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Measurement of Bose-Einstein correlations in pp collisions at $\sqrt{s} = 0.9$ and 7 TeV with the CMS detector

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Summary. — Bose-Einstein correlations are measured in samples of proton-proton collisions at 0.9 and 7 TeV centre-of-mass energies, recorded by the CMS experiment at the LHC. The signal is observed in the form of an enhancement of number of pairs of same-sign charged particles with small relative momentum. The dependence of this enhancement on kinematic and topological features of the event is studied.

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Interferometry of identical bosons is a powerful tool to investigate the space-time structure of sources emitting particles produced at different center-of-mass energies and from different initial systems. The effect manifests itself as a constructive interference at low values of the relative momentum of the pair, which can be expressed in a Lorentz-invariant form as $Q = \sqrt{-(p_1 - p_2)^2} = \sqrt{M^2 - 4m_\pi^2}$, where M is the invariant mass of the two particles, assumed to be pions with mass m_π. Experimentally, the Bose-Einstein correlation (BEC) function is constructed as the ratio $R(Q) = (\mathrm{d}N/\mathrm{d}Q)/(\mathrm{d}N_{\mathrm{ref}}/\mathrm{d}Q)$ of the Q distributions for pairs of identical bosons in the same event and for pairs of particles in a reference sample not containing the BEC effect. In the measurements discussed here a mixed reference sample is used, constructed by pairing equally charged particles from different events that have similar charged-particle multiplicities in the same pseudorapidity regions. The data have been collected by the CMS experiment in pp collisions at center-of-mass energies at 0.9 and 7 TeV in the 2010 run; the most relevant part of the CMS detector [1] involved is the inner tracking system. All pairs of same-sign charged particles with Q between 0.02 and 2 GeV are used for the measurement. The complete description of the experimental acceptance and cuts adopted in the analysis is reported in [2]. The correlation function $R(Q)$ is fitted using the commonly used parameterization $R(Q) = C[1 + \lambda\Omega(Qr)] \cdot (1 + \delta Q)$. In most formulations of BEC, $\Omega(Qr)$ is the modulus square of a Fourier transform of the space-time region emitting bosons with overlapping wave functions, characterized by an effective size r. The parameter λ reflects the BEC strength for incoherent boson emission from independent sources, δ accounts for long-range momentum correlations, and C is a normalization factor.

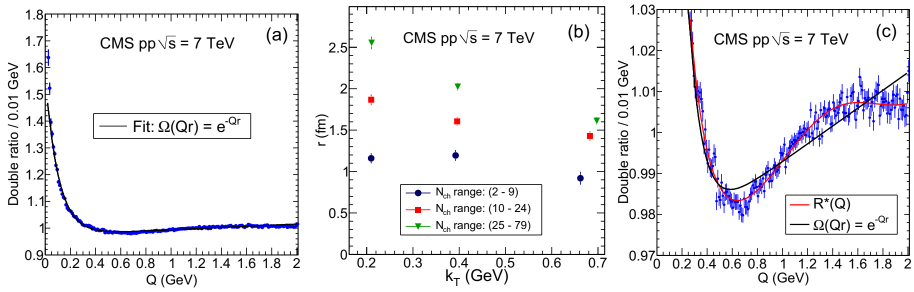

Fig. 1. – Data points for the double ratio are shown in (a), fitted with exponential form $\Omega(Qr) = e^{-Qr}$ in $R(Q)$. Part (b) shows the behavior of the r parameter obtained with $\Omega(Qr) = e^{-Qr}$ as a function of k_T for three bins in N_{ch}. The plot in (c) shows the anticorrelation structure in the double ratio with enlarged y scale with $\Omega(Qr) = e^{-Qr}$ (black) and $R^*(Q)$ (red) fit.

To reduce possible biases in the construction of the reference sample, a double ratio $\mathcal{R}(Q) = \frac{R}{R_{\text{MC}}} = (\frac{\mathrm{d}N/\mathrm{d}Q}{\mathrm{d}N_{\text{ref}}/\mathrm{d}Q})/(\frac{\mathrm{d}N_{\text{MC}}/\mathrm{d}Q}{\mathrm{d}N_{\text{MC, ref}}/\mathrm{d}Q})$ is defined, where the subscripts "MC" and "MC, ref" refer to the corresponding distributions from the Monte Carlo simulations, generated without BEC effects. More details can be found in ref. [2]. The double ratio $\mathcal{R}(Q)$ is shown in fig. 1(a) for $\sqrt{s} = 7\,\text{TeV}$ data, together with the fit obtained with the exponential parameterization $\Omega(Qr) = e^{-Qr}$ of the correlation function. The results obtained for the r parameter as a function of the average transverse momentum of the pair, $k_T = (k_{1,T} + k_{2,T})/2$, for three different bins of charged multiplicity, N_{ch} are shown in fig. 1(b) using $\Omega(Qr) = e^{-Qr}$. The effective radius r, is observed to increase with N_{ch} while is approximately independent of k_T in the smaller multiplicity range; it clearly decreases with increase k_T for larger charged multiplicity events. A dependence on k_{T} has been also observed at the SPS, at the Tevatron, and at RHIC [3], where it is associated with the collective system behavior. Similar results in pp collisions are seen by ALICE Collaboration [4]. Although the parameterization $\mathcal{R}(Q)$ could describe the overall behavior of the data, it results in poor quality of the fit, originated by the presence of an anticorrelation (dip with $\mathcal{R} < 1$) observed in the double ratio at both energies and shown in fig. 1(c) for the $\sqrt{s} = 7\,\text{TeV}$ case. Our data are better described by an alternative parameterization of the correlation function originally proposed to describe an analogous effect observed in e^+e^- collisions at LEP [5]: $\mathcal{R}^*(Q) = C[1+\lambda(\cos[(r_0Q)^2+\tan(\alpha\pi/4)(Qr_\alpha)^\alpha]e^{-(Qr_\alpha)^\alpha})]\cdot(1+\delta Q)$, as shown in fig. 1(c). The parameter r_0 is related to the proper time of the onset of particle emission, r_α is a scale parameter, and α corresponds to the Lévy index of stability. The depth in this anticorrelation region has been quantified as the difference between the baseline curve defined as $C \cdot (1 + \delta Q)$ and the value of $R^*(Q)$ at its minimum. It has been investigated as a function of N_{ch} and its decrease has been found consistent with this variable. This is the first evidence of the dip effect in pp collisions.

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