Using particle jet correlations to probe the medium at RHIC

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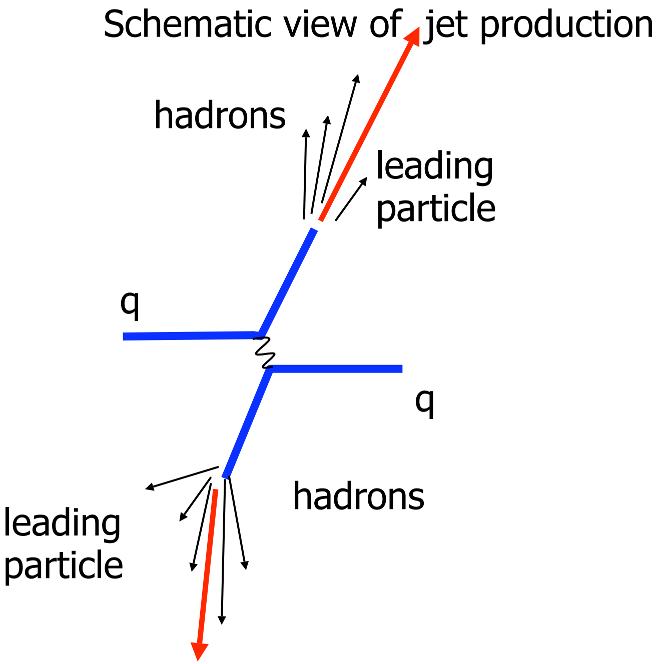
Using “jets” as probes

- Early production in parton-parton scatterings with large Q^2.
- Direct interaction with partonic phases of the reaction



Using "jets" as probes

- Early production in parton-parton scatterings with large Q^2.
- Direct interaction with partonic phases of the reaction

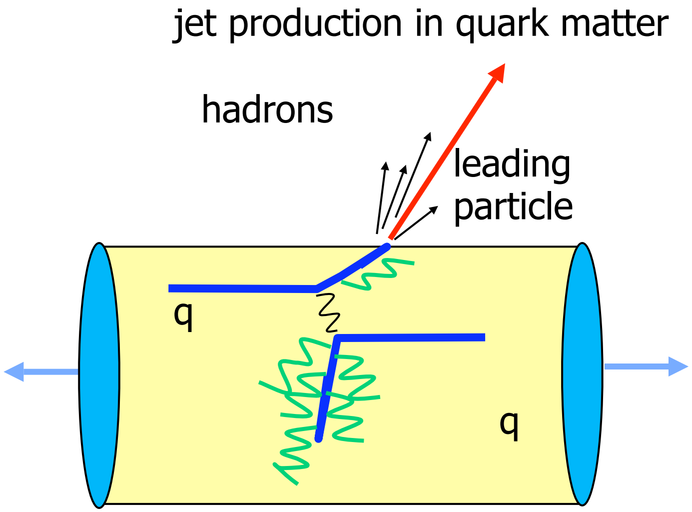
Therefore use "jets" as probes at RHIC

◆ attenuation or absorption of jets: "jet quenching"

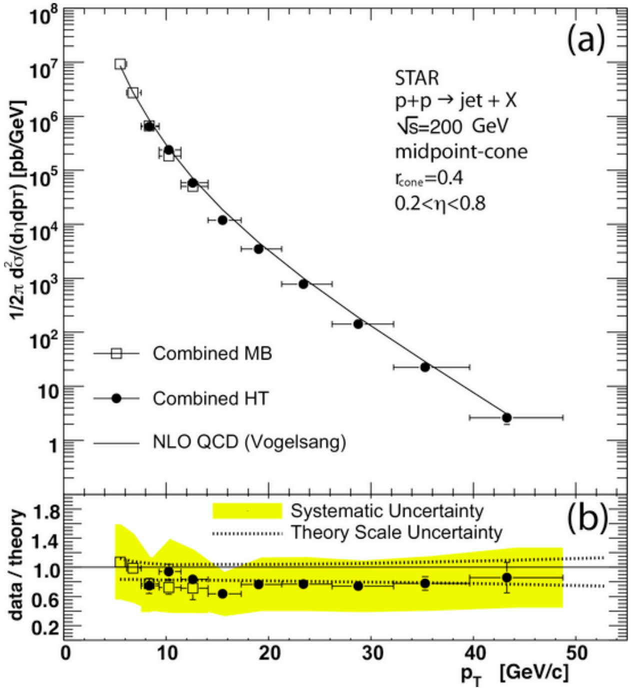
◆ suppression of high p_T hadrons

◆ modification of angular correlation

◆ changes of particle composition



Jets – a calibrated probe?



STAR : PRL 97 (2006) 252001

Jet production in p+p understood in pQCD framework

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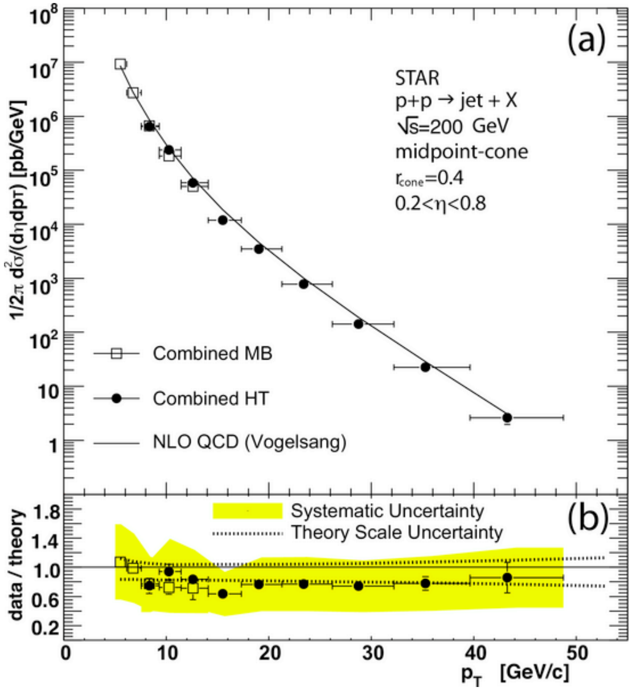

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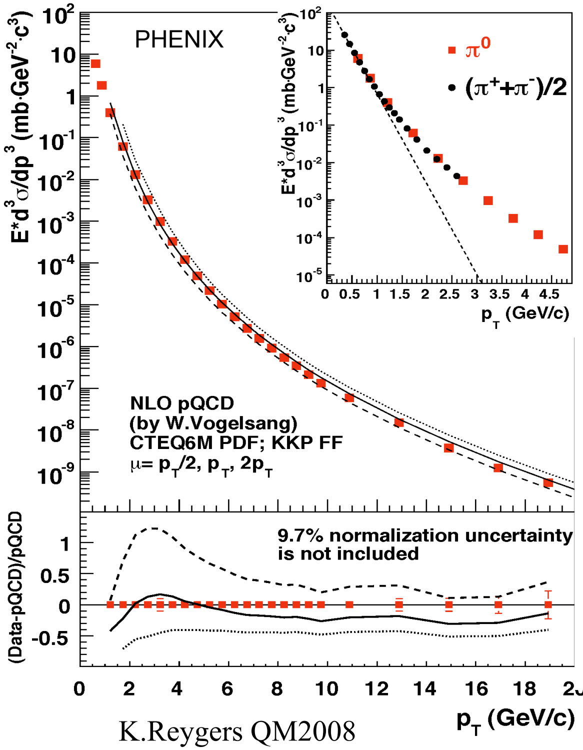
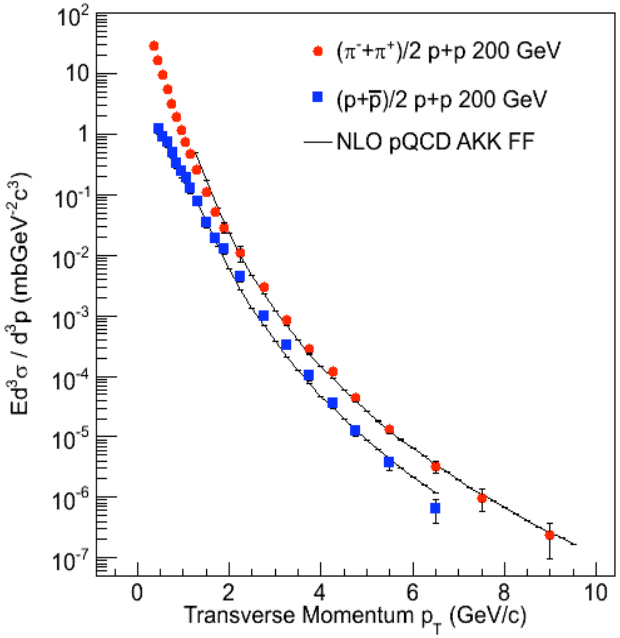


K.Reygers QM2008



STAR : PLB 637 (2006) 161

S. Albino et al, NPB 725 (2005) 181

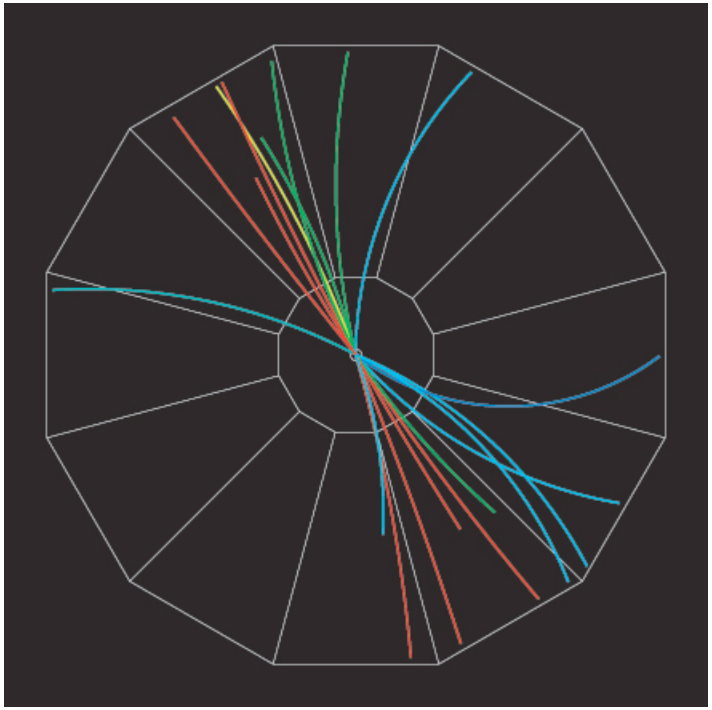
Jet production in p+p understood in pQCD framework

Particle production in p+p also well modeled.

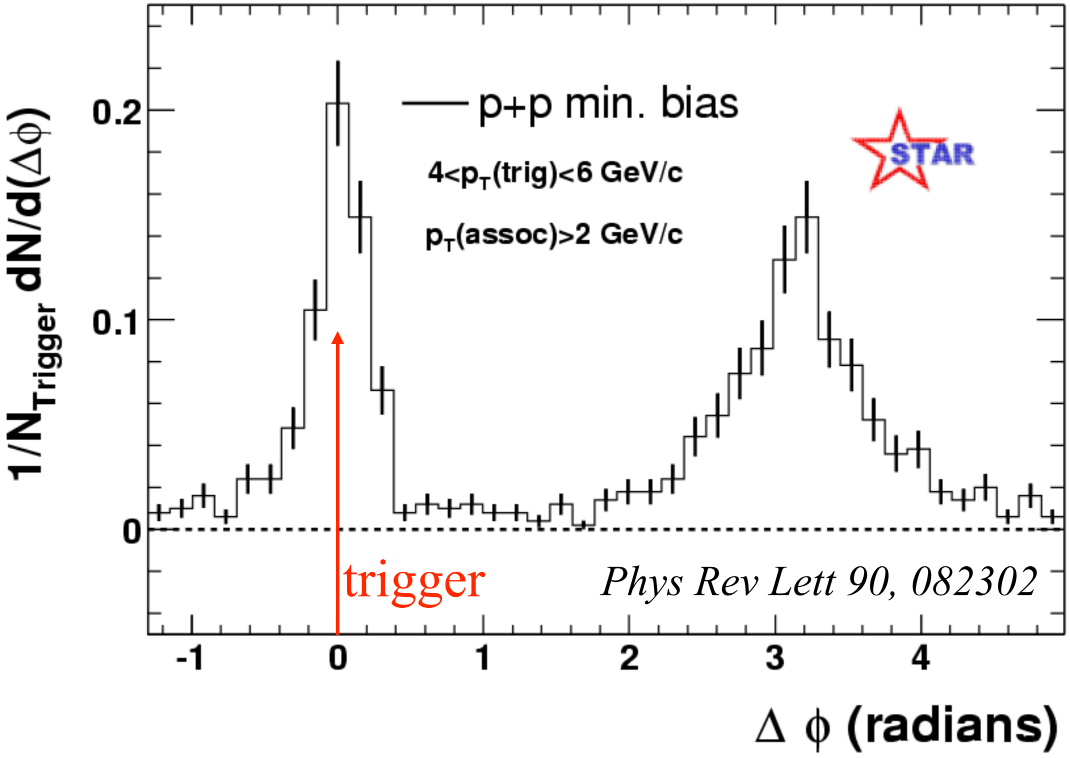
Seems we have a reasonably calibrated probe

Jets in Au+Au collisions!

p+p → dijet



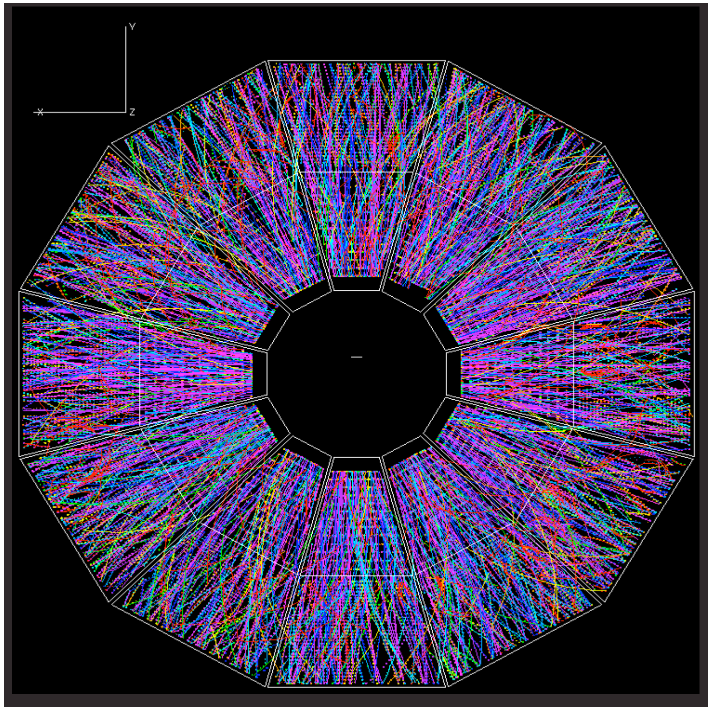
min. bias p+p collisions



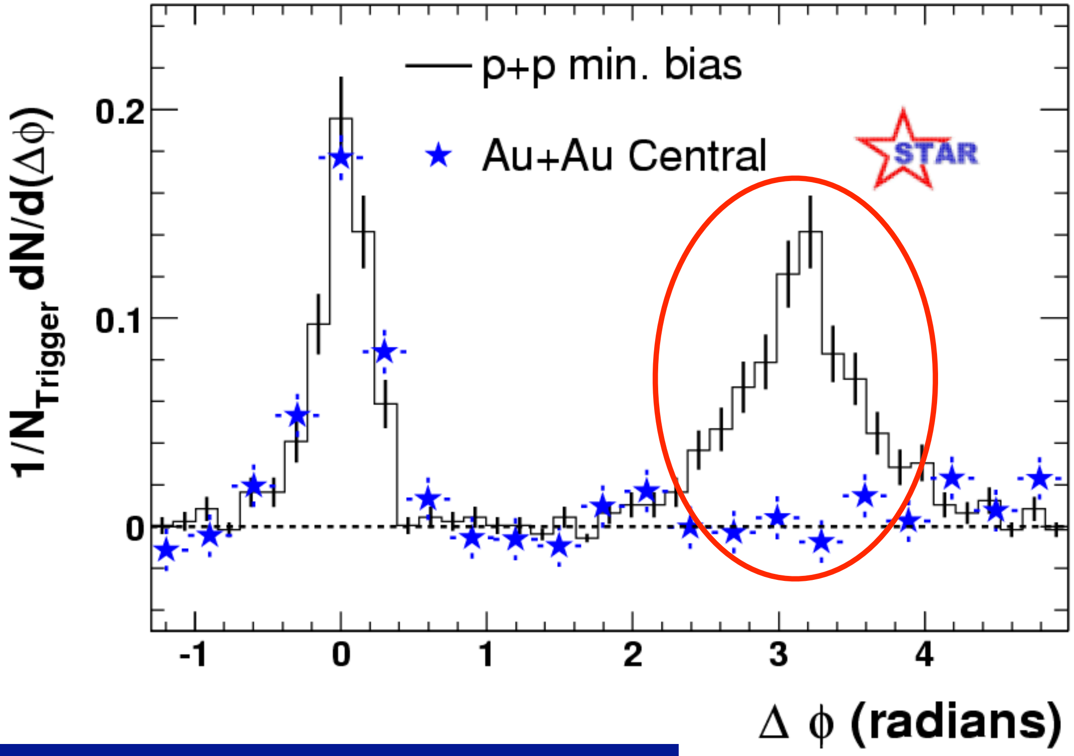
- Trigger: highest p_T track
- $\Delta\phi$ distribution:

Jets in Au+Au collisions!

p+p → dijet

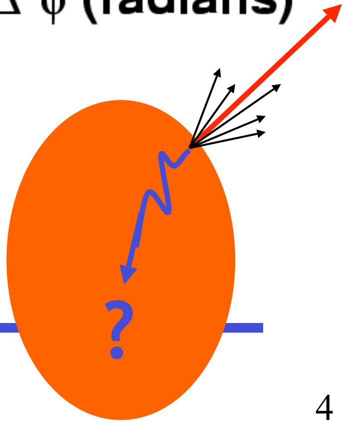


central Au+Au collisions



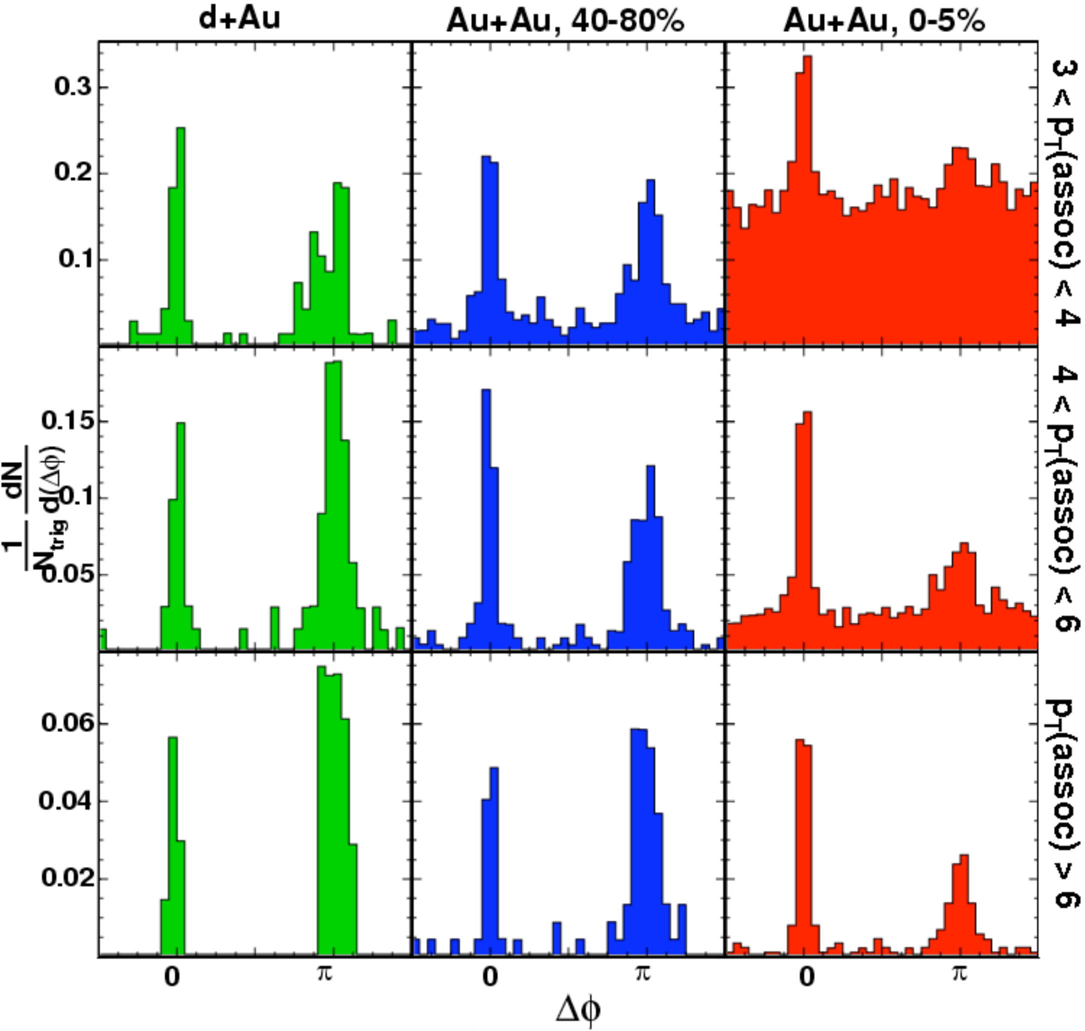
$\Delta\phi \approx 0$: central Au+Au similar to p+p

$\Delta\phi \approx \pi$: strong suppression of back-to-back correlations in central Au+Au



Observation of “Punch through”

$8<p_T^{trig}<15$ GeV/c



STAR PRL 97 (2006) 162301

If use high-p_T triggers:

- Away-side peak re-emerges
- Smaller in Au-Au than d-Au
- Virtually no background

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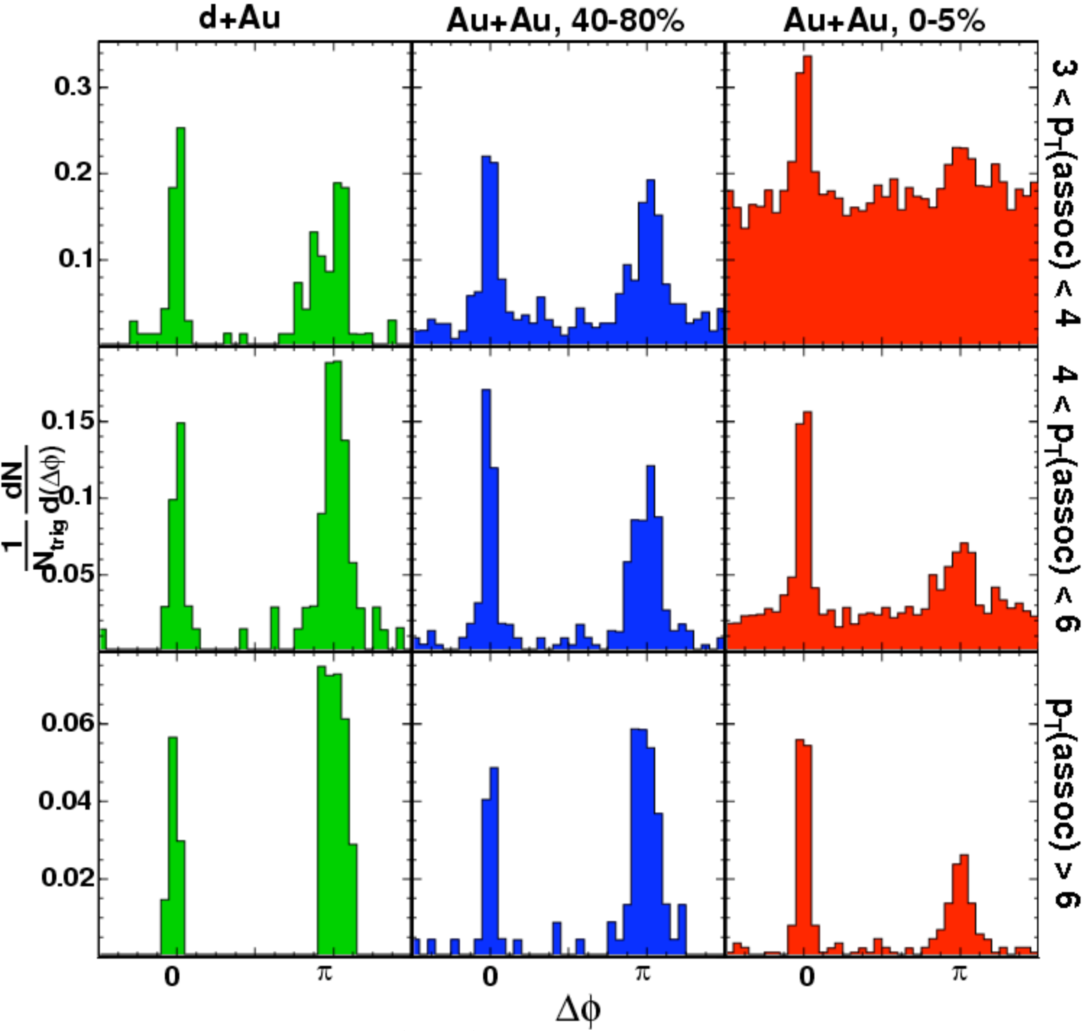

STAR PRL 97 (2006) 162301

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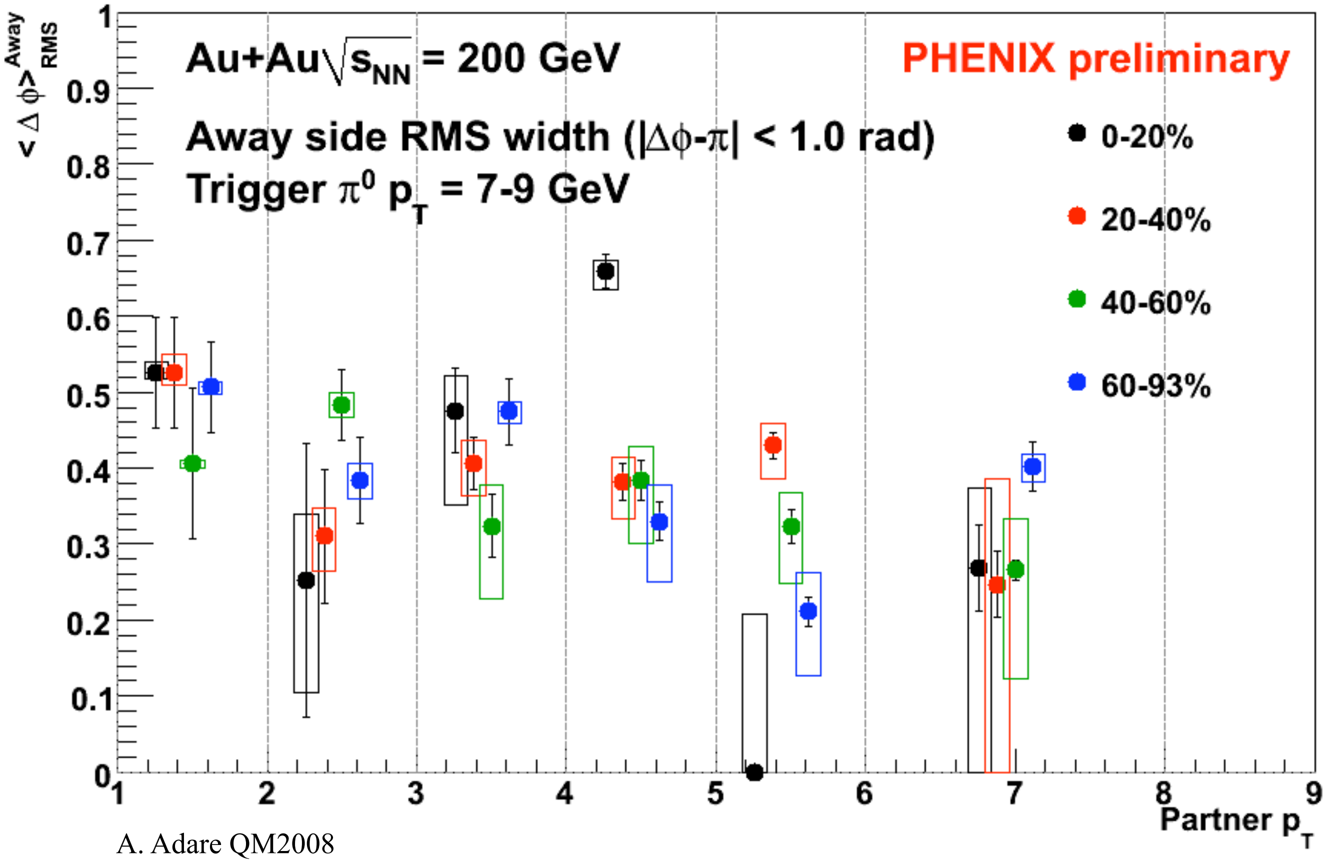
High energy jets *"punch through"* the medium.

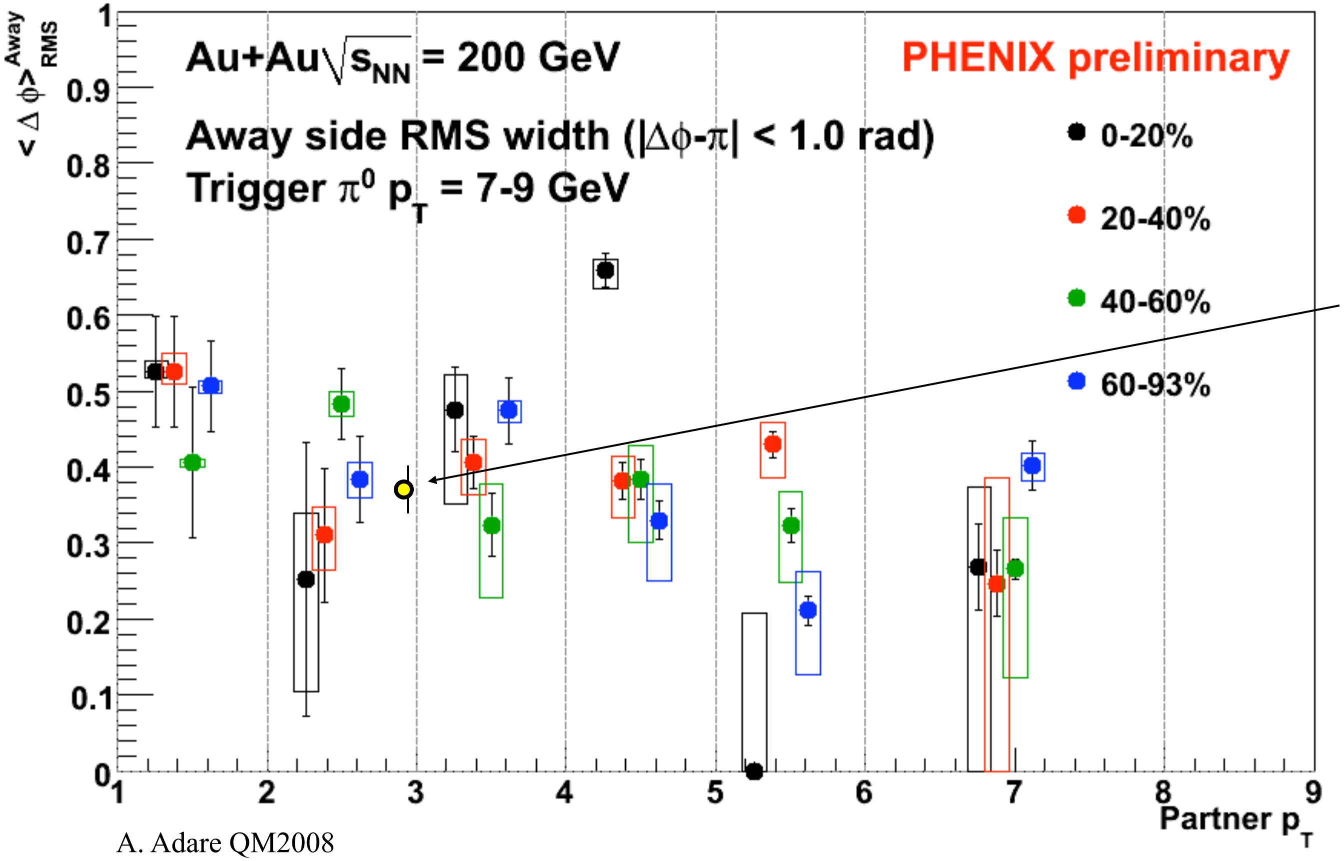
High p_T triggered away side RMS width



A. Adare QM2008

RMS Width - centrality independent

High p_T triggered away side RMS width



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- p+p π^0-h:

p_T^{trig} = 6.5-8 GeV/c

p_T^{assoc} = 1.4-5 GeV/c

RMS = 0.350 ± 0.03

PHENIX:

Phys Rev D 74 072002

RMS Width - centrality independent

Consistent with p+p data

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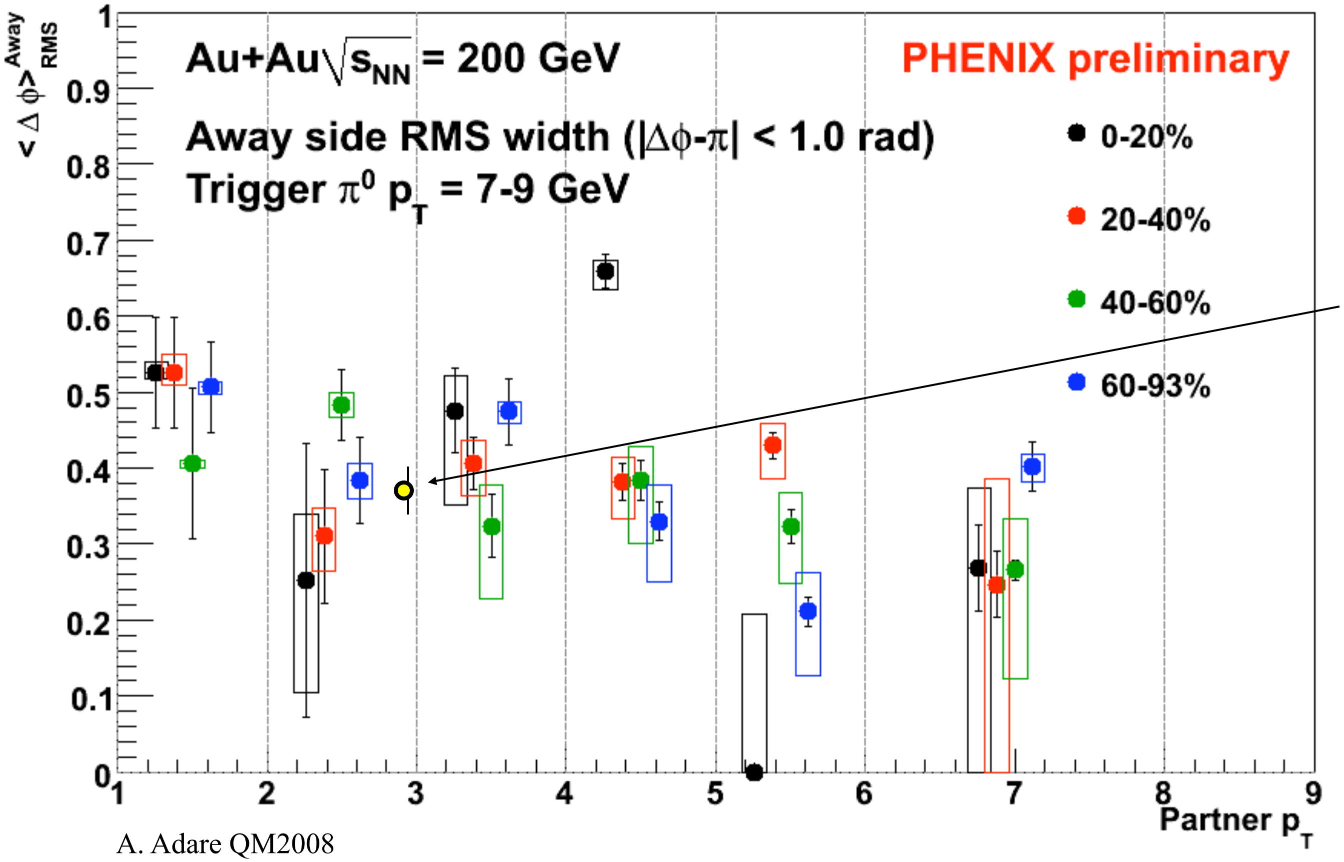

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Vacuum fragmentation?

Away-side di-hadron fragmentation functions

- Study medium-induced modification of fragmentation function due to energy loss
- Without full jet reconstruction, parton energy not measurable
  - z not measured ($z=p_{hadron}/p_{parton}$)
  - $z_T=p_{T,assoc}/p_{T,trig}$
- Di-hadron fragmentation function - di-hadron jet-like correlated yield to single hadron yield ratio

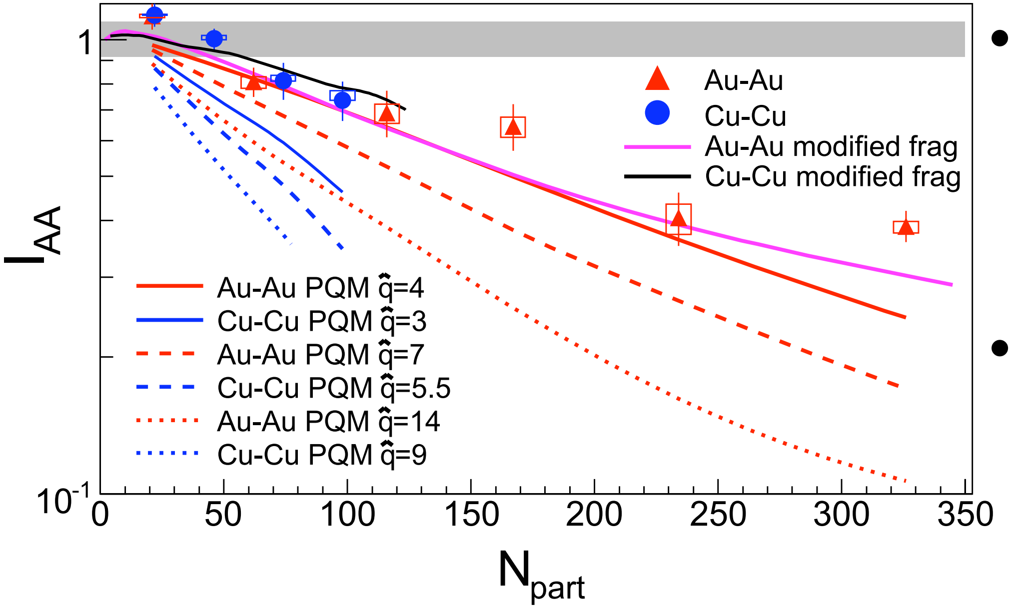
$$D^{h_1h_2}(z_T, p_T^{\rm trig}) = p_T^{\rm trig} \frac{d\sigma_{AA}^{h_1h_2}/dp_T^{\rm trig}dp_T}{d\sigma_{AA}^{h_1}/dp_T^{\rm trig}}$$

$$I_{AA} = \frac{D_{AA}(z_T, p_T^{\rm trig})}{D_{pp}(z_T, p_T^{\rm trig})}$$

Away-side di-hadron fragmentation functions

H. Zhong et al., PRL 97 (2006) 252001
C. Loizides, Eur. Phys. J. C 49, 339-345 (2007)

$6 < p_{T\ \mathrm{trig}} < 10$ GeV



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- Inconsistent with *Parton Quenching* Model calculation
- *Modified fragmentation* model better

O. Catu QM2008

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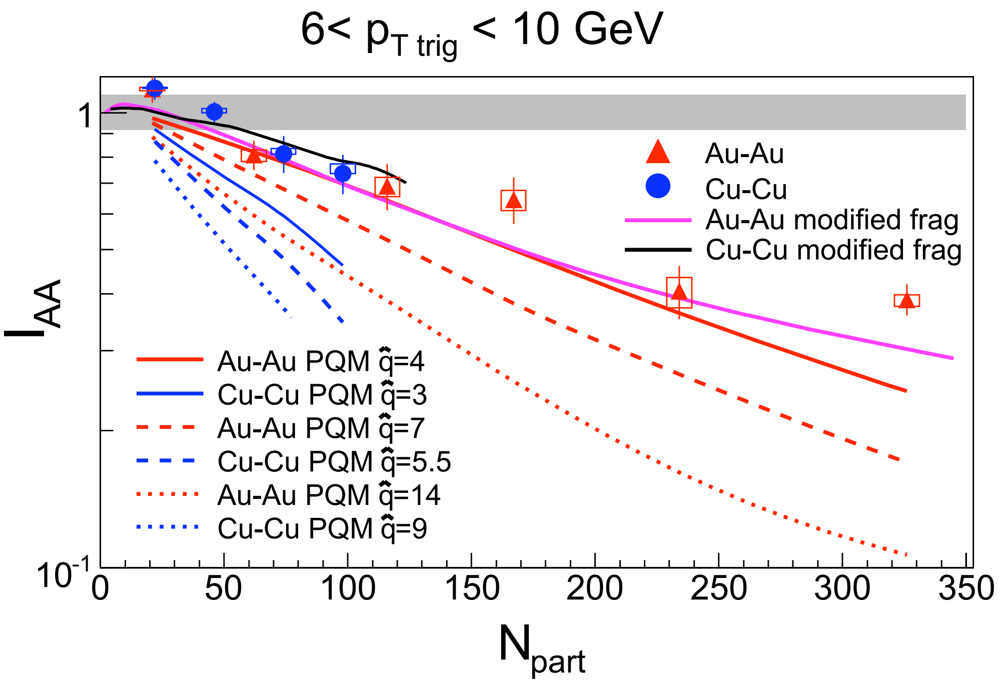

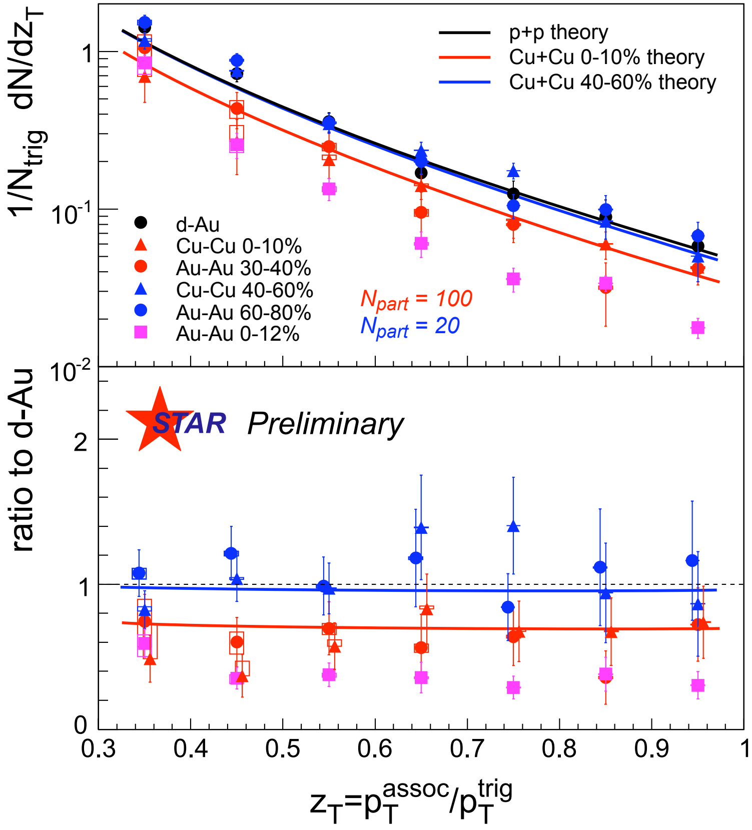

- Inconsistent with *Parton Quenching* Model calculation
- *Modified fragmentation* model better

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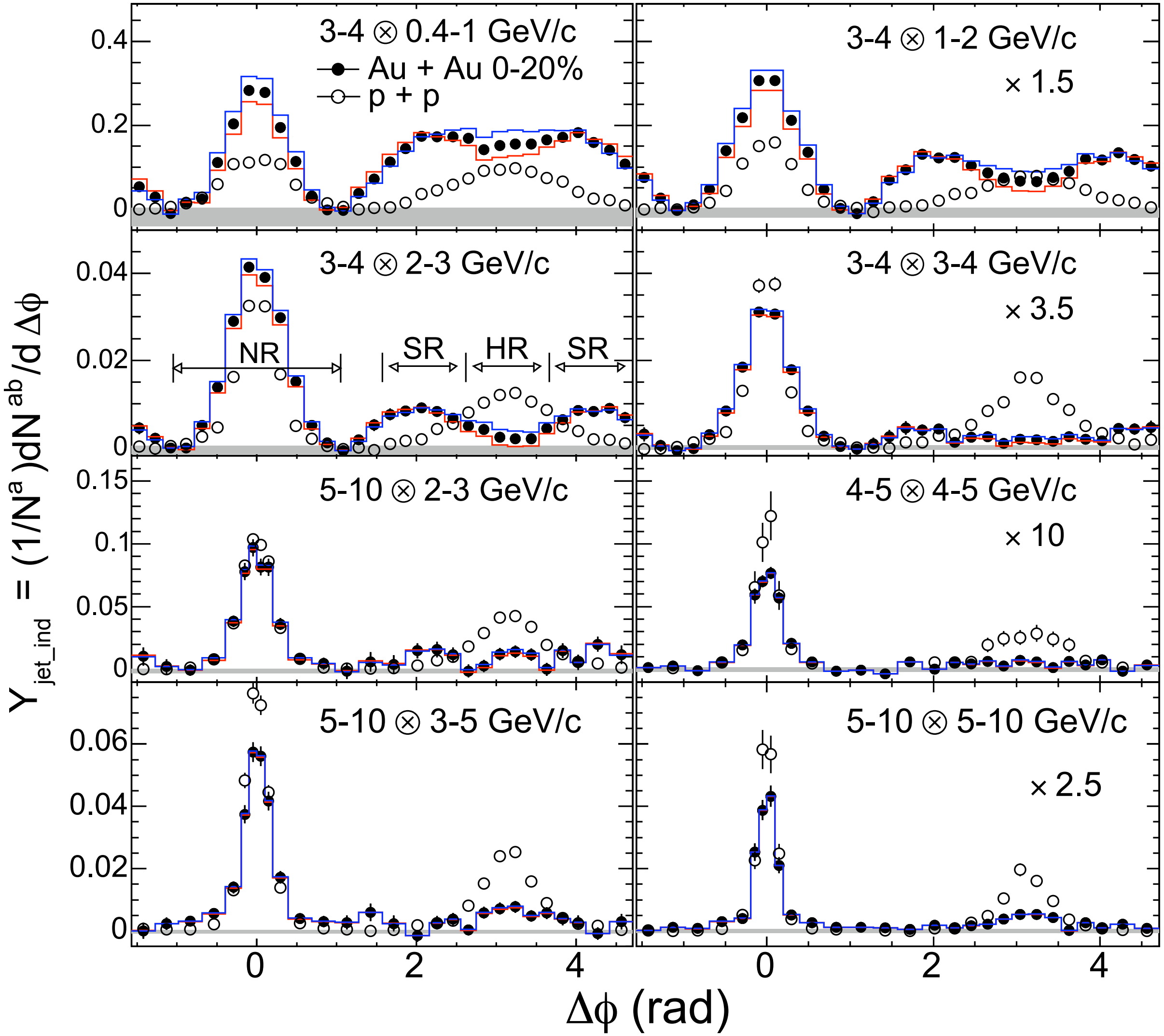
- Denser medium in central Au+Au than central Cu+Cu
- Similar medium for similar N_{part}

Vacuum fragmentation after parton E_{loss} in the medium

p_T evolution of di-hadron correlations

PHENIX Preliminary arXiv:0801.4545 [nucl-ex]

- As p_T decreases,
  - single-peak → double peak
  - Away-side yield increases

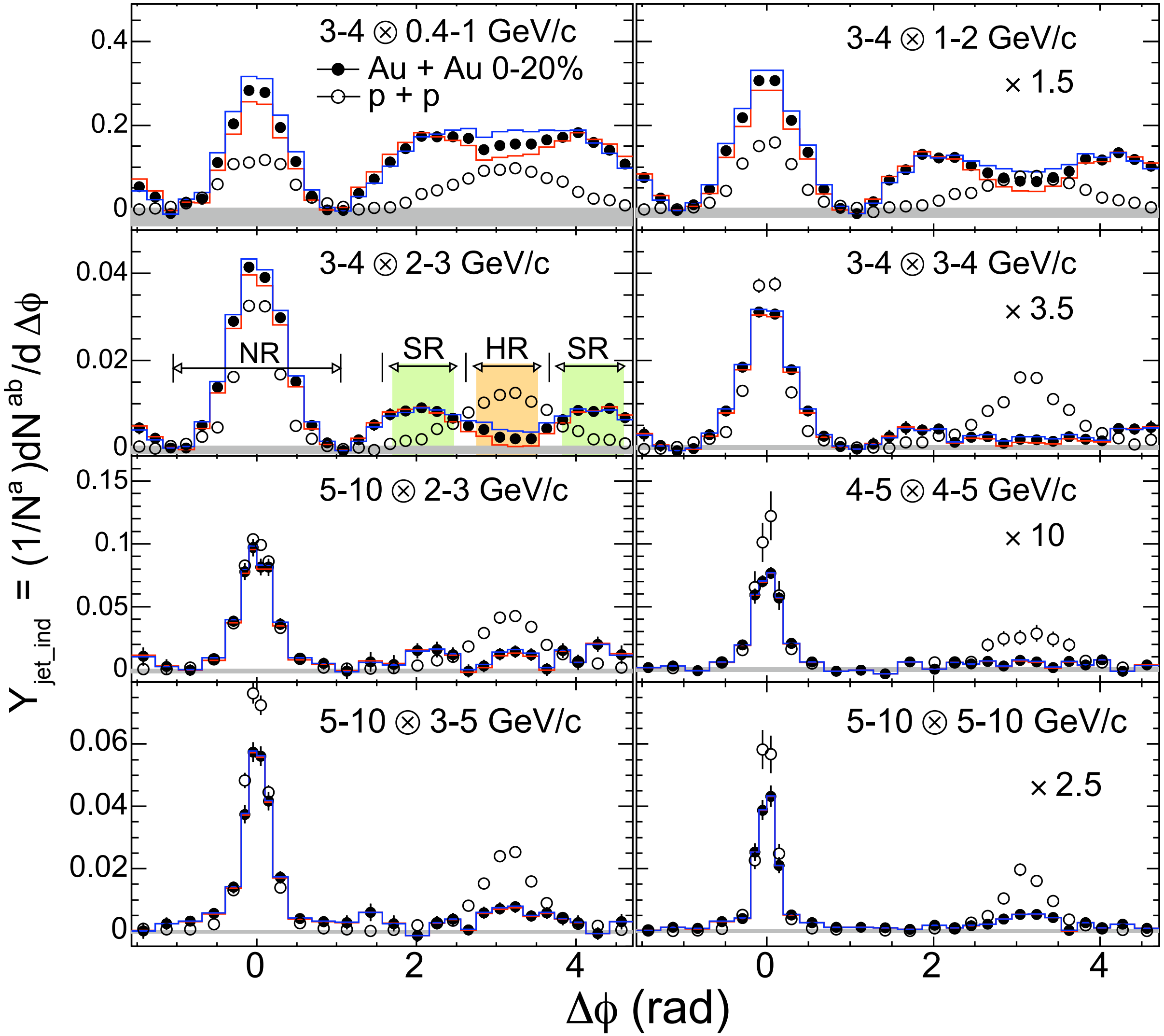


p_T evolution of di-hadron correlations

- As p_T decreases,
  - single-peak → double peak
  - Away-side yield increases

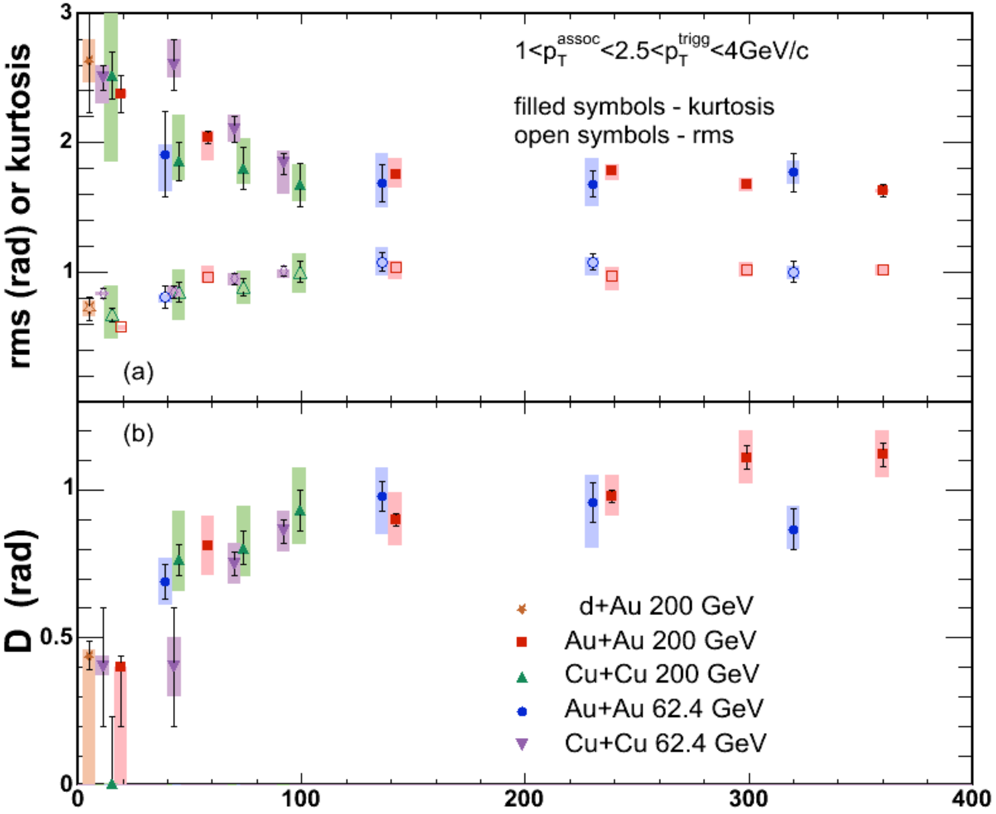
- Head region yield begins to dominate over shoulder region

PHENIX Preliminary arXiv:0801.4545 [nucl-ex]



Head and Shoulder evolution

h-h correlations $1 < p_{Ta} < 2.5 < p_{Tt} < 4$GeV/c

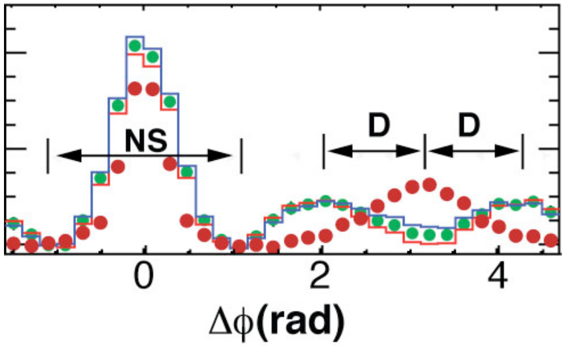


PHENIX PRL 98, 232302 (2007)

$$J(\Delta\phi) =$$

$$G(\Delta\phi) + G(\Delta\phi - \pi - D) + G(\Delta\phi - \pi + D)$$

PHENIX Phys.Rev. C 77, 011901 (2008)



$$\mu_n \equiv (\Delta\phi - \pi)^n, n = 2, 4 \ldots$$

$$rms \equiv \sqrt{\mu_2}$$

$$kurtosis \equiv \mu_4 \big/ \mu_2^2$$

Separation and width plateau for $N_{part} \geq 100$

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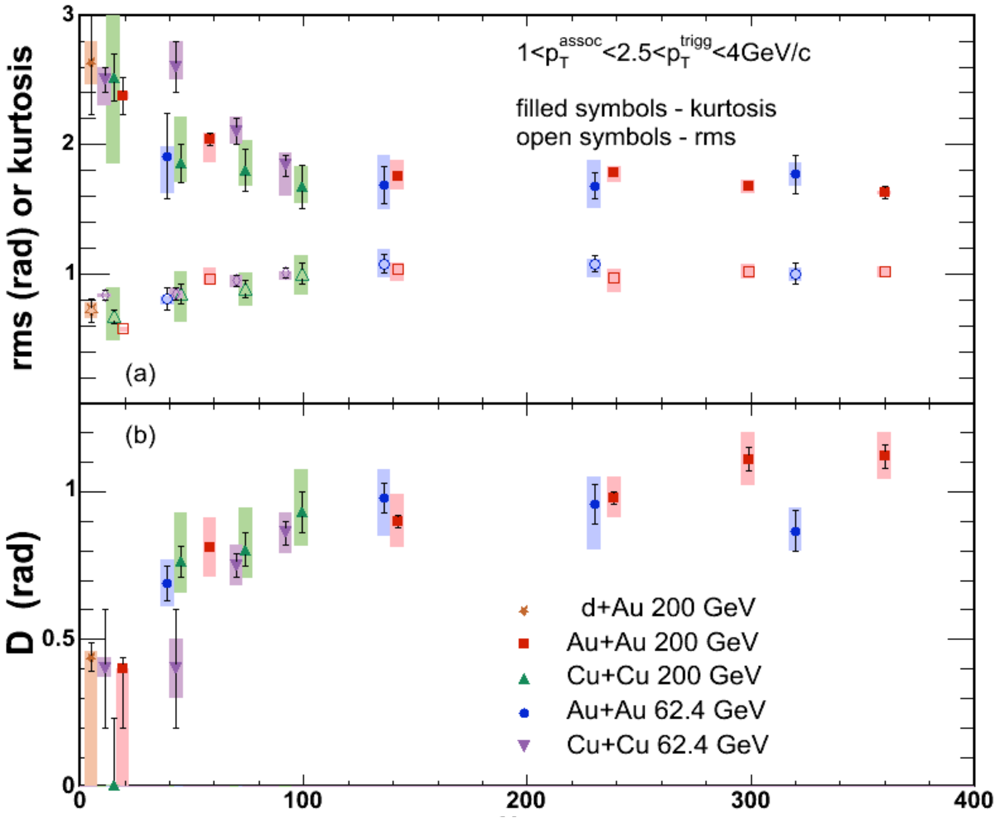

PHENIX PRL 98, 232302 (2007)

N_{part}

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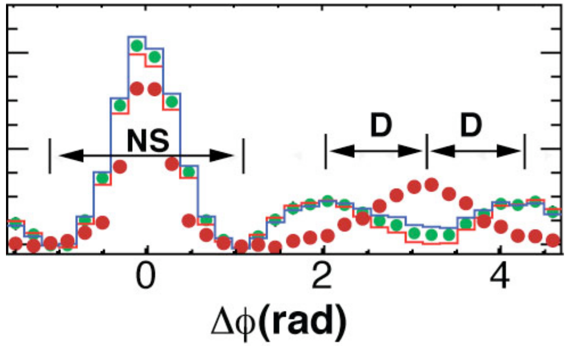

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Separation and width plateau for $N_{part} \geq 100$

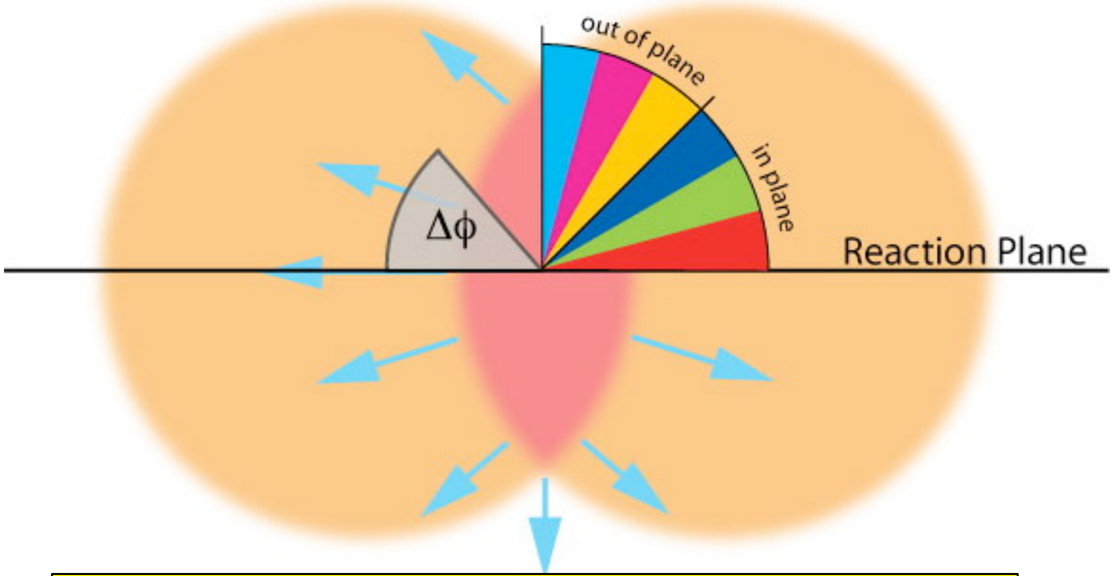
Shoulder due to away side jet interacting with medium

Path length dependencies

Non-central events have “elliptic” overlap geometries

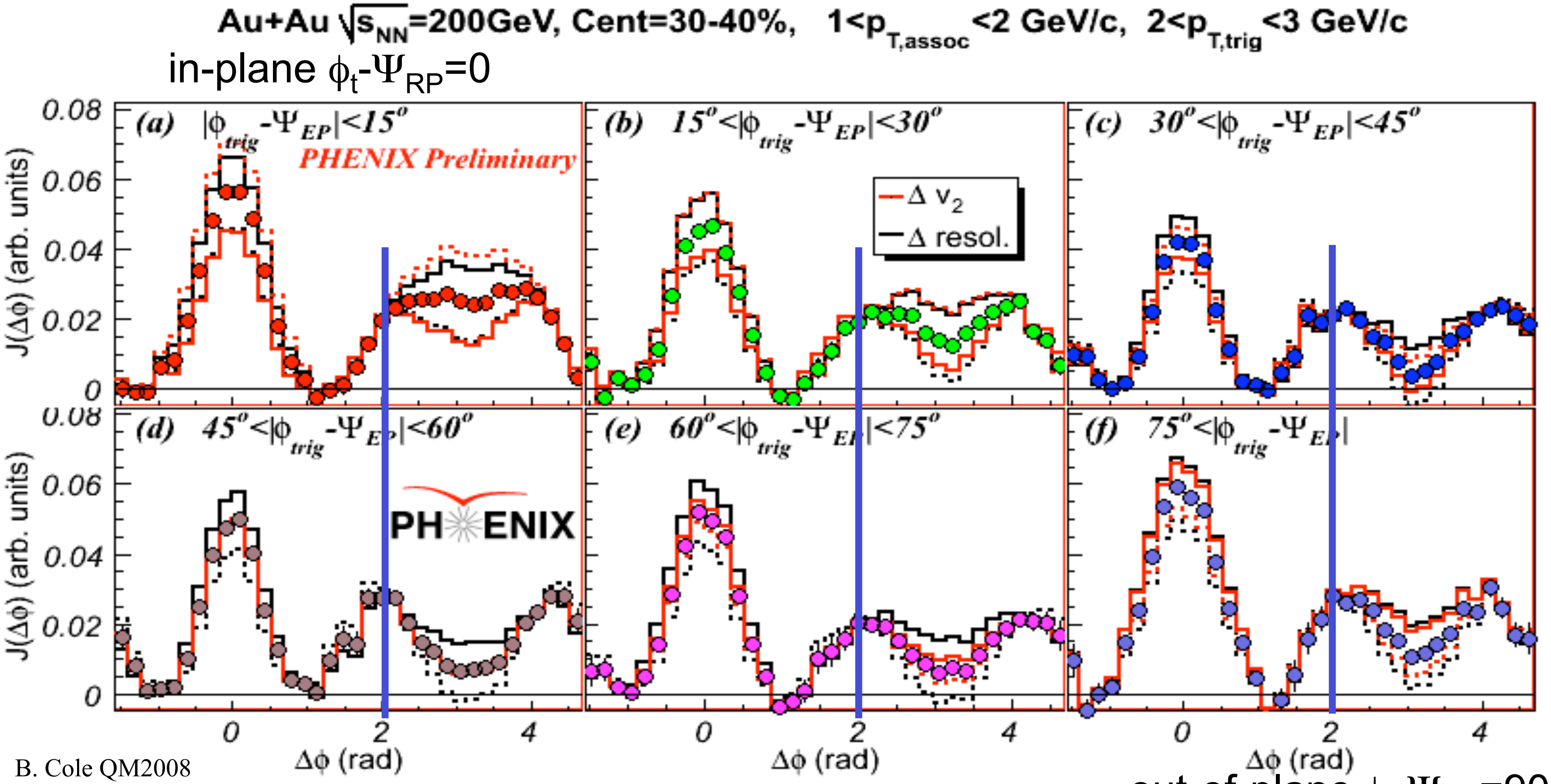
Measurements w.r.t reaction plane angle:

- Change path length
- Keep everything else same



Isolate effects due to path length

Path length effect on di-hadron correlation



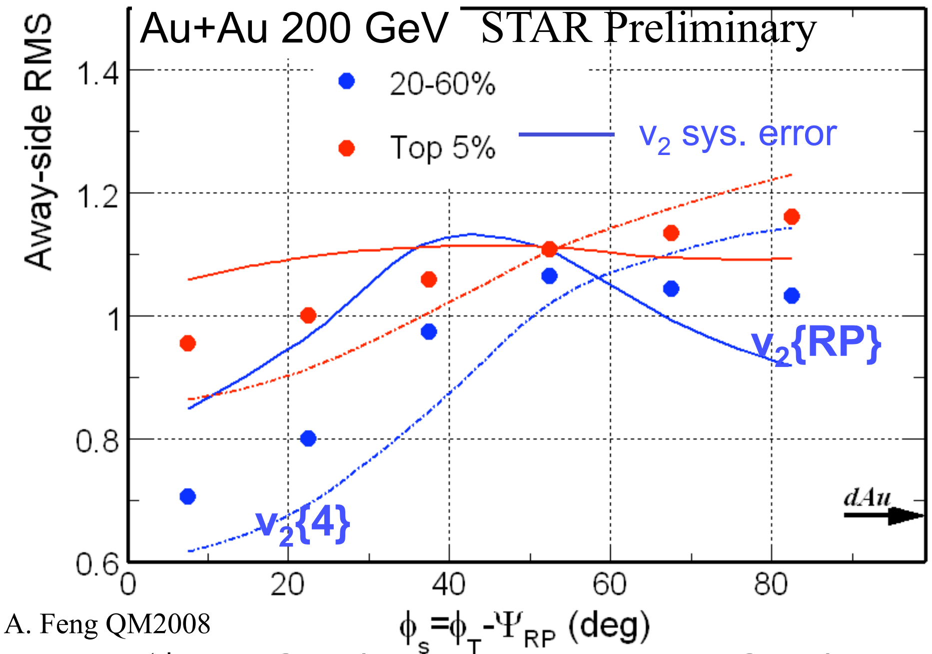
in-plane ϕ_t-Ψ_{RP}=0

B. Cole QM2008

out-of-plane ϕ_t-Ψ_{RP}=90°

- Near side peak unchanged
- Shoulder peaks emerge as ϕ_t - Ψ increases but are at fixed $\Delta\phi$
- Head peak (di-jet remnant) decreases as ϕ_t - Ψ_{RP} increases

Centrality and path length effects



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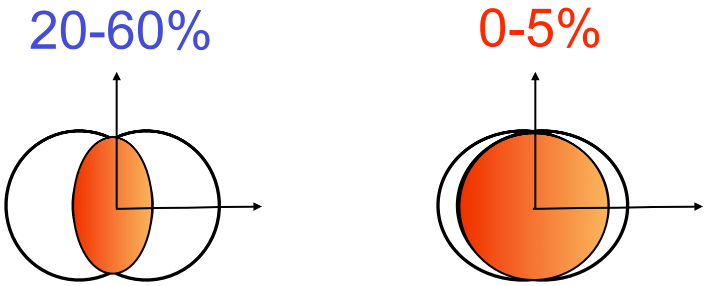
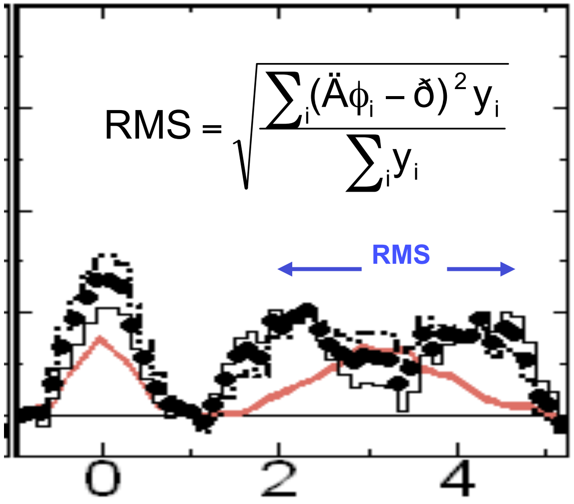
3< p_T^{trig} < 4 GeV/c, 1.0 < p_T^{asso} < 1.5 GeV/c





$$\mathrm{RMS} = \sqrt{\frac{\sum_i (Ä\phi_i - ð)^2 y_i}{\sum_i y_i}}$$

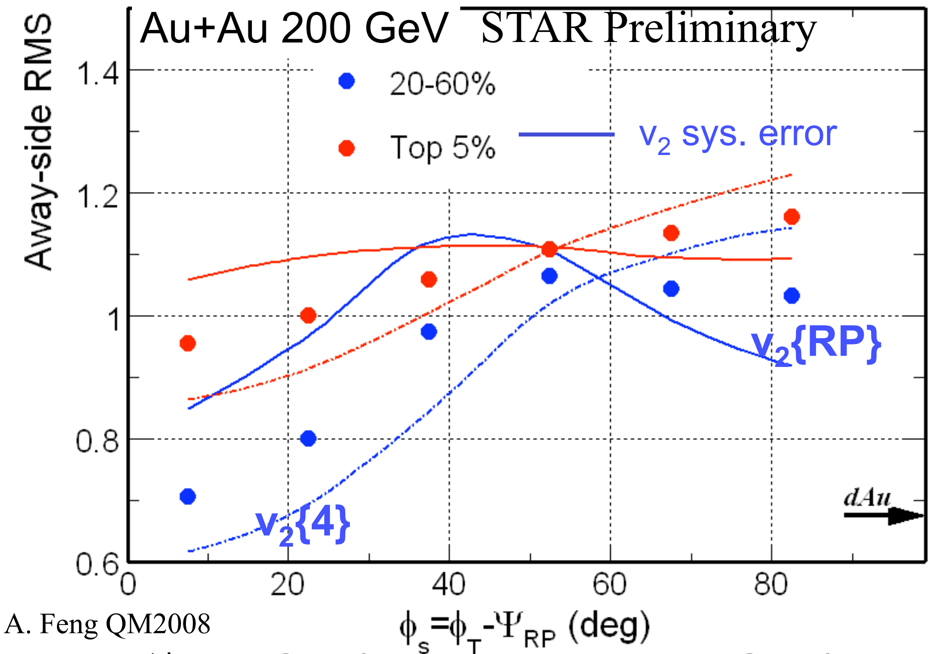
In-plane: 20-60% ~ d+Au

0-5% > d+Au

Out-of-plane: 20-60% ~ 0-5%

Au+Au > d+Au

Centrality and path length effects



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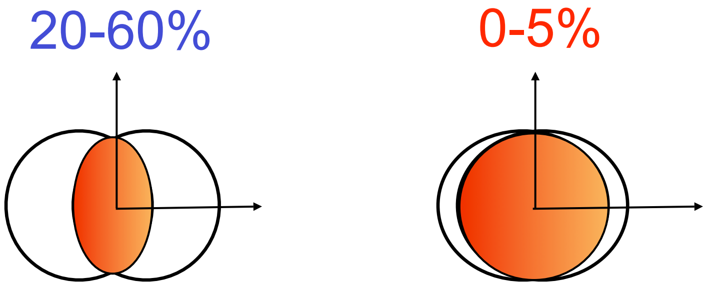

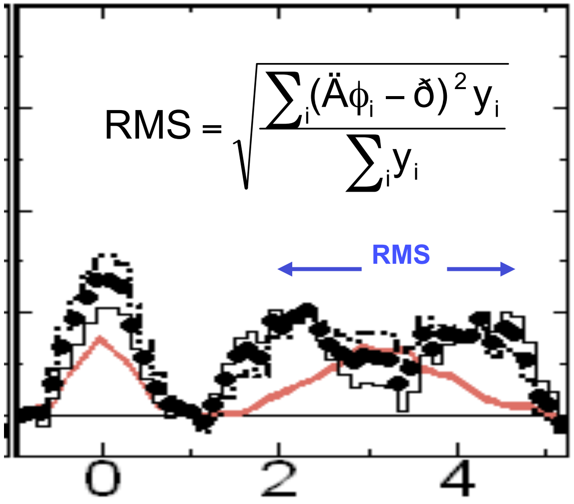

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In-plane: 20-60% ~ d+Au

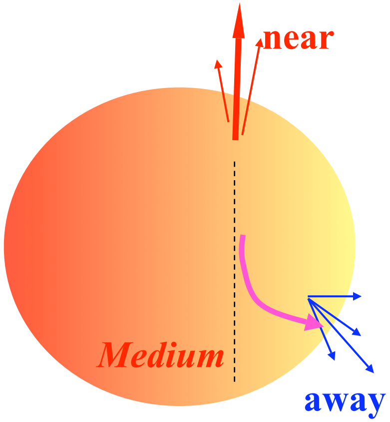
0-5% > d+Au

Out-of-plane: 20-60% ~ 0-5%

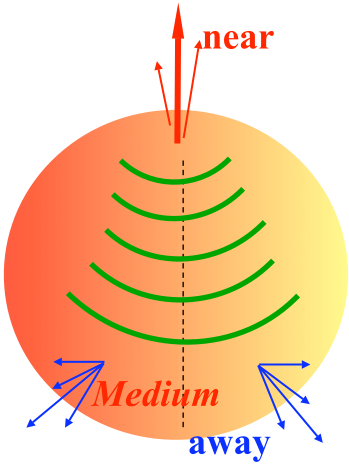
Au+Au > d+Au

Away-side features reveal path length effects

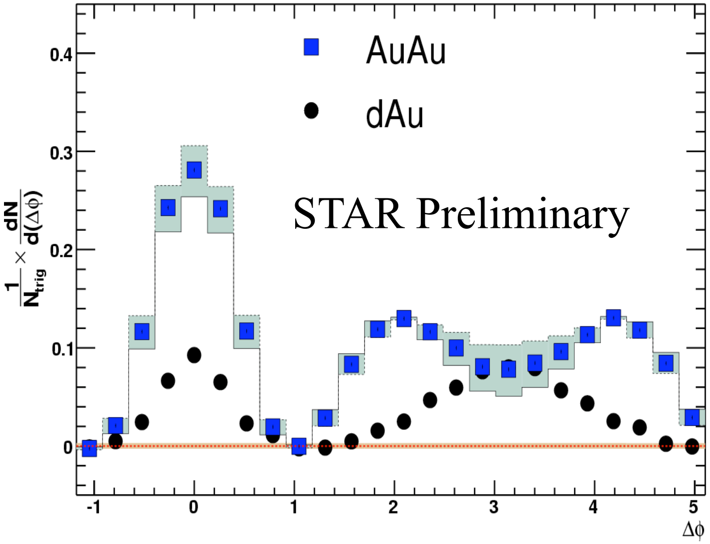
What causes shoulder peaks?



Deflected jets



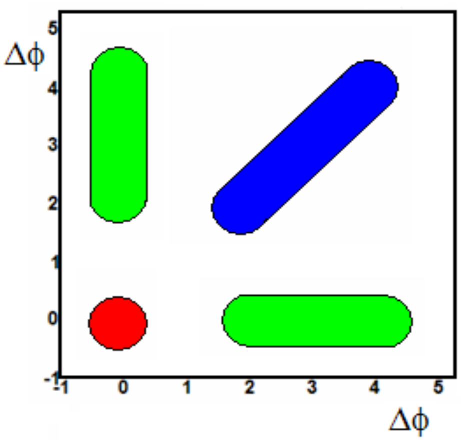
Conical Emission



Conical emission or deflected jets?

B. Mohnaty QM2008

What causes shoulder peaks?



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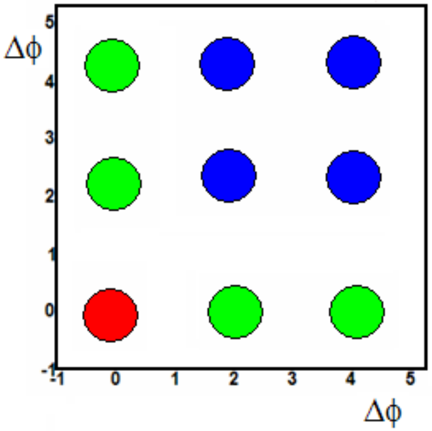

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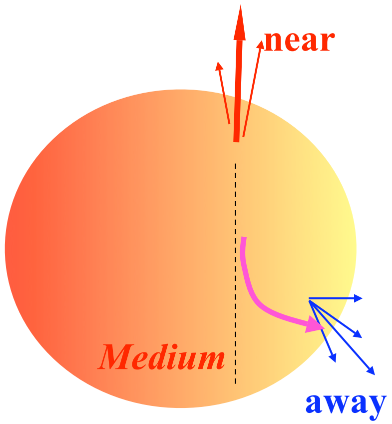

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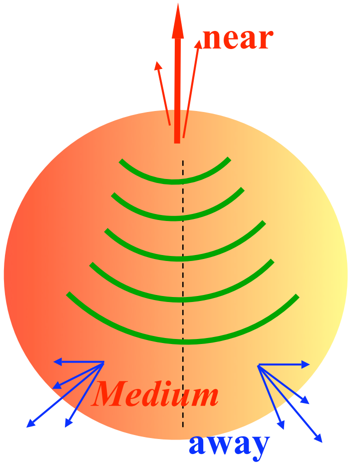
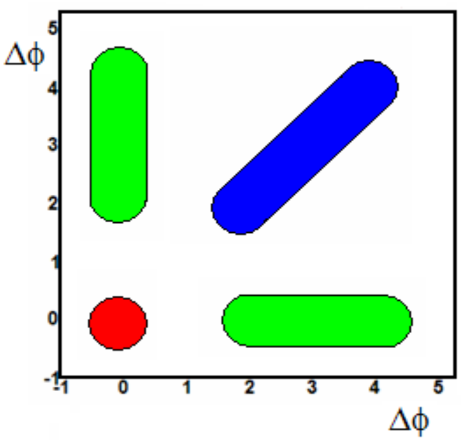


Conical Emission

Two component approach:
- Correlated to trigger (jets..)
- Uncorrelated to trigger (except via anisotropic flow)

Bkg normalization 3-particle ZYAM

What causes shoulder peaks?



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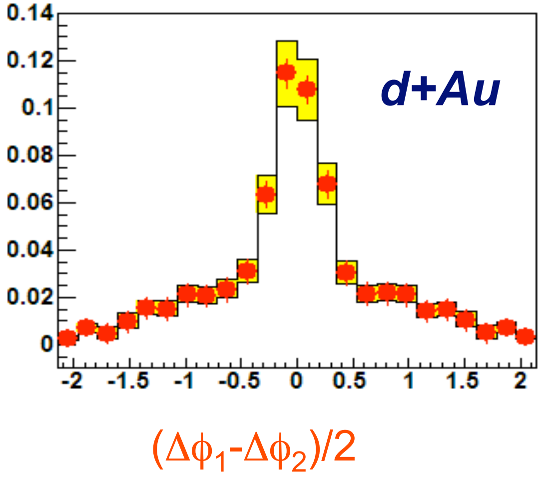
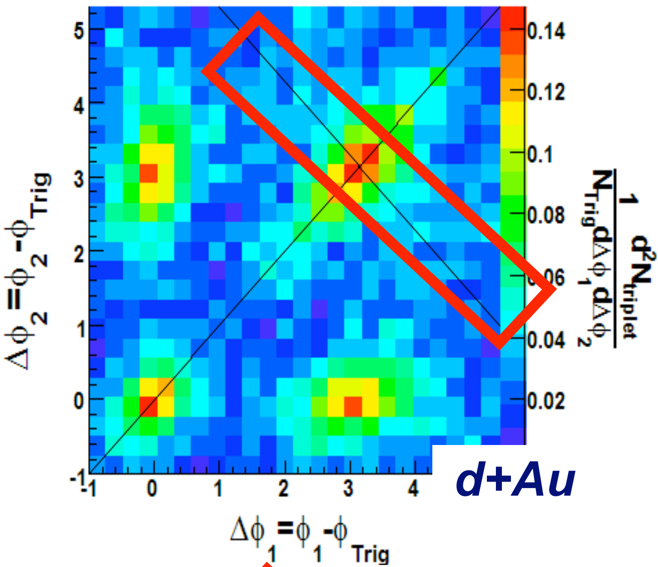
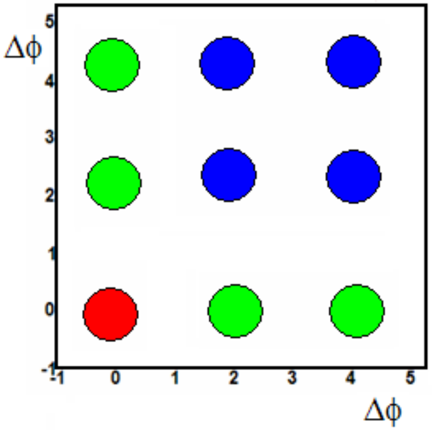


STAR Preliminary



$3 < p_{Ttrig} < 4$ GeV/c, $1 < p_{Tassoc} < 2$ GeV/c



Conical Emission

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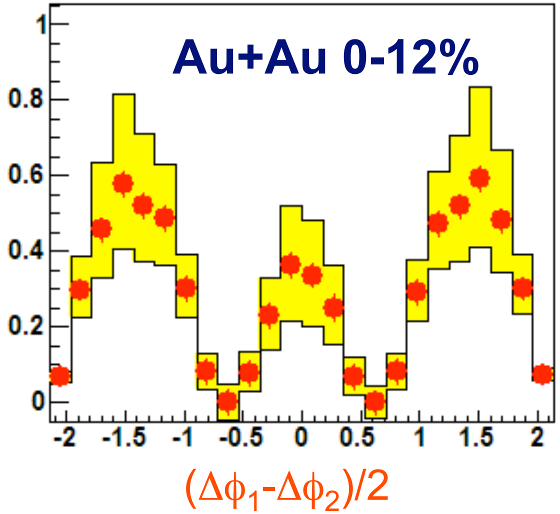
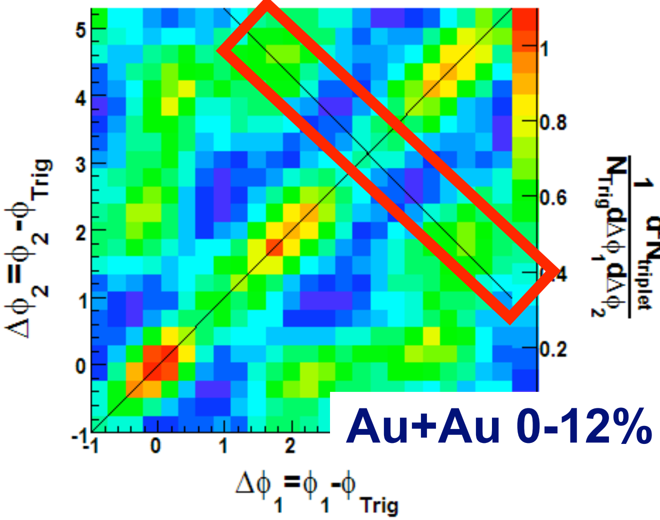
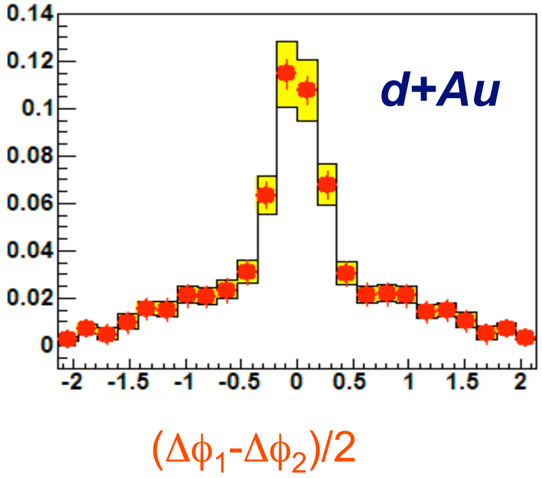
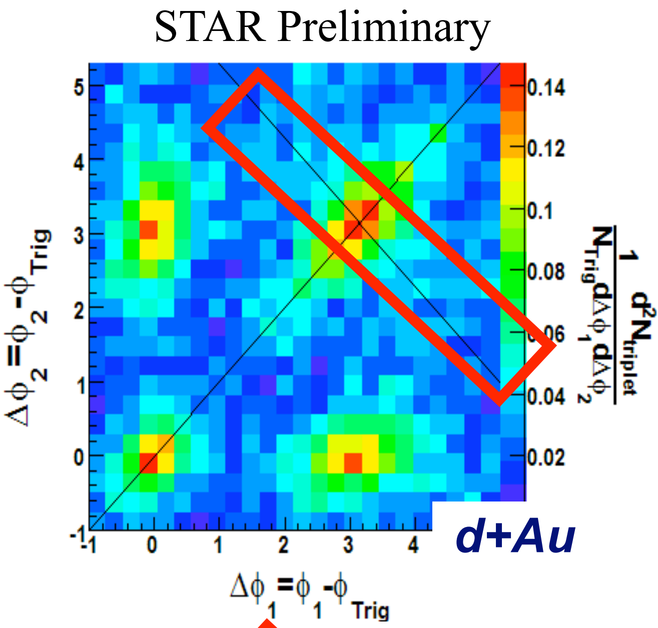




What causes shoulder peaks?

Au+Au data consistent with Conical emission





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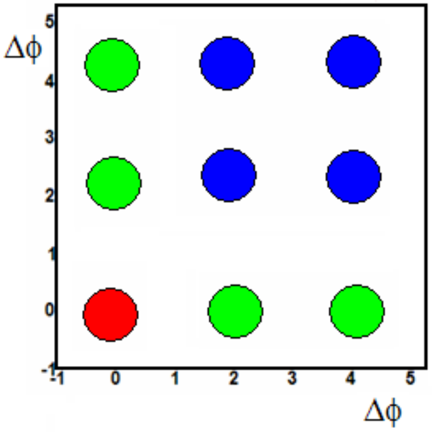

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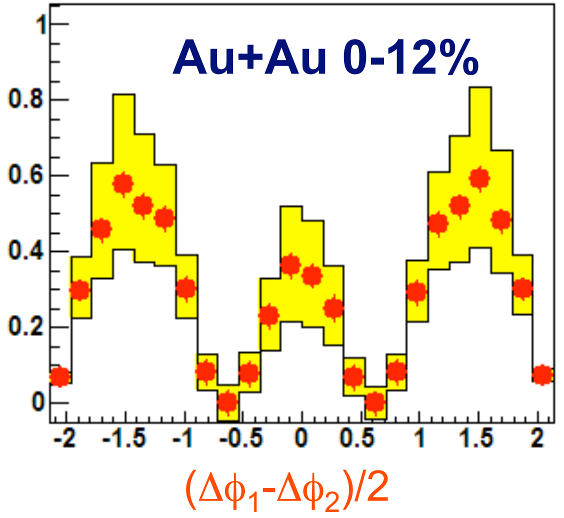

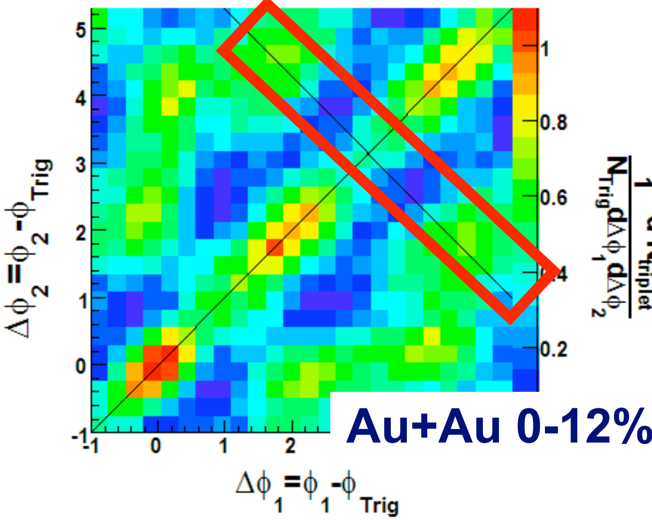

Possible causes of conical emission

Mach Cone

Similar to jet creating sonic boom in air.

- Energy radiated from parton deposited in collective hydrodynamic modes.

- Mach angle depends on C_s
  - T dependent

$$\frac{c_s}{v_{parton}} = \cos(\theta_M)$$

- Angle independent of p_T^{assoc}

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Čerenkov Gluon Radiation

- Gluons radiated by superluminal parton.

$$\frac{c_n}{v_{parton}} = \cos(\theta_c)$$

$$= \frac{c}{n(p)v_{parton}}$$

$$\approx \frac{1}{n(p)}$$

- Angle dependent on p_T^{assoc}

Conical Emission Theories

- Mach-cone:
  - Can be produced in different theories:
    - Hydrodynamics
      - H. Stöcker et al. (Nucl.Phys.A750:121,2005)
      - J. Casalderra-Solana et. al. (Nucl.Phys.A774:577,2006)
      - T. Renk & J. Ruppert (Phys.Rev.C73:011901,(2006))
    - Colored plasma
      - J. Ruppert & B. Müller (Phys.Lett.B618:123,2005)
    - AdS/CFT
      - S. Gubser, S. Pufu, A. Yarom. (arXiv:0706.4307v1, 2007)
- Čerenkov Gluon Radiation:
  - I.M. Dremin (Nucl. Phys. A750: 233, 2006)
  - V. Koch et. al. (Phys. ReV. Lett. 96, 172302, 2006)
- Parton Cascade:
  - G. L. Ma et. al. (Phys. Lett. B647, 122, 2007)

References are only a small subset of those existing. Apologies to those not included.

Mach cone or Čerenkov gluons?

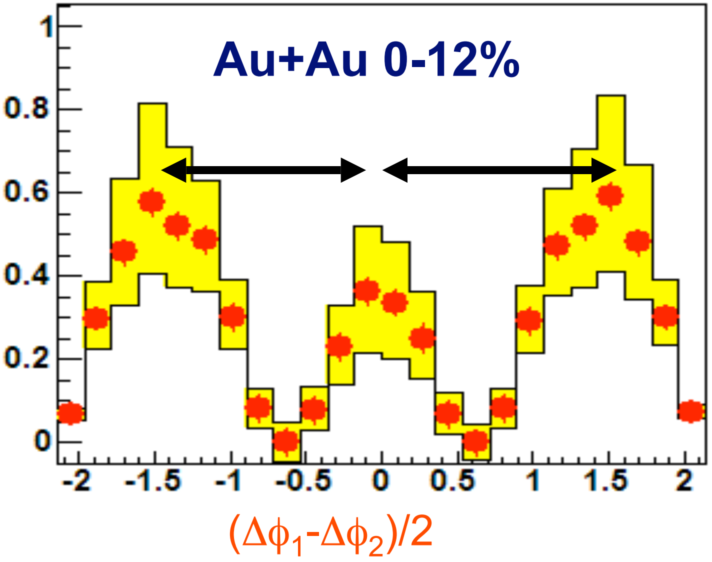
Angle predictions:

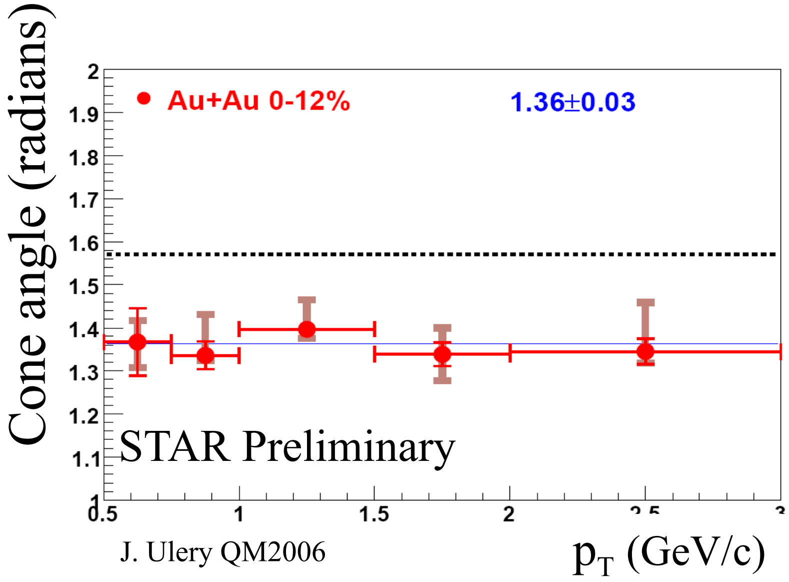
- Mach-cone:

  Angle independent of associated p_T

- Čerenkov gluon radiation:

  Angle decreases with associated p_T





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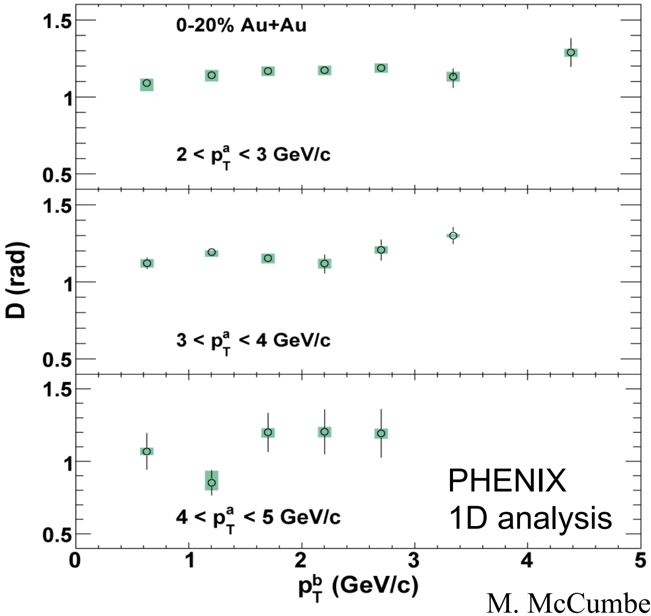
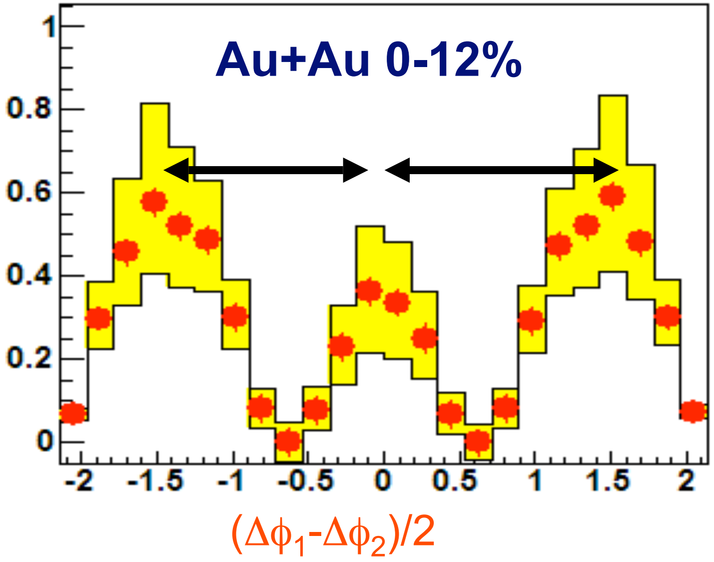
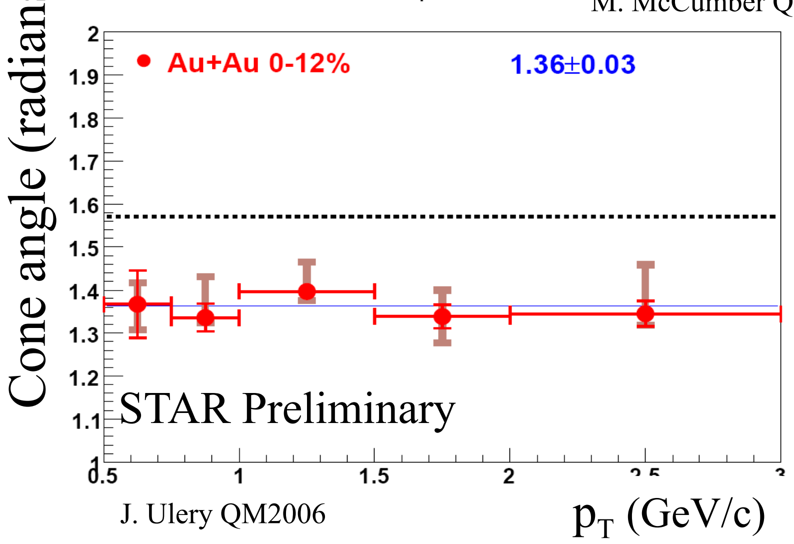


M. McCumber QM2008





J. Ulery QM2006

Mach cone or Čerenkov gluons?

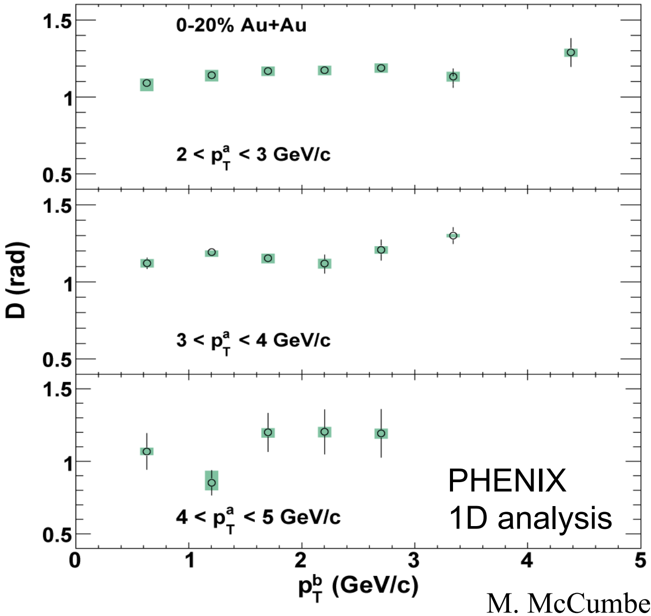
Angle predictions:

- **Mach-cone:** ✓

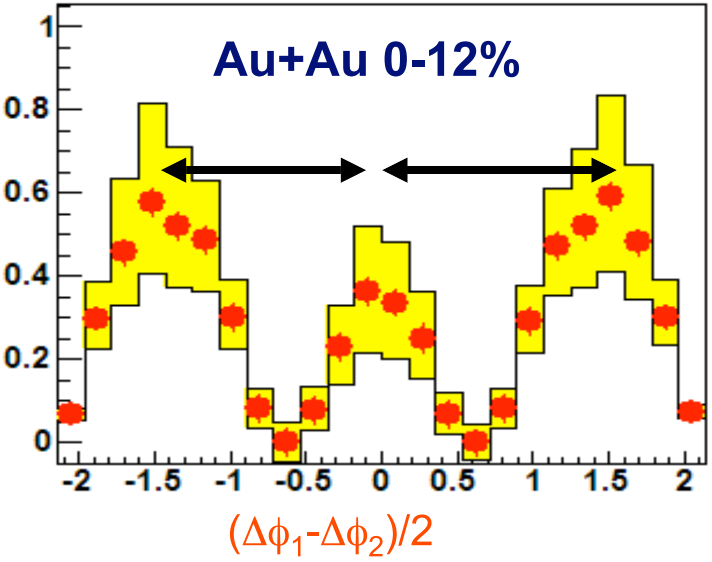
  Angle independent of associated p_T

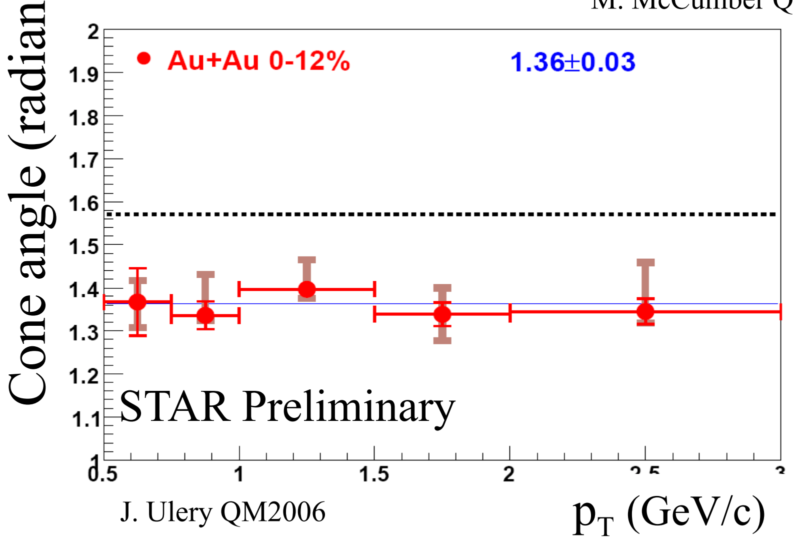
- Čerenkov gluon radiation: ✗

  Angle decreases with associated p_T



M. McCumber QM2008

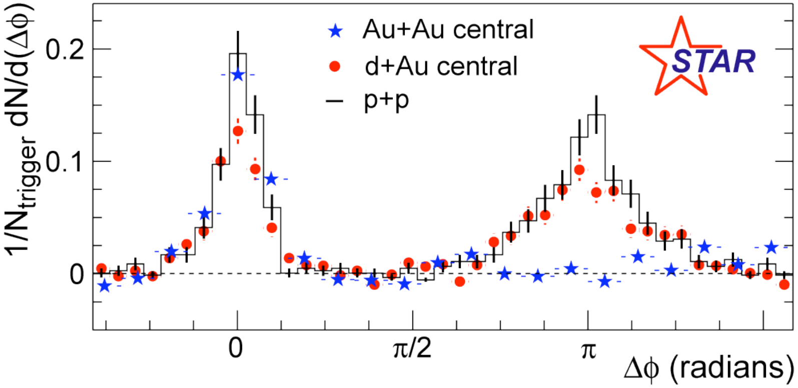




J. Ulery QM2006

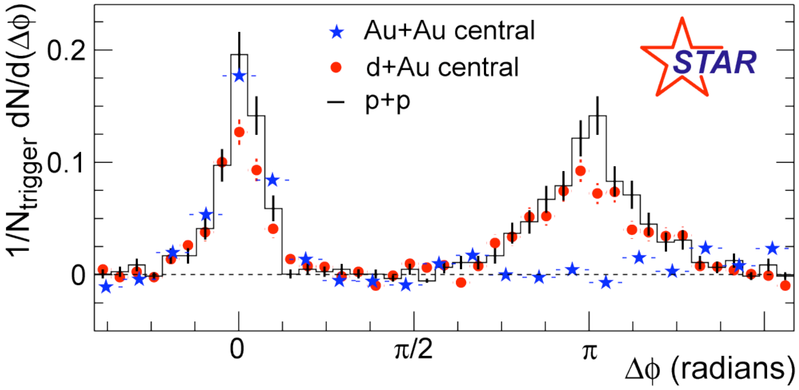
Parton interactions on near side

Δ(ϕ) correlations

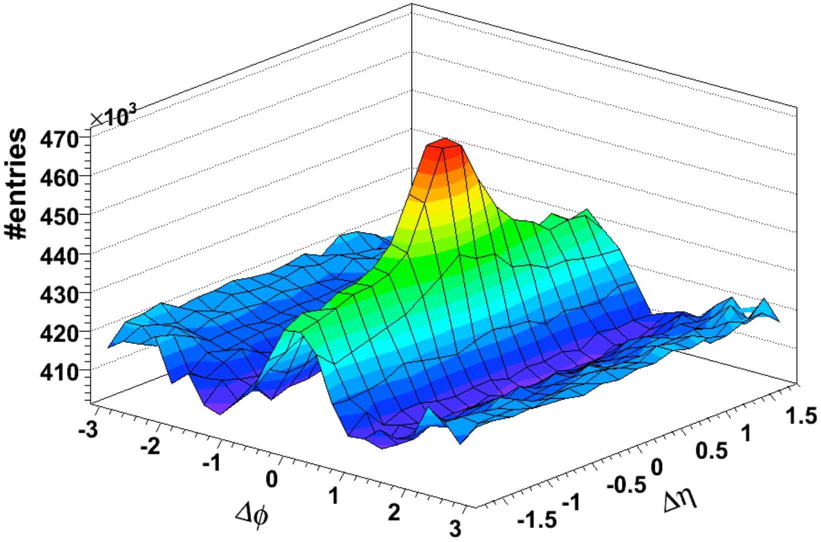


Parton interactions on near side

$\Delta(\phi)$ correlations



$\Delta(\eta)$ – $\Delta(\phi)$ correlations

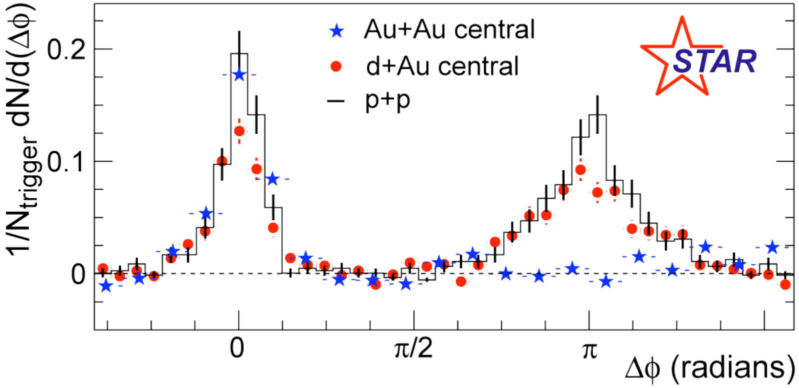


Long range $\Delta(\eta)$ correlation

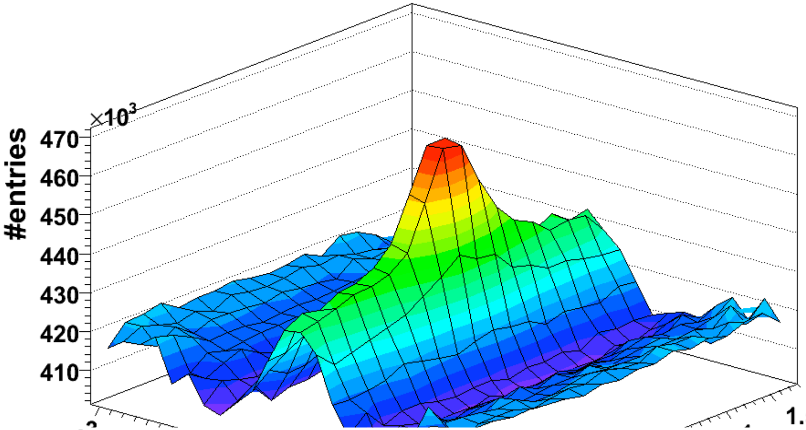
– the “Ridge”

Parton interactions on near side

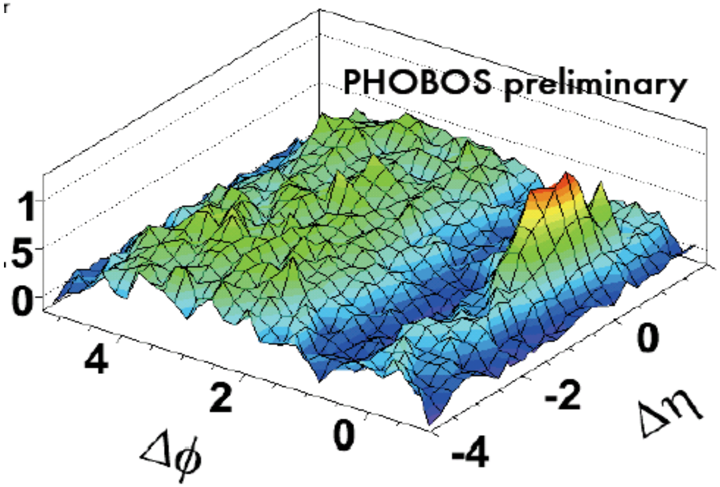
$\Delta(\phi)$ correlations



$\Delta(\eta) - \Delta(\phi)$ correlations



Au+Au 0-30% central



Long range $\Delta(\eta)$ correlation

– the “Ridge”

Persists out to very large $\Delta(\eta) > 2$

Some possible explanations of the ridge

Recombination between thermal and shower partons at intermediate p_T

R.C. Hwa & C.B. Chiu Phys. Rev. C 72 (2005) 034903

QCD bremsstrahlung radiation boosted by transverse flow

S.A. Voloshin, Phys. Lett. B 632 (2007) 490
E. Shuryak, hep-ph:0706.3531

In medium radiation and longitudinal flow push

N. Armesto et.al Phys. Rev. Lett. 93 (2007) 242301

Broadening of quenched jets in turbulent color fields

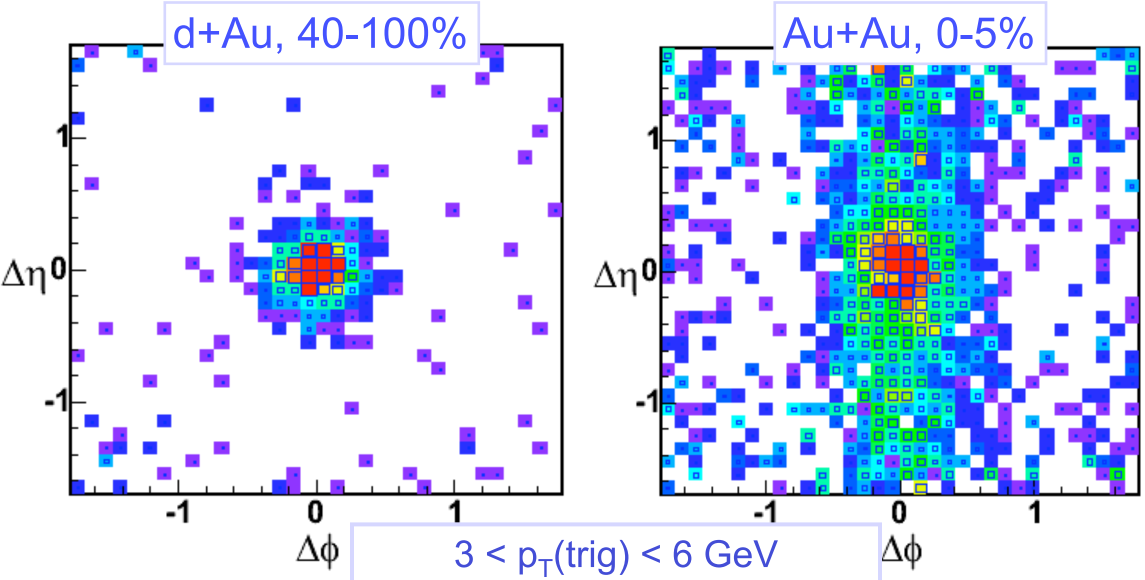
A. Majumder et.al Phys. Rev. Lett. 99 (2004) 042301

Momentum Kick Model

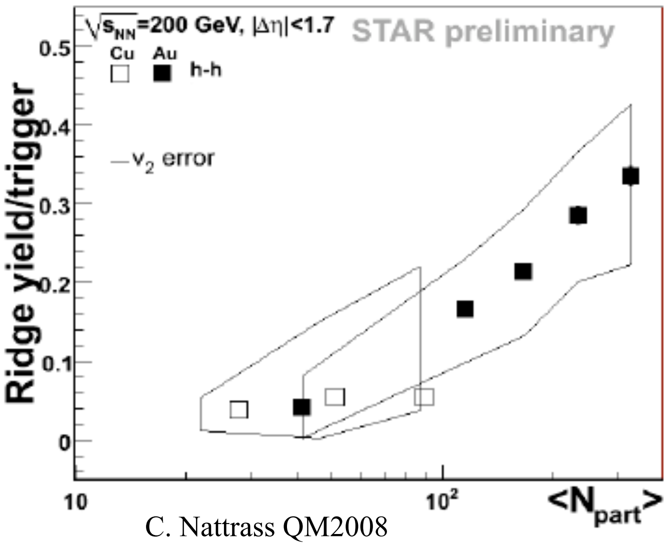
C.Y. Wong hep-ph:0712.3282

All qualitatively consistent with the features of the ridge

Path length dependence of the ridge

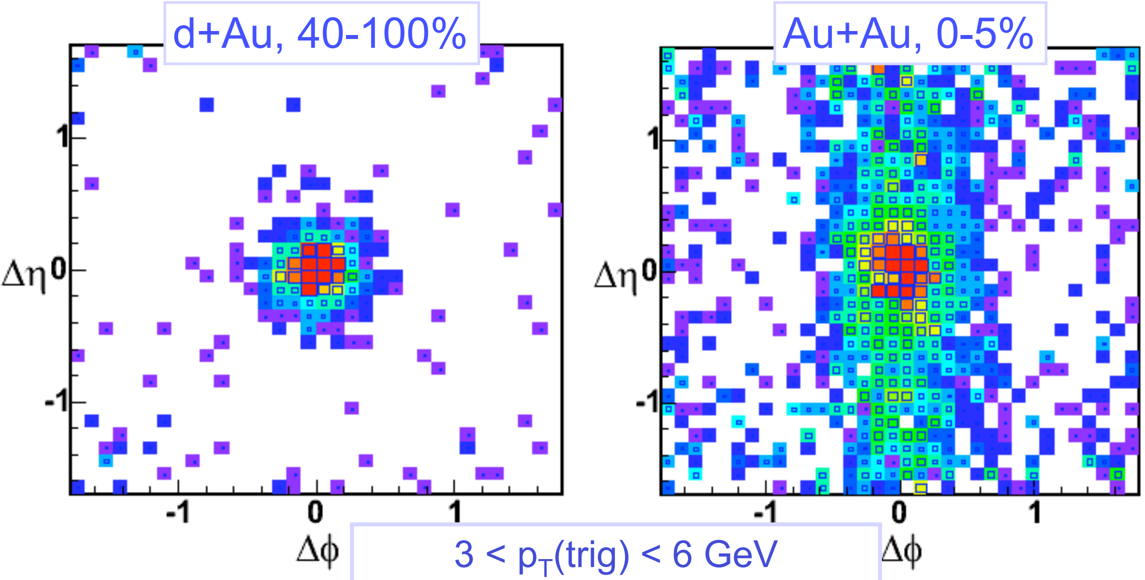


3 < p_T(trig) < 6 GeV
2 < p_T(assoc) < p_T(trig)



C. Nattrass QM2008

Path length dependence of the ridge



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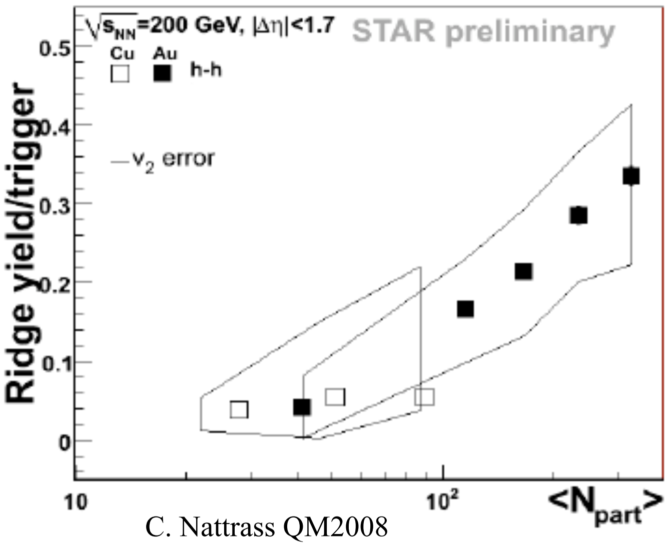
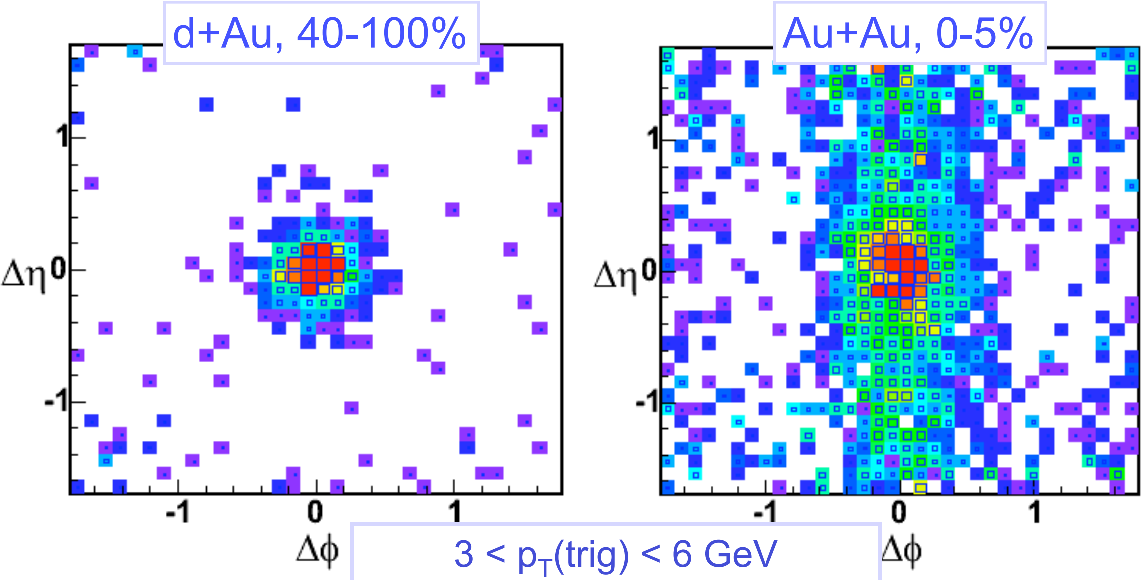


C. Nattrass QM2008

Ridge: Increases with N_{part}
Independent of colliding system
Decreases with $\phi_t - \Psi$

Path length dependence of the ridge



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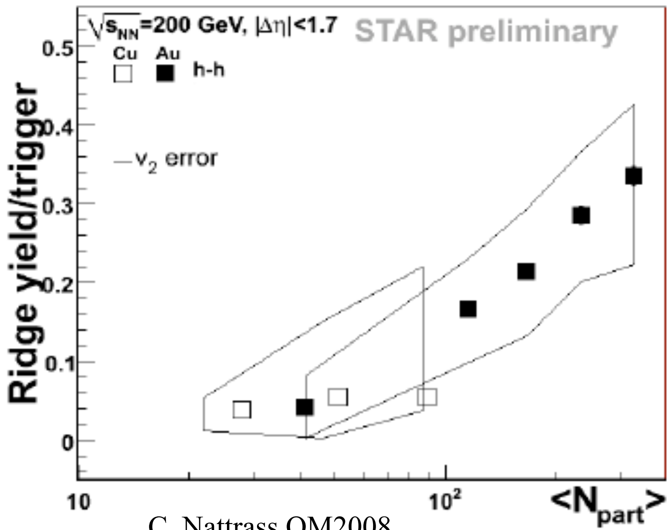
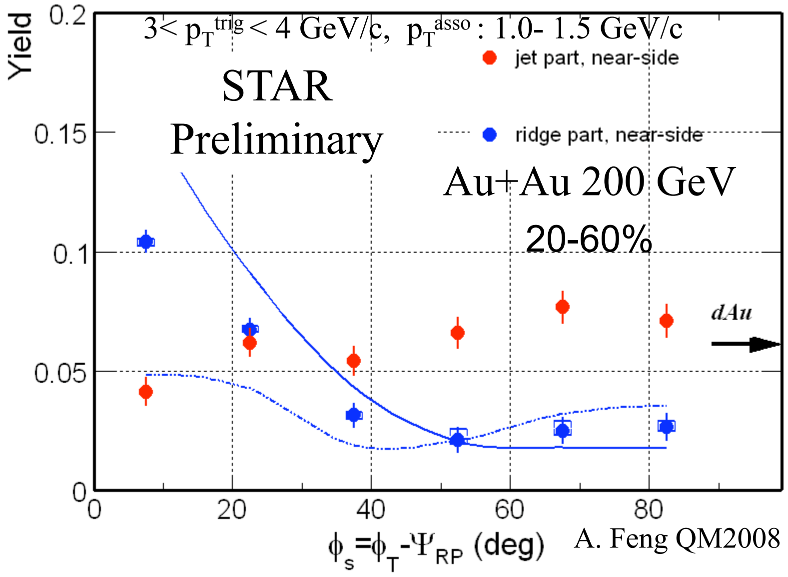


C. Nattrass QM2008

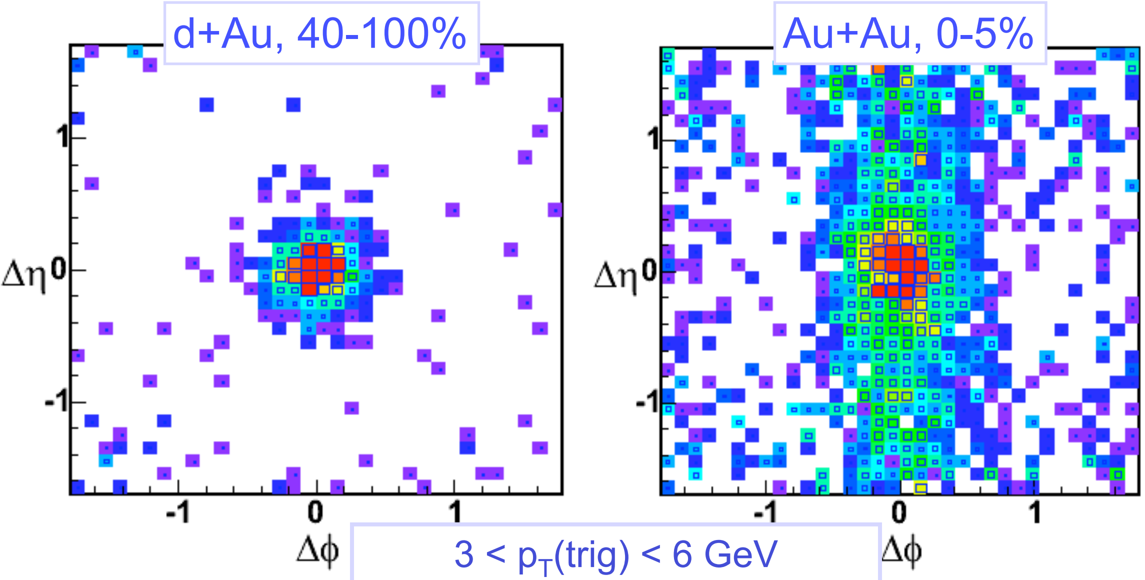


A. Feng QM2008

Ridge: Increases with N_{part}
Independent of colliding system
Decreases with $\phi_t - \Psi$

Jet: Slight to no increases with $\phi_t - \Psi$
Au+Au ~ d+Au

Path length dependence of the ridge



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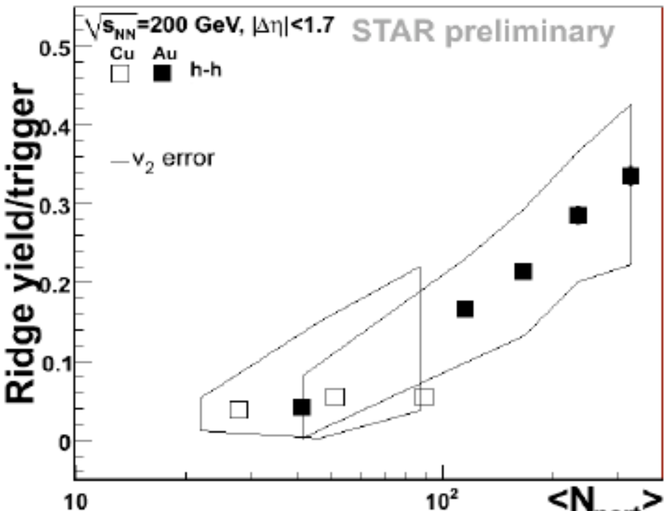


C. Nattrass QM2008

Ridge: Increases with N_{part}

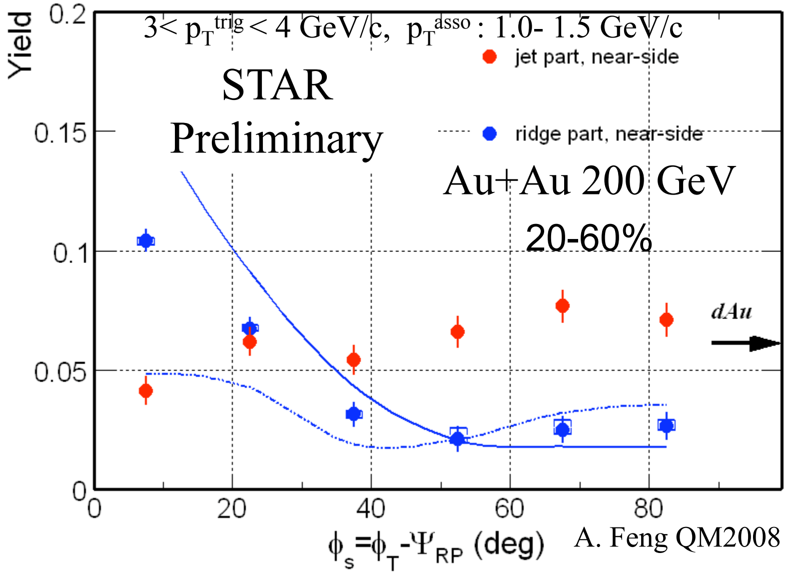
Independent of colliding system

Decreases with ϕ_t - Ψ

Jet: Slight to no increases with ϕ_t - Ψ

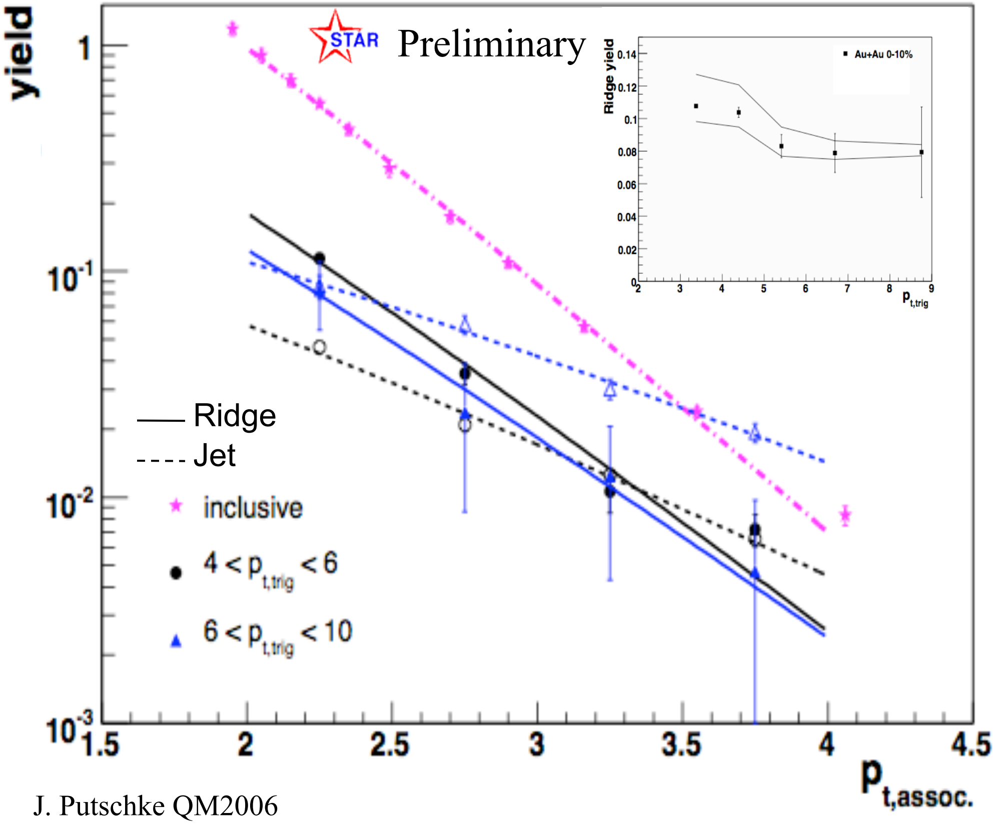
Au+Au ~ d+Au

Parton interacts with medium (ridge) and then vacuum fragments (jet)?



A. Feng QM2008

Spectra of ridge and shoulder particles



J. Putschke QM2006

$\text{slope}_{\text{ridge}} > \text{slope}_{\text{jet}}$

$\sim \text{slope}_{\text{inclusive}}$

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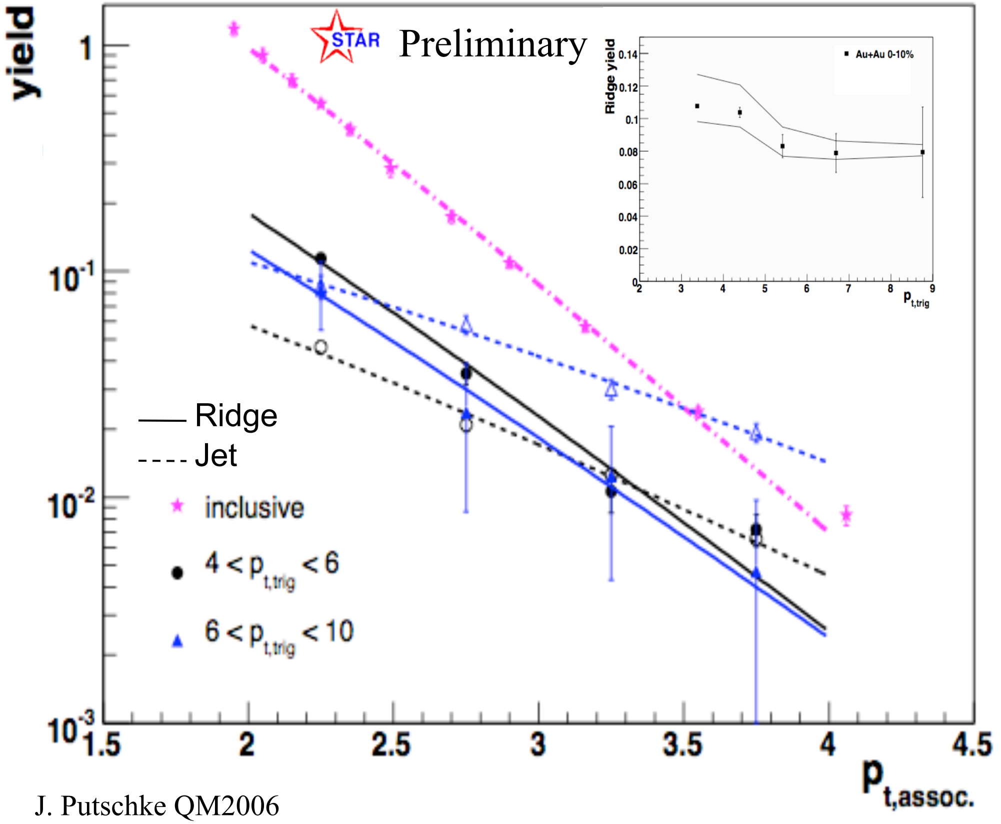
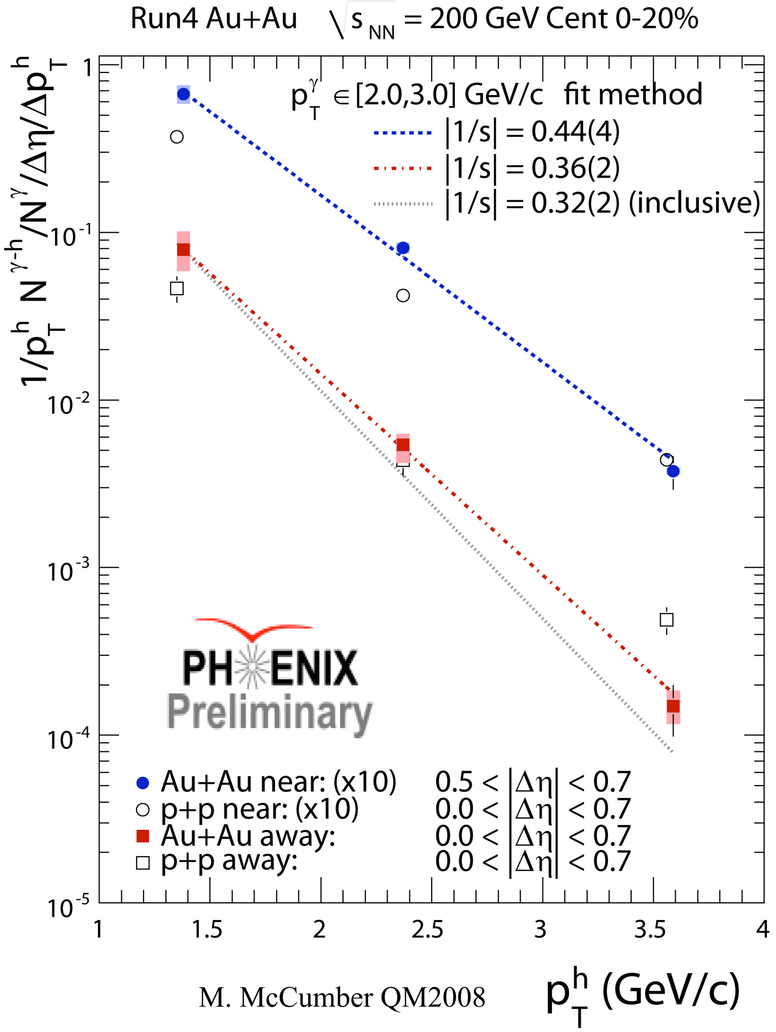


J. Putschke QM2006



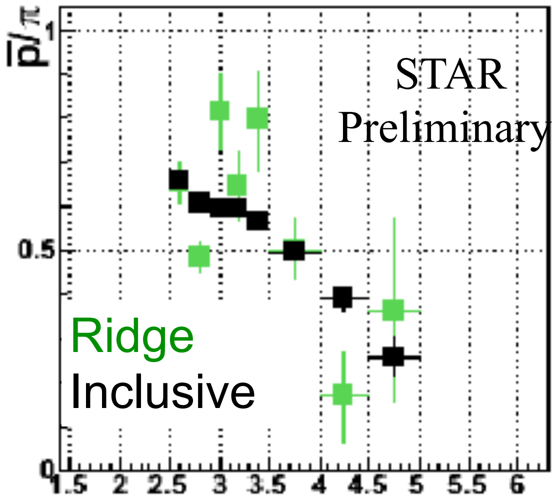
M. McCumber QM2008

$\text{slope}_{\text{ridge}} > \text{slope}_{\text{jet}}$

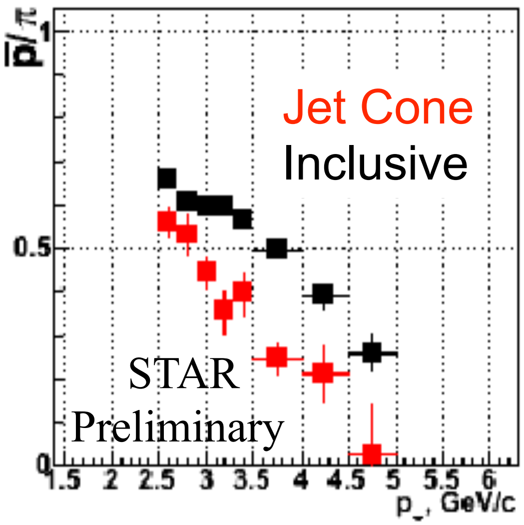
$\sim \text{slope}_{\text{inclusive}}$

$\geq \text{slope}_{\text{shoulder}}$

Composition of ridge and shoulders



C. Nattrass QM2008



ridge ratio ~ inclusive ratio
> jet ratio

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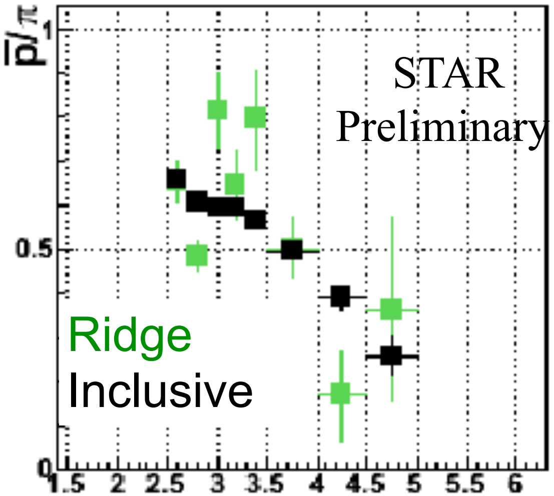
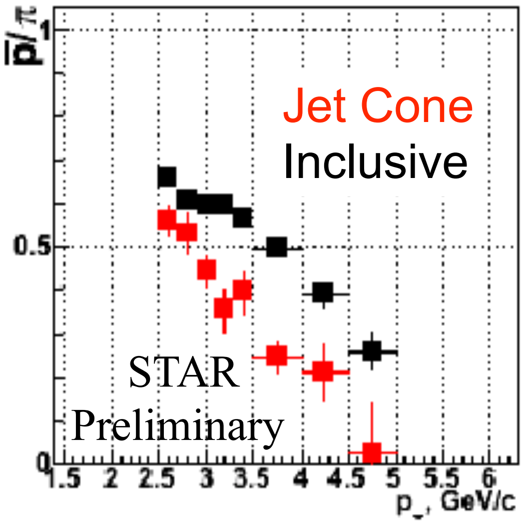
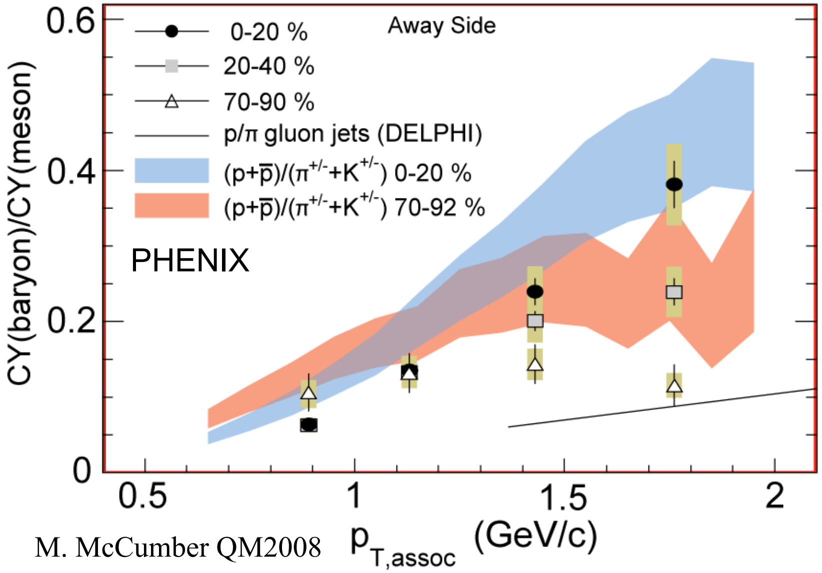


C. Nattrass QM2008



ridge ratio ~ inclusive ratio
> jet ratio

shoulder ratio ~ inclusive ratio
> jet ratio



M. McCumber QM2008

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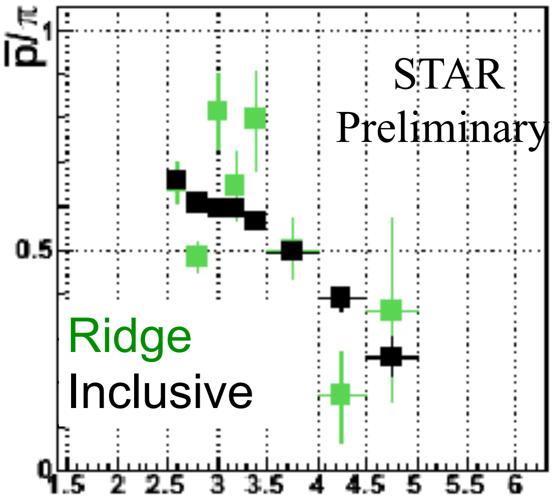

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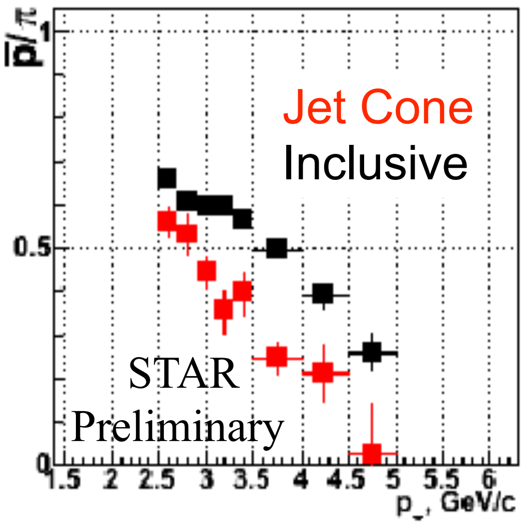

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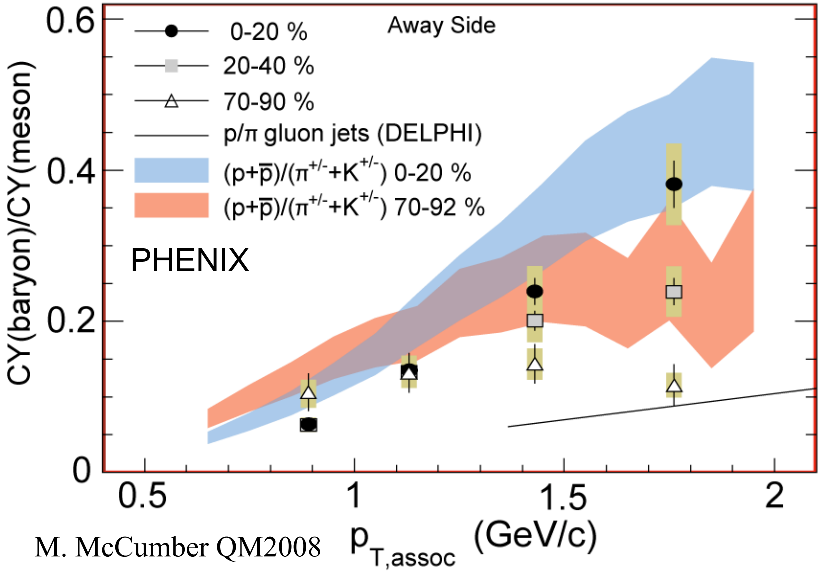

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Ridge and Shoulder similar properties
NOT vacuum fragmentation

Energy lost by jet partons seems to be re-distributed into the medium and freezes out in similar fashion

Un-triggered pair correlations

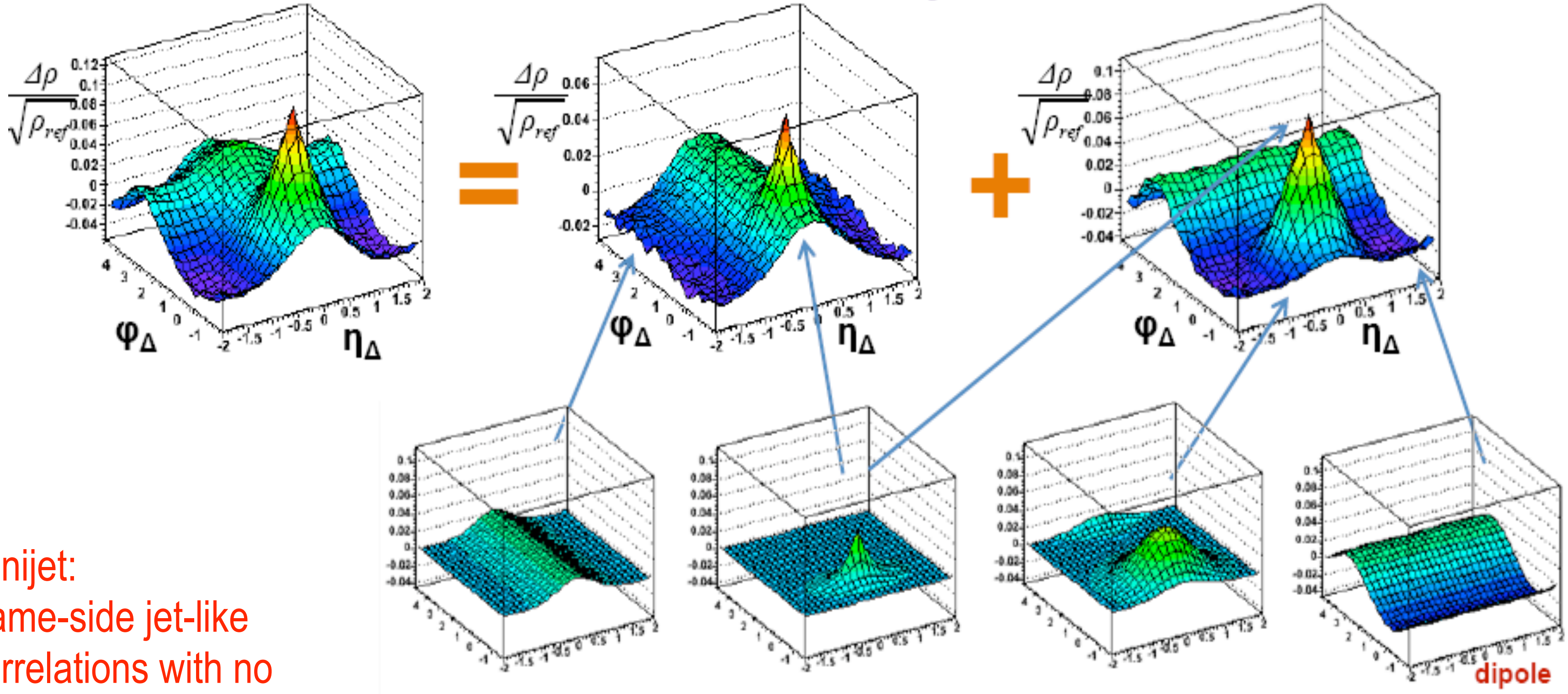
Method: measure pair densities $\rho(\eta_1-\eta_2,\varphi_1-\varphi_2)$ for *all possible pairs* in same and mixed events.

Define correlation measure as:

$$\frac{\rho_{same}-\rho_{mixed}}{\sqrt{\rho_{mixed}}} \equiv \frac{\Delta\rho}{\sqrt{\rho_{ref}}} \propto \frac{\#\,\text{correlated pairs}}{\text{particle}}$$

Proton-Proton fit function

STAR Preliminary



Minijet:
Same-side jet-like correlations with no trigger particle

longitudinal fragmentation
1D gaussian

HBT and e+e-
2D exponential

Minijet Peak
2D gaussian

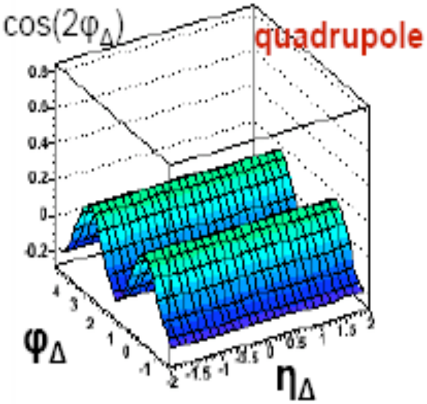
Away-side
-cos(φ)

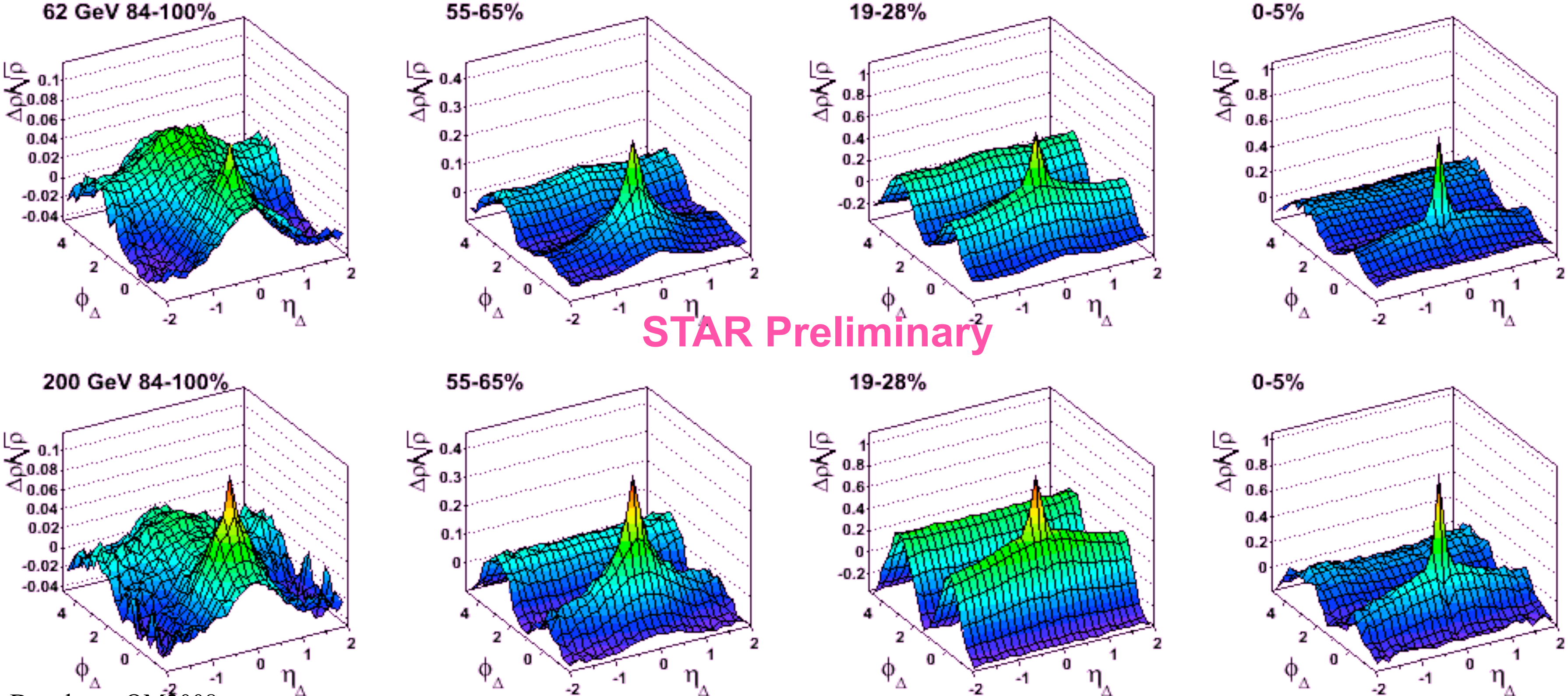
M. Daugherty QM2008

Un-triggered pair correlations

Au-Au fit function

Use proton-proton fit function + cos(2φ_Δ) quadrupole term ("flow").
This gives the ***simplest possible*** way to describe Au+Au data.





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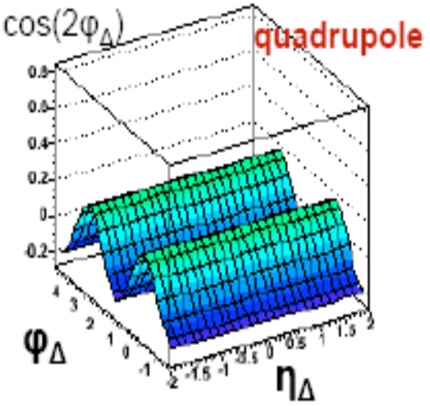
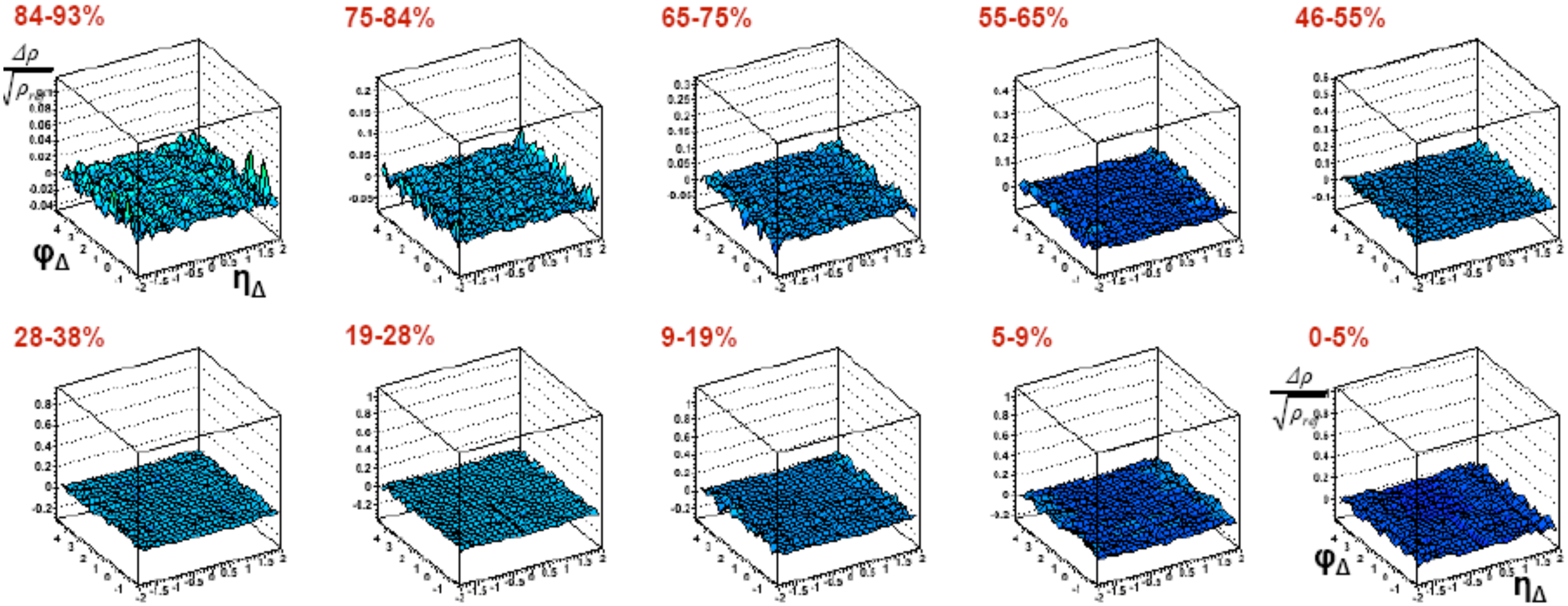


Small residual indicates goodness of fit

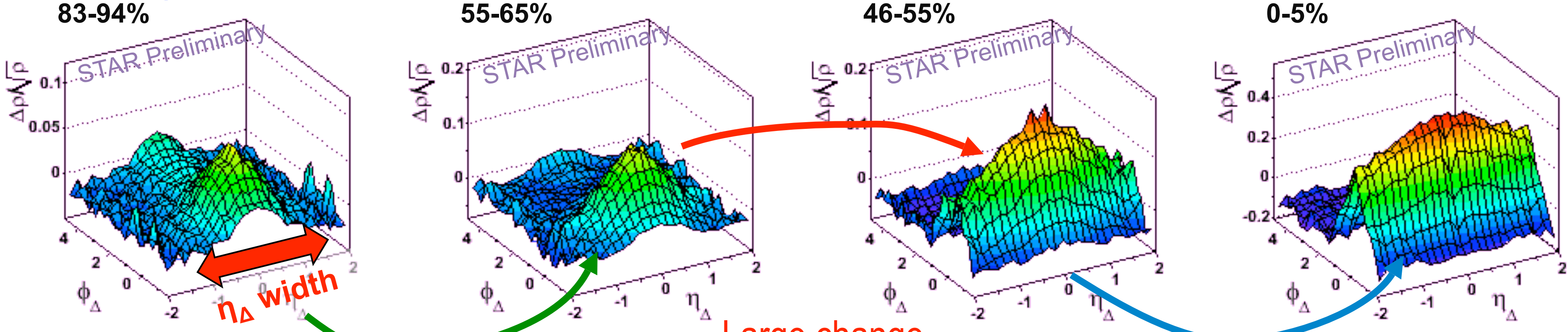
Fit residual = data - model

STAR Preliminary



Evolution of mini-jet with centrality

Same-side peak



Little shape change from peripheral to 55% centrality

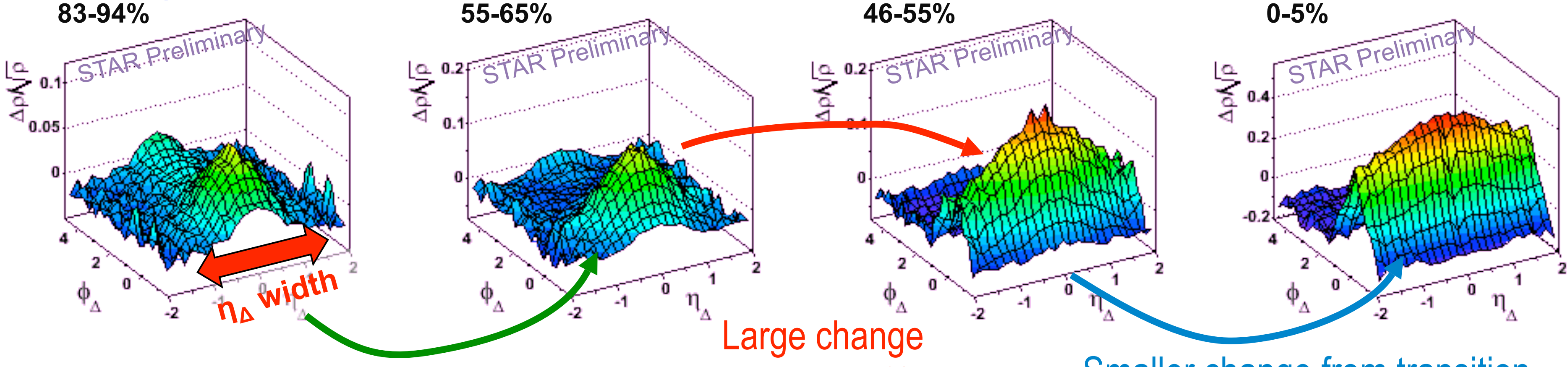
Large change within ~10% centrality

Smaller change from transition to most central

M. Daugherty QM2008

Evolution of mini-jet with centrality

Same-side peak



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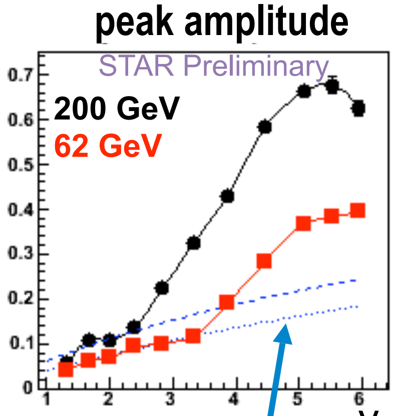
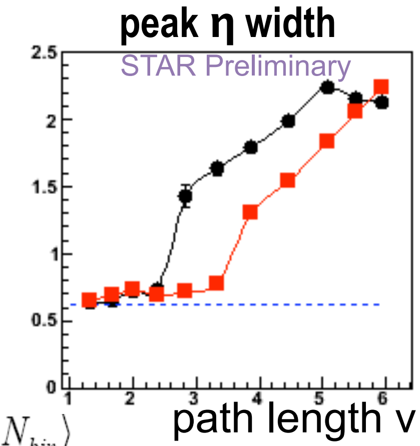


binary scaling references

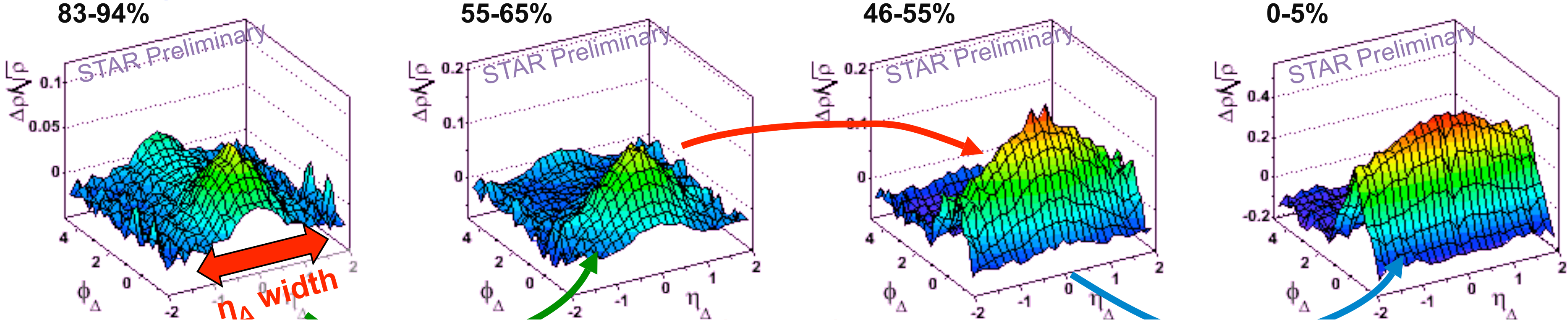


$$\nu \equiv \frac{\langle N_{bin}\rangle}{\langle N_{part}/2\rangle}$$

M. Daugherty QM2008

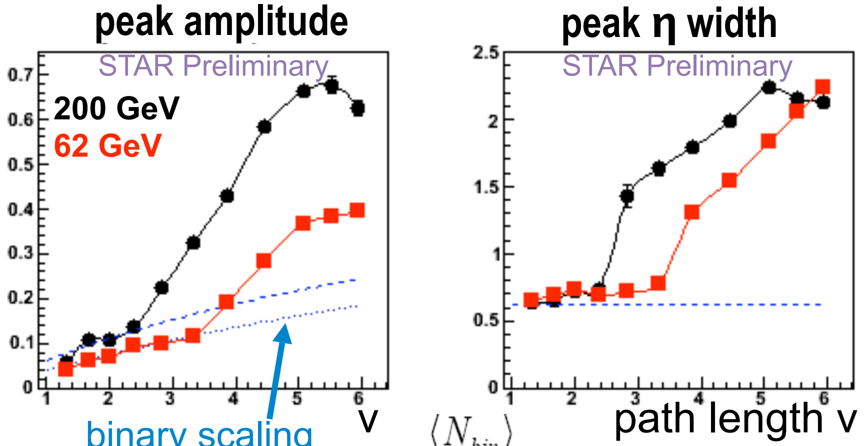
Evolution of mini-jet with centrality

Same-side peak



Binary scaling reference followed until sharp transition at ρ ~ 2.5

~30% of the hadrons in central Au+Au participate in the same-side correlation



binary scaling references

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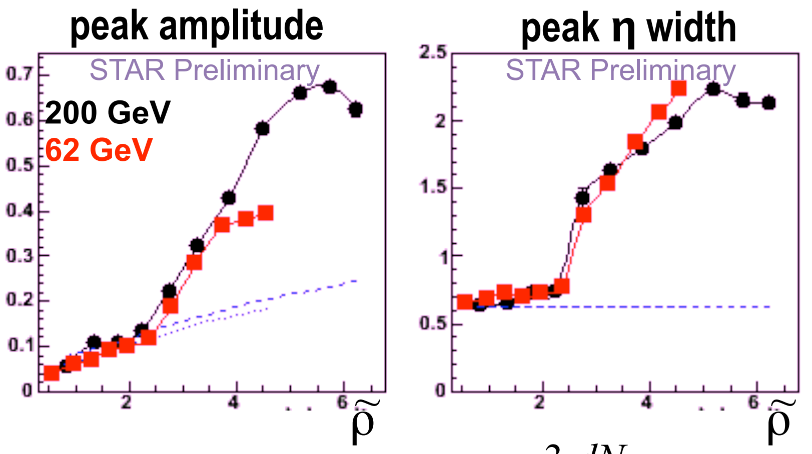
M. Daugherty QM2008



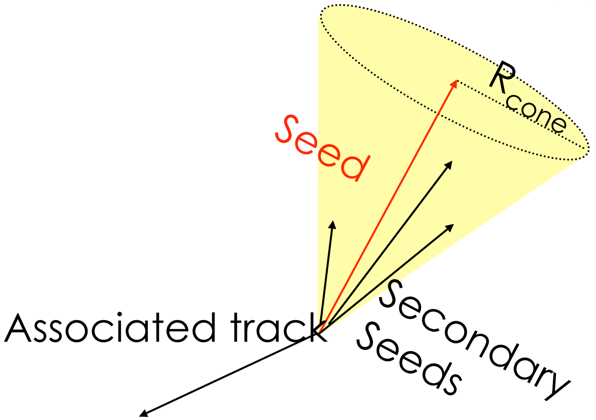
Transverse particle density $\tilde{\rho} = \frac{3}{2}\frac{dN_{ch}}{d\eta}/S$

Towards true jet reconstruction

- Reduce leading trigger particle biases from di-hadron correlations

- First step to jet reconstruction in A+A

Multi-hadron trigger



Use “cluster energy” as trigger:
- R_{cone} = 0.3
- $p_{T,seed}$ > 5 GeV
- $p_{T,sec\ seed}$ > 3 GeV

Towards true jet reconstruction

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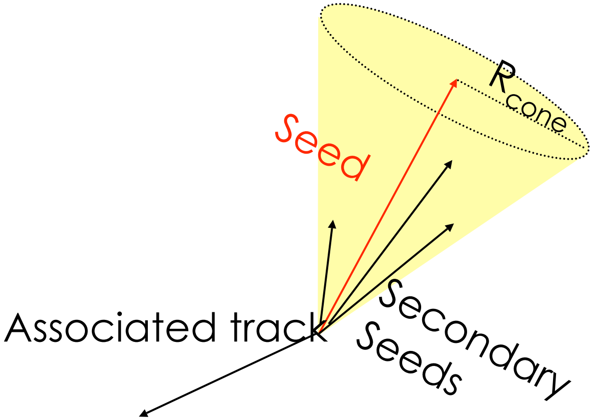

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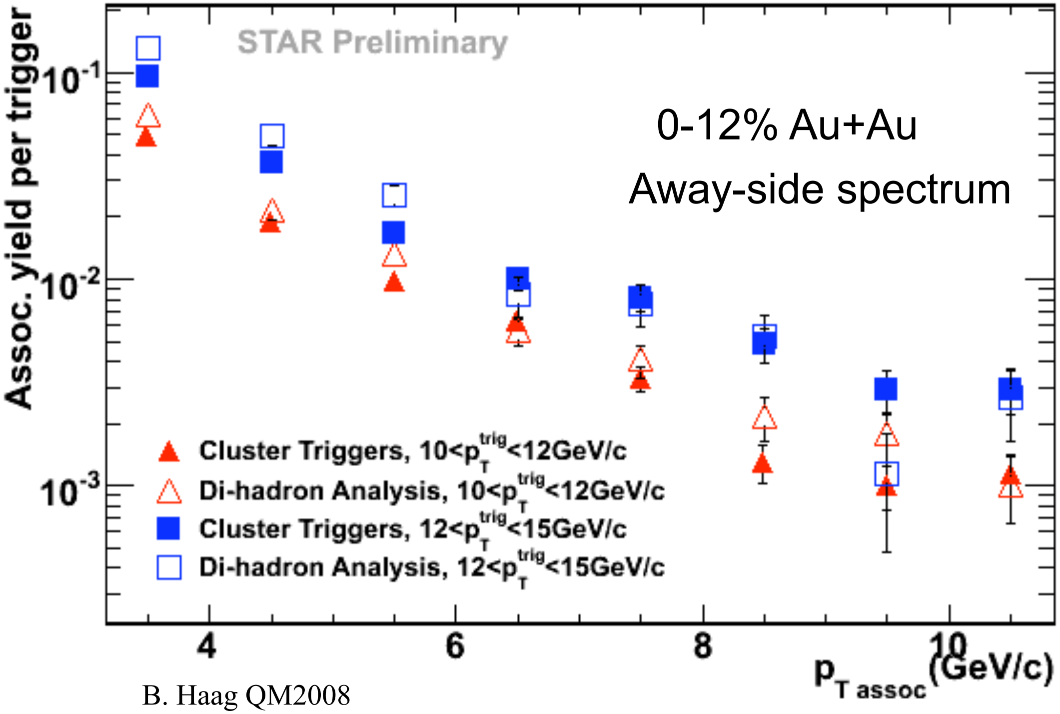

B. Haag QM2008

- Single-hadron trig. ≈ multi-hadron trig.

- Single high p_T triggered correlations prob jet-like correlations

Conclusions

Jets have been observed at RHIC

Making important steps towards constraining models that try to explain:

- How partons interact with and lose energy in the medium
- Where that energy goes
- How the medium changes with √s, centrality, and ion collided

Conclusions

Jets have been observed at RHIC

Making important steps towards constraining models that try to explain:

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- Where that energy goes
- How the medium changes with √s, centrality, and ion collided

RHIC on the threshold of new era of quantitative comparison between theory and experiment that will characterize the properties of the remarkable new matter discovered at here

BACKUPS

At RHIC we've created a new state of matter

- The QGP is the:

hottest (T=200-400 MeV ~ 2.5 10^{12} K)

densest (ε = 30-60 $\varepsilon_{\text{nuclear matter}}$)

matter ever studied in the lab.

It flows as a

(nearly) perfect fluid

with systematic patterns, consistent with

quark degree of freedom

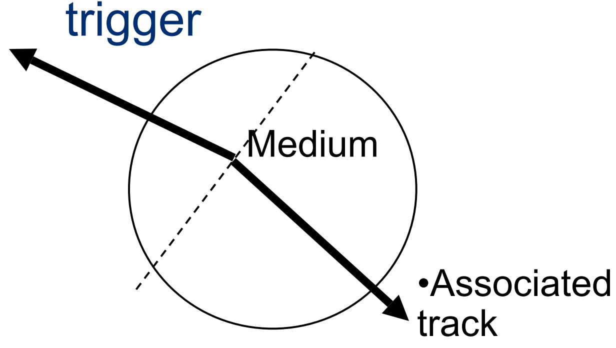
and a viscosity to entropy density ratio

lower

than any other known fluid.

Now want to learn more about properties

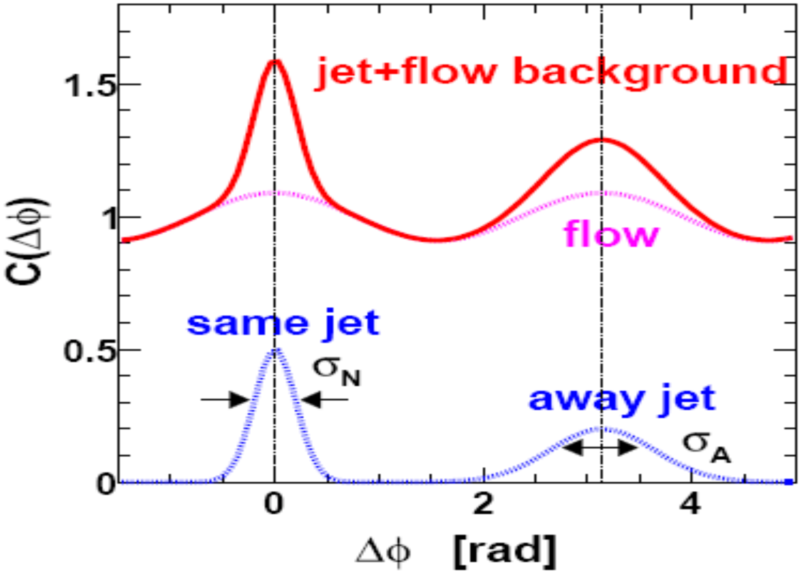
2 particle angular correlations



trigger

Medium

•Associated track

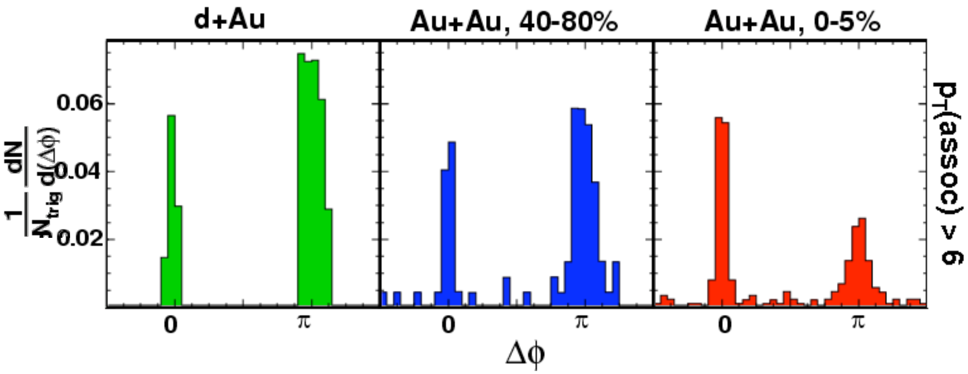


$$C(\Delta\phi) \equiv \frac{Y_{same}(\Delta\phi)}{Y_{mixed}(\Delta\phi)} \times \frac{\int Y_{mixed}(\Delta\phi)d\phi}{\int Y_{same}(\Delta\phi)d\phi}$$

$$C(\Delta\phi) \equiv b_0\left[1+2\left\langle v_2^{assoc}\right\rangle\left\langle v_2^{trig}\right\rangle\cos(2\Delta\phi)\right]+J(\Delta\phi)$$

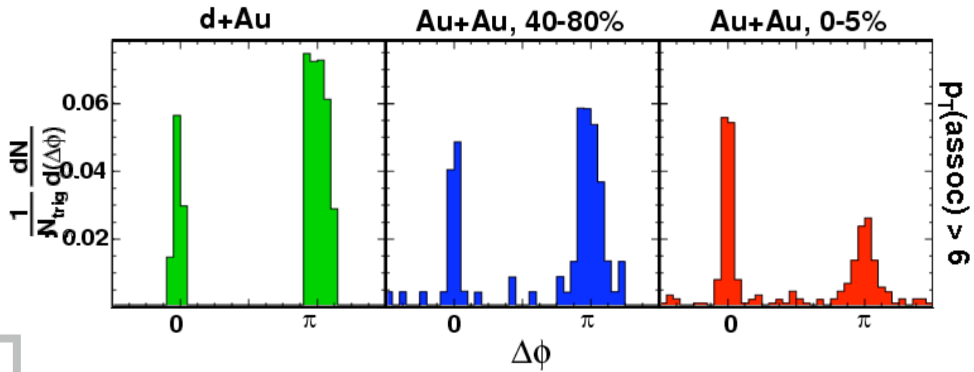
Di-jet triggered correlations

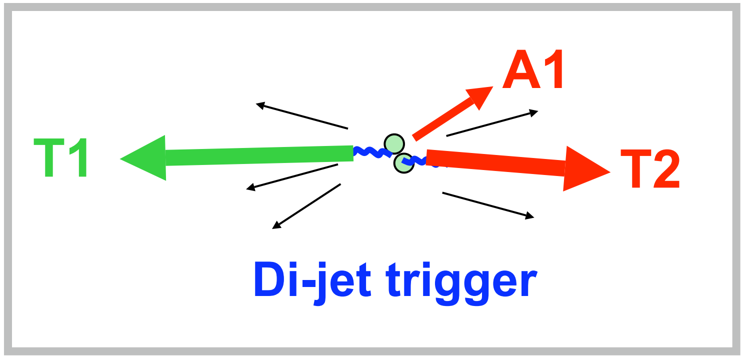
Observation of di-jets: punch through



Di-jet triggered correlations

Observation of di-jets:
punch through



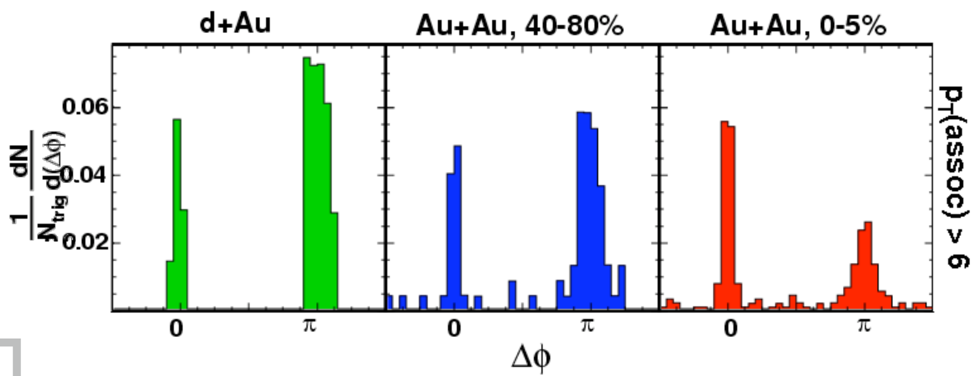


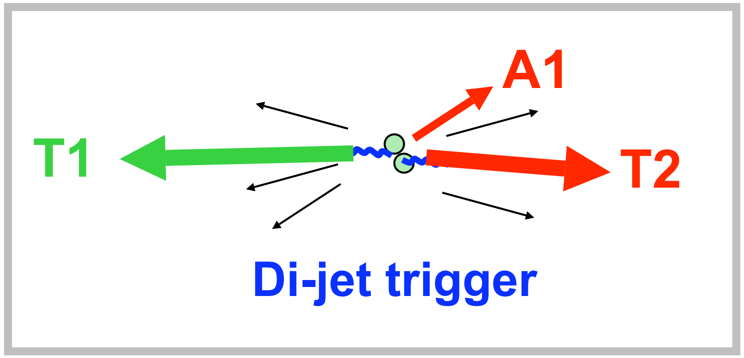
Select di-jets events:
Require T1 and T2 b-to-b

T1: p_T>5GeV/*c* **T2**: p_T>4GeV/*c*
A1: p_T>1.5GeV/*c*

Di-jet triggered correlations

Observation of di-jets:
punch through





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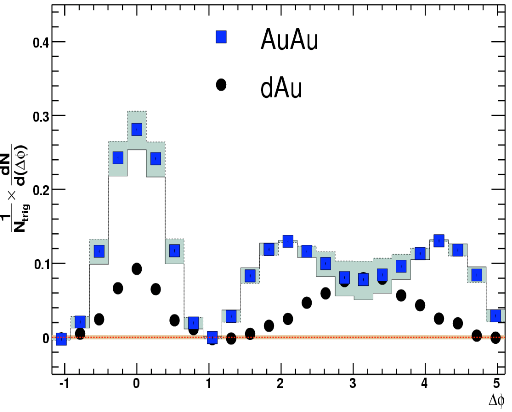
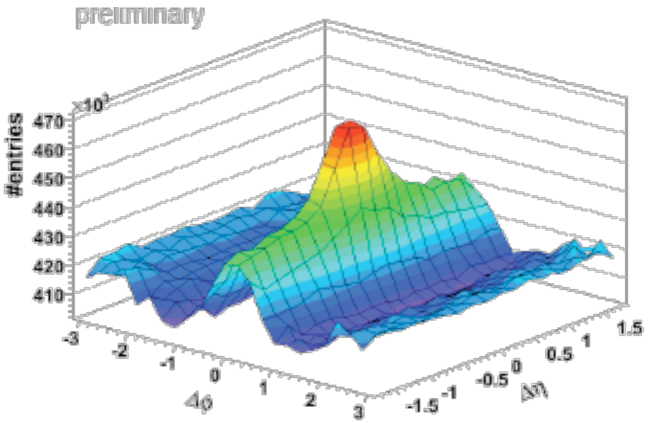
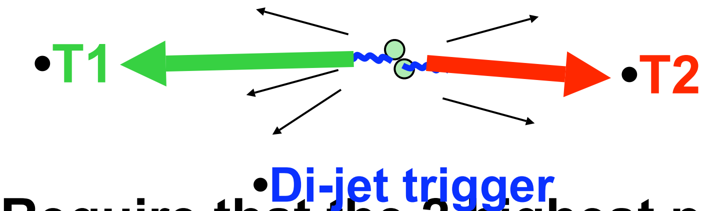


What happens to away-side hump and near-side ridge if we trigger on di-jets ?



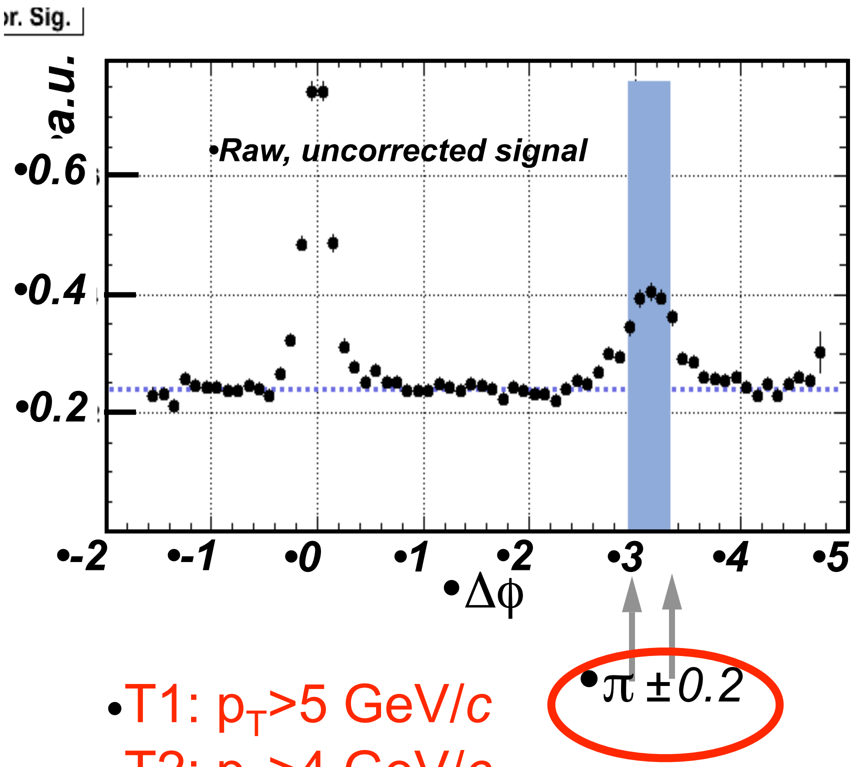
Data analysis: di-jet selection

- Correlation between primary trigger (T1) and "away-jet-axis trigger" (T2).



- Require that the 2 highest p_T particles are back-to-back in ϕ.
- *Assume* this defines the jet-axis, look in 2D-space about the second trigger.

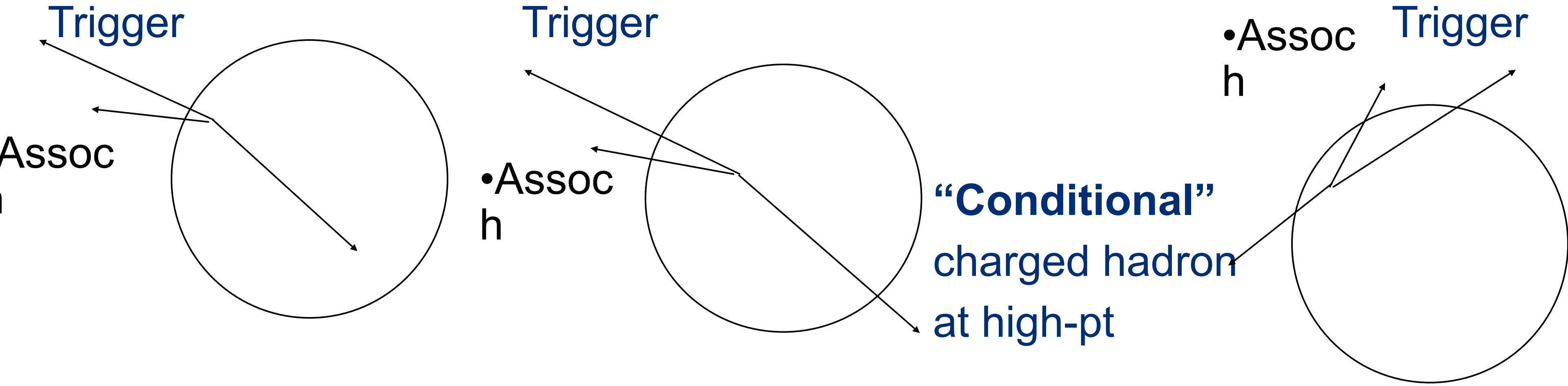
T1T2 correlation



- T1: p_T>5 GeV/*c*
- T2: p_T>4 GeV/*c*

Change the surface-bias of near-side?

- Hope to shift distribution of hard scattering <u>towards center of medium</u>. Near-side parton travels through more medium

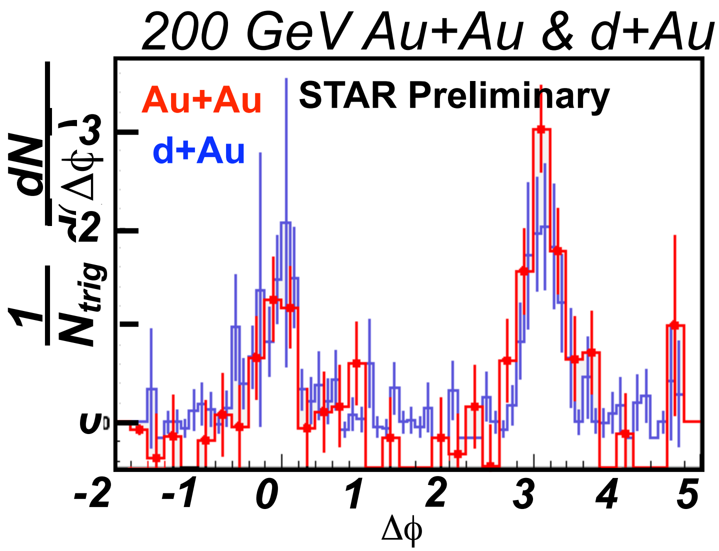


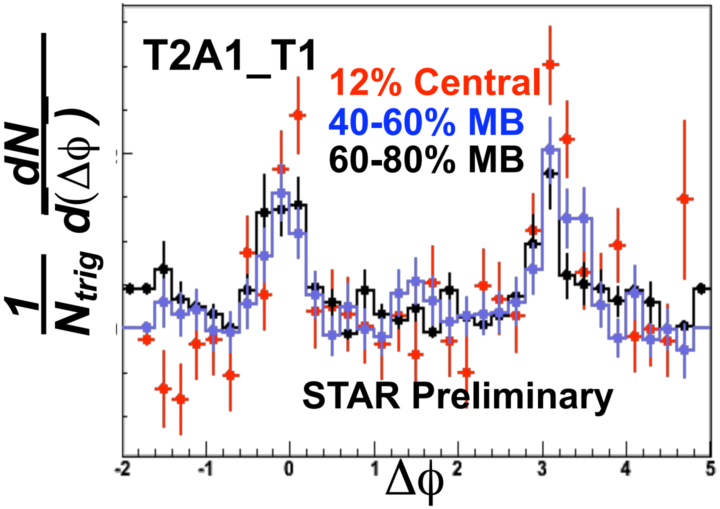
“Conditional” charged hadron at high-pt

Create path lengths **comparable** in dense medium.

However not always from center could be tangential

Di-jet triggered correlations



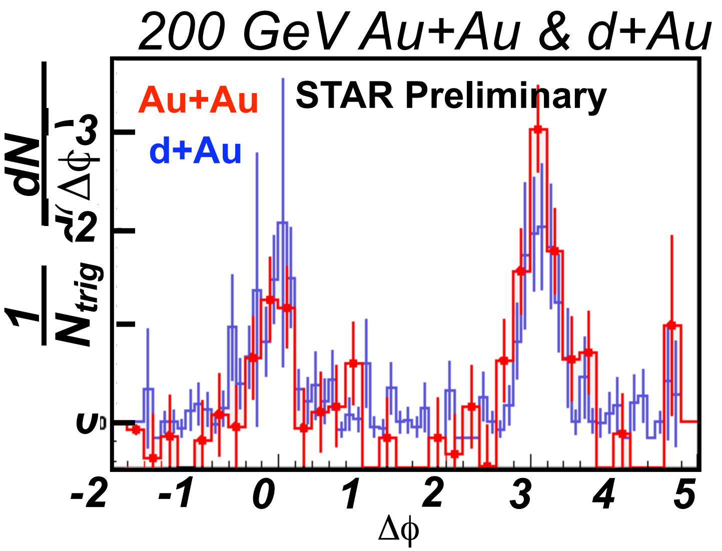


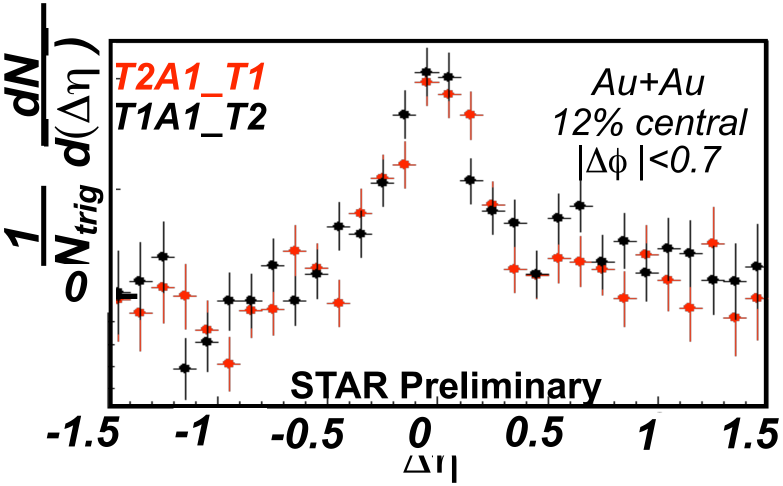
Di-jets are suppressed

Once selected:

- No Away-side suppression
  Au+Au ~ d+Au
- No Away-side shape modification

Di-jet triggered correlations





Di-jets are suppressed

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- No Away-side suppression
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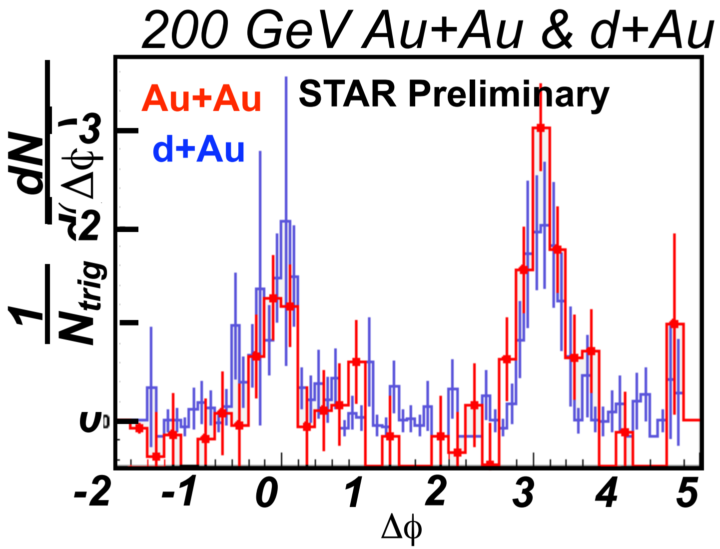
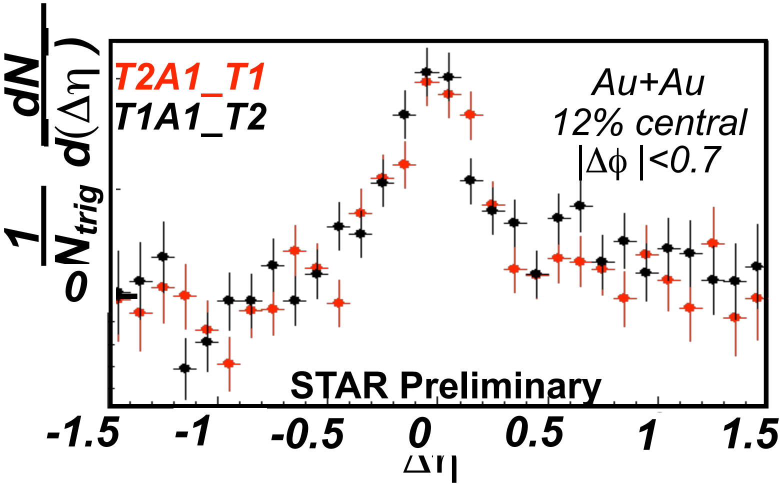
- No Away-side shape modification

- No Ridge

Helen Caines – Yale University – April 2008 – UCL – DIS2008

Di-jet triggered correlations





Di-jets are suppressed

Once selected:

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  Au+Au ~ d+Au
- No Away-side shape modification
- No Ridge

Di-Jets don’t interact with medium. Tangential jets or punch through without interaction ?

Mach-Cone

•Trigger

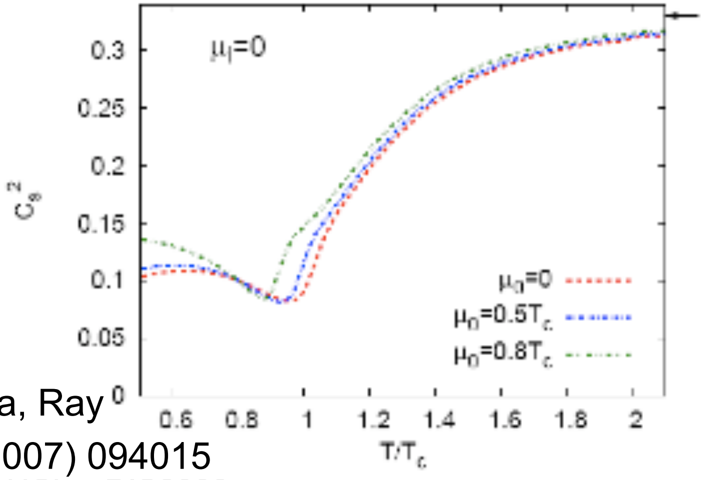
$$\frac{c_s}{v_{parton}} = \cos(\theta_M)$$

$$c_s^{\ 2} = \frac{\partial p}{\partial \varepsilon};\ v_{parton} \approx c$$

•Away-side

- Mach angle depends on speed of sound in medium
  - T dependent
- Angle independent of associated p_T.

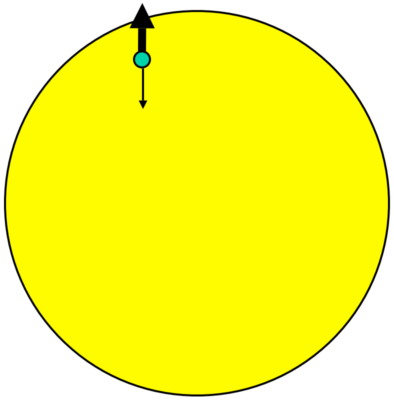
•PNJL Model



•Mikherjee, Mustafa, Ray

•Phys. Rev. D75 (2007) 094015

Mach-Cone



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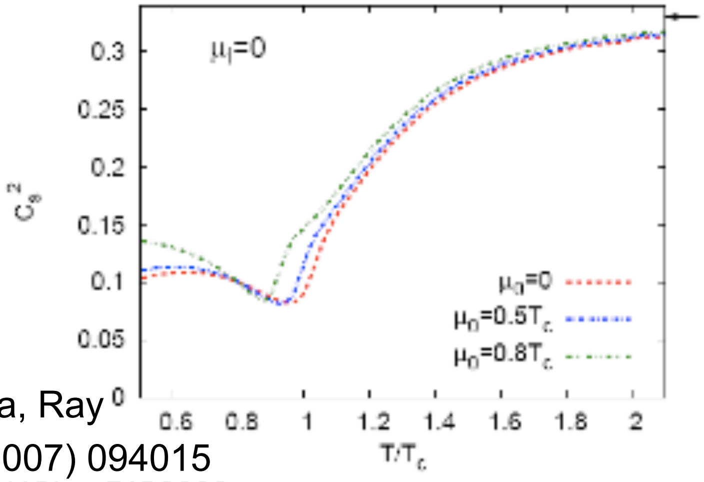

•Mikherjee, Mustafa, Ray

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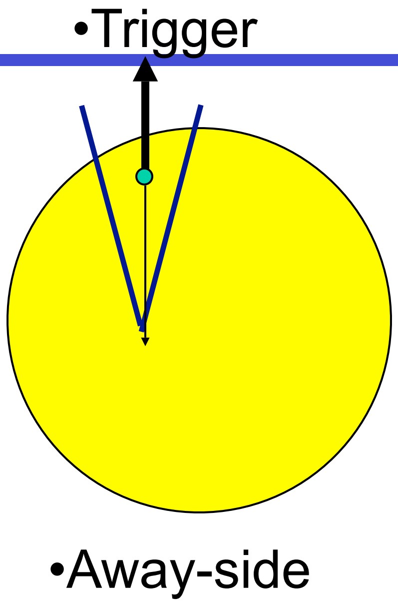
Mach-Cone



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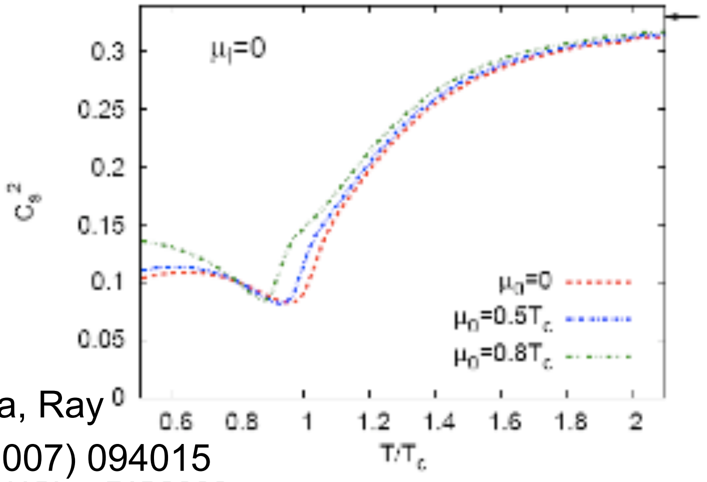

•Mikherjee, Mustafa, Ray

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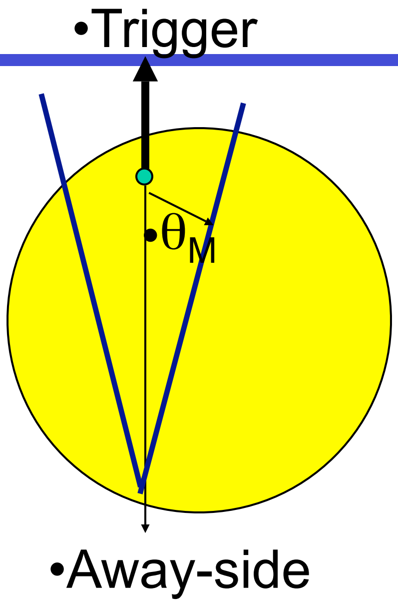

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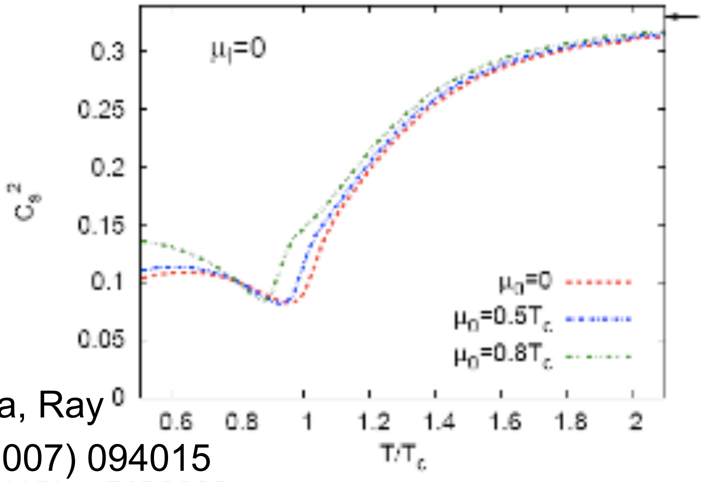

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Mach-Cone

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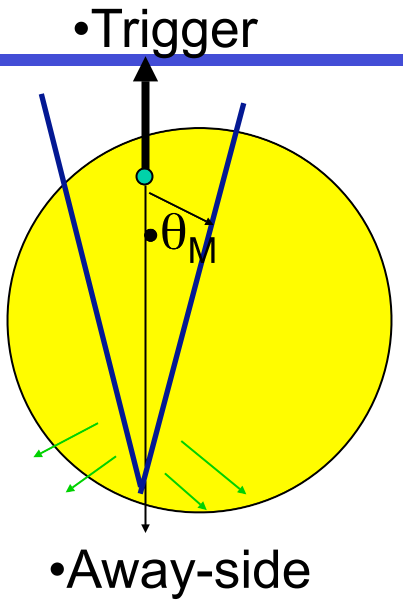

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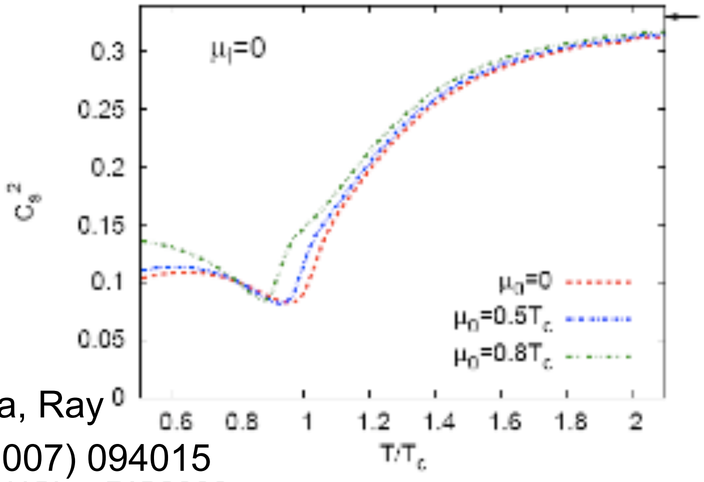


•Mikherjee, Mustafa, Ray

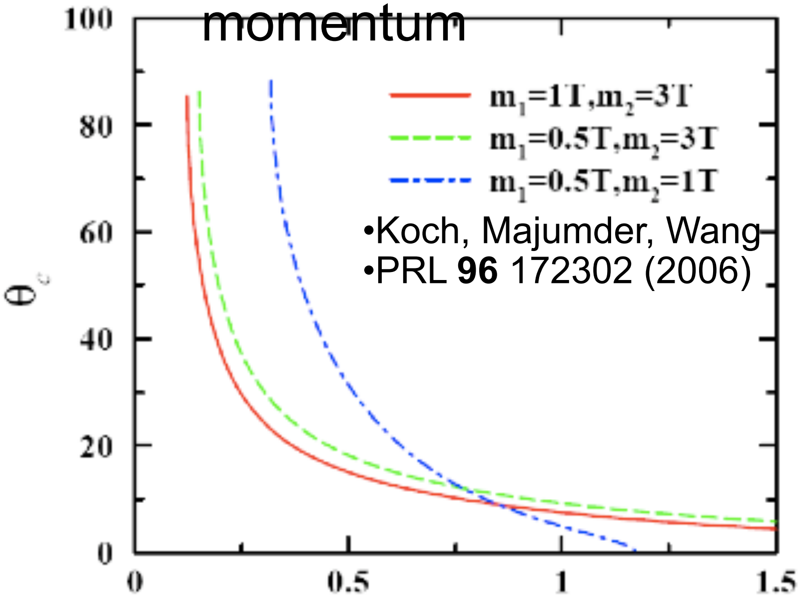
•Phys. Rev. D75 (2007) 094015

Čerenkov Gluon Radiation

- Gluons radiated by superluminal partons.
- Angle is dependent on emitte momentum.

$$\frac{c_n}{v_{parton}} = \cos(\theta_c) = \frac{c}{n(p)v_{parton}} \approx \frac{1}{n(p)}$$

- Čerenkov angle vs
- emitted particle momentum



- Koch, Majumder, Wang
- PRL **96** 172302 (2006)

- p (GeV/c)

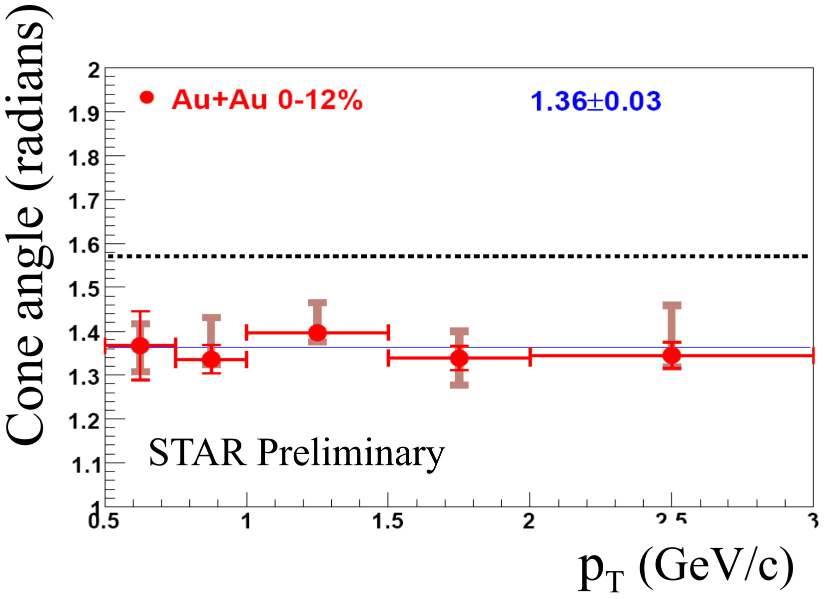
Mach cone?

Naive calc. of time averaged velocity of sound in medium:

$$\frac{c_s}{v_{parton}} = \cos(\theta_M)\ ,\ v_{parton} = c$$

Cone angle ~ 1.36 radians

$c_s = 0.2c!$



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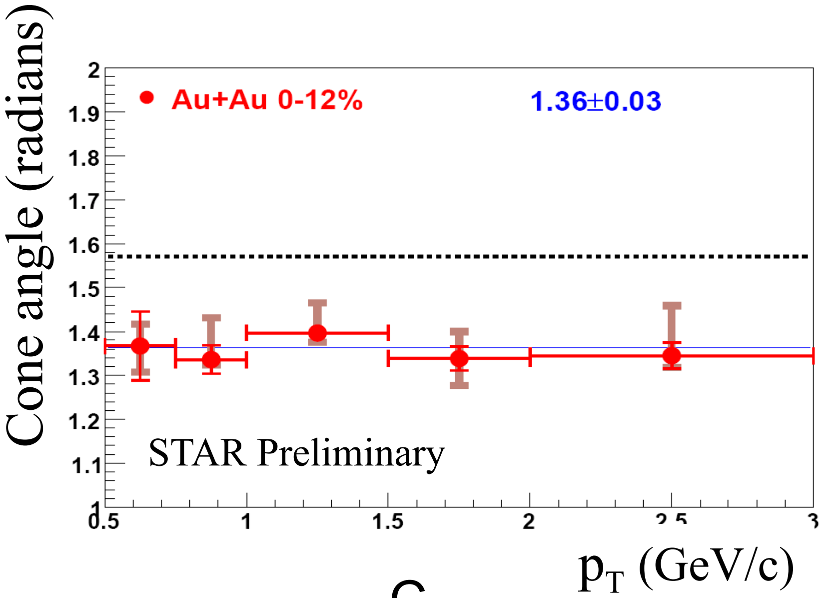
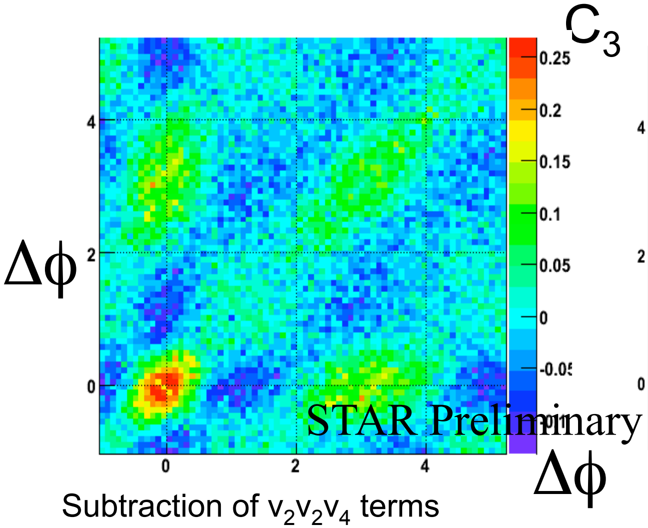
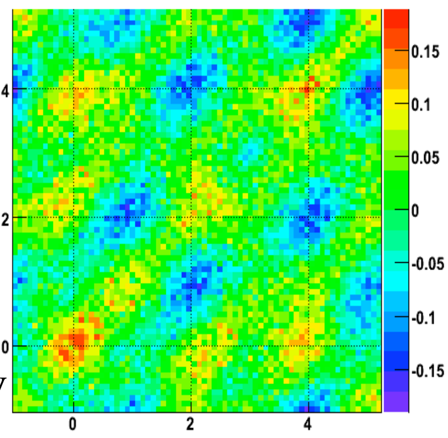


- In cumulant approach: no conclusive evidence for conical emission so far

- Strength and shape of away side structures observed depends on assumed magnitude of flow coefficients



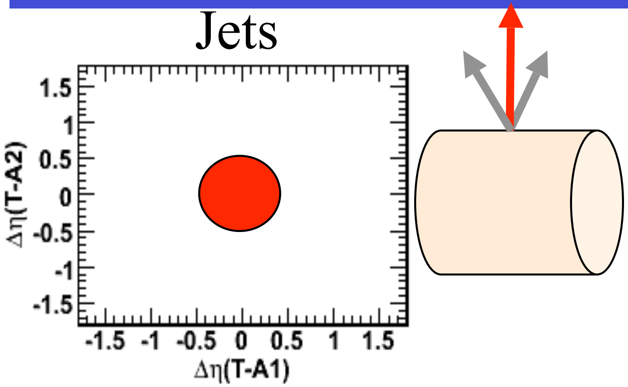
Subtraction of $v_2v_2v_4$ terms using on $v_2 = 0.06$



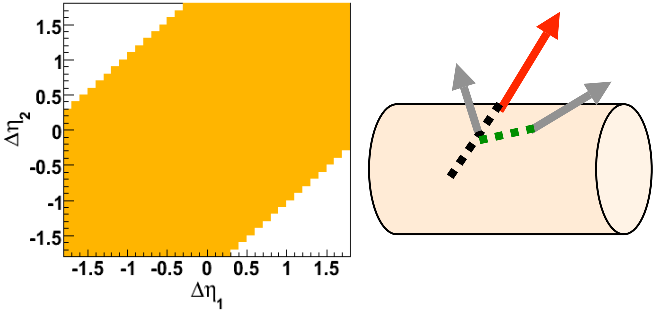
Subtraction of $v_2v_2v_4$ term using $v_2 = 0.12$

Ridge : 3-particle Correlation

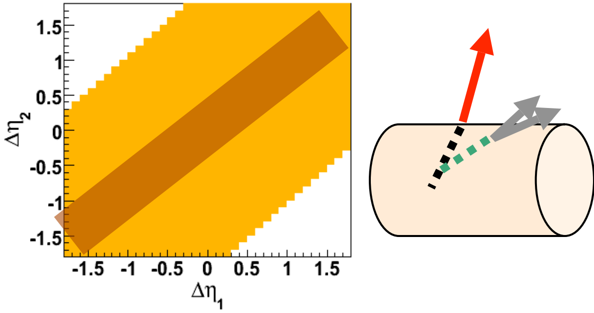
Jets



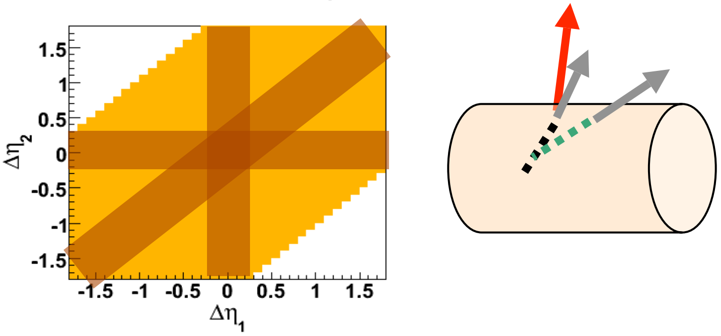
In-medium radiated gluons diffused in η



In-medium radiated gluons still collimated



Jet fragmentation and diffused gluons



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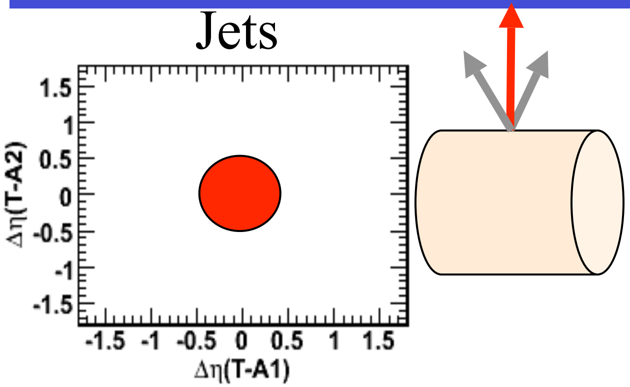
Ridge : 3-particle Correlation

Jets



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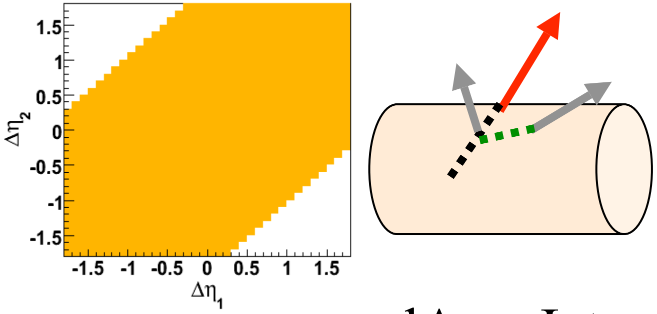
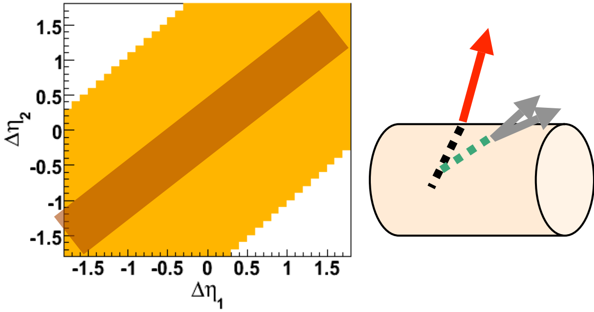
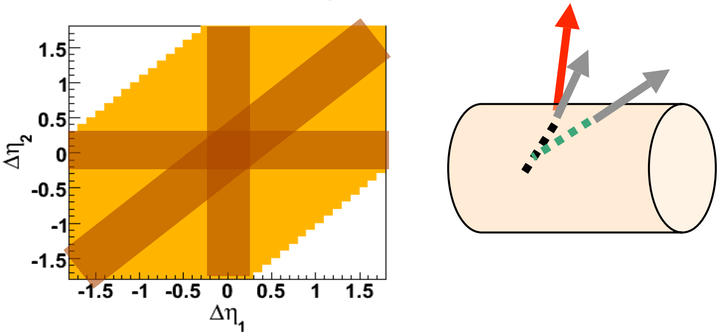


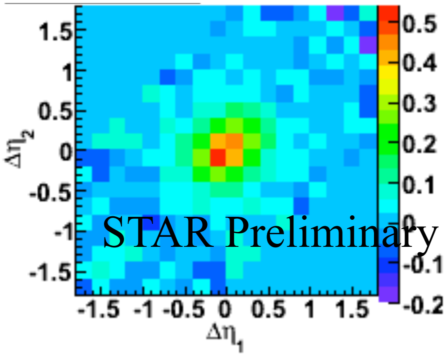
In-medium radiated gluons still collimated



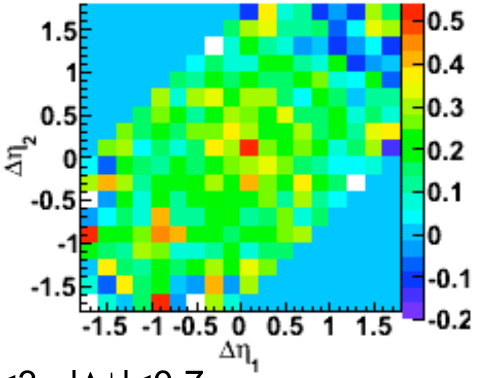
Jet fragmentation and diffused gluons



dAu : Jets



AuAu : 200 GeV



$3<p_T^{Trig}<10 \quad 1<p_T^{Asso}<3 \quad |\Delta\phi|<0.7$

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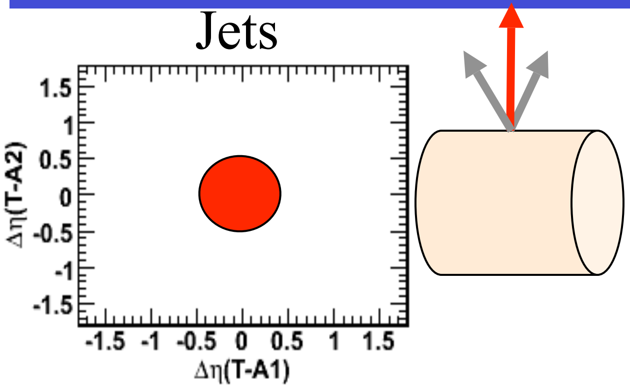
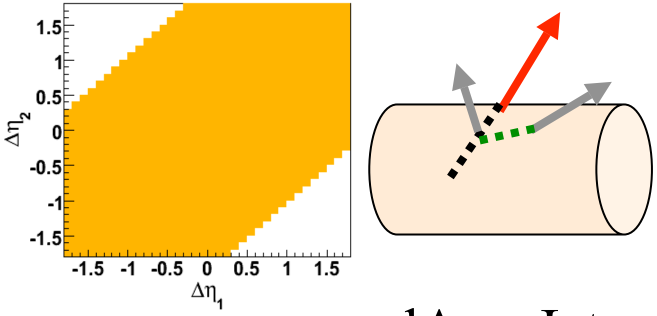
Ridge : 3-particle Correlation

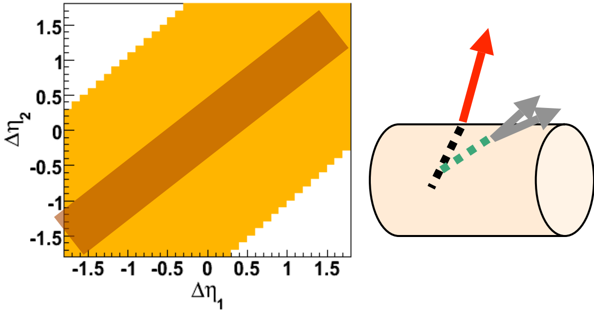
Jets



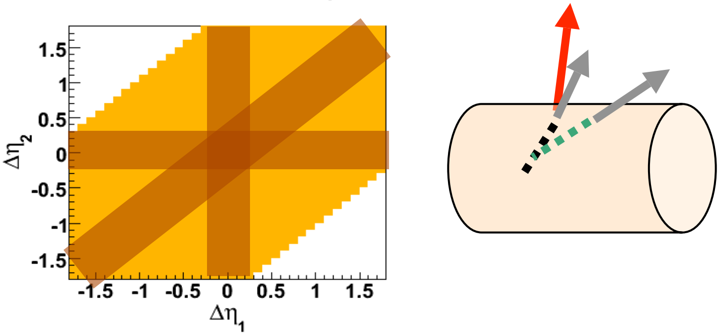
In-medium radiated gluons diffused in η



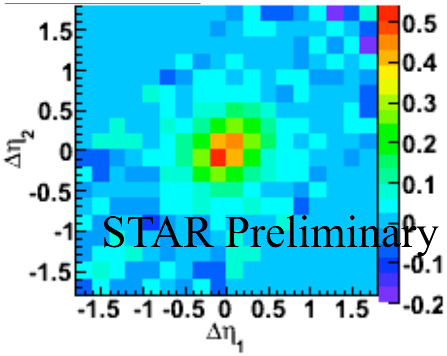
In-medium radiated gluons still collimated



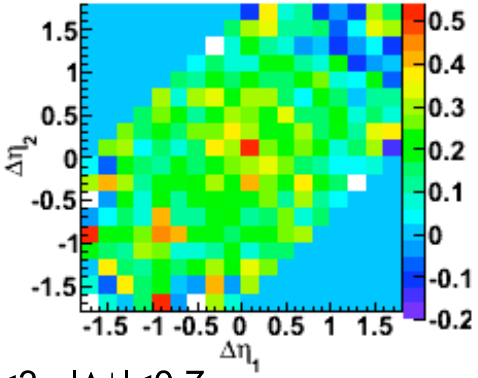
Jet fragmentation and diffused gluons



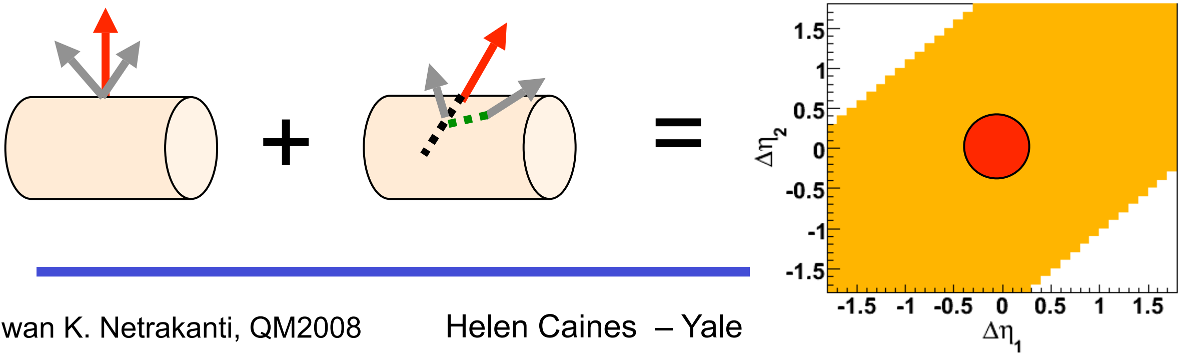
dAu : Jets



AuAu : 200 GeV



$3<p_T^{Trig}<10$ $1<p_T^{Asso}<3$ $|\Delta\phi|<0.7$



Uniform overall excess of associated particles not due to correlated emission

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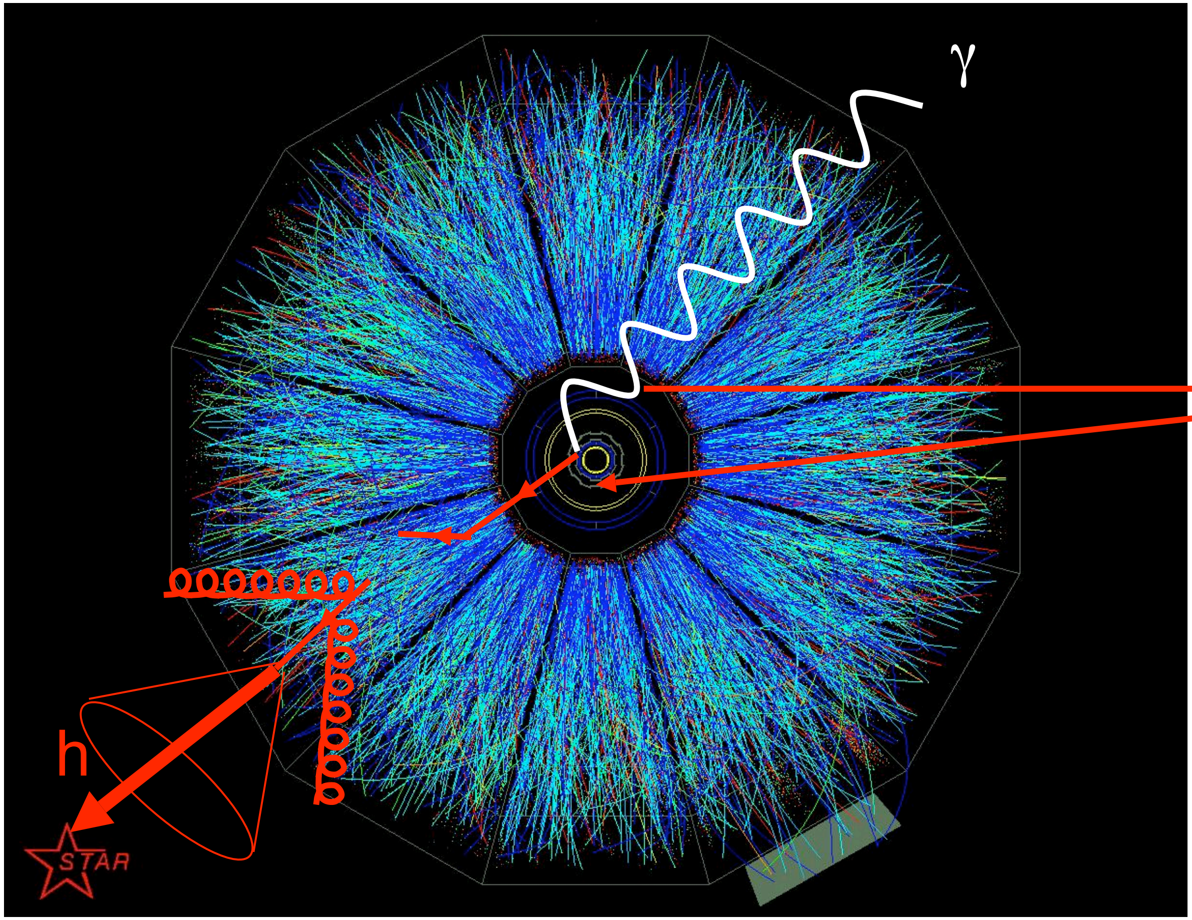
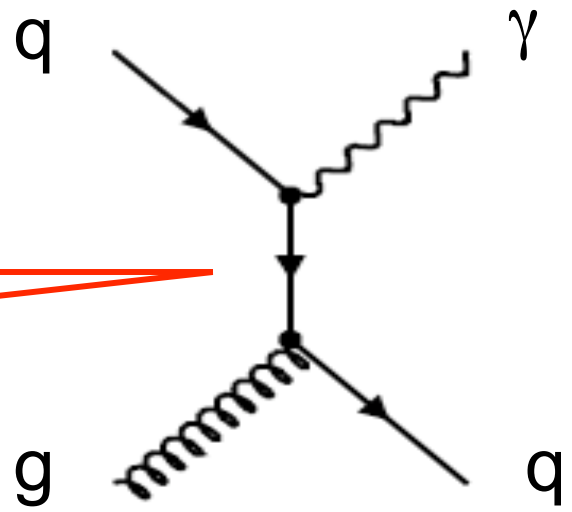
Golden Probe of QCD Energy Loss - γ-Jet

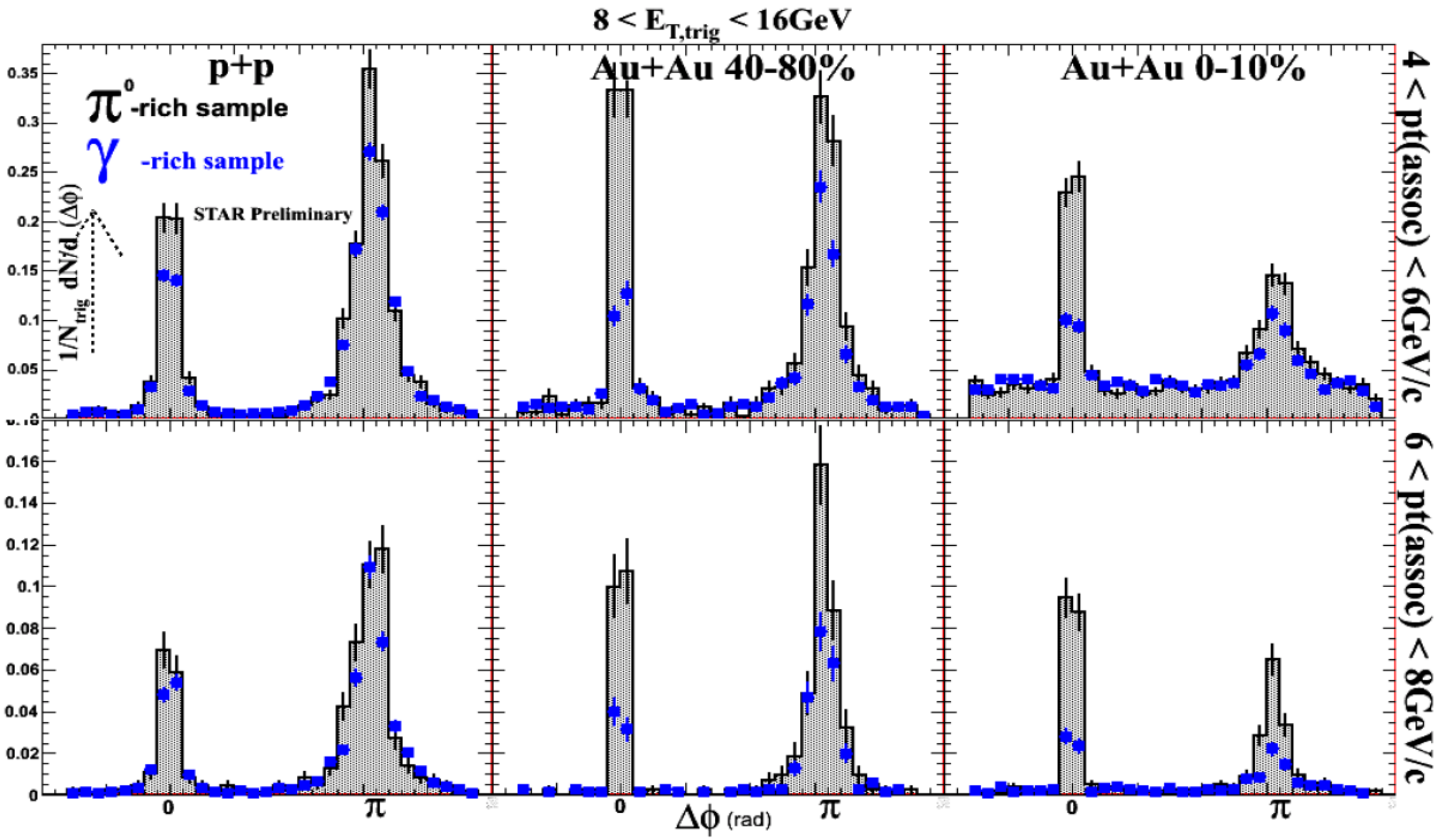




QCD analog of
Compton Scattering

- γ emerges “unscathed” from medium
  - Full reconstruction of kinematics: real fragmentation function (D(z))

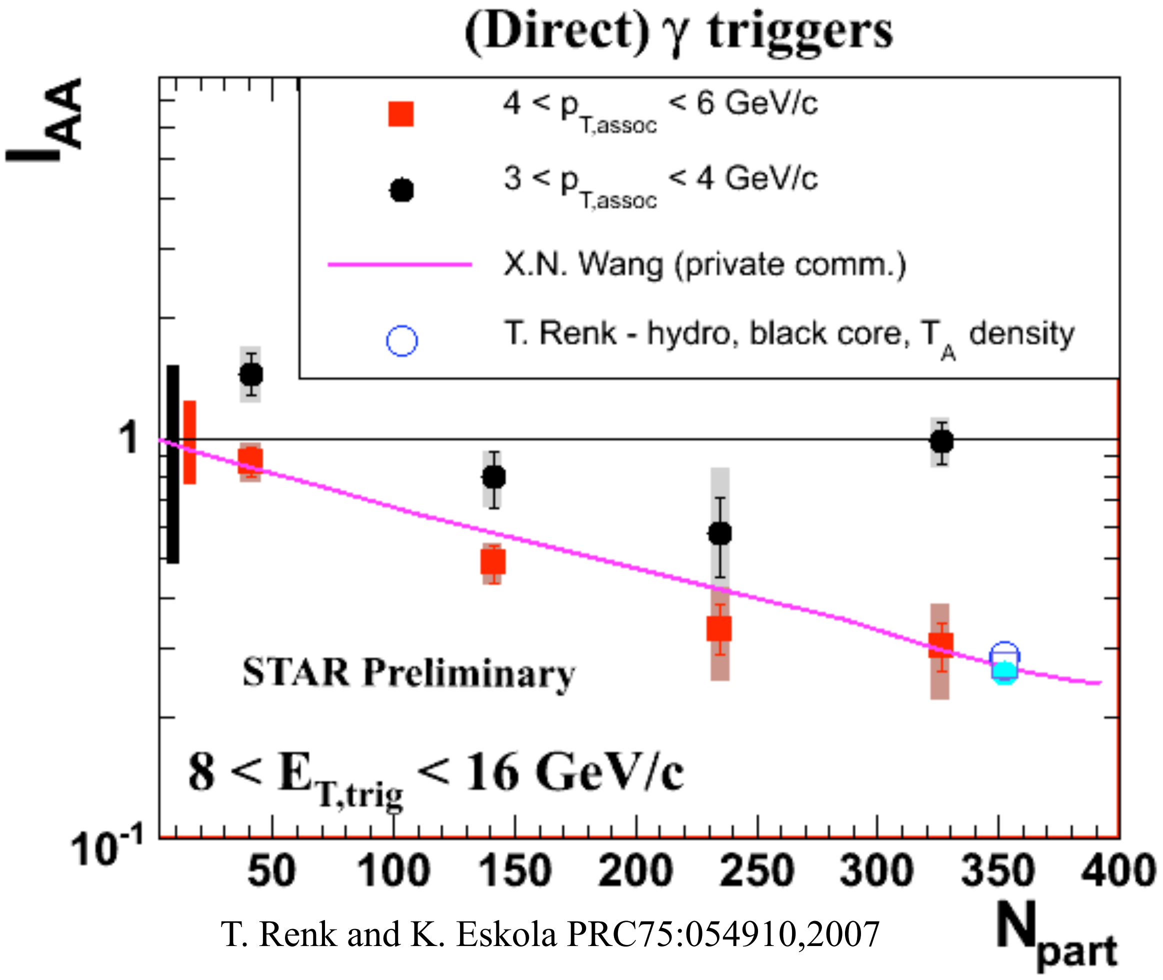
γ-hadron and π^0-hadron correlations



Shower shape in Shower Maximum Detector gives γ-, π^0-enriched samples

The γ-rich sample has lower near-side yield than π^0.

First measure of away-side I_{AA} for γ-h



T. Renk and K. Eskola PRC75:054910,2007

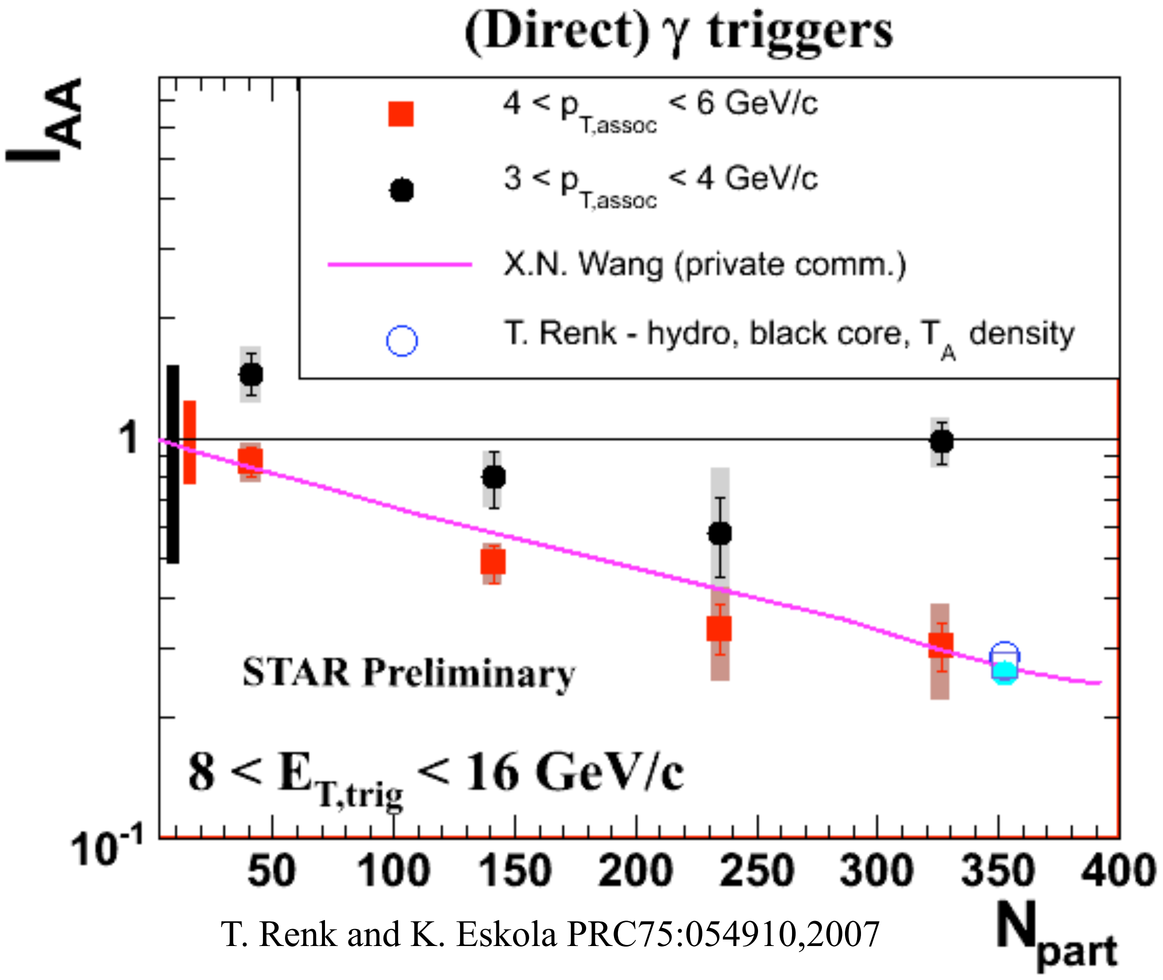
$$E_{jet} = E_{\gamma} = E_{trig}$$

$$I_{AA} = \frac{D_{AA}(z_T, E_T^{trig})}{D_{pp}(z_T, E_T^{trig})}$$

$$D^{h_1 h_2}(z_T, p_T^{trig}) = p_T^{trig} \frac{d\sigma_{AA}^{h_1 h_2}/dp_T^{trig} dp_T}{d\sigma_{AA}^{h_1}/dp_T^{trig}}$$

Good agreement between theory and measurement for higher p_{Tassoc}

First measure of away-side I_{AA} for γ-h



T. Renk and K. Eskola PRC75:054910,2007

$E_{jet} = E_{\gamma} = E_{trig}$

$$I_{AA} = \frac{D_{AA}(z_T, E_T^{trig})}{D_{pp}(z_T, E_T^{trig})}$$

$$D^{h_1 h_2}(z_T, p_T^{trig}) = p_T^{trig} \frac{d\sigma_{AA}^{h_1 h_2}/dp_T^{trig} dp_T}{d\sigma_{AA}^{h_1}/dp_T^{trig}}$$

Good agreement between theory and measurement for higher p_{Tassoc}

Suppression similar level to inclusives in central collisions