Fermilab U.S. DEPARTMENT OF ENERGY Office of Science

Cryogenic System for ArgonCube 2x2 test at FNAL

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ND-LAr Consortium Cryogenics Planning Meeting

17 March 2021

ArgonCube

Outline

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Scope of Work at Fermilab

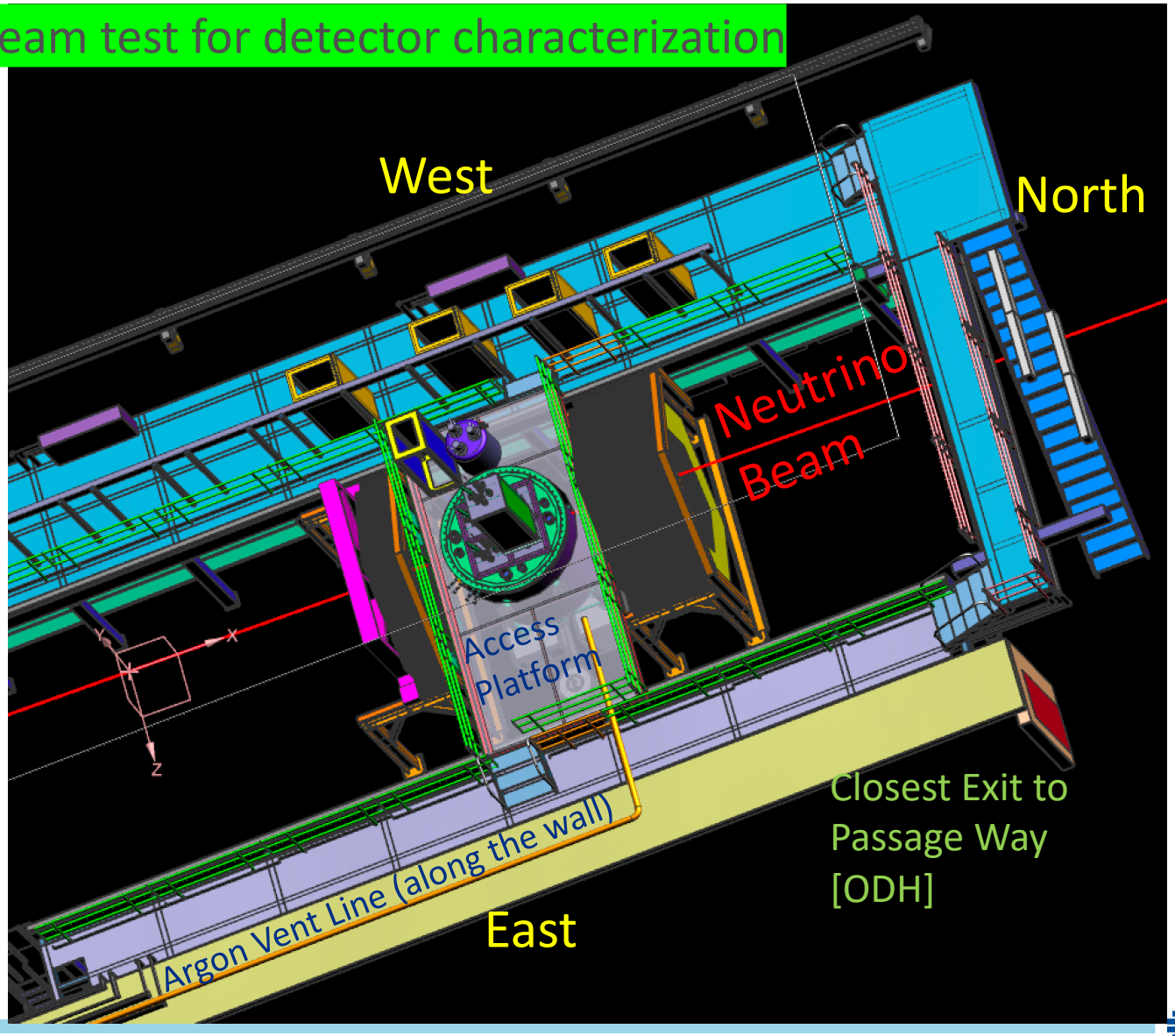
- Decommission of MINERv/MINOS detectors in the cavern
- MINERvA module re-installation (12 modules in upstream and 32 modules in downstream of the cryostat)
- Design and installation of cryogenic infrastructure in MINOS hall: Cryocoolers, chiller, condenser, vent line, etc.
- ODH Planning: ODH analysis, exhaust fan replacement, implementation of spilled argon containment and ODH controls measures, etc.
- Modification of cryogenics from Bern, as needed (e.g. external filter vessel)
- Cryostat qualification
- Design, fabrication and installation of cryostat access platform and other mechanical support structure (for cryogenic equipment, electronics, cables, etc.)
- Electronics infrastructure and integration
- Organize/prepare all the information/documentation required for the design and safety review committees and work with them to obtain approvals for the operations of the test stand on time.

Introduction of Team at Fermilab

- Ting Miao (tmiao@fnal.gov): Coordinator
- Min Jeong Kim (mjkim@fnal.gov): Leading engineering team from Neutrino Division (ND), Technical Support Department (TSD).
- Cryo-Mechanical Engineers (with a good skill set in Cryogenic Engineering):
  - Michael Zuckerbrot (mzuck@fnal.gov): Lead Cryogenic Engineer
  - Fritz Schwartz (fschwart@fnal.gov): Subject Matter Expert (SME)
  - Kathrine Laureto (klaureto@fnal.gov): P&ID, VIEs
  - Roza Doubnik (rdoubnik@fnal.gov): Design/safety documentation
  - Sai Manohari Kancharla (skanchar@fnal.gov): FEA, design and calculations for mechanical structures and equipment support
- Electrical Engineers:
  - Linda Bagby (bagby@fnal.gov): Subject Matter Expert (SME)
  - Trevor Nichols (tnichols@fnal.gov): Experts on cryogenic control system
  - Matthew Micheli (mmicheli@fnal.gov): Electronic integration & cryogenic control system
- DAQ & Computing:
  - Geoff Savage (savage@fnal.gov)
  - Donatella Torretta (torretta@fnal.gov)
  - Howard Budd (hbudd@fnal.gov)
  - Steve Hahn (Hahn@fnal.gov)

ArgonCube 2x2 Test Stand in MINOS Hall

Neutrino beam test for detector characterization



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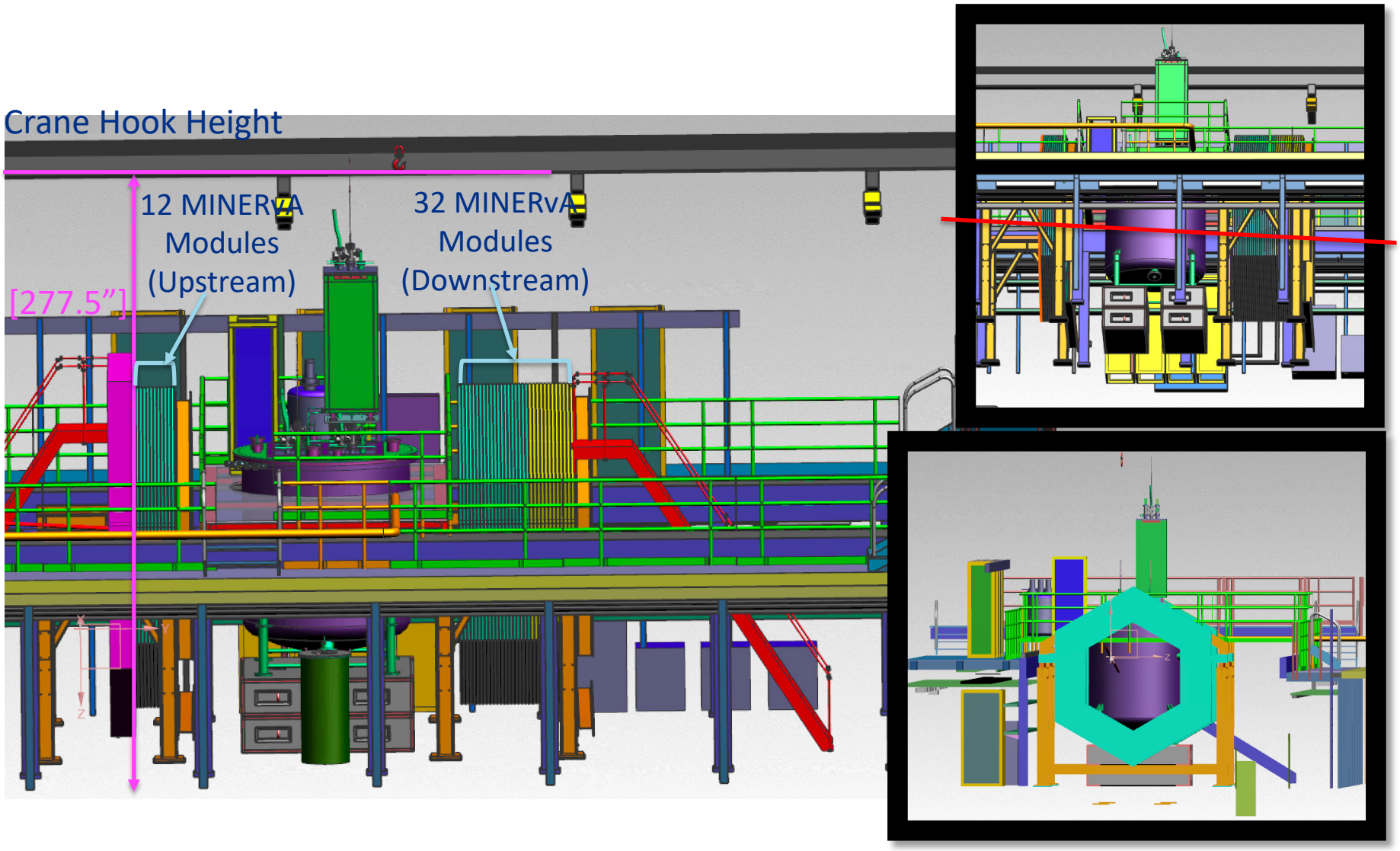
ArgonCube 2x2 Test Stand in MINOS Hall (continued)

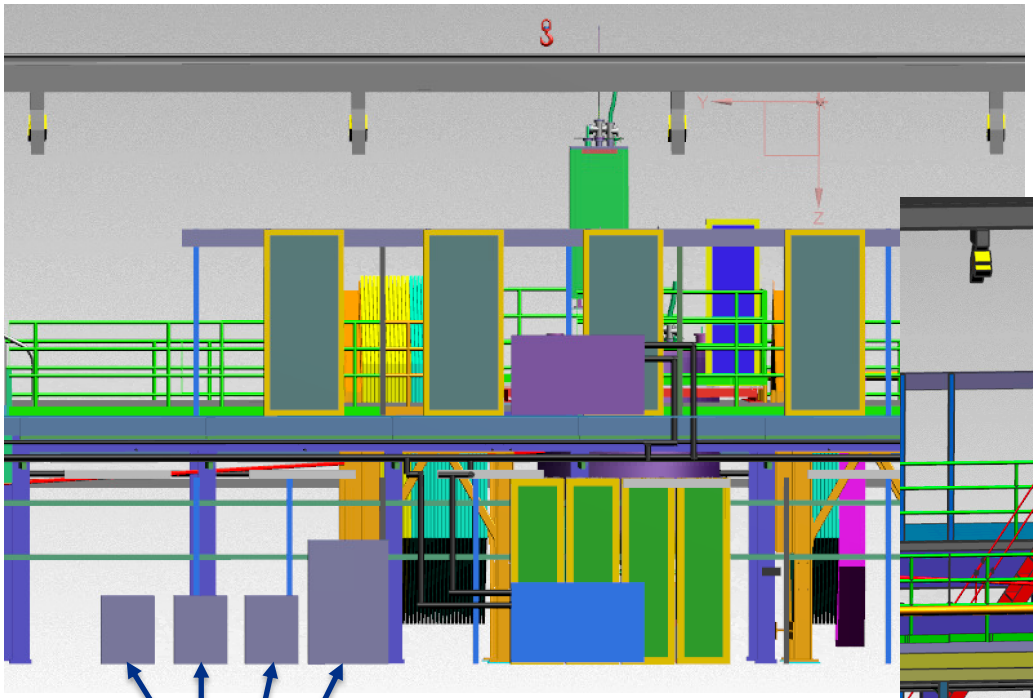


Cryogenic System

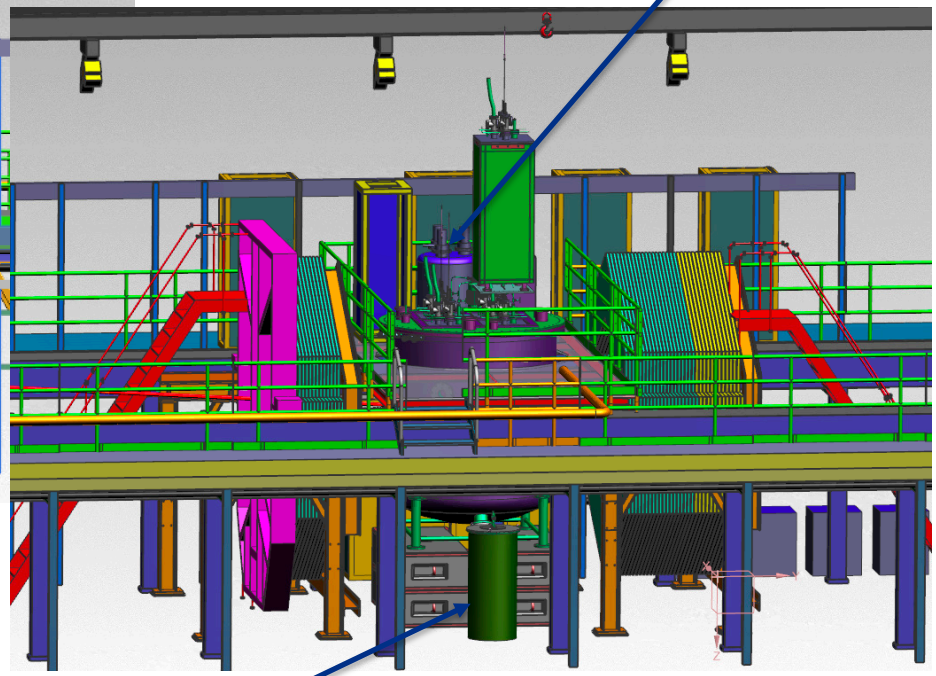
- Cryostat (low pressure vessel) qualification for the operations at Fermilab
  - Cryostat inspection per API 510 (contract with a company holding a license)
  - FEA per ASME BPVC Section 8, Division 2, Part 5 “Design-by-Analysis”
  - Pressure test (pneumatic) at Fermilab
- Reuse as much as cryogenic equipment from University of Bern, if we can qualify them for the operations at Fermilab. We have been working closely with Bern team for the 2x2 cryogenics design and implementation.
- Cryogenic Infrastructure (Major difference from set up in University of Bern)
  - Piston purge and initial fill with portable 180 liter LAr dewars (Delivery of ~35-40 dewars in elevator from the surface to the underground).
  - No use of LN_2, instead use water-cooled cryocoolers and a condenser
    - Refrigerator capacity: 1.8 kW (= 3 x 600 W)
    - Refrigerator capacity determined with total heat load estimation of ~1.2 kW. Further confirmation is required with data from the operations in University of Bern (See slide for ‘Issues & Risks’).
    - Prior to the COVID-19 pandemic, the lead time for the cryocoolers was 20 weeks after receipt of order; If more than one is ordered, each subsequent system could be shipped in two week intervals.

Cryogenic System (continued)

- Cryogenic control system developed by Trevor Nichols and used for runs in Bern will be back to Fermilab.



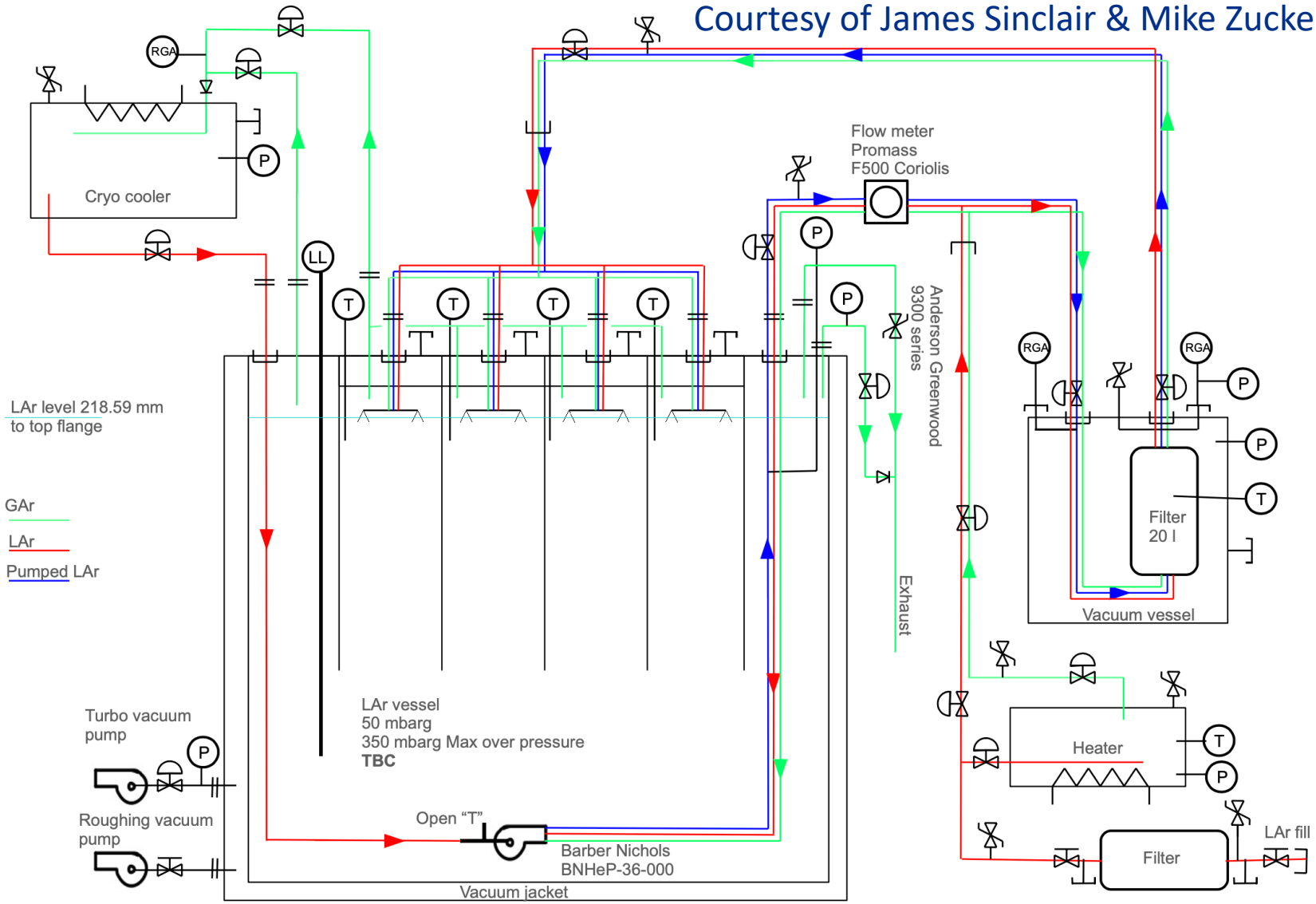
Chiller & Cryocoolers
(Under West Catwalk)



External Filter Vessel (East; Under Access Platform; on a cart for easy service)

Cryogenic System (P&ID)

Courtesy of James Sinclair & Mike Zuckerbrot



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Tasks and Schedule

WBS Tasks	Start Date	Finish Date
Preliminary Installation Design	10/25/18	10/14/21
ArgonCube 2x2 Installation Design	6/2/21	1/24/22
(2.1) Contract and ship ArgonCube 2x2 to FNAL from BERN (Cryostat & 1 module)	7/1/21	8/31/21
(2.2) Detector support and access platform in MINOS hall	2/24/21	10/13/21
(2.3) Cryogenic design and review	8/27/21	1/27/22
Detector Support and Installation Tooling Procurement	8/16/21	10/29/21
Cryogenic System Procurement	11/26/21	4/22/22
Electronics Integration Design and Procurement	8/30/21	2/11/22
Assembly and Installation	6/7/21	6/17/22
(6.1a) Completion of MINOS Decommisioning	2/1/21	5/4/21
(6.1b) Reinstallation of Minerva modules	5/5/21	7/30/21
(6.2) Certification of 2x2 cryostat: FEA, pressure test and review	6/7/21	10/28/21
(6.3) ODH control and monitoring system installation	11/26/21	1/26/22
(6.4) Cryogenic system installation	3/24/22	6/17/22
(6.5) 2x2 cryostat support safety reviews, installation	11/1/21	12/1/21
(6.6) 2x2 cryostat and TPC module installation safety reviews, installation	12/2/21	1/3/22
(6.7) Electronics support safety reviews, installation	10/28/21	12/28/21
(6.8) Electronics safety reviews, installation	12/15/21	6/8/22
ArgonCube 2x2 Commissioning	6/20/22	10/18/22

Cost (M&S)

Description	Amount [$]
MINERvA/MINOS decommissioning and MINERvA module reinstallation	1,080K (~50% spent)
Cryostat qualification (contract for cryostat inspection per API 510)	5-10K
Cryogenic infrastructure (cryocoolers, condenser, chiller, argon vent line extension):	500K
Cryogenic equipment (procurement, modification, etc.)	50K
Implementation of ODH measures, exhaust fan replacement for the test area	100K
Cryostat access platform, cryostat support, cart for external filter vessel, and other mechanical structure (cart to move the cryostat in the tunnel and cavern where we don't have crane coverage, support for cryogenic equipment, support for racks and cable trays, etc.)	50K
Cryogenic control system	40K (~75% spent)
Electrical grounding isolation and monitoring equipment (sent to BERN)	10K (100% spent)
AC transformer for low-noise AC power distribution	20K
Electronics racks, crates and DC power supplies repurposed from MINOS	50K
DAQ servers and network equipment	20K

Cost (Labor)

- FY19 - FY20

Description	FTE-Days	FTE-Hours
Cryogenic Engineers	225	1,800
Mechanical Engineers	95	760
Electrical Engineers	50	400
Process Engineers	40	320

- FY21 - FY22

Description	FTE-Days	FTE-Hours
Cryogenic Engineers	310	2,480
Mechanical Engineers	305	2,440
Electrical Engineers	180	1,440
Process Engineers	100	800
Computing Specialists	210	1,680
Technicians	280	2,240

Issues & Risks

- The determination of refrigerator capacity must be based on the *realistic estimates* of the total heat dissipation from all the components. And, this determination must be made in a timely manner. The cryogenic infrastructure (cryocoolers, condenser, chiller and other auxiliary components) has a long lead time and once it is purchased, as a set (system), it can't be extended without replacing the whole system.

Summary and Comments

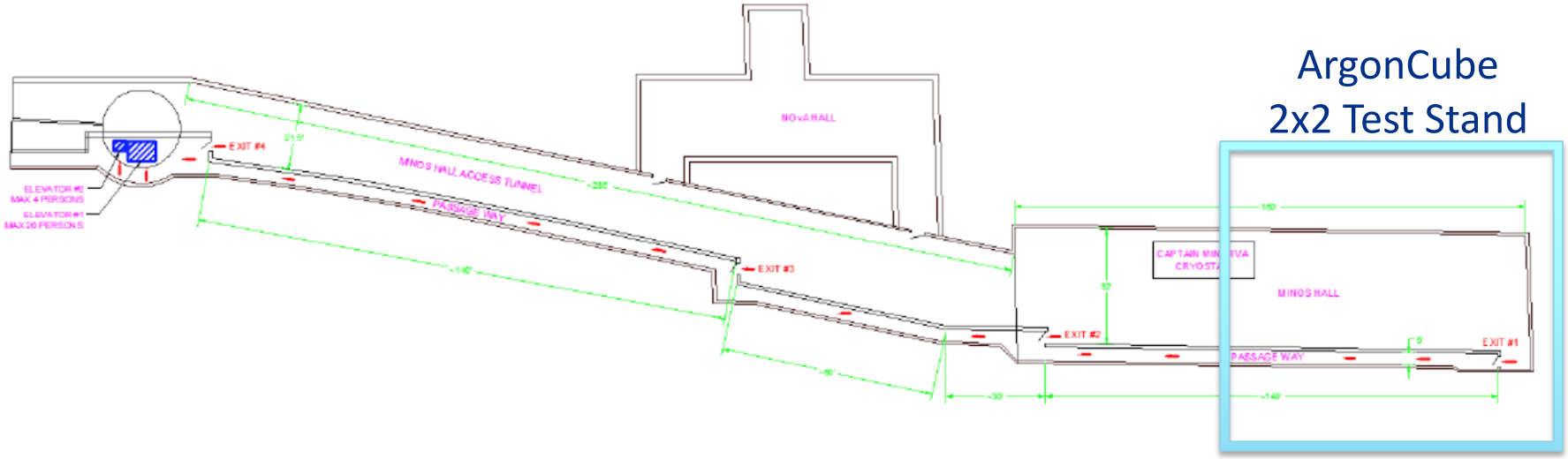
- We are making a good progress with the decommissioning of MINERvA/MINOS detector [Target Completion in May, 2021]. We will install the first piece of 2x2 configuration – two groups of MINERvA modules – this summer.
- We are making proper procurement planning for items with long lead time right now. For that, we need to make final confirmation on couple estimates and calculations (in order to determine the size and capacity of equipment). We are currently working on this.
- To start to work on documentation required by design and safety review committees to get approvals for the operations at Fermilab, we are currently gathering all the information that should come from collaborators.

  https://drive.google.com/file/d/1Y5p6RFUqLBvR3mt4utufvwcevPNRf-tn/view?usp=sharing
- For the QA/QC and potential repair of modules, we request to have a good documentation to be developed with the experience on the first module (such as, production drawings, engineering calculations, assembly procedure, QA/QC documentation describing clearly all the necessary tests and steps with well-defined acceptance criteria, lessens learned, test results, etc.).

Backup Slides

- MINERvA/MINOS cavern
- Determination of refrigerator capacity (require update!)
- Discussion on a pressure test configuration

MINERvA/MINOS Cavern



Determination of Refrigerator Capacity (Require update!)

- Estimation of total heat load: **1.2 kW**
  - Heat leak though the cryostat wall and cryostat floor: **15 W**
  - Heat leak through cryostat top, cryogenic system, and misc.: **885 W**
  - Heat load from ArgonCube Modules: **0.2 kW for 4 modules**
    - Field Shaping Cell: **15 W** / module
    - Pixel Readout: **30 W** / module
    - Light Detection: **5 W** / module

Discussion on a pressure test configuration

	Description	Pros	Cons
Method A	Method using dummy plates to cover the cryostat for a pressure test	○ Convenience in setting up a pressure test.	○ Additional cryostat FEA with dummy plates instead module top flanges. ○ Need of engineered plates (in reality, not a dummy plate) to simulate the structural strength of module top and the total weight of detector/module. ○ Separate qualification of module top flanges according to the relevant engineering standard.
Method B	Method using module top flanges to cover the cryostat for a pressure test	○ Module top flanges can be qualified together with cryostat (saving in time/labor). ○ A leak test can be planned together with the pressure test in a more realistic condition. It can be useful to check potential leak through module connection pieces and seals.	○ Need blank flanges to cap all module feedthroughs. ○ Module design must have a simple mechanism to separate module top flanges from detector/module (Yes: verified design with Bern team). ○ All module top flanges must be available at the time of pressure test (Yes: confirmed with Bern team for proper planning).