

# Photon Detector System Cost and Schedule Status

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LBNF/DUNE-US Directors Review

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# Outline

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- Cost Summary (M&S)
- Cost Summary (Labor)
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  - ProtoDUNE Plans
- Summary

# Distribution of Responsibility Across Consortium

Component	Description	Quantity (per 10 kT)	Primary Responsibility
Detector support	Support rails, electrical connectors, cables	10 per APA. 1,500 total	DUNE-US
Light collector modules	X-ARAPUCA modules (frames, filters, assembly)	10 per APA. 1,500 total	Brazil
Photosensors	6X6mm <sup>2</sup> SiPMs	192 per module. 288,000 total	Italy, Spain, Czech Rep.
Cold electronics	Photosensor ganging (6X SiPM passive, 8X active)	1 per module 1,500 total	Italy, Spain
Warm electronics	DAPHNE system. Based on Mu2e ultrasound ADC	1 unit per APA 150 total	Colombia, Peru, DUNE-US
Calibration and monitoring	Pulsed UV flasher with CPA mounted diffusers	204 diffusers, 18 control modules	DUNE-US
Installation and integration	Module insertion, installation in cryostat		DUNE-US, Brazil, Europe

# Cost Summary (M&S)

P6 cost book data are separated into DOE and non-DOE (international in this case) Contributions. Also, Detector 2 is included in international numbers.

## DOE

Sum of Value	Column Labels									
Row Labels	9/30/20	9/30/21	9/30/22	9/30/23	9/30/24	9/30/25	9/30/26	9/30/27	9/30/28	Grand Total
▼ 131.02.02 Far Detector	100,308	675,823	229,110	1,104,160	80,901	70,272	57,235	47,104		2,364,915
▼ 131.02.02.05 Photon Detector	100,308	675,823	229,110	1,104,160	80,901	70,272	57,235	47,104		2,364,915
▶ 131.02.02.05 Photon Detector	(144,579)									(144,579)
▶ 131.02.02.05.04 Photon Detector Design/Management	49,851									49,851
▶ 131.02.02.05.06 Project Management	26,340	39,284	40,070	40,871	41,688	42,522	43,373	29,108		303,257
▶ 131.02.02.05.10 Validation/Development Phase	168,696	253,256	14,050							436,003
▶ 131.02.02.05.11 Production Setup		30,536	169,975							200,511
▶ 131.02.02.05.12 Production phase, First Detector Module		352,747	5,015	1,063,289	39,213	27,749	13,862	17,996		1,519,872
<b>Grand Total</b>	<b>100,308</b>	<b>675,823</b>	<b>229,110</b>	<b>1,104,160</b>	<b>80,901</b>	<b>70,272</b>	<b>57,235</b>	<b>47,104</b>		<b>2,364,915</b>

## International

Sum of Value	Column Labels								Grand Total
Row Labels	9/30/22	9/30/23	9/30/24	9/30/25	9/30/26	9/30/27	9/30/28		Grand Total
▼ 131.02.02 Far Detector	789,162	4,029,038	5,226,367	4,481,054	1,373,444	44,679	25,521		15,969,264
▼ 131.02.02.05 Photon Detector	789,162	4,029,038	5,226,367	4,481,054	1,373,444	44,679	25,521		15,969,264
▼ 131.02.02.05.12 Production phase, First Detector Module	789,162	4,029,038	2,853,037	108,786	19,273	25,020			7,824,316
▶ 131.02.02.05.12.02 Photosensors and Active Ganging	789,162	3,144,317	782,557						4,716,036
▶ 131.02.02.05.12.03 Optical Components (Filter Plates, WLS Bars) production		782,961	1,766,185	38,182					2,587,328
▶ 131.02.02.05.12.04 PD Module Frame Component (G-10) Production		86,456	217,005	19,401					322,861
▶ 131.02.02.05.12.07 Integration and Installation		15,304	87,290	51,203	19,273	25,020			198,091
▶ 131.02.02.05.13 Production phase, Second Detector Module			2,373,330	4,372,268	1,354,170	19,659	25,521		8,144,948
<b>Grand Total</b>	<b>789,162</b>	<b>4,029,038</b>	<b>5,226,367</b>	<b>4,481,054</b>	<b>1,373,444</b>	<b>44,679</b>	<b>25,521</b>		<b>15,969,264</b>

**Total M&S, PDS Detector 1 10.2 M\$**

**Note: International validation/development phase not included**

# Cost Summary (Labor)

P6 cost book data are separated into DOE and non-DOE (international in this case) Contributions. Also, Detector 2 is included in international numbers.

## DOE

Sum of Value Row Labels	Column Labels									Grand Total
	9/30/20	9/30/21	9/30/22	9/30/23	9/30/24	9/30/25	9/30/26	9/30/27		
▼ 131.02.02 Far Detector	8,991	17,074	5,988	6,582	5,044	2,693	4,064	4,029		54,466
▼ 131.02.02.05 Photon Detector	8,991	17,074	5,988	6,582	5,044	2,693	4,064	4,029		54,466
▶ 131.02.02.05.06 Project Management	1,416	1,600	1,600	1,600	1,600	1,600	1,600	893		11,909
▶ 131.02.02.05.10 Validation/Development Phase	7,575	7,645	793							16,013
▶ 131.02.02.05.11 Production Setup		781	3,580	123						4,484
▶ 131.02.02.05.12 Production phase, First Detector Module		7,048	16	4,859	3,444	1,093	2,464	3,136		22,060
<b>Grand Total</b>	<b>8,991</b>	<b>17,074</b>	<b>5,988</b>	<b>6,582</b>	<b>5,044</b>	<b>2,693</b>	<b>4,064</b>	<b>4,029</b>		<b>54,466</b>

## International

Sum of Value Row Labels	Column Labels								Grand Total
	9/30/22	9/30/23	9/30/24	9/30/25	9/30/26	9/30/27	9/30/28		
▼ 131.02.02 Far Detector	1,946	17,446	33,387	31,272	19,196	4,879	2,352		110,477
▼ 131.02.02.05 Photon Detector	1,946	17,446	33,387	31,272	19,196	4,879	2,352		110,477
▼ 131.02.02.05.12 Production phase, First Detector Module	1,946	17,446	27,763	3,129	2,464	3,136			55,883
▶ 131.02.02.05.12.02 Photosensors and Active Ganging	1,946	7,600	1,854						11,400
▶ 131.02.02.05.12.03 Optical Components (Filter Plates, WLS Bars) production		3,181	7,035	149					10,365
▶ 131.02.02.05.12.04 PD Module Frame Component (G-10) Production		2,489	6,124	537					9,150
▶ 131.02.02.05.12.05 Module Assembly and Testing		3,903	11,948	1,997					17,848
▶ 131.02.02.05.12.07 Integration and Installation		273	801	446	2,464	3,136			7,120
▶ 131.02.02.05.13 Production phase, Second Detector Module			5,624	28,143	16,732	1,743	2,352		54,594
<b>Grand Total</b>	<b>1,946</b>	<b>17,446</b>	<b>33,387</b>	<b>31,272</b>	<b>19,196</b>	<b>4,879</b>	<b>2,352</b>		<b>110,477</b>

**Total Labor (Hours), PDS Detector 1 110k hours**

**Note: International validation/development phase not included**

# Basis of Estimate Summary

- Photosensors and Cold Electronics:
  - M&S based on vendor estimates,
  - Labor based on ProtoDUNE 1 and prototype development.
- Modules:
  - M&S based on vendor quotations for all major components.
  - Labor based on ProtoDUNE module assembly and other time and motion studies.
- DAPHNE:
  - M&S based on vendor quotes for initial prototype components.
  - Labor based on engineering estimates.
- Monitoring System
  - M&S based on vendor quotations and ProtoDUNE 1 costs.
  - Labor based on engineering estimates.
- Rails/Cables
  - M&S based on vendor quotations fro all components.
  - Labor based on time and motion studies assembling prototypes at CSU.



## ProtoDUNE-2 plans

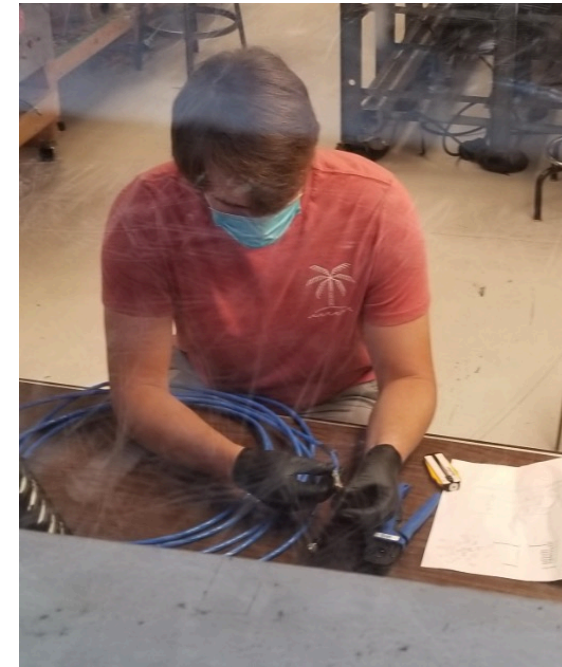
- 40 “Module 0” PD modules
  - Single- and double-sided modules
  - Two candidate SiPMs (down-select following ProtoDUNE 2)
- “Module 0” readout chain
  - Cables/connectors/flanges
  - Cold amplifiers
  - DAPHNE warm readout electronics
  - DAQ interface firmware
- “Module 0” Monitoring system
  - Single LED control unit (modified SSP)
  - 8 diffusers
  - Final candidate flanges, fibers
- Will provide final validation for PRR for entire PD system



# PD Rail/Cable System Fabrication

- PD rails and cables are mounted inside the APA frames prior to TPC wire wrapping.
- This requires ProtoDUNE-ready (post FDR) rail delivery to Daresbury in Q4 2020.
  - Special FDR for PD rails/cables Q3 2020.
  - Greatly increases necessity of re-opening rail fabrication facilities.
  - Long lead time item (Custom cable) already in hand.

Good News! CSU assembly facility began re-opening 6/18/20! Impact on schedule will be evaluated and schedules updated



# Impact of COVID-19

- Lab work stopped at nearly all national laboratories / universities worldwide in March 2020.
- Activities stopped / delayed
  - PD/APA cold integration testing at PSL halted
  - Light collector module (X-ARAPUCA) tests at ICEBERG, Milano test beds halted
  - Warm electronics (DAPHNE) prototypes fabrication delayed
  - Module mechanical prototyping/production preparation at UNICAMP Brazil delayed.
  - Impact of these delays on the ProtoDUNE 2 schedule not yet critical, but failure to restart by late June 2020 may begin to impact our schedule
- Some progress continuing however
  - Module/rail installation tests at Ash River satisfactorily completed
  - Cable bundle installation in APA frames at PSL satisfactorily completed
  - Sample photosensor fabrication/delivery continuing
    - Hamamatsu photosensors delivered to Milano late April 2020
    - FBK photosensors being delivered to Milano now

# Plans for Restart

- Some European labs/universities reopening on a limited basis
  - Photosensor testing beginning (Italy, Spain)
  - X-ARAPUCA module (small prototypes) (Italy)
  - Photosensor active ganging (cold testing) (Italy)
- APA/PD cold interface testing at PSL progressing, albeit at a reduced rate
  - Delayed by lack of PD rails, cables, test modules
- Many US and Latin American institutions beginning to evaluate schedules for re-opening, but the prognosis is unclear.
- Priority Validation Items (Critical Path for FDR, ProtoDUNE):
  - Photosensors: Progressing, but at slowed pace
  - Warm electronics: Prototype module design fabrication continuing, should proceed through delivery of fabricated modules in Summer 2020. At that point availability of US, Latin American, European testing sites becomes critical
  - PD/DAQ interface: PD/DAQ interface tests scheduled for Q3 2020 are critical to ProtoDUNE 2 electronics development. Requires re-opening of DAQ testing sites
  - CERN cold box test: Q1 2020(?)-- Critical “Vertical slice” test of electronics system
    - NOTE: 10 mechanical models/cables, ~ 10 SIPM-instrumented supercells initially, more supercells in spring.
  - Light collector module prototype components can be ordered from commercial sites in the US, Brazil, Spain but fabrication delays hindering APA testing.
- **Summary: Situation not yet critical, but will rapidly deteriorate if reopening of US, Latin American sites delayed past June 2020**

# Summary

- DUNE PD scope, schedule, and costs well understood.
- International PD consortium solidly established.
- FDR and ProtoDUNE Fabrication beginning Q4 2020.
- ProtoDUNE 2 experience will provide critical validation for PRR
- Detector 1 PD module fabrication begins Q1 2022, ends Q4 2024
- First modules delivered to SURF Q4 2023 , Installation begins Q1 2026
- Last modules delivered so SURF Q2 2025, Installation ends Q1 2027
- Approximately 1 year float in production schedule
  - **Critical exception: Rails & Cables! Initial deliveries Q4 2020**