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Temperature-Induced Aging Effect on Extruded Scintillators and Optical Fibers for the Pierre Auger Observatory Upgrade

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► To cite this version:

Z. Zong, Giulia Hull, R. Smida, K. Daumiller, R. Engel, et al.. Temperature-Induced Aging Effect on Extruded Scintillators and Optical Fibers for the Pierre Auger Observatory Upgrade. 2015 IEEE Nuclear Science Symposium and Medical Imaging Conference, Oct 2015, San Diego, CA, United States. . hal-04227150

HAL Id: hal-04227150

<https://hal.science/hal-04227150>

Submitted on 3 Oct 2023

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Introduction: The Pierre Auger Observatory upgrade foresees the installation of Scintillator Surface Detectors (SSD) placed above the Water-Cherenkov Detectors (WCD) to add an extra measurement of the particles in the Extensive Air Showers (EAS) independent of the measurements made with the WCDs. In the framework of the SSD development, we studied the light yield and the effect of temperature cycling for different extruded scintillators/optical fibers configurations, since these are crucial properties of the detector, which is supposed to reliably operate in a hostile environment with daily temperature variations of up to 30 °C. In addition, we present a mechanical solution to couple the fiber bundle to the PMT and an investigation of the way to optimize the light collection efficiency.

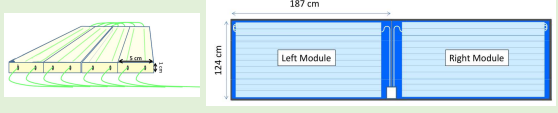


Auger upgrade Scintillator Surface Detector (SSD)

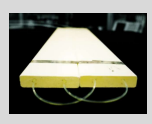
The new SSD of Auger Upgrade, which is going to be installed at 1400m altitude in Argentina, can add a different response to the basic components of the EAS compared to the present WCD stations. It has to be reliable, easy to realize and install, and has to have minimal maintenance when working in the Pampa for a life time of more than 10 years.



The Scintillator Surface Detectors basic unit consists of two modules of $2m^2$ plastic scintillator, which are read-out by wavelength-shifting (WLS) optical fibers coupled to a single photo-detector. The active part of each module is a scintillator plane made by 24 bars 1.6m long of extruded polystyrene scintillator. Each bar is 1cm thick and 5cm wide.



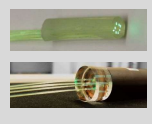
Test bench and scintillator/fiber configurations



Scintillators samples with WLS fibers. U-turn fiber routing at one end of scintillator bars. The other end of the fibers coupled to a PMT.

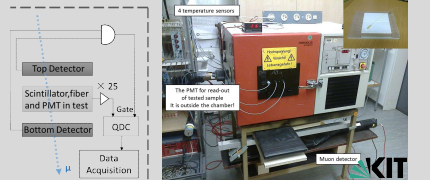
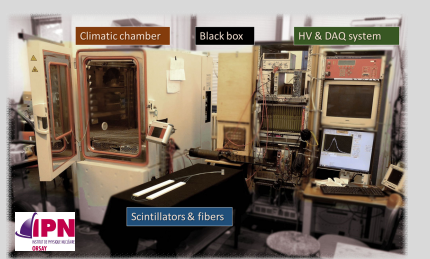


- Scintillator samples:**
- FNAL extruded plastic scintillator
 - 2 bars – 2 holes – 45x10x400mm [IPNO]
 - 2 bars – 4 holes – 100x10x200mm [KIT]
 - 2 bars – 1 groove – 41x10x200mm [KIT]

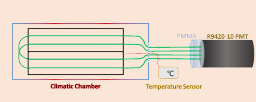


- Fiber samples:**
- Kuraray Y11(200)MSJ $\phi 1.0$ mm
 - Saint-Gobain BCF91A $\phi 1.2$ mm
 - Saint-Gobain BCF929AMC $\phi 1.2$ mm

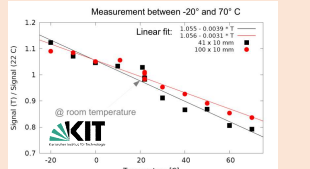
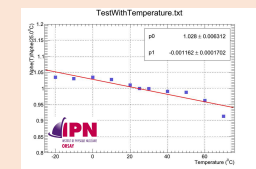
Fiber ends polished and kept in place by PMMA or silicone supports in front of the PMT window.



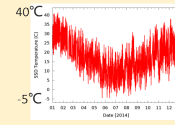
Scintillator & fiber test with temperature



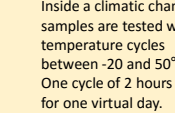
Setup for temperature test: scintillator and fiber samples are placed inside a climatic chamber while the PMT is kept outside. A sensor, placed on the scintillator surface, monitored the temperature of the samples



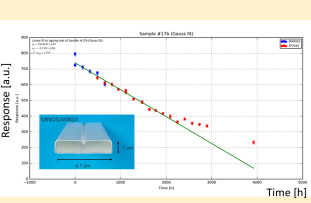
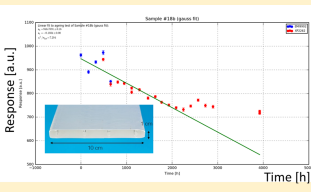
Scintillator and fiber degradation test with temperature



Inside a climatic chamber samples are tested with temperature cycles between -20 and 50°C. One cycle of 2 hours stands for one virtual day.



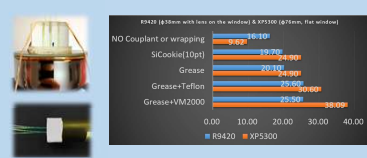
Signal(t=1700h) / Signal(t=0h) = 0.88



WLS fibers glued in the grooves with BC600 kept at constant temperature of 60°C

Smaller decrease after 2300h = 3.1 yr.

Test of coupling methods to increase PMT signal



Couplants like optical grease or RTV silicone cookies and reflective or diffusive wrapping materials at fiber/PMT coupling part increase the LCE.

Fiber ends polished with 800 and 1200-grit sandpapers

Photonis XP 5300B
3 inch (φ76mm)
Flat window
QE: 32% to 37% near 439nm

Hamamatsu R9420-10
1.5 inch (φ38mm)
Flat window with lens
QE: ~25% near 439nm
Baseline PMT of SSD design

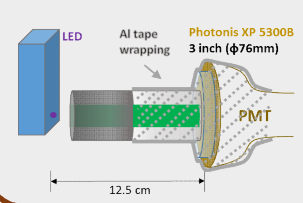
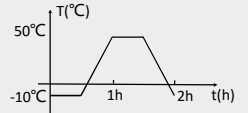
Due to the optimized ph.e. collection at the first dynode, PMT R9420-10 is less sensitive to the wrapping material than XP5300. Next step will be to test R9420-100 that combines the high QE of XP300 with the ph.e. focusing at the first dynode of R9420-10.

Aging test of the fiber bundle and RTV silicone couplant



A fiber bundle of 96 pieces has been manufactured for the current SSD design. Fibers are glued together using BC600 and placed inside a PMMA cylinder, the fiber-bundle end is then machine polished.

Two sets of temperature cycles (first 57 cycles and then 55 more) in the temperature range between -10 and 50°C were performed for both the fiber bundle and the RTV silicone cookies.



We irradiated the PMT with a LED light, located 12.5 cm from the PMT window. The signal, measured before and after the temperature cycles, remained unchanged, indicating that the light transmission performance as well as the mechanical property of the fiber bundle remained stable within the tested temperature range.

The RTV silicone cookie optical properties were not affected by the temperature cycles. The LCE improvement observed using cycled RTV cookies was comparable to the one measured before the temperature test.

Conclusion and future work

- FNAL 10-mm thick extruded plastic scintillators, with different cross sections, showed a light yield decreasing rate of ~1% - 3% per 10°C when operated in a climatic chamber in the temperature range between -10 and 70°C.
 - Scintillator samples showed 12% light loss during the operation in a temperature range between -20 and 50°C for 1700h. When kept in extreme condition of a constant temperature of 60 °C, an extruded scintillator, readout with glued WLS fibers, lost 53% of the light yield after 2300h of operation, the configuration using no glue showed a smaller aging effect (light loss of 24%) during the same operation time.
 - The R9420-10 PMT signal can be increased up to 25% by adding an optical couplant and using wrapping reflective material.
 - We proposed a mechanical solution to keep the fiber bundle stable on top of the PMT entrance window, and we tested the robustness of the proposed solution performing more than 100 temperature cycles in the range between -10 and 50°C.
- To further investigate the sustainability in the Pampa, the AUGER collaboration foresees the installation of 10 SSD prototype detectors in 2016.