Femtoscopy with identified hadrons in pp, pPb, and peripheral PbPb collisions

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Introduction

Short range correlations of identified charged hadrons in pp ($\sqrt{s} = 0.9, 2.76, \text{ and } 7 \text{ TeV}$), pPb ($\sqrt{s_{\text{NN}}}$ = 5.02 TeV), and peripheral PbPb collisions ($\sqrt{s_{\text{NN}}}$ = 2.76 TeV) are studied with the CMS detector at the LHC.

The symmetrization of the joint wave function of identical bosons leads to correlations at low values of relative momenta $\vec{q}$. We measure the ratio of signal and background distributions $C_2(q)$. The quantum correlation function $C_{\text{BE}}$, part of $C_2$, is the Fourier transform of the source density distribution.

Data analysis

Charged pions and kaons at low $p_T$ and in laboratory pseudorapidity $|\eta| < 1$ are identified via their energy loss in the silicon tracker. Particle-by-particle identification is possible with high purity (> 99.5%): $p < 1.15 \text{ GeV}/c$ for pions and kaons.

The correlation functions were corrected for the Coulomb interaction between particles using an analytic approximation of the exact calculation. The contributions from other, correlated particle emissions (mini-jets, multi-body resonance decays) were also subtracted. Their shapes were taken and parametrized from unlike-sign data, while their amplitudes were fixed from like-sign fits.

For the class of stable distributions, the Bose-Einstein correlation function has a stretched exponential shape. The form used (3D) $C_{\text{BE}}(q_1, q_2, q_3) = 1 + \lambda \exp \left[ -\sqrt{(q_1 R_1)^2 + (q_2 R_2)^2 + (q_3 R_3)^2} \right]$. 

Some results

Radii vs the corrected charged-particle multiplicity $N_{\text{tracks}}$ (in the region $|\eta| < 2.4$), and vs $k_T$ of the pair, are shown.

Two-dimensional radii (showing only $q_1$):

Three-dimensional radii (showing only $q_3$):

Conclusions

- The measured correlation functions point to a Cauchy type source distribution.
- Exponential radii for pions increase with increasing $N_{\text{tracks}}$ for all systems studied.
- In general there is an ordering, $R_l > R_t$ and $R_t > R_o$. The pp and pPb source is elongated in the beam direction. In the case of peripheral PbPb the source is quite symmetric.
- The kaon radii also show some increase with $N_{\text{tracks}}$, although its magnitude is smaller than that for pions.
- The pion radii decrease with increasing $k_T$. The dependence of the radii on the multiplicity and $k_T$ factorizes, and in some cases is less sensitive to the type of the colliding system and center-of-mass energy: $R_{\text{param}}(N_{\text{tracks}}, k_T) = [a^2 + (bN_{\text{tracks}})^2]^{1/2} \cdot (0.2 \text{ GeV}/c/k_T)^2$.
- The observed similarities may point to a common critical hadron density in pp, pPb, and peripheral PbPb collisions, since we measure the characteristic size near the time of the last interactions.

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