CENTRE NATIONAL D'ÉTUDES SPATIALES

SEUs on SPOT-1, -2, -3 on-board computers

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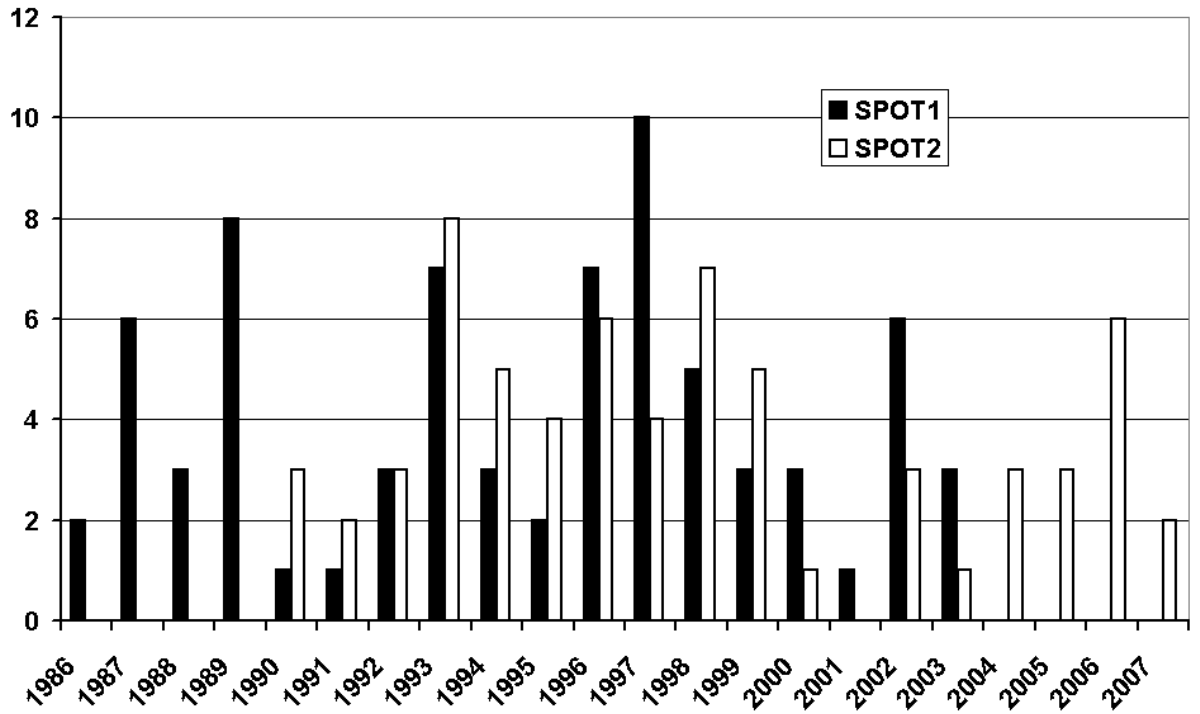
Some elements for the discussions on LET needs for component testing

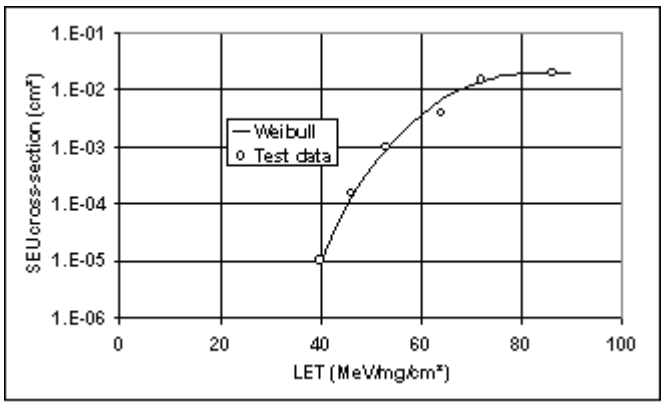
The components

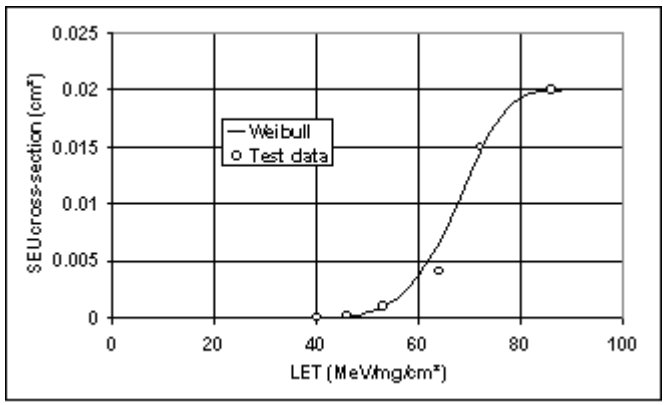
- SRAM HEF4736 Phillips 1 kbit
- 1088 active components
- SEUs recorded since 1986 – now (~2 solar cycles)
- 74 records for SPOT-1 and 66 for SPOT-2 (end January 2007)

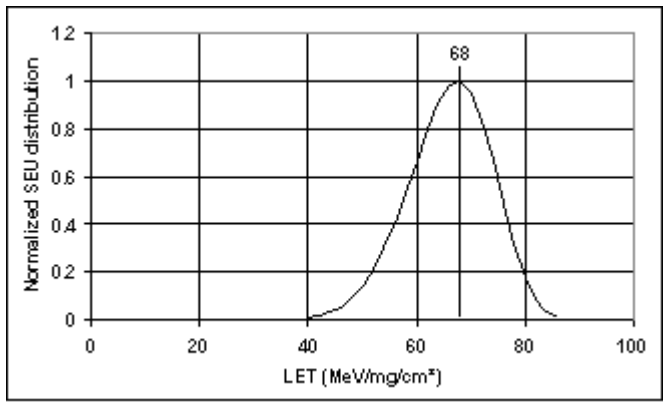


HEF4736 ground test results

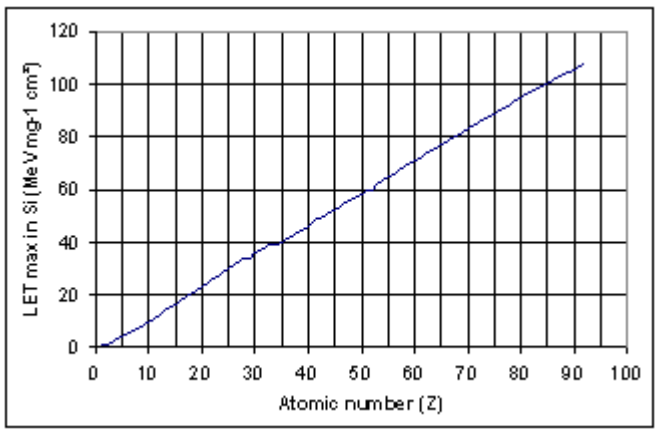
- Heavy ion (IPN) and proton (SATURNE) tests
- LET_{th} ~ 40 MeV/mg/cm²
- Test results could let one believe that SEUs are only due to very high LET heavy ions







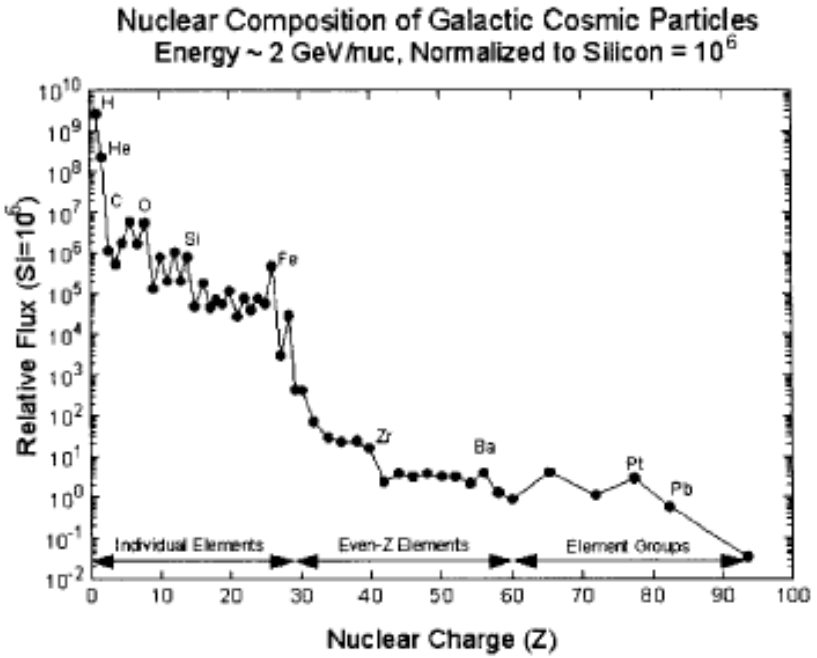
- LET> 40 → Z > 45

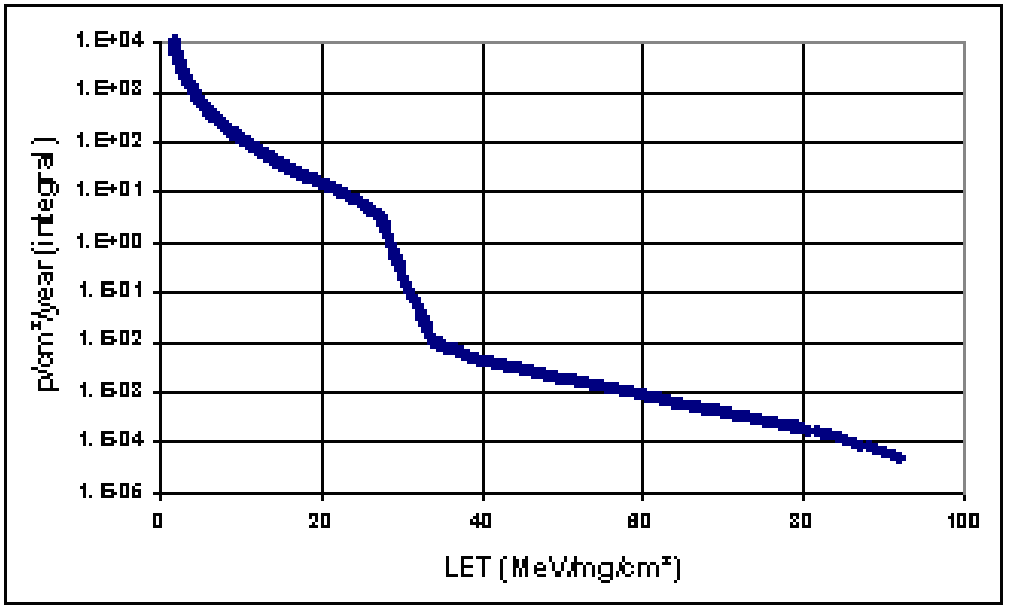


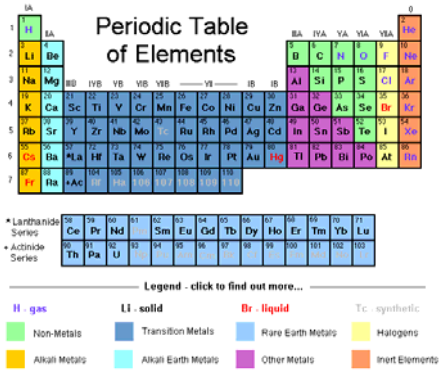
Seen like that one could believe coping with an LET detector with maximum efficiency around LET~70

High LET ions in space

- « There are no (extremely few) high LET ions ion space »
- Indeed, but we do observe SEUs in SPOT OBCs !

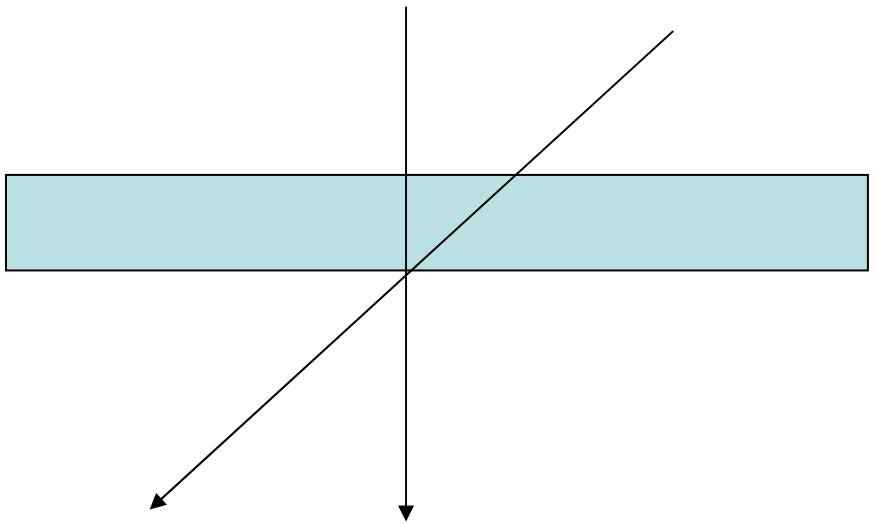


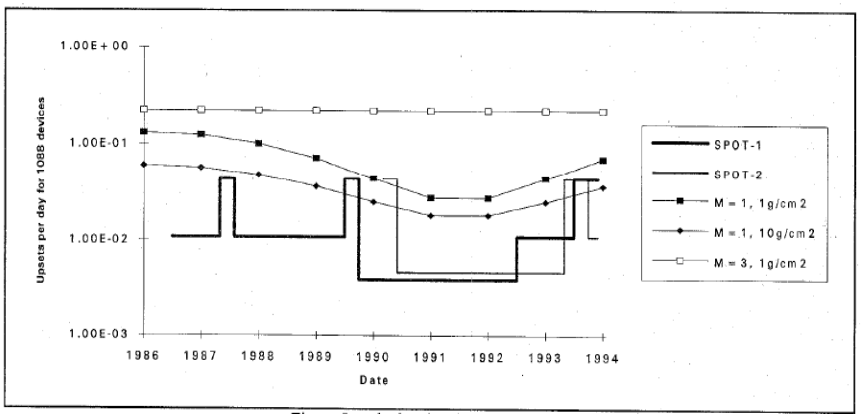




Why this discrepancy ?

- **LET (dE/dx) is an engineering "trick" , the right parameter governing SEU behavior is the deposited charge inside the sensitive volume.**
  (we stay here within the full classical sensitive volume theory)
- **Q_{dep} ~ ΔE ~ LET x z**
- **For SPOT memories this volume is taken as 44 x 44 x 2 µm**

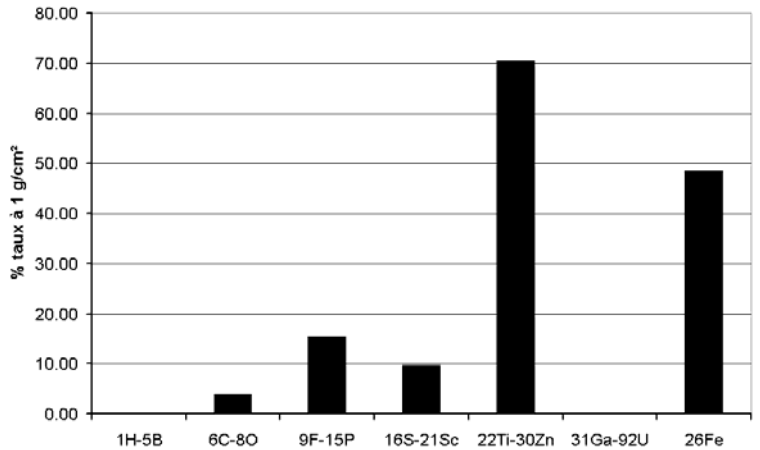


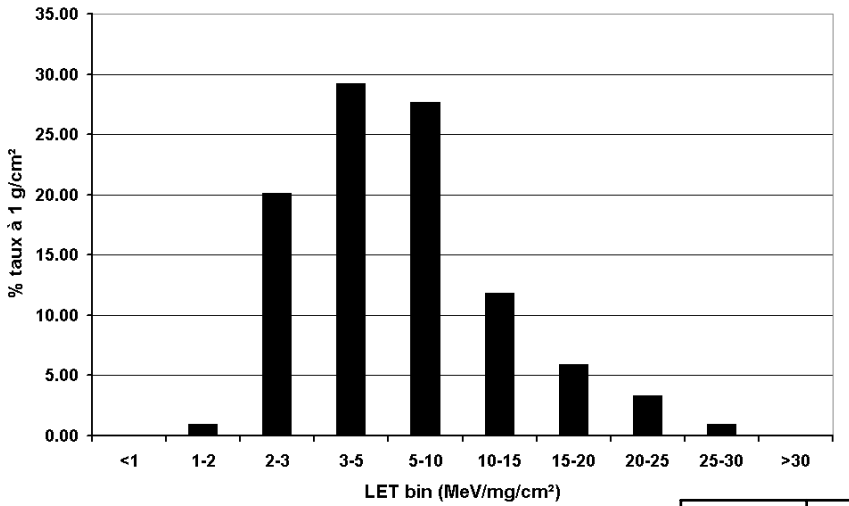


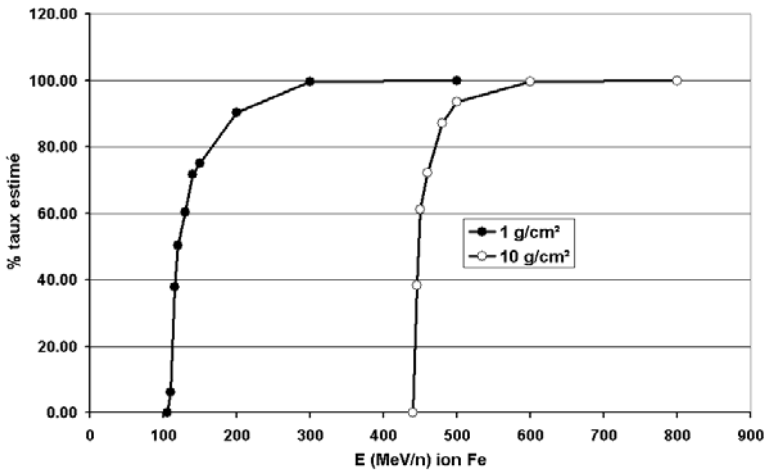
Simple convolution = 5 E-5 event / day

Parametric study using OMERE

- **As a function of Z, of LET, of energy : contributions to the estimated rate**







Critical charge =
40 (accelerator LET_{th}) x 2 µm (SV depth)

We'll have an upset if
LET / cos (incidence) > 40 MeV/mg/cm²

i.e. minimum incidence = arcos (LET/40).
and path in SV = 2µm / cos (incidence).

LET max	Incidence (°)	Path in SV (µm)
1	88.57	80.00
2	87.13	40.00
3	85.70	26.67
5	82.82	16.00
10	75.52	8.00
15	67.98	5.33
20	60.00	4.00
25	51.32	3.20
30	41.41	2.67

Conclusions

- **In the case of HEF4736, the SEU sensitivity :**
  - Is characterized **on ground** with **very heavy ions** (Z>40), **of low energy** (few MeV/n) **high LETs** (> 40), and **low incidences** (<60°)
  - Is revealed **in flight** by **much lighter ions** (Fe group and below), **of high energy** (few 100 MeV/n), **low LETs** (some MeV/mg/cm²) and **high incidences** (>60°). 28Fe alone contributes to nearly 50% of the rate.
- **The "ground" and "flight" domains are completely disjointed**
- If we had to limit SEU testing at e.g. LET=37 MeV/mg/cm² because "there are no high LET ions in space" we would have completely missed the issue
- It would be wiser to think about test criteria in more elaborated manner and eventually adapt them to the effect to be studied
- The SPOT technology is rather old for SEU, but the considerations above may still be true for other SEEs (SEL, SET,…)
- **→ Proposed 09 R&D : given {LET, sigma curve and sensitive volume} : on what ions (Z, LET, E) does this "detector" triggers in space ?**