Two-particle correlations at high transverse momenta in p-p and Au-Au collisions at RHIC

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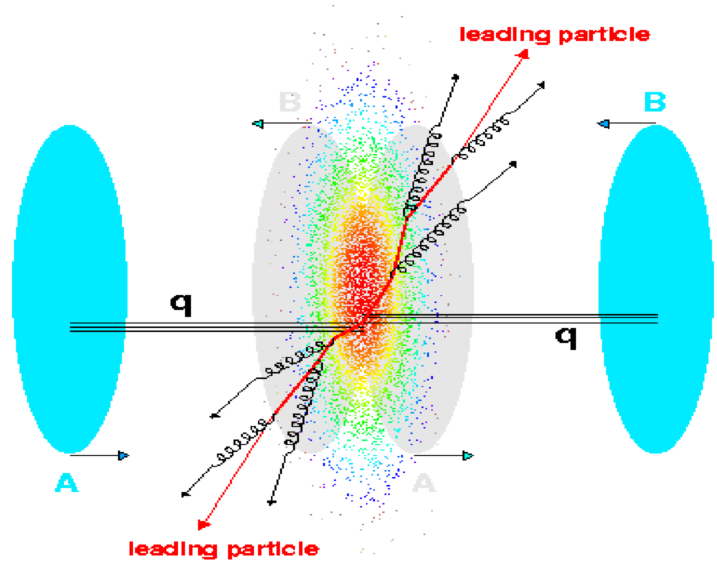
Outline

- Two-particle azimuthal correlations as a method to study jets of hadrons from partonic hard scattering and fragmentation
- Extraction of the near-angle and back-to-back widths
- Jet shape parameters: jet fragmentation transverse momentum $\langle |j_{\perp y}| \rangle$ and parton transverse momentum $\langle |k_{\perp y}| \rangle$
- Jet shape in pp data:
  - $\langle |j_{\perp y}| \rangle$ and $\langle |k_{\perp y}| \rangle$ measurements
  - comparison with previous measurements
- Jet shape in AuAu data:
  - centrality and $p_{\perp}$ dependence of relative yield
  - $j_{\perp}$-scaling of near-angle width

Main sources of two-particle correlations

JETS



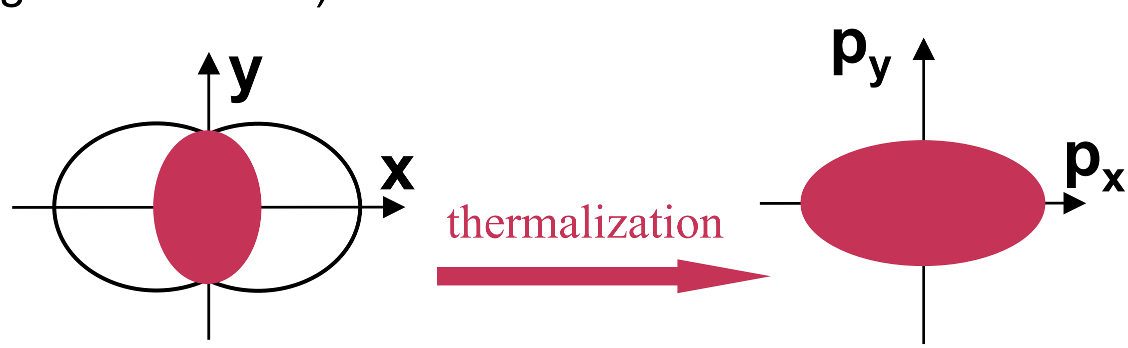
Hard scatterings:

- high Q^2 transfer - small α_s (pQCD)
- early in collision - probe early stages

Produce jets of hadrons by fragmentation:

- near-angle and back-to-back azimuthal correlations
- broadened by interaction with the hot QCD medium via dE/dx (gluon radiation)

FLOW



$$\varepsilon = \frac{\langle y^2 - x^2 \rangle}{\langle y^2 + x^2 \rangle} \qquad v_2 = \frac{\langle p_x^2 - p_y^2 \rangle}{\langle p_x^2 + p_y^2 \rangle}$$

Spatial azimuthal anisotropy in the initial state → pressure gradients → elliptic flow momentum pattern in the final state

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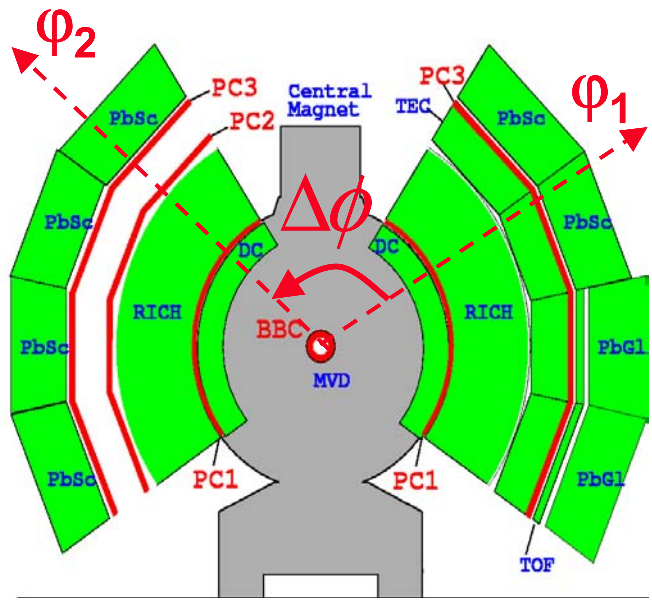
Extraction of the widths from the correlation function

Fixed-$p_\perp$ correlation function (mixed event technique):

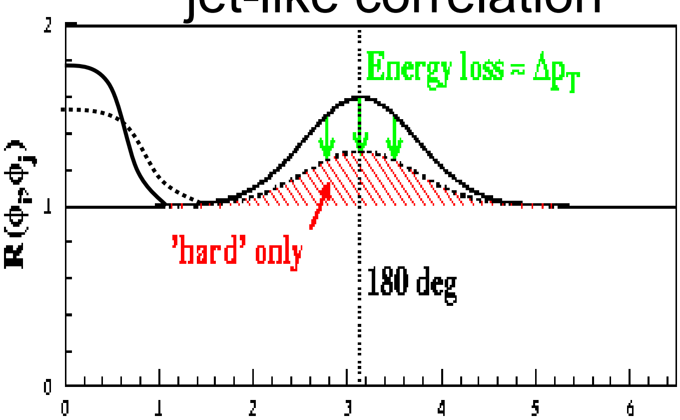
$$C(\Delta\phi) = \frac{N_{real}(\Delta\phi)}{N_{mixed\ events}(\Delta\phi)} \quad (3)$$

$$\Delta\varphi \equiv |\varphi_1 - \varphi_2|$$

$$\langle p_{\perp 1}\rangle = \langle p_{\perp 2}\rangle$$

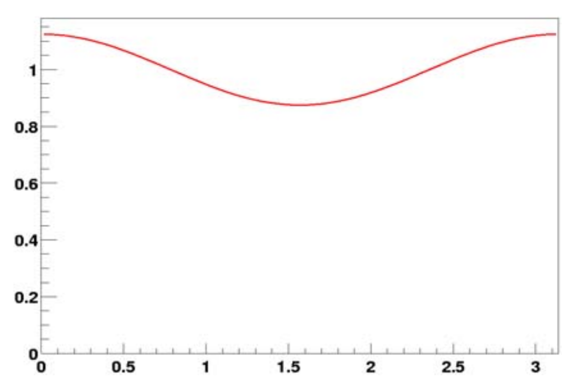


jet-like correlation



Δφ [rad]

flow-like correlation



Δφ [rad]

Run2 p-p: 120M min-bias events and 50M events triggered on energy deposited in the Electromagnetic Calorimeter. The $h^\pm$-$h^\pm$ correlations were fit with:

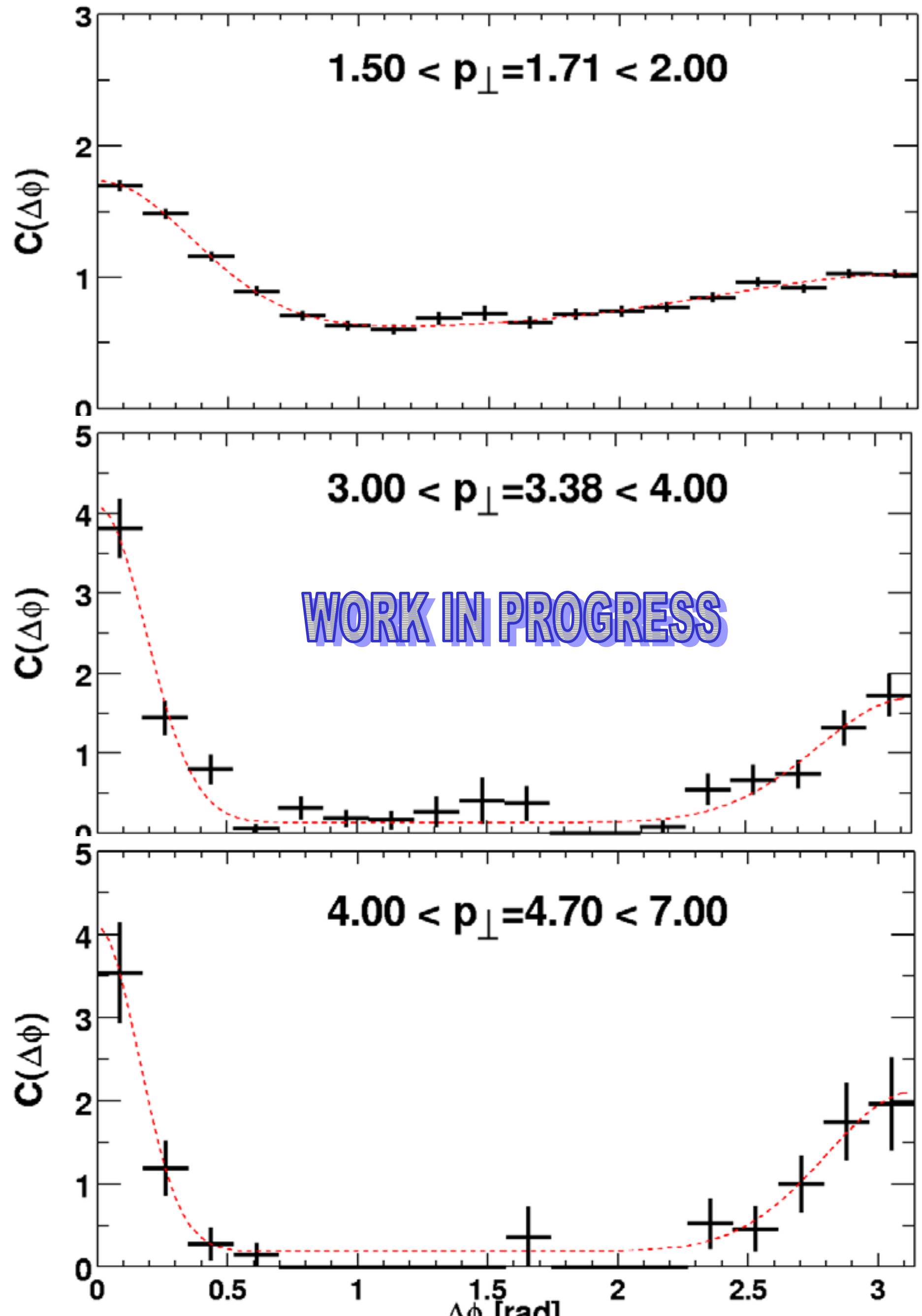
$$N + Gaus\ (\Delta\varphi = 0, \sigma_N) + Gaus\ (\Delta\varphi = \pi, \sigma_F)$$

Run2 Au-Au: 30M min-bias events. The $h^\pm$-$h^\pm$ correlations were fit with:

$$N\left[1 + 2v_2^2\cos(2\Delta\varphi)\right] + Gaus\ (\Delta\varphi = 0, \sigma_N)$$

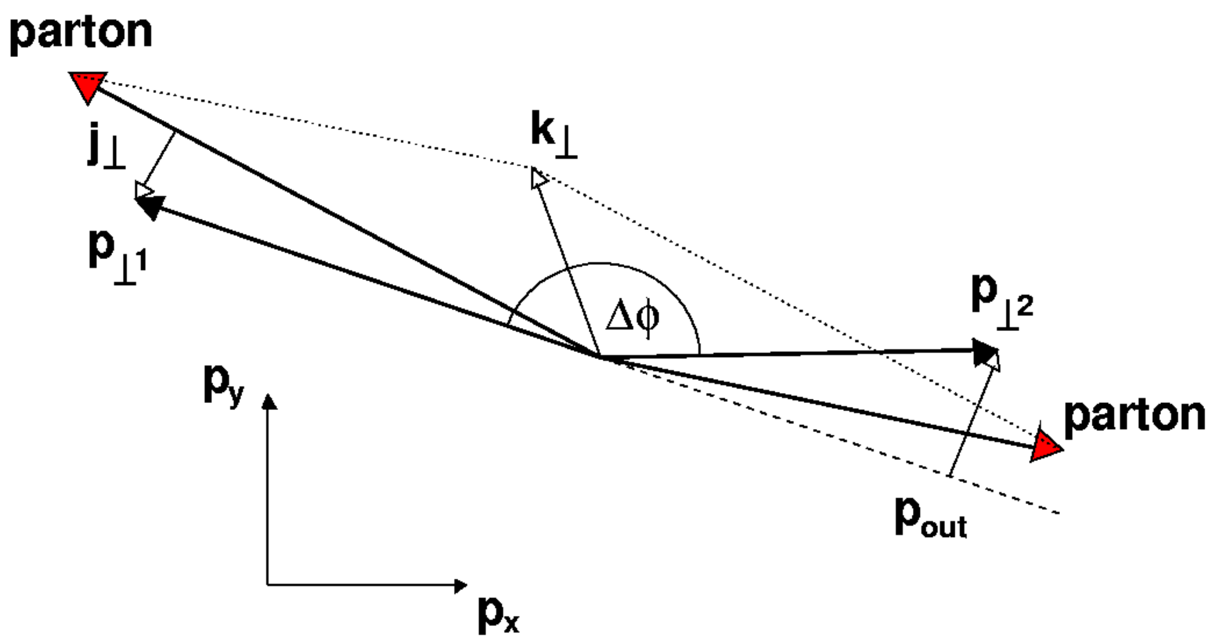
Correlation Functions in pp collisions

Fixed-$p_\perp$ (both hadrons in the same $p_\perp$ bin) correlation functions:



Which are fitted to extract the near-angle and back-to-back widths…

Jet Shape Parameters



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

$<|k_{\perp y}|>$ = the mean effective transverse momentum of the two colliding partons in the plane perpendicular to the beam axis

In the small angle limit ($\sigma_N \approx 0$ and $\sigma_F \approx 0$) they are related to the near-angle and back-to-back widths by the equations:

$$\sqrt{\langle j_\perp^2 \rangle} \approx \langle p_\perp \rangle \sigma_N \quad \sqrt{\langle k_\perp^2 \rangle} \approx \langle p_\perp \rangle \sqrt{\sigma_F^2 - \sigma_N^2}$$

The exact equations are:

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

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

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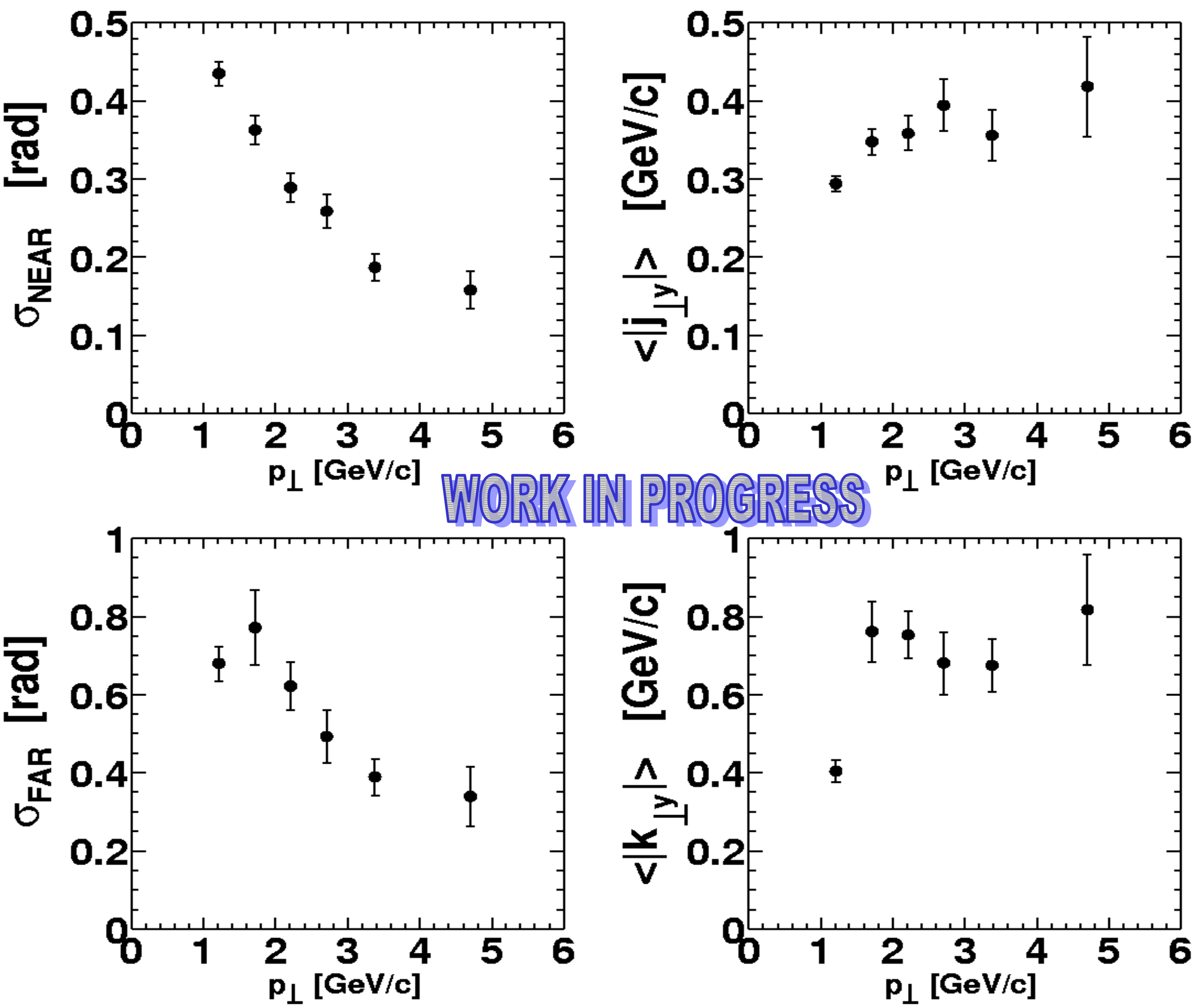
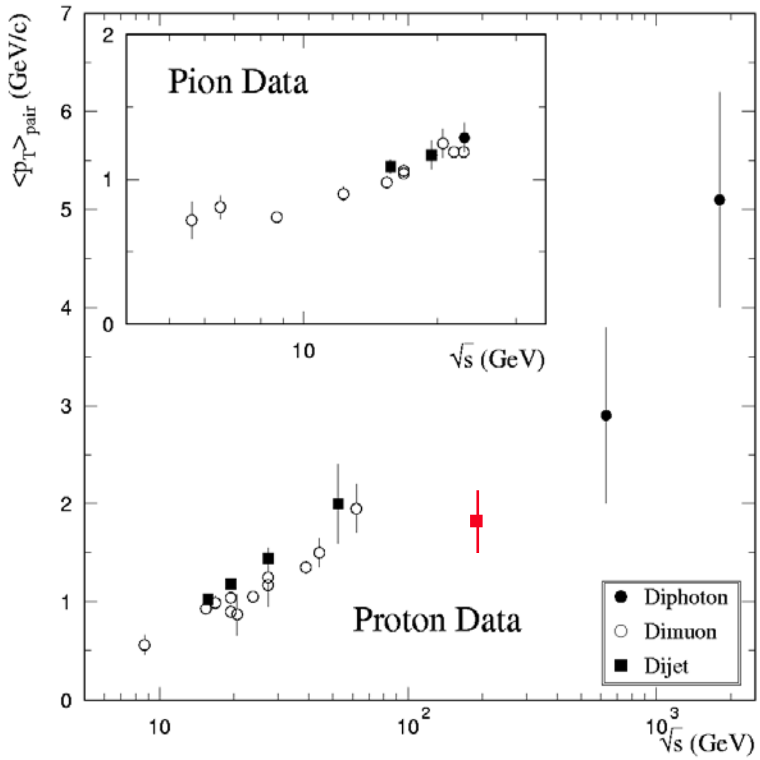
Jet Shape Parameters in pp collisions

Summary of the p-p results (no syst. errors yet):



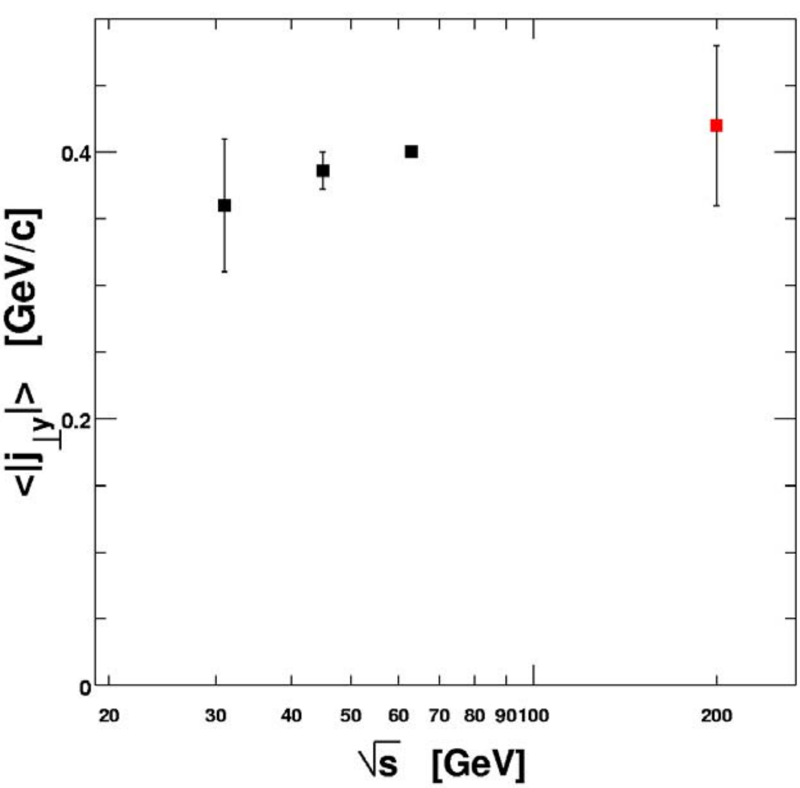
pp - Comparison with other measurements



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

$$\langle p_\perp \rangle_{pair} \approx \sqrt{2}\langle k_\perp \rangle = \frac{\pi}{\sqrt{2}}\langle |k_{\perp y}| \rangle$$

Red point corresponds to the highest p_T value of $<|k_{Ty}|>$ (4.7GeV/c)



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

$<| j_{Ty}|>$ = 400 MeV/c, independent of $p_{\perp \mathbf{Trig}}$ for $\sqrt{s} = 31, 45, 63\ GeV$

Red point corresponds to the highest p_T value of $<|j_{Ty}|>$ (4.7GeV/c)

pp Jet Shapes –
Summary and Conclusions

- Two-particle azimuthal correlations have been used to extract the *near-angle* and *back-to-back widths*

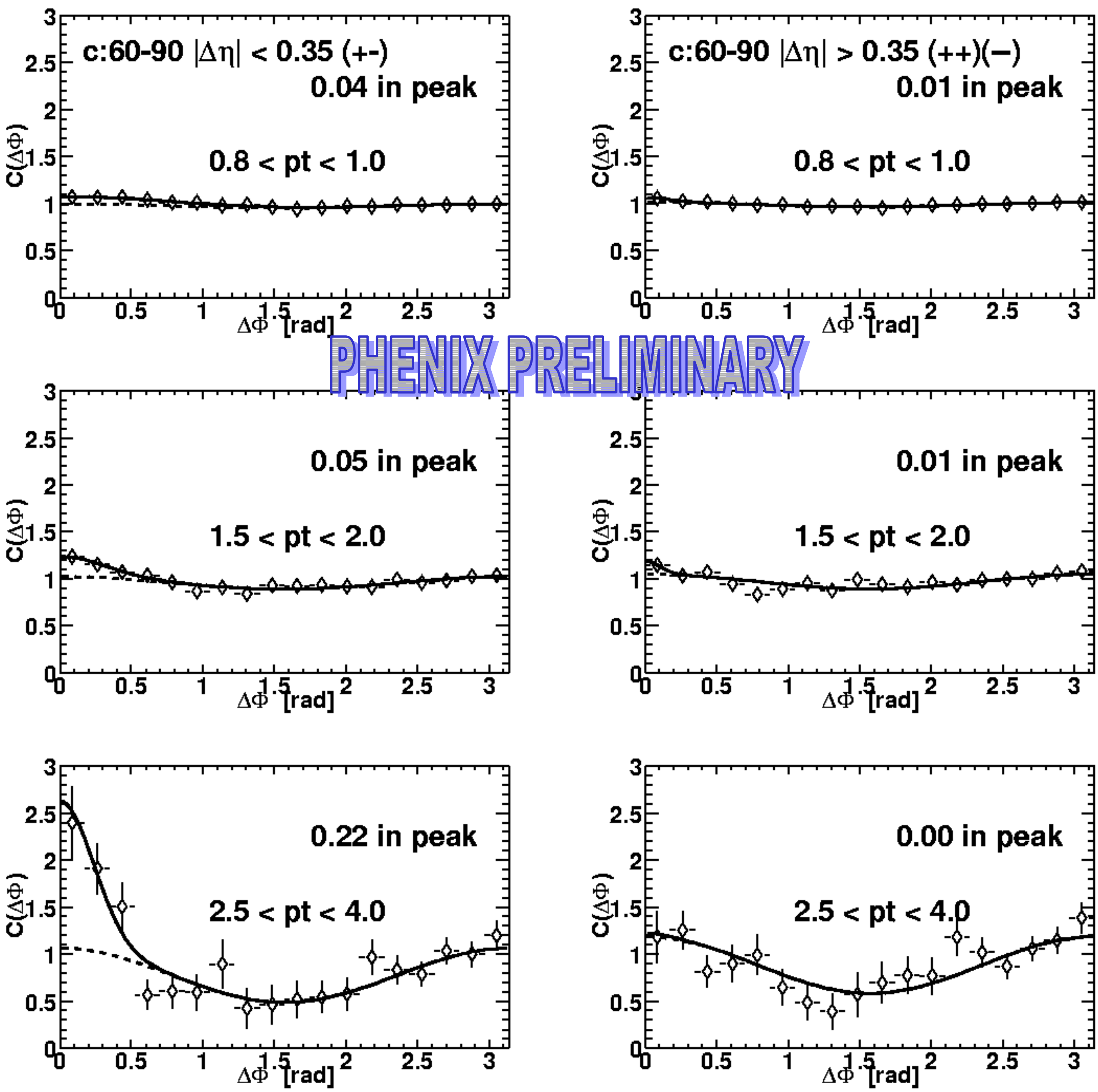
- The jet shape parameters $<|j_{Ty}|>$ and $<|k_{Ty}|>$ have been derived from these widths

- Comparisons with existing data show that
  - j_T-scaling in pp collisions is also observed at RHIC energy (with $<|j_{TY}|>$=400MeV)
  - $<|k_{TY}|>$ follows the general trend of previous measurements

AuAu - Peripheral Fixed $p_\perp$ Correlation Function

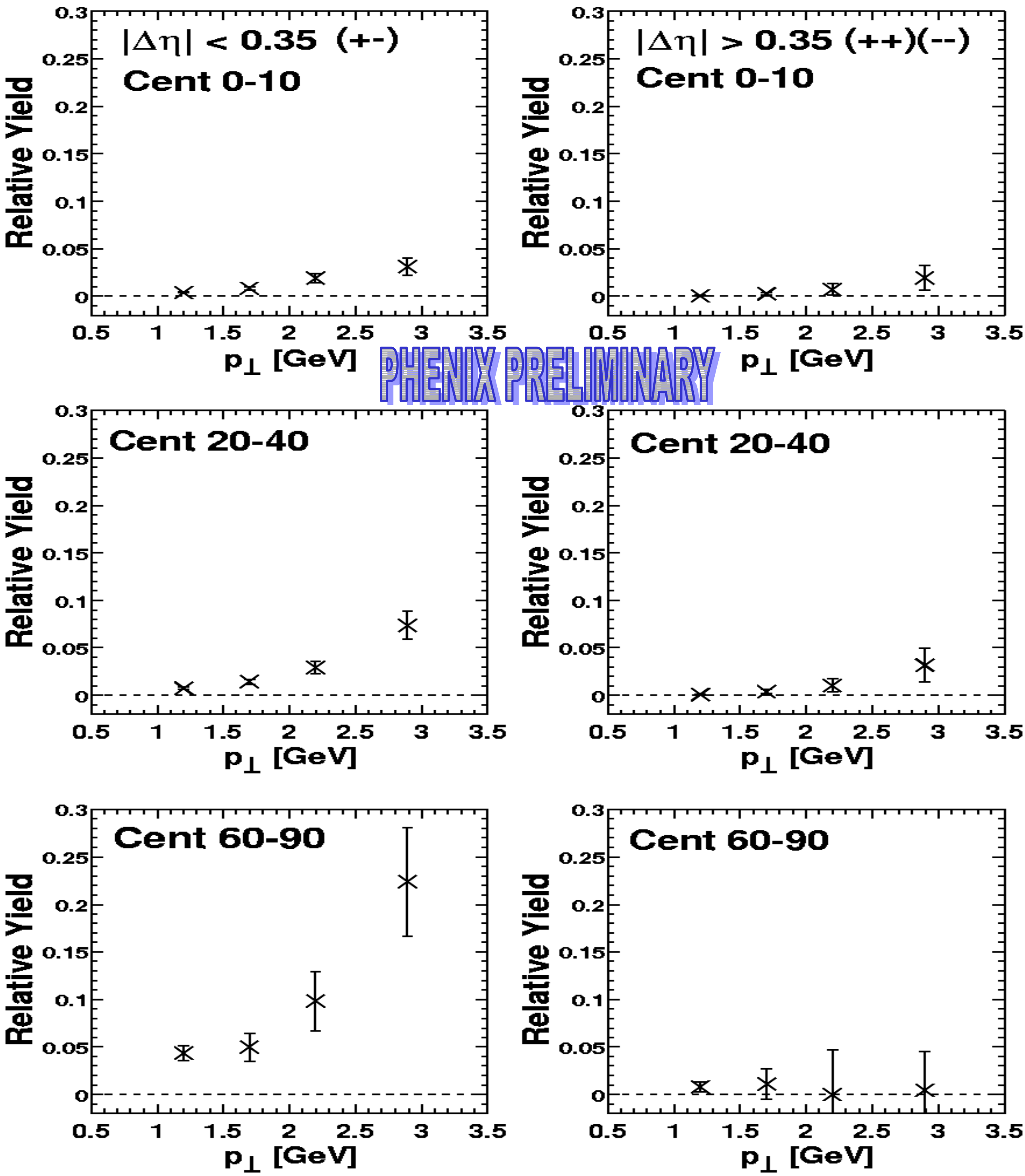
Kinematically favoured near-angle peak ($|\Delta\eta|<0.35$, $(q_1q_2)=(+\,-)$)

Kinematically disfavoured near-angle peak ($|\Delta\eta|>0.35$, $(q_1q_2)=(+\,+)(-\,-)$)



Relative Yields

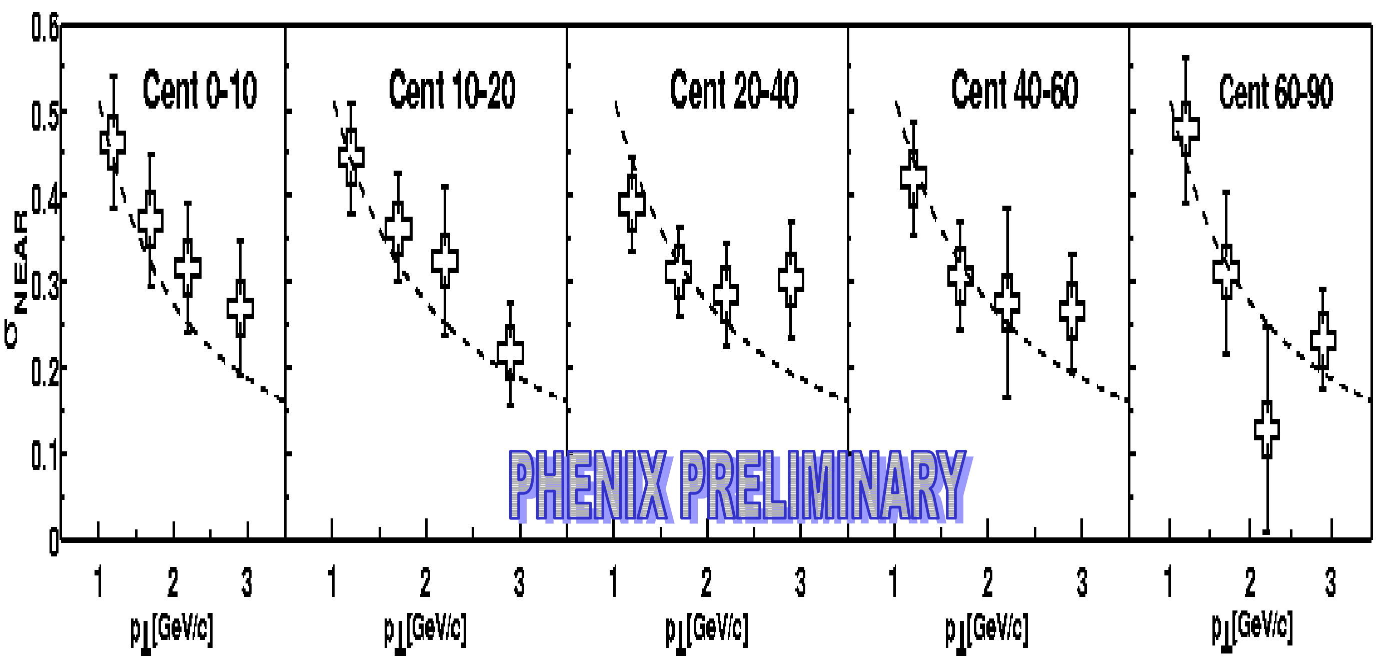
Relative yield ≡ area of near-angle gaussian / total area



Centrality and $p_{\perp}$ dependence indicative of jet-like source

AuAu Near-Angle Widths

The extracted width of the gaussian term (the dashed line - not a fit - corresponds to a constant $j_\perp$=400 MeV):



Within the present errors, no evidence of broadening

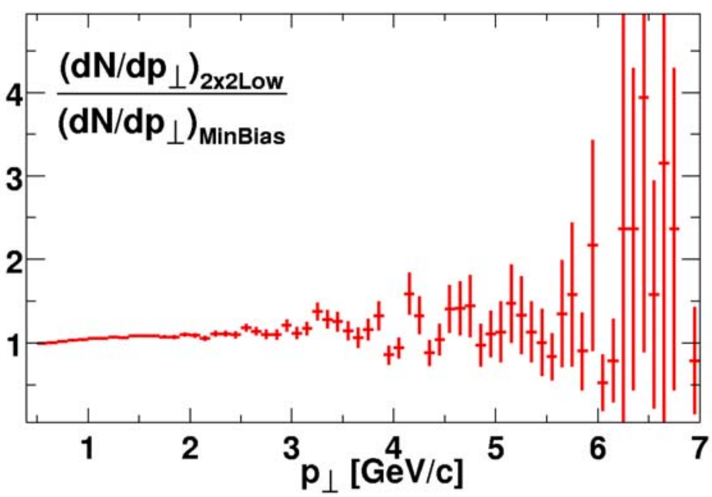
AuAu Jet Shapes – Summary and Conclusions

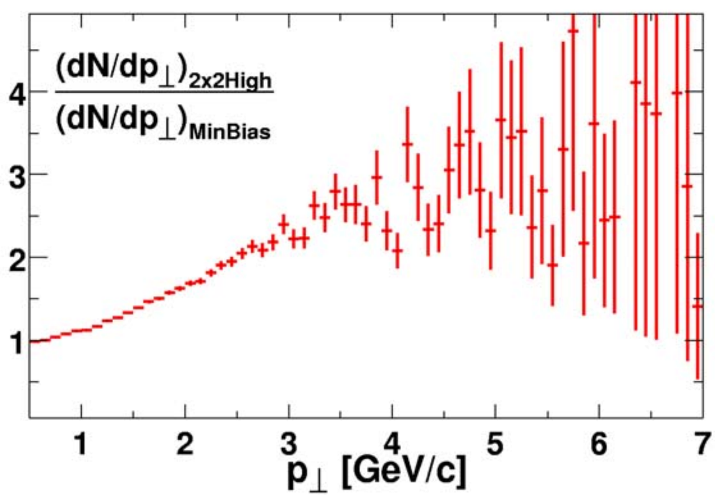
- Jet-like near-angle structure is observed in two-particle correlations in Au-Au collisions at $\sqrt{s}$ =200AGeV
- The relative yield decreases with centrality and increases with $p_\perp$.
- Near-angle widths also show a $p_\perp$ dependence characteristic for jets. No centrality dependence (broadening) within current errors.

Backup Slides

Trigger bias on <$p_{\perp}$>

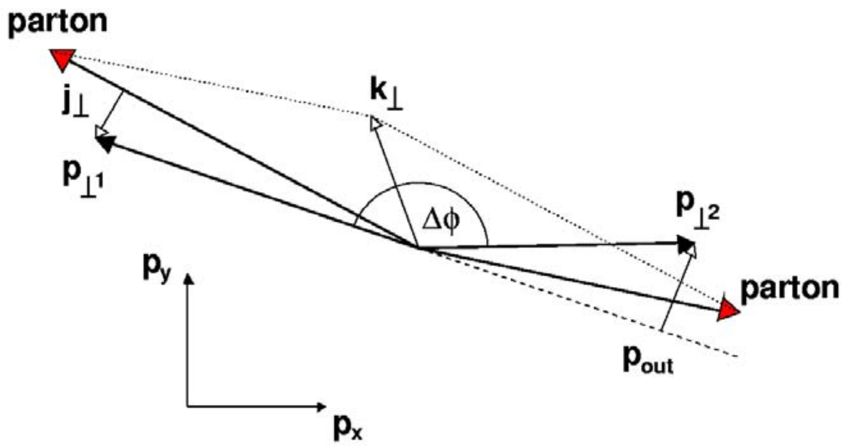
The pp data contains events triggered by the energy deposited in the Electromagnetic Calorimeter (low threshold~0.3GeV and high threshold~0.8GeV). This trigger selection biases the $p_{\perp}$ distribution by shifting its <$p_{\perp}$>.





The increase factor over minimum bias distribution is 3 over 3GeV, which produces a negligible <$p_{\perp}$> shift since it happens over a steeply falling $p_{\perp}$ distribution.
We measured this shift and it is lower than 0.5%.

More details on $j_\perp$, $k_\perp$ calculation



If the jet axis (φ_{jet}) were known, $\langle |j_{\perp y}| \rangle \equiv \langle p_\perp \rangle \sin\langle |\varphi_i - \varphi_{jet}| \rangle$

However, we measure the relative angular dispersion between two jet fragments $\sigma_N \equiv \sqrt{\langle (\varphi_i - \varphi_j)^2 \rangle} = \sqrt{2}\sqrt{\langle (\varphi_i - \varphi_{jet})^2 \rangle} = \sqrt{\pi}\langle |\varphi_i - \varphi_{jet}| \rangle$

As for $k_\perp$, we start from the formula* for the mean transverse momentum <|p_{out}|> out of the plane defined by one fragment and the beam axis (z): $\langle |p_{out}| \rangle^2 = \langle |j_{\perp y}| \rangle^2 + x_E^2 \left(\langle |j_{\perp y}| \rangle^2 + 2\langle |k_{\perp y}| \rangle^2 \right)$

For symmetric pairs ($p_{\perp 1}$=$p_{\perp 2}$),

$$\langle |p_{out}| \rangle = \langle |p_\perp| \rangle \sin(\langle |\Delta\varphi| \rangle) = \langle |p_\perp| \rangle \sin\left(\sqrt{\frac{2}{\pi}}\sigma_F \right)$$

$$x_E \equiv -\frac{\vec{p}_{\perp 1}\vec{p}_{\perp 2}}{|\vec{p}_{\perp 2}|^2} = -\cos(\langle |\Delta\varphi| \rangle) = -\cos\left(\sqrt{\frac{2}{\pi}}\sigma_N \right)$$

*Phys. Lett. B97(1980)163