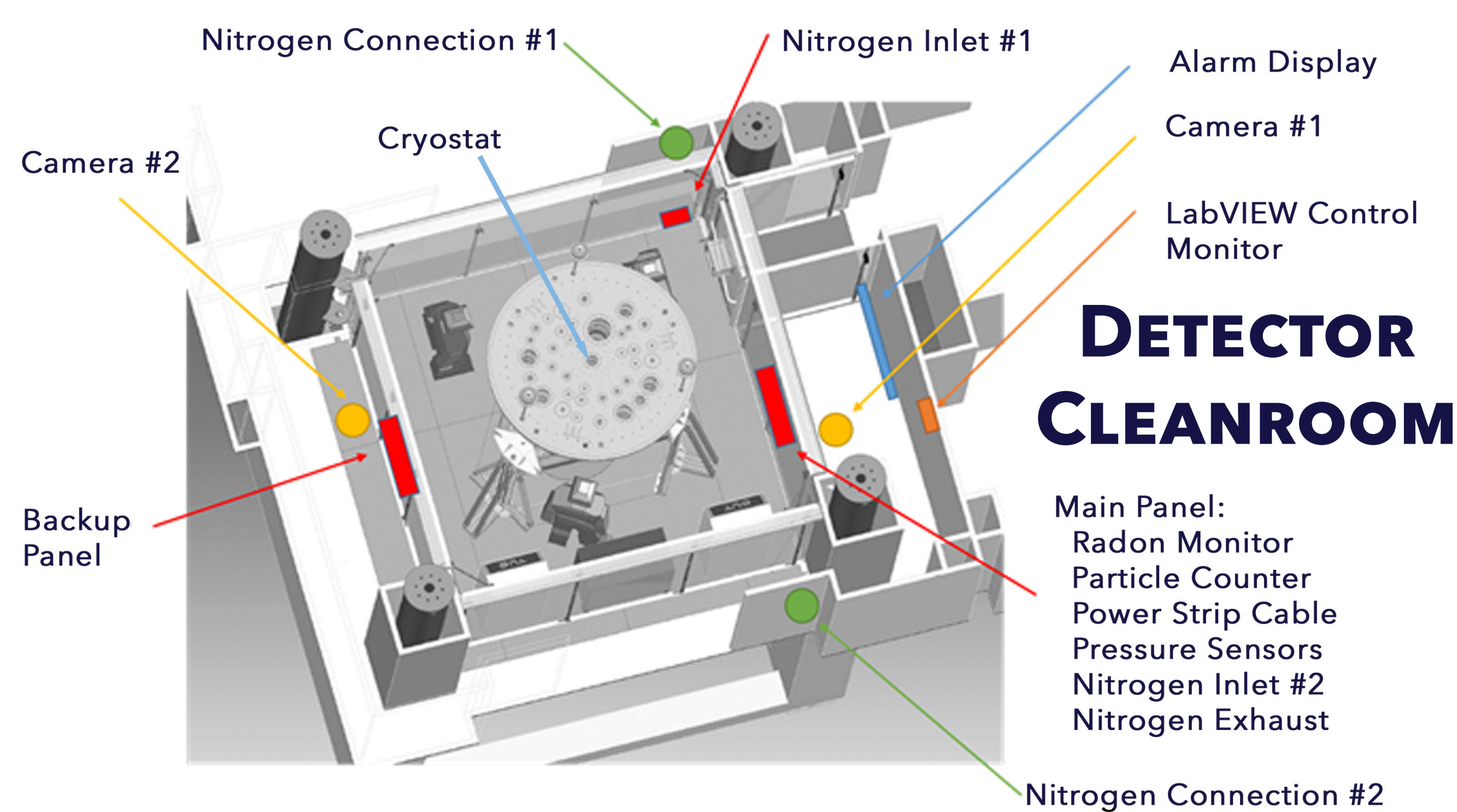
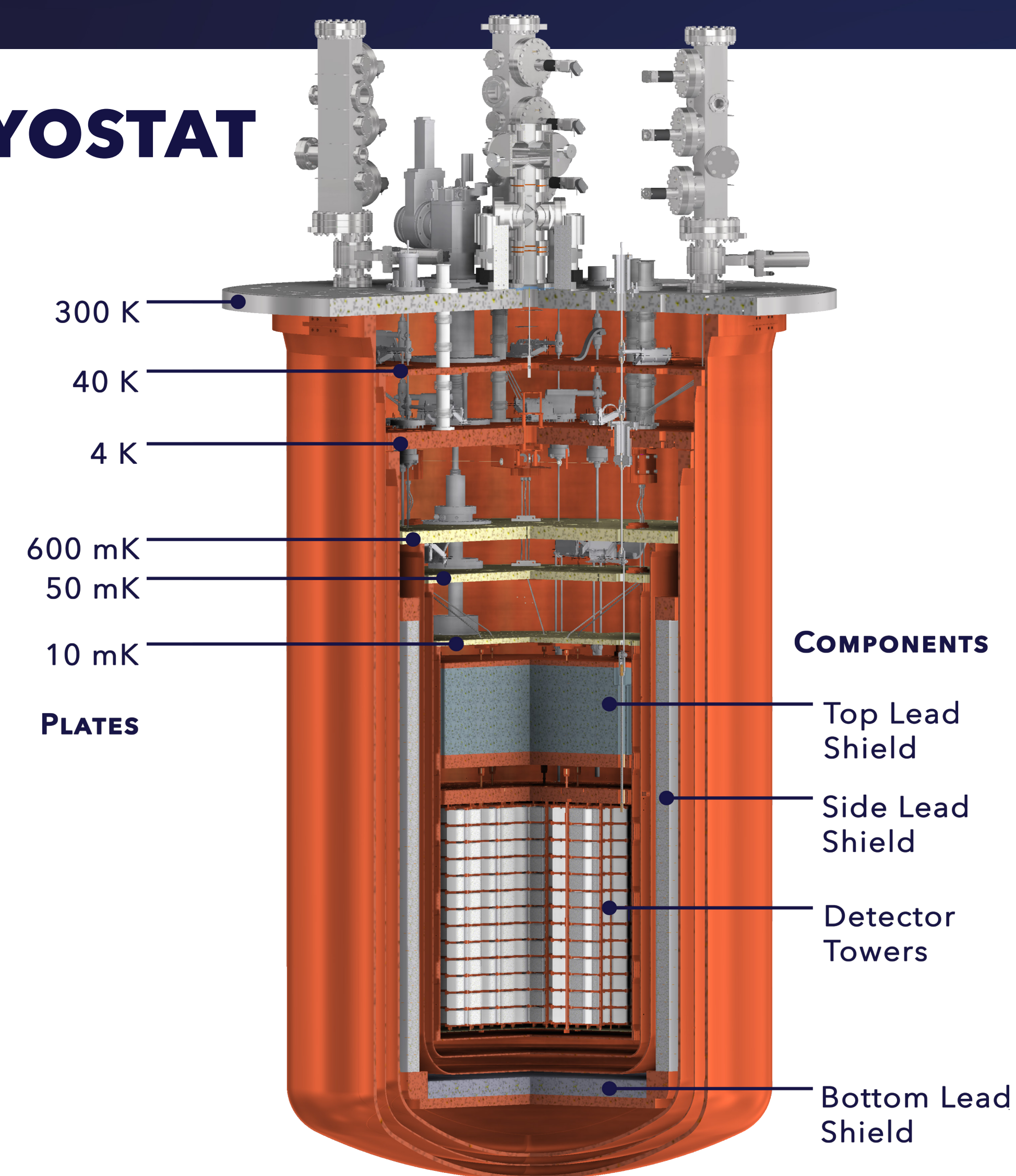


INTRODUCTION

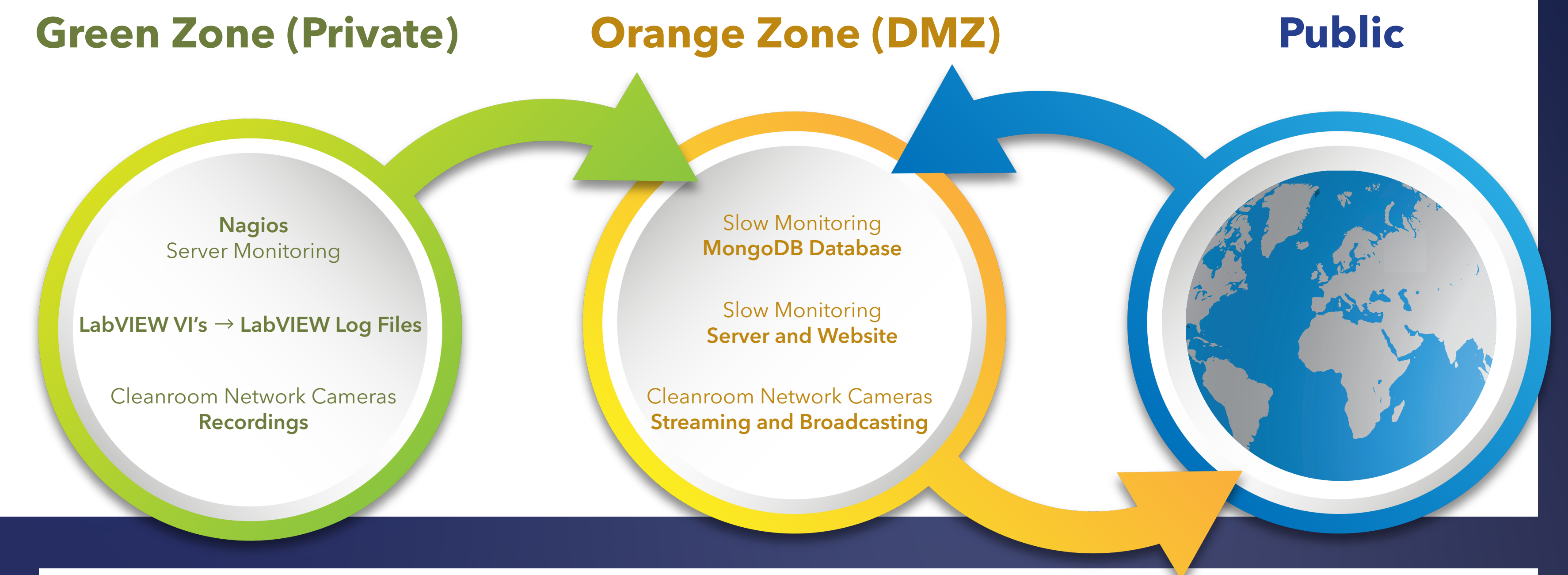
- The **Cryogenic Underground Observatory for Rare Events (CUORE)** is a **neutrinoless double-beta decay** experiment currently under construction at the Laboratori Nazionali del Gran Sasso (LNGS).
- The experiment is comprised of **988 TeO₂ bolometric crystals** arranged into **19 towers** and operated at a temperature of **10 mK**. The active mass of the detector is **206 kg**.
- We have developed **slow monitoring systems** to monitor the cryostat during detector installation, commissioning, data taking, and other crucial phases of the experiment.

CRYOSTAT



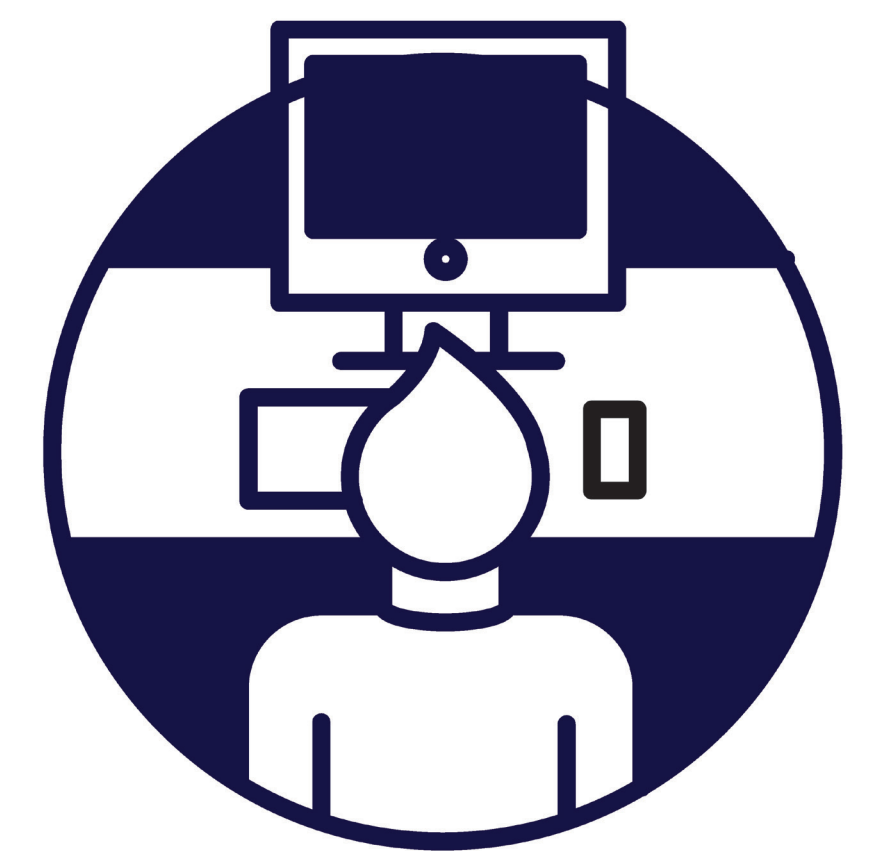
DATA FLOW

- Three-tiered network security structure enables easy and reliable access to internal monitoring data
- Green zone (private)** can only be accessed onsite or through VPN. Underground servers on the private network interface directly with hardware
- These servers collect log files from various systems (e.g. Radon Monitoring, Detector Calibration System, Thermometers, Pulse Tubes, etc)
- Nagios** monitors servers and key processes on the CUORE networks: 18 hosts, 159 services
- Orange zone (DMZ)** provides an isolated and controlled interface between the private network and all public networks. Mostly comprised of above-ground servers
- If DMZ servers are **compromised**, private servers are **unaffected**
- New data is written into a **MongoDB Database**, which is then presented on the front-end
- The CUORE **gateway public machine** allows access to various services in the orange zone network, including the CORC slow monitoring interface

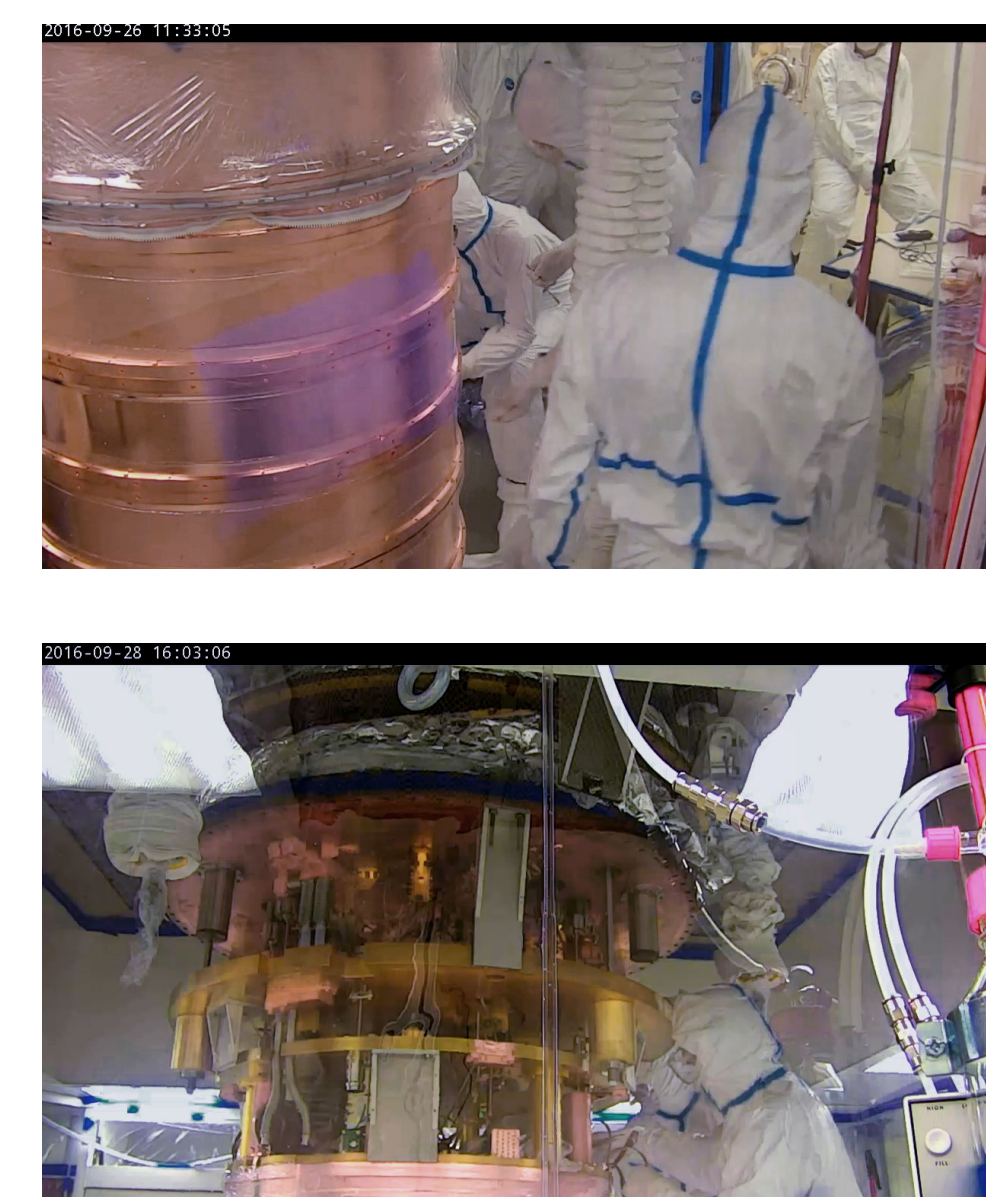


MONITORING SHIFTERS

- Onsite shifters** maintain direct communication with workers in detector cleanroom and the rest of the collaboration. Also responsible for maintaining monitoring systems and recording all pertinent ongoing activities on the cryostat
- Remote shifters** maintain 24/7 monitoring of cryostat activities to assist onsite shifters and ensure rapid response in case of emergencies
- ELOG check sheets** utilized by both shifters to maintain active record



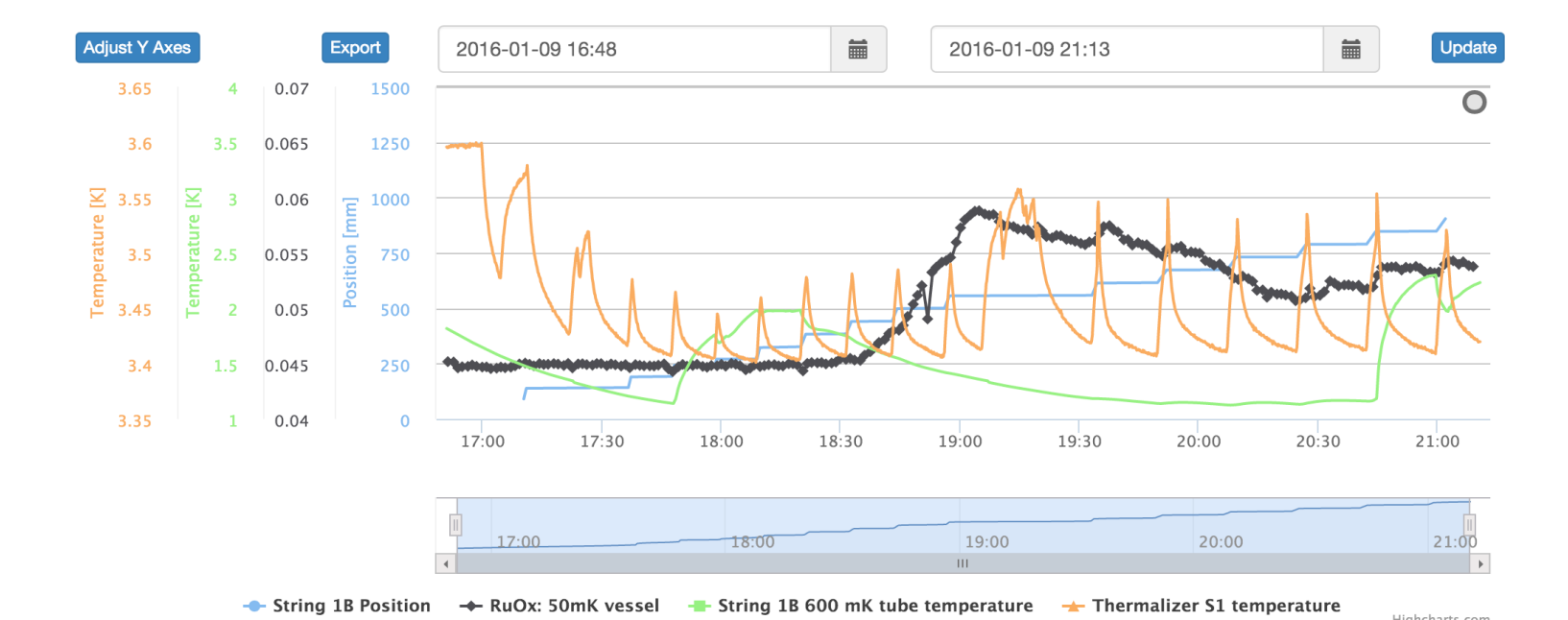
IP CAMERAS AND STREAMING



- Two high-resolution **Axis Network Cameras** inside detector cleanroom
- Onsite and remote shifters can adjust alignment and settings on web interface
- Streams **rebroadcasted** through DMZ monitoring server using VLC, and displayed on website for collaboration-wide access
- Streams **recorded and stored** on a NAS server within the green zone (private) for documentation and protection
- Implemented and used for **detector installation**

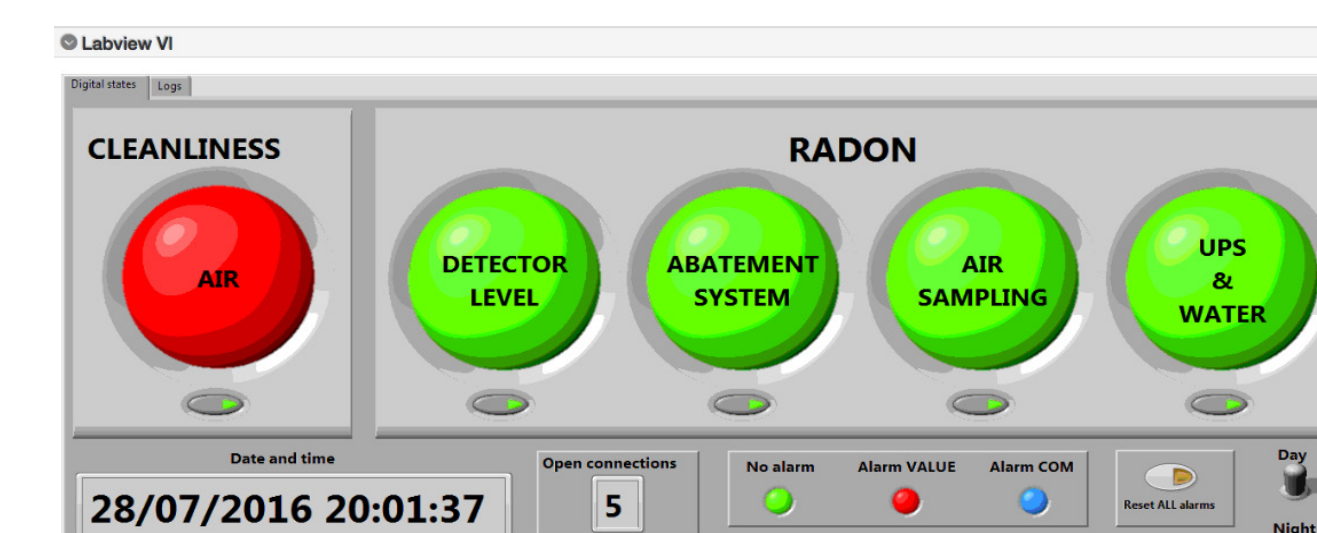
CORC INTERFACE

- CORC**: CUORE Online Run Control
- Web interface to monitor CUORE systems, containing Slow Monitoring plots, channel and run information, automatic and manual flags for problematic data, remote shifter monitoring interface, and alarms
- Fully responsive and built with **jQuery**, **Angular**, and **Bootstrap** frameworks
- Slow Monitoring Plots**: displays data from Mongo DB with interactive GUI, enables aggregation of information from various independent systems
- Remote Shifter Interface**: contains LabVIEW Control Panel, rebroadcasted cleanroom video streams, and nitrogen level monitor



LABVIEW CONTROL

- Sound-enabled alarms connected to LabVIEW Monitors for particle count, radon levels, radon abatement, and backup power and water
- Viewed by onsite and remote shifters, and by cleanroom workers to ensure rapid response and safety



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