RADSAGA

Study of SEU sensitivity of SRAM-Based Radiation Monitors

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RADSAGA Final Conference and Industrial event

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RADiation and Reliability Challenges for Electronics used in Space, Aviation, Ground and Accelerators (RADSAGA) is a project funded by the European Commission under the Horizon2020 Framework Program under the Grant Agreement 721624.
RADSAGA began in Mars 2017 and will run for 5 years.

Presentation outline

- ❑ Introduction
- ❑ SRAM Design
- ❑ Test Results
- ❑ Conclusion

SEU Radiation monitor

SRAM (Static Random-Access Memory) is one of the most comment devices used for SEU detection

- ❑ Simple for operating.
- ❑ High density, low power consumption.
- ❑ Same technology node as the device under monitor.

For commercial SRAMs

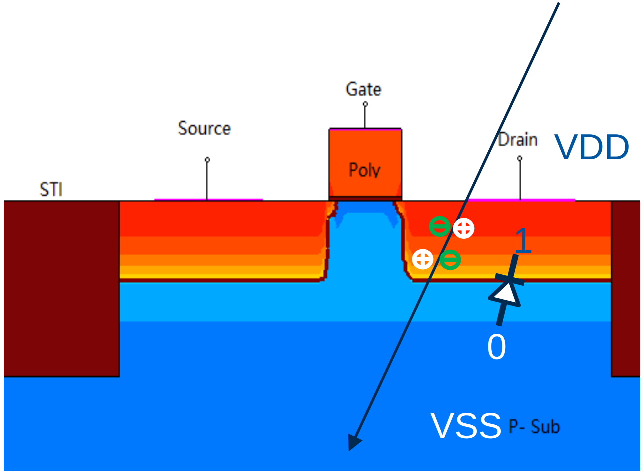
- ❑ Error correction.
- ❑ IO voltage regulator.
- ❑ Physical distribution.

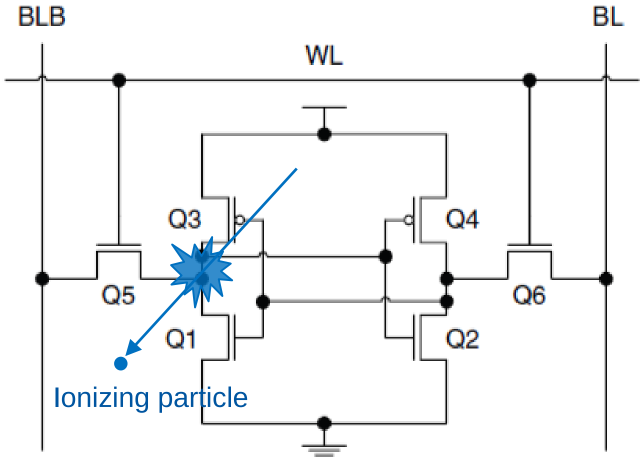
Goal of research ESR5

The goal of my research is to model, simulate, design and test a controllable SRAM based radiation monitor.

- ❑ How to design an SRAM radiation monitor in advanced CMOS technology?
- ❑ How can the radiation monitor be made flexible in terms of sensitivity?
- ❑ What dynamic range of radiation sensitivity can be achieved?

SEU on SRAM





SEU on a 6T SRAM cell will cause state change

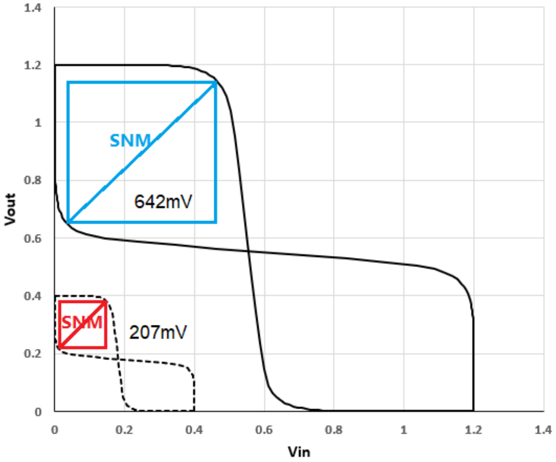
Flexible SEU sensitivity

- Critical Charge of the SRAM cell ↓
  - Lower voltage supply
- Total charge collected in sensitive node ↑
  - Bigger sensitive area*
  - Higher bulk voltage
- Leakage Qc from open MOS ↓
  - Add extra resistor*
  - Read mode

*Non-standard cell

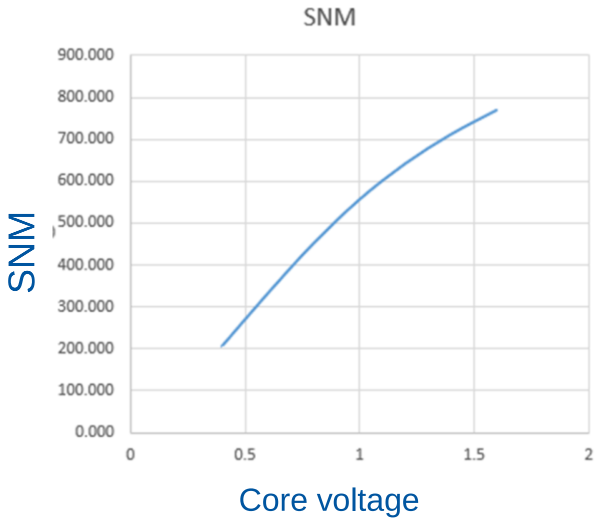
Lower voltage supply

Static Noise Margin at different voltage

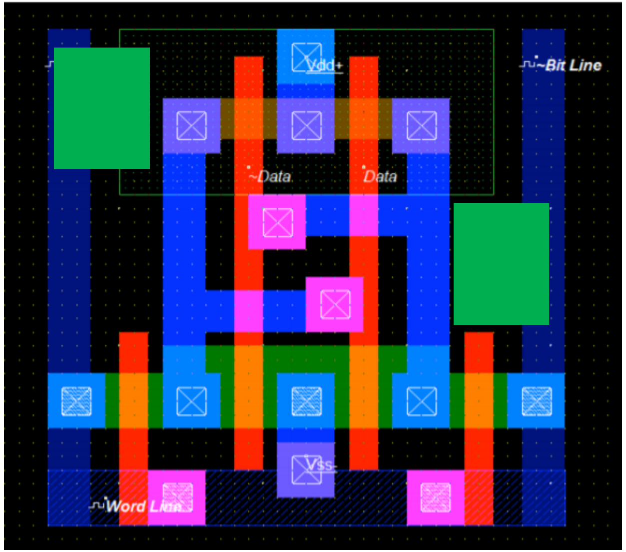


Cell type	Condition	Qc
65nm 6T	0.4V / 0.9V	0.36fC / 1.12fC
28nm 8T	0.4V / 0.9V	0.27fC / 0.94fC

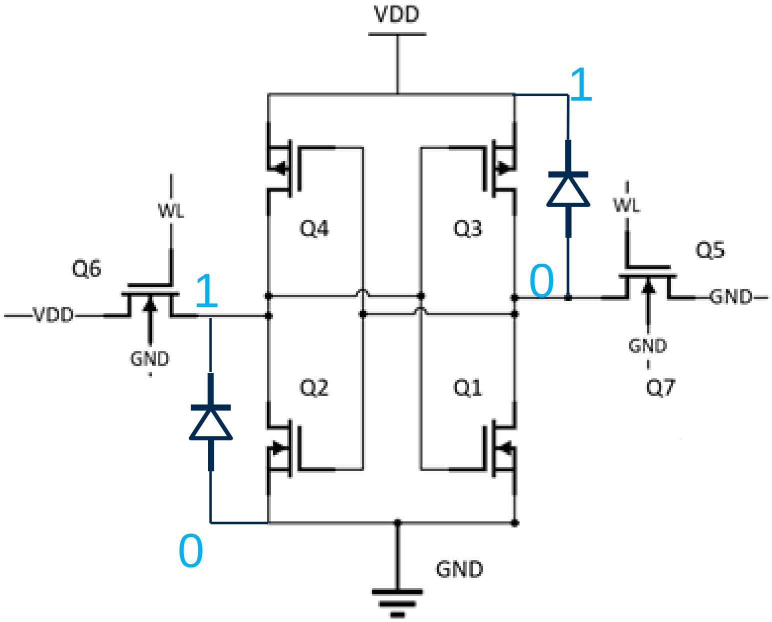
SNM represents the effort needed to change SRAM’s status, it has a linear relationship with supply voltage.



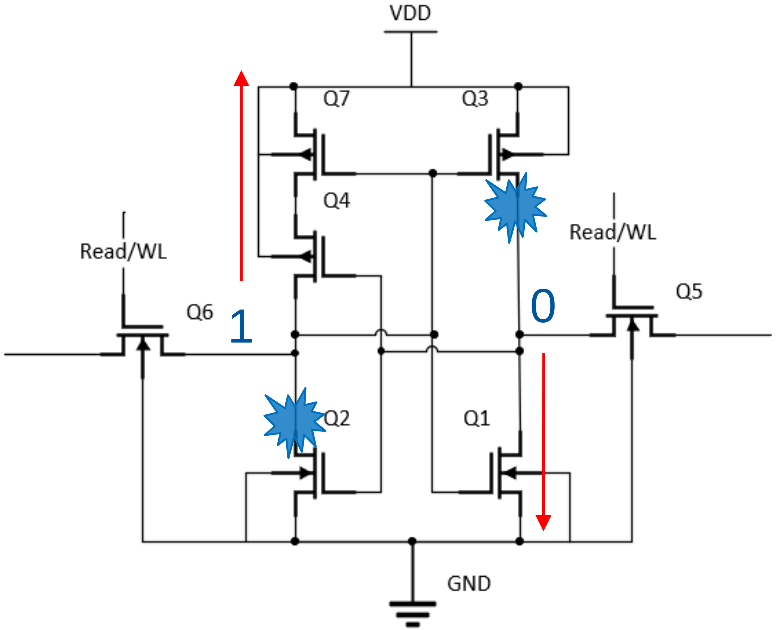
Total charge collected in sensitive node



*from Ref [1]

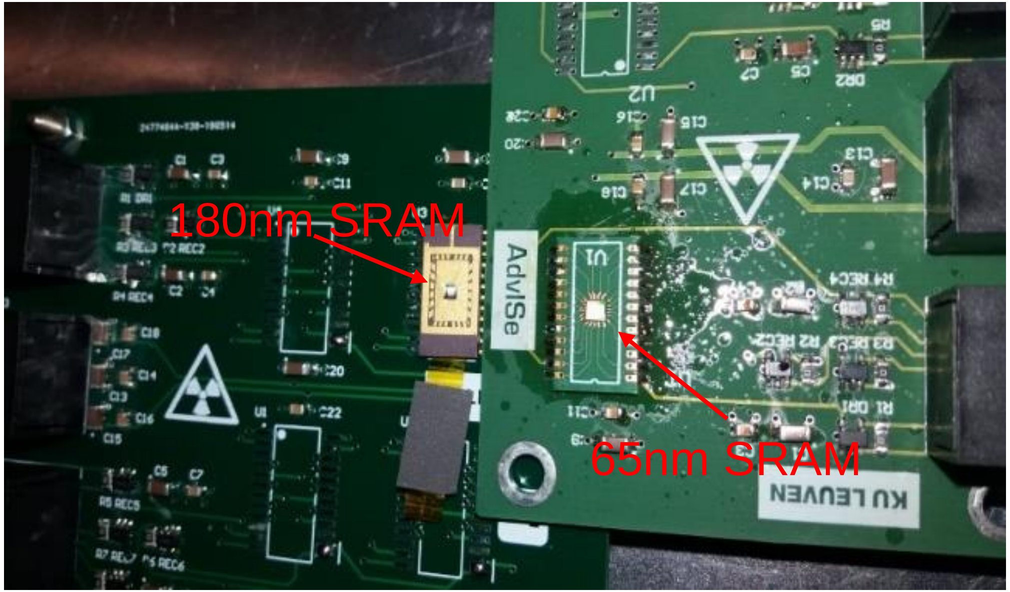


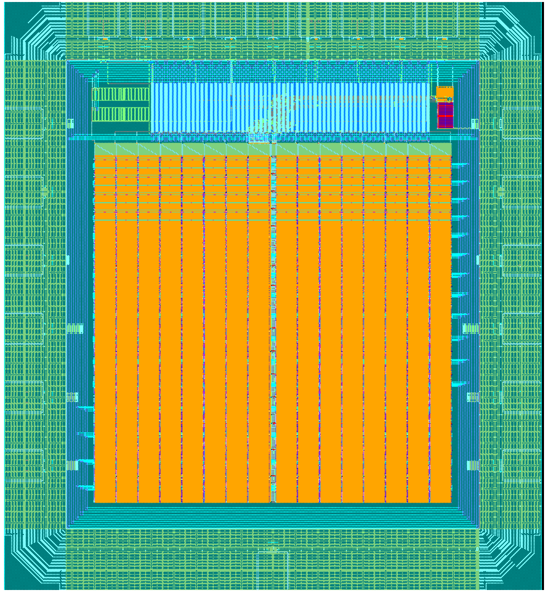
Leakage Qc



Type	Voltage	Critical Charge
8T	0.4V	0.27fC
	0.9V	0.94fC
9T	0.4V	0.16fC
	0.9V	0.35fC

Designed chips

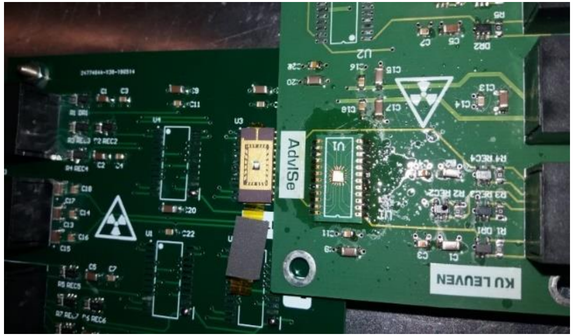




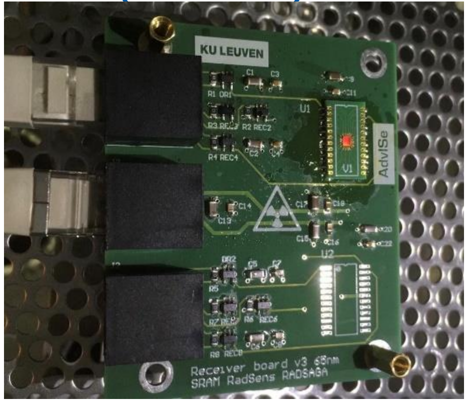
28nm SRAM & diode array

Test performed within RADSAGA

- 9.3 MeV/u Heavy ions at RADEF (180nm)
- 16.3 MeV/u Heavy ions at RADEF (65nm) (ESR6 Arijit)
- 52 MeV proton at RADEF (65nm) (ESR6 Arijit)
- KVI Proton test (180nm & 65nm)
- CERN NA UHE Pb Beam (180nm)



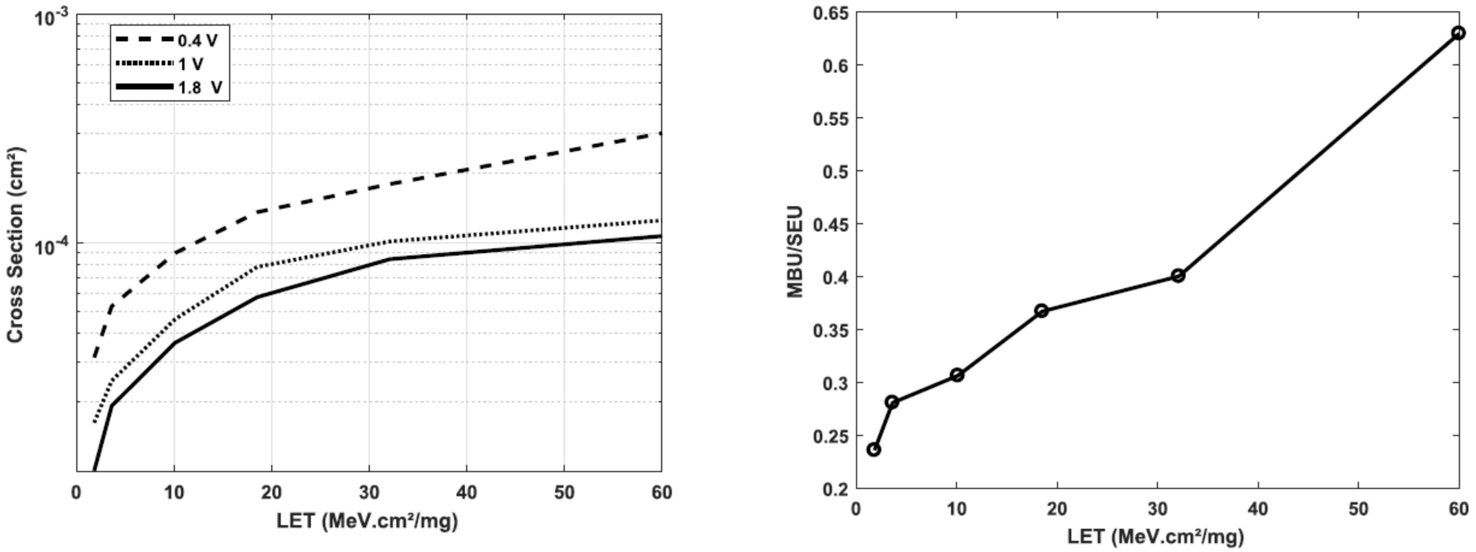
KVI-cart proton test



RADEF heavy ion test

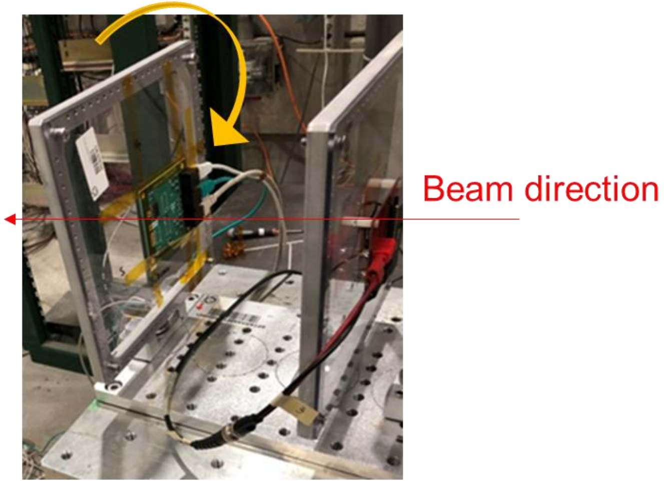
CERN UHE Pb test

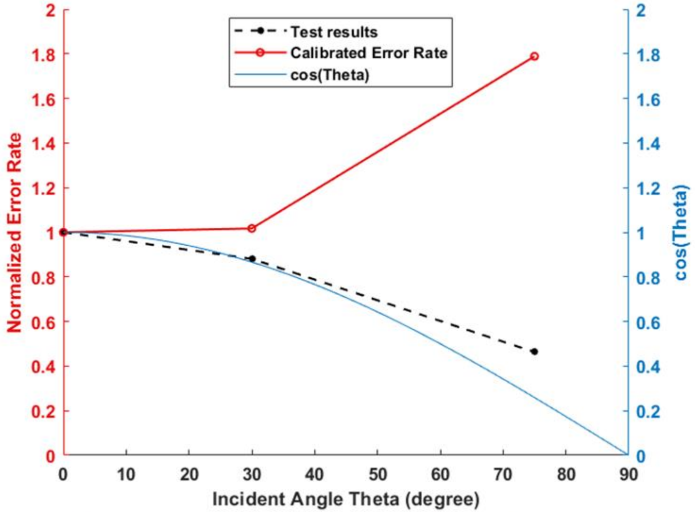
Test result 180 nm – Heavy ions

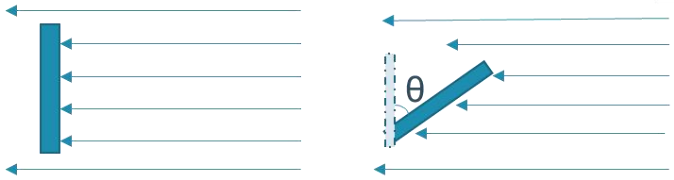


9.3 MeV/u RADEF Heavy ions test results [2]

Test result 180 nm – UHE Pb beam



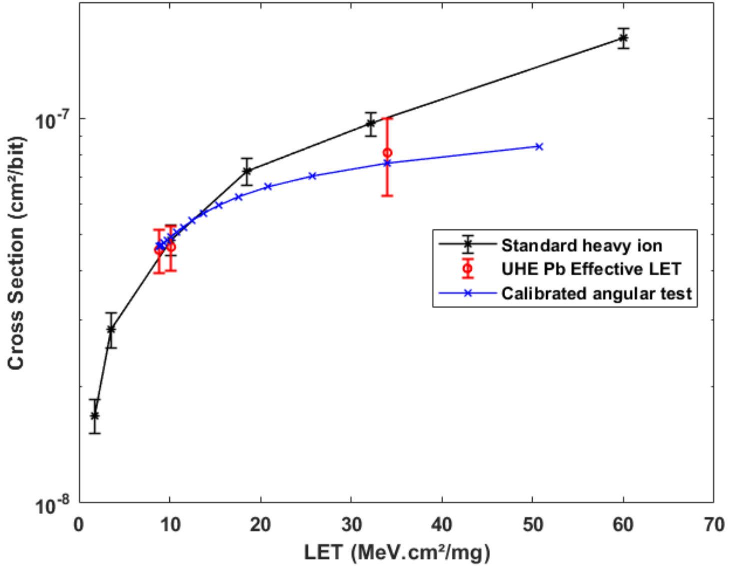


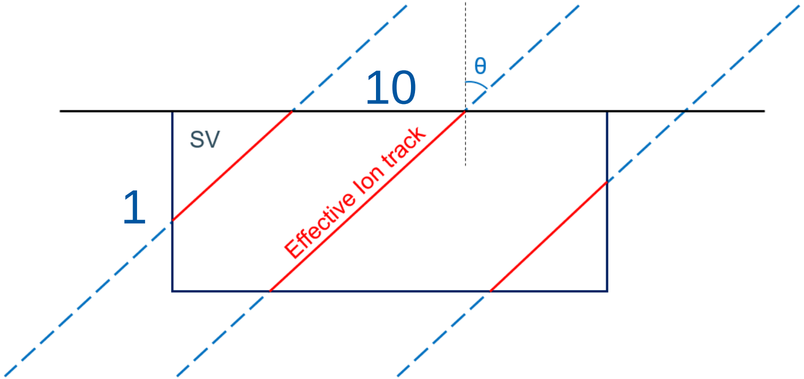


The angled test should apply decreased beam flux by cos(θ), after this calibration, the SEU rate is increased due to effective LET increased.

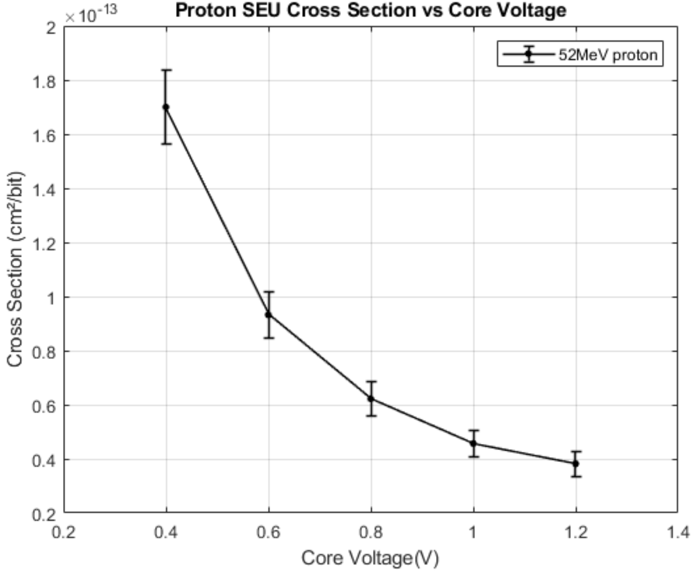
Test result 180 nm – UHE Pb beam

When comparing the SEU cross section UHE beam to data tested in RADEF, UHE cross section is slightly lower. Thus, geometry analyse was included here.

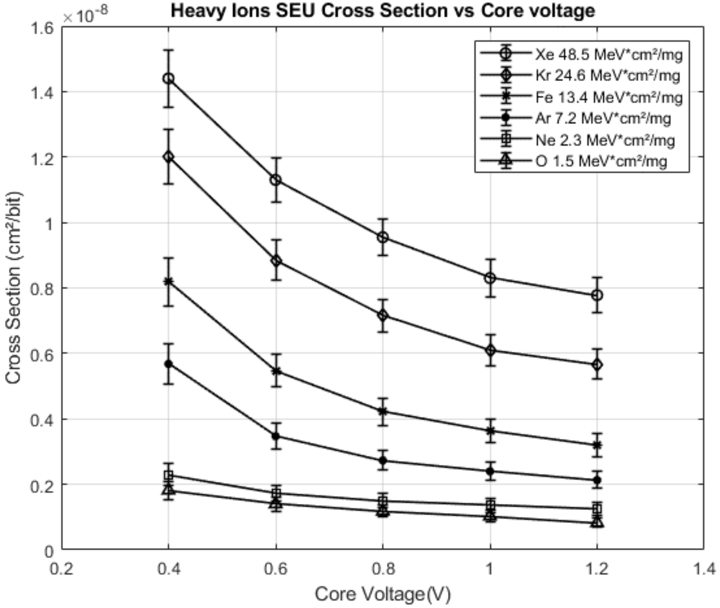




Test result 65 nm



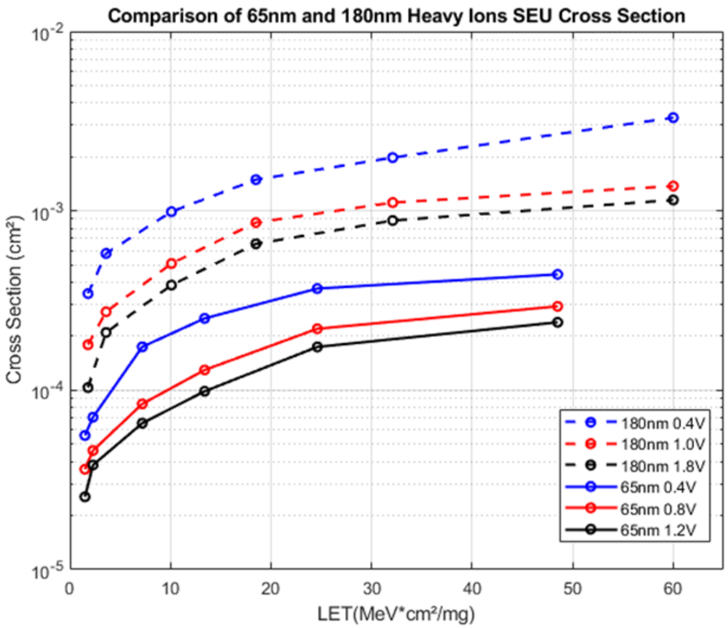
RADEF 52 MeV Proton SEU Cross Section



RADEF Heavy Ions SEU Cross Section

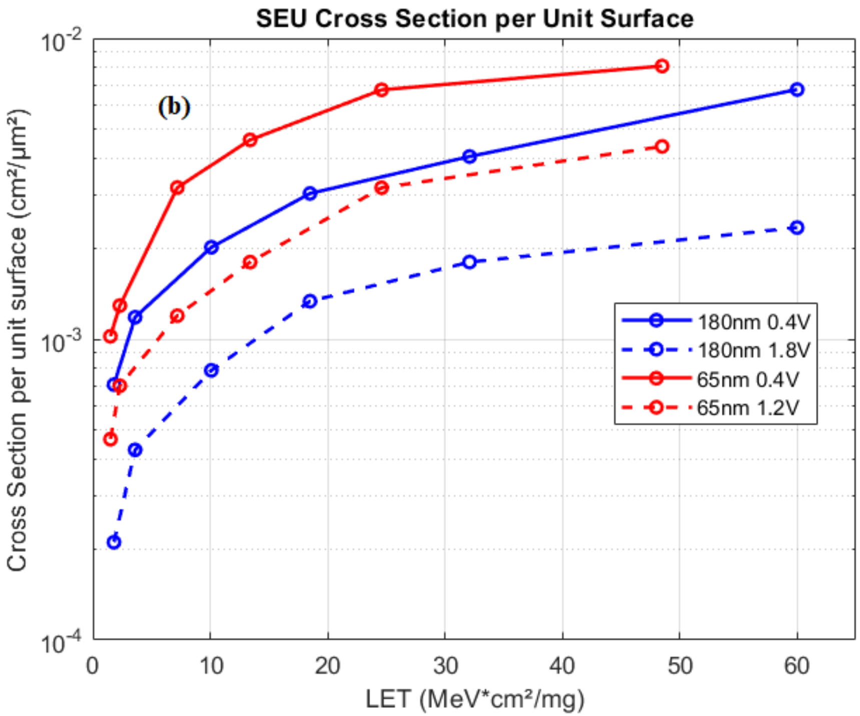
Comparison between 65nm and 180nm

Though the SEU cross section of 65 nm is 10 times less than 180 nm SRAM, the SEU rates per ion hit value is similar.



technology	Ion	Voltage	upset	Total hits	Rate
180nm	Xe	0.4	1144	1548	73.9%
		1.8	457	1548	29.5%
	Kr	0.4	1389	2322	59.8%
		1.8	540	2322	23.3%
	Fe	0.4	1340	3096	43.3%
		1.8	460	3096	14.9%
	Ar	0.4	1242	4644	26.7%
		1.8	436	4644	9.4%
65nm	Xe	0.4	820	984	83.3%
		1.2	460	1051	43.7%
	Kr	0.4	1100	1640	67.1%
		1.2	413	1298	31.8%
	Fe	0.4	1830	3983	45.9%
		1.2	735	4082	18.0%
	Ar	0.4	2070	6494	31.9%
		1.2	816	6817	12.0%

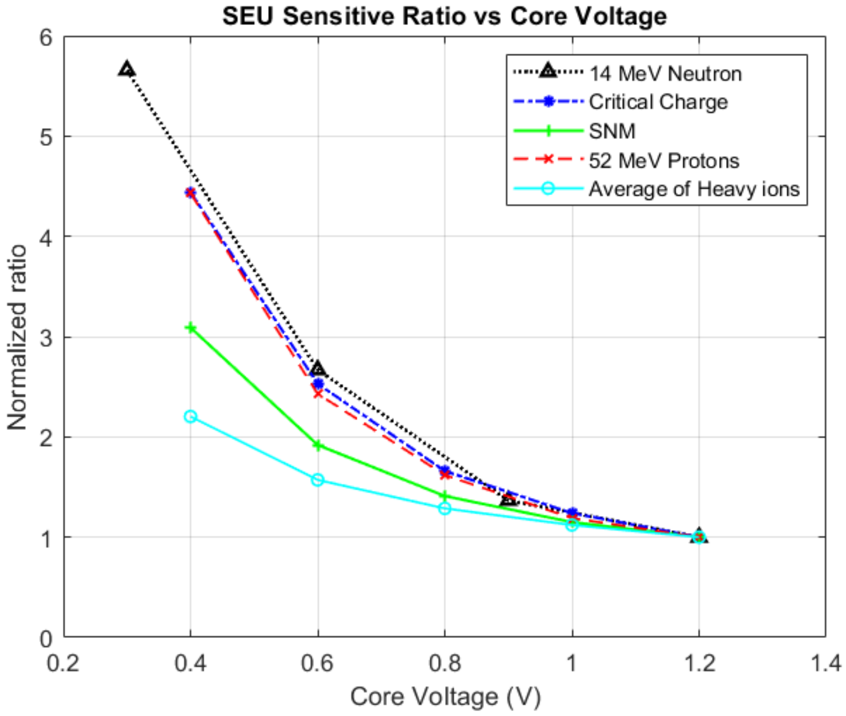
Comparison between 65nm and 180nm



Although the cell area shrinks, the sensitive area per cell raised from 8.17% to 18.7%, the SEU cross-section per unit surface increased by a factor of 2, for the 65 nm SRAM.

More advanced technology can utilize the silicon area more efficiently. [3]

Range of SEU sensitivity



high energy proton, neutron and heavy ion curves have different SEU cross section ranges:

- ❑ For low energy protons, the range of SEU cross-section is 3 to 4 orders of magnitude.
- ❑ For high energy protons and neutrons, the range is 4-5 times.
- ❑ For Heavy ions, the range is 2-3 times.

Conclusion

- 65 nm and 180 nm SRAMs did not show a much difference for the heavy ion and proton test results. Although the sensitive area in geometry layout shrunk 6 times, it did not change the single cell sensitivity. 65 nm technology only benefited from its high density, with a higher SEU cross-section per unit surface.

- Each type of particles shows a different sensitive range when varying voltage supply. Thus, the collected data enables sufficient calibration for the radiation monitor to analyse the intensity and type of the radiation environment by sweeping the supply voltage.

Reference

1. Apostolidis, G. & Balobas, Dimitrios & Konofaos, Nikos. (2016). Design and Simulation of 6T SRAM Cell Architectures in 32nm Technology. Journal of Engineering Science and Technology Review. 9. 145-149.
2. J. Prinzie, S. Thys, B. Van Bockel, J. Wang, V. De Smedt and P. Leroux, "An SRAM-Based Radiation Monitor With Dynamic Voltage Control in 0.18- μ m CMOS Technology," in IEEE Transactions on Nuclear Science, vol. 66, no. 1, pp. 282-289, Jan. 2019, doi: 10.1109/TNS.2018.2885693.
3. J. Wang, J. Prinzie, A. Coronetti, S. Thys, R. García Alía and P. Leroux, "Study of SEU sensitivity of SRAM-Based Radiation Monitors in 65 nm CMOS," in IEEE Transactions on Nuclear Science, doi: 10.1109/TNS.2021.3072328.

Thanks!

Q&A