

# The sensitivity of a new type p-MOSFET dosemeter to high energy protons

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# p-MOSFET dosimeters

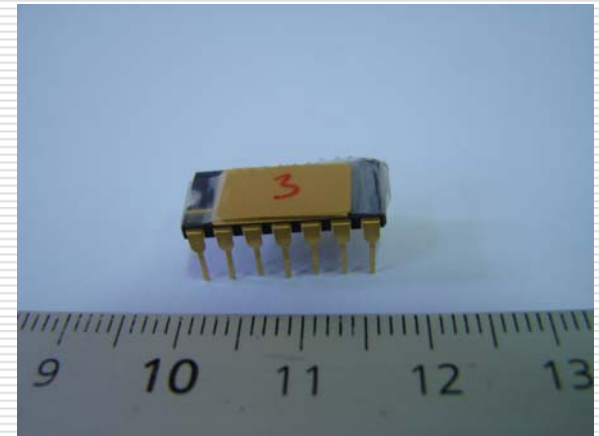
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Pictures of the Metal-Oxide-Semiconductor Field Effect Transistor, p-MOSFET dosimeter, manufactured at LAAS-CNRS Laboratory, Toulouse France.

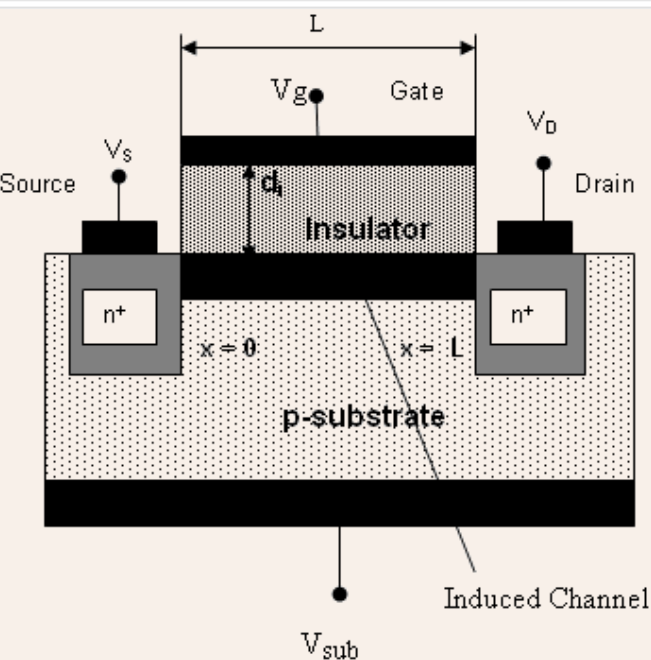
The dimensions of the dosimeter:

1 mm x 1mm

During irradiation the transistors were short-circuit while during measurement the MOSFETs were diode connected (gate and drain grounded) and the source was fed by a constant current of 100  $\mu\text{A}$ .



# Dose measurements with the new p-MOSFET dosimeters



- ❑ New type of p-MOSFETs were irradiated by high energy protons.
- ❑ They have 1.6  $\mu\text{m}$  thick gate insulator and they have been developed at LAAS-CNRS Laboratory Toulouse.
- ❑ The irradiations were performed at HIMAC accelerator, at the frame of **ICCHIBAN** collaboration.
- ❑ When ionizing radiation passes through the gate oxide in a MOSFET, electron-holes pairs are generated.



# The response of p-MOSFET Dosemeters

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- The **threshold voltage** shift,  $\Delta V_T$ , which was the measured quantity, depends upon:
  - a) the incident particle type and energy,
  - b) the ionizing particle penetration into the oxide,
  - c) the absorbed dose,
  - d) the gate bias during irradiation and
  - e) the gate insulator thickness.
  
- For this exposure mode, usually called zero bias mode, the expected response of the voltage shift  $\Delta V_T$  follows a power-law :

$$\Delta V_T = \alpha D^b$$

- Parameters a and b were experimentally determined. Parameter b was found to be close to the 1 so  
**the response of the MOSFETs was expressed by parameter a**



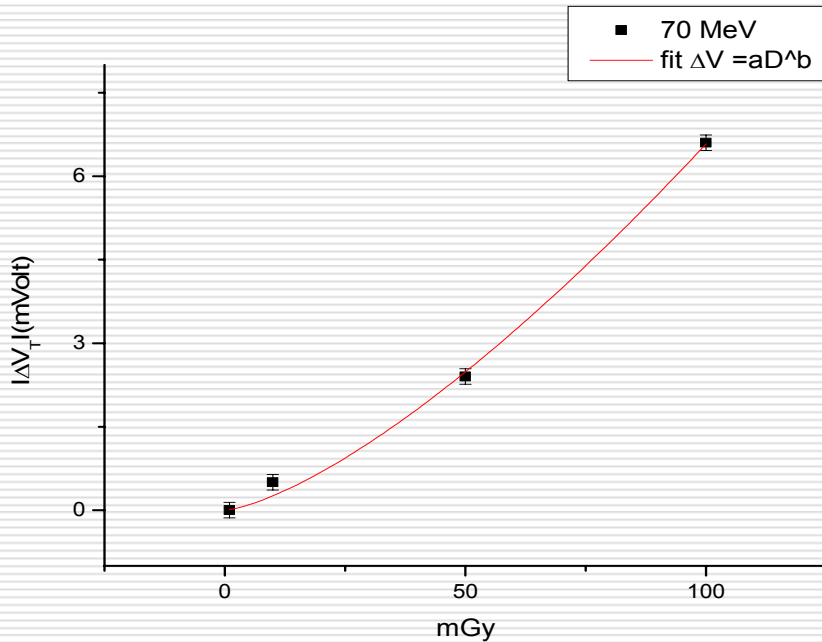
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- In passive mode, according to literature, the expected response is sub-linear and the general behavior is modeled by the equation:

$$\Delta V_T = V_o ( 1 - \exp^{-bD})$$

- Our results were fitted by both equations and although the irradiations were passive, the response of the MOSFET dosimeters in high energy protons is supra-linear.

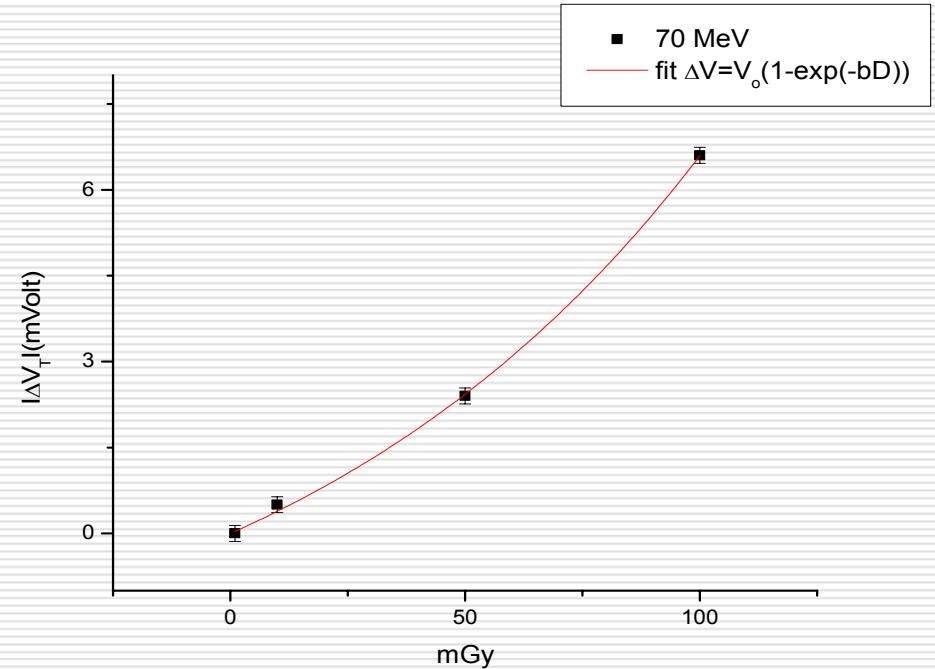


# Results from irradiation by 70 MeV protons



$$\Delta V_T = (0.010 \pm 0.004) \cdot D^{1.41 \pm 0.08}$$

( $R^2 = 99.6\%$ )

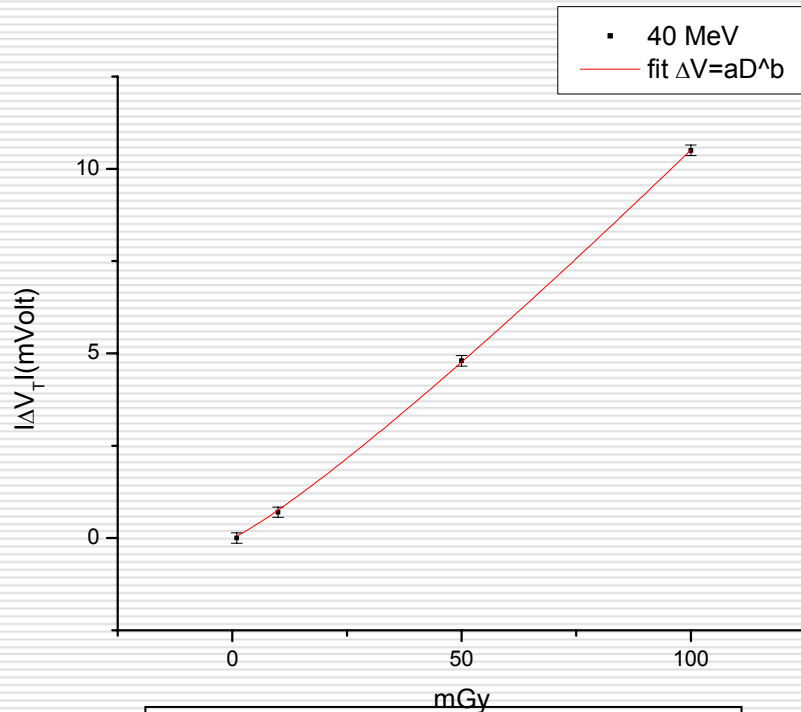


$$\Delta V_T = (-3.40 \pm 0.58) \cdot (1 - \text{Exp}^{[(0.011 \pm 0.001) \cdot D]})$$

( $R^2 = 99.9\%$ )

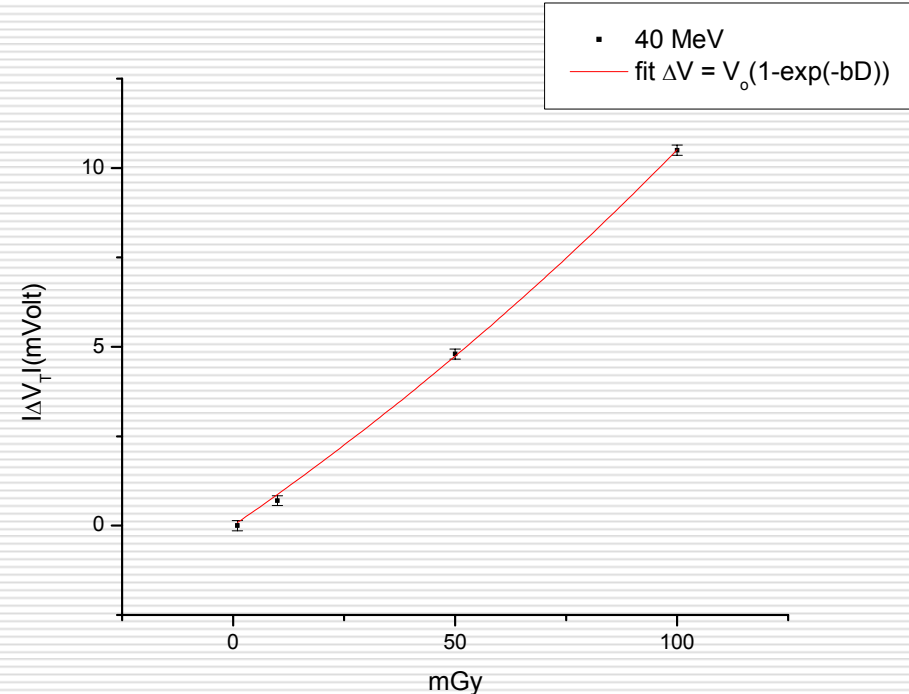


# Results from irradiation by 40 MeV protons



$$\Delta V_T = (0.055 \pm 0.005) \cdot D^{1.14 \pm 0.02}$$

$$(R^2 = 99.9 \%)$$



$$\Delta V_T = (-21.8 \pm 7.6) \cdot (1 - \text{Exp}[(0.004 \pm 0.001) \cdot D])$$

$$(R^2 = 99.9 \%)$$



# Dose estimation for **blind** experiments

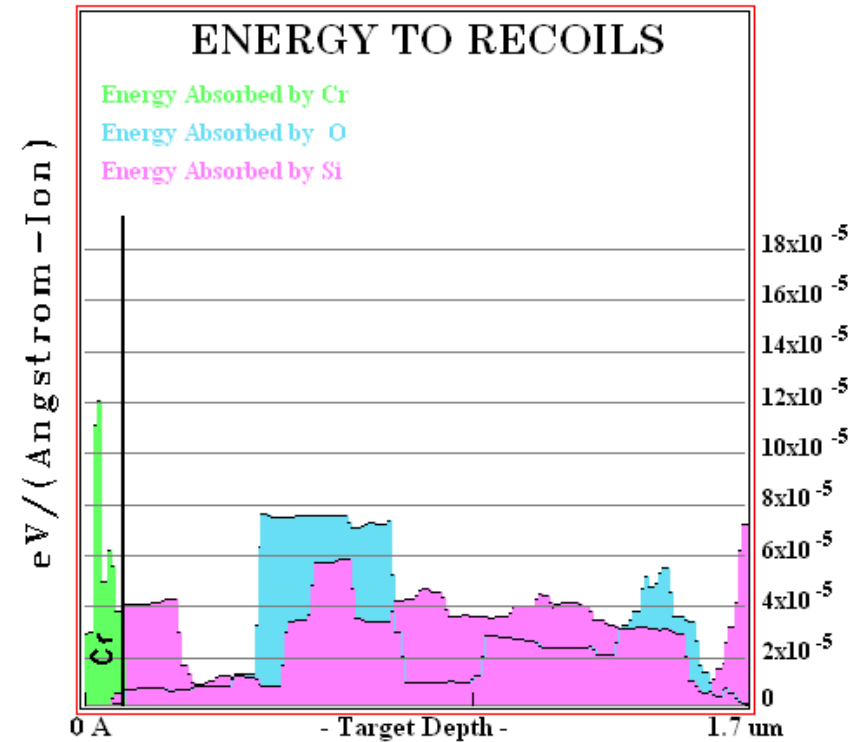
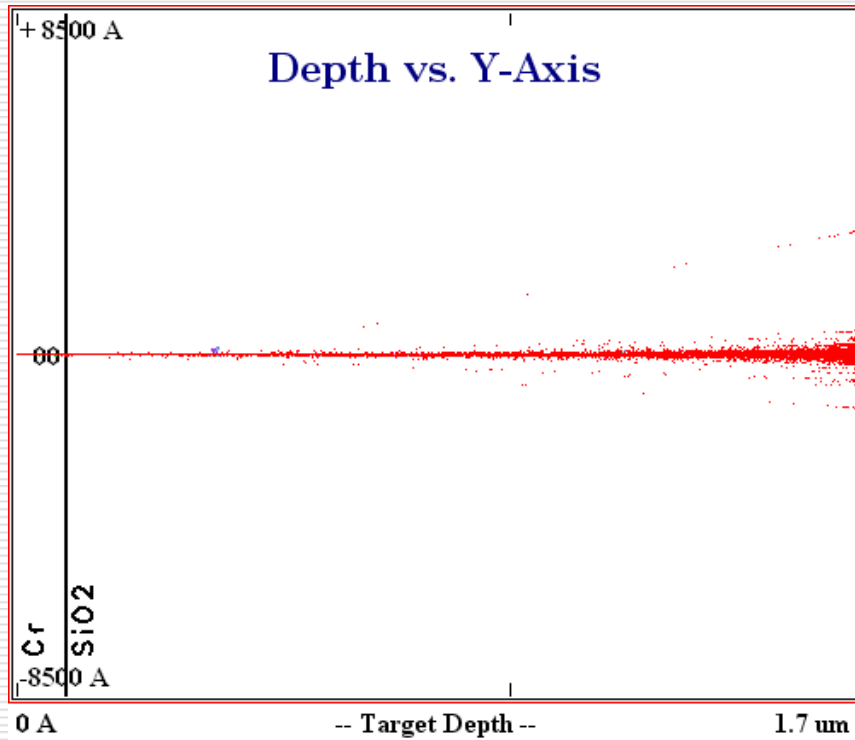
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According to the response calculations (using power or exponential function) the dose estimations of blind experiments are presented in the following table. In particular, blind experiment No1 of 40 MeV proton irradiation gave voltage increment at the lower detection limit, i.e.  $0.4 \pm 0.14$  (~35%) mV.

<b>Blind</b>	<b>Proton 70 MeV</b>	<b>Proton 40 MeV</b>
No. 1	$86 \pm 14$ mGy	$< 10$ mGy
No. 2	$47 \pm 10$ mGy	$88 \pm 9$ mGy



# Calculations using the SRIM



# Comparison with calculation

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<b>Proton energy (MeV)</b>	<b>Calculation</b>	<b>Experimental**</b>
40	$3.2 \cdot 10^{-19}$ V/ion	$3.2 \cdot 10^{-19}$ V/ion
70	$1.6 \cdot 10^{-19}$ V/ion	$1.92 \cdot 10^{-19}$ V/ion

\*\*conversion factor from Phys. Med Biol 54 (2009) 1997—2014 for AP geometry (anterior-to posterior)



# Results from current work

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<b>Proton energy (MeV)</b>	<b>Response (single MOSFET) mV/mGy</b>	<b>Response of stack (two MOSFET with Li) mV/mGy</b>
70	$0.0658 \pm 0.0065$	$2.857 \pm 0.00014$
40	$0.1067 \pm 0.0018$	$2.074 \pm 0.00014$



# Results from literature

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<b>Proton energy (MeV)</b>	<b>Response</b>
115	0.036 mV/mGy [Rad. Prot. Dos. (2009) 1-15]
62	0.04 mV/mGy [Rad. Prot. Dos. (2009) 1-15]
47	0.034 mV/mGy [Rad. Prot. Dos. (2009) 1-15]
62	0.07 mV/mGy [Physica Medica (2006) Vol XXII, N.1]



# Future work for heavy ions Calculations

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## Calculated response

Ion with Energy 100 MeV	Response V/ion
Fe	$3 \cdot 10^{-15}$
Si	$3.2 \cdot 10^{-16}$
C	$1.6 \cdot 10^{-17}$
He	$9.6 \cdot 10^{-19}$

\* With Al absorber heavy ions can be separated by protons



# Conclusion

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- Supra-linear response of the new p-MOSFET dosimeters is observed for protons. This behavior is valid for a wide dose range.
  - Their response is higher than previously reported in the literature even when a stack of dosimeters with bias during irradiation was used.
  - Their response can be increased about an order of magnitude, if a stack of two identical MOSFET dosimeters is used.
  - According to calculations MOSFET dosimeters seem to present very good response to heavy ions.
  - MOSFETs are promising devices for their use in space radiation dosimetry.
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