Floating Gate Dosimeter

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BE-CEM-EPR

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

CERN BEAMS Controls Electronics & Mechatronics R2E

Agenda

1. Overview and Applications
2. Enhanced Sensitivity Mode
3. Charge Yield Measurements

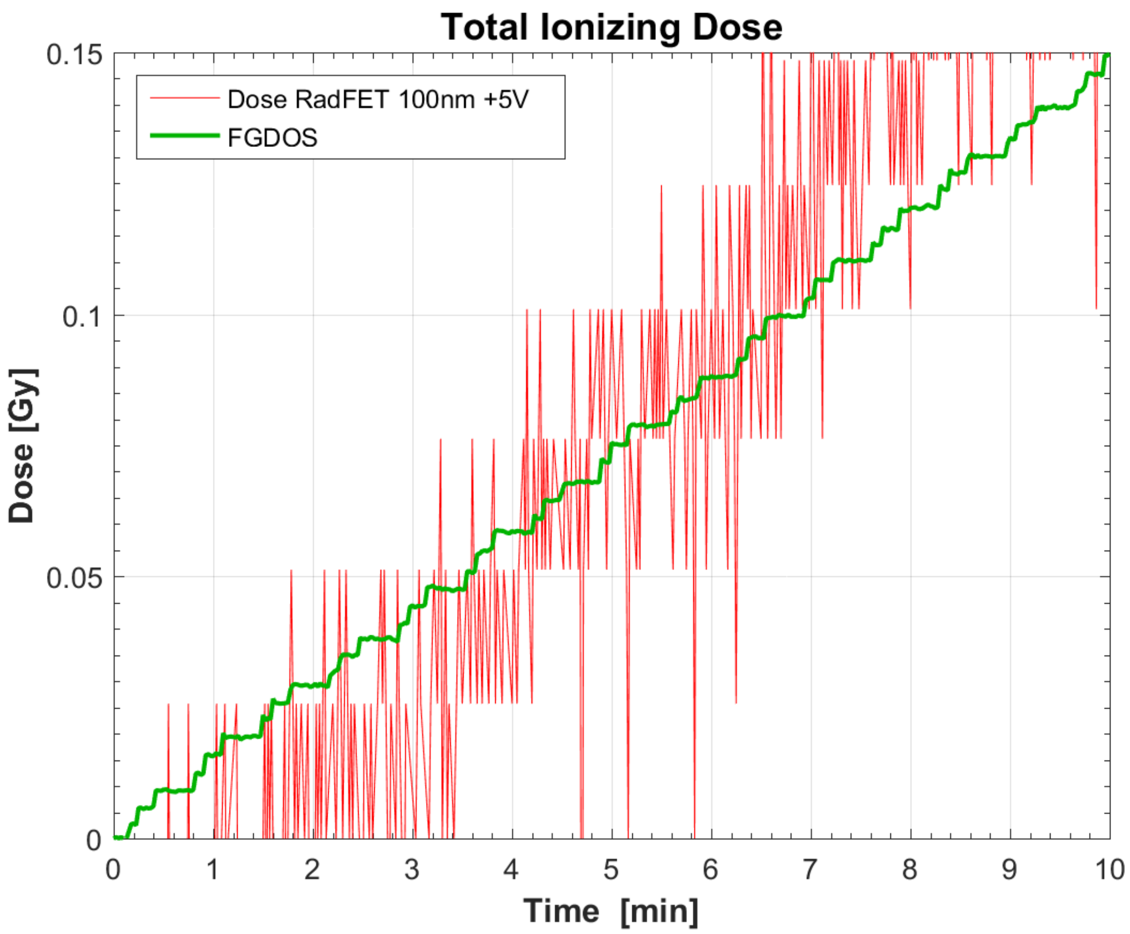
The FGDOS

The Floating Gate Dosimeter (FGDOS)

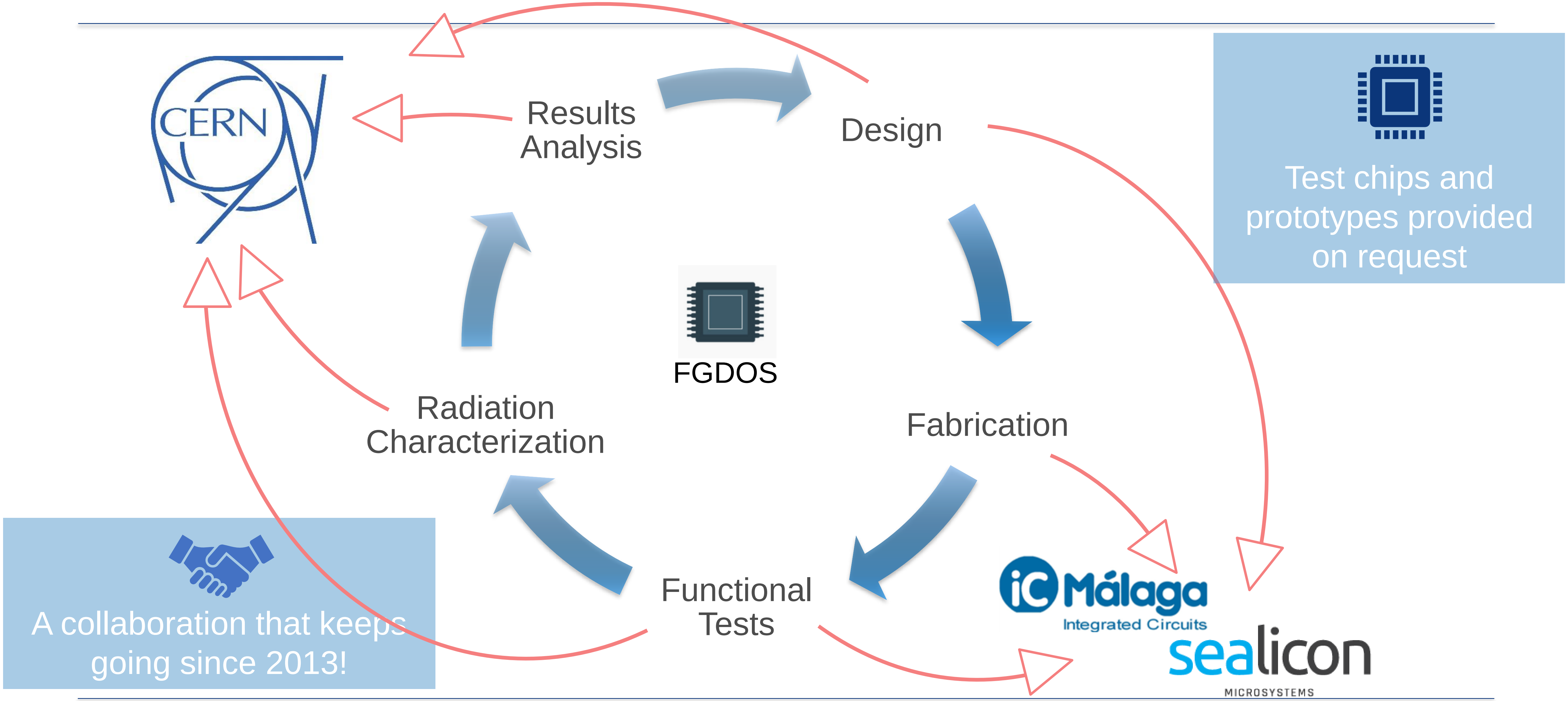
- It is developed to measure **Ionizing Radiation (TID)**
- Radiation sensor integrated in a **System-On-Chip**
  - Easy integration in more complex systems
- Linear radiation response
- High Sensitivity (resolution < 2 mGy)
- Works in mixed radiation field environment

SENSOR	BIAS	Resolution [mGy]	Dose Range [kGy]
RadFET	5V	57	2.3
FGDOS	-	2	0.3

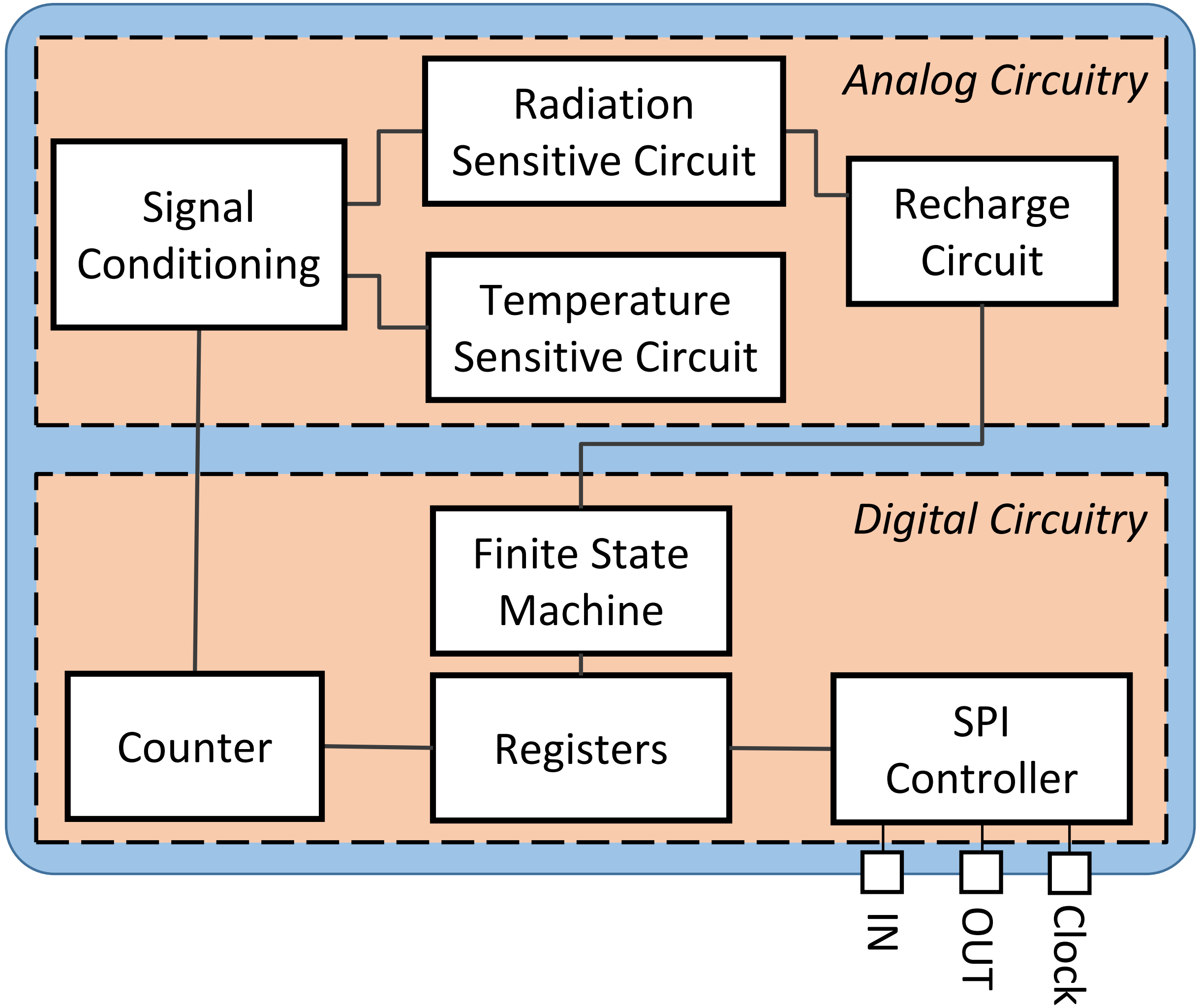
x 30



Sensor Development → An Iterative Process



FGDOS as System-on-Chip



Extremely flexible system

- Auto-recharge Control
  - Embedded Charge Pump
- Temperature Compensation Circuit
- Recharge counter

Configurable for different applications

- *Active Mode*
  - Highest resolution, High data rate
- *Autonomous Mode*
  - Low power consumption, low data rate
- *Passive Mode*
  - No power consumption, limited dose range

FGDOS in Operation

Wireless Battery-powered Radiation Monitoring System (BatMon)

- System Qualification (link)
- Radiation Measurements Campaign in the SPS accelerator

Space RadMon

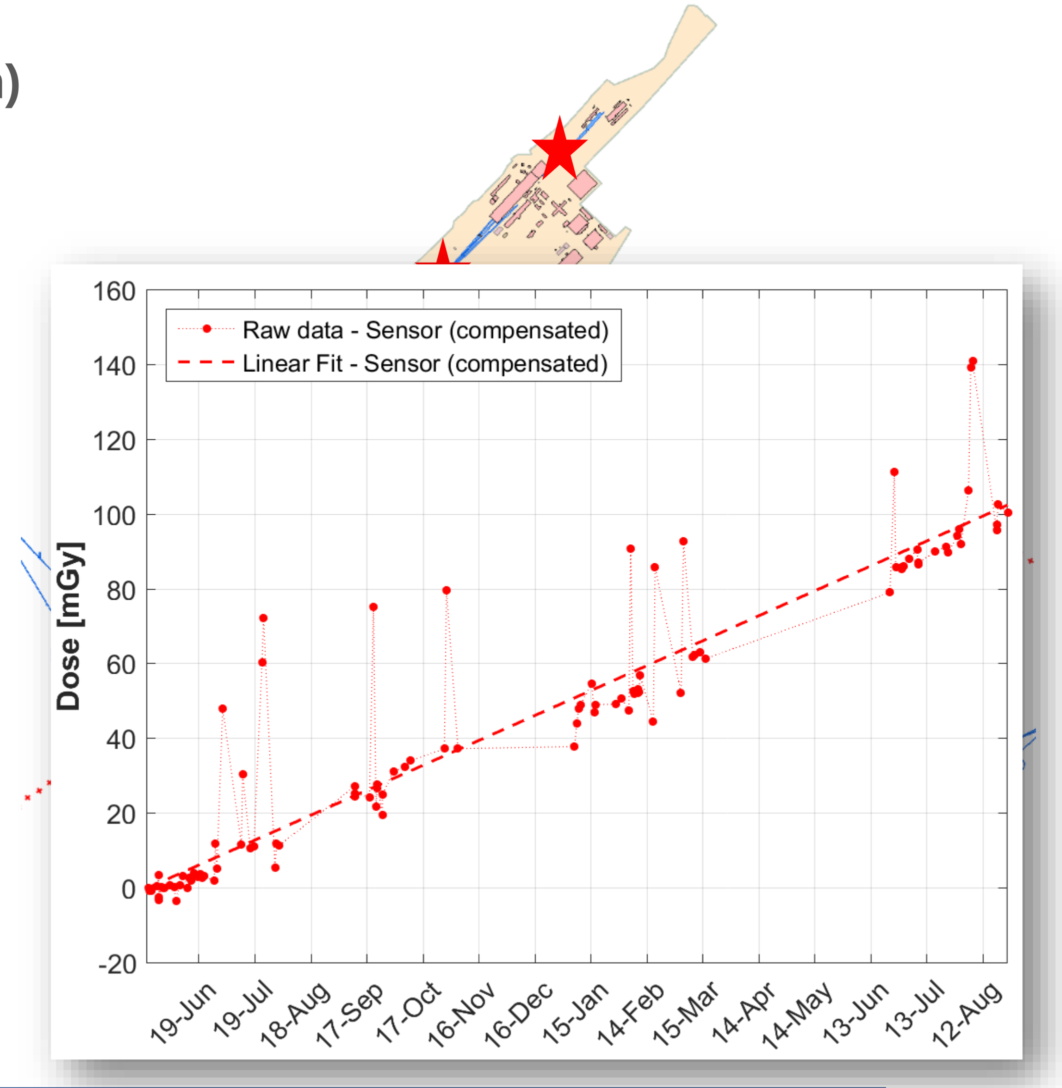
SPACERADMON NG

- System Qualification (link)

FGDOS flying on the International Space Station

- FGDOS integrated in the *CryptIC* project (link)

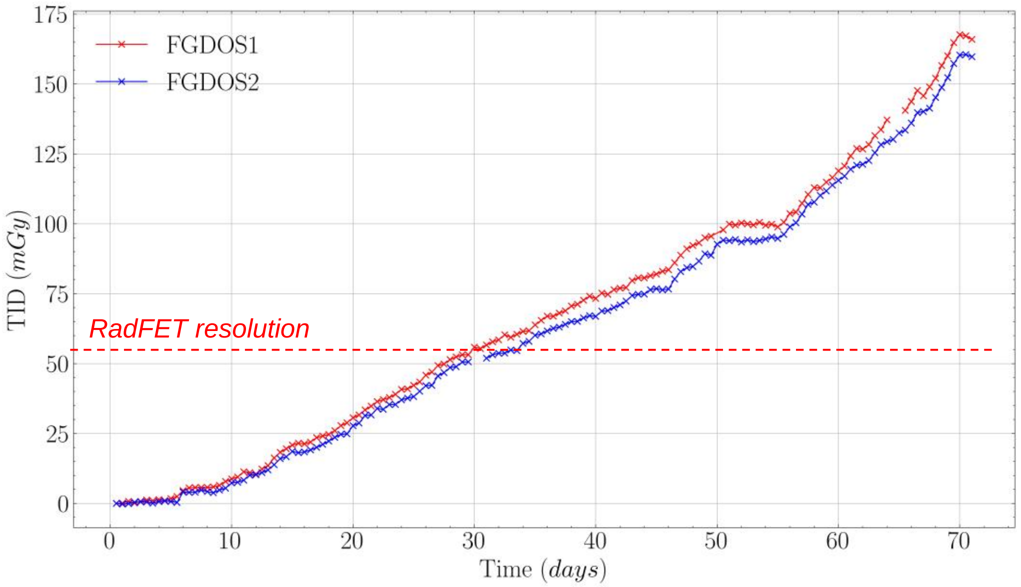
	Dose rate [mGy/day]
Expected Dose Rate by ESA	0.24
Data processed by CERN	0.22

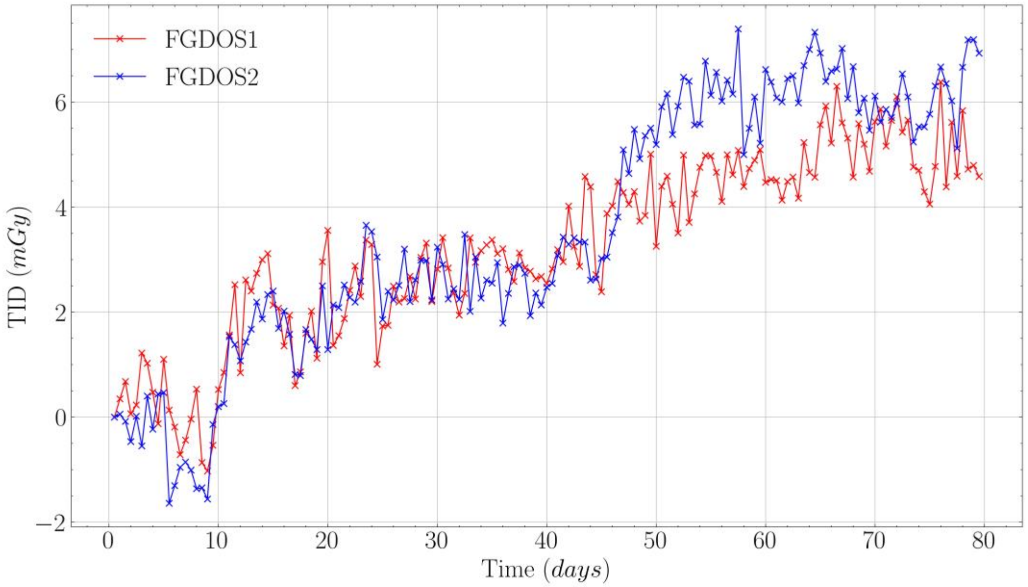


Sensitivity Enhancement Mode

Enhancing the sensitivity - Motivation

- **Sensitivity** is a key parameter for TID sensors employed in accelerator-like environments
- In the context of the R2E mitigation activities, radiation levels assessment is necessary to determine the harshness of a specific location hosting some electronic equipment
- The radiation environment characterization consists in **measuring** the radiation levels in a short time window and aims to **predict** the levels over several years of operations

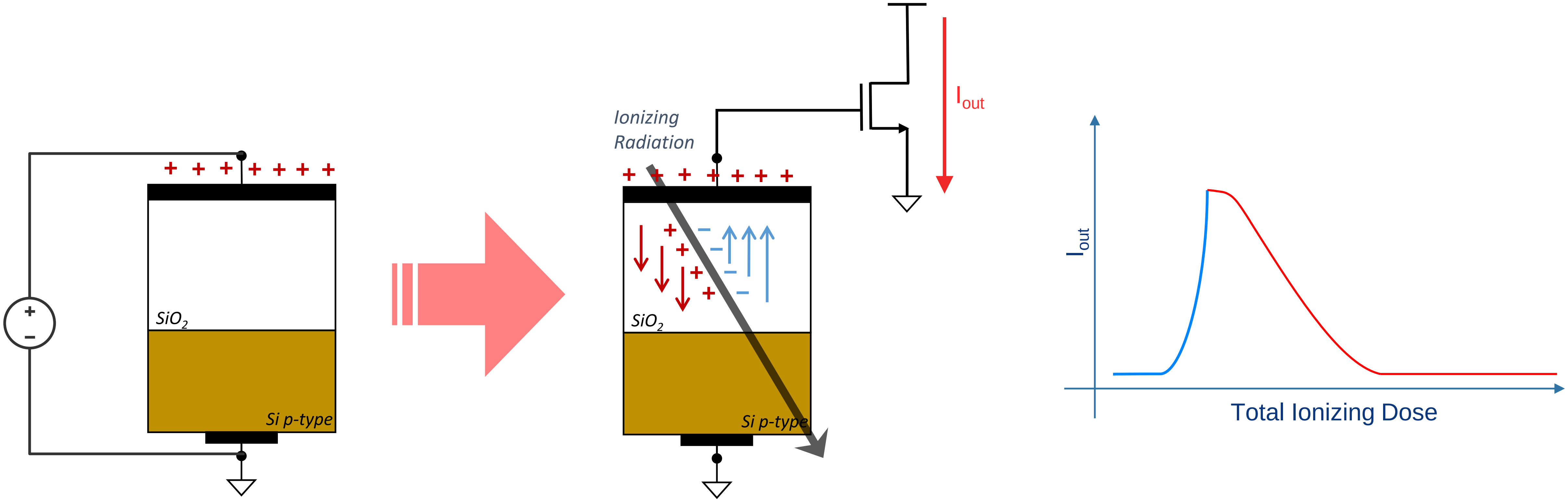




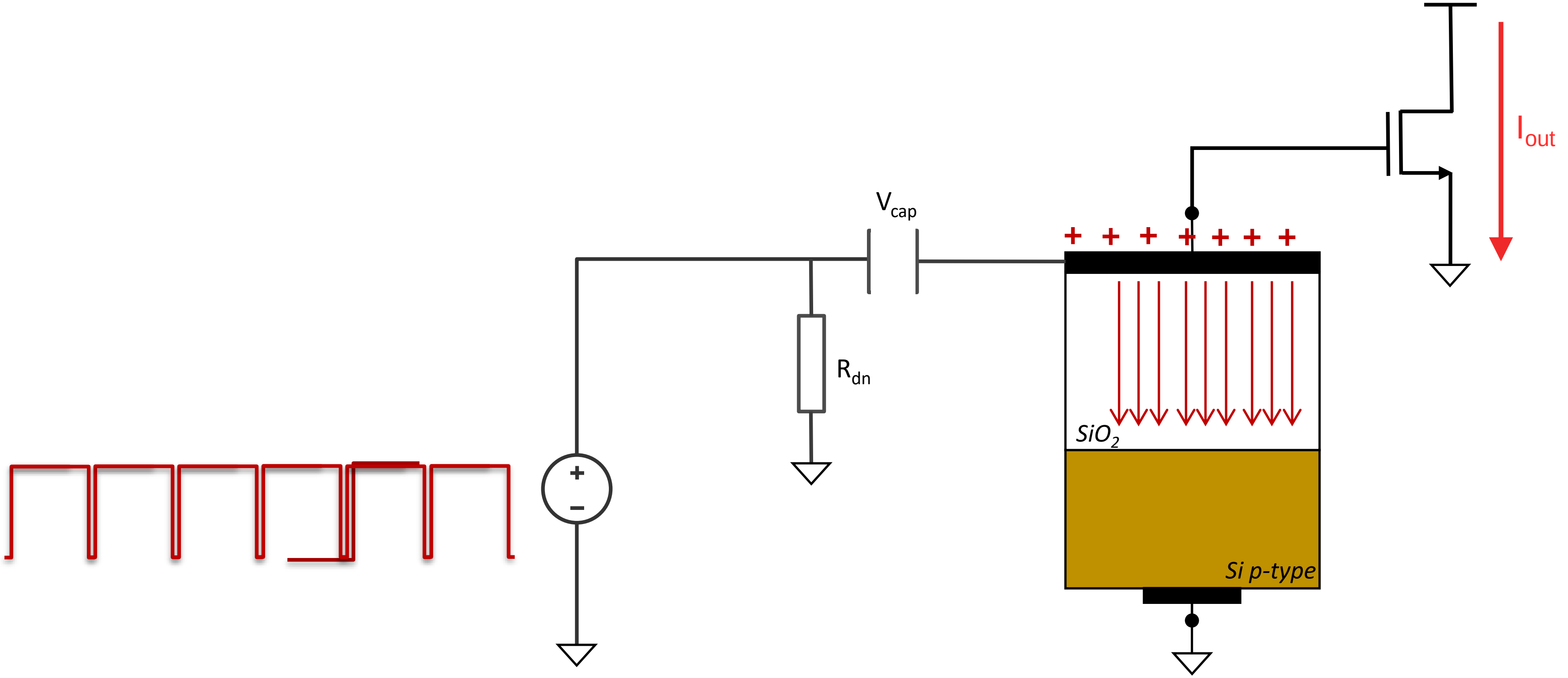
- **Higher sensitivity allows to characterize locations with low radiation levels in shorter time**

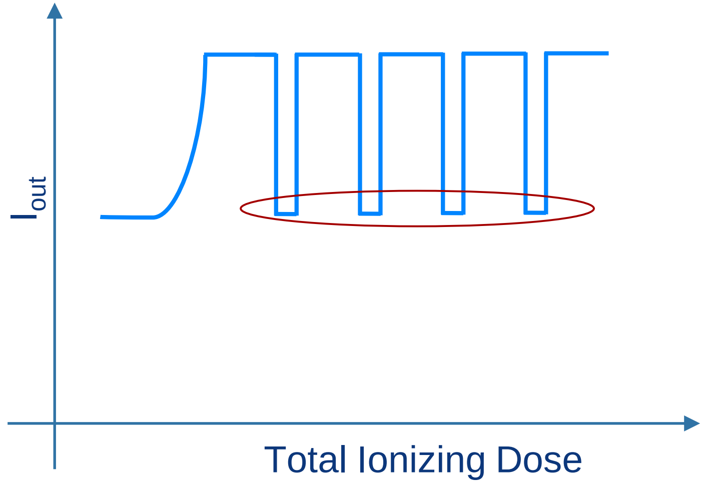
FGDOS Working principle

The radiation sensitive circuit consists in a transistor whose gate is overextended on the Field Oxide

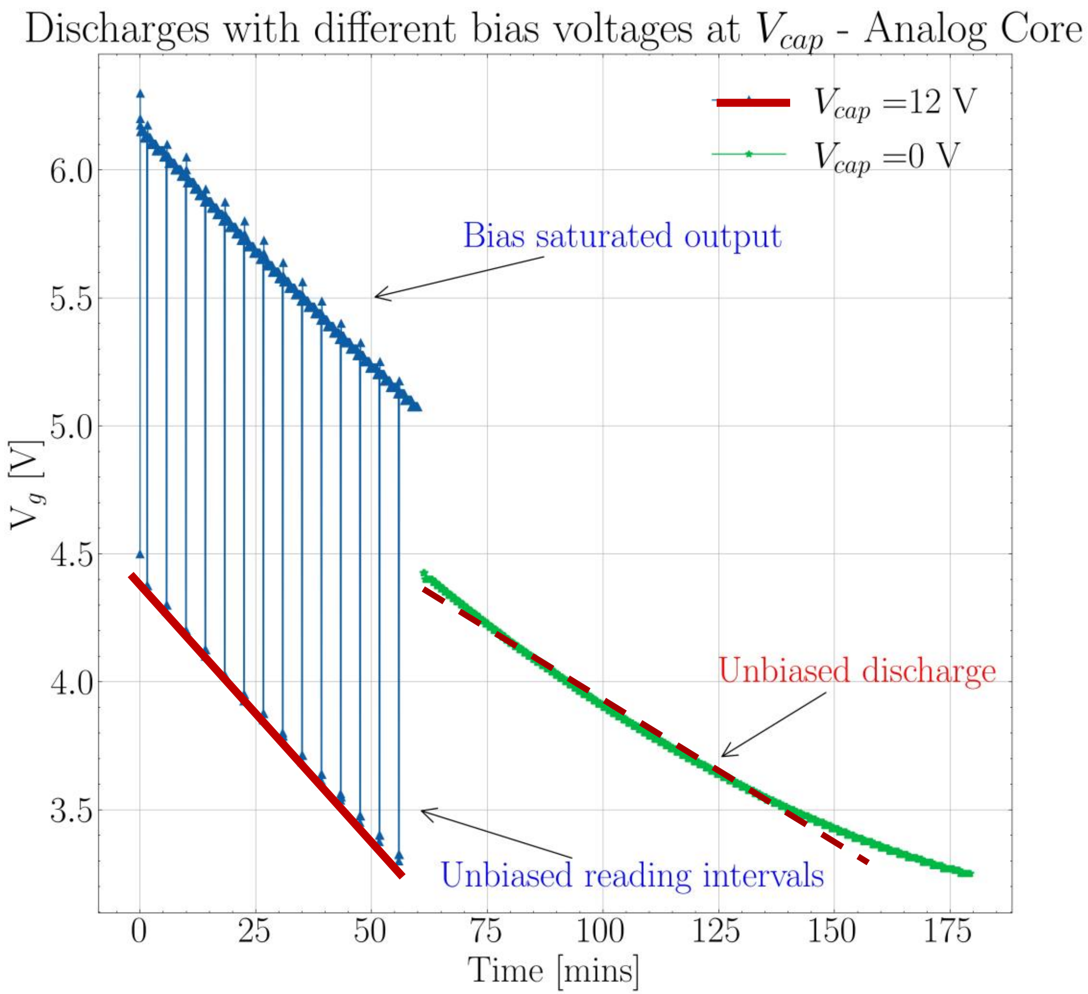


Enhancement Mode - Working Principle



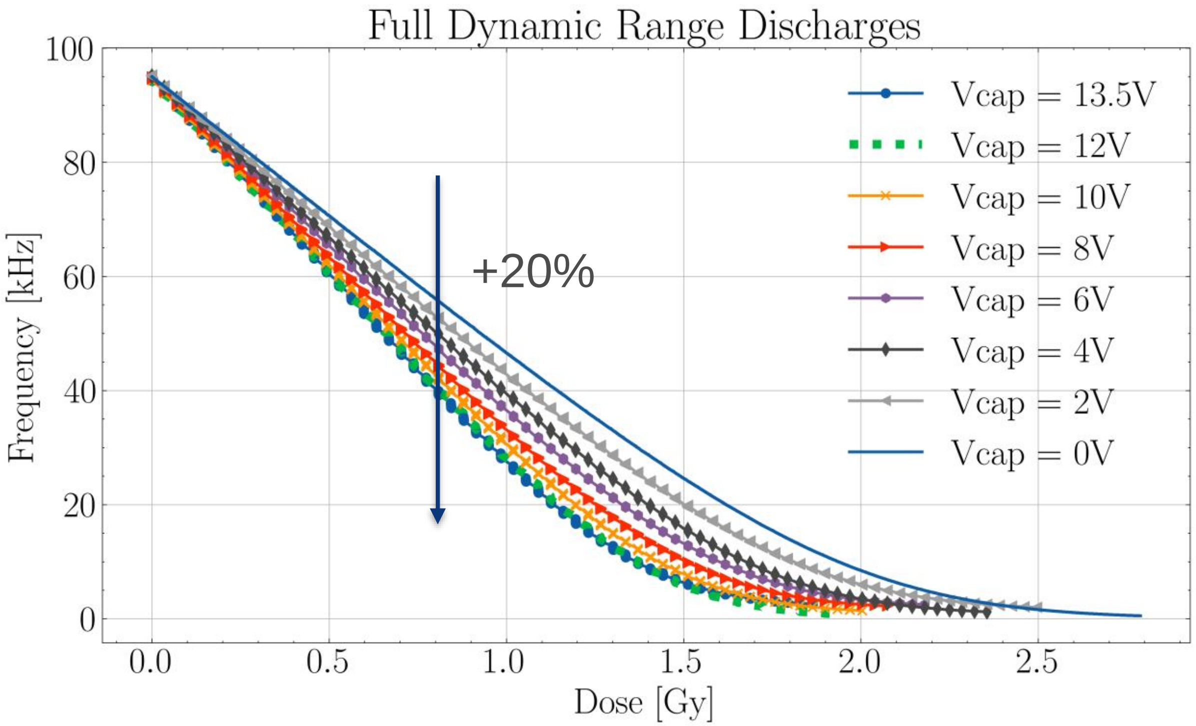


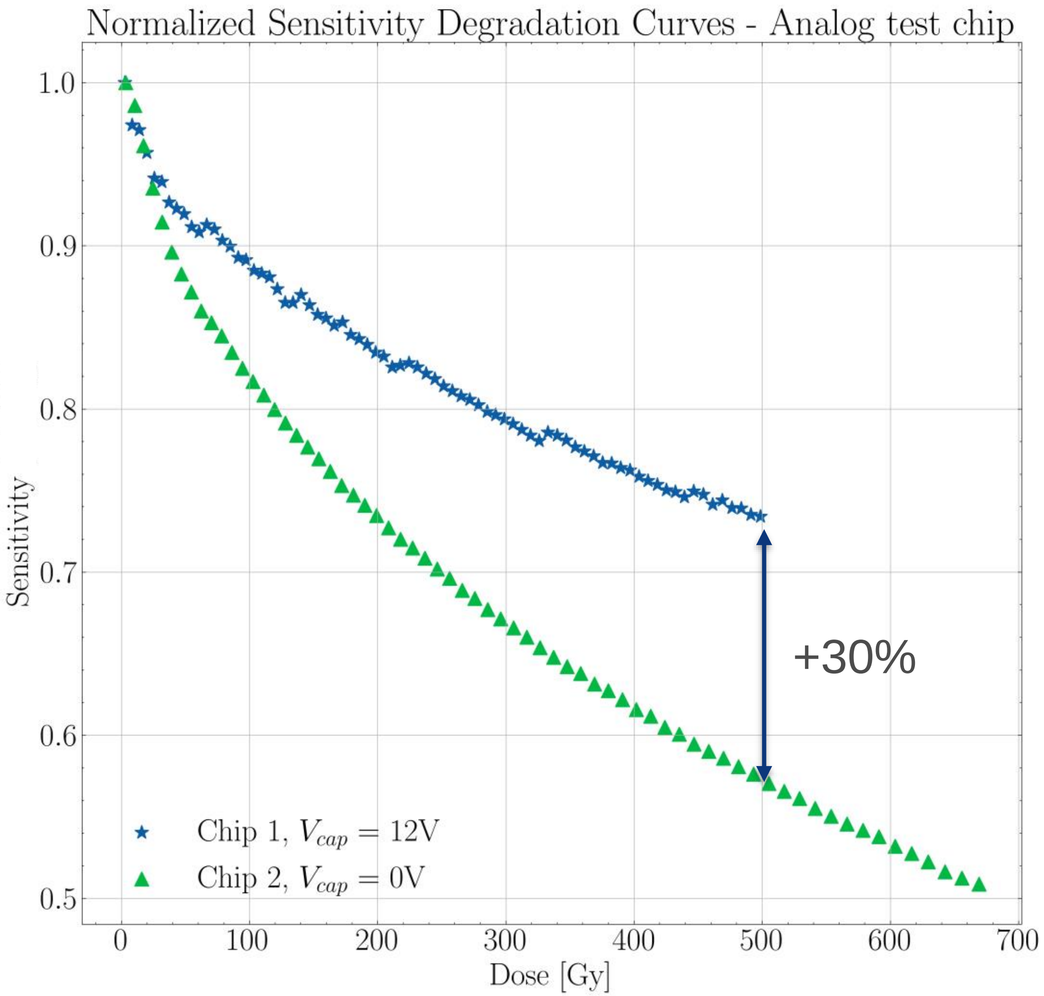
Enhancement Mode - Working Principle



Experimental Results

- The Sensitivity can be increased of 20%
- The larger V_{cap}, the larger the sensitivity increase
- The increase is stronger for larger TID
- This can be exploited for mitigate the sensitivity drift





Rizzo et al, submitted to IEEE TNS, 2021
Presented at RADECS 2021, Vienna

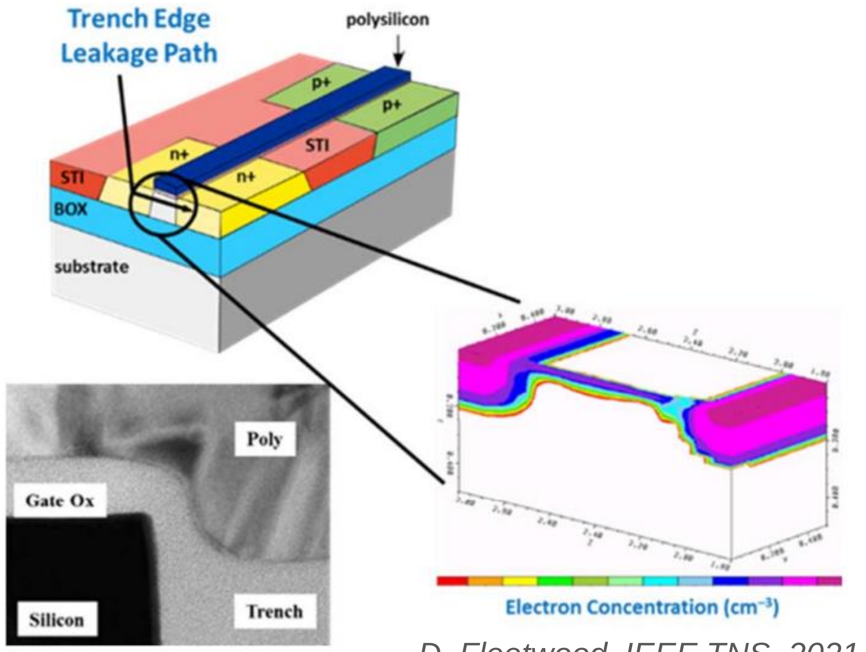
Charge Yield Measurements

Charge Yield Measurements - Motivation

- Radiation-induced charge build-up in STI, dielectric spacers and buried oxides is the main cause of TID-related ICs' degradation and failure for ***modern scaled technologies***
- Heavy Ions affect oxides by inducing SEGR and microdose effects
- Charge generated in dosimeters

- The ***charge yield*** is a crucial param … echanisms
- The charge yield has been estimate… n MOS capacitors :
  - Gate oxides as sensitive volume
  - Electric field > 1 MeV/cm

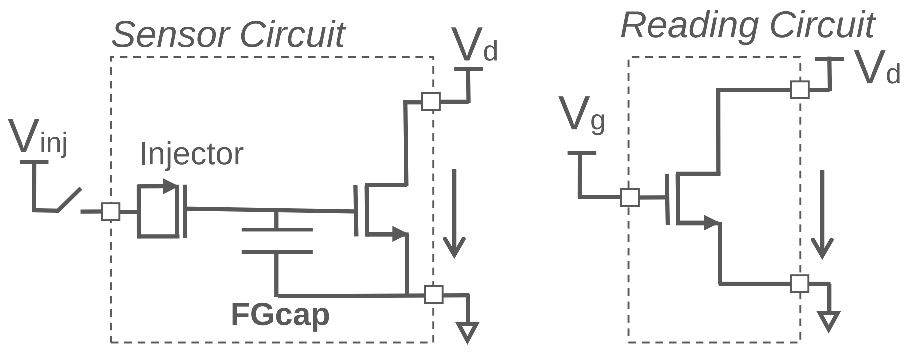
- In this work, the heavy-ion charge yi… ***er*** (FGDOS®)
  - Measure based on the electrons s…
  - Independent from oxide trapped c…
  - Low electric field (<0.1 MeV/cm)

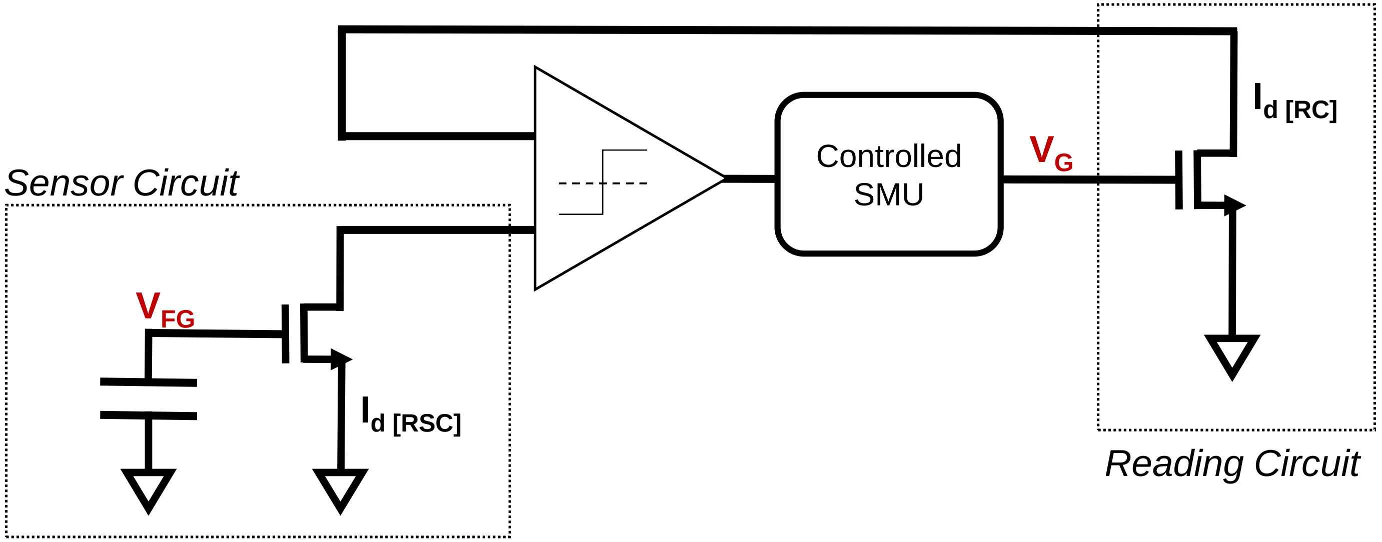


D. Fleetwood, IEEE TNS, 2021

Experimental Setup – Closed Loop Reading System

- A dedicated prototype was used for this study
- A closed loop system was designed to indirectly measure the floating gate voltage V_{FG}
  - V_G is modulated to minimize the difference between the two currents
  - The two (identical) transistors work in the same condition, thus their degradation will be identical

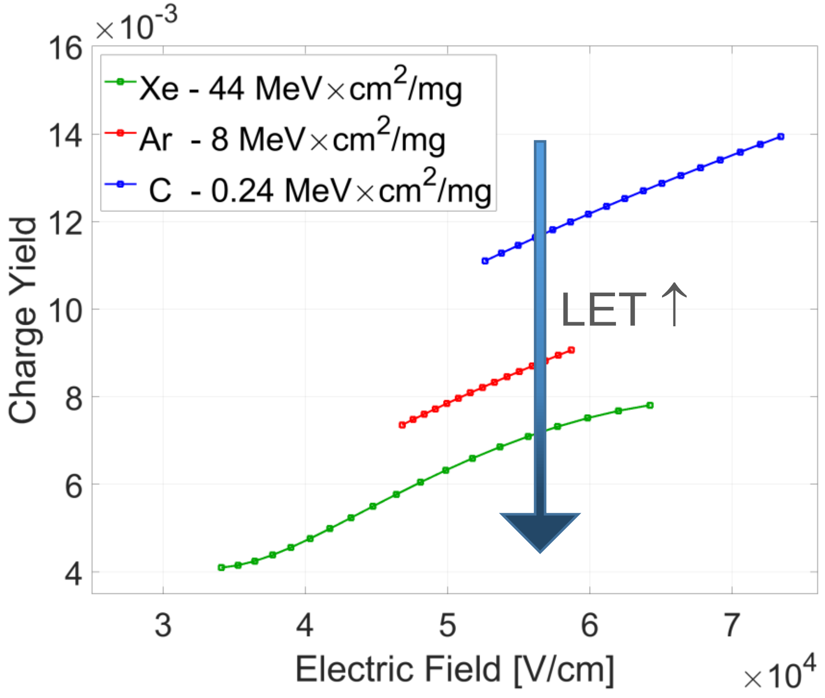




- The system makes the measurement immune to any change in the transistor characteristics:
  - Interface traps buildup
  - Oxide trapped charge
  - Temperature effect

Analysis and Discussion / Heavy Ion Charge Yield

- The Charge Yield can be calculated as: $CY = \Delta Q_{FG}/Q_{gen}$
- The ΔV_{FG} can be converted into collected charge as: $\Delta Q_{FG} = C \cdot \Delta V_{FG}$
- The generated charge can be estimated by: $Q_{gen} = q \cdot g_0 \cdot Vol \cdot D$

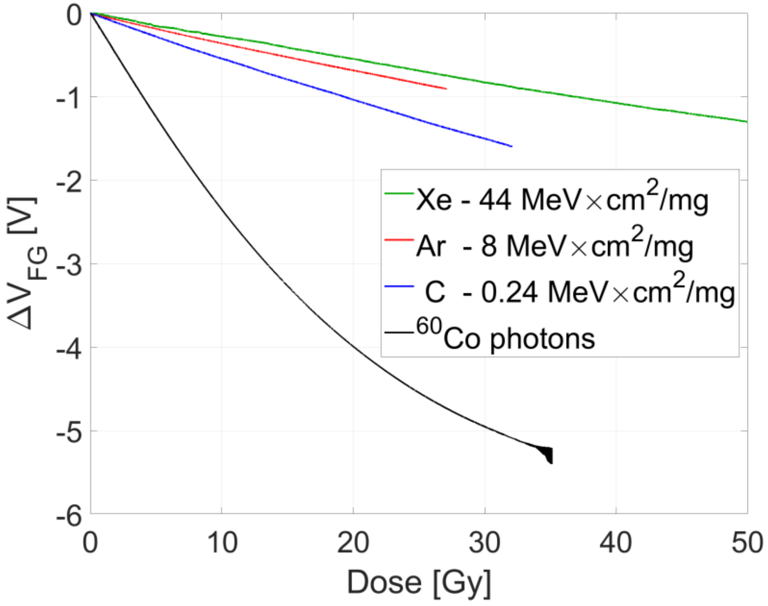


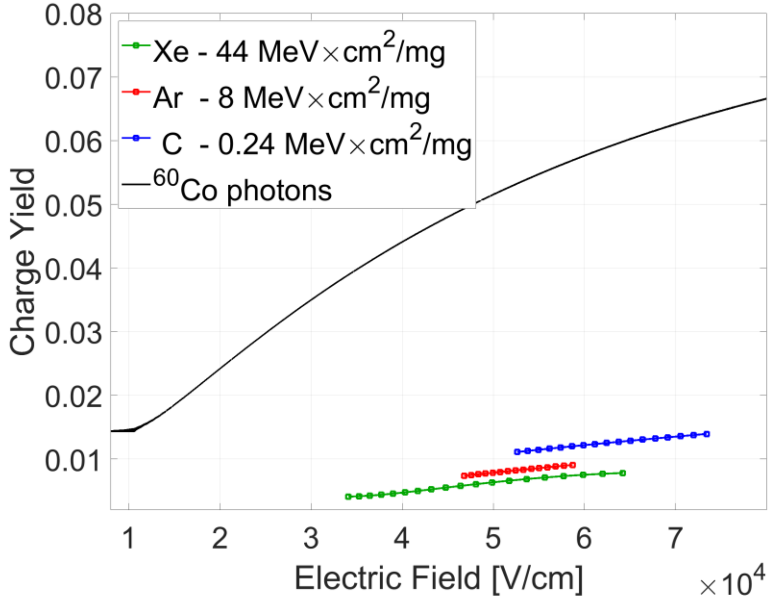
Atomic Element	LET in Si [MeV cm² / mg]	Charge Yield
^{132}Xe	44	$7.0 \cdot 10^{-3}$
^{40}Ar	8	$8.5 \cdot 10^{-3}$
^{12}C	0.24	$11.2 \cdot 10^{-3}$

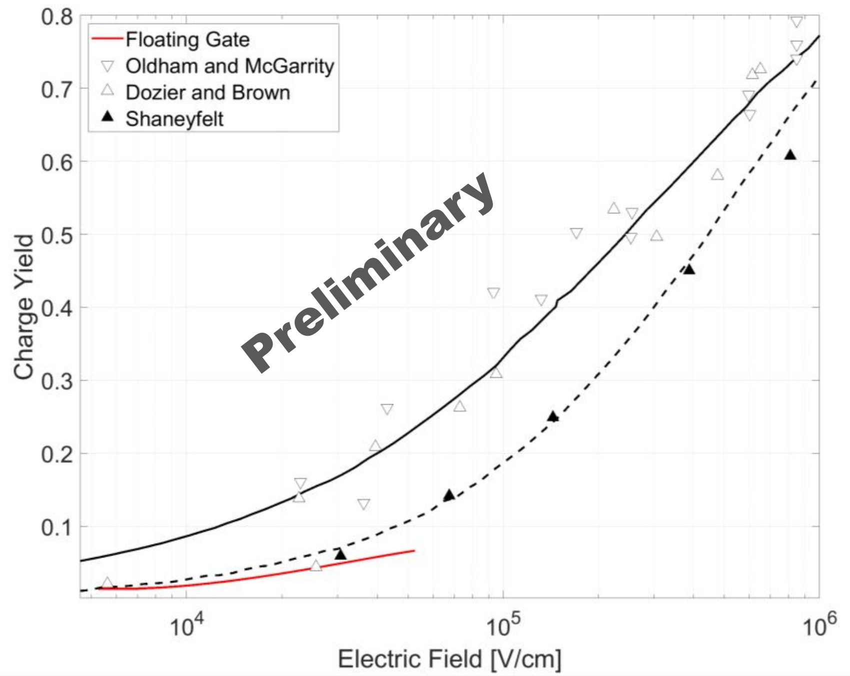
- The Charge Yield monotonically increases with the electric field as a results of a lower recombination rate

Analysis and Discussion / ^{60}Co photons vs Heavy Ions

- The same setup was exposed to ^{60}Co γ-rays at the Cern Coblat-60 facility







- The ^{60}Co charge yield results significantly higher than Heavy Ion ones
  → Geminate vs Columnar recombination

Brucoli et al, submitted to IEEE TNS, 2021
Presented at RADECS 2021, Vienna

Summary

- FGDOS Applications
  - SPS measurements, Space RadMon, International Space Station
- Sensitivity Enhancement
  - Sensitivity increase up to 20%
  - Sensitivity drift mitigation
  - Inputs for future design
- Charge yield Measurements
  - Reference measure
  - Sensor design improvement and analytic model

Thank you for your attention!