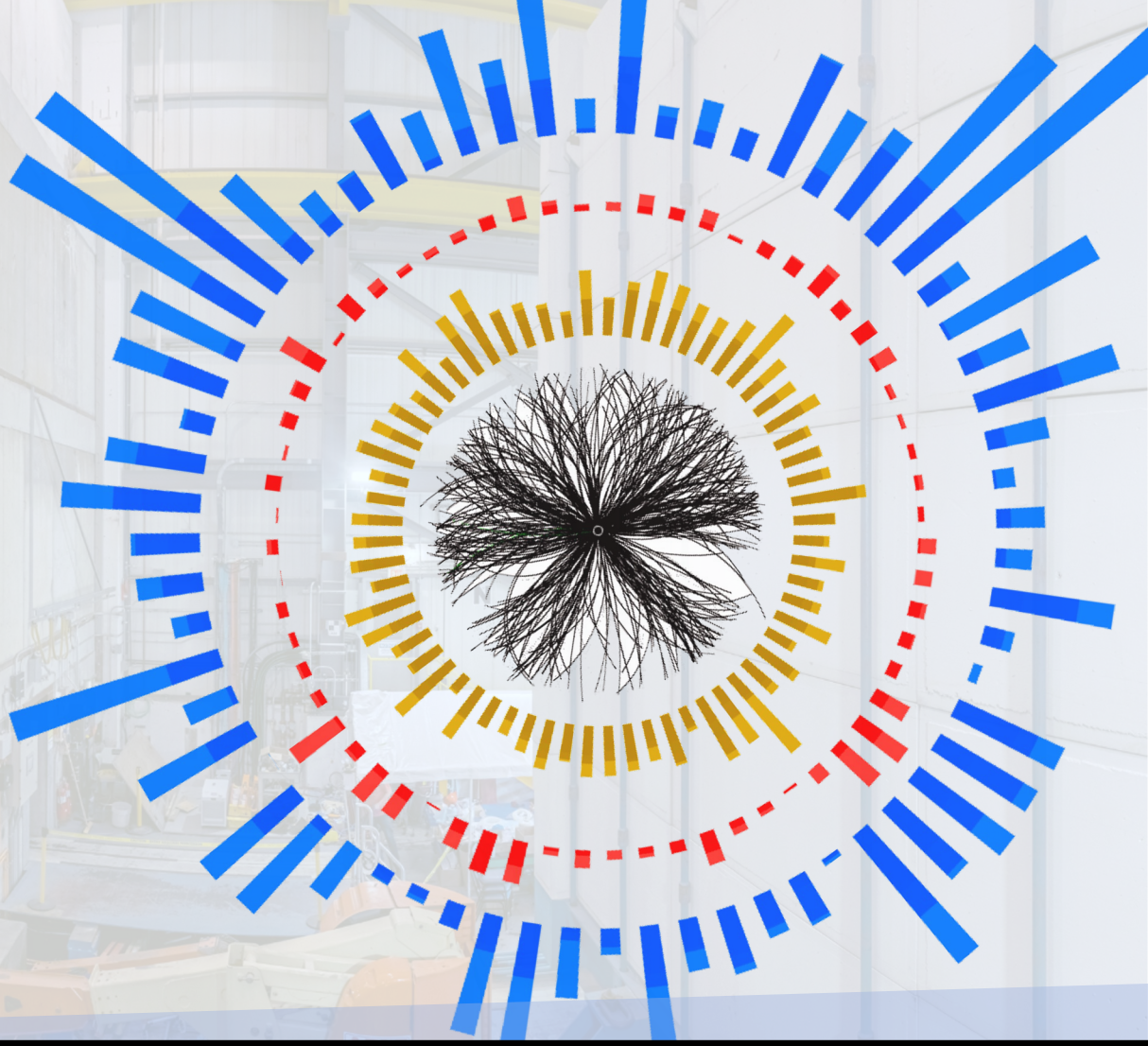
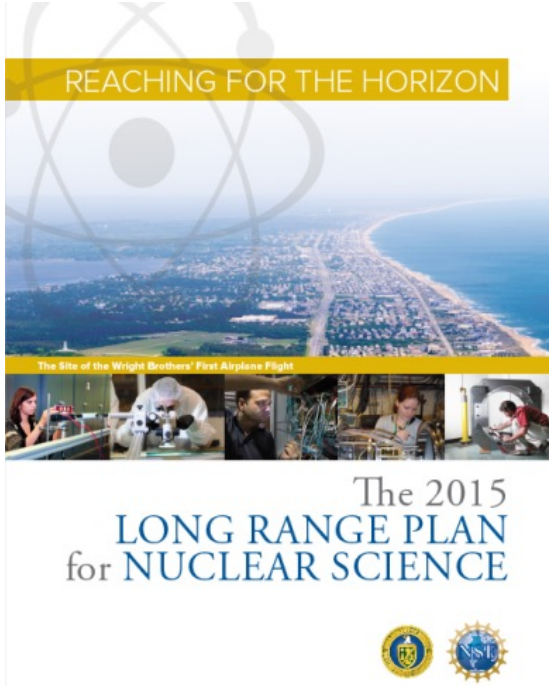
Completing the RHIC mission with sPHENIX

Megan Connors (GSU)
RHIC Science Symposium
May 15, 2026



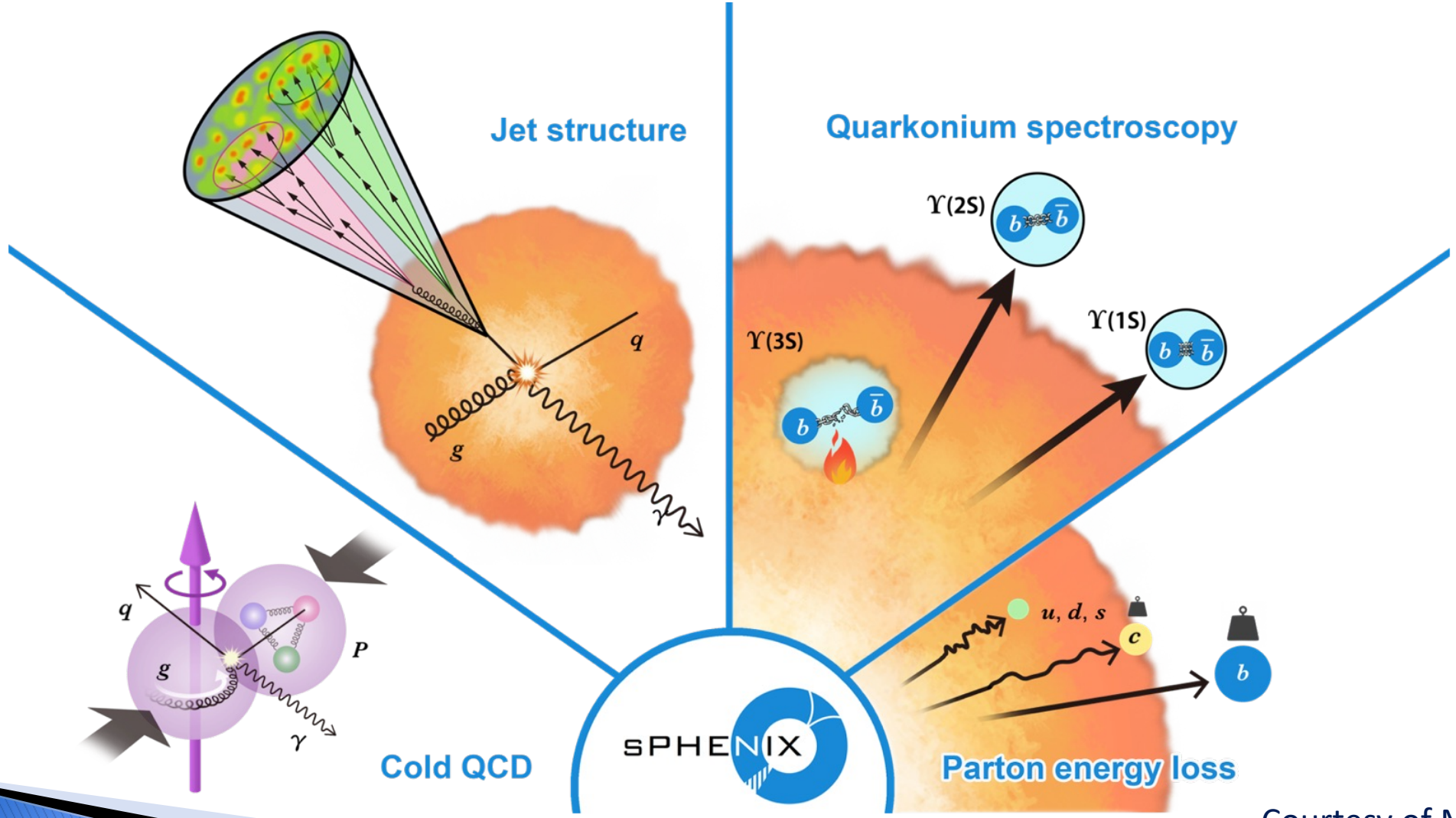
Data recorded: 2025-06-10 05:50:10 EST
Run / Event: 66641 / 146
Collisions: Au + Au @ $\sqrt{s_{NN}}$ = 200 GeV



Completing the RHIC Mission

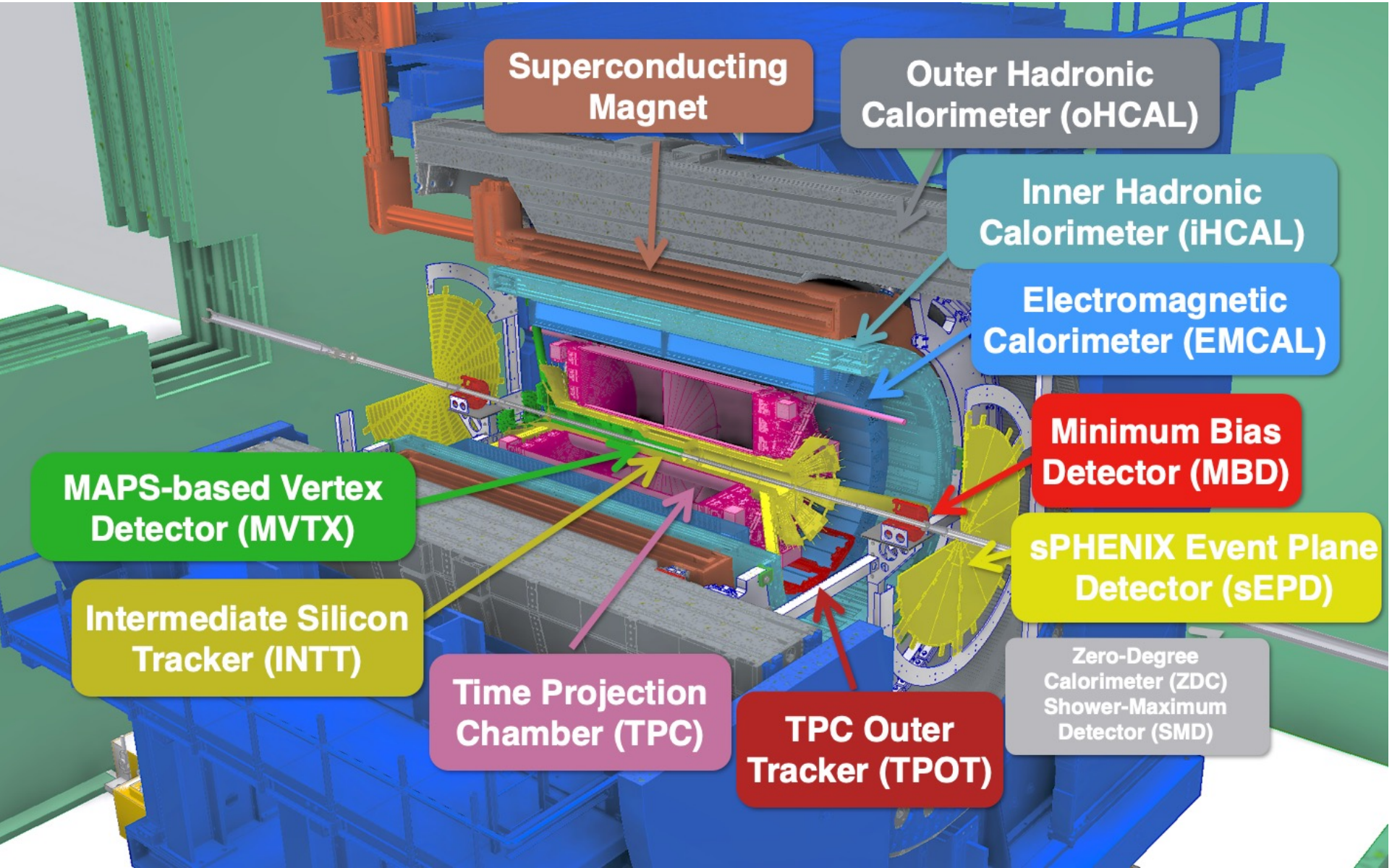
- **2015 Nuclear Physics Long Range Plan**
  - There are two central goals of measurements planned at RHIC, as it completes its scientific mission, and at the LHC: (1) Probe the inner workings of QGP by resolving its properties at shorter and shorter length scales. The complementarity of the two facilities is essential to this goal, as is a state-of-the-art jet detector at RHIC, called sPHENIX.
- **2023 Nuclear Physics Long Range Plan: Recommendation 1**
  - The highest priority of the nuclear science community is to capitalize on the extraordinary opportunities for scientific discovery made possible by the substantial and sustained investments of the United States. We must draw on the talents of all in the nation to achieve this goal. Here we emphasized that this recommendation requires (1) … (2) continuing effective operations of the national user facilities and completing the Relativistic Heavy Ion Collider science program
- **2023 Nuclear Physics Long Range Plan: Future of hot QCD facilities**
  - To successfully conclude the RHIC science mission, it is essential to (1) complete the sPHENIX science program as highlighted in the 2015 Long Range Plan, (2) complete the concurrent STAR data collection with the forward upgrade, and (3) analyze the data from all RHIC experiments.

sPHENIX Scientific Program



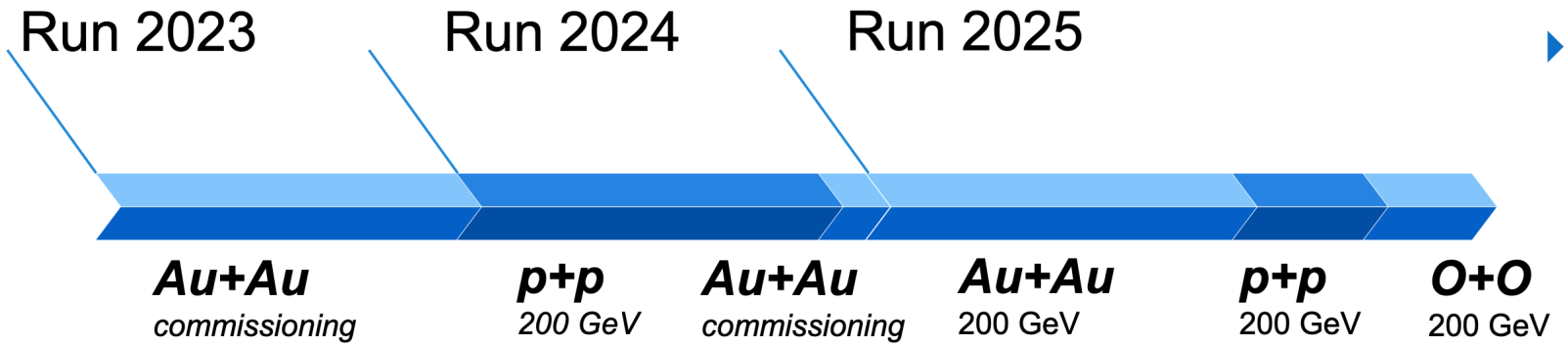
Courtesy of Misaki Ouchida (Hokkaido University)

sPHENIX State-of-the-Art Jet Detector



- Central tracking for b-tagging, quarkonia and jet substructure
- Central Calorimeters for full jet reconstruction and identification of photons and electrons
- Forward detectors for triggering and event characterization
- High rate DAQ

sPHENIX data collection Summary



- CAD and sPHENIX overcame many challenges in 3 years to collect this data
  - CAD report by Travis Shrey

System	Integrated lumi	p+p equivalent	detectors
p+p transversely polarized	107/pb	107/pb	calo
	30/pb	30/pb	calo+tracking
	13/pb	13/pb	tracking
Au+Au	7/nb	270/pb	calo+tracking
O+O	53/nb	14/pb	calo
	24/nb	6/pb	calo+tracking
	9/nb	2/pb	tracking

sPHENIX Collaboration

- A successful data campaign relied on contributions of many collaborators

4 fantastic run coordinators

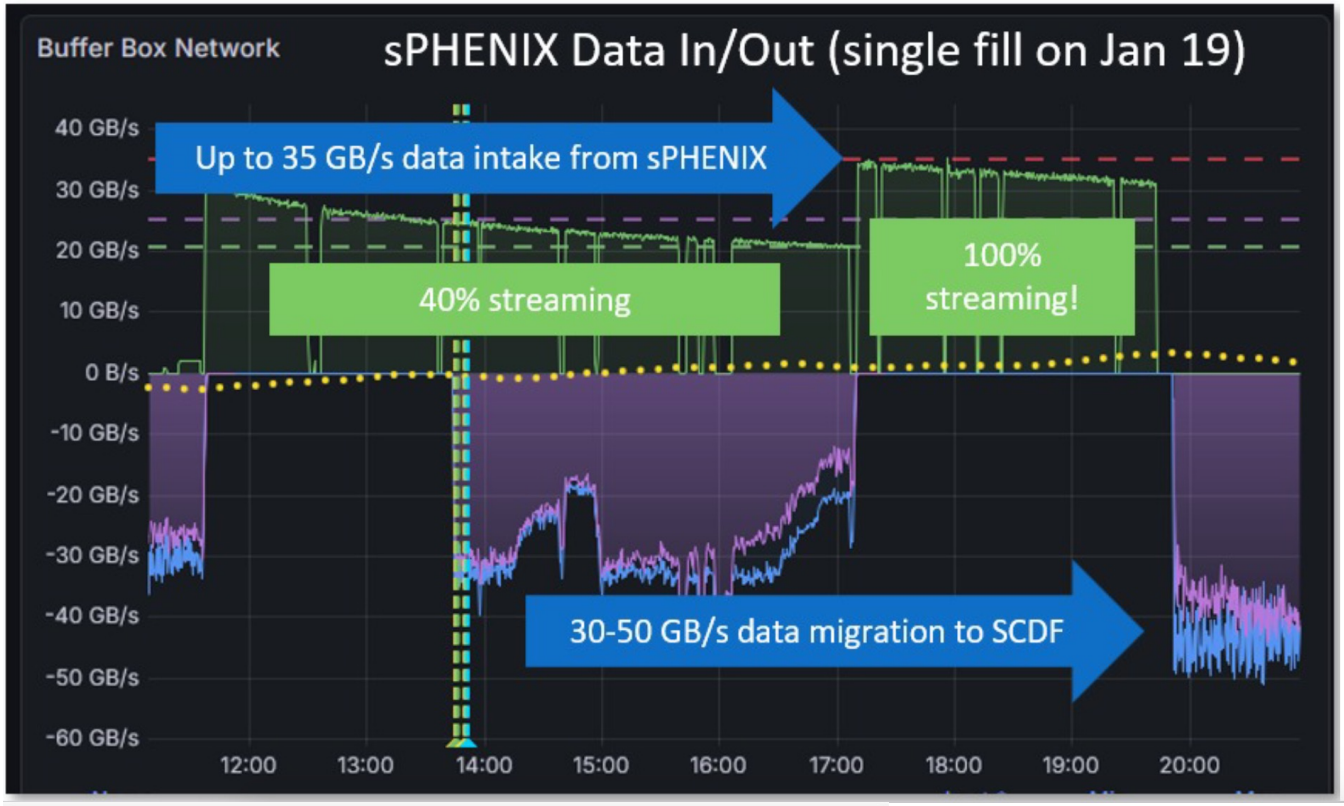
Stefan Bathe (23), Jamie Nagle (24)
Rosi Reed and Ron Belmont (25)

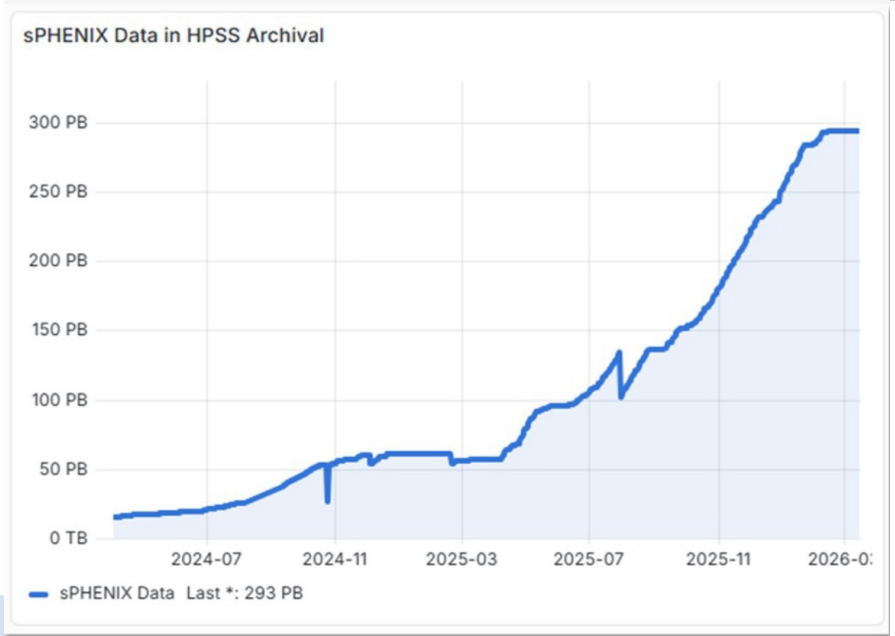
647 Run 25 shifts covered by 193 shifters

Run 25 Run summary by Ron Belmont

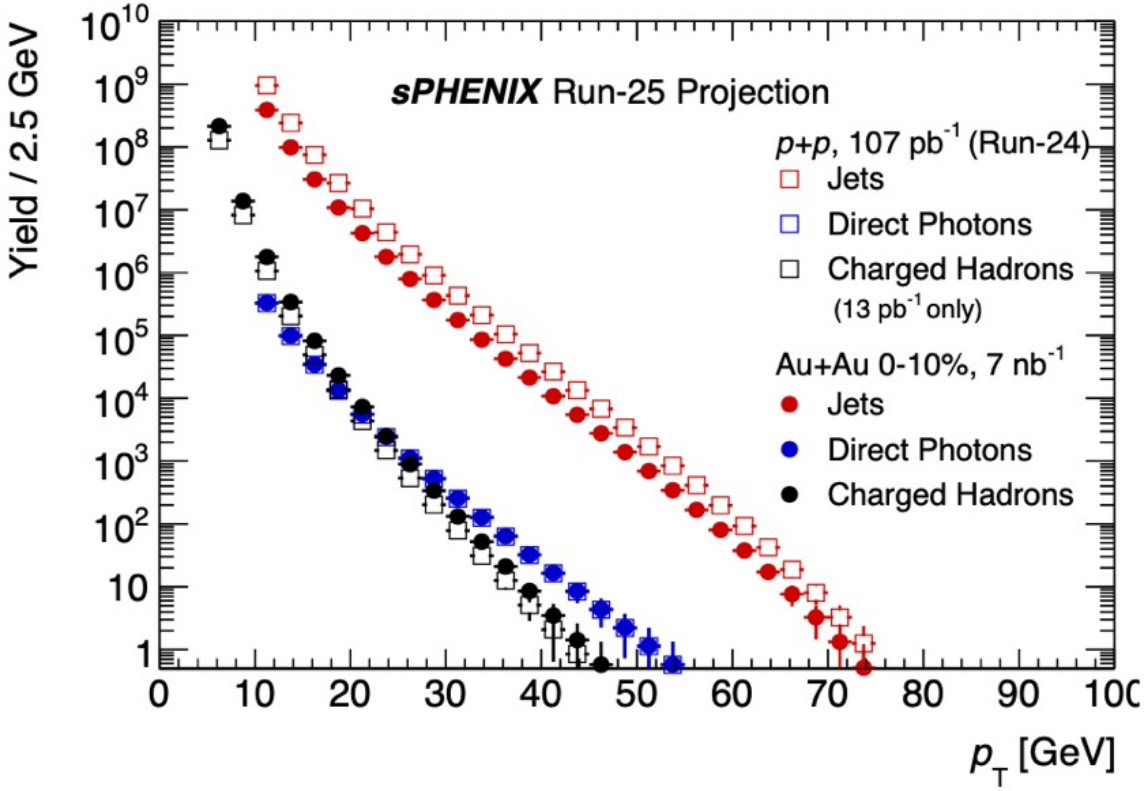
Data taking milestones

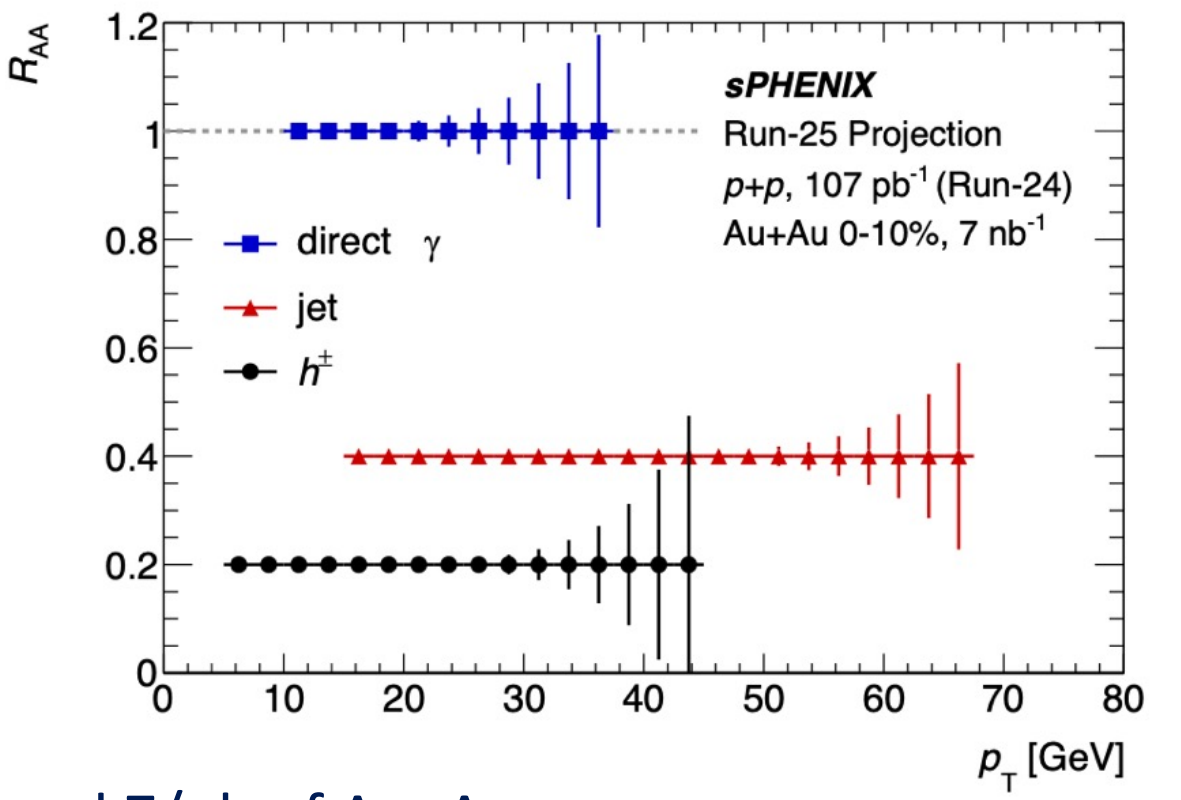
- 15 kHZ UPP achieved in Run 25
- During p+p, operated in 100% streaming mode late in stores
  - World-first for polarized collisions
- More data collected (>200PB) than all previous runs combined
  - Reaching 300PB total for sPHENIX



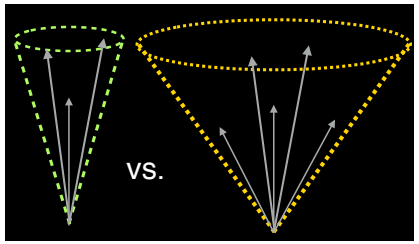


Projections: Spectra & R_{AA}

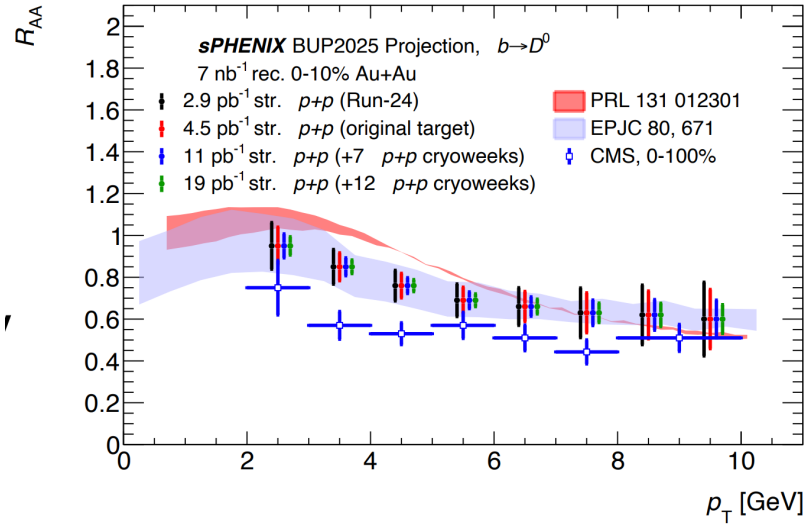


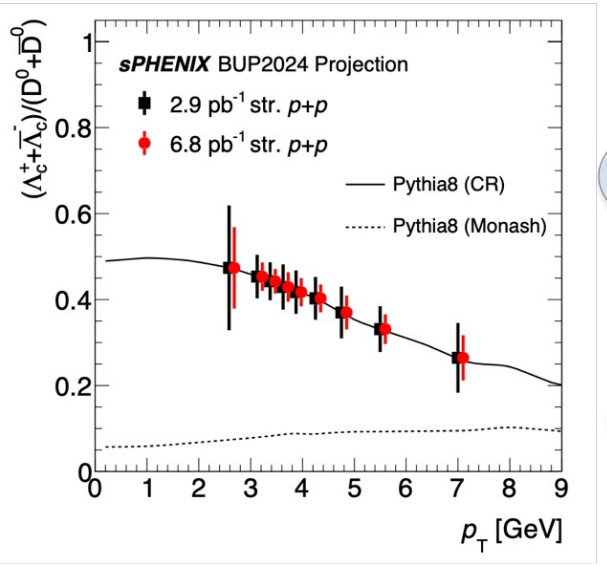


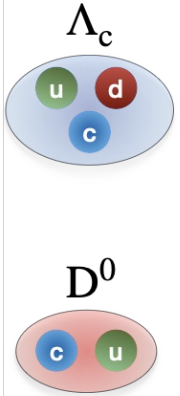
- Kinematic reach with 2024 p+p data and 7/nb of Au+Au
- Significant extension in kinematics overlaps with LHC measurements
  - Jet cone size R_{AA} comparisons at low p_T where LHC experiments differ



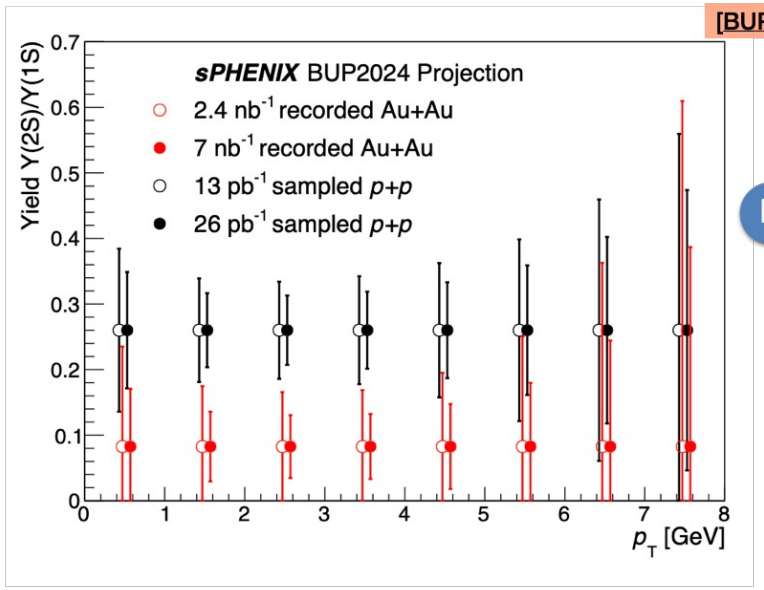
Projections for Heavy Flavor

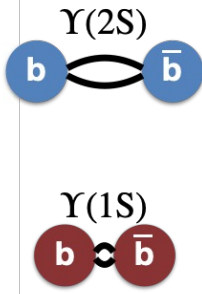






[BUP 2025]



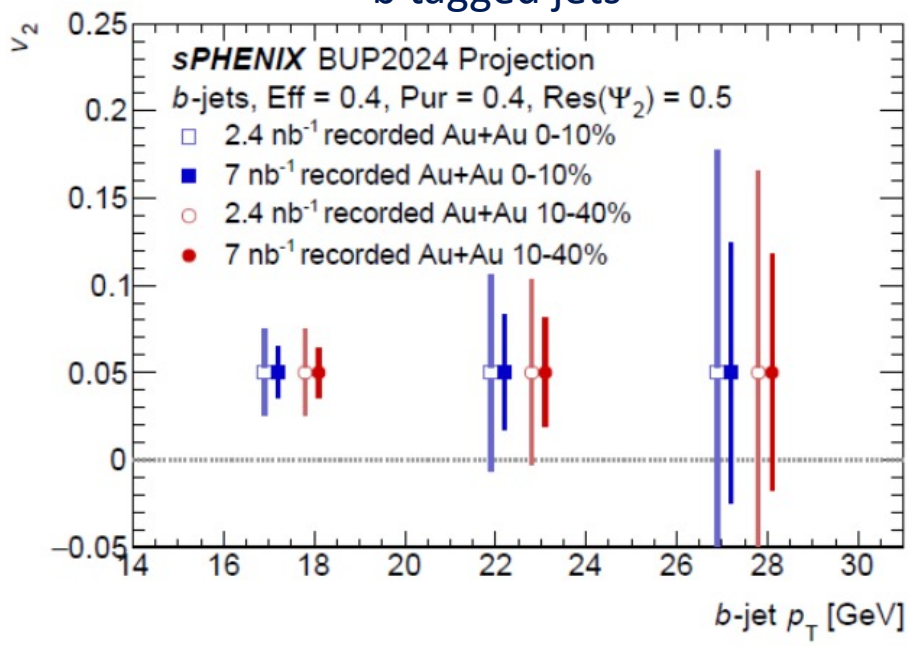


- 13/pb of p+p streaming
- Non-prompt D^0 not measured before at RHIC

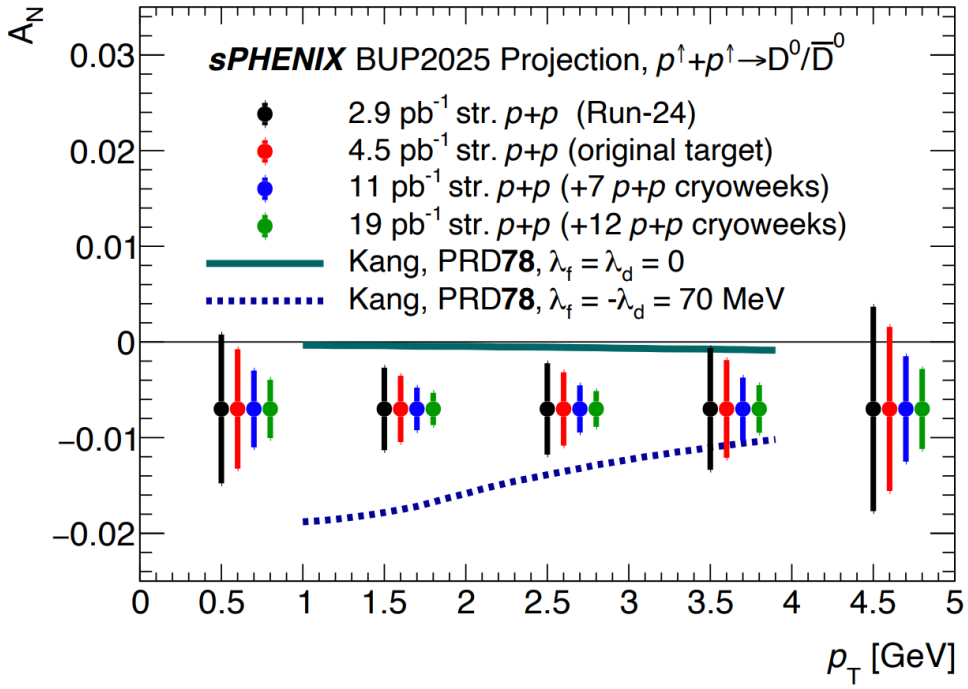
More with Heavy Flavor

- Can make novel RHIC measurements for both jet energy loss and spin physics

b tagged jets

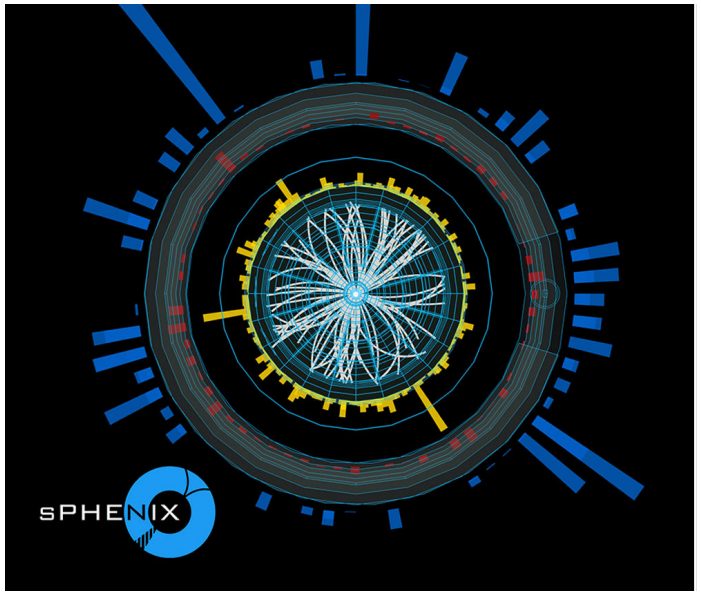


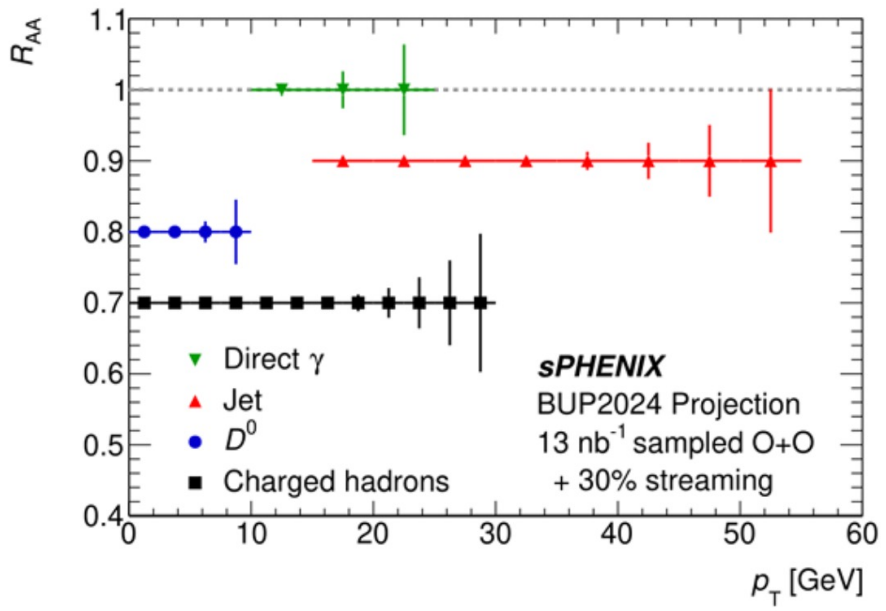
D^0 A_N

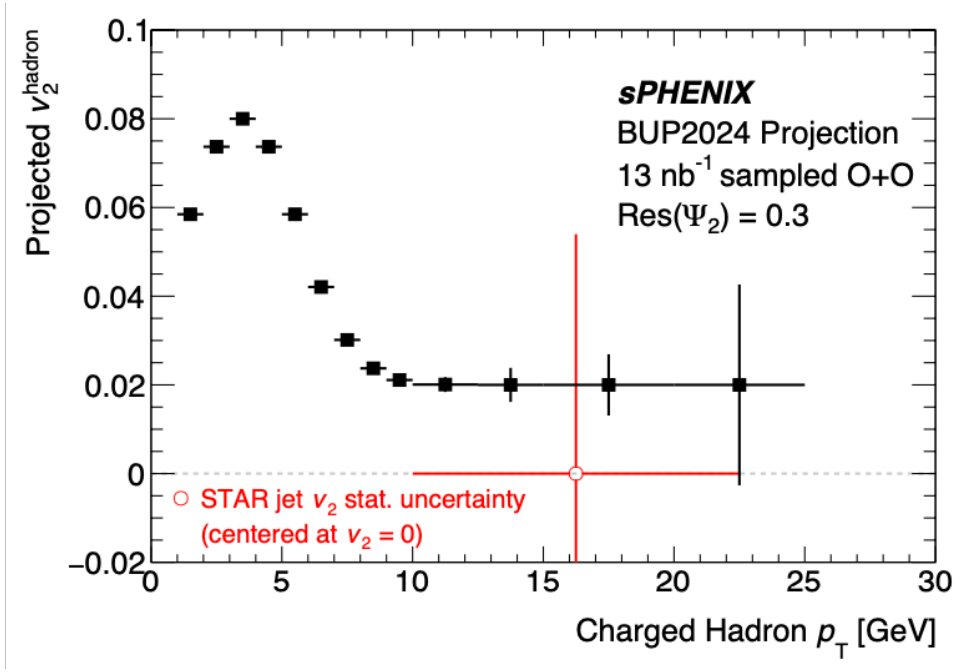


Projections for O+O

- Projection: Expected to achieve 13/nb O+O in 2 weeks
- Reality: Collected 24/nb O+O in 5 days!



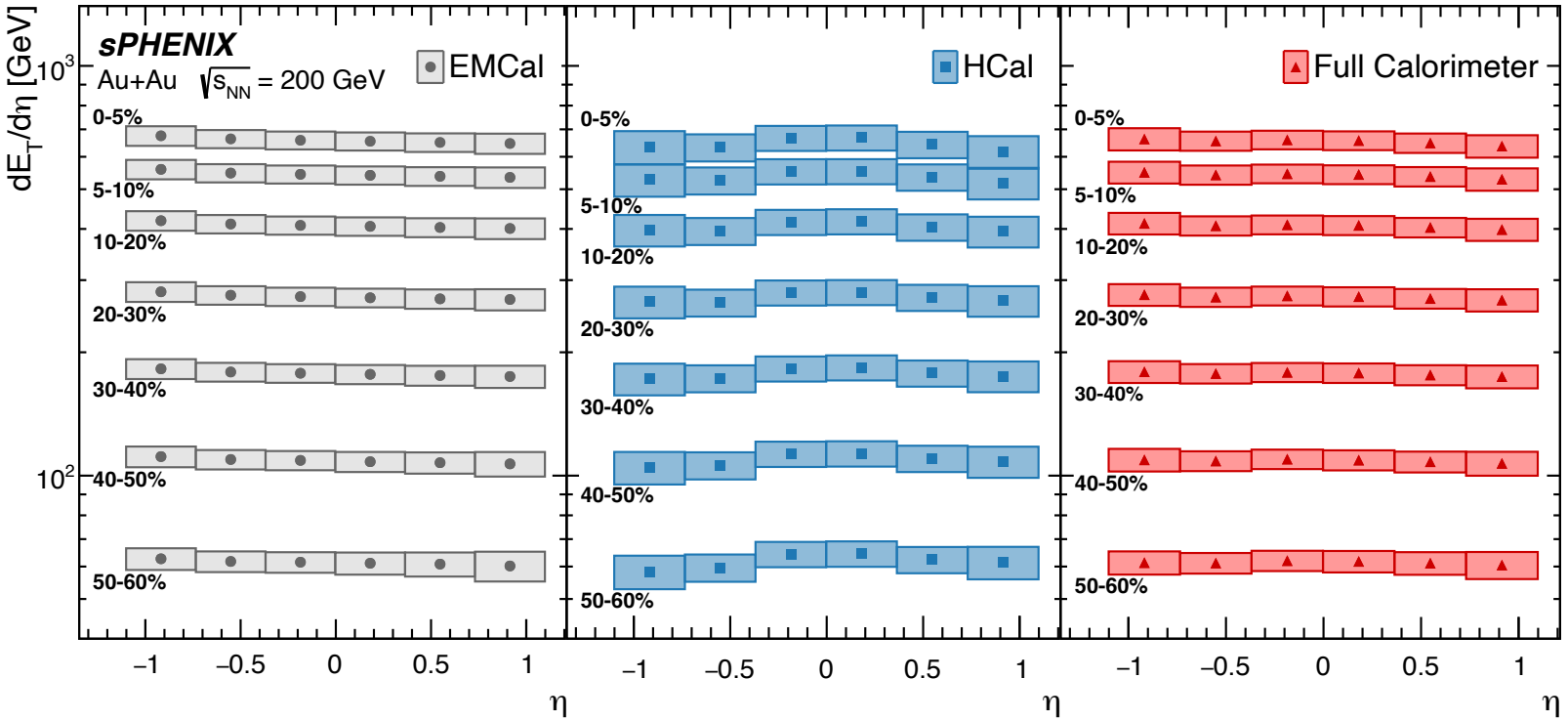




From Projections to Publications

- Collect the data
  - Run 25 Run Report by Ron Belmont
- Reconstruct the data
  - Ongoing - continued need for computing resources
- Calibrate and QA the data
  - *TPC calibration posters:*
    - *Chenxi Ma: Study of Differential Nonlinearity in TPC Cluster Reconstruction*
    - *Chenliang Jin: Direct Laser Likelihood Fit Method for sPhenix TPC Distortion Study*
- Analyze the data
  - Preliminary measurements: Tanner talk
- Publish the results
  - First 2 papers published in 2025 [BNL news], many more in the pipeline

Transverse Energy Density in Au+Au



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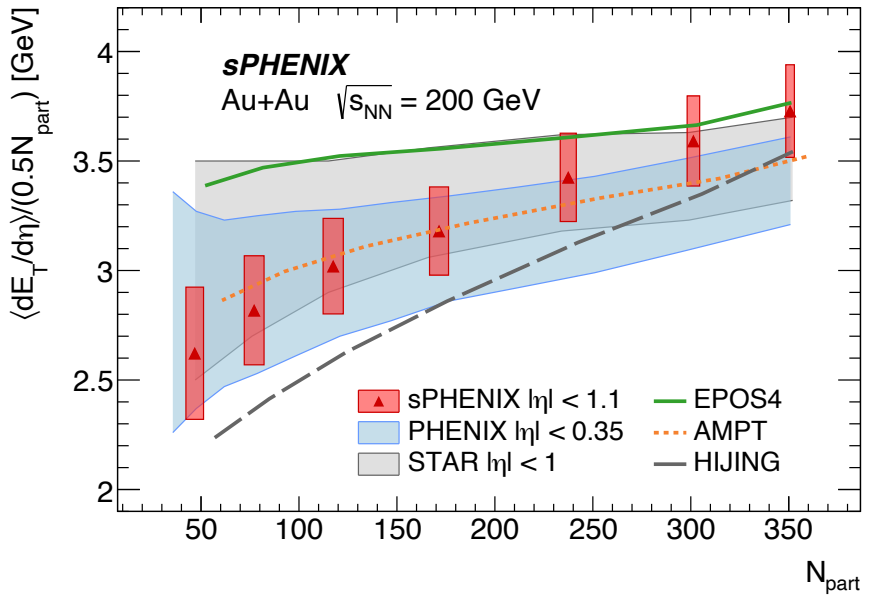
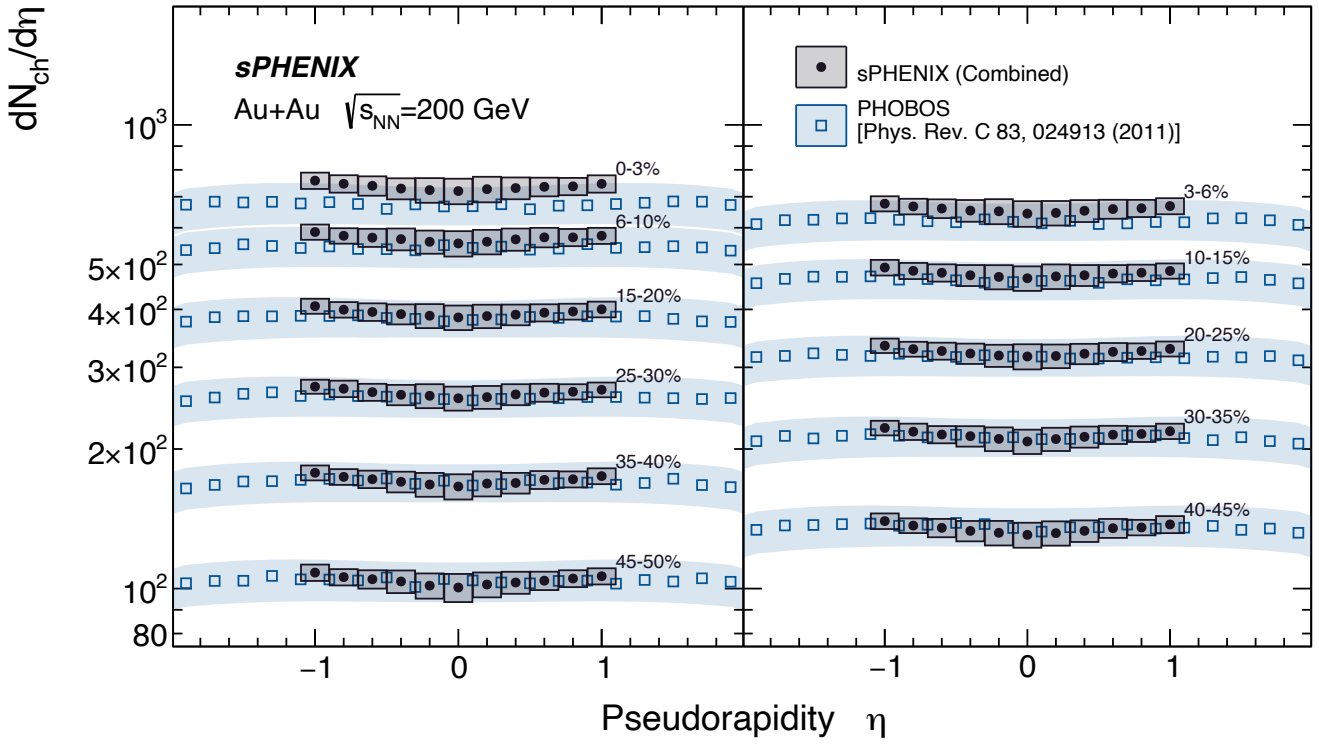
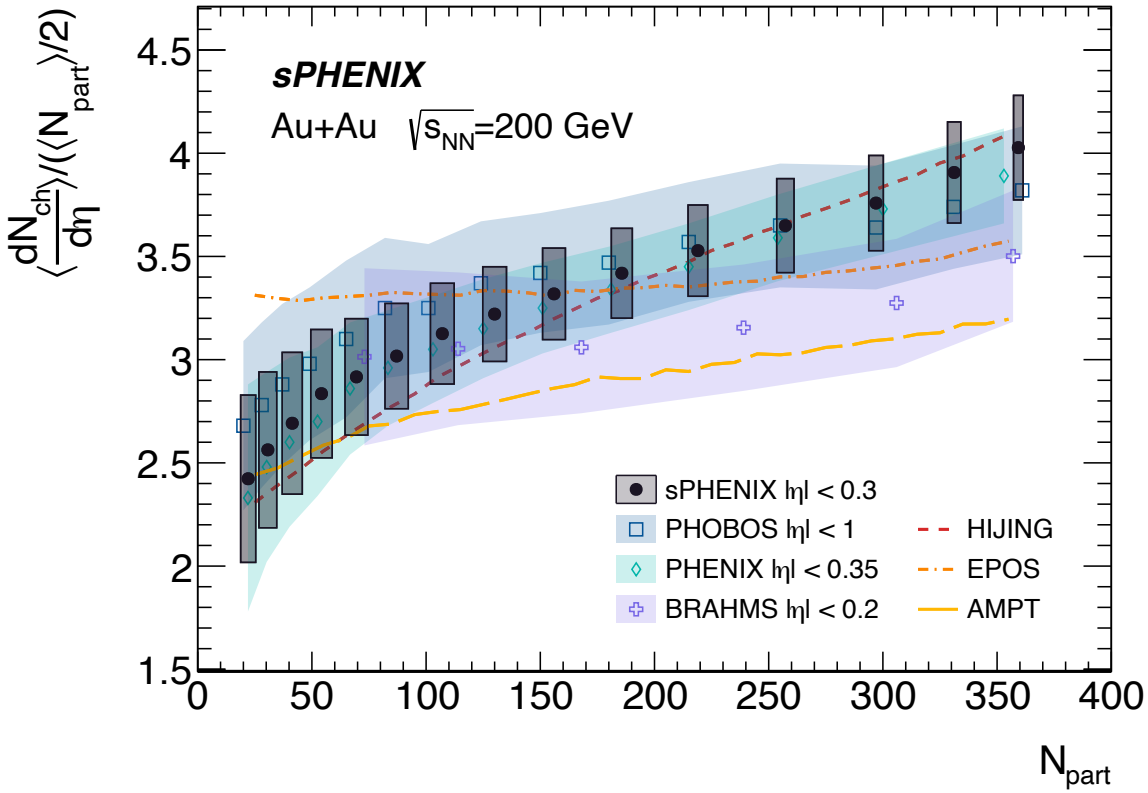


- Verification of energy calibration across calorimeter layers
- Consistent with previous RHIC measurements
- Submitted first sPHENIX papers within 5 months of collecting the data

Charged Particle Multiplicity in Au+Au

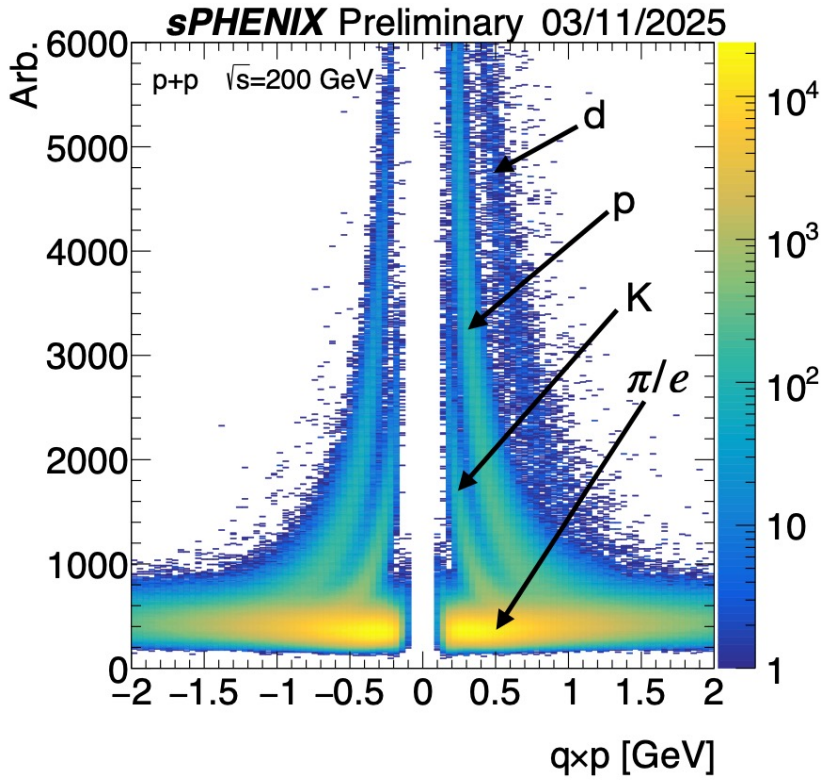
JHEP 08 (2025) 075

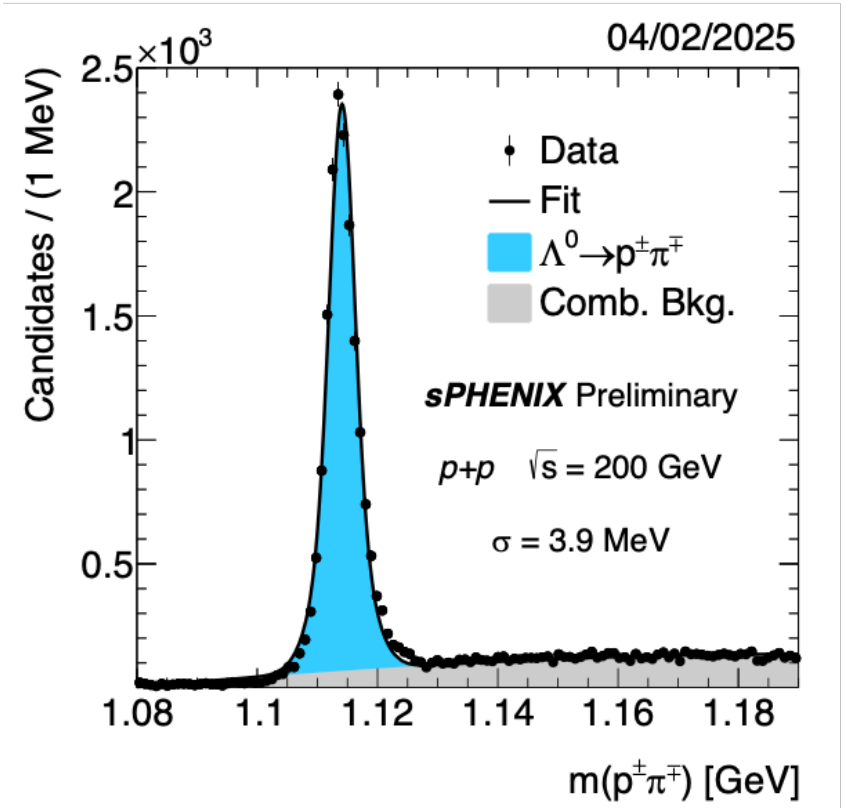


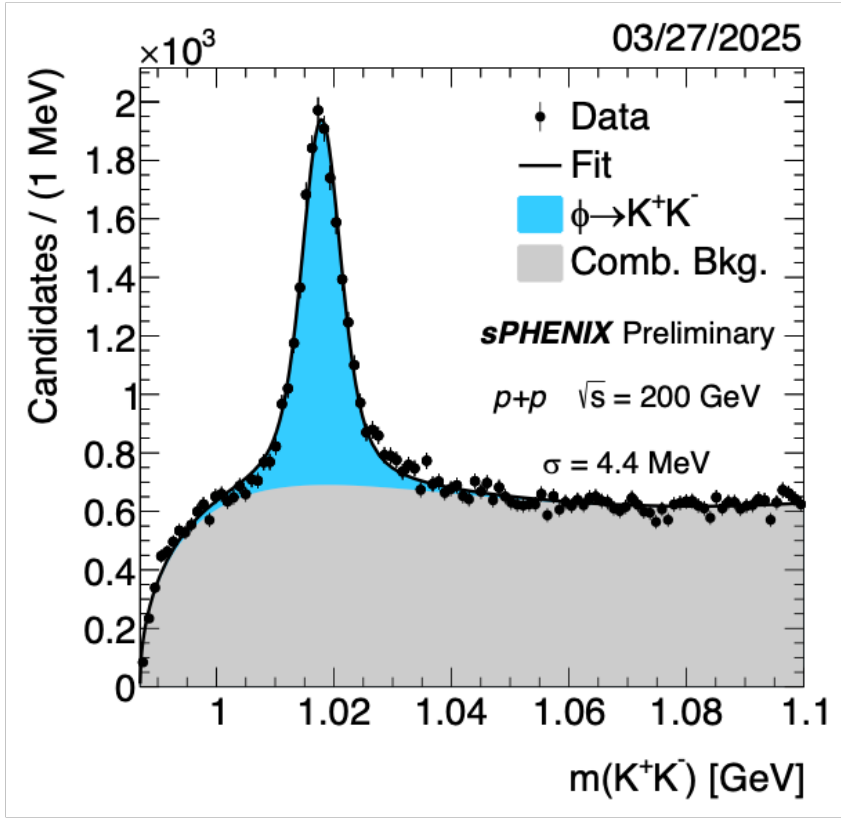


- Using INTT tracklets
- Consistent with previous RHIC results

Tracking Performance

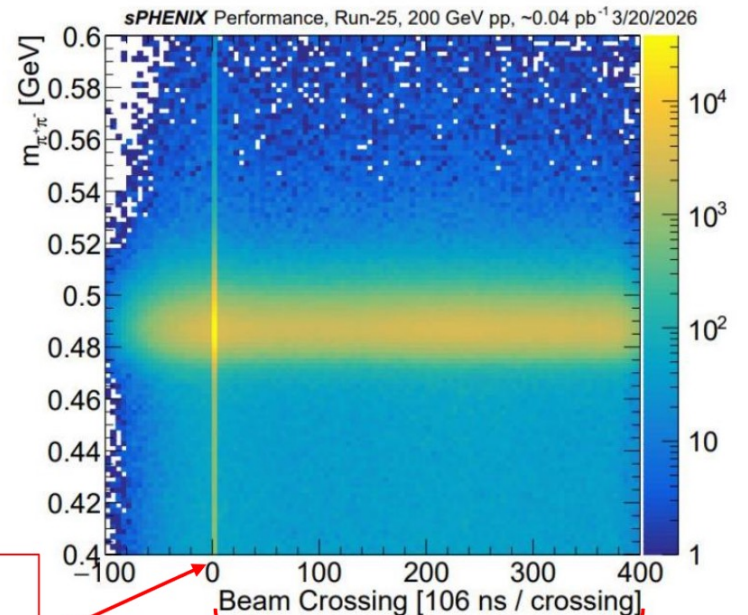


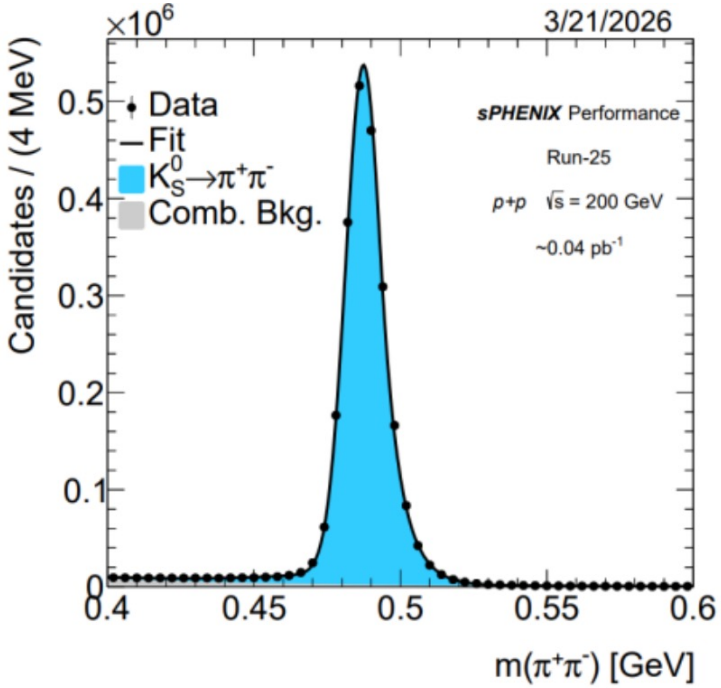




- Particle identification with TPC dE/dx
- Peaks represent only ~1 hour of data taking with early calibrations

Tracking Performance



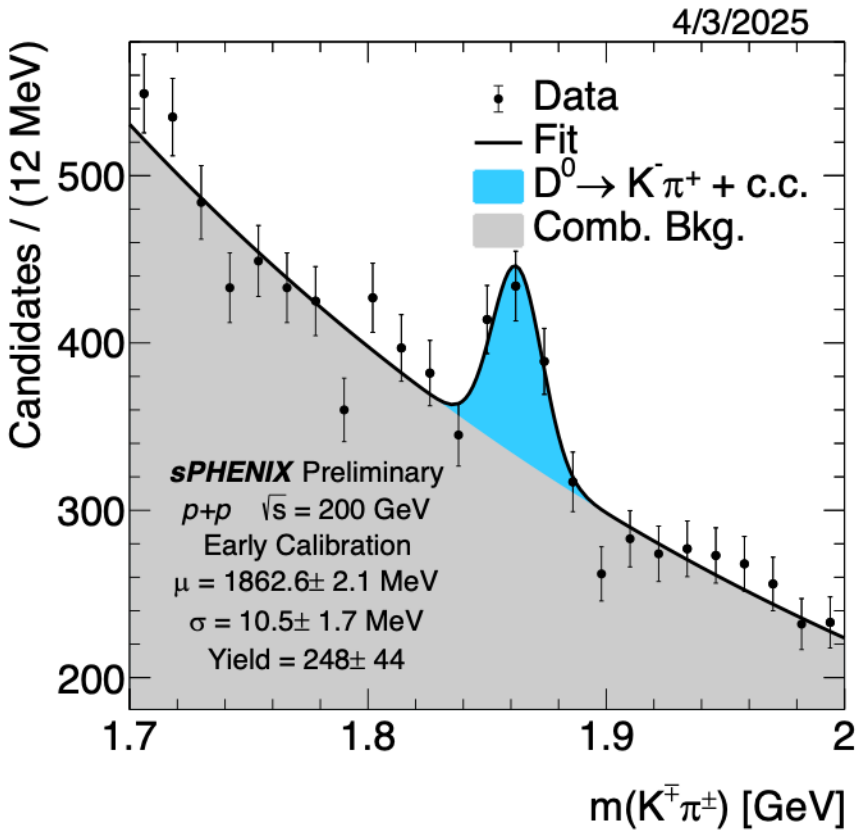


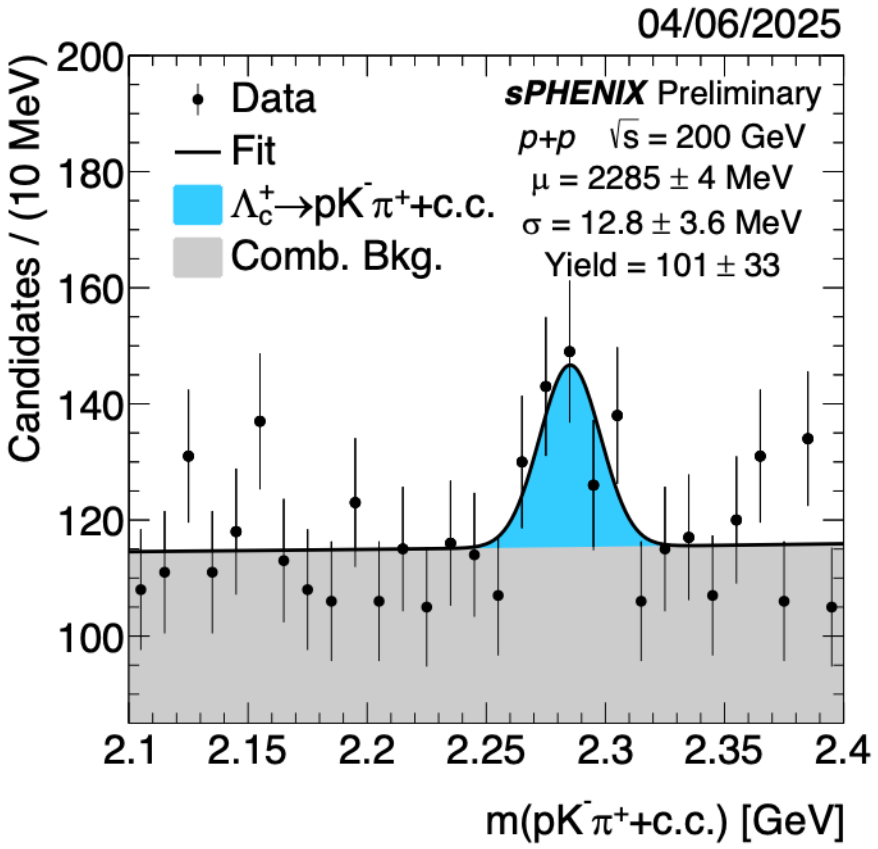
~4 hours of *p+p* data from Run 2025

- sPHENIX streaming readout recorded ~200 kHz unbiased p+p collisions
- K^0 mass peak observed across all beam crossings

s

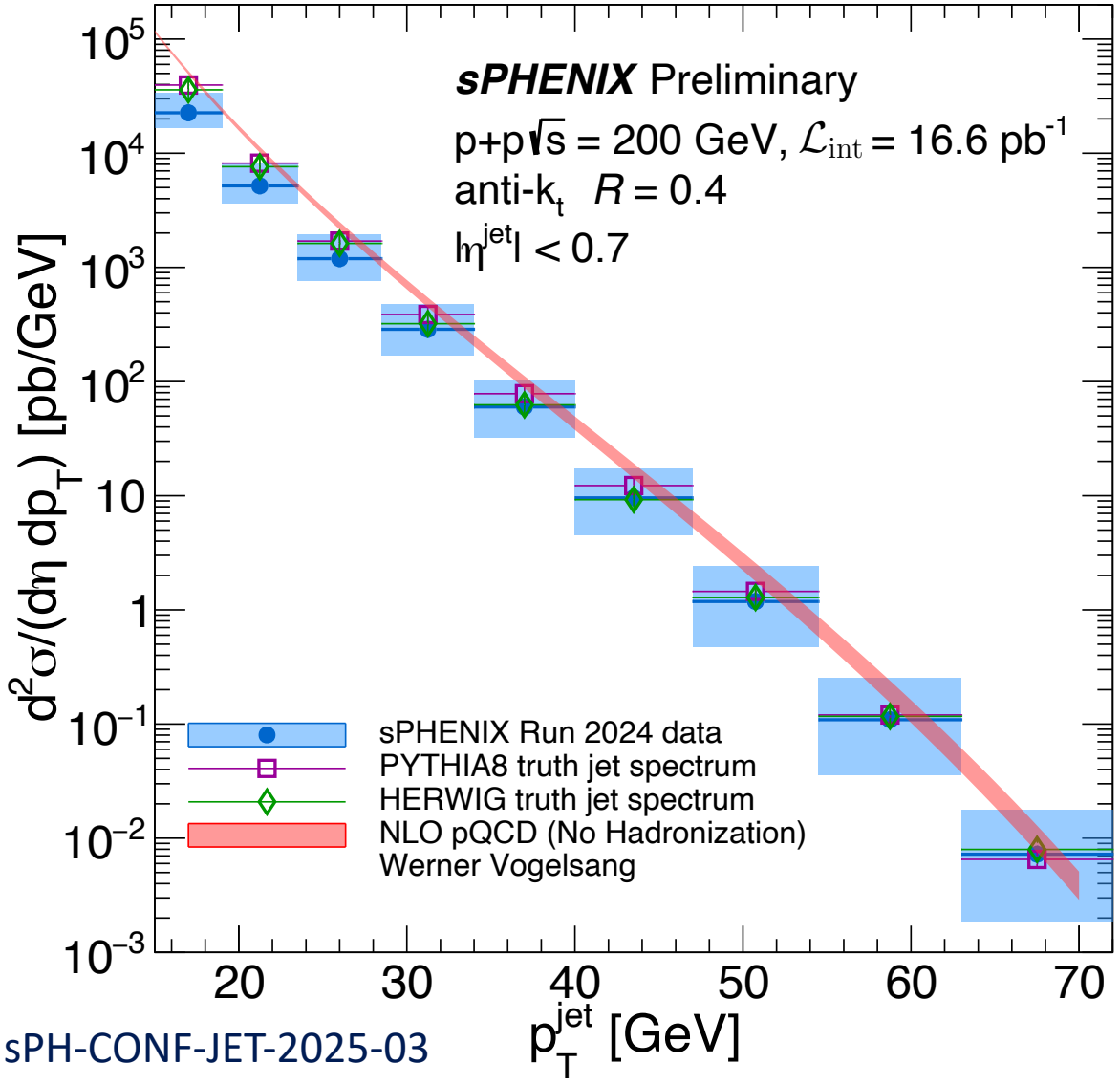
Heavy Flavor





- Peaks observed with statistical significance with only ~1 hour of data
- First Λ_c measurement in p+p collisions at RHIC!

First sPHENIX Jet Spectra



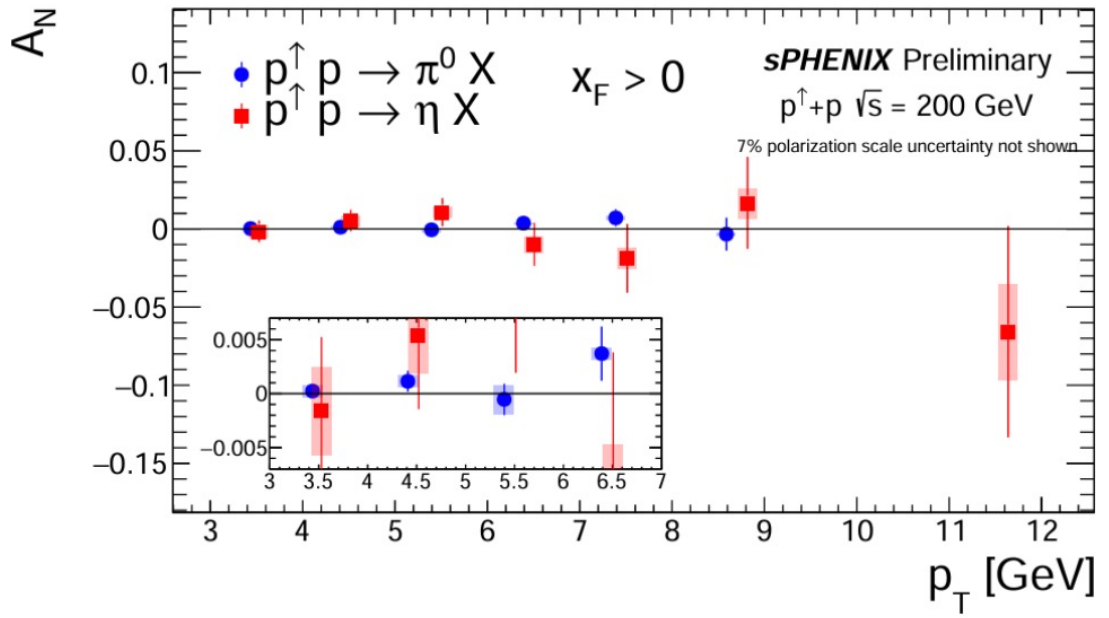
sPH-CONF-JET-2025-03

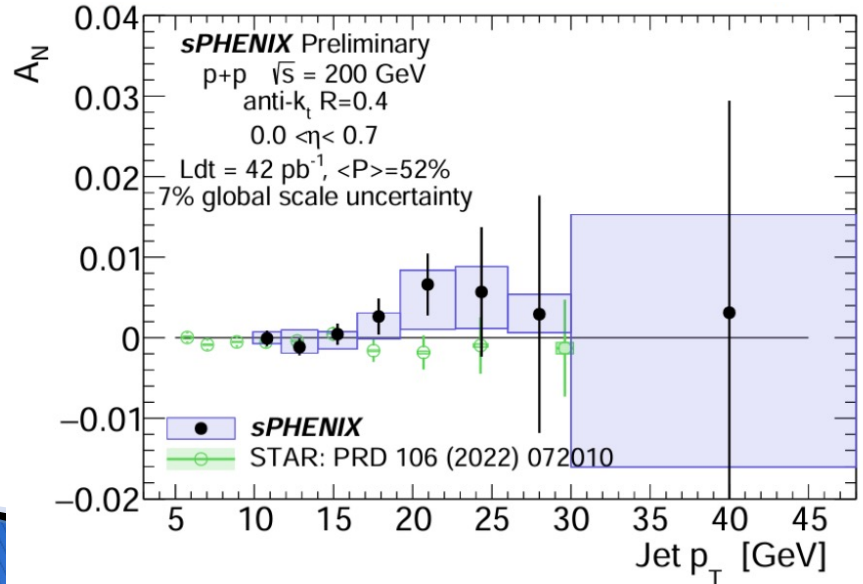
- First RHIC jet result using HCal
- Using ~15% of the calorimeter statistics
- Enhanced kinematic reach compared to previous RHIC measurements
- Jet energy scale is the dominant systematic and can be reduced with data driven corrections using full statistics

Spin Asymmetry

- A_N preliminary results with π^0, η and jets, using a subset of p+p data
  - Consistent with previous RHIC measurements
- Final results are coming soon

sPH-CONF-COLDQCD-2025-01





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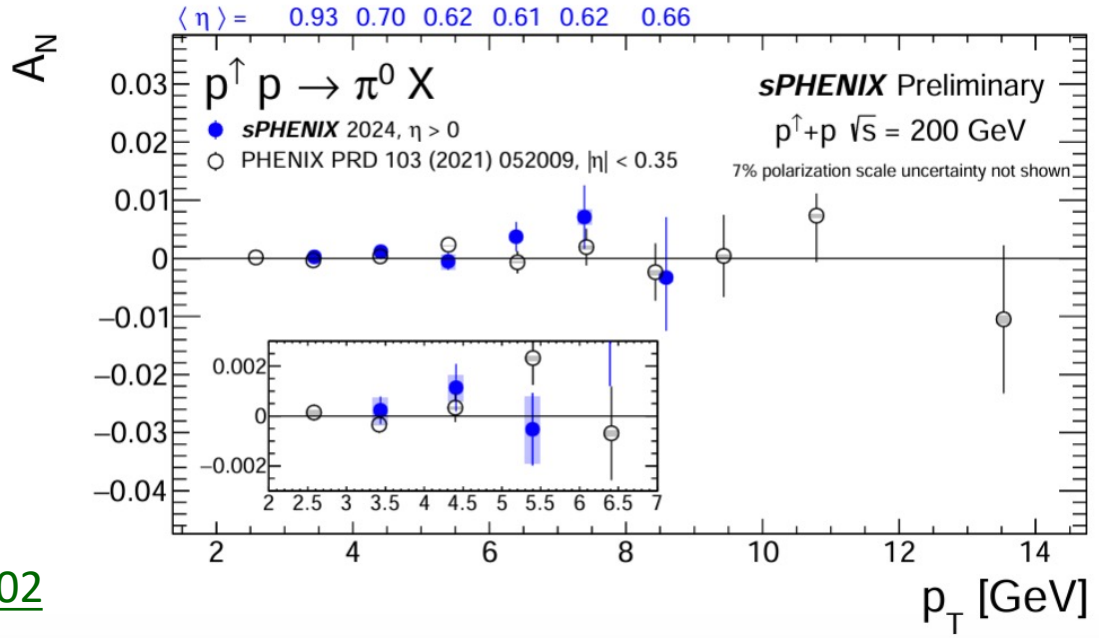
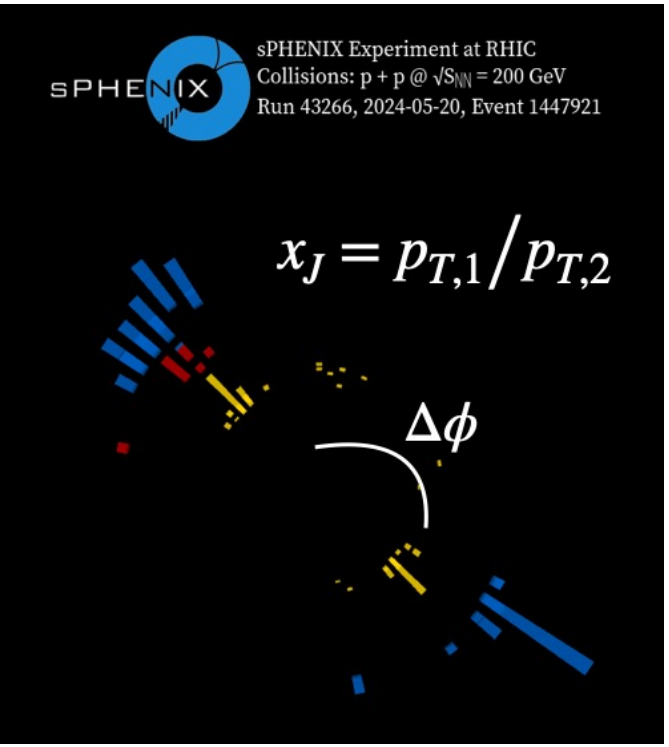
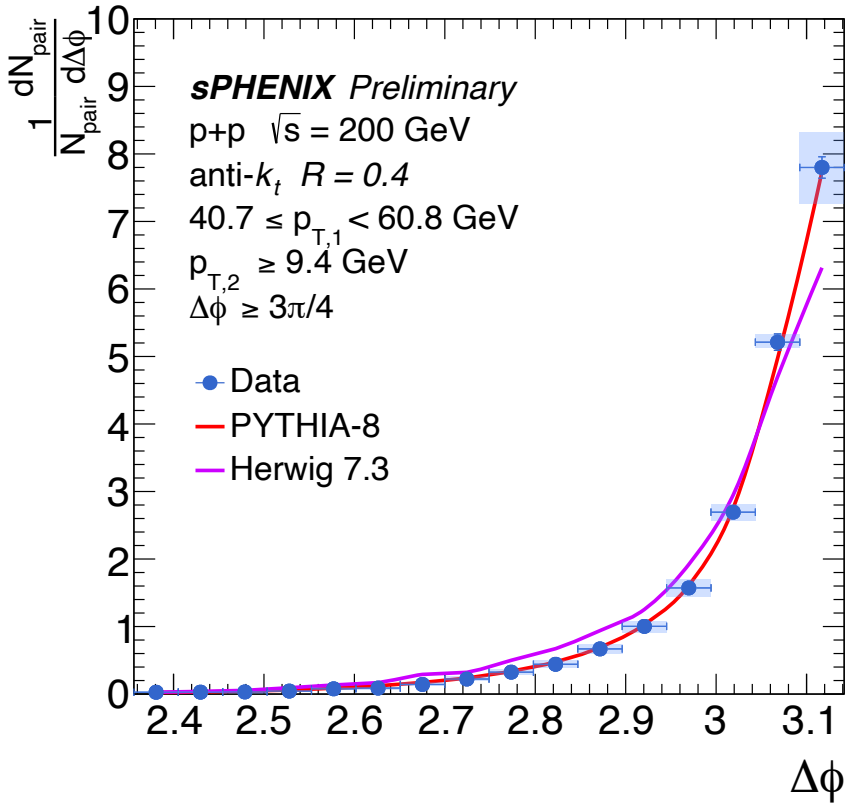


Dijets in p+p





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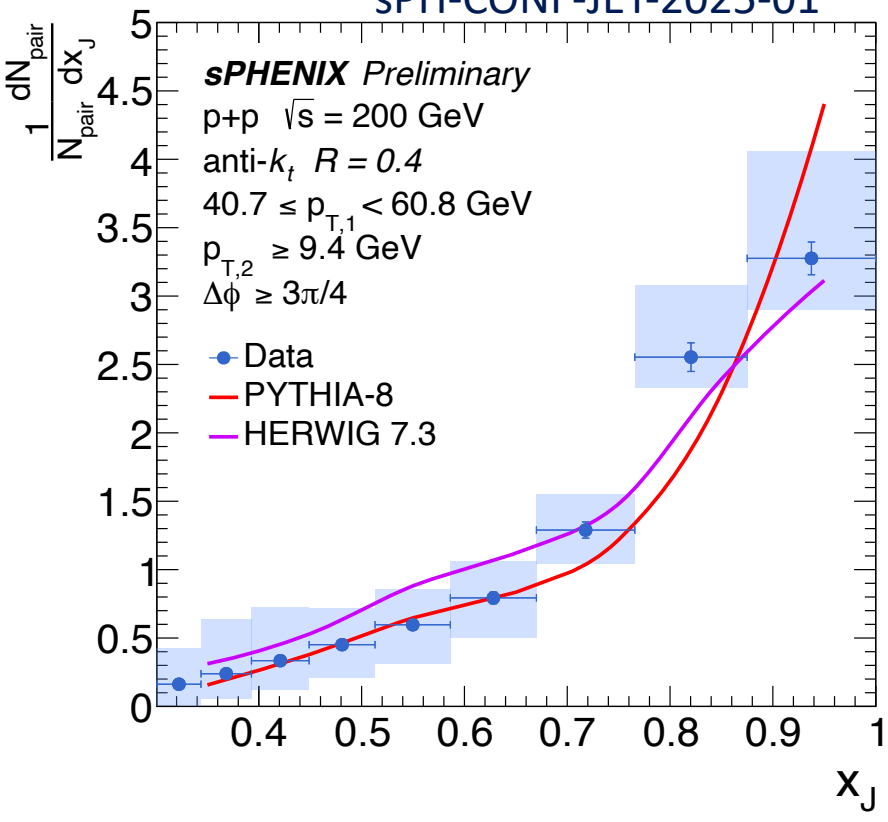
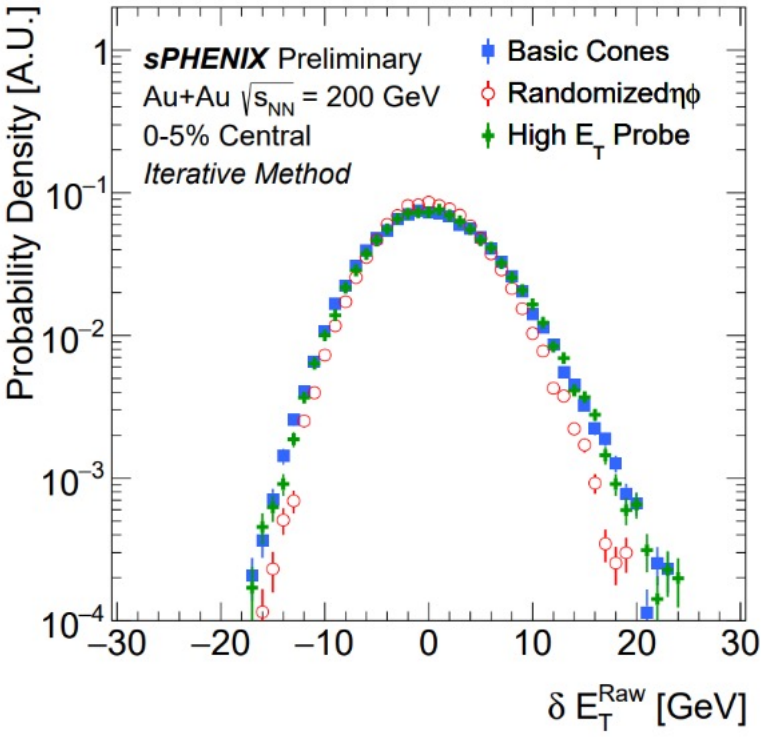


- Dijets are back-to-back (**Δφ** peaked at **π**) and balanced (x_J peaked at 1)

Underlying Event Characterization in Au+Au



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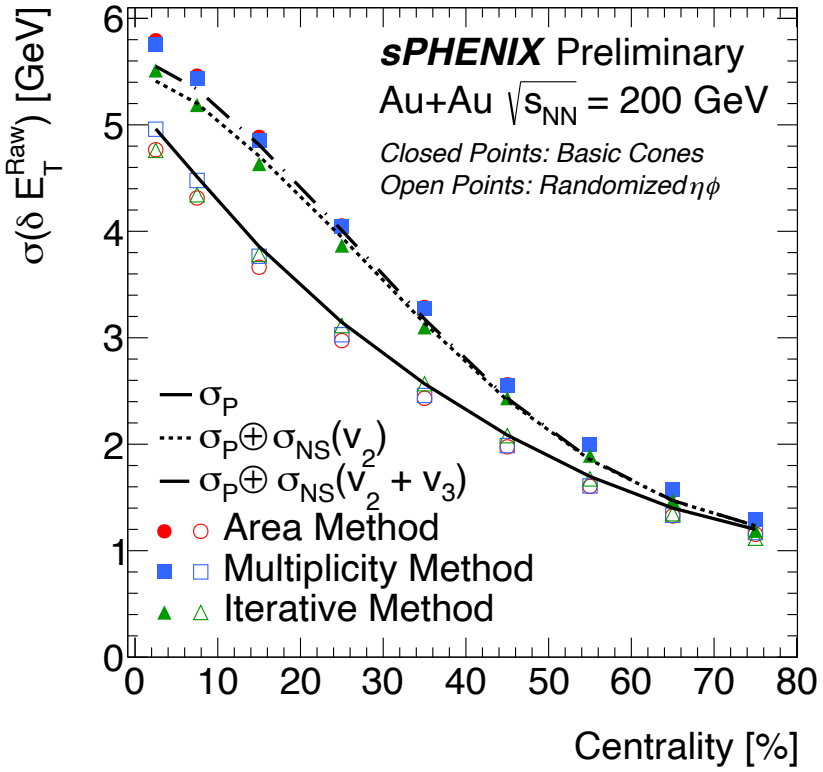


Area based method used in STAR and ALICE

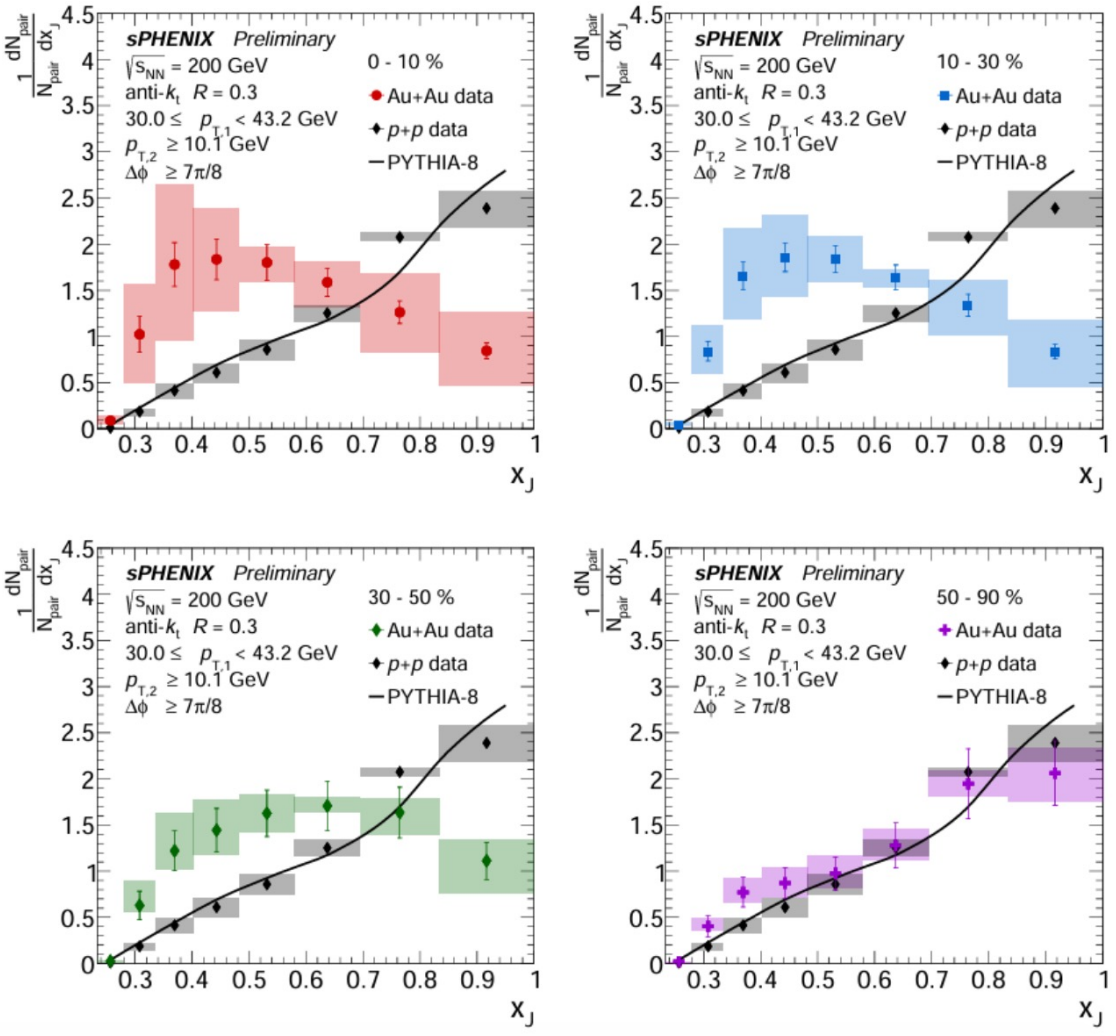
Iterative method used in ATLAS

- Crucial for Au+Au jet measurement
- Quantifying the UE and fluctuations with different subtraction techniques

First Jet Quenching Observable at sPHENIX

- Background subtracted and unfolded Au+Au dijets
- Small fraction of total Au+Au data collected

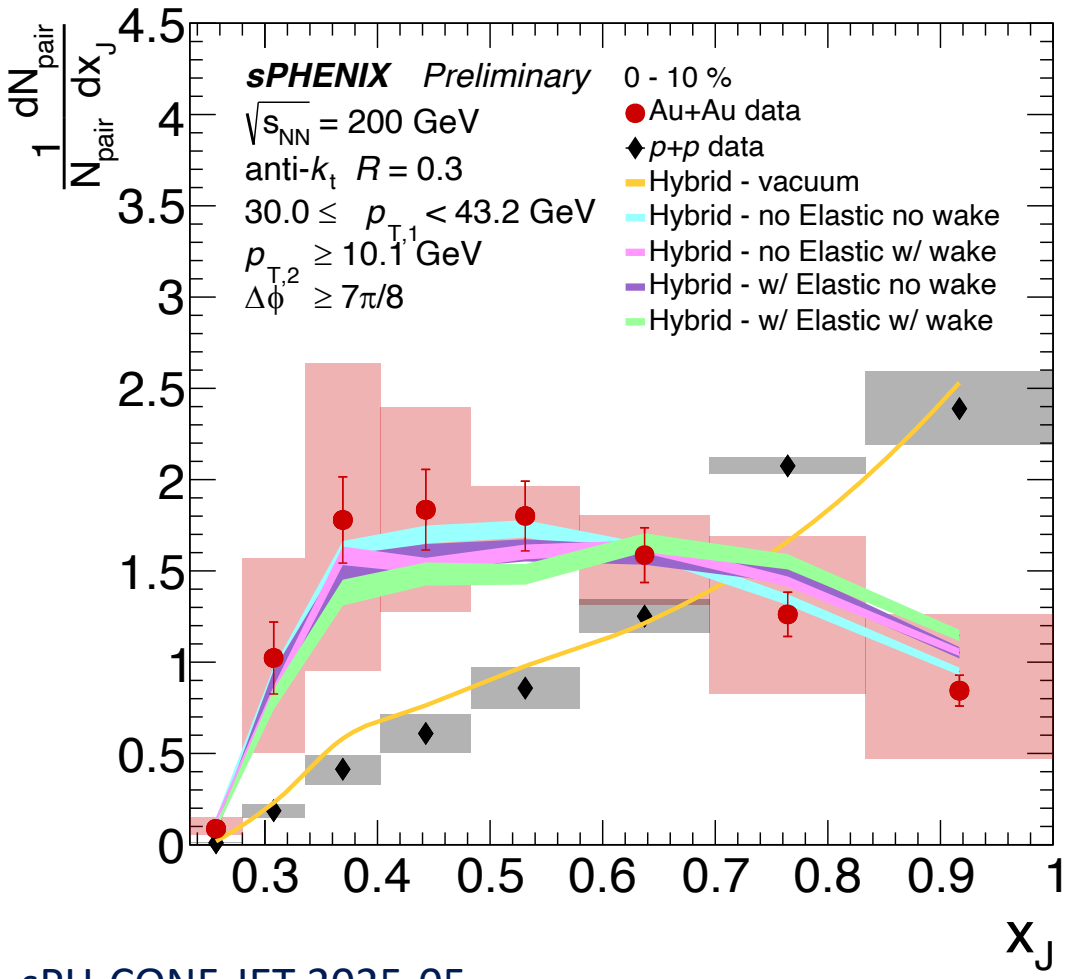
- Modification of dijet asymmetry observed for Au+Au



First Jet Quenching Observable at sPHENIX

- Background subtracted and unfolded Au+Au dijets
- Small fraction of total Au+Au data collected

- Modification of dijet asymmetry observed for Au+Au
- Hybrid model consistent with the data



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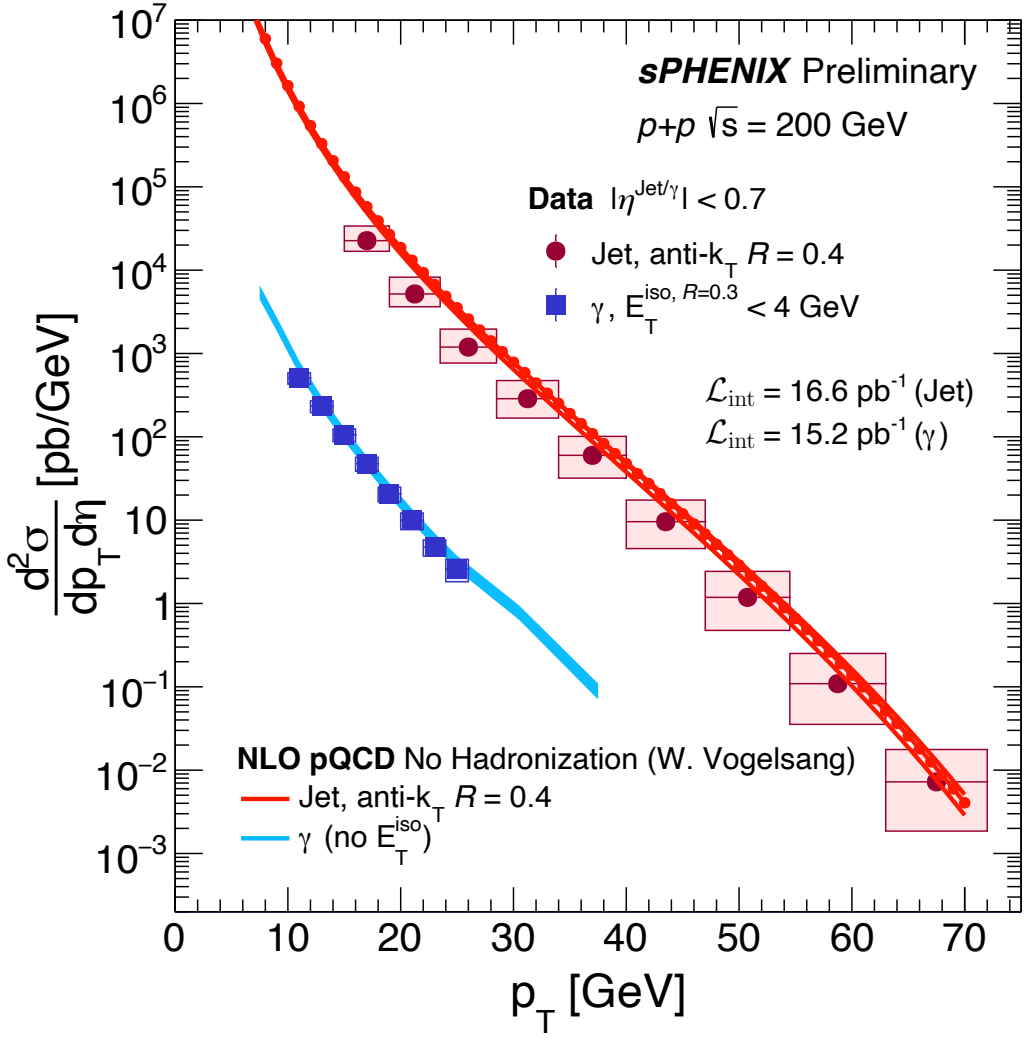
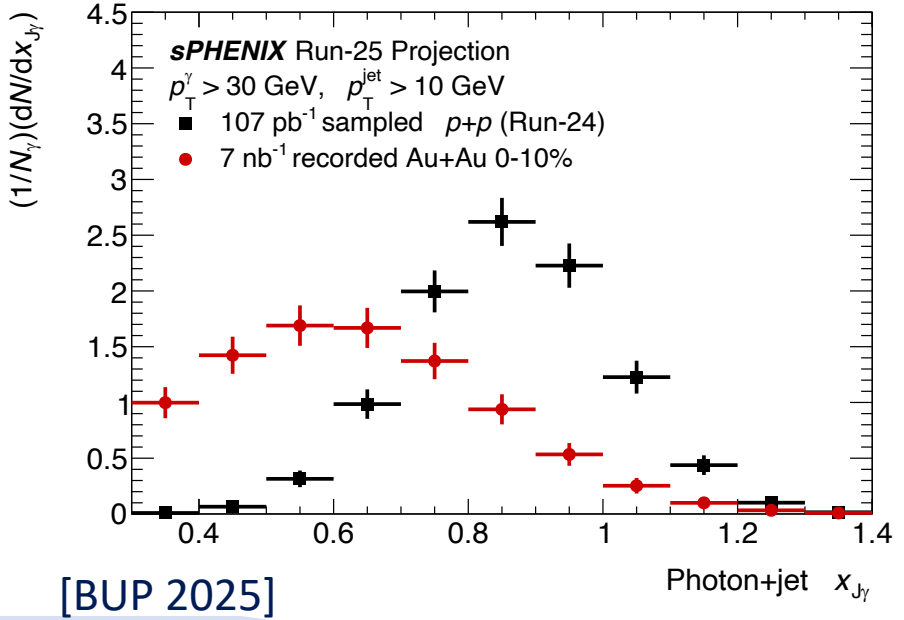
Towards photon tagged jets

[sPH-CONF-JET-2025-02 sPH-CONF-JET-2025-03]



- First sPHENIX p+p jet and isolated photon spectra are important steps toward photon tagged jet measurements
- Updated projections for photon+jet balance



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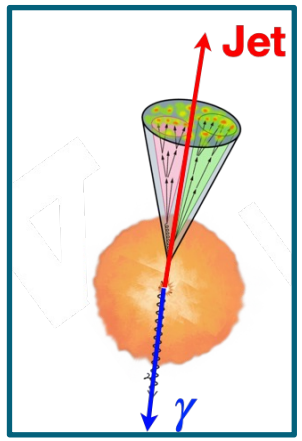
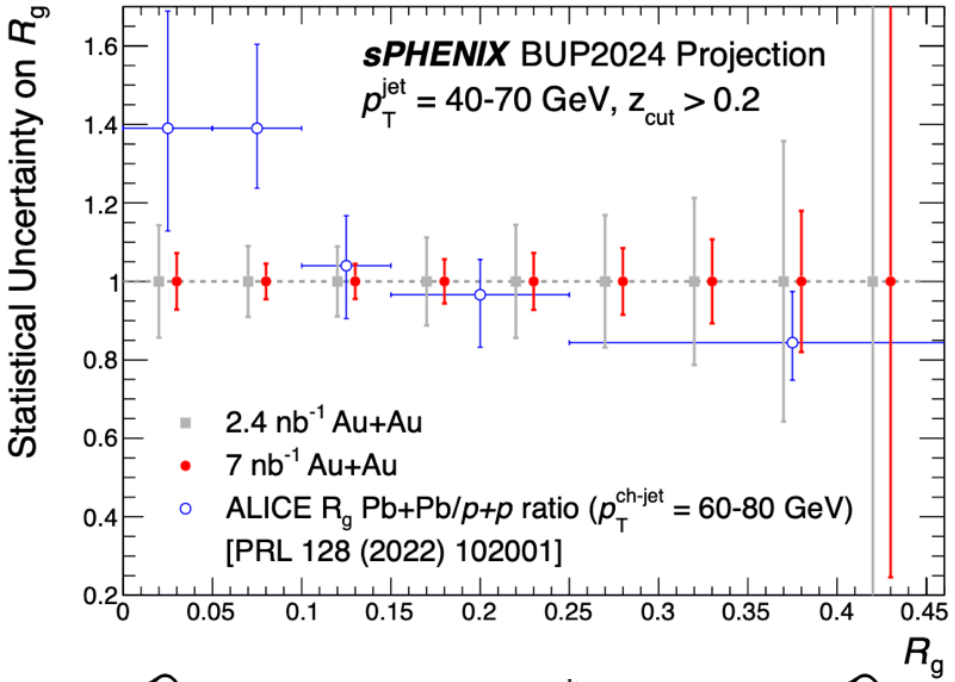
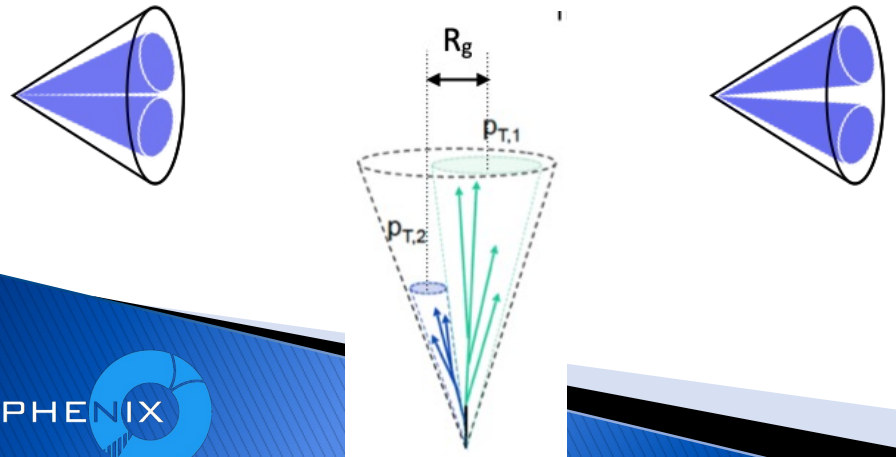
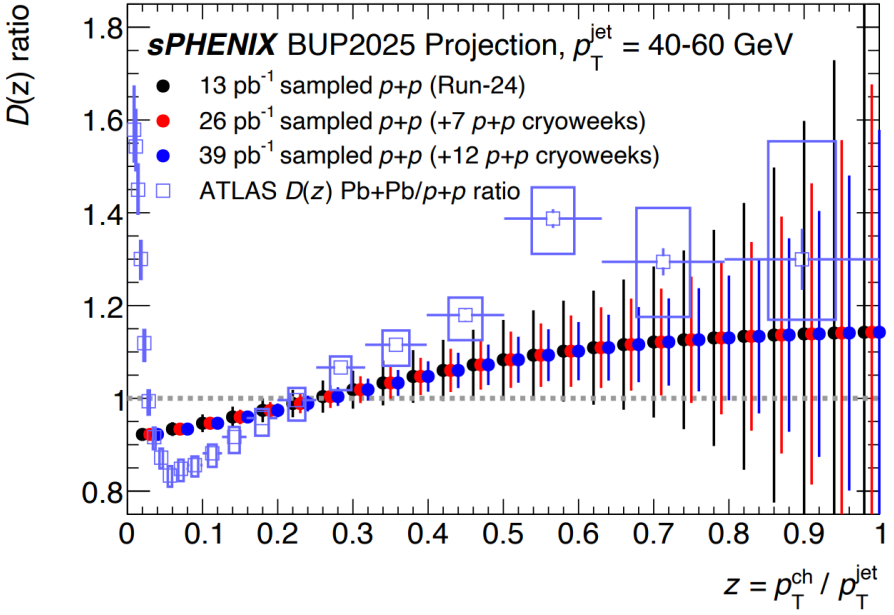


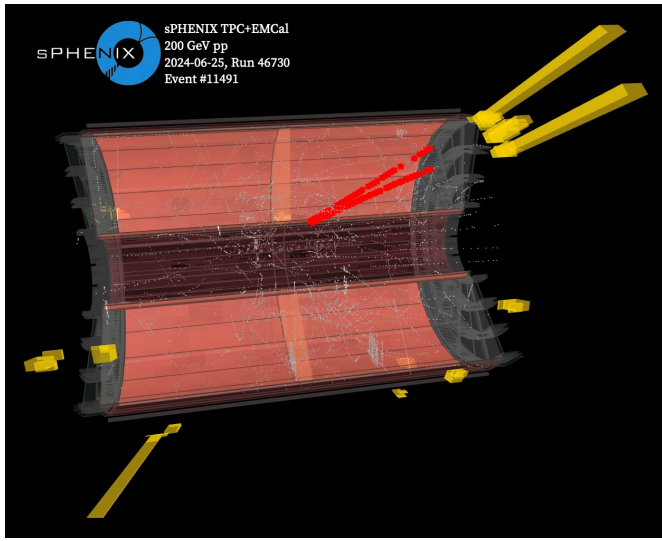
Towards Jet Structure and Substructure





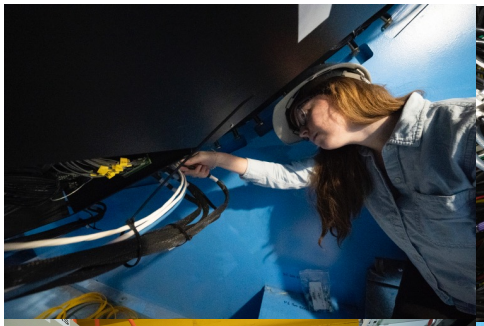
- Projections for fragmentation functions and substructure variable R_g
- Kinematic overlap with LHC
- Requires tracking and calorimetry
  - A first look at track-calo matching with conversion photons

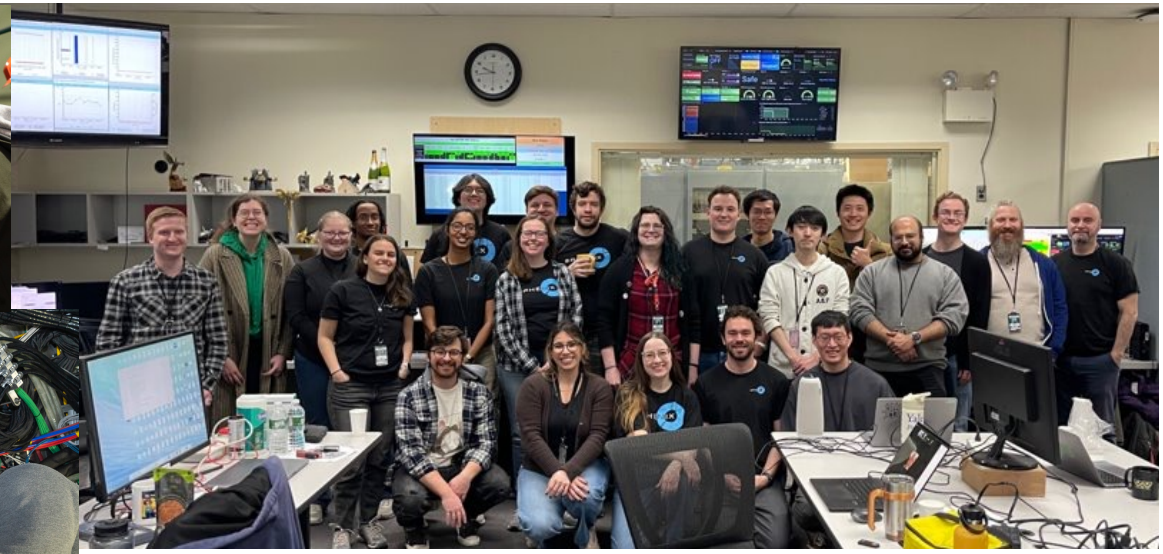




Important contributions to the field

- LRP also highlights importance of workforce development
- Students and post docs on sPHENIX developed crucial skills building, commissioning, operating and calibrating detectors which are essential for future experiments at EIC
- Heroes page: https://www.sphenix.bnl.gov/heros

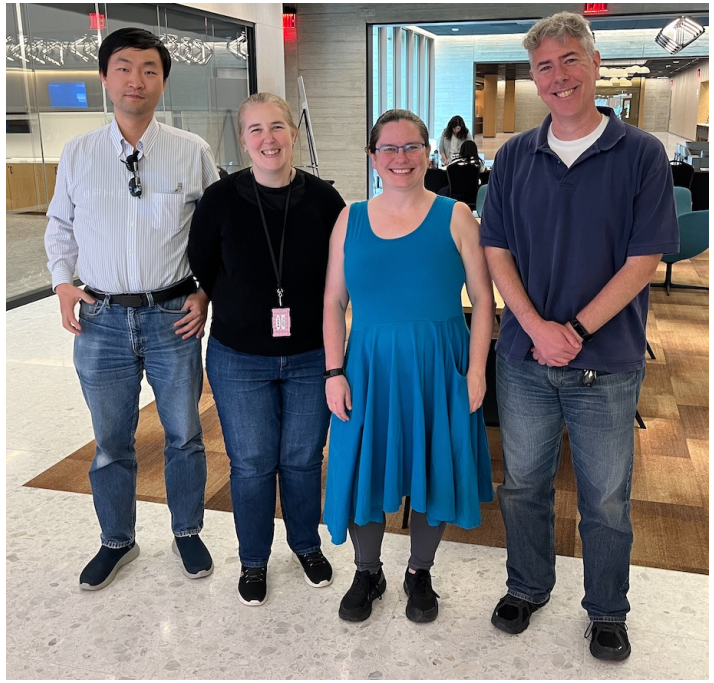



Summary

- Tremendous success constructing sPHENIX and collecting data
  - Opens door for additional discoveries and improved precision with new detector capabilities and large data sets with sPHENIX
- Early sPHENIX measurements are laying the foundation for future more differential jet observables and tracking measurements
  - Improved calibrations and complete data reconstruction in progress
- Analysis of the full suite of sPHENIX data collected will provide insights to jet quenching and heavy flavor which is **crucial to complete the RHIC's scientific mission**
- sPHENIX is also important for sustained workforce development needed for future nuclear physics experiments such as the EIC

Continuing the RHIC Legacy & Completing the Scientific Mission



Run 25 Run Coordinators and co-spokesperson
Started as RHIC PhDs or Post docs

- Stay tuned for new results from sPHENIX: www.sphenix.bnl.gov/PublicResults
- Heroes page: https://www.sphenix.bnl.gov/heros