Study of extremely high multiplicity events in the SVD-2 experiment

E. Kokoulina[1], †, *A. Kutov*[2] *and V. Ryadovikov*[3]
[1]JINR, Dubna, Russia and GSTU, Gomel, Belarus
[2]DM UrD RAS, Syktyvkar, Russia
[3]IHEP, Protvino, Russia
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Abstract

The observation of hadronic and nuclear interactions producing high charged multiplicity events is presented. These events may be the manifestation of such collective phenomena as Bose-Einstein condensation, Cherenkov gluon radiation, clusterization and abundant soft photon yield. The status of "Thermalization" project at U-70 accelerator (IHEP, Protvino) is reported. The purpose of this project is to search for new phenomena leading to final states with extremely high multiplicity.

1 Introduction

This report is devoted to the study of events with extreme multiplicity (ExMu) [1]. We define those as an event sample with the number of secondary particles considerably bigger than mean multiplicity [2]. Such events occur very rarely and their registration is highly non-trivial task. Every advance requires significant increase of total statistics. Modern theoretical models and Monte Carlo event generators do not describe the existing experimental data in this region. We think this area is unknown to most of the researches.

SVD Collaboration carries out experimental study of ExMu at the accelerator U-70 of IHEP (Protvino, Russia) at $P_{\rm lab} = 50 - 70$ GeV. This experiment is unique, because the average charged multiplicity at these energies is about 5-6 and the apparatus can register almost all secondaries.

Here I would like to mention Pavel Ermolov who was an active leader of our program. He died this year. He was known at DESY as well, as a member of ZEUS Collaboration.

2 Status of the "Thermalization" project

SVD setup (Spectrometer with Vertex Detector) [3] consists of the following basic components: the hydrogen target, microstrip silicon vertex detector (MSVD), the drift tube tracker (DTT), the magnetic spectrometer equipped with the proportional chambers, the Cherenkov counter and electromagnetic calorimeter. To register the events with high multiplicity we have designed and constructed the scintillator hodoscope. It generates the trigger signal for events with the number of secondaries exceeding given level of multiplicity.

MSVD consists of 10 silicon planes with 50 μm strip sensors. The planes have four different angular orientations: 0, $\pi/2$ and $\pm 10.5°$. Hence we distinguish coordinates x, y, u

† speaker

(+10.5°) and v (-10.5°), respectively. The size of each plane is about $50 \times 50\ mm^2$. There were no oblique planes in 2006 run. In the year 2007 only one oblique plane has been added. It is necessary to have at least two such planes to disentangle tracks in space. This will be available in the next run. The MSVD has limited acceptance and does not allow to register all the secondaries. Therefore we have constructed also the drift tube tracker. It is located between MSVD and the magnetic spectrometer. DDT consists of three modules, each having three planes oriented under the following angles: +10.5° (u-plane), 0° (y-plane), -10.5° (v-plane). Each plane consists of two layers of the 6 mm diameter drift tubes. The length of the middle drift chamber is about 1 m.

The magnetic spectrometer consists of 16 proportional chambers located inside the magnet. It provides the momentum resolution of 1.5 % in the range from 300 MeV/c to 5 GeV/c. The electromagnetic calorimeter, or gamma detector, (DeGa) consists of 1536 full absorption Cherenkov counters. Their lead glass radiators have the volume $38 \times 38 \times 505\ mm^3$ and are read out by the photomultipliers PMT-84-3.

The prime purpose of the scintillator hodoscope is to provide selective recording of interesting events, i.e. to serve as high multiplicity trigger (HMT). It consists of 19 elements called "petals of camomile". They collect light and produce the trigger signal when the number of charged secondaries exceeds given fixed level. An example of the work of this trigger is given in Fig. 1 at different levels of HMT. It illustrates that indeed we can select high multiplicity events and suppress low multiplicity ones at high level of HMT.

An important task is the alignment procedure. It is vital to provide the correct geometry of complete setup for efficient track reconstruction in space and to achieve necessary precision in determination of track parameters. For these purposes we have developed the software package based on the ideas of Millepede program of V. Blobel [4] to determine both linear and nonlinear parameters in our alignment procedure.

Detector simulation is based on GEANT-3, while the Pyhia and other Monte Carlo programs are used as event generators.

Due to economical reasons the energy of proton beam was reduced from 70 GeV in year 2002 down to 50 GeV in the later runs. At the end of 2008 we plan data taking run with fully equipped detector to collect sufficient statistics for ExMu studies, and then continue the search for collective phenomena in this area. So far we already have reconstructed events with charged multiplicity higher than those obtained with the bubble chamber (more than 18 charged particles). The addition of two silicon oblique planes in MSVD will allow us to disentangle tracks in space and to obtain their multiplicity distribution (MD).

The DTT data processing is ongoing. We performed the calibration of every tube, i.e., determined the radial position as a function of drift time (Fig. 2, left). The resolution of DTT was detemined by using the sum of radii ($r_f + r_b$) of two neighboring tubes from forward and backward layers of the plane (Fig. 2, right). Presently we are developping the algorithms for the track reconstruction in DTT.

Our preliminary data from electromagnetic calorimeter allow to obtain the dependence of the mean multiplicity for neutral particles (γ and π^0) versus charged particle multiplicity. We observe significant correlation between these spieces. In the ExMu sample this dependence has tendency to grow.

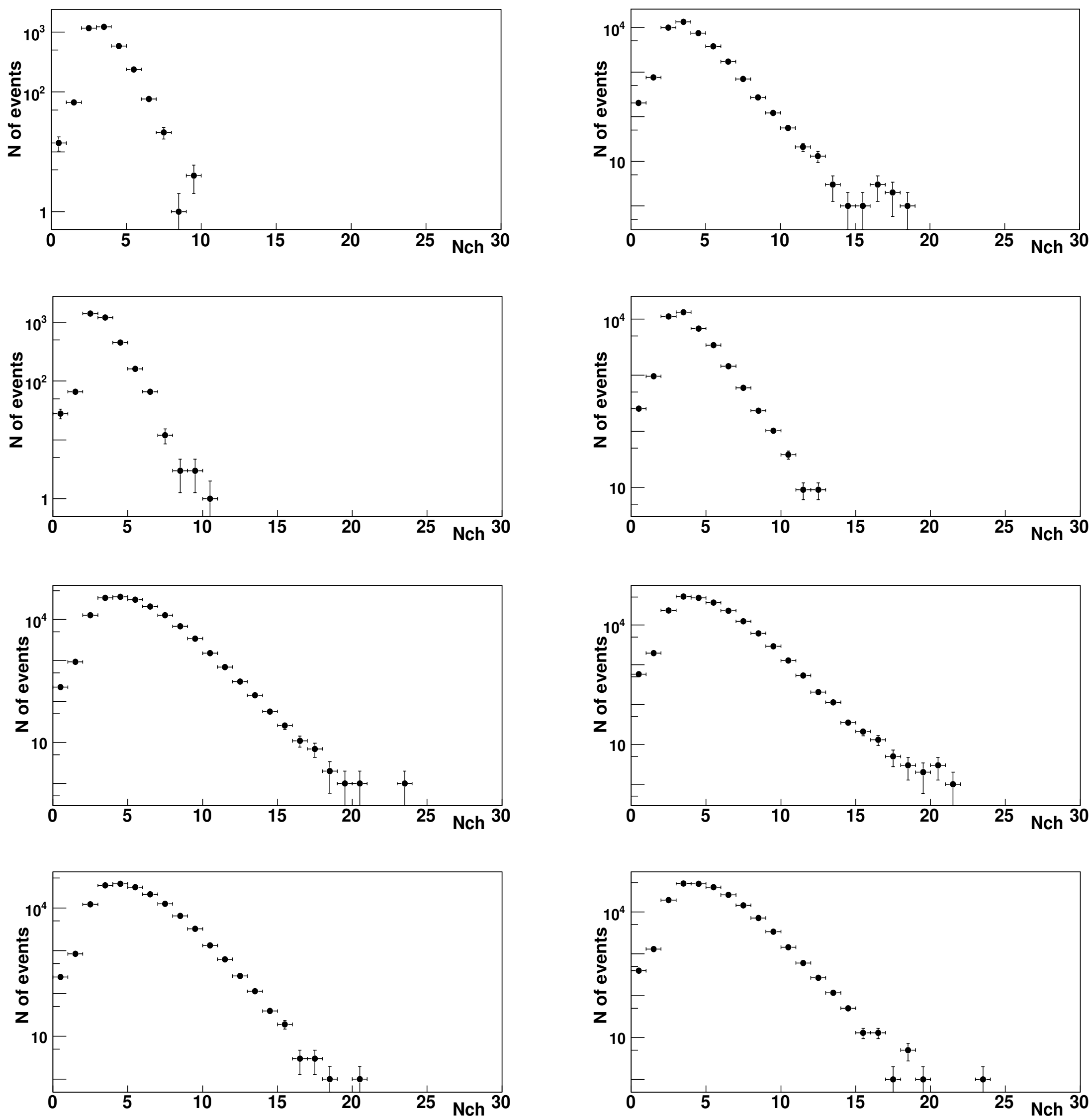

Fig. 1: MD at trigger-level 2, 4, 6 and 7 (from top to bottom). In the projections: (left) *XOZ* plane and (right)*YOZ* plane.

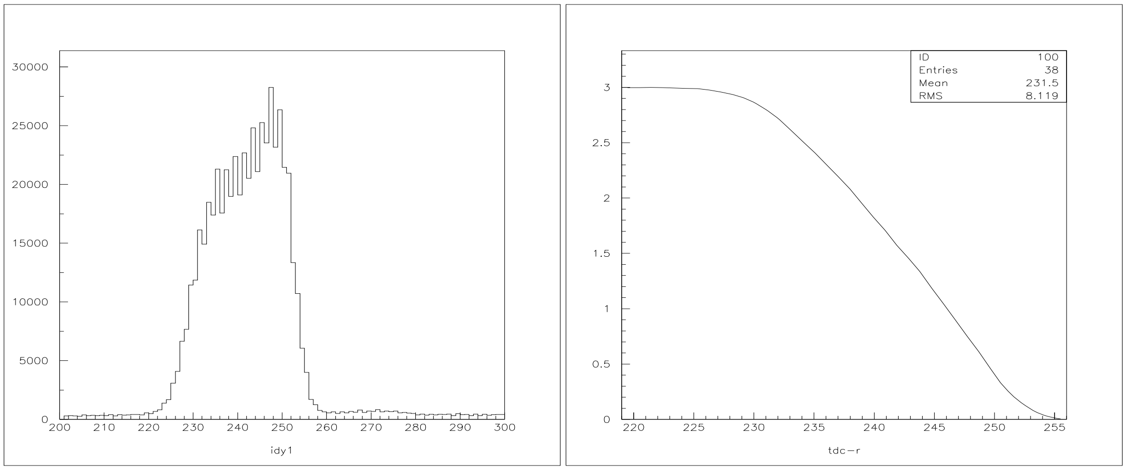

Fig. 2: Drift time distribution (left) and calibration function for drift tube (right).

3 Achievements and outlook of the ExMu studies

Our physical program is directed to the search for collective phenomena in ExMu area. At the beginning of this study we have analyzed the existing experimental and theoretical results on MD in hadronic and nuclear interactions. We have found that Monte Carlo event generators underestimate MD at 16 charged particles by about two orders of magnitude. Phenomenological models differ considerably in this region [5, 6]. To explain ExMu phenomenon we have developed the gluon dominance model (GDM) [6–8]. It is based on the main features of QCD and supplemented with phenomenological mechanism of hadronization. It states the dominant role of gluons in multiparticle production mechanism, while the valence quarks remain relatively passive. The behavior of the hadronization parameters points to this important conclusion. GDM confirms convincingly the recombination mechanism of hadronization in hadronic and nuclear interactions and fragmentation in lepton processes. We have shown [9] that with small modification the GDM is able to describe MD in $p\bar{p}$ annihilation. It also describes well MD in pp interactions from IHEP energies up to ISR and higher. Within the model two-shoulder structure of MD is explained by evaporation followed by hadronization of gluon groups, or clans consisted of single, double or more fission gluons. This can explain the nature of soft and semi-hard components in multiparticle production. We obtained the limits on the maximal observable number of charged and neutral particles at 70 GeV.

In the last years when RHIC data became available the multiparticle production mechanism was significantly revised. The CGC theory was developed and relativistic nuclear physics have got new concept. Our GDM agrees with this theory and helps to understand the nature of strong interactions.

The basic collective phenomena which we study in our project are: (1) Bose-Einstein condensation (BEC) of pions. (2) The ring events (the analogy of Cherenkov radiation). (3) The excess of soft photon yield. (4) The clusterization. (5) The turbulence phenomena.

The possibility of BEC formation in ExMu region has been demonstrated by Begun and Gorenstein [11] in the framework of the ideal hadron Bose-gas model. The pions (charged and neutral) are copiously produced at 70 GeV. They are spin zero bosons. In ExMu events their momenta are approaching to zero. Hence the BEC may be formed. The fluctuation in the number of pions will be a prominent signal in the BEC-point. As temperature of the system decreases, the chemical potential is increasing at fixed particle number density, and become zero at $T = T_0$ (BEC-temperature). In this point pions reach its lower state. Authors predict that the scaled variance of neutral and charged pion-number fluctuations, $\omega^0 = \langle(\Delta N)^2\rangle/\langle N\rangle$, in the vicinity of BEC-line have an abrupt and anomalous increase. Our apparatus allows to check this prediction experimentally.

The ring-like structures in the angular distributions of secondaries have been observed in some nuclear collision experiments close to our energies [12]. Our preliminary data analysis shows the presence of two peaks in pseudorapidity distribution for ExMu events ($n_{ch} > 18$) in pA - interactions (A = Si, C, Pb) [3, 10]. In the inclusive sample these peaks are absent. This is an indication for the appearance of the ring events at ExMu.

The puzzle of soft photons is also part of our investigation program. In GDM we estimated the size of the emission region of soft photons. It is about $4 - 6$ fm [13]. In this region hadronization process is finished and the kinematical freeze-out is realized.

By visual scanning of ExMu events we have seen few groups of particles which fly under small angles (points to clusterization). An interesting hypothesis has been proposed by V. Nikitin [14] to explain this observation. His idea is that the turbulence phenomena may occur in hadron-nuclear interactions which could lead to groups of particles lying in one plane in ExMu events. We believe the realization of our scientific program will be successful and unique for multiparticle dynamics study.

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