

# *Progress Toward Jet Physics Measurements in sPHENIX*

**Anthony Hodges**  
**For the sPHENIX Collaboration**  
**RHIC & AGS Users' Meeting**  
**Wednesday, August 2<sup>nd</sup>, 2023**



**UNIVERSITY OF  
ILLINOIS**  
URBANA-CHAMPAIGN

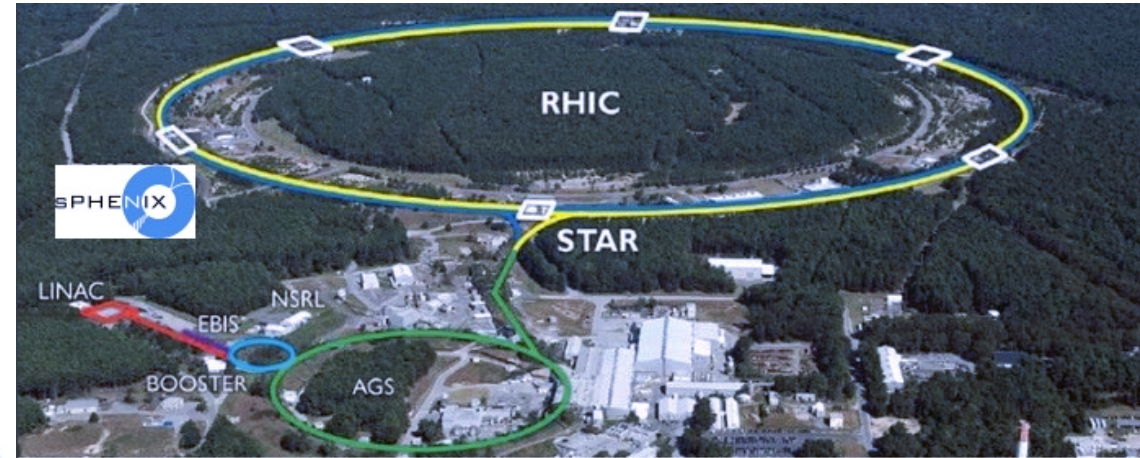


NSF Ascend Fellow



# The sPHENIX Detector

- 2015 - sPHENIX noted as “essential” for completing the RHIC mission of probing the QGP at microscopic length-scales



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 2015  
LONG RANGE PLAN  
for NUCLEAR SCIENCE

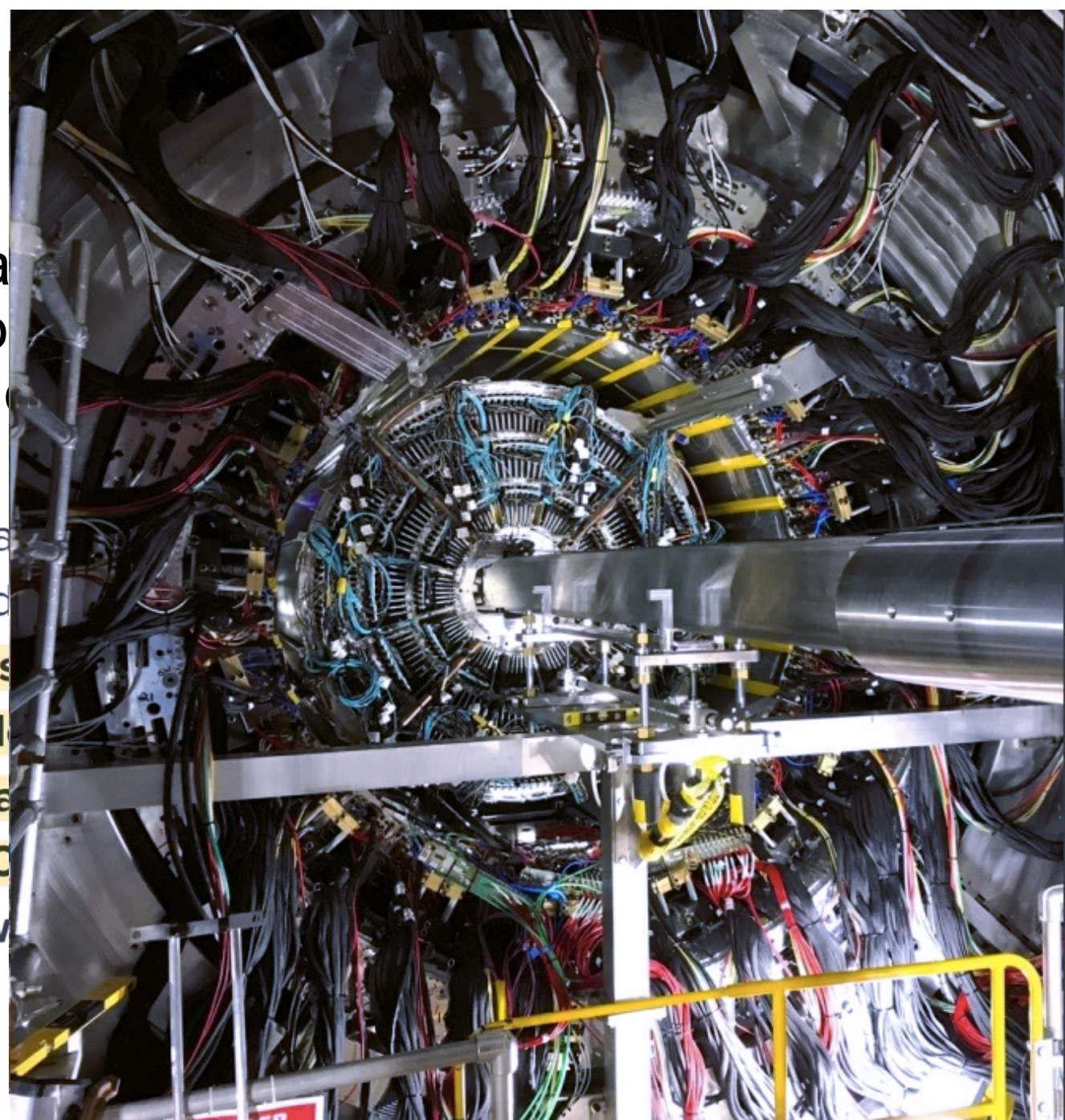
[2015 Long Range Plan](#)



# The sPHENIX Detector

- 2015 - sPHENIX noted as “essential for completing the RHIC mission of probing the QGP at microscopic length-scales”

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 measuring 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, sPHENIX. (2) Map the phase diagram of QCD with the experiments planned at RHIC.**

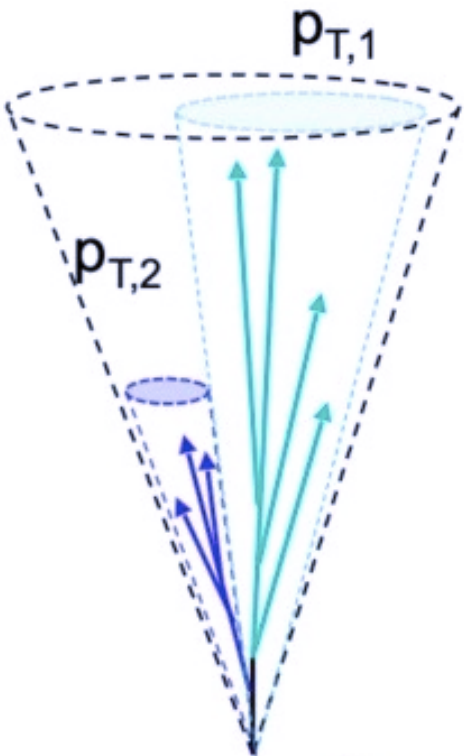




# The sPHENIX Physics Program

## Jet structure

vary momentum/angular scale of probe



## Parton energy loss

vary mass/momentum of probe

u,d,s



c



b

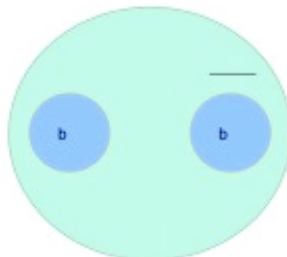


## Quarkonium spectroscopy

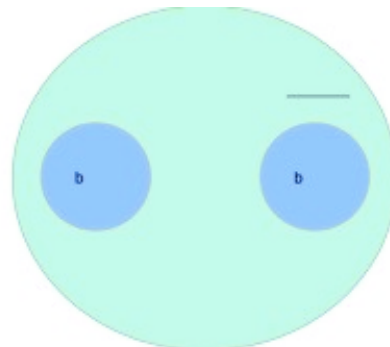
vary size of probe



$\Upsilon(1s)$  0.28fm



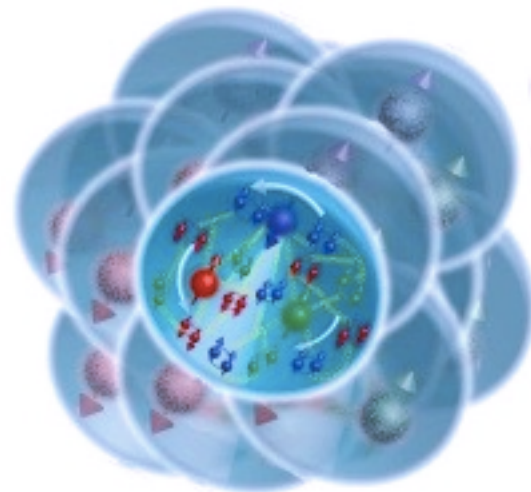
$\Upsilon(2s)$  0.56fm



$\Upsilon(3s)$  0.78fm

## Cold QCD

study proton spin,  
transverse-momentum,  
and nuclear effects

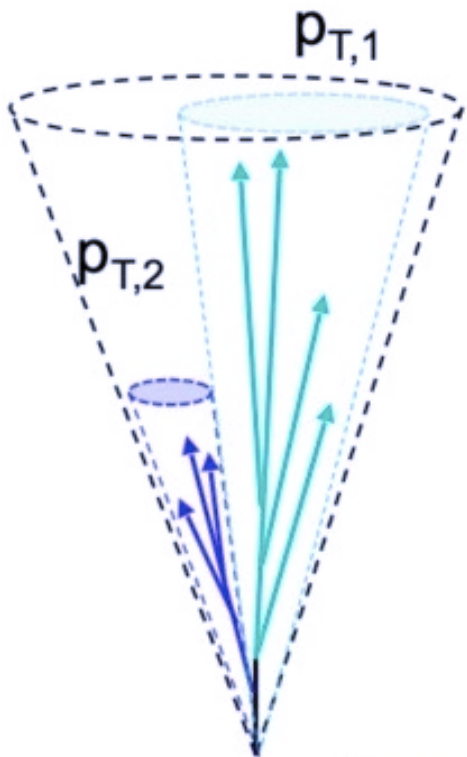




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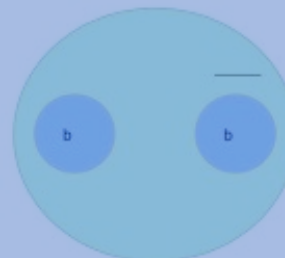


## Quarkonium spectroscopy

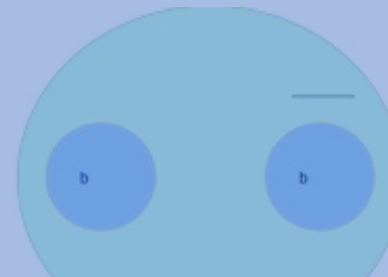
vary size of probe



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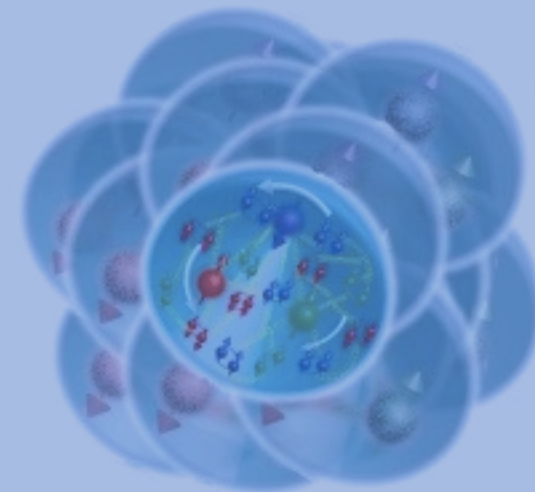


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## Cold QCD

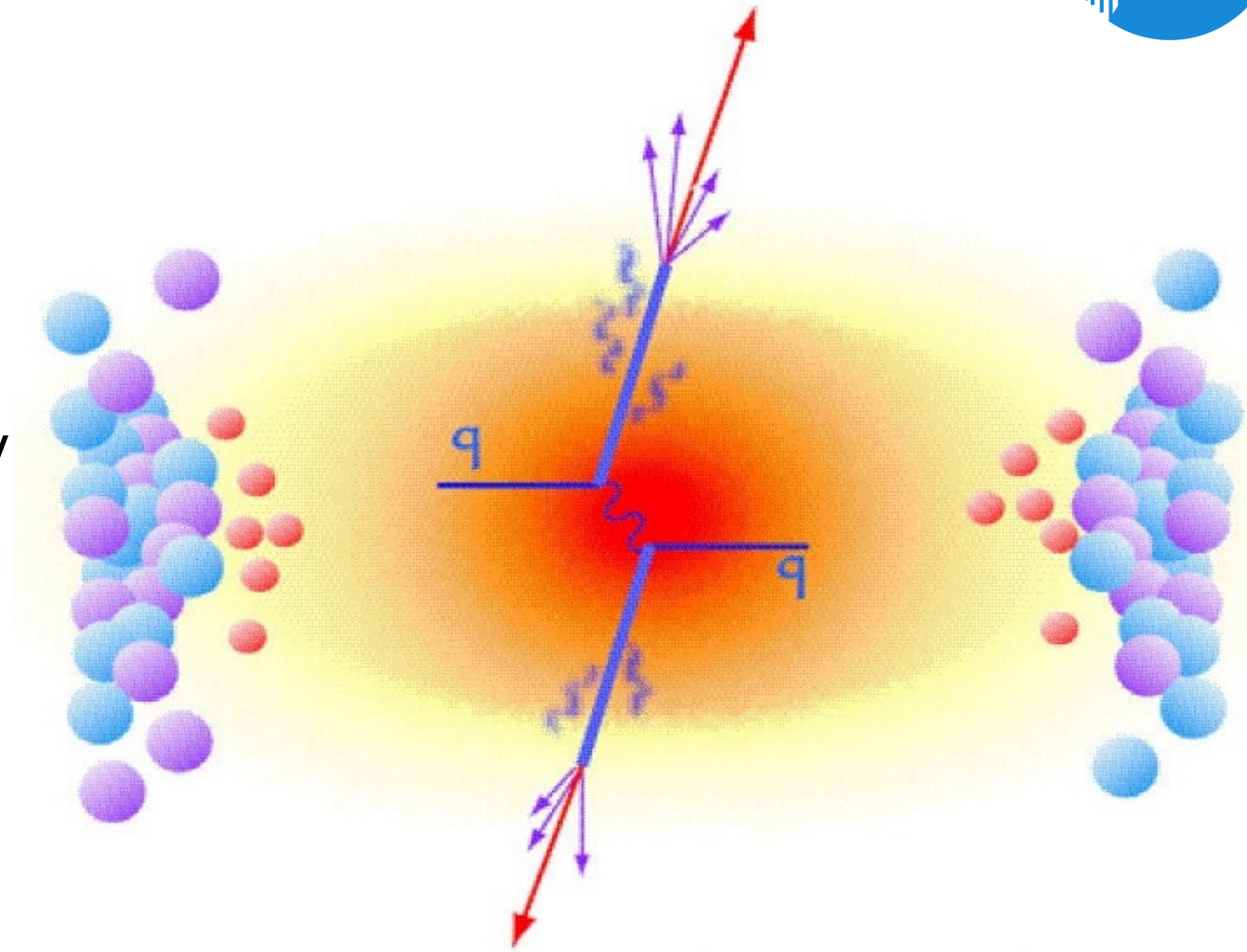
study proton spin, transverse-momentum, and nuclear effects



[sPHENIX Heavy Flavor: Antonio da Silva](#)

# Jets in Heavy-Ion Collisions

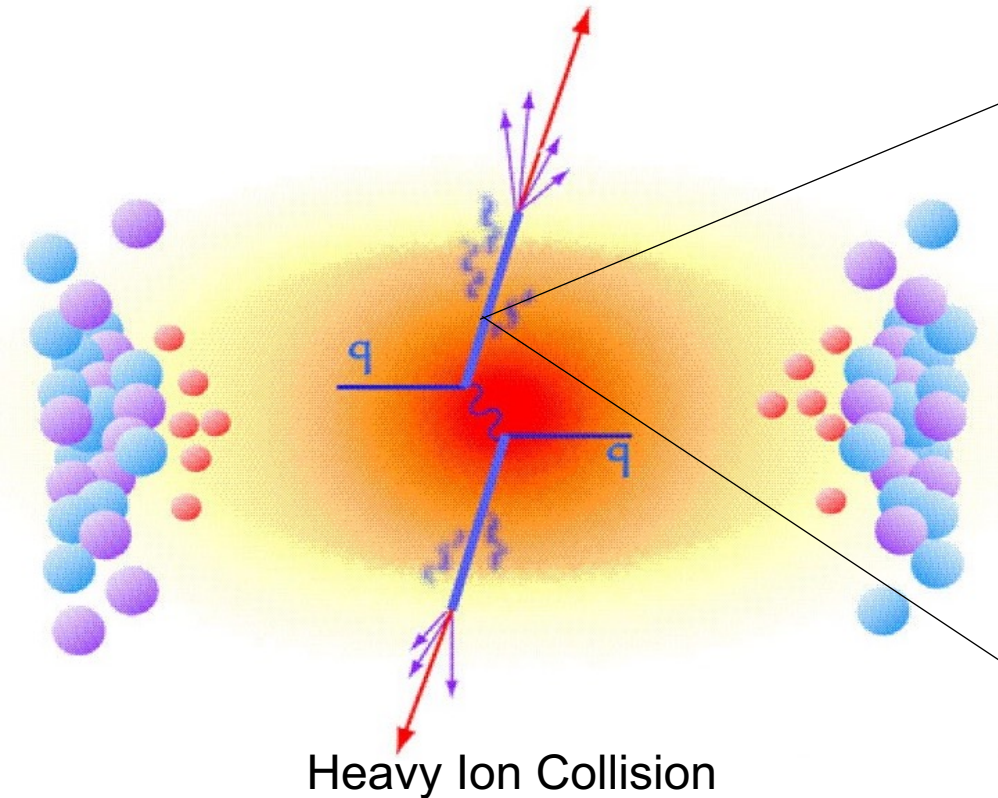
- Jets – valuable probe of partonic energy and parton-medium interactions



Heavy Ion Collision

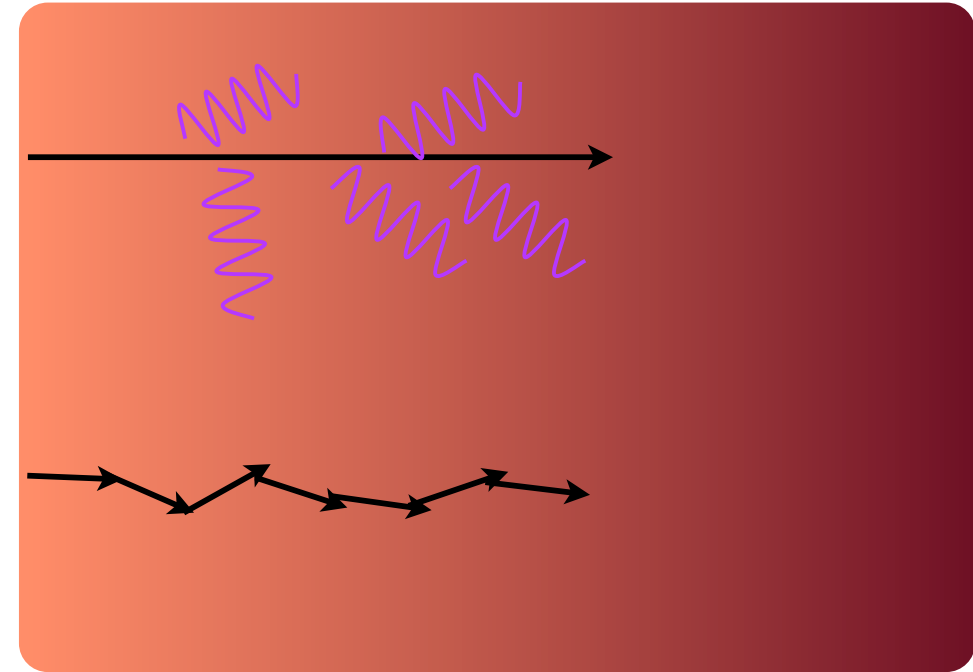
# Jets in Heavy-Ion Collisions

Inside the medium...



gluon radiation

collisional broadening

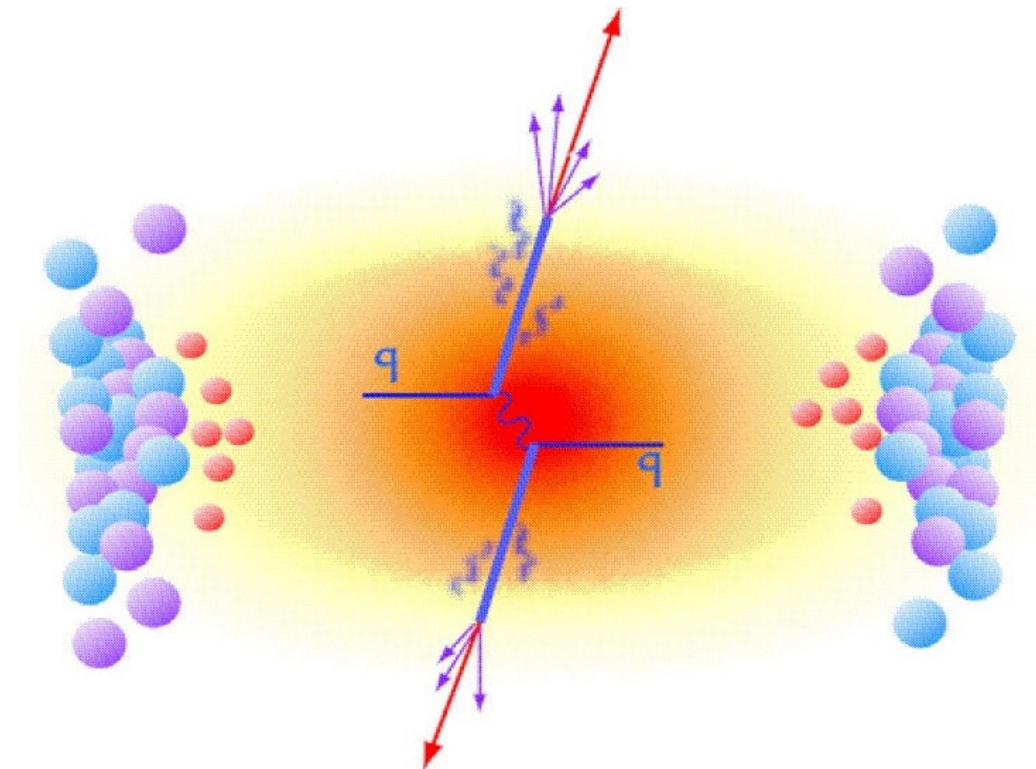


# The sPHENIX Run Plan

[sPHENIX BUP 2020](#)

Year	Species	$\sqrt{S_{NN}}$ (GeV)	Cryo Weeks	Physics Weeks	Sampled Lumi
2023	<i>Au + Au</i>	200	24	9	4.5 nb <sup>-1</sup>

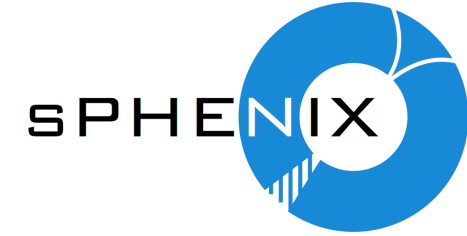
- Commissioning and first physics
- Understanding detector performance



Heavy Ion Collision



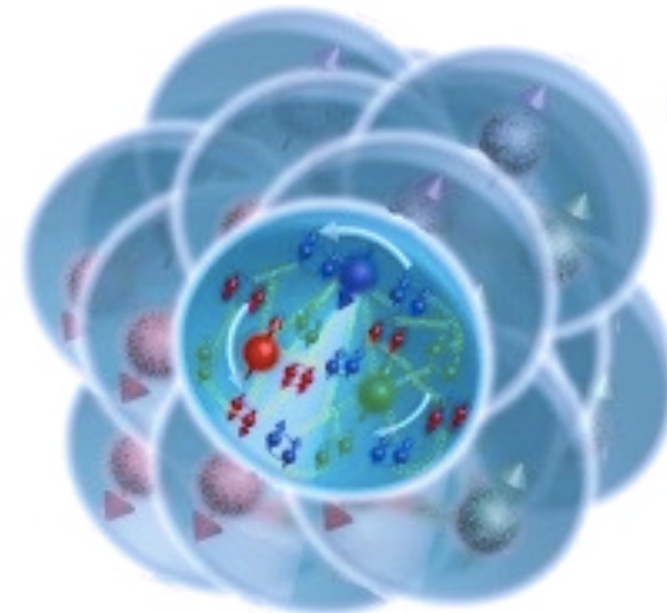
# The sPHENIX Run Plan



[sPHENIX BUP 2020](#)

Year	Species	$\sqrt{s_{NN}}$ (GeV)	Cryo Weeks	Physics Weeks	Sampled Lumi
2024	$p^\uparrow + p^\uparrow$	200	24	12	45 pb <sup>-1</sup>
	$p^\uparrow + Au$				0.11 pb <sup>-1</sup>

- Cold QCD studies
  - Spin
  - Cold nuclear matter effects
- Commissioning of calorimeter triggers

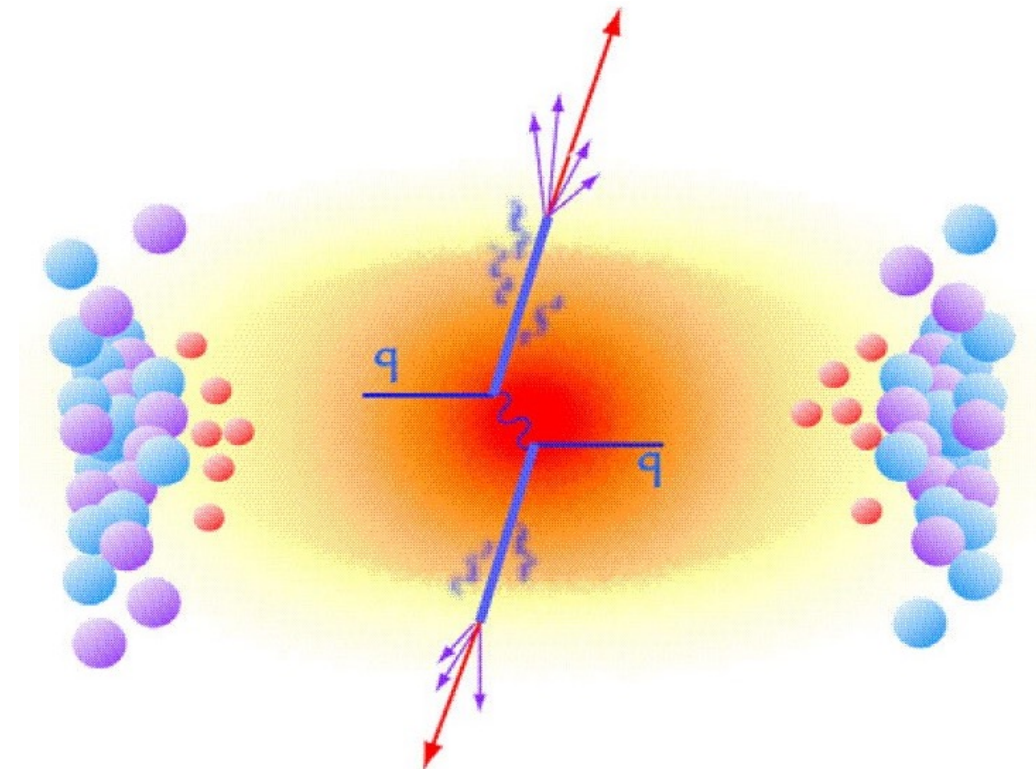


# The sPHENIX Run Plan

[sPHENIX BUP 2020](#)

Year	Species	$\sqrt{s_{NN}}$ (GeV)	Cryo Weeks	Physics Weeks	Sampled Lumi
2025	<i>Au + Au</i>	200	24	20.5	21 nb <sup>-1</sup>

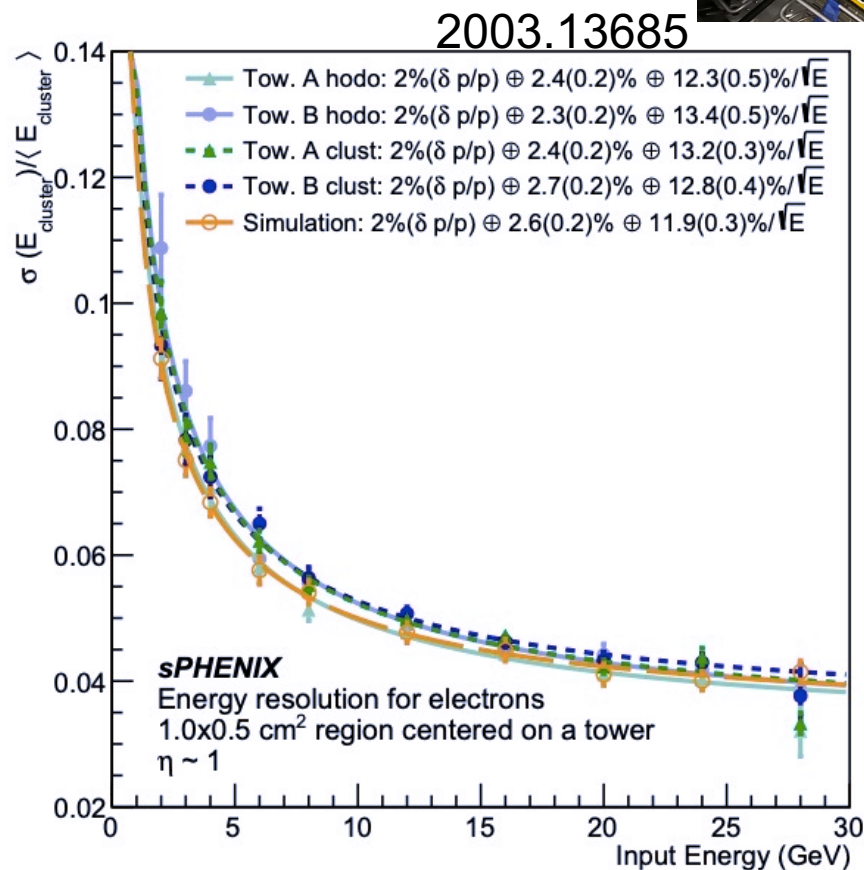
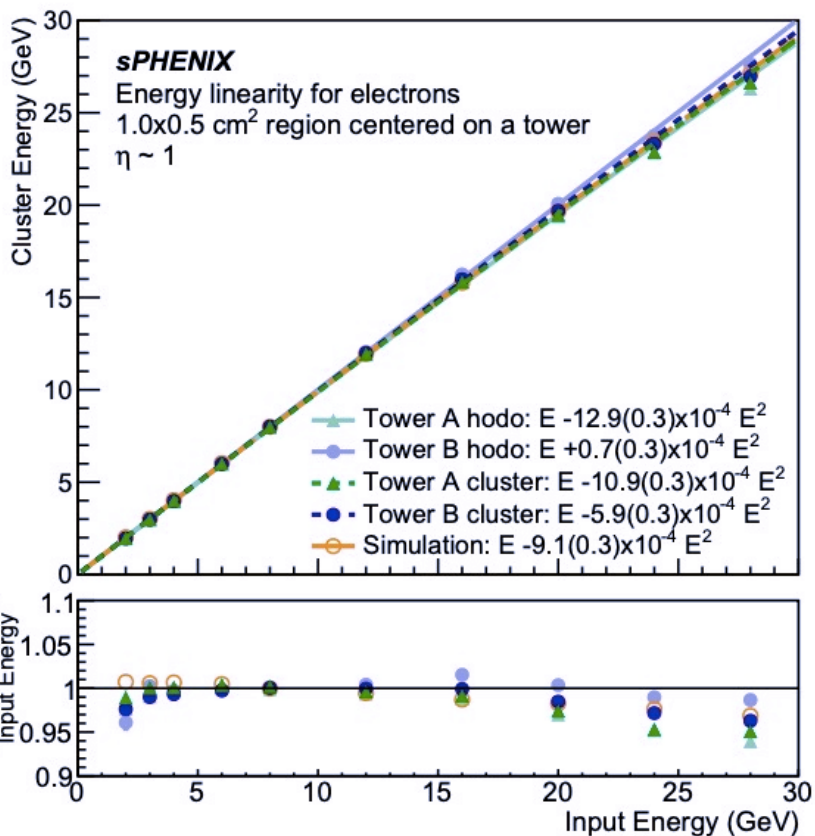
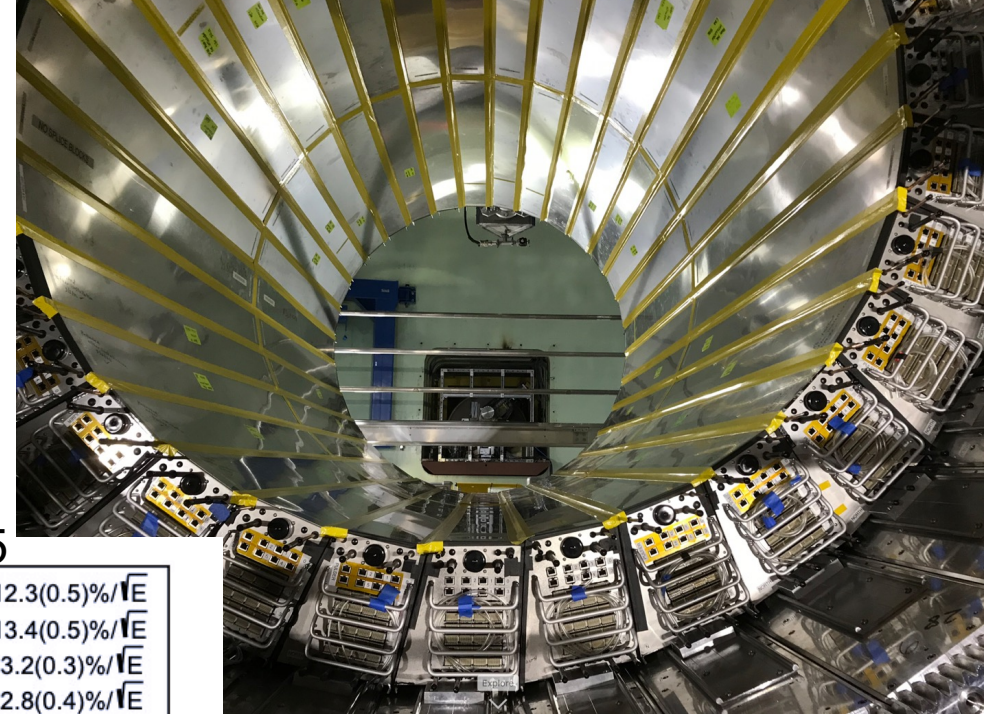
- Archival, large-statistics
- Invaluable for precision measurements of rare probes



Heavy Ion Collision

# sPHENIX Calorimetry

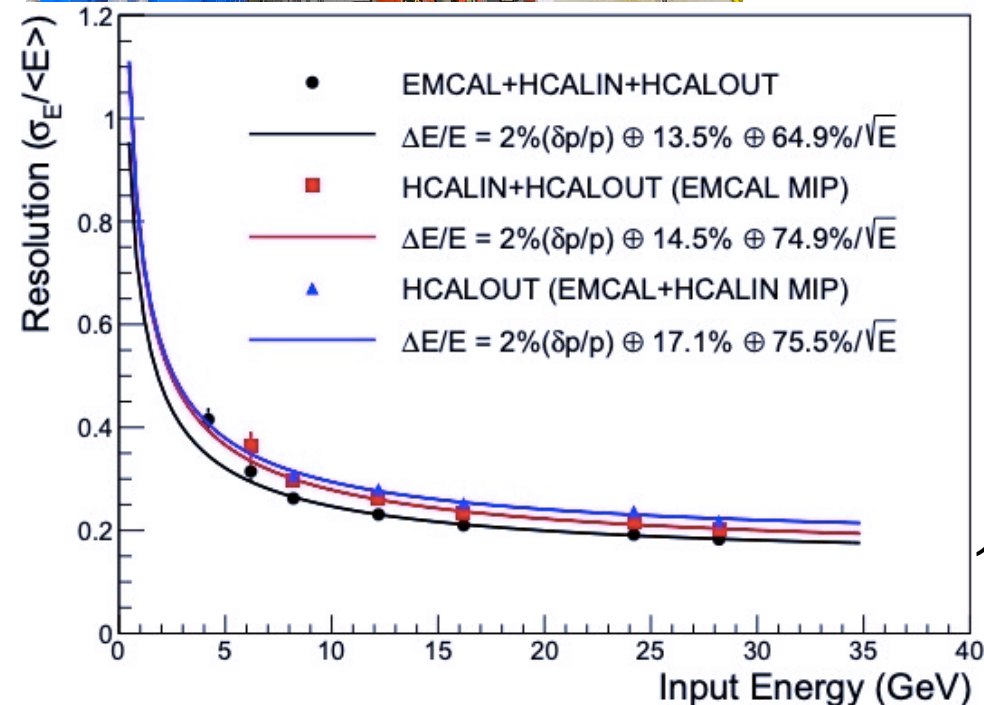
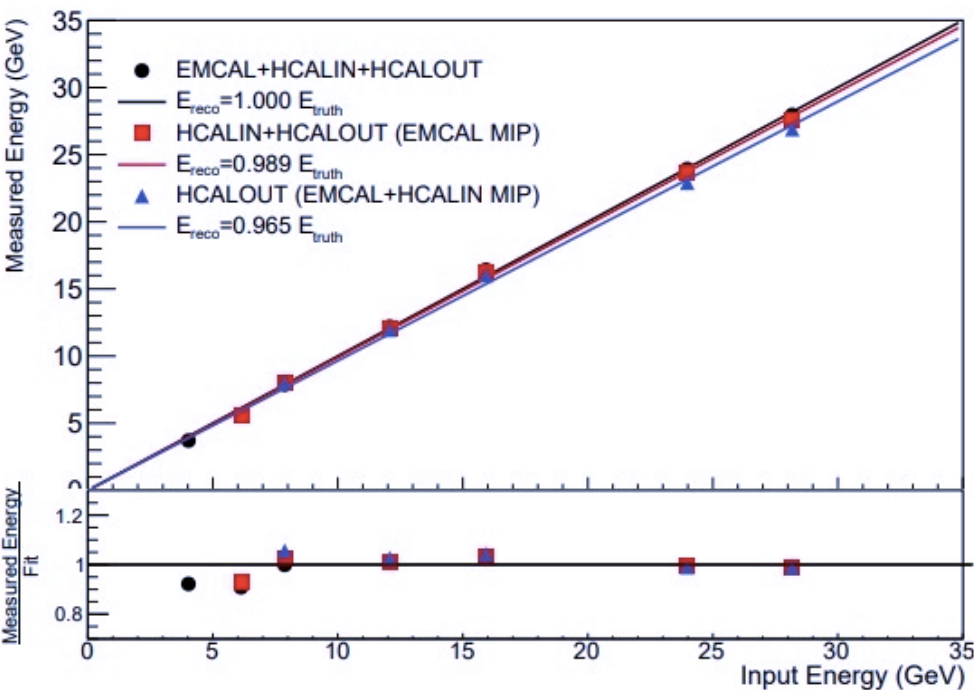
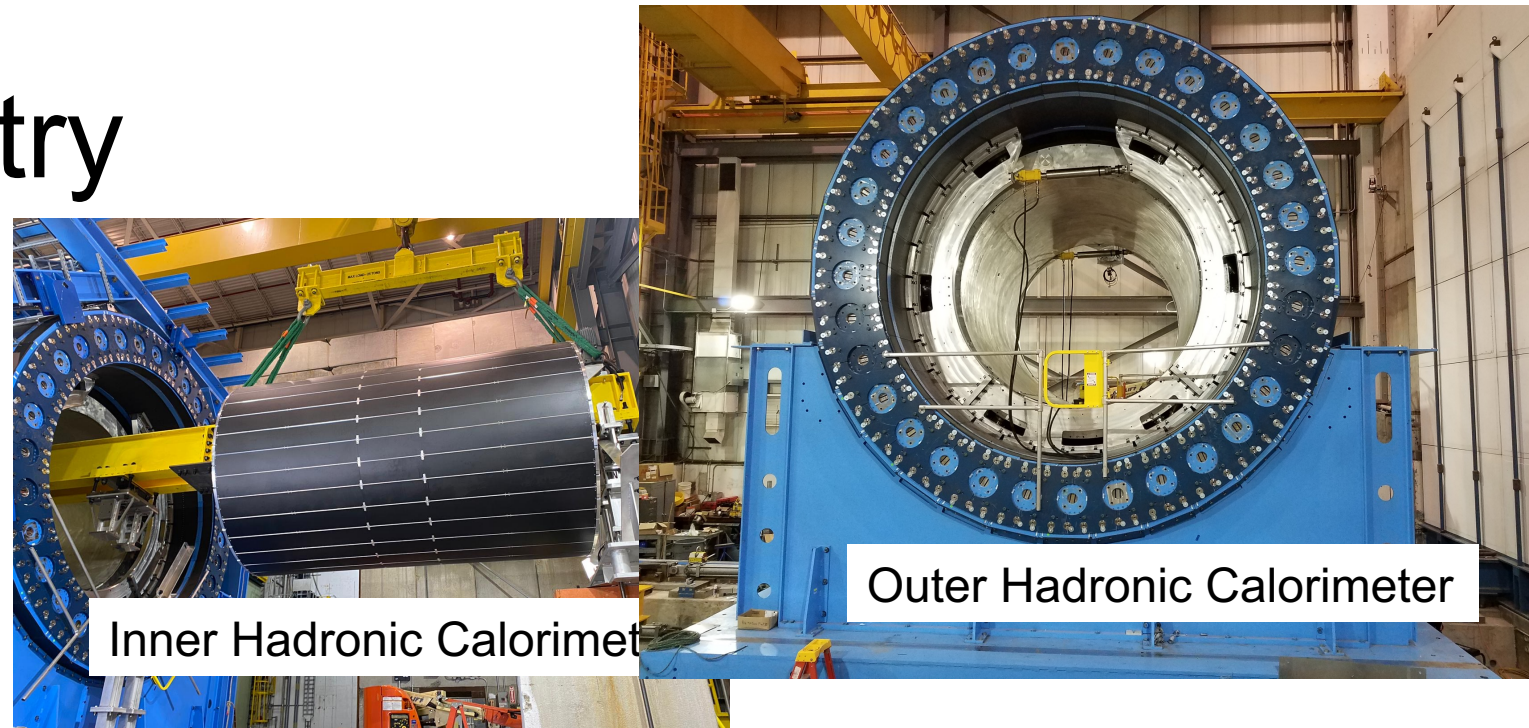
- High-granularity Electromagnetic Calorimeter for precision neutral meson, direct photon, and  $\Upsilon$  measurements



[sPHENIX Calorimetry - Hanpu Jiang](#)

# sPHENIX Calorimetry

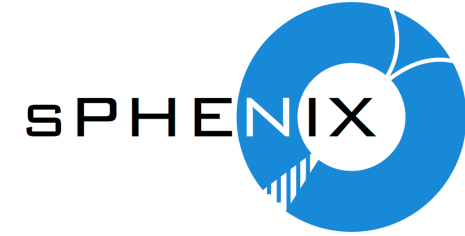
- EMCal complemented by first HCal at mid-rapidity at RHIC!
- Powerful tool for full-jet reconstruction



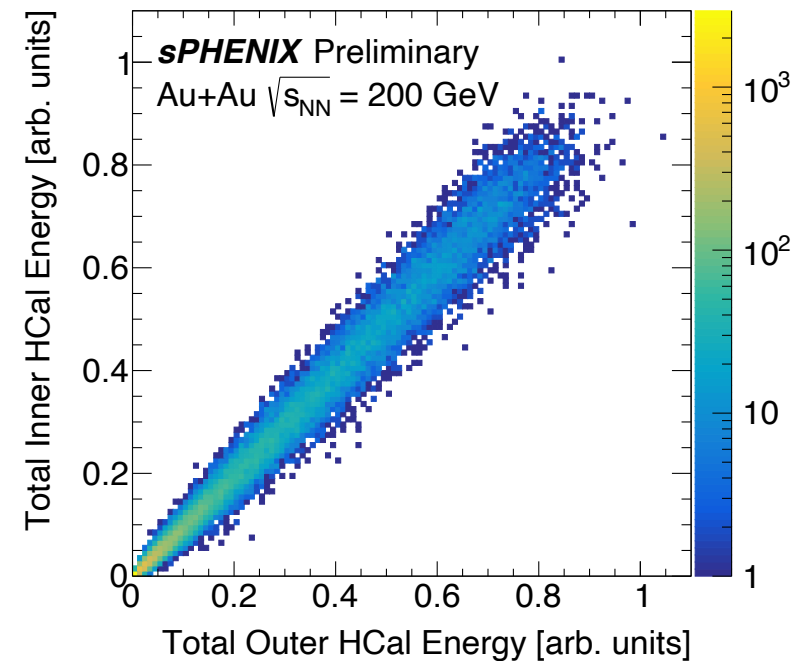
[sPHENIX Calorimetry - Hanpu Jiang](#)

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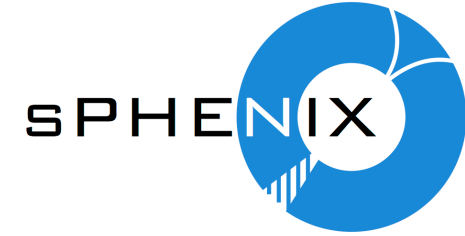
# Preparing for First Jet Measurements



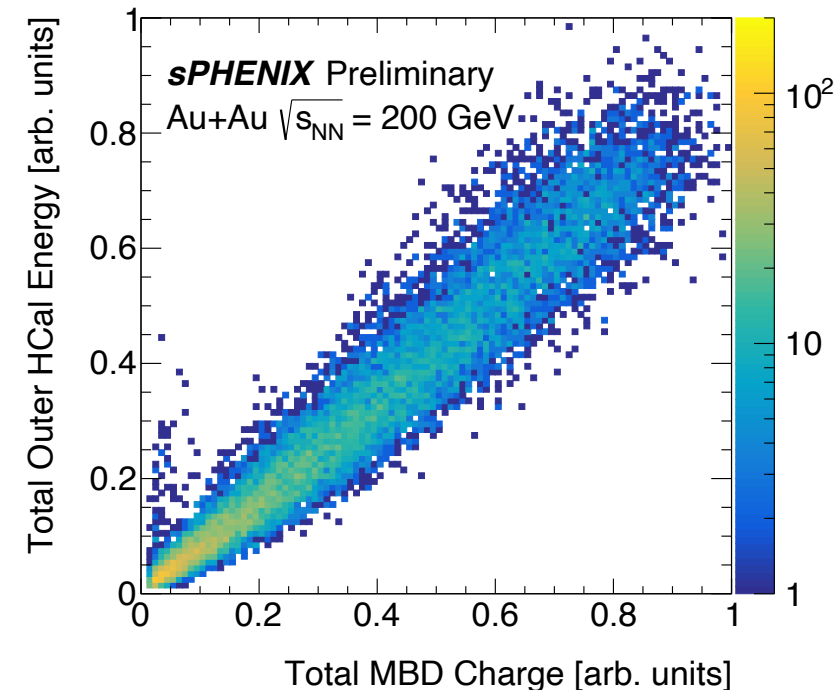
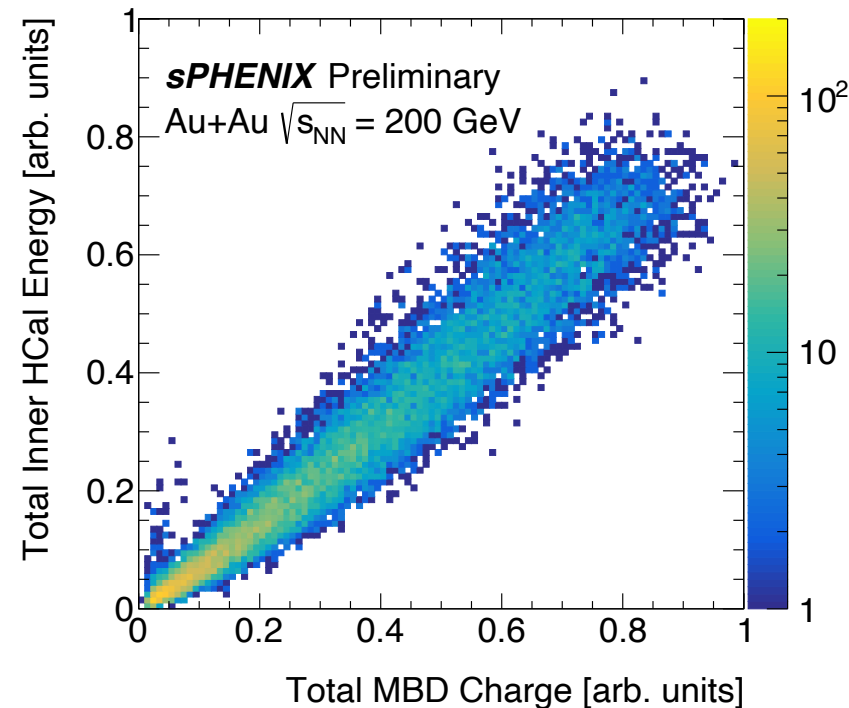
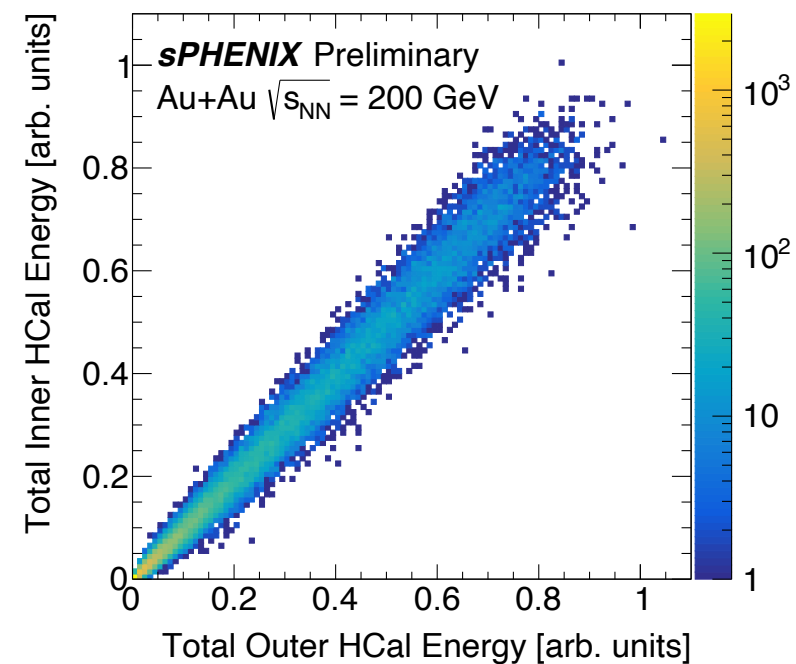
- Early jet measurements will be fully calorimeter-based
- Access to full jet energy and less susceptible to fragmentation bias
- Commissioning focused on tight correlation between calorimeters and other critical subsystems



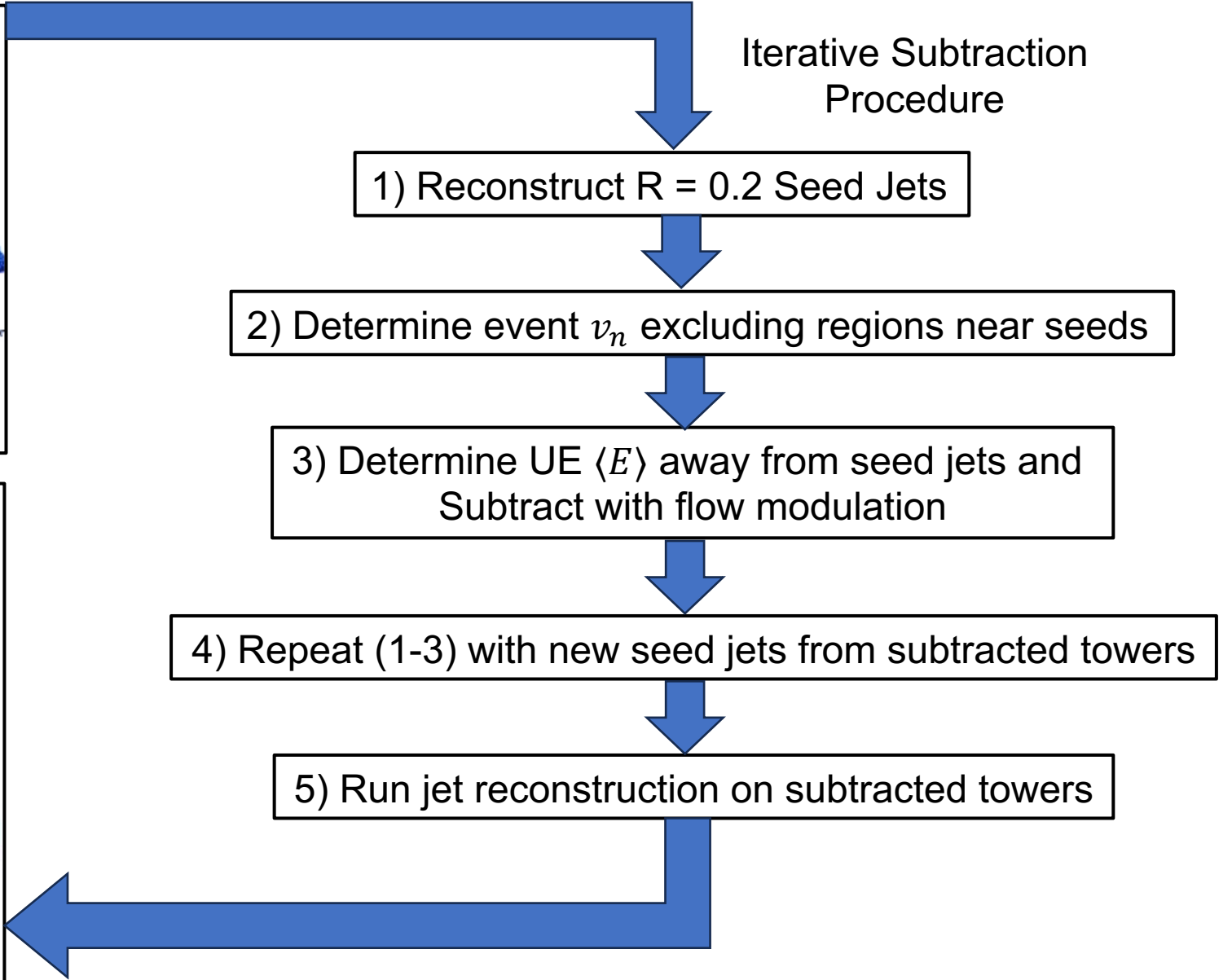
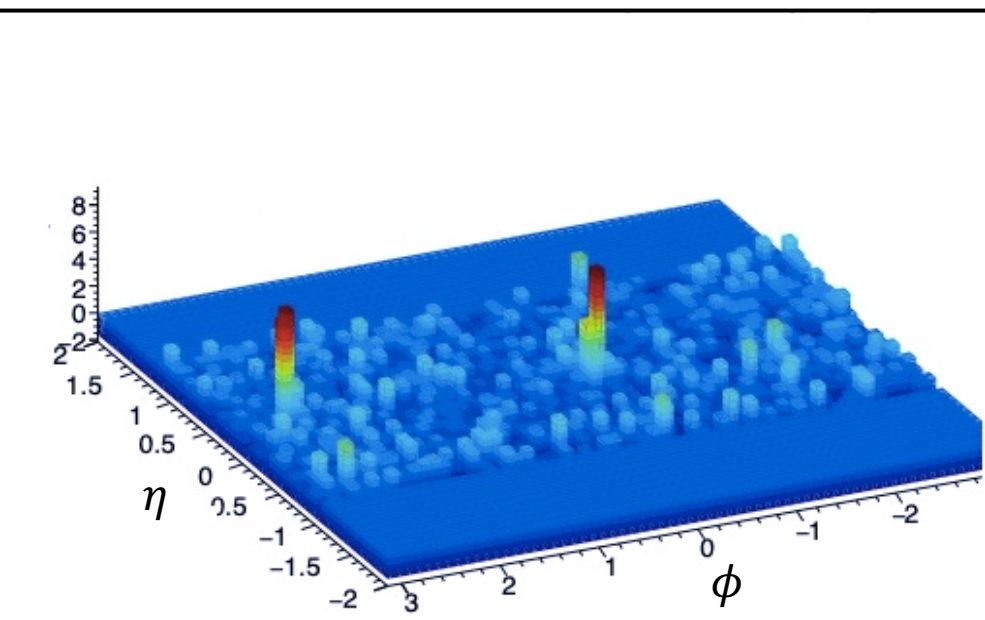
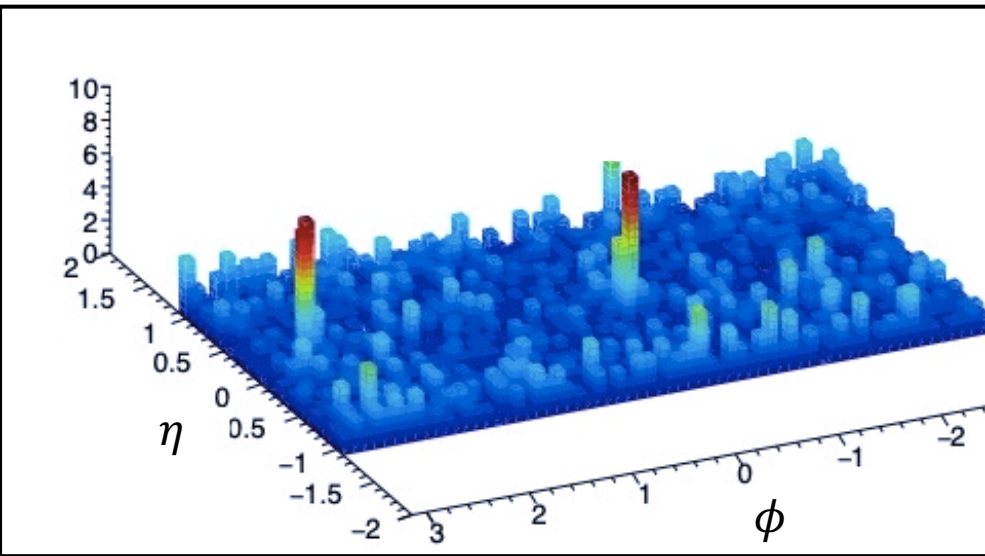
# Preparing for First Jet Measurements



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# The sPHENIX Jet Reconstruction Process

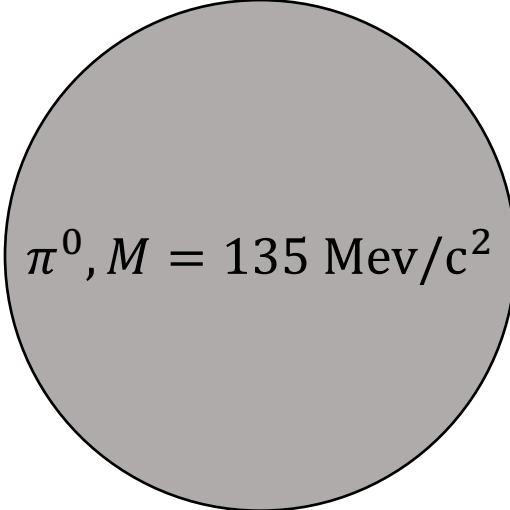


# Early sPHENIX Measurements



# Early Measurements: Neutral Mesons

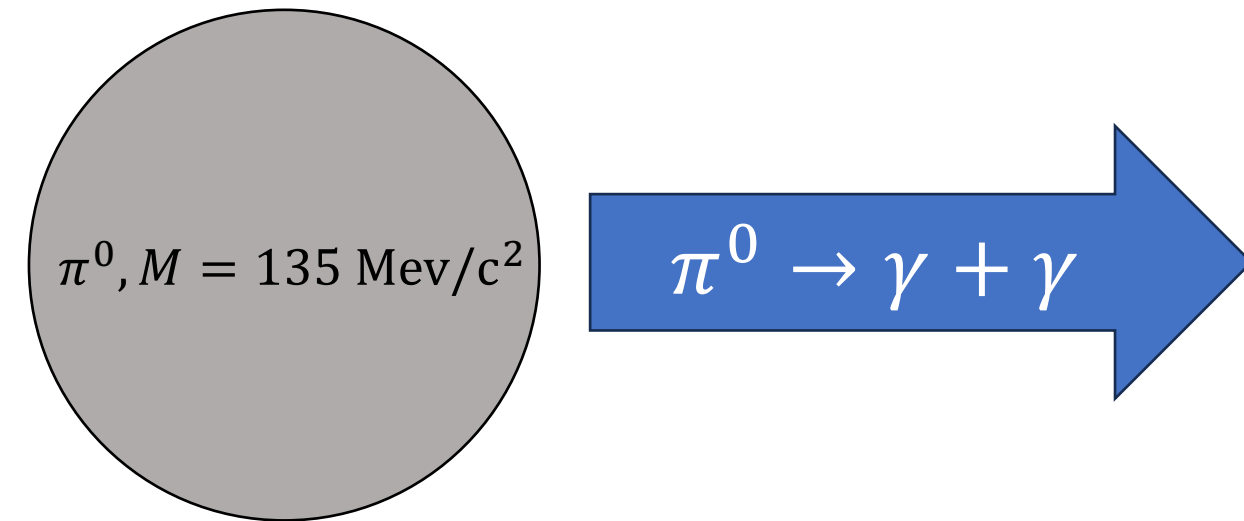
- $\pi^0$  → statistically abundant, calibration source



$\pi^0, M = 135 \text{ Mev}/c^2$

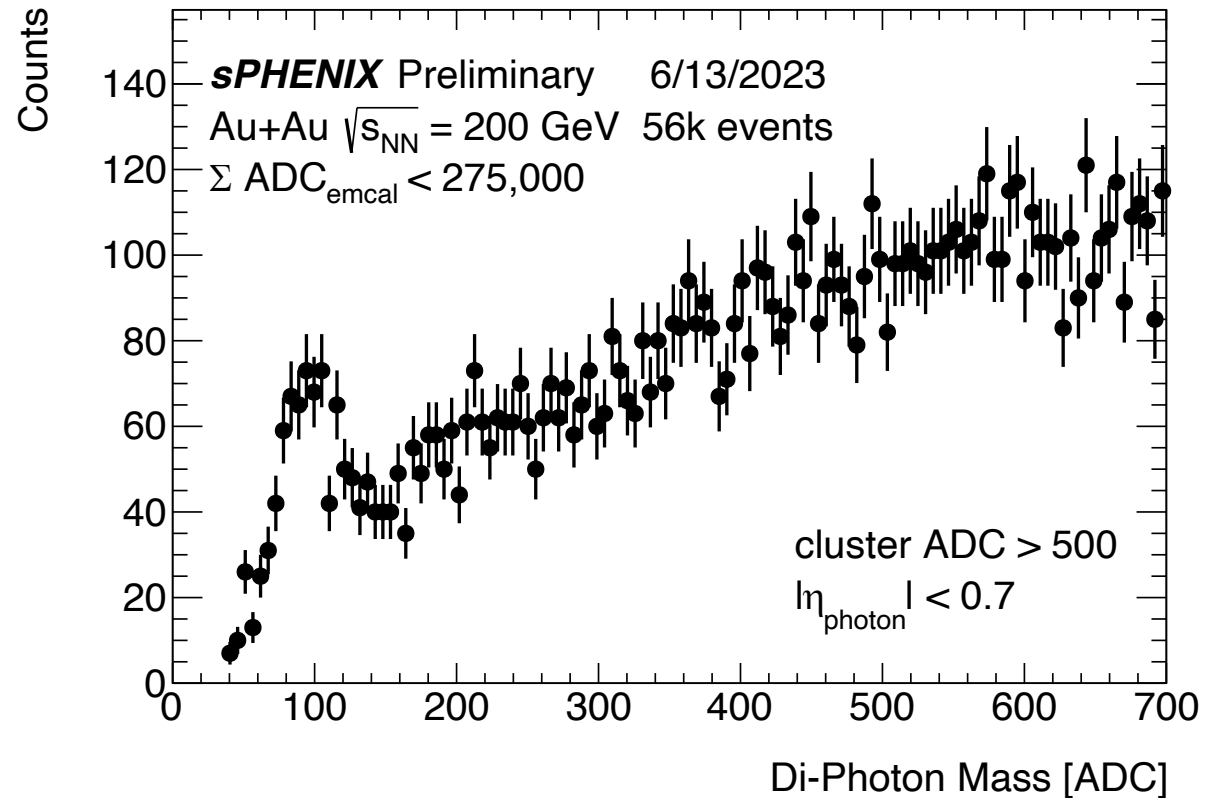
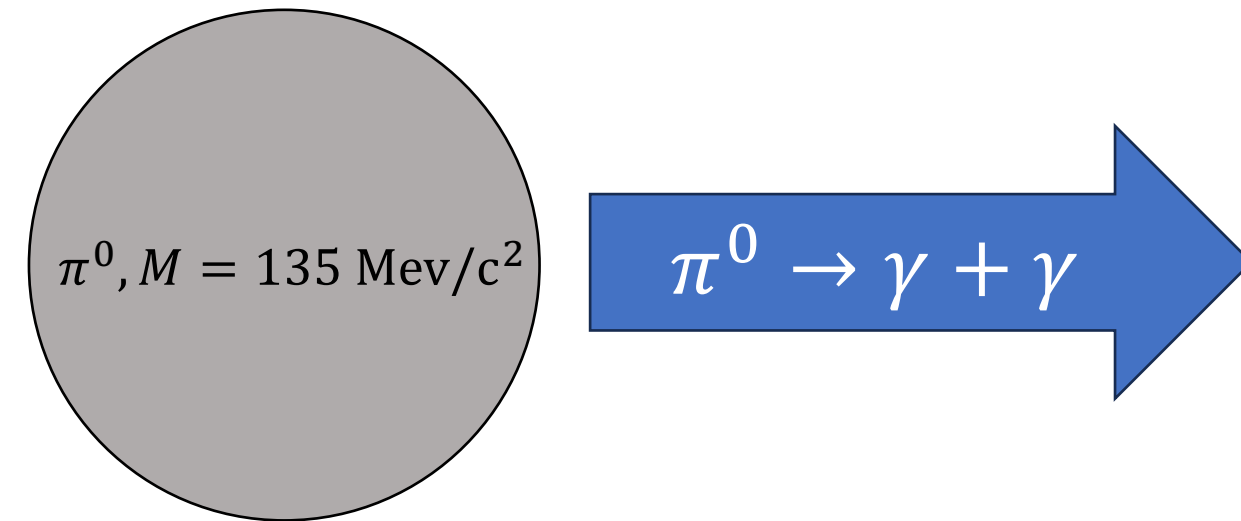
# Early Measurements: Neutral Mesons

- $\pi^0$   $\rightarrow$  statistically abundant, calibration source
  - Reconstructed via  $\pi^0 \rightarrow 2\gamma$  decay process



# Early Measurements: Neutral Mesons

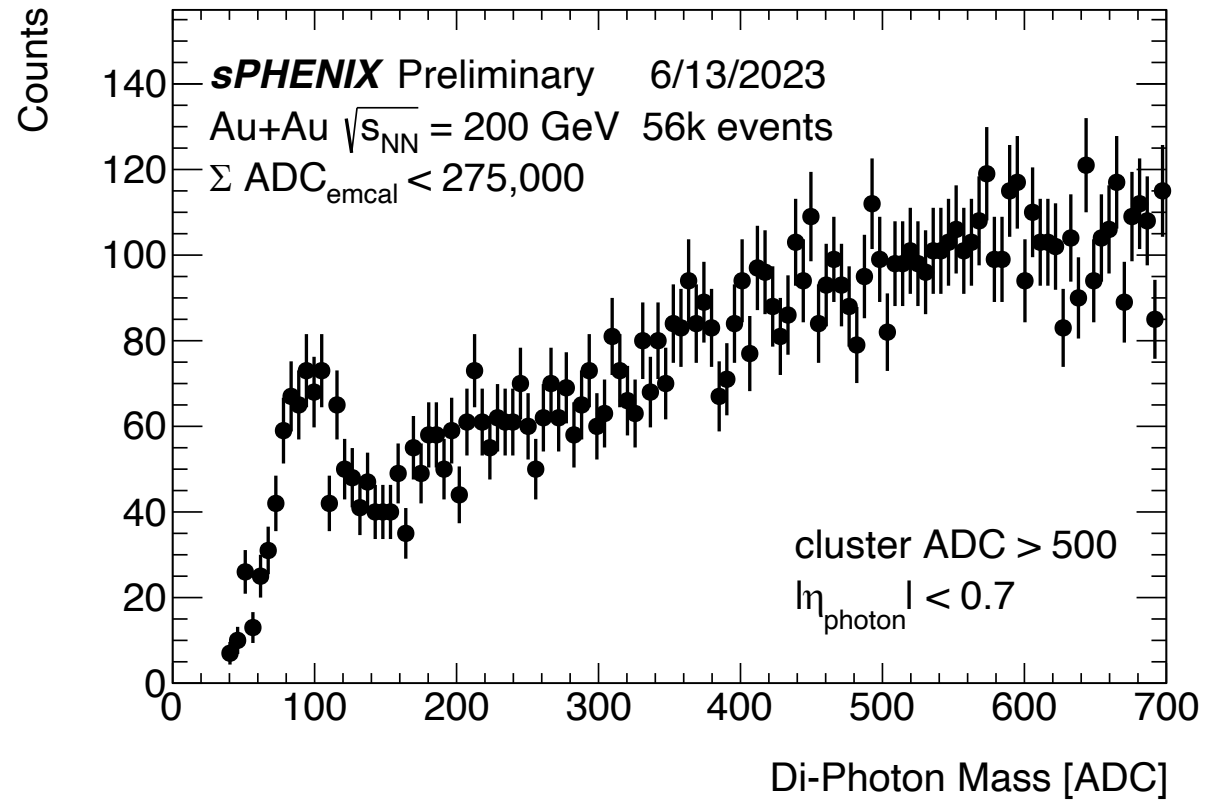
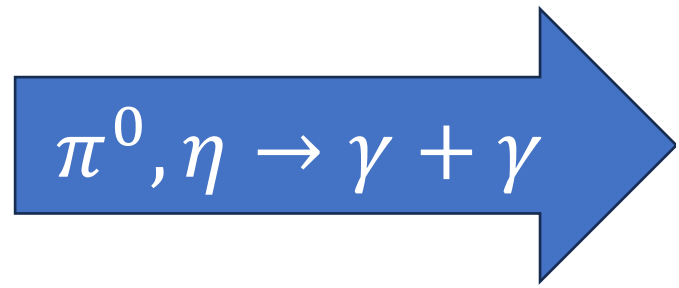
- $\pi^0$  → statistically abundant, calibration source
  - sPHENIX already measures visible  $\pi^0$  peak in early data!



# Early Measurements: Neutral Mesons

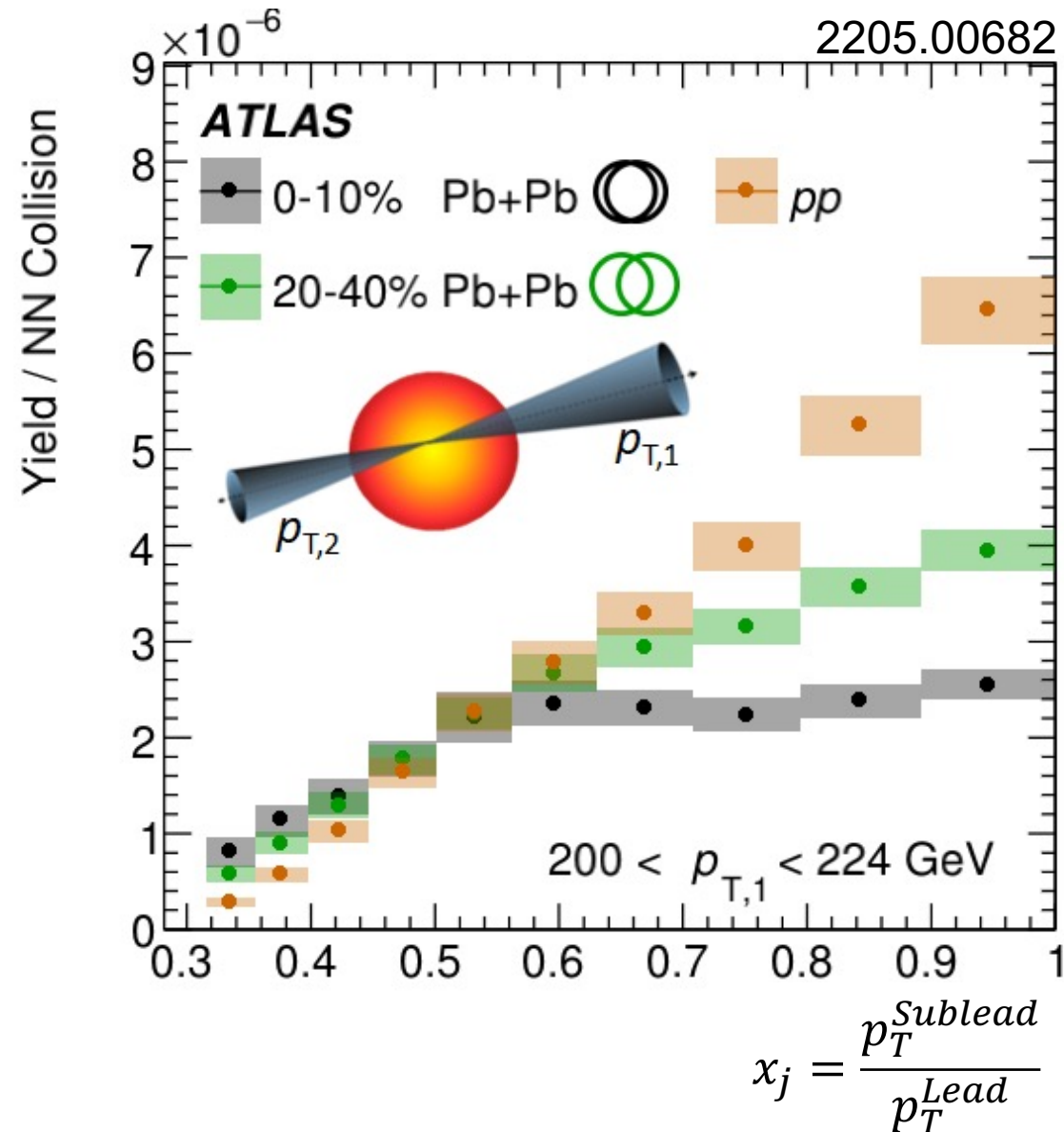
- $\pi^0$   $\rightarrow$  statistically abundant, calibration source
- $\eta$   $\rightarrow$  high  $p_T$  calibration cross-check
  - Measure out to high  $p_T$   $\rightarrow$  early energy loss measurement

$\pi^0, M = 135 \text{ Mev}/c^2$   
 $\eta, M = 547.9 \text{ Mev}/c^2$



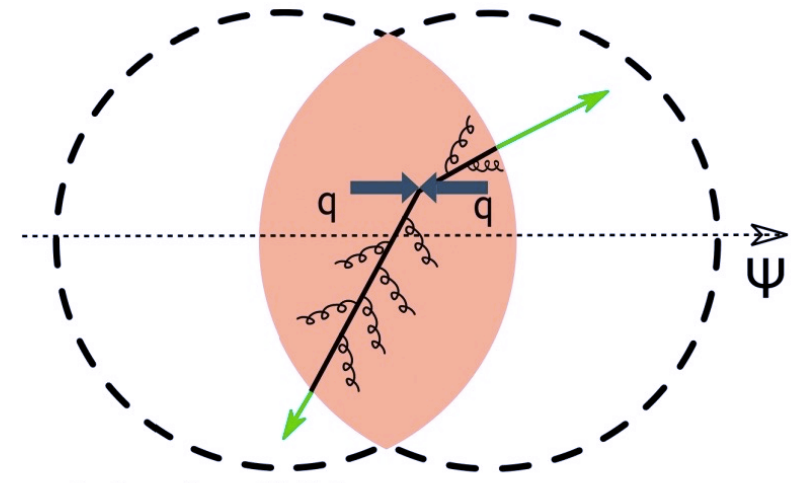
# Early Measurements: Dijet Asymmetry

- Recent ATLAS dijet  $x_j$  shows preferential suppression of symmetric dijet pairs
- LHC-style measurements at RHIC energies will probe temperature-dependence of suppression phenomena

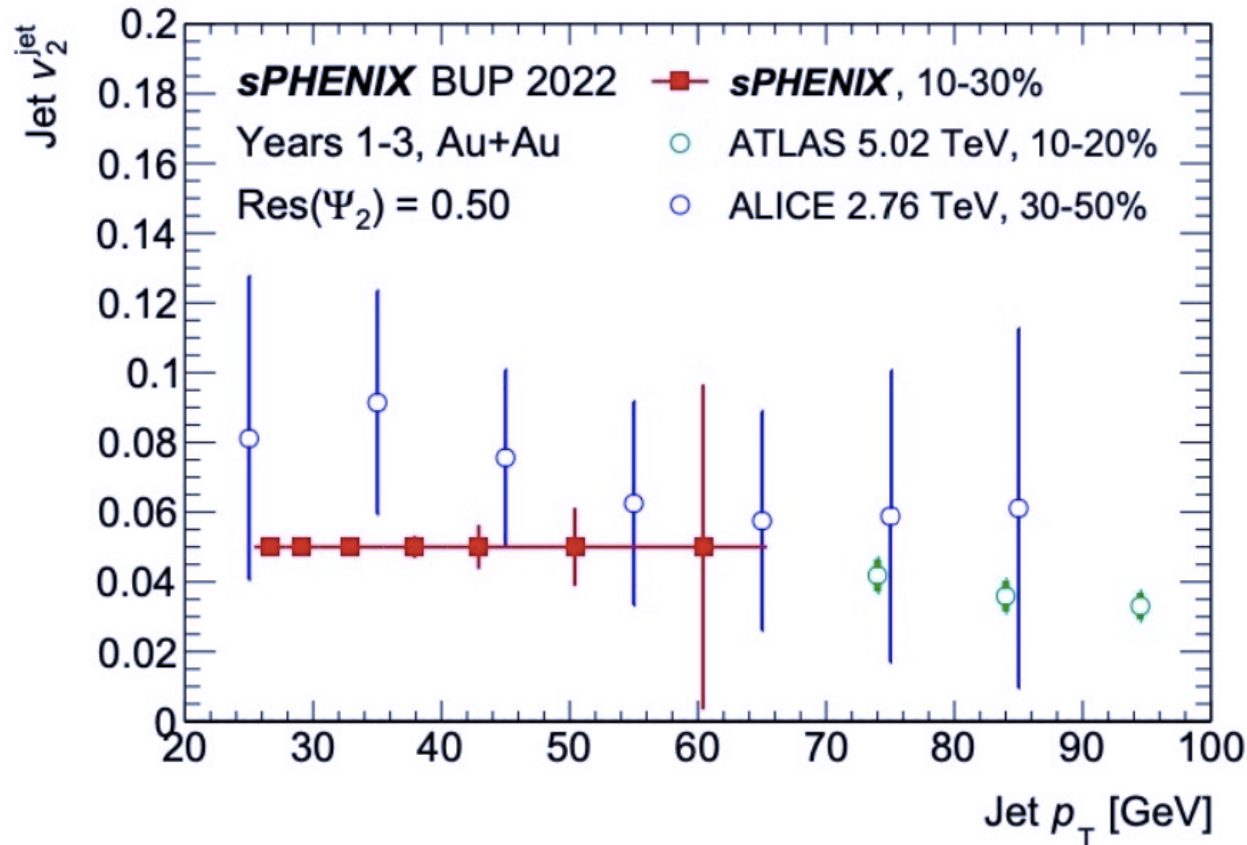


# Early Measurements: Jet $v_2$

- Jet  $v_2$  probes path-length dependence of jet-energy loss
- Aided by high-resolution sPHENIX Event Plane Detector, newly installed!

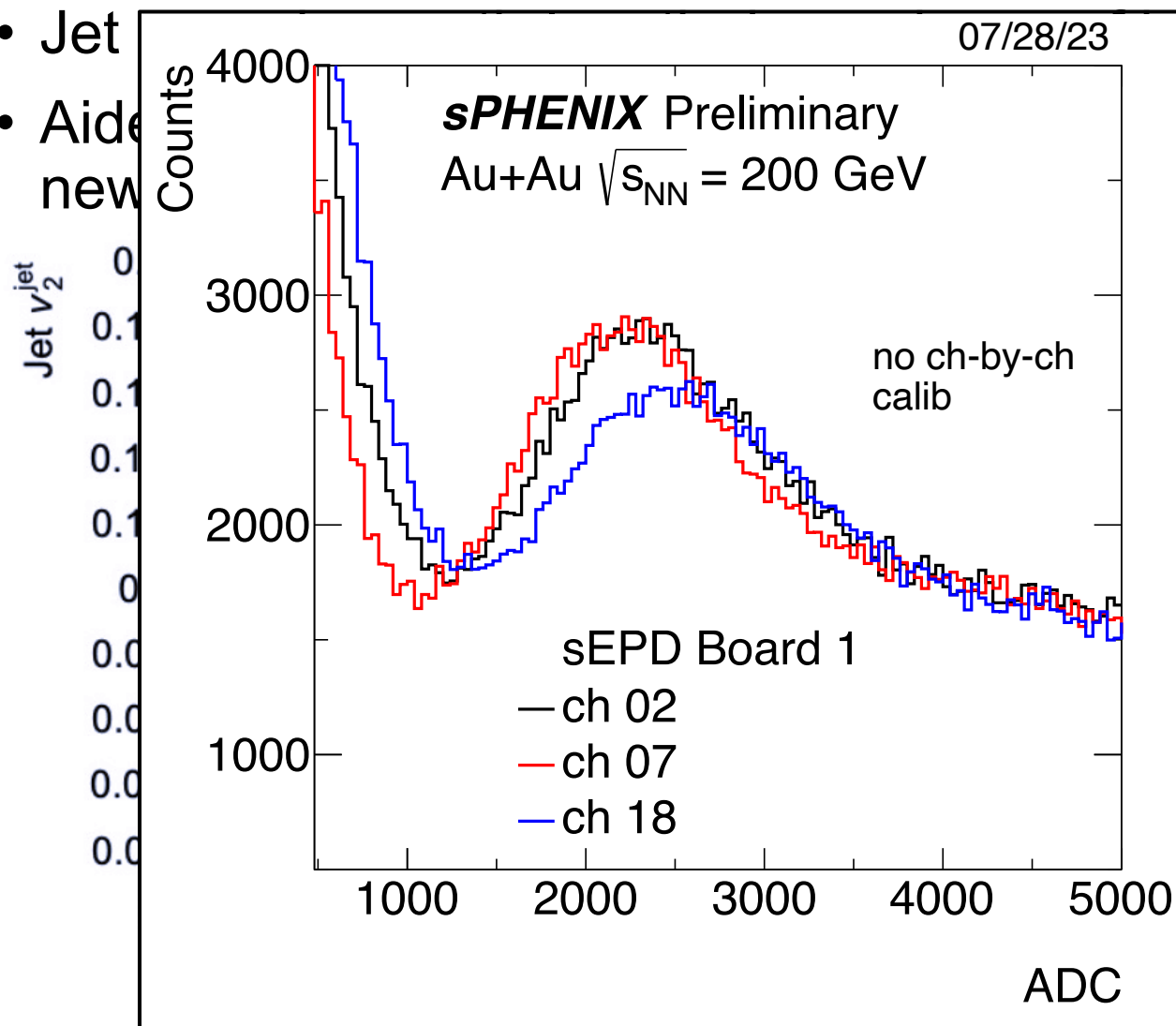


Cartoon from M. Rybar

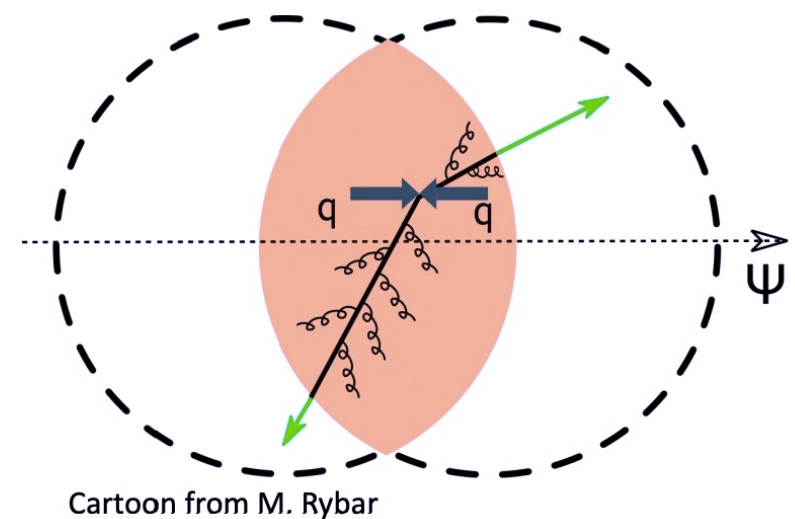


# Early Measurements: Jet $v_2$

- Jet
- Aide
- new

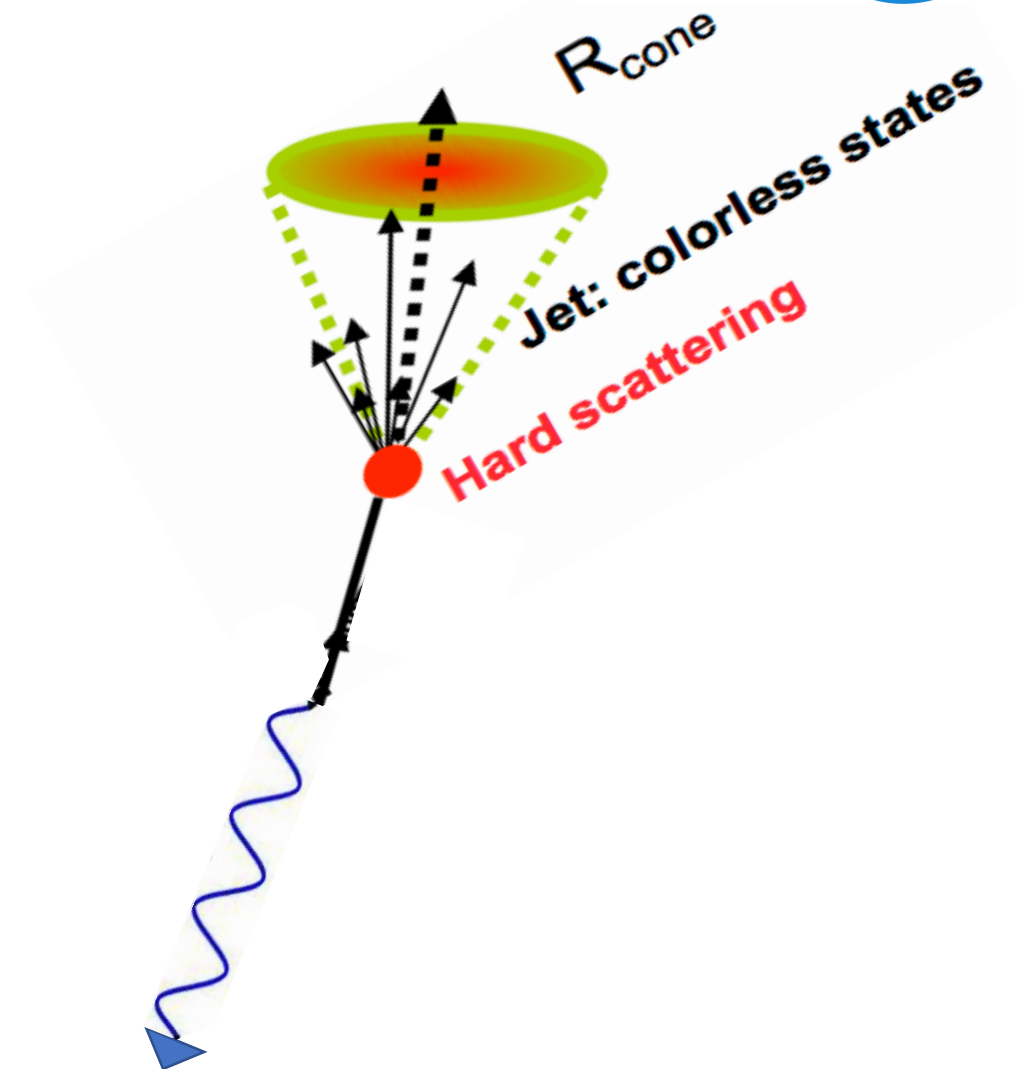


Energy loss  
Detector,



# Direct Photon-Tagged Jets

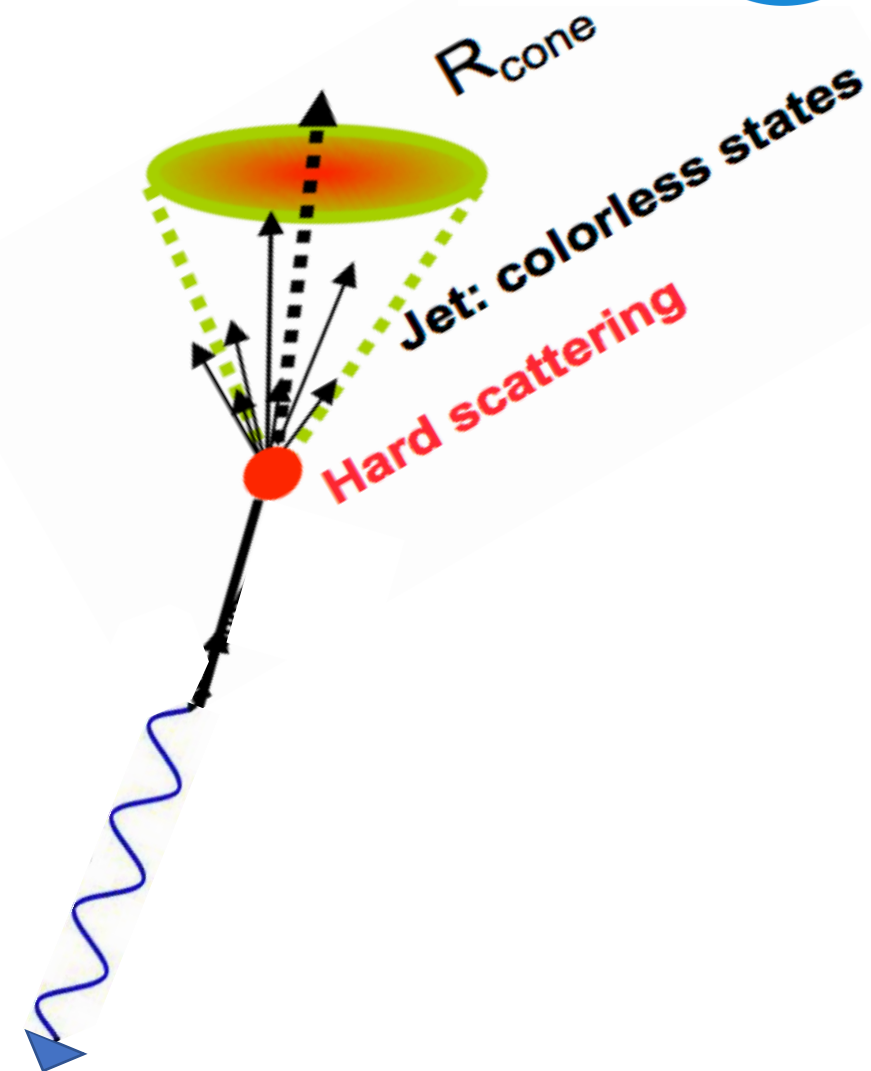
- Jet-energy loss study's "golden channel"
- Challenges:
  - Both measurements adversely effected by large HI background
  - No immediate, nice uncertainty cancellation
  - Notoriously statistics hungry





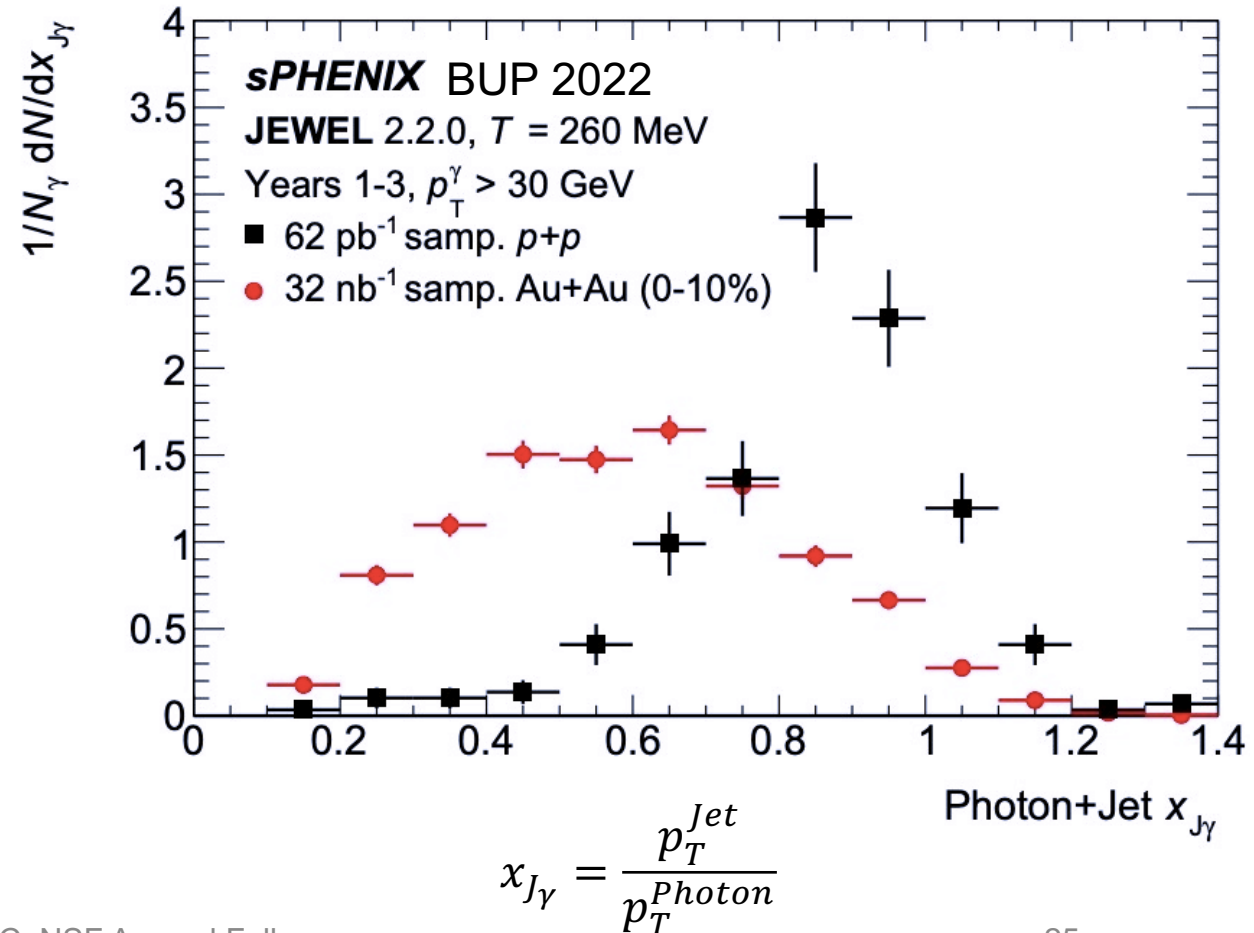
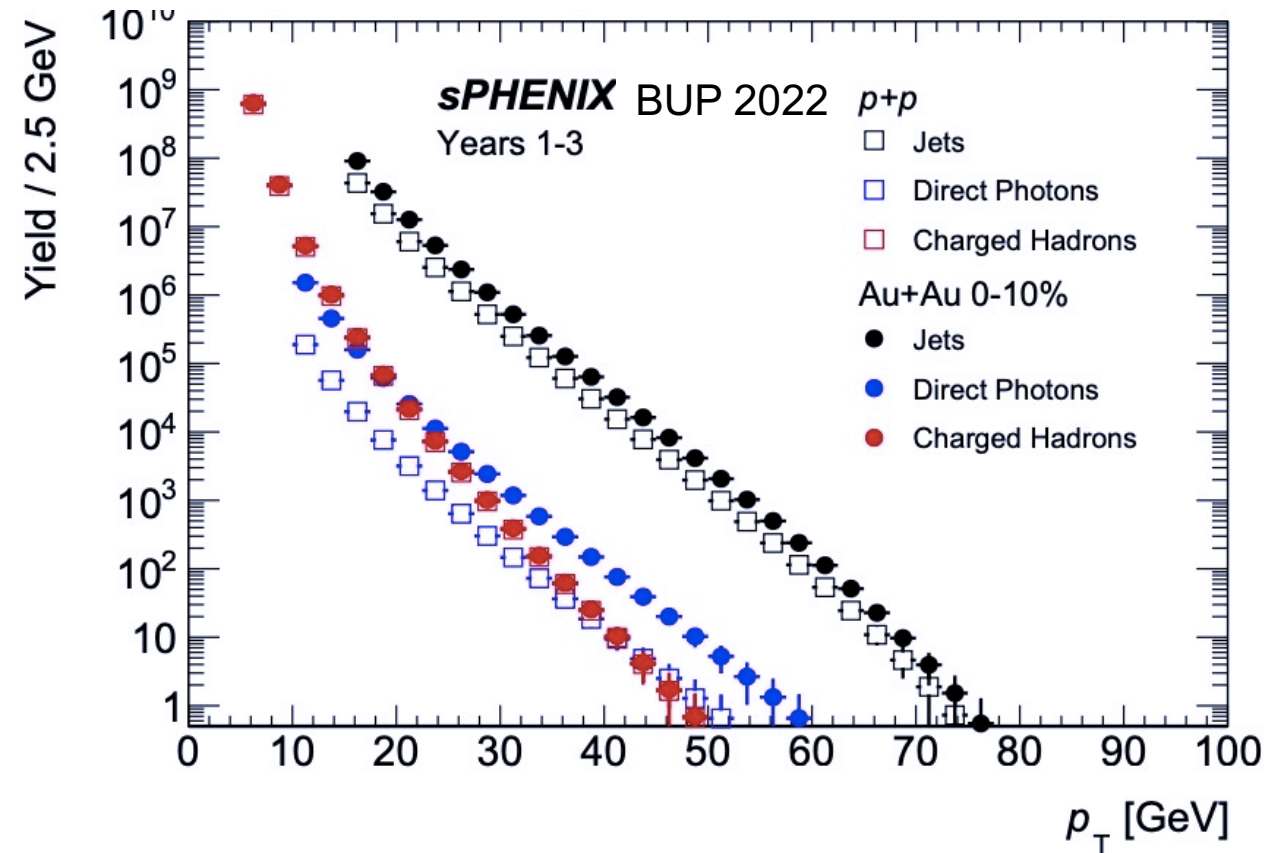
# Direct Photon-Tagged Jets

- Jet-energy loss study's "golden channel"
- Challenges:
  - Both measurements adversely effected by large HI background
  - No immediate, nice uncertainty cancellation
  - Notoriously statistics hungry
- Previous measurements, sPHENIX acceptance, and event rate will lead to precision  $\gamma$  –jet measurements!

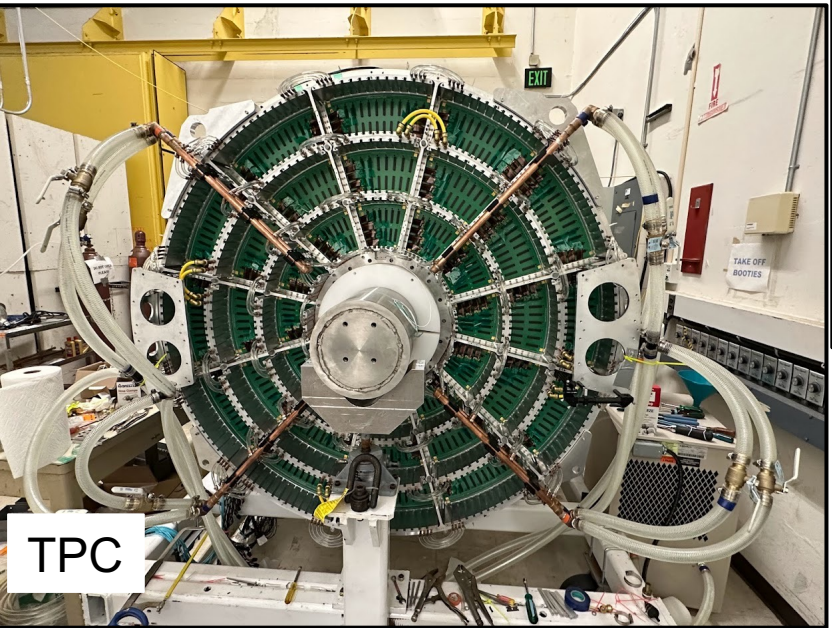


# Direct Photon-Tagged Jets

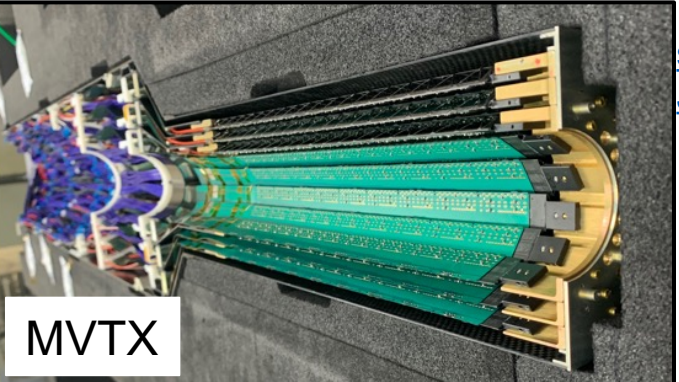
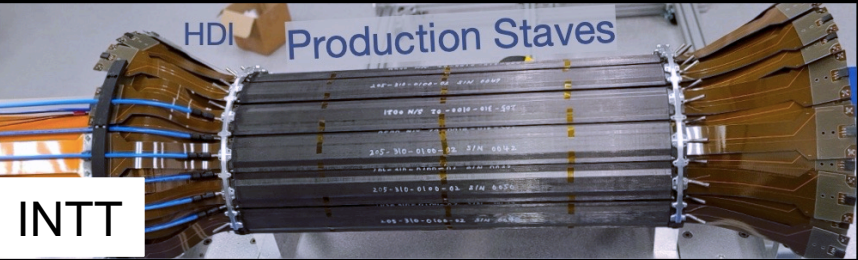
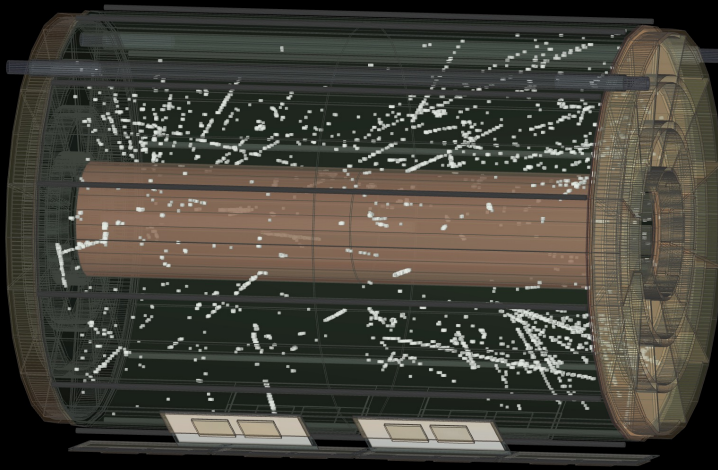
- sPHENIX acceptance + high acquisition rate excellent for high precision photon-jet measurements



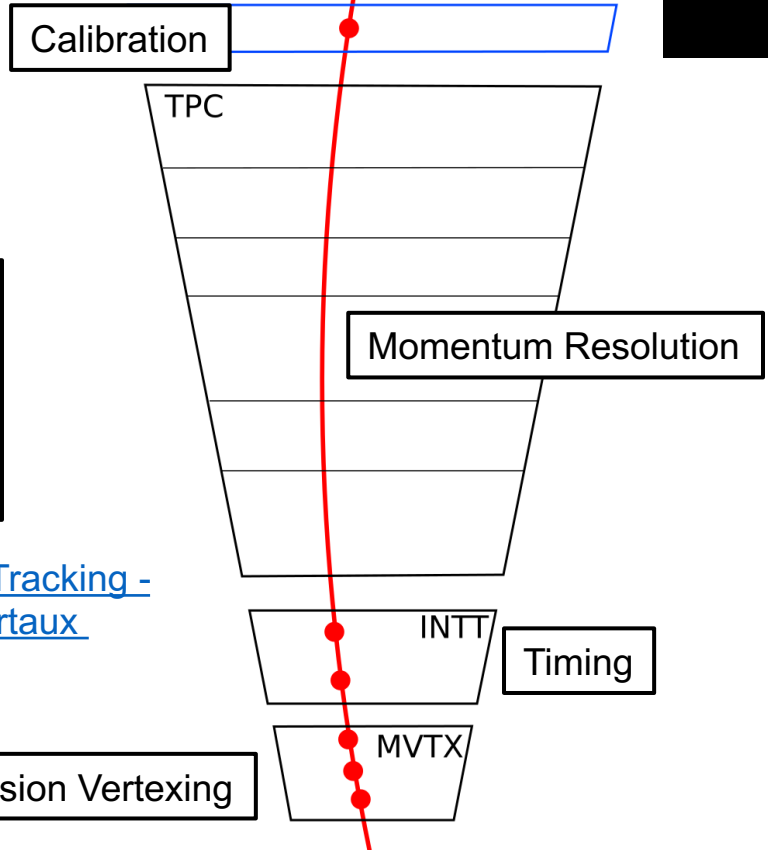
# sPHENIX Tracking



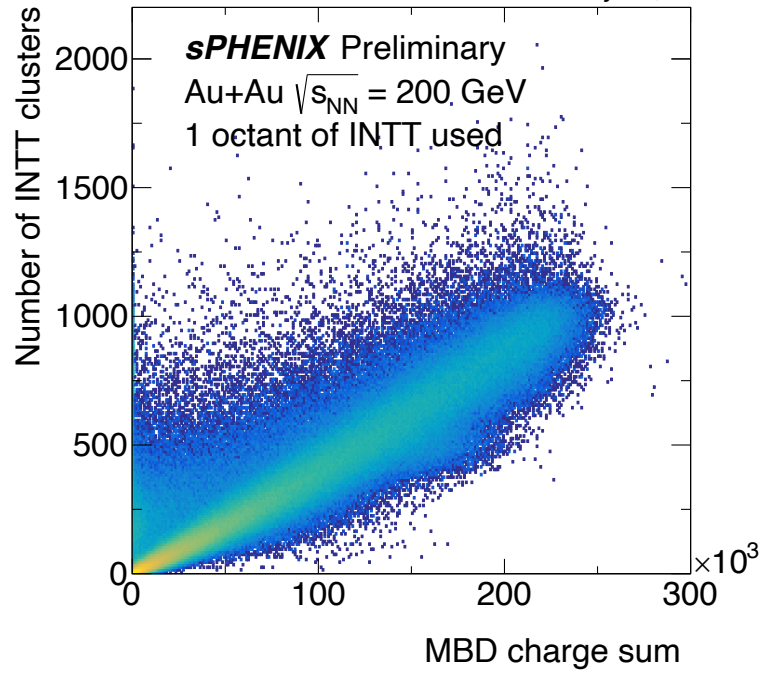
sPHENIX Time Projection Chamber  
 First collision with TPC  
 2023-06-13, Run 10771  
 Au+Au sqrt[s\_NN] = 200 GeV



[sPHENIX Tracking - Joseph Bertaux](#)

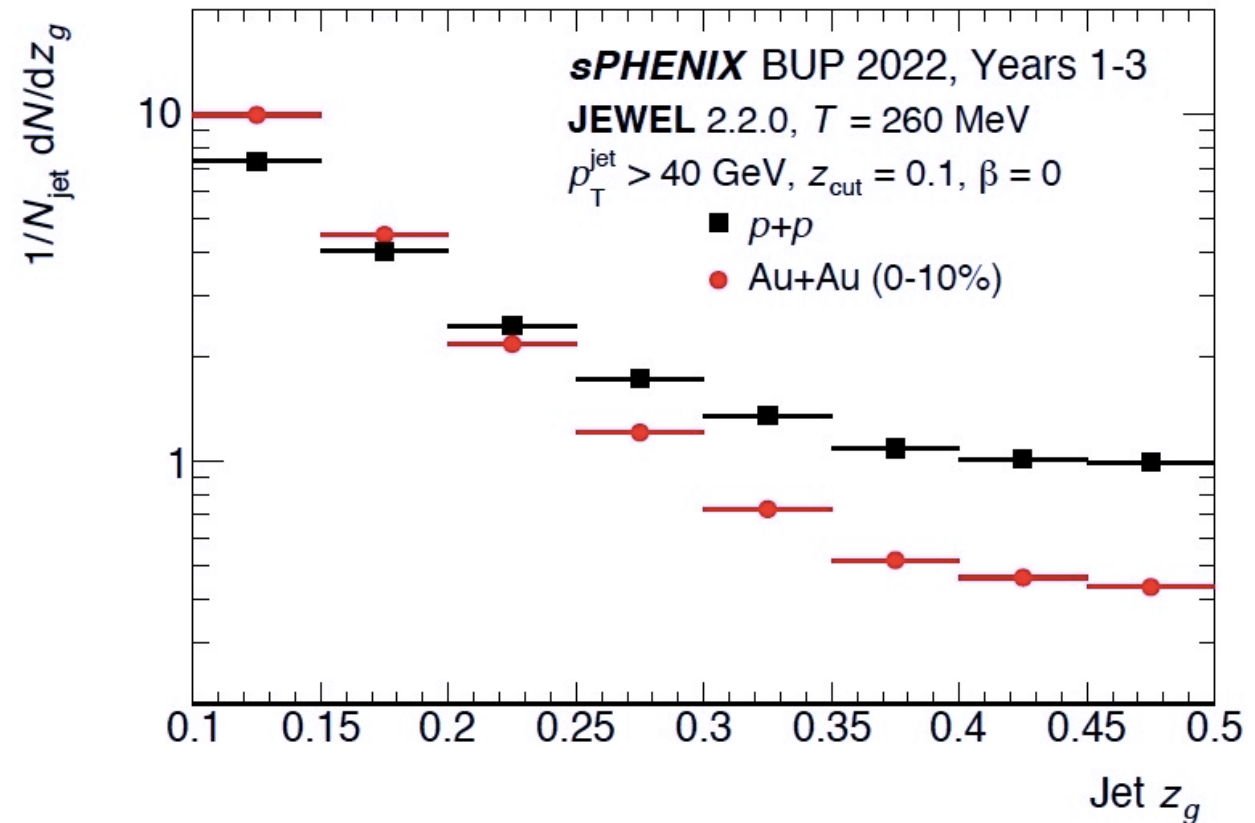
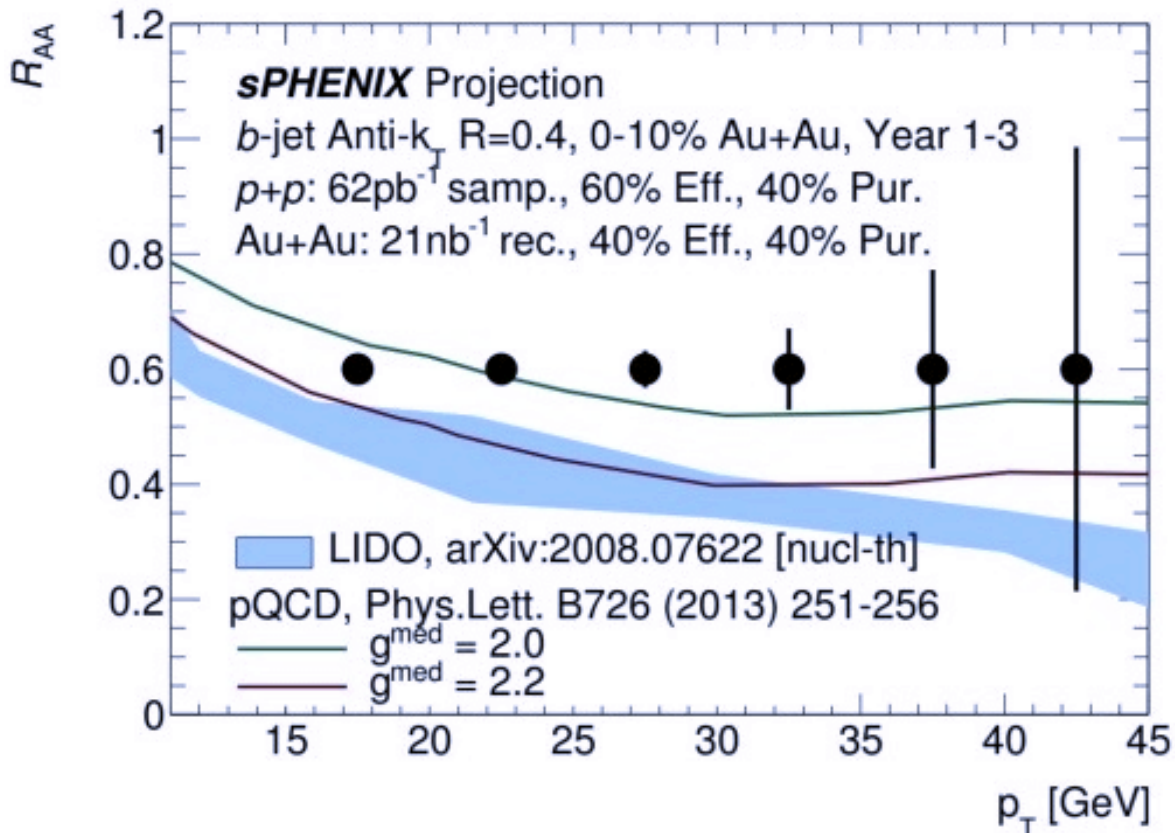


July 21, 2023



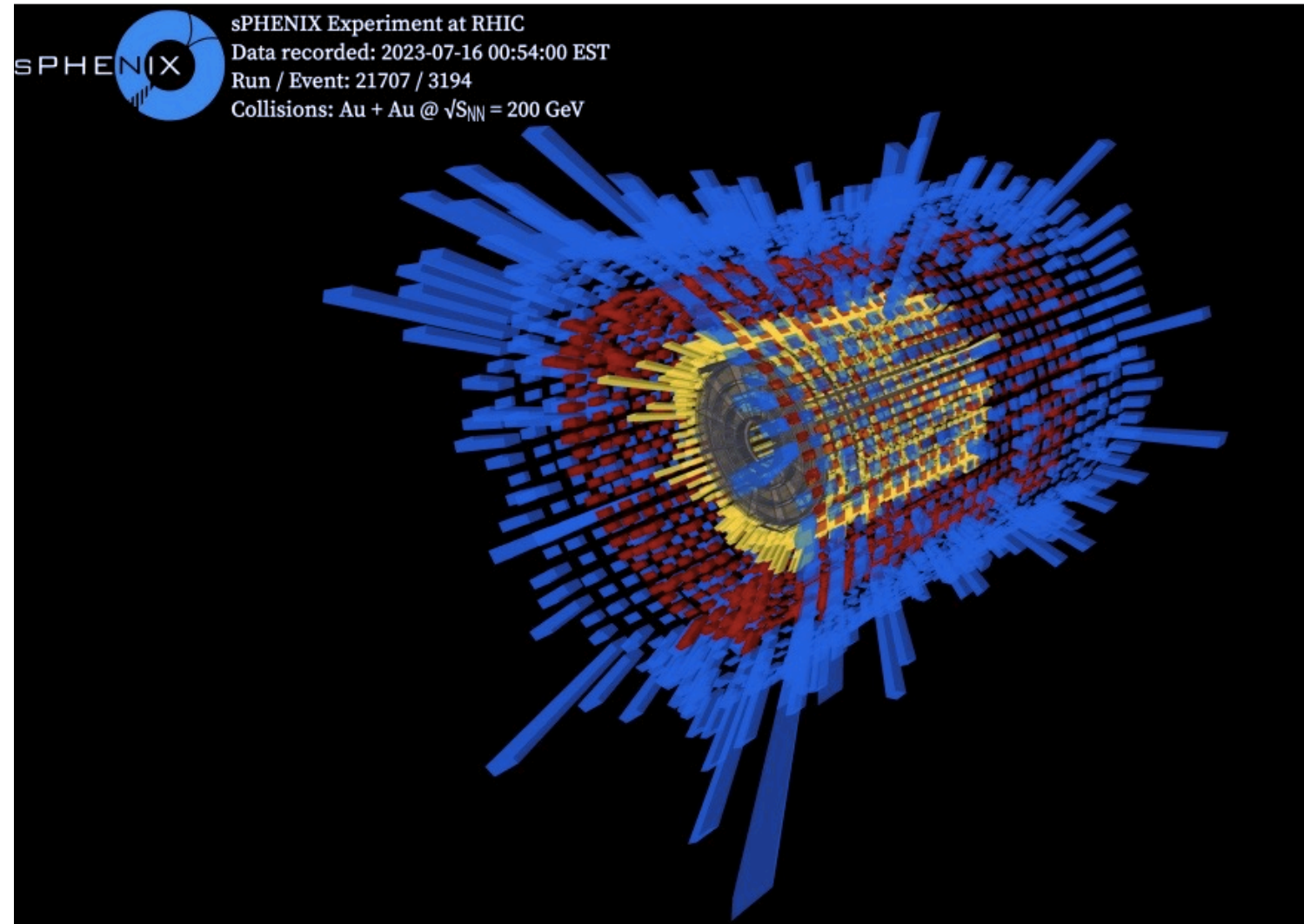
# Calorimeter + Track Jet Measurements

- Quantify parton mass dependence of energy loss
- Statistical precision will provide illuminating feedback on model predictions



# sPHENIX Commissioning Status and Outlook

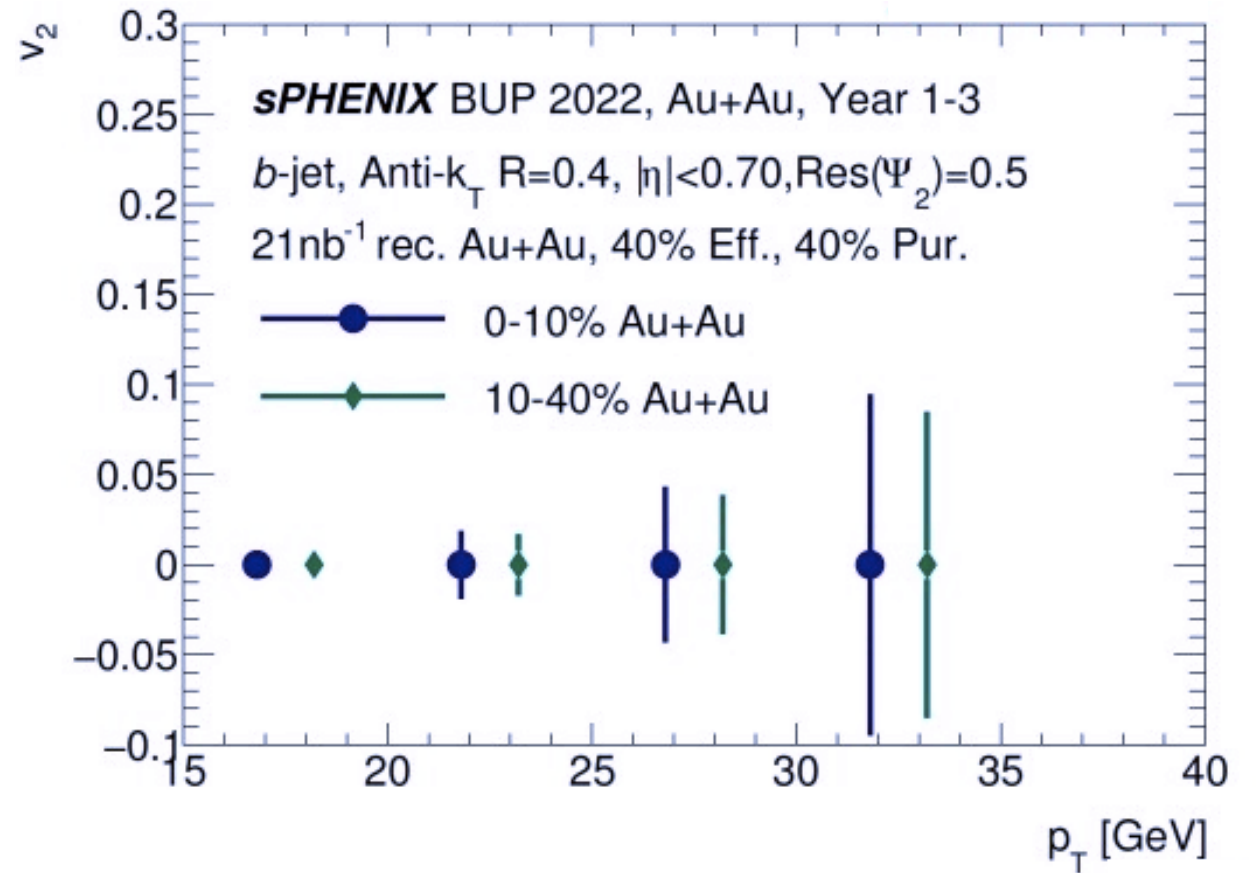
- sPHENIX taking commissioning beam data since May
- Subsystem teams working diligently to understand detector performance
- sPHENIX community looks forward to making many quality jet-related measurements in the very near future!



# Back-up

# Heavy-Flavor Tagged Jets

- b-jet  $v_2$  allows observation of path-length dependent energy loss and its mass dependence



# sPHENIX in the Physics Landscape

- Important opportunity to bridge provide insight on conflicting LHC results

