Next generation jet measurements with sPHENIX

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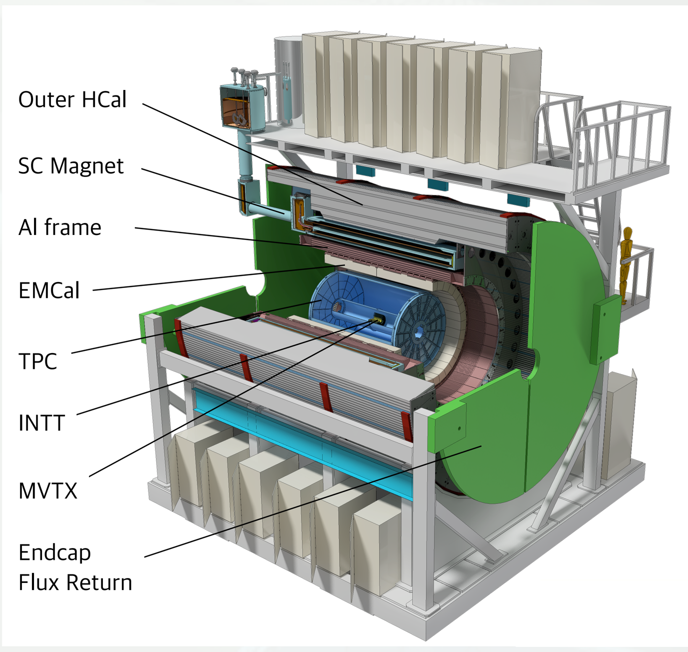
Abstract

The proposed sPHENIX detector at RHIC will allow state-of-the-art measurements of jets and jet correlations, making use of recent technological and conceptual advances. The kinematic reach of these measurements will overlap with those made at the LHC by taking advantage of the increased luminosity due to RHIC accelerator upgrades and the sPHENIX acceptance and rate capability. Particle jets, formed when a hard scattered parton fragments and then hadronizes into a spray of particles, have been proposed as a probe of the Quark-Gluon Plasma (QGP) and used extensively at the LHC. As these partons traverse the QGP, they lose energy to the medium, an effect called "jet quenching". To answer fundamental questions about parton energy loss and the microscopic nature of the QGP, we need to characterize both the medium induced modification of the jet fragmentation and the correlation of the lost energy with the jet axis. Photon+jet correlations are especially useful as the photon kinematics are more tightly correlated with the hard scattered parton. Jet fragmentation and jet structure measurements, which require the precise tracking and calorimetry that are part of sPHENIX, will provide highly detailed information about the interaction of the parton with the medium. . We will show the performance of jet and photon+jet observables within the sPHENIX simulation framework developed for understanding the performance of the new detector.

Jet physics at sPHENIX

- **Calorimeter system**
  - Uniform and hermetic in |η|<0.85 and 0 < φ < 2π
  - ElectroMagnetic Calorimeter (18 X_0, 1 λ)
    - Tungsten-Scintillating Fiber
    - Δη x Δφ ~ 0.025 x 0.025
  - Aluminum Frame (0.25 λ)
    - Located between EMCal and SC Magnet
    - Potential to be instrumented for increased performance
  - Outer Hadronic Calorimeter (3.8 λ)
    - Steel plates and scintillating tiles with WLS fibers
    - Also serves as the flux return
    - Δη x Δφ ~ 0.1 x 0.1



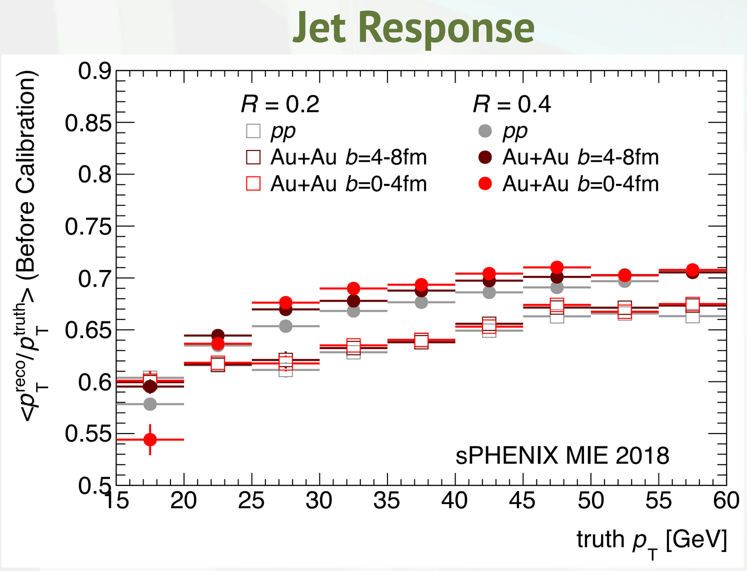
- **Detector performance requirements**
  - Jet radius down to R=0.2 (fine segmentation)
  - Jet energy resolution:
    - σ_E/E < 120%/√E in p+p for R=0.2-0.4
    - σ_E/E < 150%/√E in central Au+Au for R=0.2
  - Photon energy resolution in EMCal: σ_E/E < 15%/√E
  - Tracking resolution: dp/p < 0.2% x p (for a 40 GeV jet)
  - Track reconstruction efficiency > 90 % for p_T > 3 GeV/c

- **Jet Simulation**
  - Anti-k_T algorithm with FastJet package
  - Full Geant4 simulation
  - Jet |η| < 0.45, E=15-60 GeV, R=0.2-0.4
  - PYTHIA8 jets for p+p
  - PYTHIA8+HIJING for Au+Au
    - b=0-4 fm (0-7%)
    - b=4-8 fm (7-30%)

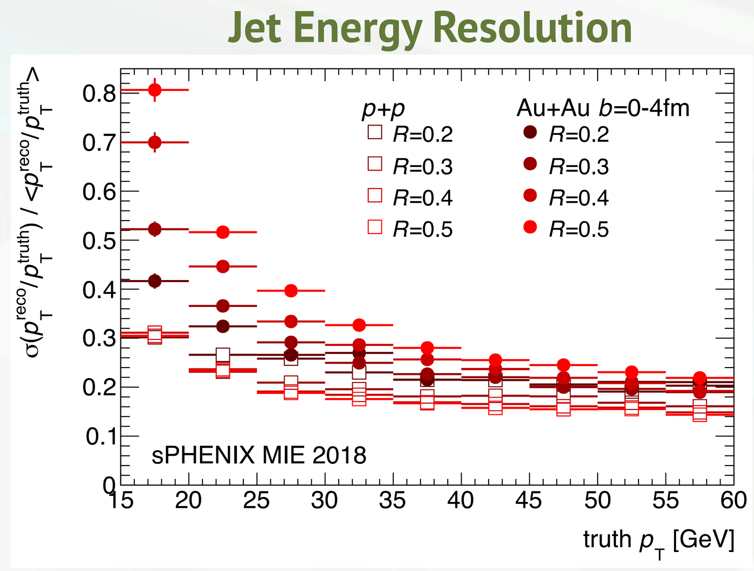
Jet Response and Resolution

- Reconstructed calorimeter jet p_T / Particle-level truth jet p_T
- Similar response in p+p and Au+Au (no centrality dependence) for the same R
- JER is worse for larger R
  - At large R and low p_T: dominated by fluctuations in the underlying event
  - At small R or high p_T: dominated by an intrinsic resolution of calorimetry system

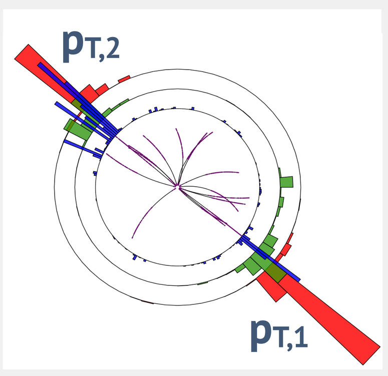
Jet Response



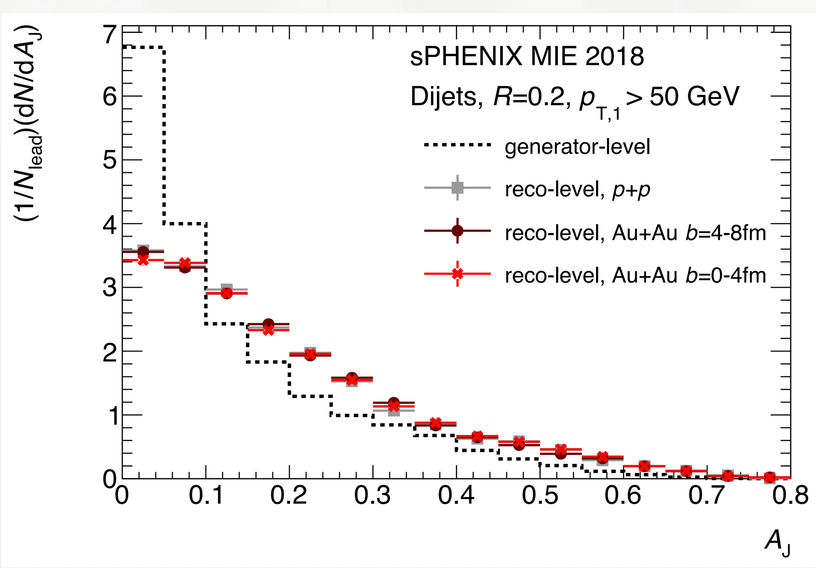
Jet Energy Resolution



Dijet Asymmetry



$$A_J = \frac{(p_{T,1} - p_{T,2})}{(p_{T,1} + p_{T,2})}$$



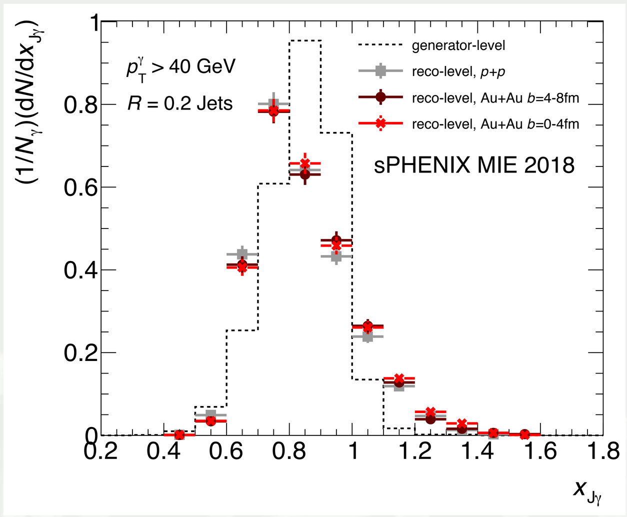
- Sensitive observable to jet quenching in QGP
- Dijet observables are much less contaminated by fake jets than inclusive jet measurements
- No centrality dependence at RECO level

Photon+Jet p_T balance

- Photon provides good access to parent parton energy of the associated jet
  - Also useful for jet energy calibration
- γ-jet events are mainly initiated by quarks
  - Flavor comparison between quark and gluon jets

$$x_{J\gamma} = p_T^{Jet}/p_T^{\gamma}$$

- Truth photon information is used (assumes resolution of photon is subdominant to that of jet)

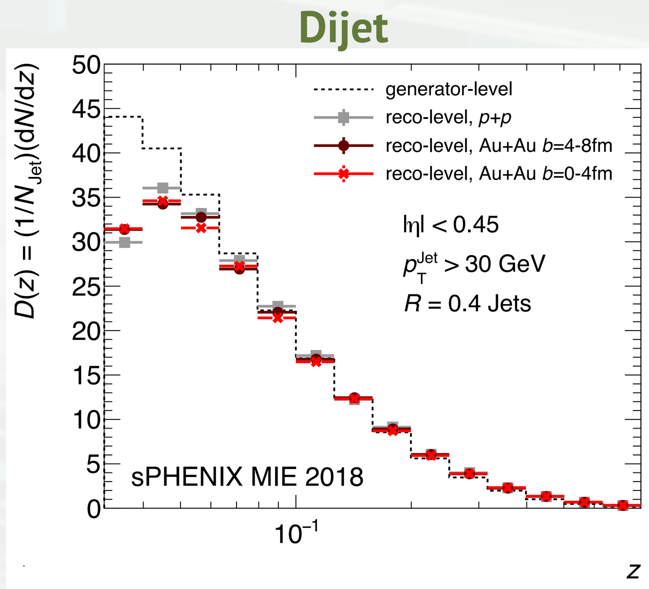


Fragmentation Function

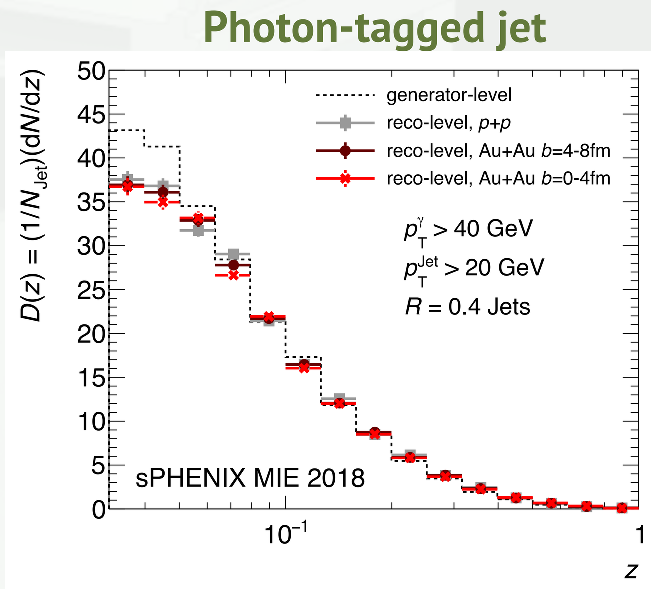
- Redistribution of energy within parton shower is an important observable for understanding the underlying dynamics of jet quenching
- Truth charged-particle kinematics are used (assumes p_T^{Track} can be measured more precisely than p_T^{Jet})

$$z = p_T^{Track}/p_T^{Jet}$$

Dijet

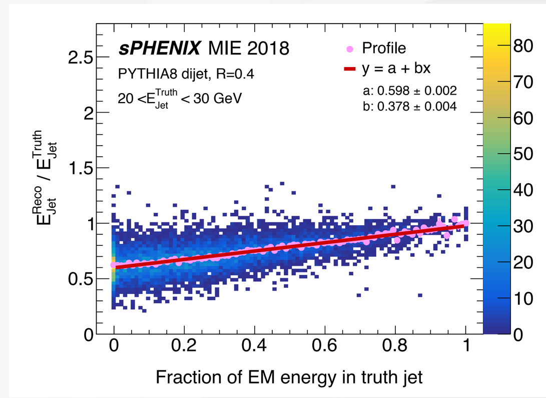


Photon-tagged jet



Calibration study in p+p

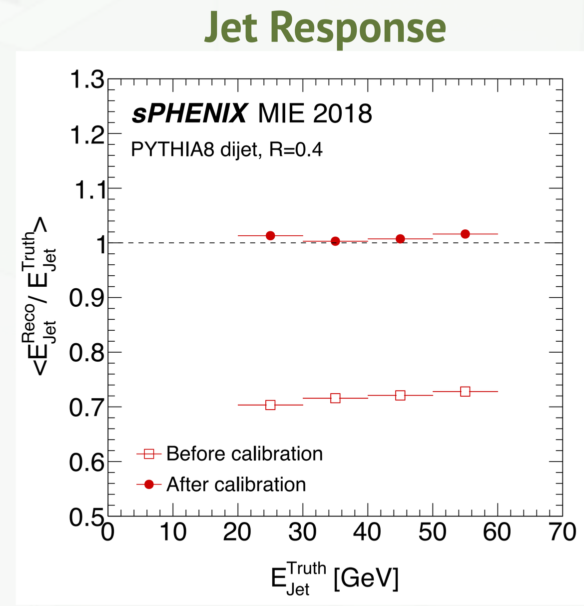
- **Jet response depends on EM fraction in a jet**
  - Different EMCal response to EM vs. hadronic showers
  - Response depends on longitudinal center of gravity
- **Calorimetry segments need to be calibrated separately**
  - EMCal clusters with hadronic energy (E_{EMCal}^{had}) and with EM energy (E_{EMCal}^{em}) are separated using 1) Cluster-Track matching and 2) E_{EMCal}/p_{Track} cut
  - Scale factors A, B, and C (B=0 for MIE 2018 configuration)



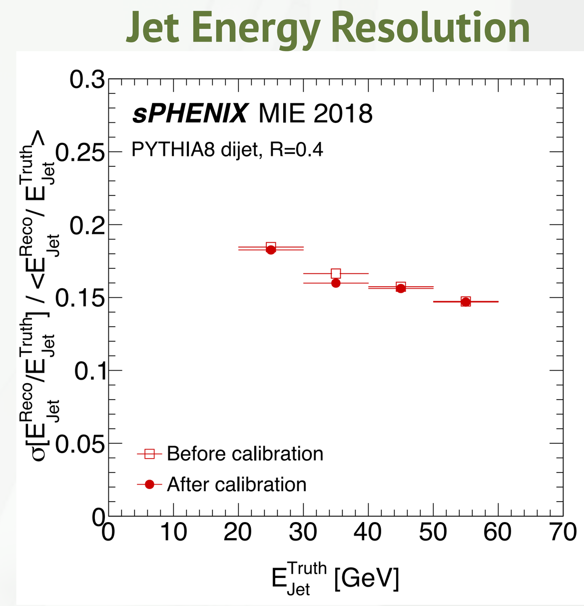
$$E_{Jet}^{Reco} = E_{EMCal}^{em} + A(E) \cdot E_{EMCal}^{had} + B(E) \cdot E_{InnerHCal} + +C(E) \cdot E_{OuterHCal}$$

- **Data-driven calibration technique using γ-jet events**
  - Reconstructed photon energy as a reference
  - A,B,C determined by minimizing the quantity with MINUIT: $\Sigma_{i=1}^{N}(E_{Jet,i}^{Reco} - E_{\gamma,i}^{Reco})^2/(E_{\gamma,i}^{Reco})^2$

Jet Response



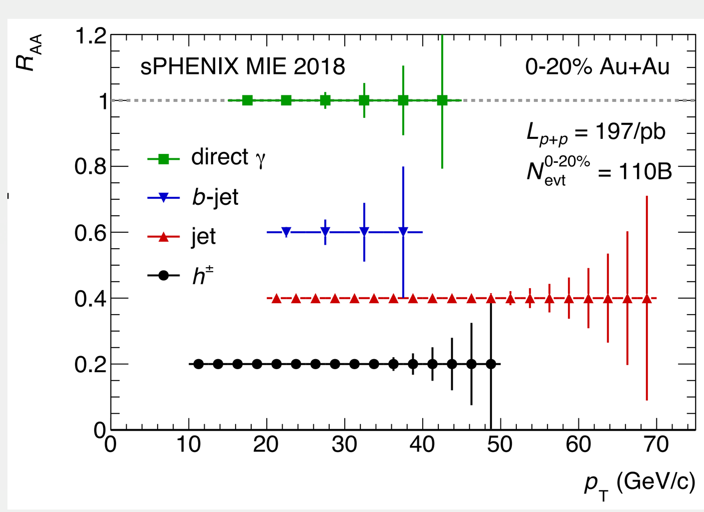
Jet Energy Resolution



- Jet response close to unity after calibration
- JER shows no significant improvement for MIE 2018 configuration
- JER is observed to be improved over the entire energy range with instrumented inner HCal

Conclusions and Outlook

- Jet measurements provides us better understanding of parton energy loss mechanisms in the QGP
- sPHENIX, the new generation experiment at RHIC, will allow a direct comparison to the LHC
  - Expanded kinematic range (jet up to ~70 GeV)
  - Jet performance satisfies our specification
  - Investigation into the various LHC-inspired observables (A_J, $x_{J\gamma}$, fragmentation, etc) is underway
- Calibration using γ-jet events is developed in p+p
  - Need further study to extend calibrations to Au+Au



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