Reconstructed Jets and Jet Substructure in 200 GeV p+p Collisions with PHENIX

John Lajoie (Iowa State University), for the PHENIX Collaboration

Abstract

Measurements of reconstructed jets and jet substructure offer opportunities to study fragmentation in a nuclear environment. However, at RHIC this promise is complicated by the low jet energies and lack of hadronic calorimetry in the current experiments. In this poster, we report new results with reconstructed jets, including substructure measurements applying jet grooming techniques, in p+p collisions at a center of mass energy of 200 GeV using the PHENIX experiment. The measurements are unfolded for detector response using a multi-dimensional algorithm to extract both the cross section and jet substructure quantities in a self-consistent fashion. These measurements have implications for developing a quantitative understanding the modification of jets in heavier systems, such as p+Au, Cu+Au collisions at RHIC.

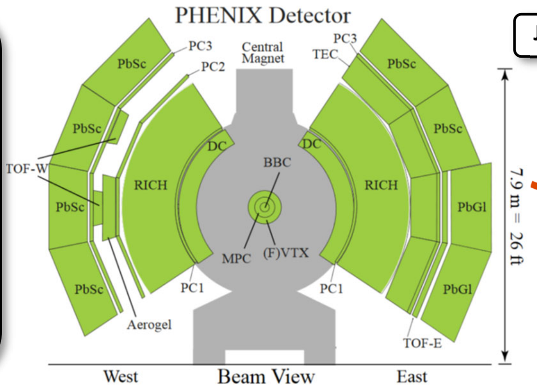
Measurement Details

PHENIX Run-8/12/15 p+p (200 GeV) datasets

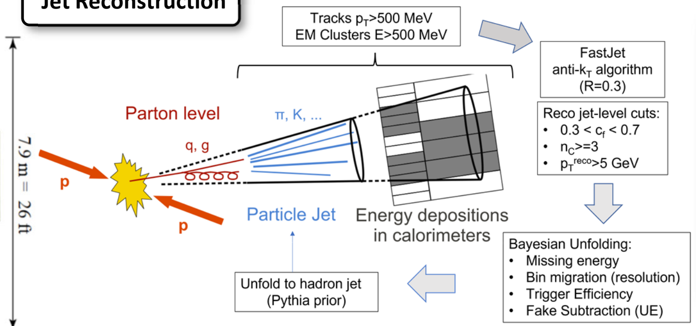
Two central detector arms
Acceptance:
$|\eta|<0.35$
$\phi \sim 90^o$

Drift and pad chambers to track charged particles

EMCal for EM energy and high tower trigger



Jet Reconstruction



Two-Dimensional Unfolding

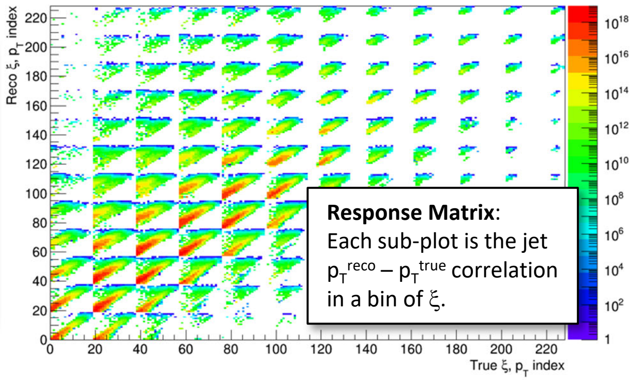
For jet substructure a 2D unfolding is done in jet p_T and the groomed momentum fraction z_g (Soft Drop[1], β=0, z_{cut} = 0.1):

$$z_g = \min(p_{T1},p_{T2})/(p_{T1}+p_{T2})$$

The jet constituent distributions are unfolded similarly for charged particles in the jet:

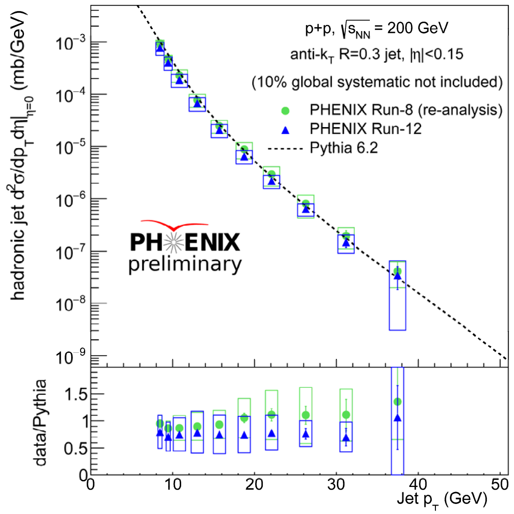
$$\xi = -\ln(z)\ ,\ j_T\ ,\ \Delta R$$

The Pythia prior is iteratively tuned to match the mean number of charged particles in the jet as a function of jet p_T. This tuning in turn affects the jet efficiency corrections used for the cross section determination.

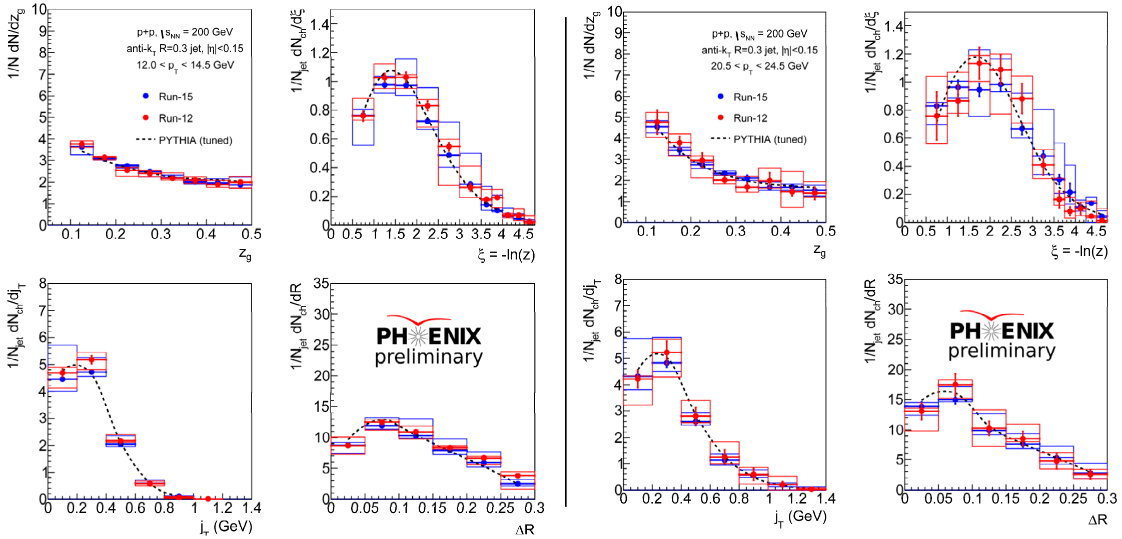


Response Matrix: Each sub-plot is the jet $p_T^{reco} - p_T^{true}$ correlation in a bin of ξ.

Cross Section



Jet Substructure



Summary

We have shown results for the anti-k_T R=0.3 jet cross section and substructure in 200 GeV p+p collisions measure by the PHENIX detector. The cross sections are consistent between PHENIX run years. A comparison with an NNLO + lnR resummation is in preparation.

The measured jet substructure is also consistent between PHENIX run years. Pythia shows a larger mean number of charged particles than the data before tuning. These results serve as baseline for similar studies of jet production in p+Au, and Cu+Au collisions from the PHENIX Run-12 and Run-15 datasets. The simultaneous, self-consistent extraction of both the jet yield and substructure can yield new insights into the interaction of scattered partons with both cold and hot nuclear matter.

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References

[1] A. Larkoski et al., JHEP 1405 (2014) 146

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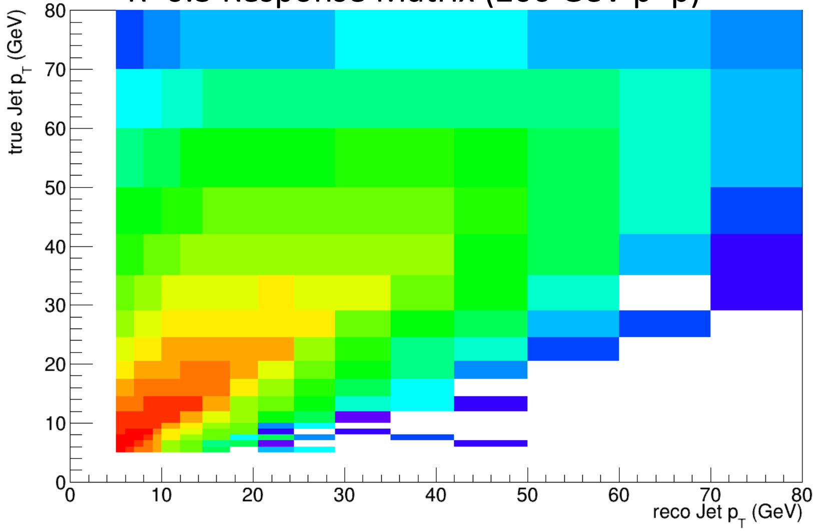
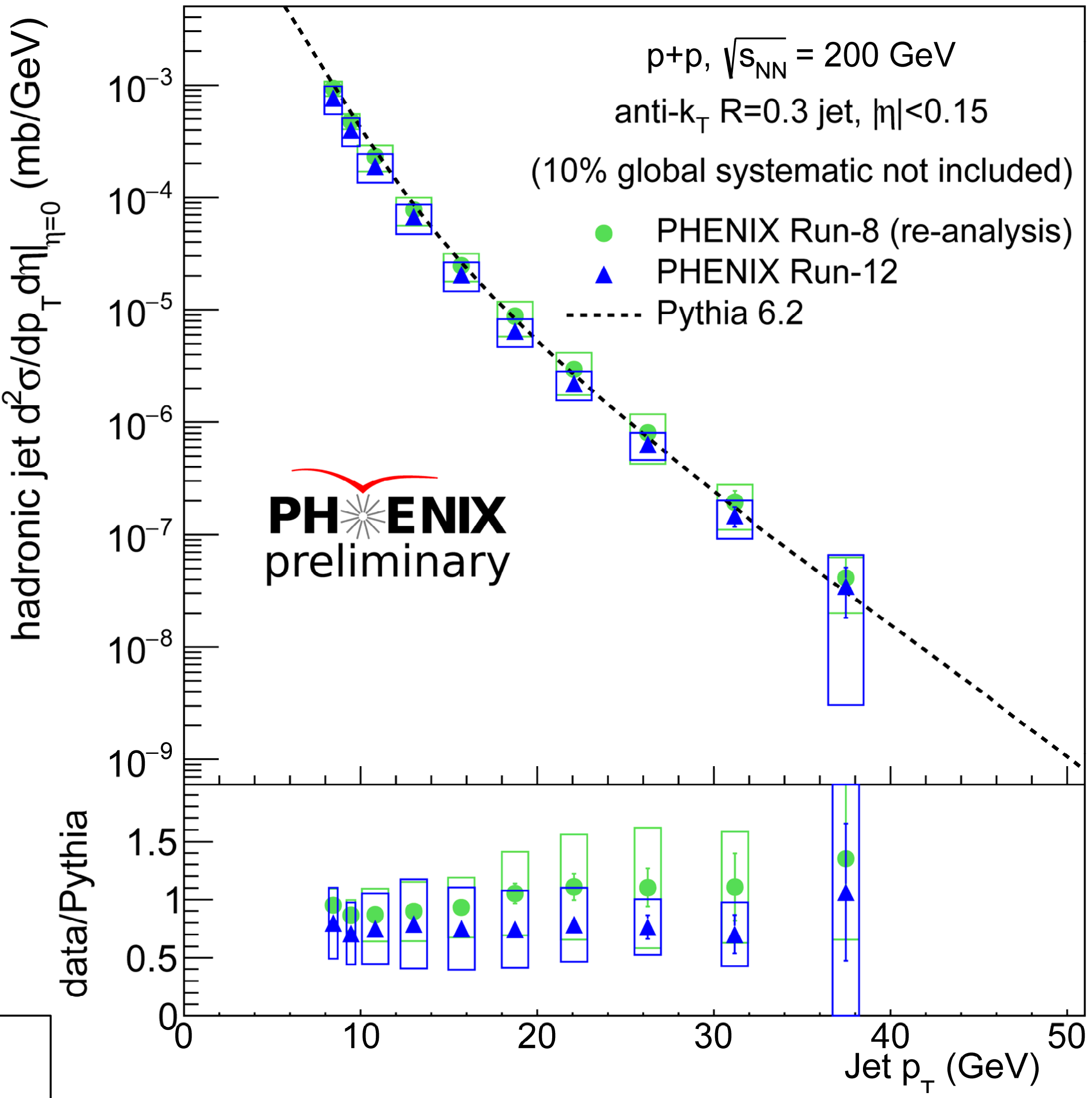
- Significant bin migration in PHENIX and large fluctuations due to lack of an HCAL
  - <JES> ~ 0.4-0.6
- Unfolding using RooUnfold
- Bayesian unfolding (2 iterations)
- Response matrix generated with Pythia 6.2 (Tune A)

R=0.3 Response Matrix (200 GeV p+p)





The new PHENIX Run-8 Preliminary supersedes the previously published result (PRL 116, 122301, erratum in preparation).

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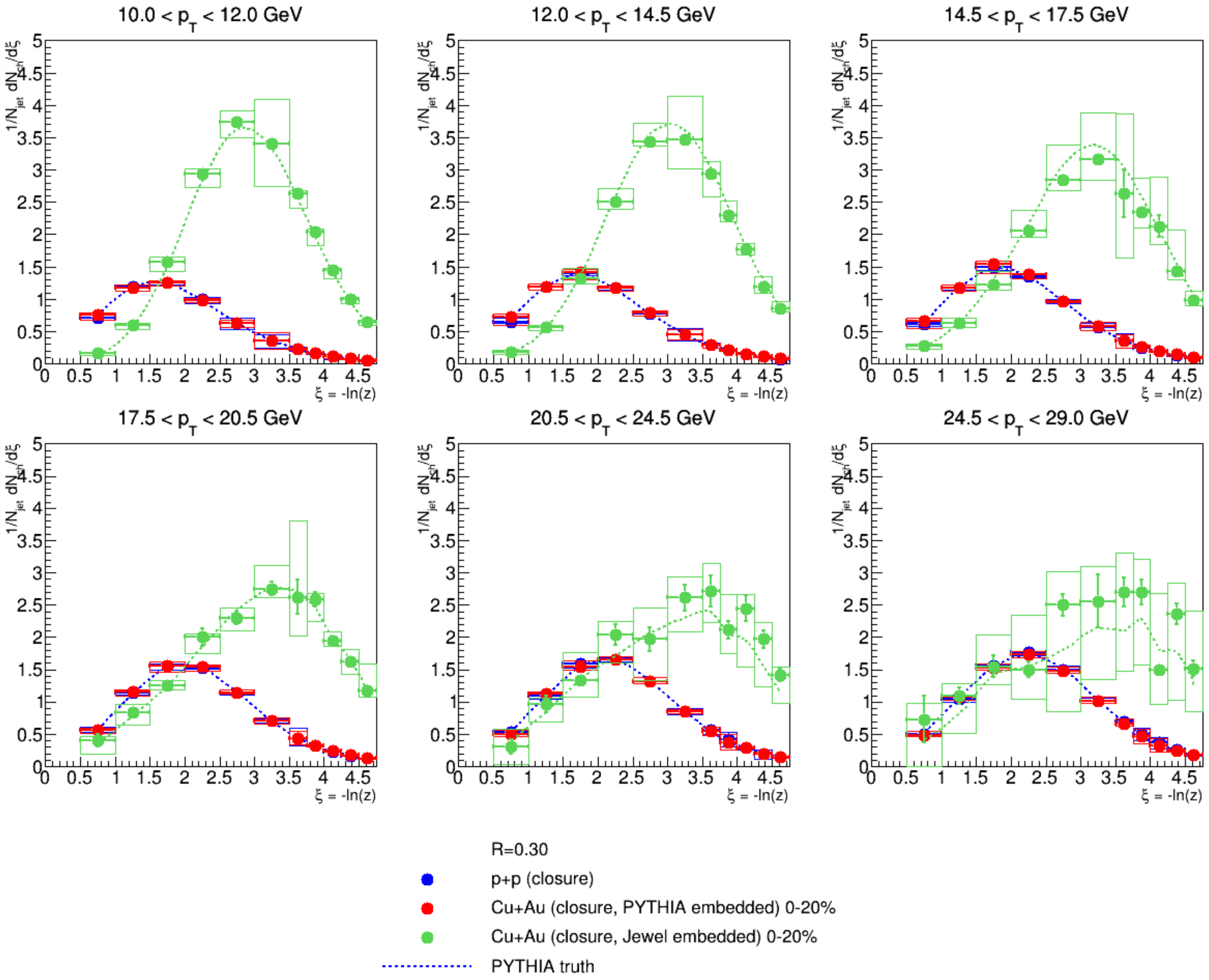
The result of 2D unfolding closure tests for the variable $\xi = -\ln(z)$ from simulated jets embedded in data for p+p and Cu+Au collisions is shown to the right. The data samples used for the response matrix and the closure test were independent.

In Cu+Au collisions the unfolding procedure also corrects for the effect of the underlying event on the unfolded distributions.

In both p+p and Cu+Au collisions the closure test demonstrates the ability of the procedure to extract the embedded distribution, showing that it is in principle possible to extract jet substructure from PHENIX measurements of jets in p+p, p+Au and Cu+Au collisions.

The performance in data will greatly depend on how closely the prior matches the data, which will be a dominant factor in the systematic uncertainties.

SIMULATION RESUTS



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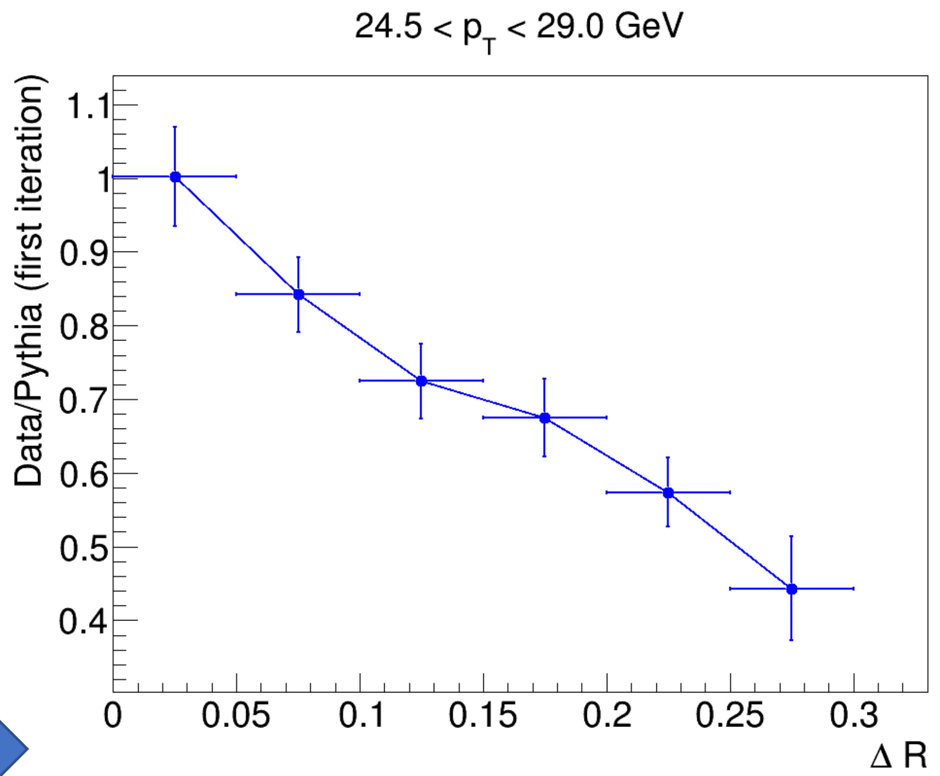
Standard Pythia 6.2 (Tune A) jets have too many particles – biases the unfolding.

Jet p_T (GeV)	$\langle N_C \rangle$ Pythia	$\langle N_C \rangle$ data unfold	Data/Pythia	$\langle N_C \rangle$ Pythia (tuned)	$\langle N_C \rangle$ data unfold	Data/Pythia (tuned)
10.0 – 12.0	2.84	2.52	0.887	2.23	2.22	0.995
12.0 – 14.5	3.13	2.75	0.879	2.42	2.41	0.996
14.5 – 17.5	3.43	2.95	0.860	2.65	2.64	0.996
17.5 – 20.5	3.72	3.16	0.849	2.80	2.77	0.989
20.5 – 24.5	4.00	3.28	0.820	2.87	2.76	0.962
24.5 – 29.0	4.30	3.50	0.814	3.10	3.04	0.981

Pythia tuned to remove particles as a function of jet p_T based on ΔR distribution in Pythia and unfolded data (2 iterations) – better match in particle yield, reduced bias.



The ratio of the unfolded

$$\Delta R = \sqrt{(\phi - \phi_{jet})^2 + (\eta - \eta_{jet})^2}$$ distribution

to the Pythia truth is used to remove particles from the R=0.3 jet. The remaining jet constituent momenta are rescaled so the overall jet momentum and cross section is unchanged.

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The resulting unfolded substructure distributions in two bins in jet p_T are shown with the final iteration of the tuned Pythia.

$$z_g = \min(p_{T1},p_{T2})/(p_{T1}+p_{T2})$$

(Soft Drop, β=0, z_{cut} = 0.1)

$$\xi = -\ln(z),\quad z = \frac{\vec{p}\cdot\vec{p}_{JET}}{p\,p_{JET}}$$

(Fragmentation Function)

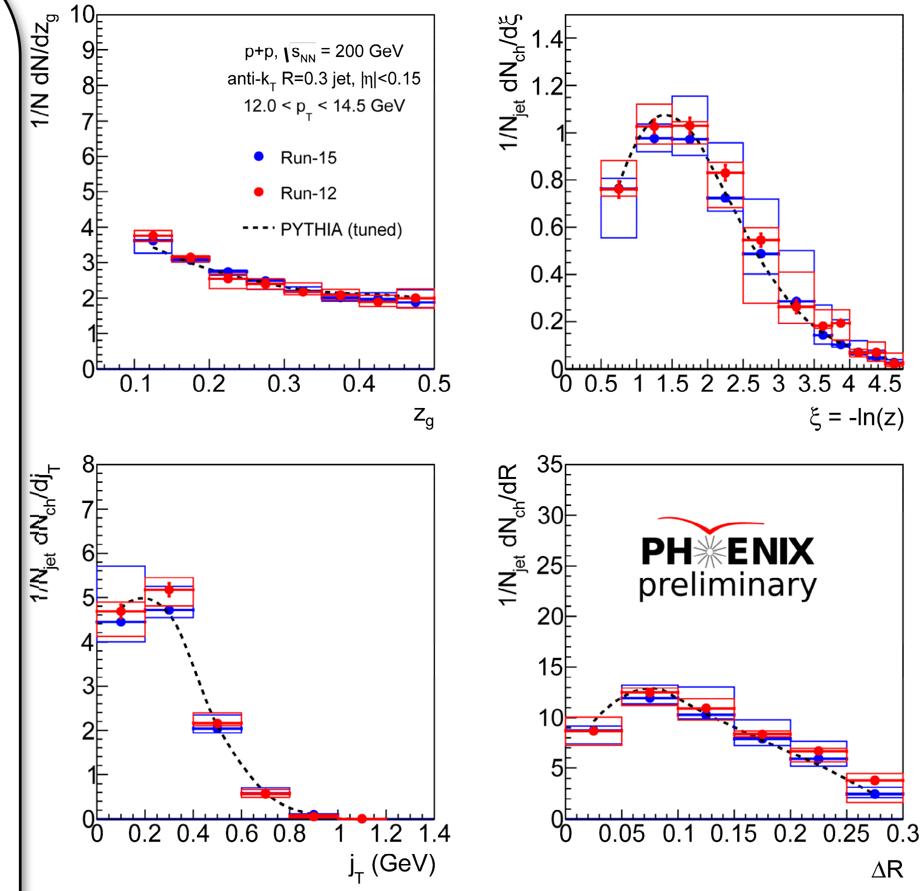
j_T (Constituent mom. ⊥ to jet axis)

$$\Delta R = \sqrt{(\phi-\phi_{jet})^2+(\eta-\eta_{jet})^2}$$

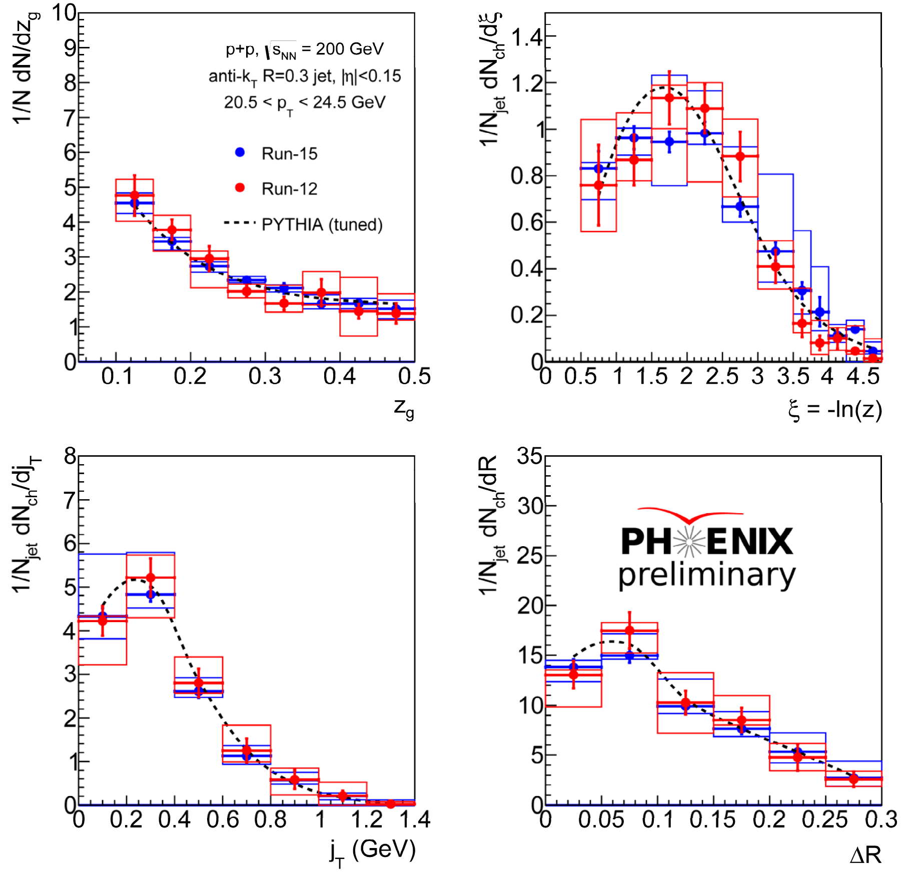
(Constituent distance from jet axis)

The groomed jet momentum fraction z_g is consistent with previously published results from STAR.
(Phys. Lett. B 811 (2020) 135846).

Low Jet p_T



High Jet p_T



These results serve as a baseline for a comparison of jet yields and substructure in p+Au, Cu+Au collisions, which can yield new insights into the propagation of partons in hot and cold nuclear matter.