End-of-Sector-Box Interface

Overview

K. Bailey, Z. Papandreou, A. Teymurazyan

BIC In-Person Workshop

May 15, 2024

with slides from N. Novitzky

ESB ESB ESB ESB ESB

End-of-Sector-Box Interface

Overview

Etymology [edit]

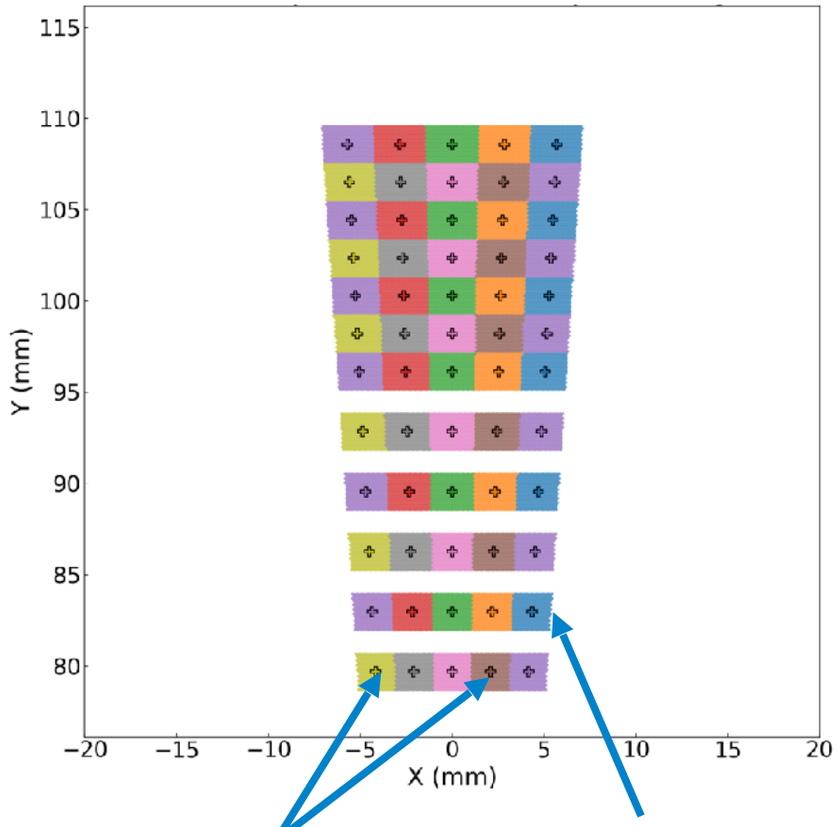
The word *acronym* is formed from the Greek roots *akro-*, meaning 'height, summit, or tip', and *-nym*, 'name'

ESB ESB ESB ESB

SiPM Readout

- **2-sided SiPM readout**
- **Lightguides** on sector sides
  - inner surface ~2×2 cm²
  - output face 1.3×1.3 cm²
- SiPMs that meet our requirements:
  - 4 x 6×6 mm² SiPMs with 50 μm pixels (e.g. 4 x S14160-6050, or a **pre-assembled S14161-3050-04 array**)
- 12 layers x 5 cells x 2 sides x 48 sectors = **5760 channels**

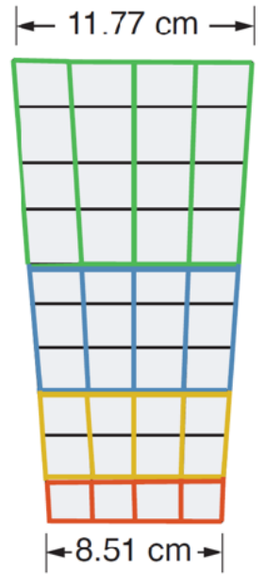
ePIC Sector End View (x-y plane view), 17.1 X0



Readout **Cell**
Has lightguide
Layer = 5 cells

Pb/SciFi **Layer**
1 sector = 12 layers
1 layer = 17 fiber rows

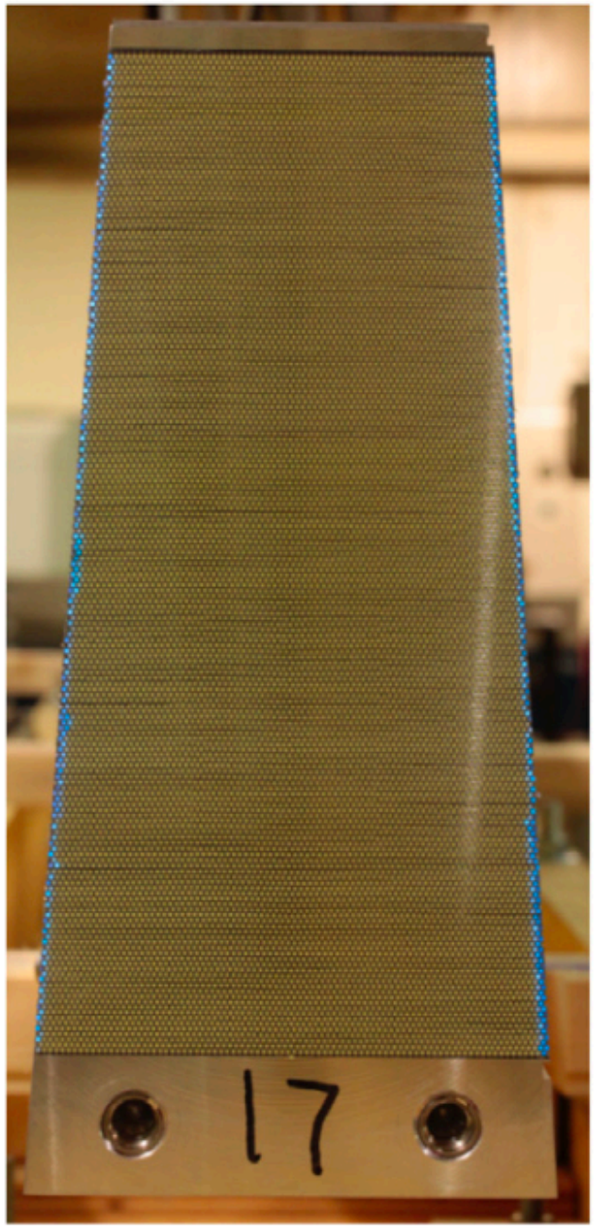
GlueX Sector End View, 15.5 X0

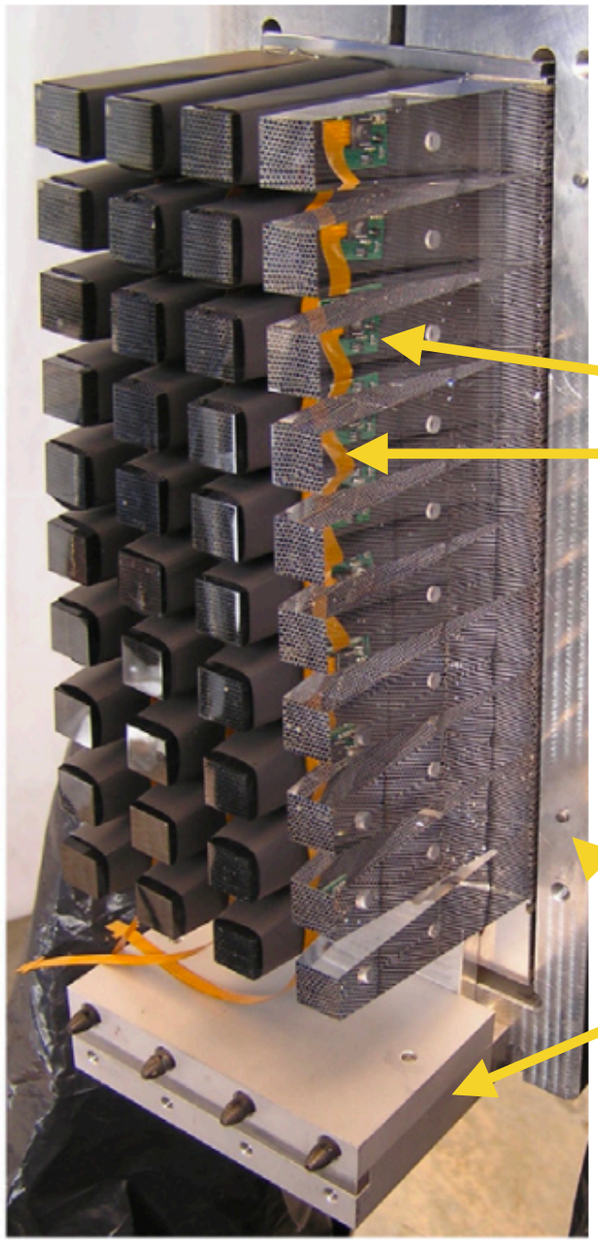


Hamamatsu S12045(X)
4×4 array of 3×3 mm²
50×50μm² pixels

16 FADC per side
12 TDC per side

BCAL Light Guides

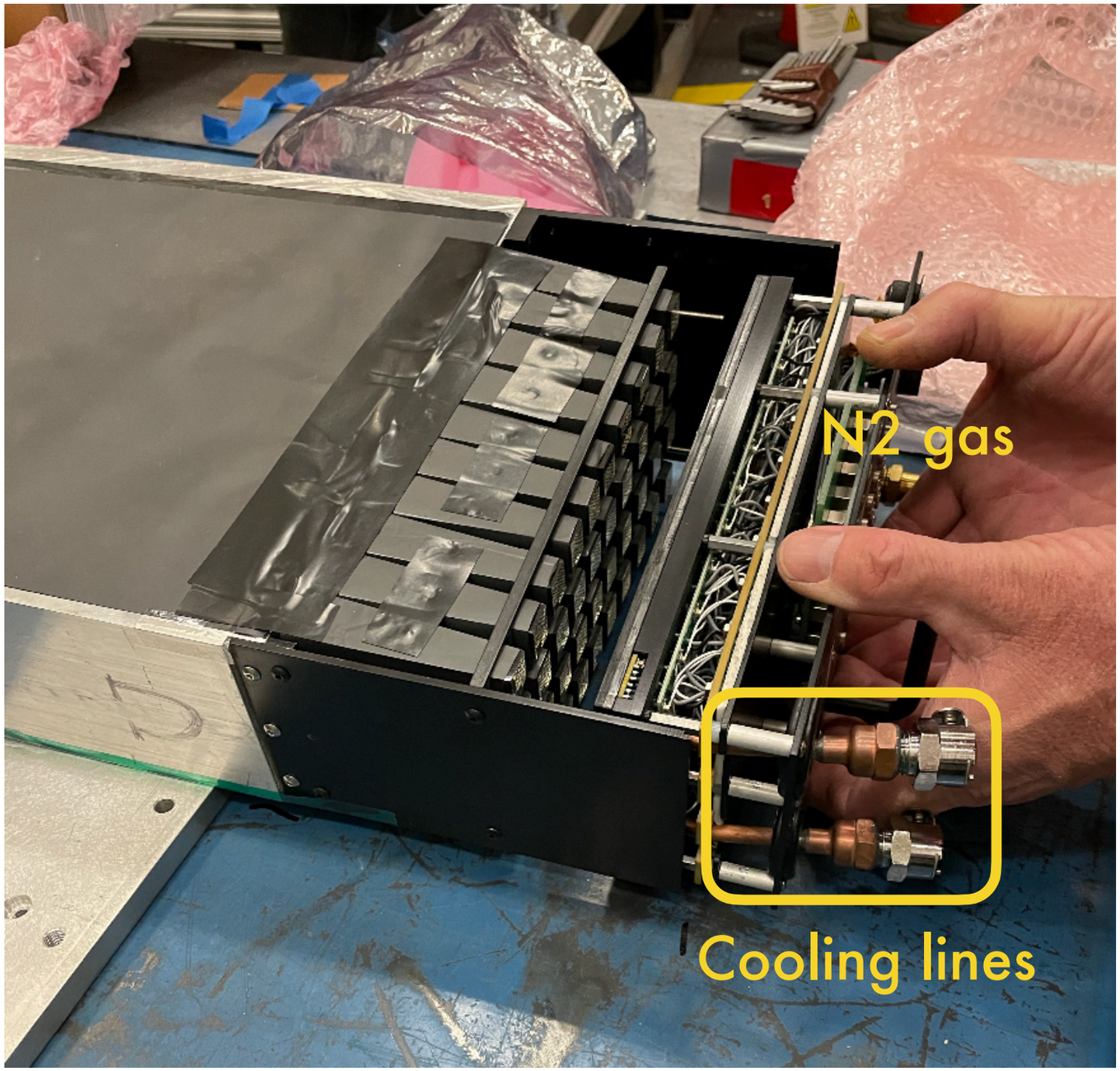




LED mini boards;
Flex cable

LG mounting jig

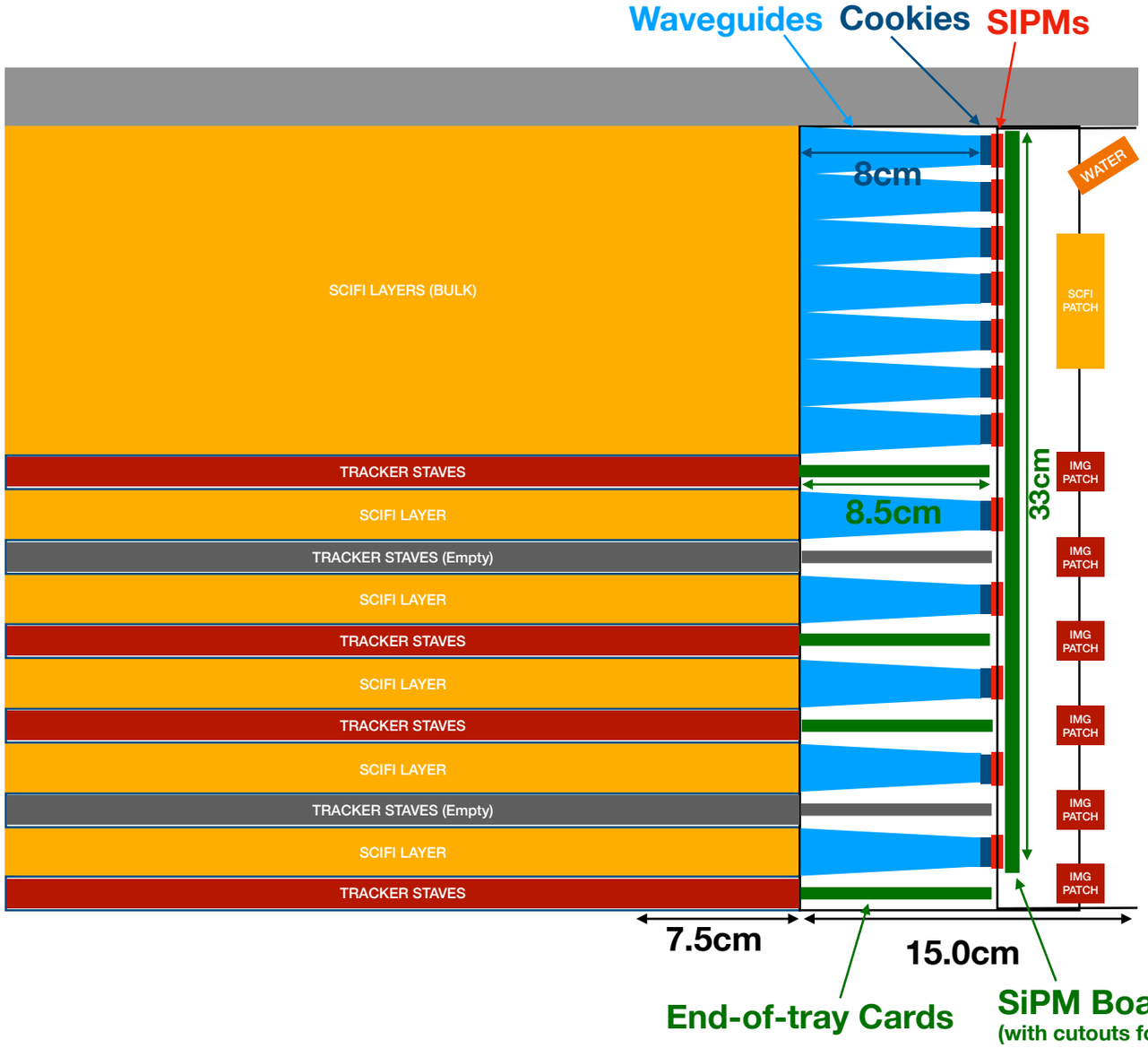
BCAL "Wedges"



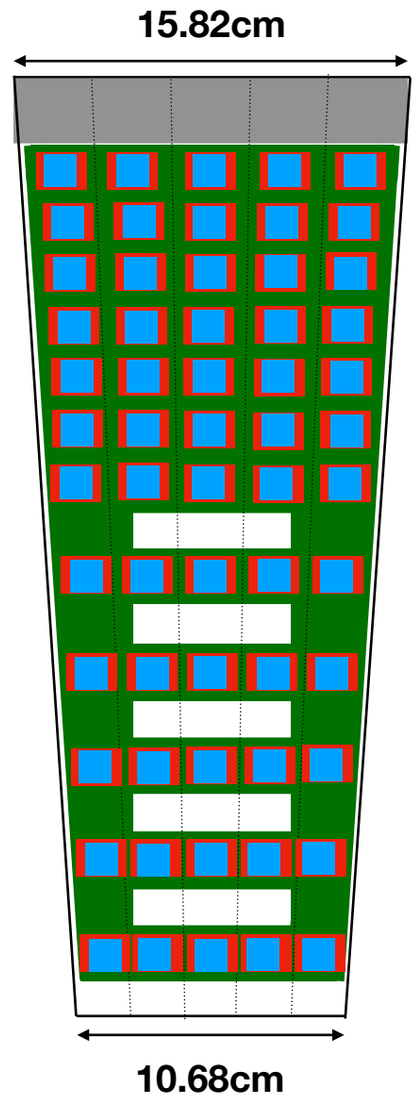
- Contiguous LG stacking
- LG-SiPM air gap
- BIC: Si cookie
- Spring loading
- Integrated ESB for installation ease

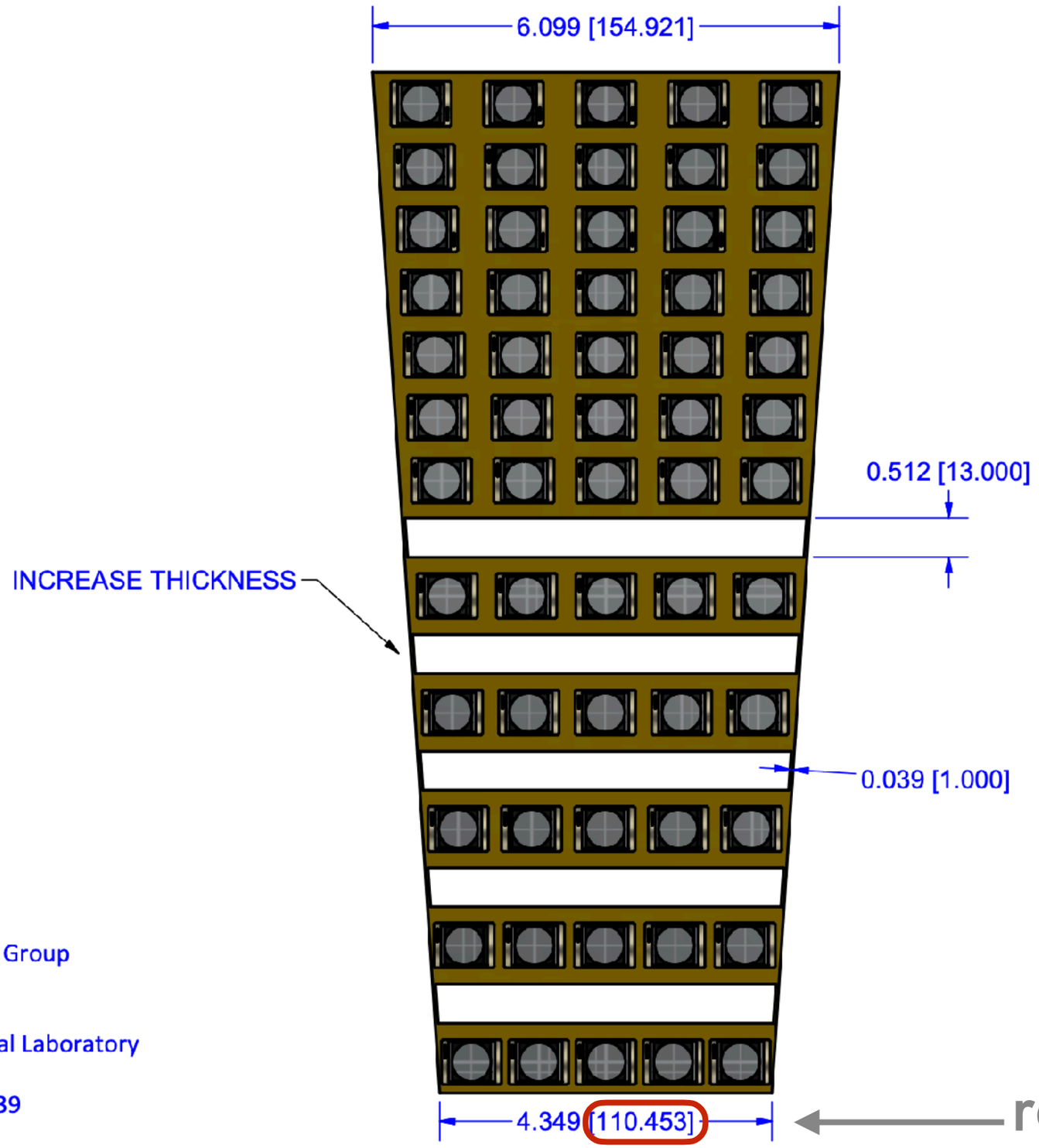
eek!

Side View for EOSB (12 modules/9 chips scenario)



Cross section at SiPM Board





Kevin Bailey
Medium Energy Group
Physics Division
Bldg 203 F-126
Argonne National Laboratory
9700 S Cass Ave
Argonne, IL 60439
630-252-4036
Telecommuting - Cell 630-776-5737

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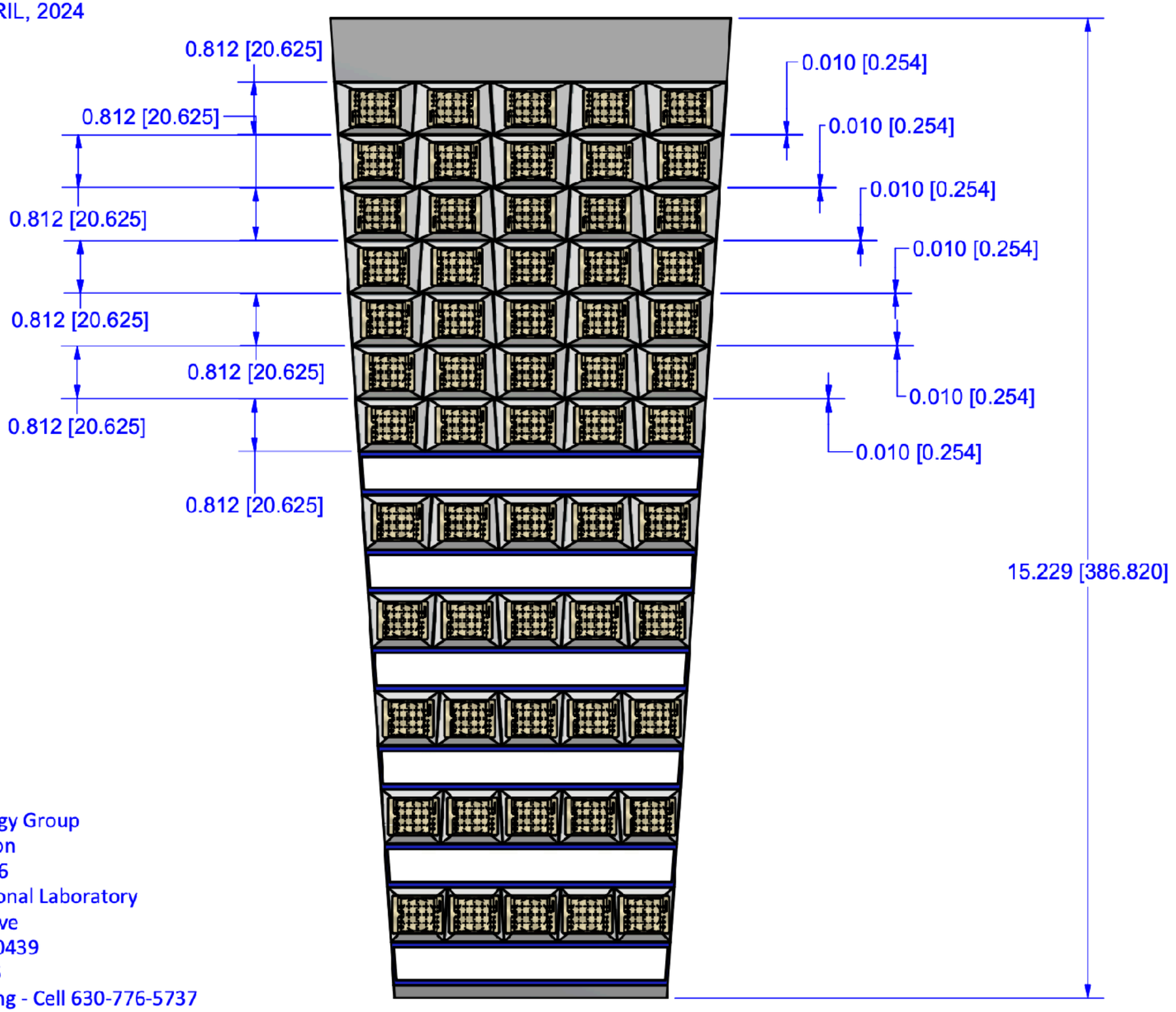

Kevin Bailey
Medium Energy Group
Physics Division
Bldg 203 F-126
Argonne National Laboratory
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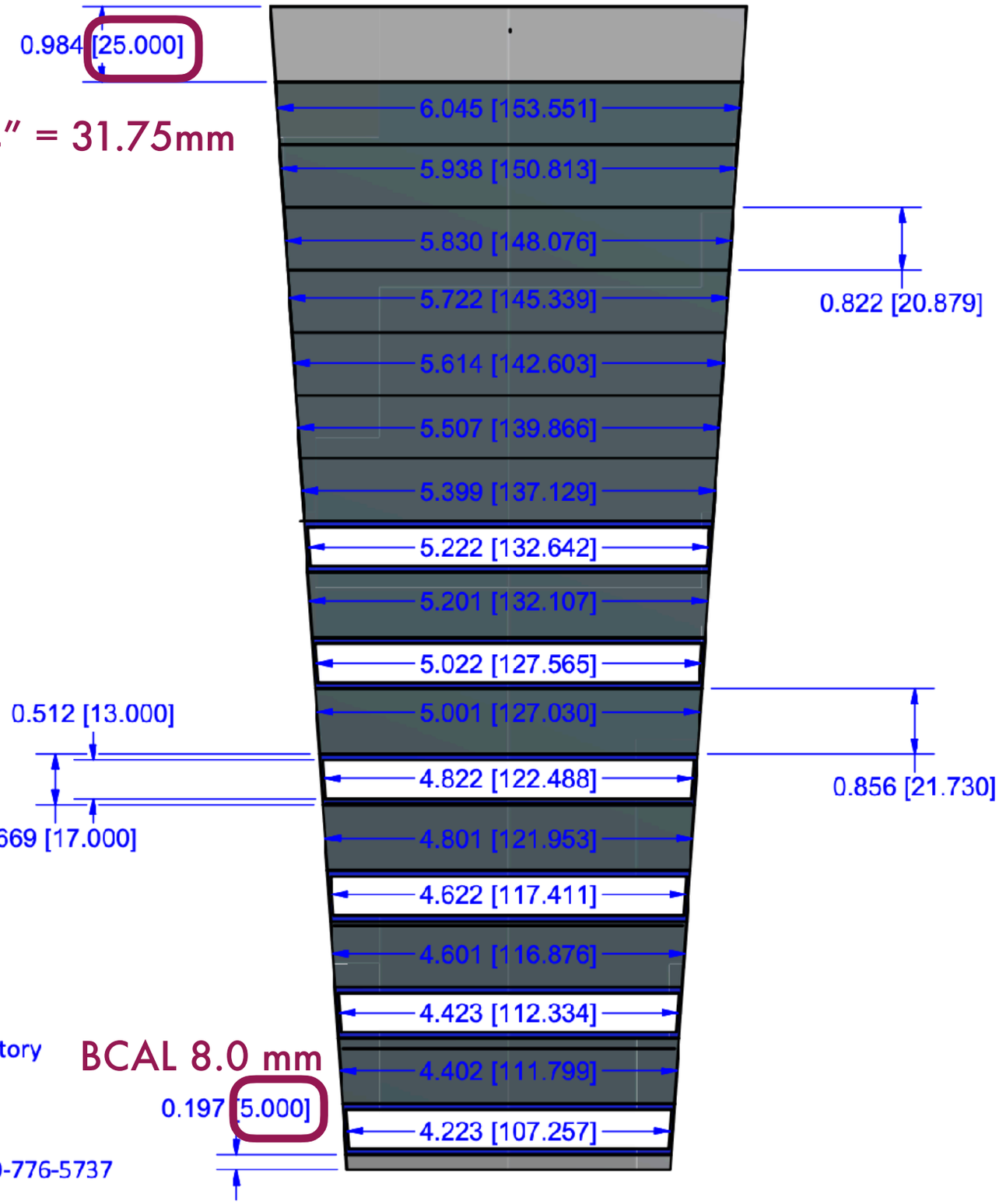
BCAL 1 1/4" = 31.75mm



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Medium Energy Group
Physics Division
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Argonne National Laboratory
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Argonne, IL 60439
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BCAL

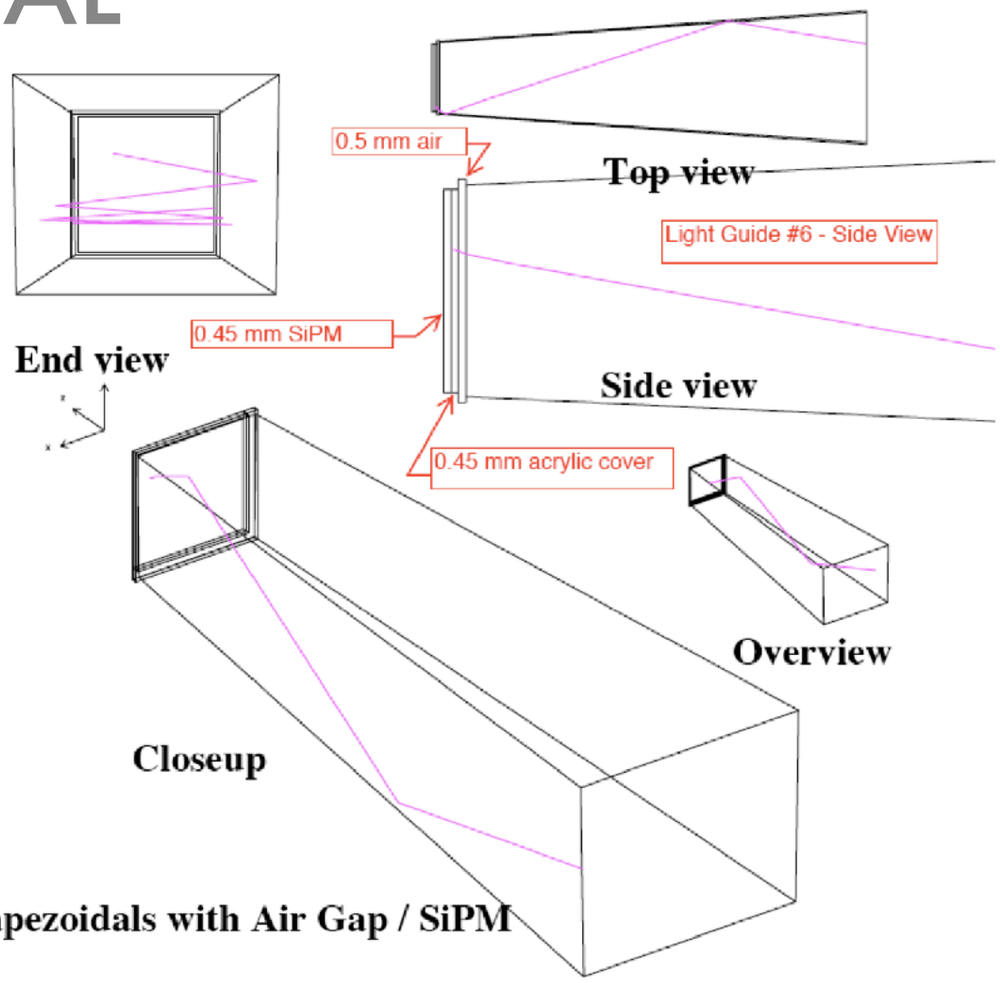
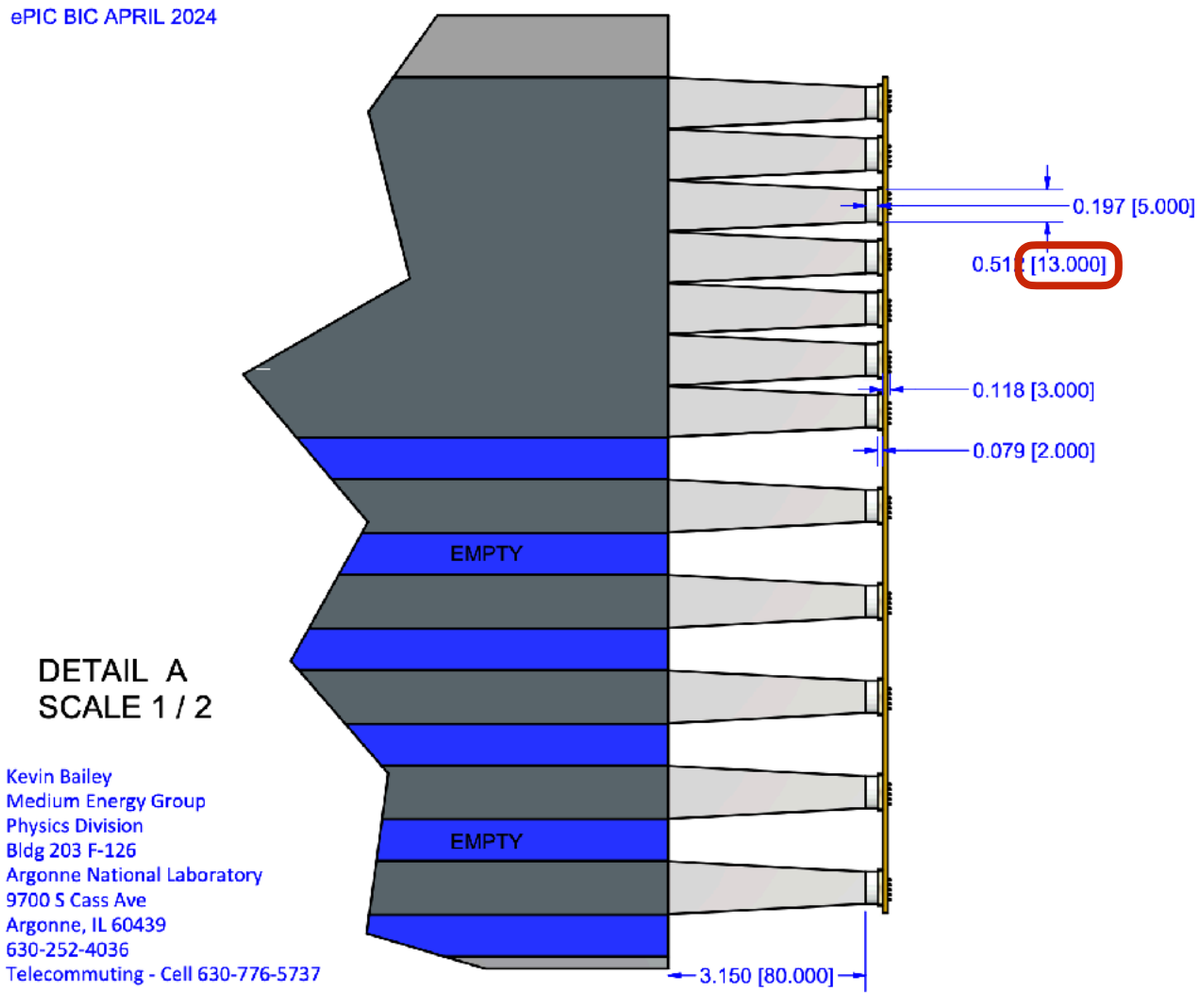


Table 1: Sizes of the ten production light guides for the Bcal. The trapezoid dimensions are denoted using the notation (bottom-top × height).

Configuration	Input Trapezoid (mm^2)	Length (cm)	Output Trapezoid (mm^2)	Eff (%)
g1	20.96-21.64 × 20.57	8	13.19-13.61 × 13.19	0.748
g2	21.64-22.30 × 20.57	8	13.19-13.61 × 13.19	0.723
g3	22.30-22.99 × 20.57	8	13.19-13.61 × 13.19	0.701
g4	22.99-23.65 × 20.57	8	13.19-13.61 × 13.19	0.683
g5	23.67-24.33 × 20.57	8	13.19-13.61 × 13.19	0.662
g6	24.33-25.02 × 20.57	8	13.19-13.61 × 13.19	0.643
g7	25.02-25.83 × 24.64	8	13.19-13.61 × 13.19	0.516
g8	25.83-26.62 × 24.64	8	13.19-13.61 × 13.19	0.503
g9	26.64-27.43 × 24.64	8	13.19-13.61 × 13.19	0.488
g10	27.46-27.84 × 24.64	8	13.19-13.61 × 13.19	0.477

LIGHT GUIDES



BIC

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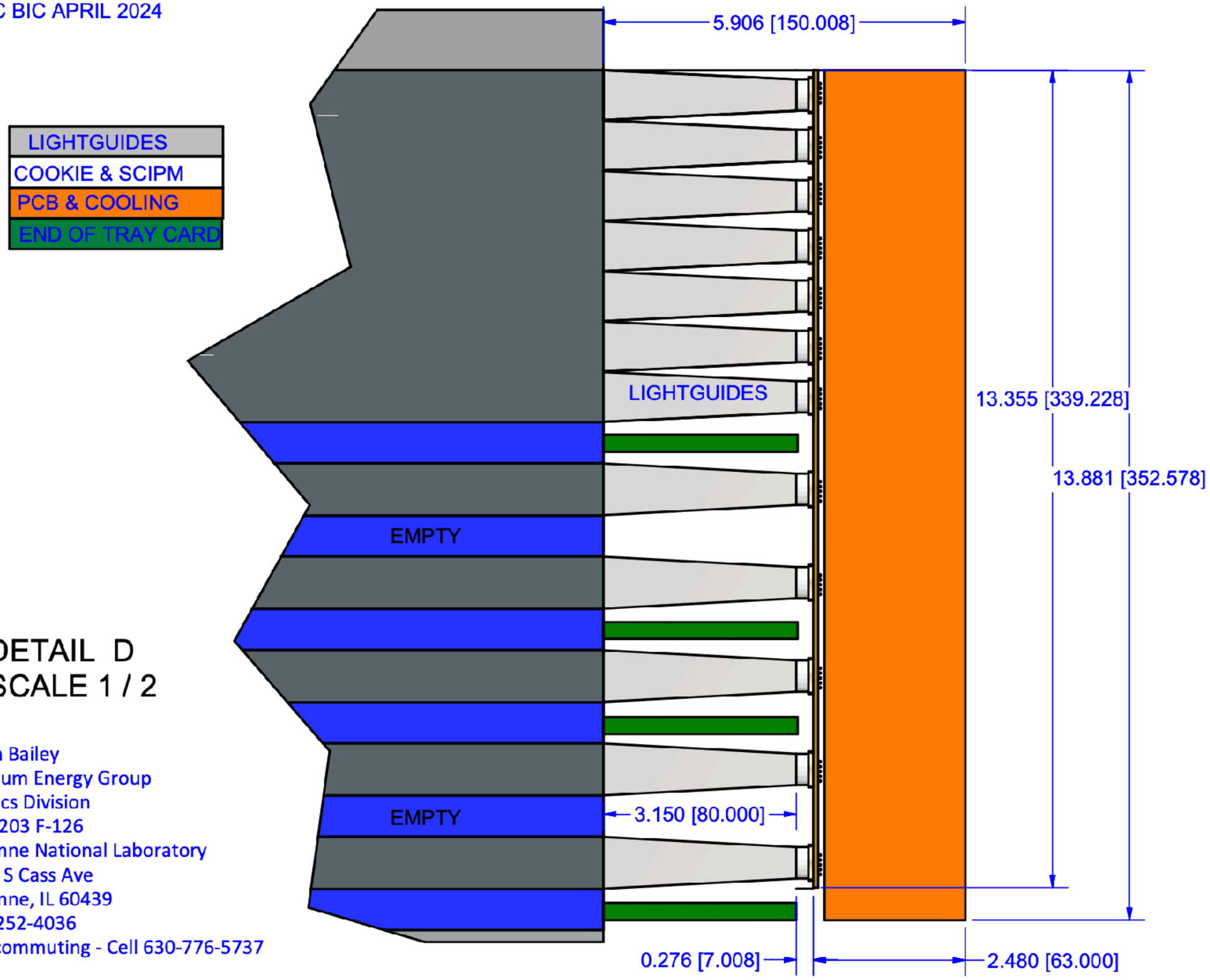
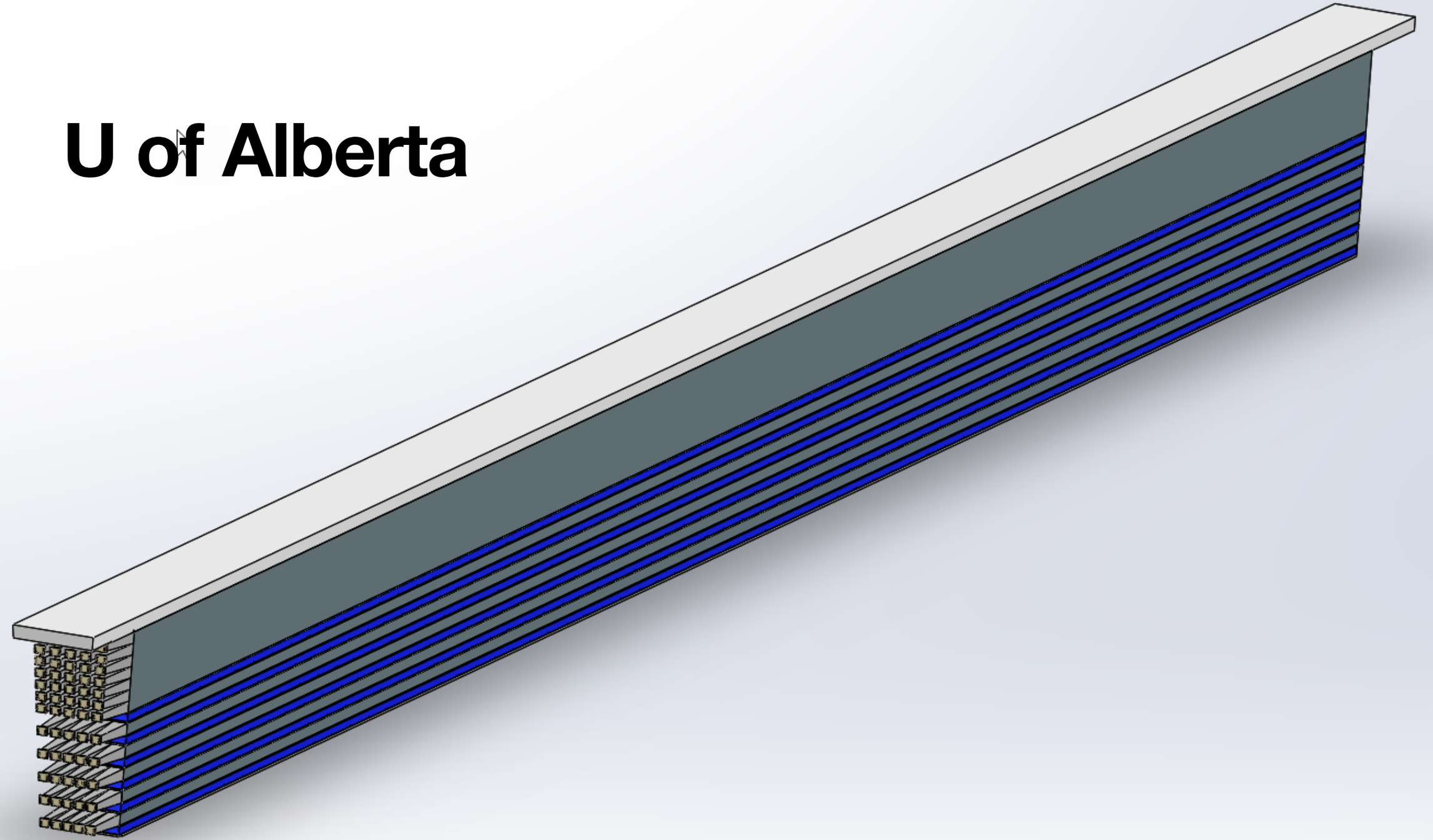


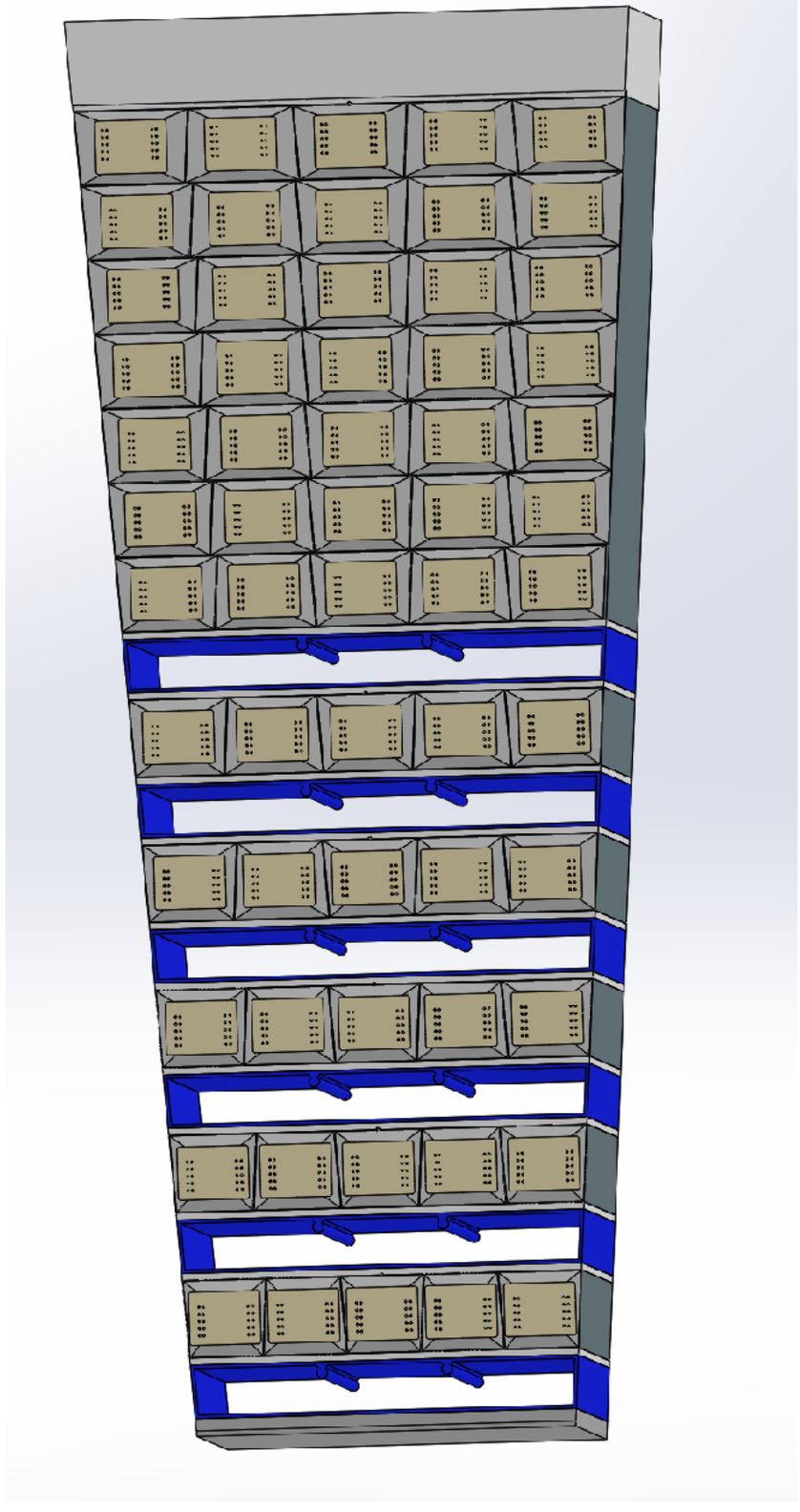
DETAIL D
SCALE 1 / 2

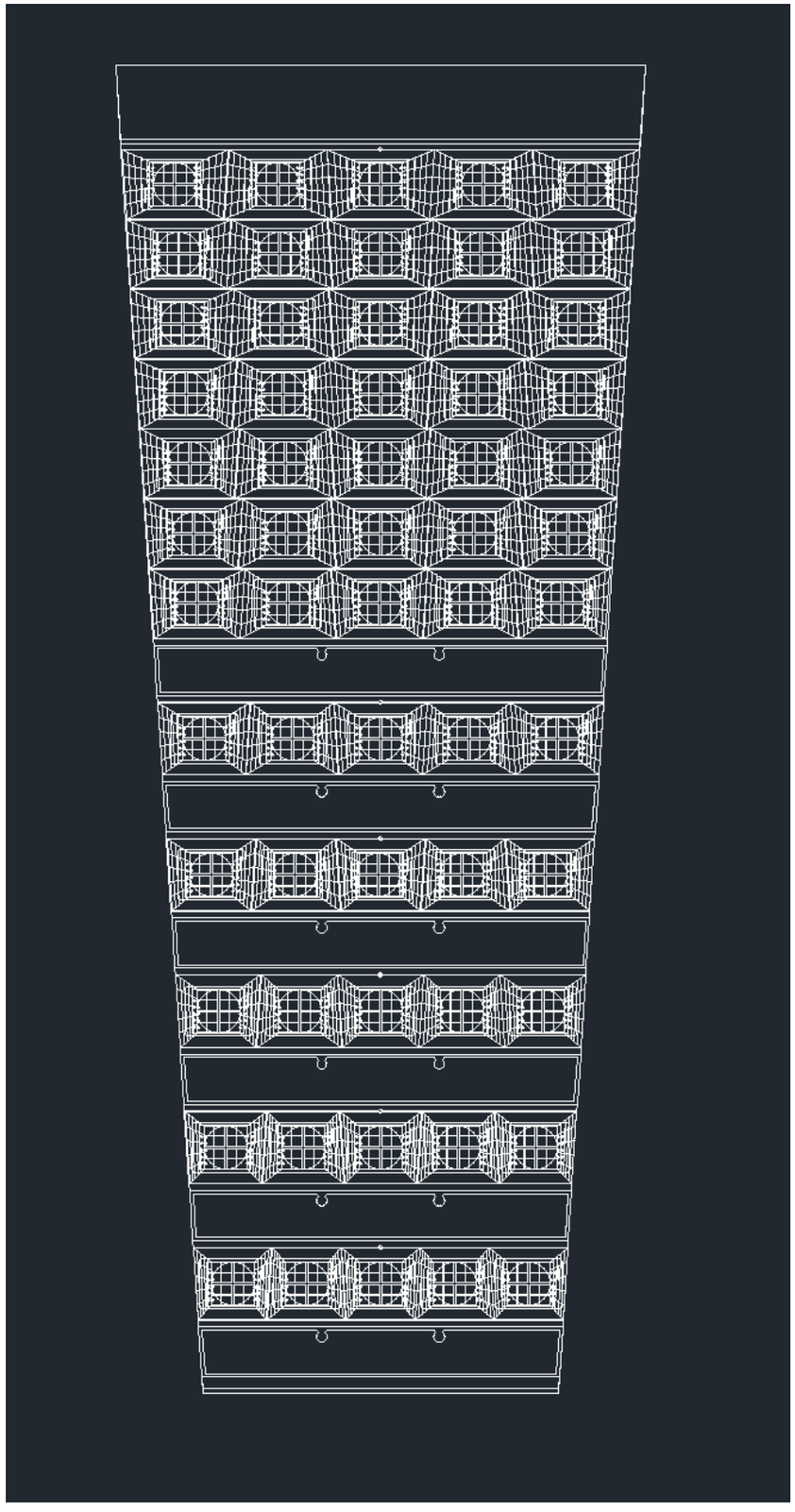
Kevin Bailey
Medium Energy Group
Physics Division
Bldg 203 F-126
Argonne National Laboratory
9700 S Cass Ave
Argonne, IL 60439
630-252-4036
Telecommuting - Cell 630-776-5737

U of Alberta



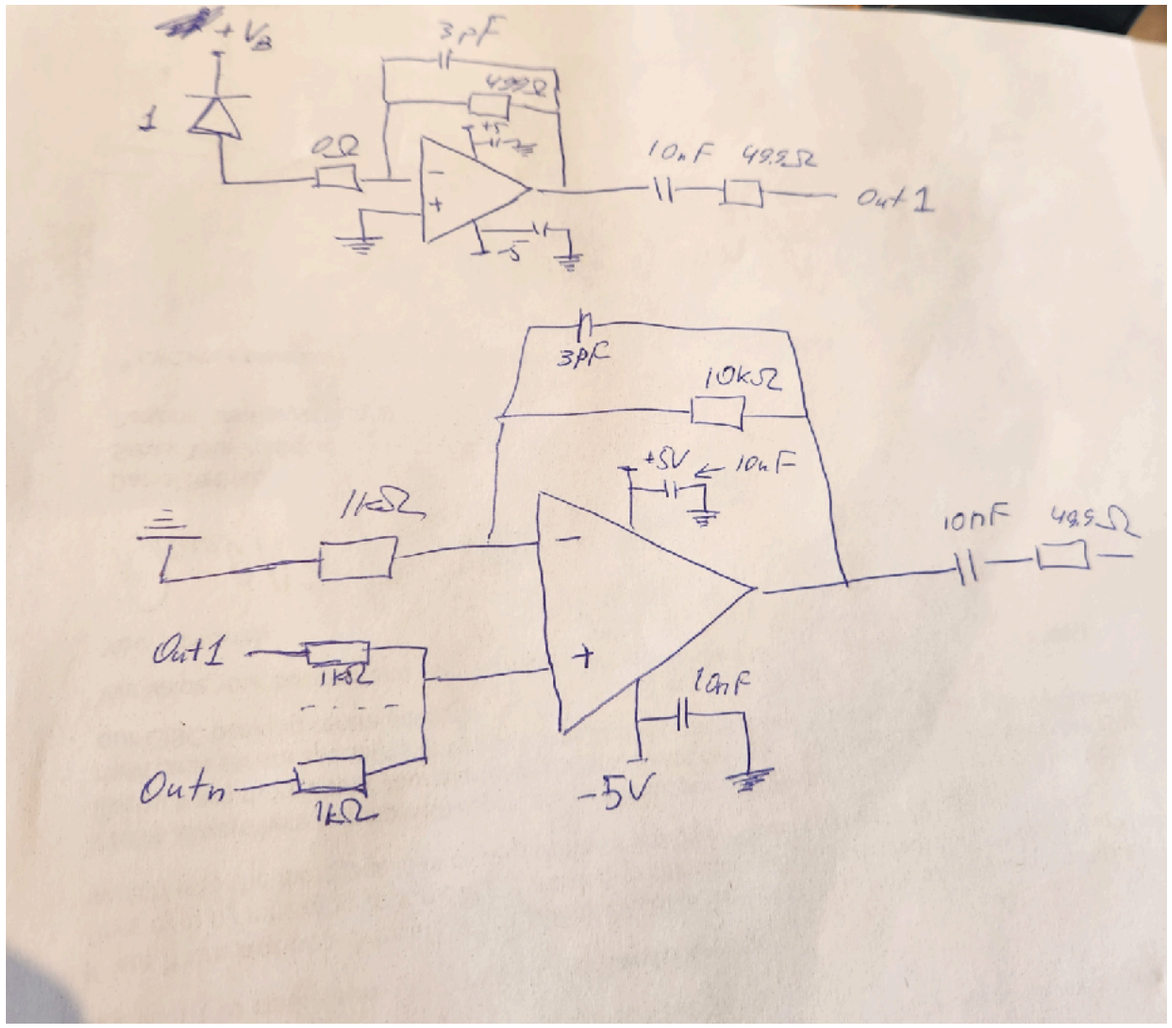
U of Alberta



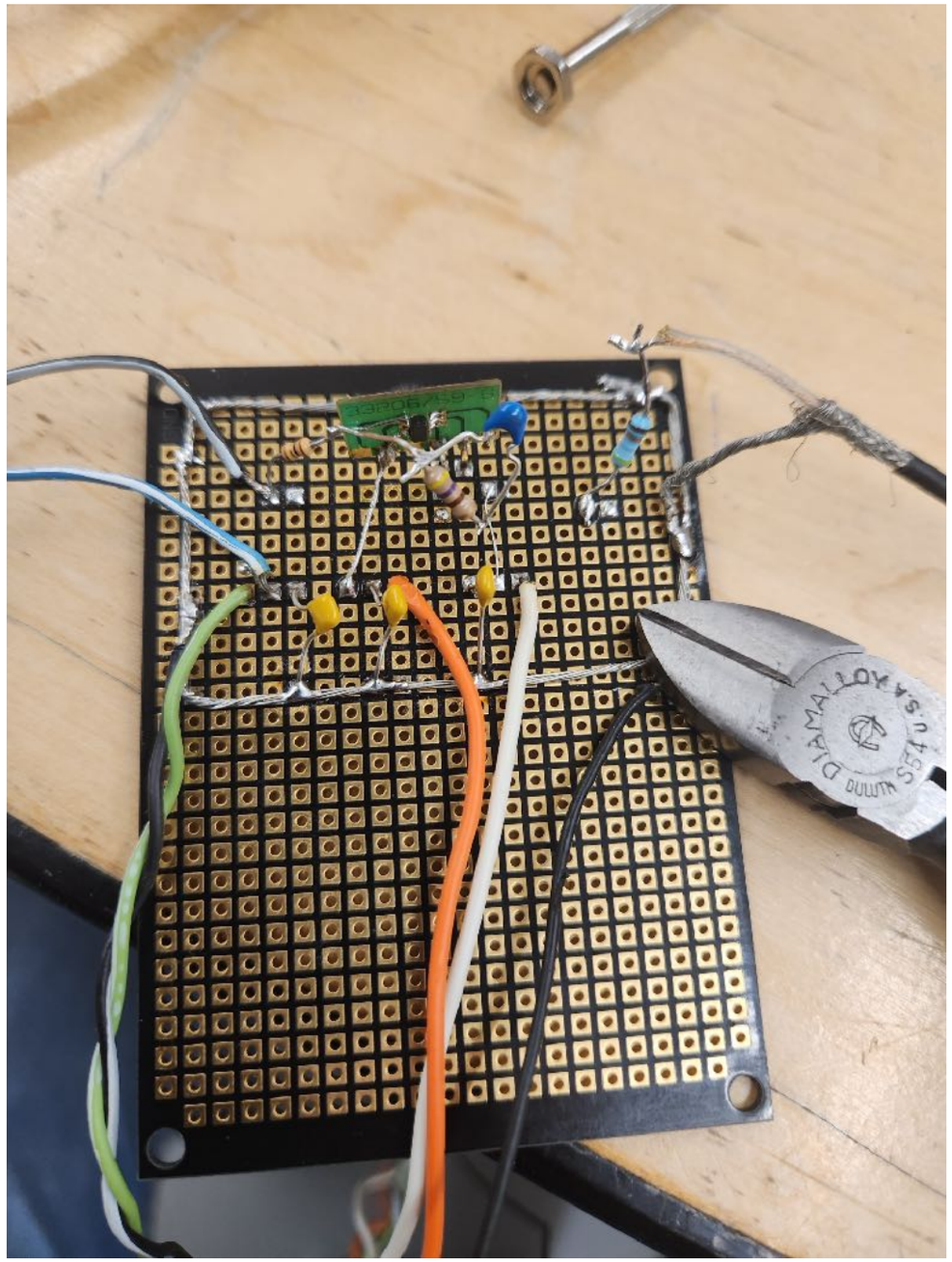


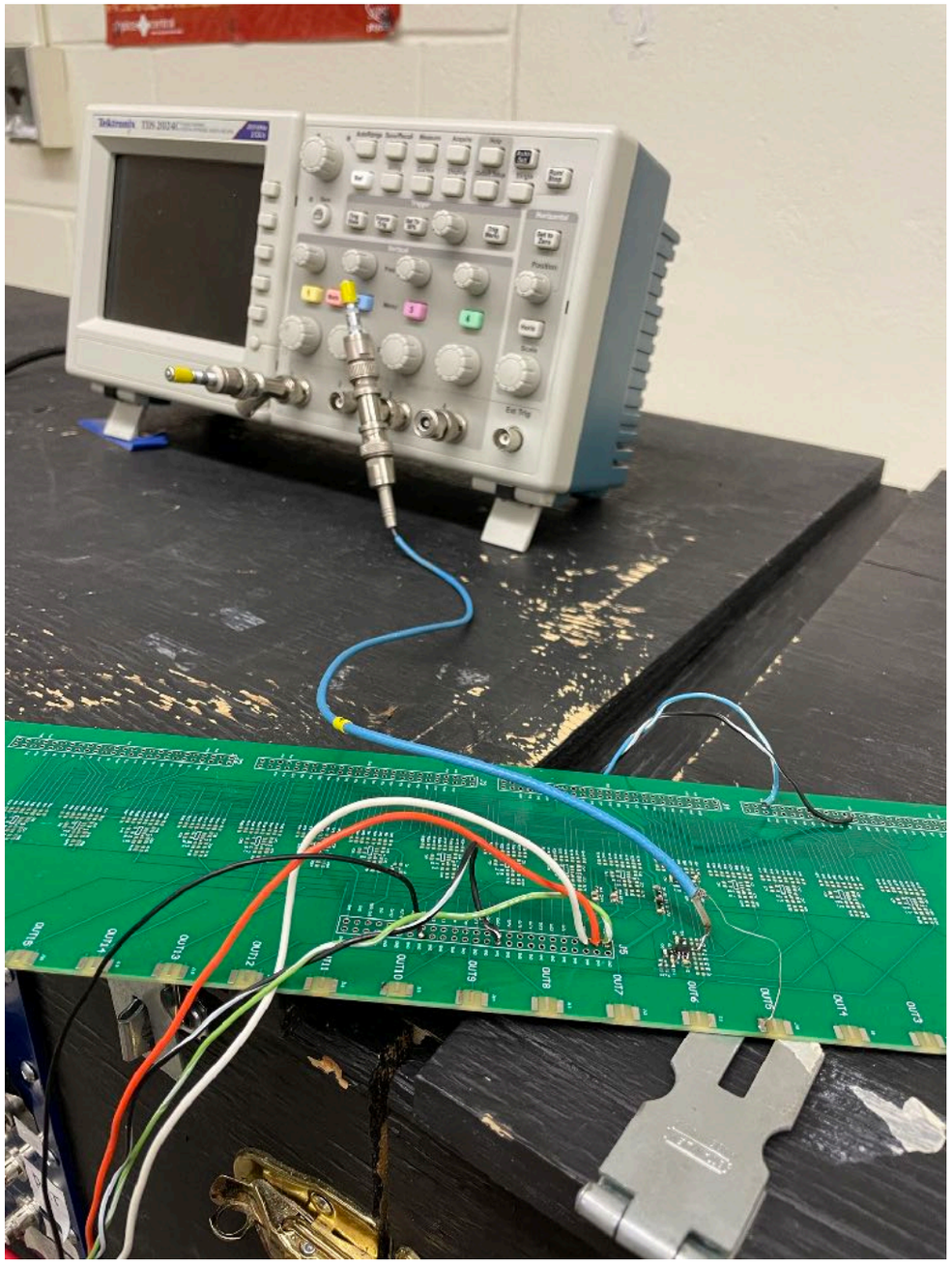
SFILs - Electronics Board

- Discrete electronics
- Fiber + ^{90}Sr source
- SiPM 3x3mm^2 vs PMT
- Two-stage amplification
- Started: S14160-3050 array

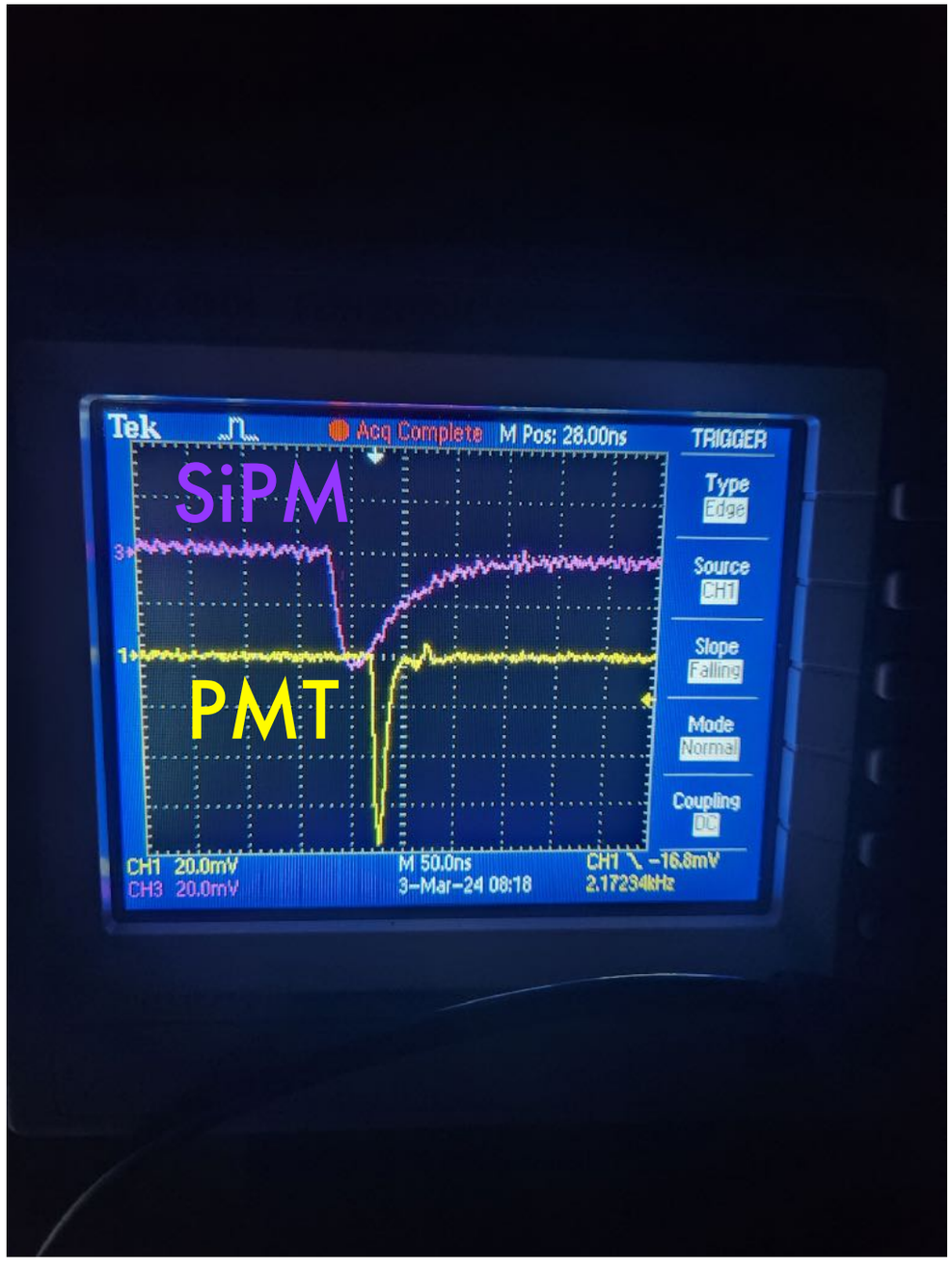


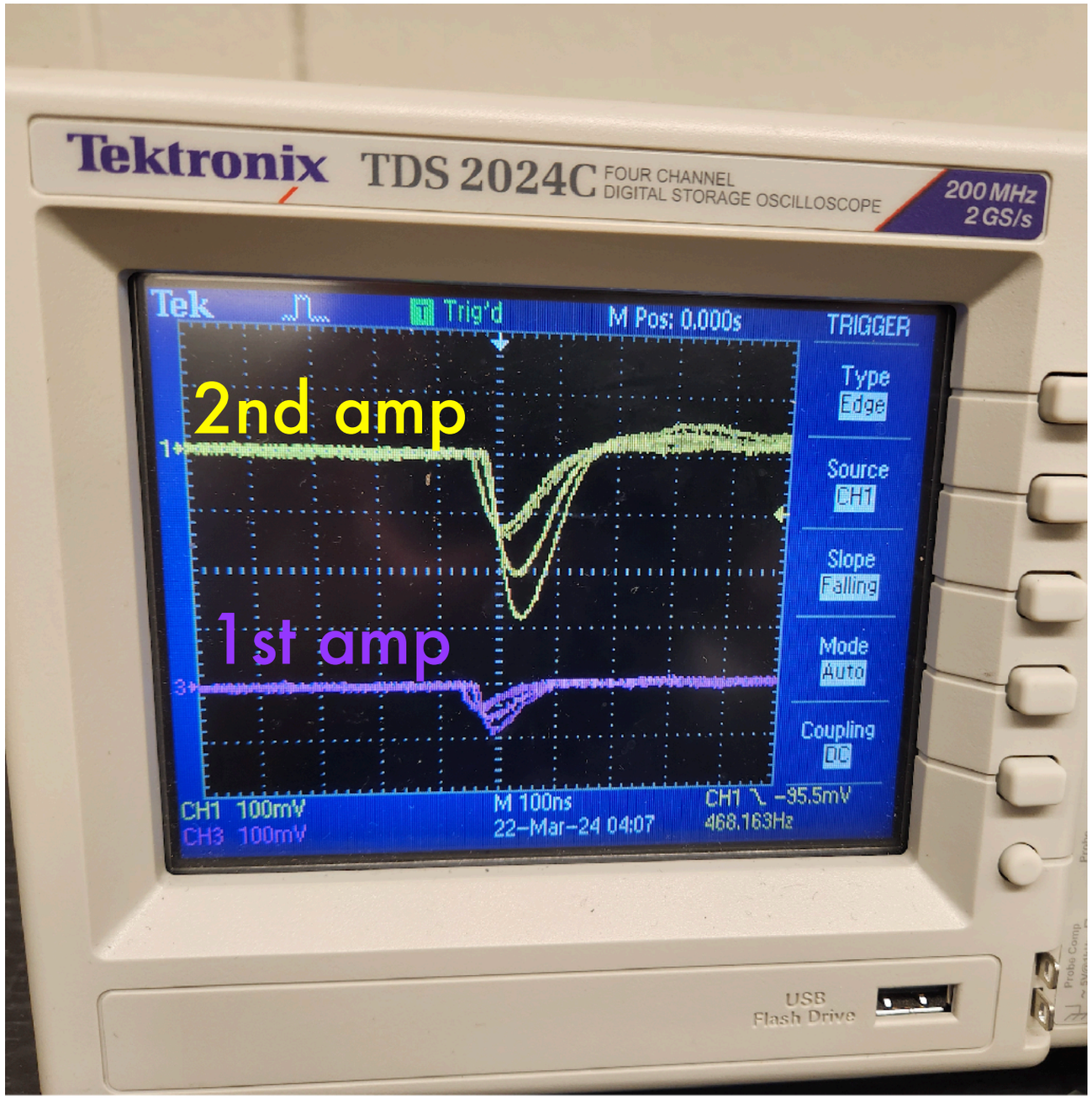
SFILs - Electronics Board



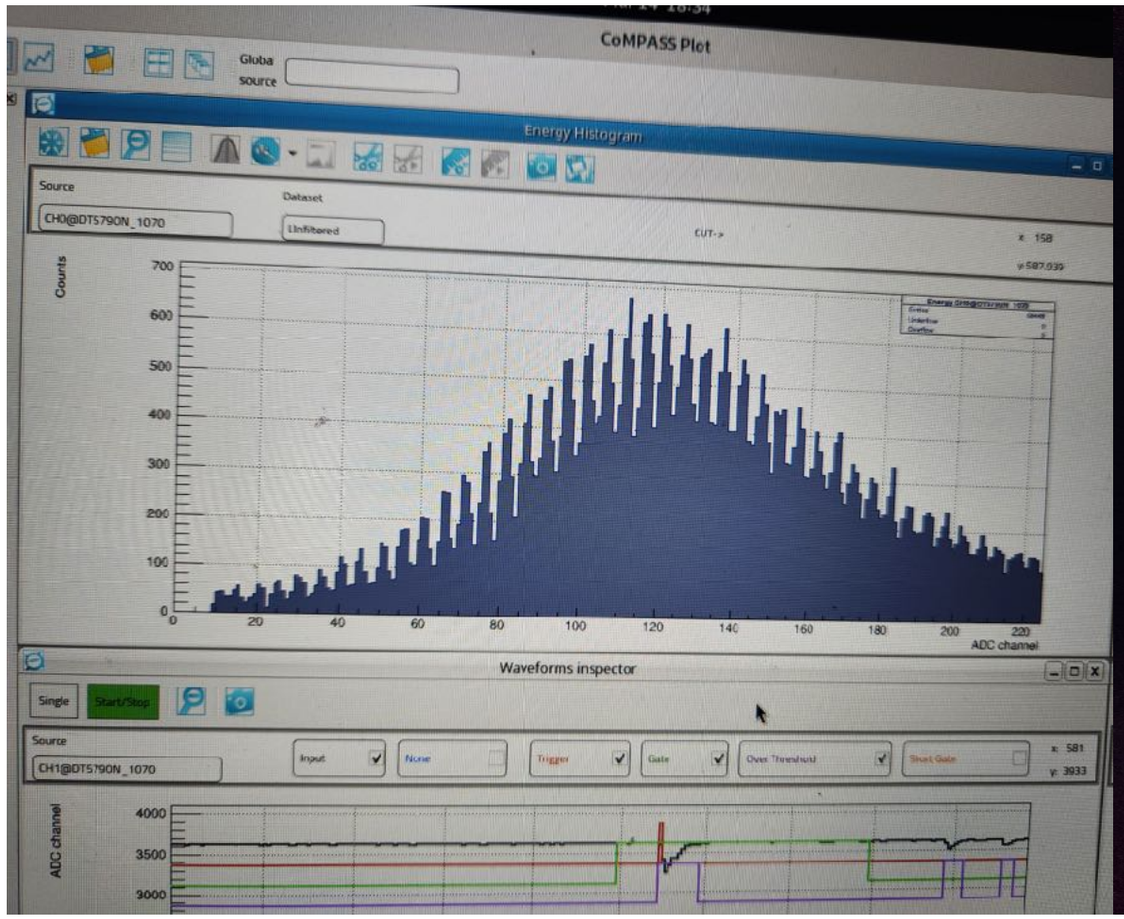


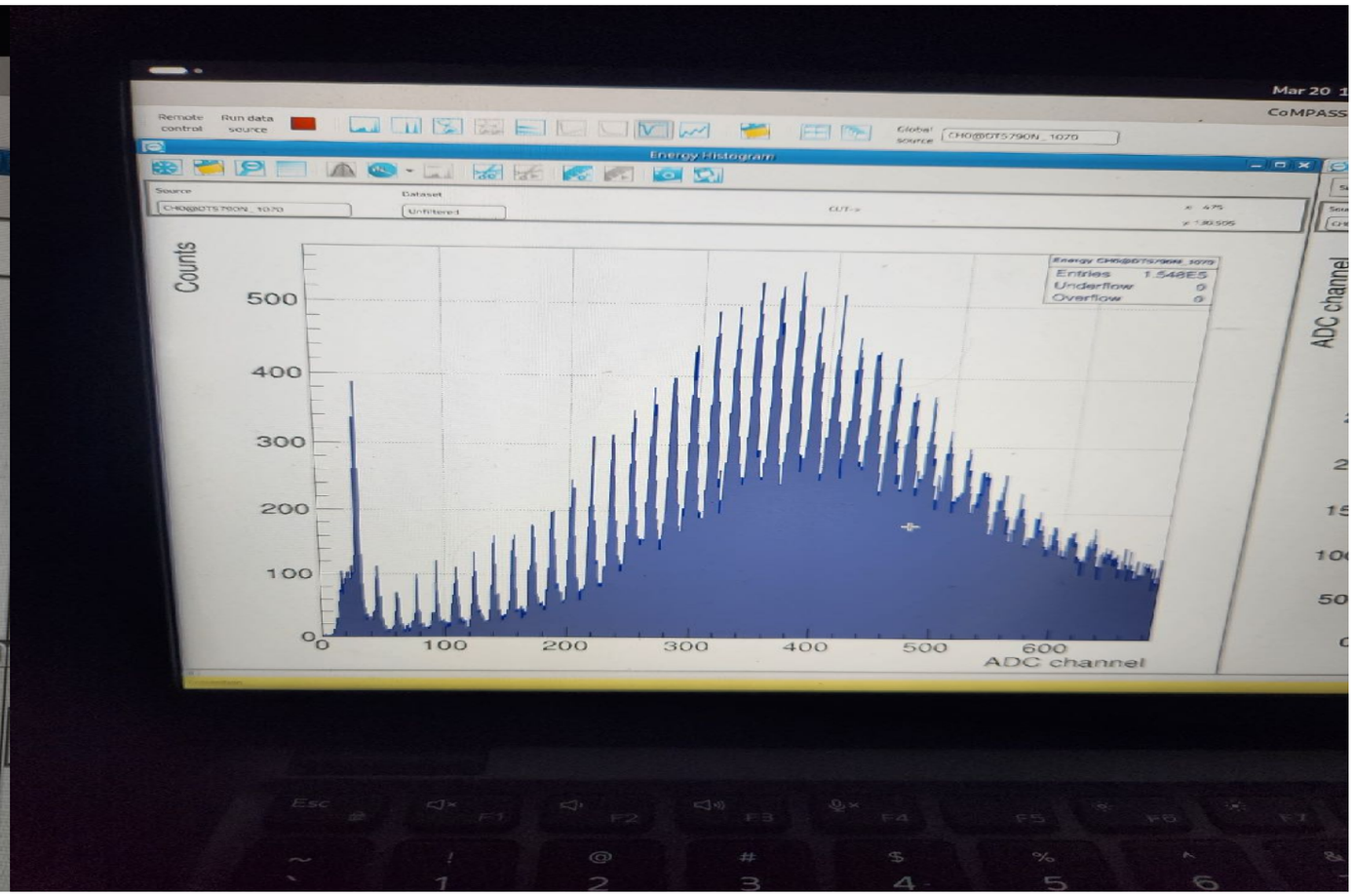
SFILs - Electronics Board





SFILs - Electronics Board



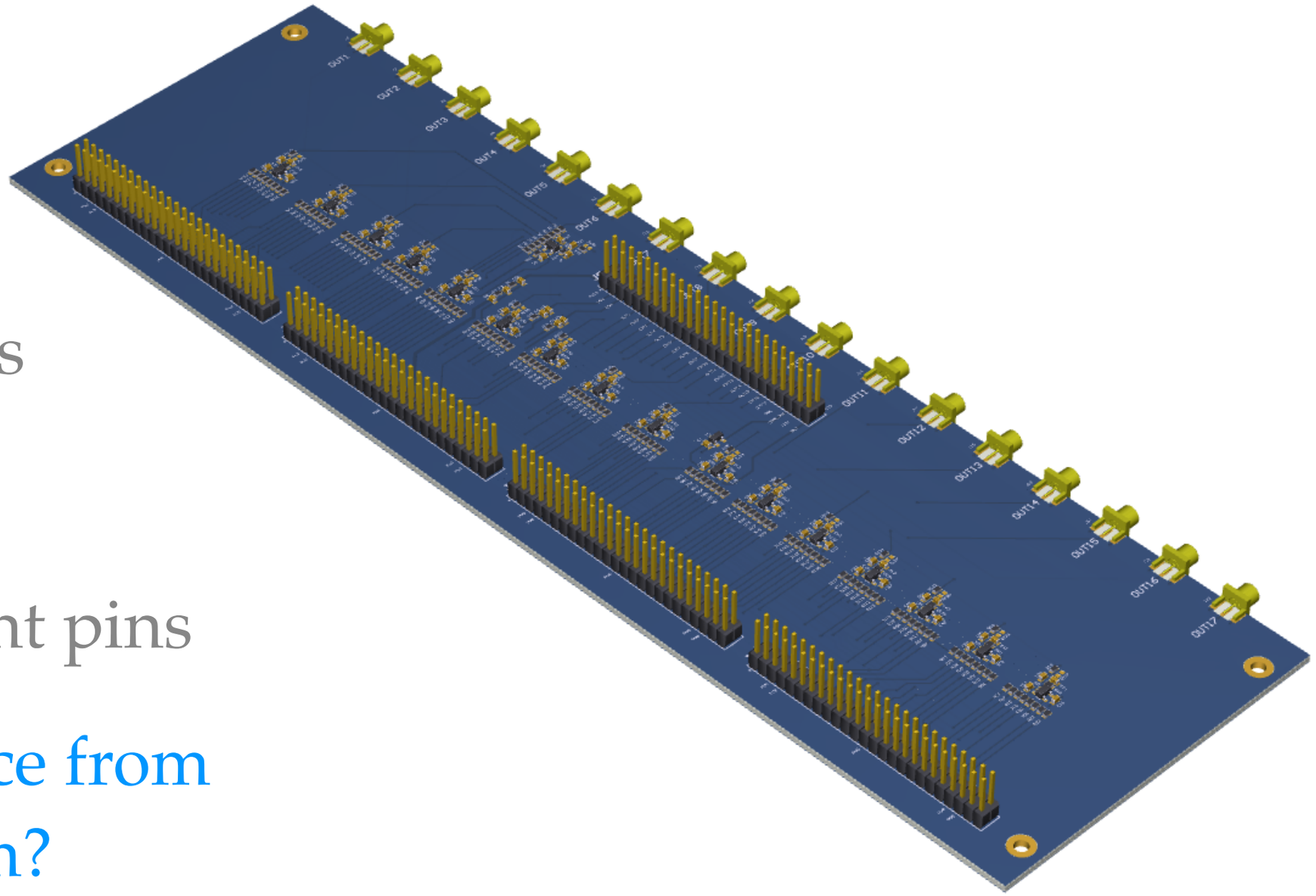


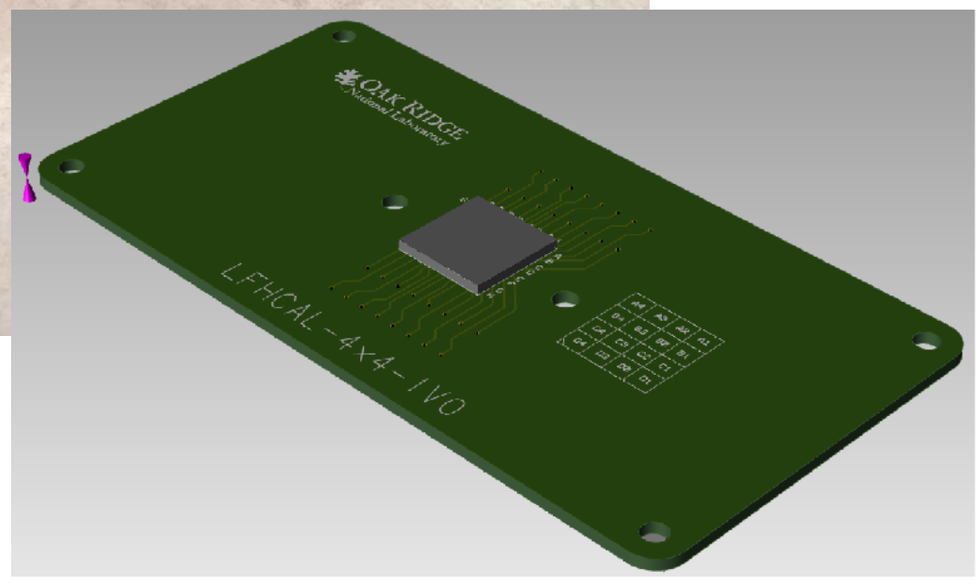
1st stage amp: x~1.3

2nd stage amp: x10

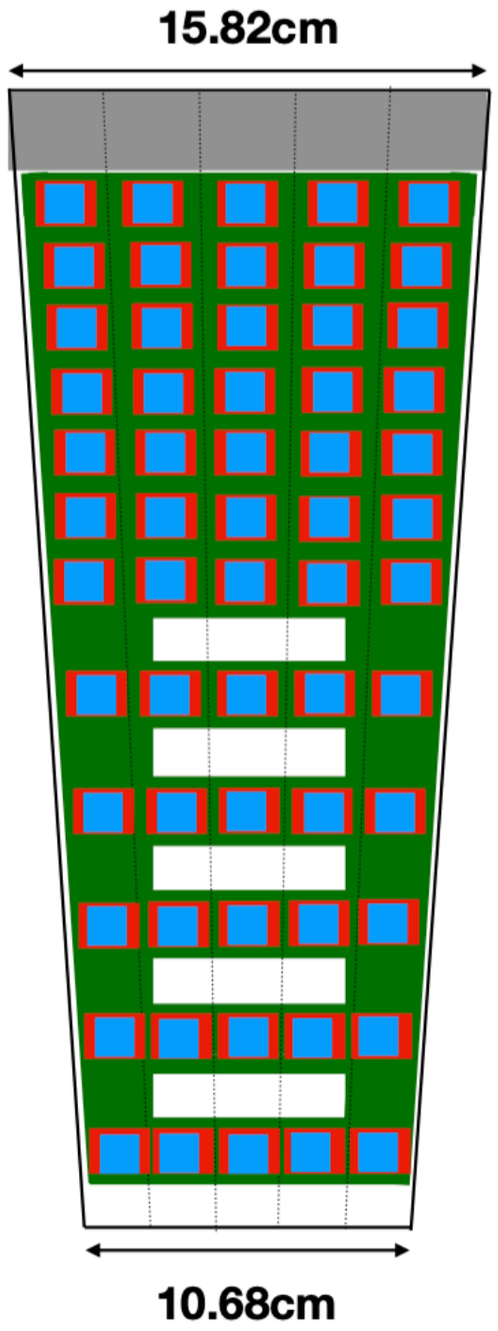
SFILs - Electronics Board

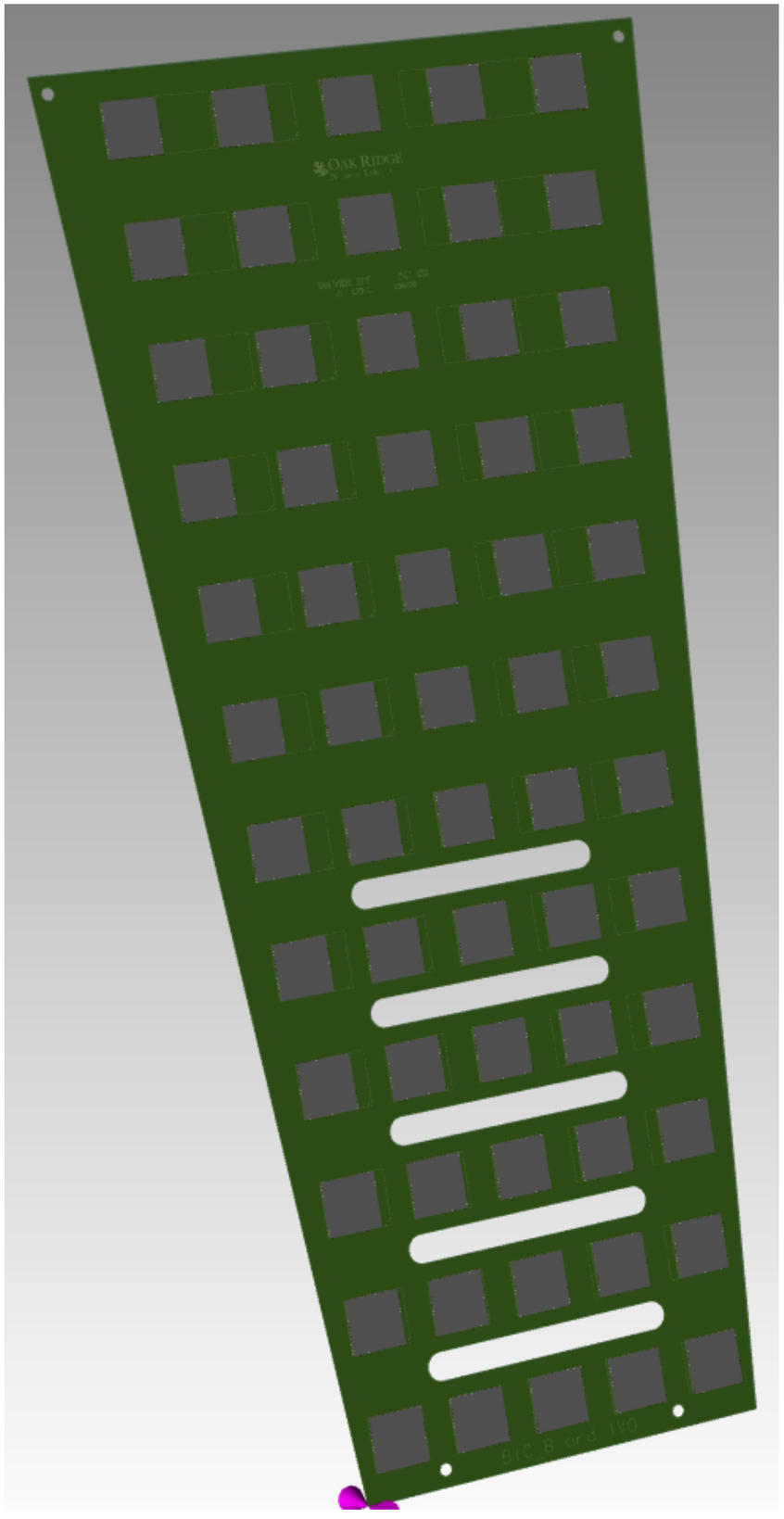
- MCX connectors
- Modify: pinout
- Keep: checkpoint pins
- Footprint: reduce from 89mm x 300 mm?





Testing at ORNL





Testing at ORNL

Summary

- **Progress in drawings at ANL**
  - U of Alberta making drawings
  - PED, First Article
    - **ESB @ Regina** (ANL, UofA-MRS, ORNL, Manitoba)
      - PED Funds: Mech Eng/Elec Eng, Postdoc, M&S
      - Timeline: ~ 15 mo for test article (June 2025++).

Backup slides

GlueX-BCAL SiPM & Electronics

Heat output

- From Fernando (2/19/2024): “SiPMs produce negligible heat but the bias distribution network does, still not anything comparable to what the preamps produce. Power consumption per wedge is less than 8 W. 400 W at each BCAL end.”
- From Tim (2/19/2024): “Each chiller is 1KW (1 at each end). There are 2 wedges in series (24 parallel circuits) and the temperature rise of the water is about 0.5C from inlet to outlet. Bias is adjusted for this”.
- HGCROC and AstroPIX contributions to heat (not in this talk).

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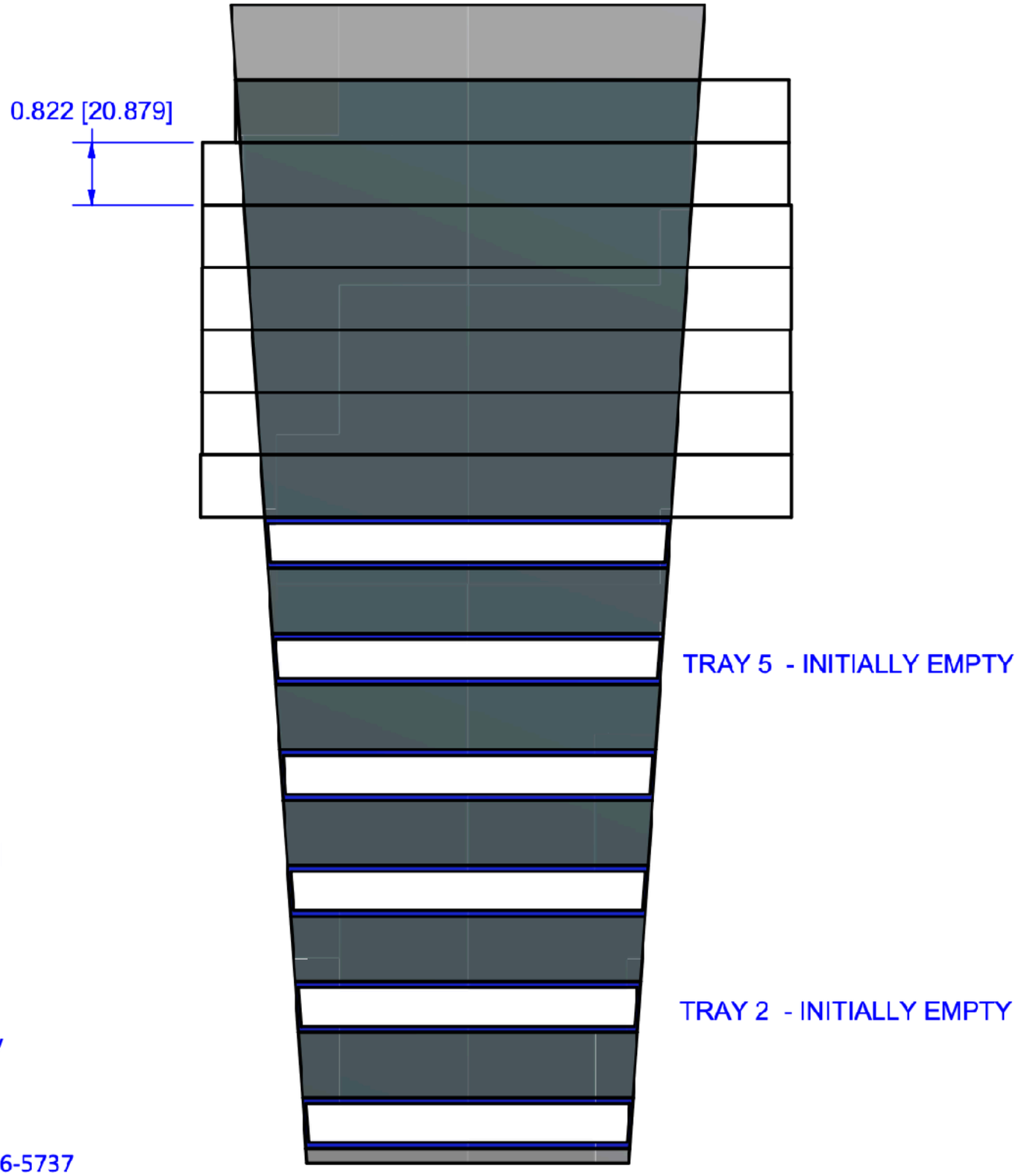
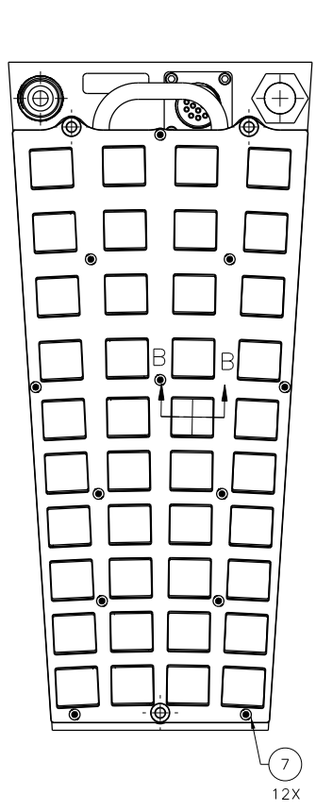
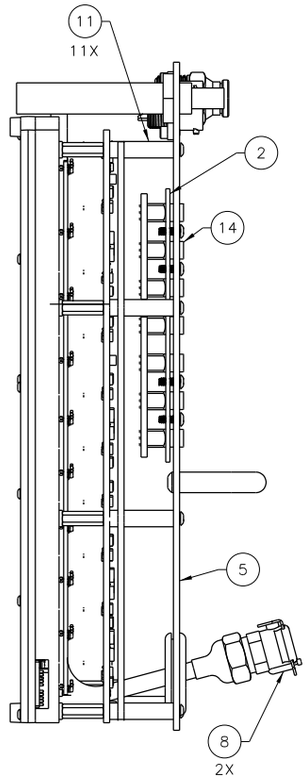


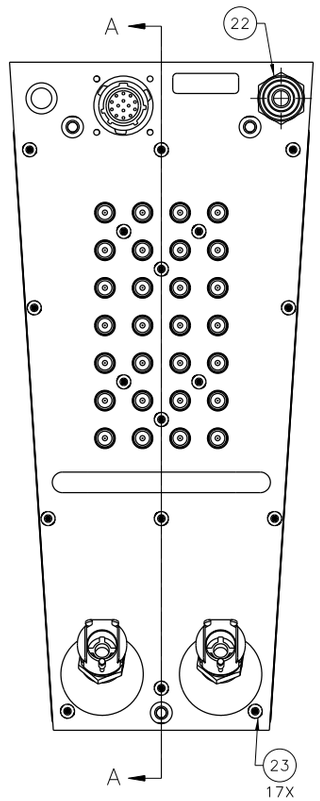
VIEW3
SCALE 1 / 2 INCHES [mm]

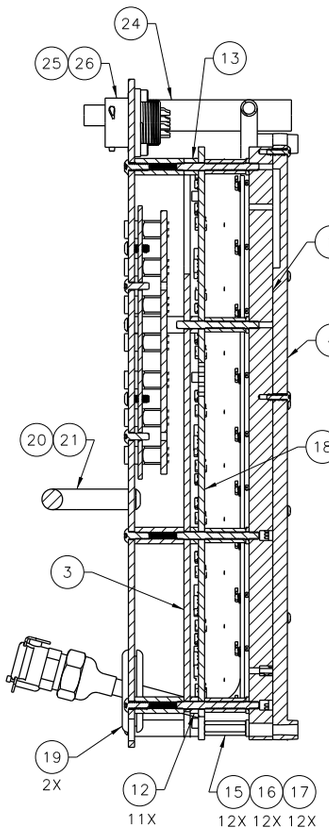
Kevin Bailey
Medium Energy Group
Physics Division
Bldg 203 F-126
Argonne National Laboratory
9700 S Cass Ave
Argonne, IL 60439
630-252-4036
Telecommuting - Cell 630-776-5737

REVISION HISTORY				
ZONE	REV	DESCRIPTION	DATE	APPROVED
VAR	A	COMPLETE REDESIGN CLH 18JAN13		









SECTION A-A

NOTES:

1. SUGGESTED SOURCE OR JLAB APPROVED ALTERNATE

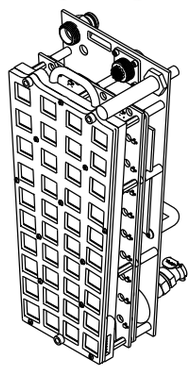
DIGI-KEY CORPORATION 1-800-344-4539 www.digikey.com	ALLIED ELECTRONICS (866) 433-5722 WWW.ALLIEDELEC.COM
MCMASTER-CARR 1-630-833-0300 www.mcmaster.com	MICHELL INSTUMENTS UK (44) 01353 658000 www.michell.com

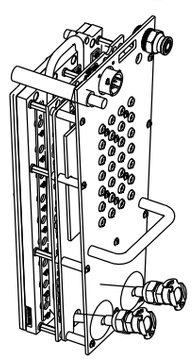
2. ITEMS 22 AND 24 ONLY USED AS NEEDED. WHEN NOT USED, HOLES IN COVER WILL BE PLUGGED.

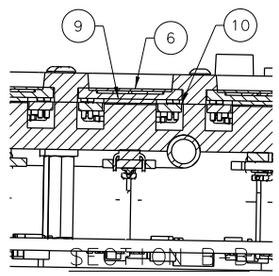
QTY REQD	ITEM NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL SPECIFICATION	NOTES
4	26	MCMASTER-CARR #92196A105	HEX HD CAP SCREW #4-40 X .18 LG	18-8 SS	1
1	25	ALLIED ELECTRONICS 70129601	SQ FLANGE RECEPTACLE W/14 PIN CONTACTS (SOURIAU #UTS012E14P)		1
1	24	MICHELL INSTRUMENTS PCMINI-52	HUMIDITY AND TEMP MINI PROBE		1 & 2
17	23	MCMASTER-CARR #92949A107	BUTTON HD CAP SCREW #4-40 X .31 LG	18-8 SS	1
1	22	MCMASTER-CARR #51915K140	PUSH-TO-CONNECT ADAPTER FOR 3/8" TUBE OD X 3/8" NPTF MALE PIPE	VARIOUS	1 & 2
2	21	MCMASTER-CARR #93310A194	BUTTON HD SOC HD CAP SCREWMMET #8-32 X 1/2" LG SELF LOCKING	18-8 SS	1
1	20	MCMASTER-CARR #1568A43	ROUND-GRIP PULL HANDLE 3" CTR TO CTR	ALUMINUM	1
2	19	MCMASTER-CARR #9307K76	PUSH-N FLEXIBLE GROMMET 1/4" ID, 1-1/4 OD	RUBBER	1
1	18		AMPLIFIER AND SIGNAL PCB		
12	17	MCMASTER-CARR #90295A346	FLAT WASHER, BLACK #4 SCREW SIZE, .25 OD	NYLON 6/6	1
12	16	MCMASTER-CARR #91115A518	FEMALE HEX STANDOFF, 4-40 3/16 HEX, 5/8 LONG	18-8 SS	1
12	15	MCMASTER-CARR #95412A360	THREADED STUD, FULL THREAD 4-40 X 1.25 LG	18-8 SS	1
1	14		INTERCONNECT PCB ASSEMBLY		
1	13	MCMASTER-CARR #94639A486	SPACER, #4 UNTHREADED 1/4" OD X 7/32 LG	NYLON	1
11	12	MCMASTER-CARR #94639A199	SPACER, #4 UNTHREADED 1/4" OD X 1/8 LG	NYLON	1
11	11	MCMASTER-CARR #93330A437	STANDOFF, #4-40 FEMALE 1/4" OD X 3/4 LG	ALUMINUM	1
40	10		FERNANDOS C-BOARD		
40	9	DIGIKEY CORP 3M9593-ND	THERMAL PAD, 3M 5519/0.5mm THICK	SILICONE	1
2	8	MCMASTER-CARR #5012K75	QUICK DIS-CONNECT COUPLING 1/4" MALENPT W/VALVE	ACETAL	1
12	7	MCMASTER-CARR #92949A078	BUTTON HD CAP SCREW #2-56 X .31 LG	18-8 SS	1
40	6	HAMAMATSU PHOTONICS K30-F10530	HAMAMATSU SiPM LIGHT SENSOR S10943-0258(X) MPPC ARRAY		
1	5	D00000-01-07-2067	READOUT MODULE COVER PLATE		
1	4	D00000-01-07-2070	SINGLE RADIAL SiPM HOLDER		
1	3	D00000-01-07-2068	HEAT TRANSFER PLATE		
1	2	D00000-01-07-2068	INTERCONNECT PULL PLATE		
1	1	D00000-01-07-1021	COOLING PLATE ASSY		

PARTS LIST

GlueX-BCAL Wedge







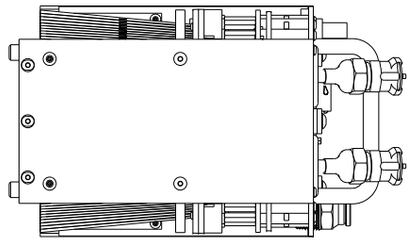
SECTION B-B

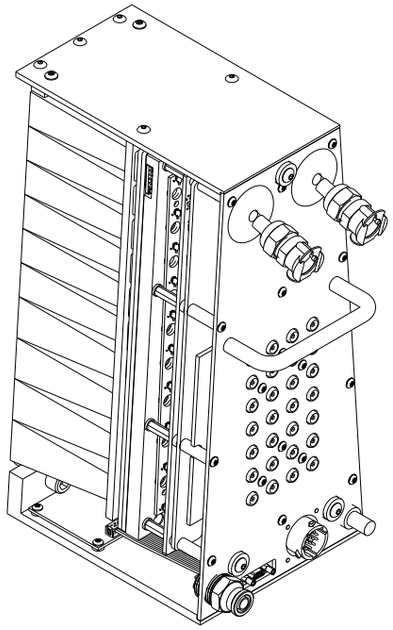
DOCUMENT CONTROL STAMP	DIM & TOL PER ASME Y14.5 UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE: FRACTIONS ± N/A DECIMAL .X ±.1 .XX ±.01 .XXX ±.005 ANGLES ± .50° THIRD ANGLE PROJECTION	TRACKING NO. N/A APPROVALS / DATE DRAWN C L HUTTON 21MAR11 CHECKED J FOCHTMAN 25MAR11 APPROVED J FOCHTMAN 25MAR11 APPROVED T WHITLATCH 28MAR11	United States Department of Energy Jefferson Lab Thomas Jefferson National Accelerator Facility Newport News Virginia HALL D - GLUEX DETECTOR BARREL CALORIMETER COOLING/ELEC MODULE
MATERIAL SEE PARTS LIST FINISH MACHINED SURFACES 125 UNLESS OTHERWISE NOTED DEBURR & BREAK ALL SHARP EDGES DO NOT SCALE DRAWING			SIZE D | DWG. NO. D00000-01-07-1023 | REV. A SCALE 1:1 | USED ON ASSY NO. D00000-01-07-1011 | SHEET 1 OF 1

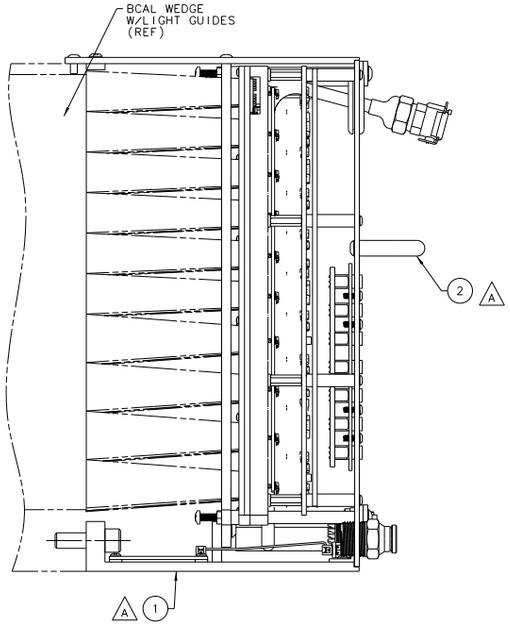
Approved: 01/23/2013; E-Sign ID: 225000; Signed By: Approver 1: T. Whitlatch; Checker: J. Fochtman; DCG: T. Fusil

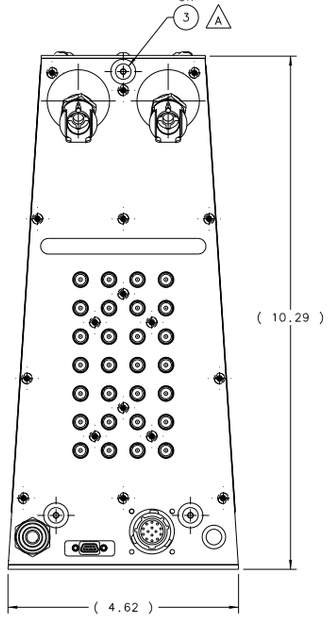
REVISION HISTORY				
ZONE	REV	DESCRIPTION	DATE	APPROVED
6C, 7B 3E, 3B	A	UPDATED ITEMS 1 & 2. ITEM 3 WAS SPACER. DELETED ITEMS 4-6 & NOTE 1. DRAWING NAME WAS READOUT MODULE - O GROOVE	04AUG14 04AUG14	R GETZ WHITLATCH

GlueX-BCAL Wedge









A

A

QTY REQD	ITEM NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL SPECIFICATION	NOTES
3	3	D00000-01-07-2097	BCAL STANDOFF ASSY		
1	2	D00000-01-07-1023	COOLING/ELEC MODULE		
1	1	D00000-01-07-1016	CAGE ASSY W/OUT GROOVE		

PARTS LIST

EACH SHEET OF MULTI-SHEET DRAWINGS SHALL ALWAYS HAVE THE SAME REVISION LEVEL.

DOCUMENT CONTROL STAMP

DO NOT SCALE DRAWING

DIM & TOL PER ASME Y14.5, UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES ARE: FRACTIONS ± N/A; DECIMAL .X ± .1, .XX ± .01, .XXX ± .005; ANGLES ± .50'

MATERIAL: SEE PARTS LIST

FINISH: MACHINED SURFACES 125 UNLESS OTHERWISE NOTED. DEBURR & BREAK ALL SHARP EDGES

THIRD ANGLE PROJECTION

TRACKING NO. N/A

APPROVALS	DATE
DRAWN C L HUTTON	01NOV10
CHECKED J FOCHTMAN	25MAR11
APPROVED J FOCHTMAN	25MAR11
APPROVED T WHITLATCH	28MAR11

United States Department of Energy — Jefferson Lab — Newport News Virginia

HALL D - GLUEX DETECTOR BARREL CALORIMETER READOUT MODULE ASSY

A

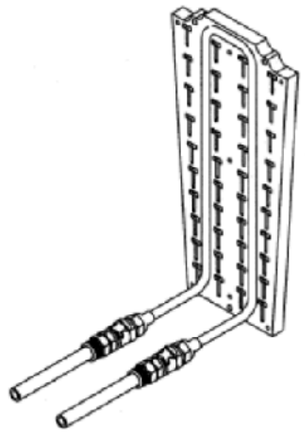
SIZE E | DWG. NO. D00000-01-07-1011 | REV. A

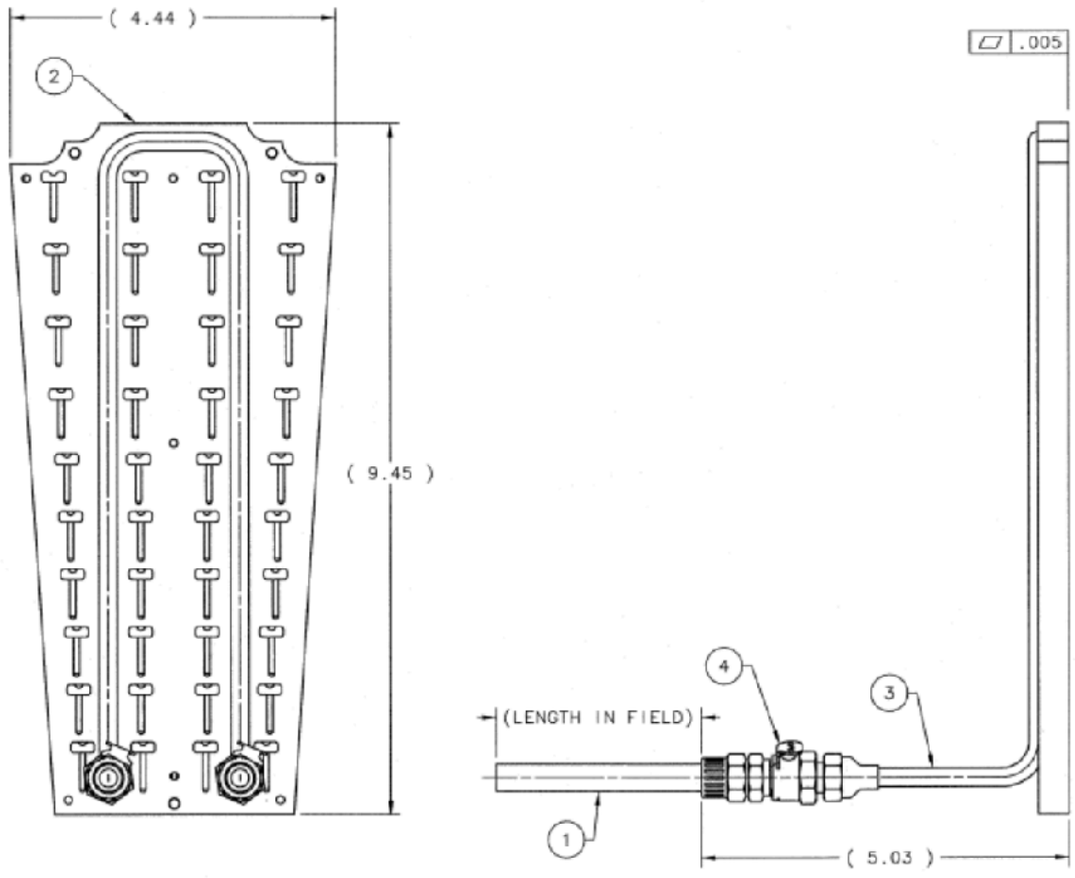
SCALE 1 : 1 | USED ON ASSY NO. D00000-01-07-1010 | SHEET 1 OF 1

Approved: 08/06/2014; E-Sign ID: 280054; Signed By: Approver 1: T. Whitlatch; Checker: R. Getz; DOE: T. Fusi

Cooling Assembly

REVISION HISTORY				
ZONE	REV	DESCRIPTION	DATE	APPROVED





NOTES:

1. SUGGESTED SOURCES OR JLAB APPROVED ALTERNATE:

   COLDER PRODUCTS COMPANY
   1-800-444-2474
   www.colder.com

2. SOLDER ITEM 2 TO ITEM 3 IN SUCH A WAY TO ENSURE GOOD THERMAL AND MECHANICAL CONTACT.

4. SOLDERING ITEMS 2 & 3 TOGETHER USING 50/50 TIN-LEAD SOLDER WITH GENERAL PURPOSE FLUX USING ANY STANDARD SOLDERING PROCESS.

5. PROCESS SHOULD ENSURE COMPONENT TEMPERATURES ARE MAINTAINED BELOW 800°F.

6. THOROUGHLY CLEAN ALL FLUXES WITH APPROPRIATE METHODS TO ENSURE REMAINING FLUX IS COMPLETELY REMOVED OR RENDERED NON-CORROSIVE

7. LENGHT OF ITEM 1 TO BE DECIDED IN FIELD TO ALLOW FOR APPROPRIATE LENGTH AND THEN INSTALLED AS SHOWN.

QTY REQD	ITEM NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL SPECIFICATION	NOTES
2	4	COLDER PRODUCTS MCD1002	1/8 NPT VALVED COUPLING BODY	BRASS	1
1	3	D00000-01-07-2041	COOLING TUBE W/FITTINGS		
1	2	D00000-01-07-2040	COOLING PLATE		
2	1	D00000-01-07-1022	HOSE ASSY		

PARTS LIST

DOCUMENT CONTROL STAMP

MATERIAL: SEE PARTS LIST

FINISH: MACHINED SURFACES 125 UNLESS OTHERWISE NOTED. DEBURR & BREAK ALL SHARP EDGES

DO NOT SCALE DRAWING

DIM & TOL PER ASME Y14.5 - UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES ARE: FRACTIONS ± N/A; DECIMAL .X ± .1, .XX ± .03, .XXX ± .005; ANGLES ± .50°

THIRD ANGLE PROJECTION

TRACKING NO. N/A

APPROVALS	DATE
DRAWN C.L HUTTON	07MAR11
CHECKED	21 MAR 11
APPROVED	21 MAR 11
	21 MAR 11

United States Department of Energy — Jefferson Lab — Newport News Virginia

HALL D - GLUEX DETECTOR
BARREL CALORIMETER
COOLING PLATE ASSY

SIZE D | DWG. NO. D00000-01-07-1021 | REV. —

SCALE 1:1 | USED ON ASSY NO. D00000-01-07-1011 | SHEET 1 OF 1

Series "ARV"
Thermoplastic Air Release Valve

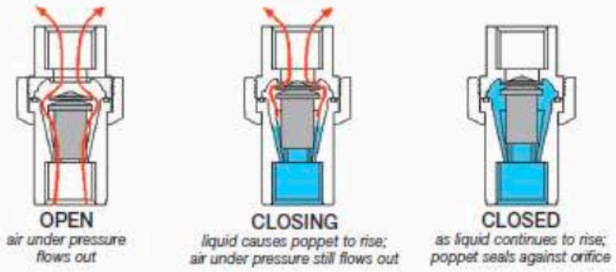
Self-Guided Poppet Assures Dependable, Repetitive Operation

Features:

- **Safety:** Allows safe expulsion of unwanted air in piping system.
- **Dependability:** Unique self-guided poppet assures minimal emission of system liquid prior to sealing.
- **Convenience:** Union simplifies valve inspection/removal with minimum piping breakdown.
- **Minimum Closing Pressure:** Closes at 0 PSI, as long as liquid is present. Valve closes as liquid rises, after virtually all unwanted air is forced out. Seals bubble-tight at system pressures as low as 10 psi (EPDM seals).
- **Cost Efficient:** Designed to improve system performance and competitively priced.
- **Superior Design** Poppet seals more reliably than ball design; does not deform under pressure like a hollow ball.
- **Corrosion Resistant:** Top quality thermoplastics and elastomers resist chemical attack and protect system purity. No metal components in Series ARV.

Description

Series ARV is a normally-open valve. Until your system is pressurized, the valve is simply open, and air is present. As pressure builds within the system, unwanted air is forced to the highest point in the system, i.e., the normally-open air release valve. When pressure within the system exceeds atmospheric pressure, air is expelled. As liquid rises, the poppet becomes buoyant and eventually closes. (Note, minimum specific gravity of liquid must be .9 or higher). It is possible that trace amounts of air will remain in the system, depending on the rapidity with which the valve closes. It is also likely that some trace amounts of process liquid will be emitted. At system pressure of 10 PSI (with EPDM elastomer), the poppet will seal bubble-tight against the orifice. When pressure and liquid level drop, the valve will automatically re-open.*



The poppet is guided by a series of thermoplastic ribs within the valve. The poppet is a unique design by Plast-O-Matic Valves, Inc. that is engineered to provide a balance of buoyancy and sealability. This balanced poppet is the key to the superior performance of this valve: it is dense enough to permit maximum emission of unwanted system air, yet buoyant enough to affect a

continued on back

PLAST-O-MATIC VALVES, INC.
1384 Pompton Avenue, Cedar Grove, New Jersey 07009
(973) 256-3000 • Fax (973) 256-4745
www.plastomatic.com • info@plastomatic.com

NEW! Degassing Valve For Continuous Automatic Venting

All Plastic Design • United States Patent #7,481,238 B2

FEATURES:

- Reduces replacement costs – no internal or external metal components; ideal for aggressive environments.
- Placed at the high point of a piping system, this innovative valve will vent gas as it occurs. A unique float/actuating lever allows the vent orifice to open when gas is present. After gas vents, liquid forces the vent to close. Whenever gas accumulates, the valve will re-open until the gas is vented.
- All-plastic construction designed for sodium hypochlorite, ozone systems, or any liquids prone to outgassing.
- Series DGV is designed for systems that continuously generate trace amounts of gasses. For system start-up requiring rapid expulsion of larger volume of air or gasses, see Series ARV.

Installation Notes

Series DGV should be installed at the highest possible point in a piping system, and it must be oriented upright. In most cases, residual liquid and/or vapor in the valve may be expelled or "spit" from the outlet vent. Therefore, it is recommended to pipe the outlet port to a safe area for hazardous liquids, or use a standpipe for non-hazardous liquids.

Important Note on DGV use with Salt Solutions & Other Liquids that may Precipitate Solids:

Should the DGV be installed in liquids which have the possibility of precipitating solids out of solution, it is recommended to periodically clean the DGV in warm or cold water to remove debris and/or precipitated salts from the orifice and the seat. To disassemble use an appropriate spanner wrench inserted into the two 1/8" holes in the top of the valve, unscrew and remove the float/seat assembly. Then clean and re-assemble the DGV.

It is further recommended to keep a spare seal kit on hand. When the DGV is disassembled for cleaning, examine the spring o-ring (the o-ring retaining the seat and float arm) for elasticity and general overall condition. If lack of elasticity or general wear is evident, replace the seals.

SPECIFICATIONS AND DIMENSIONS:

Body Materials Available:	PVC, CPVC, Polypro or PVDF
Elastomers:	FKM (Viton) or EPDM
Additional Wetted Material:	Natural Polypropylene
	Maximum Operating Pressure:100 psi
Minimum Specific Gravity:	0.9
Dimensions:	4 1/4" high x 2 1/4" diameter
Vent Port:	1/8" NPT
System Connection:	1/4" NPT; valve must be oriented vertically as illustrated above.

Specifications and Dimensions subject to change.

Series DGV Part Numbers Pipe Size (NPT)	PVC	CPVC	Polypro	PVDF
1/2"	DGV050V-PV	DGV050V-CP	DGV050V-PP	DGV050V-PF

DGV (series) **050** (size) **V** (seal material) - **PV** (body material)
Part numbers shown are **FKM** seals. For **EPDM** seals, change **"V" to "EP."** For example, DGV050EP-PV.
• Standard connections are threaded. For other connection types, consult factory.

APPENDIX 5: Tubing (Page 1 of 1)

Crack-Resistant Polyethylene Tubing

1/4" ID, 3/8" OD, 1/16" Wall Thickness, White

Semi-Clear White

Length, ft.
✓ 100

Each
ADD TO ORDER

In stock
$20.00 Each
5181K25

You'll get superior resistance to stress cracking along with flexibility at low temperatures. Made of linear low-density polyethylene (LLDPE), this tubing won't impart tastes or odors to the fluid passing through. Use with water, air, food and beverage, and ethylene glycol. Tubing is made from FDA-compliant resins.

View information about the chemical compatibility of polyethylene tubing.

ID	1/4"
OD	3/8"
Wall	1/16"
Bend Radius	3"
Maximum psi @ 73° F	210
Length	100 ft.
Temperature Range	-100° to 175° F
Additional Specifications	Semi-Clear White—Inch Sizes
	Flexible
	Firm (Shore D44)
	Use with compression fittings
	Chemical Compatibility of Polyethylene Tubing

High-Pressure Tygothane Polyurethane Tubing

Clear, 1/2" ID, 3/4" OD, 1/8" Wall Thickness

Length, ft.
✓ 100

Each
ADD TO ORDER

In stock
$443.00 Each
5439K23

APPENDIX 7: Turbine Flow Meter (Page 1 of 1)

Seametrics

S-SERIES
SPT, SPX Low Flow Meters

FEATURES

Thread-in Sensor, Field Replaceable, 6-24 Vdc pulse

18' Sensor Cable

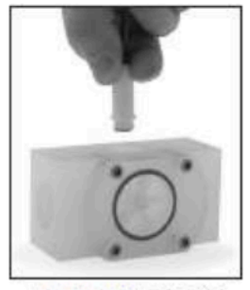
Removeable Lens Assembly

Standard Acrylic Top (SPX)

Hex Screws

Female NPT Ports (SAE optional)

(Internal)
Jewel bearings
Kynar/Carbide or Kynar/Ceramic Rotor Assembly
EPDM (SPX) or Teflon-coated Viton (SPT) O-ring



FIELD REPLACEMENT
OF SENSOR

BCAL Light Guides

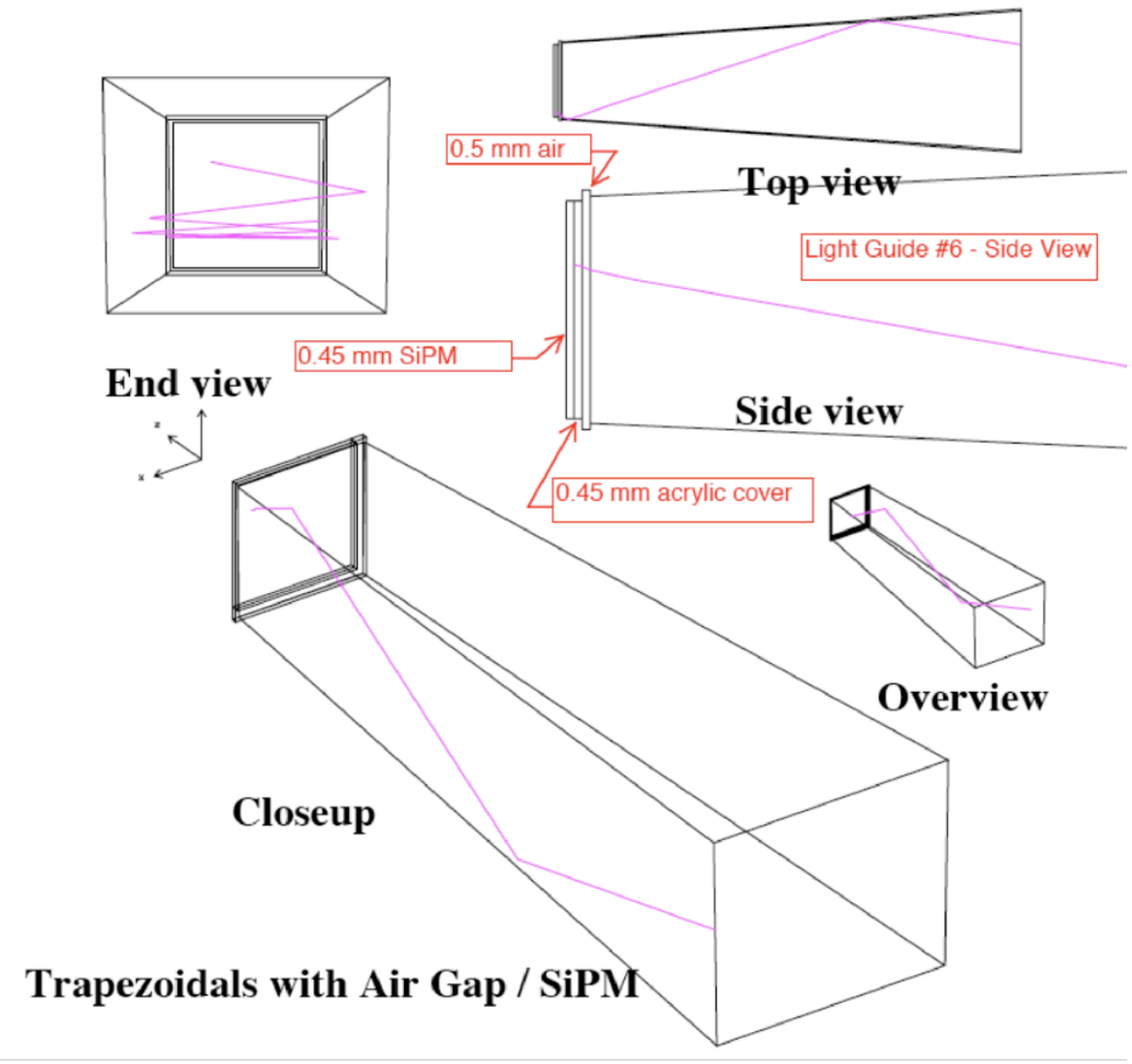
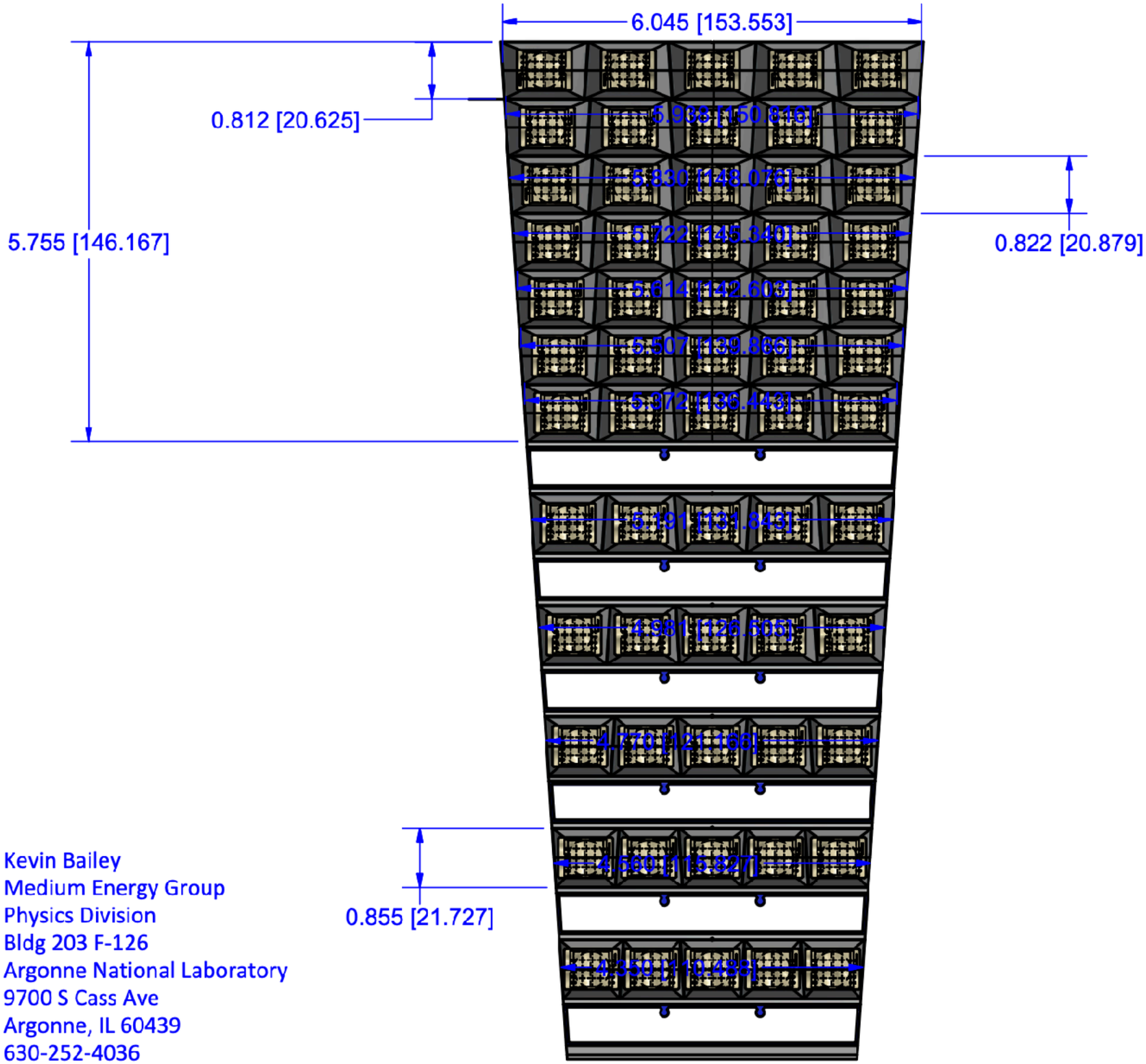


Table 1: Sizes of the ten production light guides for the Bcal. The trapezoid dimensions are denoted using the notation (bottom-top × height).

Configuration	Input Trapezoid (mm^2)	Length (cm)	Output Trapezoid (mm^2)	Eff (%)
g1	20.96-21.64 × 20.57	8	13.19-13.61 × 13.19	0.748
g2	21.64-22.30 × 20.57	8	13.19-13.61 × 13.19	0.723
g3	22.30-22.99 × 20.57	8	13.19-13.61 × 13.19	0.701
g4	22.99-23.65 × 20.57	8	13.19-13.61 × 13.19	0.683
g5	23.67-24.33 × 20.57	8	13.19-13.61 × 13.19	0.662
g6	24.33-25.02 × 20.57	8	13.19-13.61 × 13.19	0.643
g7	25.02-25.83 × 24.64	8	13.19-13.61 × 13.19	0.516
g8	25.83-26.62 × 24.64	8	13.19-13.61 × 13.19	0.503
g9	26.64-27.43 × 24.64	8	13.19-13.61 × 13.19	0.488
g10	27.46-27.84 × 24.64	8	13.19-13.61 × 13.19	0.477

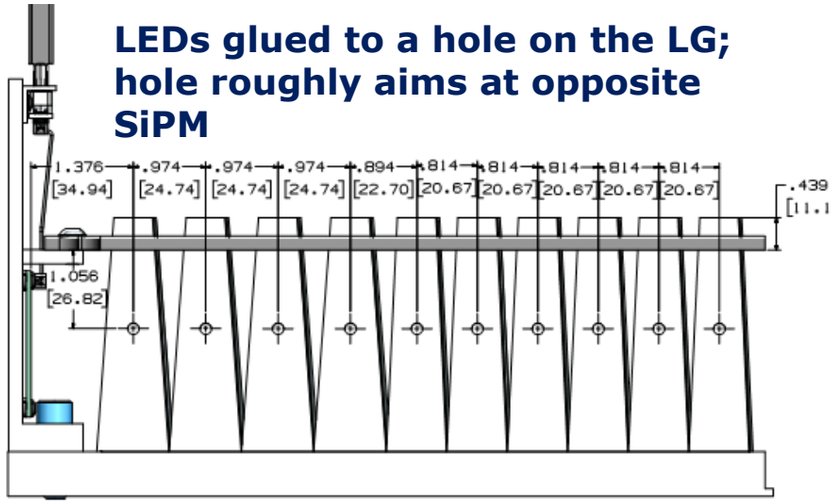


Kevin Bailey
Medium Energy Group
Physics Division
Bldg 203 F-126
Argonne National Laboratory
9700 S Cass Ave
Argonne, IL 60439
630-252-4036
Telecommuting - Cell 630-776-5737

GlueX LMS

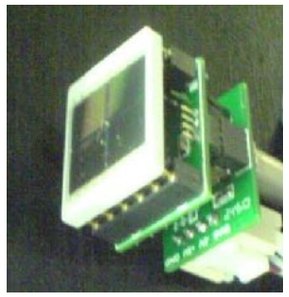
innermost LG 21x21 mm^2, outermost 27x25 mm^2; output faces are 13x13 mm^2 to match SiPM window

LEDs: Bivar, Blue, 465 nm

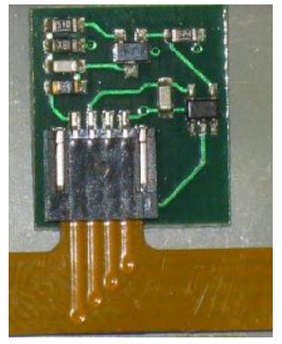


BCAL has 3840 SiPMs, and
3840 LEDs: pulsing both ends decouples SiPM from LED failure

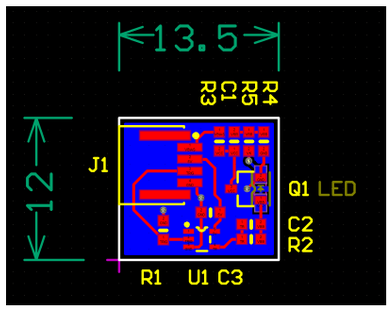
Hamamatsu S12045X



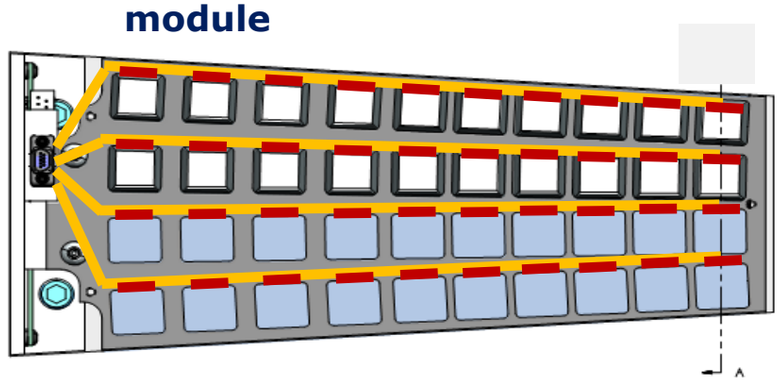
BCAL miniboard on flex cable



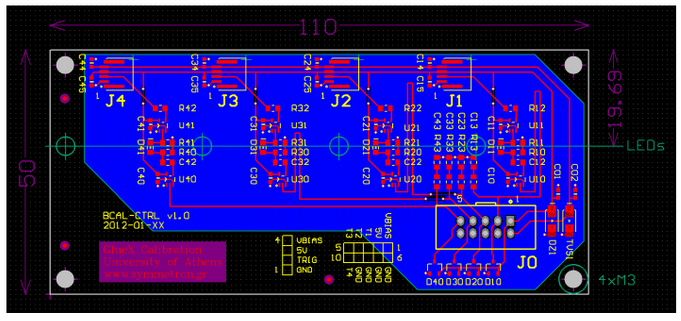
BCAL miniboard layout ("components" side, LED on the other side, shining parallel to the board towards the right)



4 flexible strips per side per module



BCAL Controller layout



- 1 flex cable per row, connecting 10 mini boards; 384 flex cables
- 4 flex cables connected **to** 1 BCAL controller**; 96 BCAL controllers**
- **1 BCAL controller per half module;** light each row independently
- System typically pulsed at 50-100 Hz

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