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Study of pp Interactions at U-70

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Study of high multiplicity events is important for understanding of strong interaction nature, especially hadronization. The Thermalization project carried out on U-70 accelerator (IHEP, Protvino) is aimed at the search for collective phenomena both in quark-gluon plasma and secondary hadron system. On the level of 7 standard deviations the evidence of Bose–Einstein condensation of pions in the high multiplicity region has been confirmed at twofold increasing sampling. There are theoretical predictions that Bose-Einstein condensate is closely connected with excess of soft photon yield [S. Barshay, Phys.Lett. **B227** (1989) 279]. To check up this assertion SVD Collaboration has manufactured a prototype of electromagnetic calorimeter with low energy threshold. The preliminary results are presented. Gluon dominance model (GDM) testifies this excess which can be stipulated by soft photon production.

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The unique project Thermalization studies multiparticle production in closed to kinematical threshold region (experiment E-190 at IHEP, Protvino) [2]. The project is carried out at SVD-2 (Spectrometer with Vertex Detector) setup disposed on the extracted proton beam of U-70 accelerator. SVD-2 setup registers secondary particles produced as a result of interaction of 50 GeV proton beam with hydrogen target: $p + p \to N + N + N_\pi \pi$, where N is a nucleon, N_π is the multiplicity of secondary pions. The main aim of this project is the topological cross section measurement at high multiplicity (HM),

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considerably more than average one; the search for collective phenomena of secondary particles and the development of theoretical models for descriptions of multiparticle production in hadron interactions.

SVD-2 setup [2] includes a hydrogen target, a high multiplicity trigger, a vertex detector (VD), drift tube chambers, a magnetic spectrometer (a magnet and proportional chambers), an electromagnetic calorimeter (ECal). To measure soft photon (SP) yield (energy lower than 50 MeV) for SVD setup the SP electromagnetic calorimeter (SPEC) has been manufactured [3]. First preliminary SP data obtained at Nuclotron JINR are shown in Fig. 1, left panel.

Physicists from BITP (Kiev, Ukraine) V. Begun and M. Gorenstein within the framework of the ideal pion gas model have pointed out the conditions for the Bose-Einstein condensate (BEC) observation in pp interactions [4]. They predicted a sharp and fast growth of scaled variance in HM region. The scaled variance ω is the ratio of variance of neutral pion number D to their mean multiplicity $< N_0 >$ at a given value of the total one: $\omega = D/ < N_0 >$. Total multiplicity is the number of charged and neutral pions: $N_{tot} = N_{ch} + N_0$. For testing of their proposition, SVD collaboration has selected events with high total multiplicity. The charged multiplicity has been restored by using a silicon VD data. The corrections to topological cross sections take into account an efficiency of registration and methods of reconstruction.

The restoration of the neutral pion number is impossible by the "event by event"method because of limited ECal aperture and the threshold on the photon detection energy. We have applied the statistical method based on Monte Carlo simulation. ECal detects photons from neutral pion decay. Efficiency of neutral pion reconstruction has been estimated by using FRITIOF7.02 codes for pp inelastic interactions at 50 GeV. After passing of MC simulated events through GEANT with accounting of setup conditions, the linear dependence of the average number of neutral pions, $< N_0 >$, on a number of photons in ECal, N_γ, has been found out.

For restoration of the number of events with N_0 neutral pions, the matrix coefficients $c_{ij} = N_{ev}(i,j)/N_{ev}(i)$ have been defined by MC simulation. They have meaning of a probability of observing i photons in ECal at the decay of j neutral pions. The observable growth of scaled variance at $N_{tot} \geq 18$ [5] evidences for the BEC formation in the pion system in pp-interactions at 50 GeV. We have estimated this signal for π^0 mesons by the significance on the level of 7 standard deviations. This effect has been observed for the first time.

To describe available data and to make predictions in the HM region we developed GDM [6]. This model has appeared from the two stage model (TSM) describing multiplicity distributions in e^+e^- annihilation at high energies [6]. Its first stage is based on QCD quark-gluon cascade: gluon bremsstrahlung by quarks and gluon fission. The second stage, hadronization, is based on the phenomenological scheme and uses binomial distribution. Two-stage model confirms oscillations H_k – the ratio of factorial cumulants K_k to factorial moments F_k: $H_k = K_k/F_k$, and points out that the responsibility for that behavior lays on hadronization stage and developed quark-gluon cascade. In Fig. 1, right panel moments H_k for quark-gluon cascade stage are presented. This figure shows that there are no oscillations and minimum at $k = 5$ for H_k in a wide region of the order k. TSM confirms the fragmentation mechanism of hadronization in e^+e^- annihilation: hadronization in vacuum when one parton fragment into one hadron.

GDM can describe hadron and nuclear interactions, in particular to pp scattering. Accounting of gluon fission gives considerable improvement for the description of topological cross sections at HM region [6]. The excess of soft photon yield can be stipulated by soft gluon excess which do not fragment to hadrons. GDM is agreed to the recombination mechanism of hadronization when hadron formation is realized in quark-gluon medium and where one gluon as a

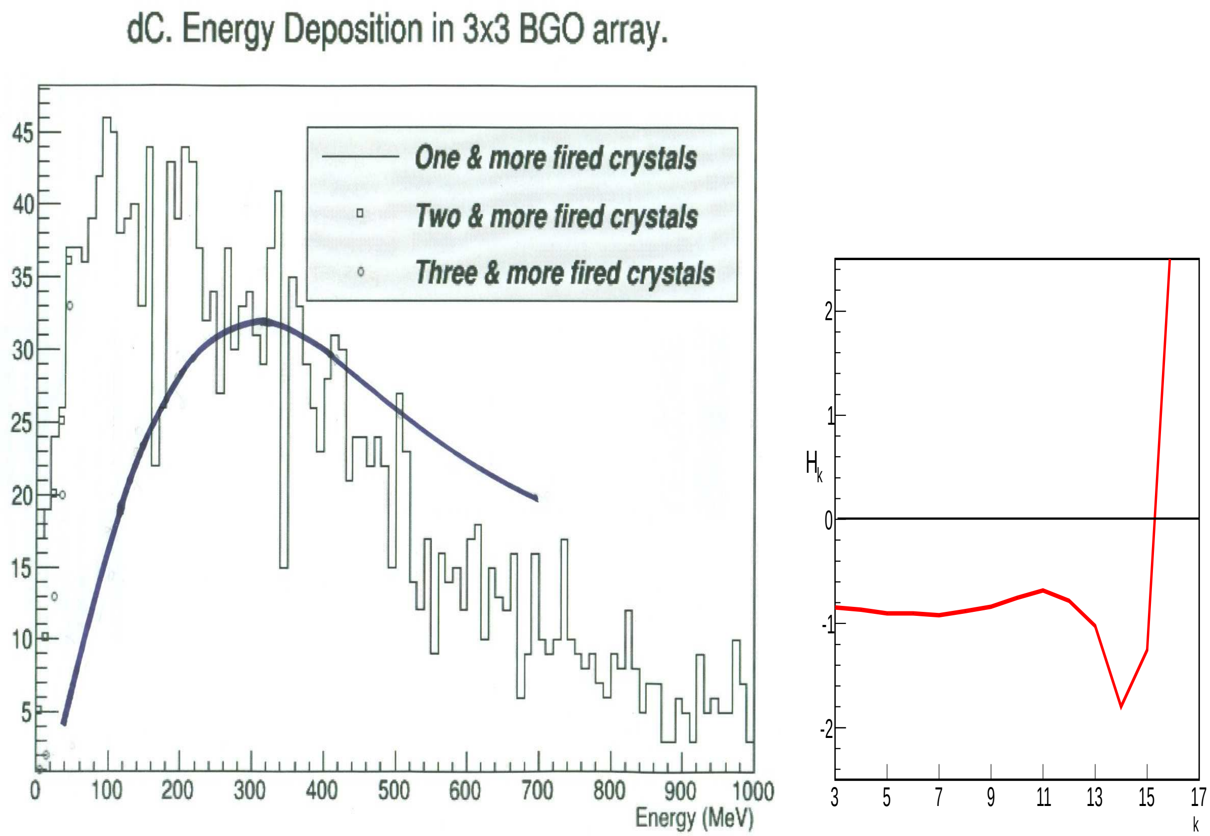

FIG. 1. Left panel: energy deposited spectrum measured by SPEC at a pre-shower response, MC prediction is shown by solid line; right panel: the ratio of factorial cumulants over factorial moments as a function of rank k at quark–gluon stage.

source can form few hadrons.

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