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

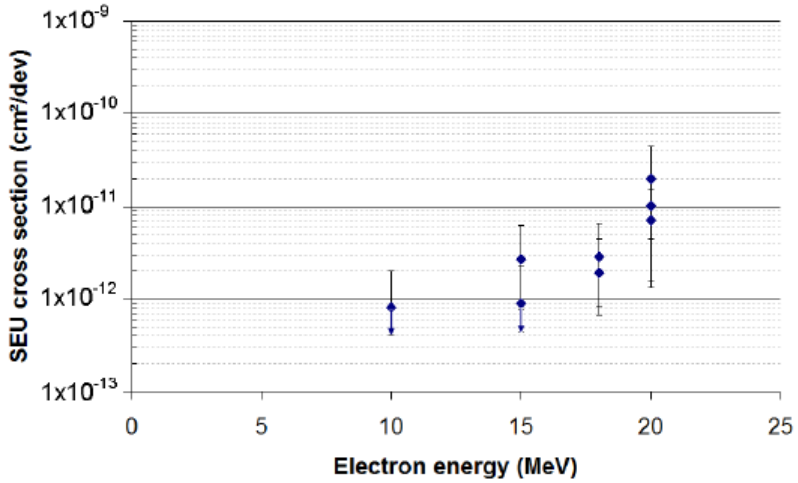
N. Sukhaseum, A. Varotsou, B. Vandevelde and C. Boatella-Polo

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

Introduction

- **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…

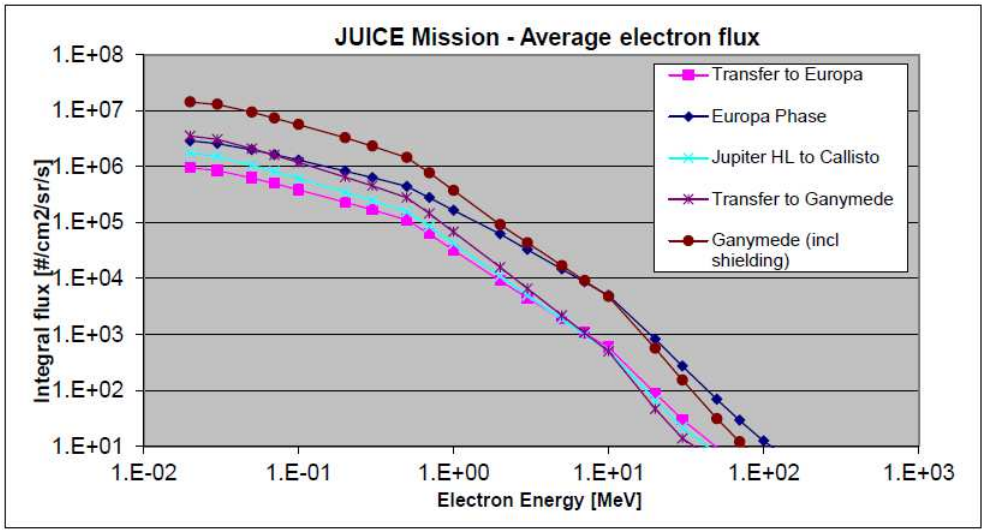
- **Studies have demonstrated potential SEE sensitivity**
  - **Electrons**
  - **Low energy protons (direct ionization)**



A. Samaras et al. NSREC 2014

Introduction

- **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

Devices Under Test

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

Devices Under Test

- **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 desabling…

- **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

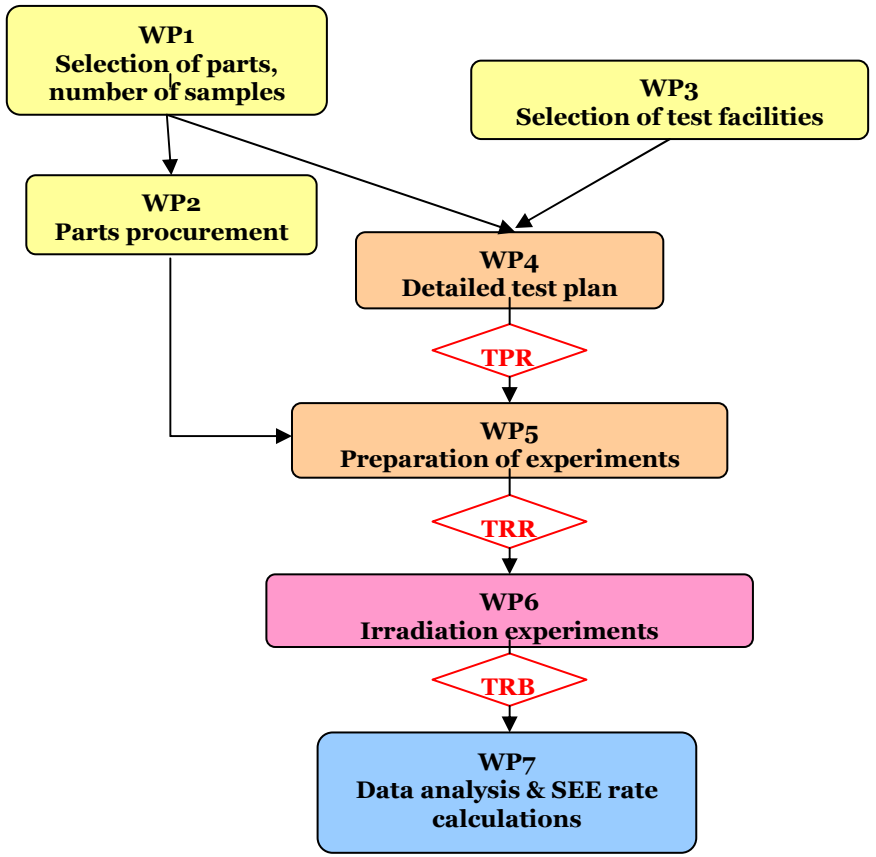
Reference	Artix 7 XC7A35T-1CPG236C	R1QBA7218ABG-22IB0	Spartan 6 XC6SLX9-TQFP144
Manufacturer	Xilinx	Renesas	Xilinx
Function	SRAM based FPGA	DDR SRAM	SRAM based FPGA
Package	CPG236	165FBGA	TQFP144
Techno	28nm	45nm	45nm

Test Facility Selection

- **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

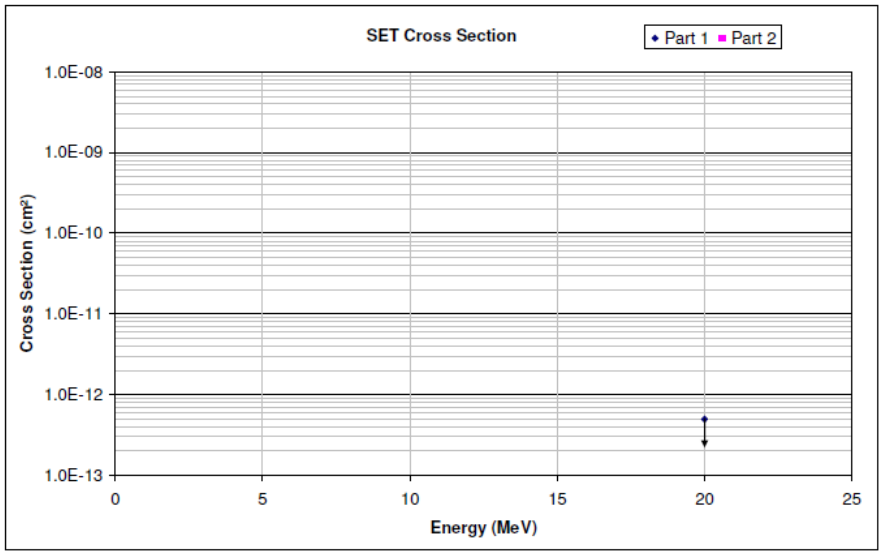
Study Progress

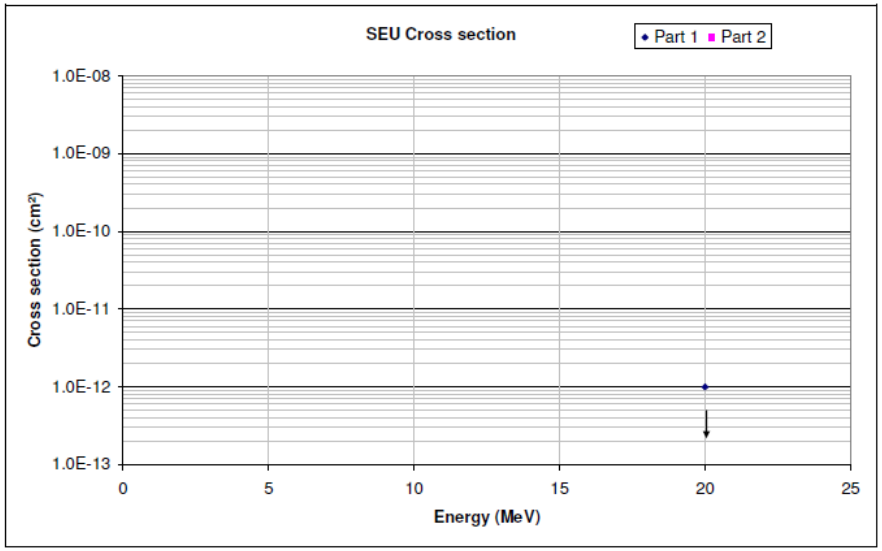
- **Tests already performed**
  - Electrons E < 20 MeV
    - NPL July 2016
  - Heavy ions RADEF
    - RADEF August 2016
  - High energy protons
    - PSI March 2017
- **Tests still to do…**
  - Low energy protons
  - High energy electrons



Electron Test Results

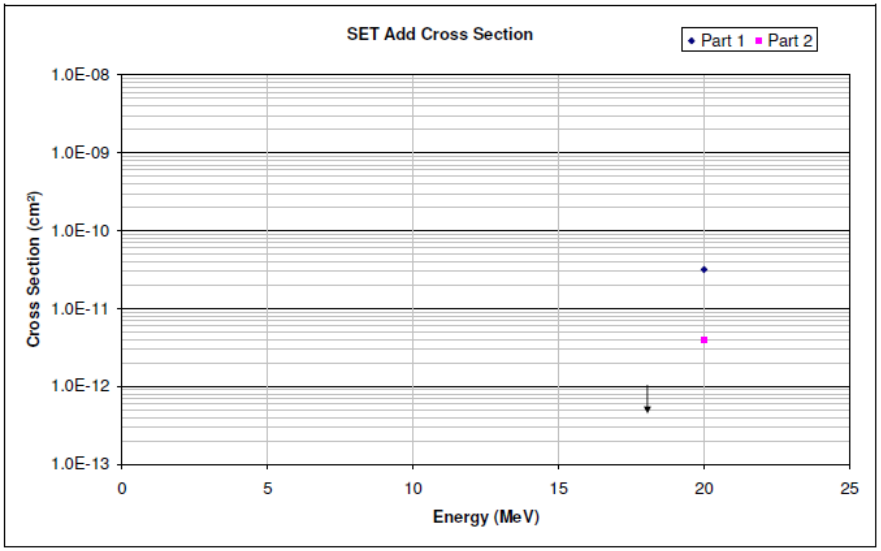
- **Artix-7 FPGA**
  - Sensitive to electrons
  - Very few events, only observed at 20 MeV (max. incident energy tested)
  - 2 SEU and 1 SET
  - No MBU, SEFI or SEL under electrons < 20 MeV

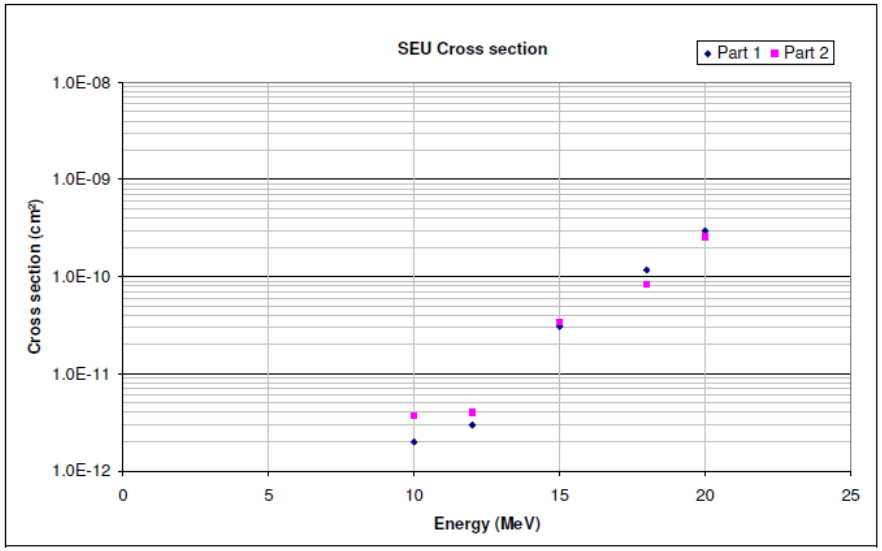


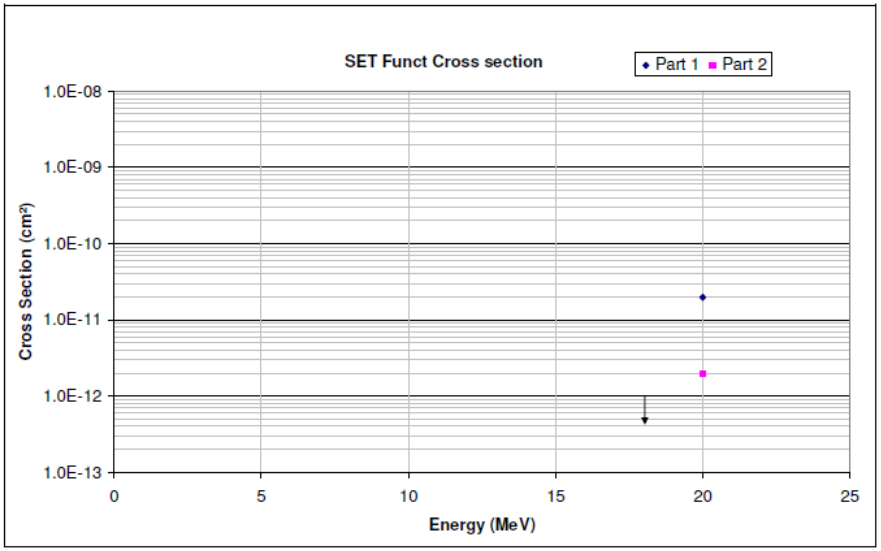


Electron Test Results

- **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

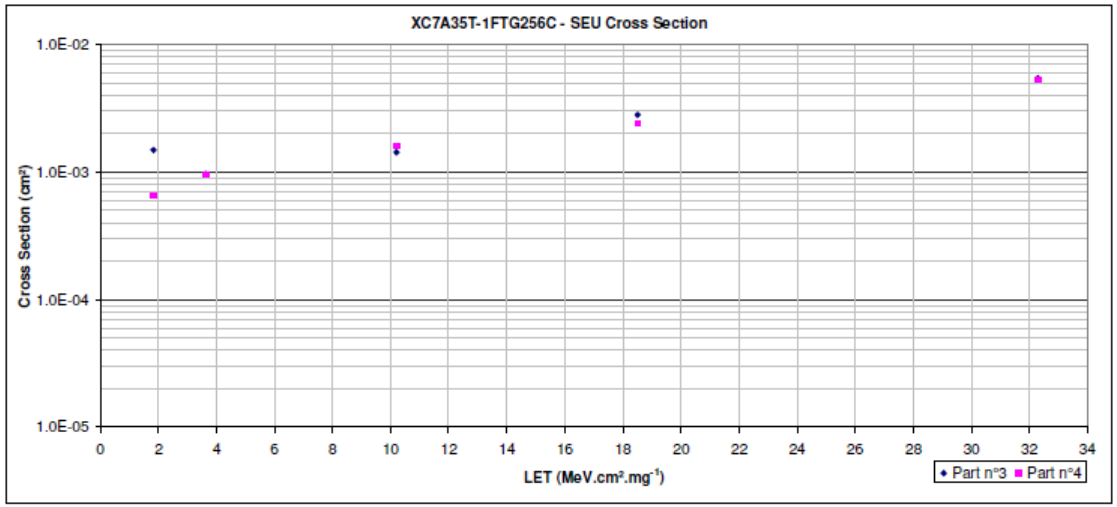


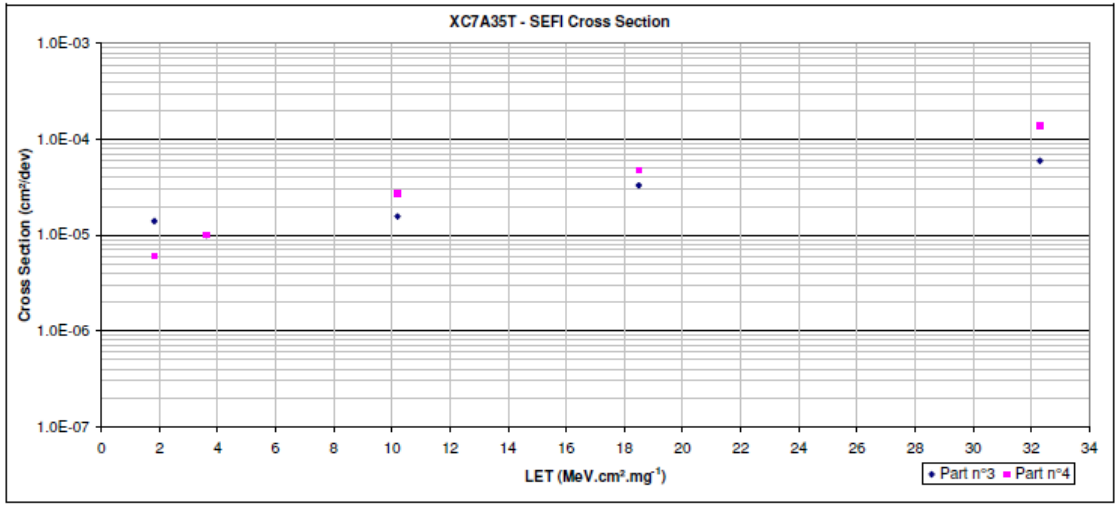




Heavy Ion Test Results

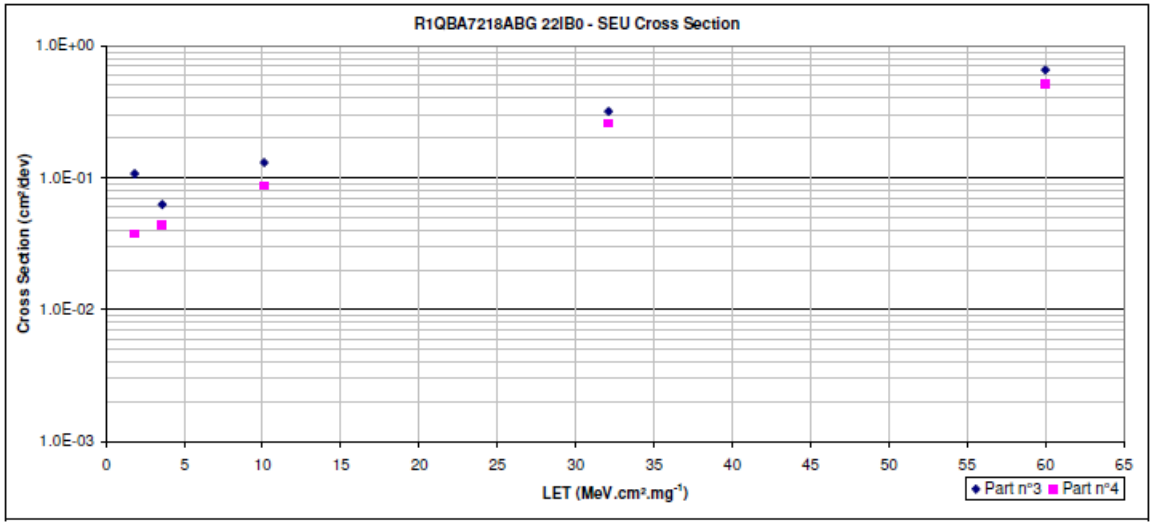
- **Artix-7 FPGA**
  - SET very few events but L_{th}<3.6MeV.cm^2.mg^{-1}
  - SEU L_{th}<1.8MeV.cm^2.mg^{-1}
  - SEFI L_{th}<1.8MeV.cm^2.mg^{-1}
  - No MBU or SEL under heavy ions up to 32 MeV.cm^2.mg^{-1}

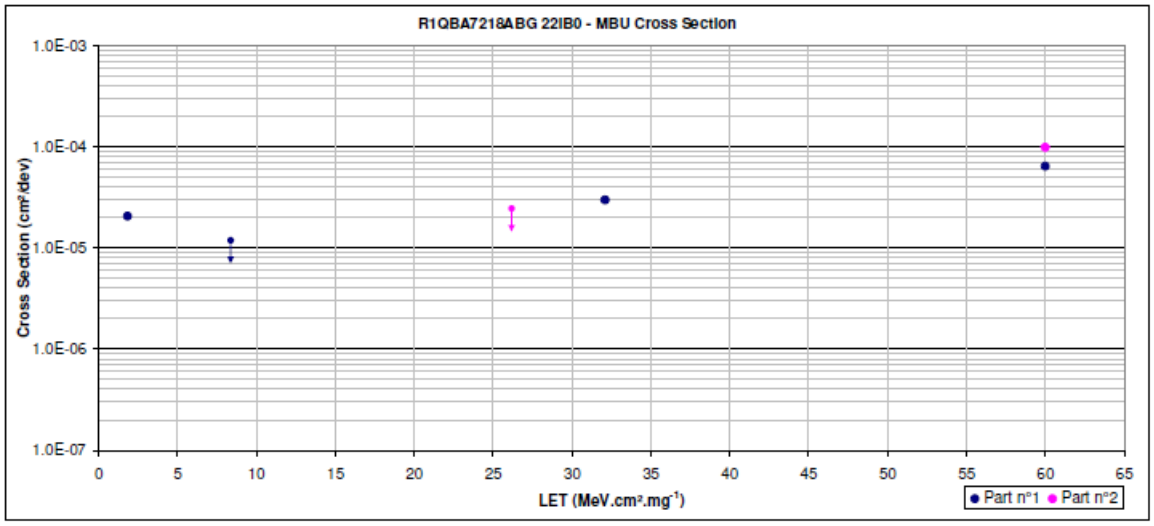




Heavy Ion Test Results

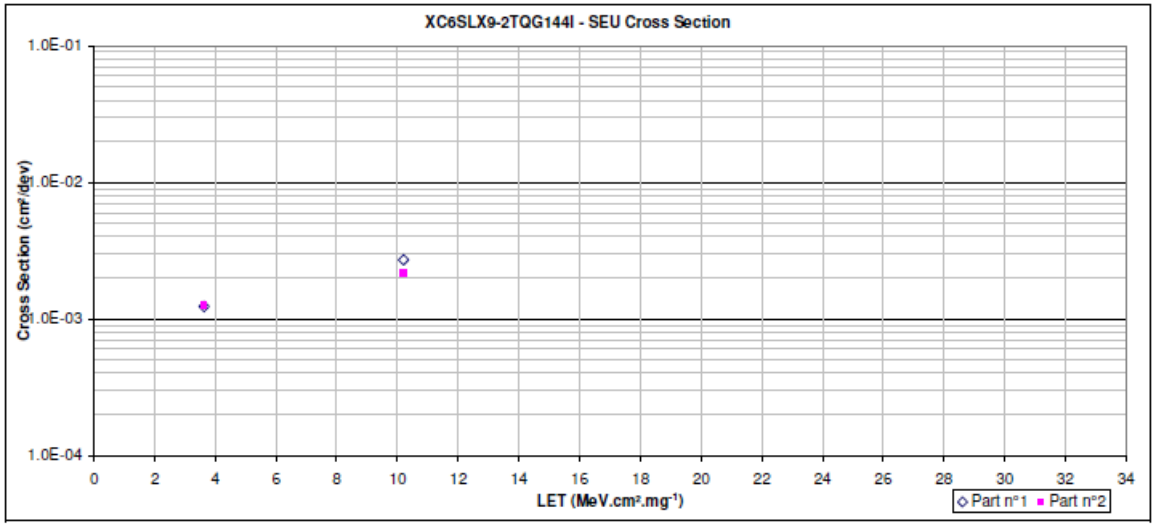
- **Renesas sync. SRAM memory**
  - SET only observed at 60MeV.cm^2.mg^{-1}
  - SEU L_{th}<1.8MeV.cm^2.mg^{-1}
  - MBU L_{th}<1.8MeV.cm^2.mg^{-1}
  - No SEFI or SEL under heavy ions up to 60MeV.cm^2.mg^{-1}

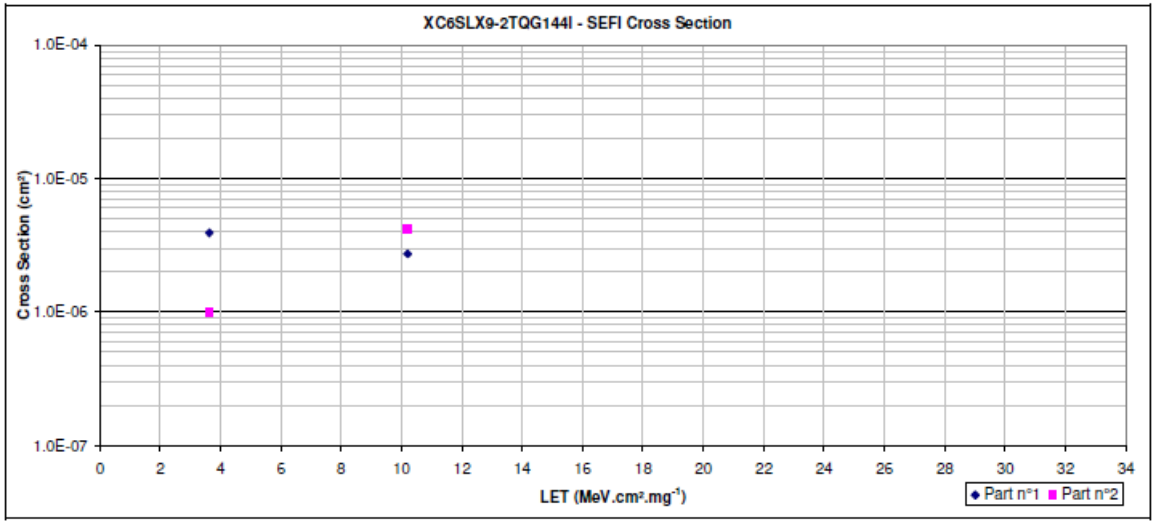




Heavy Ion Test Results

- **Spartan-6 FPGA**
  - **Partial cross-section**
    - Only 2 LET values
  - **SEU L_{th}<3.6MeV.cm^2.mg^{-1}**
  - **SEFI L_{th}<3.6MeV.cm^2.mg^{-1}**
  - **No MBU, SET or SEL under heavy ions up to 10MeV.cm^2.mg^{-1}**





Conclusion

- **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