

Strange and charged particle elliptic flow in Pb+Au collisions at 158 AGeV/c

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We present Λ and π elliptic flow measurements from Pb+Au collisions at the highest SPS energy. The data, collected by the CERES experiment which covers $\eta = 2.05, 2.70$ with full azimuthal coverage and wide p_T sensitivity up to 3.5 GeV/c, can be used to test hydrodynamical models and show sensitivity to the EoS. The value of v_2 as a function of centrality and p_T is presented. Values of v_2 observed by STAR at RHIC are larger by about 1/3. Our measurements are compared to results from other SPS experiments and to hydrodynamical calculations. Huge statistics allows for a precise measurement of the differential pion elliptic flow.

1. INTRODUCTION

Elliptic flow is described by the differential second Fourier coefficient of the azimuthal momentum distribution $v_2(\mathcal{D}) = \langle \cos(2\phi) \rangle_{\mathcal{D}}$ [1,2]. The brackets denote averaging over many particles and events, and \mathcal{D} represents a phase-space window in the (p_T, y) plane in which v_2 is calculated. The azimuthal angle ϕ is measured with respect to the reaction plane defined by the impact parameter vector \mathbf{b} and the beam direction. For non-central collisions ($b \neq 0$), v_2 is an important observable due to its sensitivity to the EoS, and through it to a possible phase transition to the QGP. The $v_2(\Lambda)$ is important because Λ is a baryon and in comparison to other particle species could be used to check the mass ordering effect and to compare it with hydrodynamical predictions which depend on EoS used. Testing the differential flow measurements of different particle species against different scaling scenarios may yield additional information about the origin of flow.

2. EXPERIMENT

The CERES experiment consists of two radial Silicon Drift Detectors (SDD), two Ring Imaging Cherenkov (RICH) detectors and a radial drift Time Projection Chamber (TPC). Due to its full azimuthal coverage close to mid-rapidity the CERES spectrometer is ideally suited for elliptic flow studies. The SDDs located behind the target were used for the tracking and vertex reconstruction. The purpose of the RICH detectors is electron identification and they were not used in this analysis. The $v_2(p_T)$ was studied in the range $0.05 < p_T < 3.5$ GeV/c using the TPC which is operated inside a magnetic field, providing a precise determination of the momentum. A more detailed description of the CERES experiment can be found in [3]. As data, we used $3 \cdot 10^7$ Pb+Au events at 158 AGeV/c

collected in the 2000 data taking period. 91.2% of events were triggered on $\sigma/\sigma_{geo} \leq 7\%$, while only 8.3% events with $\sigma/\sigma_{geo} \leq 20\%$.

3. METHOD OF Λ RECONSTRUCTION

The Λ particles were reconstructed via the decay channel $\Lambda \rightarrow p + \pi^-$ with a $BR = 63.9\%$ and $c\tau_0 = 7.89$ cm. As candidates for Λ daughters, only those TPC tracks were chosen which have no match to an SDD track. Partial PID was performed using dE/dx information from the TPC by applying a window around the momentum dependent Bethe-Bloch value for pions and protons, respectively. On the pair level, a p_T dependent opening angle cut is applied, in addition to a cut in the Armenteros-Podalanski variables ($q_T \leq 0.125$ GeV/c and $0 \leq \alpha \leq 0.65$) to suppress K_S^0 .¹

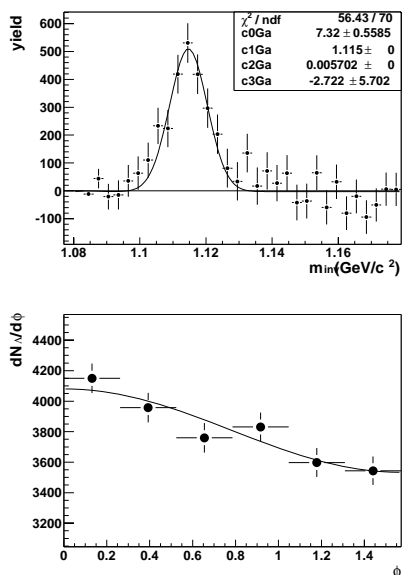


Figure 1. Top: Λ reconstructed for $1.62 \leq y \leq 1.69$, $0.675 \leq p_T \leq 0.8$ GeV/c and $15^\circ \leq \phi \leq 30^\circ$. Bottom: Elliptic flow pattern reconstructed from the Λ yield in ϕ bins for $p_T \approx 2.7$ GeV/c.

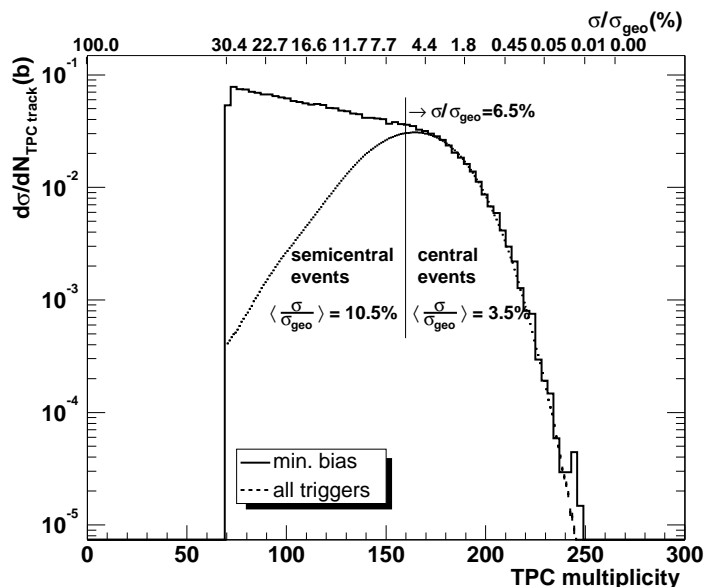


Figure 2. Determination of the centrality of events used in the analysis. The weighted mean centrality $\langle \frac{\sigma}{\sigma_{geo}} \rangle$ is calculated for 2 centrality bins. dotted: trigger data, solid: minimum bias sample.

In order to remove the effect of autocorrelation, tracks which were chosen to be candidates for daughter particles were not used for determination of the reaction plane orientation. The combinatorial background was determined by ten random rotations of positive daughter tracks around the beam axis and constructing the invariant mass distribution.

An example of reconstructed Λ in a given y - p_T - ϕ bin is shown in Fig. 1 (top). We used the area under the peak in the invariant mass distribution to measure the yield of Λ s in the given y - p_T - ϕ bin. Plotting the yield versus ϕ for different p_T and y values one can construct $dN_\Lambda/d\phi$ distribution (Fig. 1, bottom). Fitting these distributions with a

¹With these cuts optimal values for $S/B \approx 0.04$ and $S/\sqrt{B} \approx 500$ were obtained (S stands for the signal and B for the background).

function $c[1 + 2v'_2 \cos(2\phi)]$, it is possible to extract the observed elliptic flow values v'_2 for different p_T and y . The obtained v'_2 coefficients were corrected for the reaction plane resolution via $v_2 = v'_2 / \sqrt{2\langle \cos[2(\Phi_1 - \Phi_2)] \rangle}$ [4]. The resolution goes from 0.16 to 0.31.

4. RESULTS

The elliptic flow analysis was performed for two centrality classes, defined in Fig. 2, and the resulting p_T dependence of $v_2(\Lambda)$ is shown in Fig. 3. One can see a clear difference in the flow intensity between central and semicentral events. The absolute systematic

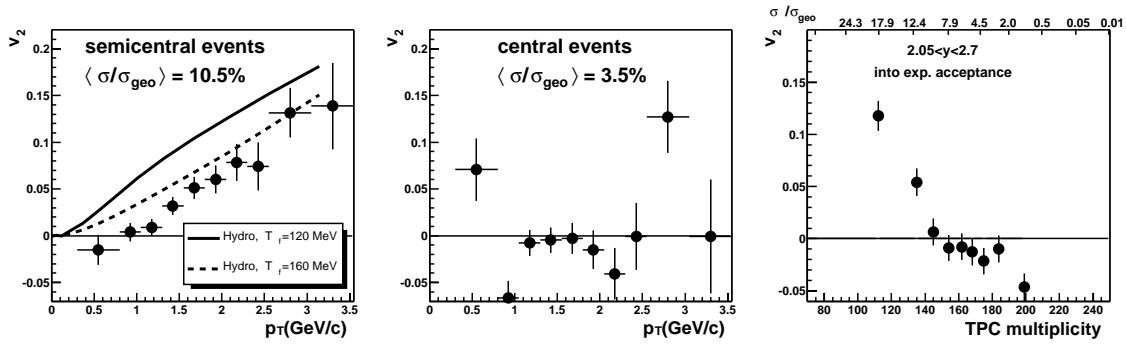


Figure 3. p_T dependence of $v_2(\Lambda)$ for semicentral (left) and central (middle) collisions. Centrality dependence of the Λ elliptic flow (right).

error Δv_2 , estimated by varying the applied cuts, is $^{+0.001}_{-0.007}$ for $p_T < 1.6$ GeV/c and $^{+0.00}_{-0.02}$ for $p_T > 1.6$ GeV/c which is small compared to the statistical errors. The decrease of $v_2(\Lambda)$ with σ/σ_{geo} is displayed in Fig. 3 (right). Fig. 3 (left) also shows a comparison

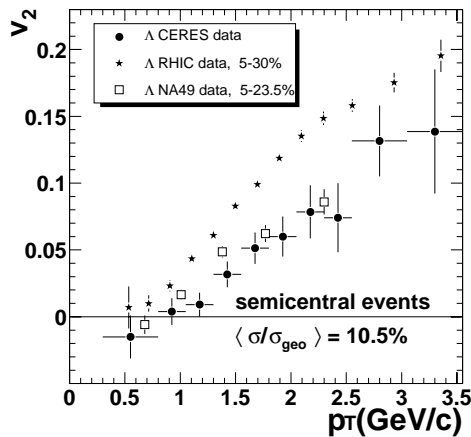


Figure 4. Comparison of $v_2(\Lambda)$ measured by CERES, STAR, and NA49.

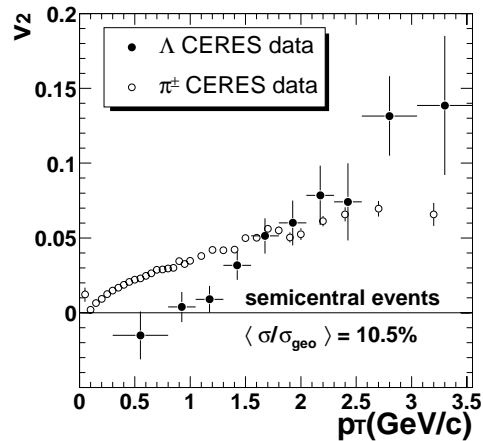


Figure 5. Comparison between Λ and π elliptic flow measured with CERES.

between our results and hydrodynamical calculations [5], assuming a 1-st order phase transition at a critical temperature of 165 MeV. The model prediction with a higher freeze-out temperature of $T_f = 160$ MeV is close to the CERES data, while $T_f = 120$ MeV

overpredicts the data. The same is observed comparing the pion flow from CERES to the same hydrodynamical model [6].

A comparison of the CERES data to results from NA49 [7] at the same energy ($\sqrt{s_{NN}} = 17$ GeV) and to STAR results [8] at $\sqrt{s_{NN}} = 200$ GeV is shown in Fig. 4. The NA49 and CERES data are in a very good agreement. The v_2 values measured at the RHIC energy are 30 – 50% higher. Partly, this is due to an effectively higher centrality in CERES as compared to the STAR experiment.

The elliptic flow coefficients measured for Λ and π detected with CERES are compared in Fig. 5. At small p_T , $v_2(\pi) > v_2(\Lambda)$, while it is opposite in case of high p_T . Two

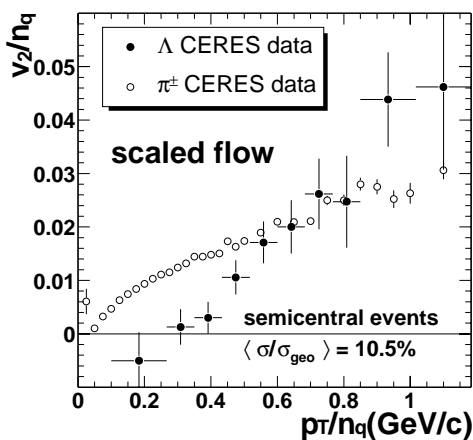


Figure 6. Comparison between Λ and π elliptic flow scaled to the number of constituent quarks.

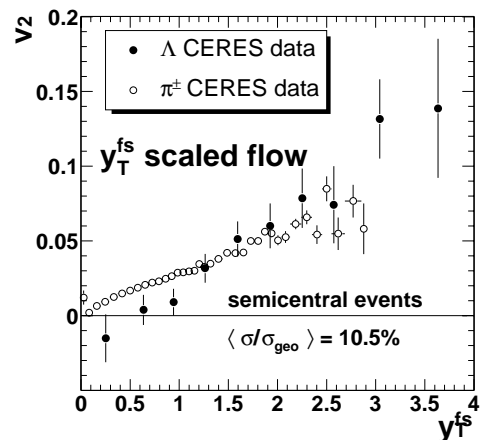


Figure 7. Comparison between Λ and π elliptic flow scaled with respect to y_T^{fs} variable.

flow scaling hypotheses were proposed. One by dividing v_2 and p_T by the number of constituent quarks [8] and the other one using flavor transverse rapidity, defined with $y_T^{fs} = k_m y_T^2 m$, instead of the transverse momentum [9]. The application of these scaling hypotheses on CERES data is shown in Fig. 6 and Fig. 7. The constituent quark scaling works approximately for $p_T \geq 1.5$ GeV/c and fails for pions of lower transverse momenta, as is observed at RHIC [8]. The transverse rapidity scaling is fulfilled reasonably well.

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