Multiplicity distribution of neutral pions in hadronic interactions

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December 2024

Introduction

The SVD(Spectrometer with Vertex Detector) collaboration aims to describe collective phenomena at high multiplicity regions of charged and neutral particles. The Bose-Einstein Condensation of pions, peak structure at angular distribution relating to Cherenkov radiation, shock wave formation and soft yield are of particular interest. BEC is a unique phase transition that occurs in the absence of thermal interactions. The atomic gases transform into liquids and solids before they reach the BEC line. And it can be avoided by considering extremely low densities. The selection of datasets is done such a way so as to consider the regions where the pions are copiously produced and consequently has a high multiplicity. In such regions, their energies decrease and they cool down, agglomerate and form BEC.

Collection of data

Most of the photons are obtained from pion decays.The number of photons depend on the number of pions detected. And by reconstruction of the photon paths, the multiplicity distributions of the pions can be obtained. The Ecal(calorimeter) of the SVD is calibrated by electron beam. It permits to restore the neutral pion multiplicity.

The correlation between the neutral and charged pions is performed using models, the π and σ models. In the π model, the pions are independently emitted; in the σ model, the pions are produced in pairs with isospin I=0. In the $\rho\rho$ model, they are neutrally emitted in double pairs with isospin I=1 for each pair.

Bose Einstein Correlation

Bose-Einstein Correlation is a phenomenon that refers to the quantum statistical correlations occurring due to the symmetrization of the bosonic wavefunction and does not require a macroscopic quantum state to occur, unlike Bose-Einstein condensation. The chaoticity in the Bose-Einstein correlation is explained in terms of Bose-Einstein condensation. The chaoticity is defined by the chaoticity parameter λ of the BEC and represents the experimental data.

Identical bosons with mutual attractive interaction generate a mean field potential, which depends on the boson density ρ(r) as:

$$V(r) = -4\pi f(0)\rho(r) \sim \frac{1}{2}\hbar\omega(\frac{r}{a})^2$$

f(0) is the forward scattering amplitude and a is the scale of the spatial expansion of the bosons.

For a given temperature T at freeze-out, a high density of produced bosons will lead to a lower value of the order parameter $\frac{T}{\hbar\omega}$, which in turn will lead to a greater condensate fraction f(0)=$\frac{N_0}{N}$, where N is the total number of bosons and N_0 is the number of bosons in the lowest state. A higher condensate fraction f (0) brings about greater coherence in Bose-Einstein correlations and reduces the degree of chaoticity. In high-energy heavy-ion collisions, when bosons (gluons or pions) are copiously produced within a small region in a short time interval, the density of the bosons increases as the collision energy increases. Following the above reasoning, generalized to systems with differential transverse and longitudinal spatial distributions, we expect the occurrence of boson condensation in high-energy heavy-ion collisions at suitable energies.

Mathematical Analysis

The Bose-Einstein Correlation that is formed by pions in their high multiplicity distribution is analogous to the Hanbury Brown Twiss effect in astronomy that describes the interference of incoherently emitted identical bosons. It is measured in terms of a two-particle correlation function, given by:

$$C_2(p_1, p_2) = \frac{\rho(p_1, p_2)}{\rho_0(p_1, p_2)}$$

where p_1 and p_2 are the four momenta of two identical bosons, ρ is the two-particle density function and ρ_0 is also a two particle density function specially constructed to exclude the BEC effects.

Experimental Setup

The basic elements of SVD-2 setup are the liquid hydrogen target, precision microstrip silicon vertex detector (PVD), straw tube chambers, magnetic spectrometer consisting of proportional chambers and magnet, Cherenkov counter and electromagnetic calorimeter (ECal).
PVD is one of the most important elements of SVD-2 setup permitted to determine the vertex of interaction position and to reconstruct the charged particle tracks. It consists of 10 silicon planes and has more than 10000 registration channels. This detector has played a significant role in defining the charged multiplicity. To select the high charged multiplicity events and to considerably suppress the low multiplicity event registration, the scintillator horoscope, known as high multiplicity trigger (HMT) has been manufactured. Owing to its small thickness, this trigger does not distort events. Nuclear interactions in the trigger hodoscope are the sources of noise in determining the event multiplicity. After applying additional criteria to the trigger conditions, the fraction of events with interactions in the trigger hodoscope did not exceed 4%. The topological cross sections have been defined by using the beam telescope and PVD information. The 5.13 millionsof 2008 year run events have been selected. From this statistics 3.85 millions of events have been taken at trigger-level 8 (lower limit of the registered multiplicity set at trigger system). Out of them 2.1 millions of events have been detected in the fiducial volume of the hydrogen target. For the final analysis almost 1.0 million of events have been retained. They were selected according to the criteria: the number of beam tracks simultaneously hitting the target not exceeding 2 and the coordinates of the vertex on two projections with a difference smaller than 5 mm.

Experimental Results

Previously, we have studied multiplicity distributions using the Gluon Dominance Model for pp collisions. Now we use the same for neutral pion productions with modifications in the formula. We consider two cases, including and excluding gluon fission.

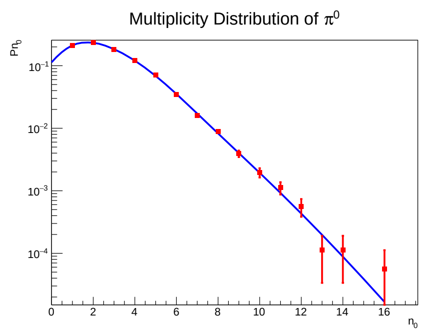

Figure 1: MD without fission

We see that the simulated function does not match the experimental results because we did not consider gluon fission. Hence, we should consider gluon fission. Including it in our calculation gives us a graph, as shown below.

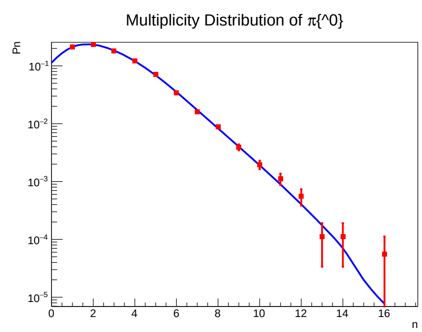

Figure 2: Multiplicity distribution of neutral pions from gluon dominance model with fission

Conclusion

The formation of pion condensate which is produced in their high multiplicity region and explains the formation of Bose Einstein Correlation is thus successfully described by the Gluon Dominance Model. And, gluon fission plays a significant role in the regions of high multiplicity.

Acknowledgement

I am extremely grateful to Prof. Elena Kokoulina and my fellow project partner Ms. Yara Shousha for their unwavering support and helping me in successfully comp;getting this project.

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