Flow and non-flow event anisotropies at the SPS

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A study of differential elliptic event anisotropies (v_2) of charged particles and high-p_T pions in 158 AGeV/c Pb+Au collisions is presented. Results from correlations with respect to the event plane and from two-particle azimuthal correlations are compared. The latter give systematically higher v_2 values at $p_T > 1.2$ GeV/c providing possibly an evidence of a non-flow semihard component.

1. MOTIVATION

Systematic investigation of elliptic event anisotropies can shed light on our knowledge of the equation of state and properties of nuclear matter under extreme conditions created in ultra-relativistic heavy-ion collisions. Using a Fourier decomposition of the azimuthal distribution of emitted particles with respect to the event plane angle (Ψ_R) the elliptic anisotropy is quantified by the second Fourier coefficient v_2 [1,2]. However an estimate of the event plane, *a priori* unknown, and dispersion corrections have to be performed [3,4]. An alternative technique [2] circumventing these difficulties is to extract v_2 from the pair-wise azimuthal distribution of the emitted particles since the correlation of particles with the event plane induces correlations among particles into which v_2 enters quadratically. Both methods are sensitive to various 'non-flow' effects [5] and one of our aims here is to investigate contributions of semihard processes.

2. DATA ANALYSIS

A large data set of $42 \cdot 10^6$ Pb+Au collisions at 158 AGeV/c was taken by CERES in 1996 at the top 30% of the geometric cross section. The experiment with its full azimuthal acceptance is well suited to study azimuthal anisotropies of charged particles and high-p_T pions. Charged particles are reconstructed combining the information from two silicon drift detectors (SDD) and a MWPC placed behind the magnetic field. Pions with $p > 4.5$ GeV/c are visible in the RICH detectors ($\gamma_{th} \approx 32$) and distinguished from electrons by a non-asymptotic ring radius. The SDD detectors are used for the event plane measurement by dividing the azimuthal acceptance into 100 samples arranged in 4 groups. The non-uniformities in the Ψ_R-distribution caused by dead regions in the detectors, beam and geometrical offsets are removed by standard correction procedures [3,4]. The correction factors for the event plane dispersion go from 3 to 6 depending on centrality.

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3. CORRELATIONS WITH RESPECT TO THE EVENT PLANE

Elliptic anisotropy of charged particles and high-p_T pions obtained from the event plane analysis has been extensively studied as a function of centrality and p_T [6]. It is found that v_2 is decreasing with centrality (Fig.1). The hydrodynamical calculations [7] overpredict the data.

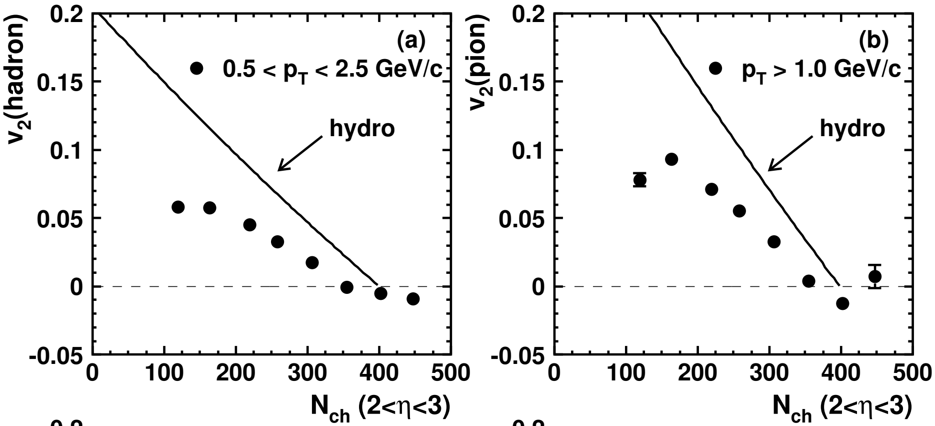

Figure 1. Centrality dependence of v_2 for charged hadrons (a) and pions (b) together with hydrodynamical calculations [7].

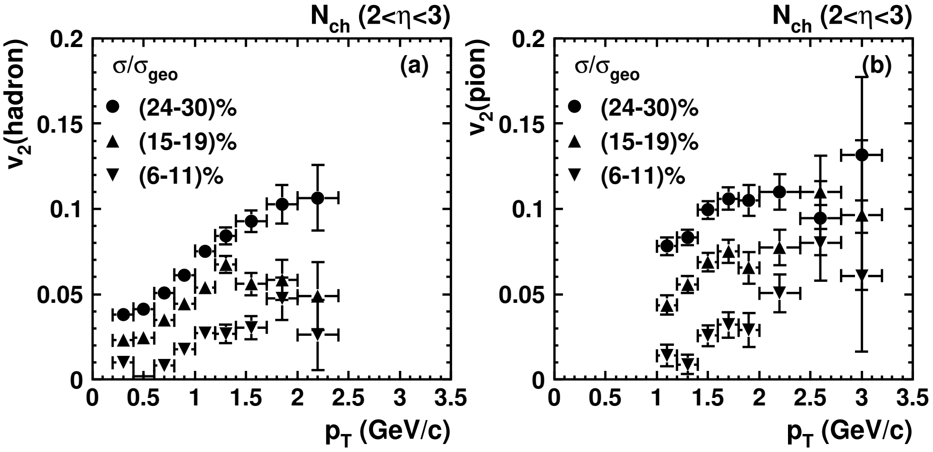

Figure 2. Dependence of v_2 on p_T for charged hadrons (a) and pions (b) for three centrality classes.

The transverse momentum dependence of v_2 for different centrality classes (Fig.2) shows a linear increase which levels off at $p_T \approx 2$ GeV/c. The onset of saturation is clearly visible in the combined data of hadrons and pions in Fig.3, which were corrected for HBT effects [8] calculated with input from [9]. The relative corrections were found to vary between –15% at $p_T = 0.25$ GeV/c and +10% at $p_T > 1$ GeV/c.

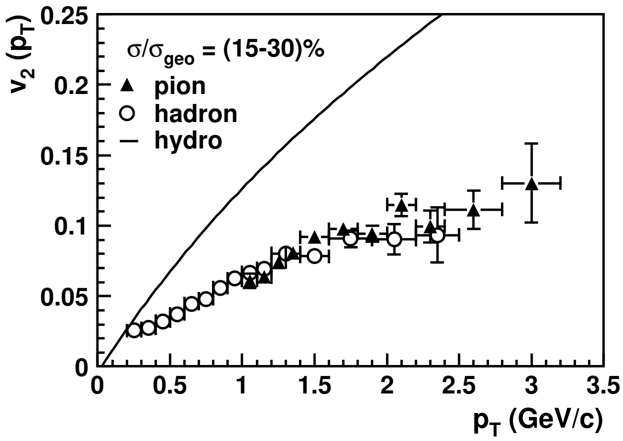

Figure 3. Combined data of $v_2(p_T)$ for charged hadrons and identified pions with hydrodynamical predictions [7]. The data were corrected for HBT effects.

4. TWO-PARTICLE AZIMUTHAL CORRELATIONS

The measured azimuthal correlation of high-p_T pions (p_T >1.2 GeV/c) was corrected for pion detection efficiency and the finite two-ring resolution of the RICH detectors using Monte-Carlo simulations [6]. The p_T-dependence of v_2 parameters obtained from the fit (Eq.(36) of [4]) is presented in Fig.4 and compared to the results from the event plane analysis for both threshold (a) and differential analysis (b). The two-particle correlations

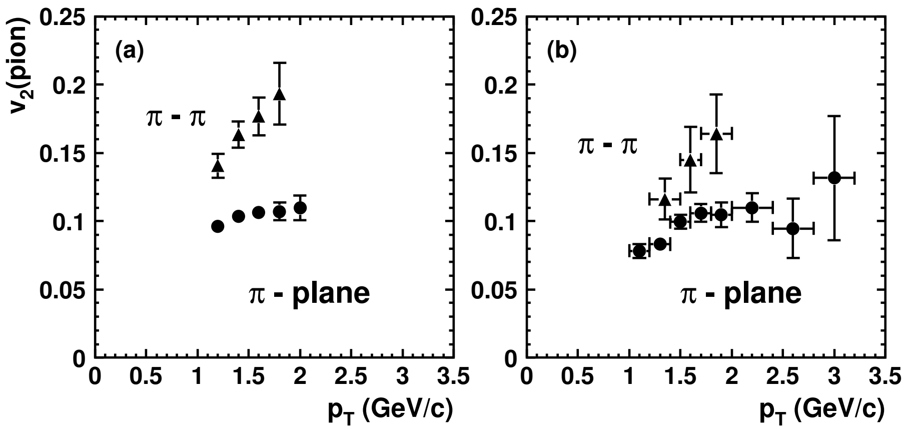

Figure 4. Comparison of v_2 from two-particle correlations and event plane analysis in centrality (24-30)% for all p_T above a certain p_T-threshold given as the abscissa (a) and for differential p_T-bins (b).

show systematically higher v_2 values indicating the presence of a non-flow component, and the observed difference grows with p_T. The ratio $v_2(\pi{-}\pi)/v_2(\pi{-}\text{plane})$ in the semicentral collisions is 1.39±0.07 averaged over the differential points (Fig.4b), which is significant compared to a downward correction due to HBT of ≈10% (not applied).

Assuming the non-flow contribution is due to an additional physics process (e.g. resonance decays, semihard scattering) the data were fitted by two gaussians at $\Delta\phi$=0, π sitting on top of the flow-modulated background (Fig.5). The widths of the gaussian peaks and their centrality dependence are different. The 'back-to-back' peak is broader than the 'near-angle' peak and its width increases with centrality (Fig.6a) whereas the near-angle peak retains its width. The 'non-flow' yield of pion pairs (Fig.6b), which is the sum of the areas under the gaussian peaks calculated from the fit parameters, grows linearly with number of binary collisions (N_{coll}).

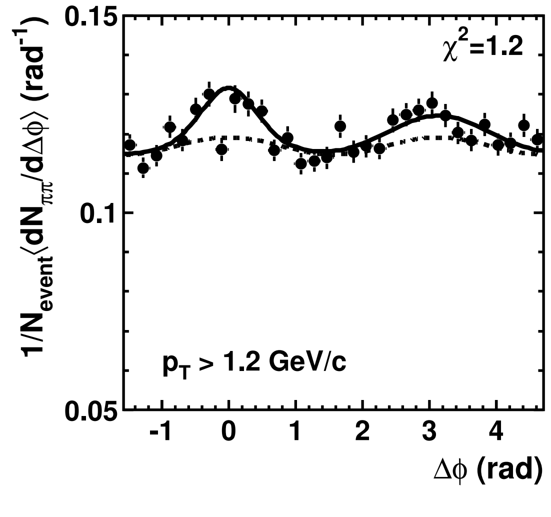

Figure 5. Two-pion azimuthal correlation for $p_T > 1.2$ GeV/c in semicentral collisions (σ/σ_{geo} = (24-30)%) after efficiency correction, where $\Delta\phi$ is the azimuthal angle difference between pairs of emitted particles. The full line is a superposition of a background contribution modulated by elliptic flow (v_2 = (9.0±0.2)% from the event plane analysis, dashed line) and two gaussians around $\Delta\phi$=0,π with amplitudes and widths as free fit parameters.

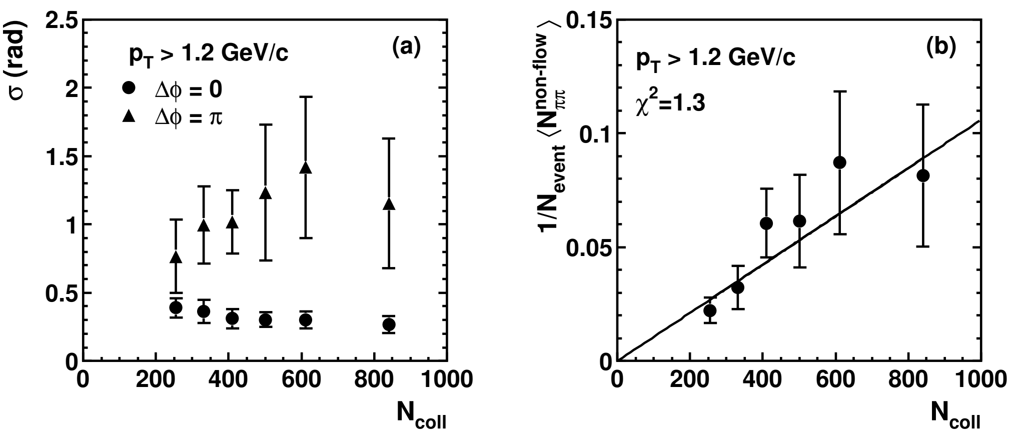

Figure 6. Centrality dependence of the gaussian width of the correlation peaks at $\Delta\phi = 0$ and $\Delta\phi=\pi$ (a) and of the non-flow yield of pion pairs, which is the sum of the areas under the gaussian peaks calculated from the fit parameters (b).

An interpretation of the non-flow component in terms of resonance decays seems rather unlikely in view of the high invariant mass required (≈ 2.5 GeV/c^2). An explanation by minijet production [10] is suggested by $\sigma(\Delta\phi = \pi) \propto N_{coll}$ indicative of semihard rescatterings, $\sigma(\Delta\phi = 0) \approx const.$ as expected for fragmentation, and the scaling of the absolute $\pi - \pi$ yield with N_{coll}.

5. CONCLUSIONS

The presented results on elliptic event anisotropies of charged particles and high-p_T pions cover a wide range of p_T and show a saturation behaviour around $p_T \approx 2$ GeV/c. The observed non-flow component grows with p_T and is significantly larger than potential contribution from the HBT correlations. The data suggest an explanation based on semihard processes.

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