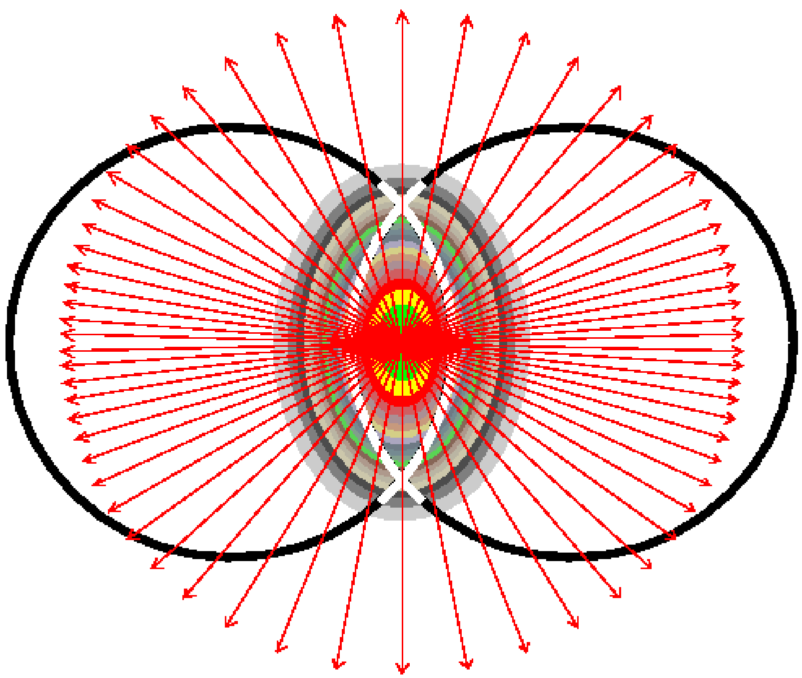
Measurement of Jet Properties in p+p and Au+Au



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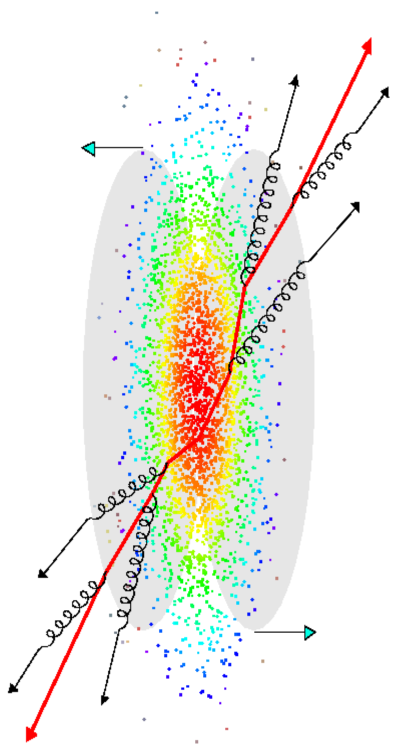
Hard scattering in Heavy Ion collisions

schematic view of jet production



Particle production @RHIC

— $dn_{ch}/d\eta\,|_{\eta=0} = 670$, $N_{total} \sim 7500$
  92% of (15,000) all quarks
  from vacuum !

Jets @RHIC:

— produced early $\tau<1$fm
— primarily from gluons
— 30-50% of particle production

Observed via:

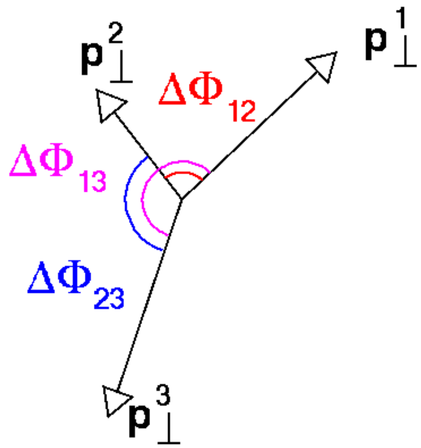
— fast leading particles
— azimuthal correlations

Scattered partons radiate energy in colored medium

→ suppression of high p_t particles R_{AA}

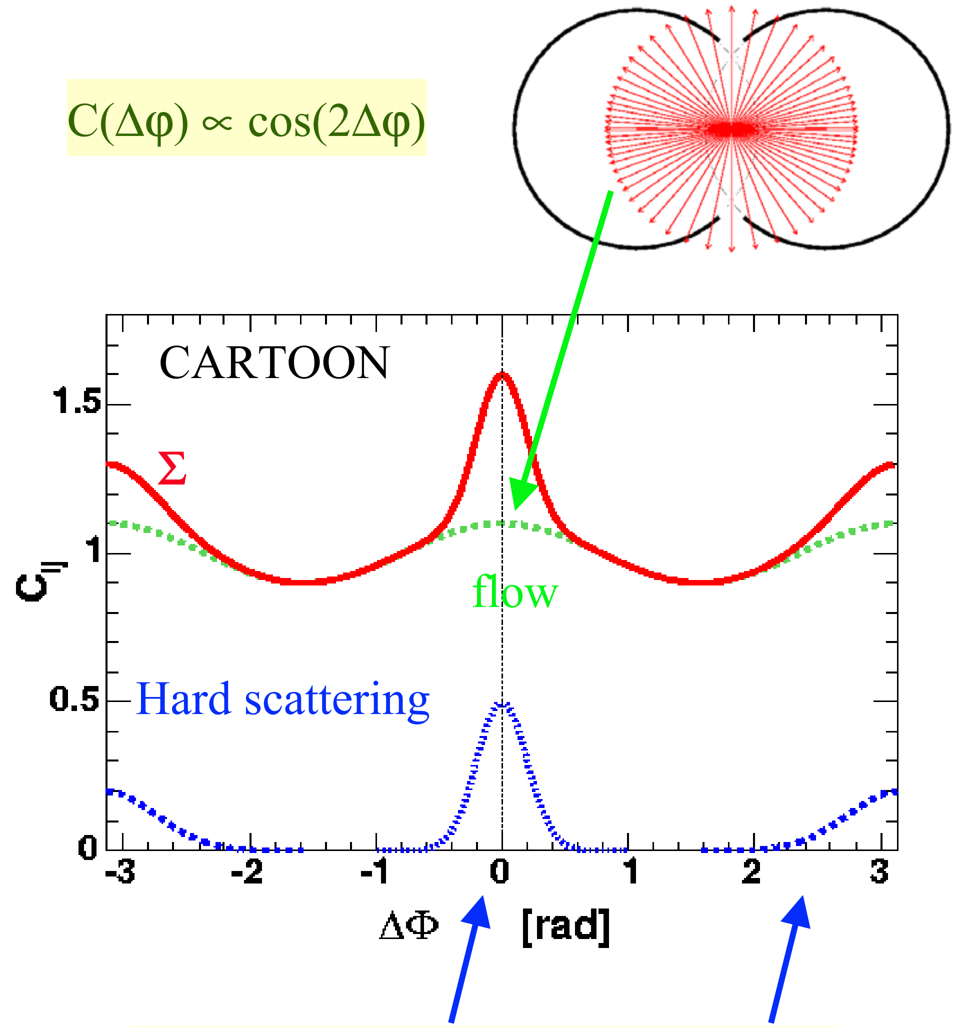
→ modification of azimuthal correlation between jet fragments $\langle k_T \rangle$

Two-Particles Correlation Function



$$C_{ij}(\Delta\phi) = \frac{dN_{ij}}{d\Delta\phi_{ij}}$$

$C(\Delta\varphi) \propto \cos(2\Delta\varphi)$



$C(\Delta\varphi) \propto \text{gauss}(\Delta\varphi=0)+\text{gauss}(\Delta\varphi=\pi)$

We observe a sum of

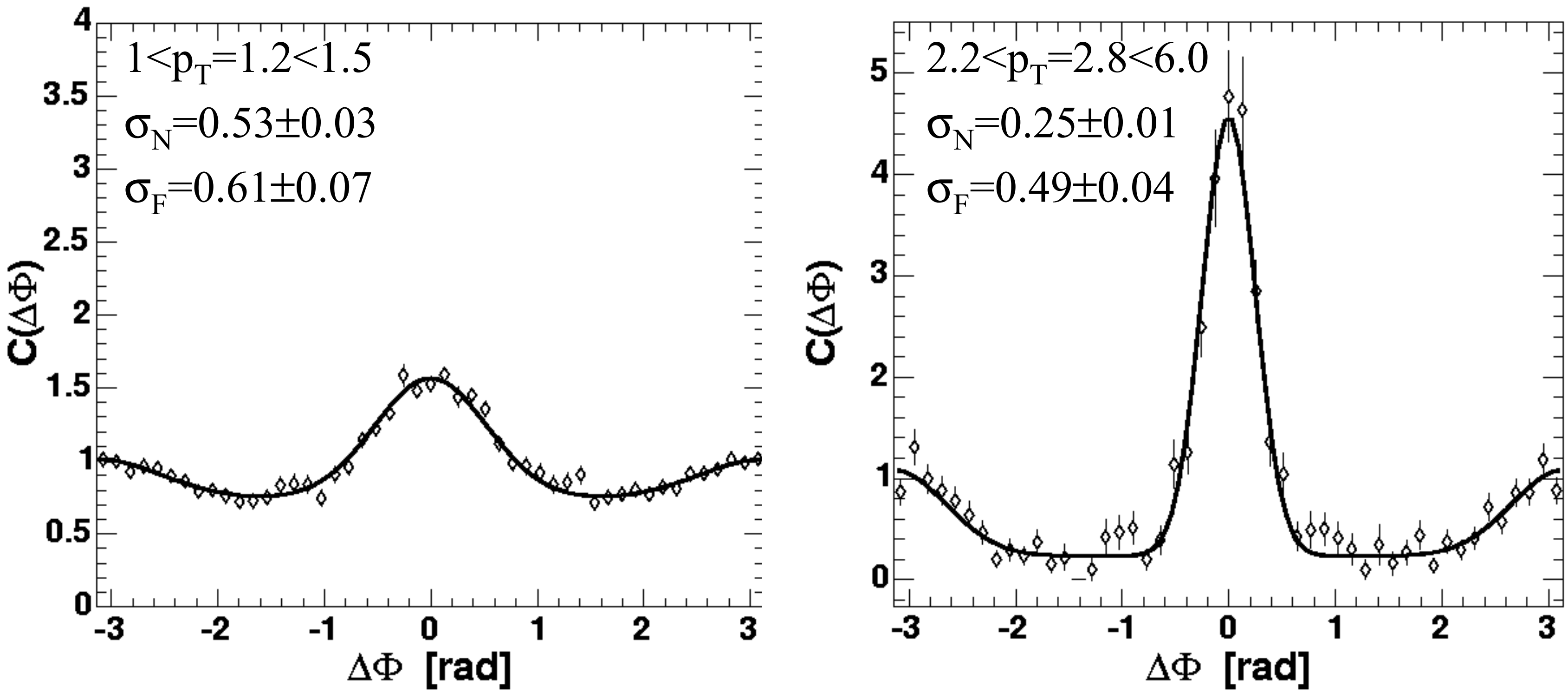
- Flow anisotropy (cos)
- Hard scattering peaks (gauss)

pp - two particle correlations

pp correlation function, even at intermediate p_T range, dominated by jet fragments.

The near angle peak width σ_N intra-jet correlations

The far angle peak width σ_F inter-jet correlations



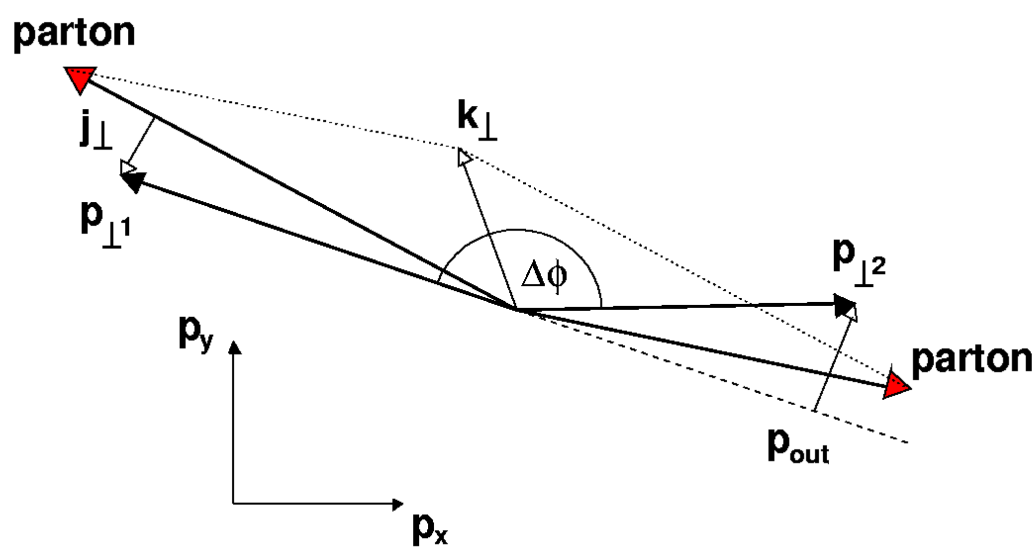
Fit = const + Gauss(0)+Gauss(±π)

jT average jet fragmentation transverse momentum

$$\langle k_\perp{}^2 \rangle = \langle k_\perp{}^2 \rangle_{\text{vac}} + \langle k_\perp{}^2 \rangle_{\text{IS nucl}} + \langle k_\perp{}^2 \rangle_{\text{FS nucl}}$$

$\langle |k_{\perp y}| \rangle$ = the mean effective transverse momentum of the two colliding partons in the plane perp. to the beam axis.

$\langle |j_{\perp y}| \rangle$ = the mean transverse momentum of the hadron with respect to the jet axis in the plane perpendicular to the beam axis.

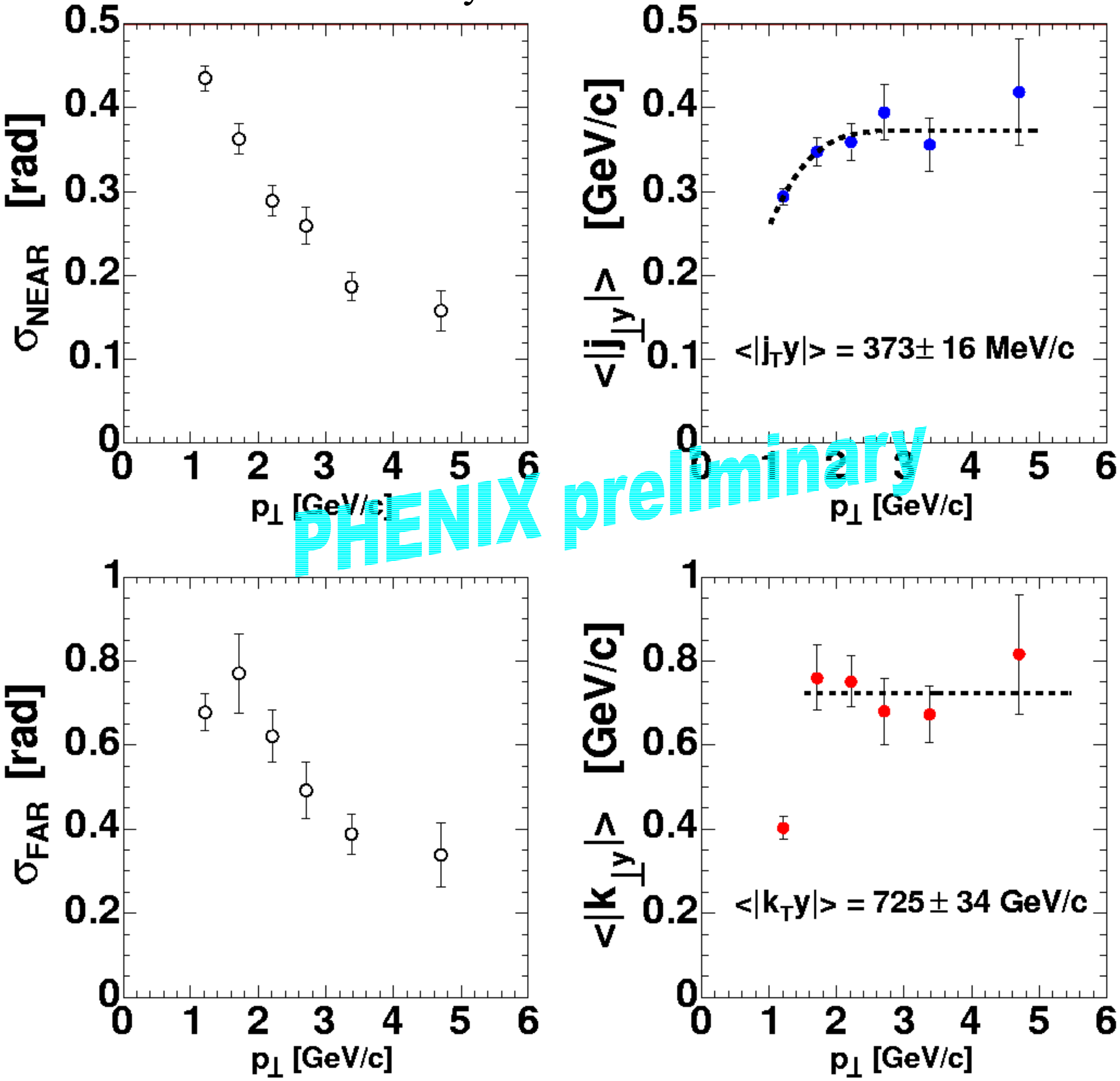


$$\langle |j_{\perp y}| \rangle = \frac{1}{\sqrt{\pi}} \sqrt{\langle j_\perp^2 \rangle} = \langle p_\perp \rangle \sin \frac{\sigma_N}{\sqrt{\pi}}$$

$$\langle |k_{\perp y}| \rangle = \frac{1}{\sqrt{\pi}} \sqrt{\langle k_\perp^2 \rangle} = \langle p_\perp \rangle \cos\left(\frac{\sigma_N}{\sqrt{\pi}}\right) \sqrt{\frac{1}{2}\tan^2\left(\sqrt{\frac{2}{\pi}}\sigma_F\right) - \tan^2\left(\frac{\sigma_N}{\sqrt{\pi}}\right)}$$

charged hadrons correlation in pp $\sqrt{s}$ = 200GeV

No systematic errors shown



At low p_T<2GeV the near angle peak width and $\langle|j_{Ty}|\rangle$ is reduced by "Seagull effect"

see. e.g **Phys.Lett.B320:411-416,1994**

pp reference

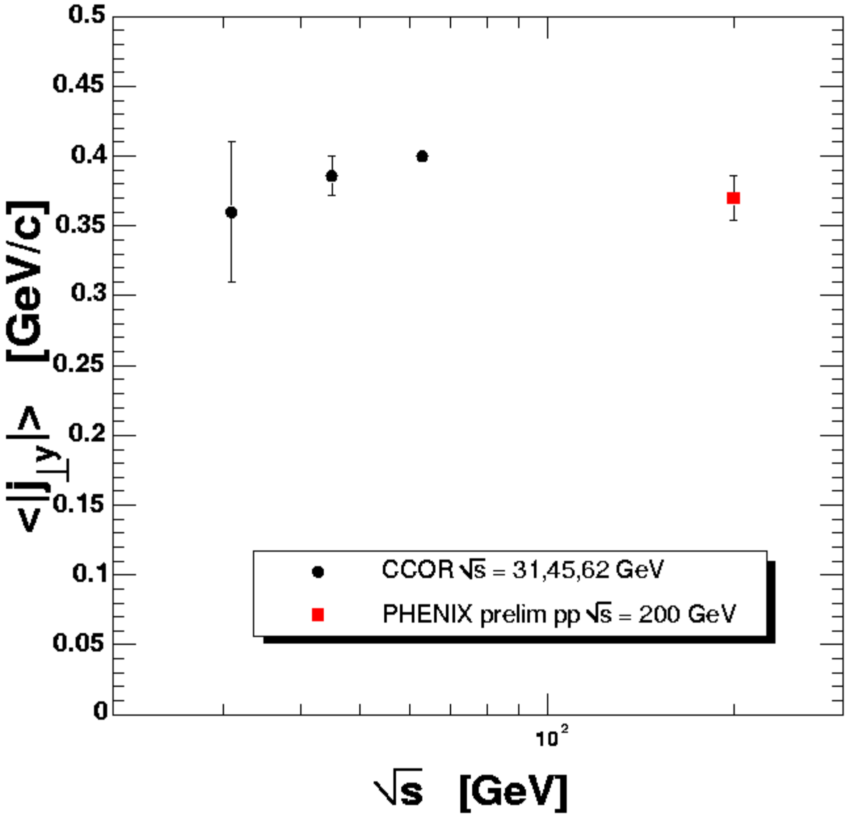
PHENIX preliminary

$\langle|j_{Ty}|\rangle$ = 373±16 MeV/c

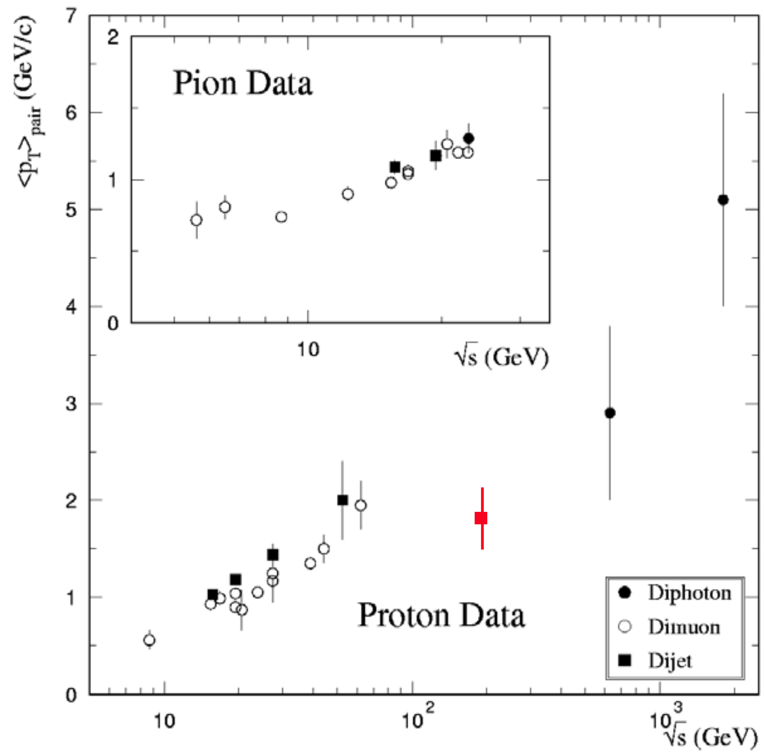
$\langle|k_{Ty}|\rangle$ = 725±34 MeV/c

P0 fit to data above 1.5 GeV/c

Comparison with $p\bar{p}$



CCOR Collaboration
Phys. Lett. 97B(1980)163

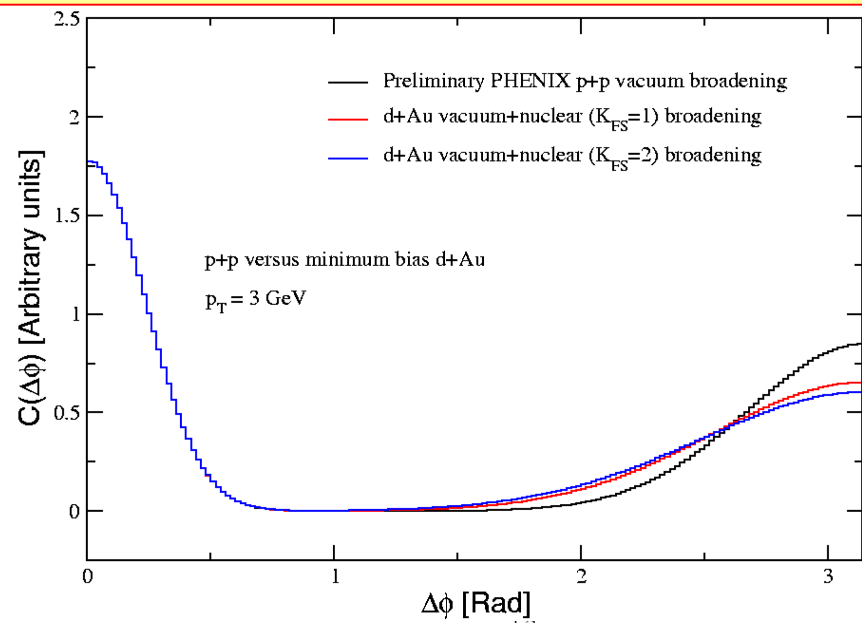


Compilation of $\langle p_\perp \rangle_{pair}$ results:
Apanasevich et al
Phys. Rev. D59(1999)074007

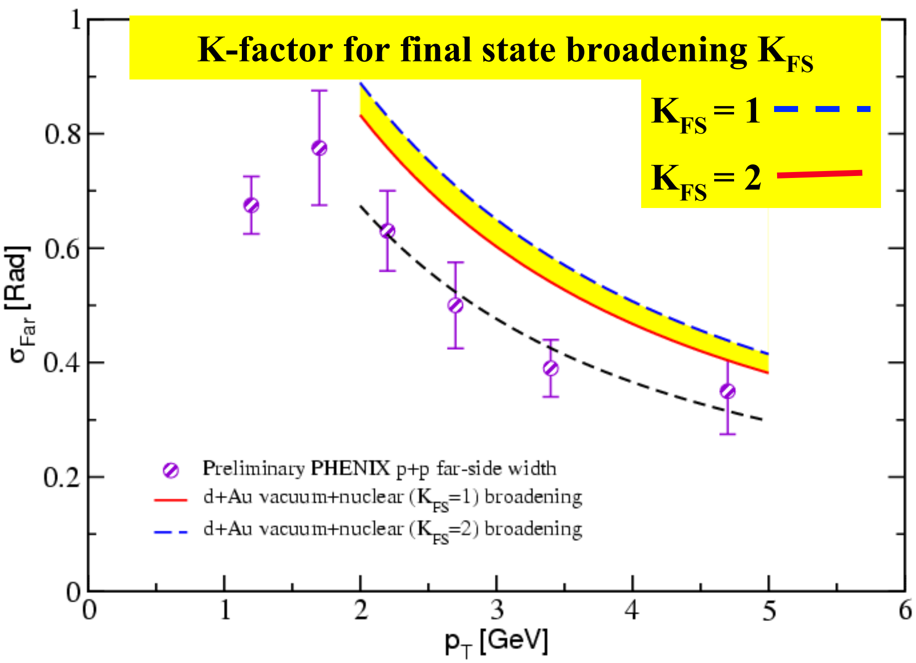
$$\sqrt{\left\langle \mathbf{p}_\perp^{\;2} \right\rangle_{pair}} = \sqrt{2}\sqrt{\left\langle \mathbf{k}_\perp^{\;2} \right\rangle} = \sqrt{2\pi}\left\langle \left| \mathbf{k}_{\perp y} \right| \right\rangle$$

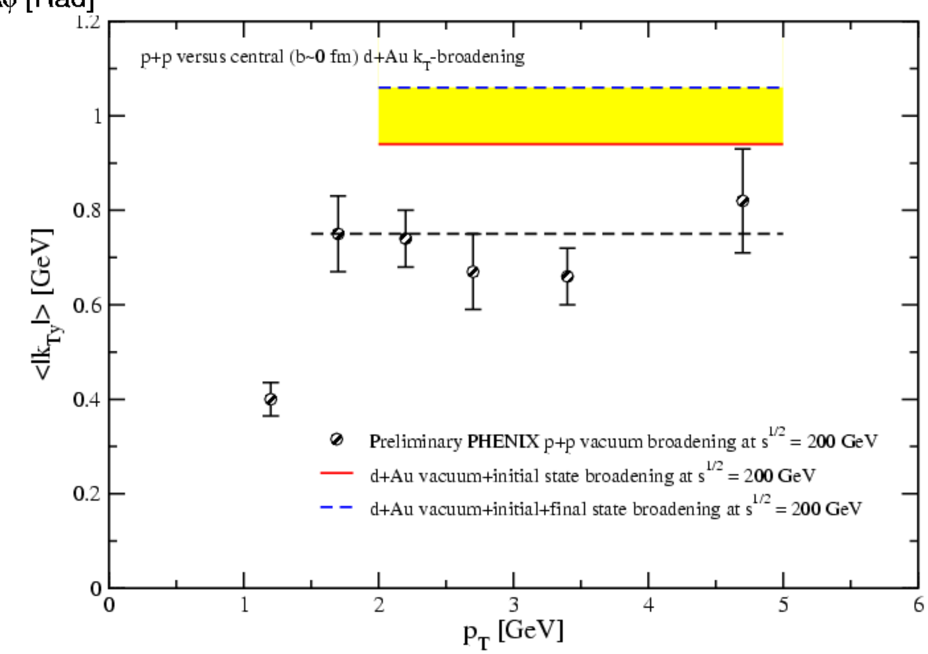
Initial state broadening - previous speaker

If the fragmentation occurs only outside QCD medium - σ_N remain unchanged by induced gluon radiation



Both initial and final state interactions lead to enlargement of σ_F observed as $\langle k_T \rangle$ -broadening

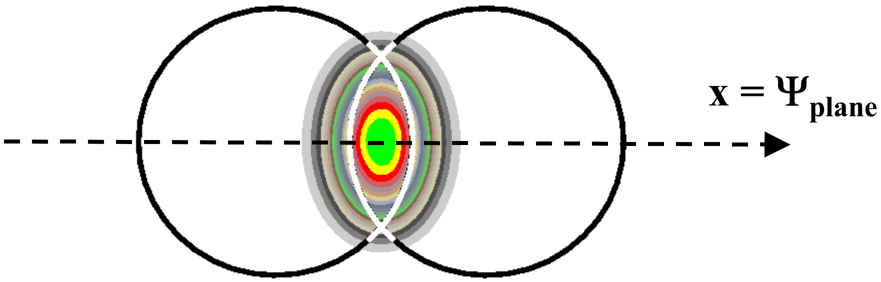


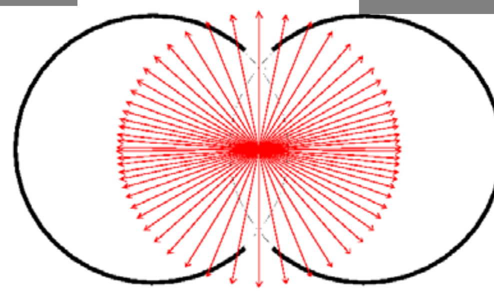


In AA some algebra of v2+jets needed

In AuAu collisions the situation is more complicated by presence of “global” correlations induced by nuclear geometry - called elliptic flow.

multiple scattering → larger pressure gradient in plane → more particles emitted in plane





spatial asymmetry
eccentricity $\varepsilon = \frac{\langle y^2 - x^2 \rangle}{\langle y^2 + x^2 \rangle}$

momentum asymmetry
elliptic flow - v2 $v_2 = \frac{\langle p_x^2 - p_y^2 \rangle}{\langle p_x^2 + p_y^2 \rangle}$

$$C(\Delta\varphi) = \frac{d^2N}{d\Delta\varphi} = \int_{-\pi}^{\pi} \frac{dN}{d\varphi}\frac{dN}{d(\varphi+\Delta\varphi)}d\varphi \qquad \frac{dN^{FLOW}}{d\varphi} \propto (1 + 2v_2\cos(2(\varphi - \Psi))) \oplus \frac{dN^{JET}}{d\varphi} \propto Gauss(\varphi, \sigma)$$

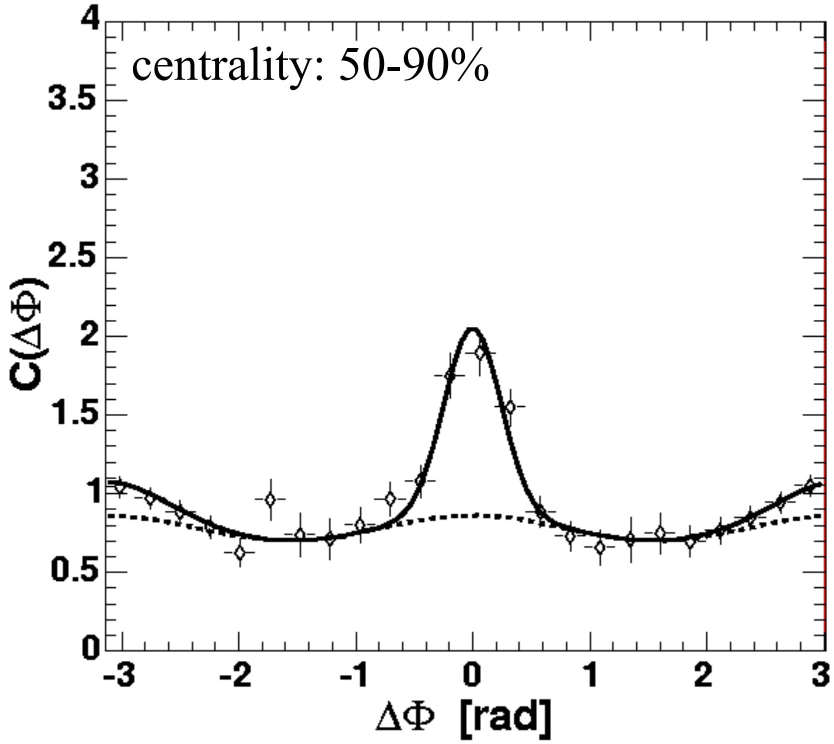
$$C(\Delta\varphi) \propto (1 + 2v^2{}_2\cos(2\Delta\varphi)) + Gauss(\Delta\varphi, \sqrt{2}\sigma) + Crossterm(\varphi_{jet} - \Psi)$$

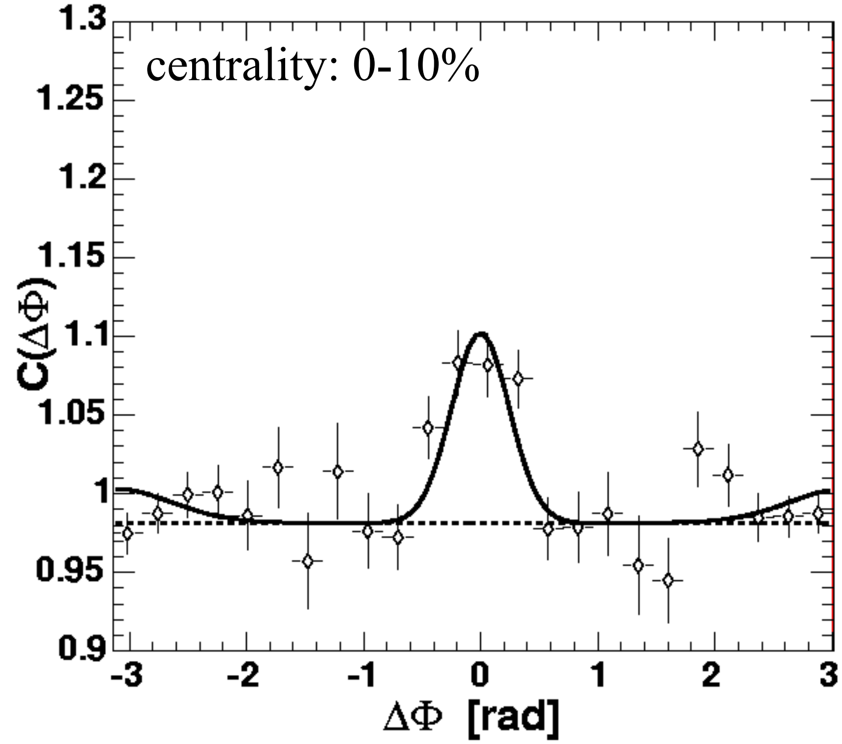
Flat if no correlation between Ψ_{plane} **and jet thrust**

AuAu charge hadrons correlation 2.2<pT<5.0 GeV/c

$$\text{Fit} \propto \underbrace{(1+2\,v_2^2\cos(2\Delta\varphi))}_{\text{AuAu}} + \text{const} \otimes \underbrace{[\text{Gauss}(\Delta\varphi=0,\sigma_N)+Y_F/Y_N\,\text{Gauss}(\Delta\varphi=\pm\pi,\sigma_F)]}_{\text{pp}} + \text{const}$$

v_2^2 determined from the fit σ_N, σ_F, $Y_F = \int \text{gauss}(0)$ / $Y_N = \int \text{gauss}(\pm\pi)$ fixed values taken from pp



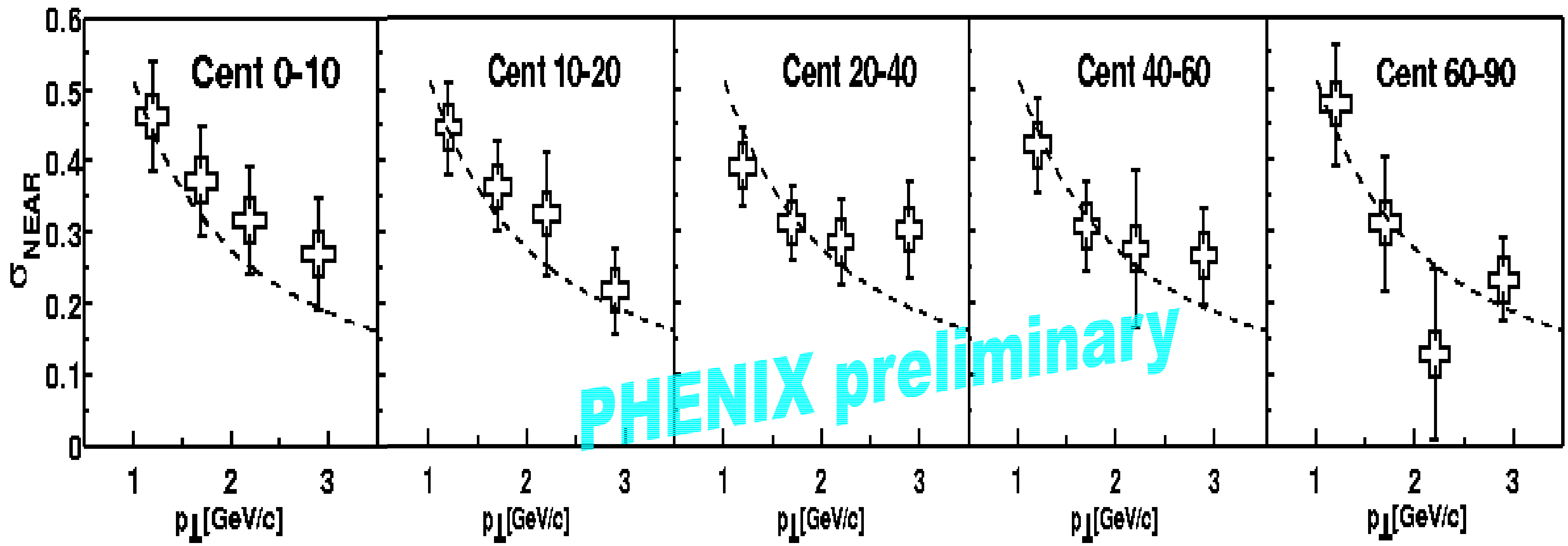


Flow and jet part can be clearly separated.

Fit forces $v_2 \rightarrow 0$, it indicates the lack of back-to-back correlation

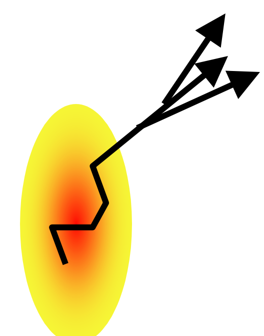
Near angle peak width in AuAu

Let us do the same fit, but σ_N fitted as well.



The dashed line corresponds to the $\langle|j_{Ty}|\rangle$ = 400 MeV/c

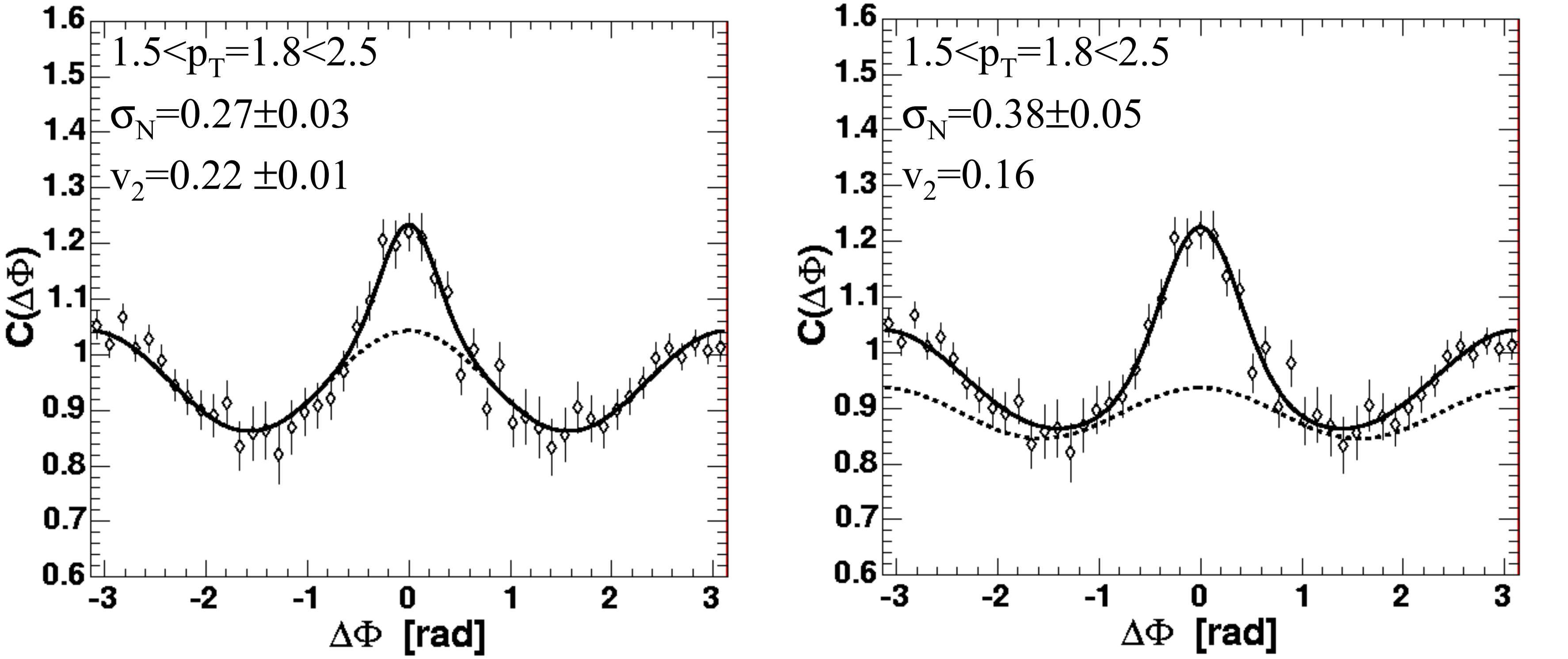
There is no significant broadening observed. Could be explained by jet fragmentation outside the QCD medium.



Far angle peak width in AuAu, v2-reduction

AuAu $\sqrt{s}$ = 200GeV centrality 50-90%

(this is only for illustration, not a physics result on v_2 or σ_N)



Fit ∝ $(1+2v^2_2\cos(2\Delta\varphi))$ + Gauss(0)

Omitting the back-to-back part leads to v^2_2 overestimation and consequent reduction of σ_N

Fit ∝ $(1+2v^2_2\cos(2\Delta\varphi))$ + Gauss(0)+Gauss(±π)

Reduced v^2_2 is fixed

In this case the σ_N has the same value as in pp and back-to-back part can be subtracted.

summary

- pp induced collisions at $\sqrt{s}$ = 200GeV:
  - From the two particle correlation function the values of mean jet transverse momentum $\langle|j_{Ty}|\rangle$ and net transverse partonic momentum $\langle|k_{Ty}|\rangle$ were deduced and found to be in good agreement with previous experiments.

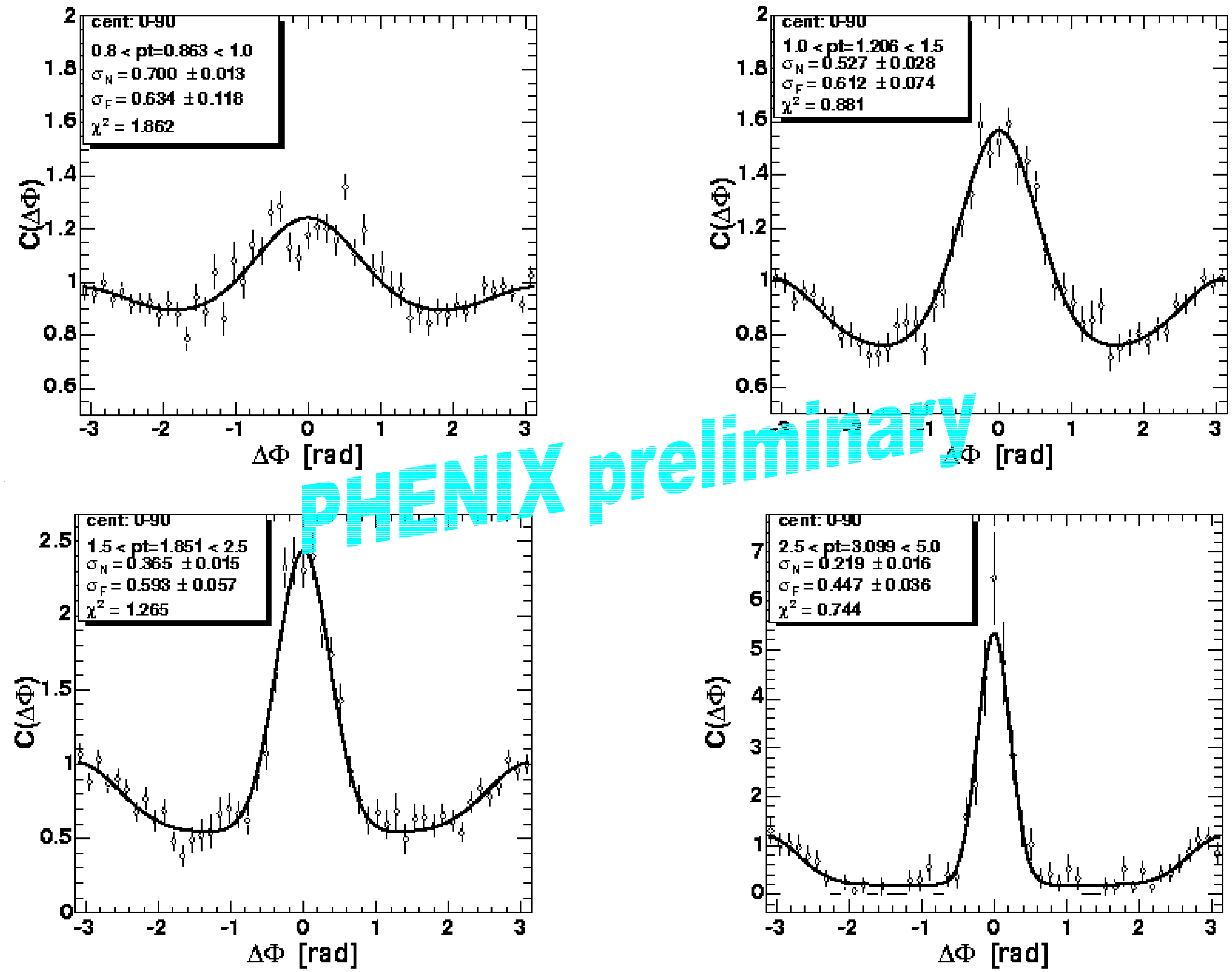
- AuAu induced collisions at $\sqrt{s}$ = 200GeV:
  - no significant $\langle|j_{Ty}|\rangle$ broadening observed - jet fragmentation entirely outside the QCD medium?
  - Back-to-back correlation clearly observed in AuAu preripheral events allowing to measure $\langle|k_{Ty}|\rangle$ - work in progress.

- Outlook there is a lot of questions one can address
  - Back-to-back jets disappearance in central AuAu events - $\langle|k_{Ty}|\rangle$ broadening
  - $\langle|j_{Ty}|\rangle$ broadening at lower p_T range
  - Cronin effect in dAu
  - pQCD resummation of soft collinear radiation (hep-ph/0305148)

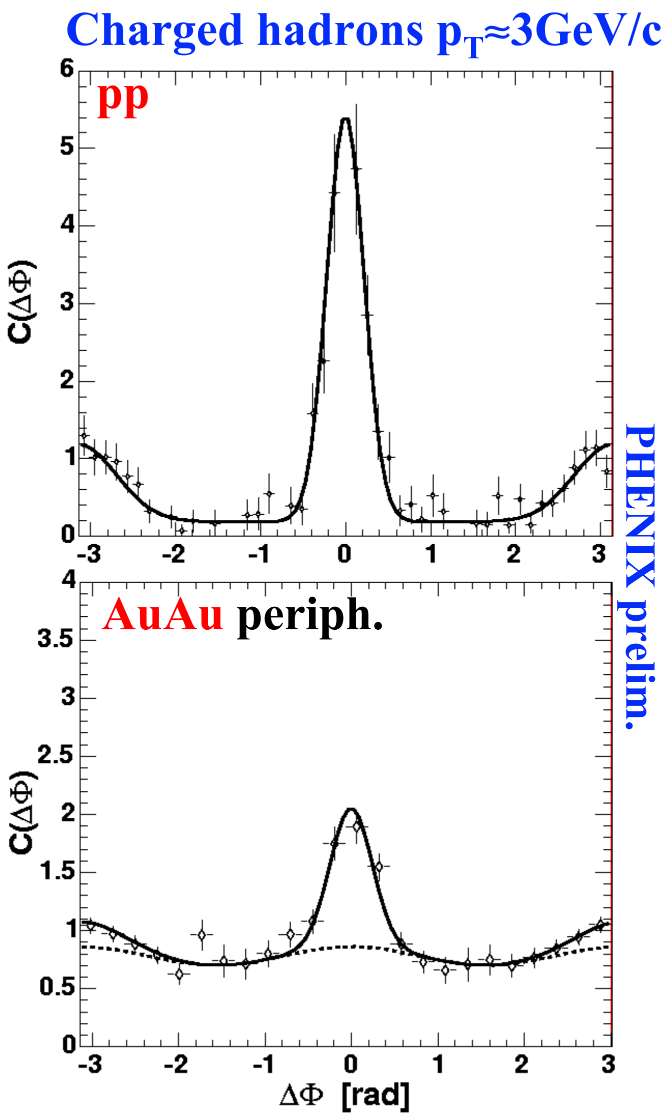
backup slides

pp correl. Function for direct comparison with AuAu

Fit = const + Gauss(0)+Gauss(±π)



pp



Quenching of high-p_T partons in AuAu coll -> modification of azimuthal correlation between jet fragments - $\langle j_T \rangle$, $\langle k_T \rangle$ - broadening.