Expected Particle Background Observed by STIX Instrument

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ABSTRACT

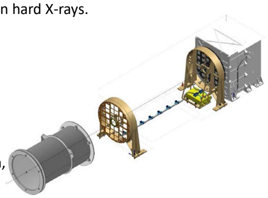
Spectrometer/Telescope for Imaging X-rays is one of the instruments on-board the Solar Orbiter mission. It will be launched in 2020 into heliocentric orbit, with perihelion distance ~0.3 AU. The instrument is a Fourier X-ray imager operating within a range of 4-150 keV. The heliocentric orbit of the spacecraft can be highly affected by streams of solar energetic particle (SEP). This will affect the instrument operation by distorting obtained spectra and will complicate image reconstruction. Therefore we performed Geant4 simulation of particles interaction with the instrument, assuming realistic scenarios SEP events. We calculated direct detectors hits as well as secondary radiation from instrumental parts. We have found that the latter may highly influence measured X-ray spectra and reconstructed images, and have to be taken into account during data reduction.

STIX/Solar Orbiter

Solar Orbiter is ESA/NASA first M-class mission of ESA's Cosmic Vision 2015-2025 programme. It will be launched in 2020 into heliocentric orbit with perihelion distance around 0.3 AU. The main objective of the spacecraft is investigation of the connection between the Sun and the heliosphere. Therefore, there will be performed simultaneously in situ measuremnts, remote high-resolution imaging and spectroscopic observation of the Sun. One of the payload instruments is STIX which provide images and spectra of the Sun in hard X-rays.

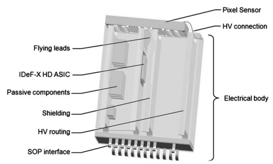
STIX consist of three module:

- X-ray Window, which stop the thermal radiation of the Sun and reject low-energy X-ray photons,
- Imager – 30 pairs of grids with different pitches and orientations which allow obtain X-ray images after Fourier Transform,
- Detector Electronic Module – 32 Caliste-SO detectors with IDPU.



Caliste-SO detector consist of CdTe 1 mm thick sensor and a dedicated fron-end electronics manufactured in 3D Plus technology. The sensor area (100 mm^2) is divided into 12 pixels, which are grouped into four strips. Such configuration allow detect Moiré pattern shape produced by a pair of tungsten grids.

Additionally division of each strip into 3 pixels allow to limit too high photon flux observed during large solar flares by disabling some of them to reduce active area. Entire crystal is also surrounded by a guard ring which reduce edge effects.



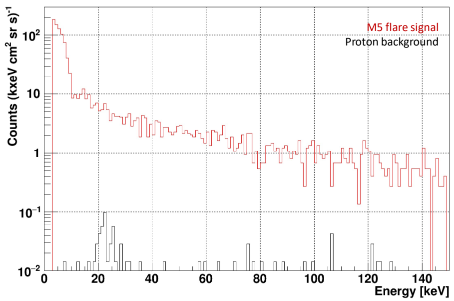
Meuris, A., et al., Nucl. Instrum. and Meth. A 695, 288-292 (2012).

Geant4

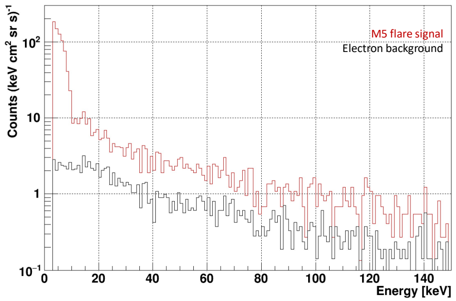
We used Geant4 toolkit to simulate passage particles through the matter with all accompanying physical processes. This software uses Monte Carlo method and allow to implement whole complicated geometry of the simulated instrument. The simulation was extended by detector effects implemented in C++ and compatible with Geant4 [2].

The Geant4 package collects knowlegde of a broad suite of physical models (including electromagnetic, hadronic and optical). They cover a wide range of energies from around 250 eV up to several TeV and existing physical models are being improved and extended continuosly. The toolkit is used in many fields of science like nuclear physics, particle physics, accelerators, space engineering, and medical physics.

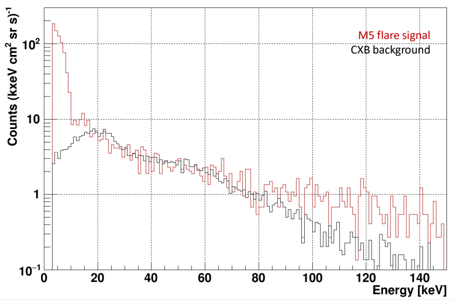
Protons from SEP



Electrons from SEP

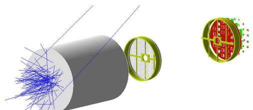


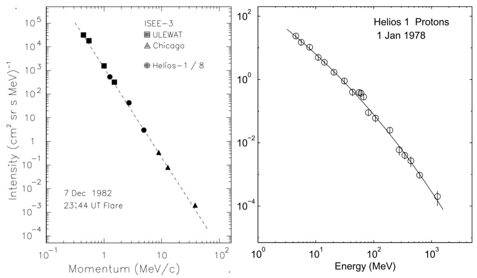
CXB



SEP sources

We took Helios maximum registered flux of electrons (left panel) and protons (right panel). The particles illuminated the whole X-ray window surface under angles from 0 to 90. The angel distribution was homogenous.

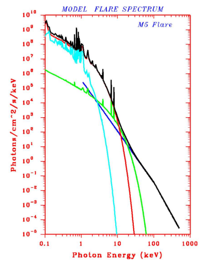




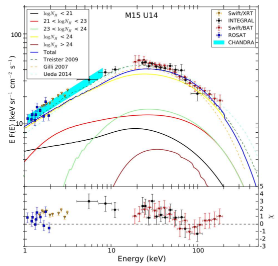
Dröge, W., "Acceleration and Propagation of Solar Energetic Particles" in: Klein KL. "Energy Conversion and Particle Acceleration in the Solar Corona. Lecture Notes in Physics", vol. 612. Springer, Berlin, Heidelberg (2003).

CXB & M5 –Class flare sources

Simulating Cosmic X-ray Background (CXB) we took sources spectra from Esposito (2016) - right panel. In order to compare obtained background levels with solar flux we took solar M5 class flare spectrum with low non-thermal component (left panel). Solar flare x-ray flux in our simulation was originating from a perpendicular direction in respect to the entrance window with deviation equal 1.7 deg. CXB sources were distributed homogenously.



https://www.prl.res.in/~library/submillimeter_and_solar_x.html



Esposito, V., & Walter, R. *A&A, 590*, A49 (2016).

Conclusion

- Background from SEP protons is low (2 times lower than the solar M5 flux)
- Electrons background can influence the data during very strong SEP events. This background can be take into account during data reduction, due to presents of situ instruments measuring particle fluxes on-board Solar Orbiter
- CXB can influence on non-thermal flare emission measurements. The CXB background is steady in time, therefore it could be taken into account during the data reduction.

Referencess

1. J. Barylak, A. Barylak, T. Mrozek, O. Grimm, A. Howard, P. Podgórski, M. Stęślicki, *Simulation of charge sharing in the Caliste-SO detector,* Nuclear Instruments and Methods A, 903, p. 234-240 (2018);
2. J. Barylak; A. Barylak; T. Mrozek; M. Stęślicki; P. Podgórski, *Investigation of cosmic ray and solar energetic particle background of STIX using GEANT4 simulation,* Proc. SPIE 10808, 1080848 (2018);

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