PROCEEDINGS OF SCIENCE

Analyses of cosmic ray tracks registered in transport test emulsion films for the GRAINE 2023 experiments

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The GRAINE project aims to observe gamma-ray sources that are subGeV and GeV in high detail. The GRAINE experiment aims to image the direction of arrival of gamma rays in high detail by making long balloon flights of large-area emulsion films with high angular resolution to earn the total amount of cosmic origin gamma rays, and to elucidate unsolved problems such as the production mechanism of high-energy gamma rays. Three previous flight experiments have been conducted in 2015, 2018, and 2023. In the previous experiment (2018), a balloon-borne experiment with an aperture area of 0.38 m2 and a flight time of 17 hours was conducted in Australia, where the Vela pulsar was successfully captured. The current experiment (2023) is larger in scale than the previous experiment, with an aperture area of 5 m2 and a flight time of 26 hours. The GRAINE 2023 balloon experiment took off on April 30, 2023, at 6:00 a.m. Japan time, and after 26 hours of flight, landed at a point 220 km south of Longreach, Queensland, Australia. After the successful recovery, the local researchers returned to Japan and began developing the nuclear dry plates used in the experiment.In this presentation, the GRAINE 2023 experiment will be reported and the HTS for analysis will be introduced. In this presentation, the air transport test will be introduced and the results of the film analysis will be reported.

38th International Cosmic Ray Conference (ICRC2023)
26 July - 3 August, 2023
Nagoya, Japan

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PoS(ICRC2023)811

1. Introduction

The most distant objects in the universe currently captured by mankind are gamma-ray bursts, phenomena that shine brightly for only a few milliseconds to a few hundred seconds. The latest observations show that the source of gamma-ray bursts is an intelligence-versus-intelligence velocity jet produced by the collapse of massive stars or the fusion of neutron stars and black holes in the cosmological distance, and that the radiation is seen head-on. This information was revealed by the Fermi Gamma-ray Space Telescope, launched in 2008, which has been at the forefront of gamma-ray astronomy. However, observing cosmic gamma rays at tens to hundreds of MeV is difficult, and the angular resolution is several orders of magnitude worse than observations at other wavelengths. GRAINE (Gamma-Ray Astro-Imager With Nuclear Emulsion) is a project that aims to observe and analyze cosmic gamma rays in high detail using nuclear dry plates as detectors.(figure.1)In this experiment, the film needs to be brought back to Japan to be developed, so we are analyzing the transportation method to avoid exposure to X-rays at the airport and to minimize noise that may interfere with the experimental data.

Figure 1: GRAINE2023 Flights in Australia

2. Transport film test

GRAINE 2023 will be sent to Japan because the amount of film is 6.5 times larger than in 2018, so the film needs to be developed in Japan instead of in Australia. The transportation test was conducted in October-November 2022, using the same method as for the production 2023. The method of transportation was to prepare two types of chambers, one with several dummy films stacked on top of each other, one placed vertically, and the other placed flat.(figure.2)The chambers were stored in cooler boxes and transported by air to the site and by land from the site. The transport film test consists of the following steps: checking to see that the film has not been exposed to X-rays for baggage inspection, inserting a logger to check the temperature history to see how the film is being controlled, storing film with the same nuclear emulsion and coating conditions in the laboratory to be used as control film, and then sending the film back from Australia for transport and control. After the film was returned from Australia, the transport film and the control film were developed simultaneously, and the track data was analyzed by the High Speed Track Detection System (HTS).

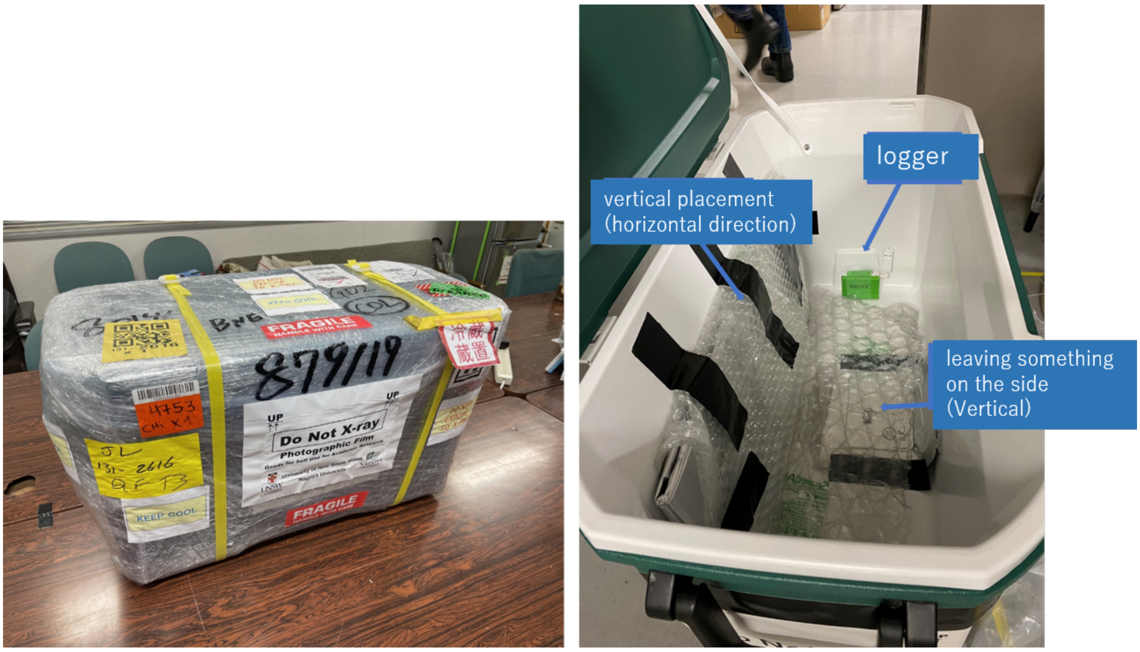

Figure 2: A cooler box with a chamber to transport to Australia and a logger to measure air pressure and temperature history.

3. Analysis of observation data

After acquiring and binarizing a tomographic image of the emulsion layer, the image is shifted and the amount of vertically aligned hit pixels added up (pulse height) is used to determine the trace-like characteristics. This enables a three-dimensional search for linear trails that penetrate the emulsion at various angles by simply shifting and accumulating images. As development progressed, the reading speed increased dramatically, and the fastest current system, the Hyper Track Selector (HTS)(figure.3), is capable of reading 4700 cm2/h. The HTS is capable of reading 5,000 cm2/h of film placed on the operating stage, and is capable of reading 5,000 cm2/h of film placed on the operating stage. A film placed on the operating stage is read by an objective lens with a wide field of view of 5 mm x 5 mm, and the image is processed by 36 PCs to read the tracks. The next-generation HTS2 (2021-) is under development, which is expected to improve the reading speed by a factor of 5 from the HTS. These developments have made it possible to perform experiments such as reading the entire volume of a large-area dry plate.

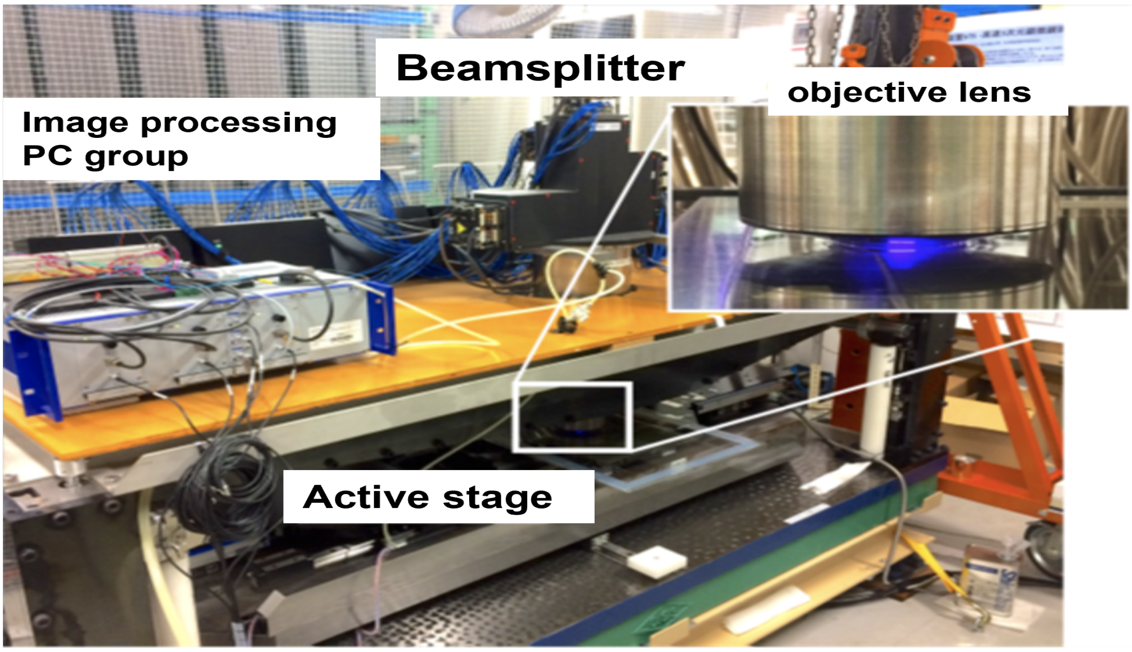

Figure 3: Hyper Track Selector(HTS)

4. Evaluation of angle in m2b,linklet process

m2b is an abbreviation for micro track to base track, and outputs the base track, which is two micro tracks in one emulsion of a nuclear dry plate joined into one track. Linklet is a method to identify the base track connected to the top and bottom two films based on the distribution of misalignment and angular misalignment, and to analyze the angle distribution of the cosmic radiation incident on the film (zenith angle) and the pulse height, which indicates how many silver particles (grains) that make up the track were connected, Linklet is the process of identifying the base tracks connected to the two films above and below based on the distribution of misalignment and angular misalignment, and confirming that the tracks are connected in a straight line in multiple films. The angular distributions obtained from these two operations are compared. For this comparison, we will compare the flat film that was transported to Australia with the flat film that was stored at Nagoya University. Figure.4 photos were output by m2t, with the Australian film on the left and the film stored on the ground on the right. The first difference between these two is by far the difference in the amount of cosmic rays and noise that have invaded the film. In the photo on the left, a large circular trace of a flying trail can be seen in the center of the image. Also, the highest peak is seen at ax,ay=0. In the right photo, the peak is less intense than in the left photo, but there is an obstacle at ax=-1 0 and the entry is asymmetrical. m2b has a very large amount of noise, so a linklet was performed to remove it and show only the signal, which is shown in figure 5.Unlike m2b, the eyeball-like pattern appeared more clearly. In addition, in the left photo, the

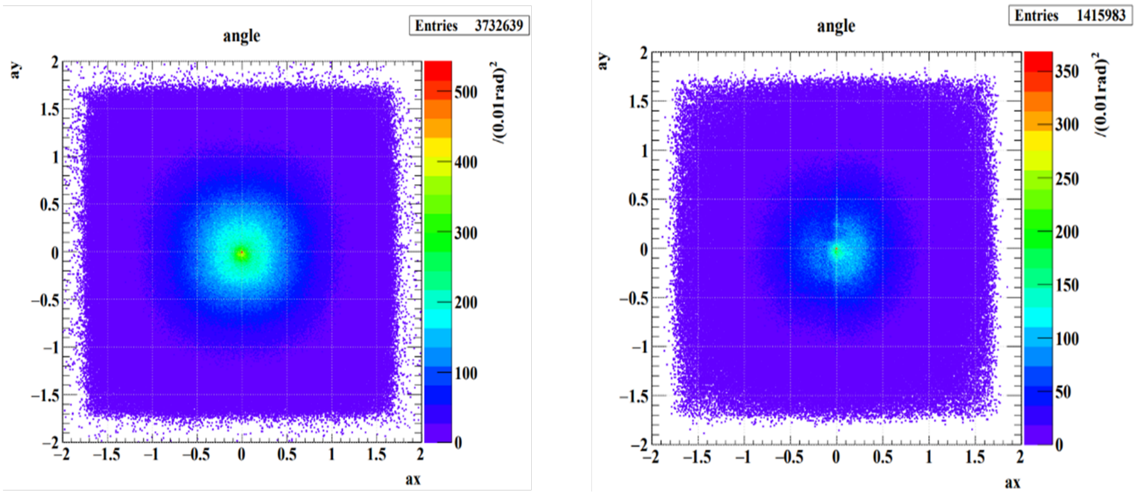

Figure 4: Angular distributions of two flat outputs by m2b (left: Australia, right: Nagoya University)

presence of obstacles is depicted more clearly.The reason for this is that in previous analyses, the targeted signals and chance coincidences were mixed in the picture, making the graph difficult to see due to the large number of entries. However, by performing linklet, excess noise is removed, and a graph showing only the targeted signals is completed. This allows us to see how cosmic rays are arriving at each angle. In Figure 6, the left side is the film that was transported and the right

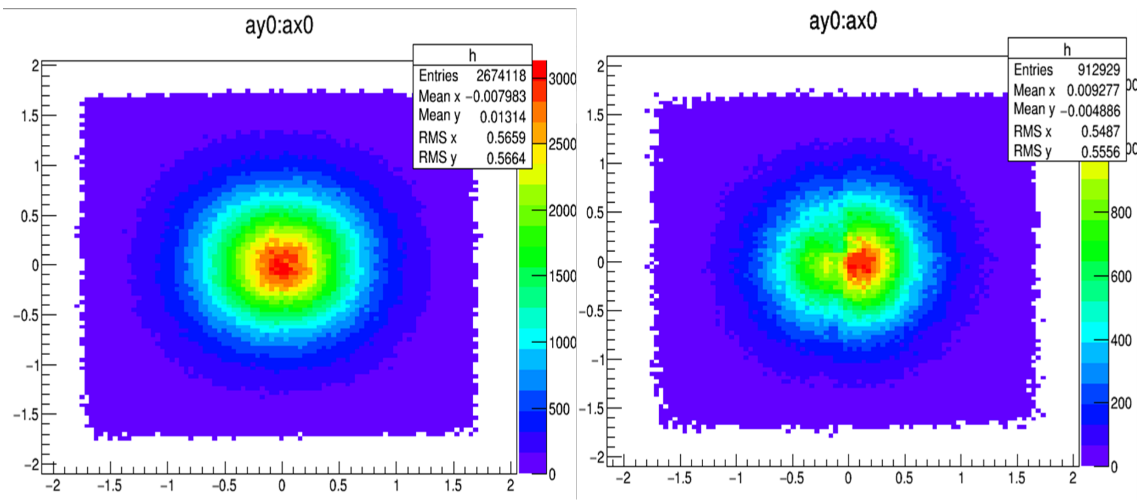

Figure 5: Angular distributions of two flat outputs by linklet (left: Australia, right: Nagoya University)

side is the film that was stored on land.The film that was stored on land has an obstacle on its side, so the graph is missing, but the other shapes are the same. Based on this graph, it is necessary to determine the difference between the transport film and the land-based film to estimate how much cosmic rays entered the film on the outbound flight. This is not limited to flat films, but vertical films are also analyzed to determine the amount of cosmic rays that entered during the flight.

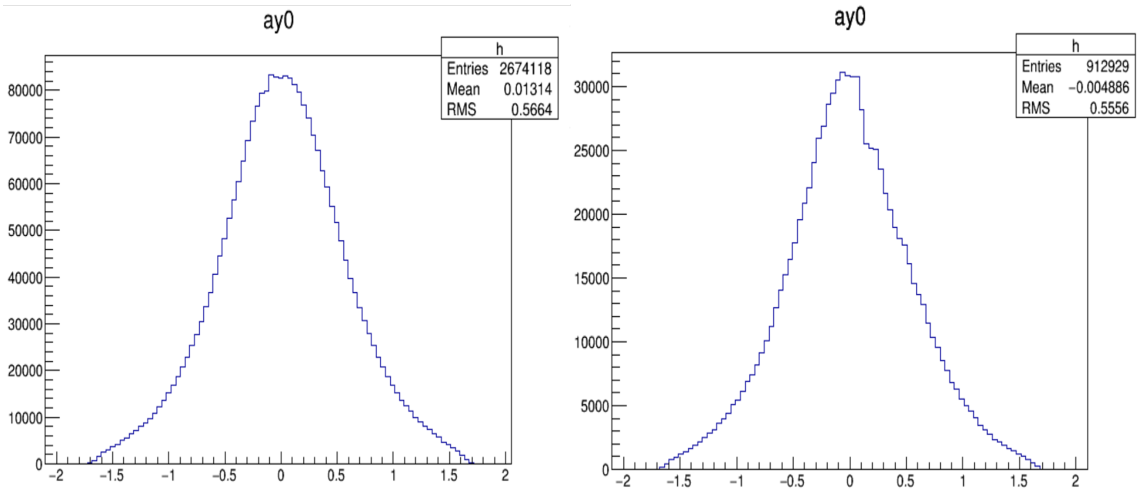

Figure 6: Angular distributions of two flat outputs by linklet (left: Australia, right: Nagoya University)

5. Summary and Conclusion

A film test during transportation was conducted for the GRAINE 2023 balloon experiment. Various tests were conducted, including avoiding X-rays at airports and customs, and checking the air pressure and temperature conditions inside the cooler box. The returned films showed no difference in noise level from those stored at Nagoya University, and we were able to establish a method for transporting the films in production. From the Linklet results, we were also able to determine the flight differences for each of the vertical and flat placements. Currently, the nuclear dry plates used in the GRAINE 2023 experiment are being developed at the Gifu University facility. The data analysis has begun in order to take highly detailed cosmic gamma-ray images in the GeV band from now on.

References

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