Study of RADFET Sensitivity – Dependency on Proton Energy

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Outline:

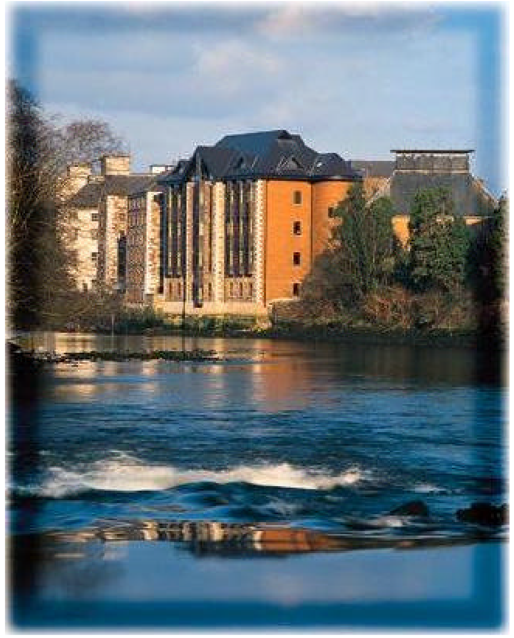
- Where do I come from?
- What is RADFET and how does it work?
- Last ESA sponsored RADFET contract (overview)
- RADFET pre-irradiation characterisation
- Co-60 irradiation results
- Proton irradiation results
- Electron and X-ray irradiation results
- Future work

Where do I come from?

Ireland

Cork

NMRC



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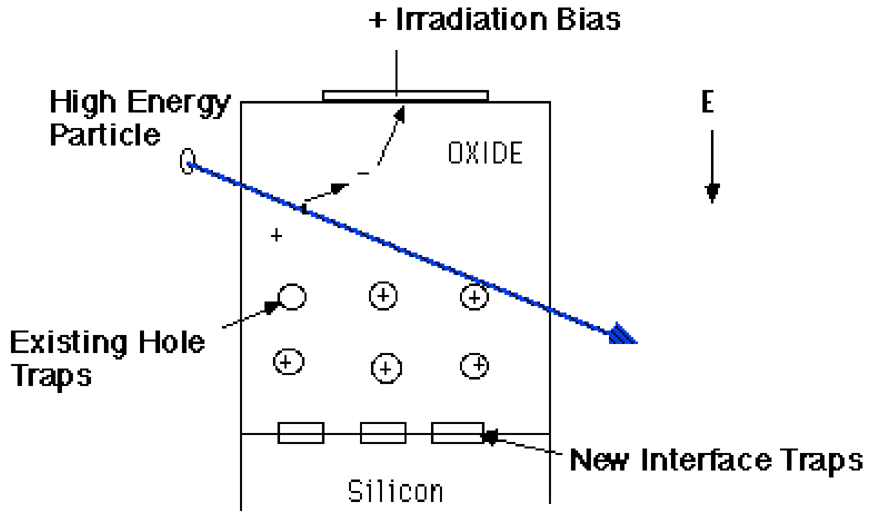
RADFET operating principle:

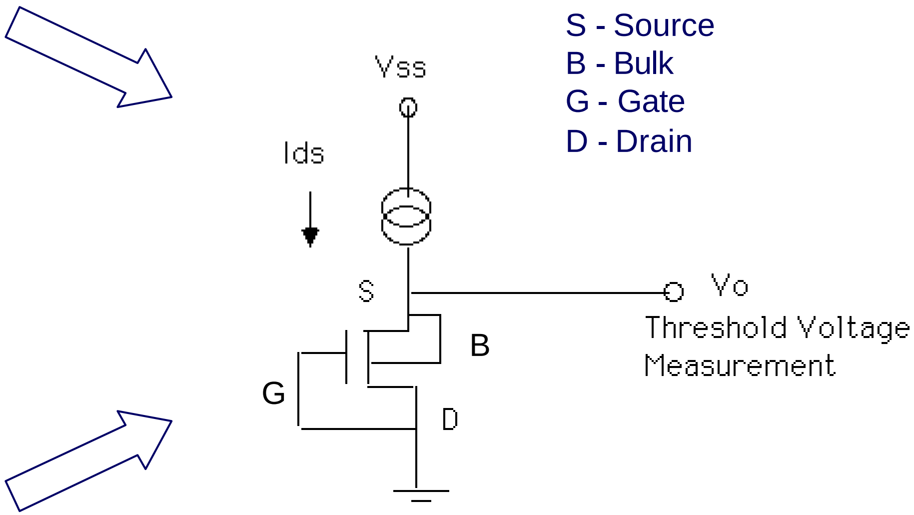


- Radiation creates electron-hole pairs
- Initial recombination of electrons and holes happens
- Non-recombined electrons leave the oxide;
  holes are trapped in the vicinity of the oxide/silicon interface
- RADFET threshold voltage (V_T) changes (ΔV_T ~ Dose)

RADFET biasing configurations:

- Irradiation (sense mode): zero current; (B, S and D grounded); G can be:
  - Grounded ($V_{IRR}=V_{GS}=0V$)
  - Biased (typically $V_{IRR}=V_{GS}>0$)

  Read-out mode: specified current applied to S=B; G=D grounded



- Irradiation (sense mode) and Read-out mode are the same

RADFET advantages over other dosimeters:

- Immediate read-out without destroying the data
- Extremely small sensor chip
- Very low or zero power consumption
- Technology suitable for connection to a microprocessor
- Low cost (especially of a reader device)

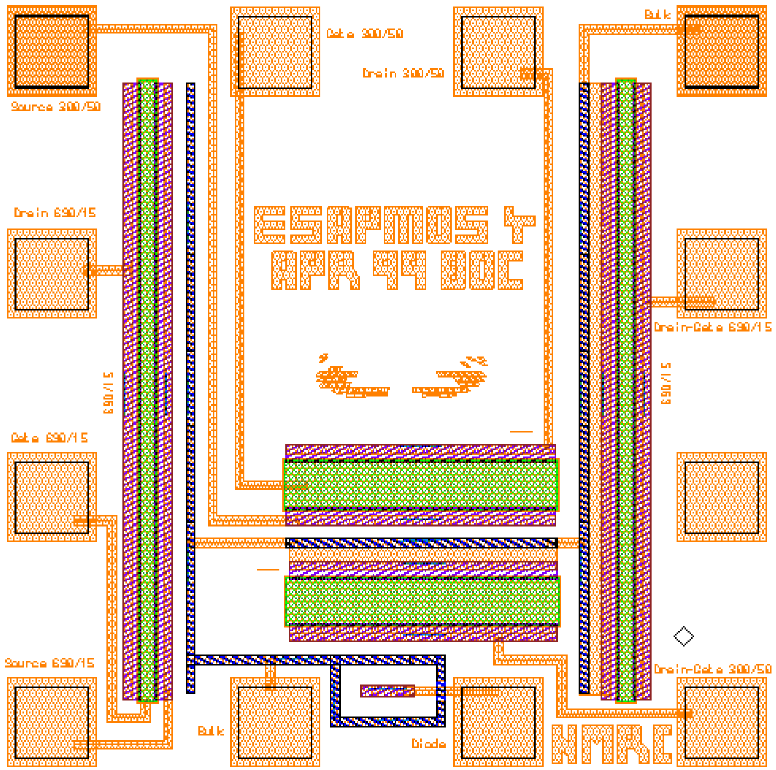
Applications:

- Nuclear industry and research
- Space dosimetry
- Radiotherapy
- Personal dosimetry [?]

Last ESA sponsored RADFET contract:

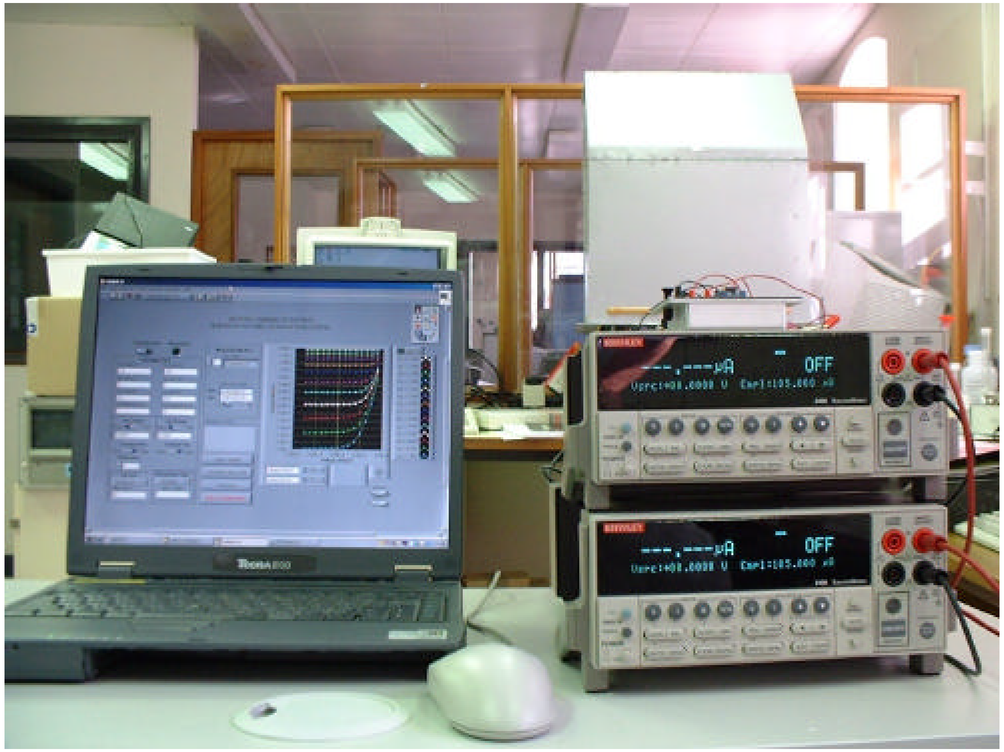
- Part of the ESTEC Frame Contract with NMRC
- Contract No.:10582/93/NL/PB; COO No.: 46
- Start date: May 2002
- Duration: one year
- Description of work (work-packages):
  - Pre-irradiation and Co-60 characterisation
  - Passivation layer introduction
  - Energetic particle response

ESAPMOS4 RADFET chip:



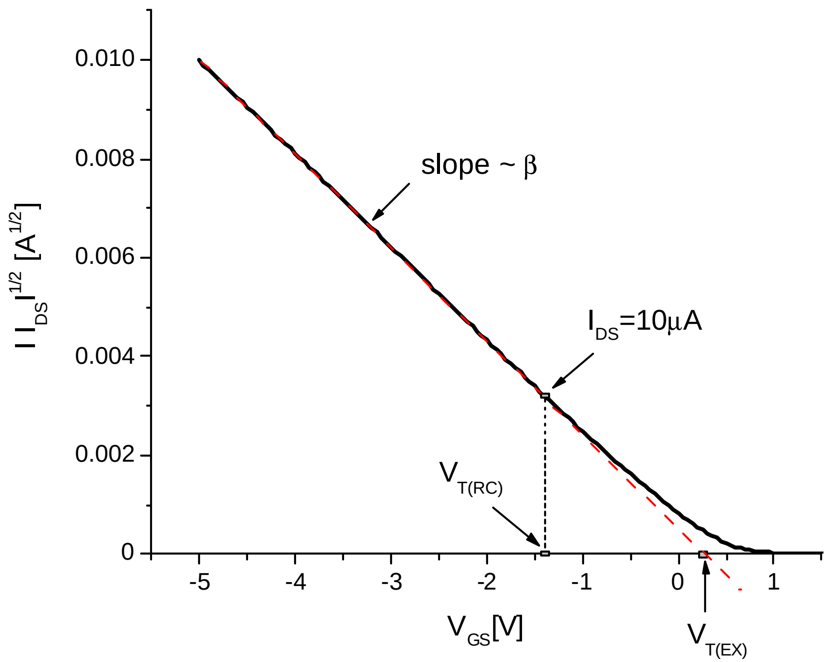
- Chip size: 1mm x 1mm
- Contains four RADFETs:
  - two 300/50 devices
  - two 690/15 devices
- Chip types (gate oxide):
  - 100 nm
  - 400 nm
  - 400 nm Implanted (IMPL)
  - 1 µm
  - 1 µm Implanted (IMPL)

2400 SourceMeter system:

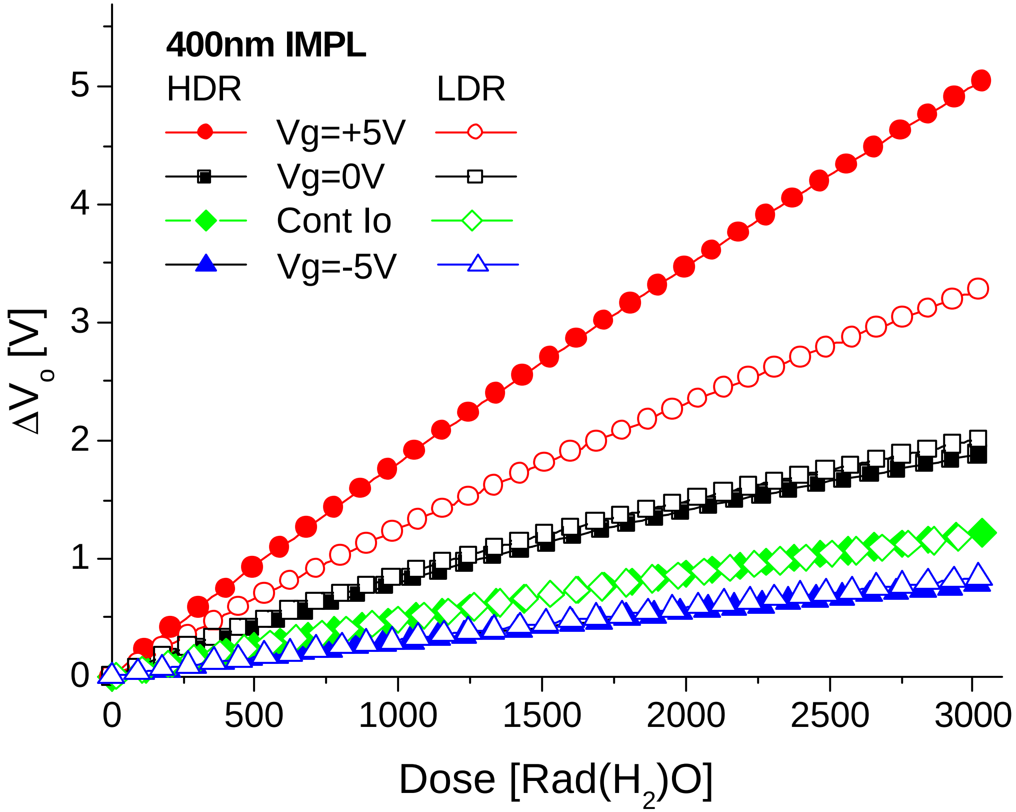


Passivated vs. unpassivated RADFETs:

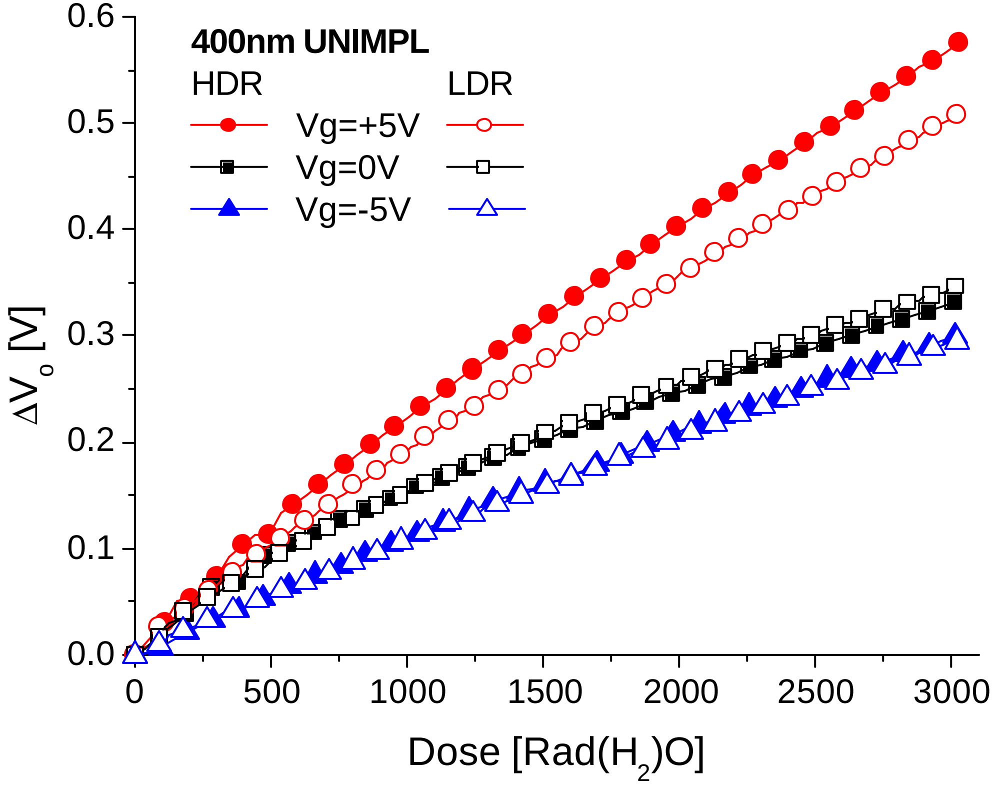
Device type	$V_{T(RC)}$ @ 10mA [V]	$V_{T(EX)}$ [V]	b [´ 10^{-6} A/V^2]	SS [mV/decade]
300/50 standard	-1.524 ± 0.124	0.193 ± 0.111	6.947 ± 0.127	263 ± 8
300/50 passivated	-1.630 ± 0.097	0.092 ± 0.105	6.986 ± 0.167	254 ± 9
690/15 standard	-0.201 ± 0.084	0.293 ± 0.072	75.370 ± 1.288	228 ± 5
690/15 passivated	-0.330 ± 0.067	0.148 ± 0.064	78.130 ± 1.956	225 ± 6



Co-60 irradiation (400nm IMPL):



Co-60 irradiation (400nm UNIMPL):



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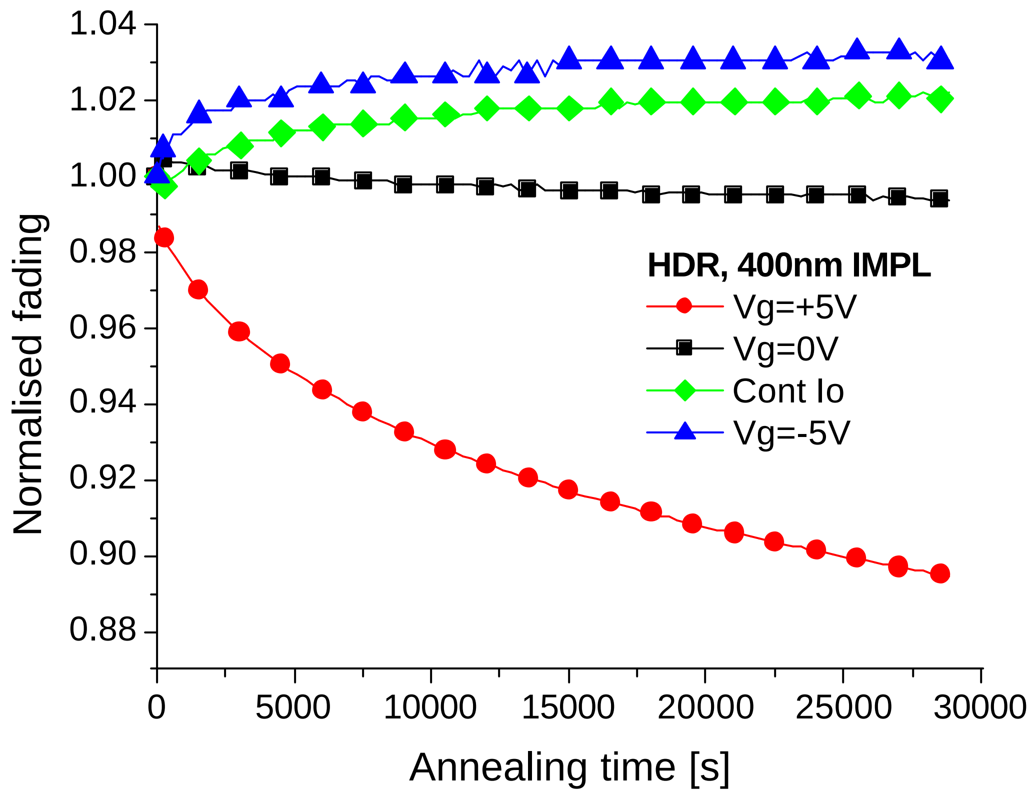
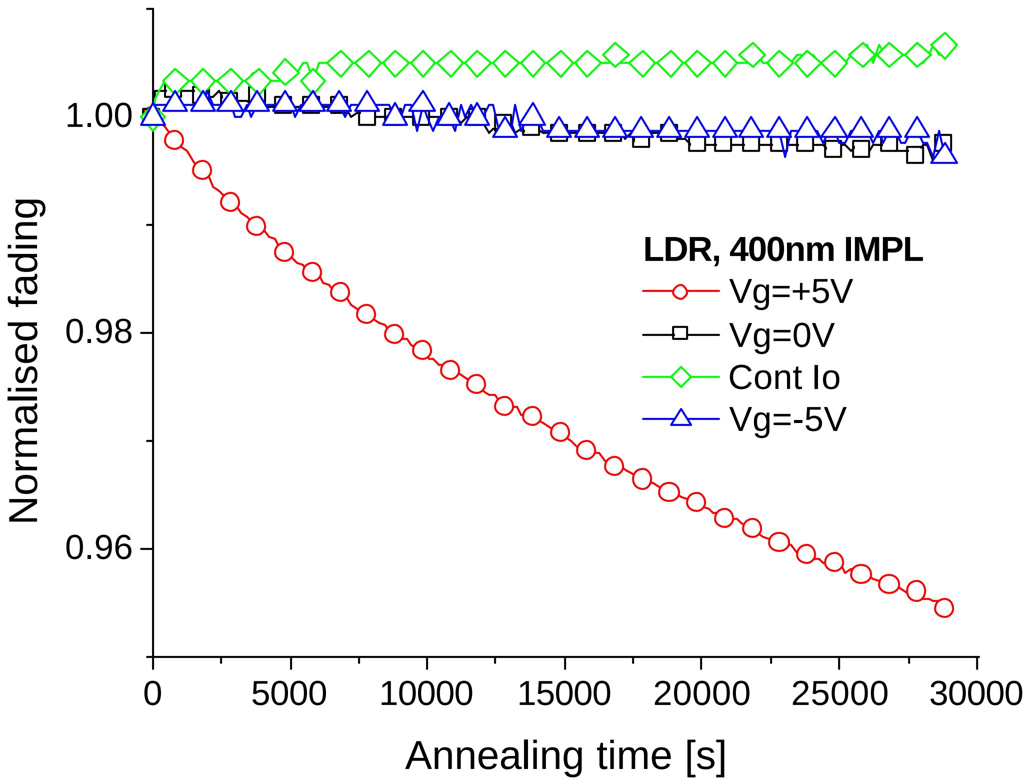
400nm IMPL annealing (HDR):



400nm IMPL annealing (LDR):



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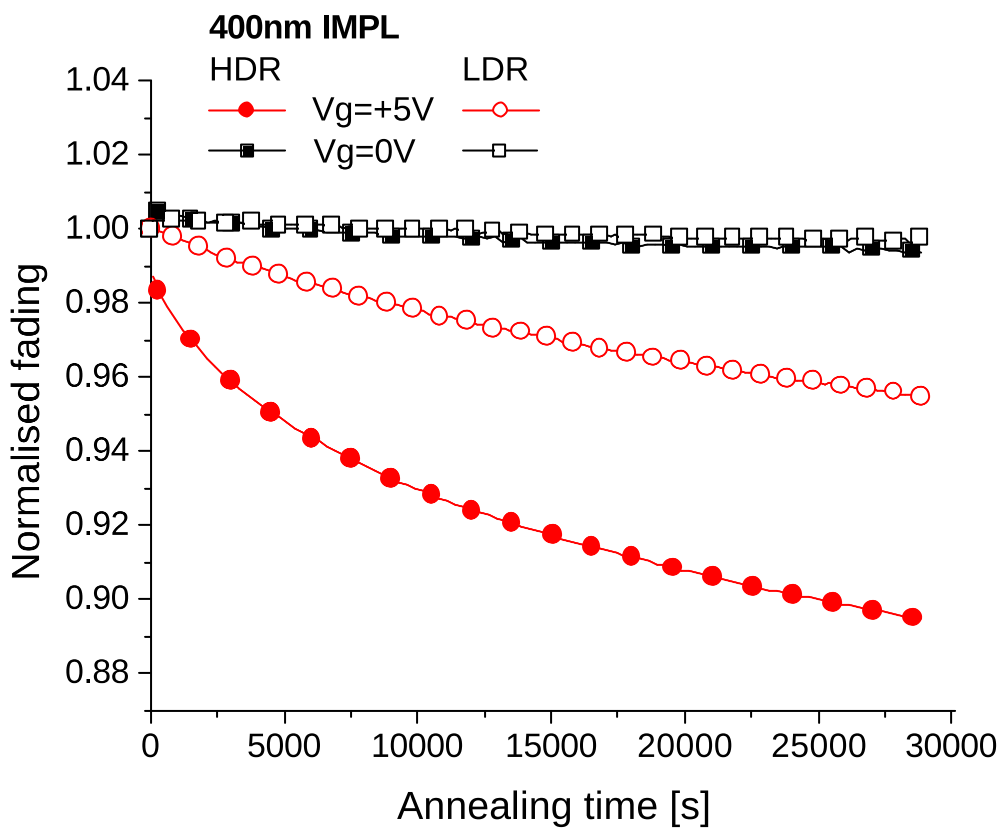
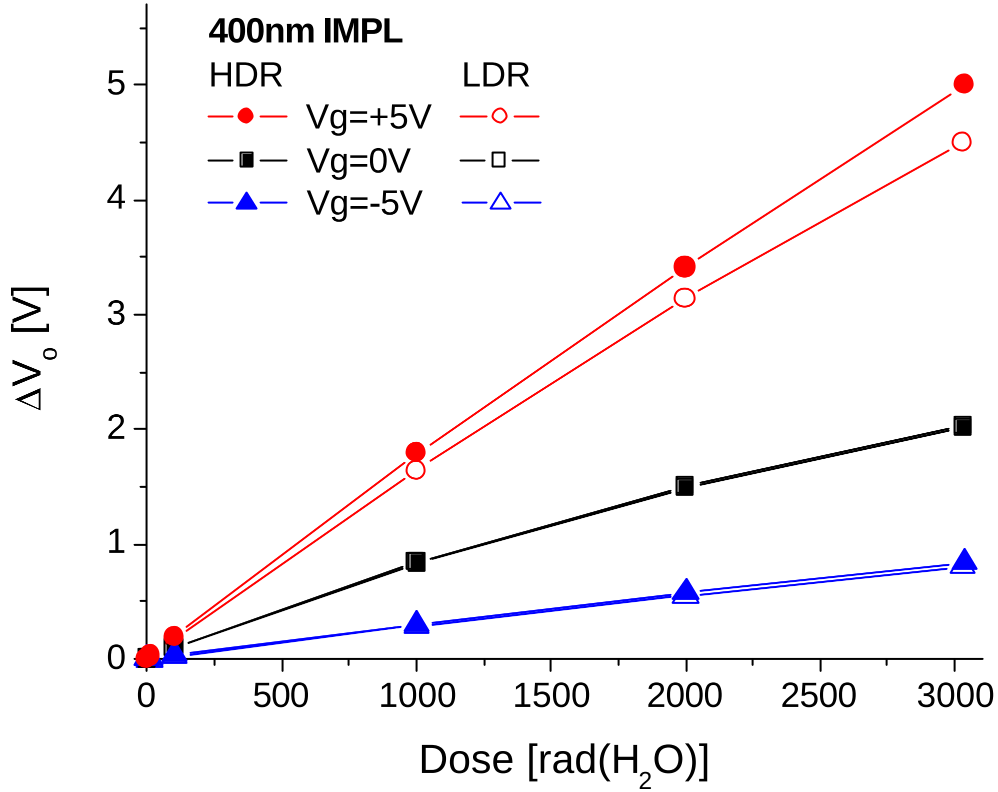
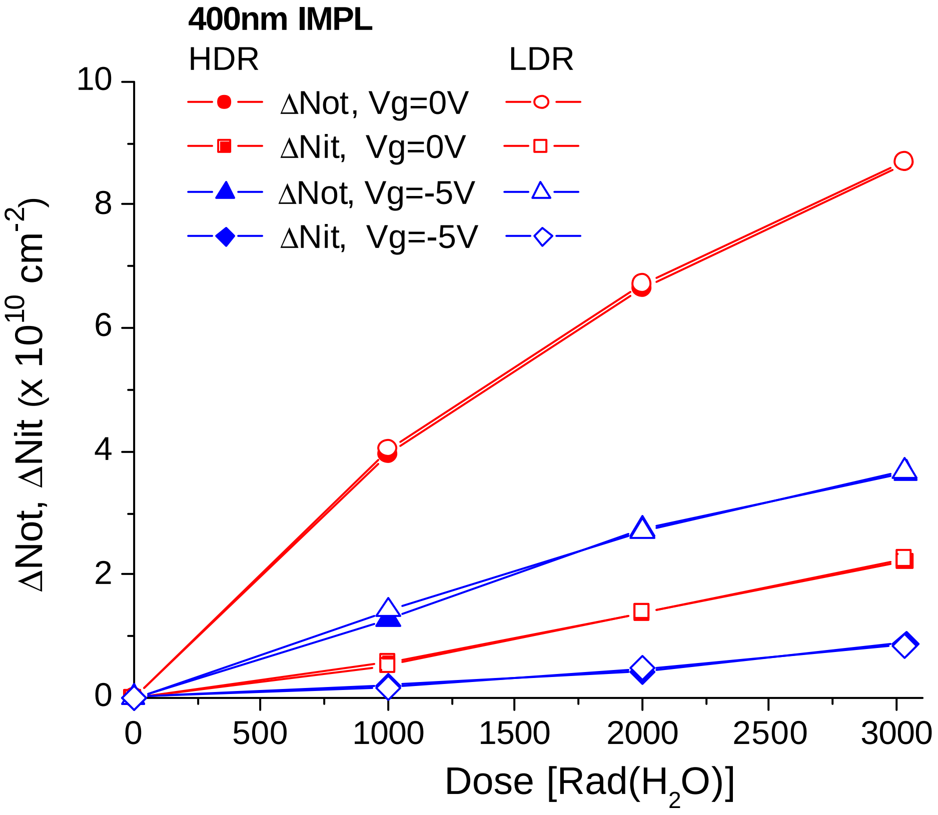
400nm IMPL annealing (HDR vs. LDR):



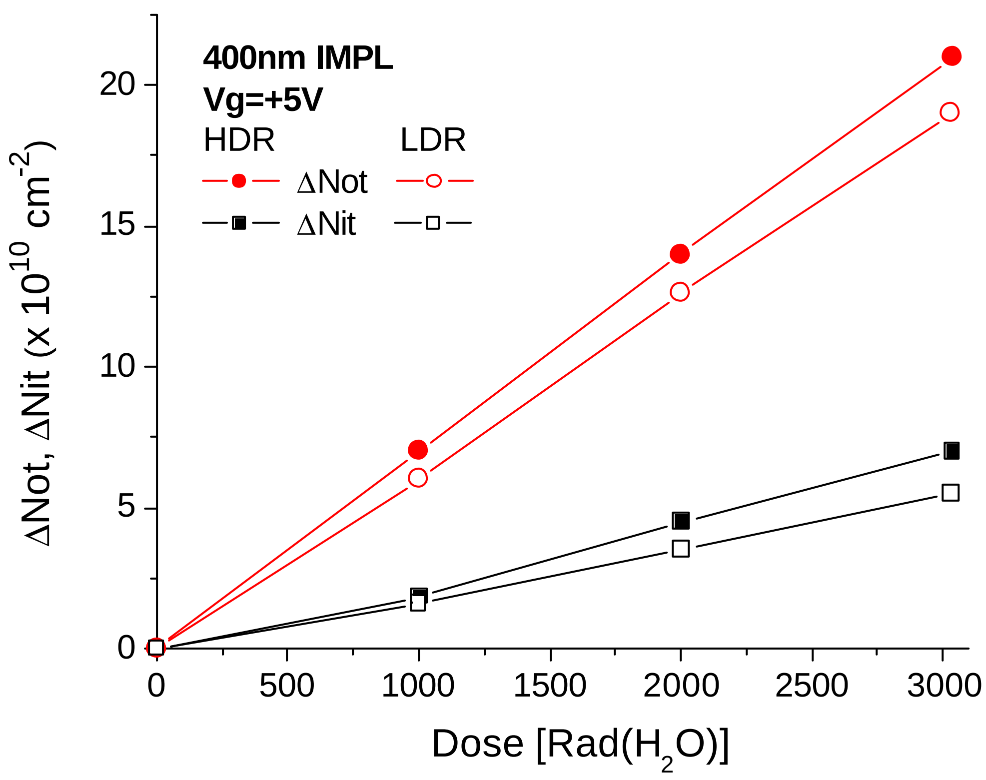
Co-60 irradiation (400nm IMPL, manual):



Co-60 irradiation (400nm IMPL, manual):



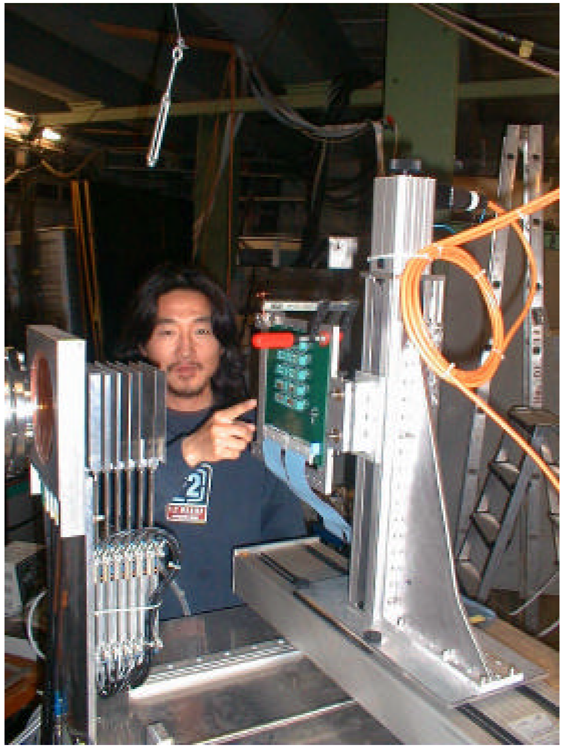
Co-60 irradiation (400nm IMPL, manual):

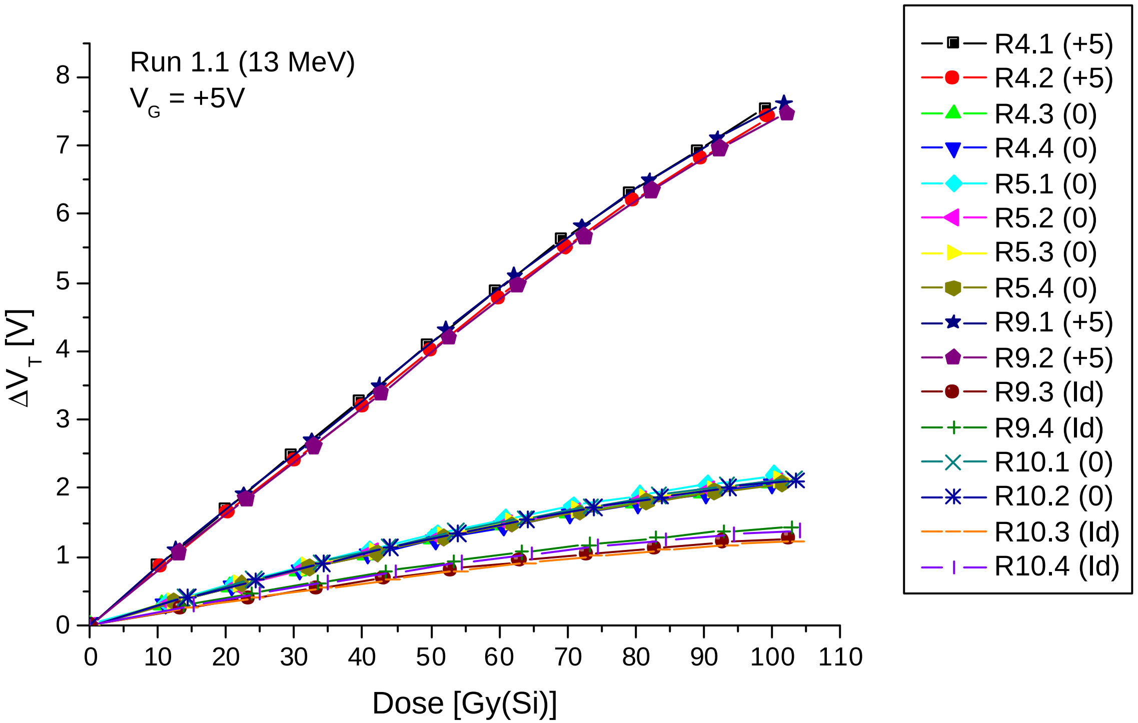


Co-60 irradiation (conclusions):

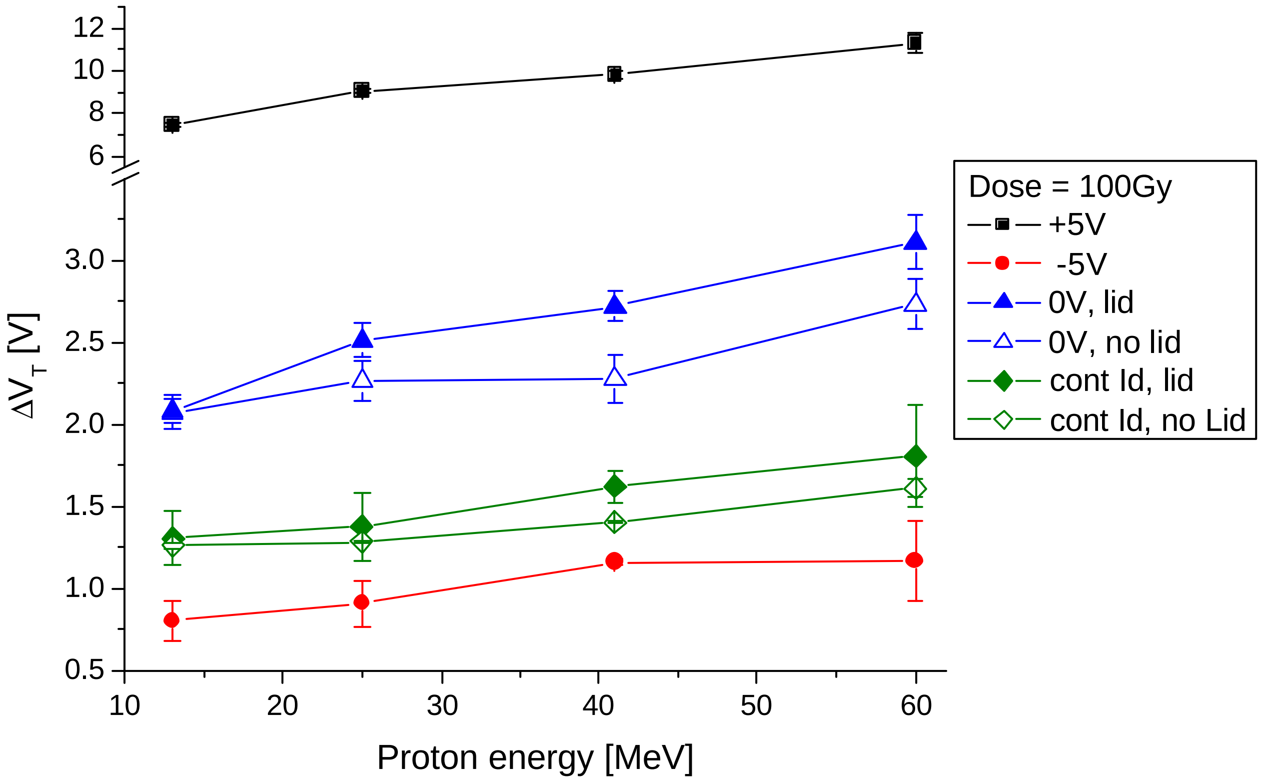
- Higher sensitivity for 400nm IMPL then UNIMPL
- Response increased with increase in irrad. bias
- Dose rate effect observed for positive V_{IRR}
- No apparent dose rate effect for other configurations
- Dose rate effect is a consequnce of different rates of formation of oxide trapped charge and interface traps at different dose rates

Proton irradiations:





Proton energy dependence:



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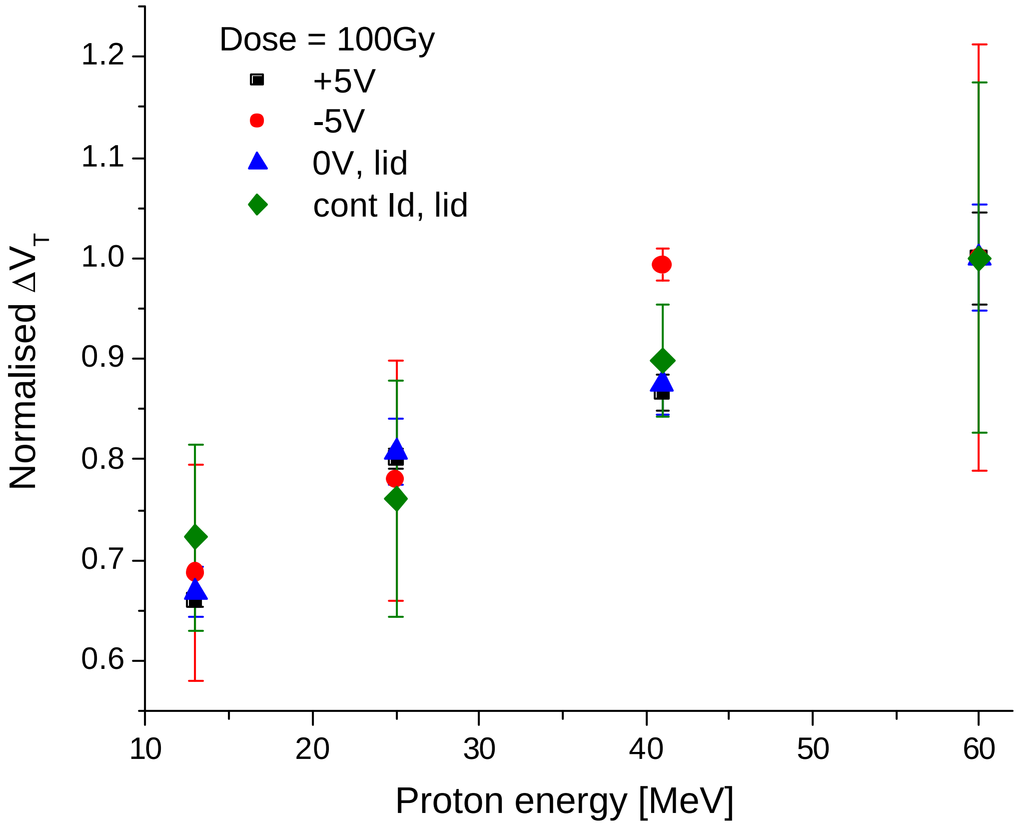
Proton energy dependence (normalised):



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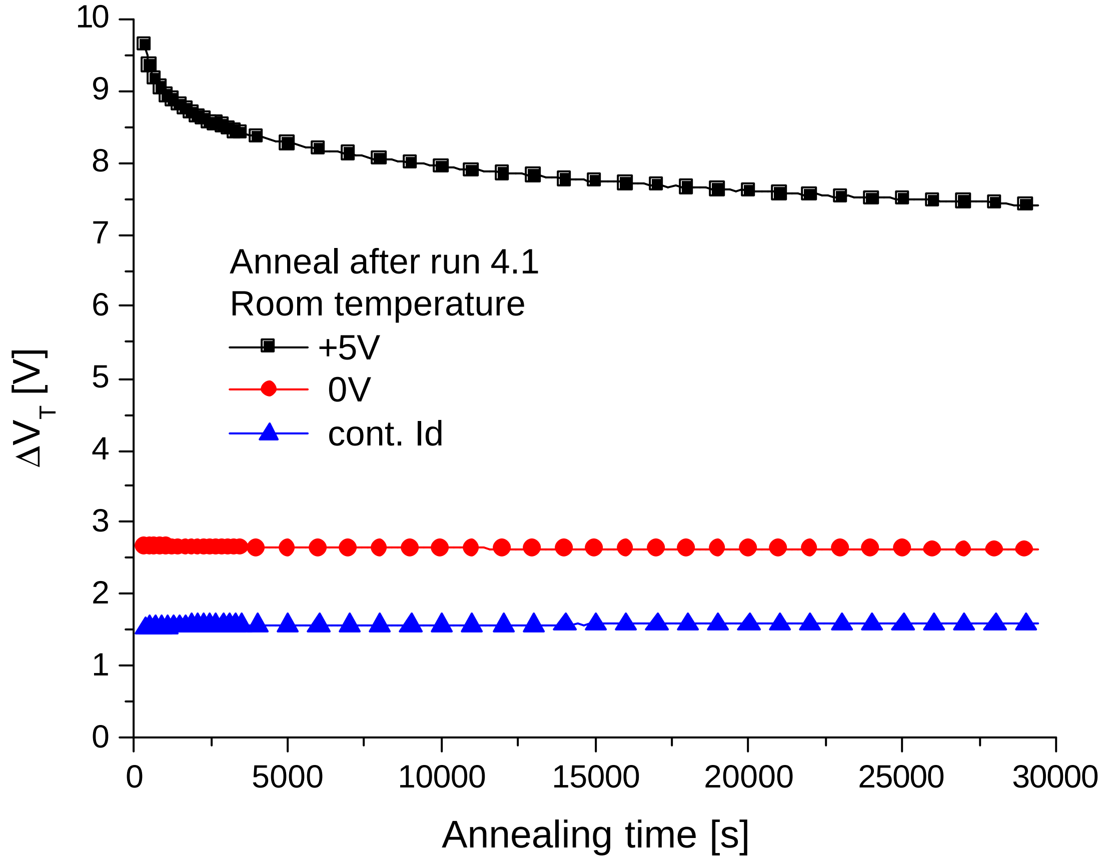
Proton irradiation (annealing):



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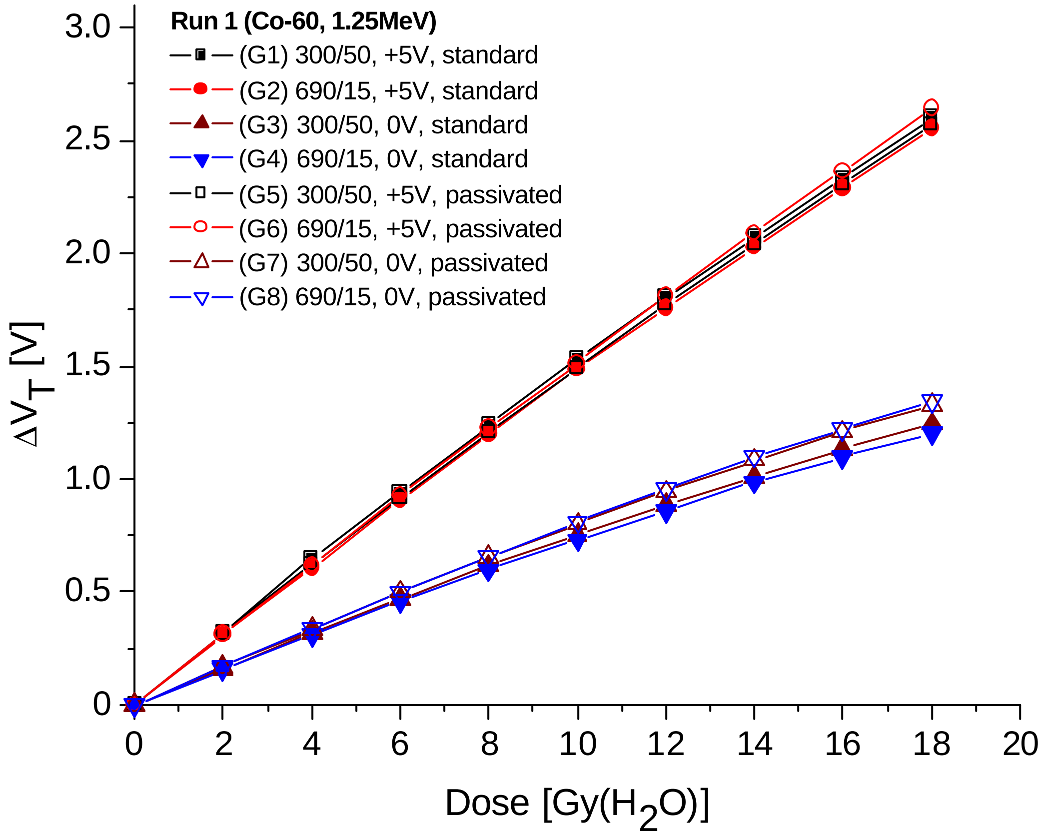
Proton irradiation (conclusions):

- Small variations in data
- Response increased with increase in irrad. bias
- Response increased with proton energy (max by 35%)
- Lid effect present (except for the lowest proton energy)

Electron irradiation campaign (Co-60):



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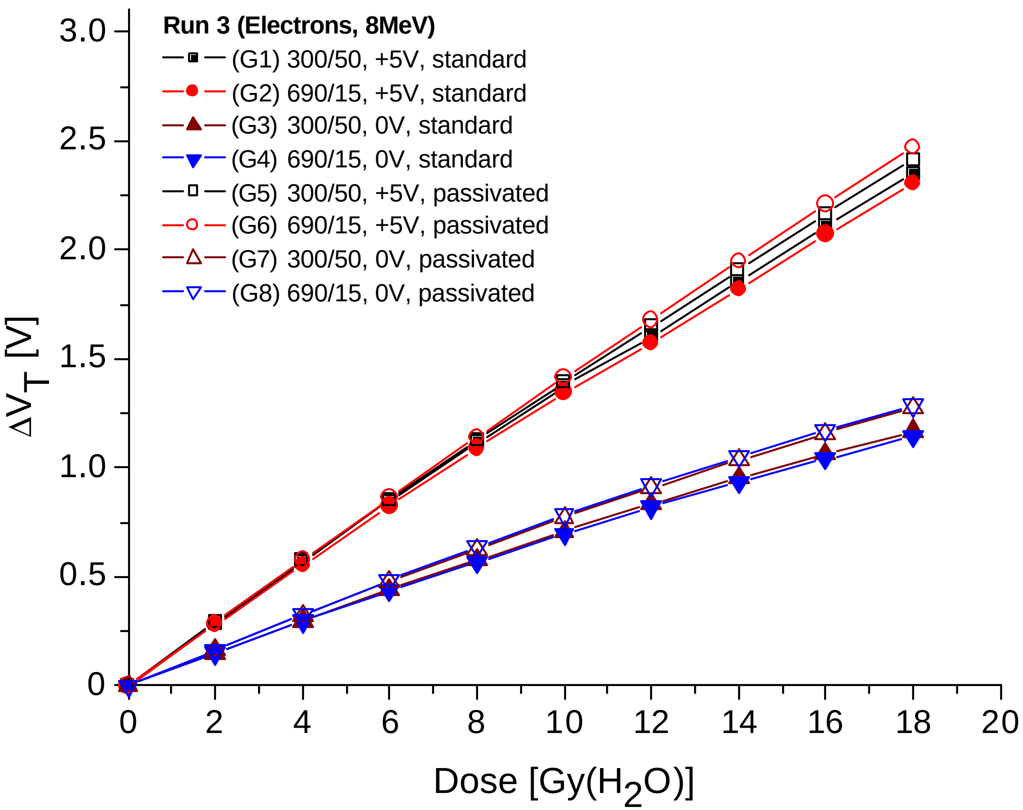
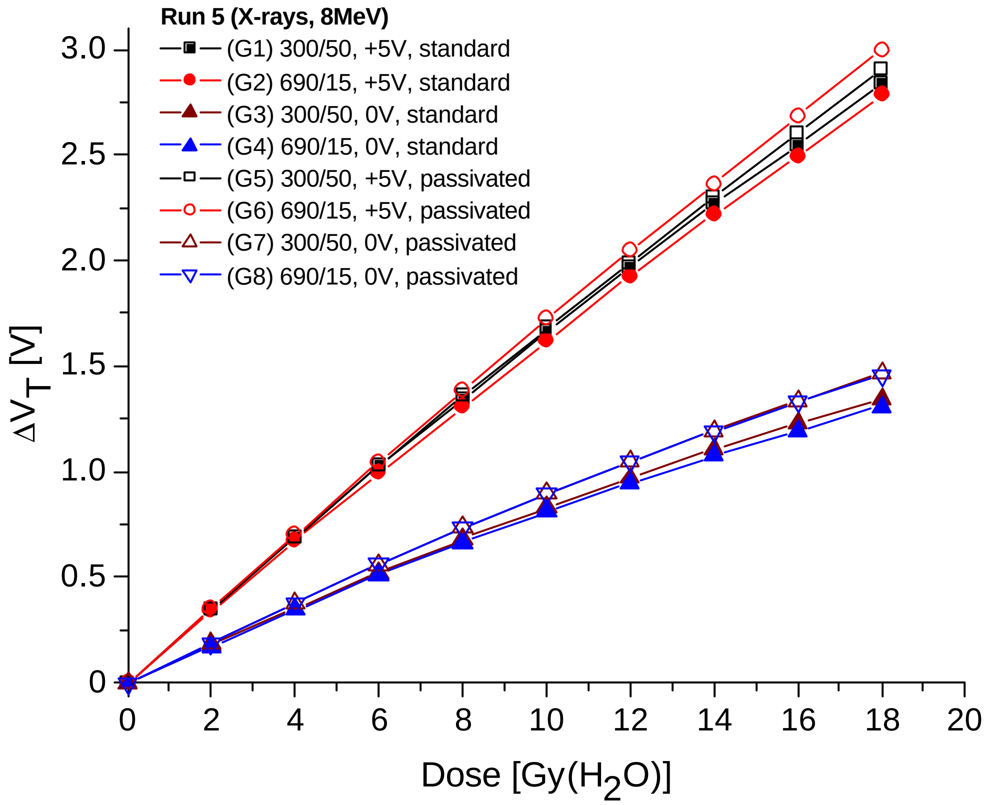
Electron irradiation campaign (8MeV electrons):



Electron irradiation campaign (8MeV X-rays):



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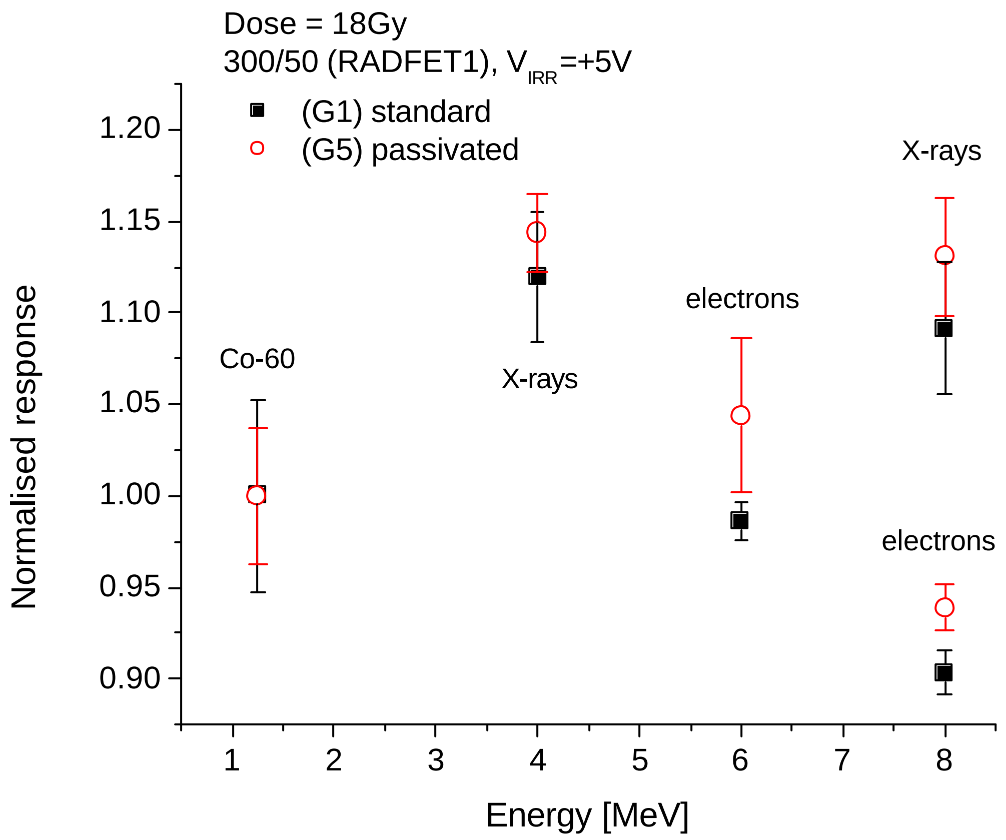
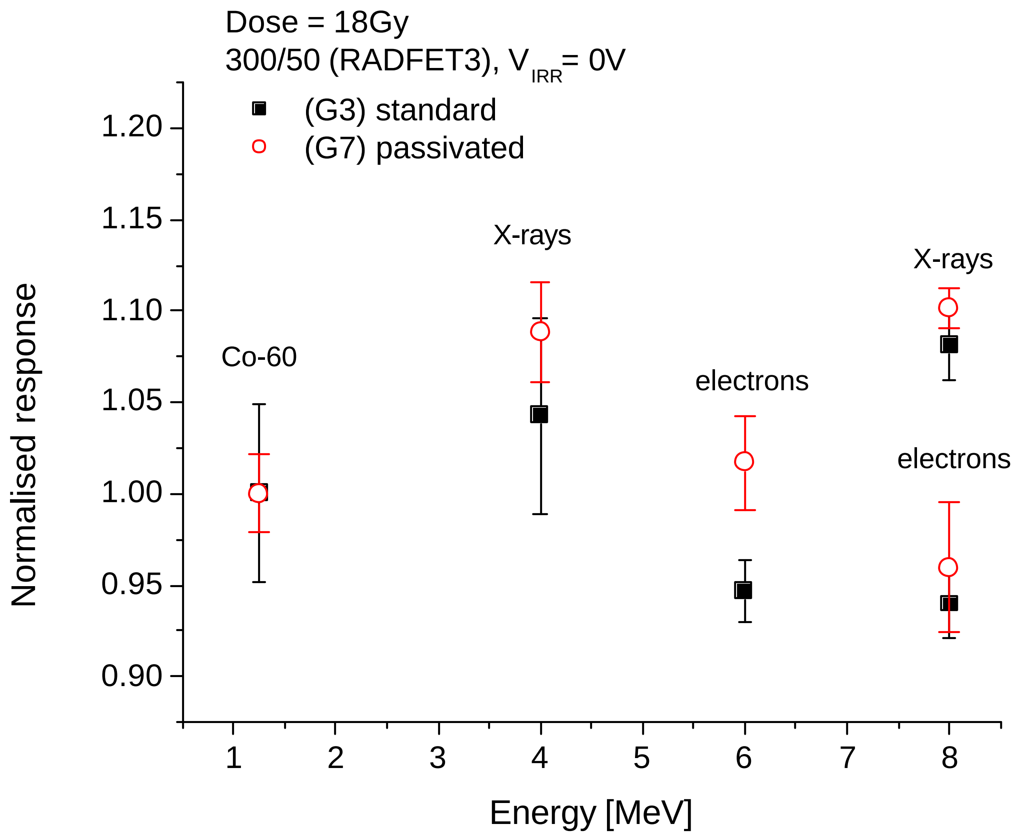
Normalised energy response (positive V_{IRR}):



Normalised energy response (zero V_{IRR}):



Electron irradiation campaign (conclusions):

- Small variations in data
- Response increased with increase in irrad. bias
- Energy response flat from 1-8 MeV
- Passivated devices give slightly higher response
- No significant dependence of response on device geometry

Summary of 2004/2005 proposal:

- New BIOPAN board
  - BIOPAN board design
  - BIOPAN board fabrication
  - BIOPAN board tests – electrical, environmental, irradiation
- RADFET characterisation in various radiation environments
  - RADFET fabrication and test
  - Diode on chip characterisation
  - Co-60 radiation characterisation
  - Proton radiation characterisation
- Improved RADFET Reader Board System
  - RADFET Reader Board design
  - RADFET Reader Board fabrication and test
  - Application software design and test