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Evidence for a pion condensate formation in pp interactions at U-70

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Experiments at LHC give evidence of similarity of multiple production mechanisms in proton interactions at high multiplicities [1] and central collisions of relativistic heavy ions (RHIC). Studies at high multiplicity (more than mean value) region are carried out at U-70 accelerator at IHEP (Protvino). They are aimed at the search for collective phenomena.
It is known that mainly pions are produced at U-70 energies. Their mean energy decreases with multiplicity increase. In that system Bose-Einstein condensate (BEC) [2] can be formed. The theoretical and experimental studies of BEC are continuing from 70es. M. Gorenstein and V. Begun [3] have shown within the framework of an ideal pion gas model that sharp growth of the neutral pion number fluctuations will be a signal of BEC formation with the increase of total multiplicity (a sum of neutral and charged particles). They proposed to measure scaled variance, ω. It is defined as the ratio of variance of neutral pion number distribution to mean multiplicity. In the thermodynamic limit ω approaches to infinity. This value reached the finite quantity for the restricted system formed in the collisions of two protons.
SVD Collaboration (JINR, IHEP and SINP MSU) [4] investigated neutral pion number fluctuations in pp interactions at 50 GeV/c incident beam at U-70 versus total multiplicity and has revealed noticeable growth of ω with the total multiplicity increase. This work was carried out in two stages. At the first stage the charged-particle multiplicity distribution was measured. At the second stage the neutral pion number distributions were restored. We could go down three orders on topological cross sections up to ˜ 10 nb. Events with high multiplicity are extremely rare therefore we have designed a sophisticated trigger to suppress the recording of events with the multiplicity smaller than the given value, called a trigger level. The measured topological cross sections have been corrected with taking into account trigger conditions, a detector acceptance, the detection efficiency of setup and the reconstruction algorithm. The measurements have been fulfilled with the silicon vertex detector.

Summary

Comparison of the topological cross sections with models has shown that the negative binomial distribution (NBD) overestimates experimental data at high multiplicity region, Nch > 20, but describes well the region of a small multiplicity. Good agreement has been received using the gluon dominance model with including the gluon sources fission.
To restore neutral pion multiplicity, the electromagnetic calorimeter (EMCal) is used. Owing to its restricted aperture and threshold energy of a gamma-quantum registration, the restoration of a π0- meson number in every single event is impossible. This multiplicity is restored by means of simulation of EMCal work. For this purpose we have used Monte Carlo event generator PYTHIA5.6. For 10 mil simulated inelastic events the linear dependence between the mean multiplicity of π0- mesons and the number of EMCal registered photons has been revealed. Besides, the next procedure was carried out. The simulated events were broken up into samples according to charged particle number, Nch. Every sample was divided into groups of events by EMCal registered photon number, Nγ. In each group the π0- meson number distribution was restored. This distribution determines the share of events with a possible number of neutral mesons. By means of these distributions the multiplicity distributions of neutral mesons, N0, has been received from experimental data

for photons.

To analyze neutral pion number fluctuations versus total multiplicity, Ntot = Nch + N0, the variable n0 = N0 / Ntot, (a region of change [0, 1]) is used. These distributions were parameterized by Gauss function to restore the missing regions. The found values of scaled variance are agreed well with the magnitude of ω defined on simulated events at Ntot < 22. At the same time we reveal the significant growth of ω, reachable by more than 7 standard deviations at Ntot ˜ 30 as opposed to the tendency for the simulated events. This growth has been observed both registered photons (Ntot = Nch + Nγ), and restored neutral pions.

Critical point of pion condensation is determined in statistical physics by an expression [2]. The density, ρ , is equal to 0.2 fm-3 at interaction region size for two protons ˜ 3 fm. In this case the critical energy is resulted to Ecrit = 100 MeV. At 50-GeV proton beam and Ntot = 30 the mean energy of pion, Eπ = (Ecms −2 mN −Ntotmπ)/Nπ , is equal to 120MeV. This value is compatible with Ecrit. Thus the experimental observable growth of scaled variance at U-70 for registered gamma-quanta and restored neutral pion multiplicity can testify to BEC formation in the pion system at high multiplicity events.

At present we are planning to study soft photon (Eγ < 100 MeV) yield versus neutral, charged and total multiplicities. Experiments carried out in last year's point to the excess its yield in comparison with theoretical estimations. The exhaustive explanation of this collective phenomenon is absent. In the approach developed by S. Barshay [6] the excess of soft photon yield is connected with BEC formation in the pion system. Also we will increase statistics to move forward to a totally much higher multiplicity region.

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