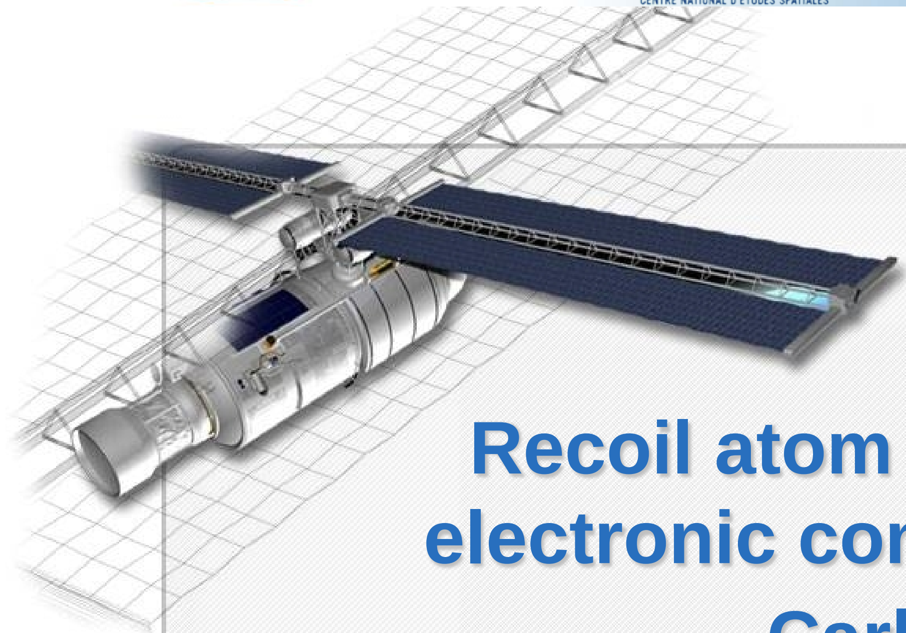


Recoil atom flux calculation in electronic components by Monte Carlo method

P. Pourrouquet, V. Traisnel and N. Chatry (TRAD)
G. Rolland and R. Ecoffet (CNES)

Context

- **Introduction of high Z metals in CMOS technology evolution (memories, FPGA…)**

- **Noticeable effects (SEE) on electronic parts:**
  - **R&T CNES 2015 for studying components with Copper back-end**

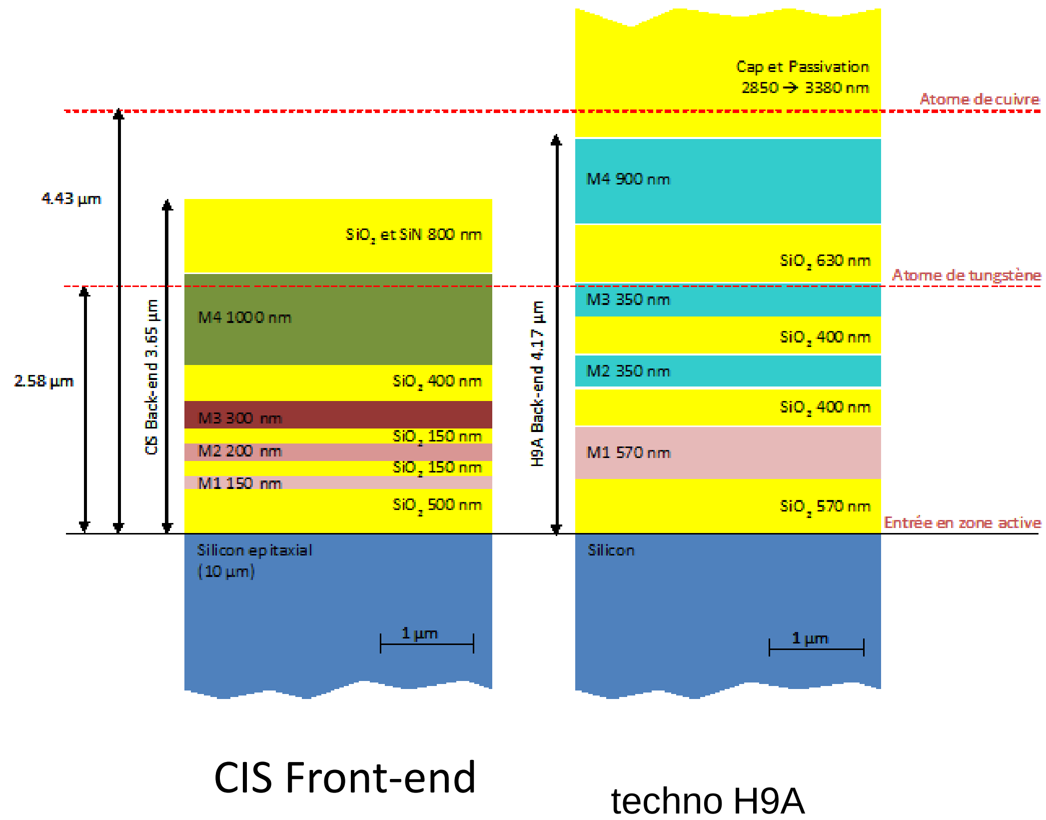
- **Presence of recoil atoms with LET > 15 MeV.cm²/mg in sensitive layer?**
  - **NASA's Guide Test Proton**
    - Proton SEE testing is required when: a device has an heavy ion **LET_{th} < 37 MeV*cm2/mg** where no events occur at a test fluence of $1x10^7$ particles/cm2, and, mission proton exposure is significant
  - **Cu LET > 15 MeV.cm²/mg for Energy > 9 MeV**
  - **W LET > 15 MeV.cm²/mg for Energy > 0.2 MeV**

Outline

- Theoretical study
- 3D model description
- Results
- Conclusions
- Perspectives

Theoretical study

- **Recoil atom creation areas**
  - Metallization (Cu)
  - At the Via level between the first metal layer and the sensitive area
  - Silicide/nitride layer (10 nm)



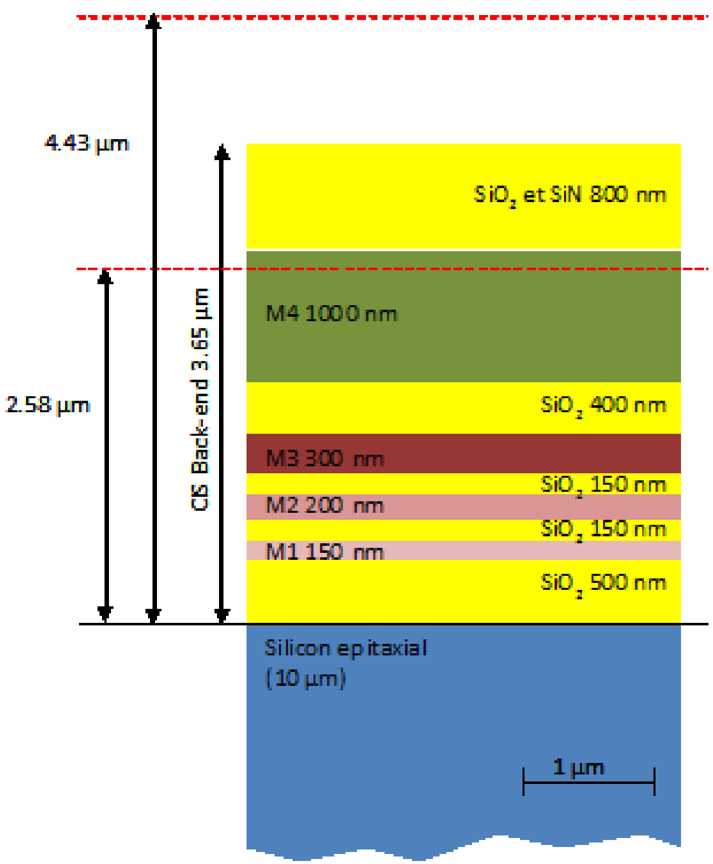
- **Creation energy and range**

  => Study of the 4 metal layers

- **Definition of representative 3D models for the study**

Recoil atoms can reach the sensitive area from all the 4 metal layers

3D Models



CIS Front-end

Metal layers

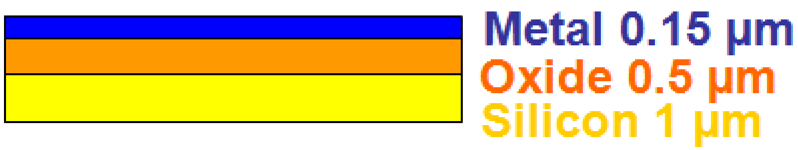


Figure 2 : First metal layer

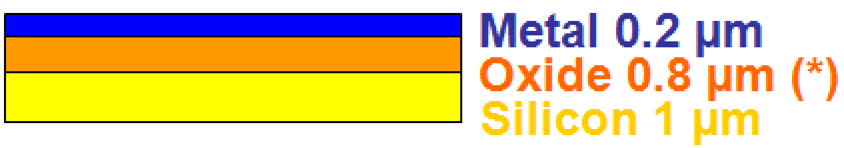


Figure 3 : Second metal layer

(*) The oxide layer replaces the different layers between the second metal layer and the silicon sensitive area.

Metal1 + Via in Copper

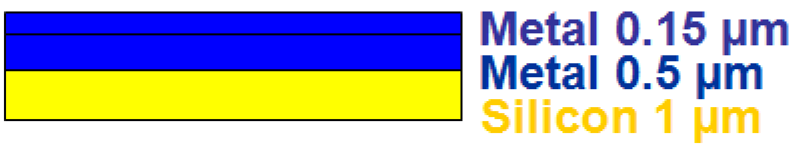
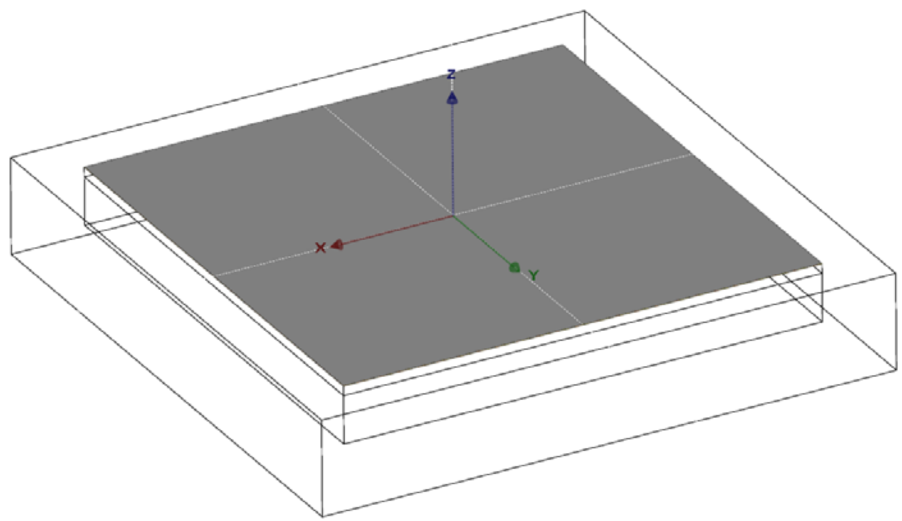


Figure 6 : First metal layer and via just above the sensitive layer

Metal1 + Via in Copper

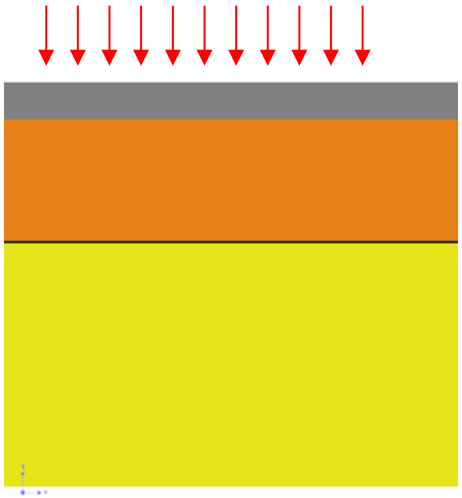
« Forbidden area » to prevent particles from entering through the lateral or the bottom sides

Cross section view



Calculation description

Simulation of a proton irradiation beam



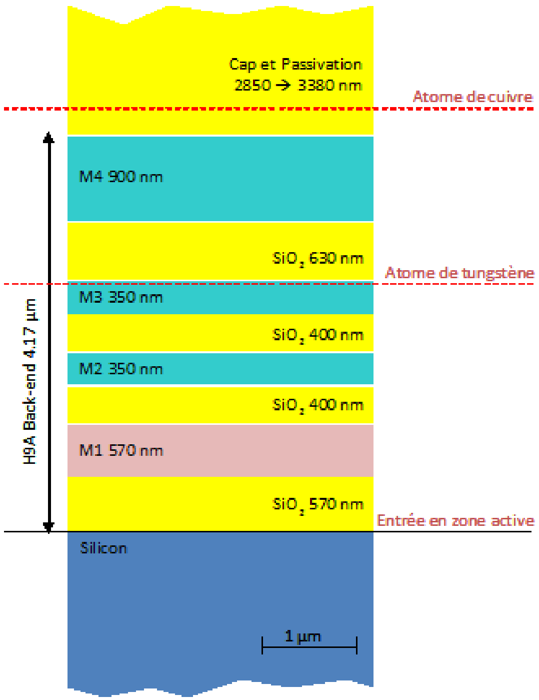
- Mono-energetic protons with a normal incidence
- Sampling energies from highest available (480 MeV) to 0 MeV
- For each component the simulations are repeated for all the 6 models

- **Modification of TRADCARE tool to compute an LET Spectrum in the Silicon sensitive volume instead of carried deposition**

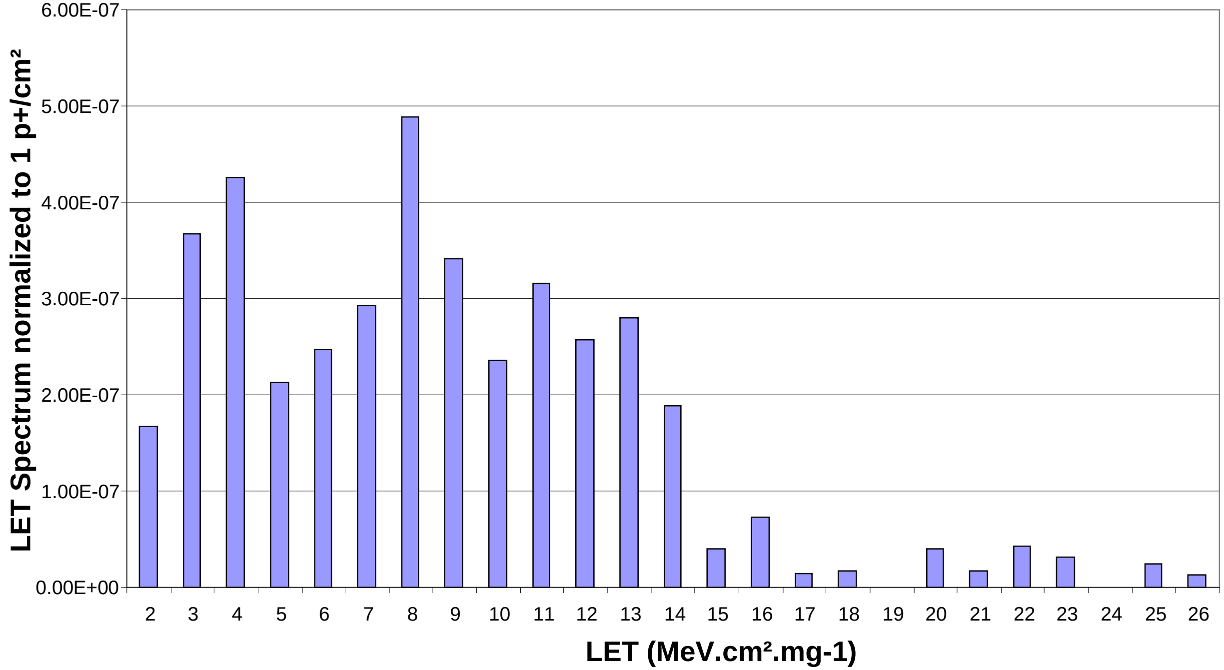
- **For each calculation, creation of an LET spectrum for each ion species depending on their atomic mass (Z)**
  - Useful to establish the list of ions reaching the sensitive volume

Results

H9A Component



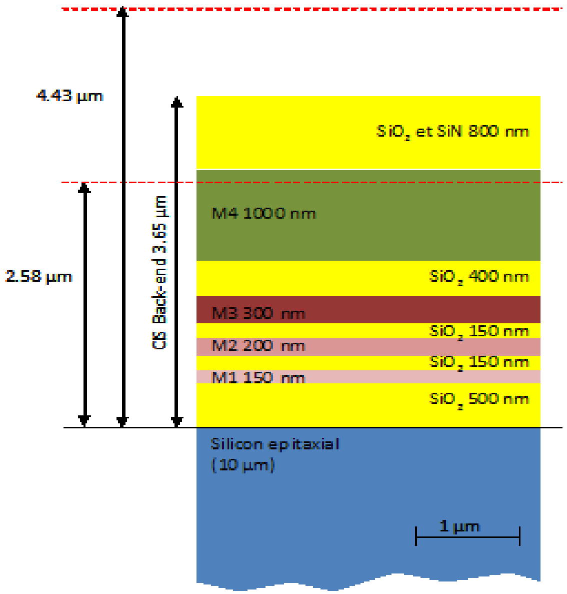
Metal 1-Via + W 480 MeV

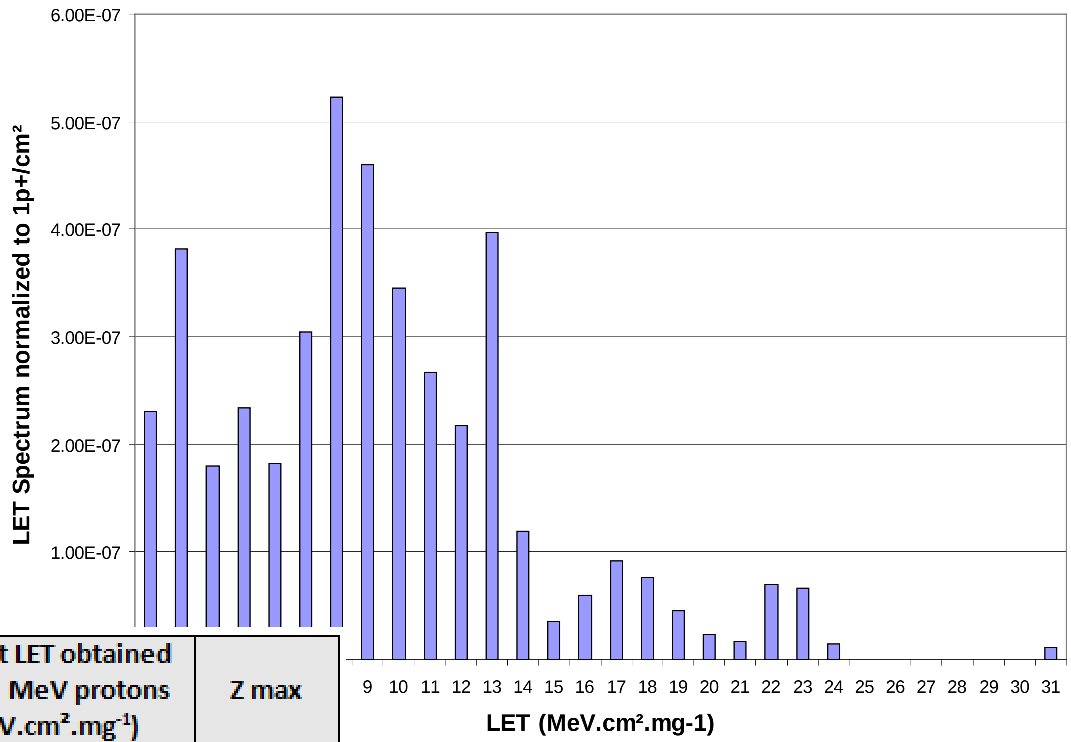


Model	Number of tracked protons	Proton lowest energy to obtain LET > 15 $MeV.cm^2.mg^{-1}$	Highest LET obtained for 480 MeV protons ($MeV.cm^2.mg^{-1}$)	Z max
Metal 2	1.00E+08	/ (*)	15	14 (Si)
Metal 1	1.00E+08	355 MeV	26	28 (Ni)
Metal 1 + Via	1.00E+08	105 MeV	25	30 (Zn)
Metal 1 + Via + W	1.00E+08	55 MeV	26	75 (Re)

Table 1 : Result summary for proton normal beam on H9A component

CIS Component





Model	Number of tracked protons	Proton lowest energy to obtain LET > 15 $MeV.cm^2.mg^{-1}$	Highest LET obtained for 480 MeV protons ($MeV.cm^2.mg^{-1}$)	Z max
Metal 4	1.00E+08	460 MeV	27	29 (Cu)
Metal 3	1.00E+08	380 MeV	19	28 (Ni)
Metal 2	1.00E+08	290 MeV	19	29 (Cu)
Metal 1	1.00E+08	140 MeV	24	29 (Cu)
Metal 1 + Via	1.00E+08	50 MeV	26	30 (Zn)
Metal 1 + Via + W	1.00E+08	50 MeV	31	75 (Re)

Tableau 3 : Result summary for proton normal beam on CIS component

Conclusions

- **Recoil atoms creation areas:**
  - **All the metal layers**
  - **Highest LET for particles created in the via and the silicide/nitride layer: 31 MeV.cm²/mg^{-1}**
  - **50 MeV protons are energetic enough to have atoms with a LET higher than 15 MeV.cm²/mg^{-1} present in the sensitive layer**

- **Creation energy :**
  - **Necessary proton energy decreases when the creation areas are closer to the sensitive layer:**
    - More than 300 MeV for layers above Metal2
    - 140 MeV for Metal1 layer
    - 50 MeV for the Via et silicide/nitride

- **Processes creating the recoil atoms**
  - **Fragmentation ($Z < Z_{target}$)**
  - **Recoil ($Z = Z_{target}$)**
  - **Fusion (Z = Ztarget + 1)**

Perspectives

- **Qualitative and not quantitative study**
  - **Hypotheses for the silicide/nitride composition**
  - **Hypotheses for the metal layer and via area**
  - **Sensitive layer thickness fixed to 1 µm**
  - **Passivation layers not considered**

=> Worst case study for LET calculation and not possible to conclude on the actual probabilities of high LET atom creation

- **Next year study will consider the quantitative aspect considering more realistic cases:**
  - **More realistic component model definition,**
  - **Proton environment: real spectrum**

Thank you for your attention