Online Monitoring

External Links

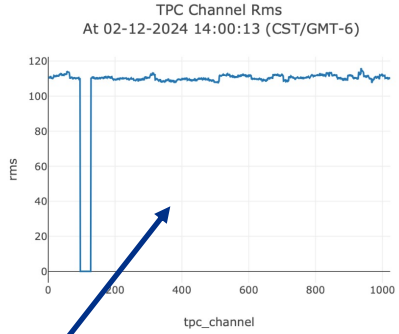
shifter feedback: click here
operations wiki: click here
BNB Status: click here
E-Log: click here

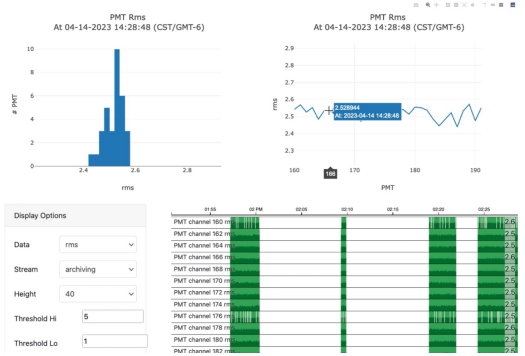
Meta Data

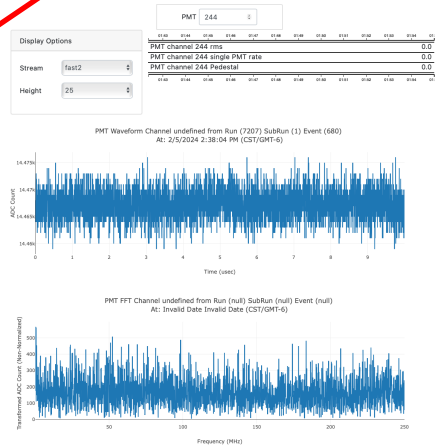
Redis memory usage:	0.07GB / 1.11%
Redis heartbeat:	ON
DAQConsumer:	OFF

Detector Status

TPC Status:	OK
PMT Status:	NOT OK, Bad PMT: 160
CRT Status:	OK
Trigger Status:	OK

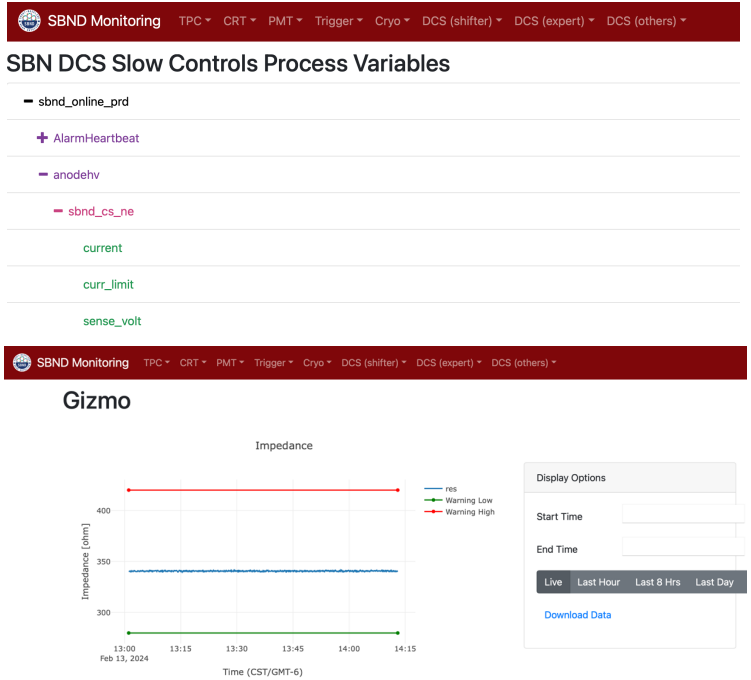


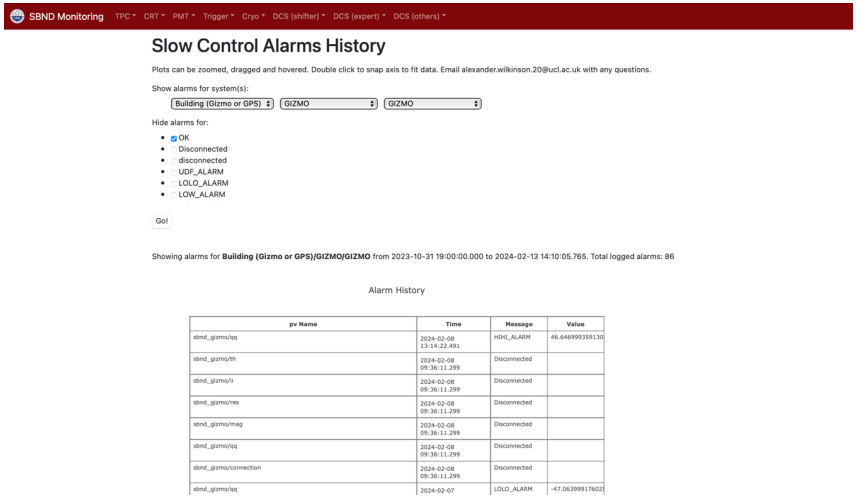




DCS Monitoring

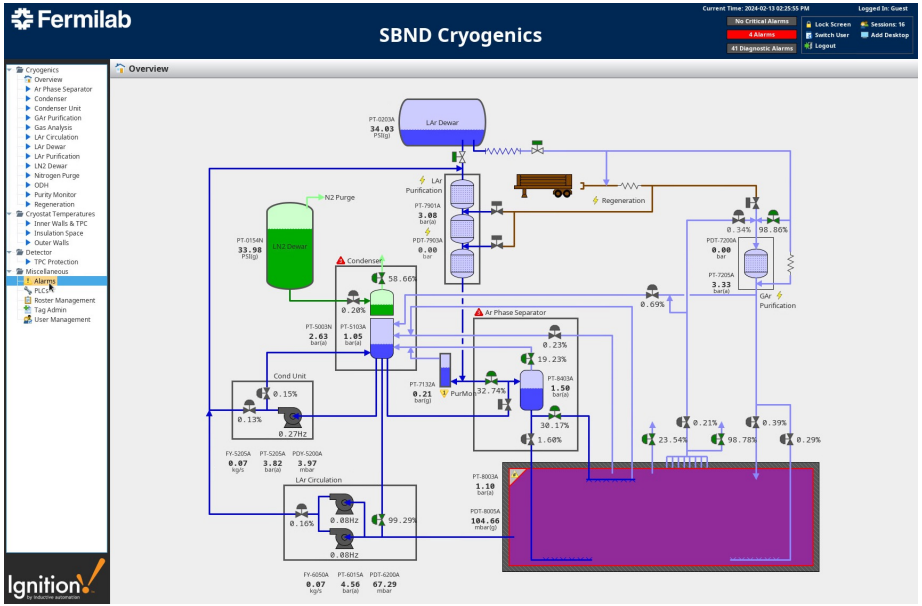
- The Minargon website is connected to the EPICS database and supports browsing history of DCS process variables and their alarms

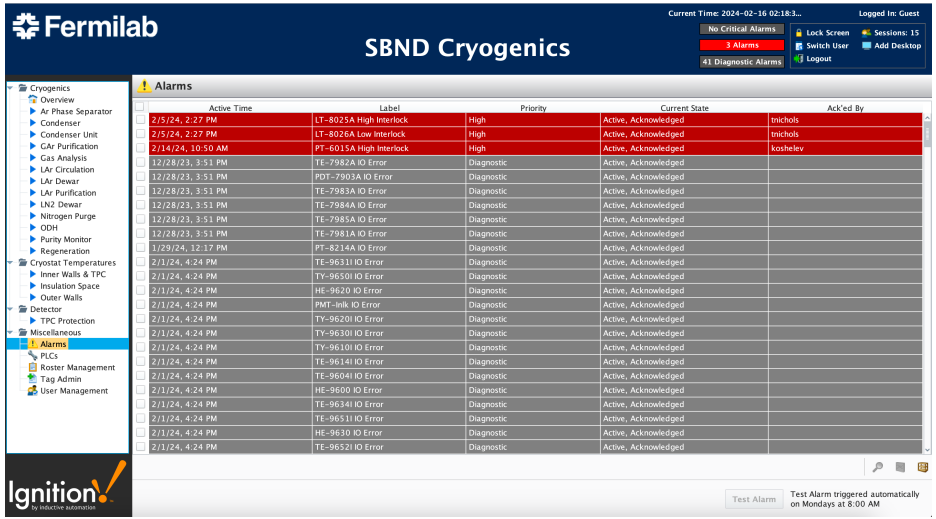




Cryogenic & Drift HV Monitoring

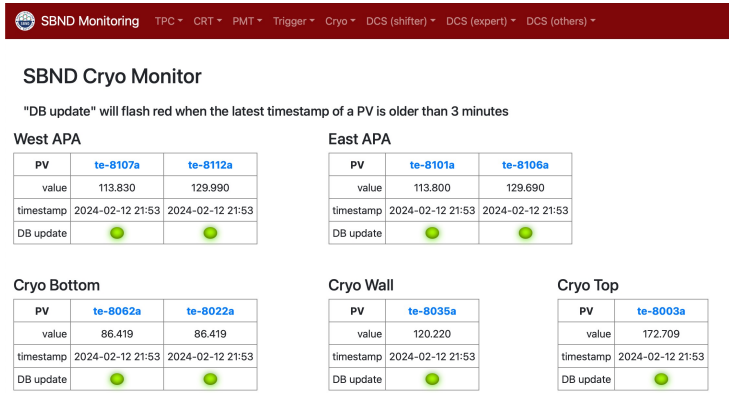
- The Ignition program provides control and detailed summary of the status of the cryogenic system and drift HV, including alarms that can be set dynamically
- The Software license is supported by Fermilab

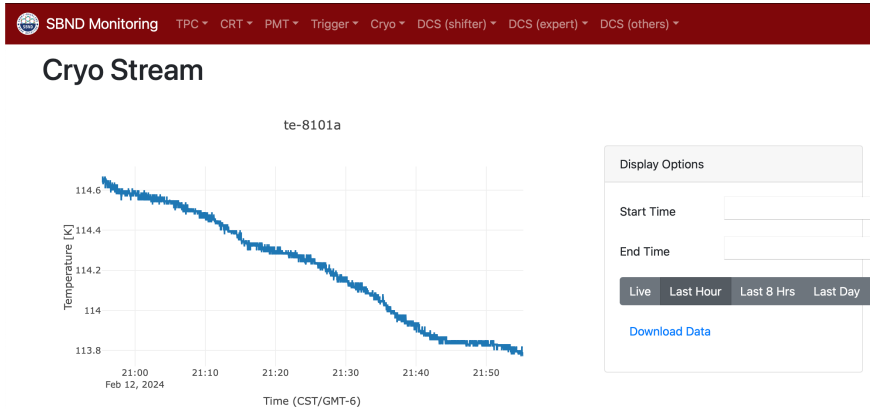




Cryogenic & Drift HV Monitoring

- The Minargon website is connected to the Ignition database and supports browsing of selected cryogenic process variable values
- Drift HV will be added into the Ignition system soon
  - A channel of TPC plane power supply is being used for temporary purpose

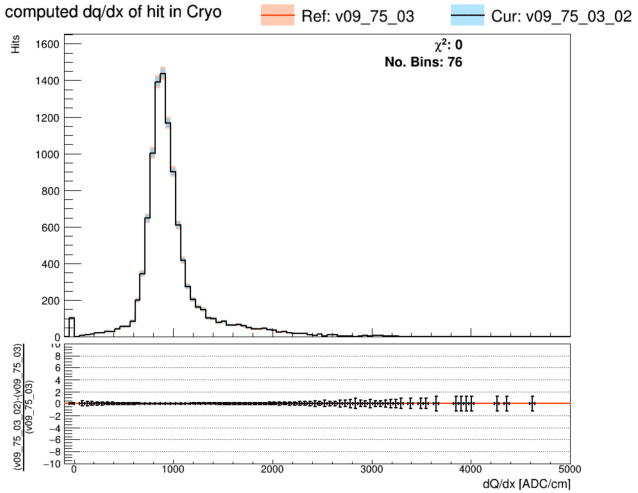


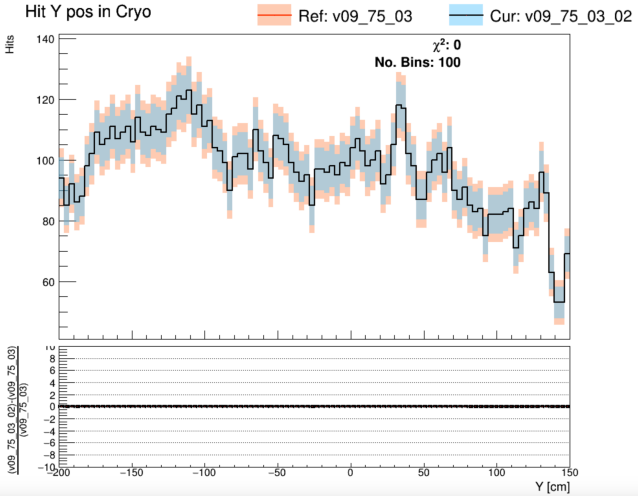


Nearline Monitoring

- Developing a nearline workflow for shifters
  - Higher level metrics using fast reconstruction of TPC, PDS, and CRT data
  - To validate neutrino interaction data quality before full data processing
  - Using continuous integration (CI) for comparison with reference runs that are confirmed as stable

CI test result
Using MC sample



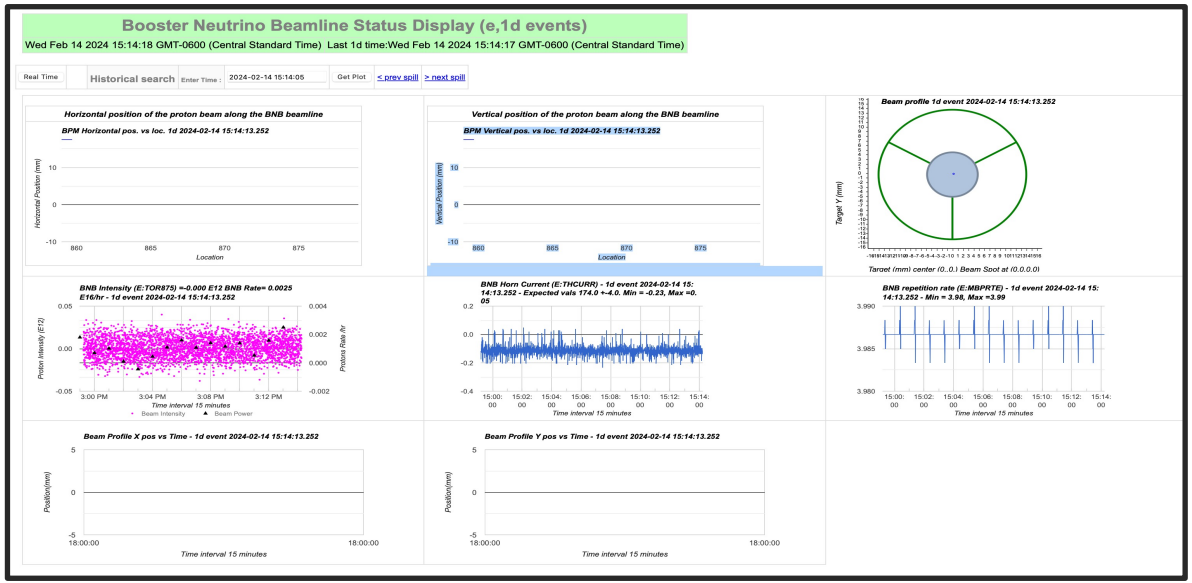


Link

Booster Neutrino Beamline Monitoring

The neutrino beam is monitored using tools

- Supported by Fermilab Beams Division and Computational Science and AI Directorate (CSAID)
- It includes proton intensity, BNB repetition rate, horn current, position of the proton beam along the BNB beam line and beam profile versus time



Databases

Databases Summary

- PostgreSQL DBs for EPICS, Ignition, and DAQ metrics
  - Supported by the Fermilab Information Technology Division
    - Main contact : Olga Vlasova
  - A main DB is hosted by the Fermilab computing resource *sbnd-db01*
  - A hot-backup is running on the *sbnd-db02* server at the SBN-ND building
  - A replica for offline access is at the Feynman Computing Center

- An Elasticsearch DB for archiving alarms from the EPICS
  - Hosted by a server (sbnd-dcs01) at the SBN-ND building
  - It uses SBN-ND NFS disk space

Summary

Summary

Auxiliary Instrumentations in the Cryostat

- Values from RTDs and LAr purity monitors are accessible from the Ignition and the Phoebus, respectively
- Cryostat camera is independent system

Detector control system

- The EPICS and Phoebus provides control system for power supplies and rack monitoring system
  - Windows for both shifters and detector experts are ready
- The Ignition provides control system for cryogenics and drift HV
  - The drift HV power supply will be added into the Ignition soon
  - Software license is supported by Fermilab

Summary

Monitoring system

- A set of various software packages monitors all components used for the SBND operation
  - The Minargon webpage, the Ignition, the Grafana, the Phoebus, and Fermilab Beams Division's beam monitoring tool
- DBs for archiving important variables are supported by Fermilab Information Technology Division
- Nearline monitoring workflow for data quality validation using reconstruction level metrics
  - Under development : CI test using MC sample was successful

For ORR charge question 2-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?*"
  - 1) Booster Neutrino Beam (BNB) monitoring tool is supported by Fermilab Beams Division/CSAID - ready
  - 2) Data quality monitoring modules and workflows are ready for TPC, PMT, CRT, and trigger
  - 3) Nearline monitoring for reconstruction level metrics is under development

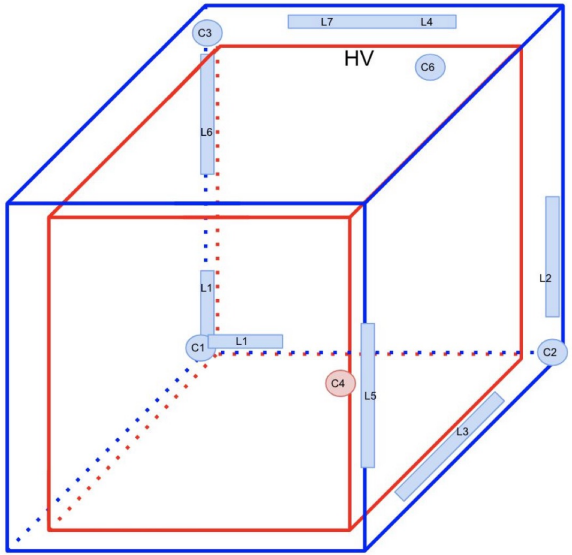
Back Up

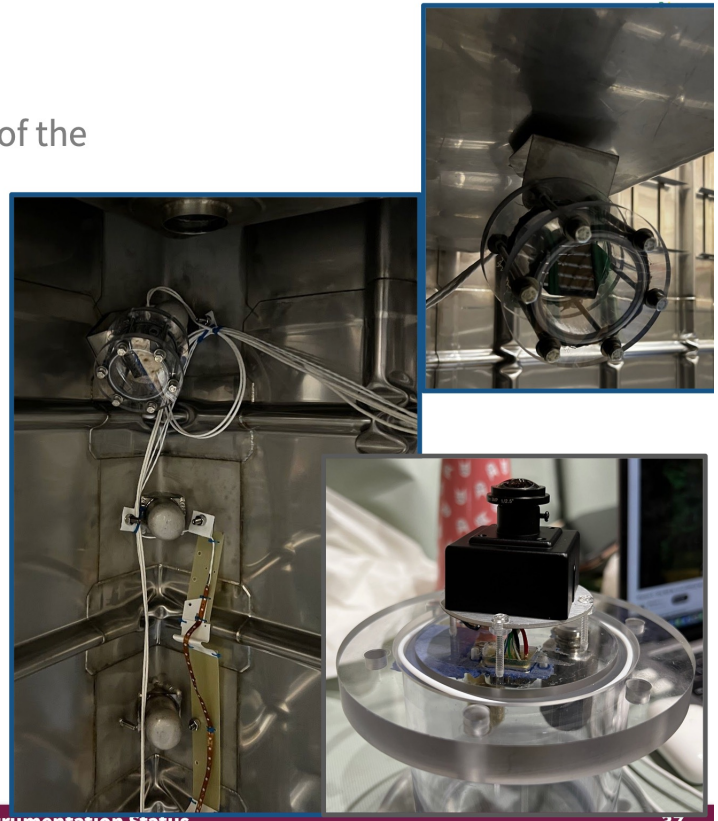
Auxiliary Instrumentations in the Cryostat

Auxiliary Instrumentation in the Cryostat - Cameras

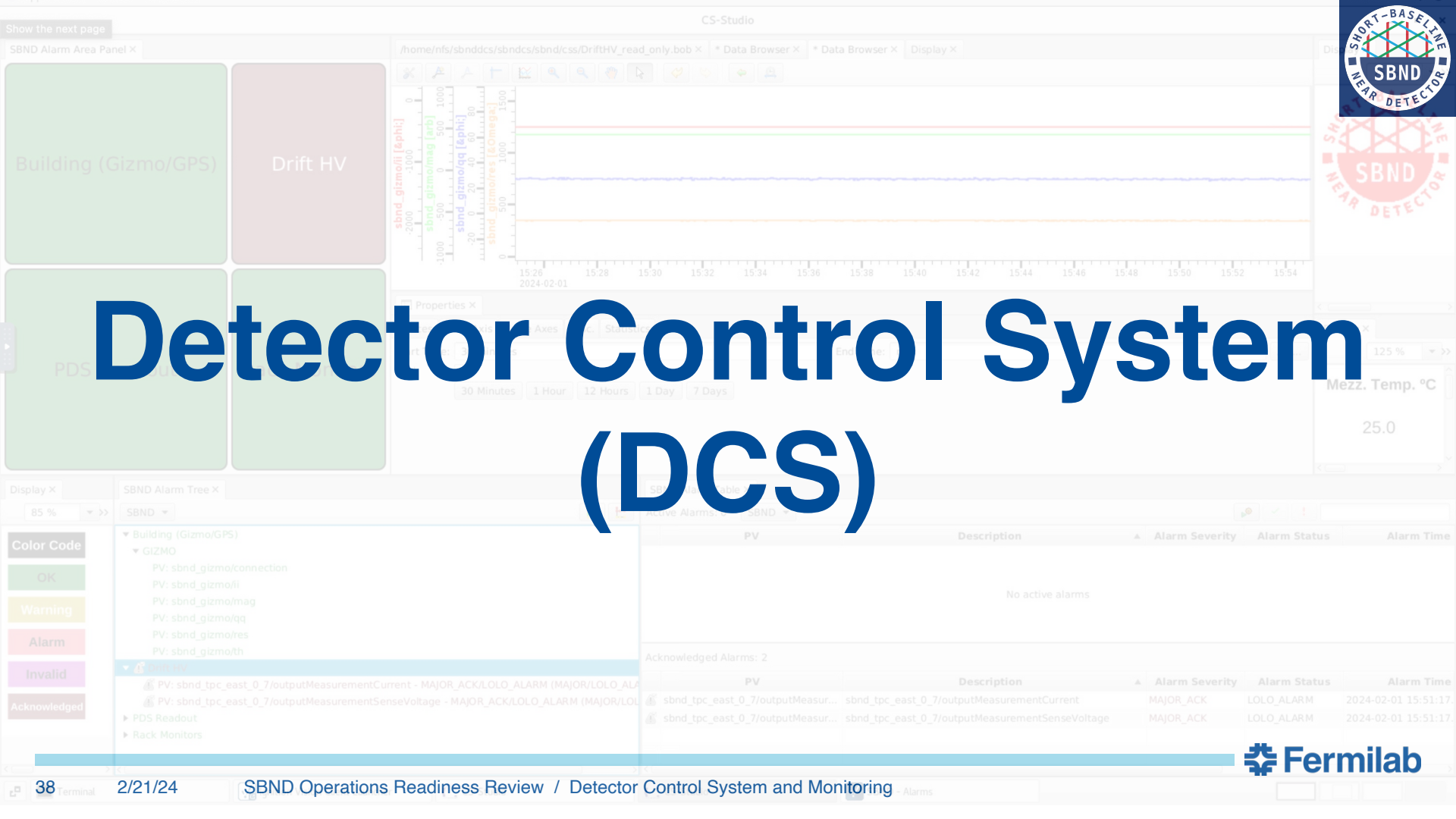
Cameras and LEDs

This diagram shows the approximate position of the cameras and LED strips inside the cryostat.





Credit
Mônica Nunes

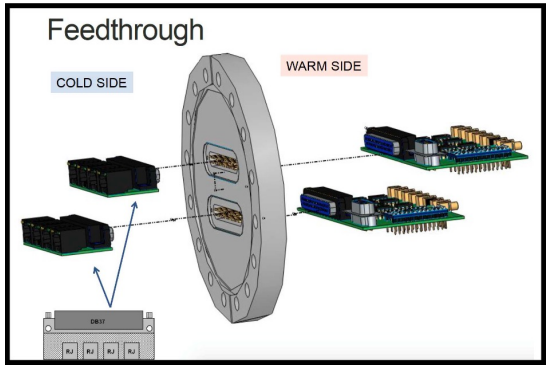


Detector Control System (DCS)

Detector Control System (DCS) – Detail (2) The EPICS

Each hardware has own communication protocol

Example) APSAIA : 8 channels for each port, total 4 ports
(Each ARAPUCA uses 2 channels)



- “d” : command dump operating conditions
- VCnXX.X<CR> : Set channel “n” voltage to X.XX volt
- vc335.2 : set CH3’s voltage to 35.2
- Two gains : H (high, 40) and L (low, 20)

Example) CAEN VME8100 (PDS readout)

CAEN *Tools for Discovery*

Document type: User's Manual (MUT) | Title: Mod. VME8100 VME64/64X 21 Slot 8U Crate Series | Revision date: 14/09/2017 | Revision: 11

8. Communication Protocol

This protocol is based on commands made of sequences of ASCII characters. The format of one command is the following :

$CMD:*,CH*,PAR:***,VAL:***.**<Cr>**

field 'CH' is:

- 0..7 for commands related to one of possible channels
- 8 for commands related to the Crate.

The format of the response string is one of the following:

#CMD:ERR<Cr>	Command Format wrong or command not recognised
#CH:ERR<Cr>	Channel Field not present or channel value wrong
#PAR:ERR<Cr>	Field parameter not present or parameter not recognised
#VAL:ERR<Cr>	Set Value wrong (<Min or >Max)
#CMD:OK,VAL:***<Cr>**	Command Ok ***** = value

8.1 Monitor Commands related to channel 'X' :

$CMD:MON,CH:X,PAR:NAME<Cr>	Readout channel name (ex. +5V..)
$CMD:MON,CH:X,PAR:VSET<Cr>	Readout value of the voltage Set
$CMD:MON,CH:X,PAR:VMIN<Cr>	Readout minimum value of the voltage Set
$CMD:MON,CH:X,PAR:VMAX<Cr>	Readout maximum value of the voltage Set
$CMD:MON,CH:X,PAR:VRES<Cr>	Readout resolution value of the voltage Set
$CMD:MON,CH:X,PAR:OVP<Cr>	Readout value Over Voltage Protection

Detector Control System (DCS) – Detail (2) The EPICS

The EPICS translates different communication protocols into a single protocol

- Channel access (ca)
  - Each variable from hardware are defined as a process variable (PV) inside the EPICS
  - To read a value
    - $ caget <pv_name>

```
(base) -bash-4.2$ caget sbnd_tpc_west_2_1/outputMeasurementSenseVoltage
sbnd_tpc_west_2_1/outputMeasurementSenseVoltage -1477.82
```

  - To write a value
    - $ caput <PV_name> <value>

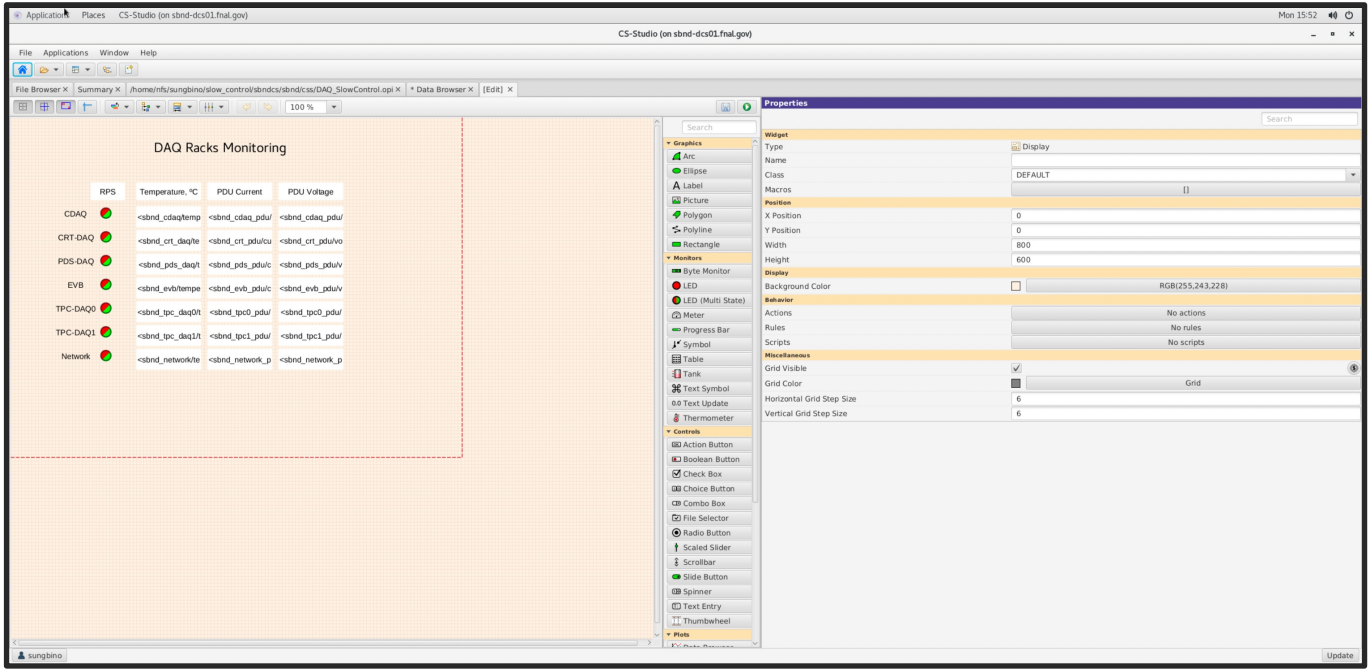
- Then, we use PV names for archiving, building GUI page, and alarming

Detector Control System (DCS) – Detail (3) The Phoebus

The Phoebus is GUI page viewer/editor dedicated to the EPICS

- Can be used for both shifters and sub-system experts

(Example)
Editing DQA rack Monitoring GUI page

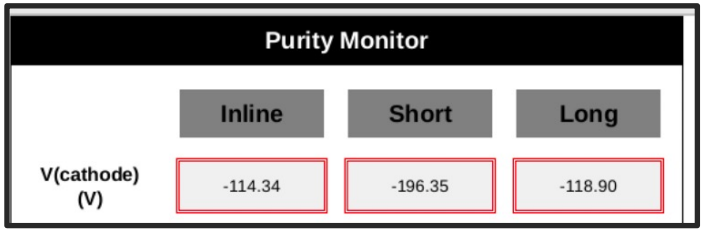


Detector Control System (DCS) – Detail (4) Alarms

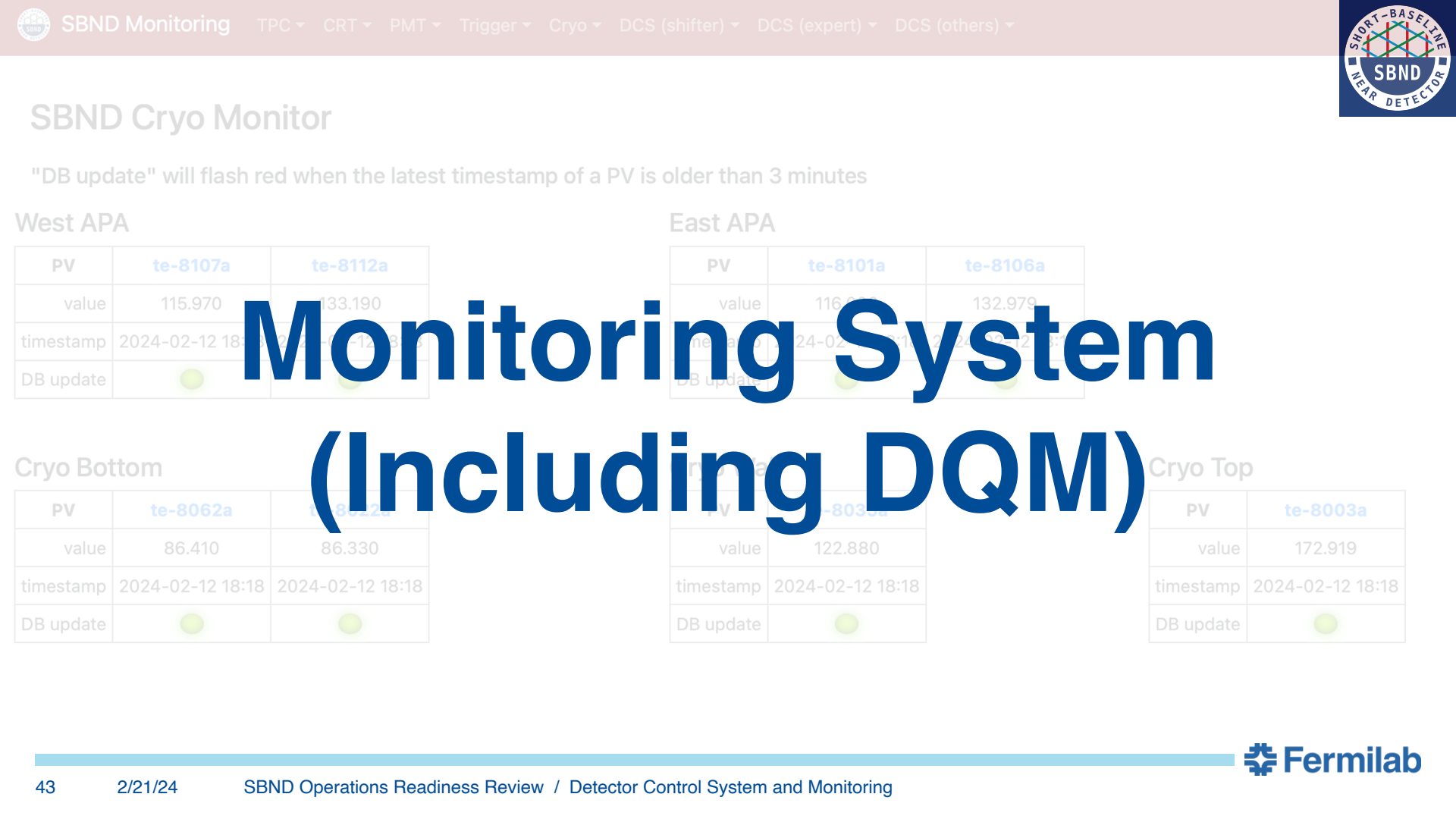
Alarm is important for recognizing problems with operation of the detector

- The EPICS : define safe ranges of each PV
  - There could be two ranges, MINOR alarm and MAJOR alarm
- The Phoebus : presents alarm status for each PV with alarm boarder

(Example)
Red boarders for MAJOR alarm



  - Alarm-server
    - Read an .xml configuration file that defines alarm tree structure
    - Alarm summary panel and table are also supported
  - Alarm-logger : archives alarm history into an Elasticsearch DB



Monitoring System (Including DQM)

DAQ Monitoring Metrics

- Run number
- DAQ server time
- Memory metrics
- Event-building metrics such as
  - The number of empty or missing fragments
  - The time taken waiting for a process or to build events
- Board-reader metrics
- The status of various memory buffers
- Trigger and event rate metrics

DQM Metrics

- TPC
  - Channel waveforms and fast Fourier transforms (FFTs) will be monitored
  - Along with computed metrics such as noise RMS, baseline, hit occupancy and mean peak height
  - The values will be compared to reference values from stable operation
- PDS
  - RMS, baseline, hit occupancy and mean peak height will be monitored per photon detector (PD)
  - The values will be compared to reference values from stable operation
- CRT
  - Baseline, hit time, and maximum ADC value will be monitored per board
  - The values will be compared to reference values from stable operation

DQM Metrics

- White rabbit TDC
  - Timestamps of the different signals that are inputs to the White Rabbit TDC will be monitored and compared to ensure stable time alignment between beam, timing, and trigger signals
- Trigger
  - Low- and high-level trigger (LLT and HLT) production and analog sum of the MTC/A will be monitored.