Calibration of depleted type p-MOSFET dosemeter to high energy protons

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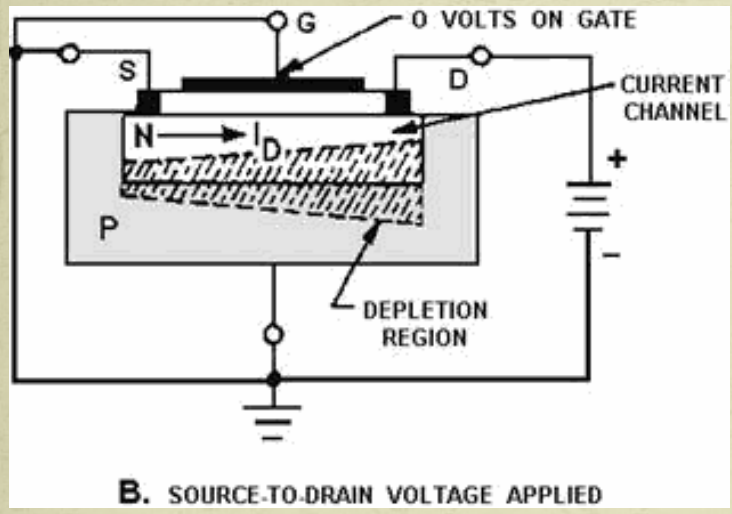
Depletion-mode MOSFETs



B. SOURCE-TO-DRAIN VOLTAGE APPLIED

The *depletion-mode* MOSFET devices, are less commonly used than the standard *enhancement-mode* devices already irradiated in the previous experiments.

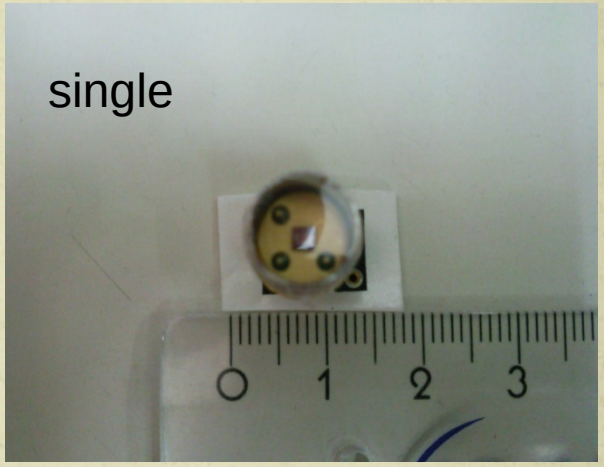
The *depletion-mode* MOSFET devices are doped so that a channel exists even with zero voltage from gate to source.

p-MOSFET dosemeters

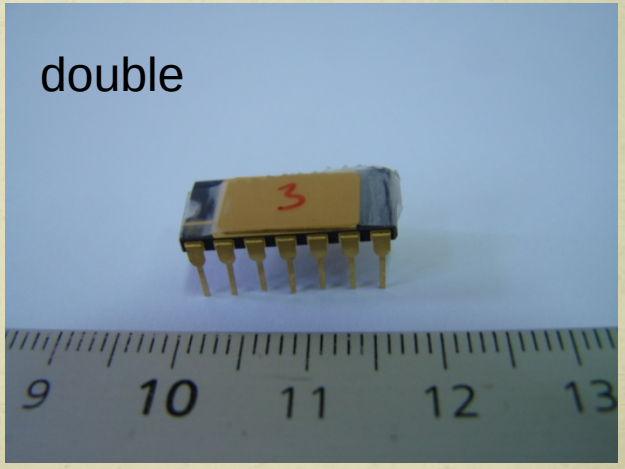
Pictures of the Metal-Oxide-Semiconductor Field Effect Transistor, depleted p-MOSFET dosimeter, manufactured at LAAS-CNRS Laboratory, Toulouse France.

The dimensions of the dosemeter:

1 mm x 1mm



During irradiation the transistor was 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 μA.



The response of p-MOSFET Dosemeters

- The **threshold voltage** shift, ΔV_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 ΔV_T follows a power-law :

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

- Parameters a and b were experimentally determined.

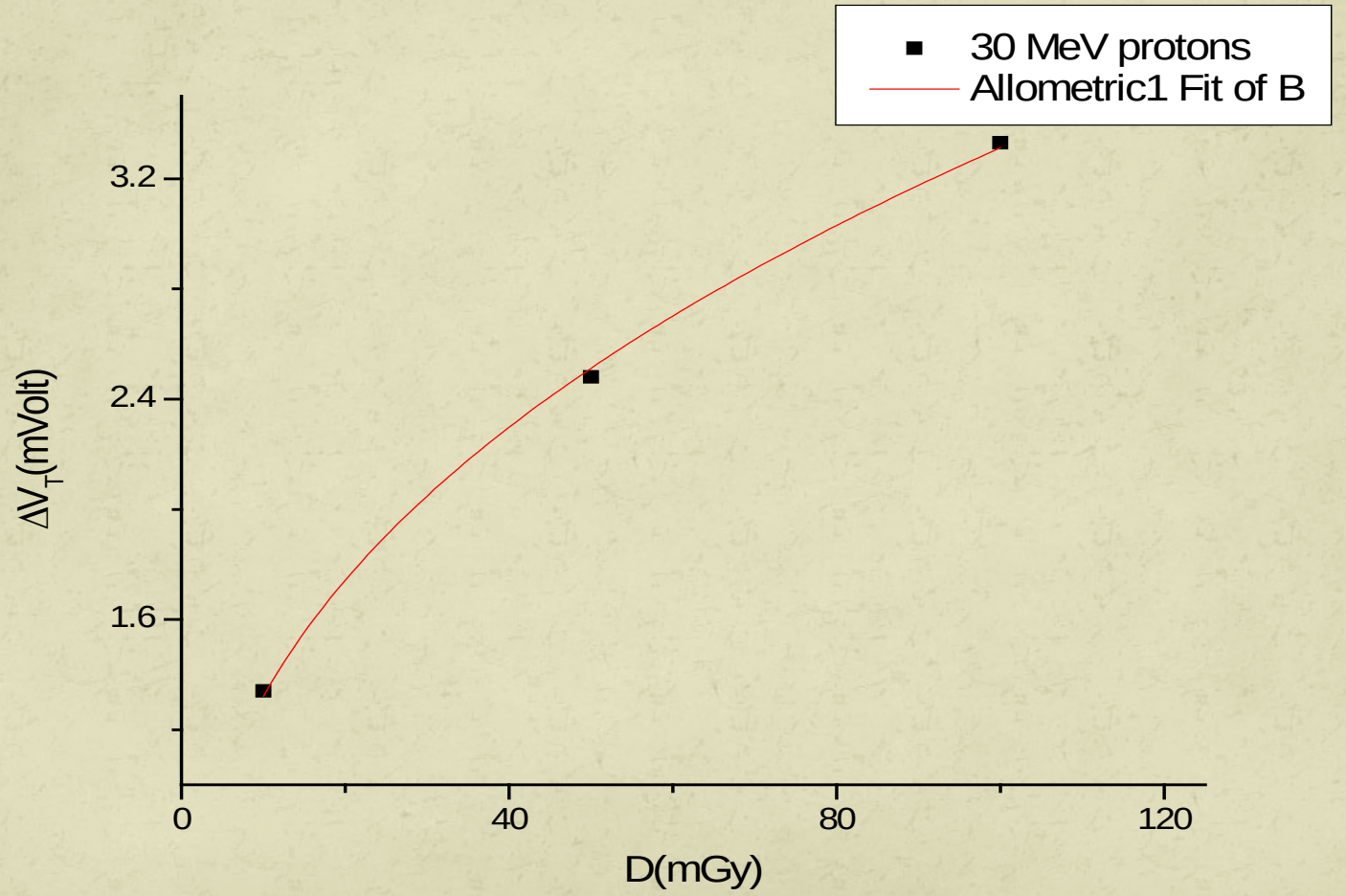
- In passive mode, according to literature, the expected response is sub-linear and the general behavior is modeled by the equation:

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

- The results obtained by the irradiation of the enhancement-mode dosemeters were fitted by both equations and although the irradiations were passive, the response of the MOSFET dosemeters in high energy protons is linear.

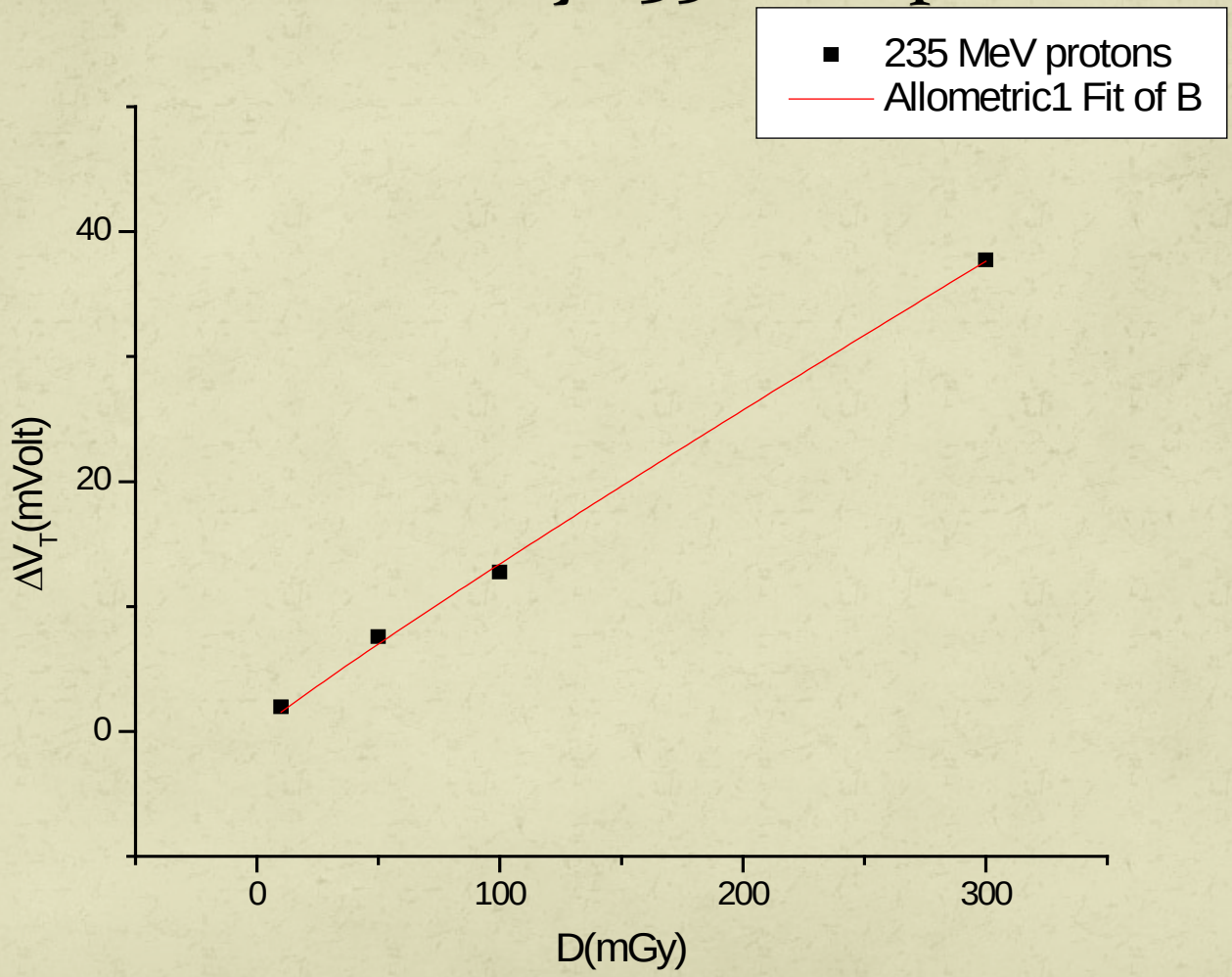
- The results obtained by the irradiation of the depleted-mode dosemeters can be fitted only by a power low equation their response is sub-linear for low energy protons and linear for higher energy protons.

Results from irradiation by 30 MeV protons



$\Delta V_T = (\mathbf{0.53} \pm 0.03) \bullet \mathbf{D}^{\mathbf{0.40}\ \pm 0.02}$ $(R^2 = 99.9\ \%)$

Results from irradiation by 235 MeV protons



$\Delta V_T = (\mathbf{0.18} \pm 0.04) \bullet \mathbf{D}^{\mathbf{0.94}\ \pm 0.04}$ $(R^2 = 99.8\ \%)$

Response of the single Depleted-mode p-MOSFET dosemeters

Proton energy (MeV)	Response Without LiF	b parameter
30	0.53 ± 0.03 mV/mGy	0.4 ± 0.02
235	0.18 ± 0.04 mV/mGy	0.94 ± 0.04

Response of the enhancement and depleted p-MOSFET mode

Proton energy (MeV)	Response (enhancement MOSFET) mV/mGy
70	0.0658 ± 0.0065
40	0.1067 ± 0.0018

In both devices mode the response is increasing with the decrease of the proton energy

Proton energy (MeV)	Response (depleted MOSFET) mV/mGy
235	0.18 ± 0.04
30	0.53 ± 0.03

The depleted p-MOSFET dosemeters seems to present higher response than that of the enhancement p-MOSFET

Dose estimation for **blind** experiments

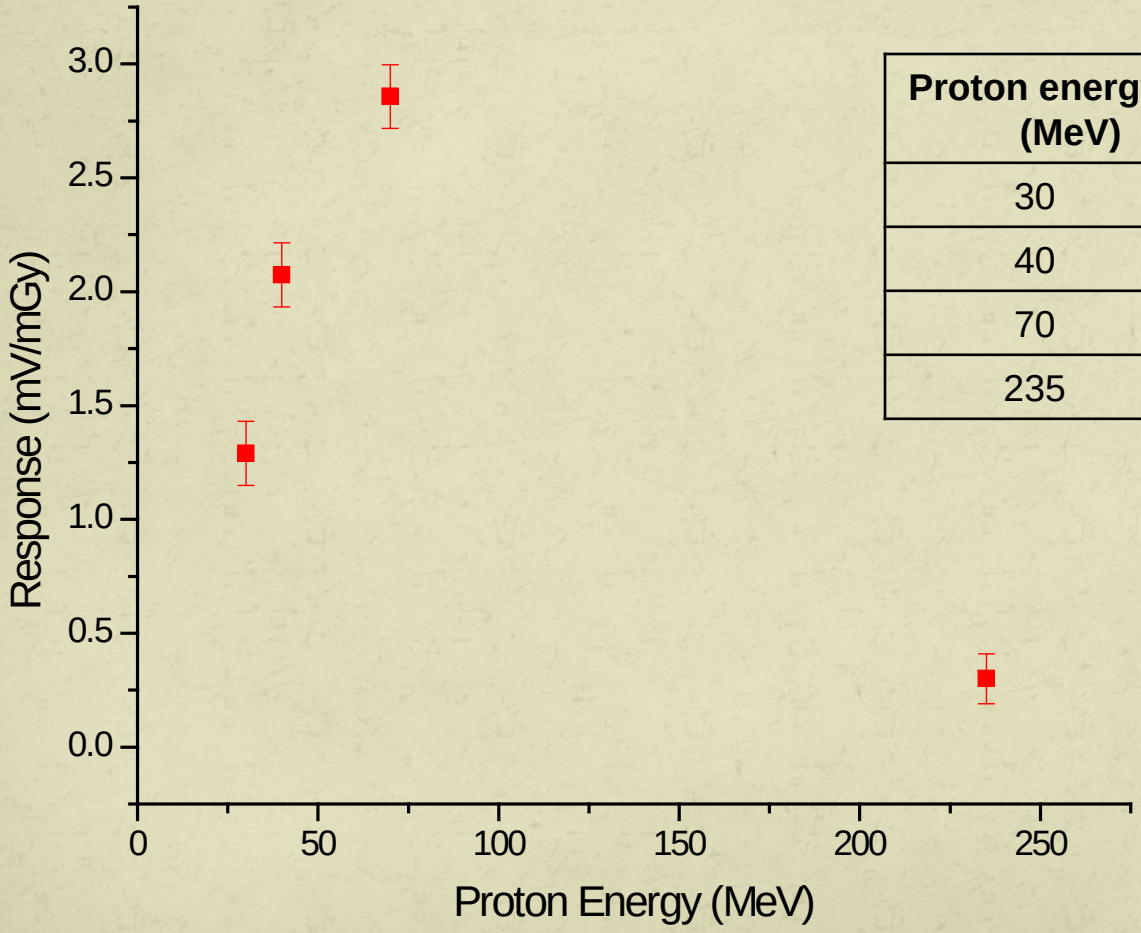
According to the response calculations the dose estimations of blinds irradiations are presented in the following table.

Blinds	**Proton 30 MeV**	**Proton 235 MeV**
No. 1	78 ± 15 mGy	
No. 2	500 ± 70 mGy	25 ± 5 mGy
No. 3		96 ± 14 mGy

Response of the **depleted** p-MOSFET mode with and without LiF converter

Proton energy (MeV)	**Response (without LiF) mV/mGy**	**Response (with LiF) mV/mGy**
235	0.18 ± 0.04	0.19 ± 0.02 mV/mGy
30	0.53 ± 0.03	0.11 ± 0.05 mV/mGy

Response of the stack of depleted-mode dosemeters



Proton energy (MeV)	Response of stack With LiF
30	1.29 ± 0.14 mV/mGy
40	2.074 ± 0.14 mV/mGy
70	2.857 ± 0.14 mV/mGy
235	0.30 ± 0.11 mV/mGy

Conclusion

- The depleted type p-MOSFET dosemeters present higher response than that of the enhancement p-MOSFET irradiated at the previous ICCHIBAN experiment (about 5 times higher).

- The response of these dosemeters is about one order of magnitude higher than the response of the MOSFETs dosemeters presented in literature, which are enhancement type MOSFETs.

- This response can be increased even more, about one order of magnitude, if a stack of 2 identical depleted p-MOSFETS dosemeters is used.

- For low energies the response of the depleted dosemeters as a function of the dose is sub-linear while at higher energies is almost linear. This is in agreement with the results presented in literature, but in contrary with the results obtained during the previous irradiation of the enhancement p-MOSFET in which the response curve was found to be linear.