THE EUROPEAN SPACE AGENCY

Irradiation characterization of EEE components for space application

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ESA-ESTEC

RADSAGA Initial Training Event
5 October 2017, Geneva

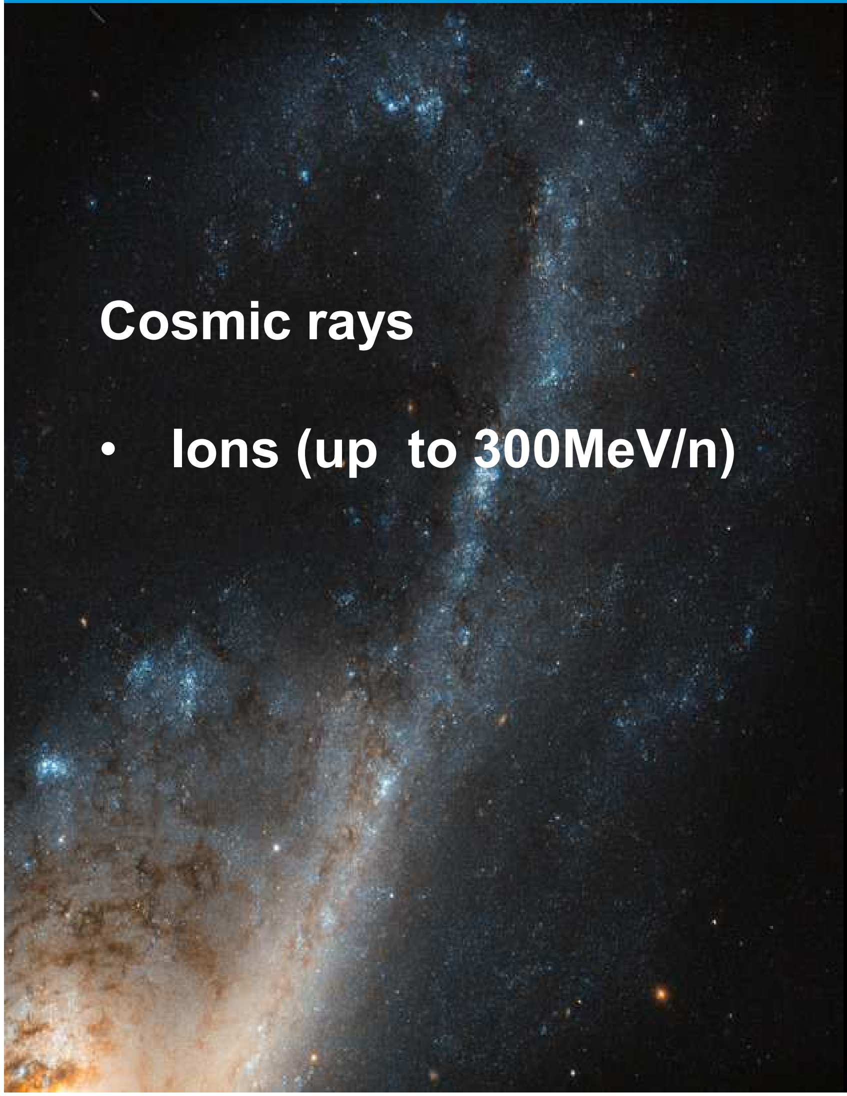
RADSAGA

European Commission

RADECS 2017
CERN, Geneva

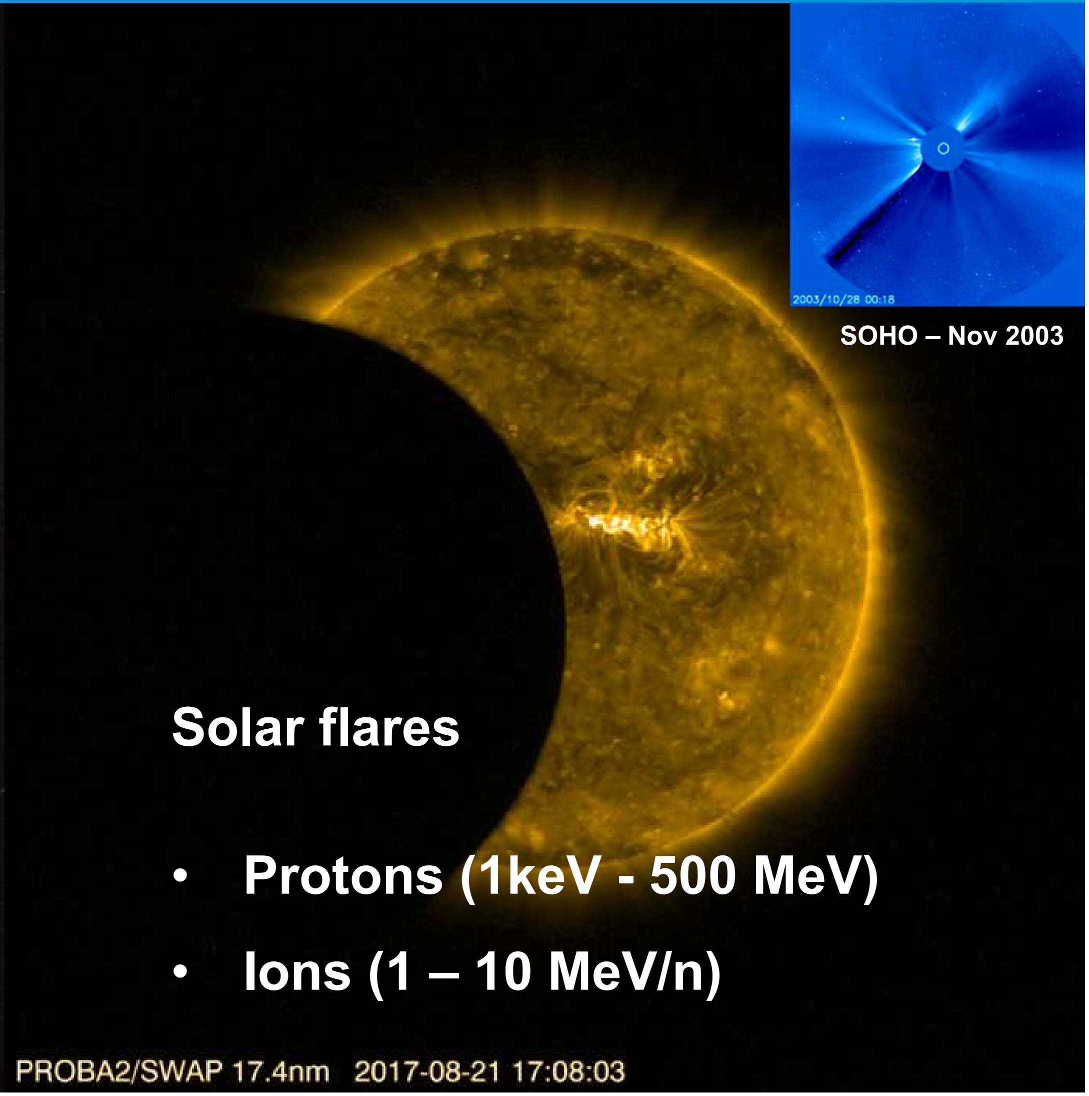
European Space Agency
www.esa.int

Space environment



Cosmic rays

- Ions (up to 300MeV/n)



SOHO – Nov 2003

Solar flares

- Protons (1keV - 500 MeV)
- Ions (1 – 10 MeV/n)

PROBA2/SWAP 17.4nm 2017-08-21 17:08:03

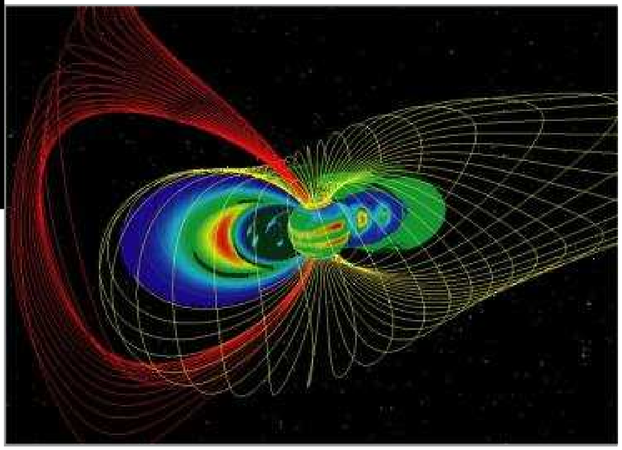
Space environment radiation

www.esa.int

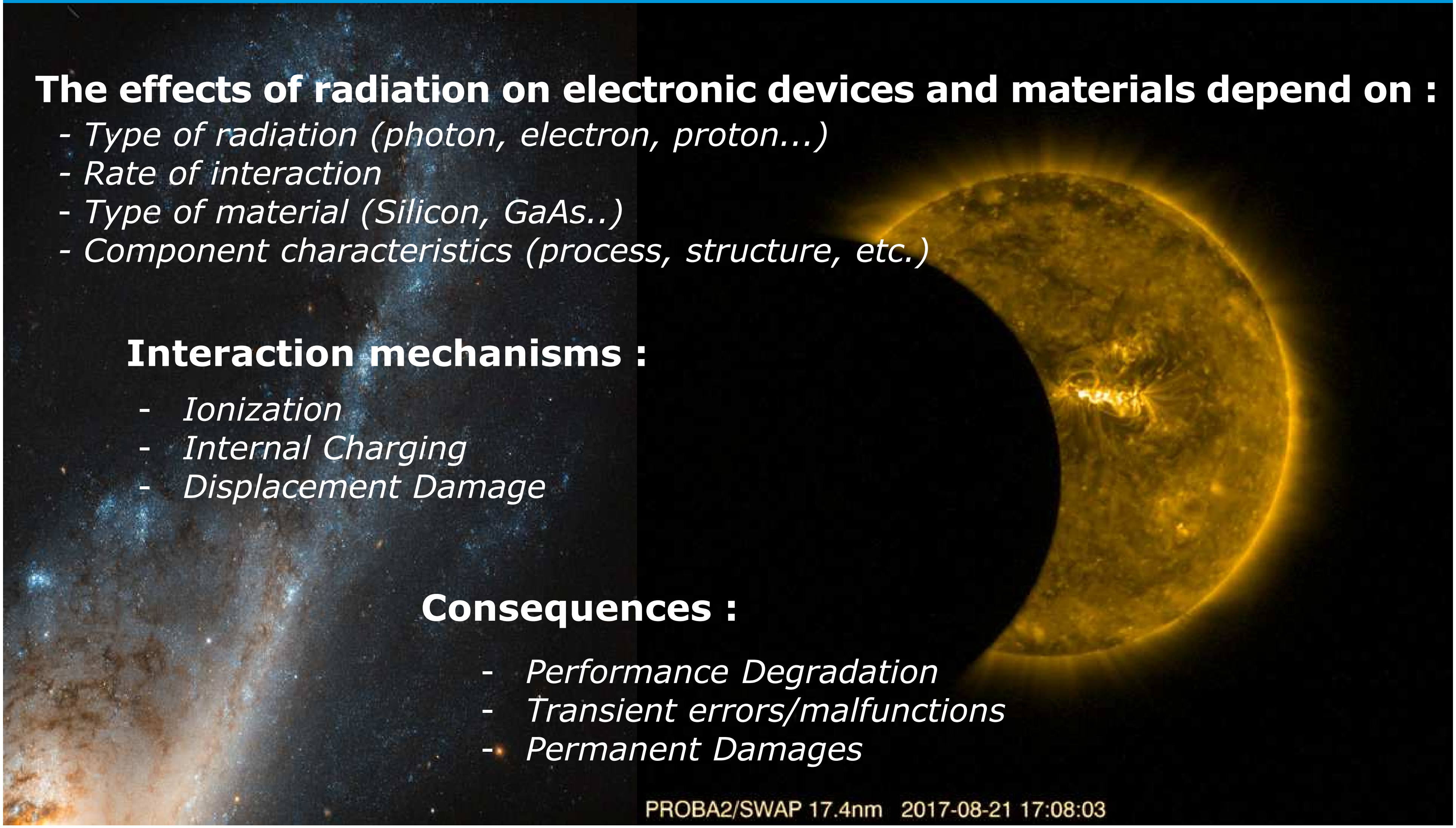
Van Allen belts: the trapped radiation environment

Trapped in the earth magnetic field:

- Protons < 400MeV
- Electrons < 7 MeV



Interaction of Radiation Particles with Electronic Devices and Materials



The effects of radiation on electronic devices and materials depend on :

- *Type of radiation (photon, electron, proton...)*
- *Rate of interaction*
- *Type of material (Silicon, GaAs..)*
- *Component characteristics (process, structure, etc.)*

Interaction mechanisms :

- *Ionization*
- *Internal Charging*
- *Displacement Damage*

Consequences :

- *Performance Degradation*
- *Transient errors/malfunctions*
- *Permanent Damages*

PROBA2/SWAP 17.4nm 2017-08-21 17:08:03

Radiation Hardness Assurance for Space

Radiation hardness assurance methodology is followed to ensure that the radiation environment does not compromise the functionality and performances of electronics during the system life.

ECSS European Cooperation for Space Standardization
ESCC European Space Components Coordination (escies.org)

RHA: ECSS-Q-ST-60-15C, ECSS-E-ST-10-12C, ECSS-E-HB-10-12, ECSS-Q-HB-60-02A

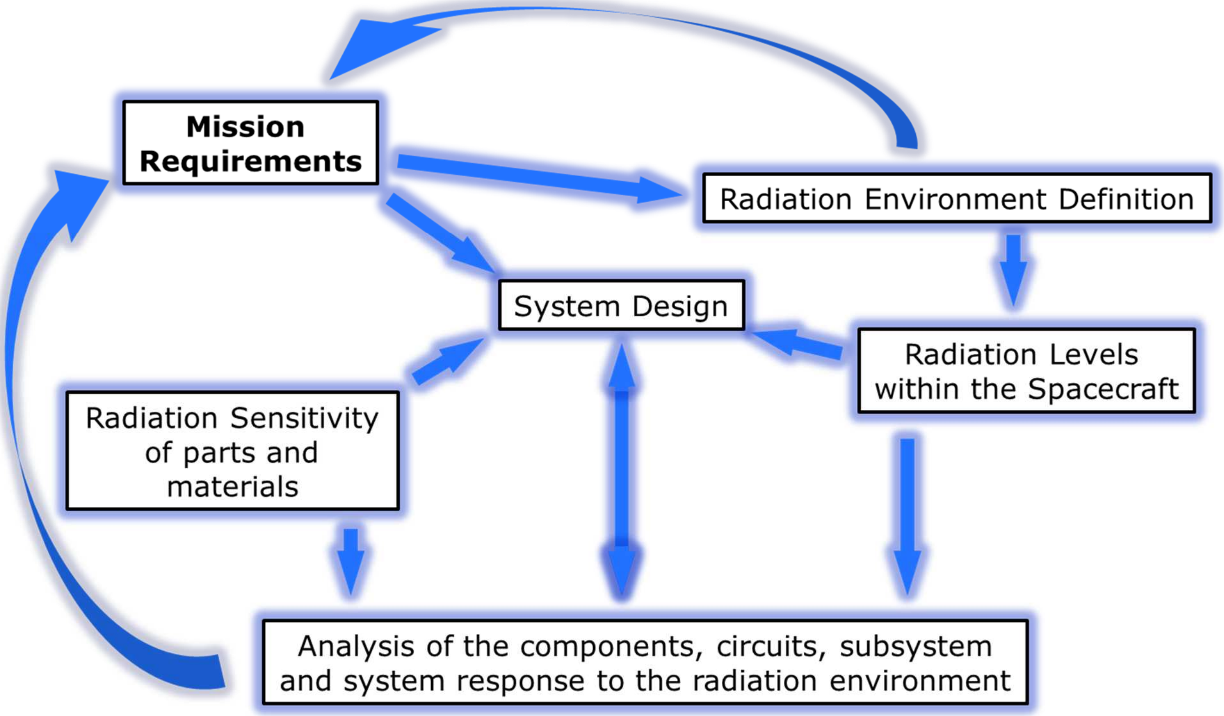
TID : ESCC 22900 **SEE**: ESCC 25100

http://ecss.nl/

Radiation Hardness Assurance for Space

Radiation Hardness Assurance (RHA) deals with:

- system requirements,
- space environment definition,
- radiation tolerant design,
- part selection,
- **part testing,**
- shielding
- etc…



Mission Requirements

Radiation Environment Definition

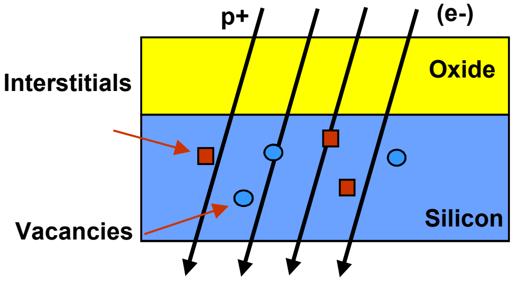
System Design

Radiation Levels within the Spacecraft

Radiation Sensitivity of parts and materials

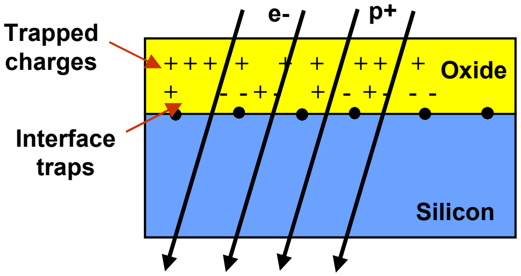
Analysis of the components, circuits, subsystem and system response to the radiation environment

Main radiation effects in Electronic component materials



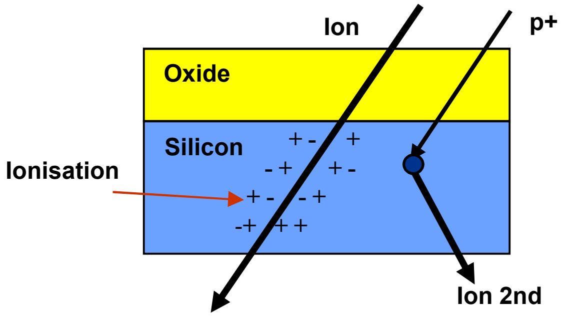
Displacement Damage (DD)

Cumulative effect result of particle energy deposition in the bulk of the semiconductor. It is also referred to as Total Non-ionizing Dose (TNID) damage



Total Ionising Dose (TID)

The creation of electron-holes pair in the material cause long term effects in the oxide (charge trapping) and at oxide-semiconductor interface (interface states)

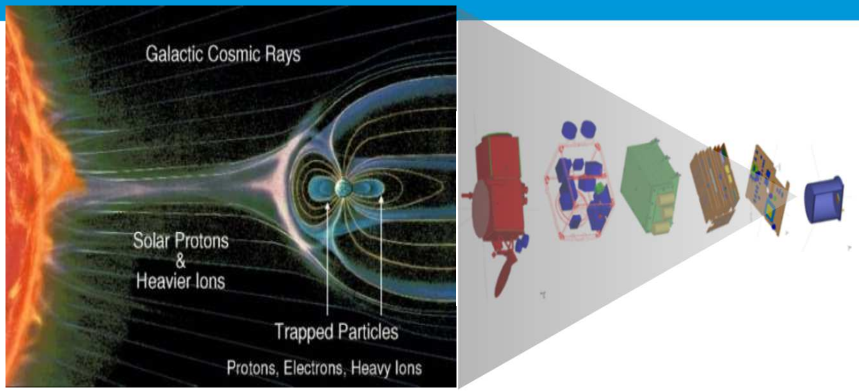


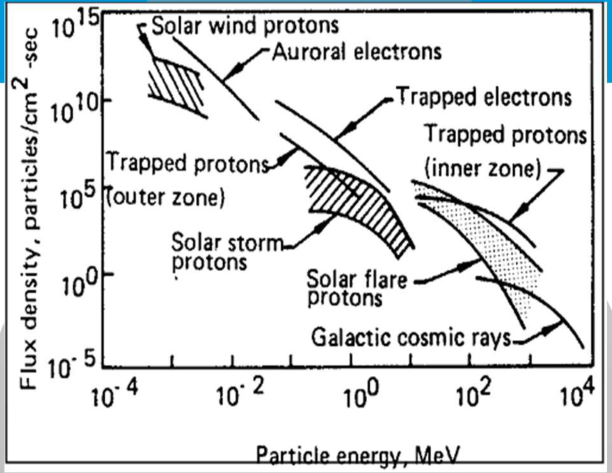
Single Event Effects (SEE)

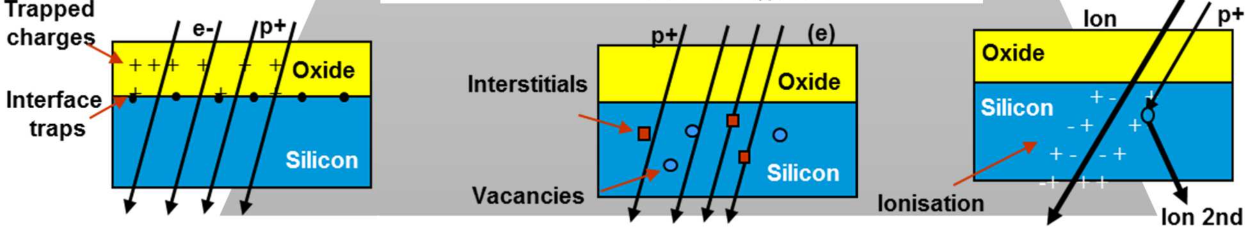
Ionization is created by direct energy deposition along ion tracks or the energy is deposited by fragments of nuclei from inelastic collision between a proton and a lattice nucleus.

The fragments usually deposit in turn all their energy along their track or produce a cascade of secondary particles.

From space environment to EEE components testing

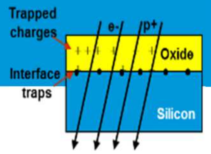


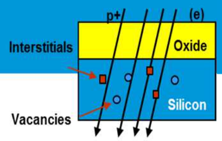


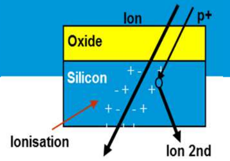


Radiation/Matter interaction	Ionising process	Non ionizing process	Charge deposition
Radiation effects on semiconductors: 3 Mechanisms Model	Total Ionising Dose	Displacement Damage	Single Event Effects
Standard source to create these effects in LABORATORY	High energy **Photons**	High energy **protons**	High energy **ions**

What to expect from testing







Total Ionising Dose	Displacement Damage	Single Event Effects

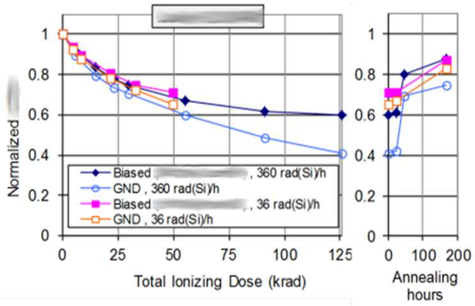
Cumulative effect:
Gradual global degradation of device parameter

Probabilistic effect:
transient, permanent or static errors.

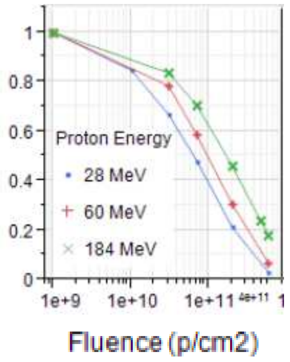
PERFORMANCE DEGRADATION
as function of :

CROSS SECTION
(=Probability of SEE occurrence)
as function of:

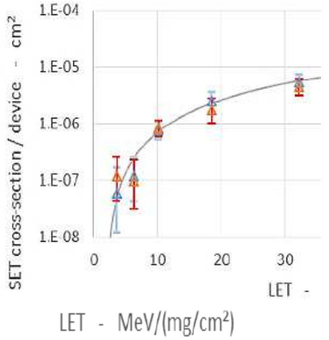
Total dose [rad(Si)] [Gy(Si)]



Fluence [p/cm^2]



Linear energy transfer [MeV/mg/cm2]



Other parameters:
Dose rate [rad(Si)/s] [Gy(Si)]

Other irradiation test parameter:
Proton Energy [MeV],
Flux [p/cm^2/s]

Other irradiation test parameter:
Flux[p/cm^2/s] , particle range [um]

TID testing

ESA ^{60}Co facility for TID testing at ESTEC

ESA Co60 Facility

European Space and Technology Research Center (ESTEC)

The Netherlands

Info on ESCIES :
https://escies.org/webdocument/showArticle?id=227&groupid=6

Beamtime reservation and current schedule:
https://estecco60facility.esa.int/

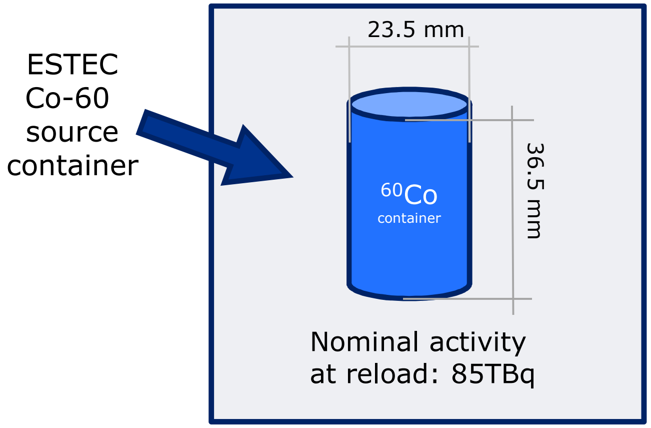
E-mail
Co60admin@esa.int

The **ESTEC GAMMABEAM 150C Co-60** facility was first installed in **1988** and has been in use ever since.

The source housing has **collimated layout and allows DUTs to be exposed to different dose rates** by varying their distance over a range up to 8 meters away from the source.

The initial activity at each reload is ~85 TBq with a half life of 5.3 years, the source has been re-loaded several times. The last reload was in May2016

The ^{60}Co facility – source characteristics

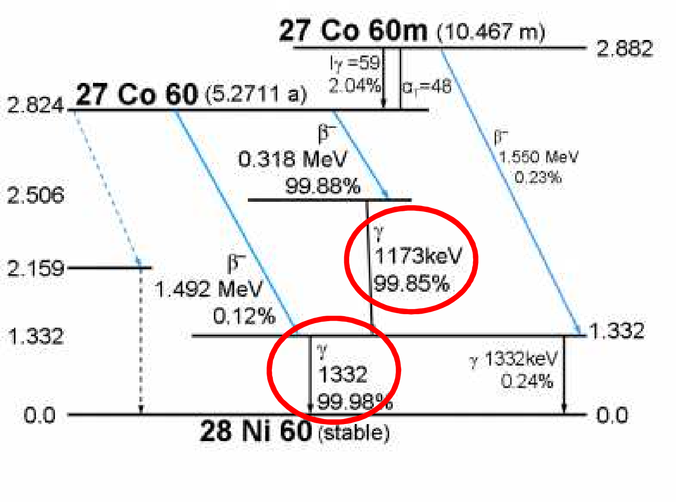


ESTEC
Co-60
source
container

Nominal activity
at reload: 85TBq

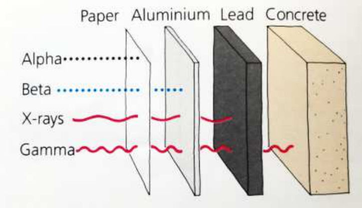
The ^{60}Co isotope undergoes beta decay with a half-life of 5.272 years producing the nuclear excited state of ^{60}Ni from which it emits either one or two gamma ray photons to reach the Nickel ground state.

- ^{60}Co Decay products => photons 1.173 MeV, 1.332 MeV
- ^{60}Co Half life =5.27 years

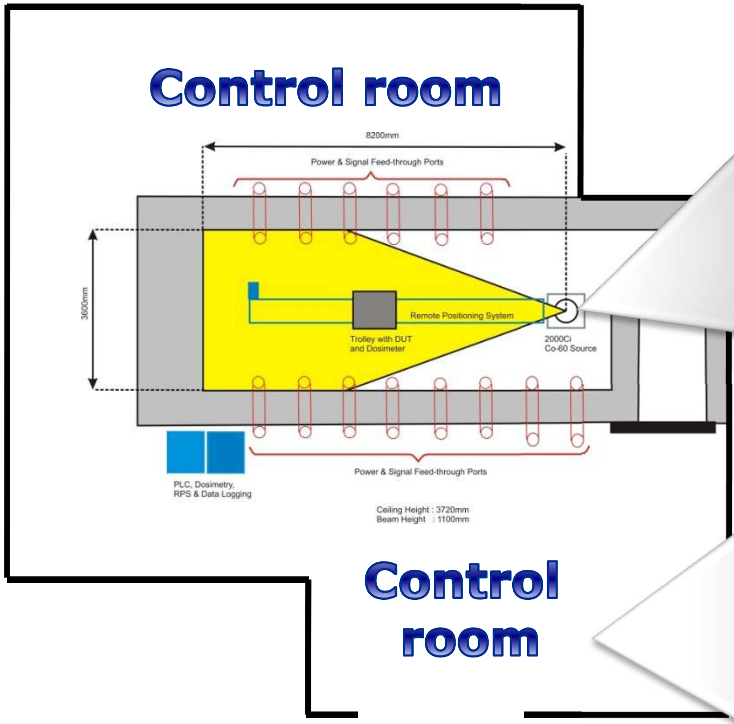


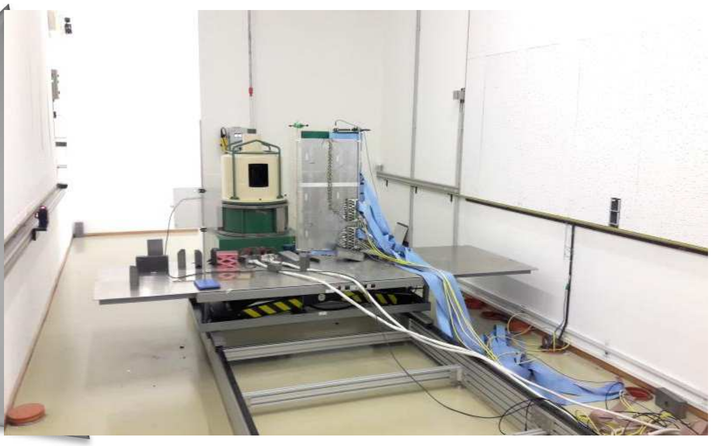
Advantages of using gammas:

- **No material activation**.
- Irradiation in **air**
- **No de-lidding necessary**



The ESA-ESTEC ^{60}Co facility



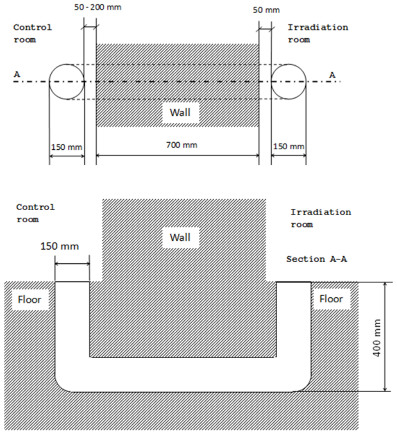


^{60}Co facility – The control room

Operator area

Equipment for DUT monitoring / characterization

Feedthough layout:

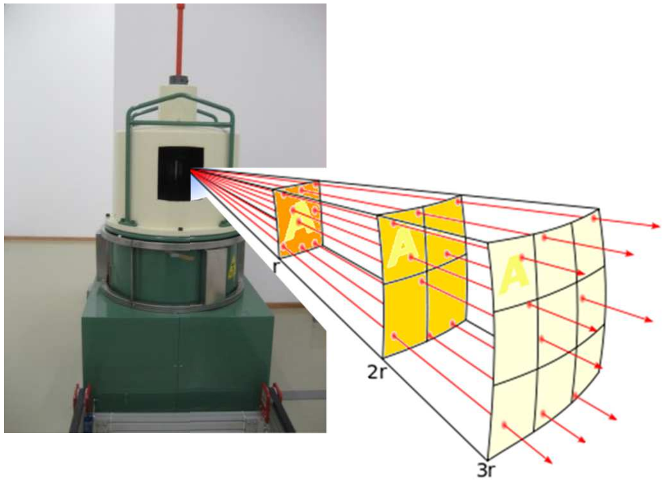


Feedthrough Layout

Recommended
~ **6m** cable length
to connect DUT in the
irradiation room to
equipment in the control
room

^{60}Co facility – The irradiation room

Min distance Max dose rate
Irradiation area 20cm x 20 cm
Dose rate 10-5krad (Si)/h
Distance 50 cm

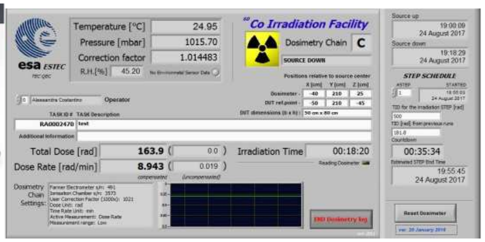


Source Irradiator:
Lead container with an opening window to expose the source and collimate the beam

Max distance Min dose rate
Irradiation area 3.6 m x 3.6 m
Dose rate 40-20 rad (Si)/h
Distance 7.5m

Table for DUT's installation
Variable height, remote controlled distance

Dosimetry based on:
- Farmer type 0.6 cc ionization chamber



^{60}Co Irradiation Facility

Temperature [°C] 24.95
Pressure [mbar] 1015.70
Correction factor 1.014483
R.H.[%] 45.20

Dosimetry Chain C
SOURCE DOWN

Operator Alessandra Costantino
TASK ID # RA0002470
TASK Description test
Additional information

Positions relative to source center
	X [cm]	Y [cm]	Z [cm]
Dosimeter	-40	210	25
DUT ref.point	-50	210	-45

DUT dimensions (B x H): 50 cm x 80 cm

Total Dose [rad] 163.9 (0.0)
Dose Rate [rad/min] 8.943 (0.019)
compensated (uncompensated)
Irradiation Time 00:18:20

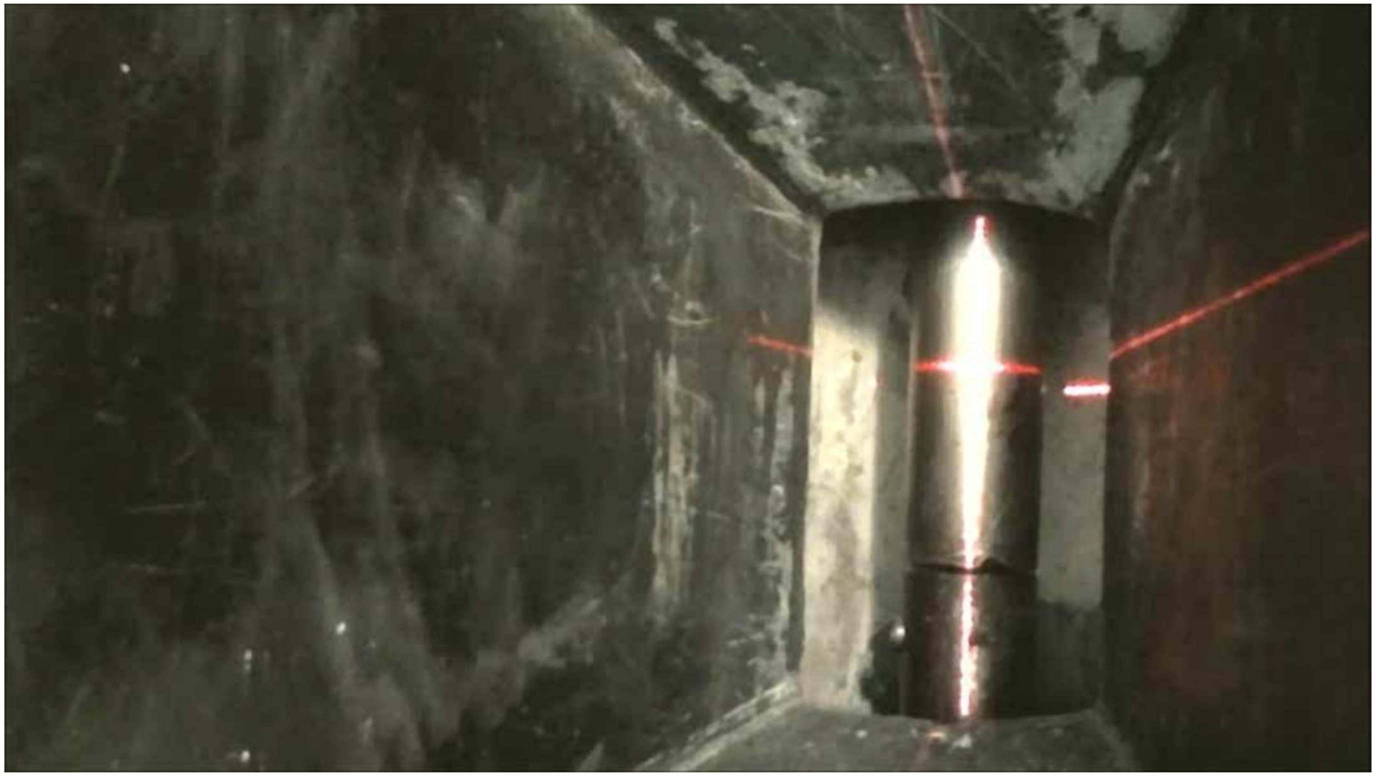
Dosimetry Chain Settings:
Farmer Electrometer s/n: 491
Ionisation Chamber s/n: 3573
User Correction Factor (1000x): 1021
Dose Unit: rad
Time Rate Unit: min
Active Measurement: Dose Rate
Measurement range: Low

Source up 19:00:09 24 August 2017
Source down 19:18:29 24 August 2017

STEP SCHEDULE
#STEP 1
STARTED 18:55:03 24 August 2017
TID for the irradiation STEP [rad] 500
TID [rad] from previous runs 181.8
Countdown 00:35:34
Estimated STEP End Time 19:55:45 24 August 2017

sw for dosimetry data logging

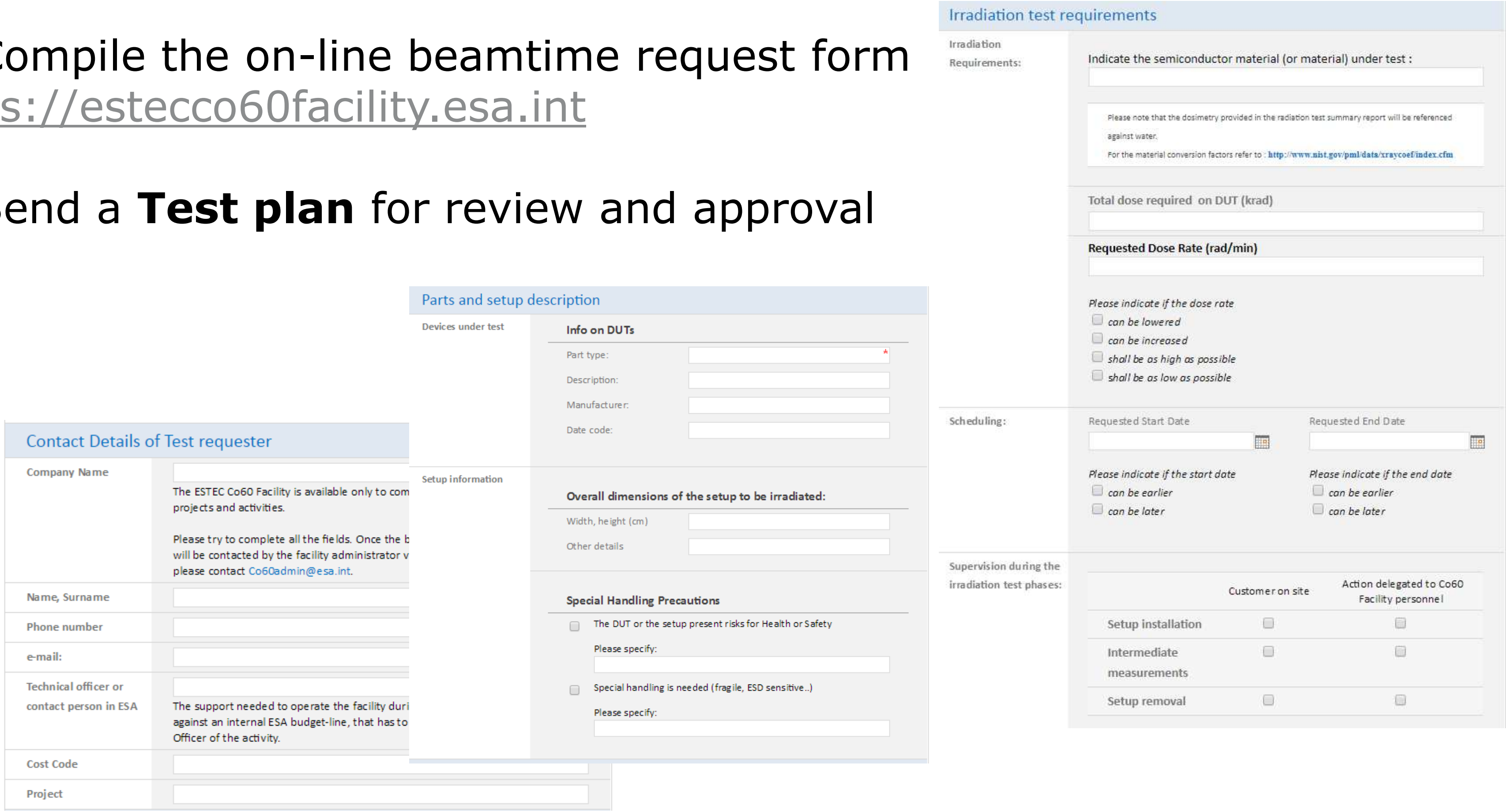
^{60}Co facility – Live footage



^{60}Co facility – how to request beam time

1) Compile the on-line beamtime request form
https://estecco60facility.esa.int

2) Send a **Test plan** for review and approval



Contact Details of Test requester

Company Name	The ESTEC Co60 Facility is available only to com projects and activities. Please try to complete all the fields. Once the b will be contacted by the facility administrator v please contact Co60admin@esa.int.
Name, Surname	
Phone number	
e-mail:	
Technical officer or contact person in ESA	The support needed to operate the facility duri against an internal ESA budget-line, that has to Officer of the activity.
Cost Code	
Project	

Parts and setup description

Devices under test

Info on DUTs

Part type: *

Description:

Manufacturer:

Date code:

Setup information

Overall dimensions of the setup to be irradiated:

Width, height (cm)

Other details

Special Handling Precautions

☐ The DUT or the setup present risks for Health or Safety

Please specify:

☐ Special handling is needed (fragile, ESD sensitive..)

Please specify:

Irradiation test requirements

Irradiation Requirements:

Indicate the semiconductor material (or material) under test :

Please note that the dosimetry provided in the radiation test summary report will be referenced against water.

For the material conversion factors refer to : http://www.nist.gov/pml/data/xraycoef/index.cfm

Total dose required on DUT (krad)

Requested Dose Rate (rad/min)

Please indicate if the dose rate
- ☐ *can be lowered*
- ☐ *can be increased*
- ☐ *shall be as high as possible*
- ☐ *shall be as low as possible*

Scheduling:

Requested Start Date

Please indicate if the start date
- ☐ *can be earlier*
- ☐ *can be later*

Requested End Date

Please indicate if the end date
- ☐ *can be earlier*
- ☐ *can be later*

Supervision during the irradiation test phases:

	Customer on site	Action delegated to Co60 Facility personnel
Setup installation	☐	☐
Intermediate measurements	☐	☐
Setup removal	☐	☐

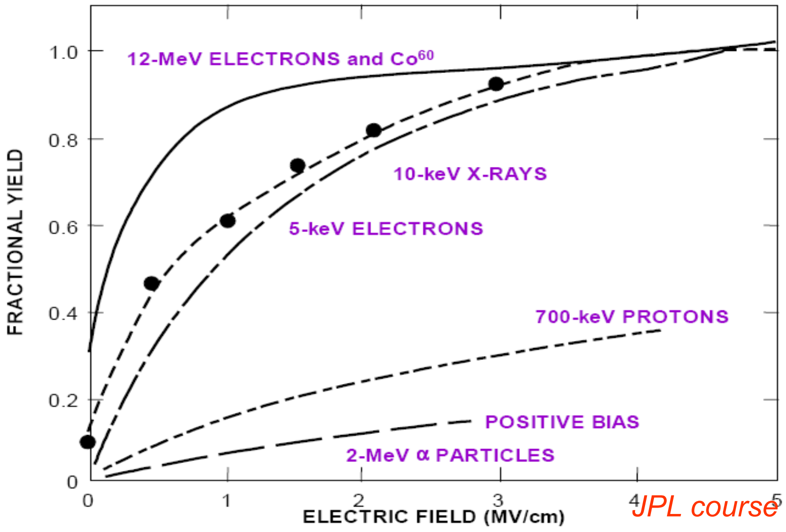
Why using a Co60 source for TID testing

TID testing employing ^{60}Co facilities (gamma source) has, over the years, become the de-facto standard test method.

This is due to the high yield of the Co60 gamma ray beam,
long heritage of Co60 use in industry and medical application,
availability of the isotope…

- In some cases electrons, protons and x-rays are also used to perform TID testing.
- Care has to be shown when employing other sources than ^{60}Co (range in the material, dosimetry …)

In space high energy photons are not a concern compared to the other sources of radiation. However, it has been empirically shown that ^{60}Co testing is conservative compared to testing with protons or electrons.

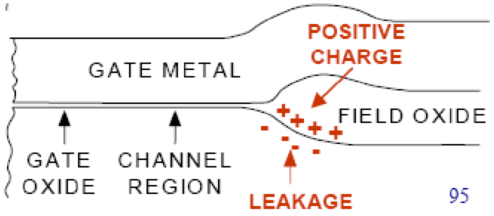


JPL course by J.Conley

Fig: electron-hole pair generation (ionisation) yield in matter for various particle species, energy and field across oxide.

Total Ionizing Dose (TID) effects

The total dose deposited by electrons or protons alters the electrical characteristics of electronic components



Some effects in MOS transistors:

- Gate voltage threshold shifts
- Leakage increases, flat band shift
- Channel resistivity increase

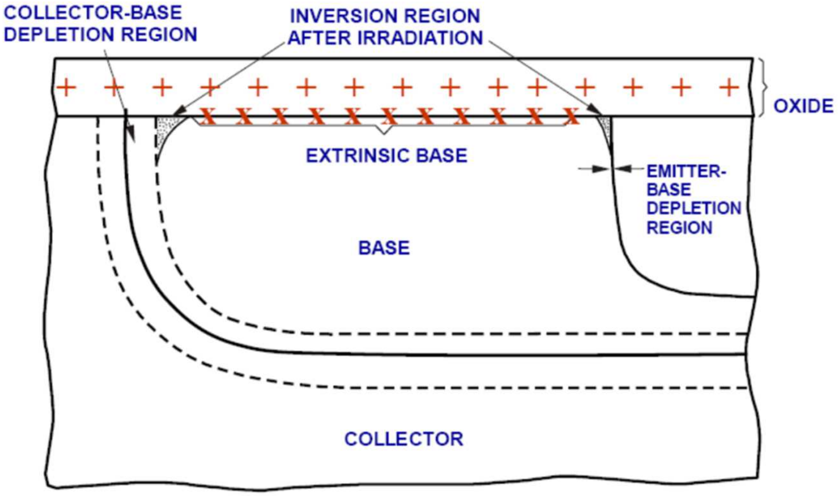
Caused by oxide and interface traps

In Bipolar transistors:

- leakage increase
- Reduction of the gain
- Noise figure worsening

A variety of factors influence the TID effects on the devices:

- Temperature
- Electric fields over oxides (magnitude and polarity)
- Dose rates
- Technology
- Process (including lot to lot variation)
- Design rules
- …



After Space Radiation Effects on Microelectronics course from JPL, J.F. Conley

TID Test preparation

ESCC Basic Specification 22900 :
Total Dose Steady-State Irradiation Test Method

Specification -> https://escies.org/download/specdraftapppub?id=3413
Test plan template -> https://escies.org/download/webDocumentFile?id=62995

SCOPE

The specification defines the basic requirements applicable to the **steady-state irradiation testing** of **integrated circuits** and **discrete semiconductors** suitable for space applications.

PURPOSE

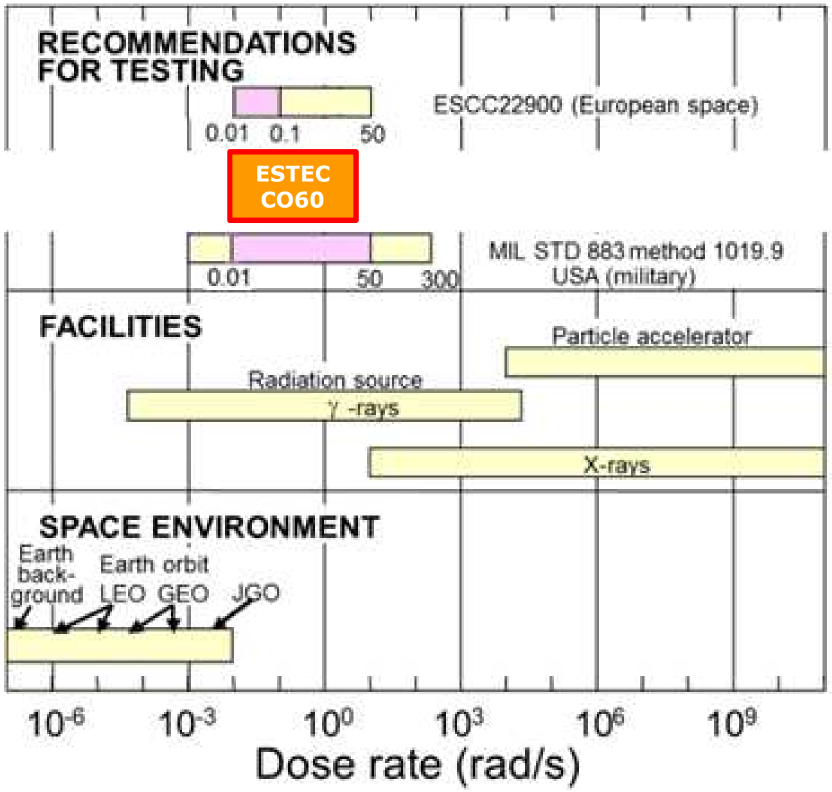
1. The specification addresses three cases:
   - The **evaluation** testing procedure: main objectives to establish worst case conditions for TID qualification (dose level, dose rate effects, bias dependency, critical parameters, annealing effects, etc..)
   - the **qualification and lot acceptance** testing procedures: test conditions identified in the evaluation phase
   - the testing **outside ESCC context**: no hard requirements in terms of sample size, dose rates, pass/fail criteria (can be project and/or application specific not just related to the datasheet).

1. ESCC22900

Other standards and references:
- MIL-STD883 Method 1019.9 “Ionizing Radiation (Total Dose) Test Procedure”
- MIL-STD750 Method 1019.5 “Steady-state Total Dose Irradiation Procedure”
- ASTM F 1892-06 “Standard Guide for Ionizing Radiation (Total Dose) Effects Testing of Semiconductor”

TID Test:
dose rate ranges comparison

Dose rate (DR = dD/dt)
the quantity of radiation absorbed per unit time



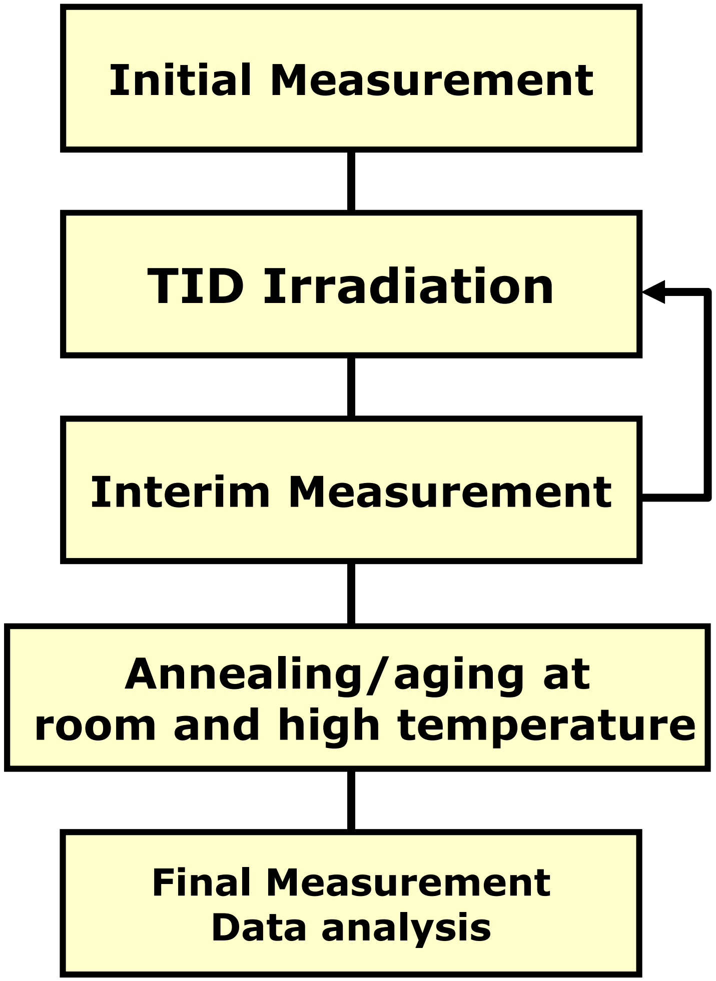
Absorbed dose (D)
the **mean energy imparted to matter** per unit mass by ionizing radiation

The SI unit of measure is **gray** [Gy]
1Gy equals 1 joules per kilogram
The historical, and most used unit is **[rad]**
1 rad =100 Gy

The dose depends on the matter considered =>
specify dose in matter (eg. rad(Si), Gy(SiO2)…)

TID Test Flow

Irradiation testing is performed to identify whether a component meets specification/application requirements when exposed to desired/application radiation doses.



Initial Measurement

TID Irradiation

Interim Measurement

Annealing/aging at room and high temperature

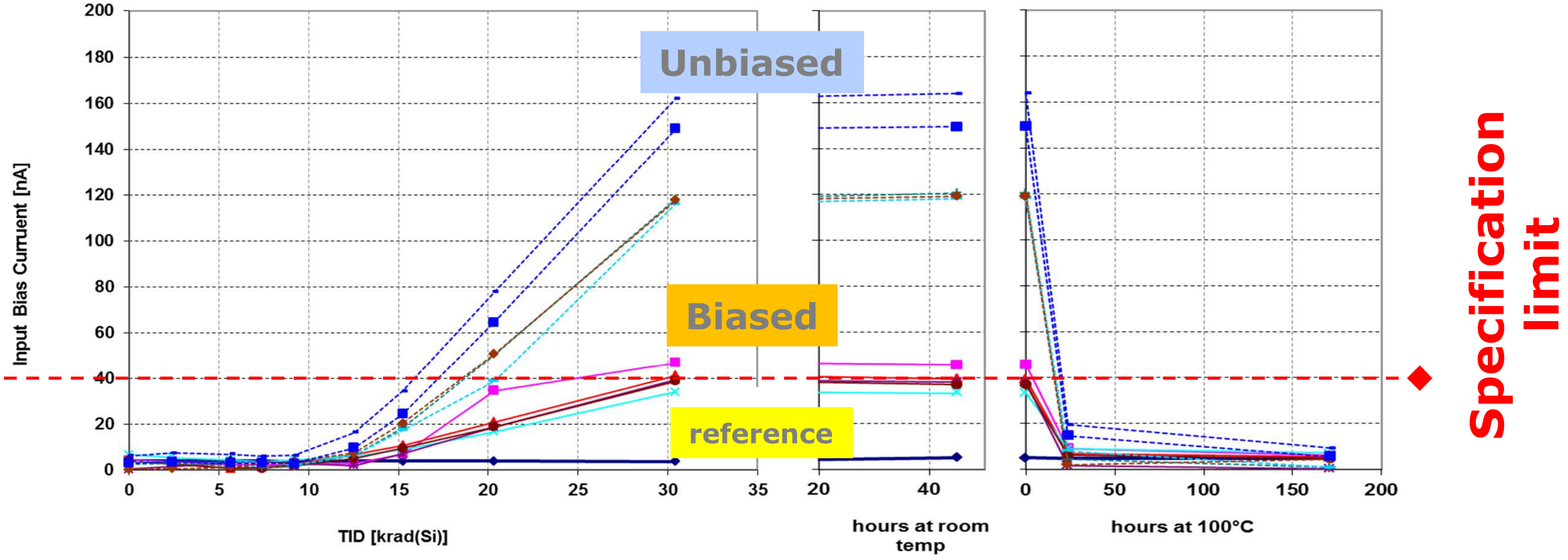
Final Measurement
Data analysis

TID TEST RESULTS

TID effects - TEST CASE 1

Device under test: Low noise precision Operational Amplifier

100krad rad hard qualified has failed at 20krad(Si)



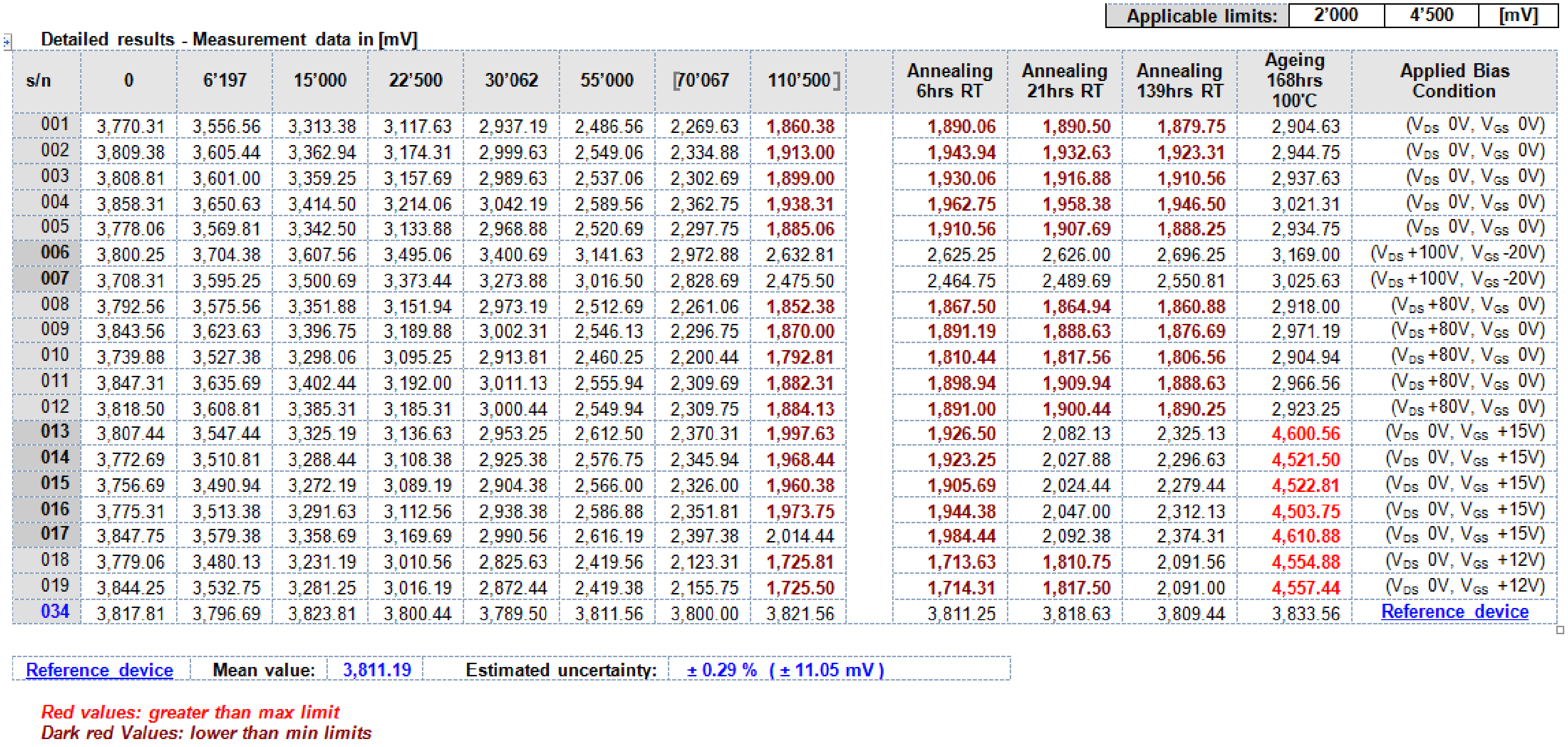
Why so far from qualification data?

a. dose rate – *this test* :~ 10mrad(Si) s^{-1} *qualification:* 50-300rad(Si) s^{-1}

b. biasing condition – qualification requests only one biasing condition (V=+-15)

In this case the worst case is unbiased
Unbiased case is important for cold redundancy and off period during transfer orbit

Ionizing Radiation induced charge trapping and interface state generation in MOS Structure



Applicable limits:	2’000	4’500	[mV]

Detailed results - Measurement data in [mV]

s/n	0	6’197	15’000	22’500	30’062	55’000	[70’067	110’500]		Annealing 6hrs RT	Annealing 21hrs RT	Annealing 139hrs RT	Ageing 168hrs 100'C	Applied Bias Condition
001	3,770.31	3,556.56	3,313.38	3,117.63	2,937.19	2,486.56	2,269.63	1,860.38		1,890.06	1,890.50	1,879.75	2,904.63	(V_{DS} 0V, V_{GS} 0V)
002	3,809.38	3,605.44	3,362.94	3,174.31	2,999.63	2,549.06	2,334.88	1,913.00		1,943.94	1,932.63	1,923.31	2,944.75	(V_{DS} 0V, V_{GS} 0V)
003	3,808.81	3,601.00	3,359.25	3,157.69	2,989.63	2,537.06	2,302.69	1,899.00		1,930.06	1,916.88	1,910.56	2,937.63	(V_{DS} 0V, V_{GS} 0V)
004	3,858.31	3,650.63	3,414.50	3,214.06	3,042.19	2,589.56	2,362.75	1,938.31		1,962.75	1,958.38	1,946.50	3,021.31	(V_{DS} 0V, V_{GS} 0V)
005	3,778.06	3,569.81	3,342.50	3,133.88	2,968.88	2,520.69	2,297.75	1,885.06		1,910.56	1,907.69	1,888.25	2,934.75	(V_{DS} 0V, V_{GS} 0V)
006	3,800.25	3,704.38	3,607.56	3,495.06	3,400.69	3,141.63	2,972.88	2,632.81		2,625.25	2,626.00	2,696.25	3,169.00	(V_{DS} +100V, V_{GS} -20V)
007	3,708.31	3,595.25	3,500.69	3,373.44	3,273.88	3,016.50	2,828.69	2,475.50		2,464.75	2,489.69	2,550.81	3,025.63	(V_{DS} +100V, V_{GS} -20V)
008	3,792.56	3,575.56	3,351.88	3,151.94	2,973.19	2,512.69	2,261.06	1,852.38		1,867.50	1,864.94	1,860.88	2,918.00	(V_{DS} +80V, V_{GS} 0V)
009	3,843.56	3,623.63	3,396.75	3,189.88	3,002.31	2,546.13	2,296.75	1,870.00		1,891.19	1,888.63	1,876.69	2,971.19	(V_{DS} +80V, V_{GS} 0V)
010	3,739.88	3,527.38	3,298.06	3,095.25	2,913.81	2,460.25	2,200.44	1,792.81		1,810.44	1,817.56	1,806.56	2,904.94	(V_{DS} +80V, V_{GS} 0V)
011	3,847.31	3,635.69	3,402.44	3,192.00	3,011.13	2,555.94	2,309.69	1,882.31		1,898.94	1,909.94	1,888.63	2,966.56	(V_{DS} +80V, V_{GS} 0V)
012	3,818.50	3,608.81	3,385.31	3,185.31	3,000.44	2,549.94	2,309.75	1,884.13		1,891.00	1,900.44	1,890.25	2,923.25	(V_{DS} +80V, V_{GS} 0V)
013	3,807.44	3,547.44	3,325.19	3,136.63	2,953.25	2,612.50	2,370.31	1,997.63		1,926.50	2,082.13	2,325.13	4,600.56	(V_{DS} 0V, V_{GS} +15V)
014	3,772.69	3,510.81	3,288.44	3,108.38	2,925.38	2,576.75	2,345.94	1,968.44		1,923.25	2,027.88	2,296.63	4,521.50	(V_{DS} 0V, V_{GS} +15V)
015	3,756.69	3,490.94	3,272.19	3,089.19	2,904.38	2,566.00	2,326.00	1,960.38		1,905.69	2,024.44	2,279.44	4,522.81	(V_{DS} 0V, V_{GS} +15V)
016	3,775.31	3,513.38	3,291.63	3,112.56	2,938.38	2,586.88	2,351.81	1,973.75		1,944.38	2,047.00	2,312.13	4,503.75	(V_{DS} 0V, V_{GS} +15V)
017	3,847.75	3,579.38	3,358.69	3,169.69	2,990.56	2,616.19	2,397.38	2,014.44		1,984.44	2,092.38	2,374.31	4,610.88	(V_{DS} 0V, V_{GS} +15V)
018	3,779.06	3,480.13	3,231.19	3,010.56	2,825.63	2,419.56	2,123.31	1,725.81		1,713.63	1,810.75	2,091.56	4,554.88	(V_{DS} 0V, V_{GS} +12V)
019	3,844.25	3,532.75	3,281.25	3,016.19	2,872.44	2,419.38	2,155.75	1,725.50		1,714.31	1,817.50	2,091.00	4,557.44	(V_{DS} 0V, V_{GS} +12V)
034	3,817.81	3,796.69	3,823.81	3,800.44	3,789.50	3,811.56	3,800.00	3,821.56		3,811.25	3,818.63	3,809.44	3,833.56	Reference device

Reference device	Mean value:	3,811.19	Estimated uncertainty:	± 0.29 % (± 11.05 mV)

Red values: greater than max limit
Dark red Values: lower than min limits

REFERENCE SAMPLE

-Setup measurement long term stability over time

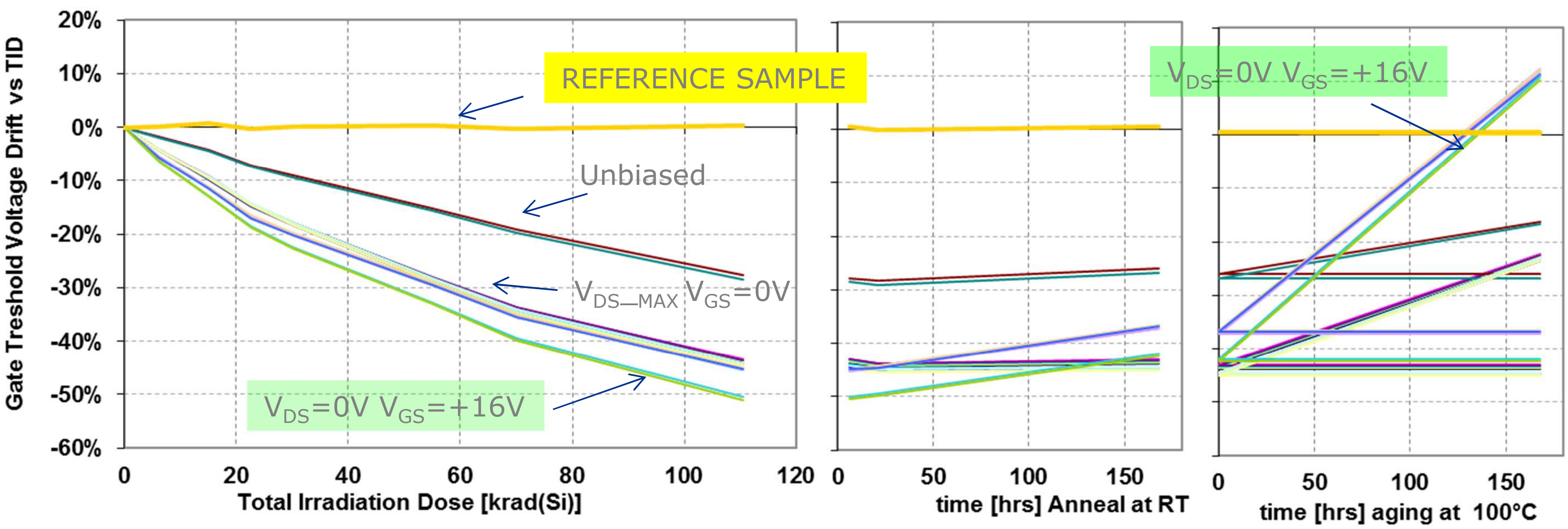
- Environmental effects
- Setup functionality

- Statistical contribution to uncertainty

TID effects – TEST CASE 2

Device under test: Power Mosfet

Dose rate: **~ 100 mrad(Si) s^{-1}** worst case for V_{DS}=0V V_{GS}=V_{GSmax}



Irradiation: negative shift due to the oxide traps prevails on the interface traps effect. The worst case for V_{GS} max

Ageing: positive shift due to the interface traps prevails. The worst case for V_{GS} max

TID effects – TEST CASE 2

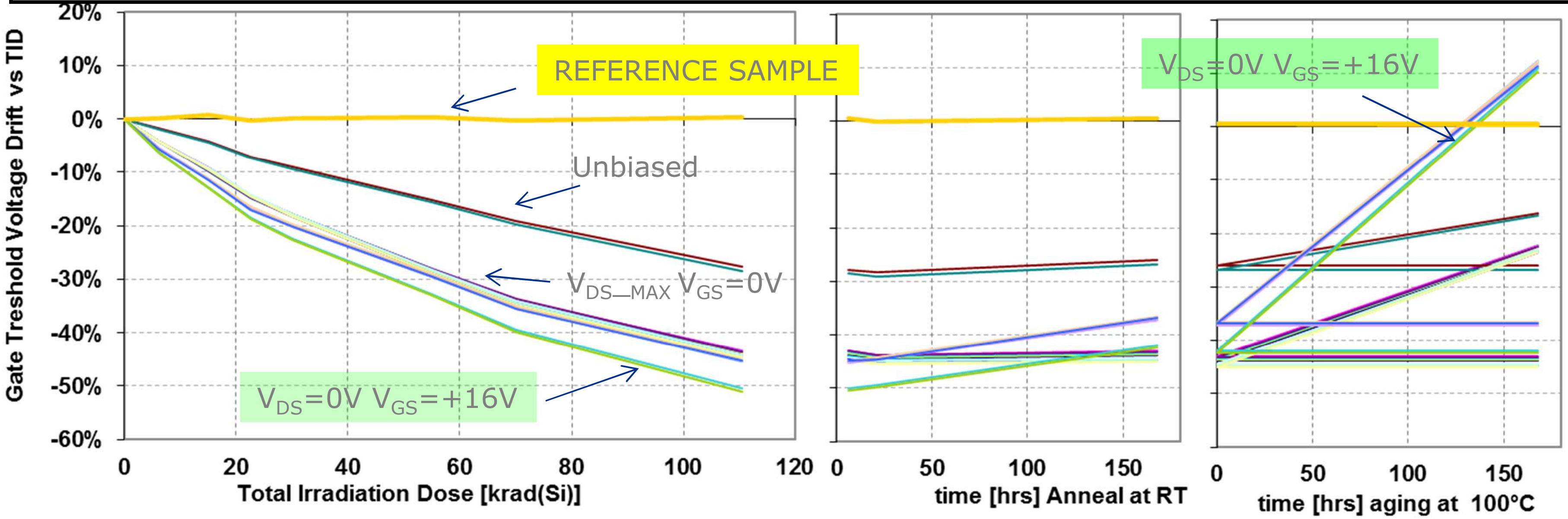
Device under test: Power Mosfet

Test condition : Dose rate: **~ 100 mrad(Si) s^{-1}**

worst case always for V_{DS}=0V V_{GS}=+16V

After the aging: minimum drift (≈10%) on the bias condition V_{DS}=0V V_{GS}=+16V

the "always worst case condition" is actually the better one?

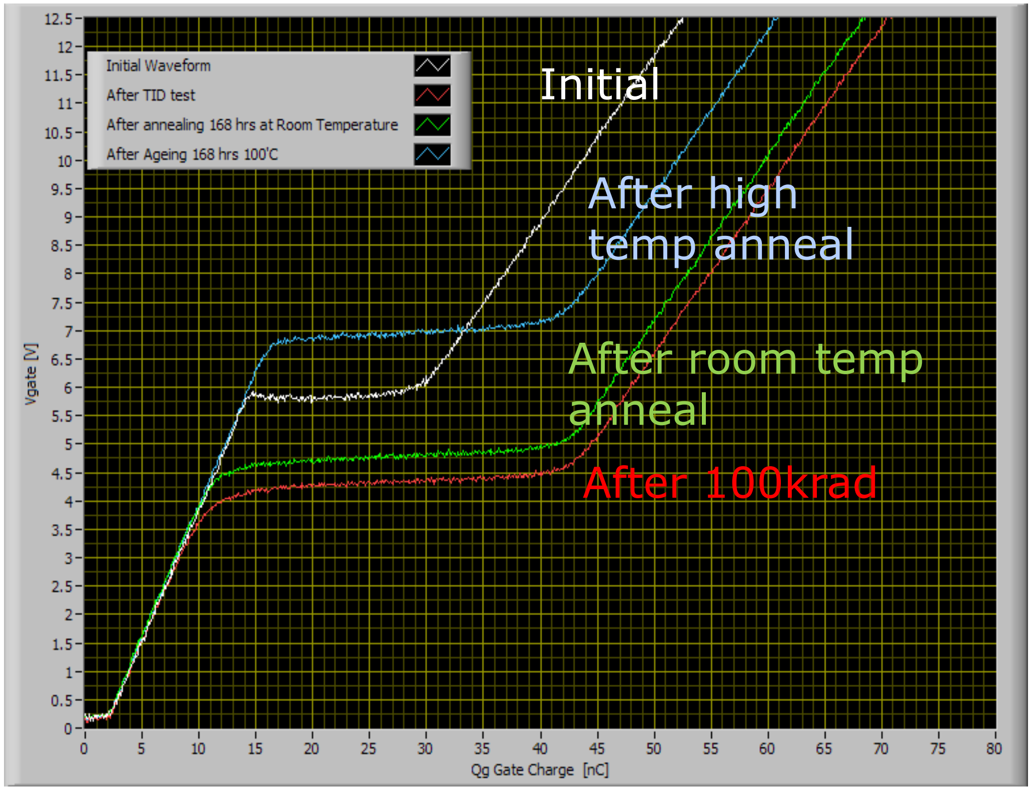


For oxide and interface trap dynamics, see D.M.Fleetwood short course lecture

TID effects – TEST CASE 3

Device under test: MOSFET

Result: at the end of the test static parameters seems still “OK”



However, the charge needed to **switch on/off** the MOSFET is about 30% higher than the initial value.

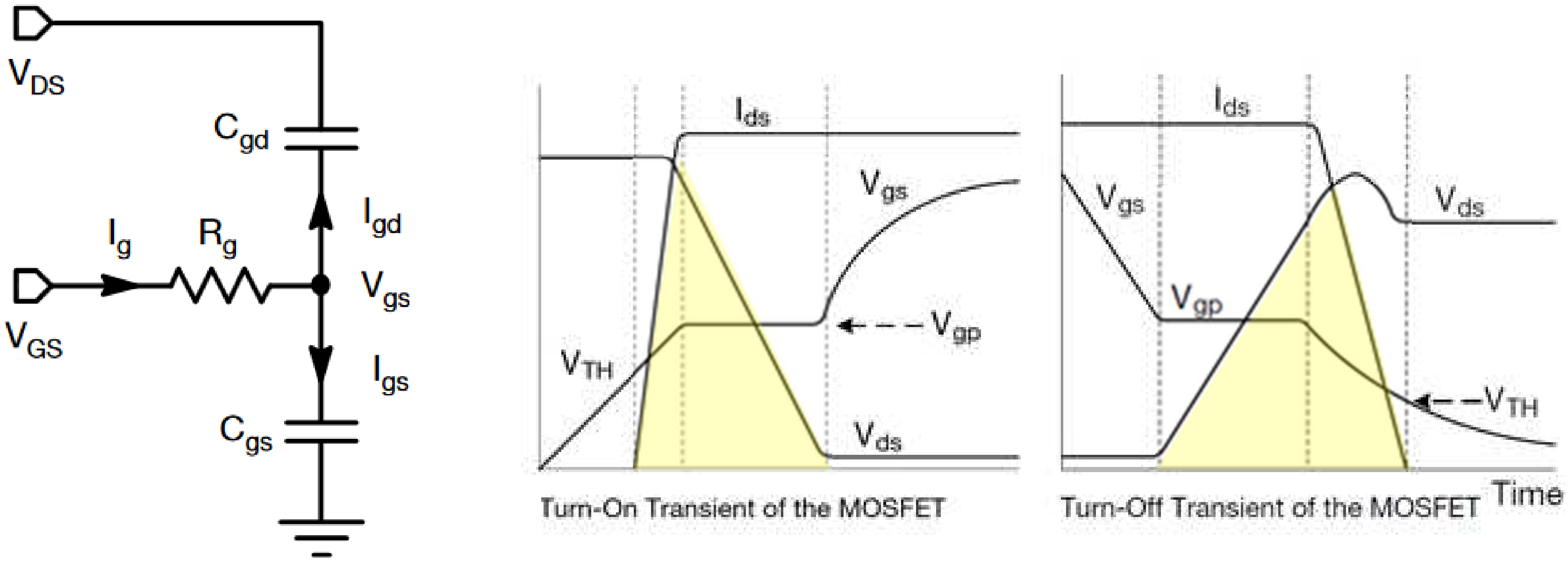
The MOSFET switching characteristics will be significantly degraded!

Ref: MIL STD 750 method 3471

TID effects – TEST CASE 3

Device under test: MOSFET

Result: at the end of the test, the trapped charges at the interface will still affect the switching characteristic of the MOSFET



Turn-On Transient of the MOSFET

Turn-Off Transient of the MOSFET

(www.vishay.com AN608A)

TID effects – to keep in mind

- TID predominantly affects the device oxide resulting in device parameter degradation
- Co-60 gamma ray most common used radiation source
- Sensitivity to TID is strongly technology and manufacturing process dependent.
- ELDRS can be an issue for bipolar based devices
- Lot-non-uniformity is an issue for TID specifically with respect to Enhanced Low Dose Rate Sensitivity (ELDRS) issue
- New Deep Sub Micron (DSM) technologies **seem** quite TID tolerant…
  … keep testing! (see D.M. Fleetwood, RADECS 2017 short course)

DD testing

The Displacement Damage is not an oxide effect but is a result of the particle energy deposition in the bulk of the material that creates defects in the semiconductor lattice.

As for TID, DD (or TNID) is a cumulative effect and produces parametric degradation of the device performances.

The ECSS-E-HB-10-12A standards provide detailed guidelines
For DD testing of electronic devices.

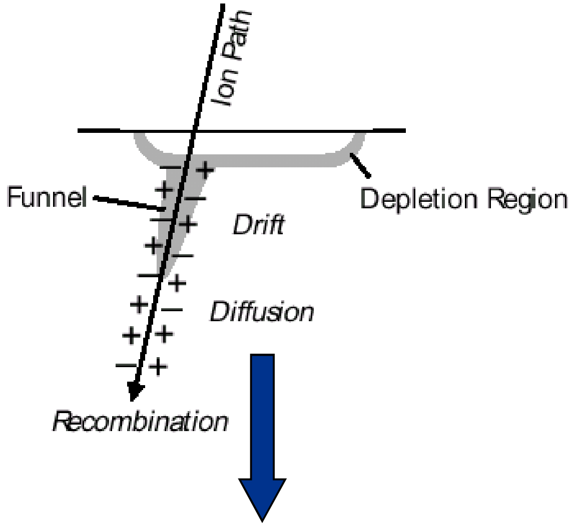
Displacement Damage
– some effects

Technology category	sub-category	Effects
General bipolar	BJT	hFE degradation in BJTs, particularly for low-current conditions (PNP devices more sensitive to DD than NPN)
	diodes	Increased leakage current increased forward voltage drop
Electro-optic sensors	CCDs	CTE degradation, Increased dark current, Increased hot spots, Increased bright columns Random telegraph signals
	APS	Increased dark current, Increased hot spots, Random telegraph signals Reduced responsivity
	Photo diodes	Reduced photocurrents Increased dark currents
	Photo transistors	hFE degradation Reduced responsivity Increased dark currents
Light-emitting diodes	LEDs (general)	Reduced light power output
	Laser diodes	Reduced light power output Increased threshold current
Opto-couplers		Reduced current transfer ratio
Solar cells	Silicon GaAs, InP etc	Reduced short-circuit current Reduced open-circuit voltage Reduced maximum power
Optical materials	Alkali halides Silica	Reduced transmission

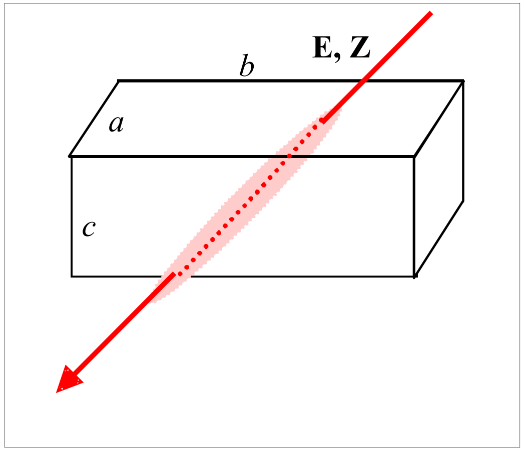
see the ECSS-E-HB-10-12A standard, paragraph 7 for more details

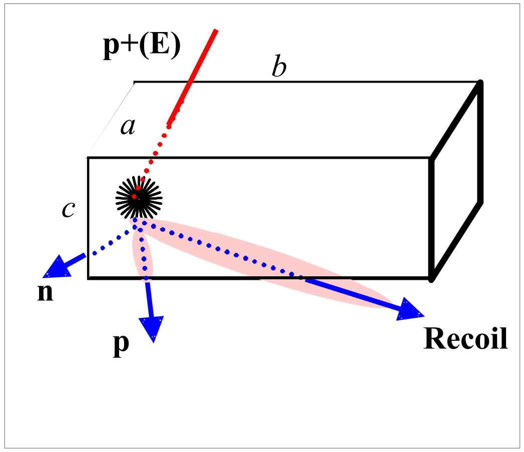
SEE testing

Single Event Effect (SEE) basic mechanism



The volume responsible for charge collection for a SEE (in μm^3)





Real sensitive volumes do not really have regular shapes and therefore, not only incidence angle but also pitch and tilt may have an impact in the total amount of charge collected triggering the SEE.

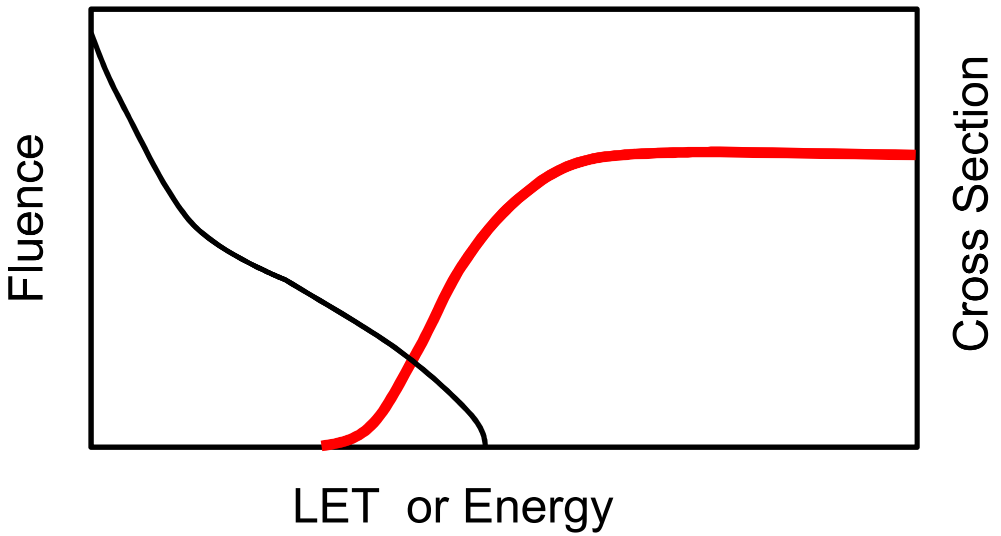
Why SEE testing? SEE rate prediction

Estimate the sensitivity to SEE in order to predict the SEE rate during the system life in space.

Need to know:

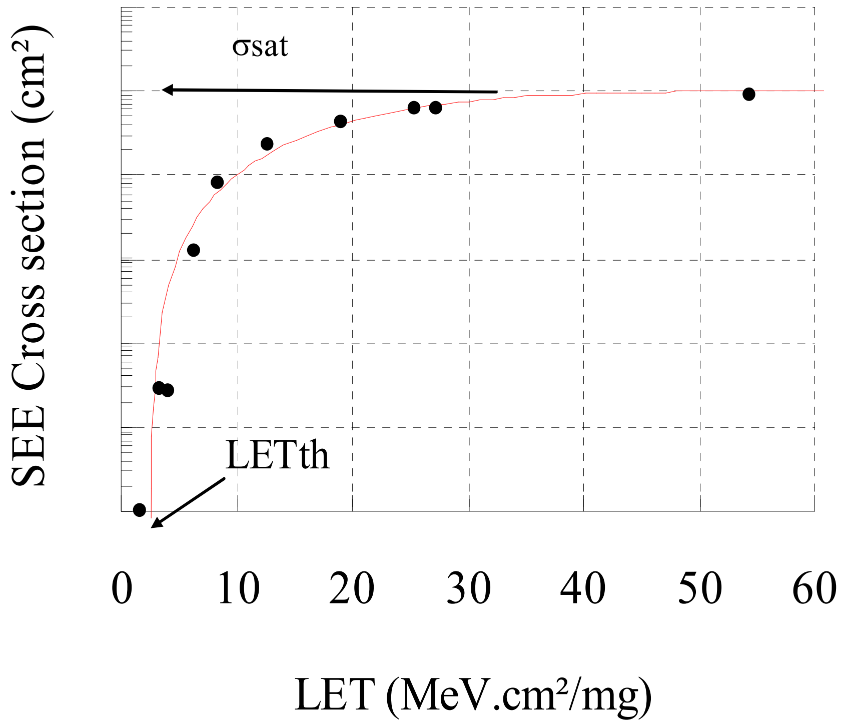
a. Space Environment: Integral flux as a function of LET or energy

b. Cross-section vs. ion LET or proton energy



SEE Cross Section Curve vs LET

ESCC 25100 Single Event Effects Test Method and Guideline



The SEE cross section measures the probability for a SEE to occur

$$[\mathrm{cm}^2] \longrightarrow \sigma = \frac{N_{events}}{\mathrm{Fluence}} \longleftarrow [N_{particles}/\mathrm{cm}^2]$$

Fit with Weibull (integral form)

$$\sigma = \sigma_{sat}\left(1 - \exp\left(\frac{LET - LET_{th}}{W}\right)^{S}\right)$$

W and S are fitting parameters

SEE cross-section is a crucial input for in-orbit SEE rate prediction.

Some classes of SEE

Soft Errors (no permanent damage)

- SEU Single-Event Upset
- MBU, MCU Multiple Bit (or Cell) Upset
- ASET Analog Single Event Transient
- DSET Digital Single Event Transient
- SEFI Single Event Functional Interrupt
- (*) Others…

(*) the one that <u>always</u> occurs when you do not expect it !

Hard Errors (permanent damage of device)

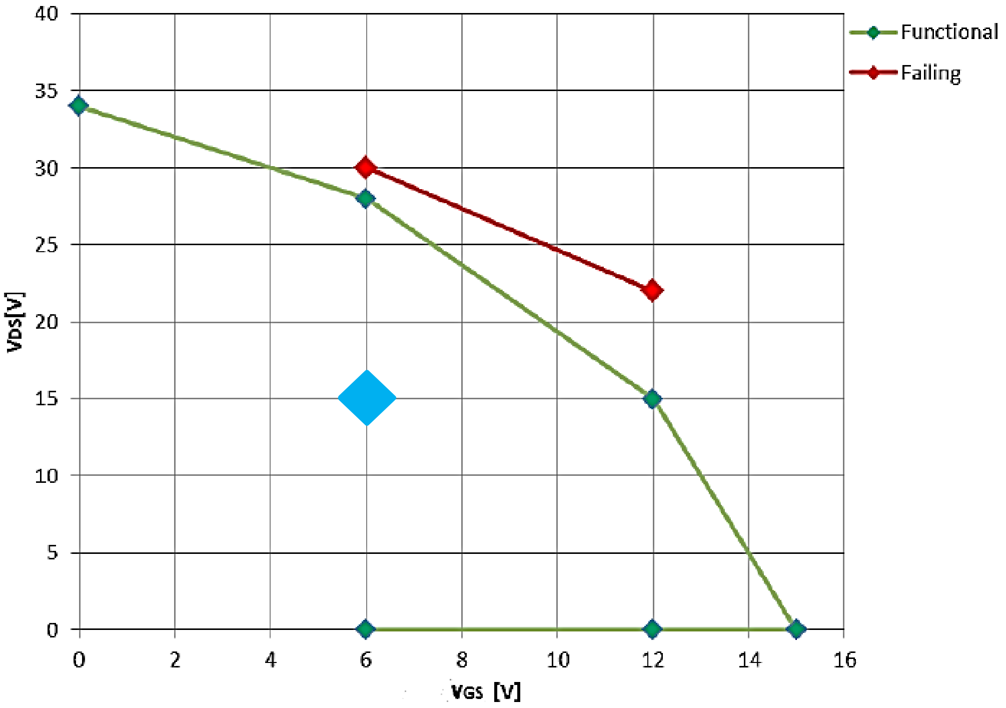
- SEL Single-Event Latchup (non destructive test still possible…)
- SEDR Single-Event Dielectric Rupture
- SEB Single-Event Burnout
- SEGR Single-Event Gate Rupture
- (*) Others...

} When possible, identify the Safe operating area

SEE testing – TEST CASE 4
Safe Operation Area (SEGR - SEB)

	V_{GS} = 0 V	V_{GS} = 6 V	V_{GS} = 12 V	V_{GS} = 15 V
V_{DS} = 0V	not tested	pass	pass	pass
V_{DS} = 15V	pass	pass	pass	
V_{DS} = 22V	pass	pass	(FAIL)	
V_{DS} = 28V	pass	pass		
V_{DS} = 30V	not tested	FAIL		
V_{DS} = 34V	pass			

The application requirements are appropriate since they fall within the SOA



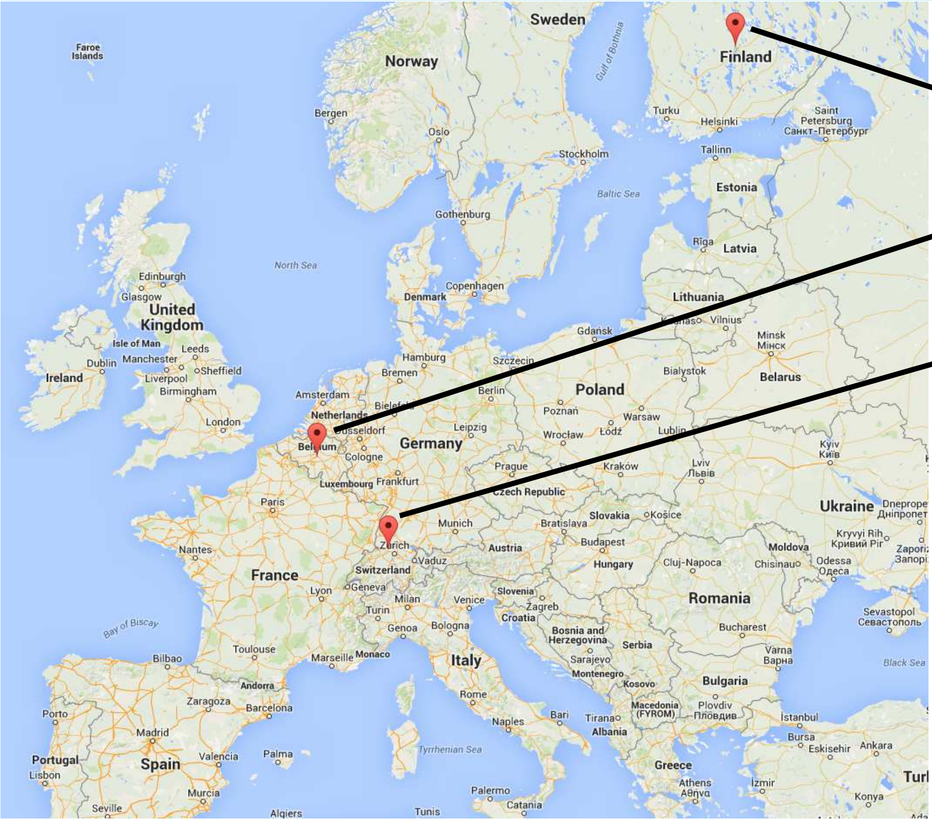
Nominal Device characteristics:

- V_{DSmax}= +60V
- V_{GSmax}= ±20V

◆ Application requirements:

- 0V ≤ V_{DS} ≤+15V
- 0V ≤ V_{GS} ≤ +6V

External irradiation test facilities – supported by esa



RADEF, JYFL
Jyväskylä,
Finland

Heavy ions, protons, electrons

UCL
Louvain-la-Neuve
Belgium

Heavy ions, protons

PSI
Villigen
Switzerland

Protons, electrons

ESA has been collaborating with the three external test facilities for more than 25-years.

Aiming at continuous improvement of the quality of the beam, dosimetry and testing infrastructure

(Stable flux and energy levels, high particle selectivity, accurate dosimetry, electrical/optical interfaces for cabling…)

The support from the cooperative funding programmes has been crucial for the success of this collaboration.

The network has been supporting most of the space programs worldwide becoming a well established reference for the scientific and industrial community in the field of radiation effects on electronic components.

External Facilities factsheet

	PSI (Switzerland)	RADEF (Finland)	UCL (Belgium)
Proton Beam	74 - 200 MeV	0.5 - 52 MeV	14 - 62 MeV
Heavy ion beam		7.16 - 69.2 MeV/cm2/s	1.3 - 62.5 MeV/cm2/s

Practical aspects of Testing

	TID test	DD test	SEE test
Source type	Co60 gamma rays	Proton Irradiation	Heavy Ions Irradiation
	Decay of radioactive source	Particle accelerator (cyclotron)	Particle accelerator (cyclotron)
Irradiation in	Air	Air	Vacuum
Die need to be exposed? 	No	No	**YES**
Activation of irradiated DUT? ☢	No	**YES**	NO
Test duration ⌛	Days / Weeks	Some hours (8 h)	Some hours (8 h)
Irradiation execution 🕓	Irradiation 24/7 Access to the facility: office hours	Irradiation in shifts **(24/7)** Typically 8/12h	Irradiation in shifts **(24/7)** Typically 8/12h
How in advance to book	1 Month	**3 Months**	**3 Months**
Beam sharing	Yes (up to 3 tests at different dose rates)	No	No
Beam diameter ⌖	From 20 cm to 3 m	Approx **8 cm**	Approx **3 cm**
Cable length from control to DUT	6 m	**10-20 m**	3m
	€	€€€	€€€

What we would like to achieve when we do testing ?

… just do our best to have satellites performing “simple tasks” in space

according to the plan… after 12 years from the launch.

Thank you !

Undergraduate programs
    Stages

Graduate programs
    Young Graduate Training

PhD programs
    Networking Partner Initiative

Staff positions
Contractor positions

http://www.esa.int/About_Us/Careers_at_ESA