First results on particle correlations in ALICE

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We report on the measurement of two-pion correlation functions from *pp* collisions at $\sqrt{s} = 900$ GeV performed by the ALICE experiment at the Large Hadron Collider. Our analysis shows an increase of the HBT radius with increasing event multiplicity, in line with previous experiments. Conversely, the strong decrease of the radius with increasing transverse momentum, as observed at RHIC and at Tevatron, is not manifest in our data.

1 Introduction

ALICE (A Large Ion Collider Experiment) has been designed to investigate the physics of strongly interacting matter at extreme values of energy, density, and temperature in PbPb collisions [1]. These studies are to be complemented by measurements of light nuclei and *pp* collision systems. A distinguishing feature of the system created in heavy-ion collisions is the collective expansion. This view was recently challenged by the observation that at RHIC energies the transverse expansion is already manifest in the transverse momentum spectra of particles emitted in *pp* collisions, provided the energy and momentum conservation has been properly accounted for in the data analysis [2]. Moreover, dropping of the particle-source size with increasing transverse momentum – another signature of transverse expansion – was reported to be similar in *pp* and AuAu systems [3].

In this paper, we are looking for signatures of collective behavior in *pp* collisions at LHC energies by studying the size of the pion source as a function of event multiplicity and particle transverse momentum. The source size is deduced from the width of the peak representing the Bose-Einstein enhancement of identical-pion pairs at low relative momentum. This technique (Hanbury Brown - Twiss, or HBT, analysis [4, 5]) has been previously successfully applied in elementary particle [6, 7], and heavy-ion [8] collisions.

2 Data analysis and inclusive correlation functions

The results discussed here were obtained from analysis of the 250 k *pp* collision events recorded in December 2009, during the first stable-beam period of the LHC commissioning. The correlations analysis was performed using charged particle tracks registered in the ALICE Time Projection Chamber (TPC) [9]. The fiducial kinematical region was $|\eta| < 0.8$ and $0 < \phi < 2\pi$. Pion tracks were identified via the specific ionization in the TPC gas. The running conditions and the event and track selections are described in detail in Ref. [10].

The two-particle correlation function is defined as the ratio $C(\mathbf{q}) = A(\mathbf{q})/B(\mathbf{q})$, where $A(\mathbf{q})$ is the measured distribution of pair momentum difference $\mathbf{q} = \mathbf{p}_2 - \mathbf{p}_1$, and $B(\mathbf{q})$ is a similar distribution obtained via event mixing. The limited statistics available allowed us to perform a detailed analysis only for the one-dimensional two-pion correlation functions $C(q_{\rm inv})$. The $q_{\rm inv}$ is, for equal mass particles, equal to the modulus of the momentum difference $|\mathbf{q}|$ in the pair rest frame.

Figure 1 shows the $\pi^+\pi^+$ and $\pi^-\pi^-$ correlation functions from pp collisions at $\sqrt{s} = 900$ GeV. The two functions agree within the statistical errors. The Bose-Einstein enhancement at low $q_{\rm inv}$ is clearly visible. The high $q_{\rm inv}$ part of the correlation function is not flat and it is difficult to separate the Bose-Einstein enhancement from other sources of correlations like those arising from jets or energy- and momentum conservation. The situation is different in nuclear collisions where the baseline – the underlying two particle correlation without any Bose-Einstein enhancement – is flat, and the BE peak can be clearly identified (Fig. 2).

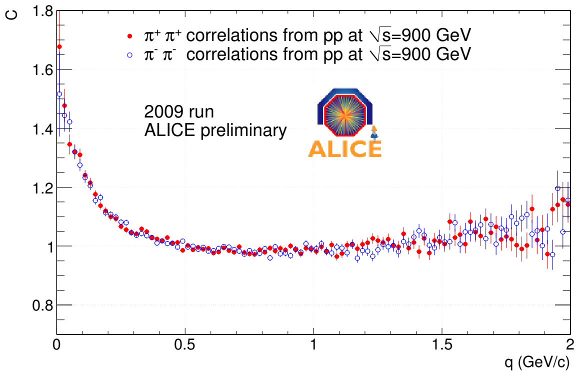

Figure 1: Correlation functions for positive (red filled dots) and negative (blue open circles) pion pairs from pp collisions at $\sqrt{s} = 900$ GeV.

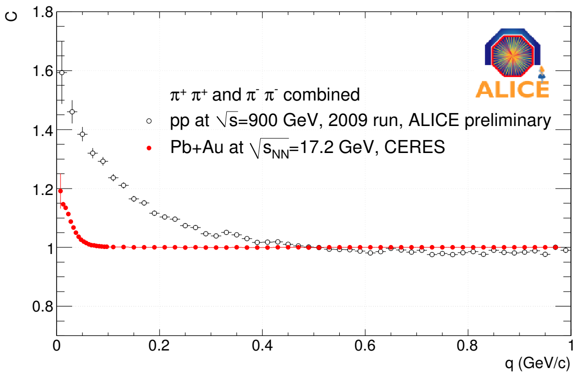

Figure 2: Comparison between the two-pion correlation functions in pp (black open circles) and PbPb collisions (red filled dots). Two-track effects, momentum resolution, and Coulomb interaction have to be corrected for in case of nuclear collisions. For hadron collisions, the non-Gaussian shape of the peak and the lack of a well defined flat baseline are the main difficulties.

In order to isolate the Bose-Einstein effect from other correlation sources, it is helpful to study the unlike-sign pion correlations for which the Bose-Einstein effect is absent. Their correlation function (Fig. 3) exhibits, in addition to the Coulomb interaction peak at low $q_{\rm inv}$ and the peaks coming from meson decays, broad structures that can be reproduced with Monte Carlo simulations using PHOJET [11] and PYTHIA [12] event generators, combined with a full simulation of the apparatus. The same calculations can thus be used to describe the baseline under the Bose-Einstein peak in the identical-pion correlation function. The fact that the structures are different for the like-sign and unlike-sign pions prevents us from using a ratio of the two correlation functions directly.

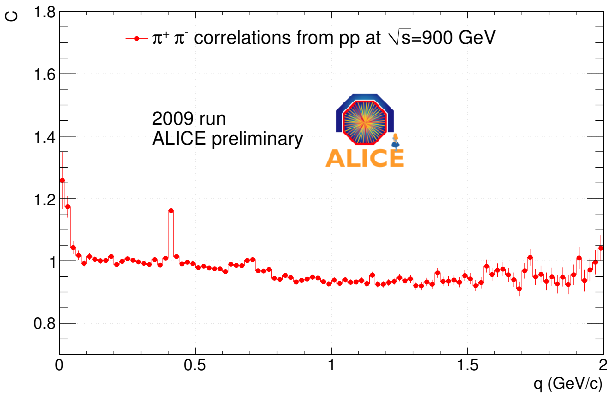

Figure 3: Correlation function for unlike-sign pion pairs from pp collisions at $\sqrt{s} = 900$ GeV.

The dynamics of the system created in the collision shows up as the dependence of the width of the Bose-Einstein peak on the multiplicity and the transverse momentum. In order to study this dependence quantitatively and to be able to compare to the existing systematics, the Bose-Einstein peak in the correlation functions was fitted by a Gaussian $G(q_{\rm inv}) = \lambda \exp(-R^2_{\rm inv} q^2_{\rm inv})$, with the correlation strength λ and the HBT radius $R_{\rm inv}$, sitting on a fixed baseline with the shape taken from Monte Carlo as explained before.

3 Multiplicity and transverse momentum dependence

The dependence of the HBT radius on the event multiplicity is shown in the left hand panel of Fig. 4. The tracks used in determining the multiplicity were the same as those used for the correlation analysis except that pion identification cuts were not applied. The raw multiplicity was corrected for the reconstruction efficiency and contamination, determined from a Monte Carlo simulation with the PHOJET event generator and with the full description of the ALICE apparatus. Like at RHIC and at Tevatron, the ALICE measured HBT radius increases with particle multiplicity. Such an increase is well known in nuclear collisions; its presence in hadron collisions indicates that the HBT radius is coupled directly to the final multiplicity rather than to the initial collision geometry.

The transverse momentum dependence is shown in the right hand panel of Fig. 4. The ALICE measured HBT radius is practically independent of $k_{\rm T}$ within the studied range. It should be noted that this result crucially depends on the baseline shape assumption: if the baseline is not taken from event generators but assumed to be flat then the high $k_{\rm T}$ points drop by about 30% and an apparent $k_{\rm T}$ dependence emerges. This is because the broad enhancement caused by other correlations will be attributed to Bose-Einstein correlations, giving rise to smaller radii (wider correlation function).

4 Summary

In summary, ALICE has measured two-pion correlation functions in pp collisions at $\sqrt{s} =$ 900 GeV at the LHC. Consistent with previous measurements of high-energy hadron-hadron and nuclear collisions, the extracted HBT radius $R_{\rm inv}$ increases with event multiplicity. Less consistent is the relation between $R_{\rm inv}$ and the pion transverse momentum where the ALICE measured HBT radius in minimum bias events is practically constant within our errors and

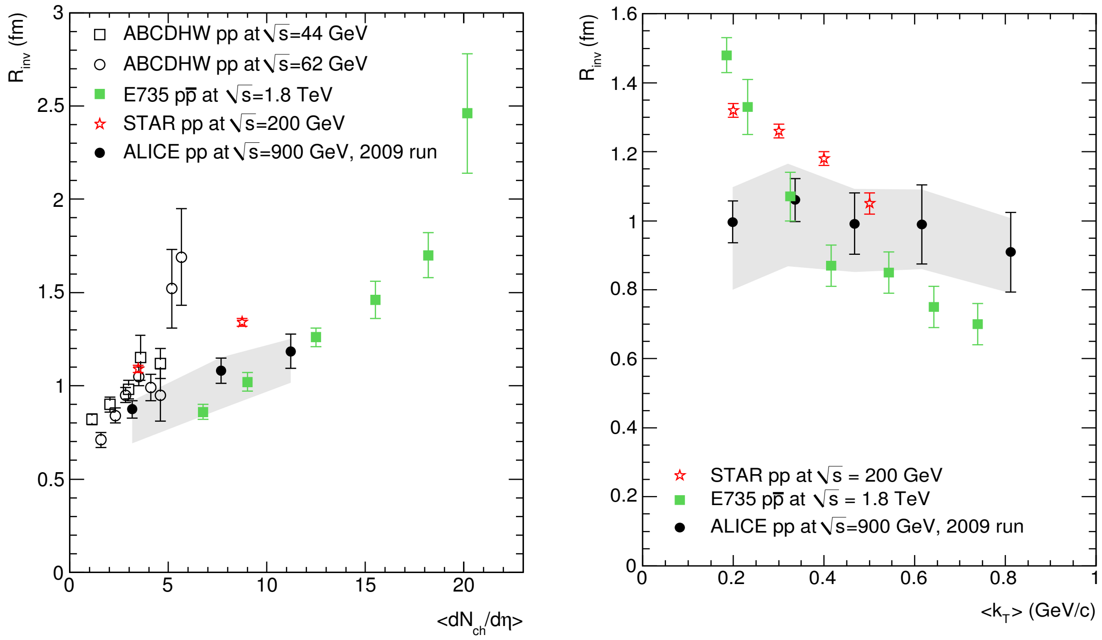

Figure 4: Dependence of HBT radius on multiplicity (left) and transverse momentum $k_T = |\mathbf{p}_{T,1}+\mathbf{p}_{T,2}|/2$ (right). The error bars are statistical; the shaded area represents the systematic errors (for details see Ref. [10]). The ALICE results are compared to RHIC [3] and Tevatron data [13] (compilation taken from [14]).

within the transverse momentum range studied. Our data, thus, shows no signature of strong transverse expansion.

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