

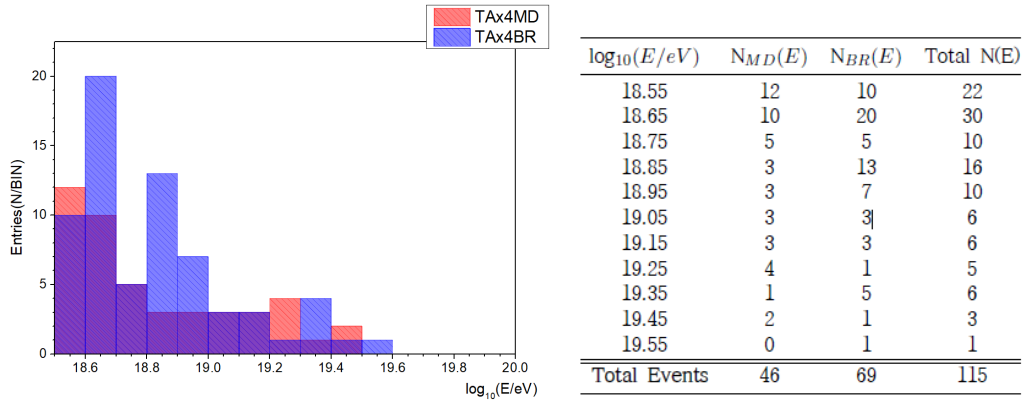
# Research Report

## ICRR Inter-University Research Program 2021

Research Subject: Energy Spectrum of Ultra High Energy Cosmic Rays
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Participating Researchers: Sangwoo Kim, Kwangho Lee, Hyomin Jeong, Minhyo Kim

### Summary of Research Result :

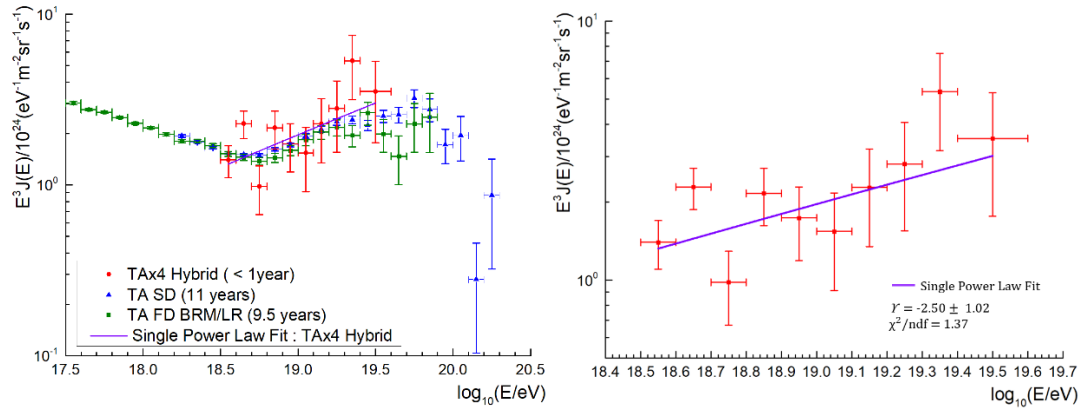
Telescope Array times 4 (TAX4) Surface Detector (SD) and Fluorescence Detector (FD) had been built since early 2019, and keep operating until now. After trigger bug fix in Oct. 2019, we are stably accumulating data from TAX4 SD and FD.



**Fig. 1. (left) The distribution of reconstructed TAX4 hybrid energy by  $\log_{10}(\frac{E}{eV})$ . Total 115 events, northern(MD) 46 hybrid events described in blue and southern(BR) 69 hybrid events described in red. Getting energy range of reconstruction events is about  $10^{18.4}eV \sim 10^{19.6}eV$ . (right) This table shows the number of events per energy bin used to draw the energy spectral flux.**

The present study includes 115 hybrid events, as shown in Fig. 1, selected from a total of 46623 TAX4 hybrid candidates that were successfully reconstructed during the period 2019/08/01 - 2021/10/11. Quality cuts were applied to all successfully reconstructed events. 46 MDTAX4 reconstructed hybrid events from 2019/08/01 - 2021/10/11. 69 BRTAX4 reconstructed hybrid events from 2020/11/22 - 2021/10/11.

The quality cuts were applied to all events.



**Fig. 2. (left) The comparison of energy spectrum for TAx4 hybrid (red) with 11 years TA SD data (blue) and 9.5 years TA BRM/LR FDs data (green) The purple line is the TAx4 hybrid fitted line by single power law. (right) Cosmic ray spectrum measured by the TAx4 hybrid detector with single power law fit. Red squares are measured energy spectrum. Solid line with violet color in this figure shows the single power law fitting. A value of chi-square / degree of freedom is  $\chi^2 / \text{ndf} = 1.37$ .**

Fig 2 left shows the TAx4 hybrid energy spectra in comparison to 9.5 years TA FD monocular data at Black Rock Mesa (BRM), Long Ridge (LR), and 11 years TA SD data. We can observed ankle ( $\sim 10^{18.7}$  eV) and GZK cut-off ( $\sim 10^{19.7}$  eV). However, in this study, we used only above  $10^{18.5}$  eV energy range for energy spectrum measured by  $\sim 1$  year TAx4 hybrid. Therefore, we can observed increasing characteristics by TAx4 hybrid data as other experiments. Red in Fig. 2 indicates TAx4 hybrid (this work), blue indicates TA SD, and green indicates TA BRM/LR FDs. The purple line is the TAx4 hybrid fitted line by single power law.

In Fig 2 right, we show the single power function fitting result for TAx4 hybrid energy spectrum multiplied by  $E^3/10^{24}$ . The cosmic ray spectrum measured by the TAx4 hybrid detector with single power law fit. Red points are measured energy spectrum. Solid line with violet color in this figure shows the single power law fitting. A value of chi-square / degree of freedom is  $\chi^2 / \text{ndf} = 1.37$  and fitted index is  $\gamma = -2.50 \pm 1.02$ .

No.