**Effect of longitudinal asymmetry on pseudo-rapidity distributions in Pb-Pb collisions at 5.02 TeV centre of mass energy**

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**Introduction**

The overlapping region of a heavy-ion collision, called the participant zone, is shifted in rapidity with respect to nucleon-nucleon CM frame due to unequal number of nucleons participating from each nucleus. This shift in rapidity causes a longitudinal asymmetry, defined as

\[ \delta_A = \frac{A - B}{A + B} \]

Where A and B denote the of participating nucleons from the two colliding nuclei.

In general, the rapidity shift \( y_0 \) depends on the beam energy but can be expressed as

\[ y_0 \approx \frac{1}{2} \ln \left( \frac{E}{E_0} \right) \]

This approximation introduces an error of less than 10^-3 at LHC energies in the estimate of \( y_0 \).

**Motivation**

To investigate the effect of longitudinal asymmetry on measurable observables.

**Goals**

- Define an experimental measure of the longitudinal asymmetry and estimate its value.
- Investigate the effect of the asymmetry on \( dN/d\eta \) distributions and quantify it to define a measure.
- Estimate the rapidity shift \( y_0 \) for asymmetric events.
- Look for correlations in the measure of effect on \( dN/d\eta \) and rapidity shift \( y_0 \).

**Methodology**

- Denoting the total number of nucleons in the nucleus by \( N \), the asymmetry in the number of participants is related to the asymmetry in the number of spectator nucleons through

\[ \delta_{A/N} = \frac{\delta_A}{N} \]

- The spectator fragments into single neutrons, single protons and (light) nuclei. We measure the number of single neutrons on both sides of the interaction vertex in the neutron zero degree calorimeters (ZNK and ZNC on A and C-side of ALICE). For each event, asymmetry is estimated using energy measured in the ZNK and ZNC, and is a good substitute for \( \delta_{A/N} \), with reduced resolution \( \delta_{A/N} \)

\[ \delta_{A/N} = \frac{E_{ZNK} - E_{ZNC}}{E_{ZNK} + E_{ZNC}} \]

\( \delta_{A/N} \) is negative when there are more participants from nucleus moving towards positive (pseudo) rapidity region; net momentum in positive z-direction.

Events are classified as symmetric (region 3) or asymmetric (regions 1 or 2) using an arbitrary choice of \( \delta_{A/N} \).

**Experimental Details: The ALICE Detector**

Data of Pb-Pb collisions at 5.02 TeV, used for analysis was recorded during LHC Run2 in 2015. In the centrality interval 0-30%, used here, we have analysed ~4M events.

**Asymmetry Distribution**

Collision centrality determined using
- V0M (Amplitudes measured in V0A and V0C)
- CL1 (Number of tracks in 1st layer of ITS – SPD)
- \( dN/d\eta \) estimated using
  - V0A (2.8 < \( \eta \) < 5.1)
  - ITS + TPC (-0.9 < \( \eta \) < 0.9)

Event asymmetry is determined using energy measured in ZNK and ZNC at 114 meters from Interaction vertex.

**Ratios of \( dN/d\eta \) asym/(\( dN/d\eta \) sym)**

The open blue squares are obtained by reflecting the filled squares about \( \eta = 0 \)

\[ \frac{dN_{\text{asym}}}{dN_{\text{sym}}} \]

When net momentum of participant zone is in positive direction, then more particles are produced in positive \( \eta \).

Distributions of ratios fitted to a linear function \( (1 + c_{\eta} \eta) \)

\( c_{\eta} \) quantifies the effect of asymmetry on \( dN/d\eta \).

**Centrality and \( q_{\text{limit}} \) dependence of \( c_{\eta} \)**

Value of \( c_{\eta} \) for a particular choice of \( q_{\text{limit}} \in q_{\text{limit}} \)

**TGMC: Response matrix, \( q_{\text{asym}} \) and \( y_0 \)**

For any range of \( \delta_{A/N} \) the response matrix (shown on the left) is used to produce a distribution of \( y_0 \) (shown on the right). The \( y_0 \) for different \( \delta_{A/N} \) are shown below.

**Correlation between \( c_{\eta} \) and \( q_{\text{asym}} \)**

The measured and simulated distribution of energy in ZNC. These are used to obtain \( c_{\eta} \) for each simulated event. Knowing \( y_0 \) and \( \delta_{A/N} \) determines response matrix.

**Conclusions**

- Longitudinal asymmetry [LA] estimated.
- LA affects \( dN/d\eta \); quantified by slope parameter \( c_{\eta} \).
- Events of different asymmetry regions have different values of \( c_{\eta} \).
- Different values of mean rapidity shift \( y_0 \).
- \( c_{\eta} \) and \( y_0 \) correlated.

**References**