Semi-inclusive jets from γ_{dir} and π^0 triggers in central Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV in STAR

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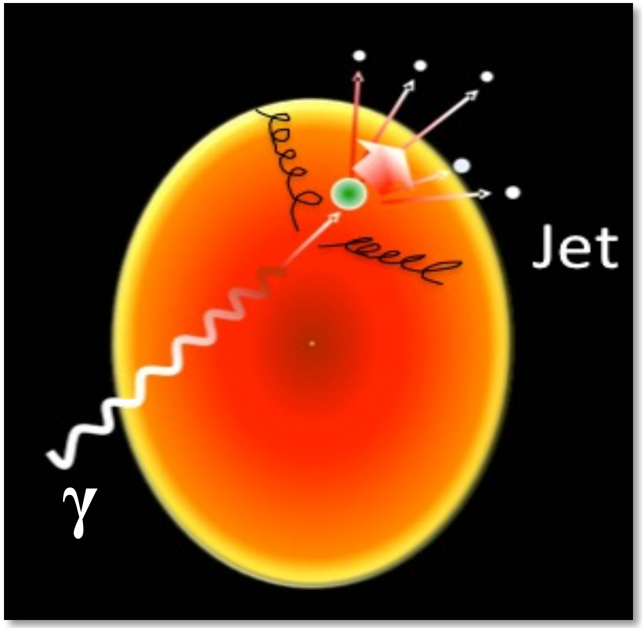
Introduction

- Quantitative understanding of parton energy loss in QCD medium
  - Parton energy loss as a function of path length, color factor, parton energy
  - Redistribution of lost energy inside the medium [Jet radius]
  - RHIC vs. LHC [dependence on temp. and initial gluon density]

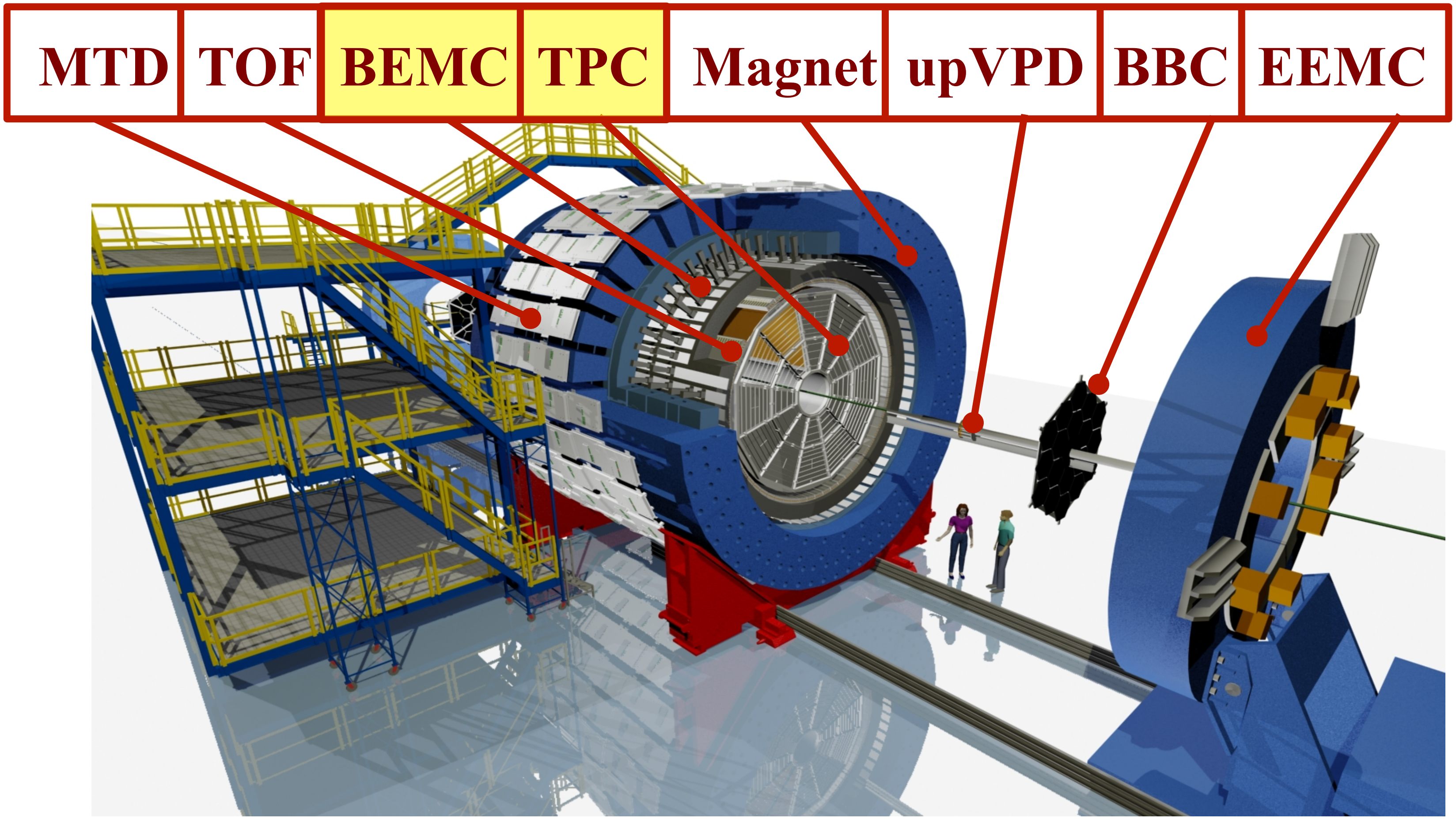
- This can be addressed using vector-boson-tagged jet
  - Trigger energy approximates the initial recoil parton energy
  - At RHIC, γ_{dir}+jet is accessible

This is the first fully corrected γ_{dir}+jet measurement at RHIC energy.

And a comparison between γ_{dir}+jet and $h(\pi^0)$+jet.



STAR detector system



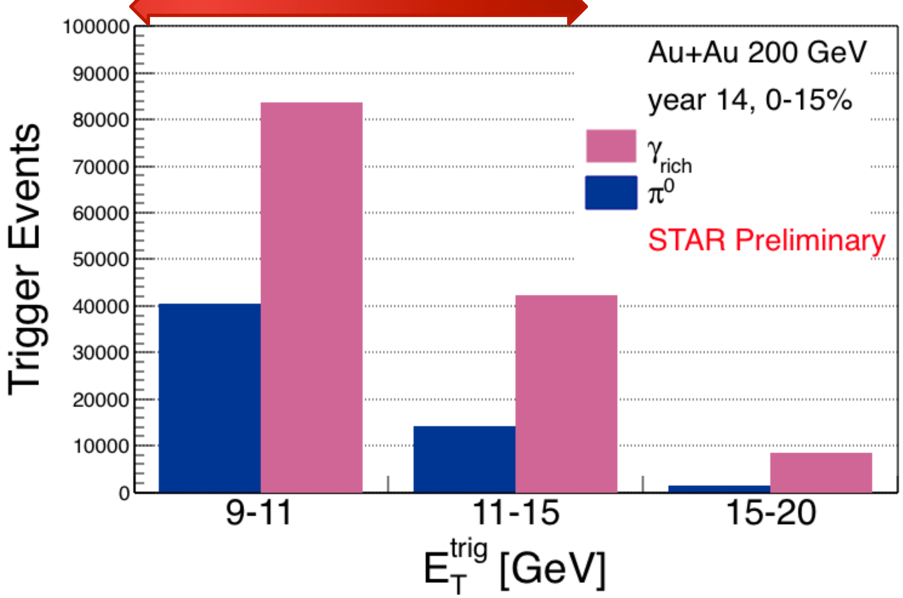
- Special High Tower trigger for π^0/γ event [BEMC]
- Discrimination between $\pi^0 \rightarrow \gamma\gamma$ and γ_{dir}
  - By Transverse Shower Profile (TSP) method
  - Using Barrel Shower Maximum Detector [BSMD]

- Kinematic coverage:
  - $-1 < \eta < 1$
  - 2π-azimuth

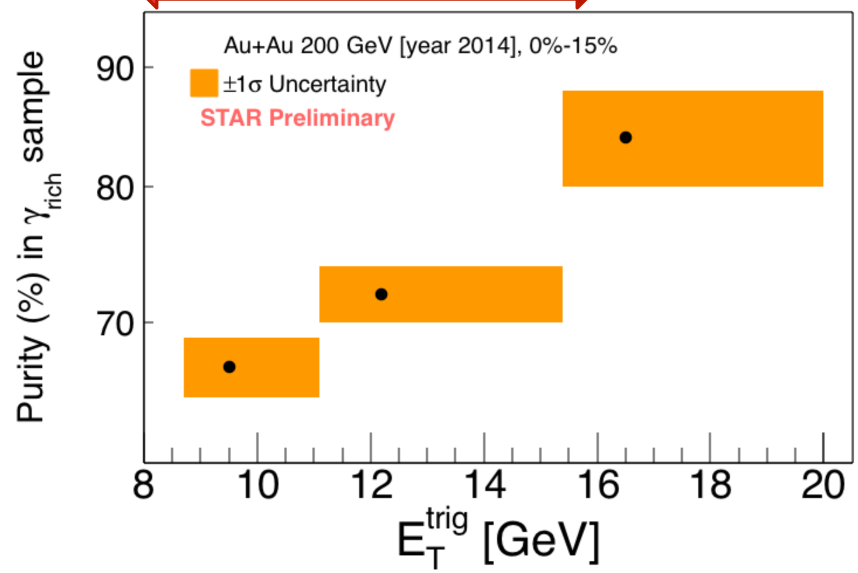
Event statistics and γ_{dir} purity

- Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV
- Integrated luminosity of 13 nb^{-1} in the year 2014

Results in this talk



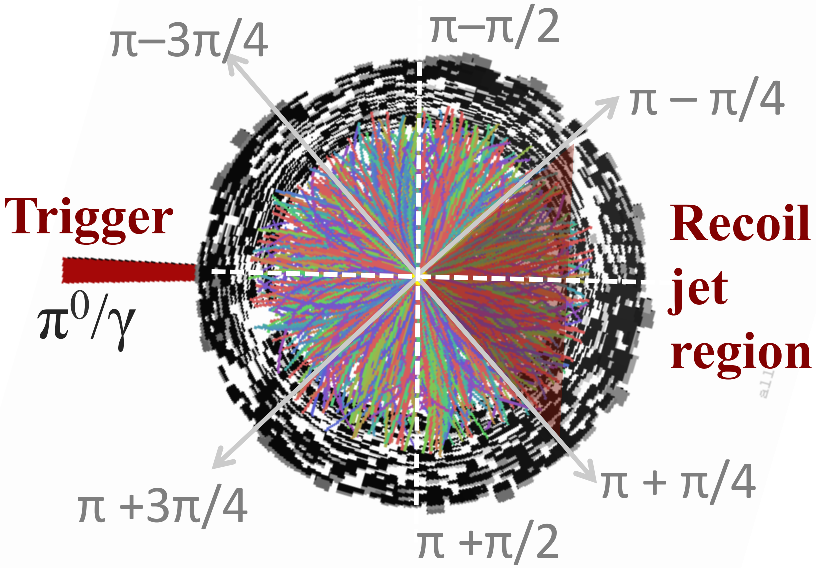
Results in this talk



- γ_{rich}: Mixture of decay and direct photons
- Purity of direct photons varies between 65% and 89% for $9 < E_T^{trig} < 20$ GeV
- High-purity criteria for π^0 selection limits the statistics
  - Similar procedure as in the previous STAR γ_{dir}+hadron correlation analysis [PLB 760 (2016) 689-696]

Semi-inclusive π^0/γ+jet

- Recoil jets from triggered events



- With high-E_T trigger: $E_T^{trig} > 9$ GeV
  - High-Q^2 process
- (Charged) Jet reconstruction:
  - Charged hadron constituents: $p_T^{const} < 15$ GeV/c
  - Same constituent p_T cut also applied at the truth level
  - Algorithm: anti-k_T [Fastjet]
  - Recoil jet region:[π-π/4, π+π/4]
  - Jet radius = 0.2, $|\eta_{jet}| < 1$-R
- Event-mixing technique
  - Uncorrelated jet background
  - Based on h+jet analysis [STAR: PRC **96**, 024905 (2017)]
  - Using same analysis conditions as applied in Same Event (SE)

Full analysis chain

- Discrimination between π^0/γ_{rich}-triggered events
  - Using Transverse Shower Profile method
- Recoil jets from high-tower-triggered events (SE)
  - Estimation of reconstructed jet p_T and background energy density (ρ)

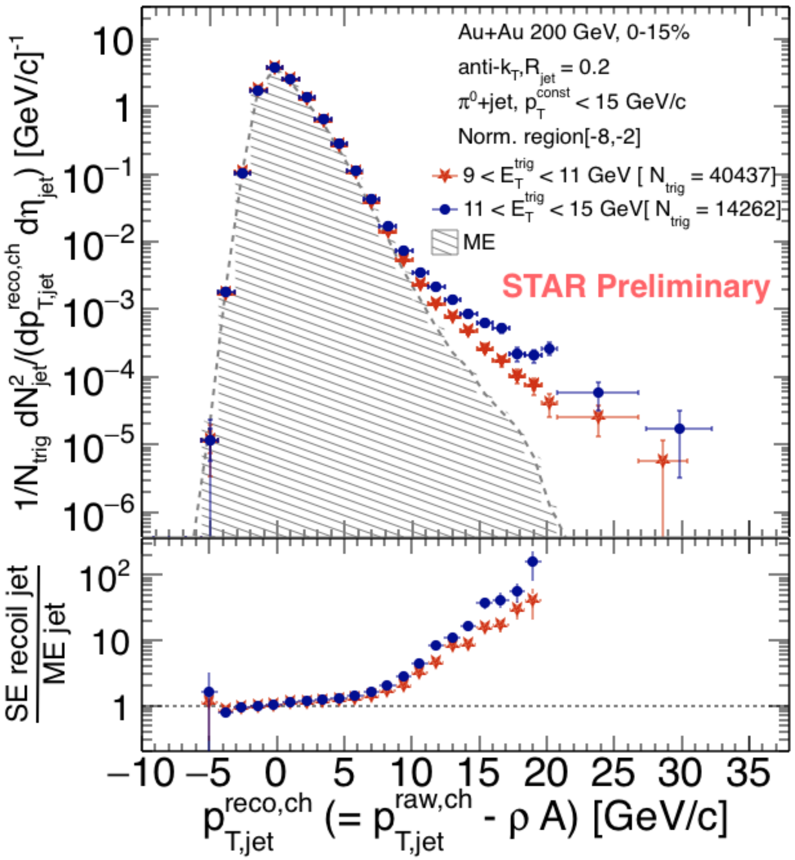
$$p_{\mathrm{T,jet}}^{\mathrm{reco,ch}} = p_{\mathrm{T,jet}}^{\mathrm{raw,ch}} - \rho \cdot A$$

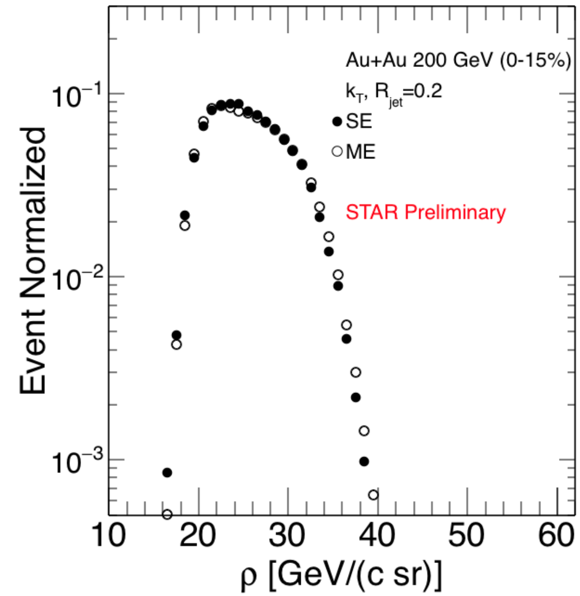
$$\rho = \mathrm{median}\left\{ \frac{p_{\mathrm{T,jet}}^{\mathrm{raw,i}}}{A_{\mathrm{jet}}^{\mathrm{i}}} \right\}$$

- Subtraction of uncorrelated jet background in recoil region
  - Using mixed-event subtraction method
- Correction for detector and heavy-ion background fluctuation effects
  - Using unfolding technique [RooUnfold]
- Conversion from γ_{rich}+jet to γ_{dir}+jet
  - Statistical subtraction based on previously determined purity
- Major sources of systematic uncertainty
  - Unfolding [Prior, methods e.g, SVD and Bayesian, iterations]
  - Mixed-event normalization region
  - Track-reconstruction effects
  - γ_{dir} background subtraction [contributes only to γ_{dir}]

Uncorrelated jet background: π^0+jet

SE: Same Events from triggered events, **ME**: Mixed Events from MB dataset



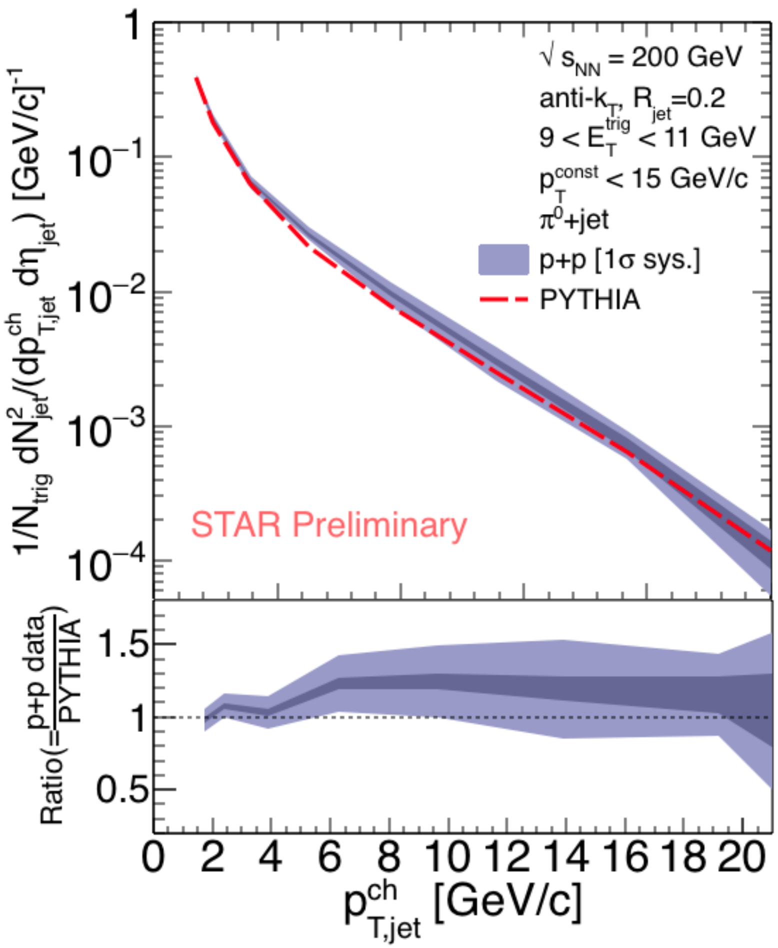


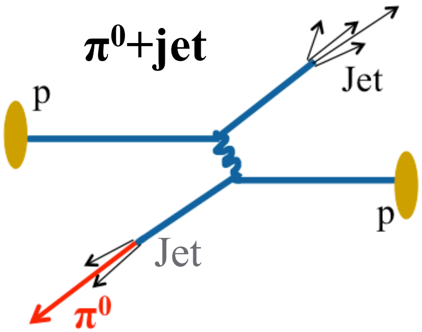
$$\rho = \text{median}\left\{ \frac{p_{\mathrm{T,jet}}^{\mathrm{raw,i}}}{A_{\mathrm{jet}}^{\mathrm{i}}} \right\}$$

Similar background density distribution for SE and ME

- Recoil charged jet p_T shows π^0-trigger E_T^{trig} dependence for 9-11 and 11-15 GeV
- Recoil charged jets dominate (above ~10 GeV/c) over uncorrelated jet background from mixed events

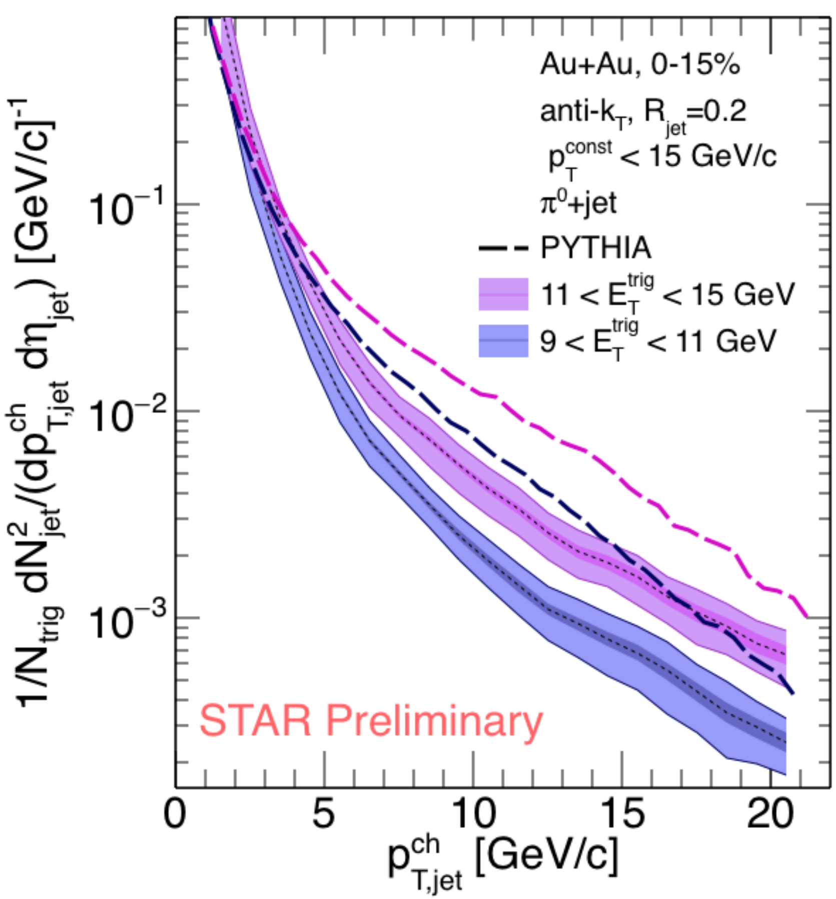
π^0-triggered charged recoil jets in p+p collisions





- p+p $\sqrt{s_{NN}}$ = 200 GeV/c
- π^0 triggers with $9 < E_T^{trig} < 11$ GeV, fully unfolded charged jets
  - Higher E_T^{trig} analysis underway
  - Systematic (lighter band) and statistical (darker band) uncertainties
  - Almost zero background energy density(ρ)
- π^0-triggered charged-jet spectrum consistent with PYTHIA8.

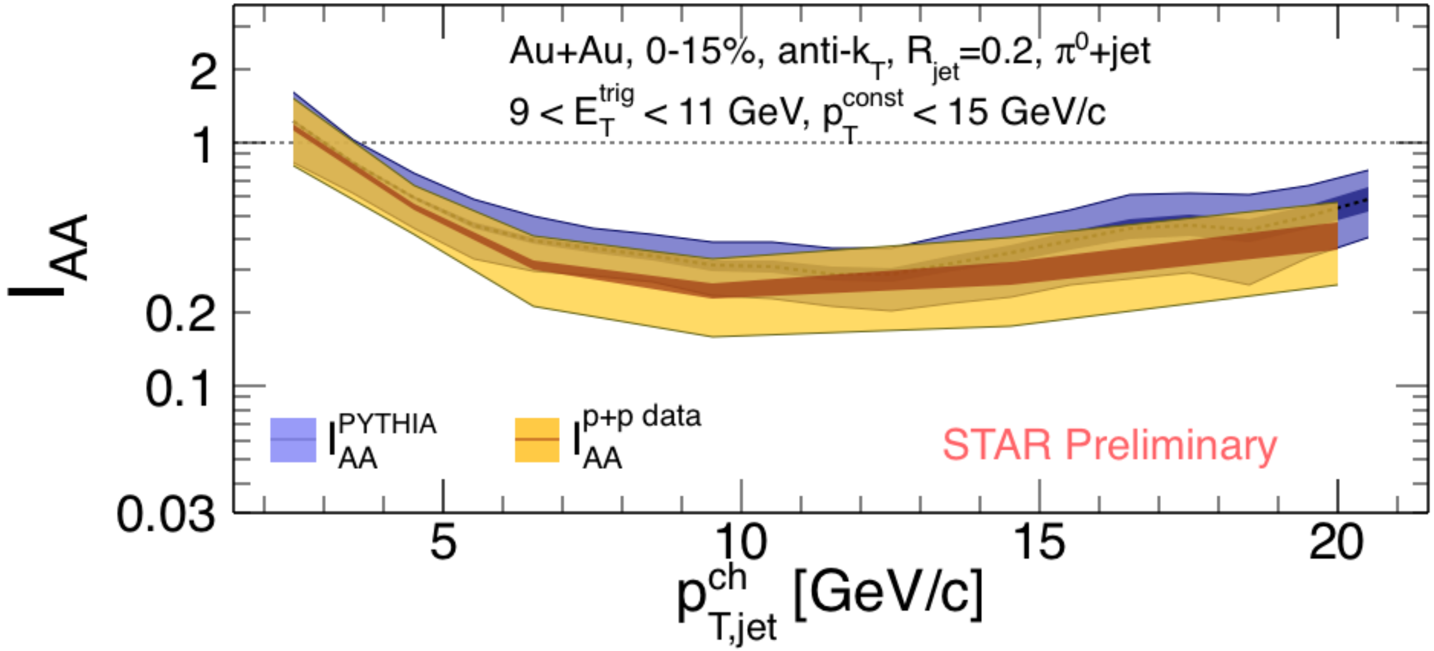
π^0-triggered charged jets in Au+Au collisions



- π^0-triggered charged recoil jets
  - Fully unfolded spectrum
  - $9 < E_T^{trig} < 11$ GeV: $N_{trig} = 40437$
  - $11 < E_T^{trig} < 15$ GeV: $N_{trig} = 14262$
- A clear difference between recoil-jet spectra for different trigger-E_T: $9 < E_T^{trig} < 11$ GeV vs. $11 < E_T^{trig} < 15$ GeV
  - Dominant systematic uncertainty is from unfolding
  - Systematic (lighter band) and statistical (darker band) uncertainty
- Clear suppression with respect to PYTHIA8
- Higher E_T^{trig} (>15 GeV) and $p_{T,jet}^{ch}$ (> 20 GeV/c) in progress

Recoil jet yield suppression: pp vs. PYTHIA

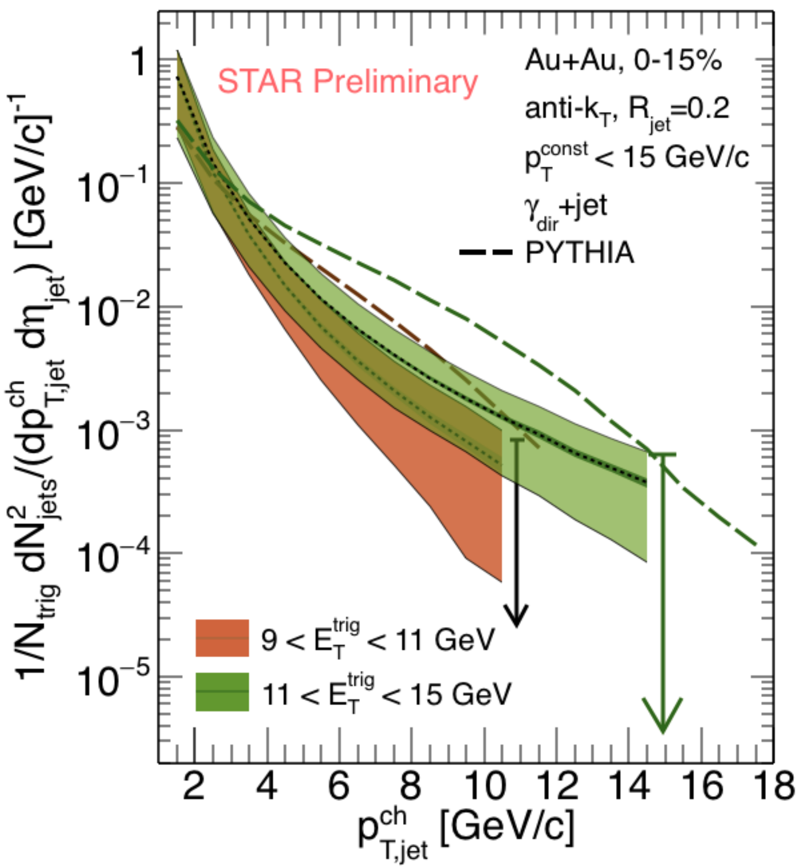
π^0+jet: $9 < E_T^{trig} < 11$ GeV



Systematic (lighter band) and statistical (darker band) uncertainties

- I_{AA} is the ratio of per triggered recoil jet yield in central Au+Au to p+p collisions
- Comparison between π^0-triggered charged jet I_{AA}^{PYTHIA} and $I_{AA}^{p+p\ data}$
- Consistent within uncertainties
- PYTHIA8 provides good representation of p+p data

γ_{dir}-triggered charged jets in Au+Au collisions

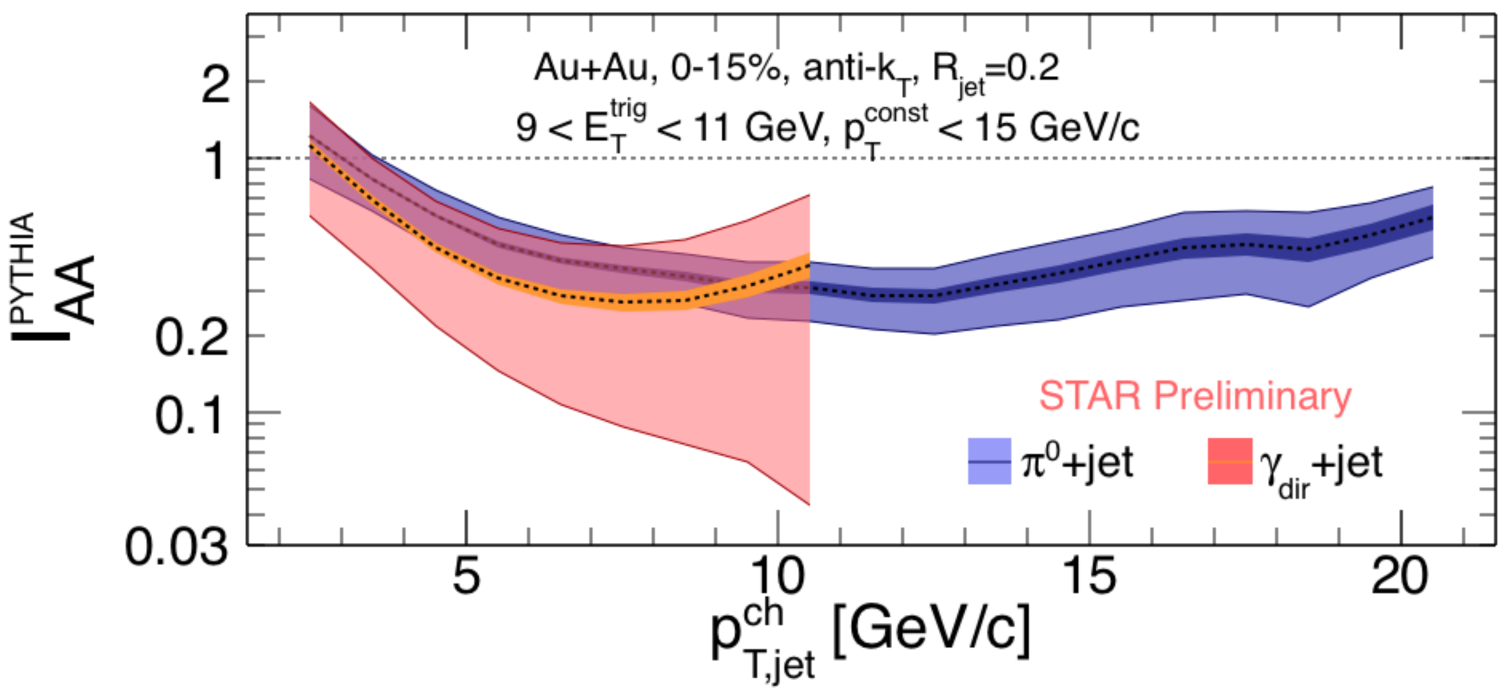


Fully unfolded recoil charged jet p_T

- Indication of systematic difference between recoil-jet spectra for different trigger-E_T: $9 < E_T^{trig} < 11$ GeV vs. $11 < E_T^{trig} < 15$ GeV
  - Dominant systematic uncertainties are from unfolding and from γ_{dir} background subtraction
  - Systematic (lighter band) and statistical (darker band) uncertainties
  - Downward arrow represents upper limit in yield at:
    $p_{T,jet}^{ch} = 11$ GeV/c for $9 < E_T^{trig} < 11$ GeV,
    $p_{T,jet}^{ch} = 15$ GeV/c for $11 < E_T^{trig} < 15$ GeV.
- Clear suppression with respect to PYTHIA8

Recoil jet yield suppression: γ_{dir}+jet vs. π^0+jet

$9 < E_T^{trig} < 11$ GeV



Systematic (lighter band) and statistical (darker band) uncertainties

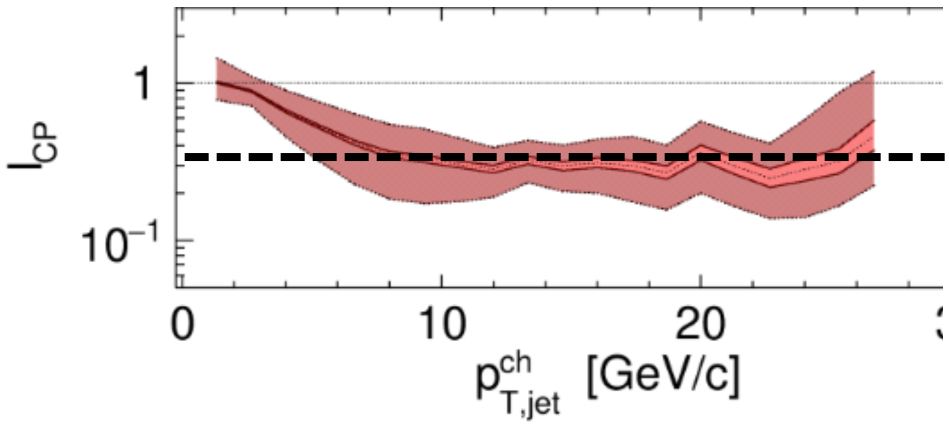
- Semi-inclusive γ_{dir}- and π^0-triggered charged-jet measurements
- Clear suppression for both trigger types with respect to PYTHIA8
- Similar level of suppression in γ_{dir}+jet and π^0+jet, within uncertainties
  - γ_{dir}+jet runs out of kinematic reach

Comparison of $h^{\pm}$+jet to π^0+jet

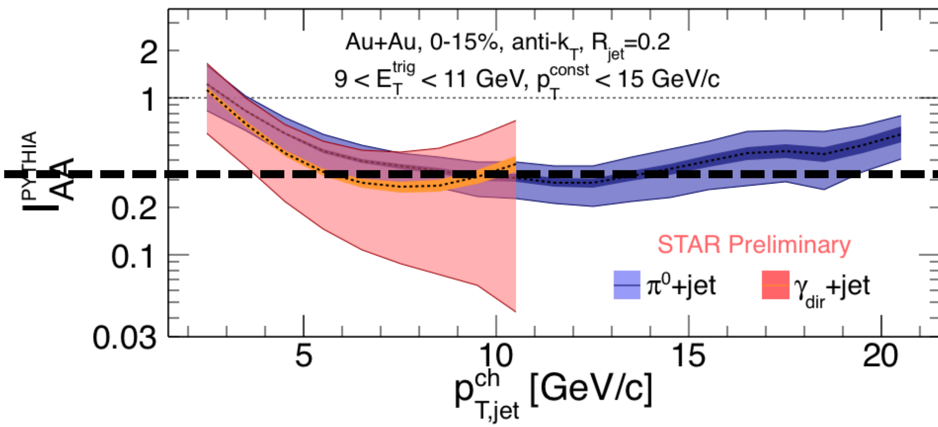
Au+Au 200 GeV

STAR: PRC **96**, 024905 (2017)

$h^{\pm}$+jet: $9 < p_T^{trig} < 30$ GeV/c



This analysis: $9 < E_T^{trig} < 11$ GeV

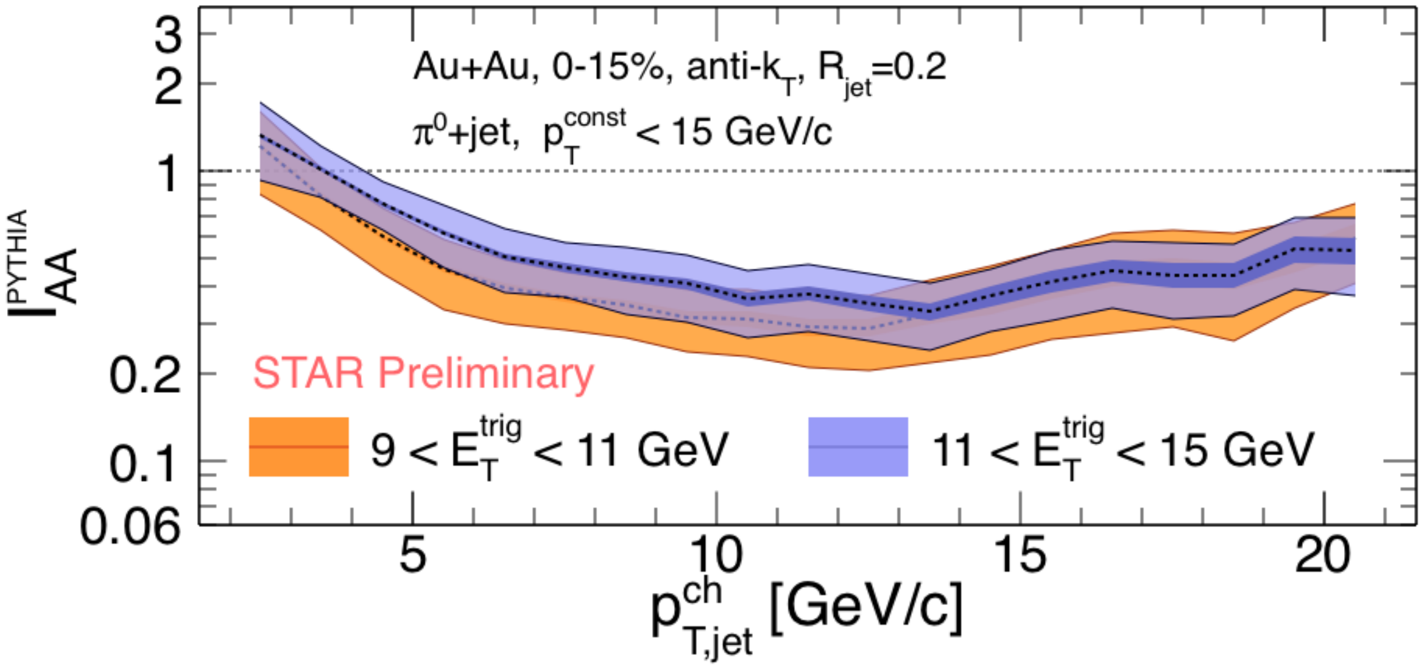


Systematic (lighter band) and statistical (darker band) uncertainties

- Same level of suppression above $p_{T,jet}^{ch} > 9$ GeV/c
  - $h^{\pm}$+jet is I_{CP}, whereas π^0+jet is I_{AA}^{PYTHIA}
  - π^0 +jet upward trend above 15-20 GeV may be due to kinematic cuts -- under investigation

Recoil-jet yield suppression at different trigger E_T

π^0 +jet



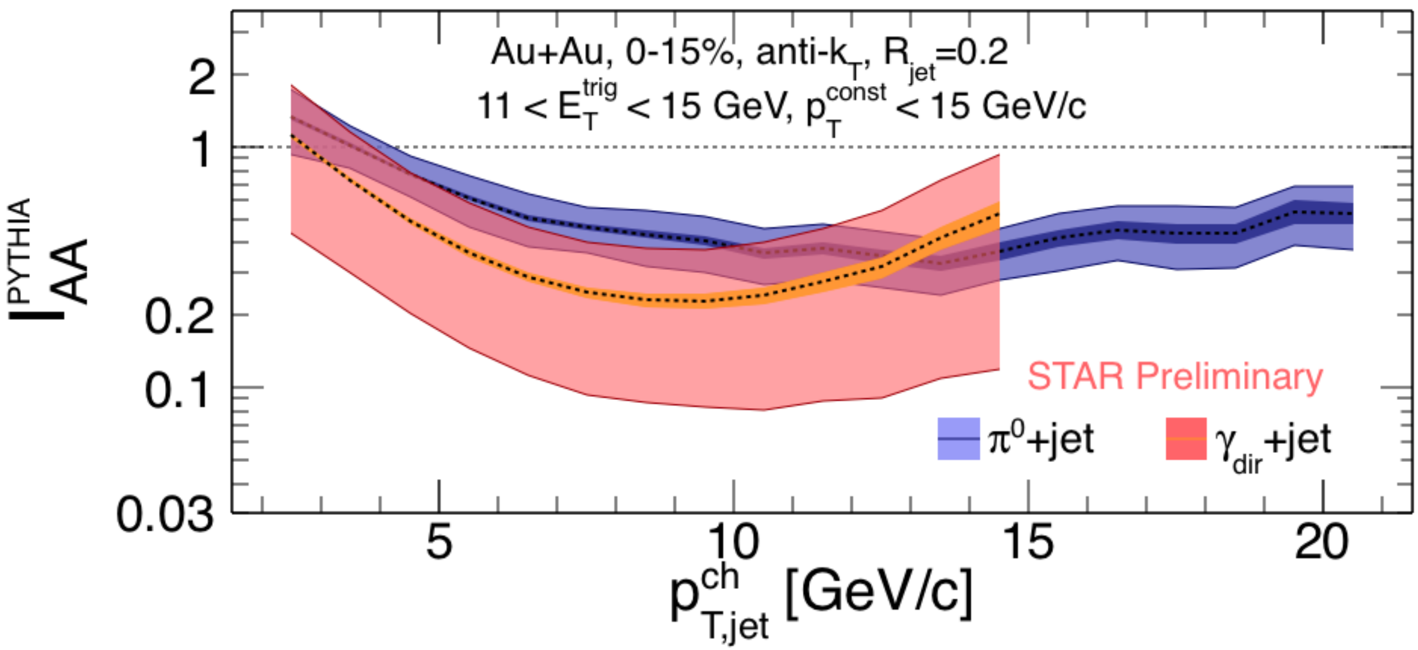
Systematic (lighter band) and statistical (darker band) uncertainties

- No clear π^0-trigger E_T dependence between $9 < E_T^{trig} < 11$ GeV vs. $11 < E_T^{trig} < 15$ GeV, within uncertainties, for jet radius 0.2

Recoil jet yield suppression: γ_{dir}+jet vs. π^0+jet

What about at higher trigger E_T?

$11 < E_T^{trig} < 15$ GeV



Systematic (lighter band) and statistical (darker band) uncertainties

- Almost same level of suppression in both cases, within uncertainties

Summary

- First γ_{dir}+jet and π^0+jet measurements in Au+Au collisions at $\sqrt{s_{NN}}$= 200 GeV at RHIC
- p+p collisions at 200 GeV: π^0-triggered recoil-jet yield consistent in data and PYTHIA8
- Central Au+Au at 200 GeV:
  - A strong suppression of γ_{dir}+jet and π^0+jet
  - Suppression of recoil-jet yield consistent in both cases, for $9 < E_T^{trig} < 15$ GeV

Outlook

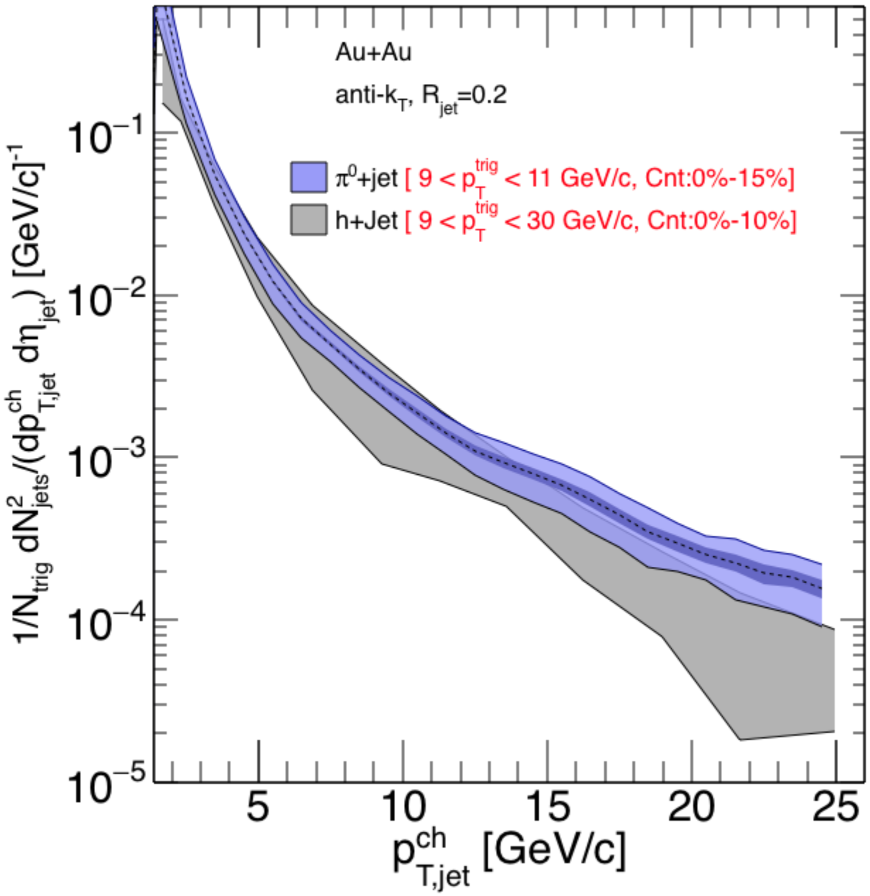
On-going work for γ_{dir}+jet and π^0+jet :

- $E_T^{trig} > 15$ GeV ; larger $p_{T,jet} > 20$ GeV/c; $R_{jet} = 0.5$


Thank you!
Je vous remercie!

Backup

h+Jet and π^0 +Jet comparison

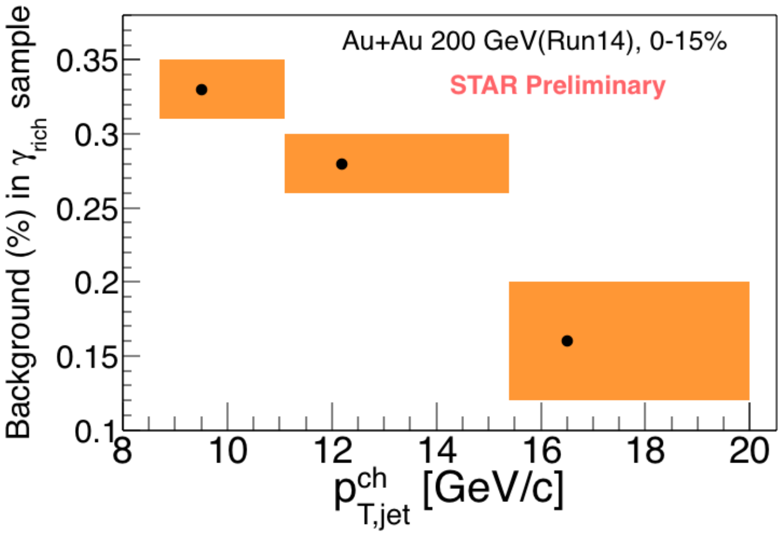


π^0+jet: p_T^{const} < 15 GeV/c

h+Jet and π^0 +Jet are in agreement

Conversion from γ_{rich}+Jet to γ_{dir} +Jet

γ_{dir}/π^0 discrimination done using Transverse Shower Profile (TSP)



- Per trigger jet yield :

$$\mathcal{D}_{\mathrm{x+jet}}(\mathrm{p_{T,jet}}) \equiv \frac{1}{\mathrm{N_{x,trig}}} \frac{\mathrm{d^2N_{jet}}}{\mathrm{dp_{T,jet}d\eta_{jet}}}$$

- Per trigger direct photon jet yield:

$$\mathcal{D}_{\gamma_{\mathrm{dir}}+\mathrm{jet}}(\mathrm{p_{T,jet}}) = \frac{\mathcal{D}_{\gamma_{\mathrm{rich}}+\mathrm{jet}}(\mathrm{p_{T,jet}}) - \mathcal{B}\mathcal{D}_{\pi^0+\mathrm{jet}}(\mathrm{p_{T,jet}})}{1-\mathcal{B}}$$