

# sPHENIX Annual MIE Review

## Hadronic Calorimeter

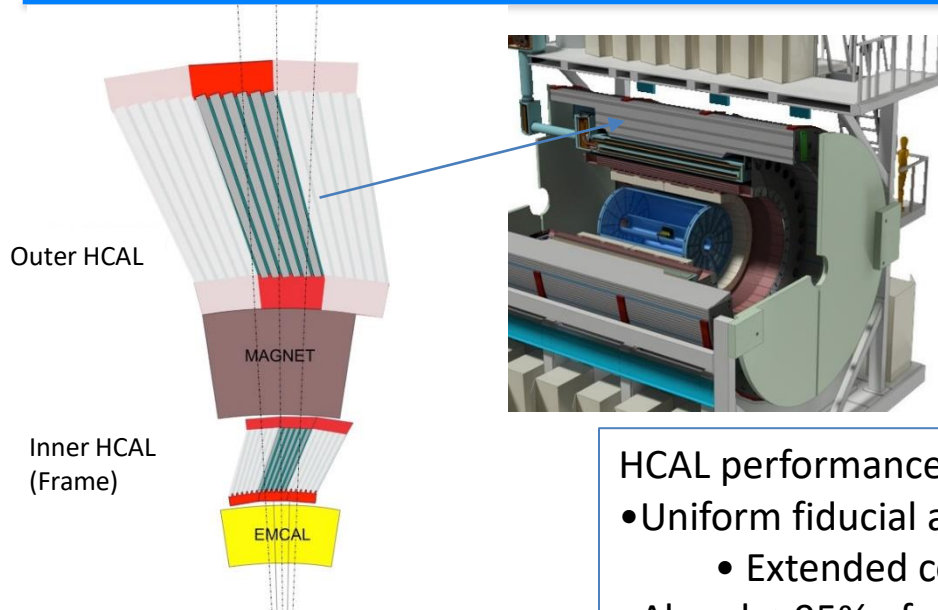


John Lajoie

July 14-15, 2021

BNL

# WBS 1.04: Hadronic Calorimeter



- HCAL steel and scintillating tiles with wavelength shifting fiber
  - **Outer HCal (outside the solenoid)**
  - $\Delta\eta \times \Delta\phi \approx 0.1 \times 0.1$
  - **1,536 readout channels**
- SiPM Readout

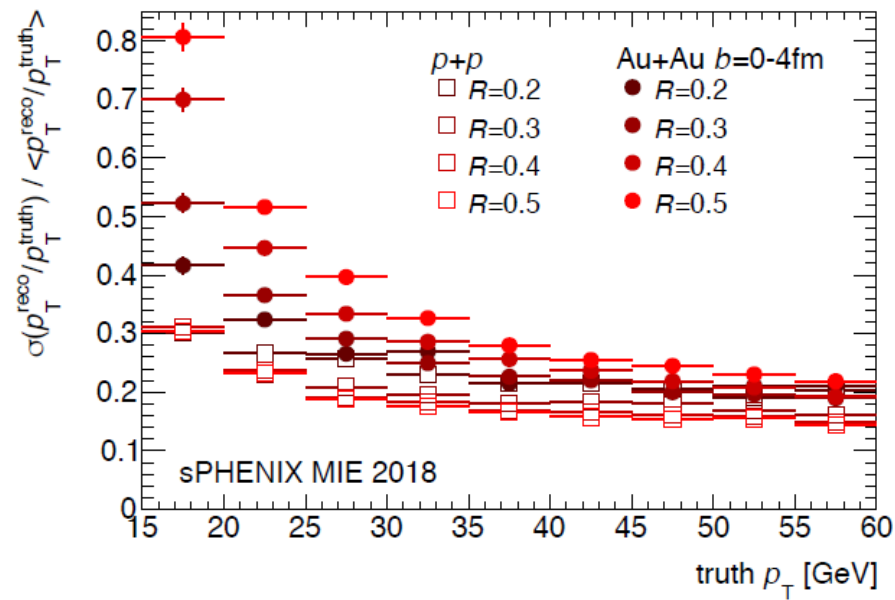
HCAL performance requirements driven by jet physics in HI collisions

- Uniform fiducial acceptance  $-1 < \eta < 1$  and  $0 < \phi < 2\pi$ 
  - Extended coverage  $-1.1 < \eta < 1.1$  to account for jet cone
- Absorb  $>95\%$  of energy from a 30 GeV jet
  - Requires  $\sim 4.9$  nuclear interaction length depth
- Hadronic energy resolution of *combined* calorimetry:
  - UPP:  $\frac{\sigma}{E} < \frac{150\%}{\sqrt{E}}$  (in central Au+Au collisions)
  - Gaussian response (limited tails)
- HCAL created by instrumenting barrel magnetic flux return

- Outer HCAL  $\approx 3.5\lambda_1$
- Magnet  $\approx 1.4X_0$
- Frame  $\approx 0.25\lambda_1$
- EMCAL  $\approx 18X_0 \approx 0.7\lambda_1$

# Physics to Detector Specs.

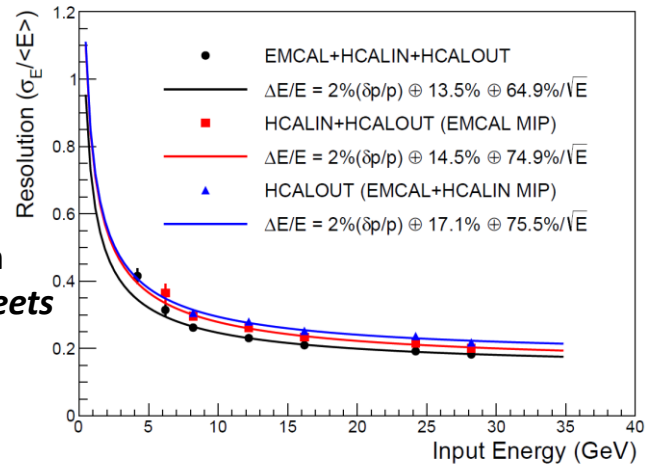
- The HCAL enables the measurement of calorimetric jets in sPHENIX:



Plot from G4 Simulations by D. Perepelitsa

HI jets determined with iterative background subtraction procedure. Note resolution comparison between Au+Au and  $p+p$  – jet resolution in HI determined by *fluctuations in underlying event*.

Performance in test beam – **meets specifications!**



# Scope and Deliverables

## Outer HCAL Sectors Assembly:

### DELIVERABLE:

32 assembled and tested sectors - 1.9m inner radius, 2.6m outer radius

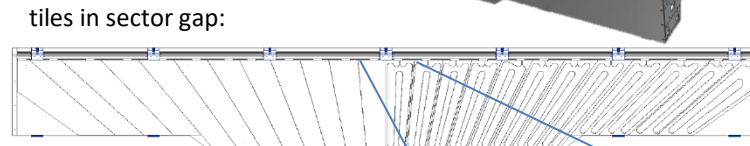
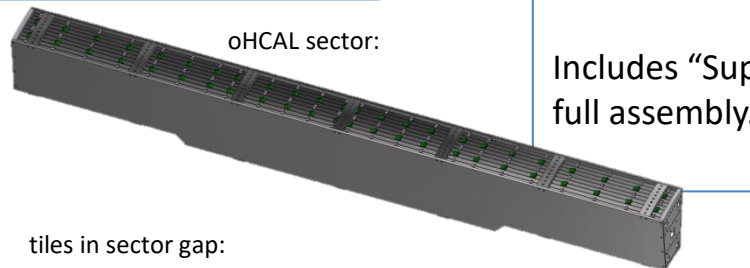
10 rows of 8mm scint. tiles (24 tiles per row), 12° tilt angle

Tapered 1020 steel plates ~26.1mm - ~42.4mm

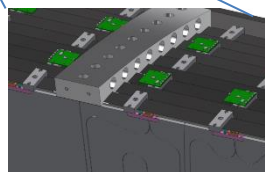
**Completed sector is 6.3m long, 13.5 tons**

### Assembly Detail:

5 scintillators/tower  
48 towers per sector  
32 sectors;  
1536 channels (7680 SiPMs)



electronics/cable routing:



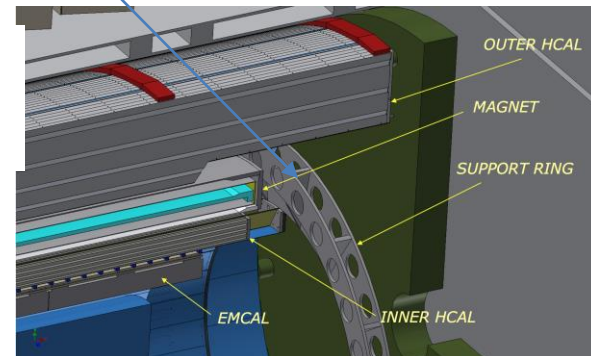
## Inner HCAL Sector and Supports

### DELIVERABLE:

32 AI sectors – 1.16m inner radius, 1.37m outer radius

Includes “Support Rings” for full assembly.

**NOTE:** iHCAL tiles and assembly **not** part of MIE.



Barrel Flux Return serves as HCAL absorber (WBS 2.3)  
Electronics are in WBS 1.05

# Subsystem Collaborators

- Brookhaven National Lab

- Engineering
- **L3 Chris Pontieri**



- Georgia State University

- Tile Testing
- Student labor
- **L3 Megan Connors**



- Baruch College

- oHCAL assembly
- **L3 Stefan Bathe**



- Iowa State University

- Inner HCAL
- Student labor

- Augustana, GSU, ISU, Rutgers, UNCG

- Inner HCAL

- MEPHI

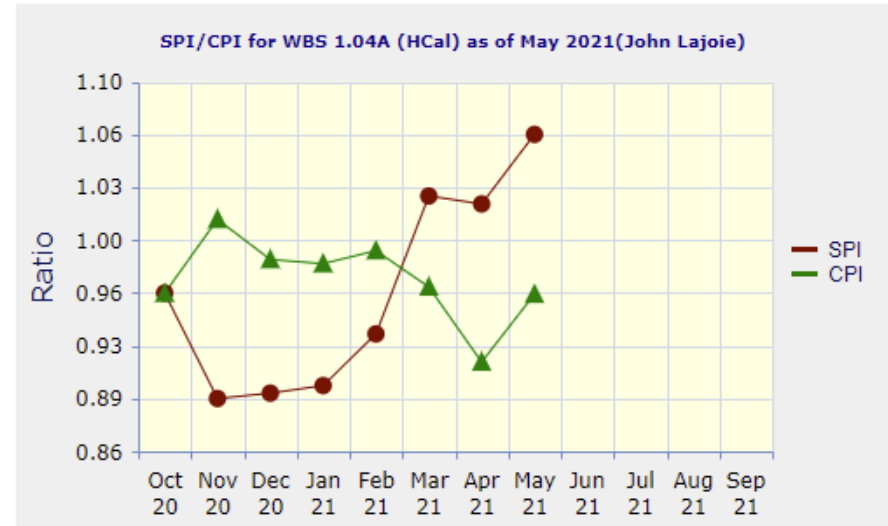
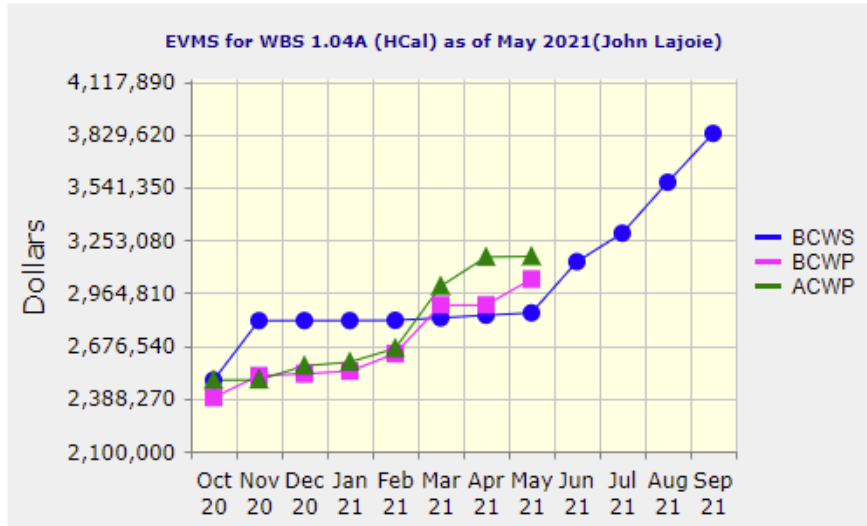
- Tile mapping

1.4 HCal  
J. Lajoie

Inner HCal  
Frame  
J. Lajoie

Outer HCal  
M. Connors\*  
C. Pontieri\*  
S. Bathe\*

# Schedule/Cost Performance and To Go



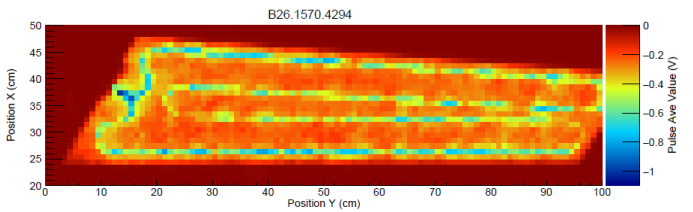
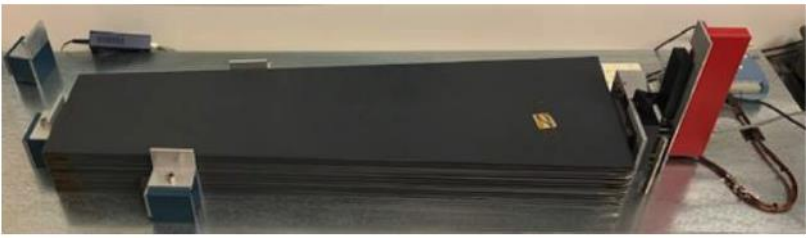
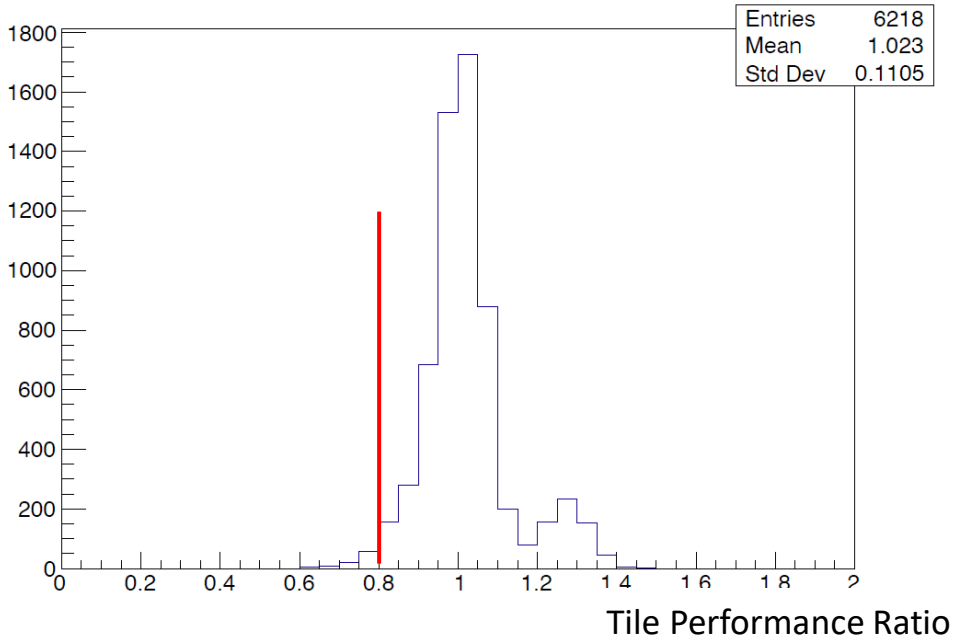
- SPI > 1 mainly due to early completion of oHCAL sector assembly
- CPI < 1 mainly due to final costs for machine components (materials)
- Remaining BCWS is for iHCAL sectors (delivery through Nov)

# Status of Reviews

- ESRC Review of Calorimeters – **July 26<sup>th</sup>, 2021**
- iHCAL Barrel Build and Installation PRR – June 22<sup>nd</sup>, 2021
- iHCAL Barrel Build and Installation FDR – April 28<sup>th</sup>, 2021
- iHCAL Tile PRR - Jan 12<sup>th</sup>, 2021
- iHCAL, EMCAL and TPC Installation Eng. Review  
– Dec. 22<sup>nd</sup>, 2020
- iHCAL Sectors and End Rings PRR – June 10<sup>th</sup>, 2020
- iHCAL Tile FDR – March 25<sup>th</sup>, 2020
- iHCAL Sectors and End Rings FDR – March 24<sup>th</sup>, 2020

# Production Tile Performance

- Total Production Tiles for OHCAL: **6,218 (100%)**
  - Completed Jan 5<sup>th</sup>, 2021
- 1.4% with PR<0.8
  - GSU results well-correlated with Uniplast measurements
- Verified questionable tiles with mappings at Colorado



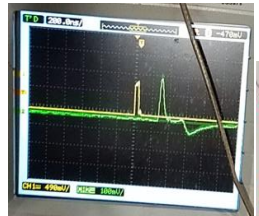
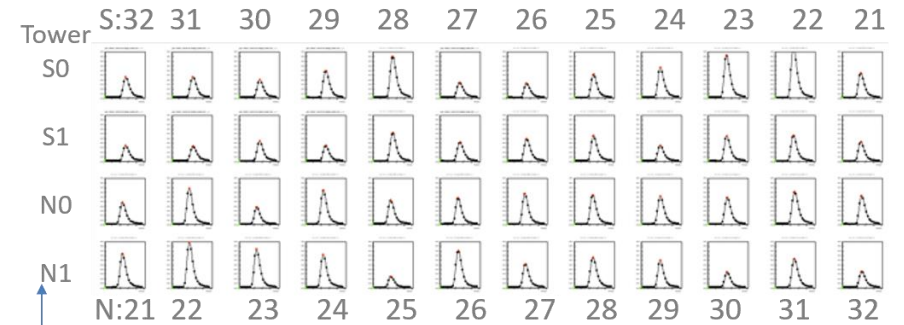
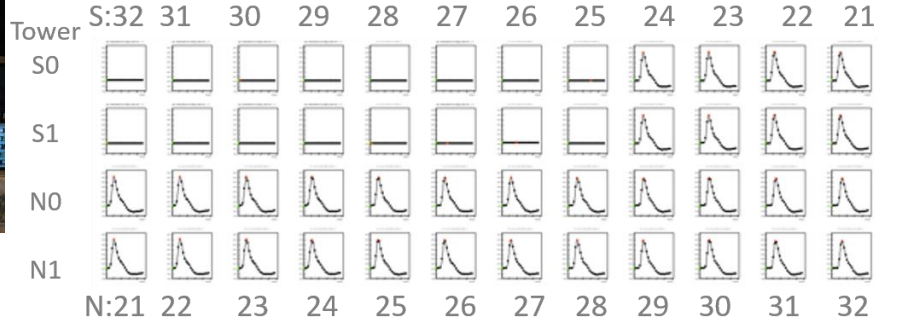
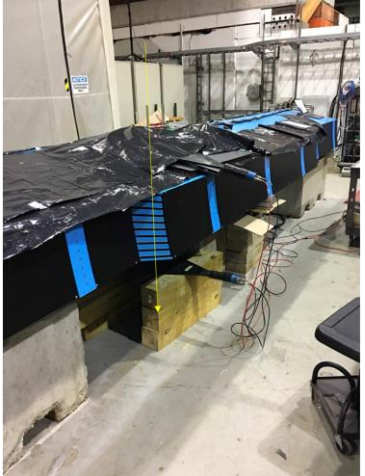


# Sector Assembly and Testing I

- Test pulse:
  - Verified all electronics in detector work & data taking software functions as expected



- LED test:
  - Verified all tiles in sector respond as expected to pulsed LED light
  - Alerted us to a problem with plastic debris in the LED connection (solved)



Test pulse response on oscilloscope



LED response on oscilloscope

# Sector Assembly and Testing II

Last sector assembly completed April 6<sup>th</sup>!

Thanks to all student and postdocs, staff and professors that joined this effort from ISU, Colorado, Baruch, Lehigh, Rutgers, Wayne State, BNL, GSU, Ohio, and make this possible.



# Sector Assembly and Testing III

- **Testing After Arrival in 1008:**
  - Tested at tower-level: all channels charge-injection test pulse and LED scan work on all towers
- **Testing After Installation**
  - on hold, for shield-wall
- **Test Details**
  - Oscilloscope + Save data
  - Test pulse & LED-all-tiles
  - Cycle through each tower for both



# Inner HCAL Sectors

First shipment of iHCAL sectors at BNL (8 total, 7 shown) on 6/21/2021



Both end rings are complete and arrived at BNL 4/22/2021



- A QA plan for the (i,o)HCAL scintillating tiles has been implemented for production:
  - Onsite testing by vendor, results available in real time
  - Additional testing/characterization at GSU
  - Production has met QA goals
- QA procedure for sector assembly process:
  - QA for assembly involved LED tests and cosmics
- Work Plan coordinated with CAD for 912 area
  - Specifies training requirements for students that will be working in assembly area
  - Updated to address COVID-19 requirements
- All work at GSU done under local safety requirements

**Detector-Specific Quality Assurance Plan  
For Hadronic Calorimeter Tile Production  
For the sPHENIX Project**

Physics Department  
Georgia State University  
Atlanta, GA

Revision 1.2  
April 23, 2019

**sPHENIX Project**

**DETECTOR-SPECIFIC QUALITY ASSURANCE PLAN**

Approved by: \_\_\_\_\_ Date \_\_\_\_\_

Megan Connors  
sPHENIX L3 Manager for i/o Tiles  
Georgia State University

Accepted by: \_\_\_\_\_ Date \_\_\_\_\_

Edward O'Brien  
sPHENIX Project Director  
Brookhaven National Laboratory

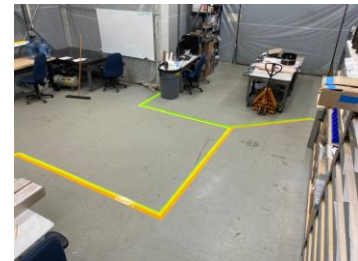
\_\_\_\_\_ Date \_\_\_\_\_

James Mills  
sPHENIX Project Engineer  
Brookhaven National Laboratory

\_\_\_\_\_ Date \_\_\_\_\_

Glenn Young  
sPHENIX Project Manager  
sPHENIX Detector QAP: i/o Tile Production Rev 1.2

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# Issues and Concerns

sPH_Hcal_005	Delay of Inner HCAL assembly due to technical or component supply issues	If HCAL components are not available on time, then the assembly of the inner HCAL barrel and	Carefully plan delivery and availability of all components.	25%	0	0	0	0.5	1.0	2.0	Negligible
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- Delivery schedule of iHCAL sectors must keep pace
- Assembly of iHCAL sectors
  - **NOT** part of MIE
  - Delivery of last 8 sectors mid-November, assembly must be quick to avoid impacting barrel assembly and installation
- Availability of students and postdoc labor onsite at BNL required for assembly and testing
  - oHCAL installation testing
  - iHCAL assembly and testing

- sPHENIX Hadronic Calorimeter provides coverage for jet reconstruction between  $-1.1 < \eta < 1.1$  and  $0 < \phi < 2\pi$  with an energy resolution better than  $\frac{\sigma}{E} < \frac{150\%}{\sqrt{E}}$  in central Au+Au collisions
  - Design meets all performance specifications
- oHCAL sectors assembled and tested
  - All 32 sectors completed and ready for barrel assembly
- Production tiles met performance specifications
  - GSU testing showed very high yield from Uniplast
- iHCAL sectors arriving at BNL
  - First 8 sectors currently undergoing inspection

# Back Up



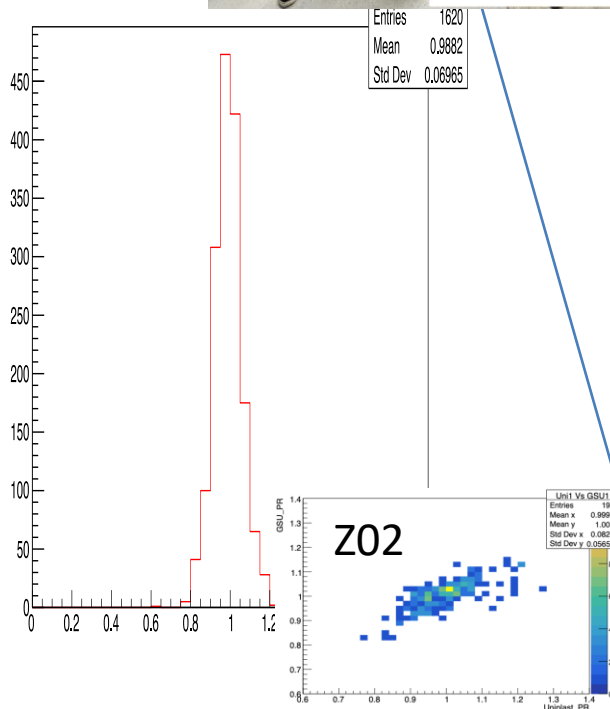
# iHCAL Tiles

(Stats current as of June 16 – courtesy of Saif Ali)



The GSU crew continues their outstanding tile testing effort!

- **1,620/6,360 (25.5%) tested**
  - Shipment 1 (Pilot Tiles)
    - Tested 338/360 (94%)
    - 22 chosen as ref. tiles
  - Shipment 2
    - Tested 564/1,098 (51%)
  - Shipment 3
    - Tested 374/1,568 (24%)
  - Shipment 4
    - Tested 344/1,430 (26%)
- 6 tiles w/ PR < 0.8 (0.2%)
  - 1 Z04
  - 5 Z06s



Tile Type	Ship No.	Tiles Received /530	Tested	Shipped to BNL
Z01	1,2	414	276	216
Z02	1,2	390	196	192
Z03	1,2,3	462	176	168
Z04	1,3	470	108	40
Z05	1,3	430	188	40
Z06	1,3	430	164	40
Z07	1,3,4	350	68	40
Z08	1,4	280	76	24
Z09	1,4	286	84	24
Z10	1,4	286	92	24
Z11	1,4	286	92	24
Z12	1,4	282	100	16
<b>Total</b>		<b>4,366/6,360</b>	<b>1,620</b>	<b>848</b>