Operations of the LHAASO-WCDA

Cheng Liu, Mingjun Chen, Minhao Gu, Xiaohao You, Huicai Li, Bo Gao, Zhiguo Yao, Shicong Hu
on behalf of the LHAASO Collaboration

Abstract: The Water Cherenkov Detector Array (WCDA) is one of the components of the Large High Altitude Air Shower Observatory (LHAASO). WCDA, divided into 3 separate arrays, will make survey observation on the gamma-ray sky of 100 GeV - 30TeV. The first array (150m×150m), denoted as WCDA-1, has already be operated since April 2019 and one more array of the same size, referred to as WCDA-2, has also been in operation since November 2019. The third array, WCDA-3, with a size of 300m×110m, has been tested at beginning of 2021 and the full array of WCDA is being in the testing since March 2021. This paper will describe the operation status of the LHAASO-WCDA since April 2019.

1. Introduction:

The Large High Altitude Air Shower Observatory (LHAASO) is a hybrid extensive air shower (EAS) detector arrays sited at Mt. Haizi (29°21'27.6" N, 100°08'19.6" E, 4410 m a.s.l.), in Daocheng, Sichuan province, China. The site of LHAASO is close to the national road G227 and about 10km from the Yading airport. The LHAASO consists of three interconnected detector arrays: an EAS array covering an area of 1.3 km2(KM2A) with 5195 electromagnetic particle detectors (EDs) and 1188 muon detectors (MDs), plus the 78,000 m^2 water Cherenkov detector array (WCDA) and an array of 18 wide field-of-view Cherenkov telescopes (WFCTA) [1]. Civil construction of LHAASO started in the middle of 2016 and the whole array will be completed in July of 2021.

2. Detector:

At the center of the LHAASO, the WCDA is composed of 3 separate arrays with a water depthof 4.4m. Each arrays is divided into 5m×5m cells partitioned by black plastic curtains to prevent the light passing through the neighboring cells. As show in Fig. 1, the first array, denoted as WCDA-1, is a square pond of 150m × 150m consisting of 900 detector cells. It has been put in operation since April 2019 and one more array of the same size, referred to as WCDA-2, has also been in operation since November 2019. The third array, WCDA-3, with a size of 300m × 110m, containing 1,320 detector cells, has been tested since the beginning of 2021.

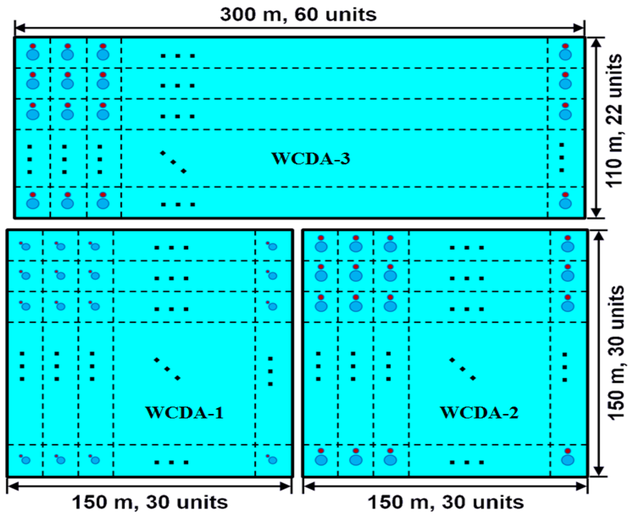

Fig. 1: Schematic of the LHAASO-WCDA layout.

In Fig. 1, two dots in each cell indicate two photomultiplier tubes (PMTs). The WCDA-1 is equipped with 8-inch and 1.5-inch PMTs at the bottom center of each cell, and the other two arrays are equipped with 20-inch and 3-inch PMTs. Each PMT is looking upward to collect Cherenkov light generated by EAS secondary particles in water. Fig. 2 shows the photograph of the four types of PMTs used in WCDA. The large PMT (8-inch or 20-inch) in each cell measures the number of photons and arrival time. The 20-inch PMT uses microchannel-plate (MCP) instead of the traditional dynodes and are produced by North Night Vision Tech. Cor. Ltd (NNVT) [4]. These large PMTs are calibrated within 0.2 ns and this enables the shower arrival direction to be measured with a resolution of 0.2° above a few TeV [5]. To enlarge the dynamic range, small PMTs (1.5-inch or 3-inch) are located beside the large PMTs in each cell. The 1.5-inch PMT is designed to make precise measurements in the core area to identify the composition of cosmic ray events from 100TeV to 10PeV [6]. The main information of PMTs used in WCDA are given in Table1. The charge calibration method and results of PMTs are presented in this talk [7].

PMT	TTS (ns)	Dynamic range (PEs)	Manufacturer	Model number	Layout
8-inch	<3	1 - 4,000	Hamamatsu	CR-365	WCDA-1
1.5-inch	-	20 - 200,000	HZC Photonics	XP-3960	WCDA-1
20-inch	<6.5	1 - 1,800	NNVT	GDB-6203	WCDA-2&3
3-inch	-	1 - 3,000	HZC Photonics	XP-72B22	WCDA-2&3

Table 1: PMT information of LHAASO-WCDA

3. Operation:

The whole construction and operation process is divided into three phases: (1) 1/4 of WCDA, also called WCDA-1, was completed in April of 2019 and put in operation since then; (2) 1/2 of WCDA, which has been in operation since March 2020 with WCDA-1 and WCDA-2; (3) Full array of WCDA started being in operation in March of 2021. In Fig. 3 show the daily live time of WCDA in different phases are plotted as a function of time. The operation status of these three phases are as follow:

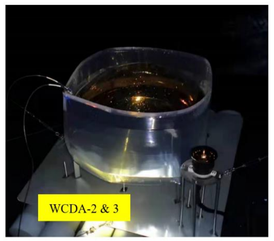

Fig. 2: Photograph of the four types of PMT using in WCDA.

3.1 WCDA-1 (2019/4/16 - 2020/3/12)

A trigger algorithm was implemented to record EAS event by requiring at least 20 groups (a group being 3×3 detector cells) with each group containing at least one simultaneous hit in a time window of 300 ns. In a group, one hit is recorded if there are signals greater than the threshold of 1/3 PE in the nine 8-inch PMTs (no matter how many PMTs in total). The EAS event trigger rate is about 20kHz. Once an EAS event trigger is formed, charges recorded by both 8-inch and 1.5-inch PMTs in 2μs are read out together with the absolute trigger time to build a complete event. By using the 179 days data, the Crab Nebula has been detected with a significance of 77.4 σ, which is in agreement with the design specification [6].

3.2 Half array (2020/3/16 – 2021/3/4)

The 20-inch PMT is greatly affected by the geomagnetic field, the TTS and collection efficiency of PMT become worse without magnetic shielding [4]. Therefor, in October 2020, a magnetic shielding has been added around the 20-inch PMTs in WCDA-2 and the hit rate of the PMT with the threshold of 1/3 PE is increased to 55 kHz. In order to reach a low energy threshold, a natural consideration on the trigger algorithm is to use the multiple zoned pattern. Once the number of fired cells in any of these zone exceeds a certain number within a short time window, the whole array is then set to be triggered [8]. For the 1/2 WCDA arrays, the EAS event trigger rate is about 80 kHz.

3.3 Full array (2021/3/5 – now)

The full array of WCDA is split into 72 approximately half-overlapped trigger clusters, each containing 144 cells and covering an area of 60 m × 60 m. During commissioning, the multiplicity threshold of the array is set to 30 hits and the 20-inch PMT signal threshold is changed from 1/3 PE to 1 PE, in order to reduce the influence of noise. With these conditions, the trigger rate of full array is about 30 kHz and the raw data is about 12 TB/day. Fig. 4 shows the daily event rate change since the April 20, 2021.

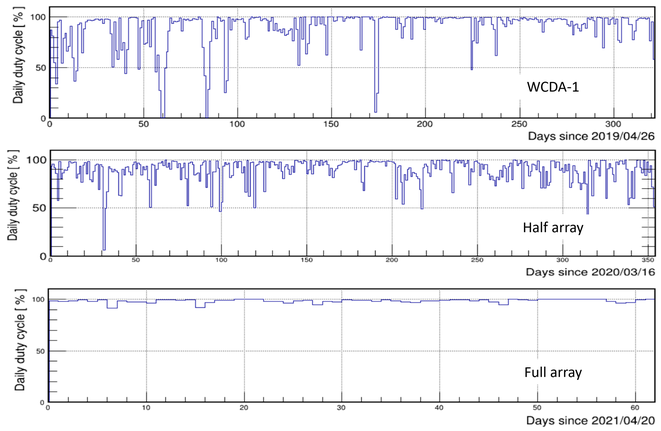

Fig. 3: The daily live time of WCDA in different phases as a function of time.

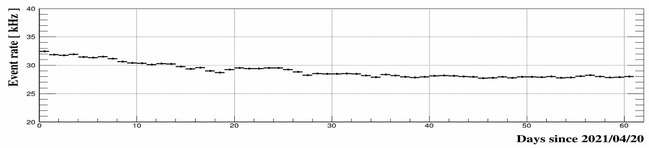

Fig. 4: The daily event rate of WCDA as a function of time since the April 20, 2021.

4. Summary:

The detector installation of WCDA started from the October 2018, WCDA-1 has already be operated in April, 2019 and the third array, WCDA-3, was test at the beginning of 2021. The full array of WCDA is being in the testing since March 2021 and runs smoothly. The preliminary analysis results, including observed significant source candidates, the spectrum measurement and other related works are presented in other contribution in this conference [9-13].

References:

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