Jet-Hadron Correlations in STAR

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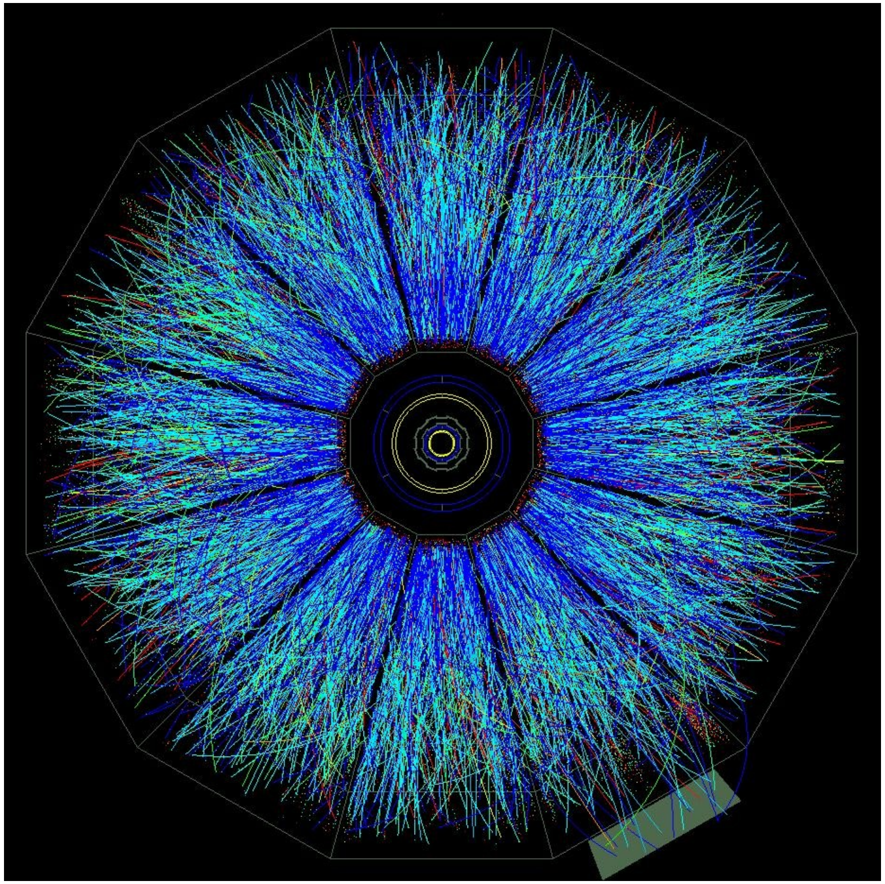
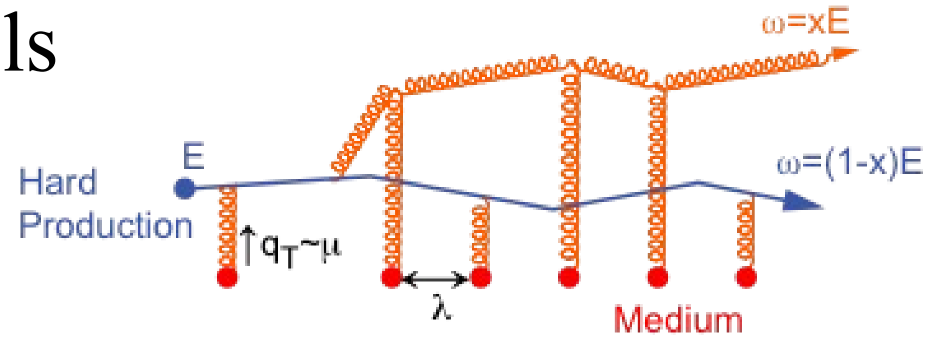


Jet Quenching

- Radiative energy loss models
  - Partons lose energy and are scattered as they traverse the medium



  - What would we see in angular correlation studies?

    Softer and broader distribution of hadrons around the jet axis than seen in pp
- "Black-and-white" models
  - Partons either escape the medium unmodified or are entirely thermalized/absorbed
  - Unmodified jet shapes compared to those in pp collisions

We can use jet-hadron correlations to study jet quenching!

Jet Reconstruction at STAR

Data sets: Run 7 AuAu and Run 6 pp

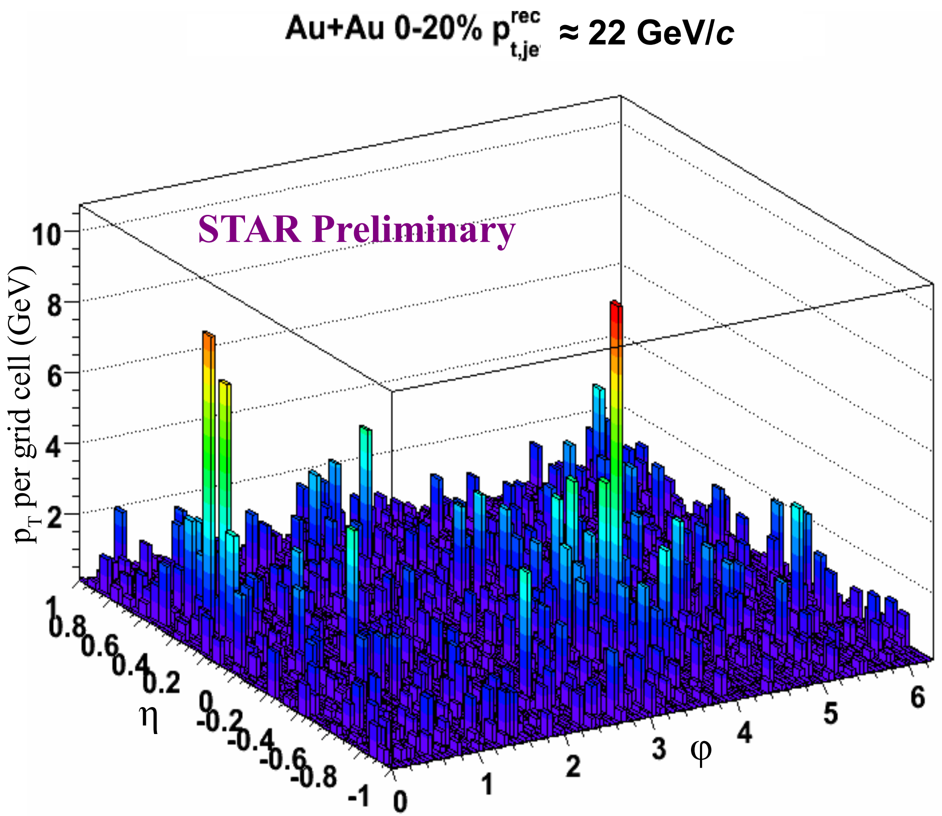
$\sqrt{s_{NN}} = 200$ GeV, High Tower (HT) Trigger.

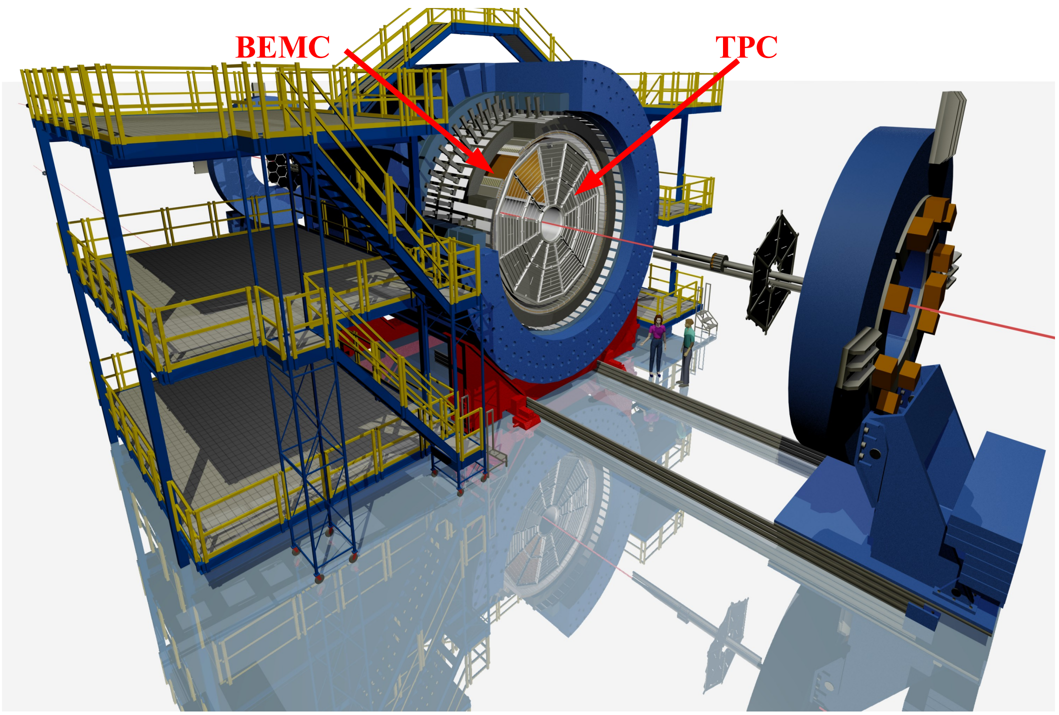
Online Trigger
$E_T > 5.4$ GeV in one tower
$\Delta\varphi \times \Delta\eta = 0.05 \times 0.05$

Trigger Jets found with Anti-kT algorithm [1]

($R = 0.4$, $p_T^{track,tower} > 2$ GeV/c).

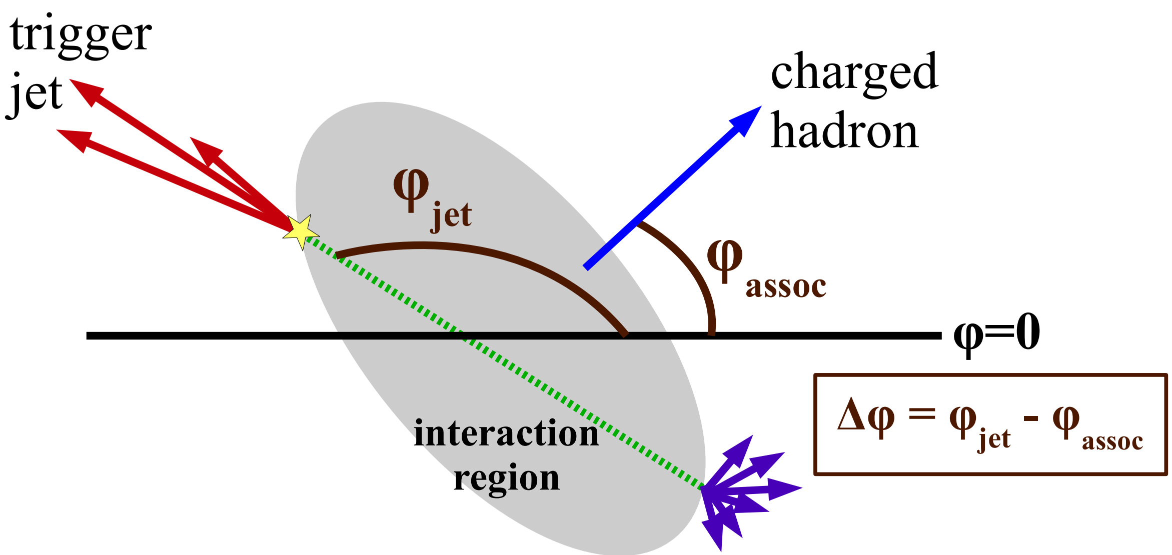
[1] M. Cacciari and G. Salam, Phys. Lett. B **641,** 57 (2006)

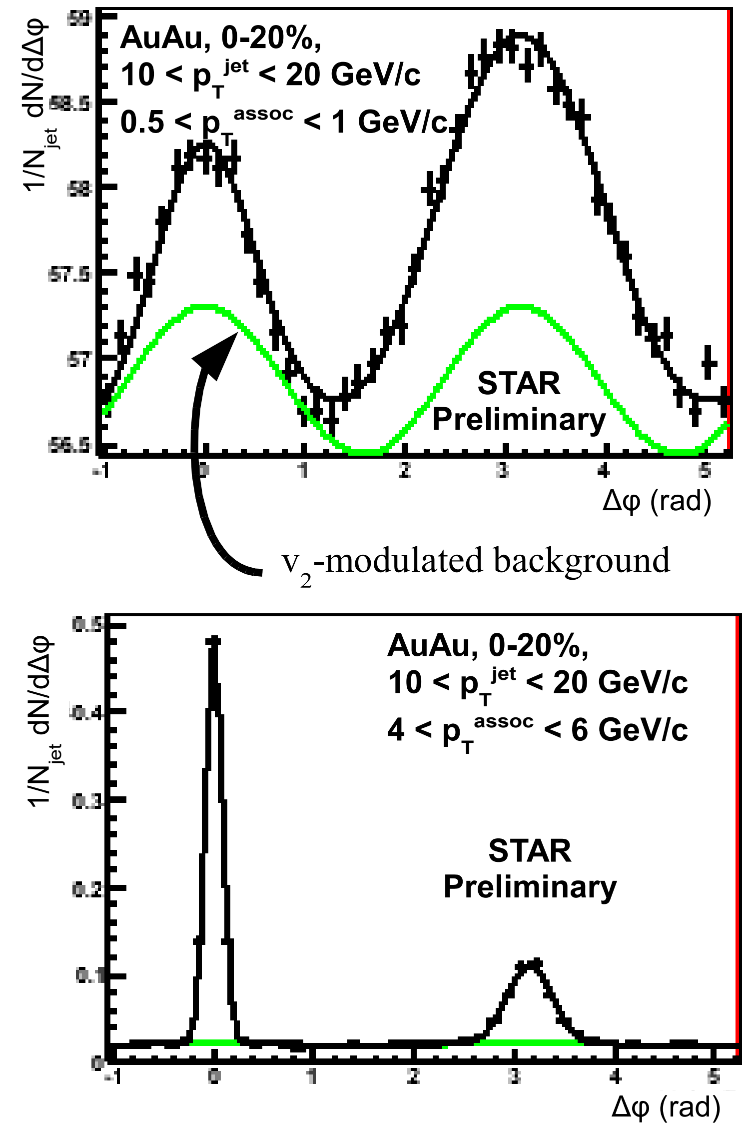




Intro to Jet-Hadron Correlations

- Study azimuthal angular correlations of associated particles (all charged hadrons in an event) with respect to the axis of a reconstructed HT trigger jet.





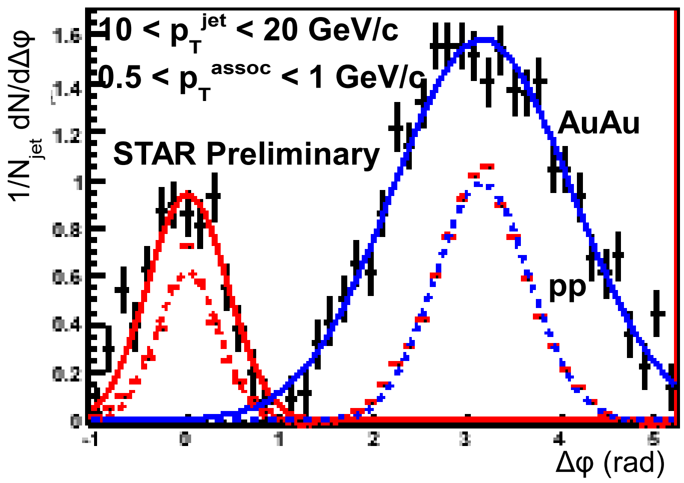
- Jet reconstruction increases the partonic kinematic reach compared to dihadron correlations.

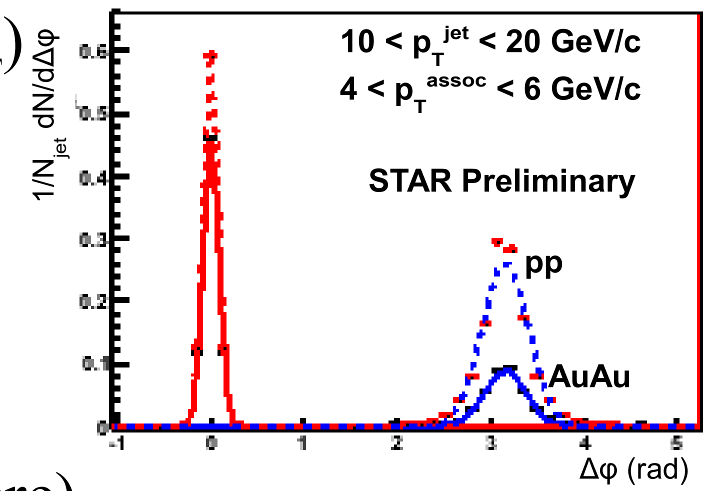
Background Subtraction

- In the presence of broad jet peaks (i.e. central collisions, low p_T^{assoc}), ZYAM overestimates background levels.
  → "Zero Yield At Minimum"
- Jet v_2 is *a priori* unknown.
- In this analysis:
  - background levels estimated by fitting

    $$2\ \text{Gaus} + B*(1+2*v_2^{assoc}*v_2^{jet}*\cos(2\Delta\varphi))$$

  - $v_2^{assoc} = (v_2\{2\}+v_2\{4\})/2$ (as a function of p_T)
  - $v_2^{jet} = v_2\{2\}(p_T = 6\ \text{GeV}/c)$
  - maximum v_2 uncertainties: no v_2 and +50% of $v_2^{jet}*v_2^{assoc}\{2\}$
  - (higher harmonic terms are not considered here)





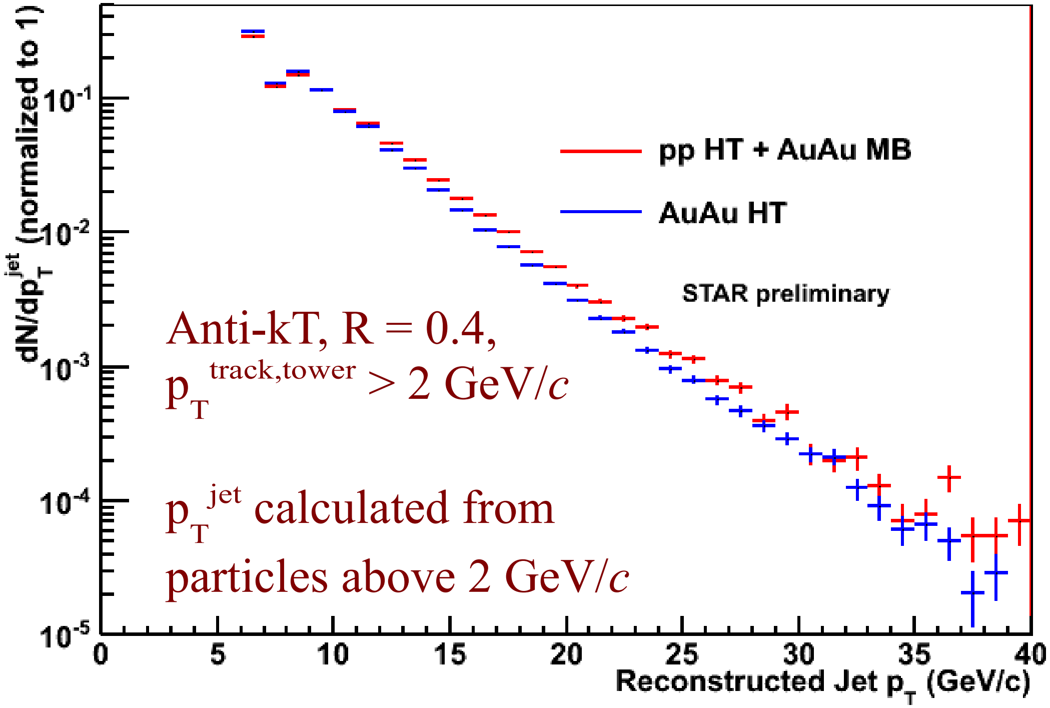
Comparing Trigger Jets

- We need to compare jet-hadron correlations in AuAu with a pp reference → How can we select similar trigger (nearside) jets in both systems?

- Assumption:

AuAu HT event	=	pp HT event	×	fluctuations (AuAu MB event)

- Embed pp HT events in AuAu MB events → Even after accounting for detector effects, the shape of the pp HT + AuAu MB spectrum does not quite match the AuAu HT spectrum.



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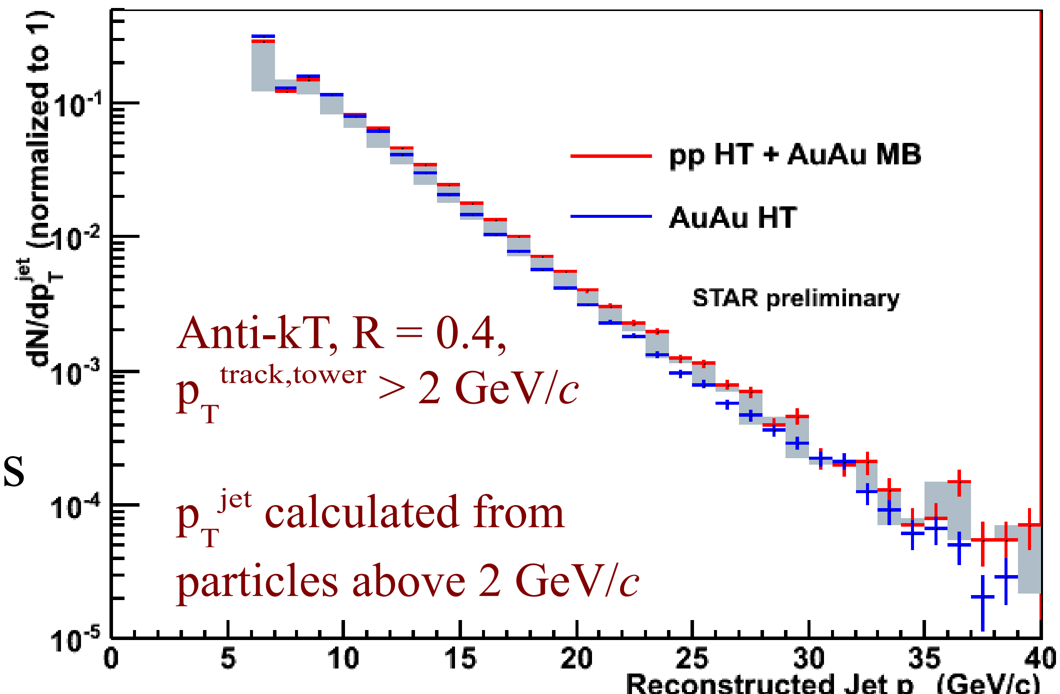
- Assumption:

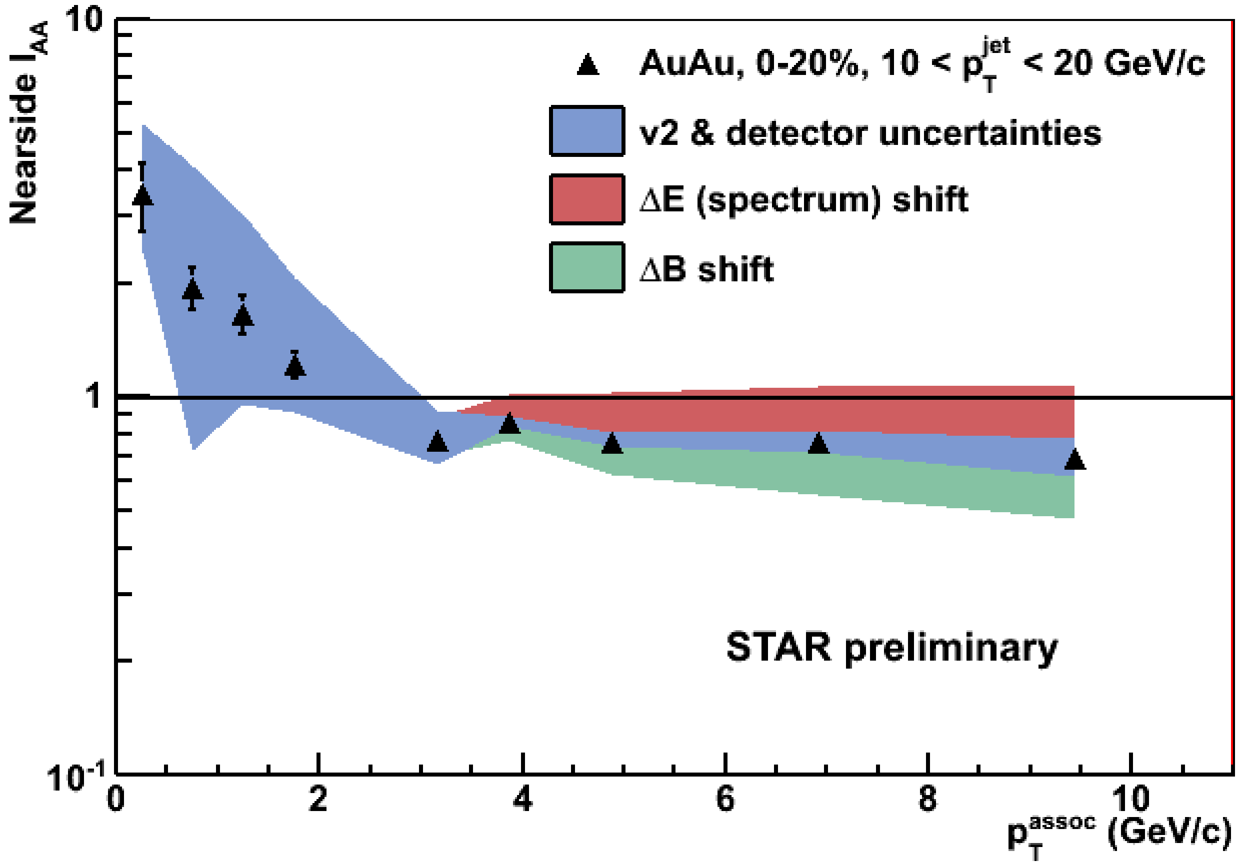
AuAu HT event	=	pp HT event	×	fluctuations (AuAu MB event)

- Embed pp HT events in AuAu MB events
  → Even after accounting for detector effects, the shape of the pp HT + AuAu MB spectrum does not quite match the AuAu HT spectrum.
  → ΔE = -1 GeV/*c* energy shift included in systematic uncertainties to account for possible trigger jet energy mismatch.



Nearside I_{AA}

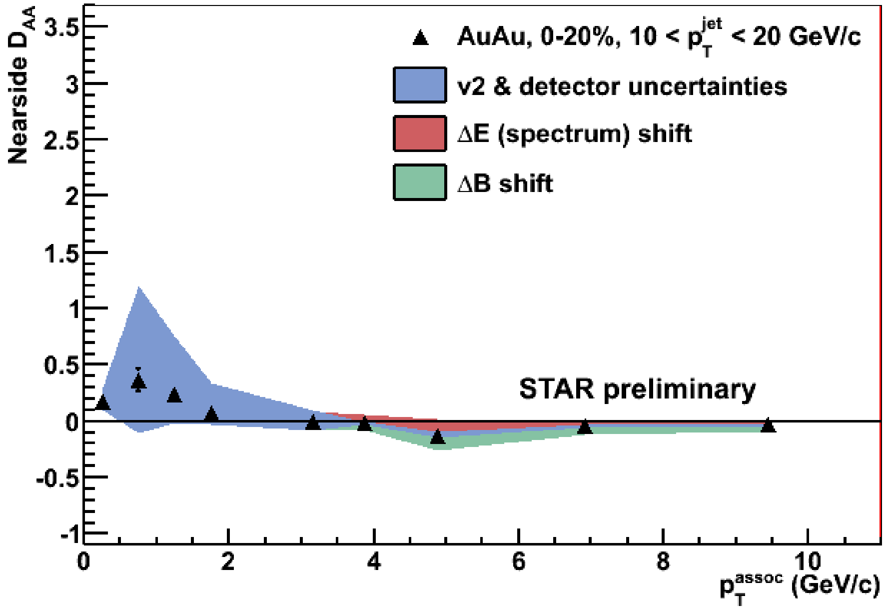
$$I_{AA}(p_T^{assoc}) = \frac{Y_{AA}(p_T^{assoc})}{Y_{pp}(p_T^{assoc})}$$



- High-p_T suppression observed in the nearside I_{AA} → consistent with apparent ΔE.
- Possible low-p_T enhancement

Nearside Energy Balance D_{AA}

$$D_{AA}(p_T^{assoc}) = Y_{AA}(p_T^{assoc}) \cdot p_{T,AA}^{assoc} - Y_{pp}(p_T^{assoc}) \cdot p_{T,pp}^{assoc}$$



$$\Delta B = \int dp_T^{assoc} D_{AA}(p_T^{assoc})$$

p_T^{jet} (GeV/c)	NS ΔB (GeV/c)
10-15	$0.6^{+1.9\,+0.5}_{-1.1\,-0.6}$
15-20	$1.7^{+2.0\,+0.6}_{-1.0\,-1.4}$
20-40	$1.9^{+2.1\,+0.4}_{-1.1\,-0.7}$

v_2 & detector uncertainties

uncertainties due to shifts

- Values of ΔB ~ 0 indicate that pp and AuAu jet energies are being matched correctly
- For 10 < p_T^{jet} < 20 GeV/c:

$$\Delta B = 0.6^{+1.9\,+0.5}_{-1.0\,-0.4} \text{ (syst.) GeV/}c$$

- Include trigger jet energy shift (+ΔB*3/2) in systematic uncertainties to force ΔB = 0

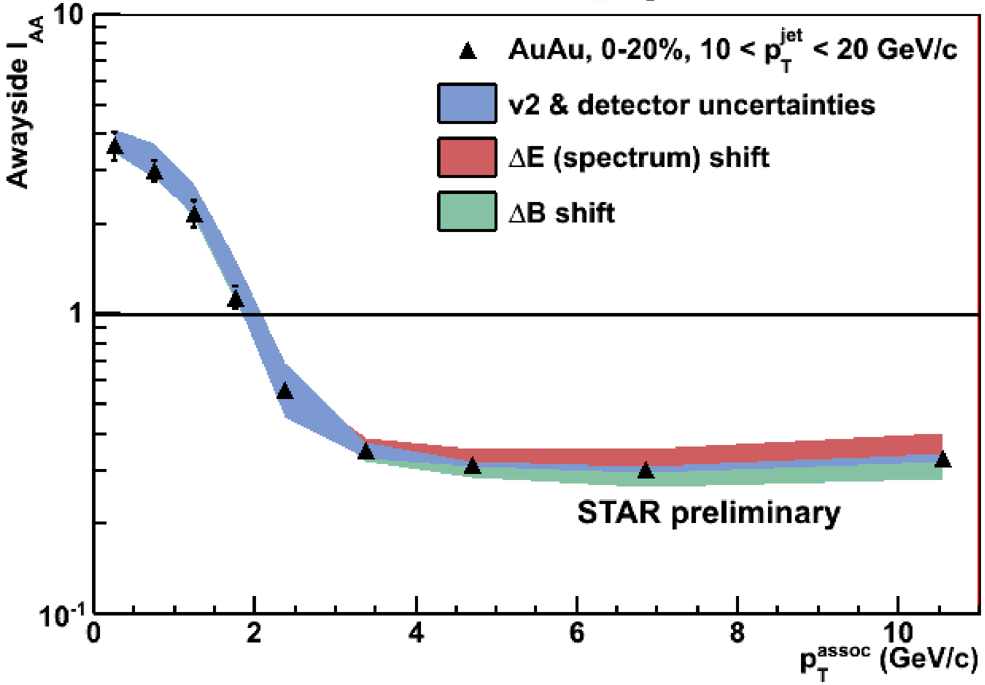
Maximum Trigger Jet Energy Scale Uncertainties

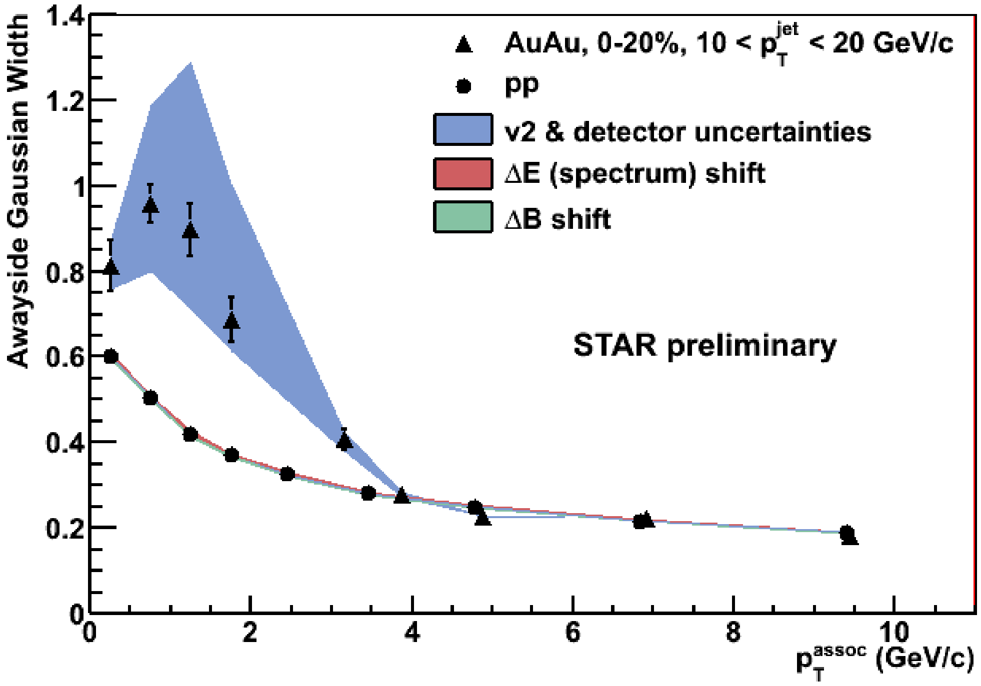
- Shift to match trigger jet spectrum with embedding → corresponds to scenario in which AuAu HT jets are pp-like (for all p_T^{assoc})
  → "low p_T^{assoc} enhancement is bulk"
- Shift to force $\Delta B = 0$ → energy mismatch is due to jet modification
  → "low p_T^{assoc} enhancement is jet"

With these two extreme cases covered, we can now move to the awayside!

Awayside I_{AA} and Width

$$I_{AA}(p_T^{assoc}) = \frac{Y_{AA}(p_T^{assoc})}{Y_{pp}(p_T^{assoc})}$$



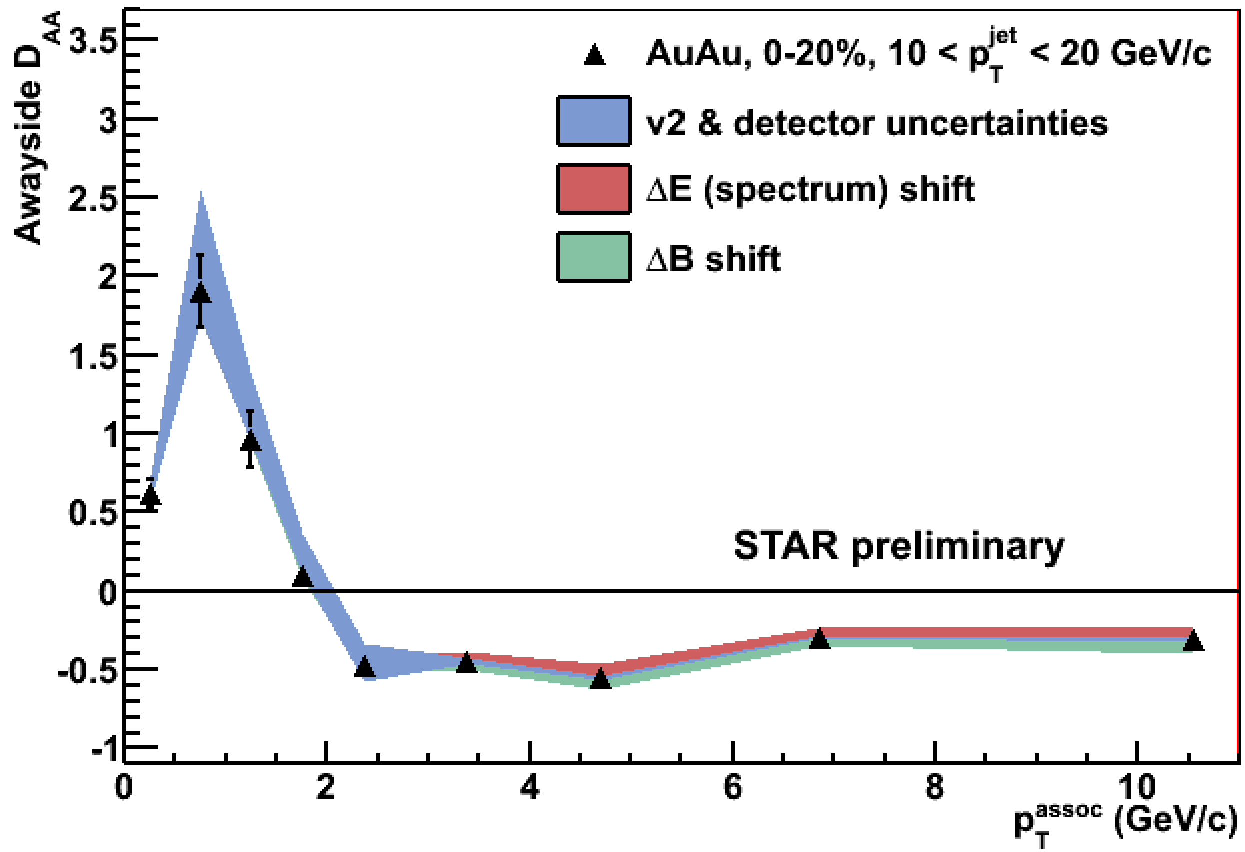


- Significant enhancement at low p_T^{assoc} and suppression at high p_T^{assoc} on the awayside.
- Significant broadening of awayside jets in AuAu compared to pp.

→ Jet quenching in action!

Energy Balance on the Awayside

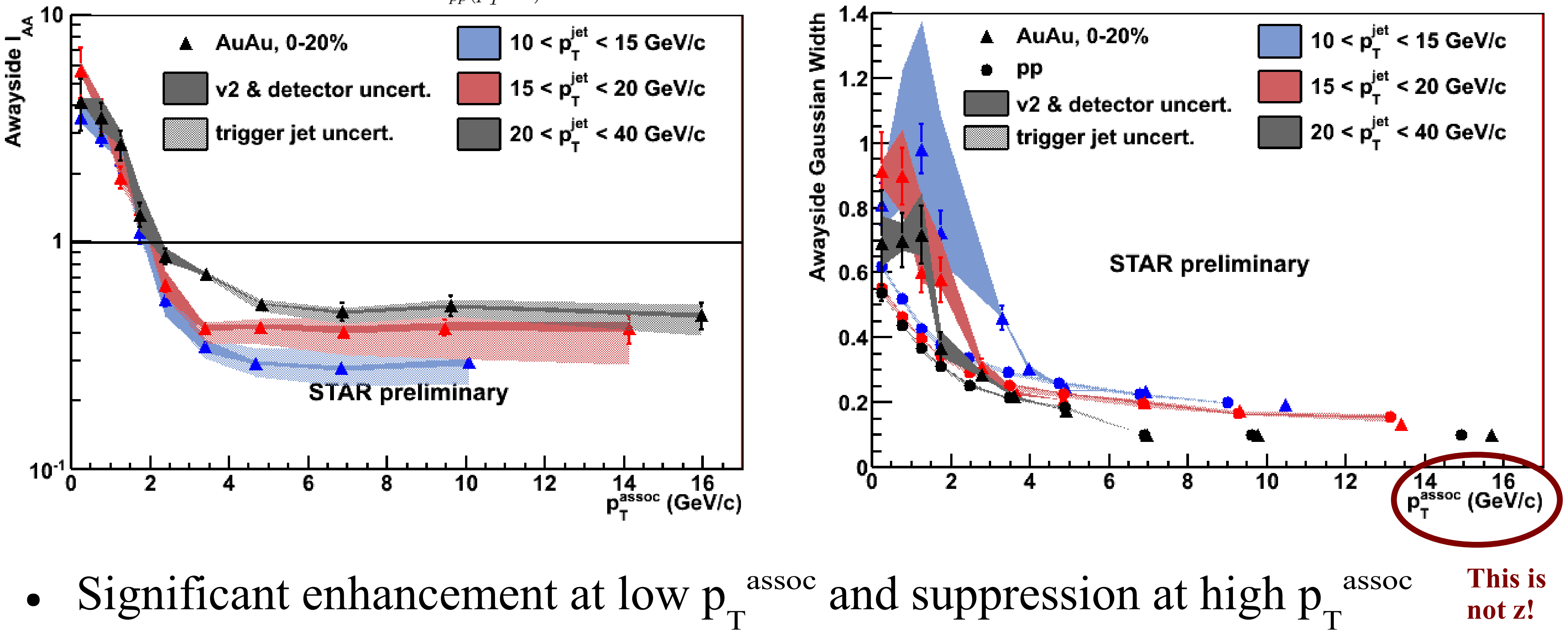
$$D_{AA}(p_T^{assoc}) = Y_{AA}(p_T^{assoc}) \cdot p_{T,AA}^{assoc} - Y_{pp}(p_T^{assoc}) \cdot p_{T,pp}^{assoc} \qquad \Delta B = \int dp_T^{assoc} D_{AA}(p_T^{assoc})$$



- Awayside $\Delta B = 1.5^{+1.7+0.5}_{-0.4-0.4}$ (syst.) GeV/c
- Significant amount of low-p_T^{assoc} enhancement balanced by high p_T^{assoc} suppression on the awayside in this p_T^{assoc} range.

Jet Quenching from 10 to 40 GeV/c

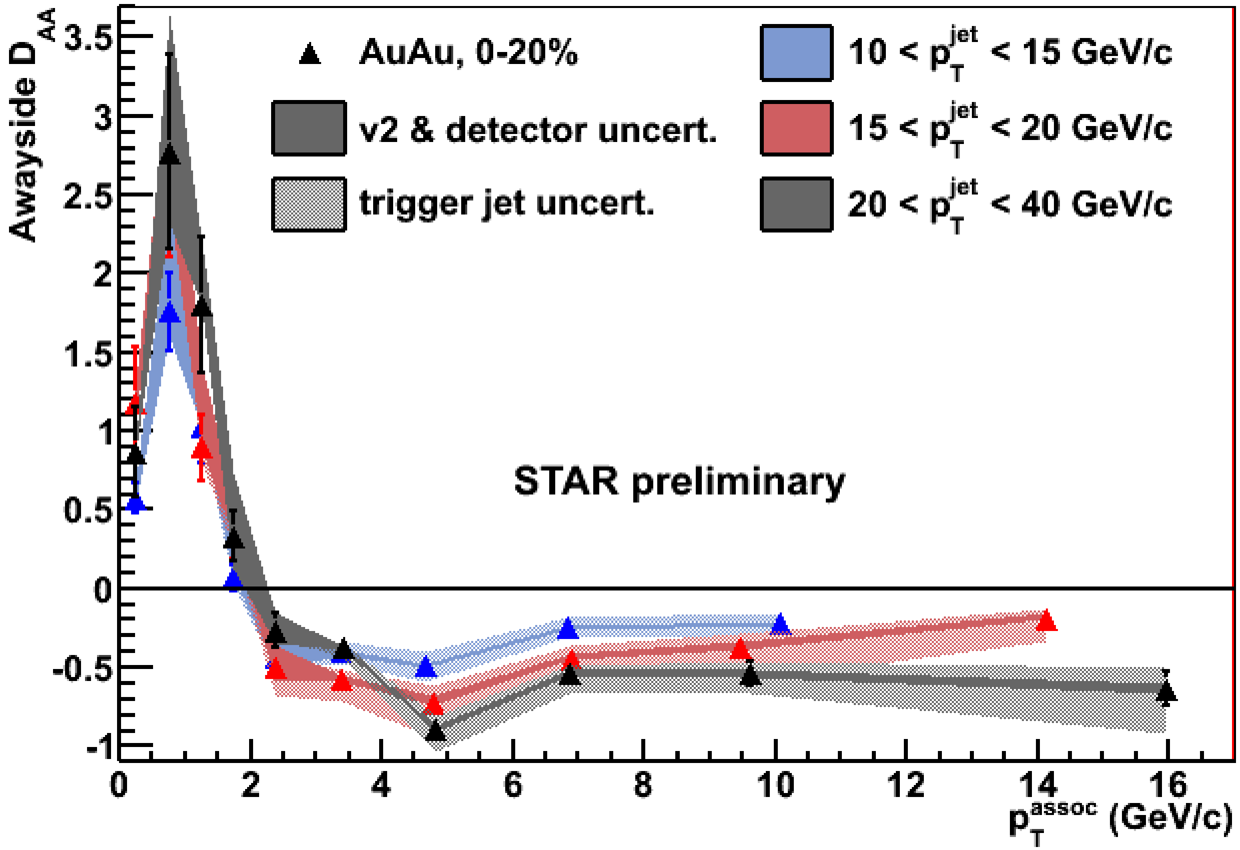
$$I_{AA}(p_T^{assoc}) = \frac{Y_{AA}(p_T^{assoc})}{Y_{pp}(p_T^{assoc})}$$



- Significant enhancement at low p_T^{assoc} and suppression at high p_T^{assoc} on the awayside as well as significant broadening of awayside jets in AuAu compared to pp.
- Conclusions hold for reconstructed jet energies between 10 and 40 GeV/c.

Jet Quenching from 10 to 40 GeV/c

$$D_{AA}(p_T^{assoc}) = Y_{AA}(p_T^{assoc}) \cdot p_{T,AA}^{assoc} - Y_{pp}(p_T^{assoc}) \cdot p_{T,pp}^{assoc}$$



$$\Delta B = \int dp_T^{assoc} D_{AA}(p_T^{assoc})$$

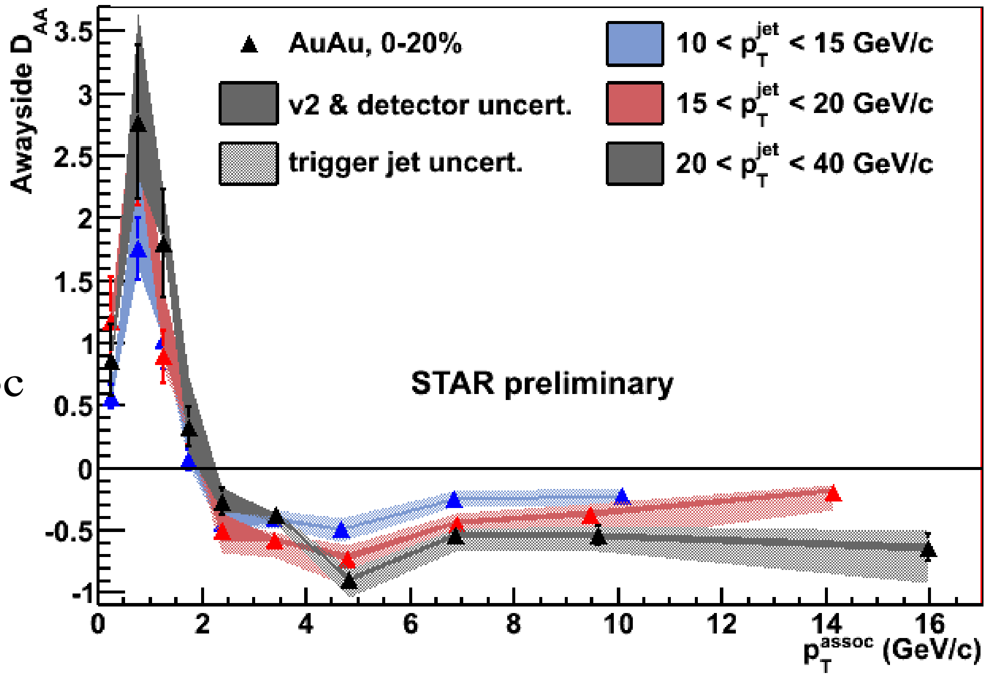
p_T^{jet} (GeV/c)	AS ΔB (GeV/c)
10-15	$1.6^{+1.5\,+0.5}_{-0.3\,-0.5}$
15-20	$2.3^{+1.8\,+0.5}_{-0.5\,-1.3}$
20-40	$2.5^{+2.0\,+0.5}_{-0.8\,-0.8}$

- Majority of high-p_T^{assoc} suppression is balanced by low-p_T^{assoc} enhancement for all p_T^{jet}.

Conclusions

Using jet-hadron correlations we observe:

1) Significant broadening and softening of jets which interact with the QGP.
2) High-p_T^{assoc} suppression in large part balanced by low-p_T^{assoc} enhancement.
3) Nearside/trigger jet needs more study...

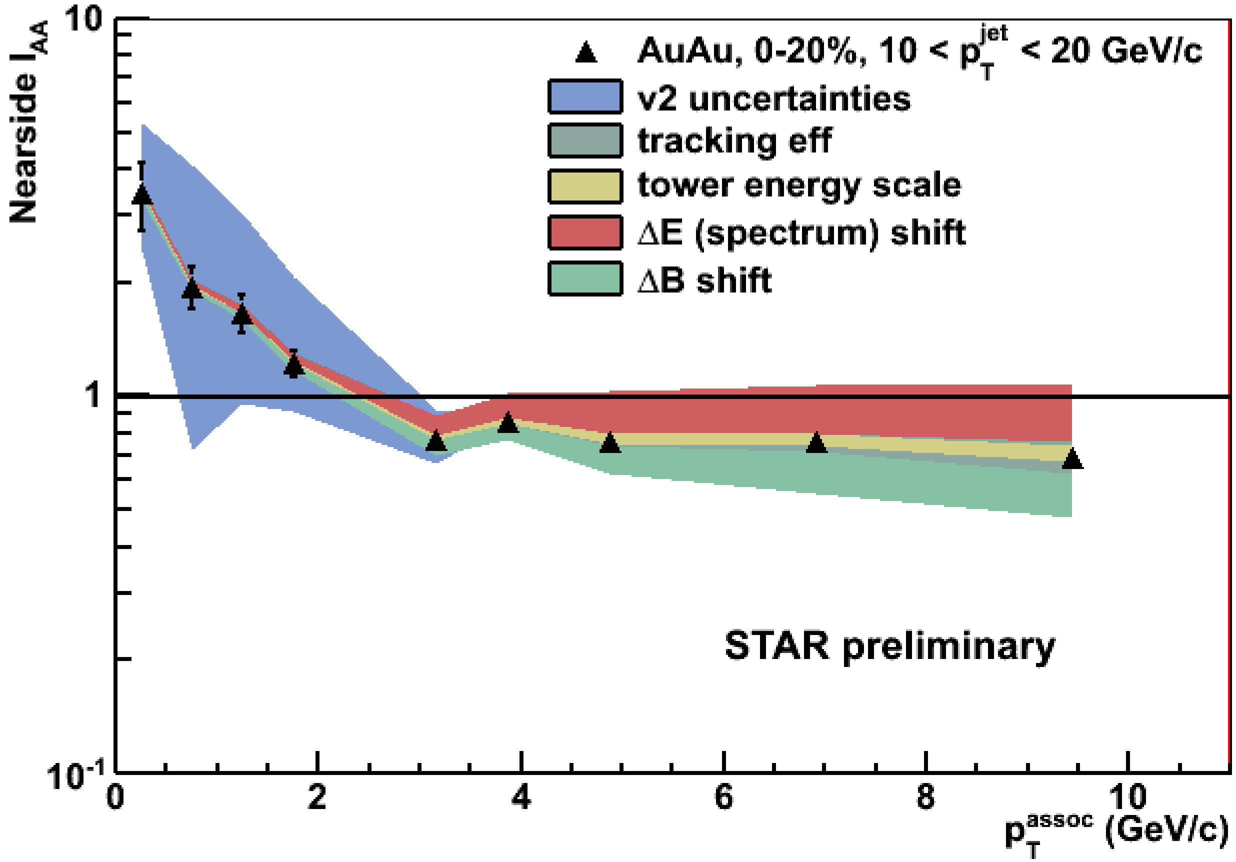


Jet modification seems to be consistent with radiative energy loss picture; black + white models are disfavoured.

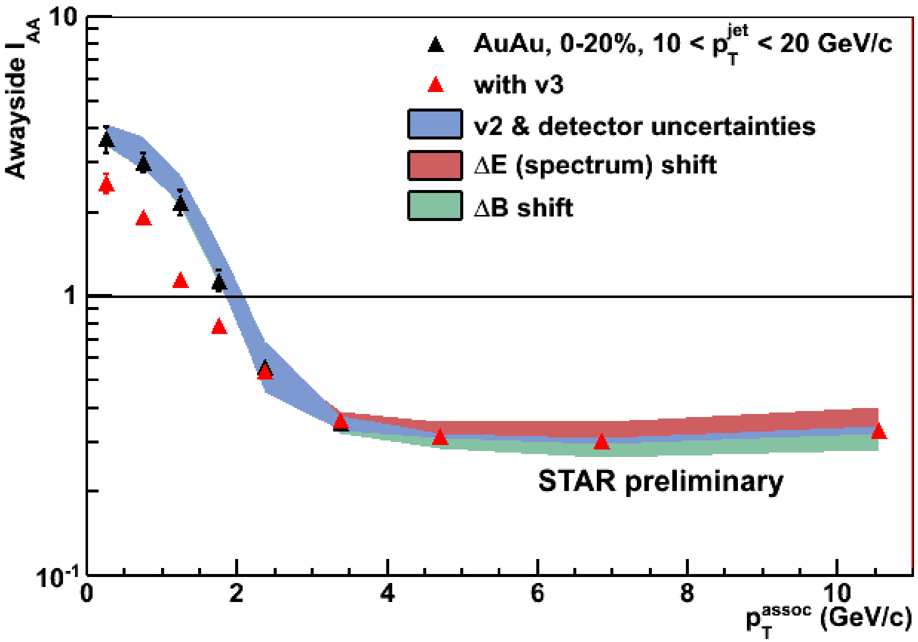
Backup

Uncertainties

- Detector uncertainties include:
  - relative tracking efficiency between AuAu and pp
  - tower energy scale
  - jet v_2 uncertainties

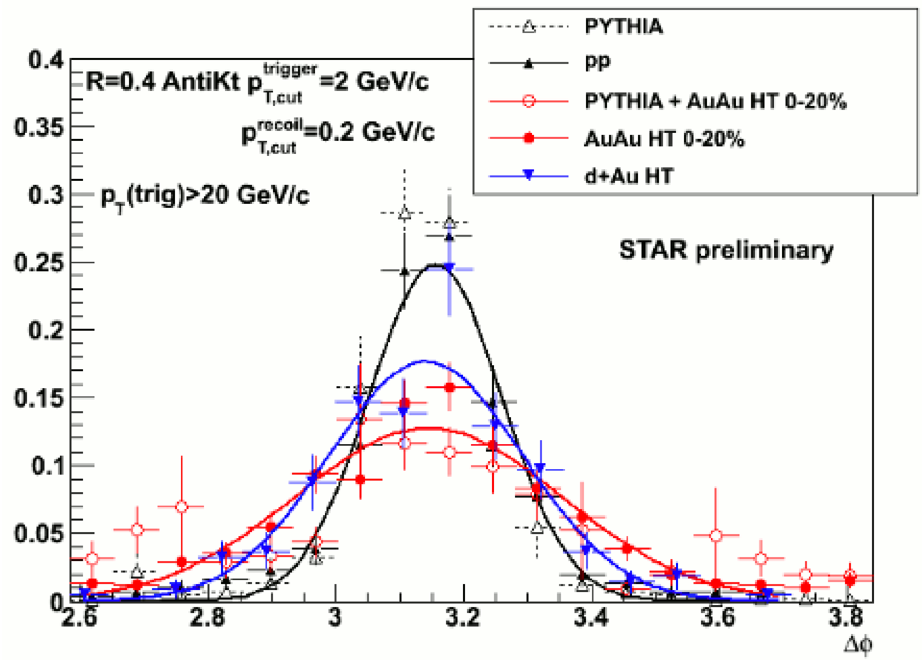


The Effect of v_3



- Do jets to have a non-zero v_3? If yes, must include a cos(3Δφ) in background subtraction.
- Even with extreme v_3^{jet} assumption, the qualitative conclusions about quenching on the awayside hold: low-p_T enhancement, high-p_T suppression, p_T redistribution

Broadening, Not Deflection



$p_{T rec,jet}$ > 20 GeV/c, $p_{T rec,dijet}$ > 10 GeV

Di-jet: highest p_T with $|\varphi_{jet}-\varphi_{dijet}| > 2.6$

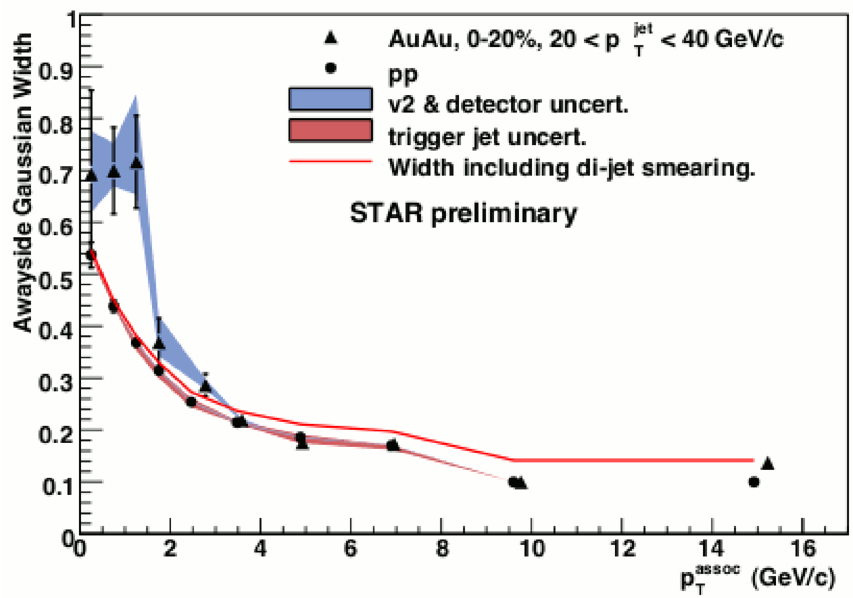
Δφ of identified di-jets

$\sigma_{Au\text{-}Au}$ = 0.2

$\sigma_{PYTHIA,Embed}$ = 0.14

$\sigma_{d\text{-}Au}$ = 0.15

$\sigma_{p\text{-}p} \sim \sigma_{PYTHIA}$ = 0.1



Low p_T assoc

Au-Au away-side width broader

High p_T assoc

Au-Au away-side width same

Majority of broadening due to fragmentation not deflection

Helen Caines - QM - May 2011 15