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PROCEEDINGS

Non-identical strange particle correlations in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV from the STAR experiment

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Abstract Information about the space-time evolution of colliding nuclei can be extracted correlating particles emitted from nuclear collisions. The high density of particles produced in the STAR experiment allows the measurement of non-identical strange particle correlations. Due to the absence of Coulomb interaction, p-Λ and $\bar{p}\Lambda$ systems are more sensitive to the source size than p-p pairs. Strong interaction potential has been studied using p-Λ, and for the first time, $\bar{p}\Lambda$ pairs. The experimental correlation functions have been described in the frame of a model based on the p-n interaction. The first preliminary measurement of π-Ξ correlations has been performed, allowing to extract information about the freeze-out time and the space-time asymmetries in particle emission closely related to the transverse radial expansion and decay of resonances.

Key words interferometry • non-identical particles • final state interactions

Introduction

The Relativistic Heavy Ion Collider (RHIC) provides the facility for colliding gold ions at 200 GeV per nucleon pair in the center of mass. The STAR detector (a Solenoid Tracker at RHIC), installed at RHIC collider, allows the reconstruction of the particles produced during the collisions. Non-identical particles are correlated due to final state Coulomb and nuclear interactions. So one can use the correlation technique to study the Final State Interaction (FSI). In addition, non-identical particle correlations are sensitive to the space-time asymmetries of the emission points of different particle species [6].

Contrary to p-Λ [1, 2, 7], the nuclear FSI of $\bar{p}$-Λ is still unknown. In the following, data are shown and p-Λ correlations are analysed using the Lednický & Lyuboshitz model [5].

Preliminary results on π-Ξ correlations are also shown and the dominated Coulomb FSI is observed.

Experimental correlation functions

Particles are measured in Au-Au collisions at $\sqrt{s_{NN}} = 200$ GeV using the Time Projection Chamber (TPC). Central events accounting for 10% of the total cross section are selected. Protons and anti-protons are selected using their specific energy loss (dE/dx). This selection limits the acceptance of particles to the transverse momentum range of 0.4–1.1 GeV/c in the rapidity interval $|Y| < 0.5$.

The contamination and the feed-down have been studied in order to estimate the purity (λ) of protons as a function of the transverse momentum (p_t). The purity is defined as the product of the probability of identification (Pid) times the fraction of primary protons (Fp).

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(1) $\lambda(p_t) = \mathrm{Pid}(p_t)^*\mathrm{Fp}(p_t)$.

Values of purity indicated in the following correspond to the average transverse momentum of protons ($<p_t> =$ 0.70 GeV/c) in the studied range. The fraction of identified protons is estimated to be 76.5%. The feed-down study leads to an estimated purity of 54% for primary protons. Secondary protons are weak decay products or electromagnetic decay products. Most of the secondary protons come from lambda decay and represent 35% of the protons used to construct the correlation function. Other sources of contamination of protons are provided by decay products of Σ^+ and pions interacting with matter, which represent, respectively 10% and 1% of the sample.

The same study has been done for anti-protons ($<p_t>$ = 0.73 GeV/c), and the fraction of identified anti-protons is estimated to be 73%. The feed-down study leads to an estimated purity of 56% for primary anti-protons. Most of the secondary anti-protons come from anti-lambda decay and represent 32% of the anti-protons used to construct the correlation function. For anti-protons, the additional source of contamination, which is the decay products of Σ^+, represents 12%. Lambdas are reconstructed through the decay channel $\Lambda \to \pi + \mathrm{p}$ with a corresponding branching ratio of 64%. Pions and protons are selected using their specific energy loss. In addition, some geometrical cuts are applied, giving a lambda purity sample of 80%, the remaining 20% representing the combinatory background. Only lambdas in the rapidity range $|Y| < 1.5$ are selected. Due to the acceptance of the detector the transverse momentum range is 0.3–2.0 GeV/c. By reconstructing invariant mass of lambdas, we estimate misidentified lambdas as the combinatory background. The sample of lambdas includes secondary particles such as decay products of Ξ, Ξ^0, Σ^0. Identified lambdas ($<p_t> = 1.20$ GeV/c) represent 80% of the particle sample used to construct the correlation function. Moreover, an in-depth study of feed-down leads to the estimated lambda purity of 46%.

Pair purity plays a crucial role in the correlation study. The estimated value of the pair purity for p-Λ and $\bar{p}$-Λ systems is 15%.

Ξ are reconstructed through the decay channels $\Xi \to \Lambda + \pi$, with a corresponding branching ratio of 99.9%. Ξ are not contaminated notably by any kind of particles. The Ξ contamination due to Ω decay represents less than 3%. The study of particle and pair purity is under progress. Pions are selected using their specific energy loss (dE/dx).

The contamination tends to reduce the correlation strength. The non-correlated background is constructed by mixing events with primary vertex separated from each other by less than 10 cm.

The relevant variable is the momentum of one of the particle in the pair rest frame called here $\overline{k}^*$.

The correlation function has been extracted by constructing the ratio of two distributions. The numerator is the modulus $\overline{k}^*$ distribution of pairs from the same event. The denominator is the modulus $\overline{k}^*$ distribution of pairs composed of particles from different events. The $p\Lambda$ correlation function is presented in Fig. 1. Figure 2 represents the $\bar{p}\Lambda$ correlation function, which appears to be negative, measured for the first time.

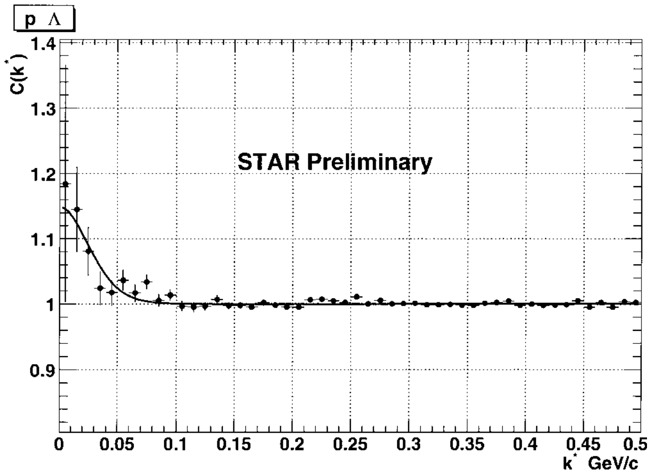

Fig. 1. The measured $p\Lambda$ correlation function described by Lednický & Lyuboshitz analytical model.

Lednický & Lyuboshitz analytical model

The analytical model used to study the correlation functions is based on the p-n final state interaction, described in the frame of the effective range approximation [4, 5] since only nuclear FSI is present in $p\Lambda$ and $\bar{p}\Lambda$ systems. The correlation function ($C(k^*)$) is the average of the wave function (ψ^*) over spin state (s) and over the distribution of relative distance (r^*) of particles in the source:

$$C(k^*) = \left\langle \left| \psi^*_{-\overline{k}^*}\left(r^*\right) \right|^2 \right\rangle_{r^*,s} . \tag{2}$$

The wave function is assumed to be equal to the leading term s-wave, plus the scattering amplitude:

$$\psi^*_{-\overline{k}^*}\left(r^*\right) = e^{-ik^*r^*} + \frac{f^s\left(k^*\right)}{r^*} e^{-k^*r^*} \tag{3}$$

with the scattering factor:

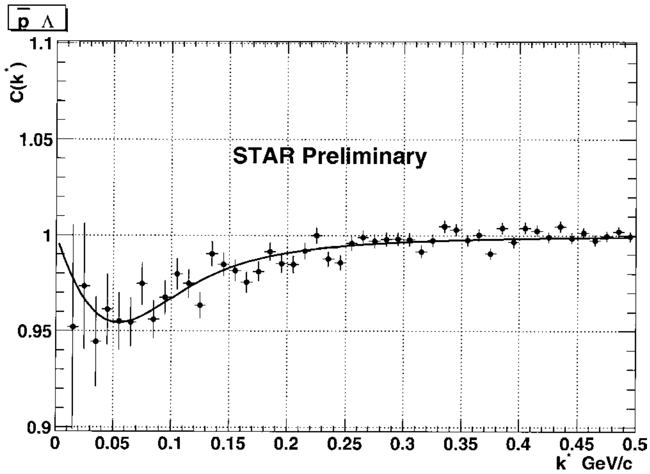

Fig. 2. The measured $\bar{p}\Lambda$ correlation function by Lednický & Lyuboshitz analytical model.

(4) $$f^s\left(k^*\right)=\left(\frac{1}{f_0^s}+\frac{1}{2}d_0^s k^{*2}-ik^*\right)^{-1}$$

where f_0^s the scattering length and d_0^s is the potential effective range, for the spin state (s), which is triplet (T) or singlet (S) for the p-Λ system.

The correlation function has the following expression:

(5) $$C\left(k^*\right)=\left\langle\left|e^{-k^*,r^*}+\frac{f^s\left(k^*\right)}{r^*}e^{-k^*,r^*}\right|^2\right\rangle_{r^*,s}+O\left(\frac{1}{r_0^3}\right).$$

The relative position distribution is assumed to be a Gaussian distribution, r_0 is the radius of the source.

(6) $$r^* \sim e^{-r^{*2}/4r_0^2}.$$

We consider that particles are not polarized. For p-Λ, the purity parameter is introduced as a suppression parameter to take into account the pair contamination.

For $\bar{p}$-Λ, the spin dependence is neglected $f^S=f^T=f$ and the effective range (d_0) is set to zero, in order to stronger constrain fitted parameters. Indeed, an extra parameter, Im(f_0) should be introduced to take into account the annihilation channel $B\bar{B}$.

The fit parameters from [7] have been used for p-Λ to extract values of the radius (r_0) and the purity (λ) (Table 1). Fits are stable with the values of parameters given in [4].

The extracted source parameters are close to values obtained in measurements performed by NA49 (CERN) collaboration in Pb+Pb collisions at 158 AGeV [1] and by the E895 (AGS) experiment in Au+Au collisions at 4, 6, and 8 AGeV [2].

Table 1. Parameters of p-Λ interaction, the symbol * indicate the fitted value. Only statistical errors are indicated. λ is the pair purity.

Parameter	Value
f_0^s (fm)	2.88
d_0^{T} (fm)	2.92
f_0^{T} (fm)	2.66
d_0^{T} (fm)	3.78
r_0 (fm)	2.71 ± 0.33*
λ	0.15

Table 2. Parameters of $\bar{p}$-Λ correlation, the symbol * indicate the fitted values, imaginary and real part of the scattering length and the radius. Only statistical errors are shown. λ is the pair purity.

Parameter	Value	
Im(f_0) (fm)	1.21	0.94*
Re(f_0) (fm)	–2.65	1.26*
d_0 (fm)	0.0	
r_0 (fm)	1.43	0.07*
λ	0.15	

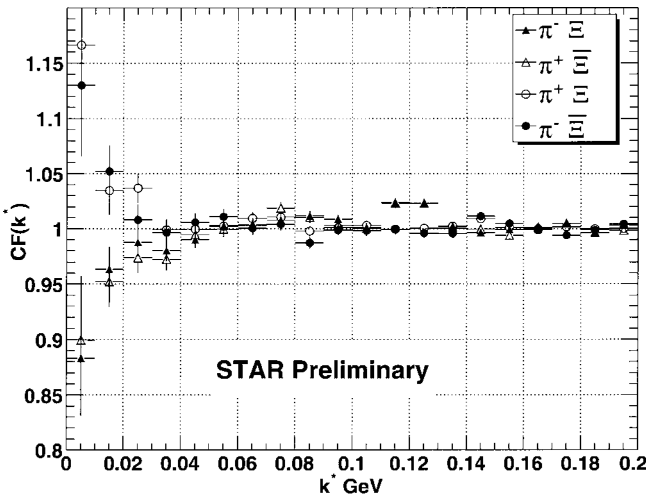

Fig. 3. π-Ξ correlation functions.

The radius extracted from p-Λ correlation function, is smaller than the one extracted from $\bar{p}$-Λ correlation function.

Using the correlation function allows to estimate the final state interaction parameters for the $\bar{p}$-Λ system (see Table 2).

One can notice that the value of the imaginary part of the scattering length obtained for $\bar{p}$Λ (Table 2) is in agreement with the scattering length (0.8 fm) for $\bar{p}p$ spin averaged in [3].

A preliminary study of π-Ξ has been done (Fig. 3). The dominant Coulomb FSI is visible for like-sign and unlike-sign systems. The Ξ^*(1530) resonance is observed at k^* = 145 GeV/c, the shift from 152 MeV/c to 145 MeV/c is due to a Lorentz boost to the pair rest frame. The peak for like sign particles, at 120 MeV/c, is under investigation.

Conclusion

Preliminary results on p-Λ, $\bar{p}$Λ and π-Ξ correlations have been shown. The analysis is still under progress.

It has been shown that by studying p-Λ one can estimate the size of the source of particles.

The surprising shape of the $\bar{p}$Λ correlation function has been shown for the first time. Final state interaction parameters, such as the scattering length, can be extracted from $\bar{p}$Λ. The studied momentum resolution does not have any relevant effect. The pair purity has a stronger effect on the correlation function than momentum resolution and is an important source of systematic errors. In addition, the purity study is based on the assumption that the contamination is uncorrelated. Residual correlations may contribute to measured correlation and should be investigated. The first π-Ξ correlation functions show a dominant Coulomb FSI.

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