The CUbesat Solar Polarimeter (CUSP) mission overview

Abstract

The space-based CUbesat Solar Polarimeter (CUSP) mission aims to measure the linear polarization of solar flares in the hard X-ray band by means of a Compton scattering polarimeter. CUSP will allow to study the magnetic reconnection and particle acceleration in the flaring magnetic structures of our star. CUSP is a project in the framework of the Alcor Program of the Italian Space Agency aimed to develop new CubeSat missions. It has been proposed as a constellation of a two Cubesat mission to monitor the Sun for Space Weather.

In the frame of CUSP's Phase B study, lasting for 12 months starting September 2024, we present the development status of this dual-phase polarimeter. Preliminary laboratory results using two chains of acquisition will be discussed. The first chain of acquisition, based on the Hamamatsu R7600 multi-anode photomultiplier tubes coupled to plastic scintillator bars and read out by the MAROC-3A ASIC, is used to detect the Compton scattering of incoming photons. On the other hand, GAGG crystals coupled to avalanche photo-diodes with a readout based on the SKIROC-2A ASIC are used to absorb the scattered photons. By reconstructing the azimuthal scattering direction for many incoming photons, one can infer the linear polarization degree and angle of the source.

Motivation for Solar Flare polarimetry

- Studying *Solar Flares* (SFs) in relevant both for solar physics and space weather as solar activity can be disruptive for human technological activities
- SFs are often associated to *Coronal Mass Ejection* (CME) and *Solar Energetic Particle* (SEP) events
- The most powerful eruptions are associated to powerful flares, from which the *soft X-ray* component of the flux is linked to the CME velocity and the hard X-rays to the CME acceleration
- Hard *X-ray polarimetry* can improve the knowledge of the initial conditions of the eruption of powerful CMEs

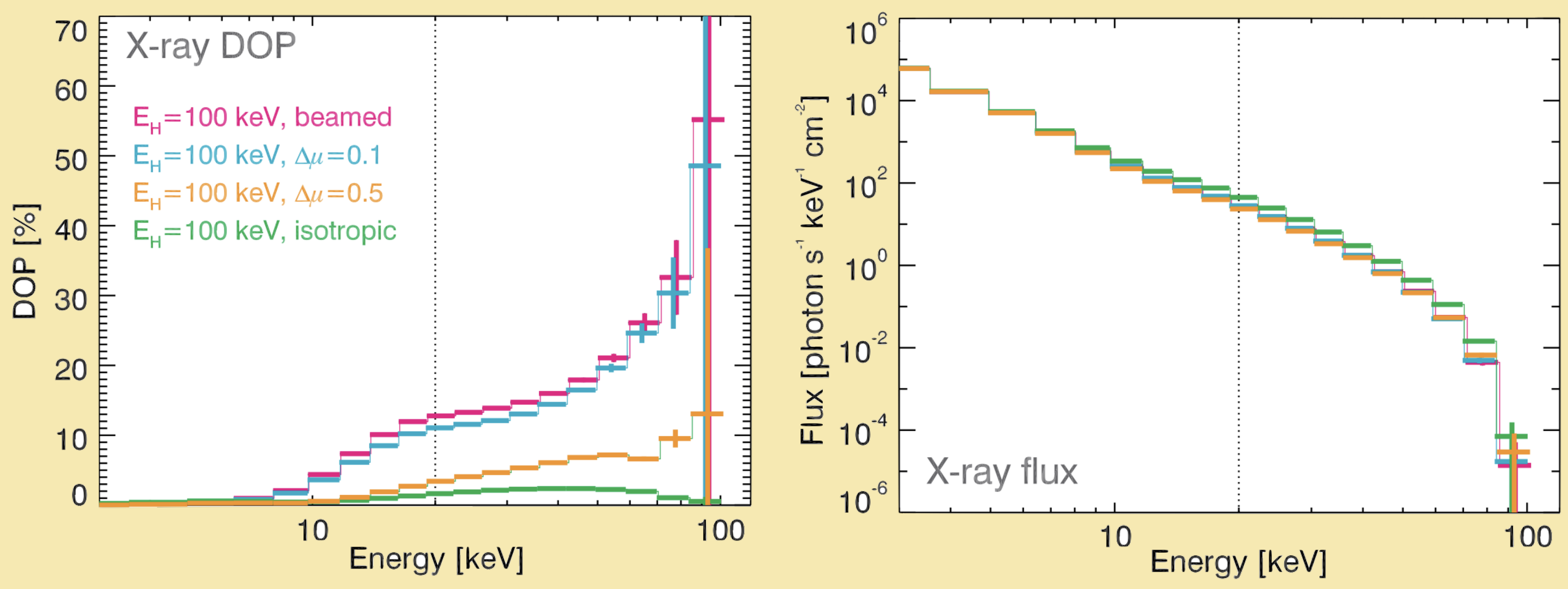

Figure 1: Expected Solar Flare polarization degree (left) and spectrum (right) for different emission models. Taken from [7].

- SFs originate from *magnetic reconnection* in loop structures in the solar corona
- SFs' X-ray spectrum is composed of a *thermal Bremsstrahlung* component and emission lines below 10 keV as well as a *non-thermal Bremsstrahlung* component above 10-20 keV expected to be highly polarized
- X-ray polarimetry (linear) would allow to disentangle degeneracies in models of particle beaming and magnetic field structure (even without imaging of the SF). More details in [1, 2, 3, 4, 5, 6, 7]

The CUSP Mission and Team

- CUSP [10] is part of the *Alcor program* of ASI (Italian Space Agency) for funding the development of Cubesat techonologies and missions
- It is one of the 20 selected missions among 49 proposals
- 2 satellite constellation, 6U Cubesat platform with 2.5U for payload
- Nominal life time of 3 years in LEO (SSO orbit, 500-600 km), 1σ pointing accuracy of $\pm 2^\circ$ peak power $\sim 30\,W$, spurious effects removed by rotating at 1 RPM around pointing axis
- Ground station in Viterbo (IT) with VHF/UHF for uplinking and VHF/UHF/S-band for downlinking
- Collaboration led by *INAF-IAPS* (PI-ship and payload development) with the participation of *INAF-OAS* (Detector Simulation), *INAF-OAR* (Lab-SW support), *IMT s.r.l.* (Platform), *SCAI Connect s.r.l.* (Payload Electronics), *University of Bologna - CIRI AERO* (Mission Analysis), *University of Tuscia* (Ground Segment), and *ASI* (Project Control)

The Payload

- Dual-phase *Compton polarimeter* in the 25-100 keV energy band
- >68% Sun coverage with 2 satellites
- The 64 *scatterers* are made of low-Z plastic scintillators coupled to MAPMTs read out by the MAROC-3A ASIC from WEEROC
- The scatterers are surrounded by 32 *absorbers* coupled to ADPs read out by the SKIROC-2A ASIC from WEEROC
- CUSP will measure SFs' X-ray polarization with a better MDP that any past mission, see Table 1

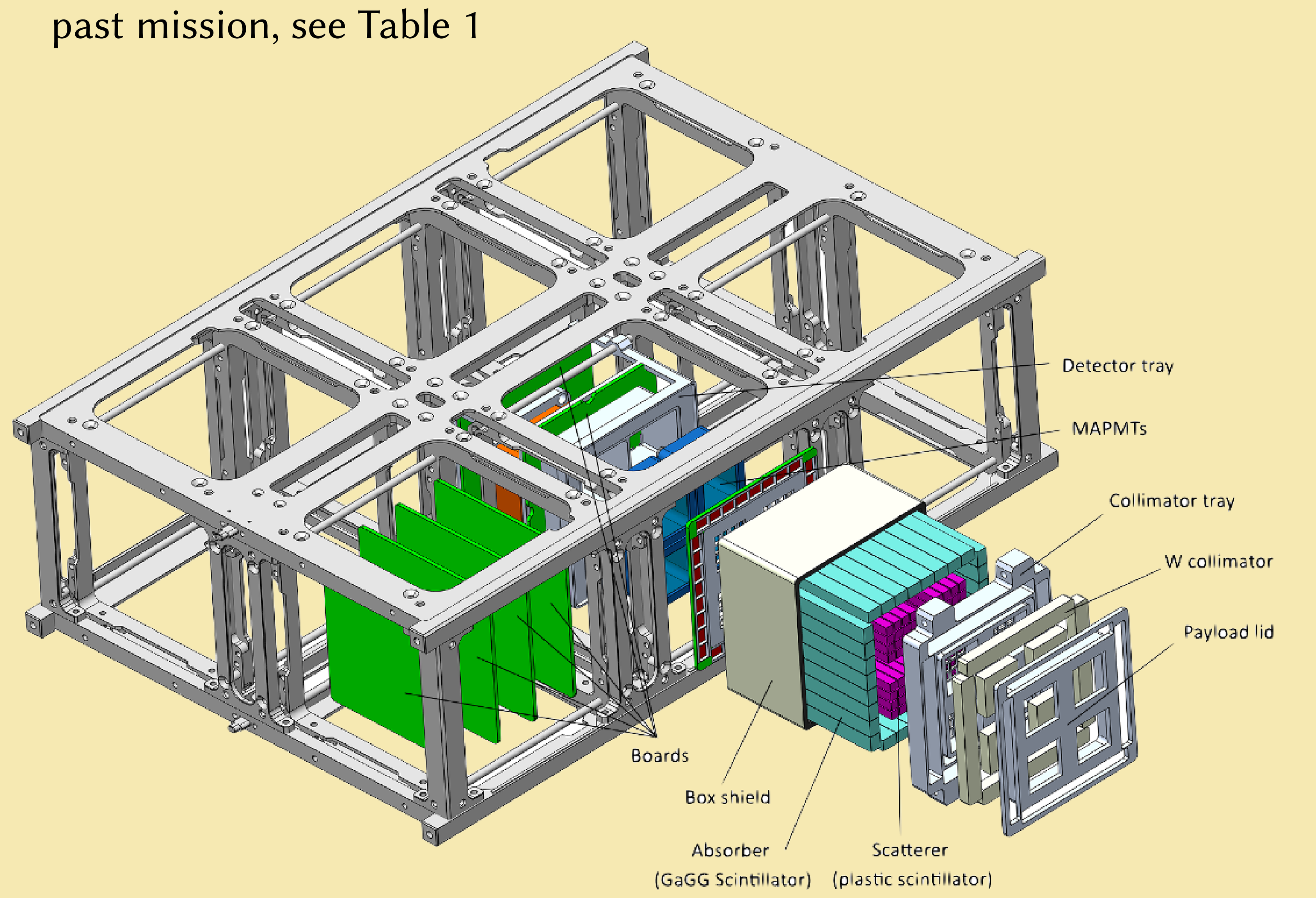

Figure 2: Exploded view of the CUSP CAD design [10]

Flare Class	Integration Time (s)	$MDP_{99\%}$ in the 25-100 keV range (%)
M5.2	284	10.2
X1.2	240	5.9
X10	351	1.1

Table 1: CUSP *Minimum Detectable Polarization* [8, 9] for different classes of flares

Current Status of Laboratory and Simulation Activities

- Geant4 simulations of the detector performances are under development [11], see the simulated effective area in Figure 3
- Scatterer and absorber prototypes are being tested/calibrated [12]

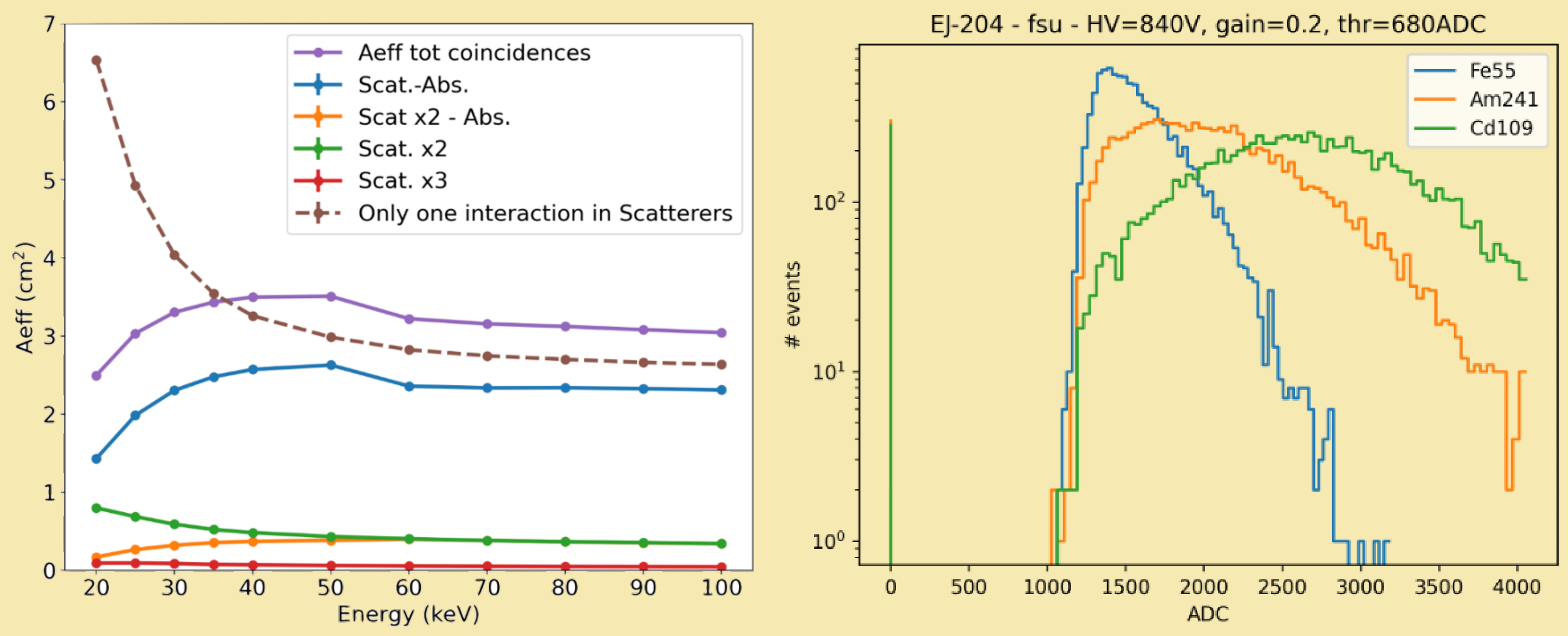

Figure 3: CUSP effective area for several topology of events (left) and measured calibration spectra (Fe55, Cd109, Am241 sources) with a scatterer prototype (right).

Project Status

- A 1-year *phase B* should start in September 2024 to define a preliminary design and deliver a representative payload prototype
- Next step is to propose a combined 15-months *phase C/D*

References

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