Jet Measurements with Neutral and Di-jet Triggers in Central Au+Au Collisions at $\sqrt{s_{NN}}$ = 200 GeV with STAR

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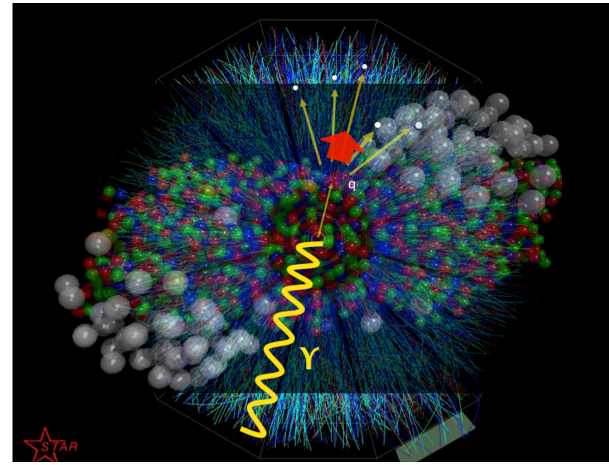
Outline

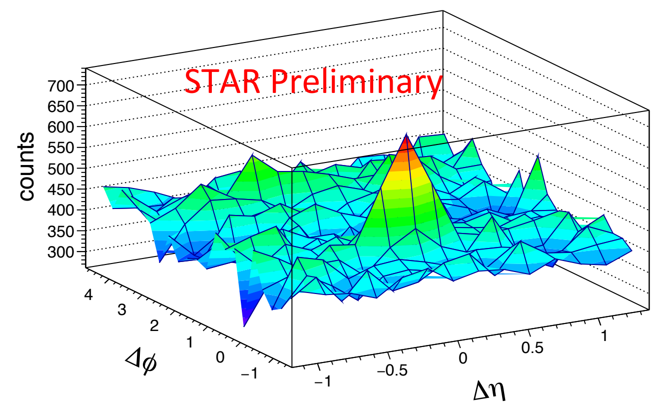
Two measurements

1. Neutral trigger jets:
   γ+jet and **π^0+jet**

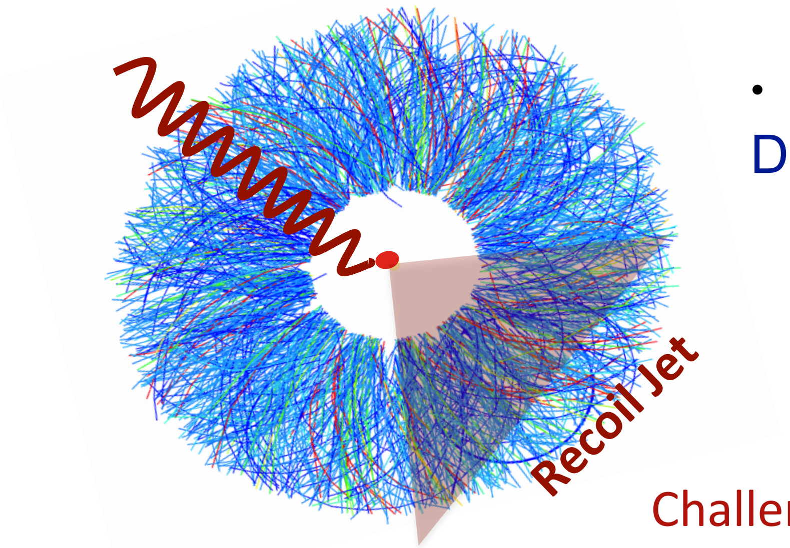
2. Di-jet energy imbalance

in heavy-ion collisions at the STAR experiment





Motivation for γ+jet



- Good tomographic probe

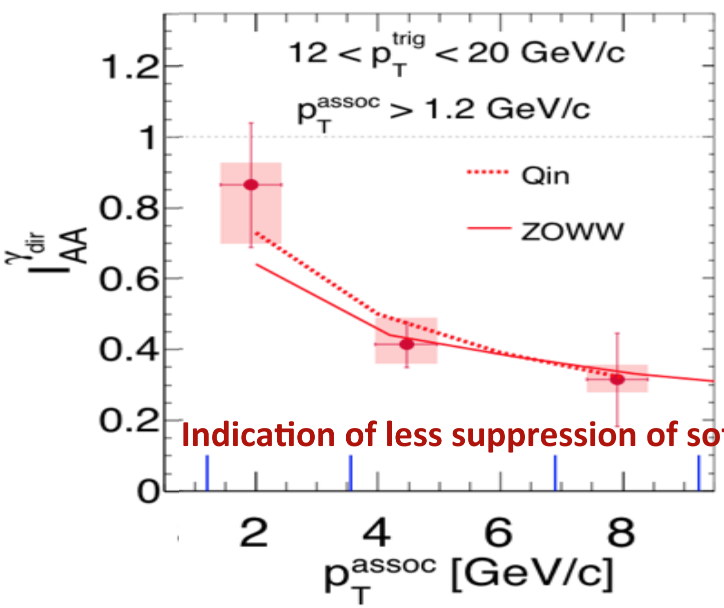
Direct photon:

- Transverse energy approximates that of initial recoil parton p_T
- Not surface biased

Challenging γ+jet measurement

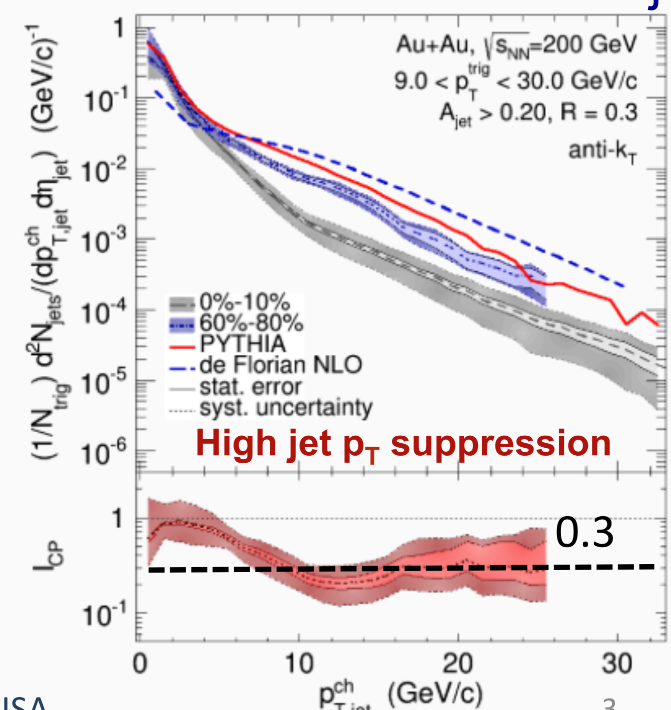
($h^{\pm}$+jet: arXiv:1702.01108)

γ+hadron correlation [PLB 760 (2016) 689]



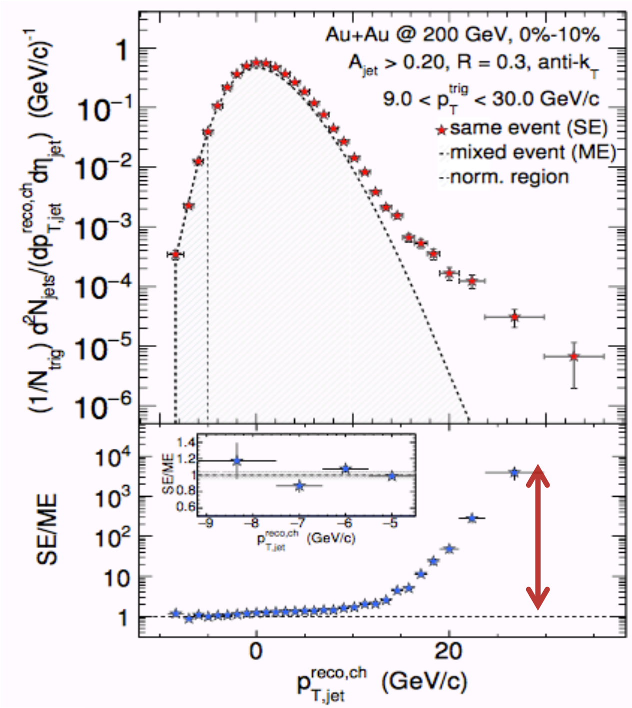
Investigating γ+jet events by combining these two analyses

Semi-inclusive $h^{\pm}$+jet



Semi-inclusive recoil jets

h± +jet : 9 < p_T^{trig} < 30 GeV/c



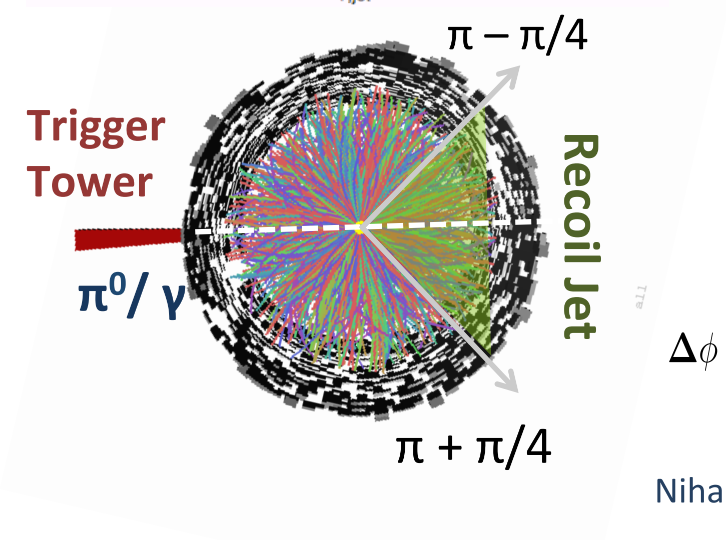
- A new mixed event (ME) method to correct the uncorrelated background jets in HIC
- Large signal to background at high jet p_T^{reco}
- Charged jet reconstruction (using FastJet3.0.6)
  - k_T algo. for bkgd. Subtraction and anti-k_T algo. for jet reconstruction

$$p^{\rm reco,ch}_{\rm T,jet} = p^{\rm raw,ch}_{\rm T,jet} - \rho A_{jet}$$

R: Jet resolution parameter (jet radius), **A_{jet}**: Active jet area and **ρ**: ave. momentum density (k_T- algo.)

$$\rho \equiv \text{ median}\left[\left\{\frac{p_T^{jet}}{A_{jet}}\right\}\right]$$

[h±+jet: arXiv:1702.01108]



$$\Delta\phi \in [\frac{3\pi}{4}, \frac{5\pi}{4}]$$

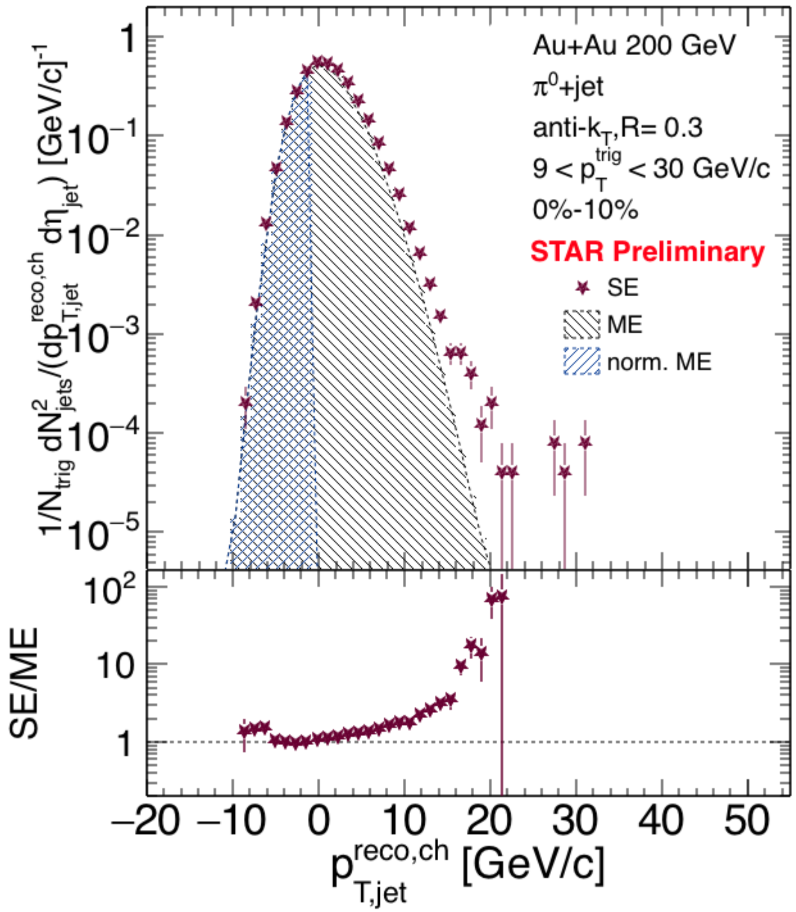
- π^0/γ discrimination in heavy-ion experiment
  - STAR barrel electromagnetic calorimeter (BEMC) and shower maximum detector (BSMD)
  - Transverse shower profile (TSP) method

[STAR:PLB 760 (2016) 689]

Now move to π^0+jet in Au+Au collisions

Background subtraction and correction

π^0+jet : 9 < p_T^{trig} < 30 GeV/c

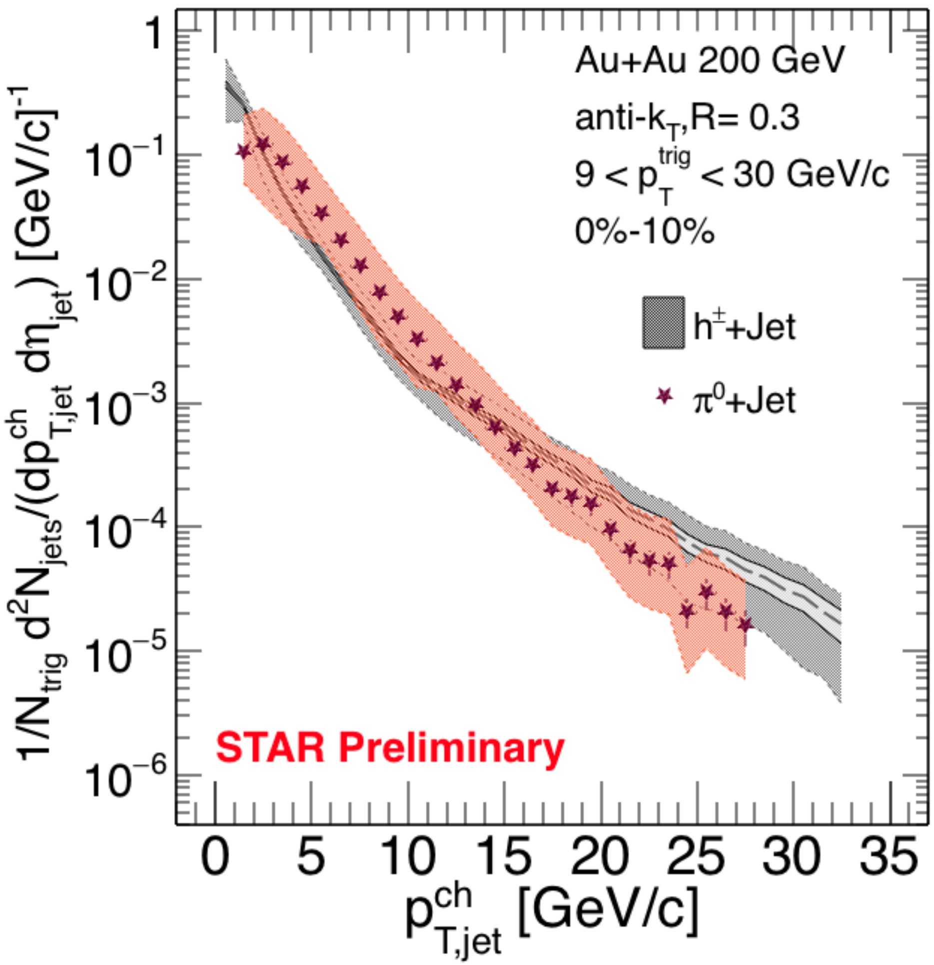


SE: Same events ME: Mixed events

- Event-by-event average background energy density correction done
- Signal dominates with respect to background at high jet p_T^{reco} and combinatorial jets at small jet p_T^{reco}
- Uncorrelated background jet contribution corrected by mixed events subtraction

Does our π^0+jet agree with $h^{\pm}$ +jet measurements in HIC ?

π^0+jet vs. $h^{\pm}$+jet



- Applying correction due to detector and background fluctuations effects
  - Singlar value decomposition (SVD) method for unfolding
- Taking into account systematic effects, π^0+jet and $h^{\pm}$+jet show agreement within uncertainties

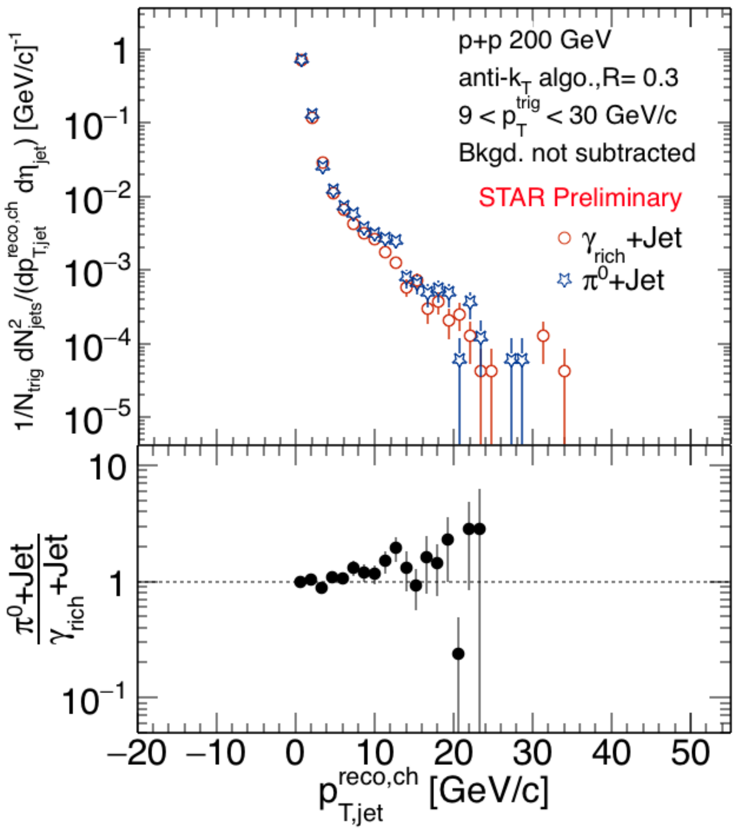
($h^{\pm}$+jet: arXiv:1702.01108)

What about comparison between π^0+jet and γ+jet ?

π^0 +jet vs. γ+jet

Raw Jet p_T without background and detector effect correction

p+p



Purity of γ_{dir} :

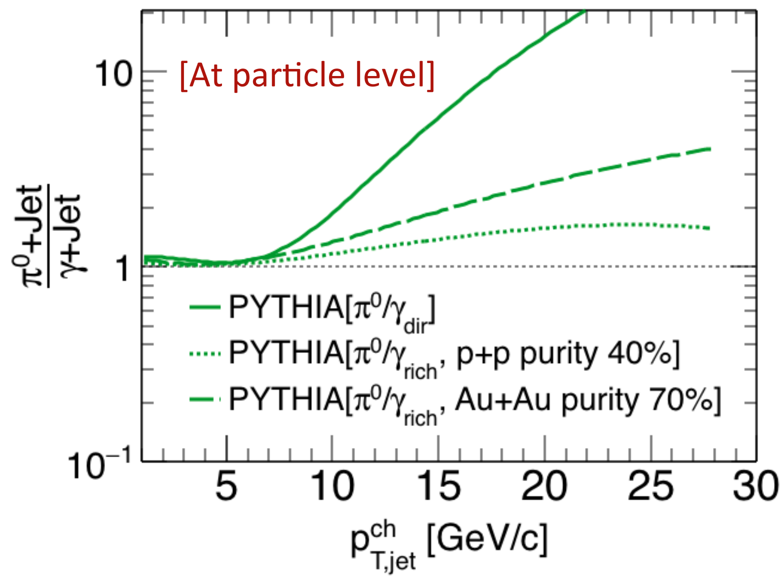
[STAR:PLB 760 (2016) 689]

p+p **~40%**

Au+Au (0-10%) **~70%**

PYTHIA expectation

(for different purity of γ_{dir})

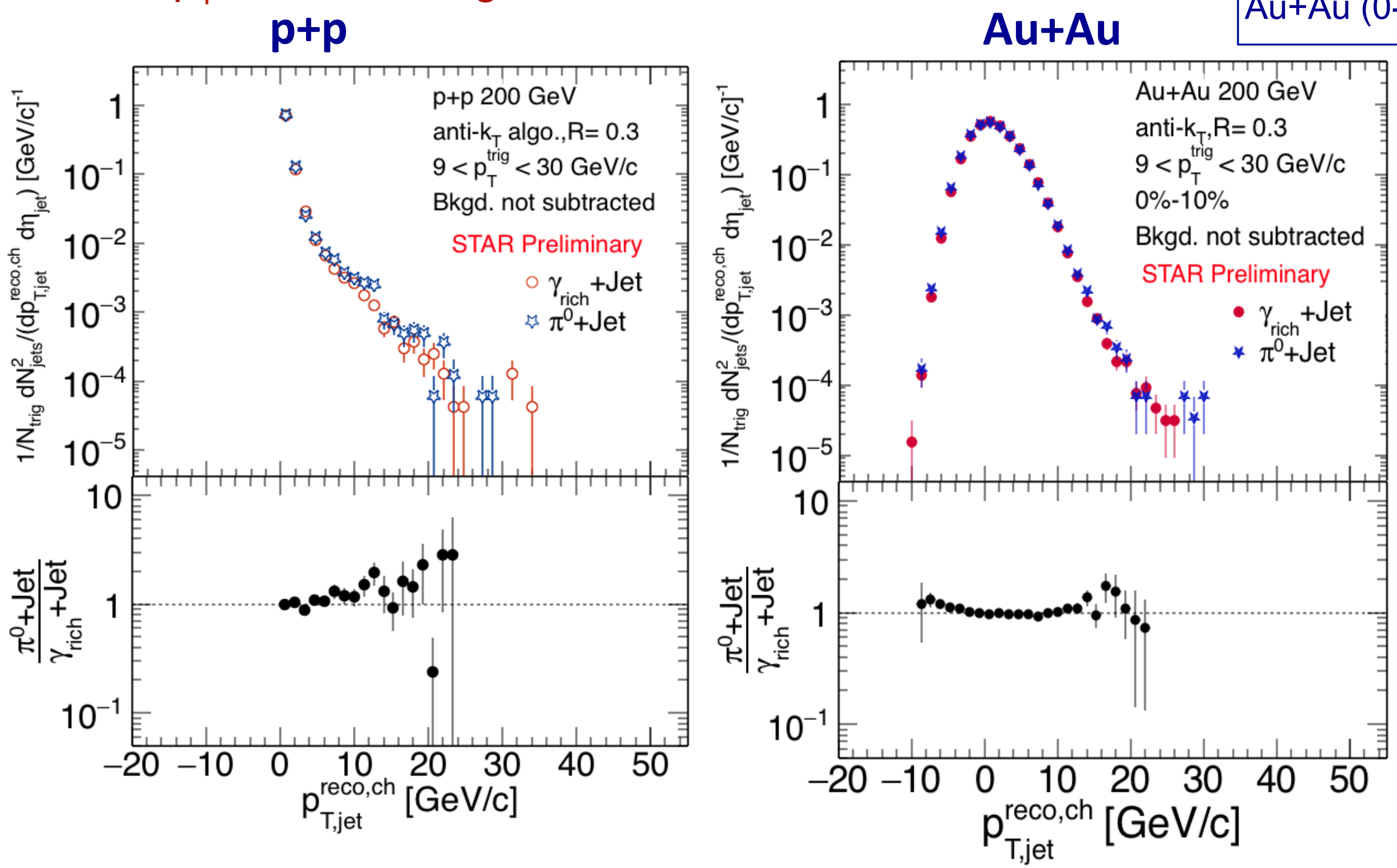


- PYTHIA predicts larger jet yield for π^0 trigger than γ_{dir}
- In p+p, reasonable agreement with standalone PYTHIA considering purity of γ_{dir}

π^0 +jet vs. γ+jet

Purity of γ_{dir} :
p+p **~40%**
Au+Au (0-10%) **~70%**

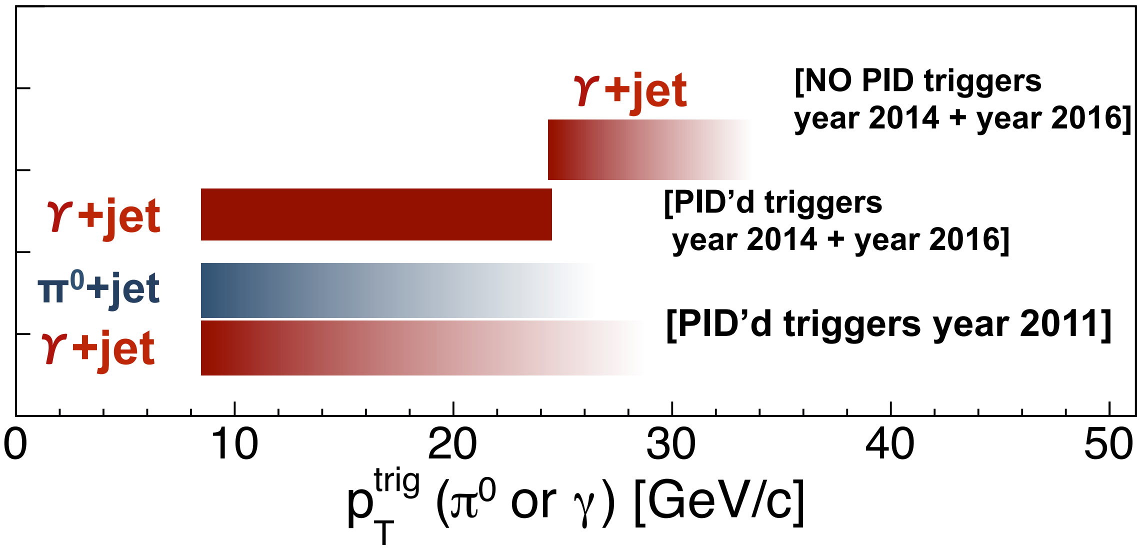
Raw Jet p_T without background and detector effect correction



- To extract medium effect for π^0 +jet vs. γ+jet, need full corrections, detailed study and large statistics

Future measurements of π^0+jet vs. γ+jet

Au+Au collisions in the STAR experiment



Int. Lumininosity sampled by BEMC trigger

Year 2011: 2.8 nb^{-1}

Year 2014+ year 2016: ~25 nb^{-1} on tape(~10 times more statistics)

- ~25 nb^{-1} corresponds to 175 billion MB events

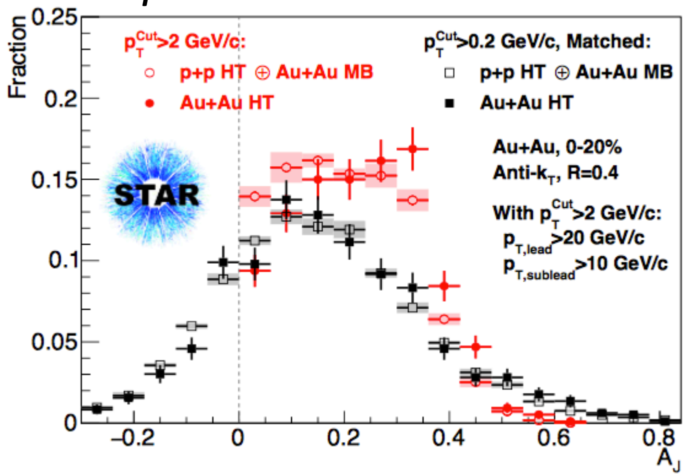
- For p_T > 9 GeV/c
  - Run11: γ+jet ~30K trigger (p_T > 9 GeV/c) events with tight PID cuts
  - Combining year 2014+ year 2016, we have 8 times year 2011 statistics on the tape.
- For p_T > 25 GeV/c
  - we don't need tight PID (Ratio γ/π^0 > ~2) and hence expect > 5K γ triggers.

…Stay tuned

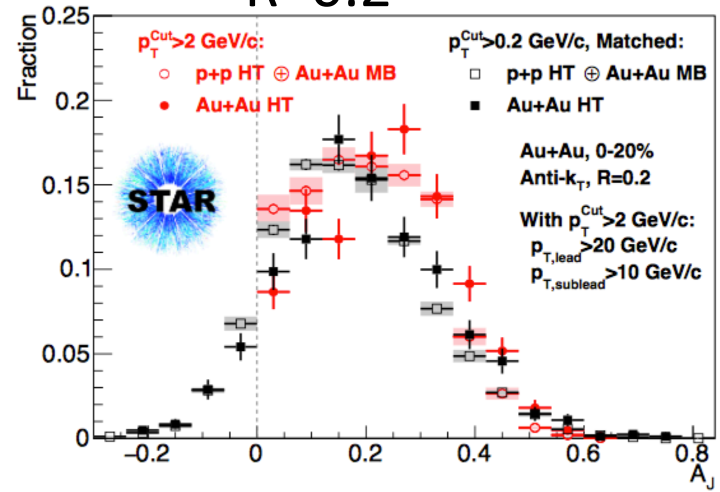
Di-jet hadron correlations

Di-Jet imbalance in transverse momentum

Jet resolution parameter R=0.4



R=0.2



p_T imbalance for back-to-back di-jet pairs

$$A_J = \frac{p_T^{\rm Lead} - p_T^{\rm SubLead}}{p_T^{\rm Lead} + p_T^{\rm SubLead}}$$

Submitted in PRL
arXiv:1609.03878

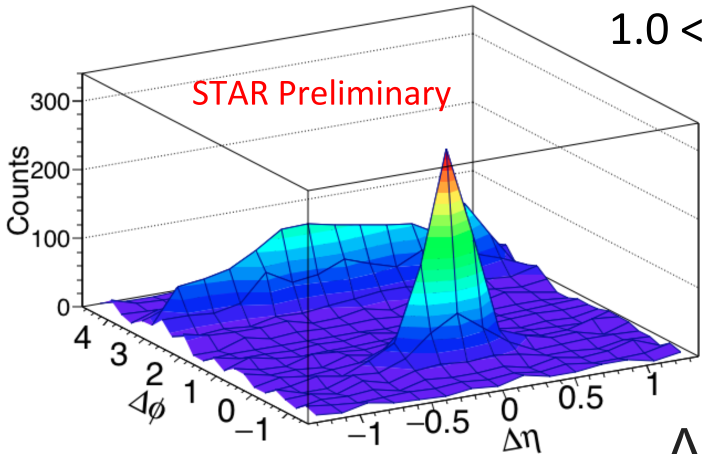
- Di-jets with "hard cores" (constituents above p_T > 2 GeV/c only) show significantly more imbalance in central Au+Au than in embedded p+p
- Balance is restored for R=0.4 (but not R=0.2!) when including jet constituents p_T < 0.2 GeV/c
- Indication of energy loss of di-jet interacting with the medium and lost energy reappears as soft particles

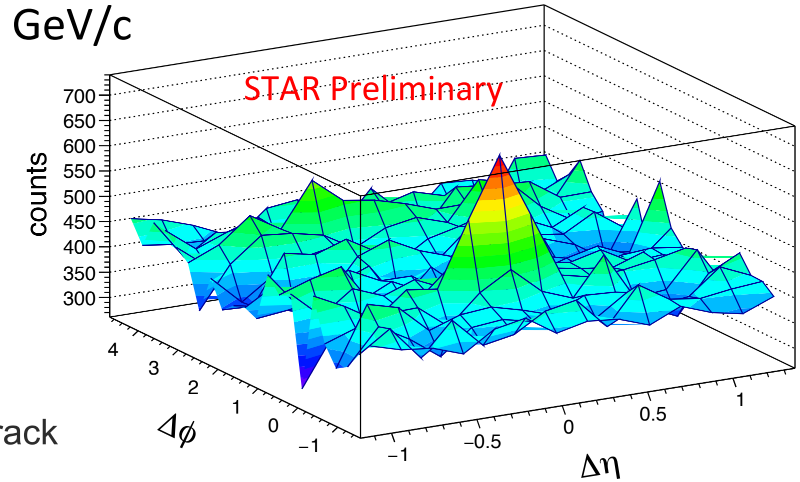
How is the recovered energy distributed?

Trigger jet+hadron correlation

p+p HT **Au+Au HT 0-20% central**

$1.0 < p_T^{track} < 2.0$ GeV/c





$\Delta\eta = \eta^{jet}-\eta^{track}$

$\Delta\varphi = \varphi^{jet}-\varphi^{track}$

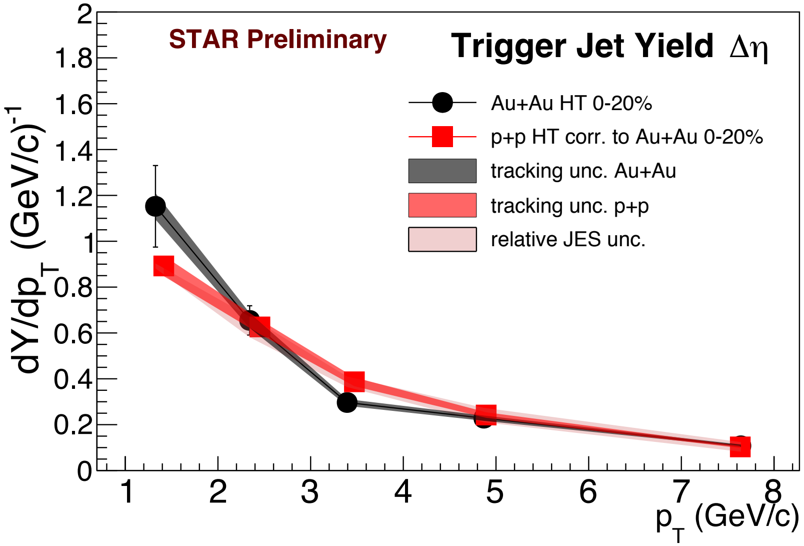
(After mixed event correction)

Di-jet Defintion:

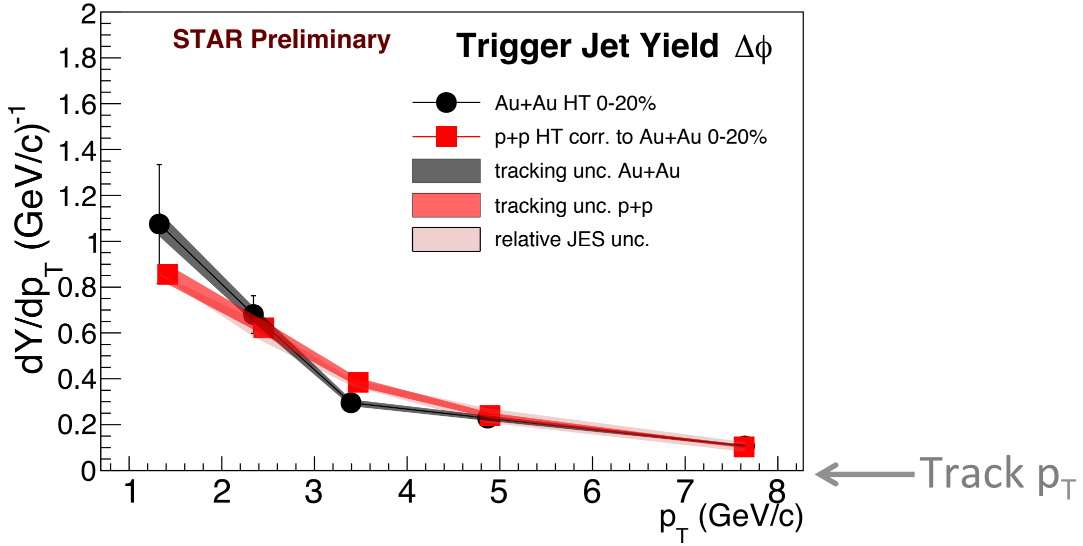
- Trigger jet containing a BEMC tower with energy E > 6 GeV (HT)
- $p_T^{cut} \geq 2.0$ GeV/c
- $p_T^{Trigger} > 20$ GeV/c
- $p_T^{Recoil} > 10$ GeV/c
- anti-k_T R=0.4

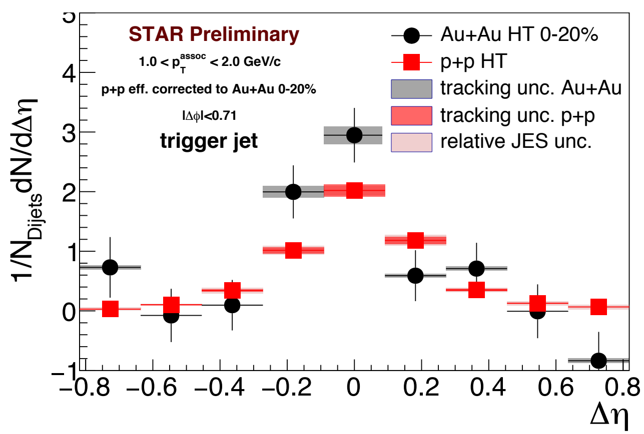
Trigger jet+hadron correlations

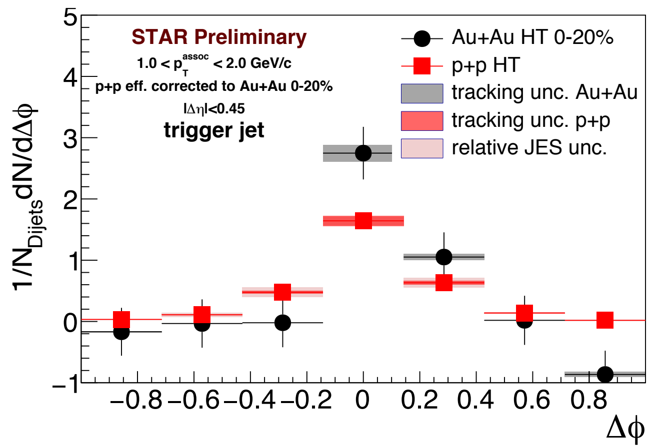
Δη projection

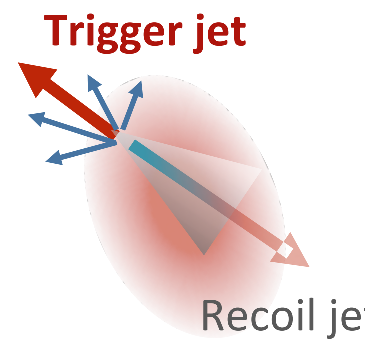


Δφ projection





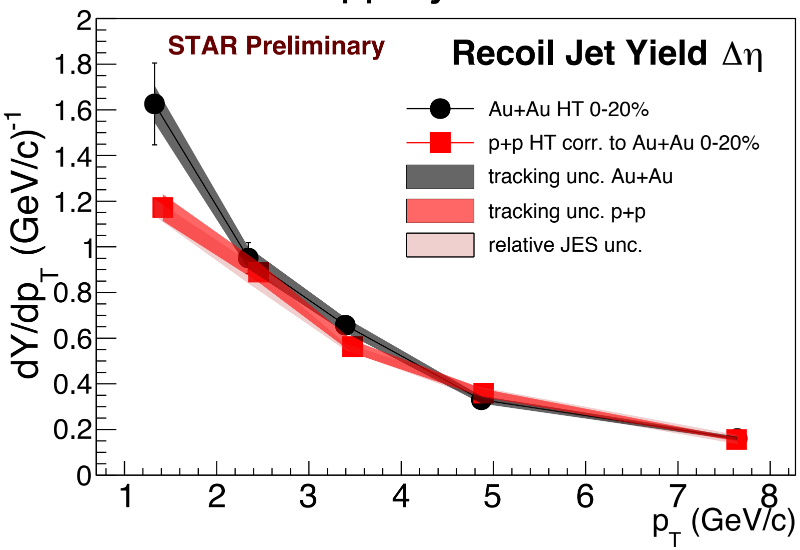




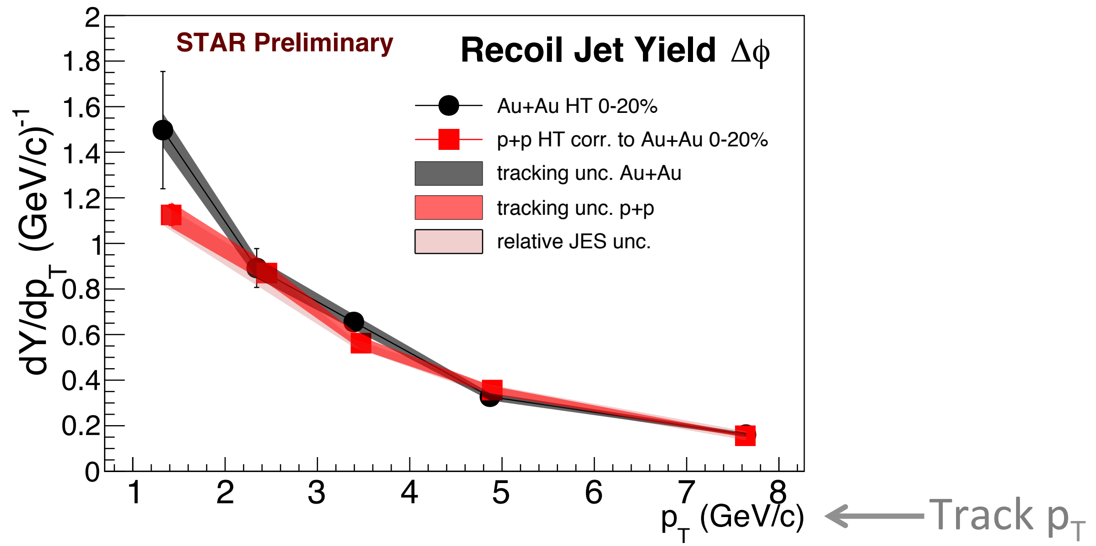
- Trigger jet +hadron yield shows no significant difference at all p_T^{assoc}
- Indication of surface bias of trigger jets in Au+Au collisions

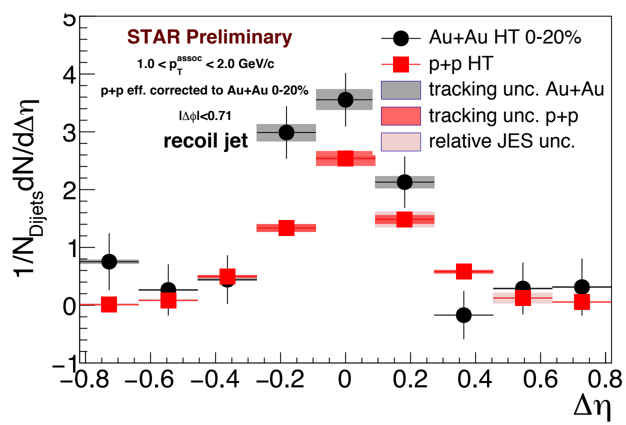
Recoil jet+hadron correlations

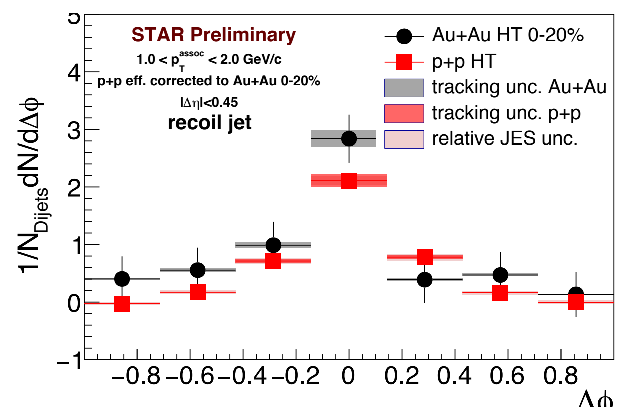
Δη projection

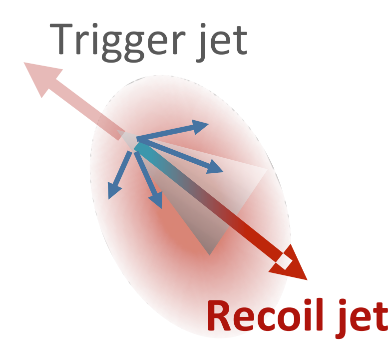


Δφ projection





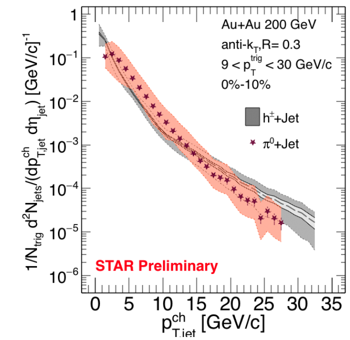


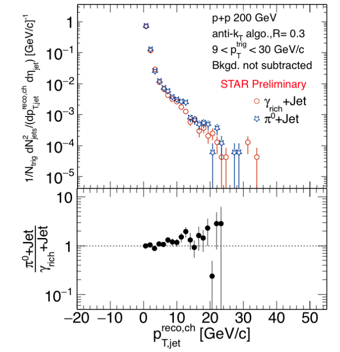


- Recoil: hints of excess low p_T yield, not significant within uncertainties
- Integrated A_J could dilute the recoil jet suppression
- Further differential measurements needed → data available!

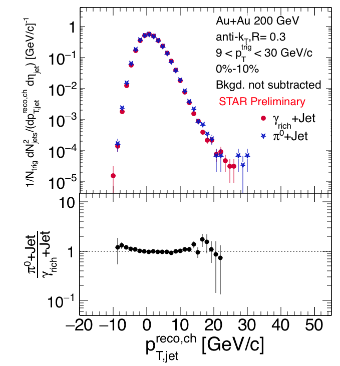
Summary

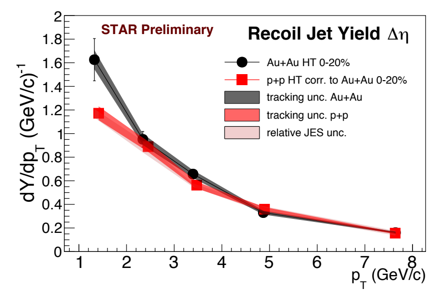
- Neutral trigger semi-inclusive recoil jets
  - Within systematic uncertainty, agreement between π^0 +jet and $h^{\pm}$ +jet for R=0.3
  - working to extract medium effect on γ+jet vs. π^0 +jet
    - Larger statistics from year 2014+2016 data





- Dijet hadron correlation
  - Soft particles (p_T < 2.0 GeV/c) redistributed in $\Delta\eta$-$\Delta\phi$ in a recoil jet whereas trigger jet shows no significant modification due to surface bias in Au+Au collisions
  - Further differential measurements needed to understand redistribution of lost energy due to A_J imbalance

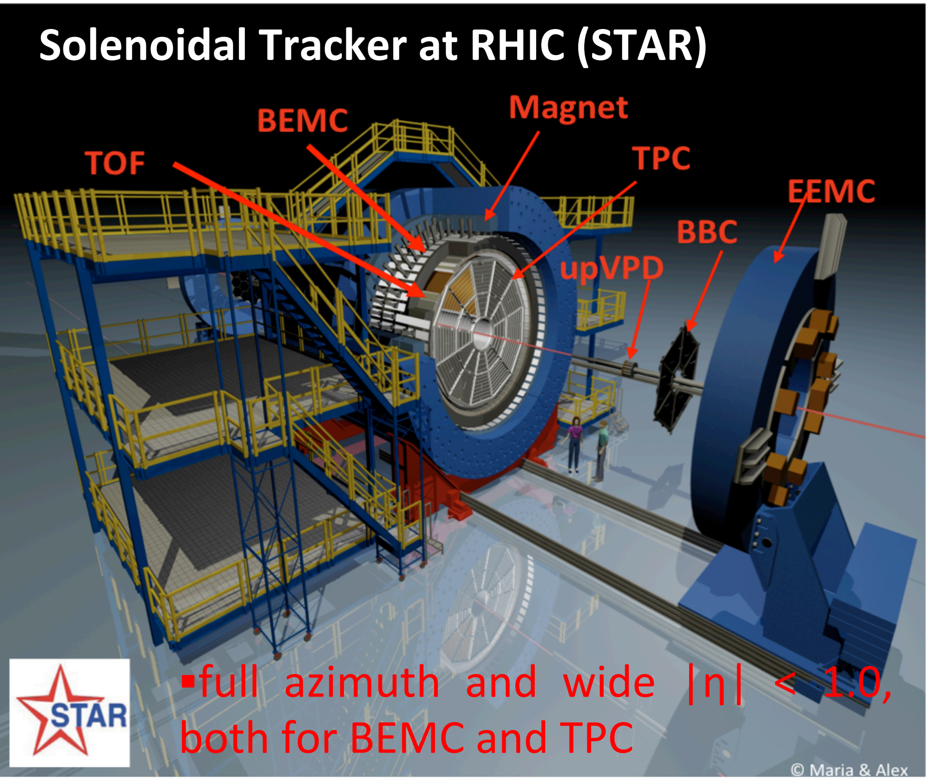




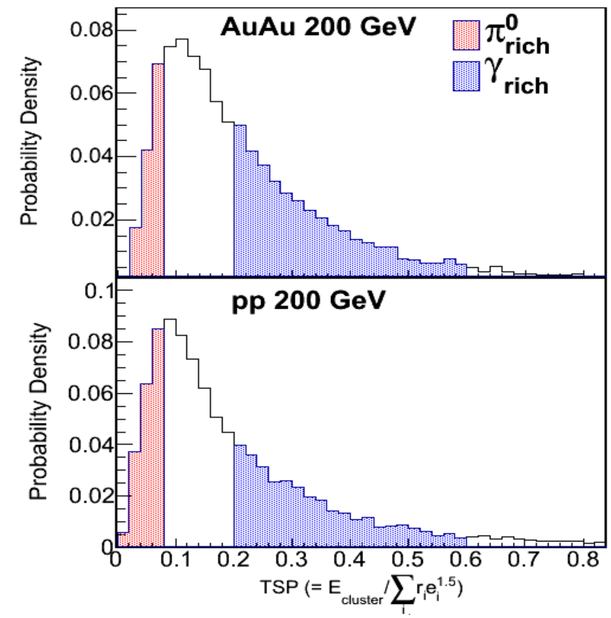
Two posters (Ph.D students):
Derek Anderson (poster#173 π^0 - jet vs. γ -jet in p+p)
and Nick Elsey (poster#571 Dijet)

Back up

STAR detector system and π^0/γ_{dir} discrimination



- BEMC to identify EM clusters and trigged on high energy tower
- Time Projection Chamber (TPC) to identify charged hadron tracks
- Au+Au (year 2011) and pp (year 2009) 200 GeV

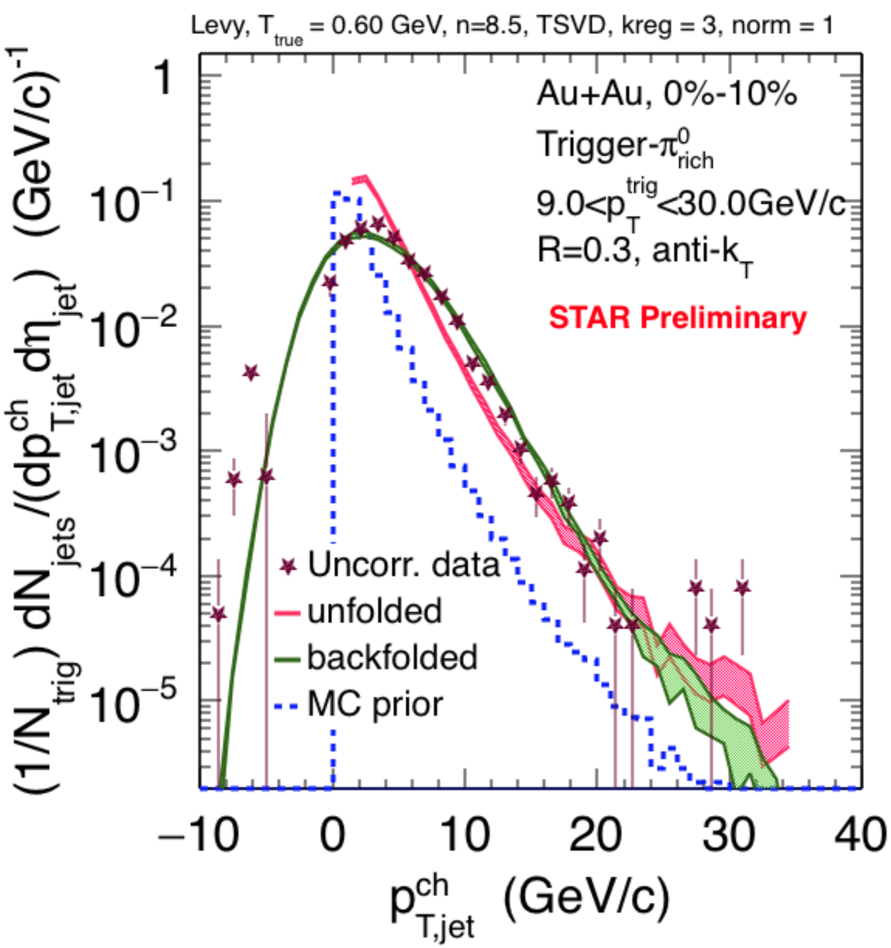


- **TSP** cuts are tuned to get
  - a nearly pure sample of π^0 (called " π^0_{rich} ")
  - a sample with enhanced fraction of γ_{dir} (called `γ_{rich} ')
  - Purity of γ_{dir} **~40%** and **~70%** for **p+p** and **Au+Au** central (0-10%) collisions, respectively

$$\mathrm{TSP} = \frac{E_{cluster}}{\sum_i e_i r_i^{1.5}}$$

***E**$_{cluster}$*: Cluster energy, ***e**$_i$*: BSMD strip energy,
***r**$_i$*: distance of the strip from the center of the cluster

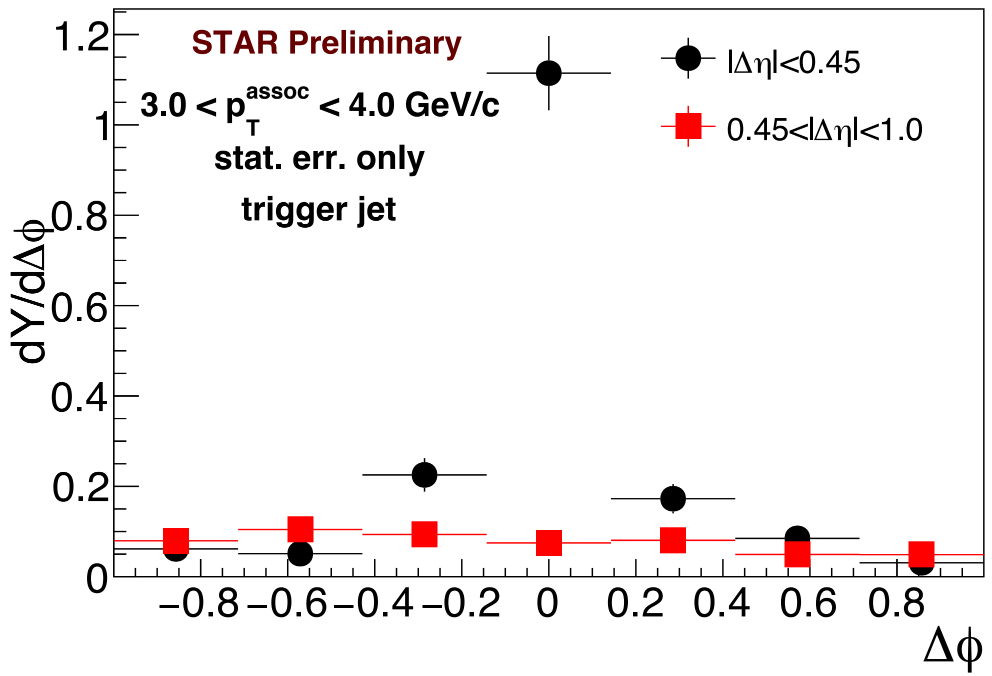
Background subtraction and correction



Di-Jet Hadron Correlation Background Subtraction

Δϕ: possible flow
→ Side band subtraction method

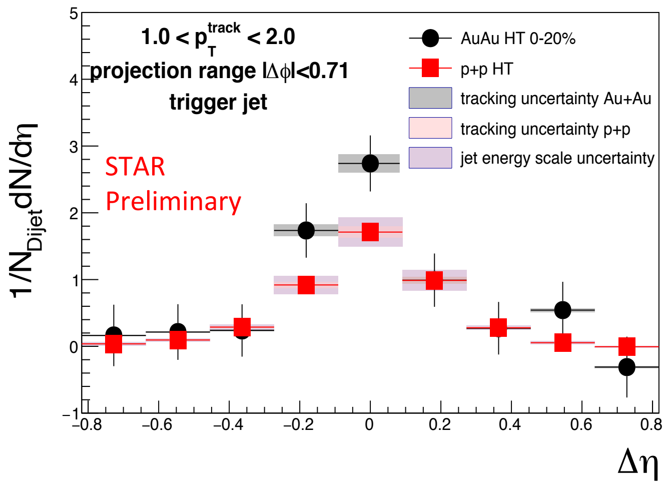
Δη: no flow
correlation fit with gaussian+constant
→ Constant subtracted from signal



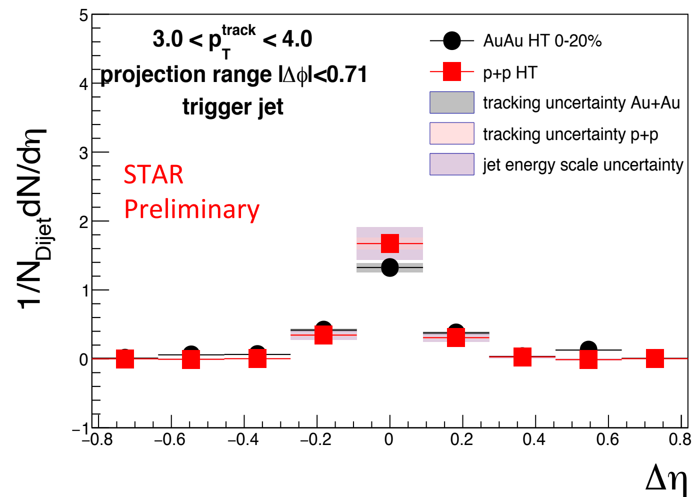
Di-jet hadron correlations in Δη

Trigger jet + hadron

$1.0 < p_T^{track} < 2.0$ GeV/c

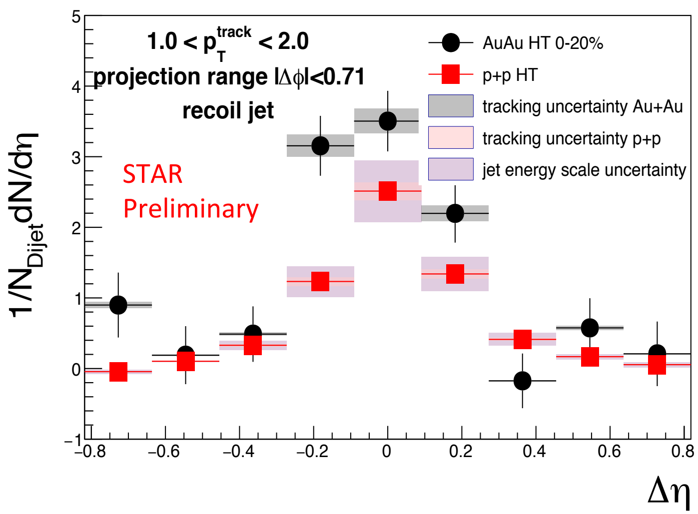


$3.0 < p_T^{track} < 4.0$ GeV/c

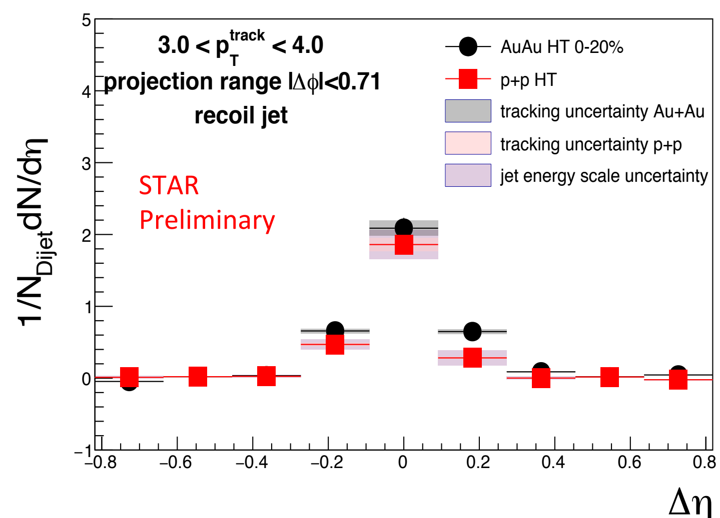


Recoil jet + hadron

$1.0 < p_T^{track} < 2.0$ GeV/c



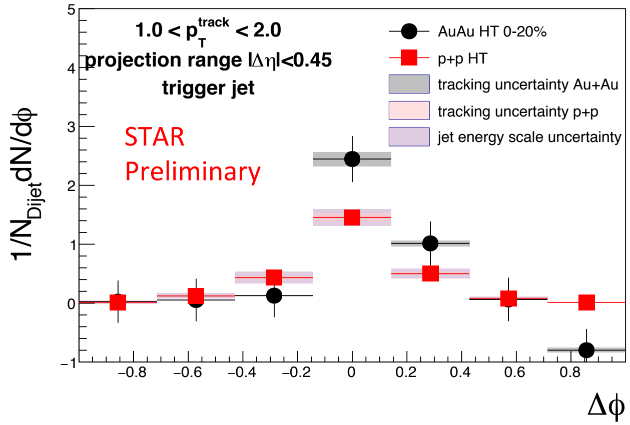
$3.0 < p_T^{track} < 4.0$ GeV/c



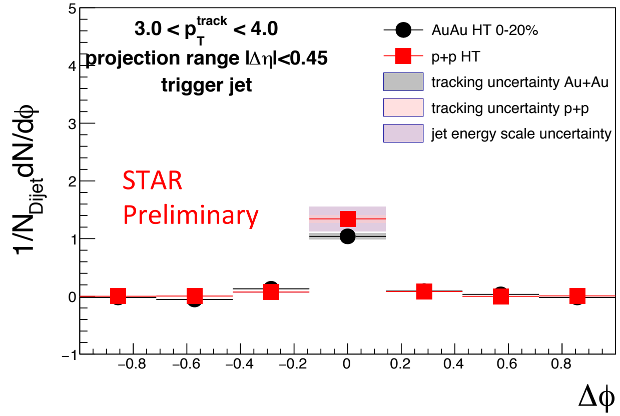
Di-jet hadron correlations in Δϕ

Trigger jet + hadron

$1.0 < p_T^{track} < 2.0$ GeV/c

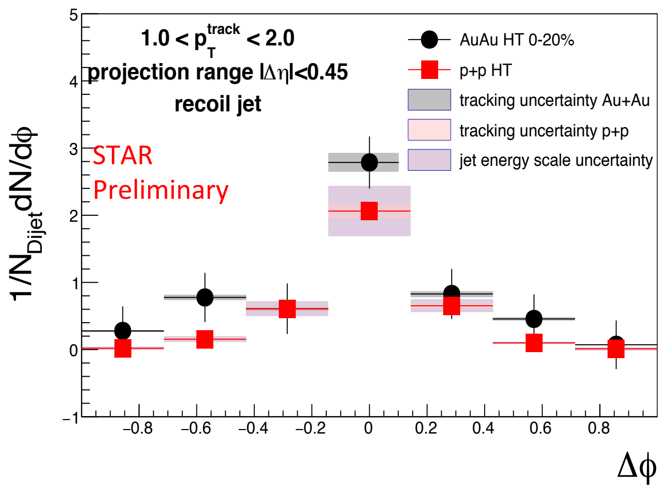


$3.0 < p_T^{track} < 4.0$ GeV/c



Recoil jet + hadron

$1.0 < p_T^{track} < 2.0$ GeV/c



$3.0 < p_T^{track} < 4.0$ GeV/c