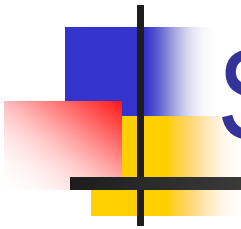


Solid-State Radiation Sensors

Federico Ravotti
TS-LEA-RAD

Maurice Glaser, Michael Moll
PH-DT2-SD

Outline

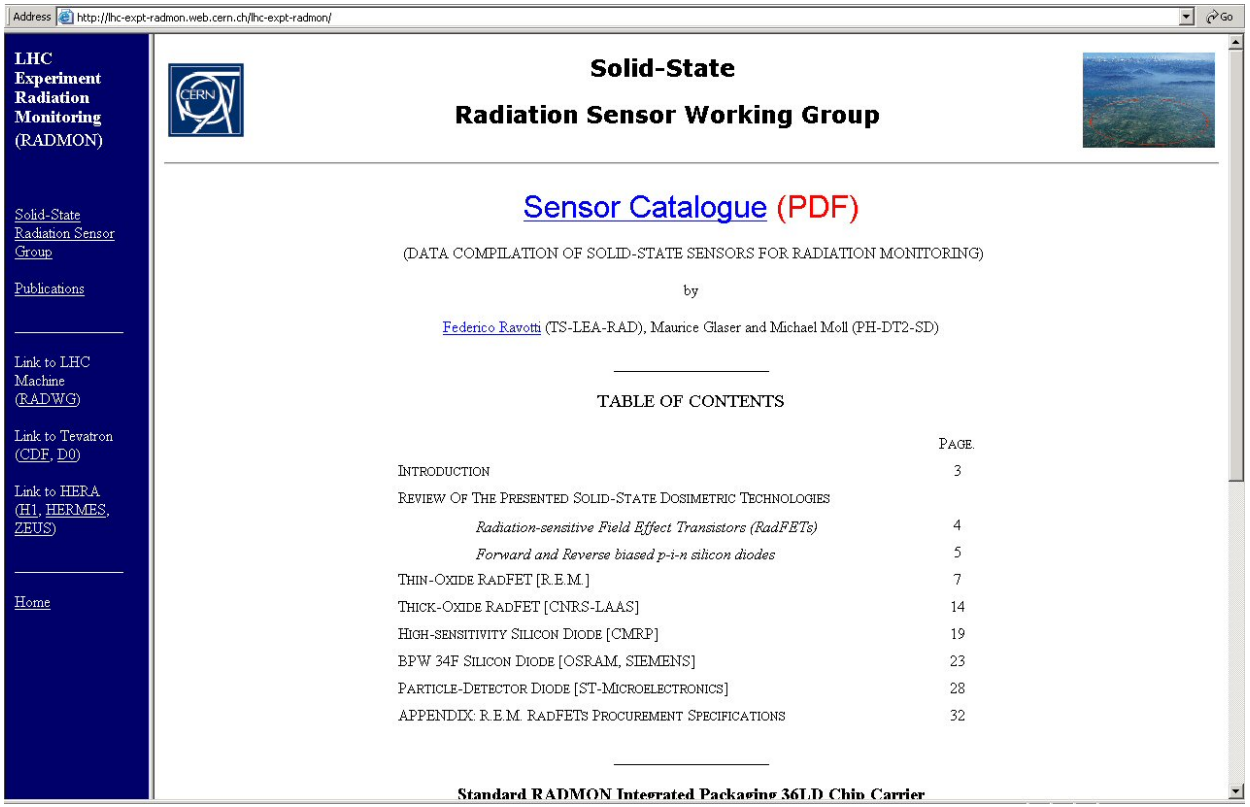
- Introduction;
- “Sensor Catalogue”;
- Dose Sensors (RadFETs);
- Fluence Sensors (p-i-n and detector diodes);
- Readout Circuitry;
- Integration Issues in the Experiments;
- Conclusions.

Introduction

- TS-LEA and PH-DT2 have characterized a set of sensors for IEL (Dose) and NIEL (Φ_{eq}) measurement;
- Sensors suited for the LHC experiments environment;
- *"Sensor Catalogue"* published in March 2005;
- R&D on sensors is ongoing: OSL, n_{th} sensors, …
- Integration into the experiments and their readout is not our responsibility!

Sensor Catalogue

http://cern.ch/lhc-expt-radmon/



Publication list, minutes of the meetings, and other informations available also through the same web-page ...

RadFETs Selection Procedure

NINE types of sensors investigated

Response to "single" fields → Response to some particle fields and at high doses were missing in literature!

SiO_2 "quality" evaluation (Annealing Studies) ← Accelerated procedure based on the scaling annealing *t* ⇔ annealing T

Response at Low Dose-Rate in Mixed Environment

Packaging Studies → *Still ongoing for validation purposes using GEANT4*

TWO types recommended for LHC expt. purposes !

RadFETs QA Procedure

Acceptance Tests

Issue for TID Measurement (RadFETs Packaging)

Electrical Tests on the purchased sensor batches to complies with specifications

Mounting bare-die sensors in a proper "CERN" packaging

Functional Verification Test

Integration in a specific PCB circuit "sensor carrier"

Functional Verification Test

For the Experiments with proper readout boards

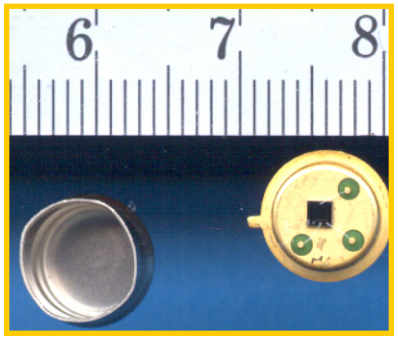
For the Experiments that need a readout board

Delivery to the LHC Experiments

TID (Dose) Sensors

RadFETs: Charge built-up in SiO_2 → V_{th} shift proportional to dose

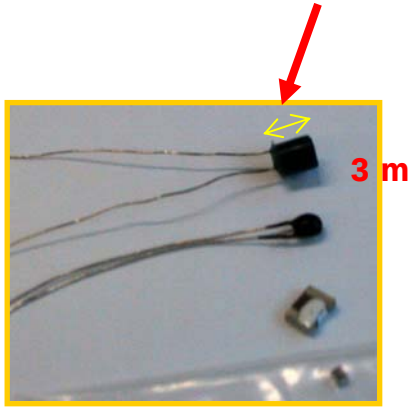
- Thin-Oxide RadFET dies (0.13-0.25 μm):
  - "low" sensitivity (0.1 Gy) – high dynamic range (~ 100 kGy);
  - Minimize SiO_2 recombination effects → mixed-LET particle fields;
  - Suited for dosimetry in inner-detector regions;



- Thick-Oxide RadFET dies (1.6 μm):
  - "high" sensitivity (mGy) – low dynamic range (~ 10 Gy);
  - Measurement in "conventional" (γ + n) radiation fields.
  - Suited for dosimetry in outer-detector regions;

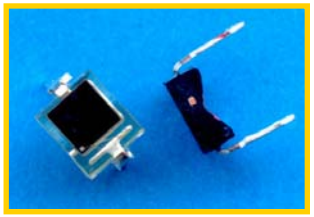
Φ_{eq} (Fluence) Sensors

p-i-n diodes: Bulk damage in Si base → V_F shift proportional to fluence

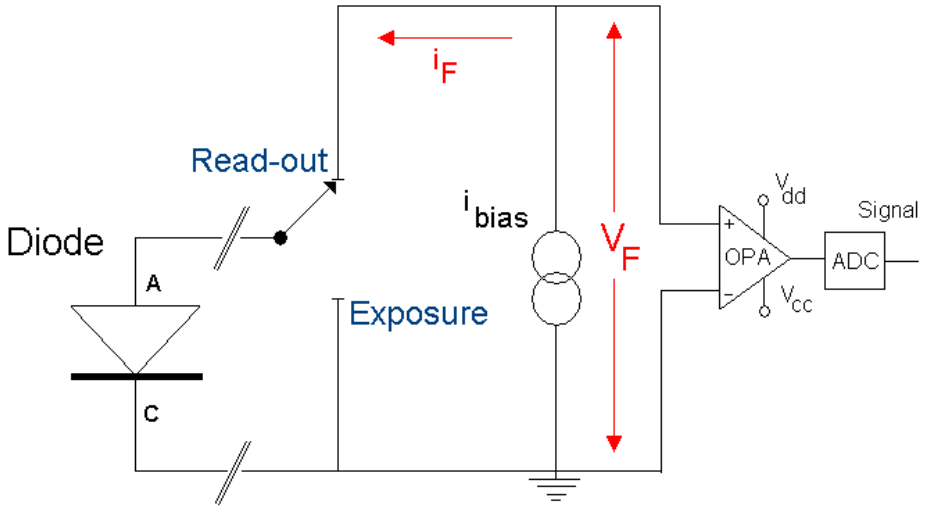


- High-Sensitivity diodes:
  - Range: $\Phi_{eq} < 2x10^{12}$ cm^{-2}; Sensitivity: ~ $2x10^{8}$ cm^{-2}/mV;
  - Packaged or Si Crystal (~ 1 mm^3) for wire-bonding;

- Low-Sensitivity diodes:
  - Range: $2x10^{12}$ to $4x10^{14}$ cm^{-2}; Sensitivity: ~ $8x10^{9}$ cm^{-2}/mV;
  - Commercial Packaging (~ 5 mm^2), no other choices!



Φ_{eq} and TID Readout

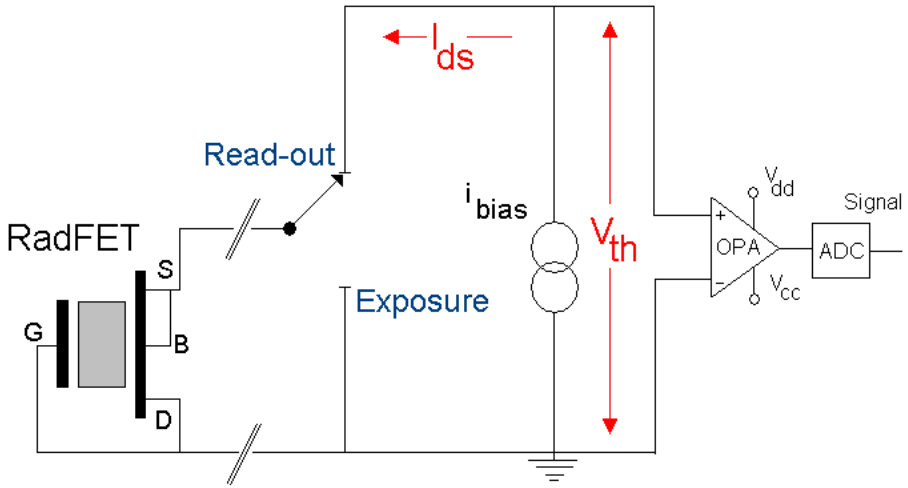


- Currents: 100 μA to 200 μA;
- Time: 5 sec (optimum),

  1 sec (minimum).

- Currents: 1 mA to 25 mA;
- Time: 50 ms (optimum),

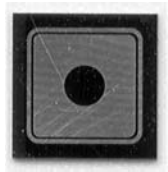
  200 ms (maximum).

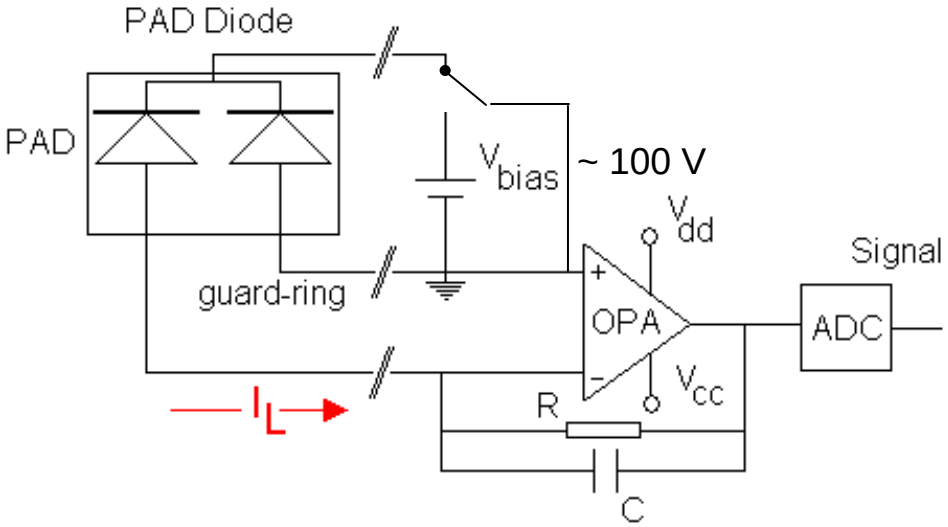


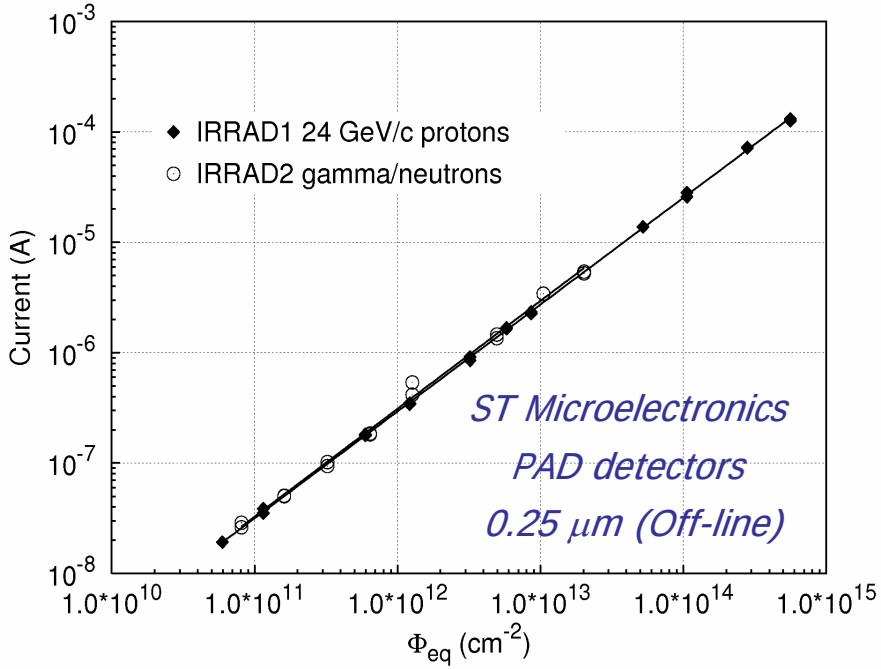
Φ_{eq} (Fluence) Sensors

Detector diodes: Bulk damage in Si base → I_L shift proportional to fluence

- Particle Detector diodes (300 μm):
  - Range: $1x10^{11}$ to $5x10^{14}$ cm^{-2}; Sensitivity: ~ $4x10^{9}$ cm^{-2}/nA;
  - some samples (7 mm^2) on stock.
  - More complicate readout!

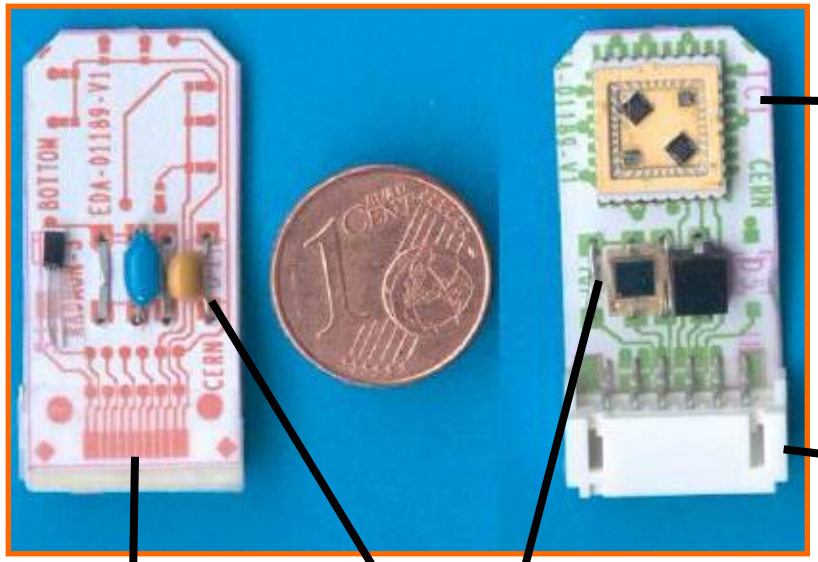


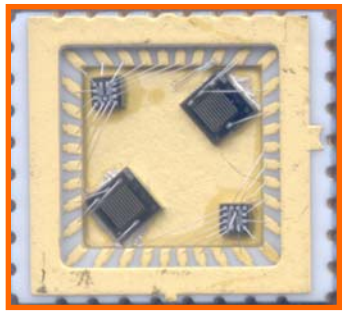




Integration Issues 1/2

about 30 x 15 x 5 mm PCB





TID sensors Package: Integration of several devices!

The TID sensors can be strongly affected by the surrounding materials

standard connector

RADMON BOARD (up to 11 sensors)

Soldering contacts

Φ_{eq} Sensors covering 2 dynamic ranges!

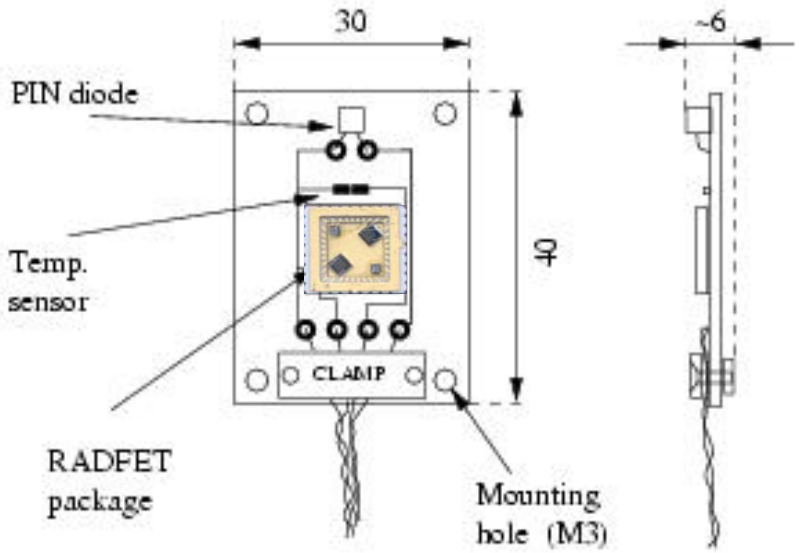
+

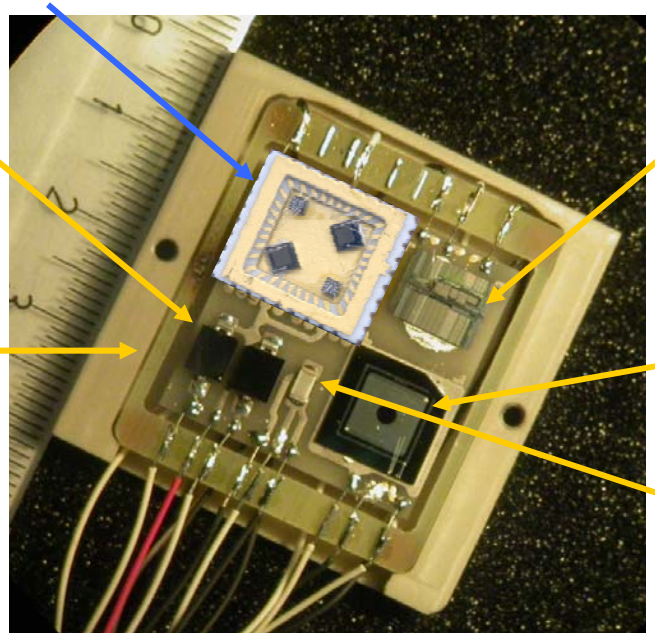
Temperature sensor

The sensors PCB can be integrated in "on-line" data acquisition systems but can be also removed and used in "off-line" mode on a laboratory test bench.

Integration Issues 2/2

ATLAS ID
(RMSB Hybrid)

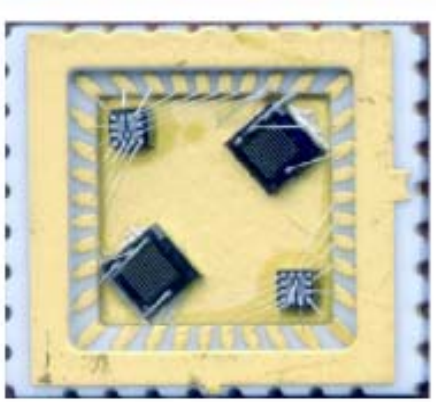




[I. Mandic, JSI]

Rest of
ATLAS

Package Geometry

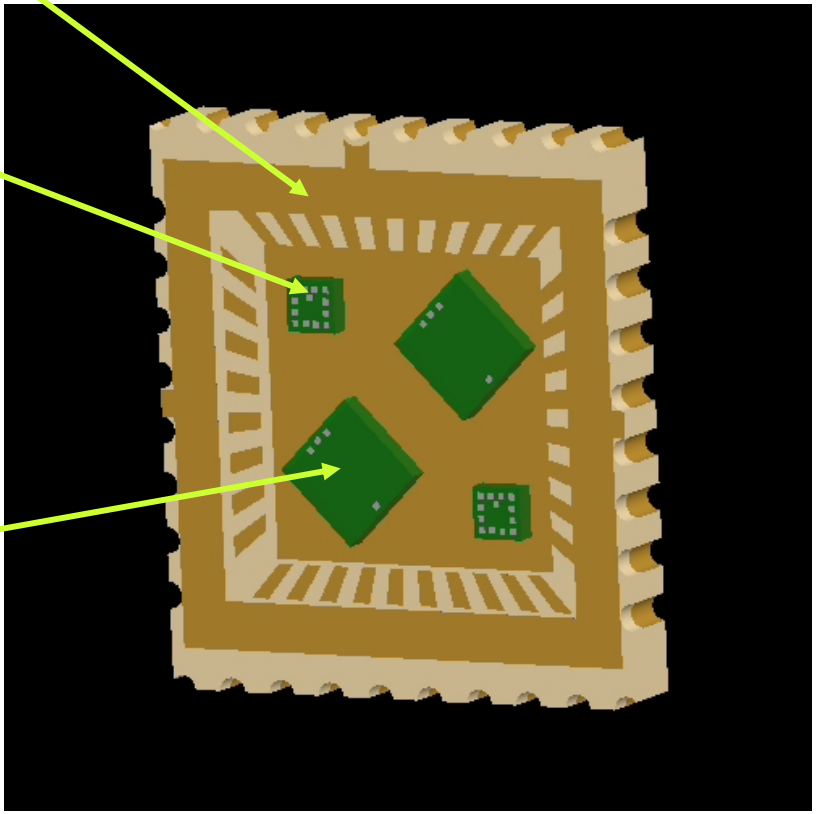


Packaging

REM-TOT-500

LAAS

Geant4 simulation



The full geometry has been designed and implemented in detail in the Geant4 simulation.

First Comparison Simulations vs. Experiments presented at CHEP06 in February 2006.

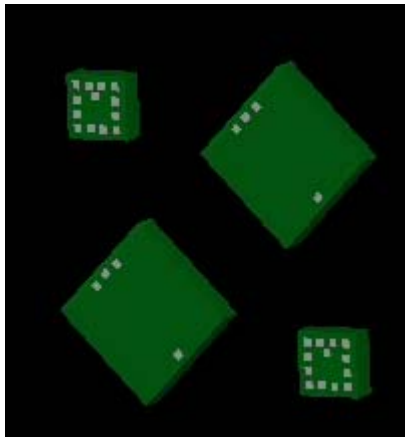
R. Capra, S. Guatelli, M. G. Pia - INFN Genova, Italy

Study of Packaging Effects

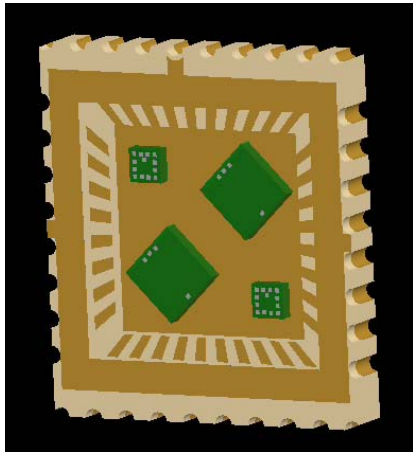
R. Capra, S. Guatelli, M. G. Pia - INFN Genova, Italy

- Experimental test
  - 254 MeV proton beam;
  - various configurations: with/without packaging, different covers;
  - dose in the 4 chips;
- Simulation
  - same set-up as in the experimental test (for validation);
  - also predictive evaluations in other conditions.

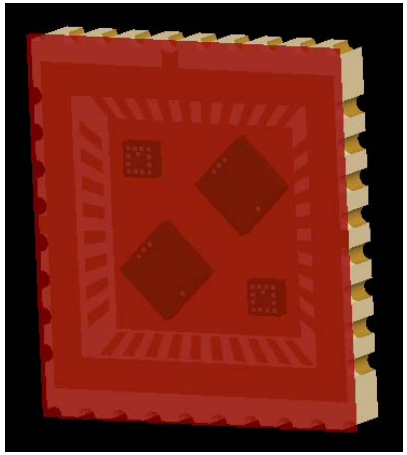
No packaging



With packaging



With a ceramic or FR4 lid



Conclusions

- A set of sensors for the radiation monitoring (IEL and NIEL) in the LHC Experiment environment is available;
- The sensor choice has to take into account: expected **type of damage**, radiation **field intensity** and **composition**;
- The sensors for the **LHC startup** have been already **procured in 2005**.
- Sensors in delivery to the Experiments – **A few parts** are now available in stock for some sensor types (new order may be needed !)
- The integration remain the responsibility of the Experiments.