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## Abstract

The transverse energy from soft particle production in the underlying event (UE) associated with a high transverse energy jet is investigated in proton-proton (p+p) collisions at center-of-mass energy of 200 GeV using the sPHENIX detector. Understanding the interplay between jets from the collision's hard scattering and soft particle emission in the region azimuthally transverse to the event's hardest jet can inform our understanding of contributions to jet events in p+p collisions from multiple parton interactions as well as final and initial state radiation. The sPHENIX calorimeter system, featuring both electromagnetic and hadronic calorimeters with full azimuthal coverage and wide rapidity acceptance, is well suited to make high-resolution measurements of jets and energy measurements of the underlying event transverse to the hard scattering in jet events. This poster shows first studies of the underlying event as a function of jet  $p_T$  using simulations of the sPHENIX calorimeter system in p+p collisions.

## sPHENIX Calorimeter System

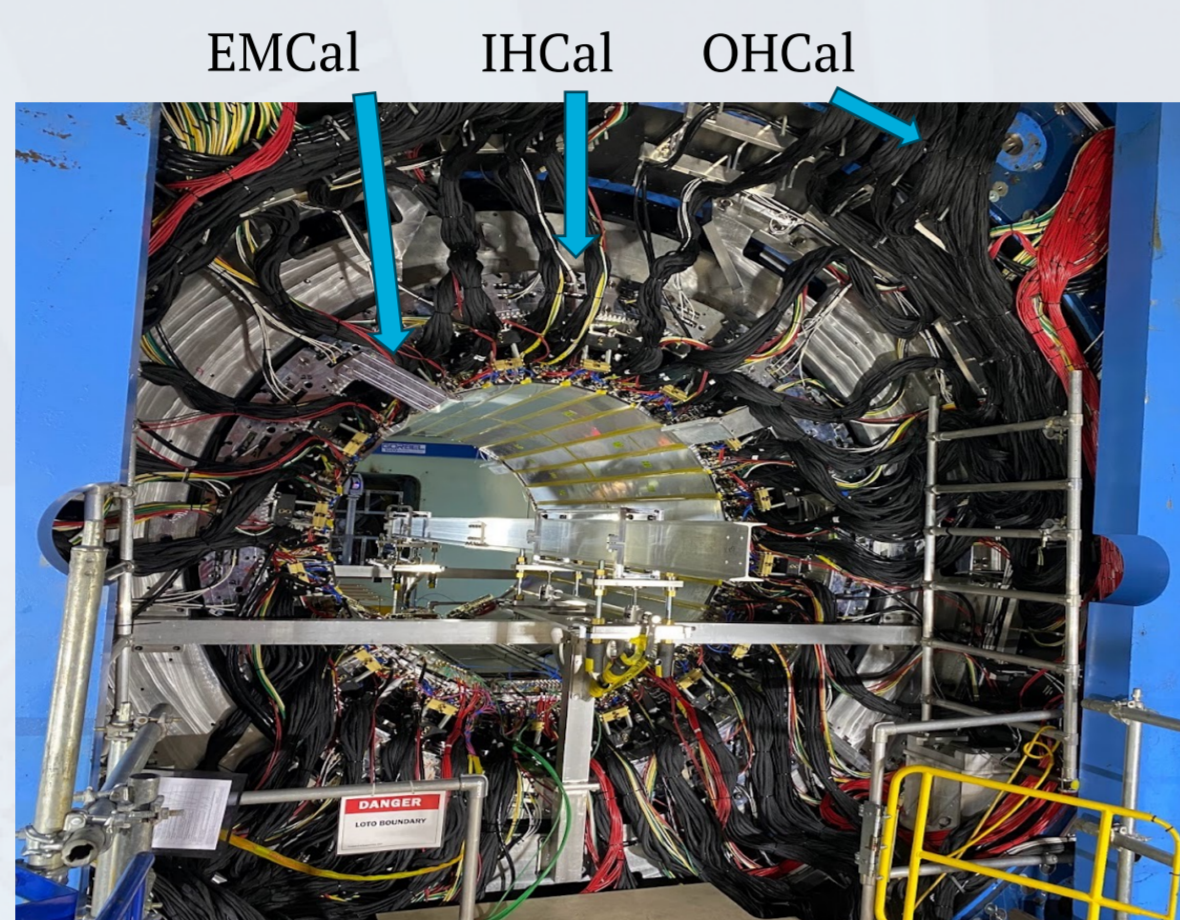
sPHENIX detector has three concentric calorimeter layers:

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

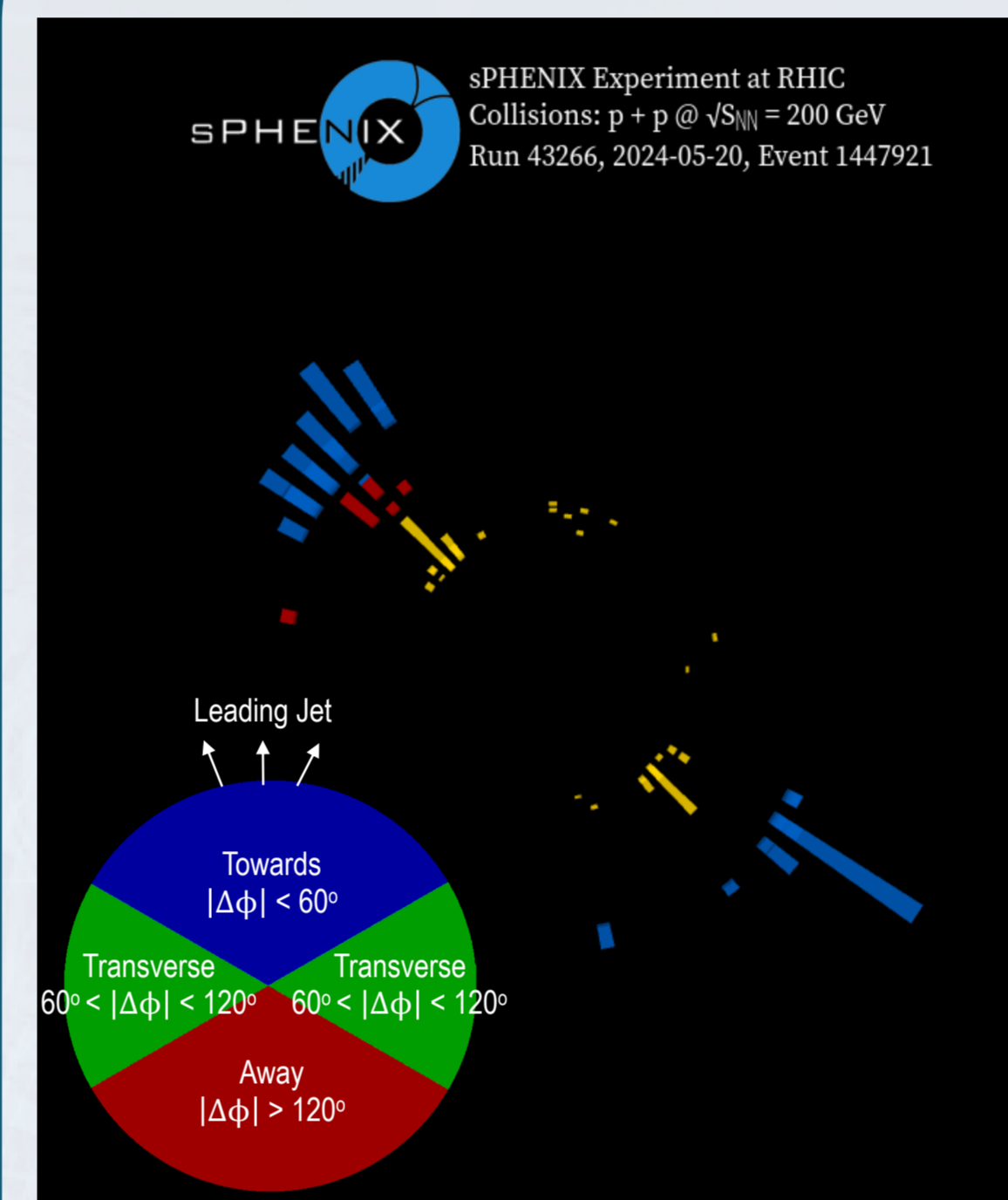
EMCal: Tungsten powder absorber & scintillating fibers of tower size  $\Delta\eta \times \Delta\phi = 0.024 \times 0.024$

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

sPHENIX calorimeter system has total depth of 4.9 hadronic interaction lengths and coverage of  $0 < \phi < 2\pi$  and  $|\eta| < 1.1$  for all layers



## Calorimeter Jet and Cluster Reconstruction



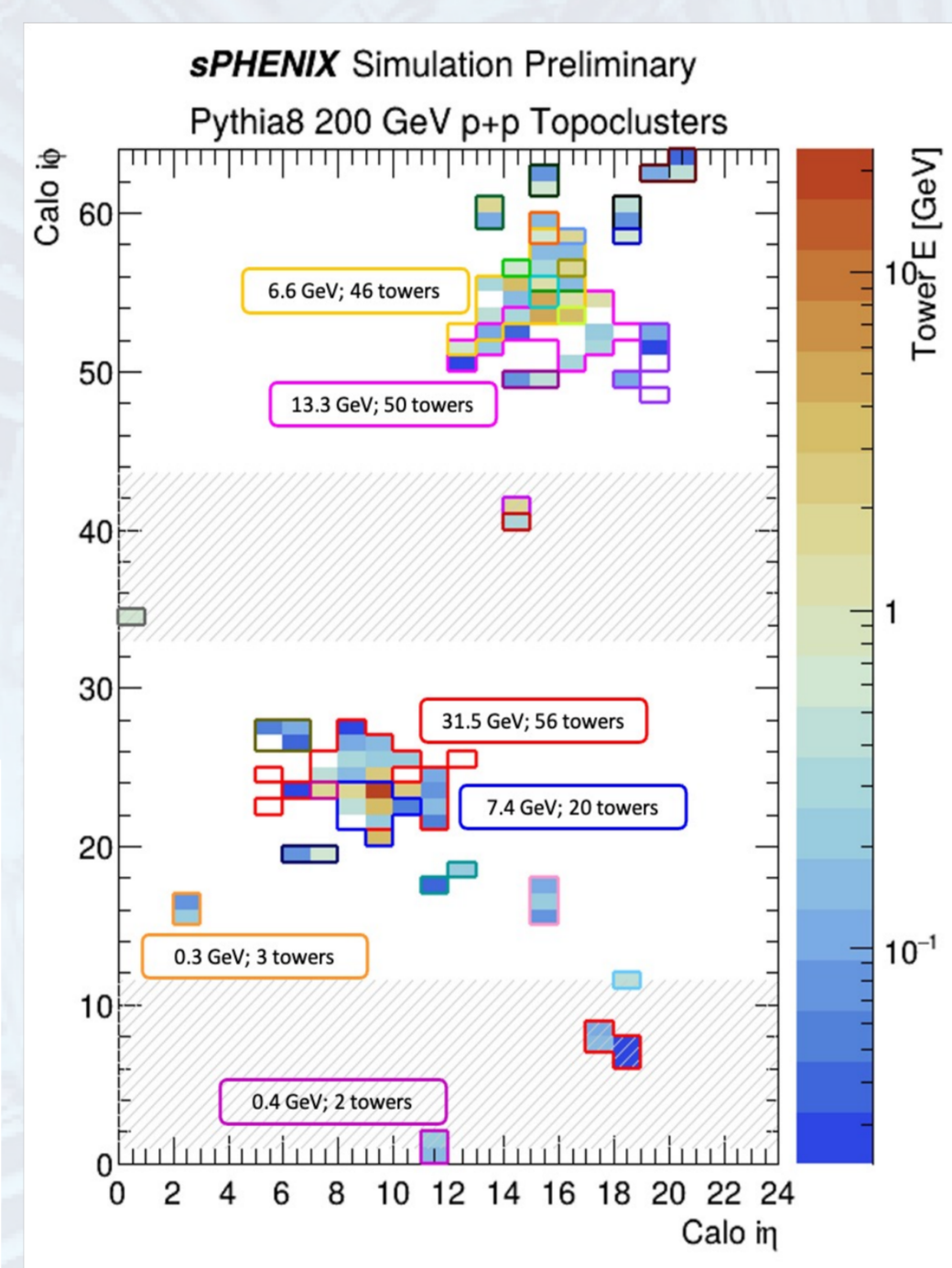
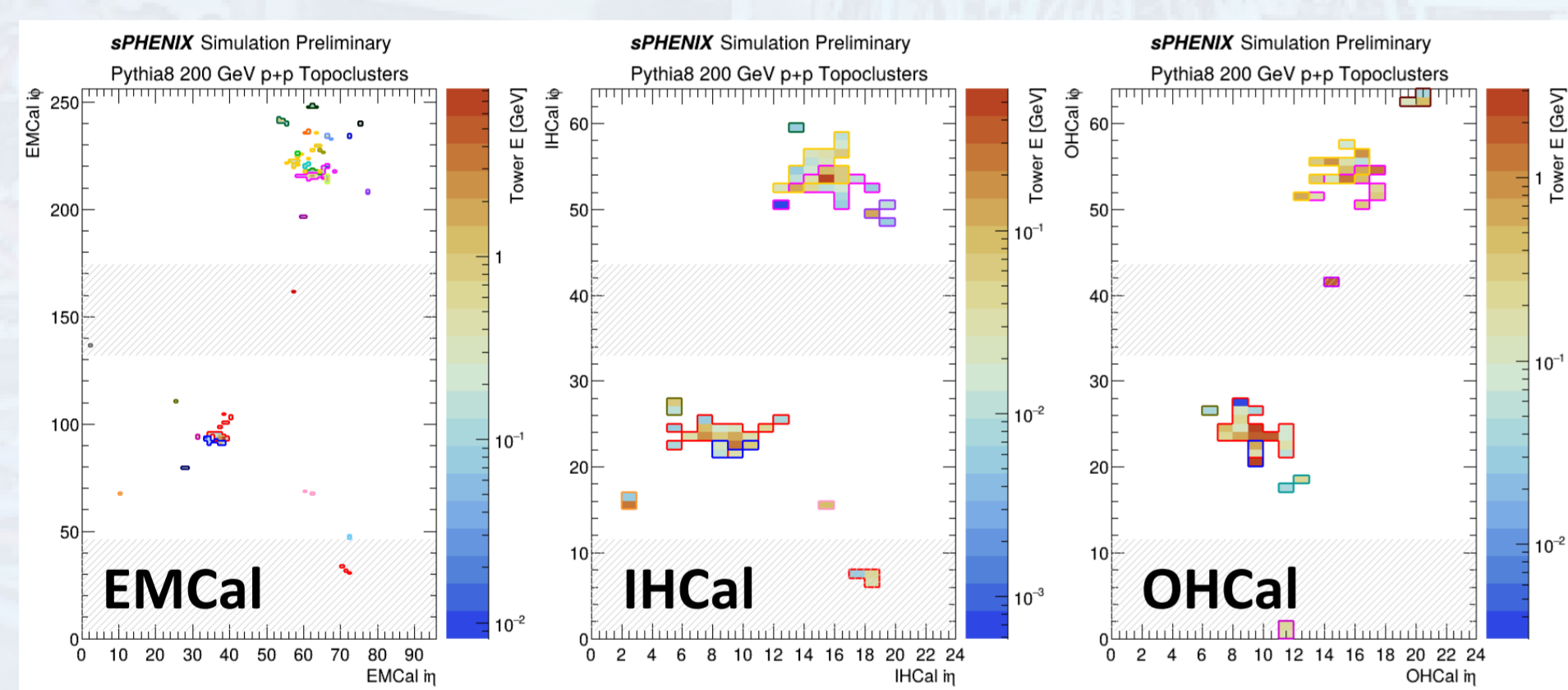
**Transverse region average total  $E_T$  density as proxy for UE activity:**

- Transverse region  $\langle \Sigma E_T \rangle$  and  $\langle \frac{dN_{ch}}{d\eta d\phi} \rangle$  used as UE proxy  
STAR: Phys.Rev.D 101 (2020) 052004 & ATLAS: Eur.Phys.J.C74 (2014) 2965
- Compare generator-level  $\Sigma E_T$  to reco-level  $\Sigma E_T$  in transverse region (TR):
  - $\Sigma E_T^{topo}$ : sum of calorimeter topoclusters in TR
  - $\Sigma E_T^{towers}$ : sum of all EMCal & HCal towers in TR
  - $\Sigma E_T^{truth}$ : generator-level sum of all particles with  $p_T > 0.2$  GeV in TR
  - $\Sigma E_T^{truth, topo reco}$ : generator-level sum of all particles in TR with topocluster energy cuts & calo reconstructed hadronic energy scaling applied to demonstrate topocluster reconstruction

## Topological Cluster Reconstruction

- Topological clusters formed from all three calo layers with tower thresholds optimized to limit contributions to reconstructed  $E_T$  from detector noise

- For cluster seed towers:  $|E_{tower}| > 4x$  calorimeter noise
- For neighboring towers used to expand cluster:  $|E_{tower}| > 2x$  calorimeter noise
- For peripheral towers that form the cluster border:  $|E_{tower}| > 1x$  calorimeter noise



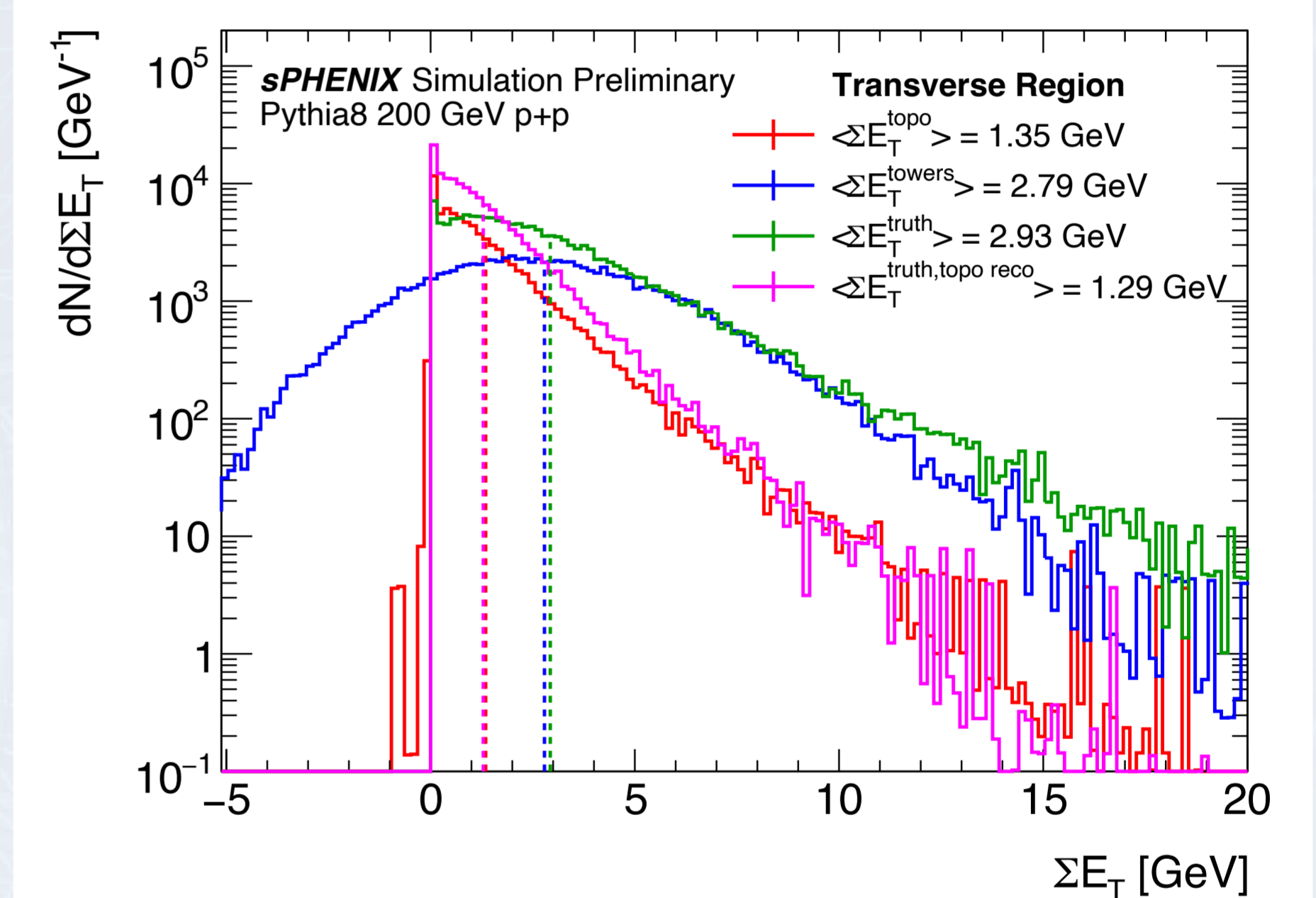
Subset of event clusters highlighted with energy and tower information shown above with calo layer depiction on left; transverse region of event shown in gray

## Analysis Event Shape:

Separation of jet event into three distinct regions in  $\phi$  w.r.t. the leading jet:  
regions towards ( $|\Delta\phi| < 60^\circ$ ), transverse ( $60^\circ < |\Delta\phi| < 120^\circ$ ) and away ( $|\Delta\phi| > 120^\circ$ ) from the leading jet

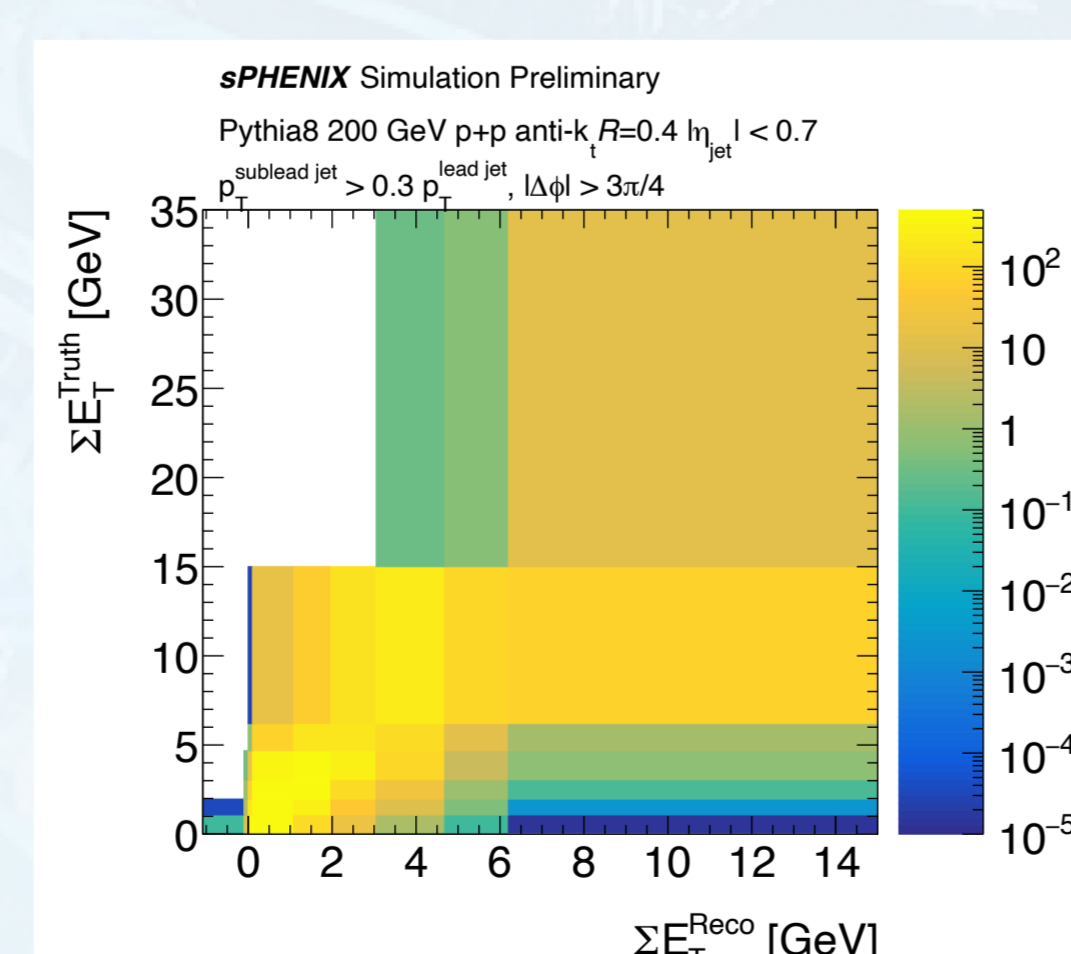
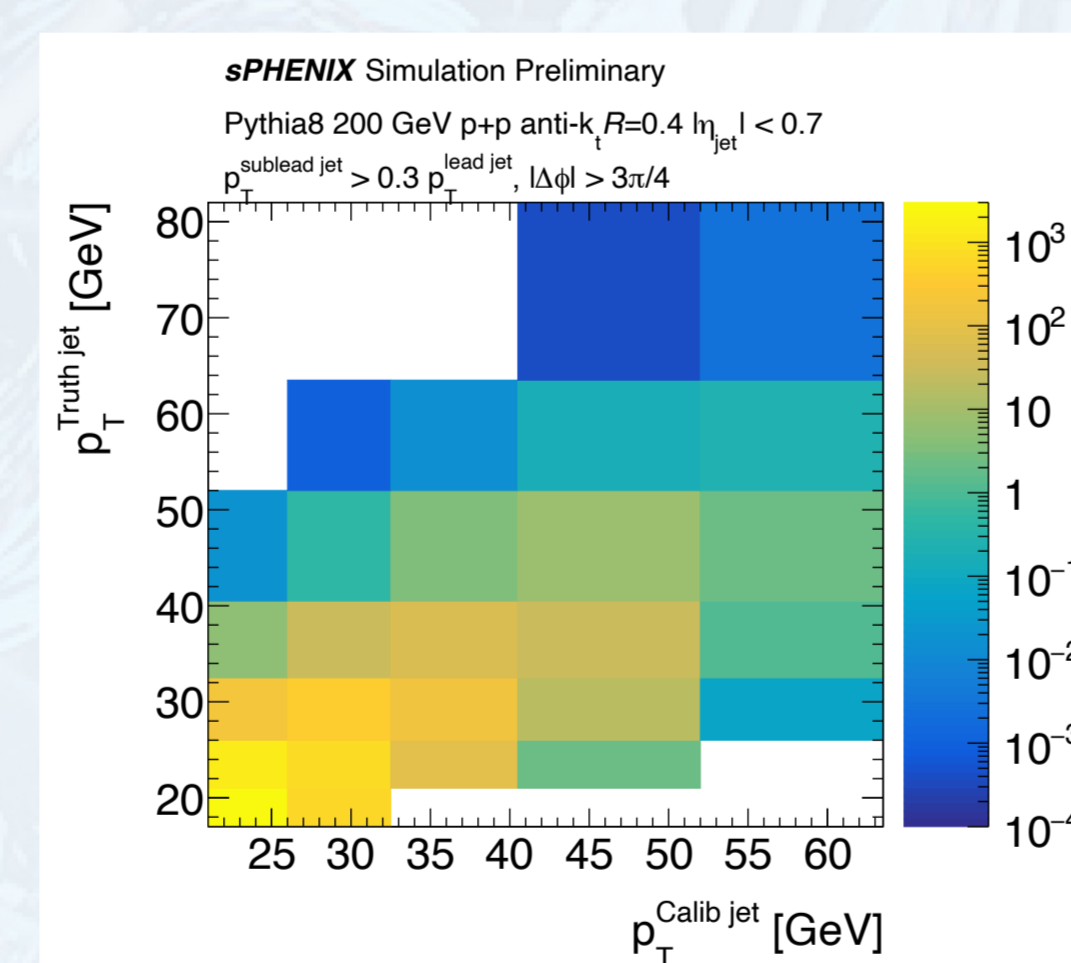
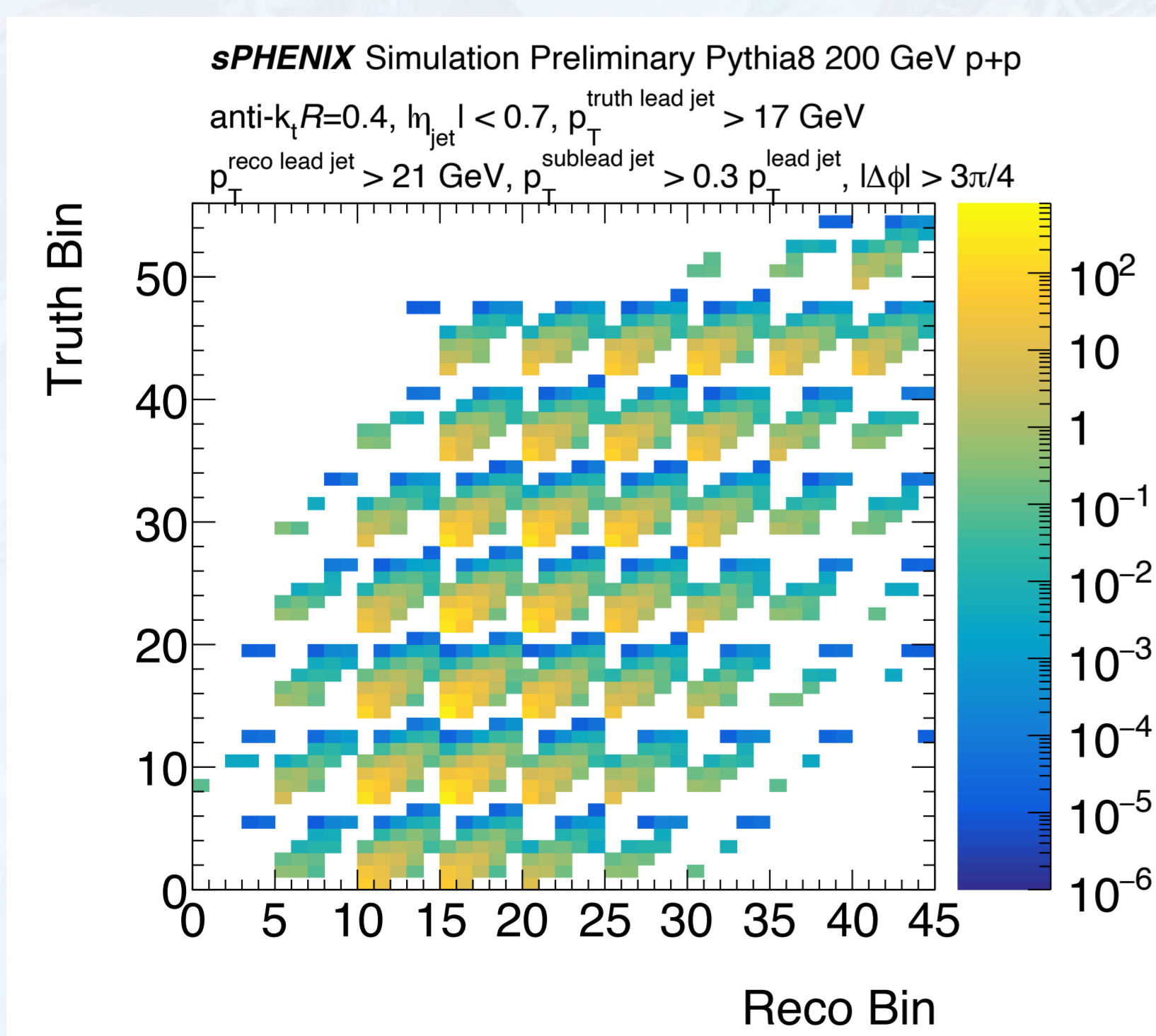
Require  $R = 0.4$  dijet events:

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



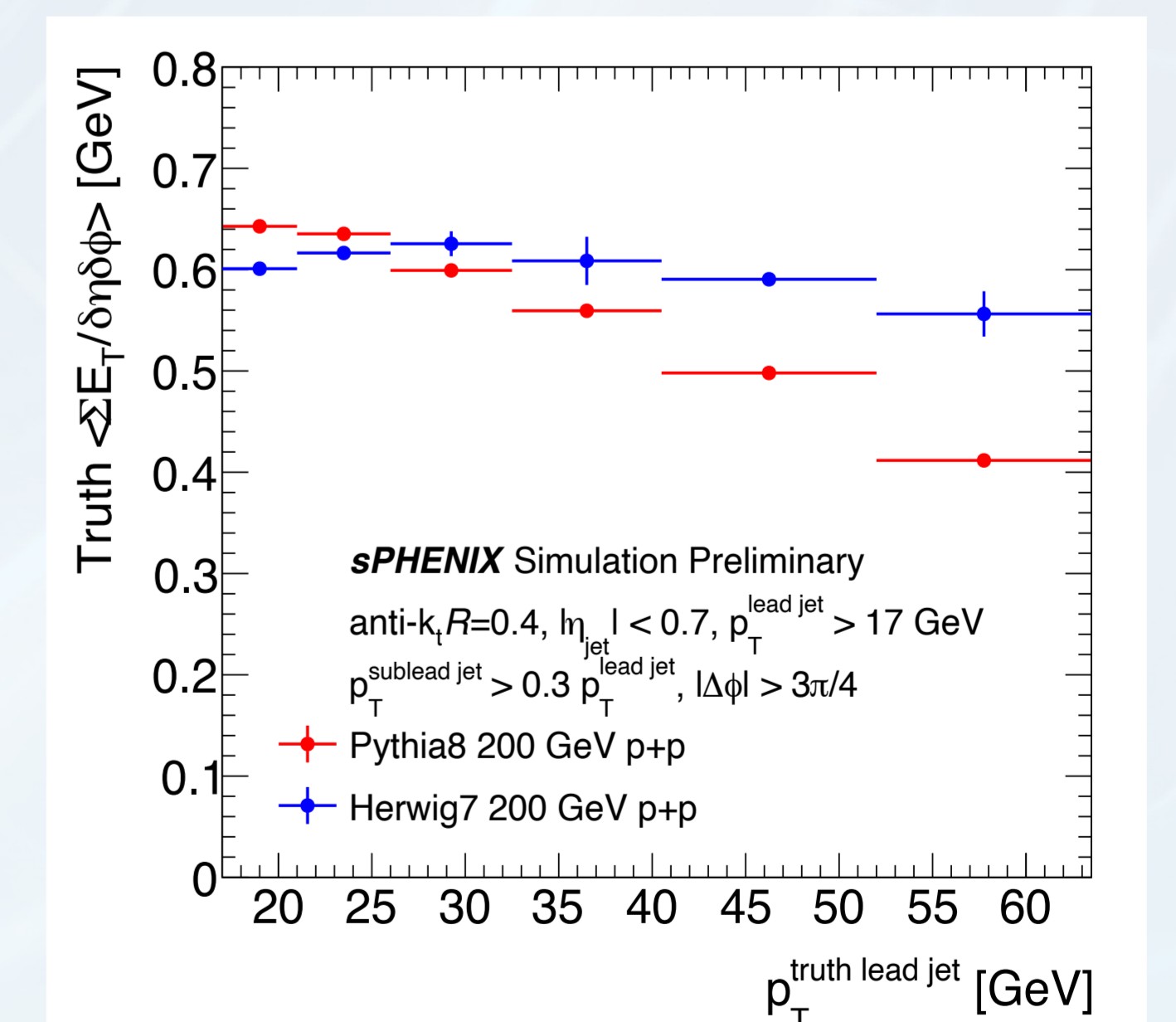
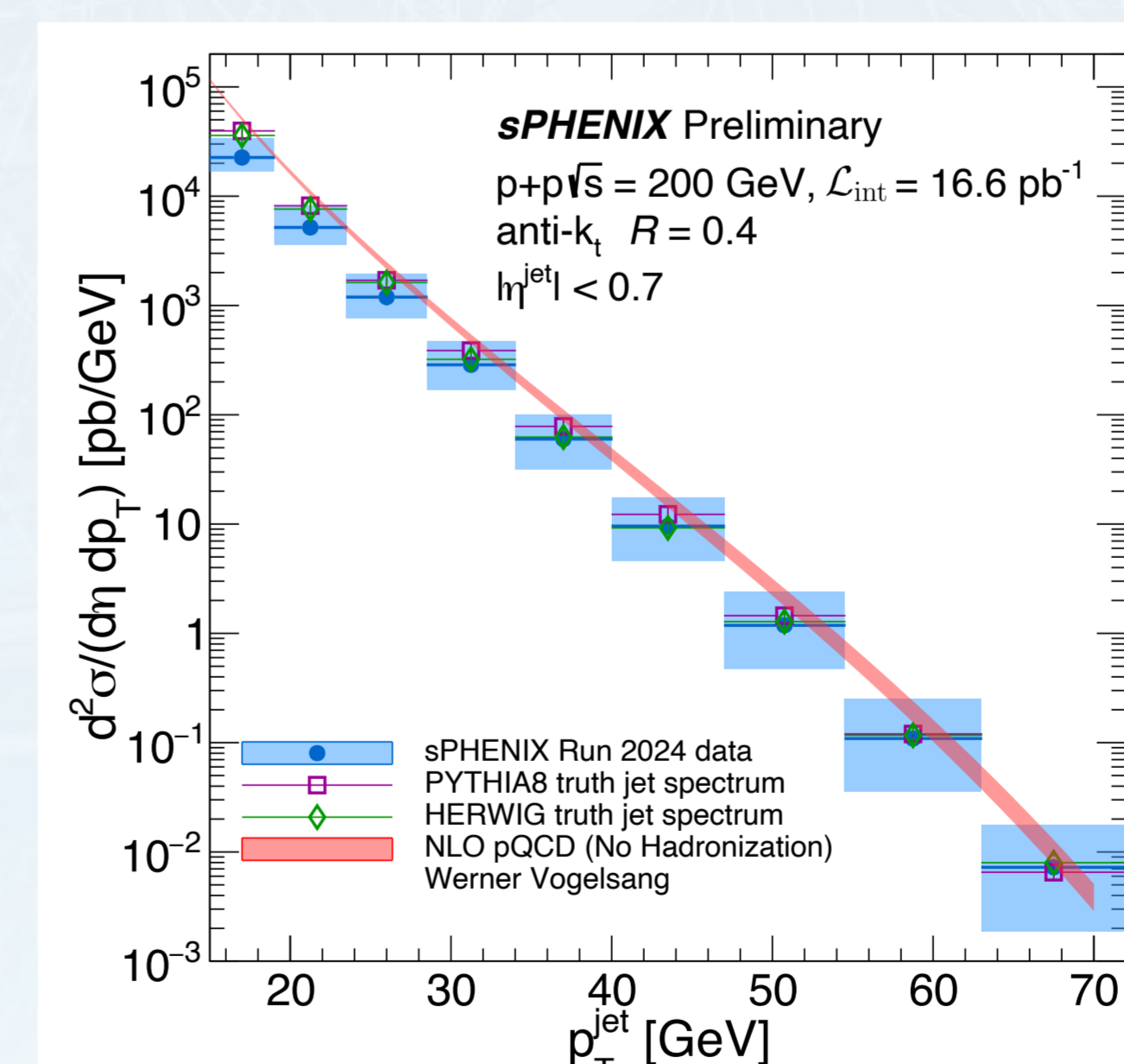
## Analysis Unfolding Procedure

- Flattened 2D unfolding response matrix shows reco to truth response in leading jet  $p_T$  (inner matrix) and transverse region  $\Sigma E_T$  (outer matrix)
- Projections along in leading jet  $p_T$  and transverse region  $\Sigma E_T$  both shown strong diagonal trend



## UE vs. Leading Jet $p_T$ Measurement

- Interplay between collision energy carried by hard scattering and UE activity in previous measurements hints at energy conservation effects at high leading jet  $p_T$  at RHIC energies
- sPHENIX primed to extend reach of jet  $p_T$  measurements at RHIC and study UE activity vs. leading jet  $p_T$  in this high  $p_T$  range



## Acknowledgements

This work supported by U.S. Department of Energy Grant DE-FG02-86ER40681