DUNE Costing

Gina Rameika

NCG Kick-off Meeting

25 October 2019

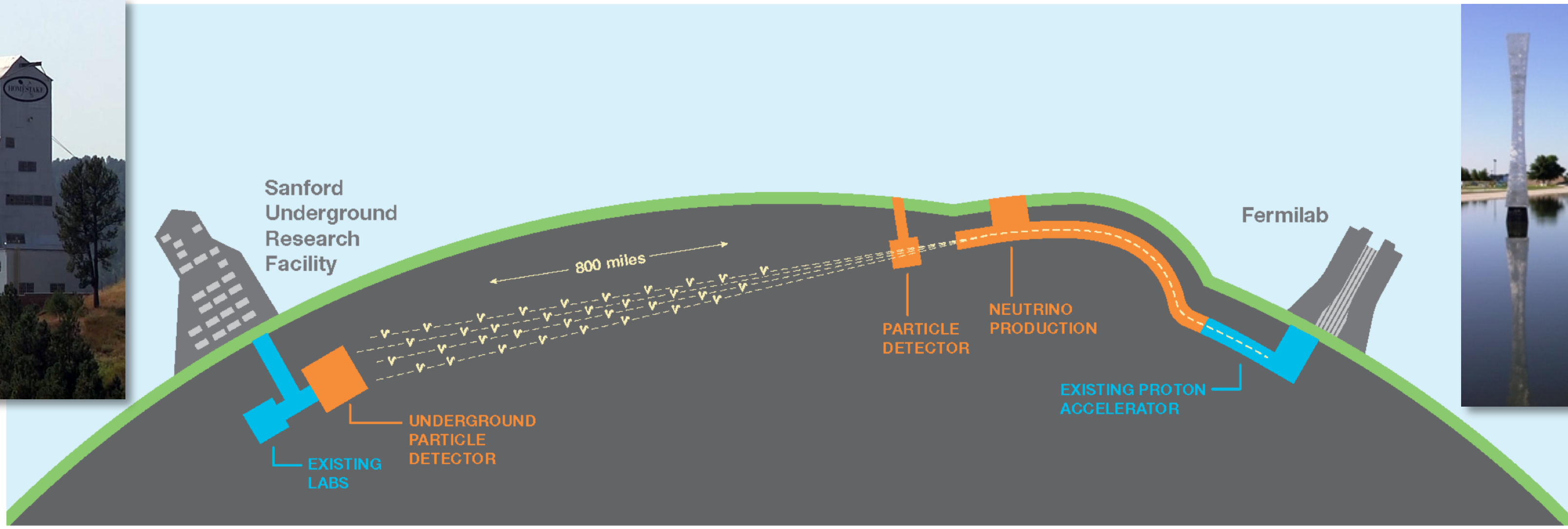
Who am I?

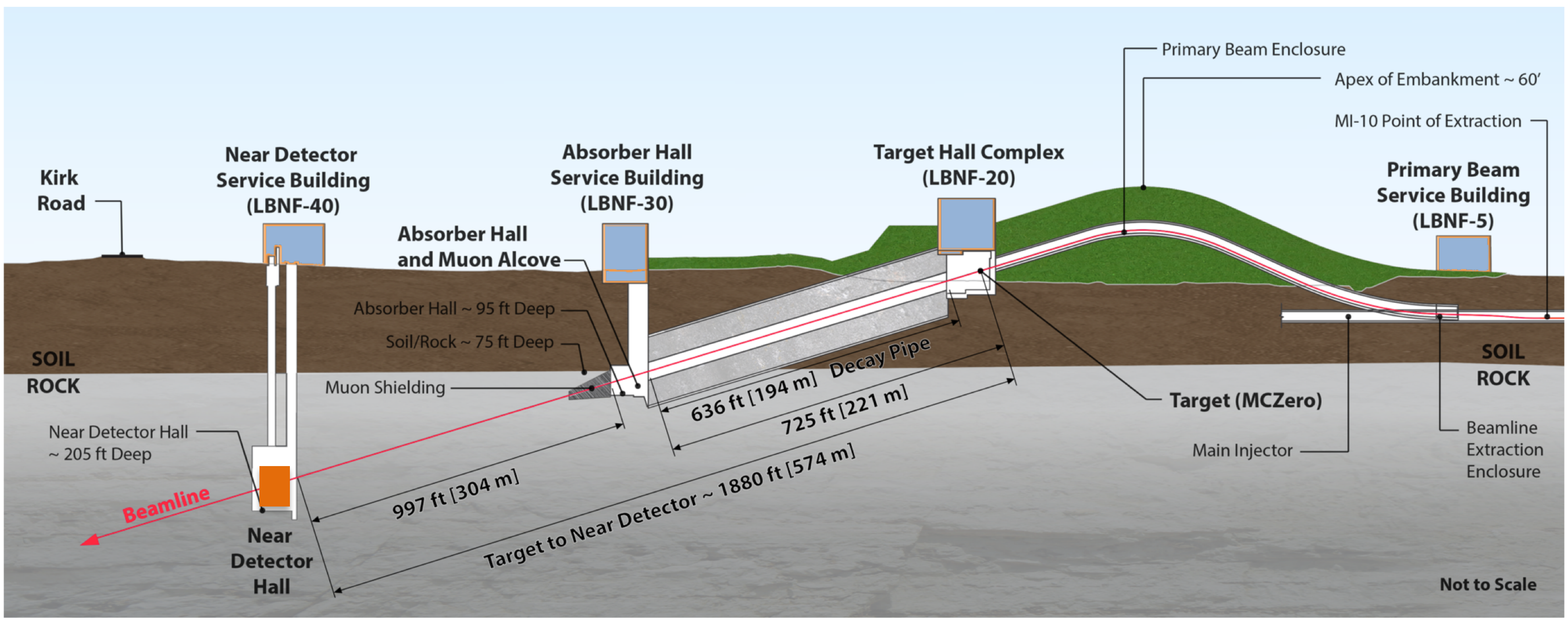
- Scientist at Fermilab since 1982
- Worked on :
  - Fixed Target : Hyperons, Neutrinos (DONUT) (‘80s & ‘90s)
  - Deputy Head of Research Division (mid ‘90s)
  - NuMI/MINOS Project management (late ’90s)
  - Soudan Laboratory Operations Manager for Fermilab (2004-2008)
  - Co-leader of Future Long Baseline Study (2006 – 2007)
  - LBNE Project (2008 – 2011)
  - MicroBooNE Project Manager (2011 – 2015)
  - Neutrino Division Head (2014 – 2016)
  - ProtoDUNE-SP Construction Coordinator (2016 – 2018)
  - DUNE Resource Coordinator (2019 -)

Outline for Today

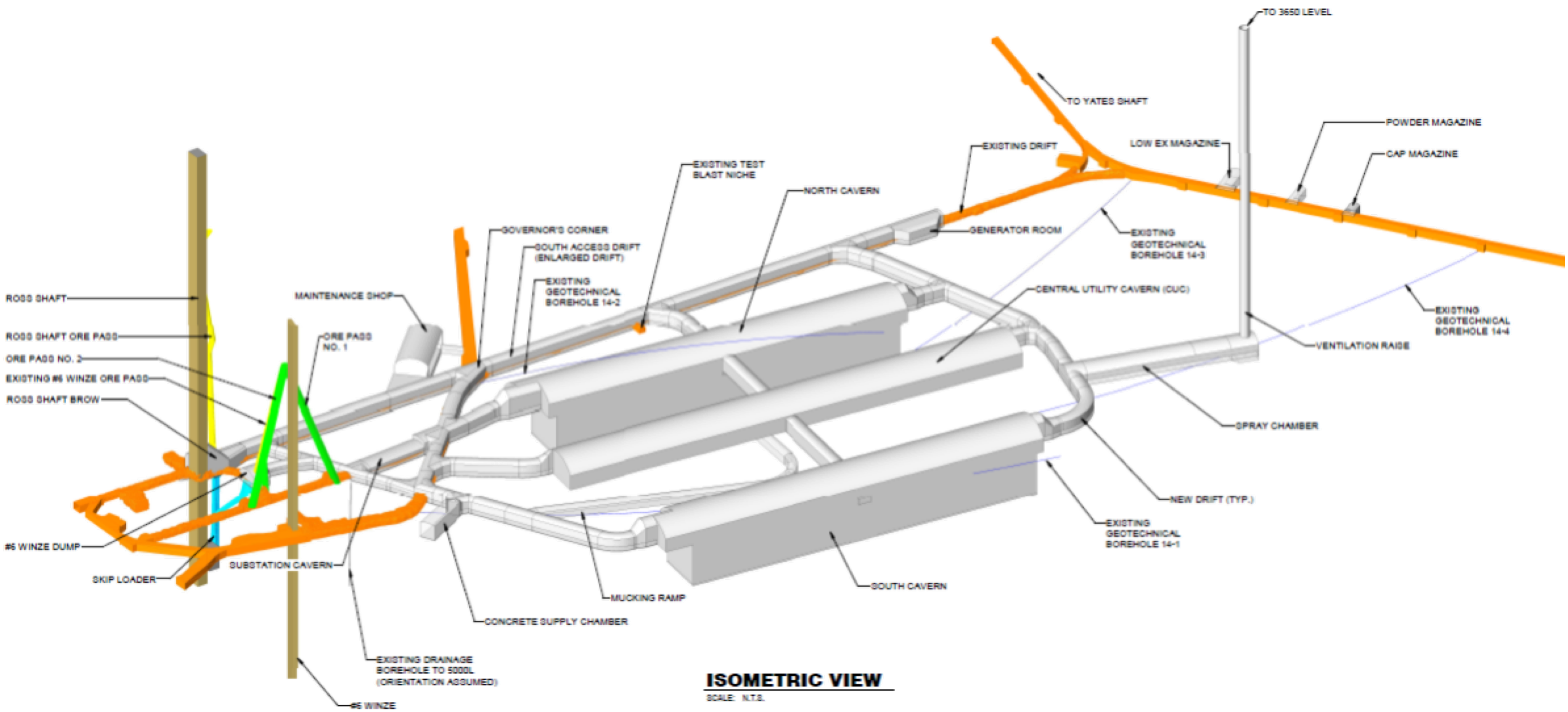
- DUNE Overview and Organization
- The DUNE Far Detector Single Phase Module
  - High Voltage : Cathode Planes and Field Cages
  - Anode Plane Assemblies
  - TPC Electronics (cold and warm)
  - Photon Detectors
  - Data Acquisition
  - Instrumentation and Calibration
- Consortia Cost Books
- Cost Book Rollup
- Resource Matrix
- Next Steps

DUNE Overview

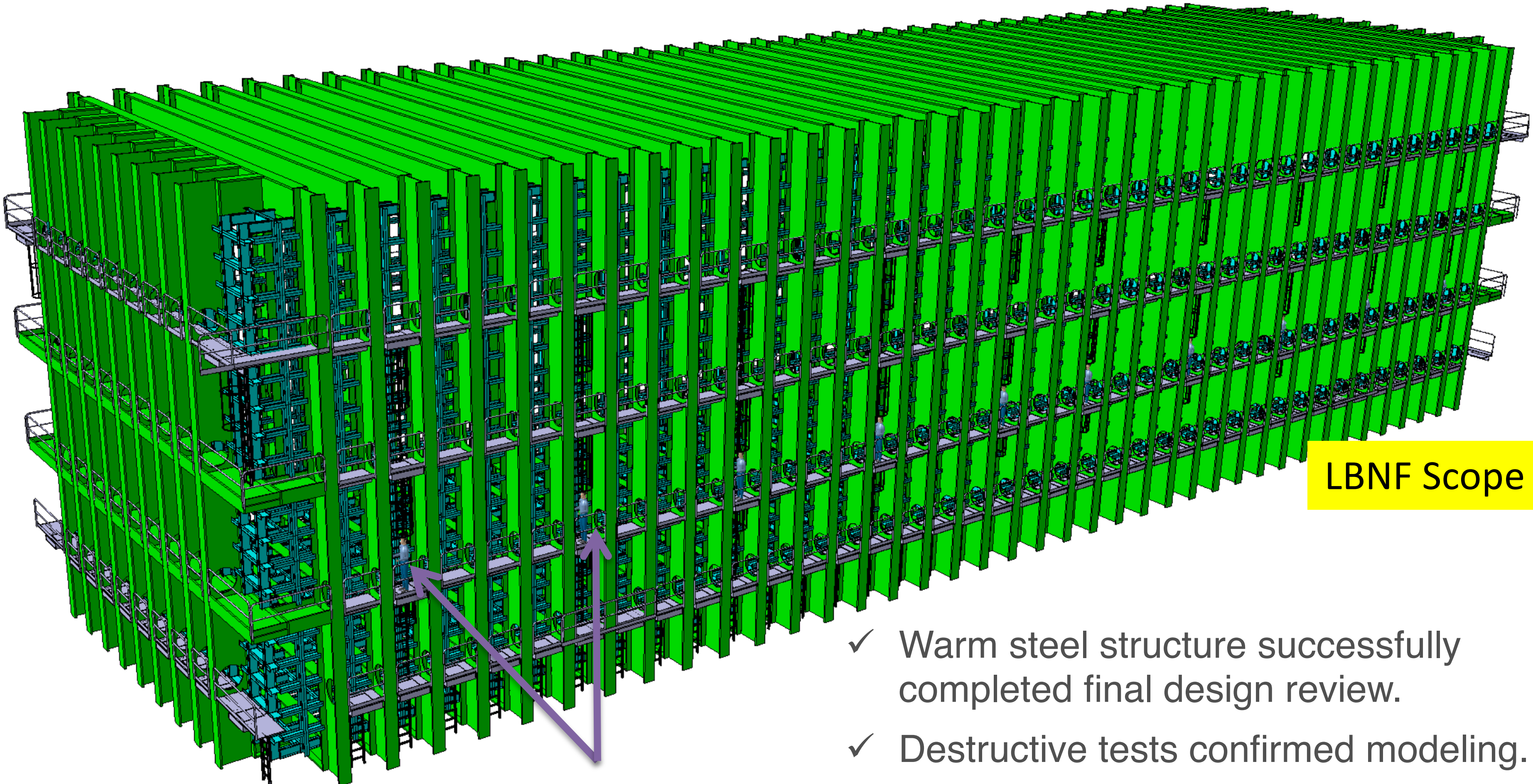




Far Site – Detector Caverns



Free-Standing Steel Cryostat Design



LBNF Scope

People for Scale

Designed and engineered by CERN

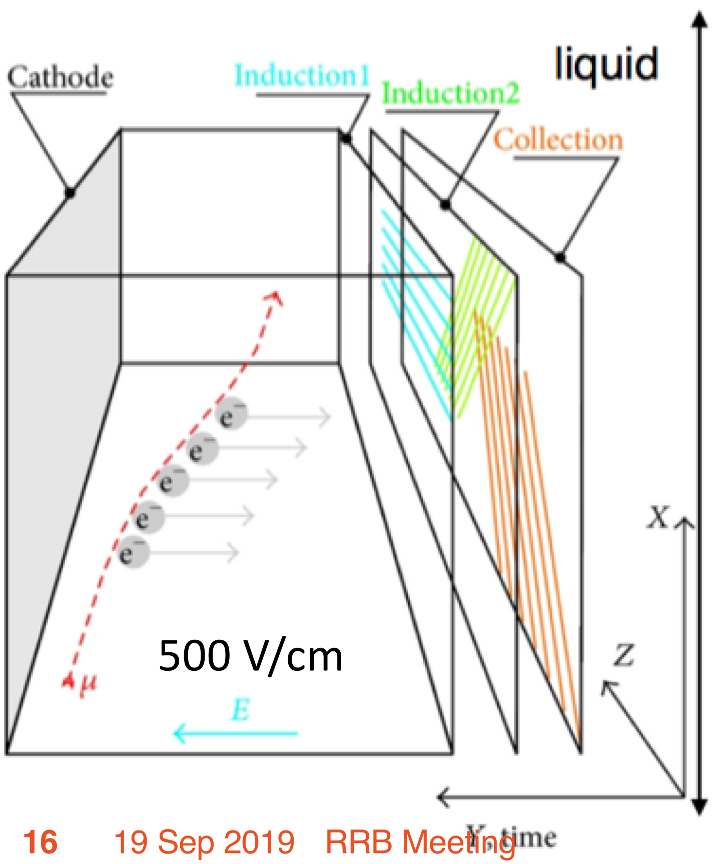
- ✓ Warm steel structure successfully completed final design review.
- ✓ Destructive tests confirmed modeling.
- ✓ Membrane design by GTT for SP detector completed.

External Dimensions
62.7’ W x 59’ H x 216.5’ L (19.1m W x 18.0m H x 66.0m L)

DUNE Detector Technologies

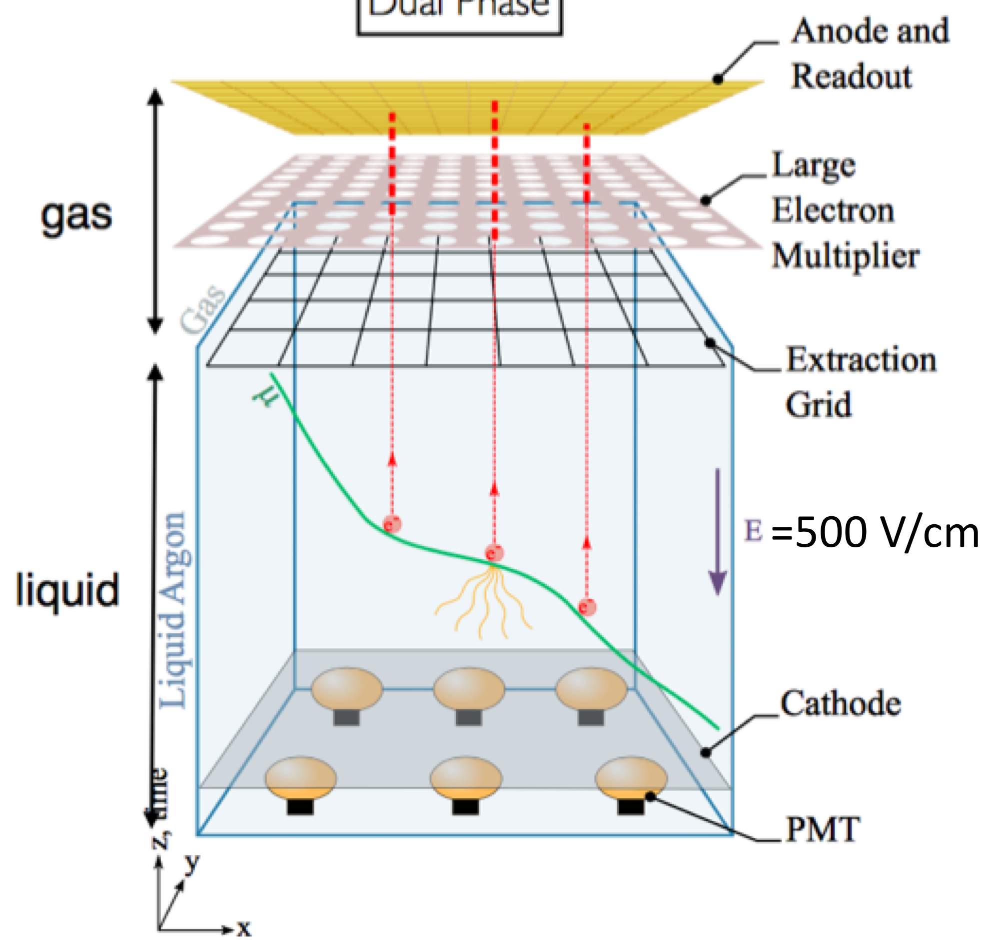
- Ionization charges drift horizontally and are read out with wires
- No signal amplification in liquid
- 3.5 m maximum drift

Single Phase



- Ionization charges drift vertically and are read out on PCB anode
- Amplification of signal in gas phase by LEM
- 12 m maximum drift

Dual Phase



16 19 Sep 2019 RRB Meeting

Far Detector Consortia

Single-Phase

- APA: Christos Touramanis (Liverpool)
- Photon Detection System: Ettore Segreto (Campinas)
- TPC Electronics: Dave Christian (FNAL)

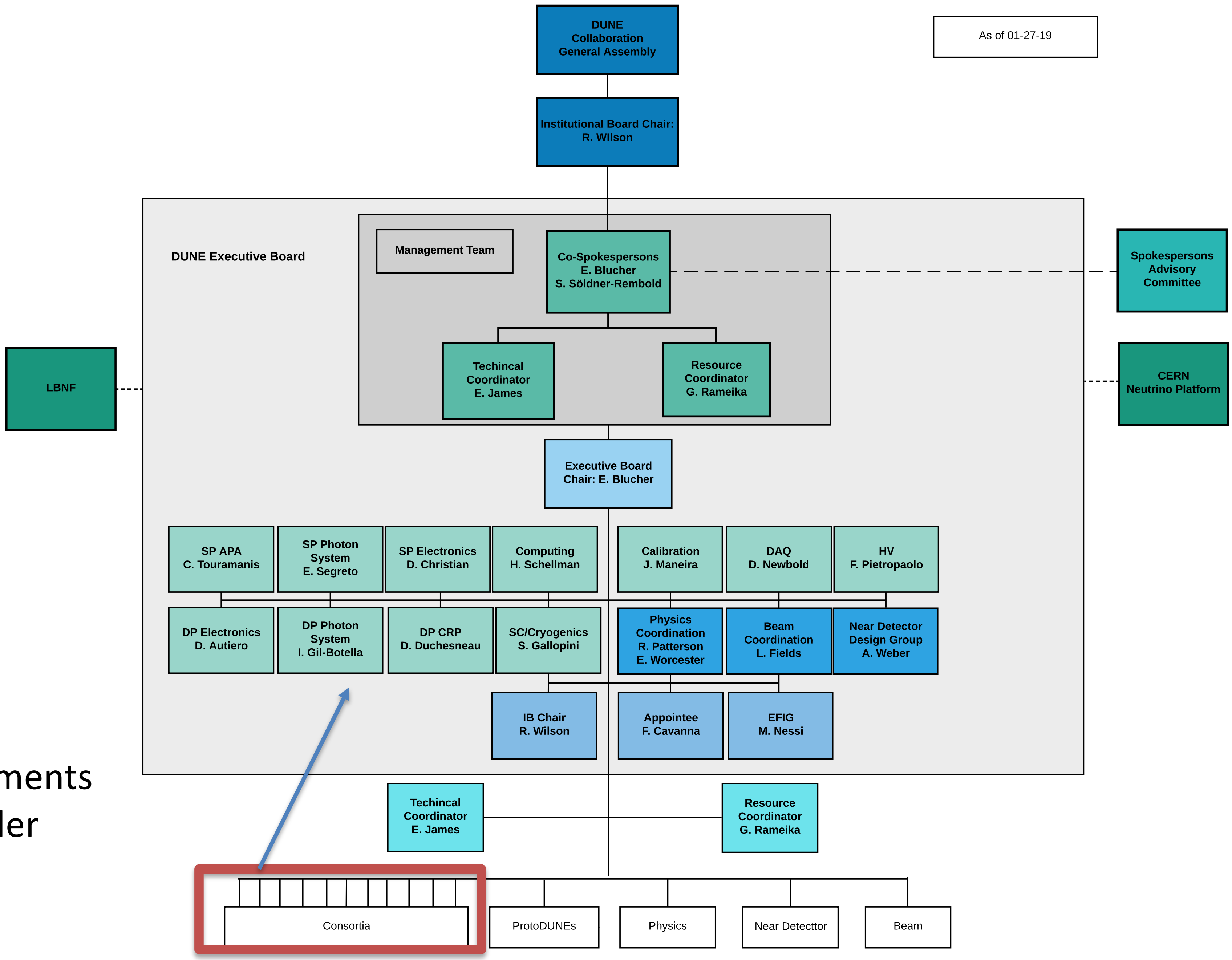
Dual-Phase

- CRP: Dominique Duchesneau (LAPP)
- Photon Detection System: Ines Gil Botella (CIEMAT)
- TPC Electronics: Dario Autiero (IPNL)

Joint SP/DP

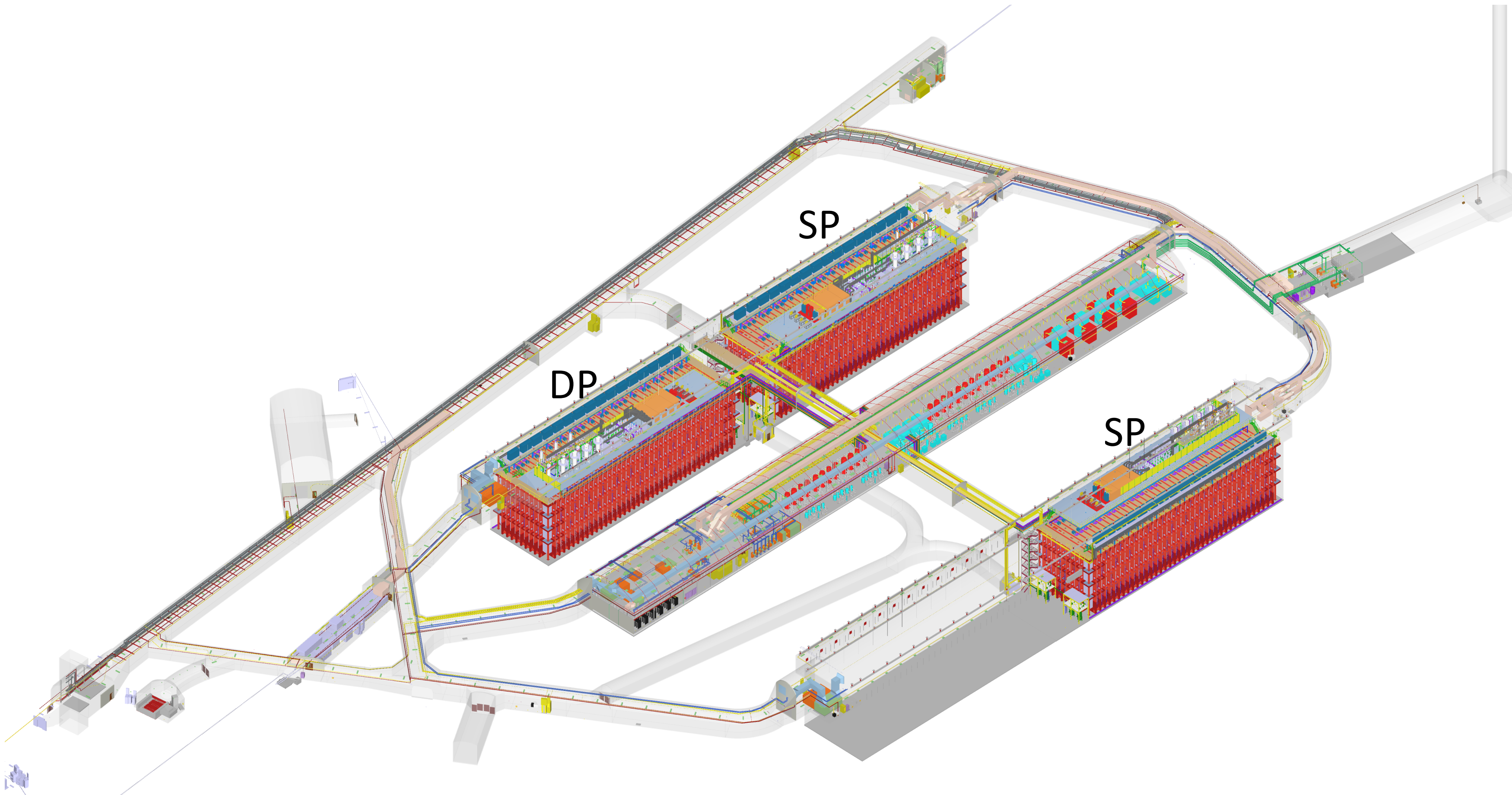
- HV System: Francesco Pietropaolo (CERN)
- DAQ: Giovanna Lehmann Miotto (CERN)
- Slow Controls/Instrumentation: Sowjanya Gollapinni (Tennessee)
- Computing: Heidi Schellman (Oregon State)
- Calibration: Jose Maneira (LIP)

Collaboration Management



Appointments now under review

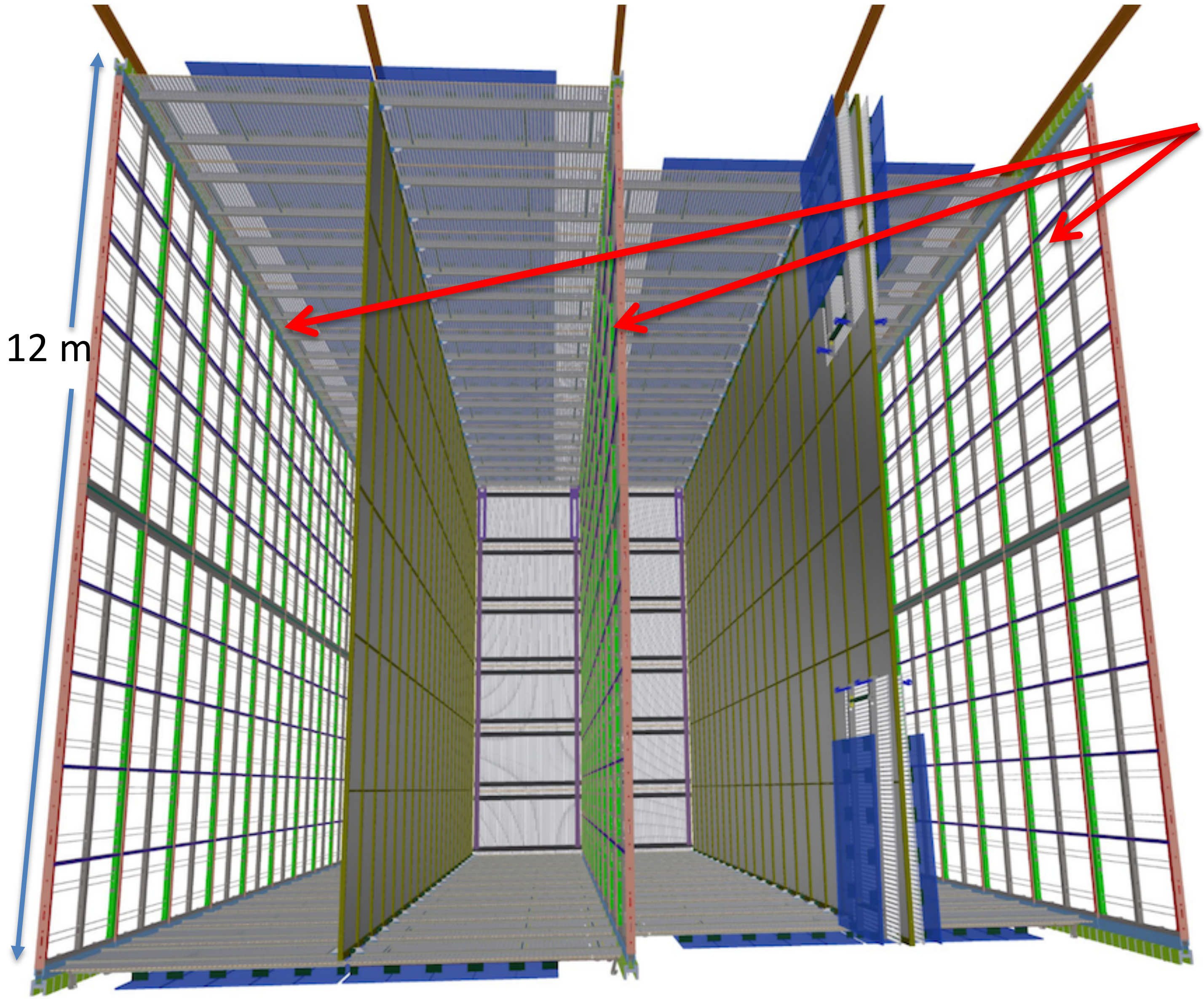
DUNE Far Detectors at SURF



Single Phase Components

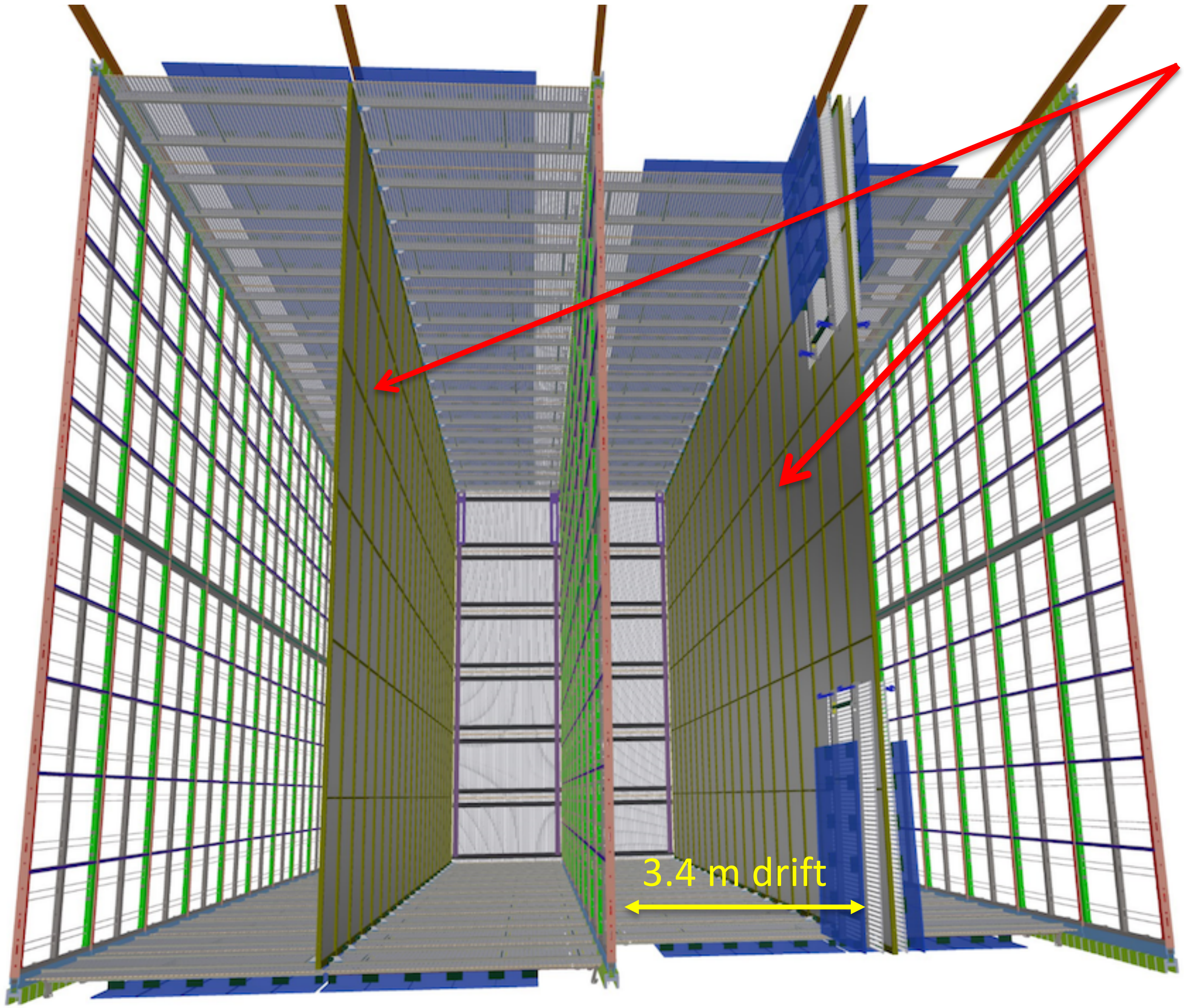
- Drift ionization charge : High Voltage
  - HV power supply and feed-through
  - Cathode Plane
  - Field Cages
    - Resistive dividers
- Collect ionization charge : Sense wires, electronics
  - Anode Planes
  - Front-end amplification, digitization, readout
- Collect scintillation light : wavelength shifters, light guides, light collection electronics
  - Photon detector modules with SiPM readout
- Data Acquisition
- Instrumentation and Calibration systems

The DUNE Single Phase Module



150 APAs arranged in three planes, double high APAs in 25 rows

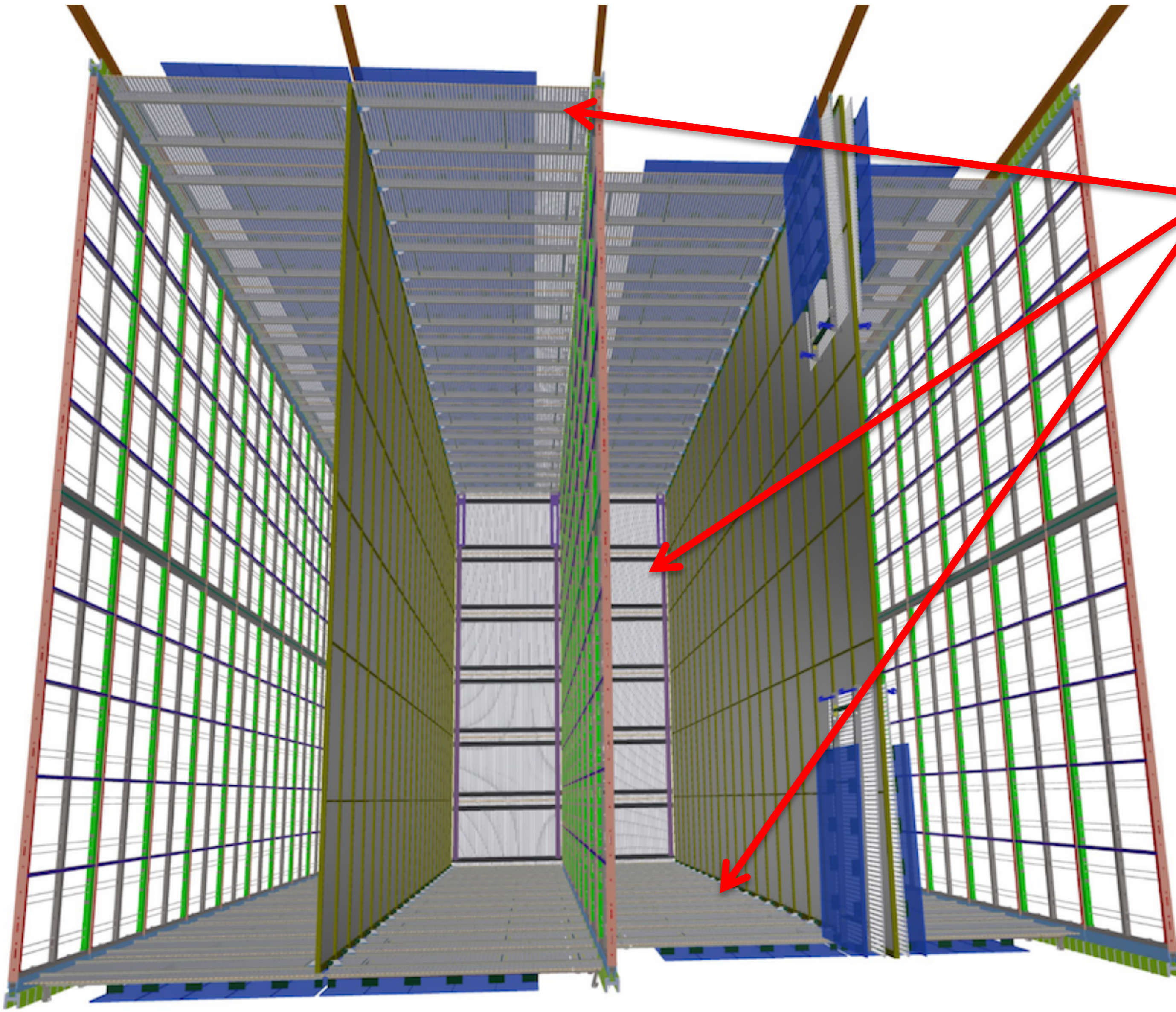
The DUNE Single Phase Module



High Voltage Cathode Planes

2 cathode planes each composed of 150 1.2m w x 4m h CPA modules

The DUNE Single Phase Module



Field Cages :

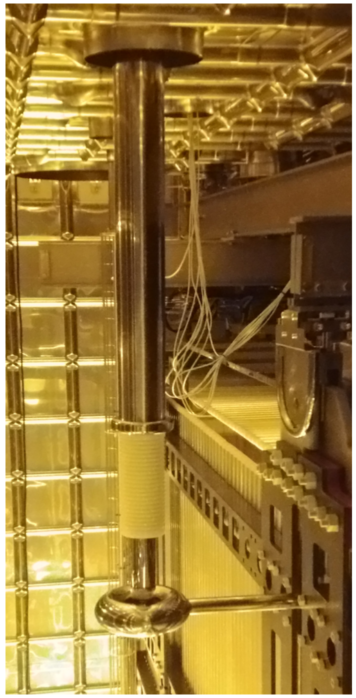
Top, Bottom and Endwalls

100 T and B modules
48 Endwall modules

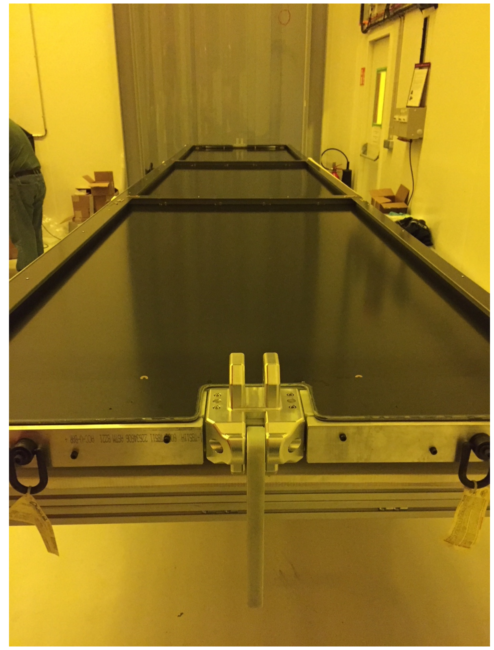
High Voltage System Components

US-DOE, CERN, INFN

Power Supply



Feed-through

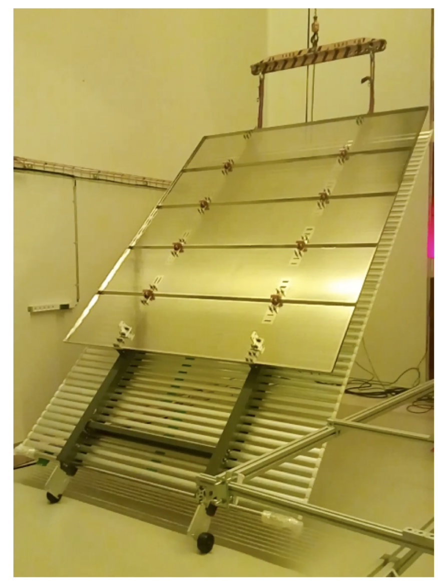


CPA Panel (from PD)
DUNE will be
2X longer

Resistor Dividers

End-wall

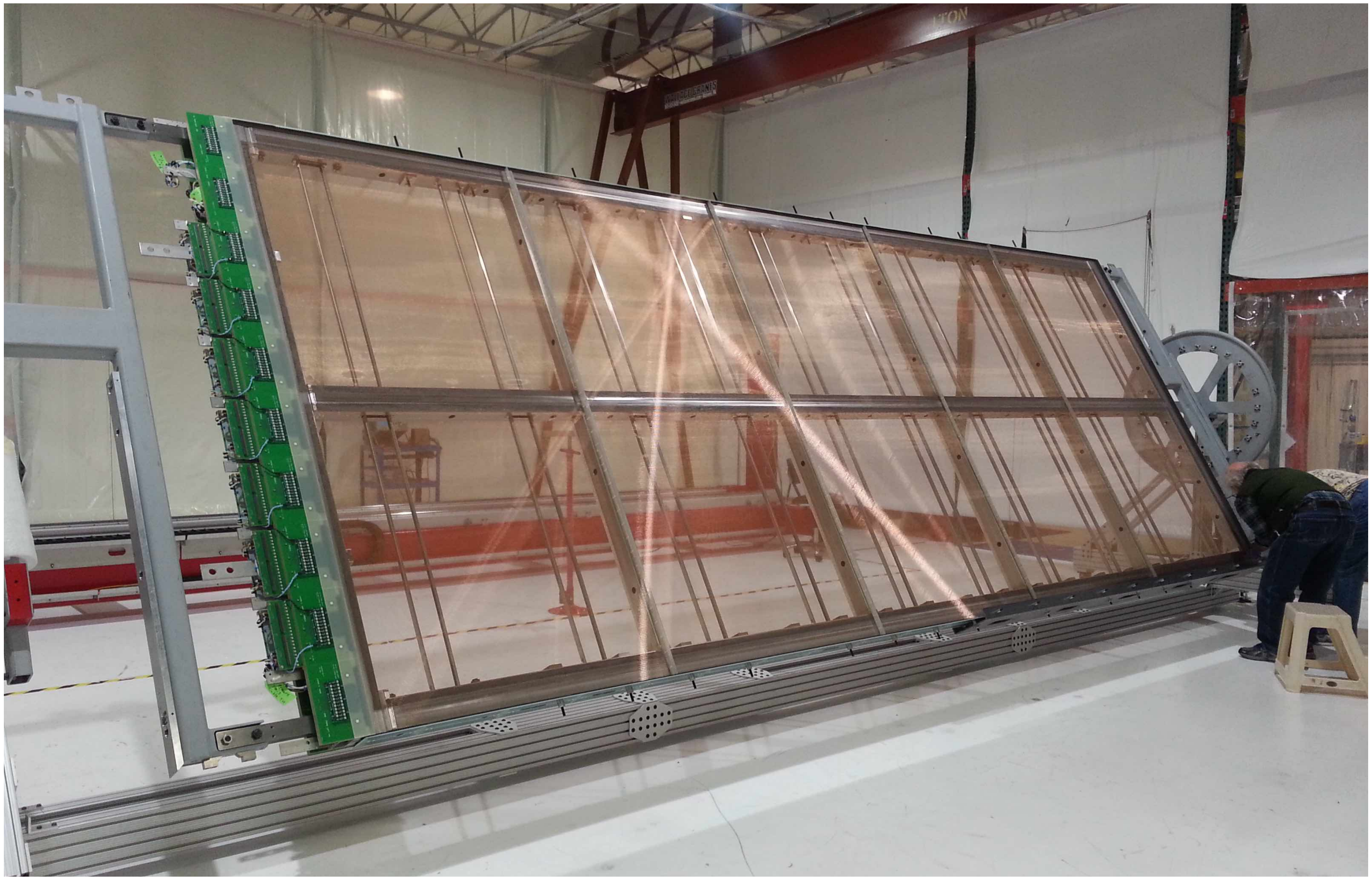
Top/bottom Field
Cage module
with Ground plane



High voltage drift volume in PD

Anode Plane Assemblies

UK - 150
US-NSF - 150



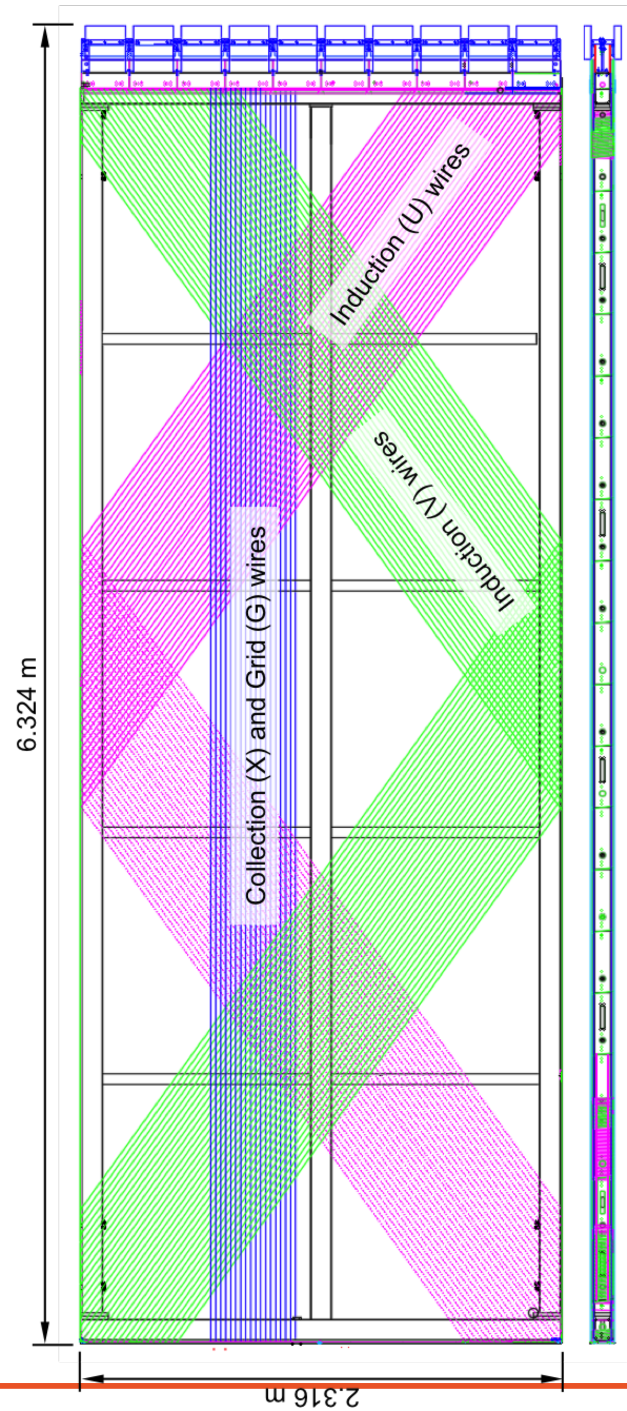
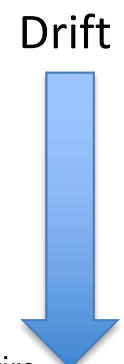


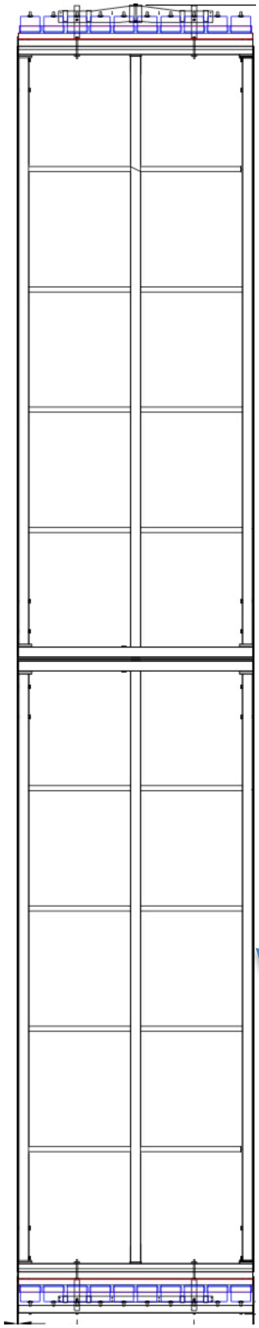
Table 1.3: APA design parameters

Parameter	Value
Active height	5.984 m
Active width	2.300 m
Wire pitch (U, V)	4.669 mm
Wire pitch (X, G)	4.790 mm
Wire pitch tolerance	±0.5 mm
Wire plane spacing	4.75 mm
Wire plane spacing tolerance	±0.5 mm
Wire Angle (w.r.t. vertical) (U, V)	±35.7°
Wire Angle (w.r.t. vertical) (X, G)	0°
Number of wires / APA	960 (X), 960 (G), 800 (U), 800 (V)
Number of electronic channels / APA	2560
Wire material	beryllium copper
Wire diameter	150 μm

Anode Plane	**Bias Voltage**
G - Grid	−665 V
U - Induction	−370 V
V - Induction	0 V
X - Collection	820 V
Grounding Mesh	0 V

Table 1.2: Baseline bias voltages for APA wire layers.

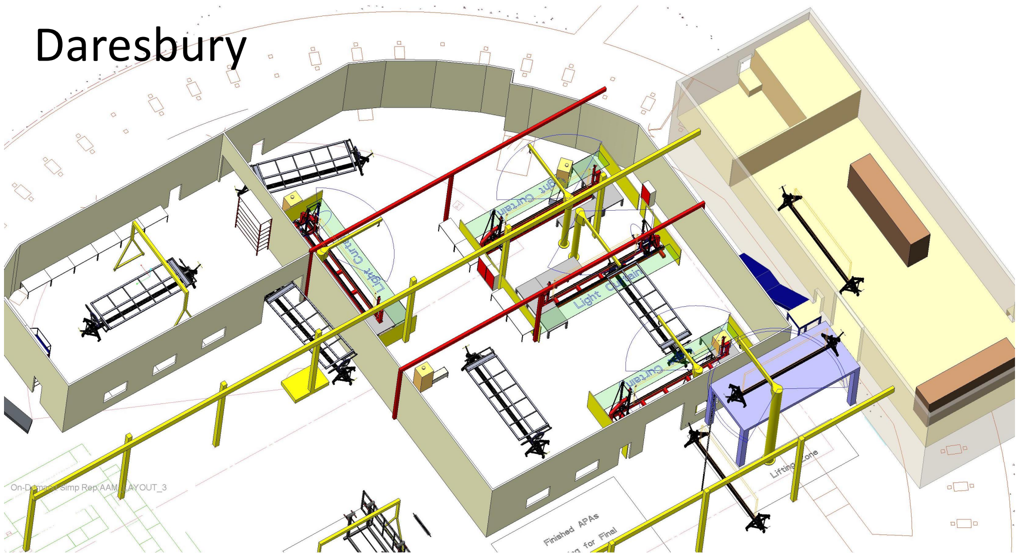


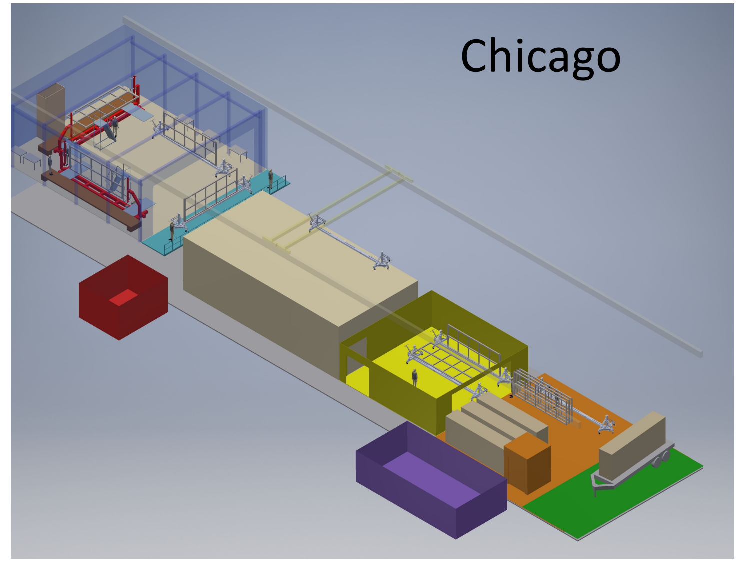


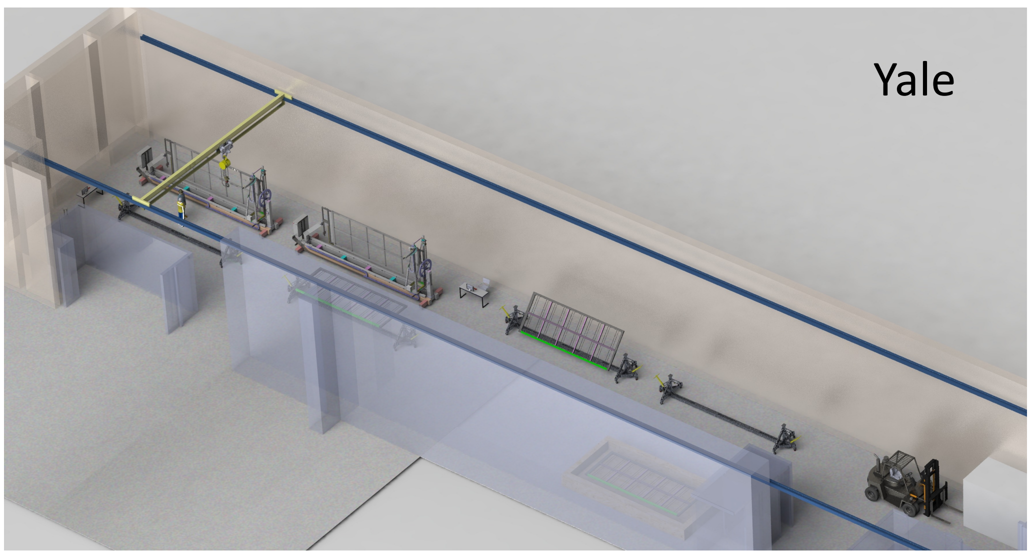
- Two APA's are stacked vertically, joined at the "feet"
- Production
  - 150 produced in UK, 150 in US
  - UK Factory at Daresbury Lab
    - 4 winding machines
  - US Production Sites : Chicago, Yale and PSL(Wisc)
    - 2 winding machines each at Chicago, Yale, PSL

This one hangs upside down

APA Factory layouts



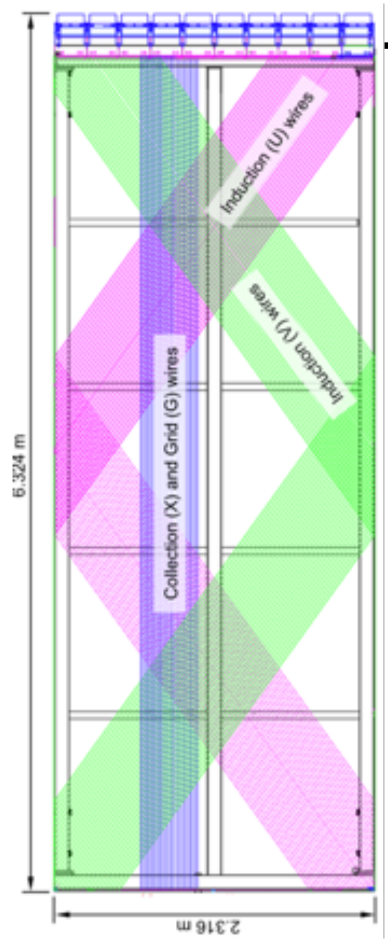




TPC Electronics

100% DOE Scope

- 2560 electronics channels (wires) per APA
- 128 channels per FE ASIC -> 20 COLD mother boards per APA
- 3000 mother boards per Single Phase module



Read out at one end of APAs
(Top end of top APAs bottom end of bottom APAs)

3 ASIC solution*

Front-end motherboard
40 u wires
40 v wires
48 x wires (collection)

FE ASIC x8 — Shaping & amplification
ADC ASIC x8 — Analogue to digital
COLDATA ASIC x2 — Merge data streams Control & comms

Outside world

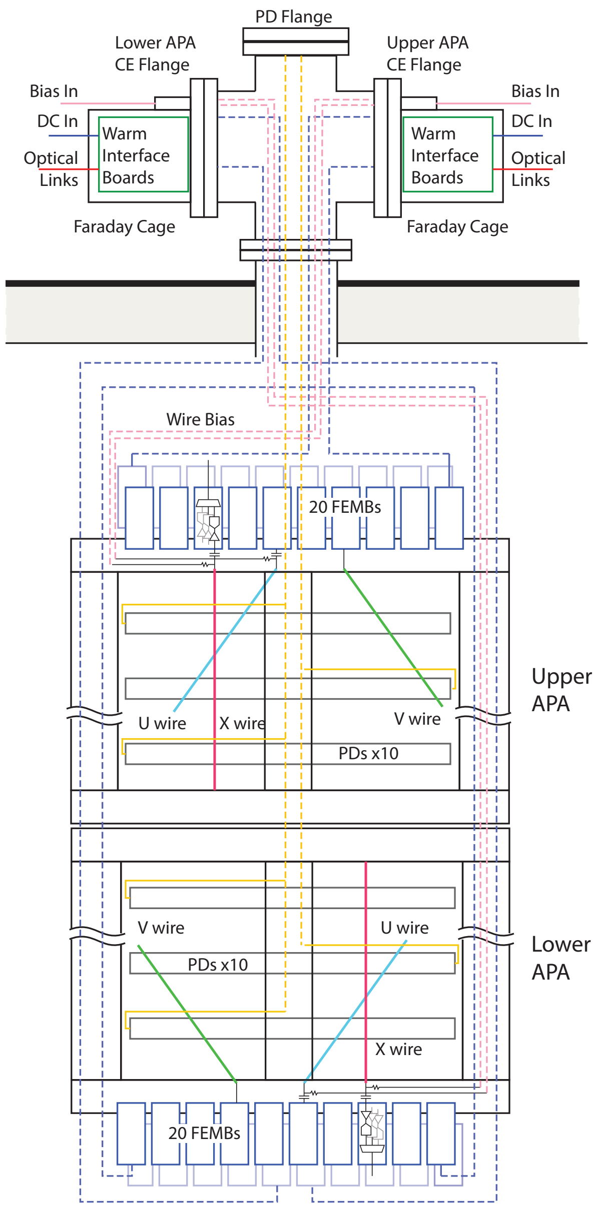
x 20 per APA

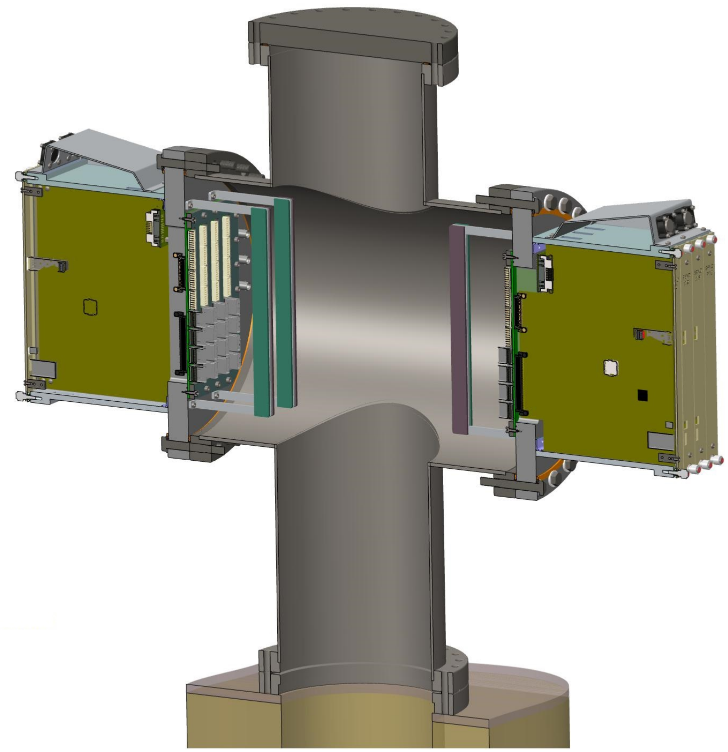
Mounted on the APAs, in the cold, which reduces noise

*alternative : single ASIC CRYO chip under development

Fermilab DUNE

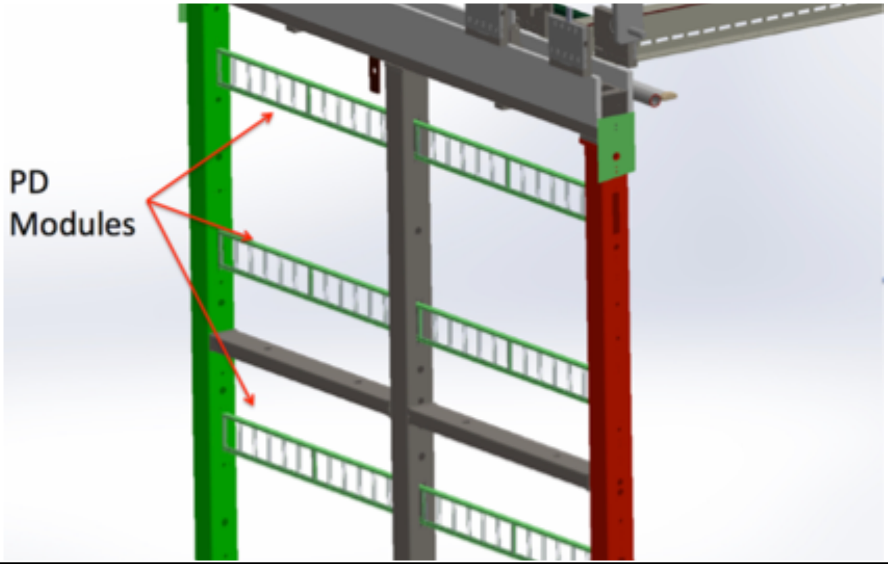
Cold cables to warm electronics





1 Feed-through per APA pair
5 WIBs per APA

Photon Detector System

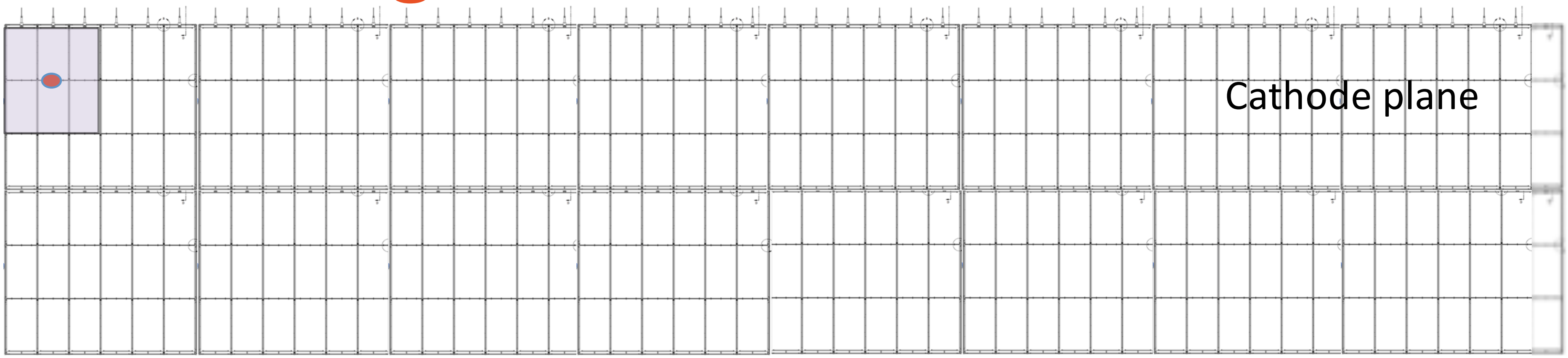


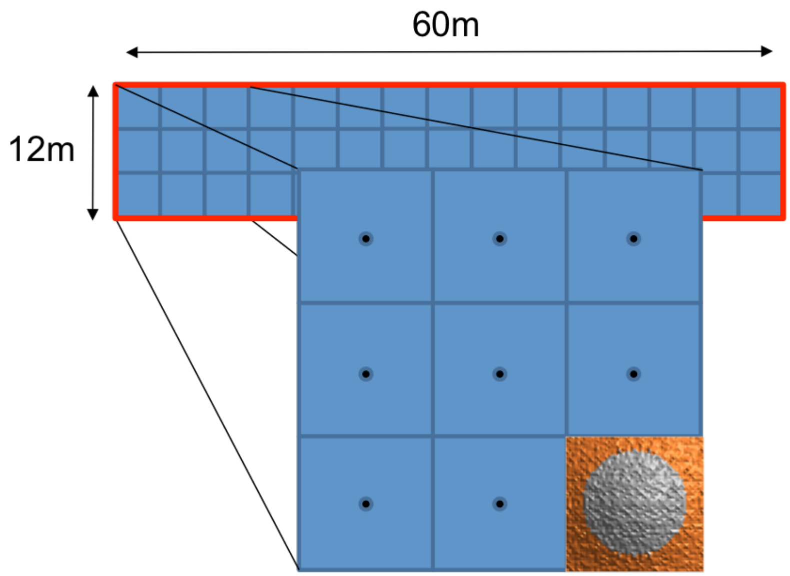
ARAPUCA Modules : Brazil
SiPMs & Summing : Italy, Spain
Readout : Peru, Columbia
Calibration : US DOE

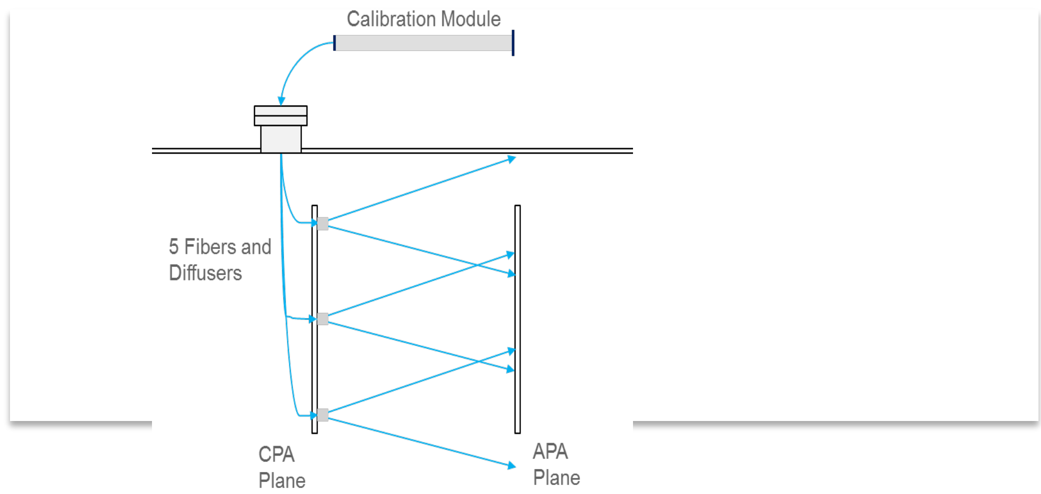
Component	Description	Quantity
Light collector	X-ARAPUCA	10 modules per APA; 1500 total (1000 single-sided; 500 double-sided)
Photosensor	Hamamatsu MPPC 6 mm×6 mm *	192 SiPM per module; 288,000 total
SiPM signal summing	6 passive × 8 active	4 circuits per module; 6000 total
Readout electronics	Based on commercial ultrasound chip	4 channels/module; 6000 total
Calibration and monitoring	Pulsed UV via cathode-mounted diffusers	45 diffusers/CPA side; 180 total

* FBK/Italy also being studied

Photon Detector Monitoring







Data Acquisition

UK | CERN

Data Selection scope (trigger) in NSF proposal

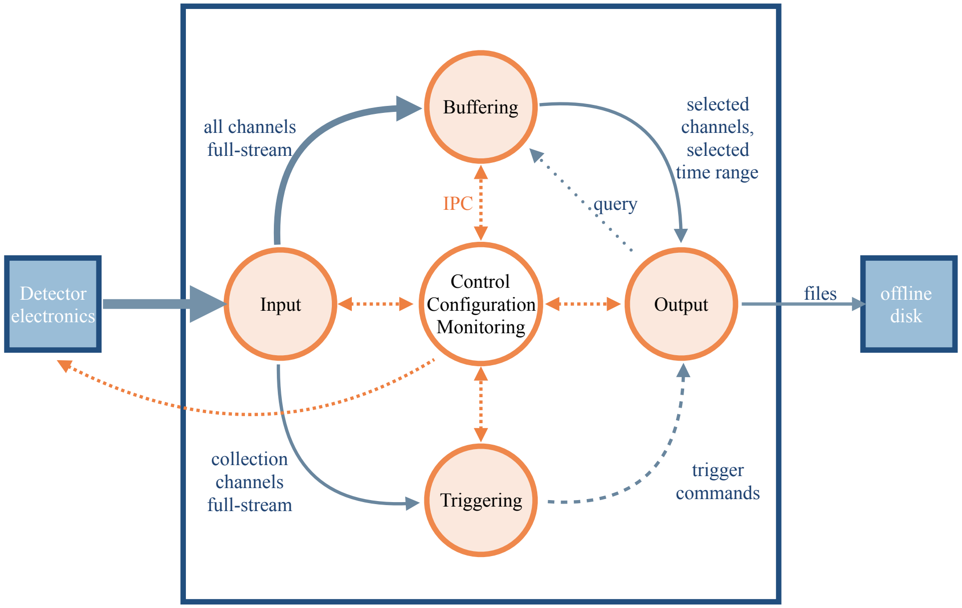
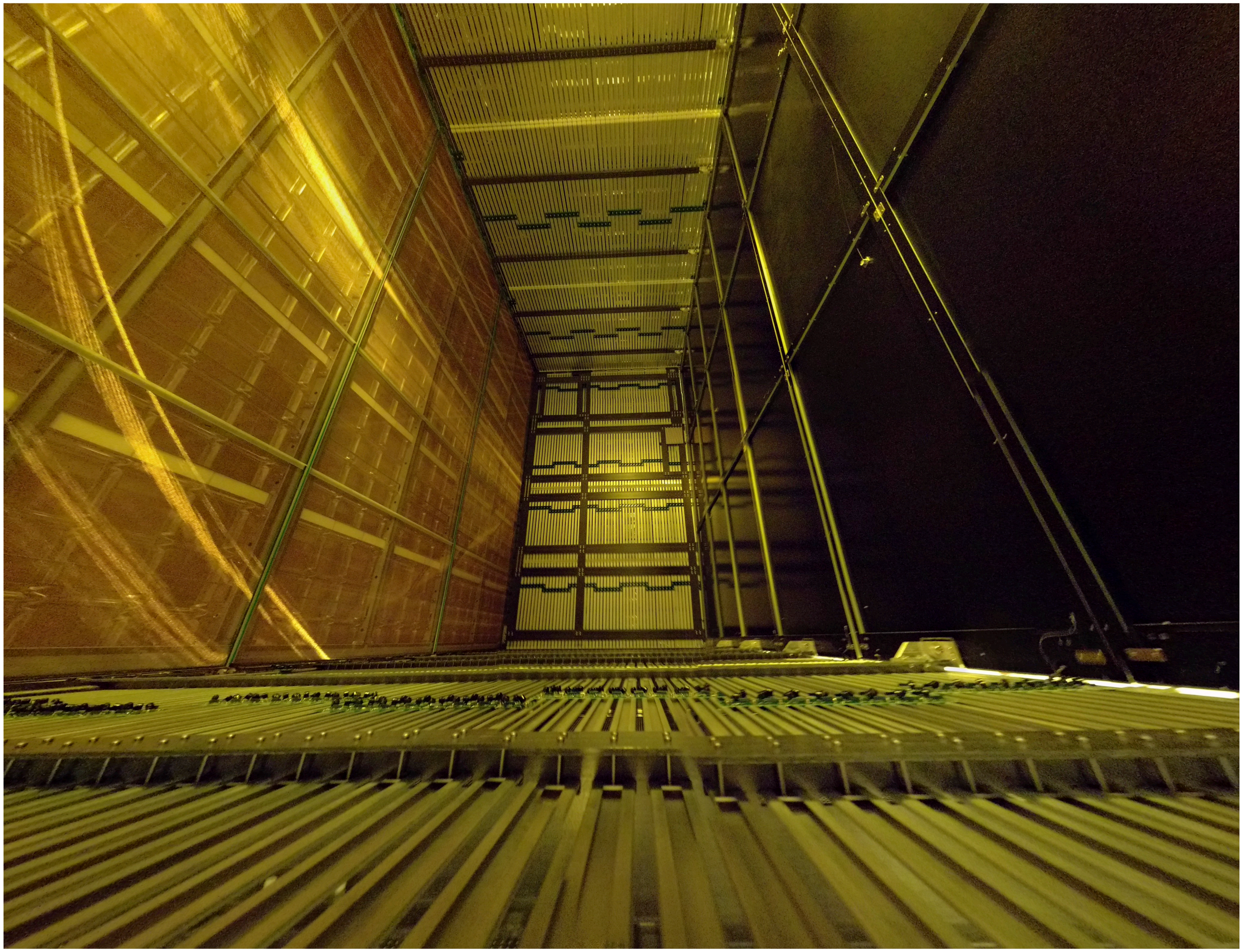


Figure 1.3: Conceptual Overview of DAQ System Functionality for a single 10 kt module

Each set of APA WIBs connects to one FELIX FPGA PCIe 3.0 board

- System requirements driven by need for
  - High uptime
  - Configurable and controllable from remote locations
  - Operational during installation and commissioning via separate partitions
  - Large buffering capability and low fake triggers for Supernova
  - Reduce data volume prior top off-line storage
- Five sub-systems
  - Upstream DAQ
  - Data selection
  - Back-end subsystem
  - Control, Configuration and Monitoring
  - Timing and synchronization

The Single Phase TPC



- APA's + electronics, along with Photon Detectors, the High Voltage and Data Acquisition Systems comprise the essential elements of the Single Phase Detector.

Instrumentation and Calibration

- Instrumentation includes :
  - Temperature probes
  - Level meters
  - Gas analyzers
  - Purity Monitors
  - Cameras

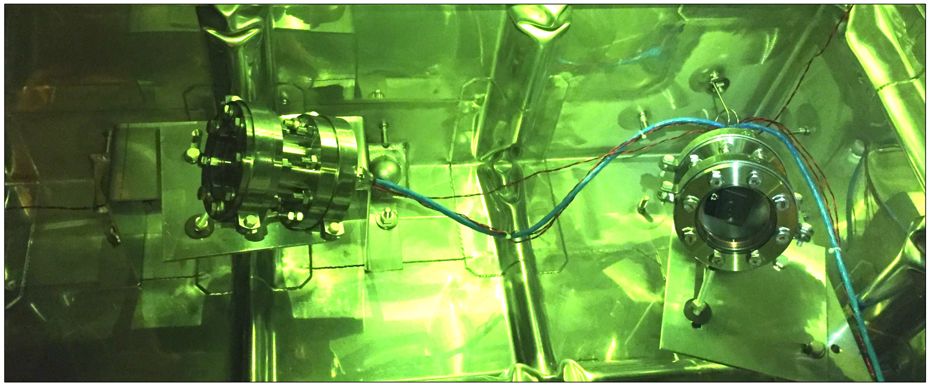
Static Temperature Probes to be provided by IFIC, Valencia

Currently no LBNF/DUNE Scope for Instrumentation or Calibration; may include small amount

Potential contributions from DUNE-US project funds or other funding sources (i.e. ECA)

- Systems proposed :
  - Laser *
  - Pulsed Neutron Source
  - Radioactive source

These systems had Scope reviews in June 2019; ProtoDUNE-II plans being developed



*Lasers are the most significant cost impact of these two areas

DUNE Costing Model : International Responsibility Matrix

- Modeled after the CERN approach to quantify international contributions
  - Based on CORE accounting (direct M&S for capital investments)
    - No R&D, escalation, overheads, contingency
    - NO LABOR Costs, hours documented
- Here's where it get tricky : different approaches …
  - Ability/desire to cover a specific scope (by %) -> $ contribution to total CORE cost
  - Ability/desire to contribute a specific $ amount
    - How much is available for M&S -> % contribution of CORE
  - Depending on the situation, developing the matrix needs to be an iterative process

Status of Cost Estimates

- Single Phase
  - Cost Workbooks (CORE accounting : M&S plus Labor hours) either complete of nearing completion for all major systems
  - P6 accounting for DOE scope
  - 1st pass CORE accounting for 2 modules
    - Some systems more rigorous than others
- Dual Phase
  - Cost Workbook (in current format) for Photon Detectors
  - Cost estimate (older format) for Electronics
  - Cost estimate (top down) for CRPs
  - Cost estimates from SP-DP Joint consortia being developed
  - Preliminary 1st pass CORE accounting for 1 module coming soon
- Near Detector
  - Preliminary estimates for a minimum reference detector being developed

Maturity of SP Estimates

- Cost estimates are prepared by the Consortia Technical Leaders
  - Technical Leads are also the L2 managers where there is DOE scope
  - We are trying to ensure that CORE costs and hours can be reconciled with the P6 costs; work in progress
- APAs, CE and HV based on actual costs from building ProtoDUNE
- DAQ based on costs of FELIX system in ATLAS; cost driver (but not CORE) is labor
- Photon system is new (Arapuca based); ProtoDUNE was strictly a development phase; SiPM cost is large, but under negotiation; readout being based on existing mu2e design to reduce cost from what was used for ProtoDUNE
- Instrumentation : material costs known from ProtoDUNE, labor is largely collaboration supplied
- Calibration : new system, scope under review, lasers are expensive; still studying technical feasibility of source calibration systems

Consortia Cost Books

- Cost Books are posted in DUNE DocDB#14458
- In order of CORE Cost :
  - SP-APA_Sept2019.xlsx : organization based on the NSF proposal; solid estimate with BOE's based on PD
  - SP-CE_May2019.xlsx : good organization; BOEs based on PD
    - Update for DOE IPR in DocDB#10315 (open to ncg)
  - SP-PD_May2019.xlsx : SiPM is cost driver; solid BOEs
  - SP-DAQ_Aug2019.xlsx : good organization; based on recent experiences; M&S is higher than earlier planned, but solid; driver in this system is labor
  - SP-HV_Sept2019.xlsx : good organization; based on PD but updated to accommodate design and assembly changes
  - SP-Cal_July2019.xlsx : not very detailed; concentration on cost of big ticket items (lasers); system scope not finalized
  - SP-CISC_May2019 : lots of smallish components here; not real cost driver

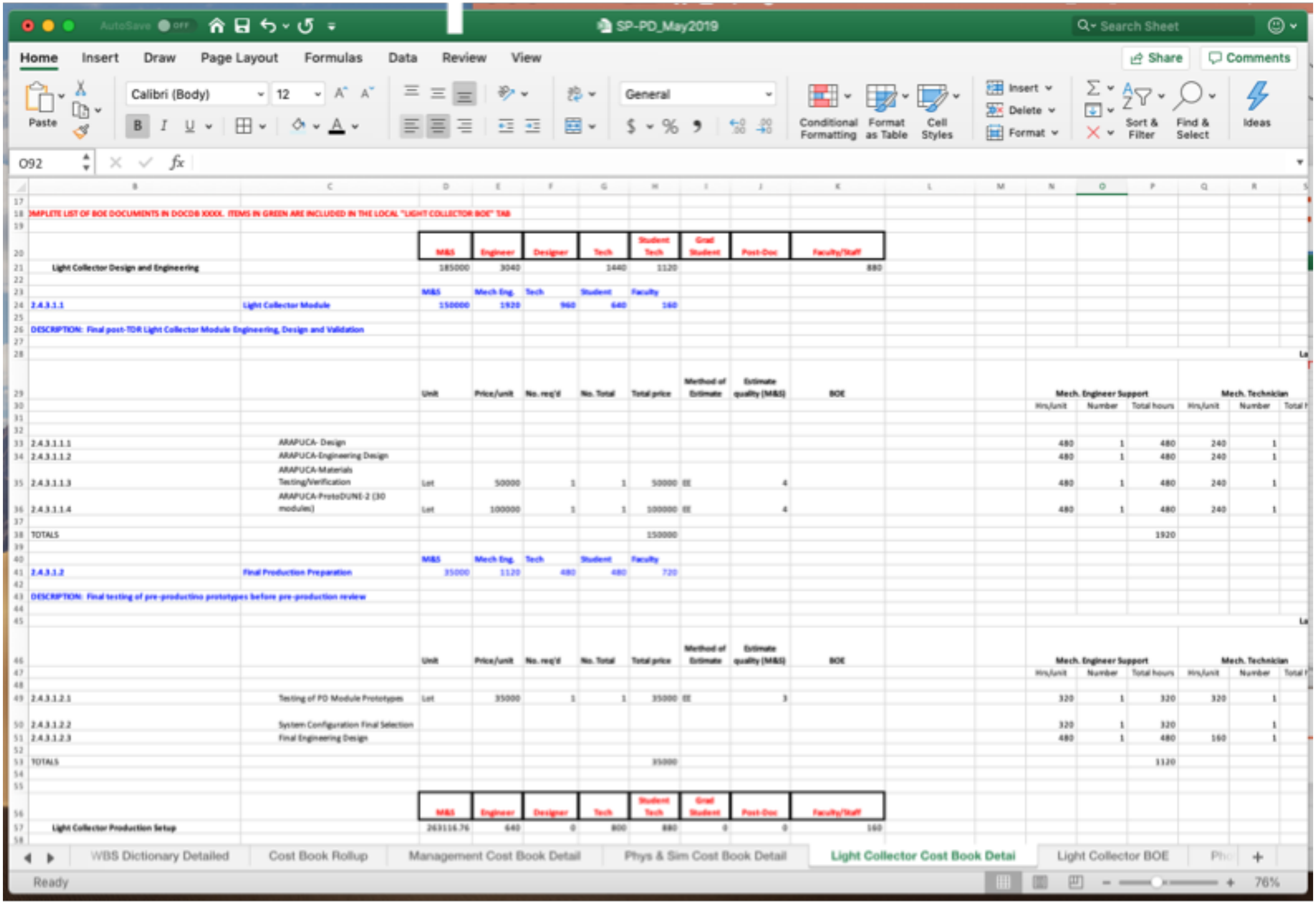
SP-PD_May2019

C13 =’Light Collector Cost Book Detai’!D57

WBS	WBS Element Name	M&S	Engineer	Designer	Tech	Student Tech	Grad-Student	Post-Doc	Faculty /Staff	
2.4	DUNE SP-PD (Single 10KT)	$9,491,035	15,620	4,320	72,403	21,290	2,660	10,485	7,919	113,633
*2.4.1**	*Project Management (Milestones, Reviews)*	*$0*	*220*	*0*	*0*	*0*	*880*	*880*	*880*	
*2.4.2**	*Physics and Simulations*	*$0*	*1960*	*0*	*0*	*0*	*0*	*2260*	*0*	
2.4.3	Design, Engineering and R&D	$555,057	5860	2120	4020	2860	1260	2270	1630	
2.4.3.1	Light Collectors Design and Engineering	$185,000	3040	0	1440	1120	0	0	880	
2.4.3.2	Photo Sensors Design and Engineering	$175,000	880	500	1340	420	300	350	150	
2.4.3.3	Electronics, Cabling and Monitoring Design and Engineering	$165,057	1360	940	880	1080	960	1460	280	
2.4.3.4	Integration and Installation Test Hardware Design and Engineering	$30,000	580	680	360	240	0	460	320	
2.4.4	Production Setup	$498,117	2220	1160	3020	1480	840	360	790	7880
2.4.4.1	Light Collectors Production Setup	$263,117	640	0	800	880	0	0	160	
2.4.4.2	Photo Sensors Production Setup	$100,000	880	520	840	600	360	240	320	
2.4.4.3	Electronics, Cabling and Monitoring Production Setup	$90,000	460	520	840	0	480	0	250	
2.4.4.4	Integration and Installation Test Hardware Production Setup	$45,000	240	120	540	0	0	120	60	
2.4.5	Production	$8,387,862	6690	240	46738	16275	560	1280	2359	69943
2.4.5.1	Light Collector Production	$3,134,179	1960	0	32575	1775	0	150	680	
2.4.5.2	Photo Sensors Production	$3,978,480	3030	0	7320	14500	200	440	1280	
2.4.5.3	Electronics, Cabling and Monitoring Production	$1,275,203	1700	240	6843	0	360	690	399	
2.4.6	Integration and Installation	$50,000	850	800	18625	675	0	6575	3140	20950
*	*not included in sums*									98773

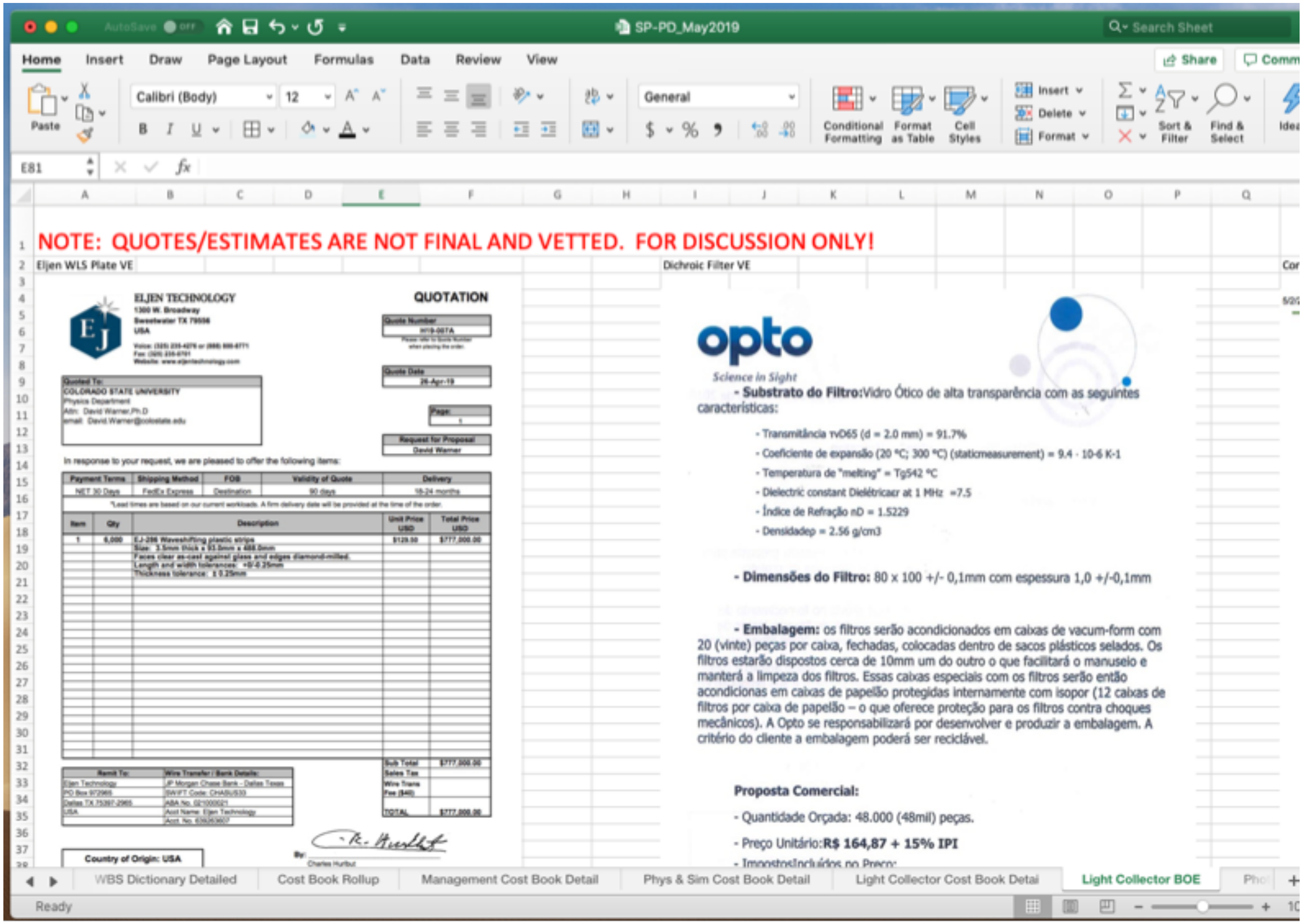
WBS Dictionary Detailed | Cost Book Rollup | Management Cost Book Detail | Phys & Sim Cost Book Detail | Light Collector Cost Book Detai | Light Collector BOE

Cost Book Detail



	B	C	D	E	F	G	H	I	J	K	N	O	P	Q	R
18	MPLETE LIST OF BOE DOCUMENTS IN DOCDB XXXX. ITEMS IN GREEN ARE INCLUDED IN THE LOCAL "LIGHT COLLECTOR BOE" TAB														
20			M&S	Engineer	Designer	Tech	Student Tech	Grad Student	Post-Doc	Faculty/Staff					
21	Light Collector Design and Engineering		185000	3040		1440	1120			880					
23			M&S	Mech Eng.	Tech	Student	Faculty								
24	2.4.3.1.1	Light Collector Module	150000	1920	960	640	160								
26	DESCRIPTION: Final post-TDR Light Collector Module Engineering, Design and Validation														
29			Unit	Price/unit	No. req'd	No. Total	Total price	Method of Estimate	Estimate quality (M&S)	BOE	Mech. Engineer Support			Mech. Technician	
30											Hrs/unit	Number	Total hours	Hrs/unit	Number
33	2.4.3.1.1.1	ARAPUCA- Design									480	1	480	240	1
34	2.4.3.1.1.2	ARAPUCA-Engineering Design									480	1	480	240	1
35	2.4.3.1.1.3	ARAPUCA-Materials Testing/Verification	Lot	50000	1	1	50000	EE	4		480	1	480	240	1
36	2.4.3.1.1.4	ARAPUCA-ProtoDUNE-2 (30 modules)	Lot	100000	1	1	100000	EE	4		480	1	480	240	1
38	TOTALS						150000						1920		
40			M&S	Mech Eng.	Tech	Student	Faculty								
41	2.4.3.1.2	Final Production Preparation	35000	1120	480	480	720								
43	DESCRIPTION: Final testing of pre-productino prototypes before pre-production review														
46			Unit	Price/unit	No. req'd	No. Total	Total price	Method of Estimate	Estimate quality (M&S)	BOE	Mech. Engineer Support			Mech. Technician	
47											Hrs/unit	Number	Total hours	Hrs/unit	Number
49	2.4.3.1.2.1	Testing of PD Module Prototypes	Lot	35000	1	1	35000	EE	3		320	1	320	320	1
50	2.4.3.1.2.2	System Configuration Final Selection									320	1	320		1
51	2.4.3.1.2.3	Final Engineering Design									480	1	480	160	1
53	TOTALS						35000						1120		
56			M&S	Engineer	Designer	Tech	Student Tech	Grad Student	Post-Doc	Faculty/Staff					
57	Light Collector Production Setup		263116.76	640	0	800	880	0	0	160					

BOE Documentation



Snapshot – 10/01/19

Cost Book Rollup

WBS	WBS Element Name	M&S	Engineer	Designer	Tech	Student Tech	Grad-Student	Post-Doc	Faculty /Staff
2.4	DUNE SP-PD (Single 10KT)	$9,491,035	15,620	4,320	72,403	21,290	2,660	10,485	7,919
*2.4.1**	*Project Management (Milestones, Reviews)*	*$0*	*220*	*0*	*0*	*0*	*880*	*880*	*880*
*2.4.2**	*Physics and Simulations*	*$0*	*1960*	*0*	*0*	*0*	*0*	*2260*	*0*
2.4.3	Design, Engineering and R&D	$555,057	5860	2120	4020	2860	1260	2270	1630
2.4.3.1	Light Collectors Design and Engineering	$185,000	3040	0	1440	1120	0	0	880
2.4.3.2	Photo Sensors Design and Engineering	$175,000	880	500	1340	420	300	350	150
2.4.3.3	Electronics, Cabling and Monitoring Design and Engineering	$165,057	1360	940	880	1080	960	1460	280
2.4.3.4	Integration and Installation Test Hardware Design and Engineering	$30,000	580	680	360	240	0	460	320
2.4.4	Production Setup	$498,117	2220	1160	3020	1480	840	360	790
2.4.4.1	Light Collectors Production Setup	$263,117	640	0	800	880	0	0	160
2.4.4.2	Photo Sensors Production Setup	$100,000	880	520	840	600	360	240	320
2.4.4.3	Electronics, Cabling and Monitoring Production Setup	$90,000	460	520	840	0	480	0	250
2.4.4.4	Integration and Installation Test Hardware Production Setup	$45,000	240	120	540	0	0	120	60
2.4.5	Production	$8,387,862	6690	240	46738	16275	560	1280	2359
2.4.5.1	Light Collector Production	$3,134,179	1960	0	32575	1775	0	150	680
2.4.5.2	Photo Sensors Production	$3,978,480	3030	0	7320	14500	200	440	1280
2.4.5.3	Electronics, Cabling and Monitoring Production	$1,275,203	1700	240	6843	0	360	690	399
2.4.6	Integration and Installation	$50,000	850	800	18625	675	0	6575	3140

* *not included in sums*

SP-Master_Oct2019.xlsx

Snapshot – 10/01/19

WBS	WBS Element Name	M&S	Engineer	Designer	Tech	Student	GS	Post-Doc	Scientist
2	**DUNE SP Far Detector**	**$105,000,670**	**170,631**	**4,474**	**442,180**	**120,838**	**268,130**	**252,677**	**151,290**
# of modules	**2**								
2.2	**SP APA System (SP-APA)**	**$29,417,102**	**69,571**	**0**	**205,918**	**0**	**129,040**	**3,772**	**1,840**
2.2.4	Production Setup	$4,219,422	7,042	-	1,992	-	4,240	-	-
2.2.5	Production	$25,197,680	61,908	-	203,044	-	112,640	-	-
2.2.6	Integration and Installation	$0	621	-	882	-	12,160	3,772	1,840
2.3	**SP TPC Electronics System (SP-CE)**	**$26,283,696**	**17,915**	**1,020**	**34,032**	**44,992**	**24,064**	**49,339**	**19,040**
2.3.4	Production Setup	$2,001,371	6095	1020	1374	2284	620	2981	2540
2.3.5	Production	$24,237,801	3320	0	8658	42708	900	11758	0
2.3.6	Integration and Installation	$44,524	8500	0	24000	0	22544	34600	16500
2.4	**SP Photon Detection System (SP-PD)**	**$17,373,840**	**15,720**	**2,080**	**131,525**	**34,780**	**1,120**	**15,710**	**11,158**
2.4.4	Production Setup	$498,117	640	-	800	880	-	-	160
2.4.5	Production	$16,775,723	13,380	480	93,475	32,550	1,120	2,560	4,718
2.4.6	Integration and Installation	$100,000	1,700	1,600	37,250	1,350	-	13,150	6,280
2.8	**SP HV System (SP-HV)**	**$10,643,310**	**2,842**	**1,374**	**31,849**	**41,066**	**13,427**	**12,528**	**14,193**
2.8.4	Production Setup	$163,000	432	250	2463	457	180	200	808
2.8.5	Production	$10,468,310	2410	660	29386	28305	13247	11800	7753
2.8.6	Integration and Installation	$12,000	0	464	0	12304	0	528	5632
2.9	**SP DAQ System (SP-DAQ)**	**$14,772,000**	**38,984**	**0**	**25,427**	**0**	**45,760**	**97,856**	**51,040**
2.9.4	Production Setup	$0	-	-	-	-	-	-	-
2.9.5	Production	$14,552,696	28864	0	25427	0	45760	97856	15840
2.9.6	Integration and Installation	$220,000	10120	0	0	0	0	0	35200
2.10	**SP Cryo Inst and Slow Control (SP-CISC)**	**$2,307,068**	**1731**	**0**	**6356**	**0**	**22896**	**23968**	**19013**
2.11.4	Production Setup	$6,706	661	0	1321	0	2917	7868	6542
2.11.5	Production	$2,126,482	589	0	3042	0	10608	4490	6460
2.11.6	Integration and Installation	$173,880	480	0	1993	0	9370	11610	6011
2.11	**SP Calibration Systems (SP-Cal)**	**$4,203,654**	23868	0	7072	0	31824	49504	35006.4
2.11.4	Production Setup								
2.11.5	Production	$4,203,654	23,868	-	7,072	-	31,824	49,504	35,006
2.11.6	Integration and Installation								

CORE Cost

Snapshot – 10/01/19

WBS	WBS Element Name	M&S	Engineer	Designer	Tech	Student	GS	Post-Doc	Scientist
2	DUNE SP Far Detector	$105,000,670	170,631	4,474	442,180	120,838	268,130	252,677	151,290
# of modules	2								
2.2	SP APA System (SP-APA)	$29,417,102	69,571	0	205,918	0	129,040	3,772	1,840
2.2.4	Production Setup	$4,219,422	7,042	-	1,992	-	4,240	-	-
2.2.5	Production	$25,197,680	61,908	-	203,044	-	112,640	-	-
2.2.6	Integration and Installation	$0	621	-	882	-	12,160	3,772	1,840
2.3	SP TPC Electronics System (SP-CE)	$26,283,696	17,915	1,020	34,032	44,992	24,064	49,339	19,040
2.3.4	Production Setup	$2,001,371	6095	1020	1374	2284	620	2981	2540
2.3.5	Production	$24,237,801	3320	0	8658	42708	900	11758	0
2.3.6	Integration and Installation	$44,524	8500	0	24000	0	22544	34600	16500
2.4	SP Photon Detection System (SP-PD)	$17,373,840	15,720	2,080	131,525	34,780	1,120	15,710	11,158
2.4.4	Production Setup	$498,117	640	-	800	880	-	-	160
2.4.5	Production	$16,775,723	13,380	480	93,475	32,550	1,120	2,560	4,718
2.4.6	Integration and Installation	$100,000	1,700	1,600	37,250	1,350	-	13,150	6,280
2.8	SP HV System (SP-HV)	$10,643,310	2,842	1,374	31,849	41,066	13,427	12,528	14,193
2.8.4	Production Setup	$163,000	432	250	2463	457	180	200	808
2.8.5	Production	$10,468,310	2410	660	29386	28305	13247	11800	7753
2.8.6	Integration and Installation	$12,000	0	464	0	12304	0	528	5632
2.9	SP DAQ System (SP-DAQ)	$14,772,000	38,984	0	25,427	0	45,760	97,856	51,040
2.9.4	Production Setup	$0	-	-	-	-	-	-	-
2.9.5	Production	$14,552,696	28864	0	25427	0	45760	97856	15840
2.9.6	Integration and Installation	$220,000	10120	0	0	0	0	0	35200
2.10	SP Cryo Inst and Slow Control (SP-CISC)	$2,307,068	1731	0	6356	0	22896	23968	19013
2.11.4	Production Setup	$6,706	661	0	1321	0	2917	7868	6542
2.11.5	Production	$2,126,482	589	0	3042	0	10608	4490	6460
2.11.6	Integration and Installation	$173,880	480	0	1993	0	9370	11610	6011
2.11	SP Calibration Systems (SP-Cal)	$4,203,654	23868	0	7072	0	31824	49504	35006.4
2.11.4	Production Setup								
2.11.5	Production	$4,203,654	23,868	-	7,072	-	31,824	49,504	35,006
2.11.6	Integration and Installation								

Responsibility Matrix

Snapshot – 10/01/19

Preliminary and Confidential – for example only

We can discuss the one with real numbers when we have the presentation

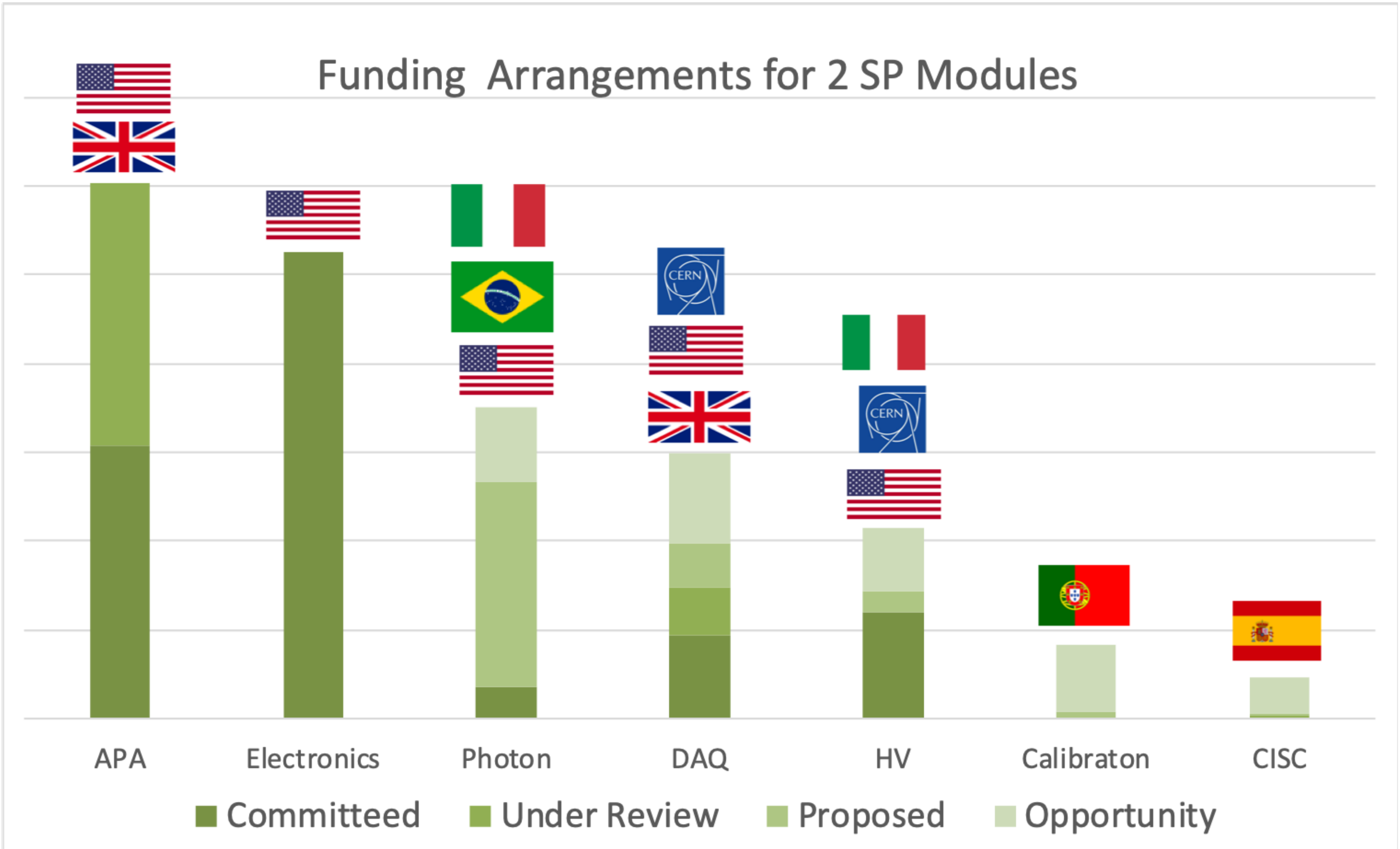
2 Single Phase Modules Responsibility Matrix	Total	US DOE	US NSF	UK	Brazil	Italy	CERN	Canada	Spain	Portugal	Opportunity
SP TPC Electronics System (SP-CE)	100%	100%									
SP APA System (SP-APA)	100%		50%	50%							
SP Photon Detection System (SP-PD)	100%	10%									24%
SP HV System (SP-HV)	100%	40%									45%
SP DAQ System (SP-DAQ)	100%		18%	32%							34%
SP Cryo Inst and Slow Control (SP-CISC)	100%	10%									82%
SP Calibration Systems (SP-CAL)	100%	10%									80%

Money Matrix	Total - CORE	US DOE	US NSF	UK	Brazil	Italy	CERN	Canada	Spain	Portugal	Opportunity
SP TPC Electronics System (SP-CE)	$ 26.28	$ 26.28	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
SP APA System (SP-APA)	$ 29.42	$ -	$ 14.71	$ 14.71	$ -	$ -	$ -	$ -	$ -	$ -	$ -
SP Photon Detection System (SP-PD)	$ 17.37	$ 1.65	$ -	$ -			$ -	$ -		$ -	$ 4.08
SP HV System (SP-HV)	$ 10.64	$ 4.20	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ 4.74
SP DAQ System (SP-DAQ)	$ 14.77	$ -	$ 2.59	$ 4.67	$ -	$ -			$ -	$ -	$ 4.98
SP Cryo Inst and Slow Control (SP-CISC)	$ 2.31	$ 0.23	$ -	$ -	$ -	$ -	$ -	$ -		$ -	$ 1.90
SP Calibration Systems (SP-CAL)	$ 4.20	$ 0.42	$ -	$ -	$ -	$ -	$ -	$ -	$ -		$ 3.36
Total contibution to M&S	$ 105.00	$ 32.79	$ 17.29	$ 19.38							$ 19.06
% of Total M&S		31%	16%	18%							18%

Common Fund for CORE Contribution	20%	$ 6.6	$ 3.5	$ 3.9							$ 3.8
From DOE	$ 10.0	covers DOE and NSF contribution									
From International Partners	$ 11.0	includes contribution from "Opportunity"									

	Color code	Detectors
Agreements in place or funding secured		43%
Proposals under review		22%
Proposals in preparation		0%
Aspirational/beginning discussions		1%
Opportunity or Scope Reduction		34%
Total CORE M&S		100%

Funding


Funding Arrangements for 2 SP Modules
CERN
CERN
APA
Electronics
Photon
DAQ
HV
Calibraton
CISC
Committeed
Under Review
Proposed
Opportunity

Next Steps

- Near Term (6 months)
  - Validate Cost Books and update summary tables as necessary
  - DOE IPR : October 30 – Nov 1, 2019
  - DOE DUNE Operations Review : January 6-7, 2020
    - **Costs for Technical Coordination and I&I**
  - Formalize responsibility for deliverables via Consortia Annexes for **Multi-institutional MOU** which is in draft status
  - Present **Common Fund Plan** at April RRB Meeting
  - Update Single Phase Cost Books in advance of DOE CD2/3 review in Spring 2020
- Longer Term
  - Form consortia and develop cost estimates and funding model for Near Detector systems
  - Develop bottoms up cost estimate and funding model for a Dual Phase module