Proton and Gamma Irradiation Response Characterisation of NMRC RADFETs

D/TOS-QCA Final Presentation Day 2002

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Outline:

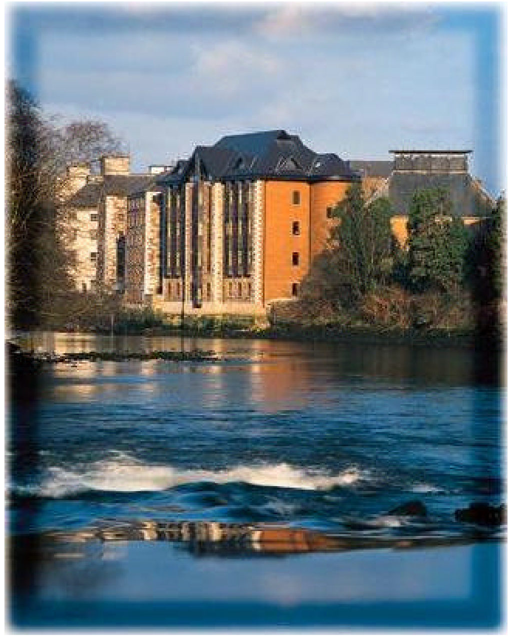
- Where do I come from?
- Where have I been during the last 33.5 years?
- Last ESA sponsored RADFET contract (overview)
- Co-60 and proton irradiation results and discussion
- New vehicle for RADFET response characterisation
- Future work

Where do I come from?

Ireland

Cork

NMRC



Where have I been in the last 33.5 years?

- Born 15/10/1968 in Nis, Serbia, Yugoslavia
- Faculty of Electronic Engineering, University of Nis
  - 1987-1993: Undergraduate studies
  - 1994-2000: Post-graduate studies (Masters plus PhD)
- NMRC, Ireland, Transducers Group, Sep 2000 - ?
  - Research Scientist, coordinator of RADFET related activities
- Research interests:
  - Radiation dosimetry (RADFETs)
  - Radiation effects in MOS devices: basic mechanisms
  - Radiation effects in MOS devices: characterisation
- Research results (publications):
  - 15 papers in refereed international journals

Last ESA sponsored RADFET contract:

- Part of the ESTEC Frame Contract with NMRC
- Contract No.:10582/93/NL/PB; WO No.: 06
- Start date: July 2000
- Duration: one year
- Description of work (work-packages):
  - Supply of RADFETs (including gamma-ray characterisation)
  - Energetic particle RADFET response (proton irradiations)
  - BIOPAN support
  - Improved stacked device
  - High range / high sensitivity RADFET configuration

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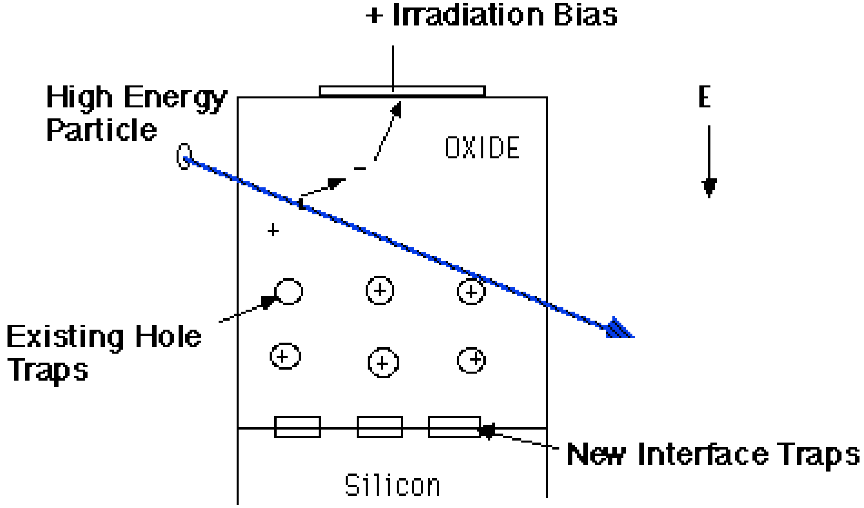
RADFET operating principle:

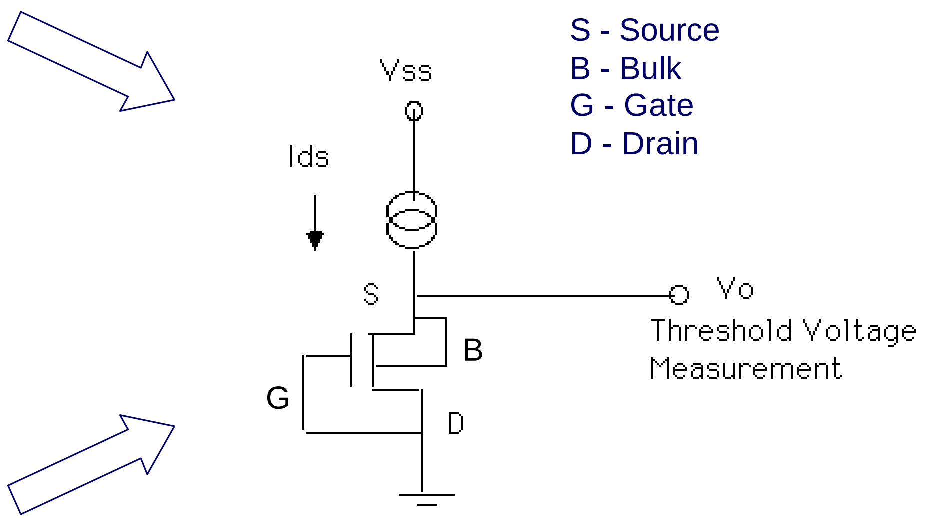


- Radiation creates electron-hole pairs
- Initial recombination of electrons and holes happens
- Non-recombined electrons leave the oxide;
  holes are trapped in the vicinity of the oxide/silicon interface
- RADFET threshold voltage (V_T) changes (ΔV_T ~ Dose)

RADFET biasing configurations:

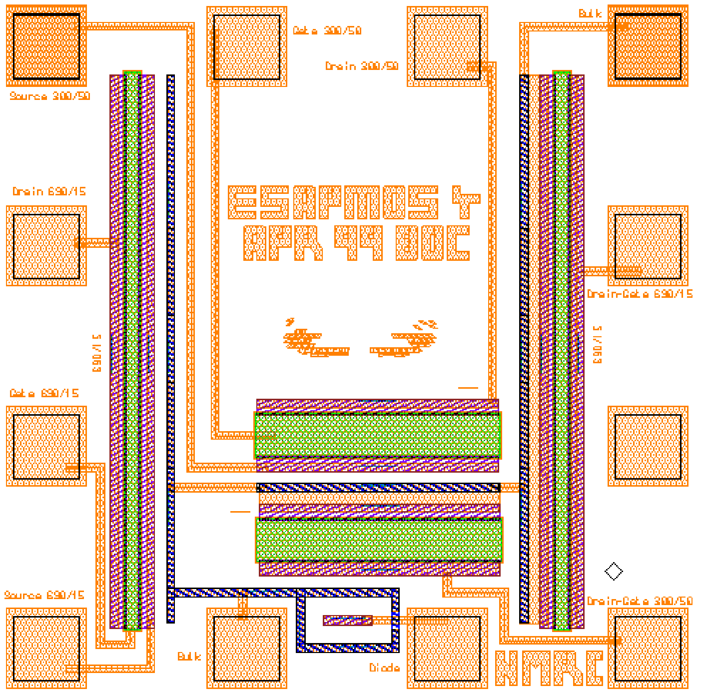
- Irradiation (sense mode): zero current; (B, S and D grounded); G can be:
  - Grounded ($V_{IRR}=V_{GS}=0V$) (config. 1)
  - Biased (typically $V_{IRR}=V_{GS}>0$) (config. 2)

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



- Irradiation (sense mode) and Read-out mode are the same (config. 3)

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)

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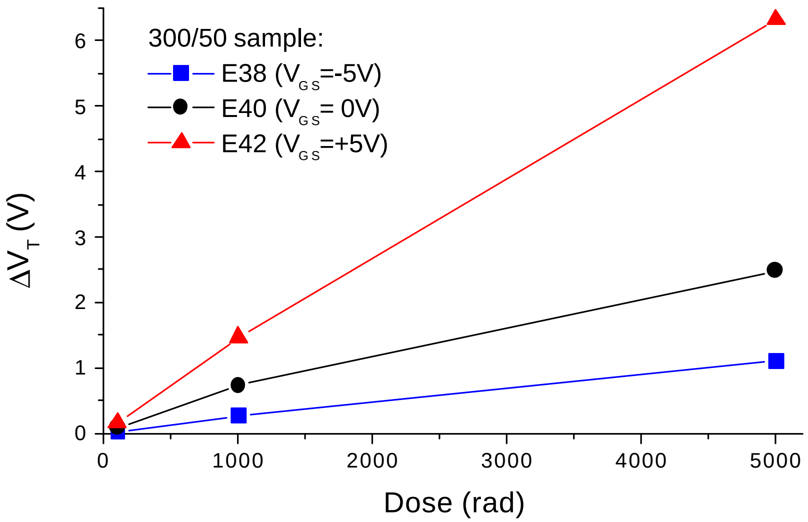
Co-60 data (300/50):

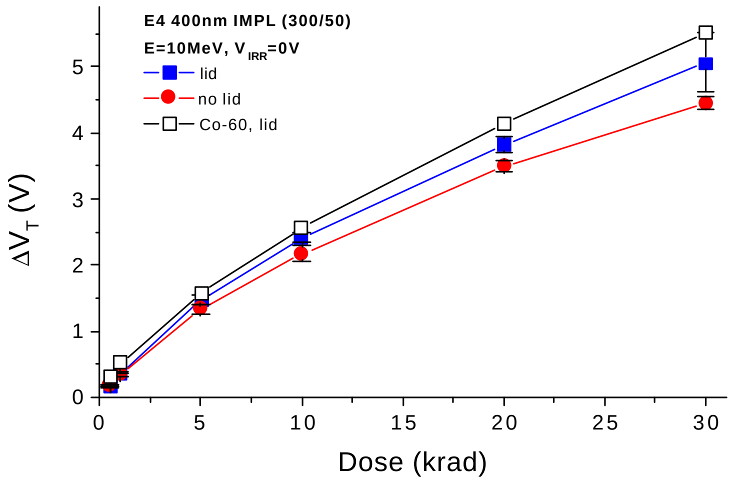


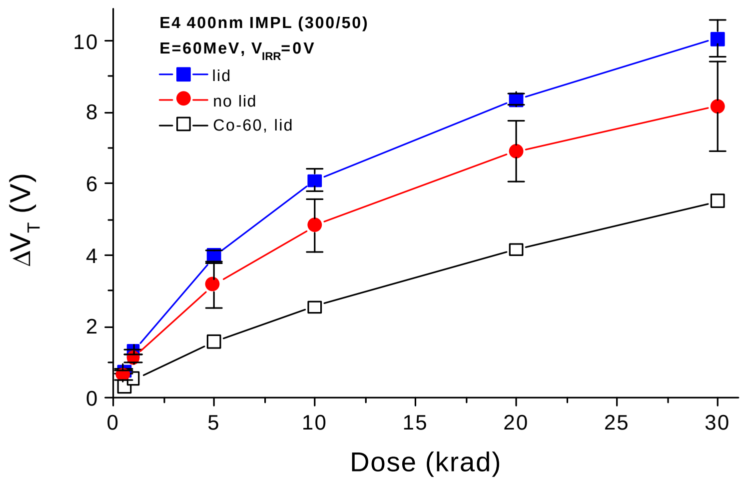
Sensitivity (mV/rad):

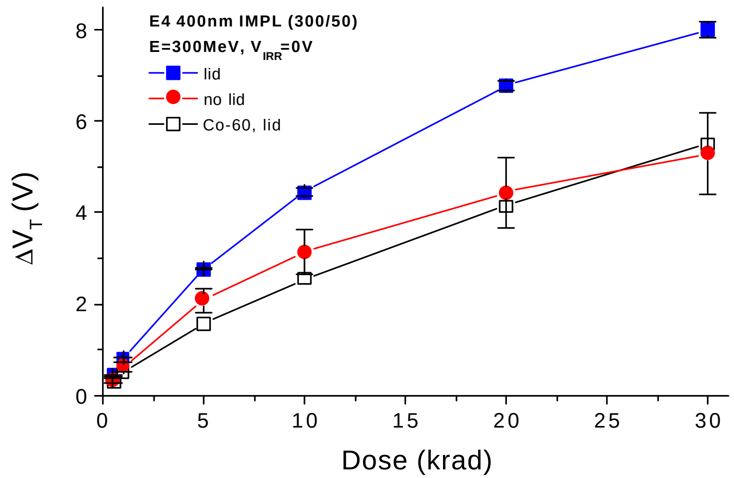
Dose (rad)\V_{irr}	V_{irr}=-5V	V_{irr}=0V	V_{irr}=+5V
100	0.28	0.82	1.56
1000	0.26	0.72	1.46
5000	0.22	0.50	1.27

- Very good agreement with previous (ESAPMOS2) results
- Very small variations between the samples (< 3%)
- Sensitivity for $V_{IRR}=V_{GS}<0$ is higher than for $V_{IRR}=0$
- 690/15 RADFETs have 2-3% lower sensitivity than 300/50 ones

Proton vs. Co-60 data for V_{IRR}=0:







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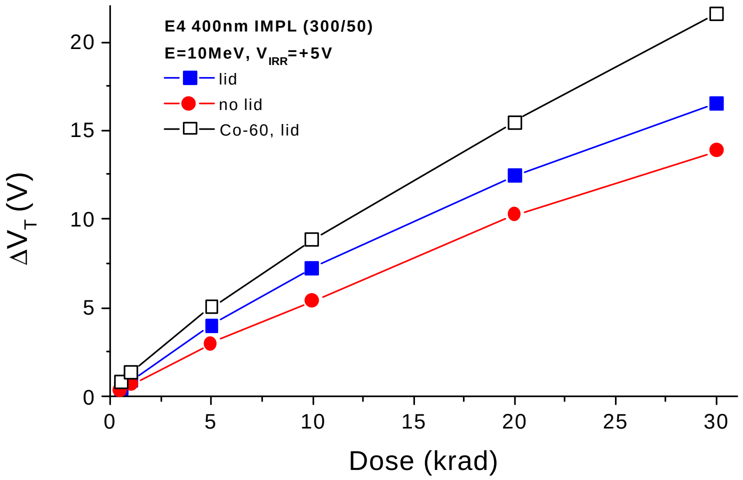
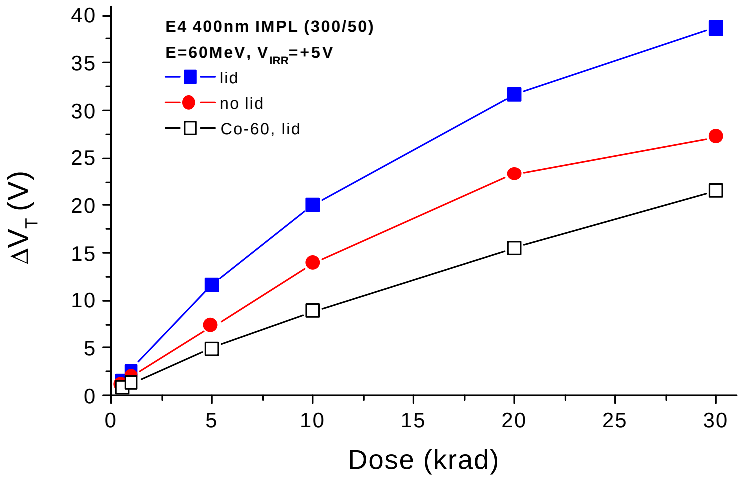
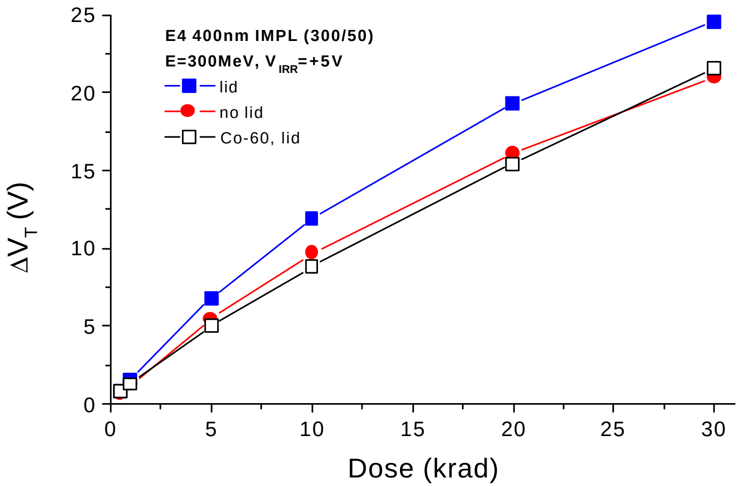
Proton vs. Co-60 data for V_{IRR}=+5V:







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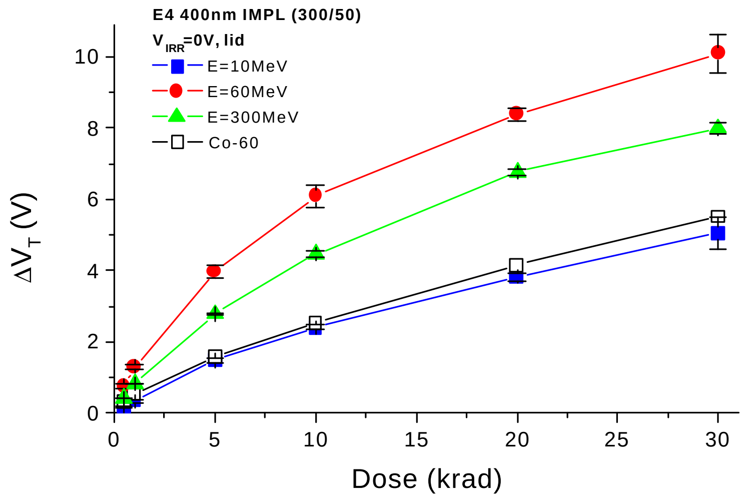
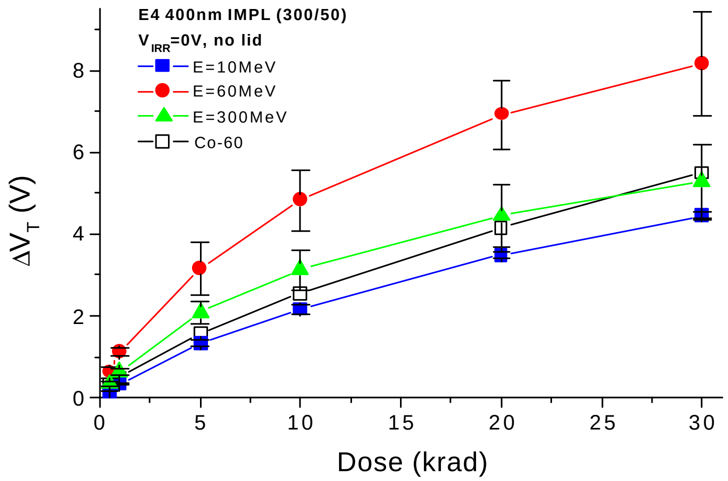
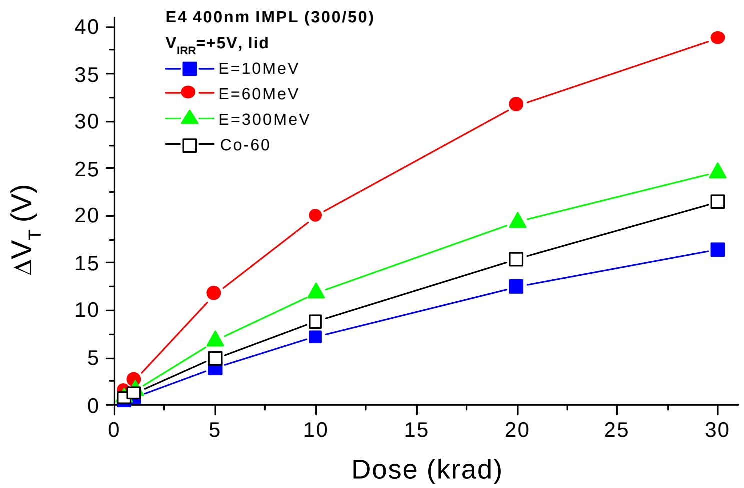
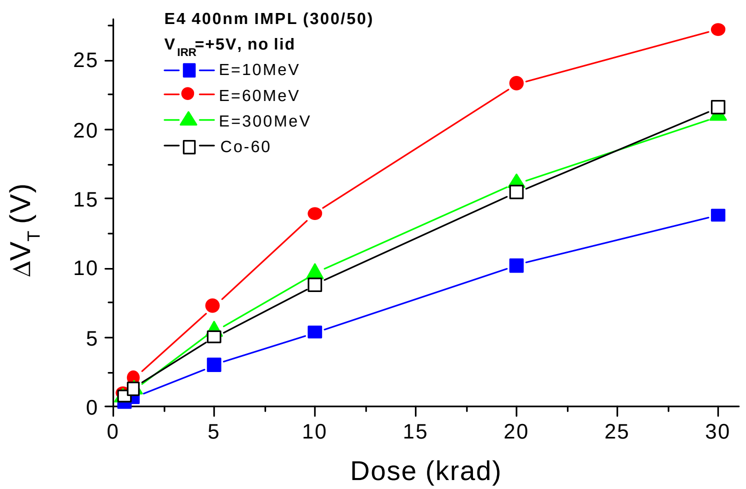
Summary of proton data at different energies:









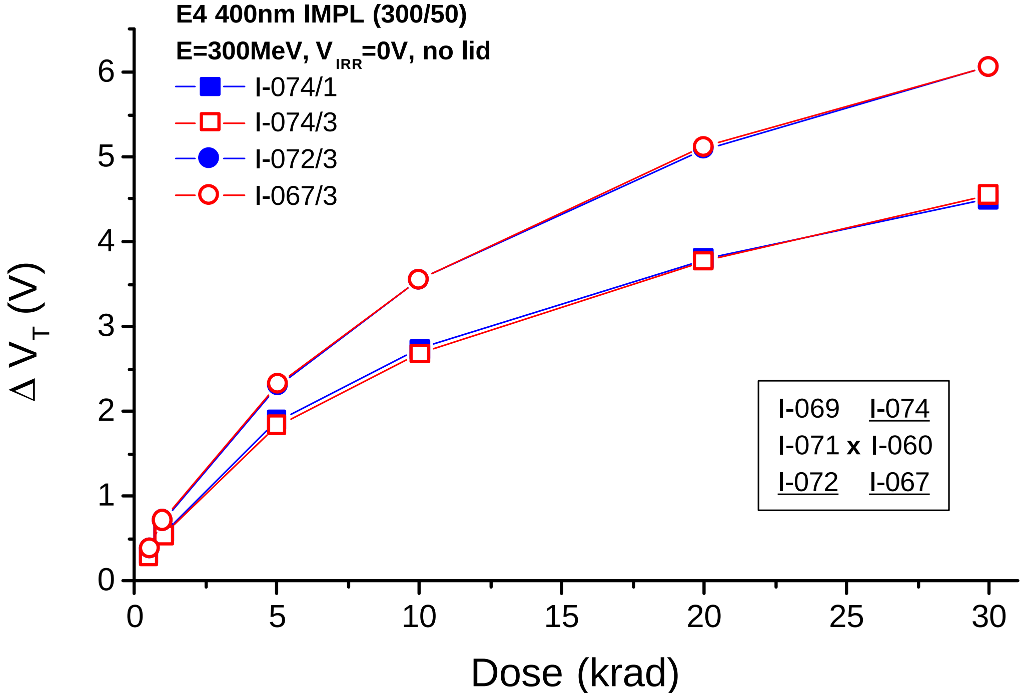
Summary of proton results:

- Discrepancies between proton and Co data
- Energetic dependence of proton response:
  - ΔV_T(10MeV p) < ΔV_T(Co) < ΔV_T(300MeV p) < ΔV_T(60MeV p)
- Response of 300/50 devices somewhat higher than response of 690/15 devices (as for Co-60)
- The presence of package significantly enhances the response and its energetic dependence
- Irradiation bias V_{IRR} has only a quantitative effect
- Variations between the samples bigger than in the case of Co-60 irradiation

Possible reasons for discrepancies:

- Experimental uncertainties:
  - RADFET read-out error
  - Proton beam non-uniformity
- Variations in dose enhancement between Co and p:
  - package lid effect evident
  - also back-scattering from die attach pad (?)
- Increased/decreased electron-hole recombination:
  - different contributions of columnar and geminate recomb.
- Different contribution of non-ionising energy transfer (displacement damage)
- Different energies needed for electron-hole recomb.

Evidence of p-beam non-uniformity (?):



- inset gives the location of six chips
- beam centre is marked with "X"
- de-lidded samples are underlined

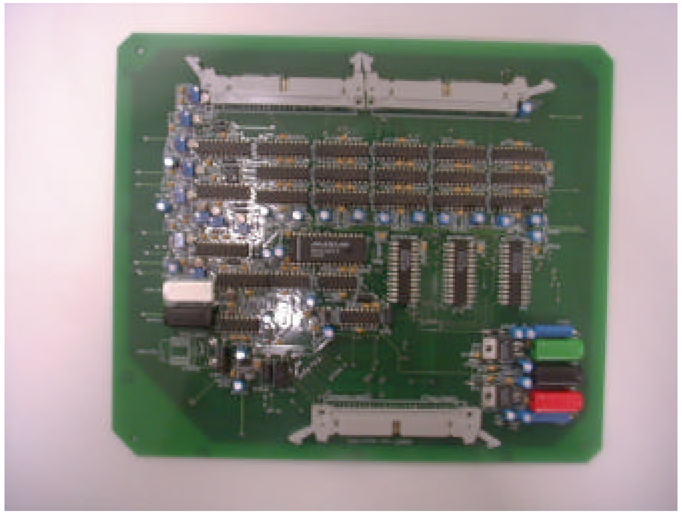
Vehicle for RADFET characterisation:

RADFET Reader Board system:

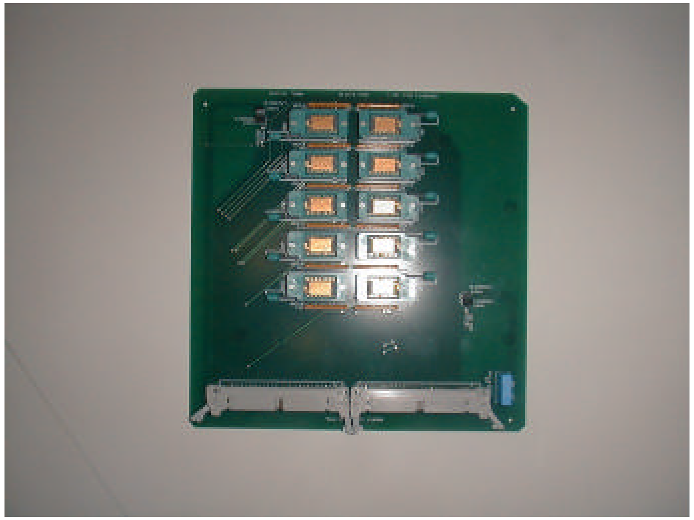
- PC (running LabVIEW software)
- Data acquisition card (NI DP 1200)
- RADFET Reader Control Board
- RADFET Socket Board

- User friendly, completely automated, computer-controlled system
- Enables on-line monitoring of RADFET V_T and the temperature
- Up to 10 RADFET chips (40 RADFETs) can be monitored simultaneously
- Independent choice of three RADFET biasing configurations (irradiation):
  - V_{IRR}=0 (zero current), (2) V_{IRR}>0 (zero current), continuous current

RRCB and RSB (detailed look):



RADFET Reader Control Board (RRCB)



RADFET Socket Board (RSB)

Future work:

- Detailed characterisation of gamma-ray response:
  - Verifying relevant RADFET pre-irradiation parameters
  - Testing RADFET Reader Board system in practice
  - Detailed calibration measurements in all configurations using RRB system
- Detailed characterisation of proton response:
  - Theoretical considerations
  - Numerical simulations
  - Comprehensive irradiation experiments