

Total Ionizing Dose and Dose Rate Switching Method

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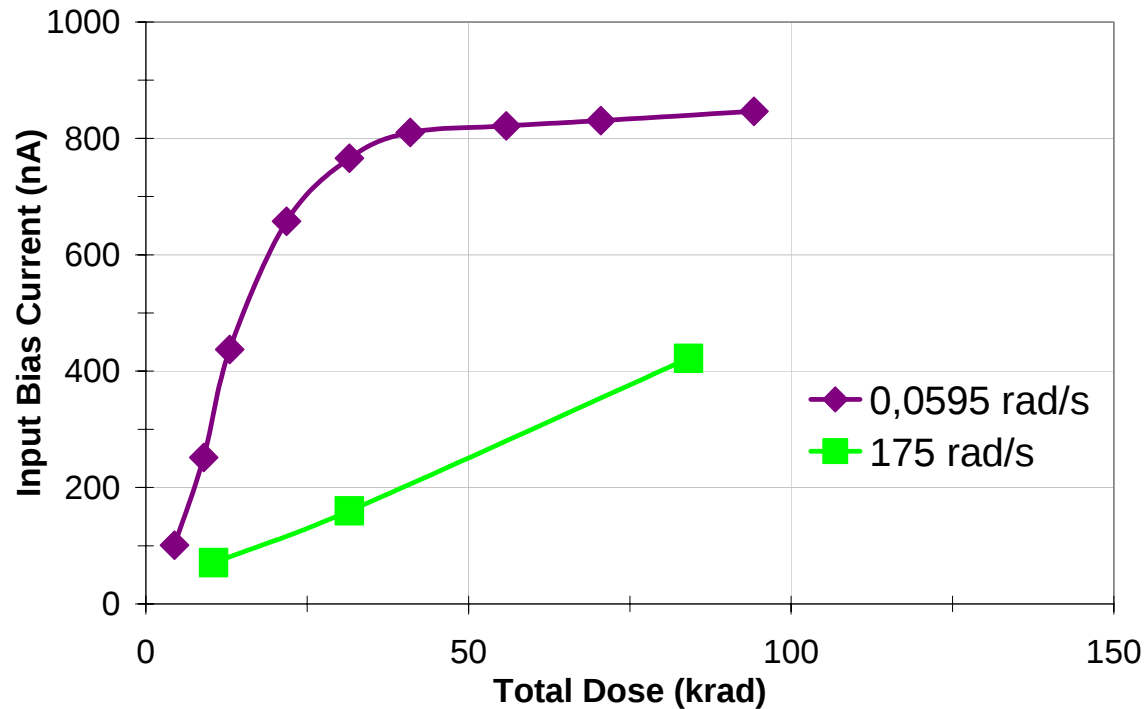
Équipe **RADIAC** « **RADI**ation et **Composants** »
Institut d'Électronique du Sud (**IES**)

- What is ELDRS
- A New Physical Model
- Switching Experiments
- A New Way to Device Evaluation

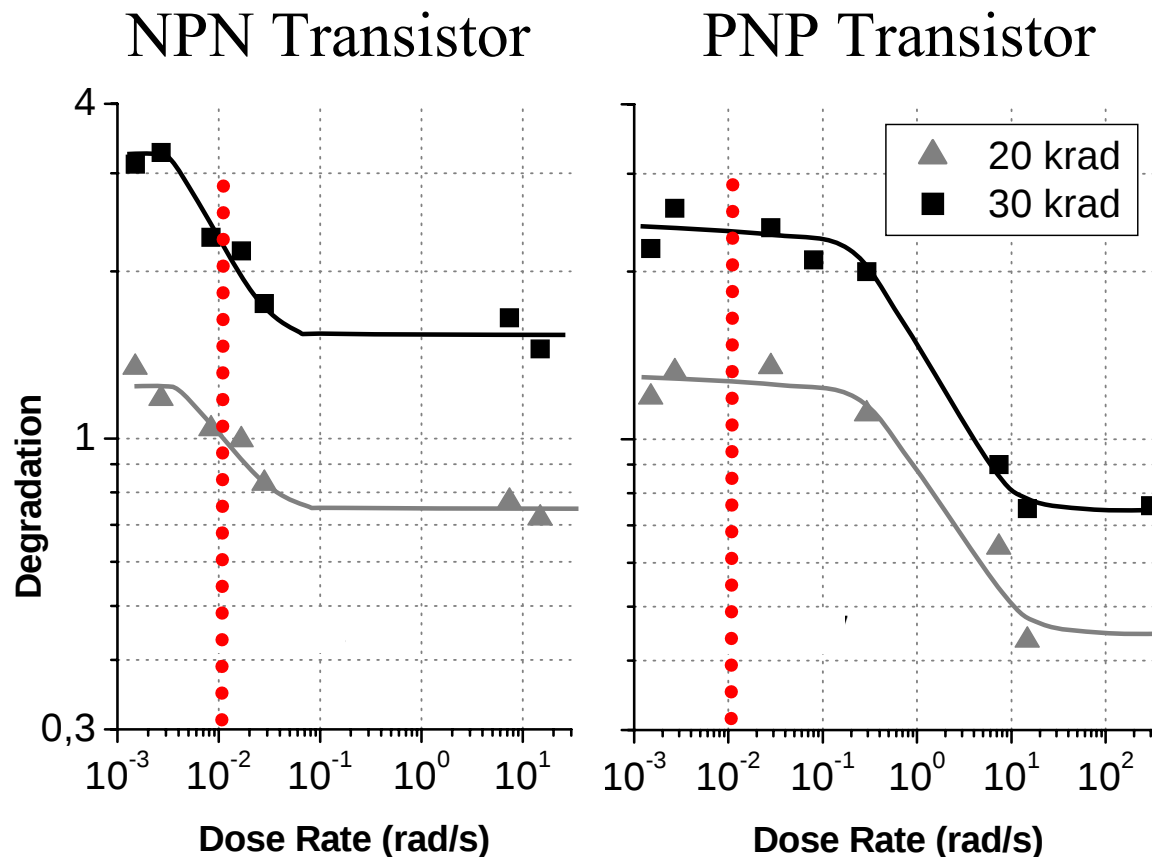
ELDRS = Enhanced Low Dose Rate Sensitivity.

Enlow - IEEE TNS (1991)

“Bipolar devices irradiated at low dose rates exhibit more degradation than devices irradiated at high dose rates.”



Usual “Inversed S-Shape Curve”

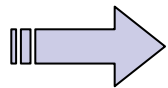


In test standards MIL-STD-883 TM1019 or ECSS-22900, the consideration of ELDRS is recent and proposes a baseline low dose rate test of 0.01 rad/s (36 rad/h).

At this dose rate, **six months** are needed to qualify a part to 100 krad (that means to reach 150 krad that corresponds to 1.5 times the dose in TM1019 condition D).

However, several parts are known to exhibit an increase of the degradation when the dose rate decreases below 0.01 rad/s [Pea08].

For these devices, if 0.001 rad/s dose rate is chosen as a baseline low dose rate test, **five years** are needed to qualify a part to 100 krad.



Accelerated test techniques are needed.

Three main accelerated test techniques have been proposed:

□ the first one is based on elevated temperature irradiation (ETI).

□ the second technique is based on experiments with externally applied hydrogen.

***Unknown
overdegradation***

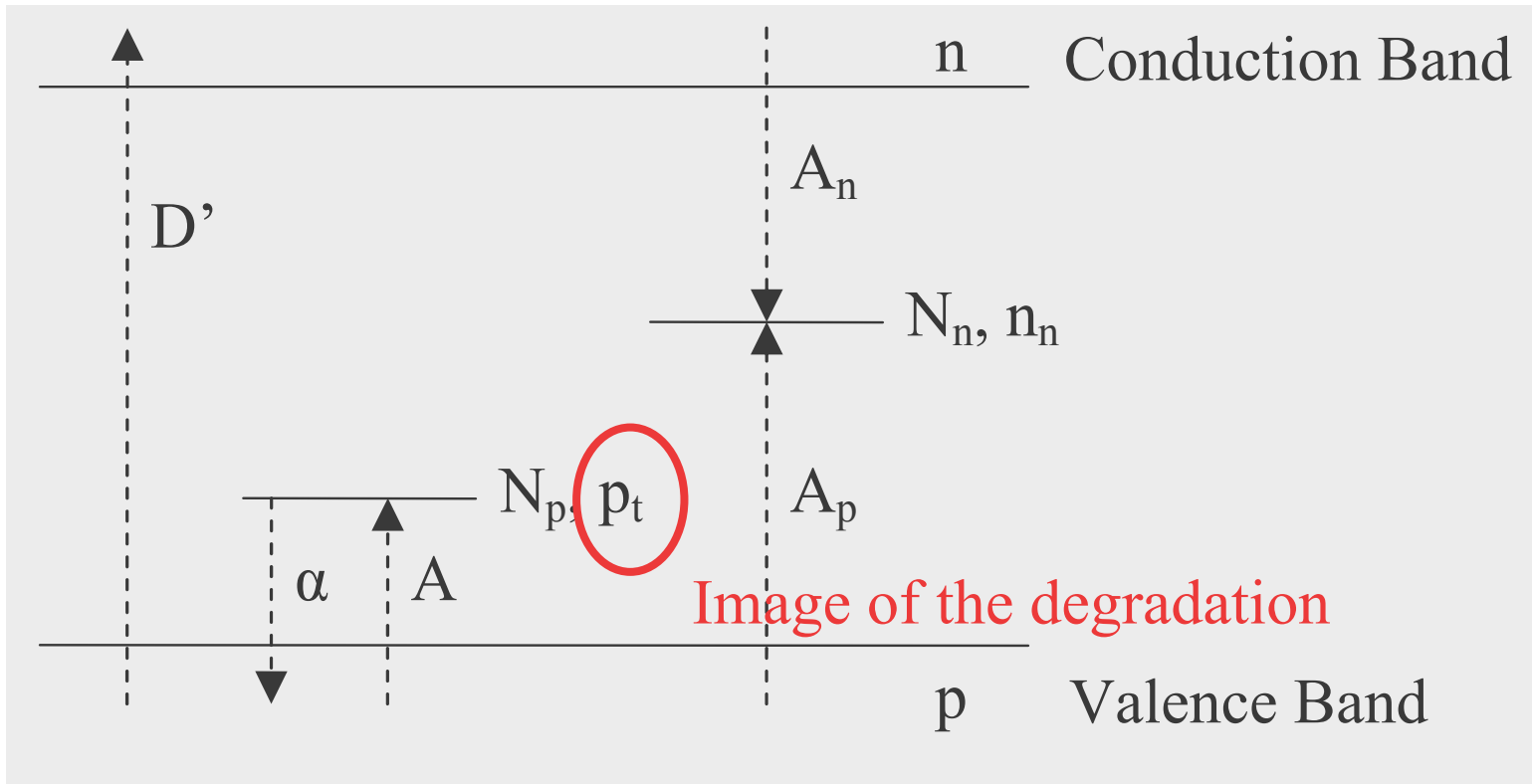
□ the last one considers a switched dose rate approach.



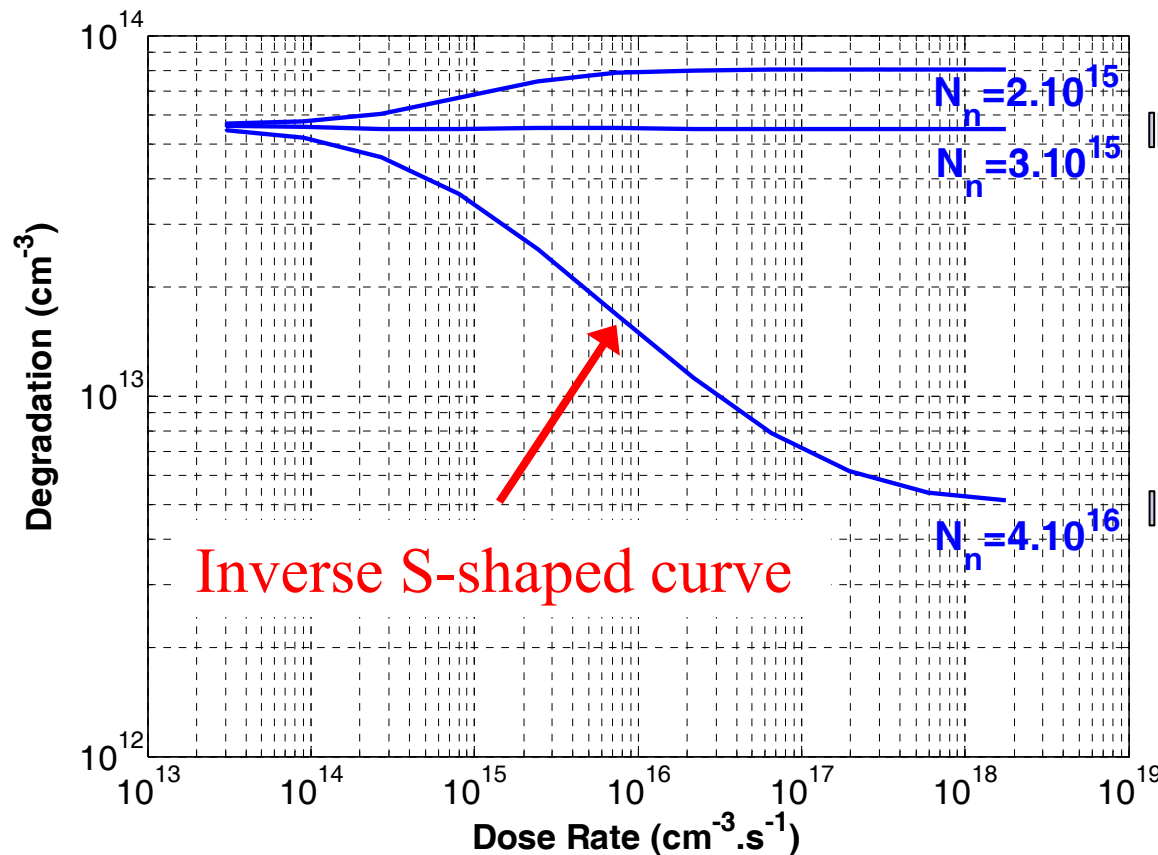
Rebuild the entire low dose rate curve

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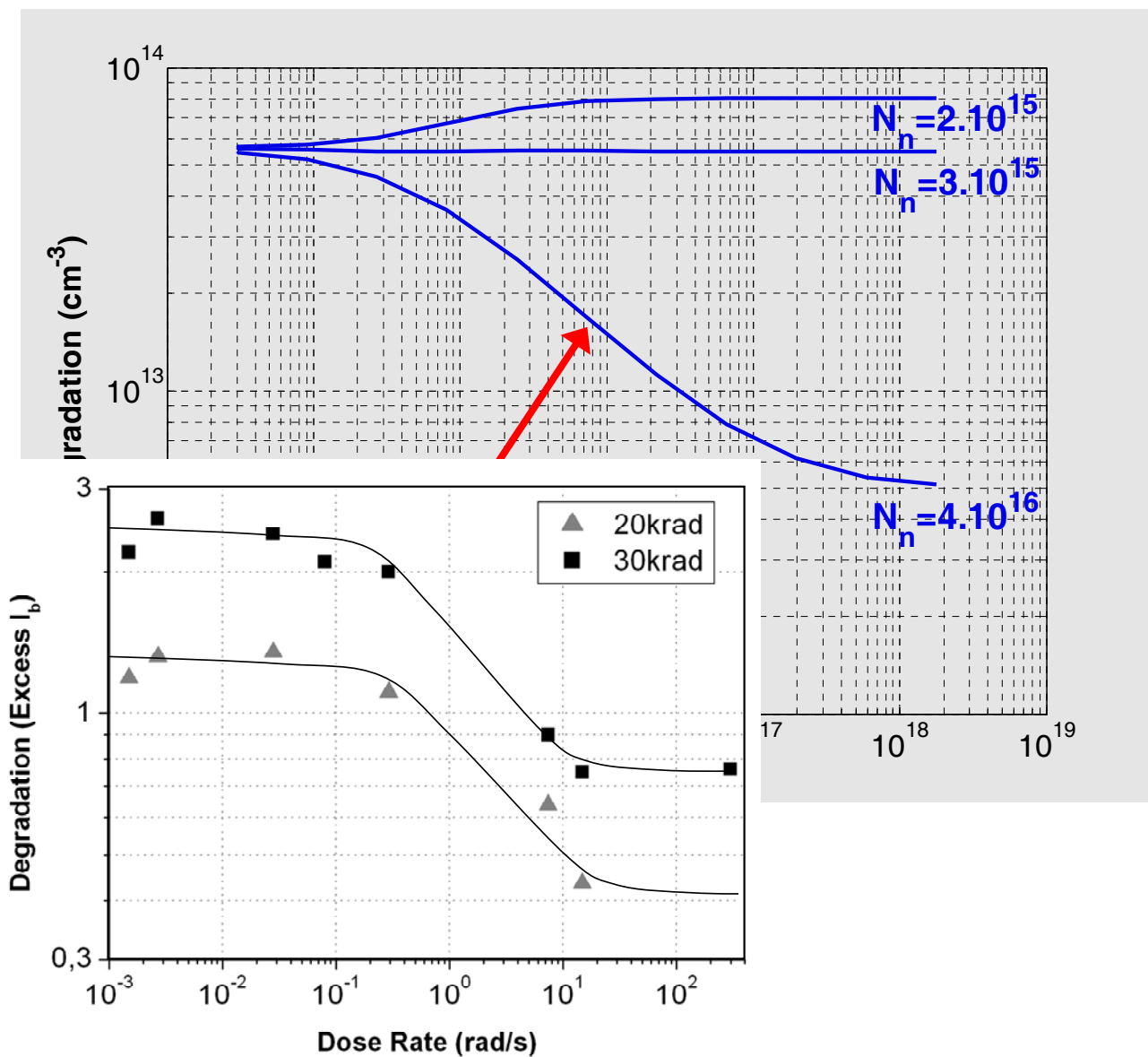
Energetic Diagram in the Oxide



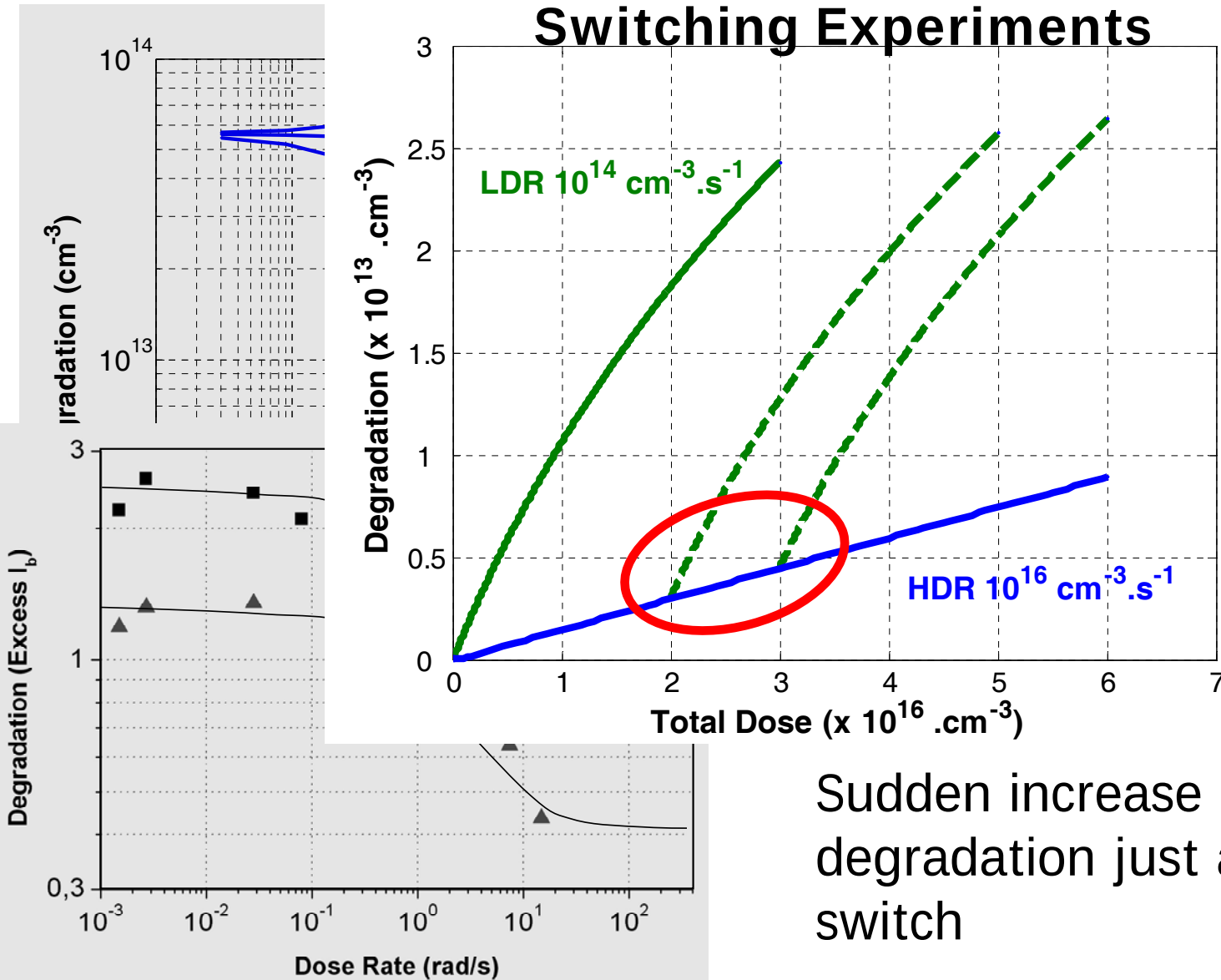
- ✓ One hole trap
- ✓ One recombination center (electron trap)



- ✓ The degradation depends of the oxide quality
- ✓ An inverse S-shaped curve is obtained for large N_h



Simulation of Switching Experiments



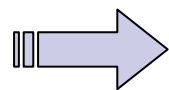
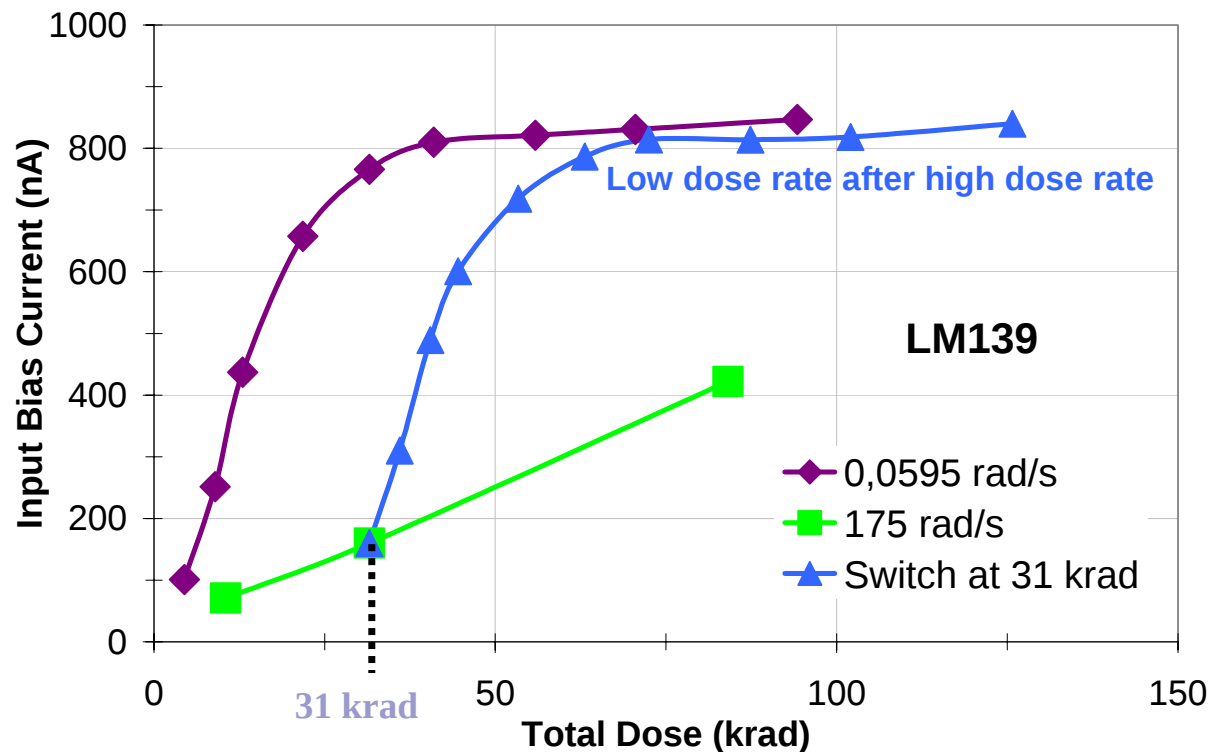
Sudden increase of the degradation just after the switch

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Switching Experiments

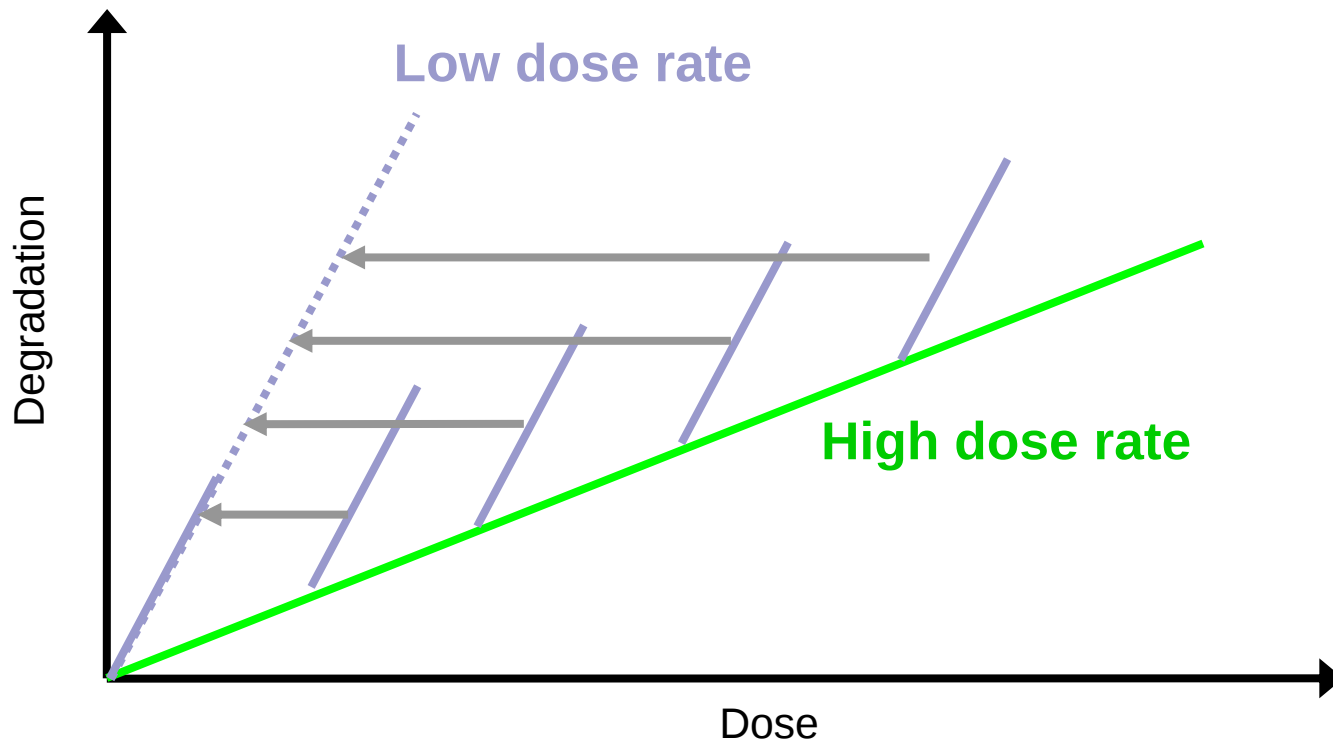
= a two-steps irradiation process:

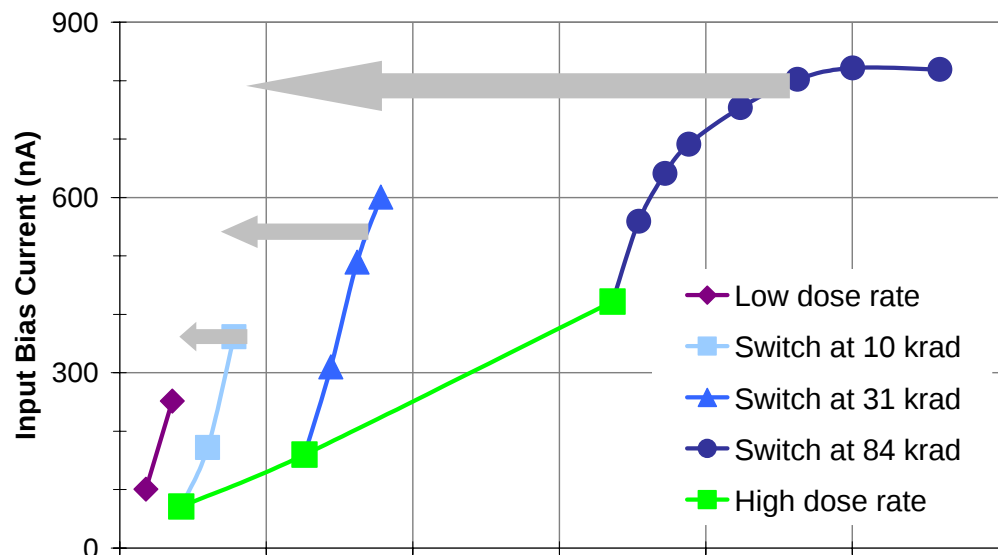
- first: a high dose rate irradiation
- second: a low dose rate irradiation



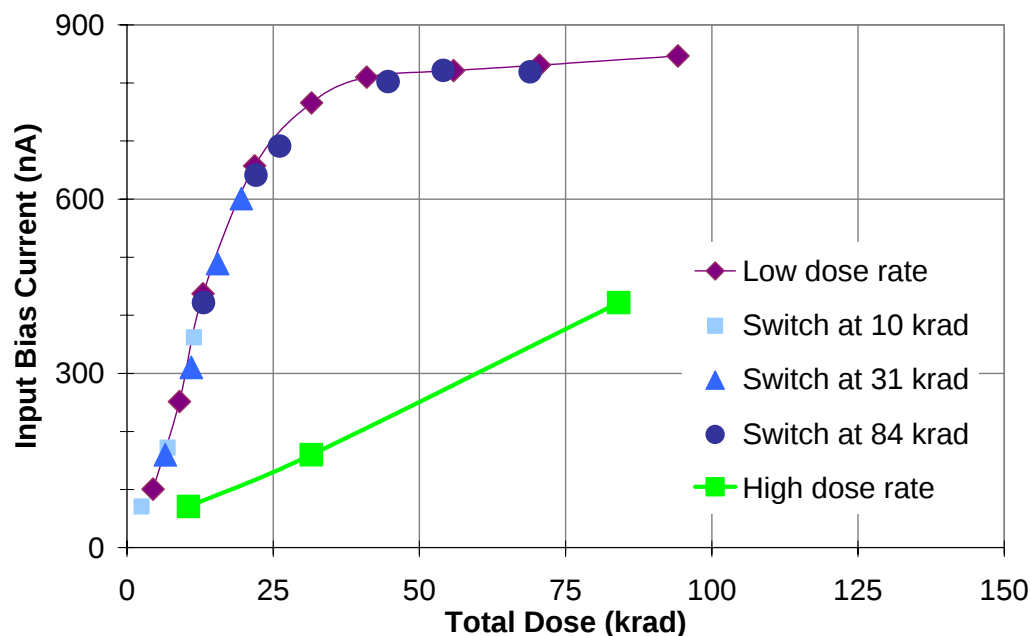
Immediately after the switch, the switched devices follow the low dose rate curve

➡ With several switching experiments it may be possible to reconstruct the low dose rate curve in agreement with the physical mechanisms at play at low dose rate.





LM139 irradiated all pins grounded



Validated

- On several circuits LM101, LM111, LM124, LM139
- On two static electrical parameters I_{in} and I_{cc}

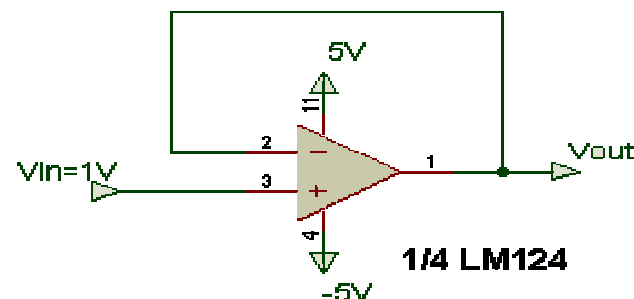
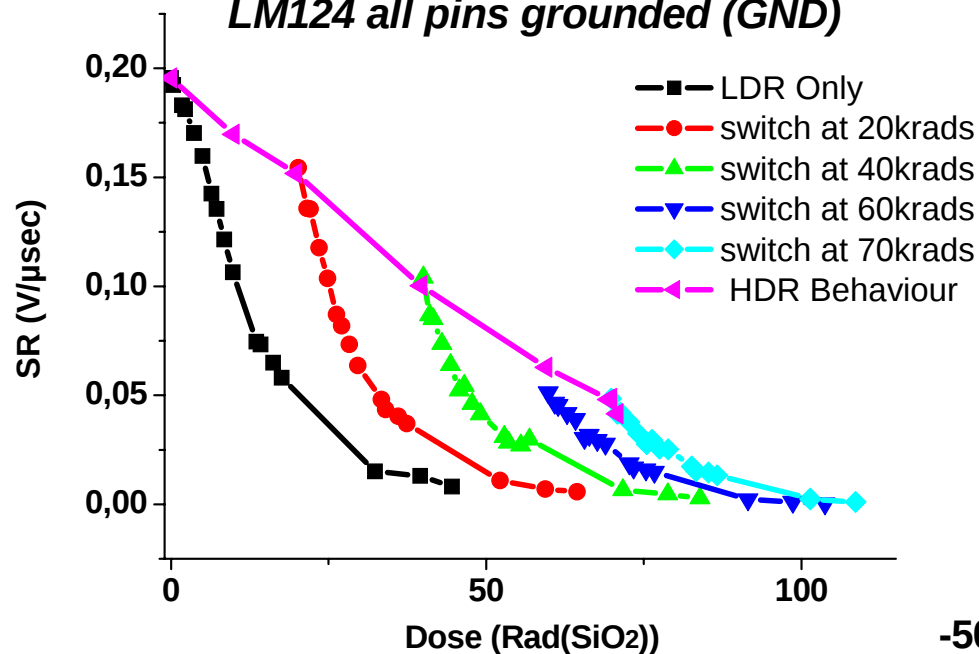
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Some concerns ?

- ☐ More electrical parameters (dynamic) ?
- ☐ Bias during irradiation ?
- ☐ The choice of the high dose rate to use ?
- ☐ ...

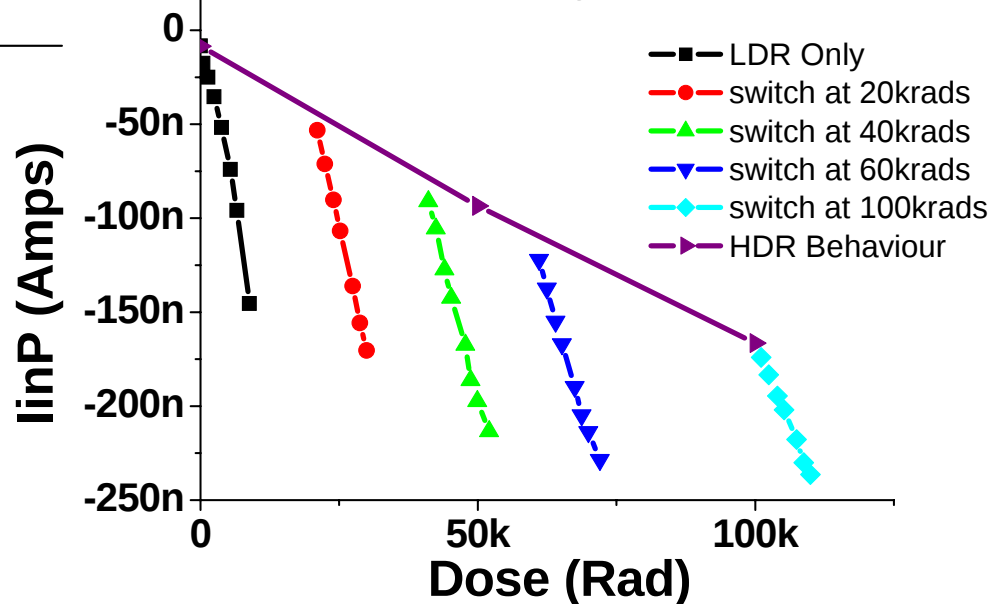
Slew Rate ($V/\mu\text{sec}$)

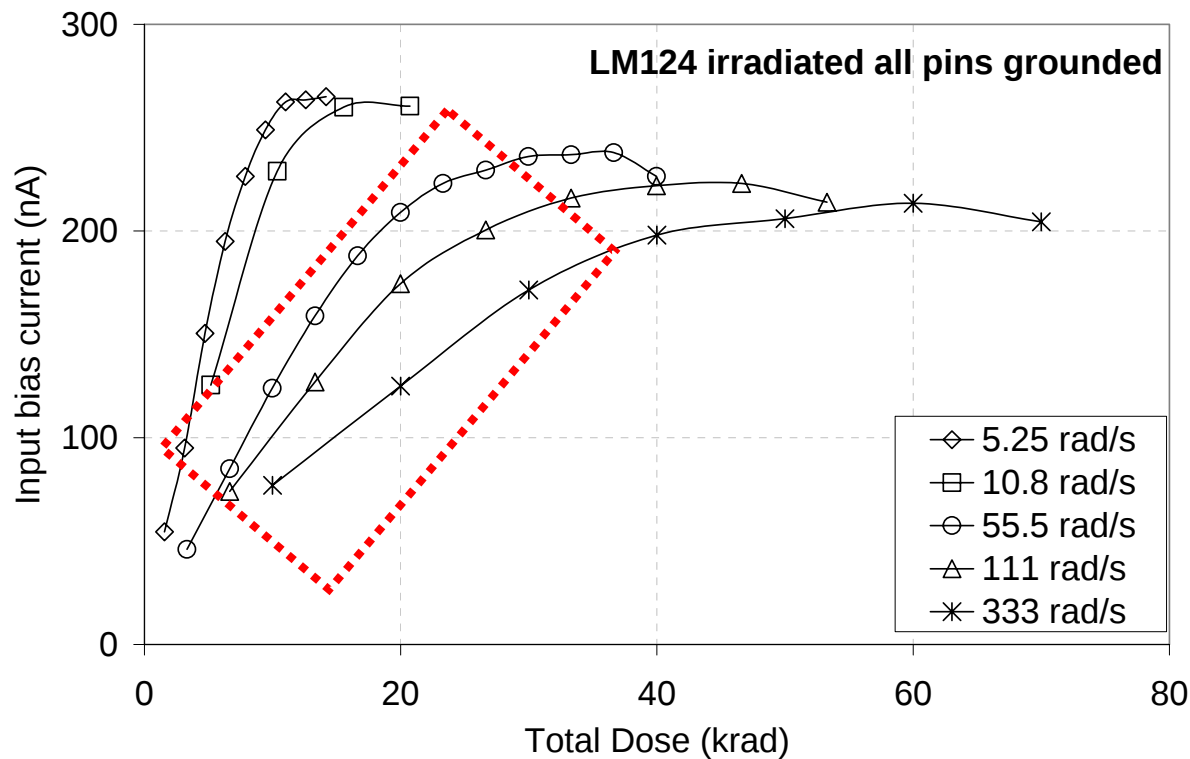
LM124 all pins grounded (GND)



Positive Input Current I_{inP} (A)

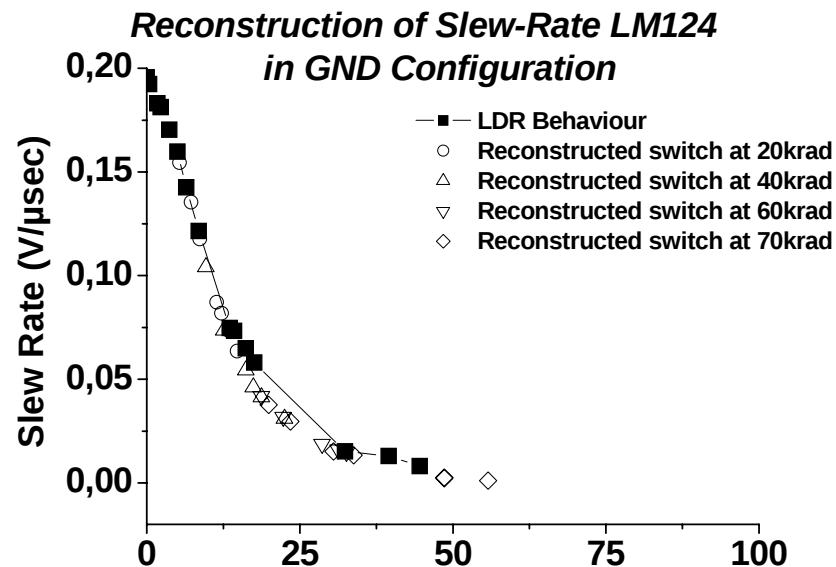
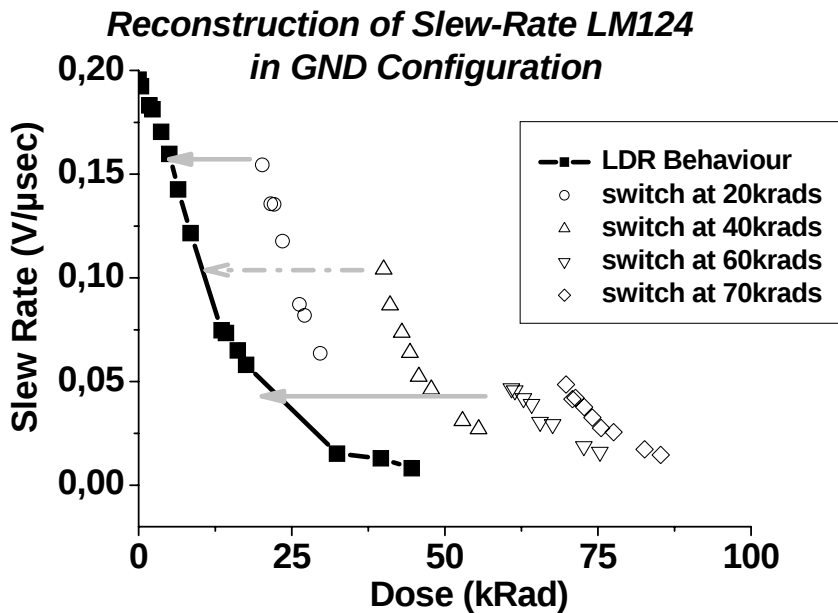
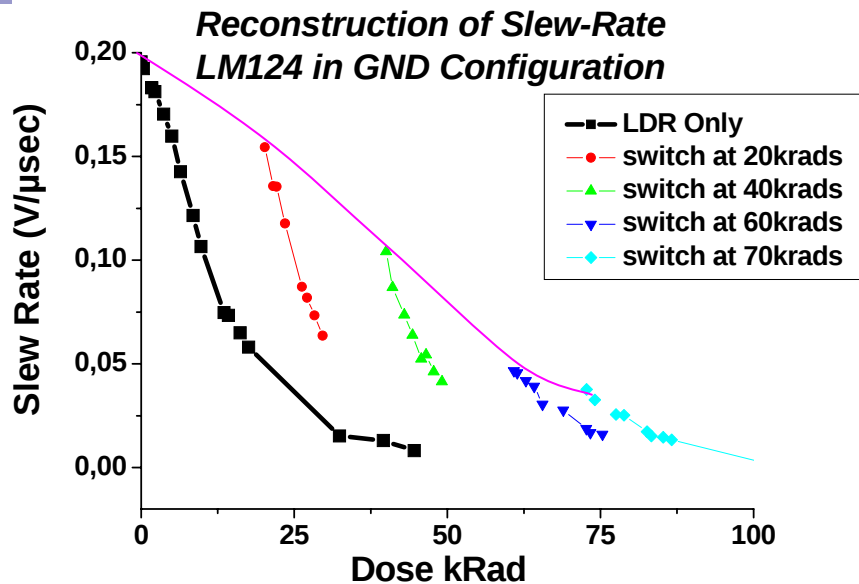
LM124 in VF Configuration



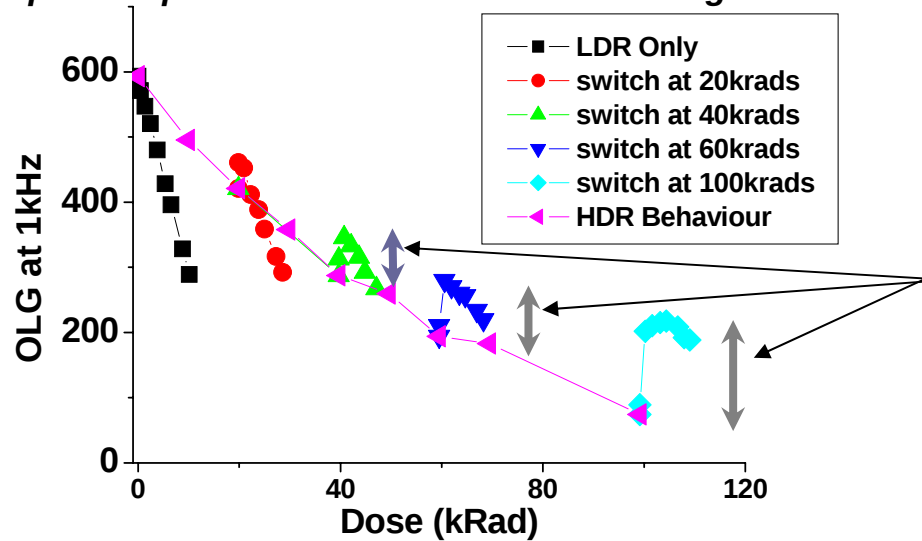


The high dose rate must be upper than 100 rad/s in order to be in the “linear” region of the HDR curve .

The low dose rate can be close to the one encountered during the mission.

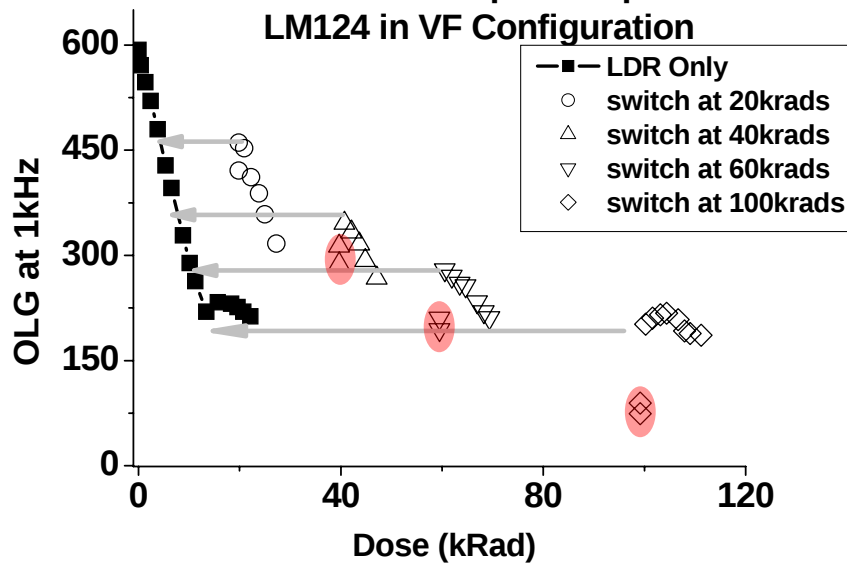


Open Loop Gain at 1kHz LM124 in VF Configuration

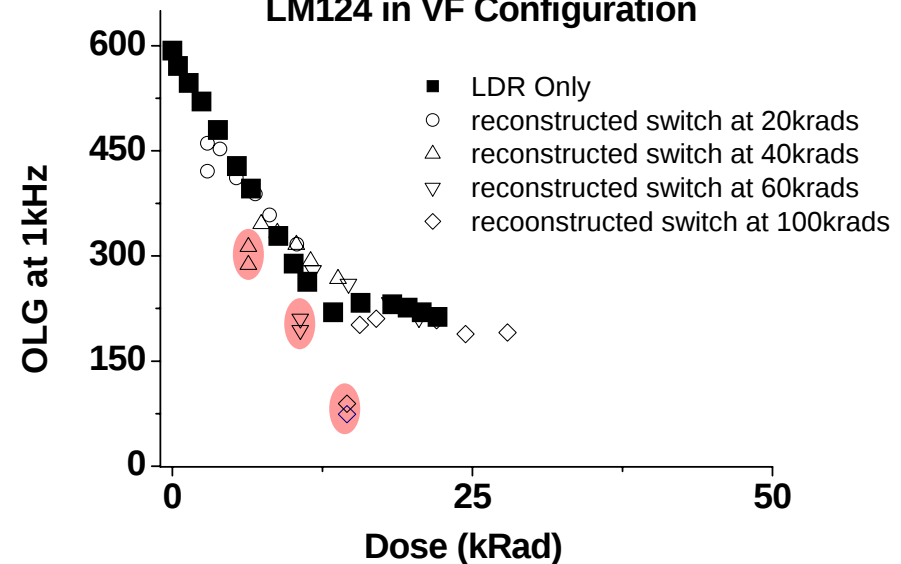


Annealing after HDR

Reconstructed Open Loop Gain LM124 in VF Configuration



Reconstructed Open Loop Gain LM124 in VF Configuration



Conclusion

- The switching approach is a promising method
 - Close to the mechanisms at play at low dose rate
 - Mechanisms are explained by the proposed model
 - Allow to rebuild the entire low dose rate characteristic

- This approach has been validated
 - Several IC (LM101, LM111, LM124, LM139, 2n2222, 2n2907 ...)
 - Several electrical parameters (I_b , I_{cc} , SR, OLG ...)
 - Several bias configurations during irradiation