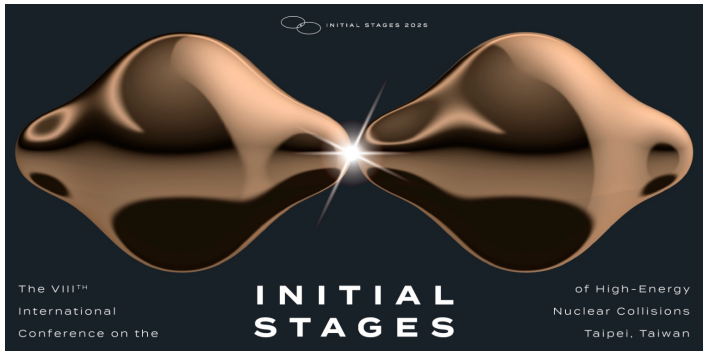


sPHENIX measurement of underlying event production in p+p collisions at 200 GeV

🧋Initial Stages 2025 Flash Talk🧋

Emma McLaughlin for the sPHENIX Collaboration

September 12th, 2025

COLUMBIA UNIVERSITY
IN THE CITY OF NEW YORK

Relationship between underlying event and hard scattering in p+p collisions

Numerous previous studies measure the relationship between the UE and hard scattering in p+p collisions:

- Tune generators for collisions at LHC/RHIC
- Study dominant UE processes for different jet p_T and $\sqrt{s}$

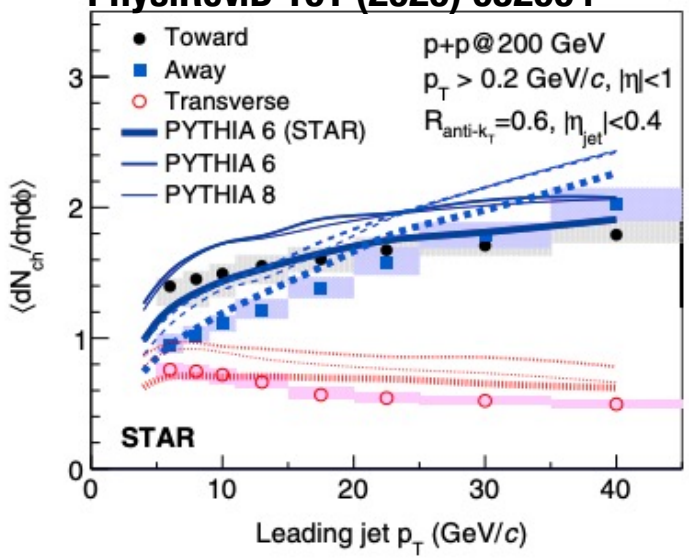
Transverse region $<\frac{dN_{ch}}{d\eta d\phi}>$ and $<\frac{\Sigma E_T}{\delta\eta\delta\phi}>$ measurements used as UE proxy

At RHIC energies, STAR transverse region $<\frac{dN_{ch}}{d\eta d\phi}>$ decreases with jet p_T

- Lower UE w/ possible hints at energy conservation behavior between the UE and hard scattering

sPHENIX with high statistics p+p data taking in Run 2024 and full central region EMCal + HCal coverage is primed to study UE and hard scattering correlation at very high jet p_T

Phys.Rev.D 101 (2020) 052004



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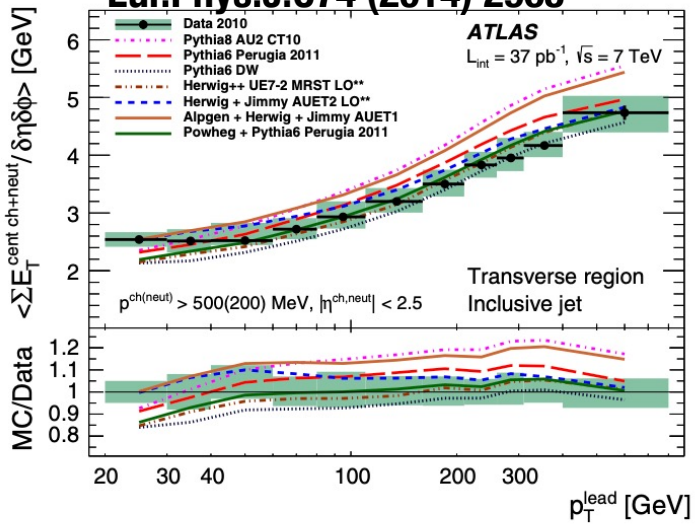
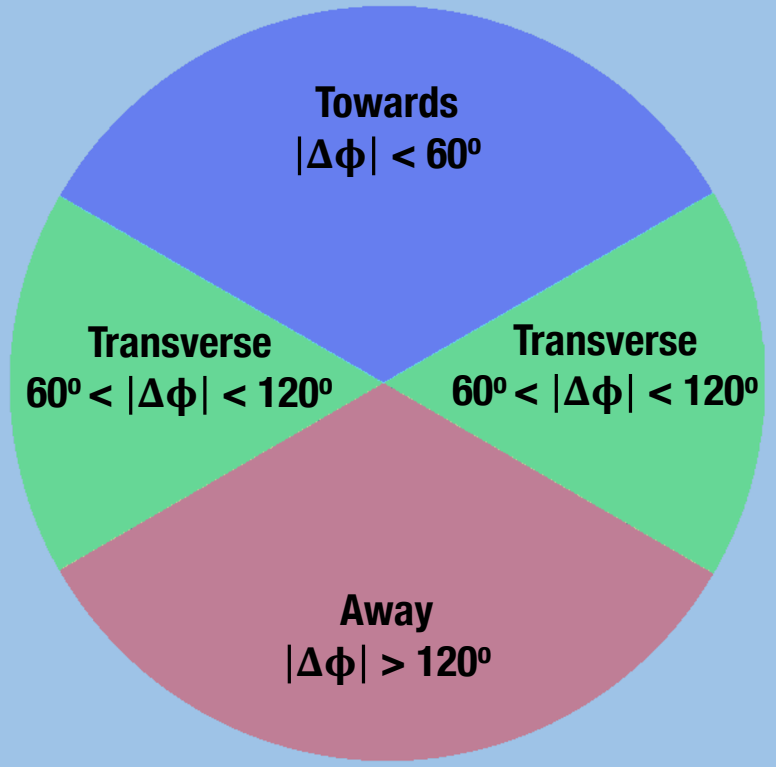
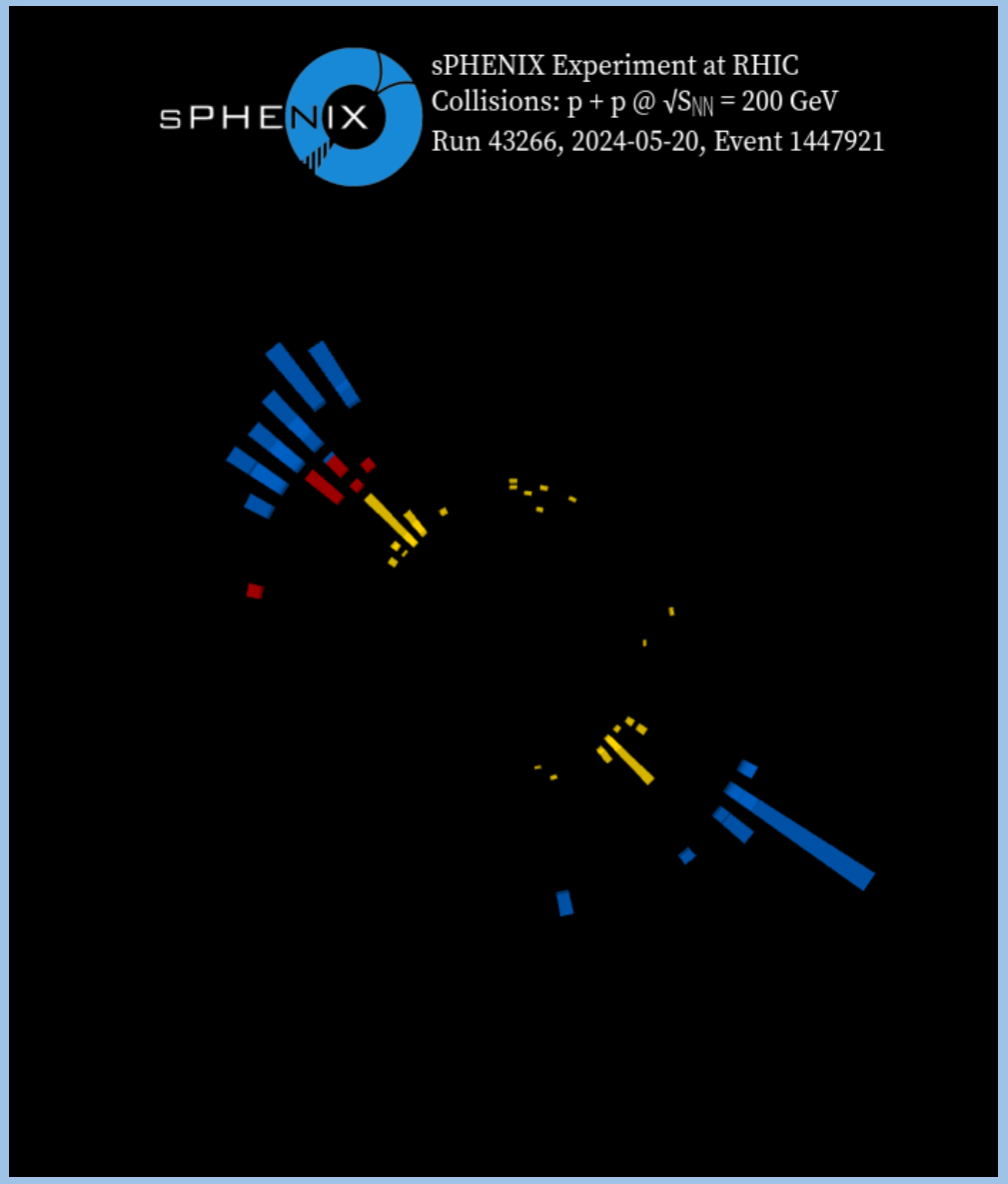


Event shape for measuring UE activity

Separation of jet event into three distinct regions in ϕ with respect to the leading jet:





Require R = 0.4 dijet events:

$$p_T^{\text{lead jet}} > 17 \text{ GeV}, \quad p_T^{\text{sublead jet}} > 0.3\, p_T^{\text{lead jet}}, \quad |\Delta\phi| > \frac{3\pi}{4}$$

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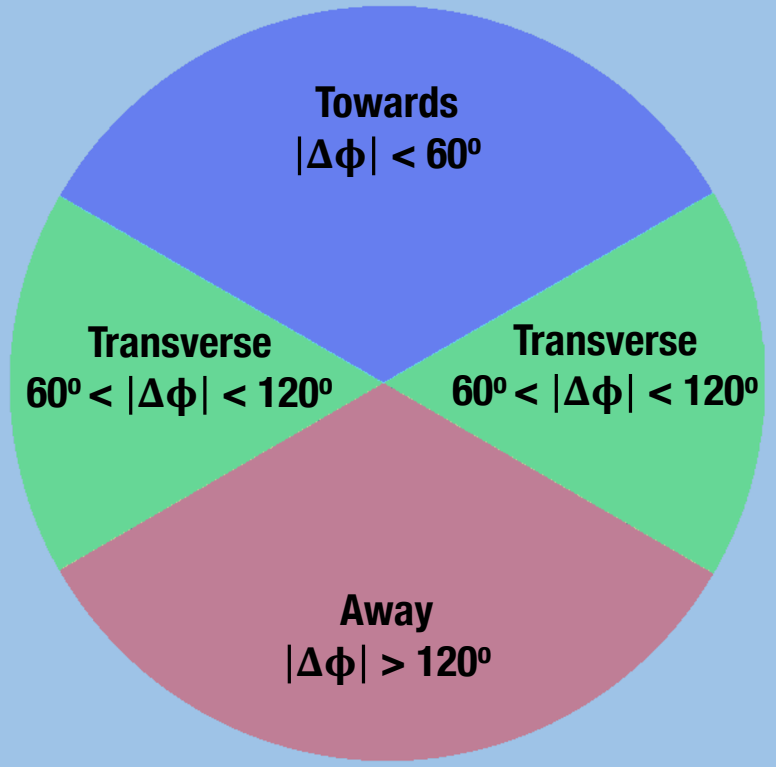

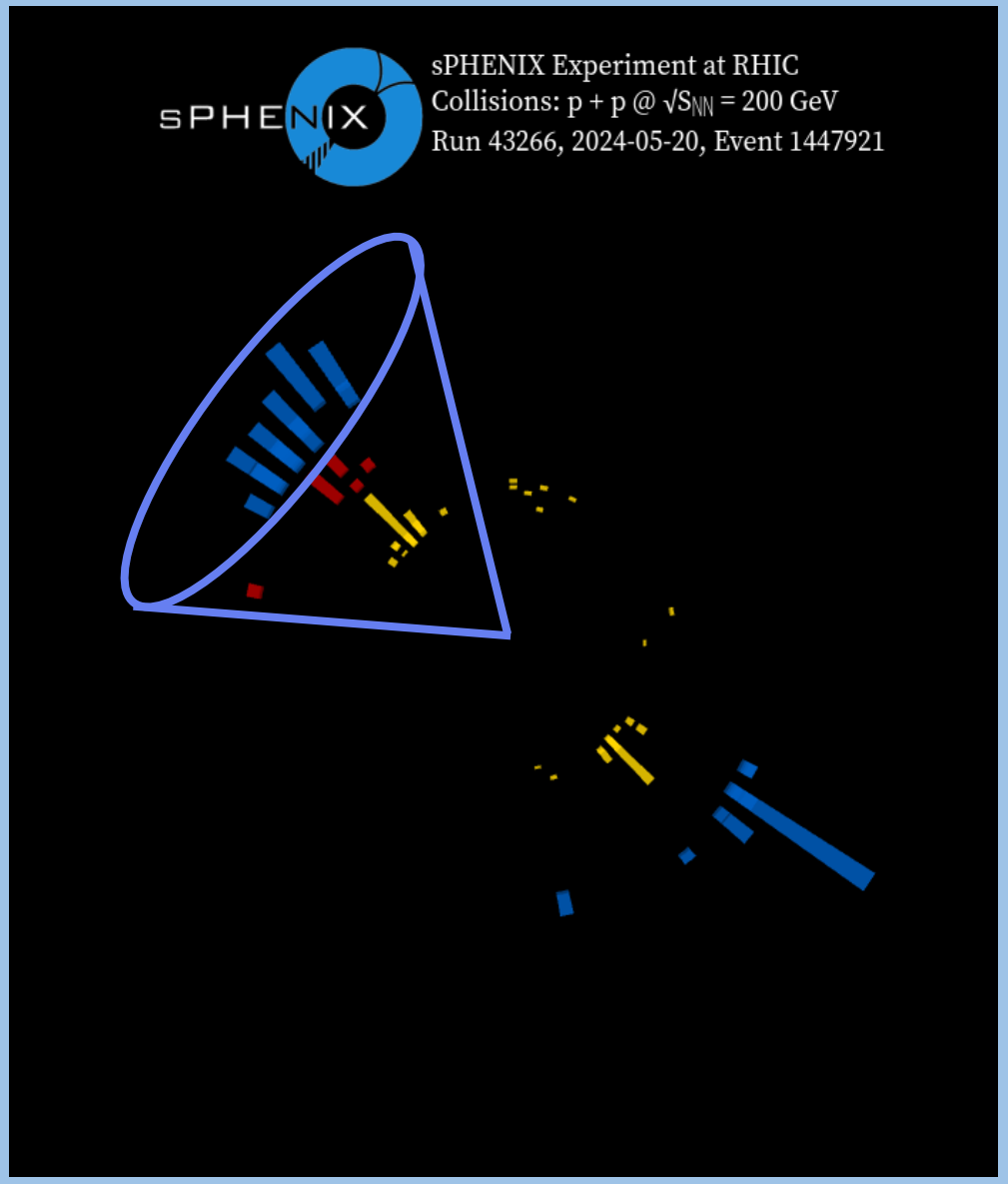

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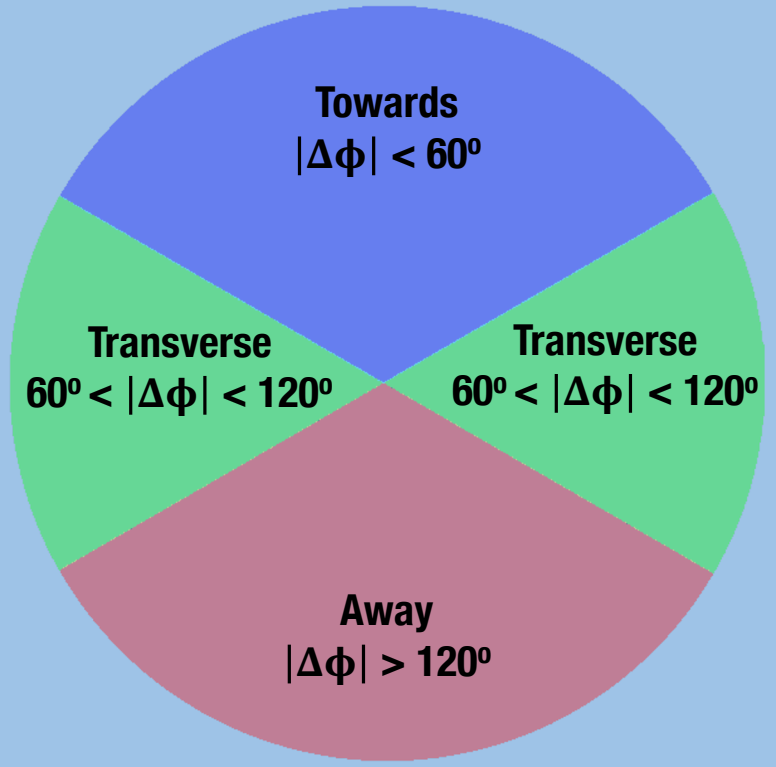

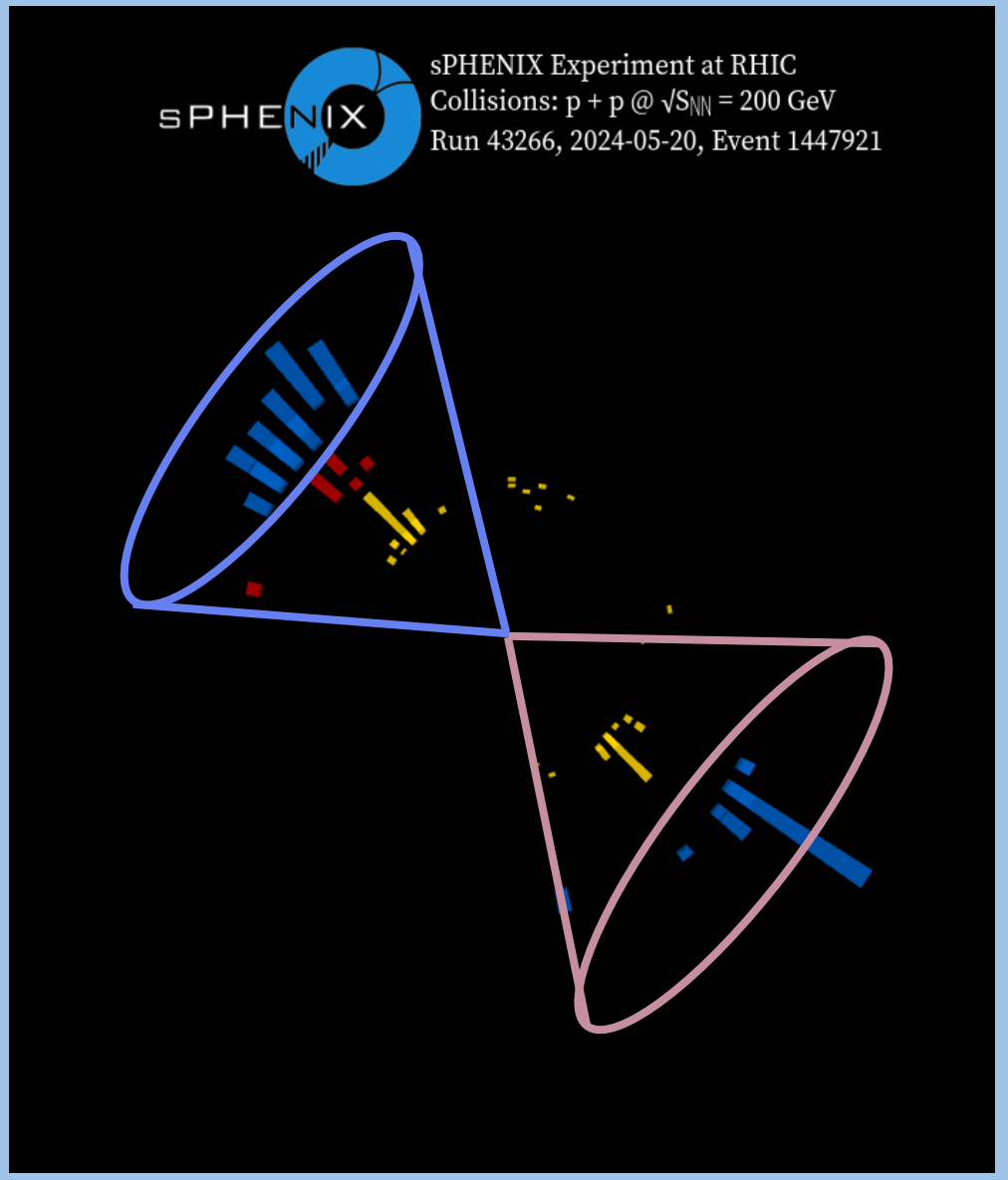

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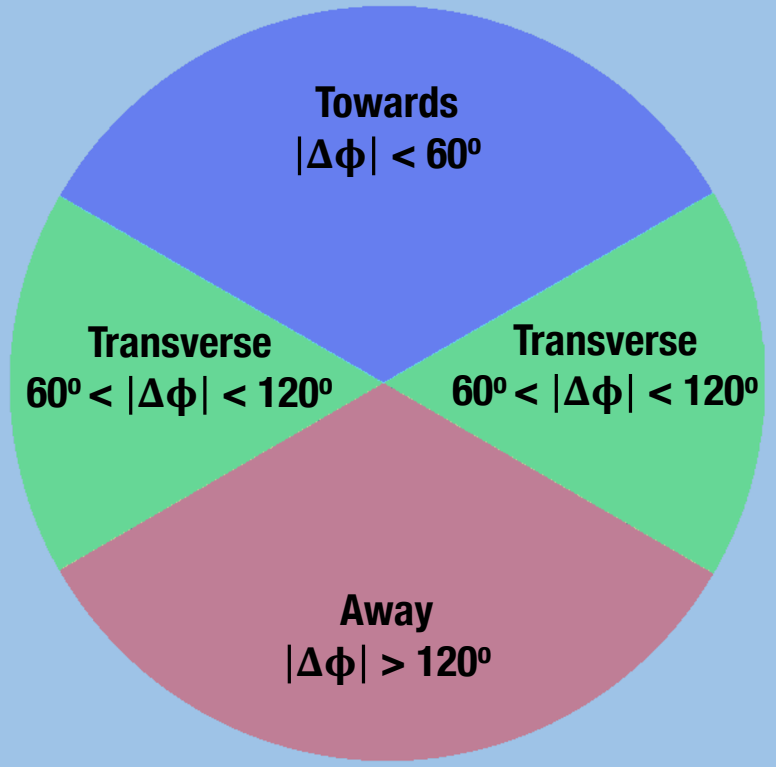

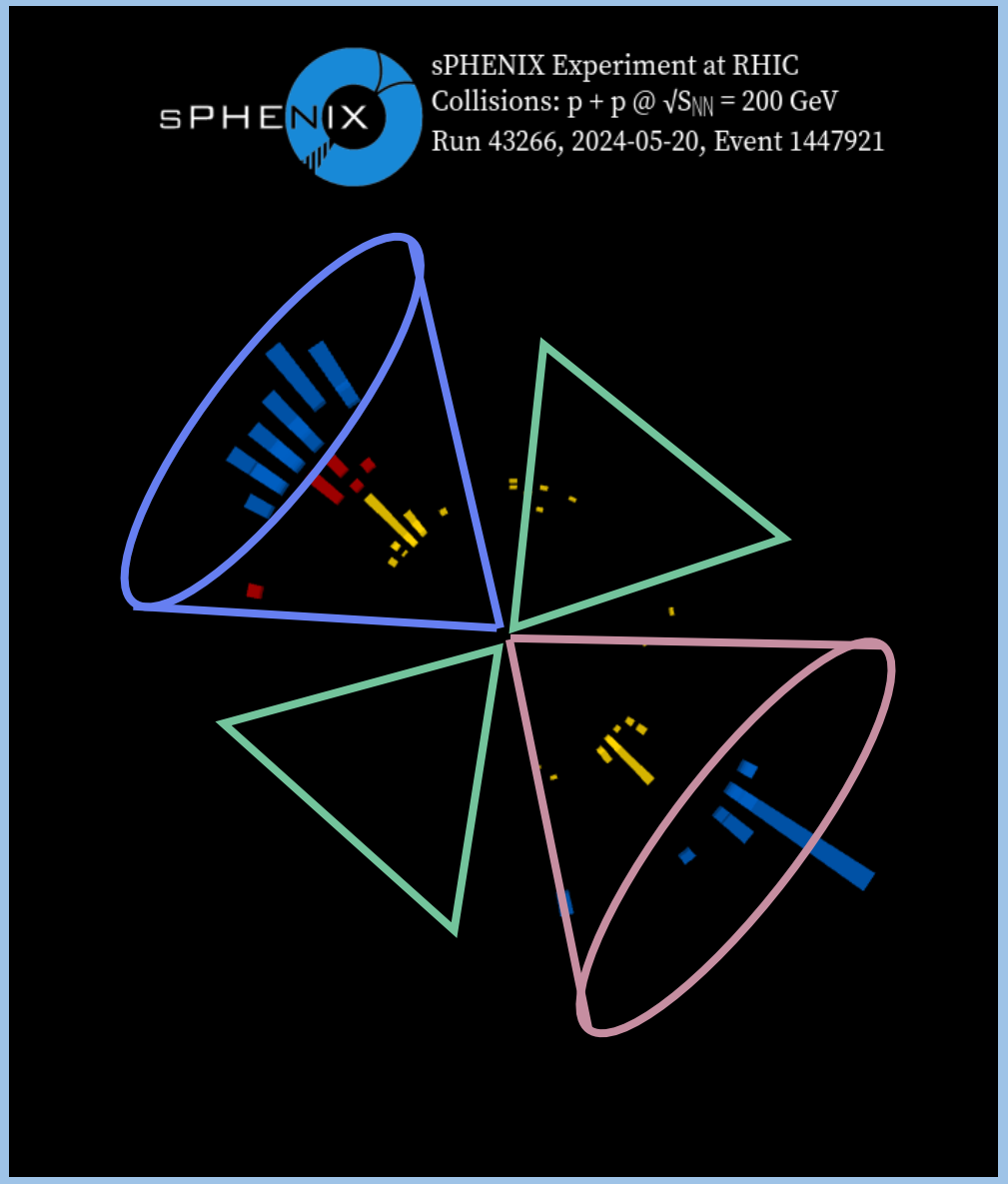

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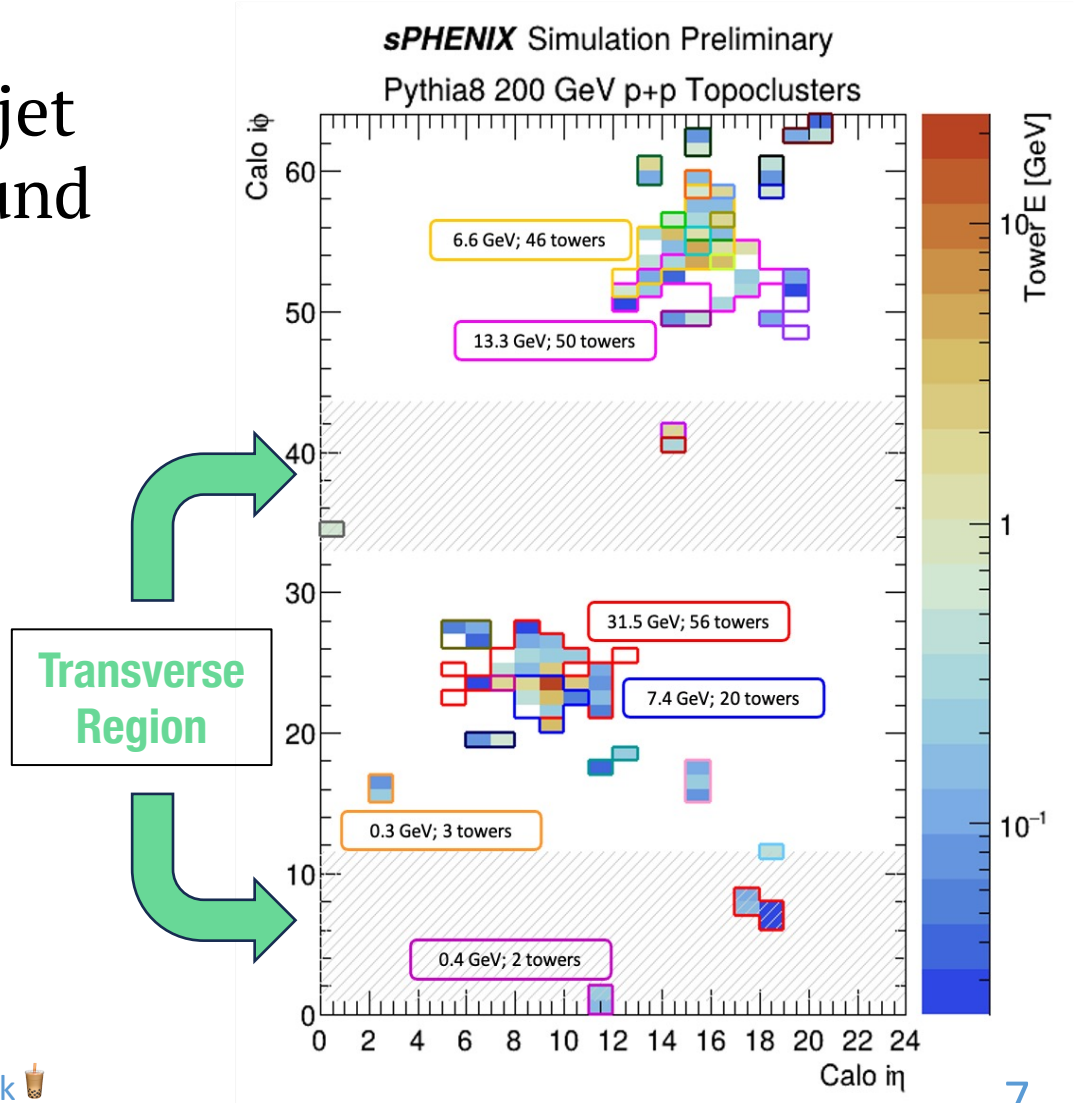
Topoclusters for low E_T measurement in transverse region

Low multiplicity in transverse region for p+p jet events ⇒ technical challenge to measure around the calorimeter noise ⇒ employ topoclusters

Tower thresholds optimized using RMS of pedestal data to limit contributions to reconstructed E_T from detector noise

Topoclusters formed from all three calorimeter layers using (seed, neighbor, peripheral) = (4,2,1) scheme



Transverse region E_T density as a proxy for UE activity

Test topocluster reconstruction effects by comparing generator-level ΣE_T to reco-level ΣE_T

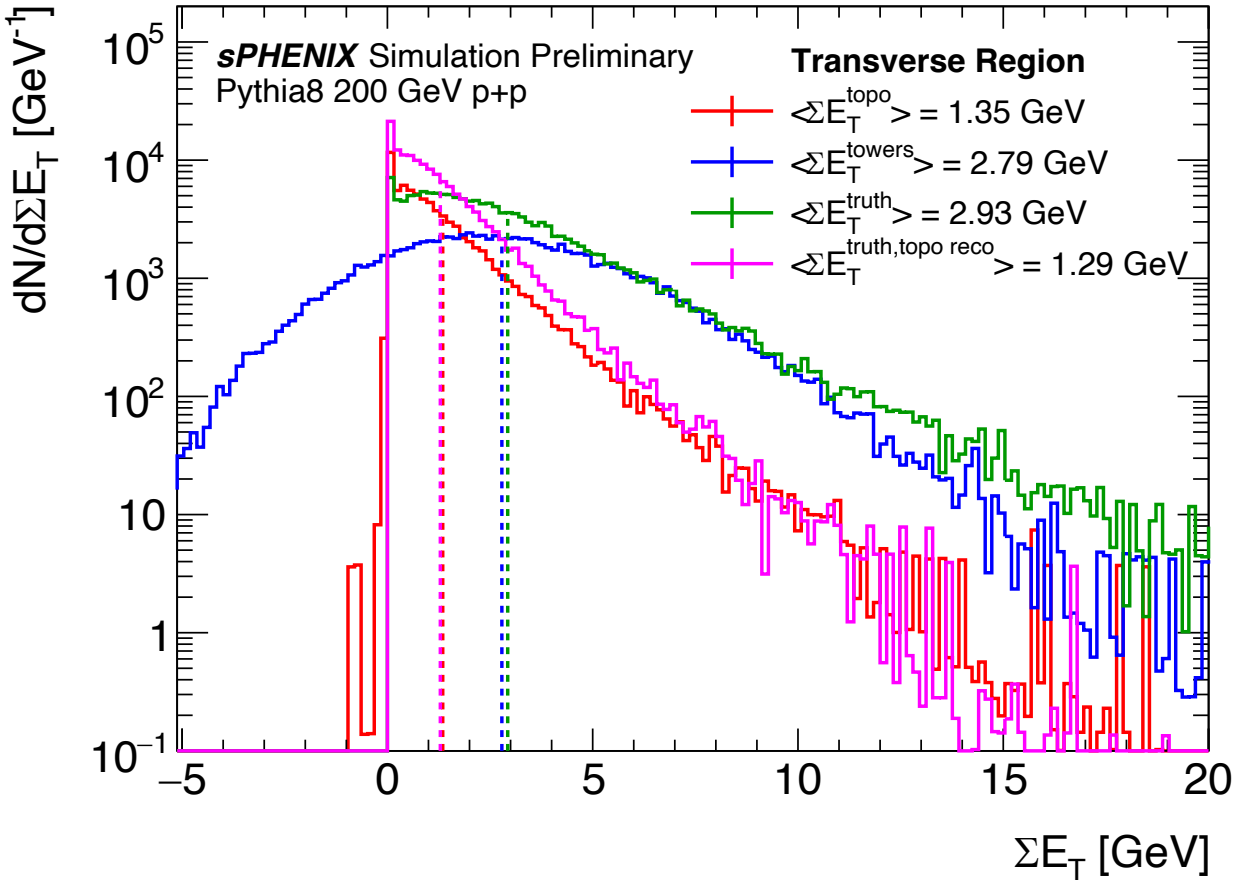
ΣE_T^{truth}: generator-level sum of all particles with $p_T > 0.2$ GeV in trans. region

ΣE_T^{towers}: sum of all EMCal & HCal towers in trans. region

ΣE_T^{topo}: sum of calorimeter topoclusters in trans. region

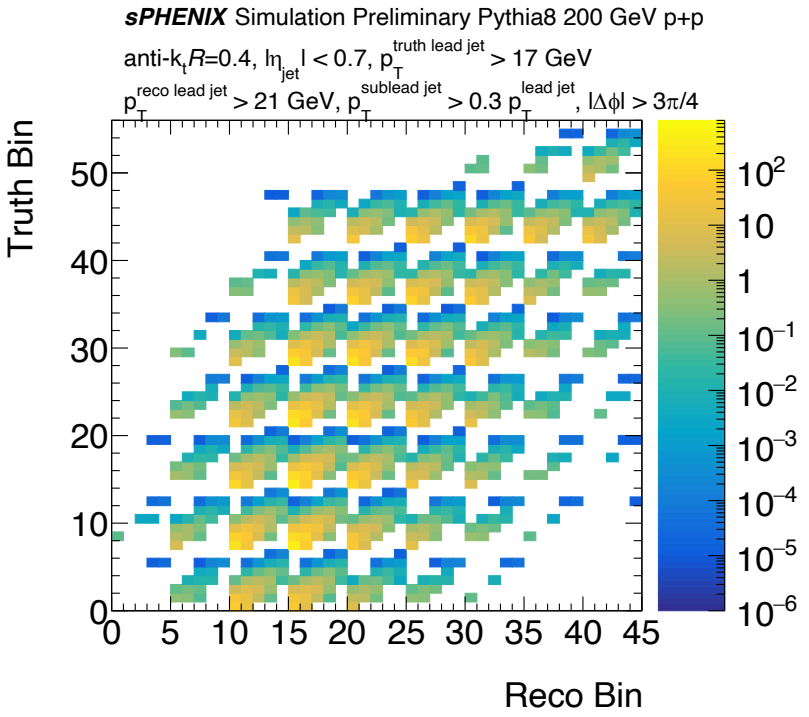
$\Sigma E_T^{truth,topo\ reco}$: generator-level sum of all particles in trans. region with topocluster energy cuts & reco. hadronic energy scaling applied

ΣE_T^{topo} distribution much more insensitive to calorimeter noise and we can manufacture topocluster reconstruction effects in truth particle spectra

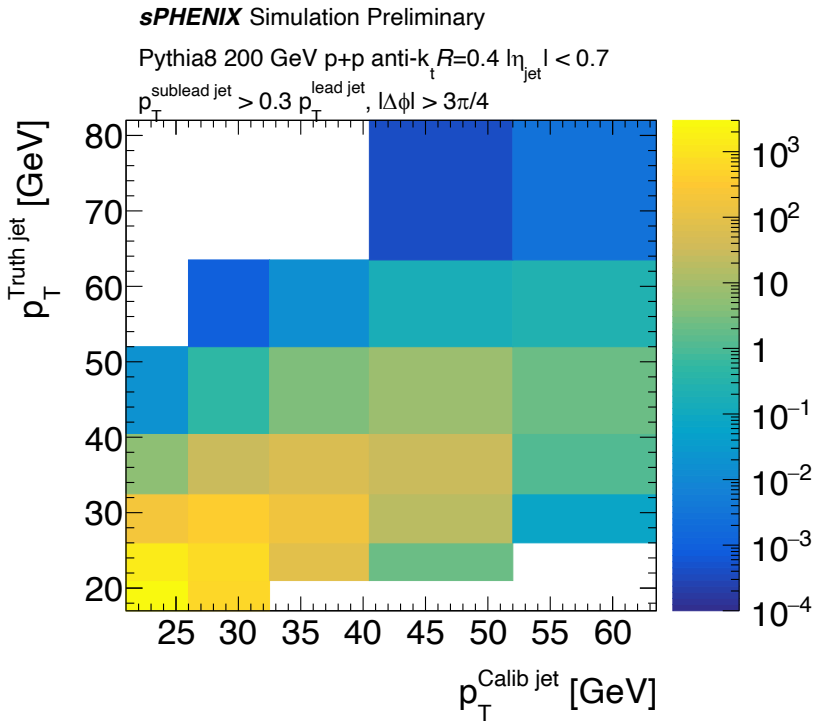


2D unfolding in leading jet p_T and transverse region ΣE_T

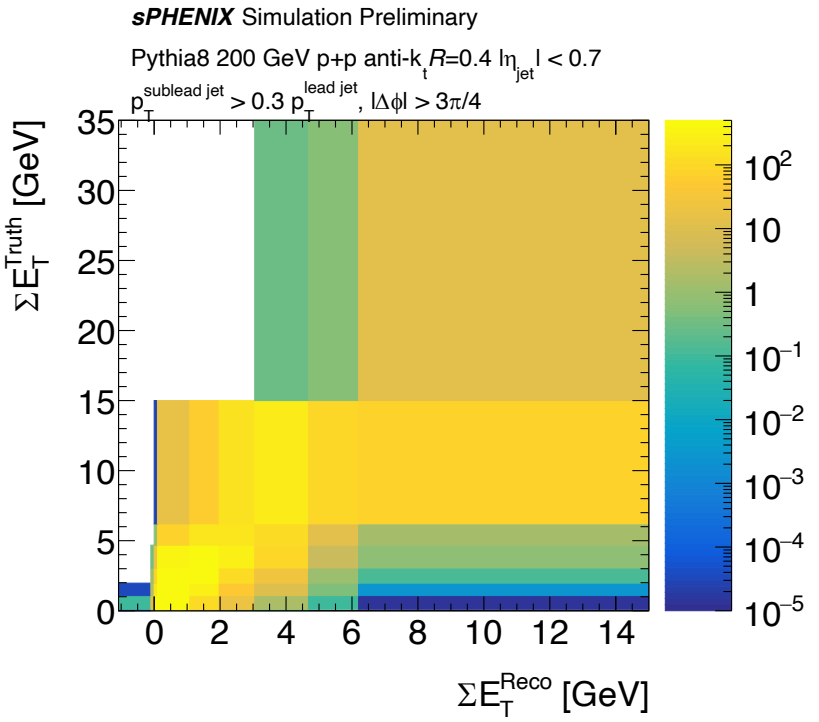
Preform 2D unfolding to maintain the correlation between leading jet p_T and transverse region ΣE_T



Jet p_T x Trans. Region ΣE_T



Jet p_T



Trans. Region ΣE_T

Summary and Outlook

Interested in interplay between collision energy carried by hard scattering and UE activity for very high leading jet p_T at RHIC

sPHENIX primed to extend reach of jet p_T measurements like this and more at RHIC

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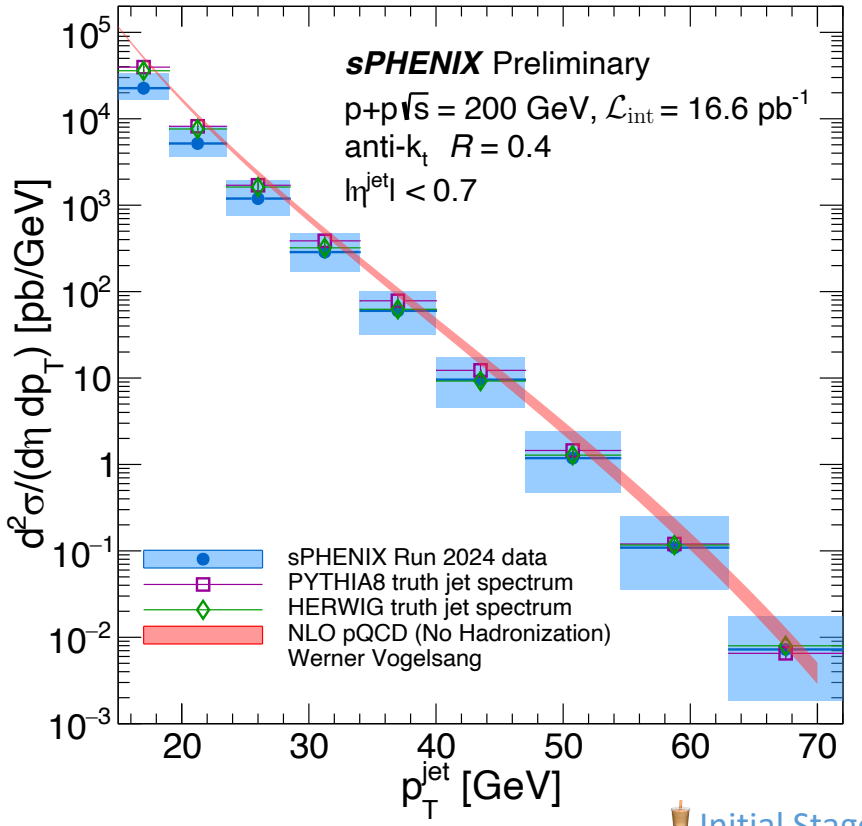

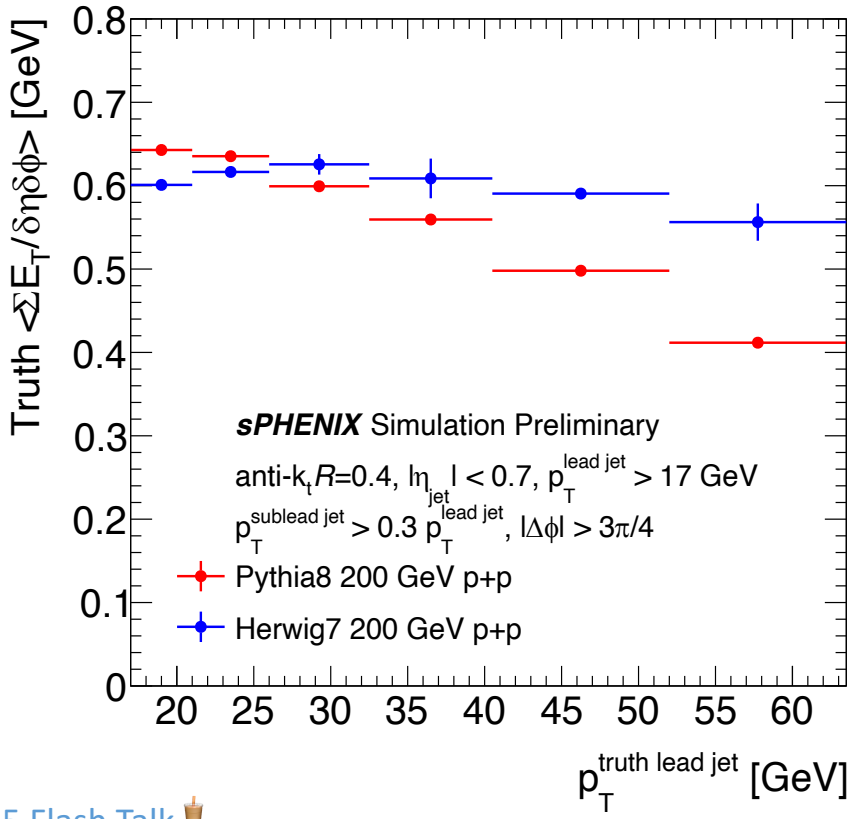

Summary and Outlook

sPHENIX Public Results

Interested in interplay between collision energy carried by hard scattering and UE activity for very high leading jet p_T at RHIC

sPHENIX primed to extend reach of jet p_T measurements like this and more at RHIC

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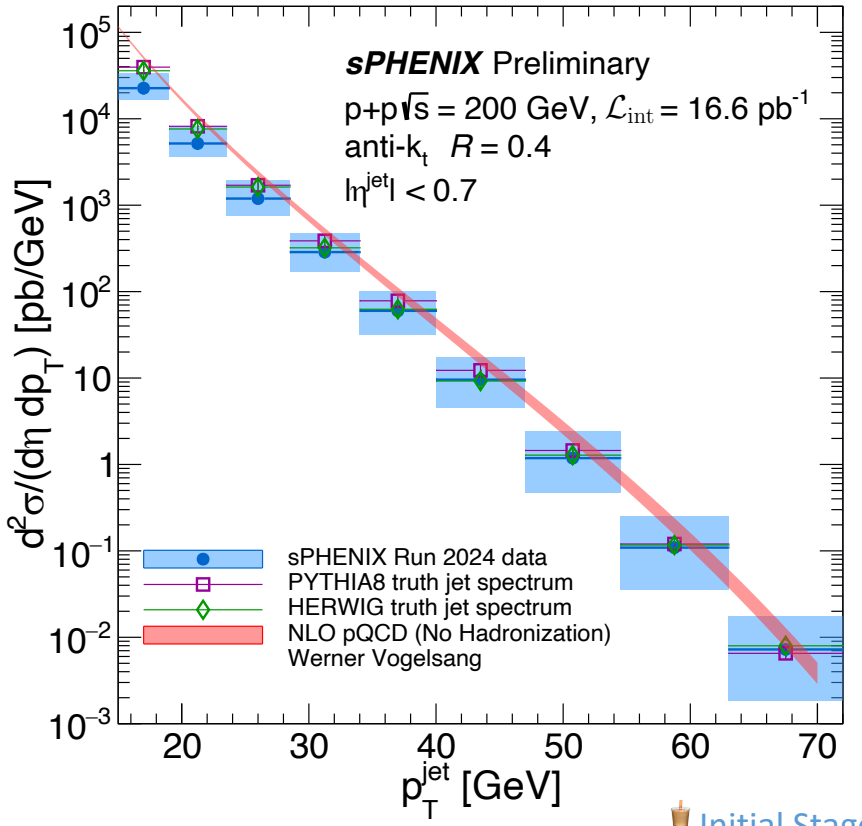
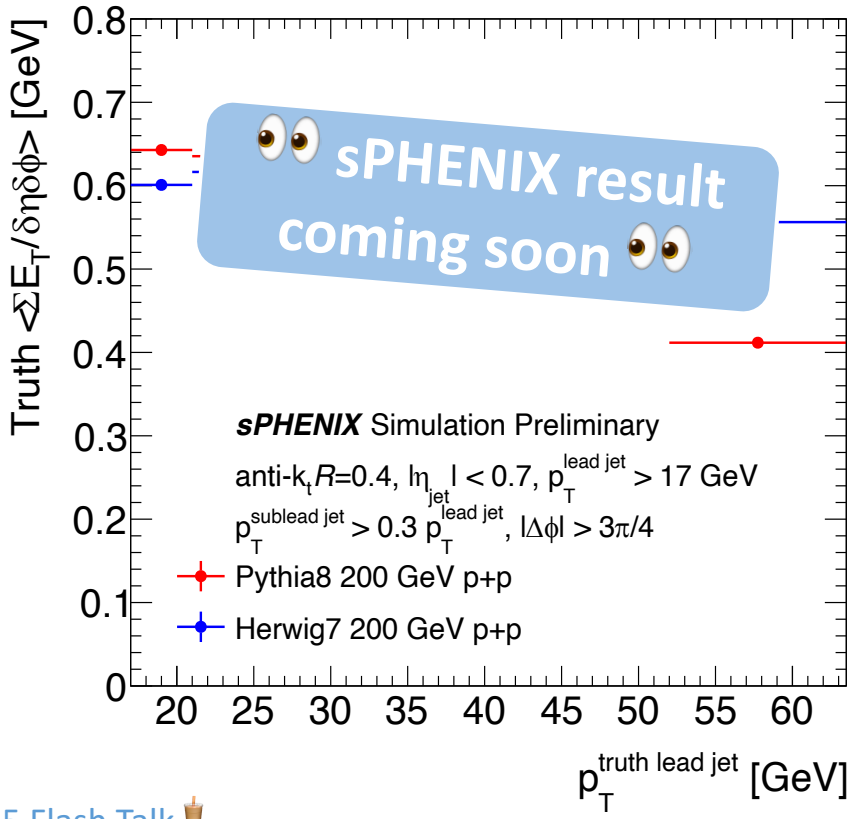




Backup

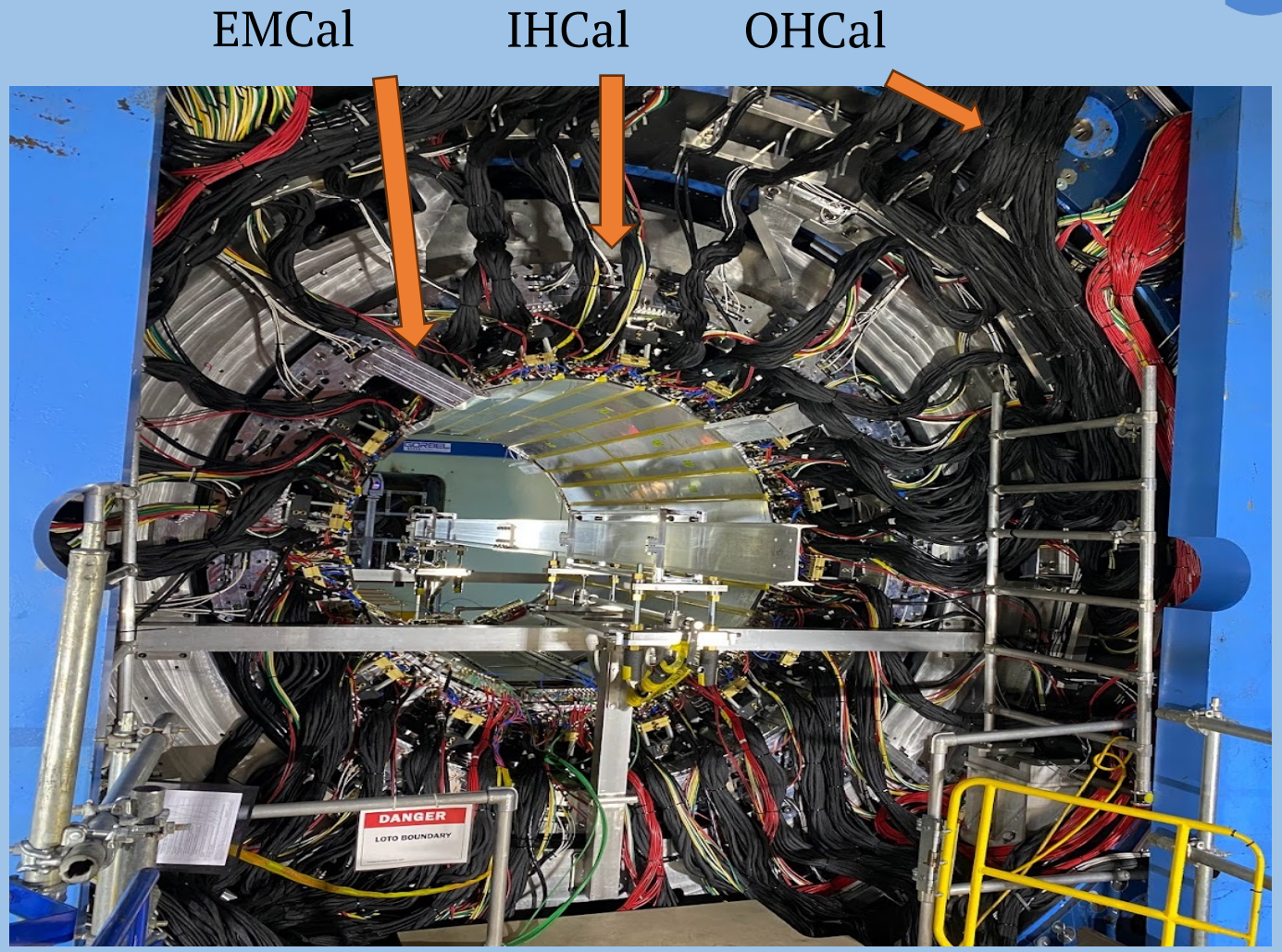
sPHENIX Calorimeter System

sPHENIX detector has three concentric calorimeter layers:

1. Electromagnetic calorimeter (EMCal)
2. Inner hadronic calorimeter (IHCal)
3. Outer hadronic calorimeter (OHCal)

EMCal: Tungsten powder absorber & scintillating fibers of tower size
$\Delta\eta \times \Delta\varphi = 0.024 \times 0.024$

HCal: Al (inner)/steel (outer) absorber plates & scintillating tiles of tower size
$\Delta\eta \times \Delta\varphi = 0.1 \times 0.1$



sPHENIX calorimeter system has total depth of ~5 hadronic interaction lengths and full coverage of $0<\phi<2\pi$ and $|\eta|<1.1$ for all layers

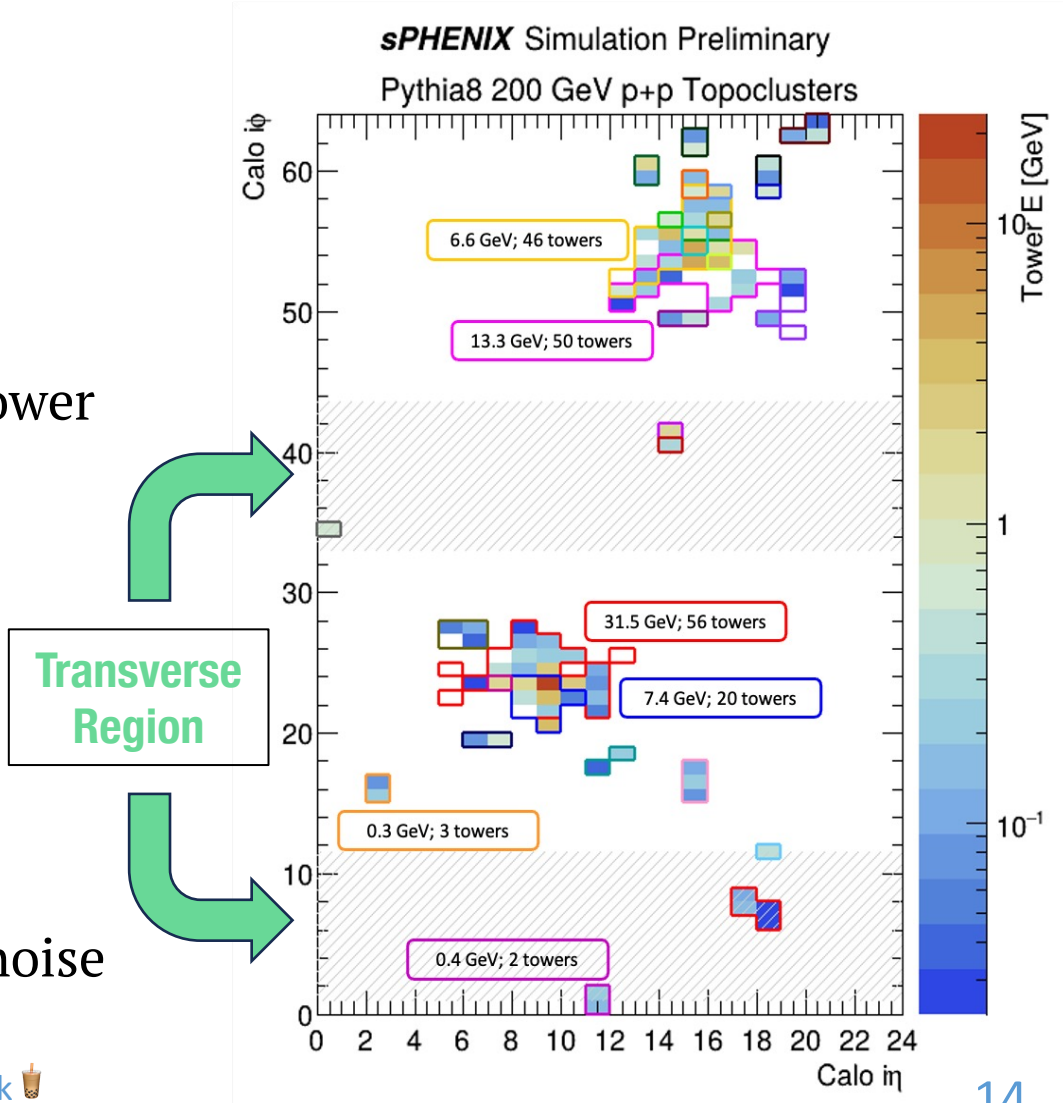
Topoclusters for low E_T measurement in transverse region

Low multiplicity in transverse region for p+p jet events ⇒ technical challenge to measure around the calorimeter noise

Topoclusters formed from all three calorimeter layers with tower thresholds optimized using RMS of pedestal data to limit contributions to reconstructed E_T from detector noise

- Cluster **seed towers**: $|E_{tower}|$ > **4x** calorimeter noise
- **Neighboring towers** (expand cluster): $|E_{tower}|$ > **2x** calo noise
- P**eripheral towers** (cluster border): $|E_{tower}|$ > **1x** calo noise

Transverse region E_T from topoclusters studied with noise variations, fairly insensitive to changes in the calo pedestal noise



Topoclusters for low E_T measurement in transverse region

Form topoclusters from all three calorimeter layers to fully encapsulate low energy particle energy deposits as well as full hadron showers