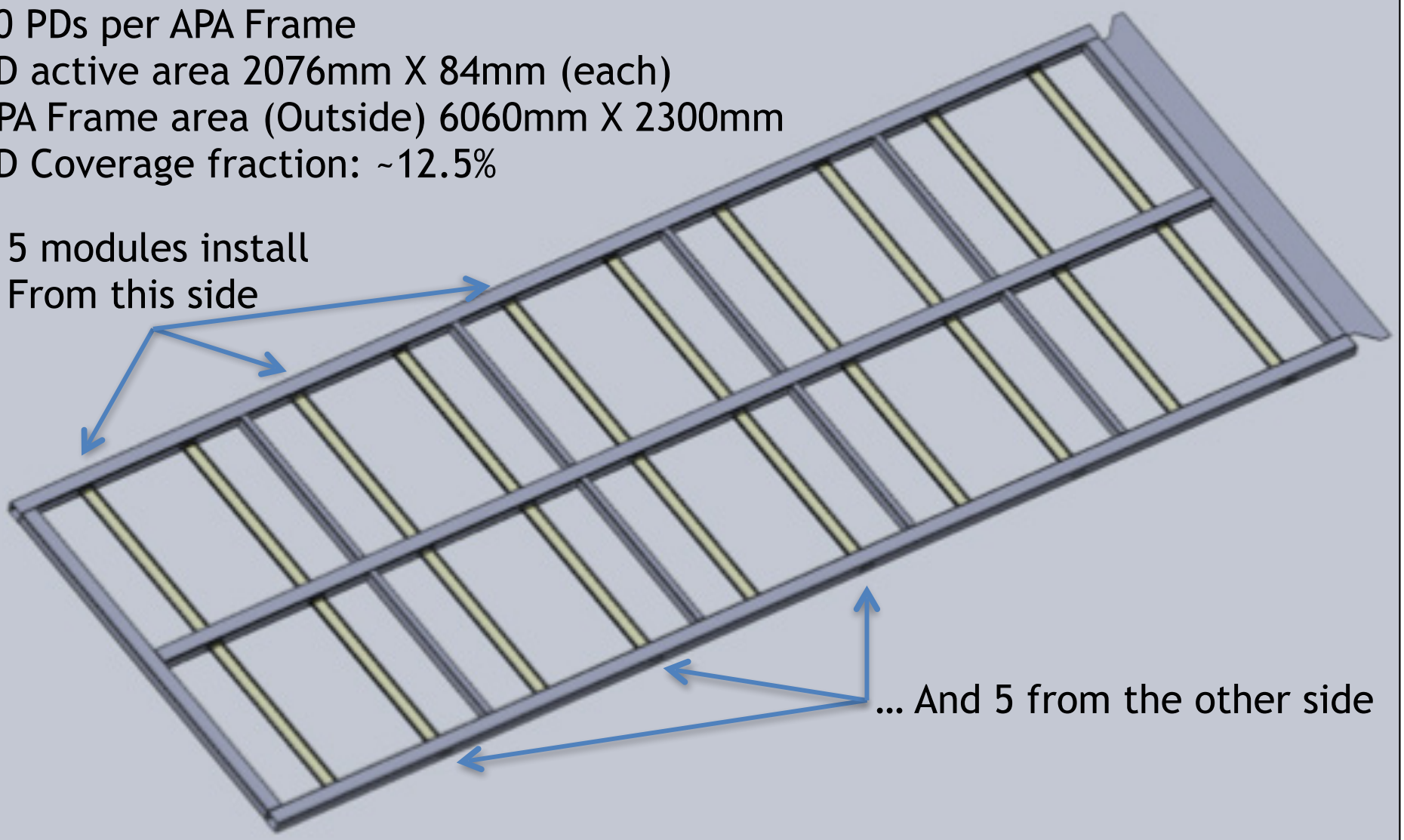
Proto-DUNE Single-Phase PD Design, Assembly and APA Interface

ARAPUCA: a new concept

Flavio Cavanna
LBNC Mtg - CERN
June 22-24, 2017

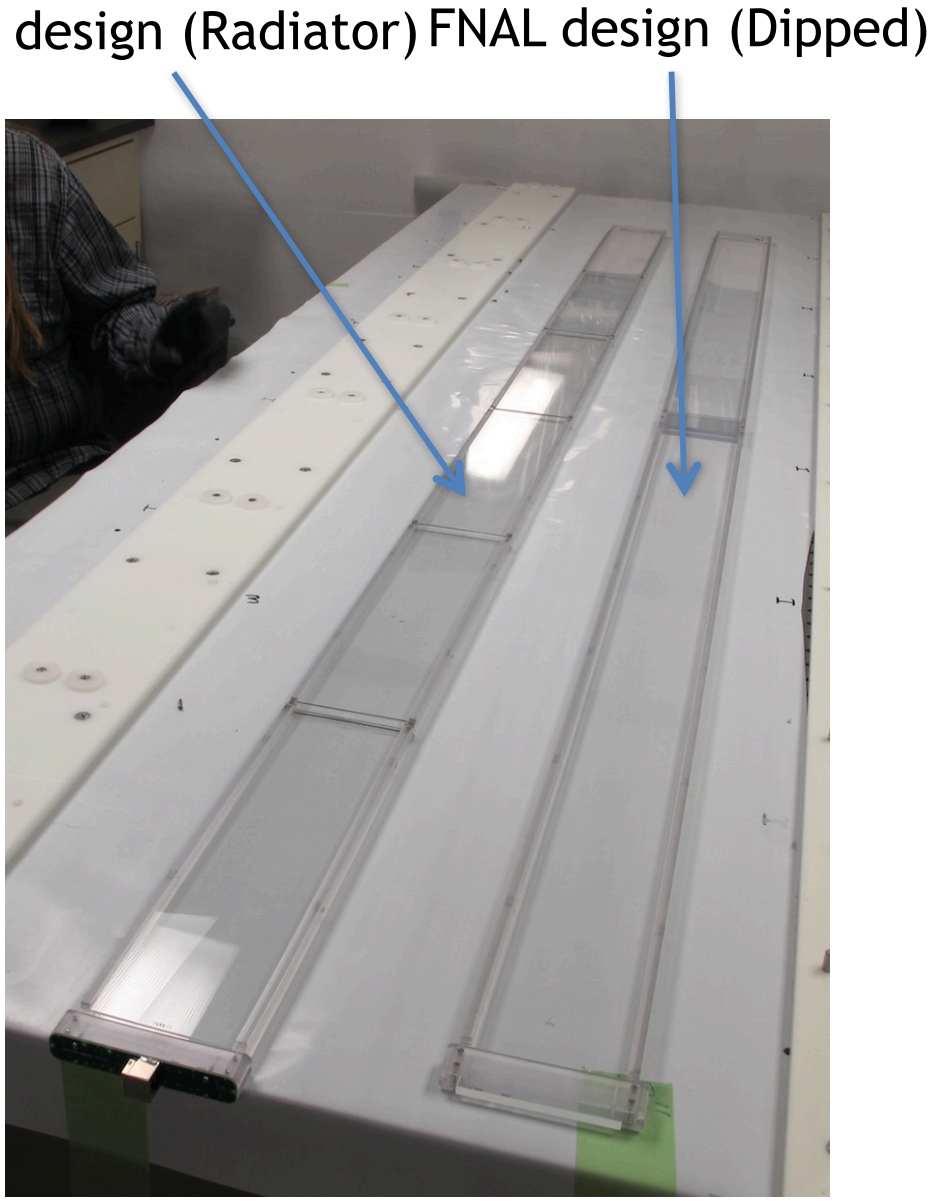
PDs Mounted in APA Frame

10 PDs per APA Frame
PD active area 2076mm X 84mm (each)
APA Frame area (Outside) 6060mm X 2300mm
PD Coverage fraction: ~12.5%



Modular PD Concept

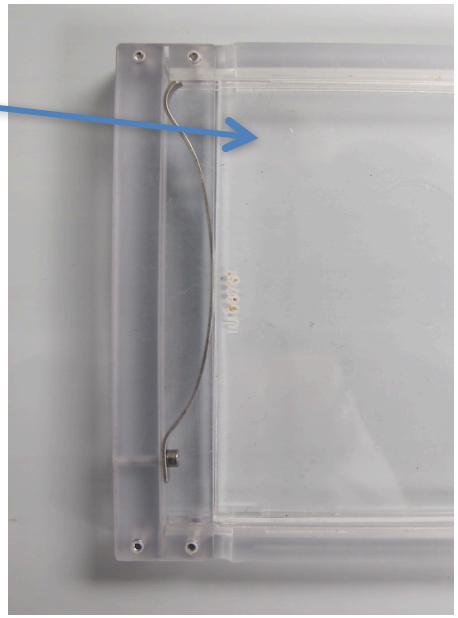
- The reference PD design for both ProtoDUNE and the single phase FD call for 10 individual PD modules per APA frame, installed following APA assembly
- Module dimensions:
  - 2127.2mm long X 107mm wide X 18 mm thick (outside)
  - 2090.5mm long X 96.1mm wide X 14.6mm thick (Inside APA)
  - PD Dimensions driven by available installation slot in the APA (108mm long X 19mm tall)
- Modules masses:
  - IU design: 2.18 kg
  - FNAL design: 1.72 kg
- Modular design and post-APA assembly installation allows for testing of different PD design concepts
- Two principle designs: IU design with radiator plates, FNAL design with TPB-dipped light guide bar



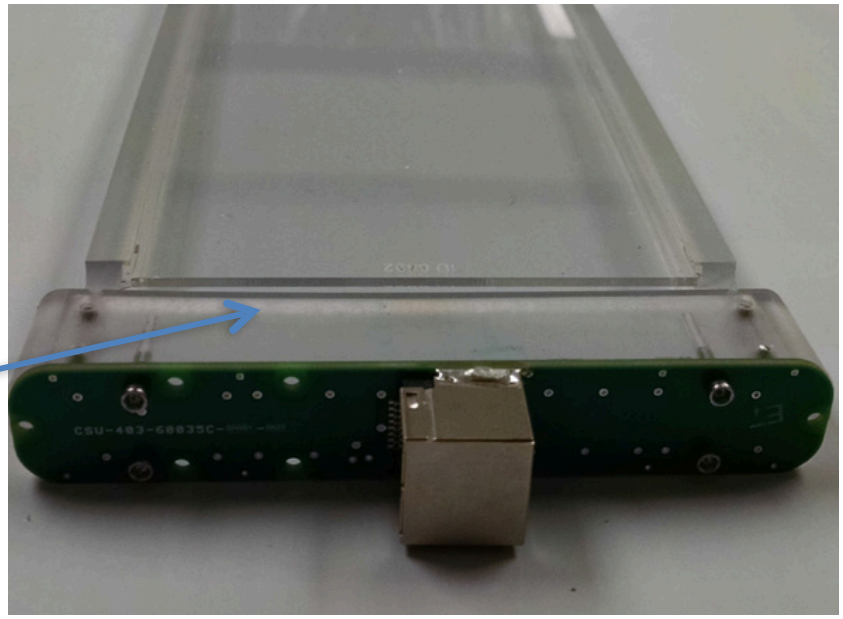
Design Summary

- Current plans call for 2 principle designs to be tested in Proto-DUNE, with a limited number (2) of promising alternate designs (e.g. ARAPUCA):
  - Radiator plate (IU) Design consists of 12 TPB-coated plastic radiator plates (to convert the 128nm scintillation light to blue light) mounted over a secondary light guide (Y-11-like bar, to convert the blue light to green and transport it to the SiPMs) (29 in ProtoDUNE)
  - FNA) design calls for a single TPB-dip-coated wavelength shifter/light guide bar to shift the scintillation light and transport it to the SiPMs (29 in ProtoDUNE)
  - N.B.: The modularity of the PD design, as well as the fact that they are installed into the APA frame immediately before the APA is installed into the cryostat at CERN, allows for other proposed designs (such as ARAPUCA)
- Modules of both designs are supported inside the APA frames in stainless steel rails, and are inserted into the APA frames after the frames are wire-wrapped. Both PD modules fit within the same APA support structure
- Both designs are read out with 12 sensL 60035 C-series SiPMs. The same readout board is used for both designs
- SiPMs are grouped into sets of 3, and signals are carried through shielded twisted pair.
  - Cables are custom PTFE-jacketed Cat 6 cables, with 4 twisted pairs per cable (1 cable per PD module)
  - Cable connectors are standard RJ-45 Cat-6 connectors
  - Two cable segments per readout path:
    - Cryogenic (13.5m long depending on the PD position in the APA) from the SIPM PCB to the cryostat flange
    - External cables (~3m long), from the cryostat flange to the readout electronics (SSPs)
    - Identical cable length for all modules to minimize fabrication and analysis complications
- Custom readout electronics (SSPs) used to read out SiPM signals are mounted on top of the cryostat.

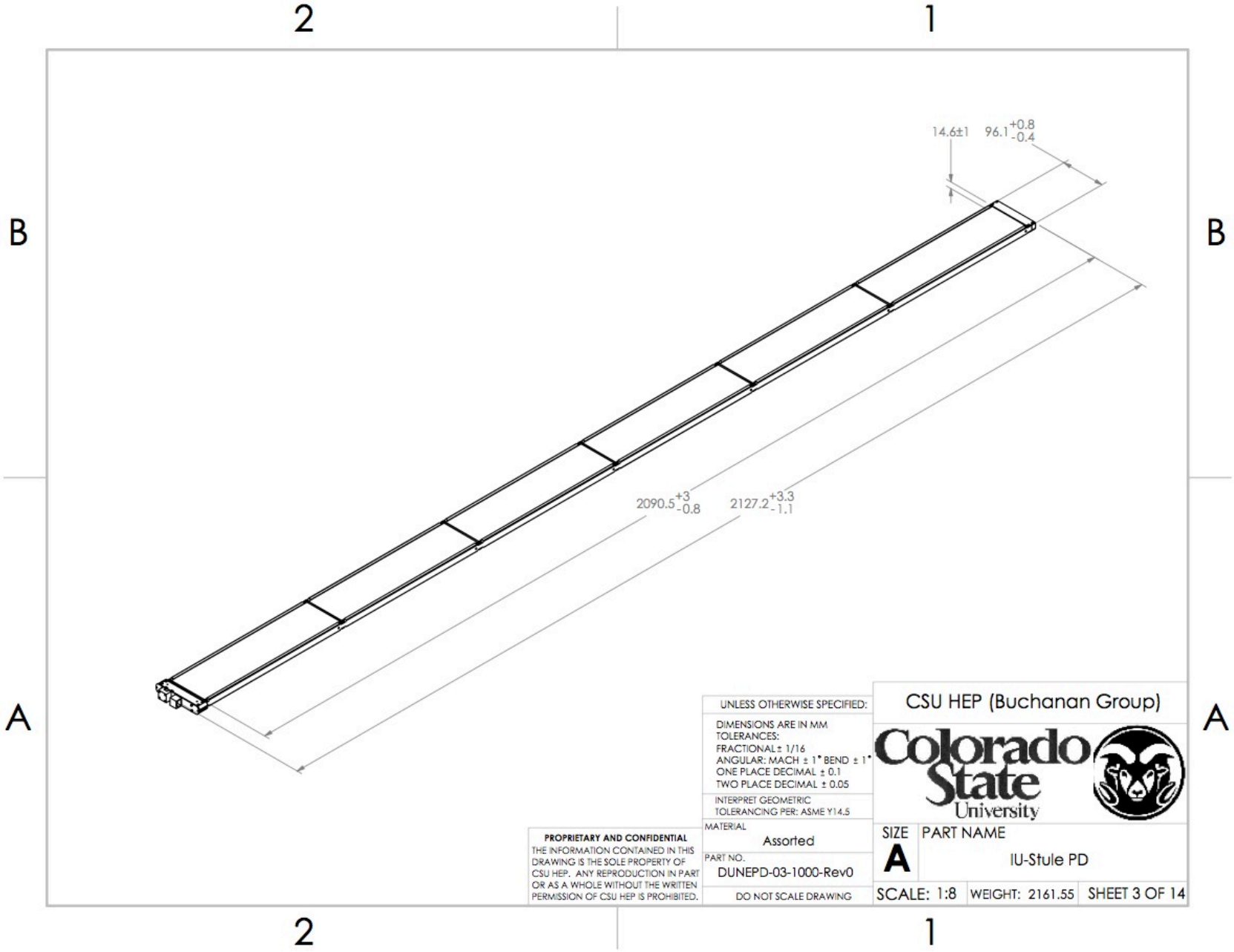
Indiana University PD Design



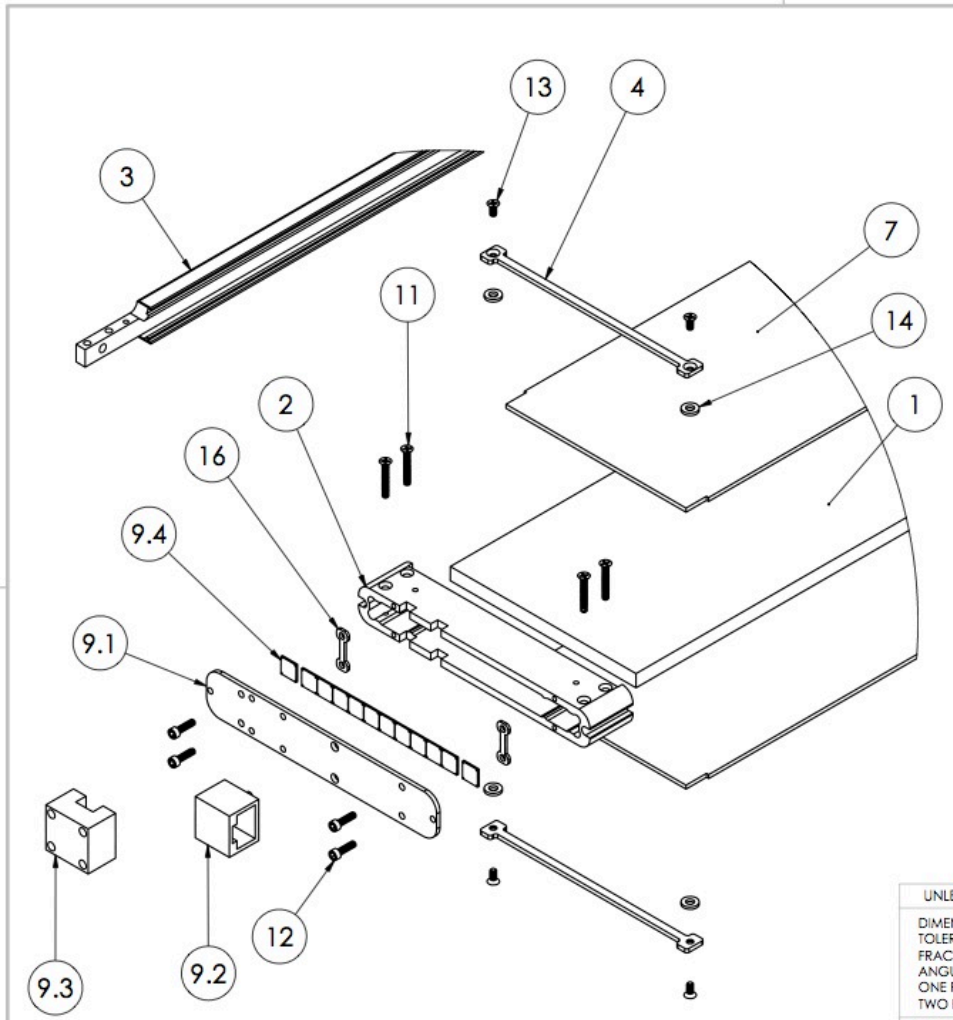
Thermal Compliance Spring



IU Maximum Module Dimensions



Readout End Detail



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	DUNEPD-03-1001-Rev0	WLS Bar	1
2	DUNEPD-03-1004-Rev0	Rail End (Near) PCB Mount Collar	1
3	DUNEPD-03-1005-Rev0	IU Side Support Rail	2
4	DUNEPD-03-1006-Rev0	Radiator End Support Cross Piece	12
7	DUNEPD-03-1002-Rev0	Radiator Plate	12
9	DUNEPD-03-3000-R1	SiPM/Mounting Board Assembly	1
9.1	DUNEPD-03-3002-Rev0	SiPM Mounting PCB	1
9.2	DUNEPD-03-3003	RJ-45 Connector	1
9.3	DUNEPD-03-3004-Rev0	Wire Management Block	1
9.4	DUNEPD-03-3001	sensL SiPM	12
11	DUNEPD-03-1010	Rail End Mount Screw	8
12	DUNEPD-03-1012	SiPM Mounting Board Screw	4
13	DUNEPD-03-1011	Radiator End Support Cross Piece Screw	24
14	DUNEPD-03-1014-Rev0	Final Radiator End Support Spacer	4
16	DUNEPD-03-1003-Rev0	PCB Spacer	2

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MM
TOLERANCES:
FRACTIONAL ± 1/16
ANGULAR: MACH ± 1° BEND ± 1°
ONE PLACE DECIMAL ± 0.1
TWO PLACE DECIMAL ± 0.05
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5

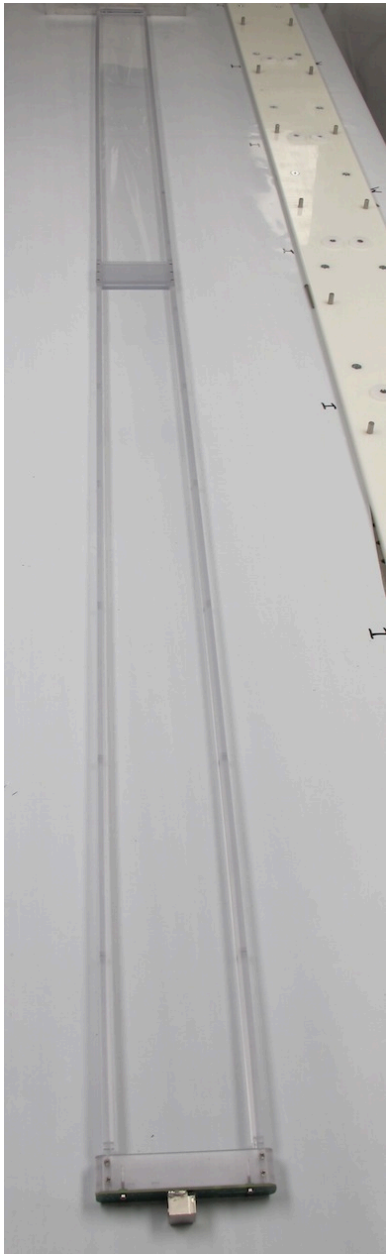
MATERIAL: Assorted
PART NO.: DUNEPD-03-1000-Rev0
DO NOT SCALE DRAWING

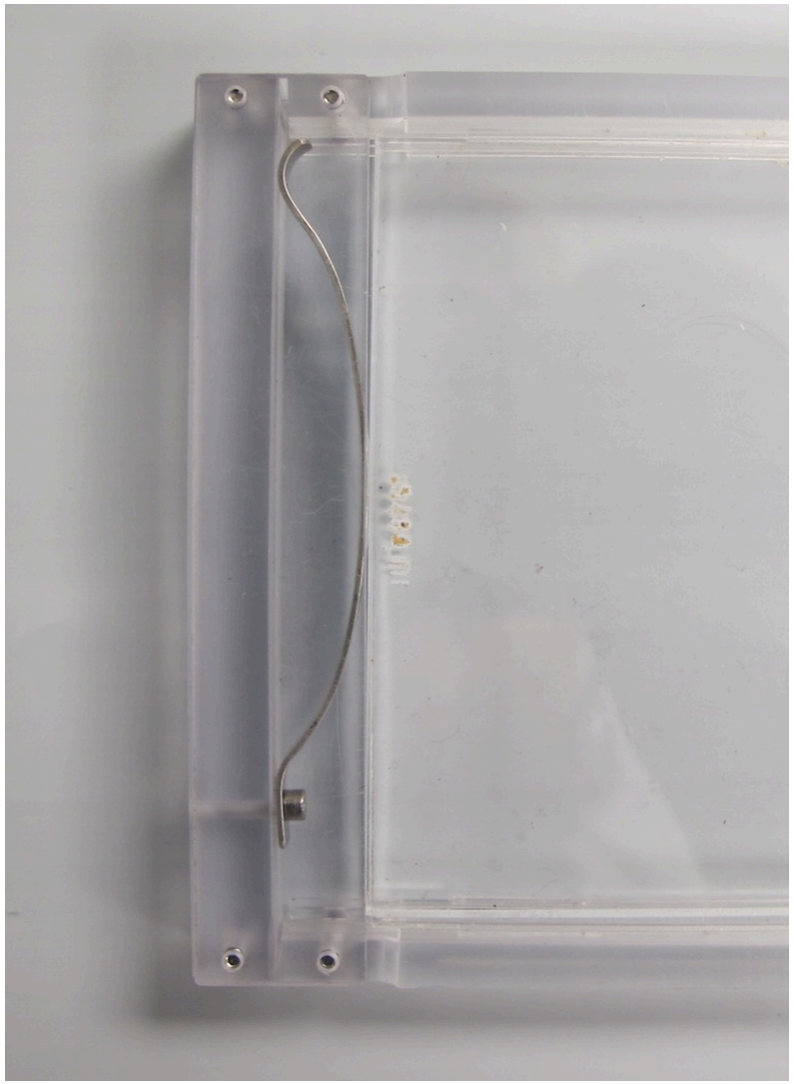
CSU HEP (Buchanan Group)

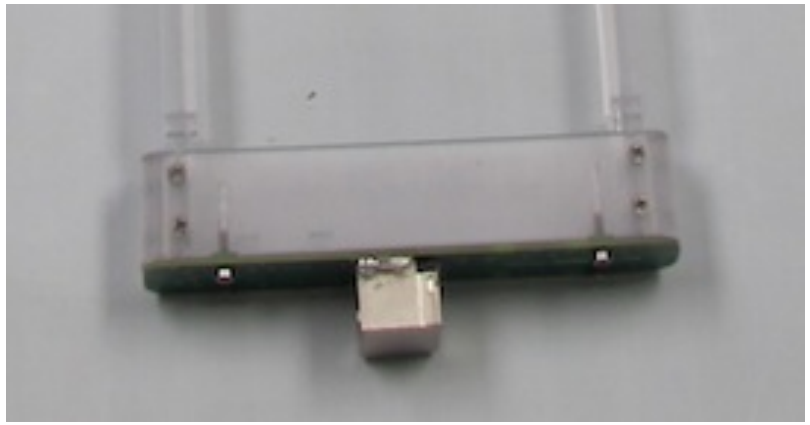
SIZE: A
PART NAME: IU-Stule PD
SCALE: 1:2 | WEIGHT: 2161.55 | SHEET 2 OF 14

PROPRIETARY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF CSU HEP. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF CSU HEP IS PROHIBITED.

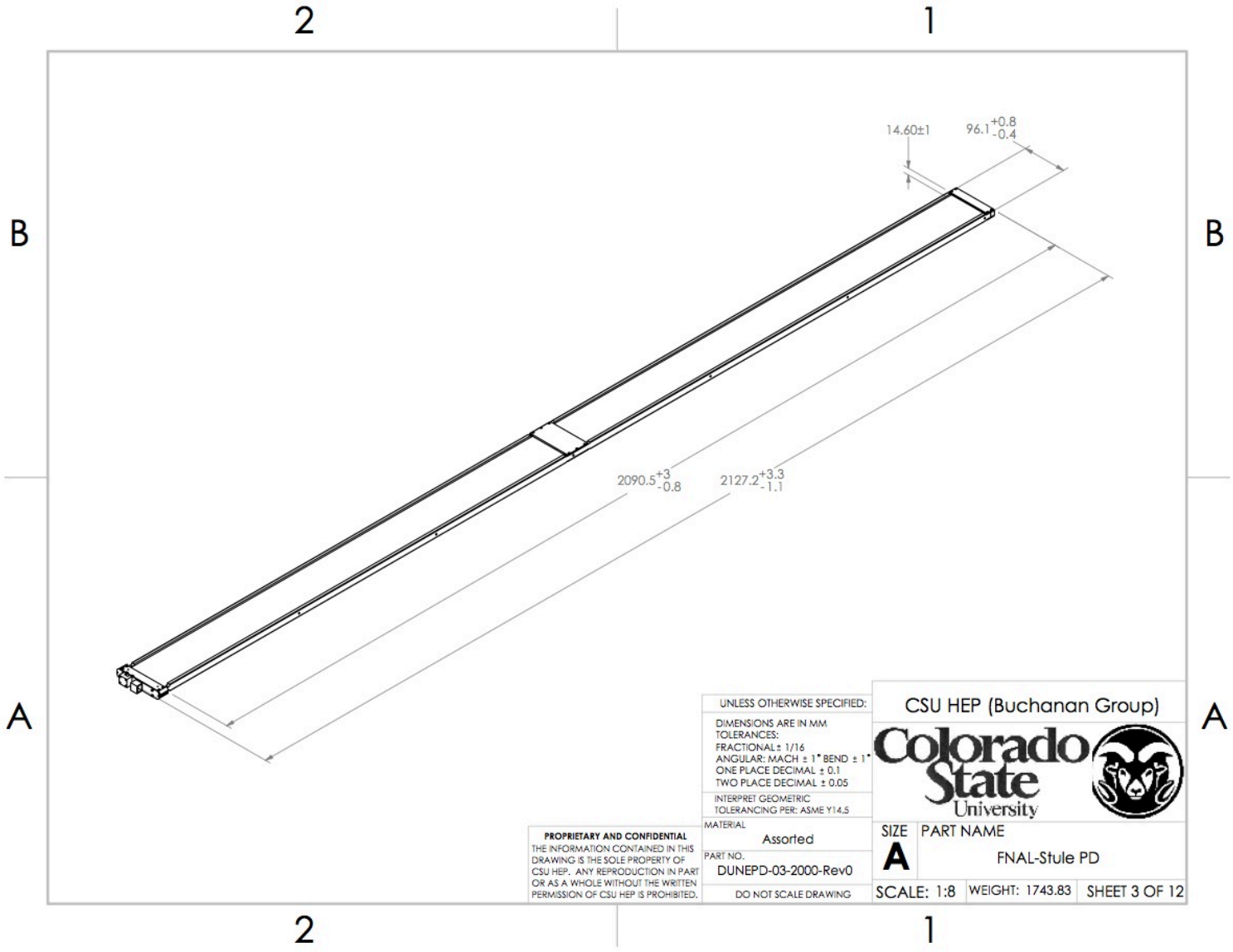
FNAL Design (Dipped Bar)



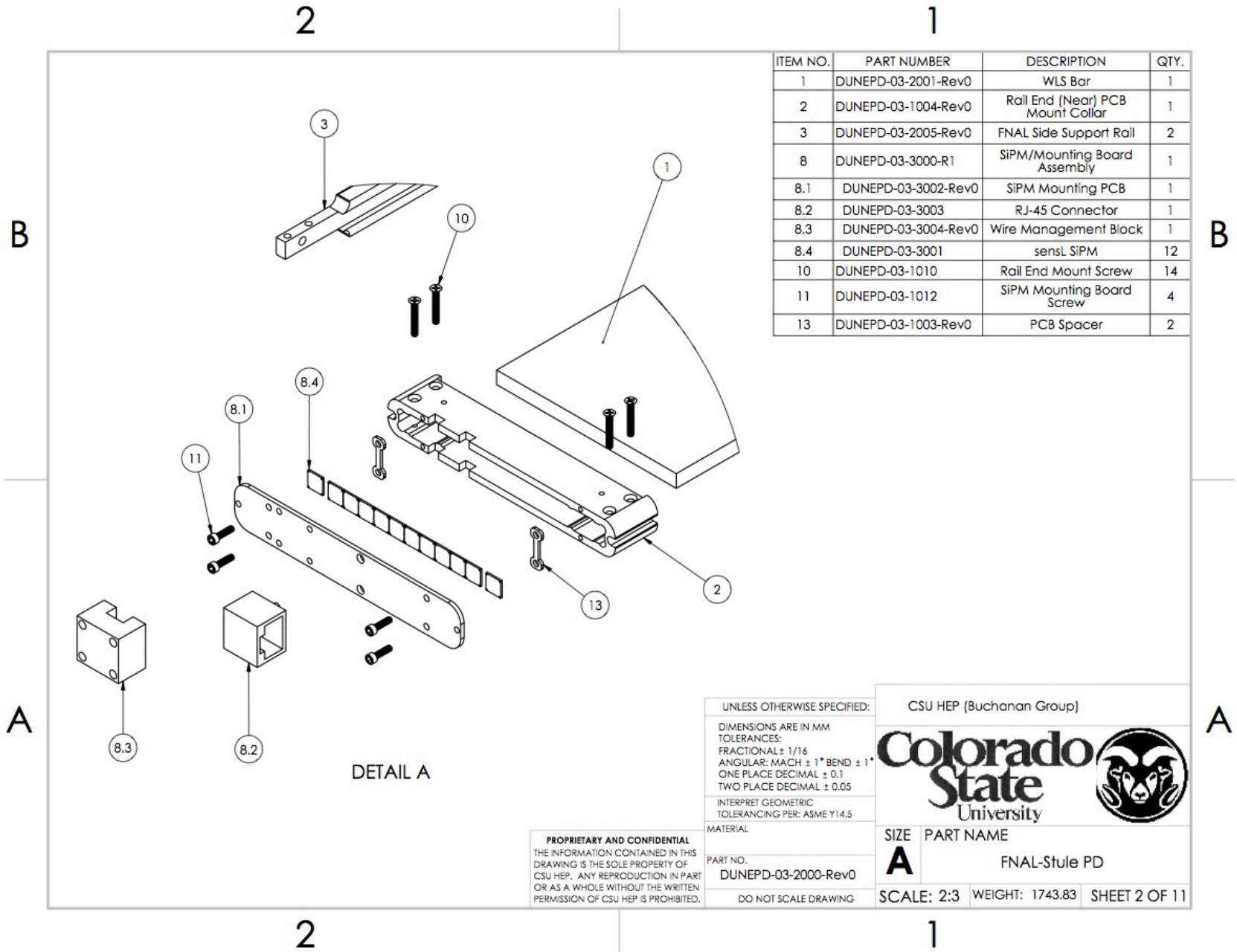




FNAL Maximum Module Dimensions



Readout End Assembly



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	DUNEPD-03-2001-Rev0	WLS Bar	1
2	DUNEPD-03-1004-Rev0	Rail End (Near) PCB Mount Collar	1
3	DUNEPD-03-2005-Rev0	FNAL Side Support Rail	2
8	DUNEPD-03-3000-R1	SiPM/Mounting Board Assembly	1
8.1	DUNEPD-03-3002-Rev0	SiPM Mounting PCB	1
8.2	DUNEPD-03-3003	RJ-45 Connector	1
8.3	DUNEPD-03-3004-Rev0	Wire Management Block	1
8.4	DUNEPD-03-3001	sensL SiPM	12
10	DUNEPD-03-1010	Rail End Mount Screw	14
11	DUNEPD-03-1012	SiPM Mounting Board Screw	4
13	DUNEPD-03-1003-Rev0	PCB Spacer	2

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MM
TOLERANCES:
FRACTIONAL ± 1/16
ANGULAR: MACH ± 1° BEND ± 1°
ONE PLACE DECIMAL ± 0.1
TWO PLACE DECIMAL ± 0.05
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5
MATERIAL
PART NO. DUNEPD-03-2000-Rev0
DO NOT SCALE DRAWING

PROPRIETARY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF CSU HEP. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF CSU HEP IS PROHIBITED.

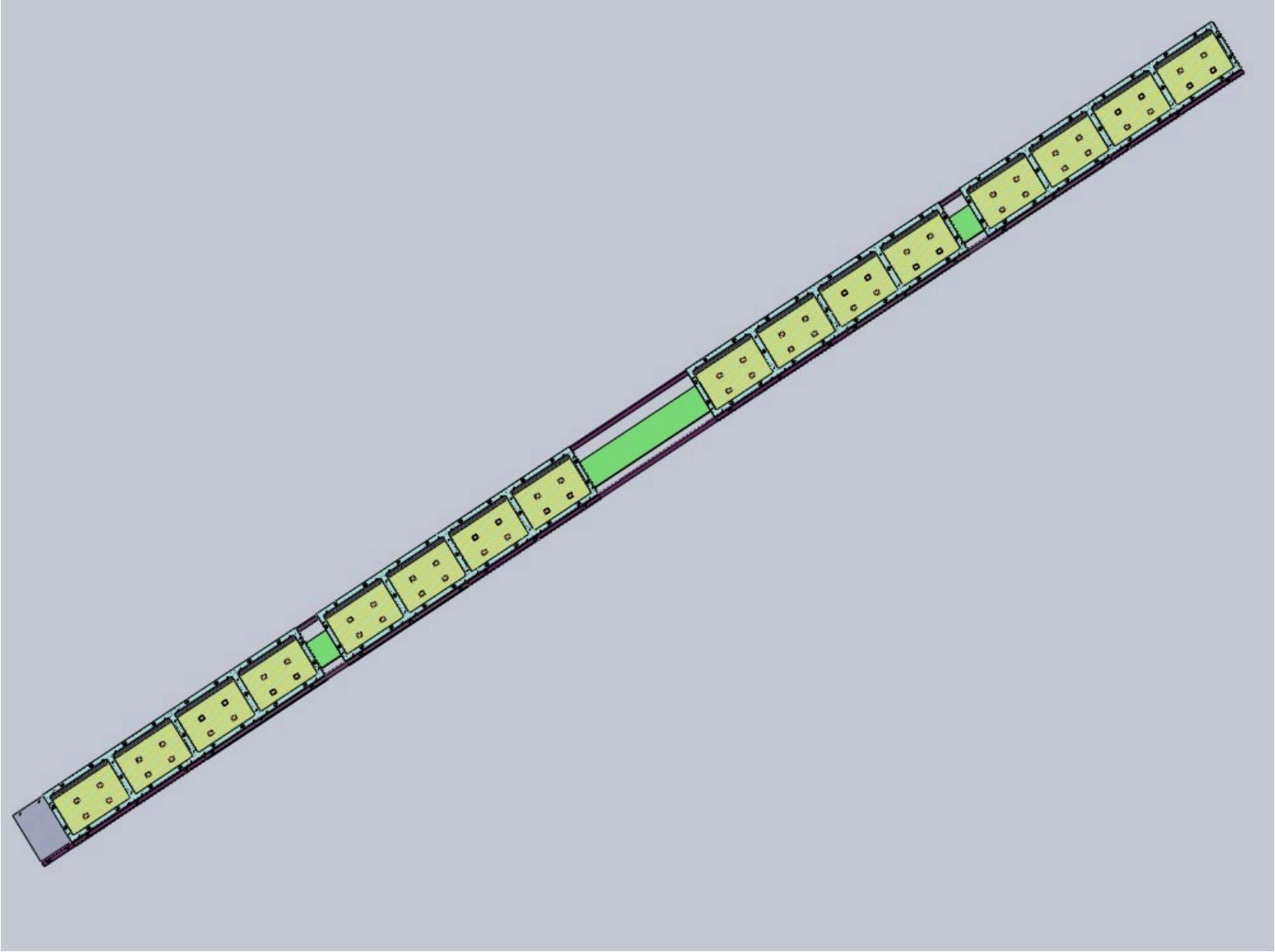
CSU HEP (Buchanan Group)

Colorado State University

SIZE	PART NAME
A	FNAL-Stule PD

SCALE: 2:3 | WEIGHT: 1743.83 | SHEET 2 OF 11

ARAPUCA PD Module Concept

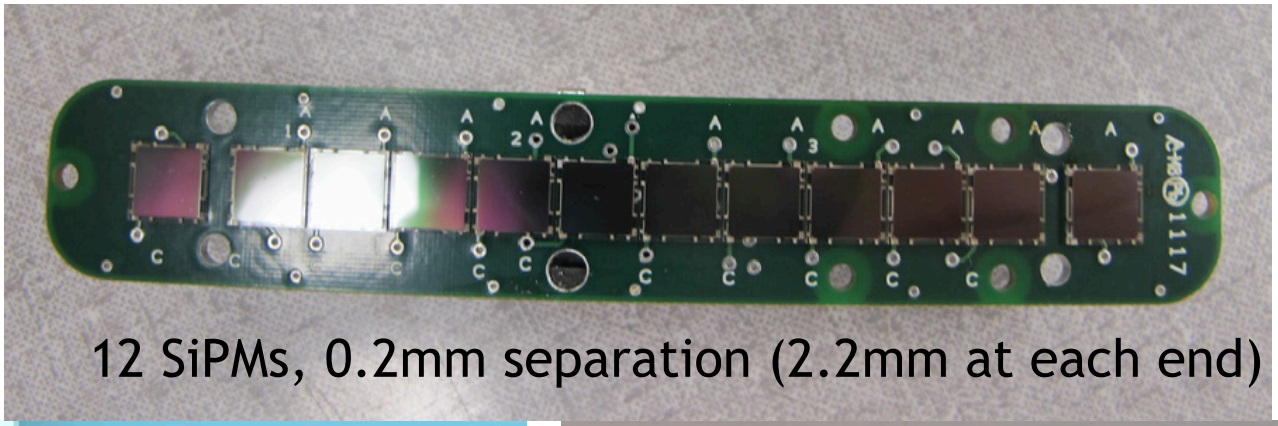


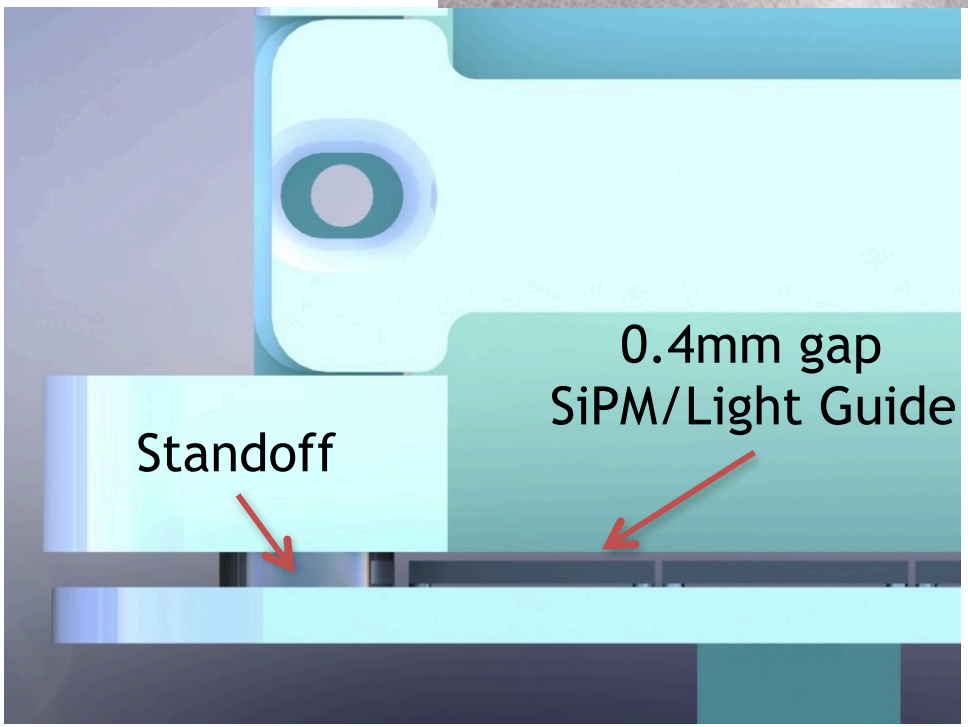
ARAPUCA Details

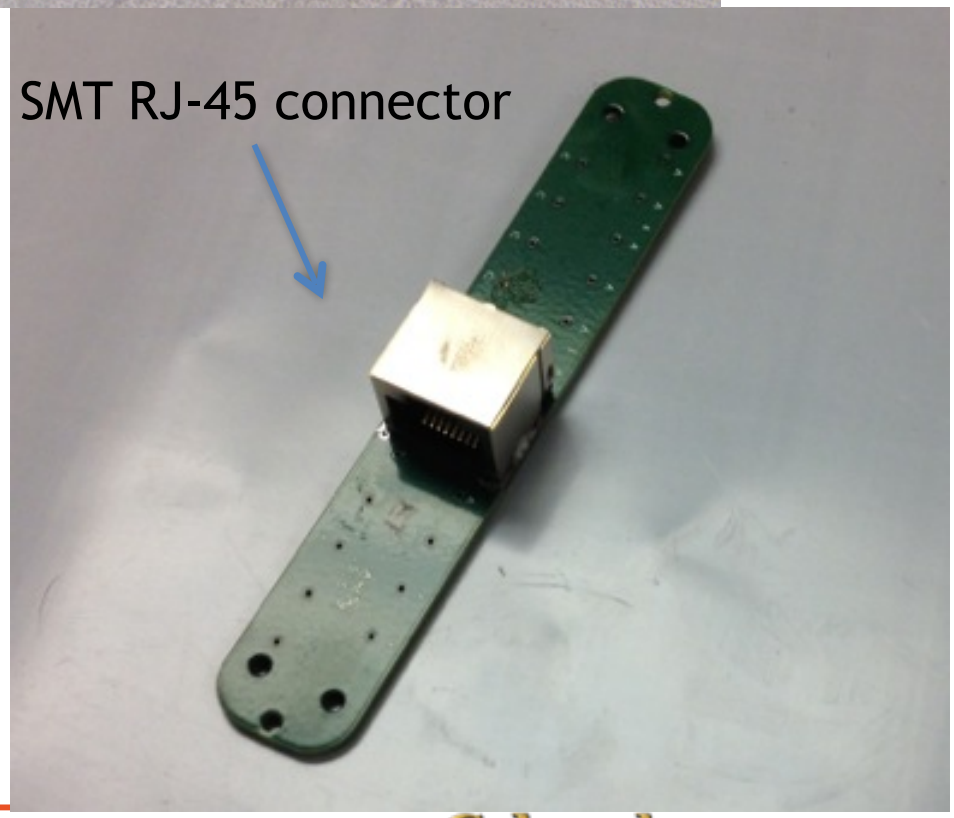
- Two of the modules in the final APA frame will be ARAPUCA modules
- **ARAPUCA modules, while very different in concept from the existing PD modules, have been designed to fit in the same slots in the APA as "Standard" PDs**
- The ARAUPCA will be tested head-to-head against IU-style PDs in TallBo in August
- Production Readiness Review in early September
- Fabrication in September-October
- Ready for shipping with final PD modules in December.
- NB: SiPM selection for ARAPUCA still under consideration.

SiPM Mount PCB ("Hover Board")

Active area
Provides ~80%
Bar end coverage

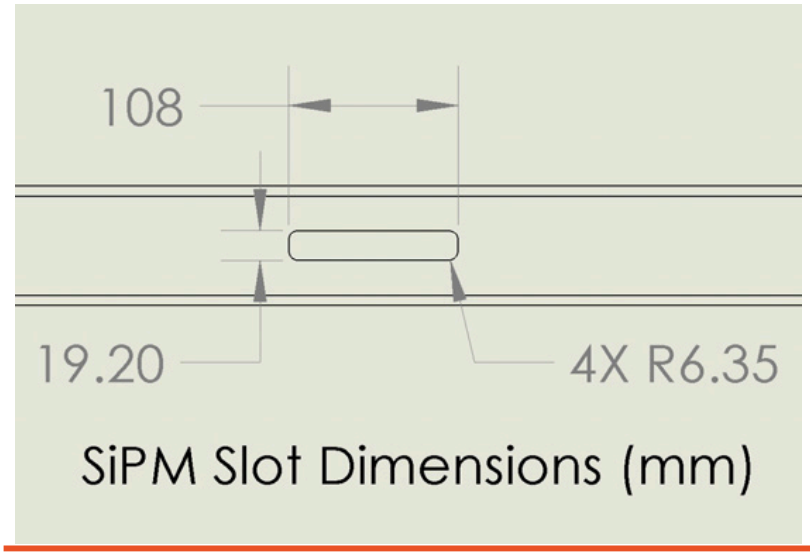






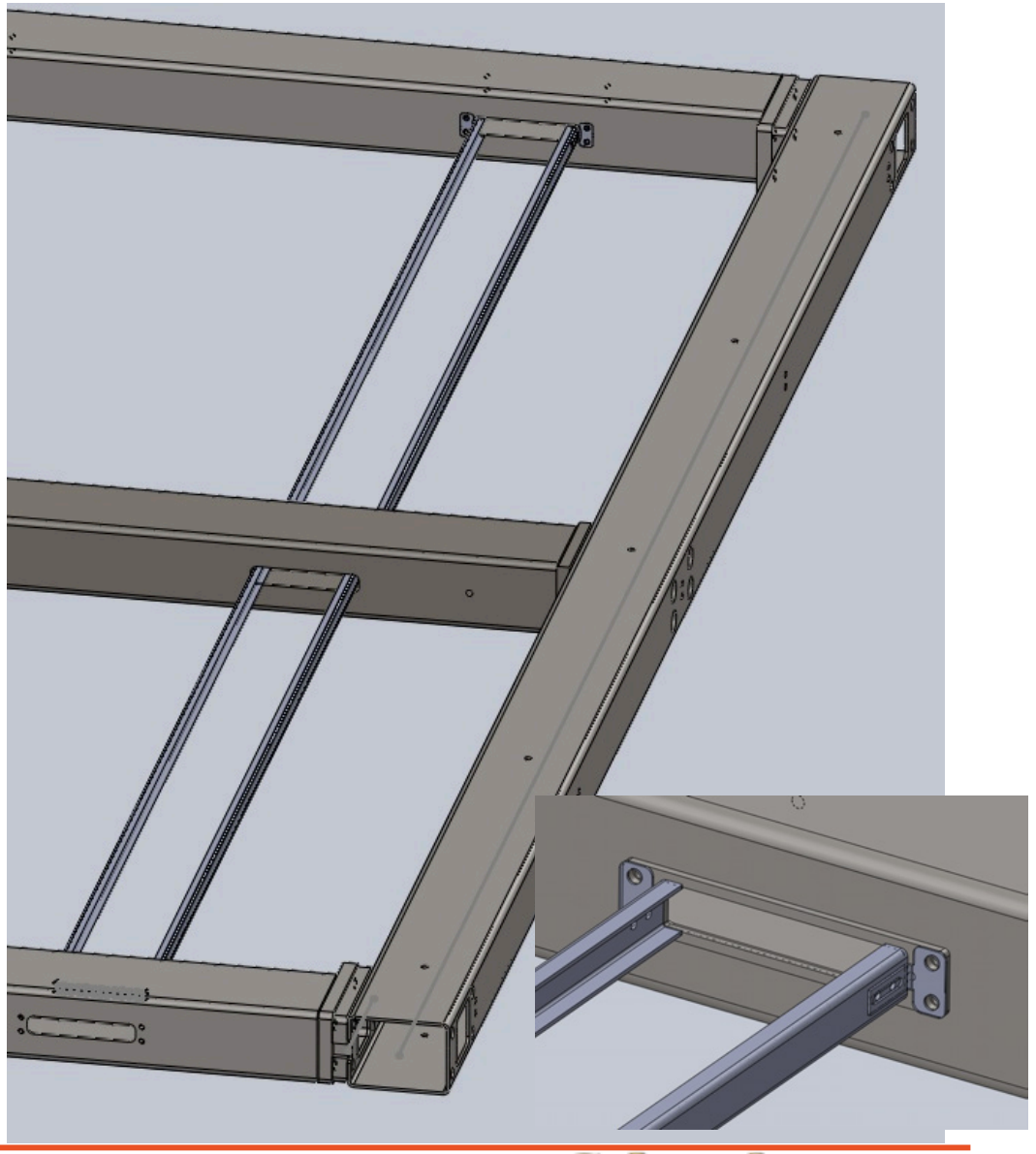
PD/APA Mounting Structure

Mounting Frame Inside Dimensions
98.1mm wide X 16.6mm tall



SiPM Slot Dimensions (mm)

Frame inside length 2096.8mm



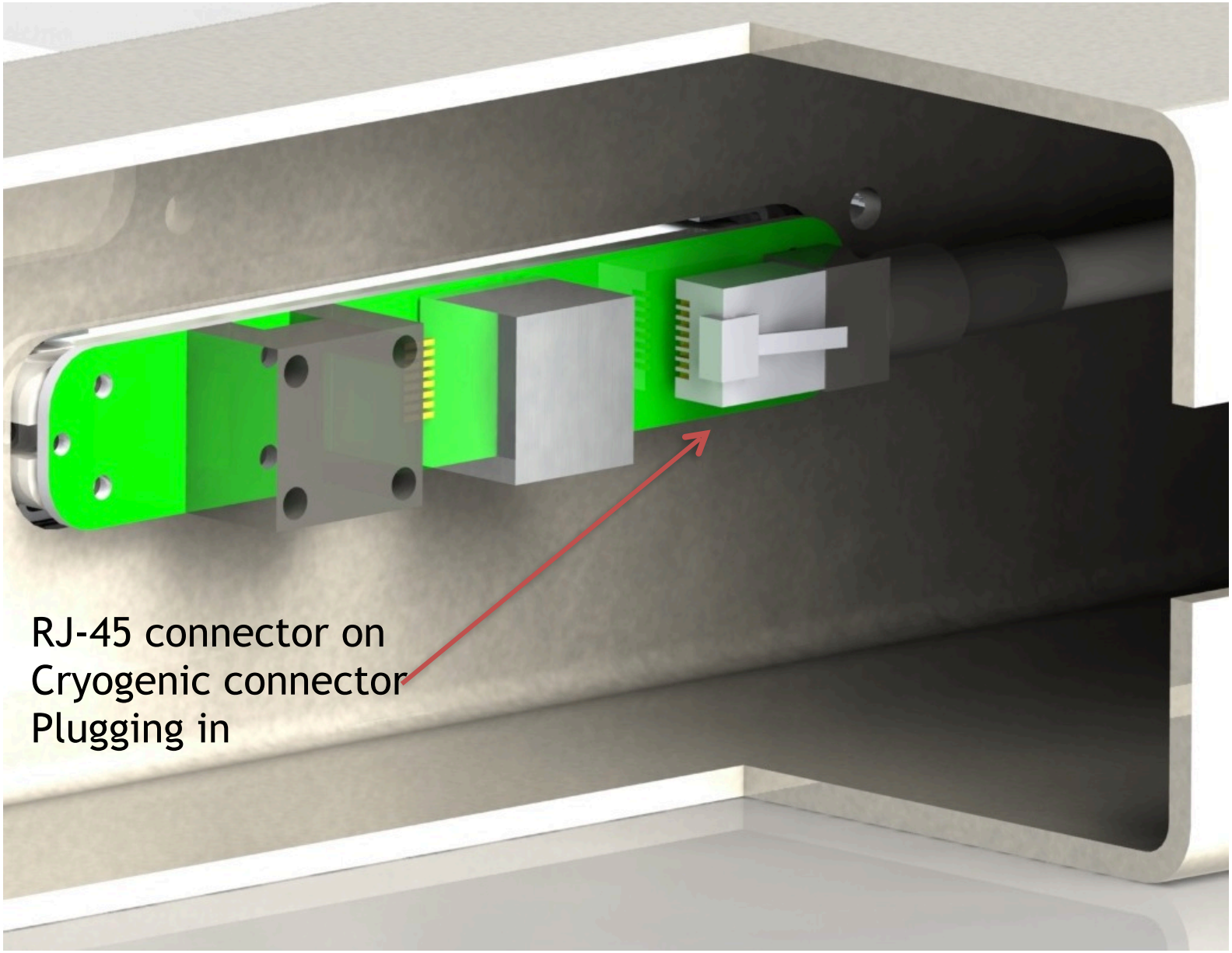
Test Installations at CSU, PSL

CSU test Installation

PSL test Installation (Full-Size APA)

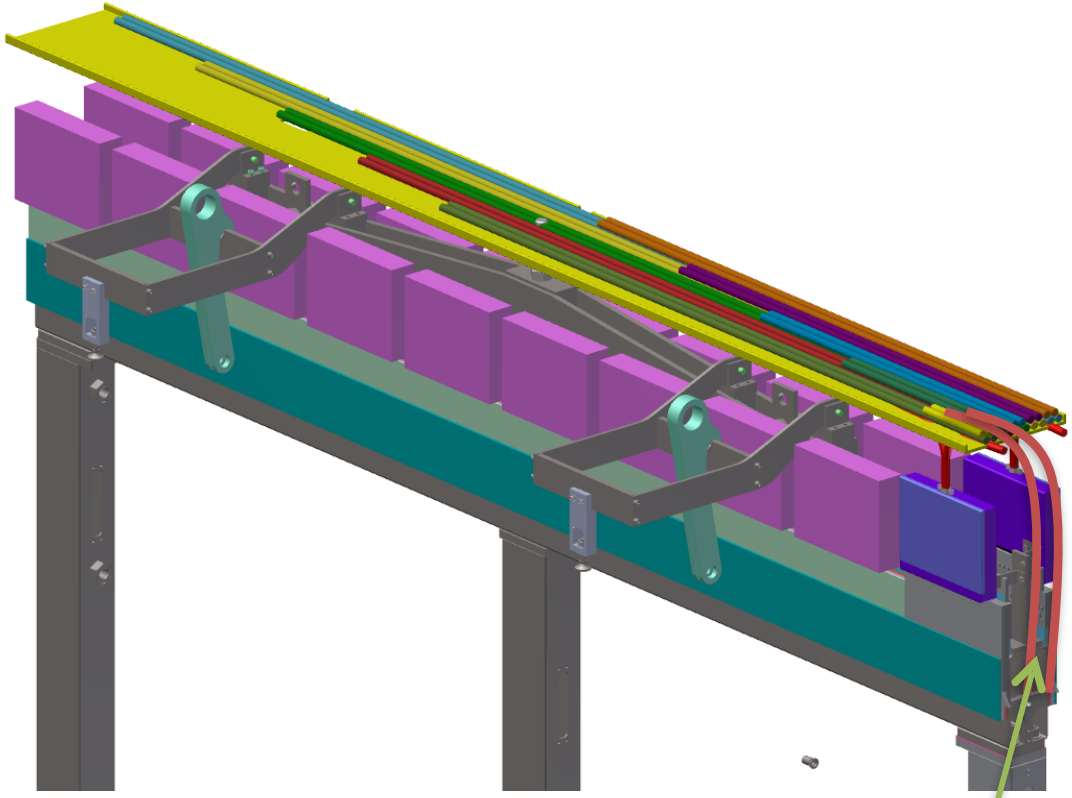
Installation Tooling

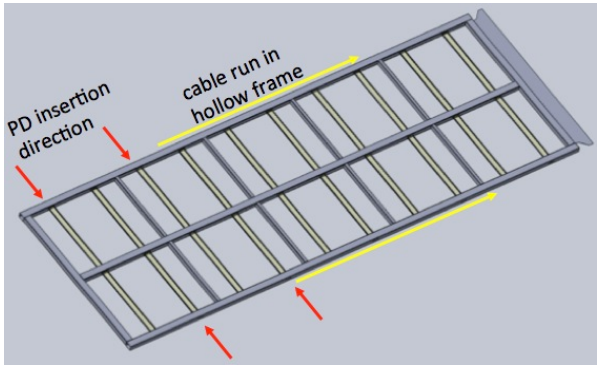
Cat 6 Connection to SiPM PCB



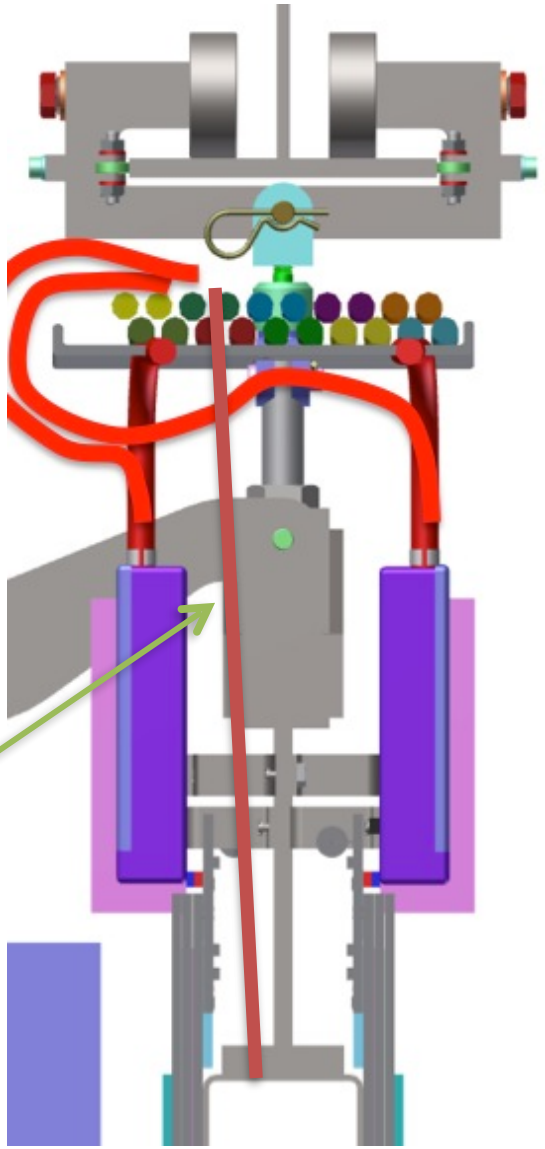
PD Cable Strain Relief

Shared Cable Tray





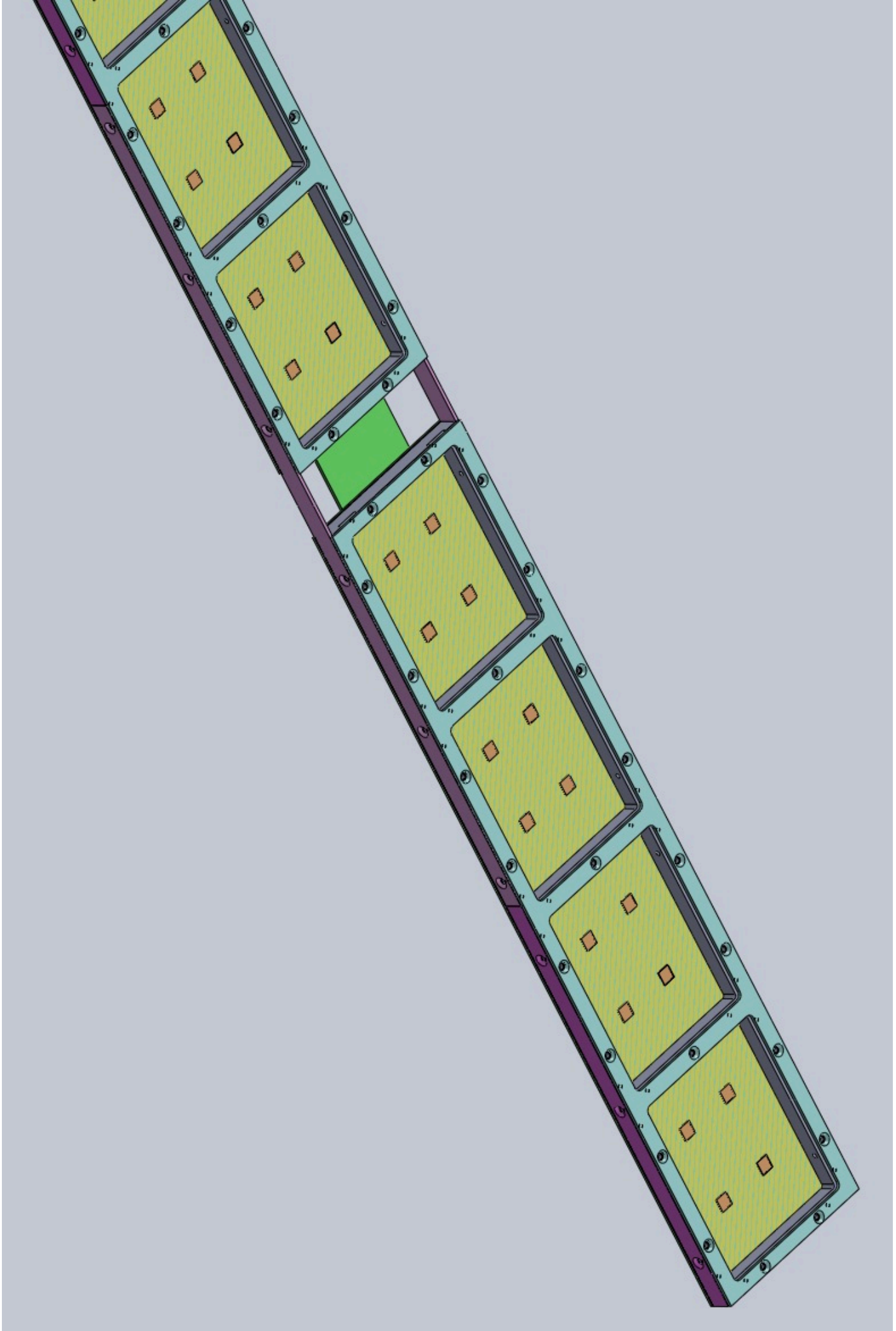
PD Cables Run Up Into APA Cable Tray (5 each side)

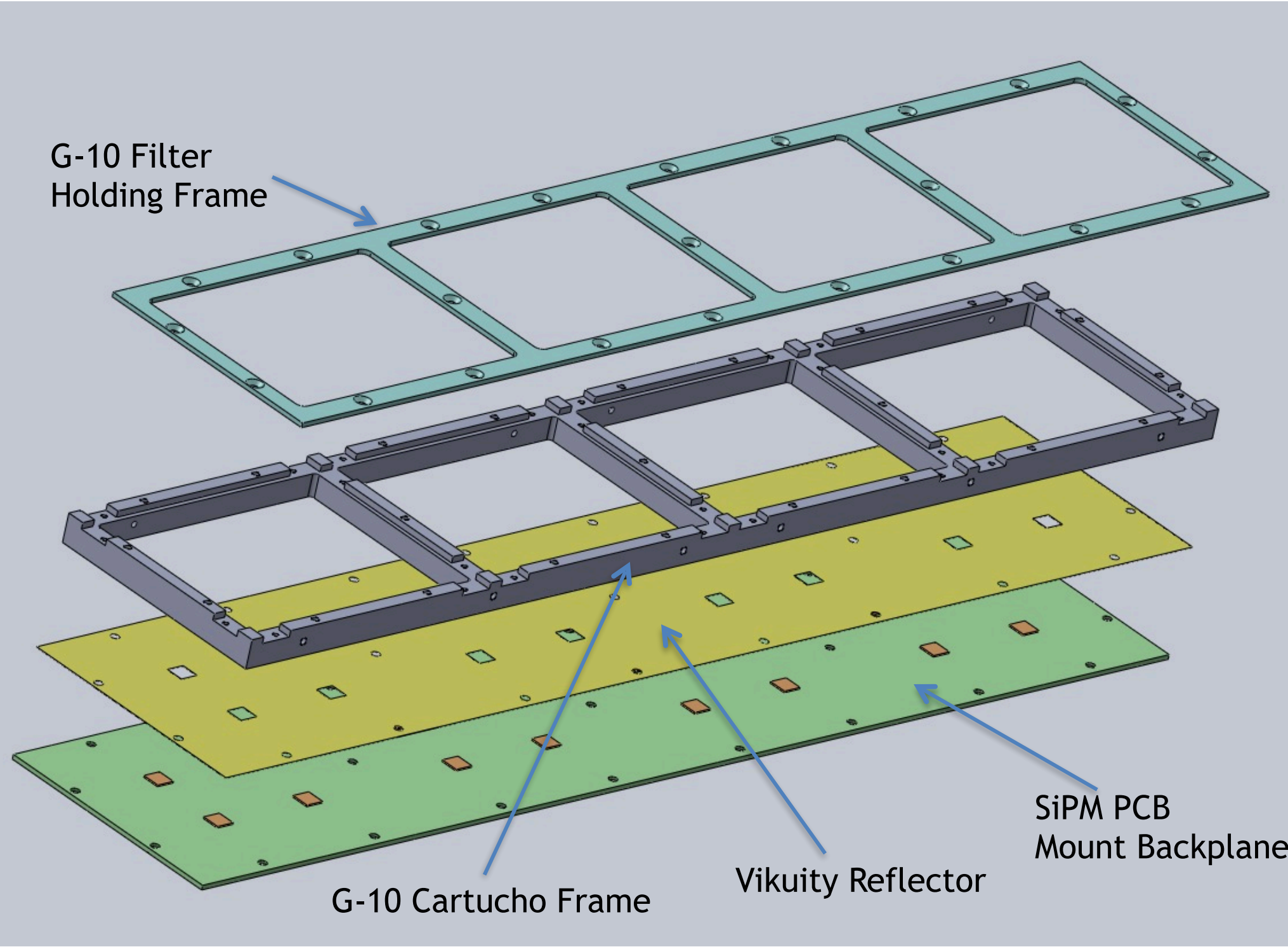


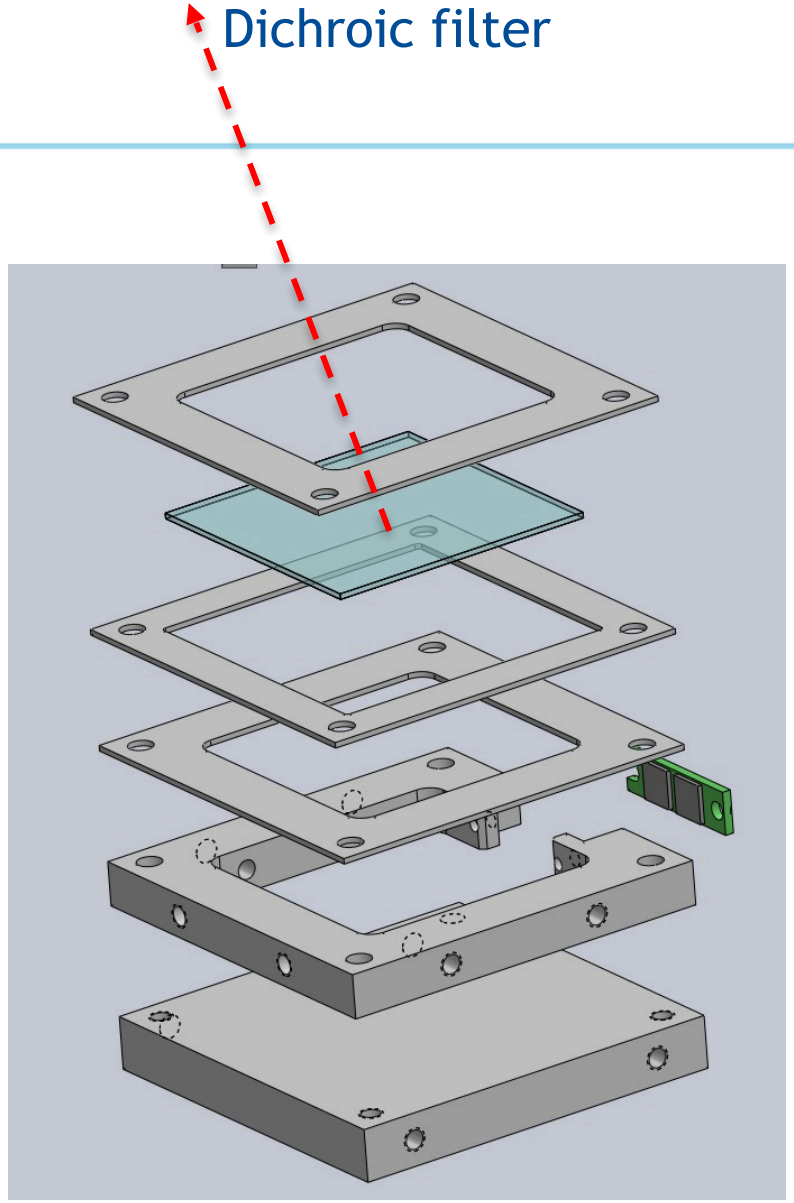
ARAPUCA
a new (LAr) Scintillation light detection concept - proposed for DUNE FD

original idea: E. Segreto (Univ. Campinas - BR)
A. Machado (Univ. Fed. ABC - BR)

current Collaboration:




G-10 Filter
Holding Frame
G-10 Cartucho Frame
Vikuity Reflector
SiPM PCB
Mount Backplane

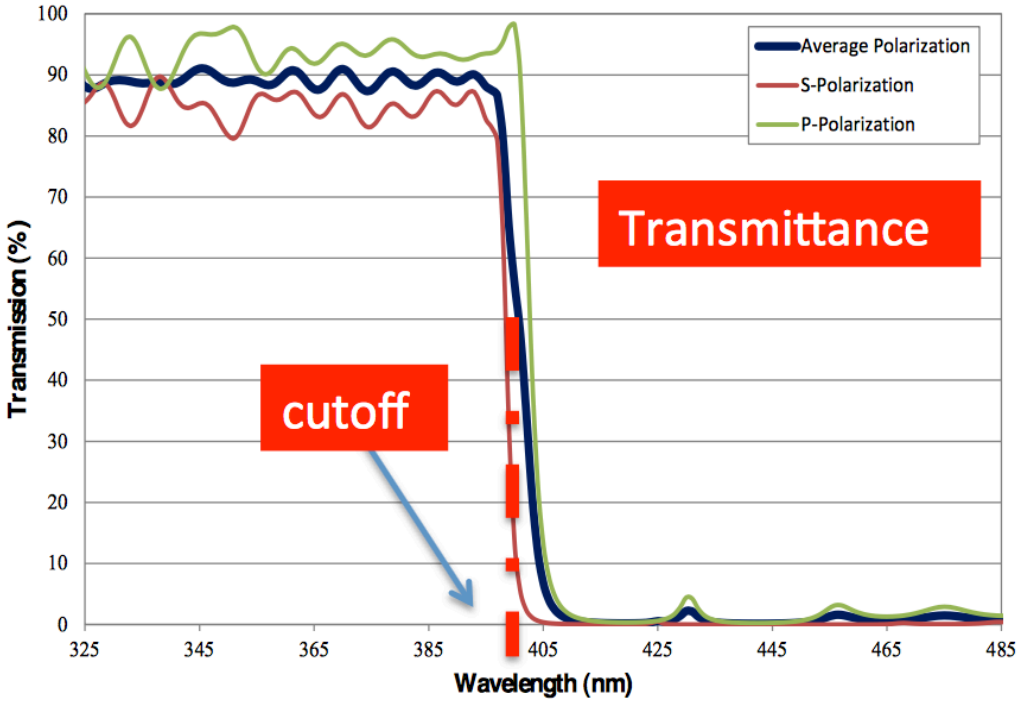


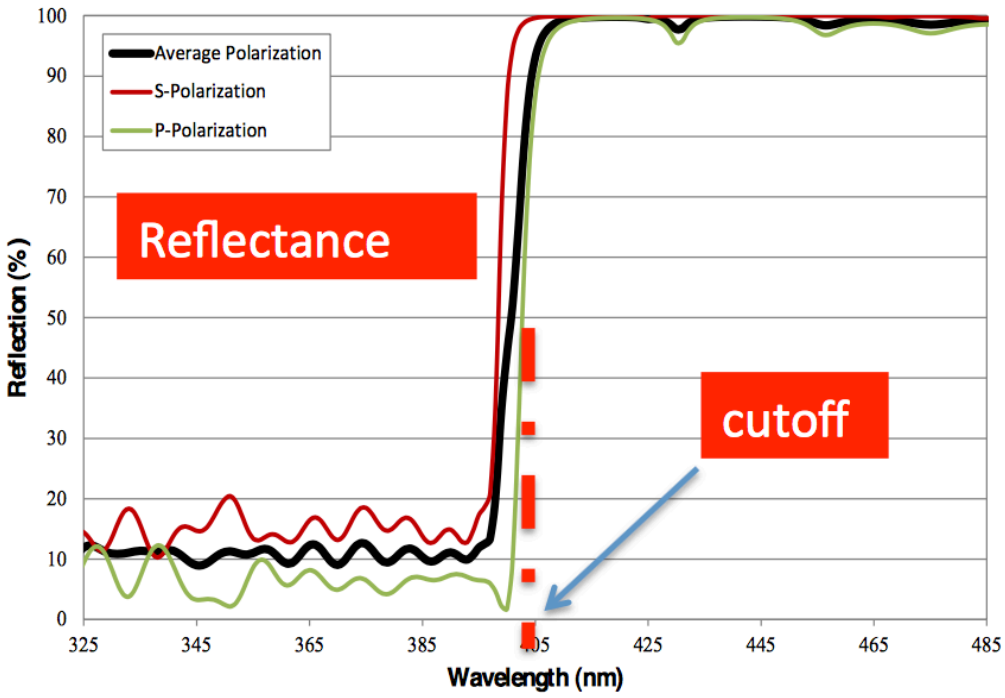
P-terphenyl on filter side (external)
TPB on filter side(internal)

- The simplest geometry is a **flattened box** with highly reflective internal surfaces (Teflon, VIKUITI, VM2000) with an open side.
- The open side hosts the **dichroic filter** that is the acceptance window of the device
- The filter is deposited with **TWO SHIFTERS** – **one on each side**
- The shifter on the **external side**, S1, converts LAr scintillation light to a wavelength L1, with **L1 < cutoff**
- The shifter on the **internal side**, S2, converts S1 shifted photons to a wavelength L2, **with L2 > cutoff**
- **The internal surface** of the ARAPUCA is observed by **one or more SiPM**

The dichroic window

- The core of the device is a **dichroic filter**. It is a **multilayer film** - same technology used to produce reflective plastic foils like 3M VIKUITI or VM2000
- It has the property of being **highly transparent** for wavelengths **below a cutoff** and **highly reflective above it**

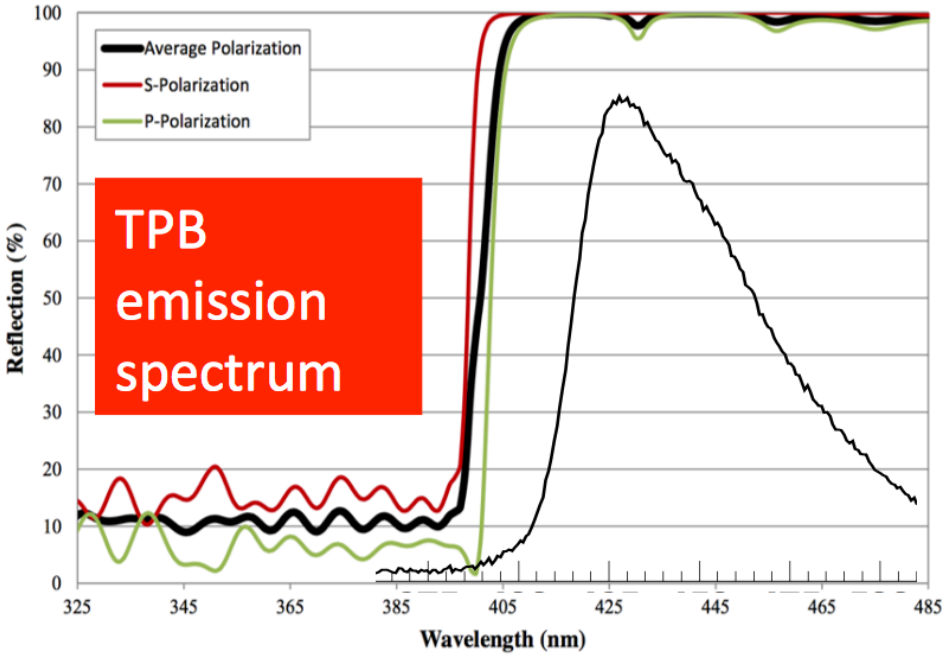


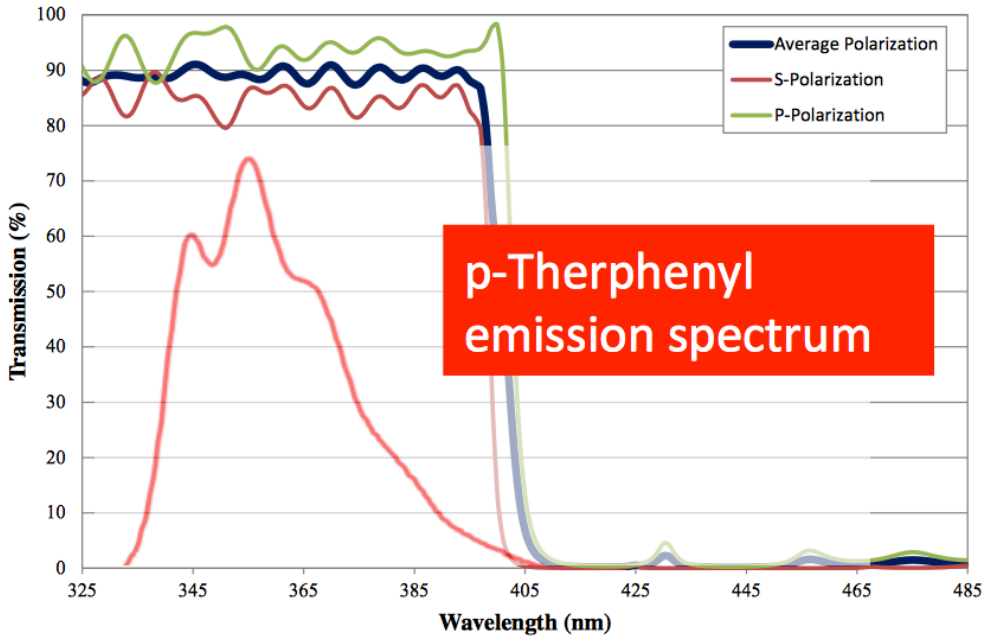


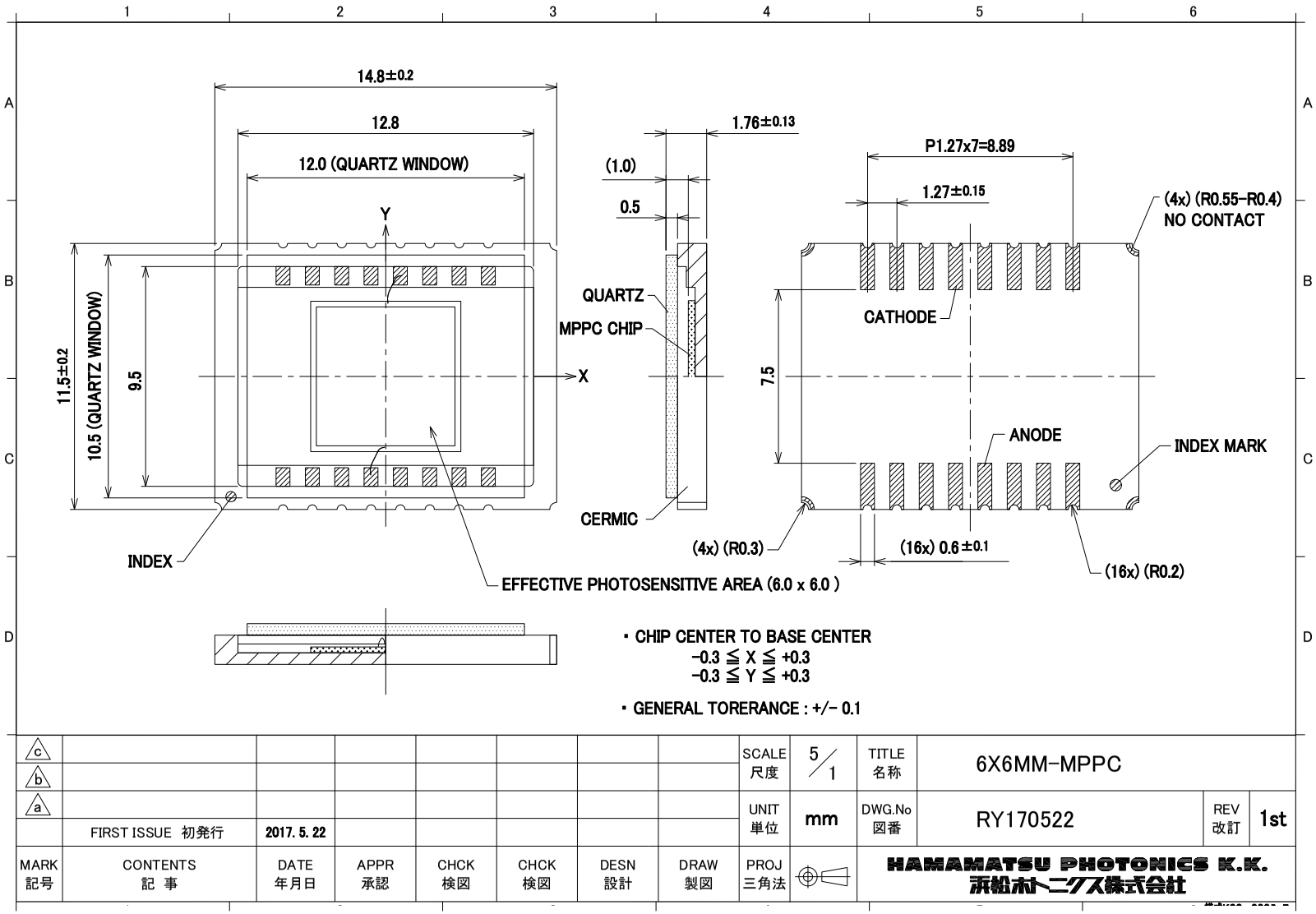
Wavelength Shifters (WS)

- We used p-Therphenyl as a WS for the external side of the ARAPUCA and Tetra-Phenyl ButadieneTPB for the internal side.

- We are studying other possible alternative WS







c								SCALE 尺度	5/1	TITLE 名称	6X6MM-MPPC		
b													
a								UNIT 単位	mm	DWG.No 図番	RY170522	REV 改訂	1st
	FIRST ISSUE 初発行	2017. 5. 22											
MARK 記号	CONTENTS 記 事	DATE 年月日	APPR 承認	CHCK 検図	CHCK 検図	DESN 設計	DRAW 製図	PROJ 三角法		HAMAMATSU PHOTONICS K.K. 浜松ホトニクス株式会社			

Issues experienced with SensL SiPM due to packaging failure (epoxy protective layer cracking in LAr)

New design developed in collaboration w/ HAMAMATSU -
packaging with protective quartz window (no issues at LAr T, better transparency), higher break-out V - need (very) minor modification of SSP - Bias V circuit.
Test ongoing at FNAL

Updates on ARAPUCA development

- **May 2016**: first test in LAr at PAB in Fermilab
  - ✓ 5x5 cm^2 window. 2 SensL SiPM (C60035)
  - ✓ Exposed to ^{241}Am alpha source
  - ✓ *Reasonable efficiency ~ 1%*. Some issues with stability of evaporations and reflectivity of internal walls

- **December 2016**: first test in LAr in Brazil
  - ✓ 3.5x2.5 cm^2 window. Exposed to ^{238}U alpha source
  - ✓ 1 SensL SiPM (C60035)
  - ✓ *Good efficiency ~ 1.8%* (as expected from MC simulations – *credits to Laura, Franciole and Ana*) . Minor issues with stability of evaporations

- **January 2017**: test of an array of 8 devices inside Tallbo
  G. Cancelo Talk

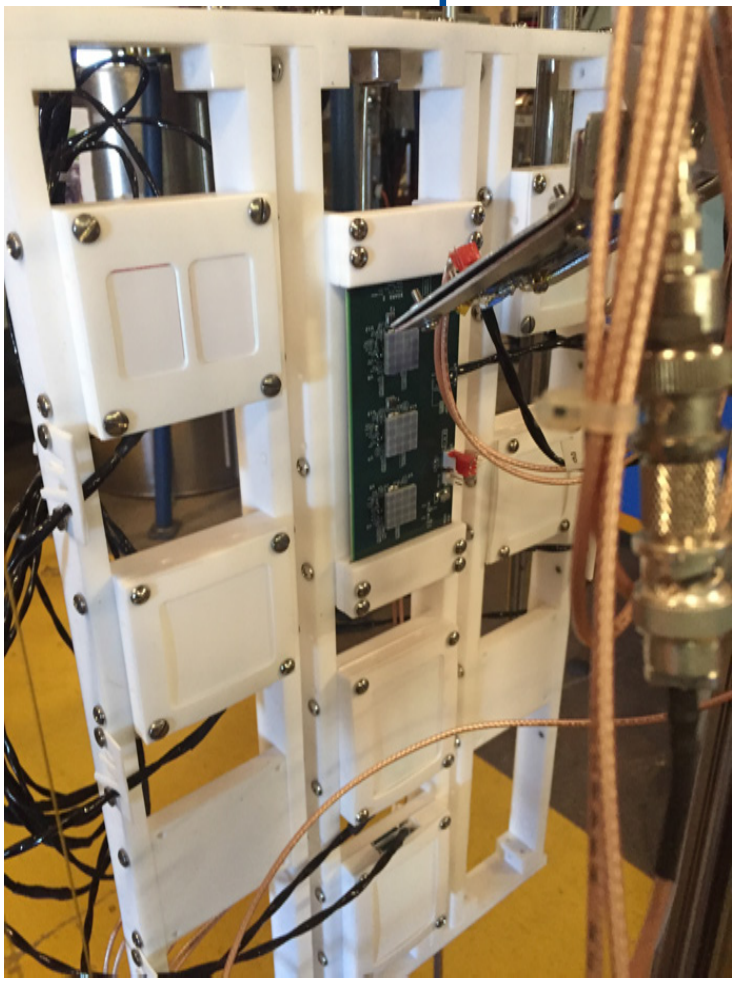
- **March 2017**: re-test of the array of 8 devices inside Tallbo
  G. Cancelo Talk

Results will be first released at TAUP Conference - Aug. 17

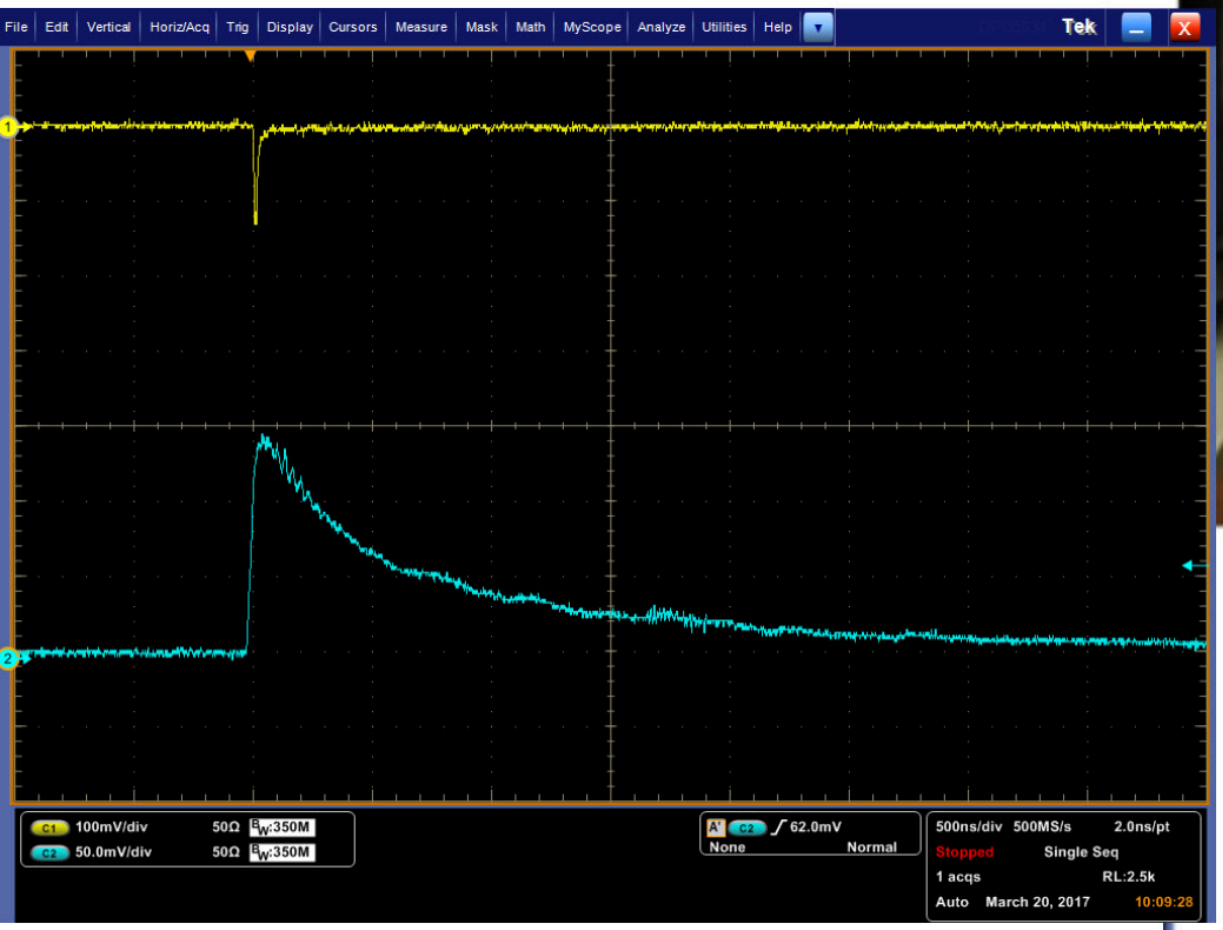
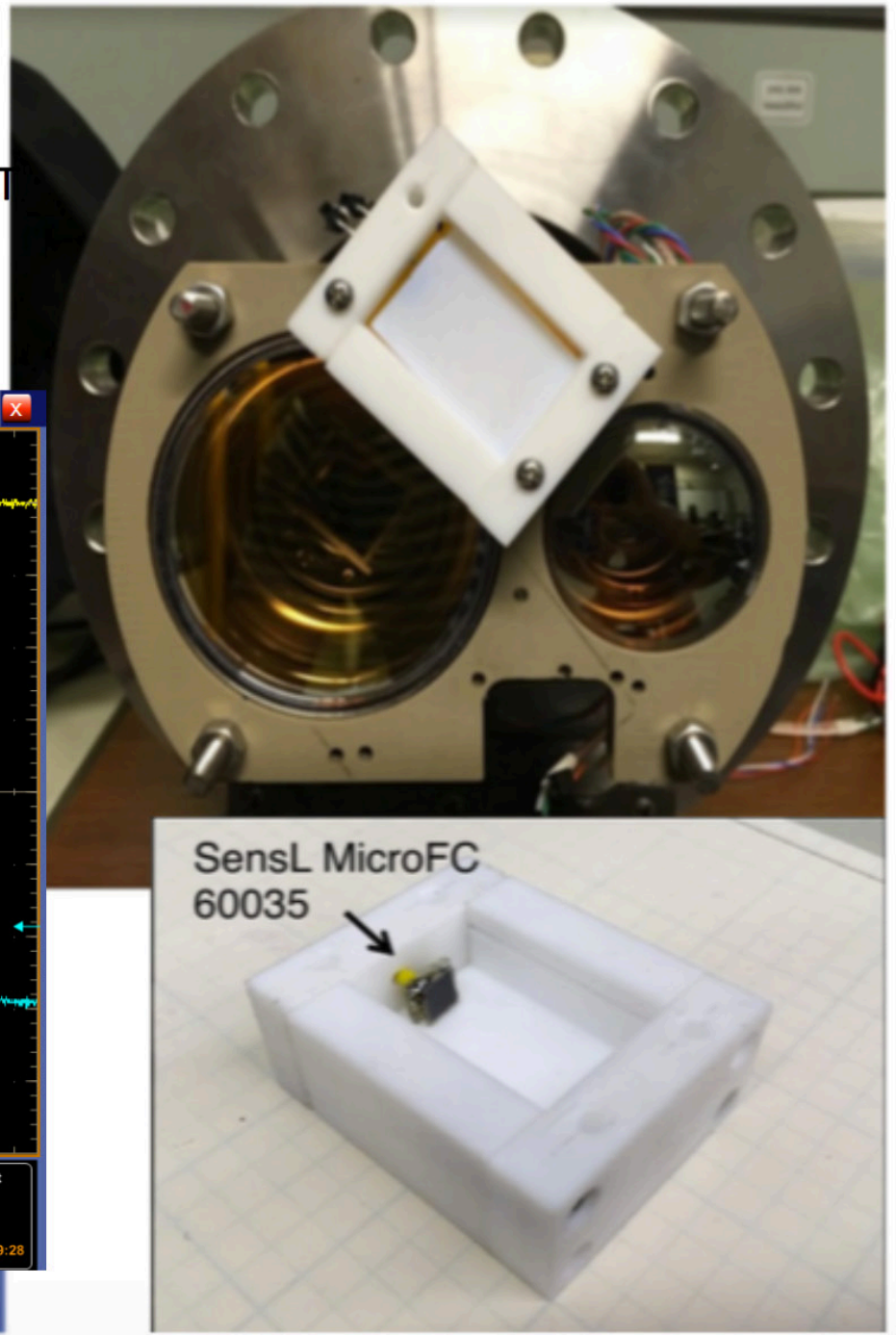
ARAPUCA tests at TallBo: Jan and March 2017

Picture of tallbo

Picture of arapuca rack



- Thanks to:
- The Fermilab LDRD program.
- Eileen Hahn, Jim Freeman, Ron Davis, Bill Miner, Brian Rebel and several others.

ARAPUCA in LArIAT

- A clone of the LNLS Campinas installed inside LArIAT
- Taking stably data right now