Conference Paper

Elliptic flow of π^- measured with the event plane method in Pb-Pb collisions at 40A GeV in the NA49 experiment at the CERN SPS

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Abstract

The measurement of elliptic flow for negatively charged pions in Pb-Pb collisions at beam energy of 40A GeV performed with the fixed target experiment NA49 at the CERN SPS is presented. Results are compared with measurements at similar energies by the STAR experiment at RHIC. Elliptic flow is measured using the event plane method. The event plane angle is estimated using negatively charged pion tracks reconstructed in the Time Projection Chambers (TPC) and from energies measured in the cells of the Ring Calorimeter (RCAL). In future, these results will be used as a reference for flow measurements in the lead ion energy scan program of the NA61/SHINE experiment at the CERN SPS.

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1. Introduction

Hot and dense matter is produced in heavy-ion collisions at relativistic energies. Anisotropic expansion of this matter results in azimuthal asymmetry of particle production relative to the reaction plane, the so-called azimuthal anisotropic flow. Azimuthal anisotropic flow as result of non-central nuclear collisions is a very informative observable closely linked with the properties of the created matter.

To quantify the anisotropic flow a standard Fourier decomposition of the distribution of the azimuthal angle ϕ of particles with respect to the n-th harmonic reaction planes Ψ_n is used:

$$\frac{Ed^3N}{d^3p} = \frac{1}{2\pi}\frac{d^2N}{p_T dp_T dy}\left(1 + \sum_{n=1}^{\infty} 2v_n \cos(n(\phi - \Psi_n))\right), \tag{1}$$

where v_n is the n-th harmonic flow coefficient and Ψ_n is the n-th harmonic symmetry plane determined by the initial geometry of the system. The second harmonic in this decomposition is called the elliptic flow.

2. The NA49 experiment

The scientific goal of the NA49 experiment [1], which recorded data in 1994-2002, was to create an extended "quark-gluon-plasma" state of strongly interacting matter and search for indications of a critical point. NA49 was one of the fixed target experiments at the CERN SPS accelerator.

Four large volume time projection chambers (TPC) are the main components of the experimental setup [1]. They were used for measurement and identification of charged particle tracks. The ring calorimeter (RCAL) with pseudorapidity acceptance $2.1 < \eta < 3.4$ is a cylinder shaped calorimeter, subdivided into 240 cells, configured in 10 radial rings and 24 azimuthal sectors. It was used for transverse energy and elliptic flow measurements.

3. Elliptic flow measurement

The current analysis used Pb+Pb collision events at 40A GeV energy with statistics of 360K events before selection cuts. 120K events passed the interaction vertex selection. Track selection is based on information from the TPCs. Transverse momenta of all charged particles are restricted to $0 < p_T < 2.5$ GeV/c and pseudorapidity in the range $1.4 < \eta < 5$. Only tracks with number of charge clusters in the TPCs of more than 55% of the maximal possible number are used to avoid "track splitting". A cut on the so-called track impact parameter, the distance between the reconstructed main vertex and the back extrapolated track in the target plane $|b_x| < 2cm$ and $|b_y| < 1cm$, is applied to reduce the contribution of secondary particles. The number of possible measured points in one of the Vertex TPCs was required > 20 and in the MTPC > 30. To select tracks with good fit quality a cut $\chi^2 < 10$ is applied. Event classes are based on the TPC multiplicity distribution parameterized with the Modified Wounded Nucleon model also known as MC-Glauber [2].

3.1. Event plane corrections

Evaluation of the symmetry plane angle is based on flow vectors [3]:

$$Q_2 \cos 2\Phi_2 = Q_{2x} = \sum_{i=1} \omega_i \cos(2\phi_i), \quad (2)$$

$$Q_2 \sin 2\Phi_2 = Q_{2y} = \sum_{i=1} \omega_i \sin(2\phi_i), \quad (3)$$

where the weights ω_i are the transverse momentum of tracks from the TPCs or the energy deposited in the modules of the RCAL and ϕ_i is the azimuthal angle of positively charged particles or the calorimeter cells.

Then, the event plane angle Φ_2 is estimated according to the formula:

$$\Phi_2 = \frac{1}{2} TMath :: ATan2(Q_{2y}, Q_{2x}). \tag{4}$$

Next, the recentering procedure [3] was applied for each 5% centrality window in order to correct non-uniform detector acceptance:

$$Q^{rec}_{2x(y)} = Q_{2x(y)} - \langle Q_{2x(y)} \rangle. \tag{5}$$

Finally, the flattening procedure was applied to remove higher order fluctuations [3]:

$$2\Delta\Phi_2 = \sum_{m=1}^{5} \frac{2}{m} \left[-\langle \sin(2m\Phi_2) \rangle \cos(2m\Phi_2) + \langle \cos(2m\Phi_2) \rangle \sin(2m\Phi_2) \right]. \tag{6}$$

3.2. Event plane resolution correction

Two and three subevent methods were used to determine the event plane resolution correction R_2 for elliptic flow measurement from the TPCs and RCAL using the following formulae [3]:

$$M_2\{A, B\} = \langle \cos(2(\Phi_{2,A} - \Phi_{2,B})) \rangle, \tag{7}$$

$$R_2\{A, B\} = \sqrt{2M_2\{A, B\}}, \tag{8}$$

$$R_2^C\{A, B\} = \sqrt{\frac{M_2\{B, C\} M_2\{A, C\}}{M_2\{A, B\}}}, \tag{9}$$

where subevent A and B are random subevents from the TPCs and C a subevent from RCAL. Results for R_2 are plotted in Fig. 1.

3.3. Results

Elliptic flow coefficients of negatively charged pions measured with the event plane method [3] are shown in Fig . 2 and Fig . 3 for different event classes and detectors. The values of v_2 were calculated as:

$$v_2 = \frac{\langle cos(2(\phi_\pi - \Phi_2^{corr})) \rangle}{R_2}, \tag{10}$$

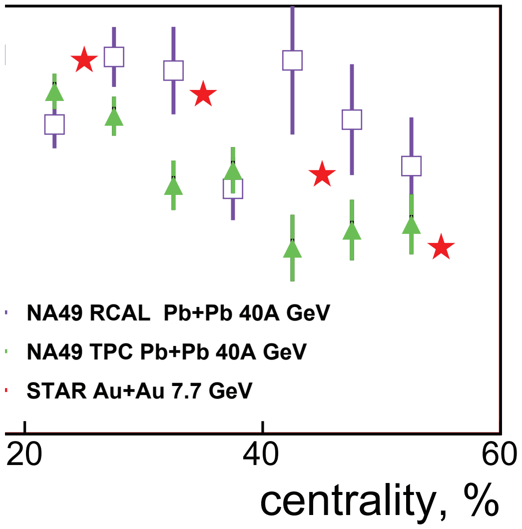

Figure 1: Resolution correction factors R_2 for elliptic flow in the NA49 and STAR experiments.

where ϕ_π is the azimuthal angle of negatively charged pions, Φ_2^{corr} is the event plane angle determined with Eq.(4) with applied corrections from Eqs.(5),(6). Results from TPC and RCAL were further corrected by the R_2 resolution factor Eqs.(8),(9) appropriate for the respective detector.

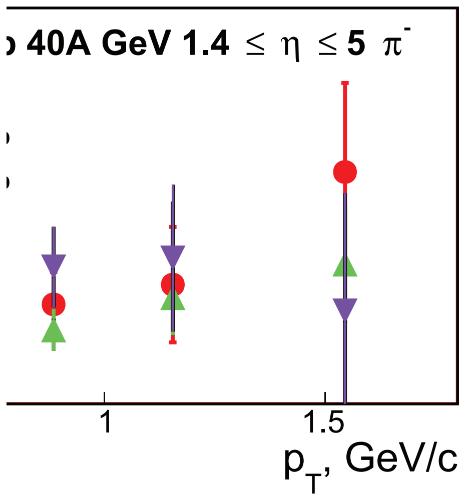

Figure 2: Elliptic flow of negatively charged pions determined with event plane from the TPCs as function of transverse momentum for different event classes (preliminary).

Measured elliptic flow of negatively charged pions from the NA49 experiment is compared with results from the STAR collaboration in Fig. 4. Results on v_2 measured by STAR at RHIC [4] and reanalyzed from NA49 data using the TPC event plane are seen to

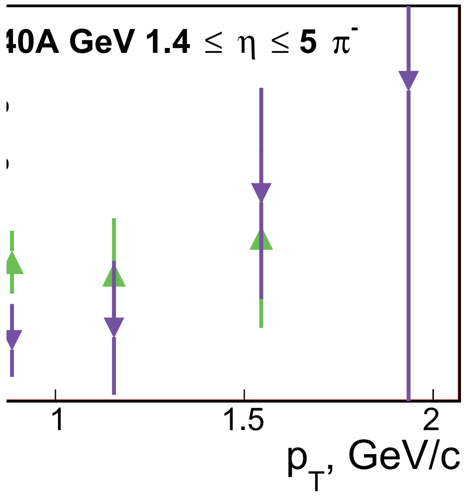

Figure 3: Elliptic flow of negatively charged pions determined with event plane from the RCAL as function of transverse momentum for different event classes (preliminary).

be consistent. The values of $v_2\{EP\ RCAL\}$ are systematically lower than $v_2\{EP\ TPC\}$. Further investigations are required.

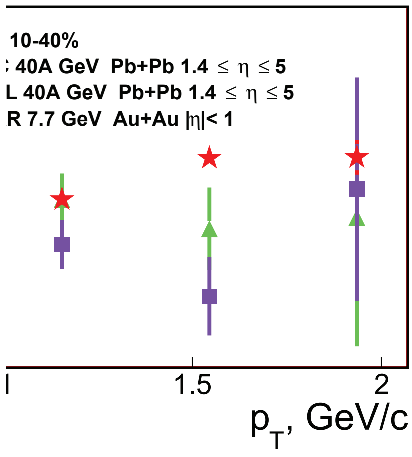

Figure 4: Elliptic flow of negatively charged pions for 10-40% centrality from the NA49 (preliminary) and STAR experiments.

4. Summary

Elliptic flow $v_2(p_T)$ is measured using the event plane method with the event plane estimated from the TPC and RCAL detectors. Detector non-uniformity is corrected using recentering and flattening procedures. Results are compared with published data from the STAR experiment. In future, these results will be used as reference for flow measurements from the lead ion energy scan program of the NA61/SHINE experiment at the CERN SPS [5].

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