# Jet quenching au (SPS et) RHIC: perspective expérimentale

**RHIC-France 2005**

Etretat, 29 juin, 2005

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# Overview

0. Physics motivation: Jet production in QCD medium (AA) vs QCD vacuum (pp) as a signature of QGP formation at RHIC.

1. Empirical observation I: High $p_T$ (leading) hadron suppression.

   - Magnitude of suppression (x5 in central AuAu @ RHIC-200 GeV) provides direct info on transport ($\langle q_0 \rangle$) & thermodynam. ($dN^g/dy$) properties of medium
   - Properties of suppression ($p_T$-, $\sqrt{s}$-, ... dependence) in agreement w/ non-Abelian gluon radiation off hard scattered partons.

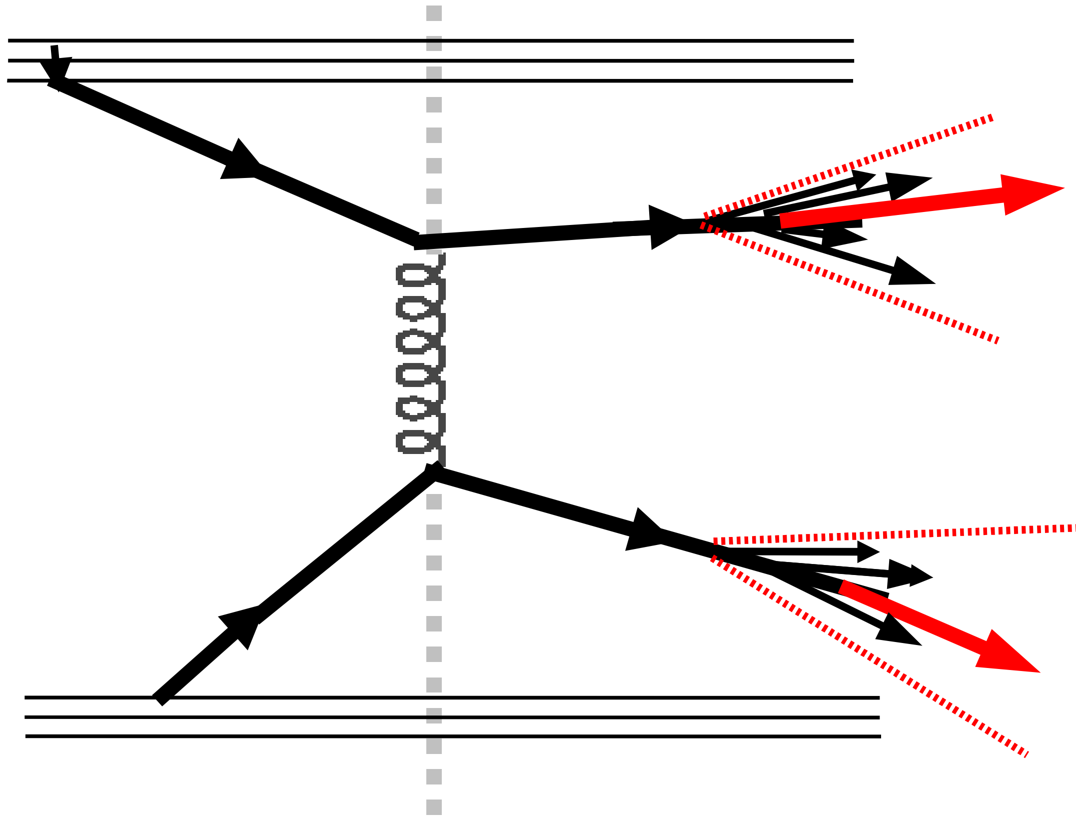
2. Empirical observation II: Modified high $p_T$ di-hadron $\phi$-,$\eta$-correlations.

   - Disappearance of back-to-back $dN_{pair}/d\phi$ peak ("monojets")
   - "Double peak" structure in away-side $dN_{pair}/d\phi$ ("Mach boom" in medium ?)
   - Di-jet pseudo-rapidity $dN_{pair}/d\eta$ broadening (coupling of g rad. w/ long. expansion ?)

3. Summary

*Disclaimer: This is a limited selection of a vast number of exp. nucleus-nucleus data (no mention to high $p_T$ baryon or heavy-Q spectra, no space for discussion on detailed jet properties $\langle j_T \rangle$,$\langle k_T \rangle$, ...)*

# Jet production in the "QCD vacuum" (pp collisions)



- Jet : Collimated spray of hadrons in a cone ( $R = \sqrt{\Delta\eta^2 + \Delta\phi^2}$ ~ 0.7) with 4-momentum of original fragmenting parton
- Leading hadron takes away large fraction (**<z>** ~0.6 –0.8 @ RHIC) of parent parton $p_T$
- Jet balanced back-to-back by other hard-scattered "parton" (jet, direct $\gamma$, ...)

# Jet production in "QCD media" (pA, AA collisions)

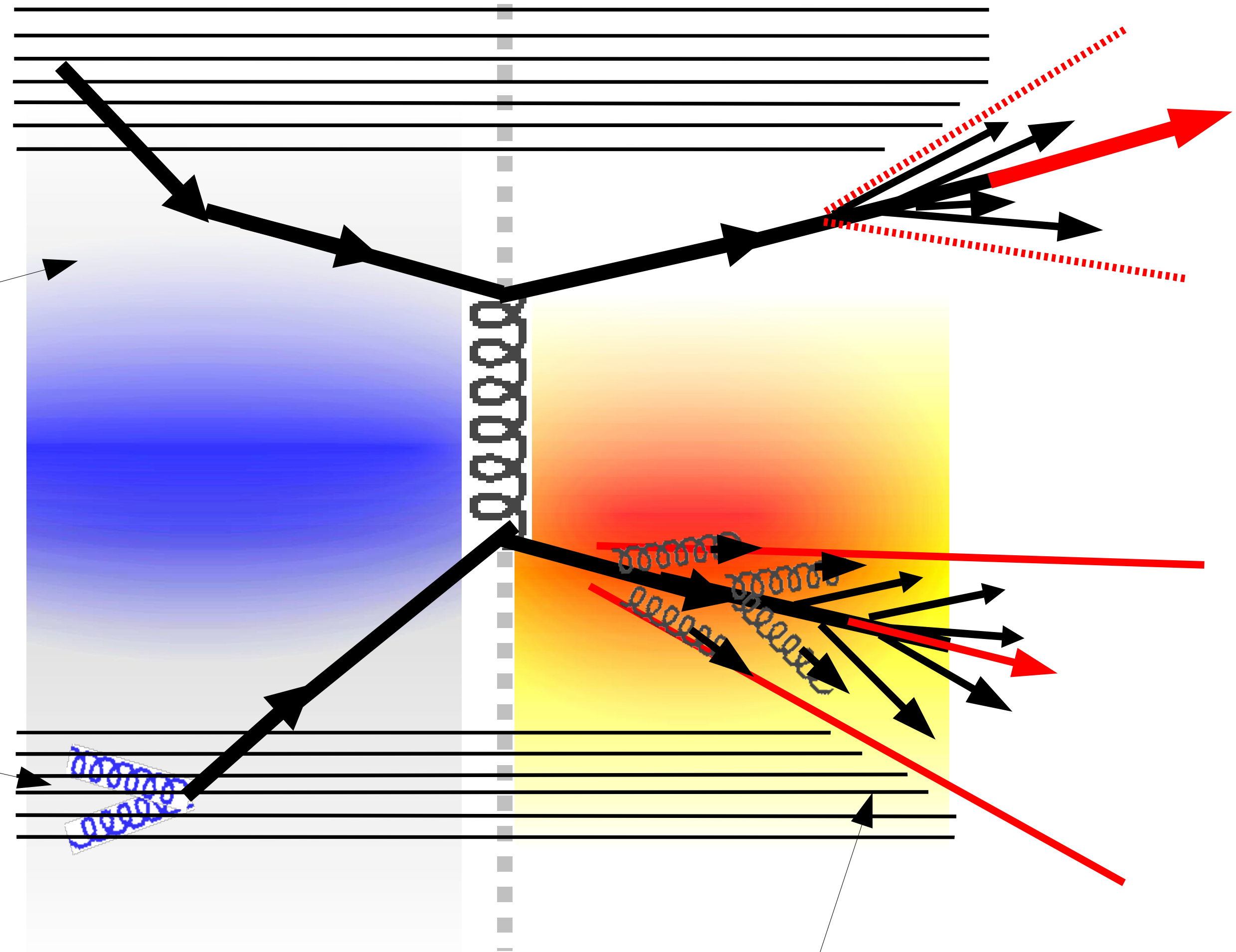
- Initial-state effects:

  (accessible via pA colls.)

  $k_T$ broadening

  (Cronin enhancement)

  (Leading-twist) shadowing or gluon saturation (**CGC**)



- Final-state effects:

  (accessible in AA colls.)

  Parton energy loss due to medium-induced gluon-strahlung in hot & dense environment

# "Jet quenching" = QGP signal

- Multiple final-state non-Abelian (gluon) radiation off the produced hard parton induced by the dense QCD medium.

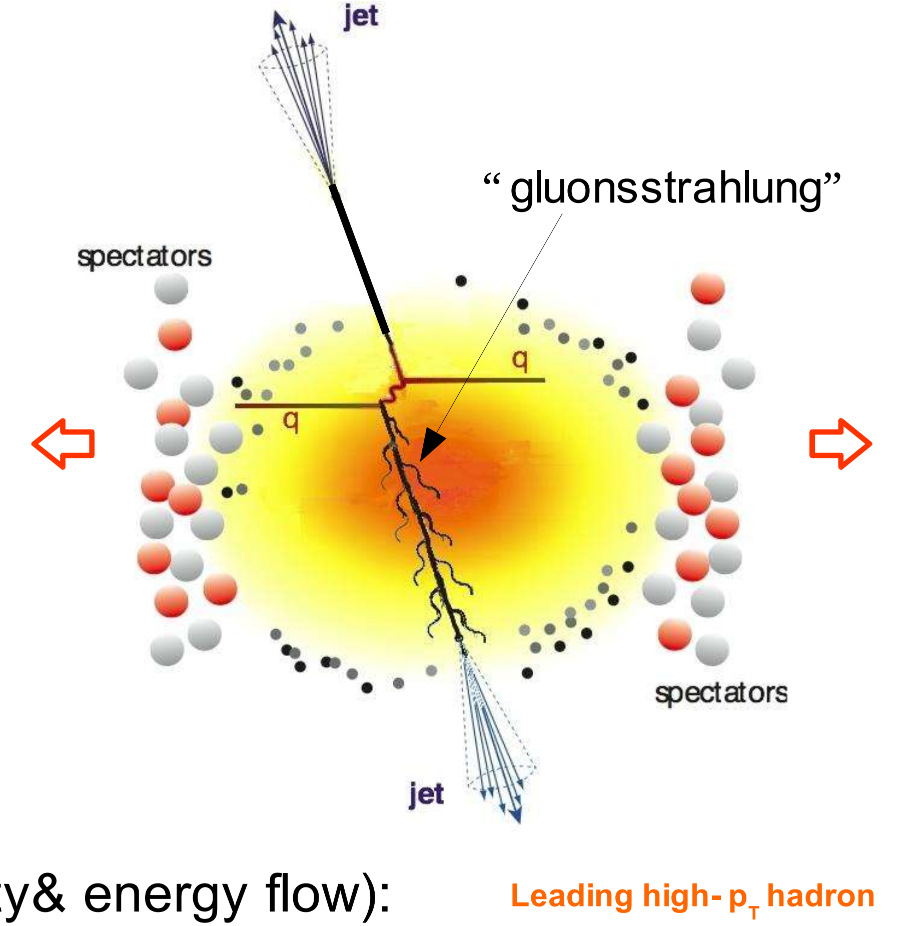
- Parton energy loss ∝ medium properties:

  $\Delta E_{loss} \sim \rho_{gluon}$ (gluon density)

  $\Delta E_{loss} \sim \Delta L^2$ (medium length)

- Energy is carried away by gluons emittted inside (broader) jet cone (modified multiplicity& energy flow):

  $dE/dx \sim \alpha_s \langle k_T^2 \rangle$



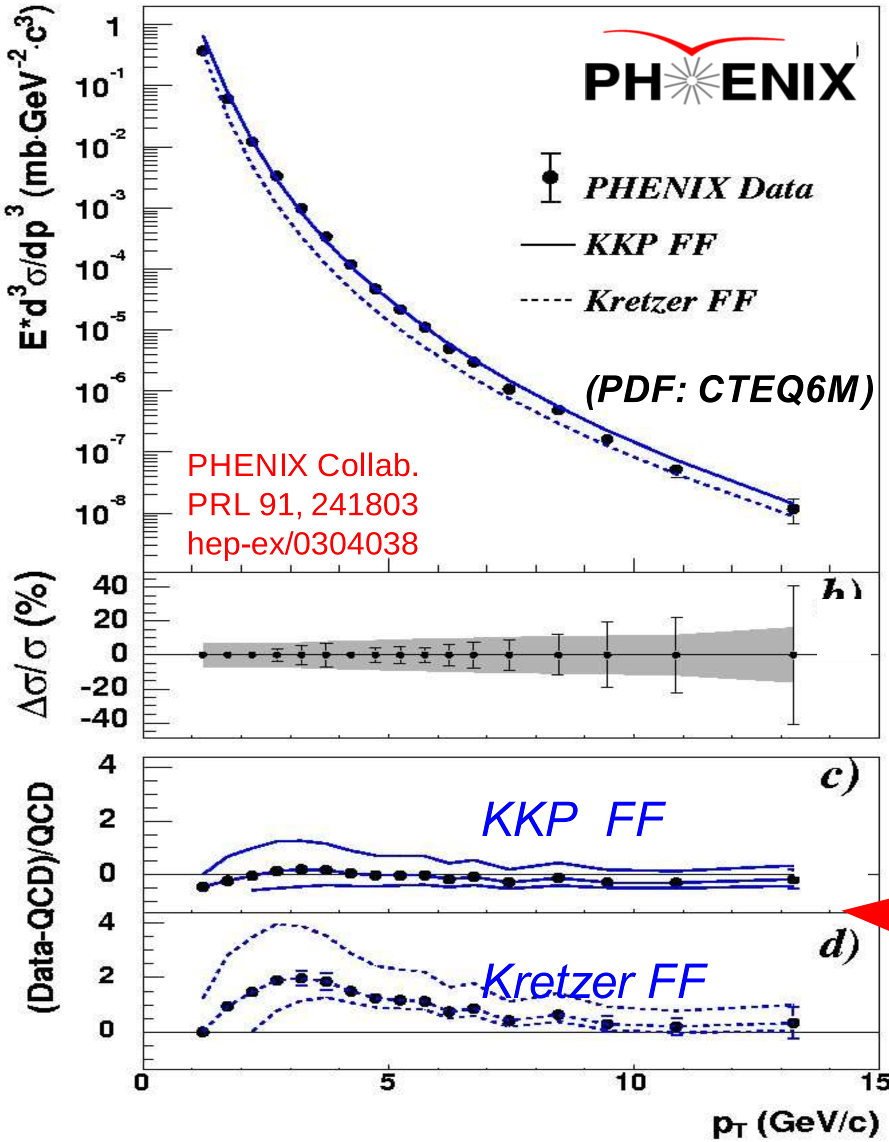

- Prediction I: Suppression of high $p_T$ leading hadrons: $dN/dp_T$
- Prediction II: Modification of (di)jet correlations: $d^2N_{pair}/d\varphi d\eta$

# (1) High $p_T$ leading hadron $p_T$ spectra in high-energy pp, dA, AA collisions

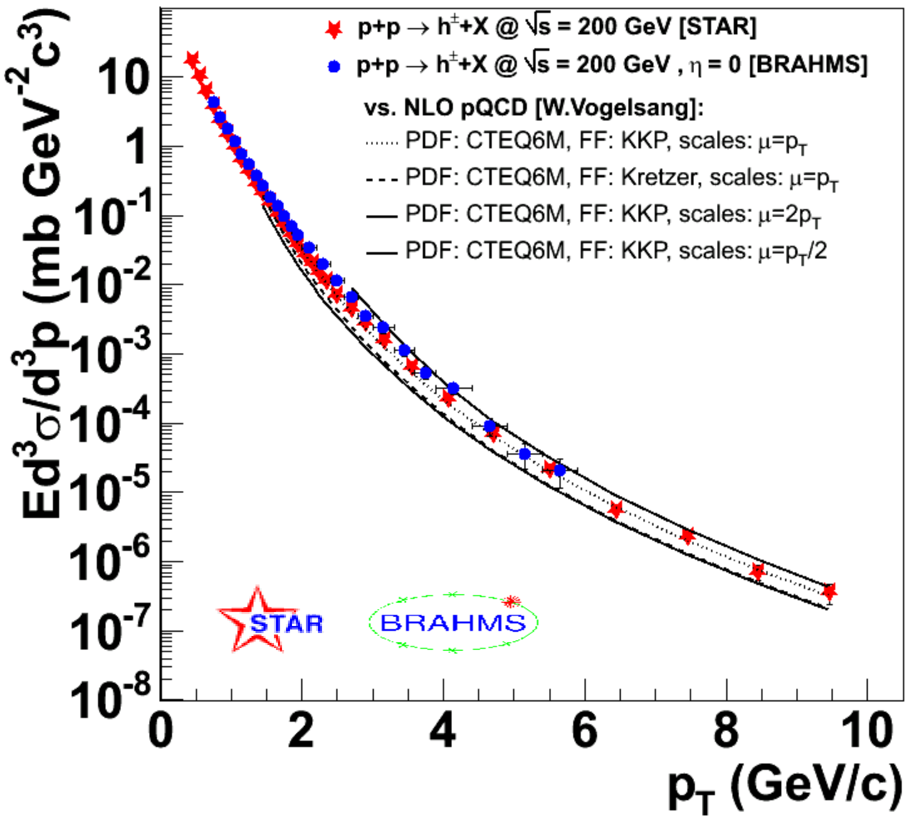
# Leading hadron spectra in free space: pp @ 200 GeV

- High $p_T$ $\pi^0$,$h^\pm$ spectra up to ~15 GeV/c. Good theoret. (NLO pQCD) description

$p+p \rightarrow \pi^0 X$




$p+p \rightarrow h^\pm X$



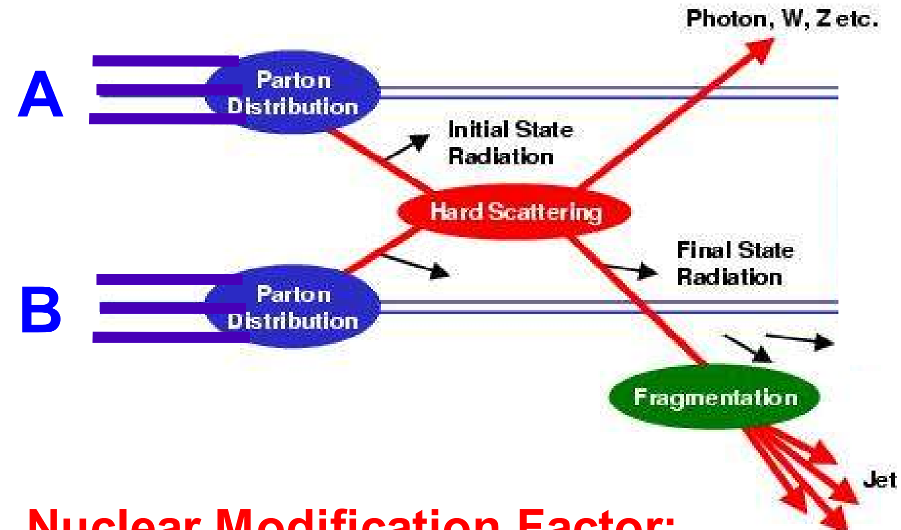

- High quality data: sensitive to different parametrizations of gluon FF
- Well calibrated (experimentally & theoret.) p+p baseline spectra at hand !

# Hard spectra: AA = incoherent sum of pp

- Hard yields calculable via perturbative-QCD:

"Factorization theorem":

$$d\sigma_{AB\to hX} = A\cdot B\cdot f_{a/p}(x_a,Q^2_a)\otimes f_{b/p}(x_b,Q^2_b)\otimes d\sigma_{ab\to cd}\otimes D_{h/c}(z_c,Q^2_c)$$




Independent scattering of "free" partons:

$$f_{a/A}(x,Q^2) = A\, f_{a/p}(x,Q^2)$$

A+B = "simple superposition of p+p collisions"

$$d\sigma_{AB\to hard} = A\cdot B\cdot d\sigma_{pp\to hard}$$

At impact parameter b:

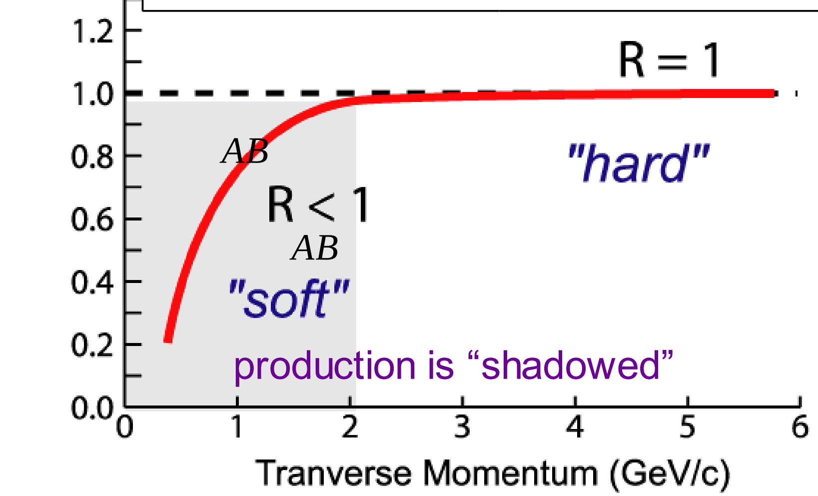
$$dN_{AB\to hard}(b) = T_{AB}(b)\cdot d\sigma_{pp\to hard}$$

geom. nuclear overlap at b

$T_{AB}$ ~ # NN collisions ("$N_{coll}$ scaling")

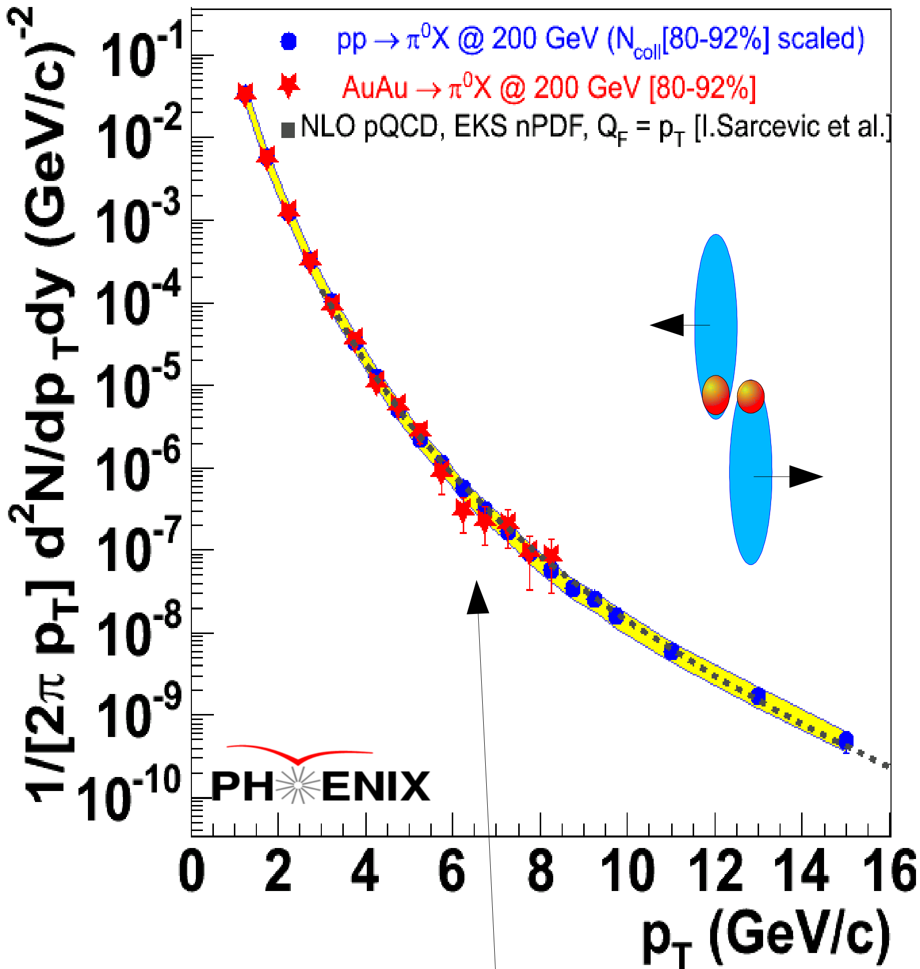
**Nuclear Modification Factor:**

$$R_{AB}(p_T) = \frac{d^2N_{AB}/dydp_T}{\langle T_{AB}(b)\rangle\cdot d^2\sigma_{pp}/dydp_T}$$

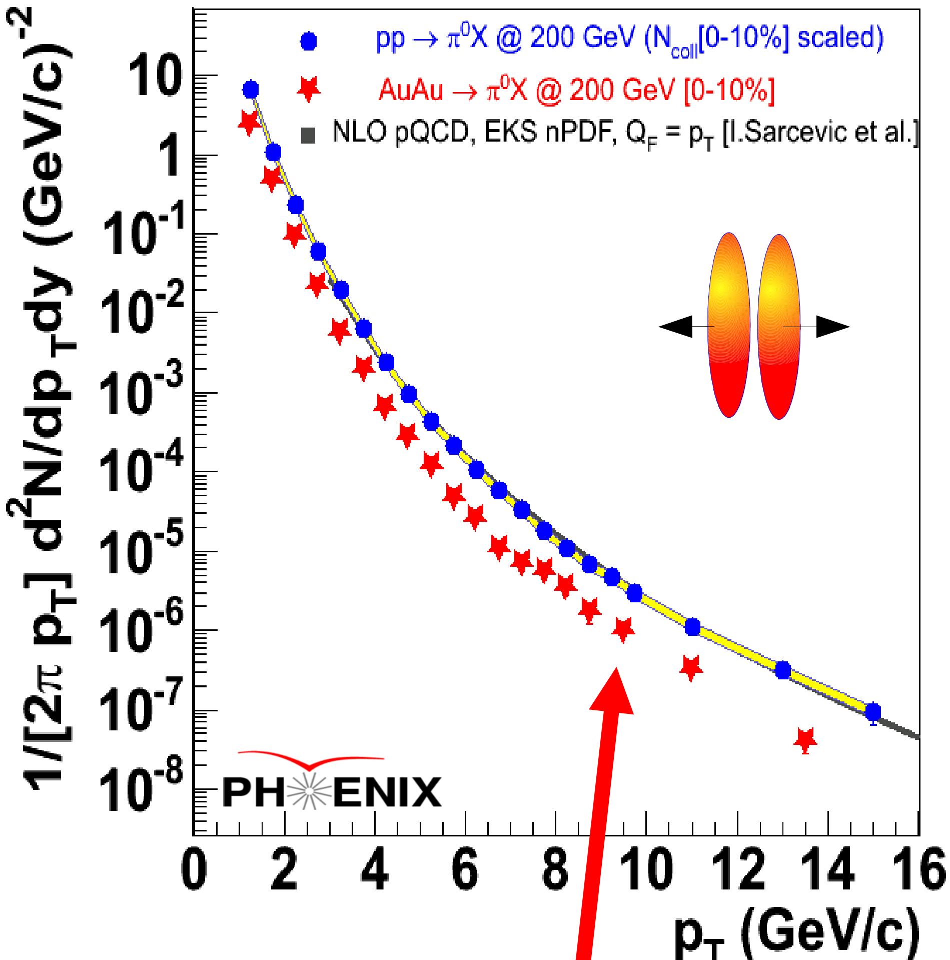


# Leading hadron spectra in AuAu @ 200 GeV

Au+Au→ $\pi^0 X$ (peripheral)




Au+Au→ $\pi^0 X$ (central)

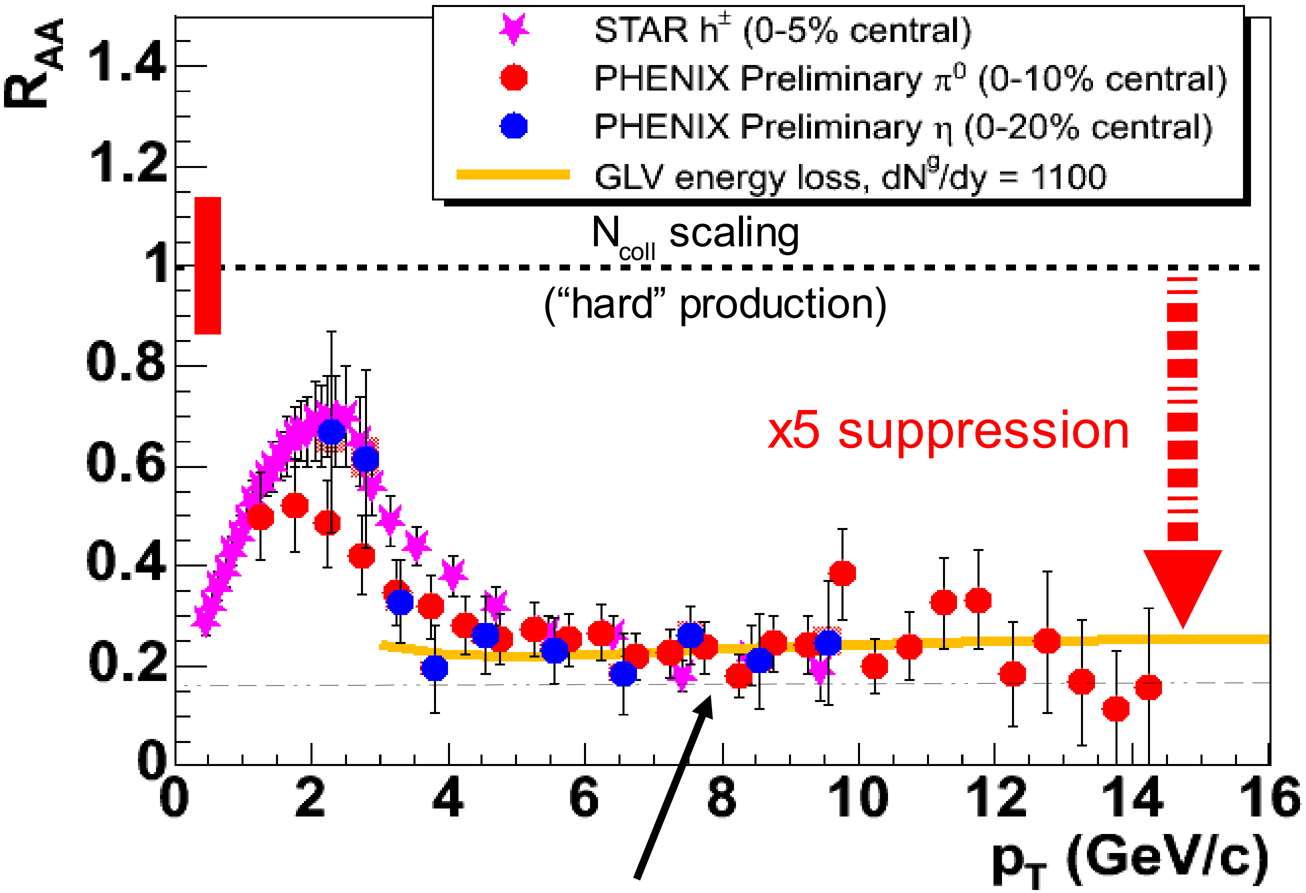



Peripheral data agree well with p+p (data & pQCD) plus $N_{coll}$ scaling

Strong suppression in central Au+Au collisions !

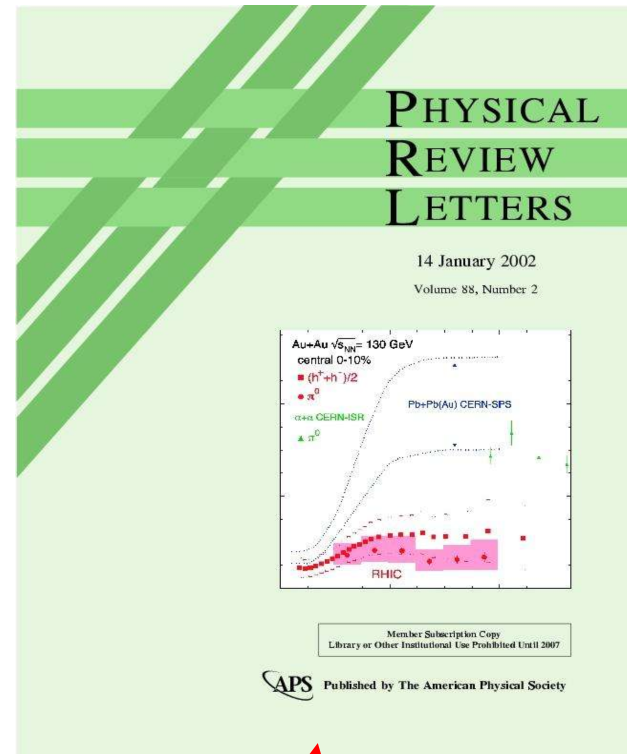
# Suppressed high $p_T$ hadroproduction in central AuAu

PHENIX Collab.
PRL 88, 022301 (2002)
nucl-ex/0109003




$N_{part}$ scaling
(surface emission)

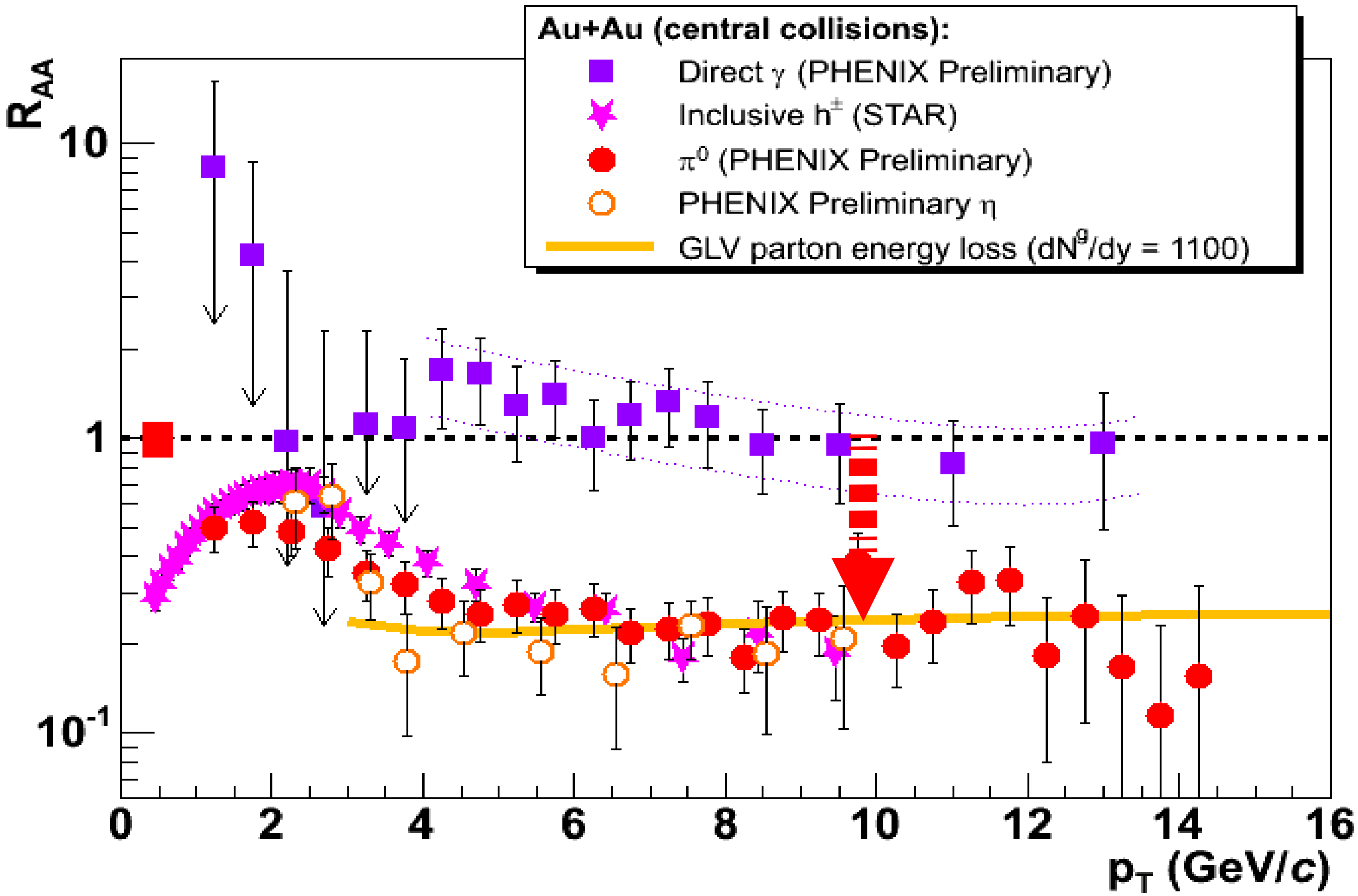
D.d'E., HP'04
nucl-ex/0504001




Discovery of
high $p_T$ suppression
(one of most significant
results @ RHIC so far)

- "Universal" (pid-wise) suppression:
  $R_{AA}$ ~ 0.2 up to $p_T$ ~ 14 GeV/c for $\pi^0$, $\eta$, $h^{\pm}$
  well below pQCD expectations for hard cross-sections

# Unquenched direct photon production in AuAu

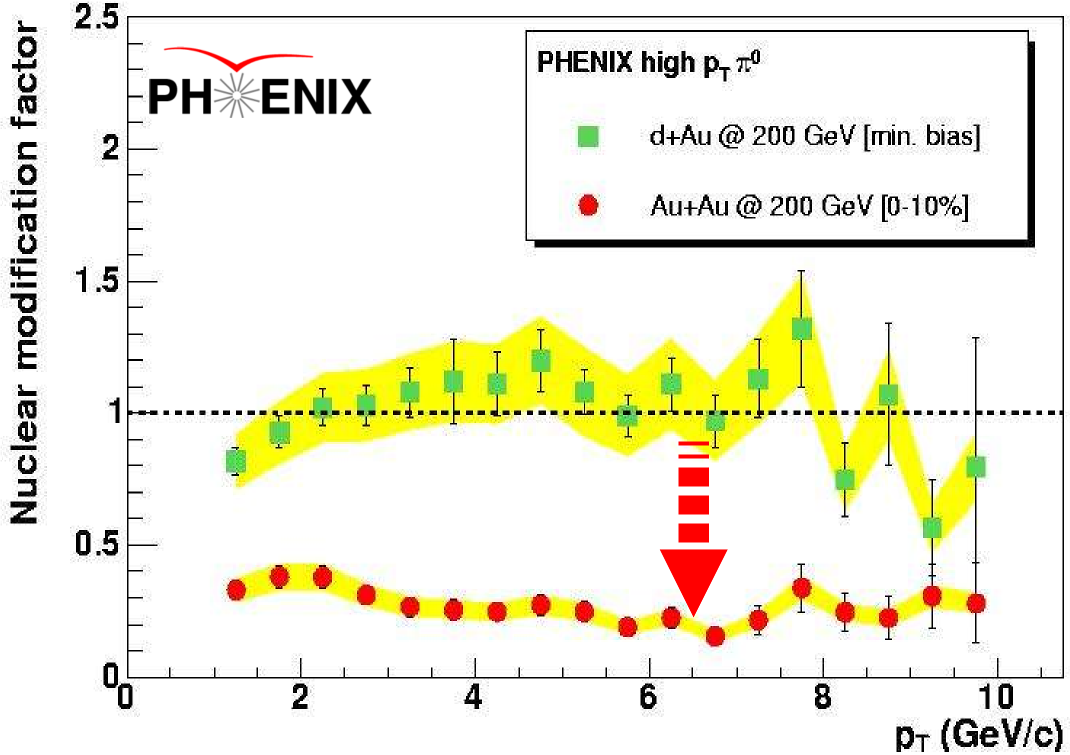



PHENIX.
PRL 94, 232301

D.d'E, HP'04
EPJ C to appear
(nucl-ex/0504001)

- Color-less hard probes (direct γ) are unsuppressed.
- AuAu collision = incoherent sum of pp collisions (expected "$N_{coll}$ scaling" for perturbative probes).

# Unquenched high $p_T$ hadroproduction in dAu

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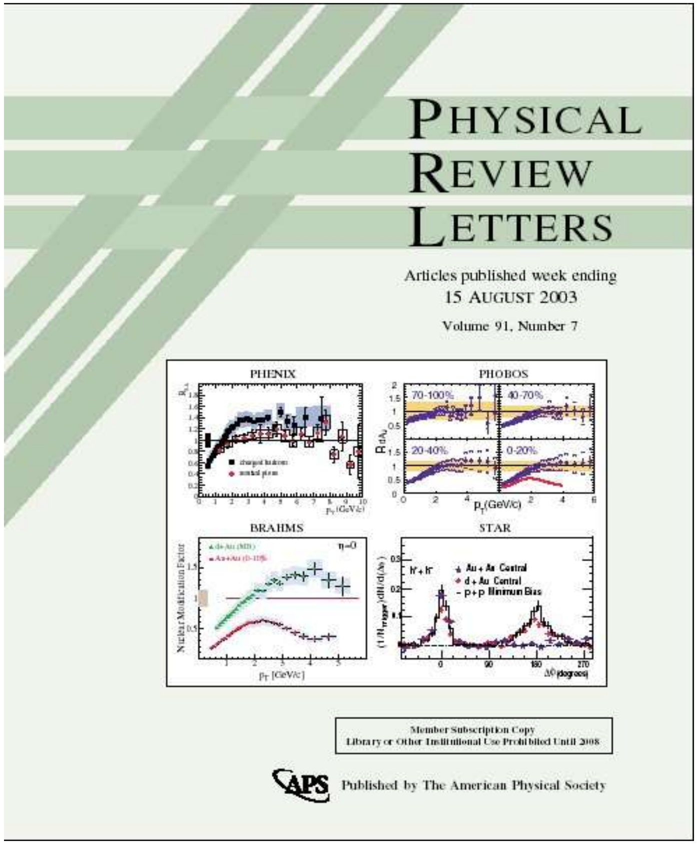
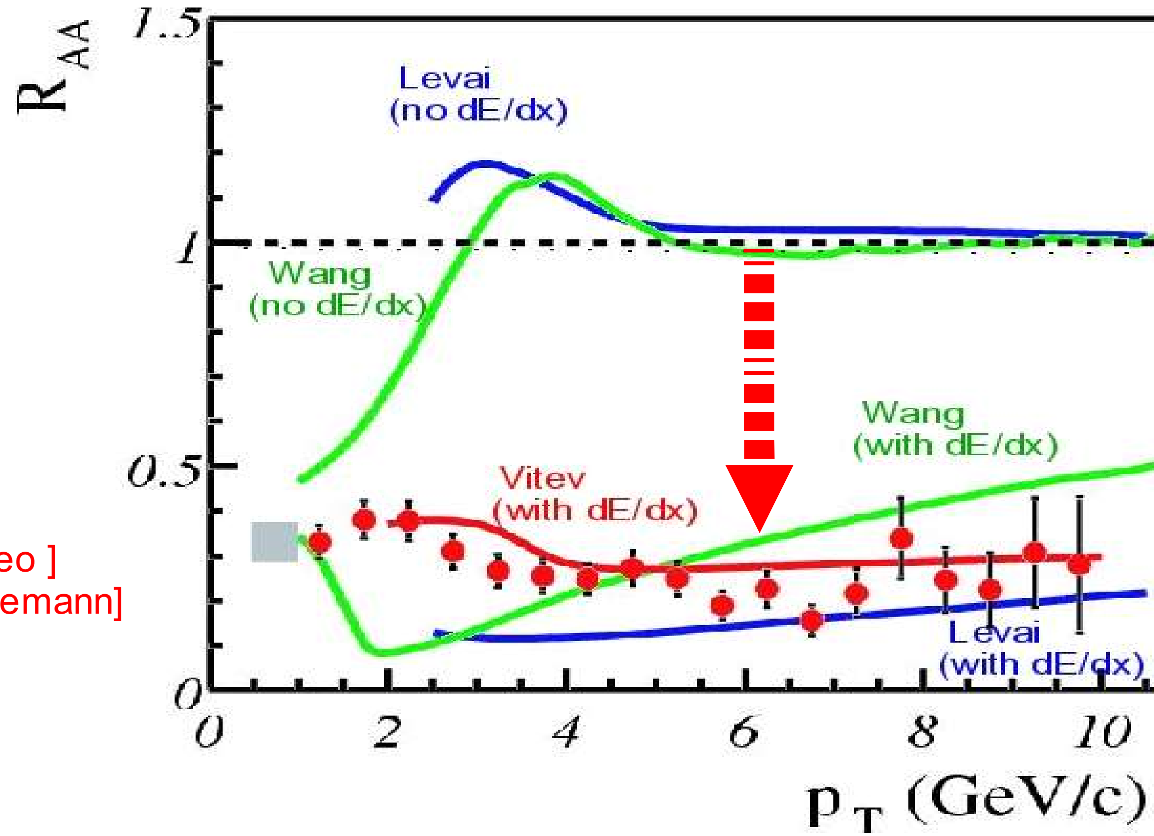
PRL 91, 072303 (2003)




- Initial-state cold nuclear matter effects (shadowing, Cronin) are small at RHIC mid-rapidity.
- High $p_T$ suppression in central AuAu is due to final-state effects (absent in "control" dAu experiment)

# Dense medium properties

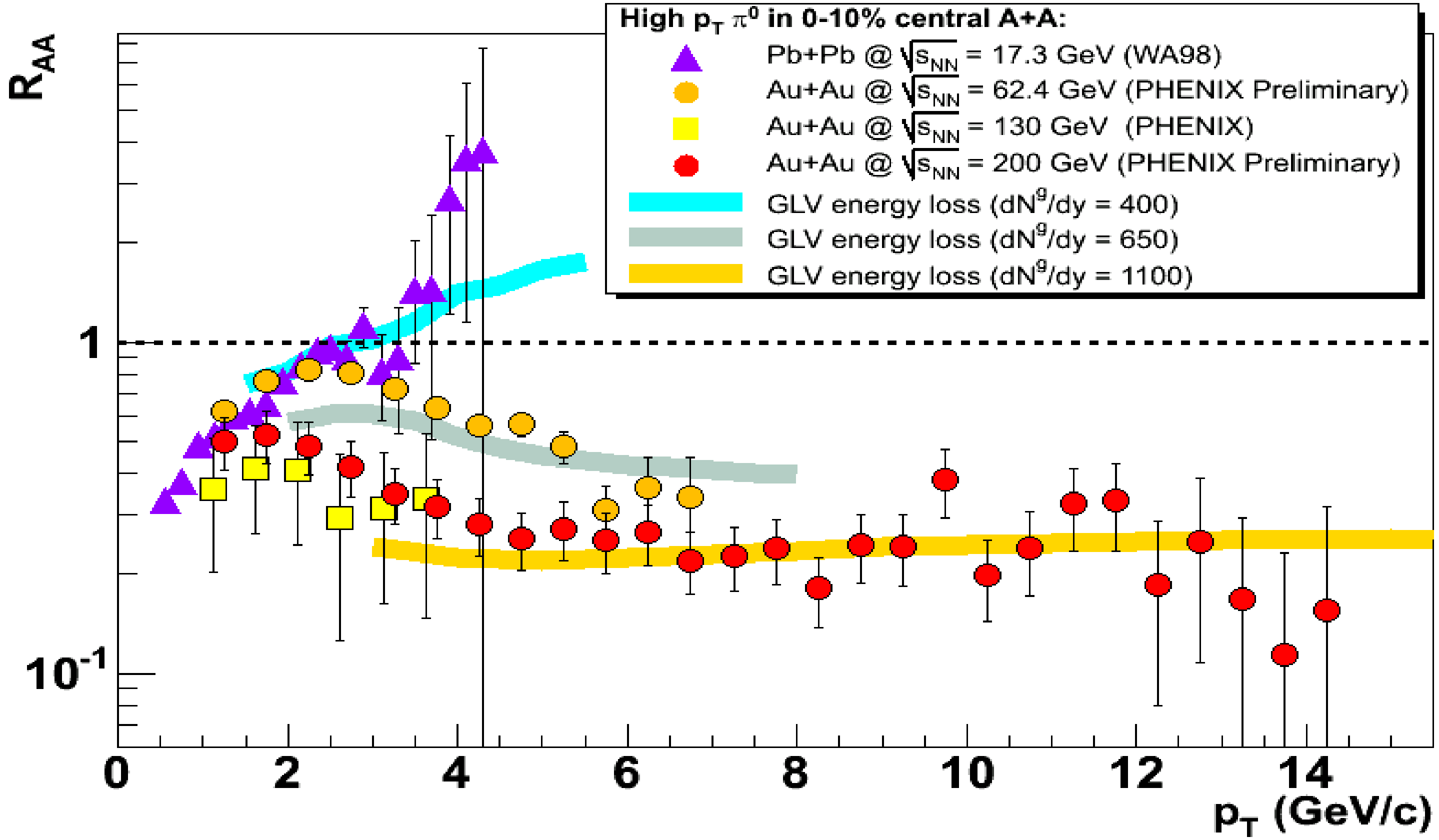
- From data vs. model (pQCD+ non-Abelian parton energy loss) comparison:
  - ✯ Initial gluon densities:
    $dN^g/dy \sim 1000$ [Vitev & Gyulassy]
  - ✯ Opacities:
    $\langle n \rangle = L/\lambda \approx 3 - 4$ [Levai et al.]
  - ✯ Transport coefficients:
    $\langle q_0 \rangle \sim 14\ GeV^2/fm$ [BDMPS, F.Arleo ] [Salgado-Wiedemann]
  - ✯ Medium-induced radiative energy losses:
    $dE/dx \approx 0.25\ GeV/fm$ (expanding)
    $dE/dx|_{eff} \approx 14\ GeV/fm$ (static source) [X.N.Wang]




- Such large opacities imply fast thermalization.
- All transport & thermodynam. values imply energy densities well above $\varepsilon_{crit\ QCD}$

# High $p_T$ suppression: $p_T$- and sqrt(s)-dependence

- $\sqrt{s}$- and $p_T$- dependence in agreement with parton energy loss in increasingly dense (expanding) medium:



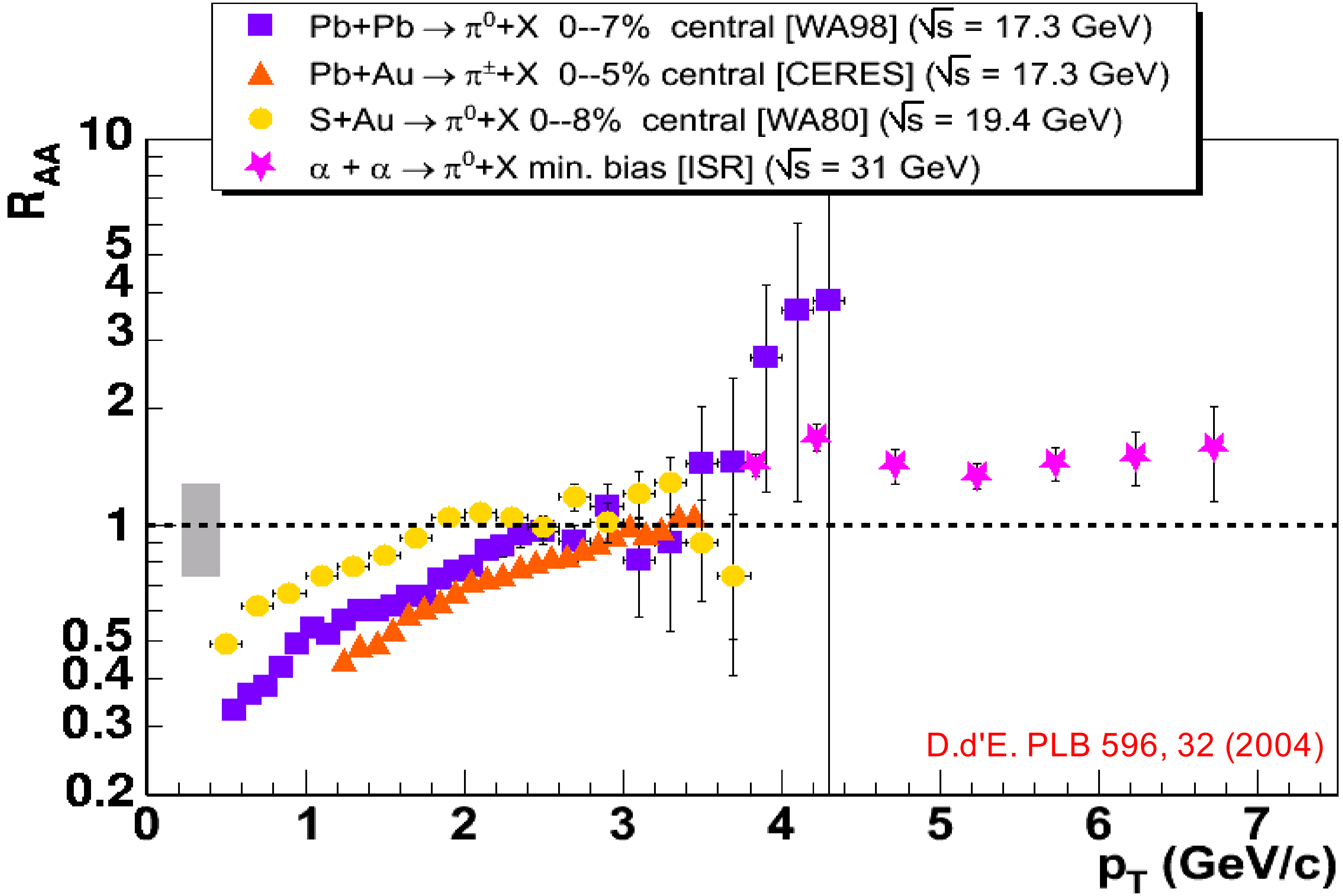

[Note: $R_{AA}$ @ SPS uses "revised" pp ref.]

D.d'E., HP'04
EPJ C to appear
nucl-ex/0504001

| | | | Initial g density: | Medium transport coeff.: |
|---|---|---|---|---|
| **SPS** | $R_{AA}$ ~ 1 @ $\sqrt{s}$ ~ 20 GeV | ⇒ | $dN^g/dy$ ~ 400 | , $\langle q_0 \rangle$ ~ 3.5 $GeV/fm^2$ |
| **RHIC** | $R_{AA}$ ~ 0.3 @ $\sqrt{s}$ = 62 GeV | ⇒ | $dN^g/dy$ ~ 650 | , $\langle q_0 \rangle$ ~ 7 $GeV/fm^2$ |
| **RHIC** | $R_{AA}$ ~ 0.2 @ $\sqrt{s}$ = 200 GeV | ⇒ | $dN^g/dy$ ~ 1100 | , $\langle q_0 \rangle$ ~ 14 $GeV/fm^2$ |

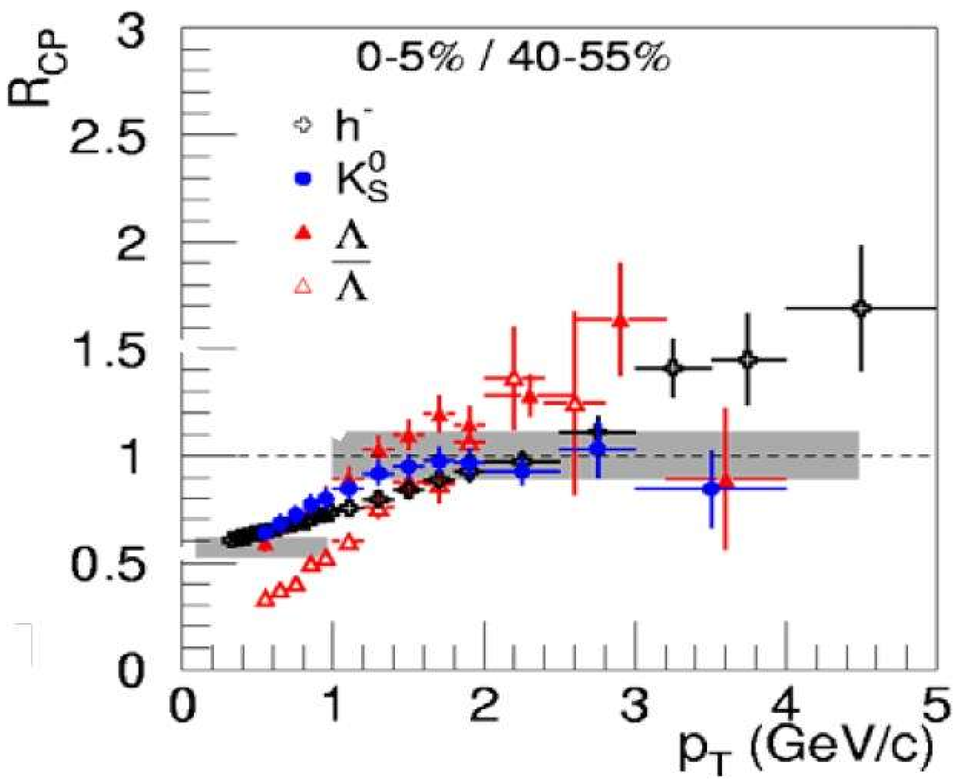
# High $p_T$ $\pi^0$ suppression in A+A @ 17.3 GeV ?

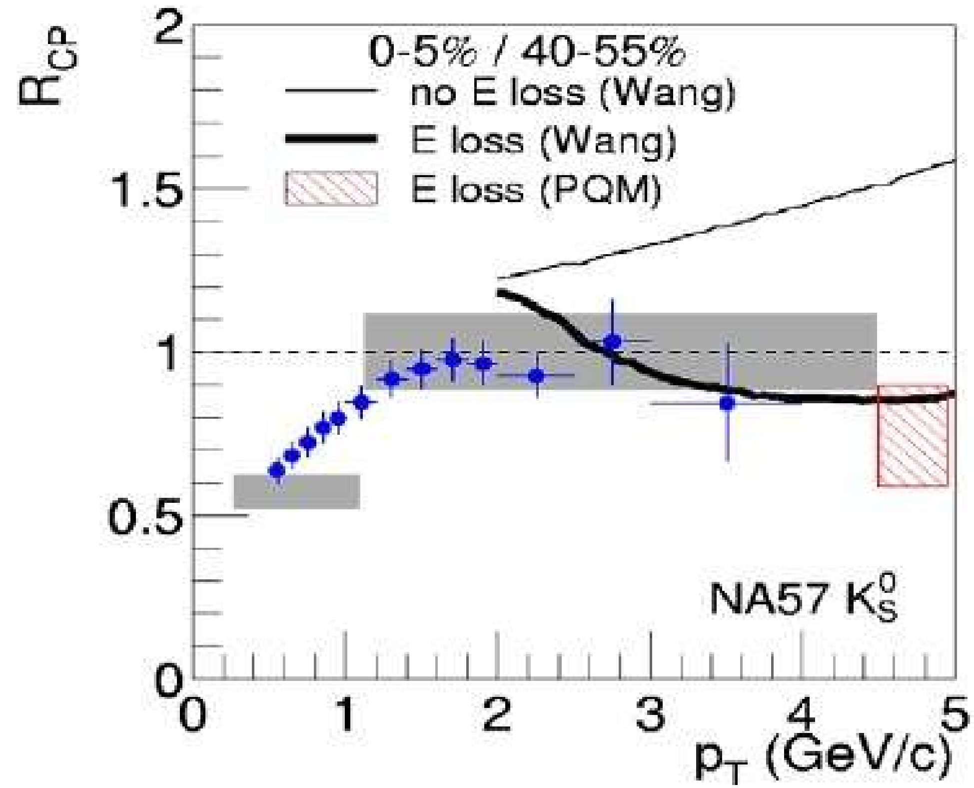
- High $p_T$ $\pi^0$ production in (0-10%) central A+A at SPS (and $\alpha+\alpha$ @ ISR) energies slighted suppressed or consistent w/ "$N_{coll}$-scaling" :



# High $p_T$ $K^0_s$ suppression in A+A @ 17.3 GeV ?

- NA57: High $p_T$ $K^0_s$ production in (0-10%) central A+A at SPS slightly suppressed:

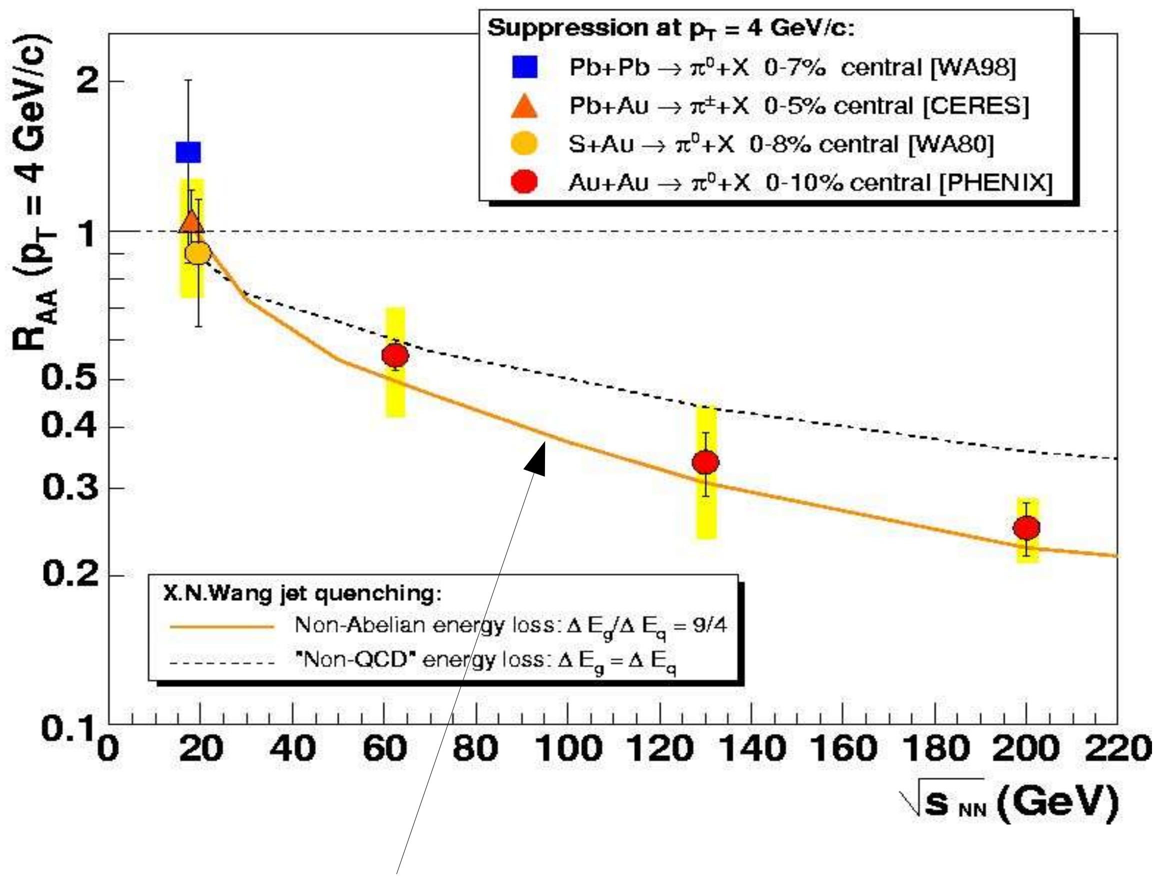



G. Bruno, NA57, QCD@Work'05

# High $p_T$ suppression: Excitation function

- $\sqrt{s}$-dependence (and non-Abelian nature of energy loss) in agreement w/ parton energy loss calculations:
  (i) rising initial parton density with $\sqrt{s}$
  (ii) increasing relative fraction of hard-scattered gluons (for fixed $p_T$) w/ $\sqrt{s}$




"Jet quenching" model + 2-D longitudinal plasma expansion

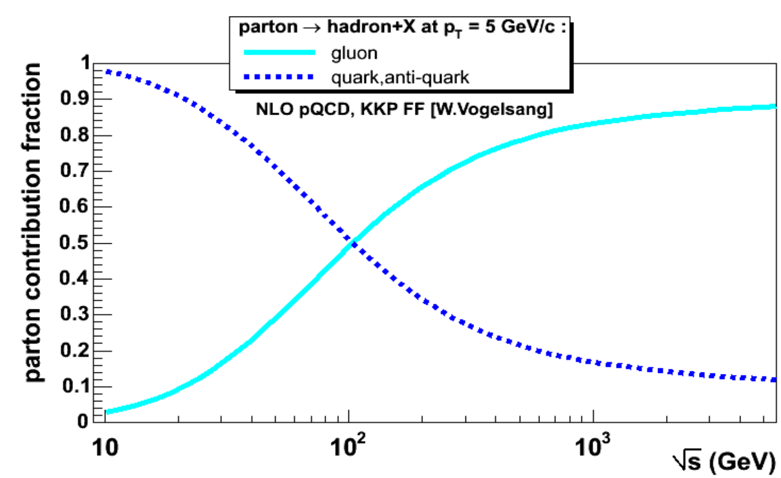
QCD radiation probability:

Gluon: $C_A = N_c = 3$

Quark: $C_F = (N_c^2-1)/N_c = 4/3$

$\}$ $C_A / C_F = 2.25$

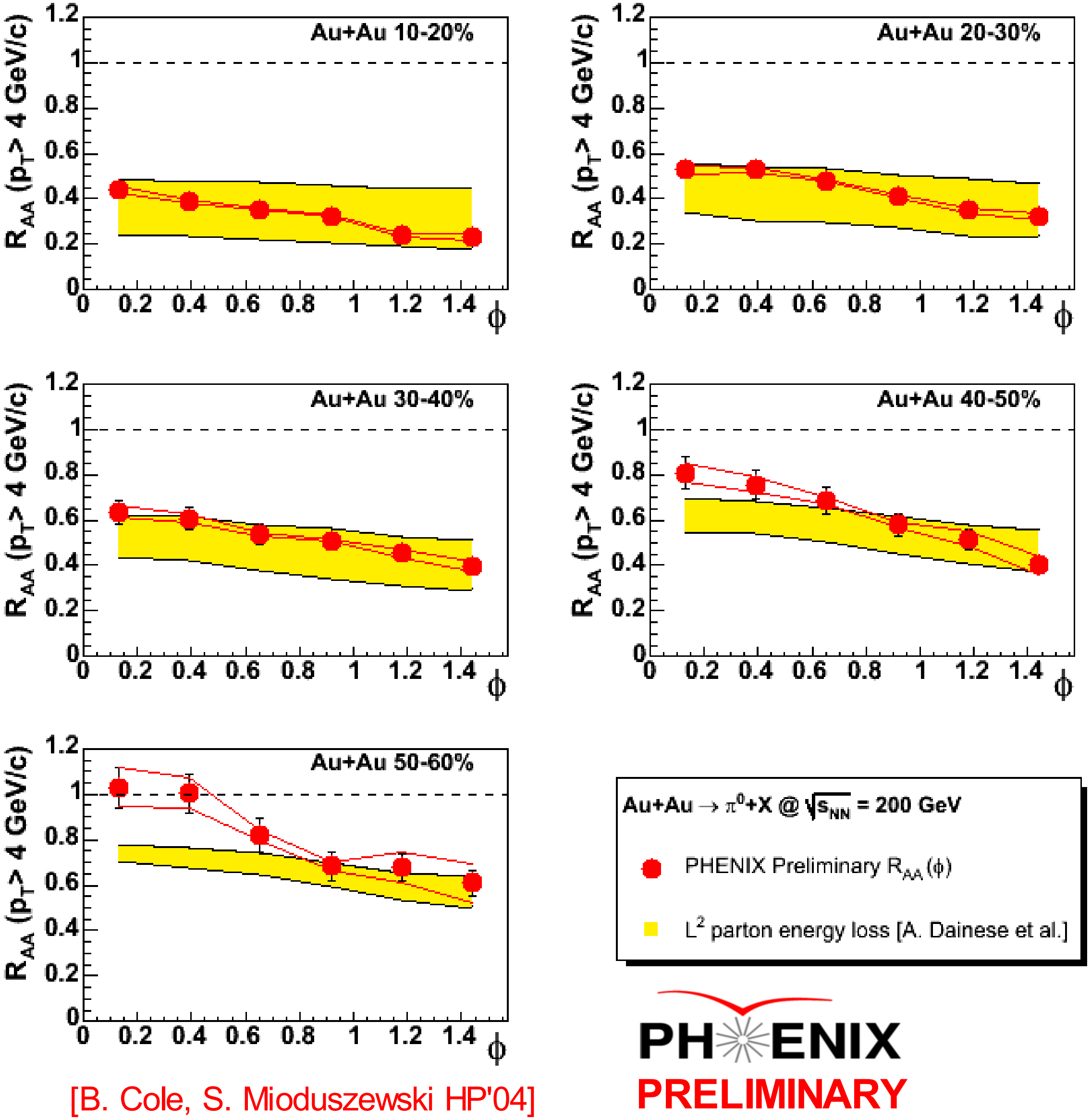
Relative fraction of q,g at $p_T$ = 5 GeV/c:




D.d'E., HP'04
nucl-ex/0504001

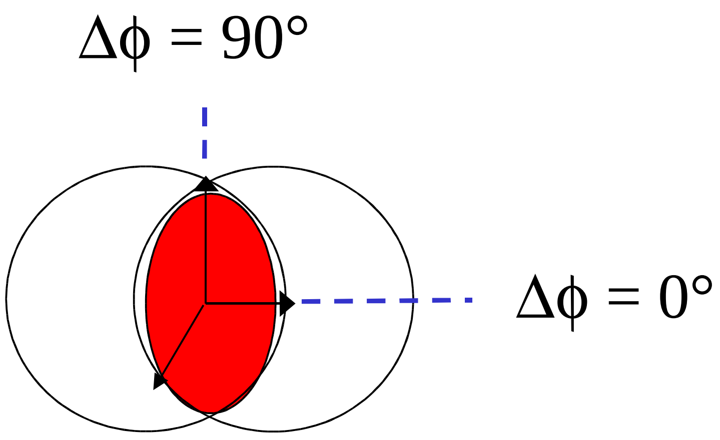
# High $p_T$ suppression: Reaction-plane dependence

- $R_{AA}(\varphi)$ versus parton energy loss model:




[B. Cole, S. Mioduszewski HP'04]

[D.d'E., HP'04, nucl-ex/0504001]

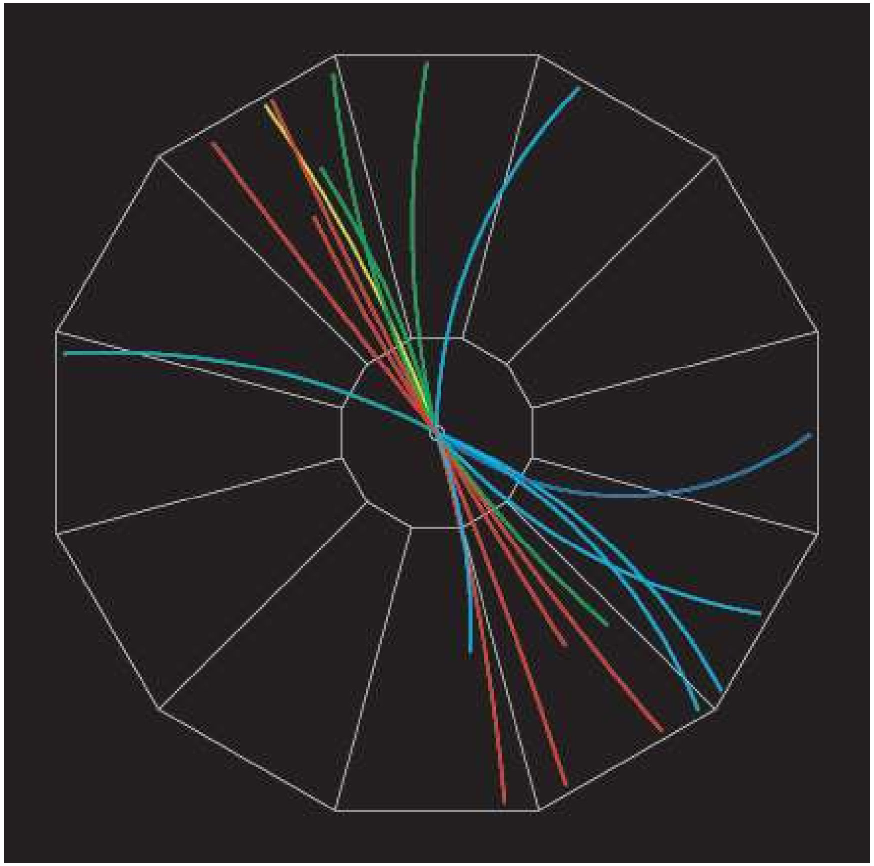


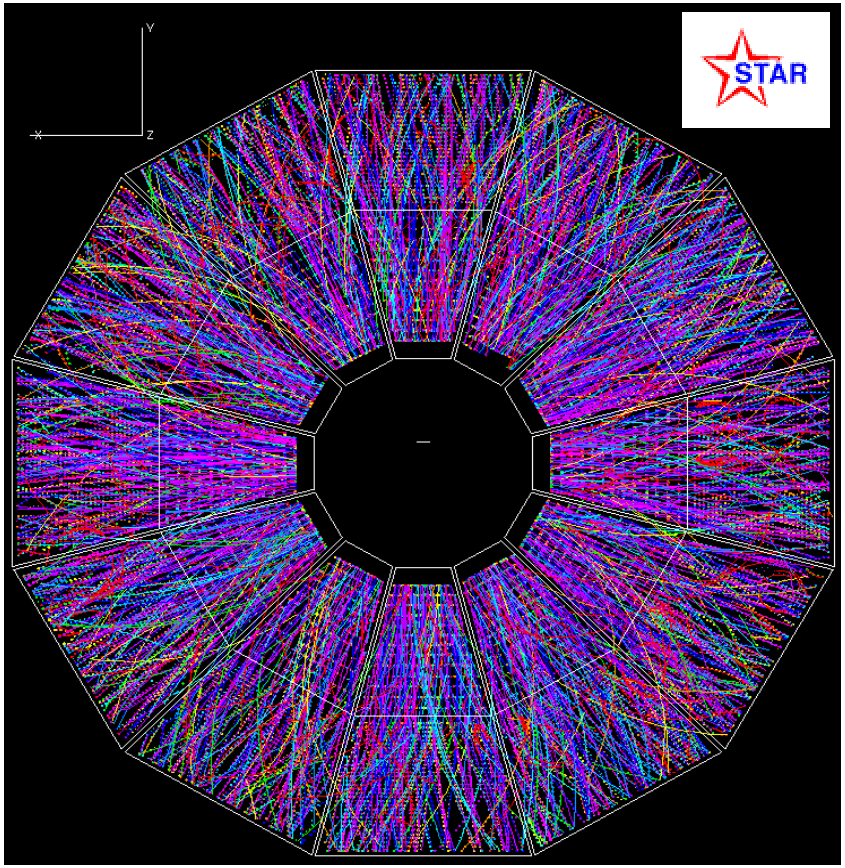

- 2 times more suppression out-of-plane ("long" direction) than in-plane ("short" direction).
- Glauber parton energy loss model predicts only ~50% increased "out-of-plane" vs "in-plane" $\pi^0$ emission
- Azimuthal anisotropy not reproduced by "canonical" $L^2$ (or L) path-length dependence.

# (2) High $p_T$ di-hadron $\phi,\eta$ correlations in high-energy pp, dAu and AuAu collisions

# Jets in AA collisions at RHIC

- Full jet reconstruction w/ standard algorithms is unpractical at RHIC due to huge soft background (large "underlying event"):



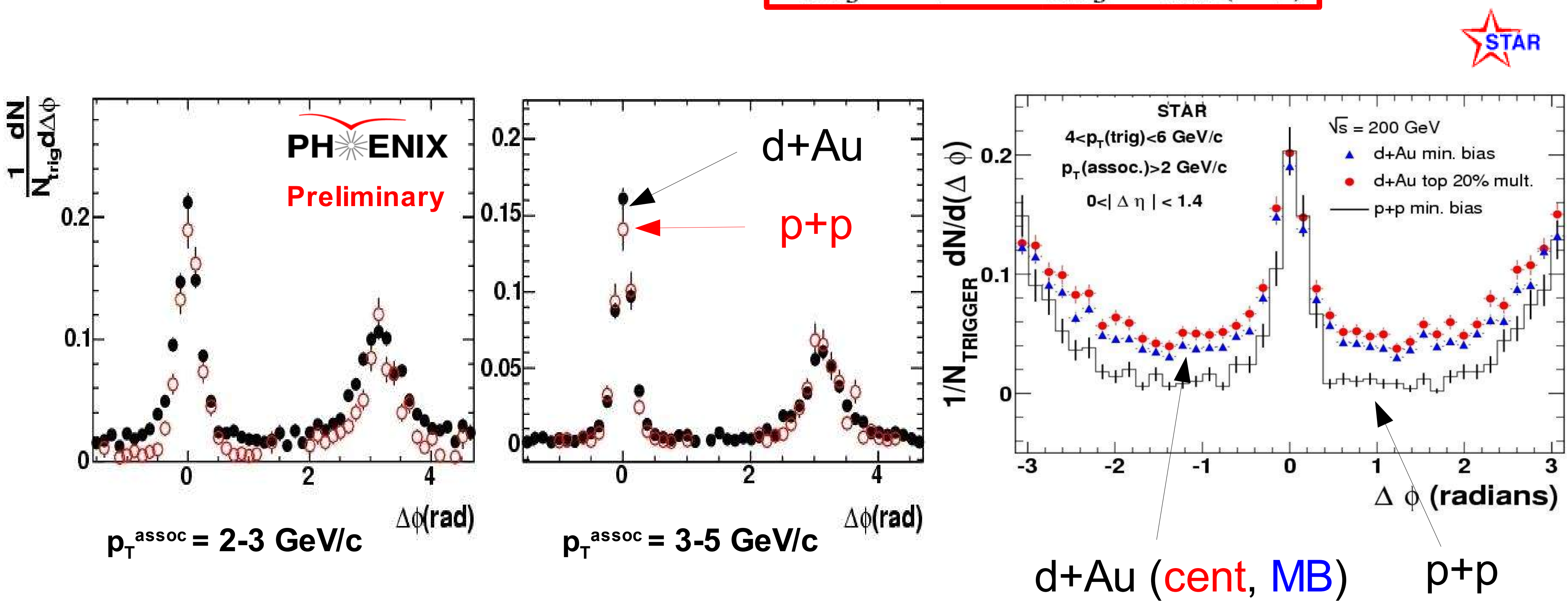



p+p → jet+jet [$\sqrt{s}$ = 200 GeV]
STAR @ RHIC (2003)

Au+Au → X [$\sqrt{s_{NN}}$ = 200 GeV]
STAR @ RHIC (2003)

# Jets via high $p_T$ di-hadron $\phi$ correlations: pp, dAu

- Two-particle correlations: $h^{\pm} - h^{\pm}$, $\pi^{0,\pm} - h^{\pm}$. Trigger: highest $p_T$ (leading) hadron.
- Associated $\Delta\phi$ distribution (e.g. "assorted": 2 GeV/c < $p_T^{assoc} < p_T^{trigger}$)
- Normalized to number of triggers: $$\frac{1}{N_{trig}}\frac{dN}{d\Delta\phi} = \frac{1}{N_{trig}}\frac{N_{cor}(\Delta\phi)}{N_{mix}(\Delta\phi)}$$

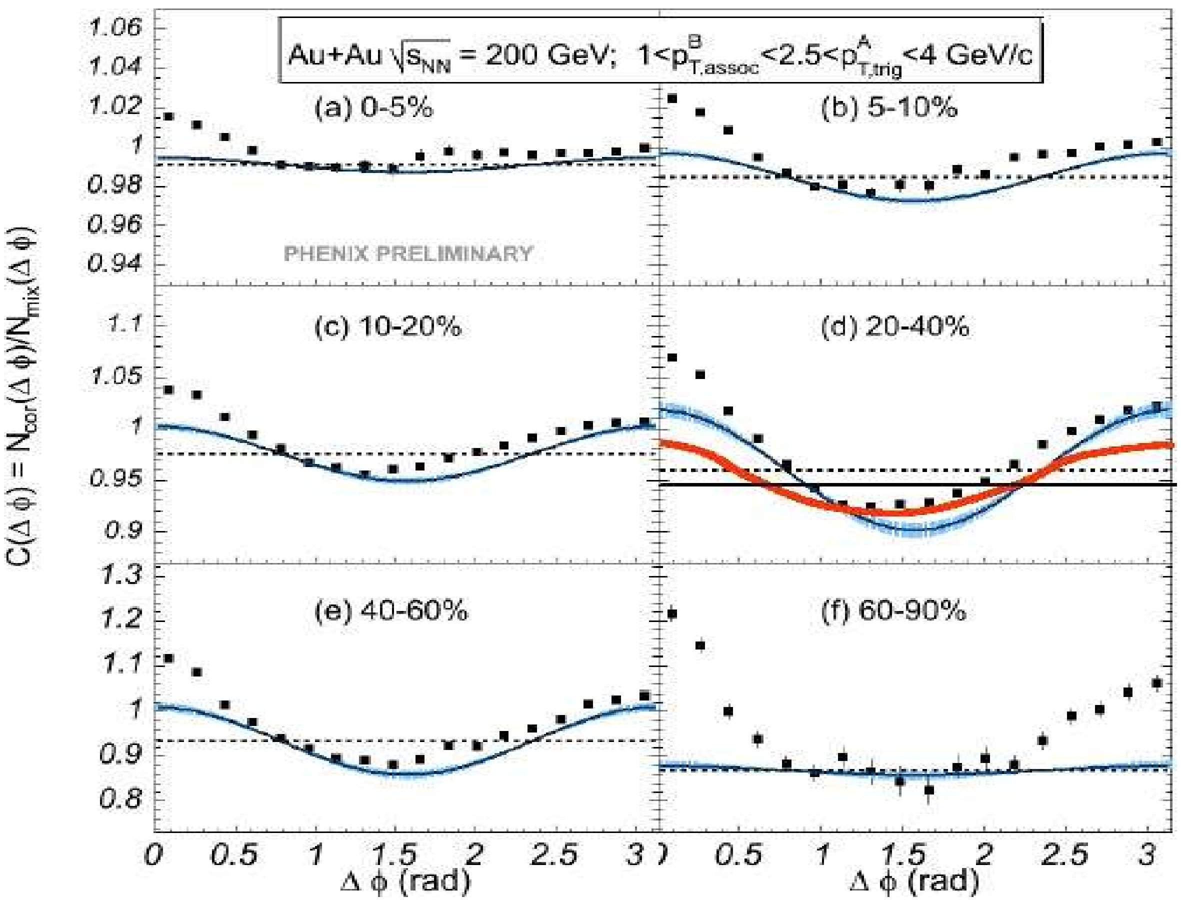



- Clear near- ($\Delta\phi \sim 0$) and away- ($\Delta\phi \sim \pi$) side jet signals

# Jets via high $p_T$ di-hadron $\phi$ correlations: AuAu

- Same $dN_{pair}/d\varphi$ analysis as in pp (dAu) but 2 extra "complications":
  - (1) Increased "underlying event" background
  - (2) Collective elliptic flow (harmonic) contribution

$$\overbrace{C(\Delta\phi)}^{\text{Correlation Function}} = a_0 \left[ \overbrace{H(\Delta\phi)}^{\text{Harmonic}} + \overbrace{J(\Delta\phi)}^{\text{Jet Function}} \right]$$

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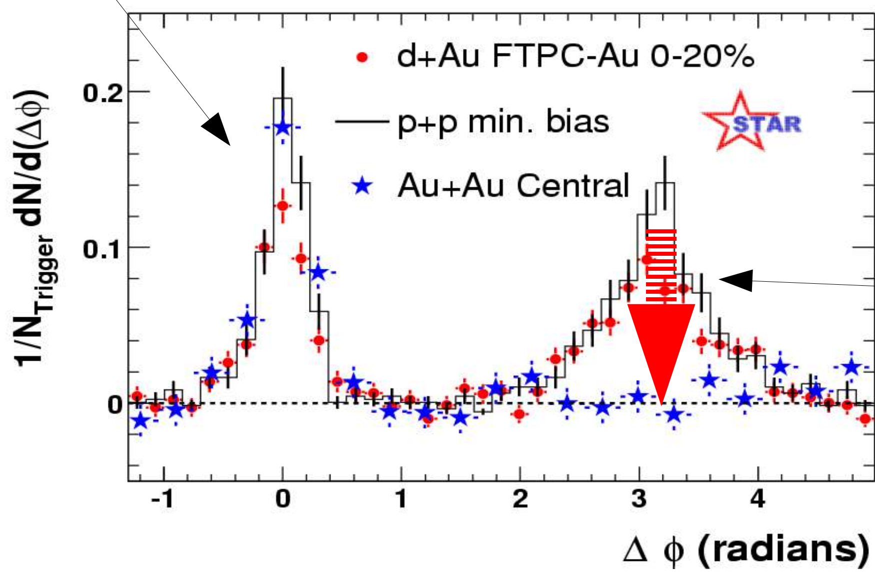
Ajitanand, ICPAQGP'04 and nucl-ex/0501025

- Delicate subtraction procedure (esp. in finite acceptances).

# Di-hadron AuAu: Δφ correlations (I)

- Near-side: Jet-like Gaussian. Unmodified (AuAu ~ dAu ~ pp)

High $p_T$ :

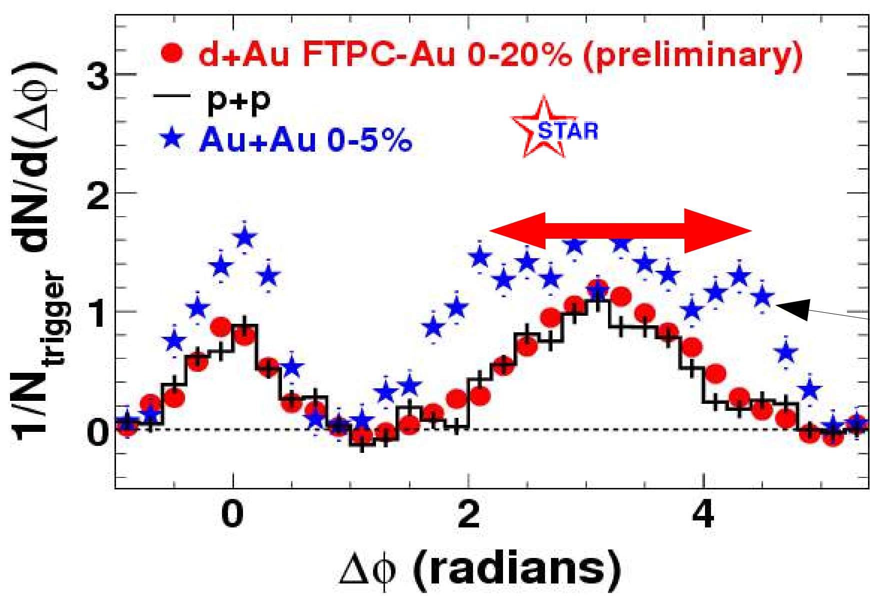



$p_{T\ trigg}$ = 4 – 6 GeV/c
$p_{T\ assoc}$ > 2 GeV/c

STAR, PRL 90, 082302 (2003)

- Away-side:
  peak disappearance.
  "monojet"-like topologies in central AuAu.

Lower $p_T$ :



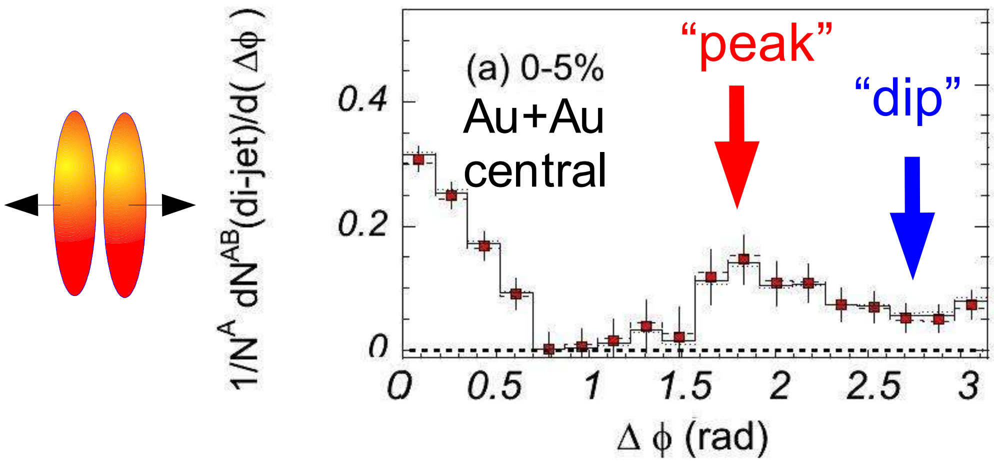

$p_{T\ trigg}$ = 4 – 6 GeV/c
$p_{T\ assoc}$ = 0.15 – 4 GeV/c

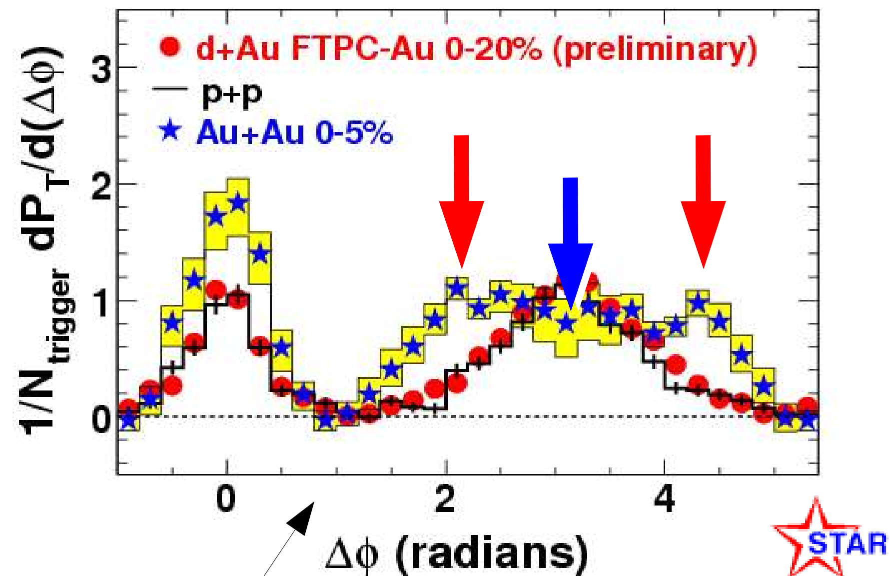
STAR, submitted to PRL
nucl-ex/0501016

- Away-side:
  Broadened distribution of associated low $p_T$ hadrons.

# Di-hadron AuAu: Δϕ correlations (II)

- Strongly modified away-side Δϕ correlations in central AuAu:

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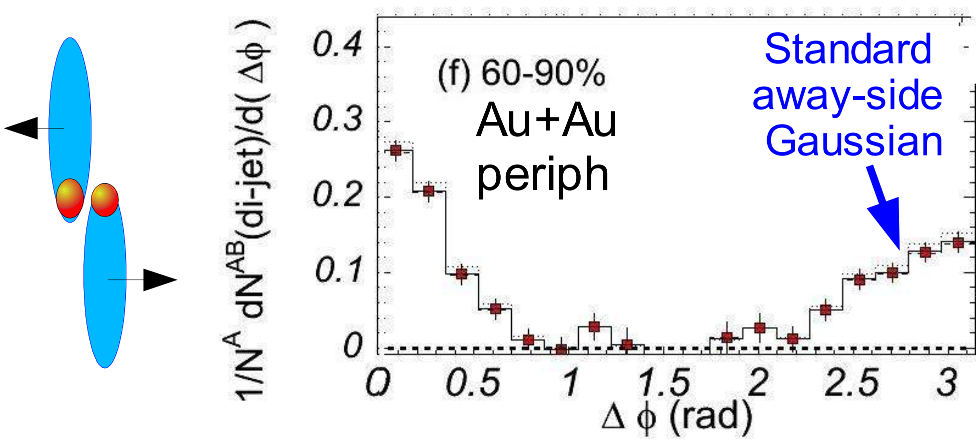
Au+Au $\sqrt{s_{NN}}$ = 200 GeV

$1<p^B_{T,assoc}<2.5<p^A_{T,trig}<4$ GeV/c

- Away-side (π) "dip" and excess of energy ("double peak") at π ±1

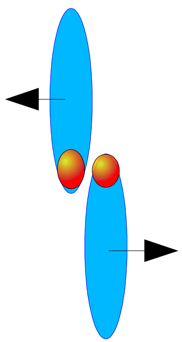


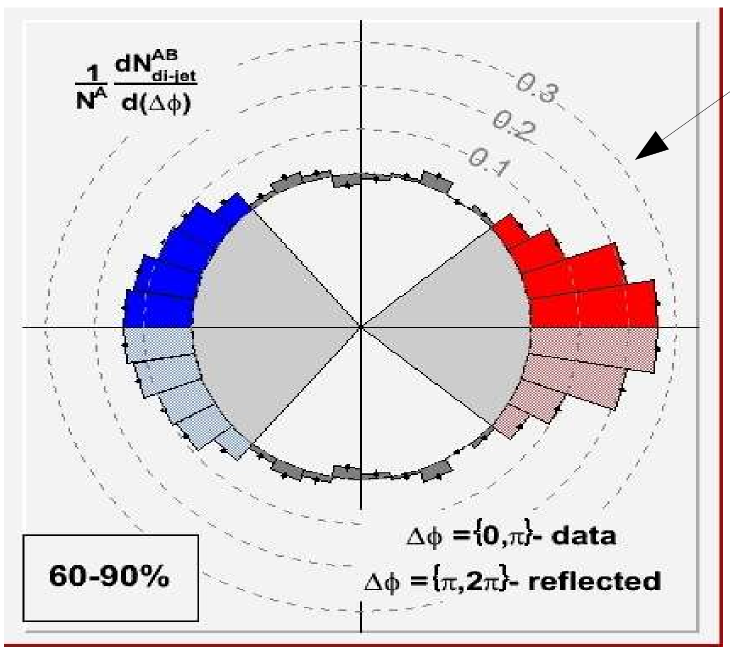

PHENIX Collab. PRL to be submitted

# Di-hadron AuAu: Δφ correlations (III)

- Same $dN_{pair}/d\Delta\phi$ result in polar coords. now:

Au+Au peripheral

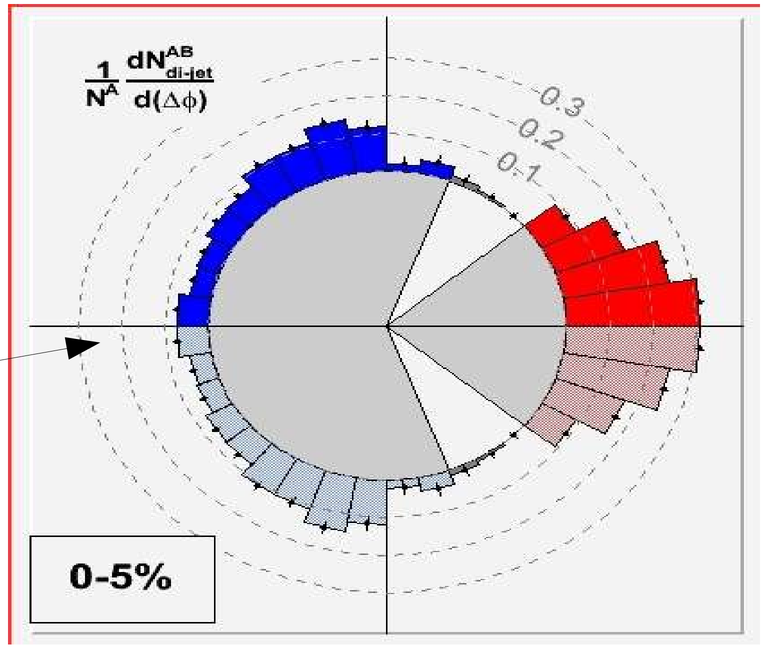


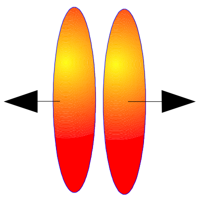



- Standard back-to-back di-jet topology.

PHENIX Preliminary

Au+Au central



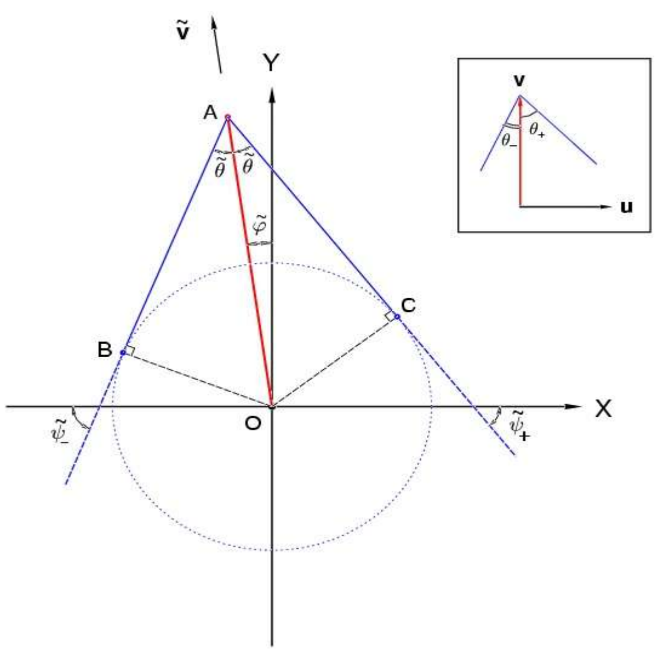
- Strongly non-Gaussian away-side “peak”.

PHENIX Collab. PRL to be submitted

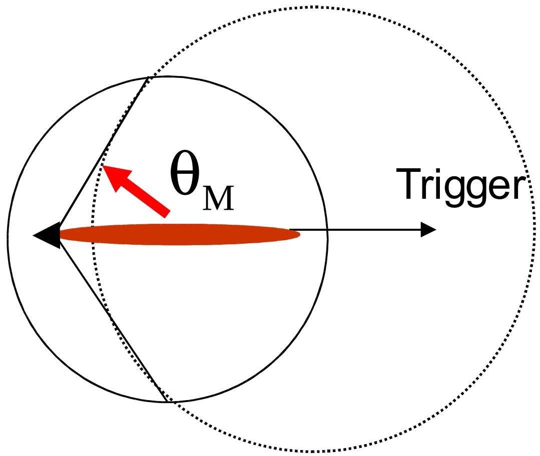
# "Double peak" = Mach wave cone ?

- Double peak structure at at $\pi \pm 1$ rad reminiscent of ...
  Mach wave conical shock ("sonic boom") $\Rightarrow$ speed of sound accessible

Stoecker, Satarov, Mishutin, hep-ph/0505245.
Casalderrey, Shuryak, Teaney, hep-ph/0411315.




Mach cone: $\cos\theta_M = c_s$




$c^2_s \neq$ constant:

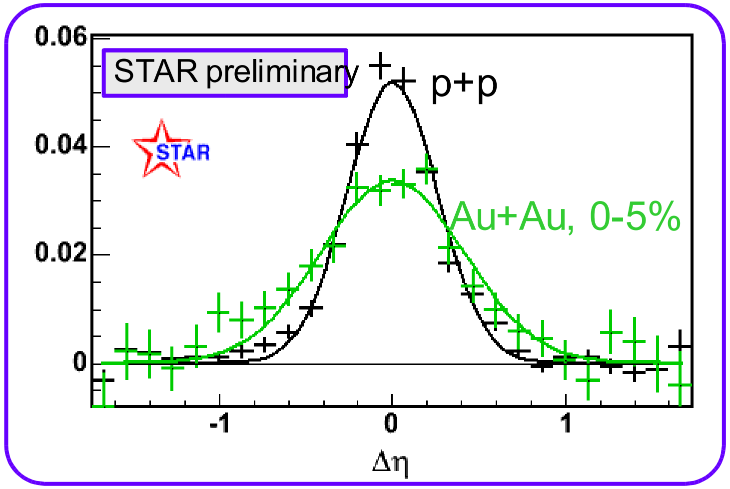
QGP ($1/\sqrt{3}$) $\rightarrow$ phase transition (0.) $\rightarrow$ HRG ($\sqrt{0.2}$) :

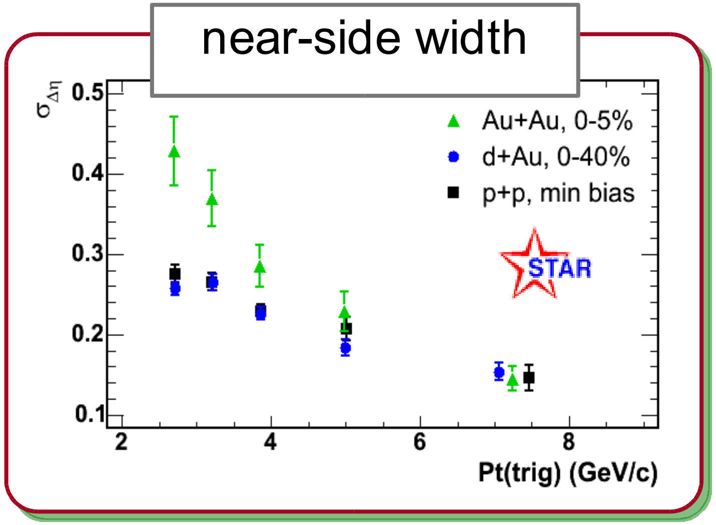
$$c_s^{av} = \frac{1}{\tau_f}\int d\tau c_s(\tau) = 0.33$$

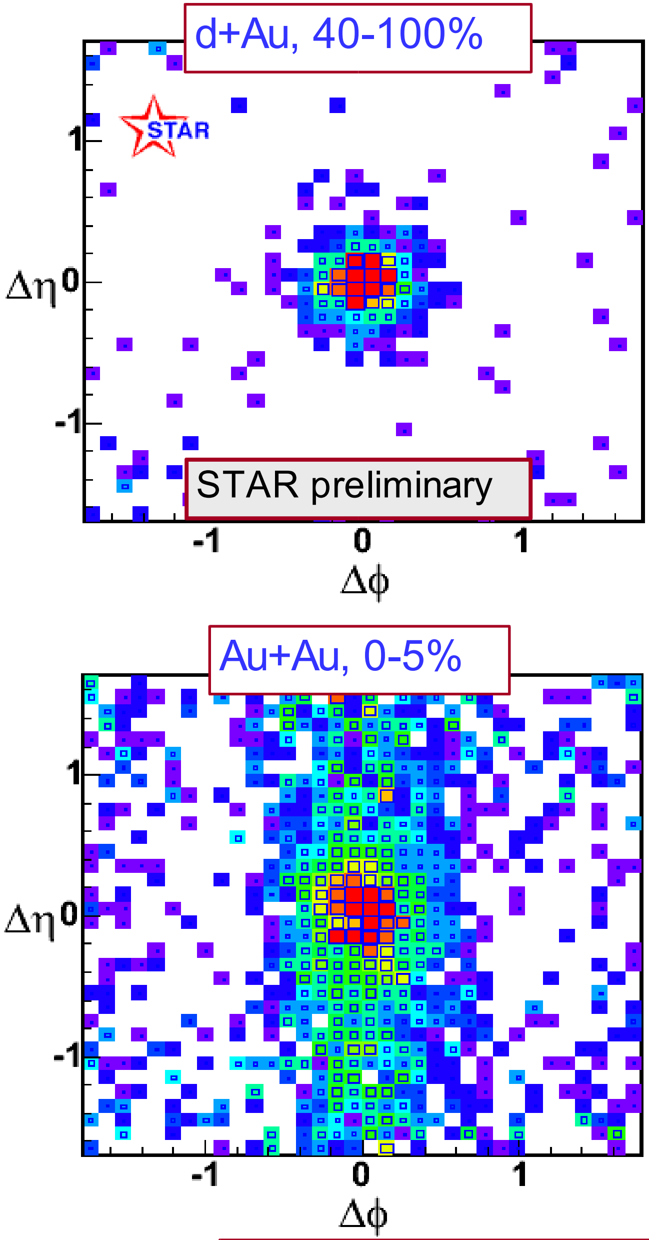
**$\theta$ = arccos($c^{av}_s$) = 1.2 rad = 71°** **($\theta_{exp}$ ~ 1. rad ~ 57°)**

# Di-hadron AuAu: Δη correlations

- Significant broadening of pseudo-rapidity correlations in AuAu compared to pp, dAu. ("stretching" of jet cone along η).



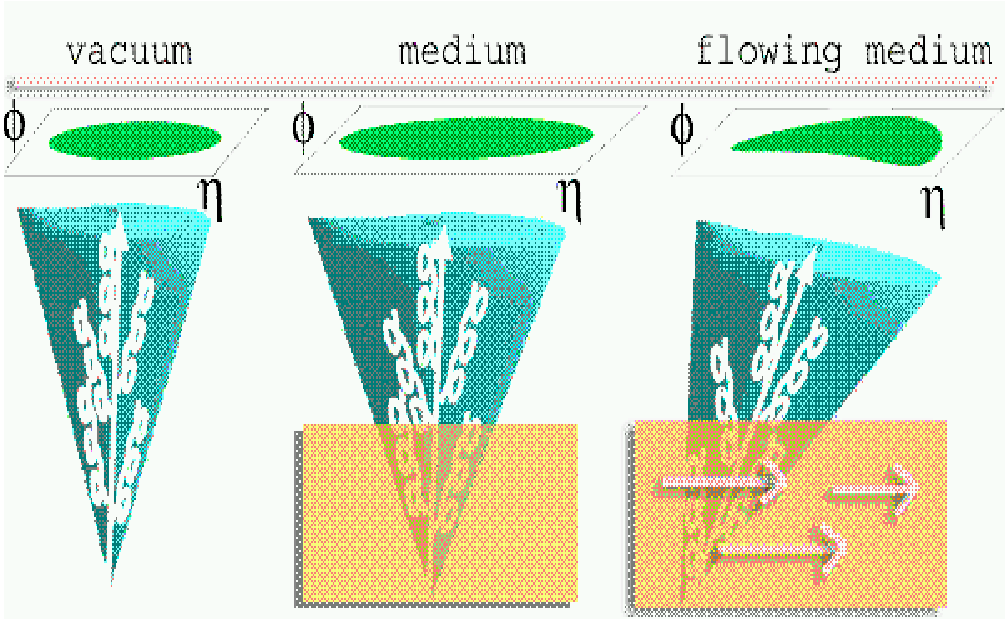




[D. Magestro, HP'04]

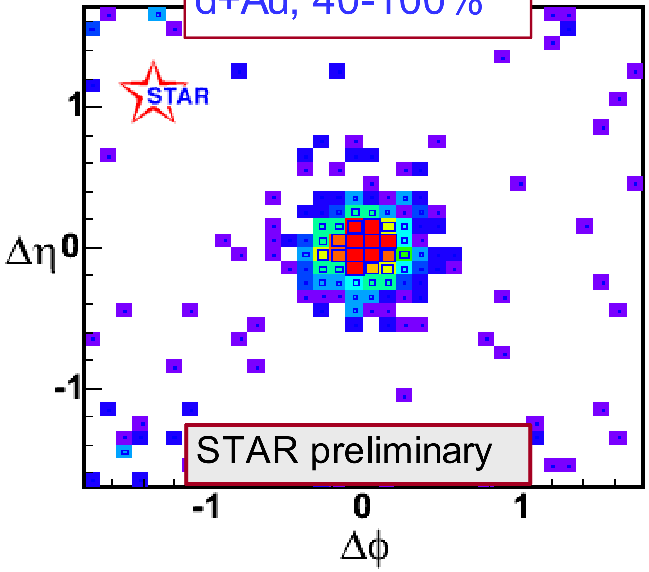
$3 < p_T(\text{trig}) < 6$ GeV
$2 < p_T(\text{assoc}) < p_T(\text{trig})$

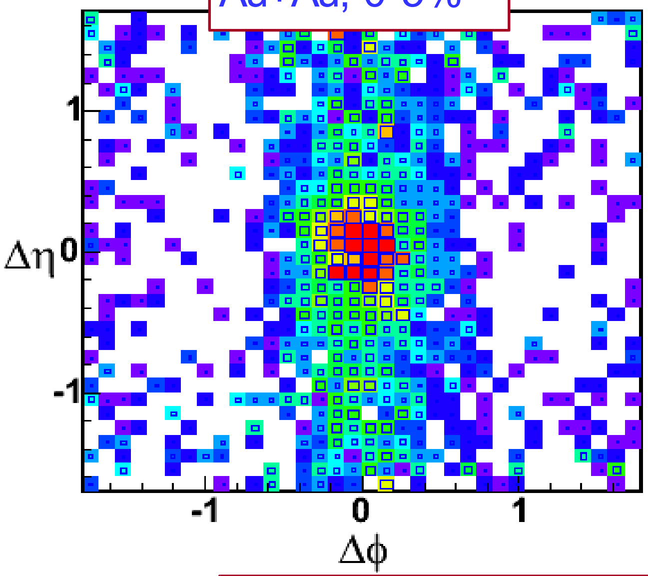
# Di-hadron AuAu: Δη correlations

- Significant broadening of pseudo-rapidity correlations in AuAu compared to pp,dAu. ("stretching" of jet cone along η).
- Coupling of *g* radiation w/ longitudinal expanding medium ?




Armesto, Salgado, Wiedemann
PRL 93, 242301 (2004)



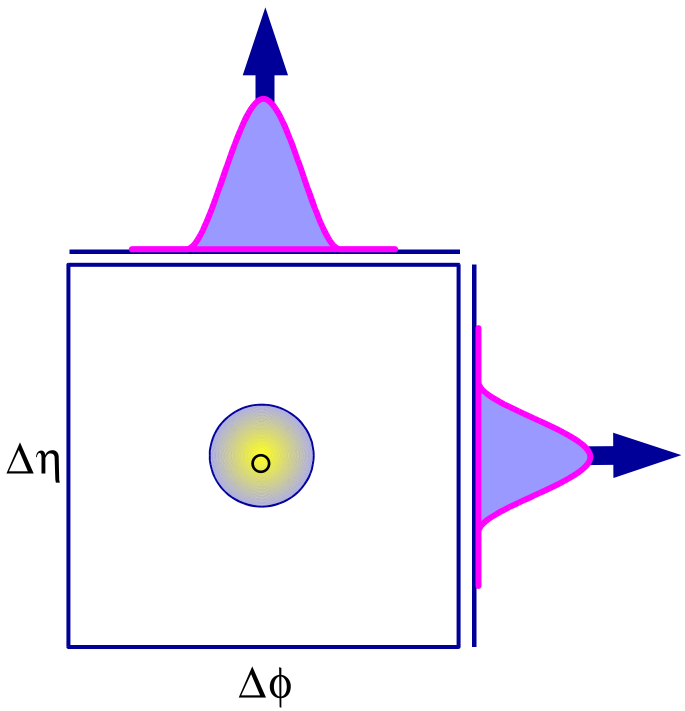




$3 < p_T(\mathrm{trig}) < 6$ GeV
$2 < p_T(\mathrm{assoc}) < p_T(\mathrm{trig})$

# "Cartoon" Summary: Jet-quenching at RHIC

"QCD vacuum" & "cold QCD medium"

- Jet profile in pp (dAu) collisions:

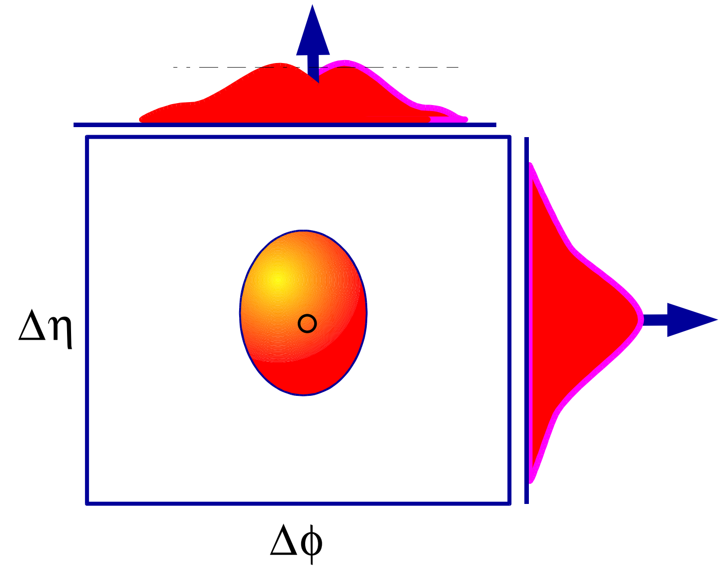



Near-side width: $\langle j_T \rangle \sim 600$ MeV/c
unmodified in pp,dAu

Away-side width and acoplanarity unmodified in pp and dAu

"hot & dense QCD Medium"

- Jet profile in AuAu central collisions:




Factor ~5 suppression of leading hadron
(very large initial parton densities: $dN^g/dy \sim 1000$)

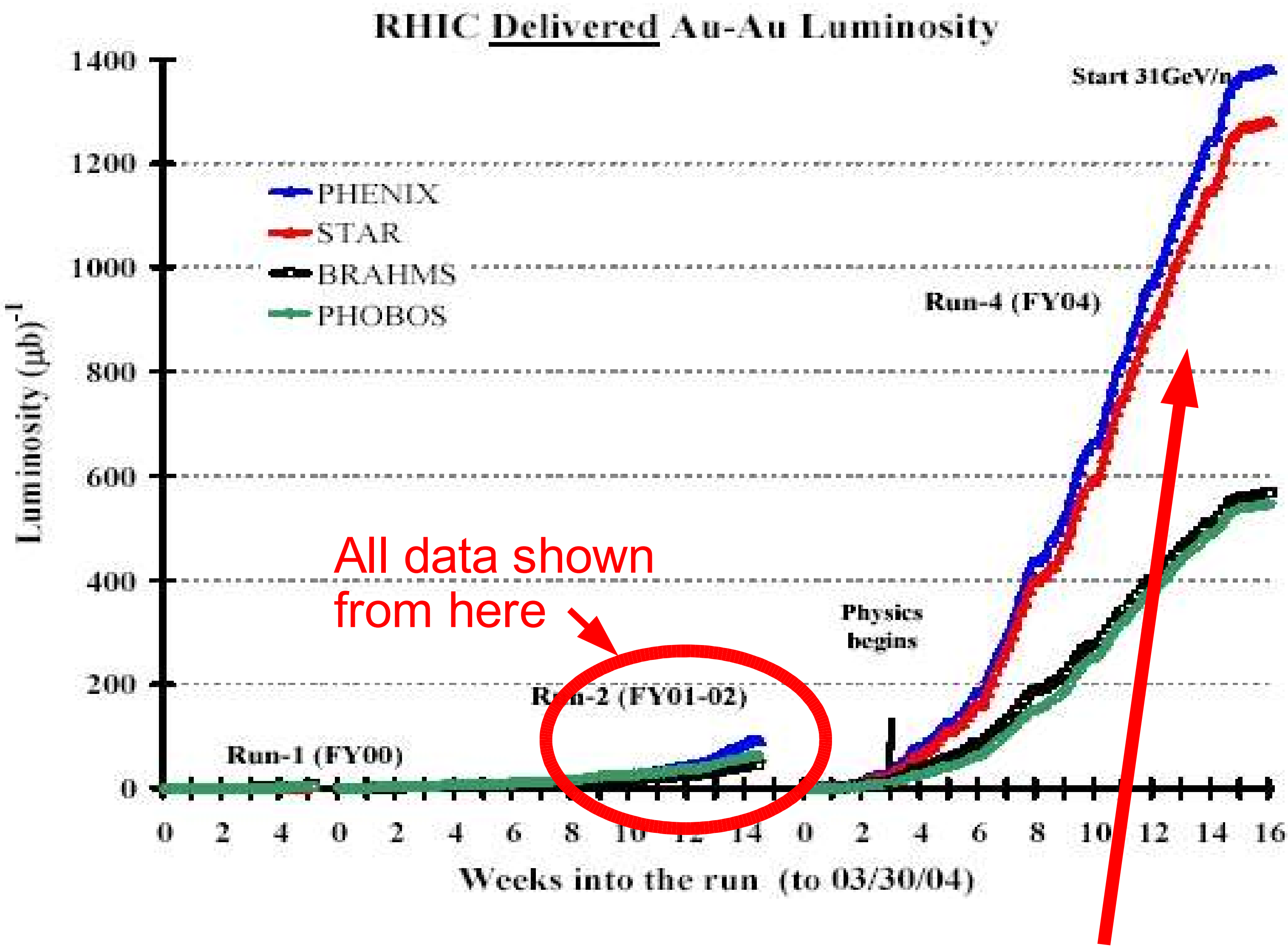
Disappearance of back-to-back peak ("monojets")

"Double peak" structure at lower $p_T$ in away-side
("sonic boom" in medium ?)

Dijet broadening in η
(coupling of g radiation w/ expanding medium ?)

**Strong QCD medium effects at work !**

# Outlook

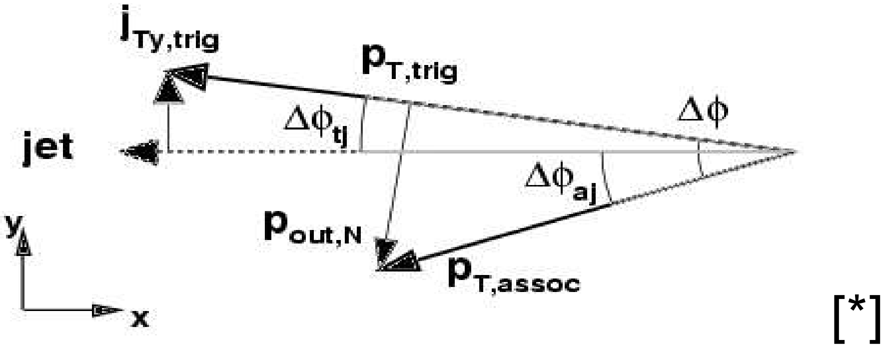



- 15 times more data available (ongoing DST production) !
- .. and exciting jet-physics expected ahead at LHC: γ-, Z-, jet-jet corrs., ...

# backup slides ...

# Jet properties from dihadron correlations

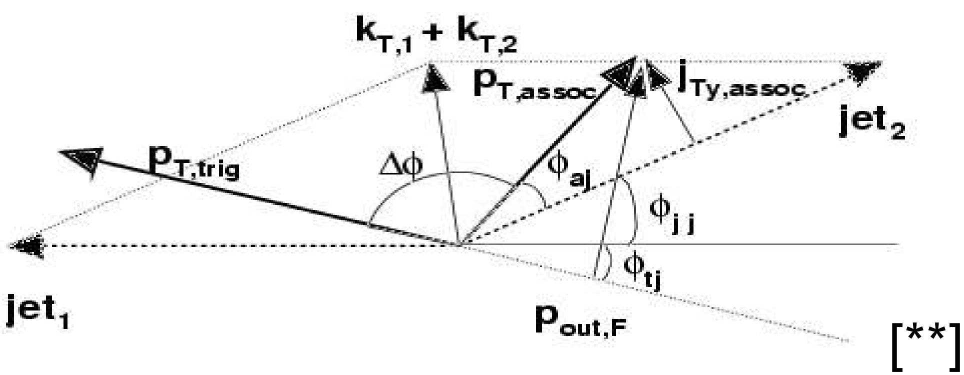
- Jet "width" $j_T$ :




$$\langle j_{T_y}\rangle_{RMS} \simeq \frac{\sigma_N \langle p_{T,asso}\rangle}{\sqrt{1+\langle x_h^2\rangle}} \simeq \sigma_N \frac{\langle p_{T,trig}\rangle\langle p_{T,asso}\rangle}{\sqrt{\langle p_{T,trig}\rangle^2+\langle p_{T,asso}\rangle^2}}$$

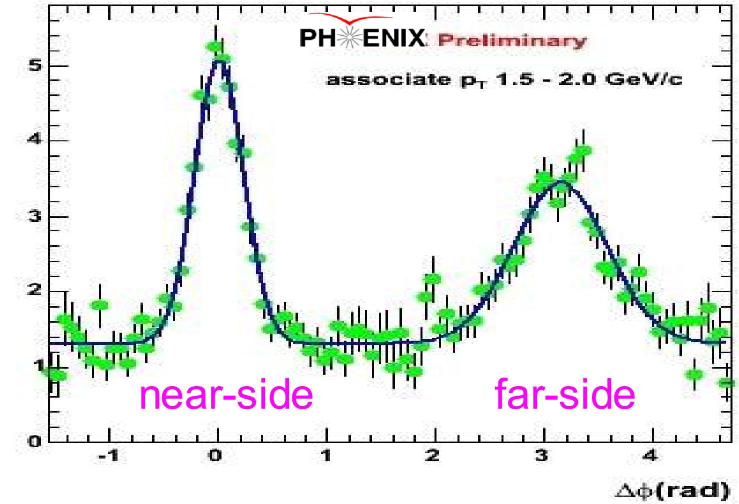
where $x_h = p_{T,asso}/p_{T,trig}$

- Di-jet acoplanarity $k_T$:




$$\langle k_{Ty} z_{trig}\rangle_{RMS} = \frac{1}{\sqrt{2\langle x_h^2\rangle}}\sqrt{\langle p_{T,assoc}\rangle^2 \sin^2\sigma_F - (1+\langle x_h^2\rangle)\,\langle j_{T_y}\rangle^2_{RMS}}$$

(1) 2-hadron correlation function:




(2) Fit to 2-gaussians:

$$\frac{1}{N_{trig}}\frac{dN}{d\Delta\phi} = B + \frac{Yield_N}{\sqrt{2\pi}\sigma_N} e^{\frac{-\Delta\phi^2}{2\sigma_N^2}} + \frac{Yield_F}{\sqrt{2\pi}\sigma_F} e^{\frac{-(\Delta\phi-\pi)^2}{2\sigma_F^2}}$$

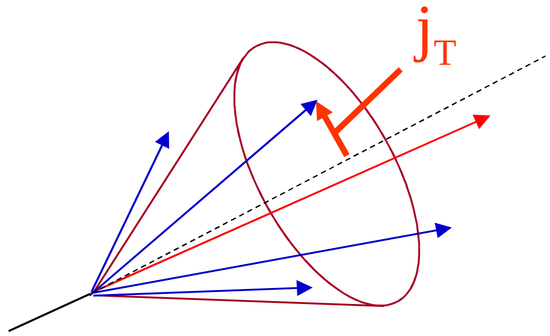
$\Longrightarrow$ near-side $\sigma_N$, far-side $\sigma_F$ widths

(3) Extraction of $j_T$, $k_T$ from $\sigma_N$, $\sigma_F$ via [*], [**] (and $dN/dx_E$ from $Yield_{N,F}$)

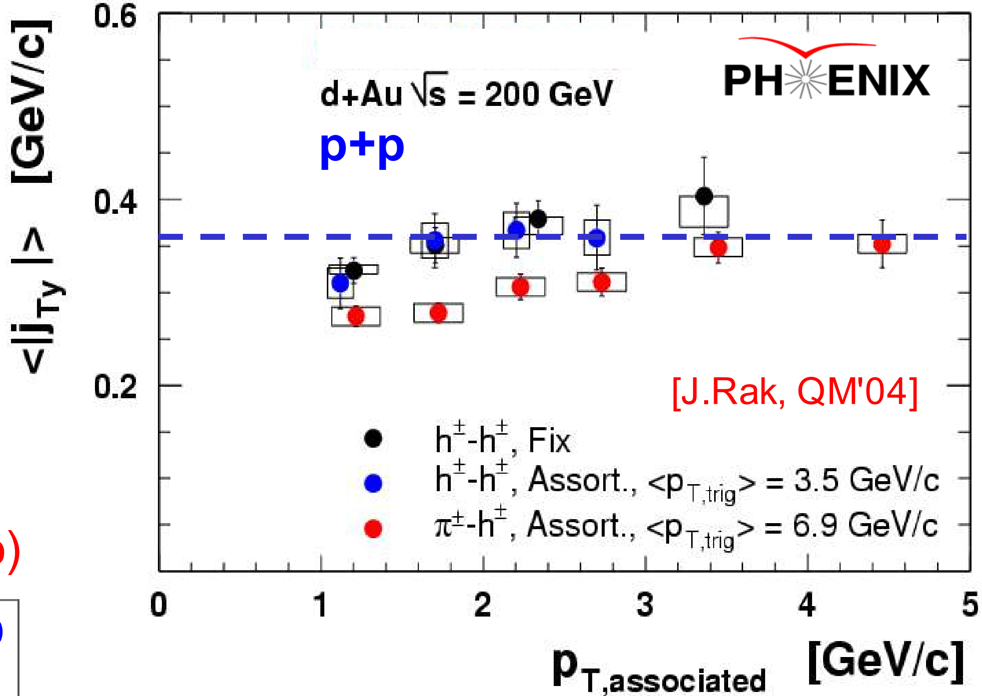
[details in J.Jia, nucl-ex/0409024]

# Mean transverse momentum of jet hadrons ($j_T$): pp, dAu

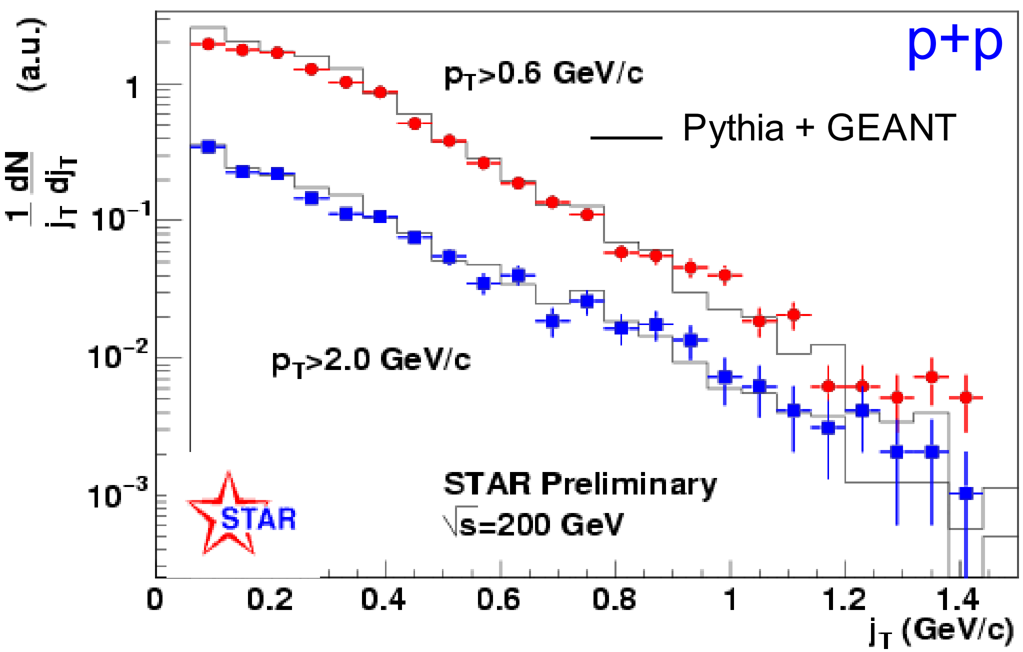
- Jet (near-angle) "width" $j_T$ :




$< j_{Ty}> \sim$350 MeV/c $\equiv < j_T> \sim$ 500 MeV/c



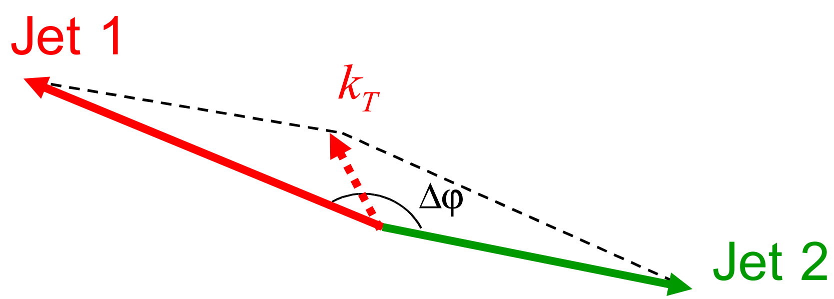

$< j_T> \sim$ 500 MeV/c (from full jet reco)



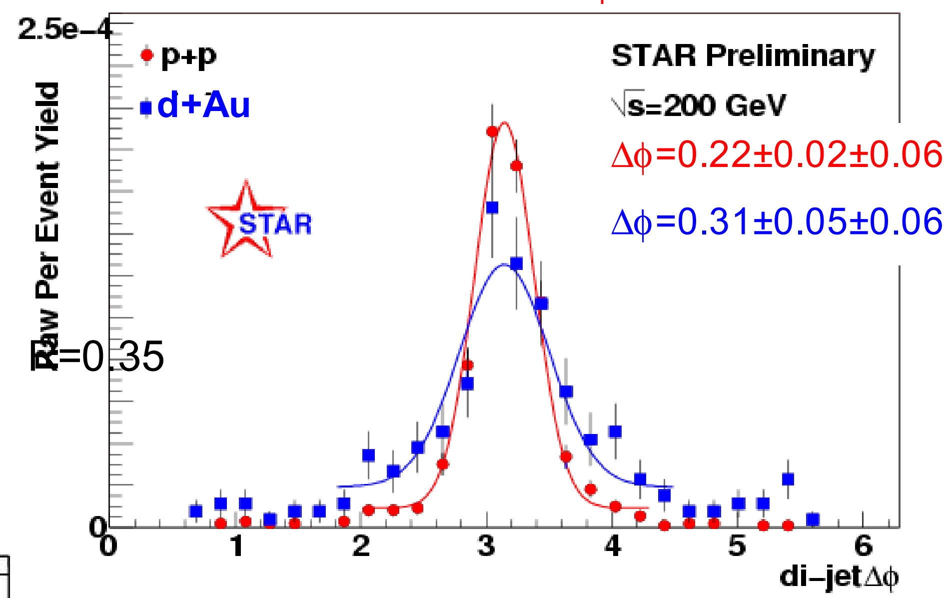

- $< j_T> \sim$ 500 MeV/c: Agreement between RHIC and ISR data.
- No apparent difference between dAu and pp.
- Fragmentation not affected by cold QCD medium.

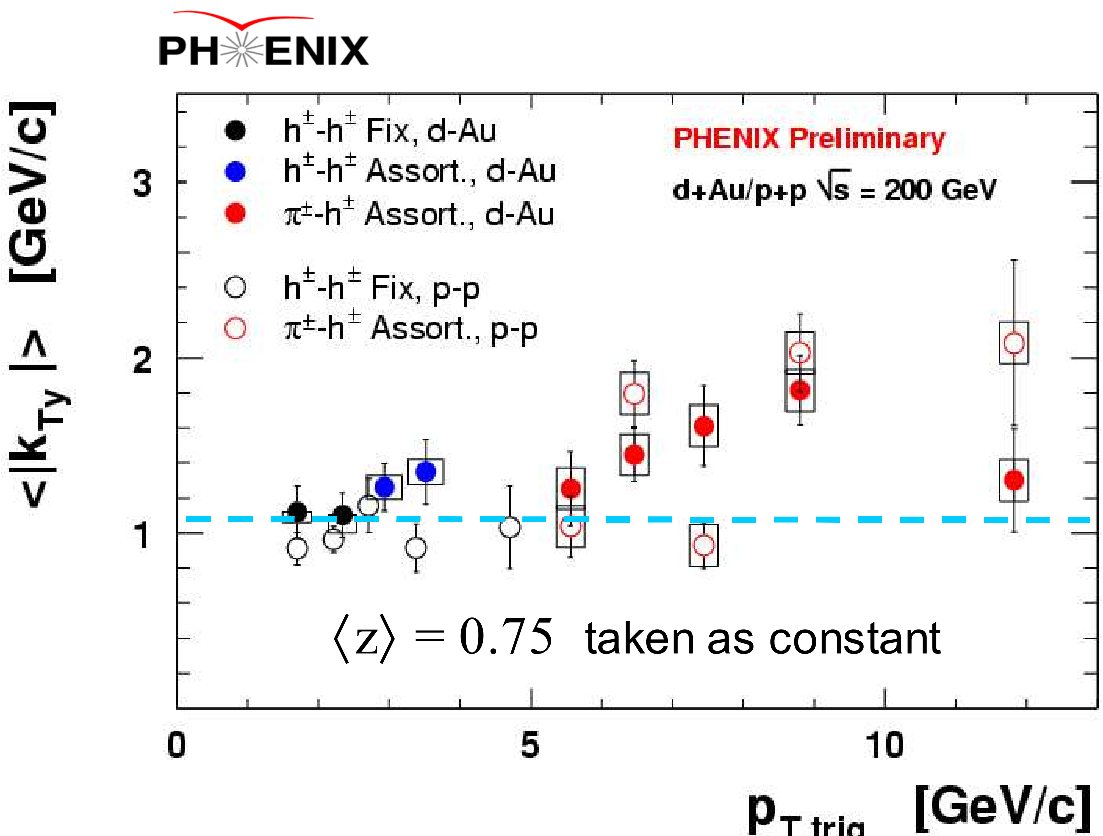
# Di-jet acoplanarity ("intrinsic" $k_T$) : pp, dAu

- Intrinsic $k_T$ (di-jet acoplanarity):




(from full jet reco: $E_T$~13 GeV)

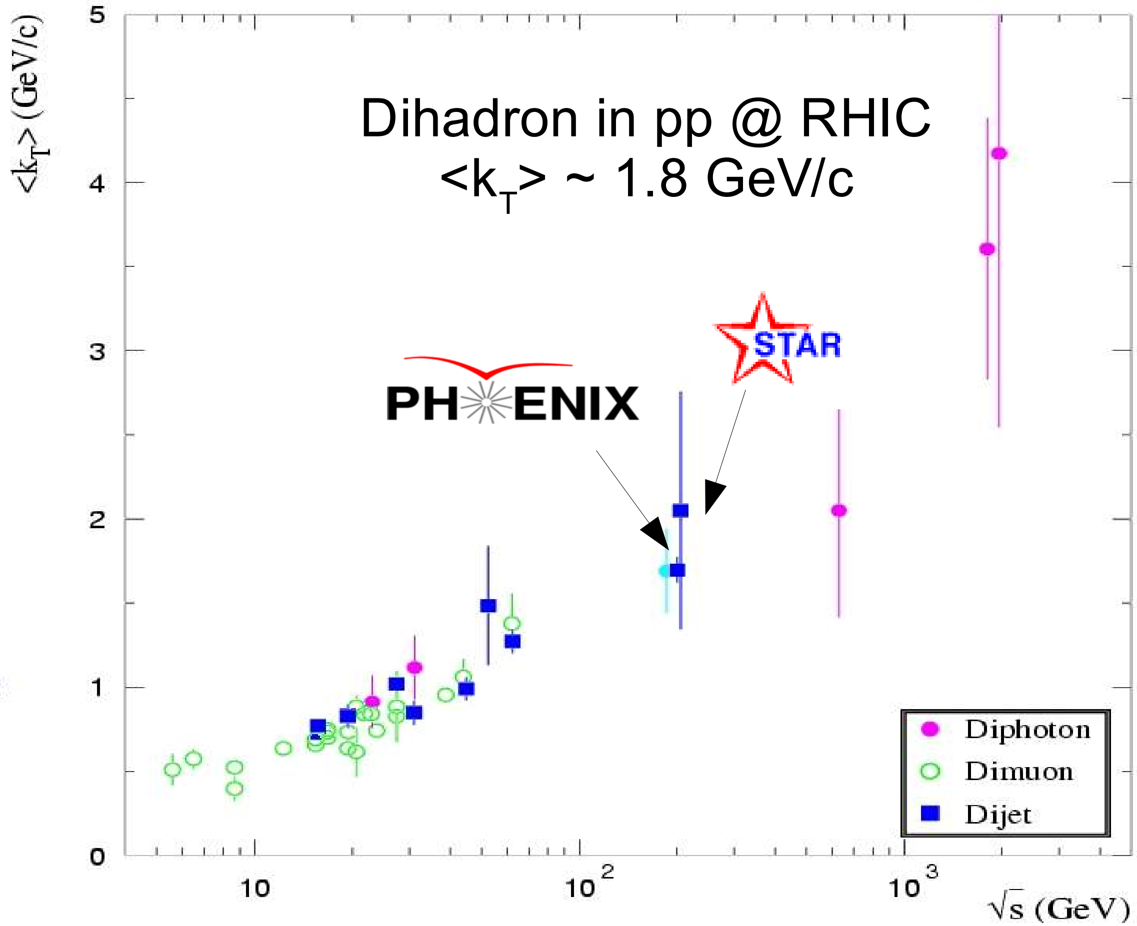



- Non-negligible **$k_T$ broadening in pp: $\langle k_{Ty} \rangle$ ~ 1.1 GeV/c**
- In dAu: $\langle k_T^2 \rangle_{dAu} \equiv \langle k_T^2 \rangle_{pp} + \langle k_T^2 \rangle_{nuclear}$
- Non-null (but small) $\langle k_T \rangle_{nuclear}$ (constraints models of multiple scattering in cold nuclear medium)

# Excitation function of pp di-jet acoplanarity ("intrinsic" $k_T$)

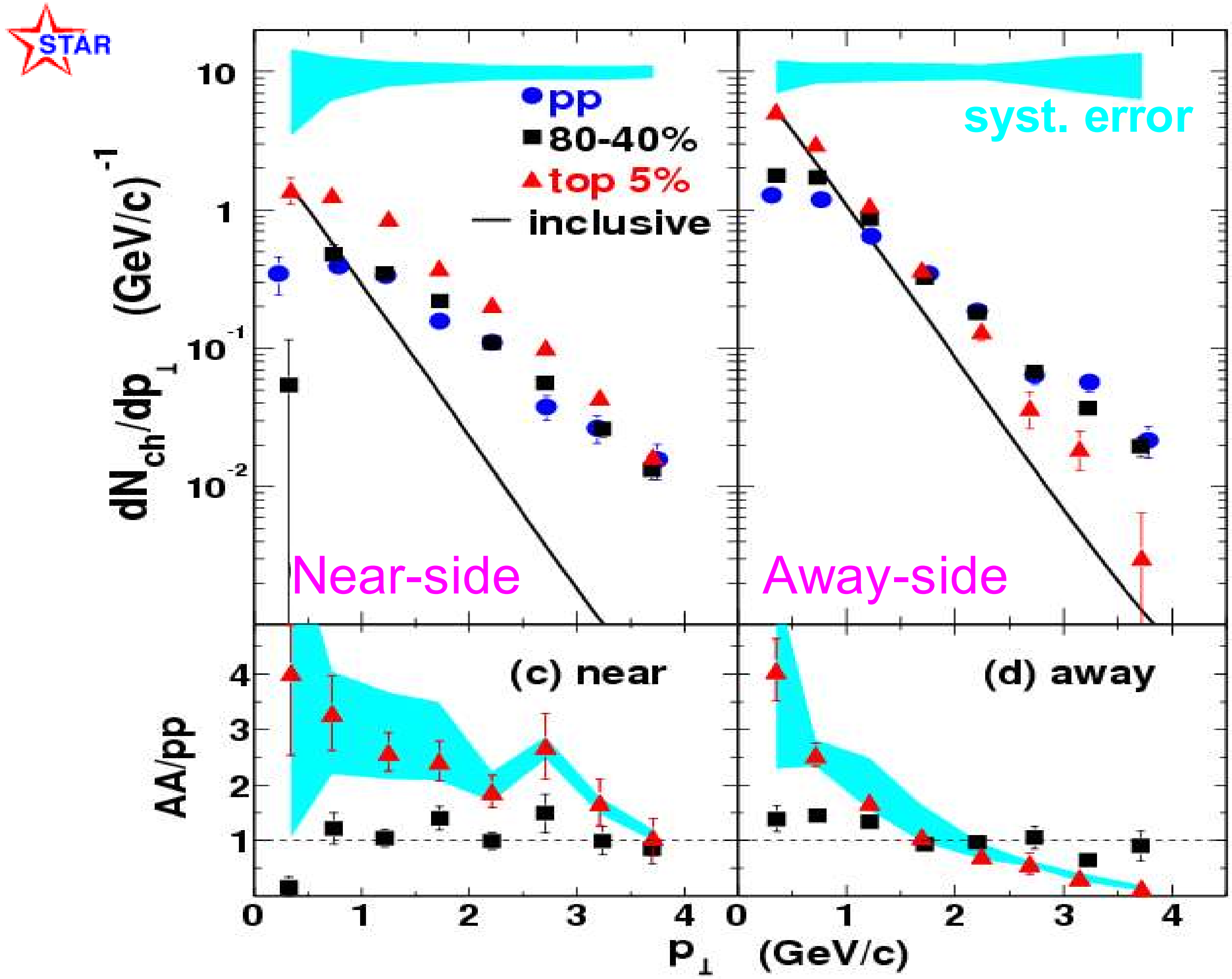
- sqrt(s)-dependence of $\langle k_T \rangle_{pair}$:




- (Logarithmic) increase with sqrt(s) consistent with growing gluon radiation contribution (not just intrinsic parton Fermi motion).

# "Fragmentation functions": Central AuAu

- Associated ($p_{T\,assoc}$ = 0.15 – 4 GeV/c) near- and away- side hadron $p_T$ spectra:




$p_{T\,trigg}$ = 4 – 6 GeV/c
$p_{T\,assoc}$ = 0.15 – 4 GeV/c

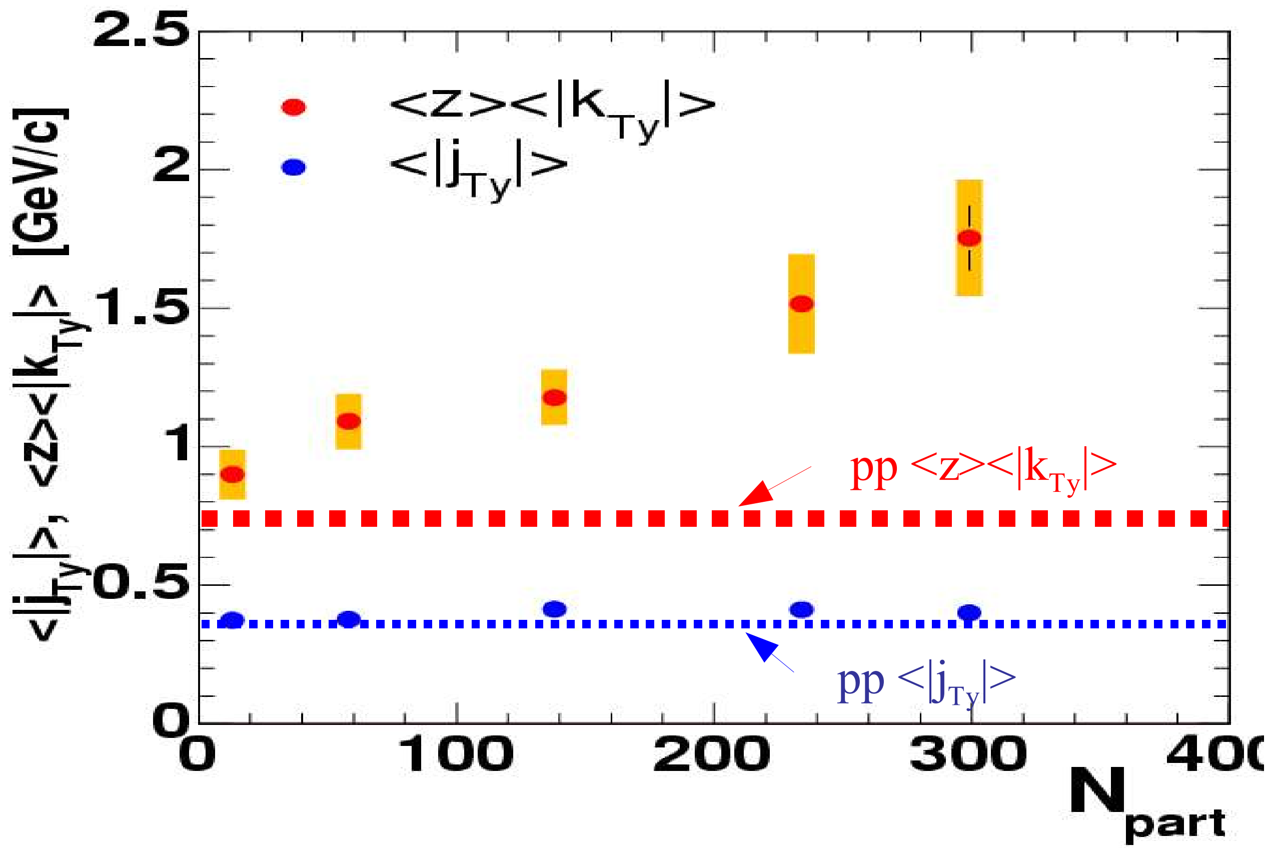
STAR, submitted to PRL
nucl-ex/0501016

- Associated near-side jet yields overall enhanced (enhanced underlying evt.)
- Associated away-side jet yields "shifted down" in $p_T$: spectra closer to pure "soft" inclusive hadron production ("thermalized")

# Centrality dependence of AuAu jet properties: $j_T$, $k_T$

- $\langle j_T \rangle_{AuAu} \approx \langle j_T \rangle_{pp}$: Near-side fragmentation unaffected by QCD medium.

$p_{Ttrigg}$ =2.5 – 4.0 GeV/c , $p_{Tassoc}$ = 1.0 – 2.5 GeV/c



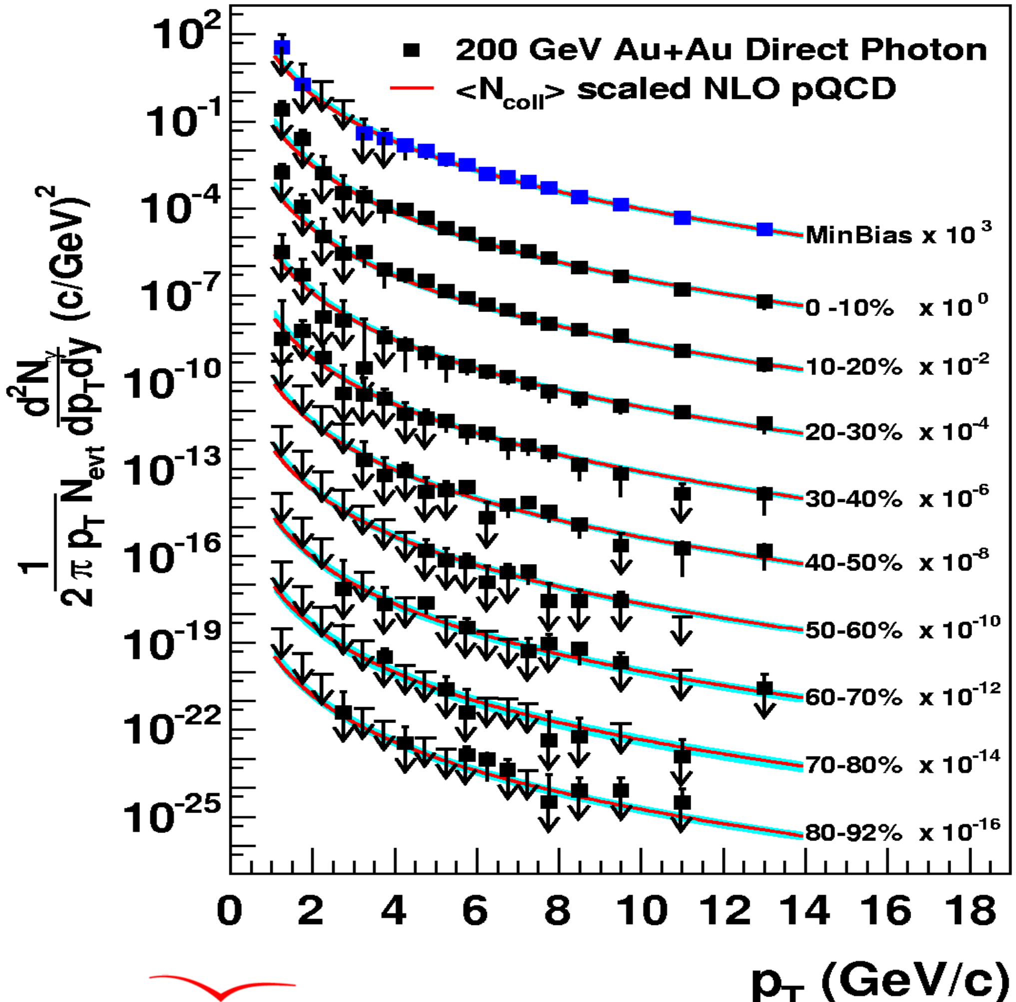

PHENIX Preliminary

[J.Rak, QM'04]

- $\langle k_T \rangle_{AuAu} \approx$ 3 GeV/c: Significant $k_T$ broadening (strongly centrality dependent) indicating substantial final-state rescattering of away-side fragmenting parton.

# Unquenched direct photons in AuAu collisions

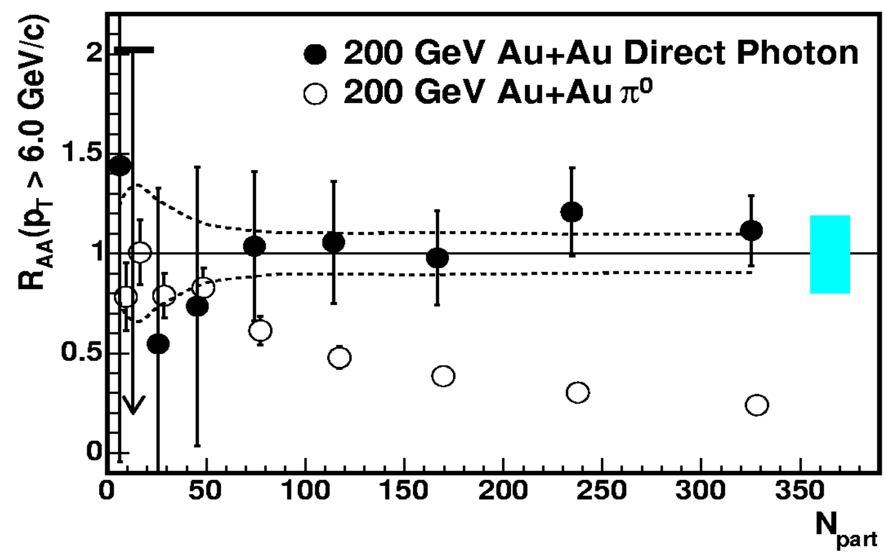
- Direct photon production in Au+Au (all centralities) consistent w/ p+p incoherent scattering ("NN-scaled" pQCD) predictions:




PHENIX

Submitted to PRL
nucl-ex/0503003

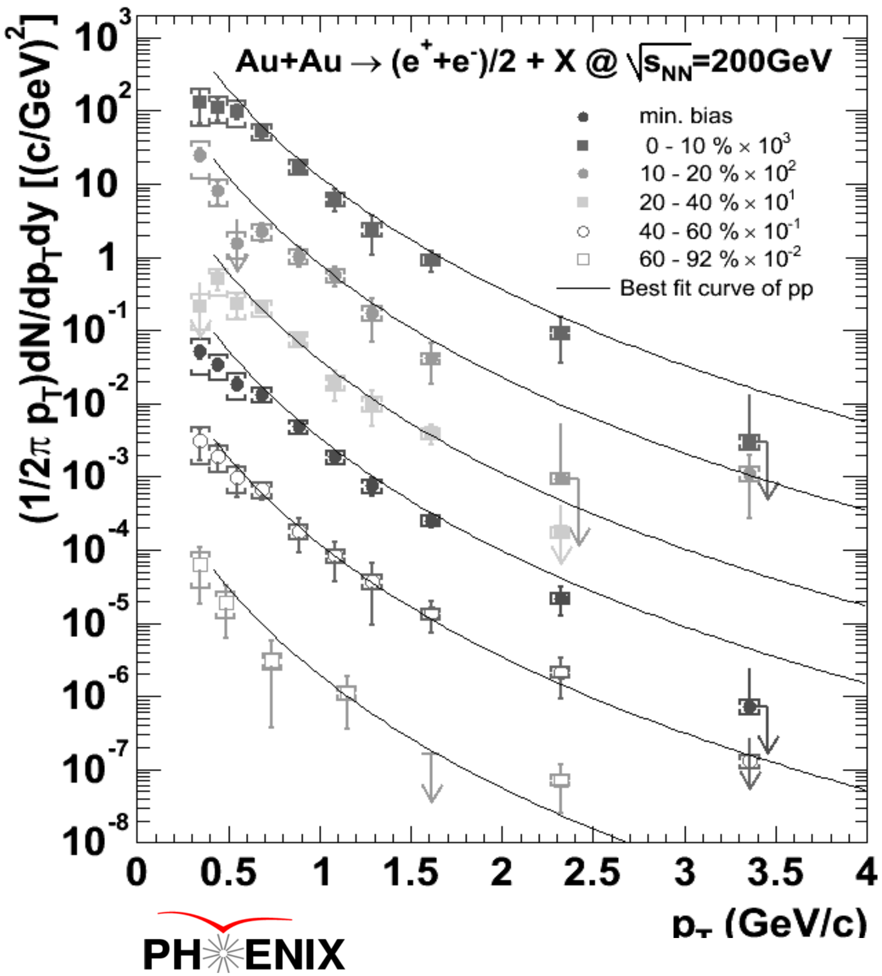
$$R_{AA}(p_T, y; b) = \frac{\text{“hot/dense QCD medium”}}{\text{“QCD vacuum”}} = \frac{d^2N_{AA}/dydp_T}{\langle T_{AA}(b)\rangle \cdot d^2\sigma_{pp}/dydp_T},$$



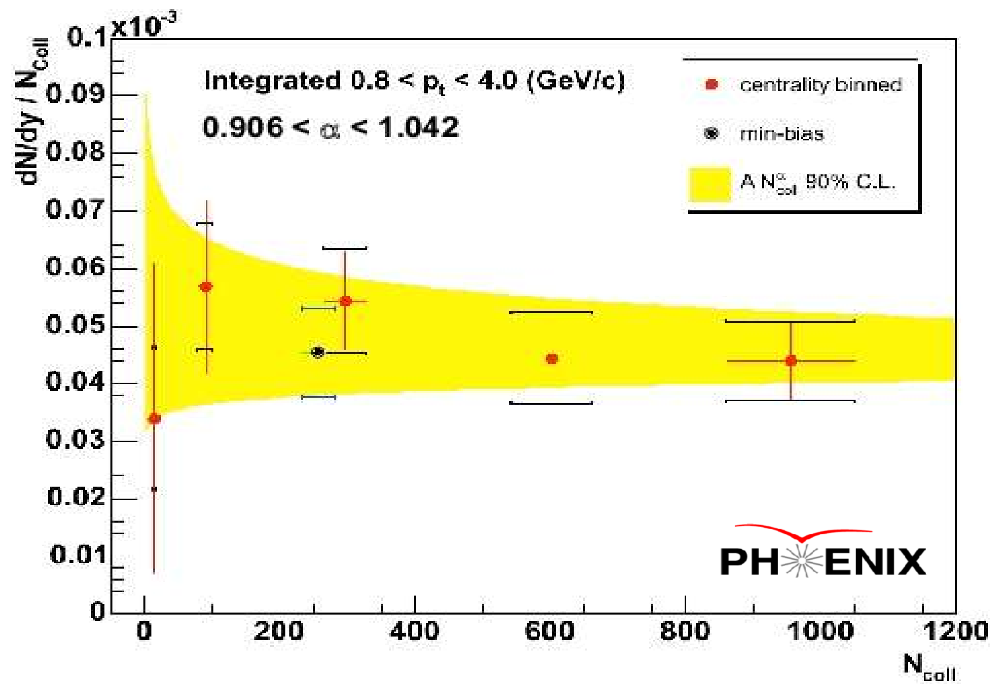

- pQCD parton scattering holds for hard (colorless) QCD processes in AuAu (all centralities).

# Charm production in AuAu: "NN scaling"

- Open-charm (indirect) measurement via semi-leptonic channel: $D \rightarrow e^{\pm} + X$
- Single $e^{\pm}$ AuAu spectra ($p_T \sim 0.3 - 2$ GeV/c) & total cross-section consistent w/ $N_{coll}$ -scaled pp charm production:




$$N_{charm}^{AuAu} = (N_{coll})^{\alpha} * A$$




Note: $\alpha = (0.906 - 1.042) \Rightarrow$
$N_{coll}^{\alpha} \approx (0.6 - 1.2) * N_{coll}$

PHENIX.
PRL94, 082301 (2005)

# High $p_T$ suppression: charm quark (theory)

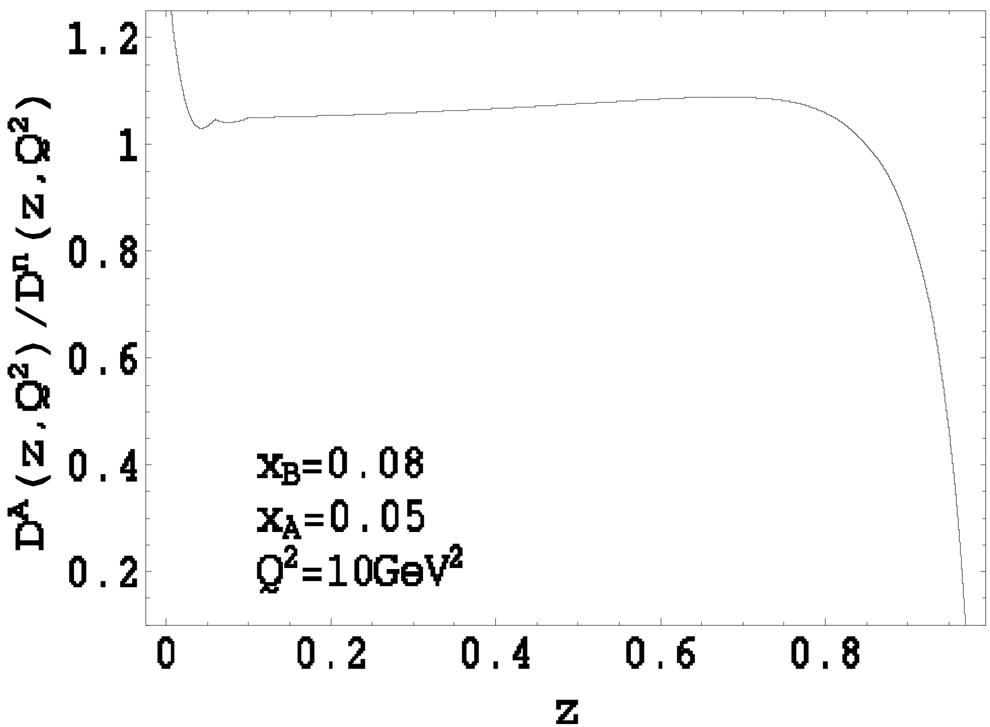
(1) Slow clock for formation time

$$\tau_f^H = \frac{1}{1/\tau_f + (1-z)M^2/2zq^-}$$

(2) Color factor

(3) Dead cone effect

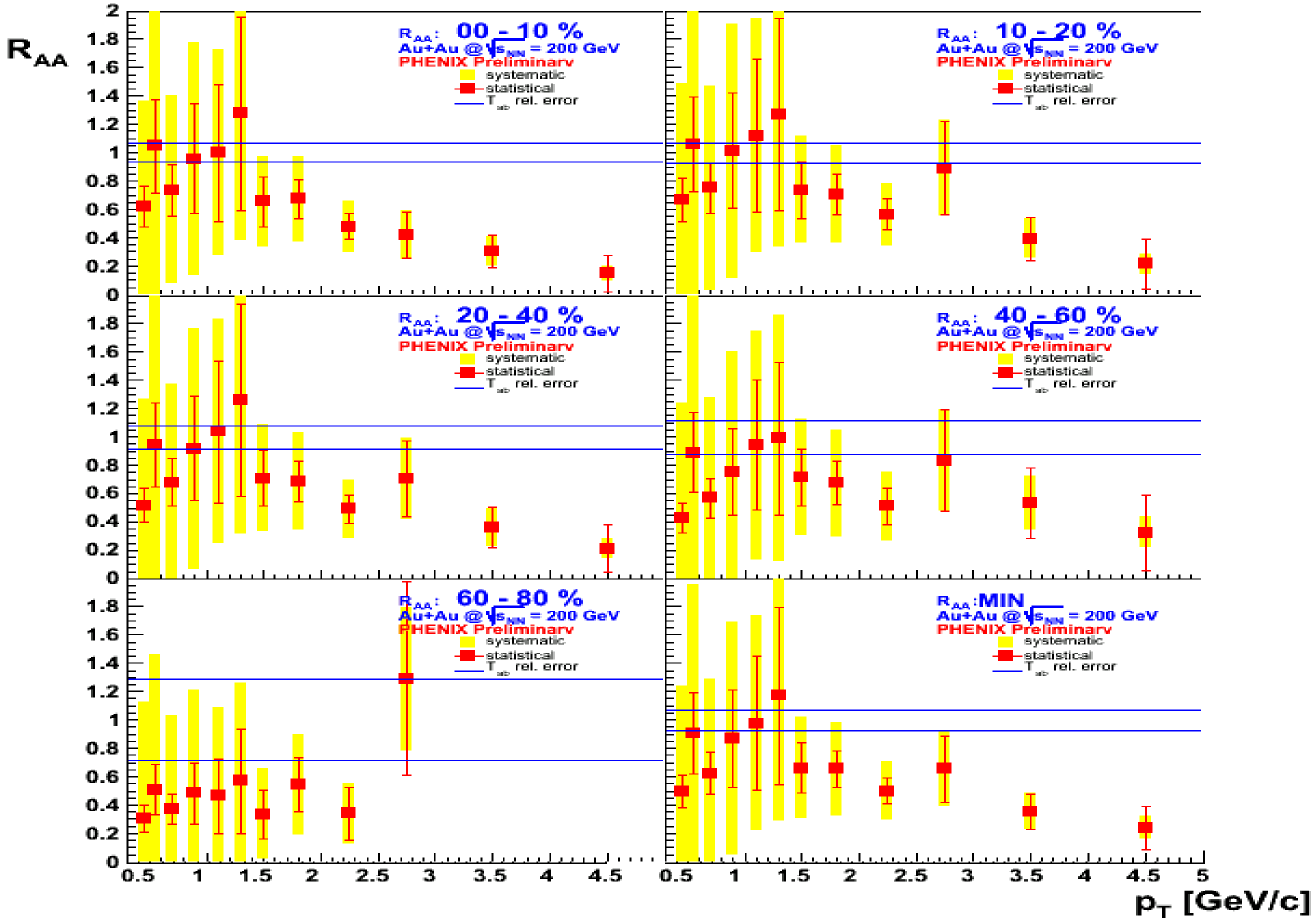
$\Delta E_Q < \Delta E_g, \Delta E_q$




Djordjevic & Gyulassy
Zhang & XNW
Armesto,Dainese, Salgado & Wiedemann

# Charm quark suppression at high $p_T$ ?

- Latest single $e^{\pm}$ $R_{AA}$ at higher $p_T$ < 4.5 GeV/c (large uncertainties still @ low $p_T$):




PHENIX
Preliminary

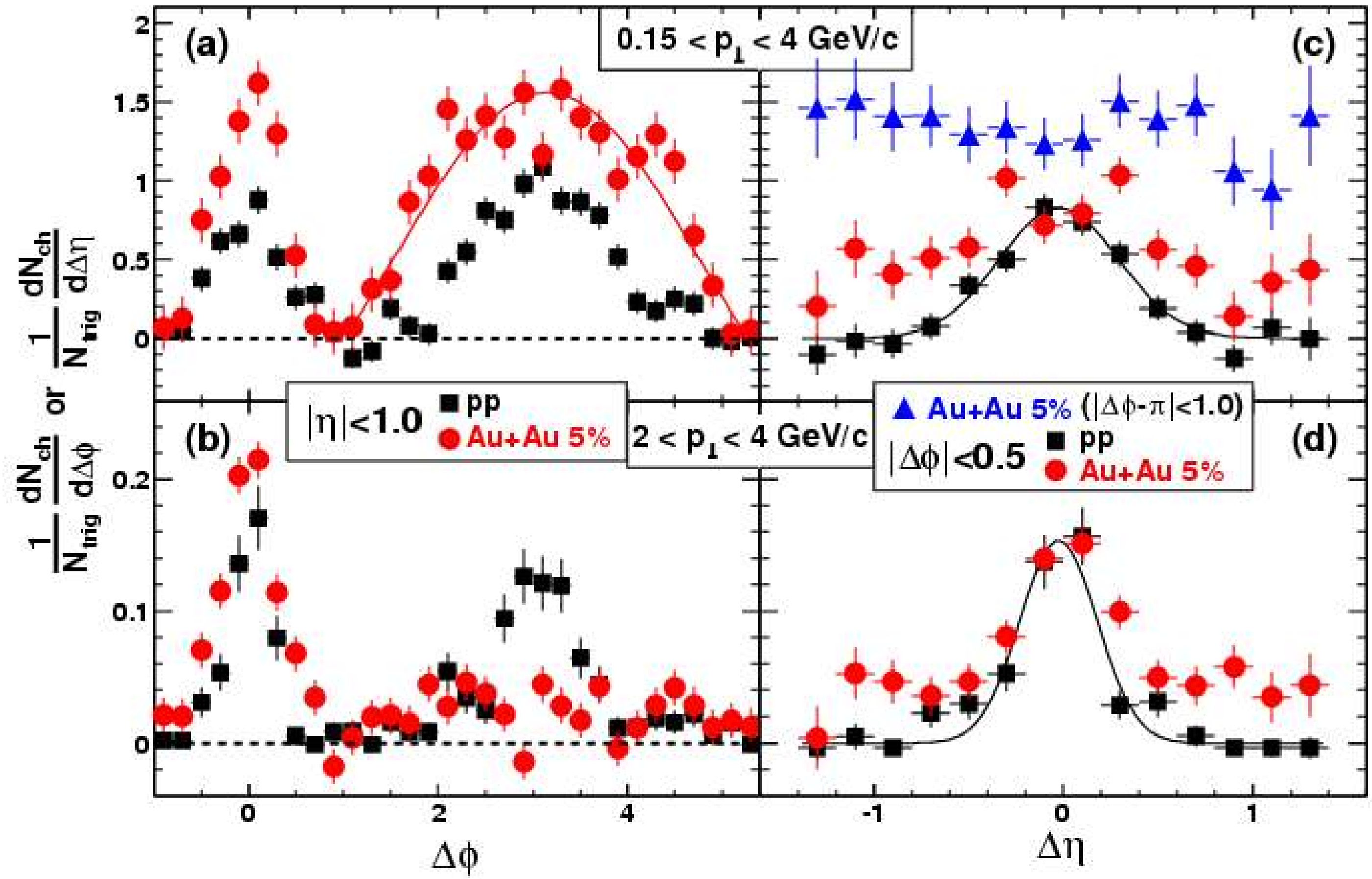
- Suppressed charm production above $p_T$~2 GeV/c ?

- New kinematic domain accessible with heavy-Q: Hard production at low $p_T$
- $R_{AA}$(lo $p_T$) ~1 >> $R_{AA}$(hi $p_T$) ~ $R_{AA}(\pi^0)$: Energy loss for fast heavy Q shifts them down to low $p_T$? No en. loss effect for slow Q (flatter charm $dN/dp_T$ at low $p_T$) ?

# "Jet quenching": modified (di)jet structure

- Strongly modified away-side $dN_{pair}/d\varphi$ correlations in central AuAu:

STAR, nucl-ex/0501016.



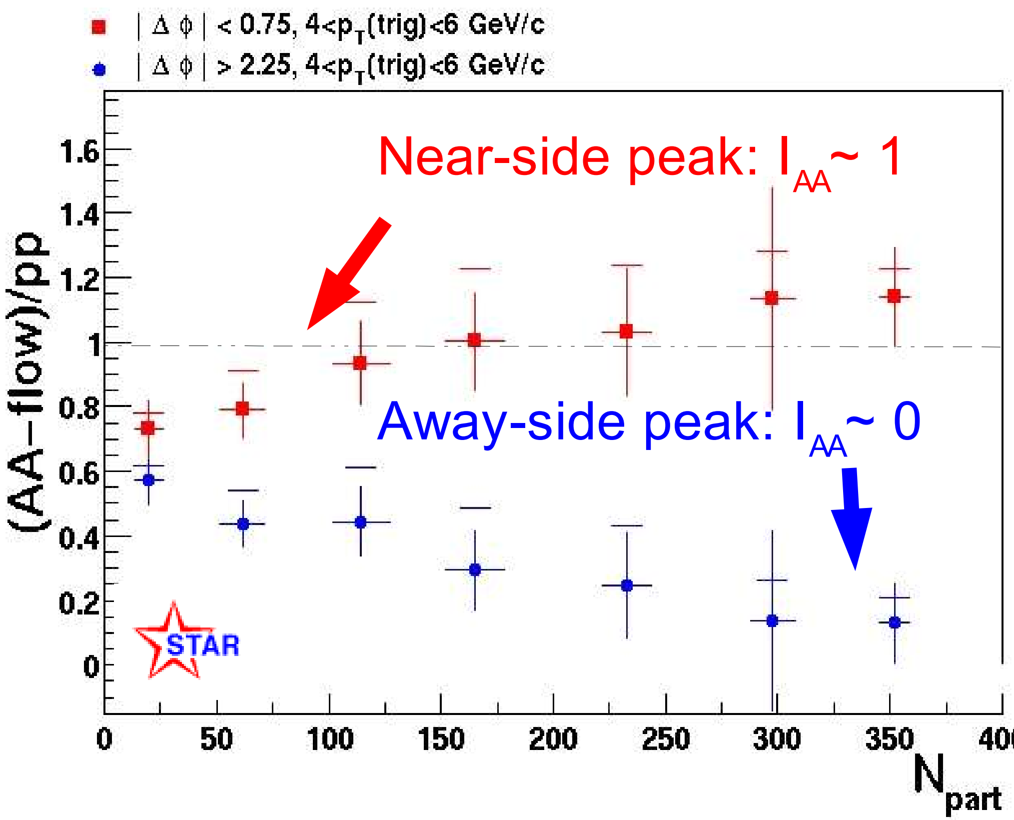

Enhanced and broadened distribution at low pT.

Away side suppression at high pT.

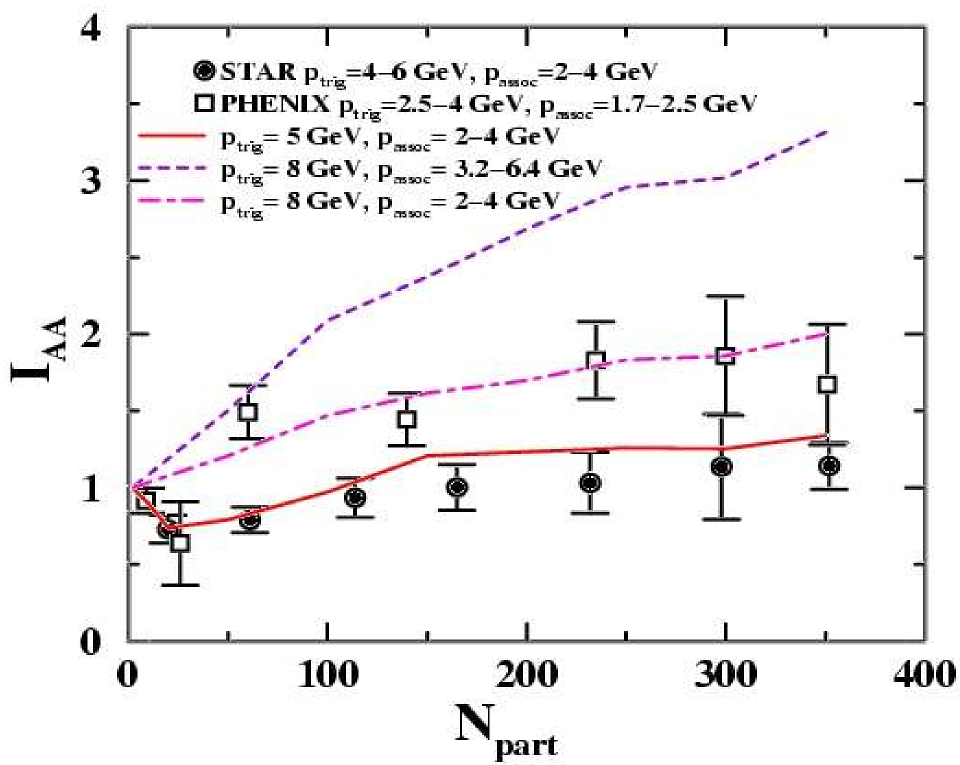
# Dihadron azimuthal correlations: AuAu "mono-jets"

- Centrality dependence of near- and away- side correlations "strengths":

$$I_{AA}(\Delta\phi_1, \Delta\phi_2) = \frac{\int_{\Delta\phi_1}^{\Delta\phi_2} d(\Delta\phi)[D^{\mathrm{AuAu}} - B(1 + 2v_2^2\cos(2\Delta\phi))]}{\int_{\Delta\phi_1}^{\Delta\phi_2} d(\Delta\phi) D^{\mathrm{pp}}}$$




STAR, PRL90, 082302 (2003)

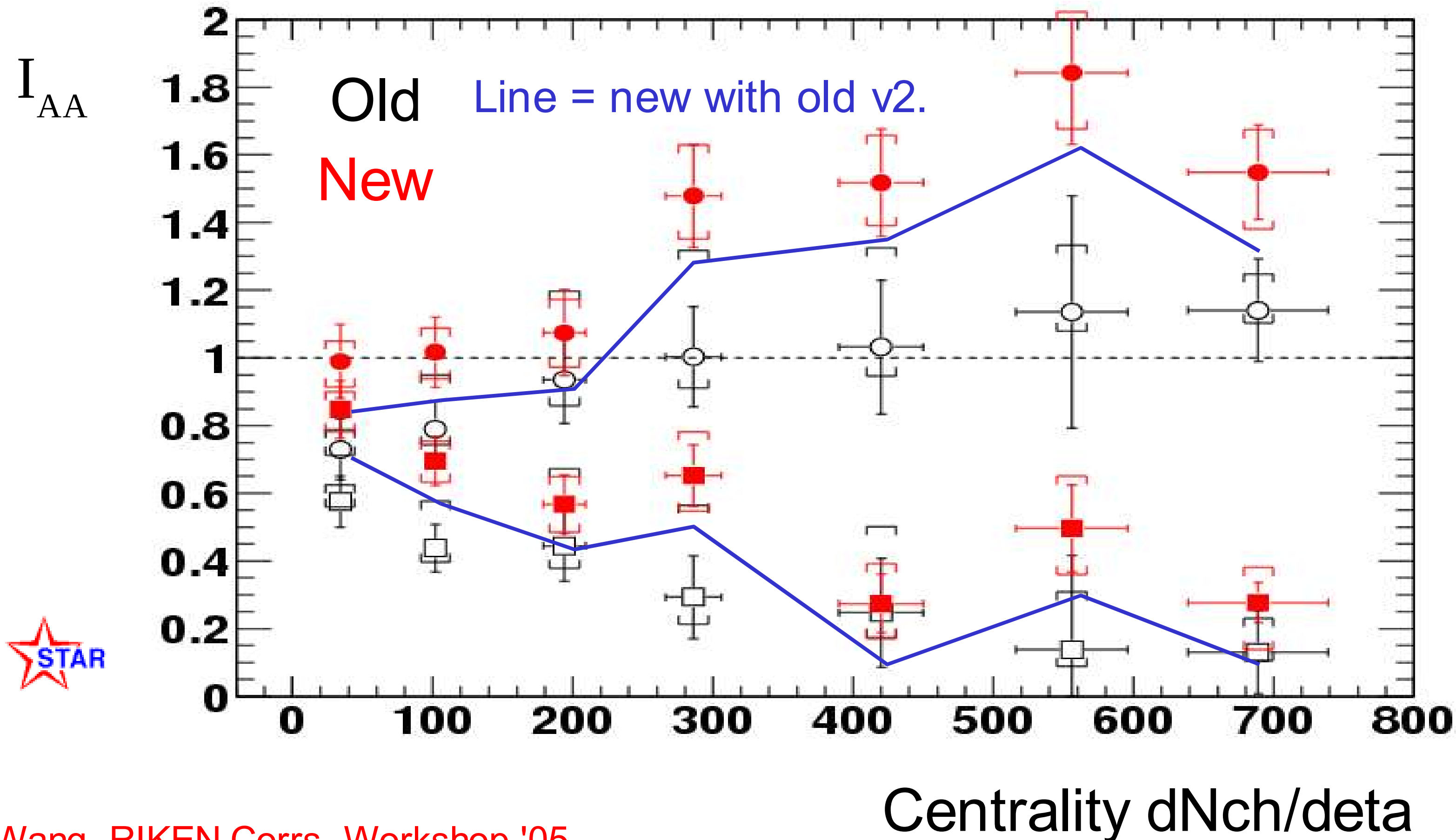



[A.Majumder, nucl-th/041261]

# Dihadron azimuthal correlations: AuAu "mono-jets"

- Centrality dependence of near- and away- side correlations "strengths":

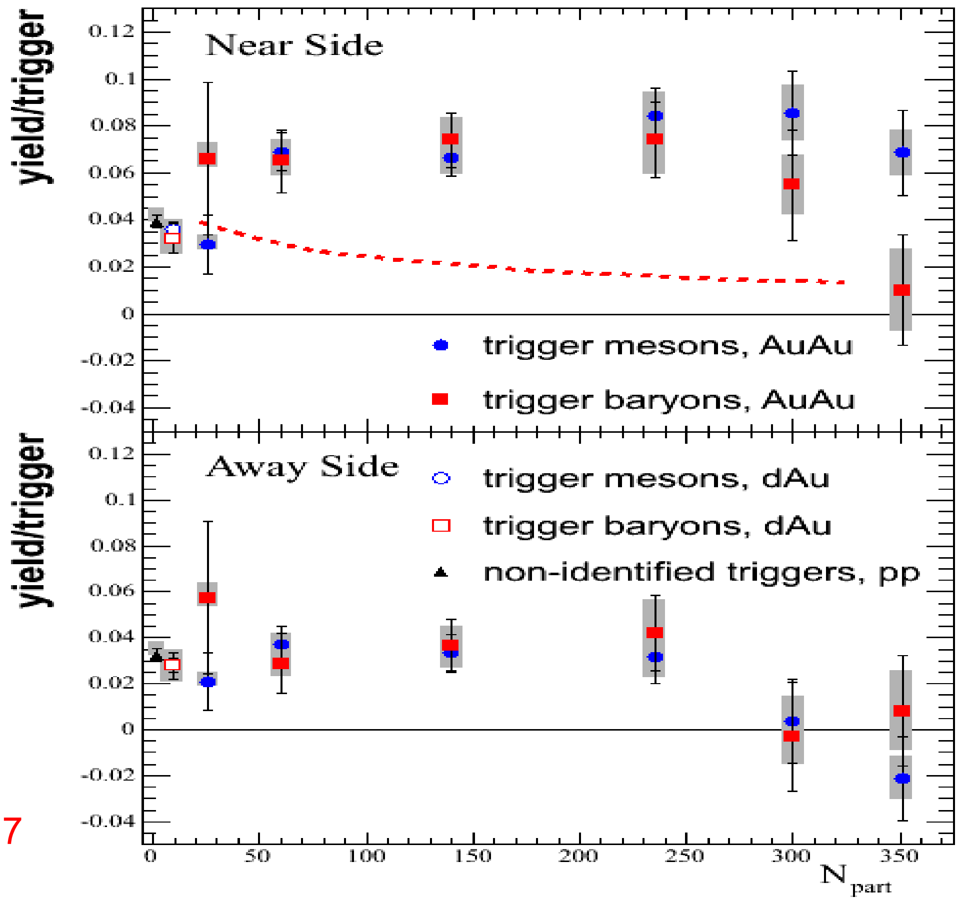
$$I_{AA}(\Delta\phi_1, \Delta\phi_2) = \frac{\int_{\Delta\phi_1}^{\Delta\phi_2} d(\Delta\phi)[D^{\mathrm{AuAu}} - B(1 + 2v_2^2 \cos(2\Delta\phi))]}{\int_{\Delta\phi_1}^{\Delta\phi_2} d(\Delta\phi) D^{\mathrm{pp}}}$$




F.Wang. RIKEN Corrs. Workshop '05

# “Fragmentation functions”: Central AuAu (200 GeV)

- Baryon-meson dependence of associated near- and away- side hadron $p_T$ spectra:




$p_{T\,trigg}$ = 2.5 – 4 GeV/c
$p_{Tassoc}$ = 1.7 – 2.5 GeV/c

**Near-side**

**Away-side**

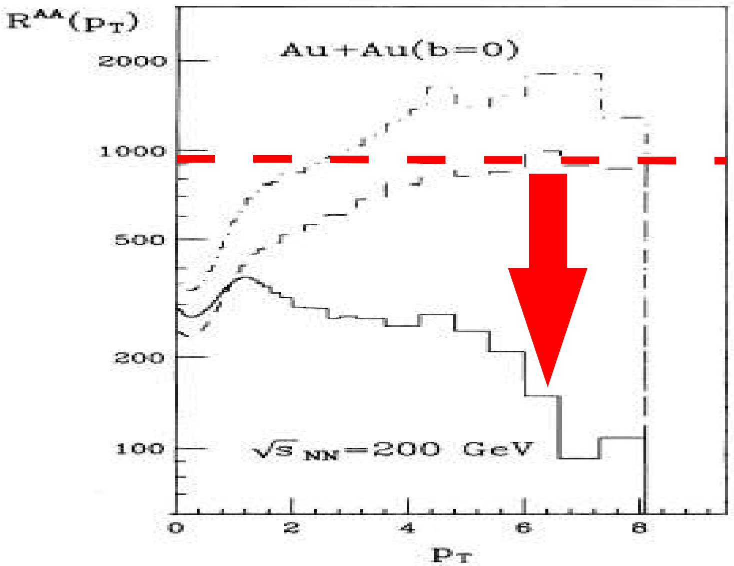
PHENIX
nucl-ex/0408007

- Associated yields similar for meson & baryon triggers (perhaps weak reduction for baryons in very central collisions).
- Slight increase of associated near-side jet yields in mid-central AuAu.
- Jet-like production but different suppression for leading baryons and mesons !?

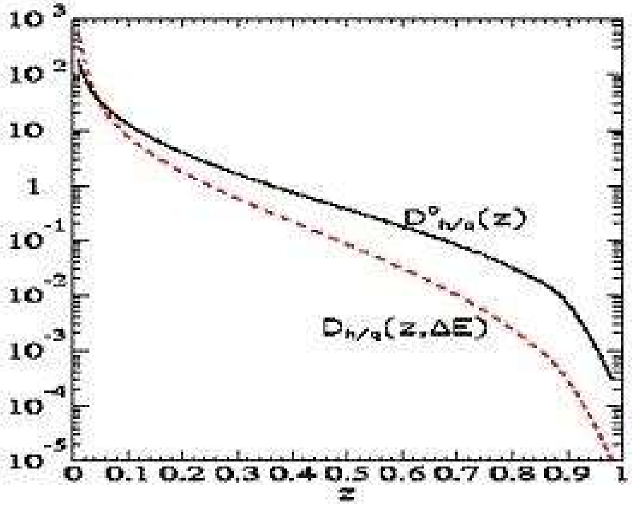
# Jet production in AA : (a few) theoretical expectations

- Leading hadron suppression:

Wang&Gyulassy PRL 68, 1480 (1992)



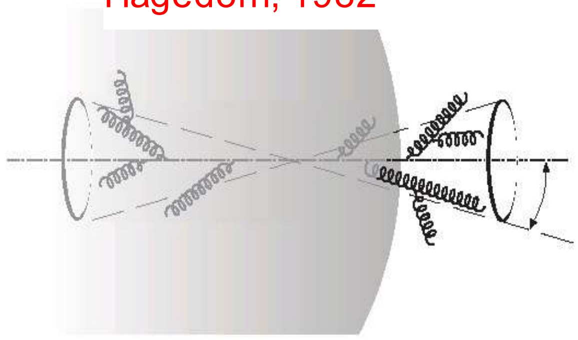

- Medium-modified FFs:



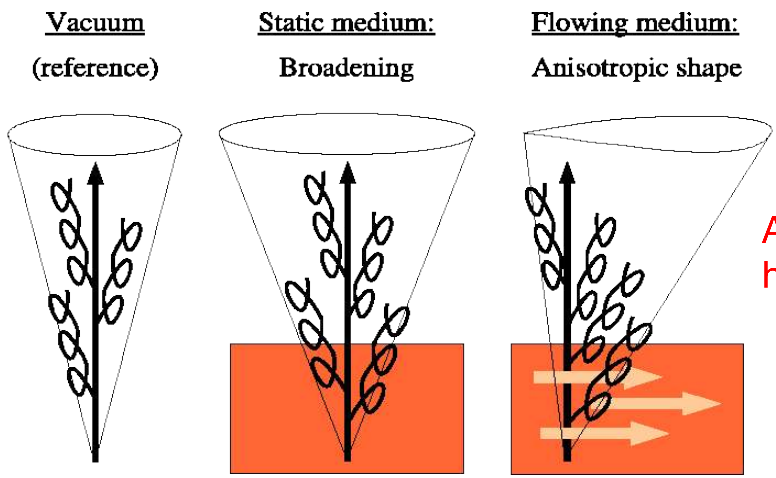

X.N.Wang; Salgado&Wiedem. Arleo, ...

- Mono-jets:

Hagedorn, 1982



- Jet broadening in eta:




Armesto et al hep-ph/0405301

- Valuable diagnostic tools of QCD medium ($dN^g/dy$, $<q_0>$, ...)