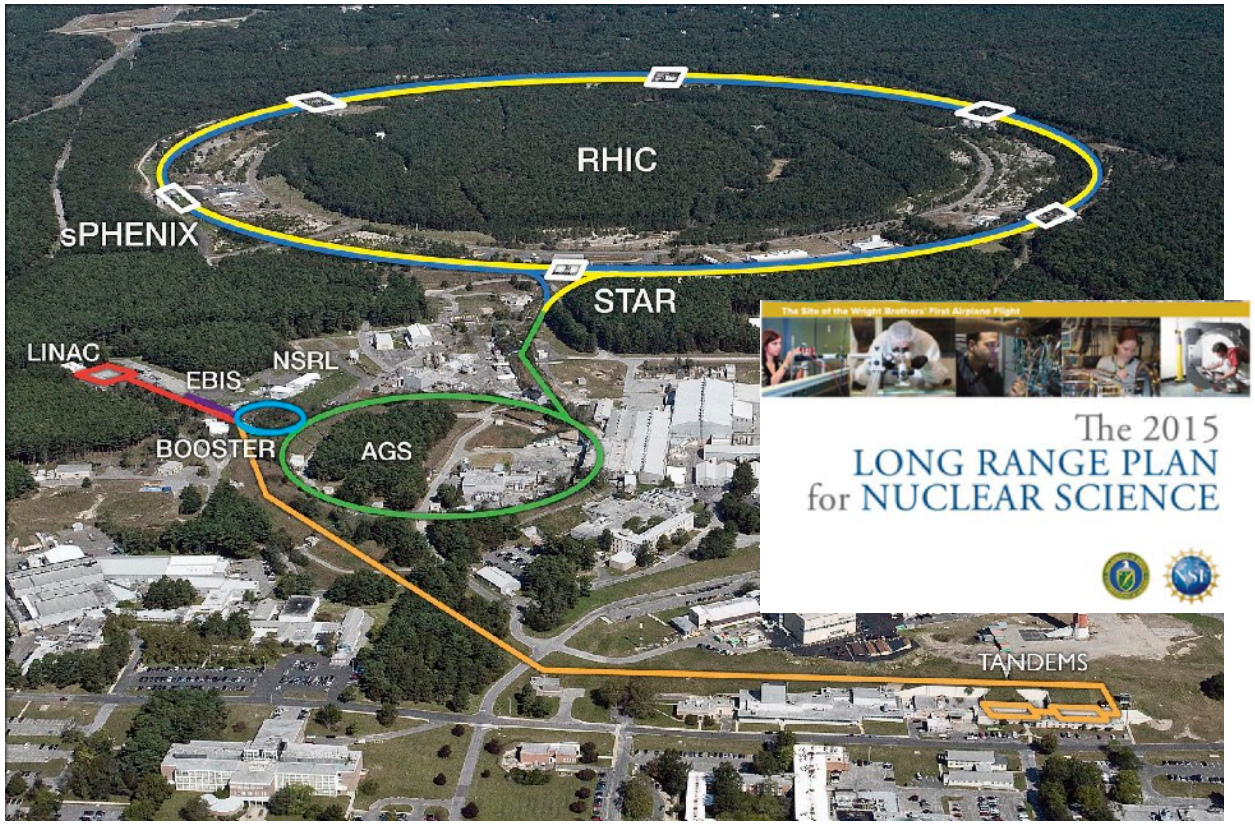
Building and Commissioning the sPHENIX Hadronic Calorimeter

Xiaochun He
Department of Physics and Astronomy
Georgia State University

For the sPHENIX Collaboration

Physics Needs sPHENIX at RHIC



sPHENIX is the first new major detector at RHIC in over 20 years

https://www.sphenix.bnl.gov

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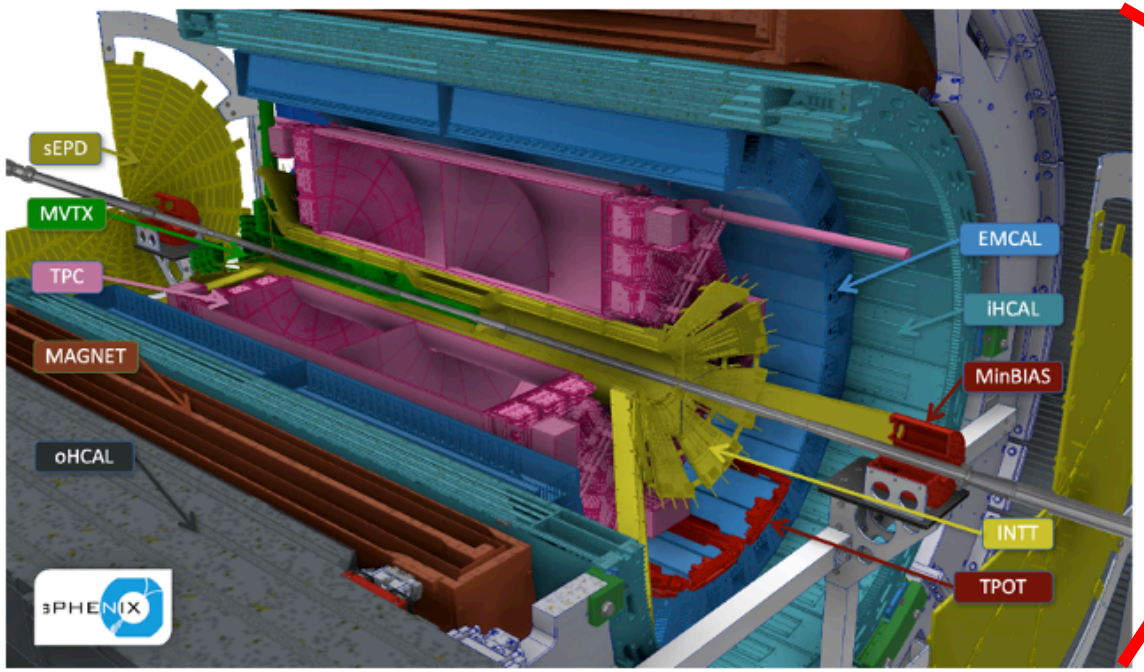

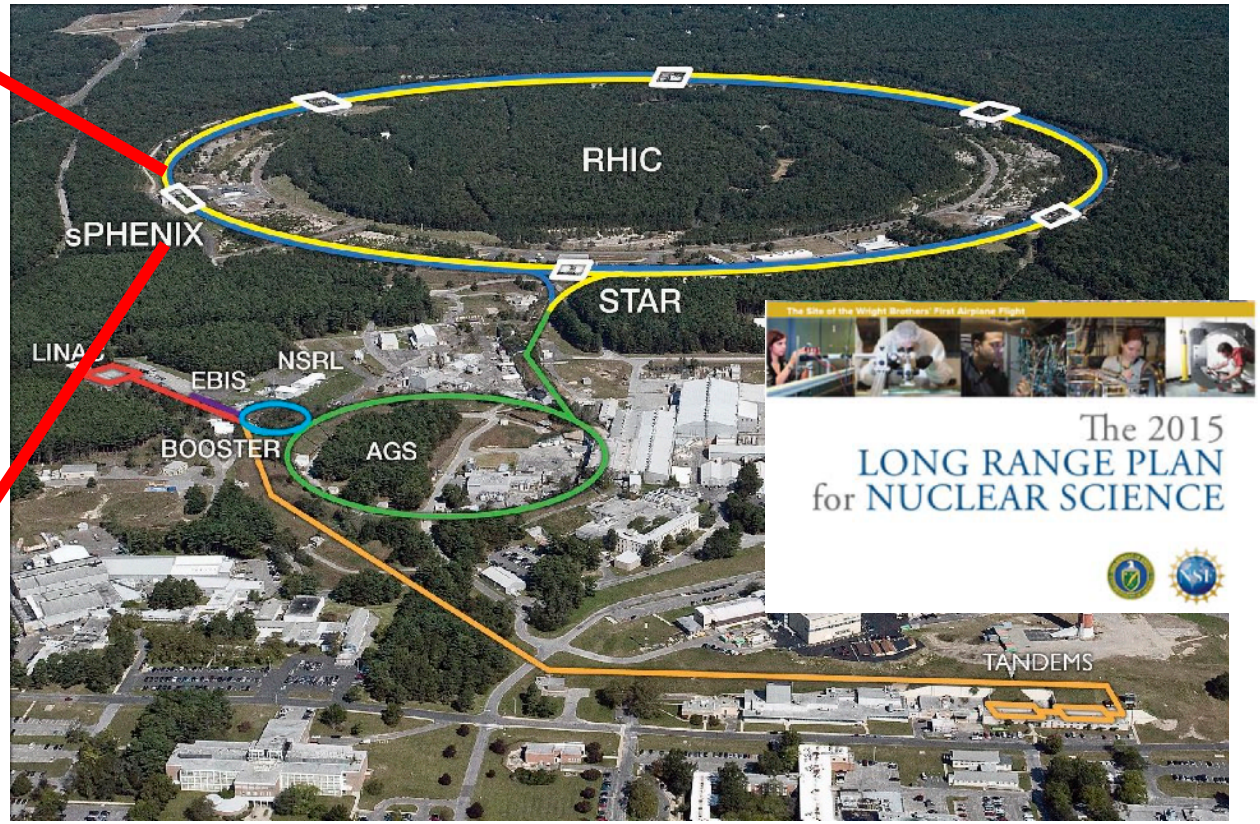

There are about 400 members in the collaboration which consists of 81 institutions from 14 countries

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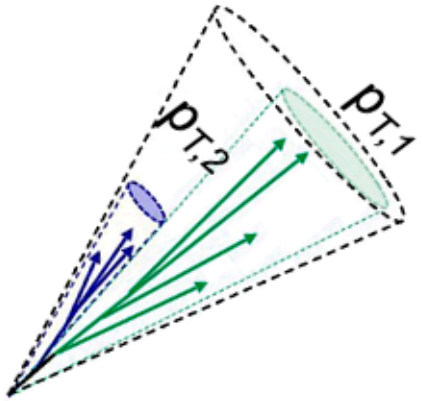
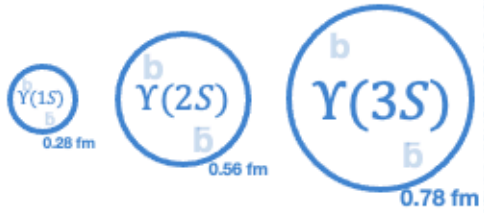
sPHENIX Physics Needs Calorimeters

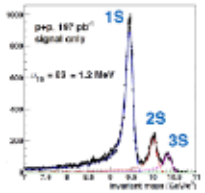
Jet Physics



- Jet correlations
- Nuclear Modification Factor R_{AA}
- Jet structure
- Jet flavor dependencies

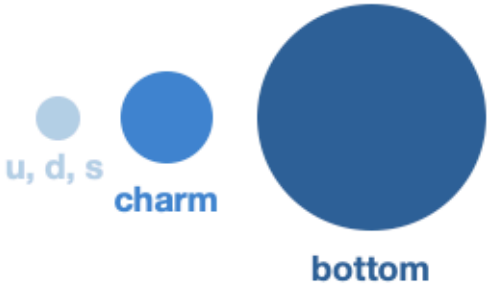
Quarkonium Spectroscopy





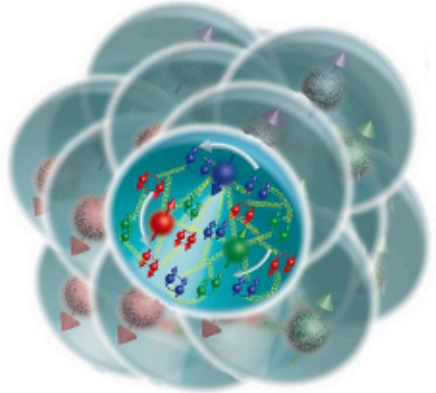
- Sequential quarkonia melting: Suppression of quarkonium depending on the state

Heavy flavor



- Flavor (mass) dependence of parton energy loss in QGP

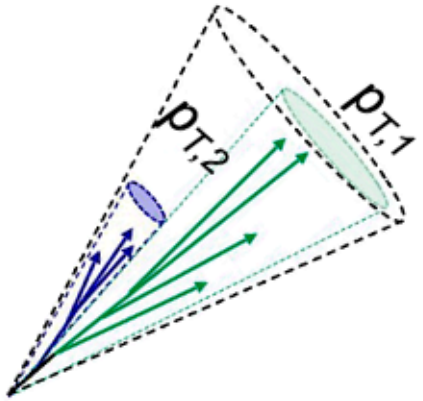
Cold-QCD



- Origin of the transverse single spin asymmetries
- Nucleon structure
- Fragmentation functions

sPHENIX Physics Needs Calorimeters

Jet Physics



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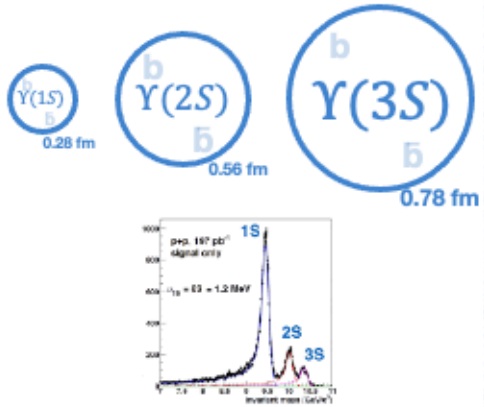

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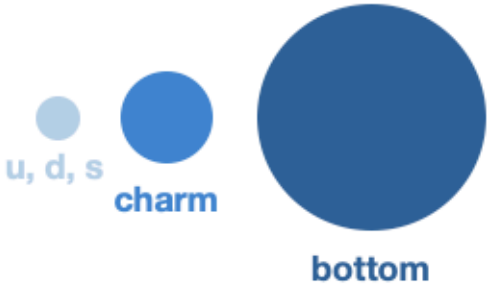

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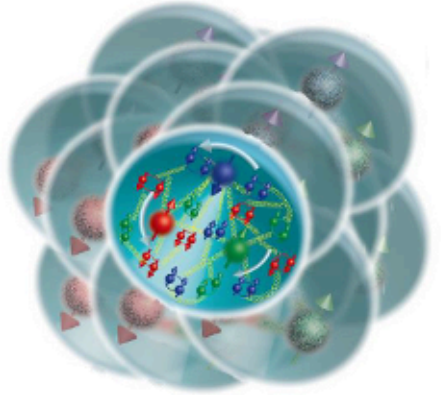

- Origin of the transverse single spin asymmetries
- Nucleon structure
- Fragmentation functions

Probing QGP with precise jet, direct photon, and hadron is the core physics of sPHENIX. HCal & EMCal enable us to reconstruct the full jet in midrapidity up to 70 GeV/c, which overlaps with LHC. sPHENIX can precisely measure the low p_T region, which is challenging at LHC.

The focus of this talk

sPHENIX Hadronic Calorimeter

Concept*, *Prototype*, *Design*, *Construction*, *Installation* and *Commissioning

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A first hadron calorimeter in midrapidity at RHIC for jet reconstruction

Acceptance of the full azimuthal angle 2π and $|\eta| < 1.1$ in $|z_{vtx}| < 10$ cm

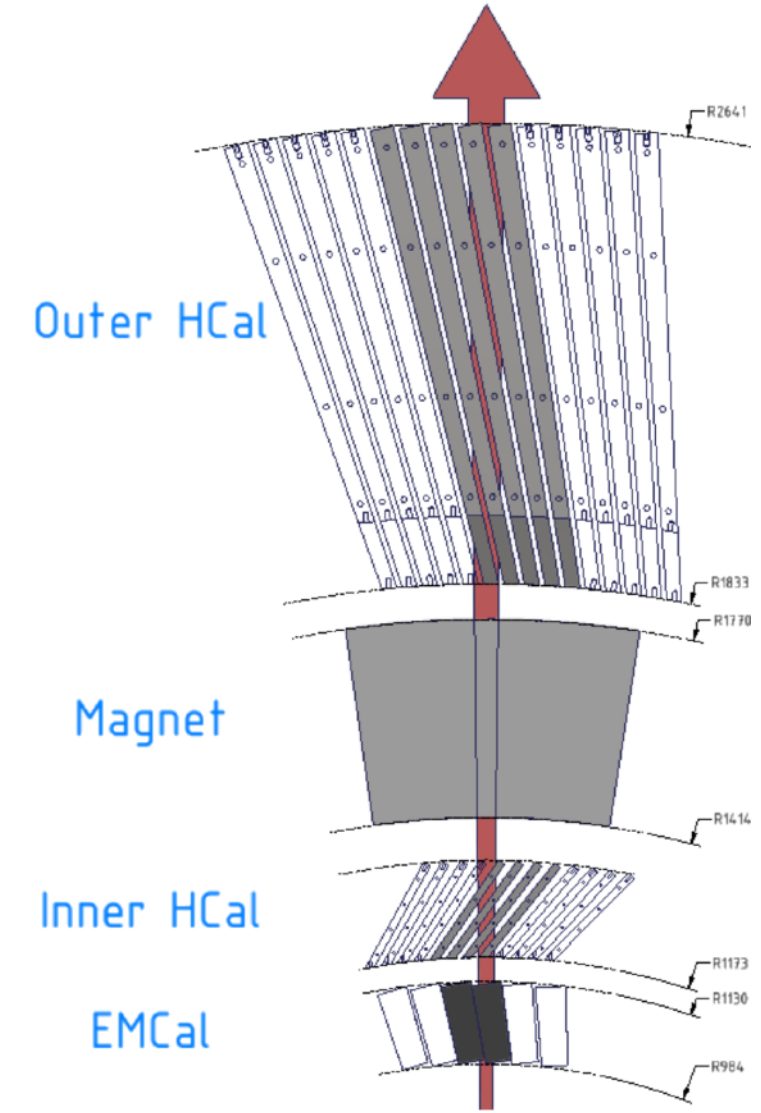
sPHENIX Hadronic Calorimeter - Concept

Presented by E. Kistenev at CALOR 2018

HCAL requirements are driven by measuring jets in heavy ion collisions

- **Uniform and nearly deadzone free**
- **$-1.1 < \eta < 1.1$, 2π in ϕ**
- **$\Delta\eta \times \Delta\phi \sim 0.1 \times 0.1$ fits the jets with R<0.4**
- **$24 \times 64 = 1536$ channels (called towers)**
- **Sampling fraction 2.8-3.7% (varies in depth)**

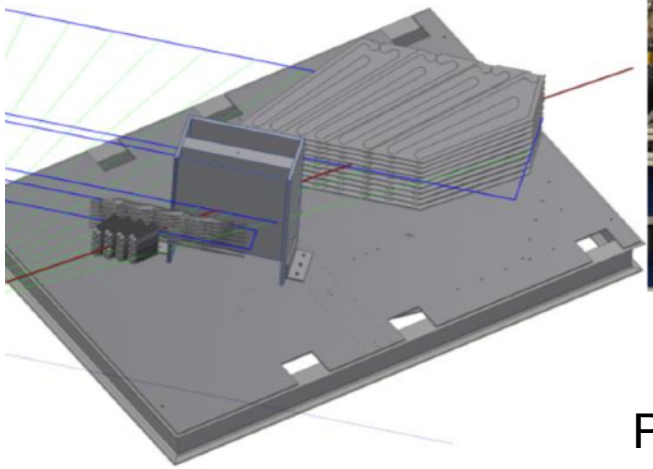
The Outer HCAL doubles as the flux return of the solenoid

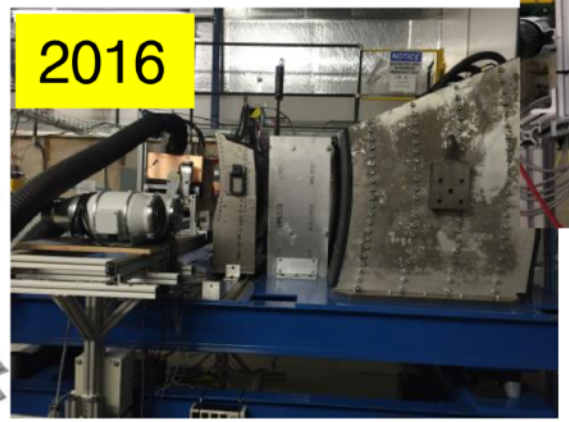


sPHENIX Hadronic Calorimeter - Prototyping

History

2/2014	Proof of principle
2/2016	System at η~0
2/2017	System at η~0.9
2/2018	System at η~0.9.
	”Production” components





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DOI: 10.1109/TNS.2018.2879047
December 2018

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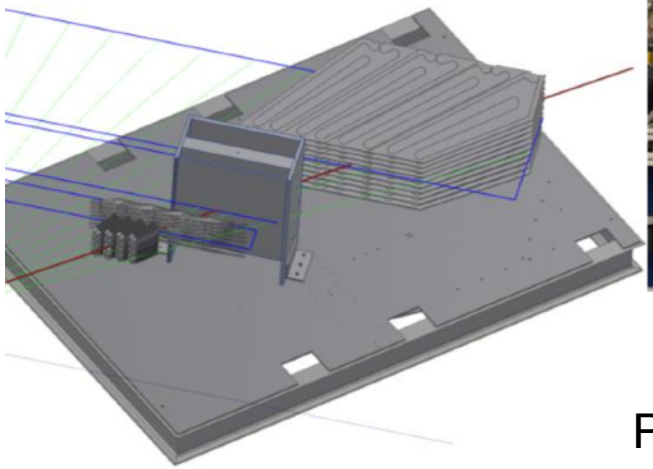
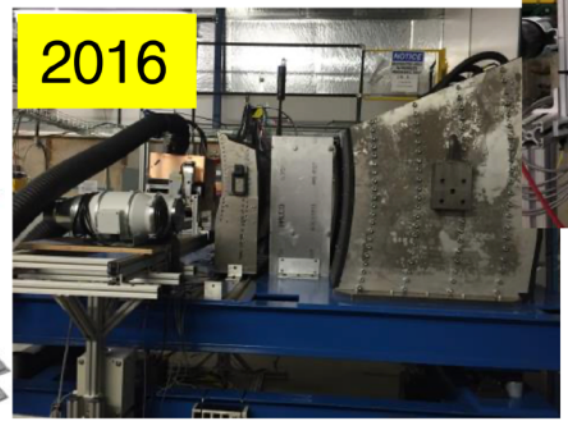
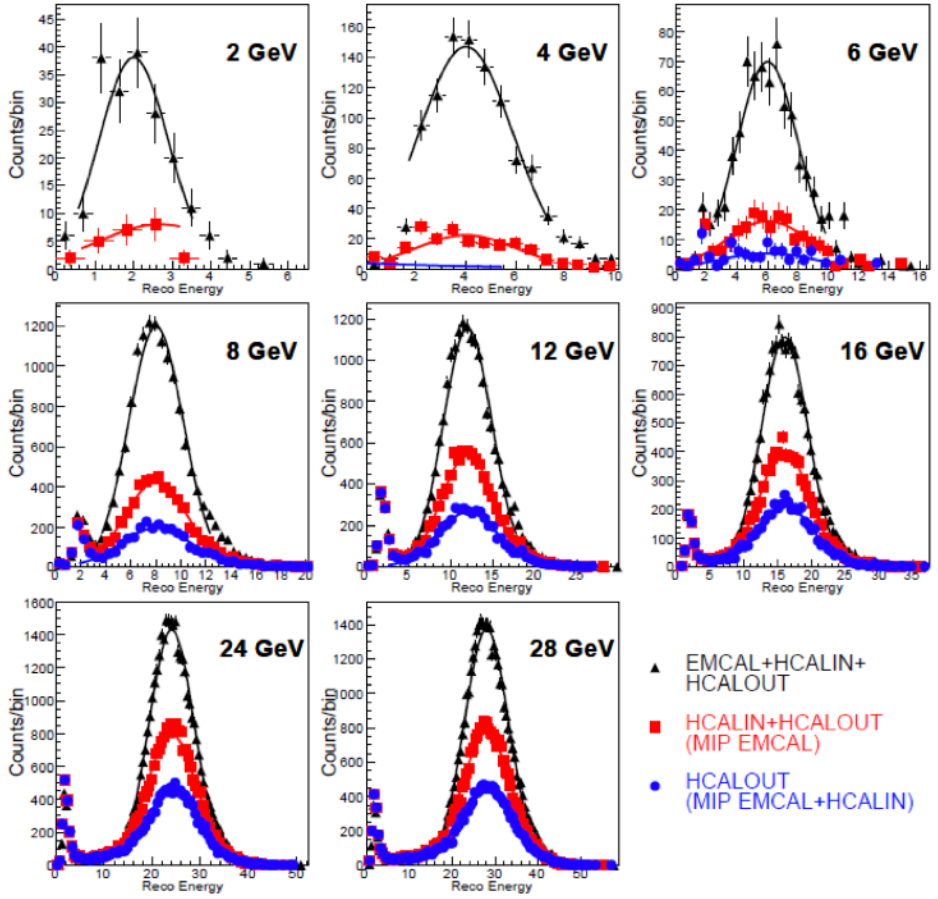


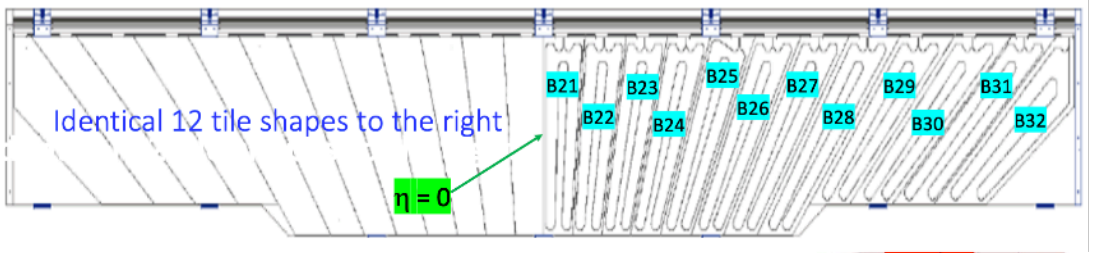




Presented by E. Kistenev at CALOR 20

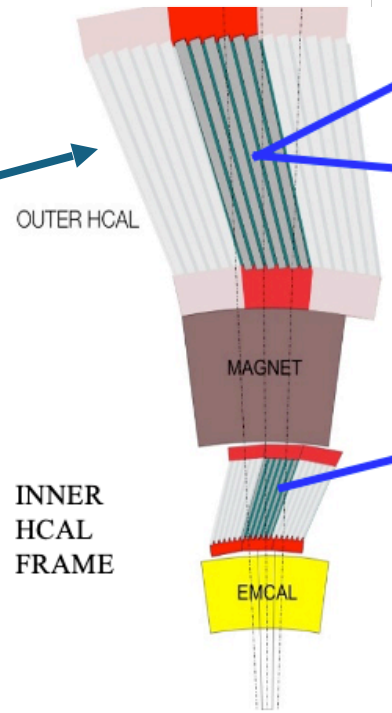
sPHENIX Hadronic Calorimeter - Design

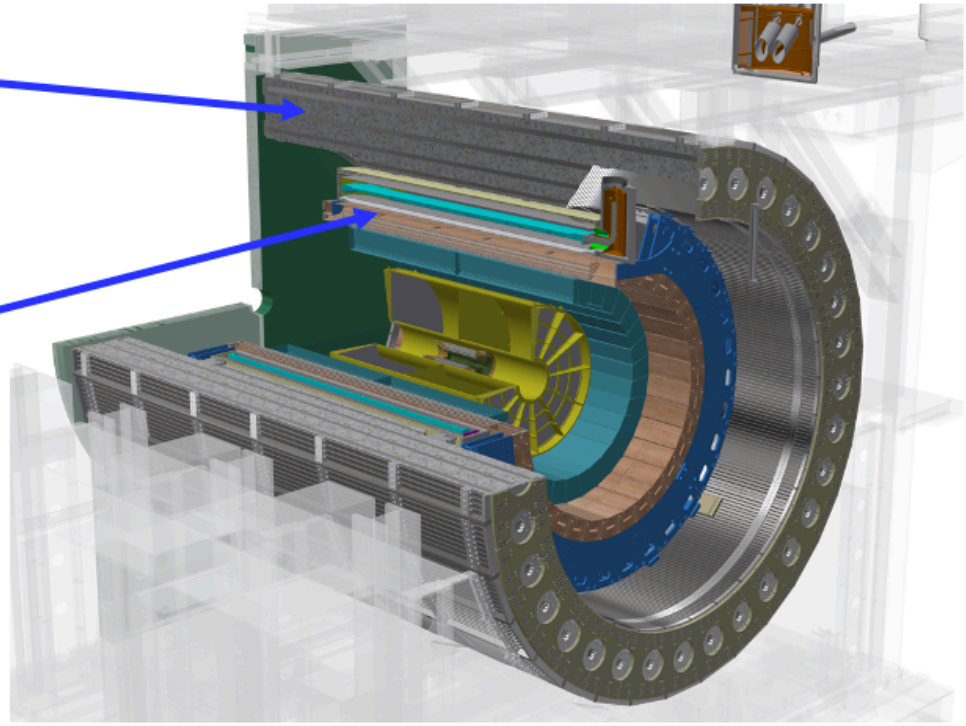
12 different tile shapes covering different pseudorapidity range



Outer HCal

- 32 sectors
- 48 towers
- 5 tiles per tower
- 1536 readout towers
- 7680 SiPMs
- 10 steel plates per sector
- 8 mm gap between plates
- 24 tiles per gap
- 240 tiles in each sector
- 12 different tile shapes





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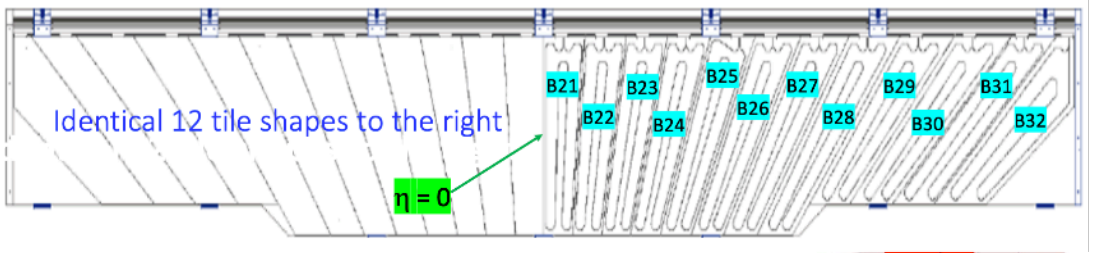

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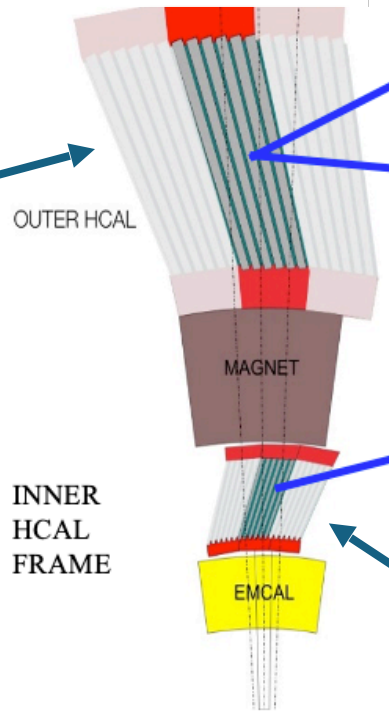

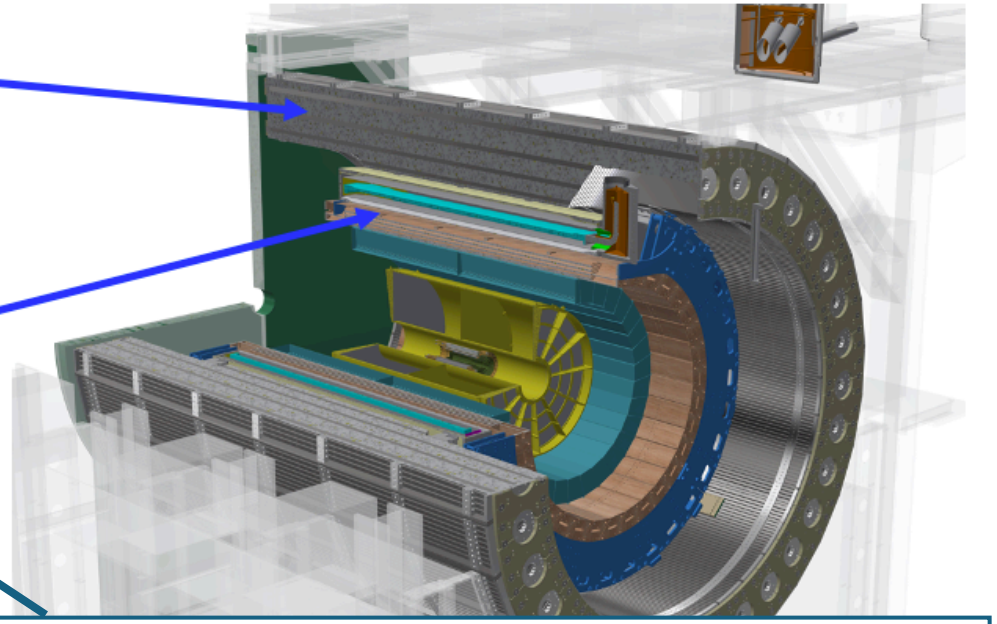

Inner HCal has a similar sector-tower structure but much smaller. Absorber material is aluminum and each tower consists of 4 tiles.

sPHENIX Hadronic Calorimeter - Construction

- Over 14k scintillator tiles (24 different shapes) were tested at GSU from summer of 2019 to Oct. 2021. Thanks go to an arm of GSU undergraduate and graduate students.
- The tiles were then sorted and installed in the HCal sectors at BNL assembly factory.

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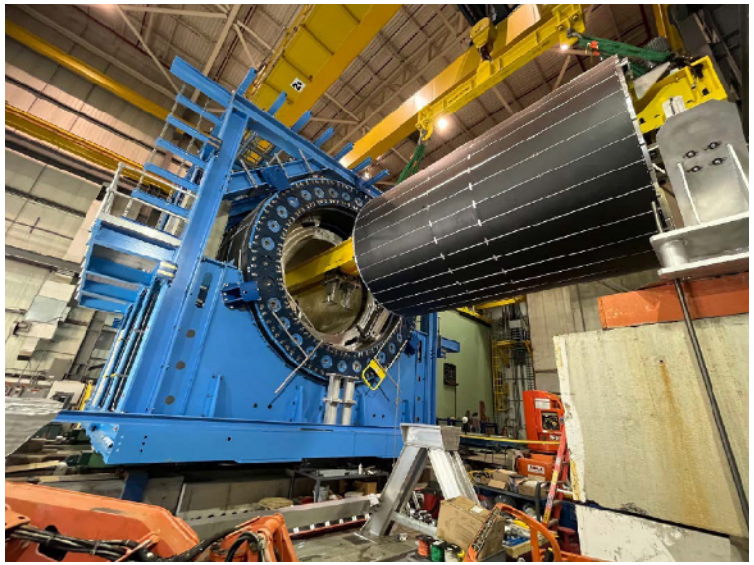

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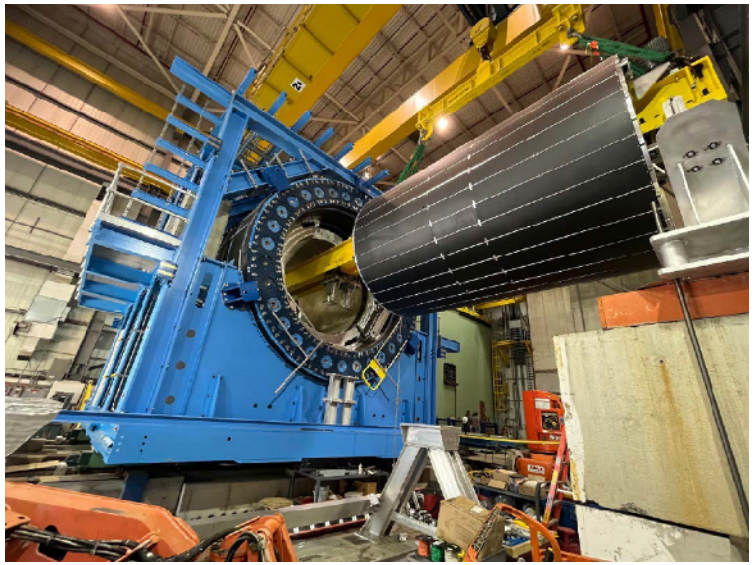

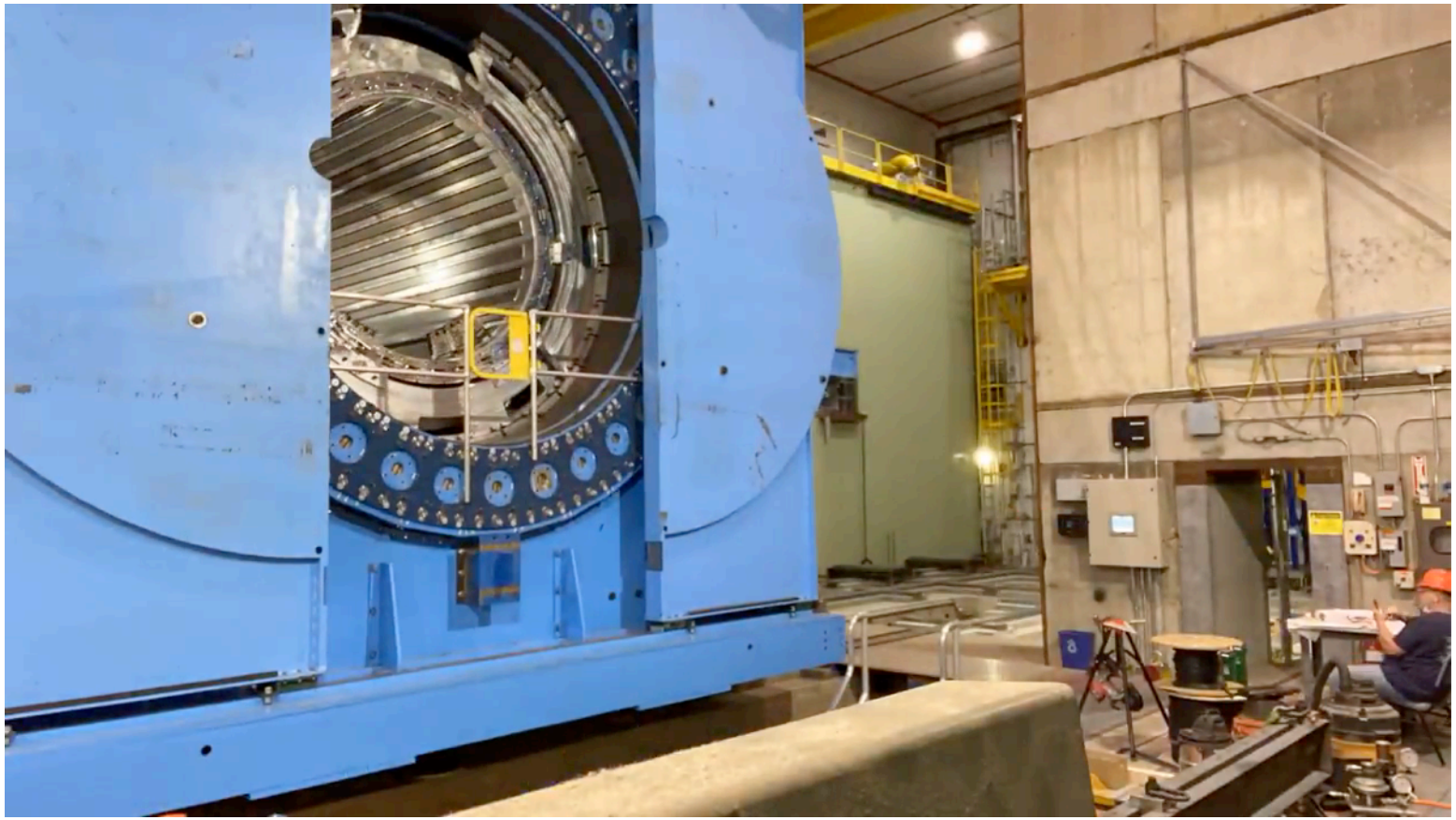

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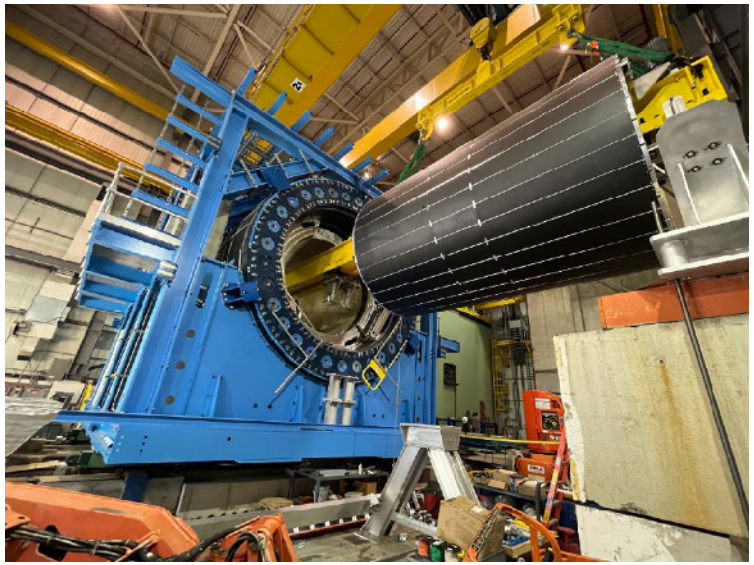

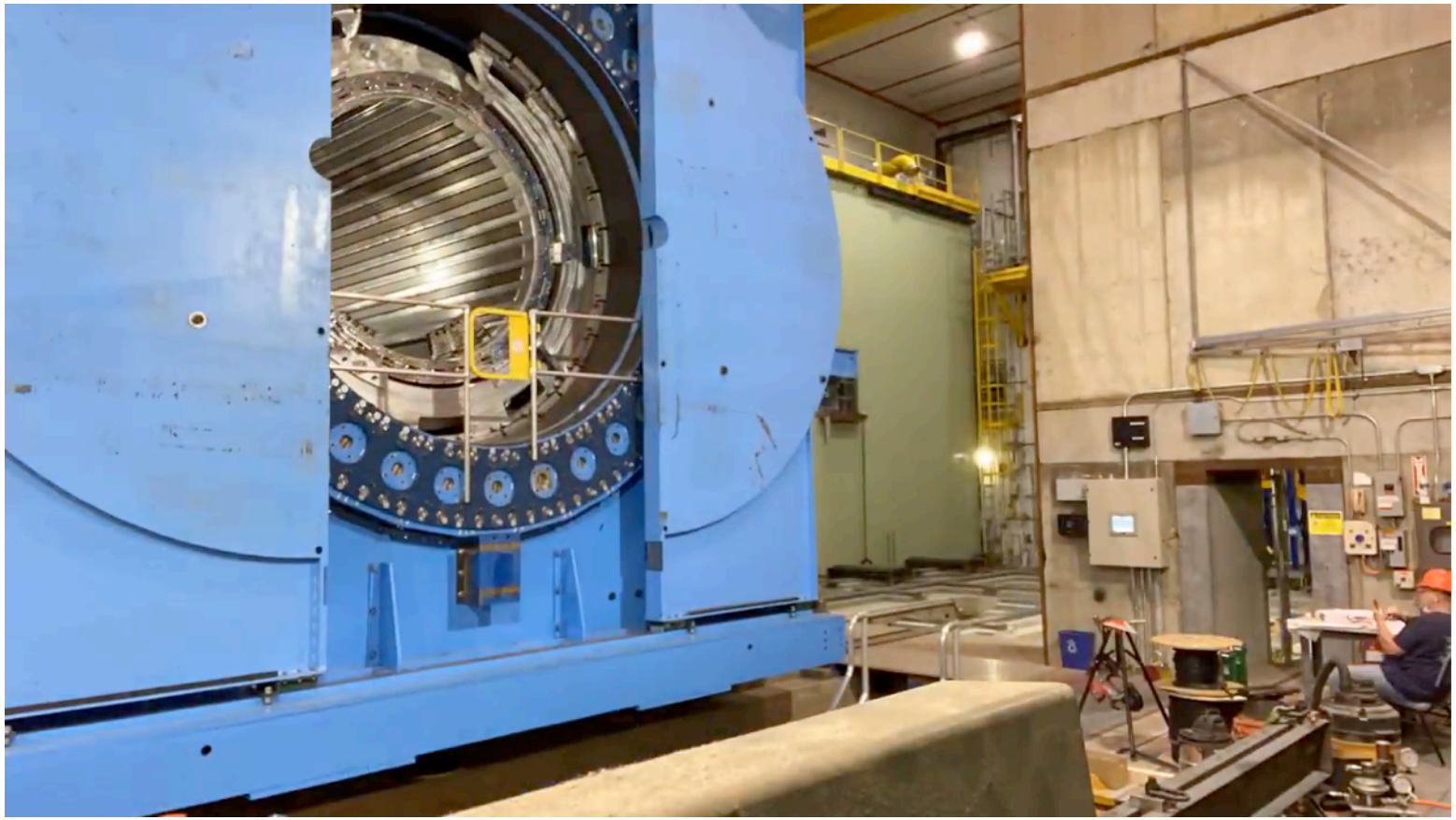

sPHENIX HCal Commissioning and Performance Monitoring

- Started in 2023 with Au+Au collisions (the run was ended early because of a problem in the accelerator.
- Monitoring the gain stability of each tower is important for the energy measurement, which mainly uses two techniques:
  - Taking routine LED-data (see the setup on right)
  - Taking cosmic ray data

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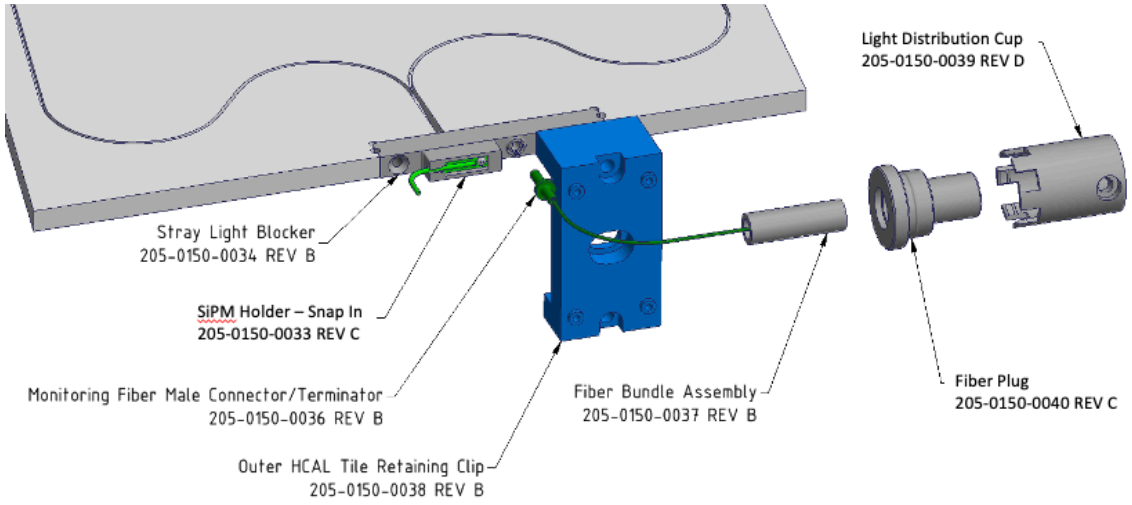
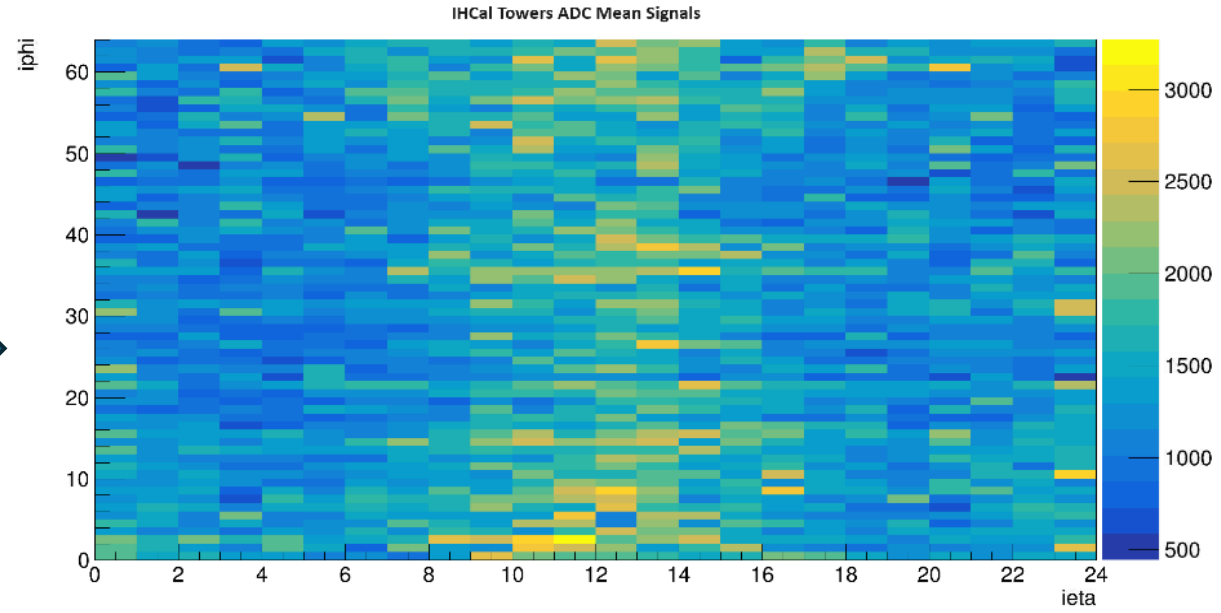
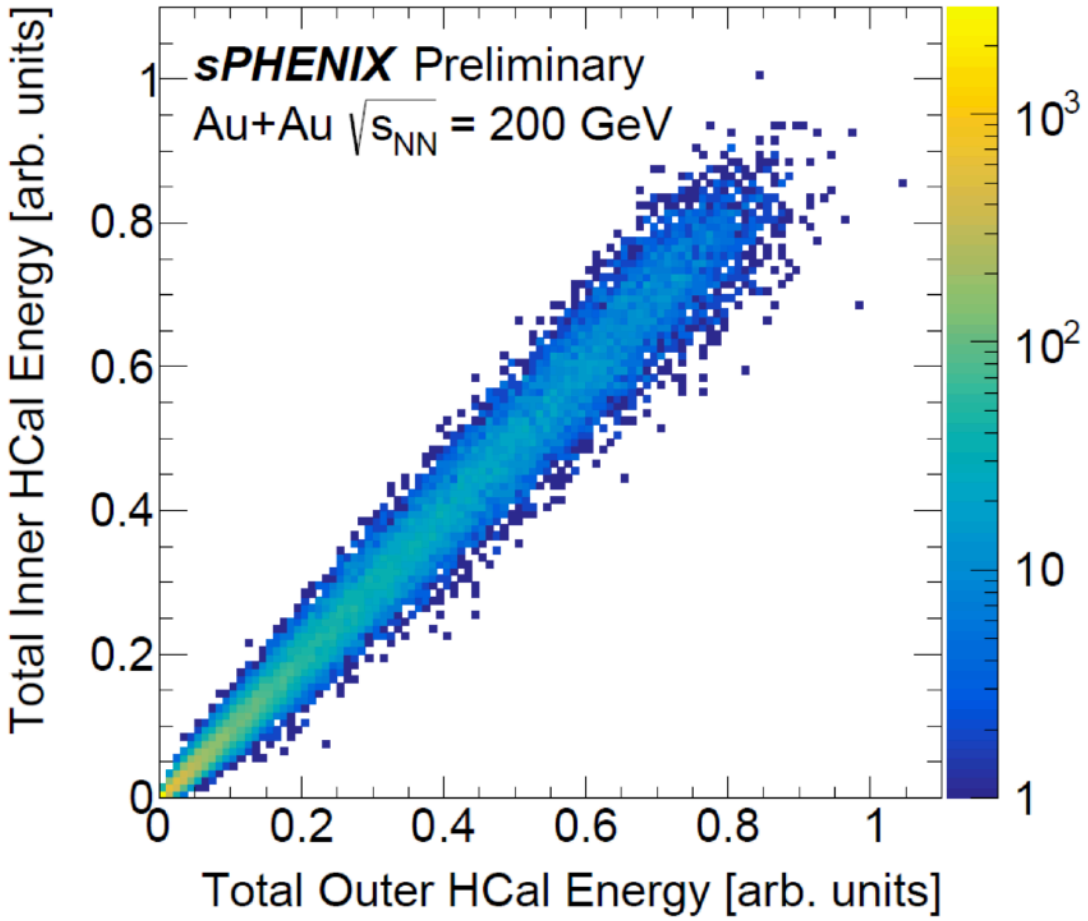
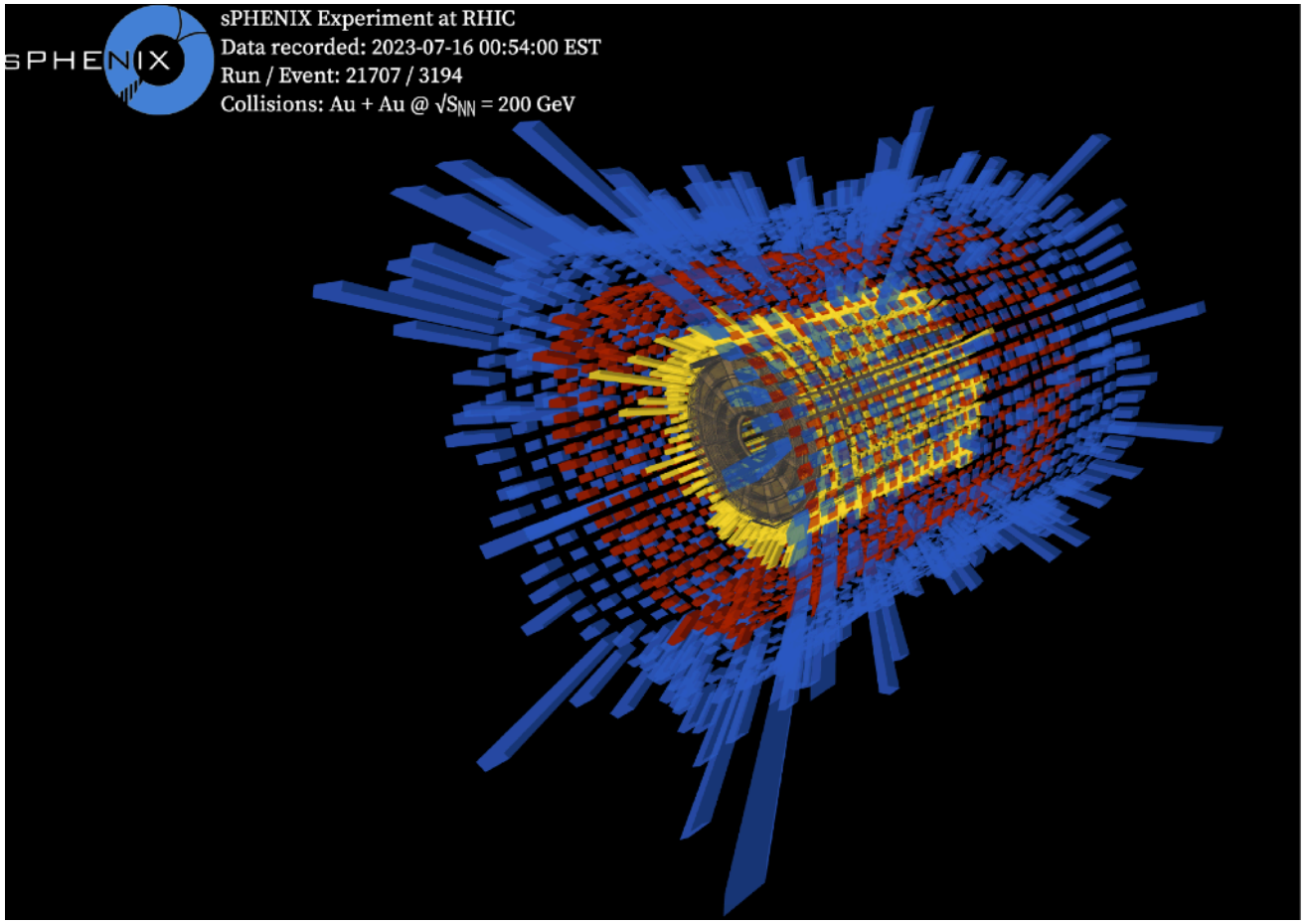








Inner & Outer HCal correlation in 2023 commissioning run

Year	Beam	$\sqrt{s_{NN}}$ (GeV)	Data taking (week)	Luminosity, (|z| < 10 cm)	
				Recorded	Sampled
2023	Au + Au	200	~~9~~	~~3.7 nb^{-1}~~	~~4.5 nb^{-1}~~
2024	$p^{\uparrow}+p^{\uparrow}$	200	17	0.44 pb^{-1} (5 kHz)	31 pb^{-1}
2024	Au + Au	200	3	0.4 nb^{-1}	-
2025	Au + Au	200	24.5	6.3 nb^{-1}	-

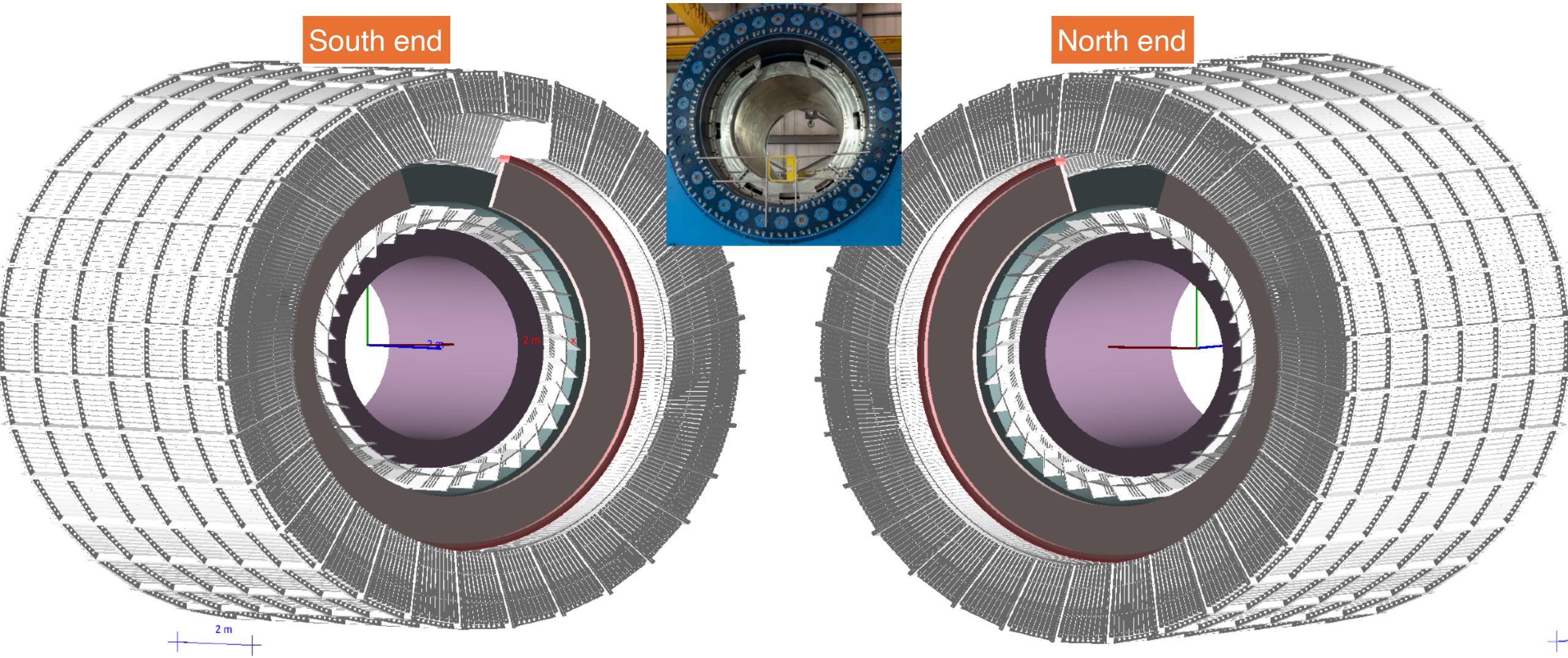
Both the Outer HCal and the Inner HCal are running well in sPHENIX. We continue taking cosmic ray data when there is no beam and taking LED data on a regular basis for monitoring the HCal gain stability over time. Calibrating the HCal energy measurement is still the most task for the sPHENIX HCal, which includes the detailed study of the energy sampling fraction via accurate GEANT4 simulations.

Ongoing Data Taking in 2024

sPHENIX Hadronic Calorimeter - Simulation

Precision simulation is crucial for determining the material budget and the energy sampling fraction.

sPHENIX Hadronic Calorimeter - Simulation



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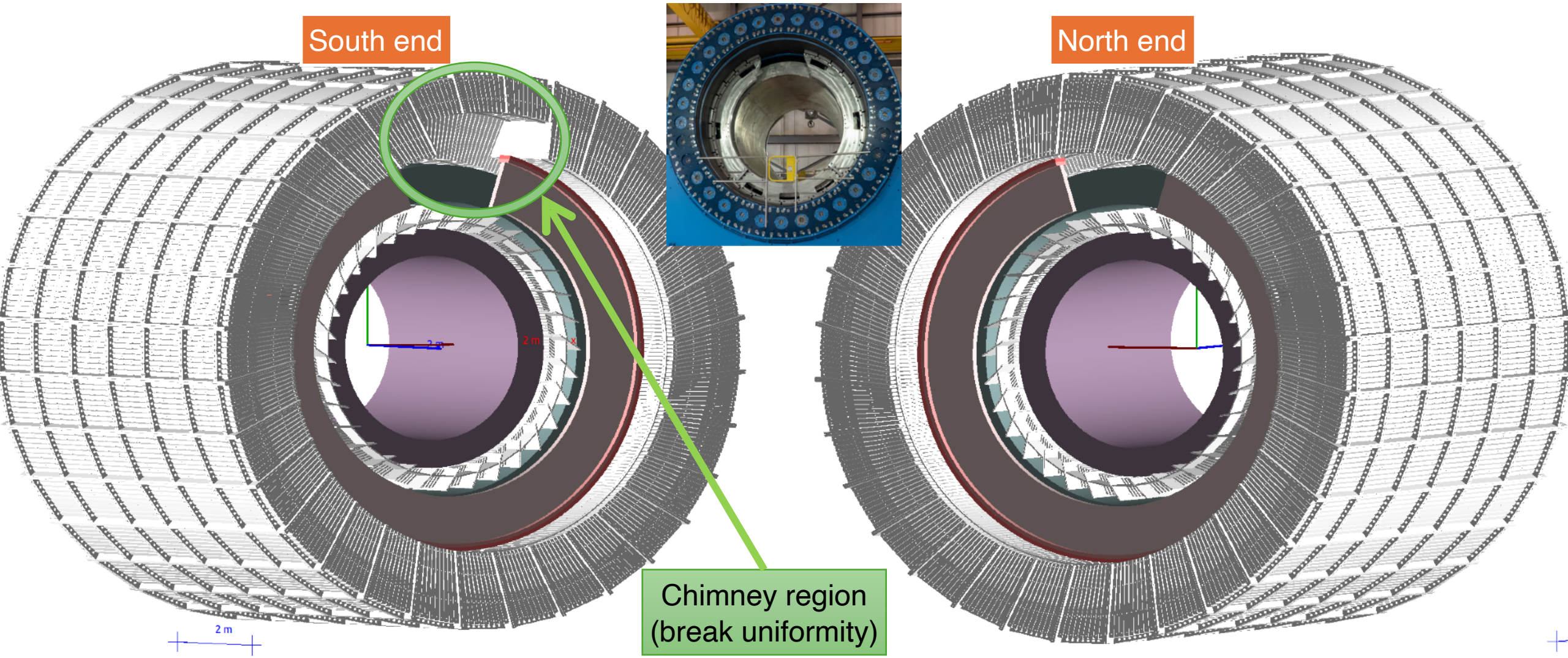

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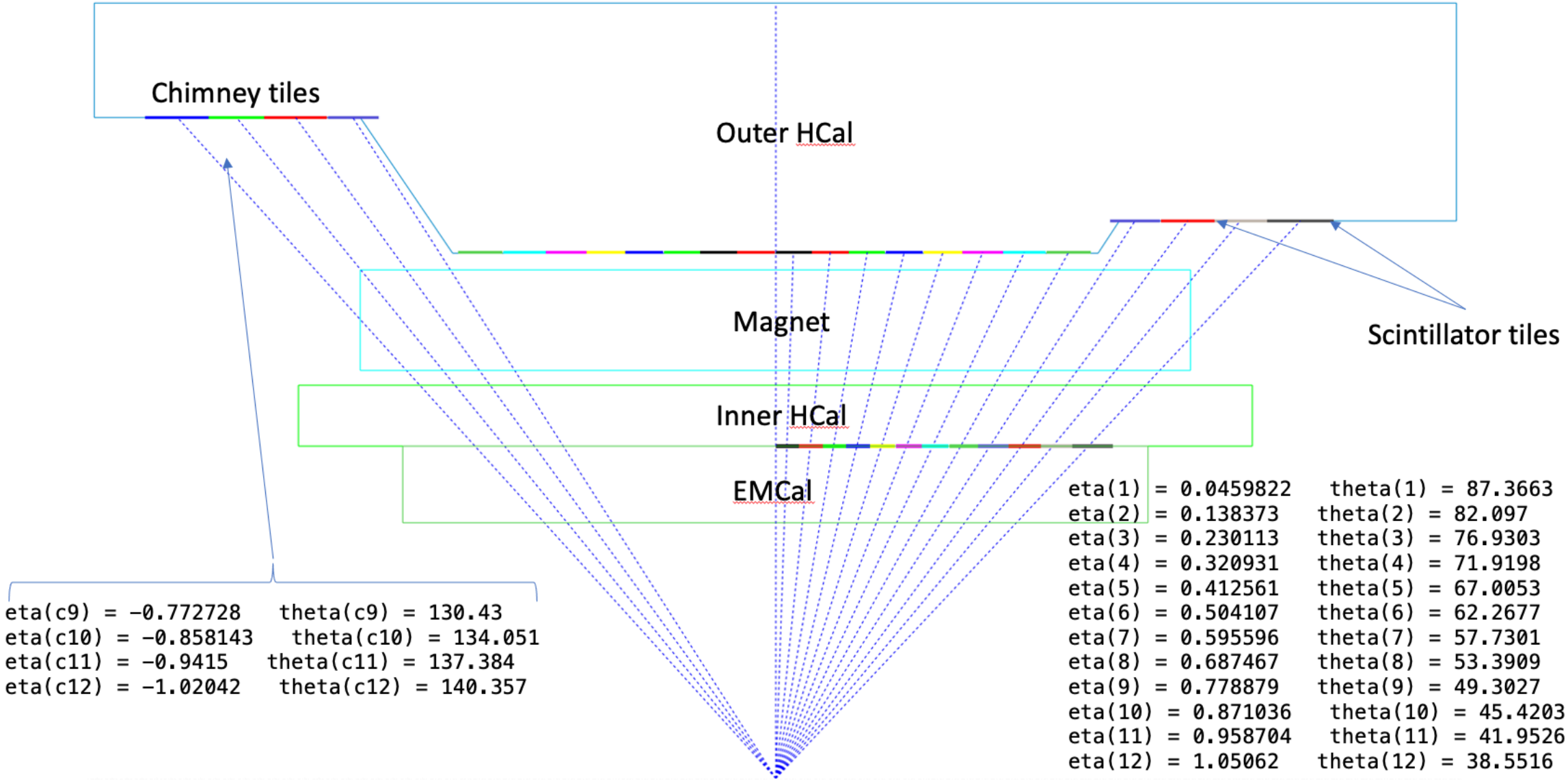
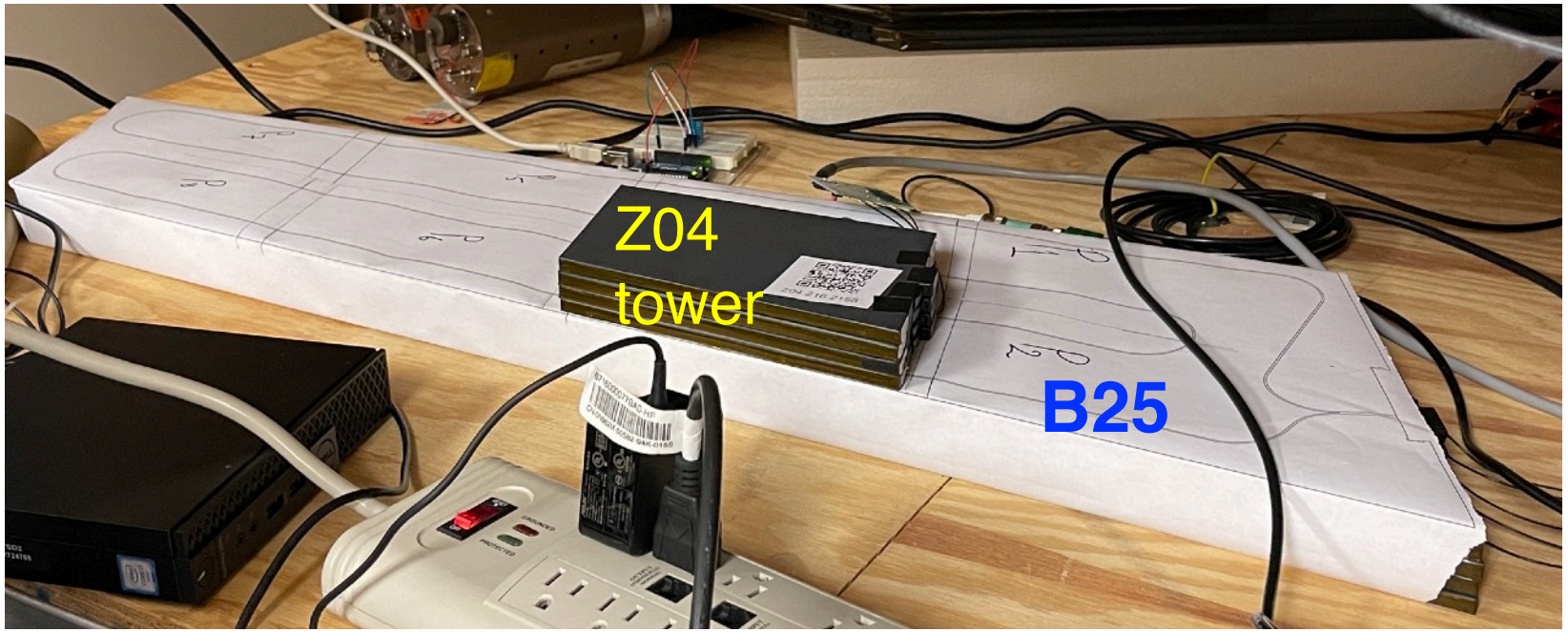
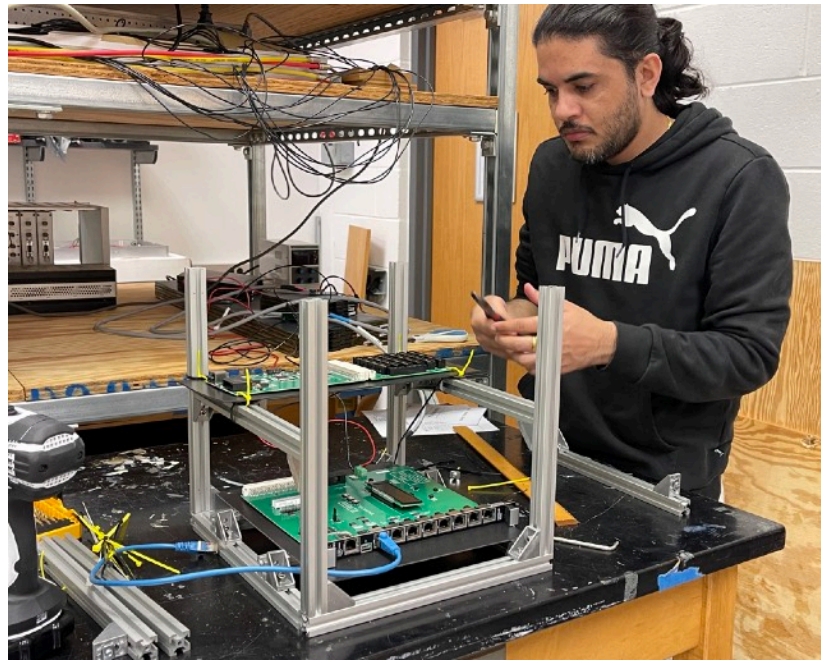
Understanding Energy Sampling Fraction



HCal Tower Gain Stability Monitoring in a HCal Lab at Georgia State University (ongoing)





One Outer HCal tower (**B25**) and one Inner HCal tower (Z04) by recording signal waveforms.

Using sPHENIX front-end electronics

Summary and Outlook

- This short presentation highlights the design concept, prototyping study, construction, installation, simulation, and commissioning of the sPHENIX Hadronic Calorimeter (HCal), which is the first hadron calorimeter in midrapidity at RHIC.
- The HCal enables us to reconstruct the full jet in midrapidity up to 70 GeV/c, which overlaps with the jet energy coverage at LHC. At the same time, sPHENIX can precisely measure the low p_T region, which is challenging at LHC.
- sPHENIX is currently collecting data in p+p collisions at 200 GeV for 17 weeks which will be followed with a 3-week Au+Au collisions. The detailed HCal performance study, including LED-based performance monitoring is ongoing.
- The Outer HCal is likely to be re-purposed for the ePIC experiment at the Electron Ion Collider.

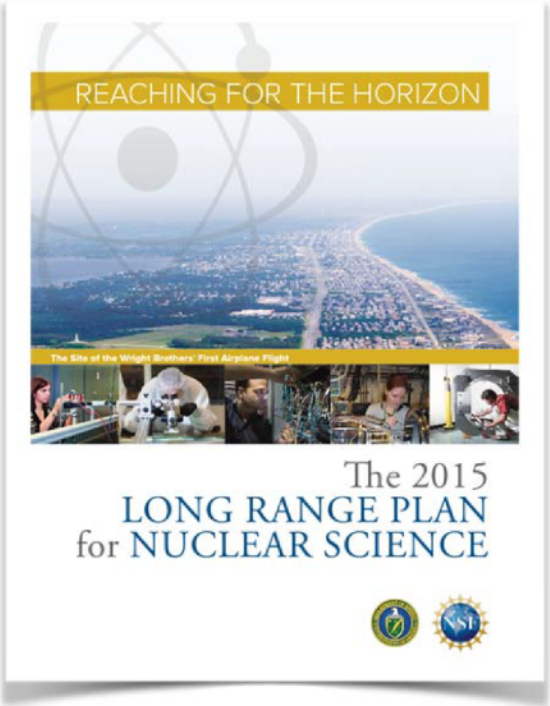
Thank you for your attention!

Acknowledgement

This work was supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics under Award Number DE-FG02-98ER41068

Extra

sPHENIX Hadronic Calorimeter - Concept



There are two central goals of measurements planned at RHIC, as it completes its scientific mission, and at the LHC. (1) Probe the inner workings of QGP by resolving its properties at shorter and shorter length scales. The complementarity of the two facilities is essential to this goal, as is a state-of-the-art jet detector at RHIC, called sPHENIX. (2) Map the phase diagram of QCD with experiments planned at RHIC.

p.22

State of the art detector for:

Jets

Upsilons

Open heavy flavor