Terzina on board NUSES: a pathfinder for EAS Cherenkov Light Detection from space

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Abstract. In this paper we introduce the Terzina telescope as a part of the NUSES space mission. This telescope aims to detect Ultra High Energy Cosmic Rays (UHECRs) through the Cherenkov light emission from the extensive air showers (EAS) that they create in the Earth's atmosphere. The Cherenkov photons are aligned along the shower axis inside about $\sim 0.2 - 1^{\circ}$, so that they become detectable by Terzina when it points towards the Earth's limb. A sun-synchronous orbit will allow the telescope to observe only the night side of the Earth's atmosphere. In this contribution, we focus on the description of the telescope detection goals, geometry, optical design and its photon detection camera composed of Silicon Photo-Multipliers (SiPMs). Moreover, we describe the full Monte Carlo simulation chain developed to estimate Terzina's performance for UHECR detection. The estimate of the radiation damage and light background rates, the readout electronics and trigger logic are briefly described. Terzina will be able to study the potential for future physics missions devoted to UHECR detection and to UHE neutrino astronomy. It is a pathfinder for missions like POEMMA or future constellations of similar satellites to NUSES.

1 The NUSES mission and its scientific goals

NUSES is a pathfinder satellite project (Fig. 1) for two innovative detectors dedicated to the study of cosmic radiation and the Sun-Earth environment [1]. They are Terzina, devoted to high-energy cosmic rays beyond 100 PeV, and Ziré devoted to cosmic rays below 250 MeV. The NUSES mission will last about three years and the satellite, with the two payloads, will orbit at 550 km altitude at the beginning of life (BoL) and at about 525 km at the end of life (EoL). The orbit inclination will be 97.6° with LTAN 18:00:00.

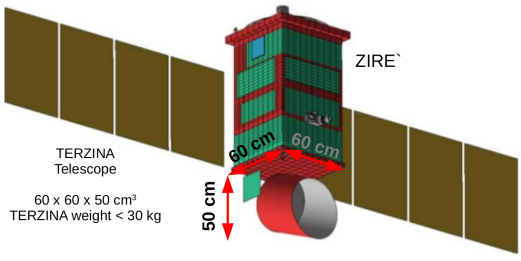

Figure 1: The NUSES satellite containing the Ziré apparatus at the top and the Terzina telescope at the bottom during the flight.

Ziré is made of a scintillating fiber tracker, a stack of plastic scintillator counters and an array of LYSO crystals. An active veto system and a Low Energy Module (LEM) are also part of the payload. SiPM will be used as light sensors. The instrument will perform spectral measurements of electrons, protons and light nuclei from few up to hundreds of MeV, also testing new tools for the detection of 0.1-10 MeV photons [2], and monitoring Van Allen radiation belts and space weather effects.

Terzina is a satellite-based detector designed for Cherenkov light detection from EAS induced by UHECR in the Earth's atmosphere. Terzina will aim to the detection of Earth-skimming ultra-high energy neutrinos [3] and ultra-high energy cosmic rays with energy above 100 PeV [4]. It will prove for the first time the space-based detection of Cherenkov light from EAS. The detection principle is discussed in [4–6].

We expect to see the highest rate of detectable signal from UHECRs when their interactions happen at the atmospheric height of about 30 km for protons of 100 PeV (see Fig. 2)

2 The Terzina telescope

The Terzina payload is composed by the following elements: the optical head unit, which is a near-UV-optical telescope, the focal plane assembly (FPA), the thermal control system, and the external harness and electronic units which will be in a separate box.

The optical system of the telescope is based on a dual mirror configuration composed of two parabolic primary and secondary mirrors with a corrector lens in order to cope with aberrations on the photon detection plane,

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