Irradiation studies in the VESPER test stand

CLIC Week 2019

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on behalf of the CERN R2E project

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Background

Radiation Effects
Electrons an SEEs

VESPER Facility

VESPER
VESPER road map
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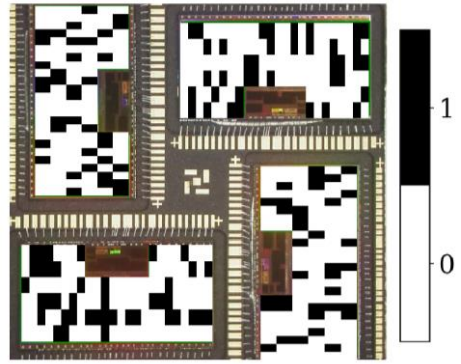
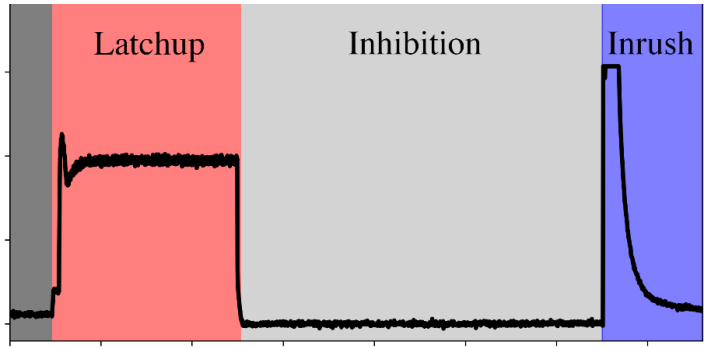
Summary

Brief introduction to Radiation Effects on Electronics

- **Single Event Effects (SEEs)** caused by single particles
  - Single Event Upset (SEU) → single bit-flip
  - Single Event Latchup (SEL) → abnormal current in device

- **Cumulative effects** generating progressive degradation of component
  - Total Ionizing Dose (TID)
  - Displacement Damage





SEEs and electrons

Traditionally, electrons have been neglected due to their relatively low LET (e.g. compared to ions), very low nuclear reaction probability, and/or low relative flux and energy in operational scenarios

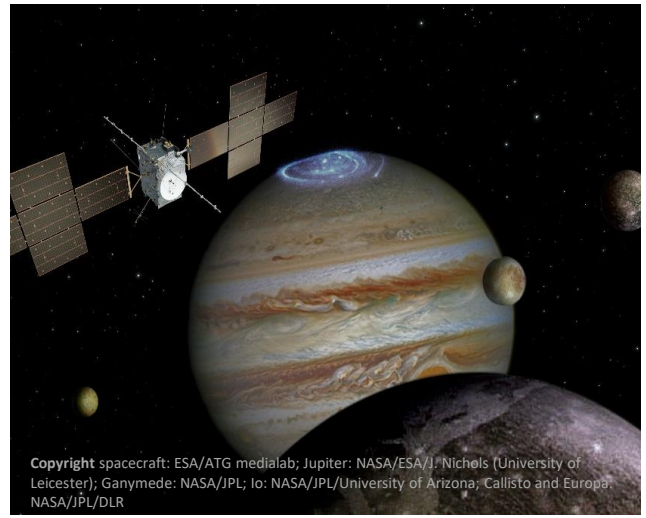
Recent studies (2013+) show that **single electrons are capable of inducing SEEs**, resulting in researching the:

(i) underlying physical mechanisms

(ii) implications on qualification approaches

Electrons and SEEs

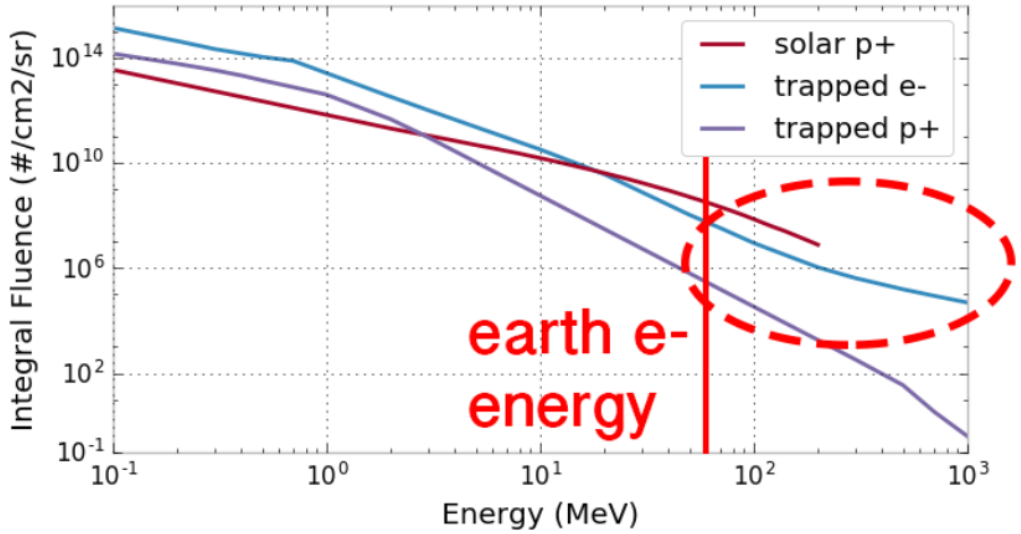
- Delta ray electrons from high energy hadrons (cosmic rays / particle accelerators)
- Damage/degradation of detectors and electronics in HEP experiments
- High energy electron linacs
- Missions near Jupiter



ESA mission to Jupiter - JUICE (JUpiter ICy moon Explorer):
Study the Jovian system (Jupiter, Europa, Ganymede and Callisto)

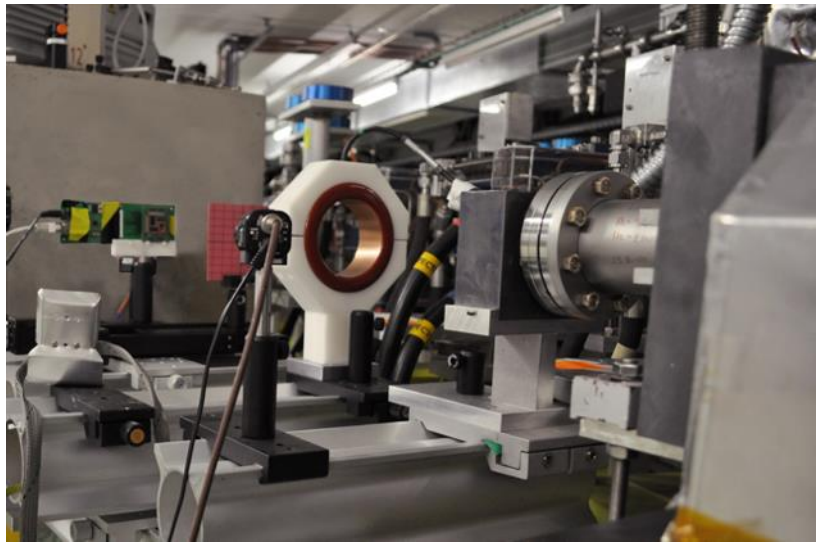
VESPER Motivation - Energetic particle environment

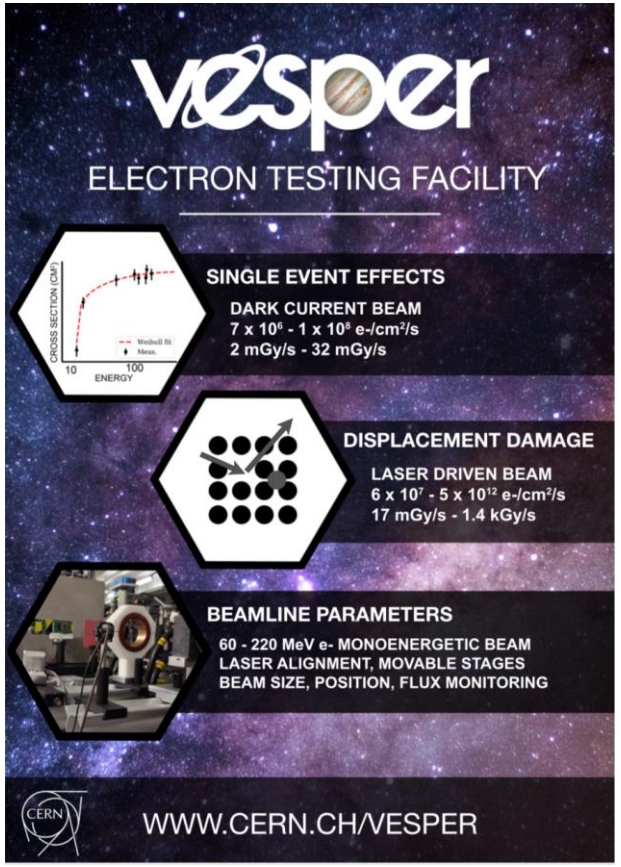
- Magnetically trapped charged particles, solar protons and galactic cosmic rays
- Main contribution to dose: high-energy trapped electrons
- Secondary radiation generated by the interaction of the environment with the spacecraft



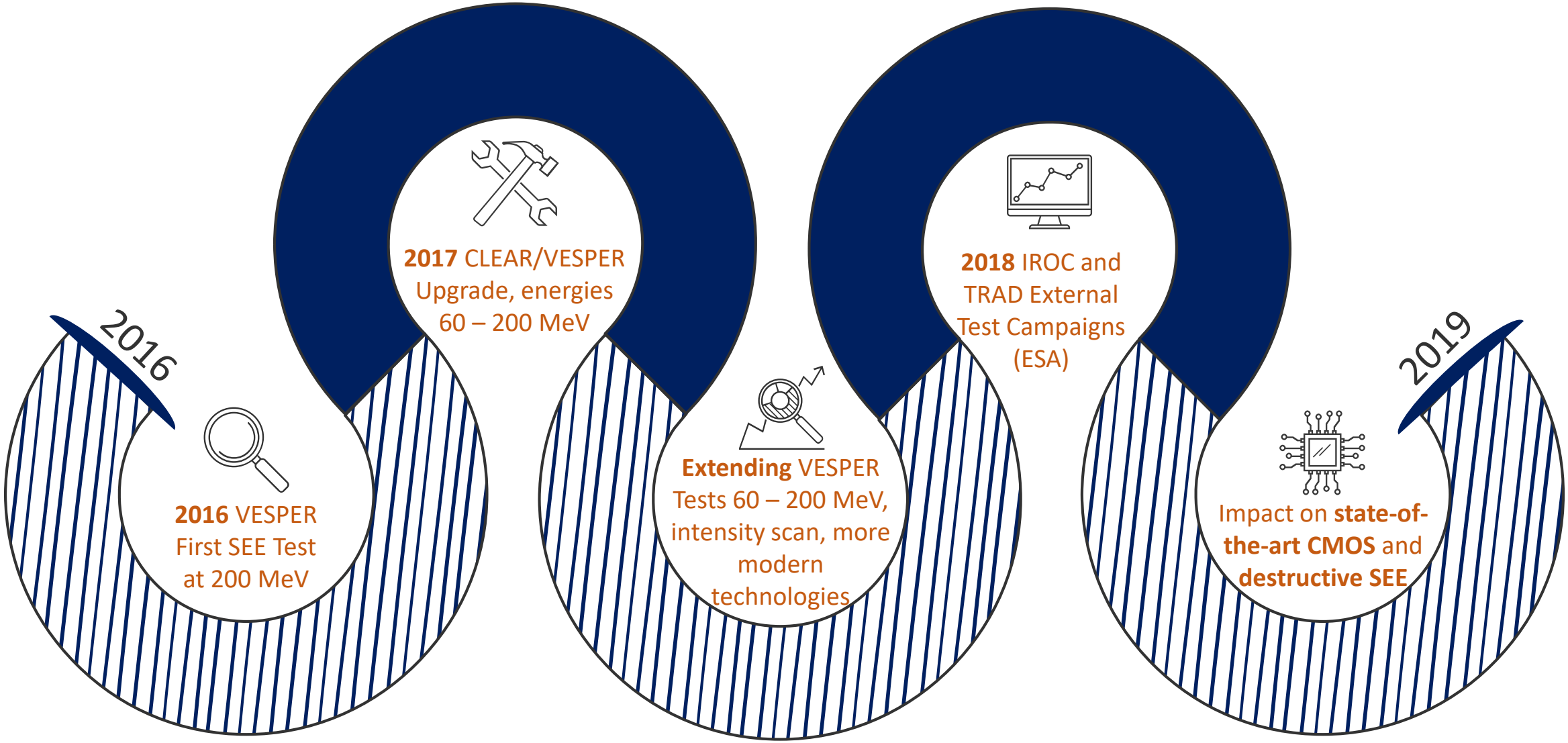
VESPER

- Part of the CLEAR electron accelerator
- Test bench for general purpose radiation testing, e.g. electronics
- Can be operated with laser driven electron beam or dark current, 60-200 MeV
- Beam monitoring using the FBCT, BTV YAG screens and radiochromic films
- 2 movable stages
- R2E contribution in VERPER through (Maris Tali and R2E):
  - The calibration of the facility using RadFET, the ESA SEU monitor and gold activation measurements
  - FLUKA simulations
  - Website (http://vesper.web.cern.ch/)
  - RADECS2018 poster





VESPER road map



A. Destructive Event Experiment

- **Motivation**:
  To demonstrate that electrons can cause destructive events ⟶ SELs are a “no-go” for parts tested for space
- **Test setup**

  - Several experimental runs with 3 different memories

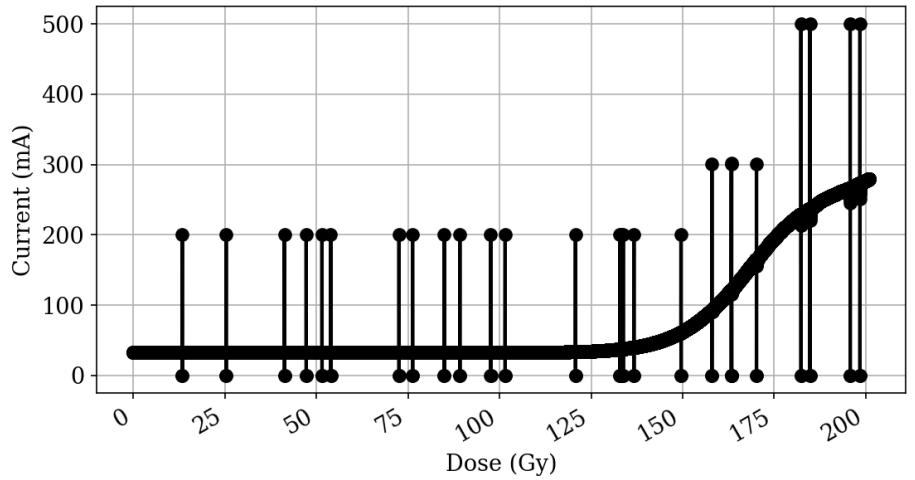
  - A set of memories sensitive to the latch-up effect were irradiated (Alliance, BSI, ISSI)
- **Results**

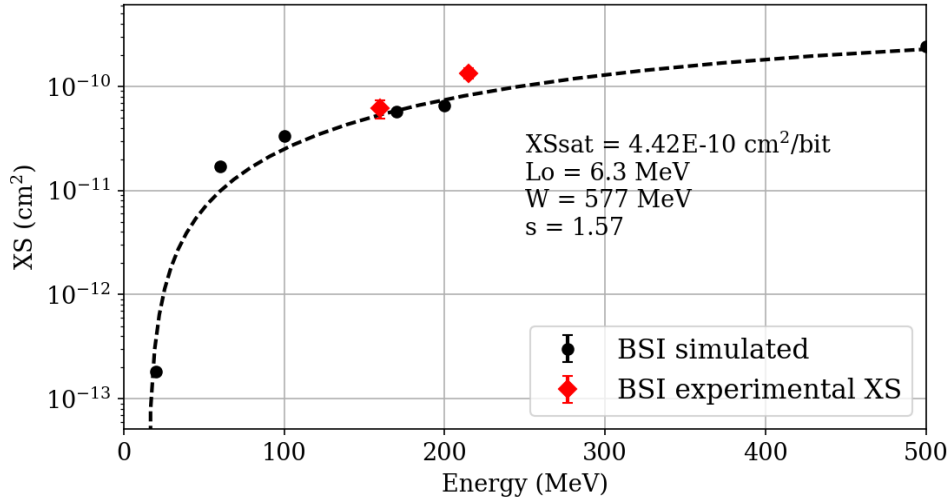
  - Proof of first experimental electron-induced SEL

  - Parts are protected through current limitation

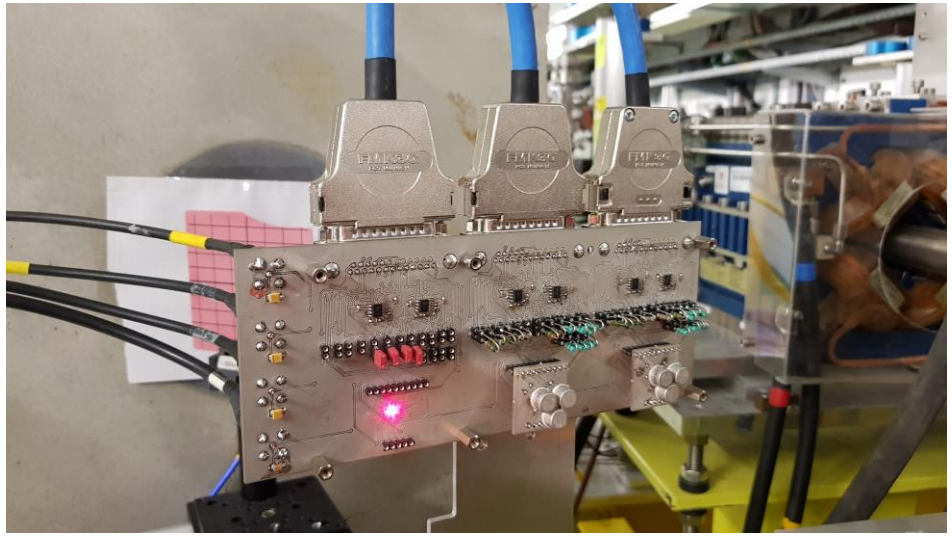
  - A combined effect of TID and SEE was also observed experimentally

  - Results presented at NSREC 2018 and published in IEEE TNS





B. Displacement damage tests



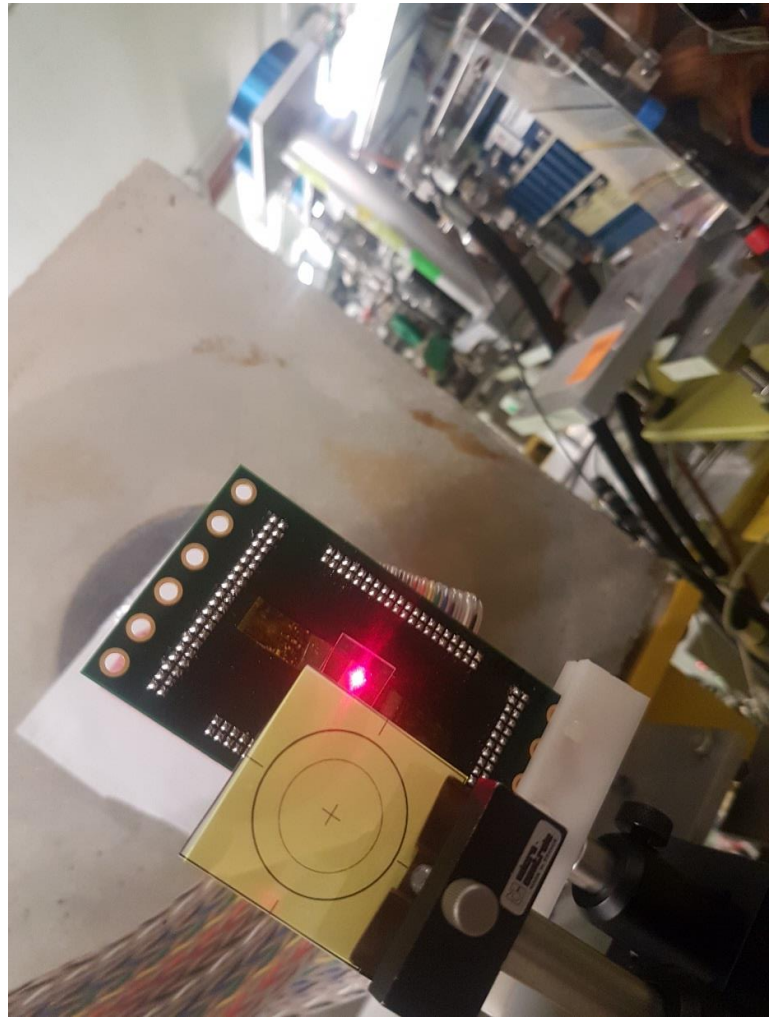
- **Objectives:**
  - Investigate TID-DD synergistic effect on bipolar IC
  - Investigate DD effects on optocouplers
  - Beam cross-calibration
- **Test setup:**
  - Multi-purpose test board (compatible with all the DUTs)
  - DUTs: 2xNPN BJTs, Current source, voltage reference, 2xoptocouplers
  - TIDMon for calibration (RadFET, PINDIODE)
- **Test conditions:**
  - Energy: 200 MeV
  - Dose rate: 20-50 Gy/h
  - Test performed from ~20:00 to 8:00

B. Displacement damage tests - outcomes

- **Preliminary Results:**
  - Dose rate effect on the current source and BJTs (to be further analyzed)
  - Good response of the optocouplers, to be compared with neutron test campaigns
  - No synergistic effects observed on the voltage regulator
  - RADFET response compliant with the expected dose
- **Test issues:**
  - Laser-driven beam used (Dark current beam not available due to some issues)
  - Difficulty to keep a low flux and to monitor the beam profile
  - Difficulty to setup the correct beam parameters at the beginning

C. External Campaigns

- Two external companies (TRAD and IROC) conducted tests at end of 2017/start of 2018
- Part of the ESA assessment of electron contribution to the upset rate during the JUICE mission
- The high-energy electron tests were conducted at VESPER
- Highly integrated FPGAs and SRAM (28 nm) were tested
- The electron sensitivity of the tested devices can lead to a non-negligible electron contribution in the JUICE environment
- The two high energy cross section points (VESPER) are more than one order of magnitude above the medical facility data:
  The VESPER energies are absolutely essential to find the saturation value
- Test reports have been produced, incl. RADECS2018 contribution



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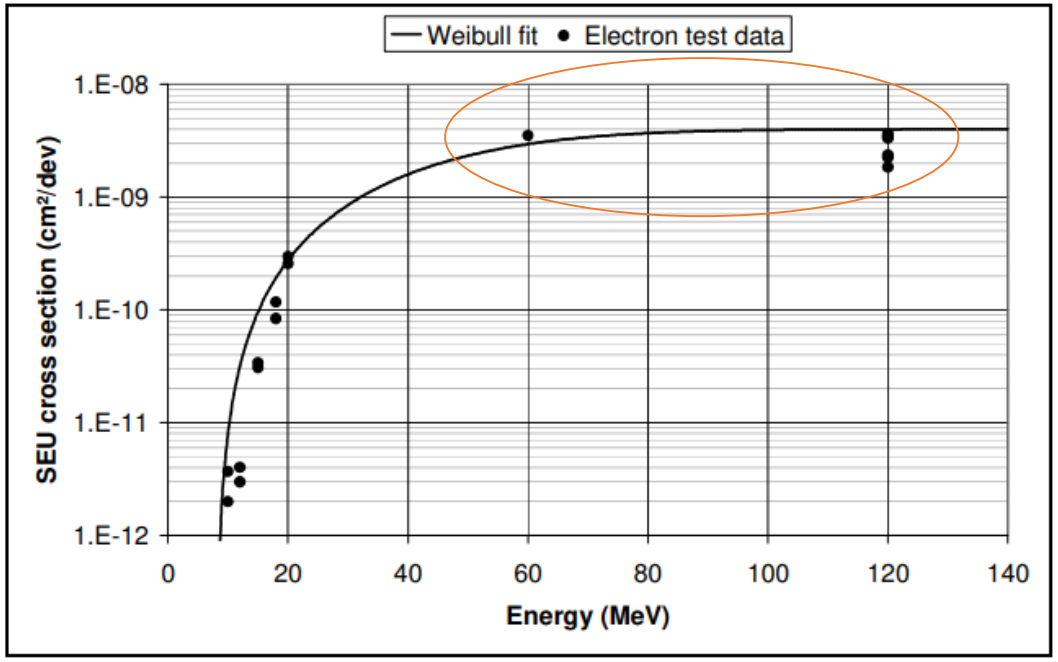
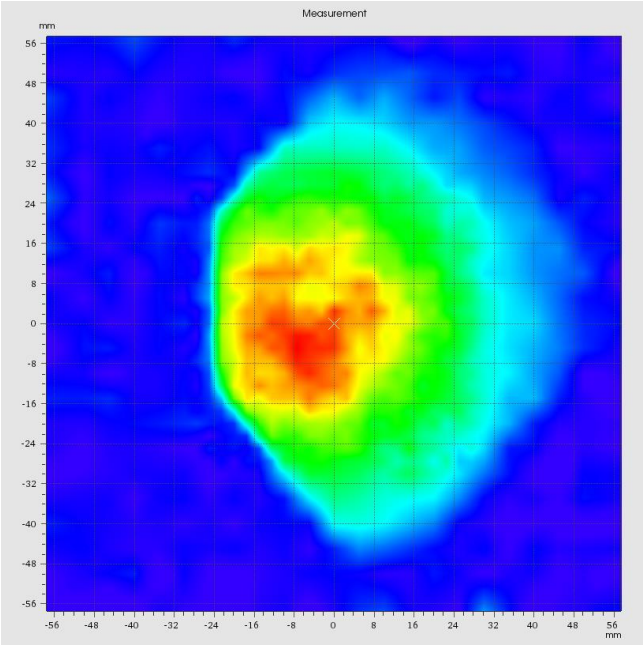


Outlook

- For 2019 VESPER dosimetry, the collaboration with the facility and beam experts (W. Farabolini) is always necessary
- Possibility of dosimetry enhancement by using a medical 2D-array liquid ionisation chamber (1000SRS by PTW) – tested also at the CERN North Area with Pb beam
- Several potential R2E related tests are planned for testing new devices and more effects (also in collaboration with the RADSAGA network):
  - Timepix detector
  - Optical fibre radiation induced luminescence sensors
  - DRAM memories
  - Displacement damage tests on diodes
  - 1000 SRS ionisation chamber
  - SEU tests on 65nm SRAM memories
- Interest from NASA in relation to the US Clipper mission

RADSAGA



Summary

- ✓ Experimental demonstration of the potentially destructive electron-induced events
- ✓ Successful external campaigns. Both ESA and the external companies were satisfied with the obtained results
- ✓ Many proposals for R2E tests at the CLEAR beam suggest a very active and fruitful 2019
- ✓ On behalf of the CERN/R2E team and the external users:
  Many thanks to the CLEAR team for their big support and their availability !

Thank you!