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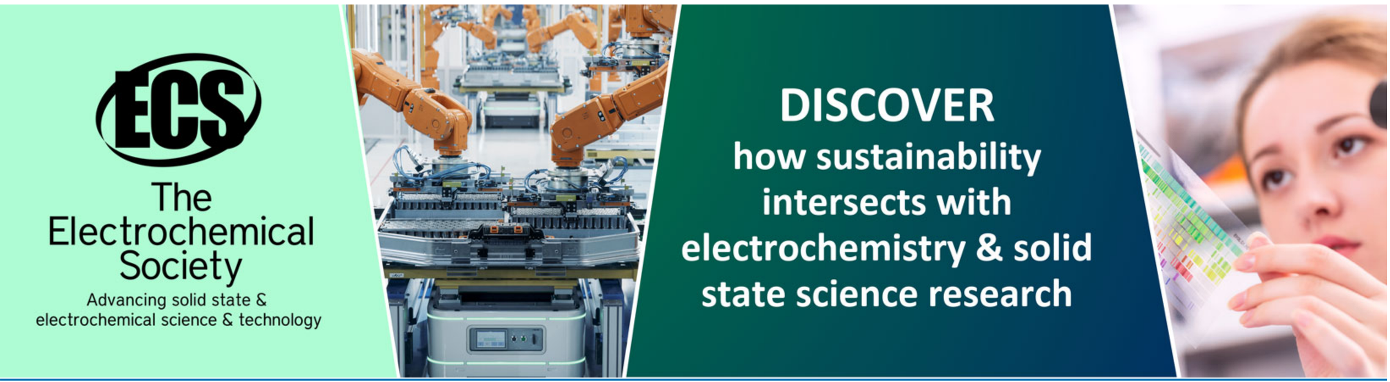

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Search for simultaneous and parallel cosmic gamma rays in the balloon-borne emulsion telescope experiments (GRAINE2015)

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Abstract. The emulsion chamber telescopes for observing 10 MeV - 100 GeV gamma rays have been developed by GRAINE (Gamma Ray Astro-Imager with Nuclear Emulsion) projects. We have performed the balloon filight in May, 2015 at Alice Springs, Australia, with 14.4 hours duration (including 11.5 hours of level flight) and 0.378 square meter aperture (GRAINE2015). GRAINE experiments utilized the multiple stage systems of emulsion films for timestamper of registered tracks.

In this paper, we report the potential of GRAINE2015 experiments to detect the parallel and simultaneous cosmic gamma rays such as charged particles due to hadronic interactions, EAS (Extensive Air Shower) and GRBs (Gamma Ray Bursts).

1. GRAINE project in 2015 (GRAINE2015)

1.1. GRAINE: Gamma Ray Astro-Imager with Nuclear Emulsion

GRAINE project is joint experiment by using the balloon-borne gamma ray telescope with high spatial resolution and large area emulsion films. The purpose of GRAINE project is to carry out the precise gamma ray imaging of high energy (energy range of 10 MeV - 100 GeV) astrophysical objects by utilizing milliradian angular resolution and to explore the origins and the emission mechanisms of gamma rays.

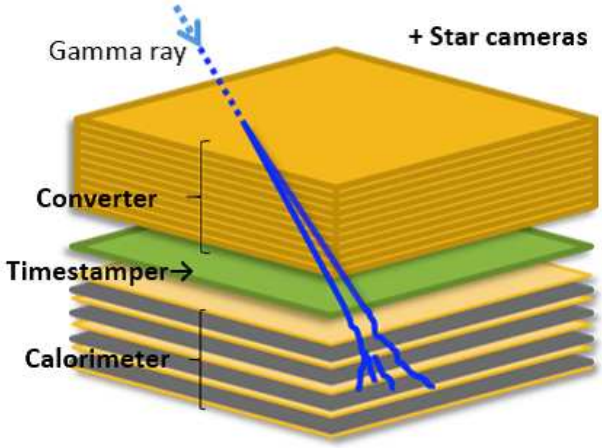

Figure 1. Constitution of main detector in gondola of GRAINE2015. This detector consists of converter, timestamper, calorimeter and three star cameras. Three star cameras are out of gondola.

1.2. Flight of GRAINE2015

GRAINE2015 flight in Australia, from Alice Springs to Longreach (about distance of 1000 km). Flight time is 14.4 hours in 37.2 km (including 11.5 hours of level flight). Expore area is 0.38 m^2. Purposes of GRAINE2015 flight were to confirm the overall system functions and to observe the morphology of the well-known and brightest gamma ray object, vela pulsar.

The main detector of GRAINE2015 consists (Fig. 1) of converter, timestamper[3], calorimeter and three star cameras. The converter's consist is stacking of one hundred emulsion films. Gamma rays were converted into electron-positron pairs in converter. Electron momenta were measuring with multiple scattering deflection angles. The timestamper's consist is three stages (top stage, middle stage, bottom stage) configuration using emulsion films. By move differently each stages, it can provide the track arrival time information (see 2.2). The calorimeter's consist is stacking of seventeen emulsion films and sixteen stainless steel plates. It measures the total energy of particles. And the three star cameras registeres the stellar objects. It evaluates the attitude of gondola in the flight.

2. Track data for analyze

2.1. Scan of emulsion filmes

After flight completed, developing emulsion films in Sydney University, scanning with HTS (Hyper Track Selector) were performed in Nagoya University. Scanning with HTS, the tracks in emulsion film are convert to data. Scanning and analyzing were done by dividing the emulsion film into nine areas (Fig. 2). In this paper, we used one scan area (about 9 cm $\times$ 13 cm including overlap) for this analysis.

Track data contain as coodinate (x, y, z) in each area, projected zenith angles ($\tan\theta_x$, $\tan\theta_y$), darkness of track called PH (Pulse Height) and PHV (Pulse Height Volume) about one emulsion film. HTS scan sixteen layer in emulsion, and PH is layer count of HTS can scanning. PHV is total density in sixteen layer of PH seven or more.

2.2. Time data

Arrival time data are obtained from timestamper. The timestamper utilized three motorized stages with different speeds (Fig. 3). The top stage moves 18.8 min/step, the middle stage moves 9 sec/step, and the bottom stage moves 500 um/s in vela mode. And vela mode is observable

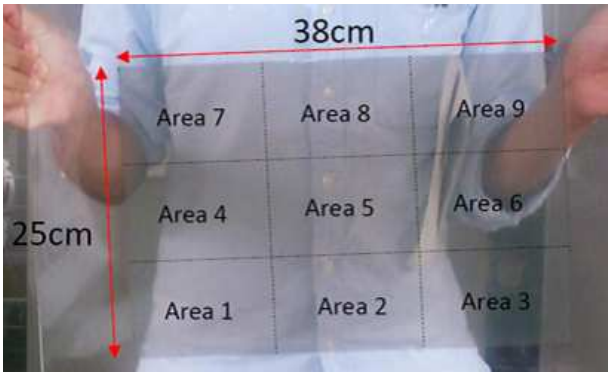

Figure 2. One of the emulsion film of GRAINE2015's converter and dividing into nine areas. In this paper, we used one scan area (about 9 cm × 13 cm including overlap) for this analysis.

time of vela pulsar. Determining the arrival time of tracks displacements by connecting them at all stages (Fig. 4). For example, in Fig. 4, the track of orange line passed in this time, and other tracks (green and blue lines) passed in other time.

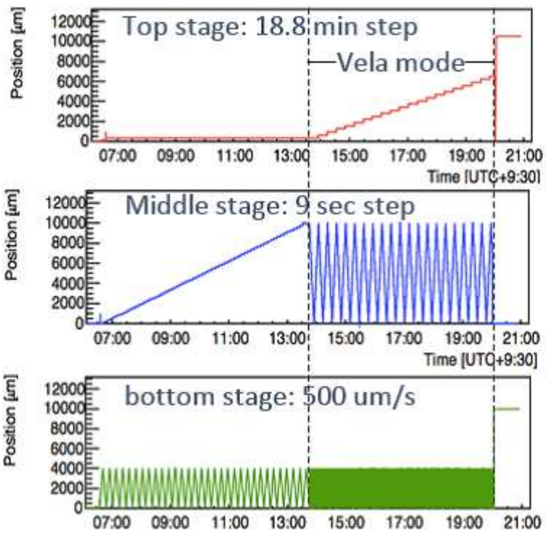

Figure 3. Movement of timestamper. Vertical axis is the shift position, and horizontal axis is the time in ACST (UTC+9:30). Vela mode is observable time of vela pulsar.

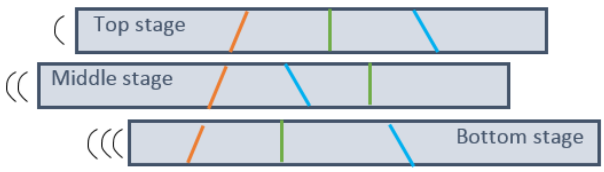

Figure 4. The track of orange line passed in this time. And other tracks (green and blue lines) passed in other time.

3. Selection of electron pair and gamma ray from data

3.1. Selection of electron pair

The method of electron pair selection is to eliminate tracks unrelated to pair-production. Tracks unrelated to pair-production are defined as penetrated track in converter, not found midway track due to energy threshold, and track of scattered in large angle. The track penetrating converter is not to make pair-production in converter. And the track scattered in large angle is too small energy to tracking. Finally, the track of non pair were eliminated.

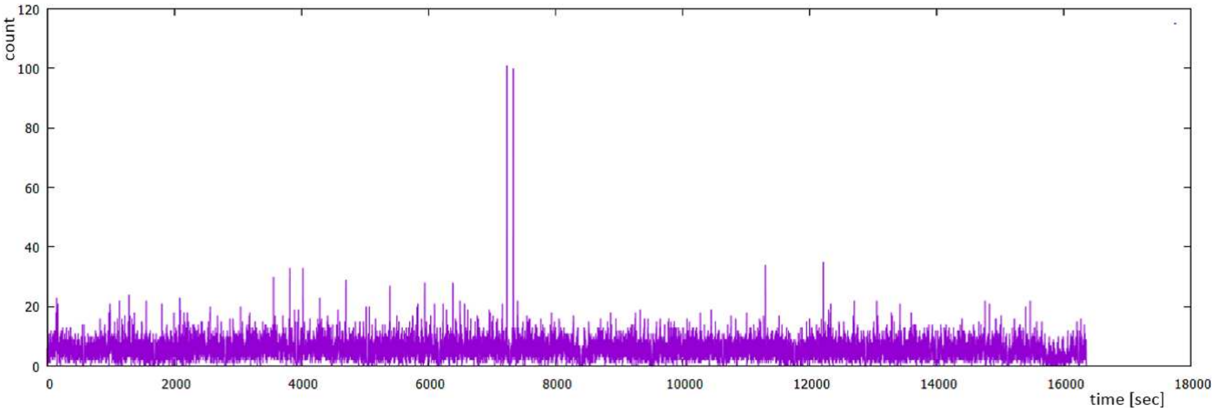

Figure 5. Timeline of count rate for timestamper data that could be decide a track time and that was able to see vela pulsar within zenith angle of 40 degrees. The horizontal axis is elapsed time from could see vela pulsar within zenith angle of 40 degrees to observated end time. The bin is one second.

3.2. Time stamp of electron data

Timestamper data at three stages data (top stage, middle stage, bottom stage) and the bottom layer in converter. Converter data and timestamper data can be combined by using the bottom data in converter. Fig. 5 is histogram of timestamper data that could be decide a track time and that was able to see vela pulsar within zenith angle of 40 degrees. And the bin is one second. The horizontal axis is elapsed time from could see vela pulsar within zenith angle of 40 degrees to observated end time. The start time of Fig. 5 is about 15:30 in ACST. Highest could comes from hadron interaction.

3.3. Selection of electron pair with timestamper data

The method of electron pair selection with timestamper data is as follows. At first, combine electron pair data and timestamper data. Next, selected the electrons that could determine the time. And third, selected the electrons that could determine the time two or more. This order select both electrons at the same time. And finaly, selected the electrons that have PHV<150. This order select the electrons that low charge. The electron pairs selected would come from in this method as gamma rays conversion.

Gamma ray counts in electron pair time is shown in Fig. 6. Fig. 6 left graph shows gamma ray data which can timestamp in bottom stage and which can connect to converter, and right graph shows the last two bins in top stage. Also, both graph in Fig. 6, the upper graph is histogram of top stage, the middle graph is histogram of middle stage, and the lower graph is histogram of bottom stage. In Fig. 6 right graph, we can see bottom stage can distribute among more detailed time than Middle stage. And Fig. 6, we could not show the simultaneous gamma rays in this analyze area. Also GRB also did not occur in the catalog of website of [5] observing from 10 MeV to 100 GeV gamma rays.

Summary

GRAINE carried out the emulsion gamma ray telescope balloon flight in Australia in 12th May 2015 (GRAINE2015). Converter and timestamper data were combined and track's arrival time were able to be determined. We could not find the simultaneous and parallel gamma rays in this analysis so far. Also GRB also did not occur in the catalog of website of [5] observing from 10 MeV to 100 GeV gamma rays.

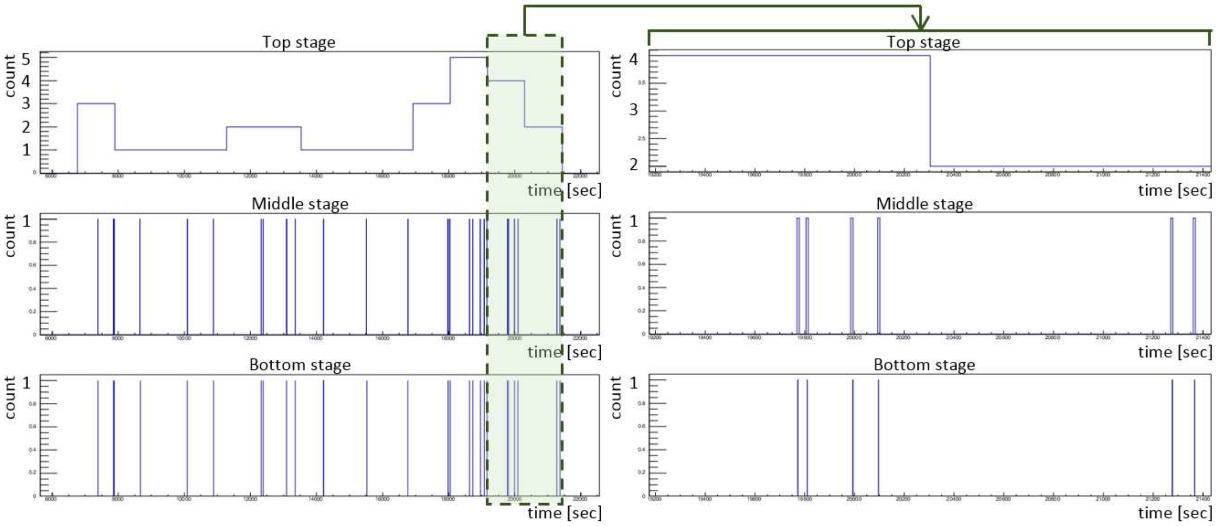

Figure 6. Left graph is Histogram of detected gamma ray times using all gamma ray data. And right graph is Histogram of detected gamma ray times using last two bins in top stage.

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[5] GRBs localized with BSAX or BATSE/RXTE or ASM/RXTE or IPN or HETE or INTEGRAL or Swift or AGILE or Fermi or MAXI, http://www.mpe.mpg.de/ jcg/grbgen.html