Exploring two-particle correlations in p+Nb reactions*

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The HADES collaboration measured in 2008 the collision of a proton with a niobium nucleus ($\mathrm{p} + ^{93}\mathrm{Nb}$), where the kinetic energy of the proton was $E_{\mathrm{kin}} = 3.5\,\mathrm{GeV}$. This pA system offers the possibility to study two-particle correlations in an interesting environment, namely in a small system at rather low energies which means low multiplicity. On the one hand side we can compare the results with trends established in heavy-ion collisions at much larger energies to see similarities or find differences and their explanations and on the other hand the measurements are free from correlation-disturbing effects like mini-jets which are produced at LHC energies. The latter point is a good reason to investigate the interaction of particles where the interaction strength is not well established (e.g. between Λ hyperons and protons). It was found in [1] that the $\mathrm{p}\Lambda$ correlation function is sensitive to the size of the particle emission region because the strong interaction between both particles is large enough that they can interact in their final state.
Two-particle correlations are experimentally determined by the ratio:

$$C(k) = \frac{A(k)}{B(k)}. \tag{1}$$

Here $A(k)$ is the distribution of particles from the same event as a function of the relative momentum in the pair rest frame $k = \frac{1}{2}|\mathbf{p}_a - \mathbf{p}_b|$ and $B(k)$ is the corresponding distribution of pairs from mixed event. This ratio is sensitive to the spatial extension of the particle emitting region for small relative momenta $k < 100\,\mathrm{MeV/c}$. We started in the analysis to establish features of the source e.g. its size and shape. For this purpose we used particles where the interaction is well known: protons and pions. For pions it is also possible to extract a three dimensional source information by measuring the correlations in the longitudinally comoving system (LCMS). In the proton case we can apply the Koonin model with a Gaussian source assumption to the data, which describes the proton-proton correlation function theoretically. We extracted a source size of $2.078 \pm 0.010\ (\mathrm{stat})\ \mathrm{fm}$. For negatively charged pions we extracted a slightly smaller Gaussian source size of $1.797 \pm 0.016\,(\mathrm{stat})\,\mathrm{fm}$. In a next step we compared our measurements to predictions of transport models (UrQMD [2]) and we calculated the correlation function with help of the correlation afterburner CRAB [3]. The result is shown in Figure 1, which displays the comparison of the UrQMD result to the experimental measurement. UrQMD is able to describe the measurements quite well. For this reason we trust UrQMD that it also describes the momentum and configuration space of $\Lambda\mathrm{p}$, which allowed us to determine the source function from UrQMD simulations. We found that for $\Lambda\mathrm{p}$ pairs the source size is 1.24 times smaller compared to the proton-proton case. We will use this information to extract the (spin averaged) scattering length and effective range of the $\Lambda\mathrm{p}$ interaction. With help of CRAB we can also test different two-particle interaction models and constrain their parameter space.

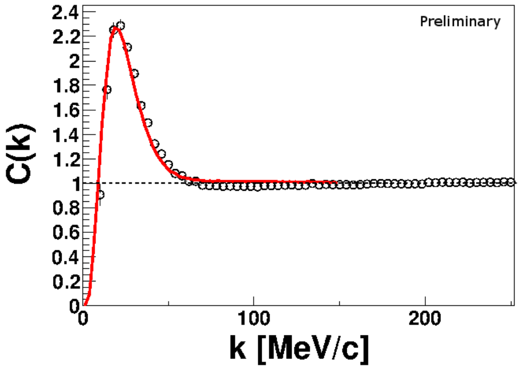

Figure 1: Proton-proton correlation function. The open circles show the experimental correlation function corrected for all inefficiencies. The (red) solid line is the correlation function determined from UrQMD simulations.

To summarize, we measured two-particle correlations in a pA system. We extracted the source size for like-sign pions and for protons. The measurement of the proton source size helped us to pin-down the interaction region of the $\Lambda\mathrm{p}$ pair. With this information we are able to study the interaction between these particles and test different interaction hypothesis with help of the correlation afterburner CRAB.

References

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