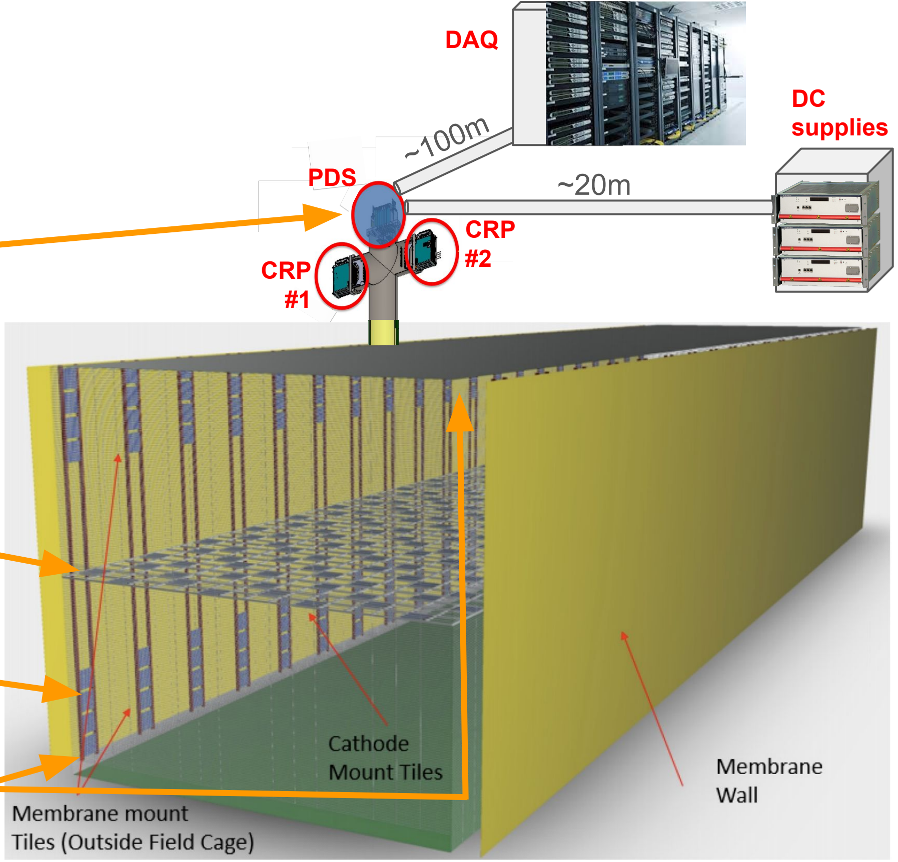
FD2 PDS
Cost, Schedule, & Risks

05 May 2022
DUNE FD2 PDS Preliminary Design Review
Ryan Rivera

FD2 PDS Scope

- Warm electronics
  - 1280 digitizer channels (640 opto-electrical)
  - Cathode fiber power supplies
  - DC copper power supplies
  - Calibration source modules
- 320 Cathode modules
  - Each module has 8 fibers:
    - 2 signal-over-fiber channels out
    - 6 power, calibration, control, redundancy
- 320 Membrane modules
  - Each module has 6 conductors:
    - 2 differential signal pairs out w/Bias
    - 1 low voltage and return pair
- Response & Stability Monitoring light diffusers
  - O160 LED flasher fibers + diffusers
- 40 Penetrations
  - Each services 8 cathode modules + 8 membrane modules



2022 and Beyond

Parasitic ARIADNE run run complete!

Cold Box A PDS install is 18 April 2022

Preliminary Design Review (PDR) is 1st week of May 2022

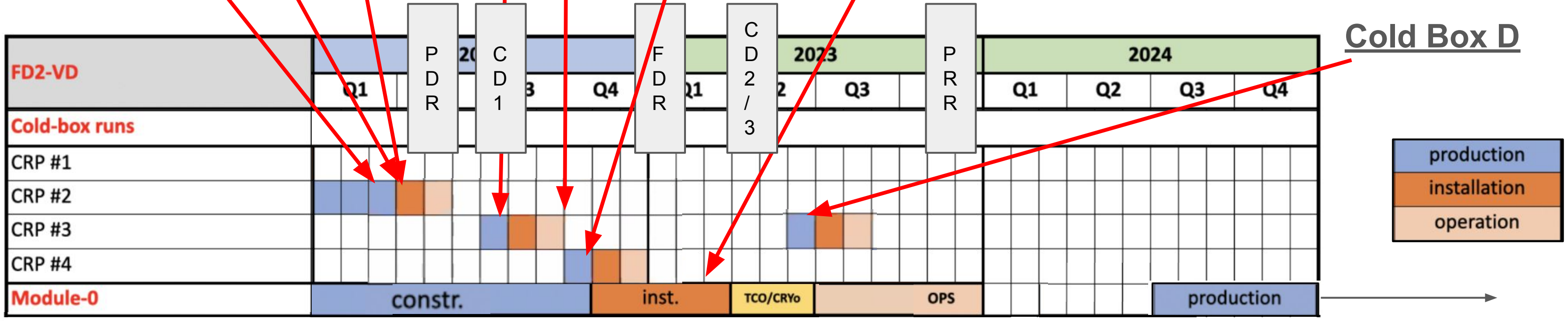
Cold Box B PDS install is July 2022

Cold Box C PDS install is October 2022

Cold Box B+ (No CRP)

FD2 PDS Module-0 install thru March 2023

Cold Box D



Far Site Construction

- Mid-2024 launch production.
  - +320 modules (double-sided) in US and +320 modules (single-sided) in EU
    - +9% spares
- Mid-2026 Warm Electronics installation starts
- Early-2027
  - Cathode module cavern assembly starts
  - Feedthroughs, fibers, cables installed
  - Membrane module installation into Cryostat starts
- End-of-2027 commissioning complete.

Scope Split with EU/Brazil

Core M&S/Labor Line Item	Cathode	Membrane
Production SiPMs w/9% spare	EU/Brazil	EU/Brazil
Production Dichroic Filters w/9% spare	EU/Brazil	EU/Brazil
Production WLS plates w/9% spare	EU/Brazil	EU/Brazil
Production Warm Electronics w/9% spare	EU/Brazil	EU/Brazil
Production Support Structure Mechanics	US	EU/Brazil
Production Monitoring System w/9% spare	US	EU/Brazil
Production xARAPUCA mechanics w/9% spare	US	US
Production Cold Electronics w/9% spare	US	US
Production Power-over-Fiber w/9% spare	US	-
Production fibers/cables/flanges w/9% spare	US	EU/Brazil
module-0 SiPMs w/20% spare	EU/Brazil	EU/Brazil
module-0 Dichroic Filters w/20% spare	EU/Brazil	EU/Brazil
module-0 WLS w/20% spare	EU/Brazil	EU/Brazil
module-0 Warm Electronics w/20% spare	EU/Brazil	EU/Brazil
module-0 Monitoring System w/20% spare	US	EU/Brazil
module-0 xARAPUCA mechanics w/20% spare	US	US
module-0 Cold Electronics w/20% spare	US	US
module-0 Power-over-Fiber w/20% spare	US	-
module-0 fibers/cables/flanges w/20% spare	US	US

EU/Brazil Scope

EU/Brazil Core M&S Line Item	USD	
All Production SiPMs w/9% spare	$	1,562,624
All Production Dichroic Filters w/9% spare	$	1,009,567
All Production WLS plates w/9% spare	$	279,040
All Production Warm Electronics w/9% spare	$	470,880
Membrane Production fibers/cables/flanges	$	175,000
Membrane Support Structure Mechanics	$	30,000
Membrane Production Calibration System w/9% spare	$	231,080
All module-0 SiPMs w/20% spare	$	129,024
All module-0 Dichroic Filters w/20% spare	$	83,359
All module-0 WLS w/20% spare	$	23,040
All module-0 Warm Electronics	$	60,000
Membrane module-0 Calibration System	$	30,000
EU/Brazil Core Total USD:	$	4,083,613
USD to EURO conversion		0.85
EU/Brazil Core Total Euro:	€	3,471,071

DOE Scope

US Core M&S Line Item	USD	
All Production xARAPUCA mechanics w/9% spare	$	1,078,720
All Production Cold Electronics w/9% spare	$	837,120
All Production Power-over-Fiber w/9% spare	$	1,183,304
Cathode Production fibers/cables/flanges	$	180,000
Cathode Support Structure Mechanics	$	30,000
Cathode Production Calibration System w/9% spare	$	231,080
All module-0 xARAPUCA mechanics w/20% spare	$	48,845
All module-0 Cold Electronics w/20% spare	$	115,200
All module-0 Power-over-Fiber w/20% spare	$	116,544
All module-0 fibers/cables/flanges	$	16,641
Cathode module-0 Calibration System	$	50,000
US Core Total USD:	$	3,887,453
USD to EURO conversion		0.85
US Core Total Euro:	€	3,304,335

DOE 'Build to Cost' policy:

Fermilab

Fermi National Accelerator Laboratory

Memorandum

Christopher J. Mossey

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Date: February 16, 2022
To: LBNF/DUNE-US Deputy Project Directors
From: Chris Mossey
Re: Change Control Process Related to "Build to Cost"

Message:

LBNF/DUNE-US Project has been exercising a change control process since 2015 to track changes to scope, cost, and schedule. As of January 2022, this has not generally included limiting budgets or drawing down contingency from a fixed amount; rather, as costs have increased as the designs matured and contracts were awarded, contingency associated with the increased cost was allowed to grow in parallel.

To control cost growth and demonstrate cost stability on this mostly very mature project, LBNF/DUNE-US Project will begin a process to limit increases in budget and to contain cost contingency need growth, particularly in cost estimate uncertainty as the designs mature. These principles will guide this process, in conjunction with the change control process described in the *Systems Engineering Management Plan* (dune-doc-49):

FSCF-EXC Subproject has set a practice baseline in advance of CD-2 approval, with a fixed TPC, budget, and contingency. This subproject will:

- Draw down contingency and increase budget if changes are approved in accordance with the established change control thresholds for this subproject.
- Have changes to budget and contingency usage tracked as part of the regular EVMS process.
- Stay within its established funding allocation and contingency during execution.
- Regularly revisit estimate uncertainty contingency and risks to ensure cost contingency need (and that related to schedule contingency burn rate) is not overstated.

FSCF-BSI, FDC, and NSCF+B subprojects are quite mature (in some cases, 100% designed and ready for execution) but have not yet established a baseline with a set budget, contingency, and TPC. (Note that most DOE projects at this level of maturity are usually baselined by this point.) These subprojects will:

- Work to stay within existing subproject budgets as of January 2022 by looking for offsets to any cost changes that may be required.
- While possibly reworking existing plans or identifying good ideas, subproject should work to stay within 5% of existing subproject annual obligations to minimize strain on overall annual funding limits. The subproject making such changes must work with possibly affected subprojects to minimize impacts overall. Such changes should be discussed with project leadership before implementing.

P6 WBS

Far Detectors + FS Cryogenic Infrastructure

Activity ID	Activity Name	Planned Duration	Start	Finish	Total Float
131.FDC	Far Detectors + FS Cryogenic Infrastructure	2574.0d	30-May-19	01-Oct-29	433.1d
131.FDC.01	FDC PM	2574.0d	30-May-19	01-Oct-29	309.1d
131.FDC.03	Far Detector 2 (FD2)	2158.0d	01-Mar-21	01-Oct-29	433.1d
131.FDC.03.01	FD2 Project Management	1949.0d	01-Mar-21	30-Nov-28	642.1d
131.FDC.03.02	FD2 Charge Readout Units (CRU)	1505.0d	01-Oct-21 A	30-Sep-27	935.1d
131.FDC.03.03	FD2 Charge Readout Plane (CRP)	1546.5d	01-Oct-21 A	01-Dec-27	893.6d
131.FDC.03.04	FD2 Top Drift Electronics (TDE)	1999.0d	01-Oct-21 A	01-Oct-29	308.1d
131.FDC.03.05	FD2 Bottom Drift Electronics (BDE)	1951.0d	01-Oct-21 A	12-Jul-29	365.1d
131.FDC.03.06	FD2 High Voltage (HV)	1842.0d	14-Jun-21 A	29-Sep-28	597.1d
131.FDC.03.07	FD2 Photon Detector System (PDS)	1862.0d	03-May-21	29-Sep-28	684.1d
131.FDC.03.07.01	PDS Management	1756.0d	01-Oct-21 A	29-Sep-28	684.1d
131.FDC.03.07.02	PDS R&D	763.0d	03-May-21	15-May-24	129.2d
131.FDC.03.07.03	Cathode PDS	854.1d	16-May-24	11-Oct-27	173.9d
131.FDC.03.07.05	Membrane PDS	872.3d	16-May-24	04-Nov-27	155.7d
131.FDC.03.08	FD2 Data Acquisition (DAQ)	1749.0d	01-Oct-21 A	29-Sep-28	678.1d
131.FDC.03.09	FD2 Cryogenic Instrumentation	1114.5d	30-Oct-23	17-Apr-28	793.6d
131.FDC.05	FS Integration & Installation	1558.5d	04-Jan-22	20-Mar-28	155.5d
131.FDC.05.04	Far Detector #2 Installation	1558.5d	04-Jan-22	20-Mar-28	155.5d

FD2 PDS Collaboration

- How do we make progress?
  - We layout the parallel tasks and their sequence of steps
  - We have responsibility assignments
    - We have a strong team!
      - We have assembled a team consisting of 21 institutions
  - The plan is to utilize **breakout meetings**
    - A periodic landing point on various tasks
    - Each meeting we hear progress reports and align plan for next meeting
  - We have an **activity assignment matrix**
- All 2022 SOWs have been written (all but a couple are established)
- 2023 SOWs should be written in July-August 2022 timeframe
- 2024+ SOWs will be for Production (i.e., junior technicians/engineers)

Responsibility Matrix (1 of 2) link

Breakout Meetings / Tasks / Subtasks Activity Matrix	Flavio Cavanna	Min Jeong Kim	Paul Rubinov	Ryan Rivera	Bill Pellico	Hucheng Chen	Larry Minjoo Lee	John Harton	Vishnu Zutshi	Xiao Luo	Josh Spitz	Yasar One	Marcos Turqueti	Jon Urheim	Sabrina Sacerdoti	David Martinez Caicedo
End-of-February Tasks and Subtasks	FNAL-ND Sci	FNAL-ND Mech	FNAL-PPD/EED	FNAL-SCD/FDE	FNAL-AD	BNL	UIUC	CSU	NIU	UCSB	UMich	Iowa	LBL	Indiana	Paris	SDSMT
Photo-collector" -- biweekly Wednesdays 12:00 CST 19:00 CET led by Carla Cattadc	X			X				X	X	X		X			X	
-- SiPM Mounting								X	X			X				
-- Cathode Frame design								X	X							
-- Cathode Frame CPA interface									X			X				
-- Cathode Frame Electronics interface									X			X				
-- Membrane Frame design																
-- Membrane Frame CPA interface																
-- Membrane Frame Electronics interface																
-- WLS bars acquisition																
-- WLS sculpting R&D									X							
-- Dichroic Filters																
-- SiPM acquisition																
-- SiPM Selection	X					X			X	X					X	
"Analog Readout" -- Thursdays 09:00 CST 16:00 CET led by Dave Christian	X			X		X			X	X	X	X	X		X	
-- CB#3 Cathode module cold electronics repackaging design	X			X						X		X	X		X	
3. -- Reliability analysis	X			X		X				X	X	X	X	X	X	
---------- define how to qualify and quantify reliability	X			X		X				X	X	X	X	X	X	
---------- conduct tests to qualify and quantify reliability		X								X		X				
-- Reliability optimization						X				X			X		X	
2. -- Understand which analog readout components have warm/cold variation	X									X				X	X	
-- S/N optimization									X	X					X	
-- Warm electronics integration									X	X					X	
-- Membrane cold electronics repackaging									X		X				X	
~~1. -- Evaluate need for Electrical pulse calibration~~	X			X					X		X				X	
"Digital Readout" -- Thursdays 10:00 CST 17:00 CET led by Ryan for now	X			X							X	X	X			
-- Active/passive warm vessel prototype characterization				X												
-- Cold digital prototype characterization				X							X	X	X			
"Mechanical Design" -- Wednesdays 13:00 CST 20:00 CET led by Vishnu Zutshi		X		X				X	X		X	X			X	
1. -- External Cathode Fiber/Conduit Routing		X							X						X	
-- Internal Cathode Fiber Routing		X							X						X	
-- Internal Cathode Copper Cable Routing		X						X	X							
-- External Membrane Copper Cable/Conduit Routing																
-- Internal Membrane Copper Cable Routing																
2. -- Cathode Flange and Feedthrough		X						X				X				
-- Membrane Flange and Feedthrough								X			X					
-- Warm Class 4 laser routing		X														
10. -- Warm rack location and cable/fiber routing		X							X		X					
"Power-over-Fiber" -- biweekly Tuesdays 12:00 CST 19:00 CET led by Ryan for now	X			X	X		X						X			X
-- Efficiency optimization	X				X		X									
-- Cost estimates for topology scenarios	X			X	X											
-- Apply reliability analysis to PoF topology	X			X	X											
1. Evaluate need to control bias voltage																
-- Receiver Reliability analysis	X				X		X						X			X
---------- define how to qualify and quantify reliability	X				X		X						X			X
---------- conduct tests to qualify and quantify reliability																X
-- Fiber Reliability analysis (bending radius, conduit, light leakage)	X				X								X			X
---------- define how to qualify and quantify reliability	X				X								X			X
---------- conduct tests to qualify and quantify reliability																X
-- Fiber Connector Reliability analysis	X				X								X			X
---------- define how to qualify and quantify reliability	X				X								X			X
---------- conduct tests to qualify and quantify reliability																X
"Cathode HV impact" -- monthly led by Ryan for now	X		X	X		X										
-- Understand implications of sim on xARAPUCA layout			X			X										

Responsibility Matrix (2 of 2) link

Breakout Meetings / Tasks / Subtasks Activity Matrix	Bill Pellico	Hucheng Chen	Larry Minjoo Lee	John Harton	Vishnu Zutshi	Xiao Luo	Josh Spitz	Yasar One	Marcos Turqueti	Jon Urheim	Sabrina Sacerdoti	David Martinez Caicedo	Chang-Kee Jung	Dave Newbold	Ines Gil-Botella	Carla Cattadori	Francesco Terranova	Jaroslav Zalesak	Ettore Segreto	Zelimir Djurcic	Santosh Parajuli
End-of-February Tasks and Subtasks	**FNAL-AD**	**BNL**	**UIUC**	**CSU**	**NIU**	**UCSB**	**UMich**	**Iowa**	**LBL**	**Indiana**	**Paris**	**SDSMT**	**SBU/S. Korea**	**UK/RAL**	**Spain**	**INFN Milano**	**INFN**	**Cz**	**Brazil**	**ANL**	**SMU**
"Photo-collector" -- biweekly Wednesdays 12:00 CST 19:00 CET led by Carla Cattado				X	X	X		X			X				X	X			X		
-- SiPM Mounting				X	X			X								X					
-- Cathode Frame design				X	X																
-- Cathode Frame CPA interface					X			X													
-- Cathode Frame Electronics interface					X			X													
-- Membrane Frame design															X						
-- Membrane Frame CPA interface															X						
-- Membrane Frame Electronics interface															X						
-- WLS bars acquisition																X					
-- WLS sculpting R&D					X											X					
-- Dichroic Filters															X	X			X		
-- SiPM acquisition															X		X	X			
-- SiPM Selection		X			X	X					X				X		X	X			
"Analog Readout" -- Thursdays 09:00 CST 16:00 CET led by Dave Christian		X			X	X	X	X	X		X				X		X				
-- CB#3 Cathode module cold electronics repackaging design						X		X	X		X										
3. -- Reliability analysis		X				X	X	X	X	X	X										
---------- define how to qualify and quantify reliability		X				X	X	X	X	X	X										
---------- conduct tests to qualify and quantify reliability						X		X													
-- Reliability optimization		X				X			X		X										
2. -- Understand which analog readout components have warm/cold variation						X				X	X										
-- S/N optimization					X	X					X										
-- Warm electronics integration					X	X					X						X				
-- Membrane cold electronics repackaging					X		X				X				X		X				
~~1. -- Evaluate need for Electrical pulse calibration~~					X		X				X										
"Digital Readout" -- Thursdays 10:00 CST 17:00 CET led by Ryan for now							X	X	X					X							
-- Active/passive warm vessel prototype characterization														X							
-- Cold digital prototype characterization							X	X	X												
"Mechanical Design" -- Wednesdays 13:00 CST 20:00 CET led by Vishnu Zutshi				X	X		X	X			X				X		X		X		
1. -- External Cathode Fiber/Conduit Routing					X						X										
-- Internal Cathode Fiber Routing					X						X										
-- Internal Cathode Copper Cable Routing				X	X																
-- External Membrane Copper Cable/Conduit Routing															X		X				
-- Internal Membrane Copper Cable Routing															X						
2. -- Cathode Flange and Feedthrough				X				X													
-- Membrane Flange and Feedthrough				X			X								X						
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---------- define how to qualify and quantify reliability	X		X						X			X									
---------- conduct tests to qualify and quantify reliability												X									
-- Fiber Reliability analysis (bending radius, conduit, light leakage)	X								X			X									
---------- define how to qualify and quantify reliability	X								X			X									
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---------- define how to qualify and quantify reliability	X								X			X									
---------- conduct tests to qualify and quantify reliability												X									
"Cathode HV impact" -- monthly led by Ryan for now		X																			
-- Understand implications of sim on xARAPUCA layout		X																			
-- Understand resulting light yield and physics performance implications																X					

FD2 PDS Risks

Open: 8 threats, 1 opportunity
Closed: 1 threat, 1 opportunity

Note:

- HV discharge ‘managed’ with alternative topologies.
- Several risks map to installation & integration unknowns.

Risk Type	RI-ID	Title	Probability	Cost Impact	Schedule Impact	Risk Rank	Risk Status
Threat	RT-131-FDC-FD2-035	FD2 PDS Cathode plane HV potential variation requires modifications to power distribution	50 %	200 -- 2000 k$	0 months	3 (High)	Closed - Managed
Opportunity	RO-131-FDC-FD2-018	FD2 PDS Insulation solution allows for warm electronics in cryostat	20 %	150 -- 900 k$	-3 months	1 (Low)	Closed - Retired
Threat	RT-131-FDC-FD2-031	FD2 PDS Production mechanical packaging costs exceed estimated cost	50 %	10 -- 80 -- 100 k$	0 months	0 (Negligible)	Open
Opportunity	RO-131-FDC-FD2-037	FD2 PDS Additional collaborating funding agencies identified	15 %	0 -- 1000 k$	0 months	1 (Low)	Open
Threat	RT-131-FDC-FD2-010	FD2 PDS Simulations show additional detector coverage required	40 %	500 -- 4000 k$	0 months	3 (High)	Open
Threat	RT-131-FDC-FD2-014	FD2 PDS Insufficient Power-over-Fiber efficiency	10 %	200 -- 1000 k$	3 months	1 (Low)	Open
Threat	RT-131-FDC-FD2-029	FD2 PDS Components fail 30-year cold validation testing	35 %	200 -- 1500 k$	0 -- 3 months	2 (Medium)	Open
Threat	RT-131-FDC-FD2-030	FD2 PDS Underestimate in level of effort required for 30-year cold validation	15 %	200 -- 500 k$	0 -- 3 months	2 (Medium)	Open
Threat	RT-131-FDC-FD2-033	FD2 PDS Production phase infrastructure and test stand M&S costs exceed initial estimates	35 %	100 -- 200 -- 500 k$	0 -- 3 months	1 (Low)	Open
Threat	RT-131-FDC-FD2-034	FD2 PDS Additional on-project labor required during installation	30 %	100 -- 750 k$	1 months	1 (Low)	Open
Threat	RT-131-FDC-FD2-036	FD2 PDS Photon detector electronics generates noise on the TPC strips readout	10 %	100 -- 500 k$	2 -- 4 months	2 (Medium)	Open

Conclusion

- We have a strong and engaged team
- Resources in place within international consortium
- Clear plan for optimization and qualification
- Risk mitigation understood