SEU SCREENING USING AN AM-BE NEUTRON SOURCE

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1. Abstract

Irradiation tests performed with an **Americium-Beryllium** (Am-Be) **neutron source at CERN**, demonstrated that this radiation environment can be used to **induce SEUs in commercial SRAM memories**. The flux assessment was performed through **FLUKA simulations** using the model of the facility. The upset events measured with the aforementioned source and those retrieved by typical **mono-energetic facilities are compared**, showing that the **Am-Be can be efficiently used for screening of components**.

2. Introduction

- The Single Event Upset (SEU) characterization of electronic components, requiring characteristics of radiation tolerance and employed in high-energy accelerators, relies on the **knowledge of high-energy hadron cross sections typically measured with high-energy protons**.

  ➡ Pros: exact cross section representative of the memory
  Cons: facility availability, costs

- General **approach for SEUs induced by neutrons**: The memory is assumed to be equally sensitive to HEH above 20 MeV and a weighting function has to be accounted for the **intermediate energy neutrons**, considered from 0.2 MeV to 20 MeV, where the cross section is strongly energy dependent.

$$\varphi_{HEHeq} = \underbrace{\int_{0.2MeV}^{20MeV} w(E)\frac{d\varphi_n(E)}{dE}}dE + \int_{20MeV}^{+\infty}\frac{d\varphi_{HEH}(E)}{dE}dE$$

Weibull function w(E) convoluted with the differential flux.

- As the maximum energy of the Am-Be source is 10 MeV only the first term is considered and therefore the **Weibull function plays an important role**.

3. Americium-Beryllium source

- The Am-Be facility is located at CERN. Neutrons are generated by the beryllium after the absorption of an alpha particle emitted from the americium. The source **activity** is of **888 GBq**.
- The source is composed by a cylindrical capsule containing the two elements, which is housed below the floor. It can be easily turned on/off in a few seconds and once activated is maintained in the middle of the room inside the aluminium pipe by means of compressed air (see Fig. 1). This aspect allows an **isotropic flux of 5.03×10⁷ [s⁻¹/4π]**.

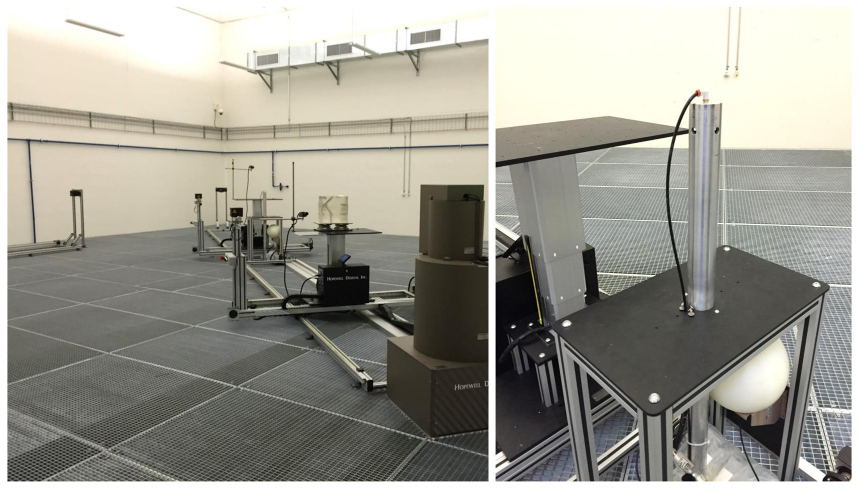

Figure 1: CERN Am-Be facility irradiation room (to the left) and test position (to the right)

4. FLUKA simulations and measurements

- The **source provides a spectrum** with a peak around 3 MeV and reaches a **maximum energy of about 10 MeV** as shown in the FLUKA simulation of Fig. 2.
- The HEHeq flux (see section 2) of the Am-Be source is highly dependent on the Weibull function of the specific memory (Tab. 1).

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It's therefore important to have an estimation of the Weibull fit of the new memory to test (for instance, with data on the same technology).

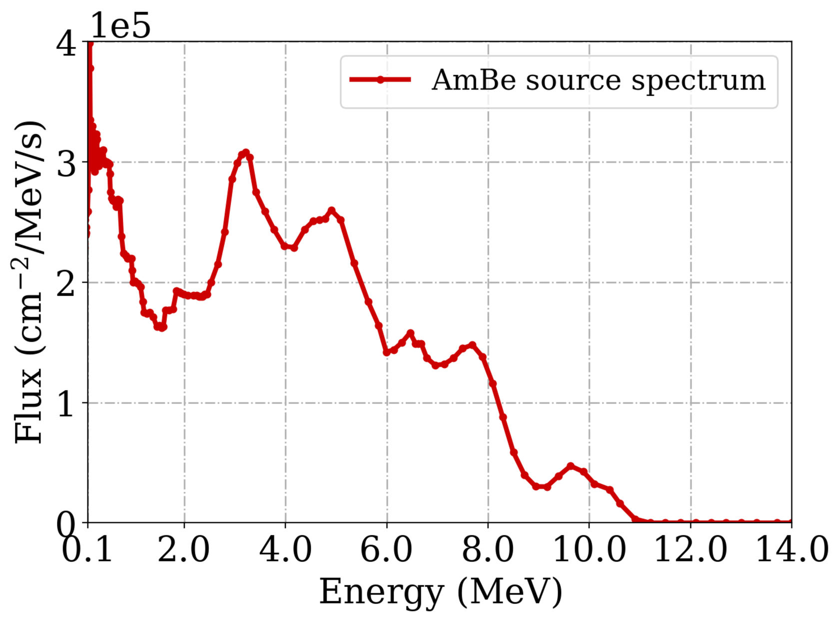

Figure 2: FLUKA Simulation of the Am-Be differential spectrum as a function of the energy (at the source edge). Axis are in linear scale to highlight the flux between 0.1 -10 MeV

5 cm	ESA M.	Cypress	Toshiba
HEHeq $[cm^{-2}s^{-1}]$	9.3×10^3	6.3×10^3	1.8×10^4

Table 1: FLUKA equivalent fluxes at 5 cm from the middle of the source. The considered response functions w(E) were obtained using quasi-monoenergetic neutrons at PTB

Measurements

- The **ESA SEU Monitor** (0.25 µm CMOS technology) is an SRAM-based detector calibrated in a broad set of facilities and used by the R2E project at CERN to **cross validate the facility flux**. In addition, it shows the beam **homogeneity** over its 20x20 mm² of active surface, very **well spread for the Am-be source** (see Fig. 3).

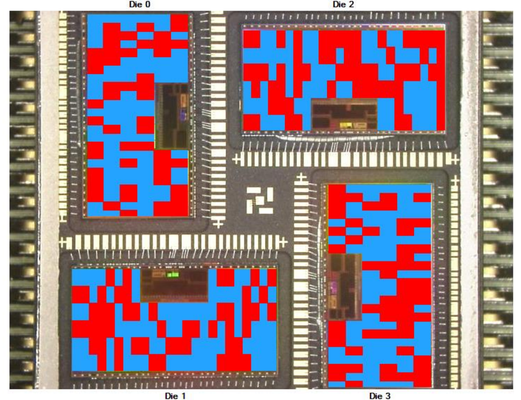

Figure 3: ESA Monitor homogeneity assessment at 5 cm from the source

- The **source and irradiation room** were **modelled thought the Monte Carlo FLUKA tool** in order to estimate the flux of the source at the desired distance.
- Tests with the ESA Monitor were performed in different positions along the three axis with respect to the source, with the aim of evaluating in a qualitative way the flux attenuation (r^{-2} law) and compare these values with those from the simulations (see Fig. 4, 5).
- The ESA Monitor reference cross section for the flux measurements is considered the one in saturation at 230 MeV. The **measurements are in agreement with the simulations within the experimental uncertainty** (of 15%).

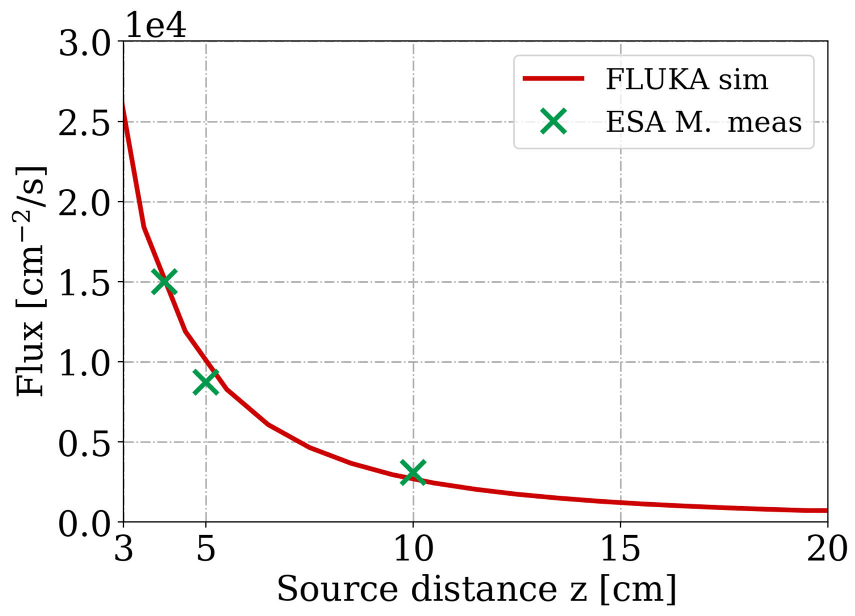

Figure 4: flux attenuation along the z (and x) axis, simulation and measurements

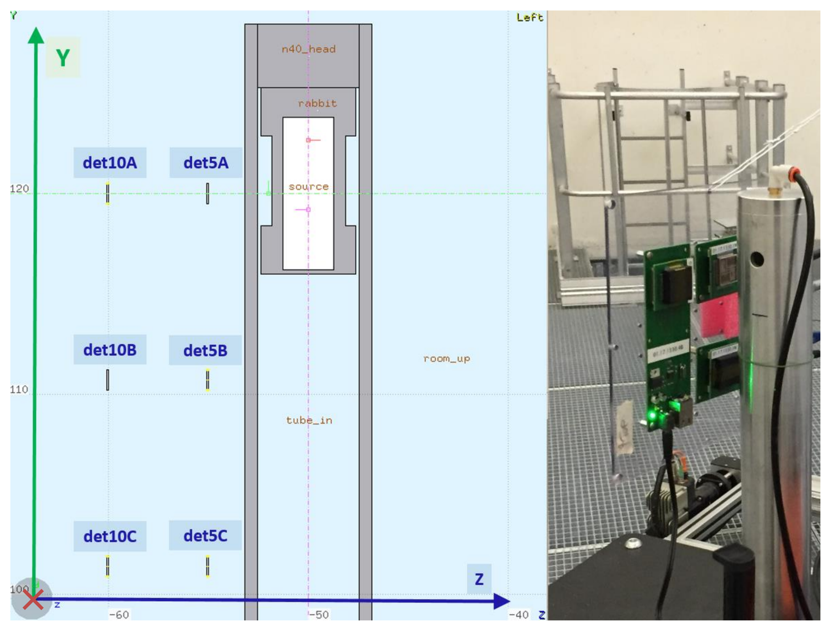

Figure 5: FLUKA source geometry with the different detector positions (to the left) and test with the ESA SEU Monitor (to the right)

5. Test results and comparison

- Together with the ESA Monitor, the **Cypress memory** (90 nm), embedded in the RadMon system used to measure the HEH flux along the LHC accelerator, was qualified.
- The **Am-Be SEU number** measured at 5 cm from the middle of the source are **compared** with the corresponding calculated values obtained by multiplying the HEHeq flux times the respective mono-energetic cross sections. The latter are considered at **230 MeV protons (PSI) for the ESA Monitor and 14 MeV neutrons (LPSC) for the Cypress**.
- The agreement for the ESA Monitor is impressive considering that the Am-Be source with energies <10 MeV yields an equivalent upset number as 230 MeV protons.

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Pros: facility availability, costs, negligible activation after the irradiation
Cons: cross section is an estimation

5 cm from the source	ESA Monitor		Cypress	
	SEU/day	%	SEU/day	%
Experimental	332		799	
Calculated	355	-6.9	617	+23

Table 2: SEU results, the percentage refers to the upsets difference calculated considering the mono-energetic facility in comparison with those from the Am-Be source

6. Conclusions

- As shown, the **number of SEUs** retrieved by **using facilities with a wide range of energies**, from less than **10 MeV (Am-Be) up to 230 MeV (PSI), is compatible** with each other. This is unfolded from the fact that the memory cross section follows the response curve implemented with the Weibull fit.
- The **Am-Be source** can therefore induce a statistically significant amount of **SEUs in a relatively reduced timeframe** (~hours), inducing a negligible activation level.
- Its employment can therefore be aimed at **screening the SEU sensitivity of SRAM** memories in a **more accessible and cost efficient way** compared to high-energy cyclotron proton testing.