Краткие сообщения ОИЯИ №1[87]-98 *JINR Rapid Communications No.1[87]-98*

УДК 539.1.074.4

METHOD OF A FAST SELECTION OF INELASTIC NUCLEUS-NUCLEUS COLLISIONS FOR THE CMS EXPERIMENT

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On the basis of the HIJING generator simulation of heavy ion collisions at ultrarelativistic energy scale, a method of a fast selection of inelastic nucleus-nucleus interactions is proposed for the CMS experiment at LHC. The basic idea is to use the time coincidence of signals with resolution better than 1 ns from the two very forward calorimeter arms covering the acceptance $3 < |\eta| < 5$.

The method efficiency is investigated by variation of energy thresholds in the calorimeters for different colliding ion species, namely, PbPb, NbNb, CaCa, OO, *p*Pb, *p*Ca, *pp*. It is shown that a stable efficiency of event selection (~ 98 %) is provided in an energy threshold range up to 100 GeV for nuclear collisions at 5 TeV/nucleon in the centre of mass system. In the *pp* collision case the relevant efficiency drops from 93 % down to 80 %.

The investigation has been performed at the Laboratory of High Energies, JINR.

Метод быстрого отбора неупругих ядро-ядерных соударений для эксперимента CMS

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На основе моделирования столкновений тяжелых ионов при ультрарелятивистских энергиях, выполненного с помощью генератора HIJING, предложен метод быстрого отбора неупругих ядро-ядерных столкновений для эксперимента CMS на LHC. Основная идея состоит в использовании временного совпадения сигнала двух плеч калориметра малых углов с аксептансом $3 < |\eta| < 5$ и временным разрешением порядка 1 нс. Исследована эффективность предложенного метода прн вариации порогов на регистрируемую энергию для случаев столкновения ядер разных типов, таких как PbPb, NbNb, CaCa, OO, *p*Pb, *p*Ca, *pp* при энергии 5 ТэВ/нуклон в системе центра масс. Показано, что при столкновении ядер эффективность отбора остается стабильной (~ 98 %) в диапазоне пороговой энергии до 100 ГэВ. В случае *pp*-взаимодействий эффективность быстро падает с 93 % до 80 %.

Работа выполнена в Лаборатории высоких энергий ОИЯИ.

Introduction

The fast selection of inelastic nucleus-nucleus collisions is one of the basic problems of experimentation with colliding heavy ion beams [1]. The knowledge of the collision rate allows one to calculate absolute cross section values for particular channels of nuclear interactions, to perform normalization of spectra obtained for various combinations of colliding ions. Besides, a direct identification of such interactions at a first level trigger is very important for an event-by-event analysis. Moreover, an inelastic interaction trigger allows one to suppress background processes such as beam collisions with residual gas of nuclei as well as with set-up material.

As was shown in Ref.1, there is a significant influence of beam particle interactions of an electromagnetic nature, like electromagnetic dissociation and electron-positron pair production, on the collision rate. An inelastic interaction trigger makes it possible to separate a part of the interaction rate related to nuclear collisions. It should be noted that luminosity of the Large Hadron Collider in nucleus-nucleus collision modes will have variation of a few orders of magnitude for various ion species (see Table 1). This variation range is affordable for operation of the CMS detector [2]. So, the CMS inelastic interaction trigger must provide an adequate counting rate to follow luminosity changes.

Table 1. Characteristics of heavy ion collisions at LHC

	^{208}Pb	^{97}Nb	^{40}Ca	^{16}O
L(A)/L(Pb)	1	90	2500	3200
Luminosity ($cm^{-2}s^{-1}$)	10^{27}	$9\cdot10^{28}$	$2.5\cdot10^{30}$	$3.2\cdot10^{31}$
σ_{AA} (barn)	7.6	4.3	2.1	100 mbn
Average collision rate (kHz)	7.6	400	5200	32000

One of the critical features of a 1st level trigger is insensitivity to details of nuclear collision dynamics in the central rapidity region. In other words, it might be sensitive to the collision geometry only. In our paper [3], it was shown that a pseudorapidity range of $3 < |\eta| < 5$ (fragmentation region) is not sensitive to the effect such as jet quenching in a dense nuclear matter [4]. So, detectors in this region provide suitable basis for inelastic event selection and estimation of a nuclear collision impact parameter (Fig.1).

In this paper we propose and explore a simple and fast method of inelastic nucleus-nucleus collision selection for the CMS.

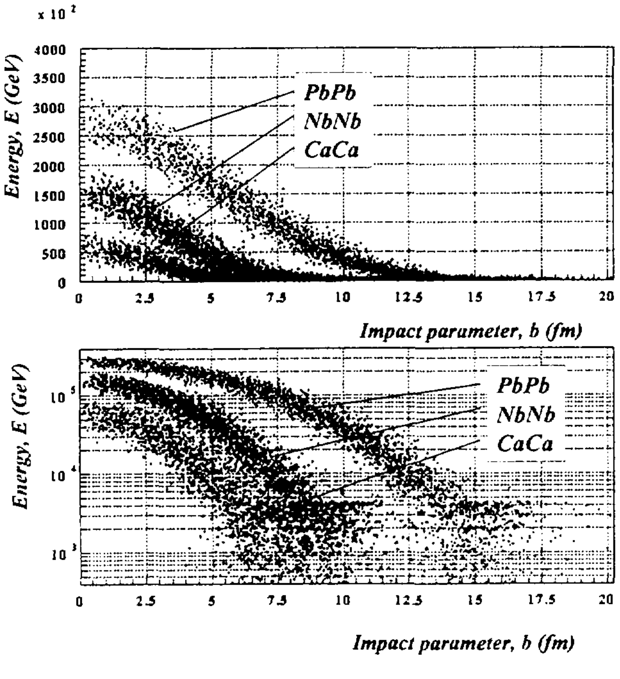

Fig.1. Dependence of the energy flow per event in the very forward calorimeter, E (GeV) *vs* the nuclear collision impact parameter, b (fm) in the HIJING model

Idea of Event Selection

The time coincidence of signals from the two very forward calorimeter arms is suggested to be used as a basic condition that an inelastic nuclear collision occurred in the LHC beam intersection. The event is accepted if the values of the total energy, E_{VF1} and E_{VF2} in each of the two calorimeter arms exceed a predefined threshold value E_{thr}. Thus, the condition of selection of nucleus-nucleus interactions is defined by the requirement:

$$(E_{VF1} \geq E_{thr})\cdot(E_{VF2} \geq E_{thr})$$

$$3 \leq |\eta| \leq 5 \text{ (fragmentation region).}$$

If the calorimeter provides the time resolution better than 1 ns, the longitudinal coordinate of the interaction vertex might be measured with precision of about few centimeters in the vicinity of a beam intersection point. We have studied an important practical task of an energy threshold dependence of the event selection efficiency, ε, defined as

$$\varepsilon = \frac{N_{\text{trigger}}}{N_{\text{simulated}}} \cdot 100\ \%,$$

where $N_{simulated}$ is the total number of simulated events, $N_{trigger}$ is the number of events satisfying the selection condition.

Simulation Details

To produce samples of inelastic events at an energy of 5 TeV/nucl in the centre of mass system, the HIJING generator [4] including soft and hard processes was used. A summary of basic physics processes and assumptions taken into account in the HIJING program is the following:

- quark and gluon hard scattering, including parton emission in initial and final states [5,6];
- multiple minijet production;
- nuclear shadowing effect of parton distribution functions;
- jet quenching relating assumed energy losses with colour screening length;
- the Glauber formalism is used to calculate the number of parton-parton collisions;
- nucleon density distributions of interacting nuclei were accepted in correspondence with the Woods-Saxon potential with a diffuse boundary [8].

To illustrate the importance of various subprocesses in nucleus-nucleus interactions, their contributions to the total cross section are given in Table 2. The generator reproduces well experimental data on the multiple particle production in collisions of relativistic nuclei up to the SPS energy scale. While using a highly developed program such as HIJING we note that a simple approach based on superposition of PYTHIA events reproduces particle production characteristics (mean energy, mean multiplicity) in fragmentation regions with less than 10 % difference with respect to the HIJING predictions.

Table 2. The contributions from the cross sections of main subprocesses of nucleon interactions for PbPb-collisions at $\sqrt{s}$ = 5 TeV/nucleon (HIJING)

Processes	Cross section (mbn)
NN processes total cross section, σ_{tot}	70.85
Inelastic scattering, σ_{inel}	53.93
Jet production, σ_{jet}	33.69
Single diffraction, σ_{dif}	0.37

An influence of the CMS solenoid magnetic field on charged hadron trajectories leads to an essential shift of a pseudorapidity distribution for a hadron component [9]. Consequently, a total registered transverse energy value per event drops down to about 70 % of initial one. Therefore the charged hadron drift effect is taken into account by introduction of a 4T homogeneous magnetic field in simulation procedure.

Proton-proton, proton-nucleus (*p*O, *p*Ca, *p*Nb, *p*O) and nucleus-nucleus (OO, CaCa, NbNb, PbPb) collisions with impact parameter $0 \leq b \leq 3R_A$ (R_A is nuclear radius) are considered. The simulation was performed for the whole pseudorapidity region with 0.5 GeV particle energy cuts. A statistics of 10,000 proton-protons and 1,000 proton-nucleus events for each type interactions was generated.

Simulation Results

Simulation results show that there is a stable correlation between the energy detected in the right (VF1) and the left (VF2) calorimeter arms for nucleus-nucleus interactions (Fig.2). In particular, such a correlation in nuclear interactions with residual gas doesn't exist and this circumstance allows one to reject background events and noise signals.

A dependence of the event selection efficiency at total energy threshold detected in the pseudorapidity region $3 \leq |\eta| \leq 5$ is obtained. Two cases are considered. In the first one the threshold is taken

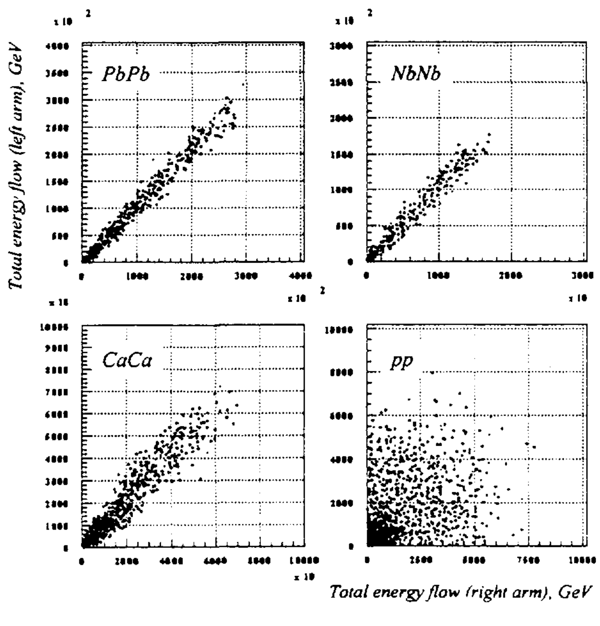

Fig.2. The correlation between the detected energy in two pseudorapidity regions $-5 < \eta < -3$ and $3 < \eta < 5$ for PbPb interaction at 5 TeV/nucleon in the centre of mass system

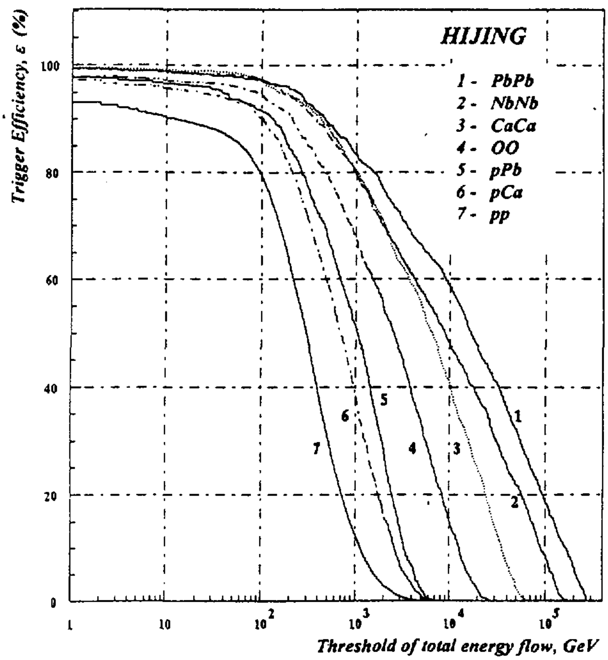

Fig.3. The efficiency of the event selection *vs* the total energy threshold for nucleus-nucleus (PbPb, NbNb, CaCa, OO), proton-nucleus (*p*Pb, *p*Ca), and proton-proton collisions at 5 TeV/nucleon in the centre of mass system

for the total energy per event (Fig.3), while in the second one there is a gamma quantum component alone (Fig.4).

A stable efficiency of an event selection is observed at a level of 98 % in an energy threshold region up to 100 GeV (up to 10 GeV for EM component) for nucleus-nucleus interactions. In the case of proton-proton interactions the similar stability is not observed and a reduction of the monitoring efficiency happens.

We remark that ε does not depend on the nuclear number in the range from Ca up to Pb at the thershold up to 500 GeV, and 25 GeV for EM component (Fig.5). An increase of energy thershold up to 500 GeV (25 GeV) leads to an efficiency decreasing only by a few per cent for the colliding nuclei with $A > 40$. The efficiency drops from 80 % down to 30 % for *pp* collision.

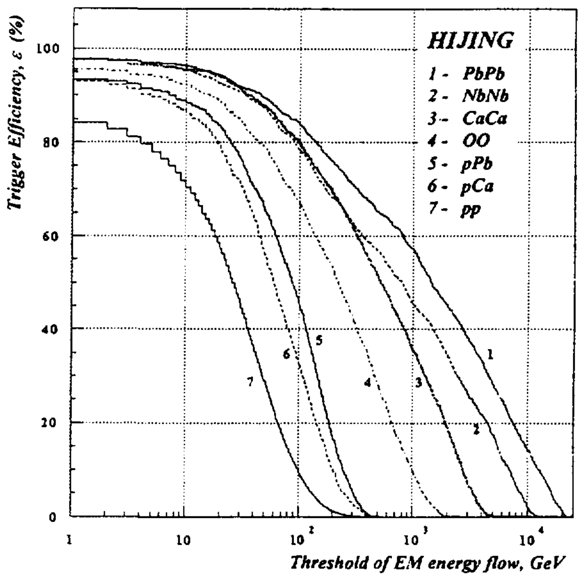

Fig.4. The efficiency of the event selection *vs* the electromagnetic energy threshold for nucleus-nucleus (PbPb, NbNb, CaCa, OO), proton-nucleus (*p*Pb, *p*Ca), and proton-proton collisions at 5 TeV/nucleon in the centre of mass system

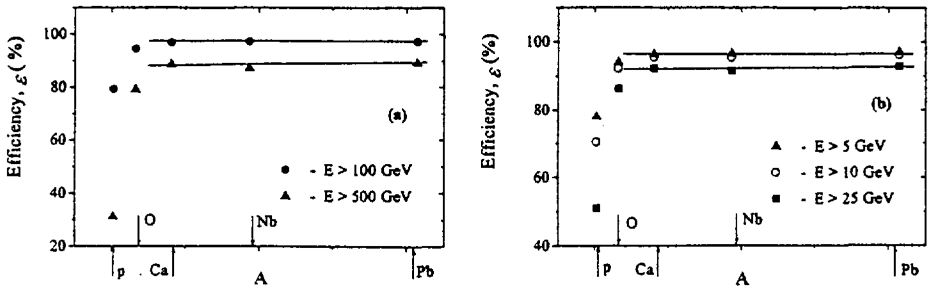

Fig.5. The efficiency of the event selection *vs* the atomic number of colliding nuclei at the particular energy threshold: (a) total energy threshold E_{thr} = 100, 500 GeV and (b) electromagnetic energy threshold E_{thr} = 5, 10, 25 GeV

Conclusion

On the basis of the HIJING Monte-Carlo simulation the simple scheme of a nucleus-nucleus interaction selection is proposed. The time signal coincidence from the two very forward calorimeter arms at 1 ns time resolution in $-5 < \eta < 5$ acceptance can be used for an effective counting of nucleus-nucleus collisions. The efficiency dependence on energy threshold value was studied. It is shown that the offered trigger scheme allows one to count nucleus-nucleus events with high efficiency up to 500 GeV energy thresholds in the VF calorimeter arms. We note that the efficiency remains stable in a wide range of colliding nuclei (from Ca up to Pb).

We would like to express our thanks to Profs. I.A.Golutvin and V.N.Penev for support and stimulating discussions.

This work was supported by the Russian Foundation for Basic Research, Grants No.96-02-17207 and No.96-15-96423.

References

1. Brandt D., Eggert K., Morsch A. — CERN AT/94-05(DI), SL/94-04(AP), LHC Note 264.
2. The Compact Muon Solenoid — Technical Proposal, CERN/LHCC 94-38, 15 December, 1994.
3. Savina M.V., Shmatov S.V., Slavin N.V., Zarubin P.I. — JINR Rapid Com., 1998, 1[87]-98, p.45.
4. Wang X.N., Gyulassy M. — Phys. Rev., 1991, v.D44, No.11, p.3501;.
5. Eichten E. et al. — Rev. Mod. Phys., 1984, v.56, p.579.
6. Duke D.W., Owens J.F. — Phys. Rev., 1984, v.D30, p.501.
7. Bjorken J.D. — Preprint FNAL Pub — TH-82/59, 1982.
8. Gyulassy M. — Proceedings of VIII Balaton Conference on Nuclear Physics, KFKI, Budapest, 1987.
9. Zarubin P.I., Slavin N.V. — JINR Rapid Com., 1995, 6[74]-95, p.115.

Received on February 2, 1998.