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A combined approach to study the composition of 1-1000 PeV cosmic rays by EAS direct and reflected Cherenkov light detection

A transition from galactic to extragalactic cosmic rays (CR) may occur at an energy E≈100–1000 PeV. The all-nuclei CR spectrum reveals a number of distinct features in the energy range of 1-1000 PeV. These features are usually attributed to the corresponding changes in the composition of the primary cosmic rays. Despite much effort invested into the CR composition studies above the energy of 1 PeV, the spectra of individual CR elements are still poorly known. Most likely, the approaches currently used to solve the CR composition problem have some limitations, and it is not possible to improve the separability of the primary nuclei groups significantly with these methods.

In the present work, we propose an alternative approach to the solution of the CR composition problem using a new proposed detector registering reflected extensive air shower (EAS) Cherenkov light. Unlike the commonly used technique of detecting EAS Cherenkov light from the Earth's surface, the reflected Cherenkov light method allows us to measure the Cherenkov light intensity near the EAS axis with high accuracy. The Cherenkov light intensity in the axis region is very sensitive to the mass of the primary nucleus.

In addition, in this method the primary energy is determined by the registered total flux of Cherenkov light, which significantly reduces the influence of fluctuations in the cascade development on the primary particle energy estimation. The data from the experimental measurements carried out with the SPHERE-2 telescope have yielded good results on the separation of the group of light nuclei (p+He). This result is only slightly dependent on the model of the primary particle interaction. However, the small number of registered events ($\sim 10^3$) did not allow us to obtain a precise measurement of the p+He spectrum with the SPHERE-2 telescope. The construction of the new SPHERE-3 telescope will allow us to solve this problem and to make a significant advance in the measurement of the heavy CR component spectrum.

The new SPHERE-3 telescope will be lifted by an unmanned aerial vehicle above the snow surface to an altitude of up to 1.5 km. The main detector of the telescope will record the image of EAS Cherenkov light reflected from the snow, and an additional direct Cherenkov light detector will record the image of the angular distribution of EAS Cherenkov light at the level of the telescope. Estimates show that the observation of both direct and reflected EAS Cherenkov light images will allow us to estimate the direction and the mass of the primary particle with a higher accuracy compared to the existing ground-based detectors.

Collaboration(s)

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