

Status and First Results of the LHAASO Experiment

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The Large High Altitude Air Shower Observatory (LHAASO) plans to build a hybrid extensive air shower (EAS) array with an area of about 1 km² at an altitude of 4410 m a.s.l. in Sichuan province, China, aiming at very high energy gamma ray astronomy and cosmic ray physics around the spectrum knees. With an extensive air shower array covering an area of 1.3 km² equipped with >40,000 m² muon detectors and 78,000 m² water Cherenkov detector array, a sensitivity of about 1% Crab unit to gamma ray sources is achieved at 2×10^{12} eV and 5×10^{13} eV, thus the LHAASO will survey the entire northern sky for gamma ray sources with full duty cycle and high sensitivity. The spectra of all sources in its field of view will be measured simultaneously over a wide energy range from 10^{11} eV to 10^{15} eV. This measurement will offer a great opportunity for identifying cosmic ray origins among the sources. The LHAASO is also equipped with 12 Cherenkov/fluorescence telescopes, so it will serve as an effective detector for energy spectrum measurement of different mass groups of cosmic rays over a wide energy range from 10^{14} eV to 10^{18} eV.

Civil construction started in the middle of 2016, two years later, detector deployment began. The first water pool with 900 detector units covering an area of 22,500 m² was put into operation in April of 2019. 1200 scintillation detectors, 300 muon detectors and 6 telescopes were deployed afterwards. 1/4 of the LHAASO array will be in operation soon. Preliminary results of the LHAASO experiment are presented.

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1. Introduction

The Large High Altitude Air Shower Observatory (LHAASO) Huihai He for the LHAASO Collaboration, Radiation Detection Technology and Methods (2018) 2:7 plans to build a hybrid extensive air shower (EAS) array with an area of about 1.3 km² at Mt. Haizi (4,410 m a.s.l., 29°21' 27.6" N, 100°08' 19.6" E) in Sichuan province, China. With a sensitivity of about 1% Crab unit to gamma ray sources (Fig. 1), the LHAASO will survey the northern hemisphere for gamma ray sources with full duty cycle and a sensitivity of about 1% Crab unit to gamma ray sources at 2×10¹² eV and 5×10¹³ eV. The spectra of all sources in its field of view will be measured simultaneously over a wide energy range from 10¹¹ eV to 10¹⁵ eV. This measurement will offer a great opportunity for identifying cosmic ray sources among the gamma ray sources Y. Liu et al. for the LHAASO Collaboration, The Astrophysical Journal, 826:63 (8pp), 2016 July 20. Through hybrid detection of showers with the other detectors of LHAASO, the Cherenkov/fluorescence telescopes of LHAASO will effectively measure energy spectra of different mass groups of cosmic rays above 10¹⁴ eV with an aperture of >4000 m²sr Liqiao Yin et al. for the LHAASO Collaboration, Chinese Physics C, Vol. 43, No. 7 (2019) 075001, aiming for study of cosmic rays with energies in 10¹⁴–10¹⁸ eV, where the cosmic ray spectrum knees around 10^{15.5} eV and 10^{17.5} eV are located.

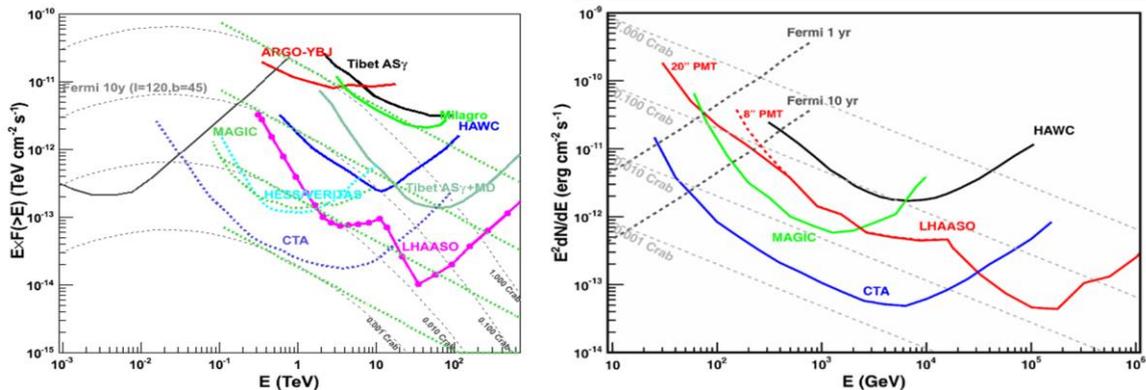


Fig. 1 LHAASO integral (left) and differential (right) sensitivity to gamma ray sources compared with other experiments/projects (1 year for Tibet AS_γ, ARGO-YBJ, HAWC and LHAASO, 50 hours for IACTs) Abdo, A. A. et al. 2010, The Astrophysical Journal, 708, 1254- A.U. Abeysekara, et al., Astroparticle Physics 50-52 (2013) 26–32. The Crab spectrum energy distribution used here is got by fitting measurements of Fermi, ARGO-YBJ, Tibet AS_γ, MAGIC, VERITAS, HESS, HEGRA and Whipple.

The LHAASO consists of an extensive air shower (EAS) array covering an area of 1.3 km² (KM2A) with 5195 electromagnetic particle detectors (EDs) and 1171 muon detectors (MDs), 78,000 m² water Cherenkov detector array (WCDA) and 12 wide-field air Cherenkov/fluorescence telescopes (WFCTA), as shown in Fig.2. The total budget is about 1.2 billion CNY, and detector construction will last 4 years. For detector design and calibration, electronics, data acquisition, etc, see S. Cui et al. for the LHAASO Collaboration, Astroparticle Physics, 54 (2014) 86-92-B. Bartoli et al., Chinese Physics C, Vol. 38, 045001 (2014) for details.

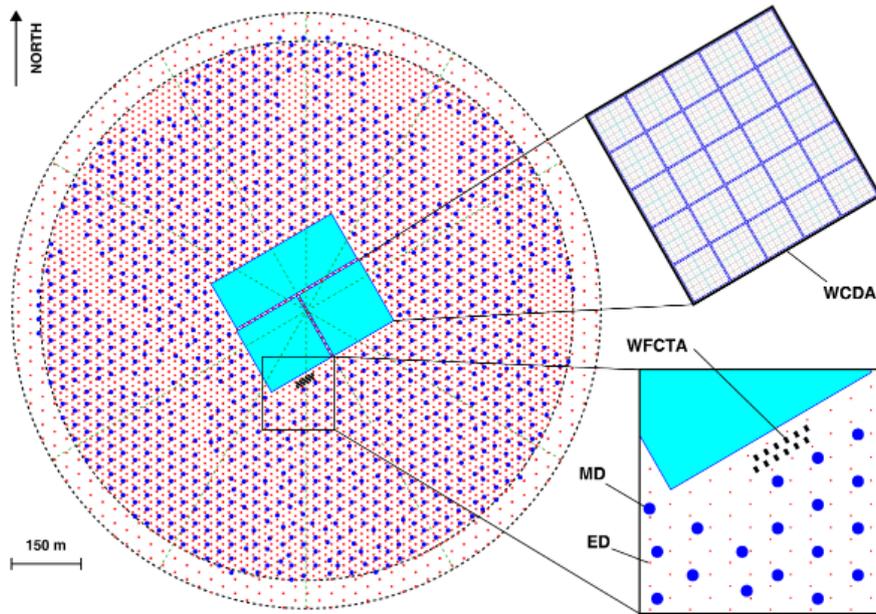


Fig. 2 Layout of the LHAASO experiment. The inserts show the details of one pond of the WCDA and of the KM2A array constituted by two over imposed arrays of EDs and of MDs. WFCTA telescopes, located at the edge of a pond, are also shown.

2. Status of the LHAASO Experiment

Civil construction started in the middle of 2016. One year later, a 35 kV power transmission line was ready, climbing 29 km from an altitude of 3,800 m upto 4,410 m a.s.l.. In November 2017, the site was ready for construction of the water pools, and roads with a total length of about 20 km were built to reach each MD as shown in Fig.3-left.



Fig.3 Photos of the LHAASO site in November 2017 (left) and in July 2019 (right).

2.1 KM2A

For field test, 33 EDs were deployed in January 2018 and have been in stable operation for about one and a half years (right part in Fig.4-left), another 33 EDs and 10 MDs, which are more than 200 m away from the first zone as shown by the left part in Fig.4-left, were deployed and added into the DAQ stream at the end of 2018. An event which fired all the EDs and MDs is shown in Fig.4. The number of muons detected by MDs as a function of the number of electromagnetic particles detected by EDs is in good agreement with MC simulation as shown in Fig.4-right. By using the data of the first 33 EDs, cosmic ray sun and moon shadows are observed as expected Hongkui Lv et al. for the LHAASO Collaboration, Offline calibration of electromagnetic particle detectors in LHAASO, ICRC2019.

After field test, detector mass deployment started Xiaopeng Zhang for the LHAASO Collaboration, Batch measurement of attenuation length of WLS fibers for LHAASO-ED, ICRC2019-Lingyu Wang for the LHAASO Collaboration, Leak test for liner of muon detector of LHAASO, ICRC2019. Until now, 1200 EDs and 300 MDs have been deployed and will be added into the main DAQ stream soon.

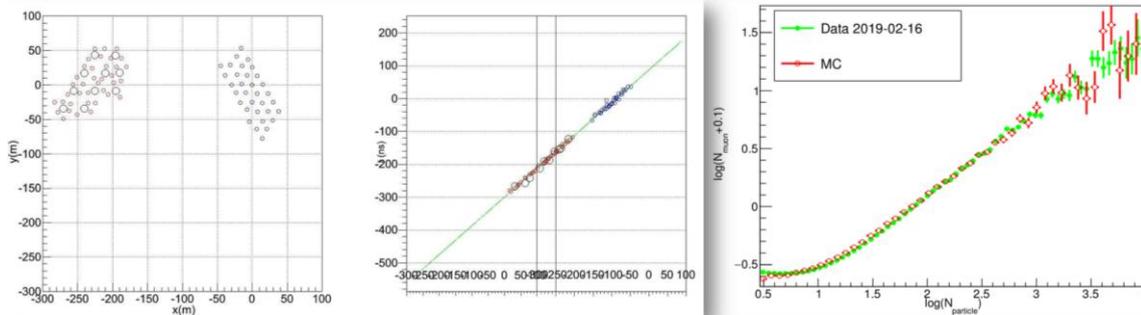


Fig.4 An event map (left) and its shower front (middle) are shown with 66 EDs (smaller circles) and 10 MDs (larger circles) in operation. The right panel shows the profile of number of muons detected by MDs vs. number of electromagnetic particles detected by EDs, MC simulation results are also shown for comparison.

2.2 WCDA

Construction of the first water pool was completed in Jan., 2018, and after one and a half years, the 3rd water pool is almost ready now (Fig.3-right). Detector deployment in the first water pool was carried out in 2018. Before the pool was filled with water (Fig.5-left), a so-called dry run was carried out, i.e. the PMTs acted as charged particle detectors. When a charged particle pass through PMT windows, it emits Cherenkov photons if its velocity exceeds the speed of light in glass, thus the PMTs form a sampling EAS array. Through dry run, the PMTs, electronics, the data acquisition system, etc, were tested. The 1st pool was then filled with water and put into operation in April 2019 Mingjun Chen for the LHAASO Collaboration, Status and first result of LHAASO-WCDA, ICRC2019-Zongkang Zeng et al. for the LHAASO Collaboration, A charge calibration method for LHAASO WCDA dynamic range expansion system, ICRC2019.

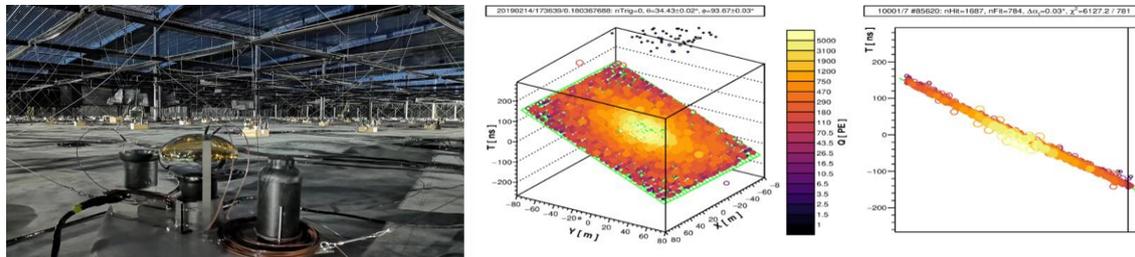


Fig.5 Photos of the 1st water pool before filled with water (left). The shower front of a huge event during dry run is shown in the right panel.

2.3 WFCTA

Six removable and adjustable containers with mirrors inside have been installed at the LHAASO site, 2 of them with SiPM camera installed are in operation. More than 220,000 EAS events coincident with the first WCDA pool have been collected with a typical event shown in Fig.6. See Shoushan Zhang et al. for the LHAASO Collaboration, Properties and performance of

SiPM based-Mingjie Yang et al. for the LHAASO Collaboration, The performance of LED calibration system for Cherenkov telescope of LHAASO for details.

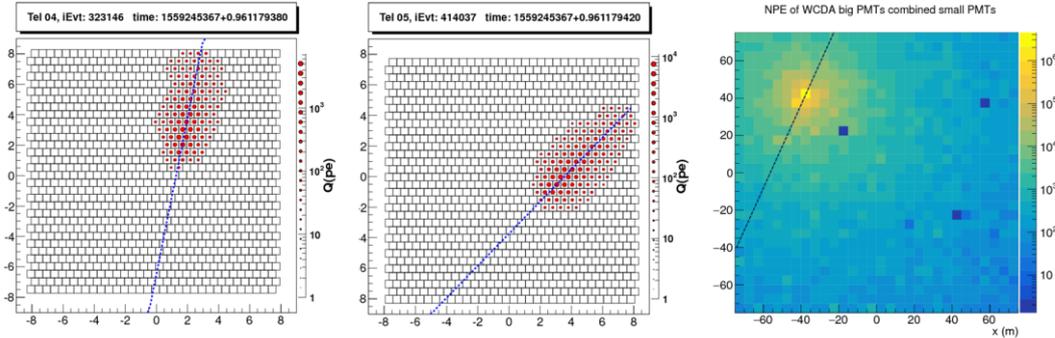


Fig.6. Images of a typical event seen by the first (left) and second (middle) telescopes located at the bottom-left corner of the first WCDA water pool, both pointing to the zenith with an azimuth distance of about 45 degrees. The blue curves in the figures are the major axes of the images, representing the shower detector planes. Map of the same event seen simultaneously by the 1st WCDA pool is shown in the right panel.

3. Preliminary Results

After three months' operation, about 30TB raw data were collected by the first WCDA pool, with a live time of about 95%. The cosmic ray Moon and Sun shadows were observed with significances as expected.

By applying a Compactness cut on the data, almost 99% of the background events are rejected, while preserving 50% of gamma events with energies about 3 TeV Xiaojie Wang et al. for the LHAASO Collaboration, Gamma Hadron separation using single parameter method and multivariate algorithms with LHAASO-WCDA experiment, ICRC2019. A full sky survey was performed on the data, more than 5 sources including Crab Nebula and Mrk 421 were detected with significances exceeding 5 sigma, as expected.

4. Conclusions

Constuction and detector deployment of the LHAASO experiment is going on smoothly. The first water Cherenkov detector array has been in data taking since April, 2019. Preliminary results show that the detectors are working as expected. A portion of KM2A with 300 MDs and 1,200 EDs have been deployed. 1/4 of LHAASO will start data taking soon. By the end of 2019, 1/2 of LHAASO will be ready for operation. The whole array will be completed by the end of 2020.

It should be mentioned that, for the 2nd and 3rd WCDA water pools, 20 inch PMTs will be used to replace the 8 inch ones, and 3 inch ones to replace the 1.5 inch ones, to lower the threshold energy and to enhance the sensitivity at low energies.

Acknowledgments

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