Single Event Effect in a Commercial MOSFET

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Universidade de São Paulo

7th International Summer School on
INtelligent signal processing for FrontIEr Research and Industry

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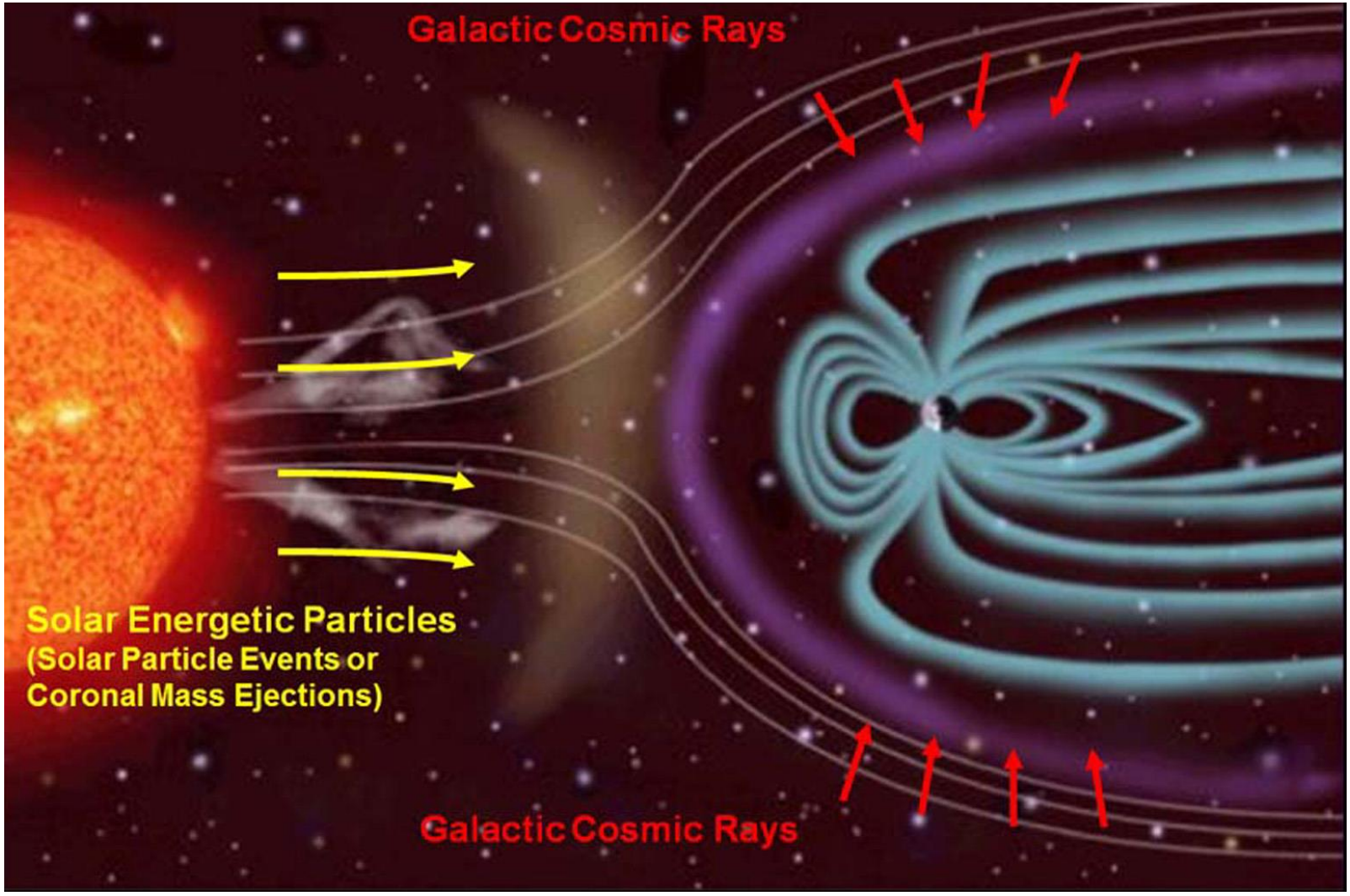
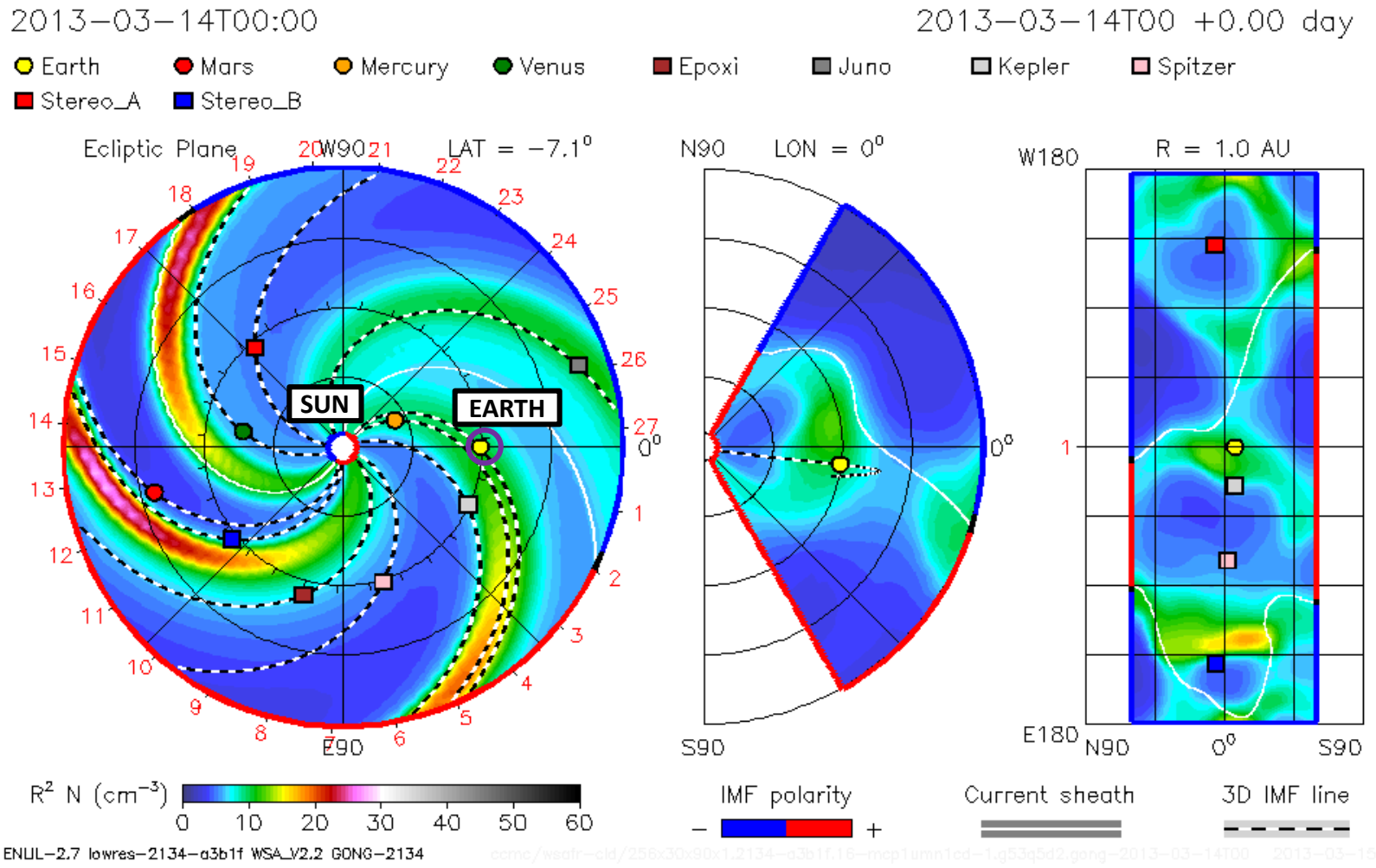


Courtesy of NASA

Coronal Mass Ejection Simulation

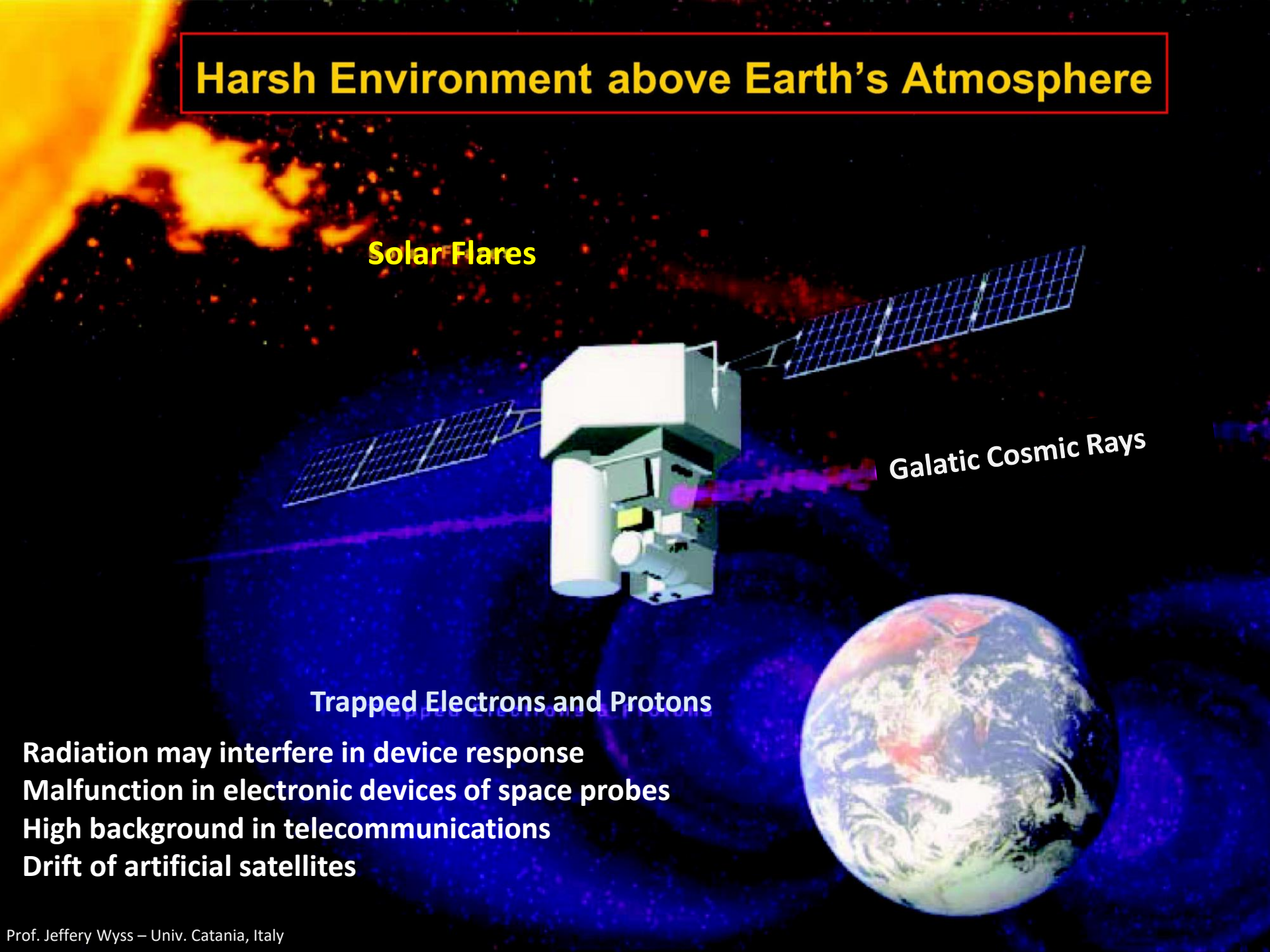
Radiation Density (cm^{-3})

Estimated speed: ~1485 km/s



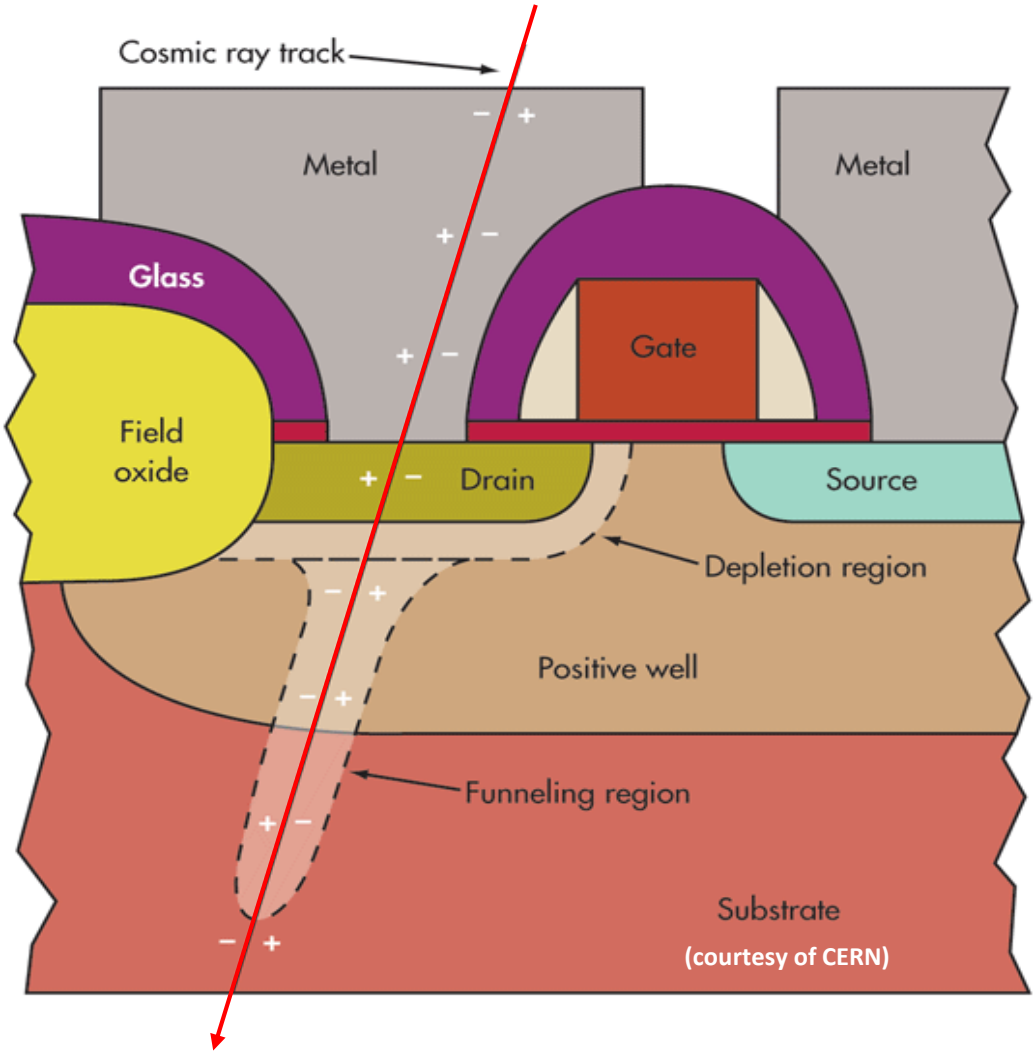
Courtesy of NASA Goddard Space Flight Center, Space Weather Research Center (SWRC) and R.R. Bühler

Harsh Environment above Earth's Atmosphere



Radiation may interfere in device response
Malfunction in electronic devices of space probes
High background in telecommunications
Drift of artificial satellites

Radiation Effects in a Transistor



All the Electronic Devices May Suffer from Radiation Effects

Space Environment

Ground High Radiation Environment

α-particle emission from radioactive contaminants

Particle and electromagnetic radiation
Ionizing and non-ionizing dose

Degradation of:
Micro-electronics, micro-processors,
solar cells, optical components, semiconductor detectors,
front-end electronics, cabling, etc

Causing: **System shutdowns**
Circuit damage
Data corruption, etc

Human beings can also be influenced by radiation effects: astronauts, airplane crew, passengers, patients, personnel, etc.

Radiation effects in electronic devices

TID, DD, and SEE

Electromagnetic radiation, eletrons, protons, neutrons and heavy ions

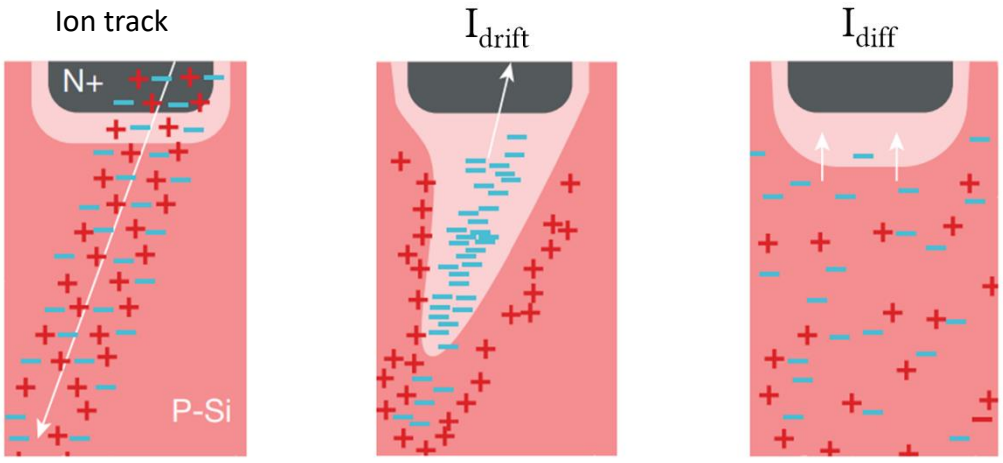
Total Ionizing Dose is a cumulative effect caused by trapped charges in the oxide. These trapped charges modify the transistor characteristics such as threshold voltage (V_{th}), mobility, leakage current, power dissipation, etc.

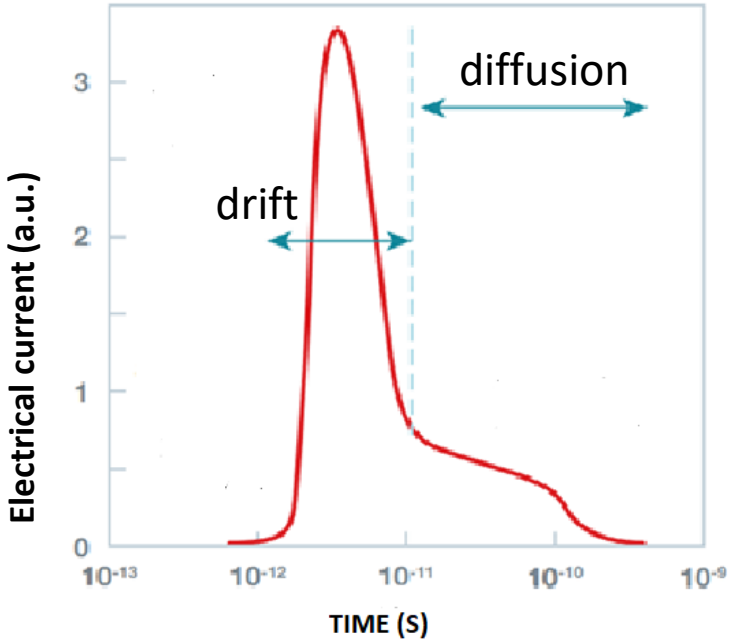
Atom Displacement Damage is provoked by protons, heavy ions, electron with high energy and neutrons, which change the arrangement of atoms in the lattice, modifying electrical properties of a device.

Single Event Effects are caused by particles of high LET (Linear Energy Transfer) due to, for example, the **strike of a single ion**. They can be non-destructive, causing current or voltage peaks, changing the state of a bit, or destructive, burning the device or destroying the gate oxide in a MOSFET.

Single Event Effects

- SEE are caused by particles of high LET (Linear Energy Transfer) due to, for example, the strike of a single ion
- Charge deposition induced by a heavy ion interaction within a sensitive volume, followed by the charge collection at the output node of the circuit.
- Charged particles generates a track of electron-hole pairs in semiconductor (Si) and dielectric (SiO_2).

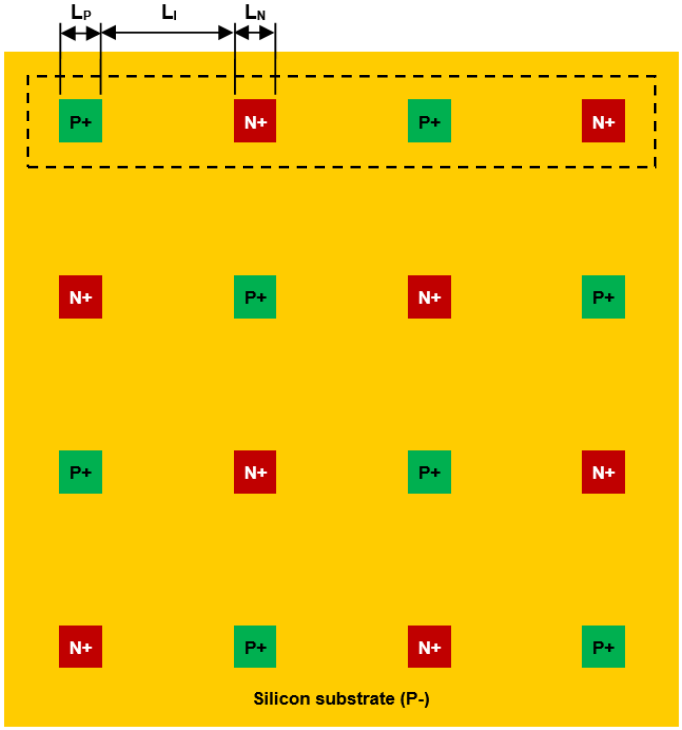


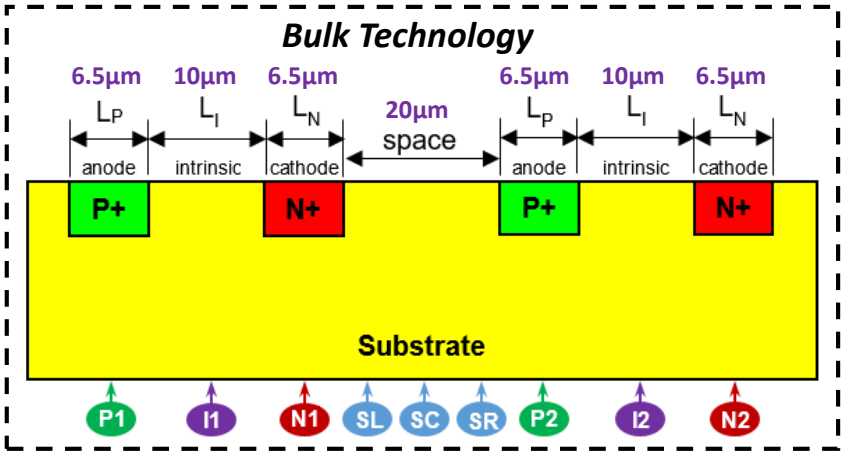


Baumann *et al., Radiation Handbook for Electronics*

PIN DIODE SIMULATION

GF BiCMOS 8HP 130 nm technology



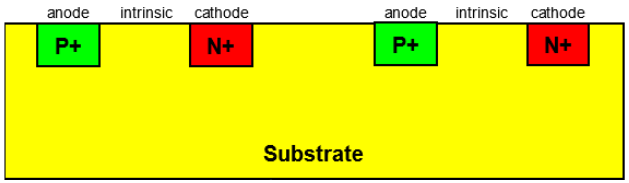


SEE Parameters:

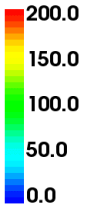
- Heavy-Ion LET = 10 MeV/mg/cm^2
- Particles Strike vertically at specified positions

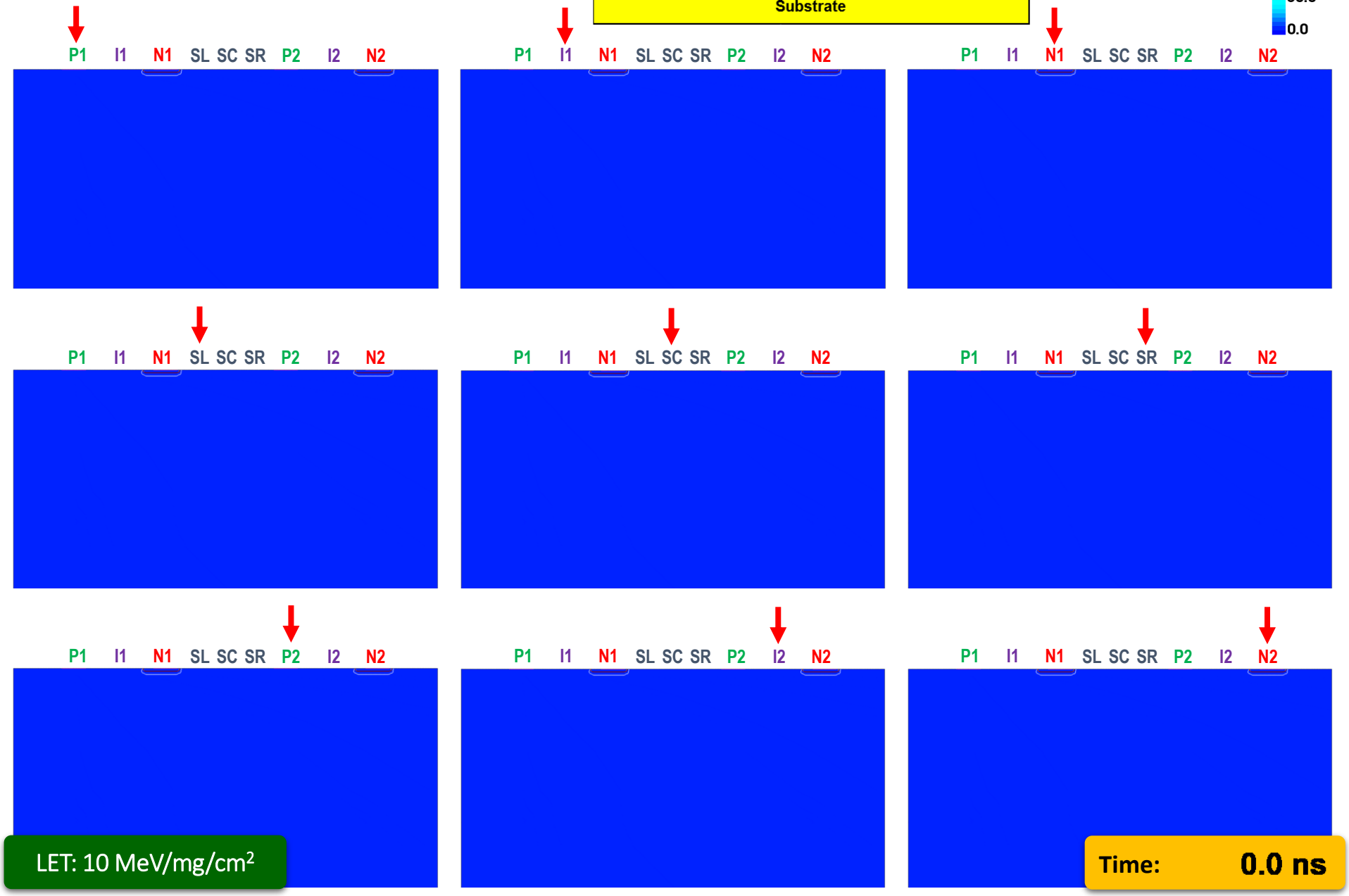
Rudolf R. Bühler and Renato Giacomini
Centro Universitário FEI

Incident Particle – 10 MeV/mg/cm^2
Calculations by Rudolf R. Bühler



Abs Total Current Density [A/cm^2]|



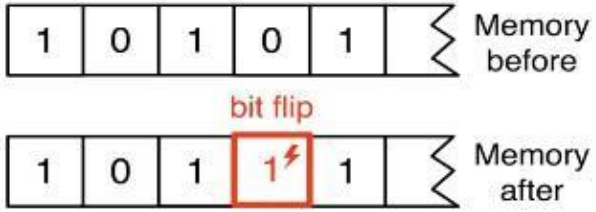


LET: 10 MeV/mg/cm^2

Time: 0.0 ns

Single Event Effects

Non-destructive Effects



Single event upset (SEU)

e.g. memory bit-flip (logic error)

Single event transient (SET)

A transient effect (voltage/current pulses) which may provoke a SEU

Single event functional interrupt (SEFI)

Logical malfunction in programmable devices

Destructive Effects

Single event latch-up (SEL)

high current flux overheated power transistors,

affecting *e.g.* CMOS devices

Single event gate rupture (SEGR)

dielectric breakdown of the oxide layer of a MOSFET

Single event burnout (SEB)

Similar to SEL. The high current damage irreversibly ,

***e.g.* power MOSFET**

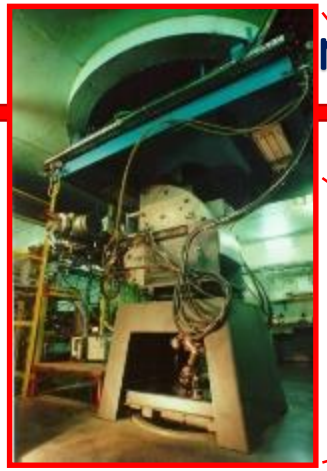
Nuclear Physics Open Laboratory

8 UD Pelletron Acelerador, tandem, V_{max} = 8 MV

rbon foil stripper)

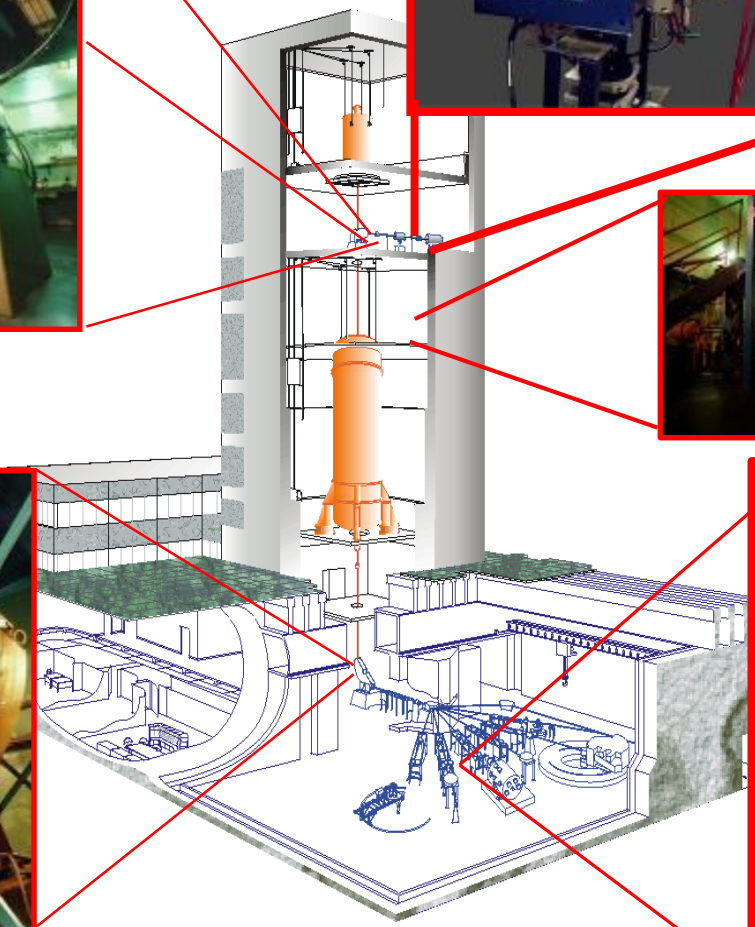
SNICS Ion source
Beams: H, Li, B, C, O, F, Si, Cl, Ti, Cu, and Ag.

Mass selection ME20



TANK

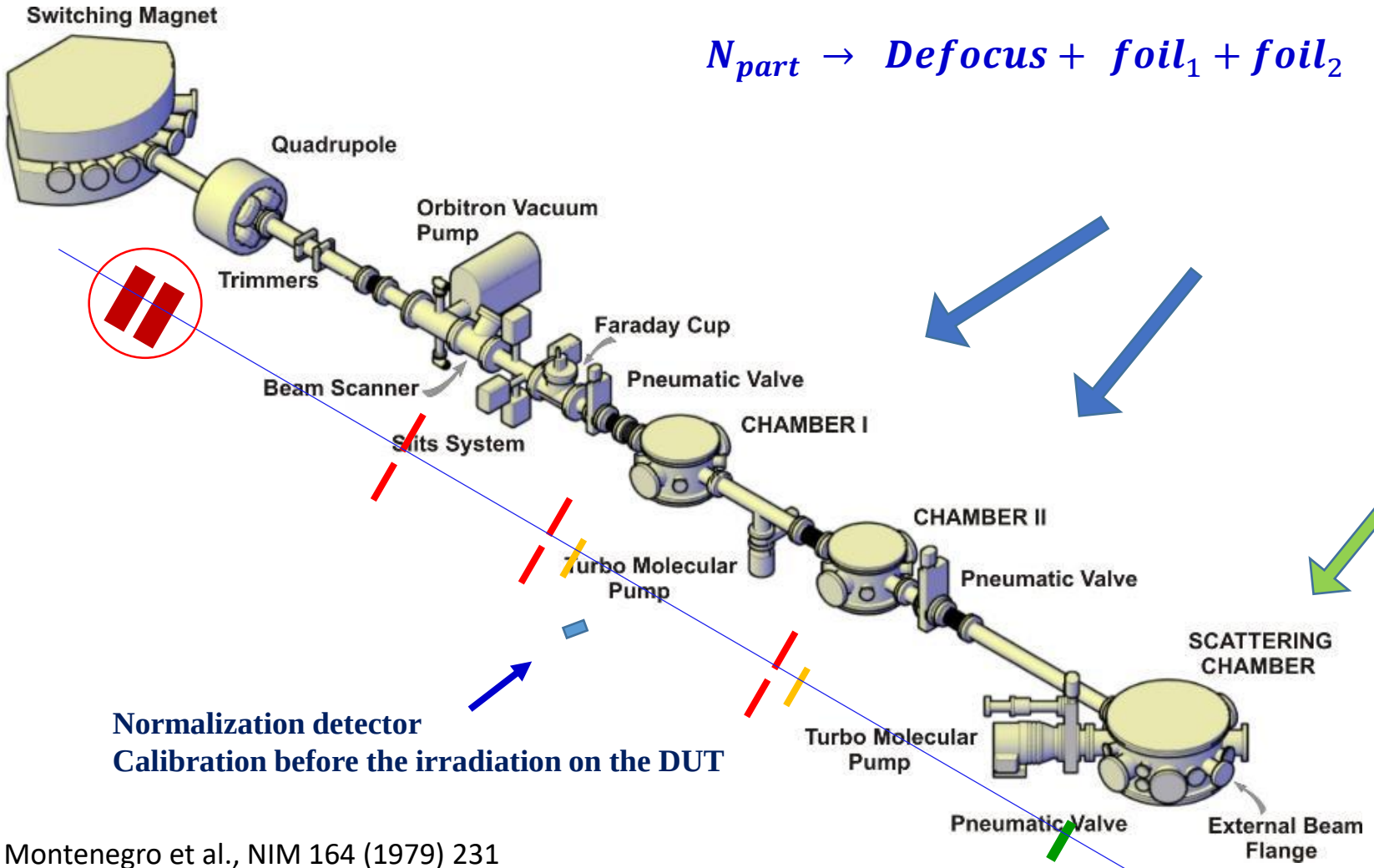
Energy Selection ME200



SAFIIRA SYSTEM

^{107}Ag beam at 115 MeV (14+)
^{63}Cu beam at 100 MeV (12+)
Faraday cup 3 ~ 500 nA (Ag); 800 nA (Cu)

SAFIIRA Beam Line



$N_{part} \rightarrow Defocus + foil_1 + foil_2$

Normalization detector
Calibration before the irradiation on the DUT

E.C. Montenegro et al., NIM 164 (1979) 231
N. Carlin et al., NIM A 540 (2005) 215

SAFIIRA SYSTEM

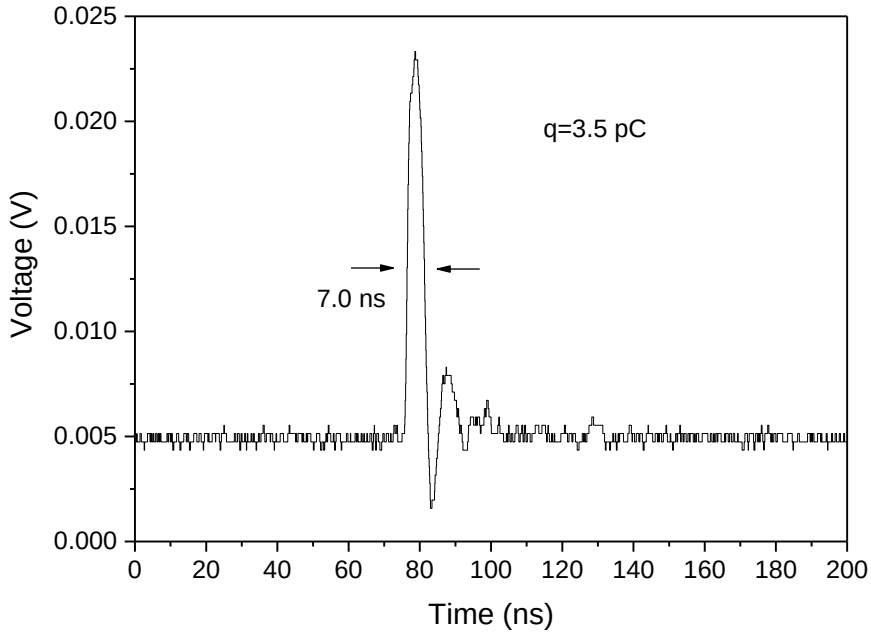
SistemA de Feixes Iônicos para IRradiações e Aplicações

Ion Beam System for Irradiations and Applications

V. A. P. Aguiar et al. - Review of Scientific Instruments 91, 053301 (2020)

SEU measurements in a p-channel MOSFET transistor (3N163) USP-FEI Collaboration

SEU signal observed with an oscilloscope due to ^{35}Cl heavy ion beam at 75 MeV.

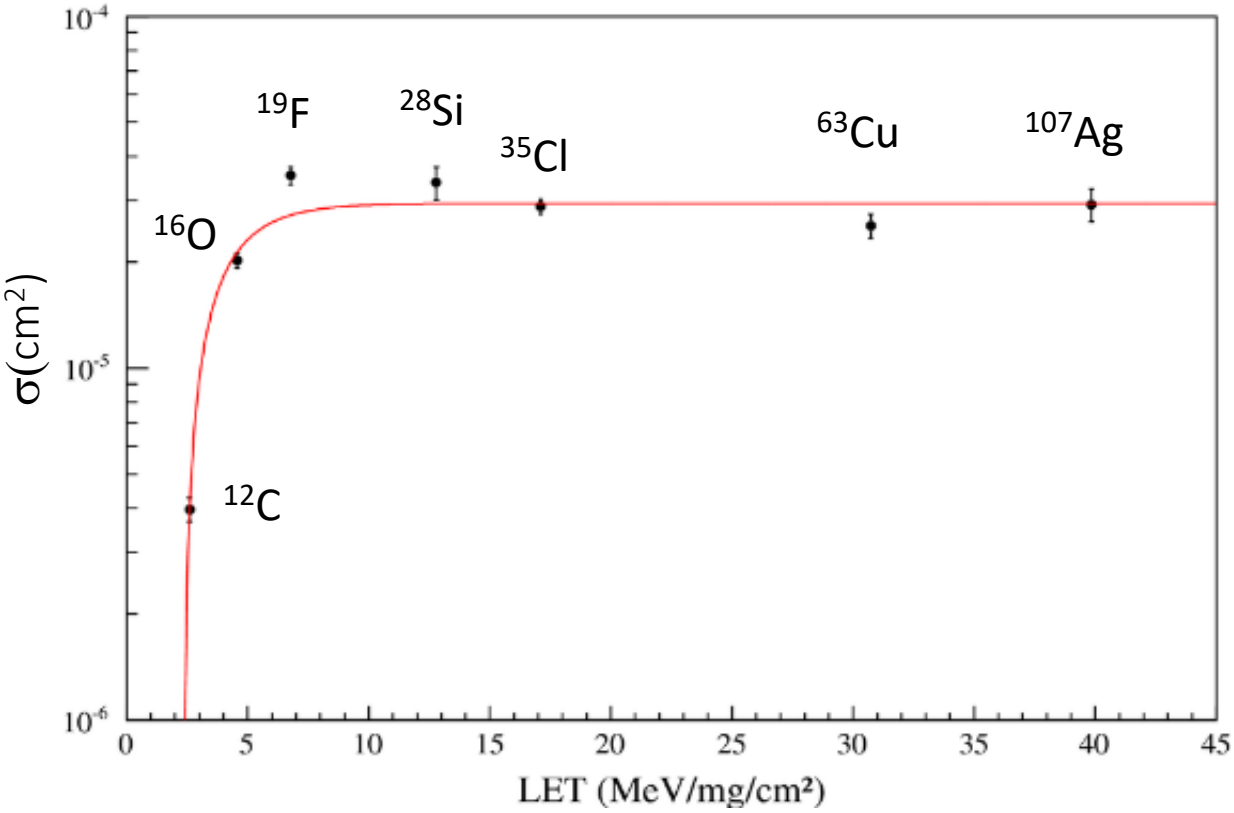


SEU Cross Section

p-channel MOSFET transistor (3N163)

$$\sigma_{SEE} = \frac{events}{\Phi}$$

$$\Phi = \frac{particles}{cm^2}$$



Weibull Function

$$\sigma = \sigma_{sat}\left[1 - e^{\left(\frac{LET - LET_{th}}{W}\right)^s}\right]$$

$\sigma_{sat} = 294(10)10^{-5}$ cm²
LET_{th} = 2.35(36) MeV/mg/cm²
W= 1.06(11) MeV/mg/cm²
S = 0.62(10)

N.H. Medina et al., Proc. 2014 IEEE Radiation Effects Data Workshop, Paris, France, pg 272

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Saulo Gabriel Alberton

Marcilei Guazzelli da Silveira
Alexis Vilas-Bôas

Thank you for your Attention