# Status of Radiation Monitor Studies

## Progress on the characterization of “on-line” dosimeters for CMS

Ravotti Federico EST-LEA CMS

# Outline …

→ CMS requirements;
→ Status until December 2002;

- RadFETs dosimeters:
  - → Last test-beam data analysis;
  - → Calibration suitable for CMS environment;
  - → Progress on instabilities studies;
- New types of on-line devices for Radiation Monitoring:
  - → OSL's
  - → OSRAM *pin*-diodes
- Conclusions & Future works

# CMS Requirements

→ Mixed radiation environment;
→ Different for each sub detector;
→ Spread requirements in terms of Sensitivity and Dynamic range:

## Requirements for radiation monitoring

- Fluence Range: *$1 \times 10^{9} \div 1 \times 10^{14}$ particle/cm$^2$*
- Fluence Sensitivity Required: *$10^{8} \div 10^{11}$ particle/cm$^2$*

- Dose Range: *$10^{-1} \div 10^{4}$ Gy*
- Dose Sensitivity Required: *$10^{-4} \div 10^{2}$ Gy*

*Values foreseen over 1 year lifetime from simulations*

# *Situation at the end of year 2002 (1)*

Several test-beam proved the feasibility of a system based on:

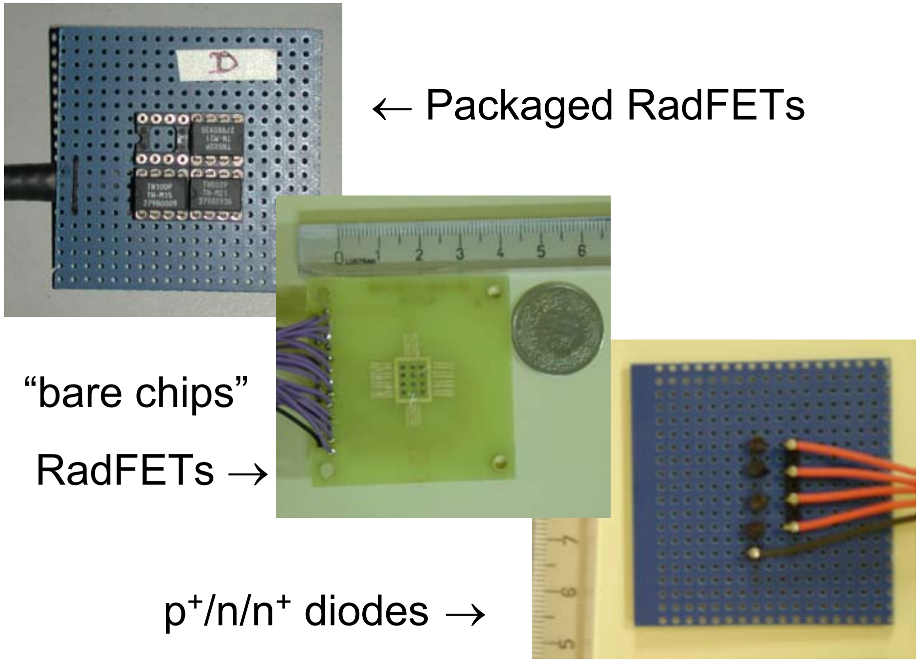
– RadFETs → deposed dose measurement (build-up of charge into $SiO_2$ MOS oxide)

– $p^+/n/n^+$ diodes → particle fluence measurement (bulk damage into n-Si base)

Devices to perform on-line measurements of integrated fluence and dose.

They need to be biased only during readout.

Different types of RadFETs and one type of diodes were tested.



# Situation at the end of year 2002 (2)

– RadFETs

- wide dynamic range (< 70 kGy)
- "low" sensitivity 0.1 Gy (max 0.01 Gy)
- Neutron response to understand (packaging ?)
- Particle dependent (not linear) response:
  - → Calibration (γ response ?)
- Instabilities:
  - → annealing of the trapped charge (interface state ?)

– $p^+/n/n^+$ diodes

- very low dynamic range ($\leq 10^{12}$ p/cm$^2$)
- high sensitivity (~ $10^8$ p/cm$^2$)
- Linear response
- Annealing not verified

# Outline …

→ CMS requirements;
→ Status until december 2002;

- RadFETs dosimeters:
  → Last test-beam data analysis;
  → Calibration suitable for CMS environment;
  → Progress on instabilities studies;

- New types of on-line devices for Radiation Monitoring:
  → OSL's
  → OSRAM *pin*-diodes

- Conclusions & Future works

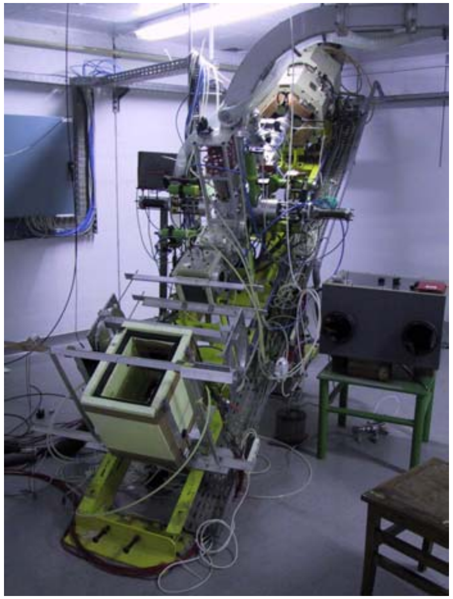
# *Last RadFETs test beam 1*

## 20 MeV n IRRADIATION

@ UCL T2 Neutron Beam (Louvain,BE)

50 MeV of primary deuteron beam on a beryllium target:

$^{9}Be\ (d,n)\ ^{x}X$



$1.96 \times 10^{13}$ n $cm^{-2}\ h^{-1}$ on 3 cm radius beam with ~ 2 % of $\gamma$ contamination

## $^{137}Cs\ \gamma$ IRRADIATION

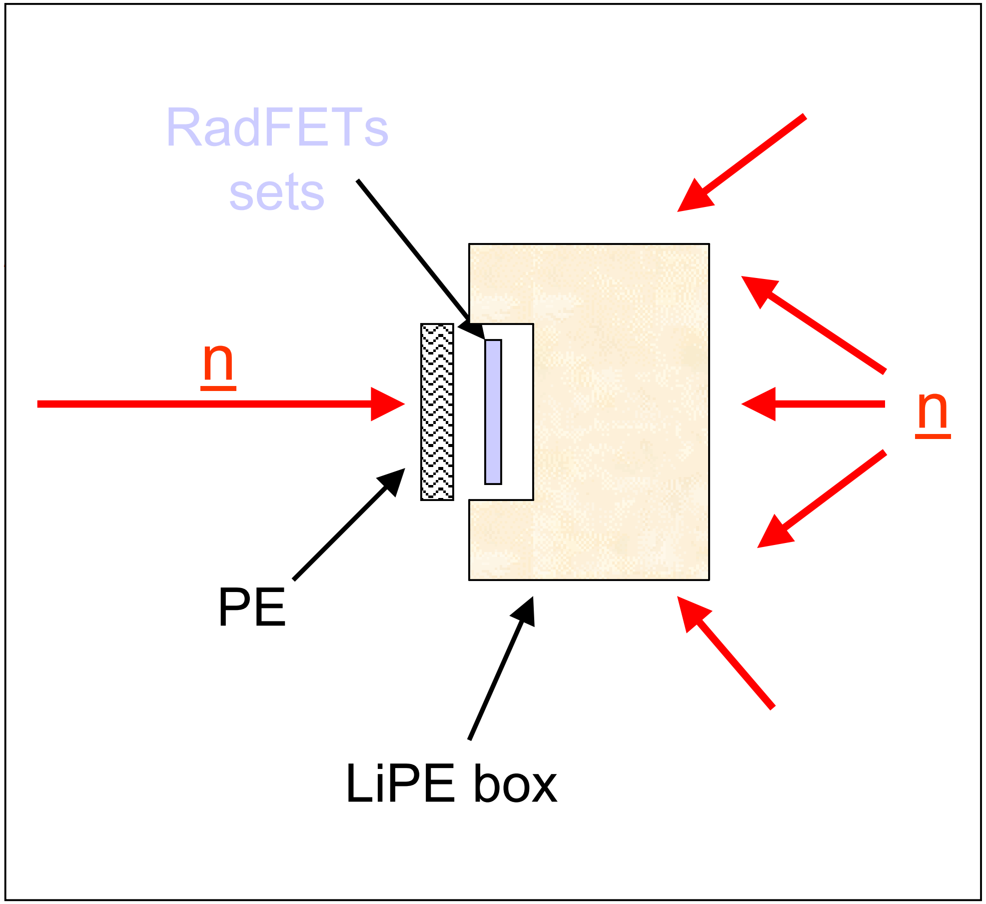
@ CERN Gamma Irradiation Facility

740 $GBq^{(1997)}$ of $^{137}Cs$

662 KeV photons in the second irradiation area

# *Last RadFETs test beam 2*

## 20 MeV n IRRADIATION – General




### Aim of the test

Understand the RadFETs neutron response and device's package influence.

### Devices used

– 1 set of bare RadFETs chips.

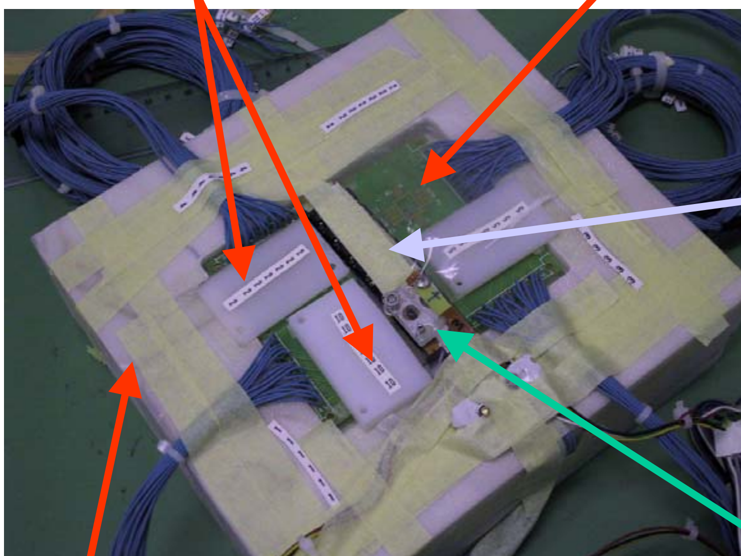
– 3 sets covered with different PE thickness (2,5,10 mm).

# Last RadFETs test beam 3

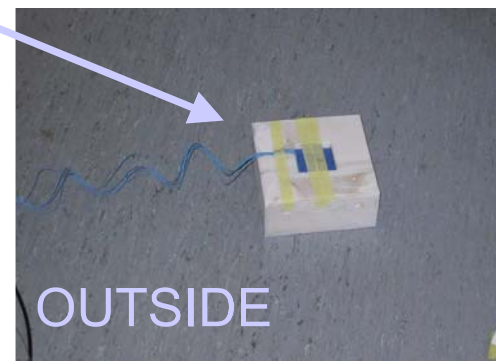
## 20 MeV n IRRADIATION – Setup

covered chips

bare chips



2 sets of dosimeter placed inside and outside the beam to evaluate the contamination → ~ 2%




LiPE box to moderate and capture the scattered neutrons via $^{6}Li(n,\alpha)^{3}H$ and no $\gamma$ emission.

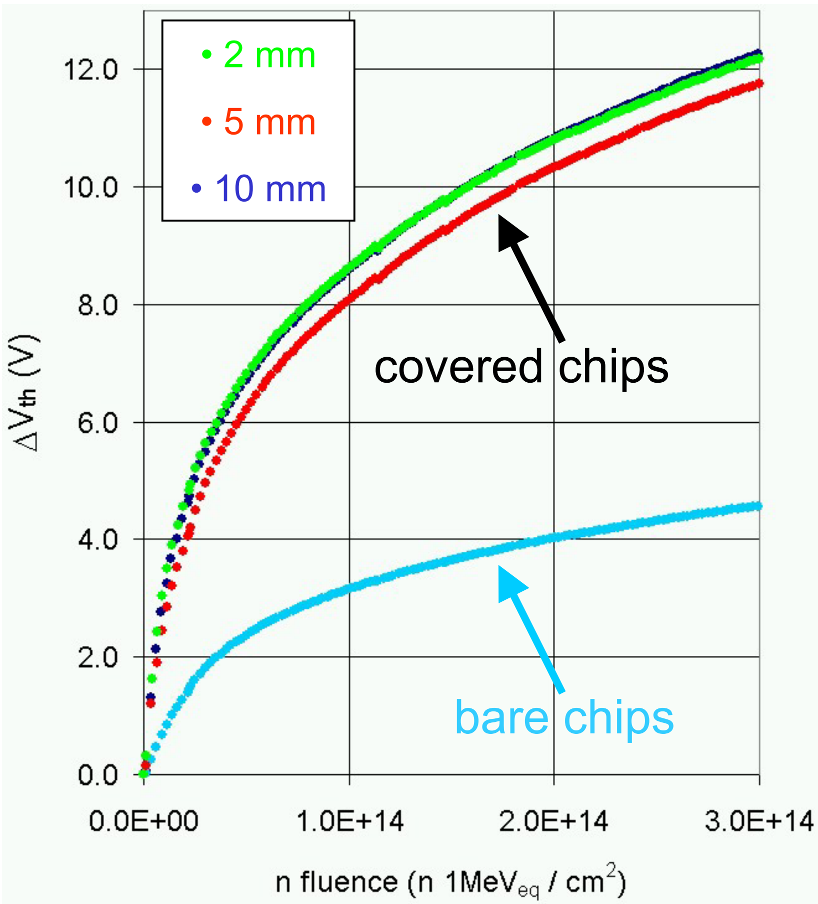
New-type flexible RadFETs

– chip mounted on thin / flexible kapton carrier

– a couple of chip were tested (bare and covered)

# Last RadFETs test beam 4

## 20 MeV n IRRADIATION – Ongoing Analysis 1



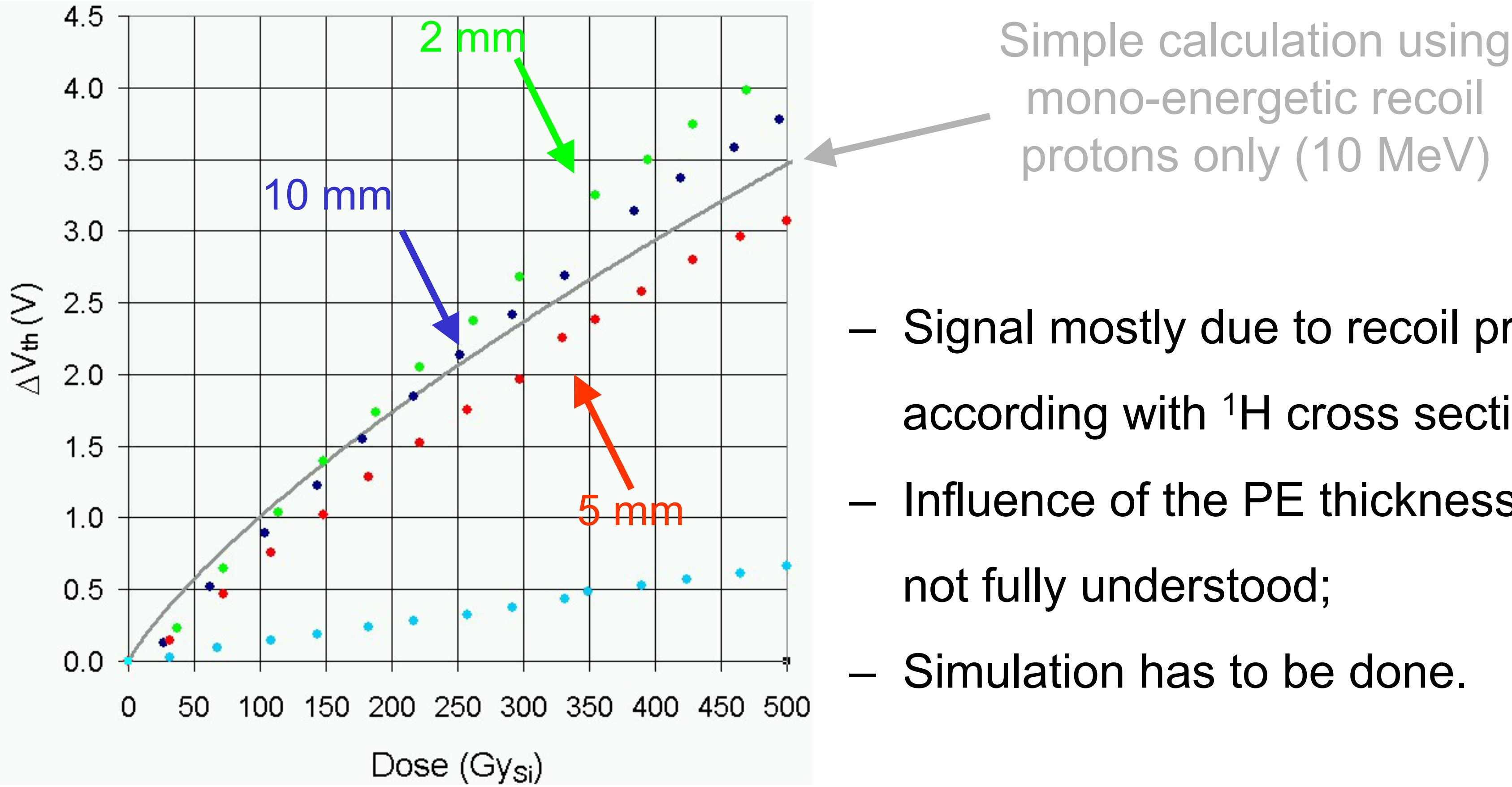

The signal of covered devices is about 3 times higher than the bare ones

→ strong package influence verified!

→ *influence of "Bulk damage" in Si layer will be investigated.*

# Last RadFETs test beam 5

## 20 MeV n IRRADIATION – Ongoing Analysis 2



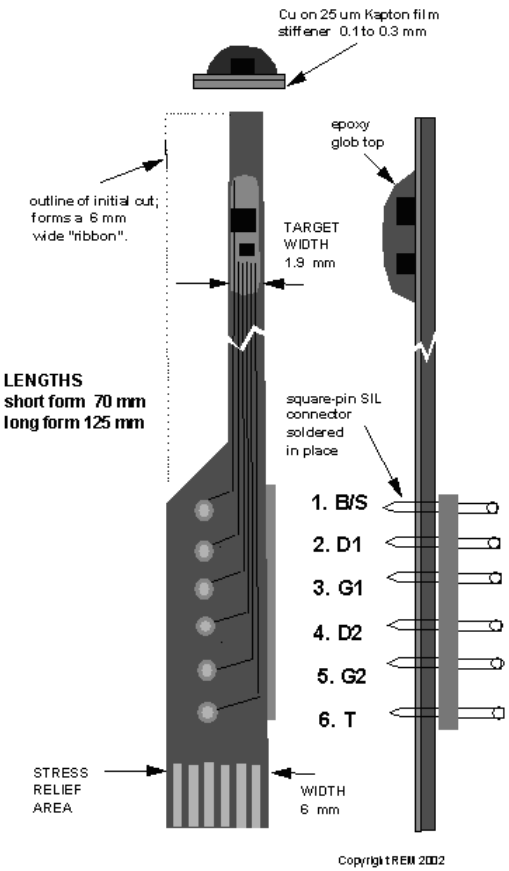

– Signal mostly due to recoil protons according with $^{1}H$ cross section;

– Influence of the PE thickness ⇒ not fully understood;

– Simulation has to be done.

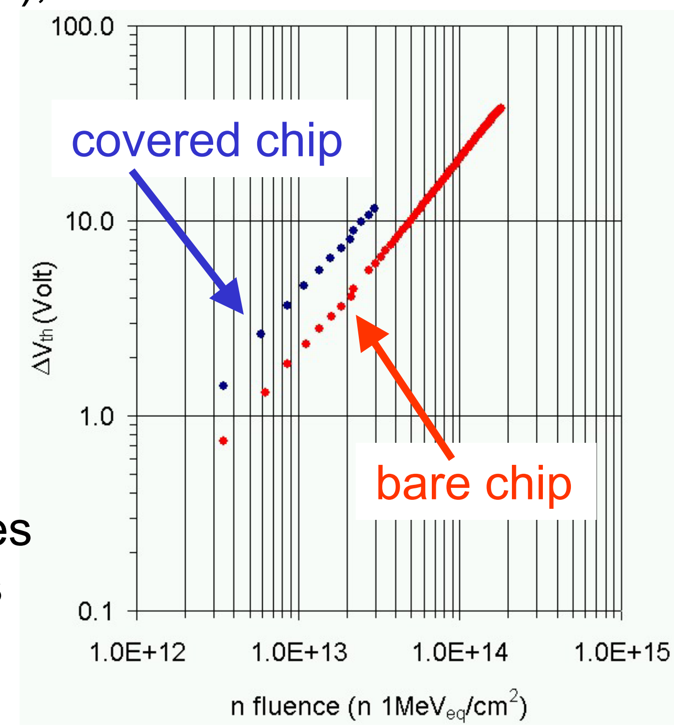
# Last RadFETs test beam 6

## 20 MeV n IRRADIATION – Ongoing Analysis 3



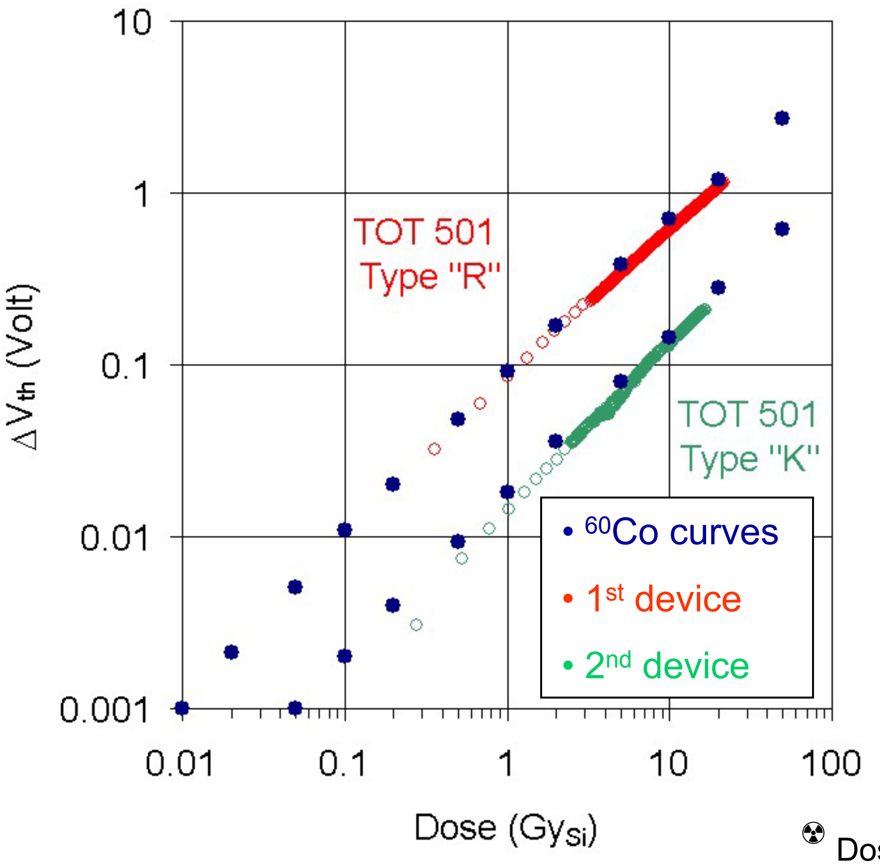

1. New chip carrier & oxide thickness (new sensitivities);
2. The devices were easy to install and provide good responses;
3. 6 mm of PMMA placed in front (covered chip) and behind (bare chip) the sensors;
4. Factor two in the responses coherent with the previous data.

Response of covered chip 2 times higher!



# Last RadFETs test beam 7

## $^{137}Cs$ γ IRRADIATION




Aim of the test → compare the usual γ calibration of RadFETs with particle responses

"parasitic use" → source available only for the 25% of the beam-time (Max. Dose < 20 Gy ☢)

Comparison with particle responses measured in the past NOT POSSIBLE (too low total dose)

Agreement with $^{60}Co$ data from producers

VERY GOOD

☢ Dose measurement with a calibrated ionization chamber by TIS-RP

# *Outline …*

→ CMS requirements;
→ Status until december 2002;

- RadFETs dosimeters:
  → Last test-beam data analysis;
  → Calibration suitable for CMS environment;
  → Progress on instabilities studies;

- New types of on-line devices for Radiation Monitoring:
  → OSL's
  → OSRAM *pin*-diodes

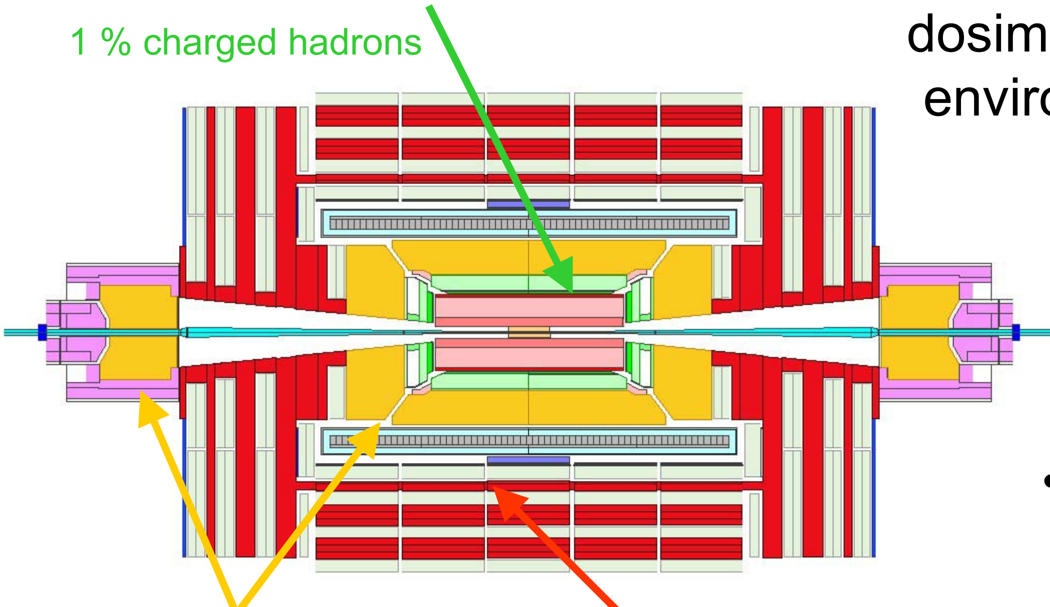
- Conclusions & Future works

# RadFETs calibration in CMS 1

ECAL+Preshower

85 % neutrons 14 % gammas

1 % charged hadrons



HCAL+HF

99 % neutrons

1 % charged hadrons

MUON

70 % neutrons

29 % gammas

1 % charged hadrons

Particle dependent response → the dosimeters have to be calibrated in an environment “similar” to the real one.

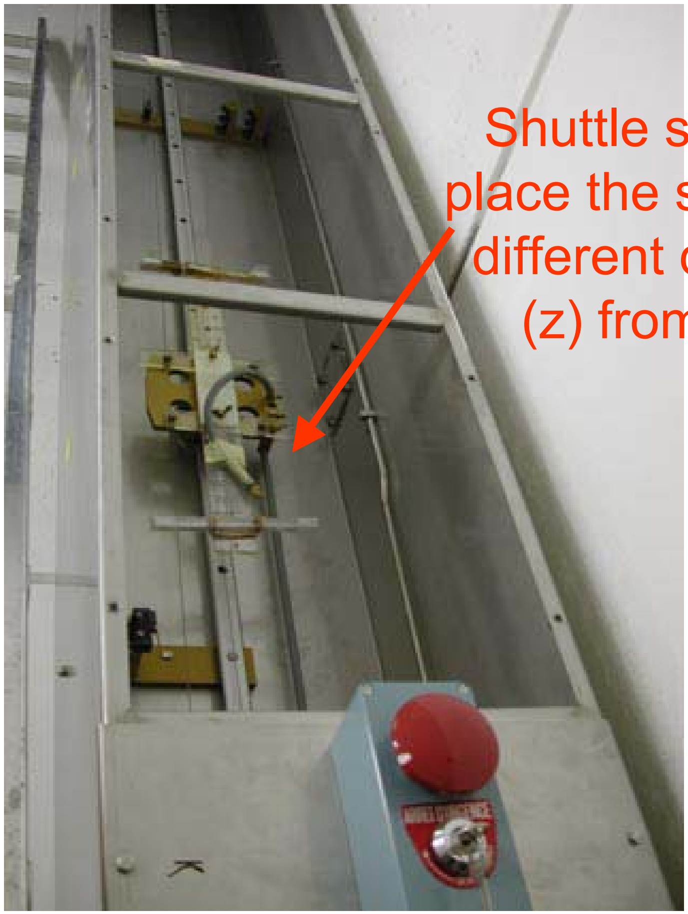
⇓ ⇓ ⇓

CERN PS IRRAD2 Facility

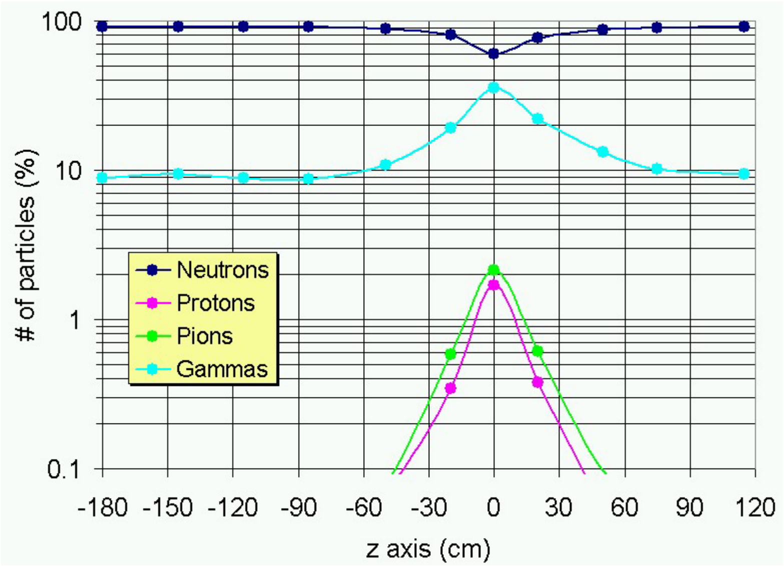
- Mixed neutron environment
  (secondary particle from target)

- CMS-like spectrum:
  - broad n spectrum (max 1 MeV)
  - broad $\gamma$ spectrum (> 100 keV, max 1 MeV)
  - charged hadrons contribution (~ 1 GeV)

# RadFETs calibration in CMS 2




After Maurice Glaser




- Deposed dose known by FLUKA simulations;
- Optimization of the calibration for the different CMS sub-detectors;
- Possibility to perform comparative tests

# Outline …

→ CMS requirements;
→ Status until december 2002;

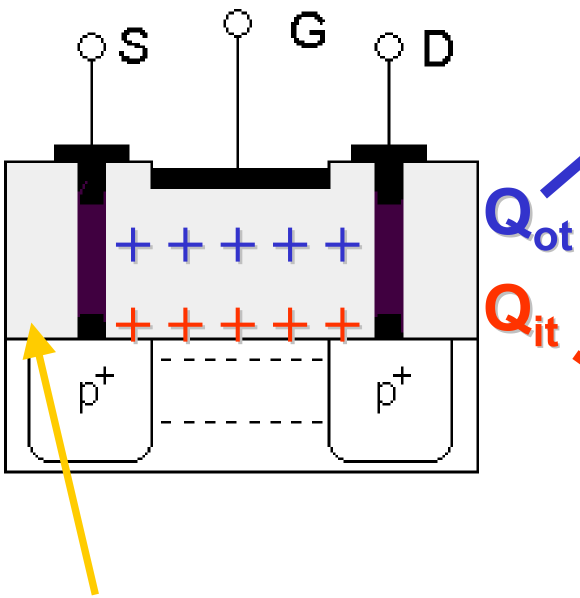
- RadFETs dosimeters:
  → Last test-beam data analysis;
  → Calibration suitable for CMS environment;
  → Progress on instabilities studies;

- New types of on-line devices for Radiation Monitoring:
  → OSL's
  → OSRAM *pin*-diodes

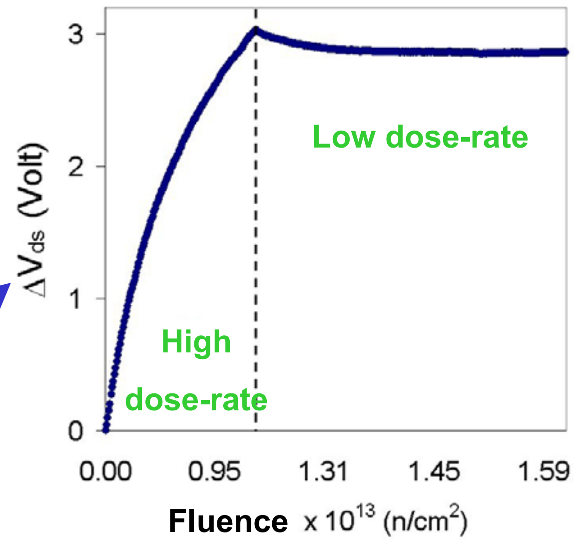
- Conclusions & Future works

# RadFETs instabilities 1

RadFETs Structure




Sensitive volume of the device: $SiO_2$




The high annealing of oxide trapped charges was bigger than the charge build-up inside the oxide itself.

("Instantaneous" effects)

Studied Phenomenon

During the life of the device under irradiation, interfaces states can be generated ⇒ The response of the device can change especially at low dose-rate! (delayed effect)

Not-studied Phenomenon!

# RadFETs instabilities 2

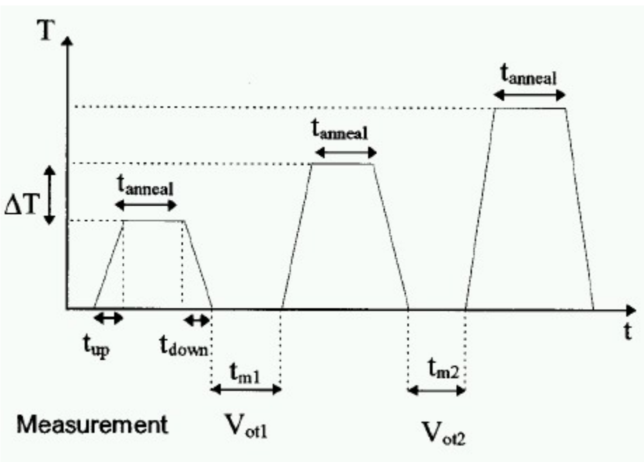
A methods to evaluate the quality of the whole Silicon Dioxide already exists:

ISOCHRONAL ANNEALING

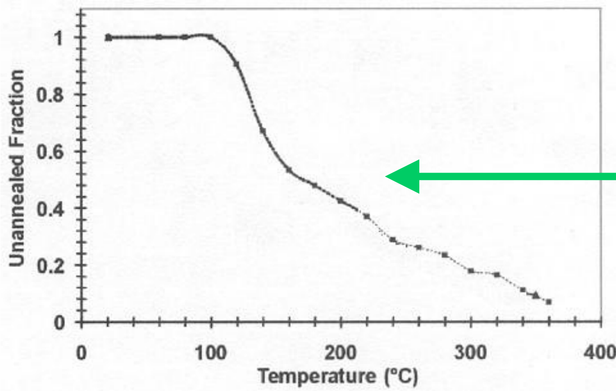
Accelerated characterization methods that predict in a short time the device long term behavior.

After Irradiation, brief annealing periods at increasing T

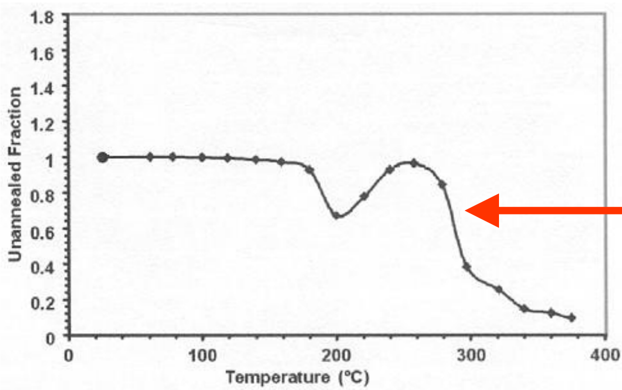
Parameters have to be chose according with the expected use of the device.




*Just an example …*




degradation is dominated by a regular oxide charge trapping process




risk of delayed effects due to interface trapped charge

After Laurent Dusseau

# Outline …

→ CMS requirements;
→ Status until december 2002;

- RadFETs dosimeters:
  → Last test-beam data analysis;
  → Calibration suitable for CMS environment;
  → Progress on instabilities studies;

- New types of on-line devices for Radiation Monitoring:
  → OSL's
  → OSRAM *pin*-diodes

- Conclusions & Future works

# *New types of on-line dosimeters*

1. RadFETs and $p^+/n/n^+$ diodes can satisfy most of the requirements, but don't match all sensitivities and dynamic ranges required from CMS sub-detectors;

2. The "sensibility" in mixed radiation environment of RadFETs silicon oxide, suggest to have an independent way to measure the deposed dose (for example to cross-check the data in critical locations).

↓ **OSL**

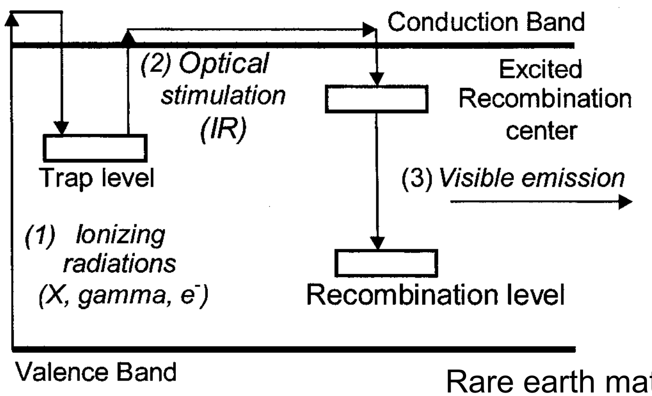
Optically Stimulated Luminescence

(dose measurement)

↓ **Osram p-i-n diodes**

(fluence measurement)

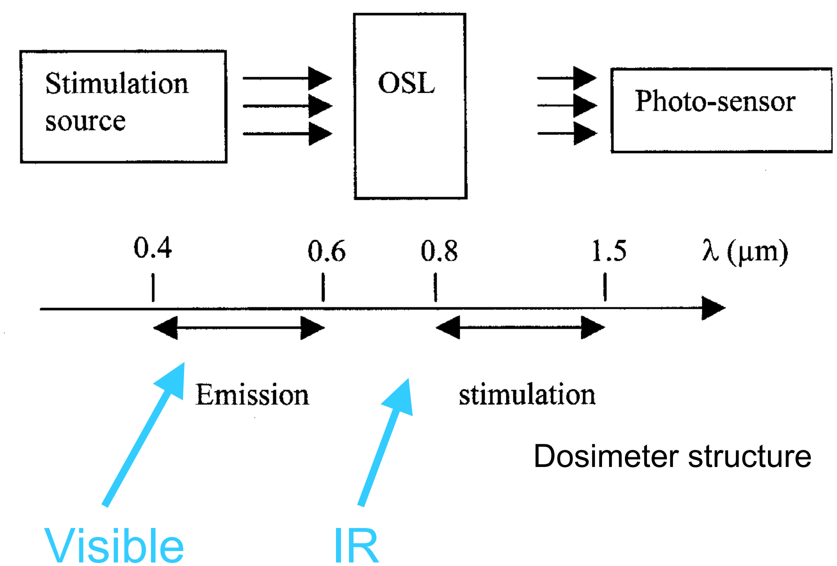
# OSL for on-line dosimetry - General




Rare earth material doped with alkaline sulfides

## WRITING …

During irradiation, secondary electrons can be trapped and the information about the irradiation is so memorized.




Dosimeter structure

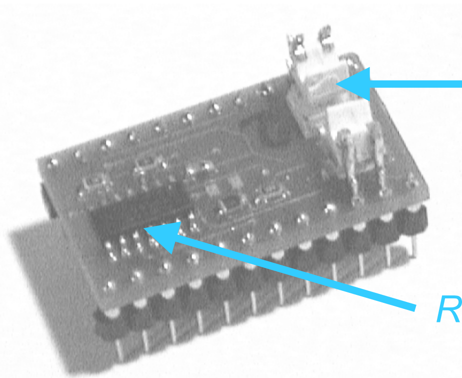
After Laurent Dusseau

## READING …

With IR stimulation the electrons are detrapped and a visible light is emitted.

- Dosimetric parameter → visible light linear with dose delivered to material.
- After the reading the material is completely reset and can reused as new.

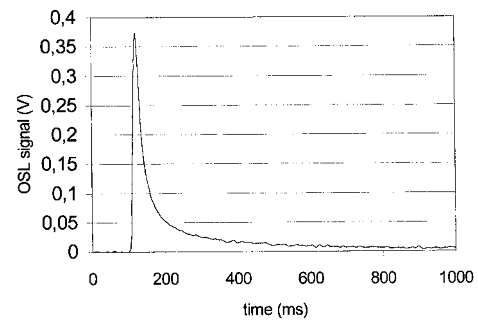
# OSL for on-line dosimetry – Sensors 1



*Sensor Cell: OSL sandwiched between LED and photodiode*

*Readout circuits*

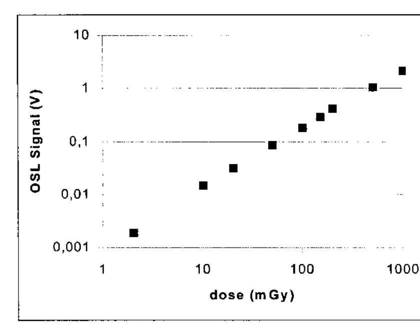
- A sensor prototype already exist;
- Sensor + readout circuit + feedback loop to control the current on the LED on PCB;




*Shape of the OSL signal: the amplitude is proportional to the absorbed dose.*

- linear response up to 400 Gy;
- very high sensitivity (max 100 μGy);
- no fading (few hours after exp.);
- particle independent response;
- characterized for LEP and photons;
- need to be studied for HEP and neutron response.

*An example of calibration curve: High linearity on the response.*

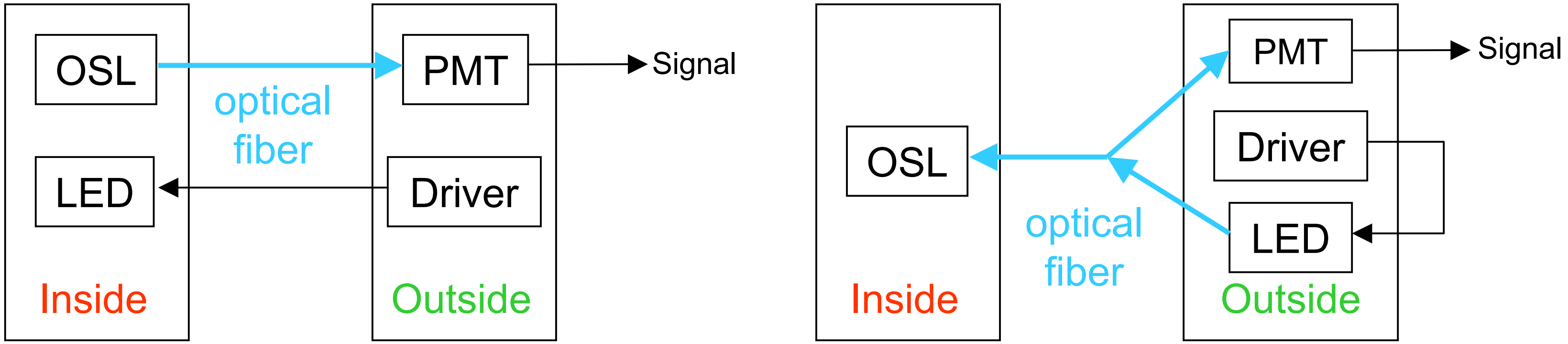



After L. Dusseau

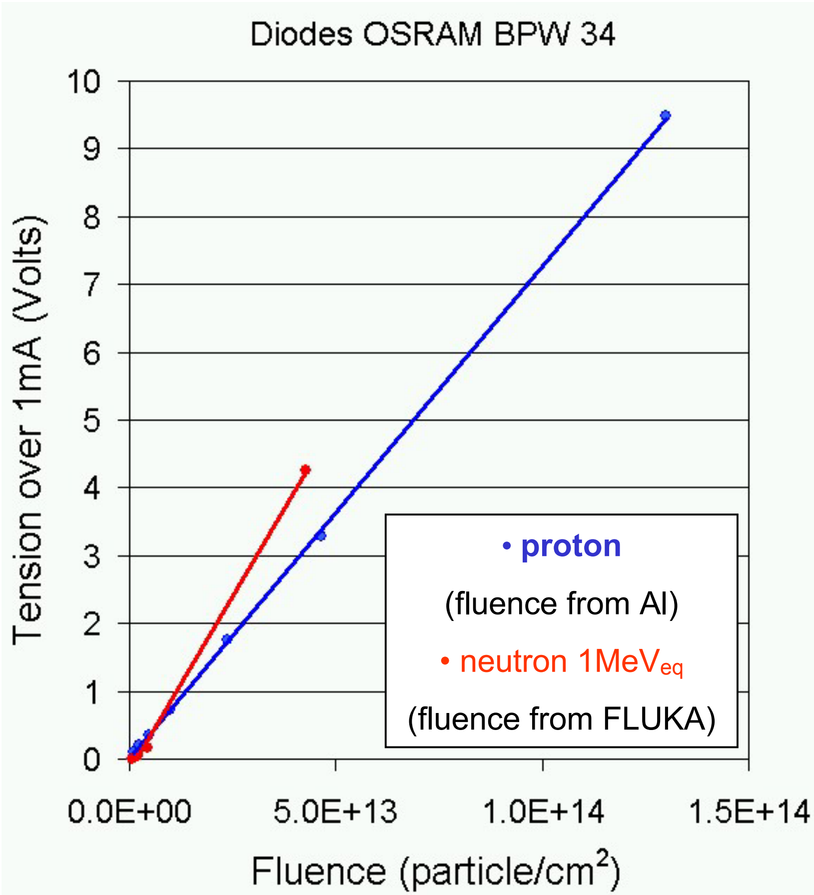
# OSL for on-line dosimetry – Sensors 2

- Low dimensions and power consumption;
- Sensitivity and dynamic range can managed by changing the readout frequency;
- The readout electronic can be placed outside the experiment:

→ This will reduce space and avoid NIEL problems in LED/photodiodes.



# OSRAM p-i-n diodes




After Maurice Glaser

- Devices not designed for dosimetric purposes;
- Already tested at CERN in the past;
- Measurement of forward voltage (direct bias);
- Seems to have linear behaviour under irradiation;
- They reach high fluences (> $10^{14}$ part/cm$^2$);
- The reproducibility of the measurement has to be tested;
- NIEL scaling has to be checked;
- Very cheap devices!

# Conclusions & Future works

1. RadFETs dosimeters:
   - Verified packaging influence in neutron environment;
   - Calibration problem & new "ready to use" devices:
     → more test beam in IRRAD2 facility;
   - Instability studies: worried about device long term behavior;
     → Isochronal annealing study has to be continued (new supplier).
2. OSL dosimeters:
   - Allow us to fully satisfy CMS requests in terms of dose measurements:
     → Fully characterization in HEP (IRRAD1) and mixed-neutron field (IRRAD2 / TCC2);
     → Construction of a bench-test to measure the dosimeters at CERN;
3. OSRAM p-i-n diodes:
   - Can help to cover CMS requirements about fluence measurements:
     → characterization in different beams and data comparison have to be continued.