MeVCube: a CubeSat for MeV astronomy.

G. Lucchetta, giulio.lucchetta@desy.de, DESY Zeuthen

INTRODUCTION: The “MeV gap”

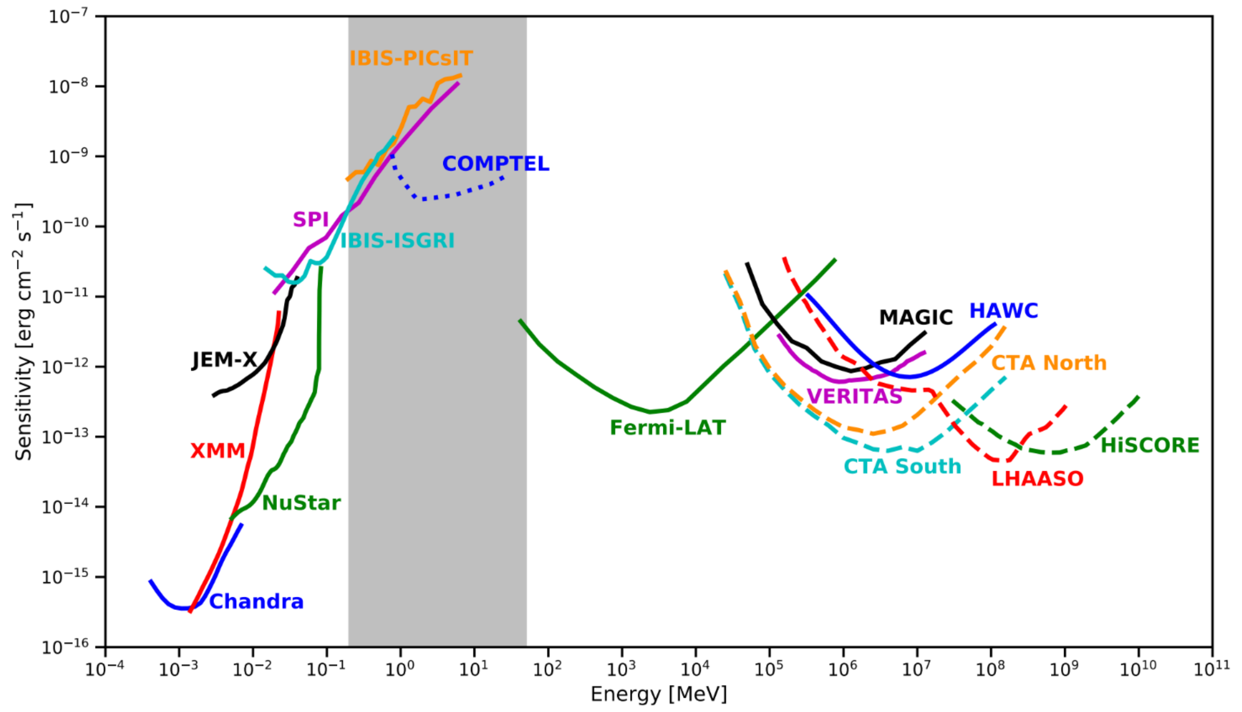

Fig. 1: Continuum sensitivity for different X-ray and gamma-ray instruments.

- Despite the great success achieved by X-ray and gamma-ray observatories in the last decades, the energy range between few hundreds keV and few MeVs remains poorly explored.
- Many missions, like AMEGO [1] and COSI [2], have been proposed, in order to fill this gap in observations.
- What is proposed is a Compton telescope based on the CubeSat standard, with small cost and relatively short development time.

CUBESAT DESIGN AND SIMULATIONS

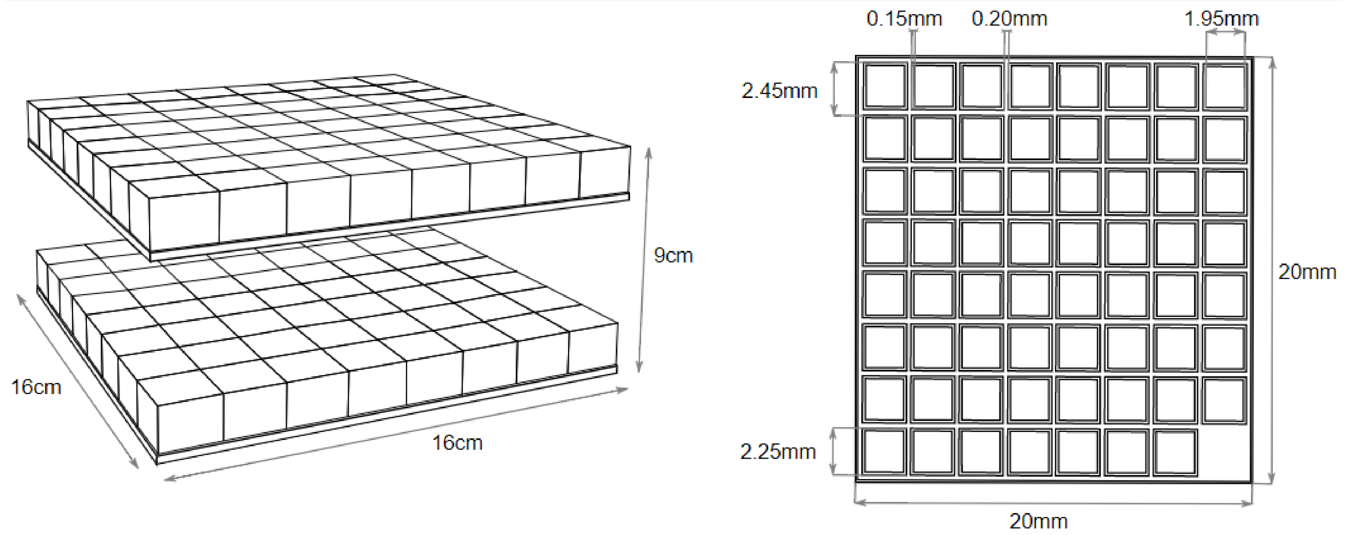

Fig. 2: Schematic model of MeVCube (left) and anode pattern of CdZnTe detectors (right).

- 6U CubeSat model (1U has a volume of 10cm x 10cm x 11.35cm).
- 128 CdZnTe [3] pixelated detectors, on two layers. Each detector is 2cm x 2cm x 1.5cm, with a 8x8 pixel structure.
- CdZnTe detectors ensure good temperature performance, energy resolution and spatial resolution.

- MeVCube response evaluated with the simulation toolkit *MegaLib* [4] and background adapted from [5].
- The continuum sensitivity quantifies the telescope’s ability to detect faint sources in presence of background and is computed based on telescope’s performance like background rate, effective area, observation time and angular resolution.
- MeVCube can cover the energy range between 200keV and 4MeV with a sensitivity comparable to the one reached by COMPTEL [6] and SPI and IBIS on-board the INTEGRAL observatory [7-8].

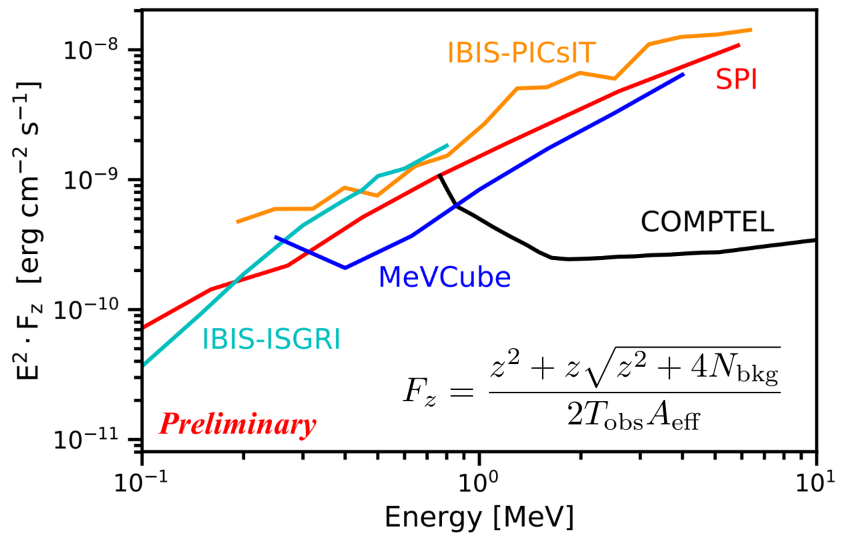

Fig. 3: MeVCube sensitivity for z=3 and 100ks observation time.

EXPERIMENTAL RESULTS: d.o.i correction

Experimental measurement on a 2cm x 2cm x 1.5cm pixelated CdZnTe detector, coupled with VATA450.3 ASIC and a preliminary cathode read-out system, has been performed as well.

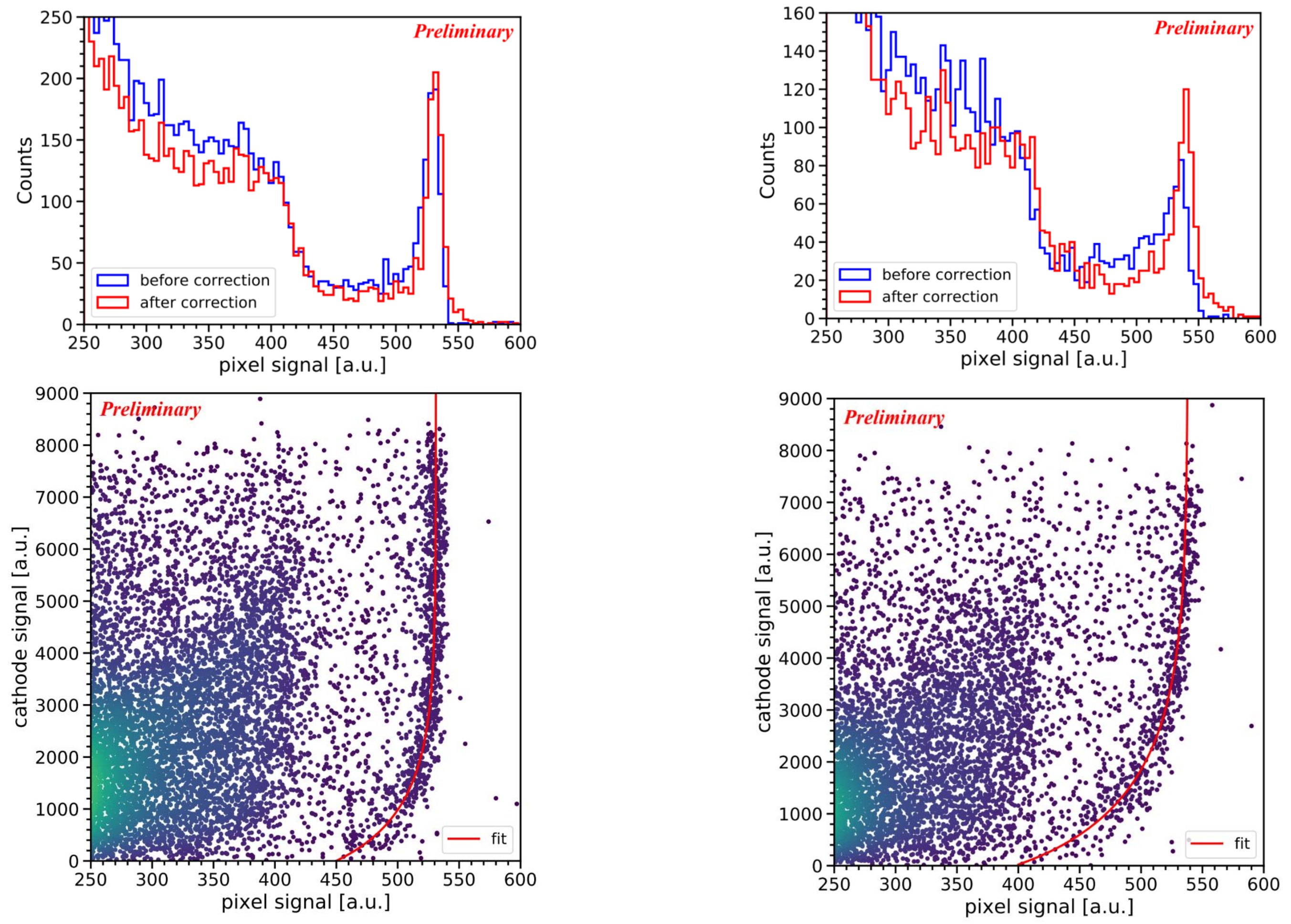

Fig. 4: Energy spectra for a Cs-137 for a couple of selected pixel and illustration of the depth-of-interaction technique .

In thick CdZnTe detectors the measured spectra might exhibit pronounced left tails due to incomplete charge collection and trapping effect. Exploiting the correlation profile between the cathode and pixels signals provide a correction for these effects, enhancing the overall spectral performance of the detector (depth of interaction correction [9]).

EXPERIMENTAL RESULTS: energy resolution

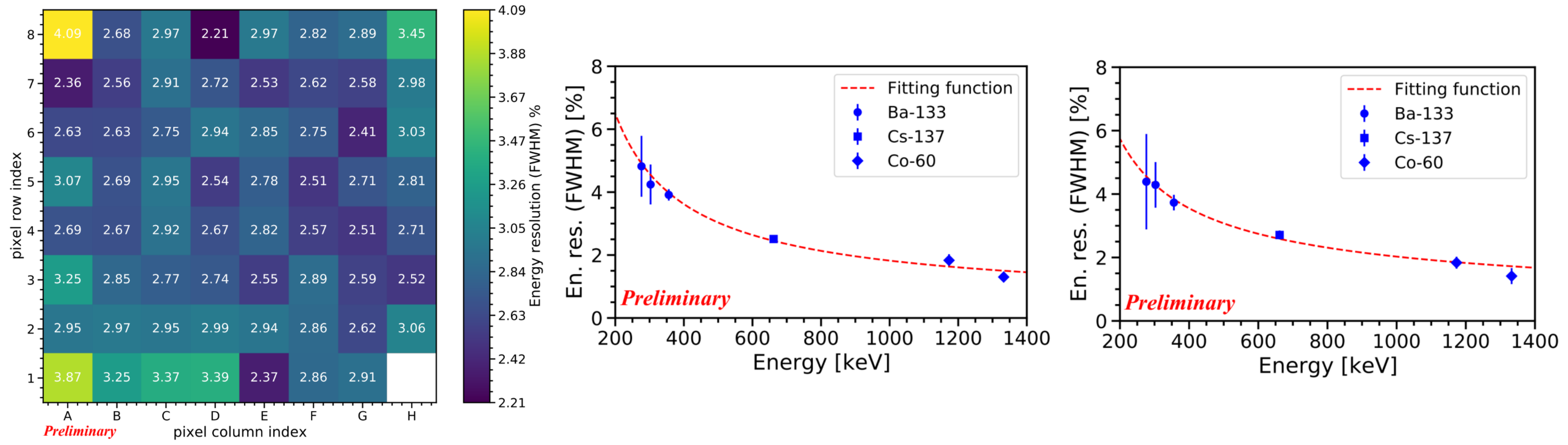

Fig. 5: Energy resolution (in FWHM) measured for all pixels for the 662 keV line of Cs-137, and as a function of energy with different radioactive sources for a couple of selected pixels.

- The spectral performance of the detector was measured with different radioactive sources, showing good uniformity for the majority of pixels.
- The measured energy resolution ranges from about 6% around 200 keV to about 2% above 1 MeV.

EXPERIMENTAL RESULTS: depth resolution

- Spatial resolution of the detector was investigated with a Cs-137 source and a copper collimator. The collimator has a length of 10 cm and a drill of 0.5 mm in diameter.
- The response was preliminary evaluated through a *Geant4* simulation [10]: the gaussian profiles exhibit pronounced tails, due to incomplete photon absorption and effect of the collimator penumbra
- Experimentally the depth resolution was measured selecting the events corresponding to the Cesium photo-peak and computing the ratio between the cathode and the anode signals.
- The depth resolution is about 1.5-1.7 mm (FWHM), after subtraction of the geometrical component due to finite size of the collimator beam.

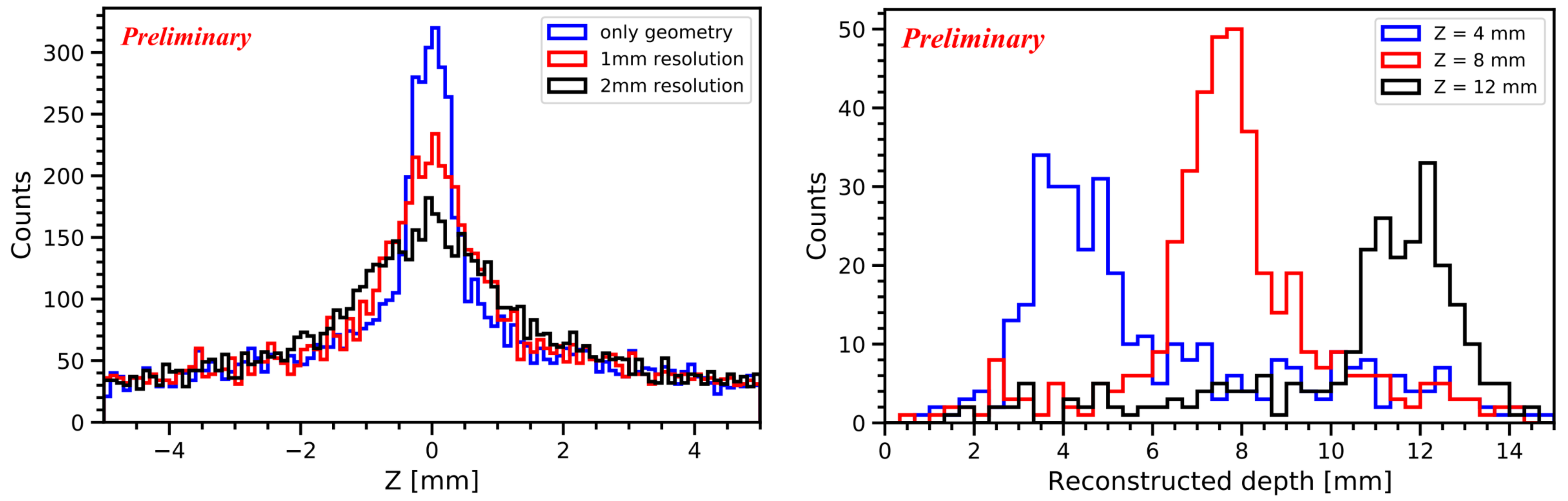

Fig. 6: Interaction depth obtained from a *Geant4* simulation (left) and measured one for three different scanning positions (right).

CONCLUSIONS

1. The viability and performance of a Compton telescope, based on the CubeSat standard, was evaluated: expected sensitivity comparable to the one achieved by COMPTEL and INTEGRAL in the energy range between hundreds keV up to few MeVs.

2. Experimental measurements on a custom design CdZnTe have shown promising results in terms of energy and spatial resolution, validating the requirements imposed in the simulation.

3. Even a small Compton camera, flying on a CubeSat can potentially have its own scientific impact and not only be a technology demonstrator.

REFERENCES

1) Carolyn A. Kierans, in *Proc. of SPIE*, 11444 (2020)

2) J. Tomsick et al., *Bulletin of the AAS*, 51 (2019)

3) T. E. Schlesinger et al., *Mater. Sci. Eng. R*, 32 (2001)

4) A. Zoglauer et al., *New Astron. Rev.*, 50 (2006)

5) P. Cumani et al., *Exp. Astron.*, 47 (2019)

6) V. Schönfelder, *New Astronomy Reviews*, 48 (2004)

7) J. P. Roques et al., *Astronomy & Astrophysics*, 411 (2003)

8) P. Ubertini et al., *Astronomy & Astrophysics*, 411 (2003)

9) A. Shor et al., *Nucl. Instrum. Methods Phys. Res. A*, 428 (1999)

10) S. Agostinelli et al., *Nucl. Instrum. Methods Phys. Res. A*, 506 (2003)