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TRIGGERING OF HIGH-MULTIPLICITY EVENTS USING CALORIMETRY

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The experimental investigation of asymptotically high multiplicity hadron reactions is discussed for the LHC, making use of calorimetry. The first investigation concerning the triggering of such events with calorimeter information only is described.

The investigation has been performed at the Laboratory of Nuclear Problems, JINR.

Триггирование событий с большой множественностью с использованием калориметрии

Г.Шелков и др.

Обсуждается экспериментальное исследование на LHC адронных реакций с асимптотически большой множественностью при использовании калориметрии. Описано первое исследование, касающееся триггирования таких событий с помощью только калориметрической информации.

Работа выполнена в Лаборатории ядерных проблем ОИЯИ.

1. INTRODUCTION

We believe now that the principle of elementary particle theory is known. It should be built on the basis of non-Abelian gauge theories, adding Lorentz covariantness and a renormalizability condition and, maybe, duality. There are only two fundamental questions: (A) the problem of mass hierarchies and (B) the problem of Grand Unification. Other questions, like confinement and so on, are more of a technical character.

An experiment may only give an answer to the above questions by searching for the (heavy) superparticles, for the 'desert', and for the vacuum structure (Higgs bosons, topological defects, and so on). It is useful to be able to separate experimentally background effects from multiparticle processes.

The asymptotically high multiplicity (AHM) processes with $n \gg \bar{n}(s)$, where the mean multiplicity $\bar{n}(s)$ introduces the natural scale for n, seem to be of interest just by this reason [1]. First of all, hadron processes become *hard* in the AHM domain. This means that

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during the process of AHM production nonperturbative effects are ‘frozen’ and perturbative QCD predictions are available. Note also the expected enhancement of heavy particles in such processes: the initial energy would be spent mostly on the creation of particle mass.

We have every reason to believe that AHM states are in equilibrium since the corresponding entropy reaches a maximum in the AHM region [3]. Therefore, secondly, the final states of AHM processes are close to *equilibrium* and a few parameters only are important for the description of such states. Indeed, the asymptotic estimation shows that $-\ln\{\sigma_n/\sigma_{\rm tot}\}/n = \mu(n) + O(1/n)$ in the AHM domain, where $\mu(n)$ is the chemical potential. Note, that the cold equilibrium state is the best arena for collective phenomena to occur.

AHM processes may also be used for the creation of a dense, practically pure, cold quark-gluon plasma (CQGP) [2]. To describe this state the collective parameters (temperature, chemical potential) would be sufficient enough. So we hope, that the observation of high-multiplicity processes will allow one to investigate the following topics [1]:

1. The creation of (super)heavy particles and gluon jets with extremely high $E_\perp$ (since the AHM processes are hard),
2. Collective phenomena in the colored system (since the final state of AHM is near the equilibrium). We want to emphasize that this information is unreachable in other type of experiments.

It is expected that at LHC energies the total mean multiplicity is $\bar{n} \sim 100$. At the same time, the maximal value of the multiplicity is $n_{\rm max} = \sqrt{s}/m \simeq 70\,000$, where m is the characteristic hadron mass scale $m \sim 0.2$ GeV. So, the AHM domain includes events containing of the order of 10 000 particles in the final state.

Studies of AHM phenomena are at the very beginning and the aim of this paper is to discuss a possible way for an experimental selection of these events, which could be used as a trigger at LHC conditions. This question seems to be the most important since (i) the cross sections σ_n in the AHM domain are extremely small, i.e., $\sigma_n \ll 10^{-6}\sigma_{\rm tot}$ and it is very difficult to measure such small cross sections in the environment of high luminosity at the LHC for events without a clear signature (such as, e.g., a high $p_\perp$ lepton). Moreover, (ii) we wish to consider n as the *total* multiplicity, including neutral particles (by triggering on the charged particle multiplicity – which in itself presents a huge challenge in the environment of the LHC – we *might* suppress the creation of neutral particles in the AHM domain). A more detailed discussion on the physics of the AHM domain will be given in subsequent papers.

Our main idea is that in the AHM domain it is unimportant to know the strict value of the multiplicity. Therefore it may be sufficient to define n with certain, but controllable accuracy. For this purpose we want to try to use information coming from calorimetry only. We will show that a measurement of the total energy deposition in the calorimeter, (having a reasonable acceptance) allows one to fix the region of values $n \gg \bar{n}(s)$.

2. MONTE CARLO SIMULATION

A sample of 10^7 events for proton-proton collisions at $\sqrt{s} = 14$ TeV was generated with PYTHIA 5.7 [4]. Hard scattering (QCD high-$p_\perp$) processes for the initial parton states qq, qg and gg (PYTHIA subprocesses 11,12,13,28,53,68), and additionally low-$p_\perp$ production

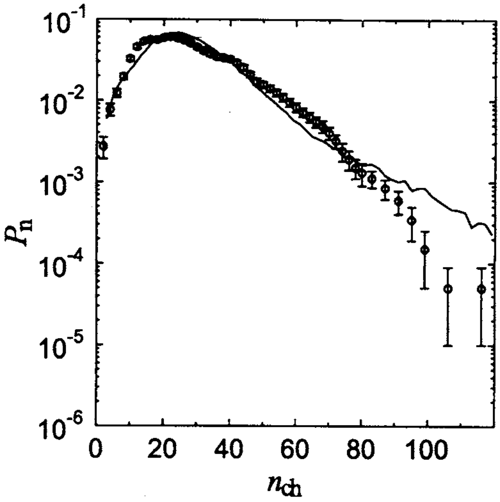

Fig. 1. Charged multiplicity distribution at 540 GeV [6], the solid line shows the prediction of the Monte Carlo calculation

(PYTHIA subprocess 95) were considered. In addition the framework of the Multiple-Interaction Model was used, with a variable impact parameter and an overlap of the hadronic matter being consistent with a double Gaussian matter distribution [5]. This model was chosen, since it is (at moderate multiplicities) in quite good agreement with the available experimental data [6] at 540 GeV and predicts a long tail in the AHM domain, as can be seen in Fig. 1. The latter provides large enough statistics for events with a very high multiplicty (the correctness of the cross section was not important at this stage).

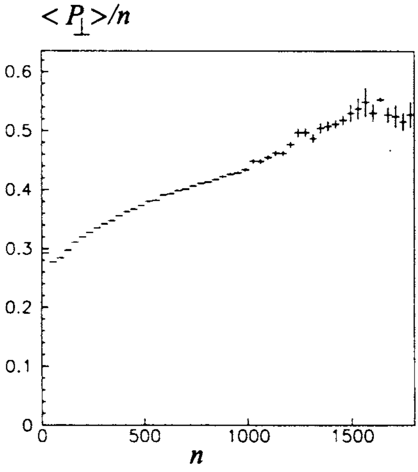

Fig. 2. Dependence of the average $< P_\perp > /n$ on the total multiplicity n

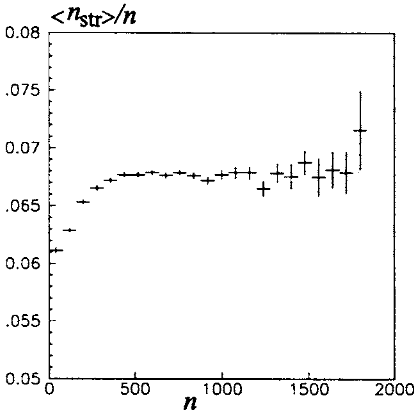

Fig. 3. Dependence of the strange particle fraction $< n_{\rm str} > /n$ on the total multiplicity n

As mentioned above, we expect that for high energies and high multiplicities the particle creation processes would have a tendency to become hard [2]. Due to this, the mean transverse momentum of all particles and the mean strange particle multiplicity should rise with growing total multiplicities. Figures 2 and 3 show the dependence of the average transverse momentum $\langle p_\perp \rangle / n$ per particle and of the yield of strange particles on the total multiplicity n as obtained from PYTHIA 5.7. One can see that the average transverse momentum and the yield of strange particles slightly grow with the total multiplicity in the model used.

Next we want to understand the effect of not being able to measure the particles themselves, but only to measure their energy deposition in a calorimeter. For this purpose, first a model of an ideal calorimeter was used. It is supposed to have a realistic angular acceptance with perfect energy resolution. In addition no lower cut-off on the momentum of the particles was required. In other words, all particles with pseudorapidities $\eta < 4.9$ (corresponding to the acceptance of the ATLAS calorimetry [7]) were considered as being detected.

Using this assumption, the total multiplicity (including neutral particles) distribution n was compared to the total energy deposition in the calorimeter, as shown in Fig. 4. A clear correlation between the two quantities is found. The mean value of the total multiplicity $\langle n \rangle$ is shown in Fig. 5 as a function of the energy deposition in the calorimeter E_{prime}. One can see that $\langle n \rangle$ increases with increasing E_{prime}.

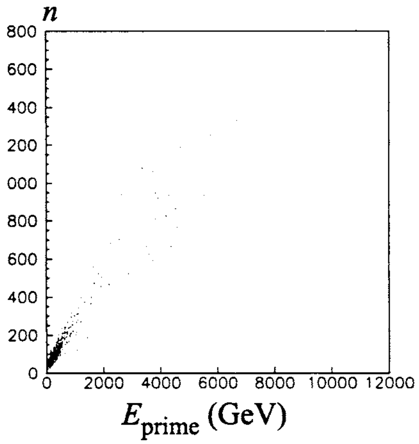

Fig. 4. Correlation between the multiplicity n and the total energy E_{prime} within $|\eta| < 4.9$

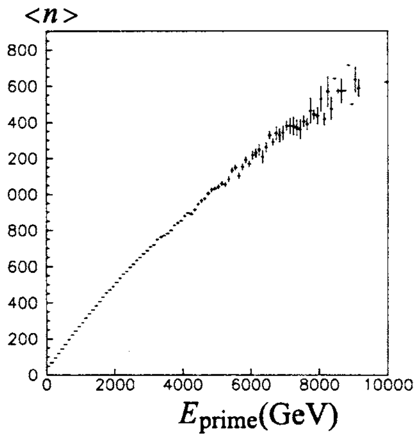

Fig. 5. Correlation between the average multiplicity $< n >$ and the total energy E_{prime} (for $|\eta| < 4.9$)

Finally, a few hundred events were simulated with the ATLSIM/DICE package [7], which contains a detailed simulation of the ATLAS detector response. This takes into account the effect of the magnetic solenoidal magnetic field on the detection of low momentum particles. In Fig. 6 one can see the same behavior for $\langle n \rangle = f(E_{\text{calo}})$, where E_{calo} is the energy deposited in the ATLAS calorimeters, as obtained from the ATLSIM/DICE simulation. Two fits of a linear dependence of $\langle n \rangle$ on E_{calo} are shown: the dotted line corresponds to the case of a 'real' ATLAS calorimeter; the solid line, to an ideal calorimeter with the same angular acceptance. The energy deposition in the case of the ATLAS calorimeter is about 20% smaller than for the ideal one.

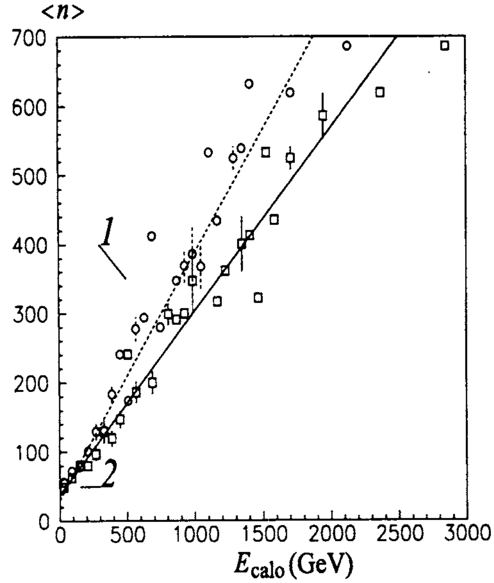

Fig. 6. Correlation between the average multiplicity $< n >$ and the total energy E_{calo} within $|\eta| < 4.9$. The circles are using the real calorimeter, and the dotted line is the corresponding fit. The squares are PYTHIA without detector simulation, the solid line is the fit to the latter points.

3. CONCLUSION

We conclude from this first study that *asymptotically high multiplicity* events can be triggered using the measurement of the total deposited energy in a calorimeter. This result is important since it opens the possibility to enlarge the experimental investigations in a domain where one may expect new physical phenomena. Further studies are needed to refine the selection criteria and on the other hand to quantify the knowledge on the value of the multiplicity from a calorimetric measurement (and to assess the capabilities of the tracking detectors to measure the charged component of the total multiplicity).

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