



Risk assessment of SEE events due to high energy electrons during the JUICE mission

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ESA contract ref. AO/1-8191/15/NL/KML

▪ **SEE risk assessment for space projects**

➤ **Particle beam testing**

- Heavy ions
- High energy protons

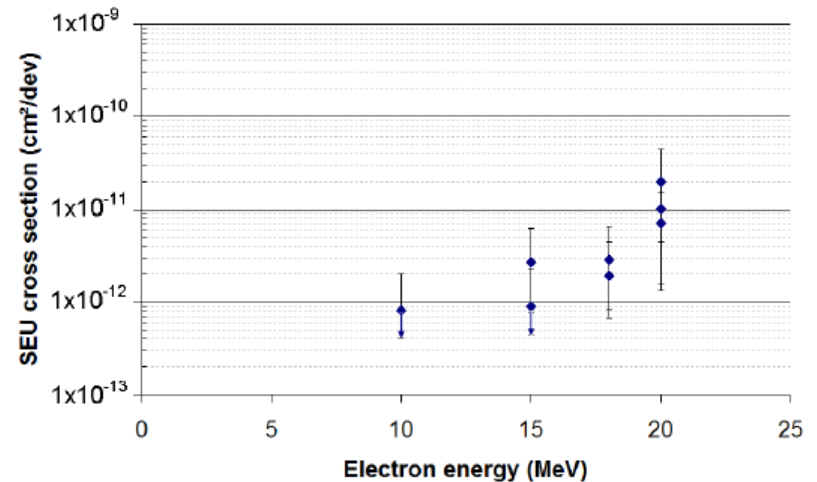
➤ **SEE rate calculation**

- Mission environment (GCR, solar particles, trapped protons)
- Omere, Spenvis, Creme...

▪ **Studies have demonstrated potential SEE sensitivity**

➤ **Electrons**

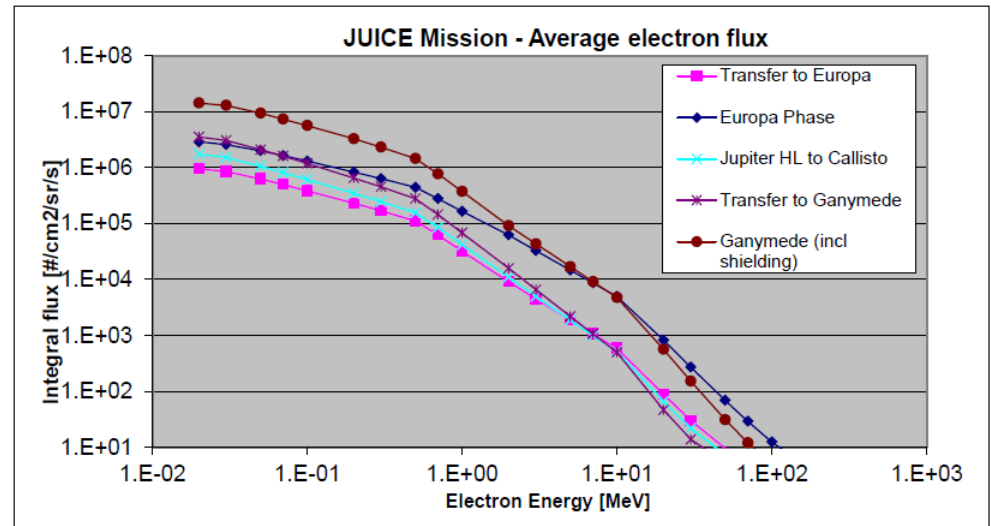
➤ **Low energy protons (direct ionization)**



A. Samaras et al. NSREC 2014

Juice mission

- Significant high energy electron fluxes
- SEE electron risk has to be investigated



Juice env. specification iss. 5.3

Aim of the study

- Measure experimentally all these contributions
 - Standard and “new” effects
- On the same devices
- Calculate the corresponding SEE rates
- Put in evidence the predominant contributions

▪ Device selection

- ▶ **SRAM technology memory for SEU testing**
 - Basic technology and event type
- ▶ **High integration level (below 45 nm tech. node)**
 - Potentially sensitive to electrons and low energy protons
- ▶ **Can be put under operation with significant distance between control board and device under test**
 - High energy electron and proton tests
- ▶ **Can be delidded**
 - Heavy ions and low energy proton tests
- ▶ **Commercially available**

Reference	Artix 7 XC7A35T-1CPG236C	R1QBA7218ABG-22IB0	Spartan 6 XC6SLX9-TQFP144
Manufacturer	Xilinx	Renesas	Xilinx
Function	SRAM based FPGA	DDR SRAM	SRAM based FPGA
Package	CPG236	165FBGA	TQFP144
Techno	28nm	45nm	45nm

- **Artix 7 Xilinx FPGA**
 - ▶ High integration scale (28nm)

- **R1QBA7218A Renesas memory**
 - ▶ Commercially available 45nm SRAM memory
 - ▶ High frequency synchronous device
 - Frequency operation can be reduced via internal PLL disabling...

- **Spartan 6 Xilinx FPGA**
 - ▶ Electron and low energy protons sensitivity already demonstrated
 - ▶ ESA/CNES collaboration
 - Test-bed developed by TRAD for the CNES on previous studies and shared for this project
 - Test results shared by the ESA with the CNES

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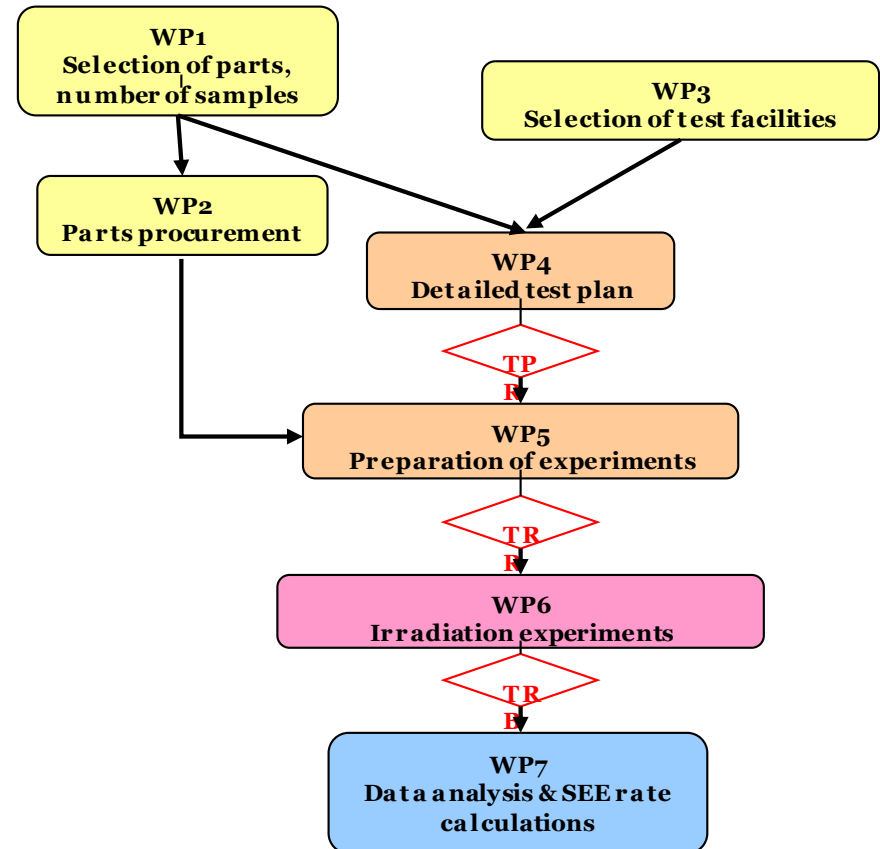
- **Heavy ions and high energy protons**
 - Plenty of existing adapted facilities in Europe
- **Low energy protons**
 - **Proton direct ionization tests already performed at European facilities**
 - CNA (Centro Nacional de Aceleradores, Spain)
 - RADEF (RADiation Effects Facility, Finland)
- **High energy electrons**
 - **Several existing facility, different beam maturity levels...**
 - **Has to be related to electron SEE experimental problems**
 - Total dose deposition
 - Potential dose rate device sensitivity

Tests already performed

- **Electrons $E < 20$ MeV**
 - NPL July 2016
- **Heavy ions RADEF**
 - RADEF August 2016
- **High energy protons**
 - PSI March 2017

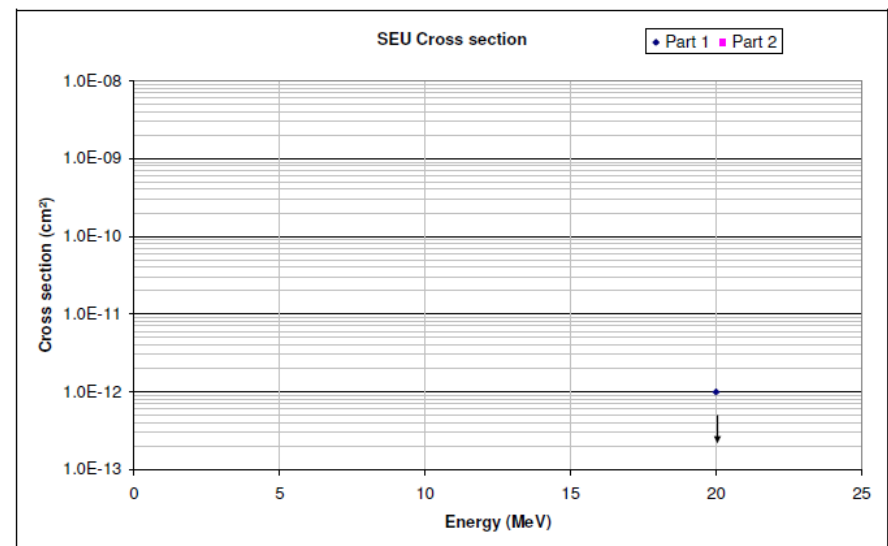
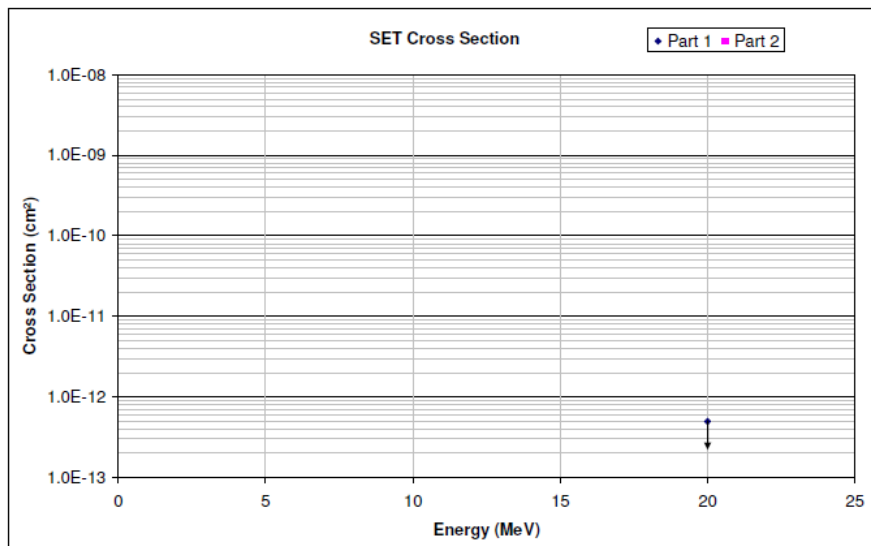
Tests still to do...

- **Low energy protons**
- **High energy electrons**



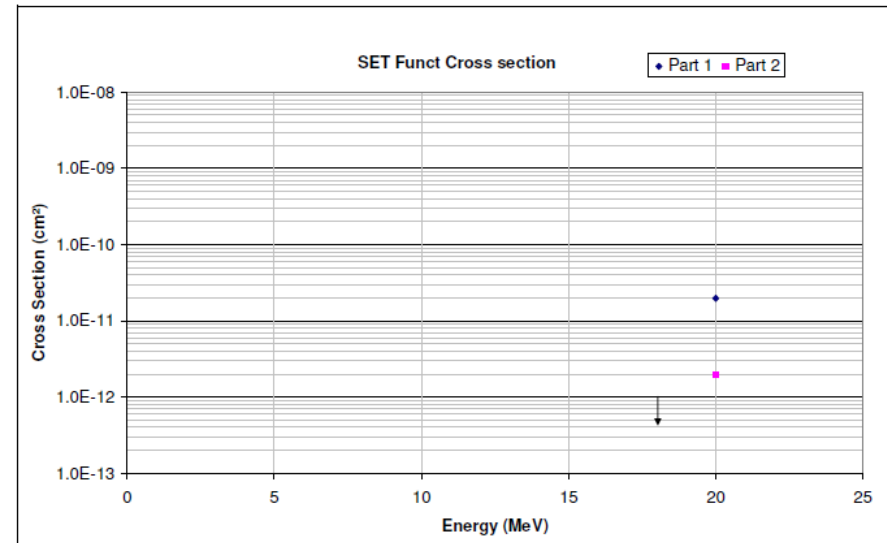
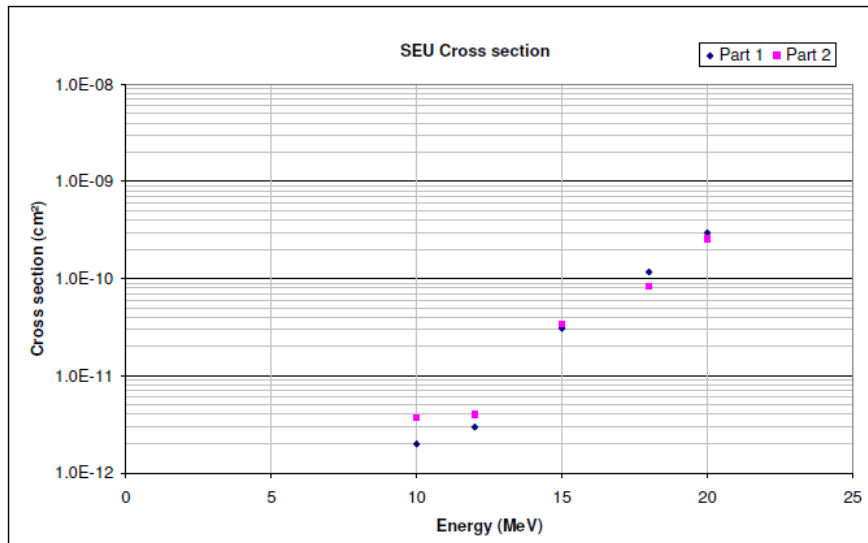
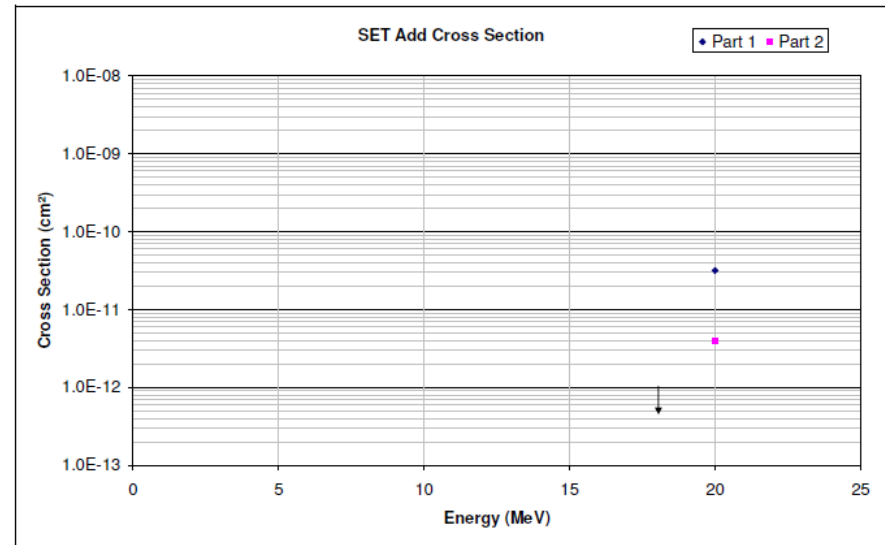
Artix-7 FPGA

- Sensitive to electrons
- Very few events, only observed at 20 MeV (max. incident energy tested)
- 2 SEU and 1 SET
- No MBU, SEFI or SEL under electrons < 20 MeV



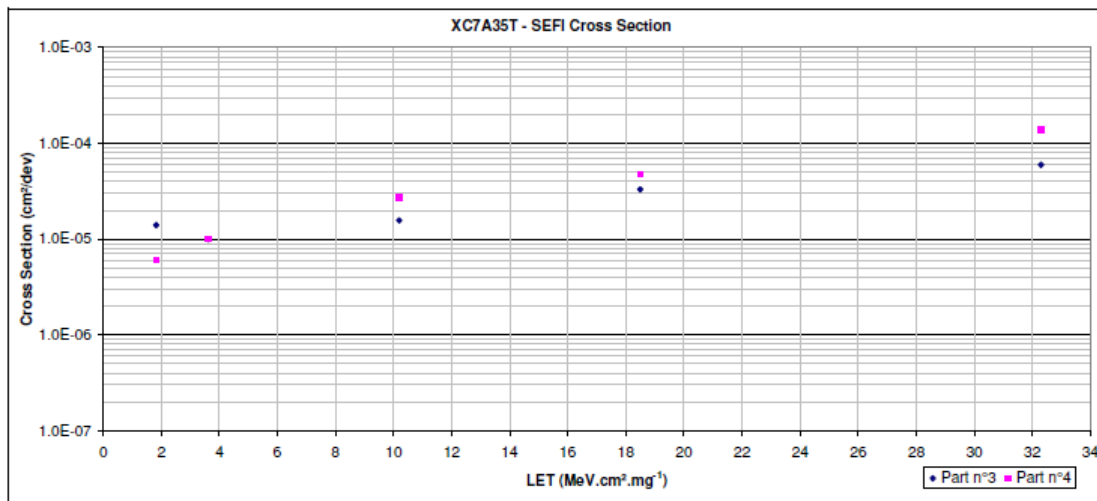
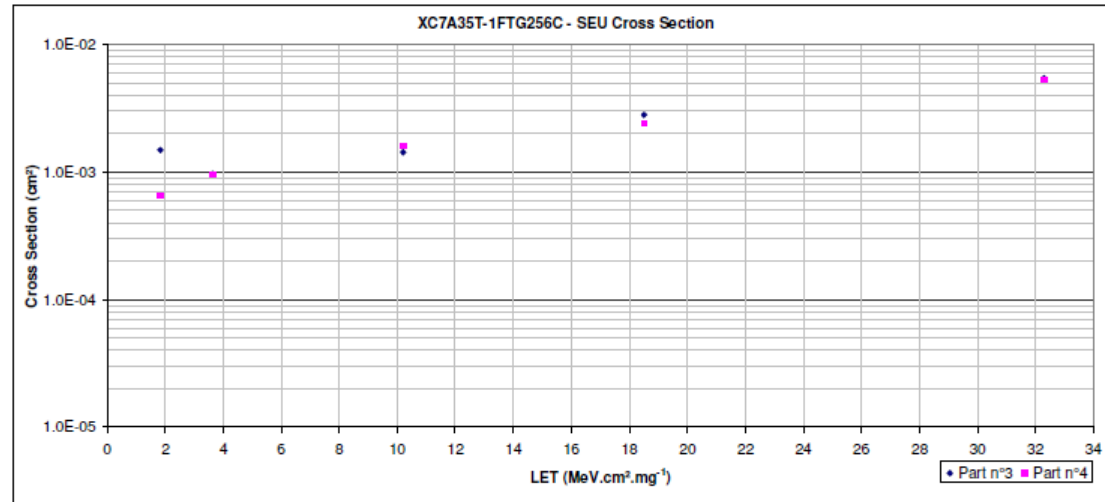
■ Renesas sync. SRAM memory

- **Sensitive to electrons**
 - Interesting sensitivity
- **SET only observed at 20 MeV**
- **SEU $E_{th} < 10$ MeV**
- **No MBU, SEFI or SEL under electrons < 20 MeV**



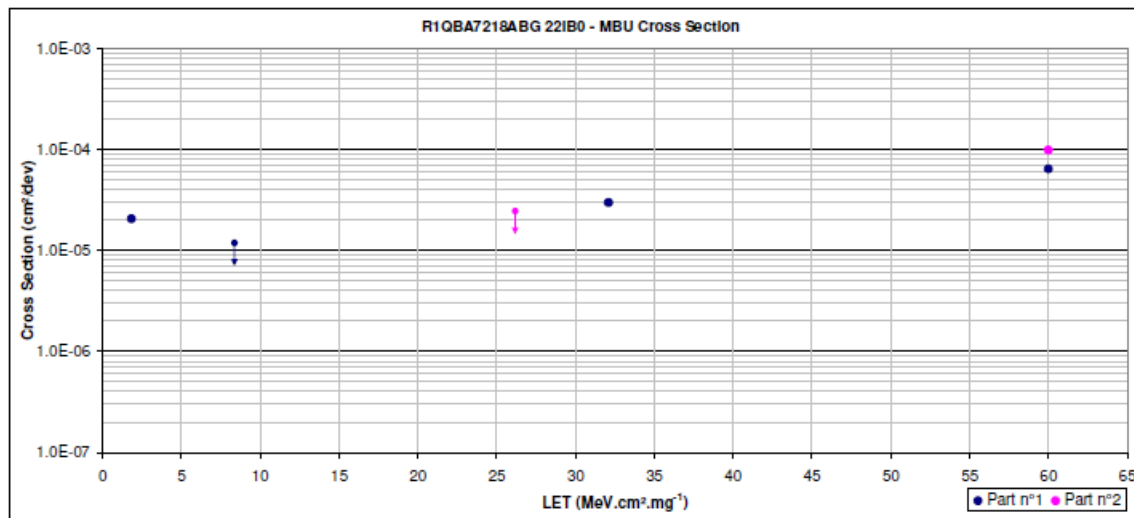
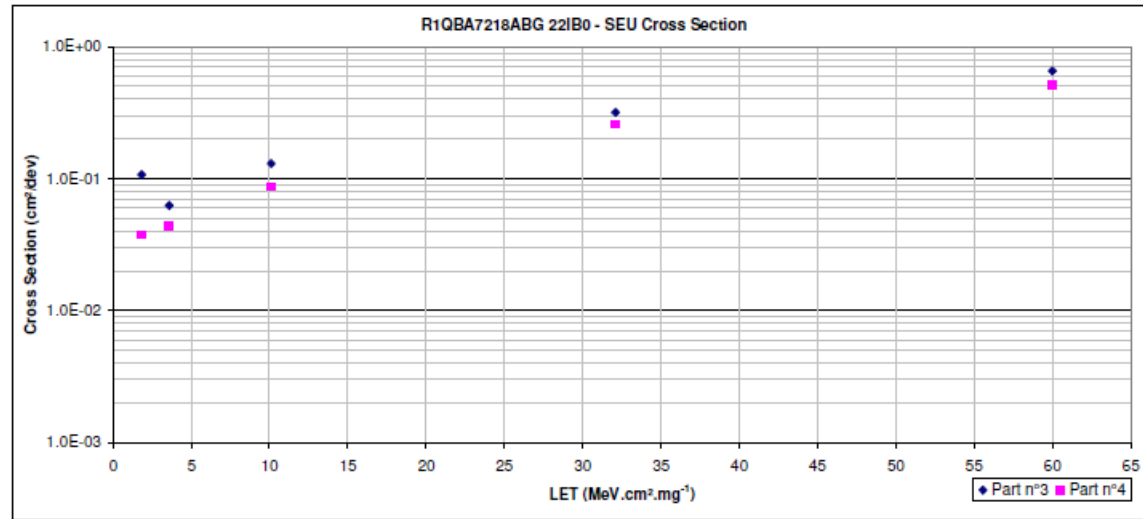
Artix-7 FPGA

- SET very few events but $L_{th} < 3.6 \text{ MeV.cm}^2.\text{mg}^{-1}$
- SEU $L_{th} < 1.8 \text{ MeV.cm}^2.\text{mg}^{-1}$
- SEFI $L_{th} < 1.8 \text{ MeV.cm}^2.\text{mg}^{-1}$
- No MBU or SEL under heavy ions up to $32 \text{ MeV.cm}^2.\text{mg}^{-1}$



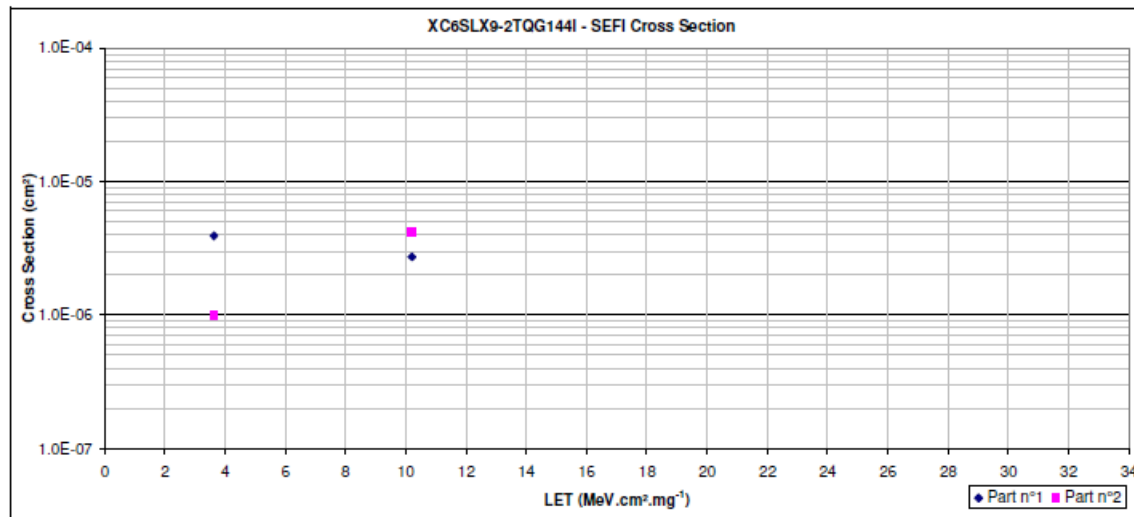
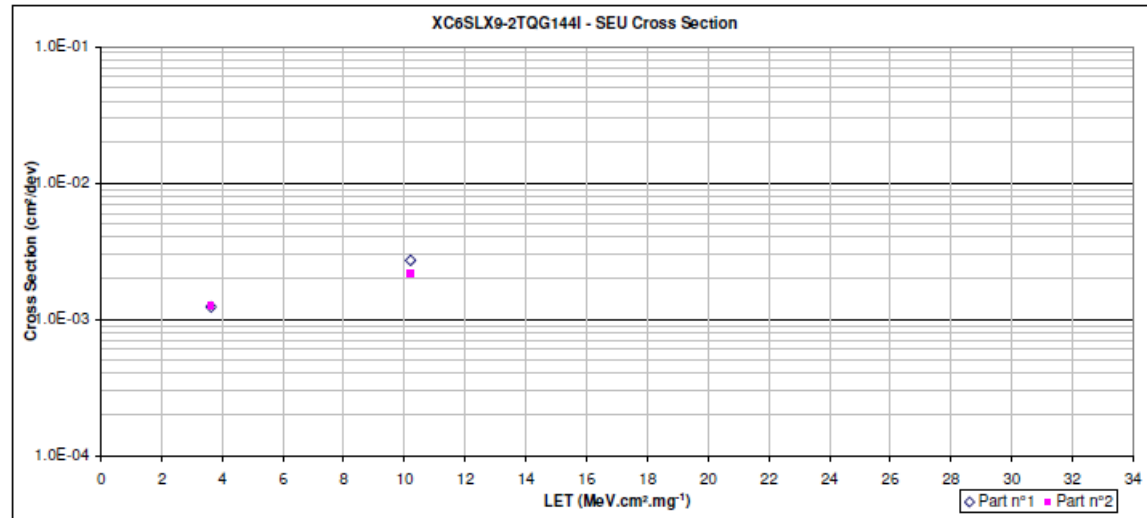
■ Renesas sync. SRAM memory

- SET only observed at $60\text{MeV.cm}^2.\text{mg}^{-1}$
- SEU $L_{th} < 1.8\text{MeV.cm}^2.\text{mg}^{-1}$
- MBU $L_{th} < 1.8\text{MeV.cm}^2.\text{mg}^{-1}$
- No SEFI or SEL under heavy ions up to $60\text{MeV.cm}^2.\text{mg}^{-1}$



Spartan-6 FPGA

- **Partial cross-section**
 - Only 2 LET values
- **SEU $L_{th} < 3.6 \text{ MeV.cm}^2.\text{mg}^{-1}$**
- **SEFI $L_{th} < 3.6 \text{ MeV.cm}^2.\text{mg}^{-1}$**
- **No MBU, SET or SEL under heavy ions up to $10 \text{ MeV.cm}^2.\text{mg}^{-1}$**



- **Test campaign in progress**
 - ▶ 3 test-beds
 - ▶ 5 test facilities

- **The 3 selected devices an interesting sensitivity**
 - ▶ All sensitive to electrons

- **Data analysis has also been started with the already collected test data**
 - ▶ Calculate the rates for all contributions in the Juice environment
 - ▶ Assess the impact of electrons compared to others

- **Next important step...**
 - ▶ 100 MeV electron test