MULTIPARTICLE PRODUCTION AT HIGH MULTIPlicITIES

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Abstract

Theoretical and experimental studies of high multiplicity events are analyzed. Some interesting phenomena can be revealed at high multiplicities. Preliminary results of project Thermalization are reported.

1 Introduction

The multiparticle production (MP) study at high energies is one of the actual topics of high energy physics. The different theoretical approaches and the experimental programs are developed. The Quark-Gluon Matter search is the complicated problem of hadron and nucleus interactions [1]. We consider that our MP study at lower energies may be useful. The purpose of the "Thermalization" experiment [2] is to investigate the collective behavior of MP particles in proton and proton-nucleus interactions

\[ p + p(A) \rightarrow n_\pi \pi + 2N \]  

at the proton energy \( E_{\text{lab}} = 70 \text{ GeV} \). We use modernized setup SVD-2 - Spectrometer with Vertex Detector (SVD). It was created to study of production and decay of charm particles, but had the basic components necessary for performance of the physical program of the Thermalization project.

At present multiplicity distributions (MD) at this energy is measured up to the number of charged particles \( n_{ch} = 18 \) (\([3]-[4]\)). In the region of high multiplicity (HM) \( n_{ch} > 20 \) we expect \([5]\): formation of high density thermalized hadronic system, transition to pion condensate or cold QGP, increase of partial cross section \( \sigma(n) \) is expected in comparison with commonly accepted extrapolation, enhanced rate of direct soft photons. We will be continue to search for new phenomena: Bose-Einstein condensate (BEC), events with ring topology (Cherenkov gluon radiation).

The available MP models and MC codes (PYTHIA) are distinguished considerably at the HM region. We also research hadronization mechanism and connected questions [6].

The review is organized as follows: section 2 presents a description of setup SVD-2, section 3 gives alignment results, section 4 informs about of new phenomena searching and our preliminary data of 2002 run. We summarize in section 5.

2 Experimental setup

2.1 Setup schematic

The layout of the SVD installation at \( U \sim 70 \text{ GeV} \) accelerator is shown on Figure 1. The basic requirements to the equipment consisted in the following:
The study is carried out on the extracted beam of protons with energy 70 GeV and intensity $\sim 10^7$ in a cycle of the accelerator.
* The liquid hydrogen target is used.
* Installation is capable to detect of events with HM of charged particles and $\gamma$ quanta. Multiplicity of photons makes up to $\leq 100$. The lower energy threshold of the photon registration is 50 MeV.
* The HM trigger system is capable to select rare events with multiplicity $n_\pi = 20 \div 30$. The suppression factor of events with low multiplicity $n_\pi < 20$ is $10^4$.
* The magnetic spectrometer has the momentum resolution $\delta p/p \approx 1.5\%$ in the interval $p = 0.3 \div 5.0$ GeV/c. At the beginning the experiment and subsequent data analysis the generator was developed. It is based on the assumption that in the HM region the particles in c.m.s. should have isotropic angular distribution and their energy distribution is Maxwell or Bose-Einstein type \[5\].

Figure 1: Schematic of the SVD installation at U-70.

2.2 Liquid hydrogen target

For a target accommodation in the design of installation there is a space along a beam only 7 cm. Design and manufacture of liquid hydrogen target is under a a complete JINR responsibility. The target has 7 cm thick and 3.5 cm in diameter vassal of liquid hydrogen. Thermostat is equipped with a thin (200 $\mu$m) lavsan windows to suppress background scattering. Successful tests of a whole target system had indicated to advanced reduction of helium consumption in which resulting factor is expected in order of 1.5.

2.3 Straw tube chambers

Straw tube chamber system is a new addition of SVD setup. This detector has been designed in the department of V. Peshehonov from LPP of JINR. It implements front end boards with preamplifiers produced in Minsk (NC PHEP BSU) and TDC modules produced in Protvino (IHEP) allowing to detect several pulses, consequently coming from the anode on each trigger signal. Typical plane dimension is 70 x 70 $cm^2$. The total of channels is about 2400.
2.4 HM trigger

Our experiment owes to carry out at suppression of low multiplicity events by a trigger. It is urgent request for it. For this purpose the scintillation hodoscope or HM trigger was designed and manufactured. It suppresses interactions with track multiplicity below 20. Beyond this it is as so thin as not distorts an angular and momentum resolution of the setup to any kind fake signal. The scintillator counter array may operate at higher counting rate and more resistant to many kinds of noise.

2.5 Vertex detector

The vertex detector (VD) is necessary constituent of SVD setup because it allows to vertex position identify. Vertex front-end uses a integrated circuit called GASSIPLEX. As the GASSIPLEX is 16-channel design, only 1280 channels of detector may be placed on one board. For 50 $\mu$m pitch detector the largest sensitive area dimension is 64 mm. To overcome this restriction the Collaboration had taken the decision to use integrated 128-channel circuits VIKING. JINR provides important technical support in this development. Now we had purchased a requisite consignment of these circuits and are installing in VD.

2.6 Magnetic spectrometer, Gamma-detector

The magnet MC-7A having length on the beam 3 m is used in spectrometer. Magnet field in the center is equal to 1.1 T at a current 4000 A. The detection system of the spectrometer includes 18 planes of proportional chambers (PC). The data analysis give the following characteristics of the spectrometer: average PC efficiency is 80%; coordinate accuracy on the reconstructed tracks is 1 mm; the momentum resolution on beam tracks (p=70 GeV/c) is 3 %; the momentum resolution on the secondary tracks is $\sim 1 \%$. Magnetic spectrometer electronics allows to register up to 1.5 thousand events per 1 accelerator cycle. Some of PC had been repaired, anode wires in beam region are covered with insulator to make them insensitive to beam particles. This modification improves efficiency of central part of chamber at high beam intensity $10^7$ required for Thermalization project.

The gamma-detector consists of 1536 full absorption Cherenkov counters. Radiators from a lead glass have the size $38 \times 38 \times 505 \text{mm}^3$ and are connected with PMT-84-3. Total fiducial area of the detector is $1.8 \times 1.2 \text{m}^2$. The energy resolution on 15 GeV electrons is 12%. Accuracy of the $\gamma$ quantum coordinate reconstruction is $\sim 2 \text{mm}$. At run 2007 the gamma-detector calibration was carried out and gamma-quantum events were recorded.

3 Alignment

The importance task of any experiment is to provide reconstruction of charged particle tracks. Spatial characteristics and geometric position of detector modules can be differ from its design values. Possible reasons of detector misalignments are the limited accuracy of initial hardware, inaccuracies in placing of detectors and their internal dimensions. The alignment procedure intends to compensate such misalignment by a mathematical way. We use for alignment procedure more
robust, efficient and high precision method based on the Linear Least Squares (LLS) \[7\].

At 2006 technical run we had obtained data on hydrogen target. We had picked out some events with good identification of 787 (single) space tracks on hits in vertex detector and carried out alignment. Histograms of $\chi^2/ndf$ for local fits before and after alignment procedure are in Figure 2. At present it is continued data processing and high multiplicity event searching. One of such events is shown on Figure 3. Preliminary multiplicity distribution of charged particles was obtained based on VERTEX detector data. It is shown on Figure 4.

4 Search for new phenomena

The HM region study is important, because MP models and Monte-Carlo generators are differed at high multiplicity ($n > \bar{n}(s)$) very considerably. There are the theoretical predictions about manifestation such phenomena as Cherenkov-like
(gluon) radiation [8], Bose-Einstein condensation (BEC) of pions [9, 10], excess of soft photon rate [11] and other collective phenomena. We like to reveal their in our findings.

For multiparticle dynamics insight and the MD description in hadron interactions we had proposed the Gluon Dominance model (GDM) [12]. In the framework of this model we research quark-gluon matter and hadronization stage detail by using MD of the charged and neutral particles and their moments [13]. GDM bases on the essentials of QCD and phenomenological scheme of hadronization. Our model studies had shown: valent quarks of initial protons are staying in leading particles (from 70 to 800 GeV/c and higher). MP is realized by gluons. We called them active ones.

Some of active gluons (∼ 50%) are staying inside quark-gluon system and do not fragment to hadrons. New formed hadrons catching up them, are excited and throw down excess of energy by soft photons (SP). We use the black body emission spectrum at the assumption that quark-gluon system or excited new formed hadrons set in almost equilibrium state during a short period. This assumption permits to estimate the line size of the SP emission region [14]. It is known that in this region hadronization is occurred.

Our model confirms the recombination mechanism of MP. We had obtained limitations on the number charged, neutral and total multiplicities in pp interactions at 70 GeV/c and higher. In project Thermalization we plan to verify these. There are many of experimental and theoretical results, which evidence of cluster nature of MP by significant short-range multiplicity correlations [15], the observed scaling of the dynamical fluctuations of mean transverse-momentum [16].

In GDM the evaporation of gluon sources may be realized by single gluons and also groups consisted from two or more fission gluons. The superposition of them explains the shoulder structure of MD at ISR and higher energies [12]. Our approach
gives the possible interpretation of soft and semi-hard components [17].

We modified GDM by including of the intermediate quark topologies to explain the experimental differences between \( p\overline{p} \) and \( pp \) inelastic topological cross sections and second correlation moment behavior at few GeV/c [18]. The high multiplicity in this process originates from "4" or "6"-topologies. Our scheme of hadronization describes well MD for hadron interactions at 70 GeV and higher and could be use to study the central nuclear collisions at low and high energies.

The Cherenkov type radiation can be emitted in the projectile and target particles. This leads to two peaks of dense groups of particles (spikes) distribution in rapidity phase-space. At the same time the particle distribution at the azimuthal angle is uniform. Study of the spike center distribution [19] in central C-Cu collisions at 4.5 GeV/c/A (all charged particles) and Mg-Mg collisions at 4.3 GeV/c/A (only negative charged particles) were found to be in agreement with the hypothesis of mesonic Cherenkov radiation. For this goal it was used transformation of pseudorapidity spectra from \( \eta \) variable to \( \tilde{\eta} \) with the uniform spectrum. In each case the distance between peaks for these experiments is in agreement with Cherenkov radiation hypothesis, the charged-dependence was absent.

The ring-like substructures of secondary in \(^{208}\text{Pb}\) at 158 A GeV/c and \(^{197}\text{Au}\) at 11.6 GeV/c induced interactions with Ag(Br) nuclei in emulsion detector were investigated [20]. The good agreement was obtained with idea of Cherenkov radiation.

It must be emphasized that such events are rare, and represent at about 1% of full statistics. Therefore high luminosity and high multiplicity trigger of SVD setup agrees to collect enough statistics to study this phenomenon. The preliminary indications to the manifestation of the ring events are in Figure 5. This pseudorapidity spectra for \( pPb \)-interactions at high multiplicity \((n > 18)\) shows up such behavior.

As it was mentioned the Bose-Einstein condensation is very interesting phenomenon. The considerable efforts are necessary to confirm it experimentally. At HM events the plentiful number of pions (charged and neutral) are produced. All of them are bosons. When the multiplicity increase moments of them are approaching to zero. In the case of relativistic ideal Bose gas the pion number fluctuations may give a clear signal of approaching the BEC point [10]. When the temperature \( T \) decreases, the chemical potential increases and becomes equal to \( \mu_\pi=m_\pi \) at BEC.
temperature $T = T_C$. At this point the total number of particles takes up the lowest energy state.

M.I. Gorenstein and V.V. Begun had viewed the case of HM events in $p + p$ interactions with beam energy of 70 GeV [10]. The volume of pion system was estimated as, $V = E/\varepsilon(T, \mu_\pi)$, and the number of pions was determined as, $N_\pi = V \rho_\pi(T, \mu_\pi)$. In the vicinity of the BEC point they revealed an abrupt and anomalous increase of the scaled variance of neutral and charged pion number fluctuations. Our experiment permits to experimental test of this phenomena. We are expected to take a lot of high multiplicity event statistics with reconstructed by gamma quantum neutral mesons and study scaled variance of neutral and charged pion number fluctuations.

5 Summary

We are continuing our work to making of program packets for data processing and new phenomena study at HM region.

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