Non-identical particle correlations at 62 and 200 GeV at STAR

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We report on STAR analyses of $p-\Lambda$, $\bar{p}-\bar{\Lambda}$, $p-\bar{\Lambda}$, $\bar{p}-\Lambda$, $p-\bar{p}$ and $\pi-\Xi$ correlations in Au+Au collisions at $\sqrt{s_{NN}} = 62$ and 200 GeV. Measured source sizes in $p(\bar{p})-\Lambda(\bar{\Lambda})$ and $p-\bar{p}$ are shown to be in qualitative agreement with flow expectations. Interaction potential between $p-\bar{\Lambda}$, $\bar{p}-\bar{\Lambda}$ was investigated by measuring scattering length, thus showing that correlation analyses in heavy-ion collisions can be used to study strong interaction potential between hadrons. We present also analyses of $\pi-\Xi$ correlations addressing independently on previous measurements the issue of Ξ flow in heavy-ion collisions.

1. Introduction

Measurements of momentum correlation of particles at small relative velocities are used to study space-time characteristics of the heavy-ion collisions [1]. Both, identical and non-identical particle correlations are sensitive to the space-time extent of the particle-emitting source. However, as suggested in [2], non-identical particle correlation measurements provide additional information about relative space-time emission asymmetry among the two particles.

Current data from Au+Au collisions [3] suggest that the hot and dense system created in the heavy-ions collision builds up substantial collectivity leading to a rapid transverse expansion. Flow induces a strong correlation between particles' velocities and emission points leading to an effective decrease of measured HBT radii and different average emission points for particles species with non-equal masses [4]. Therefore non-identical correlations can be used as an independent cross-check of flow measurements in heavy-ion collisions.

Furthermore since the correlations between non-identical hadrons arise from their final state strong and, for charged particles, Coulomb interaction, these measurements can be used to study[1,2] strong interaction potentials between particles which could otherwise be hardly accessible by other means.

2. Analyses methods, Experimental data

The correlation between non-identical particles depends on $\vec{k^*} = \vec{k_1^*} = -\vec{k_2^*}$, which is the first particles' momenta in the pair's rest frame, *i.e.* half of the momentum difference between the particles. A small value of $|\vec{k^*}|$ then means that the particles move with small relative velocity. The correlations are studied, as in previous STAR measurements [5]

*For the full list of STAR authors and acknowledgments, see appendix 'Collaborations' of this volume.

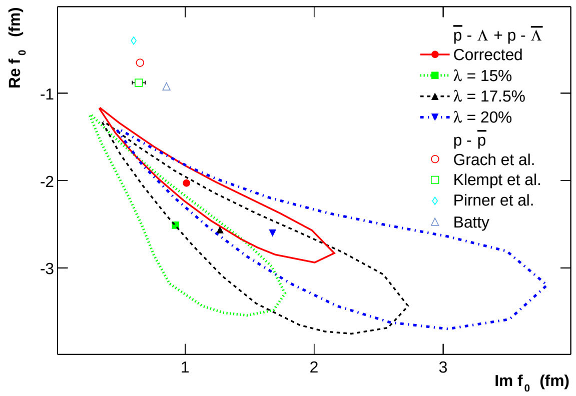

Figure 1. Spin-averaged s-wave scattering length (preliminary) for $p-\bar{\Lambda}+\bar{p}-\Lambda$ with one standard deviation contours compared to previous $p-\bar{p}$ measurements.

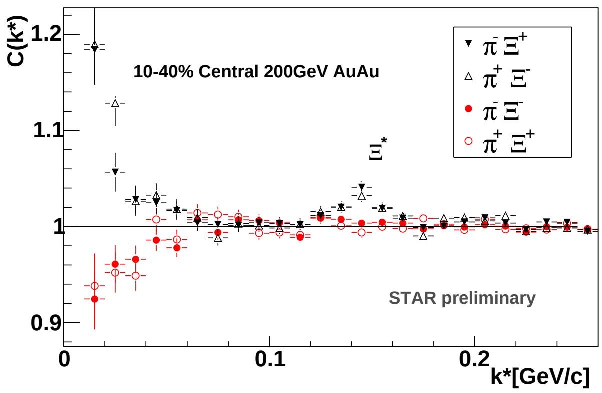

Figure 2. $\pi-\Xi$ correlation function for 10% most central Au+Au collisions at $\sqrt{s_{NN}}$=200 GeV. Peak at $k^* = 0.15$ GeV/c corresponds to $\Xi^*(1530)$ resonance.

by constructing correlation functions $C(\vec{k^*}) = A(\vec{k^*})/B(\vec{k^*})$, as a ratio of two-particle distributions; $A(\vec{k^*})$ - obtained from single event, and one where particles come from different, or "mixed" events - $B(\vec{k^*})$.

STAR main detector, the Time Projection Chamber (TPC), detects and reconstructs charged particles emerging from primary and secondary vertices. Pions, kaons and protons are identified via their specific energy loss (dE/dx). This selection limits transverse momentum acceptance of pions to $0.08 < p_t < 0.6$ GeV/c, and of protons to $0.6 < p_t < 1.1$ GeV/c. Lambdas (and anti-lambdas) as well as charged Ξ-hyperons are topologically reconstructed using decay chain $\Xi \rightarrow \Lambda + \pi$, and $\Lambda \rightarrow \pi + p$. Only events with longitudinal primary vertex position within 25 cm of the TPC center, and only particles in the rapidity window $|y| < 0.5$ are selected. This subsequently limits p_t range of our lambda-sample to $0.3 < p_t < 2.0$ GeV/c and Ξ-sample to $0.07 < p_t < 3.0$ GeV/c.

3. Results

STAR has performed correlation measurements in $p(\bar{p}) - \Lambda(\bar{\Lambda})$ and $p-\bar{p}$ systems. We refer reader to Figure 3 in [6] in these proceedings, where we present the preliminary results on m_T dependence of extracted one-dimensional Gaussian source radii for different systems including results for $p-\Lambda$, $\bar{p}-\bar{\Lambda}$, $p-\bar{\Lambda}$, $\bar{p}-\Lambda$, and $p-\bar{p}$ from 10% most central Au+Au collisions at $\sqrt{s_{NN}} = 200\ GeV$. The $p(\bar{p})-\Lambda(\bar{\Lambda})$ radii were extracted by fitting an analytical form of $C(k^*)$ using Lednický & Lyuboshitz final state interaction (FSI) model [7]. While the interaction potential for $p-\Lambda$ and $\bar{p}-\bar{\Lambda}$ is known, allowing us to extract the source size, the correlation function for $\bar{p}-\Lambda$ and $p-\bar{\Lambda}$ was measured for the first time, and the interaction is unknown. In the case of $\bar{p}-\Lambda+p-\bar{\Lambda}$ the correlation function was fitted assuming the same functional form of the interaction as in $p-\Lambda$, $\bar{p}-\bar{\Lambda}$, treating the potential parameters (scattering lengths) as free parameters. The extracted spin-averaged scattering lengths are presented in Figure 1 for different values of used pair purity corrections λ. The best results are obtained when k^* dependent purity correction is

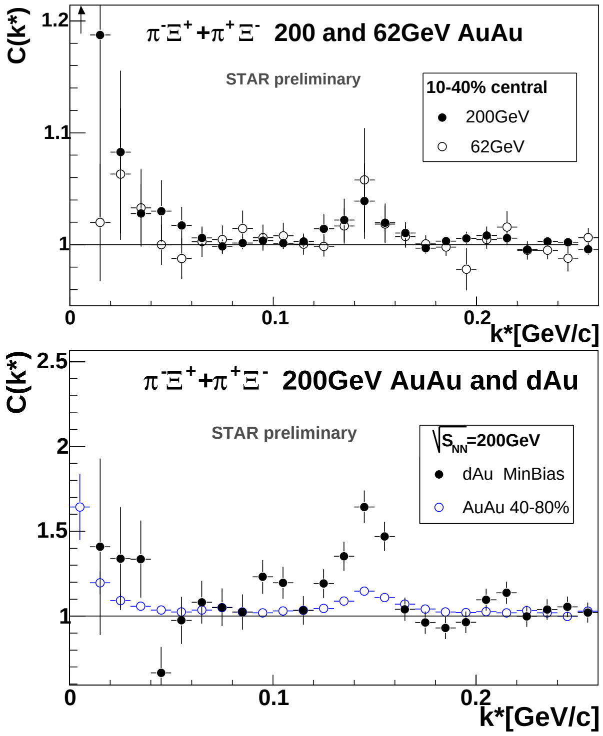

Figure 3. Comparison of combined unlike-sign $\pi-\Xi$ $C(k^{*})$: Top - for two different energies in Au+Au collisions; Bottom - for Au+Au and d+Au collisions at 200 GeV.

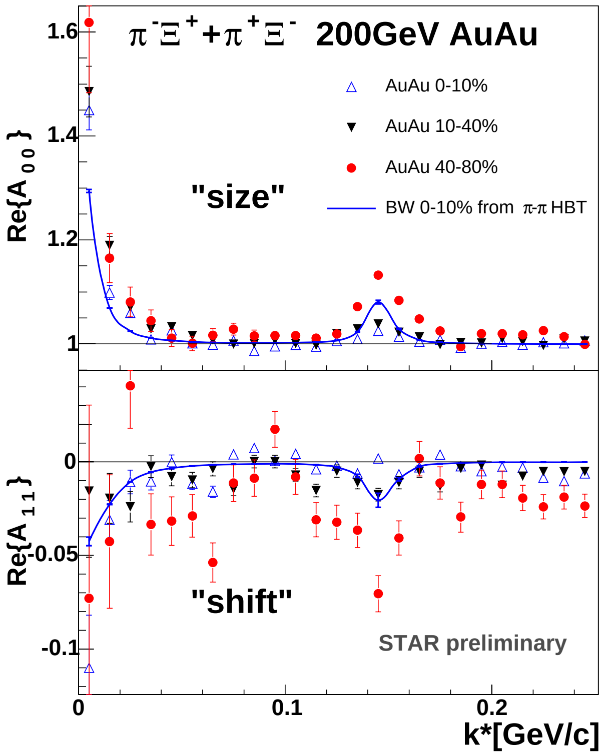

Figure 4. Combined unlike-sign $\pi-\Xi$ pairs: centrality dependence of spherical projections of $C(\vec{k^{*}})$ in 200 GeV Au+Au. Solid line is a theoretical prediction for the most central data assuming Ξ flow.

applied (the "Corrected" curve). In order to take into account annihilation channels the scattering length has to have a significant imaginary part. As can be seen, the extracted radii for $\bar{p}-\Lambda$, $p-\bar{\Lambda}$ differ from those extracted from $p-\Lambda$ and $\bar{p}-\bar{\Lambda}$. This difference can possibly be explained by a correlated feed-down, which has not been accounted for, and is now under study.

STAR has also measured $p-\bar{p}$ correlations at $\sqrt{s_{NN}} = 62.4$ GeV and at different centralities with comparable result [8]. In p–$\bar{p}$ measurements correlation functions were fitted numerically [9] using the same FSI model [7] as in $p(\bar{p})-\Lambda(\bar{\Lambda})$ case.

The relatively smaller source radii obtained from $p(\bar{p})-\Lambda(\bar{\Lambda})$ and $p-\bar{p}$, as function of m_T, when compared to lighter particles agree with effects expected from flow [4].

In Figure 2 we present the preliminary results on $C(k^{*})$ for all four combinations of $\pi-\Xi$ pairs from the 10% most central 200 GeV Au+Au collisions. In the low k^{*} region ($k^{*} < 0.05$ GeV$/c$) the correlation function is, for all charge combinations, dominated by the Coulomb interaction. Final state strong interaction is manifested in $C(k^{*})$ of unlike-sign pairs as a peak at $k^{*} = 0.15$ GeV$/c$, corresponding to $\Xi^{*}(1530)$ resonance.

In Figure 3 comparison of purity corrected $C(k^{*})$ for combined unlike-sign $\pi-\Xi$ pairs from Au+Au collisions at $\sqrt{s_{NN}} = 62.4$ GeV and 200 GeV is shown together with comparison of Au+Au and d+Au collision systems at $\sqrt{s_{NN}} = 200$ GeV. All correlation functions exhibit the same general features in all presented systems and energies.

Recent data suggest that Ξ develops substantial elliptic flow during heavy-ion collisions [3]. Independent test of this hypothesis can be pursued via decomposition of $C(\vec{k^*})$ into spherical harmonics [10]. In Figure 4 we present centrality dependence of $A_{00}(k^*)$ and $A_{11}(k^*)$ components for $\sqrt{s_{NN}} = 200$ GeV Au+Au collisions. In the same plot is shown a prediction for the most central data based on S. Pratt's model [11], where blastwave model was used to provide emission space-time coordinates taking into account the influence of flow. Blastwave parameters describing well Au+Au data were used for both particles, assuming significant Ξ flow. While $A_{00}(k^*)$ is angularly averaged $C(\vec{k^*})$, $A_{11}(k^*)$ is sensitive to emission asymmetry in the system, vanishing in a system where both particles are emitted on average at the same space-time point.

From Figure 4 and 3 we observe that $\pi{-}\Xi$ correlation function shows strong centrality and system dependence, while it doesn't seem to be significantly sensitive to the collision energy. Moreover in the region of $\Xi^*(1530)$ the $C(k^*)$ shows much stronger sensitivity to the source size than in the Coulomb region. The $A_{11}(k^*)$ differs significantly from zero in both, Coulomb and $\Xi^*(1530)$, regions qualitatively following theoretical prediction, thus implying that pions and Ξs are not emitted from the same average space-time point, and supporting evidence of Ξ experiencing transverse radial flow.

4. Conclusions

We have presented preliminary results on $p(\bar{p}){-}\Lambda(\bar{\Lambda})$, $p-\bar{p}$, and $\pi-\Xi$ correlation measurements from STAR experiment at RHIC. In $p(\bar{p}){-}\Lambda(\bar{\Lambda})$ and p–$\bar{p}$ extracted emission radii are consistent with transversally expanding particle source. In case of $p{-}\bar{\Lambda}$, $\bar{p}{-}\bar{\Lambda}$, not only size, but also scattering length was extracted from the fit for the first time, showing that non-identical correlations can be used to study hadron interactions directly. We have also presented preliminary results on π–Ξ correlations at two energies in Au+Au and d+Au collisions showing sensitivity of the $C(\vec{k^*})$ to the size of the system - mainly in the region of Ξ^* resonance peak. We have used novel technique of spherical decomposition to present independent evidence of Ξ flow in heavy-ion collisions.

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