Progress of CNA to become the Spanish facility for combined irradiation testing in aerospace

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SUMMARY

The collaborative work in between different public institutions and private companies, through different global projects (RENASER, RENASER+, RENASER3 and RADLAB), has made possible to consolidate the irradiation area in the CNA (Centro Nacional de Aceleradores), with especial emphasis on the testing of devices suitable to be used in aerospace projects. Eight years ago, one of the conclusions in our first project was that using our cyclotron facility it could be possible detecting single events on scales below 250nm. Along the second project, it was already observed this kind of effects on 130nm devices. Nowadays, the CNA facilities are used to perform irradiation testing in sequential steps with gamma photons and particles, on materials, optoelectronic and microelectronic devices. In the next future, it will be also available to perform thermal cycling tests in combination with radiation, all that simultaneously, and in the same facility of our Centre.

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.

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

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

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

Table. Experimental data on MMULT_32H

6.1 to 8.6 MeV neutrons

²H(d,n)³He Reaction

5.48 MeV deuteron primary beam
10 mm diameter focusing
TD₁D Air 11 mm; DUT 17mm x 17mm
Dosimetry by yield calculation and primary beam monitoring

Deuterated Target:
500 g/cm² thickness, 3 mm Al and D/Ti ratio 1.5

15.0 MeV protons

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

(*) Visit M. Peña-Fernández et al. in RADECS2018 F session (PF-1)

LABORATORIES AND IRRADIATION ACTIVITY AT CNA

RADLAB Facility / Co-60 Source

Range of dose rate (at July 2018)
0.05 - 240 Gy(Si)/h
Flat square irradiation fields
Dose rate uncertainty ≤ 4%
Dosimetry by Farmer ionization chambers

- TID on components and systems (ALTER, UC3M, UV, SOLARMEMS, IMSE...)
- Dosimetry intercomparison exercises (ALTER, ESA, UCL, UML, JSC-URSC-ISDE)

3MV Tandem Accelerator Laboratory

Neutrons and ions working on air and/or vacuum

Tandem (FWHM 0.03%) ion beams from H to Au (LET < 30 MeV·cm²/mg)
Energy range from 600 keV to several MeV (E=(1+q)V; e.g. 600 keV to 6 MeV for H⁺)
Maximum irradiation area 17cm x 20cm
Energy neutron below 9 MeV
²H(d,n) and ⁷Li(p,n) reactions availables

Cyclotron (FWHM 1.1%) ¹H⁺ 18 MeV and ²H⁺ 9 MeV
Lower energies are available by using foils degraders
Uniform irradiation area from 0.5 to 3.5 cm on diameter

Flux monitoring with current integrator (≈ 10⁸ - 10¹¹ p/cm²s)

SEU & DD experiments with low energy particles (0.5 - 6) & (10 - 18) MeV H; 0.5 MeV D; 8/11 MeV O; 11 MeV Al; 6/10 MeV C (TRAD, ALTER, ARTE, AIRBUS, CESI, SPASOLAB-INTA, UC3M, UA, ETSI-US...)

18/9 Cyclotron Laboratory

FACILITY UPDATE IN PROGRESS

Irradiation at elevated temperature / cryogenic temperature tests will be available; moreover, the possibility to carry out temperature cycles while samples are being irradiated, working in vacuum or another atmosphere.

Operating range: -80°C to 170°C (±1°C) with possibility to increase it.

Compatible system with all irradiation laboratories (particles and gamma radiation).

Dosimetry systems are currently under study.

Met and next challenges

It is shown the current capability to perform SEE on devices (highly integrated technologies) at CNA.

The new neutron beam line can provide similar coverage than proton beam at CNA. The fault rate in our experimental conditions, it is good enough for relative comparison studies.

More effort must be done to improve the neutron set-up and the dosimetry methodology for both neutrons and ions irradiation tests.