PROCEEDINGS OF SCIENCE

The running status of LHAASO-WCDA

Bo Gao,[a,*] Mingjun Chen,[a] Cheng Liu,[a] Huicai Li[a] and Xiaohao You[a] for the LHAASO collaboration

[a]*Institution of High Energy Physics,*
19B Yuquan Road, Shijingshan District, Beijing, China

E-mail: gaobo@ihep.ac.cn

LHAASO-WCDA has been operated in full-array mode since 2021.03. In the long-term running, the state of the detector will change with time. In this paper, the 2-year detector operation and running status has been given, including duty cycle, PMT status and data acquisition condition since 2021.07, etc.

38th International Cosmic Ray Conference (ICRC2023)
26 July - 3 August, 2023
Nagoya, Japan

*Speaker

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[1]. The LHAASO consists of three interconnected detector arrays: an EAS array covering an area of 1.3 km^2 (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)[2], as show in Fig. 1. In July 2021, the full LHAASO construction was done, and has gone into full array running. LHAASO

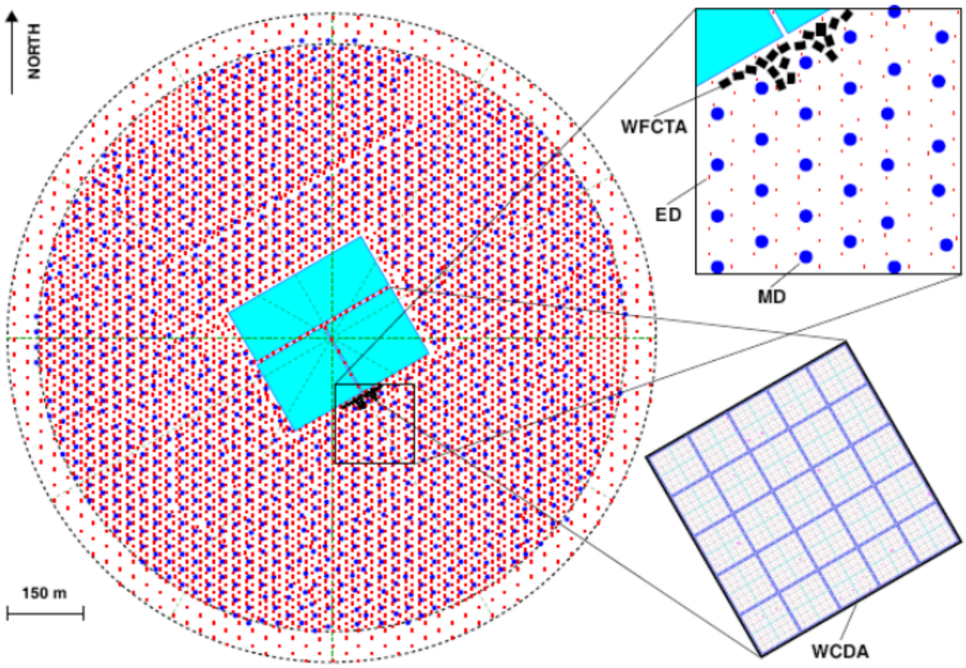

Figure 1: LHAASO layout.

is designed for the study of cosmic ray particles with energy ranging from hundreds GeV to a few EeV. The main physics objectives of LHAASO are to explore the origin of high-energy cosmic ray, full sky gamma-ray source survey, temporal phenomena of high-energy gamma-ray radiation, such as flare sources and gamma-ray bursts, and so on.

During the past two years of full-array operation, LHAASO has discovered multiple PeV (Peta-electronvolt) ultra-high-energy gamma-ray sources and dozens of new gamma-ray radiation sources. With the accumulation of data, more new high-energy astrophysical phenomena are expected to be discovered.

2. WCDA Detector

The WCDA focuses on surveying the Northern sky for steady and transient sources from 100 GeV to 30 TeV, with a very high background rejection power and a good angular resolution.

The WCDA (Water Cherenkov Detector Array) is located at the center of the LHAASO and consists of three sub-arrays. It has an effective water depth of 4.5 meters and is divided into 3120 detector units of 5×5 square meters each, separated by black light-tight curtains. Each detector unit contains one large and one small photomultiplier tube (PMT) (see in Fig. 2).

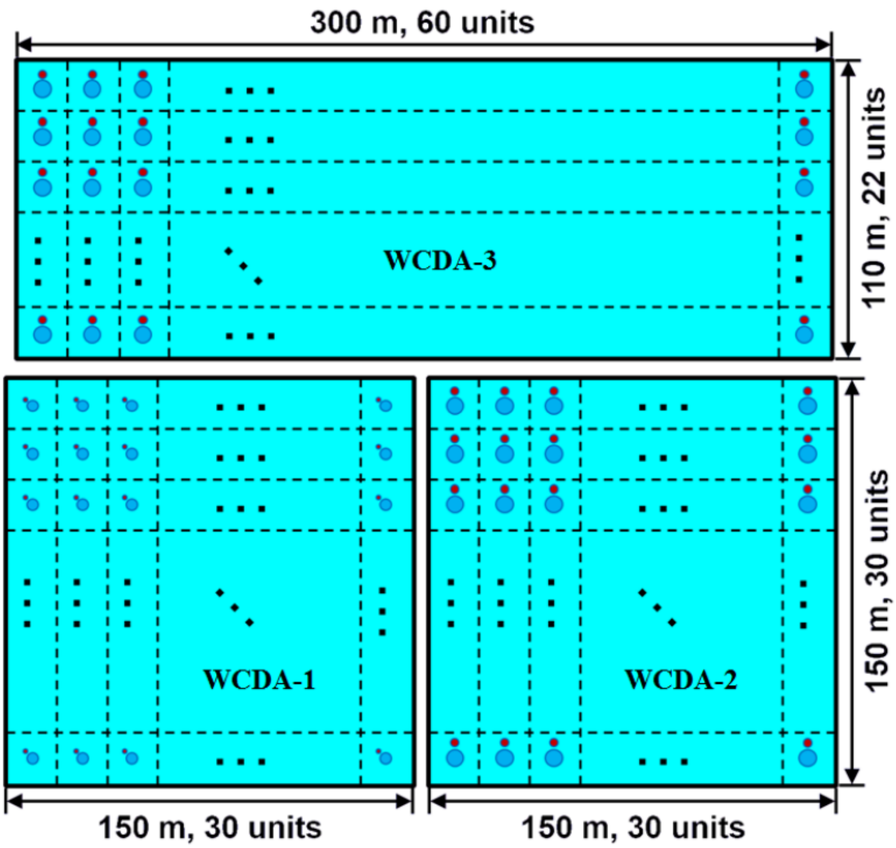

Figure 2: Schematic of LHAASO-WCDA.

Specifically, the 1^{st} and 2^{nd} sub-array occupy an area of 150×150 m^2, while the 3^{rd} sub-array occupies an area of 300 $m \times 110$ m. The 1^st sub-array was completed and officially operational in April 2019, the 2^nd sub-array was completed and started operating in November 2019, and the 3^rd sub-array was completed and started operating in early 2021. The full-array joint operation began in March 2021.

3. Running status

3.1 PMT

4 types of PMTs are applied in LHAASO-WCDA, the large PMTs (8-inch and 20-inch) are used to detect the Cherenkov photons generated by eas sub-particles in water, measuring the number and the arrival time. The 8 inch PMT is triditional dynode structure and the 20 inch PMT is micro-channel plate (MCP) structure[3], produced by BHP and NVVT Corp. seperately. With the

improvement of the large area, the 20-inch PMT can lower the gamma ray threshold to less than 100 GeV. The paired small PMTs are 1.5-inch and 3-inch, installed besides the large ones, the main function of small PMTs is enlarge the dynamic range, which could be used to measure high energy EAS events to 10 PeV. The main informations of PMTs are shown in Tab. 1. The status of the

Table 1: PMT information.

PMT	Diameter	TTS	Dynamic range	Detector
CR365	8-inch	< 3.0 ns	1 - 4,000 PE	1
GDb-6203	20-inch	< 6.5 ns	1 - 1,800 PE	2&3
XP-3960	1.5-inch	-	20 - 200,000 PE	1
XP-72B22	3-inch	-	1 - 3,000 PE	2&3

PMT can also reflect the operating status of the detector. By analyzing the PMT's count rate and charge spectrum distribution, one can determine whether the detector is experiencing light leakage and monitor the long-term efficiency changes under different operating conditions. In addition, the WCDA also utilizes a time calibration system with fiber bundles to periodically perform time calibration on the detector. This is done to check for any changes in the relative time differences between PMT channels. those large PMTs time offsets are calibrated by hardware with a precision of 0.2 ns[**?**]tcal), which enables the shower direction resolution less than 0.2°.

To obtain high-quality data, it is necessary to have a sufficient number of PMTs operating effectively and a high duty cycle. In addition to regular maintenance time, the WCDA detector has achieved an effective operating time of over 95% since July 2021, with over 98% of the detectors operating effectively.

3.2 Data acquisition

The PMT signal are transmitted through 30m long cables to a front-end electronics (FEE) board, which can handle signals from 9 big PMTs. In FEE, the signal trigger threshold are set to 1/3 PE and 1 PE for 8-inch and 20-inch respectively. In shower envent mode, the full array is split into 72 approximately half-overlapping trigger cluster, each containing 144 cells and covering an area of 60 $m \times 60$ m. Fig. 3 shows a typical EAS event recorded by WCDA. In order to reduce noise and compress data, a time window of 300 ns has been set for triggering data. Under these conditions, the current EAS trigger rate of WCDA is approximately 35 kHz (Fig.4). About 3.5 PB raw data are generated each year. For a long-term running, it is necessary to have high duty cycle. In addition to regular maintenance time, the WCDA detector has achieved an effective operating time of over 98% since July 2021 (Fig. /reffig:tlive), with over 98% of the detectors operating effectively. To study gamma-ray bursts (GRBs), WCDA has a dedicated mode for saving GRB data. The raw data is divided into two data streams, with one stream being stored in a "cache" mode. In this mode, data is cached for 0.5 hours before and 2 hours after the current time (T0). When a GRB alert is received, the cached data for that specific time period is saved separately. This cached data provides a sufficient duration for detailed analysis of the GRB, even for short-duration events.

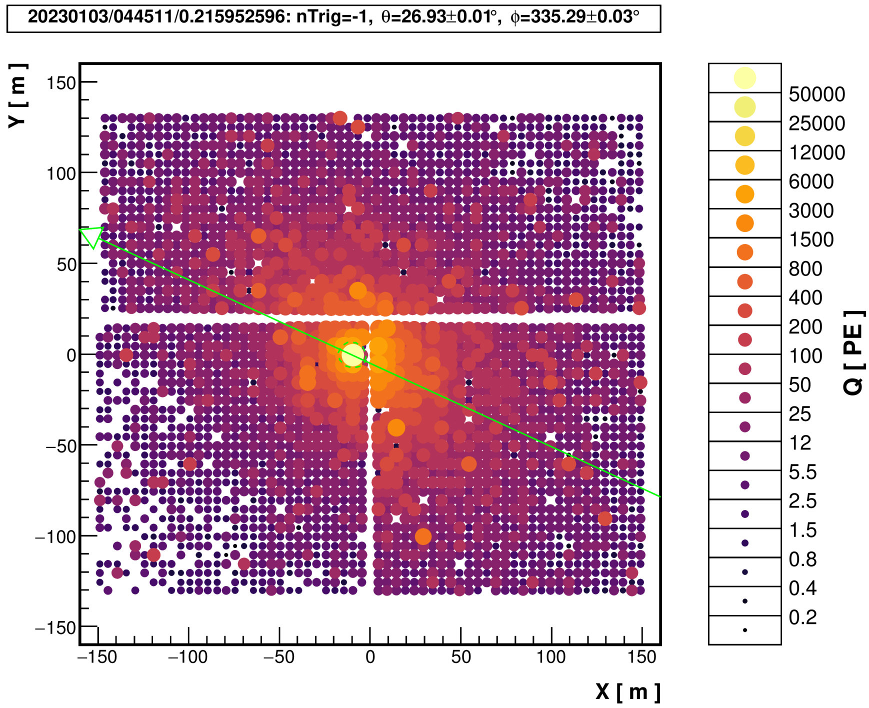

Figure 3: A typical EAS event detected by LHAASO-WCDA.

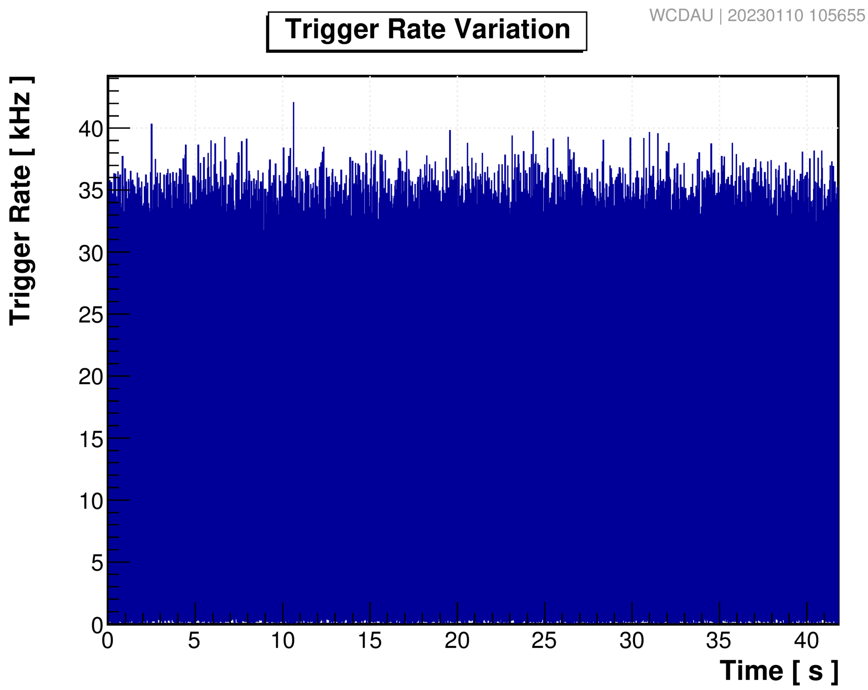

Figure 4: EAS event rate of LHAASO-WCDA.

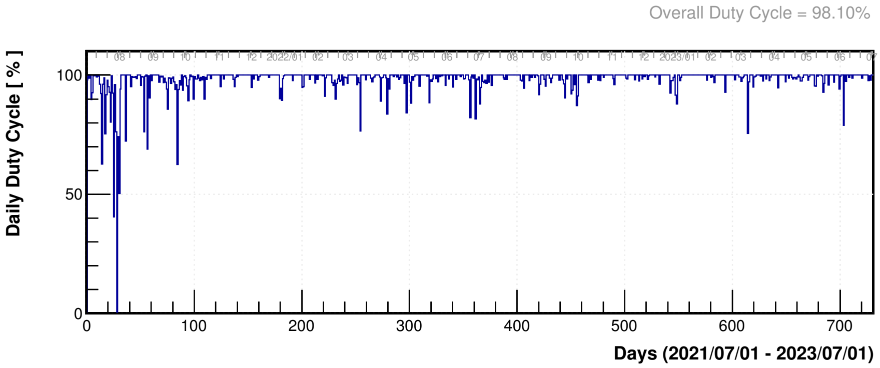

Figure 5: Dutycycle since July 2021 to June 2023.

4. Summary

WCDA officially began full-array operation and observation in March 2021. By July 2023, the operational uptime reached over 98%. During this time, WCDA has accumulated a significant amount of physical data. Specially, WCDA successfully observed the complete process of the GRB221009A on October 9, 2022[4], this result shows that WCDA have a good stability and running status. Also, base on the 2-years data, WCDA has discovered dozens of new radiation sources. Detailed analysis of these findings is currently underway.

5. Acknowledgement

The authors would like to thank all staff members who work at the LHAASO site above 4400 m a.s.l year-round to maintain the detector and keep the electrical power supply and other components of the experiment operating smoothly. At the same time, we greatly appreciate the meticulous data analysis conducted by the physics analysts. Their work is crucial for revealing the nature of radiation sources and understanding the physical processes in the universe. Their efforts enable us to delve deeper into the research and exploration of the mysteries of the universe.

References

[1] Cao Zhen et al., *Introduction to Large High Altitude Air Shower214 Observatory (LHAASO)* , *Chin. Astron. Astrophys.* **43** (4) (2019) 457-478.

[2] Huihai He et al., *Design of the LHAASO detectors Radiat. Detect. Technol. Methods* **2** (2018) 1-8.

[3] You X H et al., *The Application of 20 inch MCP-PMT in LHAASO-WCDA Proc.37th Int. Cosmic Ray Conf* (2021).

[4] LHAASO Collaboration., *A tera–electron volt afterglow from a narrow jet in an extremely bright gamma-ray burst Science* **380** (2023) 1390-1396

[5] *Time calibration of the LHAASO-WCDA detectors. Proc.37th Int. Cosmic Ray Conf* (2021).