

## Research Result Report

### ICRR Inter-University Research Program 2023

Research Subject: Study of high-energy cosmic rays at a high altitude in Tibet, China

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Participating Researchers:

Summary of Research Result :

#### 1. Tibet AS + MD experiment

The Tibet-AS+MD experiment (Tibet Air shower array + Muon Detector array experiment), which aims to develop gamma-ray astronomy in the 100 TeV region (10-1000 TeV), has been active. In FY2023, we continued to search for 100 TeV gamma-ray sources. We focused on HESS J1849-000, which is a very high energy gamma-ray source and is considered to be a middle-aged PWN. The statistical significance of this observation is  $4\sigma$  above 25 TeV and  $4.4\sigma$  above 100 TeV. The gamma-ray energy spectrum measured for the first time at  $25\text{ TeV} < E < 320\text{ TeV}$  (Fig.1). The energy spectrum given by a synthetic fit to our measurement and other experimental (sub-PeV to sub-PeV region) energy spectra can be explained by the electron origin. On the other hand, it is also consistent with the proton origin scenario (Fig.1), where gamma rays come from the region where the nearby SNRs and molecular cloud overlap, in which case the cutoff energy of the gamma ray ( $E_{p\_cut}$ ) is  $\log_{10}(E_{p\_cut}/\text{TeV}) = 3.73(+2.98-0.66)$ . This means that we have found a new PeVatron candidate, suggesting that protons may be accelerated to the PeV region (ApJ, 954:200, (2023)).

The detection of 23 sub-PeV diffuse gamma-ray ( $>398\text{ TeV}$ ) events along the Galactic plane (galactic latitude  $< \pm 10$  degrees) observed with the Tibet AS+MD experiment was published in PRL in 2021. The directions of the 23 events were compared with the directions of 43 sub-PeV ( $>100\text{ TeV}$ ) gamma-ray emitting objects in the 1LHAASO catalog (Fig 2: ApJ 961:L13, (2023)). No overlapping between the 23

events and the 43 sources supports that the 23 gamma-ray events do not originate from sources, i.e., they are diffuse gamma rays. Of course, the possibility that a large number of very weak unresolved sources could be the origin of the diffuse gamma rays cannot be ruled out, but the most natural interpretation remains that they are of neutral pions produced by collisions of PeV-region cosmic rays stored in the Galactic cosmic-ray pool with the interstellar medium.

2. Tibet AS + YAC experiment

The Tibet AS + YAC (Tibet air shower core detector array) experiment, which aims to observe the energy spectrum of each particle component in the knee region cosmic rays, is being promoted. The Tibet air shower core detector array (YAC-II), which consists of 124 air shower core detectors [burst detectors], is installed near the center of the Tibet Air Shower Observatory. In FY2014, electronics and data acquisition software were implemented, and YAC-II, which focuses on proton discrimination in cosmic rays in the Knee energy region, started data acquisition. In FY2023, software tools for analysis were actively developed using Monte Carlo simulations.

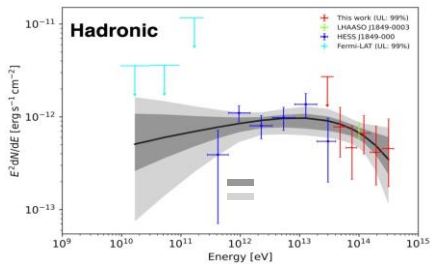


Fig.1 Gamma-ray energy spectrum from HESS J1849-000 observed by the Tibet AS+MD experiment (red circles: This work). The black curve is the prediction assuming a hadronic-origin scenario.

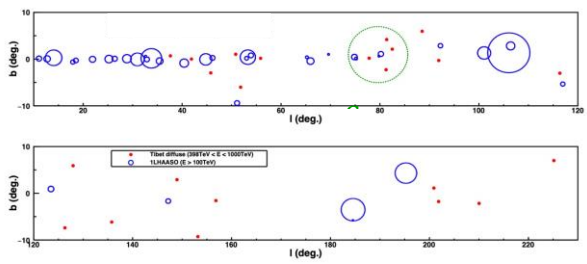


Fig. 2 Directions of the 23 gamma-ray events (>398 TeV) detected by the Tibet AS+MD experiment (red points) and the gamma-ray (> 100 TeV) emitting objects (blue circles) in the 1LHAASO catalog in the galactic coordinates.

3. International Conferences

12 presentations at ICRC2023 and others.

4. Publications

[1] M. Amenomori et al., ApJ, 954:200(7pp), (2023).

[2] M. Amenomori et al., ApJ, 961:L13 (4pp), (2023).

No.