El CNA como centro de ensayos de irradiación dentro de una ICTS interdisciplinar

Presented by Yolanda Morilla

Conferencia de Posgrado FdI-UCM, 18 de Mayo de 2021

Director: Dr. Rafael Garcia-Tenorio
(gtenorio@us.es)

ICTS Andalucía

- 🟦 Observatorio Astronómico de Calar Alto (CAHA)
- 🟦 Radiotelescopio IRAM 30M
- 🟦 Reserva Biológica de Doñana (RBD)
- 🟧 Plataforma Solar de Almería (PSA)
- ⬜ Centro Nacional de Aceleradores (CNA)
- 🟨 RES - Picasso (UMA)
- 🟩 NANBIOSIS - BIONAND
- ⬜ ELECMI - DME-UCA

Parque Científico
Tecnológico Cartuja
Avda. Tomás Alba Edison nº 7
E-41092 - Sevilla. Spain
http://www.cna.us.es

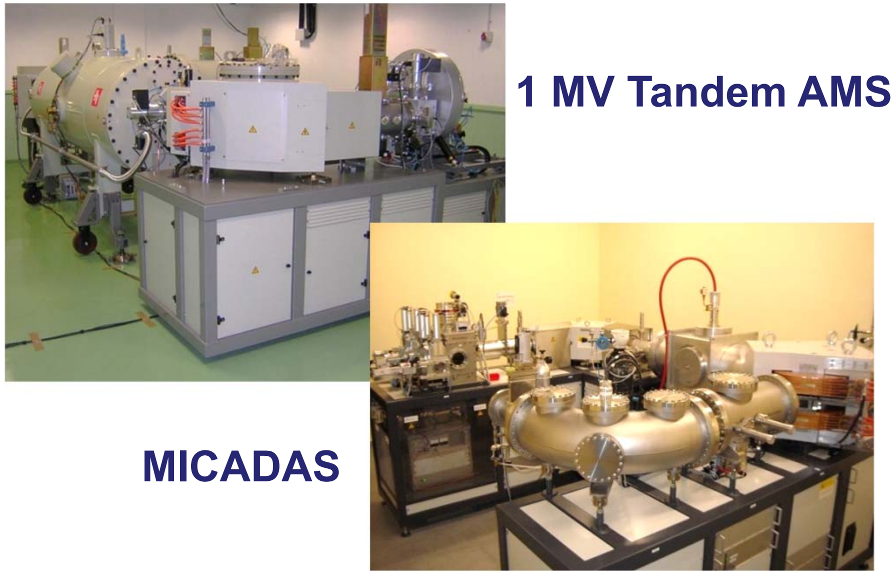
CNA – MAIN EQUIPMENTS

Spanish ICTS (singular scientific and technological infraestructure) Interdisciplinary research

3 MV Tandem accelerator

18/9 Cyclotron accelerator

Co-60 Gamma-irradiator



1 MV Tandem AMS

MICADAS

PET / CT SCANNERS

Radiopharmacy

A little bit of history...

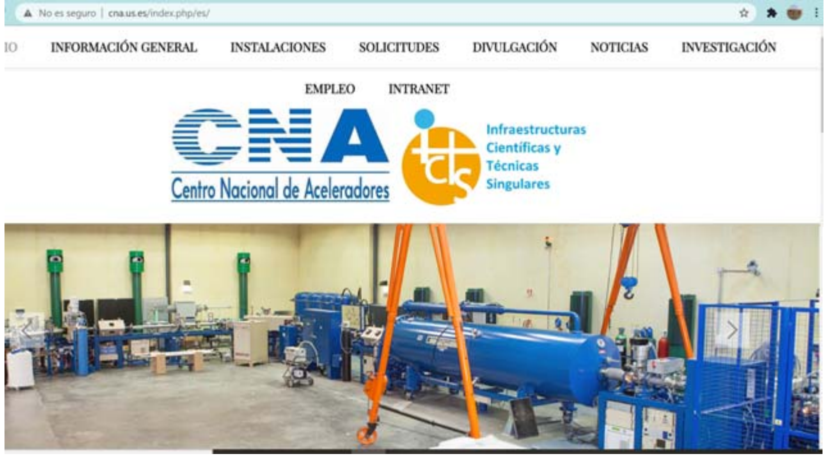
- 1997, agreement between Universidad de Sevilla, Junta de Andalucía and CSIC
- 1998, the **3MV tandem accelerator** settled in Sevilla
- 1999, the laboratory is opened to the scientific community (public or private enterprise), mainly to perform ion beam analysis (IBA)
- 2003, the **cyclotron accelerator** is installed
- Agreement CNA-Schering España. **Radiopharmacy and PET research**.
- 2005, the compact system for **accelerators mass spectrometry** (AMS) is put into operation
- 2005/06, the movable line for ion implantation and irradiation is designed and installed to be shared with tandem and cyclotron accelerators
- 2006, routine service in IBA techniques accessible

  Agreement CNA-IBA Molecular-SAS. **Radiopharmacy service for all the Andalusian hospitals.**
- 2008/09, Total dose and Microdosimetry irradiation tests (static and dynamic mode)
- 2012/13, **^{60}Co irradiation tester and 0.5 MV AMS MICADAS** have been installed
- 2013 up today, improvements of facilities and expansion of activities (projects, agreements…)

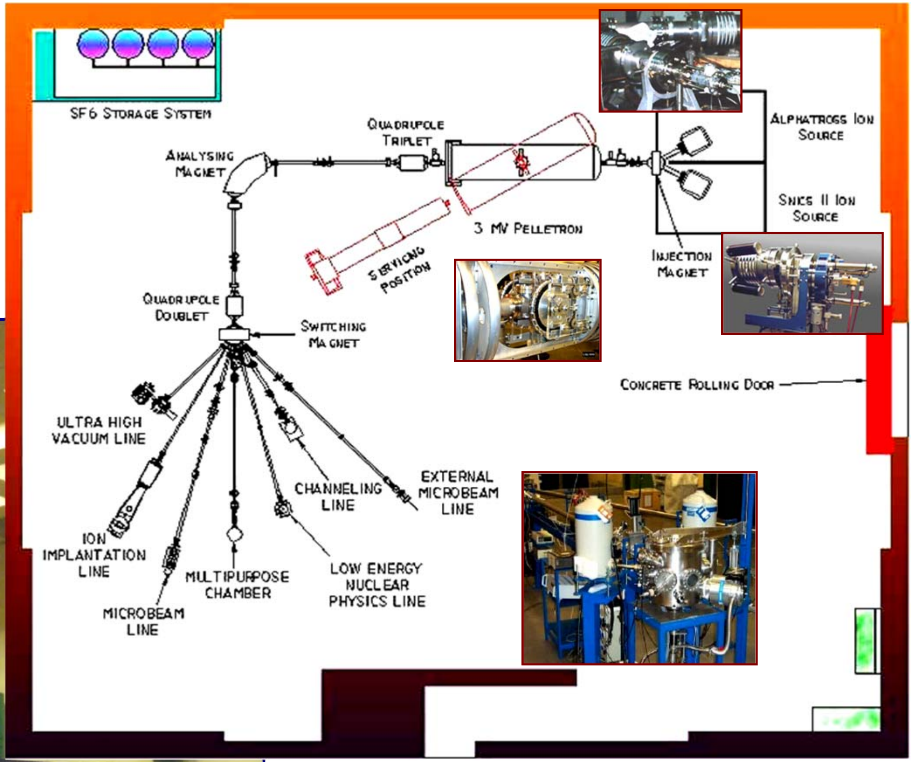
Main working scopes

- **Material Science**
  Thin films, ceramics, metallic alloys
- **Medicine and Biology**
  Organic fluids, tissues, radiopharmacy
- **Art and Archaeometry**
  Metals, ceramics, paintings
- **Environmental research**
  Water, aerosols, sediments, soils
- **Basic Nuclear Physics**
  Astrophysics, detectors, nuclear electronic
- **Mass Spectrometry with accelerators**
  Carbon dating, environmental applications
- **Accelerated irradiation testing**
  Astrophysics, detectors, nuclear electronic
- **Scholar and scientific outreach activities**
  Academic training, high and secundary school visits

www.cna.us.es



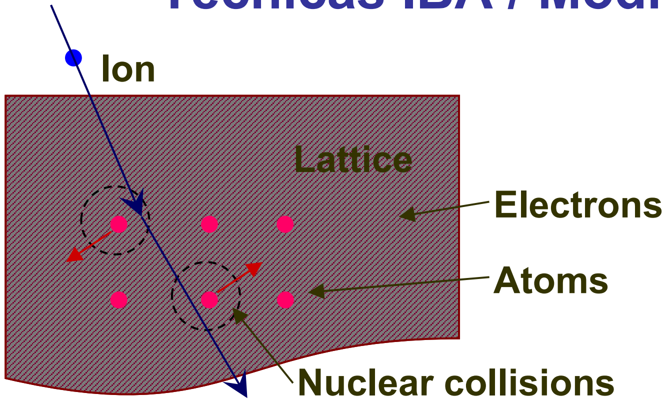
IBA Techniques
Materials Modification
Irradiation Damage
Física nuclear



TANDEM Laboratory

Ion-Solid Interaction

Técnicas IBA / Modificación de materiales / Reactions



Teoría LSS
(Linhard-Scharf-Schiøtt)

Energy Loss

$$N[S_n(E)+S_e(E)]=-\frac{dE}{dx}$$

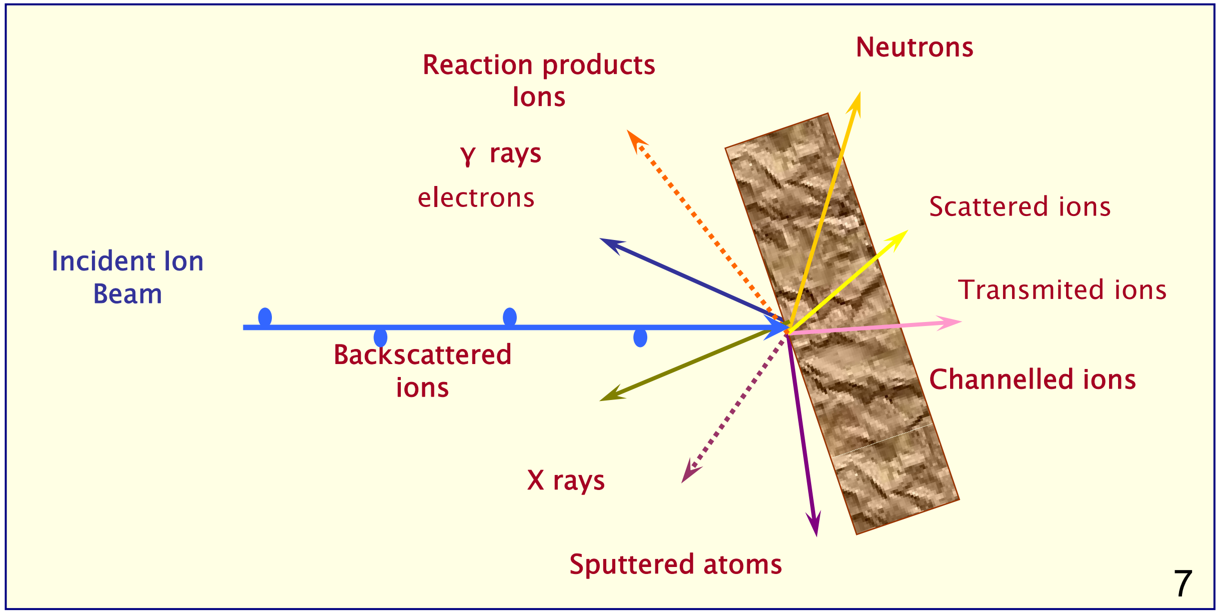
Nuclear & Electronic stopping

Ion Range

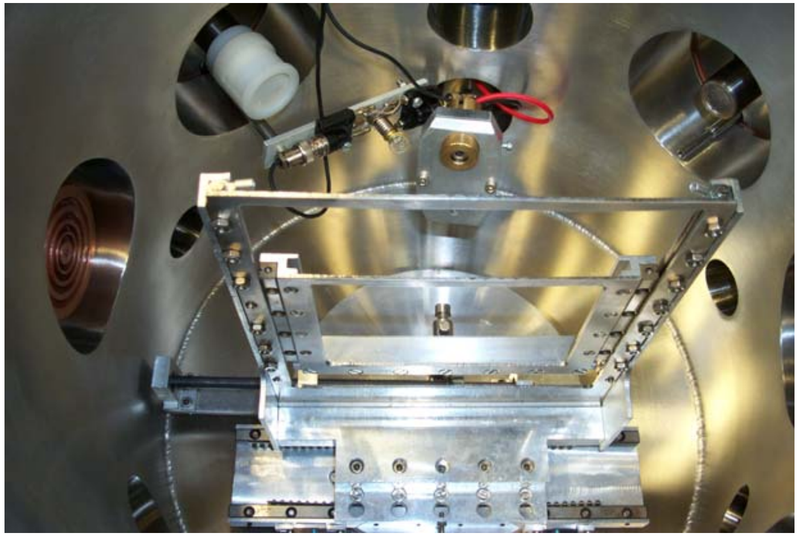
$$R=\frac{1}{N}\int_0^E\frac{dE}{S_n(E)+S_e(E)}$$

Different events

Cross section



Multipurpose line

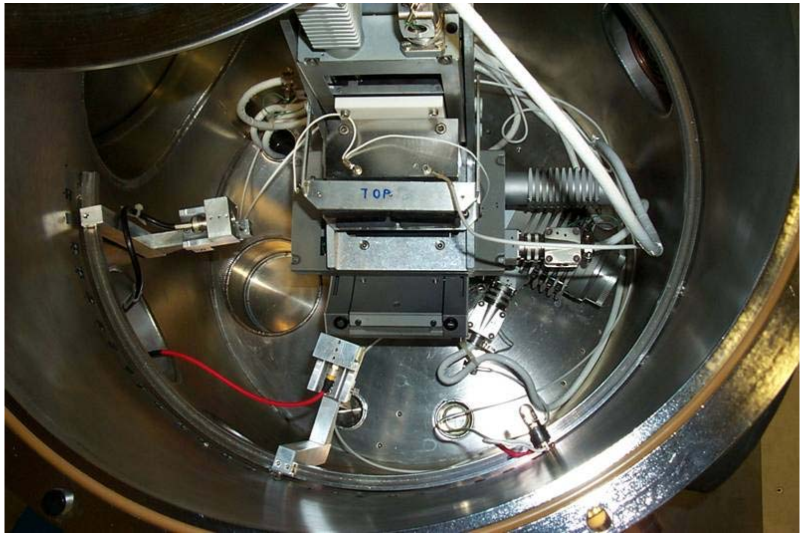


- Sample holder 150x112 mm^2
- X-Y movement
- Minimum spot size (Ø~0.5 mm)
- Electron gun

- Particle detectors (RBS, NRA, ERDA)
- X-ray detectors (SiLi, LeGe) for PIXE
- γ-ray detector (HPGe) for PIGE

Channeling line

- Sample holder (Ø~5 cm)
- Four axis (X-Y, θ-Φ) goniometer
- Minimum spot size (Ø~0.5 mm)



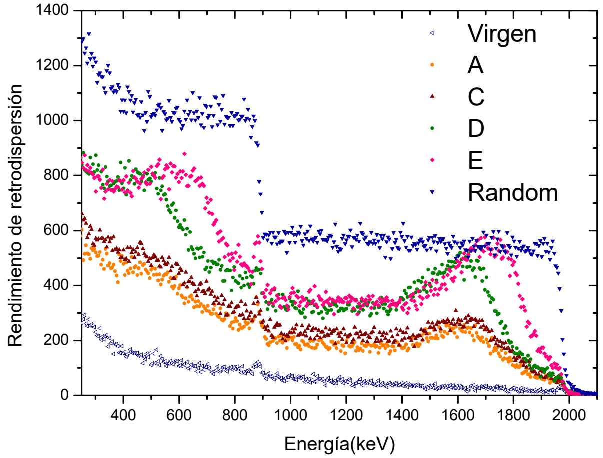
- Particle detectors (RBS, NRA, ERDA)
- X-ray detectors (SiLi, LeGe) for PIXE
- γ-ray detector (HPGe) for PIGE

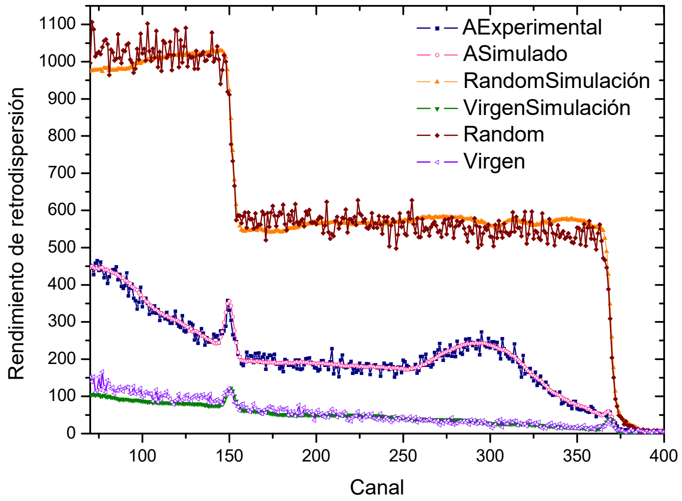
Specially to study crystalline samples

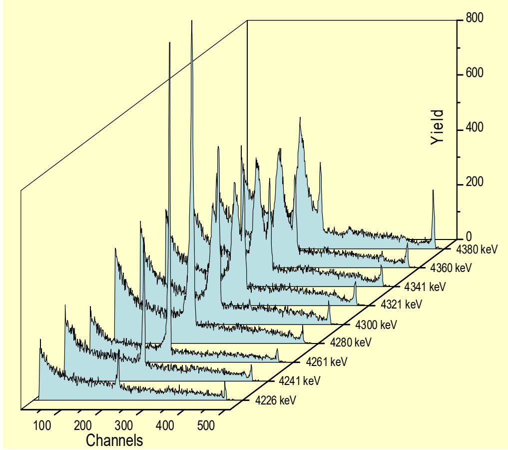
BS/C with 3.5 MeV alpha particles
Damage distribution and simultaneous analysis of C & Si sublattices

6H-SiC Implantation
2 MeV Al^{2+} , tilt = 61° , room T

MUESTRA	DOSIS (Al^{2+}/cm^2)	DENSIDAD CORRIENTE (nA/cm^2)	DESORDEN MÁXIMO RELATIVO-Si	DESORDEN MÁXIMO RELATIVO-C
A	2 X 10^{14}	21	34 %	50 %
B	2 X 10^{14}	83	36 %	52 %
C	2 X 10^{14}	105	40 %	58 %
D	4 X 10^{14}	86	90 %	100 %
E	7 X 10^{14}	86	100 %	100 %





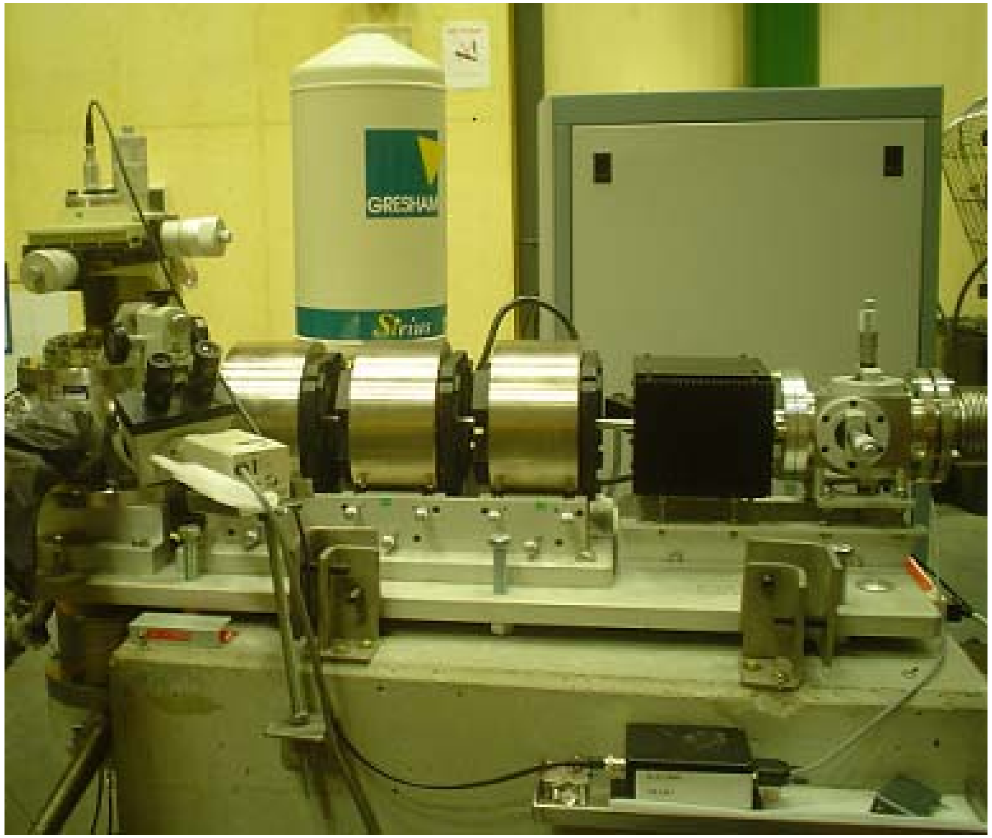


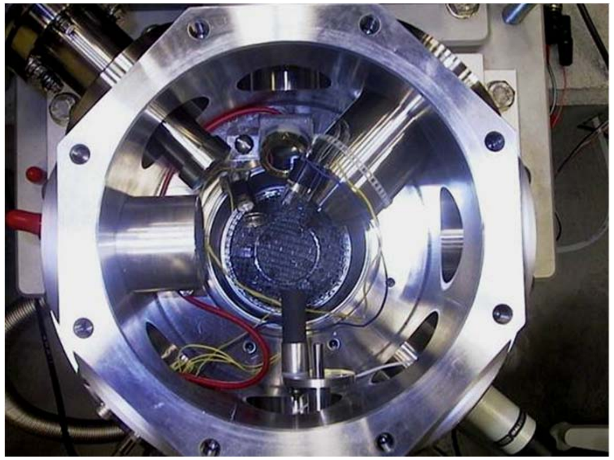
Y. Morilla, J. García-López, G. Battistig et al.

^{4}He^{2+} ~4.26 MeV Backscattering in channeling geometry {resonance ^{12}C(α,α)C}

Vacuum micro beam line

- Particle detectors (RBS, STIM)
- Secundary electrons detector (SEM)
- X-ray detector (SiLi) for PIXE
- γ-ray detector (HPGe, NaI) for PIGE

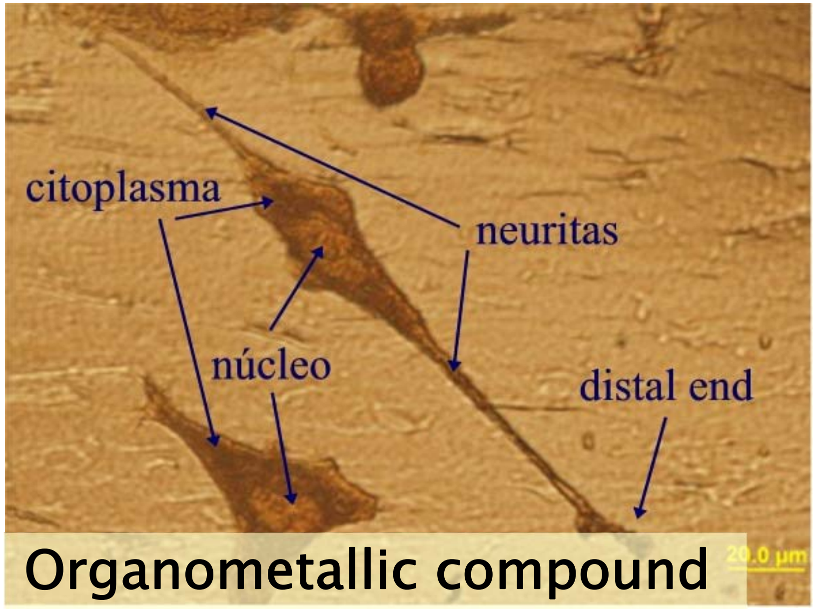




- Minimum **Ion beam size ~ 3µm**
- **Scanning system, elemental maps**
- **Small sample holder**
- **Electrons gun**

Heavy Metals in neurons

A. Carmona (CNA), R. Ortega (CENBG) et al.



Organometallic compound

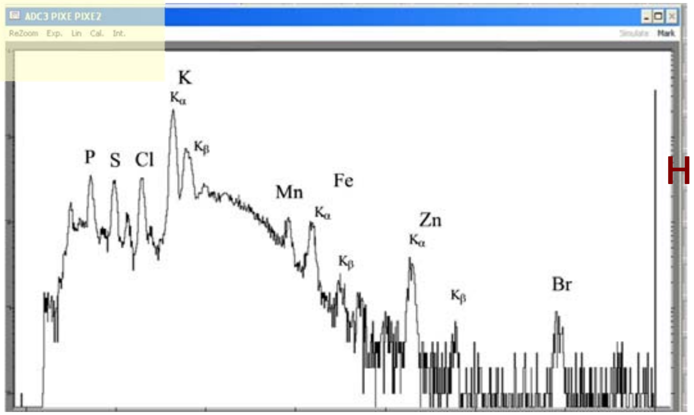
Dopamine –Fe

Parkinson's disease

Decrease [dopamine]

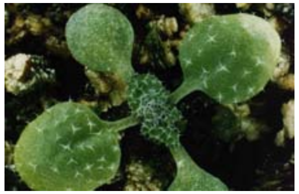
Increase of [Fe·]

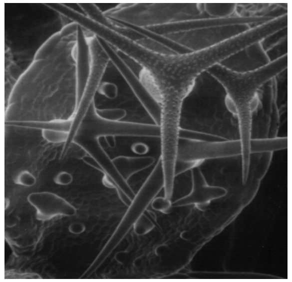
Increase [dead cells]

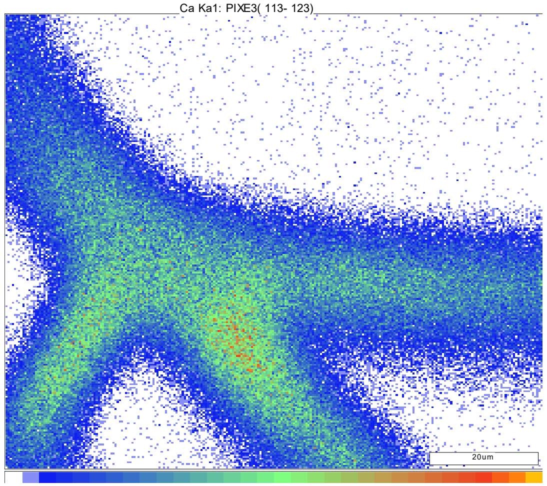


Nuclear microprobe analysis of *arabidopsis thaliana* leaves

M.D. Ynsa and F.J. Ager (CNA), J.R. Domínguez, C. Gotor and L.C. Romero (IBVFSE-CSIC)







Contaminated soils

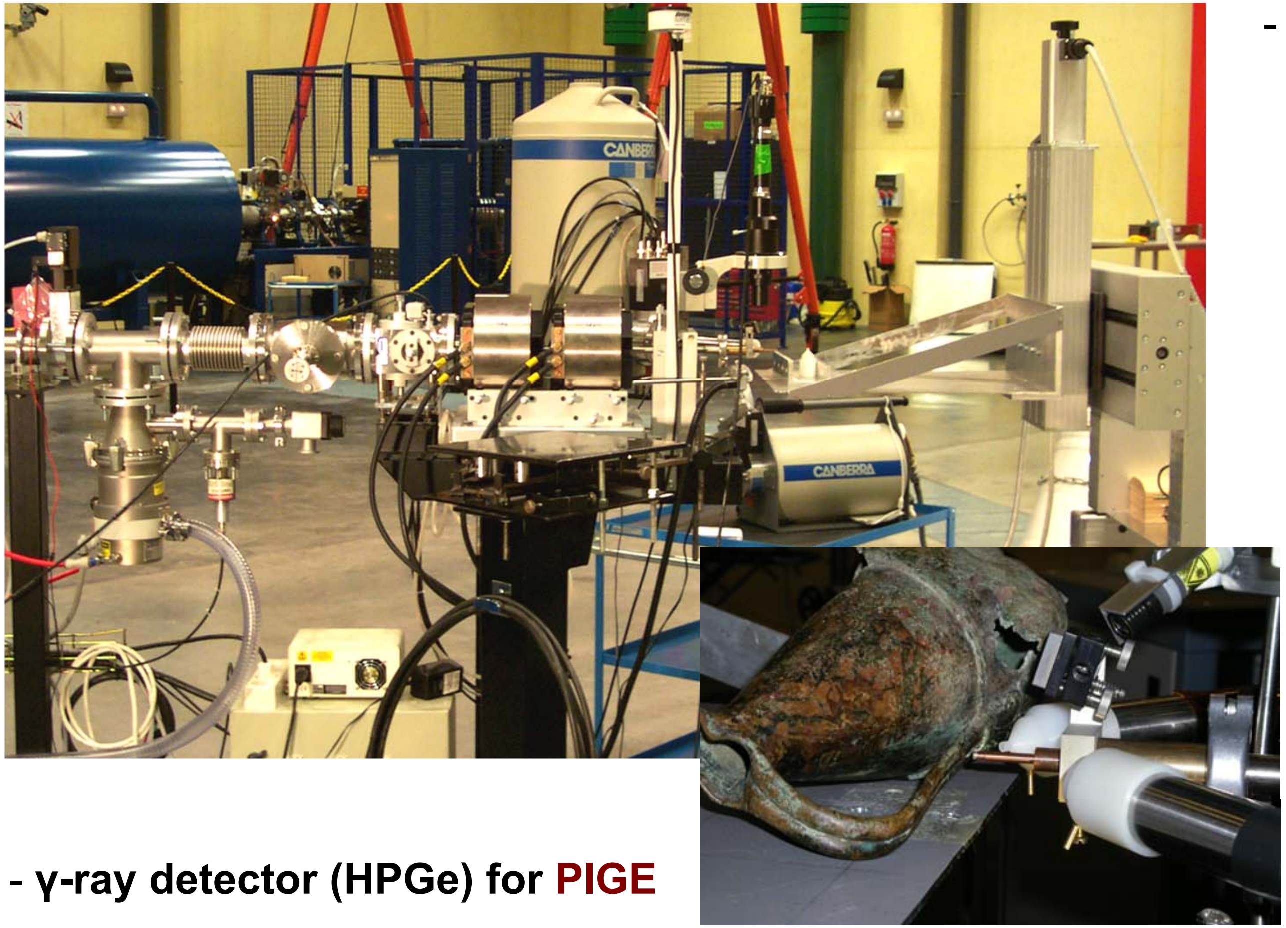
Phytorecovery

Heavy metals acumulation sites

Fe, Cd, Zn…

External micro beam line

- **Ion beam size ~ 50-100µm**
- **Versatile sample holder**



- **γ-ray detector (HPGe) for PIGE**
- **Two X-ray detectors (SiLi, LeGe) for PIXE**

Study of paintings and ceramics from Teotihuacán

Different colors characterization

Differencial-PIXE; Non destructive stratigrafy

Painting thickness

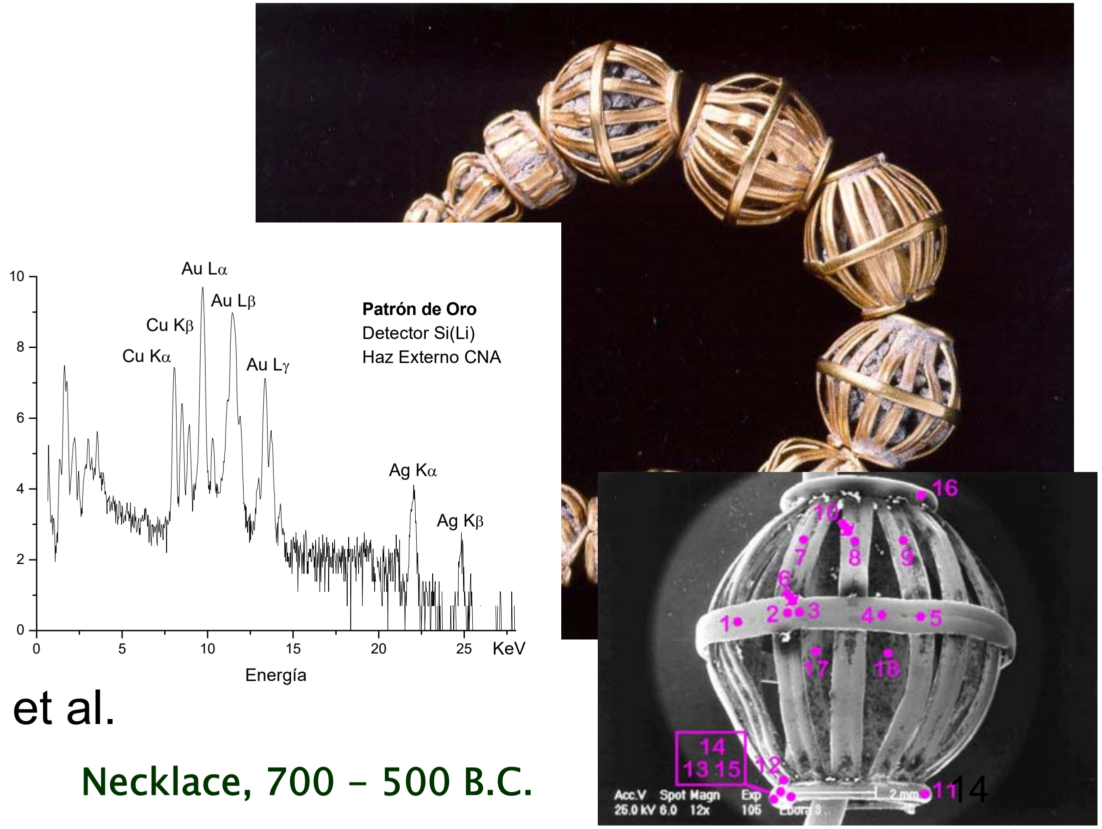
M.A. Ontalba, I. Ortega, Respaldiza et al.

Tartesic Gold Jewellery:

Ébora treasure

Two kind of solders:

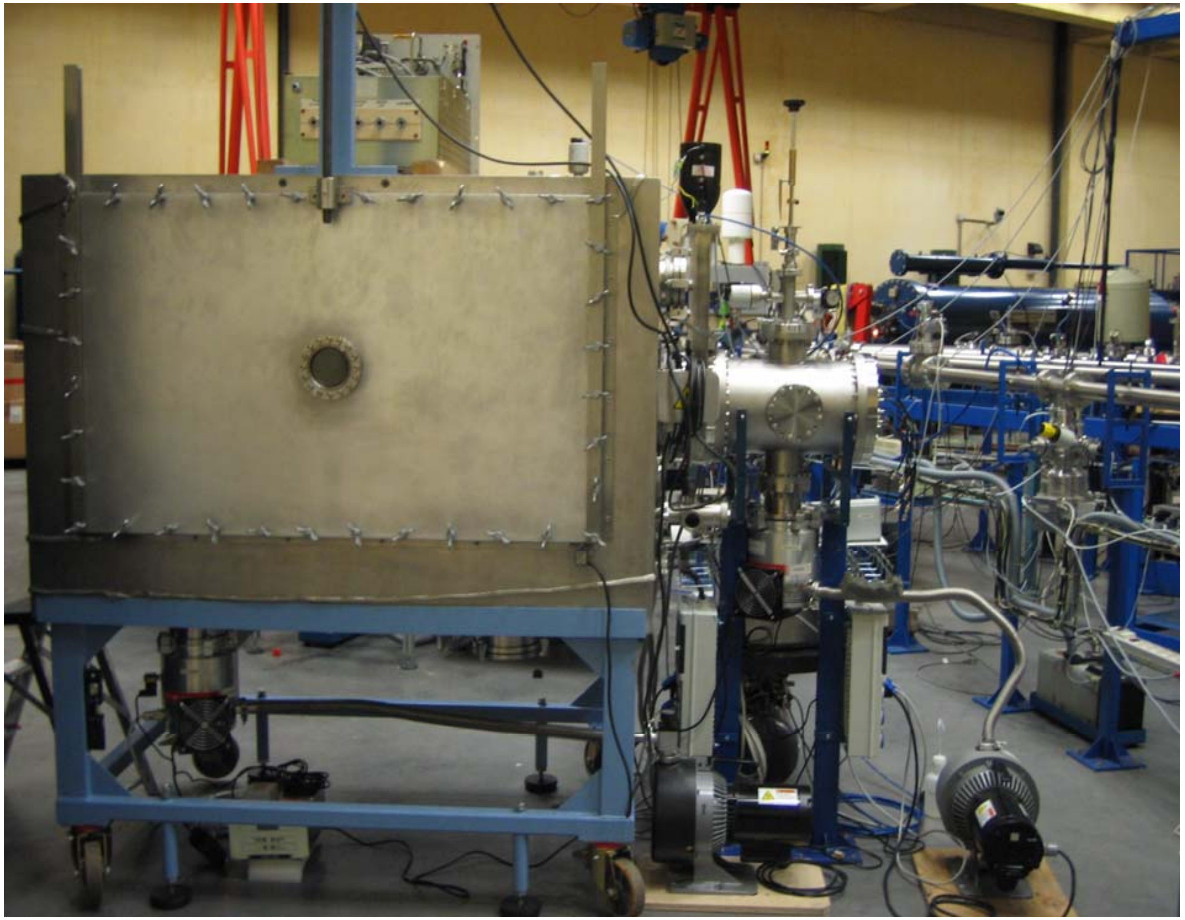
brazing, forging



Necklace, 700 - 500 B.C.

Archaeological Museum of Seville

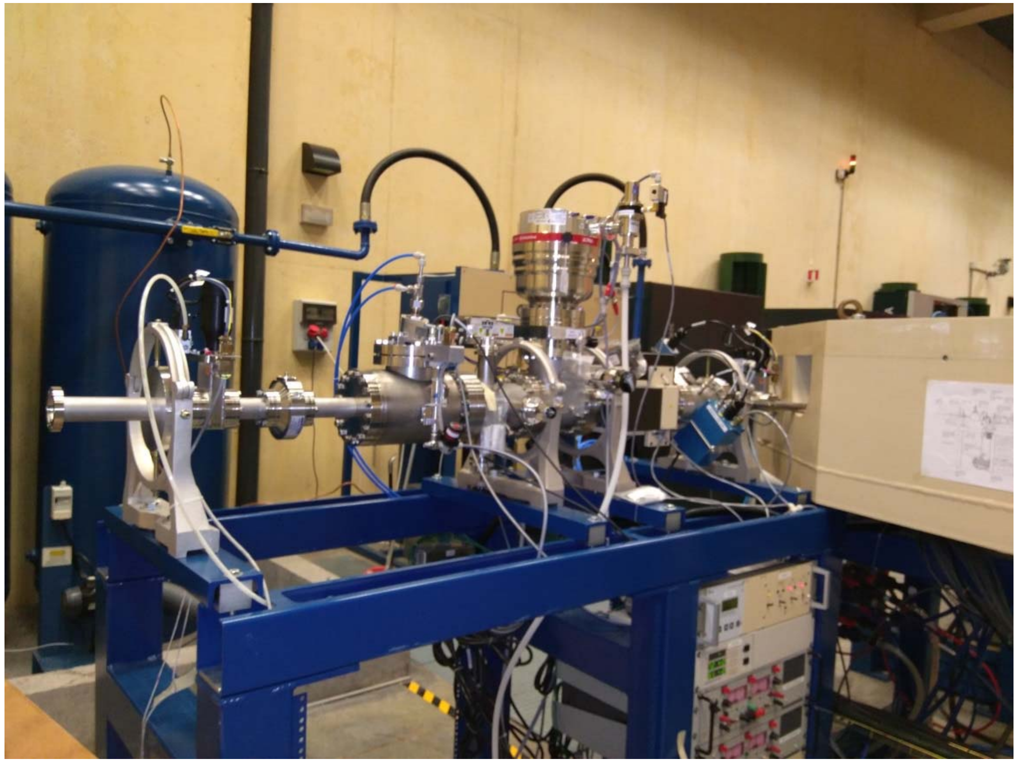
Basic Nuclear Physics



- **Exotic nuclei studies**
- **Cross section determination for astrophysical applications**
- **Development of nuclear electronics and detectors**

Neutron line

HISPANoS: pulsed / continuous neutron source at CNA



The last installed in the 3MV Tandem accelerator before the 90° magnet

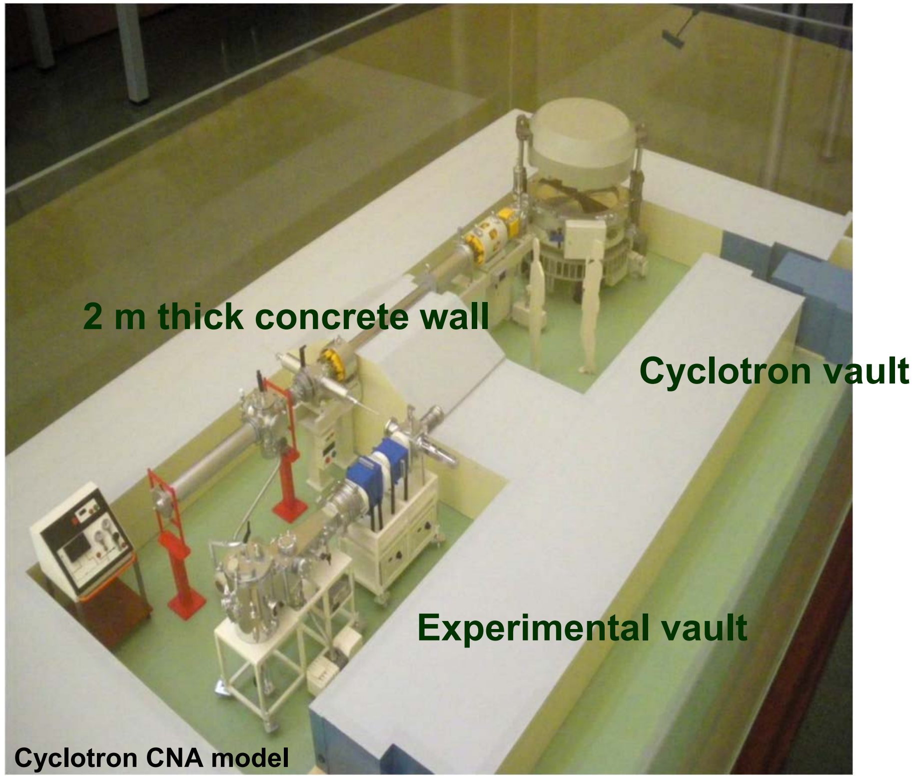
Based on deuteron nuclear reactions p(^{7}Li,n), d(D,n), p(^{9}Be,n) & d(^{9}Be,n), from thermal neutrons up to 9 MeV beams.

Cyclotron Laboratory

(18 MeV H^+ / 9 MeV D^+)

Nuclear Medicine

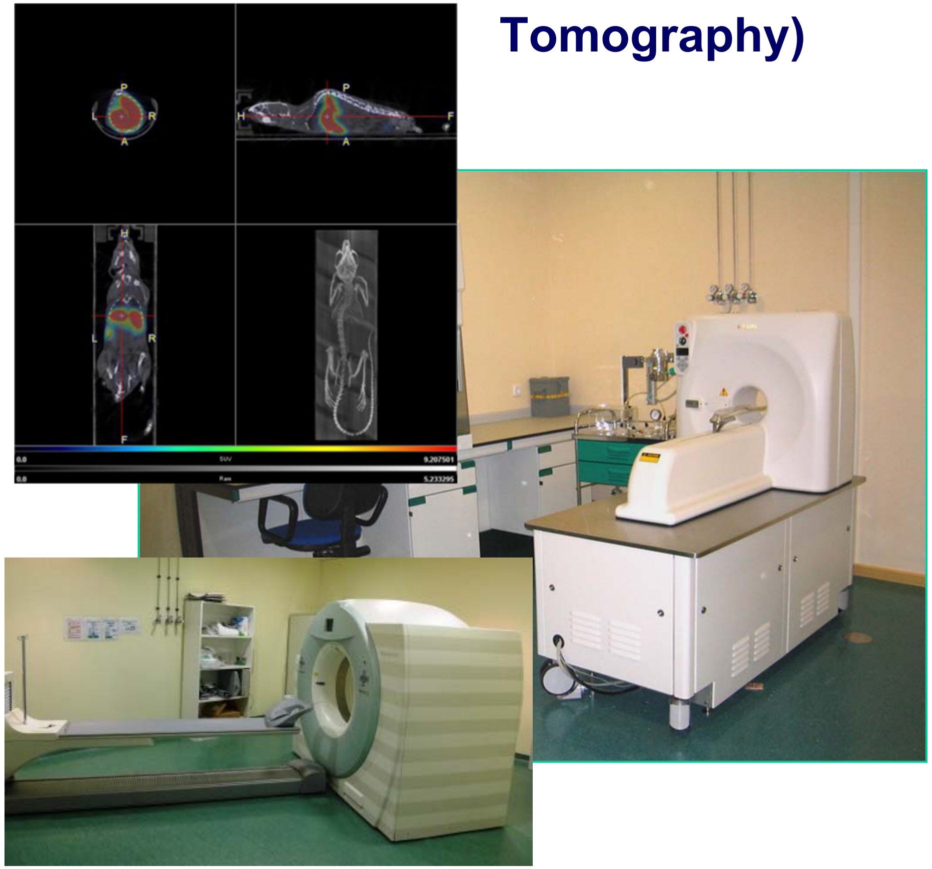
Irradiation Damage
High Energy PIXE



Radiopharmacy

(PET isotopes)

PET (Positron Emission Tomography)



Biomolecules marked with ^{18}F and ^{11}C

$^{13}NH_3$ and $H_2{}^{15}O$

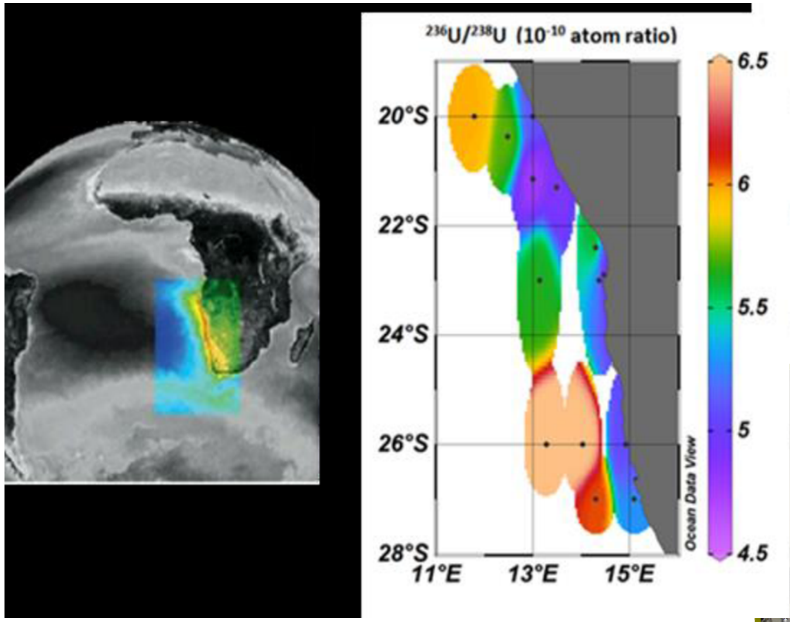
Research - Dispensation

Human & Micro-PET / TC scanning systems for medical imaging research using short life isotopes

AMS Laboratory

(^{14}C, ^{10}Be, ^{26}Al, ^{129}I, ^{239}Pu, ^{240}Pu, ^{236}U)

surface seawater off Namibian coast



Carbon dating in Spain

IAEA – CNA agreement

Co-60 gamma Laboratory

GAMMABEAM ® X200 (Best Theratronics)

Gammagraphy / TC for arts

Induction of Mutagenesis in Rice seeds

Centro Nacional de Aceleradores

Infraestructuras
Científicas y
Técnicas
Singulares

National Accelerators Centre, a facility for irradiation testing

Severe natural environment above Earth’s atmosphere

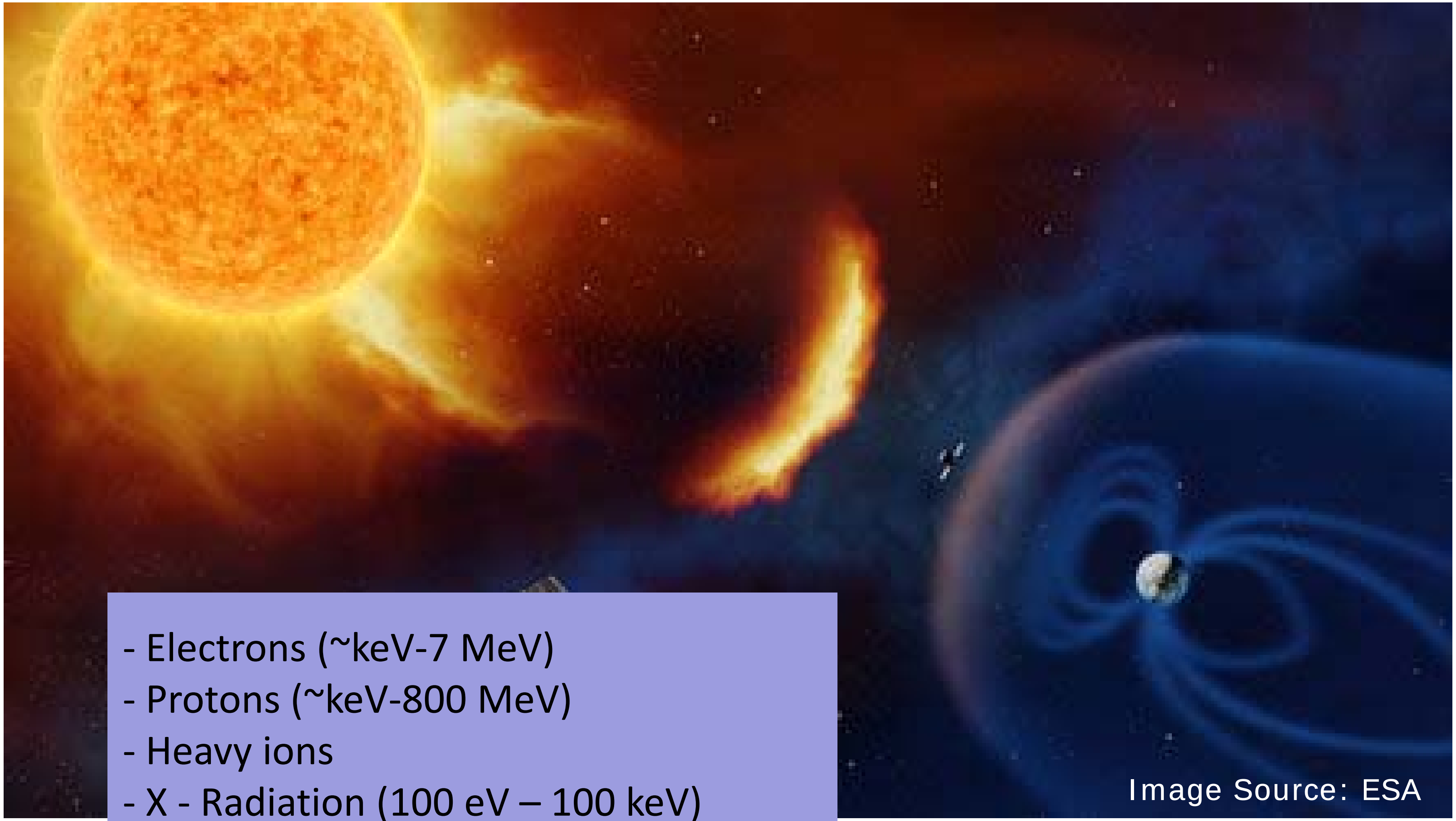


Image Source: ESA

- Electrons (~keV-7 MeV)
- Protons (~keV-800 MeV)
- Heavy ions
- X - Radiation (100 eV – 100 keV)
- γ - Radiation
- Neutrons (atmospheric level)

Type of radiation in space

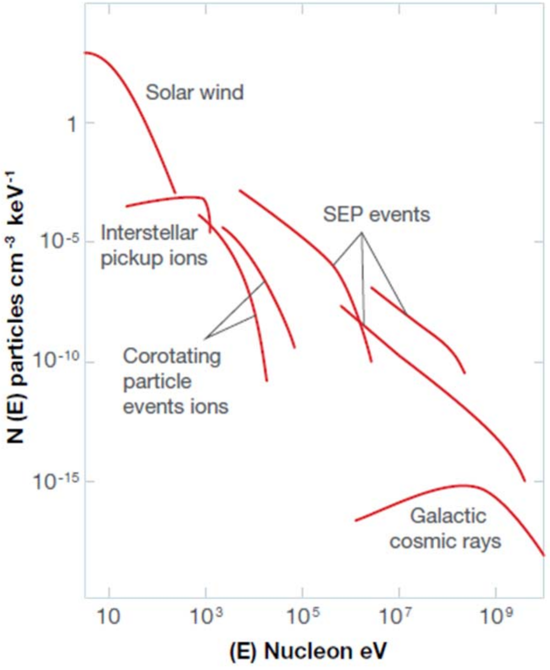


Figure 1-6. Differential proton flux as a function of proton energy for solar wind, SEPs and GCR distributions.

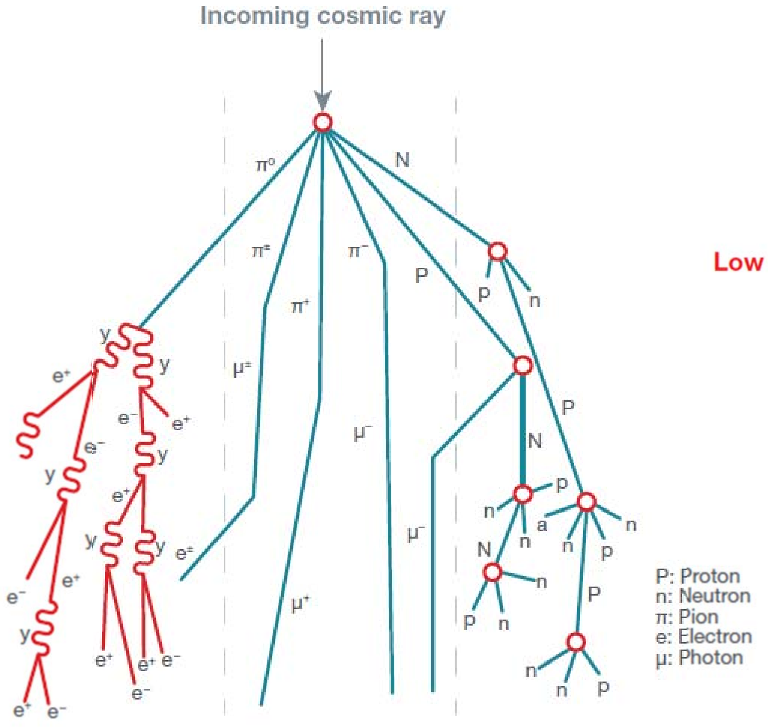


Figure 1-12. Particle cascade or "shower" created when a high-energy cosmic-ray proton interacts with a nitrogen or oxygen nucleus in the upper atmosphere.[27]

Image courtesy of International Business Machines Corp., © International Business Machines Corp.

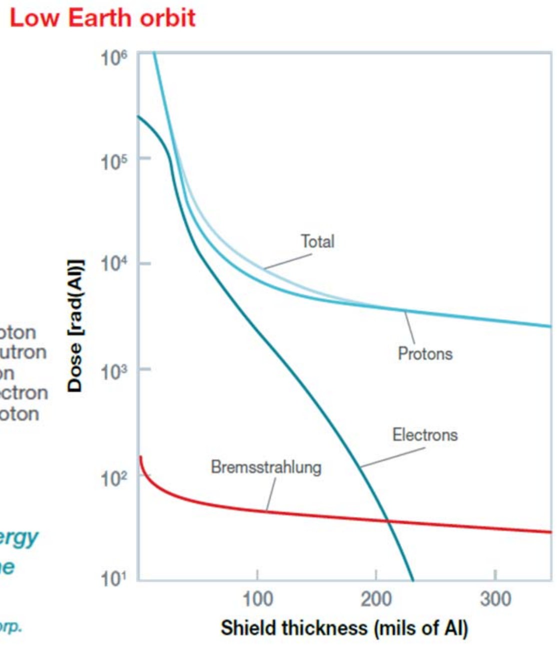
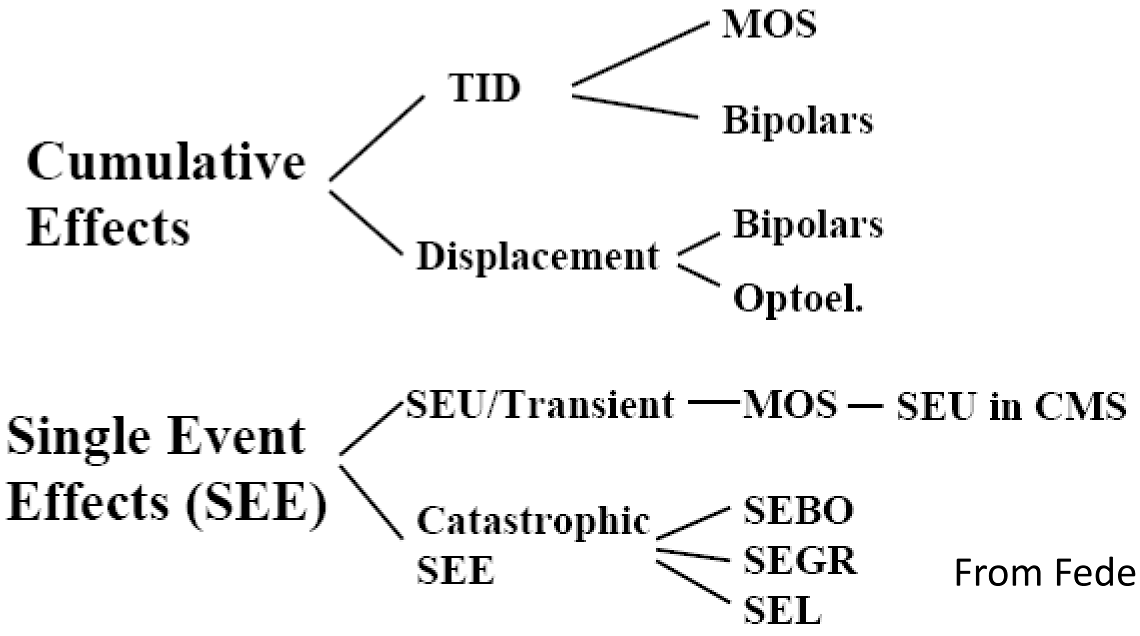


Figure 2-18. Plot of TID in low Earth orbit as a function of aluminum shielding thickness for three space radiations: protons, electrons an Bremsstrahlung.[38]

Radiation effects on components

From the point of view of the effects, **the degradation will differ according to the energy of the particles, to their nature and to the mission orbit.**

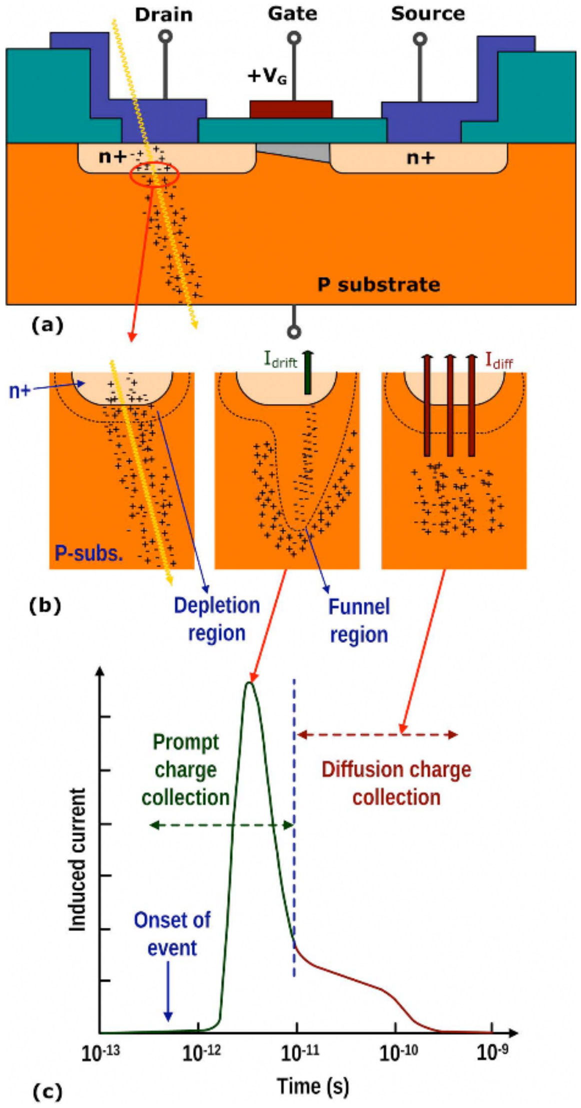
It is necessary to understand the instrument technology and geometry to determine the vulnerability to the environment. Radiation effects important to consider for instrument and spacecraft design fall roughly into three categories: degradation from **Total Ionizing Dose (TID), Displacement Damage Dose (DDD), and Single Event Effects (SEE).**



Cumulative Effects
TID
MOS
Bipolars
Displacement
Bipolars
Optoel.

Single Event Effects (SEE)
SEU/Transient — MOS — SEU in CMS
Catastrophic SEE
SEBO
SEGR
SEL

From Federico Faccio - CERN



TID is due to ionizing radiation, by primary protons and 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

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

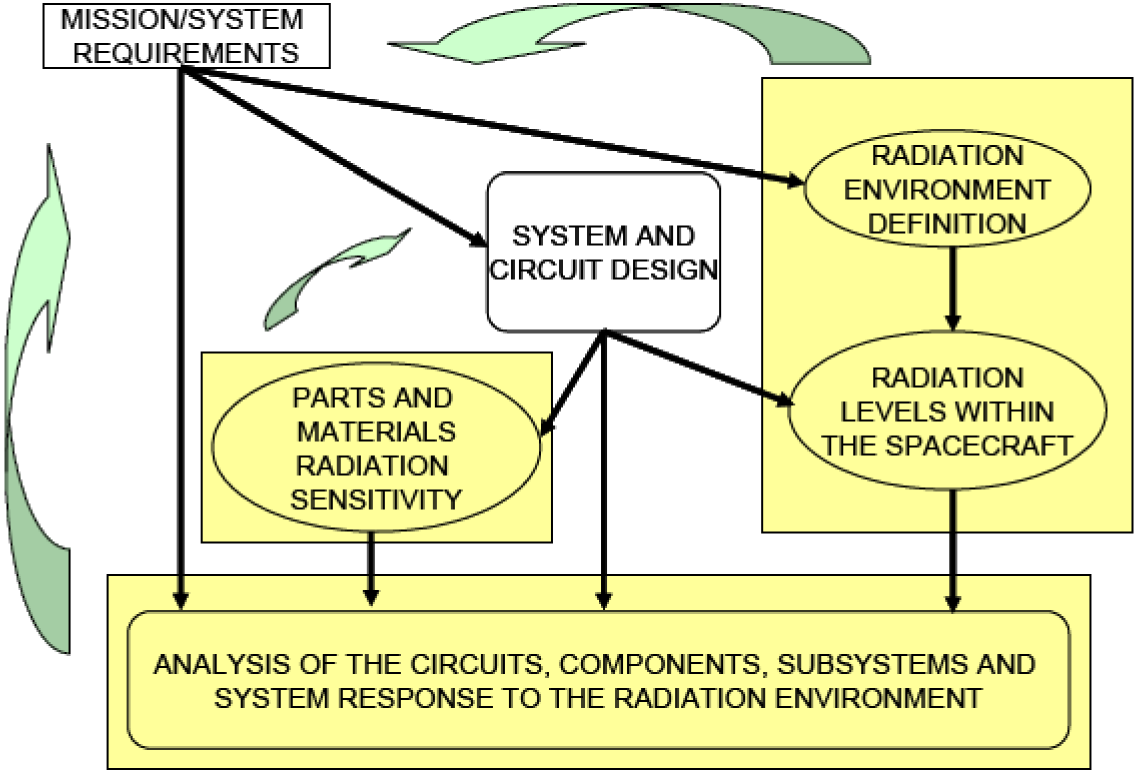
The severity of the effect can range from noisy data to loss of the mission, depending on the type of effect and the criticality of the system in which it occurs

Shielding is not an effective mitigation technique because they are induced by very penetrating high-energy particles.

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].

Radiation Hardness Assurance - RHA

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



From Christian Poivey - ESA

To produce a system tolerant to the radiation environment

Materials and devices testing

- **Field analysis**
  - Based on reports of reparations and replacing of components
  - When there is enough statistic data the products are obsolete
  - It is necessary to spend several years
- **Real time tests**
  - Based on the study of numerous chips running under natural environment
  - It is necessary to spend a lot of time and this is very expensive
- **Accelerated tests (static or dynamic)**
  - Based on the simulation of the natural radiation environment (100 years in a few minutes)
  - Adequate method but expensive (NORMATIVAS / ESCC – DLA…)
    - It is required to use radiation sources and equipments associated (particle accelerators, nuclear reactors, radioactive sources as Co^{60} or Cs^{137})
- **Laser tests**
  - Based on photoelectric prompt, try to emulate the particle track
  - It is a lower cost experiment

➢ **Development of fault injection emulators**
  - ➢ Faults prevention in the design phase of the devices

They require to be checked by the accelerated tests

Accelerated tests / Irradiation tests

Space and other hostile environments

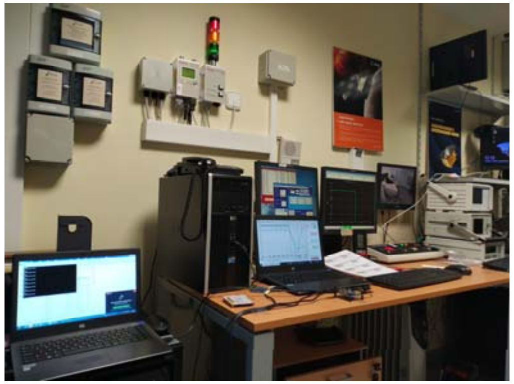
- **The nature of the radiation, energy, flux and fluence of the beam determine the type of test, which in turn will depend on the structure, design and use of the device**

- The parameters used in the tests will be determined by the flight conditions and service of the spacecraft or equipment (usually 10-30 years exposure real-time)

Irradiation capabilities at the CNA

PHOTONS

Low E-IONS & NEUTRONS



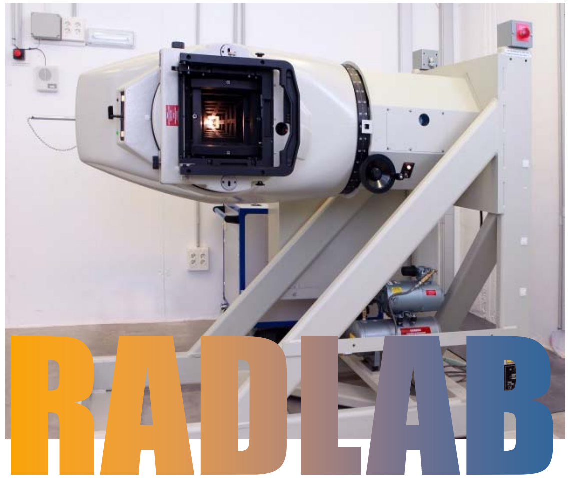
Irradiation capabilities at the CNA

PHOTONS

^{60}Co Irradiat system
(Gammabe 00, Best

- Ph 7 and 1,33
- Kerm up to 160 Gy/h (September 2019)

TID



Low E-IONS & NEUTRONS

3MV Tandem

- Ions from H to Au
- Proton Energie 550 KeV –
- Di

F ork on air or vacuum

on

y

MeV

er Energies by egraders

SEE / DD

The CNA **CECI** is the **Spanish Centre for combined irradiation tests**, implemented as a consequence of the projects:

- **RENASER / RENASER+ / RENASER3 / RENASER4**: Análisis integral de circuitos y sistemas digitales para aplicaciones aeroespaciales (Spanish calls R&D 2007-2010 ; 2011-2013; 2016-2019)
  (Total analysis of digital circuits and systems for aerospace applications)

- **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

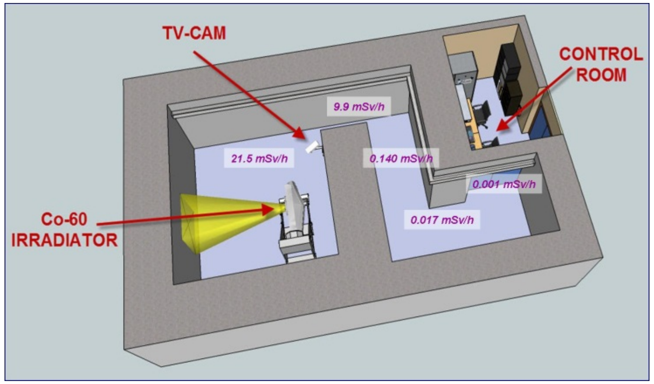
RadLab Gamma irradiation tests with Co-60

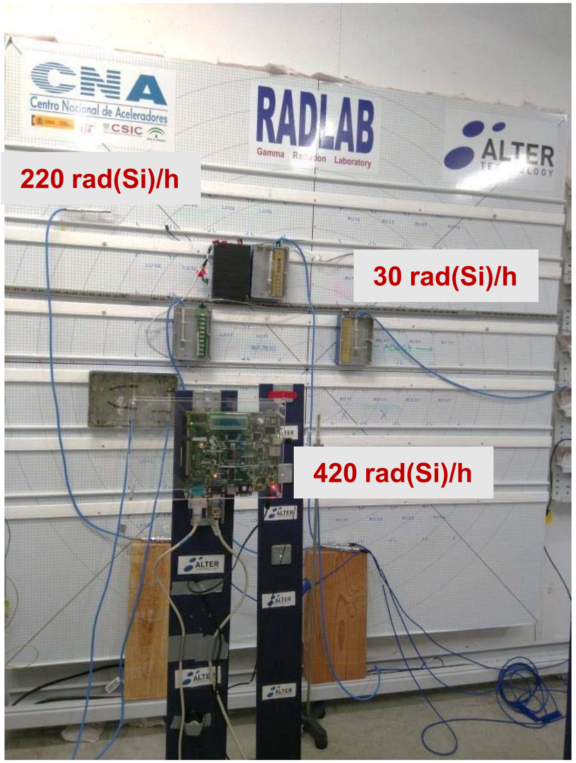
^{60}Co Irradiator system (Gammabeam ® X200, Best Theratronics)

- **Photons energies** 1,17 and 1,33 MeV (**1,25 MeV** average)
- **Activity** 144 TBq (September 2020)

Dose rate range

~14 **rad(Si)/h**
to 14 **krad(Si)/h**
u ≤ 4%



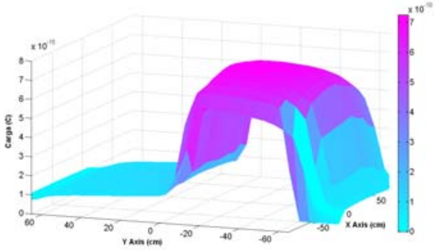


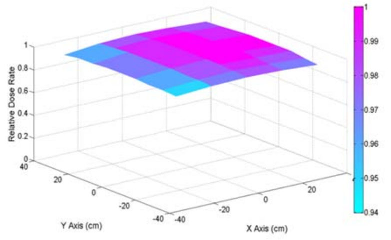
Remote access & staff support

Dynamic study can be checked by user
Step measurements in collaboration

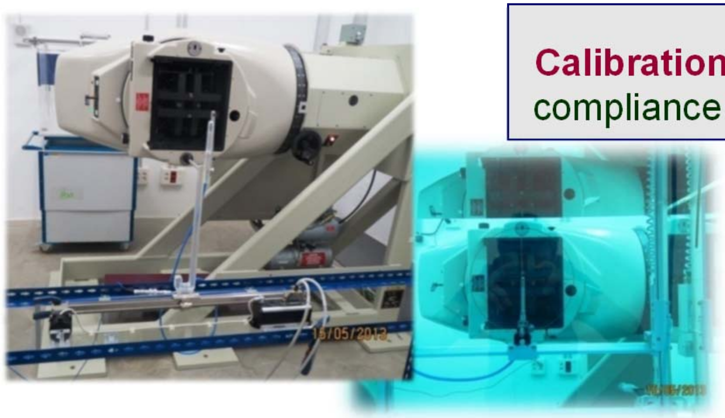
Square flat radiation fields.

Areas from about 110 cm x 110 cm meet standards homogeneity requirement, although dose rate nonuniformity ≤ 1% is also available for a wide range of field size.





Attenuation System allows to obtain different dose rates, over several irradiation field areas, to carry out independent tests, under different dose rate conditions, simultaneously.



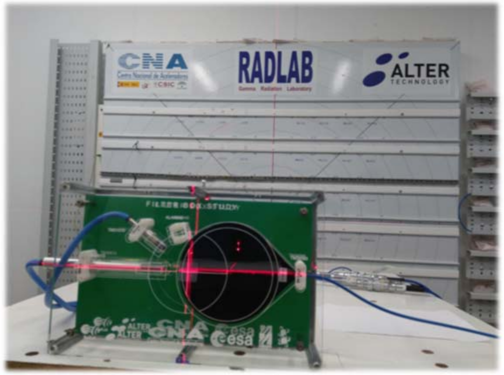
Calibration and certification by **SSDL PTW-Freiburg**.
compliance with TRS-398 and TRS-469 IAEA protocols.

Alter Technology agreement

ESCC 22900 and MIL-STD-883/750 test methods 1019
(ISO17025; DLA Lab suitability)

Dosimetry Intercomparison exercises

- **Based on ionization chamber; ESA/ESTEC, CNA-ALTER/RadLab and UCL/CRC (2013)**
- **Based on the study of the filterbox with european, american and russian institutions (2018-2021)**
- **Based on allanine dosimetry with ESA/ESTEC; SL & TRAD (2020-2021)**



Novelty incoming

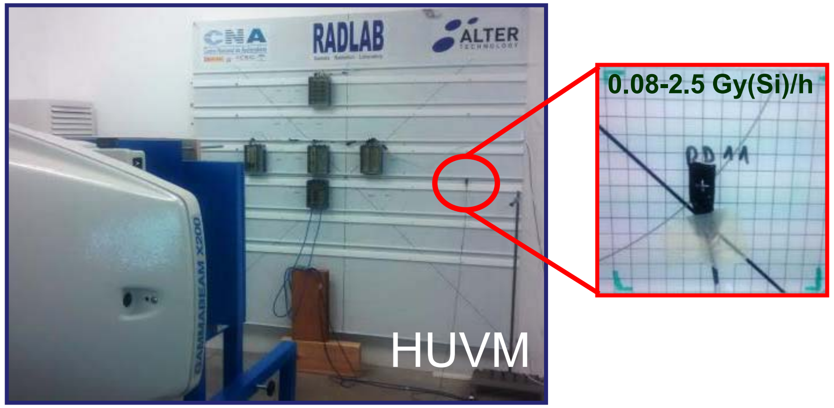
Current activity In the frame of PRECEDER Project

Prediction of the behavior for electronic devices under radiation applying "machine learning"

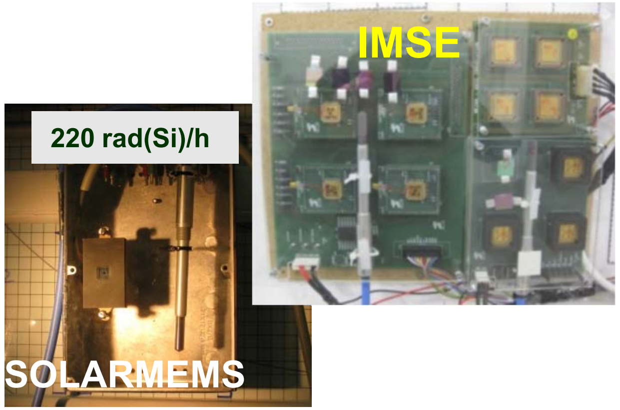
Objective: to be included in VIRTUAL-LAB
https://www.altertechnology-group.com/en/news/news-details/article/virtual-lab/

RadLab Versatile laboratory

Optical & Electronic devices



Materials & static tests



Exclusive use of laboratory

No attenuation System

Shared laboratory

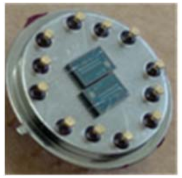
Attenuation System

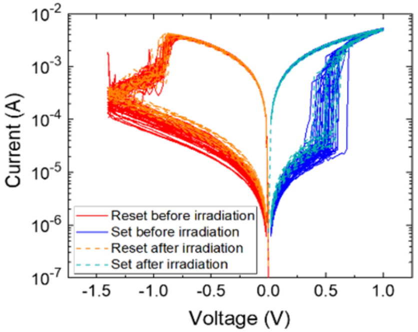
Different dose rates simultaneous tests

Thorough dosimetry study

New technologies or applications

Gamma Radiation Effects on HfO_2-based RRAM Devices





Before and after a total cumulative dose of 22.1 Mrad(Si)

Hostile environment Application

Total Ionising Dose (TID) gamma radiation testing of the lift’s electronics for Tokamak building (ITER project)

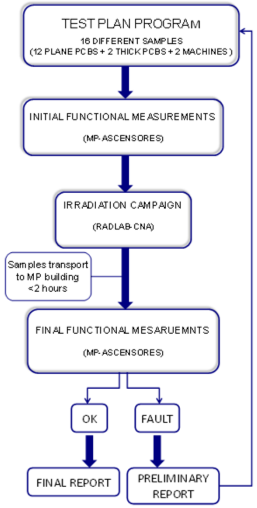
The lifts will be exposed up to 25 µGy/h over a lifetime of 25 years.

5.475

(Gy) Accumulated Dose

11

(Gy) Total Test Dose



TEST PLAN PROGRAM
16 DIFFERENT SAMPLES
(12 PLANE PCBS + 2 THICK PCBS + 2 MACHINES)

INITIAL FUNCTIONAL MEASUREMENTS
(MP-ASCENSORES)

IRRADIATION CAMPAIGN
(RADLAB-CNA)

Samples transport
to MP building
<2 hours

FINAL FUNCTIONAL MESARUEMNTS
(MP-ASCENSORES)

OK

FAULT

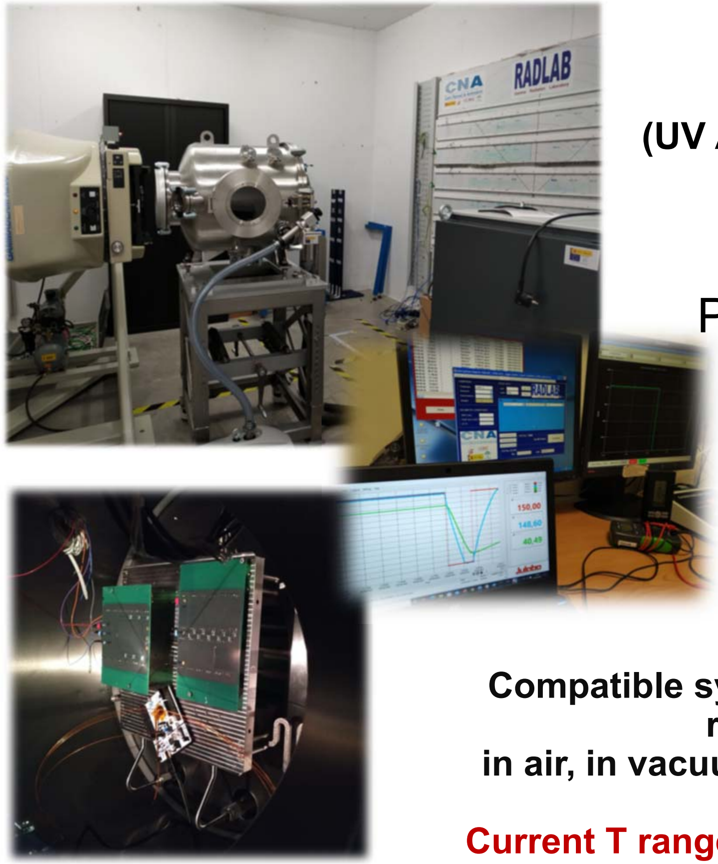
FINAL REPORT

PRELIMINARY REPORT

FACILITY UPDATE IN PROGRESS

Elevated temperature / cryogenic temperature testing

Possibility to carry out temperature cycles while samples are being irradiated.



First TID testing with temperatura cycles

(UV AlGaN/GaN Power HEMT / UC3M PUF / ETSI-US QFG MOS)

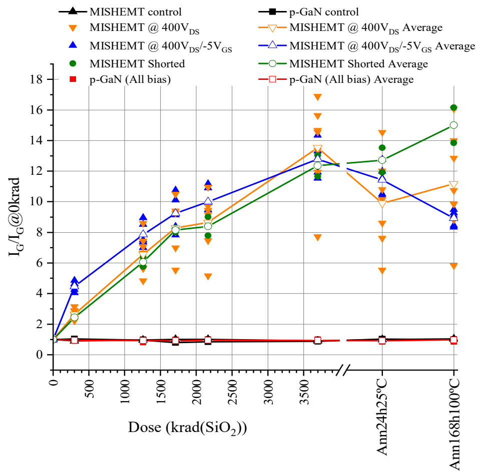
P. Martin-Holgado PhD Thesis

Design and comissioning

(Project CECI – RENASER3)

**Compatible system with particles and γ radiation labs;
in air, in vacuum or another atmosphere.**

Current T range from -70ºC to 150ºC (±1ºC) in the DUT



Normalized forward gate current of GaN HEMTs as a function of total dose

Dosimetry systems are currently under study

Irradiation tests with LEP, HI and n

3 MV Tandem Pelletron (NEC):

- Available quasi-monoenergetic (FWHM 0.2 - 0.03 %) ion beams
- $^1H^+$ [LET(Si) ~0.2 - 0.05 MeV-cm^2/mg / Range ~7-300 microns]
- Heavier ions (Range in Si, máximum in the order of tens of microns)
- Neutrons up to 9 MeV by nuclear reaction using >5MeV deuteron as primary beam

- Energy range from ~600 keV to several MeV
  (E=(1+q)V; p.e. 600 keV to 6 MeV for H^+)
- Different ion beam sizes
  - Irradiation beam line (usually 1cm^2)
  - Microprobe (beam resolution ~ µm)
- Maximum irradiated área (scanning systems):
  Irradiation beam line, 16x20 cm^2 (for mE/q^2=18)
  Vacuum Microprobe line, 2.5x2.5 mm^2 (for mE/q^2=3)

- Vacuum system (P ~ 10^{-6} mbar)
- Several opto-electrical feedthroughs

Compact 18/9 Cyclotron (IBA):

- Available quasi-monoenergetic (FWHM 1 – 3 %) $^1H^+$ 18 MeV and $^2H^+$ 9 MeV
- Lower energies are available by using foils degraders (usually $^1H^+$ 16-10 MeV)
- H [LET(Si) ~0.02 - 0.04 MeV-cm^2/mg / Range ~700-2000 microns]

- External beam line. (Possibility to couple vacuum chamber)
- Maximum achievable >90% uniform irradiated area at 10 MeV (Ø 3.5 cm)

Irradiated area uniformity better than 10%

Fluence u ~ 10-20%

Ion Implantation and Irradiation line

First designed for ion implantation (fixed energy, high fluxes and fluences)
Adaptation to irradiation testing (variable energy steps, low fluxes and fluences)
Decrease flux increasing the scanning beam area / defocusing the beam (worse quality beam)

- Scanning system

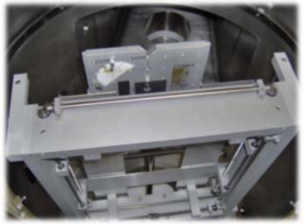
Double magnetic coils
High stability power supplies
Variable scanning frequency
1cm^2 spot scanned up to 20x20 cm^2

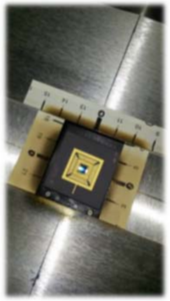
- Others

- **Lighting possibility**
- **Temperature control**
- **Opto-electrical feedthroughs**

- Sample holders

- **Maximum 20x16 cm^2**
- **X-Y movement**
- **Complete turnabout**
- **Heating / Cooling possibility**





DOSIMETRY

Current integration on sample holder and/or on the isolated sample holder and/or slits.
This is biased up to 300 volts in order to collect the secondary electrons
Integration limits the working flux, specially on real time monitoring

Brookhaven integrator

Flux range: ~ 6 x 10^{12} to ~ 1 x 10^8 p/cm^2s

Possibilities of different particle detectors

Flux range: < 1 x 10^7 p/cm^2s

External beam line

Although there is not possibility of scanning, it allows for a diverse range of irradiation areas by playing with the material of the exit window and the target distance.

SAMPLE HOLDER

Remote control (step 0.06 mm)

X 200 mm; Y 200 mm; Z 100 mm

Manual movable structure


INTA

EXIT FLANGE

Various sizes available

Internally covered with a 5 mm carbon film to avoid the activation.

Different graphite collimators with several hole diameters

Several windows


UC3M

DOSIMETRY on device under test (DUT)

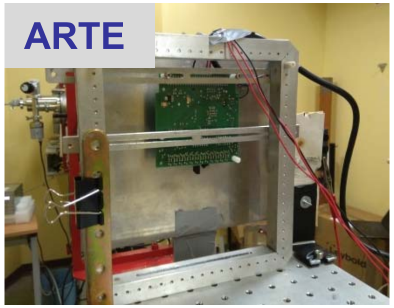
Aligned masks and collimators

Control beam spot with scintillator foils and radiochromic films

Flux monitoring on isolated graphite collimator

Previous calibration

Correlation factors depending on the set-up


ARTE


ALTER

LEP Space Applications

Proton Irradiation Test on Solar Cells cables and shielding materials

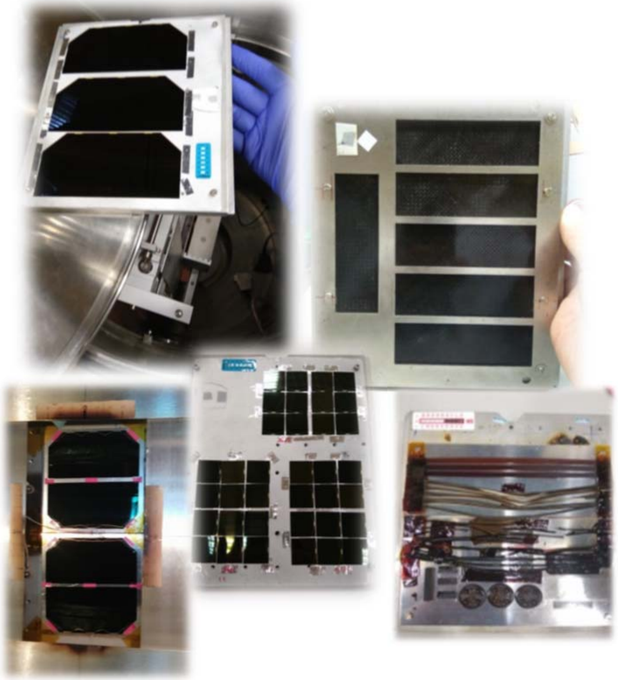
Usual requirement T<40ºC on the samples; easy reached with prompt flux <1E13 p/cm^{2}

SPASOLAB

1MeV
Proton Energy

2MeV
Proton Energy

10MeV
Proton Energy



$2x10^{10}$
$p^{+}cm^{-2}$ Fluence

$3x10^{11}$
$p^{+}cm^{-2}$ Fluence

$5x10^{12}$
$p^{+}cm^{-2}$ Fluence

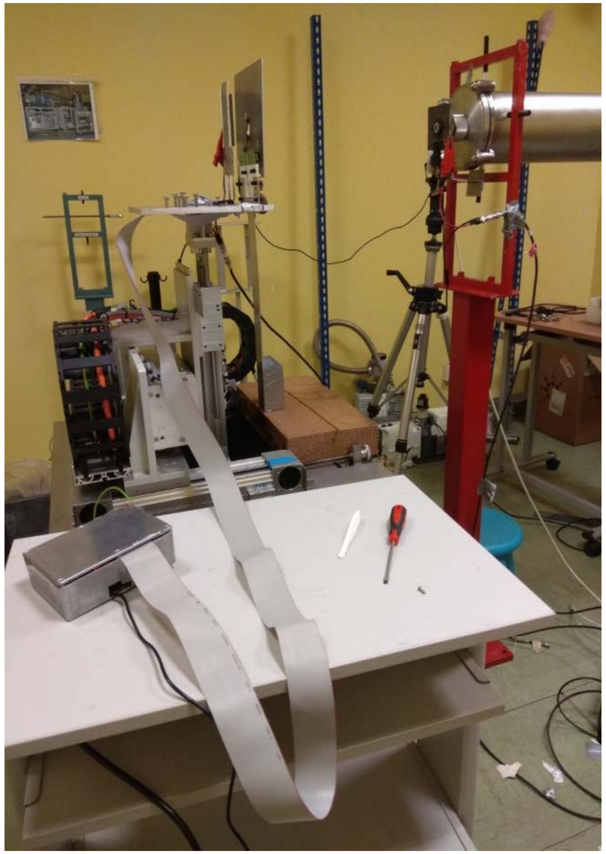
$5x10^{15}$
$p^{+}cm^{-2}$ Fluence

Irradiation campaign CNA-UCM on COTS SRAM – 65 nm at low bias voltage

TID in RadLab (Cobalt-60)

DR = 750 rad (Si) / h ; TID = 18 krad (Si)

UNIVERSIDAD
COMPLUTENSE
MADRID



M. Rezaei PhD Thesis

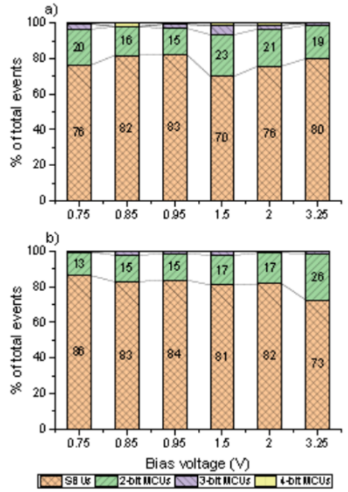


Fig. 6. Contribution of each SEU type in total number of events before (a) and after (b) the TID test

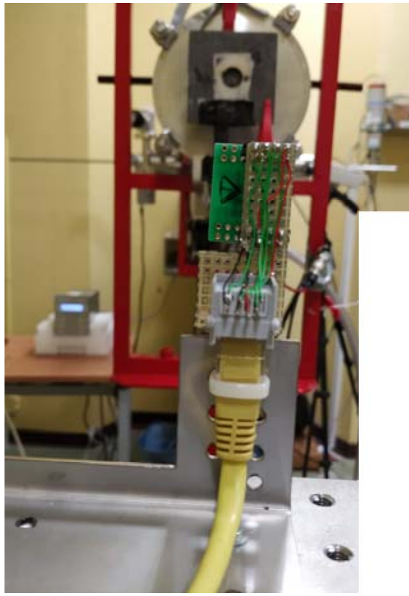
SEE campaign 15 MeV protons in the 18/9 Cyclotron

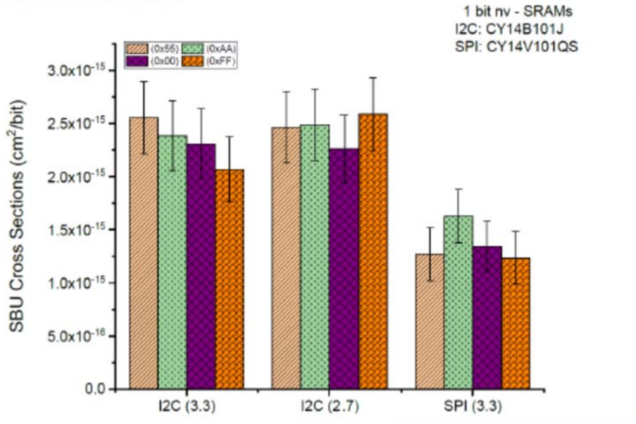
Flux 1 x10^8 p/cm^{2}s
Fluence 1x10^{10} p/cm^2
Estimated TID ~5 krad (Si)

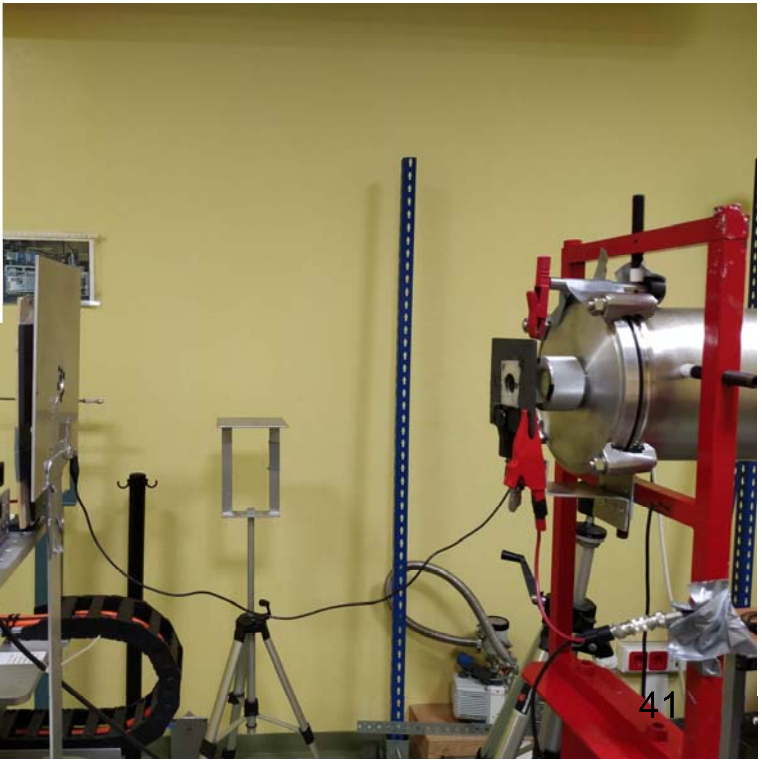
Irradiation campaign CNA-UCM on COTS SRAM & FRAM

Static and Dynamic Experiments

- Static tests: 0x55, 0x00, 0xAA and 0xFF
- Static tests were done on volatile and non-volatile parts in nv-SRAMs.
- Dynamic experiments: Using two techniques (March C and March D)







UNIVERSIDAD COMPLUTENSE MADRID

G.Korkian PhD Thesis

LEP Applications; Space, Radiation monitors

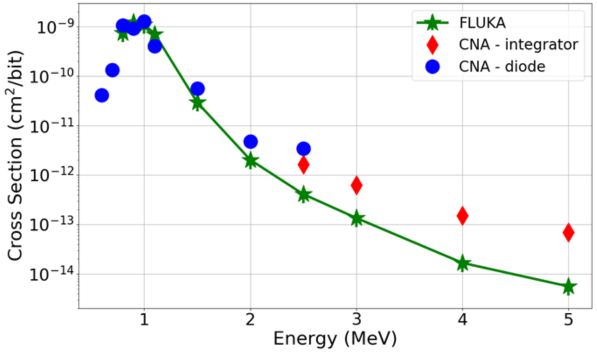
Low energy proton direct ionization testing on FPGAs
Single Event Effects (SEE) cross sections

SRAM <65 nm

0.6 – 5.5 MeV

MFlux 2E7 – 2E9 p/cm²s
PFlux 8E8 – 3E10 p/cm²s
Tilts (15º/30º/45º/60º)
Fluence 4E8 – 8E11 p/cm²

TRAD
Tests & radiations



90 & 65 nm
COTS and RADSAGA SRAMs (ESR15)

0.5 – 5.9 MeV
E steps <50 keV

MFlux 3E4 – 4E8 p/cm²s
PFlux 5E7 – 1.3E11 p/cm²s

Complementary Si diode system (by ChipIR)
MFlux 1.5E2 – 5E5 p/cm²s

Fluence 1.1E6 – 1.2E11 p/cm²

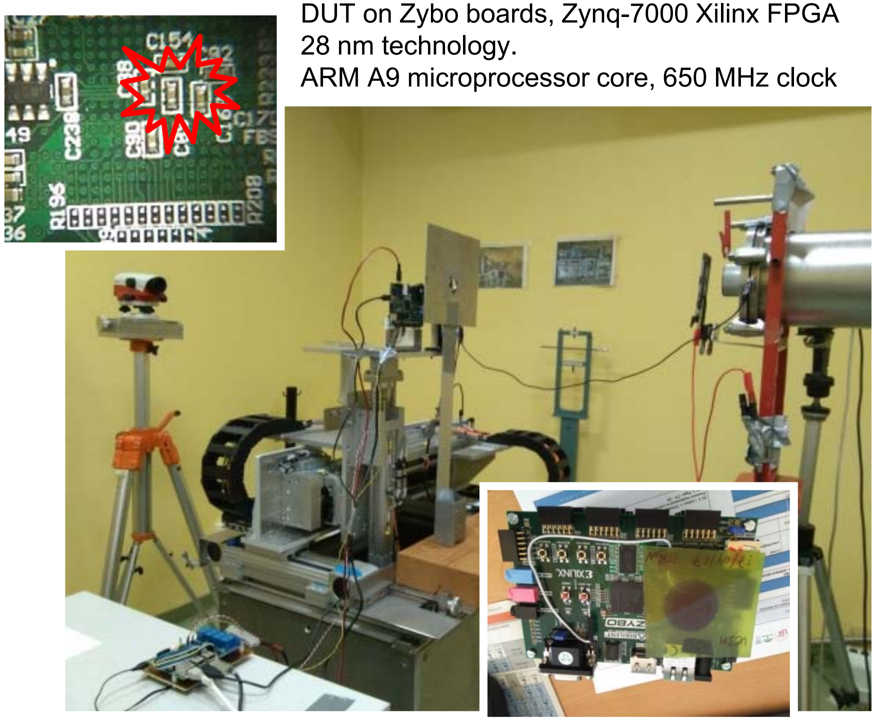
CERN
RADSAGA

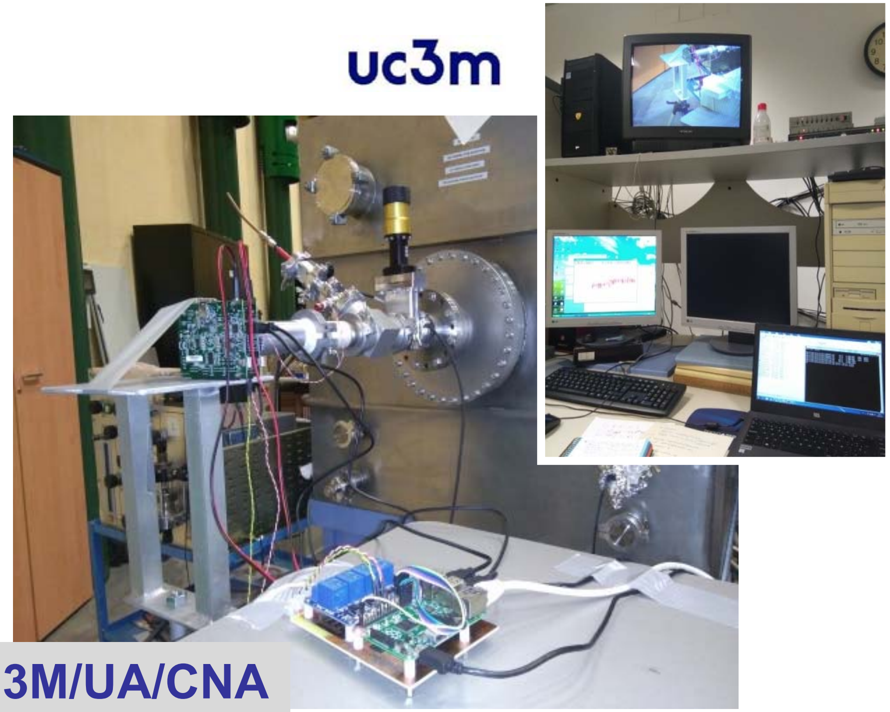
SINGULAR EXPERIMENT AT CNA
Proton & neutron irradiation campaigns on the same device

First time in our facility performing both, proton and neutron fault injection campaigns, to evaluate and compare the different robustness achieved in a microprocessor via different models of hardening software.

Benchmark based on Matrix multiplication (MMULT) with an additional circuit PDTC to observe and detect microprocessor errors during execution.

DUT on Zybo boards, Zynq-7000 Xilinx FPGA
28 nm technology.
ARM A9 microprocessor core, 650 MHz clock





UC3M/UA/CNA

15.0 MeV protons - CYCLOTRON

Exit window: Mylar® 125 µm; WDD Air 59 cm
Flux uniformity >90% in 15 mm diameter area

Beam	Flux (#/scm^2)	Time (s)	Total events	Detected events	Non detected events
Protons	$4.3 \cdot 10^8$	3718	311	85.2%	14.8%
Neutrons	$1.1 \cdot 10^6$	27360	135	82.2%	17.8%

6.1 to 8.6 MeV neutrons TANDEM 3MV

2H(d,n)3He Reaction

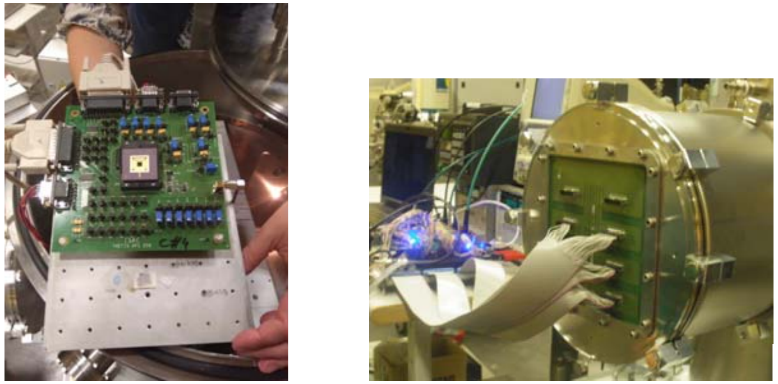
5.48 MeV deuteron primary beam
10 mm diameter focusing
TD1D Air 11 mm; DUT 17mm x 17mm

Another particles applications

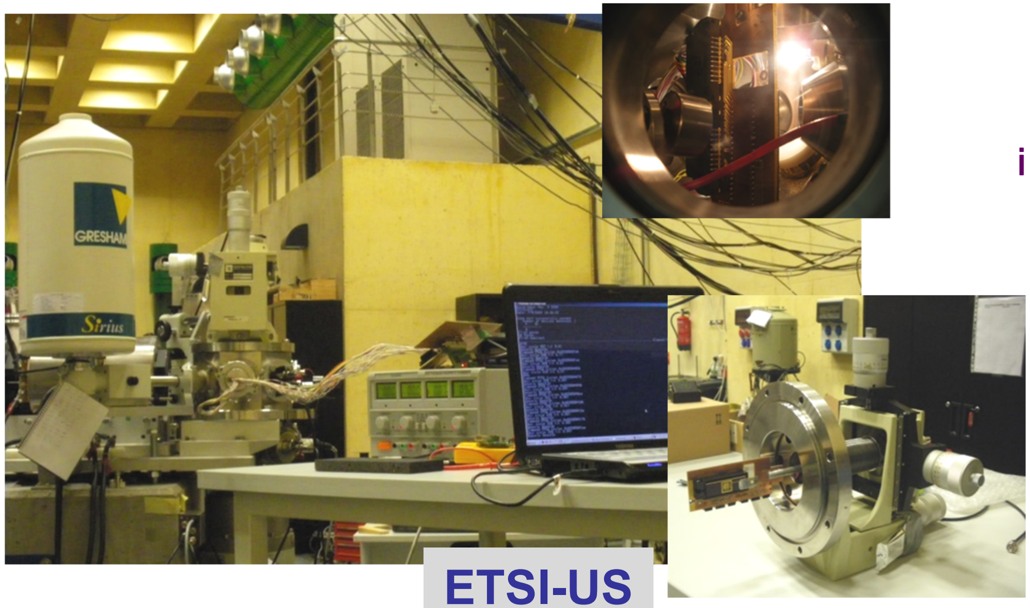
ID & DDD experiments with low energy beams
CMOS Image Sensors

0.5 to 6 MeV H^+; 0.5 MeV D
8/11 MeV O; 11 MeV Al; 6/10 MeV C

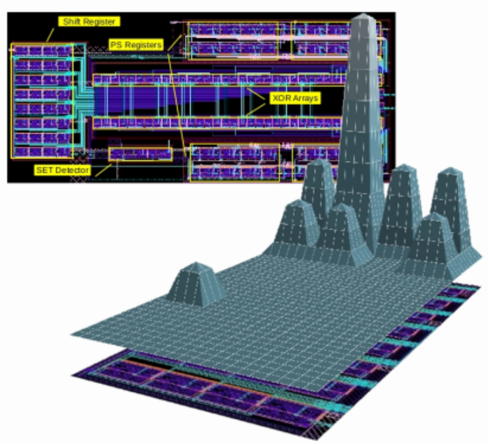
CNES



Adaptation to perform microdosimetry
irradiadiation test (static & dynamic mode)



ETSI-US



First CNA-SEU experiments with 11 to18 MeV O and C microbeams

APPLICATIONS FOR USE

Previous contact (Yolanda Morilla; ymorilla@us.es) is recommended to know in advance the test feasibility and to obtain custom budget

The use of CNA facilities requires the **approval of the Scientific Committee.**

- **FILL IN THE CORRESPONDING “BEAM TIME REQUEST”.**
  The template are available in *www.cna.us.es*
  http://institucionales.us.es/solicitudescna/index.php/en/information-and-documents-for-use-of-accelerators
  Facilitates the tedious procedure through your contact
- **SEND THE APPLICATION** TO *solicitudescna@us.es*.
  Your contact will keep you informed of the procedure progress.
- When the application is accepted, the experiment **date is planned** according to the user and depending on the staff and facility availability.
- Usually, the full process is **completed** in less than two months.
- The current **tariffs** charged will be a day of using the accelerator/irradiator system
  http://institucionales.us.es/solicitudescna/index.php/en/rates

300-600 €/day [24 h (gamma lab); less staff involvement on real time; specific use]
400-1000 €/day [8 h (particle labs); Staff limitations; multidisciplinary use; time limitation]

Acknowledgements

Projects PRECEDER-2020/00000158
ESP2015-68245-C4-4-P & IPT-2011-1603-370000

To the users and collaborators from public institutions and private companies

Your requirements are our improvements !!!

Centro Nacional de Aceleradores

Junta de Andalucía

GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA, INNOVACIÓN Y UNIVERSIDADES

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