NUKLEONIKA 2004;49(Supplement 2):S23–S25

Some new aspects of femtoscopy at high energy

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Abstract It was shown within simple model simulations that particles momenta for strange baryon decay are correlated with its parents momenta. It can affect measure correlation function for different particle species.

Key words residual correlations • strange baryon decay • reference sample • low energy scattering parameters • space-time parameters

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Received: 10 December 2003, Accepted: 10 April 2004

Low energy scattering parameters

The higher is the initial energy the longer is the list of possible particle species for femtoscopy measurements: $\pi, K, \Lambda, \Xi, \bar{p}\ldots$ Different particle species are not equally useful for femtoscopy measurements and we shall try to identify the most promising ones. The question is for what non-identical pairs the strong final state interaction will be strong enough to result in a sharp correlation function and so to be sensitive to the space-time parameters.

SU(3) based analysis (Model NSC97 [3]) provides rather large scattering lengths for $\Sigma^+\Sigma^+$, $\Sigma^-\Sigma^-$, $\Xi^0\Xi^0$, and $\Xi^-\Xi^0$, so their correlation functions can be sensitive to the emitting region. Some other pairs also need close attention, $-\Xi^0 p$, $\Xi^- n$, $\Xi^-\Sigma^-$ and $\Xi^-\Xi^-$ because the effective ranges estimated by [3] are huge, while in this approach the effective ranges supposed to be small. To summarize, it seems that the study of all listed pairs is of the most interesting for the femtoscopy study.

It should be noted, that SU(3) symmetry for potentials is slightly broken, which results in completely broken symmetry for scattering length. It means SU(3) models can provide only estimate for scattering length and effective range. The other sources of our knowledge of these parameters are: direct measurements of the cross-sections, experimental information on hypernuclei, SU(3) symmetry for potentials. The fine point is that correlation measurements itself could be a promising source of information on low-energy scattering parameters for interaction between unstable particles in case of well-known size of the emission region.

Residual correlations for decay products of strange particles

A substantial part of secondary particles is a result of non-identified strange particles decay. Such particles are usually considered as uncorrelated with particles from primary interaction due to macroscopic scale of the decay length. For example, in study of *pp* correlations at small relative momenta a significant part of protons arise from decay of non-identified Λ. Such protons are considered as uncorrelated with direct protons due to large decay length of Λ.

Our point is that particles momenta from the Λ decay in the Λ reference frame are not so large with respect to a width of possible correlation effects in $p\Lambda$ system. It means that the decay do not destroy totally $p\Lambda$ correlations and some residual correlations could contribute to pp_Λ correlations (where one *p* is direct proton and the second one is from Λ) as well as for $p\pi_\Lambda$ (π_Λ from Λ decay). Of course, such effect is not specific for *pp* correlations only and it can affect correlation functions for $p\Lambda$,ΛΞ,Ξπ, etc.

To illustrate the nature of the effect we used a toy model. We simulated proton and Λ spectra in the exponential form with the slope parameter T_0 = 200 MeV, and introduce the correlation weight between *p* and Λ in the Gaussian form $W \sim (1 + \exp(-k^{*2}/k_0^{*2}))$ with the width parameter k_0^* = 150 MeV/c, where k^* is relative momentum in center-of-mass reference frame. Then we simulated Λ decay into p_Λ and π_Λ^- (isotropic for simplicity) and constructed pp_Λ and $p\pi_\Lambda^-$ correlation functions (see Fig. 1). Original correlations between *p* and Λ is also shown in Fig. 1 for comparison.

One can see from Fig. 1 that the residual correlations between primary *p* and p_Λ from Λ decay is similar to the original $p\Lambda$ and only a little bit smaller. Of course, the difference between the residual and the original correlations depends on the values of simulation parameters. It becomes smaller with increasing ratio k_0^*/p_0, where $p_0 \sim 0.1$ GeV/c is the decay fragment momentum in the Λ reference frame.

Residual correlations between *p* and π_Λ^- from Λ are different from $p\Lambda$. It can be understood easy if we take into account small momentum difference between the proton from Λ decay and the original Λ. For pion and proton

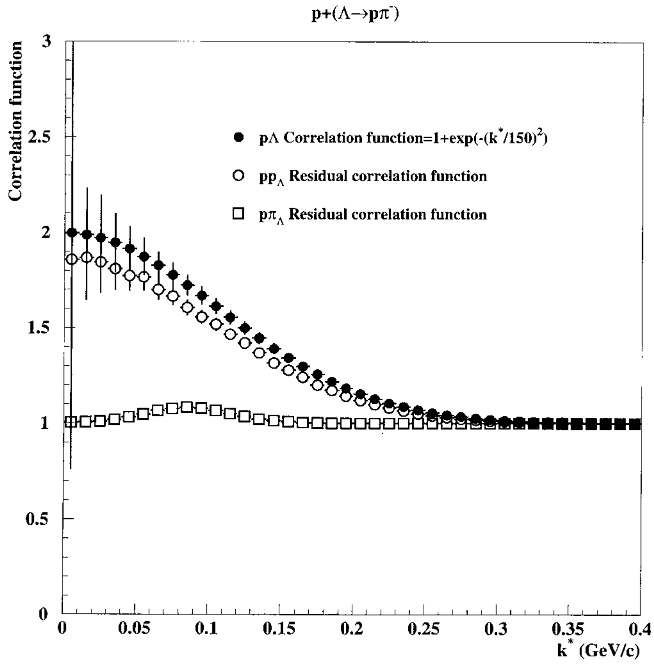

Fig. 1. Simulated correlation function for $p\Lambda$ (full circles) and residual correlations between direct *p* and p_Λ from Λ-decay (open circles).

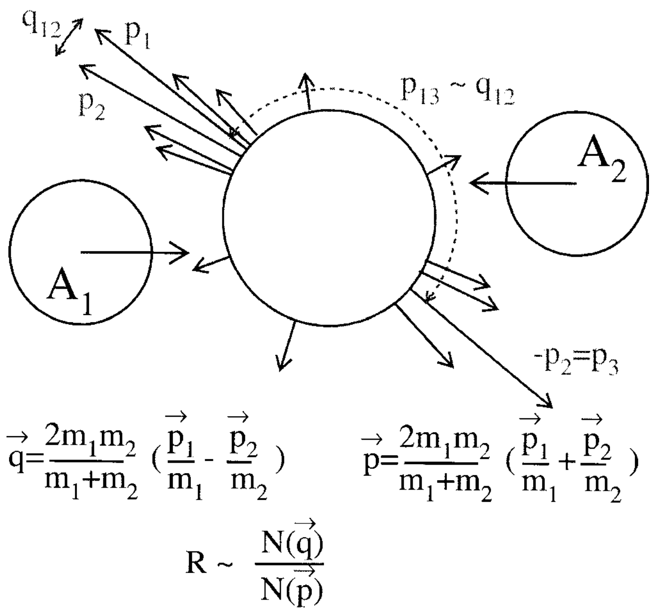

Fig. 2. Schematic illustration for the alternative reference distribution.

from Λ decay relative momentum $k^* \sim 0.08$ GeV/c. For residual correlation function this peak is only smeared and slightly shifted.

As a rule, the higher impurity means the larger residual contributions. For example, a possible residual contribution from $\bar{p}\Xi^-$ correlations (which includes destructive Coulomb contribution) can result in destructive correlations for $\bar{p}\Lambda$ [3].

Some pairs could be more or less free from corrections. For example, $\Xi^-\pi^+$ pair are expected to be much more free from residual correlations with respect to $\Xi^-\pi^-$ because the most of strange baryon decay produce π^- and π^0 rather than π^+, while the number of antibaryons is smaller than the baryon one.

Alternative reference distribution

The mixing procedure [1, 2] provides reliable background for typical events. But this procedure cannot be applied to a unique event which is the goal for one event femtoscopy. For such events, we propose alternative or complementary method.

Let us consider symmetrical interaction (for example collider experiment with $A_1 = A_2$) at sufficiently large energy (particle multiplicity $n >> 1$, see Fig. 2). Suppose the detector is also symmetrical with respect to transition $\vec{r} \to -\vec{r}$. In this case, the probability to find out isolated particles with momentum $\vec{p}$ and $-\vec{p}$ are the same. Real distribution of pairs on total momentum $\vec{p}$ can be used as background one for relative momenta distribution $\vec{q}$.

$N(\vec{p})$ distribution can be affected, in general, by correlations of our interest. This effect is only important at low particle momenta $p < q_0$, $q_0 \sim 0.1$ GeV/c. It can be avoided if apply a simple cut, – one can study $N_c(\vec{q})/N_c(\vec{p})$ distribution instead of $N(\vec{q})/N(\vec{p})$ one. Here, index *c* means cutted and refer to the relative momenta distributions for $p > q_0$ ($N_c(\vec{q})$) and total pair momentum distribution for $q > q_0$ ($N_c(\vec{p})$).

Conclusions

Correlations could provide an additional (and for some pairs the only possible) source of information on low-energy scattering parameters. Based on SU(3) inspired models one can expect a strong final state interaction for $\Sigma^+\Sigma^+$, $\Sigma^-\Sigma^-$, $\Xi^0\Xi^0$, and $\Xi^-\Xi^0$. Those pairs and also pairs where the model provides the large values of effective ranges ($\Xi^0 p$, $\Xi^- n$, $\Xi^-\Sigma^-$, $\Xi^-\Xi^-$) are perspective for femtoscopy. Residual correlations can affect correlation function for different particle species. A new method for reference sample creation is proposed.

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