Jet and jet-like correlations studies from STAR

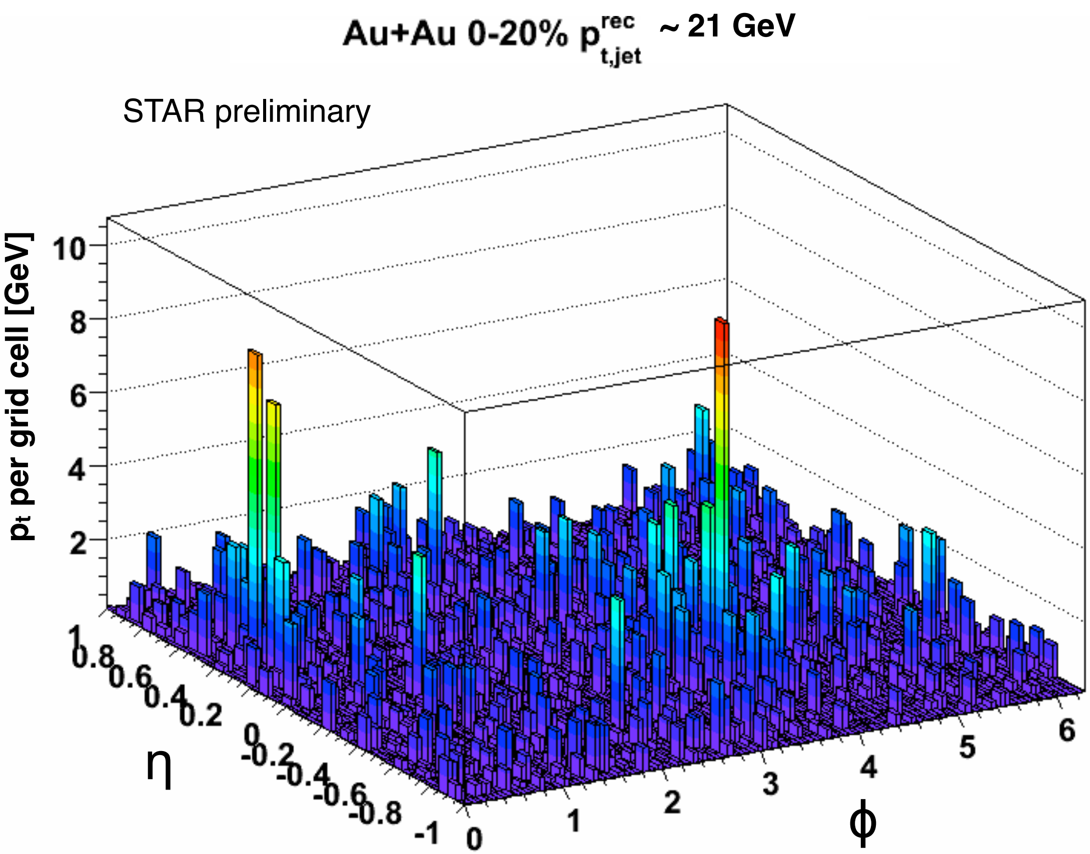
Outline

- p-p
  Setting the baseline
- d-Au
  Cold nuclear matter effects
- Au-Au
  Understanding the background
  Probing jet modifications

Helen Caines - Yale University - on behalf of the STAR Collaboration

May 23-28 2011

Jet studies in Au-Au collisions



Jets can be seen by eye in Au-Au events

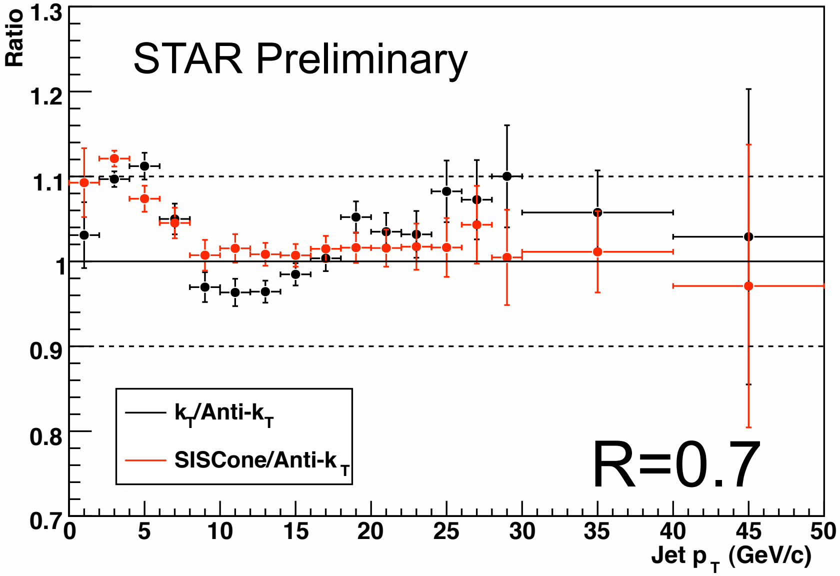
- if you can see them you can study them

di-hadron correlations, full jet reconstruction and PID →

a) understanding of parton interactions with medium

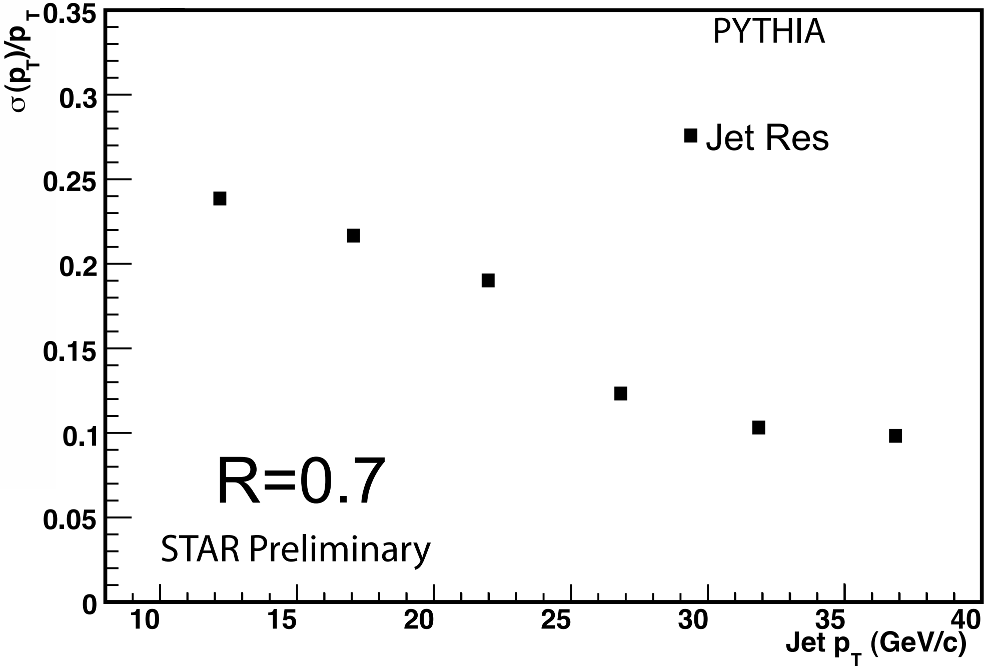
b) where the "lost" energy emerges

Measuring the p-p jet cross-section



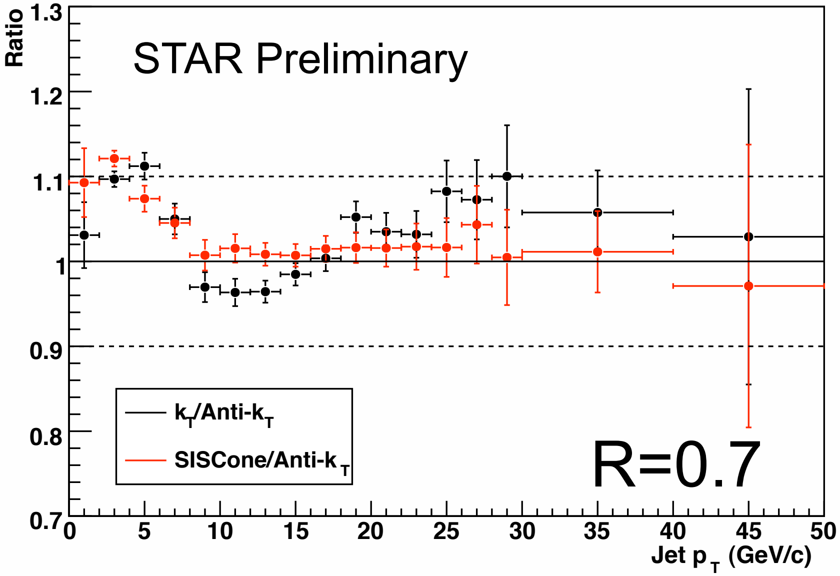
Energy resolution 10-25%

k_T, Anti-k_T, SISCone - similar behavior



Jet finders & detectors understood

Measuring the p-p jet cross-section



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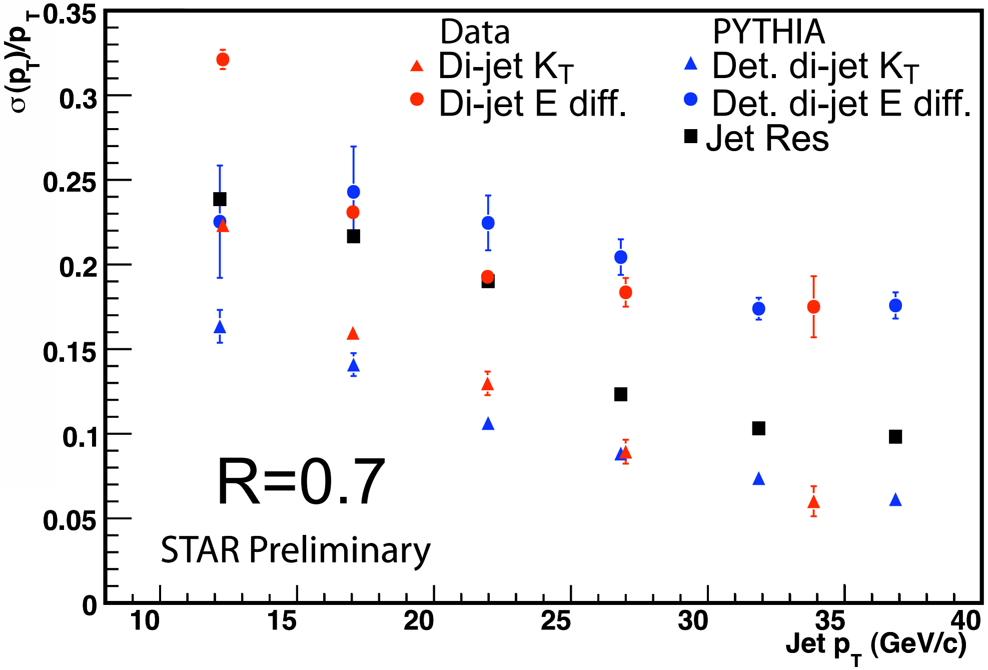

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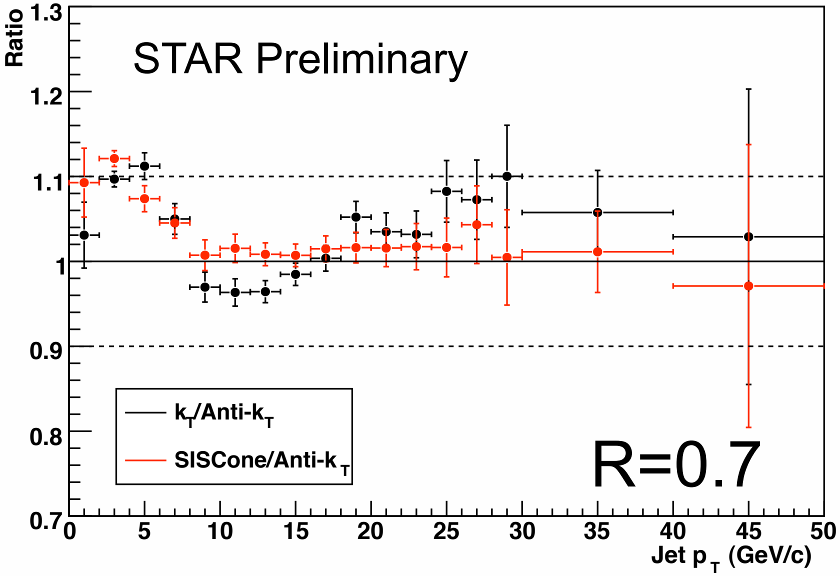

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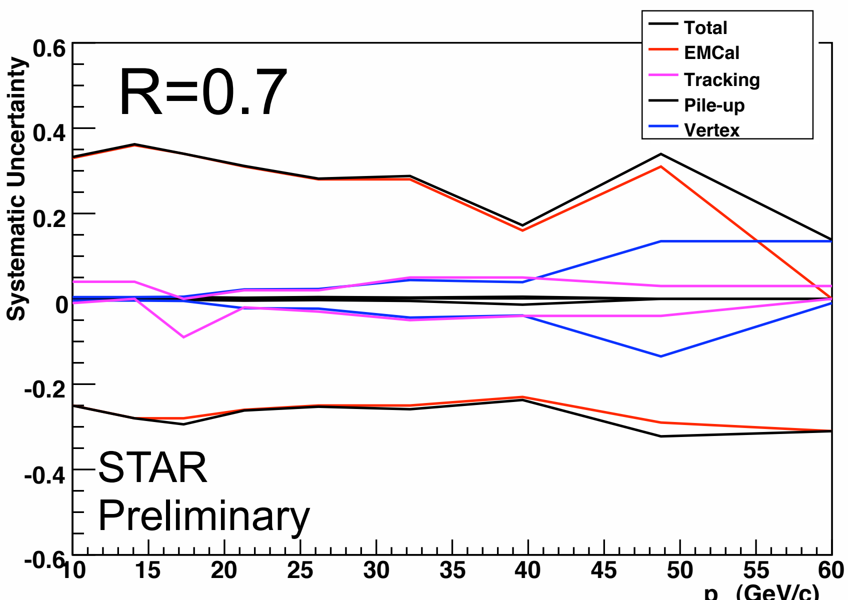

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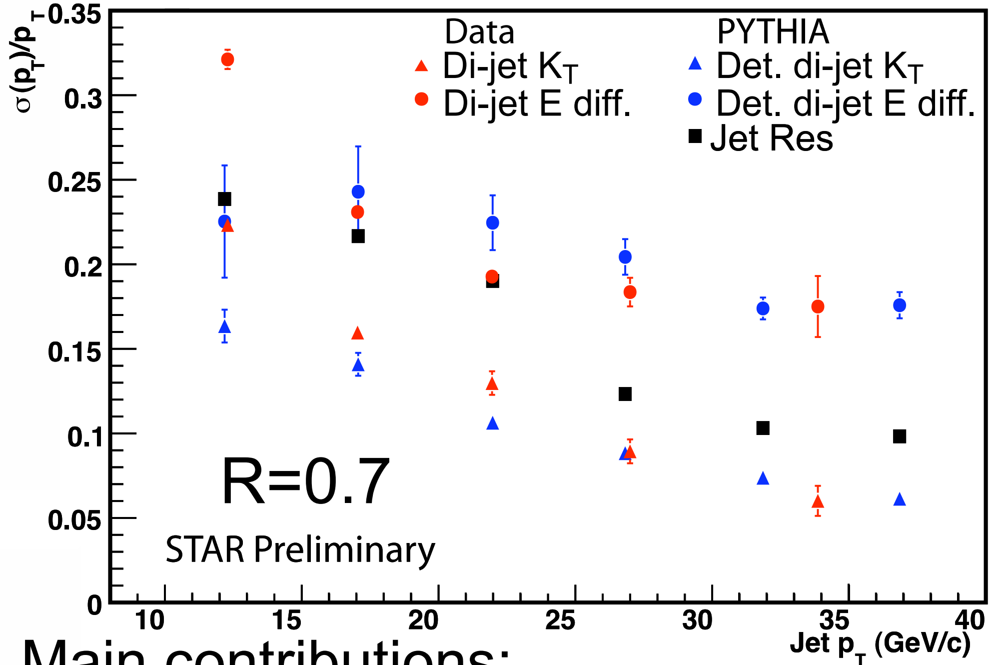


Main contributions:

EMCal calibration, Tracking effic. uncert.

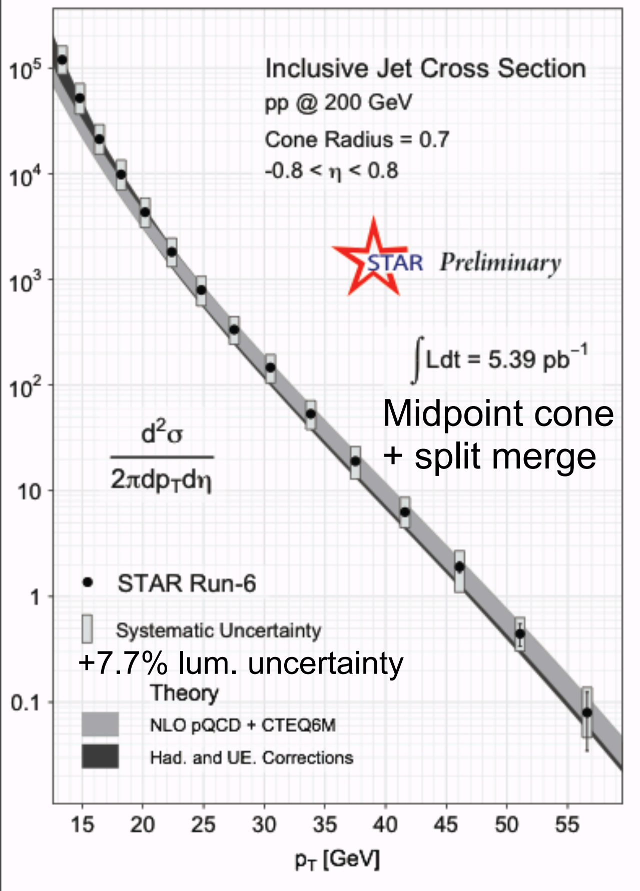
Pile-up, Vertex location selection

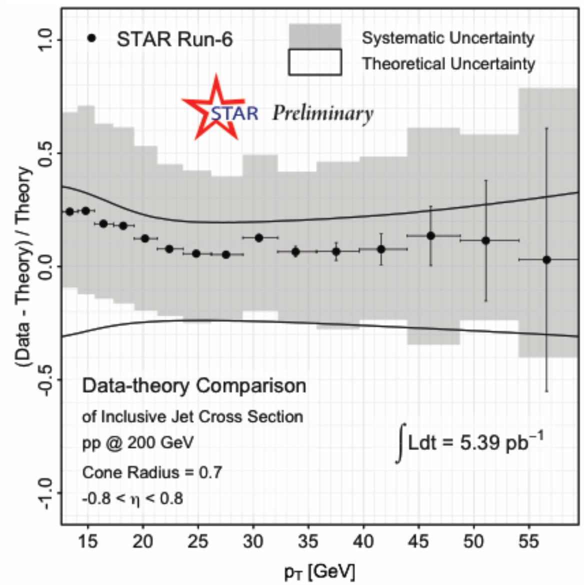
Luminosity: 7% (applied separately)

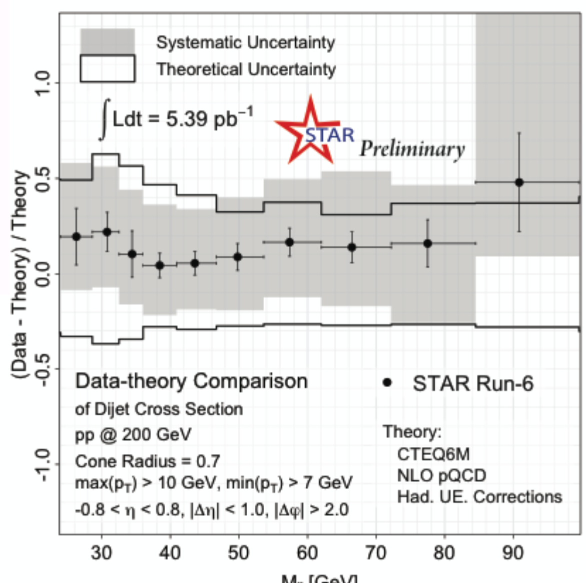
UE & hadronization (applied to theory)

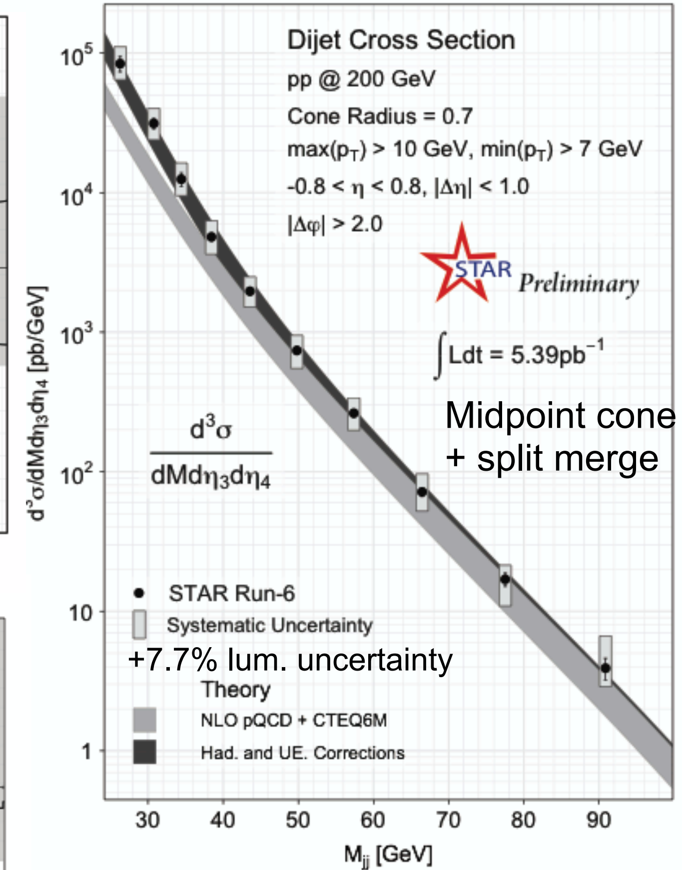
Jet finders & detectors understood

Jets in p-p







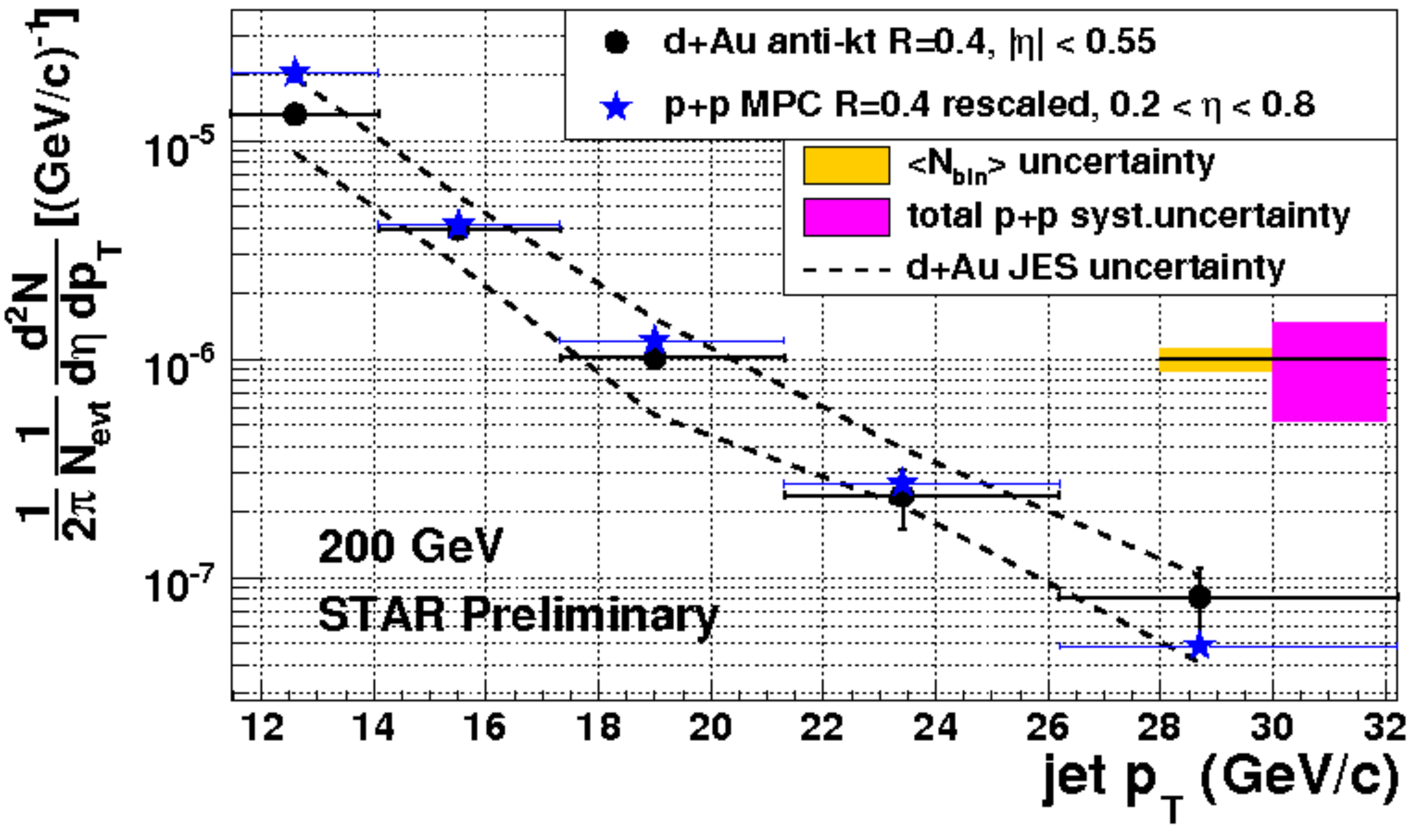


Hadronization and UE correction applied to theory

Jet and di-jet cross-section well described by NLO

d-Au: binary scaling of jet yields

Before looking at scattering effects in Au-Au we want to investigate what happens in d-Au (where we expect no QGP)



note:

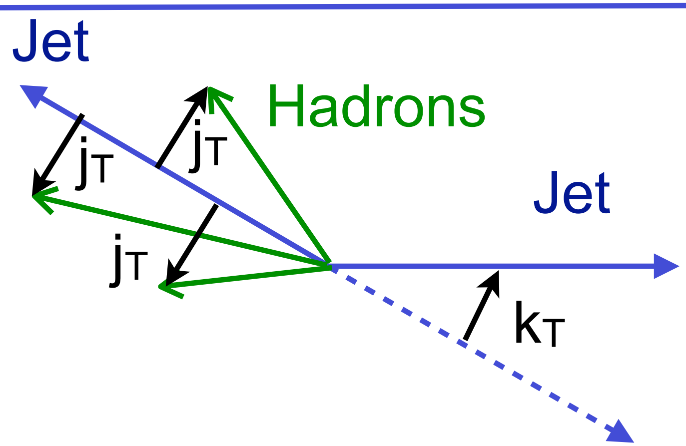
different jet finding algorithms used

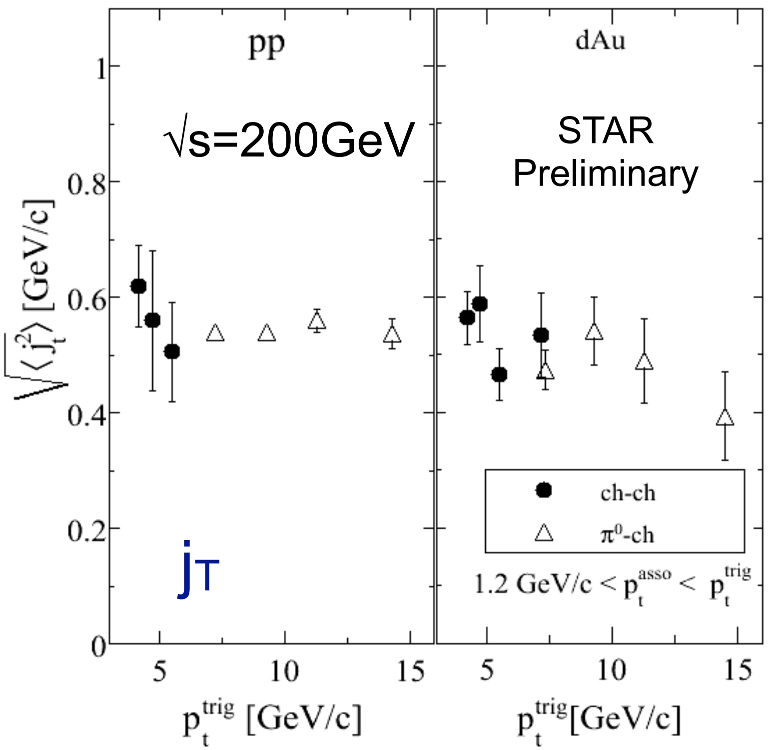
different η range used

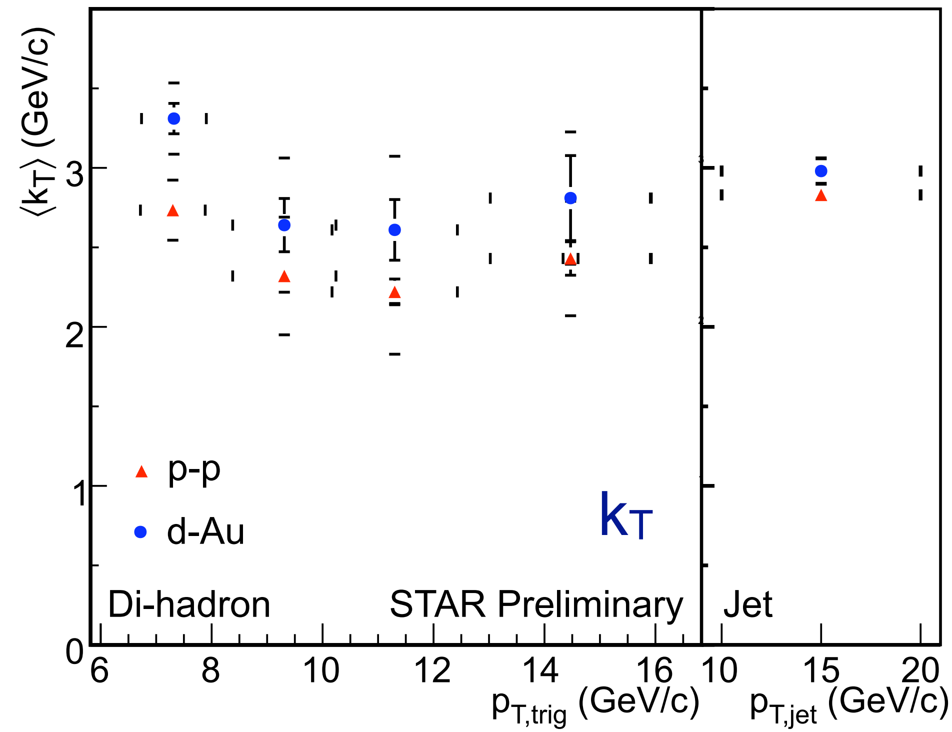
J.Kapitan:Poster#428 Board#19

Jet spectra binary scale, within errors, with respect to p-p

Cold nuclear matter effects







j_T - Constant with beam species and trigger p_T

k_T - Depends on collision energy
d-Au consistently higher than p-p

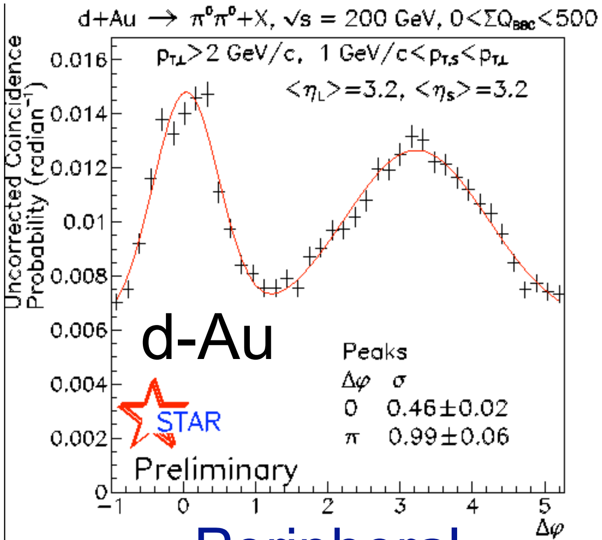
**CNM: small effect on partonic p_T
negligible effect on fragmentation**

M.Mondal:Poster#231 Board#14

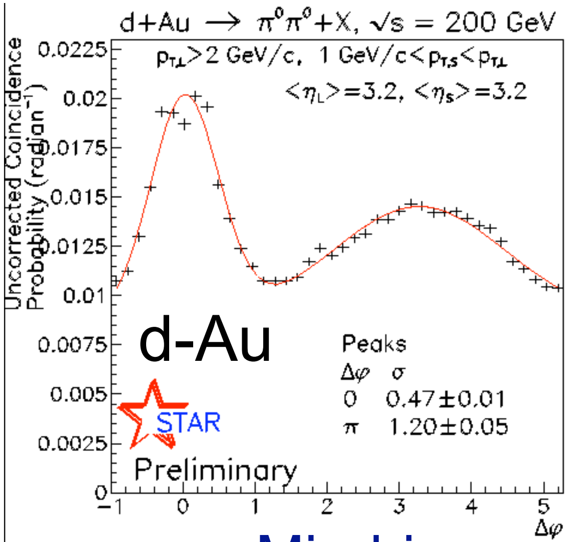
Probing the initial conditions

"Mono-jets" in central d-Au forward-forward (low-x) data - CGC hint

MPI proposed to explain high pedestal
(Strikman & Vogelsang
PRD 83:034029 2011)



Peripheral



Min-bias

C.Perkins DIS2011

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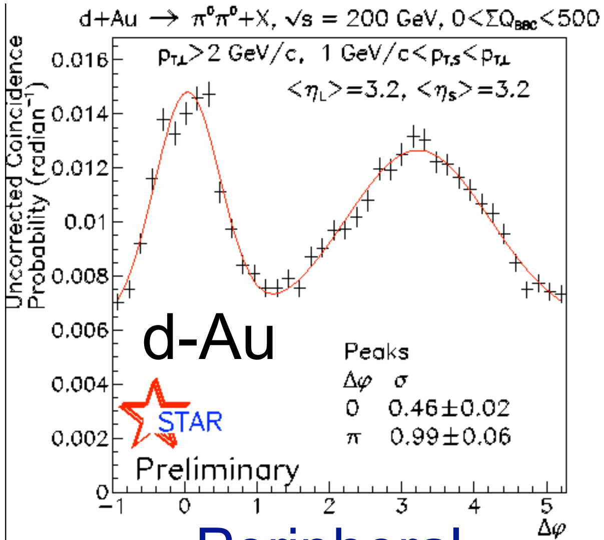

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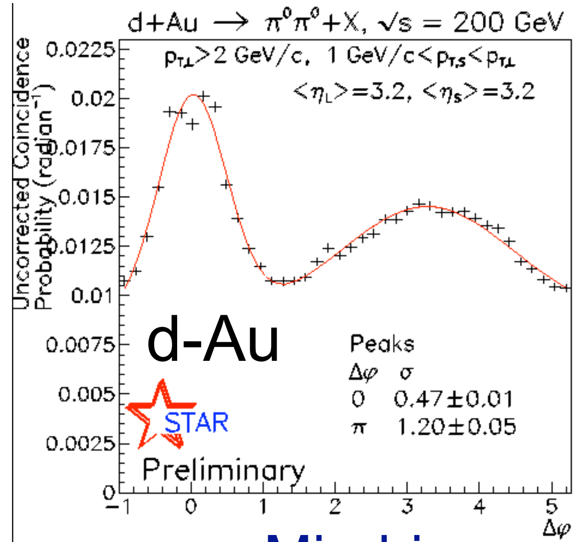
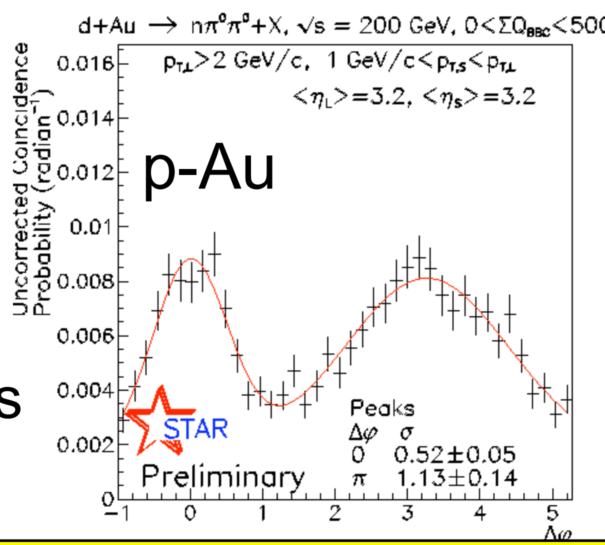
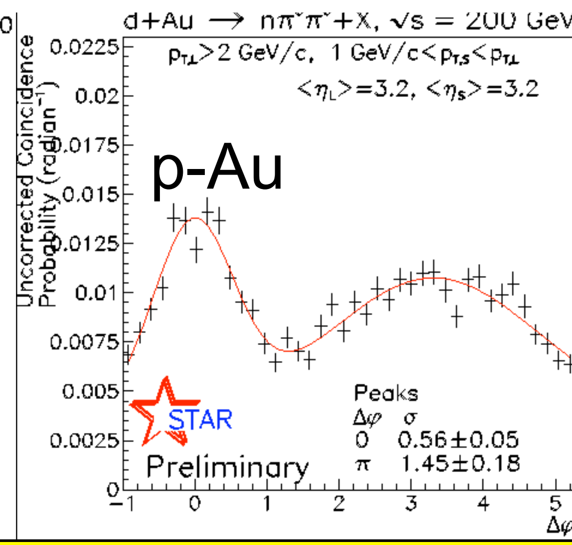


Min-bias

Study p-Au:
Neutron in West ZDC





$BG_{p\text{-}Au} \sim BG_{p\text{-}p} < BG_{d\text{-}Au}$

Near- and away-side widths unchanged

C.Perkins DIS2011

Background consistent with MPI dominating in d-Au
Away-side suppression consistent with CGC

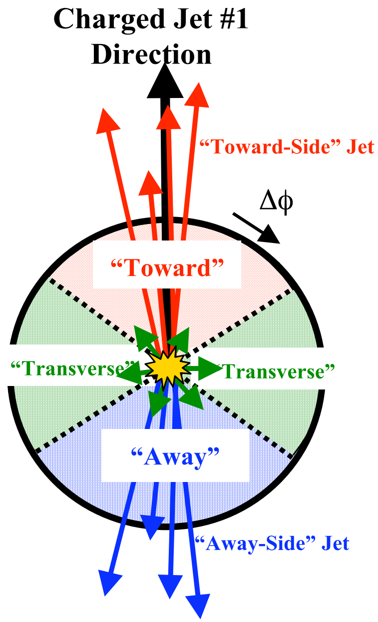
Underlying event in p-p and d-Au

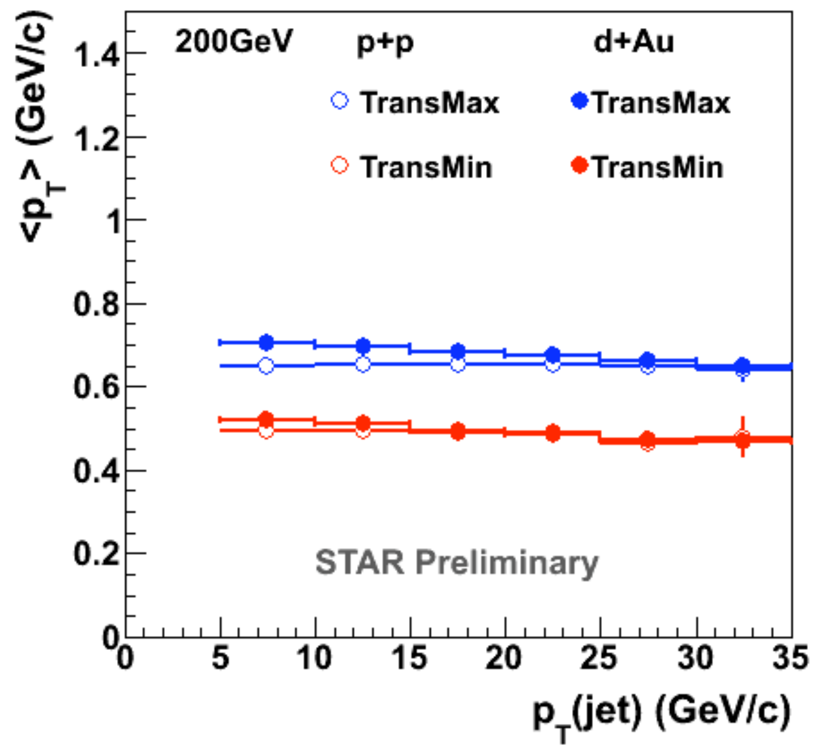
Jets:

p-p = d-Au

Underlying event:

$\langle p_{T\,d\text{-}Au} \rangle \sim \langle p_{T\,p\text{-}p} \rangle$
~ 0.6 GeV/c





J.Bielcikova:Poster#407 Board#18

Underlying event in p-p and d-Au

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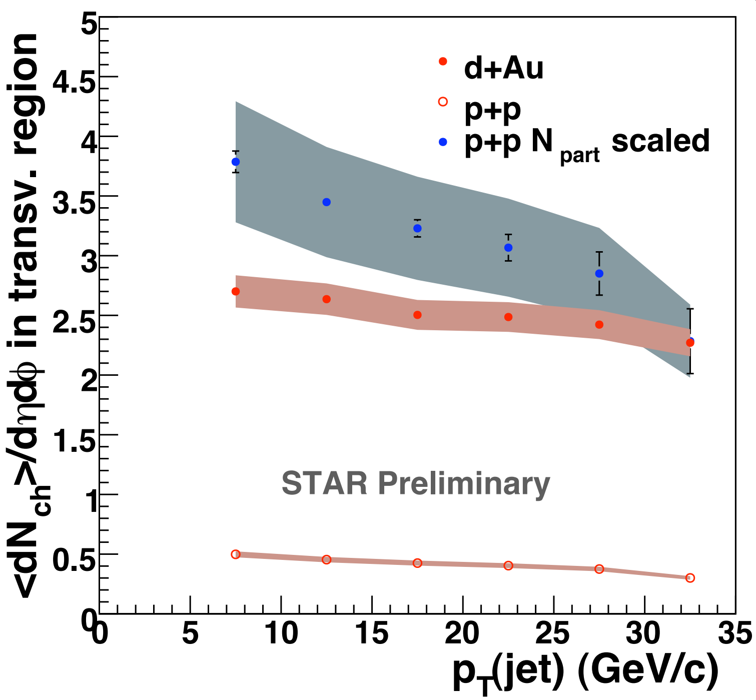
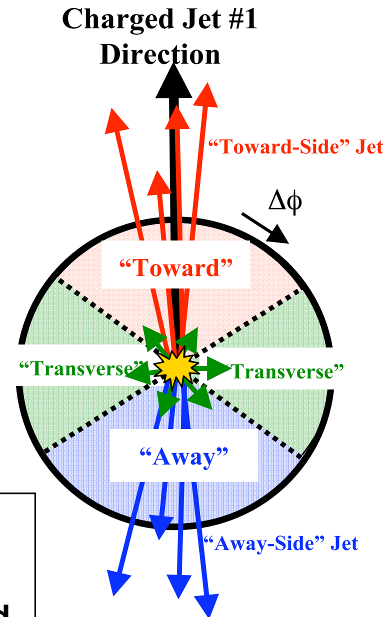
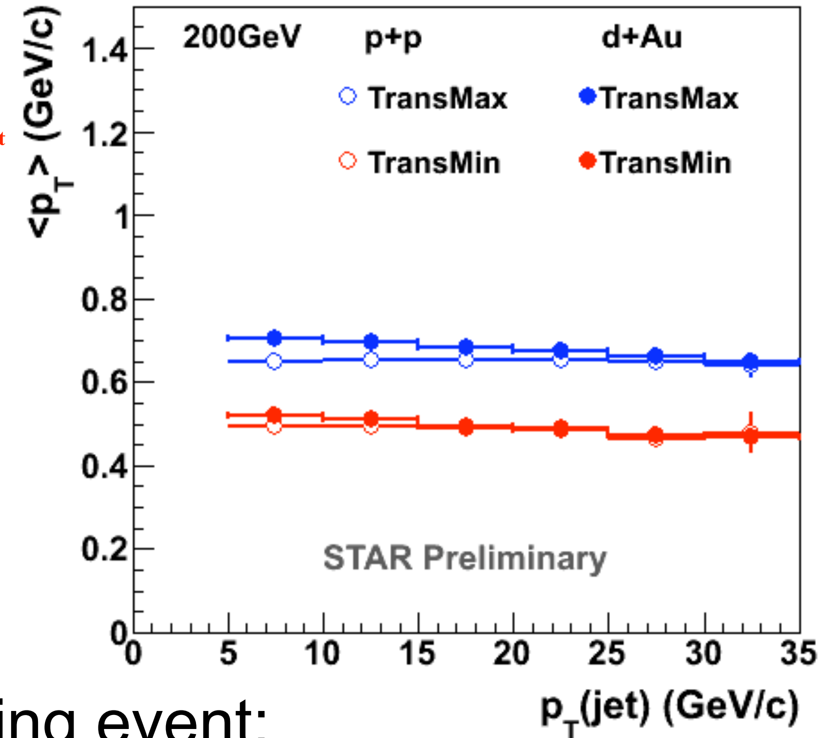






Underlying event:

$dN_{ch}/d\eta d\phi$

d-Au ~ 2.5 ~ 5 x p-p

$\sim N_{part}$ x p-p

UE multiplicity scales much slower than N_{bin}

J.Bielcikova:Poster#407 Board#18

Au-Au: underlying event fluctuations

Schematically Au-Au jet spectrum: $$\frac{d\sigma_{AA}}{dp_T} = \frac{d\sigma_{pp}}{dp_T} \otimes F(A, p_T)$$

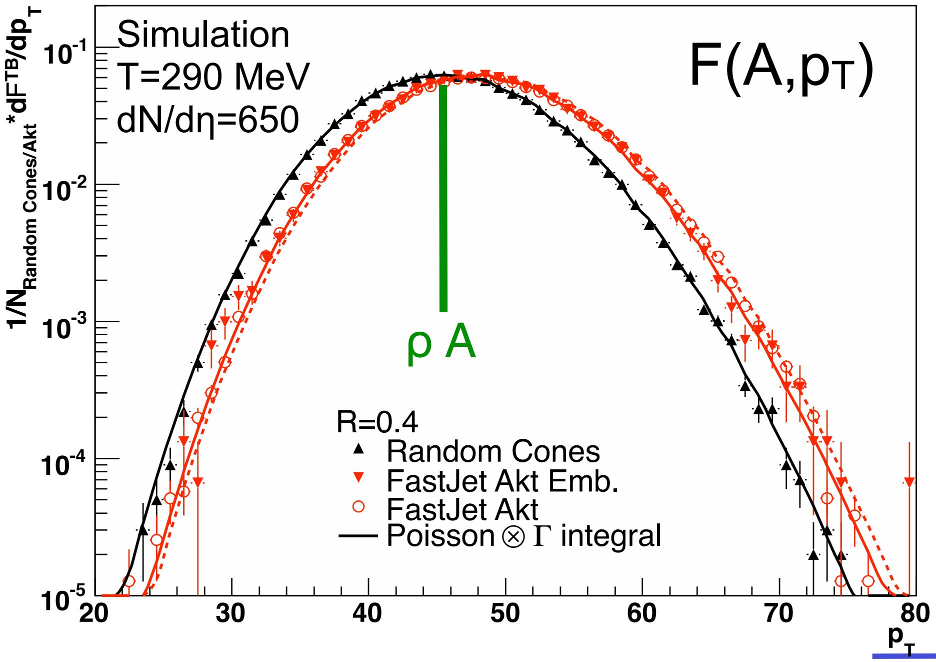
$F(A,p_T)$ - initial assumption: Gaussian distribution (a la FastJet)

If background independently distributed particles: M.Tannenbaum PLB 498 2001

number fluct ~ Poisson

$\langle p_T \rangle$ fluct (fixed M) ~ Gamma

$$F(A, p_T) = Poisson(M(A)) \otimes \Gamma(M(A), \langle p_T \rangle)$$



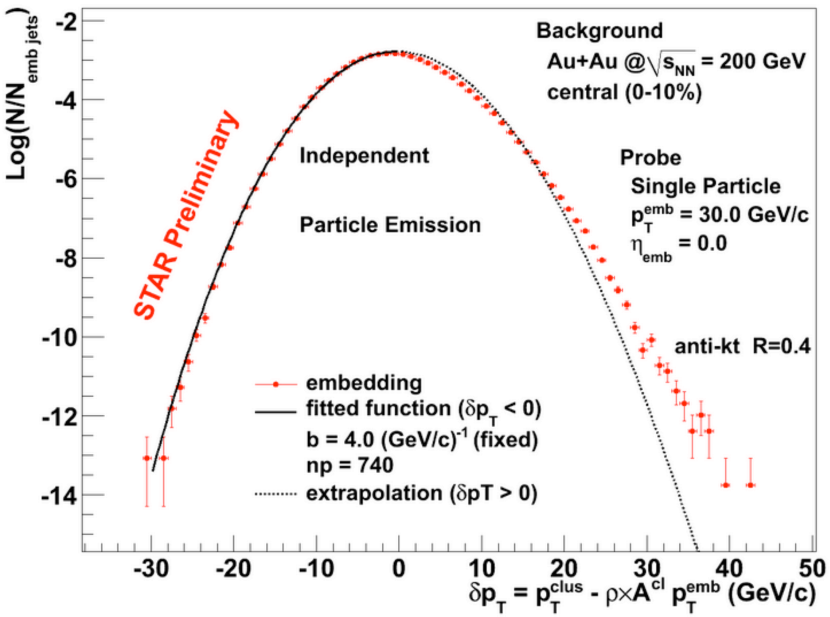
ρ A = Mean energy x Jet Area

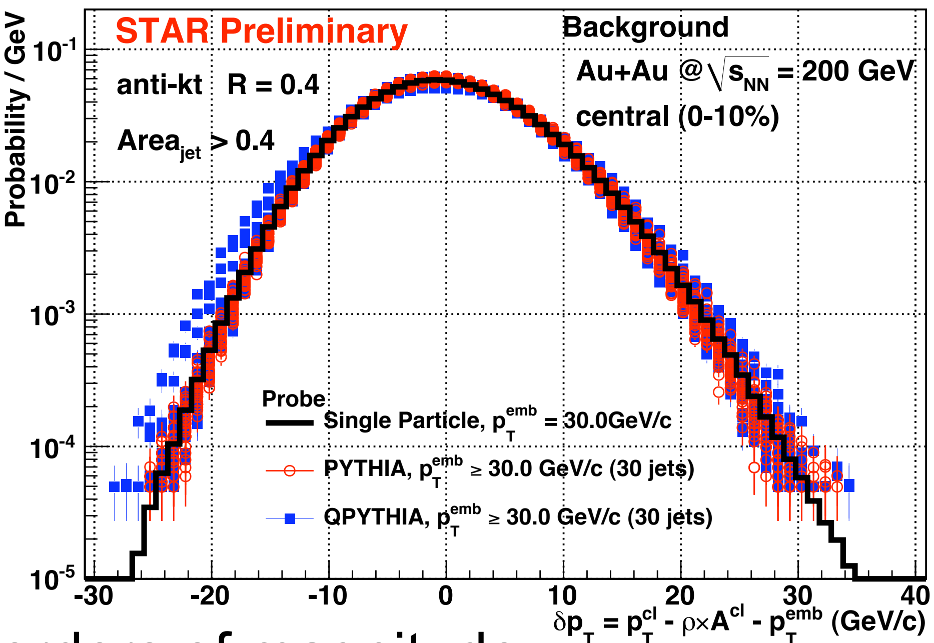
$F(A,p_T)$ closer to measurement but not exactly same - clustering occurs in non-random fashion!

Background fluctuations from data

Generalized probe embedding (GPE): data driven approach

$$\delta p_T(A) = p_T^{clus} - \rho \cdot A - p_T^{emb} \rightarrow F_{Fluc}(A, p_T^{meas})$$





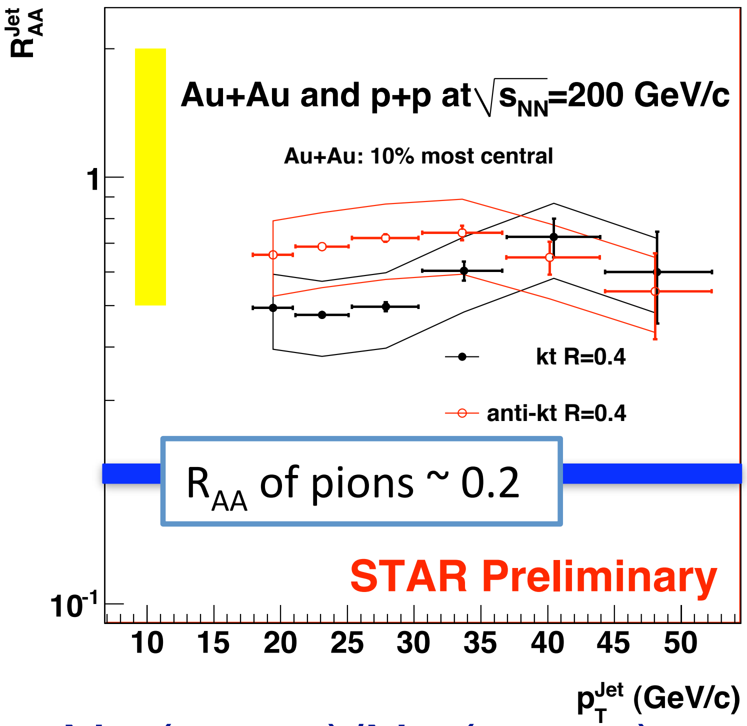
Fluctuations mapped over several orders of magnitude

→ reduction of systematic uncertainties!

δp_T distribution independent (within x2 at δp_T~30) of fragmentation model

Can perform BG subtraction before FF details known

Evidence of jet broadening

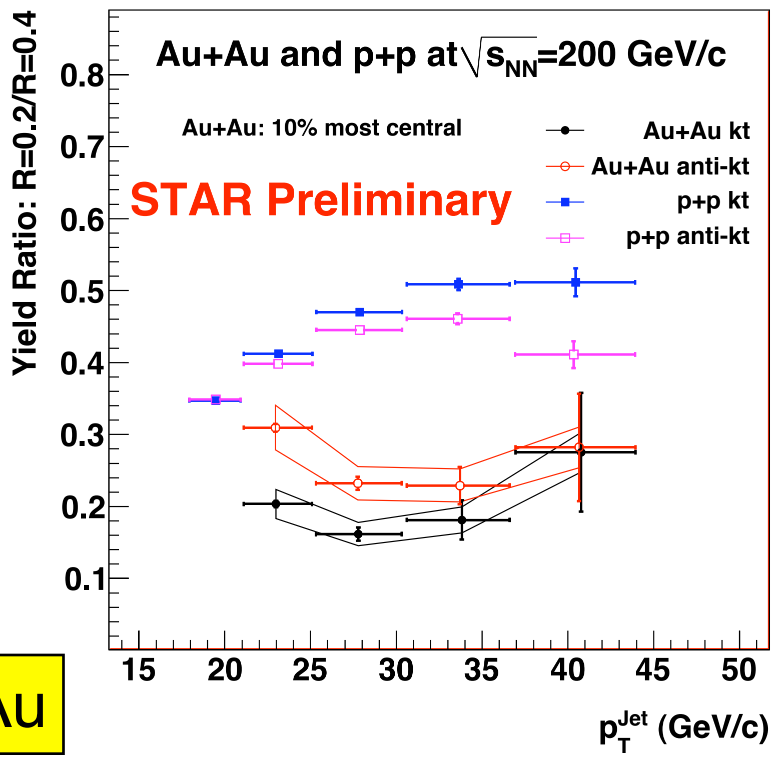


k_T and Anti-k_T known to have different sensitivities to background

Jet $R_{AA} < 1$(R=0.4)

Algorithms fail to recover all jet

N_{jet}(R=0.2)/N_{jet}(R=0.4) vs $p_{T,jet}$



p-p:

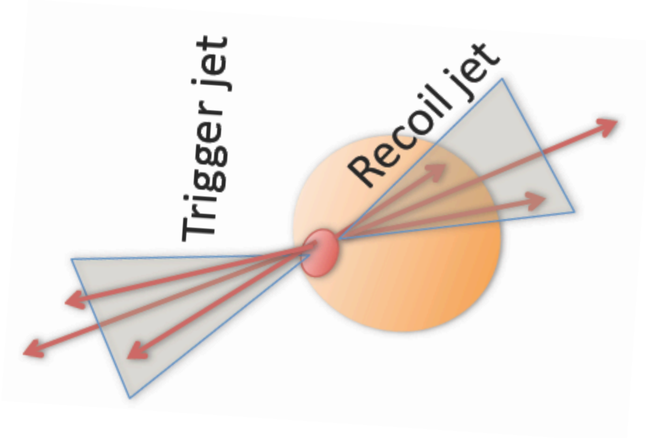
"Focussing" of jet with jet energy

Au-Au:

"Broadening" of jet compared to p-p

Jet fragmentation broader in Au-Au

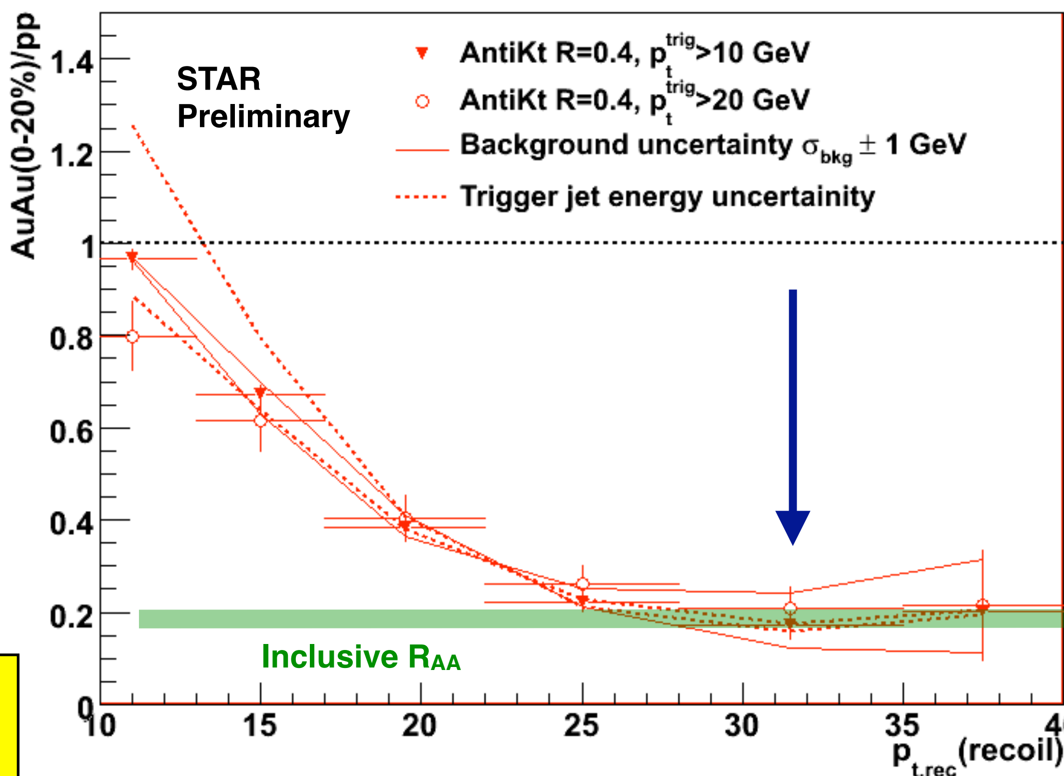
Di-jet coincidence rate



High tower trigger - single particle with high p_T

bias maximizes distance through medium recoil jet traverses

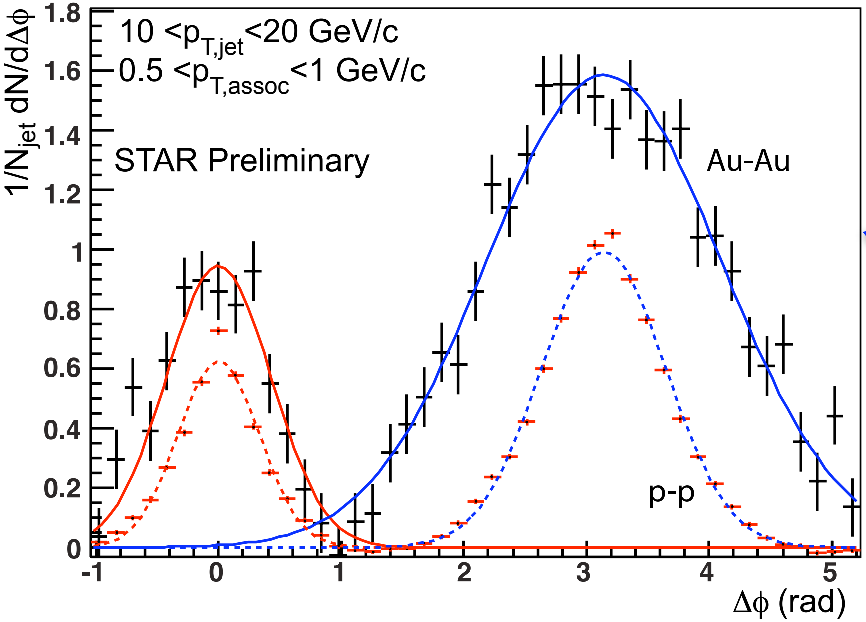
Compare yield of di-jets in p-p to Au-Au

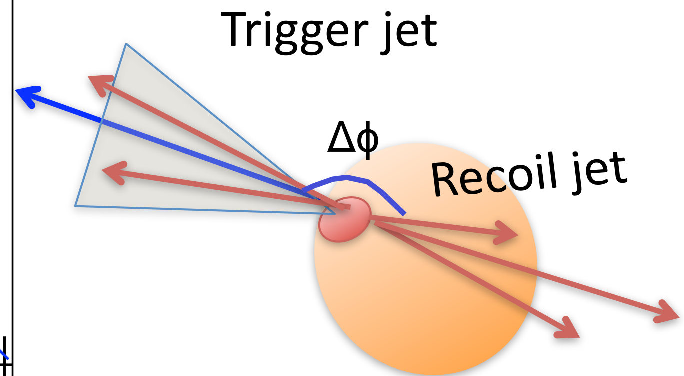


- Significant suppression of recoil jets - close to single particle R_{AA}
- Further evidence of broadening

Larger path length results in larger suppression/broadening

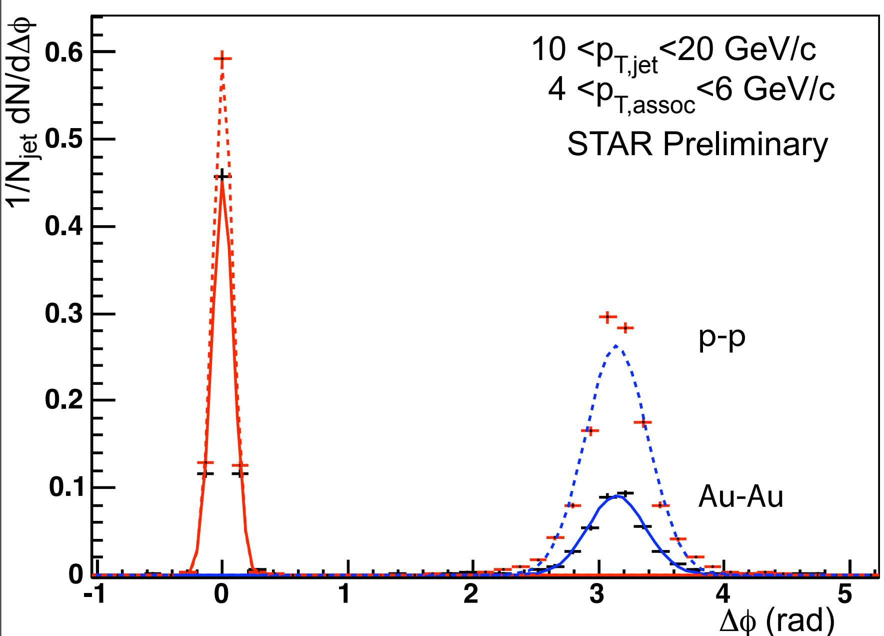
Jet-hadron correlations





Au+Au 0-20%
High Tower Trigger
1 tower
0.05x0.05 (ηxϕ)
with E_t> 5.4 GeV

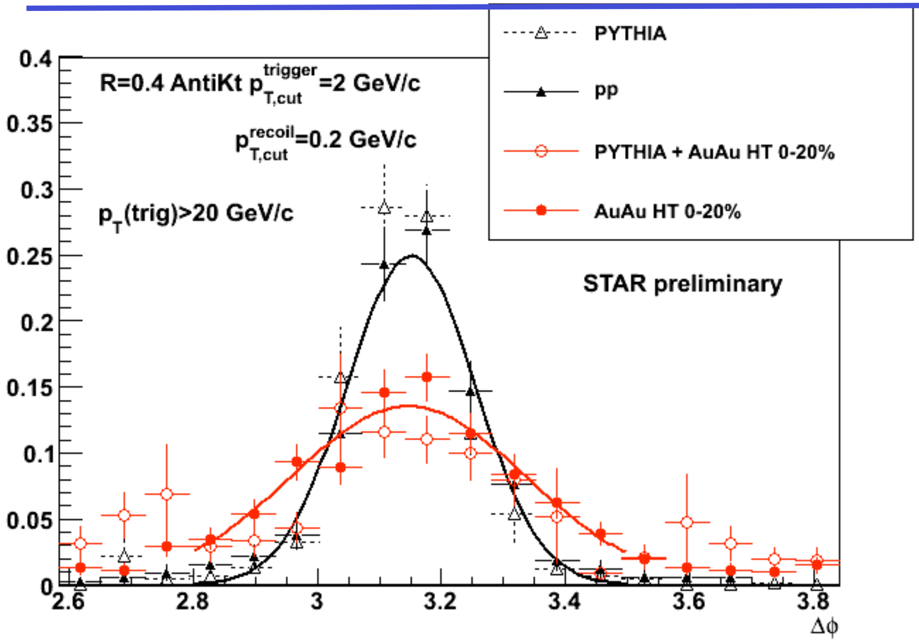
Jet trigger:
Anti-k_T,
R=0.4,
$pt_{,rec}$(jet) using
$p_{t,}$(particle)>2 GeV



Away-side: Broadening
Softening

Direct measurement of modified fragmentation due to presence of sQGP

Broadening not deflection

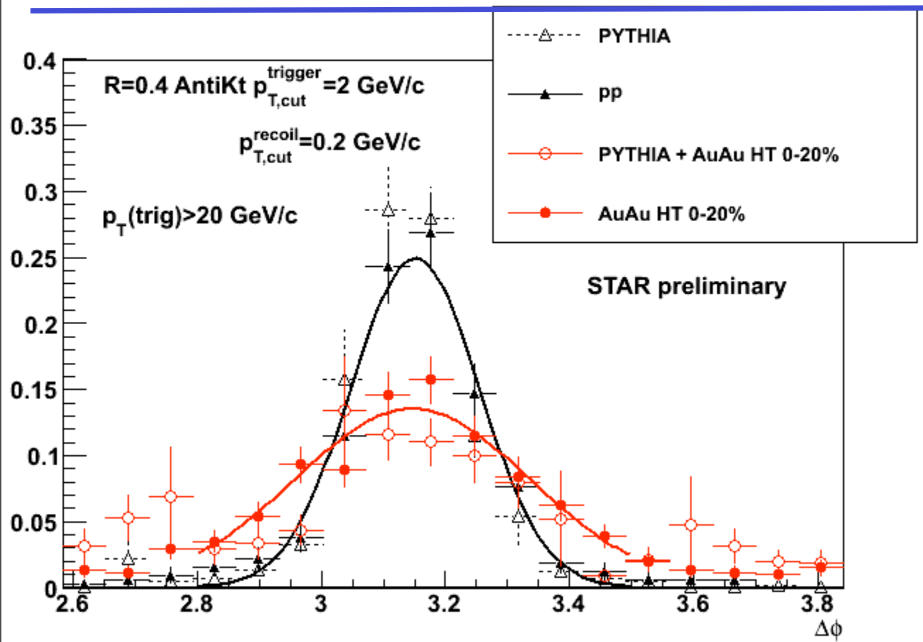


$p_{T rec,jet}$ > 20 GeV/c, $p_{T rec,dijet}$ > 10 GeV
Di-jet: highest p_T with $|\varphi_{jet}-\varphi_{dijet}|$ > 2.6

Δφ of identified di-jets

$\sigma_{Au\text{-}Au}$ ~ 0.2
$\sigma_{PYTHIA,Embed}$ ~ 0.14
$\sigma_{p\text{-}p}$ ~ σ_{PYTHIA} ~ 0.1

Broadening not deflection



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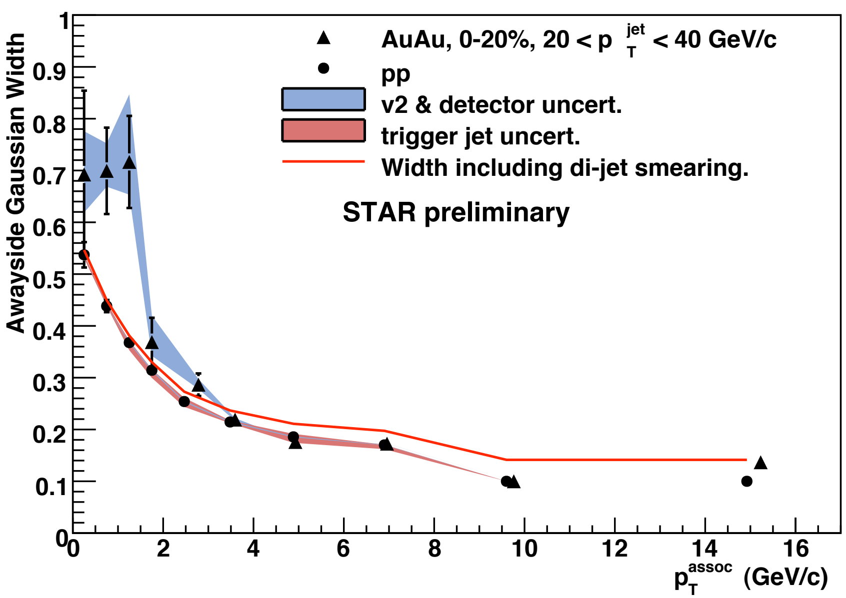


Low p_T assoc

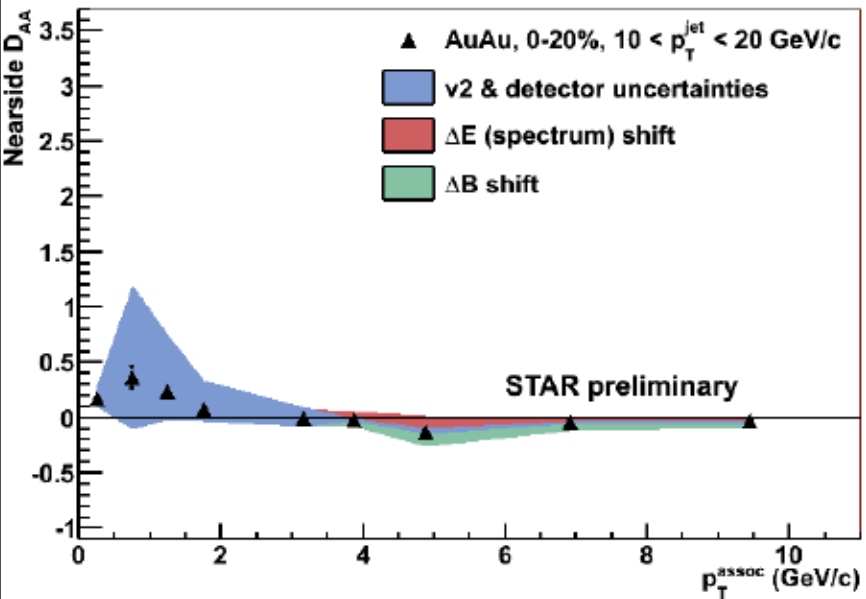
Au-Au away-side width broader

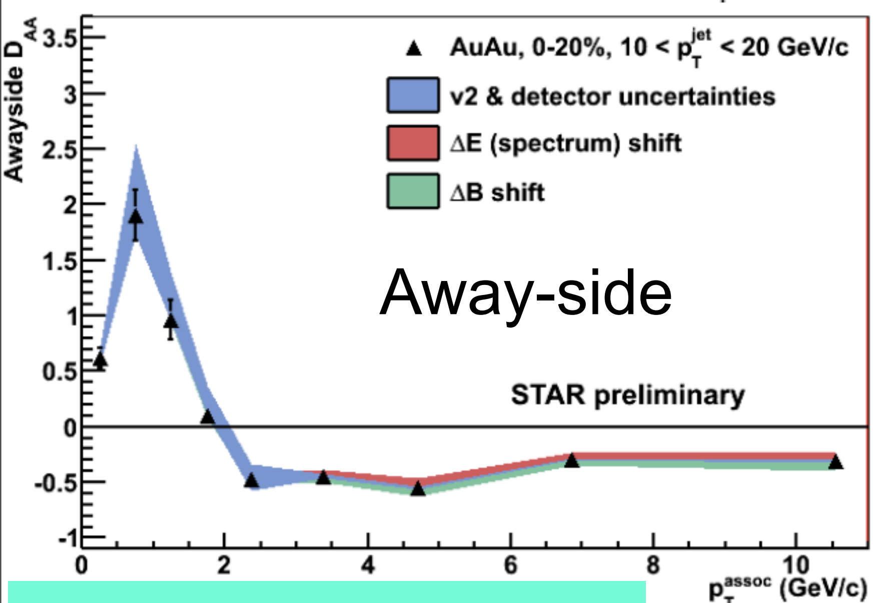
High p_T assoc

Au-Au away-side width same

Majority of broadening due to fragmentation not deflection

Jet-hadron: Energy balance





D_{AA} = Au-Au - p-p Energy difference

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

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

Near-side:

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

Away-side:

$$\Delta B = 1.5 \,^{+1.7\,+0.5}_{-0.4\,-0.4}\,(\text{sys})\ \text{GeV}/c$$

Energy lost at high p_T approximately recovered at low p_T and high R

A.Ohlson:Fri 27-18:10

PID triggered correlations

$\pi^{\pm}$, $(p^{\pm}+K^{\pm})$, $h^{\pm}$

via statistical dE/dx

Baselines:

d-Au MB:

$\pi = p+K$

Au-Au 0-10%:

$\pi < p+K$

Near-side Peaks:

d-Au MB:

lower for p+K

Au-Au 0-10%:

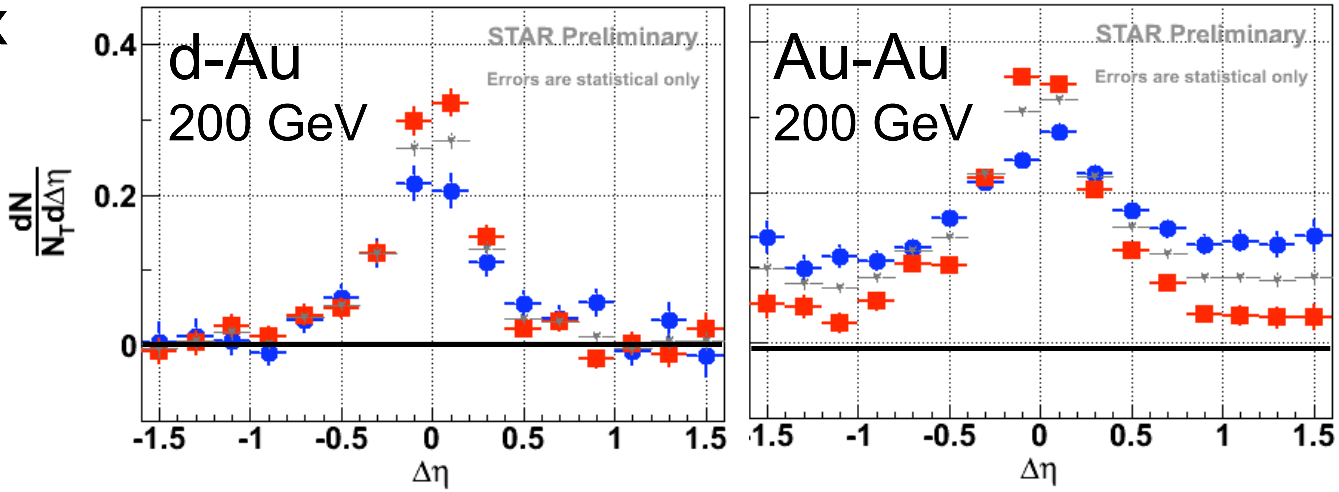
lower for p+K

Integrated Near-side yield

d-Au = Au-Au for π and p+K

K.Kauder:Fri 27-16:00

$p_{T,Trig}$ = 4-6 GeV/c, $p_{T,Assoc}$>1.5 GeV/c
$|\Delta\Phi|<0.73$



p+K → enhanced ridge

π triggers → higher jet yields

No strong dilution of near-side jet yields due to "false" triggers from recombination observed

Summary of STAR jet data at $\sqrt{s}$=200 GeV

Full jet reconstruction:

- p-p jet and di-jet cross-sections are well described by NLO
- d-Au jet cross-section consistent with binary scaled p-p data
- d-Au UE mult. shows approximate N_{part} scaling with similar $\langle p_T \rangle$
- k_T measures suggest CNM effects are small for jets
- Understanding of Au-Au background much clearer
- First clear indications of broadening of jet fragmentation in A-A

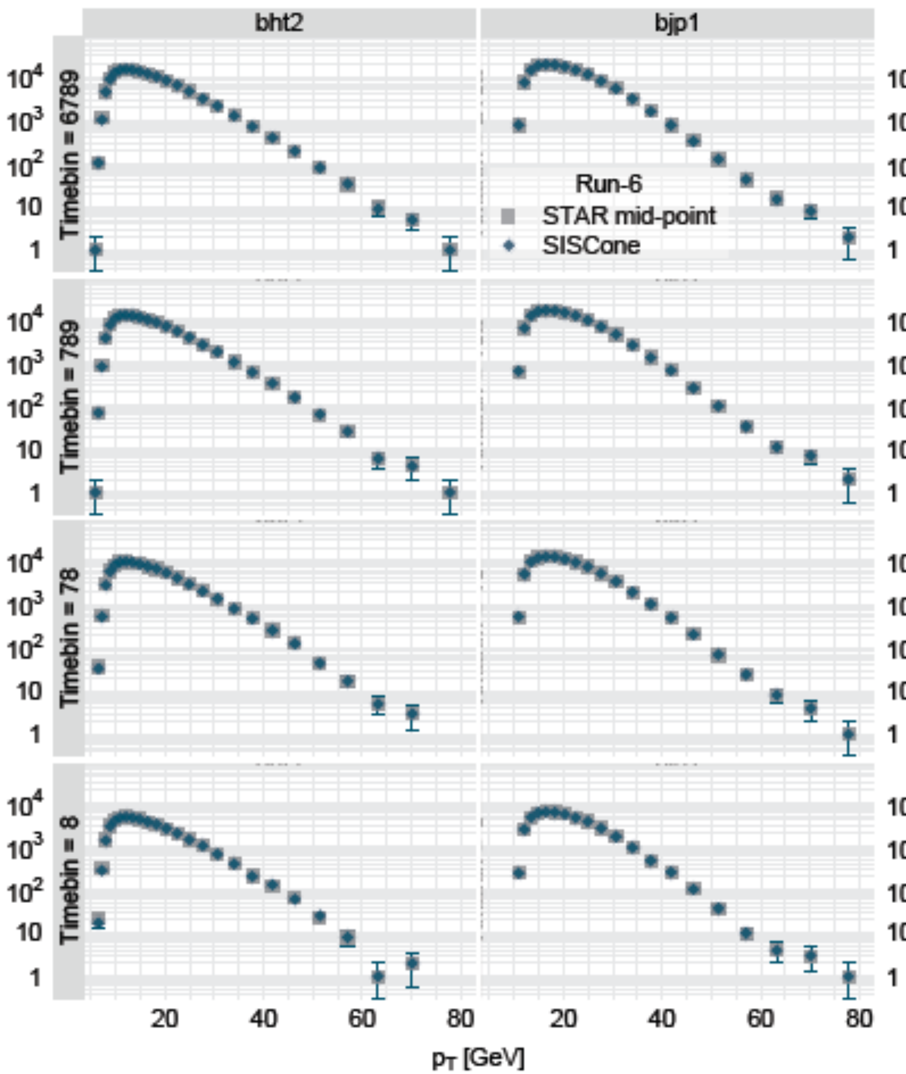
Di-hadron correlations:

- Low-x correlations indicate MPI are significant in d-Au collisions
- PID triggered correlations pose a challenge to recombination picture at intermediate p_T

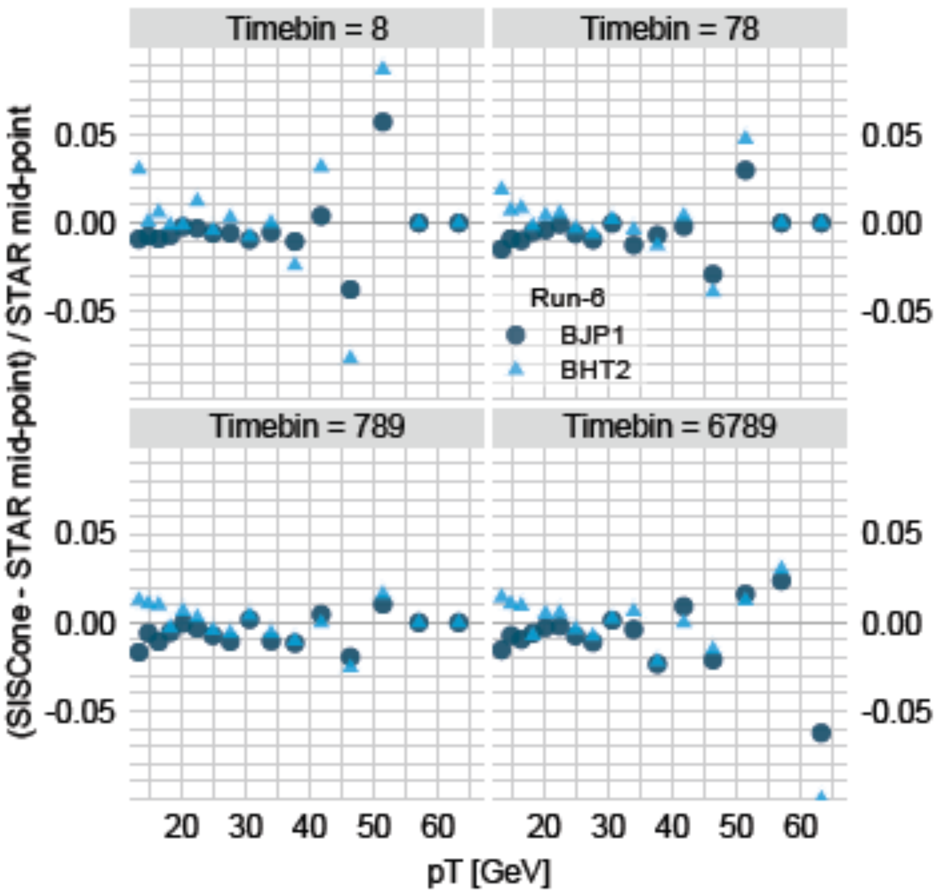
Jet-hadron correlations:

- Au-Au data indicate "lost" high p_T fragments, re-emerge as numerous low p_T particles at large cone angles

p-p - SISCone vs Midpoint cone



Raw distributions

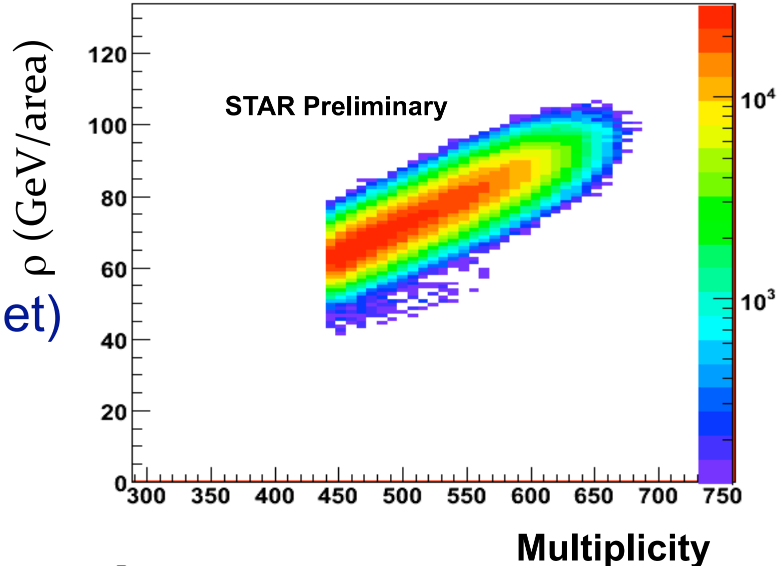


For R=0.7 agreement good to few%

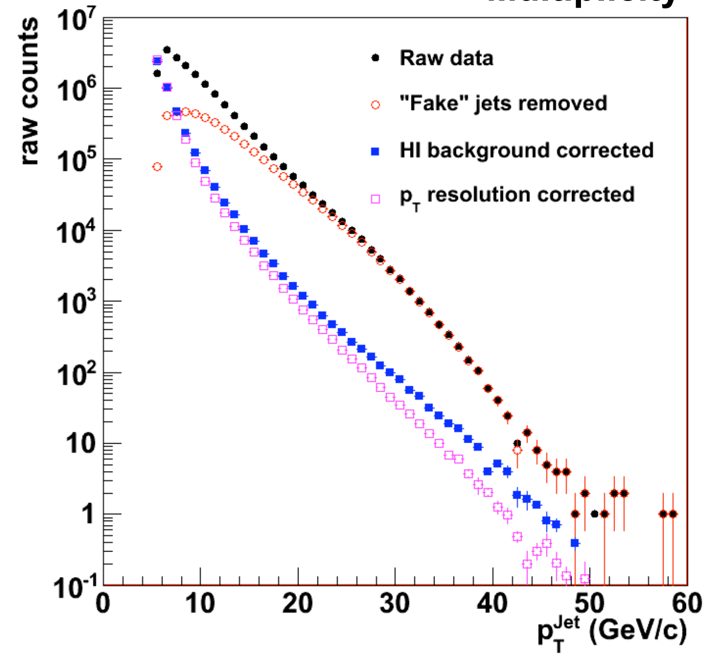
The challenge: Heavy-ion background

p_T (Jet Measured) ~ p_T(Jet) + HI BG(A) ± Fluct(A)

BG energy density per unit area ρ/A:
(determined by FastJet algorithm)
ρ A ~ 45 GeV for R_C=0.4 (S/B ~0.5 for 20 GeV jet)



Background fluctuations:
A priori unknown background fluctuation distribution Fluct(A).
Gaus approx: σ ~ 6-7 GeV for R_C=0.4

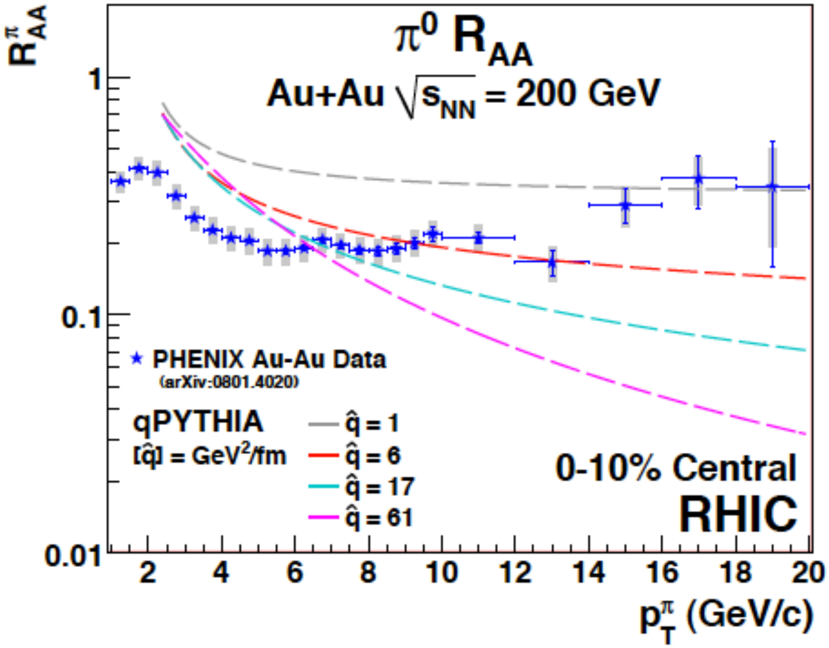


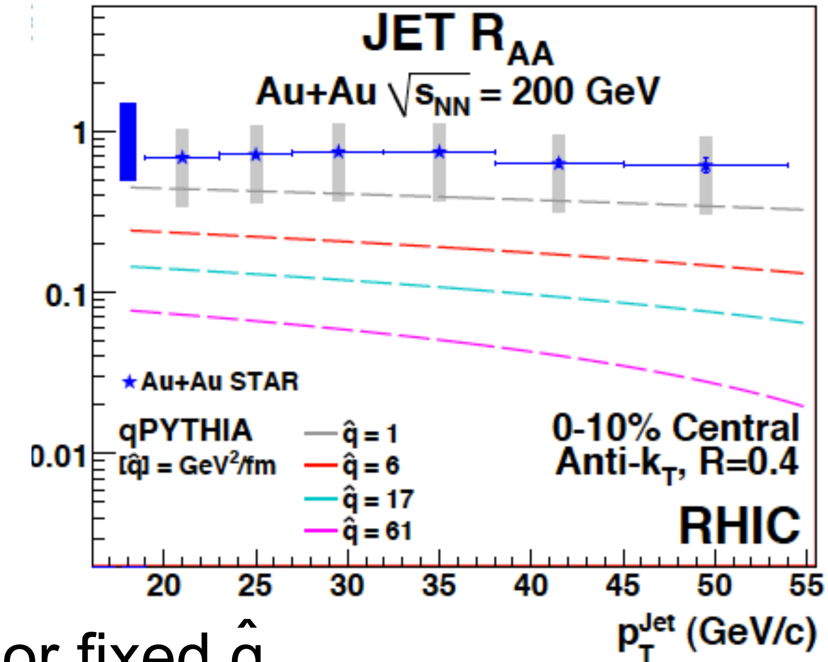
Jet energy resolution:
~15-20% also causes shift in measured energy

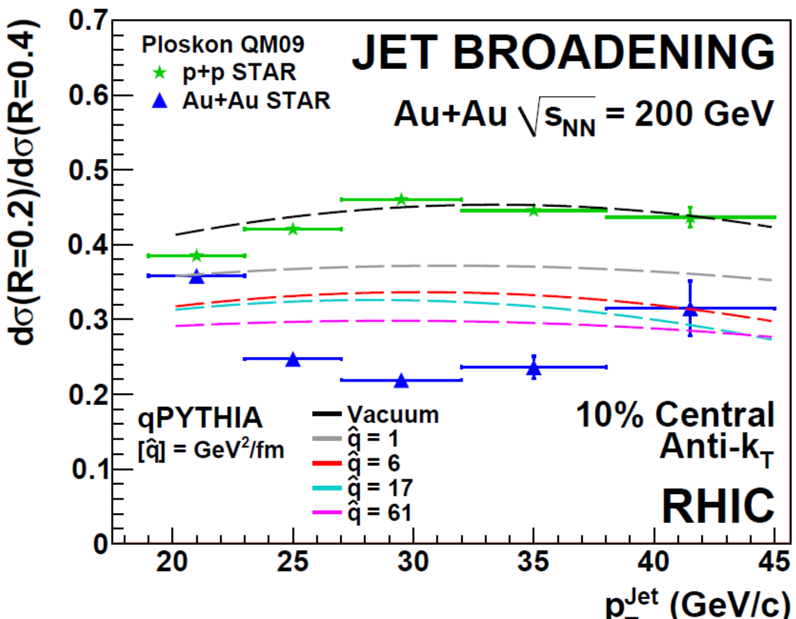
Smearing + steeply falling spectrum cause "bulge" in measured spectrum → Need to unfold

Correct BG model critical → main systematic uncertainty in HI

Confronting qPYTHIA with RHIC data







For fixed $\hat{q}$

- Single particle spectra OK
- Jet R_{AA} too low
- R(0.2)/R(0.4) OK for p-p
- R(0.2)/R(0.4) too high Au-Au

Jet quenching too extreme
broadening too little from 0.2 → 0.4