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Measurement System for cosmic ray nuclei in JACEE emulsion

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Abstract. A new semi automated system to identify the single track in photographic plates has been developed. This system is useful for analyzing the nuclear emulsion plates of long duration balloon flights efficiently and systematically. The tomographic images of nuclear emulsion plates at various depth of focal plane under the microscope, were used for track finding methods. And a CCD photometry system mounted on a microscope were also developed for charge measurements. We examine the possibility to apply these systems to the emulsion plates of JACEE experiments.

1 Introduction

Cosmic ray composition and its energy spectrum have been speculated to have some drastic change in the energy region from 10^{14}eV to 10^{15} eV toward the ”KNEE”. The JACEE collaboration has made 15 balloon-borne emulsion chamber experiments since 1979 for the purpose of direct measurements of cosmic ray nuclei at this energy region, and its last Antarctic long duration balloon flight has been completed in 1995. The nuclear emulsion plates of Antarctic flights have several ten times of low energy background tracks compared with that of previous long duration flights, due to almost zero cutoff rigidity in Antarctica and its balloon launching at almost solar minimum phase. This background tracks prevent us from systematic and efficient analysis. We have developed a semi automated system to identify and determine the charge of a single track in a photographic plate, and applied this system to the analyze of nuclear emulsion plates from JACEE long duration balloon experiments.

2 Tracing System

In JACEE's Antarctic balloon flights, emulsion chambers had been exposed more than 300 hours at 5.0 g/cm^2 of atmospheric depth with almost no geomagnetic rigidity cutoff. To avoid the high background densities of low energy tracks, chemical processing of photographic plates were optimized to slightly lower grain density of minimum ionization track in nuclear emulsion and to lower background density in X ray film, compared with previous long duration flights. In the analysis of the high energy event whose threshold energy is about $\Sigma E_\gamma \geq 20$TeV(E$_0 \sim 100$TeV), tracing process to identify the incident nuclei is completed with 100 % of tracing efficiency by even manual scanning. However to compare and confirm the absolute flux of each nuclei derived from Antarctic data with that derived from previous JACEE exposure at greater than 100 TeV, the absolute flux at the lower energy, which had been confirmed already by previous data statistically, should be compared each other to evaluate the consistency. As it is not efficient to analyze the lower energy events in the highly noised emulsion plates by manual scanning, a new semi automated tracing and tracking system is under developing by means of motorized staging system and image processing technologies. This system consists of motorized stage using Nikon L-MIC microscope(35cm $\times$ 35cm) in 0.5 μm resolution. The stepping motor controller system (Oriental Motor : αstep) were used to control stage movements, and the motor driver controller (Oriental Motor: SPG8800E) were able to communicate with serial interface of PC. The configuration of this system is shown in Fig. 1. The image processing board (HITACHI: IP-5000) was used for the image processing for track finding . In JACEE experiments, several analysis systems have been already developed and successfully worked out some subjects in emulsion plates/X-ray films analyses(Wilczynski et al, 1997, Iyono et al, 1997, Zager et al, 1997).

The concept of this method is as follows. This process is shown schematically in Fig. 2. The first step of the method is to acquire images from CCD camera on a microscope, at various depths of the focal plane of microscope. The digitized tomographical images are stored into IP-5000 on-board memories. Each image is shifted to predicted location according to the angle measured in calorimeter section or downstream side emulsion layers. After summing up all images,

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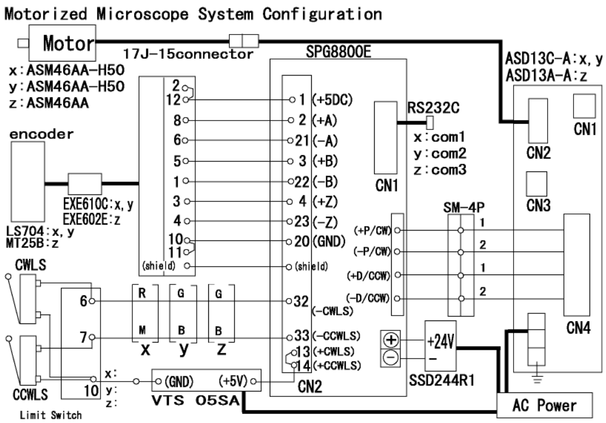

Fig. 1. Motorized Microscope system configuration. The driver controller SPG8800E can communicate with PC via serial cables

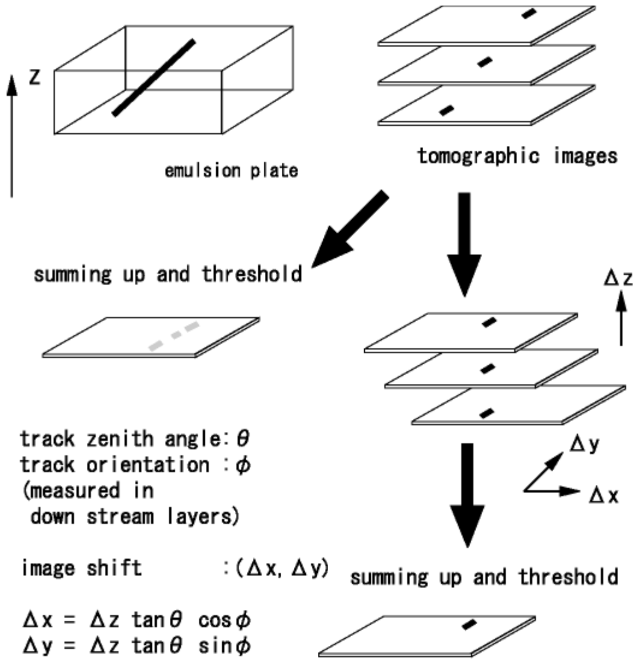

Fig. 2. Concept of track finding method in the emulsion plates. Zenith angle θ and orientation ϕ of track are measured in the downstream layers, and then expected shift values are applied to each tomographic images before summed up.

the only track of that angle makes brighter spots on the summed image. By searching spots whose brightness is higher than some threshold, the tracks can be found out. Each shift value is calculated, based on the measurements in downstream emulsion ray layers. The IP-5000 image processing board has $5\times2048\times1024$ bytes frame memories, and several image operation commands are executed in the pipeline processing. Fig. 3 shows a summed up image without shift operations. There are many gray spots, instead of track images seen in the figure. Each track is seen as a dark spot in each tomographical image, and moves with increasing the depth of focal plane. Therefore, Fig. 3 shows that a clear signal of existing track can not be detected. In Fig. 4 only sought out tracks are plotted in negative images with some circle marks. The threshold value of brightness was 128 of 256 gray scale in this case. This value is dependent of the image darkness and the inclination of track, because a spot shape varies with its zenith angle. The more inclined tracks are, the more elliptic their shapes are. The efficiency of this method depends on zenith angle, track charge value and background darkness of image. The overall efficiency is now being examined.

3 Charge measurement using a CCD camera

In the cosmic ray composition analysis of balloon-borne emulsion experiments, the charges of relativistic heavy particles are determined by delta ray counting along the track by manual work with a microscope. As it is difficult to evaluate the systematic uncertainties of manual measurement, recently an automatic measurement system using a CCD camera is in place of taking the profile of tracks systematically and quickly. We are improving the system and method, which have been developed by accelerator experiment group (Wilczynski et al, 1997), to apply to the balloon-borne cosmic ray data analysis. The system consists of a CCD camera(Sony XC-75) mounted on an optical microscope with TV zoom C-mount adapter(Sony) and PC computer with image processing board(Cyber Tech CT-3000). Photographic image under the microscope field of view are acquired by the CCD camera, and each of 640×480 pixel brightness data are digitized to one of 256 different value in gray scale. In order to get a two dimensional track image in focus, 15 successive images acquired with changing focus by 4 micron in depth are reconstructed to one image.

In the analysis of a track profile, ”obscuration” parameter, O_b, is defined as, O_b=(I-I_0) / I_0, where I_0 is initial illumination determined from background illumination value, I is brightness at the center of track after correction of CCD's dark current effect. Usually ”height” parameter defined as, I-I_0, is applied to the analysis of charge determination, but O_b is much stable for varying background illumination. To derive the relation between O_b and the charge of incident particle, the calibration using accelerator beam tracks has been done and this method has been ealuated by the Monte Carlo simulation.

In the calibration, 150 tracks of ^{16}O and 40 tracks of ^{32}S data of 200 GeV per nucleon (EMU04 experiment,200)) were examined to estimate the fluctuation of O_b in the measurement of a 90μm track length at the acquired one field of view. O_b of single silver grain in the developed emulsion plate was determined from the measurements under various background illumination. This evaluated the dependency of O_b on the condition of emulsion chemical processing for the Monte Carlo simulation. In the simulation, GEANT3 simulation package was used to create the track profile of a charged particle passing through emulsion, and the O_b value is calculated under consideration of the size distribution of silver grains. As preliminary results from the comparison of measurements and simulated O_b values, the charge derived from O_b has incident angle dependence in the resolution. The charge resolution of Z = 3 to 26 is estimated to 0.11, 0.15, 0.45 charge unit in the case of incident angle 90—50, 50—30, 30—10respectively, when O_b is determined from 90 μm track measurement. Further calibration using the balloon-borne emulsion plates will be done to apply this system to the analysis of cosmic ray composition study.

4 SUMMARY

We have developed a new semi-automated analysis system of photographic plates. The system to identify the single track is useful in the analysis of JACEE's Antarctic emulsion plates, to find shower tracks and get its threshold energy down to lower energy in the tracing process. However, tracing efficiency and threshold energy depend on the zenith angle of shower tracks. For the charge measurement system, the charge resolution of Z=3$\sim$26 is estimated to 0.11$\sim$0.45 charge unit, but we need further calibration to examine the zenith angle dependency of charge resolution under the high background emulsion plates.

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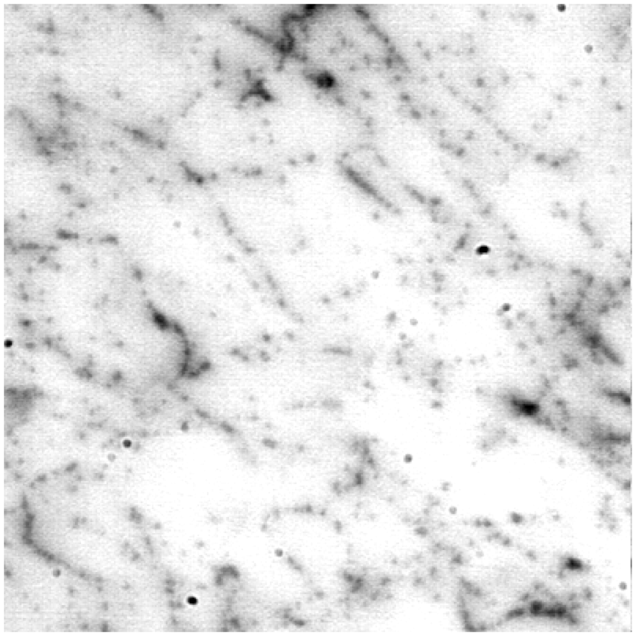

Fig. 3. Example image : tomographic images are summed up.

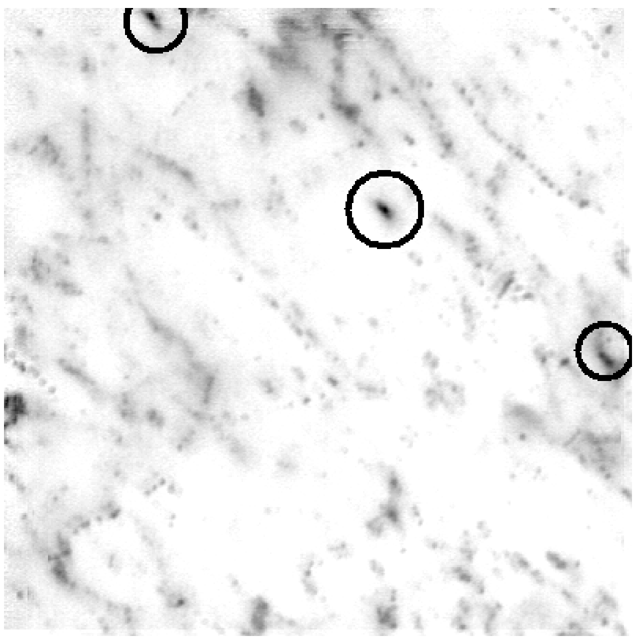

Fig. 4. Example image : shifted images are summed up by the concept of track finding method. Sought out tracks are marked with circle symbols.