RADSAGA

Predictive tools and "Radiation Hardening By Design" (RHBD) SEL and Temperature Effects

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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

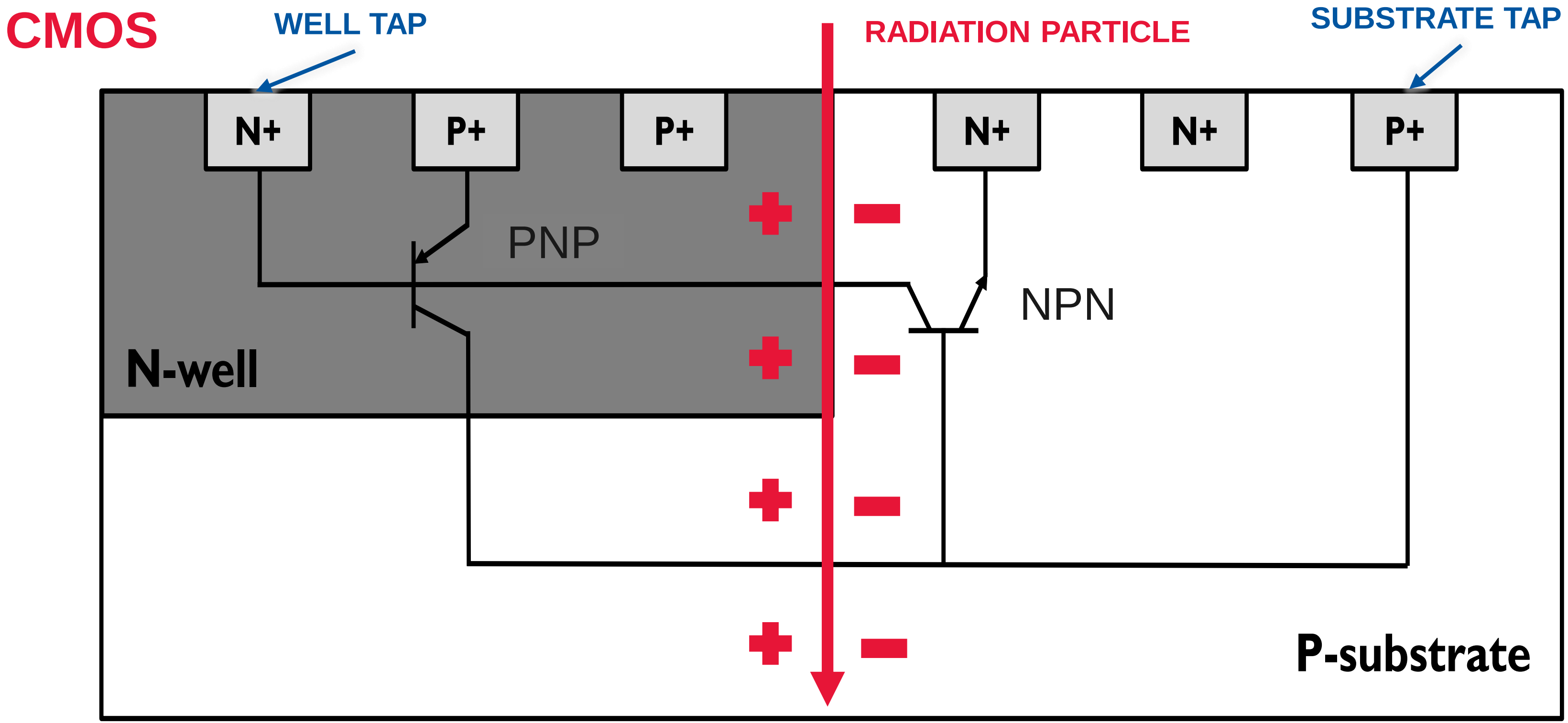
- Introduction
- Research Activities
- Ongoing work
- General conclusions

INTRODUCTION

Radiation Effects on Microelectronics

- Radiation effects pose a major threat to electronic components
- It exists a list of these effects
  - Total Ioninizing Dose
  - Displacement Damage
  - Single Event Effects (SEE)
- Simulation of those effects is crucial to understand their mechanism
- In our work, we investigated Single Event Latchup (SEL)

Single Event Latchup

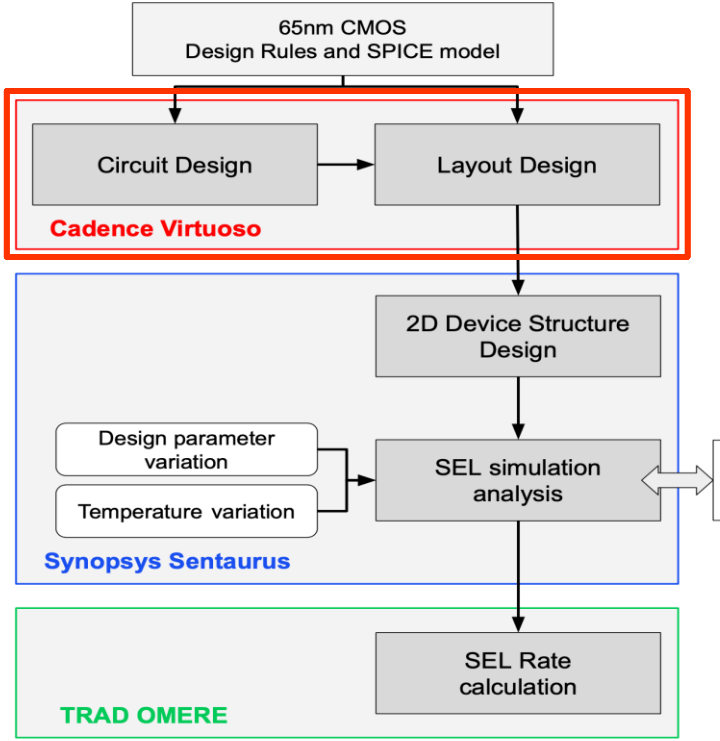


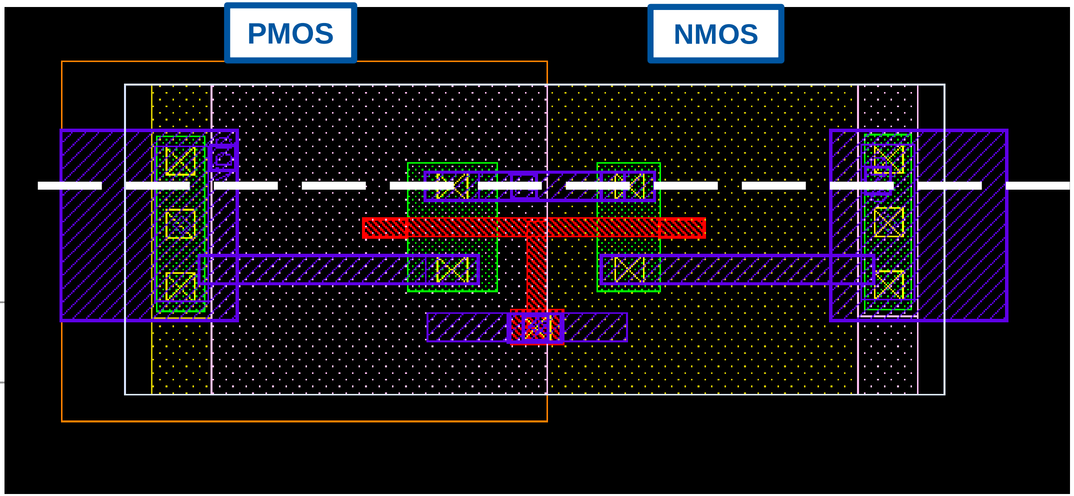
RESEARCH ACTIVITIES

GOALS

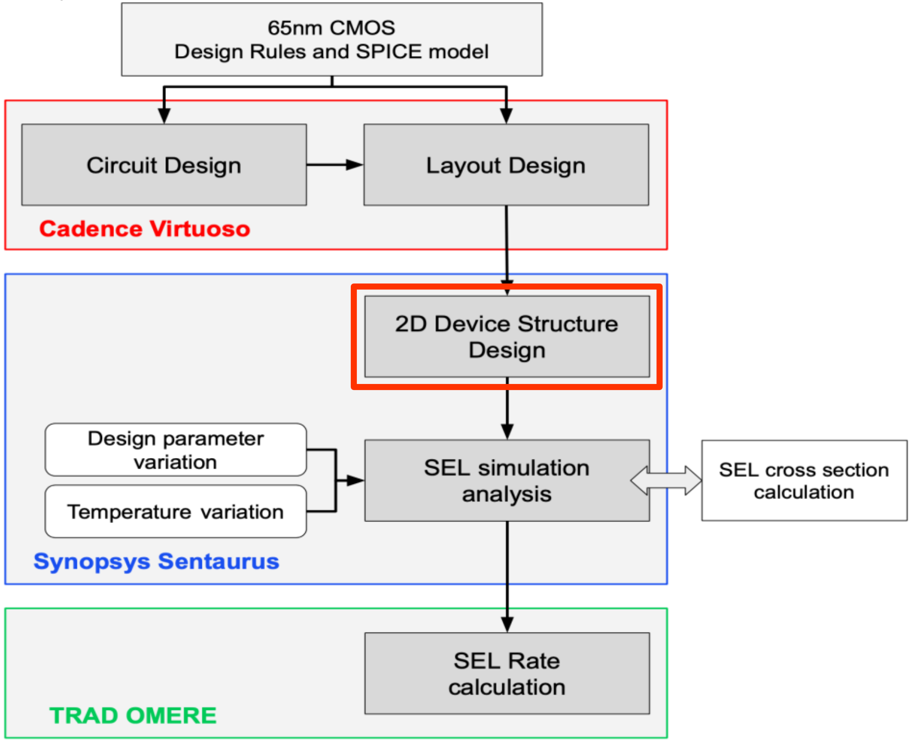
- To propose a simulation chain, that includes various environments, built on existing methodologies and tools to predict the SEL sensitivity of digital circuits.
- To investigate how certain parameters (design parameters and temperature) influence SEL sensitivity.
- To predict Single Event Latchup using SPICE simulations

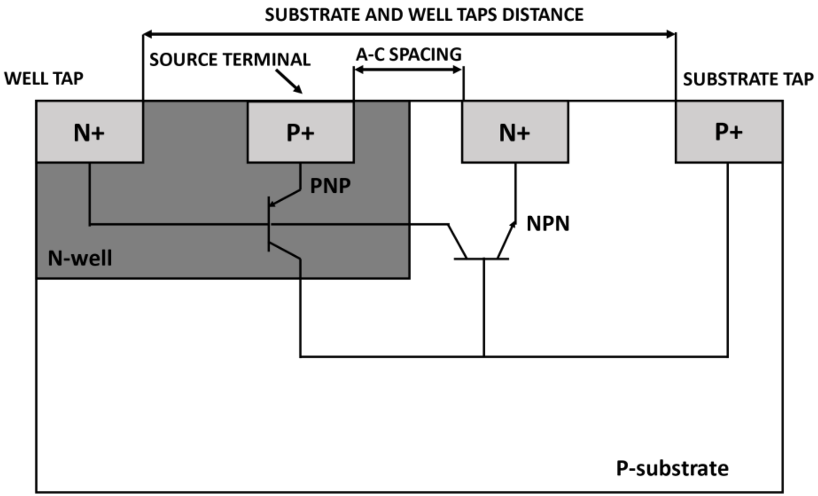
METHODOLOGY



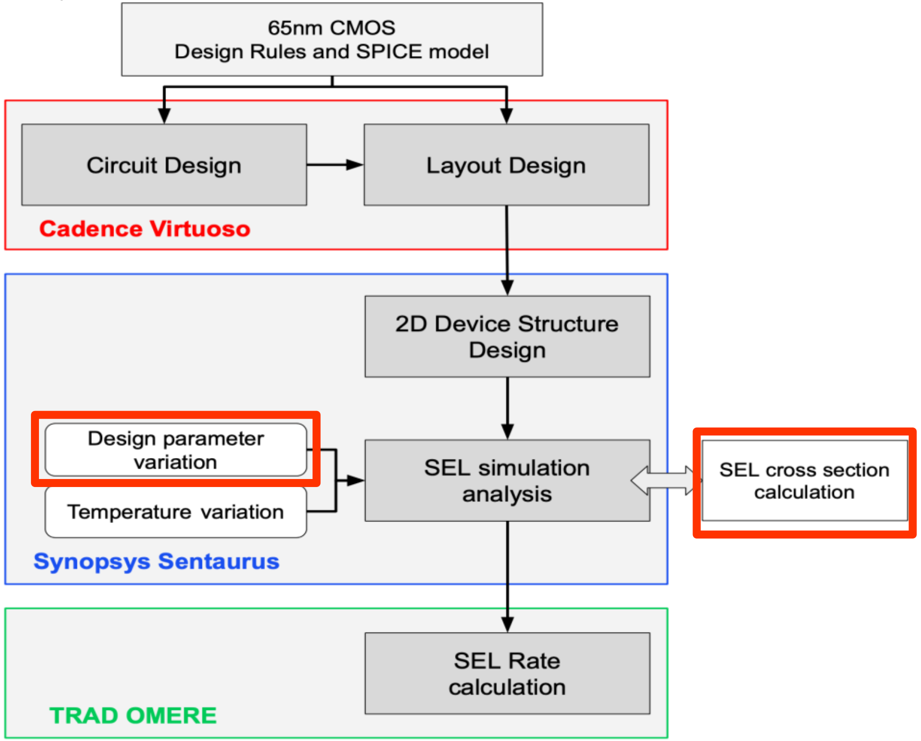


2D Device Structure Design





DEVICE PARAMETER VARIATION



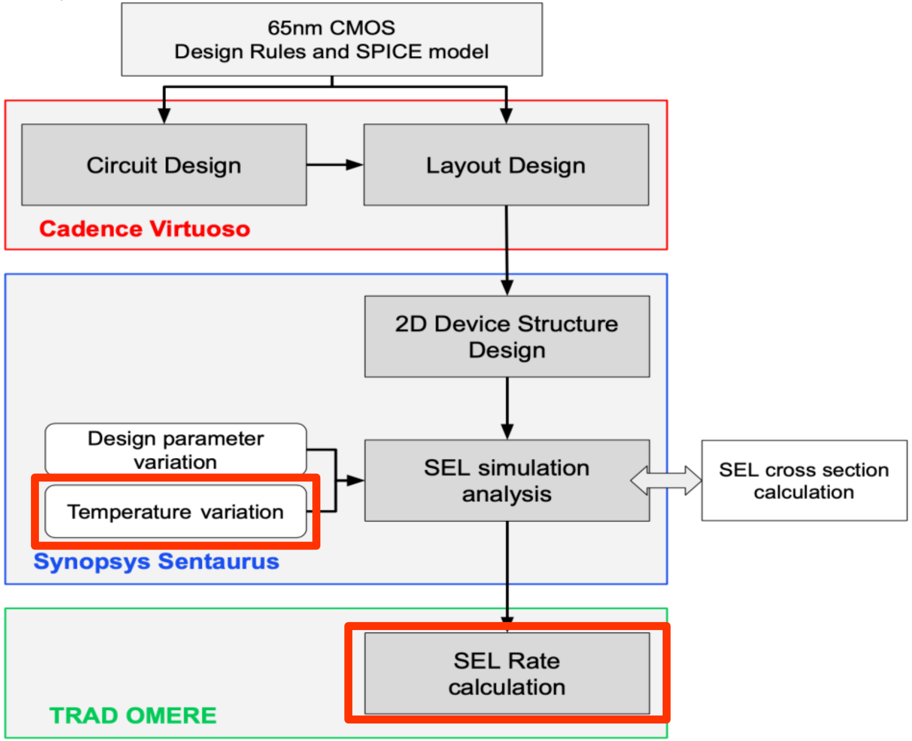
WHAT

- Investigate and compare the effects of three parameters
  - Anode to cathode spacing
  - Doping profile
  - Well and substrate taps placement

HOW

- Cross section from 2D simulations
  - Usually, only LET threshold is investigated
  - Our goal is to study the trend

TEMPERATURE VARIATION



WHAT

- ❑ Investigate the temperature variation on the three parameters

HOW

- ❑ LET Threshold
- ❑ SEL Rate in GEO orbit

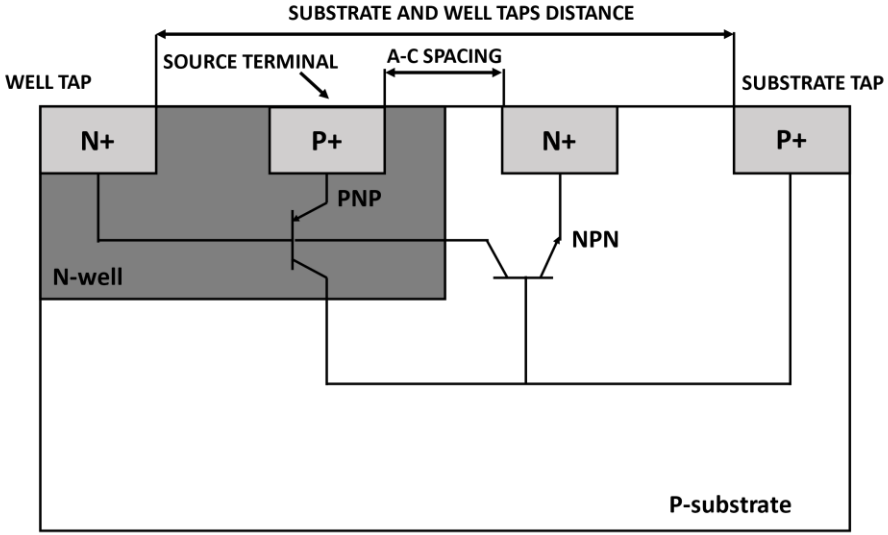
PARAMETERS

DOPING PROFILE FACTOR	x0.75
	x0.85
	x1 (Reference)
	x1.15
	x1.25

ANODE TO CATHODE SPACING	0.25 µm
	0.27 µm
	0.32 µm (Reference)
	0.35 µm
	0.4 µm

SUBSTRATE AND WELL TAPS DISTANCE	1.05 µm
	1.25 µm (Reference)
	1.55 µm
	1.85 µm
	2.15 µm

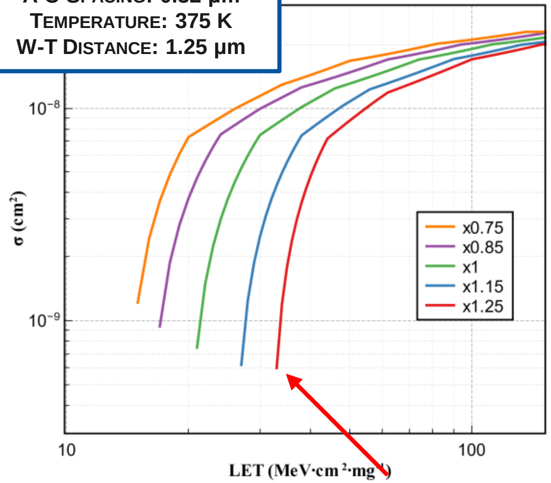
TEMPERATURE	**350 K**	**375 K (REF)**	**400 K**	**425 K**



Results – Design Parameter Variation

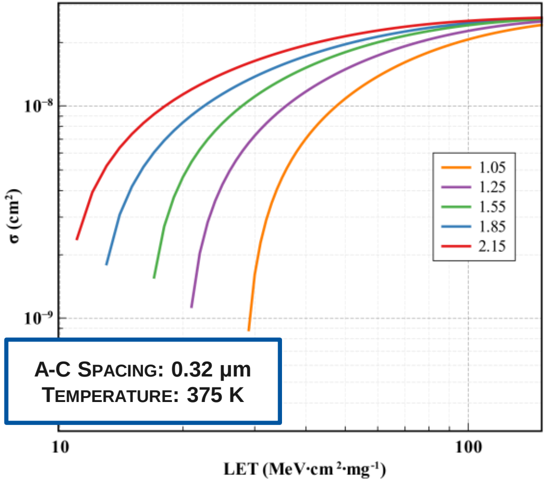
Doping Profile

A-C Spacing: 0.32 µm
Temperature: 375 K
W-T Distance: 1.25 µm



LET
Threshold

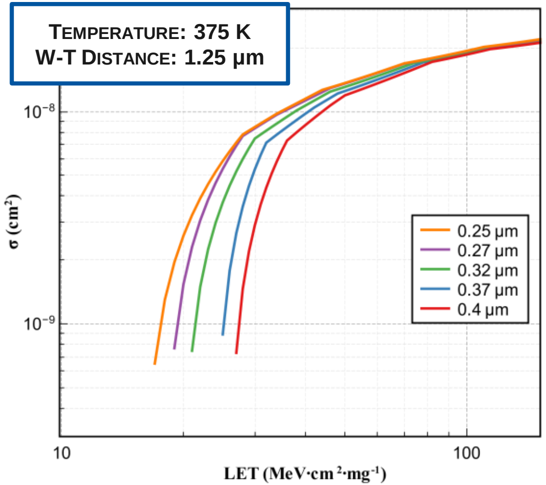
Well and Substrate Taps Distance



A-C Spacing: 0.32 µm
Temperature: 375 K

Anode to Cathode Spacing

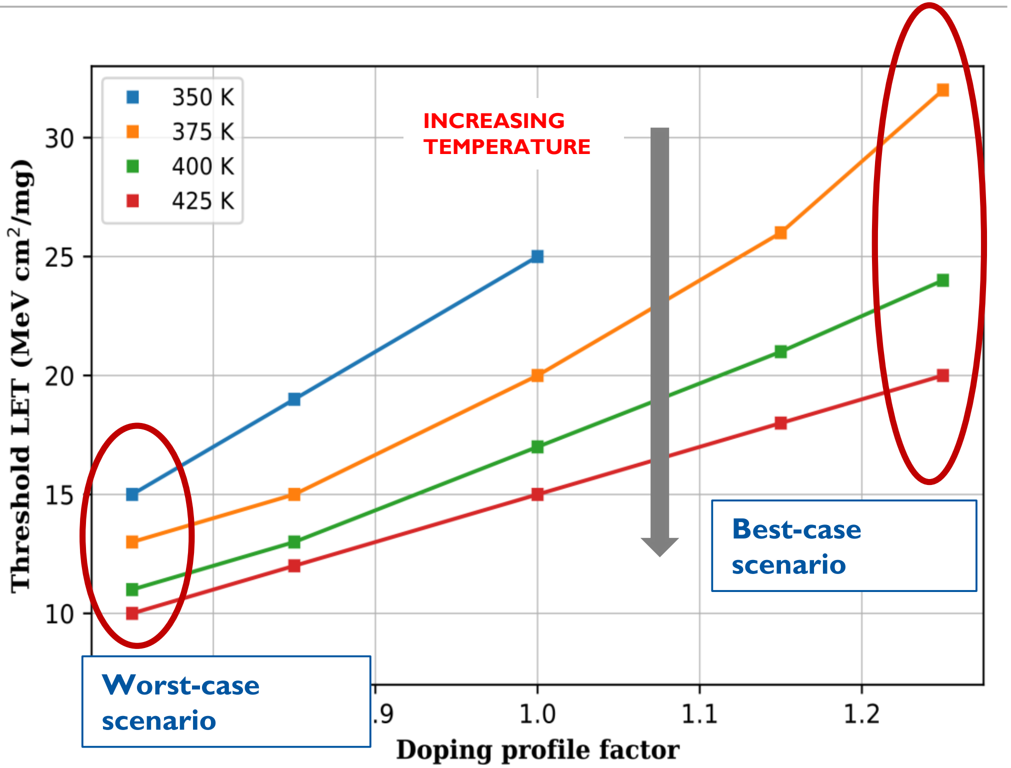
Temperature: 375 K
W-T Distance: 1.25 µm



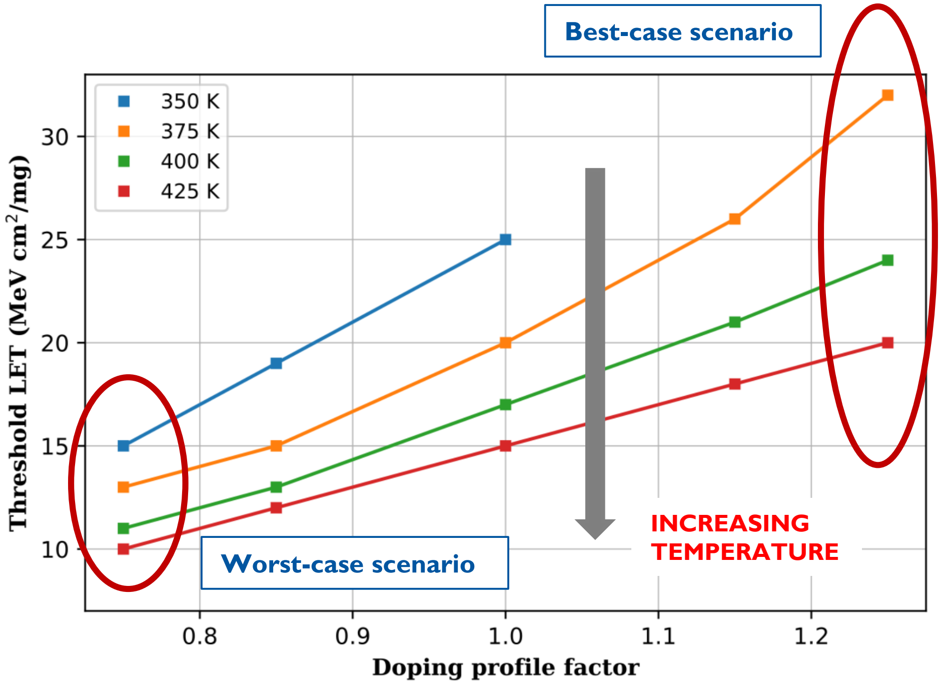
EXAMPLE

Worst-case scenario: *Favorable condition to SEL (lower threshold)*

Best-case scenario: *Device less sensible to SEL (higher threshold)*



RESULTS – TEMPERATURE VARIATION



Doping profile: 5 CASES

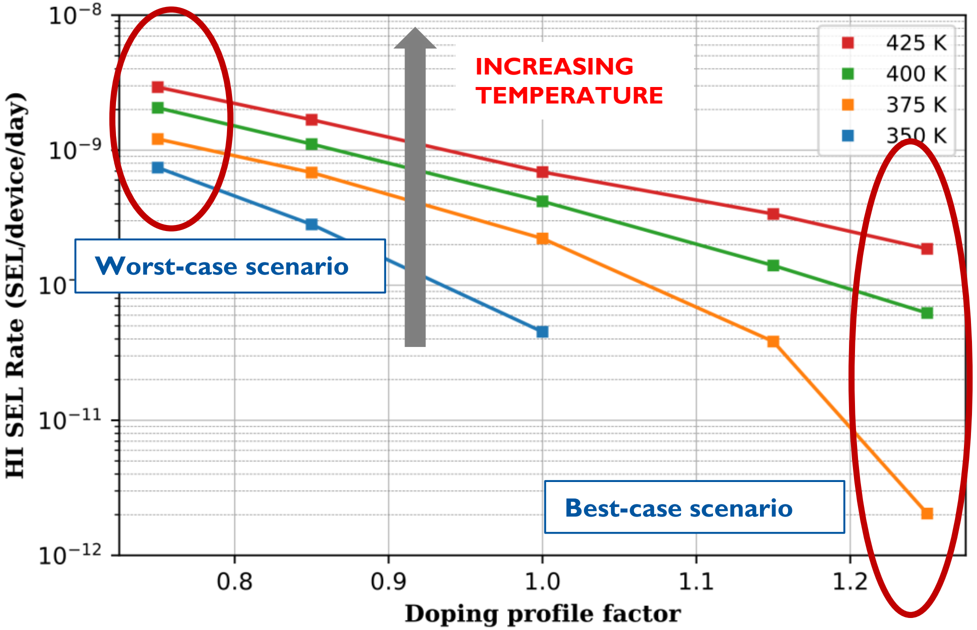
x0.75 , x0.85 , x1 , x1.15 , x1.25

Reference value

	x0.75	x0.85	x1	x1.15	x1.25
350 K	15%	27%	25%	NO SEL	NO SEL
375 K	18%	15%	18%	24%	33%
400 K	10%	8%	13%	17%	20%
425 K	0%	0%	0%	0%	0%

**No SEL at 350 K for x1.15 and x1.25*

RESULTS – TEMPERATURE VARIATION



Doping profile: ***5 CASES***

x0.75 , x0.85 , x1 , x1.15 , x1.25

Reference value

	x0.75	x0.85	x1	x1.15	x1.25
425 K	0%	0%	0%	0%	0%
400 K	-30%	-34%	-39%	-58%	-67%
375 K	-41%	-38%	-47%	-73%	-97%
350 K	-39%	-59%	-80%	NO SEL	NO SEL

**No SEL at 350 K for x1.15 and x1.25*

CONCLUSIONS

- We compared the effects of three parameters.
- We calculated cross section from 2D simulations.
  - Fast simulations.
  - Key value to estimate sensitivity.
- Doping profile variation and substrate and well tap placement have a stronger impact respect to anode to cathode spacing.
- These results are highly important in design phase to decide which strategies can be adopted to harden the component.

CONCLUSIONS

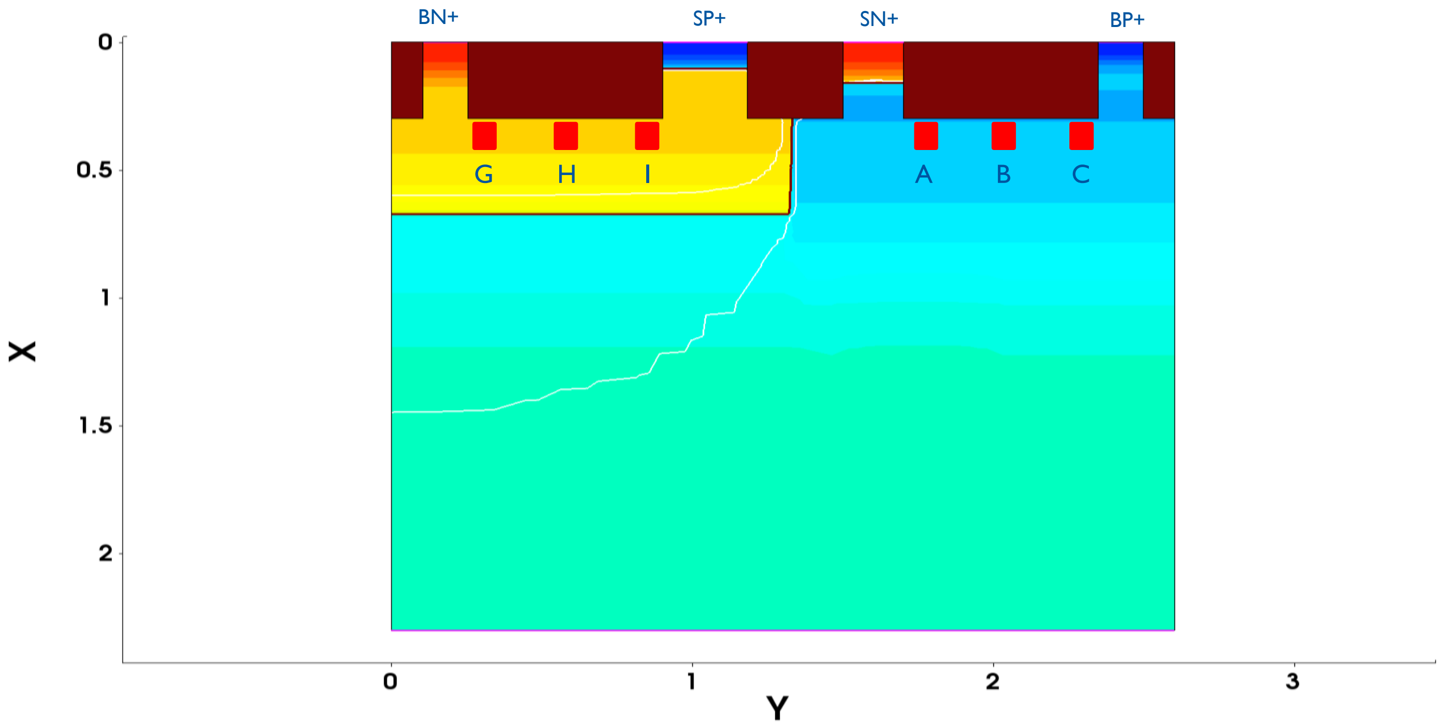
- We have observed, for every case, that when the component is less sensitive to SEL, temperature has a stronger impact on LET threshold, with respect to the opposite case
- The same trend has been observed for SEL rate

ONGOING WORK

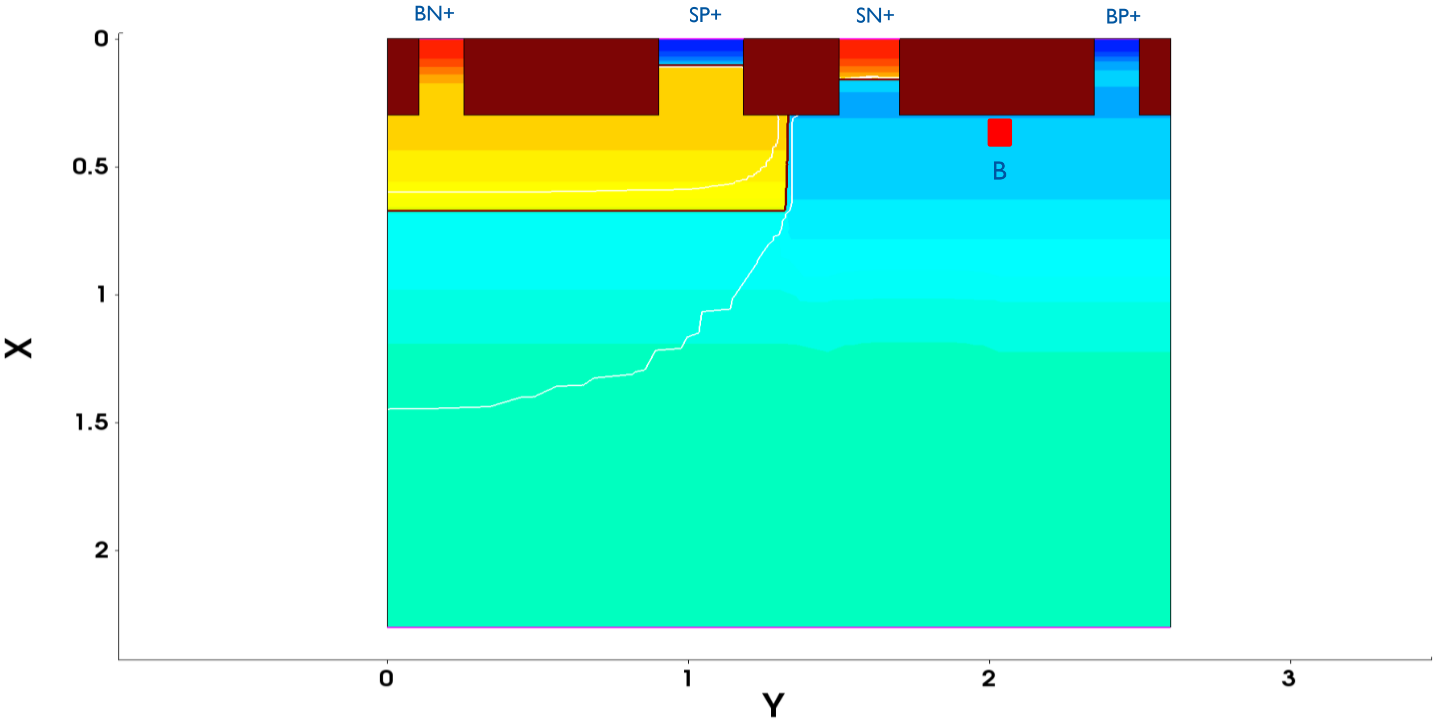
GOALS

- To define a precise dynamic of Single Event Latchup
- To predict Single Event Latchup using SPICE simulation

SEL DYNAMIC



SEL Dynamic



SEL Dynamic

1. Ion hits the device (in this example, in point B)

↓

2. A current flows from BN+ to BP+

↓

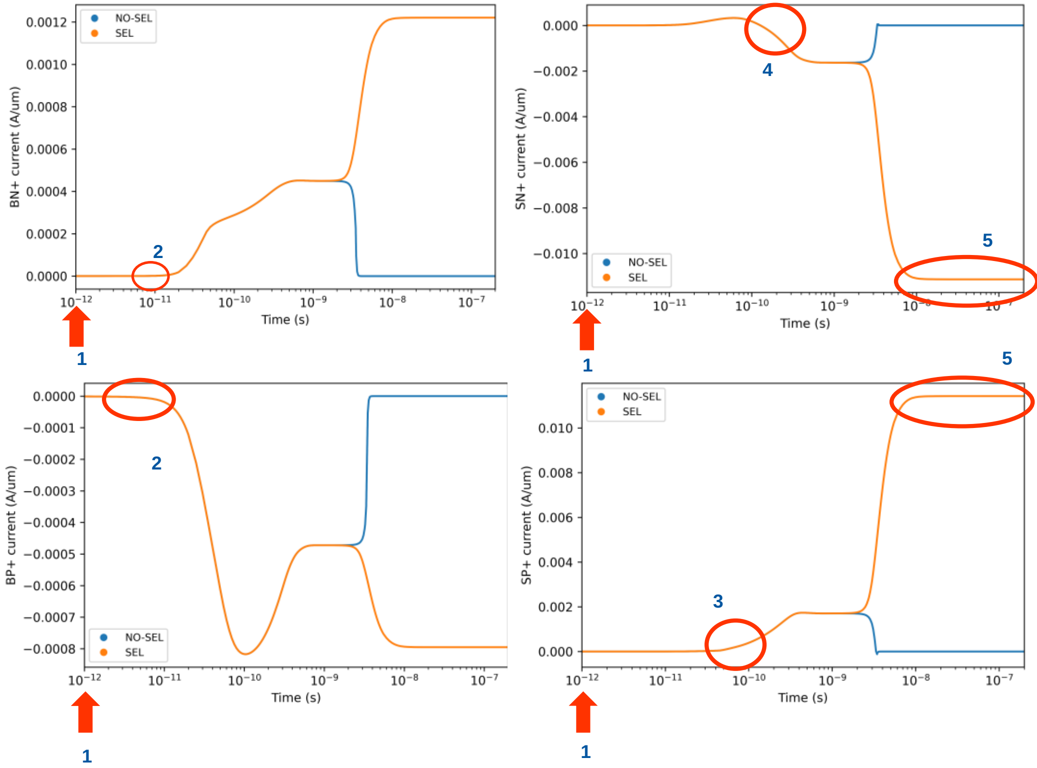
3. The current activates one of the parasitic transistor (in this example the PNP).

↓

4. The current flows in the substrate and it activates the second parasitic transistor (NPN)

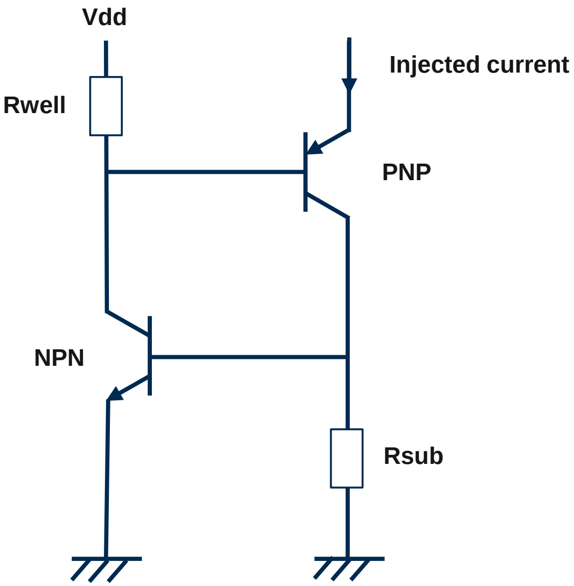
↓

5. SEL occurs



SPICE

- The PNPN structure can be also simulated in SPICE
- The ion can be modeled as an injected current
- We can predict SEL by linking the ion LET to the injected current
- We are developing a new structure to simulate SEL in SPICE



G. Bruguier and J. -M. Palau, "Single particle-induced latchup," in *IEEE Transactions on Nuclear Science*, vol. 43, no. 2, pp. 522-532, April 1996, doi: 10.1109/23.490898.

CONCLUSIONS

CONCLUSIONS

- The effects of layout design on SEL sensitivity has been investigated
- The effects of temperature has been investigated
- A new predictive method is under development

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PUBLICATIONS

- **[1] S. Guagliardo,** F. Wrobel, Y.Q. Aguiar, J.-L. Autran, P. Leroux, F. Saigné, A.D. Touboul, V. Pouget., Single Event Latchup Cross Section Calculation from TCAD Simulations—Effects of the Doping Profiles and Anode to Cathode Spacing, *European Conference on Radiation and its effects on Component and Systems (RADECS 2019)*, Montpellier, France, 2019, *to be published*.

- **[2] S. Guagliardo,** F. Wrobel, Y.Q. Aguiar, J.-L. Autran, P. Leroux, F. Saigné, A.D. Touboul, V. Pouget, "Effect of Temperature on Single Event Latchup Sensitivity," *2020 15th Design & Technology of Integrated Systems in Nanoscale Era (DTIS)*, Marrakech, Morocco, 2020, pp. 1-5.

- **[3] S. Guagliardo,** F. Wrobel, Y.Q. Aguiar, J.-L. Autran, P. Leroux, F. Saigné, A.D. Touboul, V. Pouget, "Single-Event Latchup sensitivity: Temperature effects and the role of the collected charge," *Microelectronics Reliability, Volume 119, 2021, 114087, ISSN 0026-2714,*

SPARE

Cross Section Calculation

Simulation performed with TCAD

↓

Minimum LET evaluated

↓

Calculation of sensitive zone

↓

Calculation of Cross Section