SVOM/ECLAIRs: GEANT4 simulations of the instrument and prototypes

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Abstract

The Space Variable Object Monitor (SVOM) is a Chinese-French mission for the study of γ-ray bursts and transient sources to be launched at the end of 2021. The $\sim$2 sr coded-mask imager ECLAIRs, is the leading instrument for the detection and first localization of GRBs in an autonomous manner onboard SVOM. The camera plane consists of an 80×80 Schottky-type CdTe semiconductor detectors offering $\sim$1000 cm^2 geometrical area and covering the 4-150 keV energy range. The camera is developed by a consortium of several French laboratories under the science lead of IRAP and the supervision of the French space agency (CNES). We present the GEANT4-based simulation software developed to model the experimental setups related to the detection plane and to ECLAIRs instrument in the flight configuration. We illustrate how these tools are used to help calibrate different prototypes of the camera and how the simulation tools will be used to prepare forthcoming calibration campaigns for the flight-model the camera.

Key words: Instrumentation: detectors — Methods: numerical (Monte - Carlo) — Telescopes: SVOM/ECLAIRs

1. Introduction

ECLAIRs is an X-ray/soft gamma-ray coded-mask imaging telescope with a large Field-of-View (89° × 89°) and operating between 4 keV and 150 keV (Fig. 1). The detection plane of the camera is an assembly of 6400 pixels (4×4 mm^2 × 1 mm-thick CdTe Schottky detectors) organized in elementary modules (XRDPIX) of 4×8 pixels. More details can be found in Atteia et al. (2020) and Godet et al. (2014). Simulations of ECLAIRs (camera only and whole instrument) are performed with the GEANT4 Monte-Carlo toolkit (Agostinelli et al. 2003). These simulations are used either to estimate the ECLAIRs performances (Triou et al. 2020) (e.g. the spectral response of the detection plane, the uniformity map for imaging) or to investigate specific points of the instrument design.

1.1. ECLAIRs ProtoDPIX MODEL

The prototype of the camera named protoDPIX consists of 1/8th of the ECLAIRs detection plane (Dezalay et al. 2020) illuminated with a radioactive source placed on a mast above the detector plane. The protoDPIX is placed in a thermal-vacuum chamber (Fig. 2).

1.2. ECLAIRs EQM MODEL

The EQM (Engineering Qualification Model) of the DPIX camera (Fig. 3) will be fully operational in January 2020 (Godet et al. 2020).

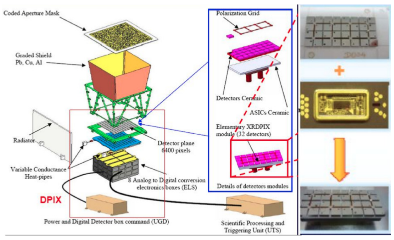

Fig. 1. (*Right*) Main components of the ECLAIRs telescope. (*Left*) Details of an XRDPIX camera module.

1.3. ECLAIRs Flight-Model (FM)

This model aims to simulate the instrument in-flight as well as the production of data (Bouchet et al. 2020b) in order to evaluate the performances, to test and set-up the data reduction pipelines (imaging and source reconstruction, transfer function in energy). The model will be refined (instrument geometry and material composition) using the successive prototypes of the camera.

1.4. ElSimulator

To produce more realistic data and also frames of data, a real-time simulator of the readout electronics (named ELSimulator) finalizes the simulations. It works with the same code as the one implemented in the flight model. It is used in a post-processing step starting from GEANT4 simulations.

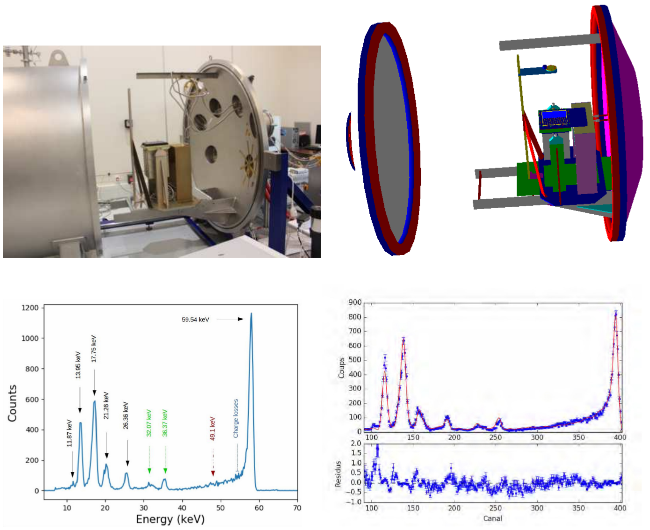

Fig. 2. (*Top-Left*) The prototype ProtoDPIX of the camera in the thermal-vacuum chamber (2 m diameter by 3 m length). (*Top-Right*) GEANT4 mass model of the ProtoDPIX in the vacuum chamber. (*Bottom-Left*) The different lines produced by a ^{241}Am radioactive source. (*Bottom-Right*) ProtoDPIX camera model: In blue, the ^{241}Am measured data (with the 1 σ statistical errors) for a specific camera configuration and for 1 hour of acquisition. In red the best data model (GEANT4 simulation) taking into account the energy resolution (Bajat 2018).

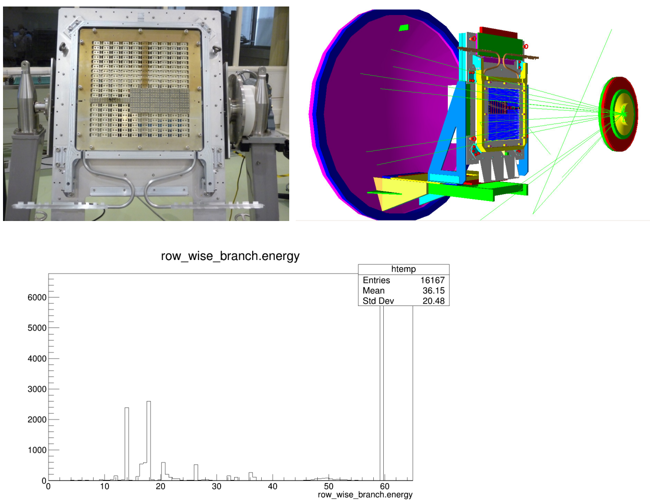

Fig. 3. (*Top-Left*) EQM model of camera with only few CdTe detectors mounted. (*Top-Right*) GEANT4 mass model of the DPIX EQM model in the vacuum chamber. Green rays figure the emitted photons from a radioactive source placed in front the camera in source holder at one end of the vacuum chamber. (*Bottom* EQM camera model) GEANT4 simulated spectrum of the ^{241}Am source.

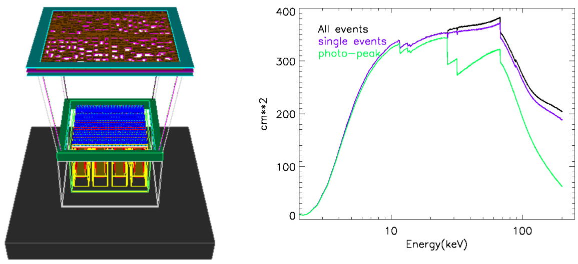

Fig. 4. (*Left*) Mass model of ECLAIRs instrument. The shielding is made transparent. The platform is actually modeled as an aluminum box (black). *(Right*) Total, single-events and photo-peak efficiency (taking into account the mask transparency (40%). In the case of the ECLAIRs pixelated detector, a primary (or its secondaries) can deposit energy either in a single pixel (single event) or in several pixels (multiple events).

2. Summary

We are currently manufacturing the various sub-systems for the camera flight model. A series of performance and calibration measures of the subsystems and the whole camera will be carried out in our testing bench using radioactive sources. Our project schedule is very tight to successfully carry out the various instrumental activities up to the instrument delivery in China at the beginning of 2021 (Godet et al. 2020). We will therefore only be able to test a small number of experimental configurations, limiting ourselves to those that are mandatory. Then, we will use simulations to extend the results to others configurations. To do so, we have built a GEANT4-based toolkit simulator enabling us to model the various experimental setups in order to prepare each test configuration, assess the test duration and to help measuring the instrument performances.

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