Study of liner for muon detector of LHAASO-KM2A

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Abstract: As a part of LHAASO, the array of muon detectors contains 1221 water-Cherenkov detectors each with a dimension of 6.8m in diameter and 1.2m in depth. In order to match the experimental requirements, the performances of the liner and the technology of keeping water quality in the liner have been studied. In this paper we describe the design features and technical characteristics of the liner and the PMT enclosure method for muon detector, also the technology of keeping water in the liner is presented.

Keywords: LHAASO, water-Cherenkov, liner, Tyvek.

1 Introduction

The large high altitude air shower observatory (LHAASO)[1] project is proposed to search for cosmic ray sources by using gamma rays up to 1PeV, to survey in the northern hemisphere for gamma ray sources above 100GeV, and to study cosmic ray physics from 20TeV to 1EeV in energy spectrum for individual composition, etc. As a main detector array, one kilometer square extensive air shower array (KM2A) contains 1221 water-Cherenkov muon detectors each with a dimension of 6.8m in diameter and 1.2m in depth. There are two functions for the muon detectors: on one hand, the detectors have strong background rejection ability to greatly improve the detection sensitivity; on the other hand, determine effectively the primary cosmic ray species.

Air showers contain a lot of electromagnetic compositions, the number of which is 1-2 magnitudes more than muons. In order to accurately detect the muon density, a certain thickness of electromagnetic absorption layer above the detector is utilized. Water Cherenkov detector is chosen because of its robustness, low cost and its rejection power to shower electromagnetic secondaries. Each muon detector includes a 6.8m-diameter concrete tank containing a sealed liner with a reflective inner surface, and the liner contains 44 tons of pure water. Cherekov light produced by the passage of particles through the water is collected by one eight-inch-diameter PMT which is at the top center of the tank and looks downwards into the water through a window of optical EVA plastic.

In order to match the requirement of experiment, the performances of the liner, the PMT enclosure method and the technology of keeping water quality in the liner are studied. These methods have been implemented in two prototype experiments successfully.

2 Linear

2.1 Development and Design

Tank liners which are put into tanks are right circular cylinders made of PE material, it should conform approximately to the inside surface of tanks. For the liners, there are three functions it should meet [2]: they enclose the water volume, preventing chemical contamination and performance of diffuse reflection. On the top of the liner, there are one window and two fill ports. The window is covered with a transparent cover which is made of EVA, a kind of optical plastic. The fill ports allow for filling and venting the tank.

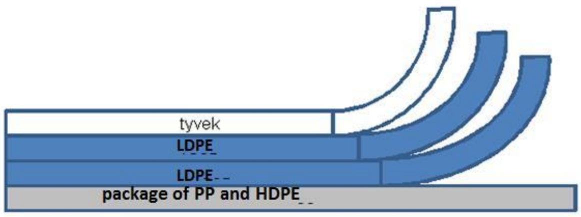

Fig. 1: The sketch of liner laminates, showing the inner Tyvek layer, two LDPE layers in the middle, the out layer of PP and HDPE.

For the material of liner, five functions have been considered [3]: the strength, strong diffuse reflectivity of inner surface for the Cherenkov light, good sealability, excellent chemical resistance and prevention from contamination of water volume by minimal extractable matter from the materials and microbe.

The liners are made of separate laminates by proper processing method, and the laminates are composed of four-layer material (see Fig. 1). Tyvek 1082D made by Dupont, which is opaque, is chosen as the inner reflective layer for its excellent strength, flexibility and diffuse reflectivity for near ultraviolet light. It is a high density polyethylene non-woven material which minimizes the chemicals available to leach into the water volume; the middle two layers are made of LDPE. It plays an important role in enclosing the water volume and preventing chemical contamination; the out layer is a package of PP and HDPE, which is well in strength. Its outstanding chemical resistance can protect the liner from abrade.

2.2 Assembly and testing

The tank is right circular cylinder with a diameter of 6.8m and height of 1.2m. As we all known, the cylinder contains top, bottom and side, there are much difficulty to assemble the three parts together. A new technology has been adopted: firstly two separate sections are manufactured with the same diameter D ($D = h + d$, where h and d are the height and

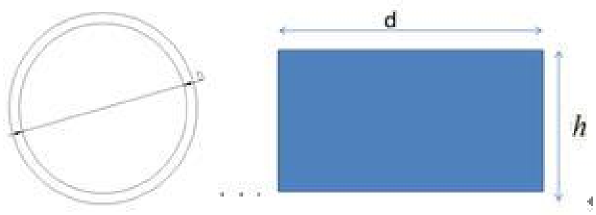

Fig. 2: The sketch of liner.

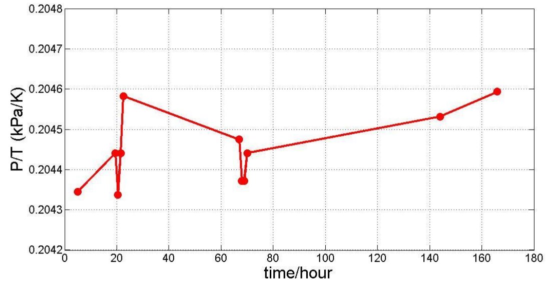

Fig. 4: Liner P/T varying with time during the test.

Fig. 3: Testing liner.

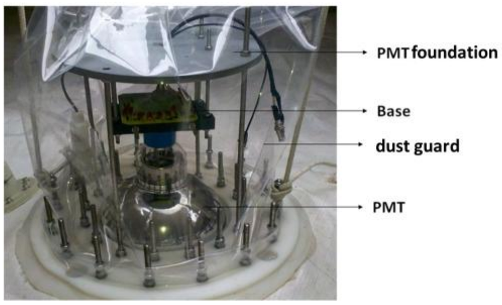

Fig. 5: PMT enclosure and assembly.

diameter of the tank respectively), then the two sections are welded together with heat seal machines in a clean room. After water is filled into the liner, the side of liner would be pushed to and shaped by the tank sides. Using this method, the liners can achieve airtight and watertight easily (see Fig. 2).

For leaks and flaws, the liner is tested after it is completed and the same tests would be repeated before installation. During test, the liner is inflated to a pressure of 500 Pa over atmospheric pressure. Fig. 3 shows a picture of liner testing. According to the ideal gas state equation:

$$\frac{P}{T} = \frac{nR}{V}, \tag{1}$$

supposing that the volume V of the liner keeps unchanged, air leakage will leads to decrease of P/T. The inner pressure P and temperature T of the liner was monitored for days with the result shown in shown in Fig. 4, from which one can see that P/T is very stable with a variation of less than 0.2% in about 6 days.

3 PMT enclosure and assembly

Using transparent cover can provide the PMT optical access to the water volume without directly touching the water. This also enables that the PMT can be replaced without exposing the water to the environment. The transparent cover was fixed by HDPE flange sealing the hole on the top of liner, PMT views the water through it. The PMT enclosures have been designed to fix PMT to the correct position and the PMT can be changed conveniently when there is any problem. The foundation of PMT is annular, as shown in Fig. 5, it is fixed on HDPE flange by screws, the distance between transparent cover and PMT can be adjusted by screws which are fixed on flange.

As shown in Fig. 6, in order to make the transparent cover, a mould of plaster stone is first made for PMT photocathode. The cover material is then fixed on the mould flat. Finally, vacuum suction can make the material shaped into the mould. Many material are tested and EVA has been chosen for transparent cover material. After successful development of the transparent cover, the transmittance of the material selected for making the cover is measured. A LED is used as light source and an 8-inch PMT is used to measure the light intensity. The LED light is firstly measured by the PMT and then measured with the PMT covered with a transparent cover, resulting a transmittance of 85%. Finally silicon oil is filled between filled between the transparent cover and the PMT photocathode to improve the optical coupling between them, the transmittance reaches 95%.

4 Tank water

Each muon detector contains 44 tons of ultra-pure water. In order to obtain the lowest attenuation for Cherenkov light and keep stability of the water during 10 years, the water purity should be as well as possible. The water is purified by deionization, filtering, etc. The conductivity of the water purified on-site is about 15M-cm.

The array of muon detectors contains 1221 tanks. Its a long distance between on-site water factory and muon tanks, A water delivery system is developed to transport purified water to the water tanks. The water delivery system contains one water bag with a volume of 10 m^3, an electrical pump and accessories. The water bag is made of soft material. The bag is vacuumed before filling water into it. The bags top and bottom would be separated from each other as water

Fig. 6: Producing the transparent cover.

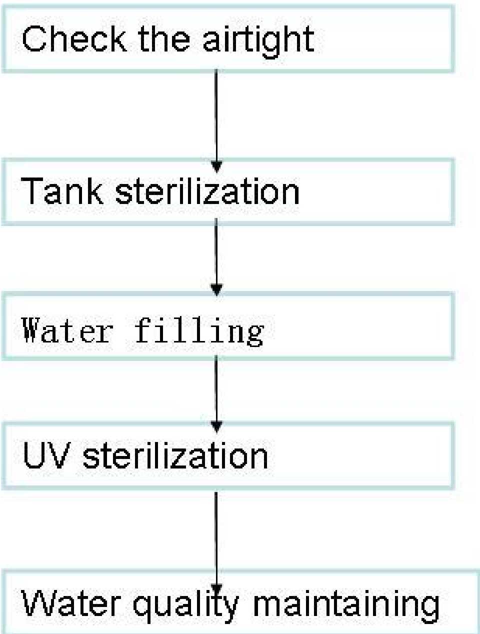

Fig. 7: Procedure of water filling.

fills in and get close to each other as water is pumped out, thus preventing air to enter during the whole process.

Fig. 7 shows the whole process of water filling. The liner is firstly checked for leaks and flaws and then flushed several times. The flushing effect is checked, for each flushing, by keeping the water in the liner for one day and monitoring the water conductivity. As shown in Table. 1, the difference between the conductivity of input water and liner water after one day decreases with flushing time. During water is filled into the liner, a short wavelength tube is used to sterilize bacteria.

4.1 Long term stability

The prototype muon detector has been operating in Tibet for more than five months, its long-term stability is studied via data analyses. The prototype is triggered by coincident events of the top and bottom scintillation detectors vertically aligned with a distance of 2m to the tank center. A stable

Flush time	Conductivity of input water	Conductivity after 1 day
1	0.26	0.38
2	0.24	0.33
3	0.23	0.31
4	0.23	0.28

Table 1: The effect of liner flushing, the unit of conductivity is $\mu S/cm$.

trigger rate between 0.3 Hz 0.32 Hz is observed. The prototype detection efficiency is higher than 97% and is very stable. Fig. 8 shows number of photoelectrons (Npe) detected by the prototype PMT varying with time. In this figure, Npe is normalized to that in the first day. Npe is very stable in 5 months, confirming that the liner and water are very stable.

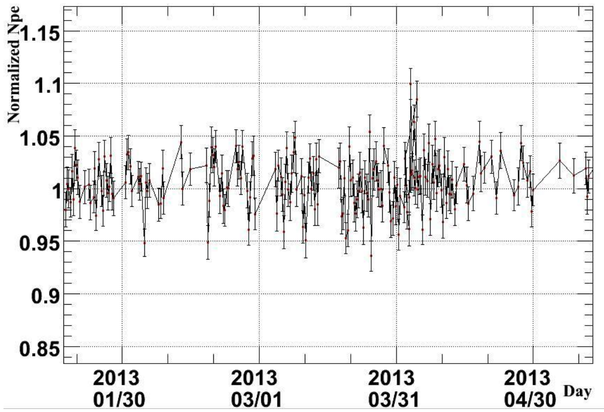

Fig. 8: The normalized number of photon electrons

5 Conclusions

A prototype muon detector for LHAASO-KM2A have been operationing for more than 5 months at Yangbajing in Tibet. All components of the above-described liner have fully met our design expectations. The design has shown sufficient robustness for the field conditions.

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