

Quark Matter 2019 - the XXVIIIth International Conference on Ultra-relativistic Nucleus-Nucleus Collisions



Contribution ID: 471

Type: **Poster Presentation**

Forward-backward centrality fluctuation and its influence on experimental observables in heavy-ion collisions

Monday 4 November 2019 17:40 (20 minutes)

In heavy ion collisions, the transverse size or centrality of the QGP is not a boost-invariant concept. Due to forward-backward multiplicity fluctuations, the centrality of the system, defined as N_{ch} in a given η range, also fluctuates in the longitudinal direction. This longitudinal fluctuation leads to decorrelation of centrality along η , analogous to the decorrelation of harmonic flow v_n along η . In this work, we quantify the strength of centrality decorrelation using multi-particle cumulants (mean, variance, skewness and kurtosis) using a sub-nucleon Glauber model as well as dynamical event generators HIJING and AMPT. We found the behaviors of multiplicity cumulants in ultra-central collisions (UCC) are extremely sensitive to the particle production implemented in the models, and therefore can be used to quantify the centrality resolution and constrain the particle production mechanism. We further studied the influence of centrality fluctuation and decorrelations on v_n and mean transverse momentum $\langle p_T \rangle$ in each event. We show that the event-by-event probability distribution of these quantities such as $p(v_n)$, $p(v_n, v_m)$, $p(\langle p_T \rangle)$ and $p(v_n, \langle p_T \rangle)$, accessible via mixed-observable multi-particle cumulants, are sensitive to the strength of the fluctuation and longitudinal decorrelations of centrality. We laid out an experimental strategy on how to constrain the centrality dependence of particle production, based on measurements of these mixed-observable cumulants in UCC for systems of different sizes.

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Session Classification: Poster Session

Track Classification: Collective dynamics and final state interaction