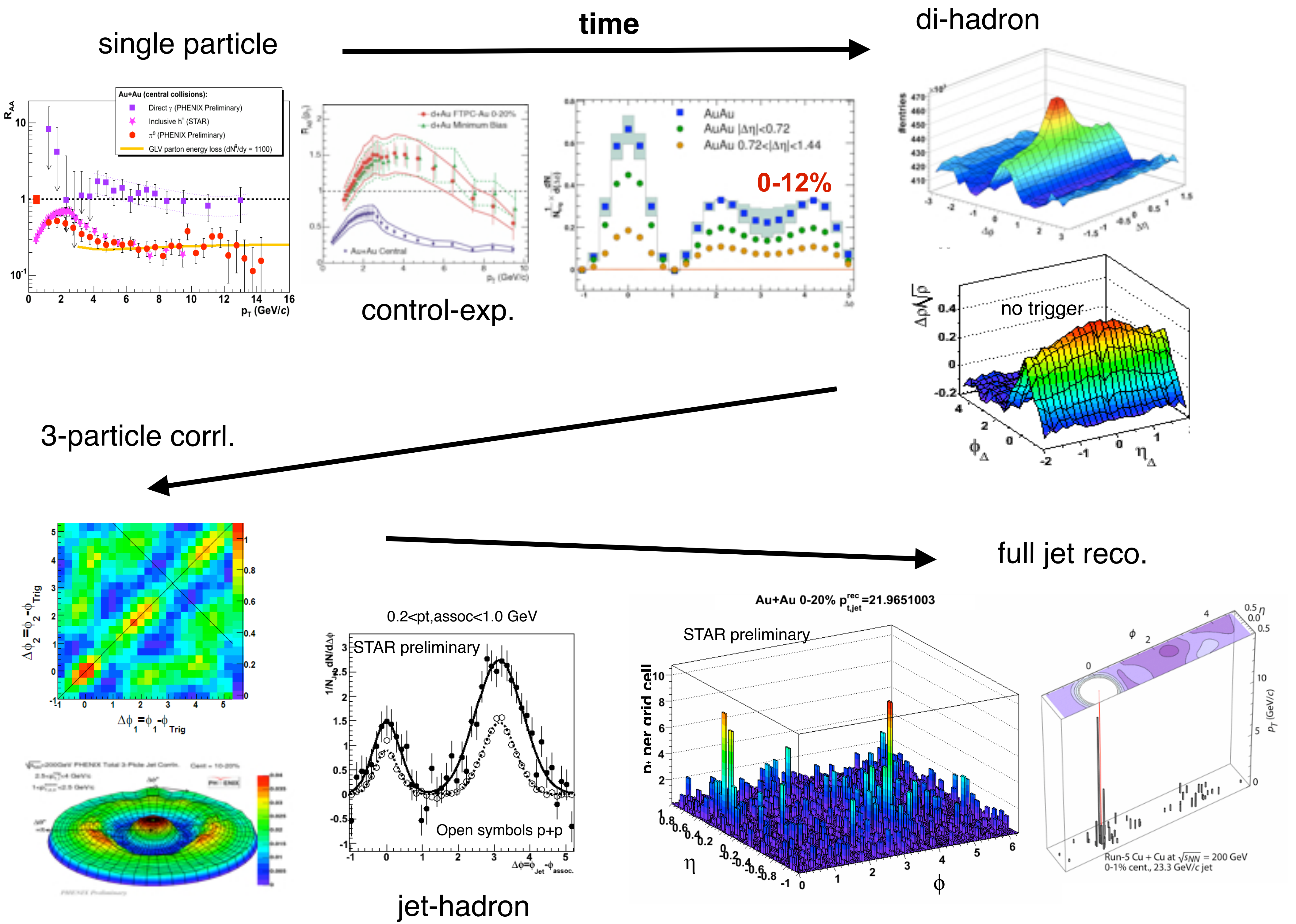
Full Jet-Reconstruction in Heavy-Ion Collisions at RHIC

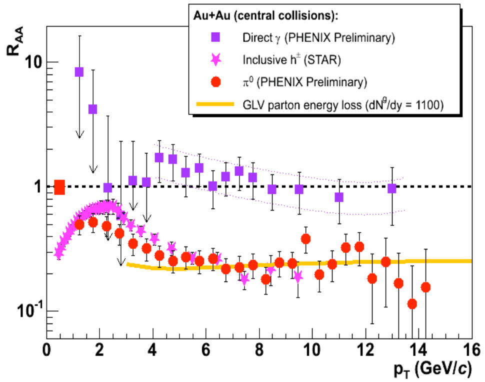
And is there a consistent jet-quenching picture at RHIC?

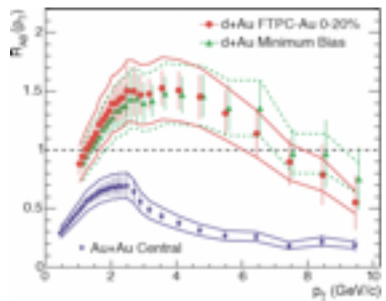
Jörn Putschke

(Yale University)

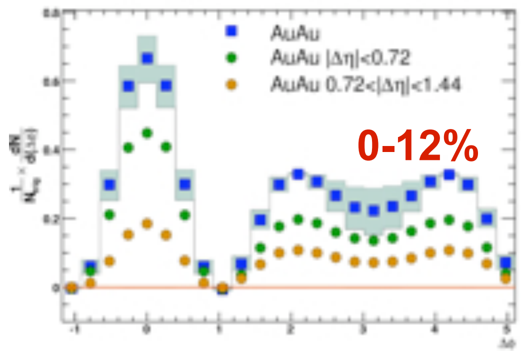

single particle
time
di-hadron
Au+Au (central collisions):
Direct γ (PHENIX Preliminary)
Inclusive h± (STAR)
π0 (PHENIX Preliminary)
GLV parton energy loss (dNg/dy = 1100)
R_AA
p_T (GeV/c)
d+Au FTPC-Au 0-20%
d+Au Minimum Bias
Au+Au Central
control-exp.
AuAu
AuAu |Δη|<0.72
AuAu 0.72<|Δη|<1.44
0-12%
no trigger
Δρ/√ρ
φΔ
ηΔ
3-particle corrl.
full jet reco.
Δφ2=φ2-φTrig
Δφ1=φ1-φTrig
0.2<pt,assoc<1.0 GeV
STAR preliminary
1/N_Jet dN/dΔφ
Open symbols p+p
Δφ=φJet-φassoc.
jet-hadron
Au+Au 0-20% p_t,jet^rec=21.9651003
STAR preliminary
η
φ
p_T (GeV/c)
Run-5 Cu + Cu at √sNN = 200 GeV
0-1% cent., 23.3 GeV/c jet

single particle

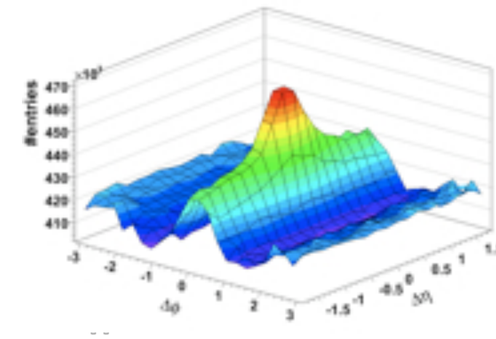


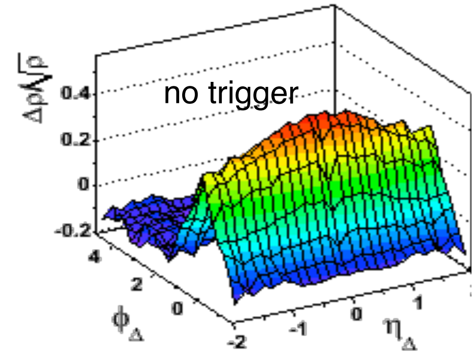


control-exp.



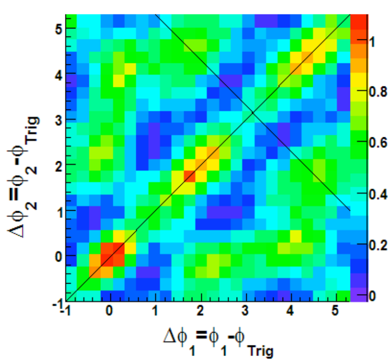
di-hadron

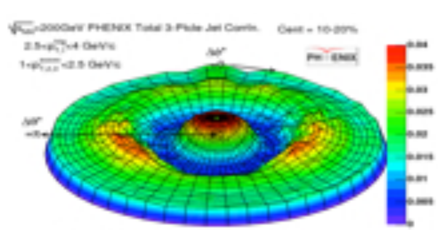


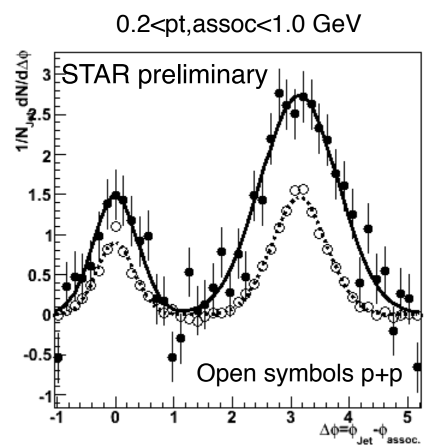


3-particle corrl.

Understanding/consistency ?

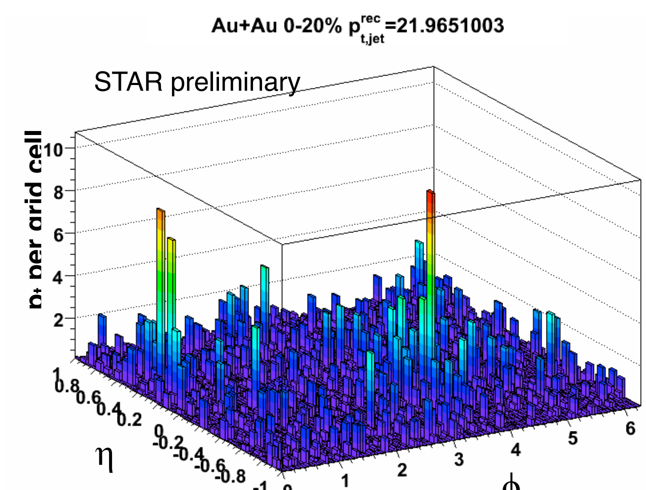


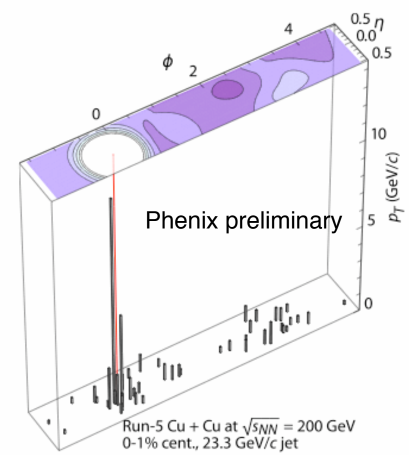




jet-hadron

full jet reco.





Outline

Short intro: Jets and Jet-Finding Algorithms

Jets as a calibrated probe: p+p and d+Au reference

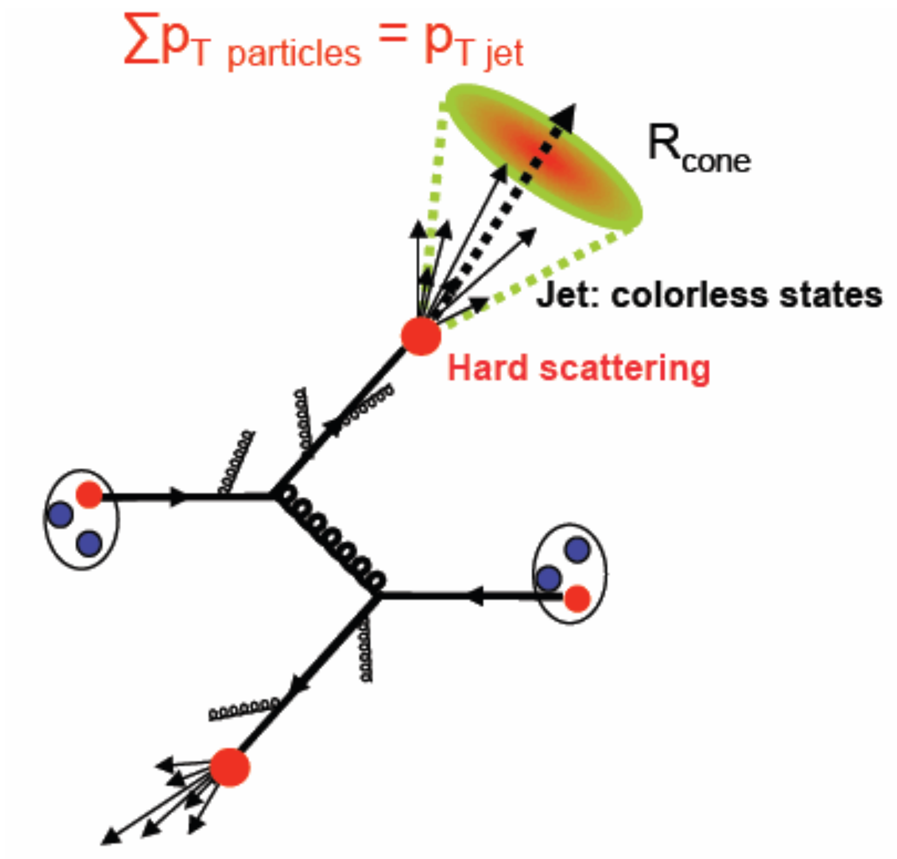
***Our new tool:* Jets in heavy-ion collisions (RHIC)**

- Background in heavy-ion collisions: fake-jets and fluctuations
- Inclusive jet spectrum and jet R_{AA}
- Jet energy profile (R=0.2/0.4)
- Di-Jet coincidence measurements

Consistency? Connection to single/di-hadron results!?

Summary

Jets connect theory and experiment



Jets are the experimental signatures of quarks and gluons. They reflect the kinematics and "topology" of partons.

Goal: re-associate (measurable) hadrons to accurately reconstruct partonic kinematics

- pQCD calculates partons
- experiments measure fragments of partons: hadrons

Tool: *Jet-finding algorithms:*
Apply same algorithm to data and theoretical calculations

pQCD factorization/jet spectrum:

$$E\frac{d^3\sigma}{dp^3} \propto f_{a/A}(x_a, Q^2) \otimes f_{b/B}(x_b, Q^2) \otimes \frac{d\hat{\sigma}^{ab\to cd}}{dt}$$

PDF **Partonic x-section**

Jet definition ⇔ Jet algorithm

The construction of a jet is *unavoidably ambiguous*.
On at least two fronts:

- which particles get put together into a common jet?
- How do you combine their momenta?

Jet definition ⇔ Jet algorithm

The construction of a jet is *unavoidably ambiguous*
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Jet Definition

jet algorithm

$$\{p_i\} \longrightarrow \{j_k\}$$

particles
4-momenta,
calorimeter towers

jets

+ parameters (at least the cone radius/ resolution parameter R)

+ recombination scheme

Jet definition ⇔ Jet algorithm

The construction of a jet is *unavoidably ambiguous*.
On at least two fronts:

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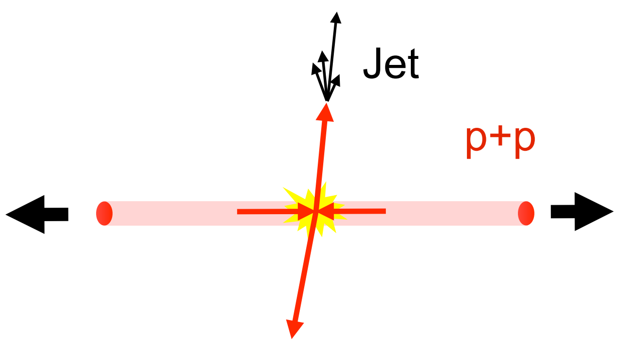
Modern Jet Finder Algorithms	
Sequential Recombination	**Cone**
• bottom-up • successively undoes QCD branching	• top-down • centred around idea of an 'invariant', directed energy flow
▸ k_T algorithm ▸ anti-k_T algorithm ▸ Cambidge-Aachen algorithm	▸ CDF JetClu ▸ CDF MidPoint ▸ D0 (run II) Cone ▸ Gaussian Filter ▸ CMS Iterative Cone ▸ ATLAS Cone ▸ PyCell/CellJet ▸ GetJet ▸ SISCone

Before we can utilize hard probes/jets (and their modifications/tomography) to probe the medium in heavy-ion collisions we first have to establish that:

1) <u>The probe is calibrated:</u>

Comparison of pQCD calculations with p+p measurements



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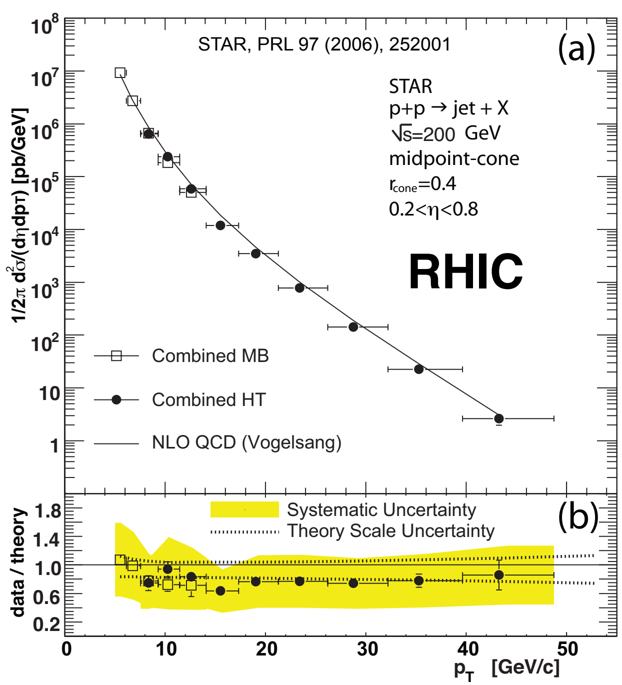

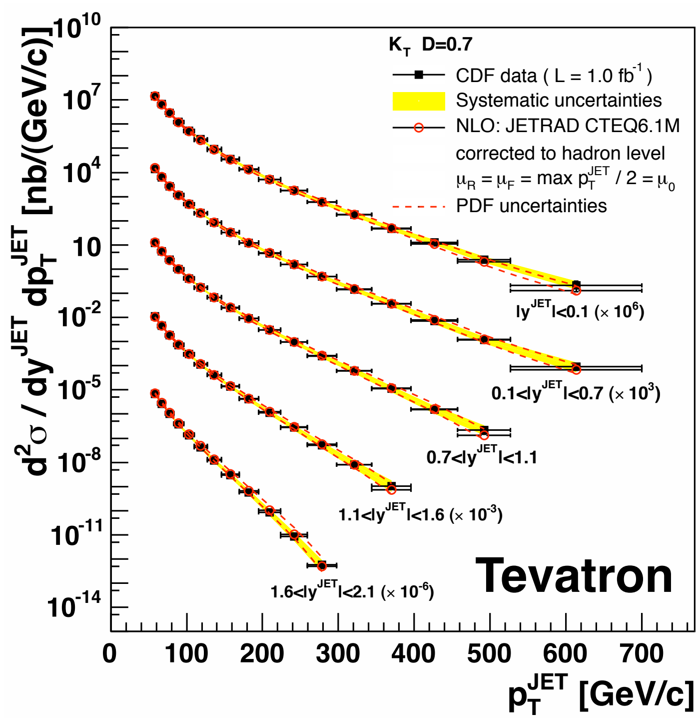

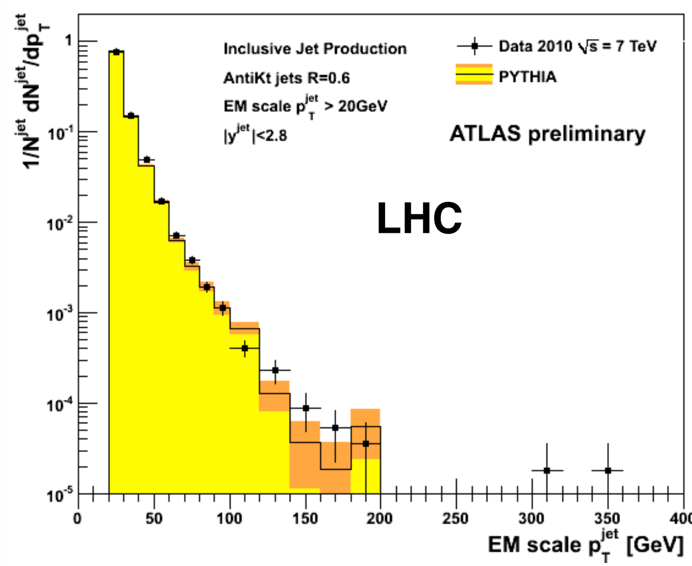

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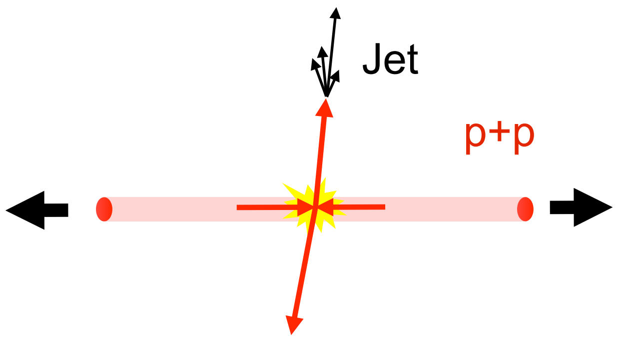
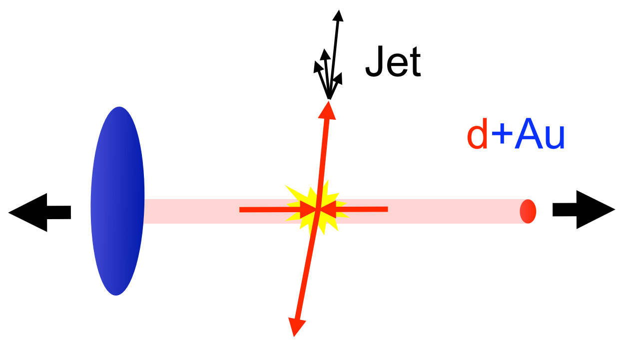


✓

2) Control experiment:

Measure initial state/Cold Nuclear Matter (CNM) effects;

Probe the “cold medium” via d+Au collisions (compare to p+p)



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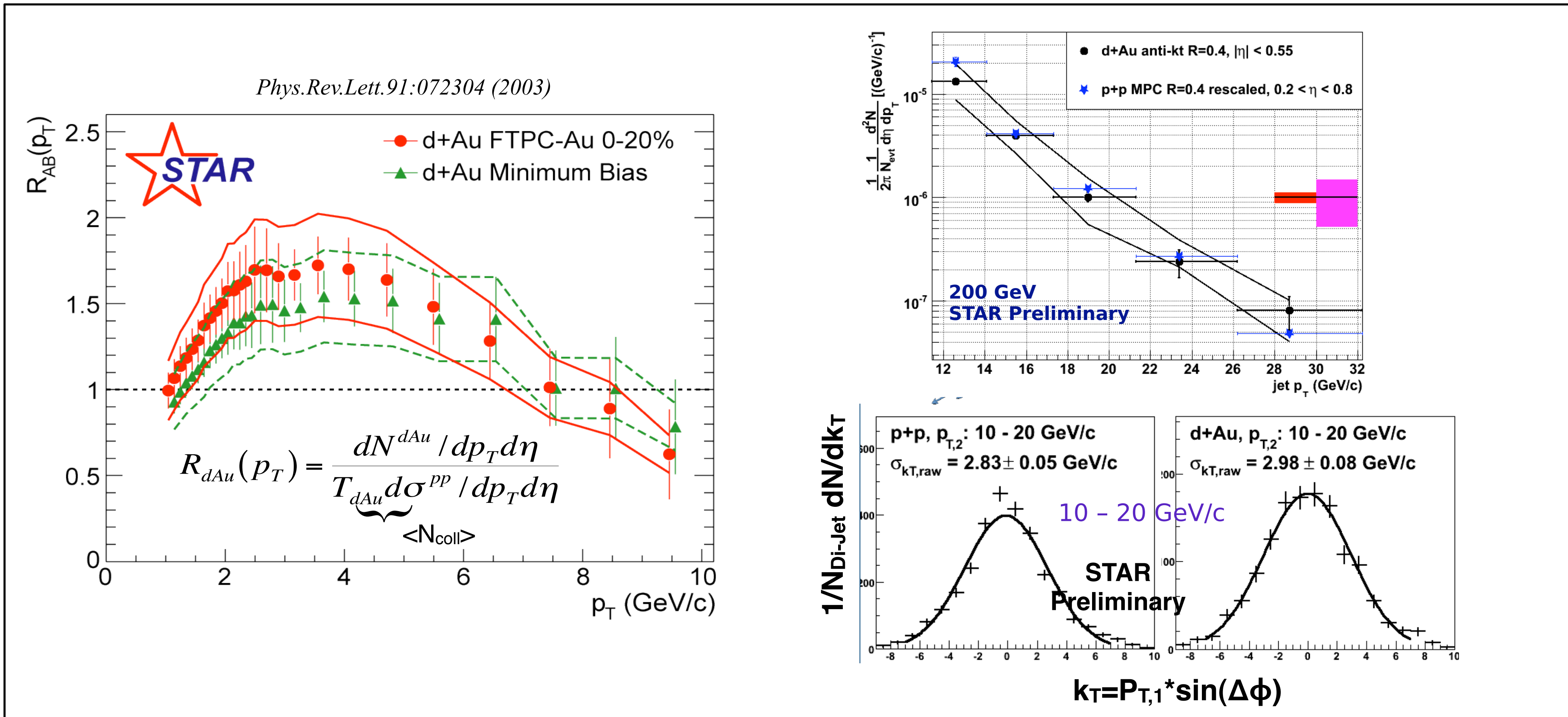

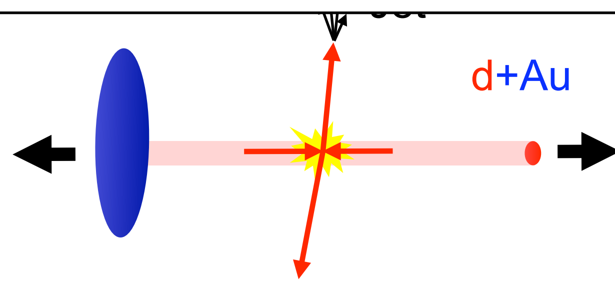

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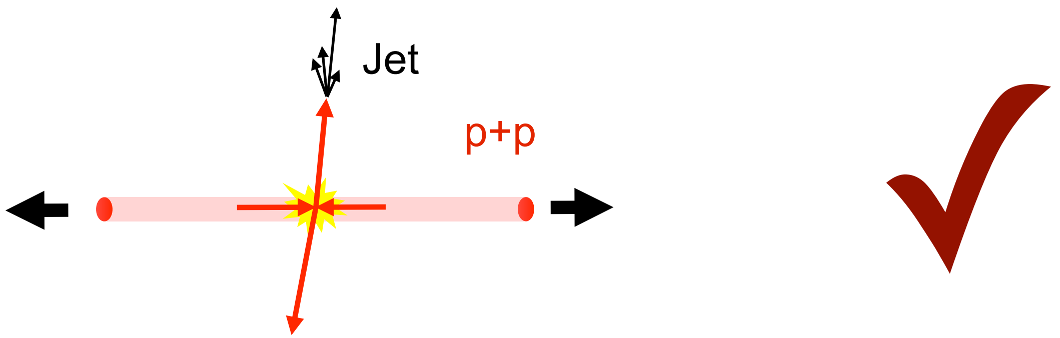

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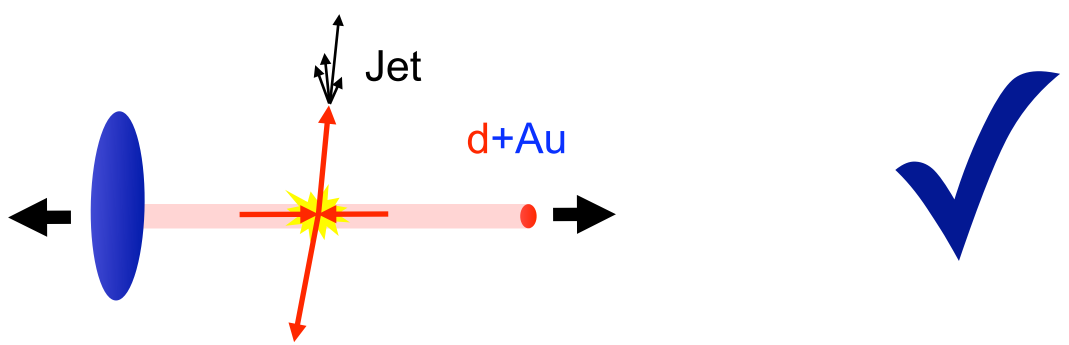
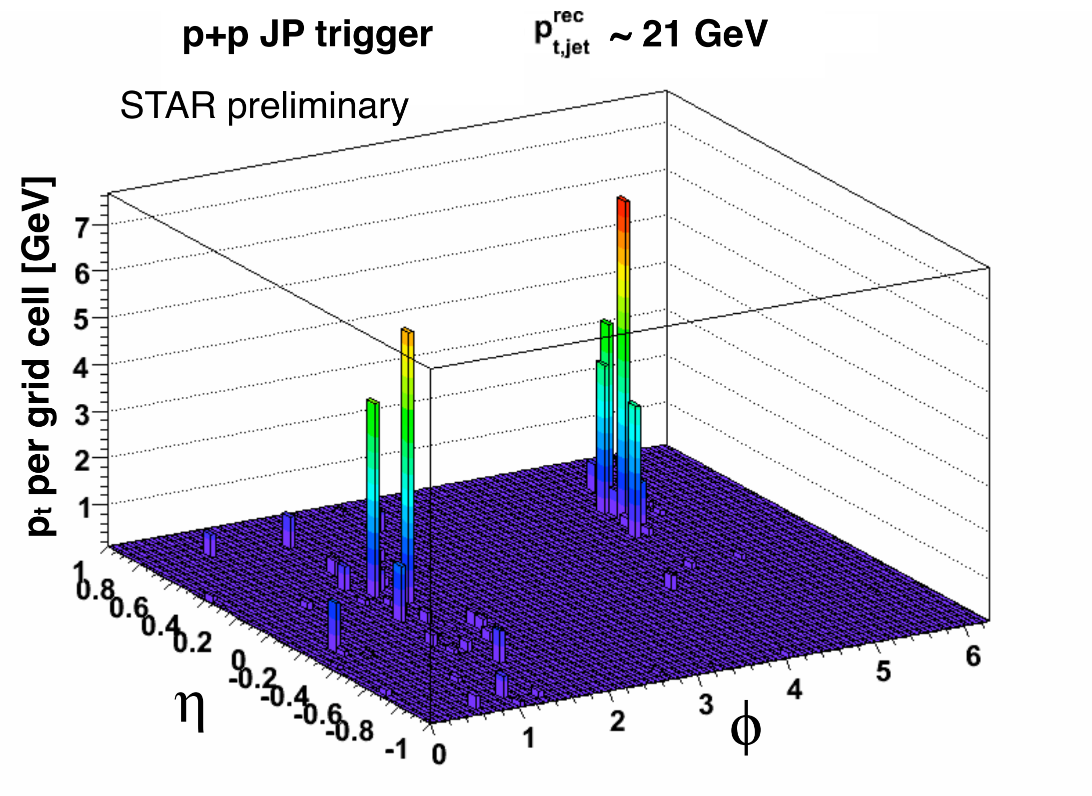


Full-Jet reconstruction in HI collisions



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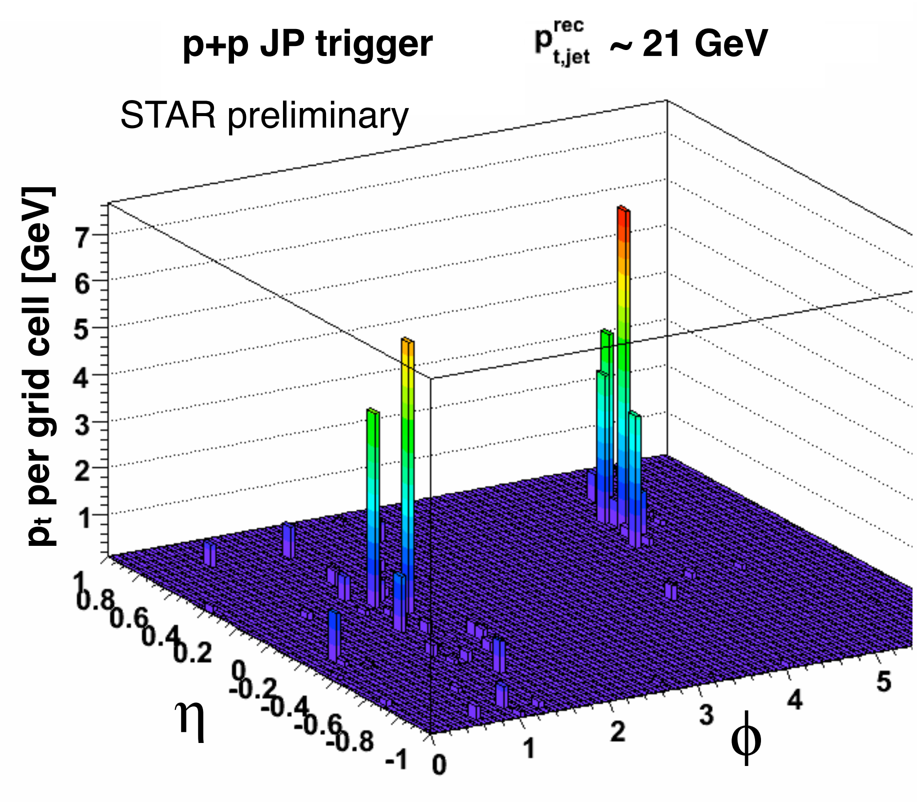

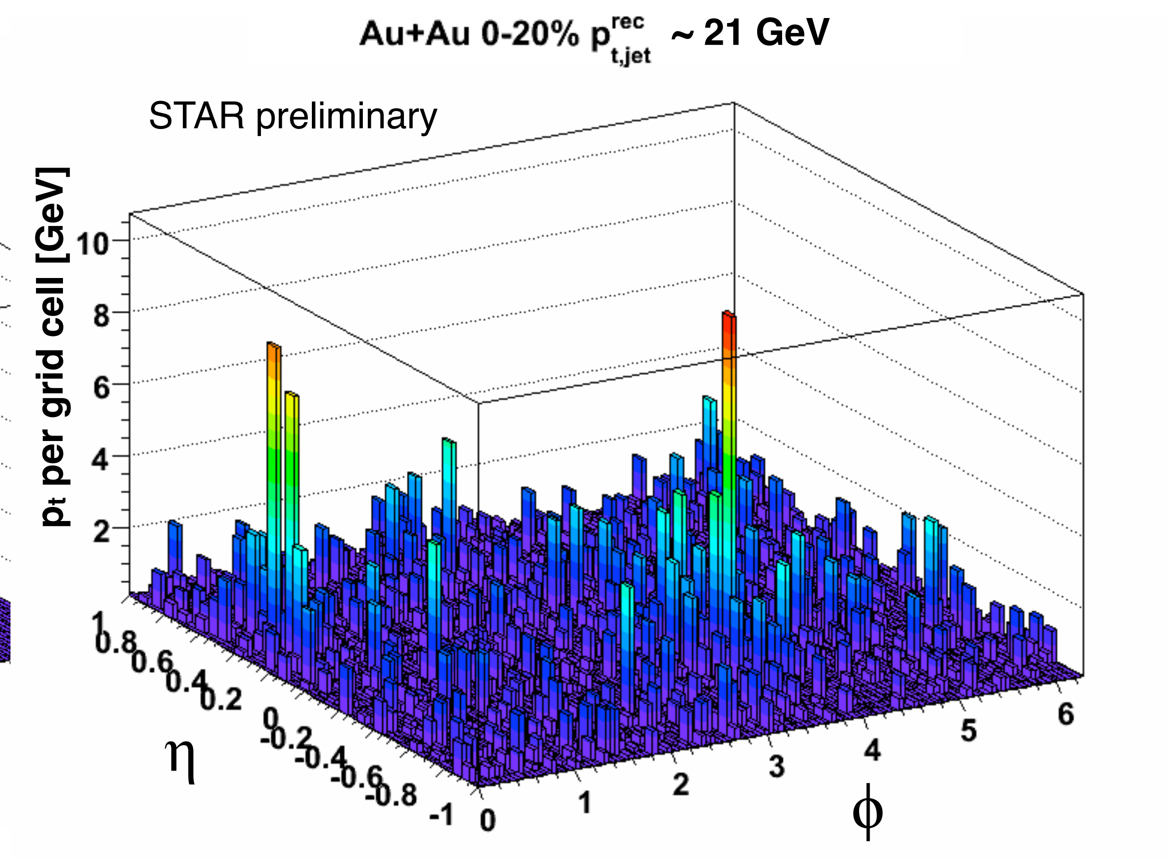

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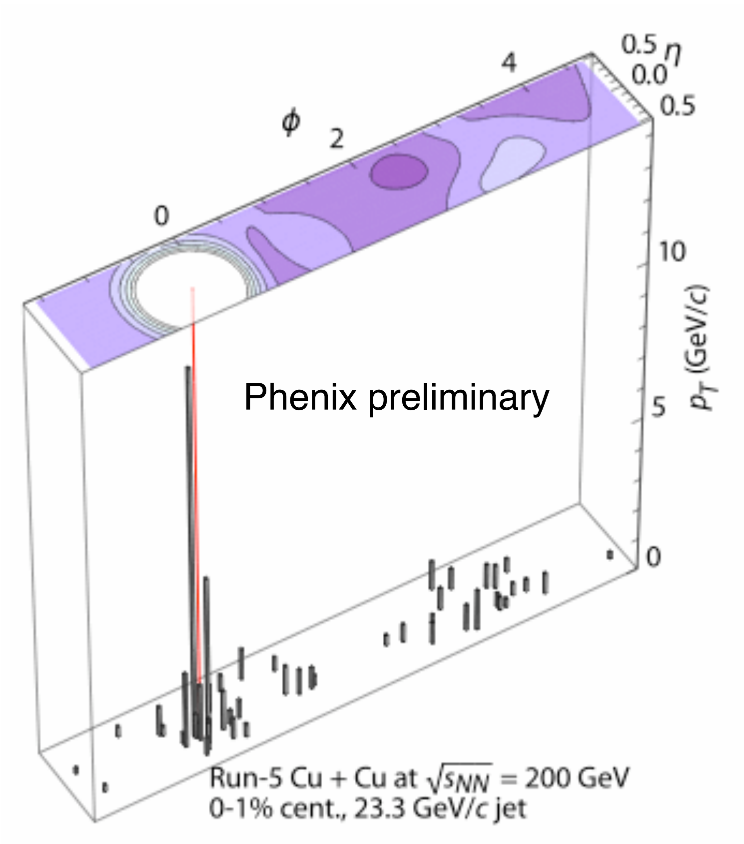
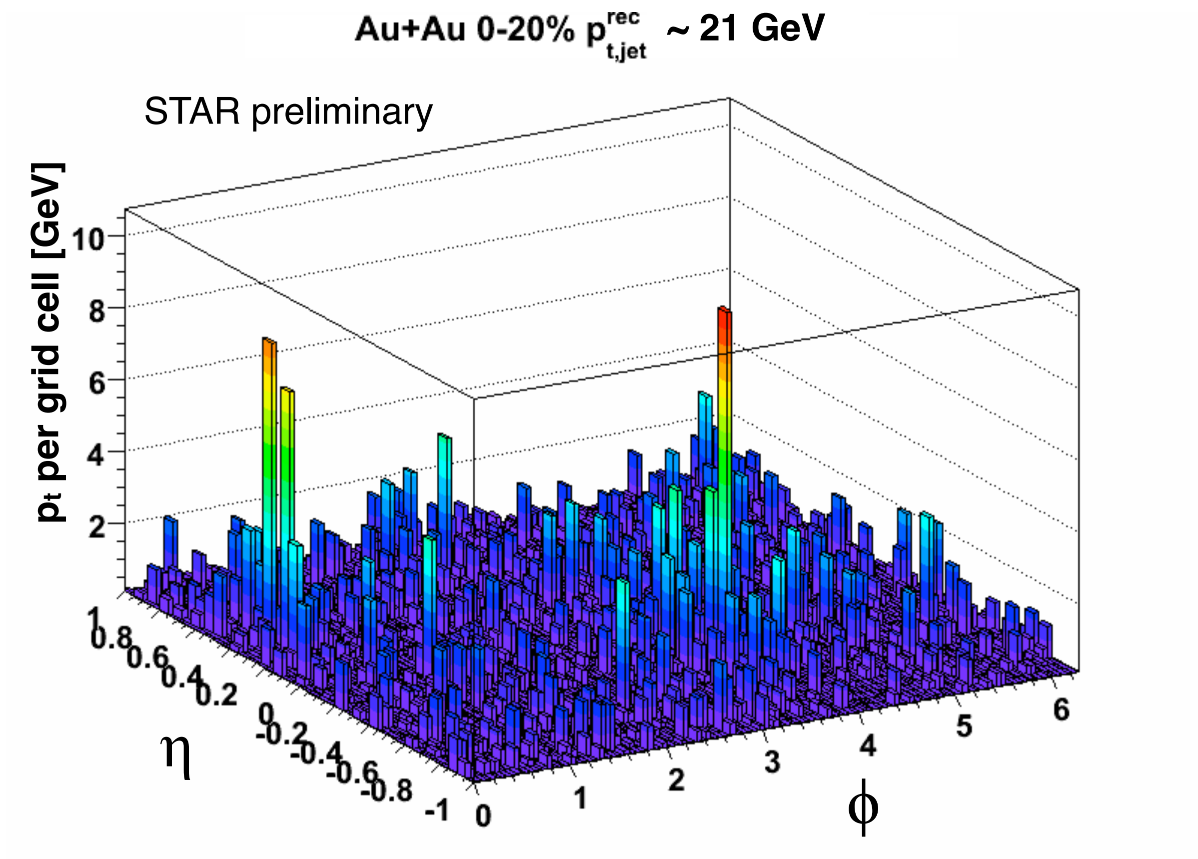
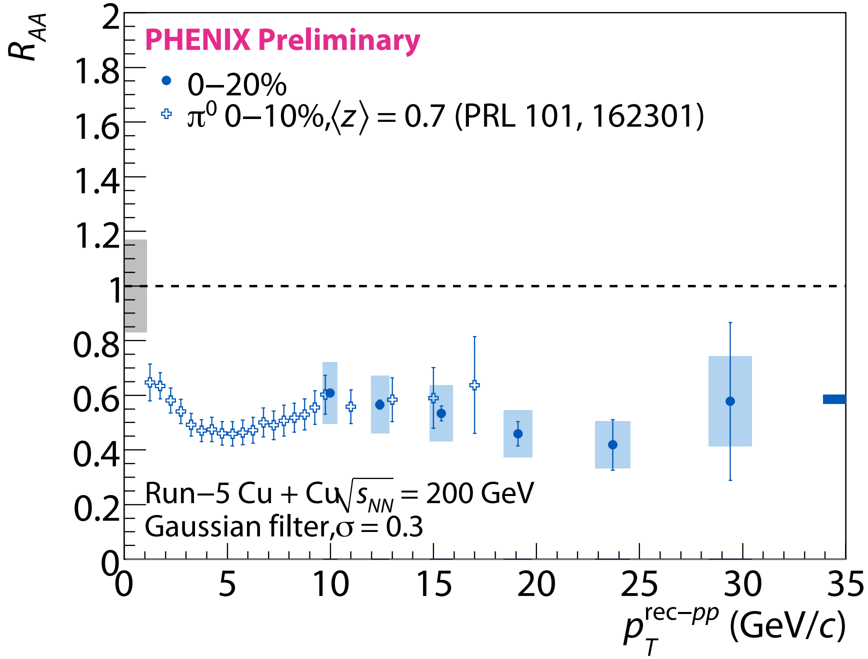




Full jet reconstruction in HI collisions is a challenge due to the underlying background !

A word of caution (especially in HI): Jet Definition ⇔ Jet Algorithm

Y. Lai QM2009



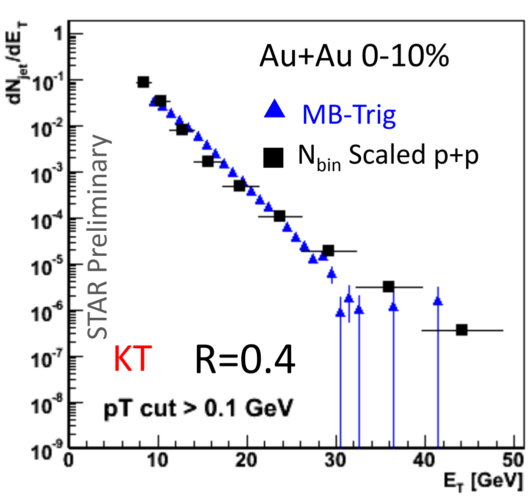
"A jet is what you ask for!"

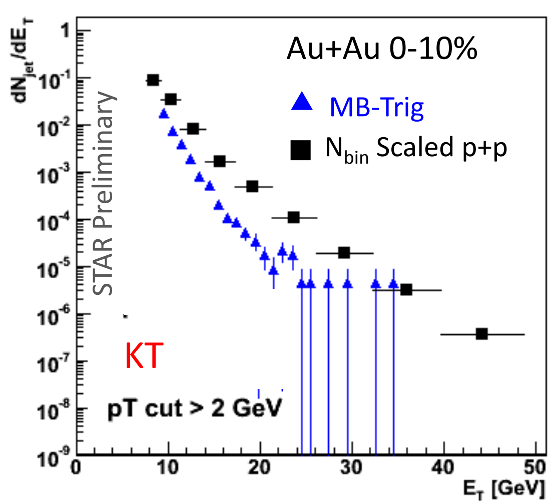
Jet-finder based on (unmodified) jet-shapes/jet core ⇒ veto against modified/quenched jets !?

p_T cut to minimize background
⇒ bias towards non-interacting jets !?

"Anti-quenching" biases are "everywhere"!

S. Salur HP08





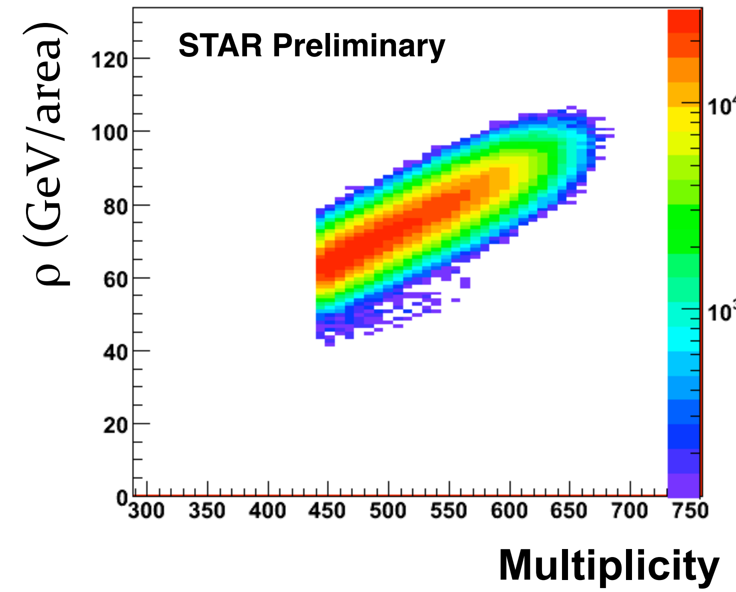
There are no shortcuts!
We have to deal with the full complexity of the heavy-ion background!

Good news:
The tools are available and our understanding is improving!

The challenge: Heavy-ion Background

A jet in HI collisions schematically:

p_T (Jet Measured) = p_T (Jet) + HI Bkg. ± F(A)

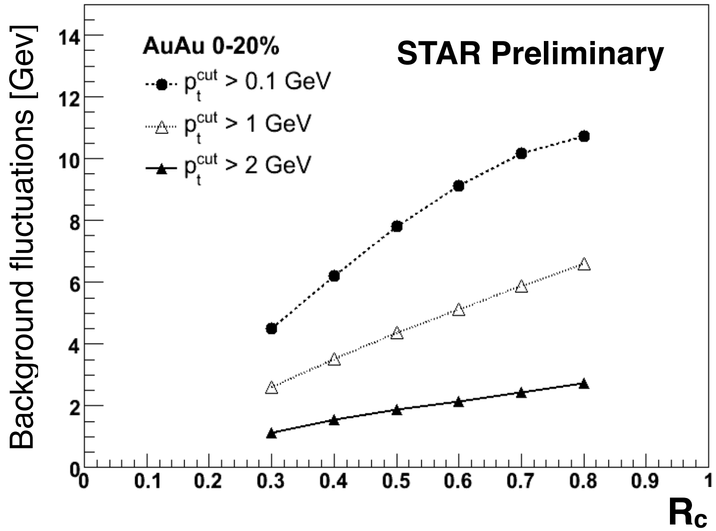


Three main components:

1. ***HI background***: for example determine energy density per unit area ρ (event-by-event) with A the jet area (determined by FastJet algorithm) ρ A ~ 45 GeV for R_C=0.4 (S/B ~0.5 for 20 GeV jet)

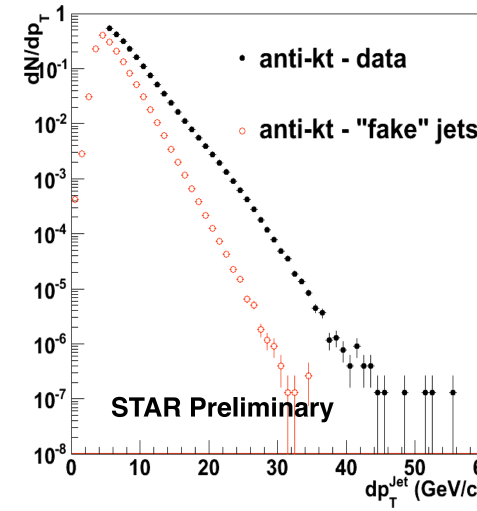
2. ***"Fake jets"*** **= signal in excess (due to jet clustering) of background model from random association of uncorrelated soft particles (i.e. not due to hard scattering)**

3. ***Background fluctuations*****:**
A priori unknown background fluctuation distribution F(A). In a gaussian (random area) approximation: ~ 6-7 GeV for R_C=0.4

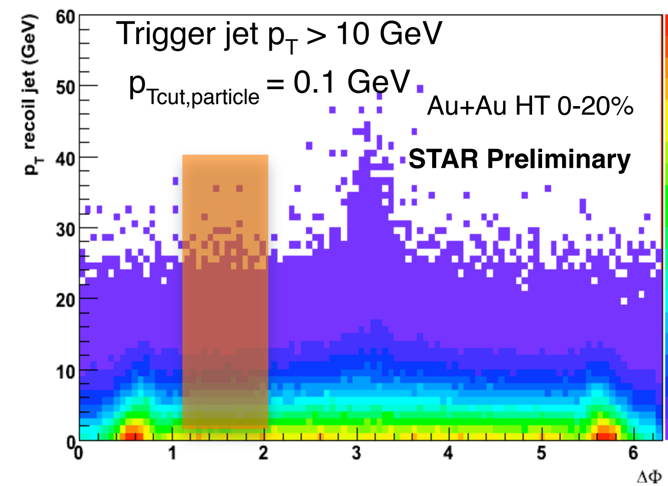


"Fake-Jet" contribution

"Fake" jets: signal in excess of background model from random association of uncorrelated soft particles (i.e. not due to hard scattering)

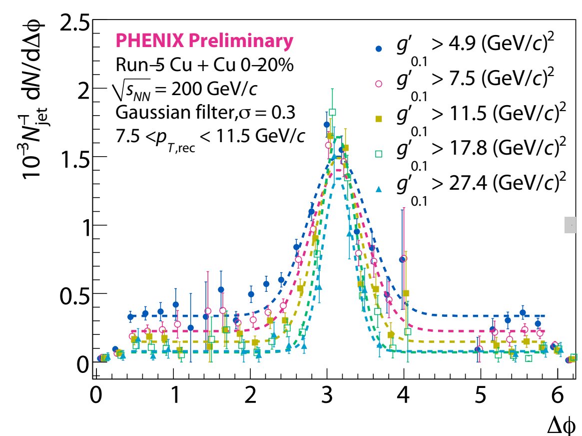


Inclusive jet spectrum (STAR):
Spectrum of "jets" after randomizing HI event in ϕ and removing leading jet particle



Di-Jet / Fragmentation function (STAR):
Background di-jet rate
= "Fake" + Additional Hard Scattering
Estimated using "jet" spectrum at 90 deg.

PHENIX (gaussian filter):
Gaussian fake-jet rejection; use overall shape of jets for discrimination



Caveat: If quenching distorts jet-shape substantially, danger of vetoing quenched jets!

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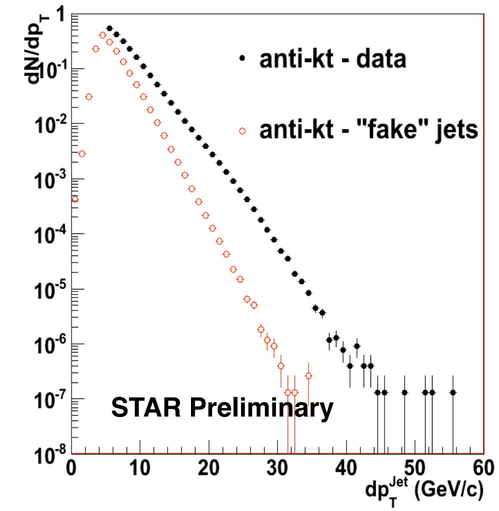

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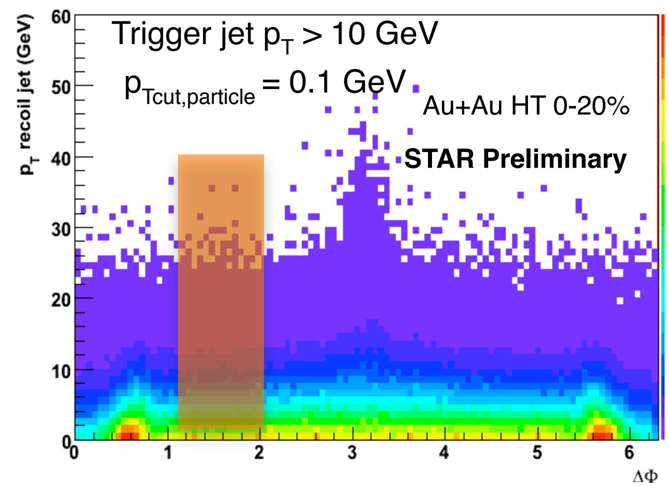

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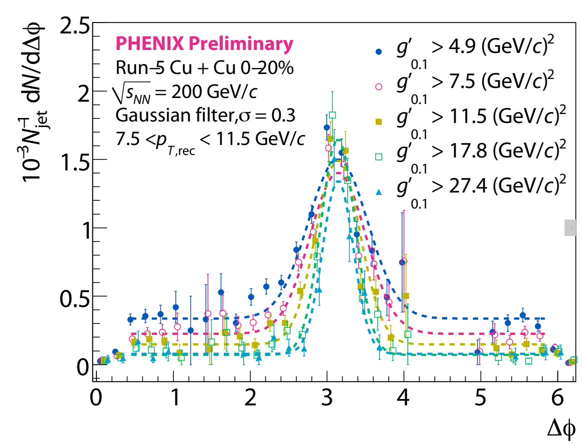
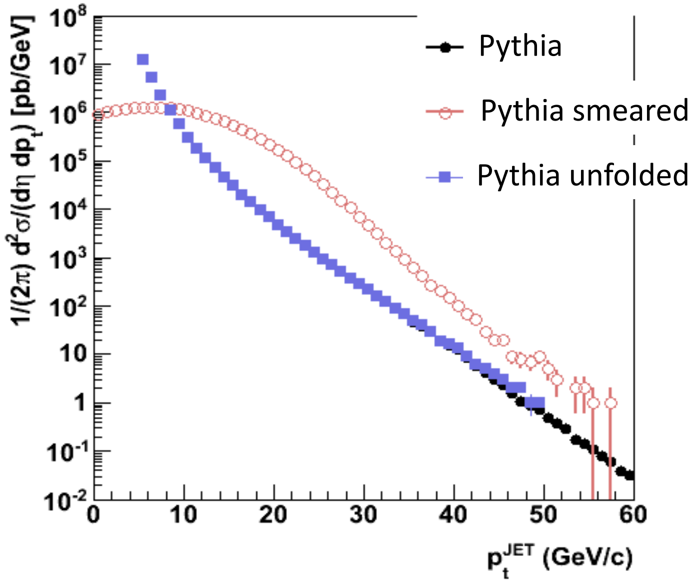
Conceptual difference between STAR and PHENIX! (Quantitative difference !?)



Background fluctuations



Jet spectrum in Au+Au (schematically):

$$\frac{d\sigma_{AA}}{dp_t} = \frac{d\sigma_{pp}}{dp_t} \otimes F(A, p_t)$$

Effect of background fluctuations F(A,p_t)
⇒ substantial "feed-up" in the jet x-section

"Generalized probe" embedding (*conceptually the same in STAR and PHENIX*)

Systematic extension of random region-to-region fluctuation estimate. Embed probes (single particles, pythia jets, p+p jets ...) into Au+Au/Cu+Cu events and measure the fluctuations spectrum (used for unfolding). Takes the effect of clustering/jet-finding algorithms into account; conceptually higher bound for fluctuations
(diluted due to random embedding; has to be estimated; and what about v_2!?)

Statistical description (strictly lower bound, in context of estimating systematics)

Conceptually F(A,p_t) for stat. independent thermal (exp.) particle emission :

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

More details/first data comparison: E. Bruna (STAR), AGS Users Meeting 2010

Background fluctuations

Jet spectrum in Au+Au (schematically):

"Fake's" and background fluctuation corrections are still work in progress!

One has to discuss the *conceptual differences*, biases (concerning "fakes") and their *quantitative effects*!

<u>But</u>, one also has to discuss how to *estimate "conservative" systematic errors* associated to these corrections!

(diluted due to random embedding; has to be estimated; and what about v_2!?)

Statistical description (strictly lower bound, in context of estimating systematics)

<u>Conceptually $F(A,p_t)$ for stat. independent thermal (exp.) particle emission :</u>

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

<u>More details/first data comparison</u>: E. Bruna (STAR), AGS Users Meeting 2010

Example STAR: Spectrum Unfolding

Corrections for smearing of jet p_t due to HI bkg. nonuniformities:

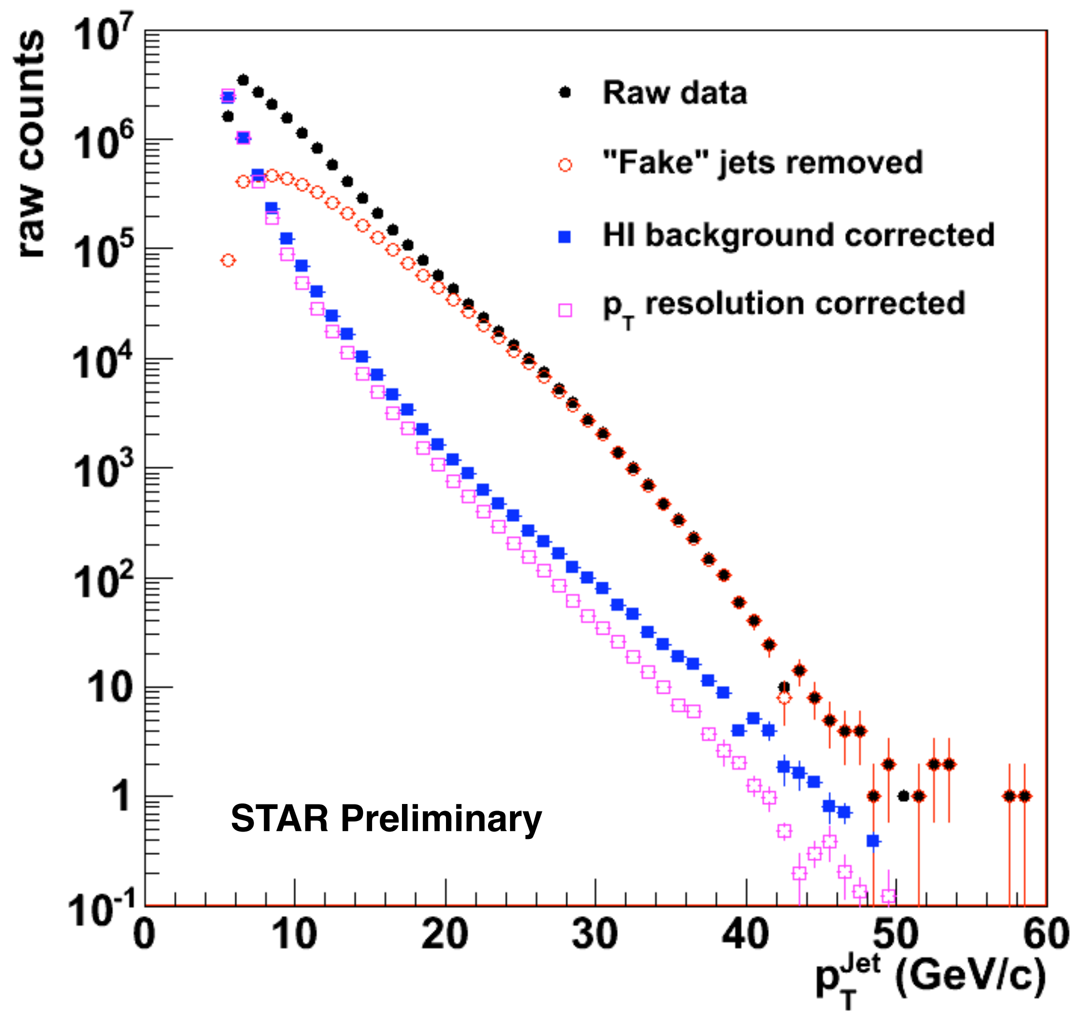
1) raw spectrum

2) removal of "fake"-correlations

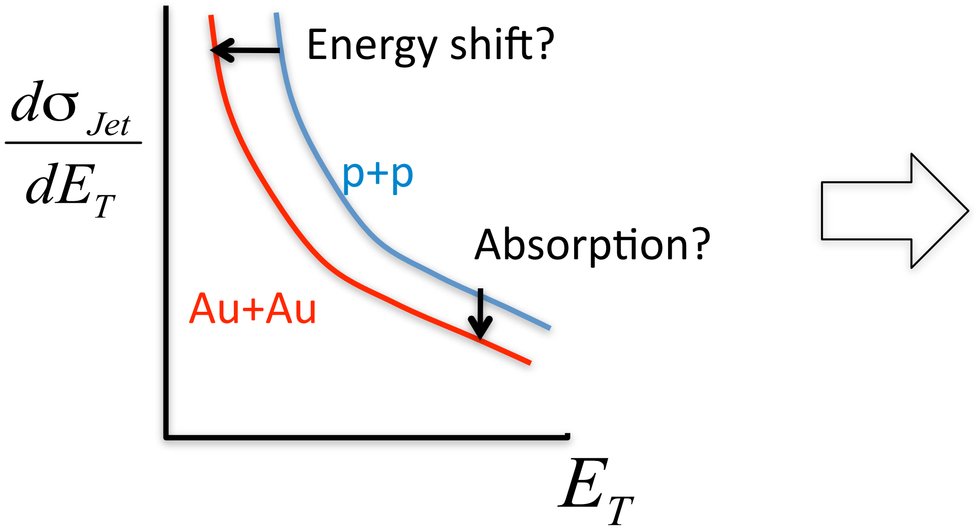
3) unfolding (bayesian) of HI bkg. fluctuations

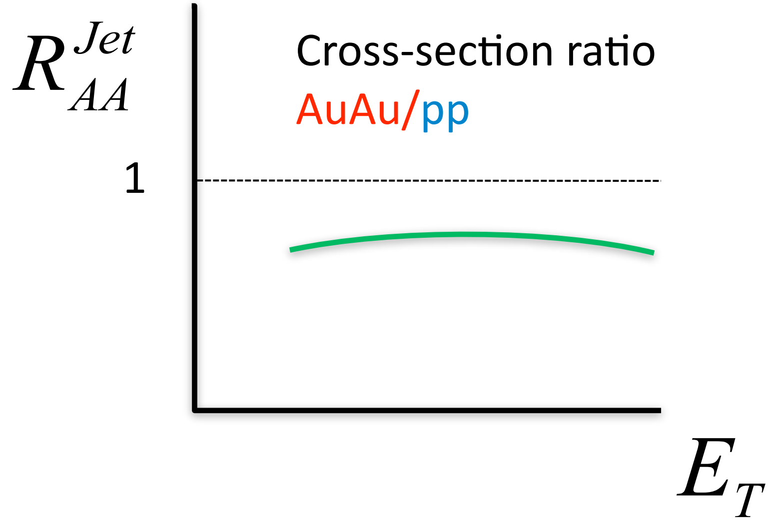
4) correction for p_T resolution

M.Ploskon QM2009



What do we learn from the Au+Au/Cu+Cu jet spectrum ?





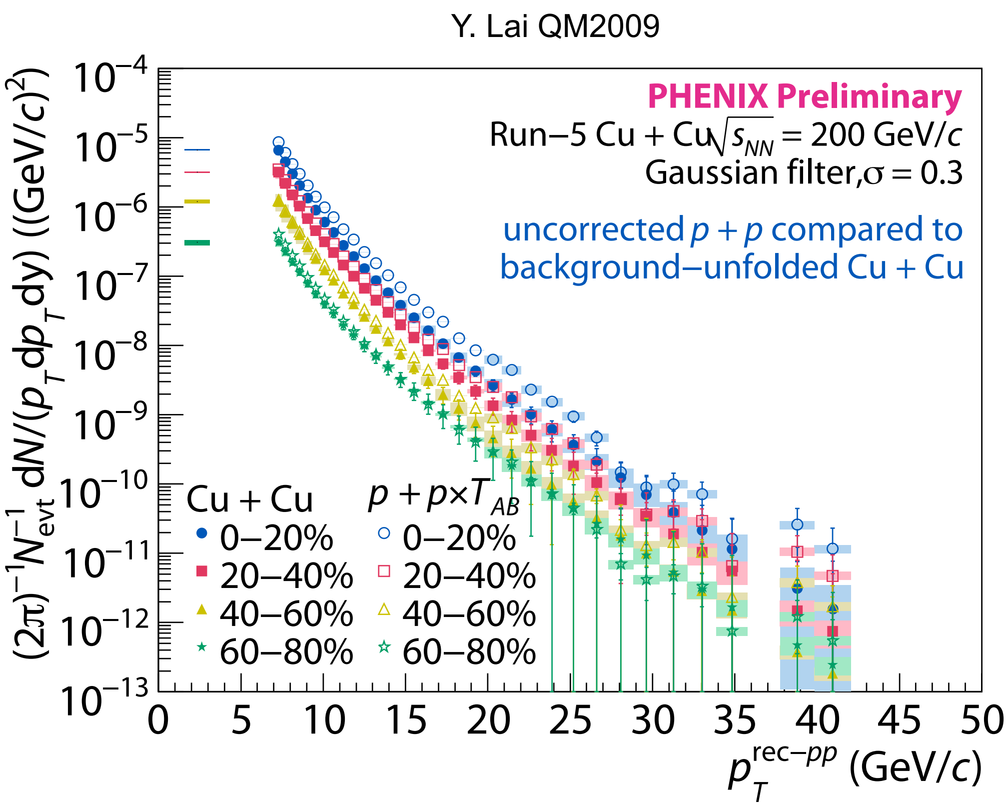
Momentum and energy is conserved even for quenched jets

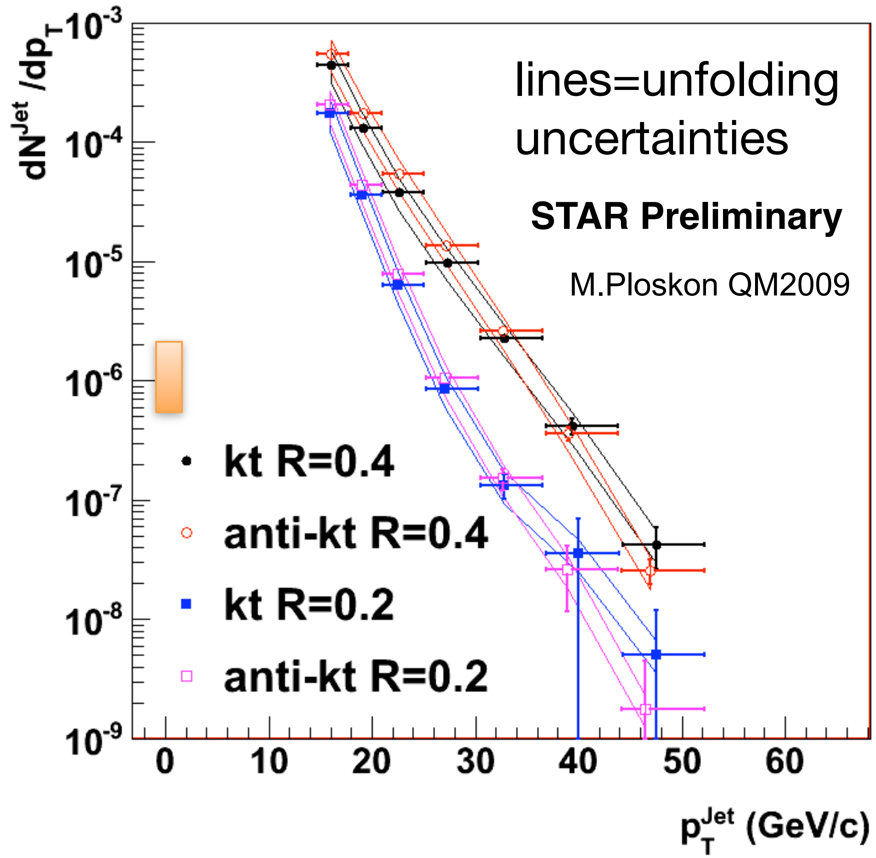
If full jet reconstruction in heavy-ion collisions are unbiased

⇒ Inclusive jet spectrum scales with N_{binary} relative to p+p

Initial state nuclear effects at large x "EMC effect" as measured in d+Au seem to be small

Inclusive jet x-section in heavy-ion collisions





- **Inclusive Jet spectrum measured in central Au+Au and Cu+Cu collisions at RHIC**

- **Extended the kinematical reach to study jet quenching phenomena to jet energies > 40 GeV**

Remark: New high statistics Au+Au runs on tape (Phenix and STAR) will increase significantly the kinematic reach!

Jet R_{AA} in central Au+Au and Cu+Cu

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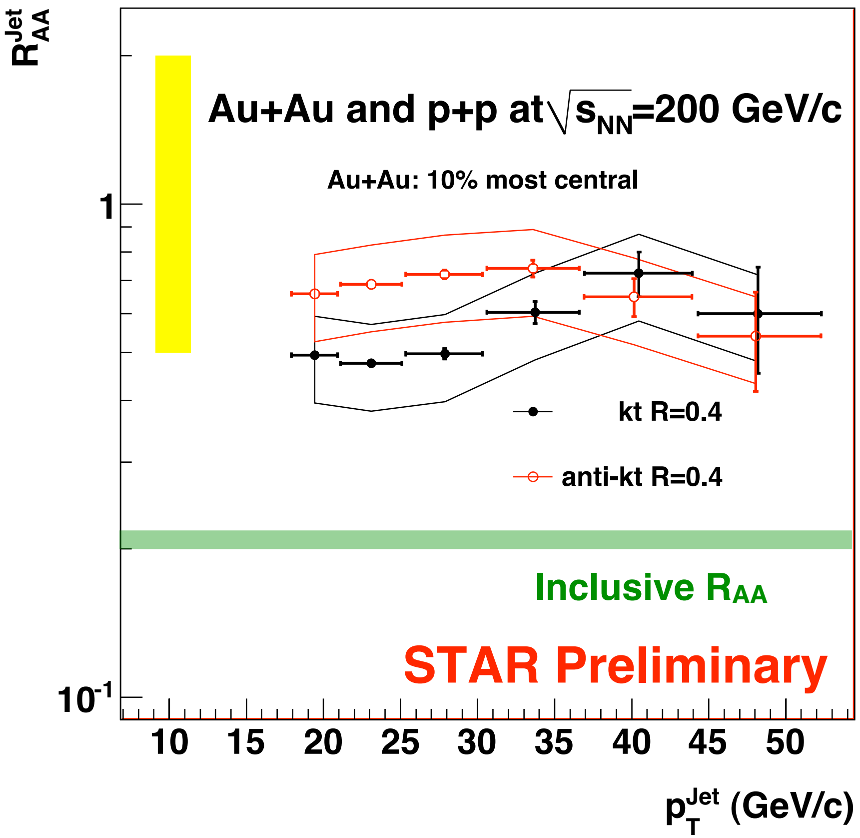
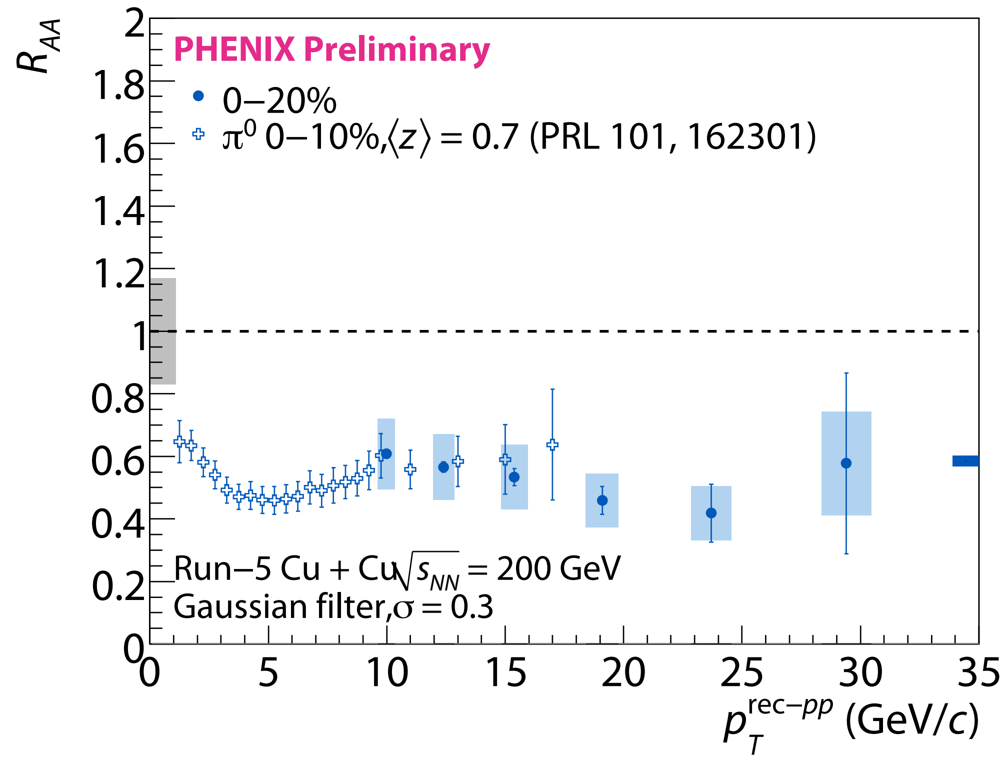


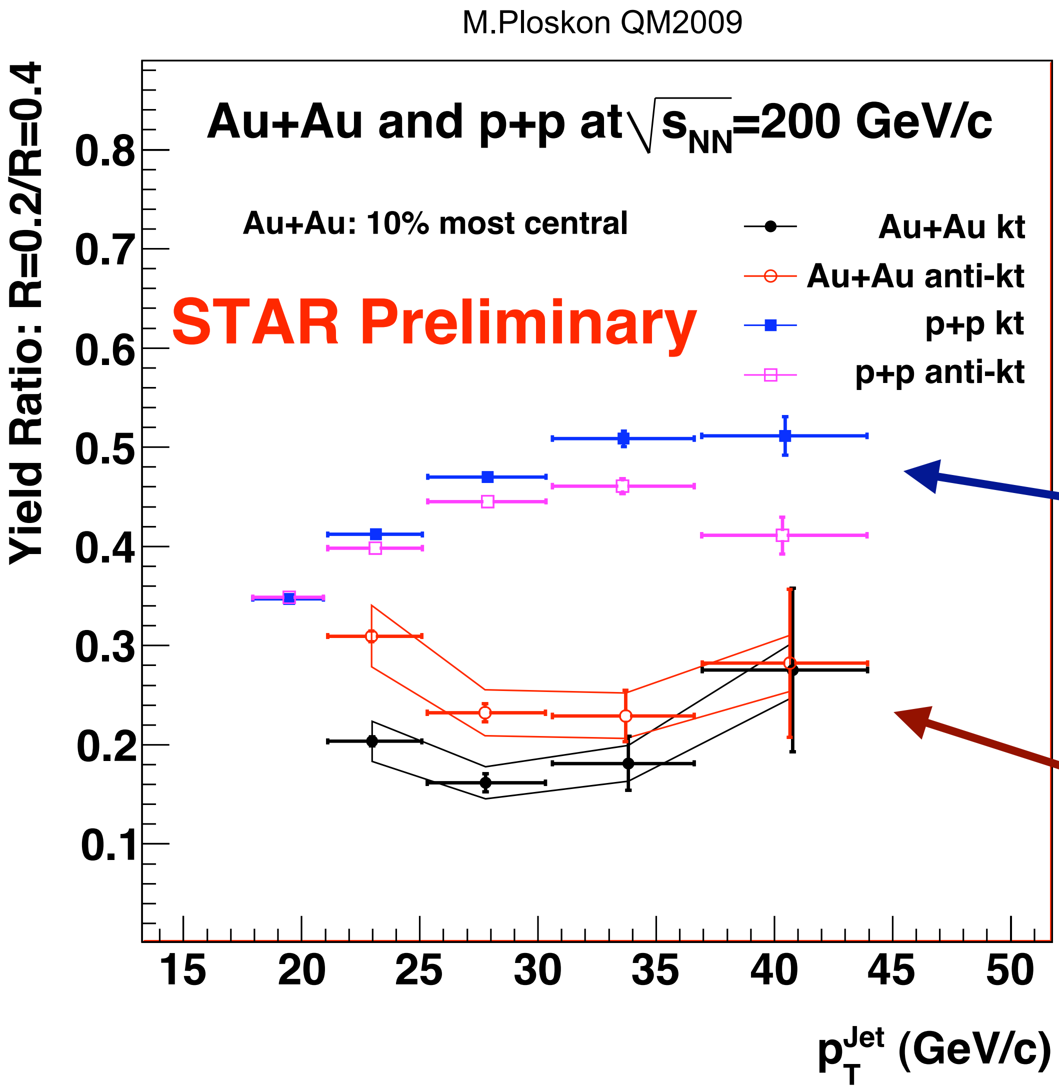
Y. Lai QM2009

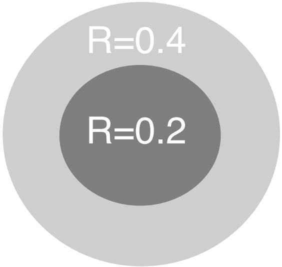


STAR sees a substantial fraction of jets in Au+Au
- in contrast to x5 suppression for light hadron R_{AA}

Strong suppression (similar to single particle) in Cu+Cu measured by PHENIX

First look at the jet energy profile



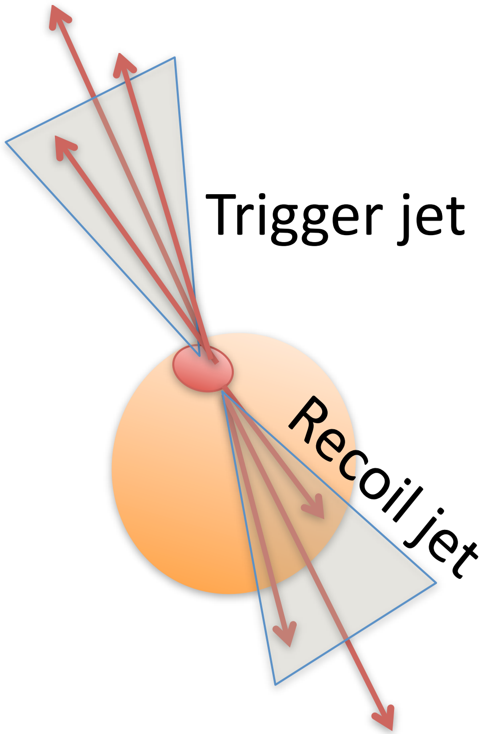


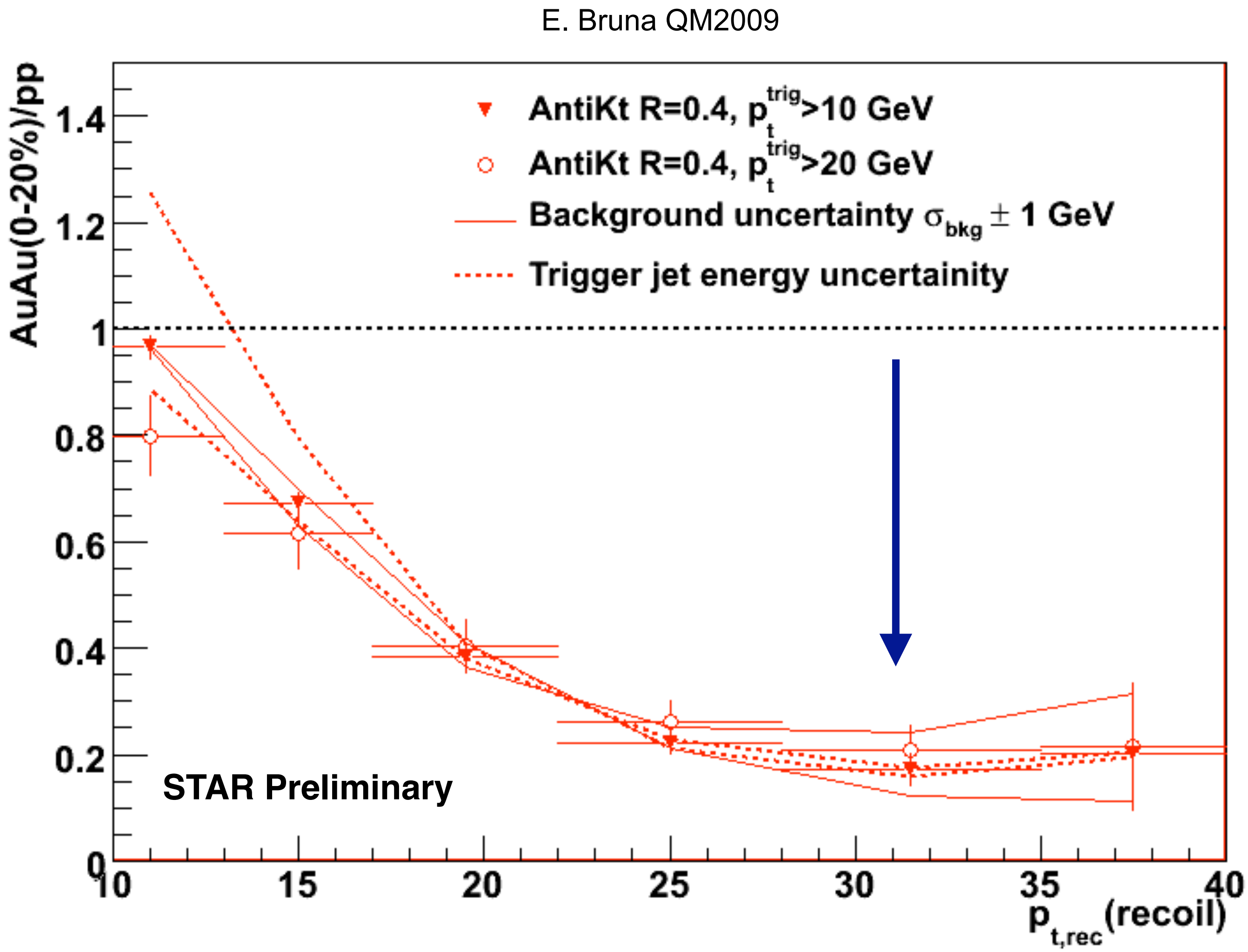
p+p: "Narrowing" of the jet structure with increasing jet energy

Au+Au: "Deficit" of jet energy of jets reconstructed with R=0.2

Strong evidence of broadening in the jet energy profile

Recoil jet spectrum R_{AA}

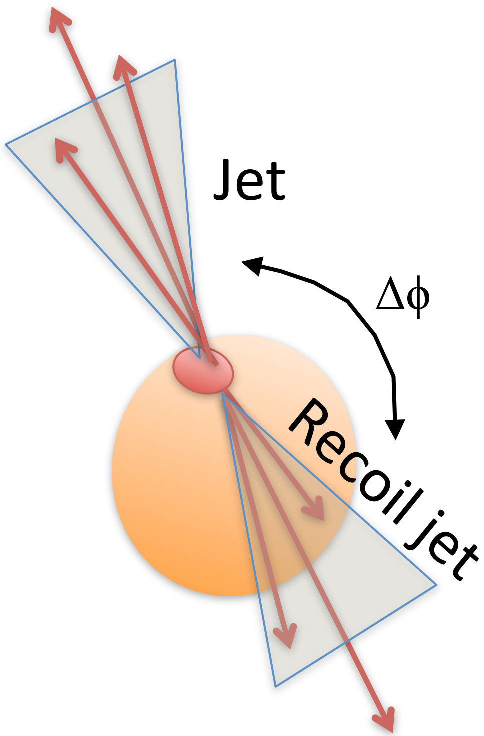


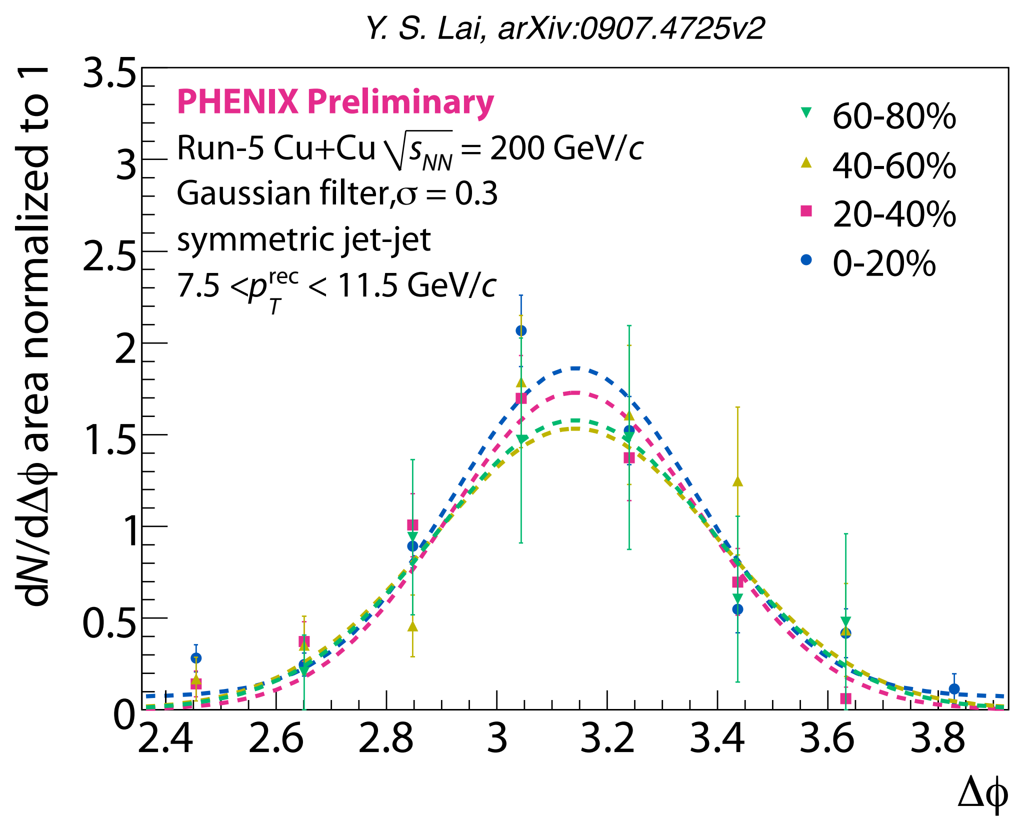


- **Selecting biased trigger jet maximizes pathlength for the back-to-back jets: *extreme selection of jet population***
- **Significant suppression in di-jet coincidence measurements!**

Remark: Compatible with a p_T shift Δ = 7-8 GeV (E. Bruna, Praque WS, 2010)

Di-jet azimuthal correlation in Cu+Cu

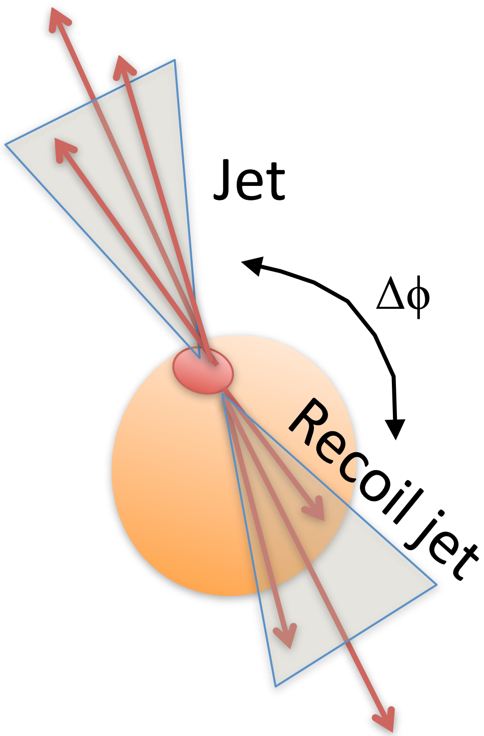


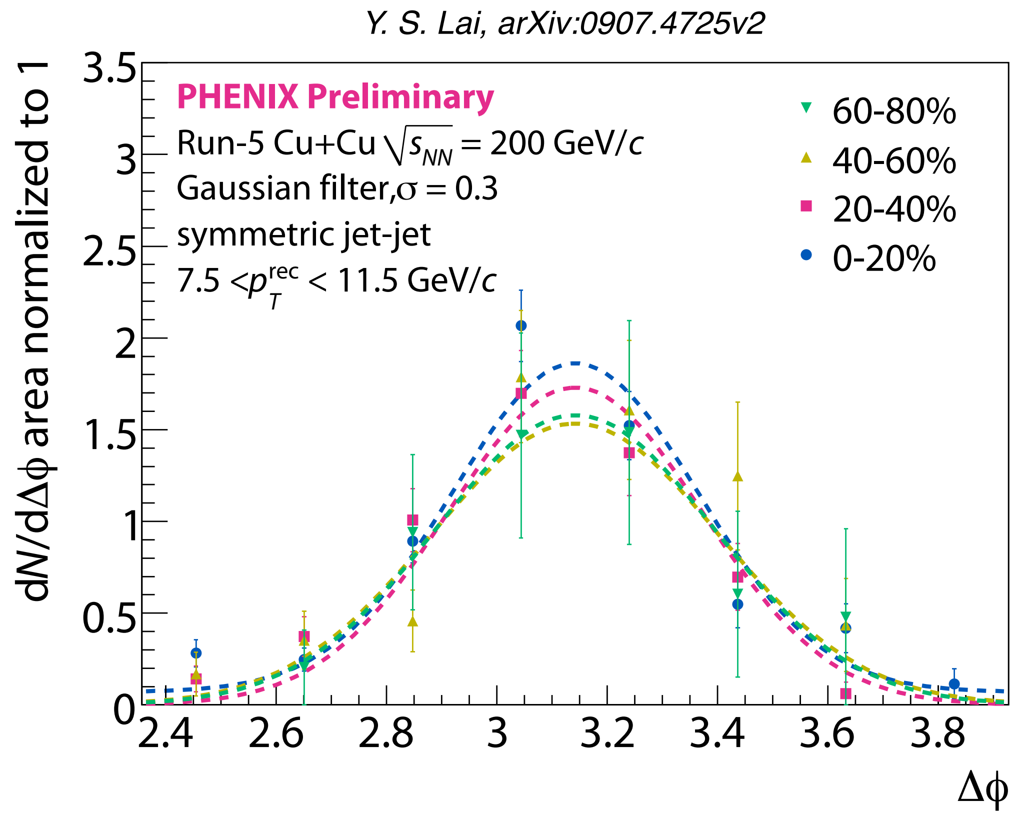


Centrality	Width
0–20%	0.223 ± 0.017
20–40%	0.231 ± 0.016
40–60%	0.260 ± 0.059
60–80%	0.253 ± 0.055

Small k_T broadening of surviving parton in Cu+Cu

Di-jet azimuthal correlation in Cu+Cu





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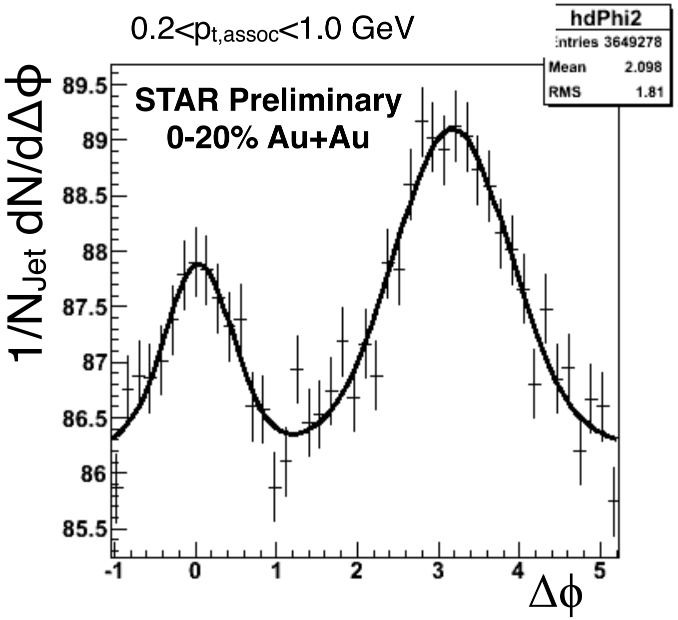
Small k_T broadening of surviving parton in Cu+Cu

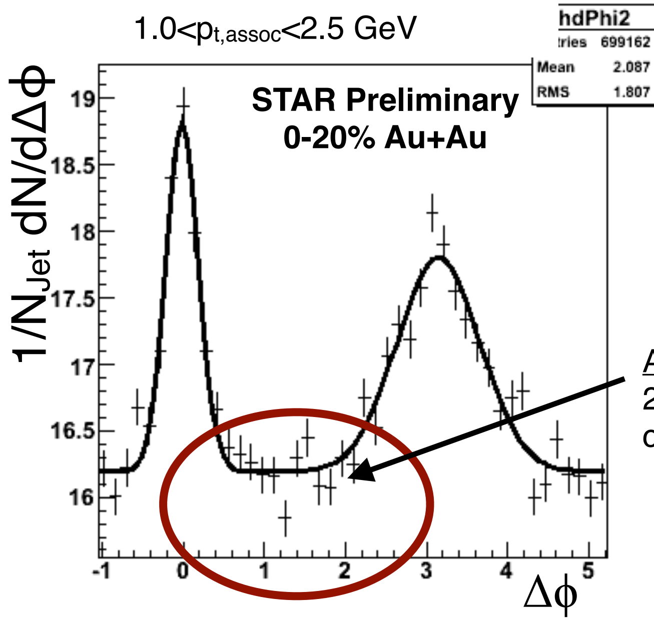
Are we biasing our (di-)jet measurements towards non-interacting jets? Or is our HI jet energy underestimated due to jet broadening!?

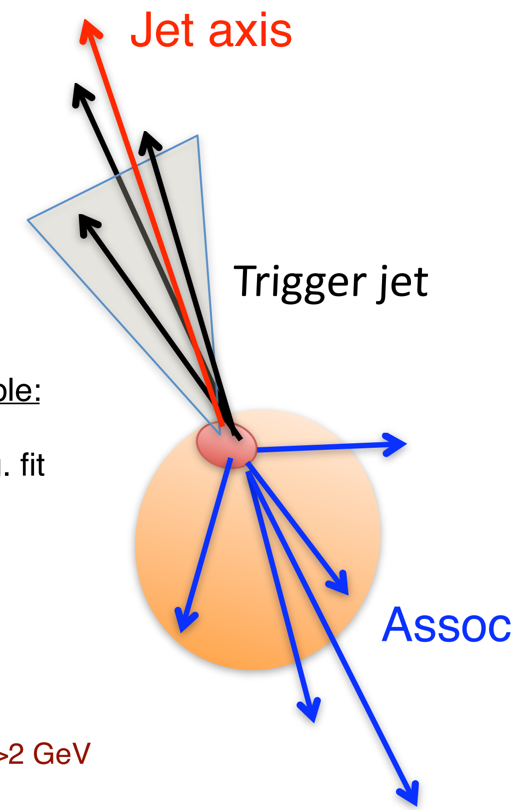
Can we test this with an *independent* measurement!?

Jet-Hadron correlations (JH) 0-20% Au+Au

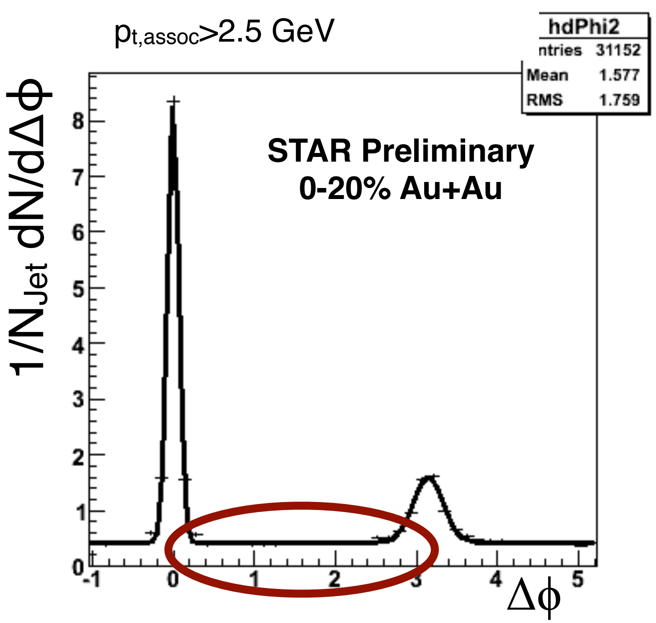
High Tower Trigger (HT): tower 0.05x0.05 (ηxϕ) with E_t> 5.4 GeV







<u>As an example:</u>
2 gaus+
constant bkg. fit



$\Delta\phi = \phi_{Jet} - \phi_{Assoc.}$

ϕ_{Jet} = HT trigger jet-axis found by Anti-kt with R=0.4, $p_{t,cut}$>2 GeV and $p_{t,rec}$(jet)>20 (10) GeV

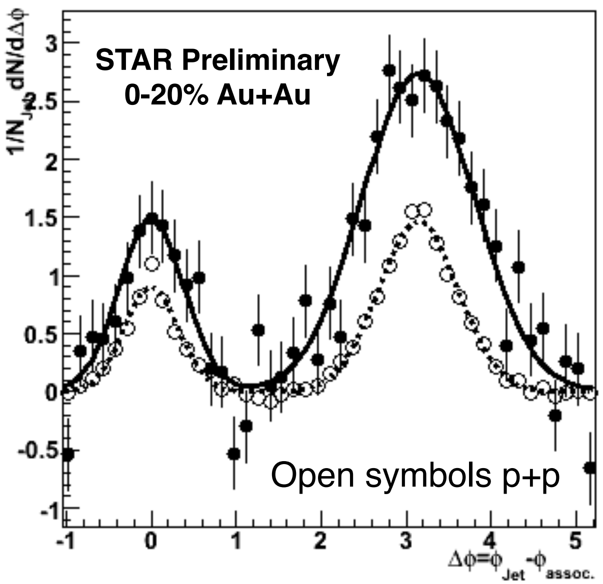
No $\Delta\eta$ "triangle acceptance" applied (in progress ...)
Corrected for single particle tracking efficiencies

Trigger jet energy: correction for tracking eff. (p+p vs. Au+Au), background fluctuations ~1 GeV; uncertainties: p+p=Au+Au and +2 GeV in jet energy (p+p relative to Au+Au)

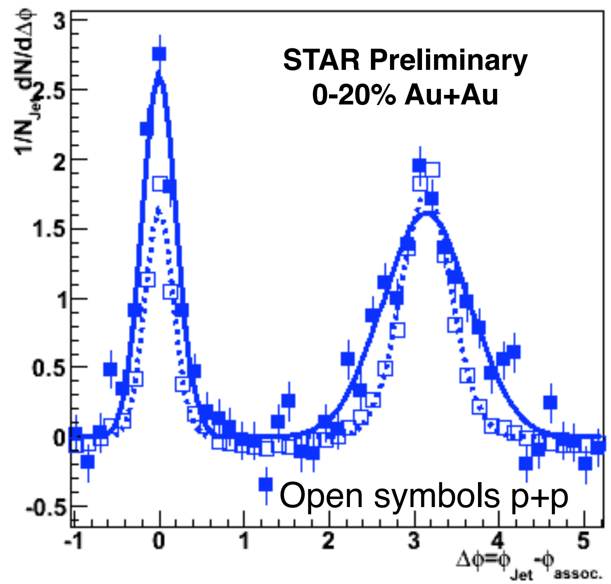
Jet-Hadron correlations (JH) 0-20% Au+Au

High Tower Trigger (HT): tower 0.05x0.05 (ηxϕ) with E_t> 5.4 GeV

$0.2<p_{t,assoc}<1.0$ GeV



$1.0<p_{t,assoc}<2.5$ GeV



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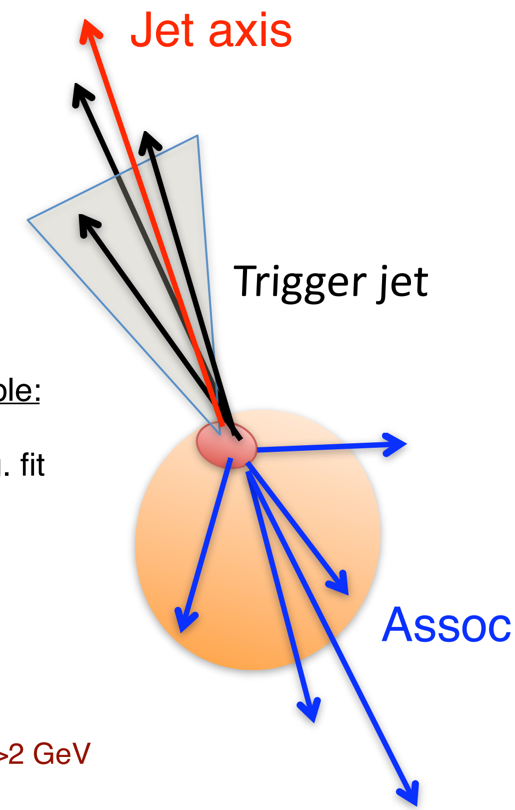
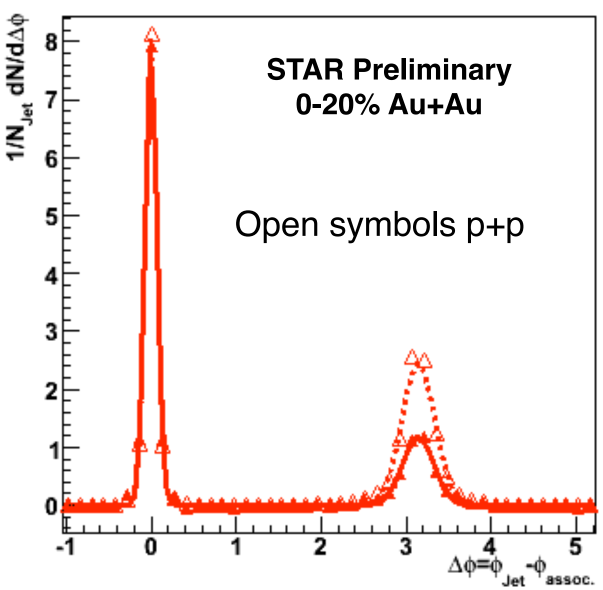


$p_{t,assoc}>2.5$ GeV



$\Delta\phi=\phi_{Jet}-\phi_{Assoc.}$

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No $\Delta\eta$ "triangle acceptance" applied (in progress ...)
Corrected for single particle tracking efficiencies

Trigger jet energy: correction for tracking eff. (p+p vs. Au+Au), background fluctuations ~1 GeV; uncertainties: p+p=Au+Au and +2 GeV in jet energy (p+p relative to Au+Au)

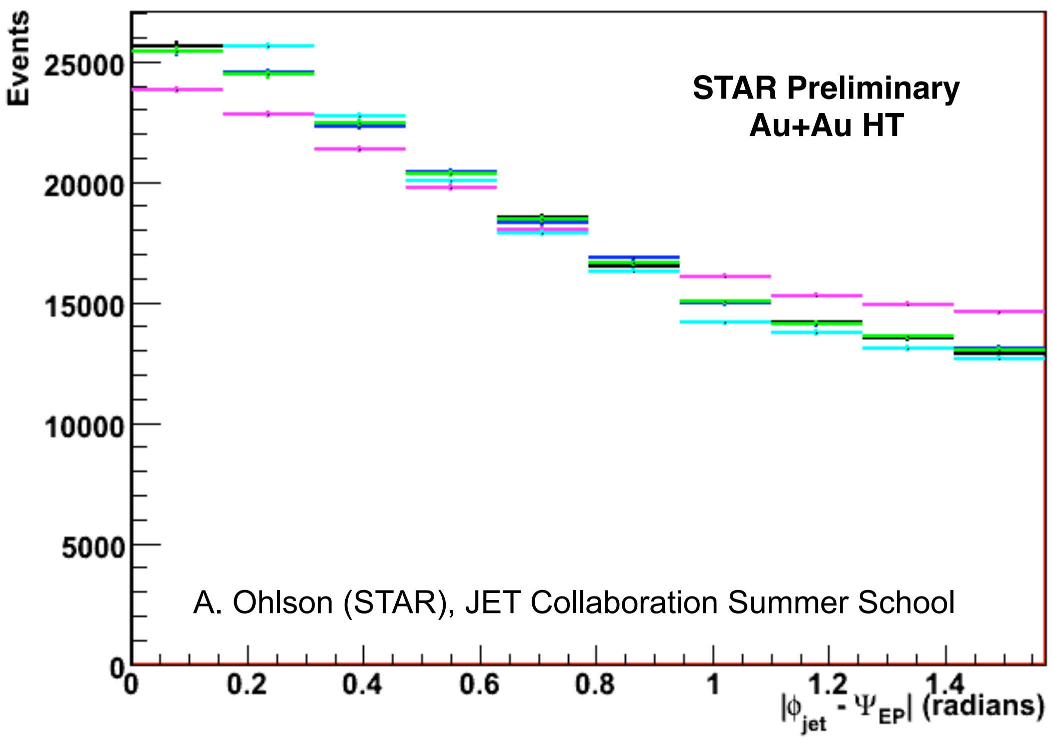
Increased kinematics in JH due to jet requirement!

Different systematics **in bkg. correction compared to full-jet measurements!**

Can be used to study *jet-finding biases* in di-jets!

First look at “Jet v_2”

STAR mid-rapidity (TPC+EMCal): Anti-k_T R = 0.4, $p_T^{track,tower}$ > 2 GeV/c, p_T^{jet} > 10 GeV/c



Is it possible to remove the jet particles from the EP calculation?

First attempts:

- All Particles Used to Calculate EP
- Jet Cone Removed
- Random Jet Cone Removed
- Specific Jet Cone Removed
- Jet Cone at Different η Removed

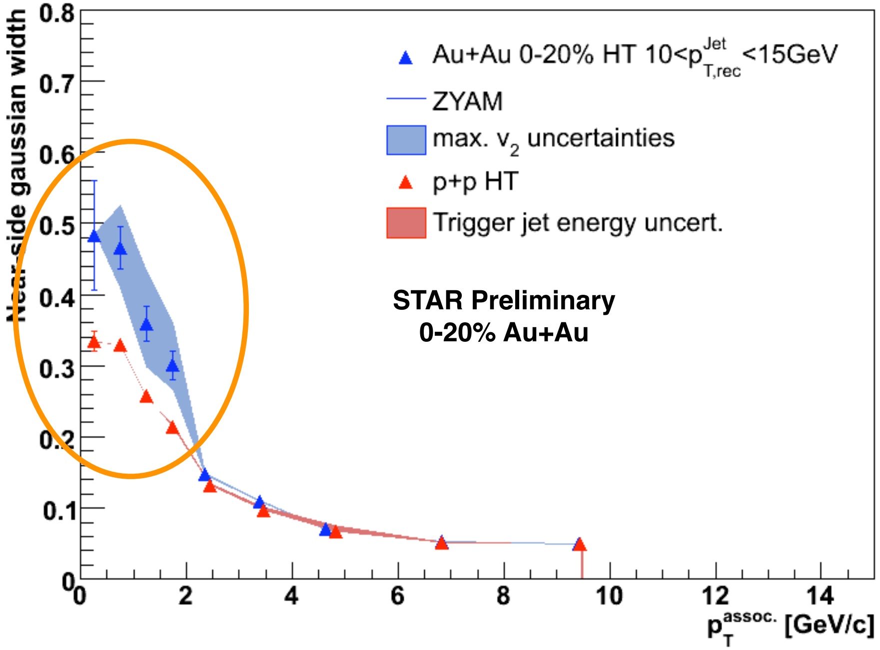
The presence of a jet influences the EP calculation!

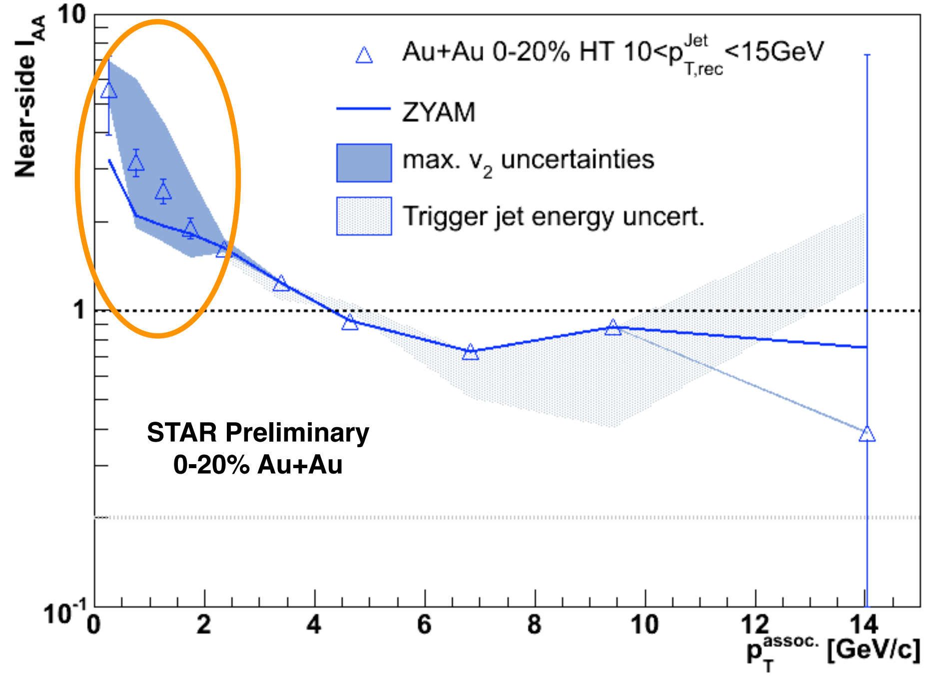
For the jet definition used: “jet v_2“~ $v_2\{2\}$

(used in jet-hadron correlations;
max v_2 uncertainties: no v2 and +50% of $v_2^{Jet} * v_2^{Assoc}\{2\}$)

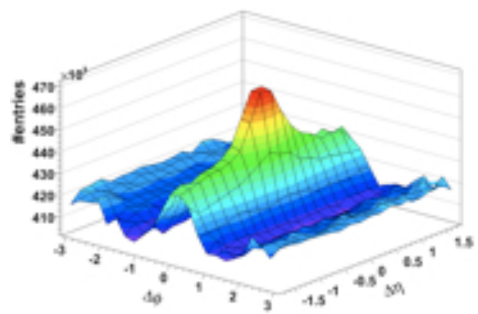
Next steps: Using forward detectors to calculate the EP (FTPC, BBC, ZDC-SMD), to suppress non-flow!

JH: Look on near-side first ...





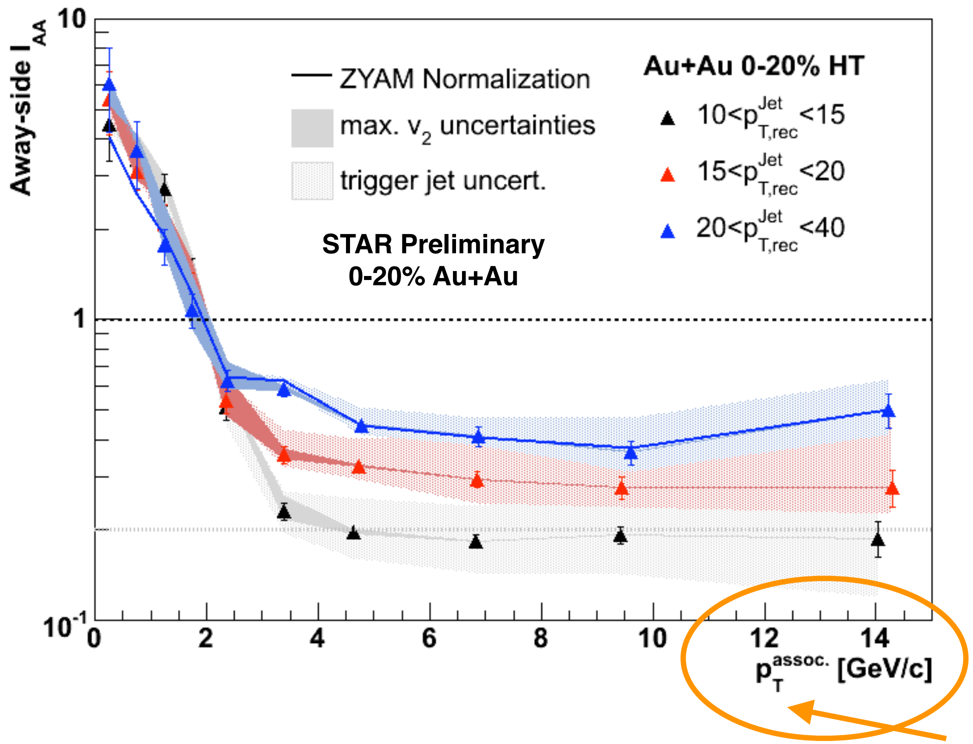
- **Jet broadening on trigger/near-side!**
- **Enhancement at low pT (pT<2-3 GeV):**
  Ridge, bkg. biases, bulk effects v_3 !?

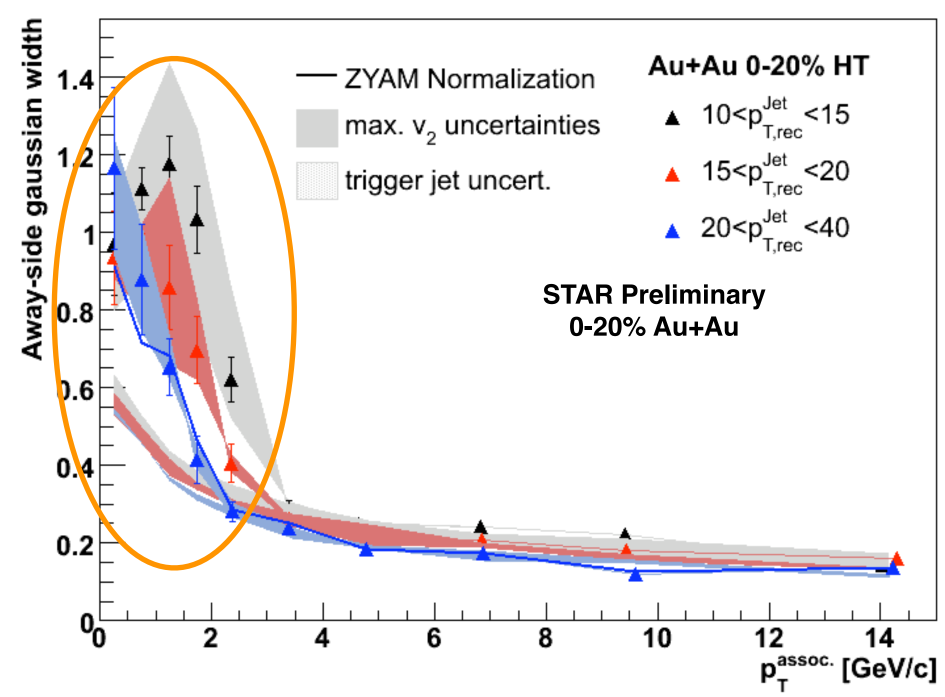


Assumption:

What if this is energy loss (ΔE~2 GeV) even on the near-side!
→ Compare to p+p jets (+ 3/2*ΔE)
→ NS (and AS) low-p_T enhancement balanced with high-p_T suppression

JH: Away-side width and I_{AA}





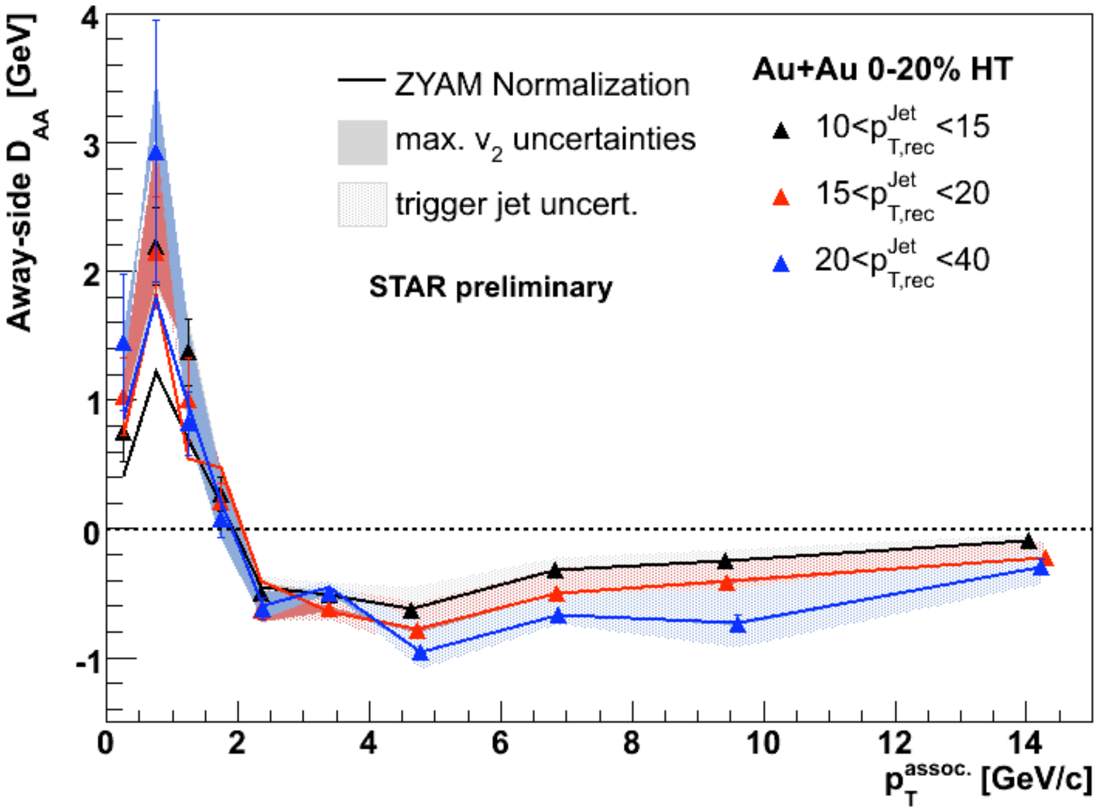
Remember:
This is not z!!!

- **Significant (gaussian) jet broadening for recoil jets**
  decreasing with increasing jet energy; ~6-9 GeV out-of-cone (R>0.4) energy
- **Softening of jet "fragmentation":**
  suppression at high pT and enhancement at low pT (pT<2 GeV)
- **Measurements/conclusions robust wrt to background subtraction**

Further studies: jet energy scale/uncertainties on near-side (Δη study), included in systematics

JH: Away-side D_{AA} vs jet energy

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



Jet energy [GeV]	ΔB [GeV] (stat. only)
10-15	2.3 +- 0.48
15-20	1.2 +- 0.64
20-40	1.5 +- 1.2

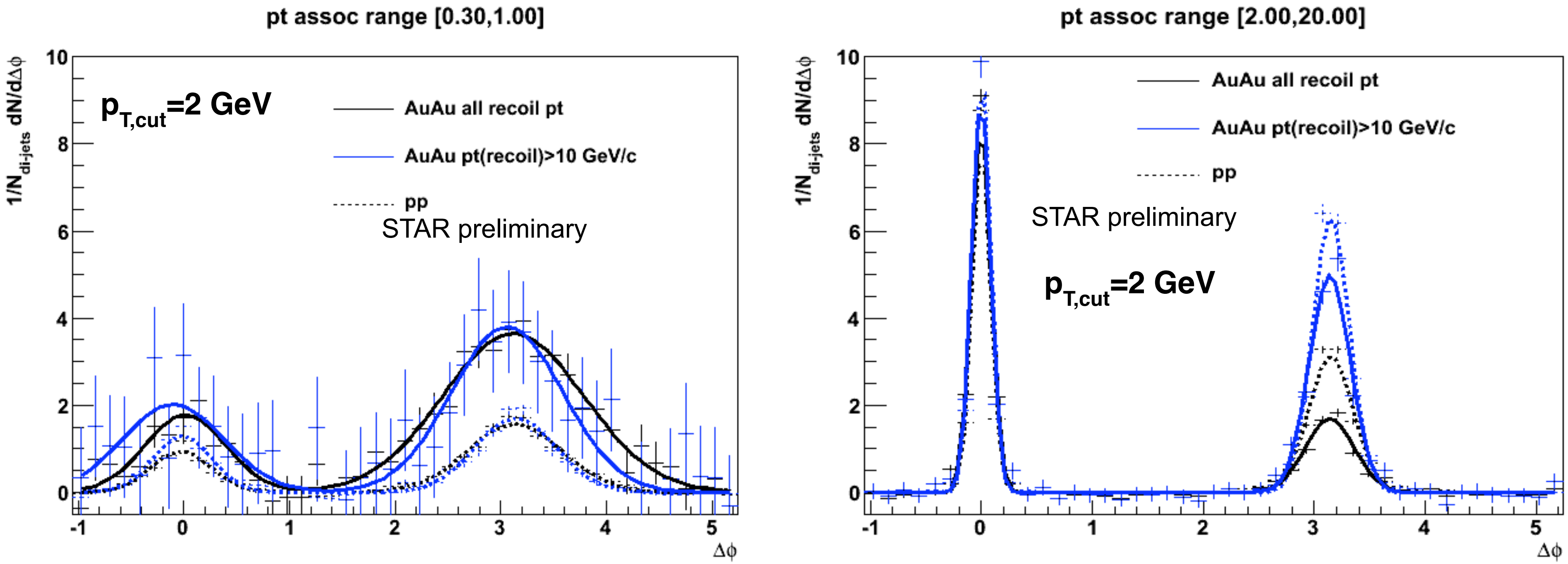
Away-side yields enhancement/suppression not fully balanced, more energy at low p_T in Au+Au

But significant amount of energy ~3-4 GeV at low p_T compensated by high-p_T suppression!

Jet-quenching at work !

"Jet-finding bias" assessment via jet-hadron correlations

E. Bruna, Praque WS, 2010



Away-side shows broadening and softening in jet-hadron correlations

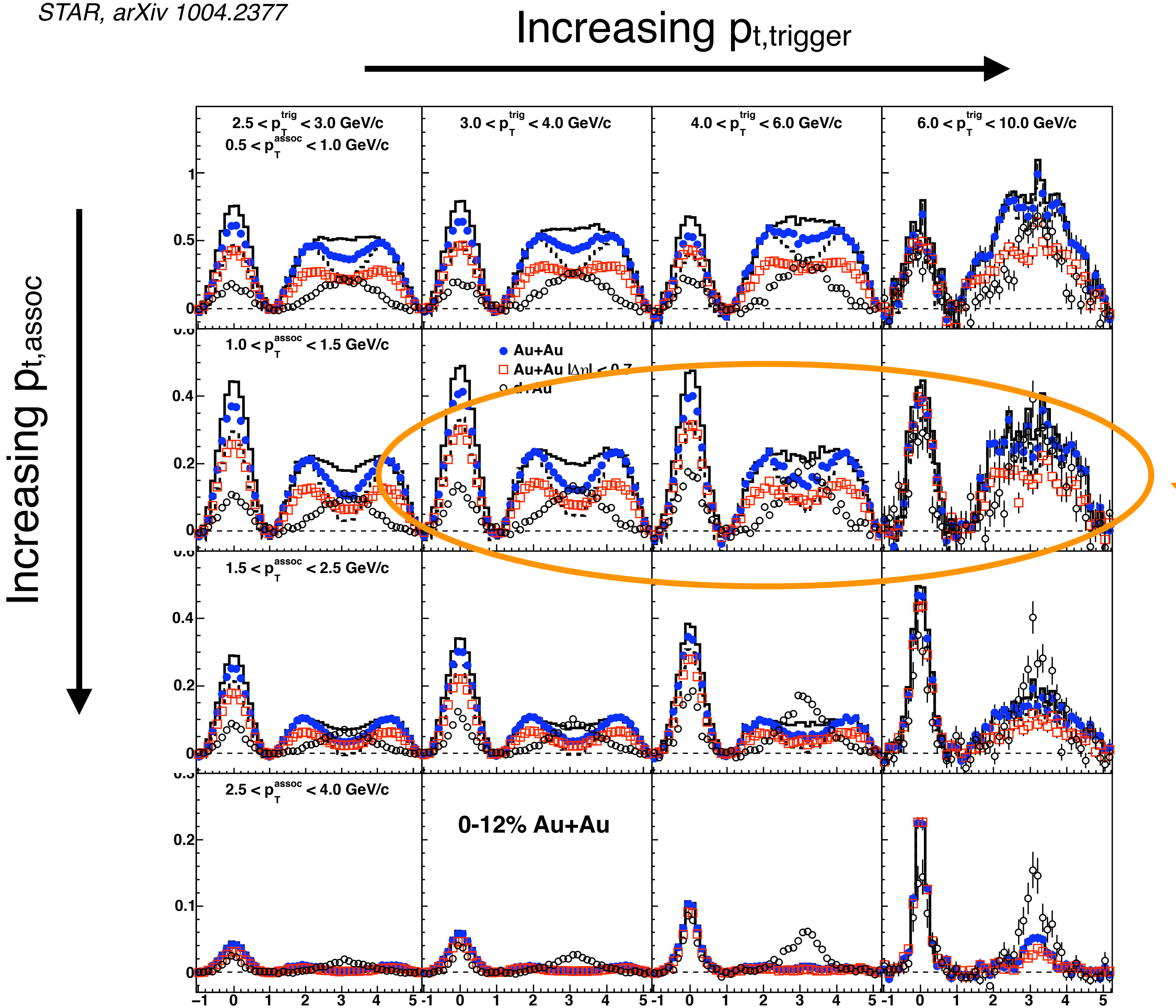
⇒ Highly biased jets seem to be modified; jet-finding algorithm not only reconstructing unmodified jet!

⇒ Suppression of di-jet coincidence due to "out-of-cone energy"

But what about di-hadron correlations at lower p_T's ?

STAR, arXiv 1004.2377

Same observation in:
PHENIX, arXiv:1002.1077
(PRL in publication)



Away-side structure dep. on p_T^{Trig} !

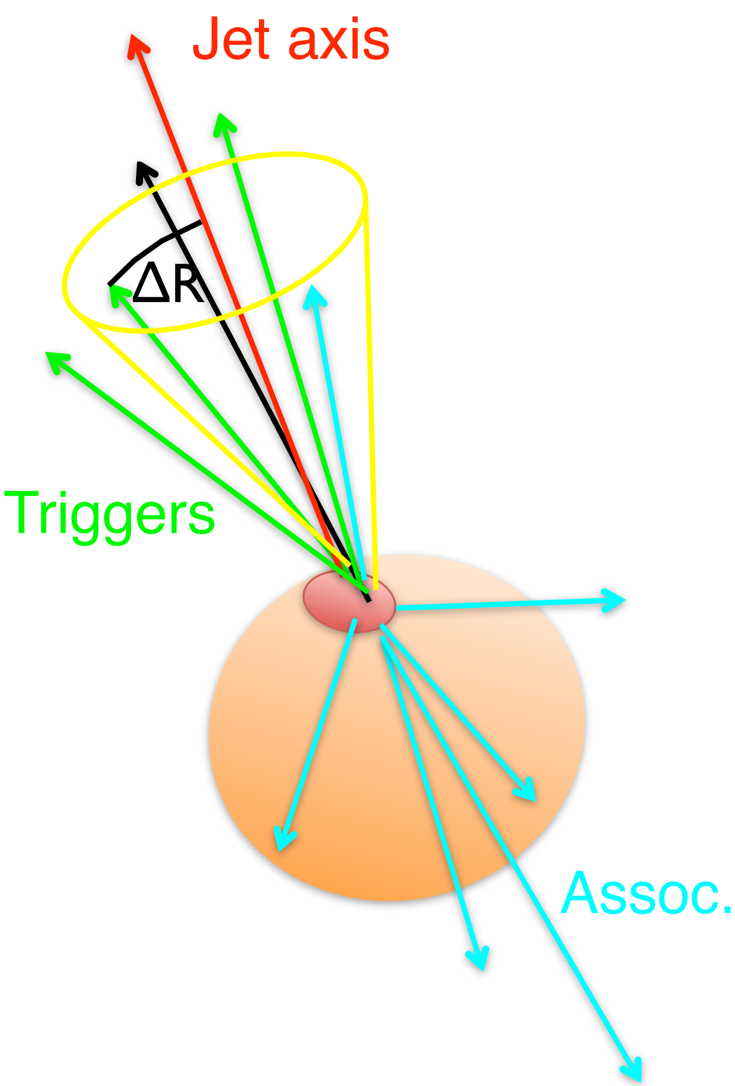
A simple model: Mono-energetic Pythia jet in thermal bkg. model

In general: Two-component (ZYAM) approach

$$\frac{1}{N_{trig}}\frac{dN}{d\Delta\phi}(\Delta\phi) = \frac{1}{N_{trig}}\left(\frac{dN_{meas.}}{d\Delta\phi}(\Delta\phi) - B_{\Delta\phi}(\Delta\phi)\right)$$

$$B_{\Delta\phi}(\Delta\phi, v_2^{trig}, v_2^{assoc}) \equiv b_{\Delta\phi}\left(1 + 2\langle v_2^{trig} v_2^{assoc}\rangle \cos 2\Delta\phi\right)$$
$$\cong b_{\Delta\phi}\left(1 + 2\langle v_2^{trig}\rangle\langle v_2^{assoc}\rangle \cos 2\Delta\phi\right)$$

$$Y|_{a,b} = \frac{1}{N_{trig}}\int_a^b d\Delta\phi \frac{dN}{d\Delta\phi}(\Delta\phi)$$



In simple model:

$$\frac{1}{N_{trig}}\frac{dN_{meas.}}{d\Delta\phi}(\Delta\phi) = \frac{1}{N_{trig}}(S(\Delta\phi) + b_{\Delta\phi}),$$

$$N_{trig} = N_{trig}^{Jet} + N_{trig}^{Bkg.} = N_{trig}^{Jet}\cdot(1+f) \text{ ,with } f = \frac{N_{trig}^{Bkg.}}{N_{trig}^{Jet}}.$$

$$I_{AA}^{Sim} = \frac{Y^{Emb.}}{Y^{Py.}} = \frac{1}{1+f},$$

Two cases:

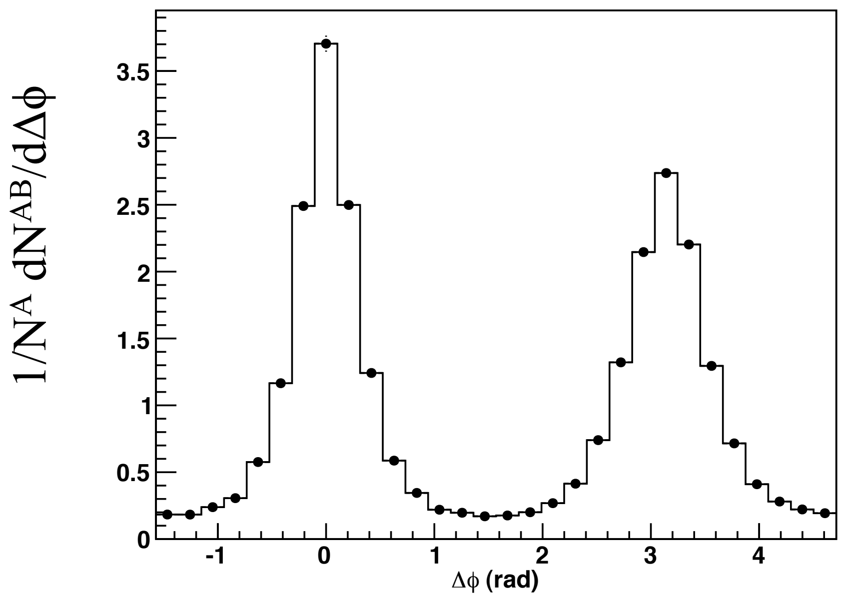
(i) h_{Jet}-h: Trigger associated to jet (ΔR<0.4)

(ii) h-h: All "trigger particles" in event

Simple MC model results

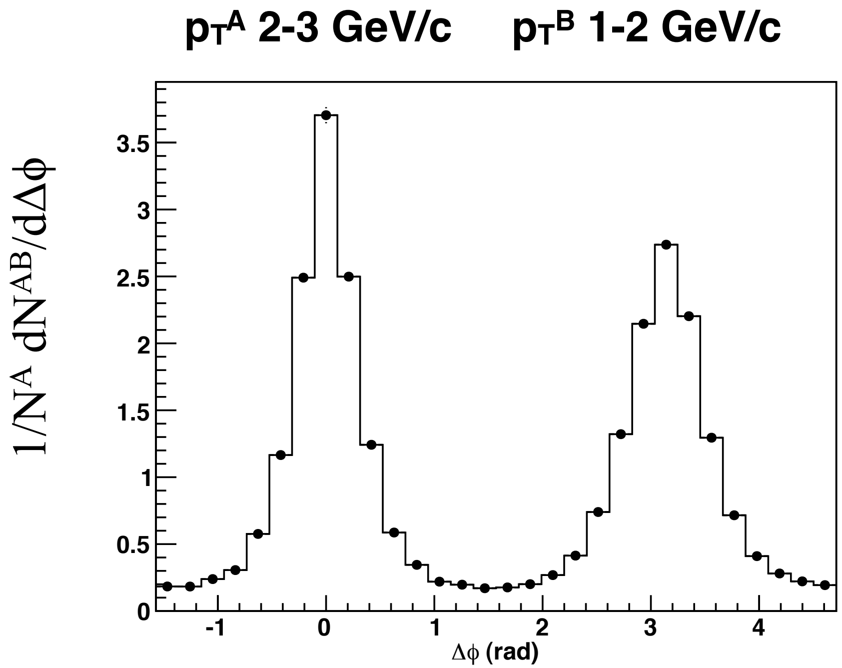
A. Adare (STAR), RHIC AGS Users Meeting 2010

p_T^A 2-3 GeV/c p_T^B 1-2 GeV/c



Simple MC model results

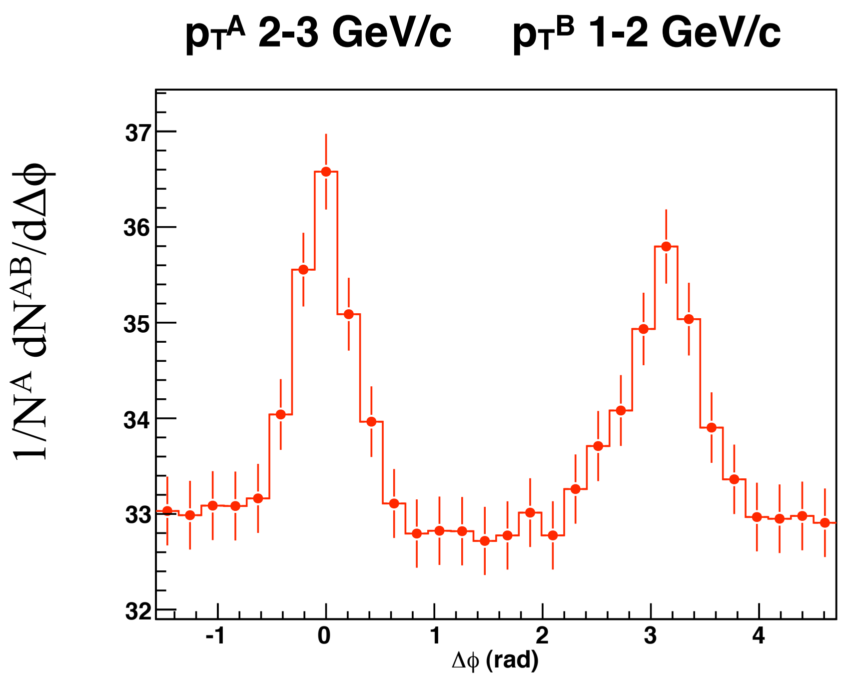
A. Adare (STAR), RHIC AGS Users Meeting 2010



<u>To start:</u> produce h-h correlations in pythia.

Simple MC model results

A. Adare (STAR), RHIC AGS Users Meeting 2010



<u>To start:</u> produce h-h correlations in pythia.

Add isotropic thermal background; calculate h_{jet}-h. Trigger particles are inside $\Delta R = R_C = 0.4$.

Simple MC model results

A. Adare (STAR), RHIC AGS Users Meeting 2010

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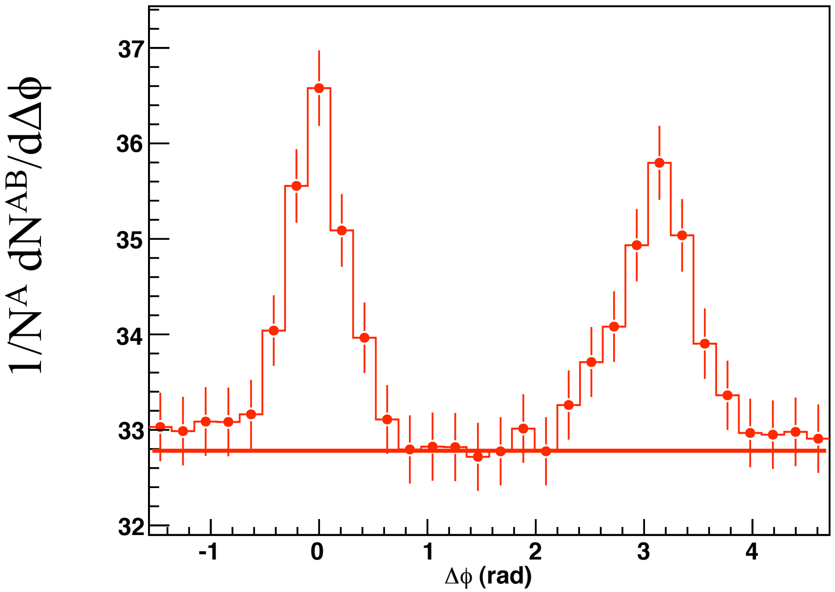

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Background pedestal calculated

Simple MC model results

A. Adare (STAR), RHIC AGS Users Meeting 2010

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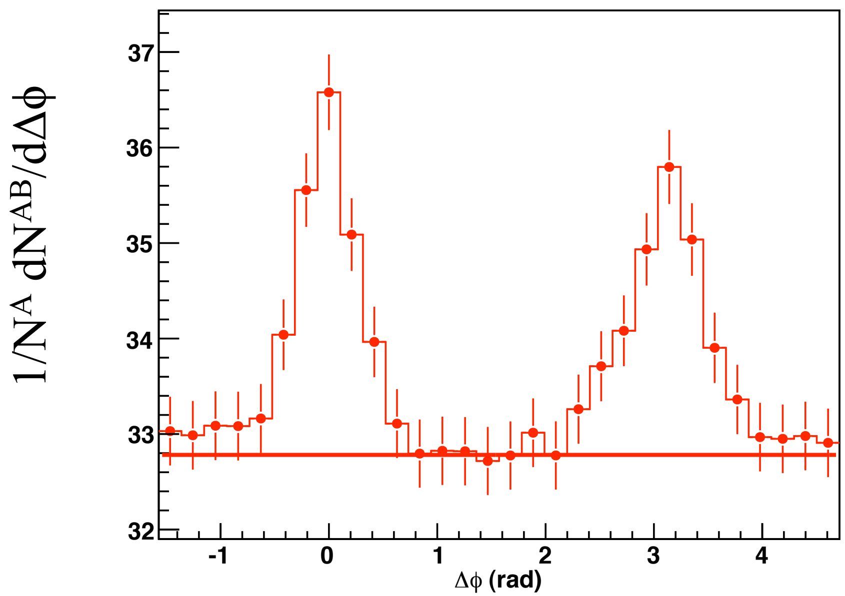

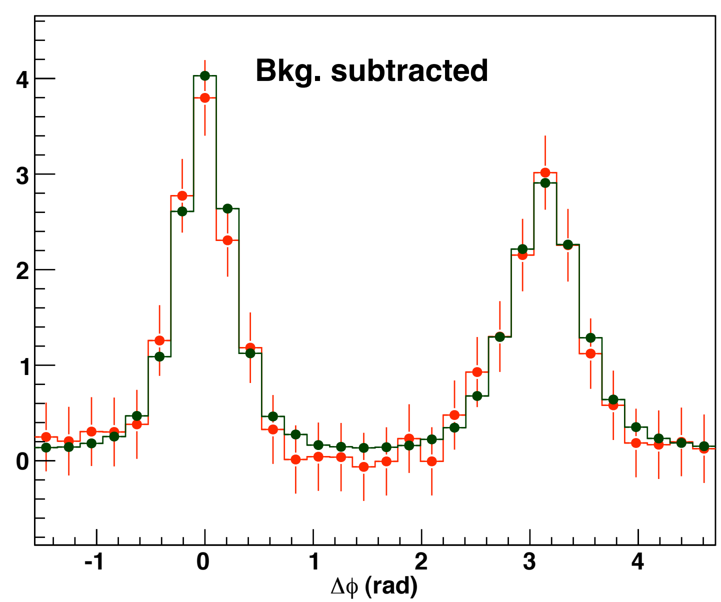

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h_{jet}-h: ***Pedestal subtraction recovers PYTHIA yield (dark points)***

Simple MC model results

A. Adare (STAR), RHIC AGS Users Meeting 2010

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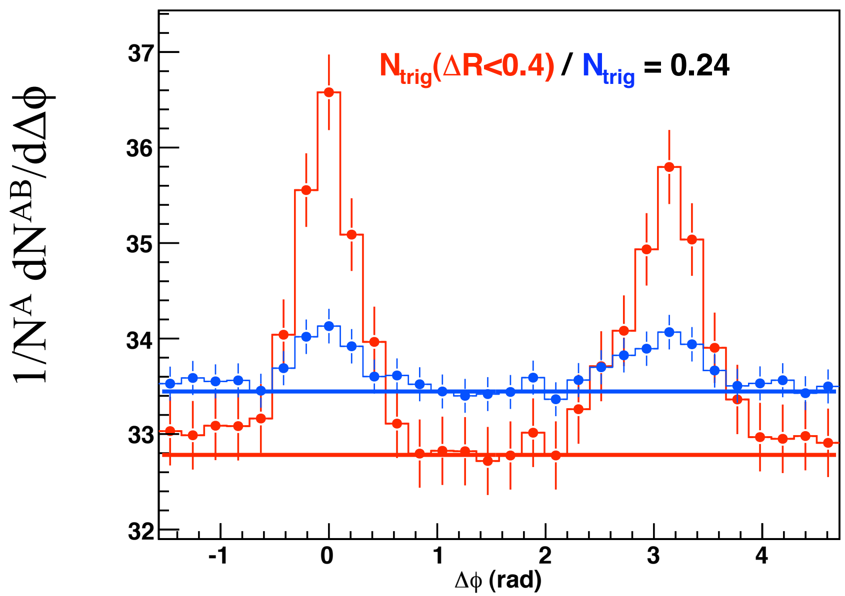

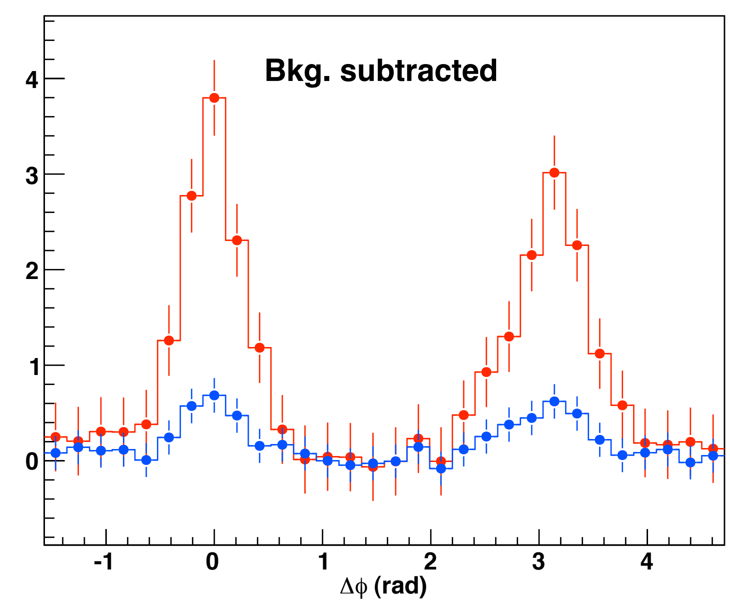

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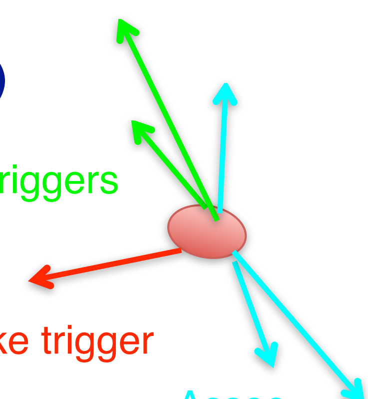
Background pedestal calculated

<u>h_{jet}-h:</u> *Pedestal subtraction recovers PYTHIA yield (dark points)*

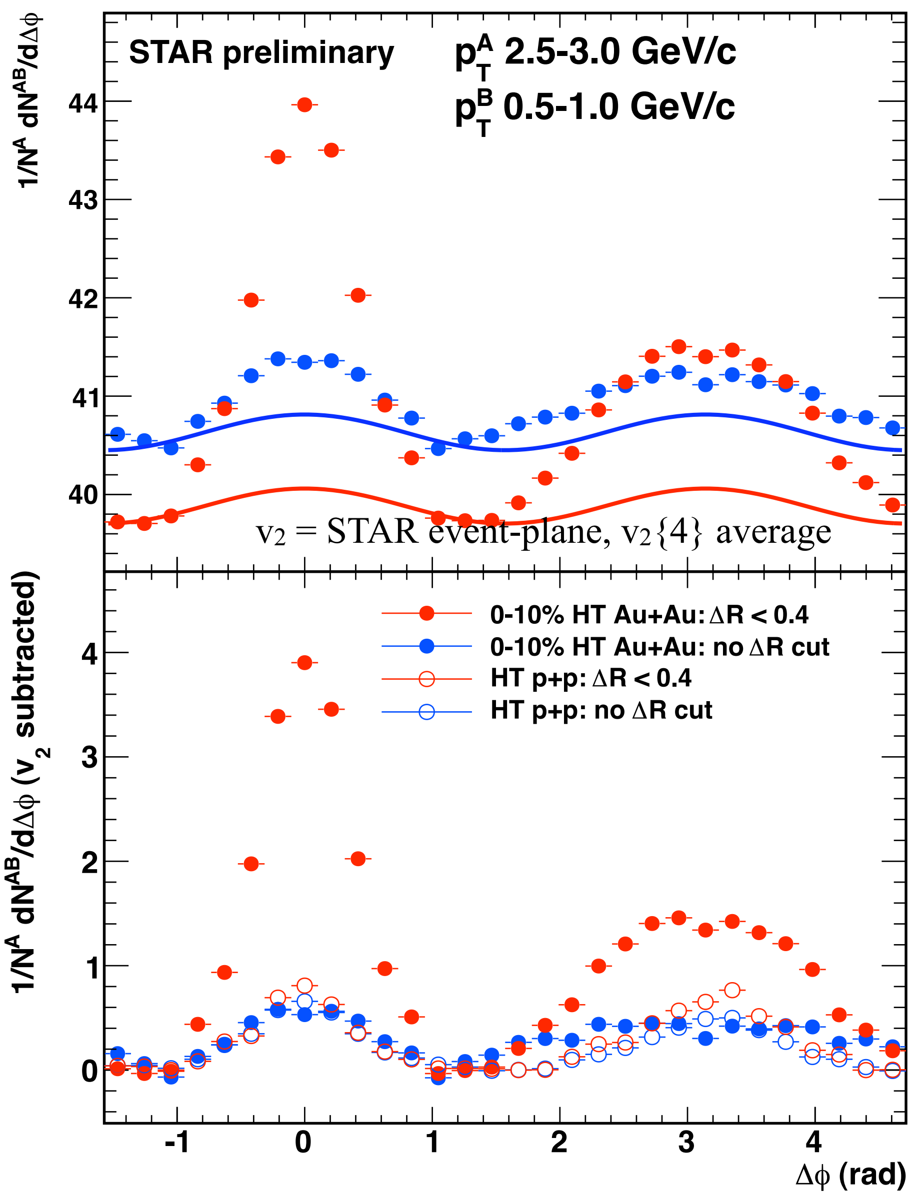
<u>Inclusive h-h:</u> many *fake/uncorrelated* background trigger particles (at "low p_T")

- ***peak yield is suppressed*** **by $1/f = 0.24$ ($1/f = N_{Trig}^{Jet}/N_{Trig}^{Bkg}$)**
- ***pedestal raised*** **by $1/2pi * (1-1/f)\, N_{Jet}^{Assoc} = 0.67$**



h_{jet}-h vs. h-h in HT Au+Au, p+p

A. Adare (STAR), RHIC AGS Users Meeting 2010



Anti-k_T R = 0.4, $p_T^{track,tower}$ > 2 GeV/c, p_T^{jet} > 10 GeV/c

h-h: Event contains a 10+ GeV jet, but no ΔR cut

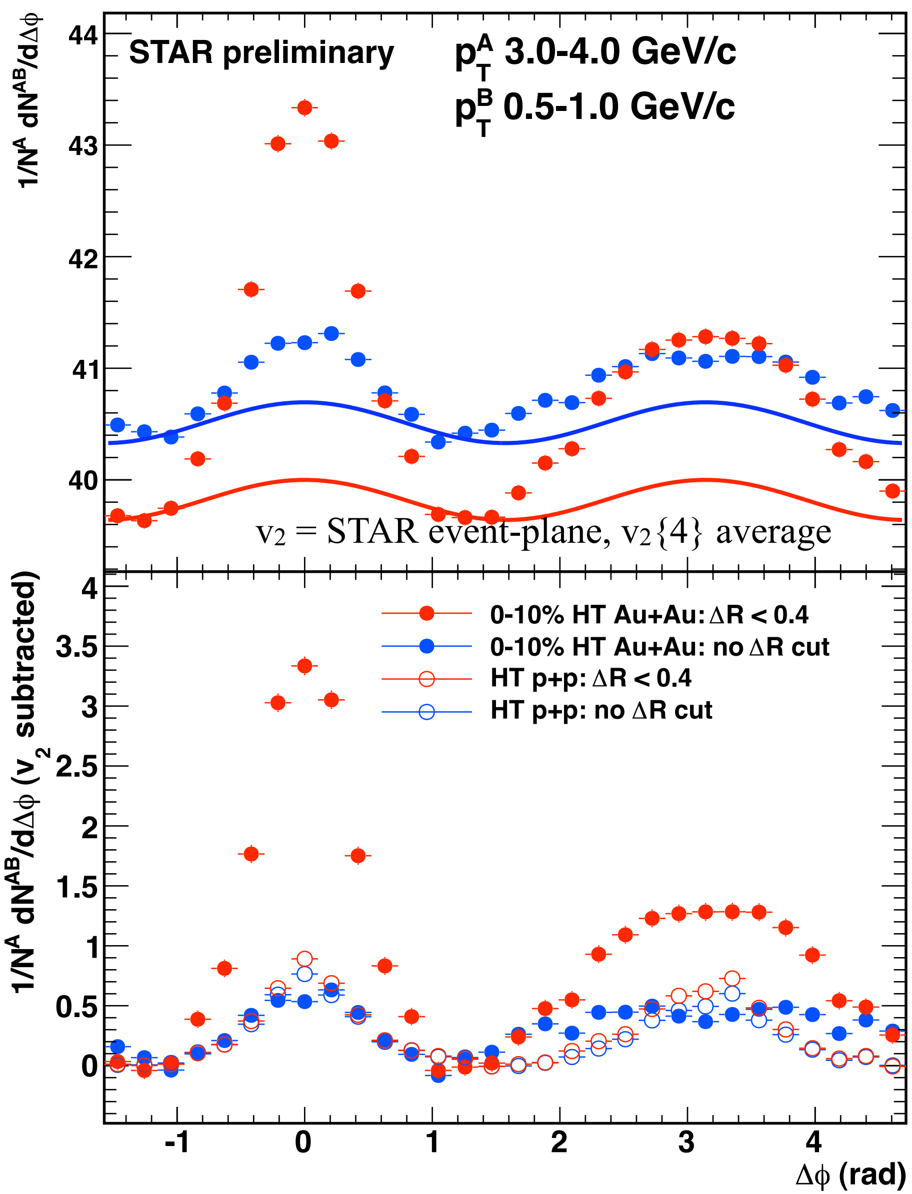
h_{Jet}-h: Same events, with ΔR<0.4

Same v_2 currently used for both as initial estimation

ZYAM applied for consistency with STAR and PHENIX h-h analyses

h_{jet}-h vs. h-h in HT Au+Au, p+p

A. Adare (STAR), RHIC AGS Users Meeting 2010



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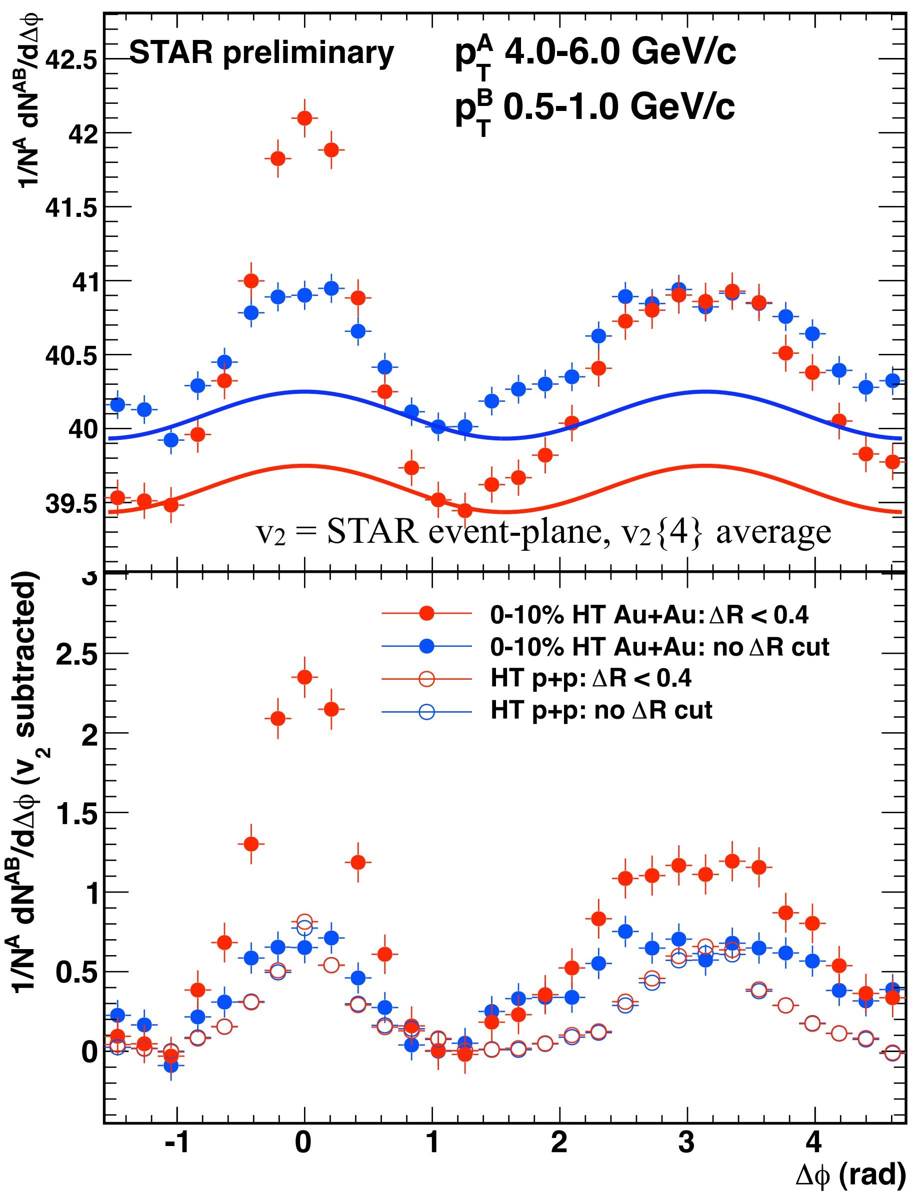

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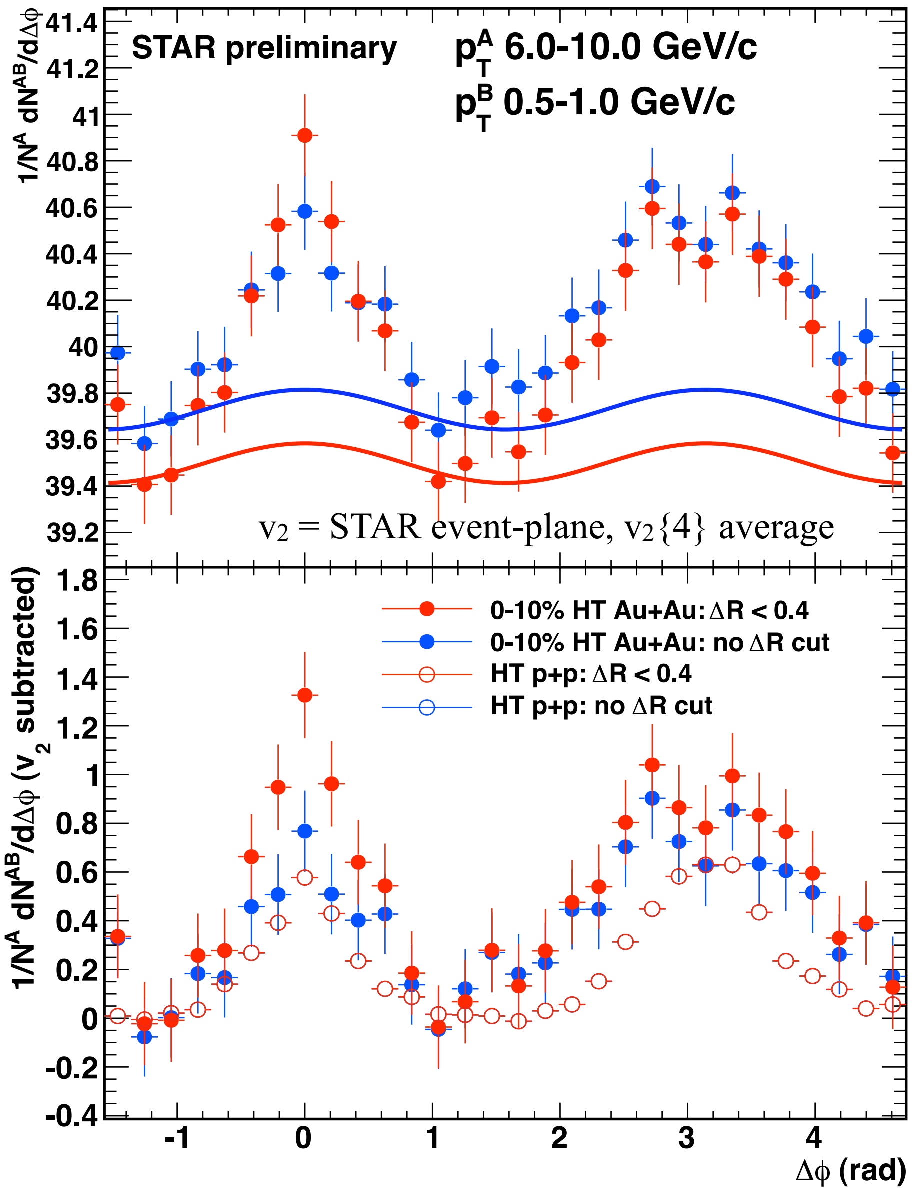

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h_{Jet}-h: Same events, with ΔR<0.4

Same v_2 currently used for both as initial estimation

ZYAM applied for consistency with STAR and PHENIX h-h analyses

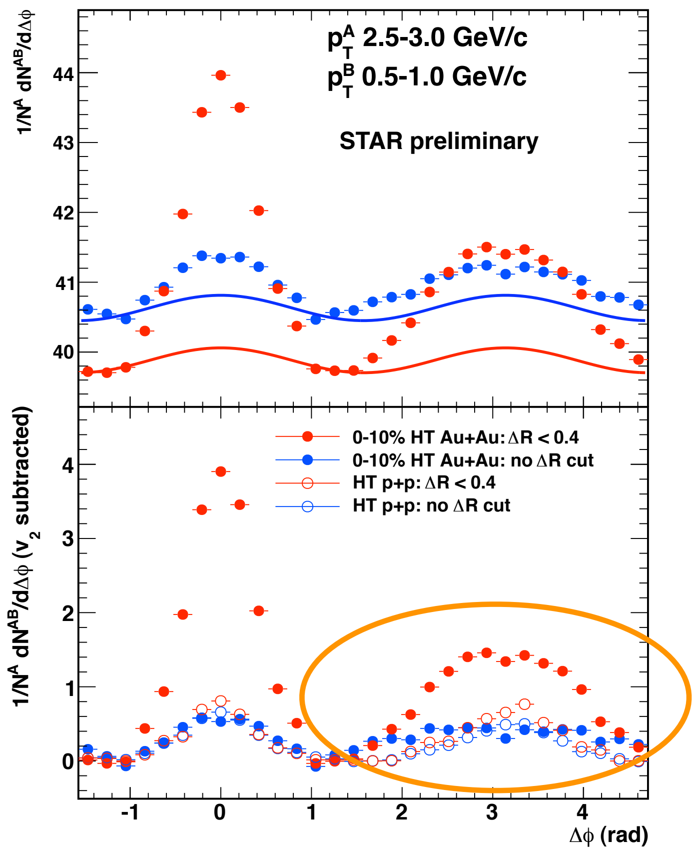
h_{jet}-h and h-h correlations similar at highest trigger p_T!

HI "trigger" and "associated" background complex ...

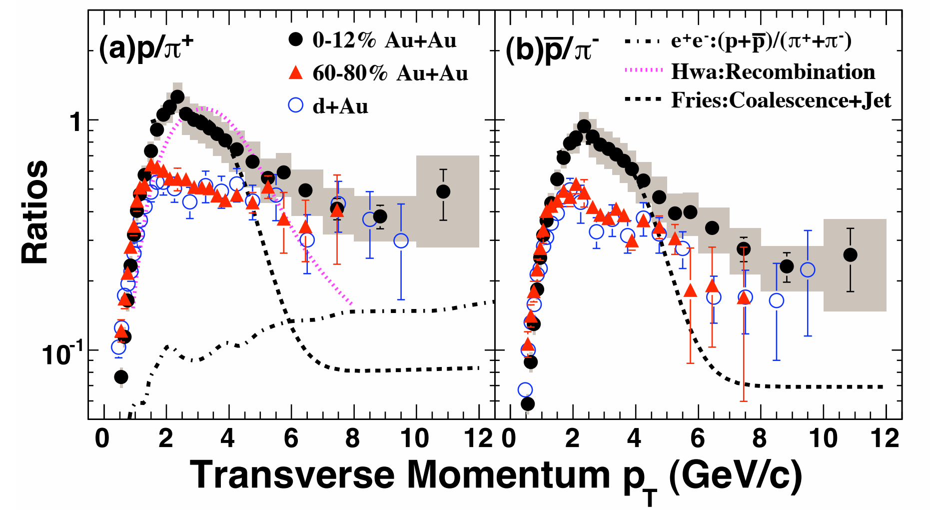
What do we measure with di-hadrons at lower trigger p_T's?

So, what do we learn ?

A. Adare (STAR), RHIC AGS Users Meeting 2010



STAR Phys. Rev. Lett. ***97*** *(2006) 152301*



Secondary (n-th) hard-scattering reduces h-h
due to different jet energy scales sampled wrt h_{Jet}-h!

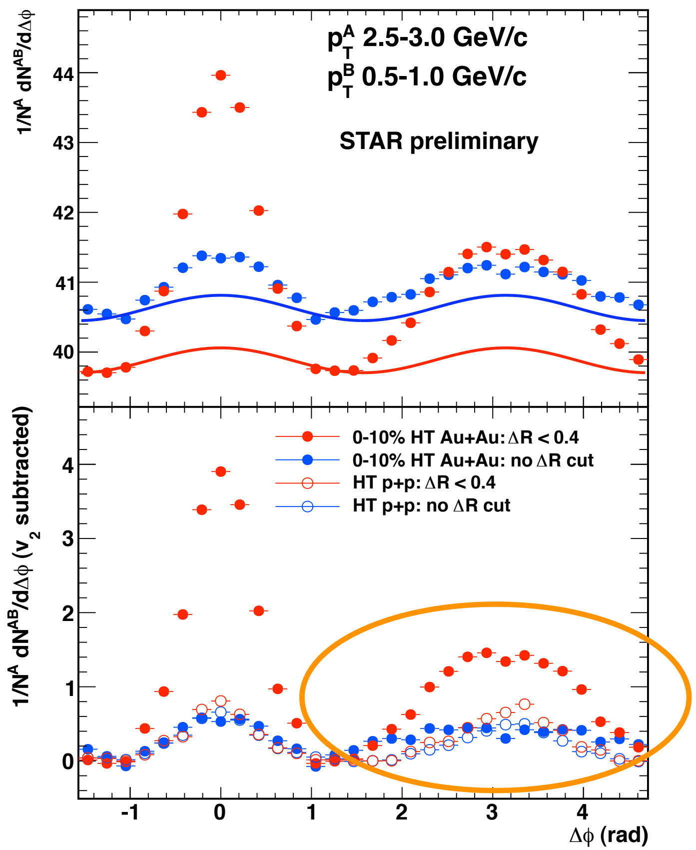
If h-h is the true Au+Au “jet” correlation
⇔ dominated by semi-hard scatterings!

But there is the B/M enhancement!
So some dilution due to “fake” triggers expected in h-h!

We can not have both!

So, what do we learn ?

A. Adare (STAR), RHIC AGS Users Meeting 2010



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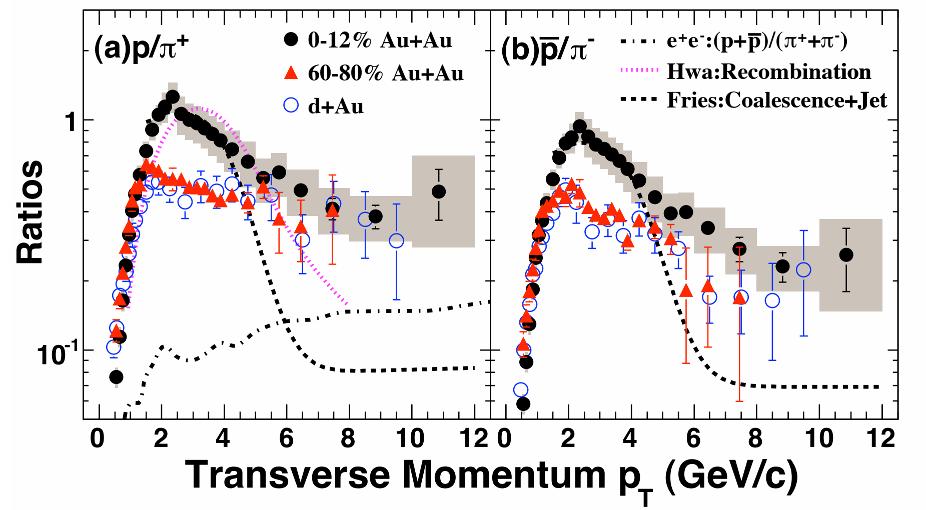

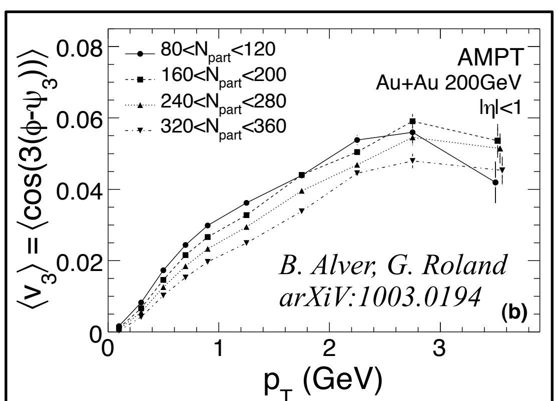

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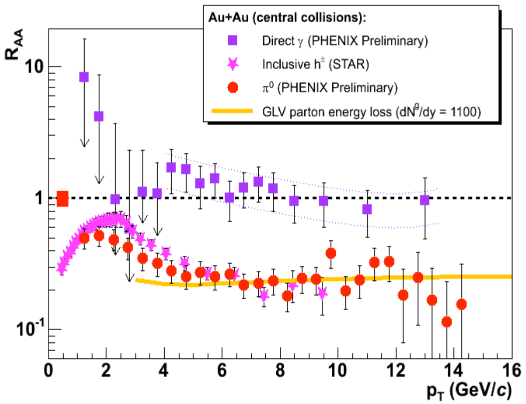
But there is the B/M enhancement!
So some dilution due to "fake" triggers expected in h-h!

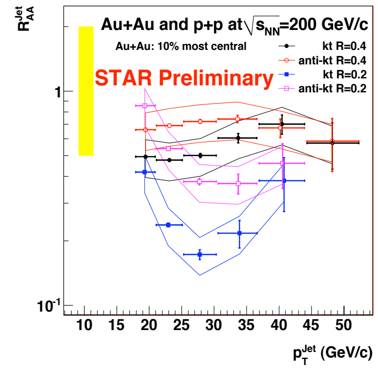
We can not have both!

My take on that: **At lower trigger p_T we are dominated by "bulk correlations"!**

Remark: More quantitative studies needed, but I think we have all the tools/measurements to answer this unambiguously!

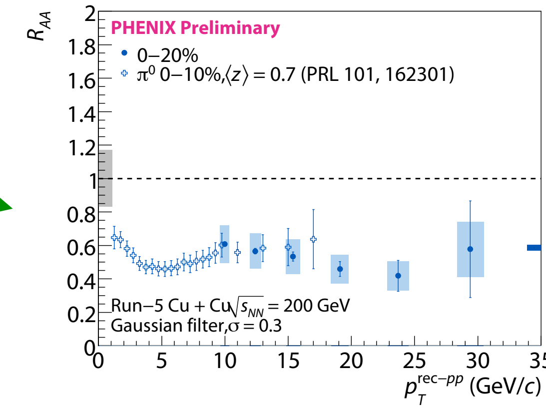
Discussion

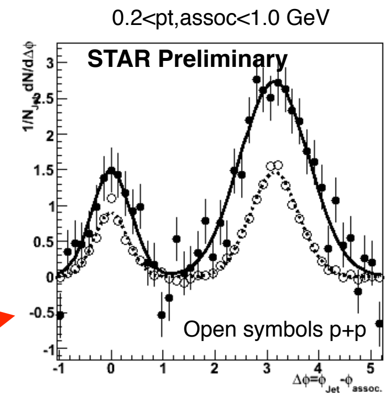


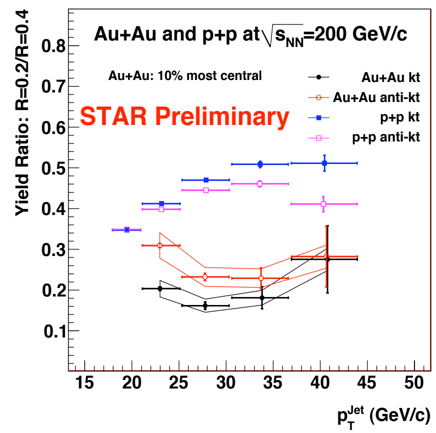


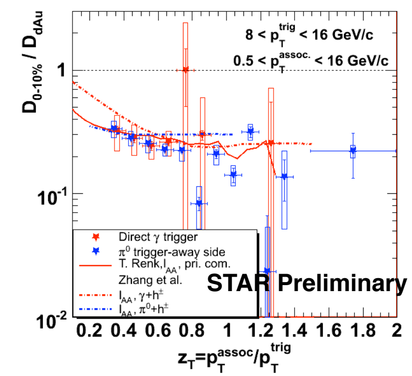
(?)

Algorithmic differences



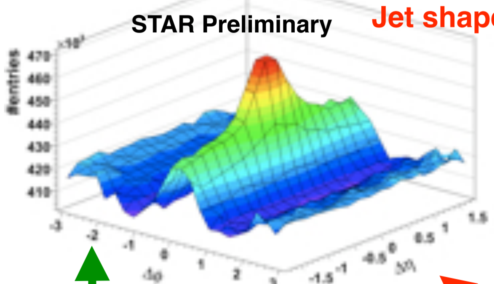






Methodical issues or bulk effects (v3)!?
Initial effect !?
Tests possible with 62 vs. 200 GeV!
Ridge in JH!?
Jet shapes!

(?)



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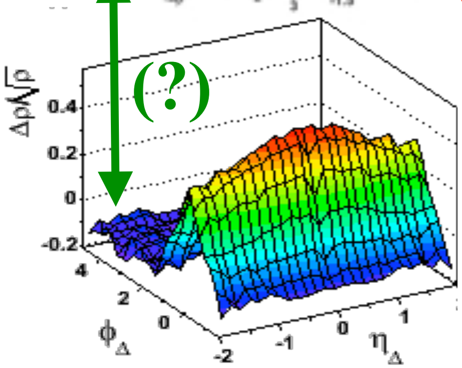
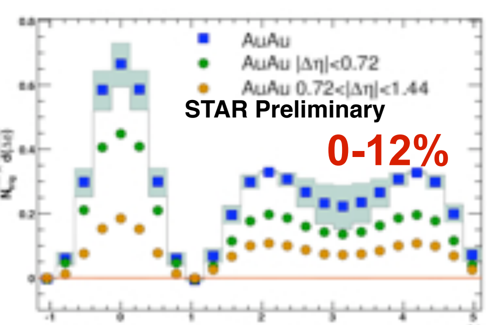


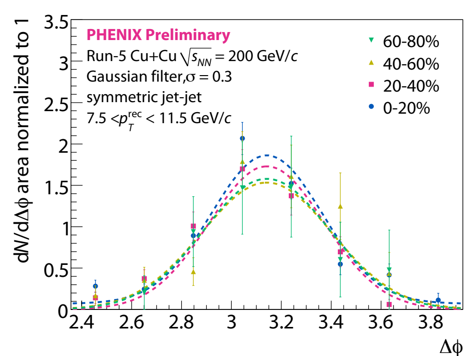
At low pT, we are maybe not looking at jet physics!
Methodical issues or bulk effects (v3)!?

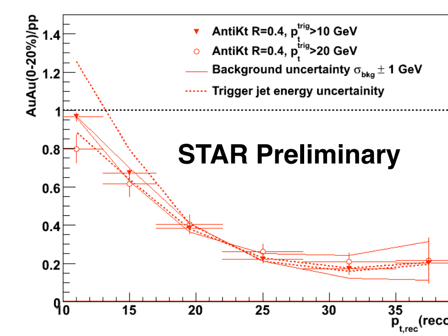
(?)

(?)

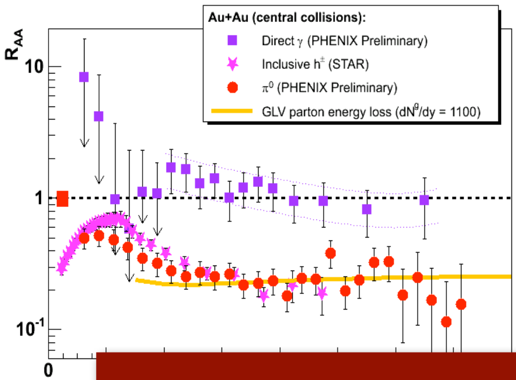
Bias or broadening? (can be tested with JH)

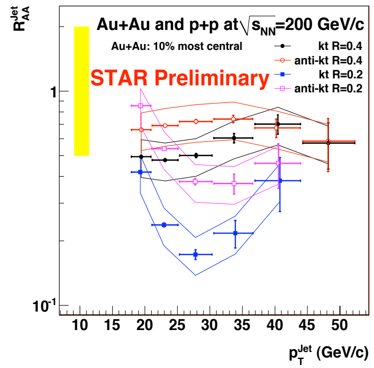






Discussion





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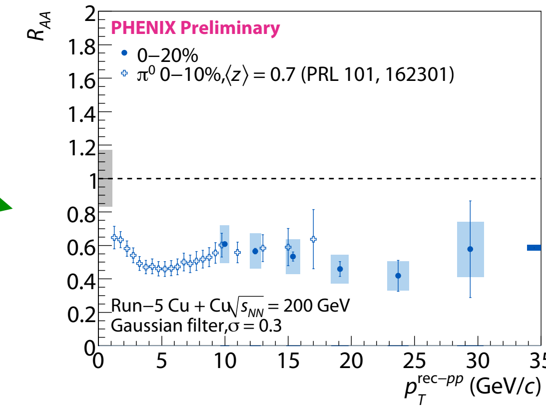
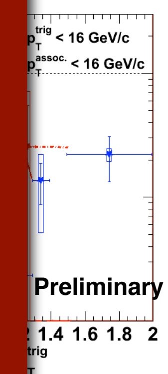
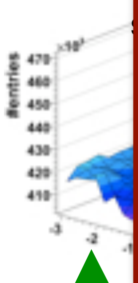
Algorithmic differences





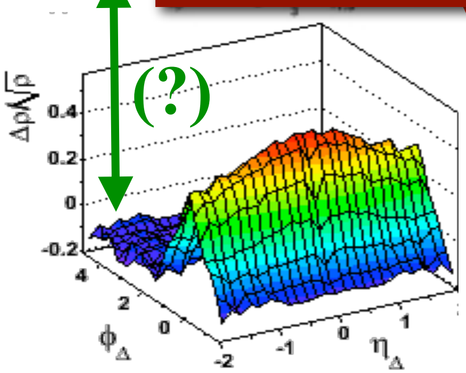


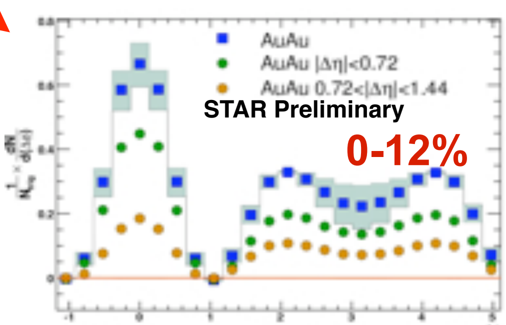
Summary from RHIC:

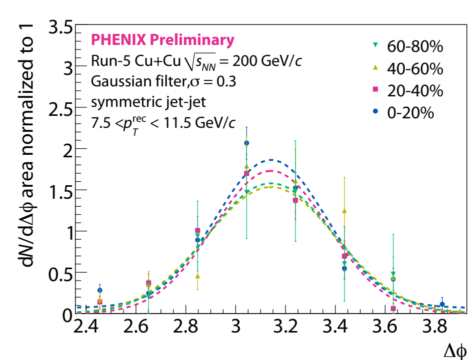
(Light flavor) Jet quenching measurements at RHIC can be (qualitatively) explained in a consistent picture by a significant broadening and softening of the jet structure caused by (pQCD-like) partonic energy loss in the medium!

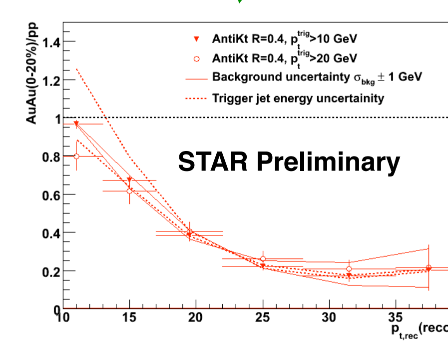
(?)

or bulk effects (v3)!?



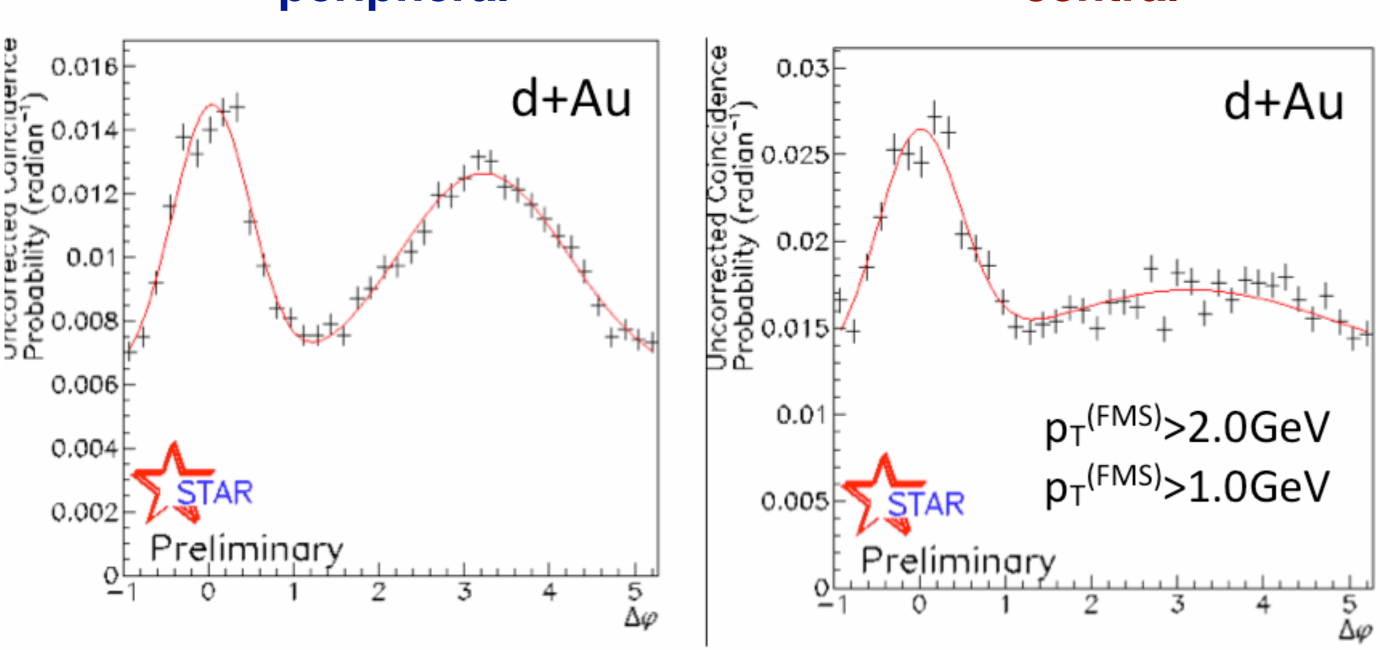


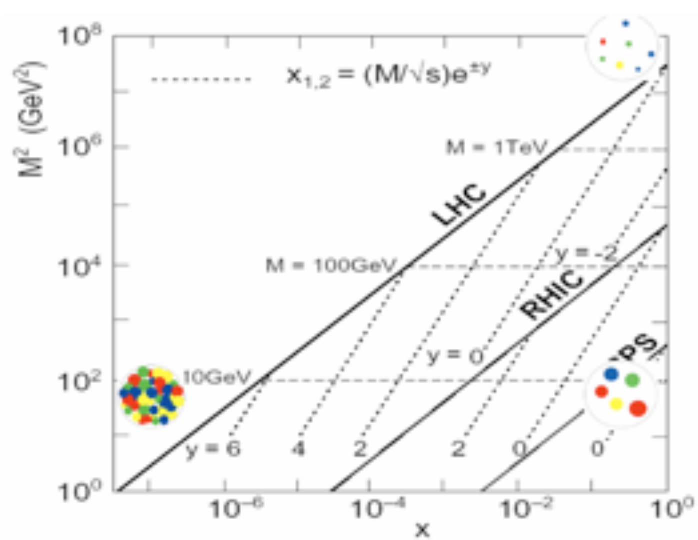




A word of caution: Initial state effects at LHC ...

peripheral central





y~3 at RHIC probes similar x as at mid-rapidity at LHC

Suppression/de-correlation at y~3 in central d+Au collisions at RHIC! Onset of CGC !?

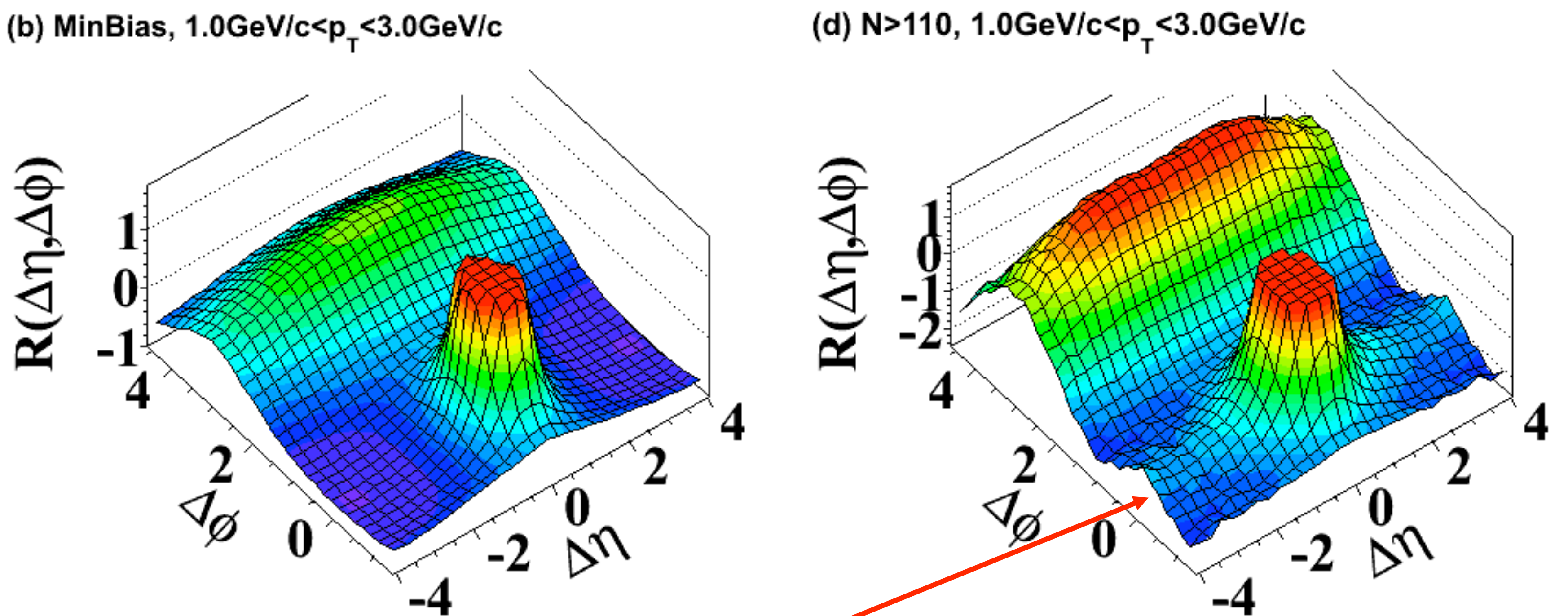
Can we learn more about the initial effects from other measurements before the p+Pb run?

The “Ridge” in p+p collisions at the LHC ...

CMS, CERN Seminar, Sept. 21, 2010

Intermediate p_T: 1-3 GeV/c

MinBias | high multiplicity (N>110)



Pronounced structure at large δη around δφ ~ 0 !

Is the ridge in p+p caused by the CGC ? Onset of CGC at same x measured at forward rapidity's at RHIC ?

(for example A. Dumitru and J. Jamal @ RBRC Workshop March 2010)

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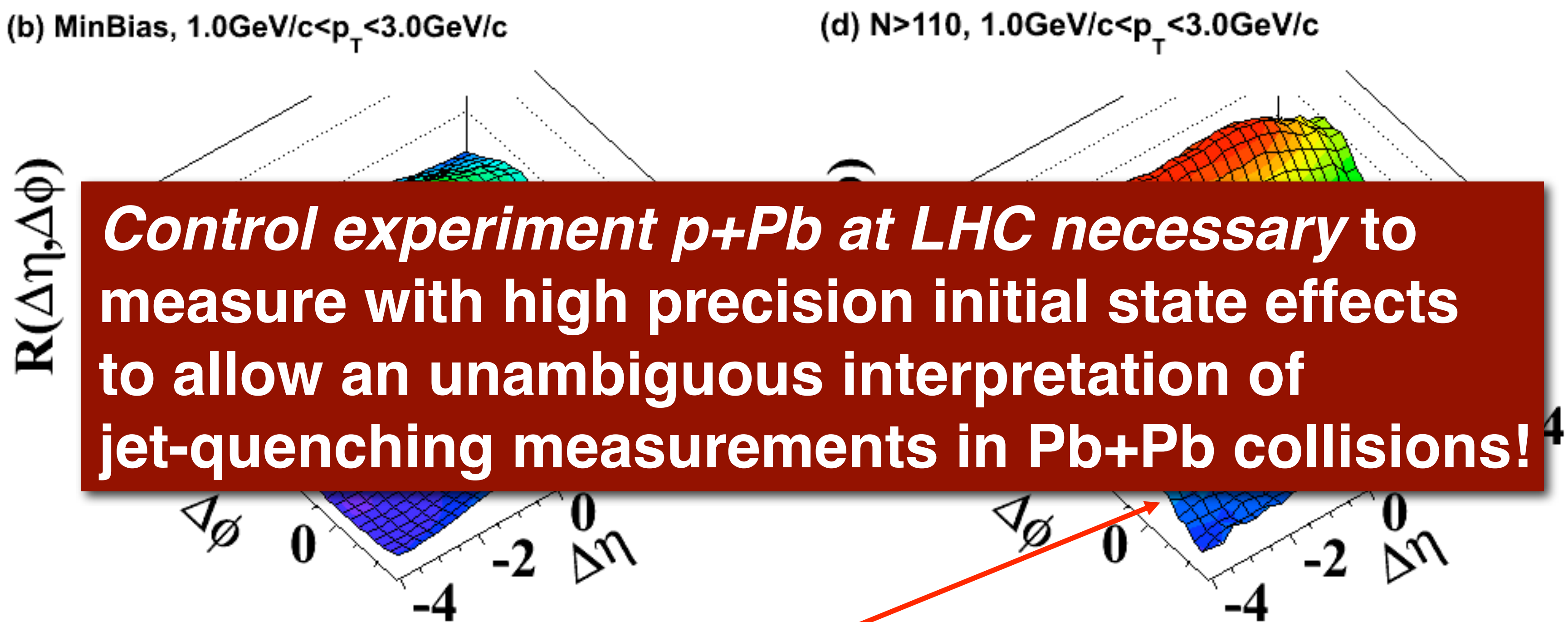

Control experiment p+Pb at LHC necessary **to measure with high precision initial state effects to allow an unambiguous interpretation of jet-quenching measurements in Pb+Pb collisions!**

Pronounced structure at large δη around δϕ ~ 0 !

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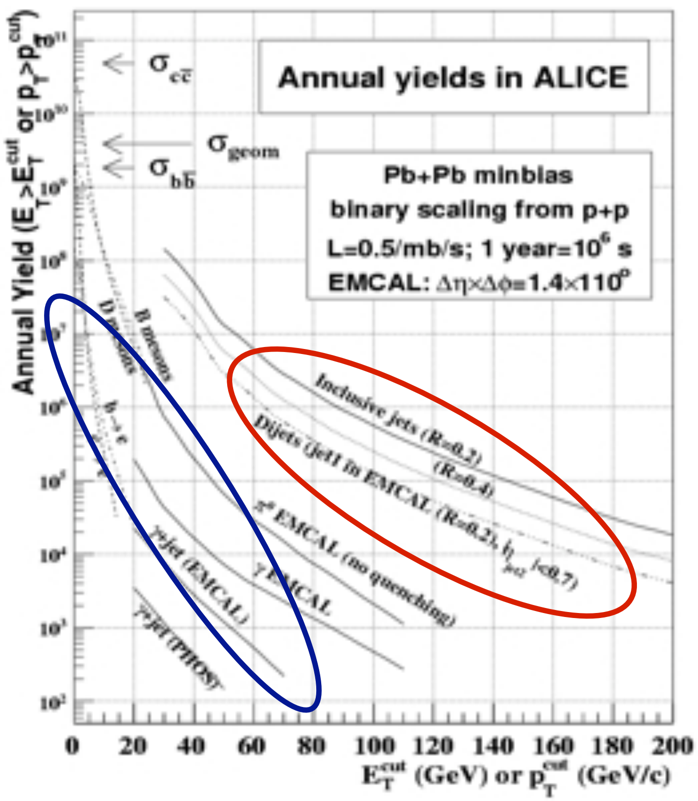
Summary

Landscape of hard probes:



Qualitative picture (so far) from RHIC:
Jet-quenching measurements can be "consistently" explained by jet-broadening/softening due to radiative energy loss in the medium!

Large kinematical reach and precise (full) jet measurements at the LHC:
⇒ Quantitative constraints on underlying partonic energy loss mechanisms (for light quarks)!

RHIC and LHC jet measurements will be complementary!

But this is just the start!

The landscape of hard probes is rich at the LHC (and RHIC II)!

Measure heavy quark energy loss (b-tagged jets), still open theoretical issue to describe heavy and light flavor energy loss in a consistent framework!