Single Event Effect test results of the ULTRASAT sensors

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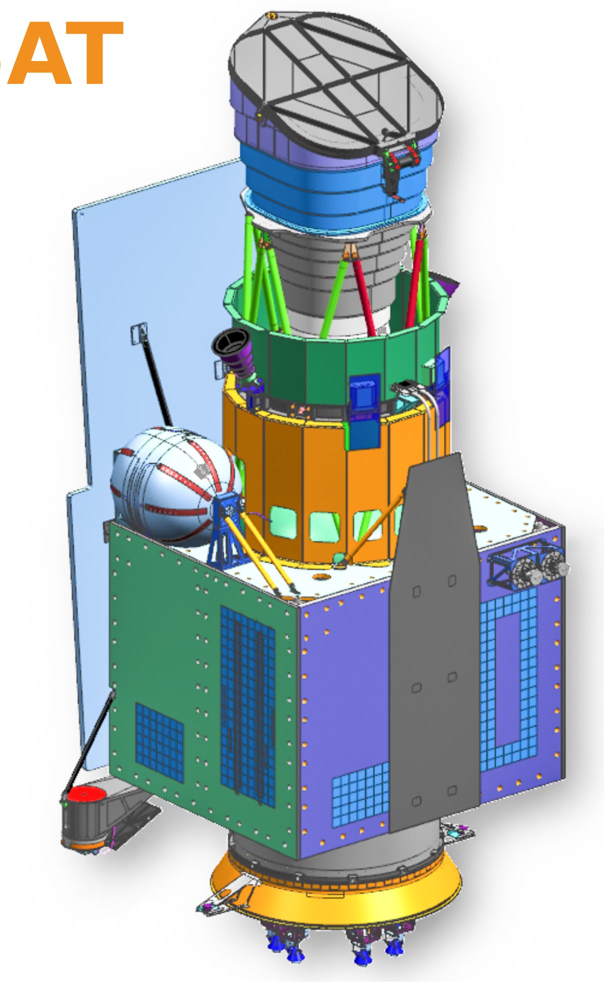

Figure 1: ULTRASAT satellite rendering[2].

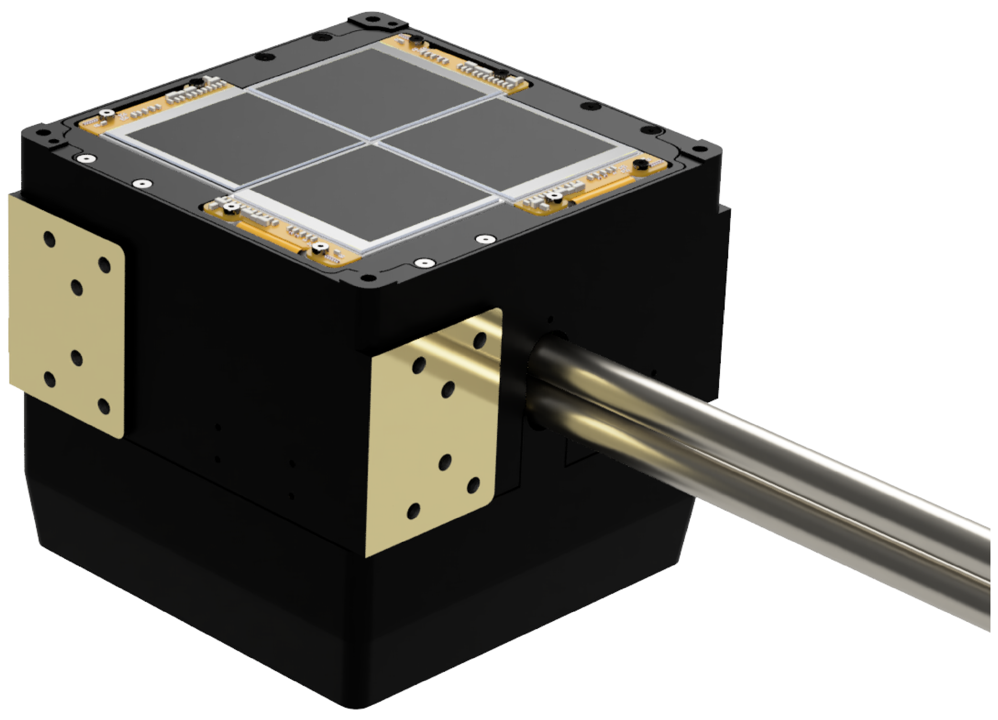

Figure 2: ULTRASAT camera rendering featuring 4 independent CMOS sensors.

The ULTRASAT mission

- First **wide-field, time-domain** survey[1] of the dynamic **near-ultraviolet** sky.
- **Key goals**: counterparts to **gravitational wave** sources and **Supernovae**[3].
- **Launch** to GEO orbit in late **2027** and 3-6 years of orbit operations [4].
- Tower Semiconductor process, 180 nm dual-gain 4T CMOS Imaging Sensor.
- **Camera**: 4 independent tiled sensors in two-butted configuration[5].
- 9.5 µm pixel pitch, 4 µm **Epitaxial** active depth, operated at **200 K**.
- 45 x 45 mm² **large** active **area**, **stitched**, Back Side Illuminated sensors.

Single Event Effect testing

- 12 hours of **heavy ion beam** irradiation at Jyvaskyla RADEF facility[6]. Linear Energy Transfer of ions: 13- 65 MeV cm²/mg.
- Irradiations performed in air on 2 DUTs. Several 25 µm thick Kapton tapes used for **enhancing** particles **LET's**.
- 2 x2 cm² square beam scanned over two "**Sectors**" of the ULTRASAT sensor.
- Upset and latchup's detected only in one sensor sector → Most probable culprit, the **digital domain**.

Figure 3: ULTRASAT sensor stitching diagram: **A,B,C,F,I**- seal rings; **D**- Row Decoders; **E**- Pixel array; **G**- digital block; **H**- ADC

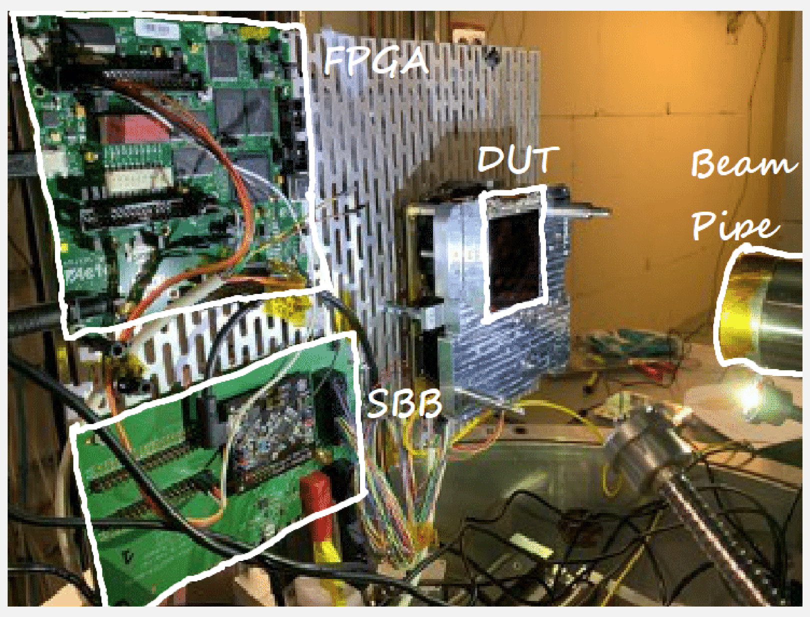

Figure 4: Set-up at the RADEF facility.

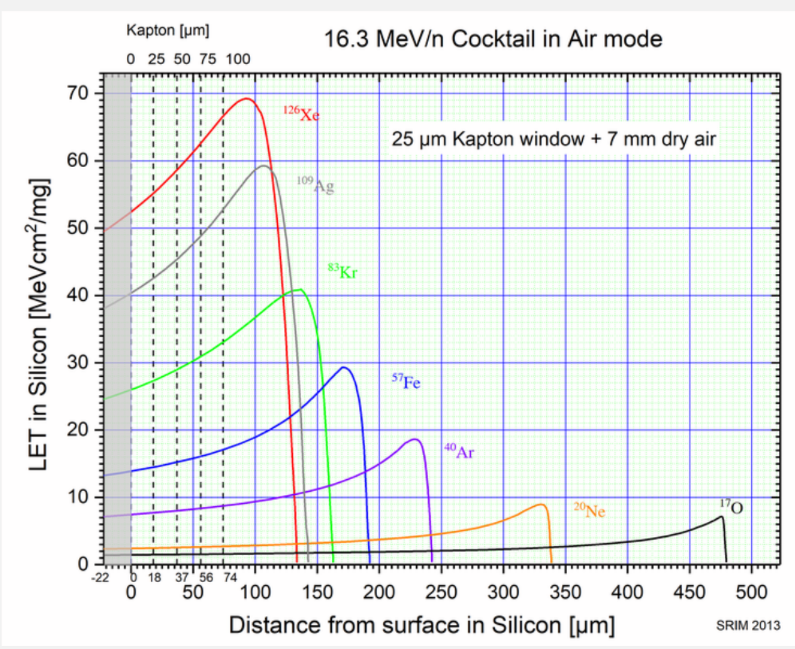

Figure 5: Heavy ion beam cone LET curves used during the experiment.[6]

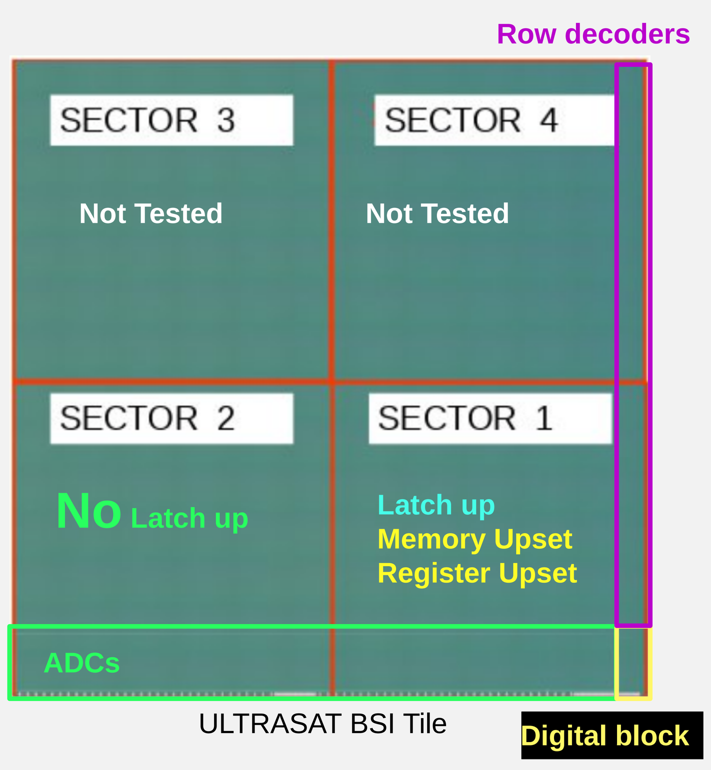

Figure 6: The 4 sectors of the ULTRASAT sensor

Single Event Upsets

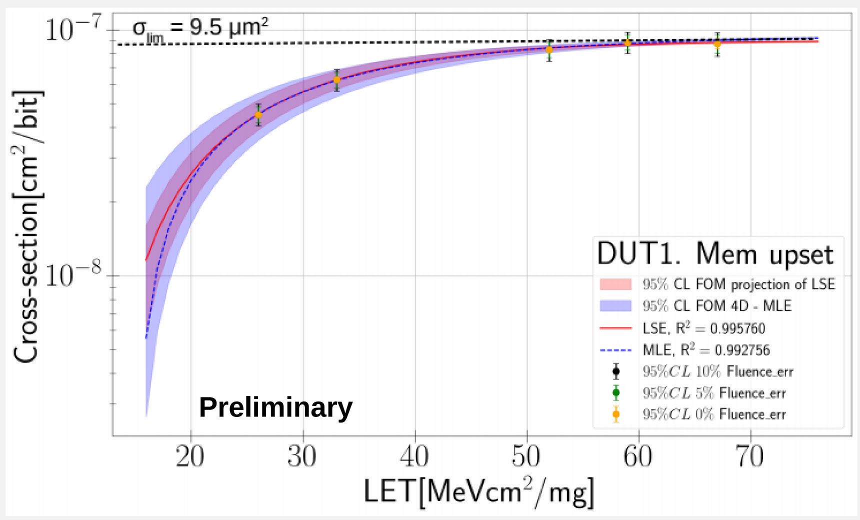

Figure 7: SEU cross-section data for the ULTRASAT sensor.

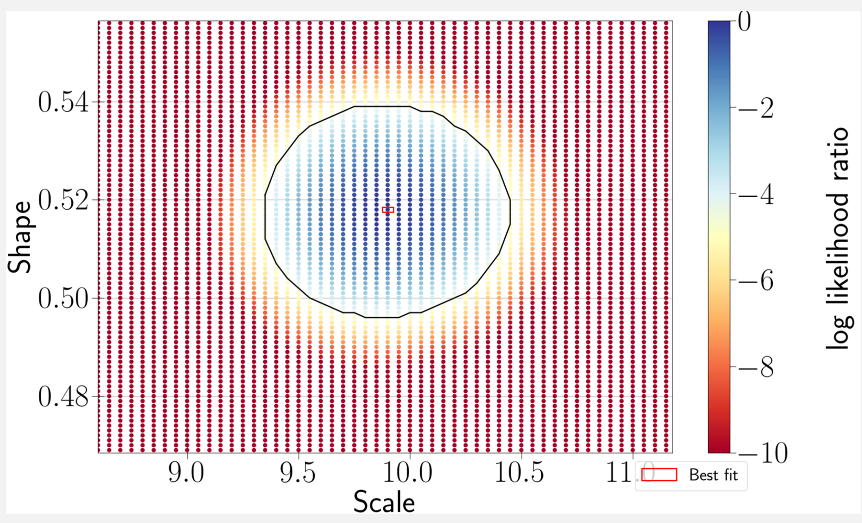

Figure 8: 2D parameter space scan of the shape and scale fit parameters.

- Memory cell array of 768 x 9 bit latches (90.25 µm² footprint).
- Maximum Likelihood Estimation fitting method (→ 99 % R²) w/ 4-parameter Weibull function.

$$f(x) = \sigma_{\lim}(1 - e^{(-(x-LET_0)/l)^k})$$

Single Event Latch-ups

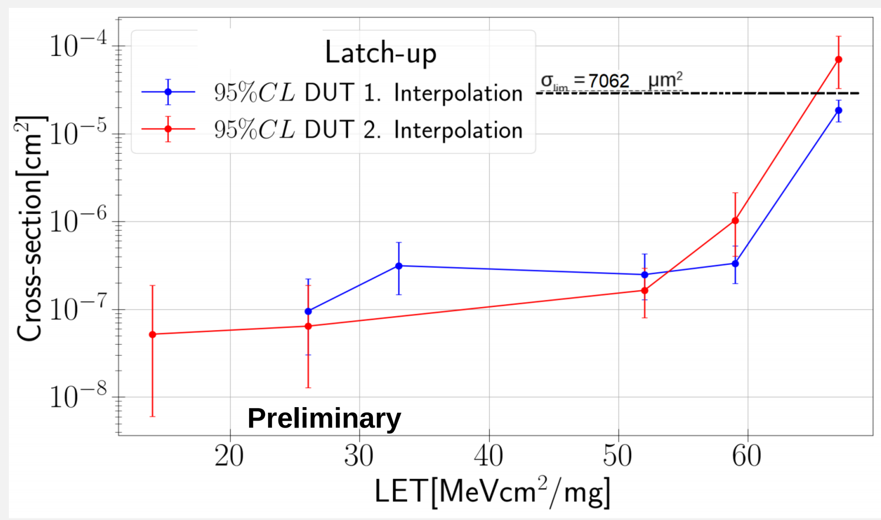

Figure 9: SEL cross-section data for the ULTRASAT sensor.

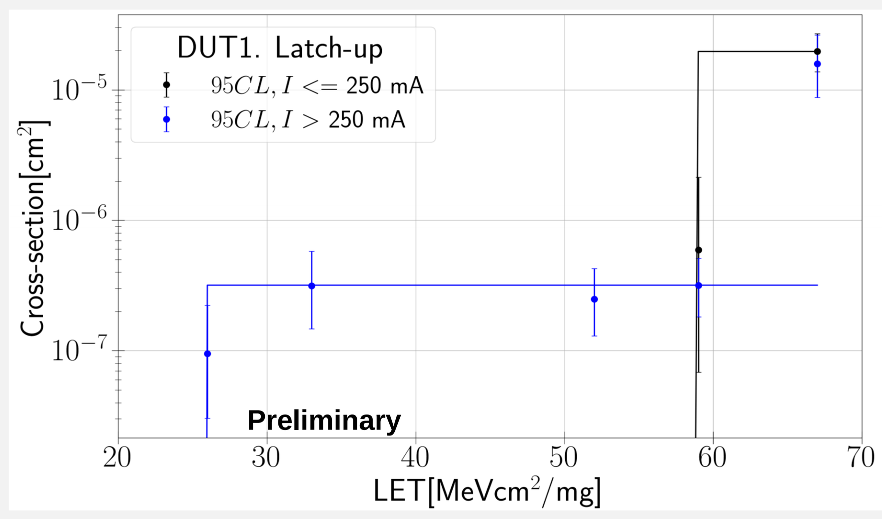

Figure 10: SEL X-section fitted w/ a step function for low/high over-currents.

- On-chip micro controller, digital circuitry (10 mm²).
- The latch-up cross-section shows an exponential increase at large LET's.
- **Hypothesis**: 2 latch-ups: Over-currents > 250 mA (high current) and <250 mA (low current).
- Measurements at room temperature → smaller X-section expected at operational temp. (200 K)

Rate prediction

- **Goal**: predict the number of SEE's during mission time:

$$R = \int\int\int f(L,\Theta,\Phi) \cdot S(Q_C/L,\Theta,\Phi)\, \sin\Theta\, dL\, d\Theta\, d\Phi$$

- **Simulate** the in-orbit flux:
  - Solar particle flux (ESP-PSYCHIC H-U)
  - Trapped proton flux (AP-8 MIN)
  - Galactic Cosmic Ray flux (CREME96 Solar Minimum)
- **Fit** the cross-section data.
- **Extrapolate** data for all angles(Chordlength Model): $dR = A * C(l) f(L) dL dl$
- **Predict** conservative SEE rate estimates based on the data.

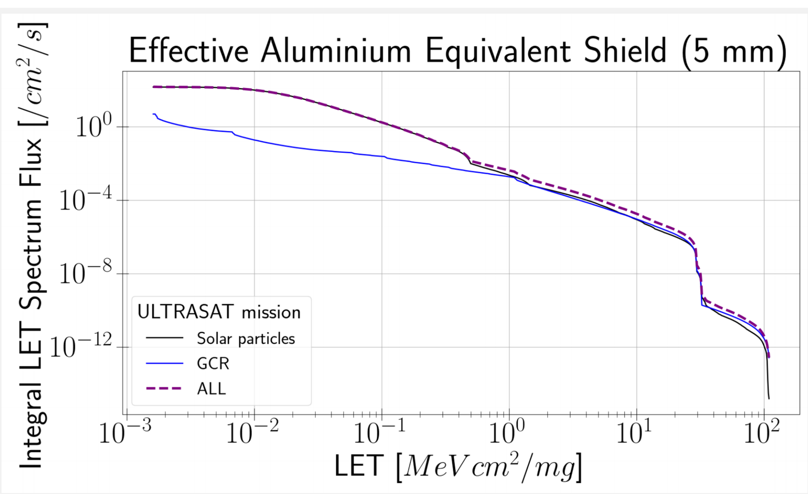

Figure 11: Integral particle flux simulated at the GEO orbit.

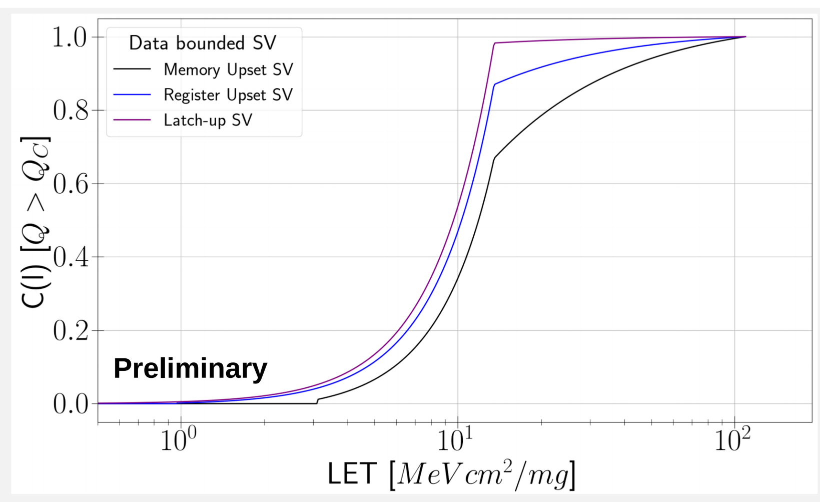

Figure 12: Critical particle length (chordlength) distribution.

SEE	Predicted Rate [# of events/ 3 years mission]
SEU	2
Low Current SEL	8.09 E-4
High Current SEL	4.03 E-3

- **Protection mechanism** (SW and HW)
- **Upcoming** campaign - extend the measured parameter space at high/lower LET's

References:

[1] https://www.weizmann.ac.il/ultrasat/

[2] https://www.iai.co.il/commercial

[3] ULTRASAT: A wide-field time-domain UV space telescope – Y. Shvartzvald et al.

[4] The scientific payload of the Ultraviolet Transient Astronomy Satellite (ULTRASAT) – Sagi Ben-Ami et al.

[5] Design of the ULTRASAT UV camera – A. Asif et al.

[6] https://www.jyu.fi/

16th Pisa Meeting on Advanced Detectors