High-pt charged particles azimuthal correlation in PHENIX

Jan Rak *for* PHENIX *collaboration*

- Searching for hard scattering in nuclear collisions.

- Azimuthal anisotropy (hydrodynamical flow versus mini-jets)
  - Reaction plane analysis
  - Two particle correlations

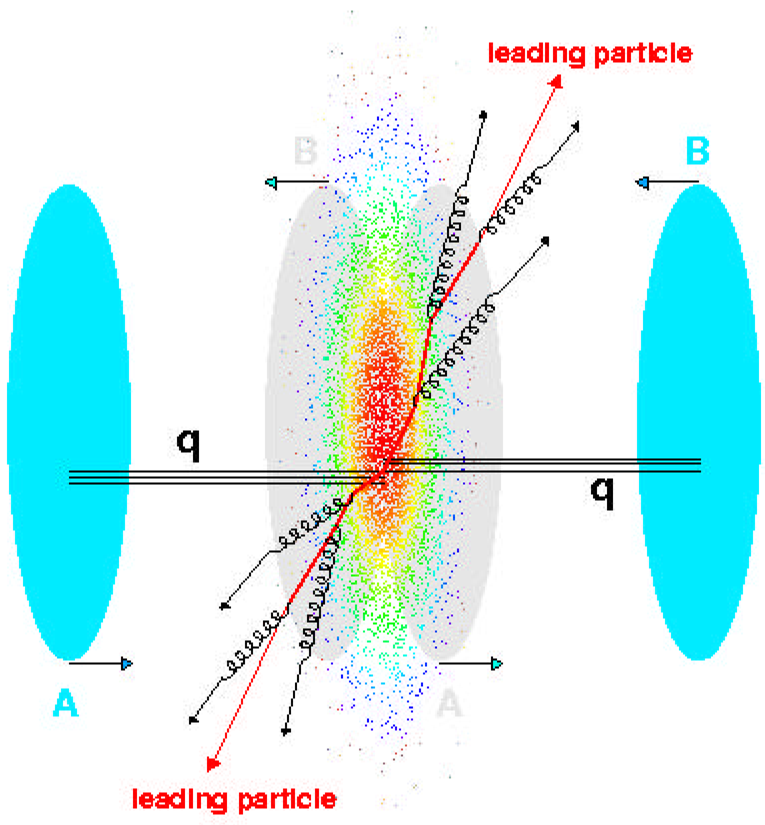
- Year 1 PHENIX azimuthal correlations @ $\sqrt{s}$ = 130 AGeV

- Is the v_2 @ RHIC too small or too large ?

- Summary

Hard scattering in Heavy Ion collisions

schematic view of jet production



Jets:

- primarily from gluons at RHIC
- produced early (τ<1fm)
- sensitive to the QCD medium (dE/dx)

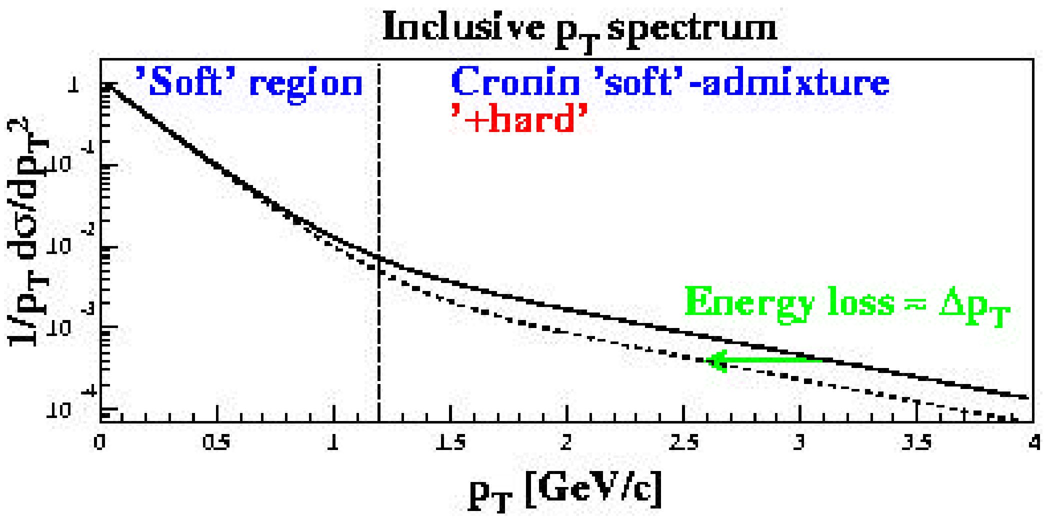
Observed via:

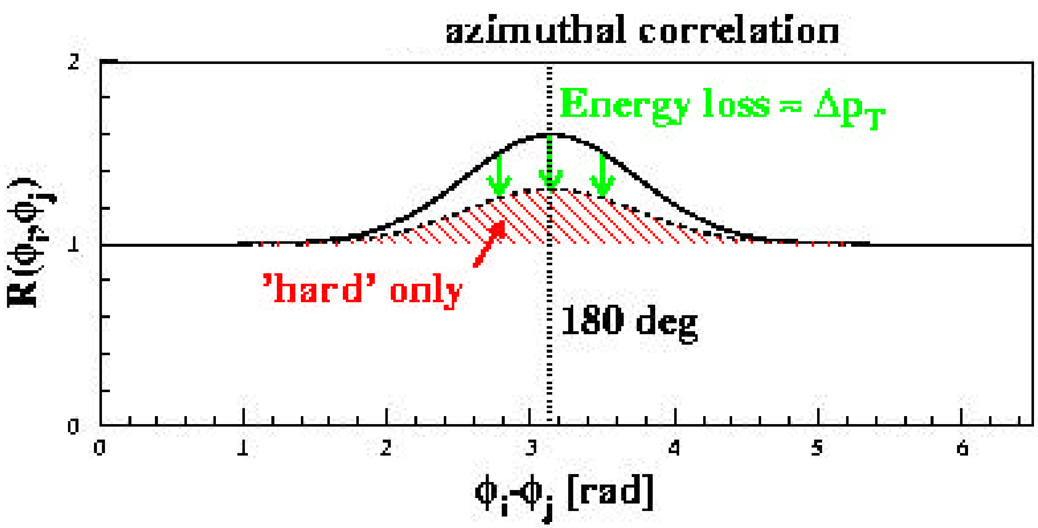
- fast leading particles or
- azimuthal correlations between them

Mechanisms of energy loss in vacuum (*pp)* is understood in terms of formation time and static chromoelectric field regeneration* . Any nuclear modification of this process could provide a hint of QGP formation.

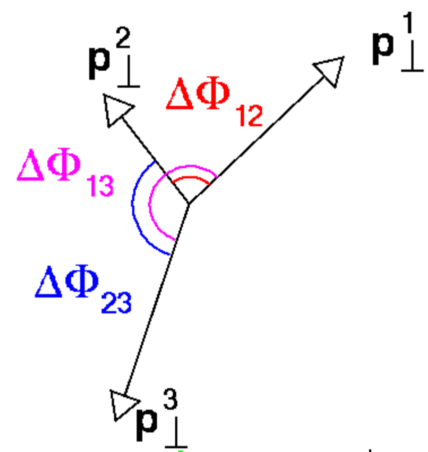
* *F.Niedermayer, Phys.Rev.D34:3494,1986.*

Hard scattering signals





Hard scattered partons should fragment into two back-to-back particles in azimuth.



Partonic energy loss may*

- reduce the back-to-back peak
- modify the fragmentation function - near angle peak

* *X.N. Wang, Phys.Rev.Lett.81:(1998)2655*

Correlation function

$$C(\Delta\phi) = \frac{N_{real}(\Delta\phi)}{N_{mixed\ events}(\Delta\phi)} \qquad \Delta\phi = \phi_i - \phi_j$$

Directed flow

Elliptic flow

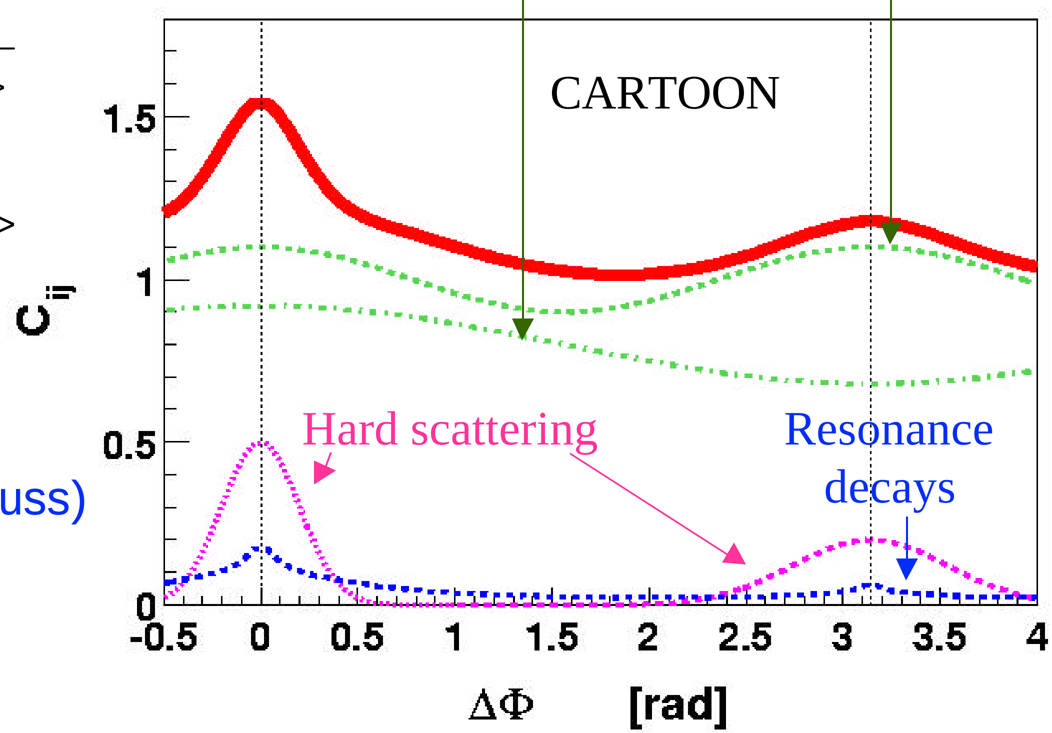
Fourier decomposition: $C(\Delta\phi)_{flow} \propto (1 + 2v_1^2\cos(\Delta\phi) + 2v_2^2\cos(2\Delta\phi))$

Correlation function

$$v_2 = \sqrt{<\cos(2(\Phi_i - \Phi_j))>}$$

Reaction plane

$$v_2 = <\cos(2(\Phi_i - \Psi_{RP}))>$$



We observe a sum of

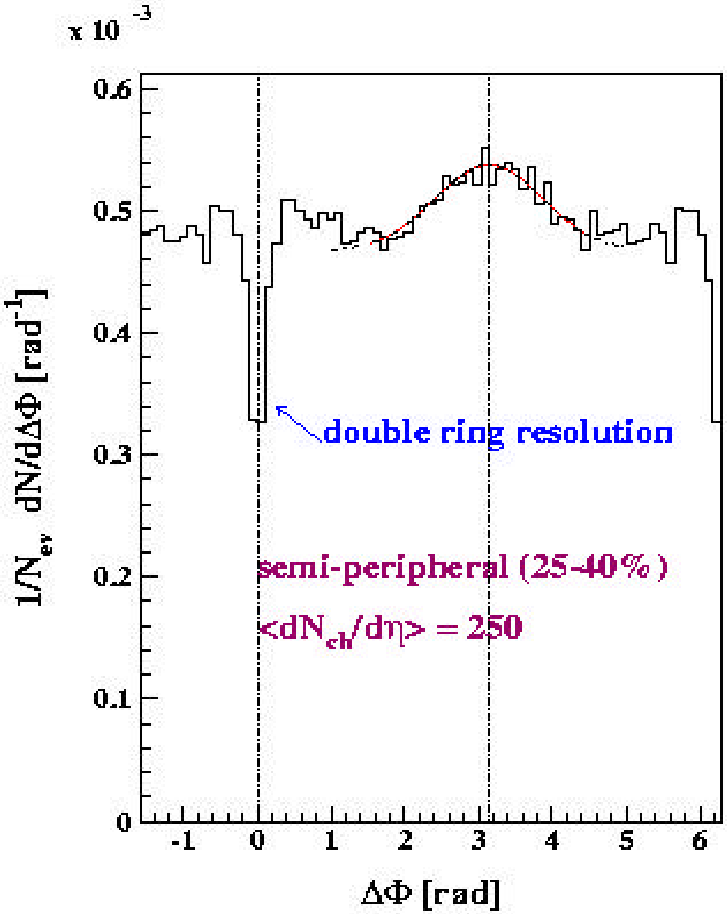
- Flow anisotropy (cos)
- Hard scattering peaks (gauss)
- Resonace decays

J.Y.Ollitrault, nucl-th/0004026

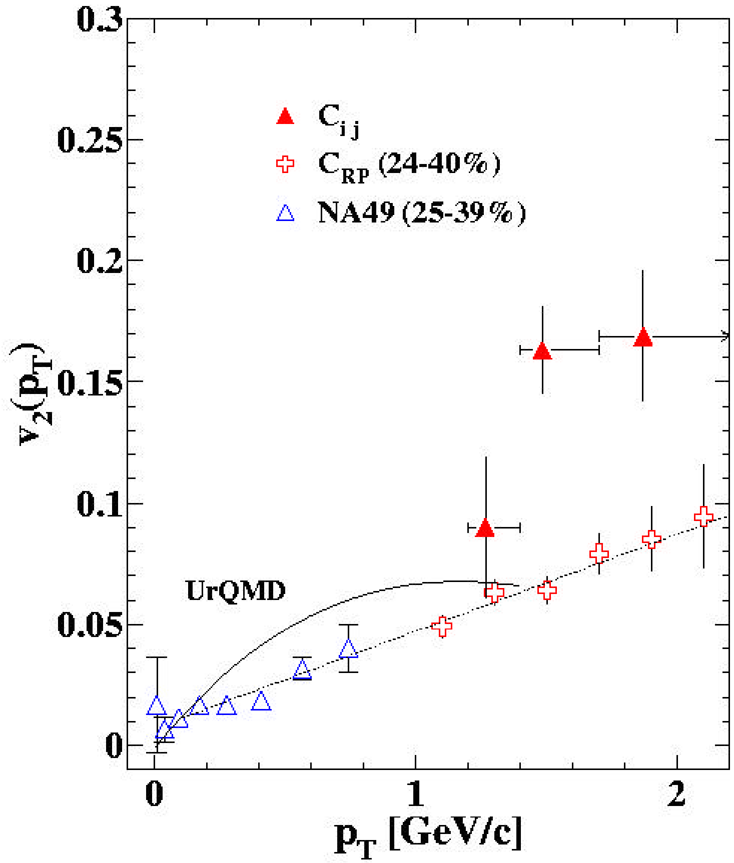
SPS high-p$_\wedge$ pions correlations

CERES experiment √s = 17 GeV/c Identified $\pi^{\pm}$

Back-to-back more pronounced



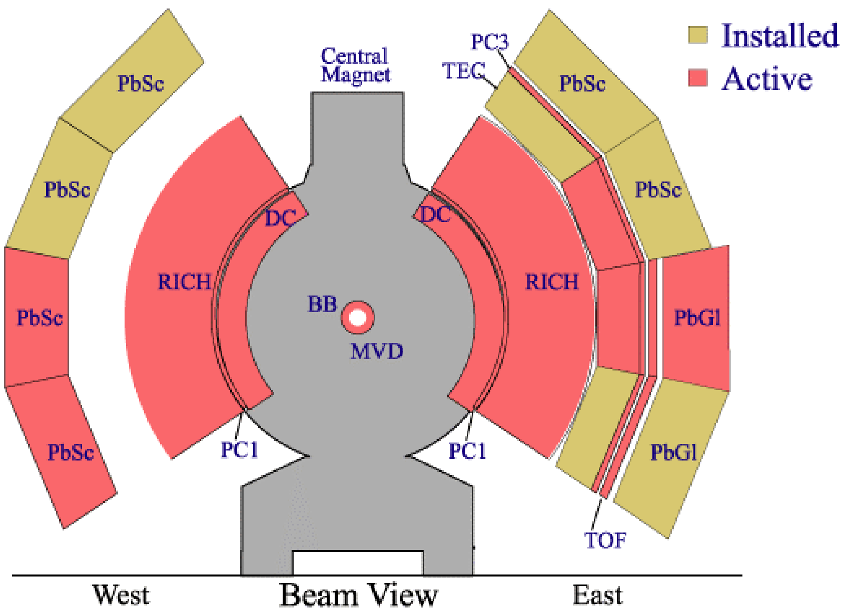
v_2 like analysis



PHENIX

RUN1: summer 2000 ~ 5M events

PHENIX Detector - First Year Physics Run



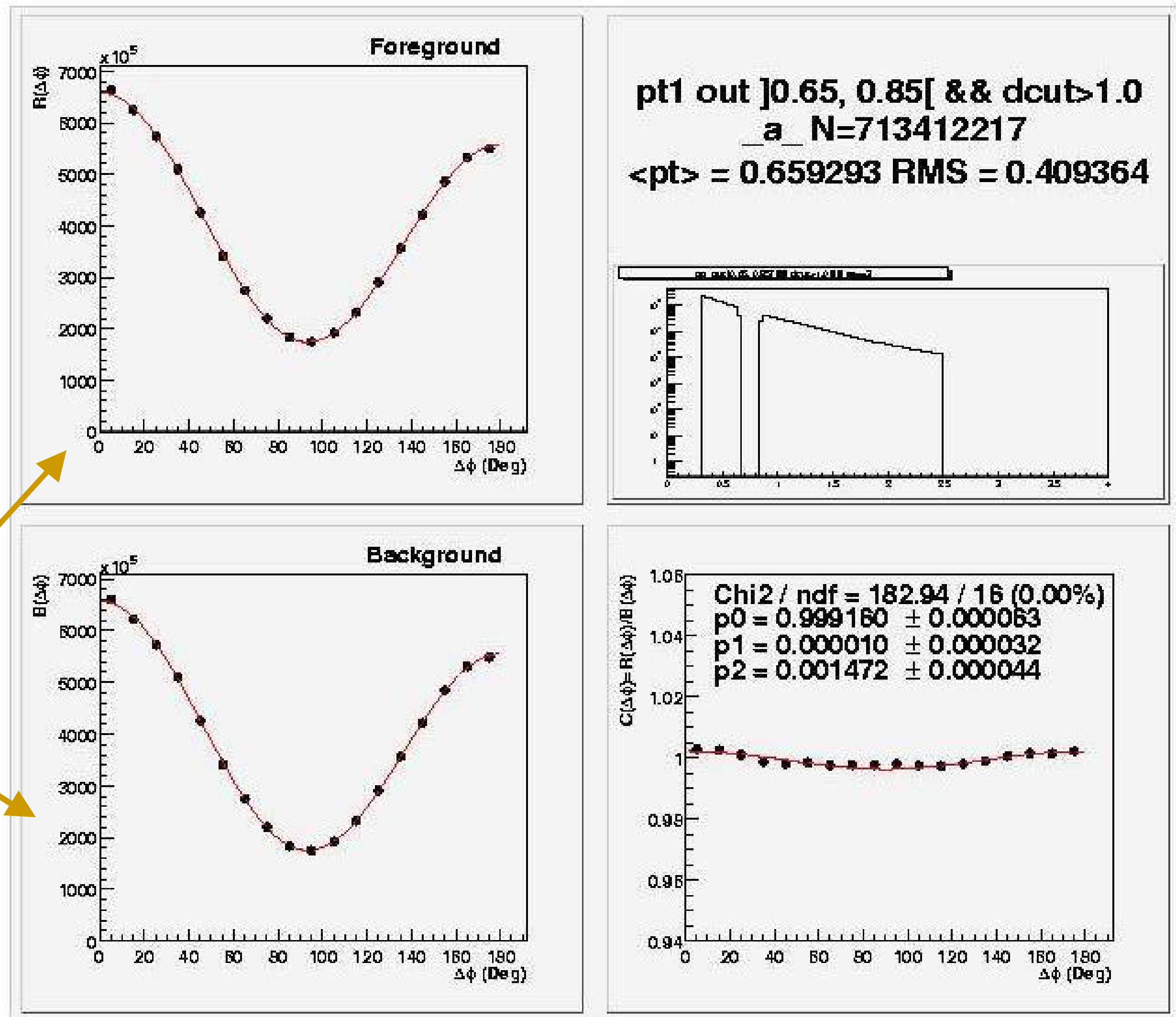
- 1.5M events analyzed
- -20 < collision vertex < 20 cm
- Central arm tracks
  - momenta from drift chamber tracks
  - 0.3 < pt < 2.5 GeV
- Correlation functions
  - mixed events from similar beam-vertex, centrality

Charged hadron Correlation function

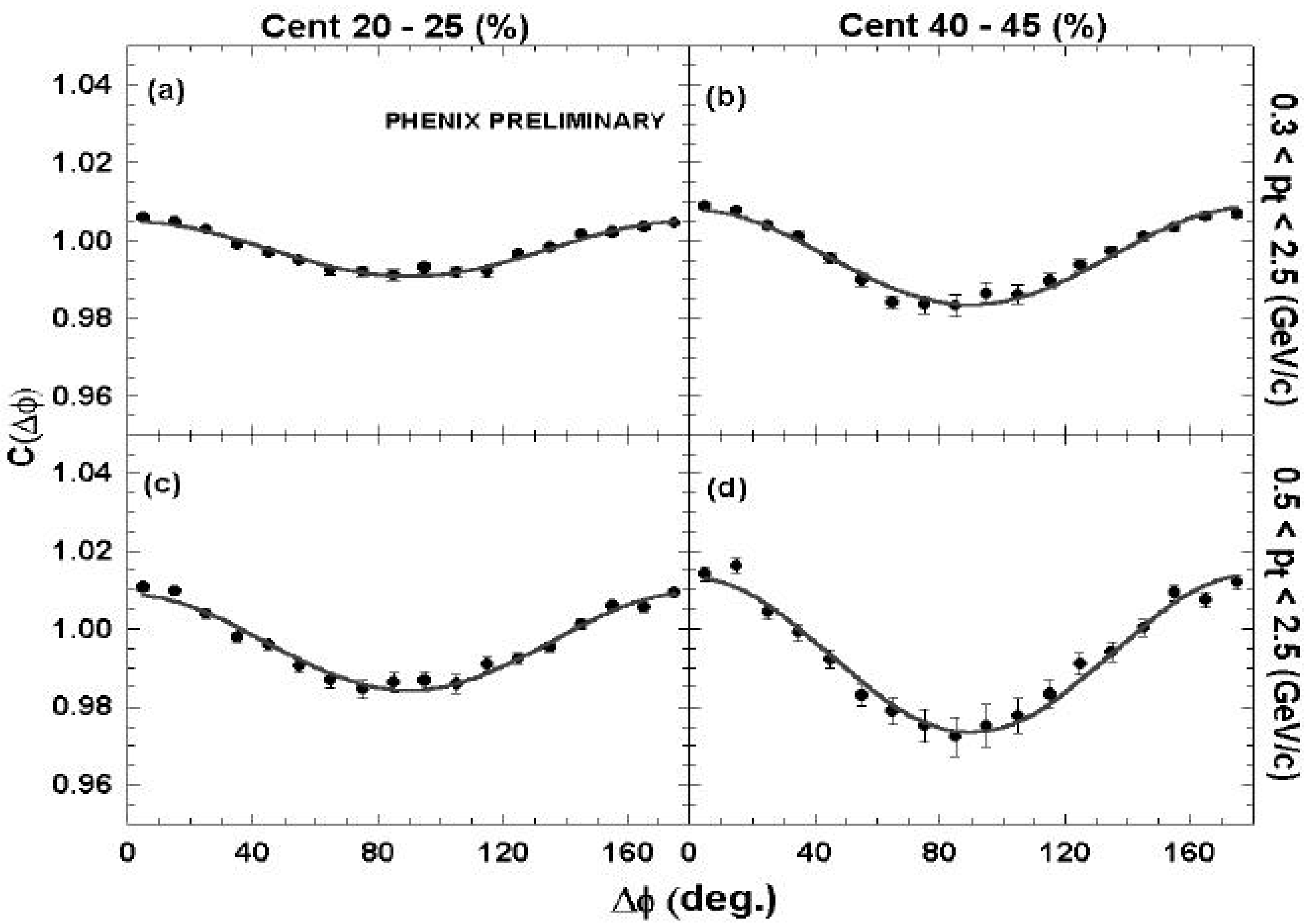
We used two approaches:

- Fixed $p_\perp$ correlation (only particles from the same $p_\perp$ bins are correlated)
- Assorted correlation particle from given $p_\perp$ bin is correlated with all other particles excluding this $p_\perp$ bin.

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



Correlation function

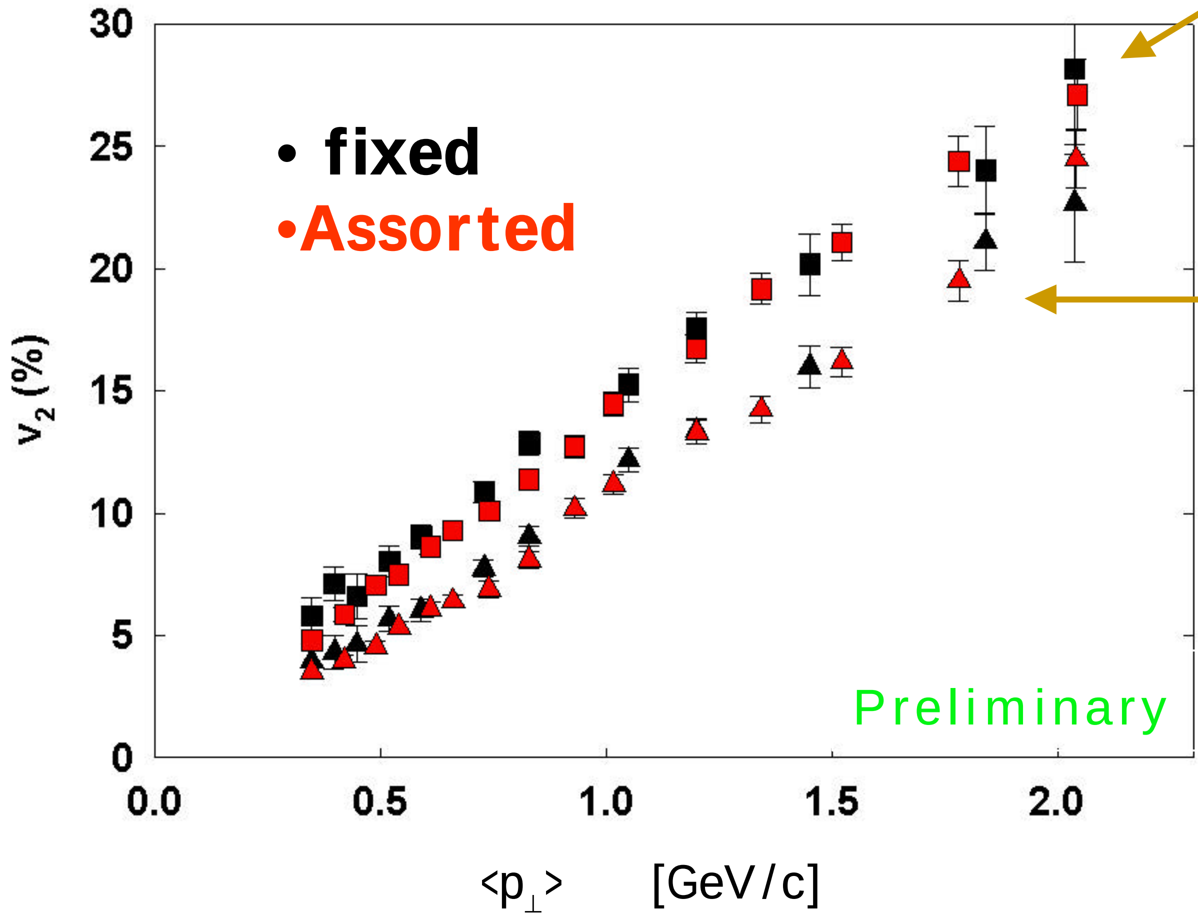


$0.3 < p_\perp < 2.5$ GeV/c

$0.5 < p_\perp < 2.5$ GeV/c

- Essentially Symmetric around 90 deg (**cos(2Df)**).
- Consistent with Elliptic flow phenomena

PHENIX differential flow



■ 30 < centrality < 60%

▲15< centrality < 30%

The fixed and assorted methods provide a good agreement.

Data Summary

Two particle correlation function

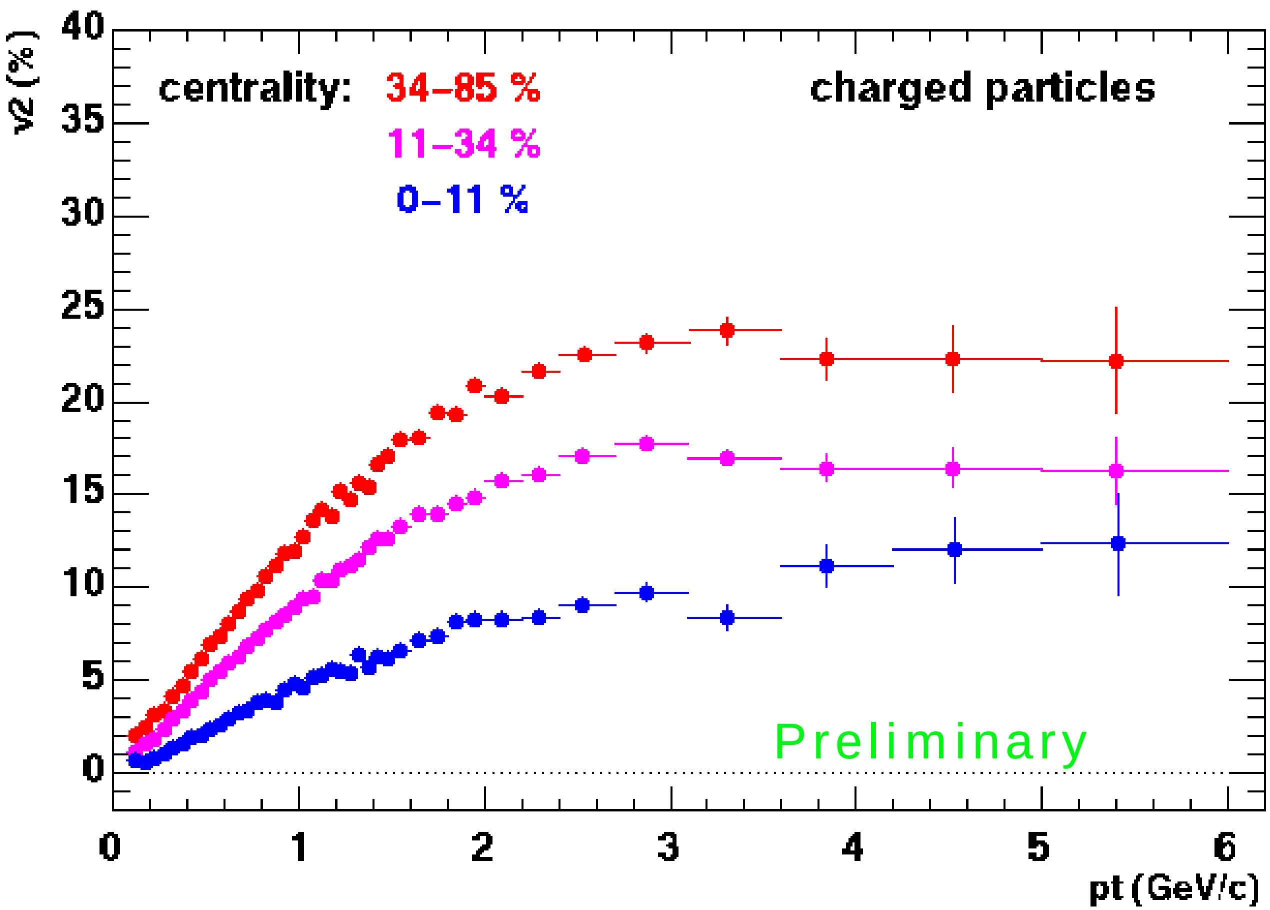
- The shape is symmetric – no room for significant v_1 (expected).
- Distortions due to resonance's not significant (expected).
- Assorted and fixed pt method gives the same results within the $0.5< p_\perp <2$ GeV/c range (surprise) .
- No strong evidence for gauss-like peaks which would indicate sizeable hard back-to-back scattering

$p_\perp$<2.2 GeV/c (surprise).

???

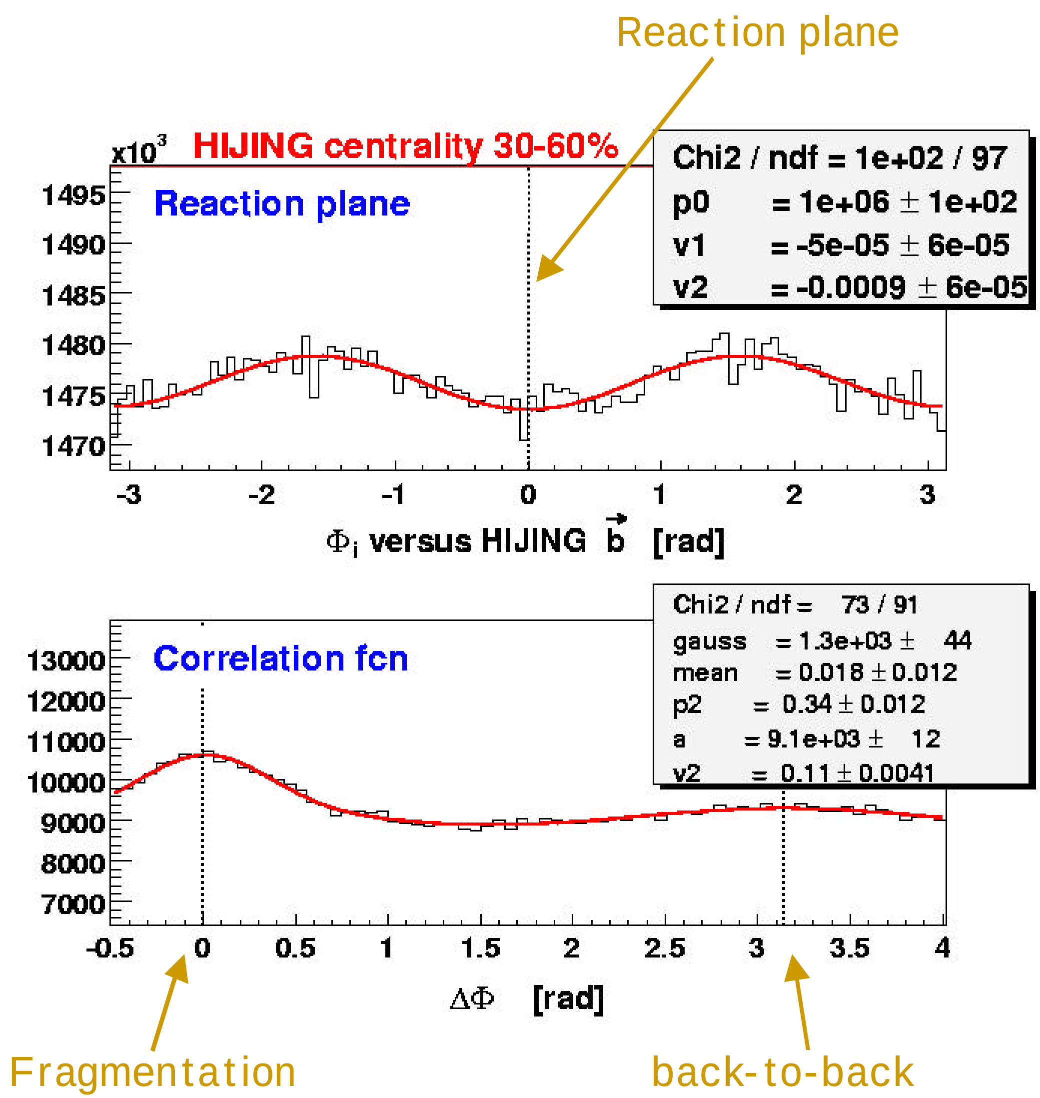
How about the reaction plane v_2 - let us ask STAR

STAR Differential Flow Measurement $v_2(b,p_t)$



Kirill Filimonov, High Pt Phenomena at RHIC, BNL, 11/1/01

HIJING azimuthal anisotropy

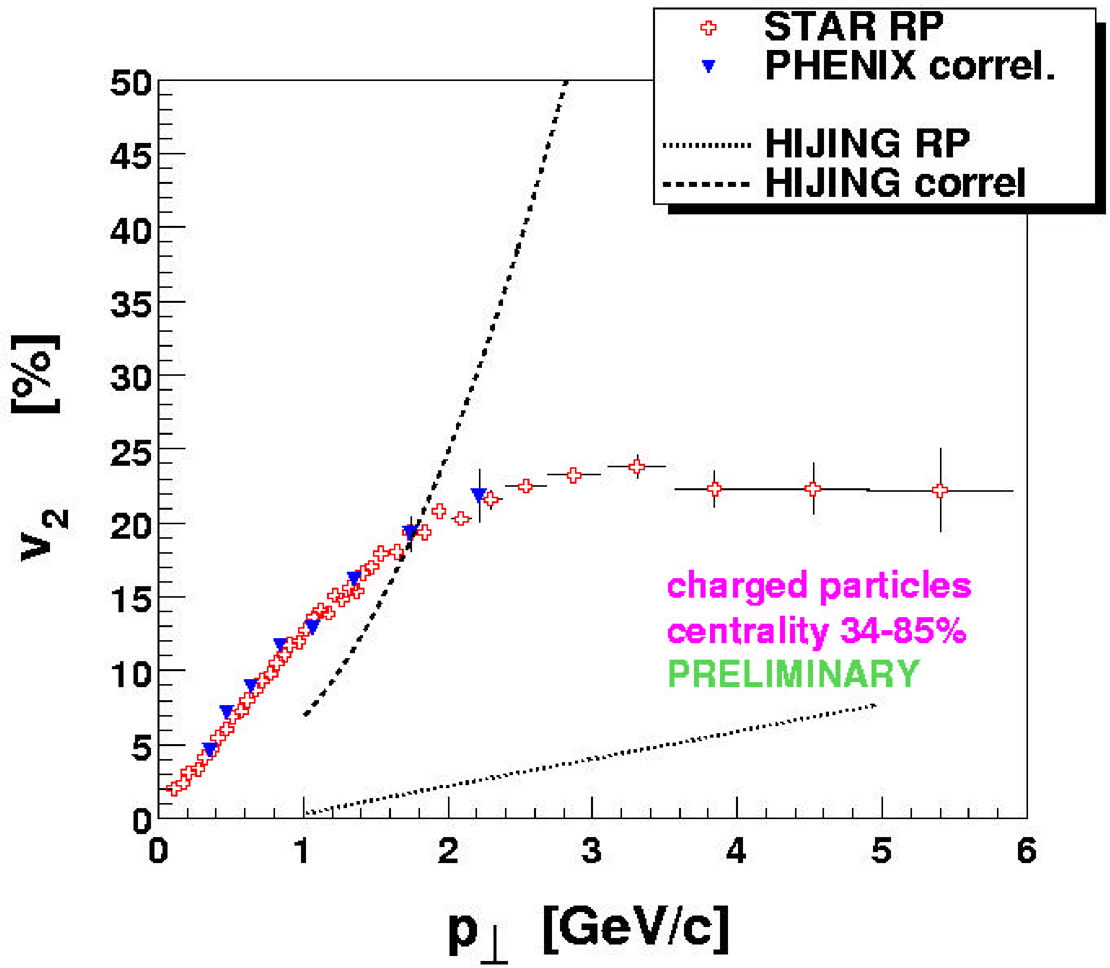


HIJING (dE/dz = 0 GeV)

(pQCD jet production – no hydro)

- Reaction plane
  - $v_2 = \langle\cos(2\phi)\rangle$ is small and negative (out-of-plane)
  - More material induces more gluon emission
- Two particle correlations
  - $v_2 = \sqrt{\langle\cos(2\Delta\phi)\rangle}$ is large

$v_2(p_\perp)$ PHENIX vs. STAR



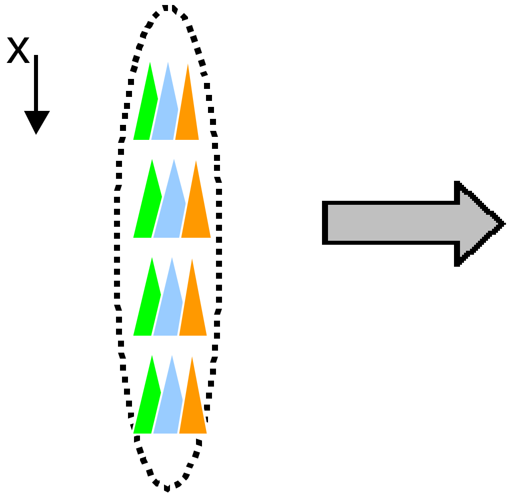
Up to 2 Gev/c there is no or very little room for non-flow anisotropy !

- STAR reaction plane analysis
  - Flattens off around 3GeV/c
- PHENIX two particle correl.
  - Good agreement with STAR RP analysis over significant range of $p_\perp$
- HIJING (dE/dz = 0 & 2 GeV/fm).
  - RP v_2 is too small over the full range, but grows with $p_\perp$,
  - Correlation v_2 is large, Grows with $p_\perp$, (not seen in data).

(See also E.V. Shuryak, nucl-th/0112042)

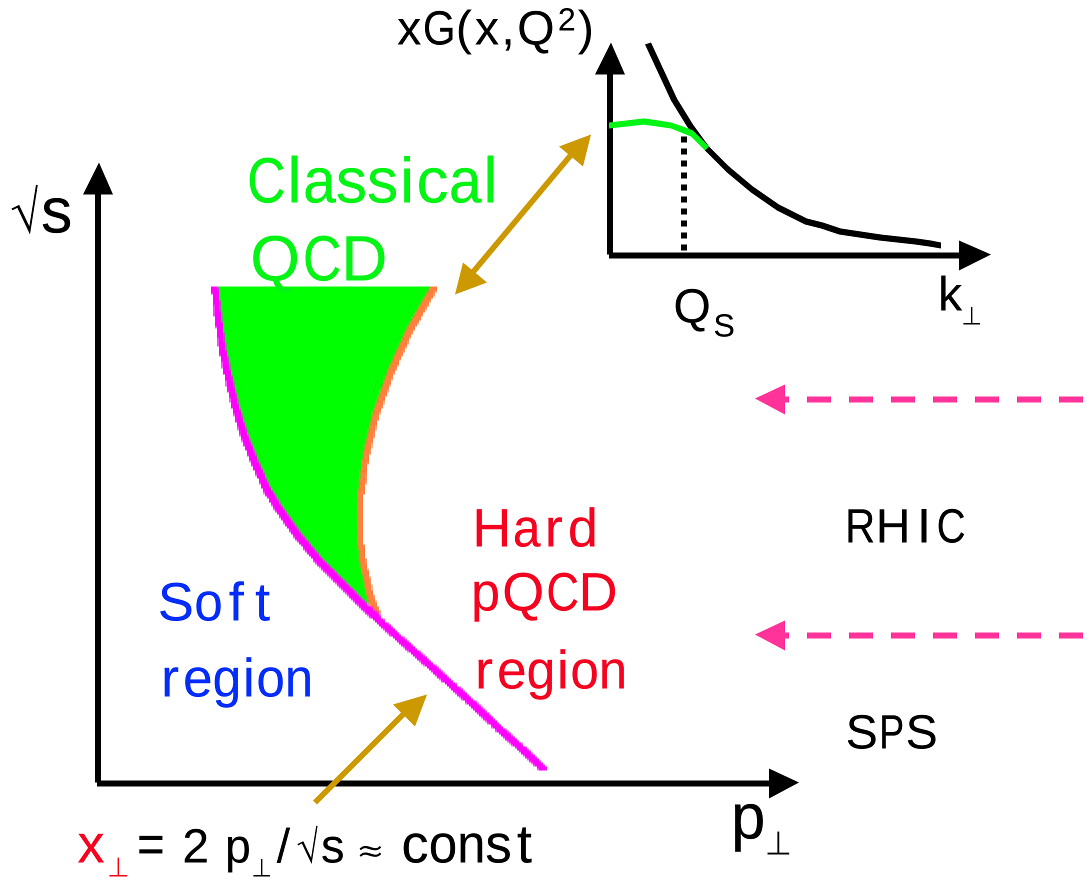
Gluon condensate at small X

See D. Kharzeev, E. Levin Nucl-th/0108006



At small Bjorken x partonic wave functions starts to overlap

- Saturation
- coherence
- multi-parton correlation breaks down



In Classical region the particle production mechanism is 2->1 unlike the pQCD 2->2. This implies:

Below $2 * Q_S \approx 2 * 2$ GeV produced particles are not correlated.

Open Questions ?

My questions:

- Where is the back-to-back scattering , or why is the correlation v_2 so small ?

- Why is the v_2 at pt>4GeV/c so large ?

  Not consistent with any "hard" scenario with $0<dE/dz<\infty$ GeV/fm (see E.V. Shuryak, nucl-th/0112042).

- How one can accommodate the universal centrality scaling of low and high $p_\perp$ particles in pQCD scenario? (See Friday talk of Axel Drees)

- Why we do not see an enhancement of charged particle multiplicity as a result of induced gluon radiation?

- 80xmore opaque gluon plasma @ RHIC then from pQCD (see D. Molnar nucl-th/0005051, nucl-th/0104073 or http://nt3.phys.columbia.edu/people/molnar)

Summary

We have studied two-particle correlation functions in the range $0.3 < p_t < 2.2$ GeV/c.

Measured v_2:

- Grows approx. linearly with pT.
- The measured anisotropy for two particle correlation functions show good agreement with the reaction plane measurement done by STAR collaboration.
- **Non-flow particle correlations at RHIC appear to be weaker than those at SPS despite lower hard cross-section**

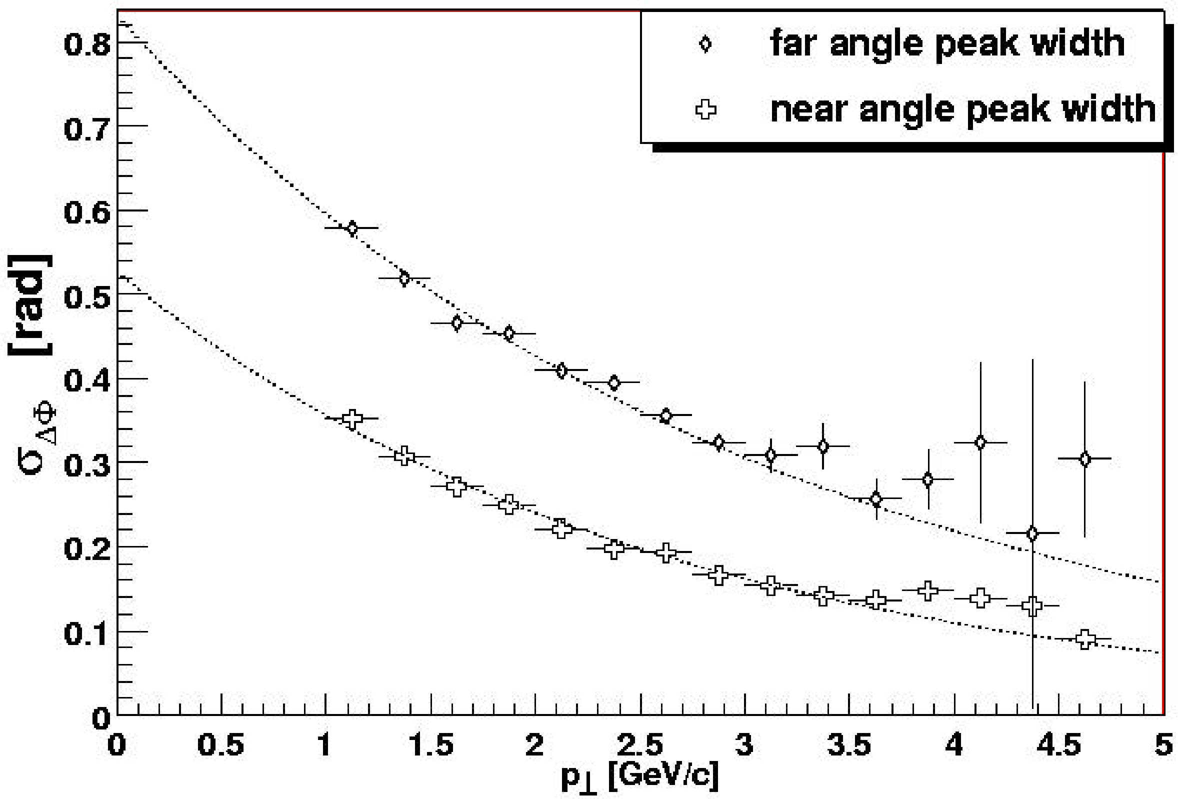
Suggests:

Low-x gluon condensation ??

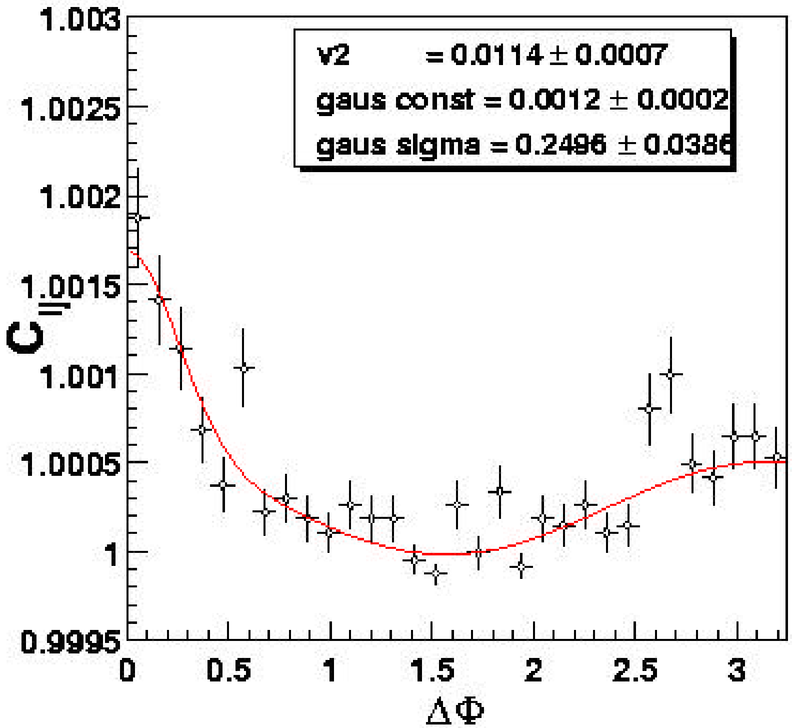
- Particles produced in this scenario are mostly uncorrelated (black body radiation) in contrast to the mini-jet production mechanism.

Pythia *pp* ös = 130 AGeV

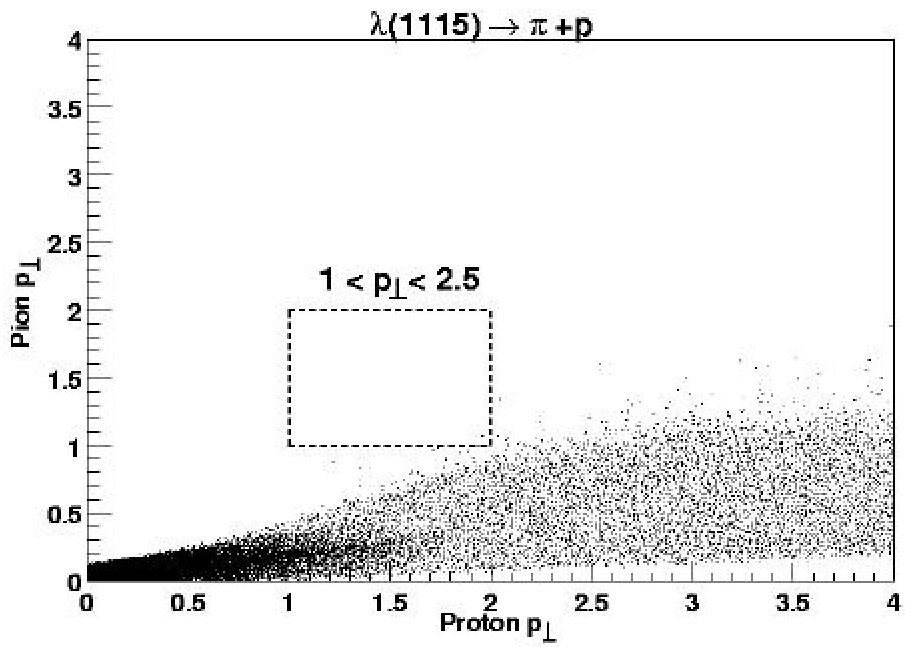
Angular width with $p_\perp$



Resonance decay – UrQMD simulations



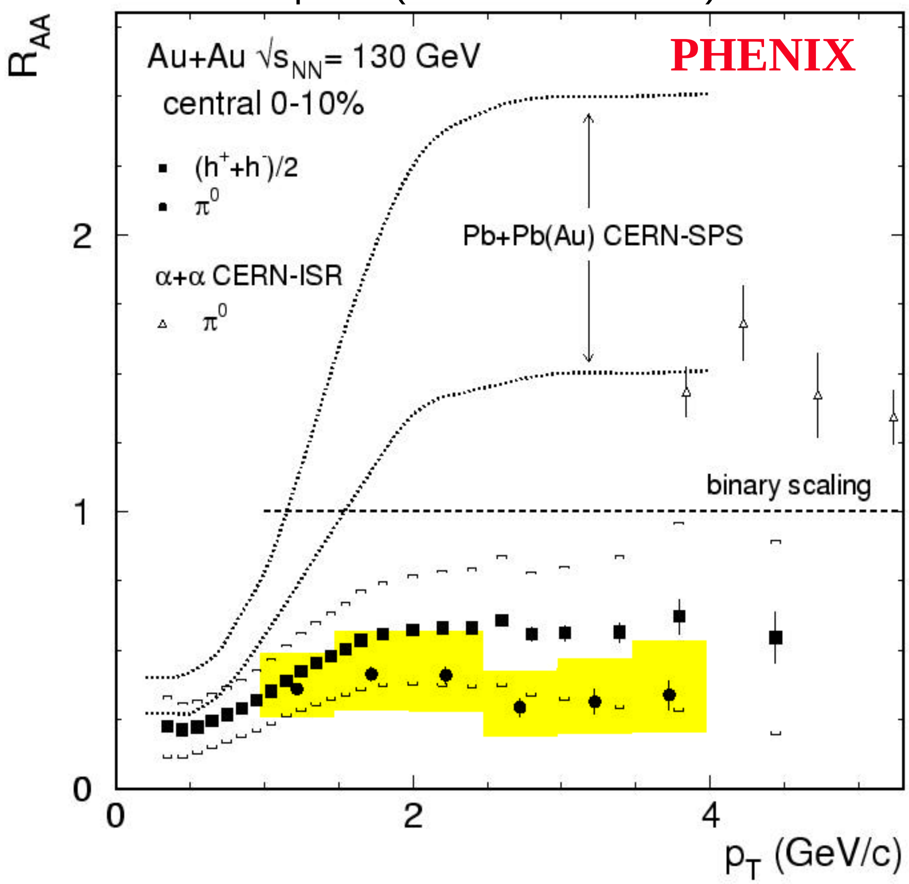
- Light resonance's :
  - contribute most to near-angle peak
  - V_2 is of order 1%.
- Weak decay:
  - Long lived particles (K_S^0 $c\tau$=2.7cm), decays in the mag. field and the daughters look like high-$p_\perp$ particles. Has been checked in GEANT.



- Baryon resonance's :
  - $p_\perp$-cut removes large fraction.

Nuclear Modification Factor Au-Au to p-p

K.Adcox et al., Phys. Rev. Lett. (2001) in print (nucl-ex/0109003)



See Friday talk of Axel Drees.

R_{AA} is significantly less then 1 over the entire range of $p_{\perp}$ consistently with the jet-quenching scenario.

BUT:

- Where is the Cronin effect ?
- Where are the azimuthal correlations?

Charged hadrons in Pythia

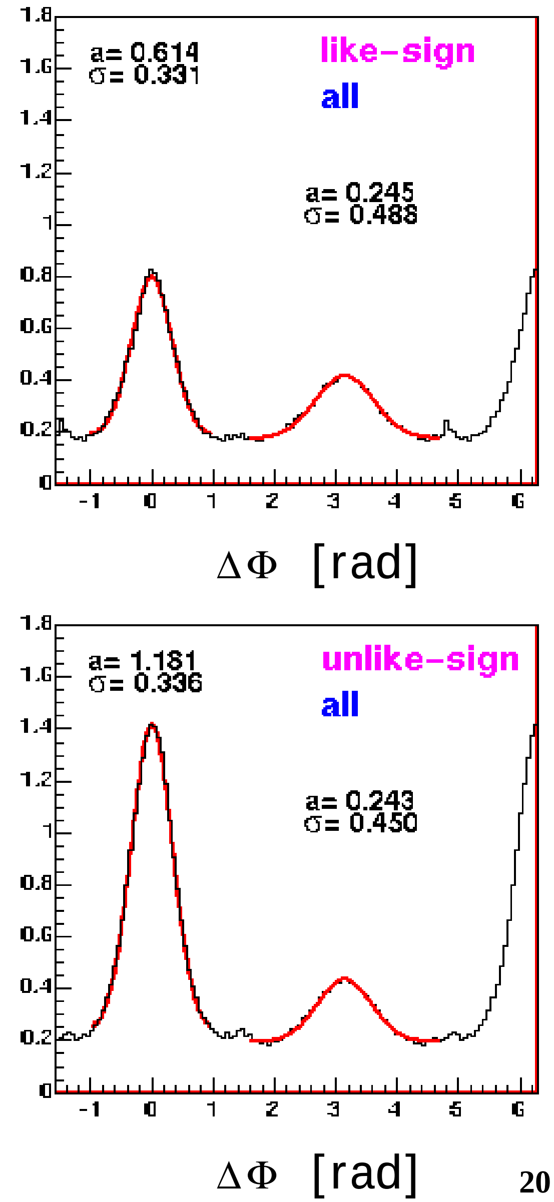
PYTHIA p+p at $s^{1/2}$ = 130 GeV
1.0 < pt < 2.5 GeV/c, $|\eta|$ < 0.35

- near-angle correlation stronger than back-to-back (opposite to what is observed for @SPS Calculations)

- near/far like-sign = 1.7 and unlike-sign = 3.6

- near-angle width of 0.35 rad = 20 deg

- far-angle width of 0.48 rad = 28 deg (near*√2)



Where is the jet quenching in Au+Au collisions at root(s)=130 AGeV/c?

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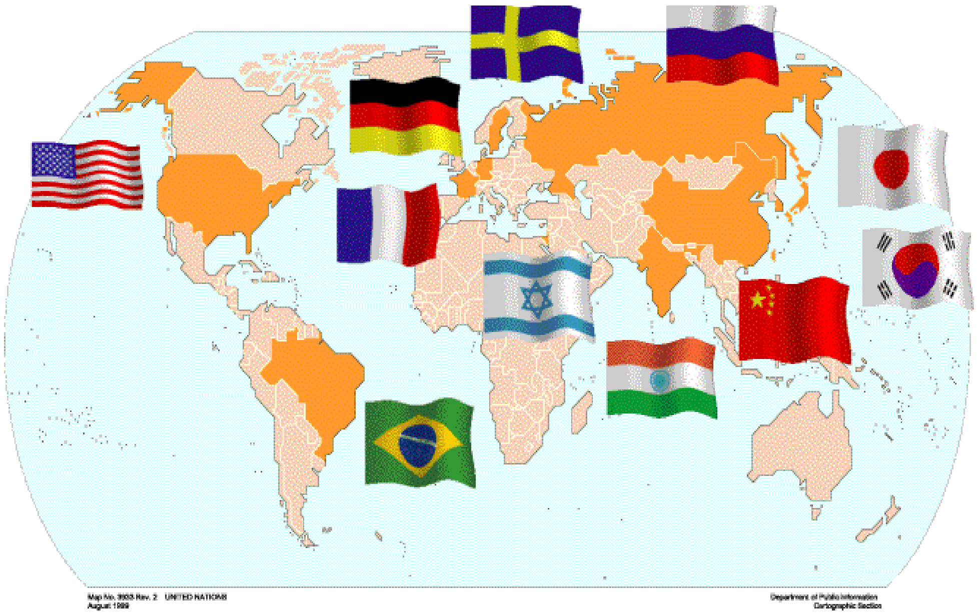
PHENIX



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