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Status of LHAASO updates from ARGO-YBJ

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A B S T R A C T

The Large High Altitude Air Shower Observatory (LHAASO) is a multipurpose project with a complex detector array for high energy gamma ray and cosmic ray detection. The array of 1 km^2 is composed of five types of detectors to measure shower arrival direction, total number of secondary particles, muon content, Cherenkov image and high energy gamma rays near shower core, respectively. The main scientific goals are (1) searching for galactic cosmic ray origins by extensive spectroscopy investigations of gamma ray sources above 30 TeV; (2) all sky survey for gamma ray sources at energies higher than 300 GeV; (3) energy spectrum and composition measurements of cosmic rays over a wide range covering knees with fixed energy scale and known fluxes for all species at the low energy end. In this paper, the progress on relevant detector developments is reported, including constructions of prototype detectors at Tibet site and coincidence operation with the ARGO-YBJ resistive plat chamber full coverage array at 4300 m a.s.l. The energy spectrum of cosmic ray hydrogen and Helium nuclei up to 0.8 PeV is reported as the first piece of physics measurements by the LHAASO experiment.

1. Introduction

The Large High Altitude Air Shower Observatory (LHAASO) is designed for three major scientific goals [1–3]. (1) Searching for high energy cosmic ray origins by extensive spectroscopy investigations of gamma ray sources above 30 TeV. More than 140 gamma ray sources have been discovered in this so-called Very High Energy (VHE) range. Observing gamma rays with good statistics and measuring their energy spectrum up to 1 PeV with high energy resolution for galactic sources is a promising approach to collect important evidences for the origins of the photons, either from cosmic ray pevatrons or well known electron sources. Besides, the high energy sky has revealed a stunning richness of new phenomena and puzzling details in the observation of the existing sources, (2) deep surveying over the whole sky for more sources with high sensitivity and clock-round monitoring for transient phenomena of the VHE sources. They are very important as an essential part of the multi-wavelength investigation in order to understand the evolution of galaxies (such as AGN) and particle acceleration procedures and radiation mechanisms in the gamma ray sources. With strong complementary to the Cherenkov telescopes, the ground-based particle detector arrays play irreplaceable roles in the gamma ray astronomy due to their large acceptance in terms of high duty cycle of $>95\%$ as well as large field of view of the whole hemisphere. Particularly, the proposed project will be at least one order of magnitude more sensitive than the Cherenkov Telescope Array (CTA) above 10 TeV and (3) measuring energy spectra above 1 PeV for individual cosmic ray species. This is the ultimate way to understand the origin of knees. Major difficulty is to distinguish different primary cosmic ray composition in the air shower observations. A detector array like LHAASO at an altitude of 4400 m could naturally be used for this purpose because air showers around few PeV just reach their maximum as they touch down the ground, thus the effects due to shower fluctuations can be minimized. In order to gain photon/hadron discrimination power, the proposed LHAASO array has been equipped with the large muon detector array. The high statistic measurements on muon content will make a significant contribution to the separation between primary species. In addition, the high altitude of the site enables a threshold energy to be lower than 100 TeV in the spectrum measurements. It is important because of the overlap with the balloon or space borne experiments such as CREAM. The comparison between the direct measurement and ground based experiments will provide a natural calibration in both energy scale and flux normalization for each species. The scales will be propagated up to higher energies in the experiments with LHAASO. This will bridge the space borne direct measurements of cosmic rays and ground-based ultrahigh energy cosmic ray experiments which are troubled by the issues.

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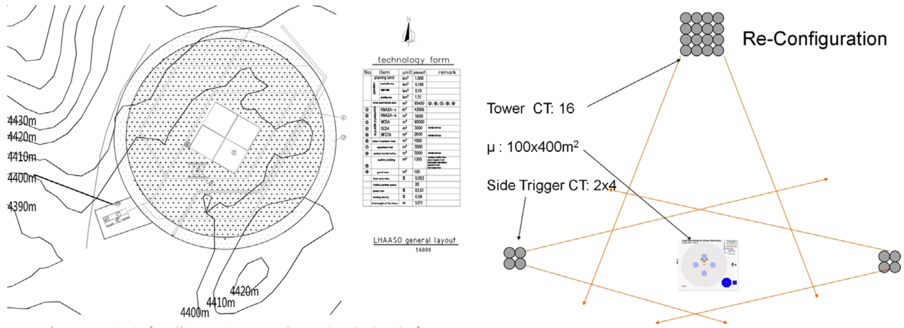

Fig. 1. Left panel is LHAASO detector layout, and on the right-hand side the layout of the fluorescence detector array and the LHAASO array.

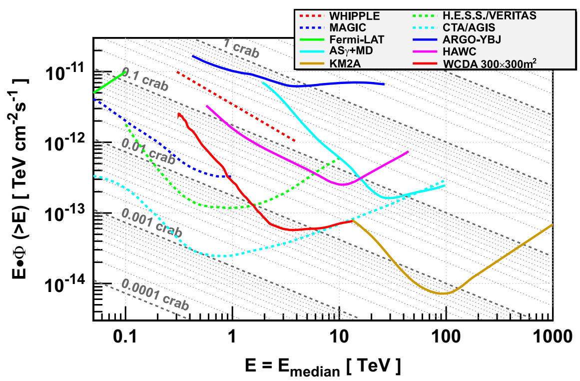

Fig. 2. The sensitivity of LHAASO-WCDA + LHAASO-KM2A. The curves for other experiments and projects are drawn for comparison. The observation times are 1 year and 50 h for wide field-of-view detectors and IACT respectively.

2. Base-line design of the detector array

In order to fulfill all the goals mentioned above, a large scale complex of many kinds of detectors is needed. Fig. 1 is a sketch map of LHAASO detector array which is composed of three major components. The simulated sensitivity curve of LHAASO project for the gamma ray observation is shown in Fig. 2. The sensitive curves for other projects are also shown in the same figure for comparison.

Among known sources discovered in the all sky survey, many of them will be investigated for their emission mechanism. This can be done by measuring the energy spectra of gamma rays up to a few hundred TeV. To search for galactic cosmic ray origins among them, the focus is the high energy ends of the spectra where one expects to see differences between origins of gamma rays, either through inverse Compton scattering of high energy electrons or from decays of neutral pions which are produced in interactions between accelerated high energy nuclei, such as proton, and ambient material near the sources. For this purpose, a particle detector array with an effective area of 1 km^2 (KM2A) is proposed, including a muon detector array using water Cherenkov technique with 40 000 m^2 active area. This allows a background-free measurement of gamma ray spectra above 50 TeV without any contamination by simply selecting muon-poor air showers. 5635 scintillator detectors (1 m^2 each) are arranged in a triangle grid with a spacing of 15 m, while the spacing is set as 30 m between 1221 muon detectors.

To survey gamma ray sources, a Water Cherenkov Detector Array (WCDA) with a total active area of 90 000 m^2 is proposed [4], marked by the four squares in Fig. 1. It is sensitive to gamma ray showers above few hundred GeV. The sensitivity to a source like the Crab Nebula is about 0.7% of the crab unit, I_{crab}, namely the significance reaches to 5σ in one year observation, shown in Fig. 2.

WCDA consists of 4 water ponds, each of which has a size of 150×150 m^2. The depth of the pond is about 4.5 m. Each pond is subdivided into $30 \times 30 = 900$ cells sized 5×5 m^2 each, partitioned by black plastic curtains to prevent the penetration of light yielded in neighboring cells. An 8 in. hemispheric PMT resides at the bottom of each cell, looking upward to collect Cherenkov lights produced by charged particles in the water pond, recording the arrival time and the charge of pulses. The later is in proportional to the product of the number of particles in the shower and their energies.

To measure energy spectra for individual species of cosmic ray particles, one needs a reliable primary particle identification algorithm for observed air showers. A multi-parameter measurement is the most plausible approach. In general, the shower maximum position, the muon content and the high energy component near the shower core are three independent parameters that can be used for deducing signatures of showers induced by different nuclei [5,6]. Thus, two more detector arrays are proposed in the LHAASO project. They are designed to measure the shower maximum location and high energy components near cores, respectively. They are Wide Field of view Cherenkov Telescope Array (WFCTA) composed of 24 telescopes and the high threshold Shower Core Detector Array (SCDA) with an effective area of 5000 m^2, shown as a rectangle and two rows of small squares near WCDA ponds at the center of the array in Fig. 1, respectively.

To extend the spectrum measurements to higher energies with calibrated energy scale and composition, we have to re-arrange the detector arrays for larger effective area and larger exposure. A simple re-arrangement of the WFCTA is necessary to form a hybrid experiment together with the 1 km^2 KM2A as a whole instead of with SCDA which is only 5000 m^2. The energy coverage can be extended to 10 PeV regime. In order to connect with other experiments, such as TA and Auger, at altitudes around 1600 m a.s.l., an even larger effective area is required. The wide FOV telescopes will be re-arranged and modified to measure shower fluorescence light and monitor the space above the ground array from a distance of 4–5 km. This modification and reconfiguration is nearly cost-free. The detector configuration is shown in Fig. 1, in which the main detector array is composed of 16 telescopes covering elevations from 3° to 59° and two other detector arrays, covering elevations from 3° to 31°, to observe showers from perpendicular directions. Showers above 100 PeV will be detected stereoscopically to maintain a high resolution of shower maximum position. Combining with the muon content measured by KM2A, the telescopes will achieve the spectrum and the composition measurements around the second knee.

3. R/D and engineering arrays

The Electromagnetic particle Detector (ED) in LHAASO-KM2A consists of 4×4 plastic scintillation tiles ($25\ cm \times 25\ cm \times 2\ cm$ each) packed in a steel box with an area of $1\ m \times 1.2\ m$.