protoDUNE-SP Photon Detector System

Leon Mualem
Caltech
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Photon Detector Review
University of Chicago

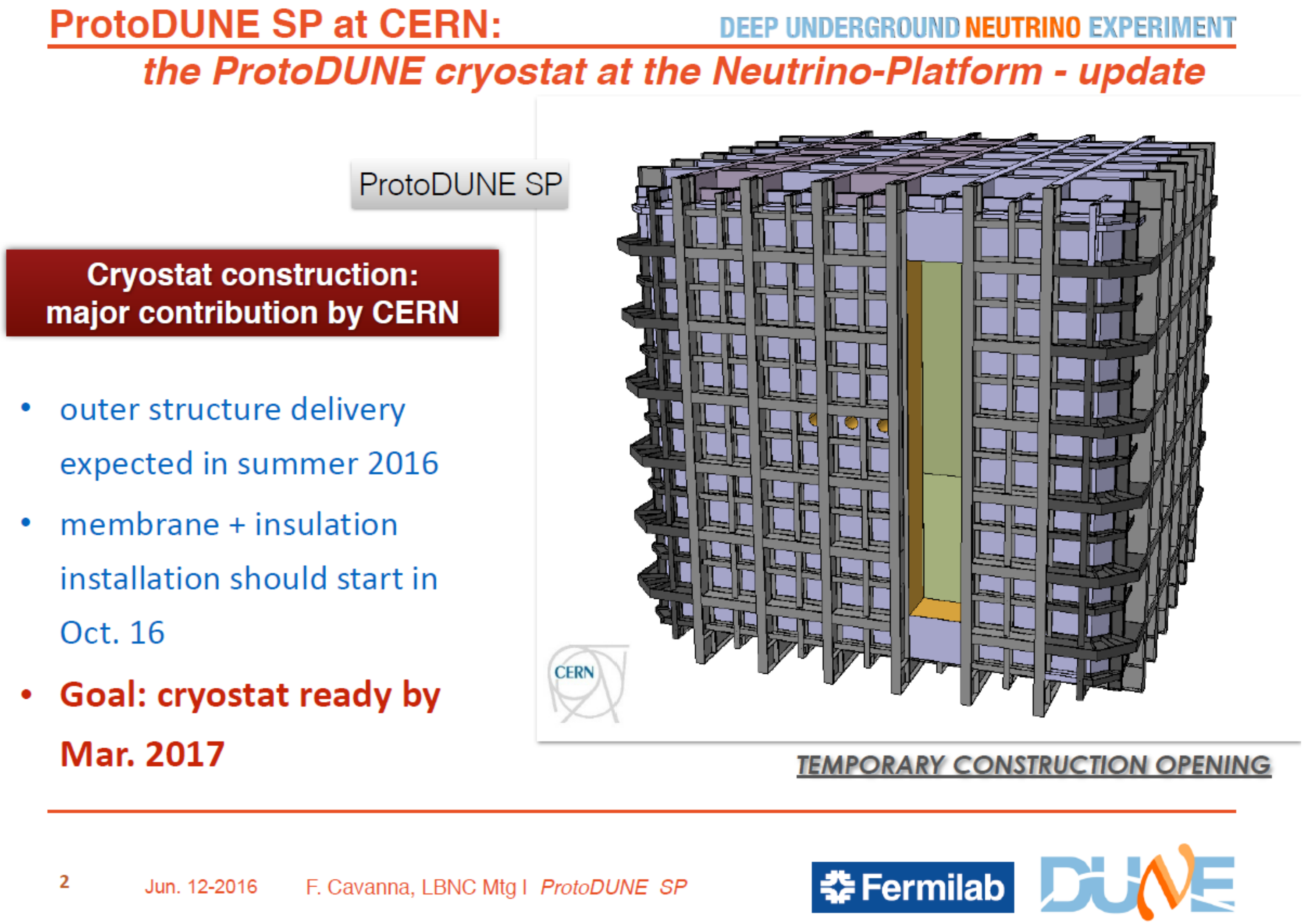
protoDUNE-SP Photon Detector System

- protoDUNE-SP
- protoDUNE-SP Photon Detector System
- protoDUNE-SP Photon Detector Goals
- Photon Detector System Requirements
- Risk
- Lessons Learned
- Schedule
- Conclusions

protoDUNE-SP

- Membrane Cryostat, approximately cube with 10m sides
- Approximately 6m cube TPC inside
- 3 beam ports
- electron,π,μ beams
- Particle ID, momentum (0.2-7GeV) and timing signals from beamline instrumentation

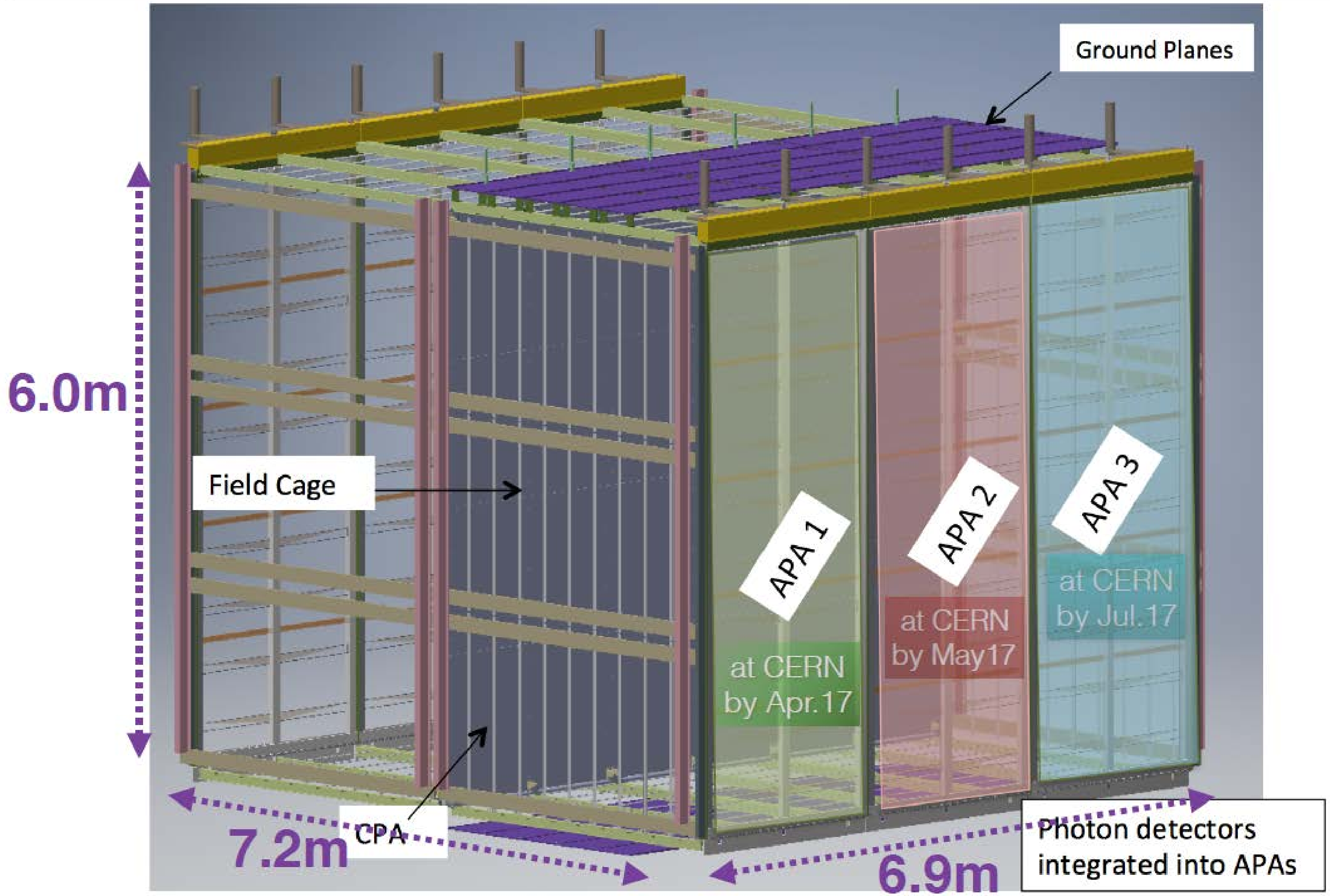
- DUNE Cryostat will be 2x taller, 2x wider, and 6x deeper
- DUNE beam event timing will be determined by Main Injector spill time of 10μs



protoDUNE-SP TPC

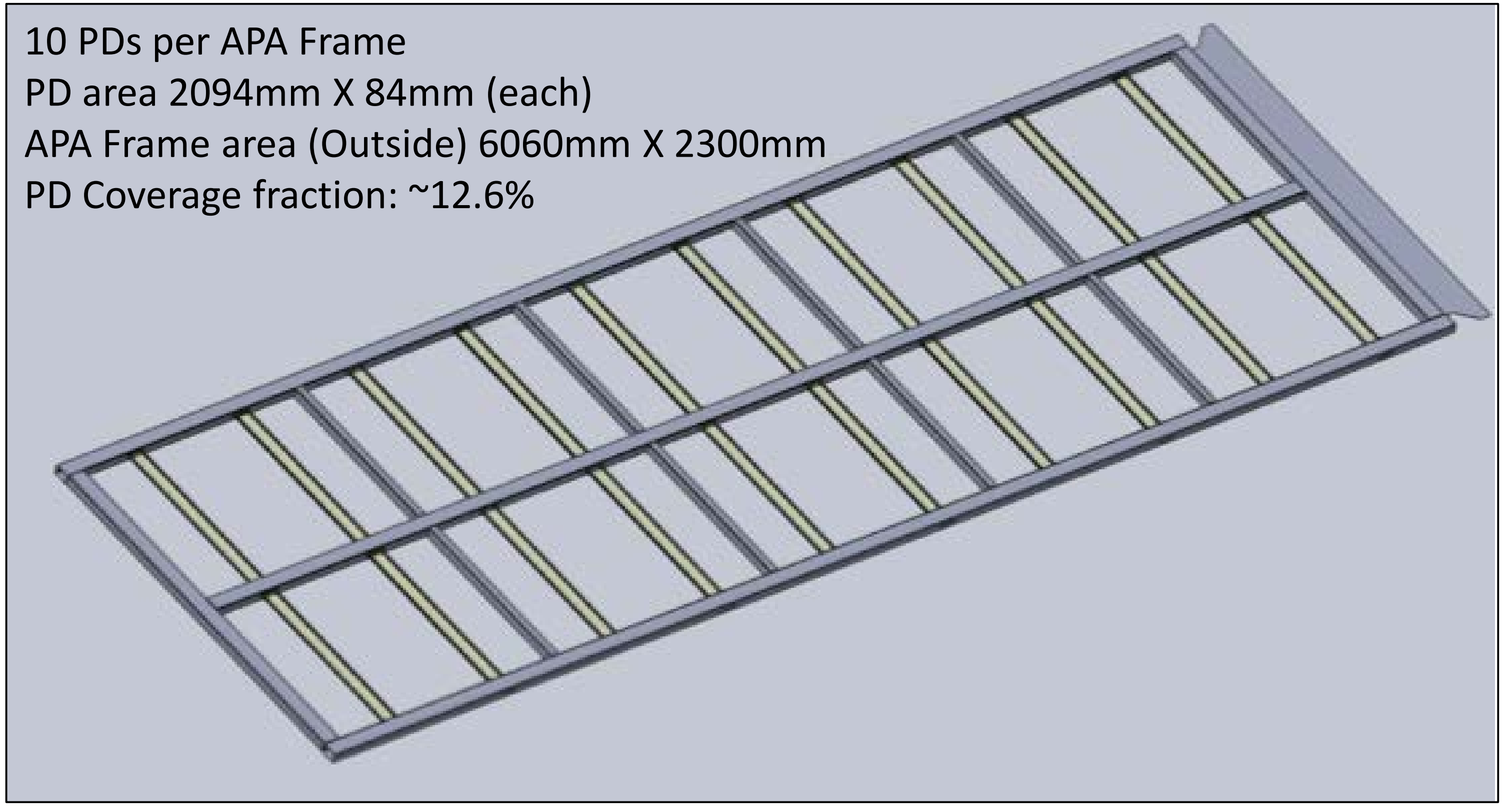
- The TPC consists of 6 anode plane assemblies (APAs) with integrated photon detectors, 3 cathode plane assemblies (CPAs)
- It is roughly 6m tall, 7m deep, and 7.2m wide

- DUNE TPC
- 2x wider, 3 APAs and 2 CPAs
- 2x taller, planes will hang from upper neighbor
- 25 planes deep in beam direction
- 150 APA planes
- 1500 photon detector modules



Photon Detector System

- 10 bars/paddles in each APA
  - 2 types, plus 2 R&D paddles
  - Radiator/WLS Bar (IU)
  - Dip-coated bars (MIT and FNAL)
  - ARAPUCA Arrays (UNICAMP)
- Array of 12 SiPMs per paddle
  - CSU, NIU, Caltech
- 6 APAs
  - 60 paddles
  - 720 SiPMs
- Bias and digitization provided by SiPM Signal Processor (SSP) (ANL)
- 240 readout channels
- External Calibration Flasher with emitters on Cathode Plane (ANL)
- MANY more details in next 12 talks



Modular PD Concept

- The reference PD design for both ProtoDUNE and the single phase FD call for 10 individual PD modules per APA frame, installed following APA assembly
- Module dimensions:
  - 2108mm long X 107mm wide X 18 mm thick (outside)
  - 2086mm long X 95mm wide X 14.5mm thick (Inside APA)
  - PD Dimensions driven by available installation slot in the APA (108mm long X 19mm tall)
- Modules masses:
  - IU design: 2.03 kg
  - MIT/FNAL design: 1.34 kg
- Modular design and post-APA assembly installation allows for testing of different PD design concepts
- Two principle designs: IU design with radiator plates, MIT/FNAL design with TPB-dipped light guide bar

IU design (Radiator)

MIT/FNAL design (Dipped)

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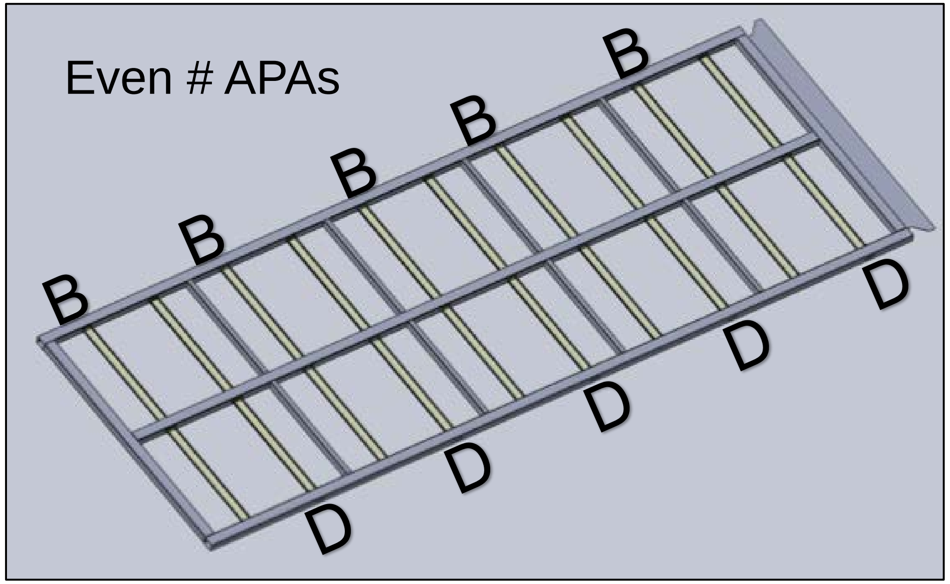
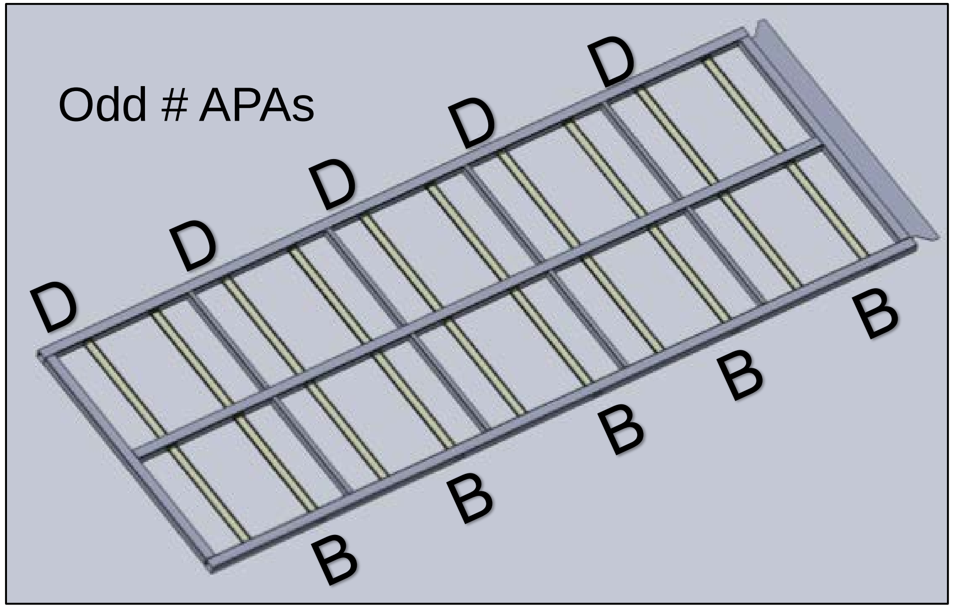
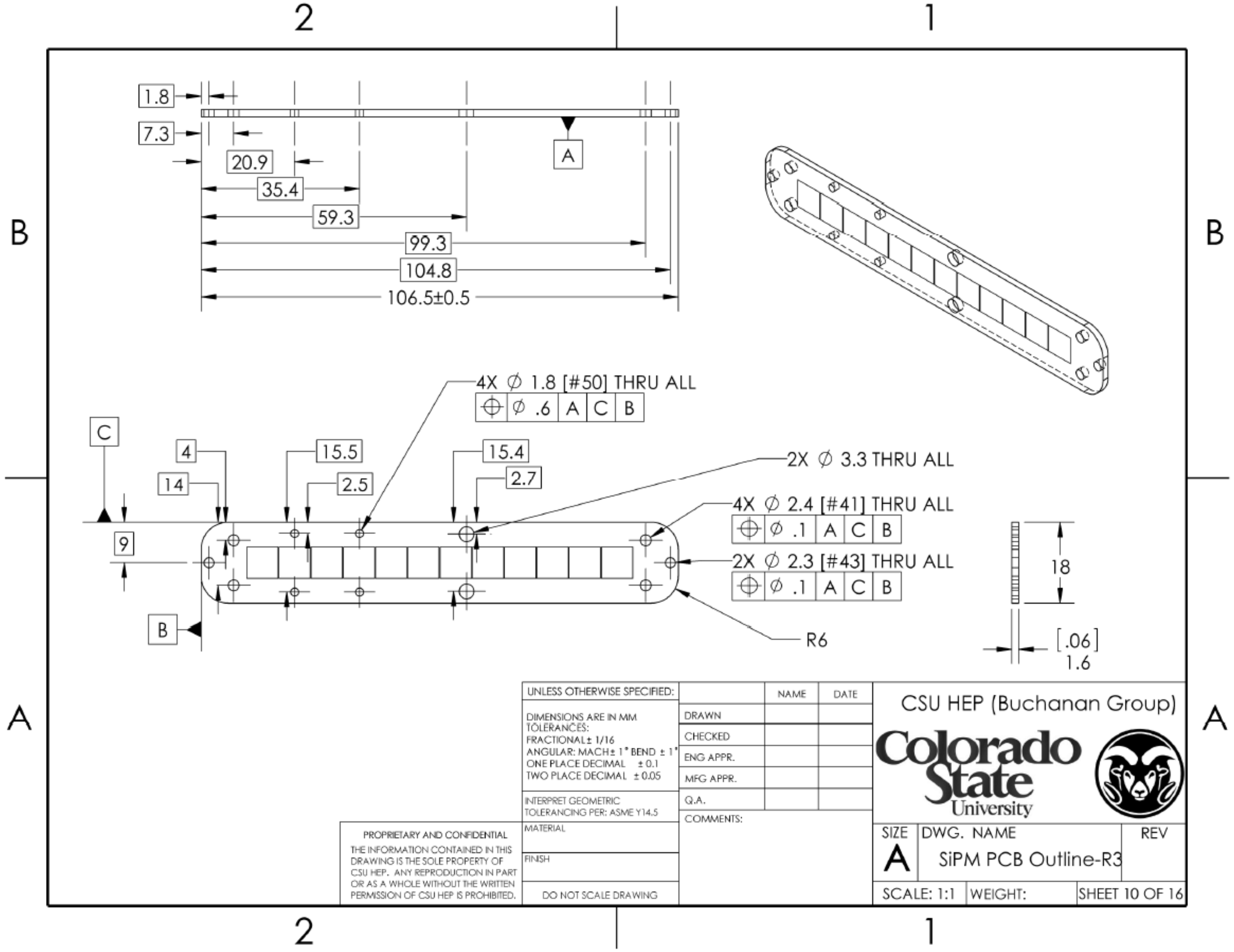
Photon Detector Deployment Plan

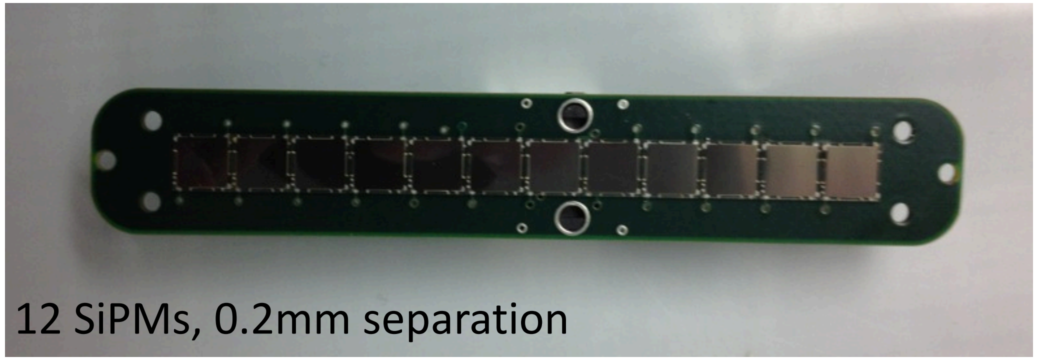
- 2 types of bars planned – Baseline (B) and Dipped (D)
- 6 APAs total
- Deploy alternating B and D style paddles to make exposure more uniform
- Alternate starting type on each APA
  - APA 1, 3, and 5 will be the same
  - APA 2, 4, and 6 will be the same
  - Later APAs could have some swapped for R&D designs, as planned for the ARAPUCA arrays

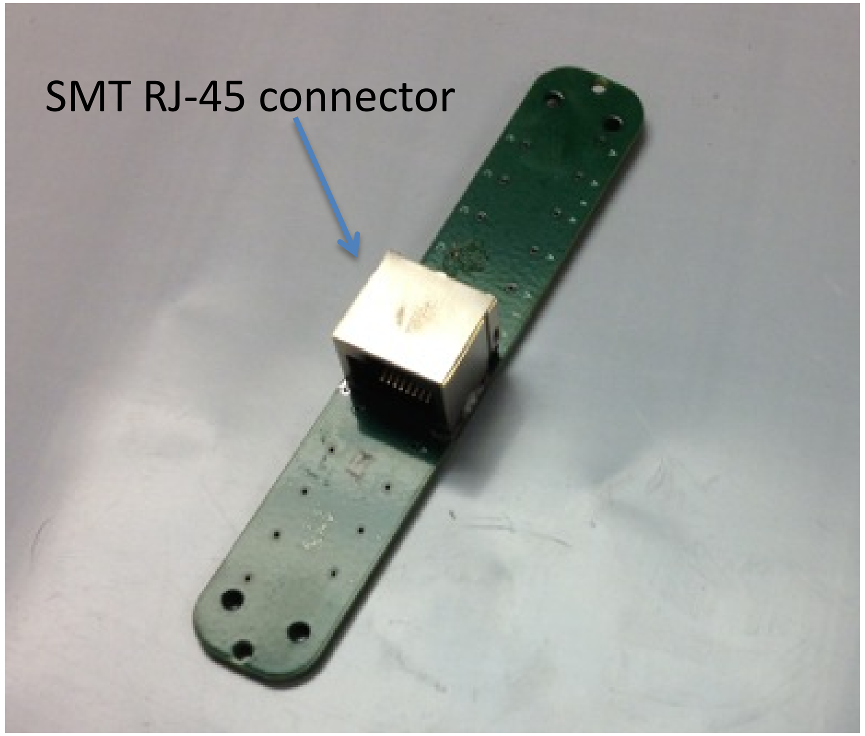




SiPM Mount PCB

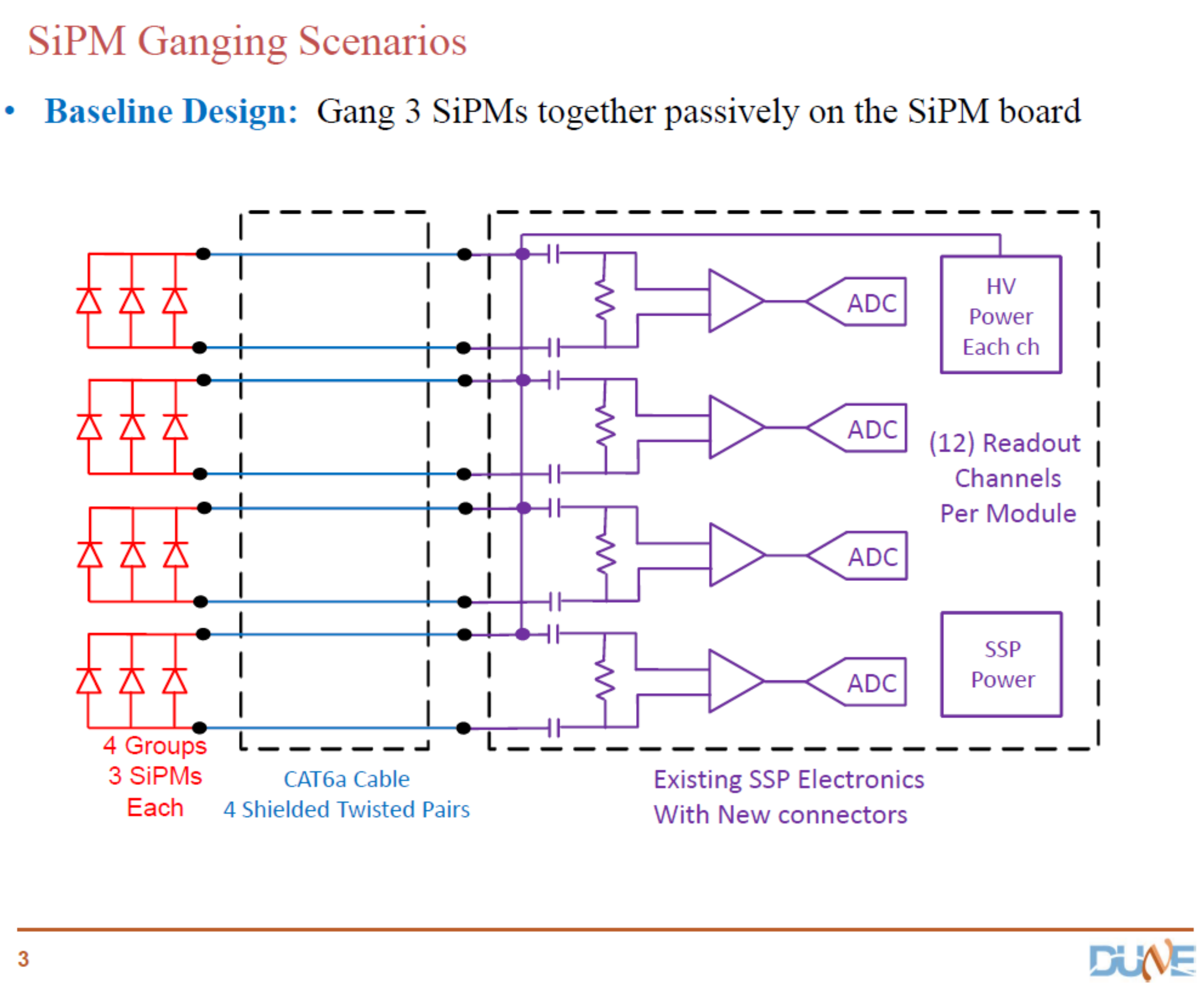






Baseline SiPM Readout Design

- Use adaptation of Argonne National Lab SSP design used at test locations and 35T
- Compatible and tested with DAQ already
- Tested with 3 passively ganged SiPMs and proposed readout cables
- See Gary Drake Talk for design, specs and pictures



protoDUNE-SP Photon Detector

- **Goals**

- Demonstrate Light Detection Capability
  - Determine Detection Sensitivity
  - Measure Background Rates
- Measure detector response to known particles for a reasonable number of production modules
- Confirm modeling and simulations
- Demonstrate interfaces have been addressed
  - Mechanical interfaces
    - Photon Detector System –Anode Plane Assembly
    - Calibration system to – Cathode Plane
    - Cryostat feedthroughs
  - Electrical interfaces
    - Grounding and shielding
    - Power Distribution
  - DAQ interfaces
    - Readout
    - Triggering
    - Data rates
    - Timing

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protoDUNE-SP Photon Detector

- **Requirements**

DUNE Requirements

- Requirements for DUNE Science:
  - Proton Decay
  - Atmospheric Neutrino
  - Supernova Neutrino
- Resulting Photon Detector Requirements
  - Parameter 0.1pe/MeV (at cathode plane)
  - 1 microsecond for position resolution
- Future Photon Detector Requirements
  - Committee to address possible updates to science and resulting PD requirements
  - protoDUNE measurements will inform possibility of extending the science and detector requirements

Global Objectives

Global objectives from requirements document dune-doc-112 define the high level measurements and drive Global science requirements

ID	Object Heading	Object Text	Rationale	Parent	Verification method
Glo-obj-4	Proton Decay	A search for proton decay in the far detector, yielding a significant improvement in current limits on the partial lifetime of the proton (τ/BR) in one or more important candidate decay modes, e.g. $p \to K^+ \nu$ or $p \to e^+ \pi^0$	As an additional note: measurements in the near detector with a neutrino beam could serve to understand backgrounds to the proton decay search.		data analysis
Glo-obj-5	Neutrino Flux from a Core Collapse Supernova	Detection and measurement of the neutrino flux from a core collapse supernova within our galaxy, should one occur during the lifetime of DUNE			data analysis
Glo-obj-6	Ancillary Science Program				
Glo-obj-8	Neutrino Oscillation Using Atmospheric Neutrinos	Measurements of neutrino oscillation phenomena using atmospheric neutrinos			data analysis
Glo-obj-13	Additional Scientific Objectives				
Glo-obj-14	Diffuse Supernova Neutrino Flux	Detection and measurement of the diffuse supernova neutrino flux			data analysis

Global Science Requirements

Global science requirements follow from global objectives, and result in performance requirements for the detectors

A few examples shown, many more in dune-doc-112

ID	Type	Object Heading	Object Text	Rationale	Parent
Glo-Sci-44	heading	LBNF/DUNE Components			
Glo-Sci-8	requirement	Charged current interactions on Ar40 due to supernova burst.	Far detector shall be capable of collecting low energy (<100 MeV) charged current electron neutrino interactions on Ar40 nucleus that arrive in a short period of time (<100 sec) . The final state electron shall be detected and its energy measured.	Most of the events from a supernova neutrino burst are expected to be neutrino absorption on Ar40 producing electrons in the range of 5 to 100 MeV and arrive in less than one minute timeframe. In such events an electron and a K40 nucleus is in the final state. The total event count from a galactic supernova (10 kpc) is expected to be approximately 3,000 events for 40 kt of LAr.	Glo-obj-5
Glo-Sci-9	requirement	Far Detector Availability	Far detector shall have high uptime with little event by event dead time to allow the capture of low probability astrophysical events that could occur at any time with no external trigger. (>90%)	Supernova events are expected to occur a few times per century within the Milky Way galaxy. For any 10 year period the probability of a supernova could be 20 to 30%. Capturing such an event at the same time as many of the other detectors around the Earth is very important.	Glo-obj-5
Glo-Sci-27	requirement	Proton Decay sensitivity	The far-detector fiducial size multiplied by the duration of operation [expressed in kiloton-years] and the rejection of background events shall be sufficient to yield a scientifically competitive result on proton decay.	The result on the kaon-neutrino channel needs to be competitive to running experiments such as Super Kamiokande.	Glo-obj-4
Glo-Sci-33	requirement	Timely trigger regarding Astrophysical Events	The DUNE detector systems shall be configured to provide information to other observatories on possible astrophysical events (such as a galactic supernova) in a short enough time to allow global coordination.	To obtain maximum scientific value out of a singular astronomical event, it is very important to inform all other observatories (including optical ones) immediately, so that they can begin observation of the evolution of the event.	Glo-obj-5
Glo-Sci-34	requirement	Time Accuracy	Individual event times shall be measured with sufficient time accuracy to allow correlation of event times between detectors that are geographically separated.	This requirement will allow time correlations of events between various detectors across the world. This could include correlation between the DUNE near and far detectors.	Glo-obj-5

Far Detector Requirements

Requirements flow down from global objectives to global science requirements and finally to lower level performance requirements

LArFD-L2-se-25	heading	Photon Detection	This is the high level for PD			Parent
LArFD-L2-se-26	design choice	Detect Scintillation light	A photon detector shall be implemented and integrated into the TPC modular design to detect the time and intensity of scintillation light from ionizing radiation in the active portion of the liquid argon detector.	It is important to integrate the photon detector into the current TPC design. This implies that the design must allow the TPC to function without interference, and the TPC must allow the scintillation light to reach the PD without being obscured.		larfd-l2-se-82 larfd-l2-se-83
LArFD-L2-se-27	design choice	Photon Detector using light guides	The photon detector shall consist of light guides suitably coated and doped to shift liquid argon scintillation photons of 128 nm and transport them into solid state detectors mounted on the light guides	Defines the geometry.		larfd-l2-se-96
LArFD-L2-se-28	requirement	Photon sytem performance I	The photon system shall detect sufficient light from events depositing visible energy >200 MeV to efficiently measure the time and total intensity.	This is the region for nucleon decay, atmospheric neutrinos. The time measurement is needed for vertex determination as specified in the parent. We require that this efficiency be high since this is high priority physics.	If proton decay vertex in the fiducial cannot be determined well , then the sensitivity will be affected by backgrounds from cosmic ray muons.	larfd-l2-se-82
LArFD-L2-se-29	requirement	Photon System perfromance II	The photon system shall detect sufficient light from events depositing visible energy <200 MeV to provide a time measurement. The efficiency of this meansurement shall be adequate for supernova burst events.	This points back to low energy measurement of vertex for supernova burst events. Since the trigger is based on burst, the background is expected to be small, and so the main rationale behind this measurment is to improve the energy resolution.	Efficiency could vary significantly from visible energy of 5 MeV to 100 MeV.	larfd-l2-se-83
LArFD-L2-se-30	requirement	photon system materials	The PD system shall use only materials compatible with high purity liquid argon and minimal natural radioactivity.			larfd-l2-se-7 glo-sci-8
LArFD-L2-se-31	requirement	Photon system readout electronics	The photon system readout electronics shall record waveforms continuously with sufficient precision and range to achieve the key physics parameters	The resolution and dynamic range needs to be adjusted so that a few photo-electron signal can be detected with low noise. The dynamic range needs to be sufficiently high to measure light from a muon traversing a TPC module.	The current design readout will output time and pulse height continuously. Need to be able to synchonize with the TPC.	glo-sci-8

Far Detector Requirements

Requirements flow down from global objectives to global science requirements and finally to lower level performance requirements

LArFD-L2-se-81	**heading**	**Time measurements**				
LArFD-L2-se-82	requirement	Event timing for high energy events	Event time shall be measured with high efficiency to allow the measurement of the drift coordinate with sufficient precision for events with visible energy above 200 MeV.	Time is needed for Proton decay and atmospheric neutrino event fiducialization and energy resolution. The minimum visible energy for a P to K+ neutrino decay is ~200 MeV including fermi motion effects. sufficient safety margin in terms of threshold needs to be discussed.	These are requirements for the photon detector	glo-sci-27
LArFD-L2-se-24	requirement	Timing Accuracy, beam events	The detector shall measure the absolute time of occurrence of events with accuracy sufficient to correlate with beam spill for beamline events	the simulation of cosmic ray backgrounds indicate that timing of cosmic ray events with respect to beam spill is critical for background suppression.		glo-sci-20
LArFD-L2-se-83	requirement	Event timing for low energy events.	Event time for events with visible energy <200 MeV shall be measured with high efficiency and sufficient precision to correct for drift time and improve energy resolution.	The drift time correction for supernova induced electron tracks is expected to improve the energy resolution from ~20% to <10%. This is only one contribution to the supernova energy resolution. The resolution contribution due to other sources such as the nuclear states and deexcitation gammas must be understood.	These are requirements for the photon detector	glo-sci-8
LArFD-L2-se-84	requirement	Absolute event timing	Absolute event time shall be measured with sufficient accuracy to allow global analysis of supernova neutrino wave front.	Needed for SN global inter-experiment absolute time measurement. Since the wavefront should take ~30 ms to cross the planet, an accuracy of <2 ms should be sufficient.	These are requirements for the photon detector	glo-sci-34

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Far Detector Parameter

Performance requirements finally give the detector parameters at the lowest level that fulfill the requirements of the higher level objectives all the way back to the global objectives. These are also found in dune-doc-112

Item	Value	Unit	Comment	Associated requirement		
Physics Measurments						
Minimum Goal Proton Decay to K+ and neutrino	>10^34	years	Set limit at 90%	glo-obj-4	These are requirements for the photon detector	glo-sci-27
Goal for Proton decay to K+ and neutrino	>3 10^35	years	set limit with the full scope detector and livetime of 10 yrs	glo-obj-4		glo-sci-20
Mass hierarchy resolution with Atmospheric neutrinos	> 3	sigma	using independent techniques from beam neutrinos	glo-obj-8	These are requirements for the photon detector	glo-sci-8
Detection of supernova	>1000	events/10 sec burst	Yield from galactic event will depend on distance, energy threshold, detector size.	glo-obj-5	These are requirements for the photon detector	glo-sci-34
Photon yield minimum	0.1	PE/MeV		Larfd-L2-se-28 => Ability to trigger @ 88 % eff. at 200 MeV visible energy		
Photon time resolution	1	Micro-sec		larfd-L2-se-28=> larfd-L2-se-82 => Proton decay larfd-L2-se-29=> larfd-L2-se-83 => SN resolu		

Project Risks

Risk Type	RI-ID	Title	Probability	---	Cost Impact	Schedule Impact	Risk Rank
Threat	RT-131-FD-073	Photon Detector light yield is too low	30 %		2500 k$	3 -- 6 -- 9 months	2 (Medium)
Threat	RT-131-FD-089	Photon detector SiPMs are not qualified for cryogenic use	15 %		1000 k$	2 -- 4 -- 6 months	2 (Medium)
Threat	RT-131-FD-098	ProtoDUNE-SP: Degraded Photon Detectors	5 %		k$	months	0 (Negligible)
Threat	RT-131-FD-117	ProtoDUNE-SP: Photon Detector monitoring software is unavailable for commissioning	15 %		k$	months	0 (Negligible)

Schedule Risk – protoDUNE-SP schedule end date is driven by Long Shutdown at CERN

Mitigation: Advance purchases – light guide bars and acrylic base

Risk FD-073 Photon light yield too low

Far detector Risk, mitigate by showing sufficient light yield in the prototype – protoDUNE-SP, mitigate by enhancement to light collection efficiency, double-ended readout, mirroring bars, increasing light yield, cathode plane radiator, xenon doping, more detectors

Risk FD-089 Photon detector SiPMs are not qualified for cryogenic use

Far detector Risk, mitigate by testing – see talk, mitigate by allowing flexibility of design to swap photon detector, not only one to make 6mm SiPM, mitigate by making a large prototype detector – protoDUNE-SP

Risk FD-098 ProtoDUNE-SP Degraded Photon Detectors

Prototype detector risk, mitigate by handling controls – shielded lighting during construction and installation specified already, protect during shipping and handling

Risk FD-117 ProtoDUNE-SP Photon Detector monitoring software is unavailable for commissioning

Mitigations: applying from lessons-learned from 35T detector, utilize software developed there, much longer assembly period for this prototype detector to enable testing and commissioning.

Lessons Learned

DUNE-DOC-913

- Pre-learned
  - Don’t freeze technology before needed
    - Install photon detectors after APA has been wound to maximize flexibility
- Operating conditions (gain and threshold) were not defined for PD modules
  - Perform and record (electronically) QA test data for use at detector
  - All components will have ID for setting operating parameters
- Software not available
  - Define tests ahead of time
  - 3 months of integration testing before install in cryostat – longer than entire 35T run
- Data Rates too high
  - Utilize coincidence triggering and digest data (vs. waveform) for self-triggering

ES&H Awareness

Production sites have been internally (local university or national lab) and externally (Fermilab) reviewed for procedures and setup

- Indiana University
  (WLS bar testing/Plate production)
  - Procedures and processes reviewed by ES&H personnel to determine requirements for new lab space
- Fermilab (Dip-coated production)
  - Setting up new lab space and procedures and getting personnel assigned requires Technical Scope of Work (TSW) where all these requirements are defined and reviewed to assure procedures, facilities and personnel meet needs
- CSU
  - Reviewed by University and Fermilab when setting up Cryogenic Detector Test Facility at CSU
- NIU
  - Reviewed by University in the course of setting up for cryogenic testing of SiPMs and cables
- Caltech
  - Space and procedures were reviewed by department safety officer, and university undergrad safety office. Trained by university personnel on hazards of liquid nitrogen use.

Schedule
Key Dates

- Integrated resources loaded schedule has been produced
- Monthly Status reports on each task
- Key links to other protoDUNE-SP subproject activities are included
- Milestones updated and tracked

- First Detector Modules to CSU
  - May 2017
- First tested SiPM modules to CSU
  - March 2017
- First Modules to CERN
  - May 2017
- Last Modules to CSU
  - July 2017
- Last Modules to CERN
  - Oct 2017
- Cryostat TCO Closed
  - Feb 2018
- Commissioning at CERN
  - May 2018
- End of Beam Operations
  - November 2018

Schedule

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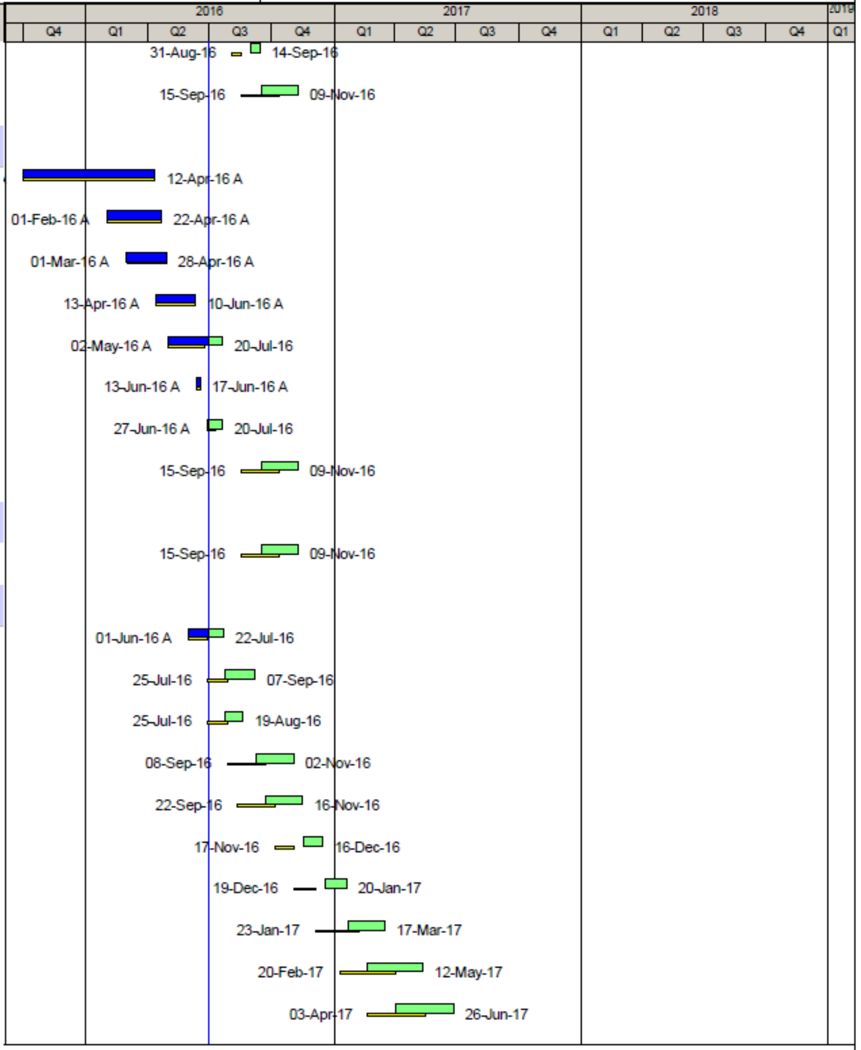
Far Detector | Far Detector - ProtoDUNE | 14-Jul-16 11:28

Activity ID	Activity Name	Original Duration	Start	Finish	Predecessors
13122.05.01.05.365	Prepare for technology selection (Wave guide/radiator cryogenic)CSU	10	31-Aug-16	14-Sep-16	13122.05.01.05.315
13122.05.01.05.410	Prepare for pre-production review (Wave guide/radiator cryogenic)CSU	40	15-Sep-16	09-Nov-16	13122.05.01.05.365, 13122.05.01.05.370MS
Proto-DUNE Design, Engineering and Integration		280	01-Oct-15 A	09-Nov-16	
13122.05.01.05.140	Initial PD/APA integration/cabling design (CSU)	132	01-Oct-15 A	12-Apr-16 A	13122.01.02.100MS
13122.05.01.05.175	Preliminary PD/APA full-scale installation test (CSU)	60	01-Feb-16 A	22-Apr-16 A	13122.02.07.01.145
13122.05.01.05.240	Proto-DUNE PD/APA integration/cabling design (CSU)	43	01-Mar-16 A	28-Apr-16 A	13122.01.02.100MS
13122.05.01.05.220	Fabricate PD Support Rail Components for APA	42	13-Apr-16 A	10-Jun-16 A	13122.05.01.05.140
13122.05.01.05.270	Prepare final PD/APA integration/cabling report (CSU)	39	02-May-16 A	20-Jul-16	13122.05.01.05.240
13122.05.01.05.260	Ship PD Support Rail Components to PSL (CSU)	5	13-Jun-16 A	17-Jun-16 A	13122.05.01.05.220
13122.05.01.05.320	Prepare for technology selection (PD/APA integration/cabling)	10	27-Jun-16 A	20-Jul-16	13122.05.01.05.270
13122.05.01.05.415	Prepare for pre-production review (PD/APA integration/cabling)	40	15-Sep-16	09-Nov-16	13122.05.01.05.320, 13122.05.01.05.370MS
Proto-DUNE Calibration system		40	15-Sep-16	09-Nov-16	
13122.05.01.05.420	Prepare for pre-production review (Calibration)	40	15-Sep-16	09-Nov-16	13122.05.01.05.320, 13122.05.01.05.370MS
Proto-DUNE Dip Coated Bar		279	01-Jun-16 A	11-Jul-17	
13122.05.01.05.690	Purchase Acrylic Sheets (FNAL)	20	01-Jun-16 A	22-Jul-16	13122.01.02.101MS
13122.05.01.05.695	Process Acrylic Sheets to Strips (FNAL)	32	25-Jul-16	07-Sep-16	13122.05.01.05.690
13122.05.01.05.700	Purchase Dipping Materials (FNAL)	20	25-Jul-16	19-Aug-16	13122.05.01.05.690
13122.05.01.05.705	Extend Annealing Setup (FNAL)	40	08-Sep-16	02-Nov-16	13122.05.01.05.700, 13122.05.01.05.695,
13122.05.01.05.710	Design 2.2m Dipping vessel (FNAL)	40	22-Sep-16	16-Nov-16	13122.05.01.05.705
13122.05.01.05.715	Purchase parts for Dipping vessel (FNAL)	20	17-Nov-16	16-Dec-16	13122.05.01.05.710
13122.05.01.05.720	Assemble Dipping Vessel (FNAL)	20	19-Dec-16	20-Jan-17	13122.05.01.05.715
13122.05.01.05.725	Dip prototype Acrylic Bars (8) (FNAL)	40	23-Jan-17	17-Mar-17	13122.05.01.05.720
13122.05.01.05.730	Dip Production Acrylic Bars (32) (FNAL)	60	20-Feb-17	12-May-17	13122.05.01.05.725
13122.05.01.05.735	Dip Acrylic Bars Testing (FNAL)	60	03-Apr-17	26-Jun-17	13122.05.01.05.730



Remaining Level of Effort | Primary Baseline | Remaining Work
Actual Level of Effort | Actual Work | Critical Remaining Work

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TASK filters: ProtoDUNE Only, WBS.

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Schedule II

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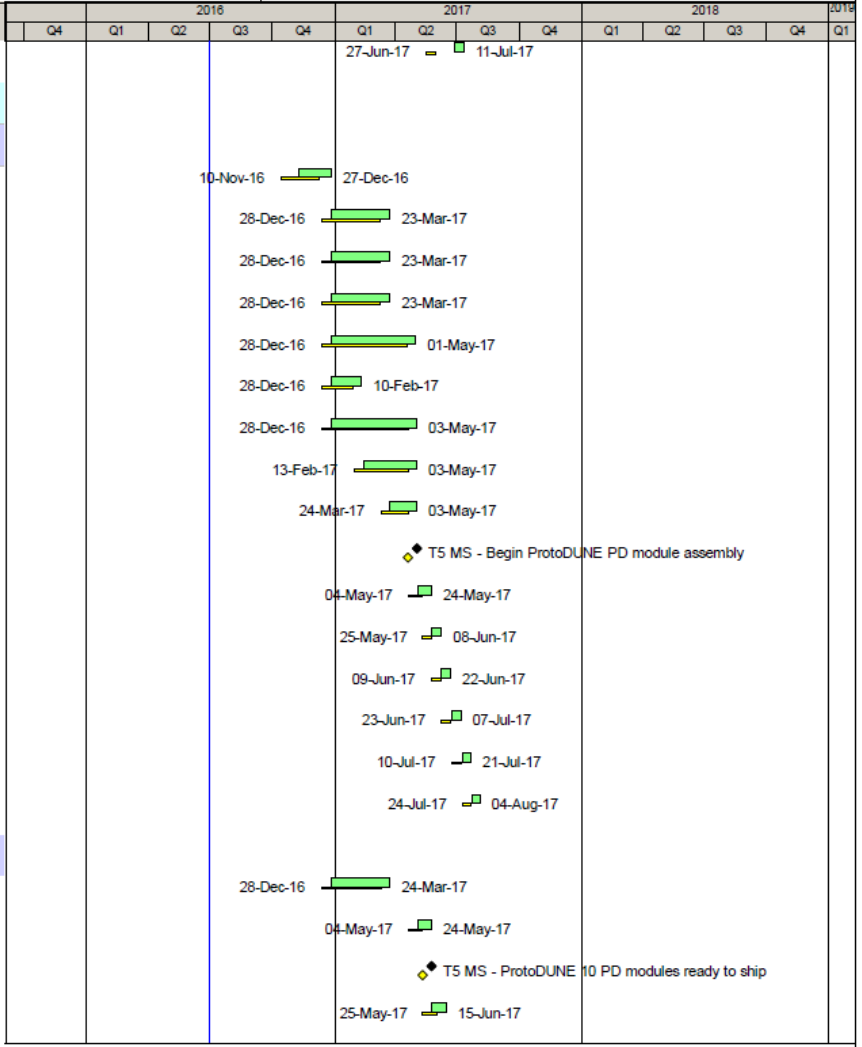
Far Detector | Far Detector - ProtoDUNE | 14-Jul-16 11:28

Activity ID	Activity Name	Original Duration	Start	Finish	Predecessors
13122.05.01.05.740	Ship Dip Acrylic Bars to CSU (FNAL)	10	27-Jun-17	11-Jul-17	13122.05.01.05.735
Proto-DUNE PD Fabrication/Shipping/Installation		238	10-Nov-16	23-Oct-17	
PD Module Fabrication/Testing		183	10-Nov-16	04-Aug-17	
13122.05.01.05.430	PD Module final design revision (CSU)	30	10-Nov-16	27-Dec-16	13122.05.01.05.415, 13122.05.01.05.425MS
13122.05.01.05.480	Procure/Fabricate SiPM PCBs (CSU)	59	28-Dec-16	23-Mar-17	13122.05.01.05.430
13122.05.01.05.485	Procure SiPMs (Caltech, NIU)	59	28-Dec-16	23-Mar-17	13122.05.01.05.430
13122.05.01.05.490	Procure SiPM PCB connectors (CSU)	59	28-Dec-16	23-Mar-17	13122.05.01.05.430
13122.05.01.05.495	Procure/test light guide bars (IU)	86	28-Dec-16	01-May-17	13122.05.01.05.430
13122.05.01.05.500	Procure WLS plate blanks (IU)	30	28-Dec-16	10-Feb-17	13122.05.01.05.430
13122.05.01.05.505	Fabricate PD module assembly components (CSU)	88	28-Dec-16	03-May-17	13122.05.01.05.430
13122.05.01.05.525	Fabricate(coat)/test WLS plates (IU)	58	13-Feb-17	03-May-17	13122.05.01.05.500
13122.05.01.05.540	Assemble SiPMs/connectors to PCBs/test (NIU/Caltech)	29	24-Mar-17	03-May-17	13122.05.01.05.490, 13122.05.01.05.485,
13122.05.01.05.560MS	T5 MS - Begin ProtoDUNE PD module assembly	0		03-May-17	13122.05.01.05.505, 13122.05.01.05.540,
13122.05.01.05.565	Assemble 10 PD modules (1) (CSU)	15	04-May-17	24-May-17	13122.05.01.05.560MS
13122.05.01.05.590	Assemble 10 PD modules (2) (CSU)	10	25-May-17	08-Jun-17	13122.05.01.05.565, 13122.05.01.05.570
13122.05.01.05.600	Assemble 10 PD modules (3) (CSU)	10	09-Jun-17	22-Jun-17	13122.05.01.05.590
13122.05.01.05.610	Assemble 10 PD modules (4) (CSU)	10	23-Jun-17	07-Jul-17	13122.05.01.05.600
13122.05.01.05.620	Assemble 10 PD modules (5) (CSU)	10	10-Jul-17	21-Jul-17	13122.05.01.05.610
13122.05.01.05.645	Assemble 10 PD modules (6) (CSU)	10	24-Jul-17	04-Aug-17	13122.05.01.05.620
Test PD modules		183	28-Dec-16	18-Sep-17	
13122.05.01.05.510	Fabricate test stand (CSU)	60	28-Dec-16	24-Mar-17	13122.05.01.05.430
13122.05.01.05.570	Test PD modules (1) (CSU)	15	04-May-17	24-May-17	13122.05.01.05.510, 13122.05.01.05.565
13122.05.01.05.580MS	T5 MS - ProtoDUNE 10 PD modules ready to ship	0		24-May-17	13122.05.01.05.570
13122.05.01.05.595	Test PD modules (2) (CSU)	15	25-May-17	15-Jun-17	13122.05.01.05.570



Remaining Level of Effort | Primary Baseline | Remaining Work
Actual Level of Effort | Actual Work | Critical Remaining Work

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TASK filters: ProtoDUNE Only, WBS.

DUNE

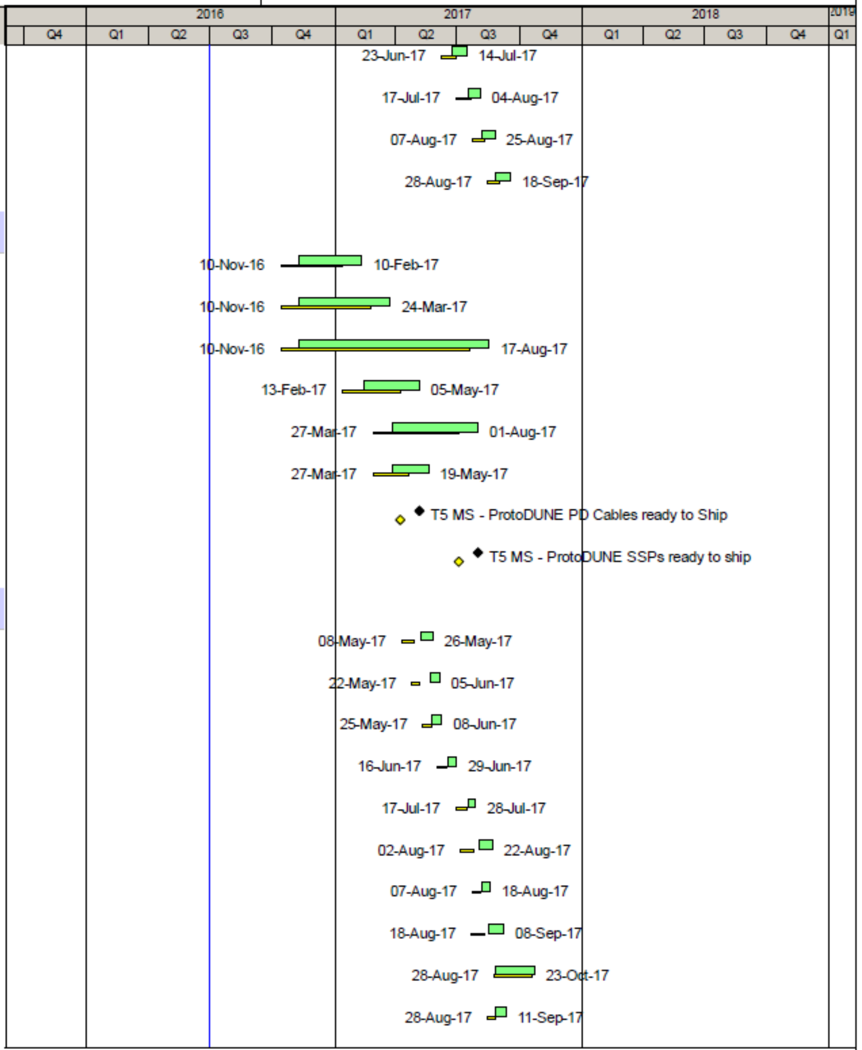
Caltech

Schedule III

- Integrated resources loaded schedule has been produced
- Monthly Status reports on each task
- Key links to other protoDUNE-SP subproject activities are included
- Milestones updated and tracked

Far Detector — Far Detector - ProtoDUNE — 14-Jul-16 11:28

Activity ID	Activity Name	Original Duration	Start	Finish	Predecessors
13122.05.01.05.615	Test PD modules (3) (CSU)	15	23-Jun-17	14-Jul-17	13122.05.01.05.590, 13122.05.01.05.600
13122.05.01.05.625	Test PD modules (4) (CSU)	15	17-Jul-17	04-Aug-17	13122.05.01.05.610, 13122.05.01.05.615
13122.05.01.05.650	Test PD modules (5) (CSU)	15	07-Aug-17	25-Aug-17	13122.05.01.05.620, 13122.05.01.05.625
13122.05.01.05.665	Test PD modules (6) (CSU)	15	28-Aug-17	18-Sep-17	13122.05.01.05.650, 13122.05.01.05.645
Proto-DUNE PD Electronics/Cabling Fabrication		192	10-Nov-16	17-Aug-17	
13122.05.01.05.435	Finalize Proto-DunePD Cabling design (ANL)	60	10-Nov-16	10-Feb-17	13122.05.01.05.420, 13122.05.01.05.415, 13122.05.01.05.425MS
13122.05.01.05.440	Finalize Proto-DUNE PD Readout Electronics Design (ANL)	90	10-Nov-16	24-Mar-17	13122.05.01.05.435, 13122.05.01.05.415, 13122.05.01.05.425MS
13122.05.01.05.445	Fabricate Proto-DUNE PD Calibration System (ANL)	192	10-Nov-16	17-Aug-17	13122.05.01.05.425MS
13122.05.01.05.515	Procure/Test PD Cables (ANL)	60	13-Feb-17	05-May-17	13122.05.01.05.435
13122.05.01.05.530	Procure/Test 16 Modified PD Readout Modules (SSPs) (ANL)	90	27-Mar-17	01-Aug-17	13122.05.01.05.440
13122.05.01.05.535	Modify/Test 8 existing 35t SSPs (ANL	40	27-Mar-17	19-May-17	13122.05.01.05.440
13122.05.01.05.550MS	T5 MS - ProtoDUNE PD Cables ready to Ship	0		05-May-17	13122.05.01.05.515
13122.05.01.05.635MS	T5 MS - ProtoDUNE SSPs ready to ship	0		01-Aug-17	13122.05.01.05.530
Ship Proto-DUNE PD system to CERN		118	08-May-17	23-Oct-17	
13122.05.01.05.555	Ship Proto-Dune Cables to CERN (ANL)	15	08-May-17	26-May-17	13122.05.01.05.550MS
13122.05.01.05.575	Ship 8 PD Electronics to CERN (ANL)	10	22-May-17	05-Jun-17	13122.05.01.05.535
13122.05.01.05.585	Ship 10 Proto-DUNE PD Modules to CERN (1) (CSU)	10	25-May-17	08-Jun-17	13122.05.01.05.580MS
13122.05.01.05.605	Ship 10 Proto-DUNE PD Modules to CERN (2) (CSU)	10	16-Jun-17	29-Jun-17	13122.05.01.05.595
13122.05.01.05.630	Ship 10 Proto-DUNE PD Modules to CERN (3) (CSU)	10	17-Jul-17	28-Jul-17	13122.05.01.05.615
13122.05.01.05.640	Ship Proto-DUNE PD Electronics to CERN (ANL)	15	02-Aug-17	22-Aug-17	13122.05.01.05.635MS
13122.05.01.05.655	Ship 10 Proto-DUNE PD Modules to CERN (4) (CSU)	10	07-Aug-17	18-Aug-17	13122.05.01.05.625
13122.05.01.05.660	Ship Proto-DUNE calibration system to CERN (ANL)	15	18-Aug-17	08-Sep-17	13122.05.01.05.445
13122.05.01.05.685	Commission PD system at CERN (CSU +?)	40	28-Aug-17	23-Oct-17	13122.05.01.05.680MS, 13122.05.01.05.740
13122.05.01.05.670	Ship 10 Proto-DUNE PD Modules to CERN (5) (CSU)	10	28-Aug-17	11-Sep-17	13122.05.01.05.650



Remaining Level of Effort — Primary Baseline — Remaining Work
Actual Level of Effort — Actual Work — Critical Remaining Work

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TASK filters: ProtoDUNE Only, WBS.

Conclusions

- Photon Detector System has been designed to meet the requirements of DUNE
- protoDUNE-SP will allow evaluation of the performance relative to the requirements
- An integrated resource loaded schedule has been completed that meets the timeline of protoDUNE
- The design builds on the lessons learned in 35T and other prototypes
- Schedule and technical risks have been addressed for protoDUNE, and protoDUNE is a risk mitigation strategy for DUNE
- The following talks will take you through the details of the protoDUNE Photon Detector System (PDS) design

Charge Matrix

Charge Item	Charge Question	Mualem	Himmel	Whittington	Mufson	Toups	Segreto	Zutshi	Mufson(2)	Warner	Warner(2)	Drake	Djurcic	Buchanan
1	Does the Photon Detector System design enable validation and refinement of the DUNE photon detector requirements?	X	X	X			X							
2	Are Photon Detector System risks captured and is there a plan for managing and mitigating these risks?	X			X	X	X		X			X		
3	Does the design lead to a reasonable production schedule, including QA, transport, installation and commissioning?	X			X	X	X	X		X	X	X	X	
4	Does the documentation of the Photon Detector System technical design provide sufficiently comprehensive analysis and justification for the Photon Detector System design adopted?	X	X	X	X	X	X	X	X	X	X	X	X	X
5	Is the Photon Detector system scope well defined and complete? Are all Photon Detector System interfaces to other detector components: APA, cryostat and DAQ systems documented, clearly identified and complete? Do the electronics feedthrough port and TPC integrated 3D models adequately represent the mechanical, electrical and electronic interfaces to the Photon Detector System? Is the cabling, power and calibration well defined and understood? Is the grounding and shielding understood and adequate?	X						X		X	X	X	X	
6	Are the Photon Detector System 3D model(s), top level assembly drawings, detail/part drawings and material and process specifications sufficiently complete to demonstrate that the design can be constructed and installed?				X	X	X	X		X	X			
7	Are operation conditions listed, understood and comprehensive? Is there an adequate calibration plan?	X						X		X	X	X	X	
8	Are the Photon Detector System engineering analyses sufficiently comprehensive for safe handling, installation and operation at the CERN Neutrino Platform? Is the installation plan sufficiently well developed? Is the design for installation tooling adequate for installing the photon system?										X			
9	Have applicable lessons-learned from previous LArTPC devices been documented and implemented into the QA plan? Are the Photon Detector System quality control test plans and inspection regimes sufficiently comprehensive to assure efficient commissioning and adequate operational performance of the NP04 experiment?	X												X