AN OBSERVATION OF HEAVY PRIMARY COSMIC RAY AT KNEE ENERGY REGION BY JET TRIGGER

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ABSTRACT

So-called "Knee" in the cosmic ray energy spectrum is quite important for a understanding of cosmic ray origin. The reliability of the data in the knee region , however, is very low because of a low flux and an inaccuracy of energy determination or detection efficiency. This report summarizes a new direct observation in the knee region. This observation is characterized in the high energy jet trigger and planed to be performed according to GOAL program.

1. INTRODUCTION

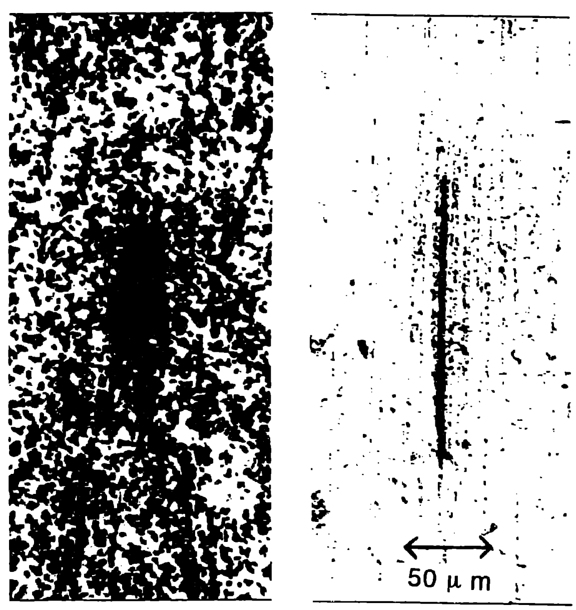
We have investigated the heavy primary cosmic-ray by a new type chamber which consists of screen type X-ray film. Our new refined results(1)(2) have shown that a smooth extrapolation of the energy spectrum does not agree with the existence of well known "knee" (3) in $10^{15}\sim10^{16}$ eV/particle. This knee is very important for understanding of the cosmic-ray origin. The direct observation at the knee energy region, however, has been severely restricted by a low flux. Air shower experiment in this energy region is also restricted by a low detection efficiency at the ground observation level. Moreover, the reliability of data in this region is quite low because of the low resolution in energy determination and the uncertainty of detection efficiency. Air shower experiment has another limitation that it is impossible to identify the primary nuclei. At this point, it is very important to obtain a reliable data in the knee region by long duration of direct observation. We have investigated a possibility of direct observation in this energy region, based on our developed technique and ability of measuring system. This report summarizes the proposal of new direct observation using jet triggering system.

2. A POSSIBILITY OF THE OBSERVATION IN THE KNEE REGION

The energy region of knee is about 1~2 order higher than the region where we have been obtaining a reliable data by direct observation. The direct observation in the knee region, therefore, requires about one hundred times scaled up observation. Such a large expansion can not be performed by a simple improvement of present method but will be performed by a original innovation. A triggering method of heavy primary particle which we have been using, holds a quite low efficiency for an analysis of high energy events. A high energy event triggering system is indispensable for the observation of knee energy region. The cascade triggering method has been using as a high energy trigger by JACEE group etc. and has been producing results(4) in high energy region. This method, however, has some problems in a viewpoint of obtaining reliable data for the analysis of knee. The first one is an ambiguity of detection efficiency caused by the non direct detection of interaction. The detection efficiency in cascade trigger largely depends on the composition of the primary particle and energy. The second one is a low accuracy of energy determination. As the cascade process severely depends on the inelasticity of interaction, it is impossible to obtain a reliable energy spectrum without a large amount of statistics. The third one is a difficulty in a mass processing of data. As the following-back from a cascade to a primary particle is carried out on a nuclear emulsion under a microscope, an automation using an image processor is difficult. We have investigated a new triggering method of high energy events, and come to a conclusion that a jet trigger method is effective for the observation in the knee energy region. In this method, the detection of high energy events is carried out by the scan of spots of jet (multi particle production) and the energy is determined by the emitting angle of secondary pions. The threshold energy for the detection of jet spot is about 1 TeV/n. As the multi production process is dominant in this energy region, and interaction points are detected directly, we can obtain an accurate absolute value of flux. As the energy is determined by using of a large number of tracks and a fluctuation is restricted small especially for heavy primary particles, we will be able to obtain a reliable energy spectrum.

3. SCANNING METHOD OF JET SPOT

First of all, let us show a real spot of jet on film. Fig.1 shows a picture of jet spot by 1989 balloon flight observation. This jet was produced by a primary particle of charge 23 and energy 1.5 TeV/n in Fe target. (a) is a pictures of spot on X-ray film (#200 type) and (b) is of spot on nuclear emulsion corresponding to spots of (a). A spot is about 50 μ m in size and is detectable by naked eye. A spot on nuclear emulsion is smaller in size than a spot on X-ray film, but is detectable easily by low magnification microscope. The rapidity η distribution, as is well known, scales according to log Eo where Eo is the incident energy. Fig.2 shows lateral distributions of track density for different depth t which is calculated by using of this scaling. Figure shows that the spot does not become large with the depth from the interaction



(a) (b)

Fig.1 Figure of jet spot (a) on X-ray film (b) on nuclear emulsion point in spite of an expansion of jet. The η scaling produces the same distribution curve in terms of t/Eo for different energy Eo, as is shown in figure. These features means that the high energy jet can penetrate to deeper depth but can not make so large spot as cascade process. The following condition, therefore, is required as the detector of new observation. (1) 2-3 mm intervals of sensitive layers. (2) Target of high density material for the high multiplicity production (3) Long cascade length material in order to avoid the influences of cascade process.

As a target material, Fe plate is most appropriate. As a sensitive layer, x-ray film and nuclear emulsion are effective. With regard to X-ray film, (1) A grain is so large that it is easy to detect jet spots. (2) Background by heavy primaries and low energy interaction is low and prefer to a long duration of flight. Regarding to the nuclear emulsion, (1) Much lower energy spots can be detected than X-ray film and the detection bias is quite small. (2) Jet spots can not be detected without microscope and is not suitable for the auto-scan. The time for scanning of spot per 1 layer ($40 \times 50 cm^2$) was estimated by 1989 observation data as follows.

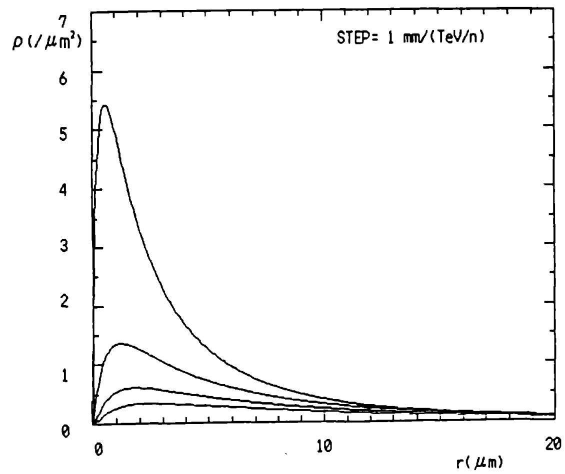


Fig.2 Lateral distributions of track density at the intervals of t/Eo =1 mm/(TeV/n) from the interaction point.

(1). 10 minutes for the scan by naked eye on X-ray film
(2) 2 hours for the scan by magnified image on monitor TV using auto XY stage and image possessor.
(3). 15 hours for the scan by microscope on nuclear emulsion.

The scanning of jet spots should be carried out on X-ray film because of shortening of scanning time. The scan on the nuclear emulsion is also needed for the calibration of detection efficiency and the check of scanning bias on X-ray film.

4. ENERGY DETERMINATION

As the emitting angle of secondary particles becomes smaller with energy, the energy determination in the new observation should be performed by using of the emitting angle of secondary pions instead of fragmented particles which is used for our present analysis. The rapidity η distribution scales with log Eo as is well known and the energy is estimated by fitting to the individual y distribution for each events. As the front part of y distribution is located at the value of log 2Eo/M (M is nucleon mass), the measurement of emitting angle on nuclear emulsion requires about 10 cm space under the interaction point at 100 TeV/n energy. The detector, therefore, would be constituted by two parts, one is a target part and another is a measuring part. The resolution of this energy determination was estimated using the accelerator data, as is shown in Fig.3. The energy is estimated in good accuracy because of the low fluctuation by high multiplicity. This method also can be used for jets produced by proton primaries.

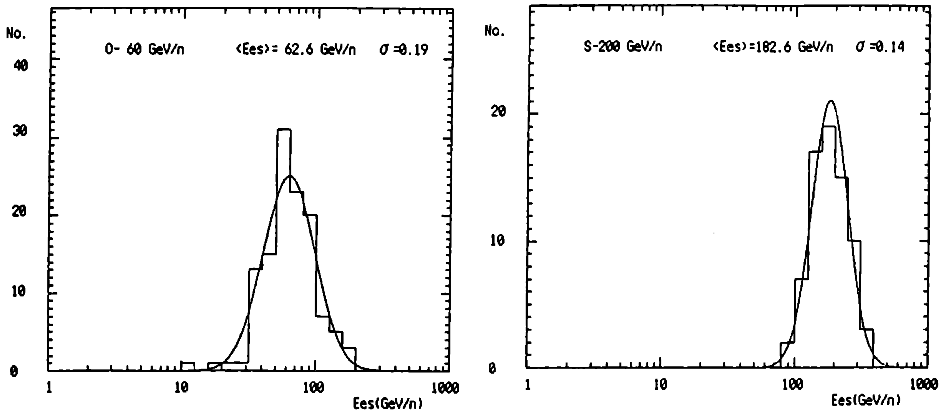


Fig. 3 The distribution of estimated energy by multi produced pion

5. NEW OBSERVATION PROGRAM

To achieve the new observation at the knee energy region by jet trigger method, a test observation will be performed by long duration flight in Antarctica in December 1993 under the joint collaboration with JACEE. This test observation will give us information about the precise feature of jet spot at the energy around 10 TeV/n and the condition of background. The final method of jet trigger and the chamber design of new observation in the knee region will be established by the analysis of this observation. A summary of this measurement is as follows.

(1). Detector (Emulsion chamber)

target layer :

500 μm Fe + #200 X-ray film + nuclear emulsion + screen type film $\times$20 cycles

measuring layer :

nuclear emulsion + screen type film + 1 mm spacer $\times$10 cycles

(2). Exposure aria 1 unit 40×50 cm^2 $\times$6 blocks=1.2m^2

(3). Exposure time 200 hours $\times$ 2 flights =400 hours

This observation will succeed to a series of regular direct observation at the knee energy region. This new observation is planed to be performed according to GOAL program under the joint research with JACEE group. The GOAL program plans 12 flights of long duration within 5 years and makes it possible to obtain about 100 times amount of data comparing with the present observation. The reliable results with good accuracy and numerous statics will surely present many information about structure and nature of universe.

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