CNA as a Combined Irradiation Testing Center

Fostering Academia & Industry Symbiosis



Yolanda Morilla

4th IFMIF-DONES User Workshop, October 13-15, 2026 – CIEMAT - Madrid (Spain)

From space enviroment to laboratory test



Mission & Enviroment

A severe natural environment exists above Earth's atmosphere.

- Solar flares
- Trapped Protons
- Galactic Cosmic Rays



Radiation & Accelerated tests

Ensuring electronic devices perform as designed after space radiation exposure.

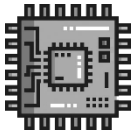
- Gamma, X-rays
- Proton, electron, ions
- Neutron



Test parameters & Effects

Study of the device degradation according to the radiation environment and mission requirements.

- TID
- DD
- SEE



Device response & Analysis

Characterization of the device under radiation exposure:

- Parametric degradation
- Functional degradation
- Failure mechanisms
- Reliability assessment

A real environment must be translated into laboratory conditions.

The radiation type, energy, flux and fluence, dose rate and accumulated dose determine the test.

CNA: a combined irradiation facility

3 MV Tandem Accelerator
Low energy Protons and Ions

- Protons ~600 keV to 6 MeV
- Ions ~600 keV to tens of MeV
- $^{1}H^{+}$ LET(Si) ~0.2 – 0.05 MeV·cm^2/mg

Irradiation Beam Line

Vacuum system ~10^{-6} mbar

Average flux range < 1 × 10^{7} to ~ 6 × 10^{12} p/cm^2·s

Pencil beam size 1 cm^2

Magnetic sweeping system

Maximum sweeping area: 16 x 20 cm^2



18/9 MV Cyclotron
Protons and Deuteron

- Primary beam $^{1}H^{+}$ 18 MeV
- Lower energies using foils degraders
- $^{1}H^{+}$ LET(Si) ~0.02 – 0.04 MeV·cm^2/mg

External Beam Line

Standard use in aire

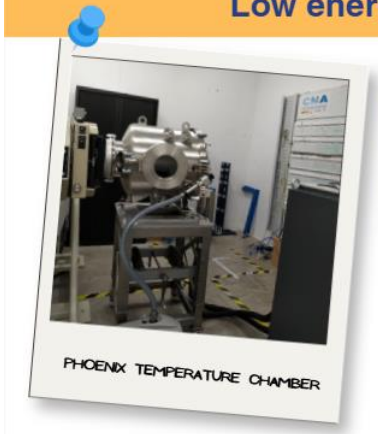
Average flux range < 1 × 10^{7} to ~ 6 × 10^{12} p/cm^2·s

Spot beam size: ⌀ 3.5 cm at 10 MeV

⌀ 2.0 cm at 15 MeV



Temperature cycling - Irradiation combination
Low energy Protons, Ions and ^{60}Co



Desing compatible with the 3 labs

PHOENIX

Temperature range: -80 °C to 170 °C

Fixed sample holder

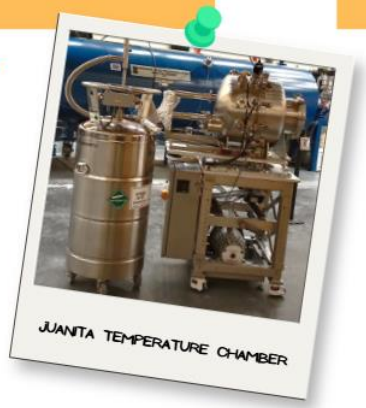
Silicon fluid system

JUANITA

Temperature range: -150°C to 200 °C

X - Y movement sample holder

Nitrogen system



RADLAB Facility
^{60}Co Gammabeam ® X200, Best Theratronics

- Photons 1.17 MeV and 1.33 MeV
- Activity 71 TBq (March 2026)
- Dose rate from ~7rad(Si)/h to 6 krad(Si)/h

Irradiation bunker:

Controlled and monitored temperature and humidity

Areas up to 110 x 110 cm^2 meet standards ≥ 90%

Possibility of independent tests simultaneuosly

Filterbox and PTW Dosimetry system



From research to industrial requirements

Space & Aerospace

Radiation reliability of electronic devices.



High - Energy Physics

Detector and electronics development and testing.



CNA Centro Nacional de Aceleradores

Irradiation Capabilities



Materials & Life Sciences

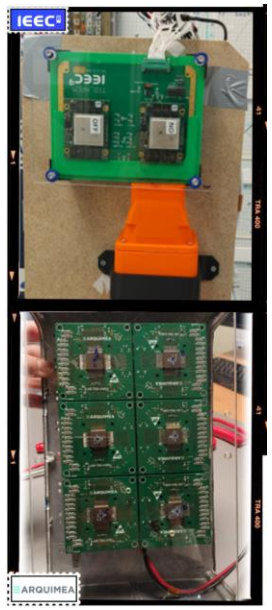
Material modification, biological studies and mutagenesis.

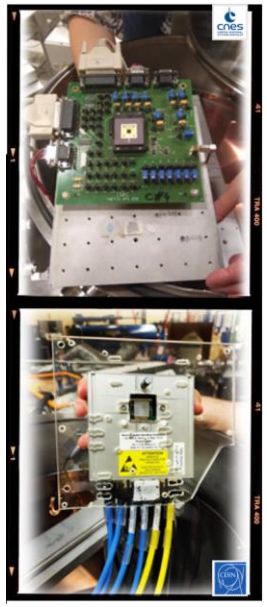


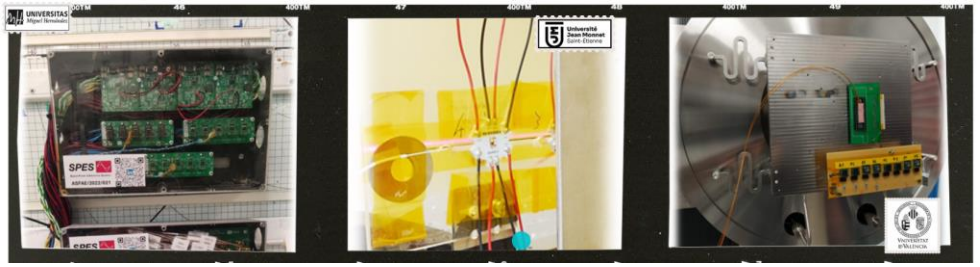
Research & Development

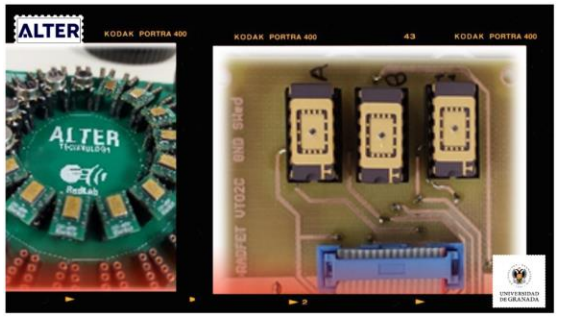
Prototyping, testing and close collaboration with industry.

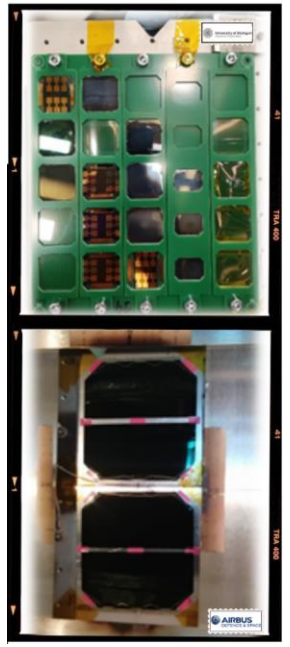
CNA Irradiation Activities

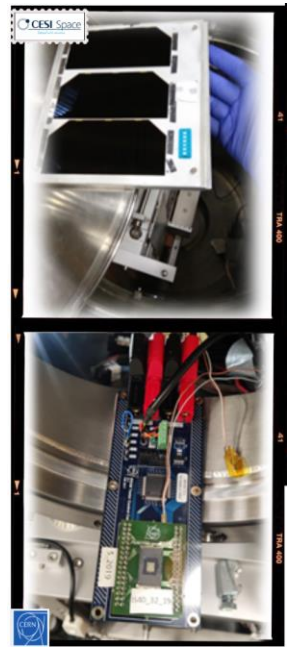














CESI Space
ALTER
AIRBUS DEFENCE & SPACE
TRAD Tests & radiations
ARTE
ARQUIMEA

INTA
SPASOLAB
CERN
IEEC
IMSE -cnm
Instituto de Microelectrónica de Sevilla
cnm
cnes
CENTRE NATIONAL D'ETUDES SPATIALES
ceit

Universitat d'Alacant
Universidad de Alicante
uc3m
University of Stuttgart
Institute for Photovoltaics
UNIVERSIDAD DE GRANADA
UNIVERSITAS Miguel Hernández
Université Jean Monnet Saint-Étienne
LMU

What needs to be tested

Total Ionizing Dose (TID)

TID is due to ionizing radiation, by primary protons and electrons and secondary particles.

Parametric degradation of the device and functional failure.

Displacement Damage (DD)

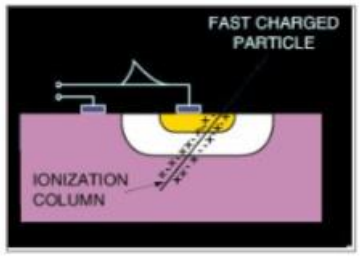
DD is long-term structural damage on semiconductors, by protons, electrons and neutrons.

Produce defect mainly in optoelectronics components.

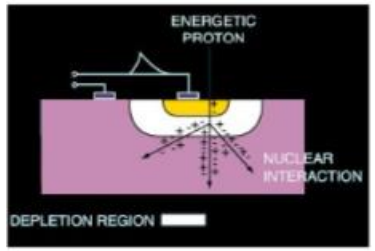
Single Event Effects (SEEs)

SEEs results from ionization by single charged, mostly caused by heavier ions but also protons.

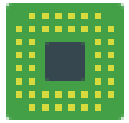
Transient or permanent effects, catastrophic failure of devices.



Depending on the application and the device under test, we need to study different radiation effects.



Components & systems testing



Device selection

- Technology: MOS, Bipolar, optoelec., CMOS, ...
- EEE category: Transistors, OPAM, SRAM, …
- Manufacturer datasheets, databases and flight/application data
- Radiation requirements and expected environment



Test planning & preparation

- Definition of irradiation parameters
- Sample preparation and mounting
- Test configuration and geometry
- Adaption to application requirement
- Compatibility with the facility capabilities



Irradiation

- Radiation type: proton, neutron, gamma, …
- Dosimetry and irradiation conditions
- Controlled parameters: temperature, pressure, vacuum, …
- Energy, flux and fluence
- Dose rate, accumulated total dose and steps



Dynamic test: *Irradiation while the device is operating, with failures detected through its operation.*

- Functional behavior
- Single Event Effects
- Real-time monitoring

Static test: *Irradiation followed by measurement of parameters of interest.*

- Parametric degradation
- Device characterization
- Post-irradiation analysis



Measurements & Monitoring

- Electrical
- Physical
- Functional
- Environmental parameters



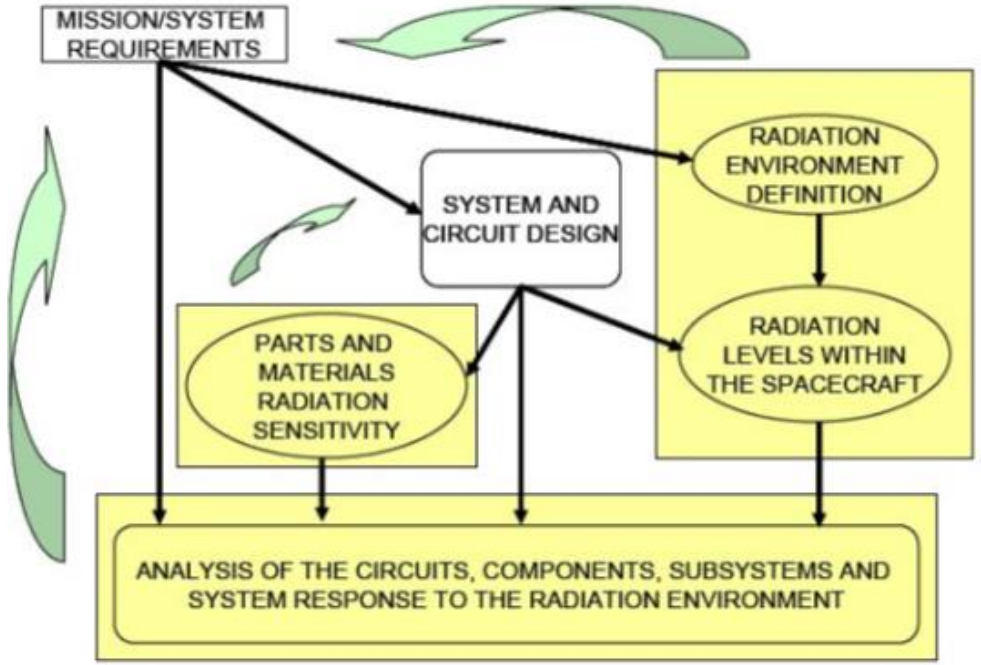
Post-test analysis & reporting

- Data analysis and interpretation
- Assessment of radiation-induce degradation
- Comparison with test requirements
- Documentation and reporting
- Database of test results and relevant information

Standards, procedures & reliability

Radiation Hardness Assurance –RHA

Activities undertaken to ensure that electronic piece parts placed in the space system continue to perform according to their design specification after exposure to the space environment



From Christian Poivey - ESA

To produce a system tolerant to the radiation environment

Standards, procedures & reliability

Standards, Guideline & Handbooks	
ECSS	ECSS-E-HB-10-12 ECSS-E-ST-100 ECSS-E-ST-10-04 ECSS-E-ST-10-12 ECSS-Q-ST-30 ECSS-Q-ST-30-10 ECSS-Q-ST-60
ESCC	ESCC22900 ESCC22500 ESCC25100
MILD-STD	MILD-HDBK-814 MILD-STD-750E Method 1019 MILD-SDT-750E Method 1080 MILD-STD-883G Method 1019

ECSS - European Cooperation for Space Standardization
ESCC - European Space Components Coordination
MILD-STD Military standards USA

Test procedures

Define methods
Qualified personnel
Controlled environment

Traceability

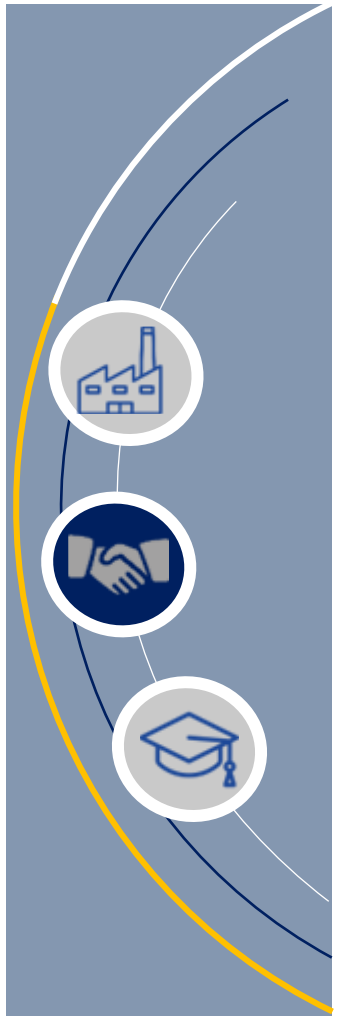
Calibration
Documentation
Reproducibility

Reliability

Compliance
Qualification
Flight / Application

For industrial applications tests **must be reproducible**, **traceable** and **aligned** with the applicable **standards and specification**

Academia & industry: a two-way transfer



RADECS ASSOCIATION – STEERING COMMITTEE – INDUSTRIAL WORK GROUP: Collaborative work on Industrial Accessibility and Beamtime Optimization into RADiation Effects on Components and Systems.

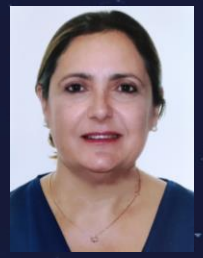
RADLAB: Laboratorio para Ensayos de Irradiación (Spanish calls R&D- INNPACTO 2011/2014)
(Laboratory for irradiation tests)

PRECEDER: Predicción del Comportamiento Eléctrico de Dispositivos Electrónicos bajo Radiación (Andalussian calls Proyecto CEI 2020/00000158)
(Prediction of the behavior for electronic devices under radiation applying "machine learning")

RADNEXT: RADiation facility Network for the EXploration of effects for indusTry and research H2020 INFRAIA-02-2020: Integrating Activities for Starting Communities EU Project 101008126

RADNEXT 2030: RADiation facility Network for the EXploration of effects for indusTry and research European Union's HORIZON Research and Innovation Actions under grant agreement number 101292931

Thank you for your attention

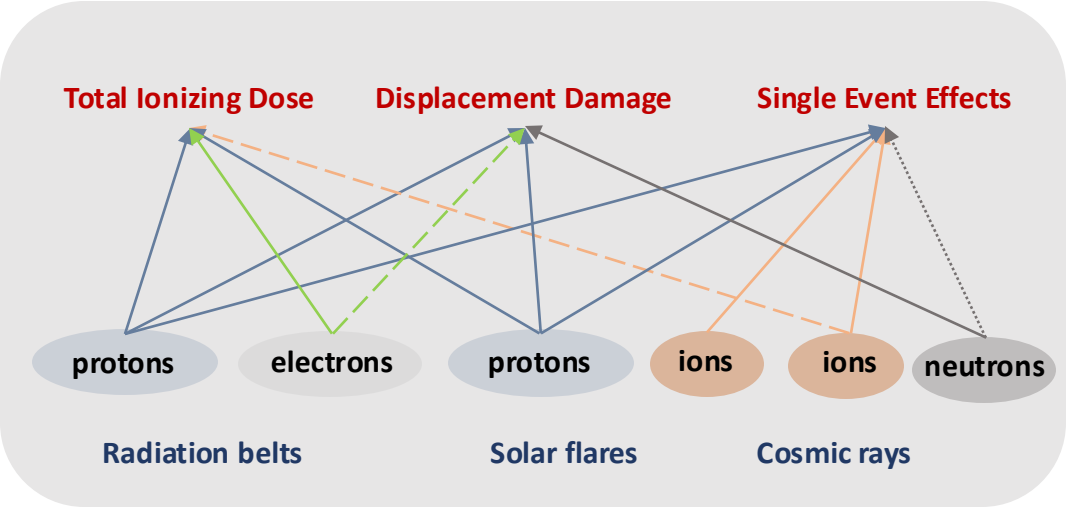


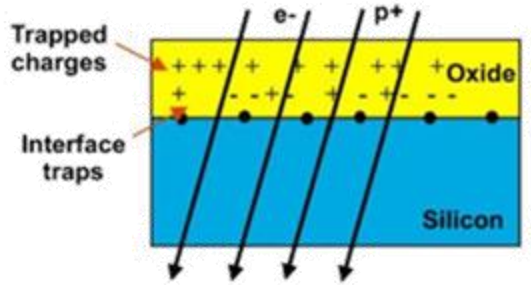
Yolanda Morilla

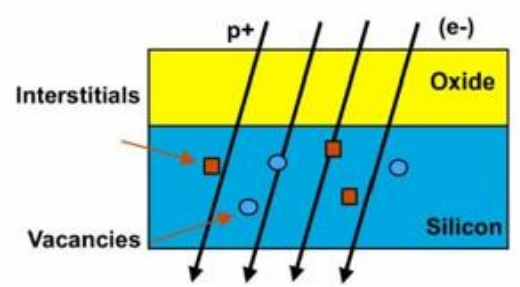
ymorilla@us.es

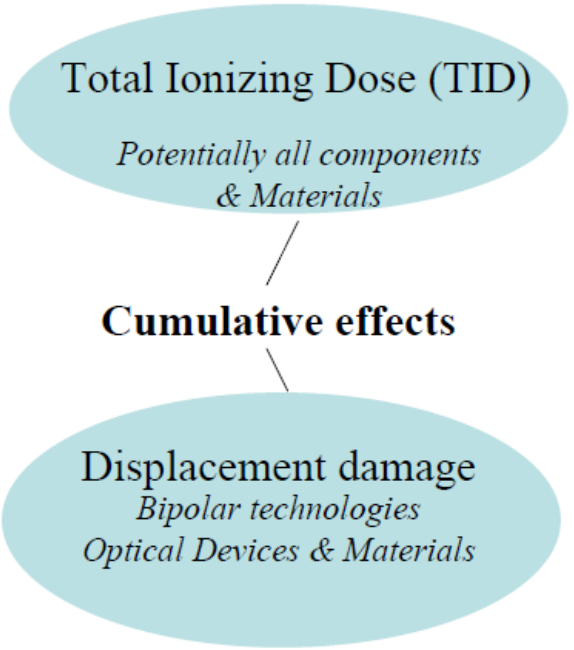
Radiation effects on components

Degradation depending on the energy of the particles, their nature and the mission orbit.









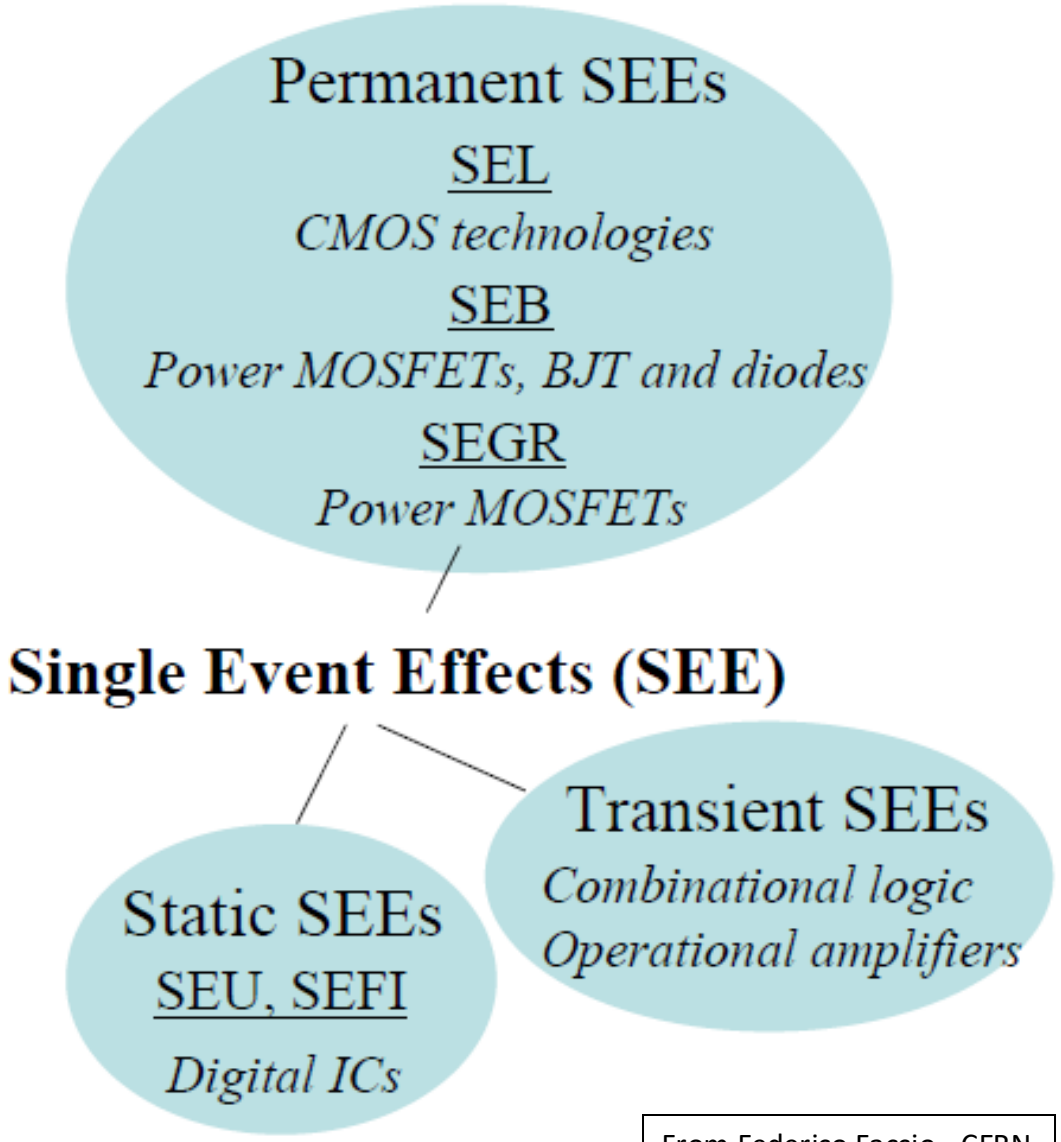
From Federico Faccio - CERN

TID, ionizing by **primary protons, electrons and secondary particles.**
It causes threshold shifts, leakage current and timing skews.
It is possible to reduce this with shielding.
The effect first appears as a parametric degradation of the device and ultimately results in functional failure.

Displacement damage is long-term structural damage on semiconductors caused by **protons, electrons, and neutrons.**
Produce defects mainly in optoelectronics components.

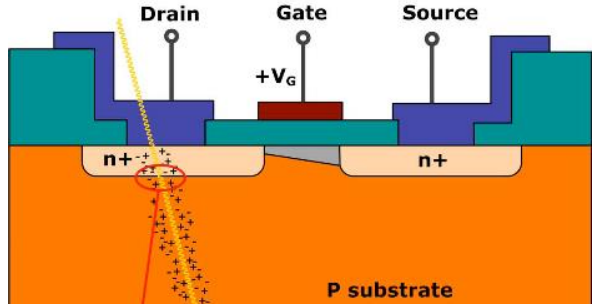
Radiation effects on materials
Ageing of thermal protection materials
Absorptivitity increase
Failure of external jacket cable material
Insulation leaks

Radiation effects on components

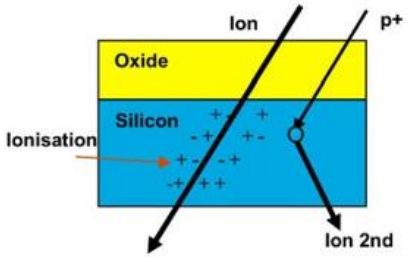


From Federico Faccio - CERN

SEEs result from ionization by a single charged particle as it passes through a sensitive junction of an electronic device, mostly caused by heavier ions but also protons and secondary particles produced by nuclear reactions.



Generation and transport of charges by the effect of a SEE in the drain region of a NMOS transistor. Image Source: [S. Sordo, Thesis IMSE-US https://idus.us.es/handle/11441/52295].



The severity of the effect can range from noisy data to loss of the mission, depending on the type of effect and the criticality of the system in which it occurs.
Shielding is not an effective mitigation technique because they are induced by very penetrating high-energy particles.