SpaceRadMon, a radiation tolerant monitor device for cubesats

P. Gkountoumis, S. Danzeca, A. Zimmaro
(BE-CEM-EPR)

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https://indico.cern.ch/event/1116677/

SpaceRadMon

- SpaceRadmon is a radiation monitor device with high TID resolution and low power consumption designed for CubeSat Satellites
- It was developed with the support of KT fund, profiting of the knowledge/experience gained from RadMon - system used for radiation monitoring in the harsh environment of LHC
- It is a flexible payload that can be embedded in several missions with little effort.
- Integrates specific sensors for space applications
- Attractive solution for space missions – close collaboration with many companies and universities

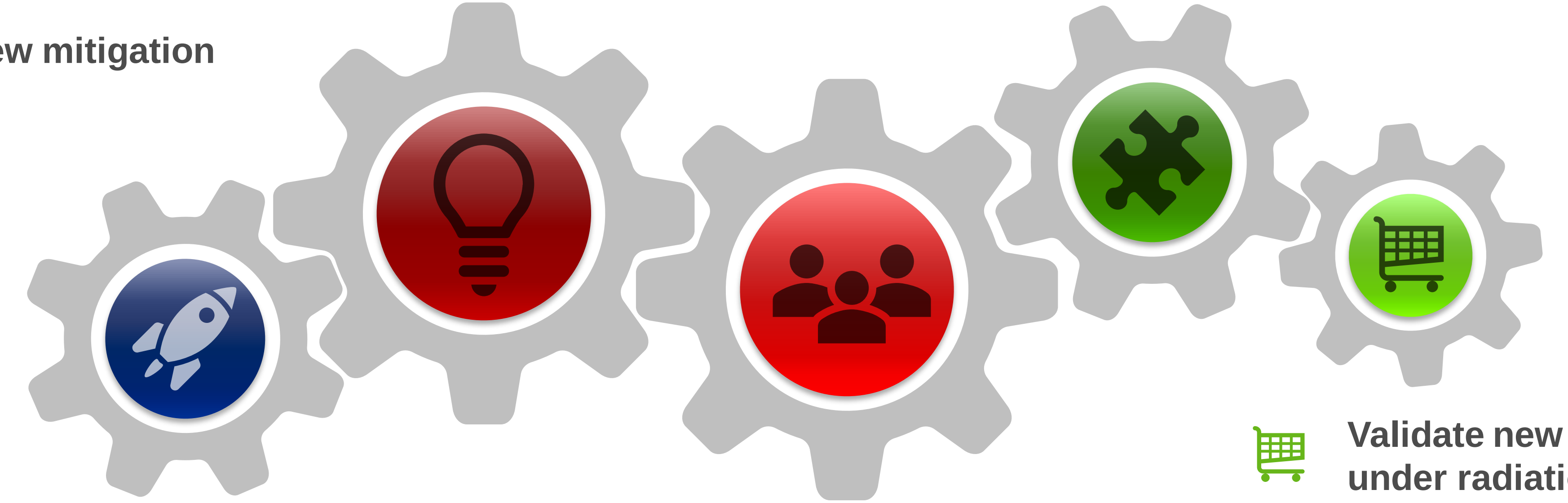
RadMon

Impact of payload development

- To design, develop, debug and validate a radiation tolerant system with a complex hardware architecture is a very complicated process and can last for years

Capable of characterizing sensors

Introduce new mitigation techniques



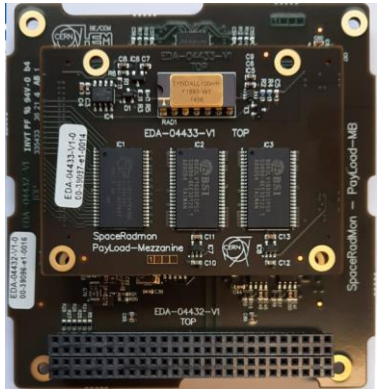
Validate new components under radiation

Provide new architecture and system level testing opportunities

Validate mitigation techniques

Timeline

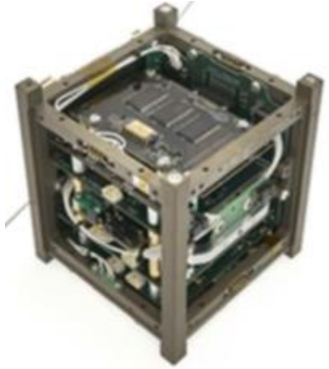
SPACERADMON V2



2015

CELESTA

- **CE**rn **L**atchup **E**xperiment and **ST**udent s**A**tellite
- The first CERN driven 1U satellite
- Collaboration of CERN and CSU



CELESTA

- SRAM Latch-up Experiment: Compare radiation levels between equator and poles
- Comparison of radiation effects between LEO space environment and CHARM
- Introduce Nanosatellites radiation qualification procedure at CHARM

2018

Space RadMon V2

- Successor of CELESTA
- Slightly modified hardware
- More flexible interface
- Complies with PC104 standard

Challenges

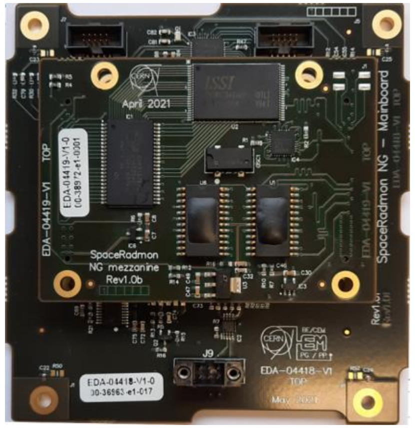
- Low power
- More radiation tolerant
- Better sensor resolution

2020

Space RadMon NG

Advanced hardware with increased capabilities and better characteristics

SPACERADMON NG



SpaceRadMon V2 VS NG

What we succeeded:

SPACERADMON V2 | SPACERADMON NG

Characteristics	V2	NG
Tolerance [Gy]	250 Gy	418 Gy
Power consumption	165 mW	63.5 mW Idle - 45.0 mW Sleep
Mass	60 g	57.5 g
Sensors	Radiation Field Effect Transistor	Floating Gate Dosimeter
Resolution (TID)	57 mGy	2 mGy
SRAMs	1 SEU and 2 SEL	4 SEUs (2 commercial and 2 custom with adjustable voltage)
Voltage monitoring	No	Yes
Temperature monitoring	Yes	Yes
Communication protocol	I^2C	I^2C

SpaceRadMon NG timeline

September 2020

Harware + firmware development, prototyping and board debugging

May 2021

Hardware was finalised

Firmware development and debugging

July - October 2021

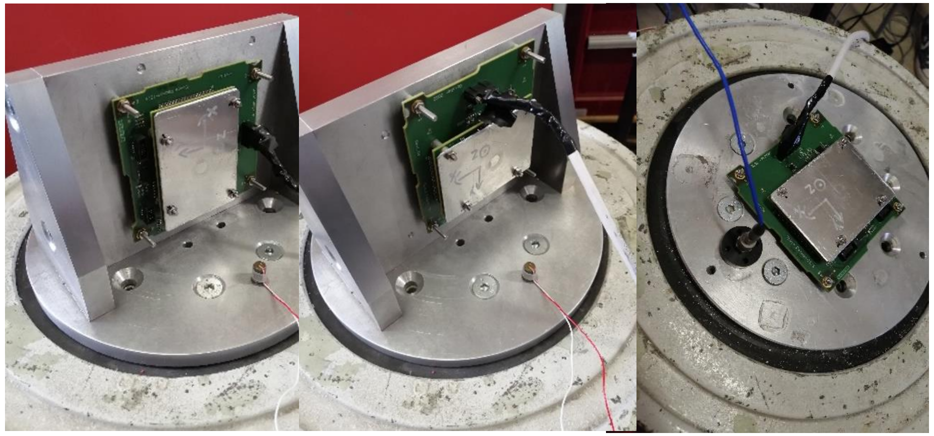
Radiation testing

- 6 Campaigns (^{60}Co, 4 at PSI, CHARM)
- TID/DDD, SEE, functional testing, firmware qualification, Cross-section calculation
- Screening process: EMC/Thermal/Vibration tests

Tests at KU Leuven

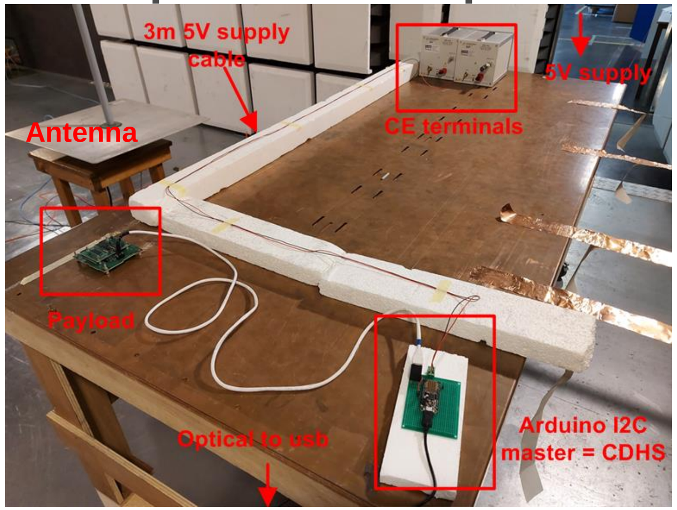
KU LEUVEN

- ❑ Vibration tests using 1 dimension shaker at the KU Leuven Noise and Vibration research lab
  - Resonance survey, Sine/Random vibration, Sine burst, Shock tests
- ❑ Thermal stress tests using a Climatic/Temperature Testing Chamber
  - 3 x Thermal cycles from -30 to 60 ºC (board not active)
  - 3 x Thermal cycles from -20 to 50 ºC (board active)
- ❑ EMC tests
  - According to US military standard (MIL-STD-461G)
  - Scanned range: 10kHz – 6GHz
- ❑ Results: No functional or mechanical failures



X position **Y position** **Z position**

CTS chamber

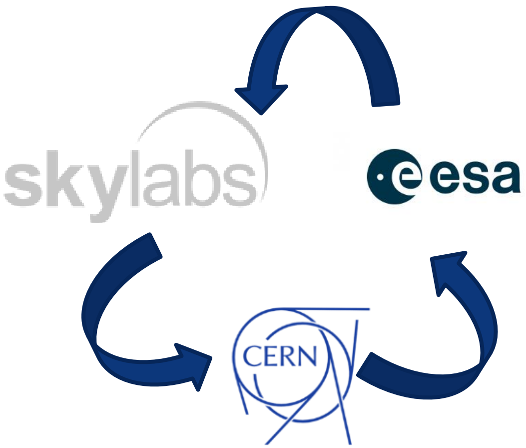


EMC test setup

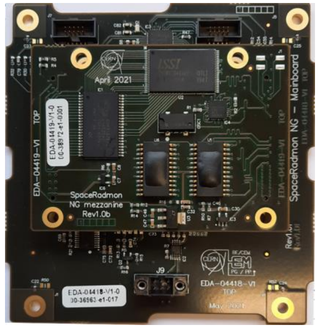
Thanks to J. Prinzie and the KU Leuven team!

CHARM irradiation tests by Skylabs

- TM/TC satellite communication sub-system (Nanolink)
- Easy payload integration
- Wireless data transmission using Software Defined Radio (SDR)
- Testing in collaboration of CERN, ESA and Skylabs
- Motivation:
  - System level testing (SpaceRadMon)
  - Test High speed data wireless link
  - Test both systems and validate the platform

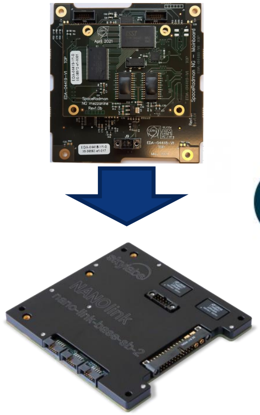


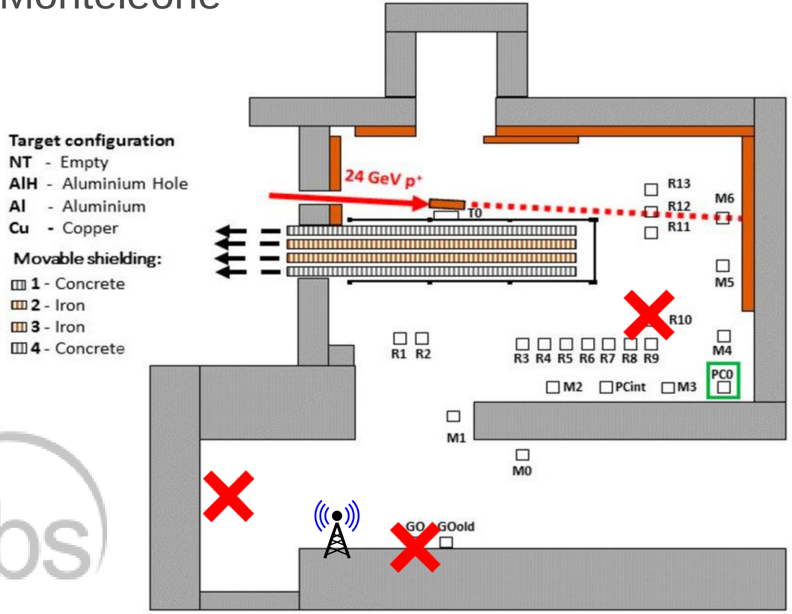
SPACERADMON NG

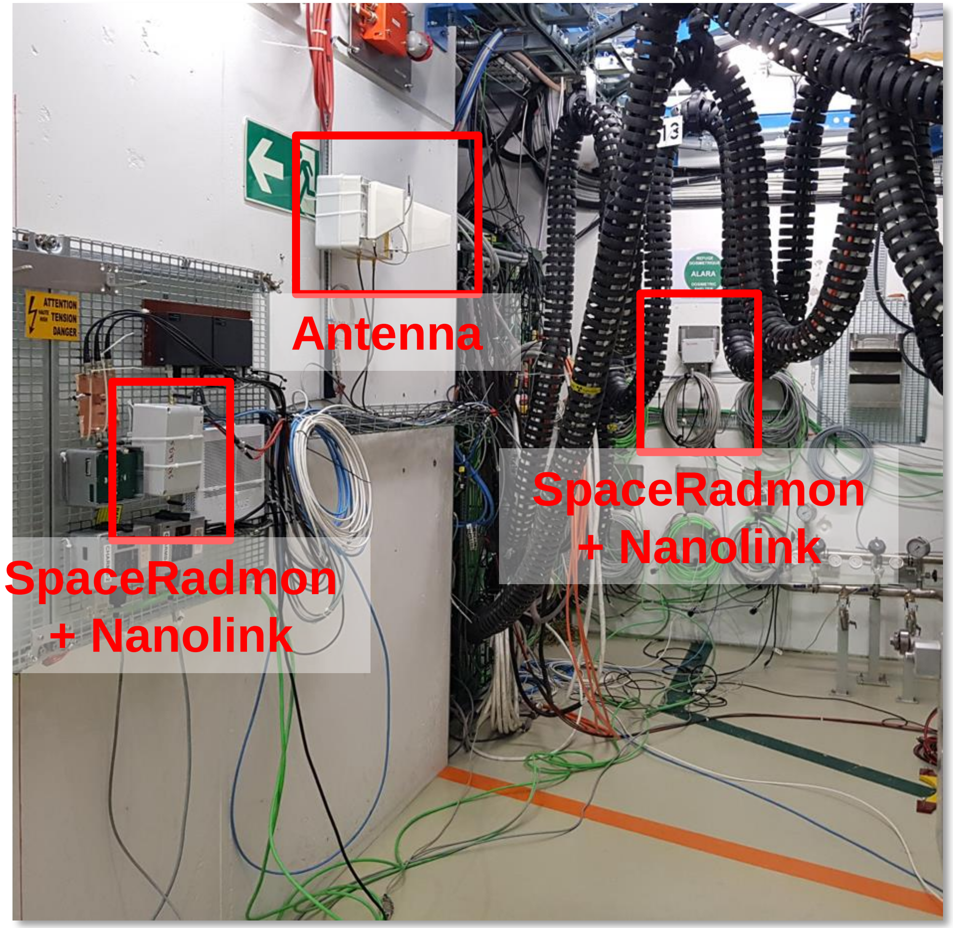


CHARM irradiation tests by Skylabs

- 3 systems (SpaceRadMon NG + nanolink) in different positions and fluxes
- Mixed particle field (mainly dominated by Hadrons: proton, neutrons, pions).
- Data analysis almost finalized – Very promising results
- Thanks to Skylab team and ESA: Gianluca Furano, Antonis Tavoularis and Claudio Monteleone

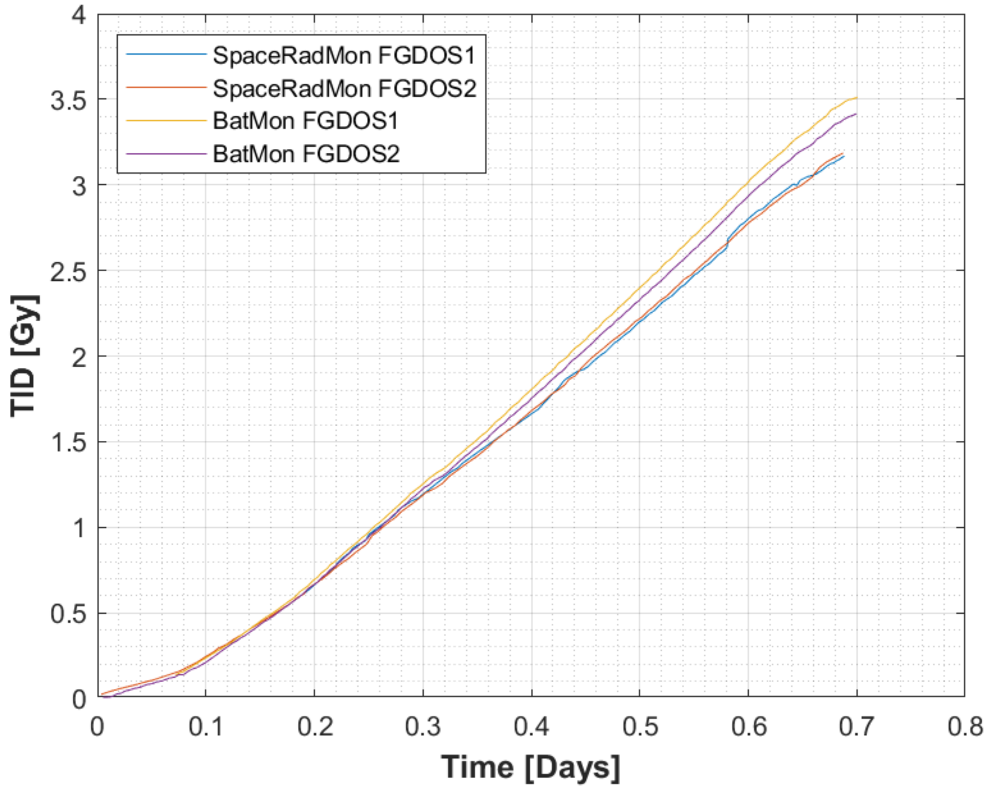






CHARM results

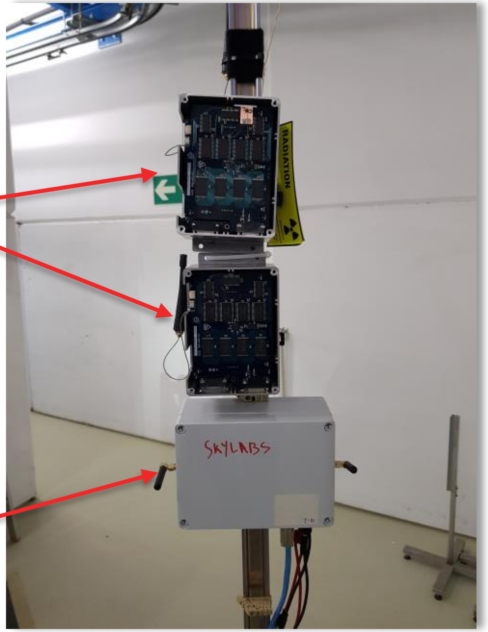
- Results compared with Batmon and RadMon (irradiated in parallel)
- R10 position - Configuration CuOOIC



System	TID [Gy]	Difference
BatMon #2	3.51	
BatMon #3	3.48	
SpaceRadMon	3.16	9.97%

BatMon

Nanolink + SpaceRadMon NG



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November 2021

Flying Model delivery

Distribution of the final product

SpaceRadMon V2 arranged missions

SpaceRadMon V2

- ❑ TRISAT-R
  - Medium Earth Orbit: 5865 km
  - Collaboration of CERN with University of Maribor
  - Expected lunch date: May 2022
  - Agency: ESA
- ❑ Pioneer-IODA
  - Orbit: 1200 km
  - Collaboration of CERN with Airbus, MCSE
  - Expected lunch date: end of 2023
  - Agency: ESA
- ❑ OGMS
  - Orbit: LEO
  - Collaboration of CERN with UPEC
  - Expected lunch date: end of 2023
  - Agency: CNES

University of Maribor

esa

AIRBUS

Micro-Cameras & Space Exploration

cnes CENTRE NATIONAL D'ÉTUDES SPATIALES

UPEC UNIVERSITÉ PARIS-EST CRÉTEIL

SpaceRadMon NG arranged missions

- RADIOX
  - LEO - Duration of 1-1.5 years
  - Collaboration of CERN with KU Leuven and ISISpace
  - Expected lunch date: end of 2022
- GOMX-5
  - LEO - Duration of ~3 years
  - Collaboration of CERN with GomSpace
  - Expected lunch date: end 2022
  - Agency: ESA

SpaceRadMon EM-QM/FM distribution

- Produced 30 V2 and 30 NG payloads
  - Engineer/Qualification Models (EM/QM) are used for system validation
  - Flying Model (FM) for system integration
- CNES : (V2 version) Delivered 2 EM/QM, 1 FM to be delivered
- ISISpace : (NG version) Delivered 2 EM/QM and 1 FM
- GOMX : (NG Version) Delivered 1 EM/QM, 1 FM to be delivered
- Skylabs : Delivered 2 V2 and 4 NG EM/QM
- Provide detail Interface Control Document + continuous support to the users

SpaceRadMon NG Interface Control Document

SpaceRadMon NG.ICD
Version 1.0

Release information

Written by:	Alessandro Zimmaro/Panagiotis Gkountoumis
Checked by:	
Approved by:	
Distribution List:	

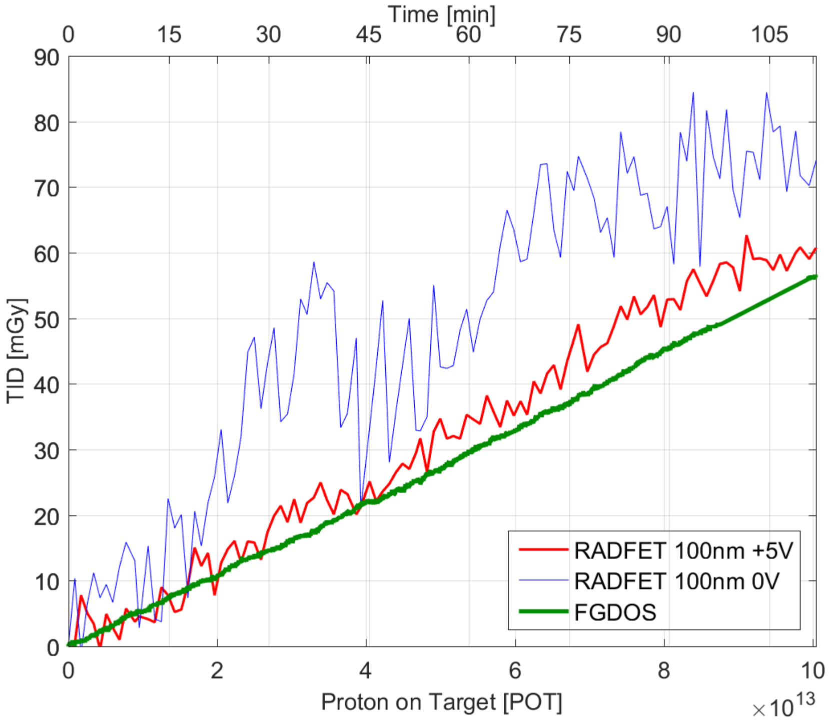
Conclusions

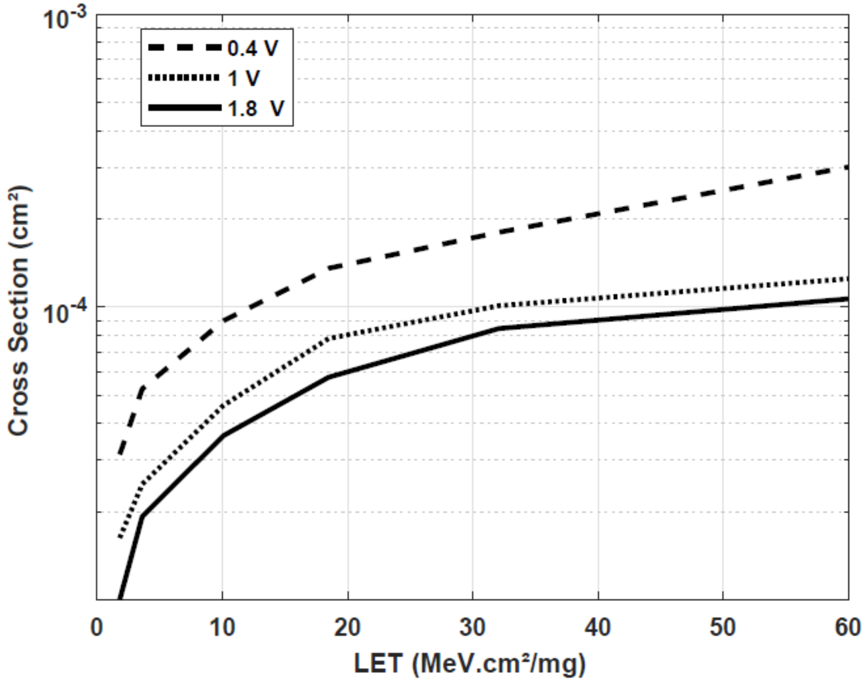
- This project is a result of the knowledge/experience gained all those years in radiation monitoring thanks to KT support
- Is a continuous effort to improve, characterize and qualify the system
  - hardware, firmware/software stability
  - SRAM calibration
  - TID/DDD/SEE
  - data analysis
- Provide new architecture and system level testing, validate mitigation techniques, characterize sensors and validate new components under radiation
- It is a flexible payload for Cubesat satellites, that can be embedded in several missions with little effort.
- Was tested extensively and was fully qualified for space missions

Thank you for your attention!

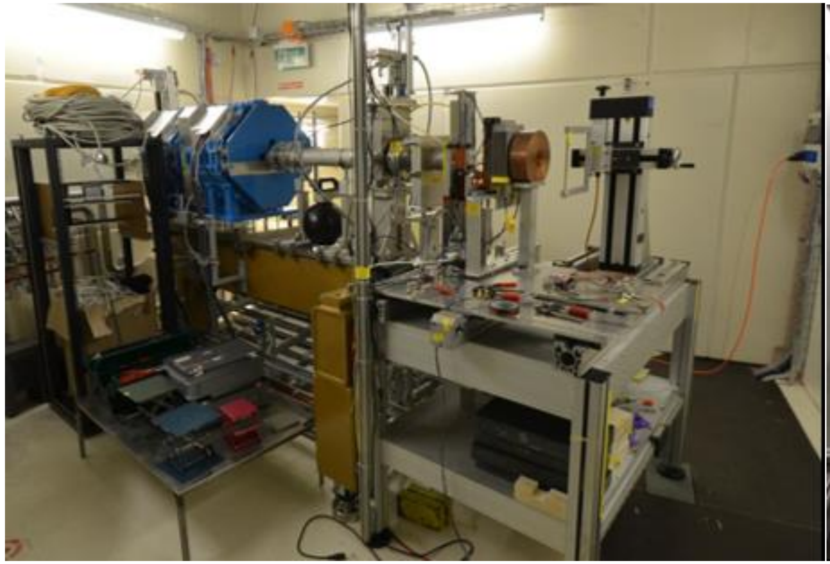
Sensor capabilities

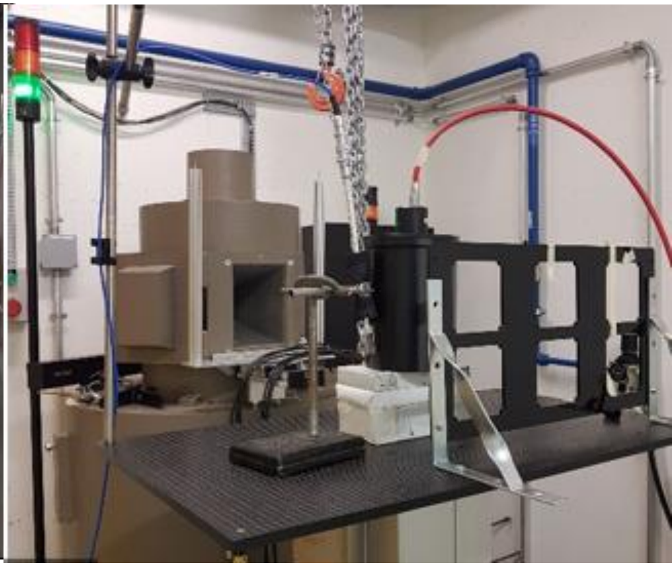
- FGDOS (linear radiation response – 2 mGy resolution)
- KU Leuven SRAMs – Powered by adjustable voltage for higher sensitivity





Radiaton test facilities





- **PSI**
- Mono-energetic proton beam
- 200 MeV – 2.5×10^8 p/cm^2/sec
- SEE, TID and DD

- **CHARM**
- Mixed-particle field
- Ideal for system level testing
- Representative radiation fields
- SEE, TID and DD

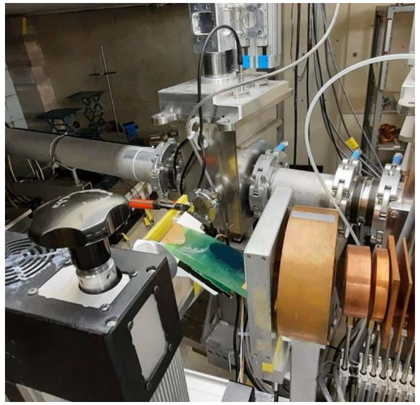
^{60}Co
- Ideal for system/component level testing
- TID

Space RadMon NG irradiation

June

^{60}Co

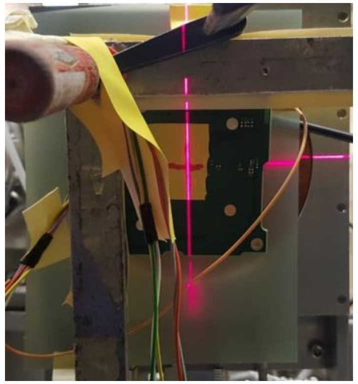
- 21.6 Gy/h
- Board survived up to 410 Gy
- TID



July

PSI

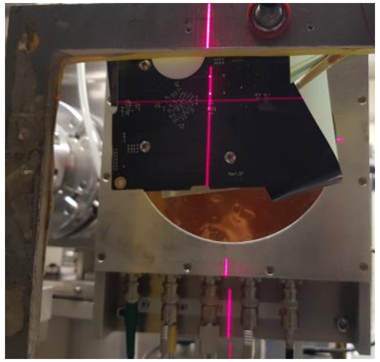
- Variable Fluxes: 1.91x10^{7} p/cm^{2}/sec to 2.5x10^{8} p/cm^{2}/sec
- Board tested up to 500 Gy
- TID/DD



August

PSI

- Variable Fluxes: from 4.8x10^{7} p/cm^{2}/sec to 2.5x10^{8} p/cm^{2}/sec
- Board tested up to 300 Gy
- TID/DD and firmware qualification



September

PSI

- Variable Fluxes: from 4.8x10^{7} p/cm^{2}/sec to 2.5x10^{8}
- Board tested up to 320 Gy
- Calculate the SEU cross-section

October

PSI

- Flux: 1.22x10^{8}p/cm^{2}/sec and to 1.22x10^{8}p/cm^{2}/sec
- Board tested up to 96 Gy
- Tested for firmware stability

CHARM

- 3 boards with variable fluxes and TID
- System failed at ~320 Gy at R10 position

SpaceRadMon NG test results

- Cross-section calculation for the 180nm SRAMs at PSI
- Test for failure mechanism and mitigations