Snowmass2021 - Letter of Interest

A potential probe of Fundamental Physics using Multi-Modal Cosmic Ray events

Topical Group(s): (check all that apply by copying/pasting ☐/☑)

☑ (CF7) Cosmic Probes of Fundamental Physics

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Abstract: (maximum 200 words)

The Multi-Modal Cosmic Rays Events (MMCRE) are recently observed high energy cosmic events of complex temporal structure, containing multiple peaks separated by tens to hundreds of ns. Experimental observations of the MMCRE at the Horizon-T experiment (FIAN, Almaty, 3.4 km altitude) carried out with time resolution ~2ns break out of the EAS paradigm, e.g. CORSIKA EAS simulation can not reproduce the observed features of these events. A further study of the MMCRE events using both the upgraded Horizon-T experimental setup and the detectors aimed at studying the MMCRE in further detail. We also propose an independent verification of these events at lower altitudes. These unusual cosmic ray events offer a potential new insight into the ultra-high energy astrophysics, the physics of fundamental particle interactions and cosmology.

Introduction: Unusual Cosmic Rays Events

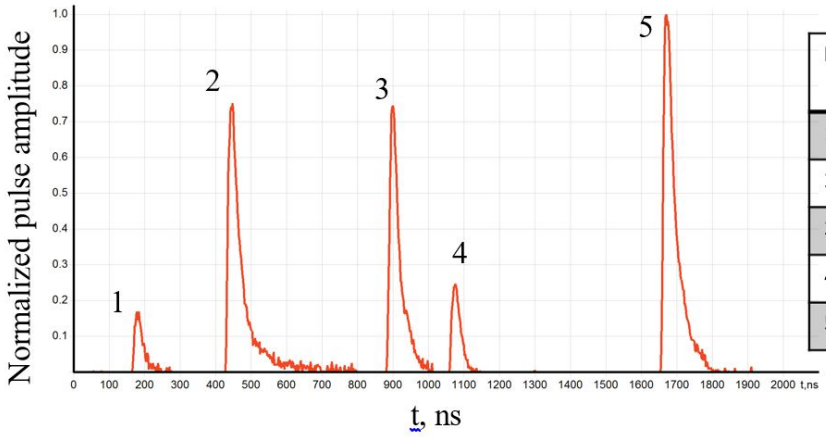
H10T Experiment

Horizon-10T [1], or H10T, is an advanced system of ~2 ns time resolution particle detectors capable of detecting Extensive Air Showers (EAS) with energy of the primary $>10^{16}$ eV in zenith angle range of 0^{o} - 85^{o}. It is the upgraded version of Horizon-T experiment [2]. H10T is built at Tien Shan High Altitude Science Station located at ~3.4 km above the sea level near the city of Almaty, Kazakhstan. It consists of the total of 10 charged particle detection points, separated by distances up to 1.3 km.

All detection points have 1 m^2 area plastic scintillator-based detectors. In addition, five central points also have glass-based detectors [3]. All detectors employ Hamamatsu [4] R7723 2-inch PMTs that are read by CAEN [5] DT5730 500 MHz flash ADCs. A hardware trigger can include any two detectors; any additional selection can be applied offline.

Unusual Cosmic Rays Events

The first hints of unusual EAS (Extended Air Showers) that did not fit the commonly accepted models were reported in the 1950's [6]. The main characteristic of such events is the presence of a second pulse in detectors. They were initially called as events with a delayed pulse or delayed particle and were characterized by two visible peaks, or maxima, in the detector during a single event. However, only the H10T experiment was able to reliably detect numerous unusual events with 2 or more peaks - now called Multi-Modal Cosmic Rays Events (MMCRE). These events tend to have not only multiple peaks in each detector, but the number of peaks seems to vary between the detectors, and the associated particle density seems to be relatively independent regardless of the detection point [7].



Peak #	Delay ns	$\tau_{0.8}$ ns	$\rho_{0.8}$ #/m^2
1	0	28	32
2	265	34	256
3	720	31	187
4	894	31	52
5	1493	35	339

Figure 1: Unusual Event from April 6, 2018, as seen by H10T detection point 9 only. Corresponding delays, pulse widths and particle density for each peak are listed

Example of the MMCRE is shown in Figure 1, where the waveform from H10T detection point 9 is presented for the event from 22h31m05s April 6, 2018. Figure 1 clearly shows five well-separated peaks. The time delay of each next peak with respect to the first one, the width of

each peak and the number of particles as corresponding particle density are listed in this figure. Fig.2 shows another clear unusual event recorded at 2h39m30s March 7, 2018. The figure additionally lists: pulse number, corresponding detection point, delay time from the first pulse, and width and the number of particles as particle density per m2 for each pulse. A zoom-in for the first three pulses is shown in the insert. In this event, four detectors registered more than one pulse. Charged particle density appears to be weakly dependent on distance from the EAS axis and at large distances measured density drastically exceeds the expected from the simulation. Pulse width has no immediate dependency on the distance from the EAS axis and it is more than ten times smaller than the expected. This is not possible within the regular model of EAS.

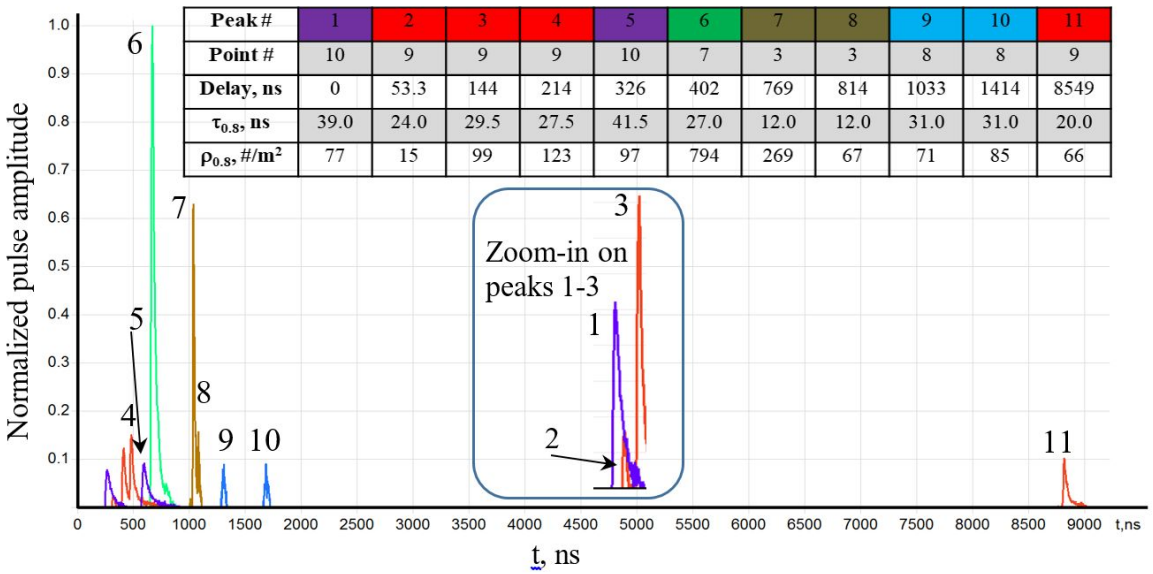


Figure 2: Unusual Event from March 7, 2018, as seen by H10T. Detection point # and corresponding color of the line, delays w.r.t first pulse, pulse widths and particle density for each peak are listed.

Scientific Potential of the MMCRE

The MMCRE events and their unusual properties do not fit the standard EAS paradigm and thus are difficult to analyse. They hint at the possibility of the new processes influencing the development of some EAS possibly above a certain threshold. Comprehensive systematic studies at the H10T setup affirm all these features to be observables. All these features combined are indicative of physical effects not present in, e.g., CORSICA simulation. Hence, the analysis methodology needs to be extended to include the multi-modal events [7].

Current plans of further studies:

Further studies will be carried by the Horizon-T collaboration. These include the modifications to the H10T detector system to explore certain features of MMCRE events in detail. We also consider possibilities to set up a separate detector system at low altitudes (sea level) for independent verification and parallel study of these unusual cosmic events.

References:

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