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The HiSCORE concept for gamma-ray and cosmic-ray astrophysics beyond 10 TeV

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ABSTRACT

Air-shower measurements in the primary energy range beyond 10 TeV can be used to address important questions of astroparticle and particle physics. The most prominent among these questions are the search for the origin of charged Galactic cosmic rays and the so-far little understood transition from Galactic to extra-galactic cosmic rays. A very promising avenue towards answering these fundamental questions is the construction of an air-shower detector with sufficient sensitivity for gamma-rays to identify the accelerators and large exposure to achieve accurate spectroscopy of local cosmic rays. With the new ground-based large-area (up to 100 km^2) wide-angle ($\Omega \sim 0.6$–0.85 sr) air-shower detector concept HiSCORE (Hundred*i Square-km Cosmic ORigin Explorer), we aim at exploring the cosmic ray and gamma-ray sky (accelerator-sky) in the energy range from few 10 s of TeV to 1 EeV using the non-imaging air-Cherenkov detection technique. The full detector simulation is presented here. The resulting sensitivity of a HiSCORE-type detector to gamma-rays will extend the energy range so far accessed by other experiments beyond energies of 50–100 TeV, thereby opening up the ultra high energy gamma-ray (UHE gamma-rays, $E > 10$ TeV) observation window.

1. Introduction

The current knowledge about the origin of cosmic rays has been accumulated following two different approaches: (i) by measuring in detail the energy spectrum and mass composition of the local cosmic-ray population and (ii) by gamma-ray ($E > 100$ MeV) observations of both individual astrophysical objects as well as the diffuse emission from the interstellar medium. Both approaches provide complementary information/constraints on the most relevant quantities: e.g. the measurement of spallation products and cosmo-genic nuclei provides information on the energy dependence of cosmic-ray transport and the escape time of cosmic rays out of the Galaxy. Gamma-ray observations constrain the spatial distribution and properties of the cosmic ray accelerators and the density of cosmic rays in the interstellar medium.

Cosmic-ray measurements through air-shower techniques are the only means to collect sufficient event statistics to measure cosmic rays at energies close to the knee ($\approx 3 \times 10^{15}$ eV) in the all-particle energy spectrum. The traditional air-shower detectors sample the lateral density function (LDF) of secondary particles or photons on the ground. Given the large intrinsic fluctuations in the shower development and that only a small fraction of the particles are sampled ($\approx 10^{-4}$), the energy resolution and sensitivity to different primary particles is rather limited. Combining detection of different components of the air shower as e.g. realized in the KASCADE air shower field [1], improves the situation considerably but suffers from limited collection area. Established techniques to follow the longitudinal air shower development include muon tracking, air Cherenkov, and air fluorescence observations.

The latter technique has been realized quite early and remains one of the most sensitive techniques at ultra-high energies [Linsley, Fly's eye, HiRes, Pierre-Auger Observatory, Telescope-Array, see [2], and references therein]. The non-imaging air Cherenkov technique measures the arrival time and the LDF of the Cherenkov photons in the air shower front. This technique is sensitive to the longitudinal air shower development (mainly position of the shower maximum) as demonstrated with e.g. Themistocle [3], AIROBICC [4], Blanca [5], Tunka [6], Jakutsk [7]. The longitudinal air shower development is sensitive to the initial

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