Underlying event characterizations in early data and simulation with the sPHENIX detector

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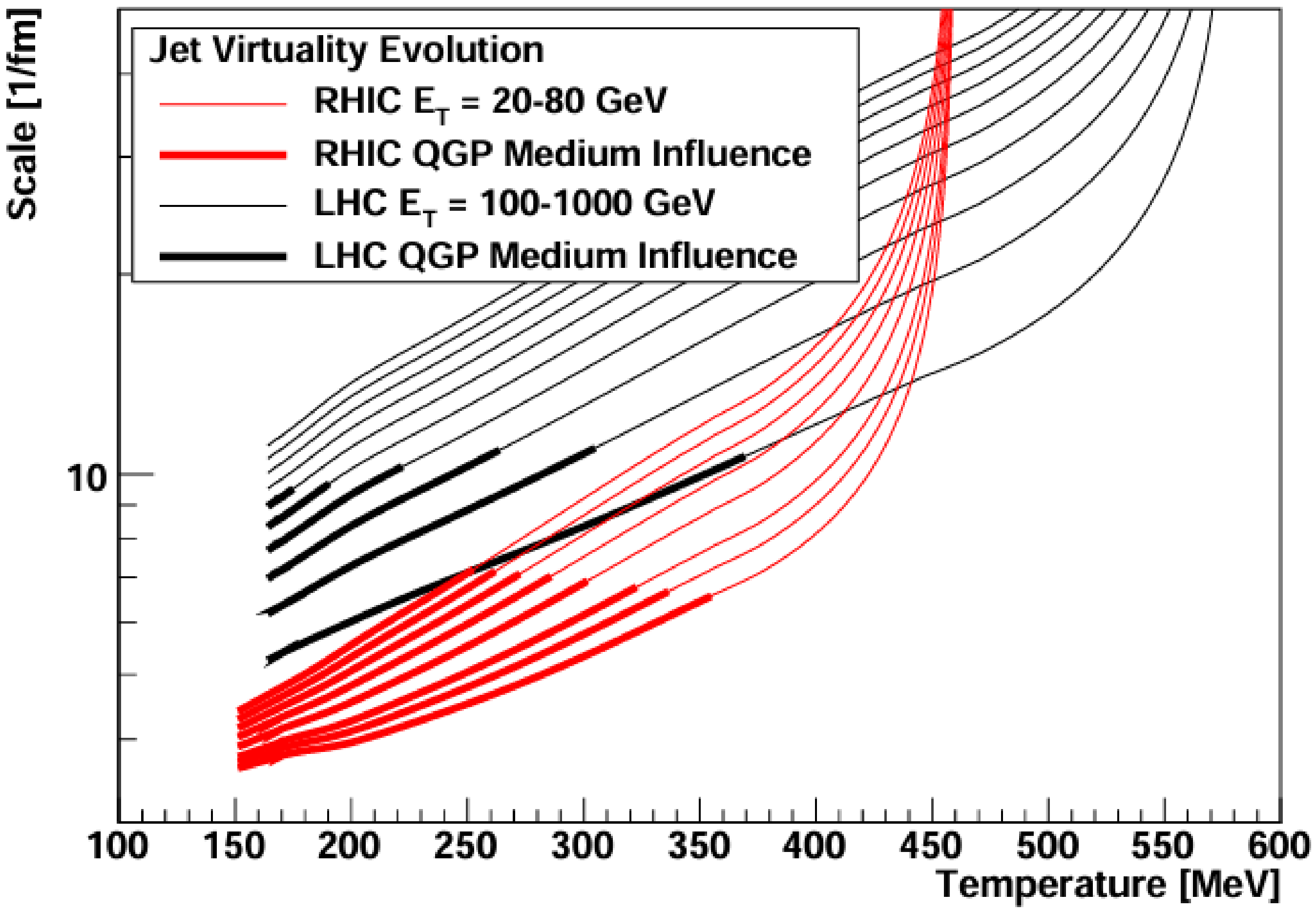
Jets at sPHENIX

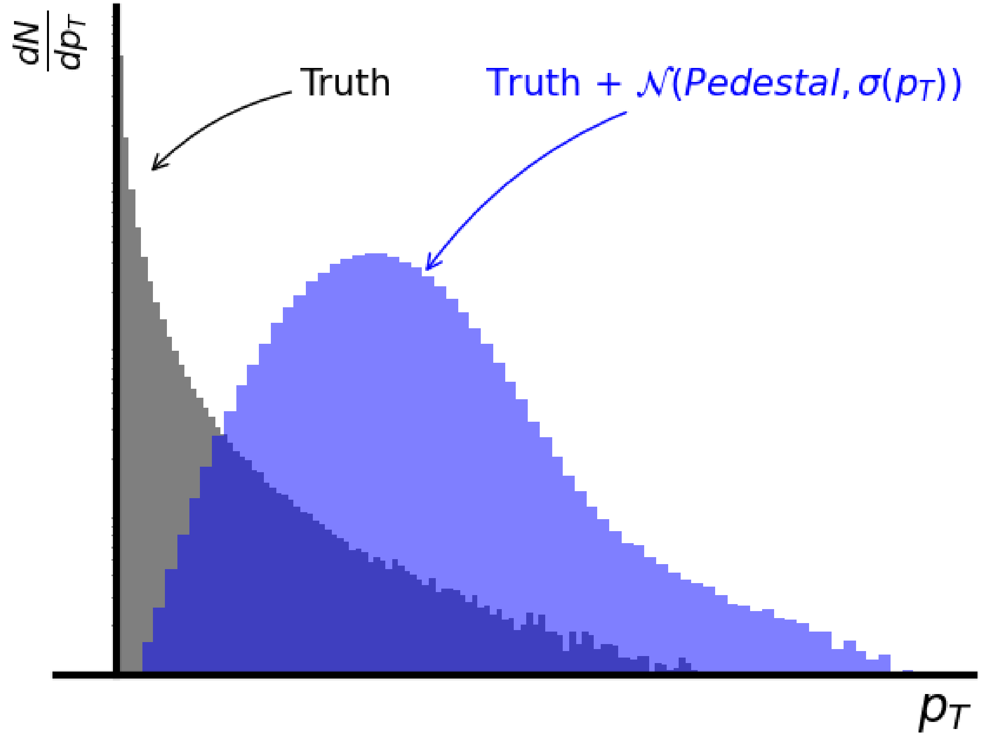
- Jets are showers of particles from initial hard scatterings before Quark Gluon Plasma (QGP) formation
- QGP at RHIC is different than QGP at LHC
- Jets at RHIC are different from Jets at LHC

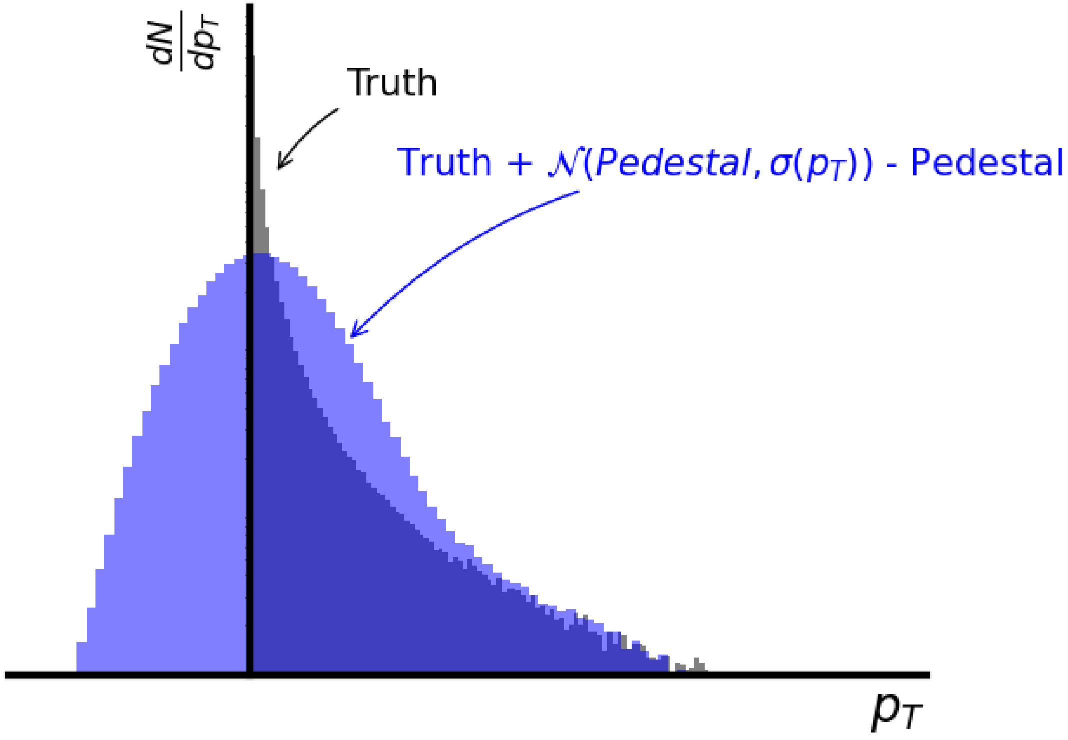
sPHENIX Proposal



Underlying Event in Heavy Ions

- Jets measurements must be corrected for soft ***fluctuating*** UE
- Pedestal is easily subtractable, fluctuations must be unfolded

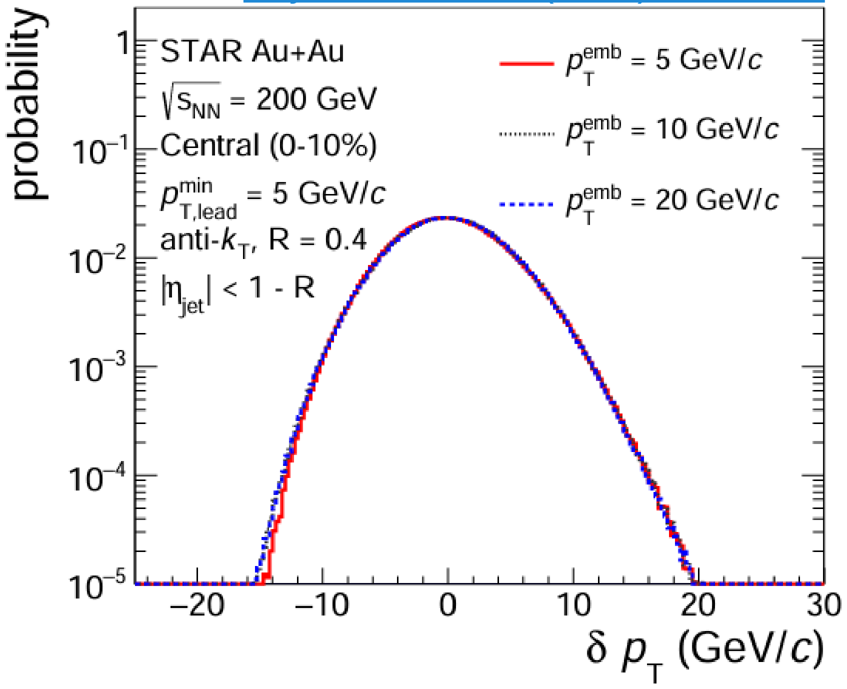




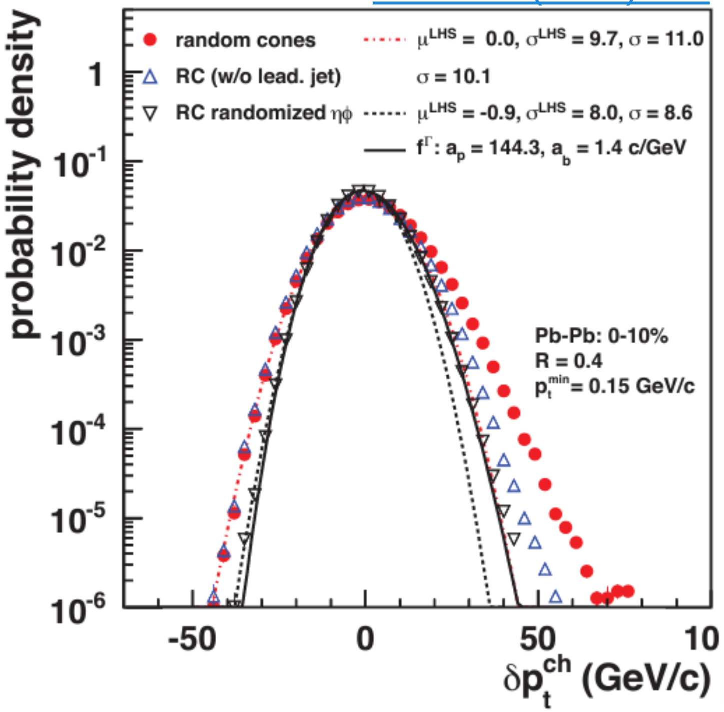
Underlying Event Characterizations

- Several methods exist to quantify heavy ion UE
- Width of $\delta p_T = p_T^{Truth} - p_T^{Reco}$ determines unfolding uncertainty and kinematic reach

Phys .Rev. C 102 (2020) 5, 054913



JHEP 03 (2012) 053



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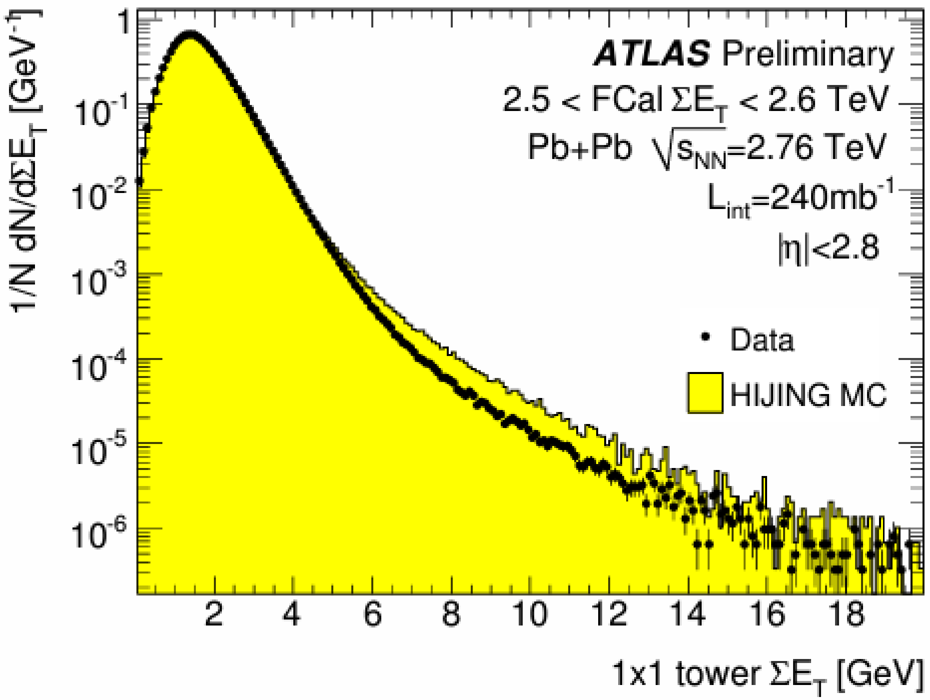
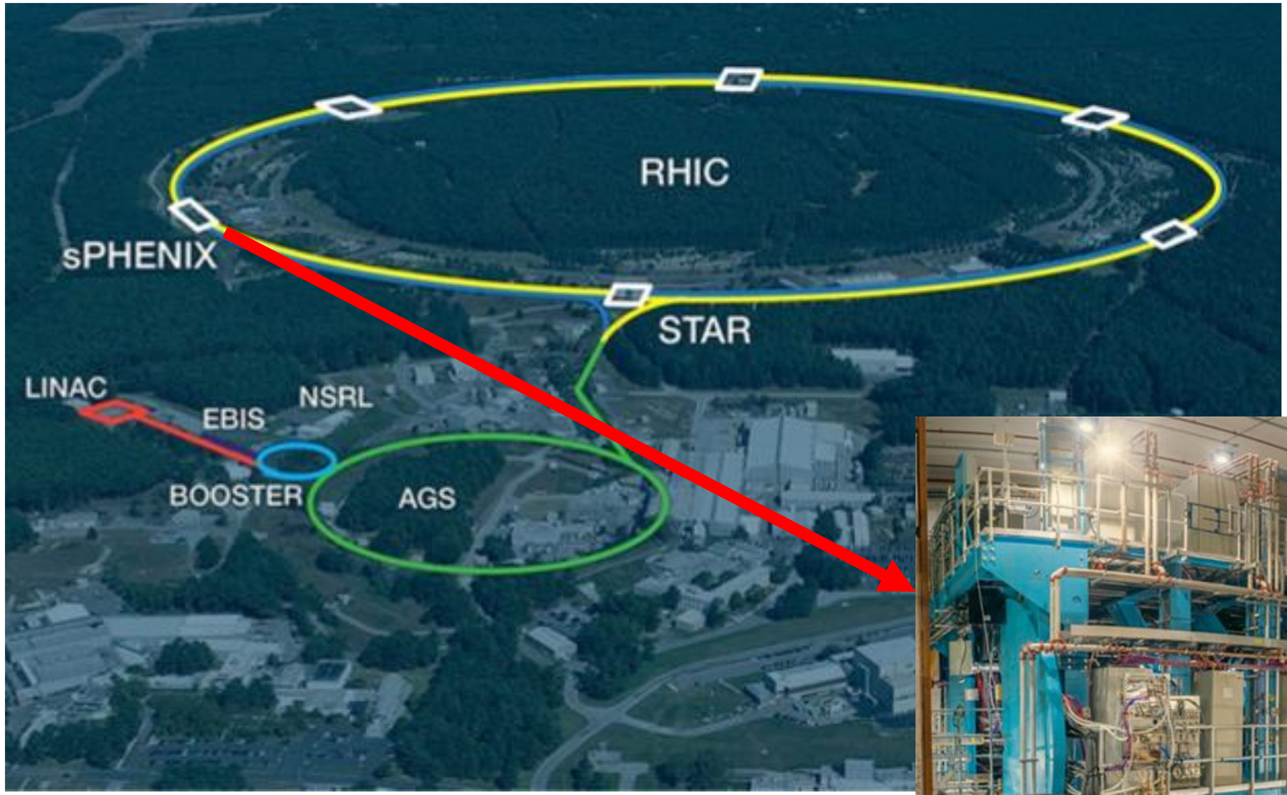


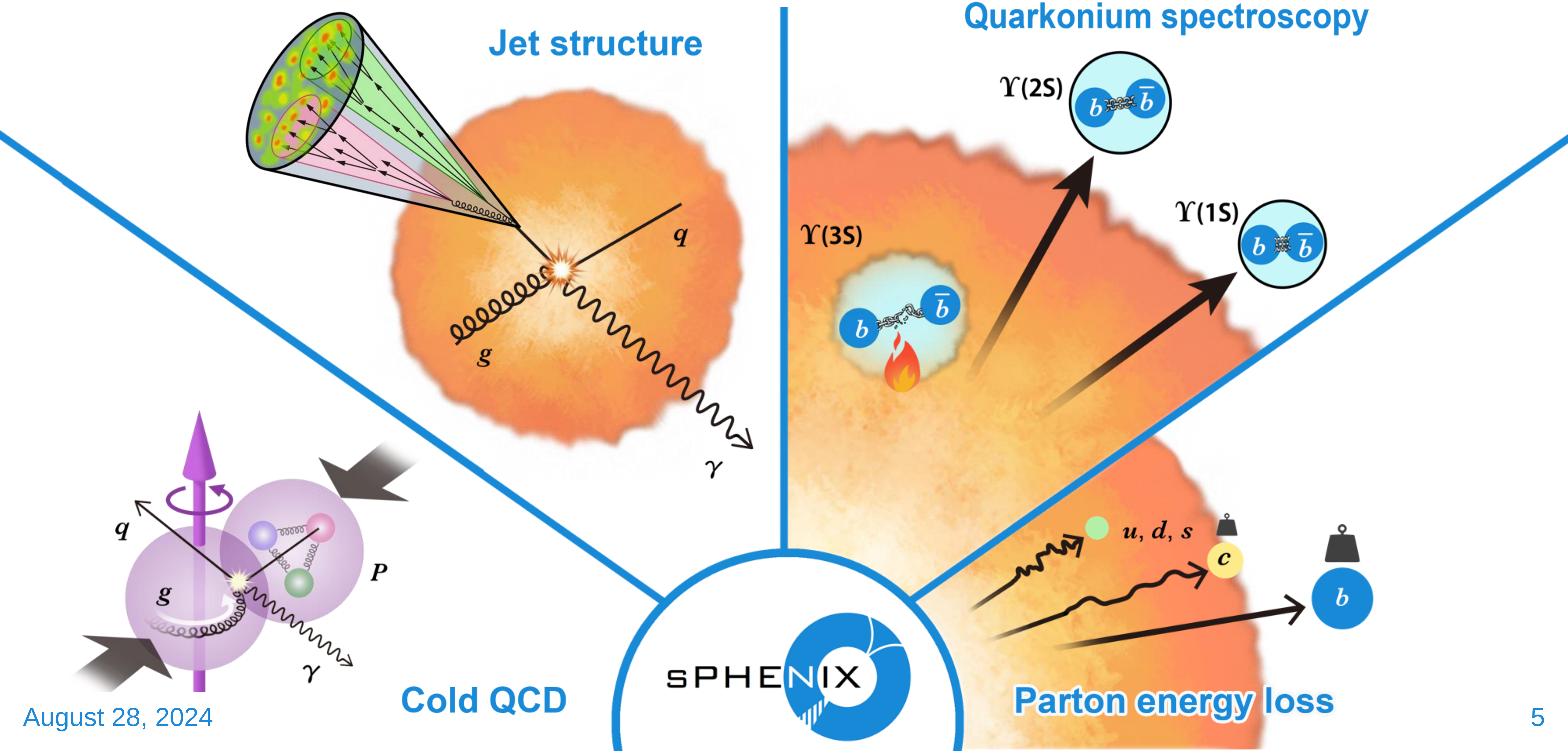
The sPHENIX Experiment

- Located at the Relativistic Heavy Ion Collider (RHIC)
- Newest high energy nuclear detector in the world
- Started commissioning in May 2023
- Started Run 2024 in April 2024



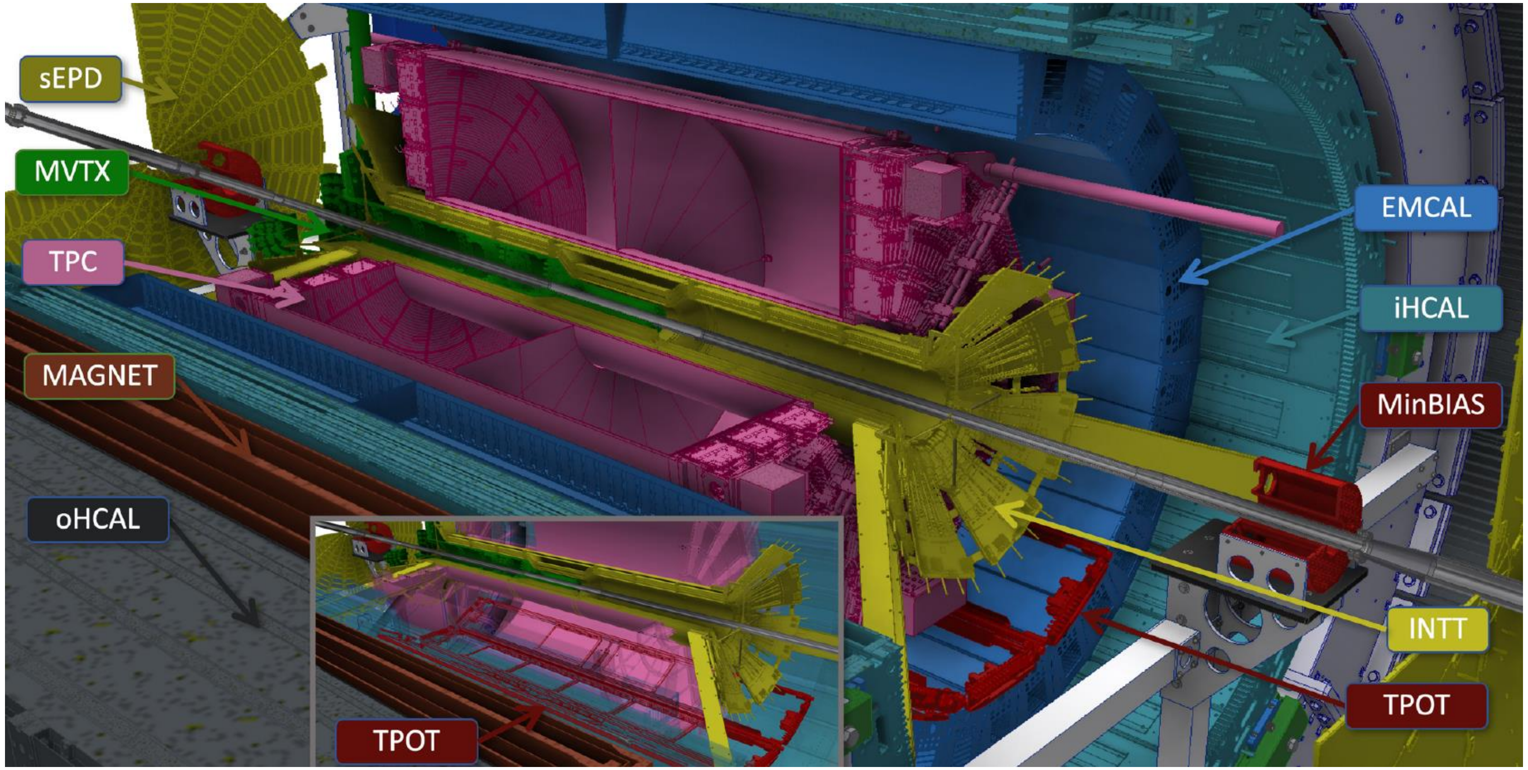
The sPHENIX Physics Program

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



sPHENIX Detector Overview

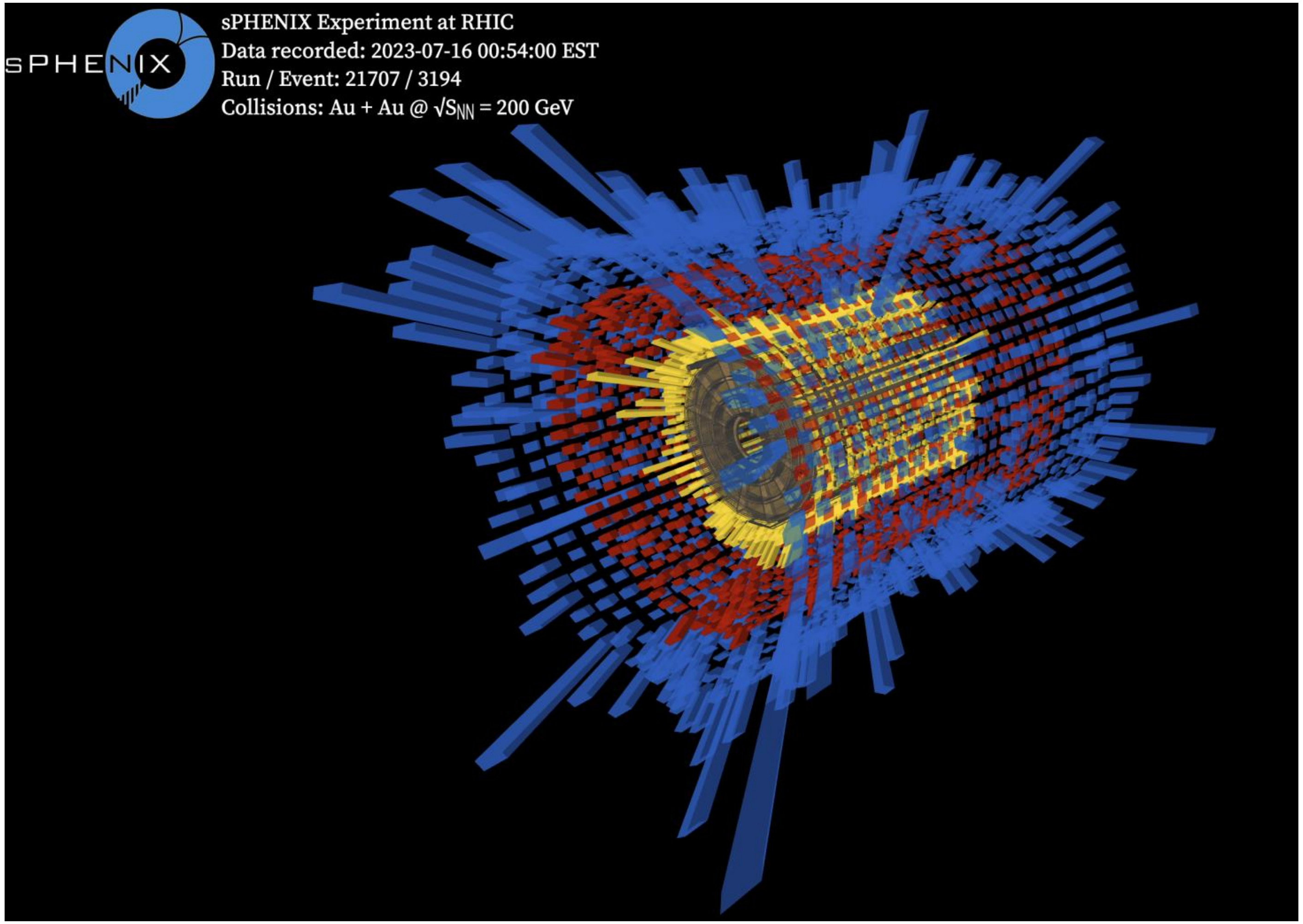
- Tracking and vertexing
  - MVTX, INTT, TPC, and TPOT
- Central calorimeters
  - EMCAL, iHCAL, and oHCAL
- Event characterization
  - MBD, sEPD, and ZDC



See Stacyann Nelson's talk *sPHENIX at RHIC*, Wednesday @ 5:00 pm

sPHENIX Calorimeters

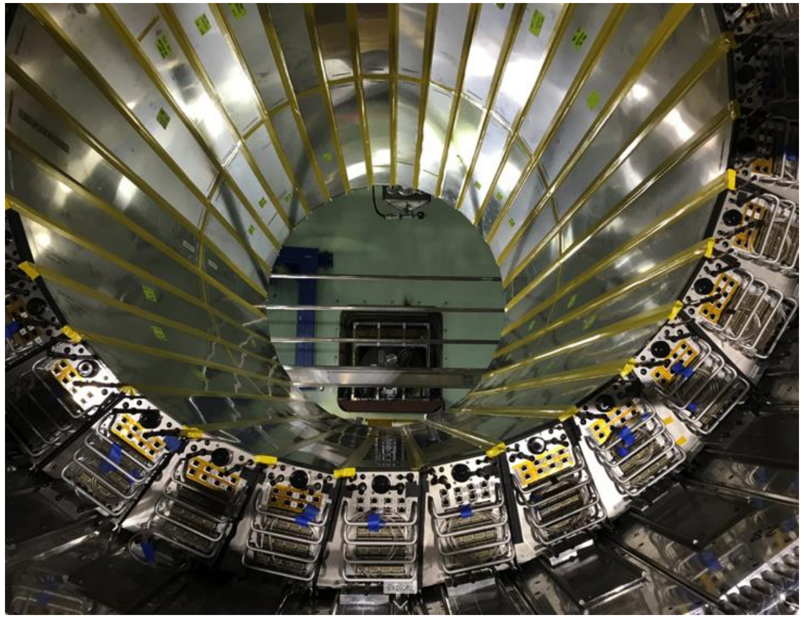
- Full azimuthal coverage electromagnetic + hadronic calorimeters with large midrapidity $|\eta| < 1.1$ acceptance
- First midrapidity hadronic calorimeter system at RHIC



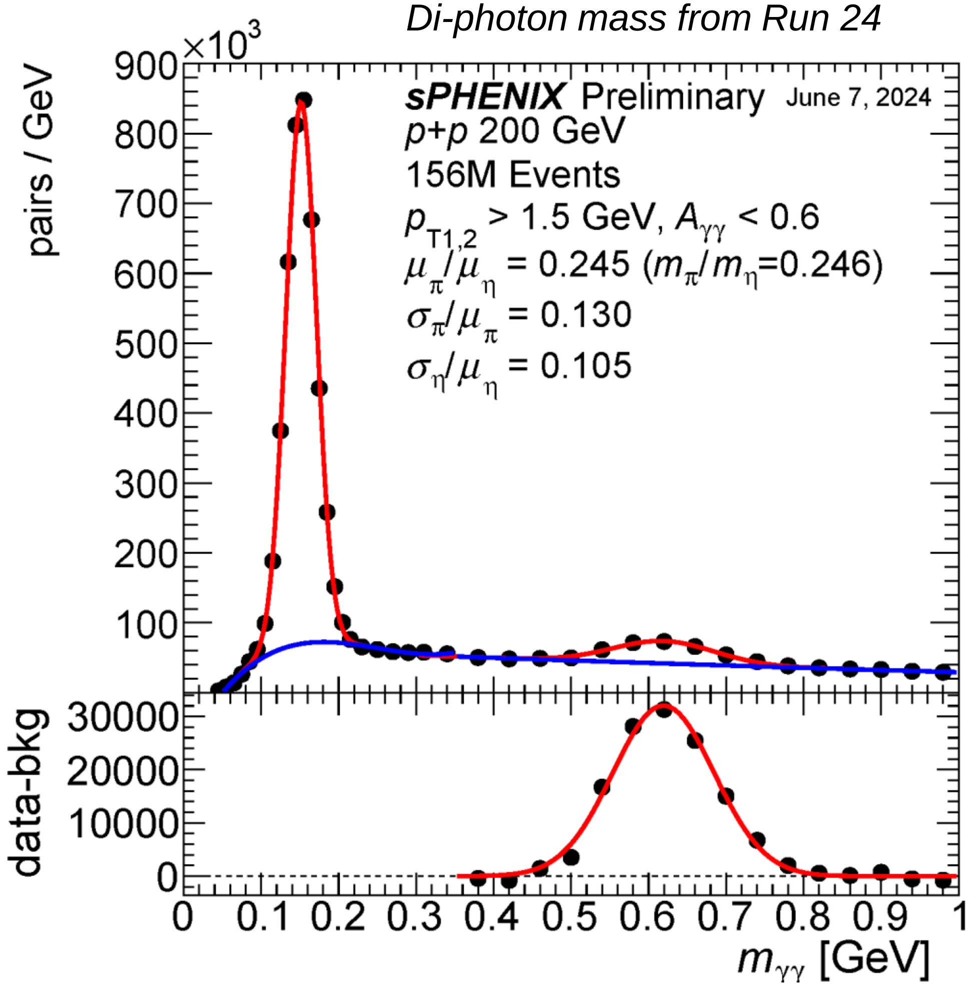
EM Calorimeter

- Tungsten powder absorber & scintillating fibers
- Tower size $\Delta\eta \times \Delta\varphi = 0.024 \times 0.024$

IEEE Trans.Nucl.Sci. 68 (2021) 2, 173-181



Di-photon mass from Run 24

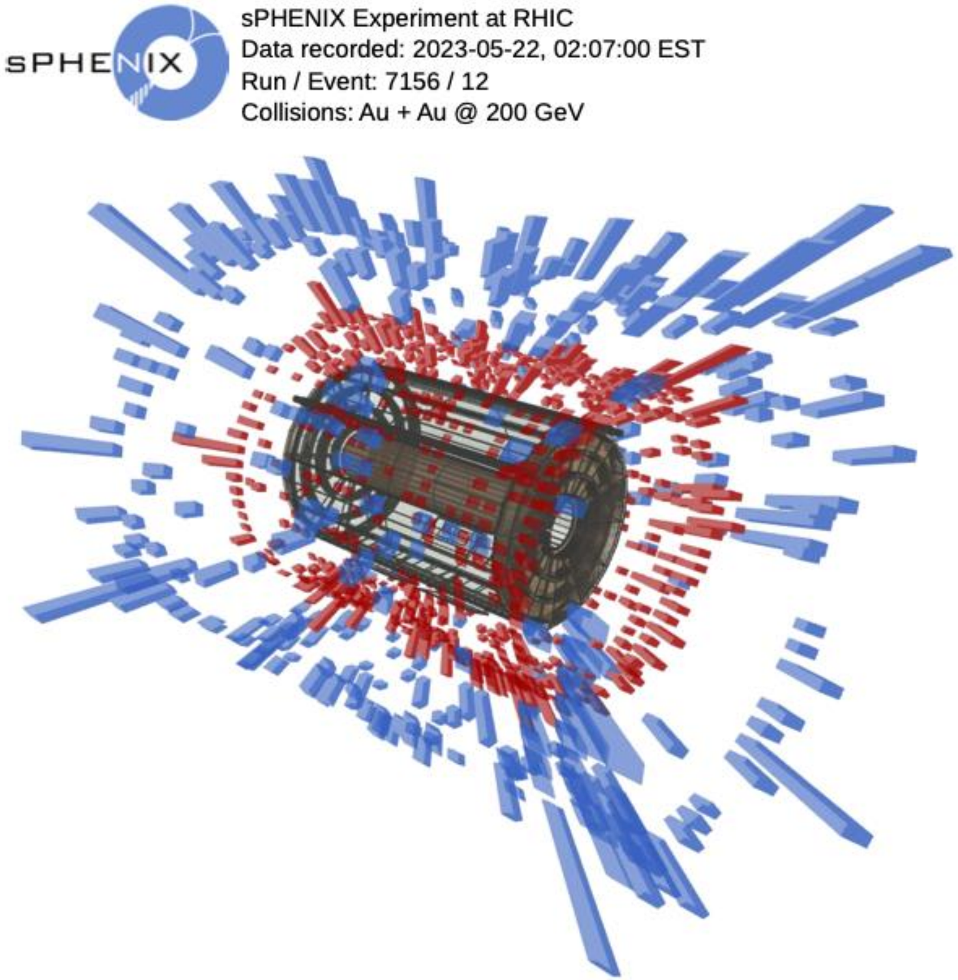


Hadronic Calorimeters

- Aluminum/steel (inner/outer) absorber plates & scintillating tiles
- Tower size $\Delta\eta \times \Delta\varphi = 0.1 \times 0.1$

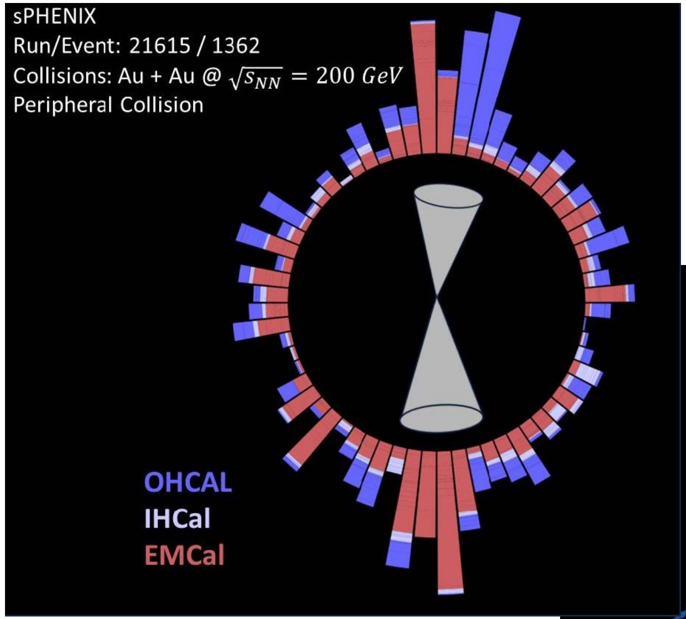
Inner HCAL 2022

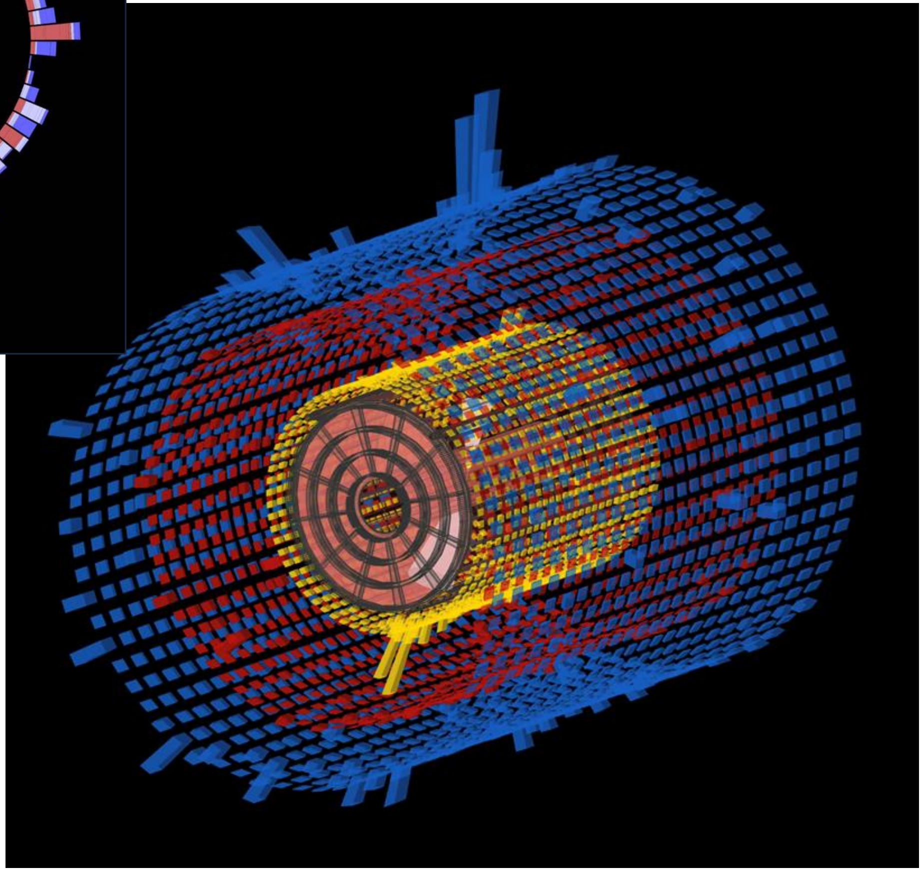
Outer HCAL 2022



sPHENIX Run 2023

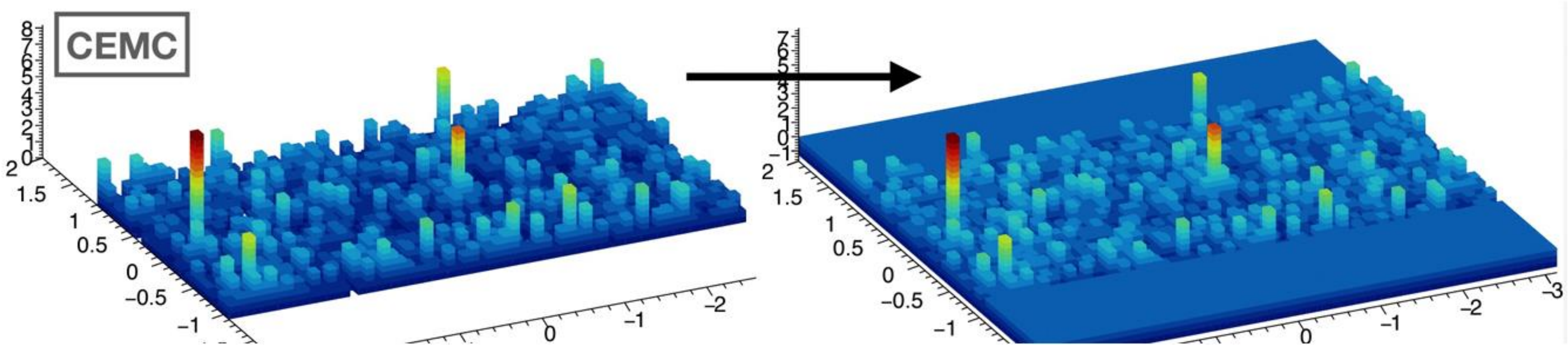
- Started commissioning Au+Au collisions in May 2023
- Early jet measurements use calorimeter towers as jet inputs
- Significant commissioning progress during and after run





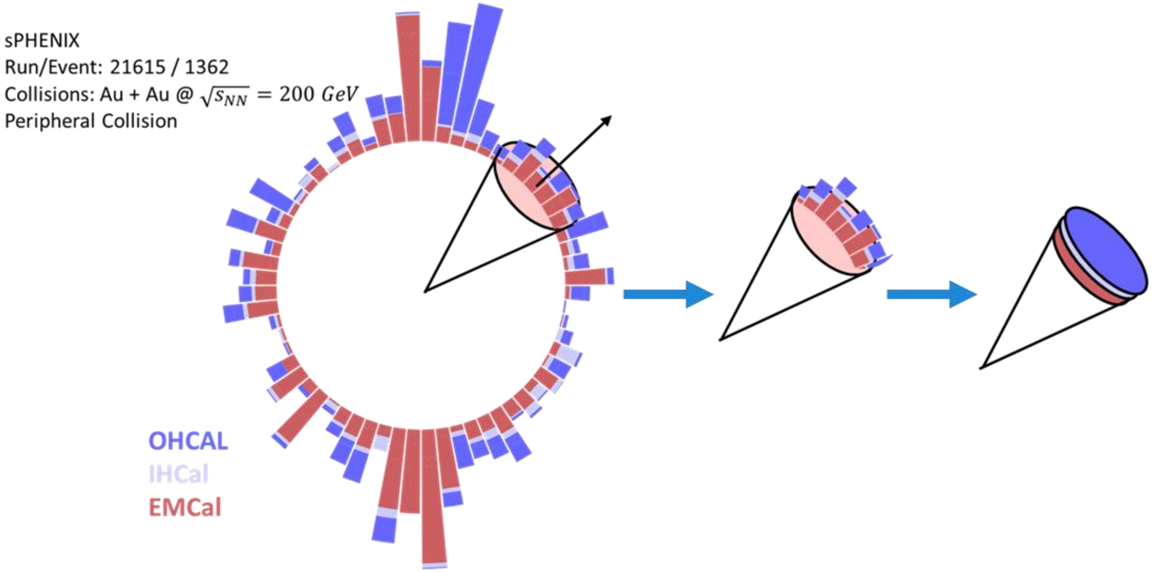
sPHENIX Characterization of UE

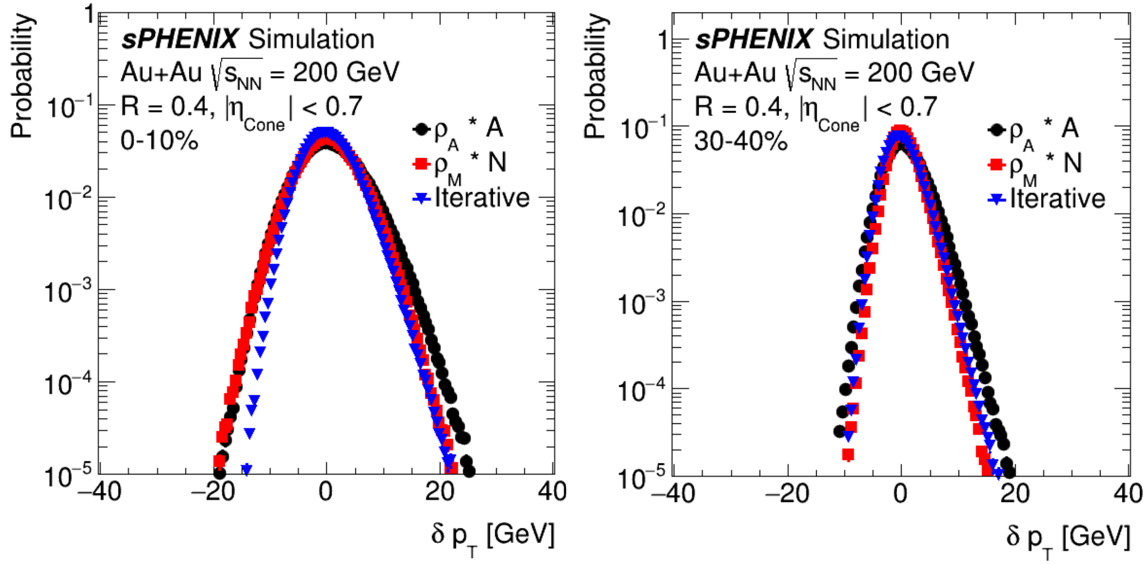
- Comparisons of UE characterizations using different methods
  - Calorimeter windows, random cones, embed probes/full jets
- Using three background sub methods
  - Multiplicity method (New!) Phys. Rev. C 108, L021901
  - Area based method (STAR, ALICE) Phys.Lett.B 659 (2008) 119-126
  - Iterative subtraction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



Random Cones

- Draw cone in random direction, sum towers within cone radii
- Compare width of fluctuations after pedestal subtraction

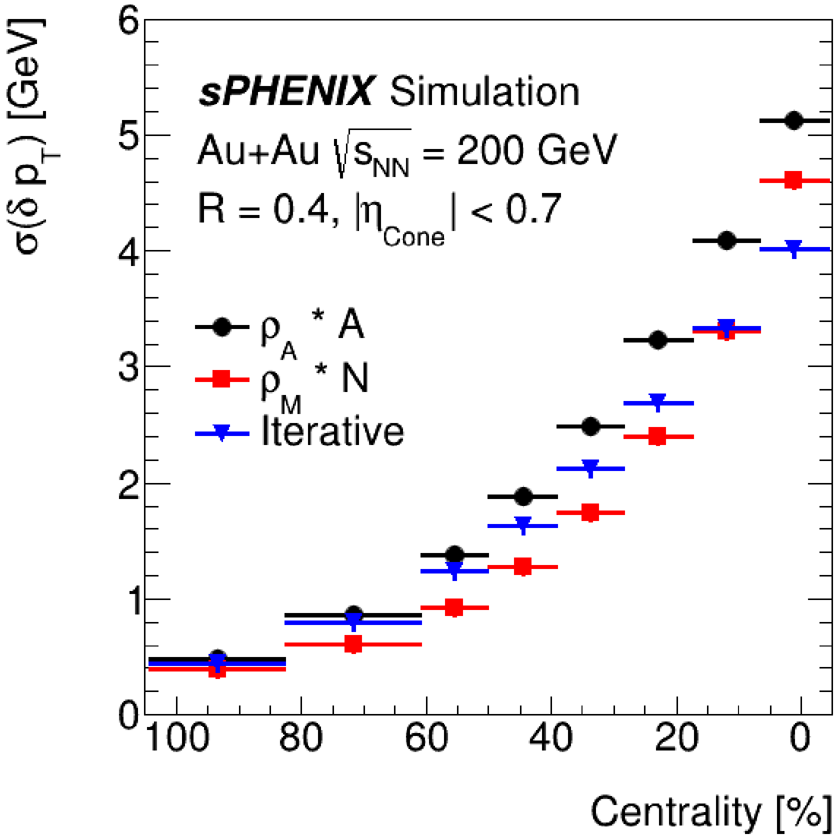




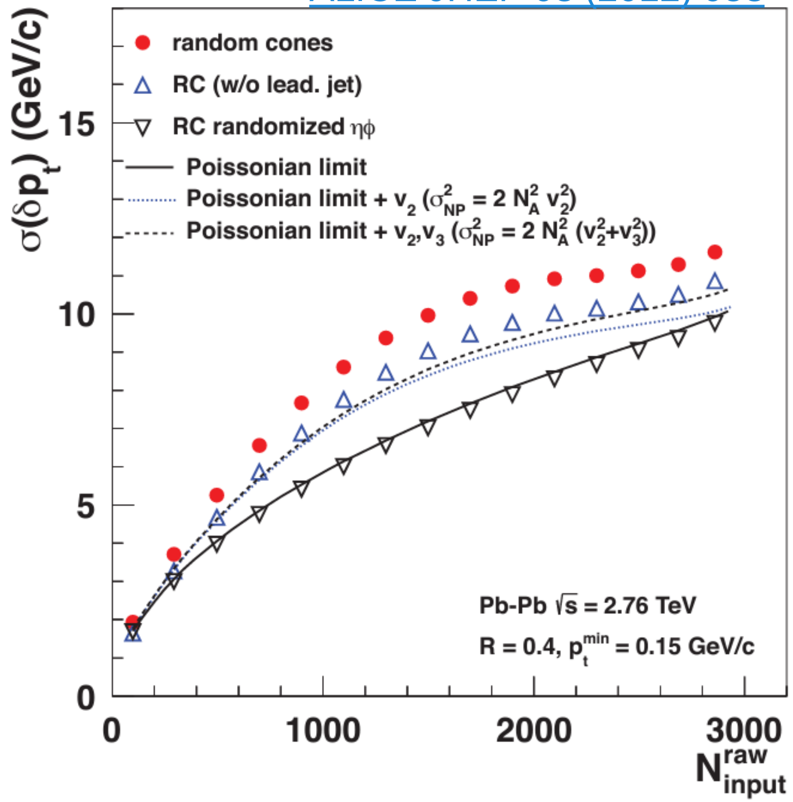
δp_T central (Left) and semi-central (Right) HIJING events

Random Cone Comparisons

- Trend of $\sigma(\delta p_T)$ is consistent to LHC random cone measurements

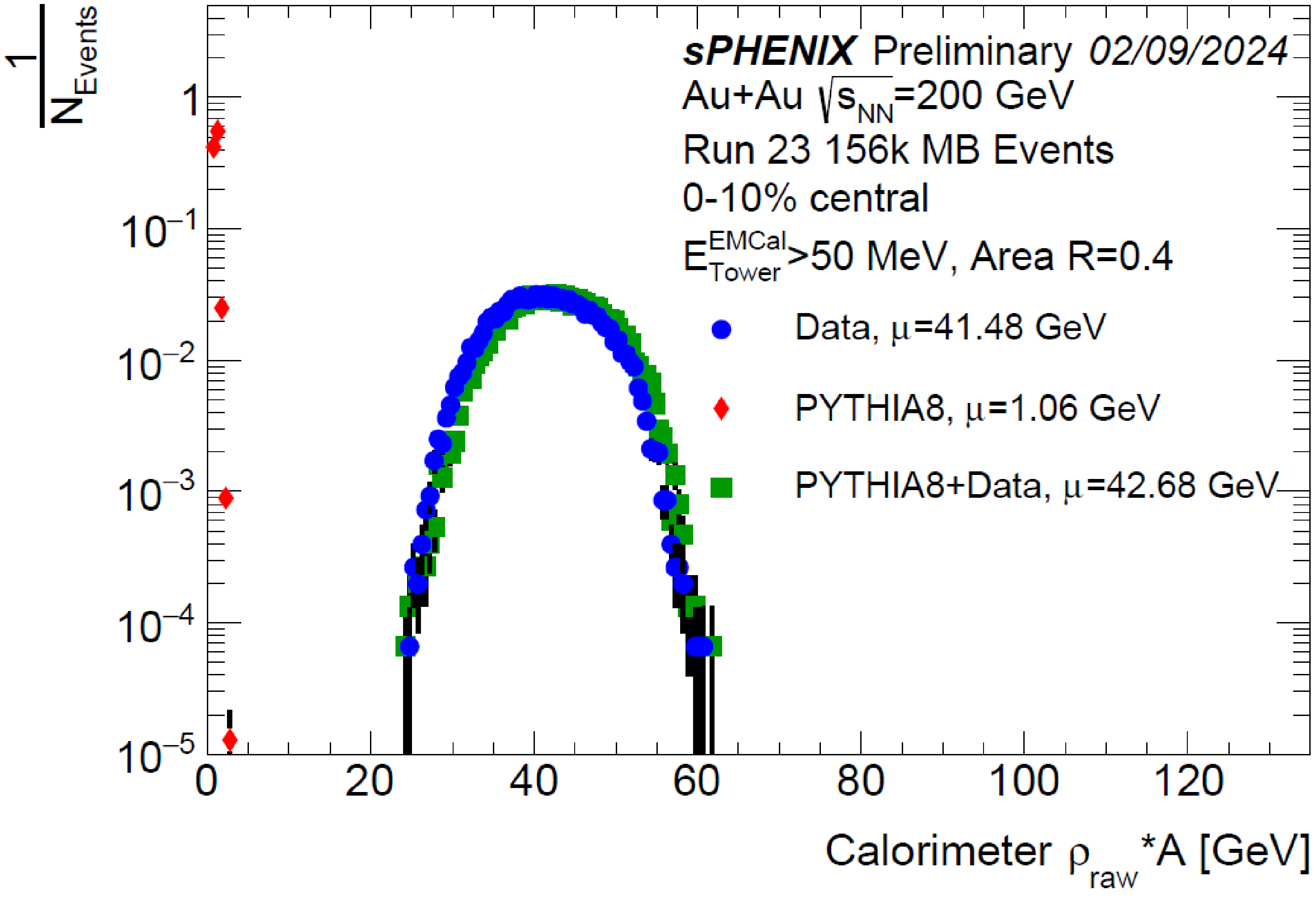


ALICE JHEP 03 (2012) 053



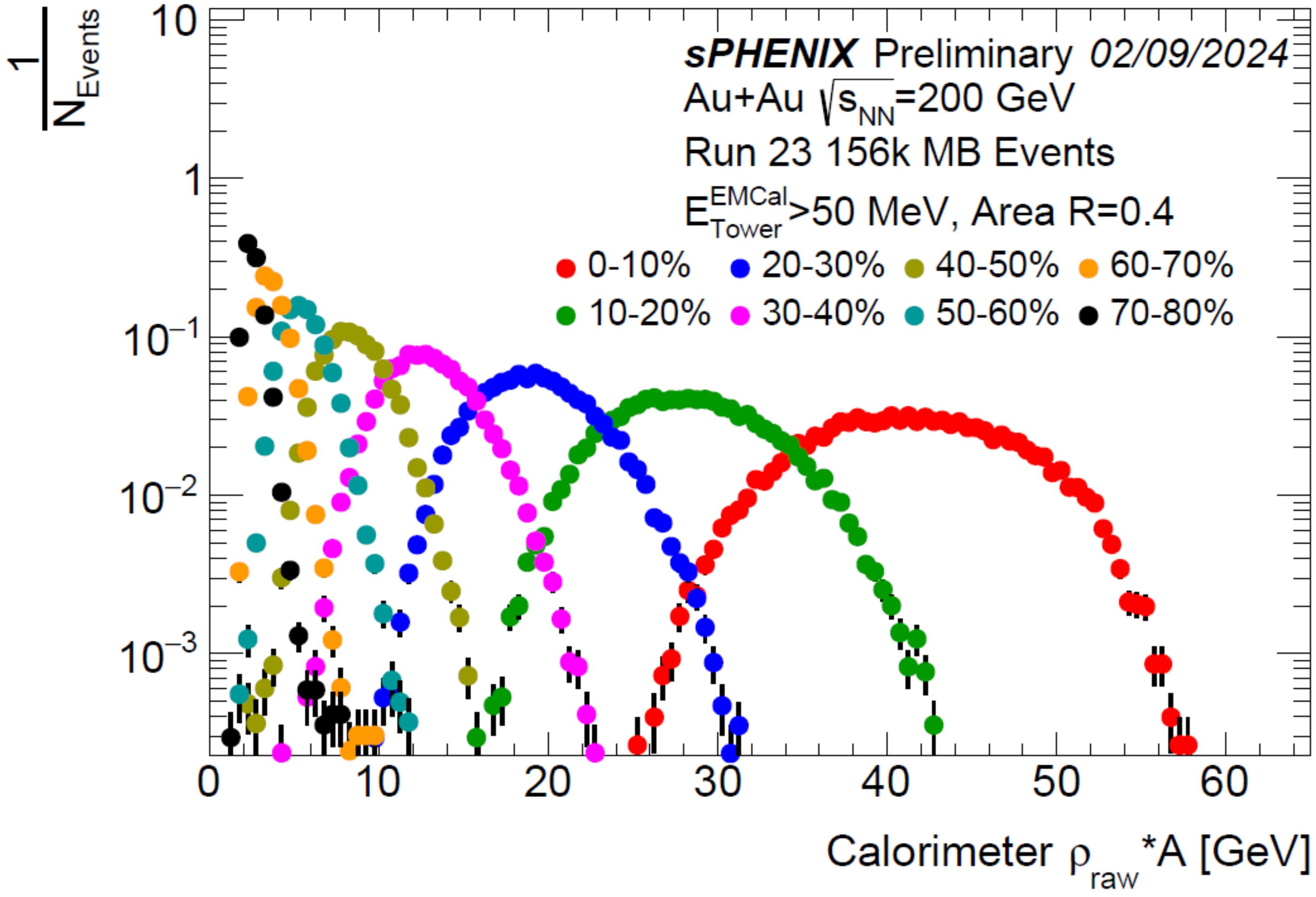
sPHENIX $\rho_A A$ in Data

- UE in calorimeter data from Run 23 shows a Gaussian-like distribution of $\rho_A A$ in central collisions
- Embedding of PYTHIA8 into data consistent with addition of UE from pp



More sPHENIX $\rho_A A$ Distributions

- Shape is consistent with our understanding of the UE



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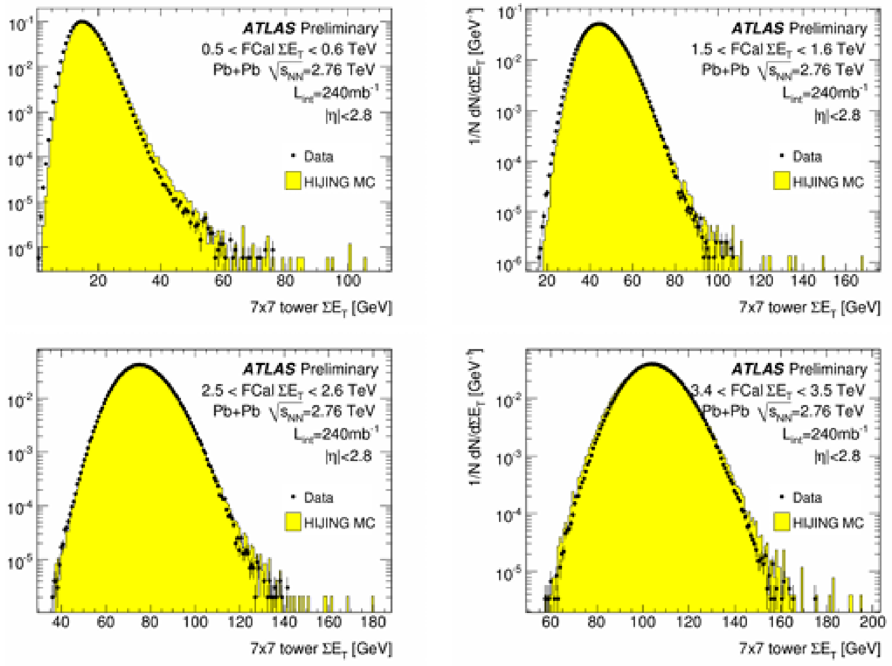
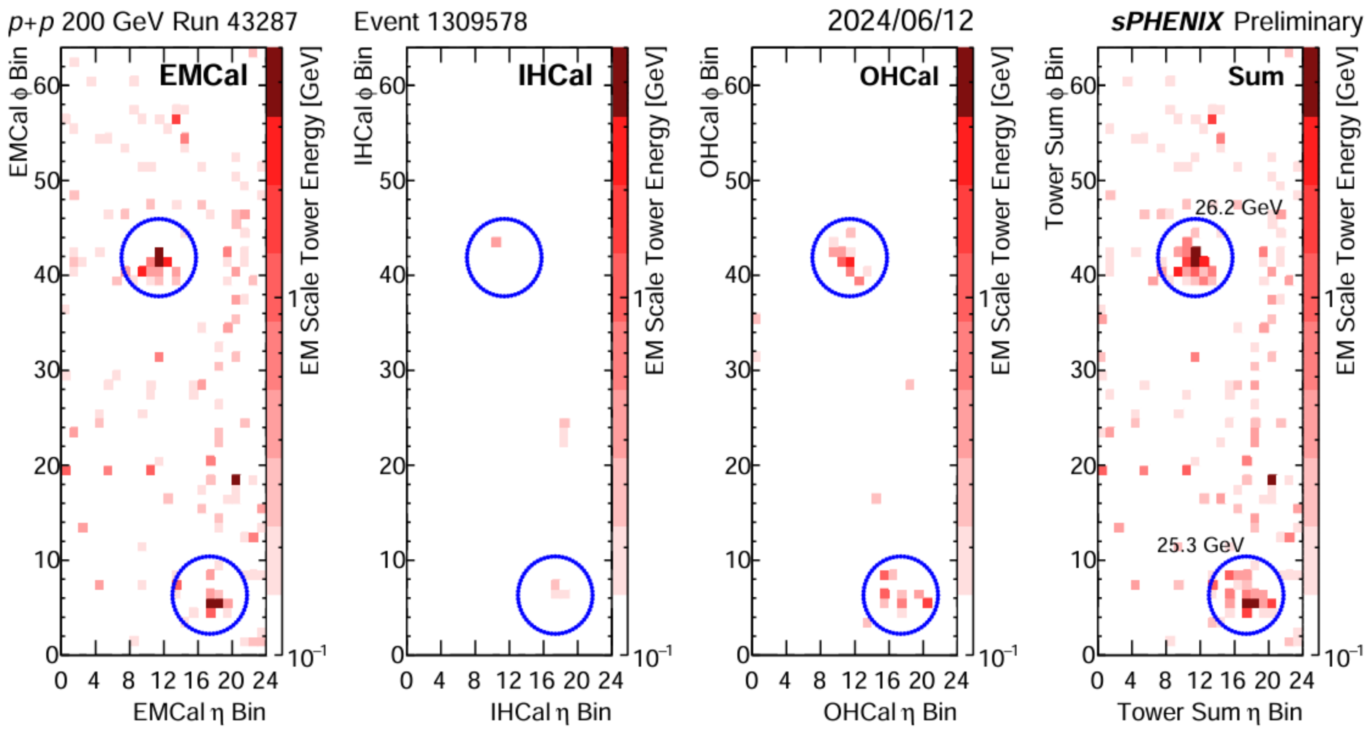
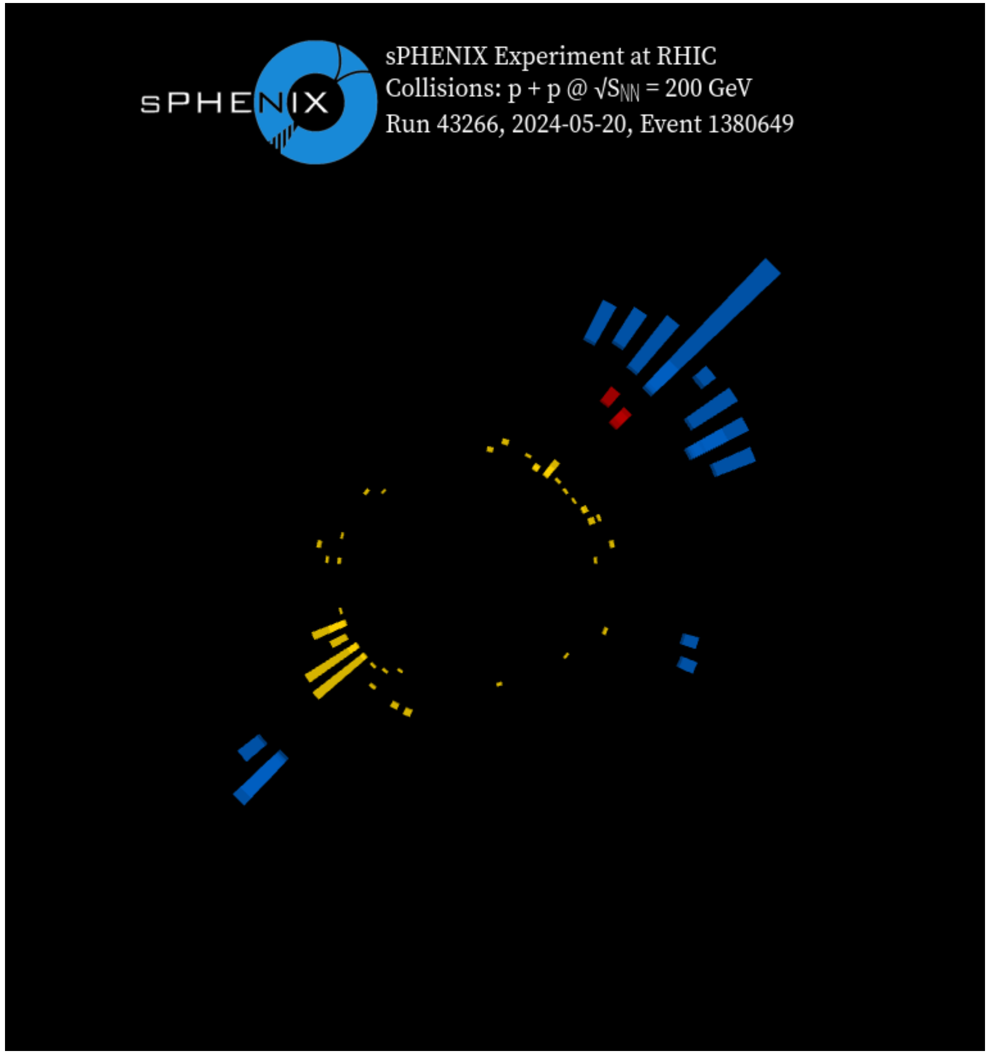


sPHENIX Run 24/25

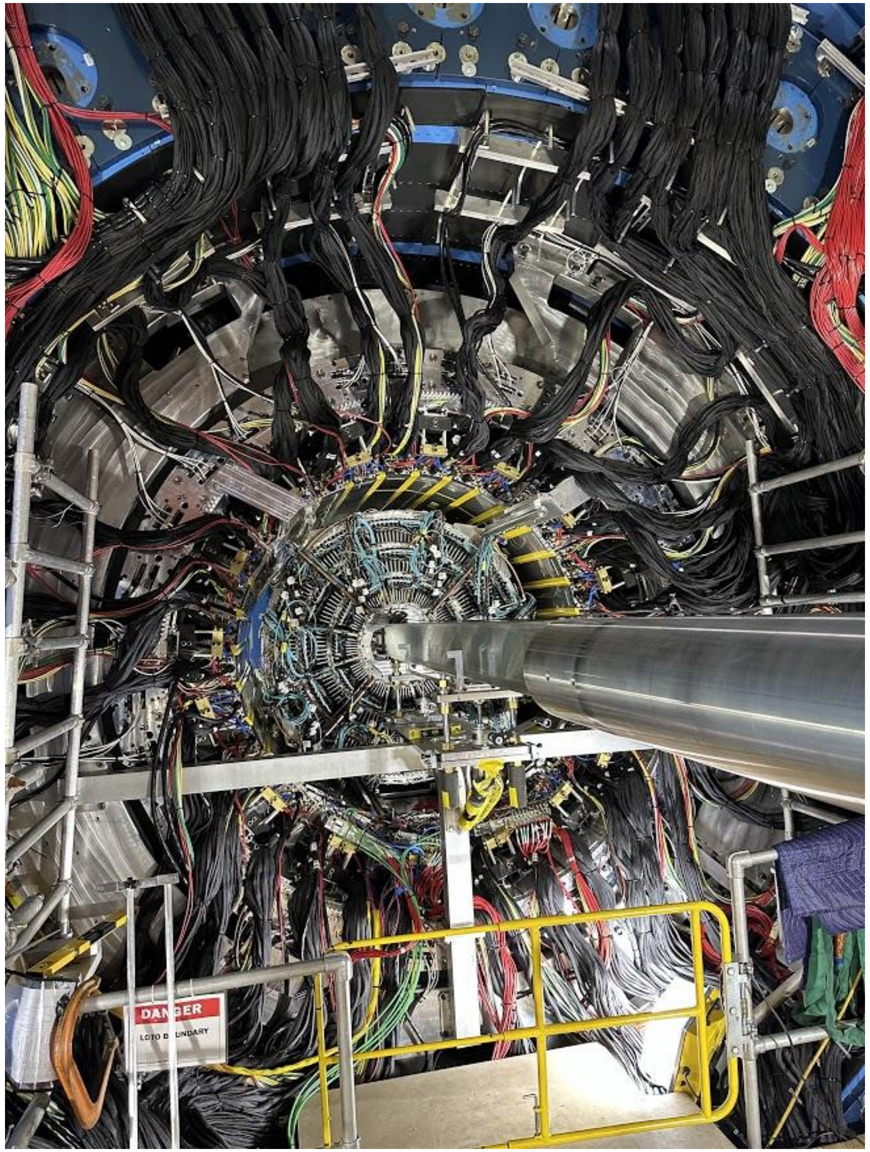
- On pace to exceed calorimeter luminosity projections
  - CalorimeterJet measurements to high p_T and precision measurements at low p_T





Conclusions

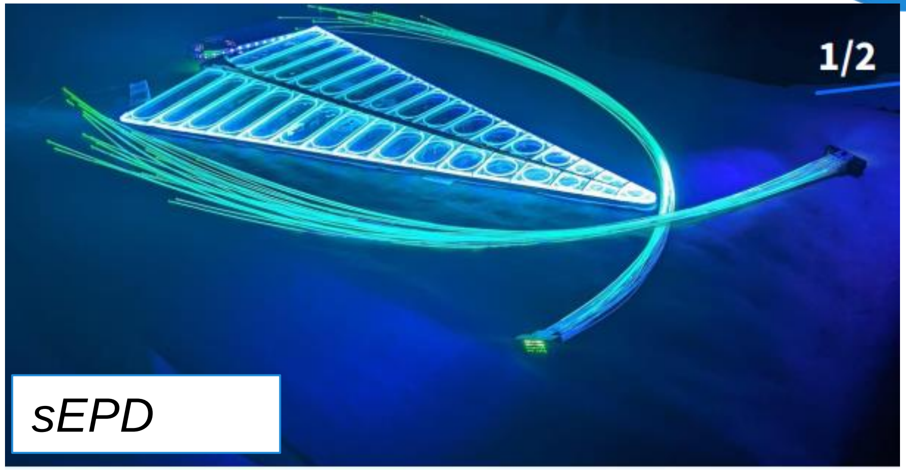
- sPHENIX is well equipped to perform precise and significant jet measurements
- Considerable progress has been made toward commissioning using Run 23 data
- Good understanding of the underlying event and how to correct for it
- Many exciting measurements to come with pp and Au+Au data in Run 24 and Au+Au in Run 25!

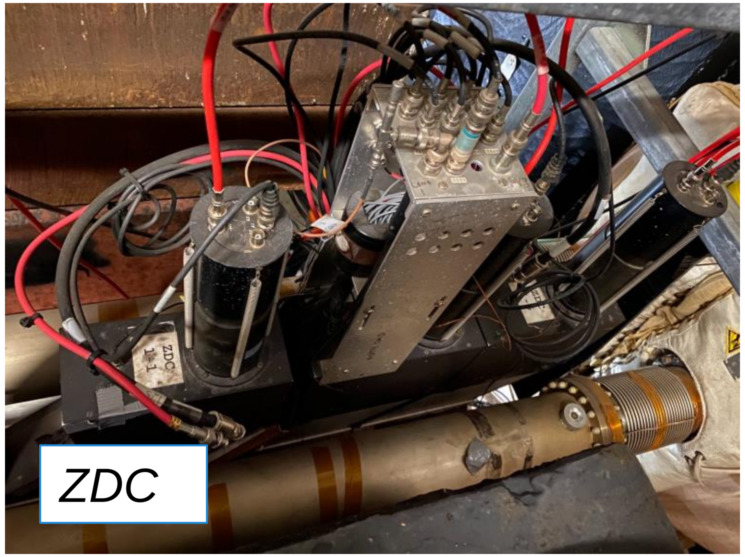


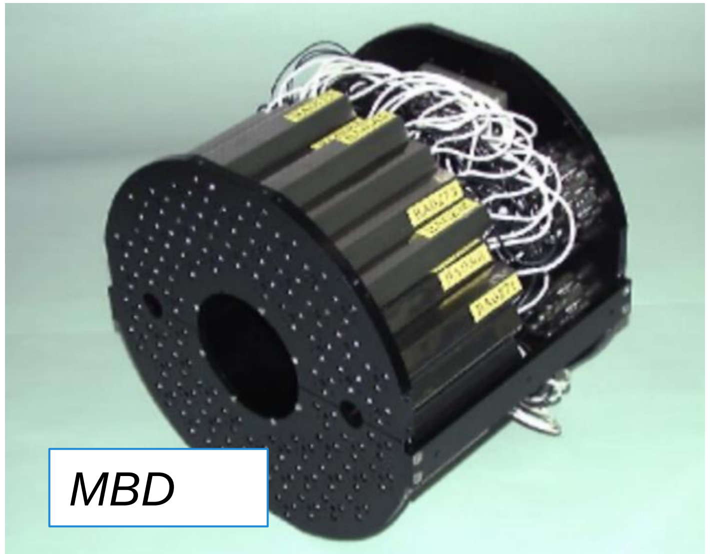
BACKUP

Event Characterization

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

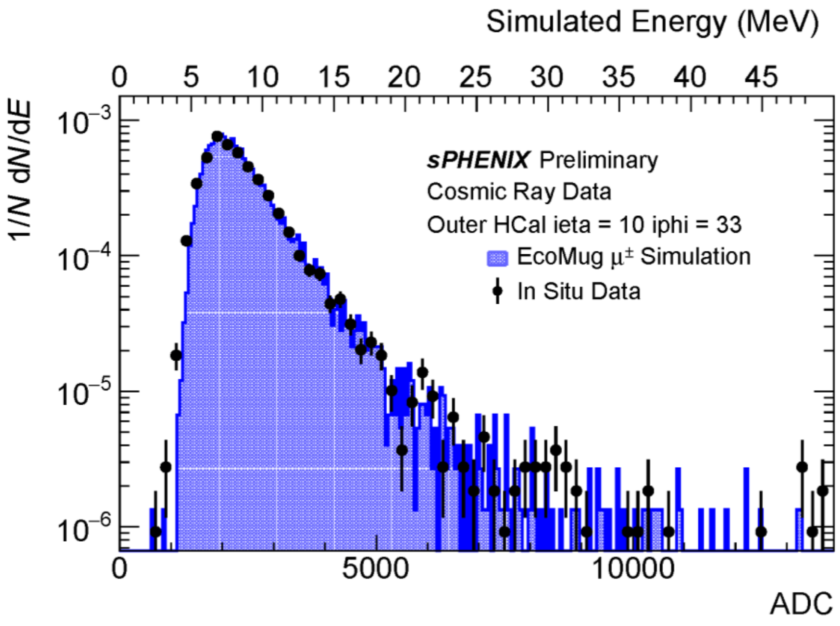




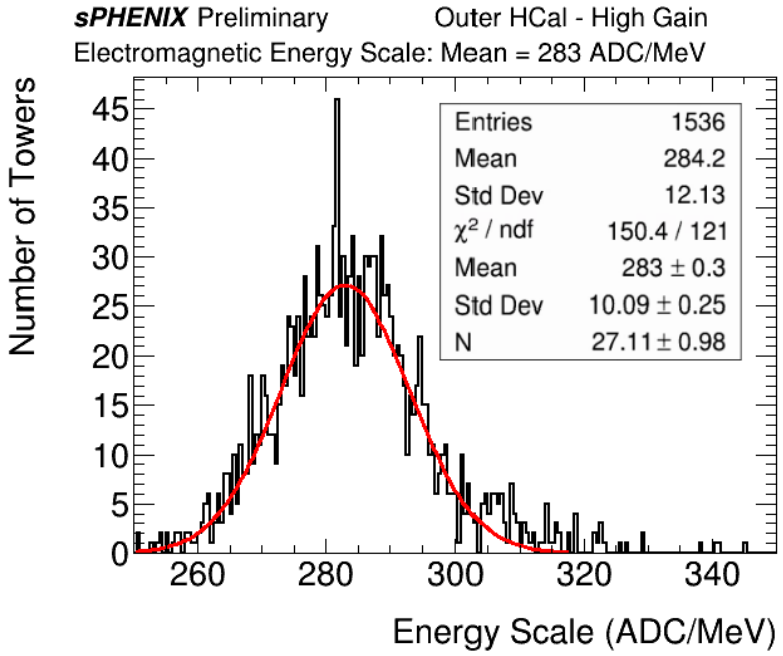


Hadronic Calorimeter Calibration

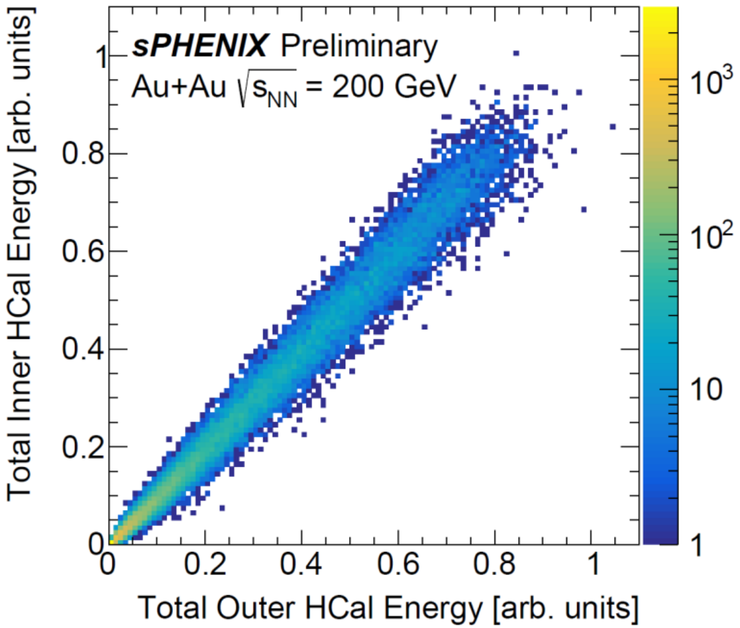
- HCAL is calibrated and ready for physics



Calibrated outer HCal data from cosmic rays matches simulation



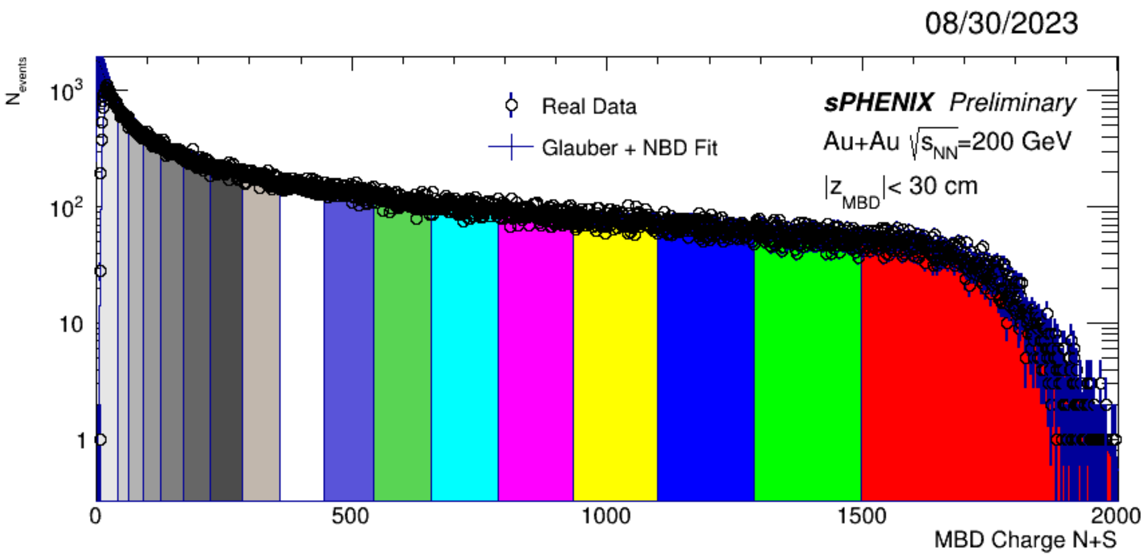
HCal calibrated to EM scale with cosmic rays

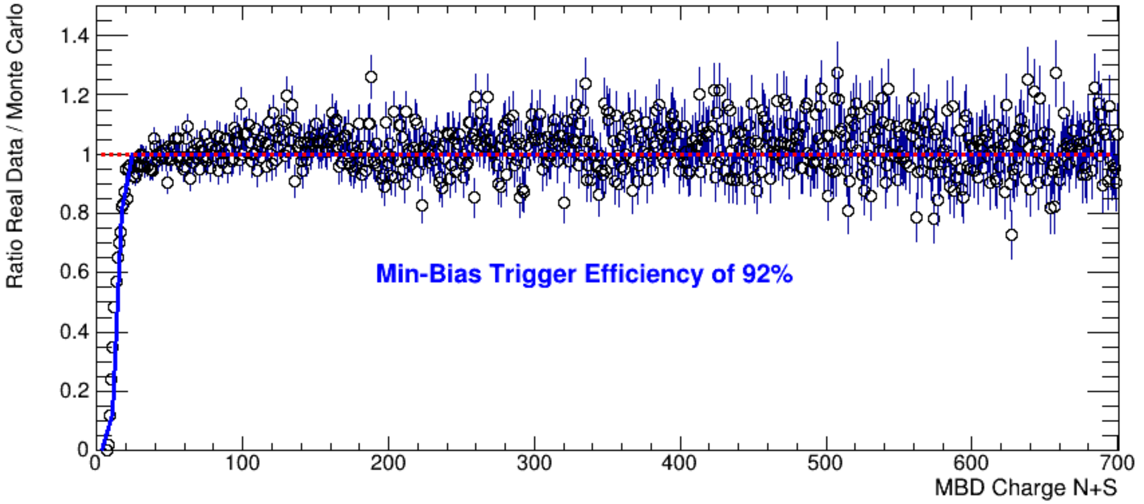


Good correlation between inner and outer HCals

Centrality at sPHENIX

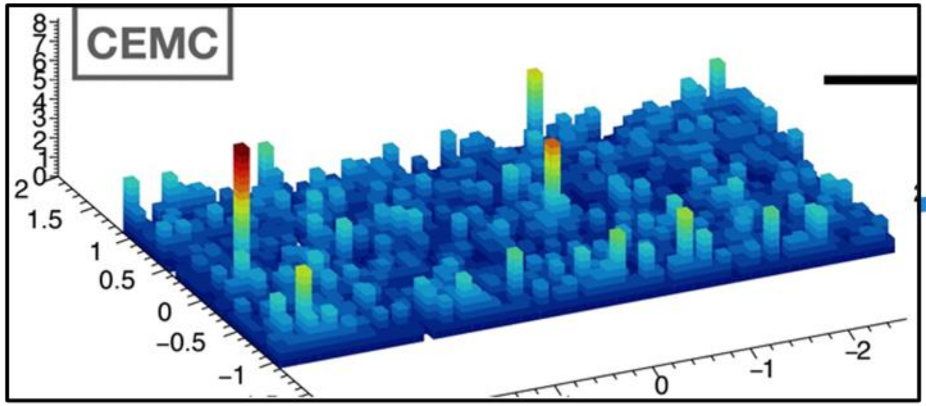
- Glauber model + NBD Fit matches MBD total charge distributions well
- High min-bias trigger efficiency of 92%





Iterative UE subtraction

[Phys. Rev. C 86, 024908]



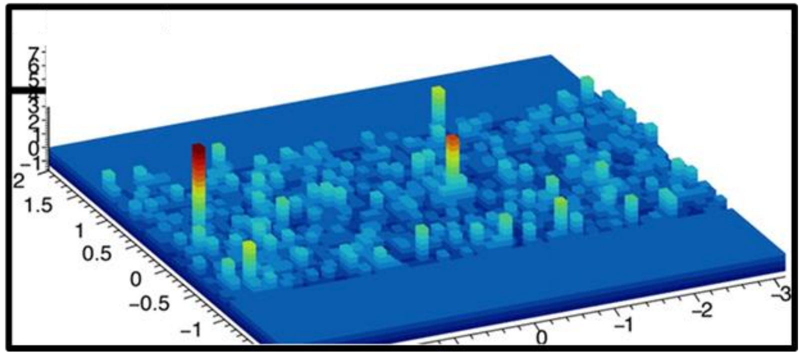
1) Reconstruct R = 0.2 seed jets

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



Area based subtraction

Phys.Lett.B 659 (2008) 119-126

- $p_T^{Corr} = p_T^{Raw} - \rho_A \cdot A$
- $p_{T,Bkgd} \sim \rho_A \cdot A \pm \sigma\sqrt{A}$
- **$\boldsymbol{\rho_A}$ is the momentum density of the event.**

1. Uniformly distribute ghost particles throughout acceptance
2.
   - Jet find with k_T algorithm
   - Throw out 2 hardest jets
3. Take the median of $\frac{p_T^{k_T\,Jet}}{A_{k_T\,Jet}}$

Multiplicity subtraction

Phys. Rev. C 108, L021901

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