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The development of measurement system for heavy primaries identification with the use of screen type films in RUNJOB experiment

P. A. Publichenko[1], A. V. Apanasenko[2], V. A. Derbina[1], M. Fujii[3], M. Hareyama[4], M. Higashida[5], Y. Horiuchi[4], V. I. Galkin[1], M. Ichimura[5], N. Inoue[4], E. Kamioka[6], T. Kobayashi[4], V. V. Kopenkin[1], I. Kudo[5], S. Kuramata[5], A. K. Managadze[1], H. Matsutani[5], N. P. Misnikova[2], R. A. Muhamedshin[7], H. Nanjo[5], S. N. Nazarov[1], S. I. Nikolsky[2], M. Nishiura[5], V. I. Osedlo[1], D. S. Oshuev[1], I. V. Rakobolskaya[1], N. G. Poluhina[2], T. M. Roganova[1], G. P. Sazhina[1], T. Shibata[4], V. A. Suhadolskaya[1], L. G. Sveshnikova[1], H. Umino[5], I. V. Yashin[1], E. A. Zamchalova[1], G. T. Zatsepin[7], and I. S. Zayarnaya[2]

[1]Moscow State University 119899, Russia
[2]P.N. Lebedev Physical Institute 117924, Russia
[3]Aomori University, Aomori 030-0943, Japan
[4]Aoyama Gakuin University 157-8572, Japan
[5]Hirosaki University 036-8561, Japan
[6]National Institute of Informatics 101-8430, Japan
[7]Institute for Nuclear Research 117312, Russia

Abstract. In 6 out of 10 successful balloon flights of RUNJOB collaboration the emulsion chambers comprised screen type X-ray films (SXF), aimed to detect and to identify vertex points of heavy nuclei interactions with low energy threshold. Intensity of tracks in SXF occurred to be very high. Here we present the reliable and effective procedure of solution of the problem in this case. It gives the possibility to obtain in future the spectrum of heavy nuclei with low threshold in wide energy range using large exposure of RUNJOB experiment.

1 Introduction

Within the framework of Russian Nippon Joint Balloon (RUNJOB) experiment we have been performing cosmic-ray observation using of a balloon-borne chamber since 1995. In 6 out of 10 flights we exposed emulsion chambers equipped with multilayered screen type X-ray films (SXF). The similar type of X-ray films was firstly used in SANRIKU (Ichimura M., 1993) experiment for detection of cosmic ray nuclei heavier than oxygen. In RUNJOB experiment the SXFs are also used for heavy primaries with Z>17.

A charged particle passing through SXF, records double dark spots on X-ray film being seen by naked eye. The duration of RUNJOB flights is much longer than SANRIKU ones, which results in much higher density of dark spots and high-level background. The number of spots is as high as 200 thousand per layer. The analysis of experimental data demands the use of fully automated measurement systems. The automatic systems have been developed for scanning and tracking in Japan and recently in Russia. Now the processing of SXF data is performed independently in two laboratories. In report (RUNJOB Collaboration, 1997) the results of Japan part work was presented. In this report we discuss results obtained by Russian automatic system PAVIKOM (Goncharova L.A., 1999).

Correspondence to: P. Publichenko
(pavel@dec1.npi.msu.su)

2 Experimental procedure

The chamber consists of five modules: primary module, target module, spacer module, calorimeter module and diffuser module. Total area of the chamber S is 0.2 m^2, total thickness is 23 cm in geometrical length, and 6.3 g/cm2 in material thickness.

The main trigger of particle selection applied in RUNJOB experiment is based on detection of energy flow released into electromagnetic component ΣE_g in calorimeter block. However, due to high energy threshold and large fluctuations of ΣE_g the resulted energy threshold in primary energy E_0 equals 20-30 TeV/particle for heavy nuclei. Another method being employed in experiment is to follow down the tracks of heavy primaries from top to bottom using screen type X-ray films. Thus we do not need the electromagnetic calorimeter block but only primary and target modules where SXFs are included. New method has the advantage in detection threshold as 0.1 TeV.

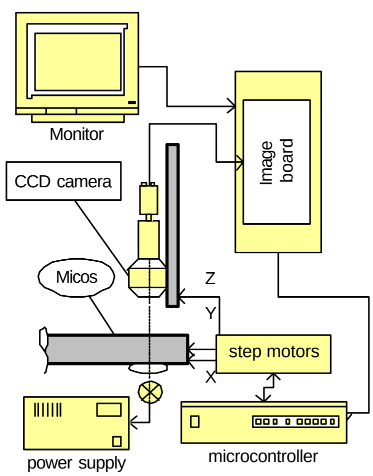

Fig. 1. The setup of CCD based automatic system.

SXF consists of two intensifying screens and one X-ray film inserted between them. When a heavy primary nucleus passes through SXF, scintillation light is radiated from both screens so that X-ray film records double dark spots which can be seen by naked eye. Tracks of particles crossed the chamber have the similar spot darkness and shape in all layers of the chamber, that allows us to select particle tracks. Since the spot darkness is proportional to the ionization loss rate we can determine the charge of a particle. If the track-producing heavy primary makes a collision in the chamber material the darkness of the track spot shows an abrupt change. Observing such a sudden change of the spot darkness we can find a vertex point of nuclear interaction.

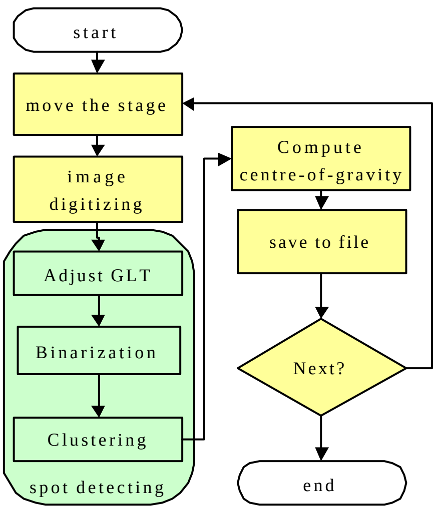

Fig. 2. The flowchart of an automatic scanning system.

3 Measurement system

The principle of this method is to scan all films and detect spots, then to find tracks. The spot density is very high, thus the measuring of dark spots on all films, reconstruction tracks positions in the chamber volume and searching for vertex points of nuclei interaction in a target becomes a very difficult task that can be solved only with the help of modern fully automatic systems. Such an automatic system based on CCD-technique and image processing has been developed in Lebedev Physical Institute (PAVIKOM). Fig. 1 shows the setup of the automatic measurement system. It consists of the microscope equipped with a CCD-camera, computer-driven motorized stage MICOS, an image digitizer and a personal computer. A movable area is 80x40 cm2, x, y and z resolution is 0.5 ì. During the auto scanning work special program controls the stage, does the image analysis, i.e. detects spots and saves the x-y coordinate and the optical darkness of each track spot in a hard disk.

Non-interacting references tracks are used to define the common coordinate system of all layers in the chamber. References tracks are found in the semi-automatic mode.

4 Image analysis for X-ray films

The image is treated by special pattern recognition module implemented in the scanning program. The image of the X-ray film in the certain field of view of the microscope is transferred to an image board, the image board performs analog-to-digital conversion of the CCD-image and digitized image is copied into the computer memory as the whole grey-level pixel map G(x,y). The size of the field of view is 2800x2300 $ì^2$.

A schematic flowchart of an image-processing algorithm is shown in Fig. 2. The algorithm consists of the following: binarization (classifying the pixels as black and white), clustering, computing centre-of-gravity (x,y) coordinates of found clusters. A binary image of black and white pixels B(x,y) can be obtained by comparing their gray level with a suitable cut-off value GLT (gray level threshold) that is adjusted locally. Next, loop over the elements of the matrix B, flag with the same cluster identifier k all the adjacent bit-1 pixels, and store this into a cluster-mapped matrix C(x,y). Finally, loop over the elements of matrix C, compute centre-of-gravity of clusters (coordinates of the spot), size (number of pixels) and spot darkness. The clusters whose size is more than a given value are supposed to be spots. Image processing functions are executed immediately after image is grabbed during the moving stage to the next field of view. A typical SXF image viewed by CCD-camera is shown in Fig. 3.

Fig. 3. The SXF image obtained by CCD-camera.

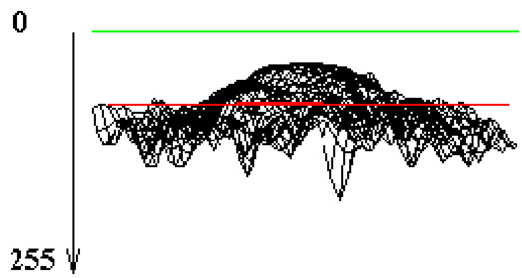

Fig. 4. Three-dimensional contour map corresponding to one spot in SXF.

5 Track finding

Having achieved the fast and efficient detection of spots, performed in all SXF layers by the method discussed above, we implemented a procedure that allows reconstructing the original trajectories of nuclei from the spots. At first we find all the combination of double spots on the top SXF layer 1, and then try to follow down these pair of spots to lower layers. In order to reduce the time of access to spots located within a given area, each layer is subdivided into cells; the coordinates of spots detected by the image analysis are stored in an array cell by cell. So, the track search routine is based on a cell-by-cell loop over the double spots of a layer. All double spots on the top layer 1 are considered as the beginning of a possible track. Since one particle leaves double spot on the SXF, knowing the effective distance between scintillation screens, we get both the zenith and azimuthal angles of the track. Using this initial direction, double spots are to be combined with all corresponding spots in layer 2. Having identified corresponding double spots on two layers we define a tentative slope, spots will be searched for in layer 3 around the impact point computed by extrapolation. Spots on the straight line are included in the track. In case of successful alignment, the track search can be continued in the next layer by updating the trajectory parameters, and so on. The number of combinations of initial double spots increases by increasing the area of cells. In order to minimize border effects, the cell must be large enough. A reasonable compromise of the cell length turned out to be in the range 10-15 mm.

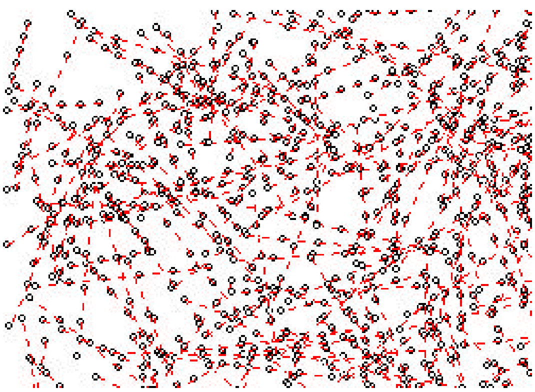

Fig. 5. Tracks found in the chamber

Once tracks have been collected as ordered trails of double spots, some selection depended on various parameters must be applied in order to take away false trajectories. At the first stage we sort tracks by $\div^2$ (actually sum of distance square to fit). To select the genuine tracks it is advisable to assume $\div^2$ and maximum darkness variation of track spots as acceptance parameters. Application of these acceptance parameters excludes false tracks from total database. Proper tracks are believed to correspond to minimum ÷ and darkness dispersion of its spots. A scatter plot of track ÷ versus the darkness dispersion of track spots shows ÷ to depend on dispersion within the certain region. So, this region of values ÷ and darkness dispersion is assumed for acceptance parameters for track validation. Fig. 5 illustrates an example of a tracking result. One can see large number of tracks found within the field of 100x150 mm^2.

The optical darkness of each track spot on the x-ray film reflects the charge of the incident heavy primaries. To find out the sort of selected events we compared dependencies of darkness of track spots on zenith angle for our events processing and corresponding data obtained in SANRIKU experiment. Our selected events refer to heavy group primaries, practically Fe.

6 Results

We have shown that modern devices, like CCD cameras, image digitizers and computers, can be assembled with a motorized optical microscope in order to realize an automatic instrument, to be able to recognize and measure dark spots in x-ray film. The main aim was the analysis tracks in our trigger, a difficult task, because of pattern recognition, high background and spot density. The automatic system developed in LPI performs real-time measurement at high speed and good accuracy. Actually, we performed auto scanning of 10 SXF layers. Total number of spots detected in one SXF layer reaches 120-180 thousand. The number of spots decreases from top to bottom. Information of all detected spots was stored in database on HDD. The full scanning of one film takes up 11-12 h.

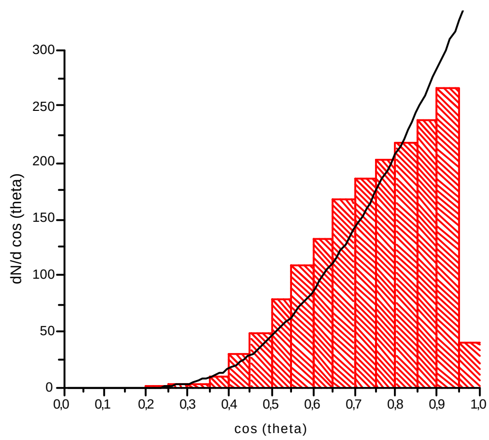

Fig. 6. Zenith angle distribution of selected tracks

Data taken by the scanning system are analyzed by special tracking program. The tracking procedure explained above find tracks of heavy primaries reasonably well. We present the angle distribution of tracks selected with criteria ÷<0.4 mm and max darkness variation of track <40% in Fig. 6. One can see that angle distribution is consistent with theoretical one.

Thus the particle trigger based on usage of SXF allows us to detect heavy primary nuclei and extend statistics covering the low energy range.

7 Conclusions

The final development of this method will give the possibility to obtain in future the spectrum of heavy nuclei with low threshold in wide energy range using large exposure of RUNJOB experiment. The utilization of the automatic system based on CCD-camera speeds up the data collection considerably. Further development of the method concerns an improvement of spots detection and tuning various criteria for more proper track selection.

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