High p_T probes at sPHENIX

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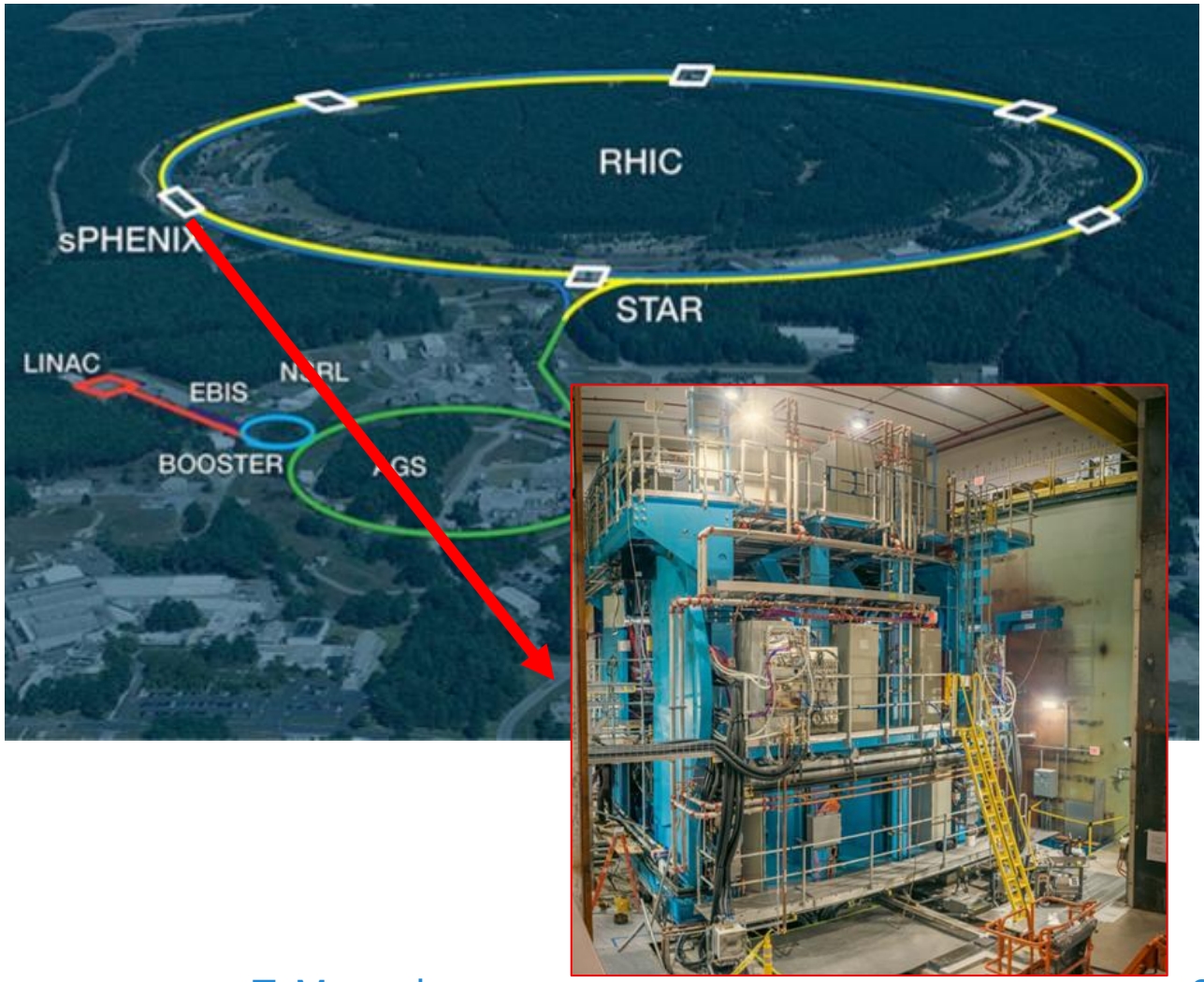
Hot Jets 2025

THE UNIVERSITY OF TENNESSEE KNOXVILLE

sPHENIX

The sPHENIX Experiment

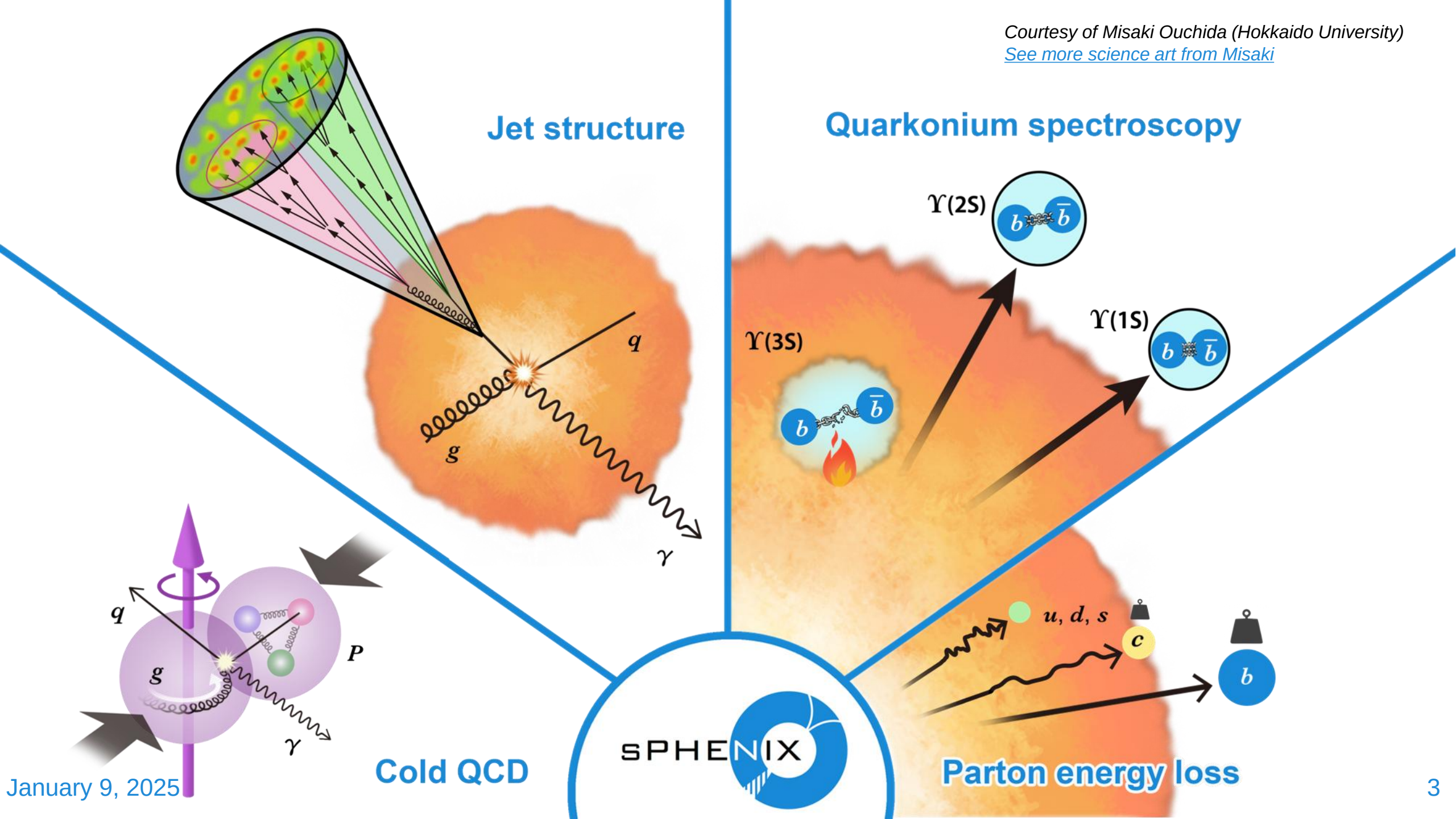
- First new detector built at RHIC in 20 years
- *Necessary* to complete RHIC science mission



[2015 US NP LRP]

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.**

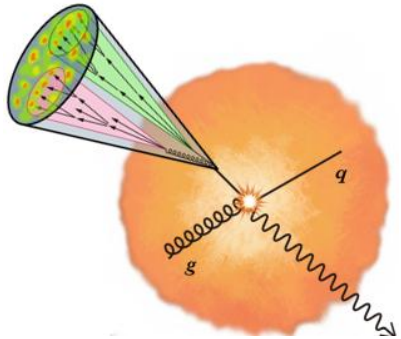
Courtesy of Misaki Ouchida (Hokkaido University)
See more science art from Misaki

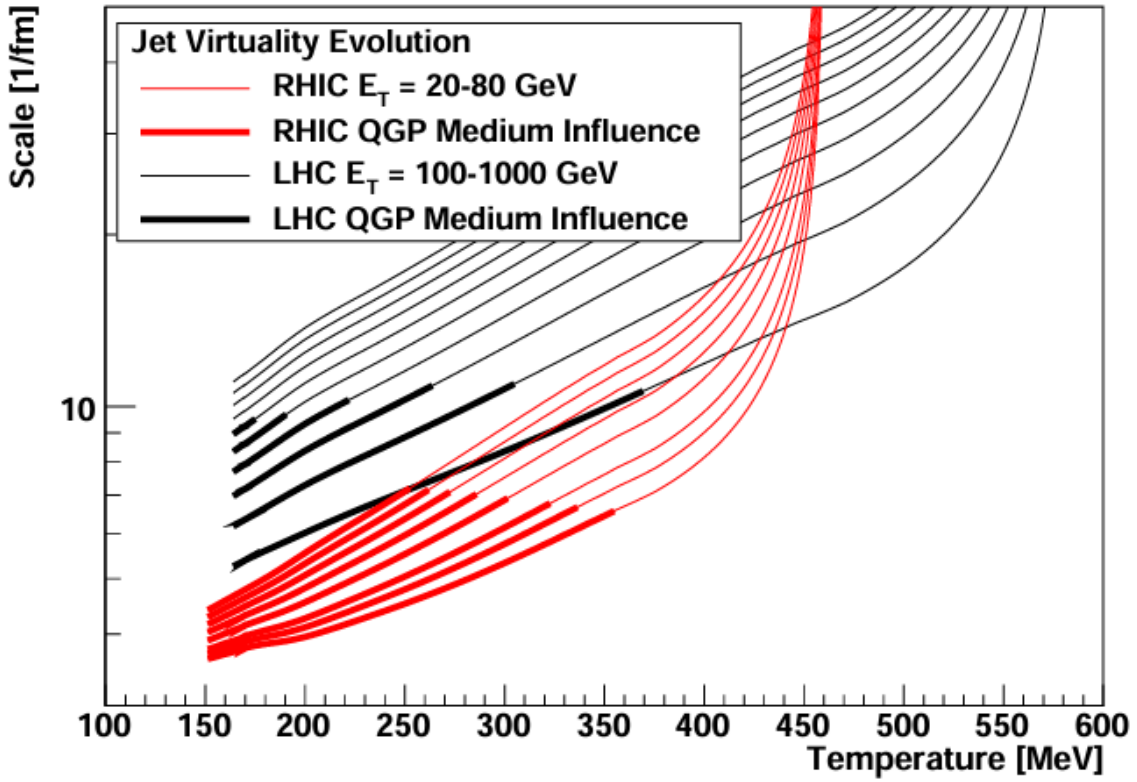


Why do Jets at RHIC?

sPHENIX Proposal

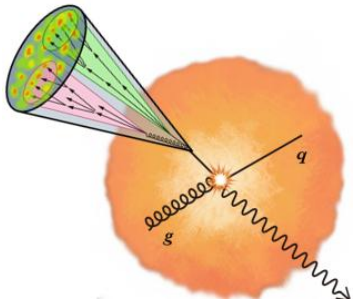
- Jets are showers of particles from initial hard scatterings before Quark Gluon Plasma (QGP) formation
- QGP temperature/temperature evolution different at LHC and RHIC



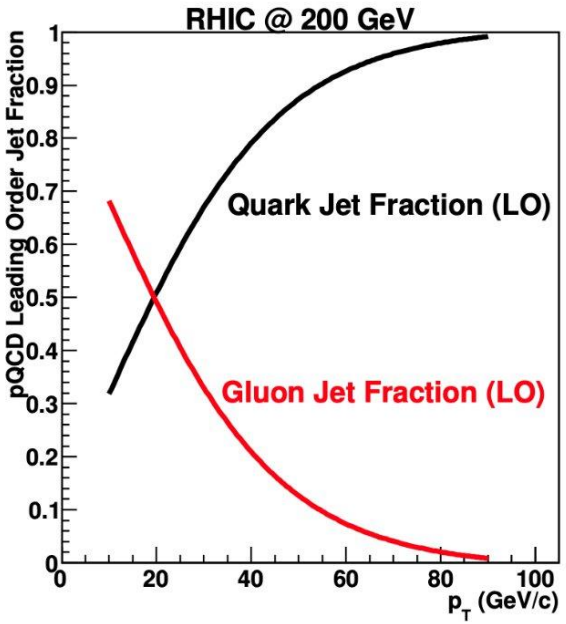


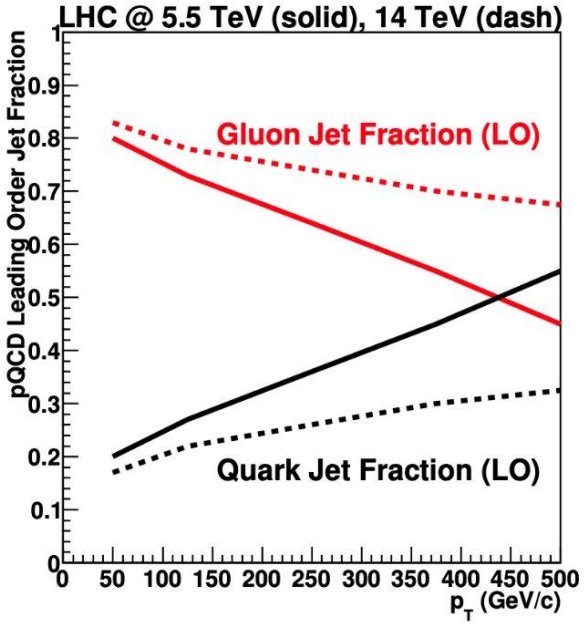
Why do Jets at RHIC?

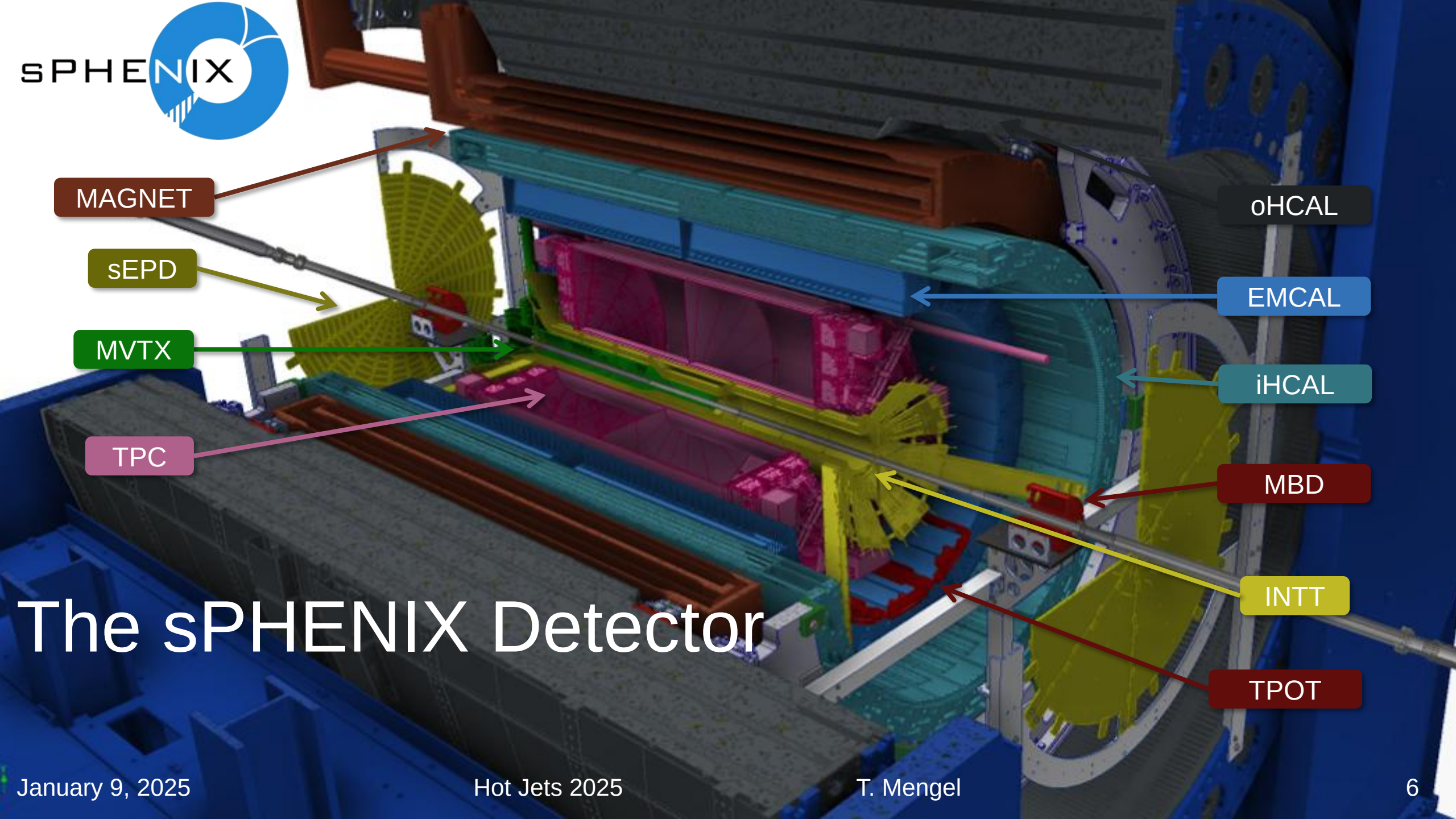
- Jets are showers of particles from initial hard scatterings before Quark Gluon Plasma (QGP) formation
- QGP temperature/temperature evolution different at LHC and RHIC
- Different mixtures of quark vs. gluon jets



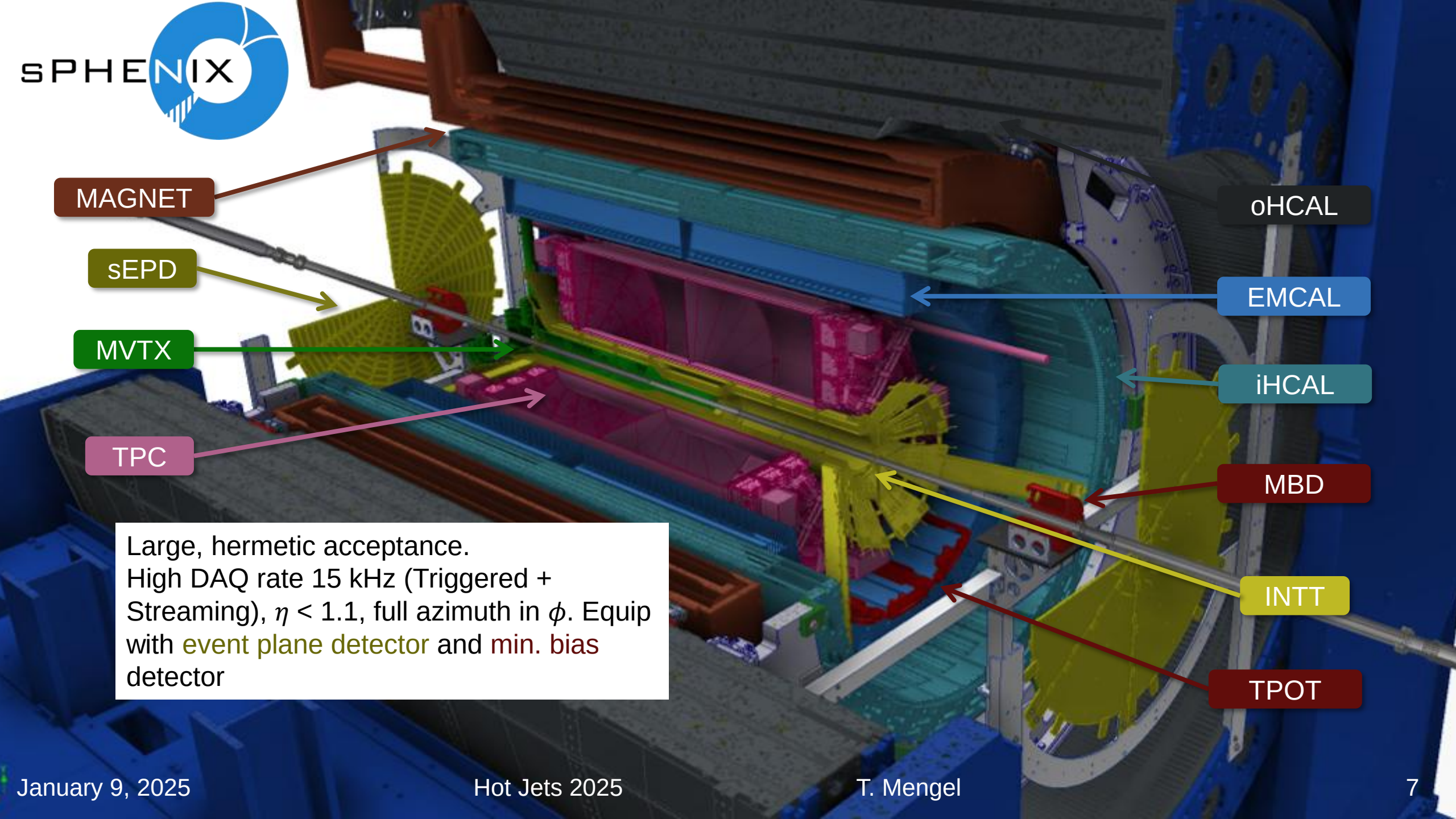
sPHENIX Proposal

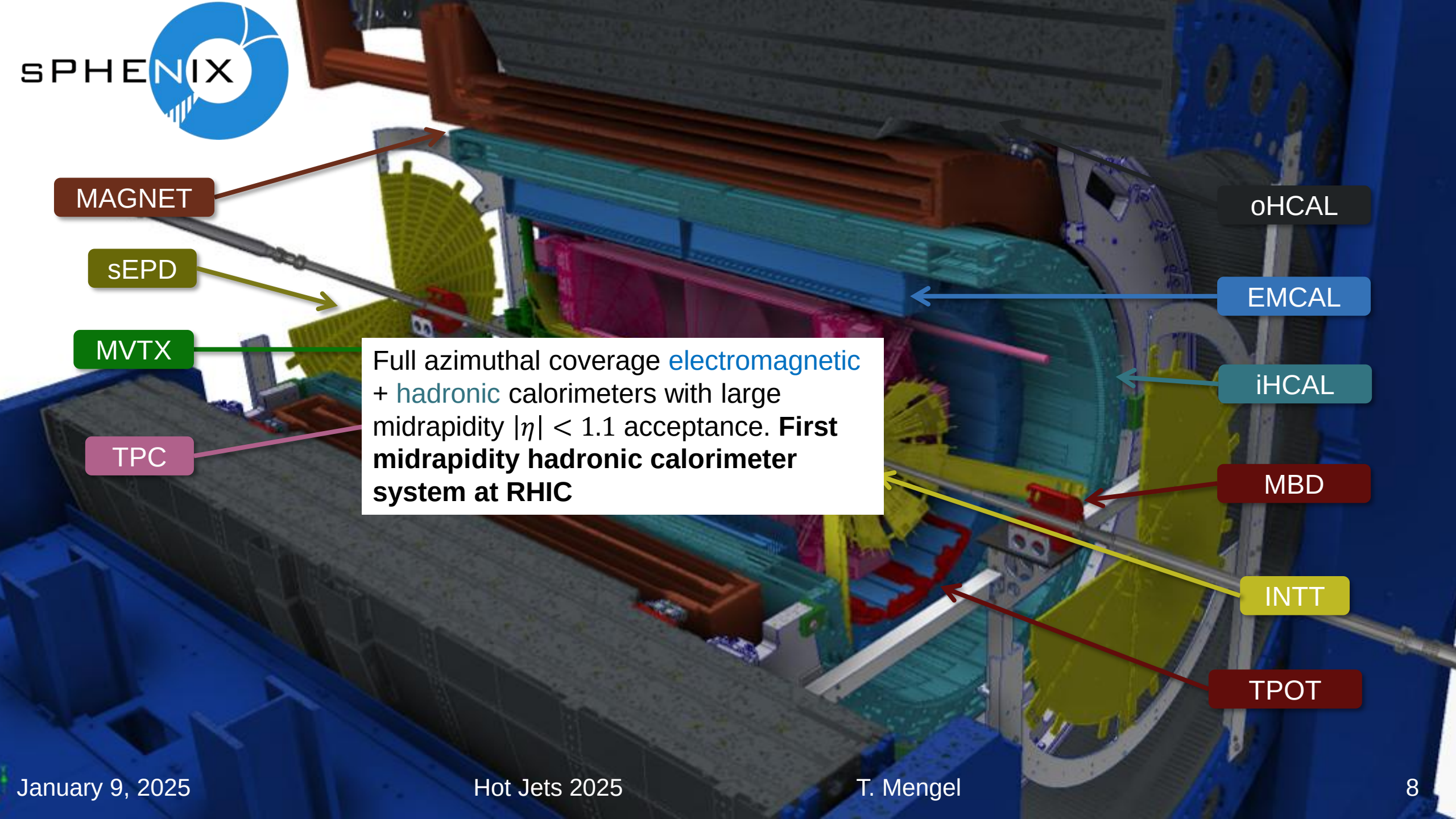


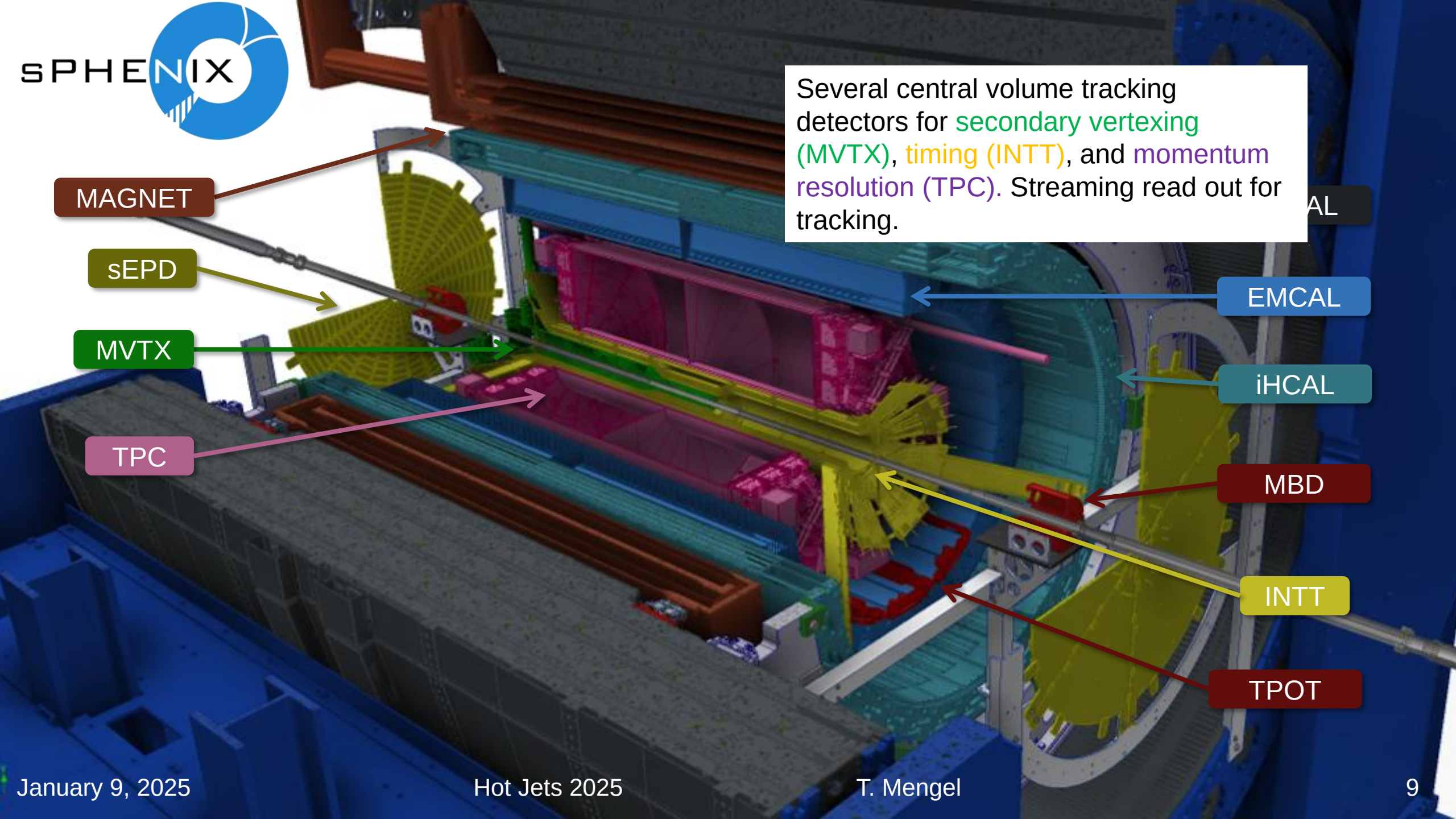




The sPHENIX Detector

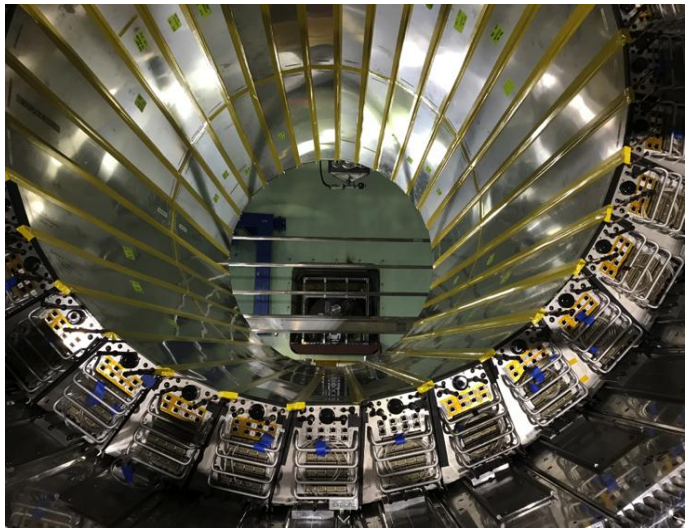

sPHENIX
MAGNET
sEPD
MVTX
TPC
oHCAL
EMCAL
iHCAL
MBD
INTT
TPOT
Large, hermetic acceptance.
High DAQ rate 15 kHz (Triggered + Streaming), η < 1.1, full azimuth in ϕ. Equip with event plane detector and min. bias detector

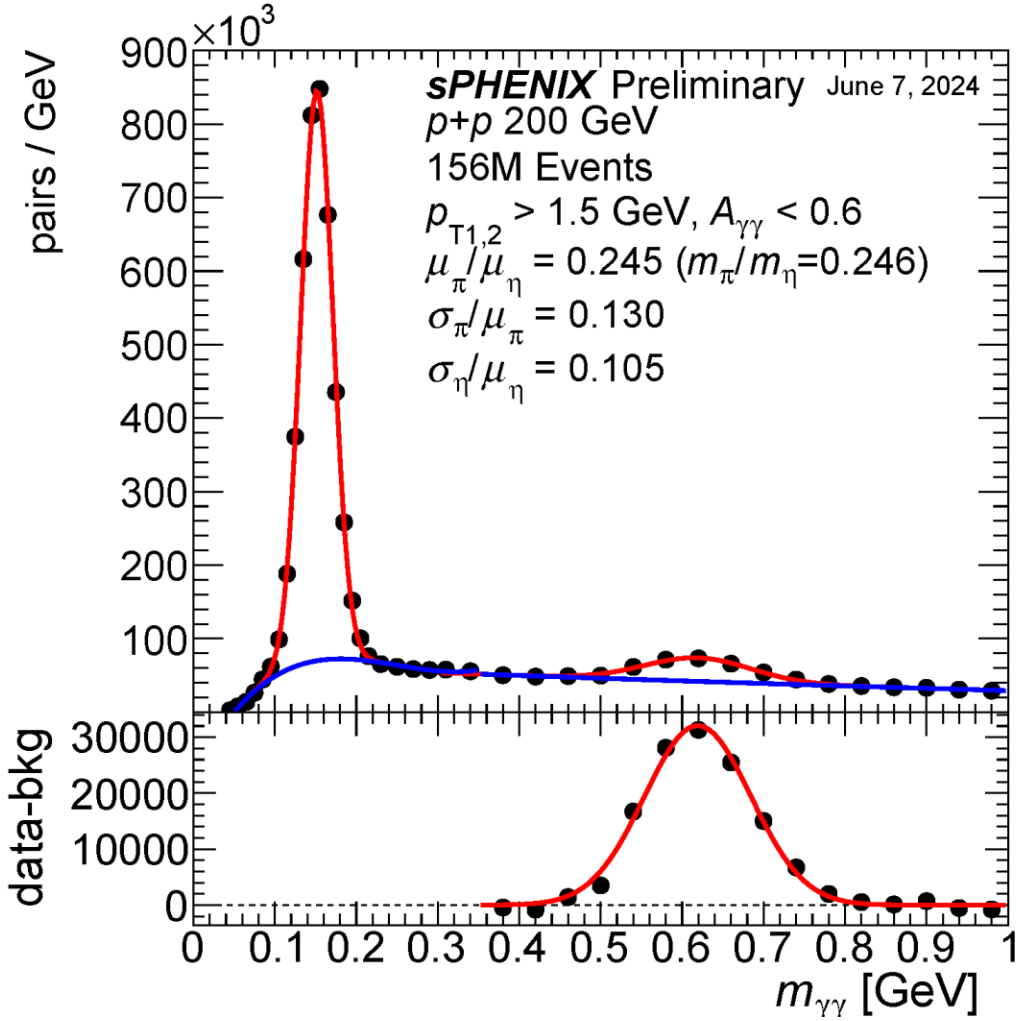

sPHENIX
MAGNET
sEPD
MVTX
TPC
oHCAL
EMCAL
iHCAL
MBD
INTT
TPOT
Full azimuthal coverage electromagnetic + hadronic calorimeters with large midrapidity $|\eta| < 1.1$ acceptance. **First midrapidity hadronic calorimeter system at RHIC**


sPHENIX
Several central volume tracking detectors for secondary vertexing (MVTX), timing (INTT), and momentum resolution (TPC). Streaming read out for tracking.
MAGNET
sEPD
MVTX
TPC
EMCAL
iHCAL
MBD
INTT
TPOT

Electromagnetic Calorimeter

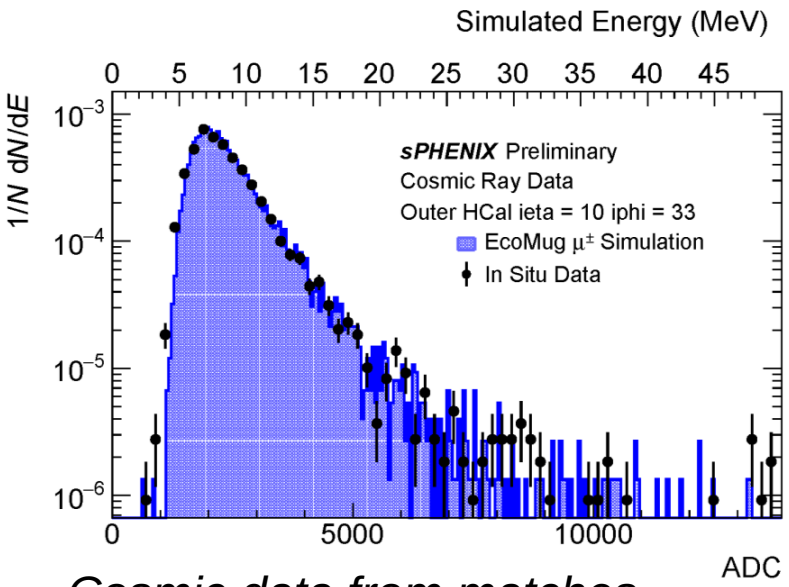
- Tungsten powder absorber with scintillating fiber
- Provides precision measurements of direct photon, electrons, and neutral mesons
- Highly granular $\Delta\eta \times \Delta\phi = 0.025 \times 0.025$



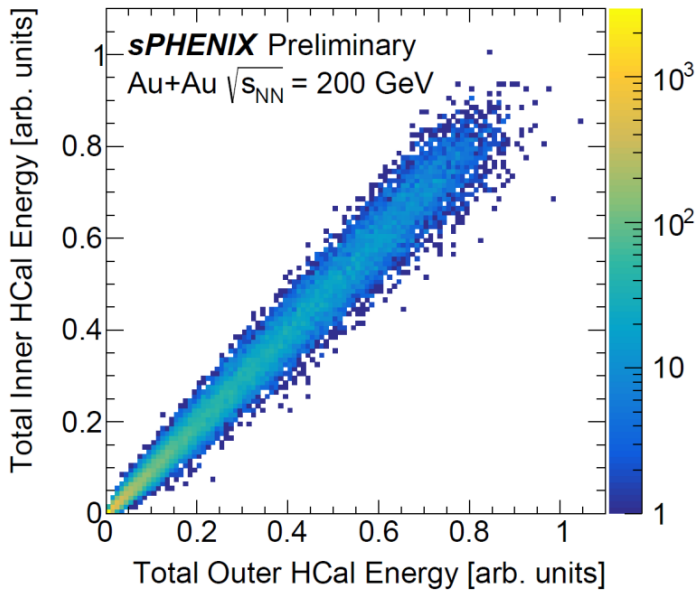


Hadronic Calorimeters

- First time neutral jet components can be measured at RHIC
- Steel/Aluminum (inner/outer) absorber plates with scintillating tiles. $\Delta\eta \times \Delta\phi = 0.1 \times 0.1$



Cosmic data from matches simulation

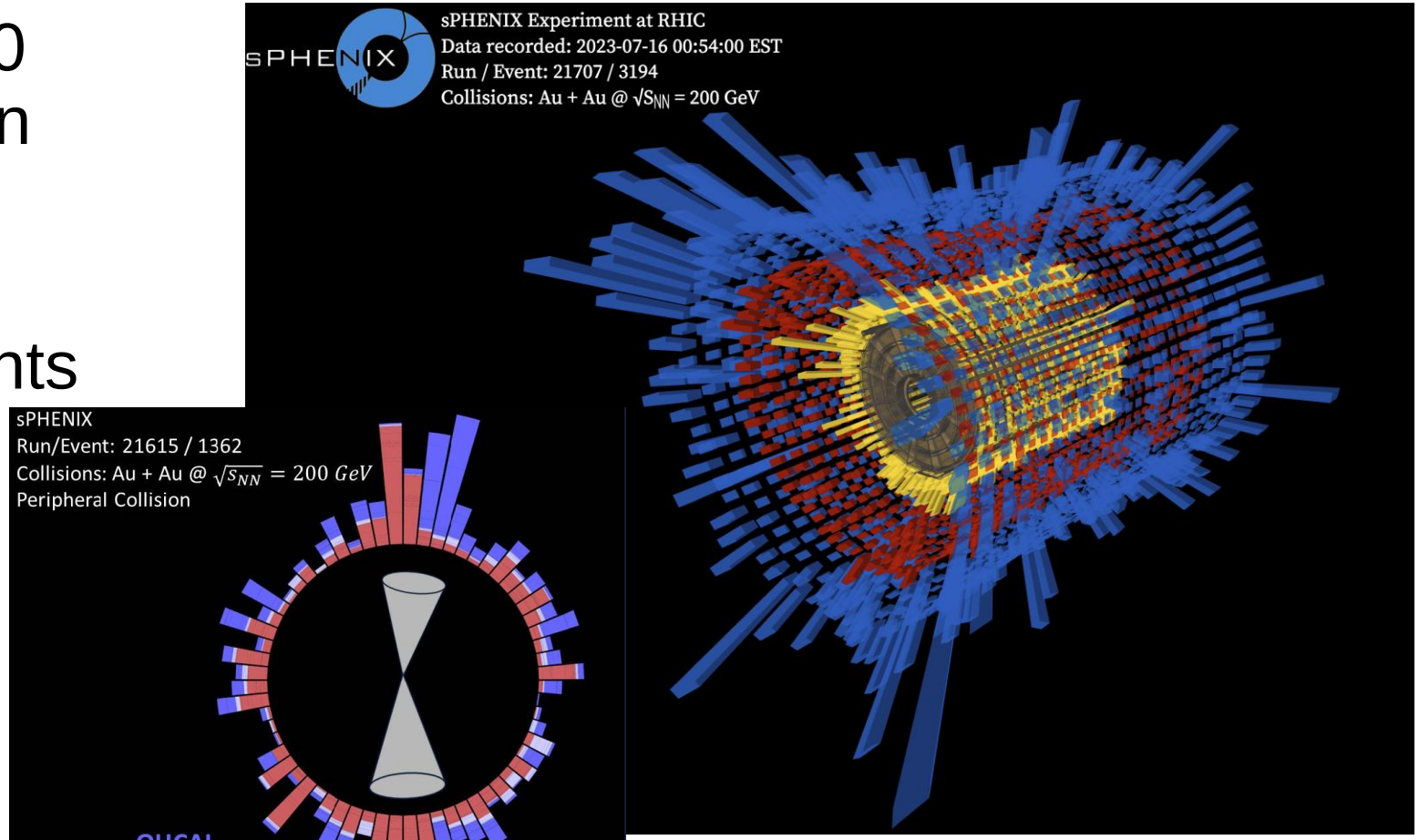


Outer HCAL 2022

Inner HCAL 2022

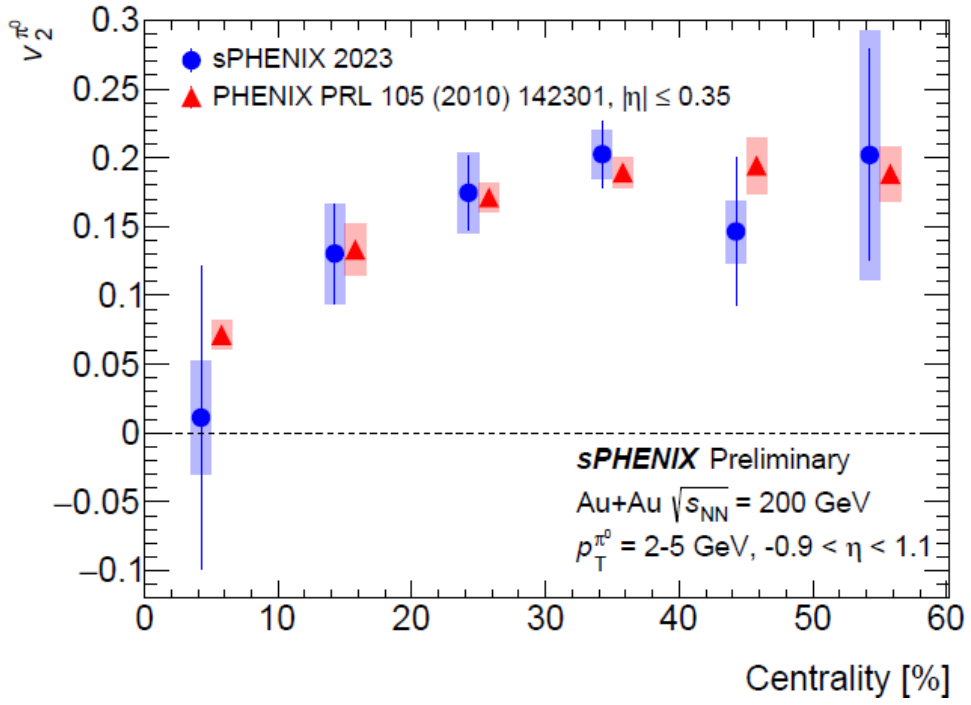
sPHENIX Run 2023

- Commissioning run with 200 GeV Au+Au collisions began May 2023
- Collected first sPHENIX physics full calorimeter events
- Early measurements using calorimeter towers

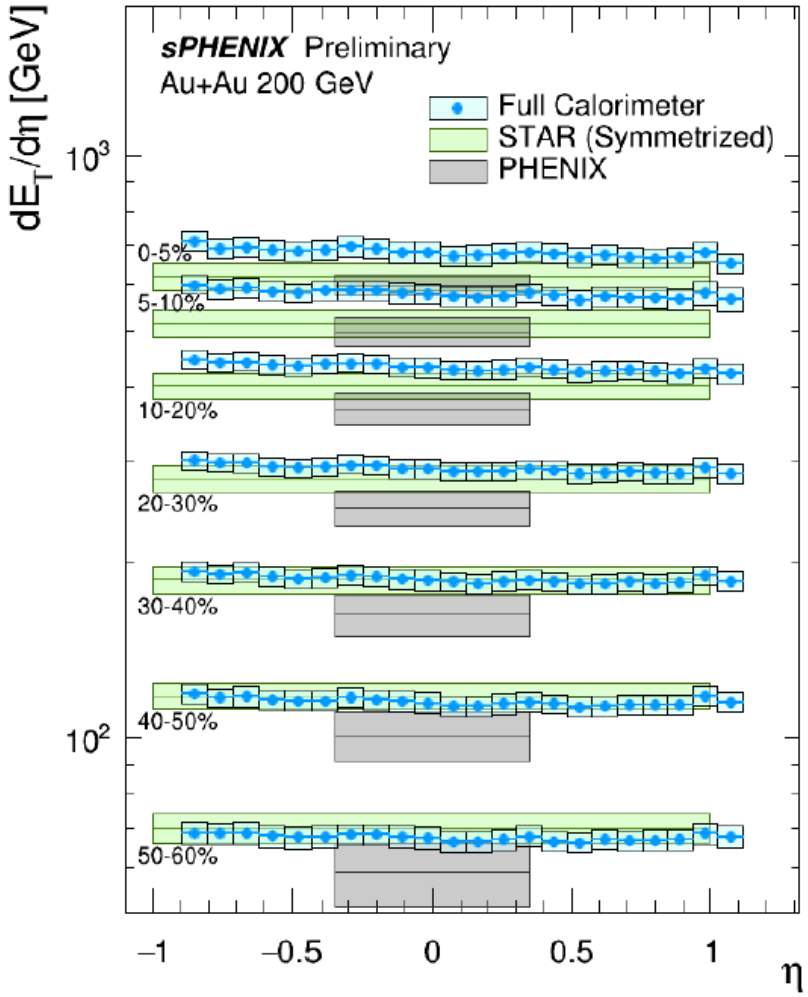


Run 2023 Initial Measurements

- Standard candles in agreement with previous RHIC measurements



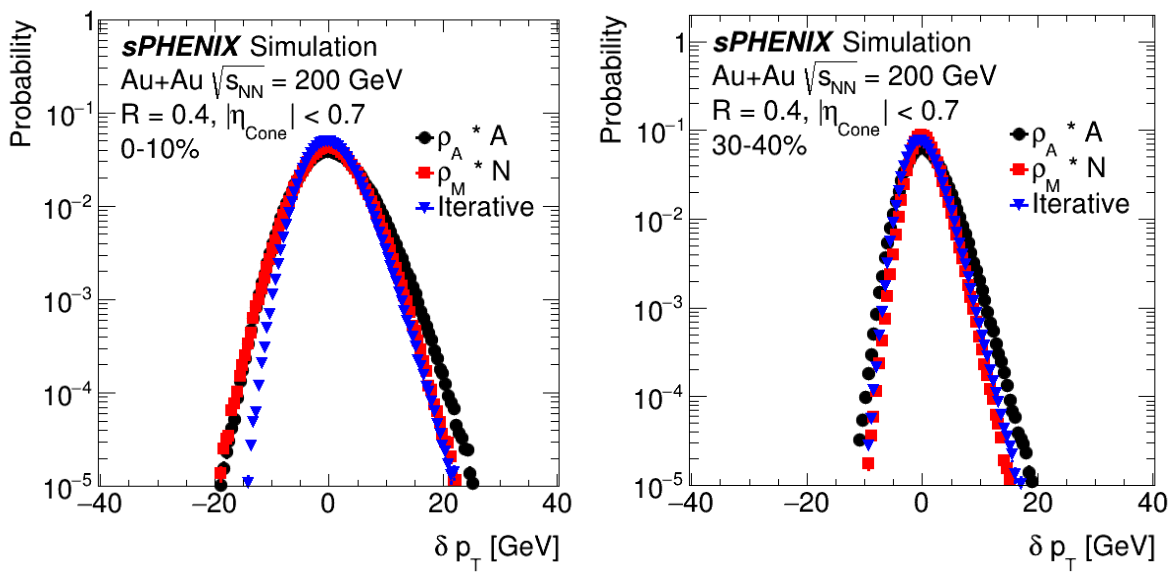
Neutral pion v_2 via scalar product method (sPH-CONF-BULK-2024-01)

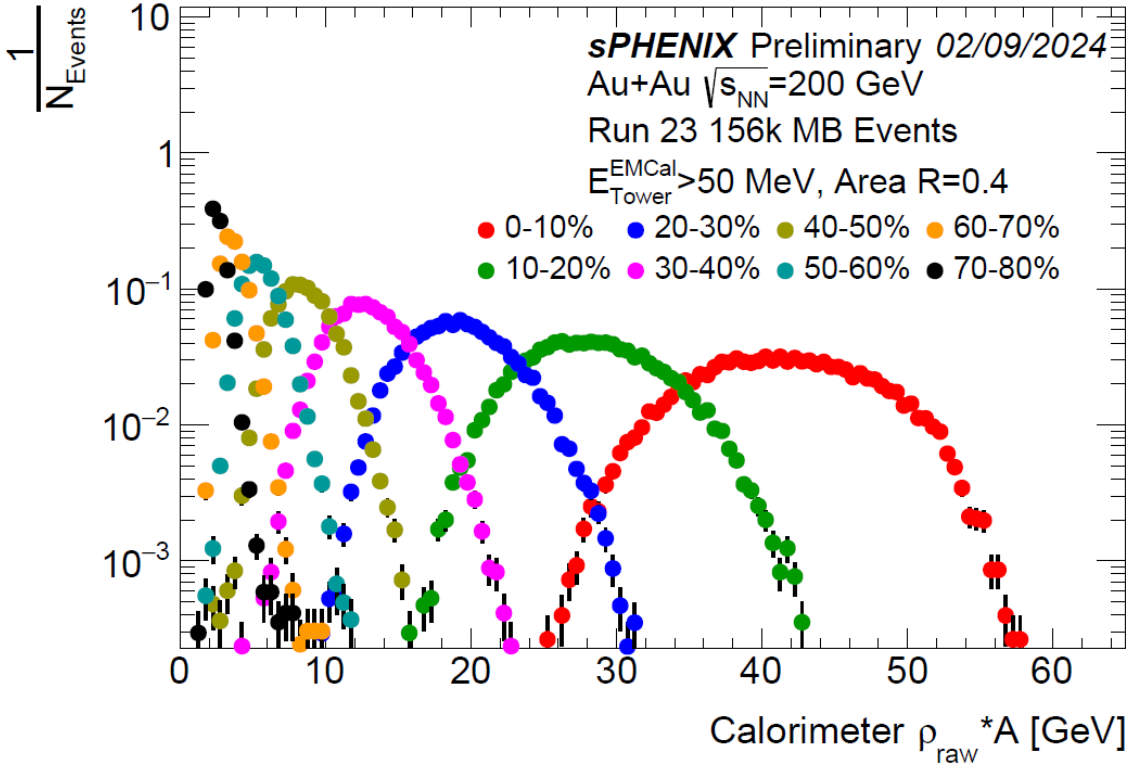


Corrected $dE_T/d\eta$ (sPH-CONF-BULK-2024-02)

Run 2023 Underlying Event

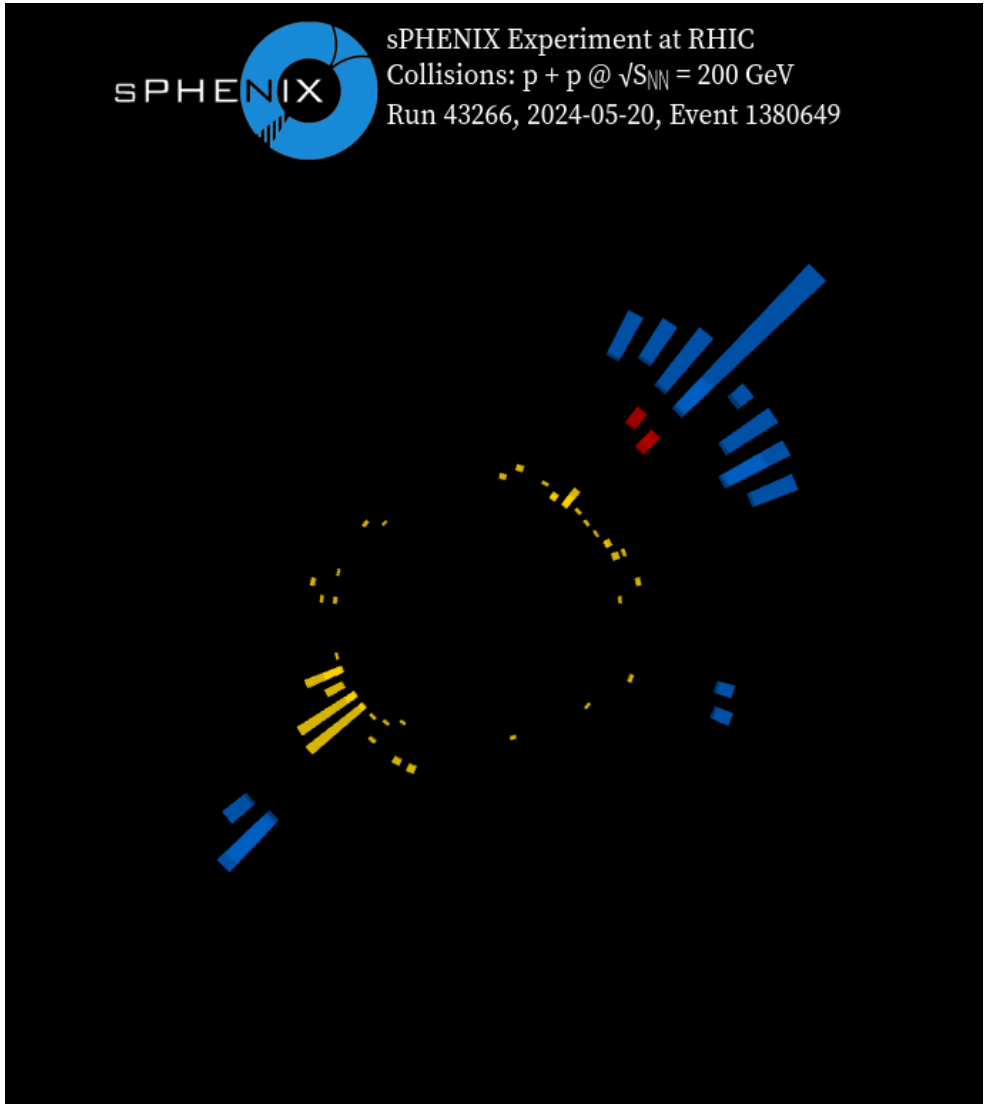
- UE characterizations with calo windows, random cones, and embed jets
- Comparisons of jet background fluctuations between subtraction methods
  - Multiplicity based (New!), Area based (ALICE/STAR), Iterative subtraction (ATLAS/CMS)





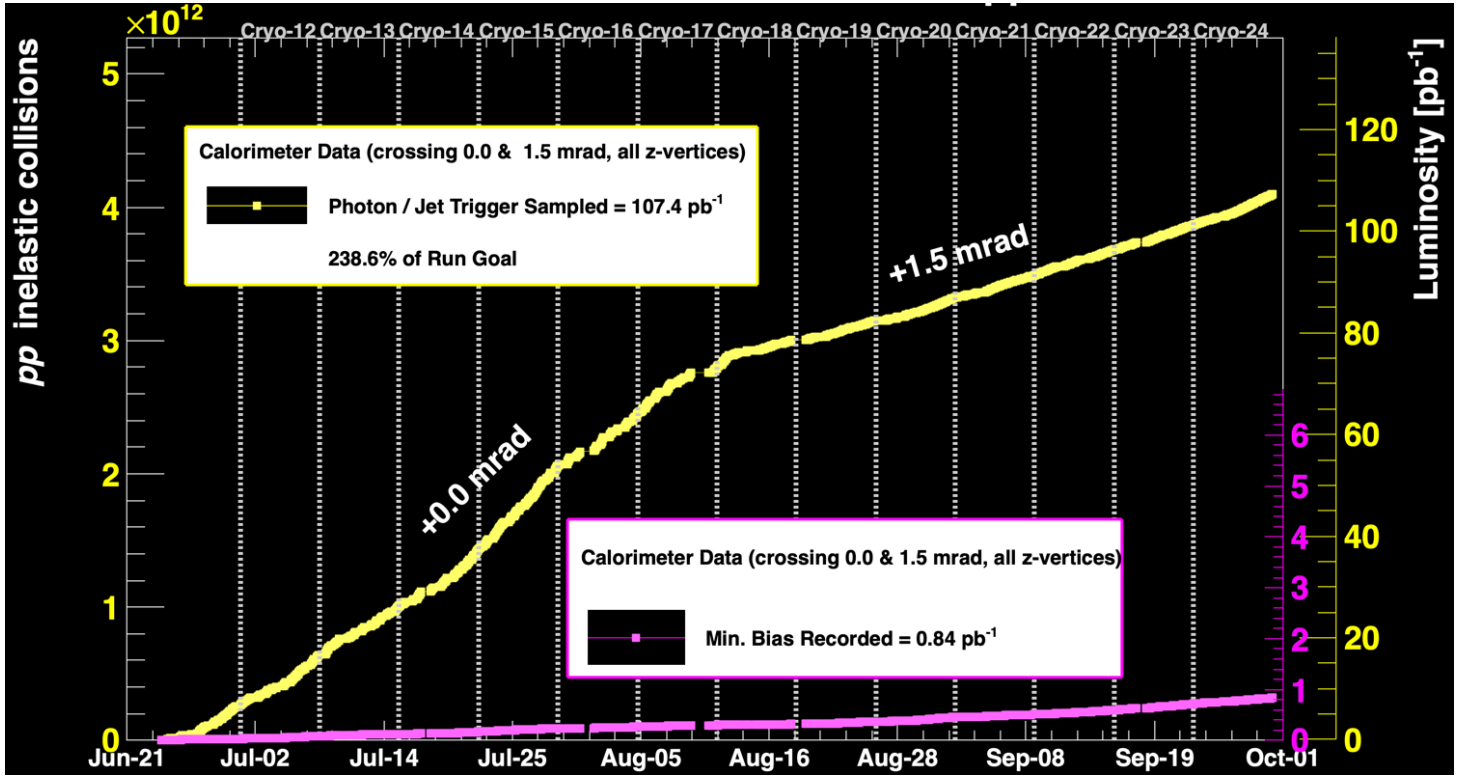
sPHENIX Run 2024

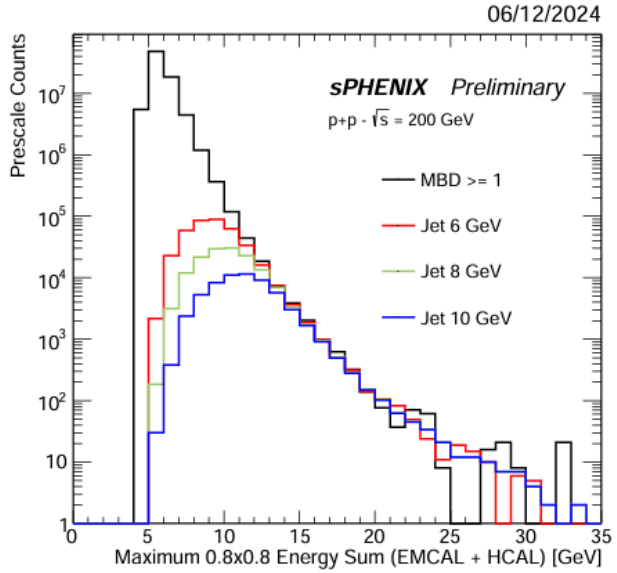
- Commission calorimeter jet and photon triggers
- Complete commission of tracking detectors, integrate streaming readout
- Record high statistics reference 200 GeV pp dataset for jet physics program

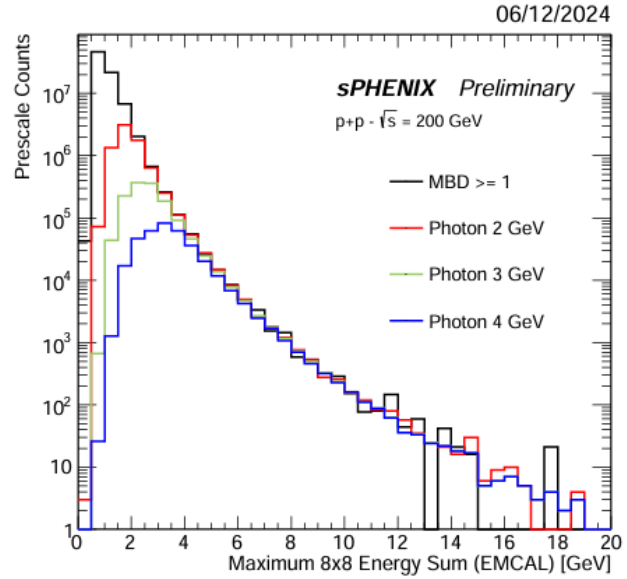


sPHENIX Run 2024

- ✓Commission calorimeter jet and photon triggers

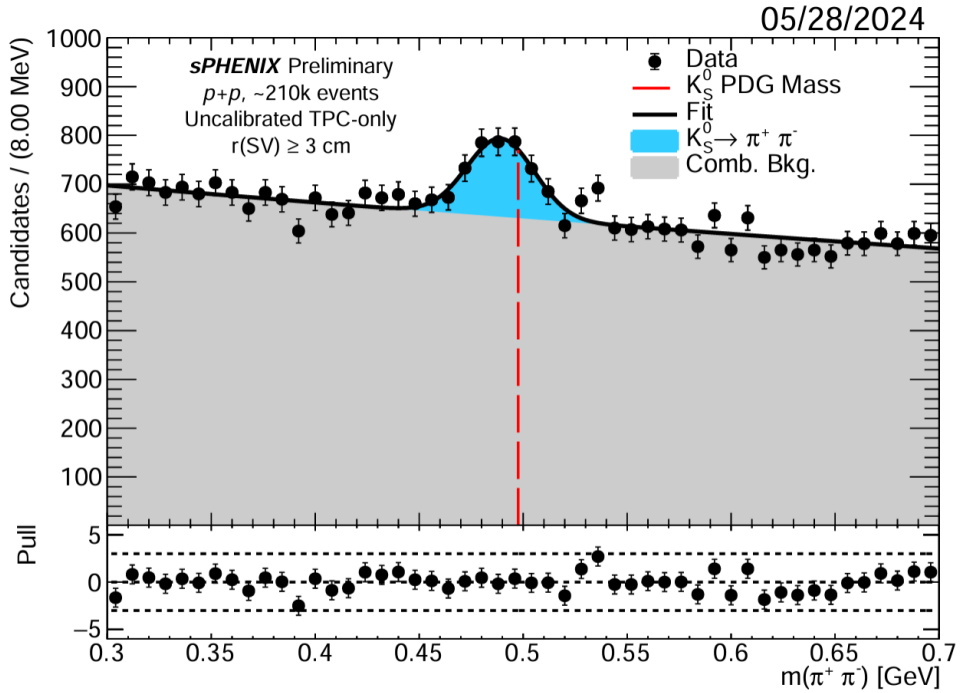


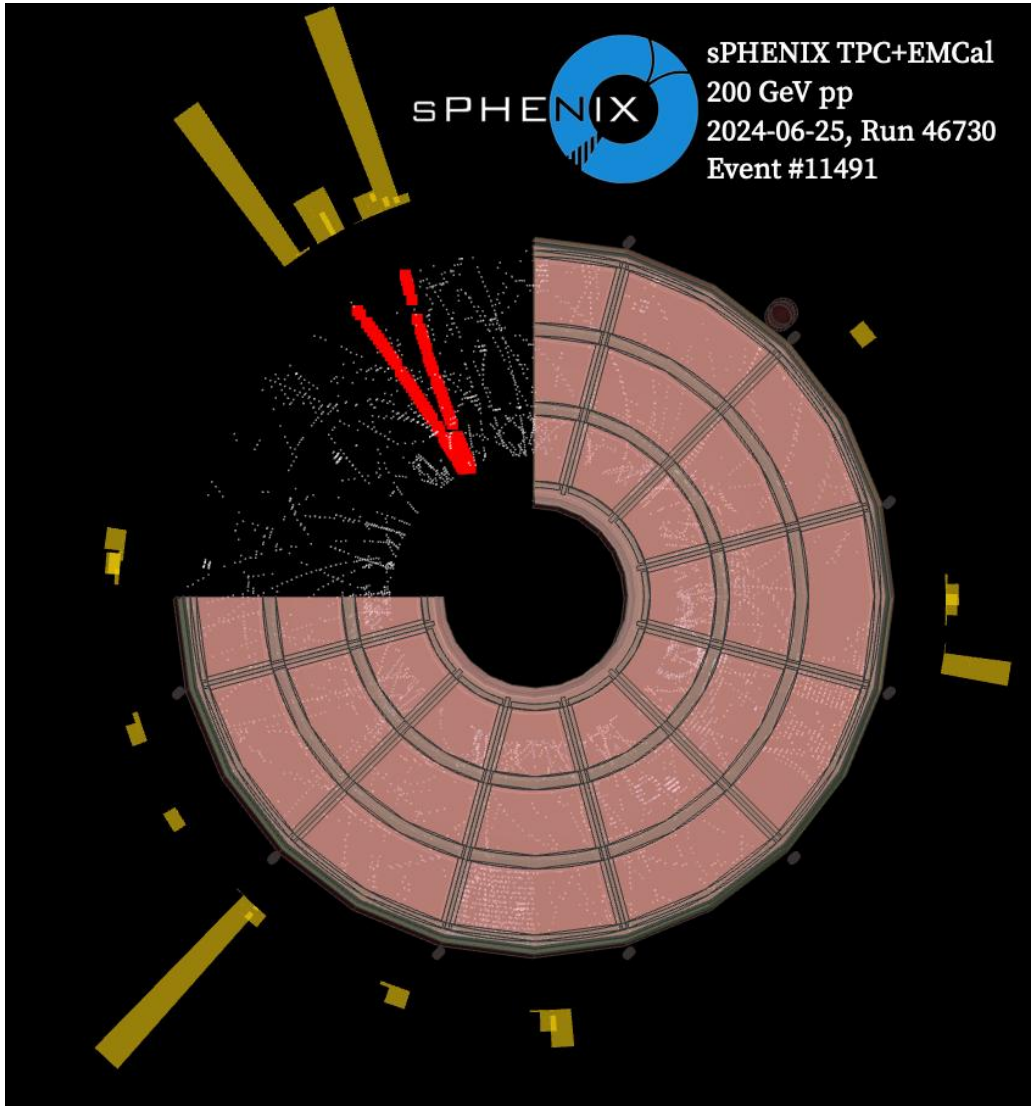


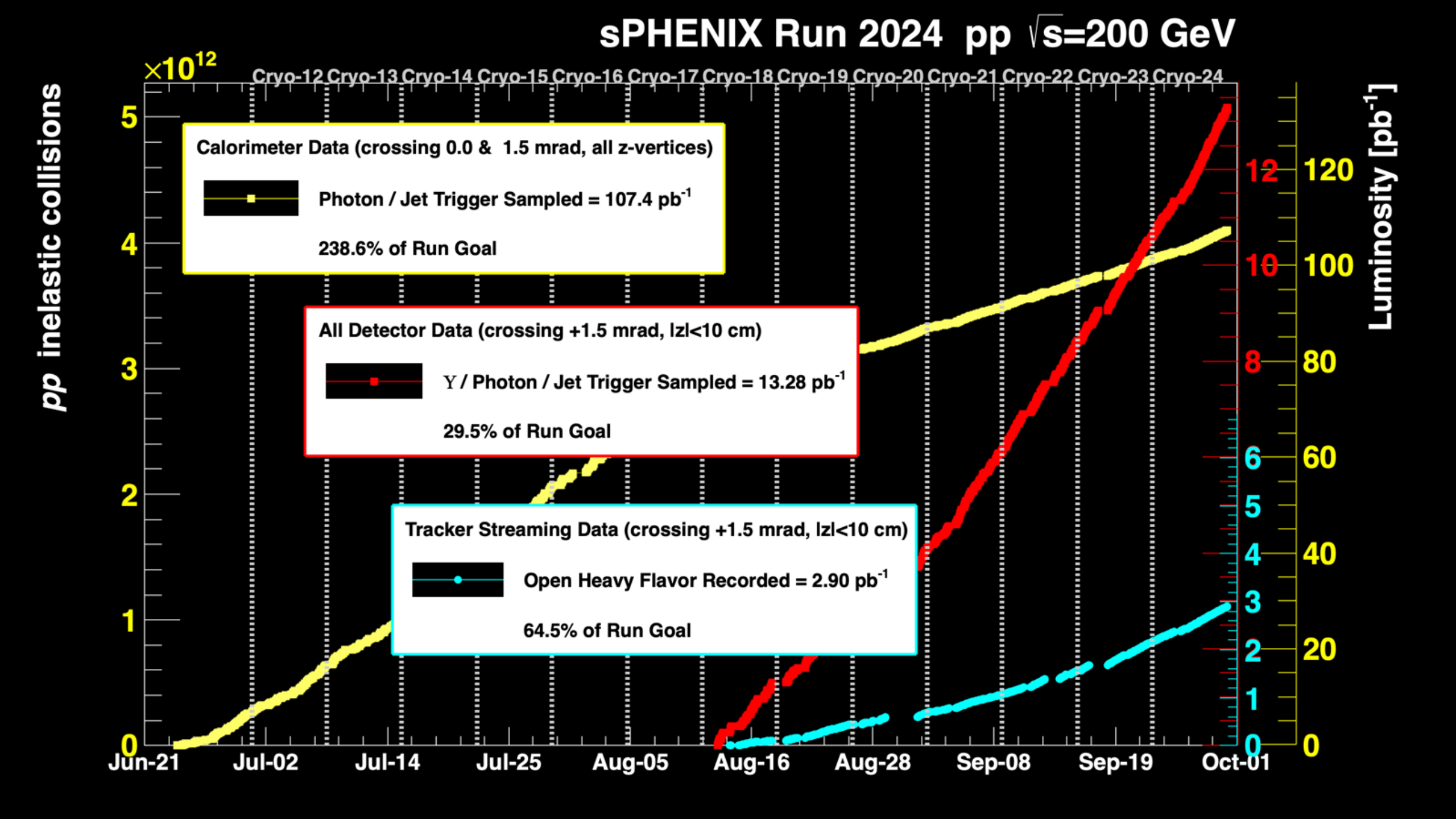


sPHENIX Run 2024

- ✓Complete commission of tracking detectors, integrate streaming readout

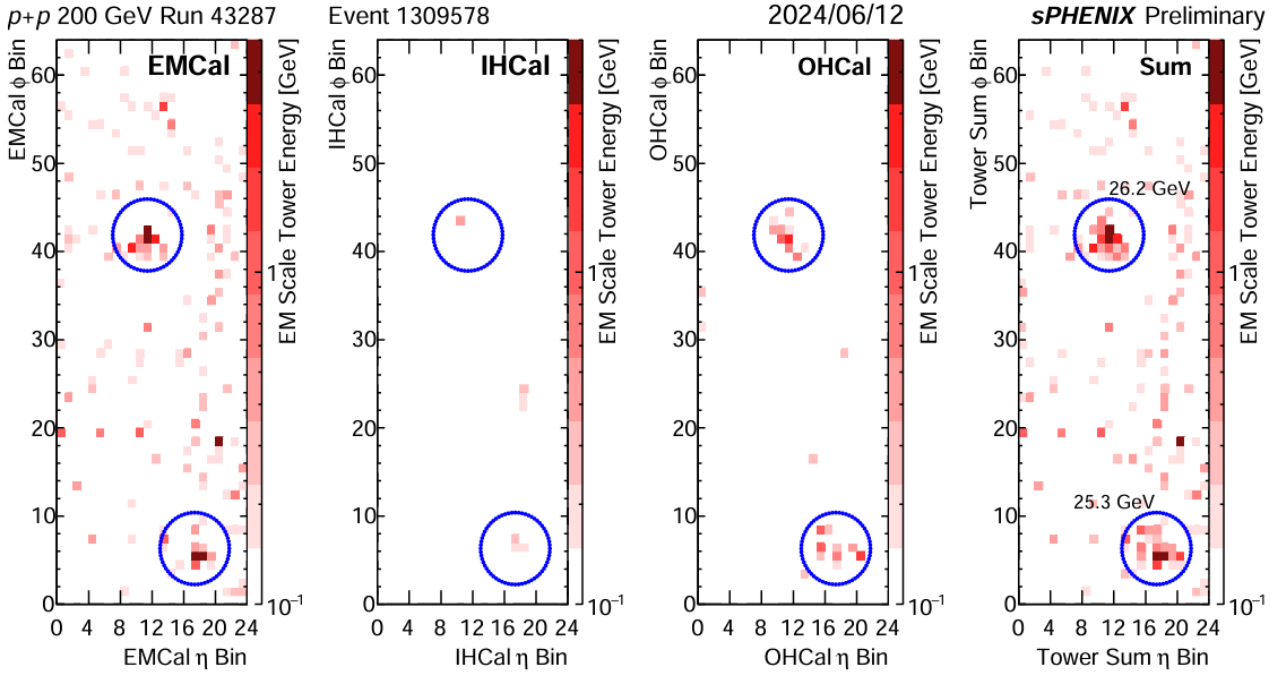


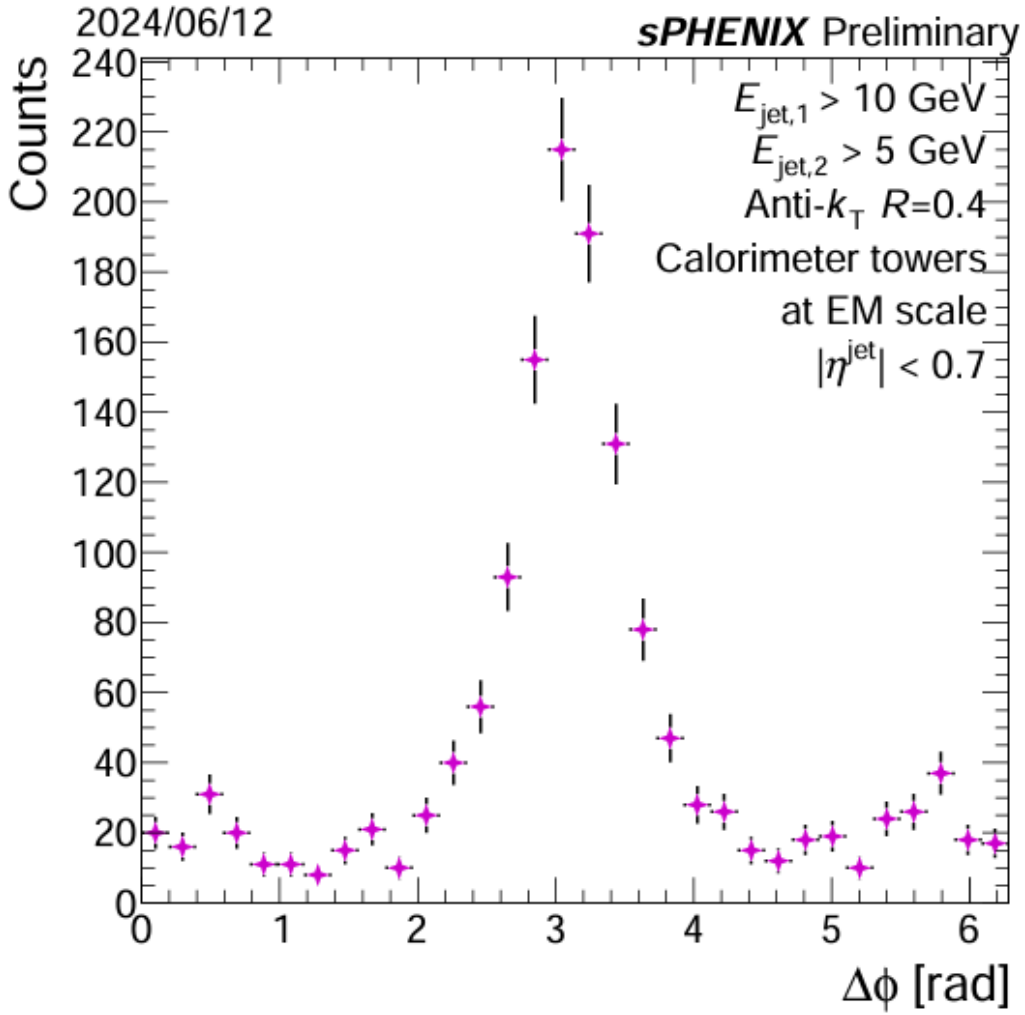



sPHENIX Run 2024 pp √s=200 GeV
×10^12
pp inelastic collisions
Luminosity [pb^-1]
Cryo-12 Cryo-13 Cryo-14 Cryo-15 Cryo-16 Cryo-17 Cryo-18 Cryo-19 Cryo-20 Cryo-21 Cryo-22 Cryo-23 Cryo-24
Calorimeter Data (crossing 0.0 & 1.5 mrad, all z-vertices)
Photon / Jet Trigger Sampled = 107.4 pb^-1
238.6% of Run Goal
All Detector Data (crossing +1.5 mrad, |z|<10 cm)
ϒ / Photon / Jet Trigger Sampled = 13.28 pb^-1
29.5% of Run Goal
Tracker Streaming Data (crossing +1.5 mrad, |z|<10 cm)
Open Heavy Flavor Recorded = 2.90 pb^-1
64.5% of Run Goal
0
1
2
3
4
5
0
1
2
3
4
5
6
8
10
12
0
20
40
60
80
100
120
Jun-21
Jul-02
Jul-14
Jul-25
Aug-05
Aug-16
Aug-28
Sep-08
Sep-19
Oct-01

High p_T Physics in Run 2024

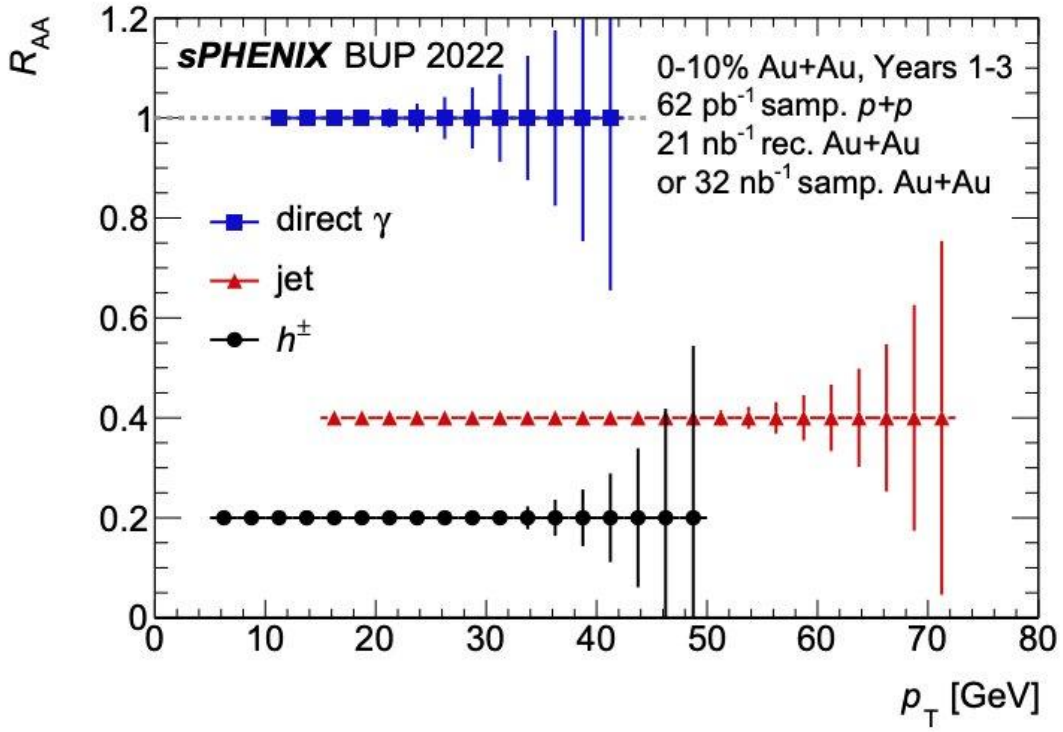
- Jet and photon trigger **107 pb^{-1}** sampled **(~240%** of target luminosity)

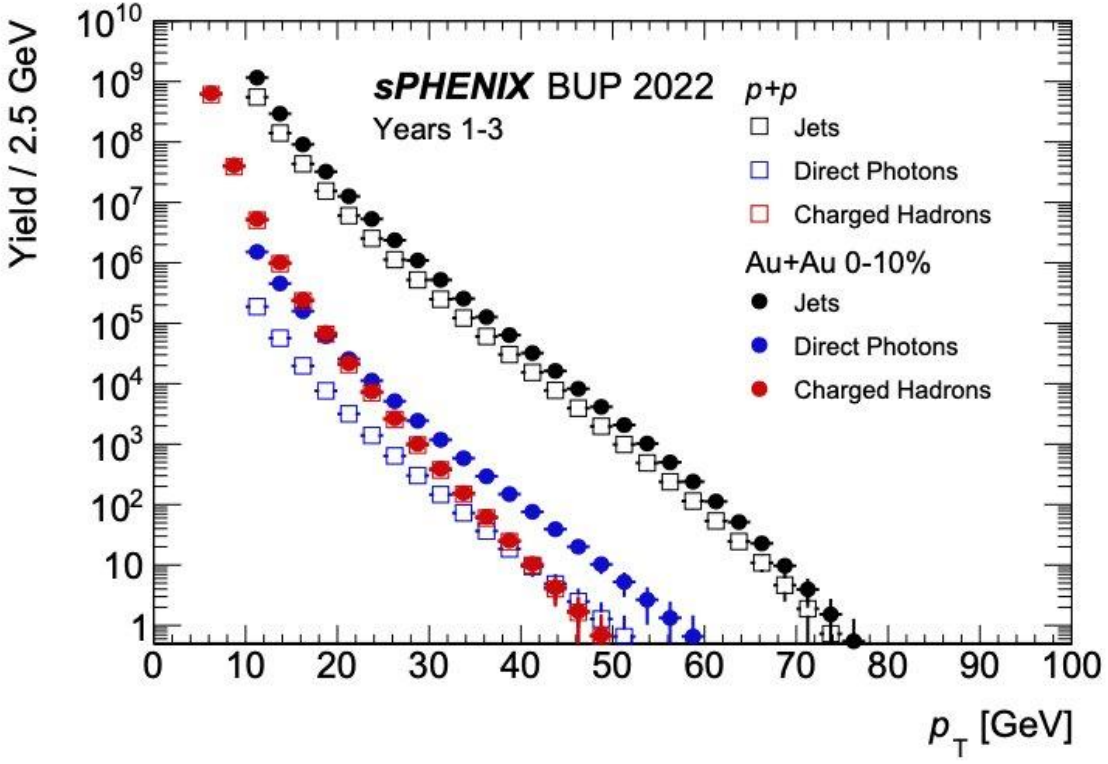




sPHENIX 2025 Projections

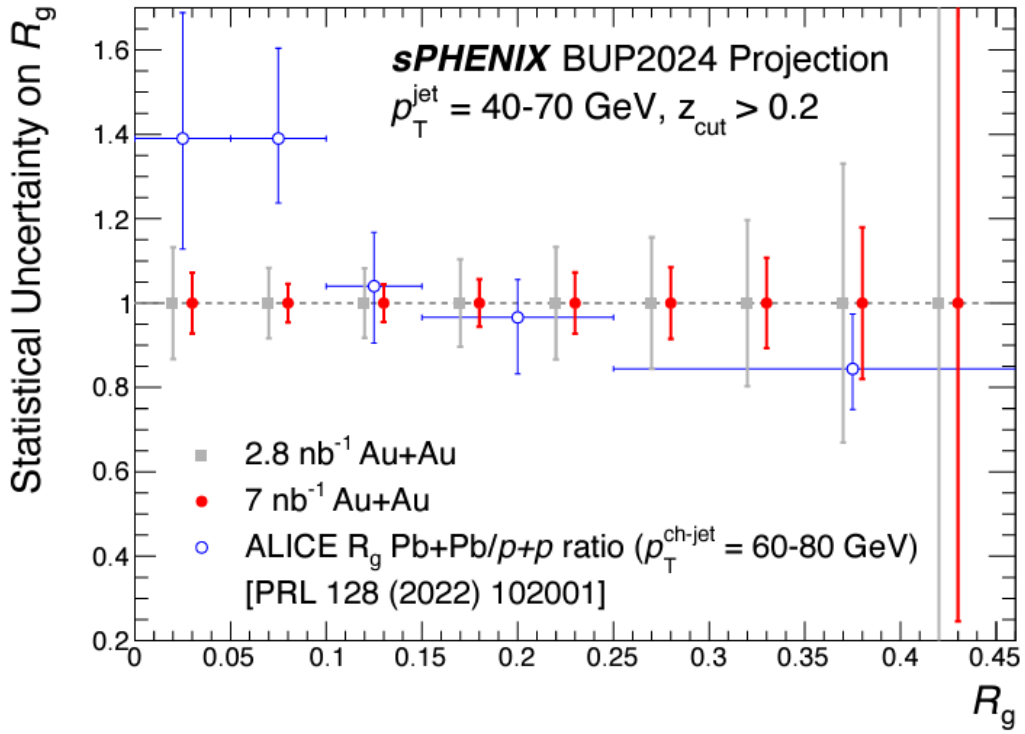
- High-statistics Au+Au physics data-taking
- Jet kinematics at overlapping p_T regimes to LHC measurements and at low p_T

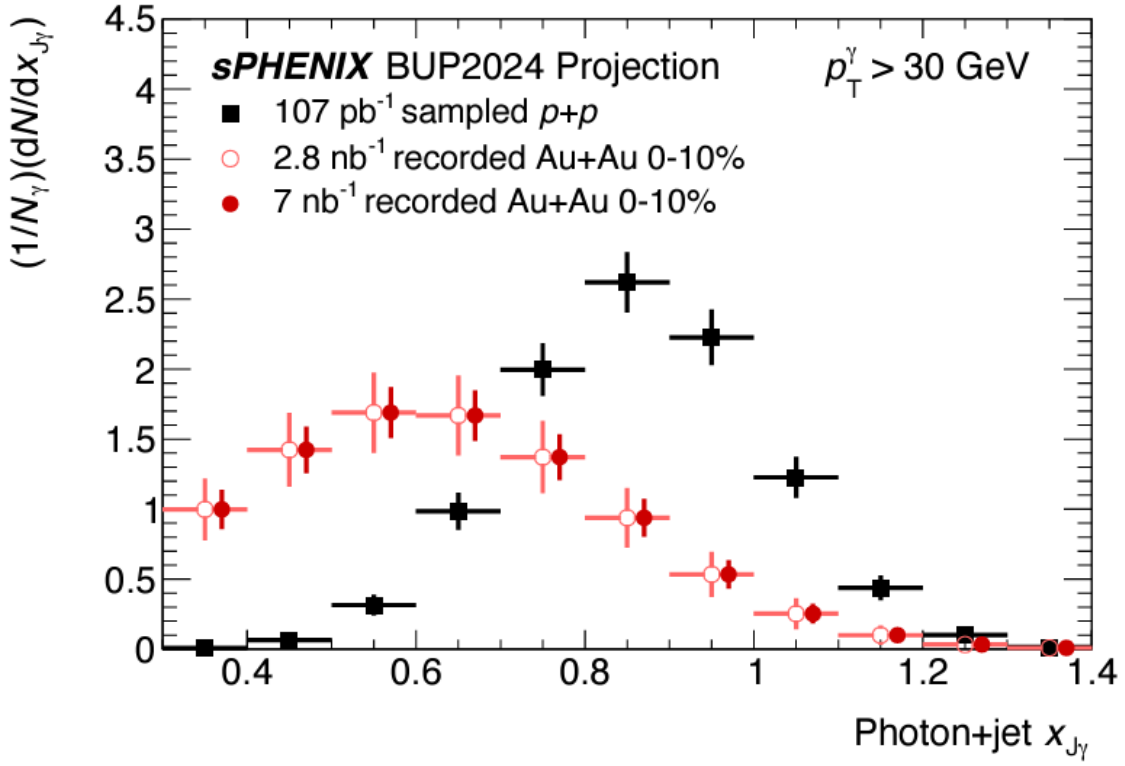




sPHENIX Jet Projections

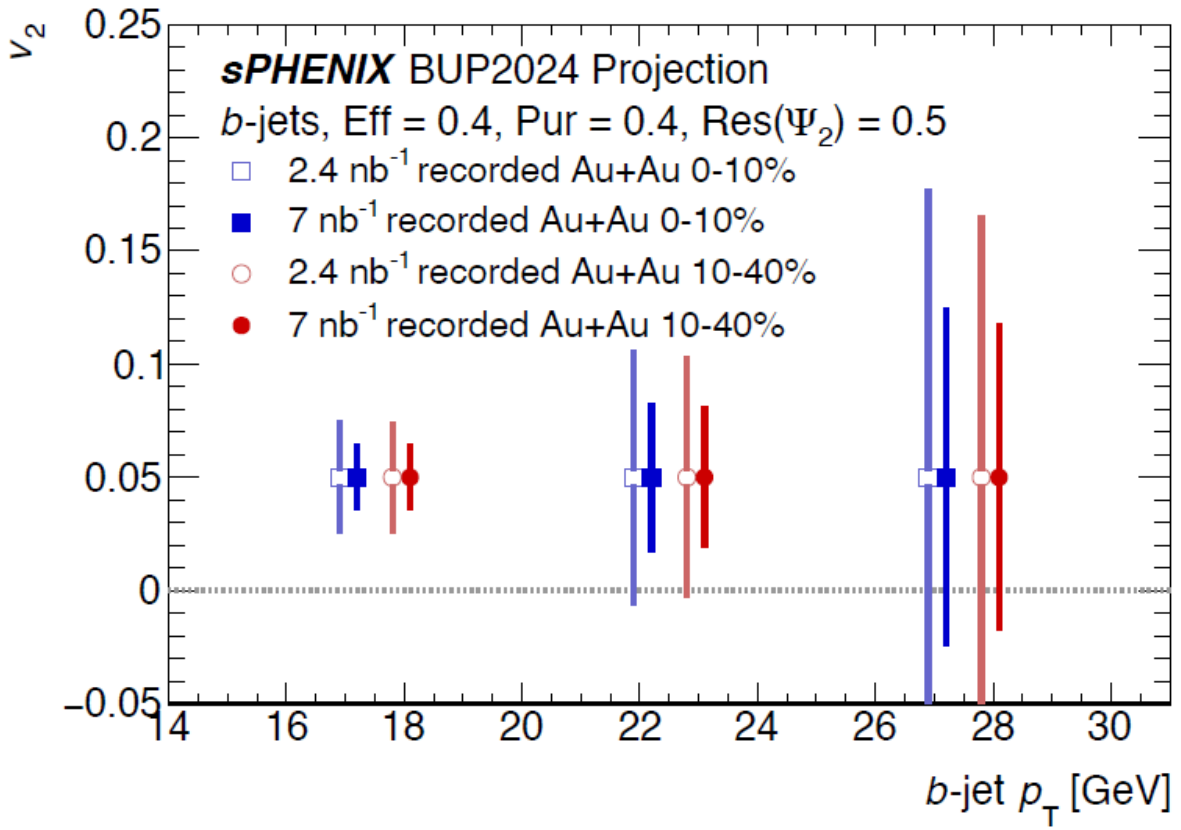
- Groomed jet radius in overlapping kinematic range with ALICE
- Projected distribution of $x_{j\gamma}$ given recorded 2024 pp





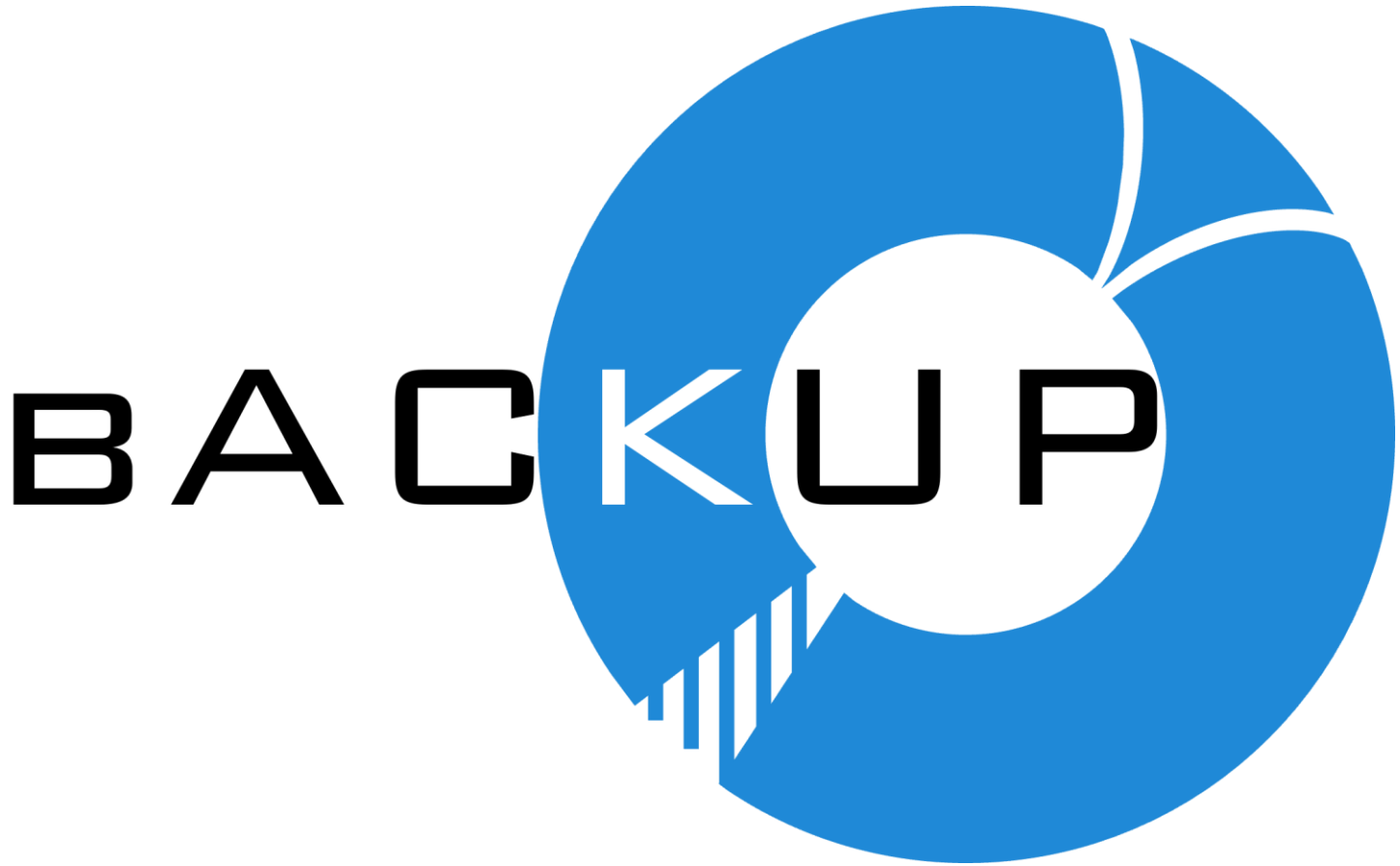
sPHENIX *b*-jet Projections

- Projected b-jet v_2, shown for **central** and **mid-central** events
- Uncertainties projection given for recorded 2024 pp data and minimum 2025 Au+Au luminosity projection



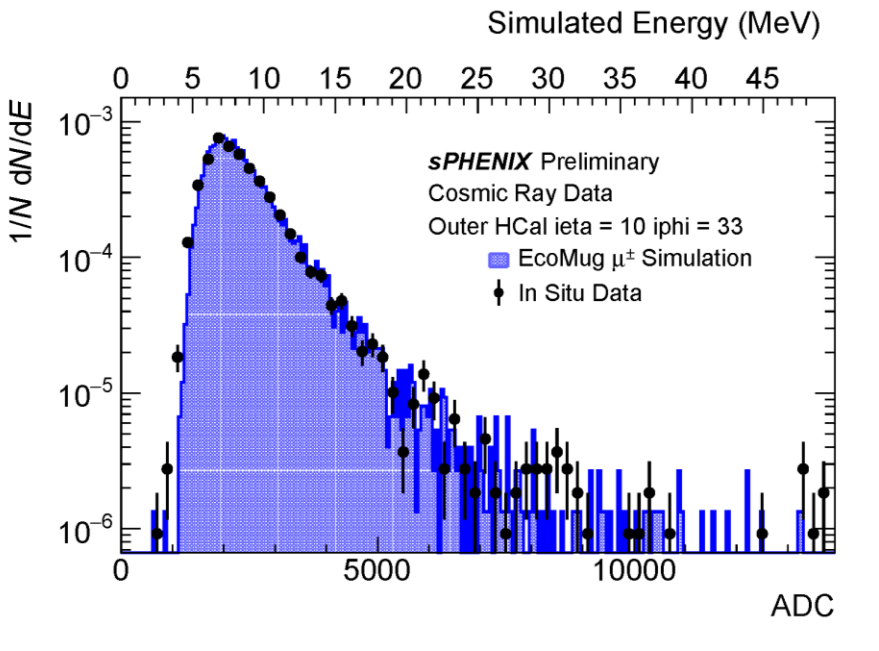
Conclusions

- sPHENIX is well equipped to perform precise and significant jet measurements with 2024 data
- Collaboration goal of first jet and neutral meson measurements from the run 2024 pp dataset

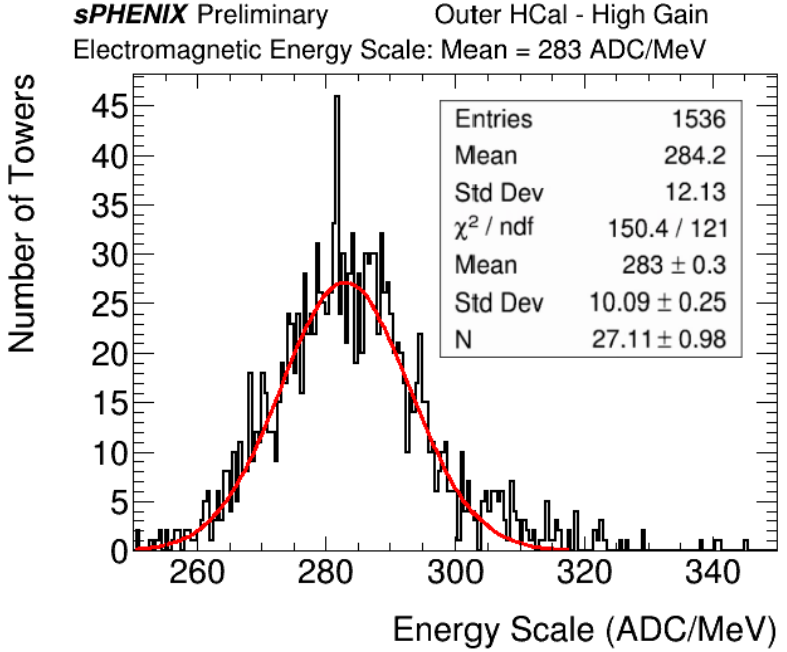

BACKUP

Hadronic Scale Calibrations

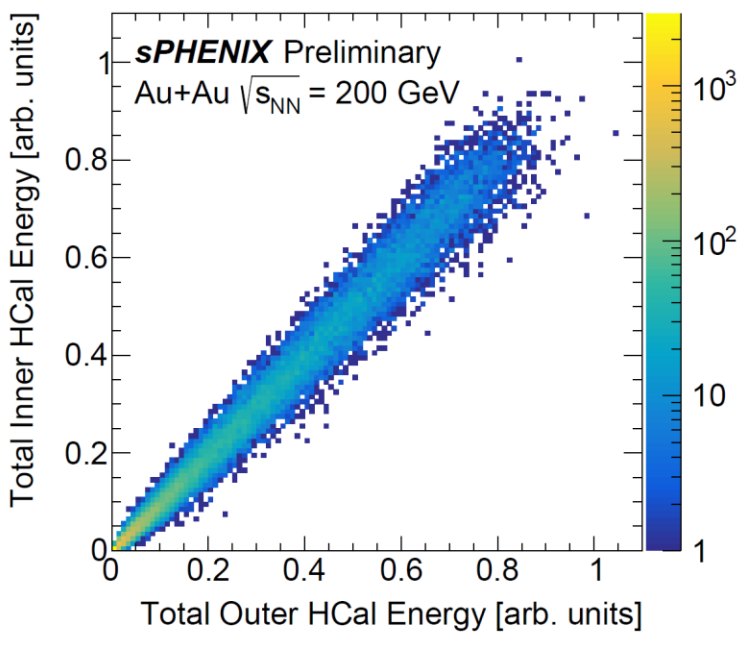
BACKUP



Calibrated outer HCal data from cosmic rays matches simulation



HCal calibrated to EM scale with cosmic rays

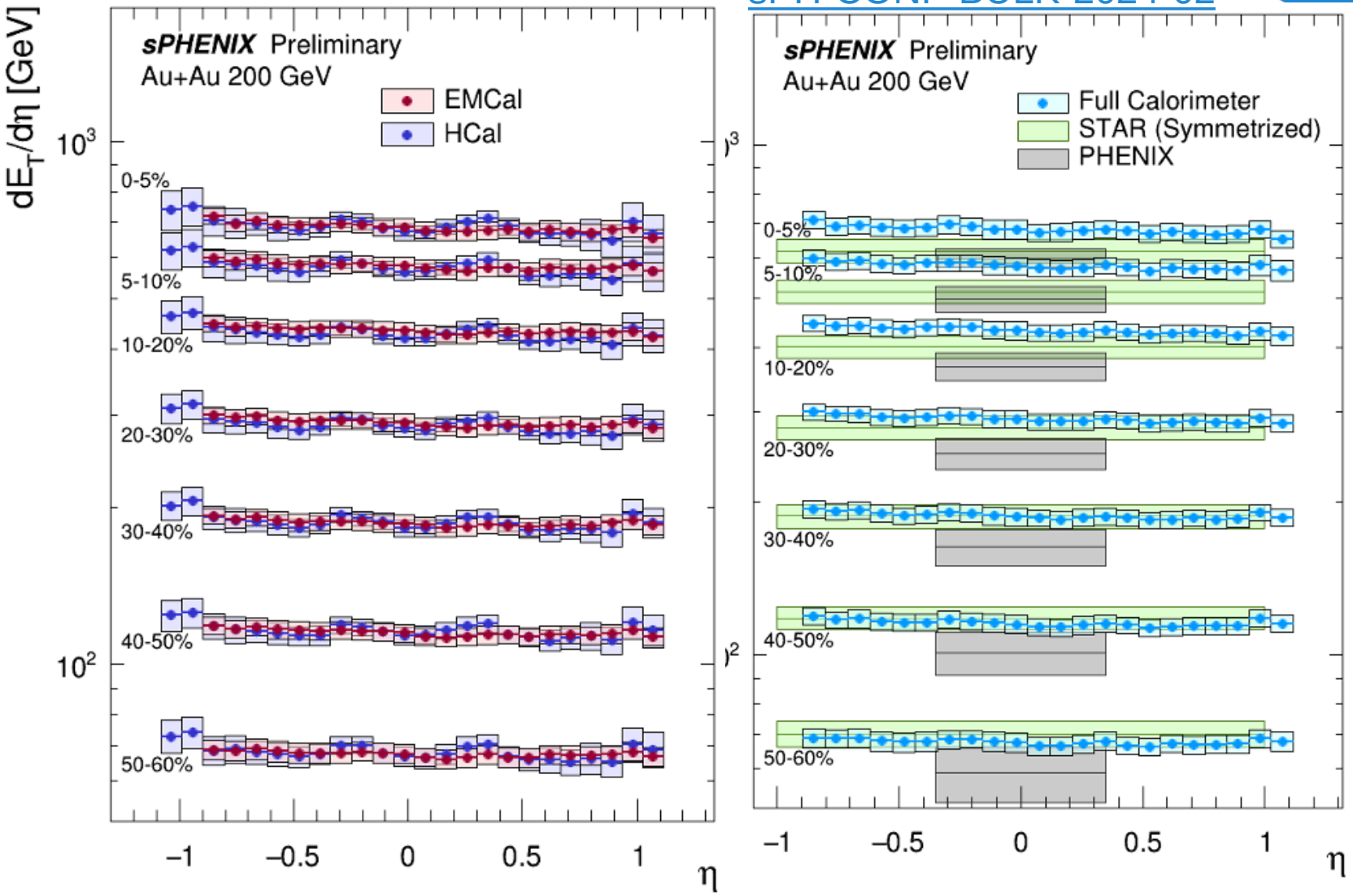


Good correlation between inner and outer HCals

Transverse Energy

- *Fully corrected* transverse energy across EMCal and HCal
- Excellent agreement between EMCal + HCal
- Good comparison to previous measurements

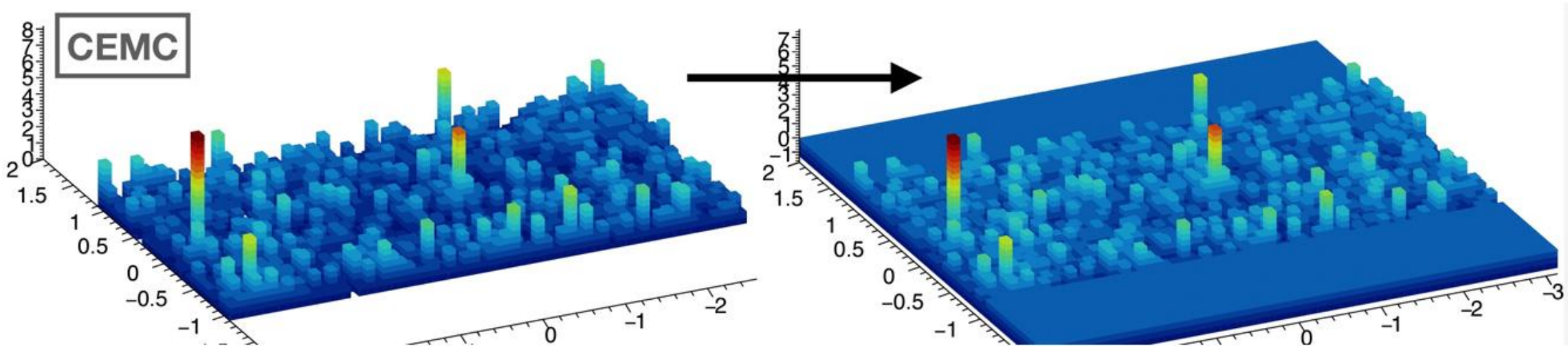
sPH-CONF-BULK-2024-02



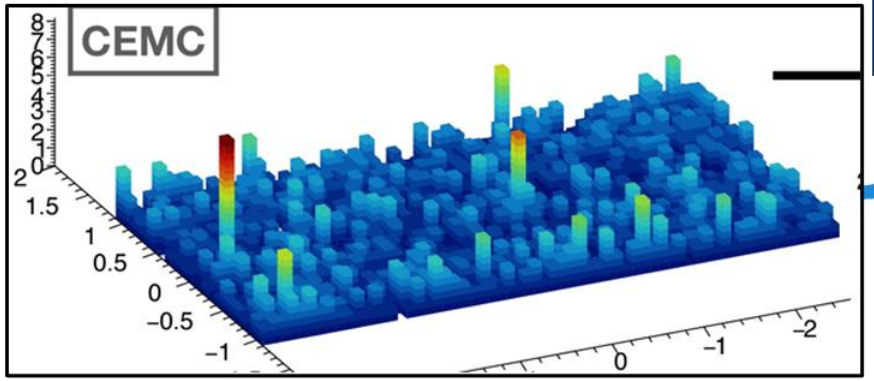
Run 2023 Underlying Event

BACKUP

- Comparisons of UE characterizations using different methods
  - Calorimeter windows, random cones, embed probes/full jets
- Using three background sub methods
  - Multiplicity method (New!) Phys. Rev. C 108, L021901
  - Area based method (STAR, ALICE) Phys.Lett.B 659 (2008) 119-126
  - Iterative subtraction (ATLAS) Phys. Rev. C 86, 024908



sPHENIX Jet Reconstruction



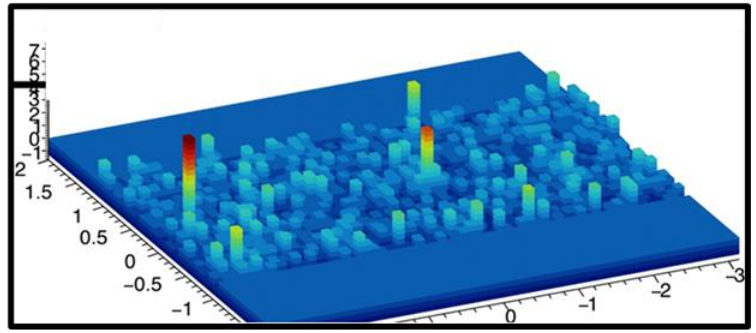
1) Reconstruct R = 0.2 seed jets

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 steps 1-3 with subtracted towers

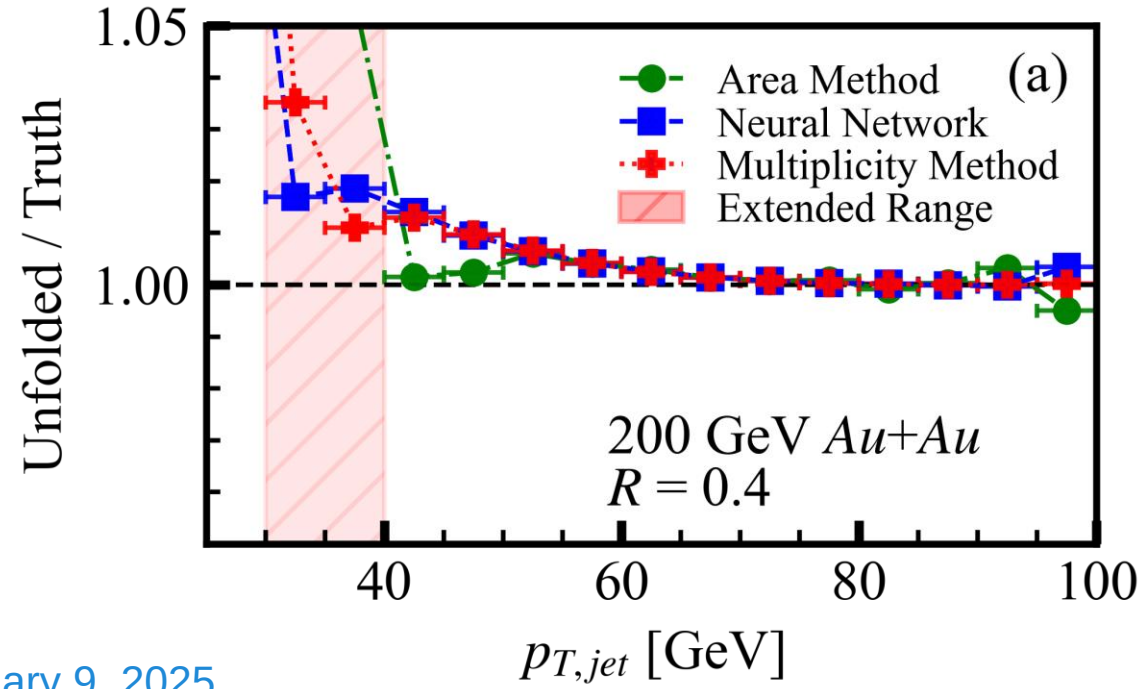
5) Run jet reconstruction on subtracted towers

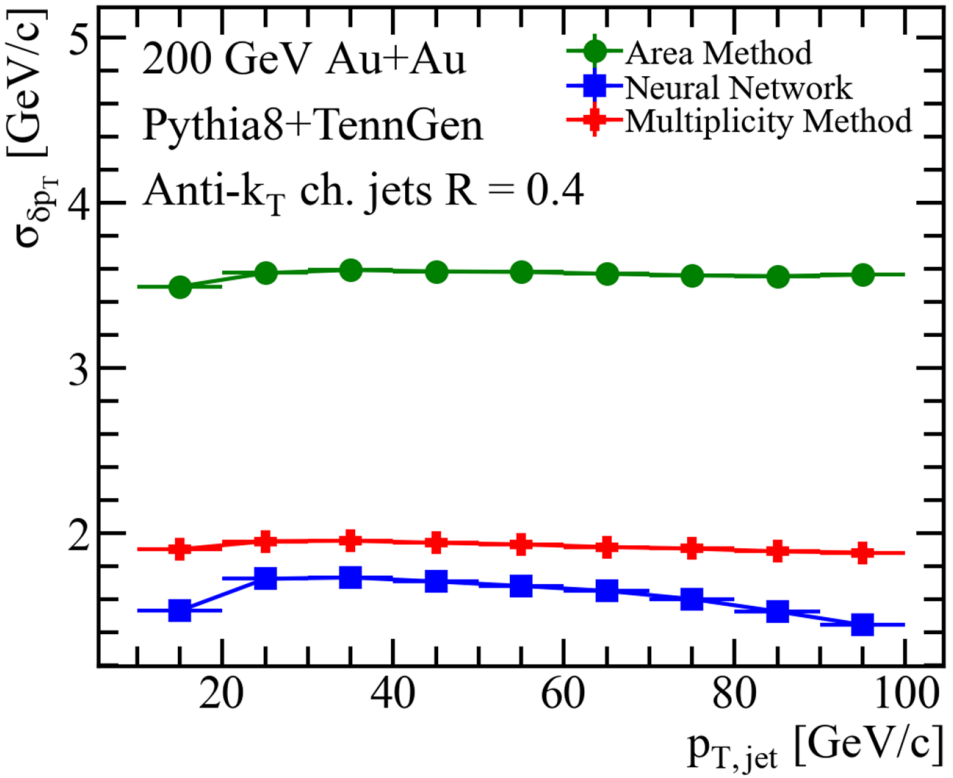


Multiplicity Subtraction

Phys. Rev. C 108, L021901

- $p_T^{Corr} = p_T^{Raw} - \rho_M \cdot (N - \langle N \rangle)$
- $p_{T,Bkgd} \sim \rho_M \cdot (N - \langle N \rangle) \pm \sigma\sqrt{N}$
- ρ_M is the average momentum of background particles

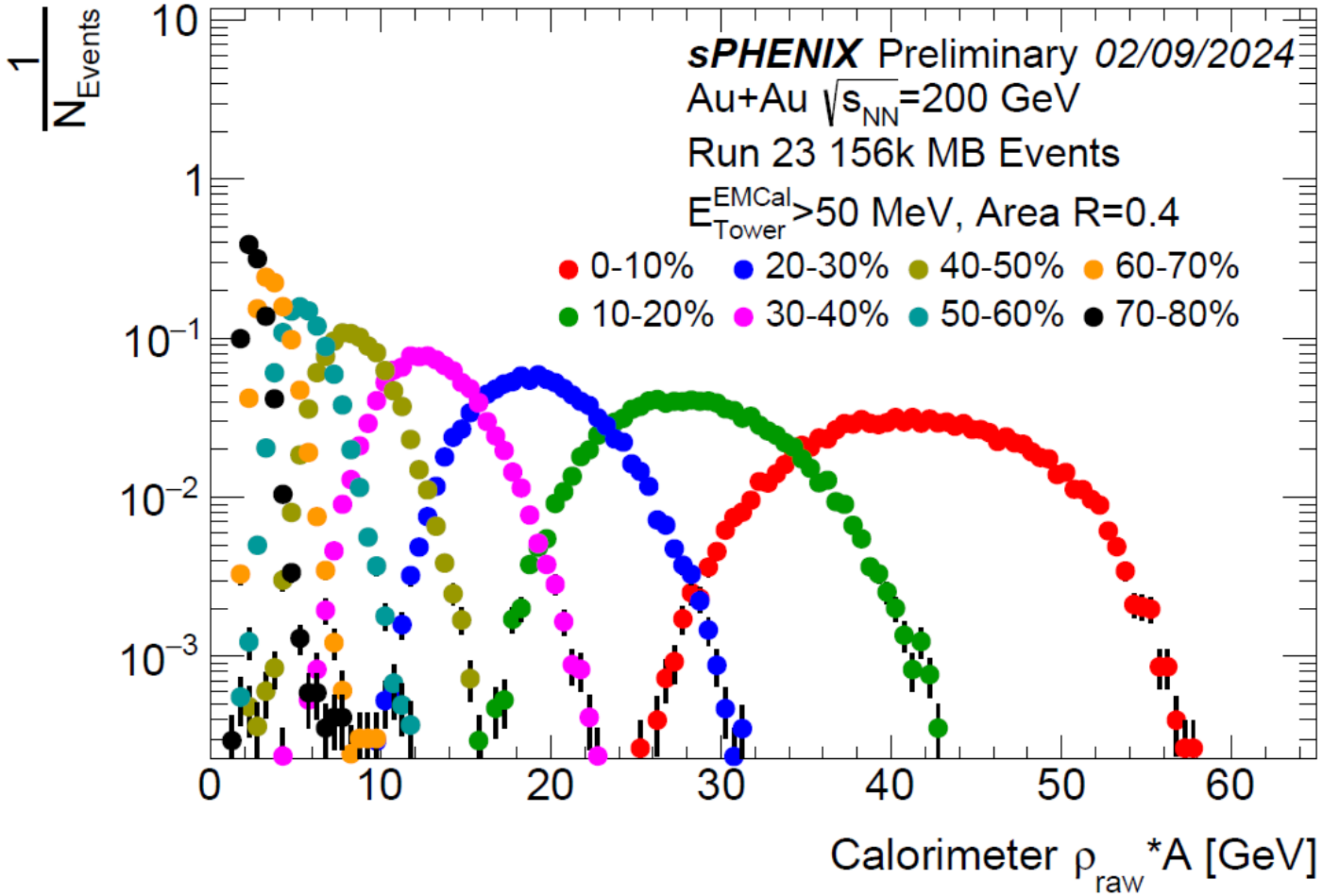


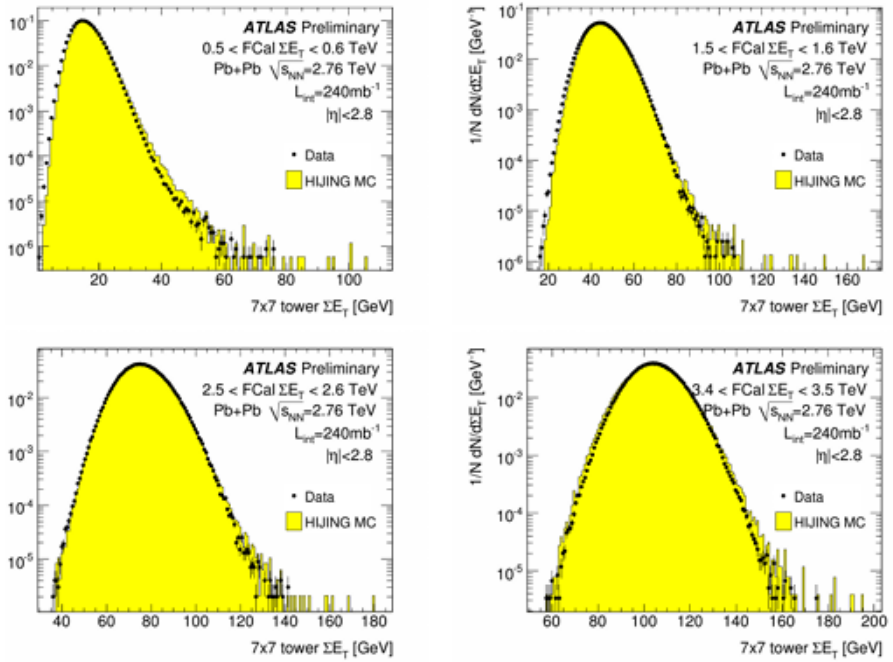


sPHENIX $\rho_A A$ Distributions

BACKUP

- Shape is consistent with our understanding of the UE

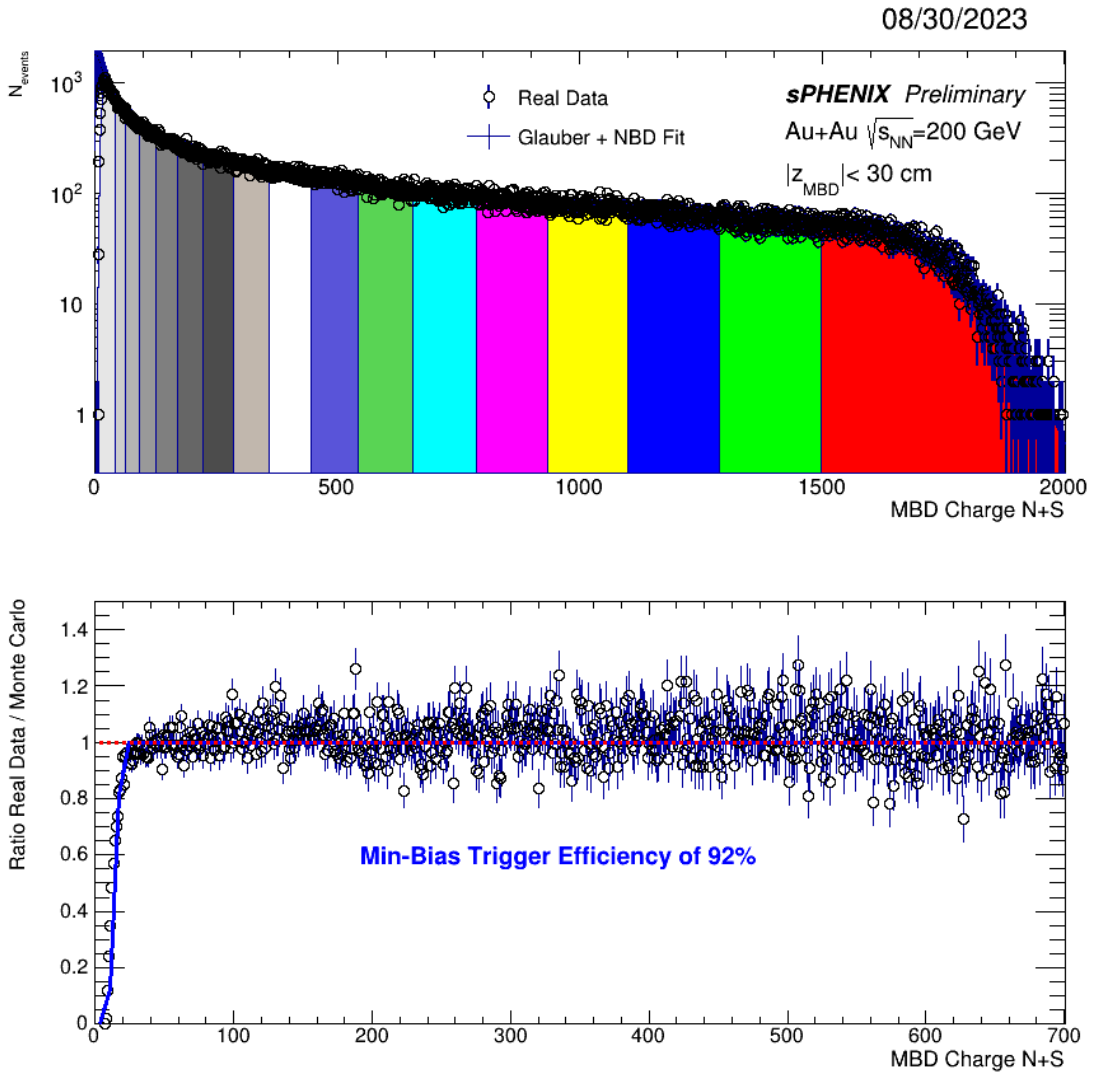




Centrality at sPHENIX

BACKUP

- Glauber model + NBD Fit matches MBD total charge distributions well
- High min-bias trigger efficiency of 92%



Event Characterization

Detectors:

- Minbias Detector (MBD)
- Zero Degree Calorimeter (ZDC)
- sPHENIX Event Plane Detector (sEPD)