Correlations among net-charge, net-kaon and net-proton at LHC energies with ALICE

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Introduction

Fluctuations and correlations among conserved quantities such as net-baryon (B), net-charge (Q), and net-strangeness (S) numbers, have sparked significant interest in exploring the thermodynamic properties of hot and dense QCD matter created in heavy-ion collision experiments conducted at RHIC and at the LHC. They can provide valuable insights into the QCD phase structure and are related to the ratios of thermodynamic susceptibilities in lattice QCD calculations. These correlations exhibit characteristic changes in the crossover region between the low- and high-temperature phases of QCD, which are correlated with changes in the quark degrees of freedom [1, 2]. Theoretical calculations suggest that the measurement of these fluctuations and correlations can substantially refine constraints on the freeze-out parameters.

The thermodynamic suceptibilities are defined as the derivatives of the reduced QCD pressure (P/T^4) with respect to the reduced chemical potential ($\hat{\mu} = \mu/T$) of the conserved charges. These susceptibilities are related to the cumulants (σ) of the event-by-event distribution of the associated conserved charges such as, $\chi^{lmn}_{\mathrm{B,Q,S}} = \sigma^{lmn}_{\mathrm{B,Q,S}}/(VT^3)$, where, $\sigma^2_\alpha = \langle(\delta N_\alpha)^2\rangle$, $\sigma^{11}_{\alpha,\beta} = \langle(\delta N_\alpha)(\delta N_\beta)\rangle$ and $\delta N_\alpha = (N_{\alpha^+} - N_{\alpha^-}) - \langle(N_{\alpha^+} - N_{\alpha^-})\rangle$. Due to the limitation in detecting all baryons and strange hadrons experimentally, net-proton (p) and net-kaon (K) are considered as proxies for the net-baryon and net-strangeness in the current analysis. Finally, the correlations between Q, K, and p are defined as: $C_{\mathrm{p,K}} = \sigma^{11}_{\mathrm{p,K}}/\sigma^2_{\mathrm{K}}$, $C_{\mathrm{Q,K}} = \sigma^{11}_{\mathrm{Q,K}}/\sigma^2_{\mathrm{K}}$ and $C_{\mathrm{Q,p}} = \sigma^{11}_{\mathrm{Q,p}}/\sigma^2_{\mathrm{p}}$. The first measurements of these correlations using data recorded by the ALICE [3] detector for different centrality classes in Pb−Pb collisons are reported in this contribution.

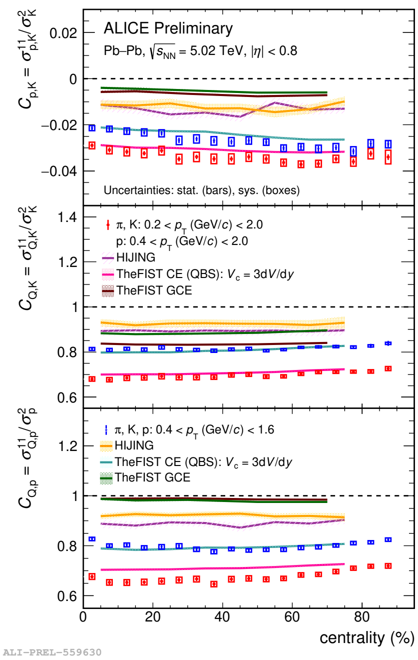

FIG. 1: $C_{\mathrm{p,K}}$ (top), $C_{\mathrm{Q,K}}$ (middle), and $C_{\mathrm{Q,p}}$ (bottom) as a function of centrality in Pb−Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV. Model calculations from HIJING and Thermal-FIST [4] (TheFIST) are represented by colored bands. The dashed lines indicate Poissonian baseline.

Analysis details

The events are selected using a minimum-bias trigger that requires at least one hit in

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both V0A ($2.8 < \eta < 5.1$) and V0C ($-3.7 < \eta < -1.7$) detectors. The definition of event centrality is based on the signal amplitudes measured in both V0 detectors. Charged particle tracks are reconstructed within the central barrel of ALICE using the Inner Tracking System (ITS) and the Time Projection Chamber (TPC), which provide full azimuthal coverage in the pseudorapidity range $|\eta| < 0.8$. The identification of pions, kaons, and protons involves analyzing the specific energy loss ($\mathrm{d}E/\mathrm{d}x$) within the TPC's gas volume and by measuring a particle's flight time from the primary vertex of collision to the Time-of-Flight (TOF) detector.

Results

Figure 1 presents the centrality dependence of the correlations observed in Pb−Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV. The correlations between net-proton and net-kaon ($C_{\mathrm{Q,K}}$), net-charge and net-kaon ($C_{\mathrm{Q,K}}$), and net-charge and net-proton ($C_{\mathrm{Q,p}}$) are unveiled for two distinct p_{T} ranges. Suppressed correlations are observed compared to the expectations from a statistically independent Poisson distribution for the associated event-by-event net-particle distribution. The results are overestimated by the HIJING model predictions for both p_{T} ranges. Calculations from thermal model employing canonical ensemble (CE) with B, Q, and S conservation, implemented in Thermal-FIST [4] are compared to the measurements. The thermal model also accounts for the incomplete equilibration of strangeness by incorporating the strangeness saturation factor, γ_{S}. Results from grand canonical ensemble (GCE) shown in Fig. 1, affirms that the CE treatment of conserved charges in thermal model is required to explain the data. Figure 2 shows the comparison of the measured correlations to thermal model results obtained with different correlation volume (V_{c}). It is worth noticing that reducing V_{c} significantly suppresses the correlations. Moreover, $V_{\mathrm{c}} = 3\mathrm{d}V/\mathrm{d}y$ shows good agreement with the data.

In conclusion, the correlations between Q, K, and p are found to be suppressed compared to the Poissonian baseline and the expectations from the GCE calculation in the thermal model. The measurements show sensitivity to the V_{c} in thermal model, which can facilitate for a deeper understanding of the particle production mechanisms and the properties of the QCD matter formed in high-energy nuclear collisions.

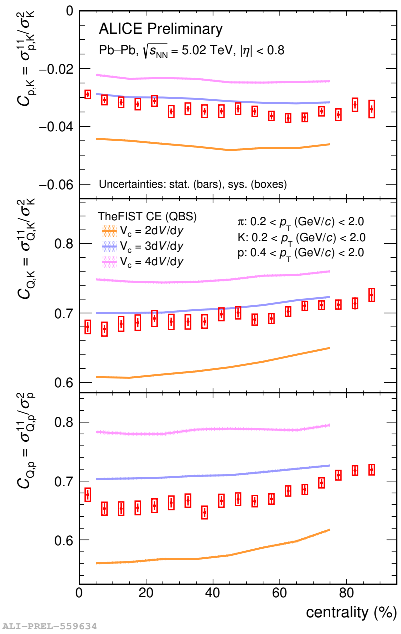

FIG. 2: $C_{\mathrm{p,K}}$ (top), $C_{\mathrm{Q,K}}$ (middle) and $C_{\mathrm{Q,p}}$ (bottom) as a function of centrality in Pb−Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV compared to results obtained from Thermal-FIST for different correlation volumes (V_{c}).

Acknowledgments

The author acknowledges financial support from DAE-DST projects.

References

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