Barrel HCAL Status

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Introduction

EIC Yellow Report

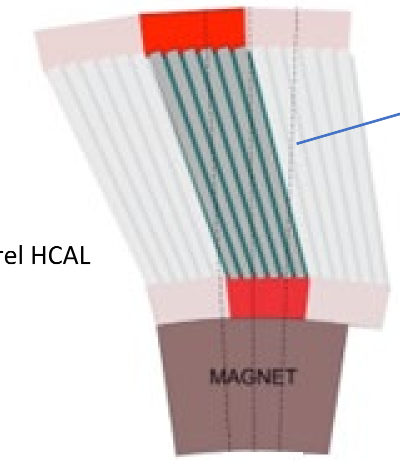
η	EIC Specifications		Conservative option	
	σ_E/E, %	E_{min}, MeV	σ_E/E, %	E_{min}, MeV
-3.5 to -1.0	$45/\sqrt{E}+7$	500	$50/\sqrt{E}+10$	500
-1.0 to +1.0	$85/\sqrt{E}+7$	500	$100/\sqrt{E}+10$	500
+1.0 to +3.5	$35/\sqrt{E}$	500	$50/\sqrt{E}+10$	500

Table 11.35: HCAL parameters from the EIC specifications (Table 10.6) and for a technically conservative option. Several ways to improve the energy resolution are described in the text.

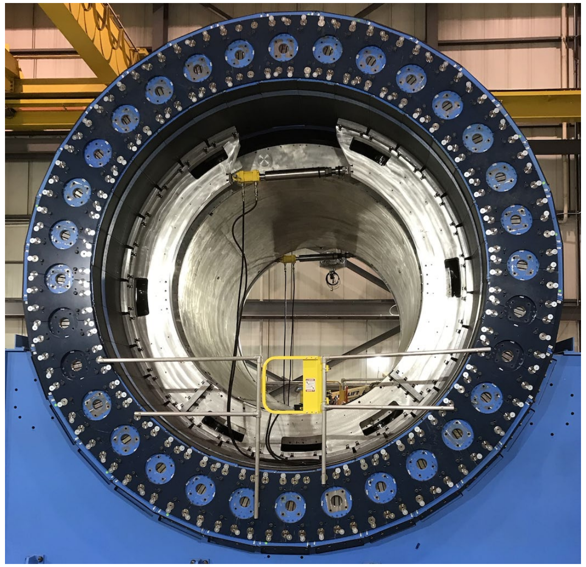
- Main goals for barrel HCAL in ePIC:
  - Precise reconstruction of jet energy
    - Jets at the EIC are relatively soft
    - Tracks will provide a better determination of momentum than hadronic calorimetry over most of the kinematic coverage.
    - HCAL provides a measurement of neutral hadrons.
  - Secondary determination of scattered electron kinematics from hadronic remnants
  - Additional capability: Muon identification (MIP)
- ePIC will repurpose the sPHENIX barrel HCAL as a hadronic calorimeter and part of the solenoid flux return

Barrel Hadronic Calorimeter

Barrel HCAL



Outer HCAL ≈3.5λ_I



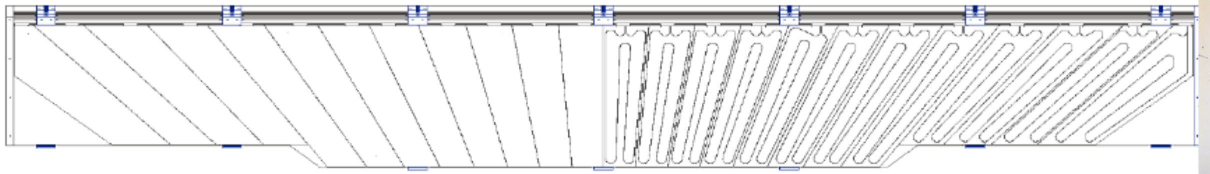
- HCAL steel and scintillating tiles with wavelength shifting fiber
  - **Outer HCal (outside the solenoid)**
  - **$\Delta\eta$ x $\Delta\phi$ ≈ 0.1 x 0.1**
  - **1,536 readout channels**
- SiPM Readout
- Repurpose of sPHENIX barrel HCAL

HCAL performance requirements driven by jet physics in ePIC

- Uniform fiducial acceptance $-1<\eta<1$ and $0<\phi<2\pi$
  - Extended coverage $-1.1<\eta<1.1$ to account for jet cone
- Hadronic energy resolution requirement:
  - $\frac{\sigma}{E} < \frac{100\%}{\sqrt{E}}$
  - Gaussian response (limited tails)
- Barrel HCAL created by instrumenting barrel magnetic flux return

Barrel HCAL Design

tiles in sector gap:



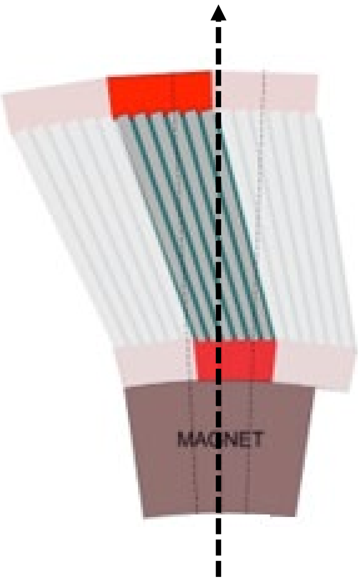
Assembly Detail:
5 scintillators/tower
48 towers per sector
32 sectors;
1536 channels (7680 SiPMs)

32 sectors - 1.9m inner radius, 2.6m outer radius

Titled-tile design:
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



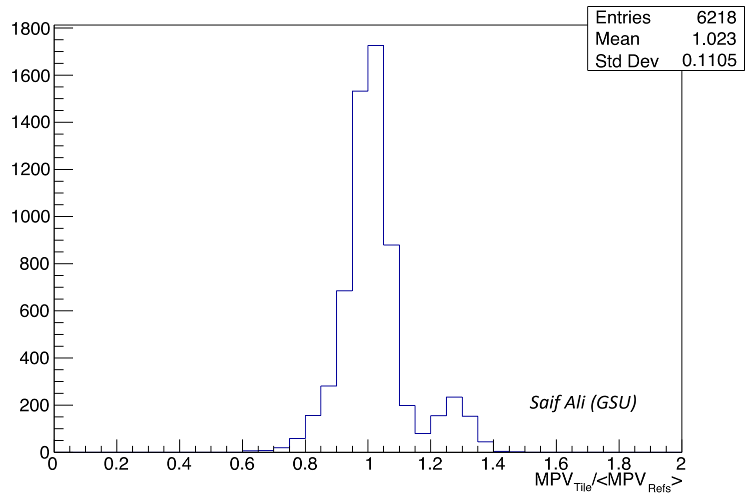
Tower preamplifiers

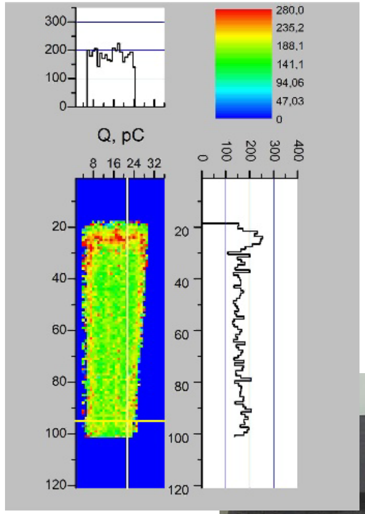
LV/Bias and slow controls.

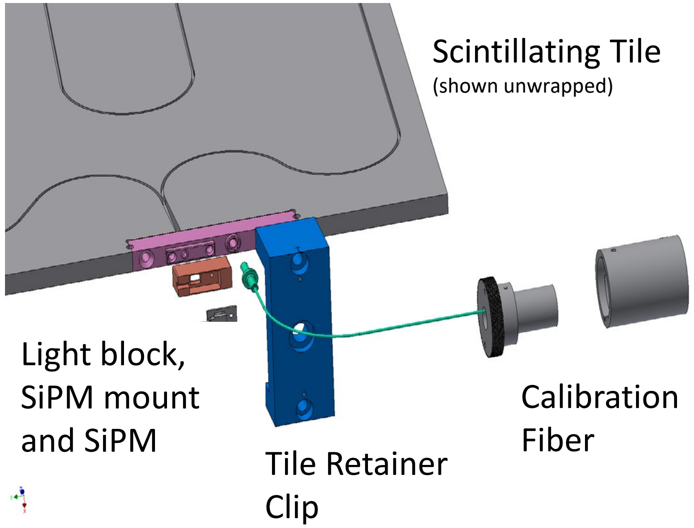
Scintillating Tiles

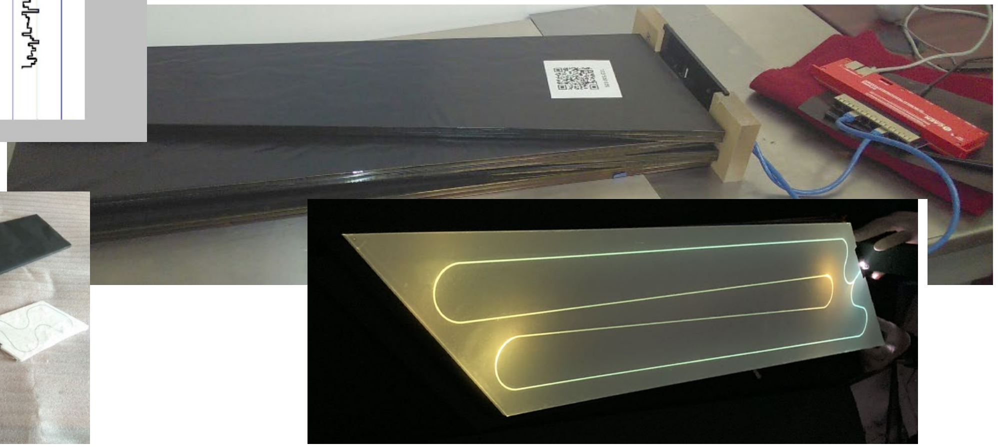
Scintillating tiles are integrated units manufactured by Uniplast.
Detailed cosmic ray response maps from MEPHI (Urugan telescope), integrated into sPHENIX simulations.

Extensive testing of produced tiles for unform response,
results used to sort tiles into a tower with variation <5%



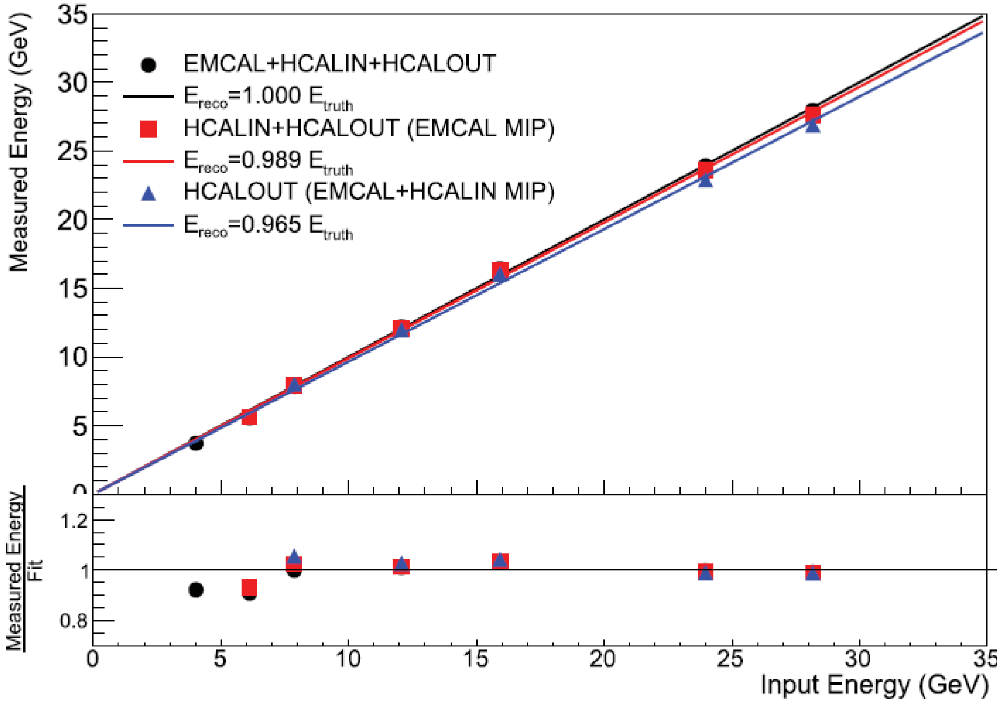


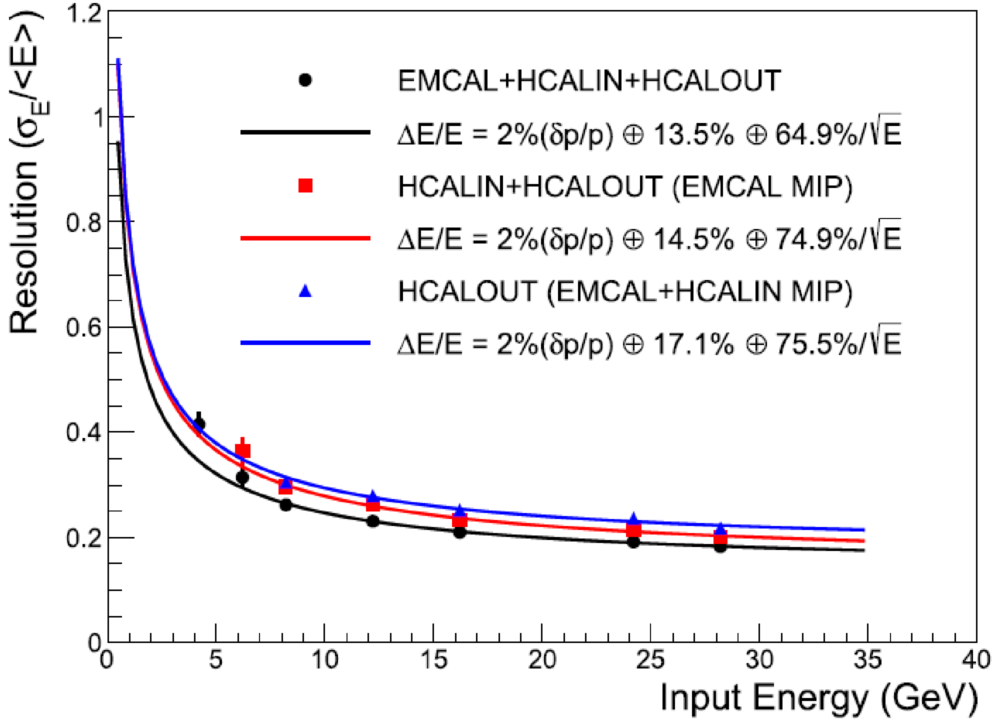


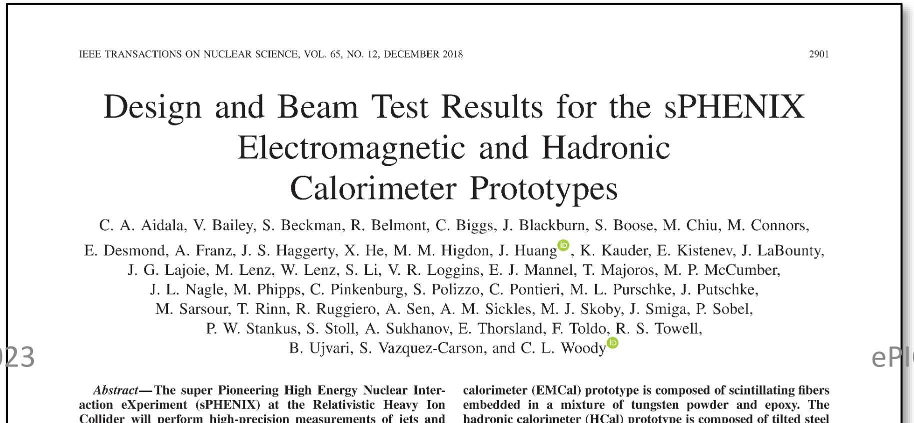


Barrel HCAL Performance (I)

sPHENIX Test Beam (T-1044)







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Design and Beam Test Results for the sPHENIX Electromagnetic and Hadronic Calorimeter Prototypes

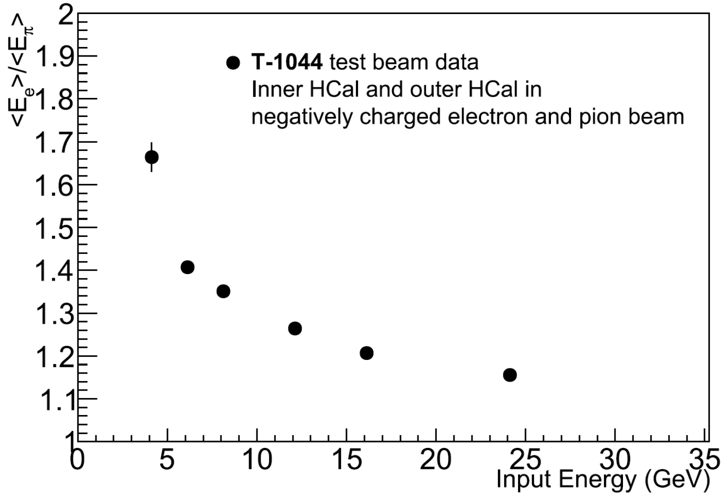
C. A. Aidala, V. Bailey, S. Beckman, R. Belmont, C. Biggs, J. Blackburn, S. Boose, M. Chiu, M. Connors, E. Desmond, A. Franz, J. S. Haggerty, X. He, M. M. Higdon, J. Huang, K. Kauder, E. Kistenev, J. LaBounty, J. G. Lajoie, M. Lenz, W. Lenz, S. Li, V. R. Loggins, E. J. Mannel, T. Majoros, M. P. McCumber, J. L. Nagle, M. Phipps, C. Pinkenburg, S. Polizzo, C. Pontieri, M. L. Purschke, J. Putschke, M. Sarsour, T. Rinn, R. Ruggiero, A. Sen, A. M. Sickles, M. J. Skoby, J. Smiga, P. Sobel, P. W. Stankus, S. Stoll, A. Sukhanov, E. Thorsland, F. Toldo, R. S. Towell, B. Ujvari, S. Vazquez-Carson, and C. L. Woody

Abstract—The super Pioneering High Energy Nuclear Interaction eXperiment (sPHENIX) at the Relativistic Heavy Ion Collider will perform high-precision measurements of jets and calorimeter (EMCal) prototype is composed of scintillating fibers embedded in a mixture of tungsten powder and epoxy. The hadronic calorimeter (HCal) prototype is composed of tilted steel

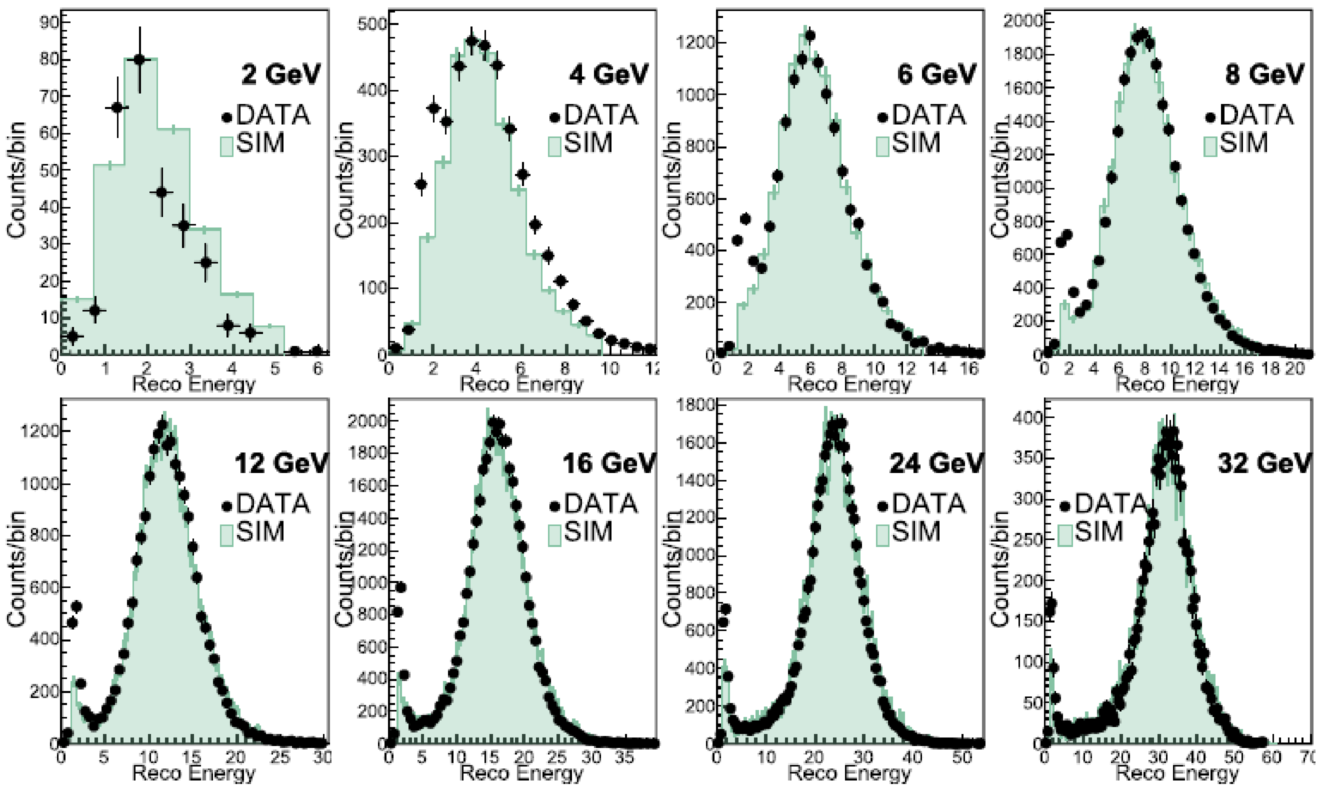
Detailed studies of performance and comparison with simulations done in test beam (T-1044).

Performance of full device will be measured in sPHENIX. We should achieve a reduced constant term due to tighter control on the scintillator variation in a tower for production sectors.

Barrel HCAL Performance (II)



$<E_e>/<E_\pi>$ in data for standalone HCAL



Comparison of standalone HCAL lineshape data/MC

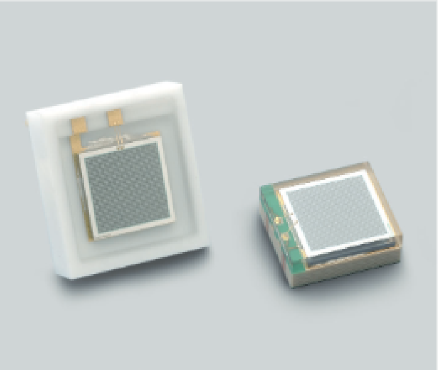
Barrel HCAL Refurbishment Plans

- SPHENIX barrel HCAL disassembly
  - In sPHENIX the barrel HCAL currently has 100% live towers (!!)
- Refurbish outer HCAL sectors:
  - Do not anticipate significant radiation damage to scintillator
  - Plan to replace SiPMs and readout electronics
    - Will require removal of scintillating tiles.
    - Potential to re-measure tile cosmics PR (we should do this)
    - Opportunity to replace/repair scintillating tiles
    - Piggy-back on HGCROC development for LFHCAL
      - Dual-range ADC/TOT very helpful for MIPs
    - Replace slow controls boards as well (LED, etc)
  - Repeat sector-level cosmics calibration
  - Potentially modify one (or more) chimney sectors to account for ePIC cryo design

Scintillating Tile SiPM's

HAMAMATSU

PHOTON IS OUR BUSINESS



NEW

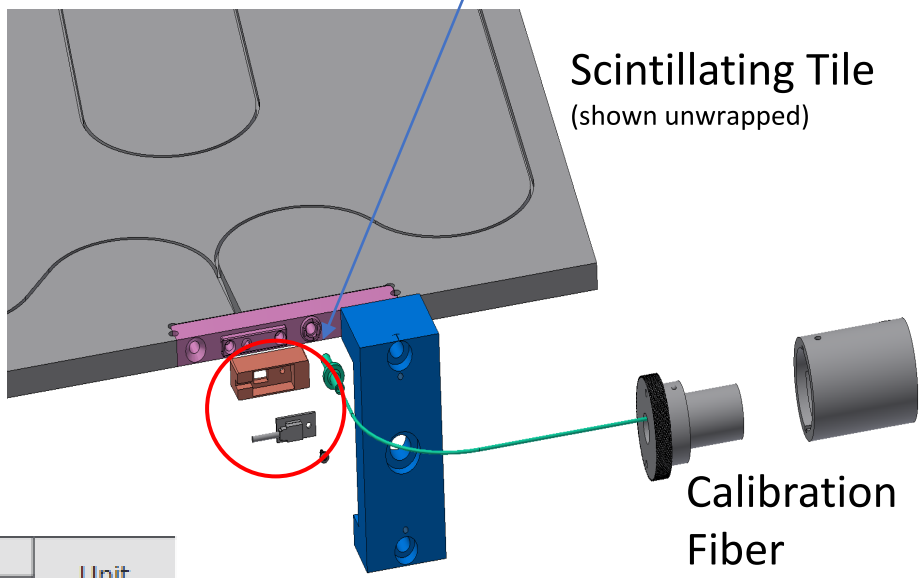
MPPC® (multi-pixel photon counter)

S12572-010, -015C/P

Low afterpulse, wide dynamic range, for high-speed measurement
Photosensitive area: 3 × 3 mm

Structure

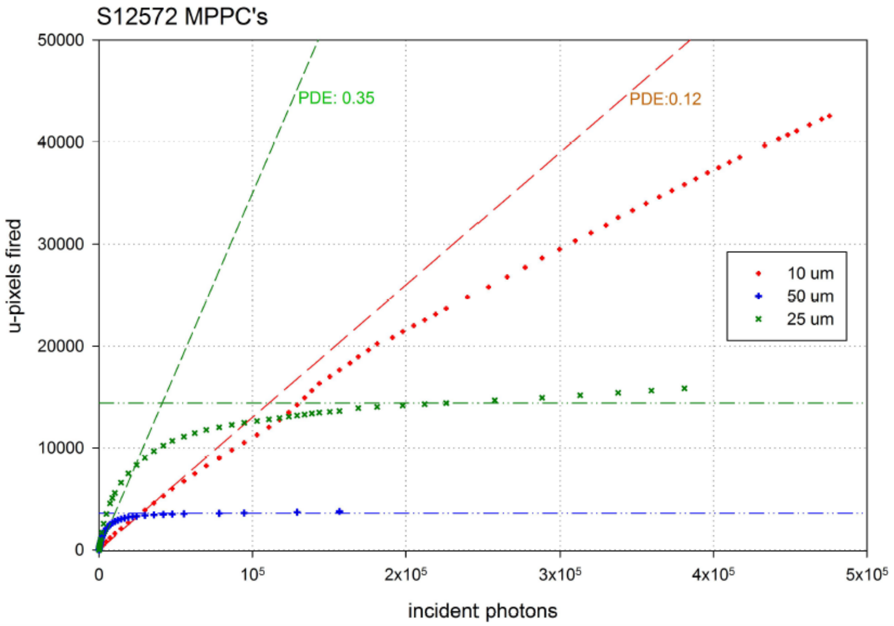
Parameter	Symbol	S12572				Unit
		-010C	-010P	-015C	-015P	
Effective photosensitive area	-	3 × 3		3 × 3		mm
Pixel pitch	-	10		15		µm
Number of pixels	-	90000		40000		-
Geometrical fill factor	-	33		53		%
Package	-	Ceramic	Surface mount type	Ceramic	Surface mount type	-
Window	-	Epoxy resin		Epoxy resin		-
Window refractive index	-	1.59	1.55	1.59	1.55	-

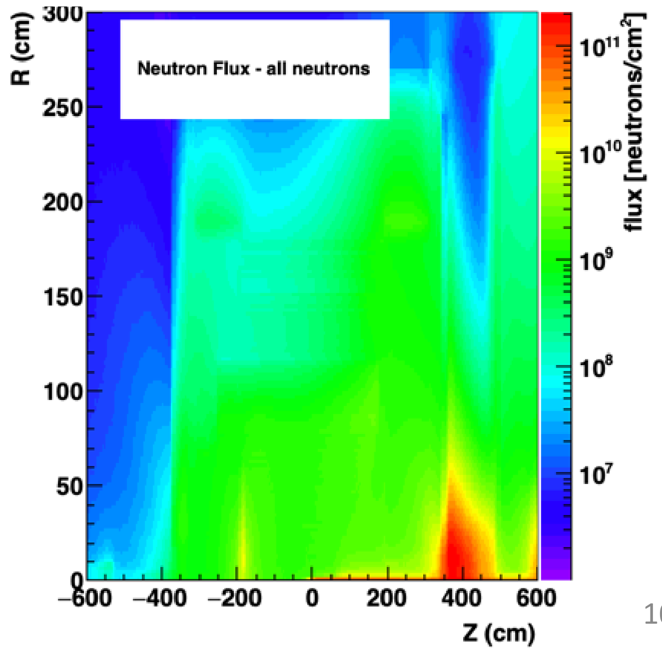


SiPM Specifications

- What is the dynamic range one needs to cover?
  - sPHENIX planned on 25 MeV – 50 GeV per tower (5 scintillator tiles) @200 GeV
    - 5 MeV – 10 GeV per tile, or 1 – 2000 (2.5 – 5000) pixels @ 200 (500) PE/GeV
    - Should look at 18x275 GeV jets at η ~ 1 to verify range, suspect OK
- What is the impact of radiation damage of the SiPMs on your system?
  - Expected to be negligible, at outer radius of detector. No degradation anticipated in 3 years of sPHENIX operation (HI).
  - Expected dose in ePIC two orders of magnitude below where serious issues show up, need to understand implications of lower dose on MIP
    - Expect this is not a problem with HGCROC dual range ADC/TOT
- What specs have you already determined and how? What needs still be determined
  - Based on existing design, we have a fixed physical package (3x3mm)
  - Designed for 40000 pixels @ 15μm. Reduced pixel count might work but needs study
- How do your SiPM specs impact the readout electronics, especially the FEEs.
  - Plan to use HGCROC, piggy-back on ORNL HGCROC development for LFHCAL
- Identified Hamamatsu S14160-3015PS as potential replacement

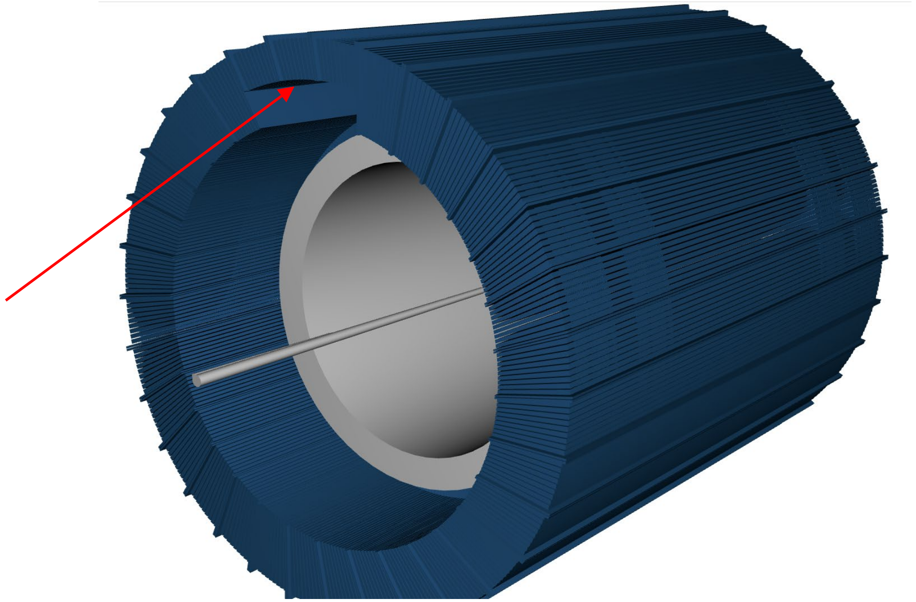
From sPHENIX TDR



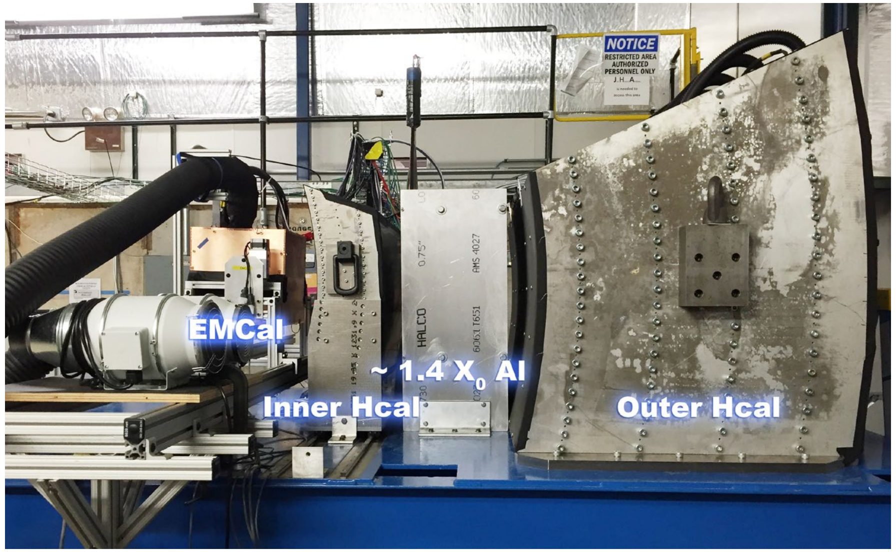


Other Items

- Modify chimney sectors for ePIC cryo:
  - Modifications to fit cryo chimney may not be needed
  - May offer opportunity to improve depth in backwards eta for these sectors, but requires new tiles

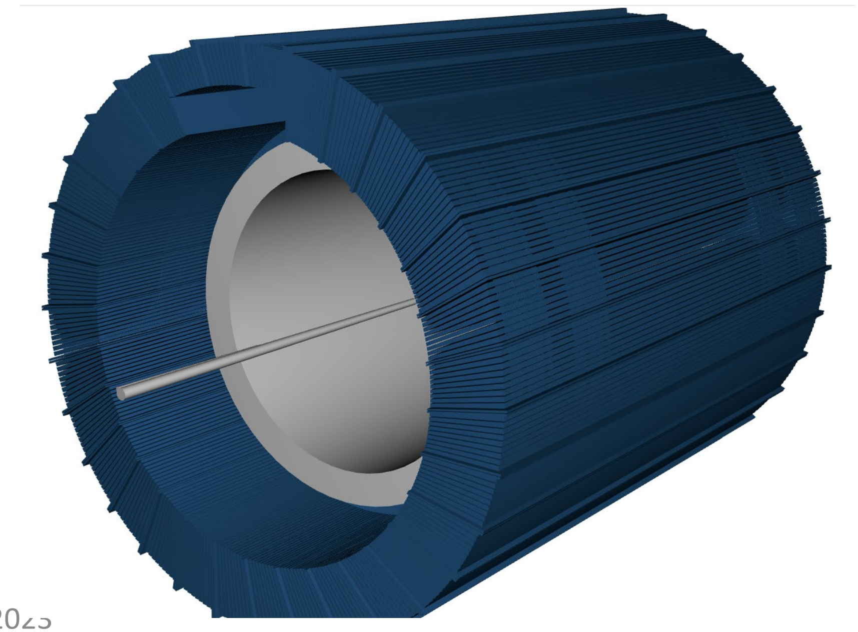


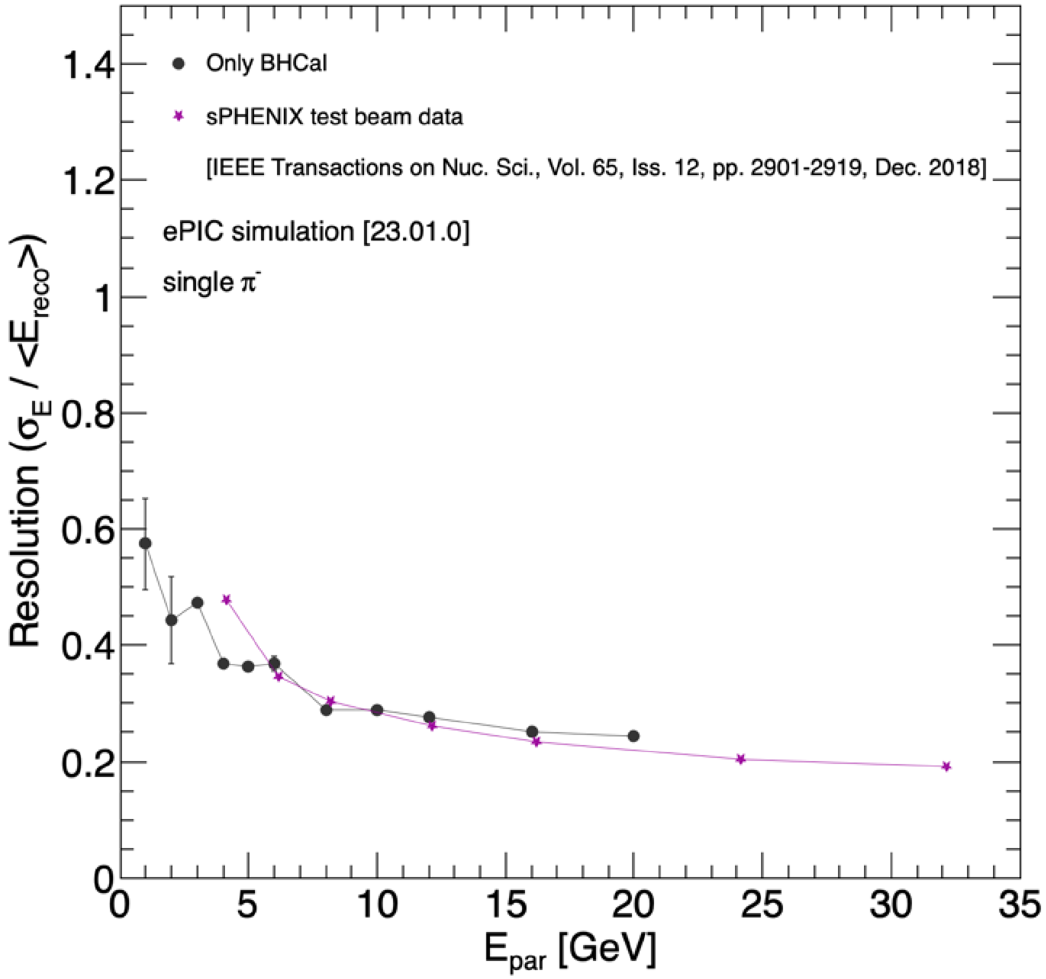
- sPHENIX test beam setup available for electronics development



Simulation Status | Implementation

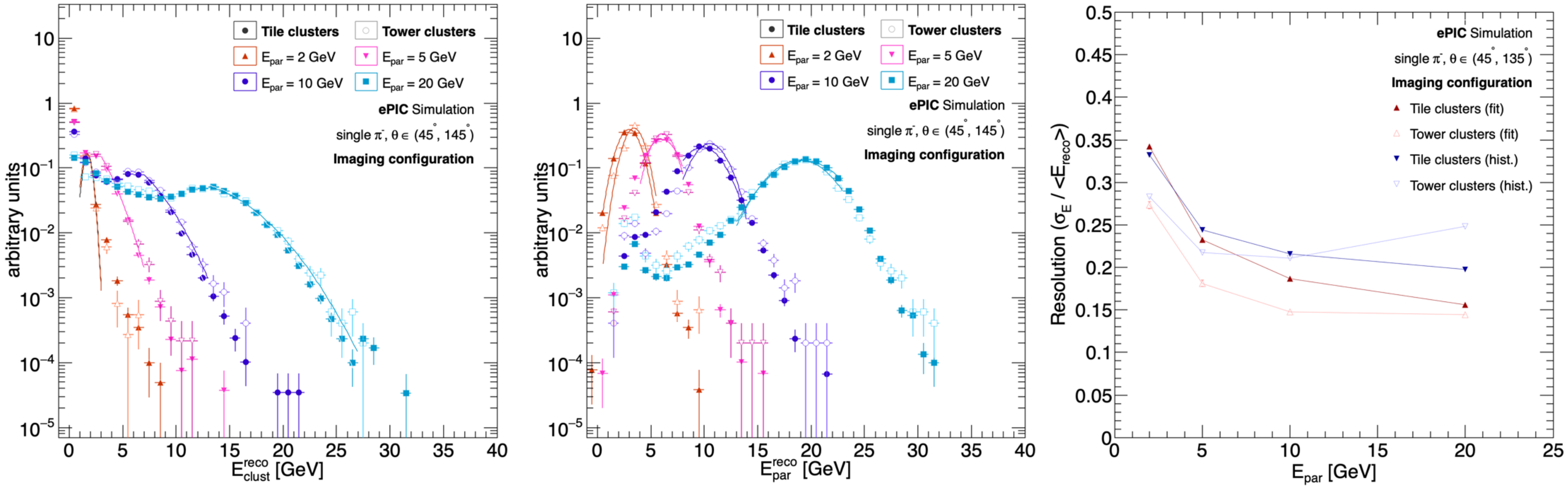
- Geometry fully implemented from tessellated 3D solids
  - Plates and tiles only
  - Issues with spurious overlaps solved (vecgeom)
  - Can/should be easily be expanded to included endplates, dogbones, large end rings
  - Performance matches sPHENIX test beam





Simulation Status | Ongoing

Derek Anderson (ISU)



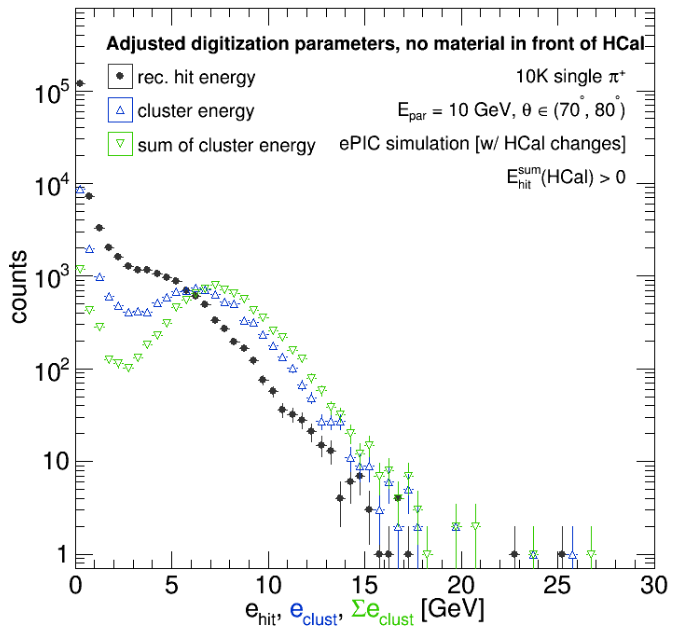
- **Transitioned to reading out tiles rather than towers**
  - ☞ Now studying impact on energy resolution
  - ☞ Need to revise clustering parameters
- **Above:** comparison of tile-based BHCal clusters **(closed markers)** vs. tower-based clusters **(open markers)** from March study
  - **Left:** Raw cluster energies
  - **Center:** calibrated energies (ML)
  - **Right:** extracted energy resolutions

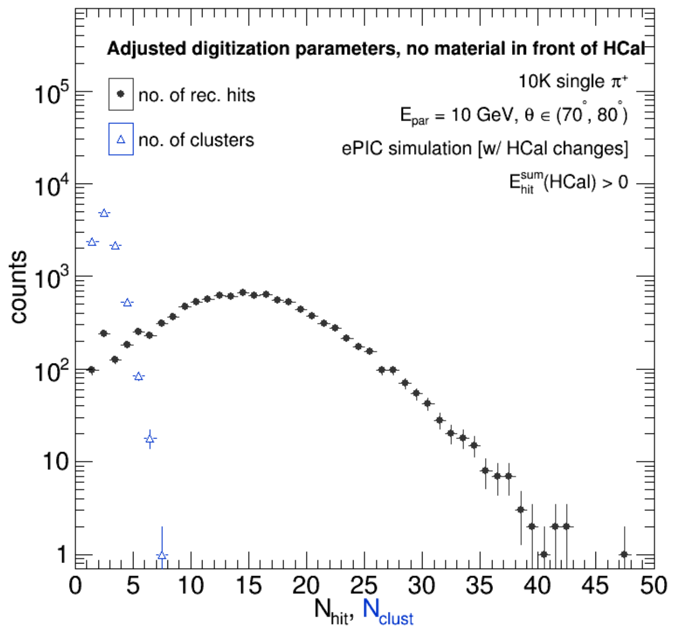
Simulation Status | Near-Term Plans

- **Expanding ML Calibration Studies**
  - More thorough study of hyperparameters
  - Expanding ML techniques used
    - ☞ e.g. ML-driven cluster splitting

- **Extending performance studies with Brian Page**
  - More thorough study of BHCal energy reconstruction
  - Study its impact on JES/JER
  - And evaluate if it aids muon identification

- **Implementing EICrecon benchmarks**
  - **Right:** representative (but ancient) plots for possible benchmarks

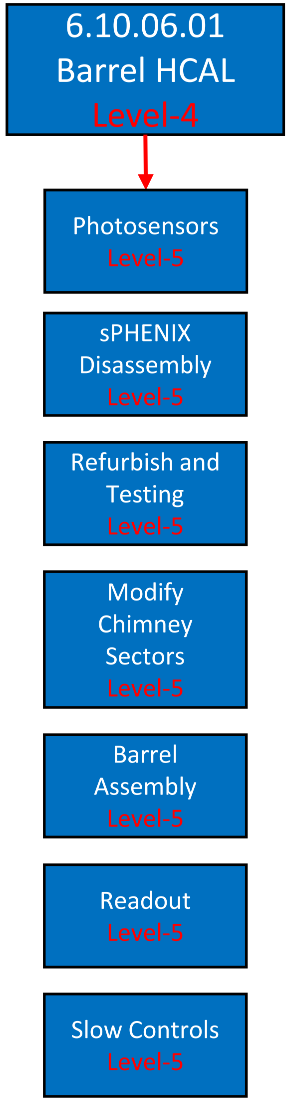




Derek Anderson (ISU)

Barrel HCAL Work Packages

Revised 6/18/2023



BNL Engineer? (sPHENIX Disassembly)

May not be required (Modify Chimney Sectors)

BNL Engineer? (Barrel Assembly)

(One work package for all HGCROC calorimeters?) (Readout)

<u>Interested Groups:</u>

ISU

Georgia State

Rutgers

Lehigh U.

Baruch College

ORNL (HGCROC)

DSC meeting 6/19/23 to work out responsibilities in more detail

Conclusions

- ePIC plans to refurbish the sPHENIX HCAL
  - Replace SiPM’s on tiles
  - Upgrade electronics

- Will the barrel HCAL work for the EIC science?
  - Yes – the refurbished sPHENIX HCAL will provide adequate hadronic energy resolution and the dynamic range to measure MIPs