1 MeVCube: a CubeSat for MeV astronomy

MeV astronomy: The measurement of X-ray and gamma-ray emission from astrophysical sources has revolutionized our understanding of the most energetic processes in the Universe. Despite the impressive progresses achieved both by X-ray and gamma-ray observatories in the last decades, the energy range between ~ 200 keV and ~ 50 MeV remains poorly explored. *COMPTEL*, on-board *CGRO* (1991-2000), was the last telescope to accomplish a complete survey of the MeV-sky with a relatively modest sensitivity. Missions like *AMEGO* have been proposed for the future, in order to fill this gap in observation; however, the time-scale for development and launch is about 10 years. On a shorter time-scale, a different approach may be profitable: MeV observations can be performed by a Compton telescope flying on a CubeSat.
MeVCube design: *MeVCube* is a 6 U CubeSat (a single unit, 1 U, has a volume of $10 \times 10 \times 11.35$ cm^3) concept currently under investigation at *DESY*. The "core" of the instrument consists of 128 Cadmium-Zinc-Telluride (CdZnTe) detectors, arranged on two layers. Soft gamma-rays in the MeV energy range predominately interact through Compton scattering in the first layer (the scattering zone) and the scattered photon is absorbed in the second layer (the absorption zone). CdZnTe semiconductor detectors are very attracting for this kind of application, due to the high atomic number, density and wide band gap, that ensure high detection efficiency and good spectral and imaging performance at room temperature. In our design, each CdZnTe detector has a volume of $2.0 \times 2.0 \times 1.5$ cm^3 and an 8×8 pixel structure (2.45 mm pitch). The triggered pixel signal gives information on the energy deposited in the detector and the x-y location, while the interaction depth (z location) is reconstructed from the ratio between the cathode and pixel signals. CdZnTe detectors are read-out by VATA450.3 ASICs, developed by *Ideas*. VATA450.3 shows promising performance in terms of dynamic range, noise and linearity, while its low-power design allows to operate the detectors under the power constrains present in small satellites.
Performance evaluation: *MeVCube* response was evaluated through the *Geant4* based simulation toolkit *MegaLib*. The continuum sensitivity, which quantifies the telescope's ability to detect faint sources in presence of background, is calculated based on telescope performance's like background rate, effective area, observation time and angular resolution. Evaluation of the telescope's performance shows that *MeVCube* can cover the energy range between 200 keV and 4 MeV with a sensitivity comparable to the one reached by *COMPTEL* or *INTEGRAL* satellites.
Experimental results: Experimental measurements on a 2.0 cm $\times$ 2.0 cm $\times$ 1.5 cm pixelated CdZnTe detector has been conducted as well. The spectral performance of the detector was investigated with different radioactive sources, and has shown good uniformity for majority of pixels. The measured energy resolution of the detector ranges from $\sim 6\%$ around 200 keV to $< 2\%$ at energies above 1 MeV (expressed in full width at half maximum - FWHM). The spatial resolution of the detector was investigated with a Cesium radioactive source and a collimator. The interaction depth was evaluated selecting events corresponding to the Cesium photo-peak and computing the ratio between the cathode and the anode signals. A spatial resolution of $\sim 1.5 - 1.7$ mm has been obtained.