NUCLEAR MODIFICATION FACTOR AT LARGE RAPIDITIES AT RHIC

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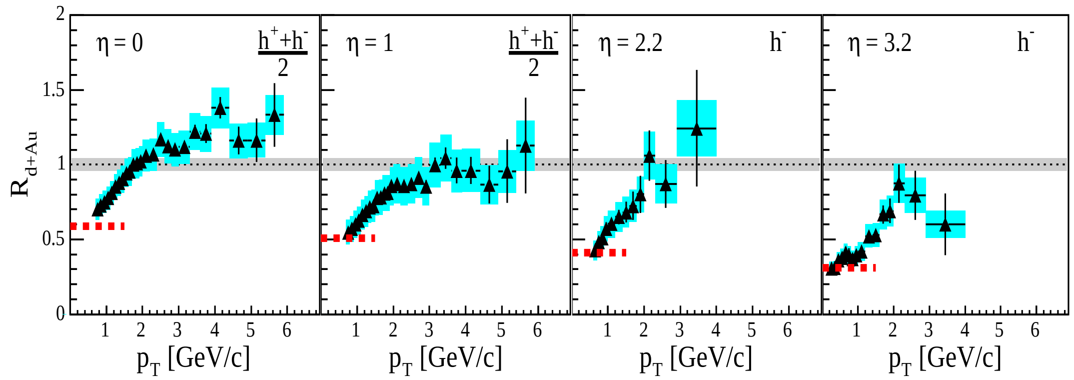
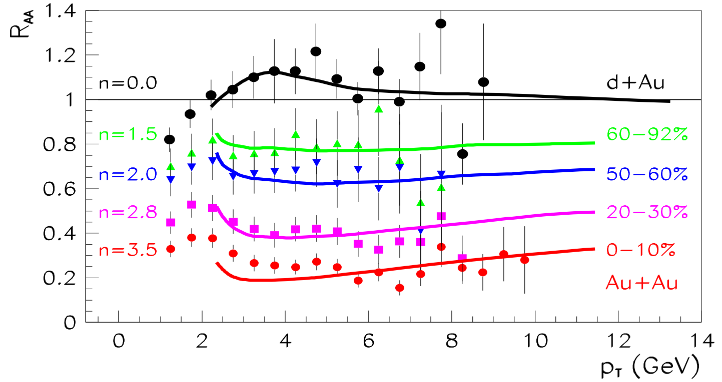
Questions and Motivation

I. We have studied π production in $(pA)dAu$ collision.

- Suppression were found at $\eta > 0$, h^+, h^- spectra at BRAHMS
- However no suppression at midrapidity at PHENIX.



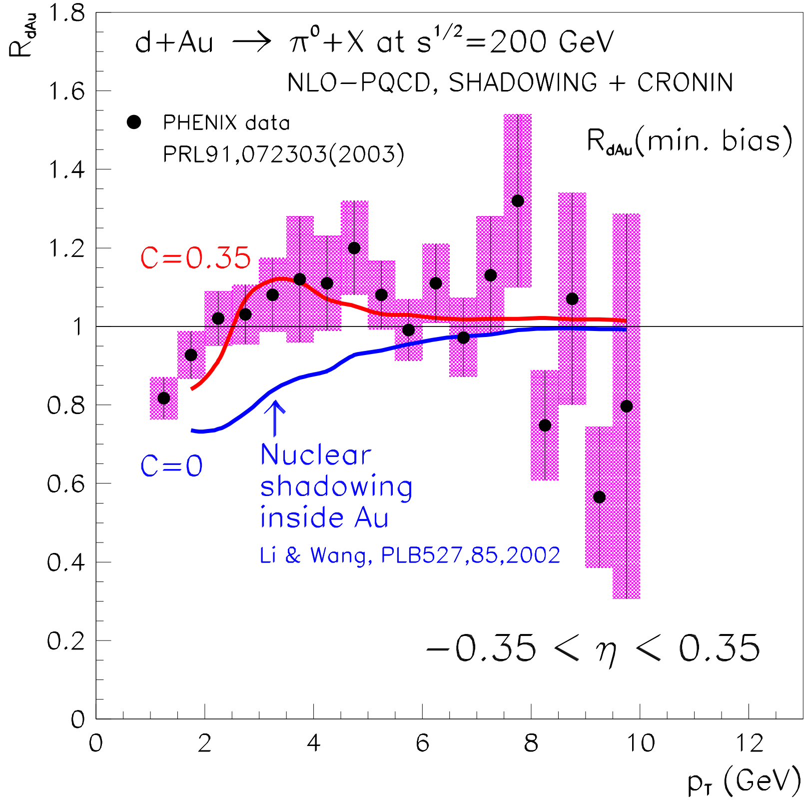
II. The jet-suppression appears in case of AA collisions



Suppression in π spectra in $AuAu$ at RHIC $\Longrightarrow$ QGP

How interplay the two effects in our modell at $\eta > 0$ for AA'?

Hunting for Nuclear Effects (Cronin) at High-p_T – $R_{AA'}$



Historically the Cronin effect:

increased particle production in

$3\ \text{GeV} < p_T < 6\ \text{GeV}$ range (1975)

"increased" means more particles

are produced in pA than expected

from N_{bin} scaled pp collisions

Nuclear modification factor

→ measuring Cronin effect: $$R_{AA} = \frac{1}{N_{bin}} \frac{\mathrm{d}N_{AA}/\mathrm{d}y\ \mathrm{d}^2p_T}{\mathrm{d}Npp/\mathrm{d}y\ \mathrm{d}^2p_T}$$

→ theoretical def.:

$$R^{\pi}_{AA'} := \frac{d\sigma^{AA'\to\pi}/d^3p\,(\text{"shadowing+multiscattering+ jet-quenching"})}{d\sigma^{AA'\to\pi}/d^3p\,(\text{"NO nuclear effect"})}$$

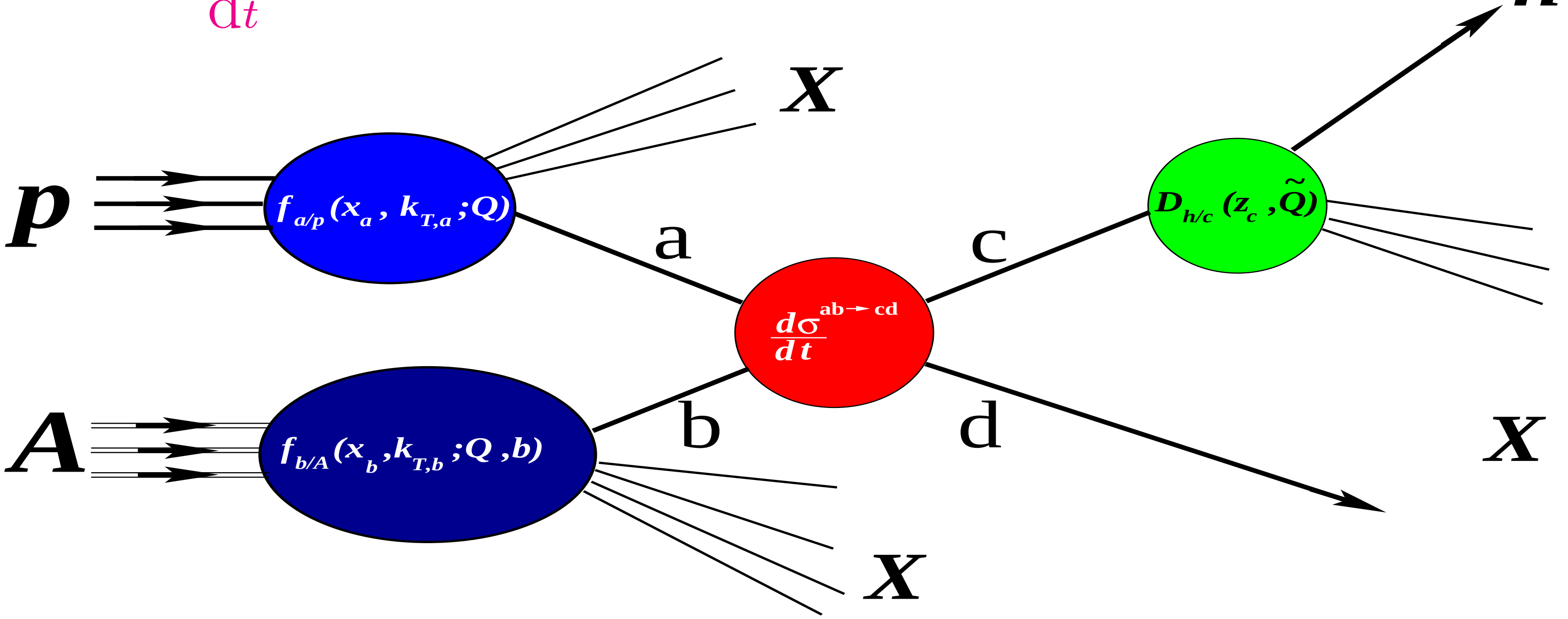
I/1. pQCD Improved Parton Model for pA Collisions

$$E_\pi \frac{\mathrm{d}\sigma_\pi^{pA}}{\mathrm{d}^3 p_\pi} \sim f_{a/p}(x_a, Q^2; k_T) \otimes f_{b/A}(x_b, Q^2; k_T, b) \otimes \frac{\mathrm{d}\sigma^{ab\to cd}}{\mathrm{d}\hat{t}} \otimes \frac{D_{\pi/c}(z_c, \widehat{Q}^2)}{\pi z_c^2}.$$

$f_{a/A}(x_a, Q^2; k_T, b)$: Parton Dist. Function (PDF), at scale Q^2

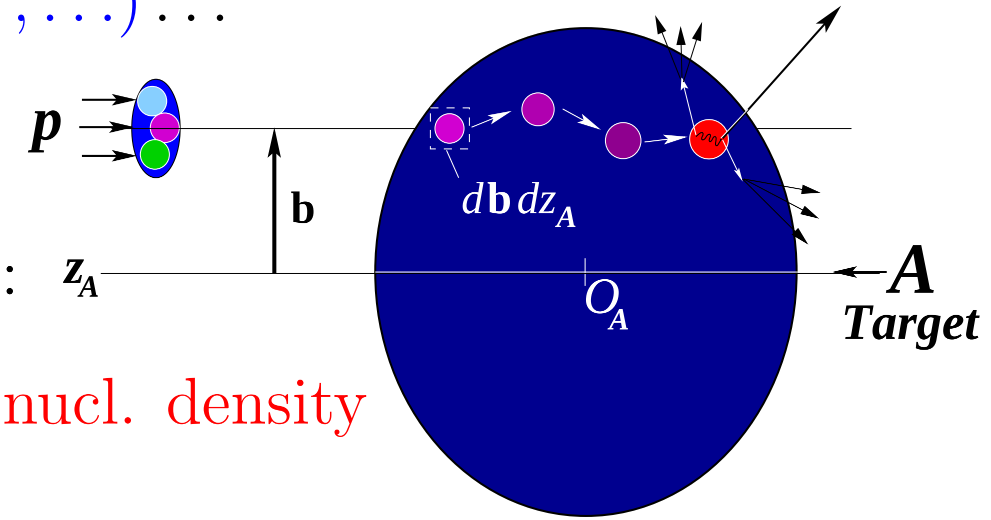
$D_{\pi/c}(z_c, \widehat{Q}^2)$: Fragmentation Function for π (FF), at scale $\widehat{Q}^2$

$\frac{\mathrm{d}\sigma^{ab\to cd}}{\mathrm{d}\hat{t}}$: Partonic cross section



I/2. Collision Geometry and Shadowing in $pA \to \pi$

$$E_\pi \frac{d\sigma_\pi^{pA}}{d^3 p} = \int d^2 b \, t_A(b) \int \ldots f_{a/A}(x_a, Q^2; \ldots) \ldots$$



(a) $\boxed{\textbf{Nuclear}}$ **thickness function:**

$t_A(b) = \int dz\, \rho(b,z)$ normalized as:

$A = \int_0^{b_{max}} t_A(b) d^2 b$, where $\rho(b,z)$ nucl. density

(b) $\boxed{\textbf{Nuclear}}$ **Shadowing – modified PDFs inside nucleus**

$$f_{a/A}(x, Q^2; b) = S_a^A(x,b) \left[\frac{Z}{A} f_{a/p}(x, Q^2) + \left(1 - \frac{Z}{A}\right) f_{a/n}(x, Q^2) \right]$$

$S_a^A(x,b)$: b-dependent or independent shadowing function;
HIJING: S. Li, X.-N. Wang: Phys.Letts. **B527**,85(2002)
A atomic- and Z the proton number

I/2. (a) Phenomenological introduction of intrinsic k_T

Introducing intrinsic k_T for colliding partons (G. Fai's talk)

Phenomenological assumption: PDFs are modified

1 dimensional PDFs are changed to 1+2 dimensional ones

$$\mathrm{d}x\, f_{a/p}(x,Q^2) \longrightarrow \mathrm{d}x\, \mathrm{d}^2k_T\ g_{pp}(\vec{k}_T)\ f_{a/p}(x,Q^2)$$

where $g(\vec{k}_T)$ is a Gauss distribution function :

$$g_{pp}(\vec{k}_T) = \frac{e^{-\vec{k}_T^2/\langle k_T^2\rangle}}{\pi\langle k_T^2\rangle} \quad \text{and} \quad \langle k_T^2\rangle = \frac{4\langle k_T\rangle^2}{\pi}$$

Baseline $\langle k_T^2\rangle$ values for pp: Phys. Rev. **C65** 034903 (2002)

$\langle k_T^2\rangle \sim$ value agrees with measured values by PHENIX,

I/2. (a) Multiple Scattering (The Cronin Effect)

Saturated NN collison numbers (in $pA \to \pi$)

- improve the Glauber model:

$$E_\pi \frac{\mathrm{d}\sigma_\pi^{pA}}{\mathrm{d}^3p} = \int \mathrm{d}^2b\, t_A(b) E_\pi \frac{\mathrm{d}\sigma_\pi^{pp}(\langle k_T^2\rangle_{pA}, \langle k_T^2\rangle_{pp})}{\mathrm{d}^3p}$$

$$\langle k_T^2\rangle_{pA} = \langle k_T^2\rangle_{pp} + C\ h_{pA}(b)$$

Total broadening = pp baseline + nuclear broad.

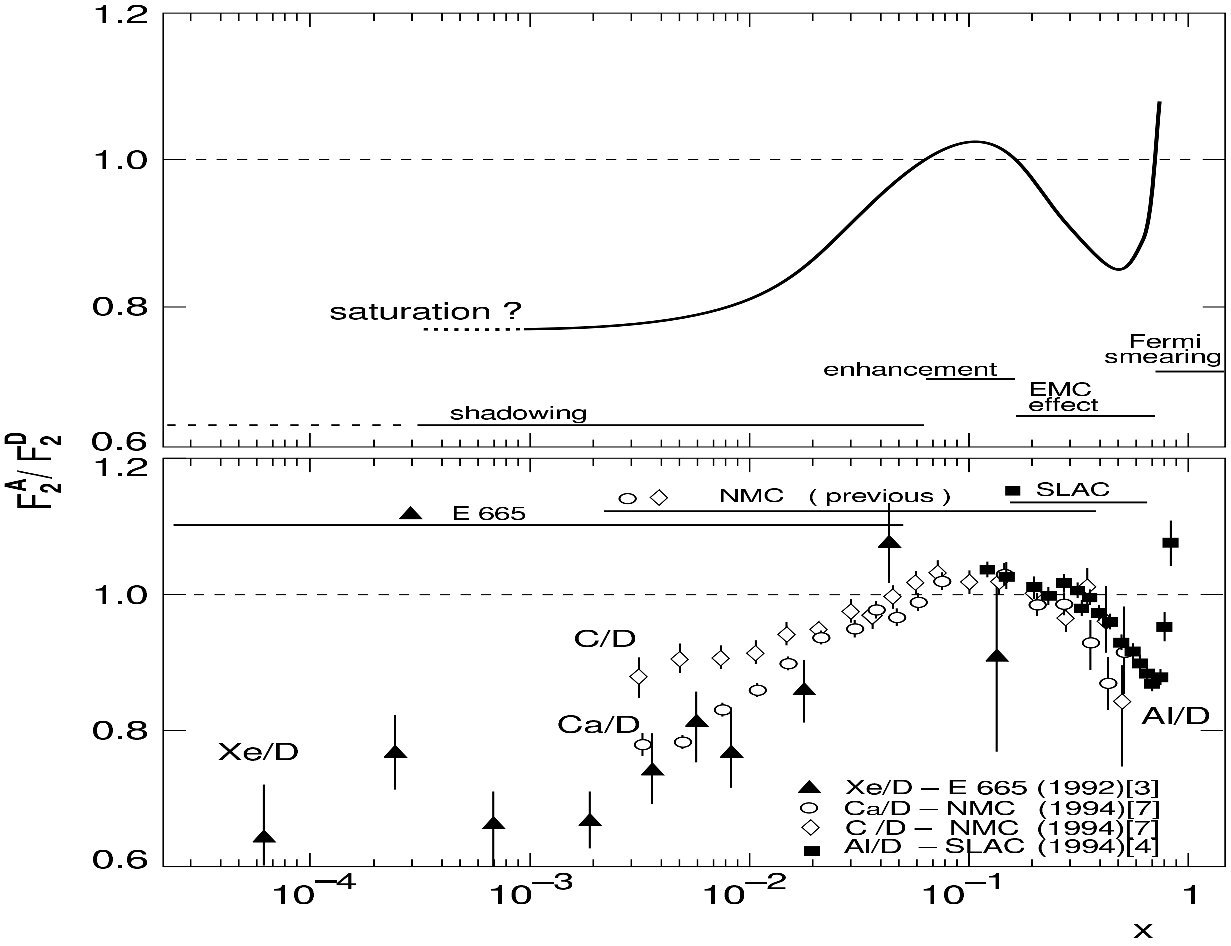
See details in PR**C65** 034903 (2002) and `hep-ph/0212249`

$h(\nu_A(b)-1)$: number of effective NN collisions $\nu_{max} = 3-4$

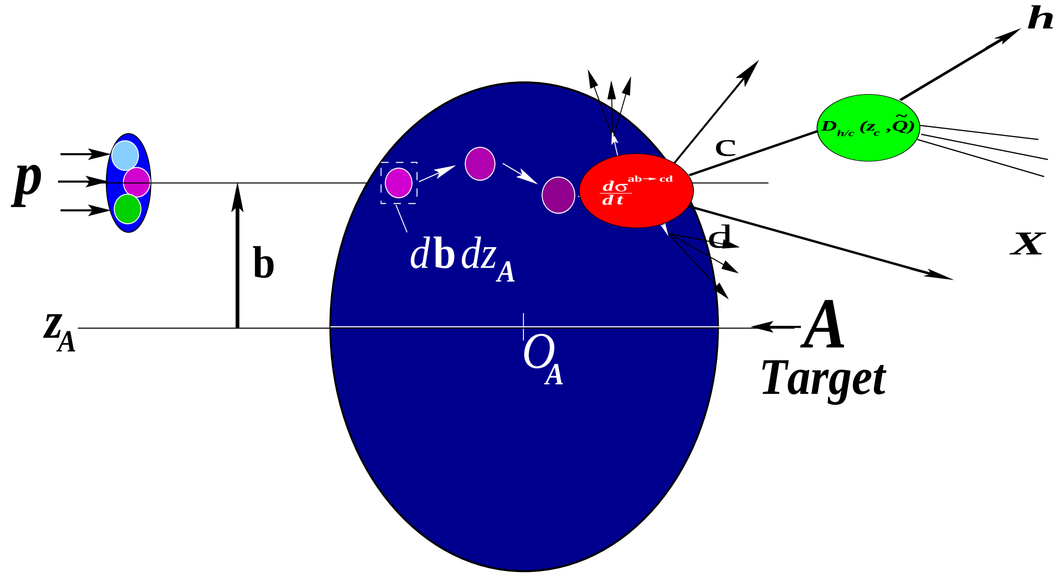
C : (average mom. broadening)^2 / coll. $C \approx 0.35$ GeV^2

$t_A(b)$: nuclear thickness function

I/2. (b) Phenomenological Shadowing functions

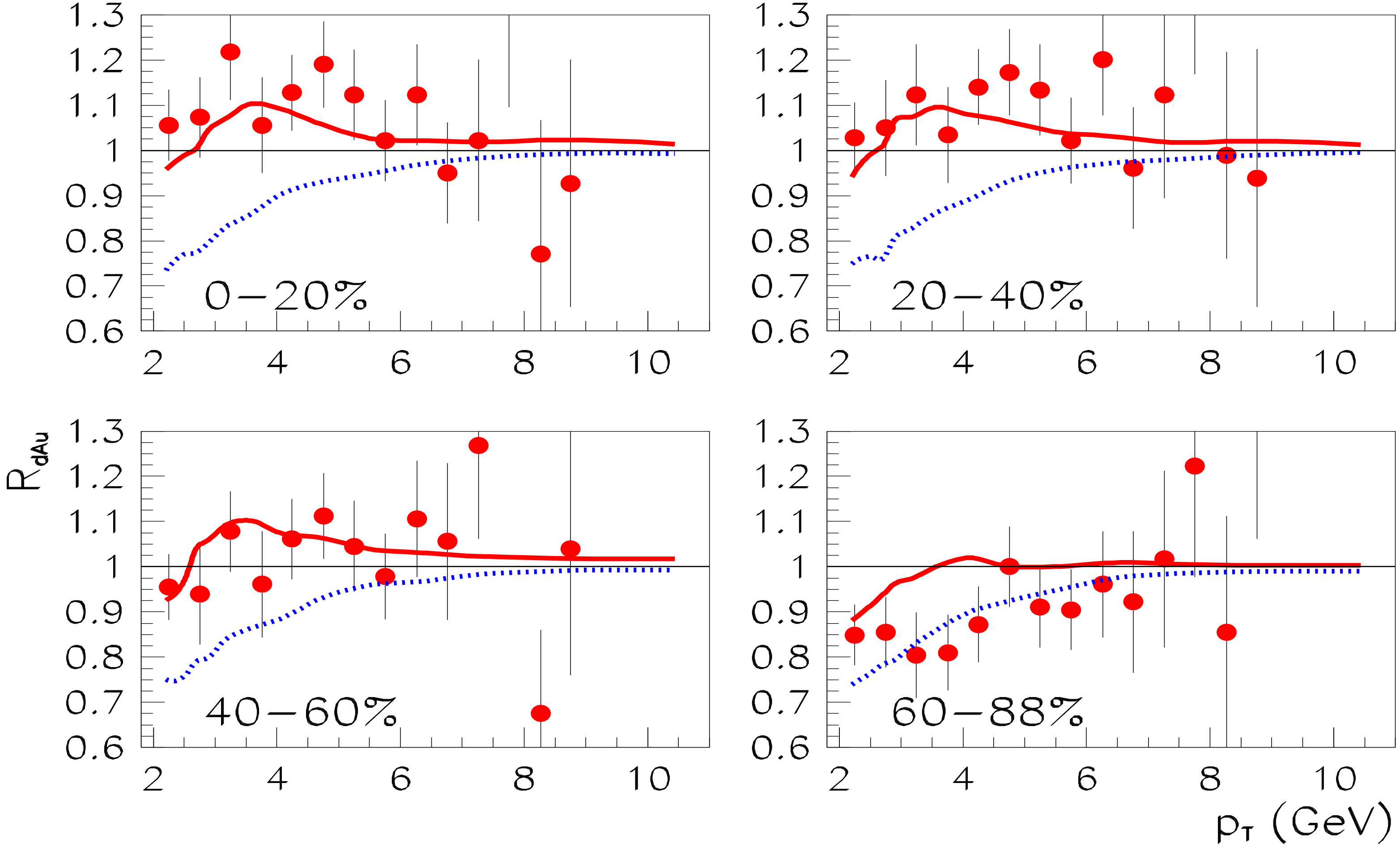


II. APPLICATION OF THE MODEL FOR



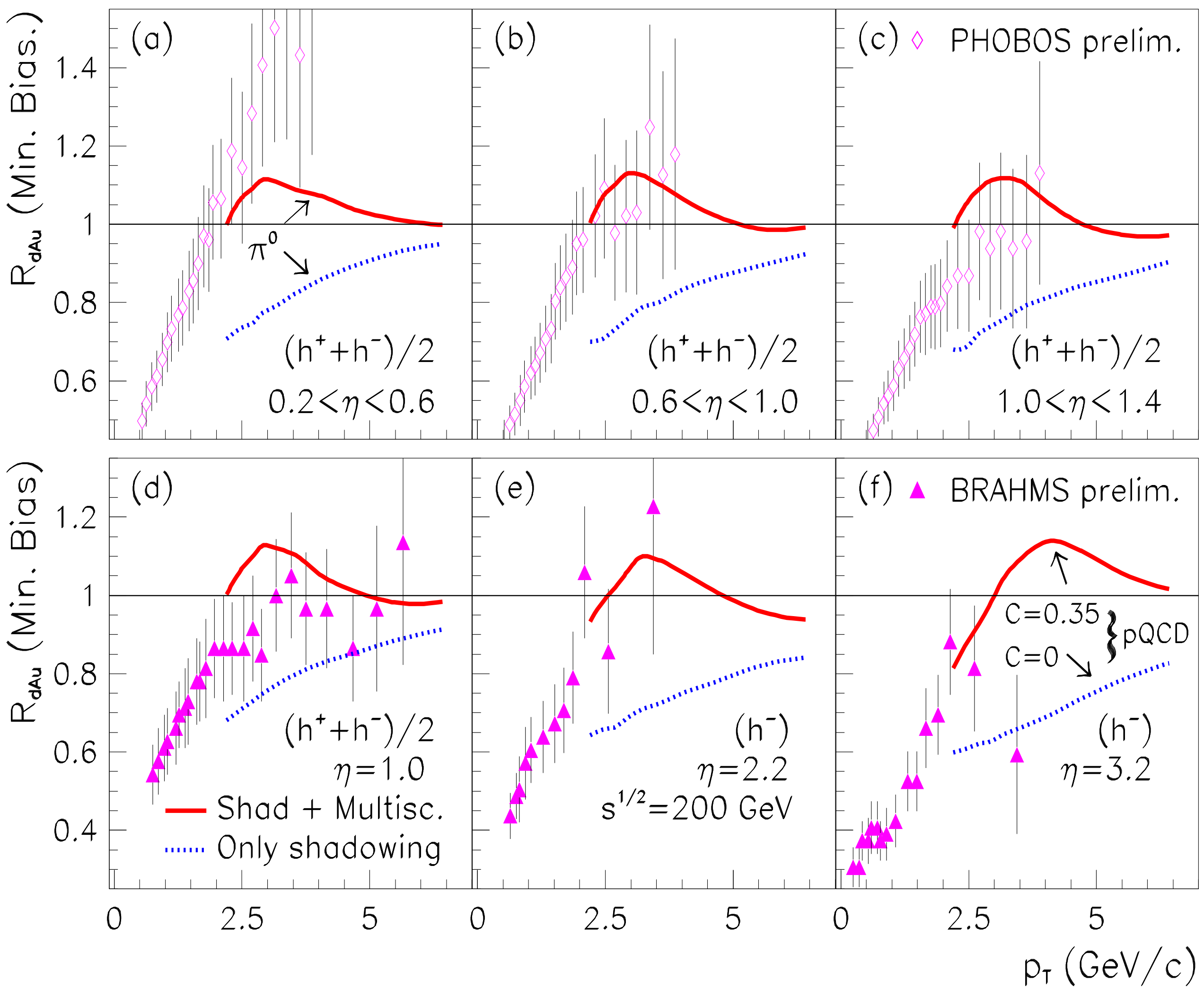
π^0 PRODUCTION IN dAu COLLISIONS

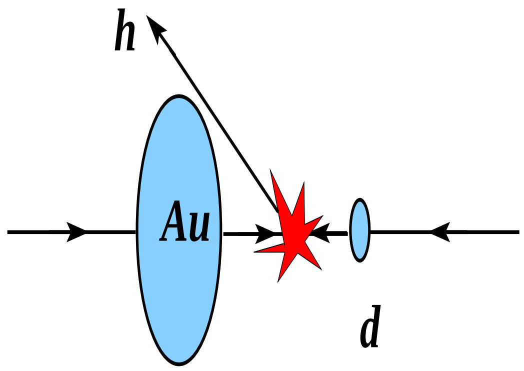
Cronin effect in different Centralities in *dAu* collision at PHENIX



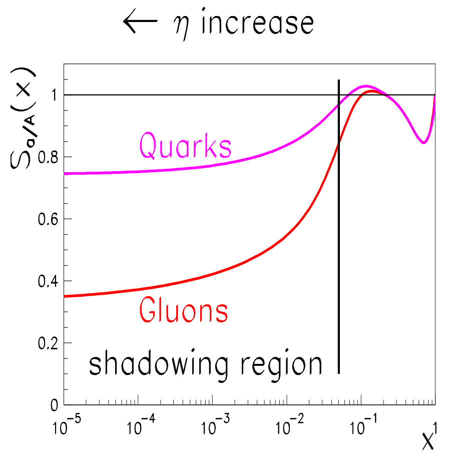
G.G. Barnaföldi *et al.*: J. Phys. G30, S1125

Cronin on min. bias $dAu \to \pi^0$ at PHOBOS and BRAHMS $\eta > 0$



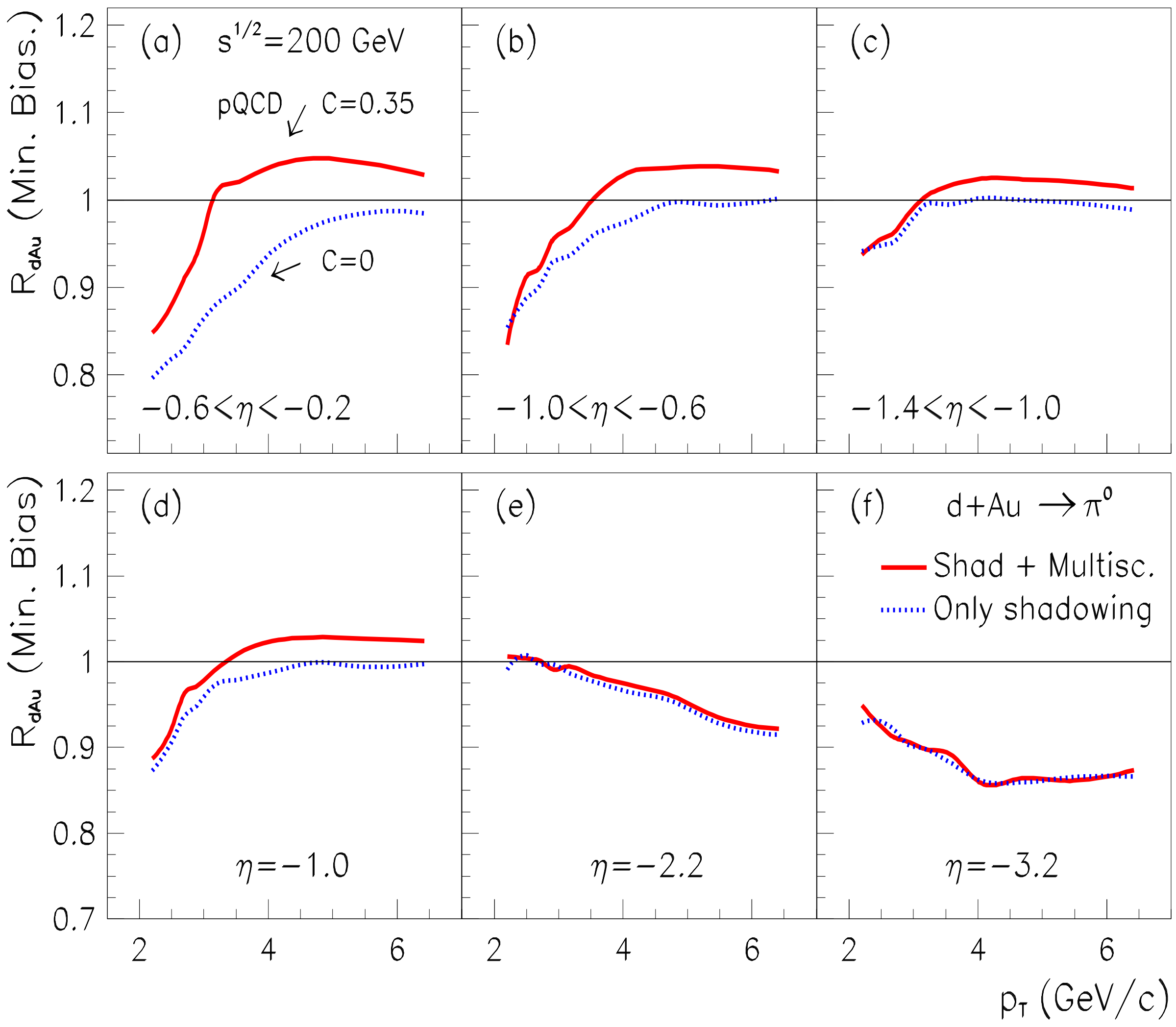


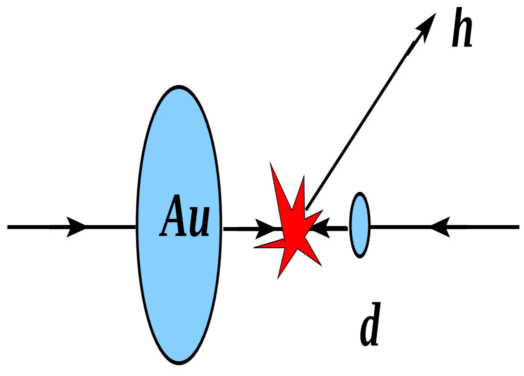
d-side



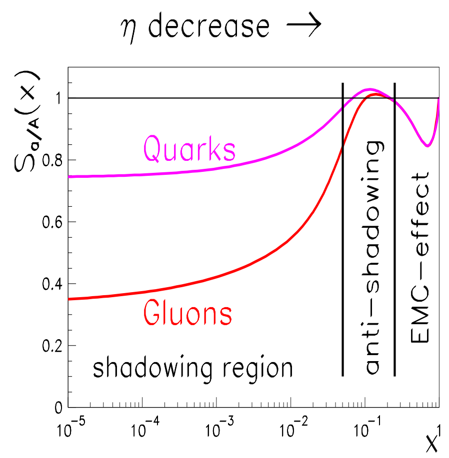
BRAHMS data: `nucl-ex/0403005` **and PHOBOS data:** `nucl-ex/0406017`

Cronin on min. bias $dAu \to \pi^0$ as inverted, $\eta < 0$

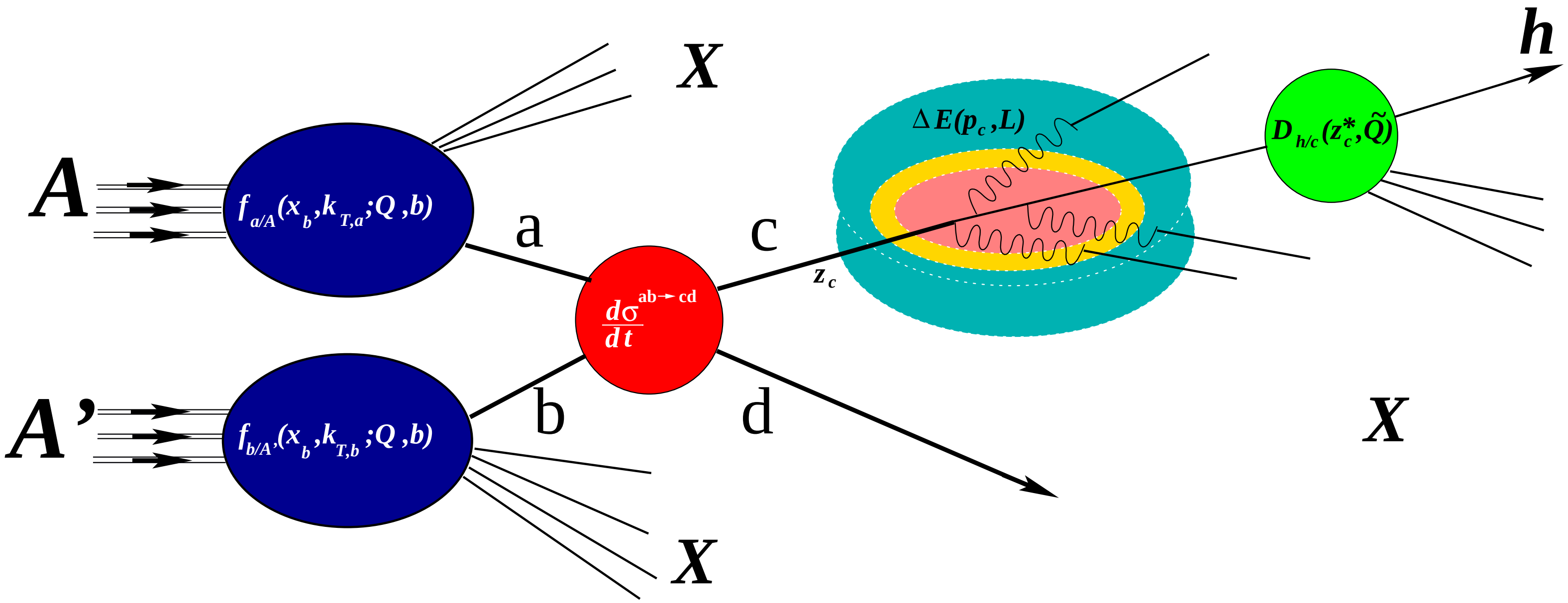




NO relevant multiscatt. in d. Au-side



III. IMPROVING THE APPLICATION FOR



π^0 PRODUCTION IN AA COLLISIONS

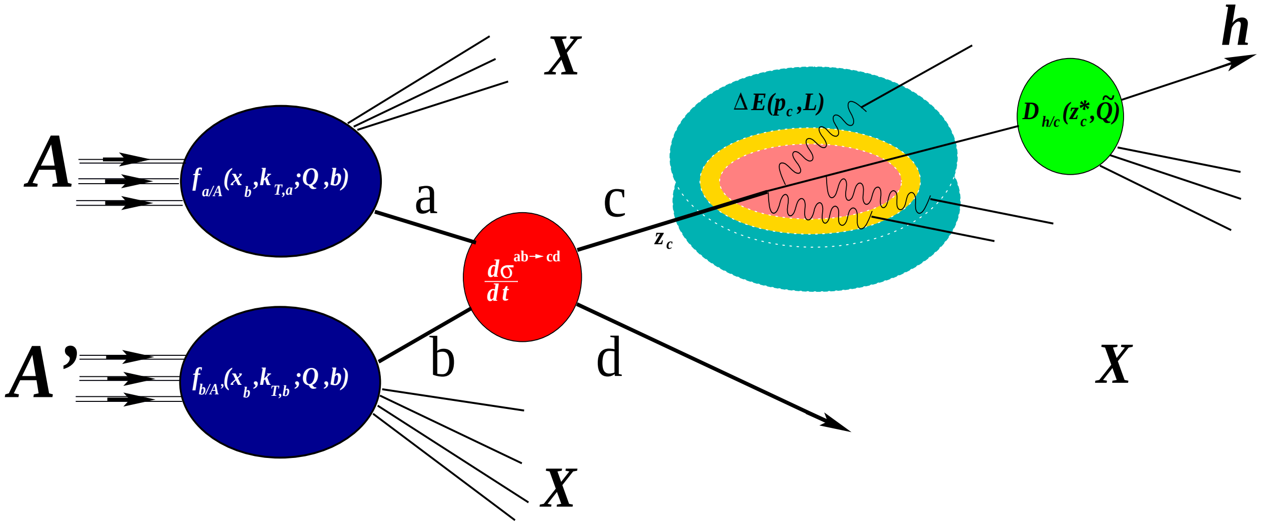
III. A π-suppression in $AuAu$ collisions at RHIC energies

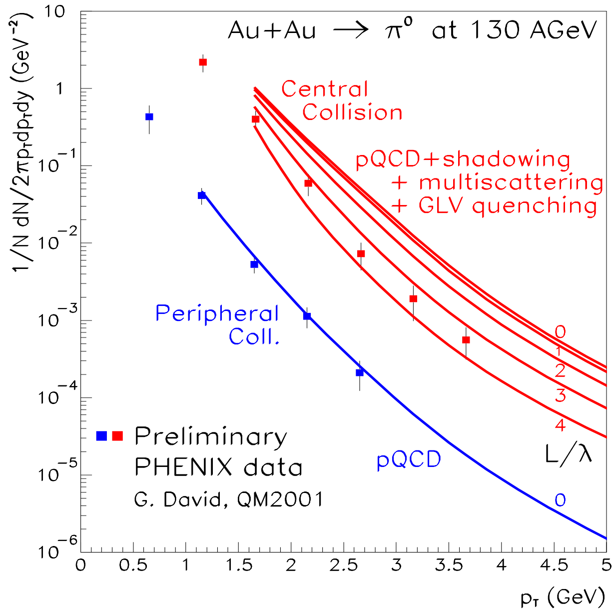
GLV jet-quenching in thin plasma approximation $L \sim \lambda_g$:

$$\Delta E_{GLV} \sim \frac{L^2\mu^2}{\lambda_g} \log \frac{E}{\mu}$$

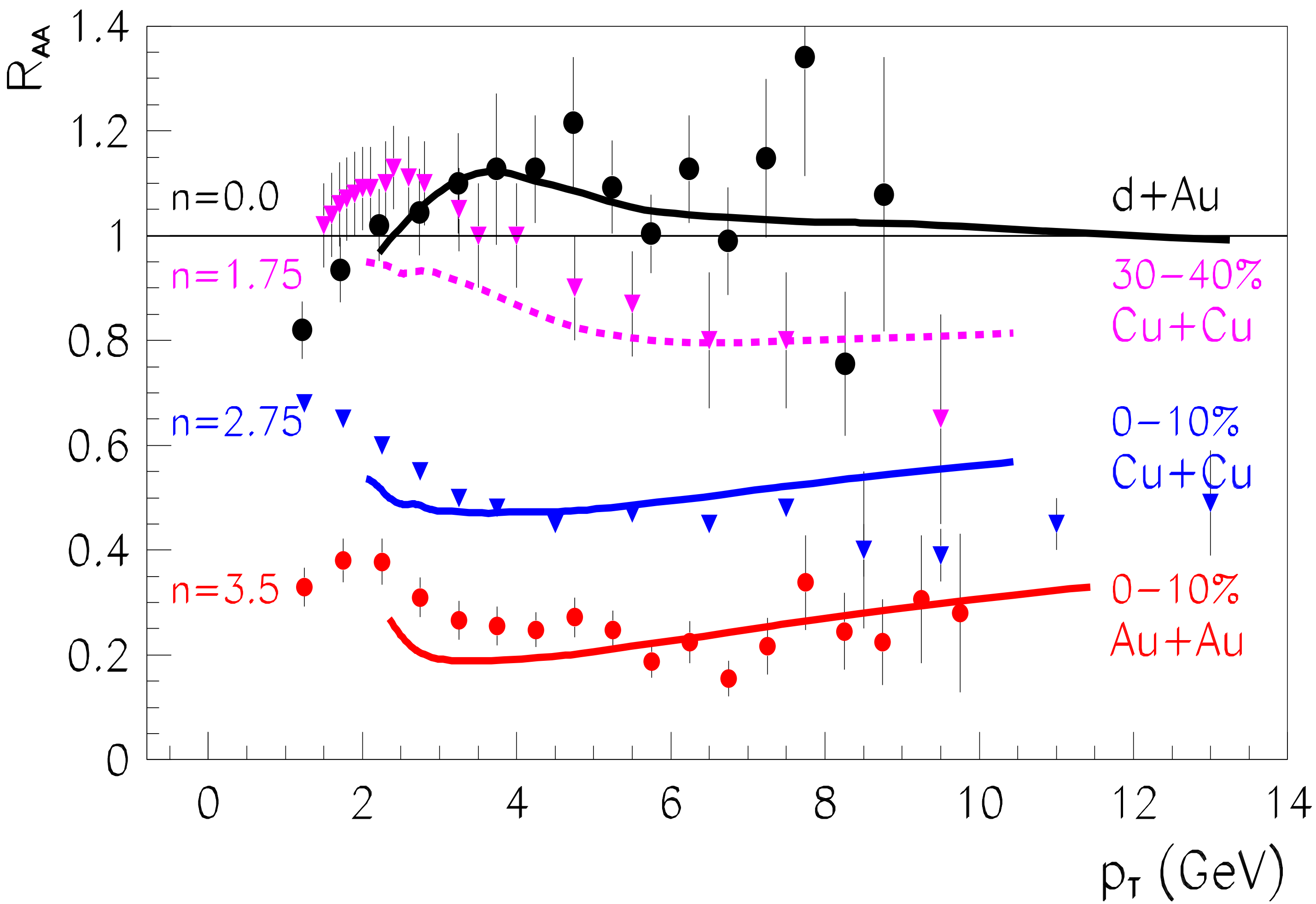
Energy loss of jets decreases the p_c momenta of c before fragmentation:

$$\frac{D_{\pi/c}(z_c, Q'^2)}{\pi z_c^2} \quad \rightarrow \quad \frac{z_c^*}{z_c} \frac{D_{\pi/c}(z_c^*, Q'^2)}{\pi z_c^2}, \quad \text{ahol} \quad z_c^* = \frac{z_c}{1 - \Delta E/p_c},$$





Calculated $R_{AA}^{\pi^0}$ for central $AuAu$ and $CuCu$ Collisions



In the smaller

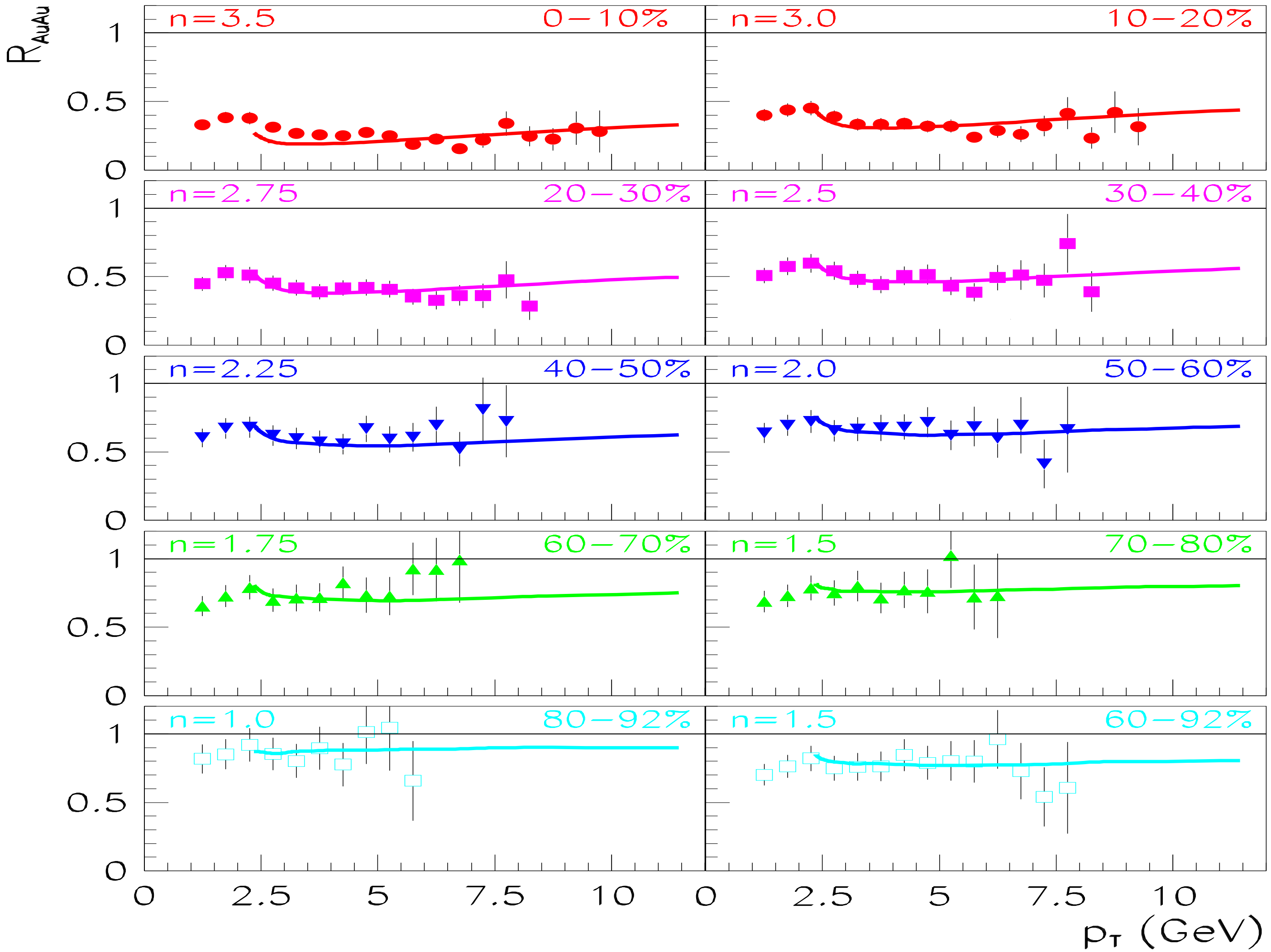
$CuCu$ system

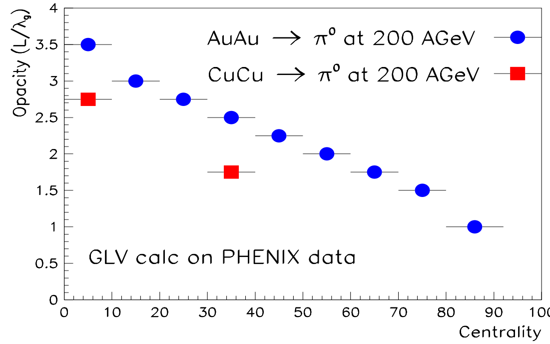
L/λ is less ~ 0.75

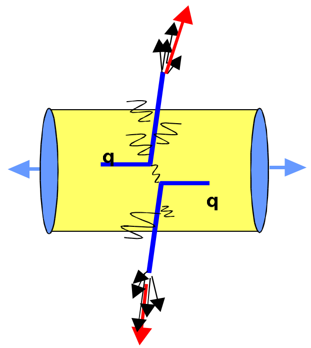
than in $AuAu$.

$AuAu$,dAu and central $CuCu$ data for π^0 by PHENIX, mid-central $CuCu$ by STAR

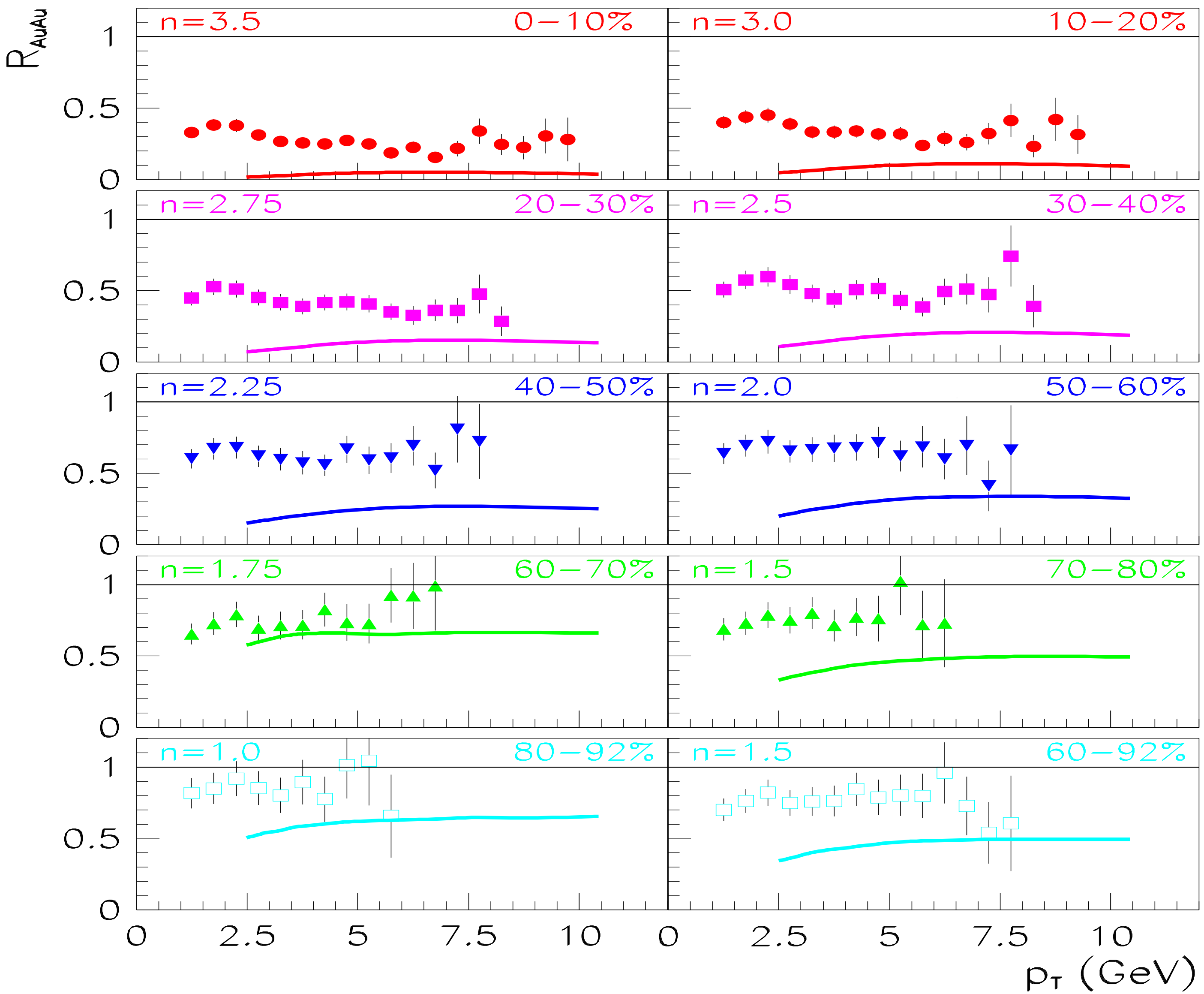
Jet-tomography in *AuAu* Collisions at PHENIX ($y = 0$)

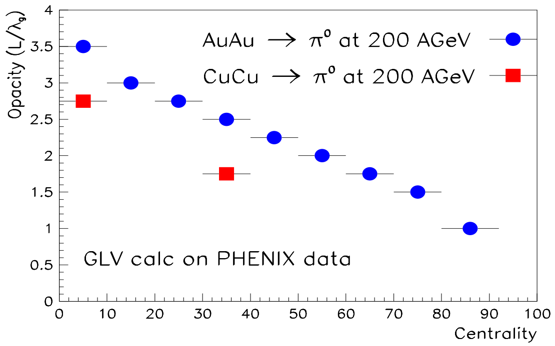


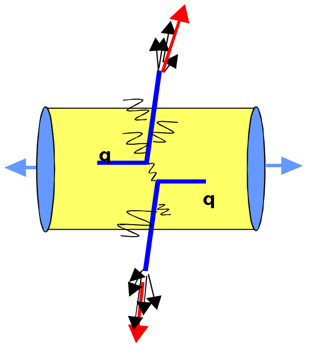




Jet-tomography in $AuAu$ Collisions at $(y \approx 2.2)$







Data: by PHENIX at $y = 0$ just for comparision

Comparing π^0 data in $AuAu$ at $\eta = 3.1$ and $y = 0$

$AuAu$ at BRAHMS $\eta = 3.1$ and PHENIX $y = 0$

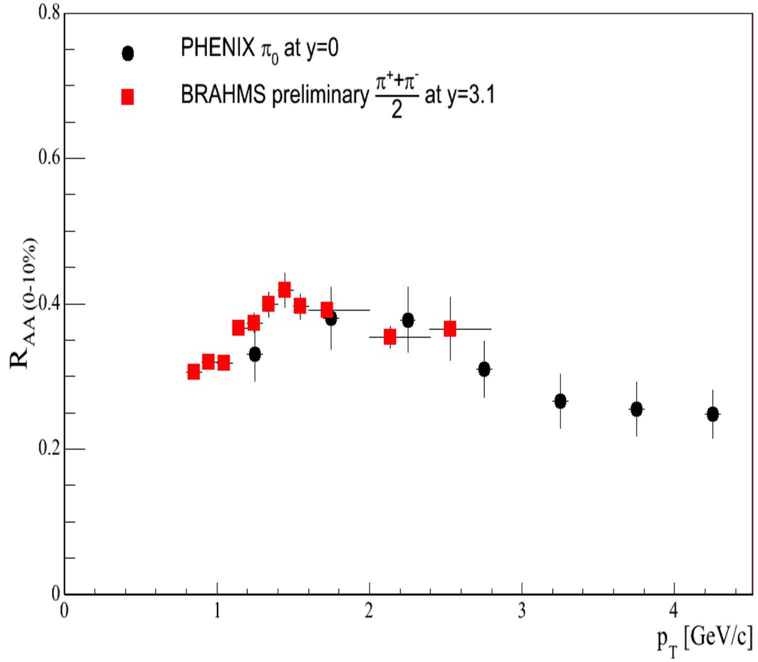
Larger shadowing in dAu at $\eta > 0$

Additional (exp.) information:

– $\boxed{R_{AuAu}(y=0) \approx R_{AuAu}(y>0)}$

– $\boxed{R_{CP} \geq R_{AA'}}$

– **See D. Rölich's talk**



$\Longrightarrow$ **Shadowing effect is stronger**

$\Longrightarrow$ **Travelling length getting smaller as going more forward**

$\Longrightarrow$ **Smaller L/λ can be extracted in the forward π production**

Summary – Outlook

Goal: Extracting the L/λ_g values in AA' in all direction

I. Description of the π^0 production in dAu collisions at all η

– Baseline: pp results for intrinsic-k_T, $\langle k_T^2 \rangle$

– HIJING shad. + Multiscat. + Sat. Galuber model

$\Longrightarrow$ RHIC data well reproduced (min. bias)

$\Longrightarrow$ NO suppression, NO need for extra shadowing

$\Longrightarrow$ For consistency we are waiting for $\eta < 0$ data

II. Results for π^0 in $AuAu$ and $CuCu$ at $\boxed{\eta = 0}$ and $\boxed{\eta > 0}$

– GLV jet-quenching with opacity parameter $n = L/\lambda$

$\Longrightarrow$ As we expected, $R_{AA}(\eta > 0)$ needs smaller L/λ.

... post conference data analysis ....

– Extracting opacity in the liu of new data

$\Longrightarrow$ At least, but not last: thank You for the nice exp. data