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BEC for photons and neutral pions

Oleg V. Utyuzh,
Grzegorz Wilk

Abstract The role of BEC for photons and neutral pions is briefly discussed and illustrated by means of a new method of numerical modelling of BEC proposed by us recently.

Key words correlations • BEC • photons • neutral pions

O. V. Utyuzh, G. Wilk✉
Nuclear Theory Department,
The Andrzej Sołtan Institute for Nuclear Studies,
69 Hoża Str., 00-681 Warsaw, Poland,
Tel.: +48 22/ 553 22 26, Fax: +48 22/ 621 60 85,
e-mail: wilk@fuw.edu.pl

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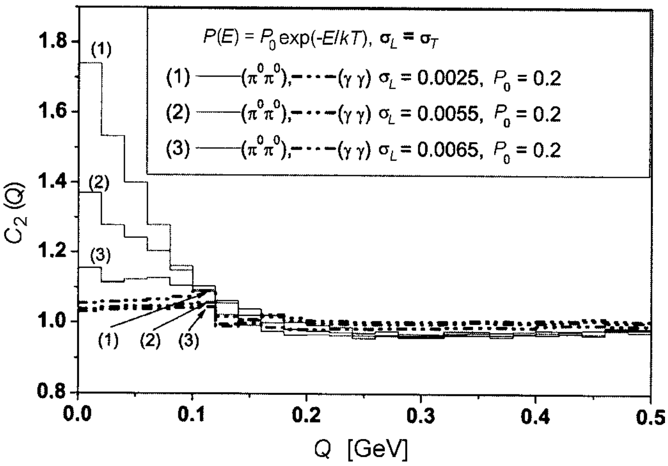
Photons and π^0's play a particular role in high energy multiparticle processes, especially in heavy ion collisions, which are believed to be the place where the Quark Gluon Plasma is possibly formed. This is because they are immune to the Coulomb final state interactions distorting BEC analysis of charged particles. The π^0 interferometry can be then used as a kind of check allowing to estimate the correctness of procedures accounting for this effect in BEC between charged particles. Of minor experimental consequence, at present, (but otherwise very interesting) is fact that, because both photons and π^0's are also their own antiparticles, one expects that for low momenta (actually, for $k_{\gamma,\pi 0} \to 0$) one should observe some additional effects emerging from the particle-antiparticle correlation, a pure quantum mechanical effect discussed at length in [6]. Photons are also the only particles which could, in principle, provide us with detailed picture of the whole history of heavy ion collision process because they are produced anywhere where one has deceleration or acceleration of charges whereas hadrons (including π^0's) are produced only at final hadronization period of collision. This means that they are produced starting with very early stage of collision (sometimes called preequilibrium), through the stage of formation and equilibration of the QGP and through the mixed stage where first hadrons are being produced in QGP environment and ending with the last kinetic freeze-out stage where hadrons are finally formed (see [3] for a most recent review; no BEC discussion is presented there, however). It is obvious that the production mechanism of photons at different periods of collision will be different, ranging from bremsstrahlung at the beginning, via thermal emission at QGP phase, to decays of neutral particles (mostly π^0's) at the end [3]. For us, the most interesting would be directly produced photons, especially the thermal ones originated from the QGP.



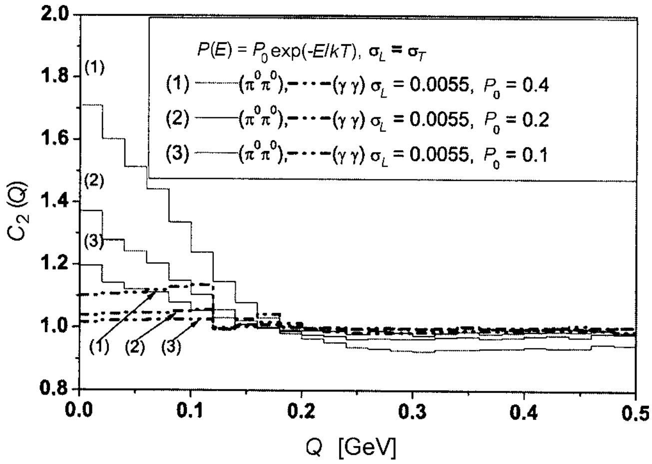


Fig. 1. Example of BEC results for π^0 as produced by our algorithm (full lines) and BEC for γ's resulting from their decays. Left panel shows results for different sizes of elementary emitting cells (EEC's) characterized by parameter $\sigma_{L,T}$. Right panel shows results for different strength of BEC effect characterized by parameter P_0 (leading to different occupancy of the average EEC, cf. [5]).

However, according to the recent WA98 data [1] they consist of only a few percent of the all photons visible.

Photons should be also copiously produced at a PHOS detector of ALICE at LHC, therefore it is fully justified to prepare for this possibility, especially for the possible BEC measurements, both with direct and decay photons (for references see [7], the most recent paper on this subject is [4] where updated references can be found). Whereas the method to be used for BEC are essentially the same as for other particles (cf. [6, 7]) there are some new problems, one is facing those which are connected with the fact that at ALICE one probably will not be able to measure directly π^0's, but only photons they are decaying to. Question which arises then is: notwithstanding this fact, can one deduce BEC characteristics of π^0's from BEC characteristics of γ's? This problem has been addressed in [2] and a positive conclusion has been reached as well as the procedure for such analysis has been provided, which can easily be applied when data will be available. However, an opposite conclusion has been reached in [4] where photons from π^0's were demonstrated to show very characteristic structure at small values of Q (of the order of pion mass) and flat distribution for larger values of Q. On the other hand, it was also shown there that, at least for SPS and RHIC energies, one can actually separate correlations of photons produced directly in the hot zone and residual correlations of decay photons (i.e., those coming predominantly from π^0's). It turns out that (at least in the framework of the hydrodynamical model of collision used there) the former contribute essentially to the region of small invariant relative momenta, $Q_{inv} \leq 50$ MeV, while the later dominate the large relative momenta.

Here, we shall present numerical calculations in which π^0's were created by Monte Carlo algorithm, which incorporates already BEC effect [5]. Referring to [5] for details and physical motivation we shall concentrate here on the same problem as was considered analytically in [4] and [2], namely, to what extent BEC picture of original π^0 is visible in finally observed γ's to which they decay and what is the chance to detect BEC of originally produced γ's as well. To this end, we have to modify slightly algorithm used in [5] by allowing for varying transverse momenta of produced π^0's (they were fixed as $p_T = \langle p_T\rangle$ in [5], i.e., the case considered was essentially a purely one-dimensional). It will be done in the following way. After choosing energy E of selected particles (done in the same way as before [5]), we shall notice that $E = \sqrt{p_T^2 + p_L^2 + \mu^2}$ (where μ denotes pion mass) and choose now $p_T = |\vec{p_T}|$ from distribution $P(p_T) = \exp(-p_T/\langle p_T\rangle)$ (in calculations presented here parameter $\langle p_T\rangle = 0.2$ GeV/c) such that $p_T \in (0, \sqrt{E^2 - \mu^2})$. Then the azimuthal angle $\phi \in [0, 2\pi]$ was selected from uniform distribution and direction right–left for longitudinal momentum p_L was chosen. In this way $p_T = \pm\sqrt{E^2 - p_T^2 - \mu^2}$. In this way we start a new elementary emitting cell (cf. [5] for more details) and add to it other particles of the same kind momenta of which were selected from Gaussian distributions with widths σ_L and σ_T treated as free parameters. It turns out that in the example considered here results are not particularly sensitive to their difference, therefore we have put them equal: $\sigma_L = \sigma_T$.[1]

Our results are shown in Fig. 1. They confirm results of [4], namely that photons from decaying pions do not follow their BEC pattern but show, instead, their own pattern, which is quite robust against different choices of parameters, and which consist in essentially constant (but small) correlations for small relative momenta vanishing after Q of the order of pion mass. The possible explanation of this result seems to be the same as in [4] (modulo possible deviations in numbers caused by our limitation in p_T and essentially 3-dimensional case considered in [4]).[2]

[1] The reason is that our example is still very much one-dimensional. The reason is that in [5] we wanted to check whether it is possible in principle to reproduce e^+e^- annihilation data and their phase space is clearly a quasi-one-dimensional. However, this limitation does not affect results and conclusions presented here.

[2] At this moment, we cannot offer any explanation of difference between the results of [4] and [2] noticing only that we do not think that explanation provided in [4] and attributing this difference to different way of introducing cuts in momenta should not work for the first panel of Figure presented in [2] where there is no limitation and result is still different from that presented in [4].

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