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Cloud Monitoring using Nitrogen Laser for LHAASO Experiment

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Atmospheric monitoring is the key for experiments using the air Cherenkov/fluorescence techniques. In particular cloud monitoring is of great importance to evaluate "clearness" of night skies which affects to shower images obtained by the Wide Field of view Cherenkov/Fluorescence Telescope Array (WFCTA). A nitrogen laser has been installed at the ARGO-YBJ site for the cloud monitoring during WFCTA observations. The testing calibration system has been in operation since March 2011. In this paper, we describe the laser system and the preliminary analysis of the cloud monitoring data.

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1. Introduction

The Large High Altitude Air Shower Observatory (LHAASO) project consists of four major components, $1km^2$ Extensive Air Shower (EAS) array (KM2A), $90000m^2$ water Cherenkov detector array (WCDA), a wide field of view Cerenkov/fluorescence telescope array (WFCTA) and $5000m^2$ burst detector array (SCDA). The main scientific goals of LHAASO project are the study of 40GeV-1PeV gamma ray astronomy and 10TeV-1EeV cosmic ray physics. The main scientific goal of WFCTA is to study the 10TeV-1EeV cosmic ray physics.[1]

The calibration system for the WFCTA consists of a series of devices, mainly including a YAG laser, a nitrogen laser, an infrared thermometer and a meteorological station. And it can study absolute calibration of photon number, air quality monitoring and back scatter method monitoring weather, also study the measurement of the horizontal attenuation length, distribution of aerosol scatter angle, aerosol effective height.

There are two kinds of laser calibration system, Nitrogen laser system and YAG laser system. The Nitrogen laser system prototype has been operating and acquired a number of data. The YAG laser system prototype is in debugging to serve the calibration in the future. In this analysis we use the data by the prototype nitrogen laser system and the prototype telescope at ARGO-YBJ site.

2. Set up of the Experiment

2.1 The prototype of laser devices

2.1.1 Nitrogen laser system

As shown in Figure 1, a nitrogen laser device installed in a quarter standard shipping container at YBJ site is running since March 2011[2]. An equatorial functions in this system and a programmable logic controller (PLC) is applied to lead the rotational system within elevation $0°$-$90°$and azimuth $0°$-$360°$at the accuracy of $0.01°$. When the laser is needed, the whole system is lifted outside the container through the skylight with an elevator with level of precision at 0.1mm. The laser beam is shot hourly during calibration experiment. The energy of laser pulse is measured at the the beginning and end of calibration experiment by the energy probe. The parameters of nitrogen laser is listed in Table 1.

Wavelength	337.1 nm
Pulse width	<3.5 ns
Pulse energy	170μJ
Energy stability (pulse to pulse)	3 % std. dev. (at 10 Hz)
Beam size	3×7 mm
Beam divergence (full angle)	5×8 mrad
Energy Scales of energy probe	2μJ-10mJ
Calibration Accuracy of energy probe	<$\pm$3%

Table 1: The parameters of nitrogen laser

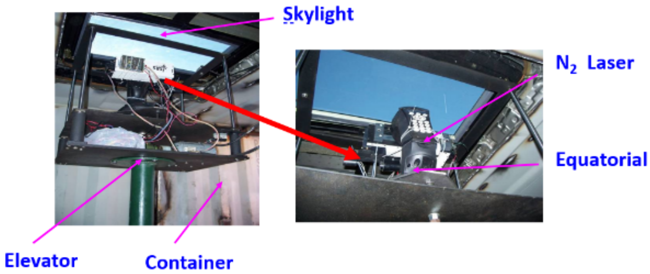


Figure 1: The structure of laser device

Wavelength	355 nm
Pulse duration	<7 ns
Pulse energy	2mJ
Energy stability (pulse to pulse)	4%
Beam size	1.3 mm
Beam divergence	1 mrad
Energy Scales of energy probe	200μJ-10J
Calibration Accuracy of energy probe	$<\pm 3\%$

Table 2: The parameters of YAG laser

2.1.2 YAG laser system

This laser system is mainly composed of a precision laser turntable, a pulsed YAG solid-state laser device and a programmable logic controller (PLC) as is shown in Figure 2. A PLC can control the rotational system within azimuth 0°-360°, elevation 0°-90°and rotation angle -45°-45°at the accuracy of 0.01°. The three angles can locate the orientation accurately and feedback the angle data to PLC to form closed-loop control. Following the localization of orientation laser is emitted for laser calibration. The pulsed YAG laser device is fixed on the turntable. The PLC is able to achieve the control by local or remote PC. Water cooling is required while solid state laser device is operating. Therewith, a water cycle system connecting to the inside of laser device can ensure the temperature in operating range.The parameters of YAG laser is listed in Table 2.

2.2 Detectors and Geometry

Since Sep. 2008, two prototypes of WFCTA employed in a container with dimension of $2.5m \times 2.3m \times 3m$ at the ARGO-YBJ site located in Tibet, China have been running in Cherenkov mode for researching the energy spectrum of primary cosmic ray.

The detected light is collected by a $5m^2$ mirror, which is an optic UV light collector with a reflectivity of 82%. Catoptric light is focused on a focal plane camera equipped with 16 photomultiplier tube (PMT) subclusters which consists of 16 40mm hexagonal PMTs that each acts as one pixel about $1° \times 1°$field of view. Therefore the focal plane camera consists of 16×16 pixels and a Field of View of 14°in elevation by 16°in azimuth. The quantum efficiency of PMTs is about 21% at 337nm which is the wavelength of Nitrogen laser. The signal of each PMT is digitalized by a

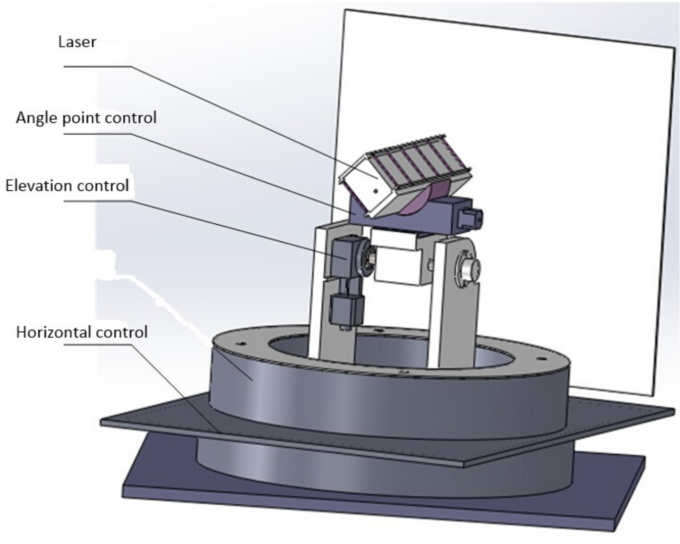


Figure 2: The architecture of YAG laser system

50MHz flash ADC, the digitalized waveform is stored in the buffer of FPGA (Field Programmable Gate Array). Trigger mode of laser events is "line" pattern which requires at least six triggered pixels forming a straight line[3].

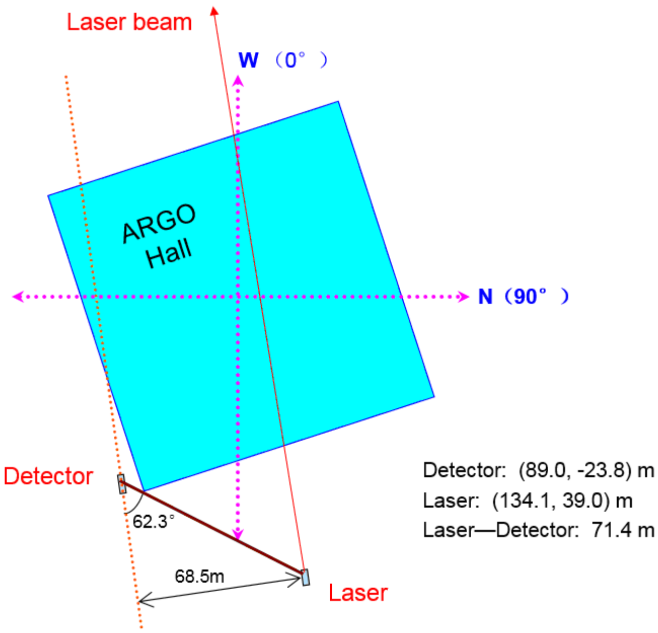


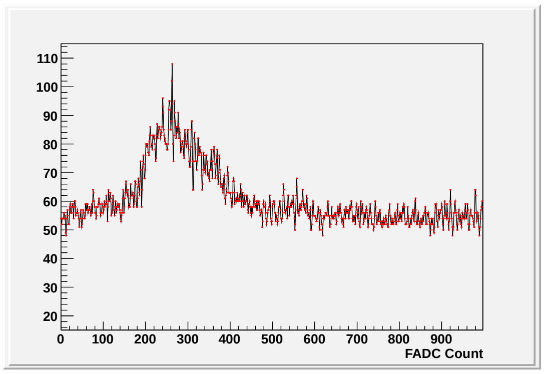
Figure 3: Geometry of laser and detector

Only one prototype of WFCTA is employed for the calibration experiment. Both of nitrogen laser system and detector are removable since they are around carpet detector array of ARGO-YBJ while operating laser calibration with a geometry shown in Figure 3. The employed data is generated when the laser is shot 71.4m apart from the detector in azimuth 346.6°and in elevation

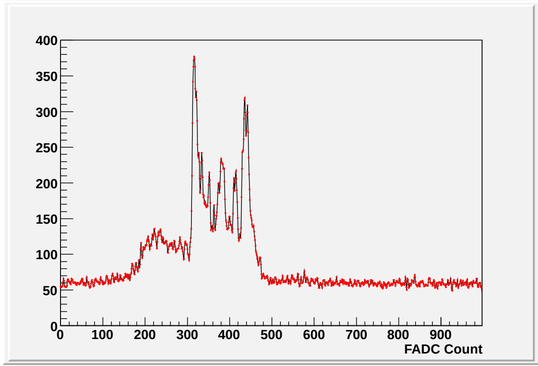
55°as well as the detector receives in azimuth 346.6°and in elevation 59.1°. And 2 days' data, Jan. 18 and Feb. 28, 2012, are picked out for analysis due to their discrepant weather conditions.

3. Data analysis and results

Jan. 18 and Feb. 28, 2012 are cloudless and cloudy respectively. Figure 4 shows a light curve recorded by FADC on these 2 days. The bin size is 20ns. The FADC count of Feb. 28 is quite larger than that of Jan. 18. And on the other aspect from the laser track of one event shown in Figure 5 on the 2 days, it obviously displays that there are more fired PMTs on Feb. 28. After multiple scattering, the laser track on Feb.28 appears as a mushroom shape while on Jan. 18 it is a thinner line.

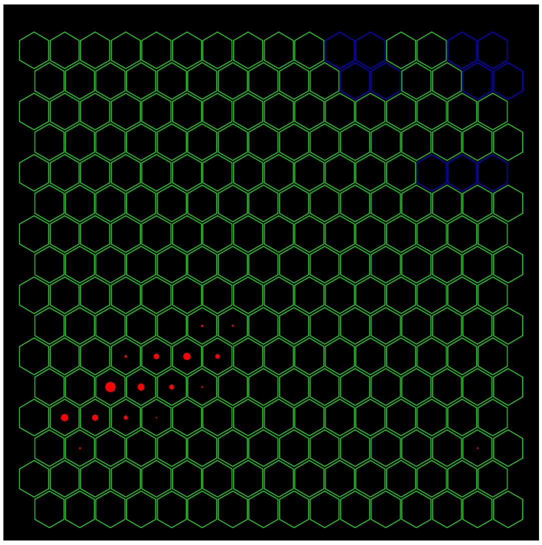


(a)

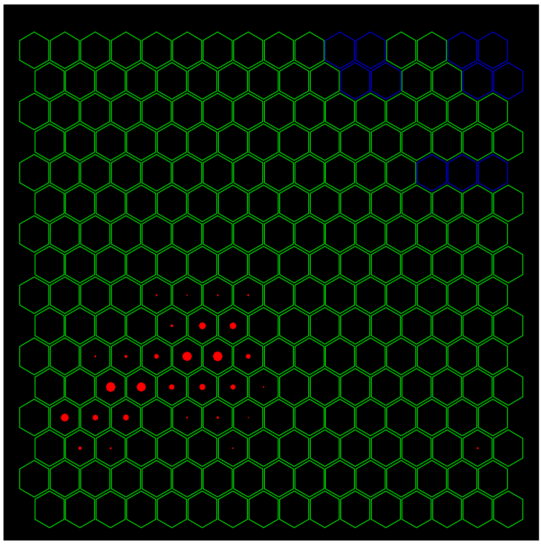


(b)

Figure 4: the electronic signal of fired PMTs on Jan. 18 (a) and Feb. 28 (b)



(a)



(b)

Figure 5: the laser track of one event on Jan. 18,2012(a) and Feb. 28,2012(b)

Therefore, with the integral of every event as shown in Figure 4, the normalized FADC count is calculated for comparison between the 2 days. As the laser is shot once one hour, the data is

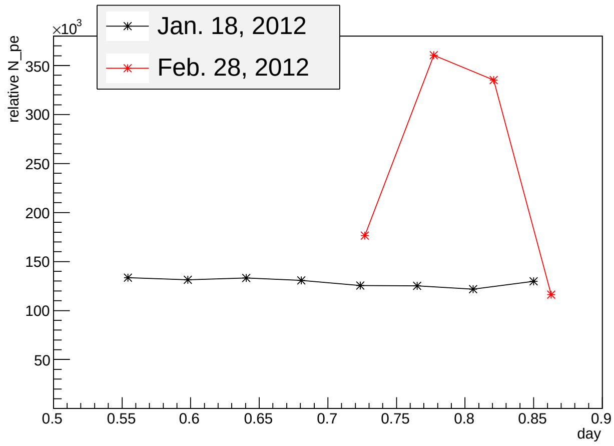


Figure 6: the laser events signal as a function of time in one day for Jan. 18, 2012 (black) and Feb. 28, 2012 (red)

processed hourly. we eliminate the background pedestal and reduce the influence of electronic noise in data processing. Eventually a relative number of collected photon can be calculated. Thus a total relative photon number of fired PMTs in each event can be approached. A series of events, from tens to more than one hundred during one single laser emitting, are recorded and made mean value of recorded events in one hourly emitting. The analysis of 2 days data, Jan. 18 and Feb.28, 2012, can provide us a apparent difference between the cloudless day and cloud day as shown in Figure 6. Here, N_pe represents the relative mean value of each collected event during one shot and day represents the time in one day. On one hand, Feb. 28, 2012 is a obvious night with much more relative photons detected by the detector and a fluctuation of nearly 350%. On the other hand, N_pe on Jan. 18 fluctuates within 10%. This indicates that Feb. 28, 2012 is a terrible day with cloud, the opposite situation to "clearness". And Jan. 18 could be a relative clear day. Therefore a cloudy day and a cloudless day can be identified for further analysis with our calibration system.

4. Conclusion

With preliminary process of the 2 days' data, we can easily distinguish cloudy day and relative clear day. And this indicates that the prototype of nitrogen laser system has been running successfully at YBJ site near the two prototypes of WFCTA and the ARGO-YBJ experiment since March 2011.The data process is undergoing and more details of analysis will be done in the future. And at the same time, the absolute calibration of photon number and air quality monitoring with a meteorological station are on the experimental schedule.

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