EMCal Module Production and Sector Assembly

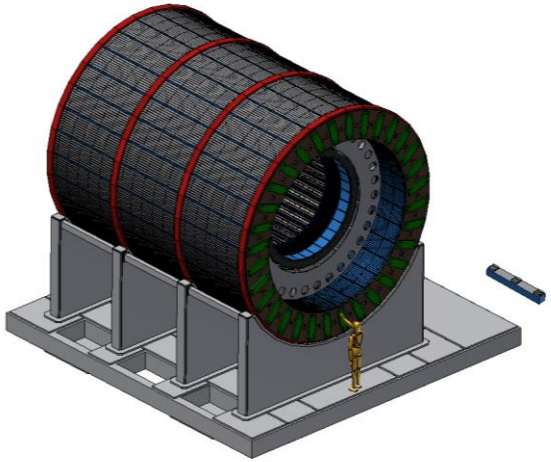
Sean Stoll (BNL)

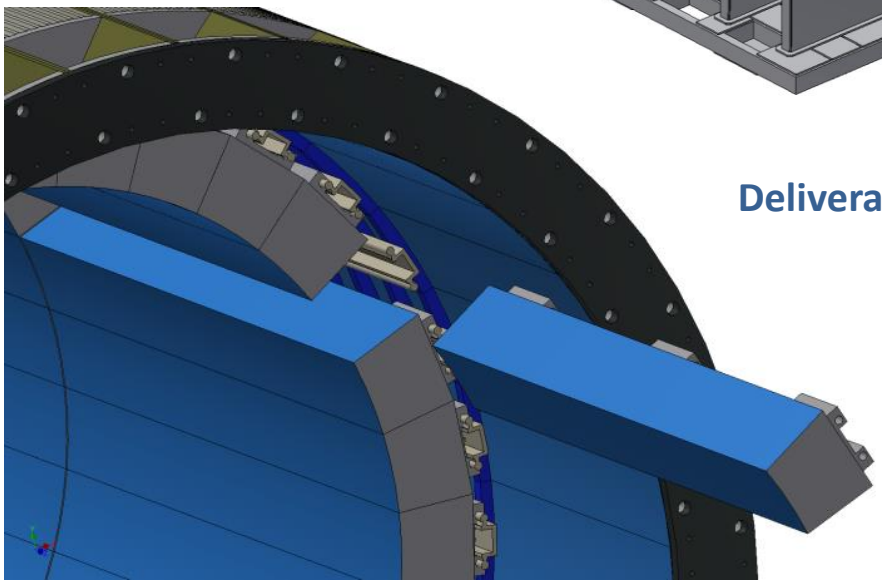
August 2-4, 2017

BNL

EMCAL Subsystem

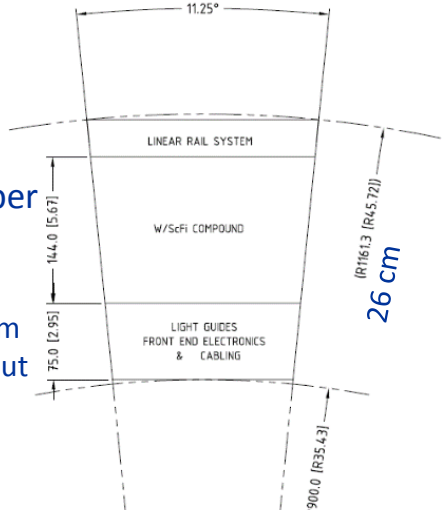
2(±η) x 32 (ϕ) = 64 Sectors





~14 cm absorber (η=0)

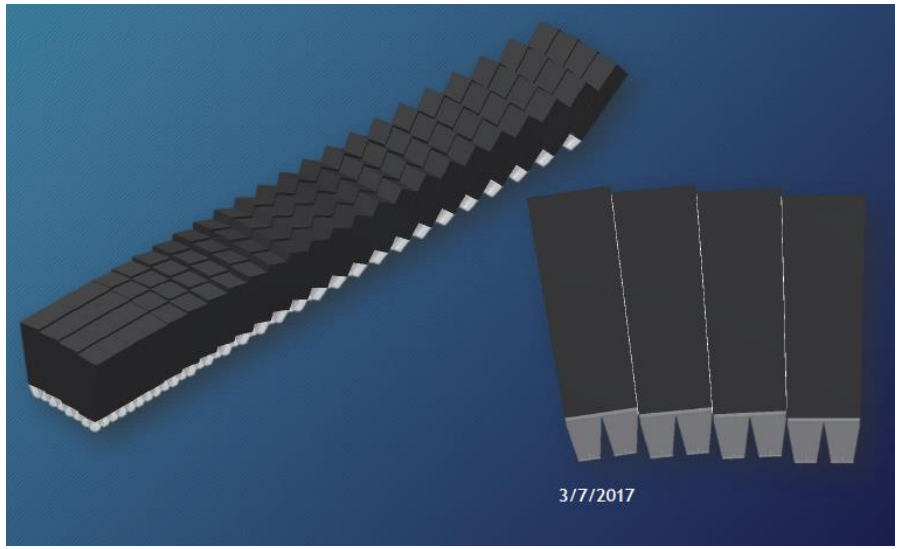
7.5 cm readout



26 cm total radial space

Deliverable: 64 EMCAL Sectors

1 Sector = 24 modules
= 96 Blocks
= 384 towers



Technical Overview

EMCAL Design Specs and Drivers:

- Coverage: $\pm$ 1.1 in η, 2π in ϕ
- Segmentation: $\Delta\eta$ x $\Delta\phi \approx 0.025$ x 0.025
- Readout channels: 96 x 256 = 24576 (towers)
- Energy Resolution: $\sigma_E/E < 15\%/\sqrt{E}$
- Provide an e/h separation > 100:1
- Approximately projective
- Compact ~ 26cm radial space (in order to fit inside Babar solenoid)
- Works inside a 1.5T magnetic field

Physics Contributions:

- Jet measurements (EM component)
- Photon measurements
- Y measurement

Scope

Inside the EMCAL Scope

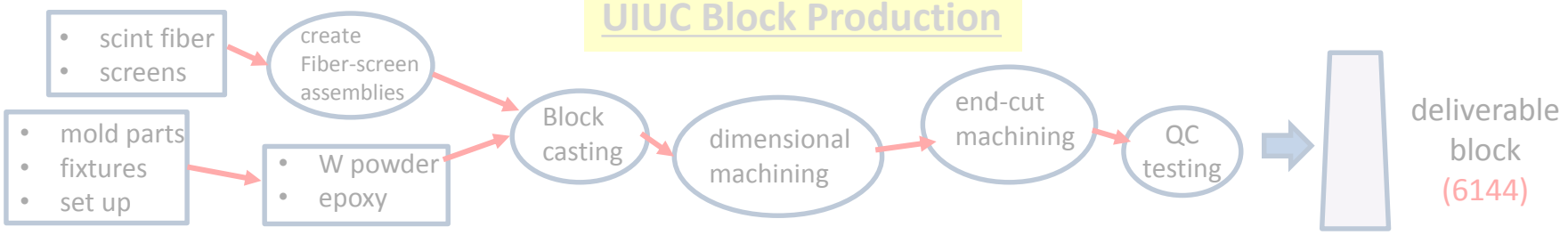
- Fabrication of absorber blocks and assembly into modules & sectors
- Design, procurement and installation of light guides
- Design, procurement and construction of mechanical structures for modules and sectors
- Design, procurement and installation of cooling system
- Installation of front end readout electronics

- The Module Production and Sector Assembly work will be performed at BNL

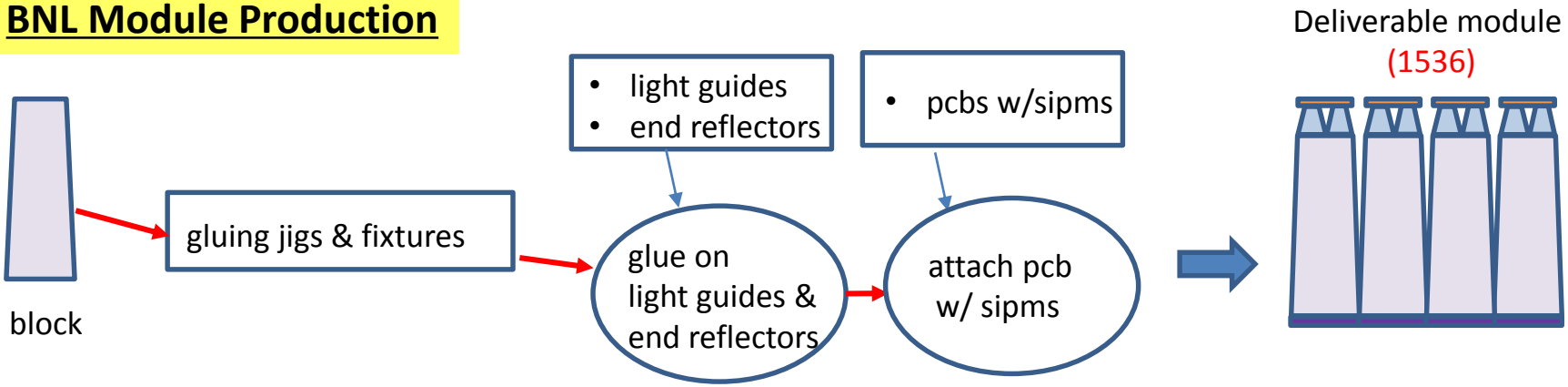
- WBS 1.3.3 - EMCal Module Production and Sector Assembly
  - **1.3.3.1 Set Up Module Production, Sector Assembly and Test Area**
  - **1.3.3.2 EMCal Module Production**
    - V2.1 Prototype ▷ Preproduction Prototype ▷ Final Production
  - **1.3.3.3 EMCal Sector Assembly**
    - V2.1 Prototype ▷ Preproduction Prototype ▷ Final Production

EMCal Production steps and Deliverables

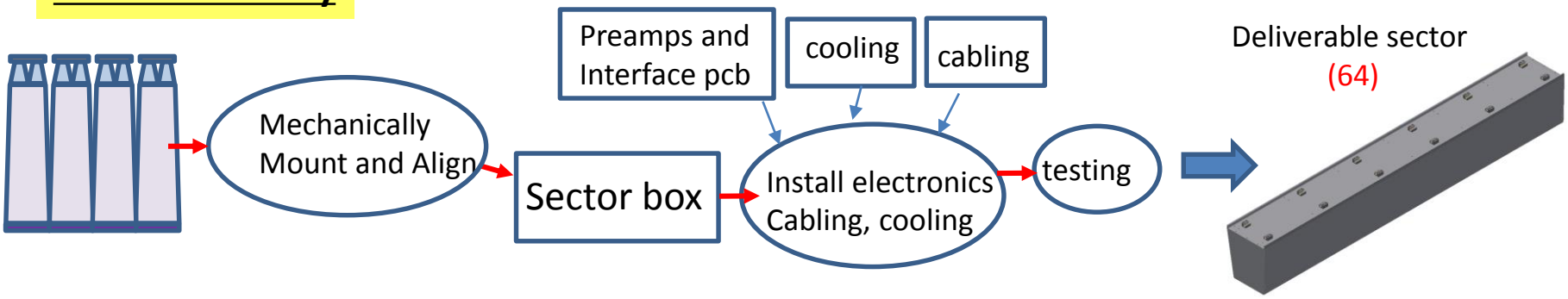
UIUC Block Production



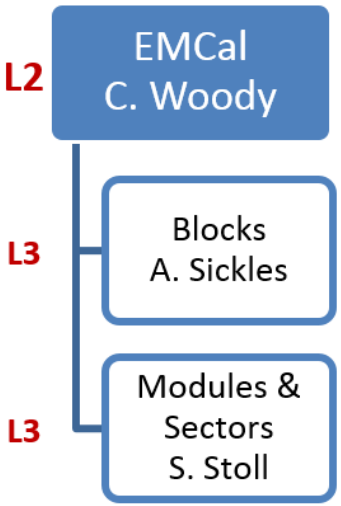
BNL Module Production



Sector Assembly



Subsystem Team



L2 Manager

Craig Woody, Senior Physicist (BNL)

40+ years of detector experience (much of it with calorimetry)

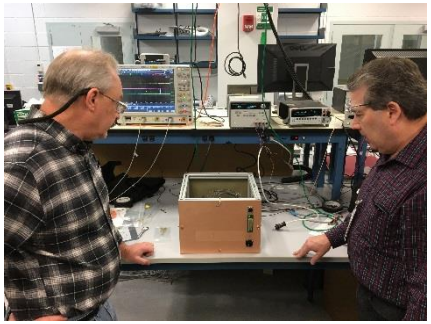
L3 Managers

Anne Sickles, Assistant Prof. (UIUC)

Access to large construction facilities with experienced staff in building large detectors

Sean Stoll, Physics Associate I (BNL)

25+ years in building and operating many kinds of detectors (including the PHENIX EMCAL)



BNL Team

Physicists: Craig Woody, Jin Huang, John Haggerty, Martin Purschke

Chief Engineer: Don Lynch

Mechanical Technicians: Bill Lenz

Engineers & Designers: Rich Ruggiero, Dan Cacace

Physics Associates: Sean Stoll, Rob Pisani

Electrical Engineer and Technician: Steve Boose, Sal Polizzo

Students: Spencer Locks

Schedule Drivers

1.3.1	EMCAL Management	644 days	Wed 2/1/17	Fri 8/30/19	$0	$0	$0
1.3.2	EMCAL Block Production	1095 days	Fri 3/31/17	Fri 8/20/21	$4,836,685	$4,091,318	$745,366
1.3.2.1	EMCAL Prototype V2.1 Block Production	100 days	Thu 4/6/17	Mon 8/28/17	$41,530	$23,250	$18,280
1.3.2.2	EMCAL Preproduction Prototype Block Production	144 days	Fri 3/31/17	Tue 10/24/17	$220,681	$167,745	$52,936
1.3.2.3	EMCAL Final Block Production	1056 days	Thu 5/25/17	Fri 8/20/21	$4,574,474	$3,900,324	$674,150
1.3.3	**EMCAL Module Production and Sector Assembly**	**1167 days**	**Wed 3/1/17**	**Mon 11/1/21**	**$3,253,278**	**$1,048,728**	**$2,204,550**
1.3.3.1	**Set up module production, sector assembly and test area**	**50 days**	**Fri 6/9/17**	**Mon 8/21/17**	**$37,847**	**$29,500**	**$8,347**
1.3.3.2	**EMCAL Module Production**	**1142 days**	**Wed 3/1/17**	**Mon 9/27/21**	**$1,011,183**	**$221,343**	**$789,840**
1.3.3.3	**EMCAL Sector Assembly**	**1144 days**	**Mon 4/3/17**	**Mon 11/1/21**	**$2,204,248**	**$797,885**	**$1,406,363**
1.3.4	Install sectors into sPHENIX	0 days	Mon 11/1/21	Mon 11/1/21	$0	$0	$0

1.3.3 Is mainly a series of assembly steps, and so relies on:

- Having all of the components available when needed
- Maintaining steady production/assembly rates

Main Schedule Drivers:

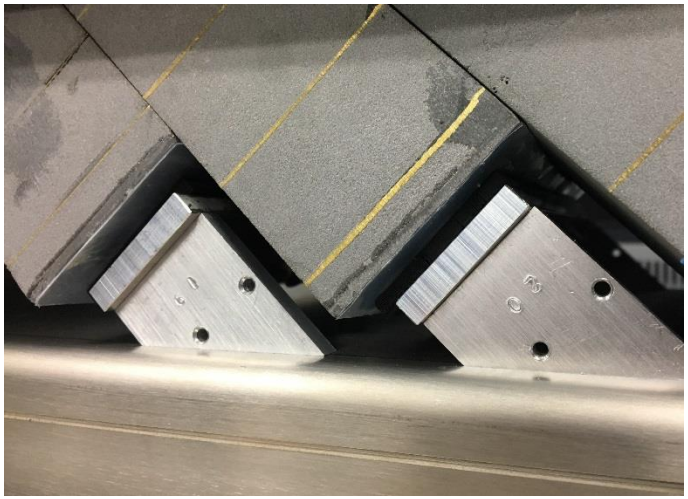
- Production of absorber blocks at UIUC
- Production of Electronics at BNL
- Obtaining components such as light guides, cooling assemblies, mechanical parts
- Maintaining module production and sector assembly production schedules

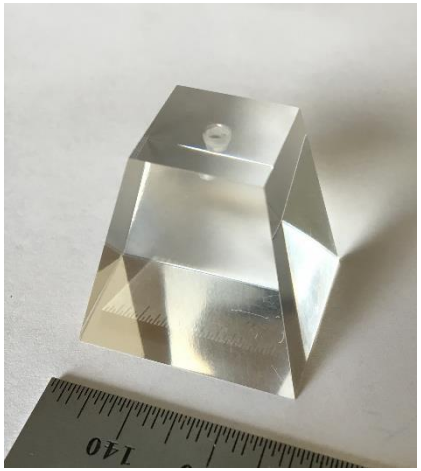
Key Milestones

1.3.3.3.1.11	Completion of v2.1 prototype	Tue 4/10/18
1.3.3.3.2.20	Completion of preproduction prototype	Fri 5/25/18
1.3.2.3.2	Readiness and Safety Review for final block production	Wed 8/12/19
1.3.3.2.3.2	Readiness Review for final module production	Thu 8/12/19
1.3.3.3.3.5	Readiness Review for final sector production	Thu 8/12/19
1.3.4	Install Emcal sectors into sPHENIX	Mon 11/1/21

Cost Drivers

- Mechanical support and enclosure $400-700k
  - **Box parts, block mounting, rail blocks**
- Light Guides $120k
  - **mold + production run, processing (BNL)**
- Cooling System (internal to sectors) $60k





Module Production and Sector Assembly BoE Overview

						Labor Costs		Fixed Costs (Material)	
						total	total w/cont	total	total w/cont
1.3.3.1	**Set Up Mod. Prod., Sector Assbly Test Area**					**$37,543**	**$42,862**	**$29,500**	**$36,200**
						total	total w/cont	total	total w/cont
1.3.3.2	**EMCal Module Production**					**$791,918**	**$956,478**	**$176,576**	**$247,352**
1.3.3.2.1	V2.1 prototype					$19,848	$23,818	$25,583	$32,837
1.3.3.2.2	PreProduction Prototype					$42,228	$50,914	$8,488	$33,749
1.3.3.2.3	Final Production					$729,842	$881,747	$142,505	$180,766
						total	total w/cont	total	total w/cont
1.3.3.3	**Sector Assembly**					**$1,696,695**	**$1,815,555**	**$809,329**	**$1,037,060**
1.3.3.3.1	V2.1 prototype					$61,557	$85,128	$25,515	$25,523
1.3.3.3.2	PreProduction Prototype					$138,789	$182,655	$30,802	$34,126
1.3.3.3.3	Final Production					$1,496,349	$1,344,609	$753,011	$977,411

Comparison of BoE and Project file:

	from BoE (no conting.)			
		mater + labor	Materials	labor
	1.3.3	$3,541,561	$1,015,405	$2,526,156
Set Up	1.3.3.1	$67,043	$29,500	$37,543
Modules	1.3.3.2	$968,494	$176,576	$791,918
Sectors	1.3.3.3	$2,506,024	$809,329	$1,696,695

from Project file (7/24/2017):			
WBS	Cost	Fixed_Cost_sPHENIX	Net Labor
1.3.3	**$3,574,881**	**$1,048,728**	**$2,526,153**
1.3.3.1	**$67,043**	**$29,500**	**$37,543**
1.3.3.2	**$1,013,259**	**$221,343**	**$791,916**
1.3.3.3	**$2,494,579**	**$797,885**	**$1,696,694**

Basis of Estimate and Resource-Loaded Schedule

1.3.3 Consists mainly of assembly processes and is dominated by labor costs

- Labor Estimates are based on experience with the production of our prototypes, and prior experience working on similar projects.

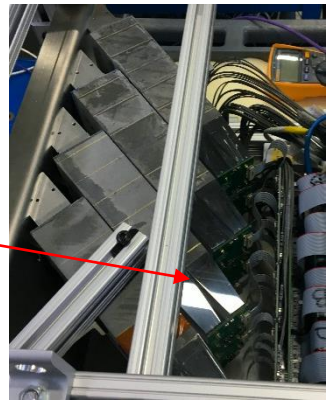
- The module production steps are well understood. *Production will involve scaling up the procedures and adding parallel production lines.*
- For the sector assembly, we have had experience assembling prototypes, but the final sectors are more complicated given the greater number of blocks, connections, cabling, and cooling. *We will produce a "Pre-production prototype" sector, which will be identical to the 64 final production sectors and will give a clearer idea of any challenges introduced when processes are scaled up.*
- Estimates for fixed-cost items such as light guides are based on manufactures quotes. *We will evaluate the performance of light guides produced for the V2.1 and preproduction prototypes before proceeding with the final production order.*
- Estimates for mechanical support and enclosures are based on manufacturers quotations and engineer's estimates for designing and producing custom parts. *We are currently evaluating alternatives to reduce the numbers of unique parts needed.*

Status of the EMCAL Design

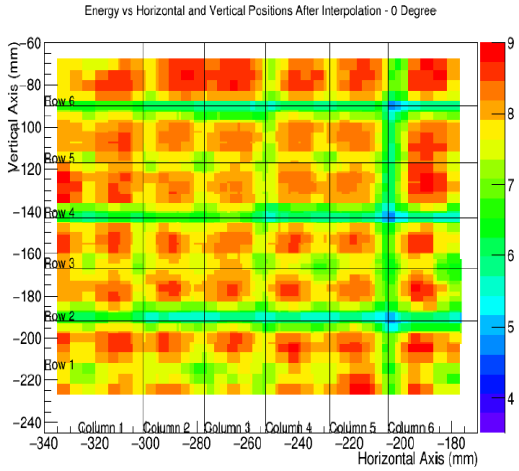
- The EMCAL subsystem is in an advanced conceptual design phase with detailed models and drawings of the absorber blocks, modules and sector assemblies.
- We have tested two prototype calorimeters in the beam at Fermilab ($\eta = 0$ and $\eta \sim 1$) and have shown that the proposed design will meet the physics requirements of the experiment. We plan to test a third and final prototype ($\eta \sim 1$) with new blocks in early 2018.
- Further work is needed on the design of the cooling system, cabling inside the sectors and the mechanical support structure for the blocks. A full scale mechanical mockup is being constructed.
- Mechanical support designs, cooling system tests, and light guides are being prototyped and evaluated in laboratory tests and simulations.
- A full scale preproduction prototype of a complete EMCAL sector will be constructed in 2018 and tested in the lab at BNL with its calibration system and cosmic rays.

Status and Highlights – Refining light guide design

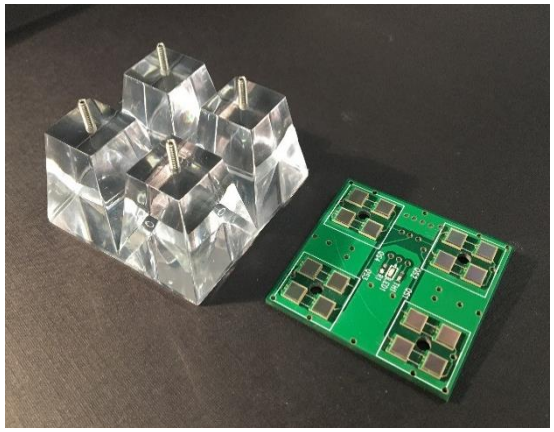
- Test beam and laboratory measurements and simulations are ongoing to improve light collection efficiency and uniformity and finalize light guide design
- We have begun Radiation damage studies of light guides.



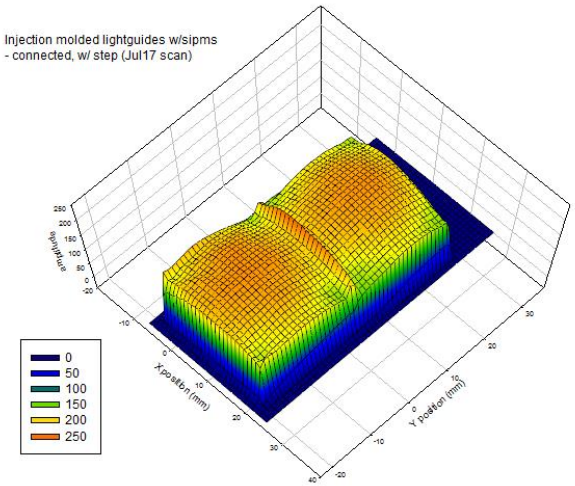
Machined 2” Lightguide

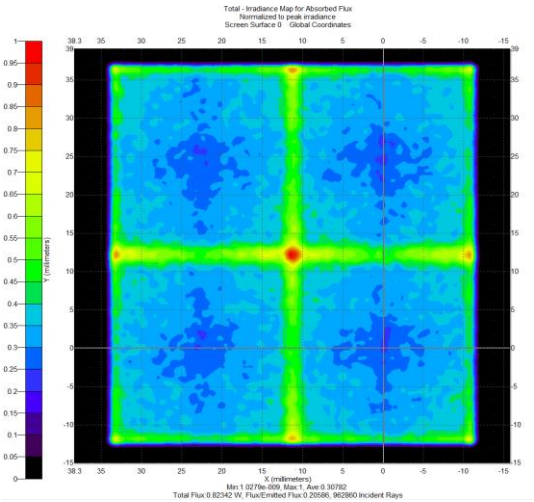


Calorimeter prototype, and response map measured in beamtest



“quad” injection-molded lightguide and 4 tower “daughterboard” with sipms

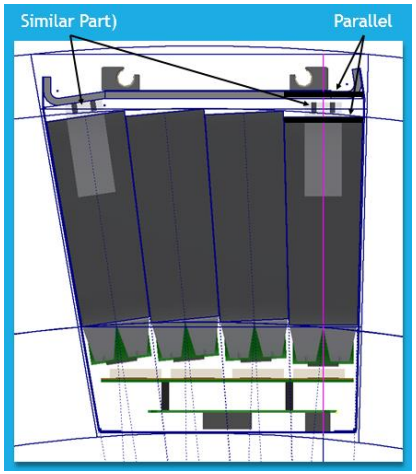


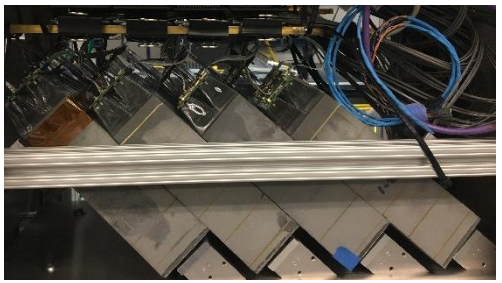


Light guides’ lab- measured and simulated response maps

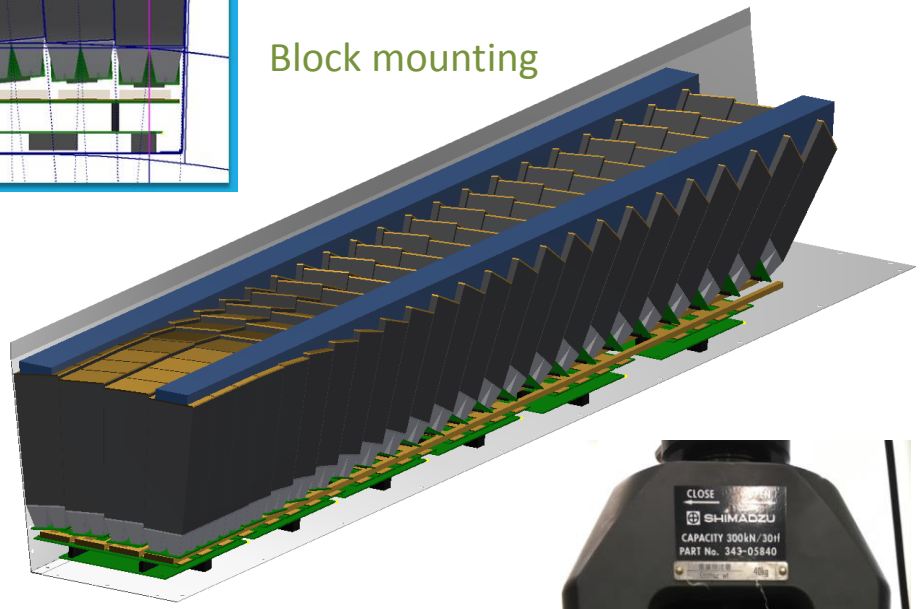
Status – Mechanical Engineering & Design

- We are continuing to refine design elements such as the mechanical support and envelope, to improve performance and reduce costs.
- We are using our detector prototyping process to test mechanical designs, cooling, and detector performance.





Block mounting



Test fit of Water Cooling on detector mockup

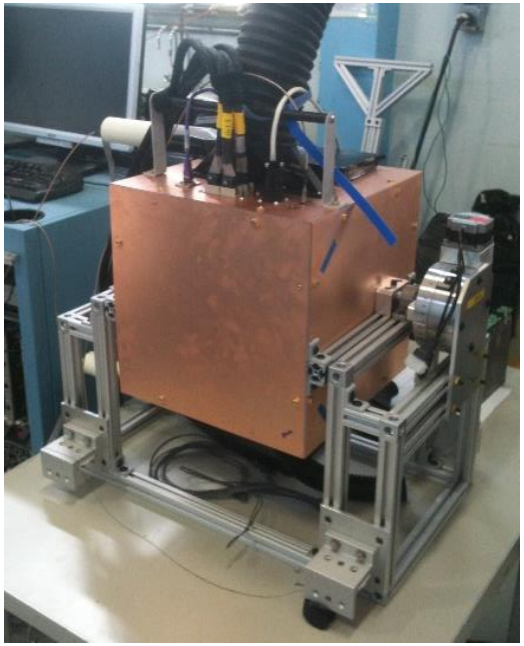
Epoxy bonding strength testing

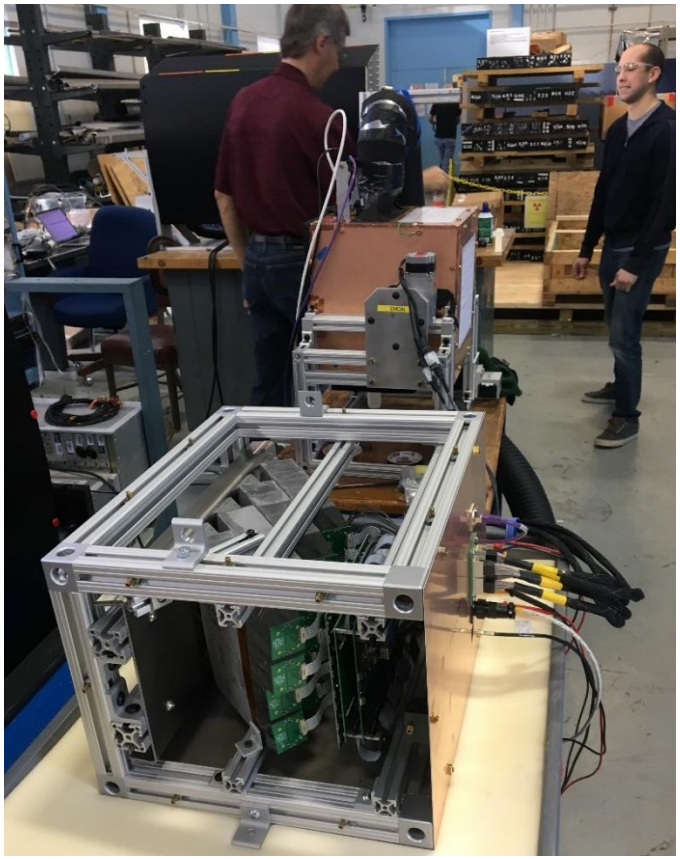
Issues and Concerns

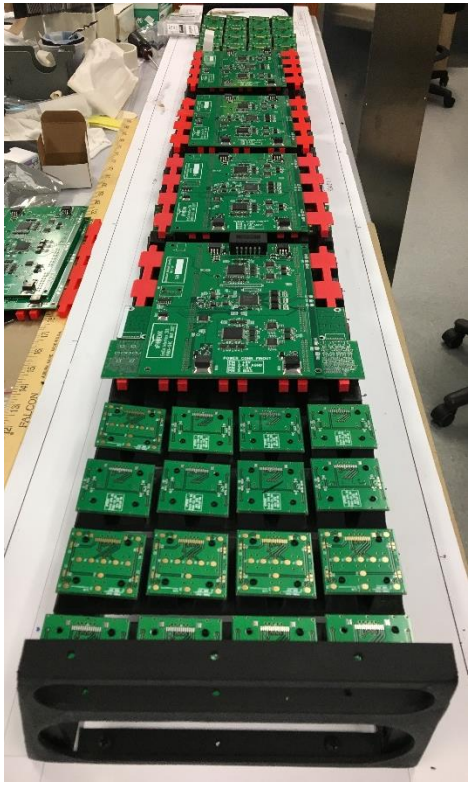
- We have a light guide design that will be produced and tested in the next prototypes to see that it meets our requirements. We need to verify that the design works and can be produced in a cost effective way.
- There is preparatory work such as producing gluing jigs and fixtures, finishing of light guides, and pre-assembly of sector cooling and enclosures that could be started early if orders can be placed.
- Maintaining the critical path module production and sector assembly production lines over > 1 year time periods will be challenging with little float built into the schedule. Problems could be mitigated by allowing for storage of partially assembled components and sectors.
- We need to test the cooling system in a working prototype and resolve space issues with electronics, cabling and cooling inside the sector box.
- We also need to test the mechanical mounting of the blocks, and find a cost-effective way to manufacture the parts.

Back Up

EMCal Prototypes







EMCal $\eta = 0$ and $\eta \sim 1$ prototypes and sector mock-up