The Application of Magnetic Shield In LHAASO-WCDA

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Abstract

In the Large High Altitude Air Shower Observatory (LHAASO), the main physics objective of the Water Cherenkov detector array (WCDA) is able to survey the gamma-ray sky continuously in the energy range from 100 GeV to PeV. The Water Cherenkov detector array, covering an area of about 78,000 m^2 area, is constituted by 3120 detector units divided into 3 separate ponds. Each unit of the second and third pond are placed 2220 20" PMTs in contrast of 8" PMT in the first $150 \times 150m^2$ pond[1]. The newly developed 20 inch PMT uses micro-channel-plate (MCP) instead of the traditional dynodes enables better energy resolution, good detector response etc. Due to the large size of 20 inch MCP-PMT, the geomagnetic field have big influence on the performance of detector, including time response, charge resolution and collected efficiency. This work focus on the effect of magnetic shield on the collected efficiency of PMT at LHAASO-WCDA.

The 20 inch MCP-PMT

The 20 inch MCP-PMT is manufactured by North Night Vision Technology Co., Ltd(NNVT) at Nanjing, China. It consists of bialkali photocathode, a focusing electrode, a MCP, and an anode. The distance between the photocathode and MCP is nearly 300 mm. Time resolution of the 20-inch MCP-PMT predominantly depends on the electrical field distribution between the photocathode and the MCP, therefore, a lotus-like focusing electrode was designed to reduse transit time spread(TTS) to 5.8 ns(FWHM)[2].

1.Dimension of 20 inch MCP-PMT

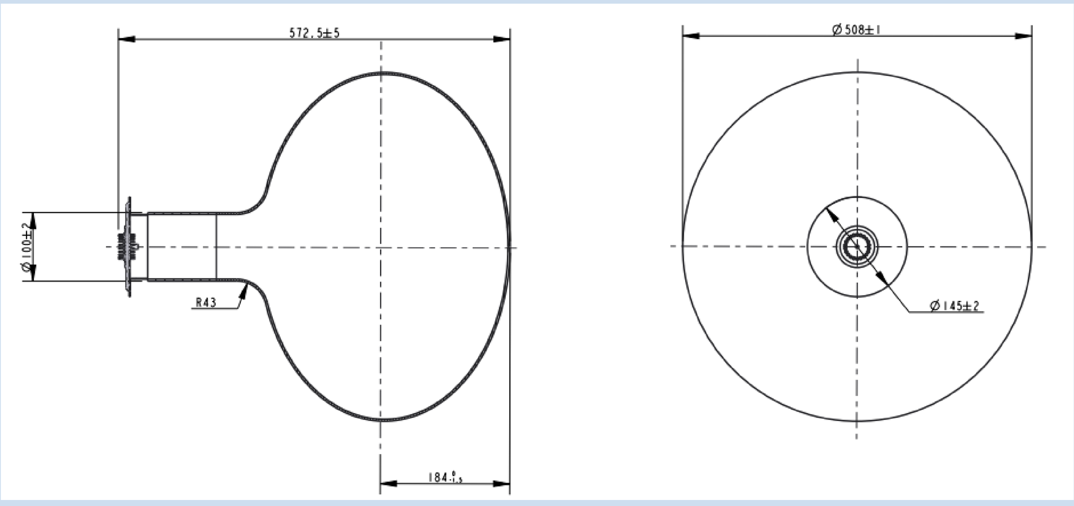

Figure 1. Dimension of 20 inch MCP-PMT.

2. Effect of Geomagnetic on 20 inch PMT

As you can see, the collection efficiency will decrease because of the photoelectron trajectory is defected in the presence of a magnetic field.

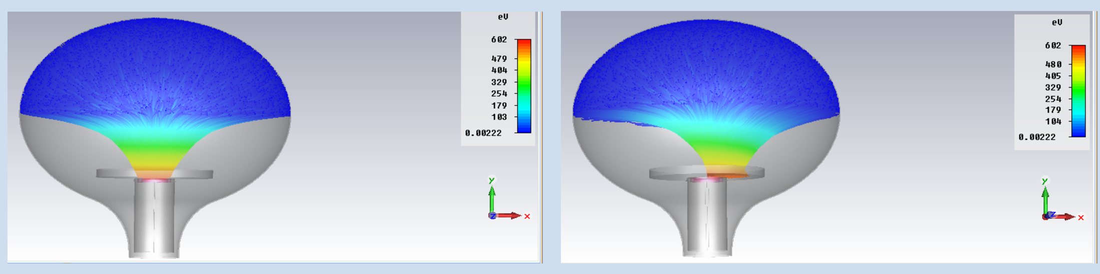

Figure 2. Left: trajectories of electrons without magnetic shield, Right: trajectories of electrons with magnetic shield.

3. Magnetic shield

We have chosen magnetic shield(1K107) fabricated by Shenzhen Magnetic Materials Technology CO.,Ltd. This soft magnetic alloy has high saturation magnetization, high permeability over a wide range of frequencies and low core loss. We used 0.1-mm-thick sheets for fabricating the magnetic shields. This thin flexible material is laminated three layers of 20 µm-thick 1K107 tape between two polyethylene terephthalate (PET) films. It can operate in a temperature range between -40°C and 120°C.

Simulation and test Result

The effectiveness of the magnetic shield depends on the height of the cylinder. We have simulated the average magnetic shield intensity inside PMT with heights range from 20 cm to 60 cm with an interval of 2 cm. As you can see at Figure 3-left, the variation of average magnetic shield intensity is less than 2% when a shield height is greater than 40 cm. Relative to the case of without any shielding, a shield with a height of 40 cm improves the average collection efficiency by 60% as shown at Figure 3-right.

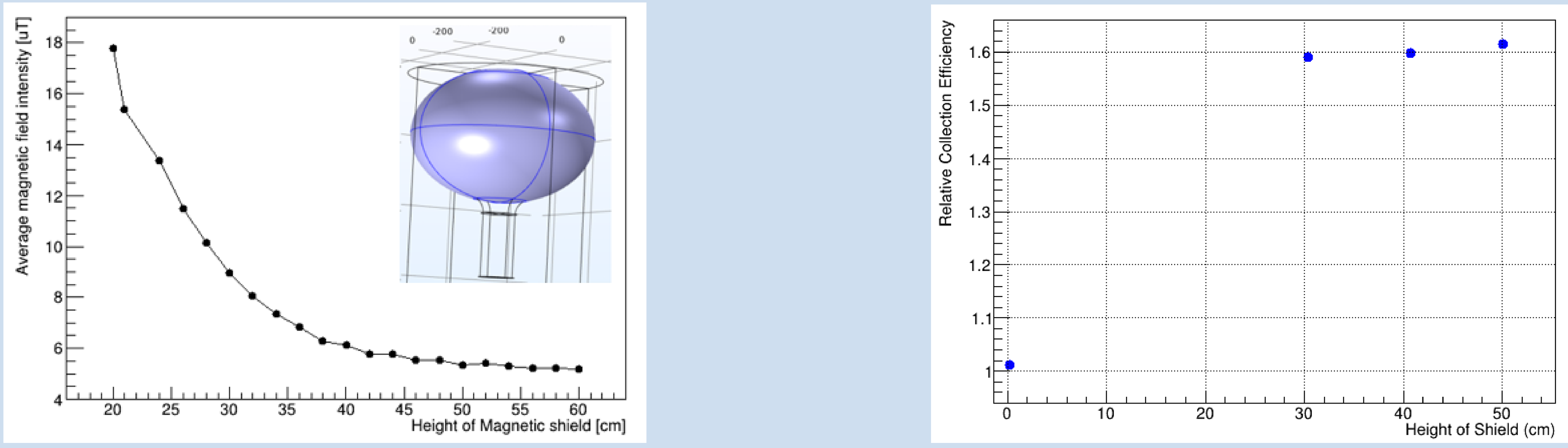

Figure 3. The amount of collected charge relative to the one without shielding at (relative collection efficiency) for the 20inch PMT as a function of the height of the magnetic shield. Left: Simulated result on the average magnetic field intensity as a function of shield height, Right: test result with three different shield heights.

Magnetic shield structure and performance at LHAASO-WCDA

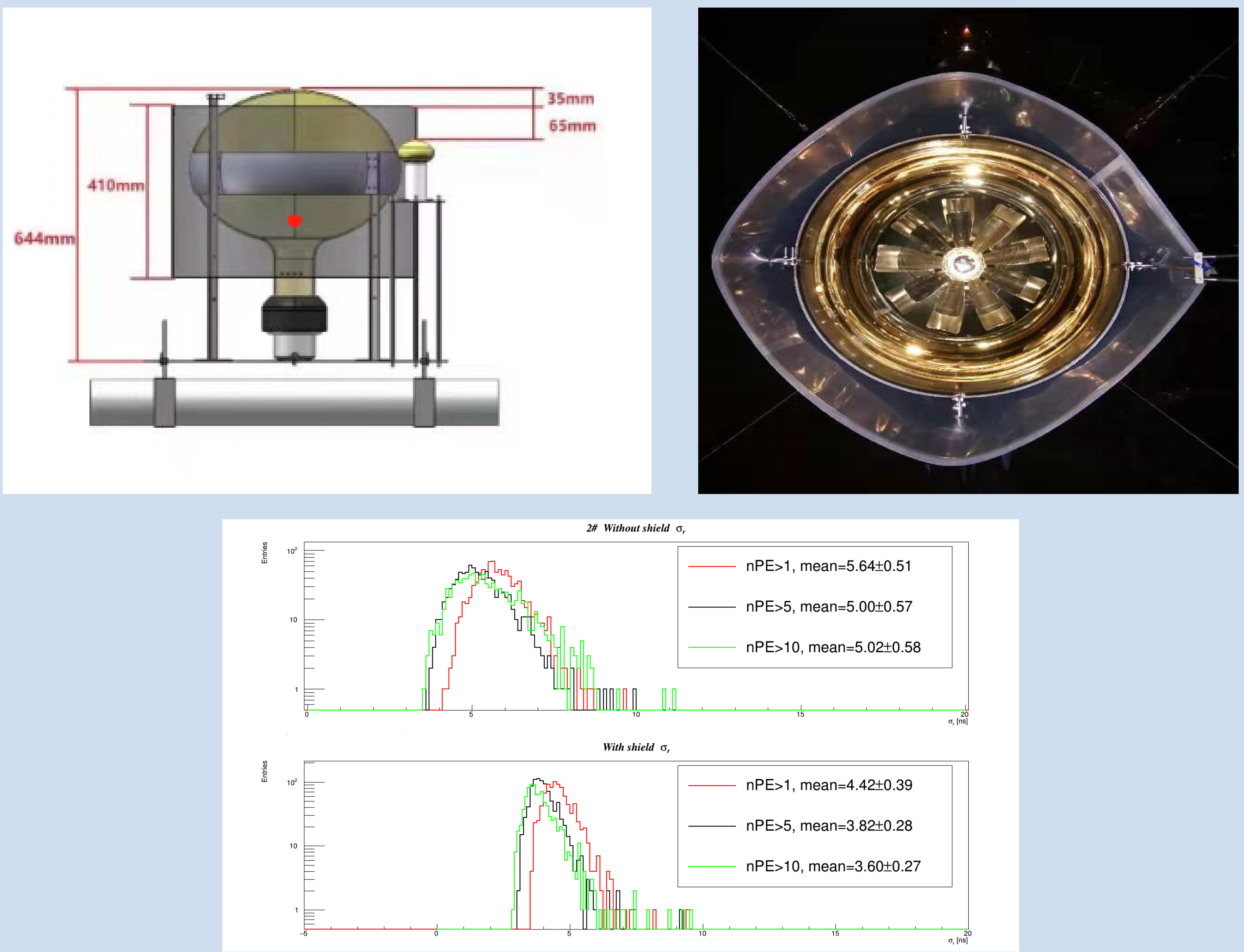

Figure 4. Up Left: final structure of magnetic shield installed on 20 inch MCP-PMT, where red dot indicate the position of microchannel plate. Up right: top view of PMT. Bottom: comparison of σ_r of time residual in 900 MCP-PMTs with/without magnetic shield. The red line represents the distribution of σ_r at nPE>1 ($E(\sigma_{without-shield})$=5.64ns, $E(\sigma_{with-shield})$=4.42ns), the black line represents the distribution of σ_t at nPE>5 ($E(\sigma_{without-shield})$=5.00 ns, $E(\sigma_{with-shield})$=3.82ns), the green line represents the distribution of σ_r at nPE>10 ($E(\sigma_{without-shield})$=5.02ns, $E(\sigma_{with-shield})$=3.60ns).

Conclusion

The magnetic shield clearly improves the collection of charge. LHASSO-WCDA is taking data and the total array results will publish at October 2021 on current schedule.

Acknowledgements

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References

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