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Unusual structure-less event, detected at mountain altitudes, suggests a heavy primary origin particle

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While analyzing an old set of data, we encountered an unexpected structure-less event of a few cm radius detected in x-ray films located at the bottom layers of the homogeneous thick lead chamber. The event looked as a diffused dark area without any individual showers within it. Contrary to the traditional image of a halo of a similar size, the event exhibited very low darkness above the background level of the x-ray film. The event penetrated a few layers of lead plates. We suggest possible explanation for the formation of the event using standard physics.

1. Introduction

In our previous study [1], through a comparison of many experimental data, we found that the apparently inconsistent results of the experiments are most likely from the differences in the estimation of the detector response. Following solution to the Centauro puzzle [2], finding a heavy primary origin explanation for a peculiar cosmic ray event detected by the balloon experiment performed in the stratosphere [3], as well as taking into account recent revival of the interest to the “exotic” signal in cosmic rays, we decided to consider once again, from a new perspective, an old data set.

In our previous study we made complete scans and measurements over the total available area, analyzing all showers (both of single and family arrival), their lateral and longitudinal profile, and taking notes of the experimental procedure. To eliminate the background, a traditional method of experimental data analysis utilizes special set of trigger conditions, such as shower location in the chamber, energy threshold ($E_{th} \sim 4$ TeV), etc. For instance, it is required to consider only those showers, which trajectory cross the top of the chamber, and eliminate those ,that come from the side of the detector. Sometimes, a family is found in the middle of the chamber, and there are no parallel shower tracks in the upper layers. In such case there is a trivial explanation: the arrival of an air family during the assembling or disassembling period which lasts a few days. Another important consideration involves the threshold problem. Setting of the threshold is crucial in counting of individual cores, particularly if one is interested in large multiplicity events .

In our new study we considered the whole data set, including all showers, without trigger conditions applied neither to energy, nor to shower location, or shower classification.

2. Experimental setup

In this work we use Waseda-MSU data from thick Pb chambers exposed at the Pamirs. In 1991, the Pamir mountain experiment group of Moscow State University (MSU) proposed, as a part of the Chacaltaya-Pamir collaboration, a joint study of cosmic ray phenomena by means of homogeneous lead chambers [1]. The detectors called thick lead chambers, were designed by the group of MSU, and constructed at the Pamirs (4370 m above sea level) in Tajikistan in 1988-1991. After the processing of x-ray films in Russia, they were shipped to Japan. X-ray films of total exposure 57 m^2 year from thick lead chambers Pb68, Pb69, Pb72, Pb73[1] have been analyzed in Japan by the joint Waseda-MSU team. The Pamir x-ray chamber has an area of 10 m^2 and consists of 20 units. The chamber is homogeneous in structure and uniform in detection efficiency of electron showers. Each unit of the 60 cm Pb chamber is a stack of 58 (59) x-ray emulsion films and 1 cm lead plates. The chamber thickness is ~ 4 nuclear mean free path (MFP). The x-ray emulsion chamber detects showers initiated by γ-rays and hadrons. Usually, the energy detection threshold in the Pamir experiment is E_{th} ~ 4 TeV.

3. Description of the event

We encountered an unexpected structure-less event of a few (~ 5 cm) radius detected in x-ray films located at the bottom layers of the homogeneous thick lead chamber. For simplicity hereafter we will call this event as SDX6987 (meaning by that the structure-less event , numbered as 6987, detected in x-ray film). The SDX6987 event looked as very faint and diffused dark area. There were no any individual showers within it. Contrary to the traditional image of a halo of a similar size, the event exhibited very low darkness (D≤0.03~0.05) above the local background level of the x-ray film. The event penetrated at least three layers of lead plates, and was recognizable even at the last one. Taking into account approximate relative position of the SDX6987 in successive layers of x-ray films, it was concluded that the arrival direction might be close to the vertical. Tracing back to the chamber top, did not reveal any shower tracks, close to the vertical direction.

4. Scenario of the event formation

It would be quite exotic to assume that the event had passed through the whole chamber without any trace, and suddenly started to develop in an unusual way, just near the bottom layers of the chamber. A possibility of some chemical, or mechanical irregularities, which could happen particularly in the geometrical area of SDX6987, for instance, during x-ray film processing, could be also ruled out. This is because the event was recognized in a few consecutive layers, the whole area of the films did not show any unusual characteristics, and above all, there were no similar events in the rest of experimental data. Thus, we assume that the event has been detected, perhaps, during period of the chamber assembling/disassembling.

To satisfy the observation, the production mechanism of the event should meet the following conditions: large multiplicity, and almost equal energy of secondaries. Proton primary would not satisfy the multiplicity criteria. Heavy primary particle is easier to consider. For instance, bundle of spectator nucleons, with Fermi momentum ~200 MeV. In this case several considerations should be taken into account. If an iron nucleus interacts at very high altitude, near the top of the atmosphere, then there will be almost no signal at the mountain altitude. Also, due to the short mean free path, it is very unlikely to get iron nucleus interaction near the chamber. The answer will be somewhere in between. Let us consider the model and the picture of the event formation. We introduce two parameters: geometrical spread of family R_f , and geometrical spread of an air cascade R_{cas} . Figure 1 shows a schematic view of the families for different values of R_f and R_{cas}. In case of structure-less event the spread of a family is comparable to the spread of an individual air cascade. Let us assume that a family is originated at the altitude H above the chamber. Multiplicity of *γ-ray*s we denote as N, individual *γ-ray* energy as E_γ , and transverse momentum - p_t .

The spread of family is given by $R_f = \frac{p_t H}{E_\gamma}$, and the spread of cascade $R_{cas} = \frac{K}{\varepsilon}$, where ε is an energy threshold in detector, and K – decascading constant (K~ 11 TeVmm). Assuming K =11 TeVmm, H~ 10 km, $p_t \approx 200$ MeV , using the condition $R_f \approx R_{cas}$, we obtain $\frac{\varepsilon}{E_\gamma} = \frac{K}{Hp_t} \approx$ (1/200) .

For a family to be structure-less, we have $\frac{\varepsilon}{E_\gamma} \approx$ (1/200). If $\varepsilon > \frac{E_\gamma}{200}$, one can recognize individual air cascade. If $\varepsilon < \frac{E_\gamma}{200}$, then we have just one center-like EAS.

For each air cascade we have $\frac{\varepsilon}{E_\gamma} \approx$ (1/200), and $E_\gamma = 200\varepsilon$. In case of the SDX6987 we can assume that the event was formed due to overlapping of numerous cascades from nucleons at the late stage of development. We have the following estimation of numerical values: $R_{cas} \approx 50$ mm (from experiment), ε ~ 200 GeV, production height ~ 10 km, the primary energy of a nucleon ~ 40 TeV .

3. Conclusions

The most likely origin of the structure-less event SDX6987 would be an iron nucleus with primary energy ~ 10^{15}eV which interacted with an air nucleus (A~14) at the height ~ 10 km above the chamber. The event is formed by overlapping of cascades (old age) from *γ-rays* initiated by spectator nucleons (multiplicity ~ 40).

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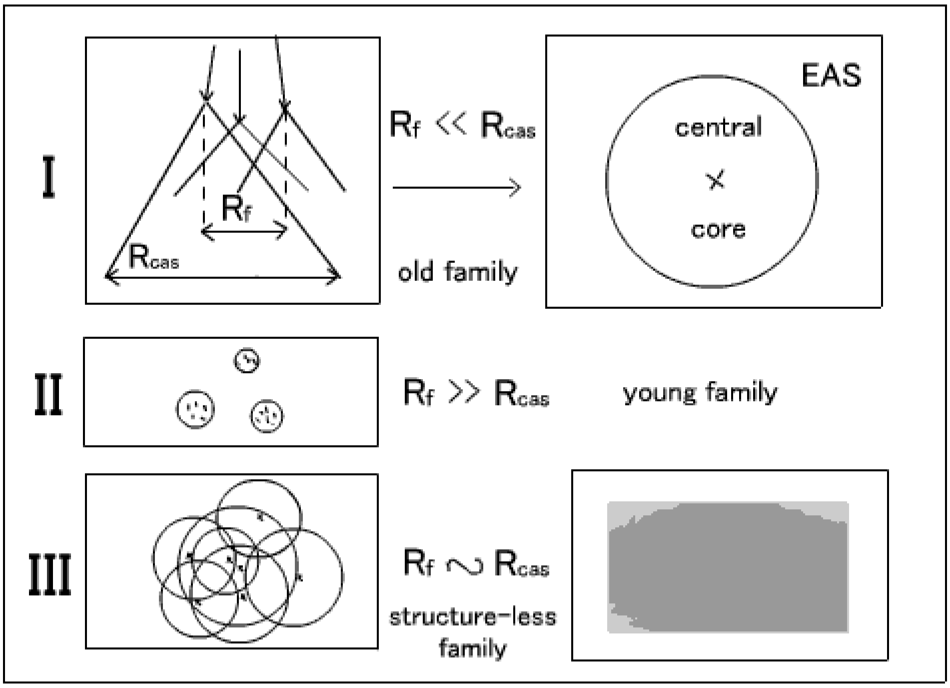

Figure 1. A schematic view of the families. The inset I shows an example of an old family (EAS stands for extensive air shower.), with $R_f << R_{cas}$, where R_f is geometrical spread of the family, and R_{cas} denotes spread of an air cascade. In this case one can recognize a core in the event. The inset II presents a young family ($R_f >> R_{cas}$), with cluster like structure.. The inset III gives an image of structure-less event similar to the SDX6987.