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NEW METHOD IN CALORIMETRY FOR SUPERHIGH ENERGY HADRONS

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A new method in calorimetry for superhigh energy hadrons is proposed. The main feature of the method is the effective detection of soft neutrons, abundantly present in the superhigh energy hadron showers, by using neutron detectors insensitive to minimum ionizing particles. Such a calorimeter allows us to selectively detect the hadrons in the environment of high backgrounds of electrons, photons and muons.

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The magnetic analysis of hadron momentum will be very difficult at superhigh energy, and the hadron calorimeters will play an increasingly important role in the high energy experiments of the next generation[1,2]. The ordinary method of hadron calorimetry is the sampling and detection of the ionizing particles (charged pions, protons, electrons, etc.) in the hadron showers by using detectors which are sensitive to the minimum ionizing particles, but in some experiments, such as those at e-p colliders, it is unavoidafle to detect hadron events under severe electron-photon background conditions. In this letter we discuss the advantages and disadvantages of a new method in the calorimetry for superhigh energy hadrons.

It is known that soft neutrons are abundantly present in the hadron showers produced by superhigh energy hadrons[3,4]. In the hadron showers developed in the heavy medium most of the neutrons produced come from evaporation of the highly excited nuclei with little contribution from the spallation process. Typical kinetic energies of neutrons are from 2 to 20MeV. These MeV neutrons undergo elastic scatterings, inelastic scatterings and nuclear reactions of different types in the medium and slow down into soft neutrons. According to different experimental measurements[5,6] in lead the typical yields are 14 to 22 neutrons per GeV of incident hadron energy, and the number of neutrons produced by a few GeV hadrons are too small, but there will be more than 10^4 neutrons per hadron of TeV energy. We may set neutron detectors which are sensitive only to neutrons but insensitive to the minimum ionizing particles at different depth of the medium to detect these soft neutrons. The energy resolution for incident hadron is determined by the fluctuation of the

fraction of purely hadronic component in the shower and the fluctuation of the number of the detected neutrons.

The recoil detectors such as the plastic scintillators or the proportional chambers with hydrogenous gas fillings have been used in which the neutrons are detected by elastic scatterings with hydrogen[4,7], but these detectors are also sensitive to the minimum ionizing particles in the showers. The neutron-induced reaction detectors such as lithium-loaded glass or BF_3 gas chamber may be used as neutron detectors insensitive to minimum ionizing particles. In some (n, α) or (n, p) reactions with large cross sections, such as ^{3}He (n, p) T, ^{6}Li (n, α) T or ^{10}B (n, α) ^{7}Li reactions, the charged particles are produced with an energy release Q. The ranges of the charged particles produced in the reactions are short, so they will stop in the detector and their kinetic enegies will totally contribute to the measurable signals. In the case of BF_3 gas detector the output signal from ^{10}B (n, α) ^{7}Li reaction is quite large, thus the detector can be operated at very low gas gain and is almost insensitive to minimum ionizing particles.

The cross section of ^{10}B (n, α) ^{7}Li reaction has 1/v dependence in keV region and σ=4010 barns for thermal neutrons. In case that the BF_3 proportional chambers are used with enriched ^{10}B, the neutrons have to be thermalized, in order to obtain high detection effeciency, in some moderators and then captured by the ^{10}B nuclei in the neutron detectors. The diffusion of the neutrons shows a gaussian distribution peaked at the average location of the point of creation[8]. The thermalization of neutrons in the moderator is a process with microsecond time scale, therefore the response of the calorimeter will depend on the gate width of the electronics. In the case of low frequency colliding beams, the slowness of the energy information due to finite slowing down time of the MeV neutrons is not a serious problem. The output of the hadron calorimeter can be splitted into two channels simultaneously: one is the fast signal from a narrow gate giving information for trigger, and the other is the slow signal from a wide gate giving information of hadron energy.

We may consider the following design of the calorimeter: the lead absorber plates are sandwiched with layers of neutron chambers. Sufficiently large volume of the medium is needed to prevent the side and back leakage of neutrons. The impurities in the medium which strongly absorb the soft neutrons, such as cadmium, should be avoided. The enriched $^{10}BF_3$ proportional chambers are equipped with moderators on both sides. The graphite or beryllium moderators can be used, in the latter case some additional neutrons can be produced by the (n, 2n) reactions. An alternative design is a mixed plastic scintillator and BF_3 neutron chamber system where the plastic scintillator layers are put on both

sides of the neutron chambers as moderators. We can obtain two pieces of information simultaneuously, one from the plastic scintillators and the other from the neutron chambers.

The ordinary hadron calorimeters are sensitive both to the electromagnetically interacting particles (electrons, photons and muons) and to the hadrons. Due to (a) the low cross sections of photoneutron reaction and photofission reaction and (b) the use of neutron detectors which are insensitive to the minimum ionizing particles, the calorimeter exploiting the new method is insensitive to the electromagnetically interacting particles but is sensitive to the hadrons only. Such calorimeter allows us to selectively detect the hadrons in the environment of high backgrounds of electrons, photons and muons. A detailed Monte-Carlo simulation is in progress for the quantitative understanding of the characteristics of the calorimeter operating in the new way, including the total number, spatial distribution and time distribution of the soft neutrons in the calorimeter.

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