Semihard scattering unraveled from collective dynamics at the SPS

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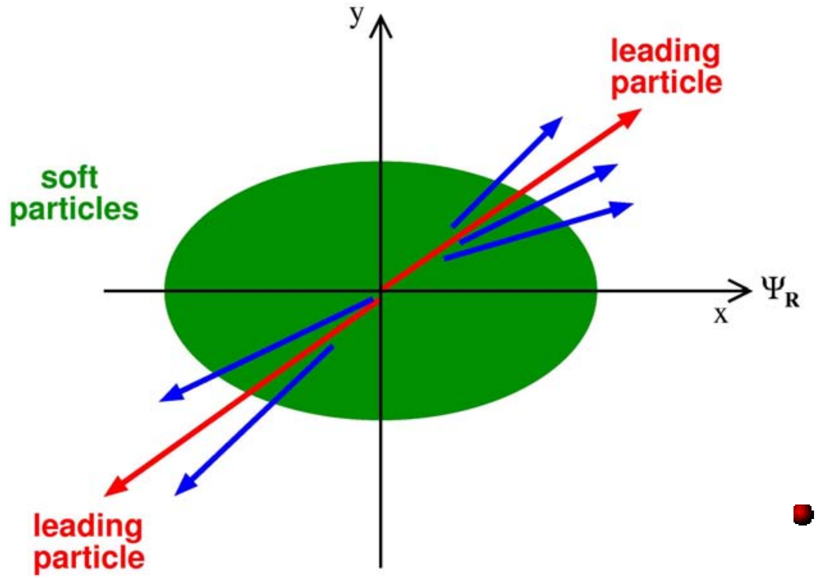
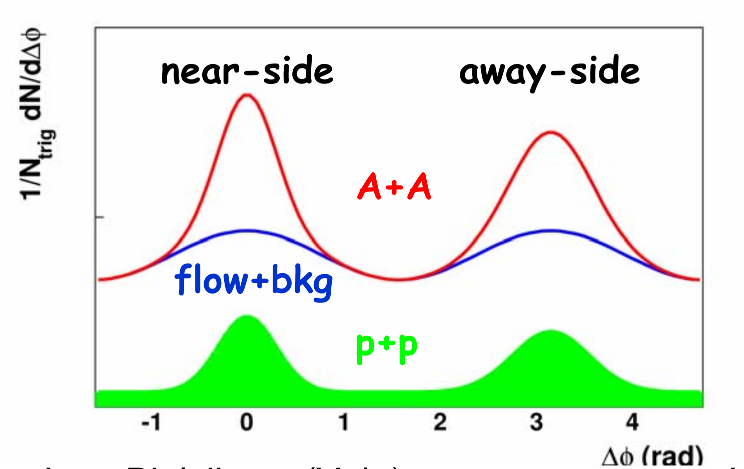
for the CERES Collaboration

- Motivation
- CERES experiment
- Elliptic flow vs two-pion azimuthal correlations
- Semihard interpretation and properties of non-flow component
- Summary

How to unravel semihard processes from collective dynamics ?





Use two-particle azimuthal correlations at high-p_t !
They are sensitive to flow and (semi)hard particle-particle correlations.

- correlation of particles with event plane (EP) induces correlations between particles

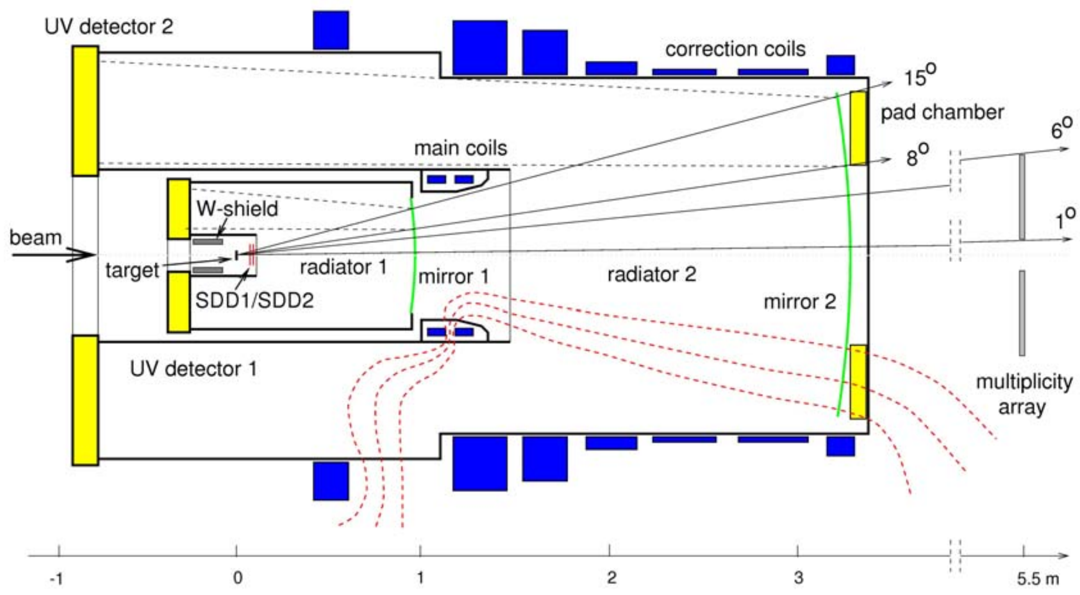
$$\frac{dN}{d(\phi_i - \phi_j)} = B(1 + \sum_{n=1}^{\infty} 2 v_n^2 \cos(n(\phi_i - \phi_j)))$$

- direct correlations:
  v_n(correlation) ≠ v_n(EP)

CERES spectrometer

Detectors:

- SDD1,SDD2: vertex, centrality, event plane
- RICH1,RICH2: PID
- MWPC: tracking
- magnetic field: azimuthally symmetric



1996 setup (before TPC upgrade)

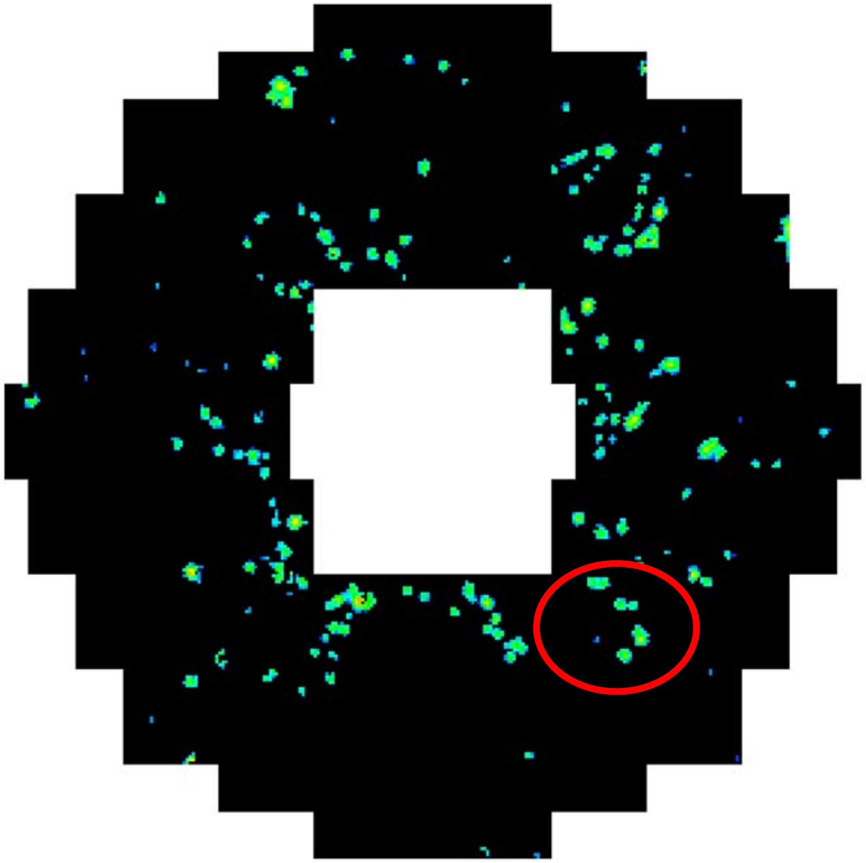
- charged hadrons: vertex+SDD+MWPC no PID (statistical)
- high-p_t pions: identified by RICH

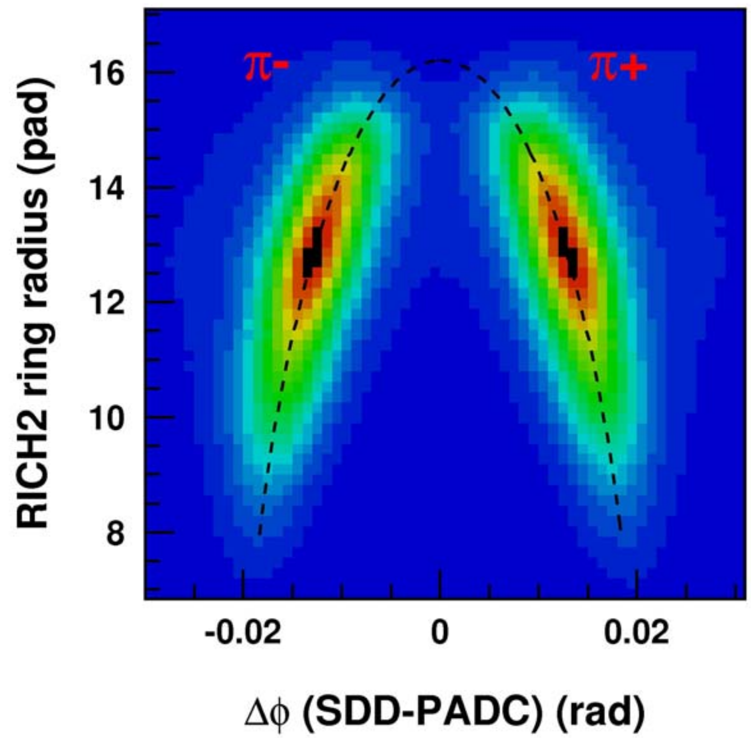
γ_{th}~32

p>4.5 GeV/c

Acceptance:
2.1 < η < 2.6
full azimuth

Identification of high-p_t pions in RICH





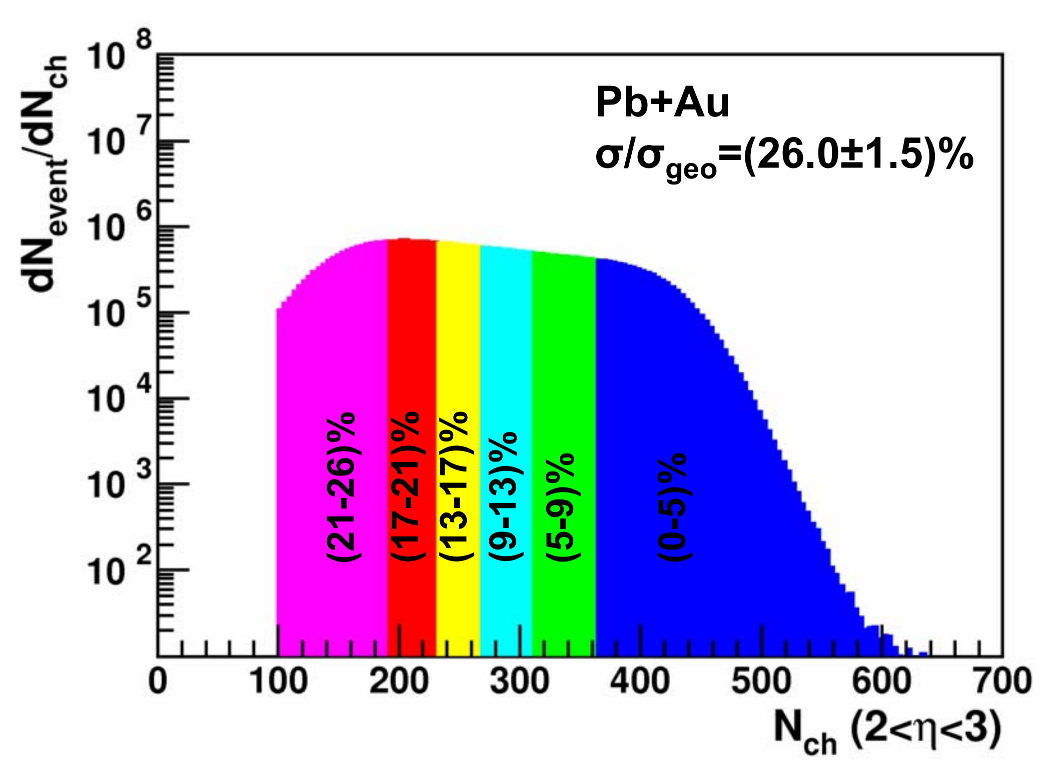
γ_{th}~32 ⟹ p_{min}>4.5 GeV/c

π distinguished from e by smaller ring radius

$$R = R_{\infty}\sqrt{1-\left(\frac{m\gamma_{th}}{p}\right)^{2}}$$

Data analysis

- 41M of Pb+Au collisions ($\sqrt{s}$=17GeV) ☺
- centrality determined from N_{ch} in SDD
- Glauber model to calculate N_{part} and N_{coll}



Pion analysis:

p_t>1.2 GeV/c:

N(pions/event) ~ 2×10^{-2}

N(pion pairs/event) ~ 4×10^{-4}

reconstruction efficiency **ε**:

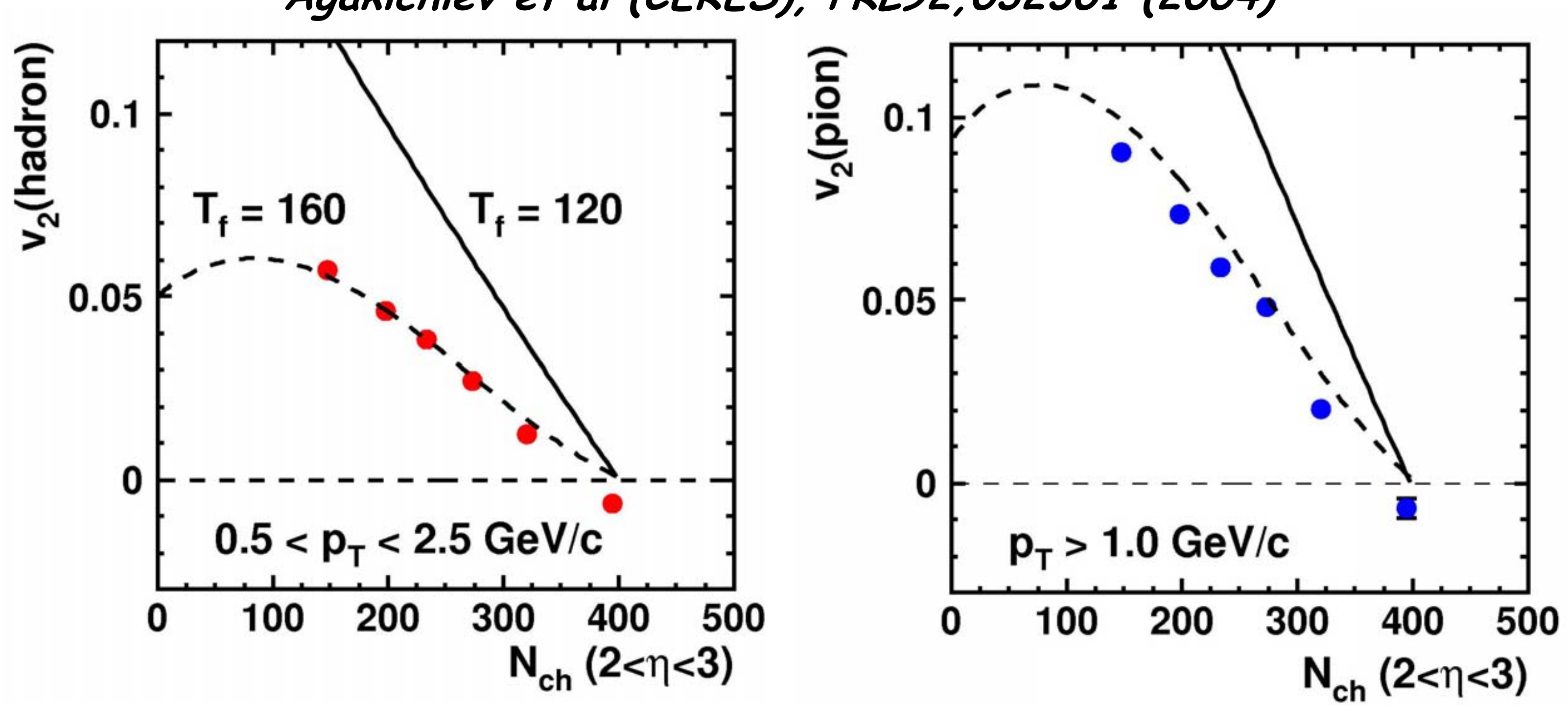
from overlay Monte-Carlo

3-dim **ε** =f(p,N_{ch},**θ**)

(ε=0.1-0.4) ☹

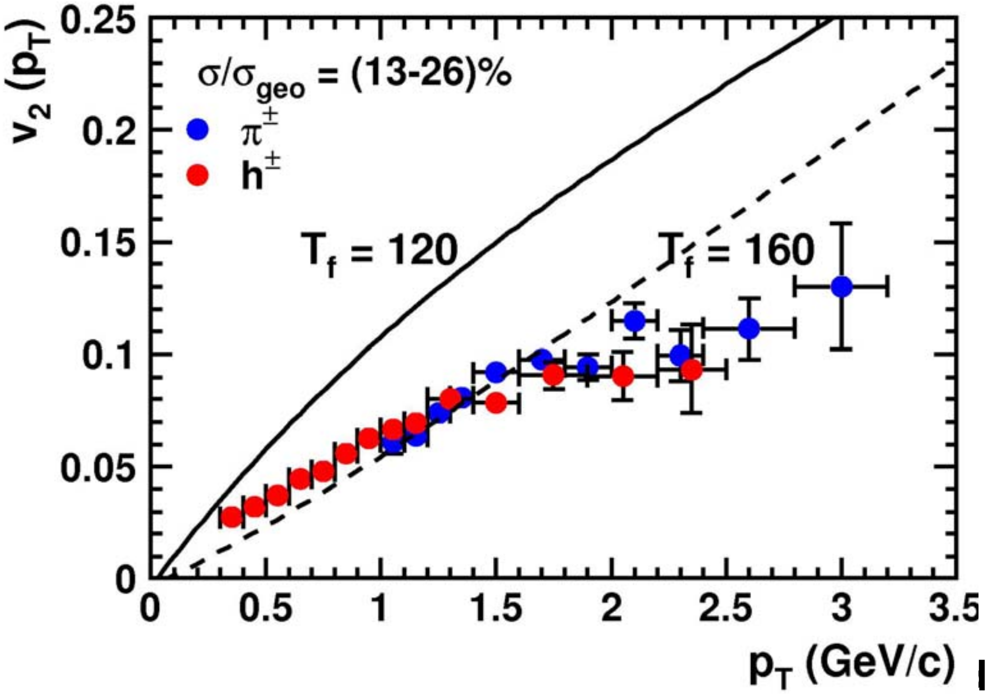
Centrality dependence of v_2

Agakichiev et al (CERES), PRL92,032301 (2004)

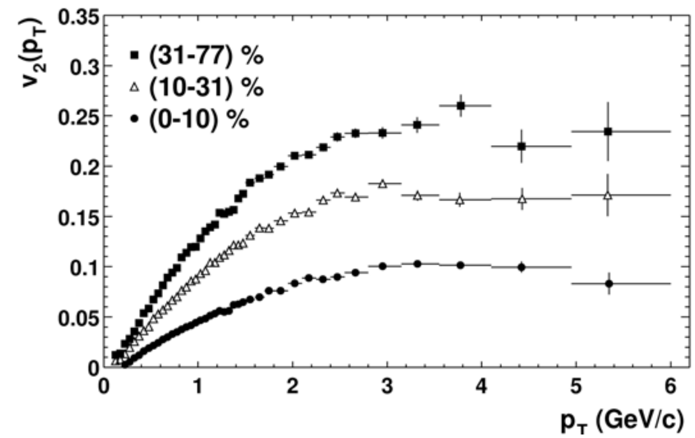


- hydrodynamical calculation: P. Huovinen (T_f=120/160MeV)
- better agreement for T_f=160MeV but proton spectra are too steep

Transverse momentum dependence of v_2



RHIC: v_2 saturates for p_t>2 GeV/c and below is described by hydro

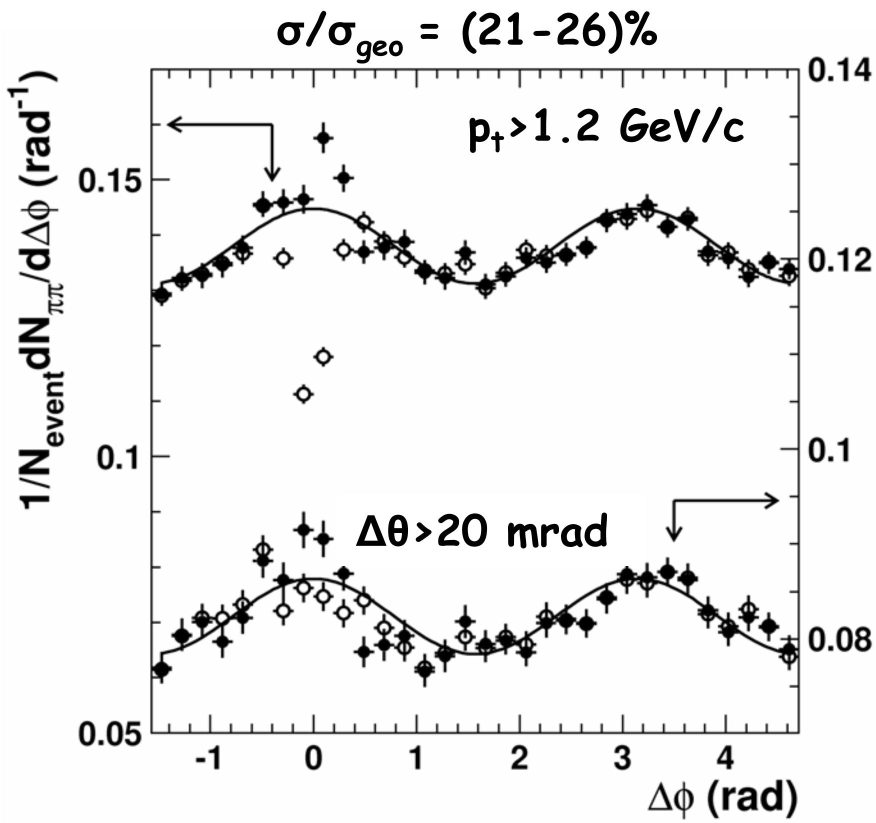


STAR PRL 90, 032301 (2003)

- non-ideal liquid at SPS ?
  viscosity needed (*D.Teaney, E.Shuryak: nucl-th/0204023, nucl-th/0301099)*

- v_2 flattens at p_t~1.5 GeV/c
- v_2(SPS) ~ 2/3 v_2(RHIC)

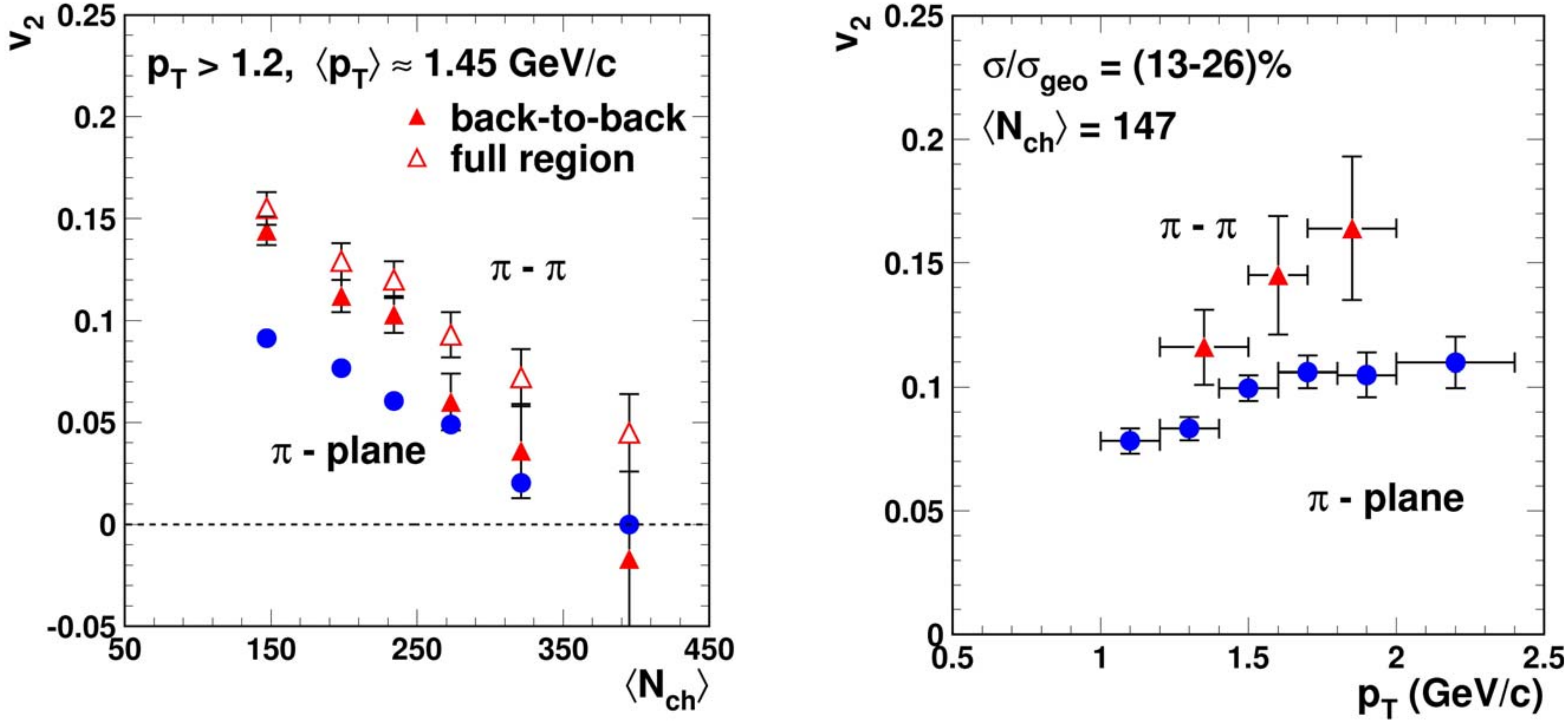
Two-pion azimuthal correlations



open symbols: raw data
closed symbols: MC corrected

- Δφ ~ 0 region strongly affected by two-track resolution (RICH)
  -> Monte-Carlo (MC) correction
- reject tracks close in polar angle (Δθ < 20 mrad) and apply MC correction of efficiency loss

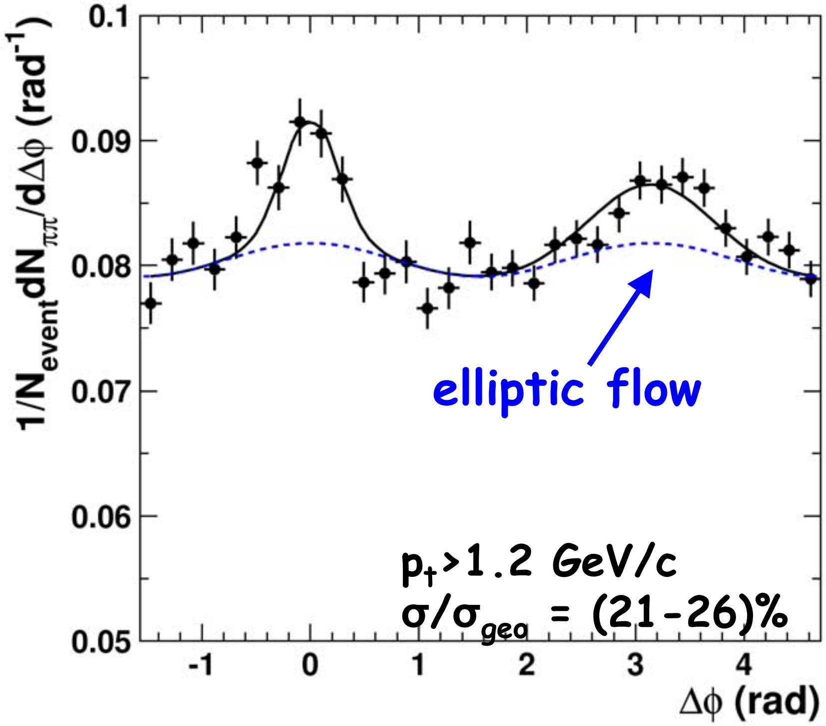
Do both ´v_2´ have same magnitude?



- v_2 from π-π correlation is systematically higher than v_2 from EP analysis
- this difference grows with p_t
- non-flow component is present !

Semihard interpretation of non-flow component

$$\frac{dN}{d(\Delta\phi)} = B(1+2(v_2^{EP})^2\cos(2\Delta\phi)) + A_0 e^{-\frac{\Delta\phi^2}{2\sigma_0^2}} + A_\pi e^{-\frac{(\Delta\phi-\pi)^2}{2\sigma_\pi^2}}$$



Peaks have different widths:

near-side:

σ_0=(0.27±0.05) rad

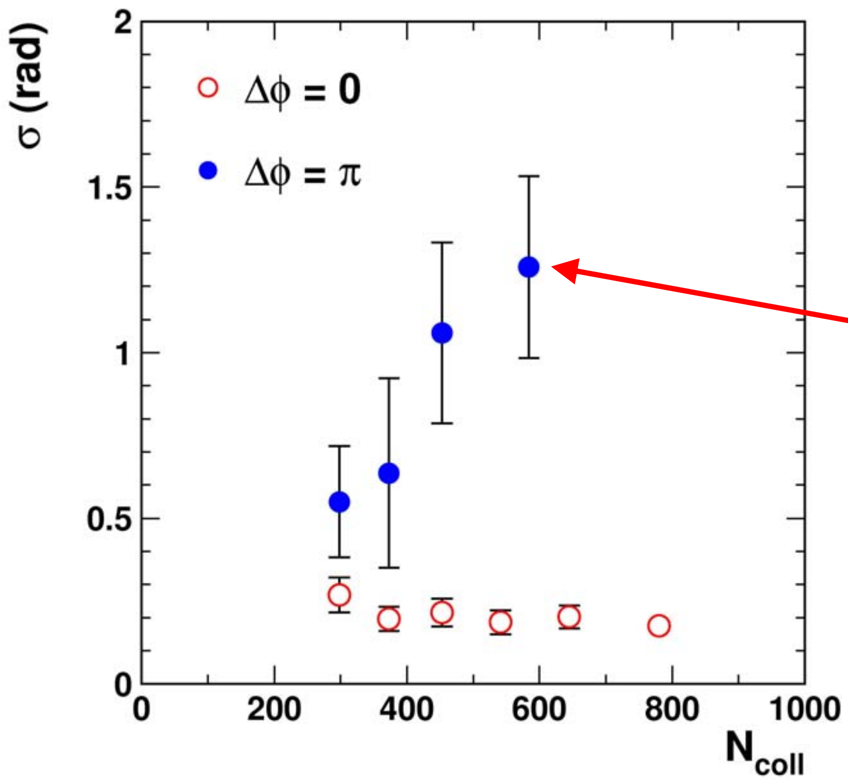
fragmentation ?

away-side:

σ_π=(0.55±0.17) rad

in-medium re-scattering?

Near-side and away-side peaks: centrality dependence of Gaussian widths



- fragmentation

  $\langle|j_{Ty}|\rangle = (190 \pm 25)$ MeV/c

- p_t-broadening

  $\langle|k_{Ty}|\rangle = (2.8 \pm 0.6)$ GeV/c

larger than cold matter in p-A collisions

M.D.Corcoran, PLB259 (1991)

very close to RHIC values

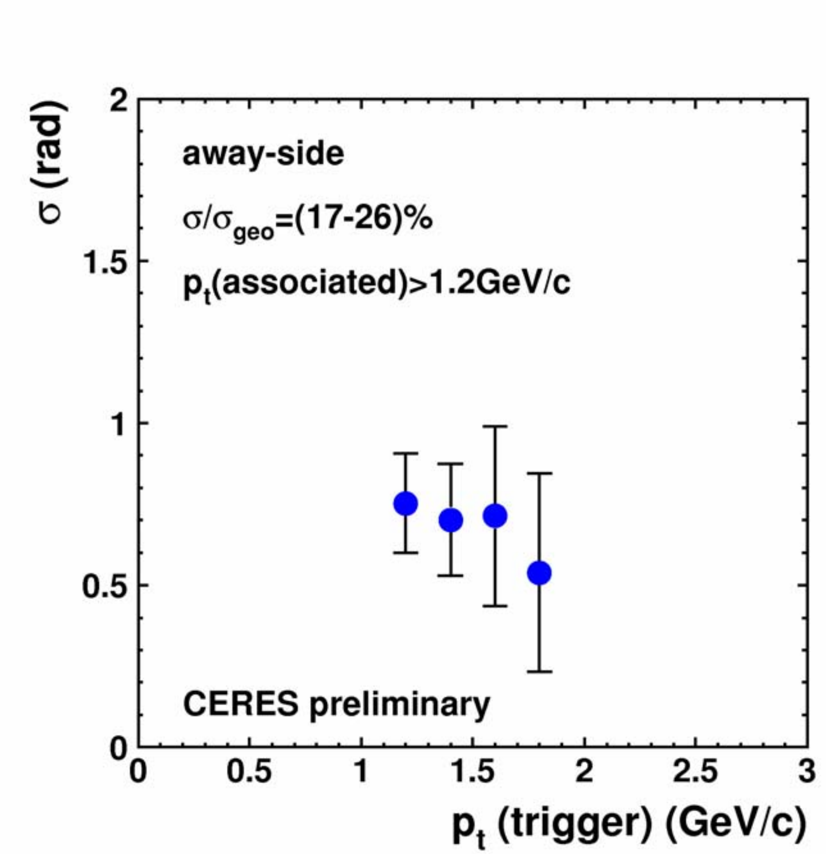
J.Rak (PHENIX), J.Phys.G30 (2004)

σ_0 is constant with centrality

×

σ_π increases with centrality

Near-side and away-side peaks: p_t dependence of Gaussian width

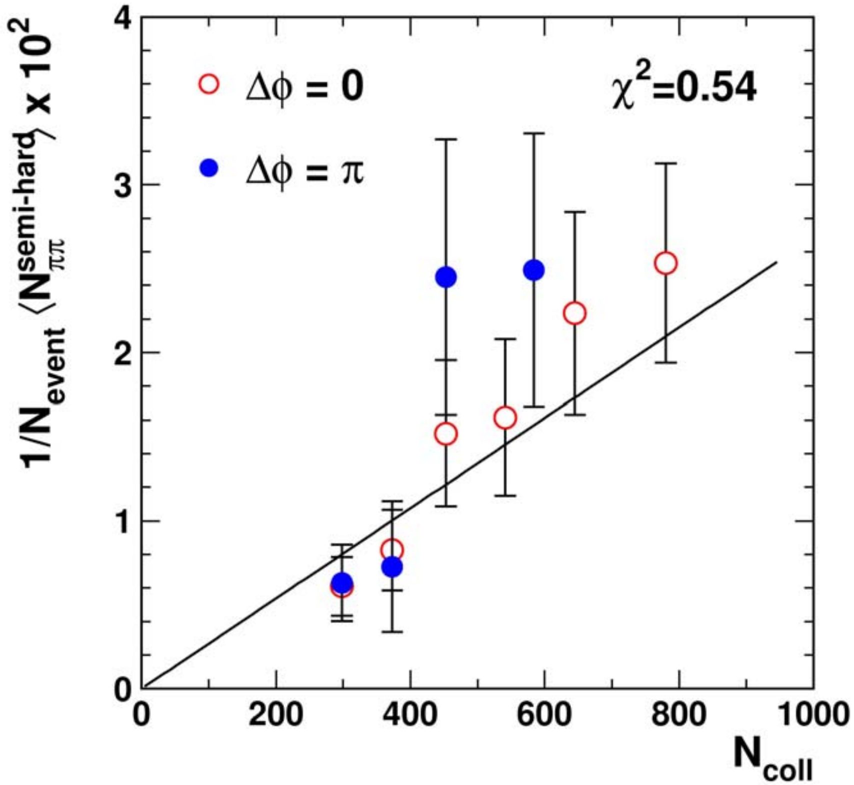


- $\sigma(p_t)$ of away-side peak decreases with increasing p_t(trigger)

  statistical errors large ☹

- $\sigma(p_t)$ of near-side peak under study (Monte-Carlo correction of $\Delta\phi \approx 0$ region vs p_t needed)

Near-side and away-side peaks: centrality dependence of semihard yield

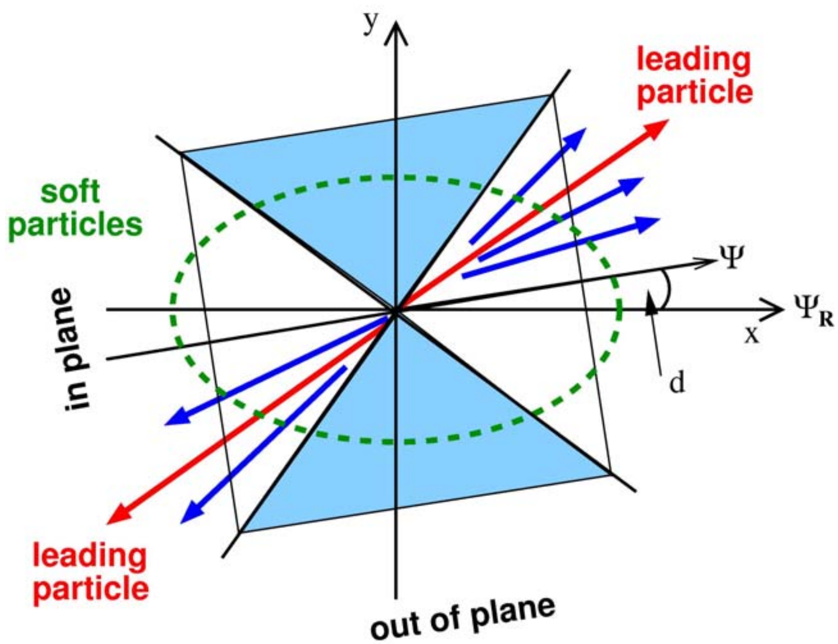


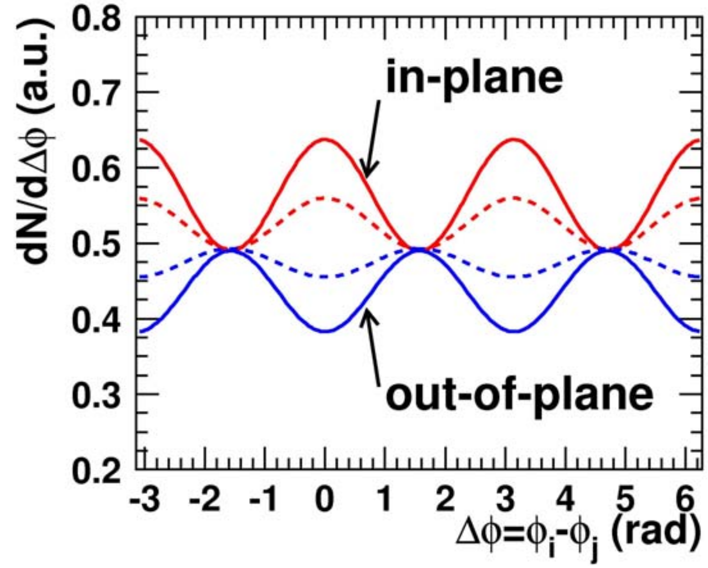
- π-π yield is defined as area under a Gaussian peak
- consistent with binary scaling
- away-side peak disappears in central collisions as at RHIC

STAR: PRL90 082302 (2003)

- no 'jet-quenching'

Are semihard pion pairs correlated with event plane ?



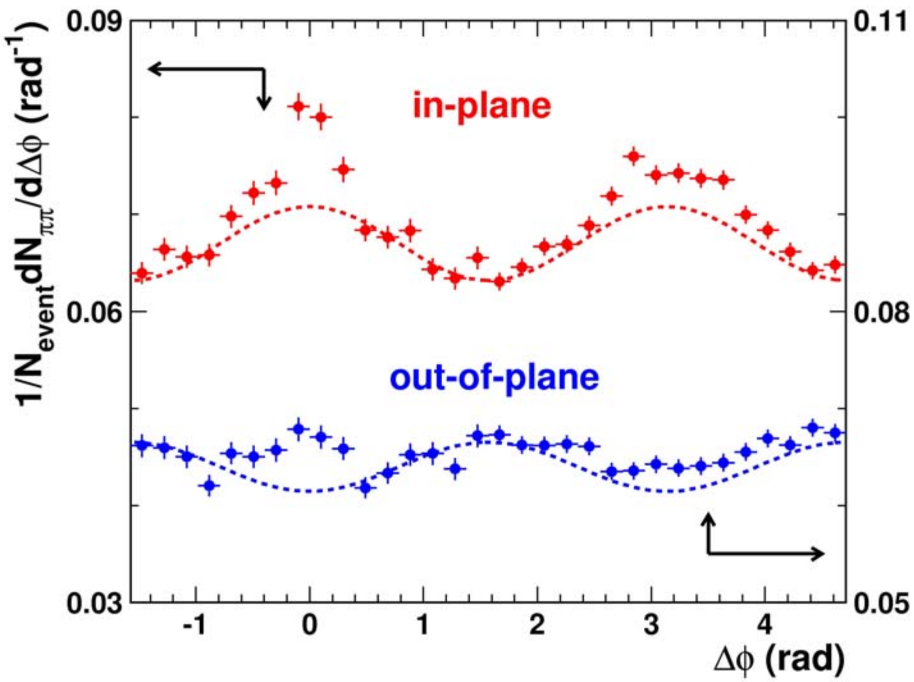


- condition that particle is out-of-plane shifts flow pattern by π/2
- influence of the EP resolution has to be accounted for (dashed)

fix one pion in the in plane (out of plane) cone and look at the correlation

J.Bielcikova, S.Esumi, K.Filimonov, S.Voloshin, J.P.Wurm, PRC69, 021901(2004)

Observed in-plane and out-of-plane azimuthal correlations



dashed line: expectation from elliptic flow

- data lie above the flow reference
- yield in/out-of-plane:
  near-side peak:
  1.32±0.37 (stat.)

  away-side peak:
  1.39±0.44 (stat.)

  syst. error estimate 15%
- weak preference to event plane orientation

Summary

We observe semihard two-particle correlations of charged pions embedded in elliptic flow at the SPS.

Elliptic flow:

- flattens at p_t>1.5 GeV/c (similar to RHIC)
- ideal hydro does not fully describe the data -> non-ideal fluid at the SPS (viscosity needed) ?

Two-particle correlations:

- yield of pion pairs grows with N_{coll}
- away-side peak: centrality dependent broadening
  $\sigma(p_t)$ decreases with p_t
- near-side peak: $\sigma(N_{coll})$ is constant (fragmentation ?)
- both components show a weak preference to the event plane orientation