



sPHENIX Experiment at RHIC

Data recorded: 2023-07-16 00:54:00 EST

Run / Event: 21707 / 36

Collisions: Au + Au @  $\sqrt{s_{NN}} = 200$  GeV

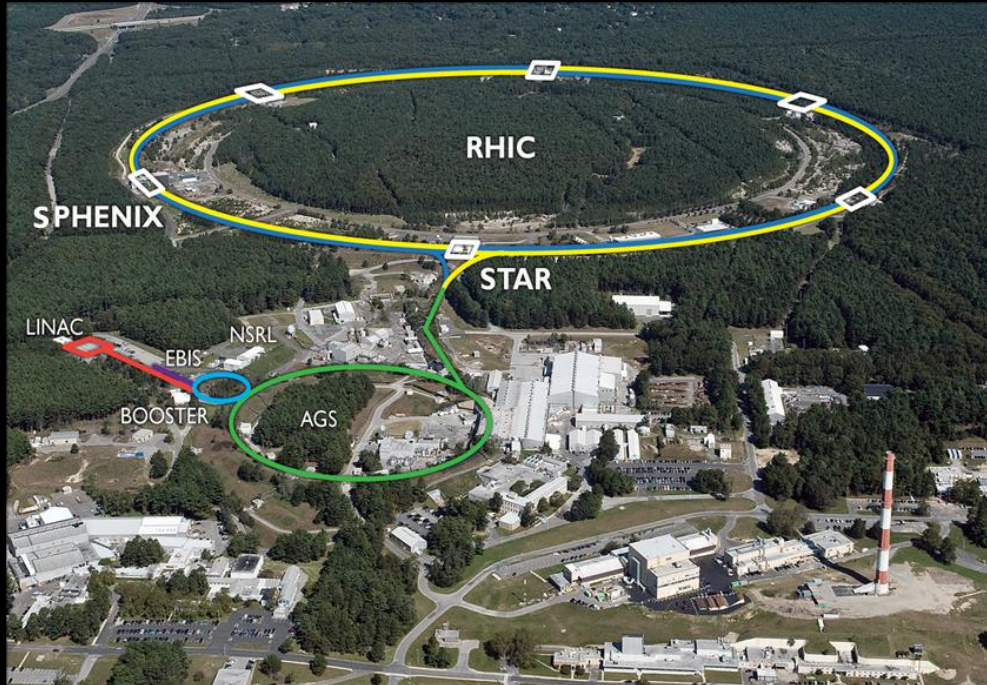
# Readiness of the sPHENIX experiment for jet physics



Timothy Rinn

On behalf of the sPHENIX Collaboration

# The sPHENIX Experiment



Brand new experiment at RHIC

Established as “essential” in the 2015 Long Range Plan for probing the microscopic nature of the QGP

Approval to operate and first Au+Au commissioning data taking began on May 18<sup>th</sup> 2023

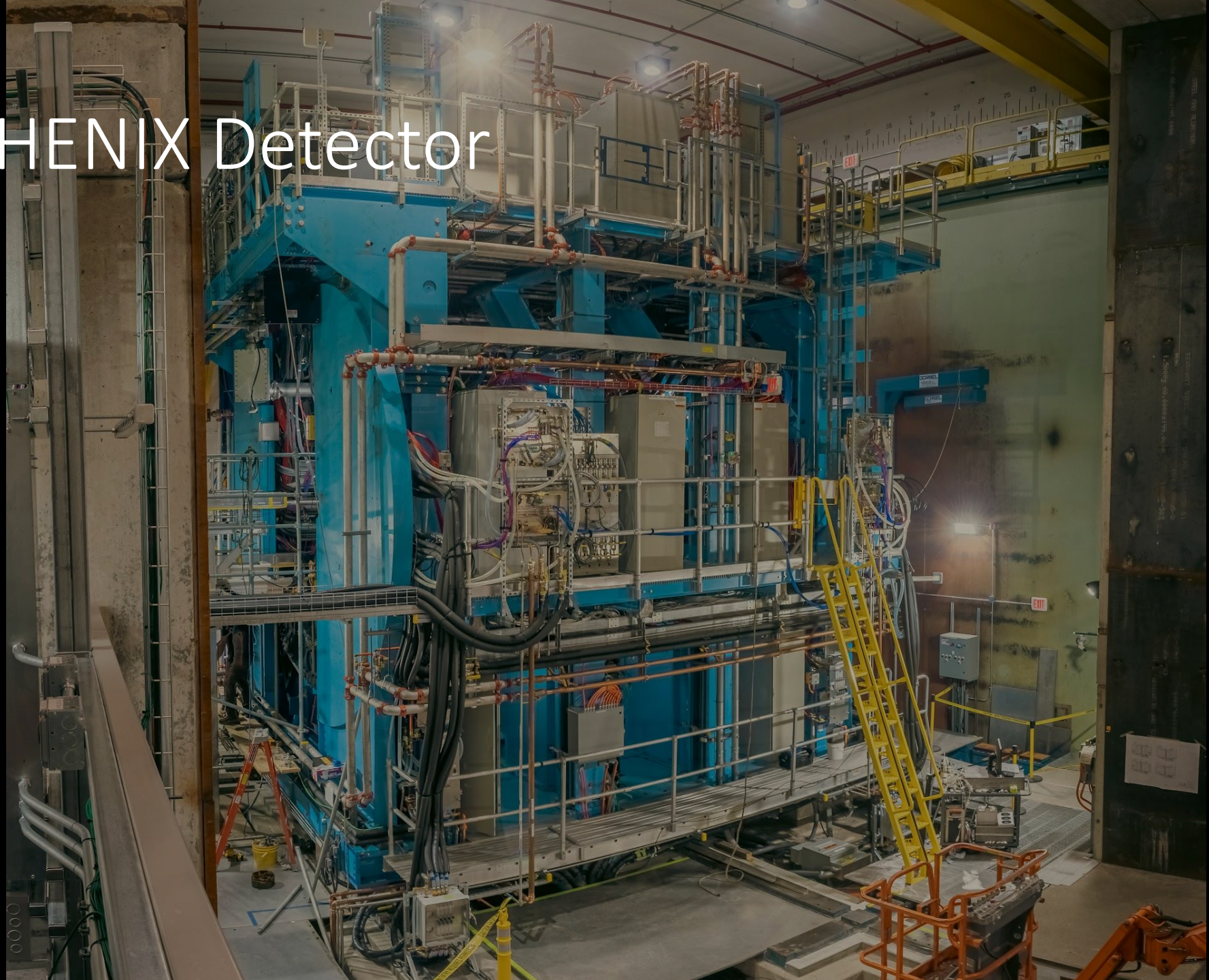
The 2015  
LONG RANGE PLAN  
for NUCLEAR SCIENCE



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.**

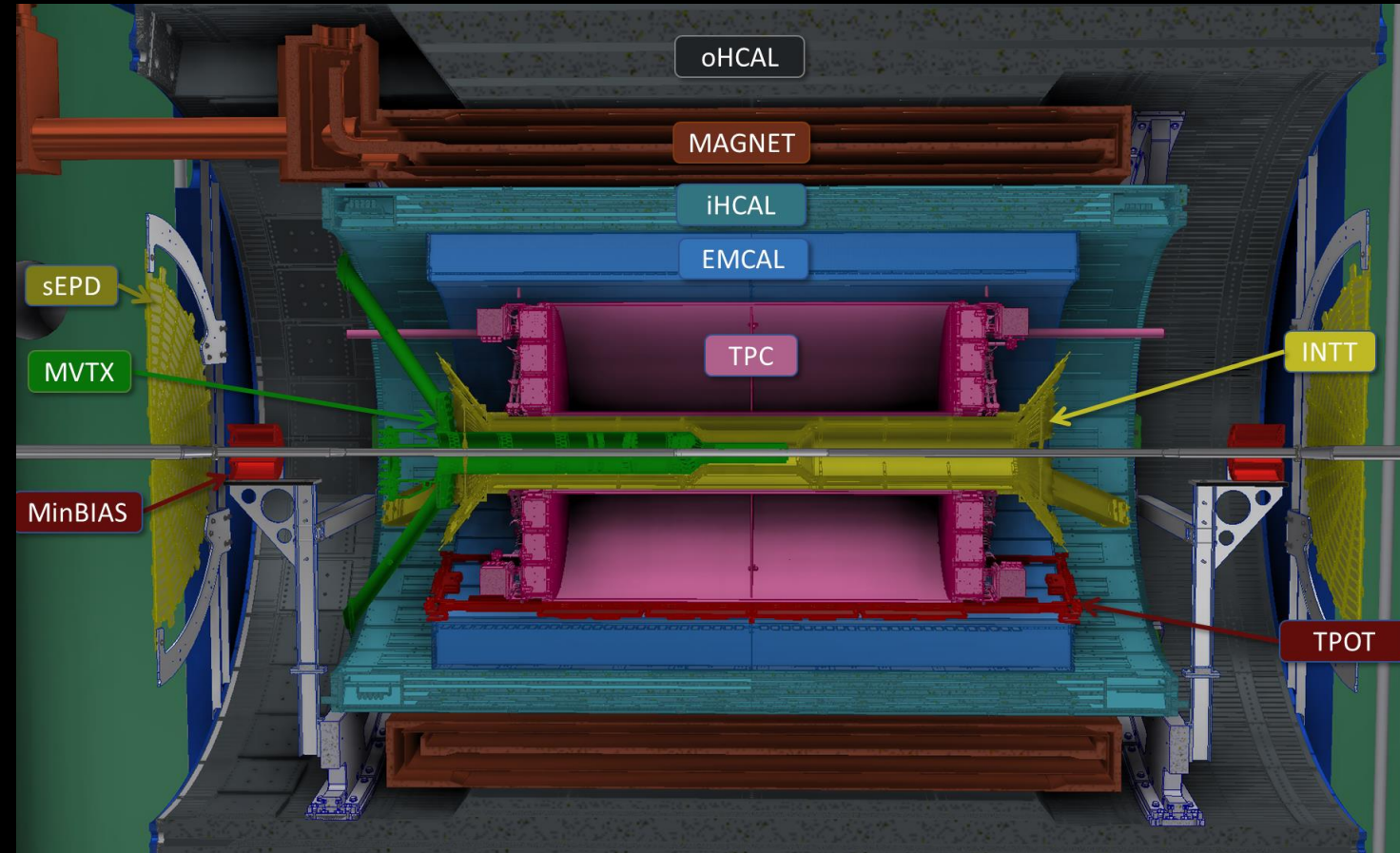


# The sPHENIX Detector





# The sPHENIX Detector



## Complete mid-rapidity calorimeter system

- First measurements of complete mid rapidity jets at RHIC

## State of the art tracking and vertexing:

- Detailed studies of jet substructure
- Precision heavy flavor jet tagging and measurements

## Event Characterization Detectors:

- Detailed study of event plane angle and centrality dependencies to jet quenching



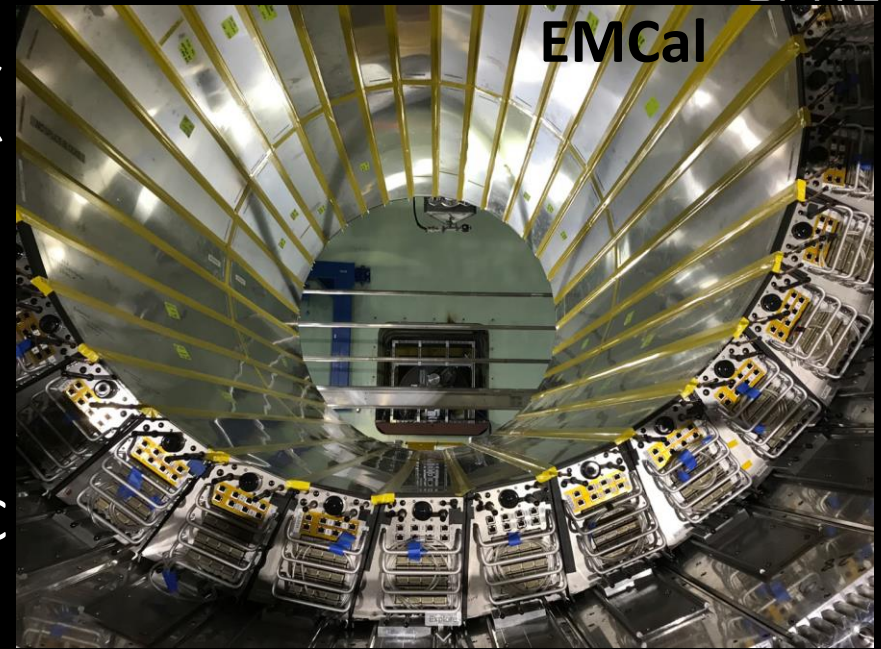
# Calorimetric Jets in sPHENIX

Large acceptance calorimeter system ideal for jet measurements

- $|\eta| < 1.1$
- Full  $2\pi$  azimuthal coverage

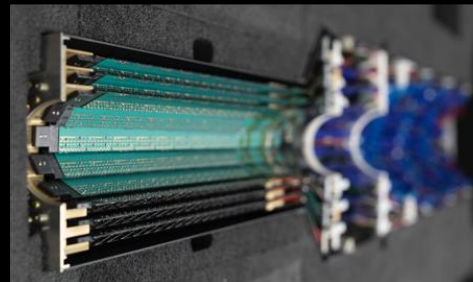
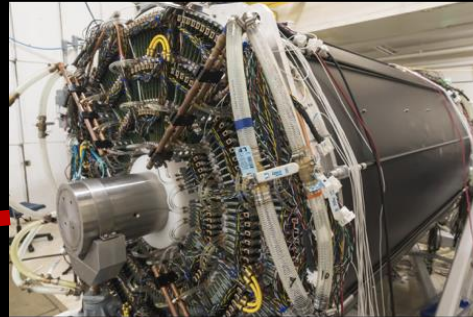
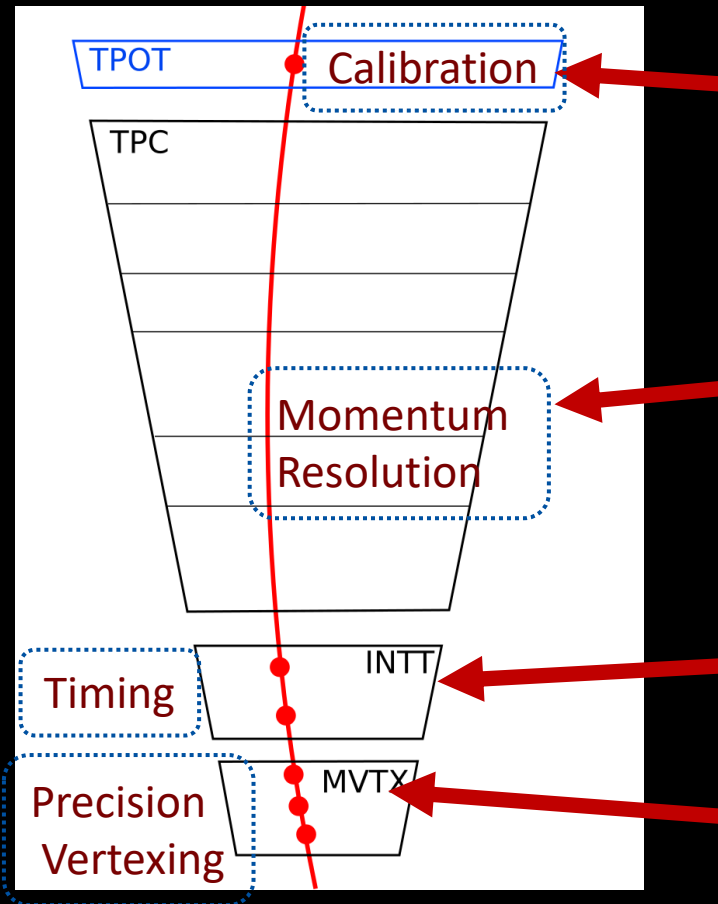
Hadronic calorimeter system enables first measurement of neutral hadron component of mid rapidity jets at RHIC

- Enables measurement of complete calorimetric jets
- Reduces sensitivity to fragmentation biases

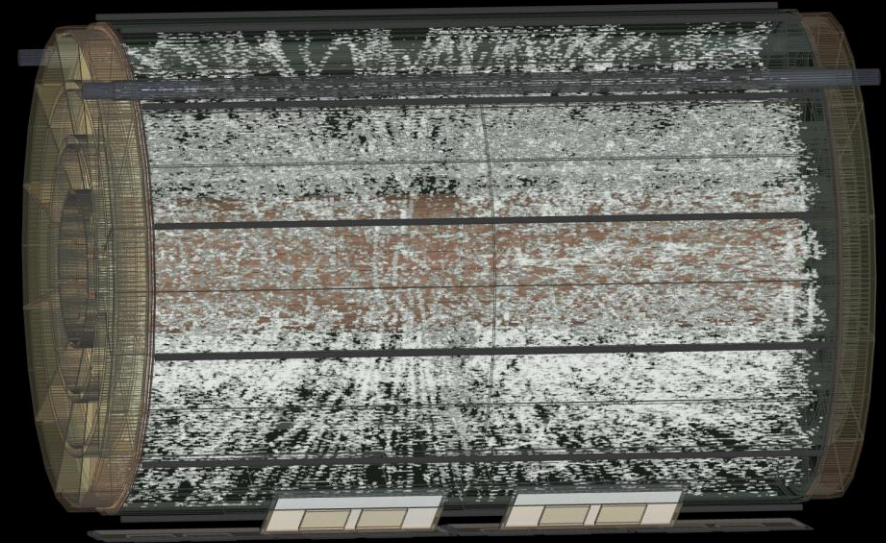




# Tracking Integration in the Jet Program



sPHENIX Time Projection Chamber  
 100 Hz ZDC, MBD Prescale: 2, HV: 4.45 kV GEM, 45 kV CM, X-ing Angle: 2 mrad  
 2023-06-23, Run 10931 - EBDC03 reference frame 43  
 Au+Au sqrt(s)=200 GeV



Multi staged tracking system to enable expanded range of jet physics

- Fine scale jet substructure and fragmentation
- Heavy flavor jet tagging
- See talk by Cameron Dean

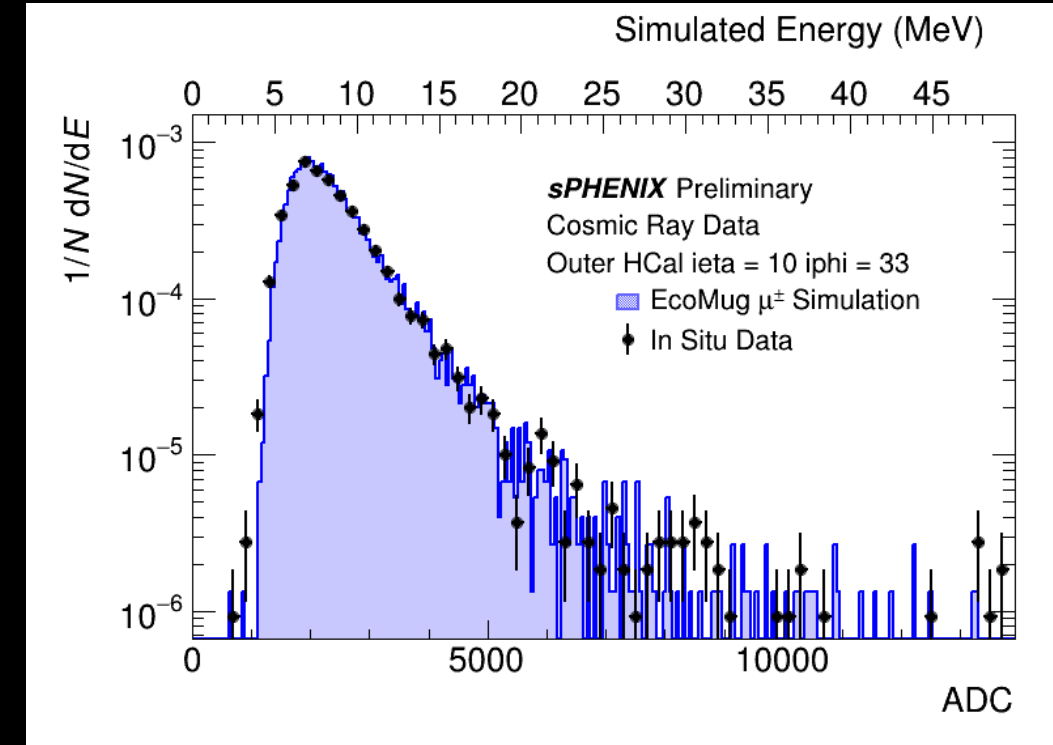
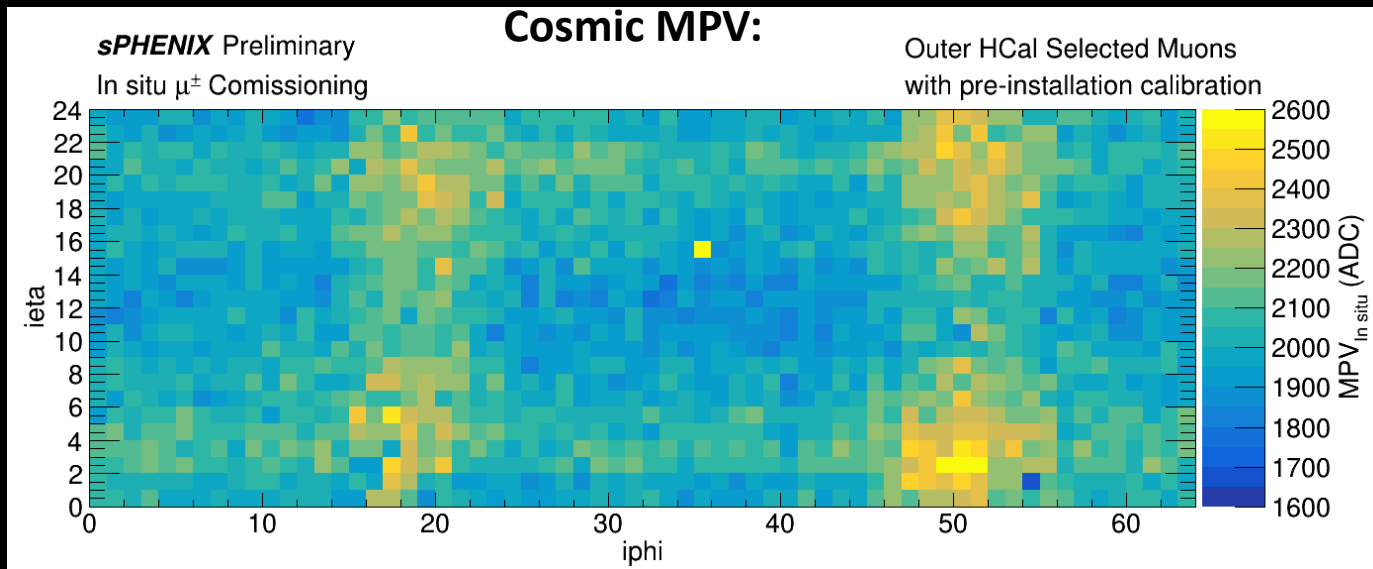
# Run 2023 status:

- Run 2023 began in May of 2023 with Au+Au collisions at  $\sqrt{s_{NN}} = 200$  GeV
  - First commissioning run for sPHENIX
- In August RHIC experienced a failure resulting in the RHIC run ending approximately 8 weeks early
  - 10 weeks in to a planned 12 week commissioning program
- The majority of sPHENIX's commissioning program was able to be completed
  - Outstanding aspects of the commissioning will be finished in early 2024
- sPHENIX is continuing to operate around the clock to use cosmics to commission all detector systems and to be ready for prime physics data in run 2024

# sPHENIX Hadronic Calorimeter

Hadronic Calorimeter functionality thoroughly validated both with and without beam:

- Cosmics well match expectations from simulations
- Cosmic signals observed in 100% of towers
  - Key for calibrating the Hcal system



For further details on cosmics in the Hcal  
see posters by Shuhang Li and Hanpu Jiang

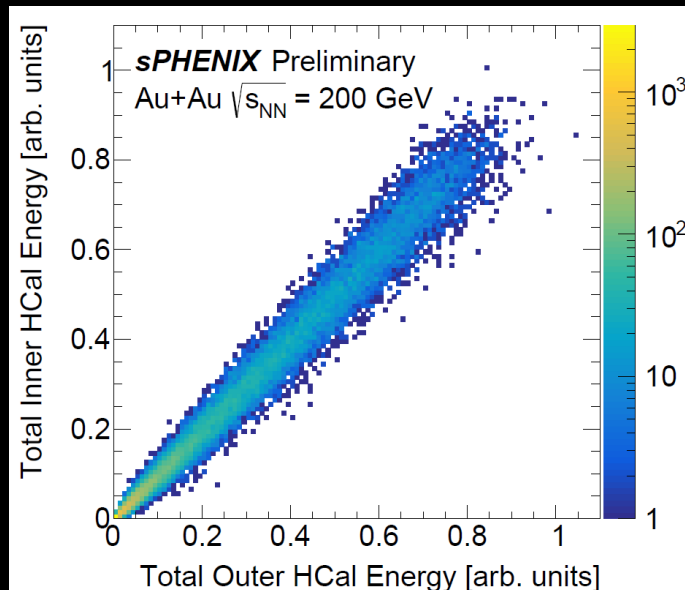


# sPHENIX Hadronic Calorimeter

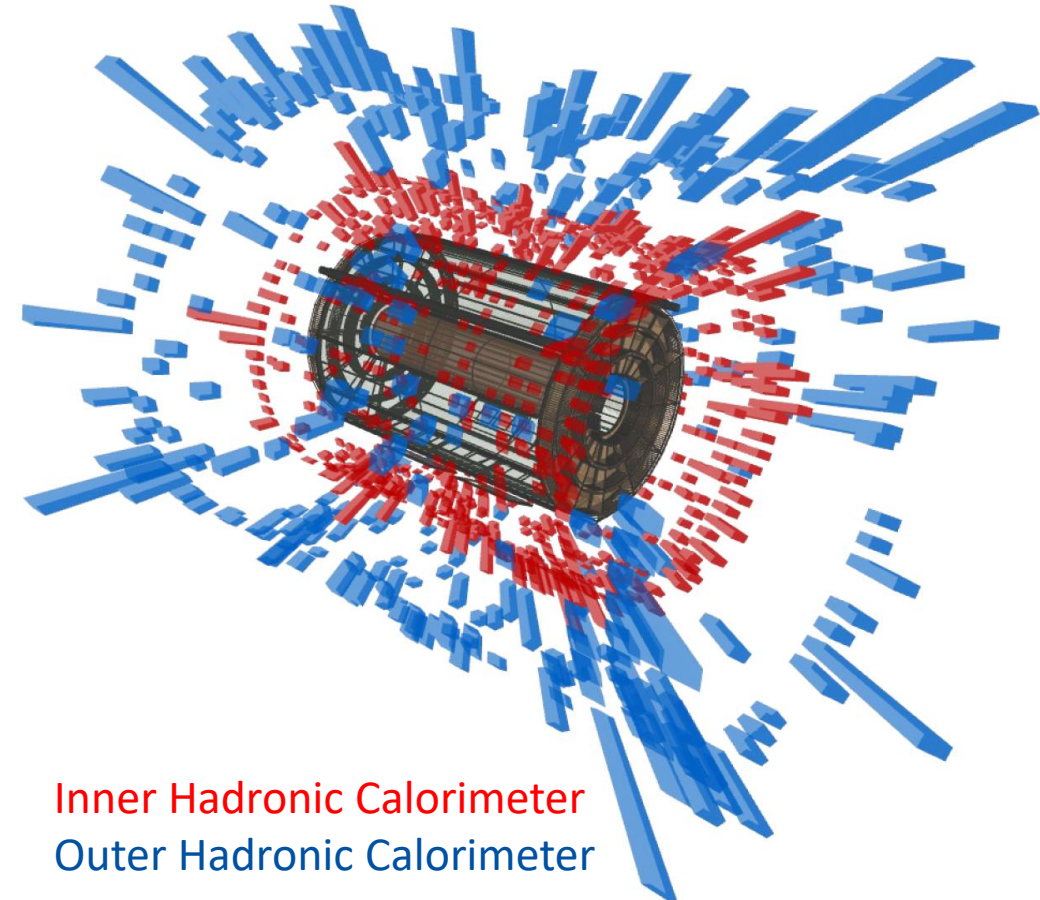
Hadronic Calorimeter functionality thoroughly validated both with and without beam:

- Cosmics well match expectations from simulations
- Cosmic signals observed in 100% of towers

Using beam the 2-part hadronic calorimeter  
Functionality was fully validated



sPHENIX Experiment at RHIC  
Data recorded: 2023-05-22, 02:07:00 EST  
Run / Event: 7156 / 12  
Collisions: Au + Au @ 200 GeV

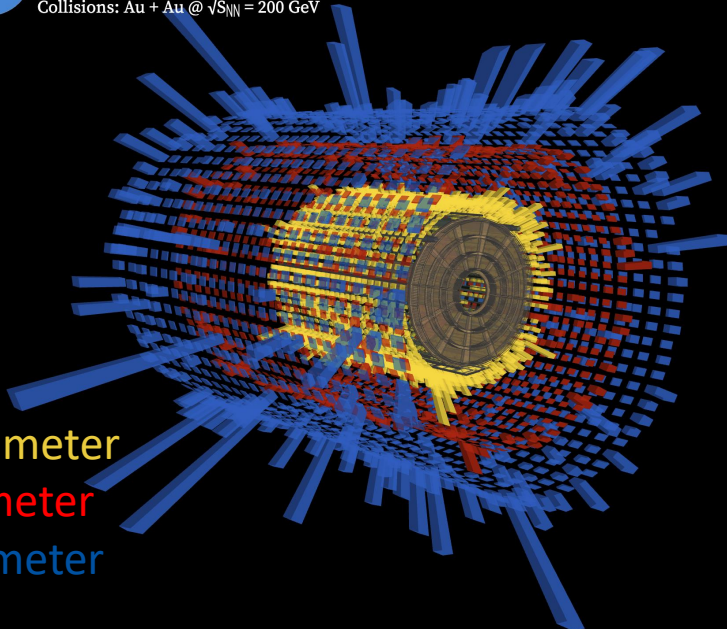


# sPHENIX Electromagnetic Calorimeter

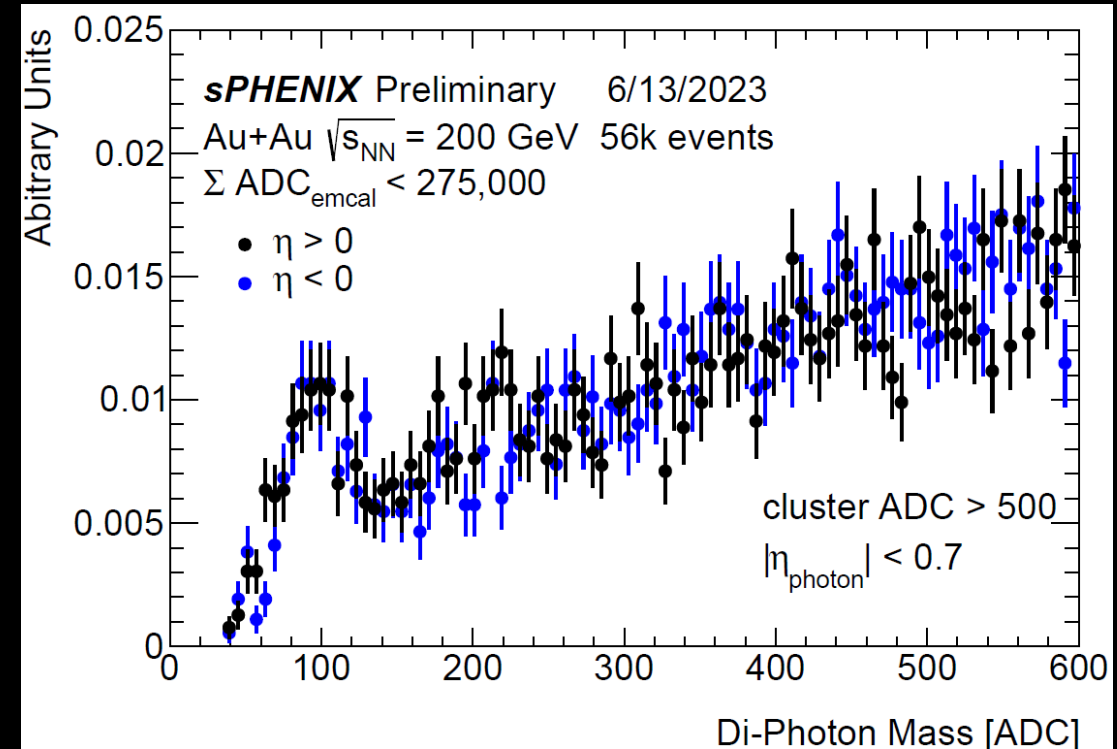
EMCal performance confirmed with over 99% live channels

Clear  $\pi^0$  mass peak observed in measured di-photon mass distribution!

sPHENIX Experiment at RHIC  
Data recorded: 2023-07-16 00:54:00 EST  
Run / Event: 21707 / 36  
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Electromagnetic Calorimeter  
Inner Hadronic Calorimeter  
Outer Hadronic Calorimeter



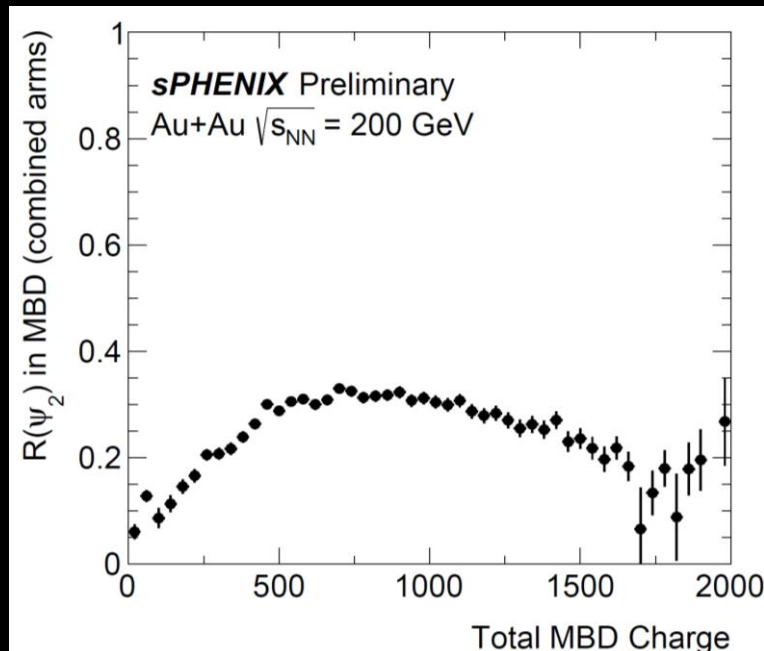
For details on neutral meson studies  
see poster by Anthony Hodges



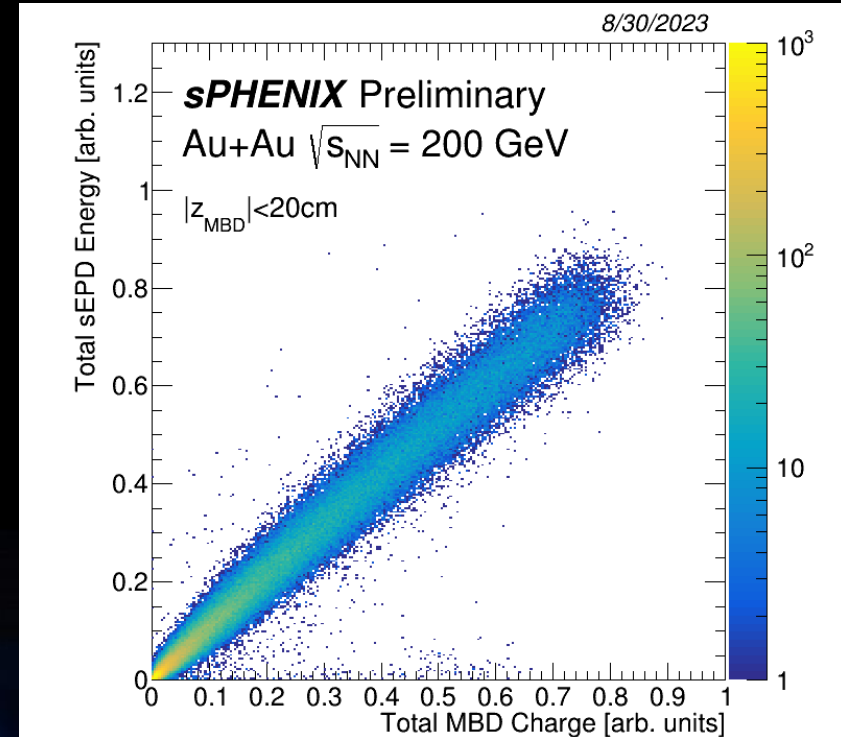
# sPHENIX Event Plane Characterization:

Event-plane characterization in sPHENIX possible with 2 independent detector systems:

- MBD and sEPD have been installed and commissioning is well under way



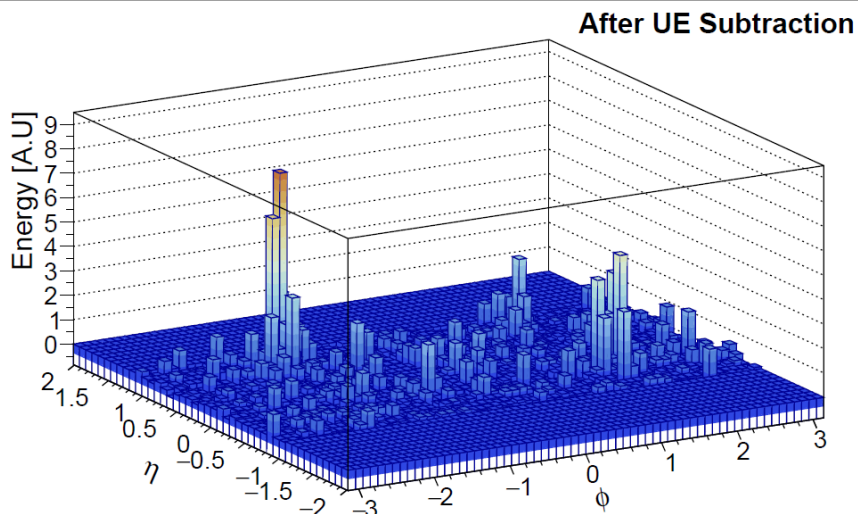
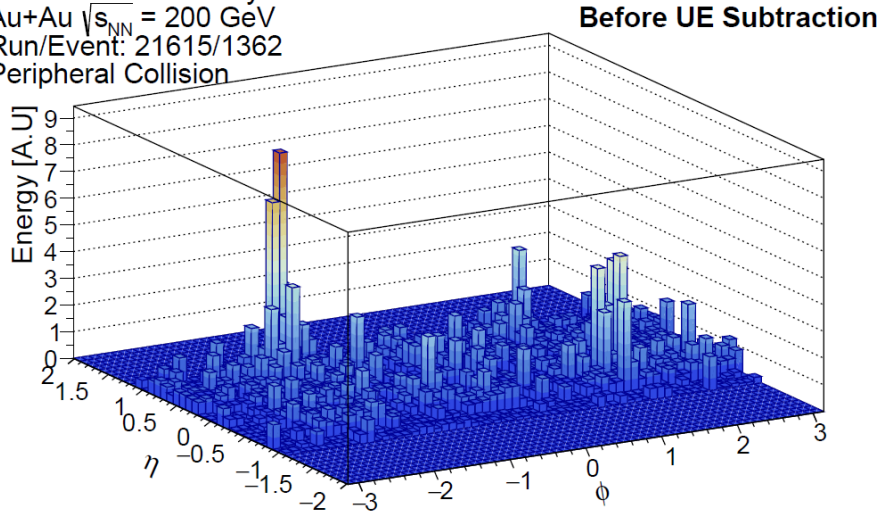
Event Plane Resolution in MBD



See Posters by Ejiro Umaka,  
JaeBeom Park and Valerie Wolfe

# Jet Reconstruction

sPHENIX Preliminary  
Au+Au  $\sqrt{s_{NN}} = 200$  GeV  
Run/Event: 21615/1362  
Peripheral Collision



Iterative Subtraction  
Procedure

1) Reconstruct  $R = 0.2$  Seed Jets

2) Determine event  $v_n$  excluding regions near seeds

3) Determine UE  $\langle E \rangle$  away from seed jets and  
Subtract with flow modulation

4) Repeat (1-3) with new seed jets from subtracted towers

5) Run jet reconstruction on subtracted towers

See posters by Virginia Bailey,  
Muhammad Shumail Khan, and Ejiro Umaka

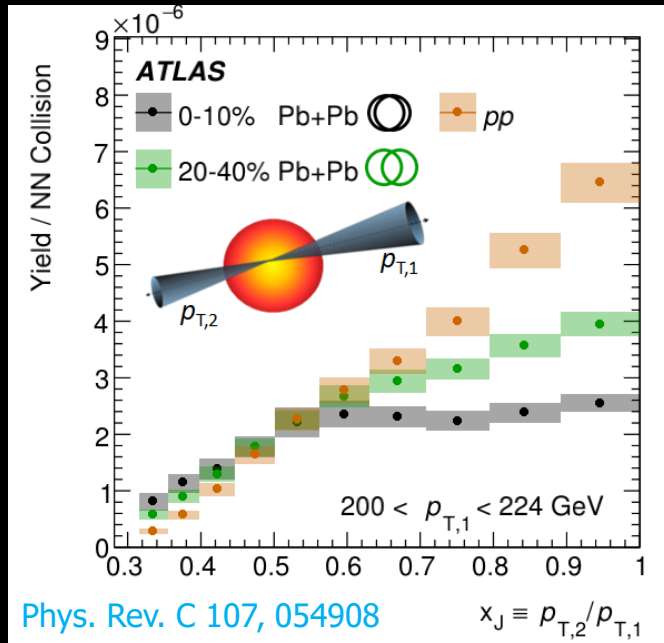


# Early Measurements Dijets

Dijets at the LHC has recently provided significant insights into the nature of jet quenching

sPHENIX will perform unfolded dijet measurements to explore the suppression of low  $p_{T,1}$  dijets

- Provide insights into path length dependent energy loss and e-loss fluctuations

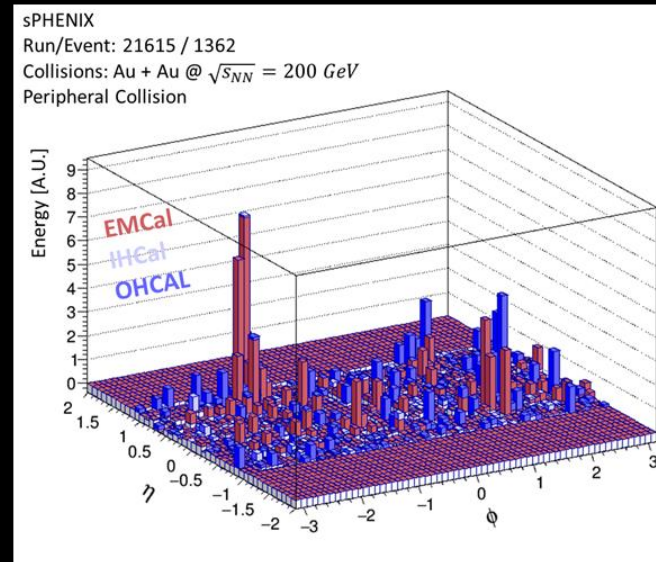


sPHENIX

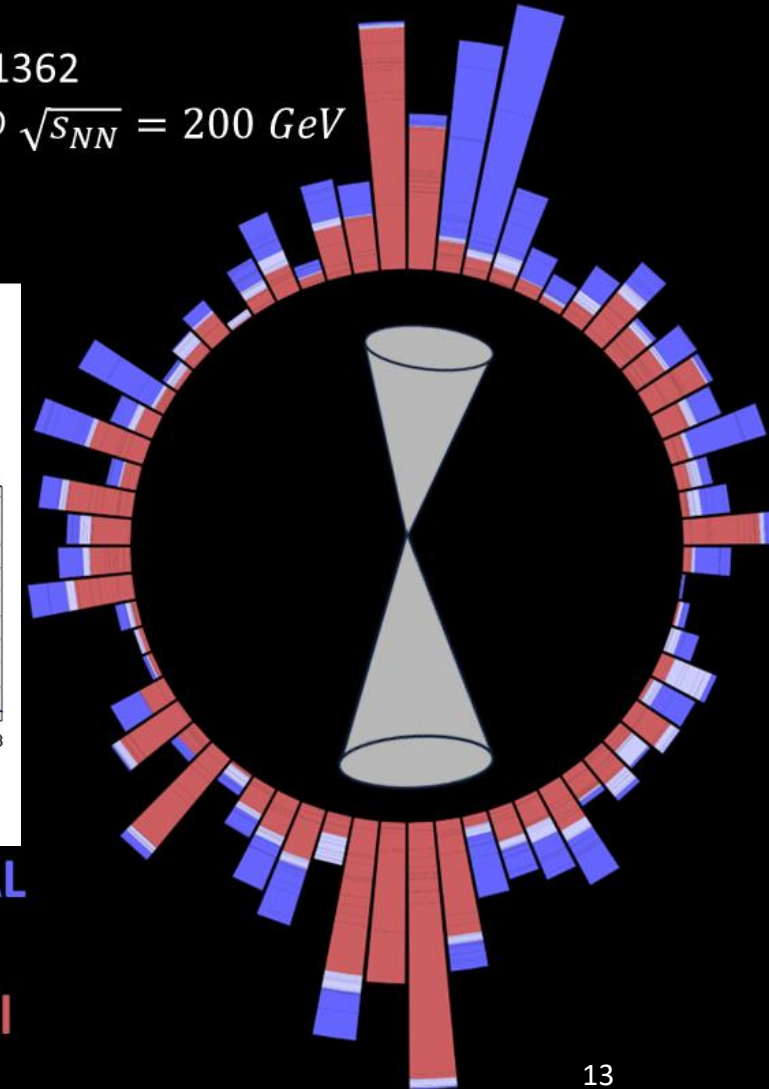
Run/Event: 21615 / 1362

Collisions: Au + Au @  $\sqrt{s_{NN}} = 200 \text{ GeV}$

Peripheral Collision

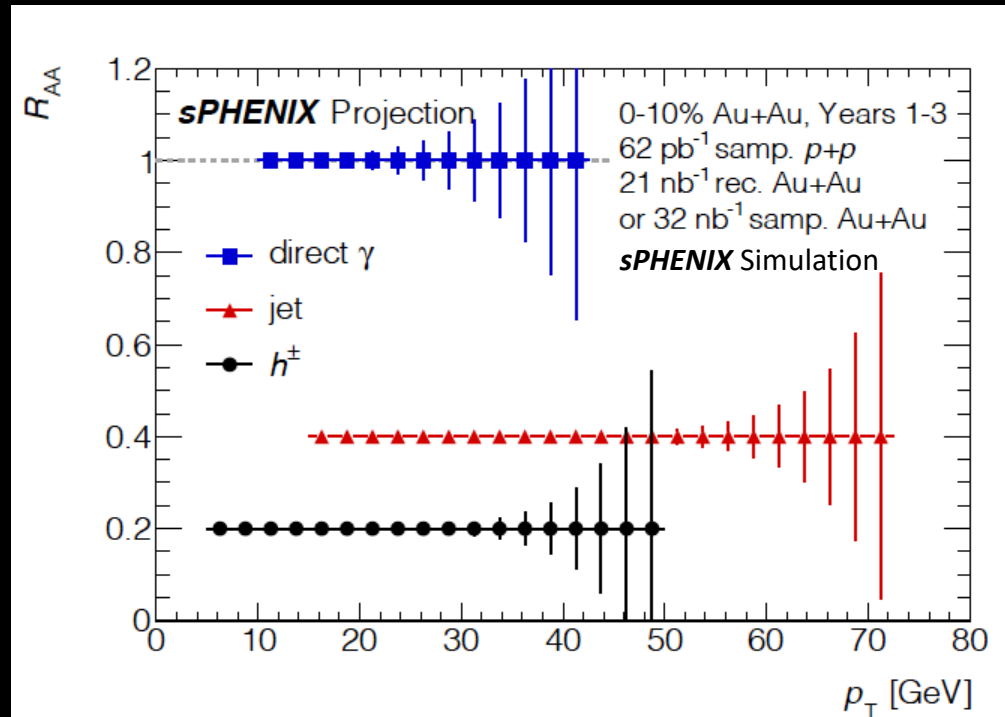


OHCAL  
IHCAL  
EMCAL



See poster by Micah Meskowitz

# sPHENIX upcoming Running:



1<sup>st</sup> Year beam of sPHENIX has enabled a significant commissioning program

- Including data sets for first physics using calorimeter systems

sPHENIX has two+ years of high statistics *pp* (2024), Au+Au (2025), running ahead

Will provide high statistics data samples for differential jet measurements and rare probes

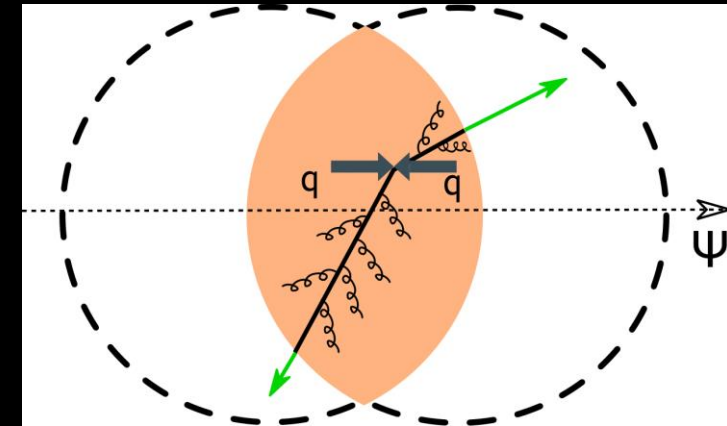
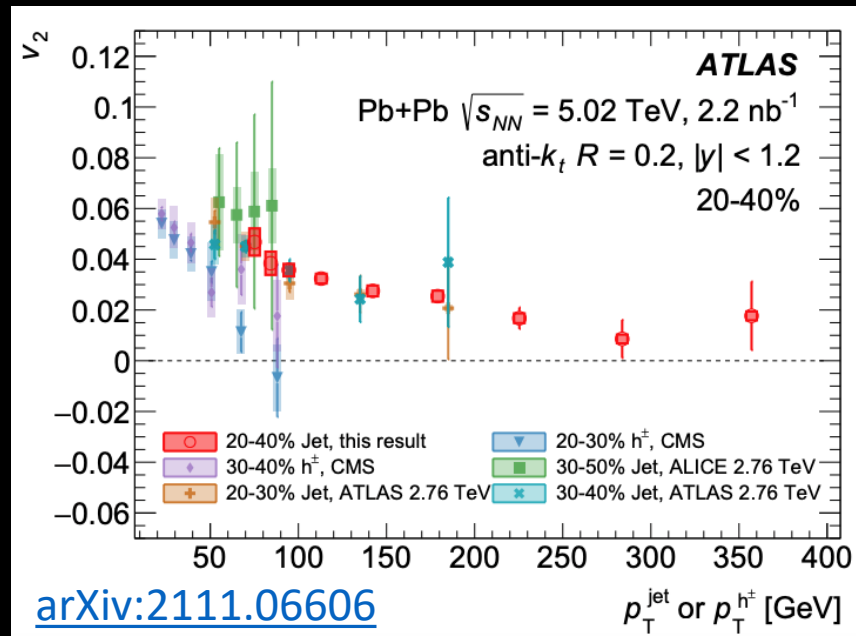


# Early Measurements: $v_2$

$v_2$  can provide insight into both hydrodynamic effects (low  $p_T$ ) and path length dependent energy loss (high  $p_T$ )

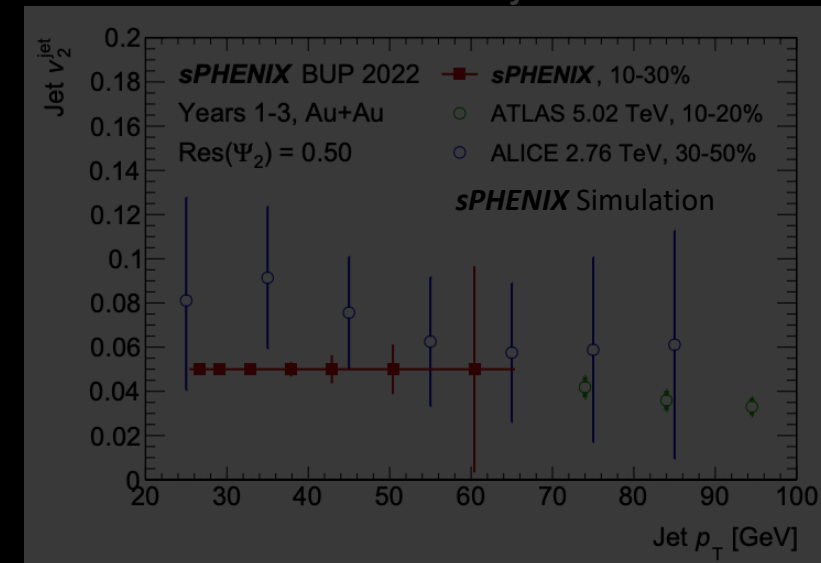
Precision measurements of jet  $v_2$  at **High**  $p_T$  have been performed

From the LHC



Cartoon from Martin Rybar

sPHENIX Projection

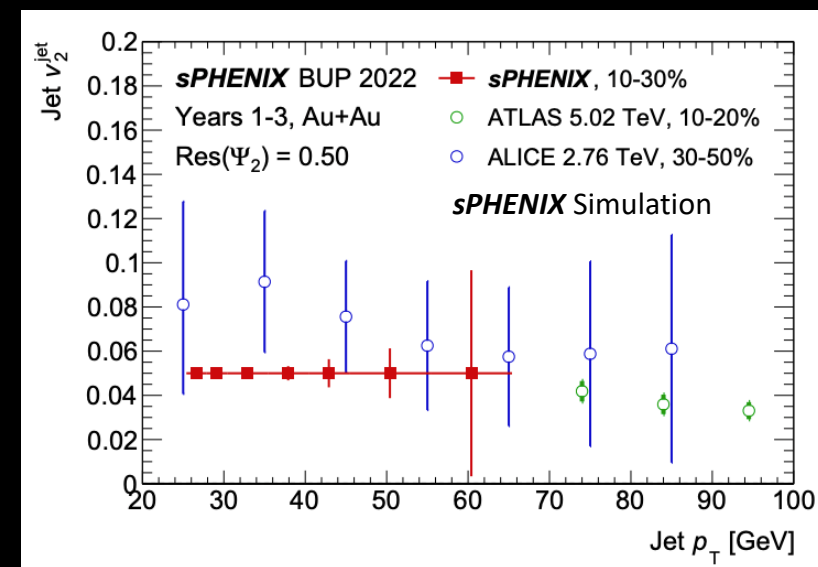
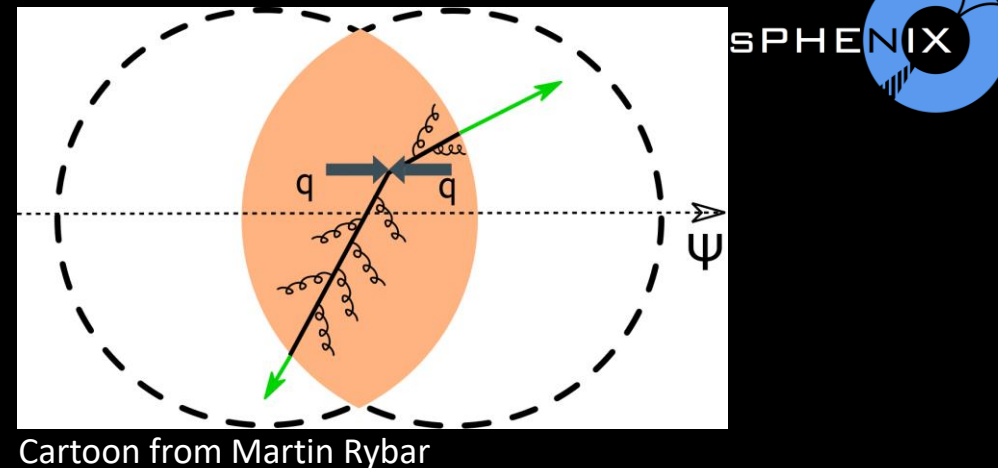
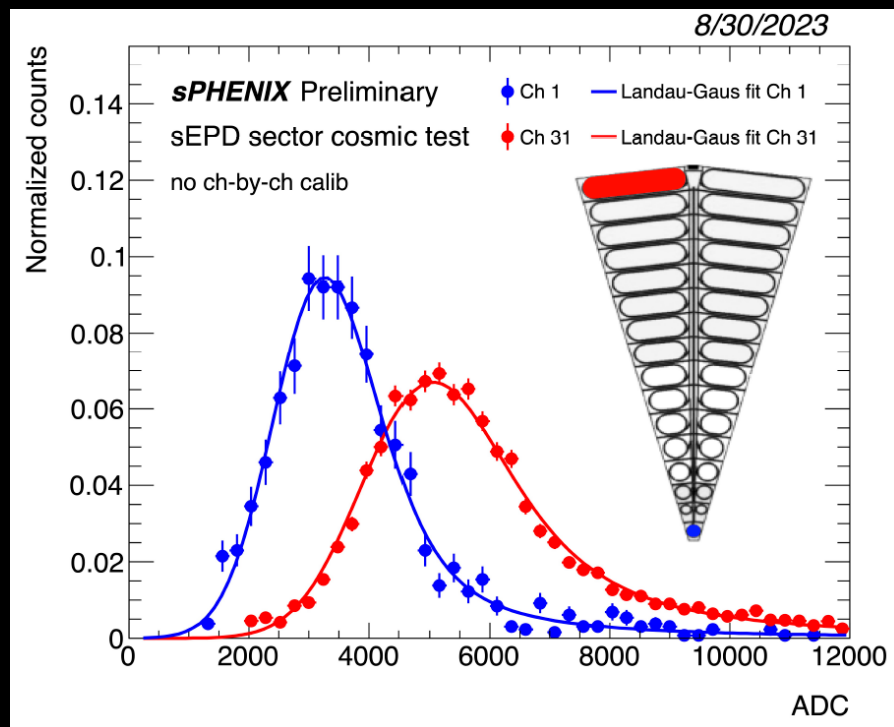


sPHENIX will enable precision measurements of **low**  $p_T$  jet  $v_2$

# Early Measurements: $v_2$

$v_2$  can provide insight into both hydrodynamic effects (low  $p_T$ ) and path length dependent energy loss (high  $p_T$ )

Precision measurements of jet  $v_2$  at **High**  $p_T$  have been performed



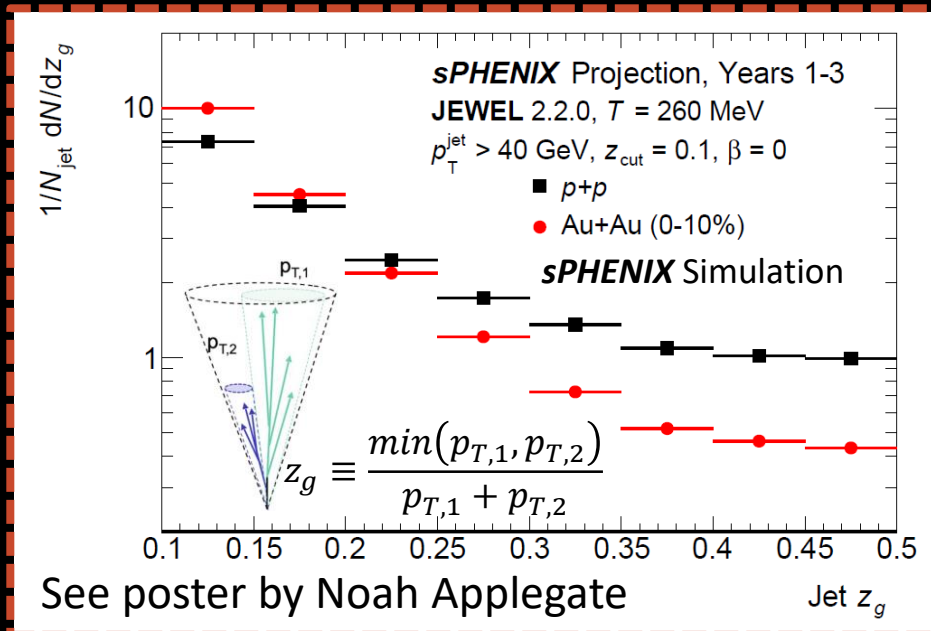
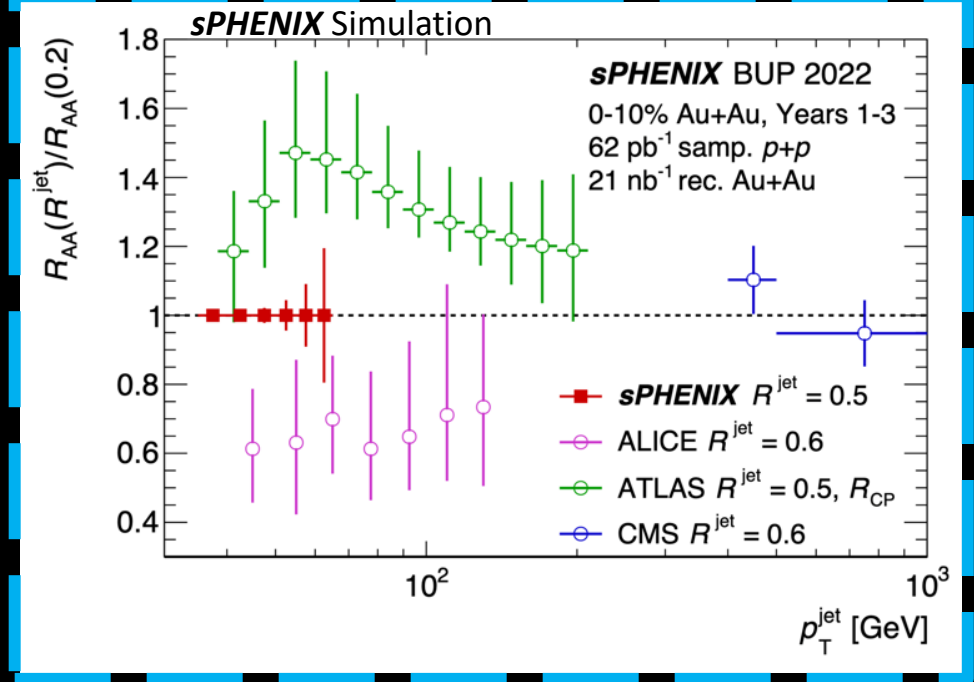
sPHENIX will enable precision measurements of **low**  $p_T$  jet  $v_2$



# Jet Size and Substructure

sPHENIX will measure jets as a function of the jet size

- Explore balance of competing increased energy loss and energy recovery effects
- Address tensions between LHC jet results at low  $p_T$



See poster by Noah Applegate

Through calorimetric jets and particle-flow objects sPHENIX will perform precision measurements of jet (sub)structure

- Access to QGP resolving power
- Parton shower dependence to energy loss

# Summary


sPHENIX is well ready and has already begun its jet physics program using year one data!

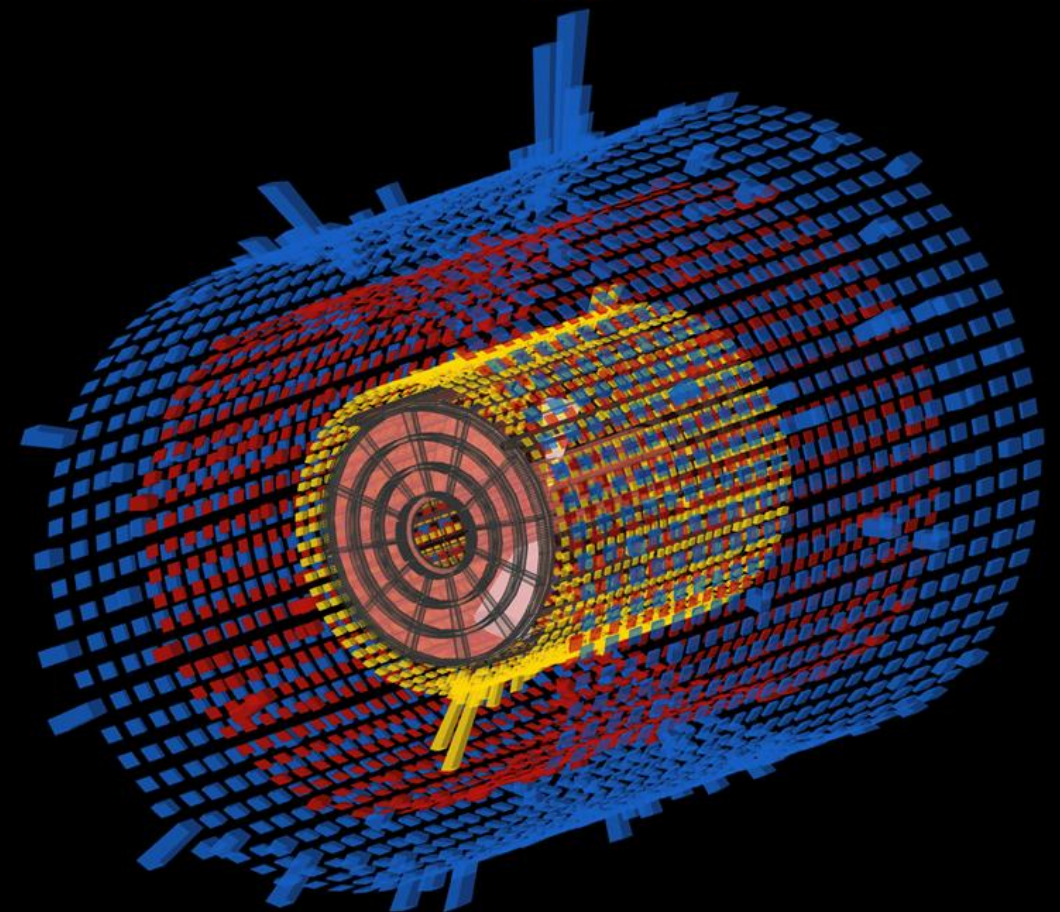
Year 1 of RHIC operations has ended

- Strong performance of all calorimeter systems has been demonstrated
- More performance figures than I could include!

Commissioning efforts continue to be under way around the clock

Years 2+3 data samples will enable precision measurements of complete jets with sPHENIX


 sPHENIX Experiment at RHIC  
 Run / Event: 21615 / 1362  
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# Backups



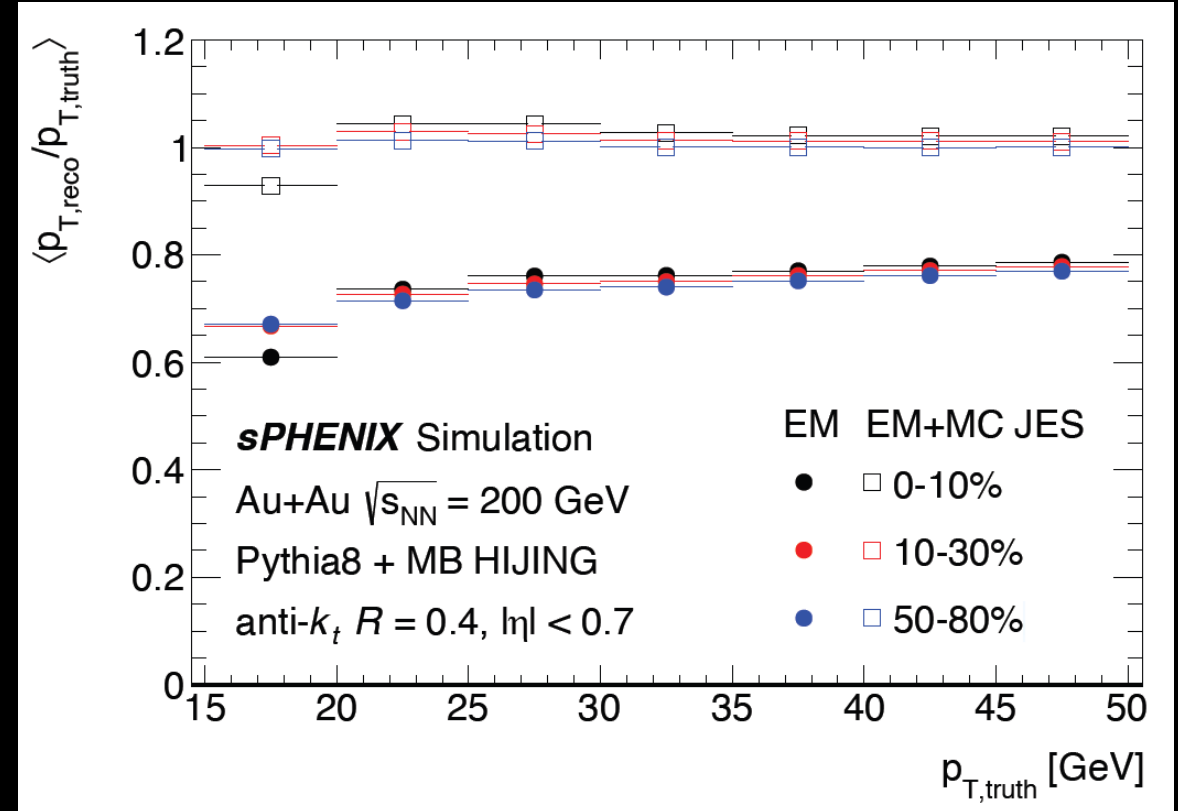
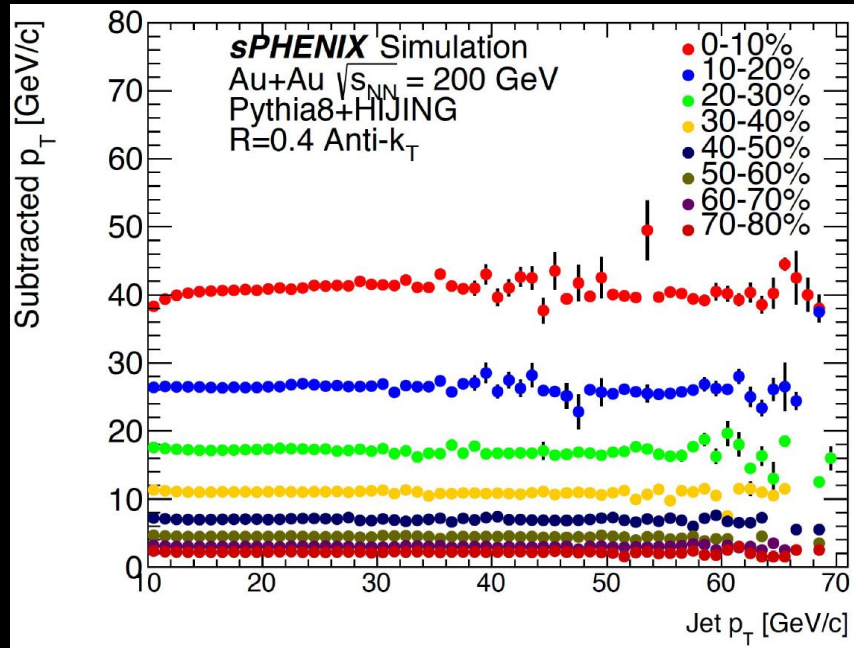
# Jet Reconstruction and calibration

Jets in sPHENIX are reconstructed from EM-scale calibrated electromagnetic and hadronic calorimeter towers

- Utilizing an iterative event-by-event UE subtraction

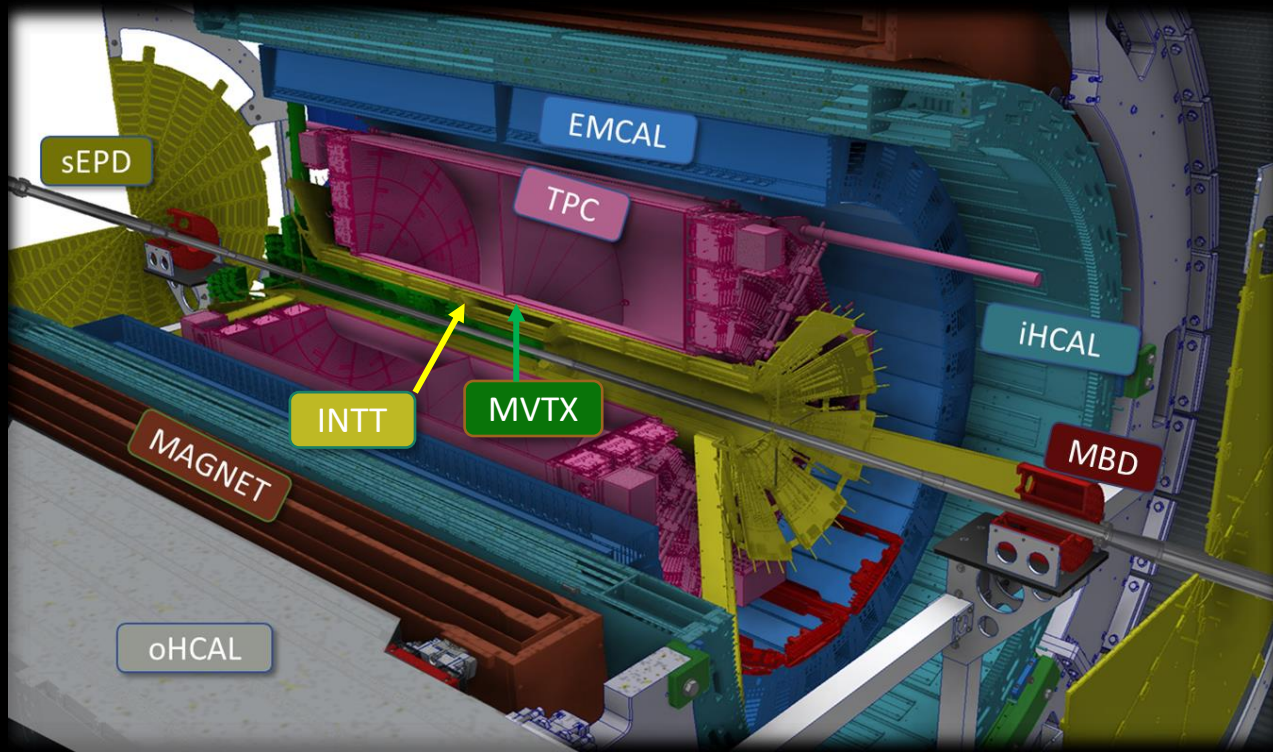
Jets are calibrated with a multi part calibration

- M.C. derived MC JES calibration
- Data driven calibration which accounts for data-MC differences



See posters by Muhammad Shumail Khan  
 and Virginia Bailey

# The sPHENIX Detector



First new detector at RHIC in 20 years!

State of the art tracking and vertexing:

- MAPS-based Vertex Tracker (**MV**TX)
- Intermediate Silicon Tracker (**INTT**)
- Time Projection Chamber (**TPC**)
- TPC Outer Tracker (**TPOT**)

Complete mid-rapidity calorimeter system

- Electromagnetic Calorimeter (**EM**Cal)
- Inner Hadronic Calorimeter (**iH**Cal)
- Outer Hadronic Calorimeter (**oH**Cal)

Event Characterization:

- Minimum Bias Detector (**MBD**)
- Event Plane Detector (**sEPD**)
- Zero Degree Calorimeter (**ZDC**)