2x2 Overall Schedule and Cost

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2x2 Project Documentation

- Project documentations are linked in the indico page
- WBS schedule is with resource loaded
- Cost tables for equipment and services
  - M&S cost for cryogenics and installation support
  - M&S cost for electronics support
- Milestones and risks are tabulated and being tracked
- Interface issues between subsystems is being documented
- DUNE docDB is used to achieve technical notes
  - Tagged with topic “ArgonCube2x2”

Interface Documetnation – DUNE docDB 23046

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2x2 subsystem	Subsystem lead/contact
Installation and integration	**Min Jeong Kim**
FNAL Cryogenics design	**Mike Zuckerbrot**
Electronics integration	**Linda Bagby**
Light readout electronics	Nikolay Anfimov/Sasha Selyunin (Dubna)
Charge readout electronics	Armin Karcher (LBNL)
Drift HV - power supply, cable, filter box	Saba Parsa (Bern)
Drift HV - feedthrough	Knut Skarpaas (SLAC)
TPC module structure	Davide Porzio (Bern)
Cryostat, cryogenics and cryo feedthrough	Igor Kreslo / Roger Haenni (Bern)

- Major issues are captured
- Responsibilities are being spelled out

Interface Issues and Responsibilities

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Interface Issues	Subsystem Responsibly	DUNE docDB
Rack layout and installation	**Electronics group** provides list of racks, size of racks, access and space clearance requirement	22971, 22639
	Installation groups provides layout 3d model and installation support	
Cable routing and cable tray	**Electronics group** provides cable routing scheme from TPC to electronics on the cryostat top and in the electronics readout racks	
	Installation group provides layout 3d model, cable length calculation and installation support	
Cable tray support installation	**Electronics group** provides list of cable trays and their locations	
	Installation group provides layout 3d model and cable tray support design	
Layout and AC support for on-detector TPC electronics	**Dubna/LBNL/Bern groups** provide equipment list, AC/DC power budget and networking requirement for light/charge/drift HV electronics located on top of cryostat flange	21540, 20615, 20681, 18300
	Electronics and installation groups provide AC distribution, electrical safety protection, network switch and layout 3d model	
Rack building for electronics and DAQ	**Dubna/LBNL/Bern groups** provide single line electrical diagram of light/charge/drift HV readout and control electronics placed inside electronics racks	22809, 21809, 20490, 20943, 20681
	Electronics group provides clean AC outlets, racks, rack protection, network switch, cabling support and guidance for operation readiness clearance (ORC) review	
Cryostat feedthrough and safety review	**Bern/SLAC/DUBNA/LBNL** groups provide list of feedthrough, design file and their pressure test of module structure, drift high voltage, light and charge readout systems	21579
	Cryogenics group provides 3d layout, guideline for feedthrough pressure test, guidance for operation readiness clearance (ORC) review	
Cryostat and TPC module installation	**Bern/LBNL groups** provide CAD file, equipment list on cryostat and TPC modules	
	Installation group provides integration 3d model, lifting fixture and installation engineering and safety review	
TPC module assembly and QA/QC	**Bern provides** TPC module QA/QC procedure and instruction from module-0 experience.	
	Installation group to provide mechanical support	

Interface Topics and Responsibilities (cont.)

Interface Issues	Subsystem Responsibly	DUNE docDB
Cryogenic equipment specification and procurement	**Bern** provides initial P&ID and list of equipment, their connection on main cryostat top and on TPC modules	
	FNAL Cryogenics group completes the P&ID and equipment list, and specify additional procurement	
LAr filter vessel design	**Bern** provides CAD file of filter vessel from singleCube test and list of equipment and connections implemented	
	FNAL Cryogenics group modifies the vessel diameter and specify procurement plan	
Cryo equipment AC and networking requirements	**FNAL Cryogenics group** provides AC power and networking requirements for cryogenics equipment	
	Electronics group provides AC outlets and network switch	
Cryo control rack layout and networking	**FNAL Cryogenic control** to provide specification of PLC rack, its power budget and network connection	21459, 21958
	Electronics group provides AC outlets, emergency backup power and network switch	
Cryo equipment layout and support requirement	**FNAL Cryogenics group** provides dimension of cryogenics equipment and piping connection scheme	
	Installation group provides layout design and installation support	
Piping routing and length	**FNAL Cryogenics group** provides piping scheme of cryogenics, venting and ODH mitigation	
	Installation group provide layout design and installation support	
Cryostat and cryogenics equipment access support	**FNAL Cryo group** provides cryostat and cryogenics operation and access requirement	
	Installation group designs and builds access platform, support stand and transfer cart	

2x2@LArTF Schedule

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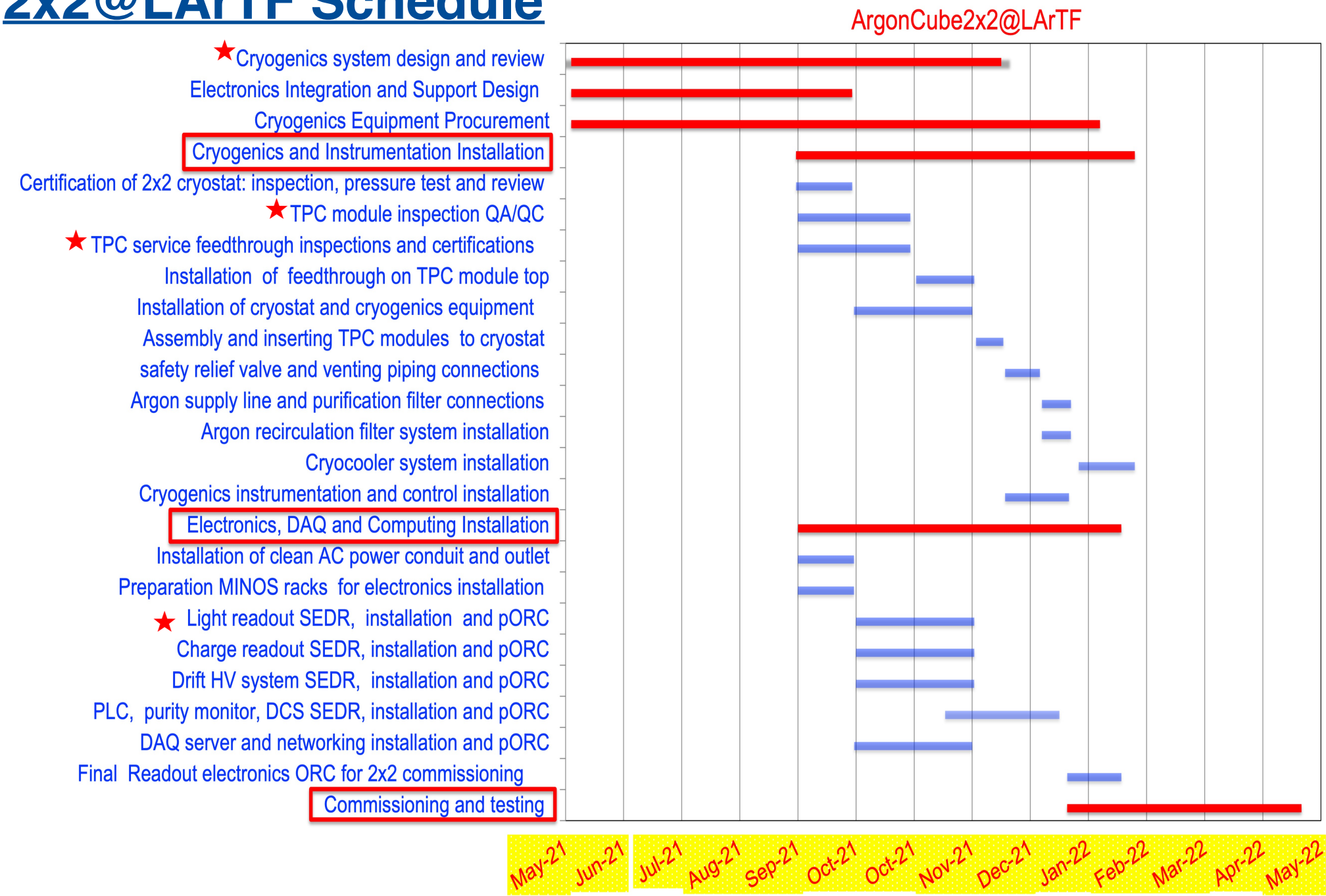
- Schedule-driven tasks
  - Cryogenics engineering and safety reviews (May 2021–Feb 2022)
    - P&ID, VIE, piping, ODH analysis, process and control
    - Cryogenics equipment specifications and procurements
    - Safety reviews – CSS panels for LArTF and for MINOS
  - TPC module QA/QC and service feedthrough qualification (Sept 2021–Oct 2021)
    - Consortium subsystem groups to be onsite for module QA/QC
    - Potential impact from travel limits
  - Readout electronics ORC (ongoing, to complete before Dec 2021)
- Resource demand is high especially for Oct 2021—Feb 2022

2x2@LArTF Schedule



2x2@LArTF Tasks with Detail Dates

Tasks for 2x2@LArTF	*Start*	*Finish*
Cryogenics system design and review for 2x2@LArTF	5/7/2021	12/15/2021
Electronics Integration and support Design for 2x2@LArTF	5/7/2021	10/29/2021
Cryogenics equipment procurement	5/7/2021	2/4/2022
Cryogenics and Instrumentation Installation	8/31/2021	2/22/2022
Certification of 2x2 cryostat: inspection, pressure test and review	8/31/2021	9/29/2021
TPC module inspection QA/QC	9/1/2021	10/29/2021
TPC service feedthrough inspections and certifications	9/1/2021	10/29/2021
Installation of feedthrough on TPC module top	11/1/2021	12/1/2021
Installation of cryostat and cryogenics equipment	9/30/2021	11/30/2021
Assembly and inserting TPC modules to cryostat	12/2/2021	12/16/2021
safety relief valve and venting piping connections	12/17/2021	1/4/2022
Argon supply line and purification filter connections	1/5/2022	1/20/2022
Argon recirculation filter system installation	1/5/2022	1/20/2022
Cryocooler system installation	1/24/2022	2/22/2022
Cryogenics instrumentation and control installation	12/17/2021	1/19/2022
Electronics, DAQ and Computing Installation	9/1/2021	2/15/2022
Installation of clean AC power conduit and outlet	9/1/2021	9/30/2021
Preparation MINOS racks for electronics installation	9/1/2021	9/30/2021
Light readout SEDR, installation and pORC	10/1/2021	12/1/2021
Charge readout SEDR, installation and pORC	10/1/2021	12/1/2021
Drift HV system SEDR, installation and pORC	10/1/2021	12/1/2021
PLC, purity monitor, DCS SEDR, installation and pORC	11/16/2021	1/14/2022
DAQ server and networking installation and pORC	9/30/2021	11/30/2021
Final ORC of readout electronics and DAQ for 2x2@LArTF	1/18/2022	2/15/2022
Commissioning and testing	1/18/2022	4/20/2022
HV, PLC and detector control commissioning	1/18/2022	2/15/2022
DAQ commissioning	2/16/2022	3/17/2022
LAr filling and purifying	2/23/2022	4/20/2022
Commissioning runs to reach stable HV setting	4/6/2022	4/20/2022
Cosmic Ray and BNB Runs	4/21/2022	5/19/2022

2x2@MINOS Schedule

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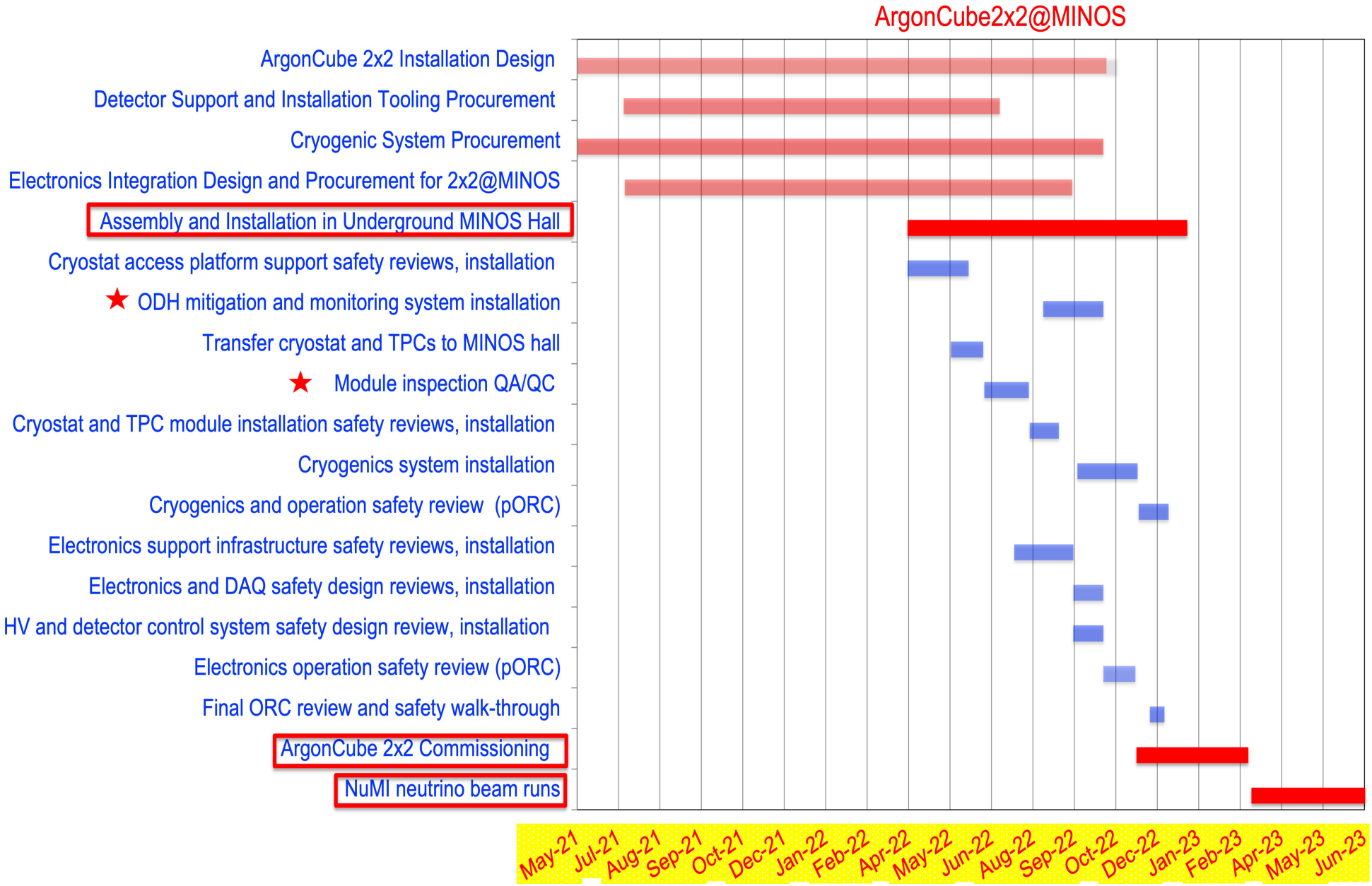
- While testing 2x2 in LArTF, support infrastructures for MINOS hall will be designed and installed in parallel
  - Cryostat access platform to cryostat
  - Low noise transformer and AC distribution for LAr TPC electronics
- ODH mitigation is one key design for cryogenics underground
  - ODH mitigation involves FESS for updating exhaust fan and extra duct work
- The 2x2@MINOS schedule is also driven by the delivery and QA/QC time of the last 2 TPC modules
  - Last two modules are scheduled to be available in early summer 2022

2x2@MINOS Installation Schedule



2x2@MINOS WBS Tasks

WBS Tasks	Start Date	Finish Date
Preliminary Installation Design	**10/25/18**	**7/8/21**
ArgonCube 2x2 Installation Design	**5/7/21**	**10/17/22**
Cryogenics design and review for 2x2@LArTF	5/7/21	12/15/21
Cryogenic design and review for 2x2@MINOS	5/20/22	10/17/22
Transportation and installation tooling	5/10/21	6/6/22
Detector support and access platform in MINOS hall	9/13/21	4/7/22
Detector Support and Installation Tooling Procurement	7/8/21	7/6/22
Cryogenic System Procurement	5/7/21	10/14/22
Electronics Integration Design and Procurement for 2x2@MINOS	7/9/21	9/14/22
ArgonCube 2x2@LArTF Installation and Test	9/1/21	5/19/22
Assembly and Installation in Underground MINOS Hall	7/9/21	1/3/23
Re-installation of Minerva modules for ArgonCube test	7/9/21	11/2/21
Cryostat access platform support safety reviews, installation	4/8/22	6/6/22
ODH mitigation and monitoring system installation	8/17/22	10/14/22
Decommissioning of 2x2@LArTF and transfer cryostat and TPCs to MINOS hall	5/20/22	6/20/22
Module inspection QA/QC	6/21/22	8/3/22
Cryostat and TPC module installation safety reviews, installation	8/4/22	9/1/22
Cryogenics system installation	9/19/22	11/16/22
Cryogenics and operation safety review (pORC)	11/17/22	12/16/22
Electronics support infrastructure safety reviews, installation	7/20/22	9/15/22
Electronics and DAQ safety design reviews, installation	9/15/22	10/14/22
HV and detector control system safety design review, installation	9/15/22	10/14/22
Electronics operation safety review (pORC)	10/14/22	11/14/22
Final ORC review and safety walk-through	11/28/22	12/12/22
ArgonCube 2x2 Commissioning	11/15/22	3/3/23
NuMI neutrino beam runs	3/6/23	6/30/23

2x2 Milestones and Critical Tasks

- Three sets of milestones to track 2x2 progress
  - TPC module and electronics delivery
  - 2x2@LArTF installation
  - 2x2@MINOS installation
- Similarly, critical tasks with high impacts on schedule, cost and technical are compiled in the risk table
  - Most of the risk impacts are on schedule
  - Cost and technical risks are likely to be reduced with LArTF test

2x2 Milestones

#	Milestone Tasks	Completion
1	2x2 cryostat arrives Fermilab from BERN	July 30, 2021
2	First TPC module and major cryogenics equipment received by FNA	August 31, 2021
3	Last TPC module received for LArTF test (2nd TPC)	October 29, 2021
4	All drift HV component received for 2x2@LArTF	November 1, 2021
5	All light readout electronics received for 2x2@LArTF	November 1, 2021
6	All charge readout electronics received for 2x2@LArTF	November 1, 2021
7	Completion of preliminary installation design	July 8, 2021
8	Completion of 2x2@LArTF cryogenics design	December 15, 2021
9	Electronics and DAQ are ready for 2x2@LArTF test	February 15, 2022
10	Cryogenics system is ready for 2x2@LArTF test	February 22, 2022
11	Completion of LArTF test and 2x2 is ready to move to MINOS hall	May 19, 2022
12	Final TPC modules received for MINOS test (3rd and 4th TPCs)	July 6, 2022
13	Completion of 2x2@MINOS cryogenics design	October 17, 2022
14	Cryogenics system is ready for 2x2 commissioning	December 16, 2022
15	Electronics and DAQ are ready for 2x2 commissioning	November 14, 2022
16	2x2 is ready to start commissioning	January 3, 2023
17	2x2 is ready for physics data running	March 3, 2023

Risk Table

Ranking	Critical Tasks	Risk Impact	Task Completion Dates
1	Cryostat vessel certification	Schedule	9/29/21
2	Cryocooler system specification and delivery	Schedule & Cost	1/21/22
3	Cryogenics P&ID and equipment specification	Schedule	9/29/21
4	Cryocooler system installation	Schedule	2/22/22
5	Final ORC of readout electronics and DAQ for 2x2@LArTF	Schedule	2/15/22
6	TPC module inspection QA/QC	Schedule & Cost	10/29/21, 8/3/22
7	Additional cryogenic equipment procurement for MINOS	Cost, Schedule & Technical	10/14/22
8	ODH mitigation and monitoring system installation for 2x2@MINOS	Cost & Schedule	10/14/22
9	Cryogenics and operation safety review for 2x2@MINOS	Schedule	12/16/22
10	Cryostat access platform support installation	Cost & Schedule	6/6/22
11	Low-noise transformer and AC distribution in MINOS	Cost	11/2/21
12	Networking upgrade in MINOS hall	Cost	9/14/22
13	Timing and trigger interfaces with ACNET system	Schedule	9/14/22

Resource and Cost

- Resource and cost estimates are based on experiences of LAr TPC experiments and underground installations
  - 2x2 has a very strong engineering team
- Engineering resources are drawn from neutrino division and PPD
  - Engineers from both divisions have good record of working together
- Most M&S estimates are from vendor quotes or old procurements
  - Major procurement for cryogenics are almost completed
  - Key electronics equipment are none-cost: uBooNE spare AC transformer, racks from MINOS decommissioning, Weiner PS from MINOS etc.

Technical Labor and M&S Cost

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All Divisions	Cryo Engineer (FTE days)	Mech Engineer (FTE days)	Mech Designer (FTE days)	Process Control Engineer (FTE days)	Mech Technician (FTE days)	Electrical Engineer (FTE days)	Electrical Technician (FTE days)	Computing Specialist (FTE days)
Technical support for FY2019-20	105	105	50	10	0	50	0	0
Technical support for FY2021	190	125	70	10	104	125	25	95
Technical support for FY2022-2023	367	205	117	189	225	213	155	327

All Divisions		Cryo Engineer (FTE days)	Mech Engineer (FTE days)	Mech Designer (FTE days)	Process Control Engineer (FTE days)	Mech Technician (FTE days)	Electrical Engineer (FTE days)	Electrical Technician (FTE days)	Computing Specialist (FTE days)
Support for FY2022	$450 K	277	200	117	147	225	153	155	162

Summary

- 2x2 schedule was put together with past experience of LAr TPC experiments and underground installations
- High level milestones was defined
- Interfaces between 2x2 subsystems are being developed and documented
- Time-critical tasks of TPC module delivery, cryostat certification, and cryogenics procurement are identified. Risk mitigations are being investigated
- 2x2@LArTF is a critical step to work out technical and schedule issues before underground installation
- Thank you all for the help!

Overall Schedule 2x2 Test at Fermilab

WBS Tasks	Start Date	Finish Date
Preliminary Installation Design	10/25/18	7/8/21
ArgonCube 2x2 Installation Design	05/07/21	10/17/22
Detector Support and Installation Tooling Procurement	7/8/21	7/6/22
Cryogenic System Procurement	5/7/21	10/14/22
Electronics Support Design and Procurement for 2x2@LArTF	5/7/21	10/29/21
Electronics Integration Design and Procurement for 2x2@MINOS	7/9/21	9/14/22
ArgonCube 2x2@LArTF Installation and Test	9/1/21	5/19/22
Assembly and Installation in Underground MINOS Hall	4/8/22	1/3/23
ArgonCube 2x2 Commissioning	11/15/22	3/3/23
2x2 NuMI Runs	3/6/23	12/29/23