

RD50

Irradiation of gate-controlled diodes and MOS capacitors with ^{60}Co -gamma photons

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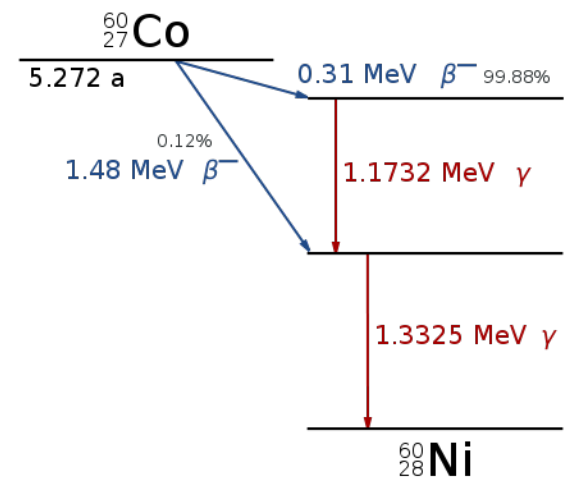
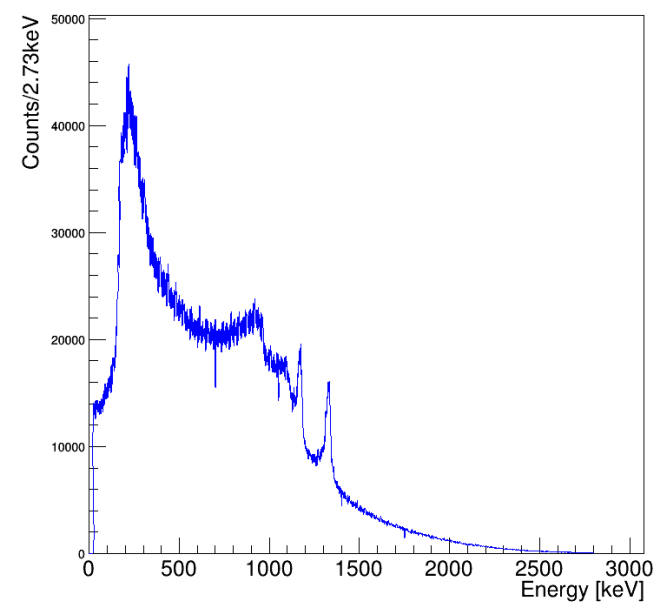
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We performed irradiations at the secondary standard ionizing radiation laboratory of the **Greek Atomic Energy Commission (GAEC)**, accredited according to ISO 17025 among others in calibration in the field of radiotherapy, and the relevant CMCs (calibration and measurement capabilities) are published in the BIPM database (<https://www.bipm.org/en/about-us/>).

**^{60}Co source: Picker therapy unit 30 TBq (March 2012)
horizontal orientation (~9.86 TBq in August 2020)**

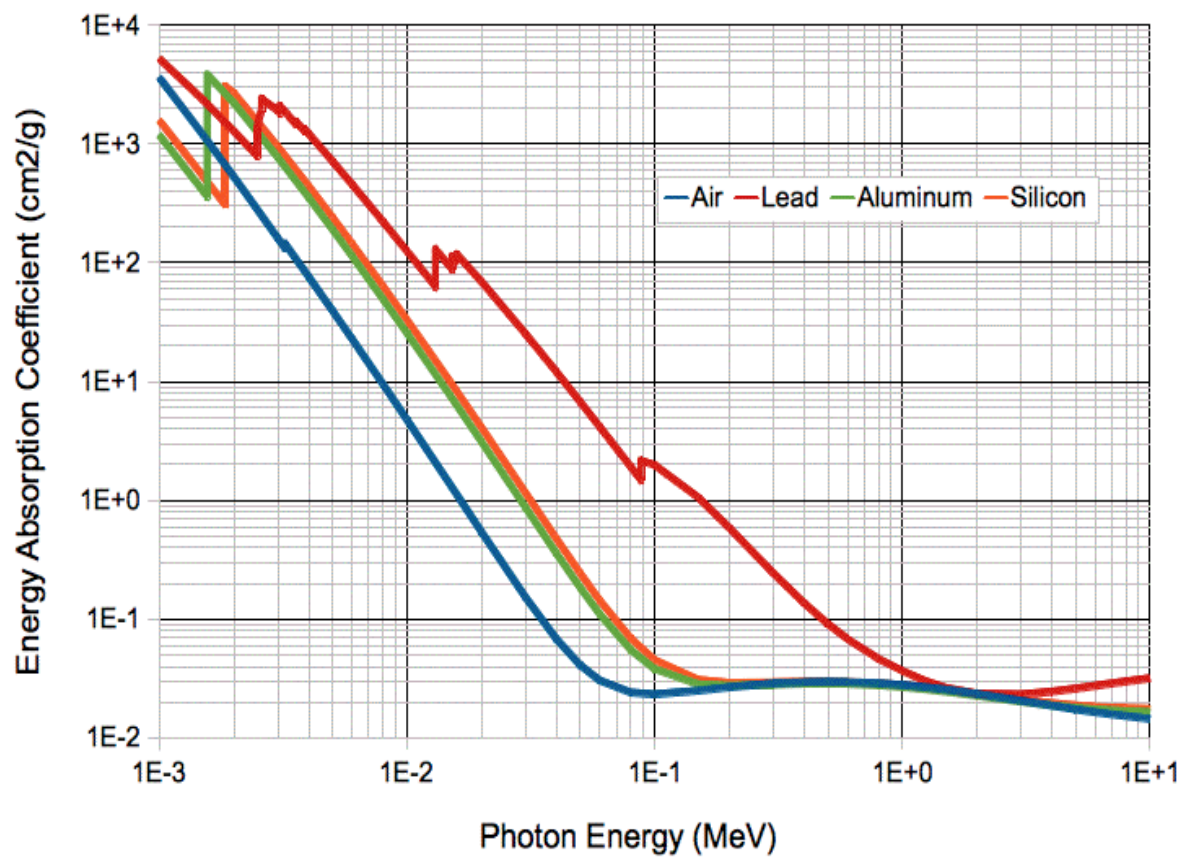


^{60}Co Spectrum





μ/ρ [cm²/g] vs. Energy



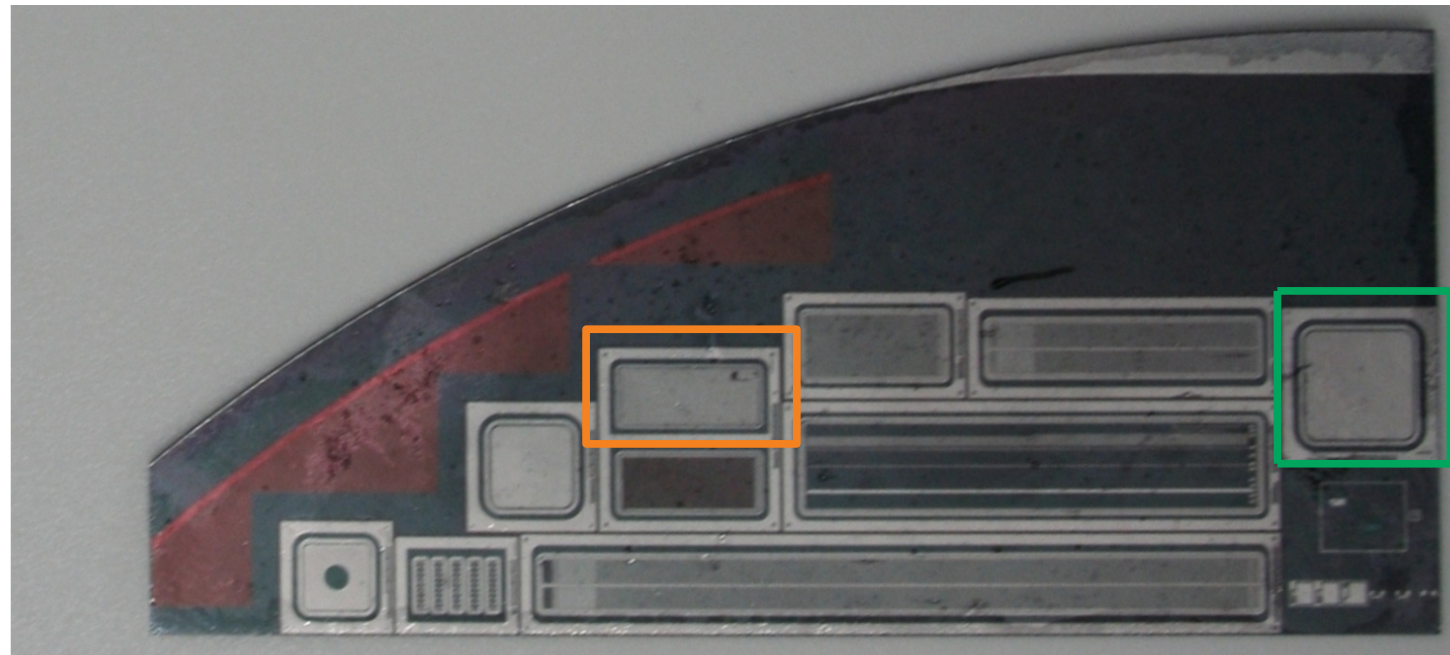
For γ -rays of energy 200 keV to 2 MeV, converting from Gray in Air to Gray in Silicon is easy: we multiply by 1.0.

<https://www.nist.gov/pml/x-ray-mass-attenuation-coefficients>

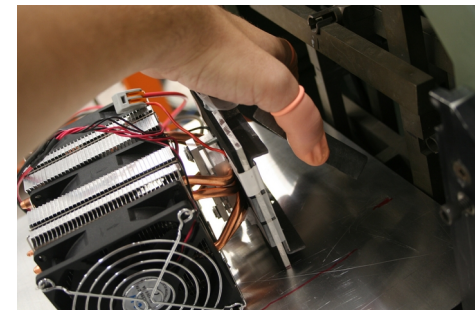
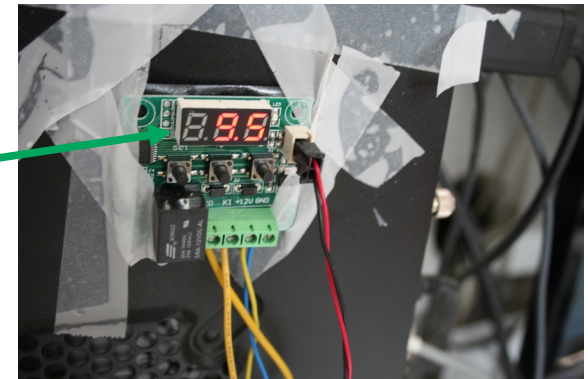
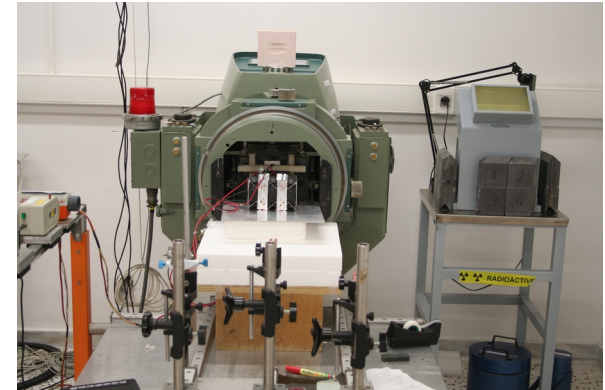


Float zone oxygenated silicon n-in-p test structures: Thinned 240 μm ;
produced by Hamamatsu Photonics K.K.

The irradiated sample contains among others: **GCD**
(with metal gate), **MOS Rectangular**



- Calculated dose rate (in air) at irradiation point (40 cm from the source): ~ 0.96 kGy/h using FC65-P Ionization Chambers from IBA Dosimetry.
- <https://www.iba-dosimetry.com/product/fc65-g-fc65-p-ionization-chambers/>
- Peltier element/thermoelectric cooler with glue protection to withstand radiation, fan, microcontroller for stabilization of temperature, power Supplies.
- Charged particle equilibrium (CPE) \rightarrow box of 2 mm-thick Pb and 0.8 mm of inner lining Al sheet \rightarrow lead-aluminum container for absorption of low energy photons and secondary electrons (ESCC Basic Specification No. 22900)





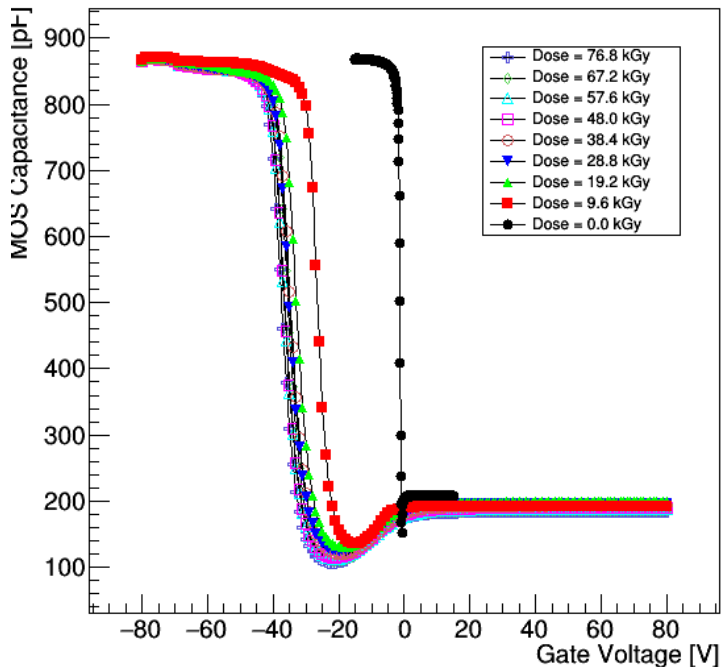
Irradiation Protocol

- Irradiation procedure was split in slots of **8-10 hours** of irradiation
- During irradiation temperature kept at **$(10.0 \pm 0.5) ^\circ\text{C}$**
- After every irradiation slot:
 - **Annealing** in the climate test chamber at **80 °C** for **10 min**
 - **Electrical tests** after annealing performed using our experimental setup
 - **Electrical measurements:**
 - **1) Oscillation level = 250 mV**
 - **2) Frequency = 10 kHz**
 - **3) Waiting time = 0.5 s**
 - **4) Diode voltage on GCD: varying**
- Between irradiation slots: samples stored in freezer at **-28 °C**

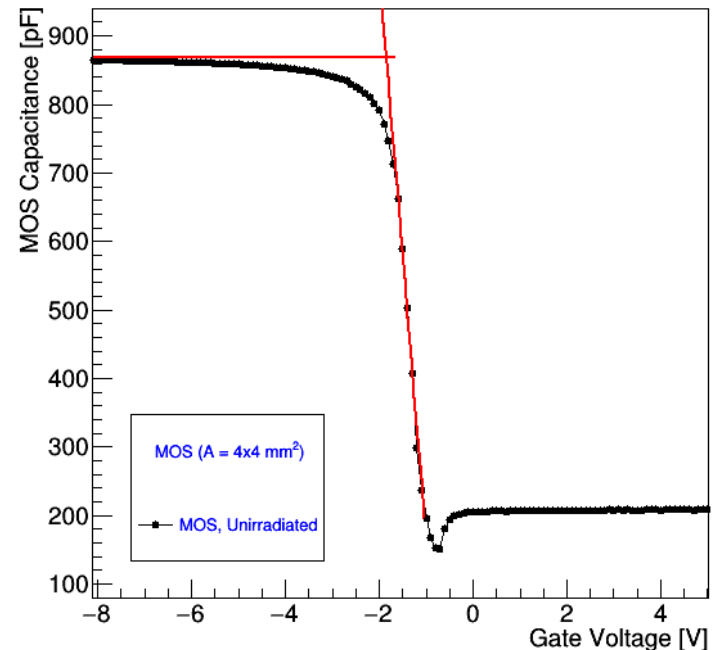


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- Clear evidence of **positive charge** induced in the oxide of the **MOS structures** after **exposure to γ photons**
- Initial shift of the **flat band voltage (V_{fb})**, i.e. the voltage where the MOS behavior changes from accumulation to depletion, to higher absolute values



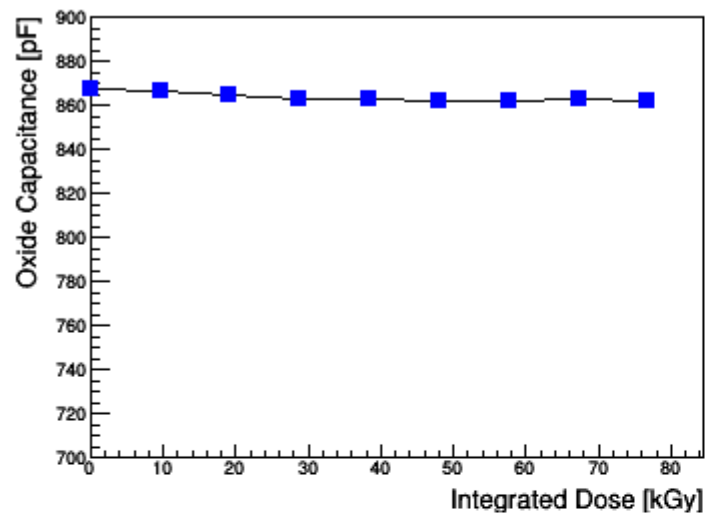
MOS (f = 10 kHz): Capacitance vs. Voltage



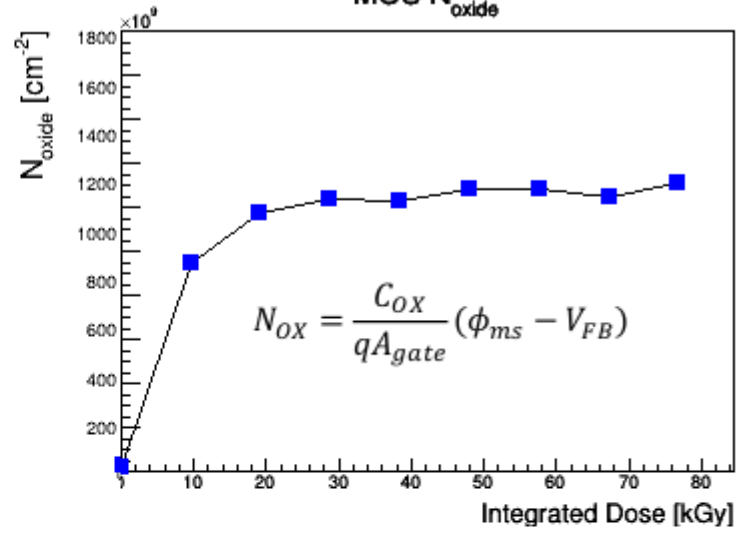


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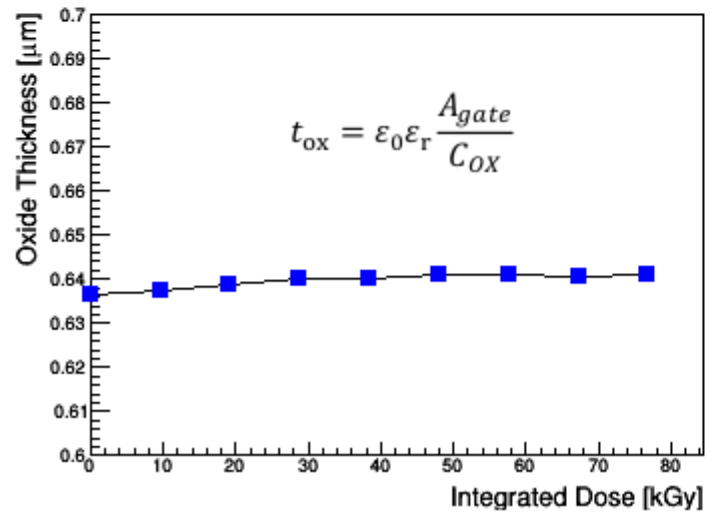
MOS Oxide Capacitance



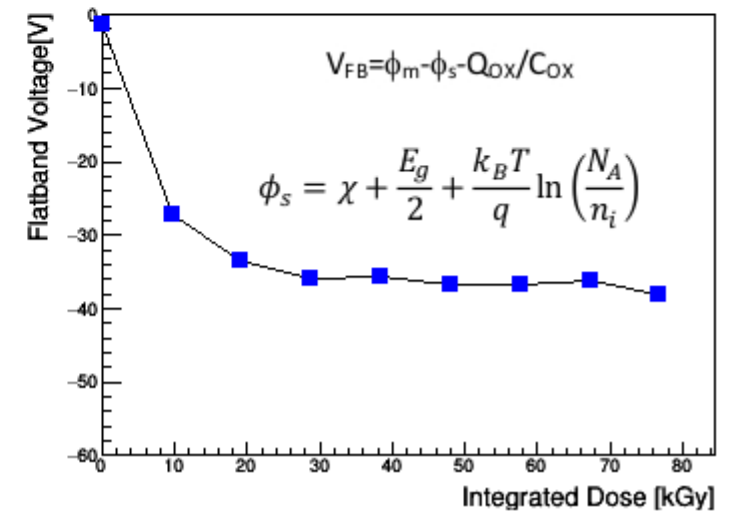
MOS N_{oxide}



MOS Oxide Thickness



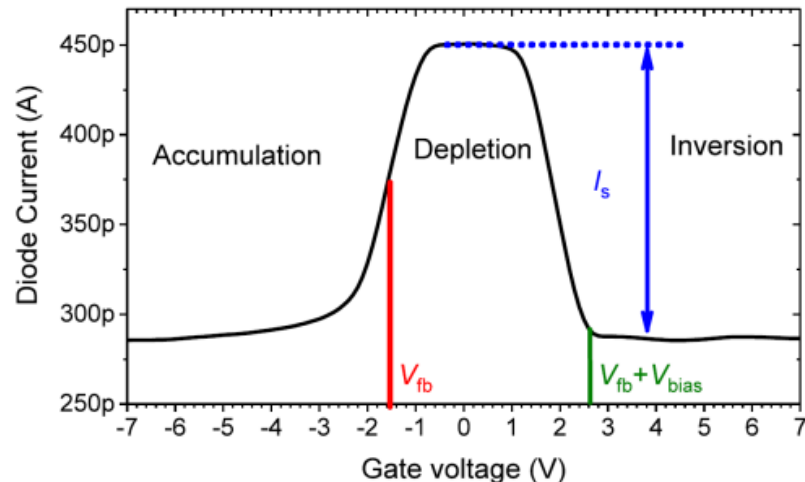
MOS Flatband Voltage





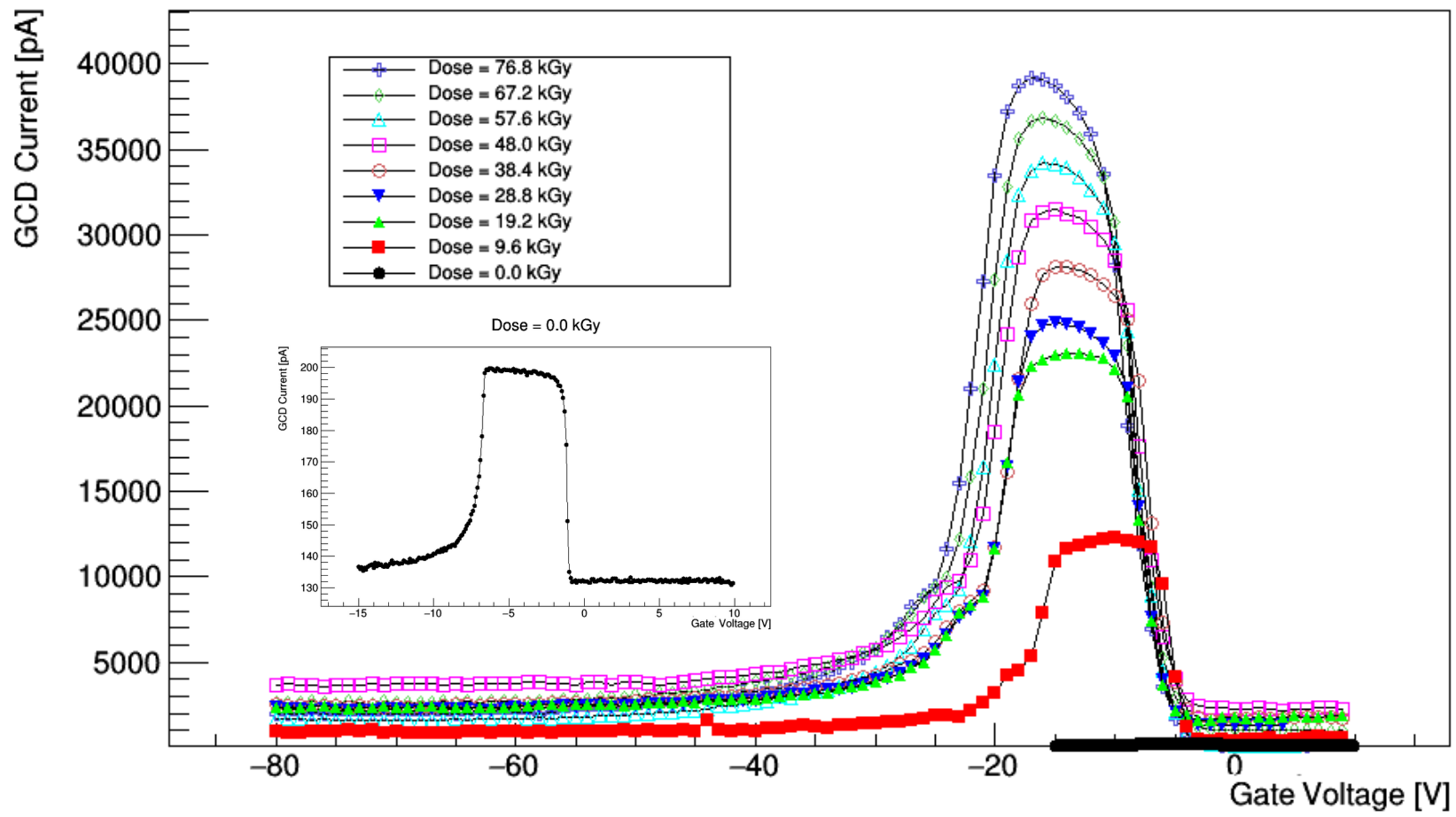
Gate-controlled diodes

- Increase of diode total current with irradiation dose due to surface current component
- Flatband voltage almost stable after initial irradiation; surface generation velocity (s_0) and surface current (I_s) increase with total irradiation dose
- Small absolute values of bias voltage optimal for GCD control



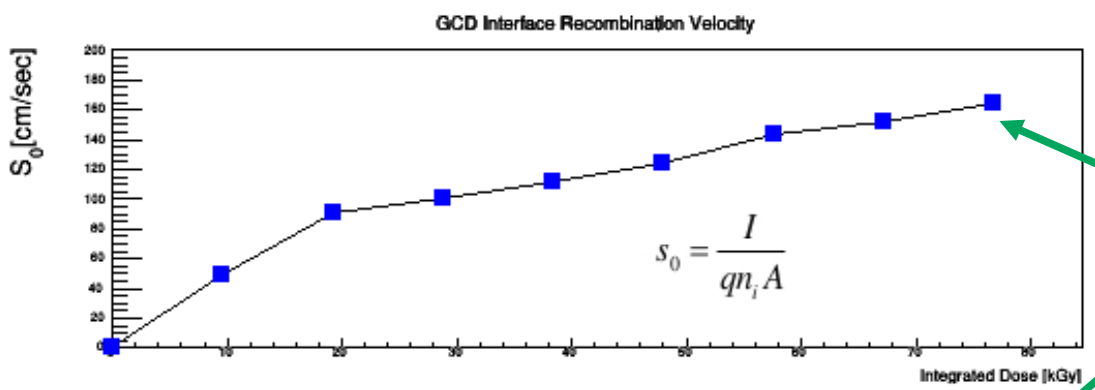
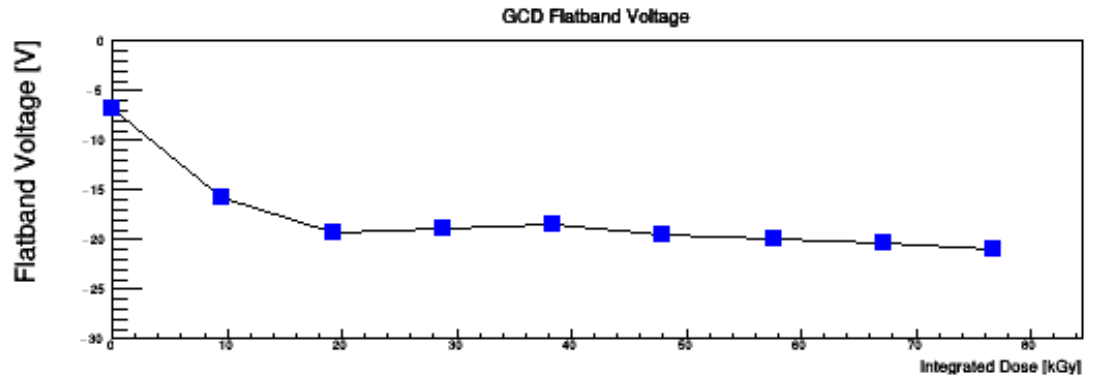


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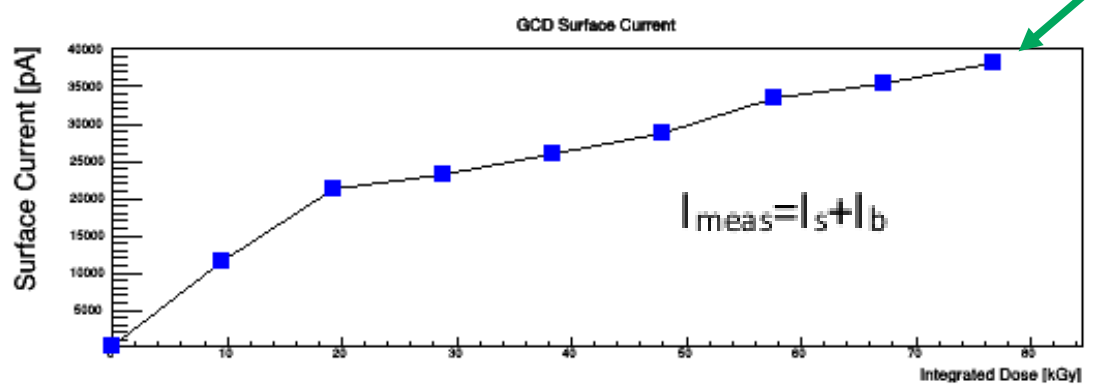




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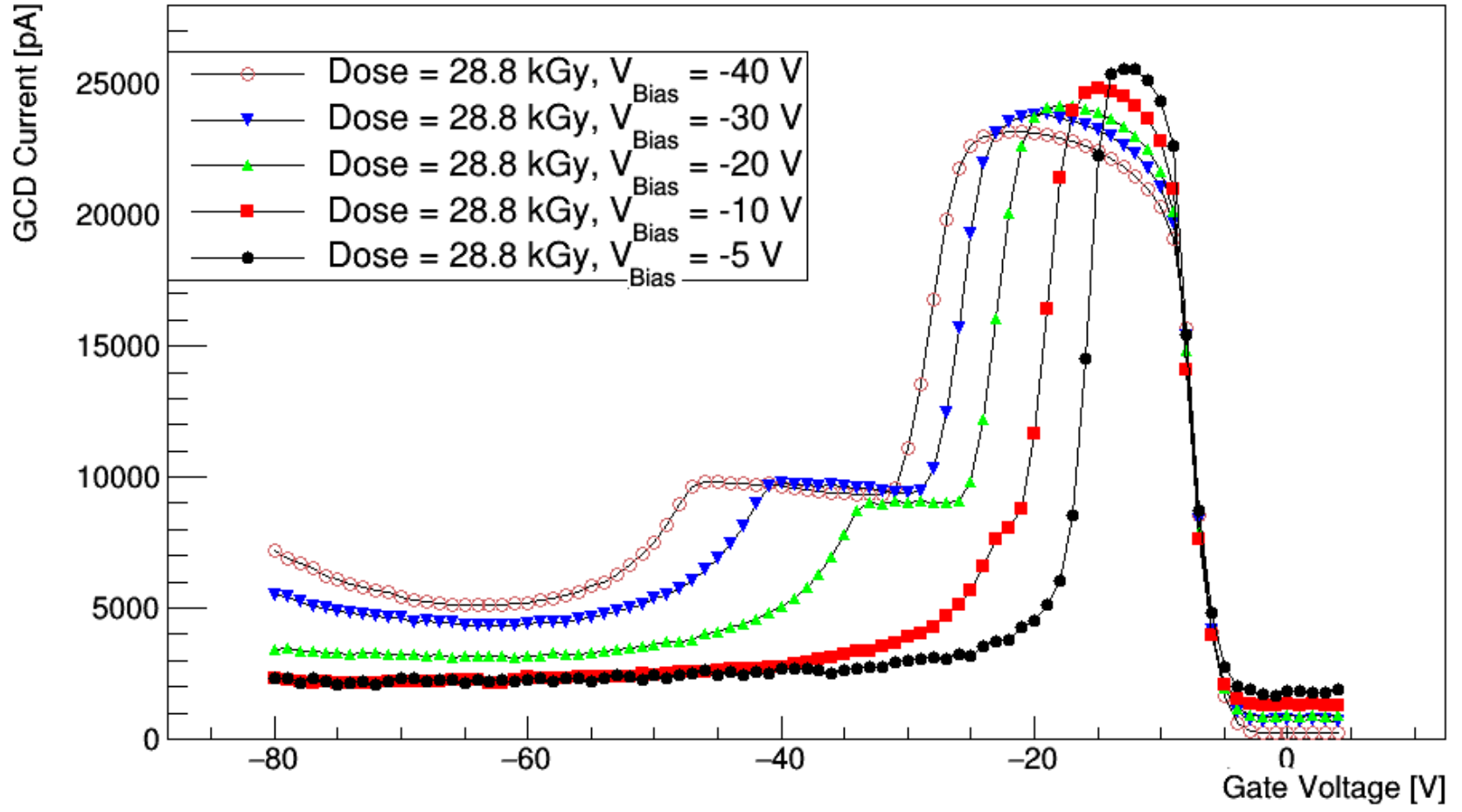


It only increases up to our final dose





Dose = 28.8 kGy





Summary

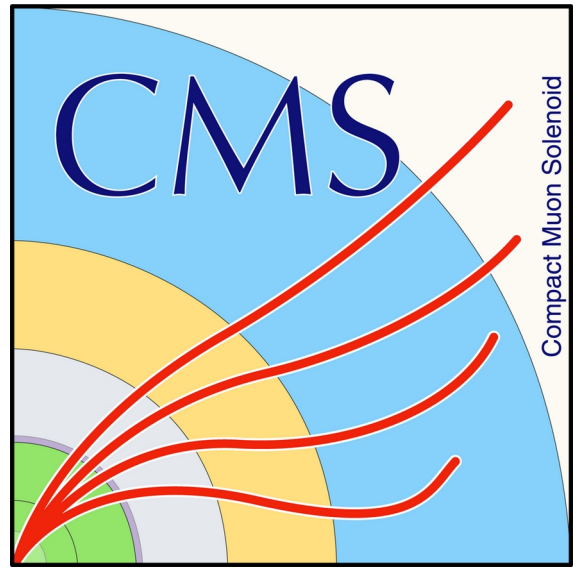
- Silicon MOS capacitor & GCD irradiated by ^{60}Co γ ; doses up to 76.8 kGy
- MOS capacitor: initial shift of V_{fb} to higher absolute values and increase of N_{oxide}
- GCD: Even at the highest achieved total irradiation dose, GCD current < 50 nA \rightarrow suitability of the device for high-luminosity applications
- Irradiation results consistent with other studies*

■ *F. Moscatelli et al., Analysis of surface radiation damage effects at HL-LHC fluences: Comparison of different technology options, Nucl.Instrum.Meth.A 924 (2019) 198-202.



Acknowledgments

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