Conference Paper

Procedure for event characterization in Pb-Pb collisions at 40A GeV in the NA49 experiment at the CERN SPS

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Abstract

The time evolution of the strongly interacting matter created in a heavy-ion collision depends on the initial geometry and the collision centrality. This makes important the experimental determination of the collision geometry. In this paper a procedure for event classification and estimation of the geometrical parameters in inelastic Pb-Pb collisions at the beam energy of 40A GeV recorded with the fixed target experiment NA49 at CERN SPS is discussed. In the NA49 experiment, event classes can be defined using measured multiplicity of particles in the Time Projection Chambers (TPC) or energy of spectators deposited in the forward Veto or Ring calorimeters. Using the Monte-Carlo Glauber model, these event classes can be related to average values of the geometric quantities such as impact parameter or number of nucleon-nucleon collisions. The implementation of this procedure within a software framework of the future CBM experiment was adopted for event classification in the NA49 experiment. In future, this procedure will be used for analysis of the new Pb-Pb data collected by the NA61/SHINE experiment and for comparison with the results previously obtained by STAR at RHIC and NA49 at the CERN SPS.

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1. Introduction

In relativistic heavy ions collisions, strongly-interacting matter is formed at high temperatures and densities. The initial geometry of two nuclei in the collision affects its evolution. The region of the nuclei overlapping after the collision depends on the impact parameter, which is the length of the vector connecting the centers of the two colliding nuclei. Event classes are used to study the geometry of collisions. A more central collision corresponds to a higher multiplicity of the produced particles and a lower energy in spectators. The Glauber model is used to map the event classes to a range of model parameters, i.e. impact parameter, number of participant nucleons and number of nucleon-nucleon collisions which can not be measured in the experiment. In the NA49 experiment, the event classes can be determined using the multiplicity of the produced particles and/or the energy in spectators.

2. NA49 experimental setup

Main components of the NA49 experimental setup are four large-volume time projection chambers (TPC). The vertex TPCs VTPC-1 and VTPC-2, are placed in the magnetic field of two superconducting dipole magnets VTX-1 and VTX-2. The other two TPCs (MTPC-L and MTPC-R) are positioned downstream of the magnets. The TPCs serve to measure multiplicity of produced charged particles. A Veto Calorimeter placed about 20 m downstream of the target behind a collimator measures the energy carried by spectators [1].

The data on Pb+Pb collisions at 40A GeV were collected within the energy scan program at the CERN SPS. After event selection 120K events remain for further analysis. To ensure good fit quality tracks are required to have a fit χ^2 in the range $0 \leq \chi^2 \leq 10$. It is further required that tracks contain at least 55% of the maximum possible number of points to avoid split tracks. Tracks are further required to have distances of closest approach at the interaction vertex of $|b_x| < 1cm$, $|b_y| < 2cm$. At least in one of the detectors the number of hits should exceed 20 in the VTPCs and 30 in the MTPC. Kinematic cuts select particle pseudorapidity in $1.4 \leq \eta \leq 5$ and transverse momentum $0 < p_t < 2.5$ GeV.

3. Centrality determination procedure

In current analysis Modified Wounded Nucleon model (MWN) [2] was used to map particle yield of event to geometrical quantities of the initial state. MWN originates from Glauber MC model and describes procedure of mapping between MC results and experimental data. According to MWN emitted particles are produced by a set of ancestors with negative binomial distribution. MWN suggests the following form of multiplicity distribution

$$\frac{dN_{ev}}{dM_{trk}}(f_M, \mu, \sigma) = P(\mu, \sigma) \times N_a = P(\mu, \sigma)[f_M N_{part} + (1 - f_M) N_{coll}] \quad (1)$$

where f_M, μ, σ – free parameters of the distribution; μ, σ – mean value and width of negative binomial distribution, respectively. N_{part} is a number of participants, N_{coll} – number of binary collisions.

Similarly one can write probability density of spectators energy as follows

$$\frac{dN_{ev}}{dE_{spec}}(f_E, \mu, \sigma) = P(\mu, \sigma)[f_E N_{part} + (1 - f_E)N_{specA}], \quad (2)$$

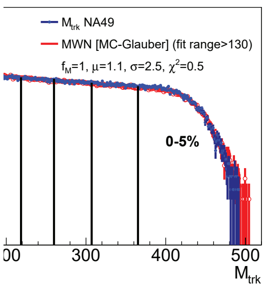
Assuming M_{trk} and E_{spec} independent one can build 2-dimensional distribution as $dN_{ev}/dM_{trk}dE_{spec}[f_M, f_E, \mu, \sigma] = dN_{ev}/dE_{spec} \times dN_{ev}/dM_{trk}$. Experimental distribution of multiplicity was obtained from TPC data and spectator energy was retrieved from VETO calorimeters. Using 2-dimensional histogram of (M, E_{spec}) one can find f_M, f_E, μ, σ giving the best match of experimental distribution to MC simulated data.

Determination of event centrality classes involves the following steps [3]:

- Move to dimensionless quantities $m = M/Max(M)$, $\varepsilon = E_{spec}/Max(E_{spec})$
- Parametrize correlation of (m, ε) with polynomial function
- Slice 2d correlation with lines perpendicular to fitting function in percentiles of total number of events obtained with MC-Glauber

4. Results and Discussion

The fit ranges were $E_{veto} < 4500\ GeV$, $M_{trk} > 130$. 300k MC events for multiplicity distribution and 400k events for spectators energy distribution were generated. Centrality class events separation was performed according to procedure described in previous section and results are shown in fig. 1, 2a. Since not all emitted particles get caught by detector due to ineffectiveness of trigger system, in the region of the most peripheral collisions MC results deviate from the experimental data. A point where deviation starts is called anchor point. For multiplicity distribution it is 25% and 40% for spectators energy distribution.



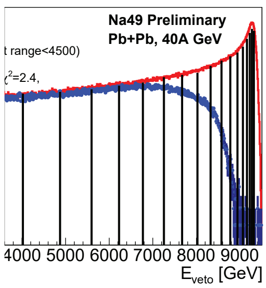


Figure 1: (a) Track multiplicity distribution obtained with TPCs compared to the fitted distribution using the MWN model. (b) Spectator energy distribution obtained with the Veto calorimeter compared to the fitted distribution using the MWN model.

On the fig. 2a profile histogram is built horizontally to the correlation and is shown as black triangles, then this correlation was fitted with a polynomial function (black line). Profile the correlation along the polynomial fit line is indicated with red triangles and refit with red line.

After mapping procedure one can use MWN model to estimate geometrical parameters of initial state of event. On fig. 2b are shown impact parameter distributions for events in specific centrality class. For each centrality class mean value and width was obtained. The resulting dependency of b and σ_b on centrality are shown on fig. 3a. Dependency of relative error on centrality is shown on fig. 3b.

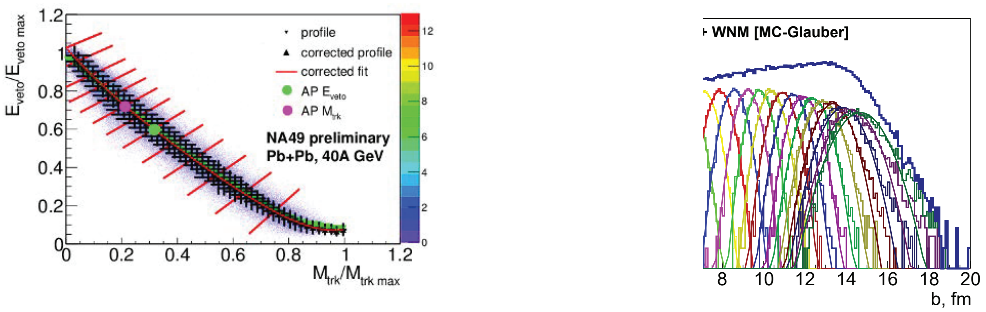


Figure 2: (a) The correlation between the energy deposited in the Veto calorimeter and track multiplicity. Green and pink circles correspond to the location of anchor point for spectators energy a;nd multiplicity of produced particles. (b) Distribution of impact parameter in different centrality classes obtained based on TPC track multiplicity. Color lines: 5% Event classes from M_{trk}.

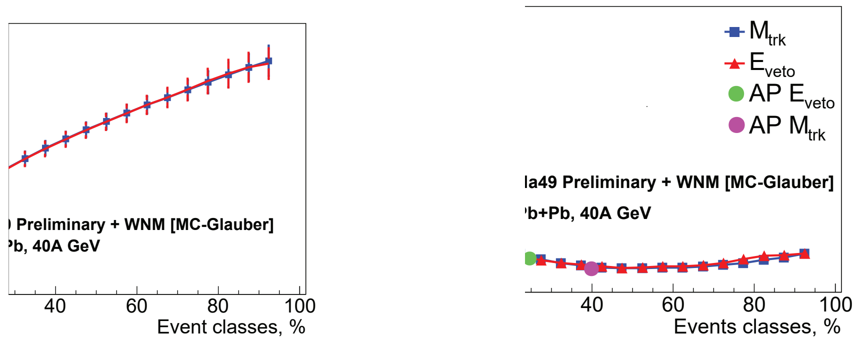


Figure 3: (a) Distribution of mean value of impact parameter in different centrality classes. (b) Distribution of impact parameter resolution in different centrality classes. Green and pink circles correspond to the location of anhor point for spectators energy and multiplicity of produced particles.

5. Summary

The implementation of the procedure within the software framework of the future CBM experiment was adopted for event classification in the NA49 experiment. Event classes in the experiment and parameters of the MWN model in event classes are determined. Impact parameter resolution is similar for centrality determination via spectator energy and track multiplicity. In future, the procedure will be used for analysis of the new Pb-Pb data collected by the NA61/SHINE experiment and for comparison with the results previously obtained by STAR at RHIC and NA49 at the CERN SPS.

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