Measurements of Λ-Λ Correlation Function at $\sqrt{s_{NN}}$ = 3 GeV Au+Au Collisions at RHIC-STAR

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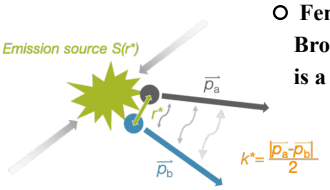
Abstract

In heavy-ion collisions, two-particle femtoscopy is a powerful and method for extracting information about the spatio-temporal properties of the source, and characterizing the final state interactions (FSI). Among the less explored cases is the hyperon-hyperon (Y-Y) interaction, which is crucial for understanding the neutron star equation of state and searching for exotic hadrons. In this poster, the Λ-Λ correlation function measurements in Au+Au collisions at $\sqrt{s_{NN}}$ = 3 GeV (run21) from STAR fixed-target Beam Energy Scan II are presented.

Femtoscopy



- Femtoscopy, inspired by Hanbury Brown and Twiss (HBT) interferometry, is a unique tool to study[1-4]
  - Spatial and temporal extent of emission source
  - Final-state interactions (coulomb, strong interaction)
  - Bound state structure
- Two-particle correlation function in ***statistics***[3]:

$$C(k^*) = \frac{P(\vec{p}_a, \vec{p}_b)}{P(\vec{p}_a)P(\vec{p}_b)} \quad k^*: \text{reduced relative momentum, with } \vec{p}_a^{\,*} + \vec{p}_b^{\,*} = 0$$

- Two-particle correlation function in ***theory***[3]:

$$C(k^*) = \int S(\vec{r}^*)\,|\Psi(\vec{k}^*, \vec{r}^*)|^2\, d^3\vec{r}^*$$

$S(\vec{r}^*)$: source function; $\Psi(\vec{k}^*, \vec{r}^*)$: wave function; r^*: relative distance

Scattering Amplitude: $f_c(k^*) = \left(\frac{1}{f_0} + \frac{1}{2} d_0 k^{*2} - i k^*\right)^{-1}$

f_0 : scattering length (> 0 attractive; < 0 repulsive / bound)
d_0: effective range

- Two-particle correlation function in ***experiment***[3]:

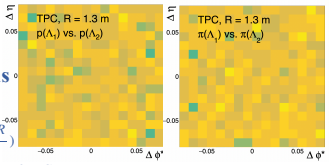
$$C(k^*) = \mathcal{N} \frac{N_{\text{same}}(k^*)}{N_{\text{mixed}}(k^*)}$$

$\mathcal{N}$: normalization parameter

Experimental Effects & Corrections

Detector effect — Daughter sharing:

- Possible effect: $p(\Lambda_1) \leftrightarrow p(\Lambda_2)$, $\pi^-(\Lambda_1) \leftrightarrow \pi^-(\Lambda_2)$
- Solution: Check $\Delta\phi^*$ vs. $\Delta\eta$ at various radial distances within TPC volumes



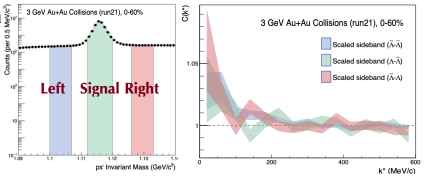
$\Delta\phi^* = \Delta\phi + sin^{-1}\left(\frac{0.15 q_1 B R}{pT1}\right) - sin^{-1}\left(\frac{0.15 q_2 B R}{pT2}\right)$

$\Delta\eta = \eta_1 - \eta_2$ B is magnetic field intensity, R is the radius of TPC

Background estimation:

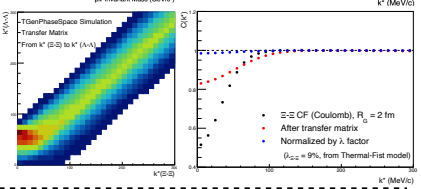
1. Particle mis-identification

- Possible effect: mis-id of daughter particles (p/π) to reconstruct Λ
- Solution: sideband method (select Λ from $[5\sigma, 8\sigma]$ away from peak



2. Residual correlation

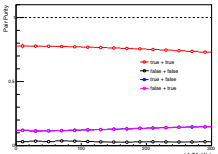
- Possible effect: Decayed Λ (from Ξ or Σ) may cause residual correlation
- Solution: Calculate parent correlation and transfer to Λ-Λ correlation



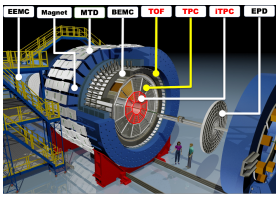
Pair Purity:

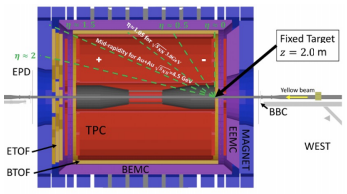
- PP(signal) = Purity(Λ_1) * Purity(Λ_2)
- PP(sideband) = Purity(Λ_1) * Purity($\bar{\Lambda}_2$) + Purity($\bar{\Lambda}_1$) * Purity(Λ_2) + Purity($\bar{\Lambda}_1$) * Purity($\bar{\Lambda}_2$)

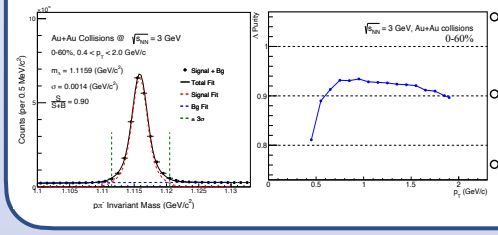
$\bar{\Lambda}$: mis-id Λ



STAR Detector & Λ Reconstruction

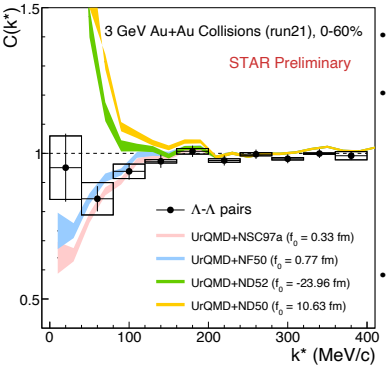






- Au+Au Collisions @ $\sqrt{s_{NN}}$ = 3 GeV (run21), ~2 billion events from BES-II
- KFparticle for Λ reconstruction: $\Lambda \rightarrow p + \pi^-$, BR = 63.9%
- Fit function: Double Gaus.+2nd ord. poly.

Correlation Function



- Λ-Λ correlation function shows suppression at small k*.
- Compared with UrQMD+potential, it is found that the simulation with positive f_0 is in better agreement with data -> **Hints at an attractive interaction in Λ-Λ pairs.**
- Need more precise data to confirm.

Potential	f0 (fm)	d0 (fm)	Chi2/NDF
NSC97a [5]	0.33	12.37	1.53
NF50 [6]	0.77	4.27	1.61
ND52 [7]	-23.96	2.59	2.24
ND50 [7]	10.63	2.04	4.02

Summary

- We present the measurements of Λ-Λ correlation function in $\sqrt{s_{NN}}$ = 3 GeV (run21) Au+Au collisions at STAR.
- Compared with UrQMD simulation, the data hints at an attractive interaction in Λ-Λ pairs. This needs high precision data to confirm.

Outlook: Lednicky-Lyuboshitz model fitting to extract physics parameters.

Reference

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