Anisotropic Azimuthal Distributions of Identified Particles in Au+Au Collisions at 11.5 A GeV/c

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Anisotropy in the azimuthal distribution of the reaction products in heavy-ion collisions is an important observable which, in particular, contains information on the evolution and amplitude of the pressure gradient in the compressed nuclear matter formed in the collision and thus on its equation of state. It was first observed in ultra-relativistic collisions in 1994 and is now considered one of the best tools to elucidate the dynamics of heavy-ion collisions.

In this contribution we present recent results on the study of azimuthal distributions of produced particles in Au+Au collisions at 11.5 A GeV/c obtained from the analysis of the last E877 data taking run in 1995. Other E877 results on the flow of particles, particularly on the elliptical flow, are also presented in the contribution of K. Filimonov at this conference.

1. EXPERIMENTAL METHOD

The E877 set-up is discussed in detail in [3, 4]. The azimuthal anisotropy of the particle production is studied by means of Fourier analysis of the azimuthal particle distributions measured with respect to the reaction plane orientation [7]. In this representation, the dipole ($v_1$) and the quadrupole ($v_2$) coefficients in the Fourier decomposition represent the shift (directed flow) and the eccentricity (elliptical flow) of the particle azimuthal distribution.

In E877, the reaction plane angle is determined for every event using the direction of the transverse energy flow measured in calorimeters surrounding the target. The details of this procedure are given in [4]. The measured anisotropies are corrected for the reaction plane resolution.

2. RESULTS

Results on the directed flow of protons, pions and light nuclei have been published previously [5, 6]. It was shown, in particular, that in semicentral Au+Au collisions, protons exhibit strong directed flow that is well reproduced by RQMD if the effects of mean-field are included. Here we present results on flow measurements of other produced particles.

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Model calculations show that the kaon flow is sensitive to the value of the kaon potential in the nuclear medium [8]. In Fig. 1 we present the measured directed flow amplitude \( v_1 \) as a function of \( p_t \) for \( K^+ \). The \( K^+ \) flow signal is weak but clearly negative, i.e in the direction opposite to that of protons. The measured \( K^+ \) directed flow is in good agreement with the predictions of RQMD 2.3 run in cascade mode whereas the agreement is not as good when the effect of mean field is included.

In the same rapidity window \( K^- \) show, within error, a smaller flow than \( K^+ \) (See Fig. 4 in [2]). This result is contrary to the predictions of RQMD which predict a larger negative flow for \( K^- \) than for \( K^+ \).

It was shown that the \( \Lambda \) flow in heavy-ion collisions is sensitive to the properties of \( \Lambda \)-hyperons in dense matter [9]. Using information from new upstream tracking chambers added to the E877 set-up for the 1995 running period, we could isolate secondary decay vertices and identify \( \Lambda \)'s through the reconstruction of \( p\pi^- \) pairs (Fig 2). Due to the limited angular acceptance of the E877 spectrometer we are mainly sensitive to \( \Lambda \)'s emitted at forward rapidity (\( y > 2.2 \)) and the total geometrical acceptance for the produced \( \Lambda \)'s is of the order of \( 10^{-3} \). A further reduction of about a factor of ten in the efficiency for detecting \( \Lambda \)'s results from additional cuts that are introduced in the analysis to reduce the background from uncorrelated tracks.

The azimuthal distribution of \( \Lambda \)'s for semicentral collisions (Fig. 3) shows a clear positive anisotropy for the most forward rapidity window. Interpretation of the \( v_1(p_t) \)-dependence

\[
M_{\Lambda} = 1.116 \pm 0.001 \text{ GeV/c}^2
\]
\[
\sigma_{\Lambda} = 3.10 \pm 0.17 \text{ MeV/c}^2
\]
is limited due to low statistics. However, one can conclude that the measured $p_t$ dependence is consistent with the predictions of RQMD(2.3) with, as in the case of $K^+$, a better description being observed for the pure cascade calculation.

The production of antiprotons at AGS energies is near threshold in the nucleon-nucleon rest frame. The yield and distribution of $\bar{p}$ is the result of both the production and subsequent annihilation. Antiprotons co-moving with the nucleons have a greater probability of annihilation and rescattering resulting in an anticorrelation with the nucleon directed flow leading to the so-called anti-flow of antiprotons in nuclear collisions predicted in [10].

The addition of the new tracking detectors has allowed a clean identification of $\bar{p}$ with however limited statistics due to the small $\bar{p}$ production cross section. Because of the amplitude of the spectrometer magnetic field selected in 1995 the acceptance for $\bar{p}$ is close to mid rapidity where the directed flow signal is minimal. To optimize a possible flow signal we are presenting the measured azimuthal distribution of $\bar{p}$ emitted at rapidity $y>1.8$ which leaves about 400 $\bar{p}$ in the sample. The azimuthal distribution of antiprotons with respect to the reaction plane measured in the forward rapidity ($1.8<y<2.2$) for two centralities is shown in Fig 4. For clarity, taking into account that for reason of

Figure 3. (left) Lambda azimuthal distribution at forward rapidity. (right) Comparison of $v_1(p_t)$ of Lambdas with the predictions from RQMD(v2.3) run in cascade (dashed lines) and mean-field (full lines) modes.

Figure 4. Antiproton azimuthal distribution at forward rapidity.
symmetry the distribution has to be symmetric about $\phi=0$, the data in the angular range $[-\pi,0]$ have been averaged with the data in the range $[0,\pi]$ and the resulting data have been reflected about $\phi=0$. A pronounced minimum is observed at $\phi=0$ for semicentral collisions indicating that the antiprotons are, as predicted, strongly anticorrelated with the nucleons. The corresponding transverse momentum dependence of $v_1$ is presented in [2]. The observation of the large $\bar{p}$ antiflow confirms that strong annihilation processes are involved in the dense nuclear matter and more precise data could provide a better understanding on how this annihilation is modified in the nuclear medium.

The larger statistics obtained in 1995 has allowed to obtain more extensive data on the elliptic flow of produced particles. Fig. 5 presents the measured $v_2(p_t)$ of forward rapidity pions as function of centrality. Both pion types exhibit a similar behaviour within experimental uncertainties. Weak positive values of $v_2$ are observed with larger signals for peripheral collisions. This corresponds to an elliptically shaped distribution with the major axis lying in the reaction plane. This is opposite to what is observed at lower beam energies [11].

Financial support from US DoE, the NSF, the Canadian NSERC, is acknowledged.

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