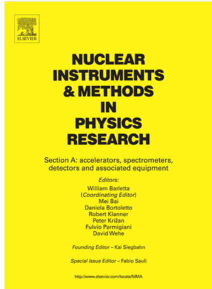

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Hermann-Josef Mathes, Michael Riegel, Markus Roth,
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Study of light yield for different configurations of plastic scintillators and wavelength shifting fibers

Zizhao Zong, Giulia Hull, Miktat Imre, Michaël Josselin, Alain Maroni, Tiina Suomijärvi

Institut de Physique Nucléaire d'Orsay, CNRS-IN2P3/Université Paris-Sud, Université Paris-Saclay, Orsay, France

Kai Daumiller, Ralph Engel, Hermann-Josef Mathes, Michael Riegel, Markus Roth, Radomir Šmída, Alexander Streich, Darko Veberič

Institute for Nuclear Physics, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

Abstract

In the effort of the AugerPrime scintillator surface detector R&D activity, we investigated the performances of different extruded and cast plastic scintillators that were read out with wavelength-shifting (WLS) optical fibers and then coupled to a PMT. In particular we compared the light yield of eighteen scintillator/fiber configurations, obtained combining eight different scintillator bars with six fiber types, in order to investigate which was satisfying the AugerPrime specifications in terms of light production ($>$ 12 photoelectrons per minimum ionizing particle). In this paper, we present the results of the study on different scintillator bar geometries, scintillator production techniques, and wavelength-shifting optical fiber types. We also propose an effective way to optically couple the fibers to the PMT entrance window.

Keywords: Plastic Scintillator, WLS fiber, Optical coupling

1. Introduction

Since the start of data collection in 2004, the Pierre Auger Observatory [1] improved the understanding of ultra-high energy cosmic rays significantly. Fundamental results and unexpected discoveries were achieved, e.g. the verification of the strong flux suppression for cosmic rays above 5×10^{19} eV, the indication of a mixed mass composition at the highest energies, or the observed anisotropy of cosmic rays above 8×10^{18} eV [2]. Still, the origin of these discoveries and their consequences on the understanding of the acceleration and propagation processes in the universe are unknown. Furthermore, the ultimate goal of the Observatory, the identification of sources of ultra-high energy cosmic rays, is still not reached.

For this reason, the Observatory will be upgraded in the following two years. The upgrade, called AugerPrime, is realized with several changes of detector electronics, as well as an installation of new detectors and detection devices increasing the exposure time and providing additional measurements to the already existing detectors. In addition, the enhanced mass sensitivity of the upgraded detectors will improve the determination of the characteristics of cosmic particles significantly [3].

One major step in the upgrade is the installation of a Scintillator Surface Detector (SSD) on top of each of the 1660 Water-Cherenkov Detectors (WCD) which originally form the surface detector (SD) [3]. With the new SSDs, complementary measurements of the extensive air shower particles arriving at the ground level are possible. Due to the different sensitivity to different shower components, the combination of scintillator detectors and water-Cherenkov detectors provides a significant improvement in the discrimination of shower particles, and therefore, facilitates the analysis of cosmic rays. Each SSD consists of an aluminum box filled with plastic scintillator bars, which are separated into two active modules with an area of approximately 1.9 m^2 each. The scintillator bars are coupled with wavelength-shifting (WLS) plastic fibers which guide the scintillation photons by utilizing total internal reflection effects towards a single photomultiplier tube (PMT) placed in-between the two modules. The use of a scintillator-fiber combination and the WLS characteristics of the optical components are necessary to reduce the attenuation effects inside large sized detectors, such as the SSDs.

In general, the light yield of a scintillator-fiber combination, i.e., the detection efficiency, is the major criterion to describe the quality of the detection set-up. In this study, the performance of multiple configurations of scintillators and fibers is tested under equal conditions in a dark box experiment. Each configuration contains short scintillator bars coupled with plastic fibers in different combinations which were candidates for the installation inside the SSDs. The components differ in their profiles and dimensions, as well as in their material purity depending on the production process. In addition, the performance of scintillators and fibers experiencing aging effects is studied. The sample tests were performed independently from each other in two different laboratories, at the Institut de Physique

*Corresponding author
Email address: hull@ipno.in2p3.fr (Giulia Hull)