Switched Dose Rates as an Alternative Method for EDLRS Testing

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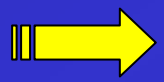
Outline

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

 A New Testing Method

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Dose Rate Effect

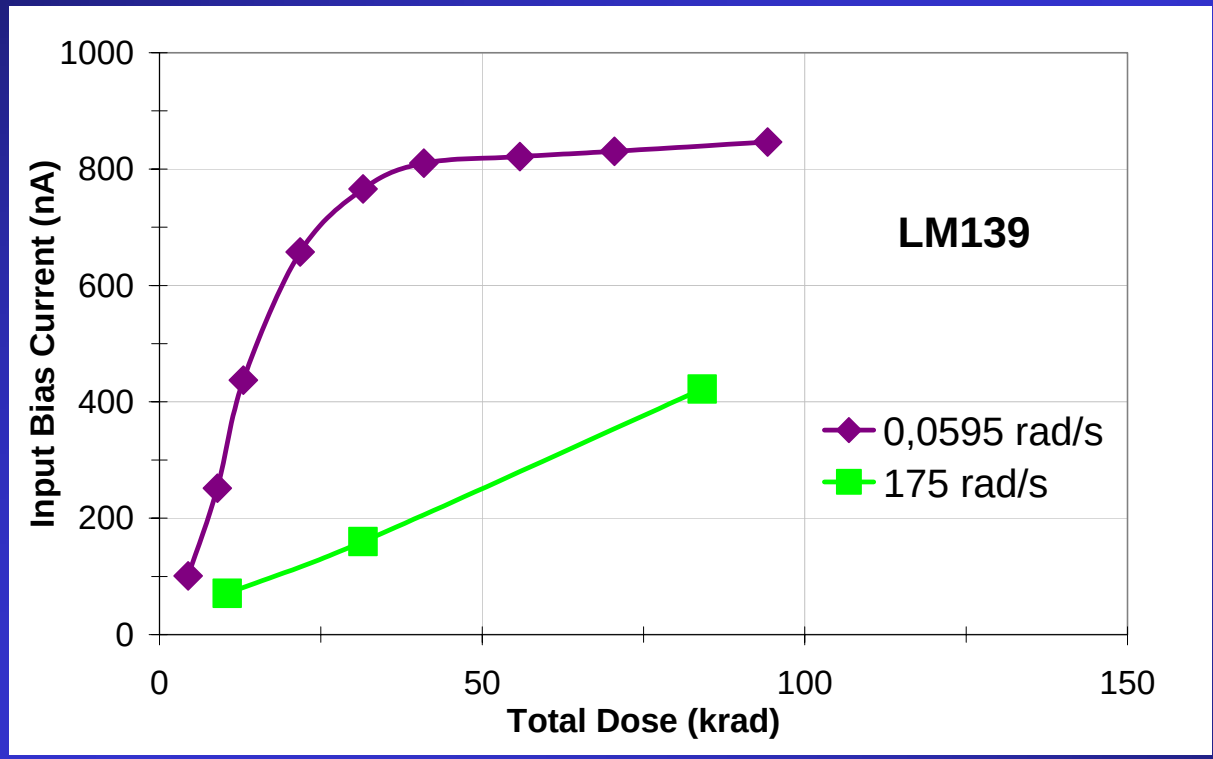
ELDRS = Enhanced Low Dose Rate Sensitivity.

Enlow - IEEE TNS (1991)

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

⇒ Validity of accelerated tests at ground level ?

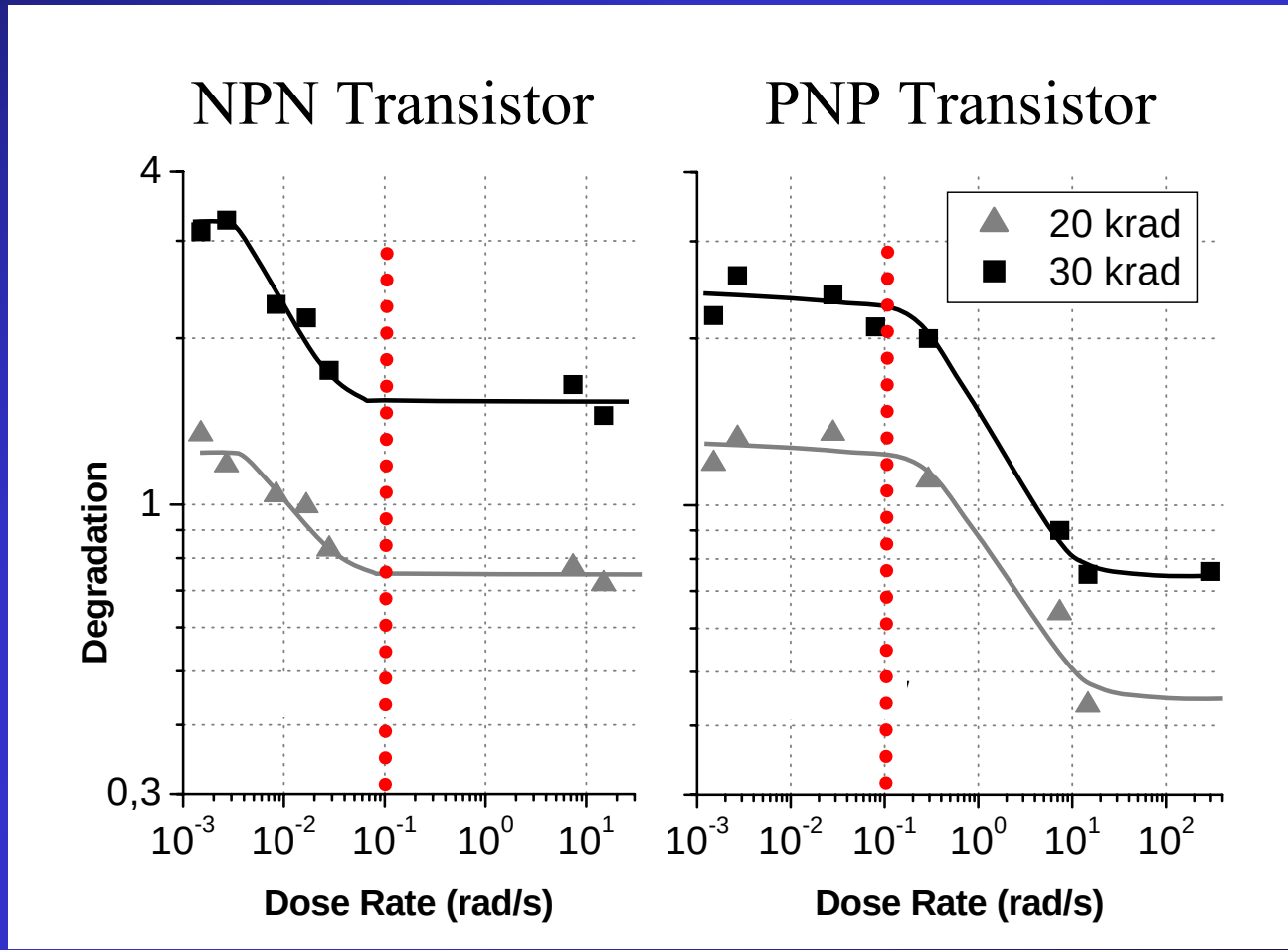
Dose Rate Effect



✓ More degradation at low dose rate than at high one

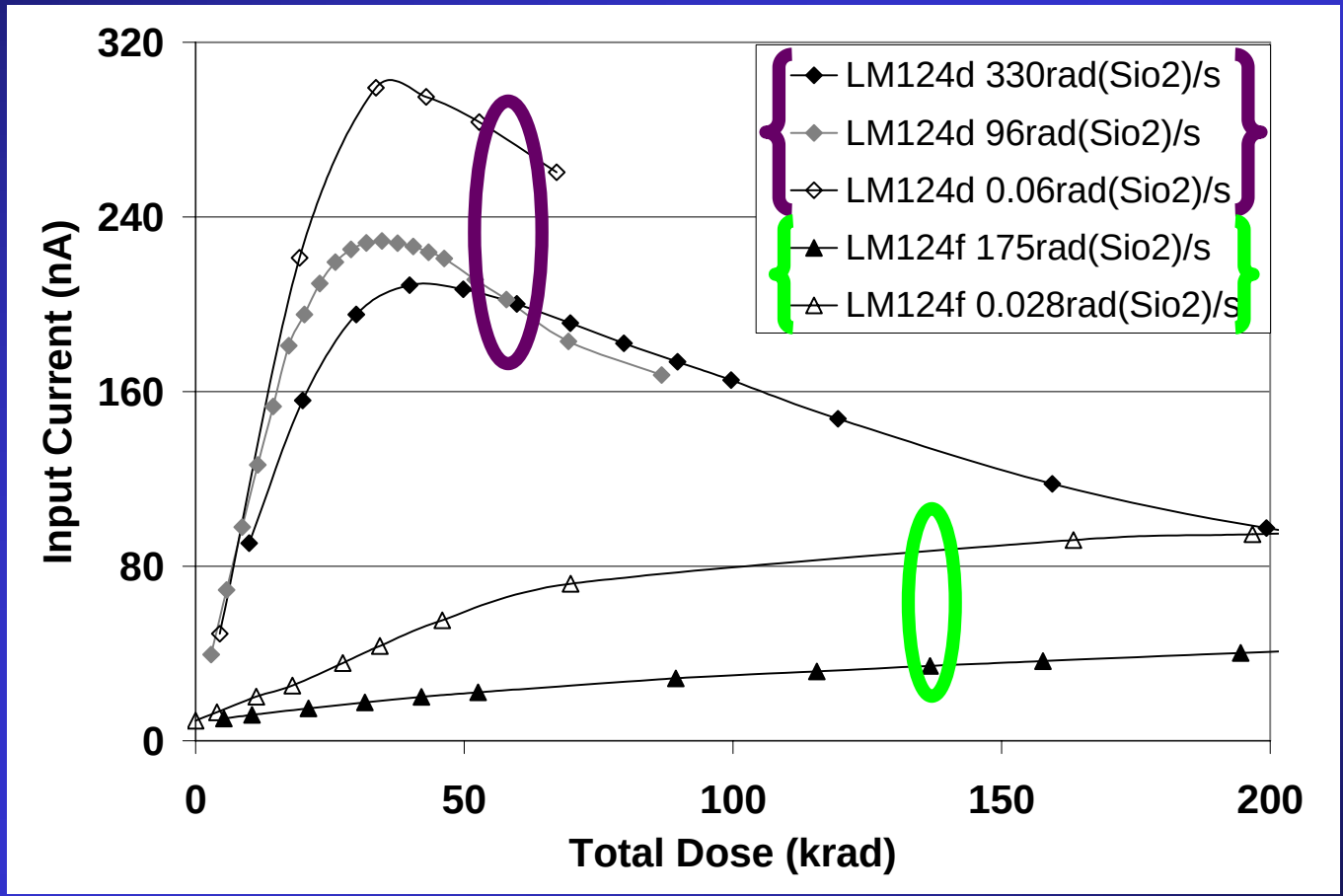
Dose Rate Effect

- ✓ Usual “Inversed S-Shape Curve”



Dose Rate Effect

- ✓ Importance of the Date-Code



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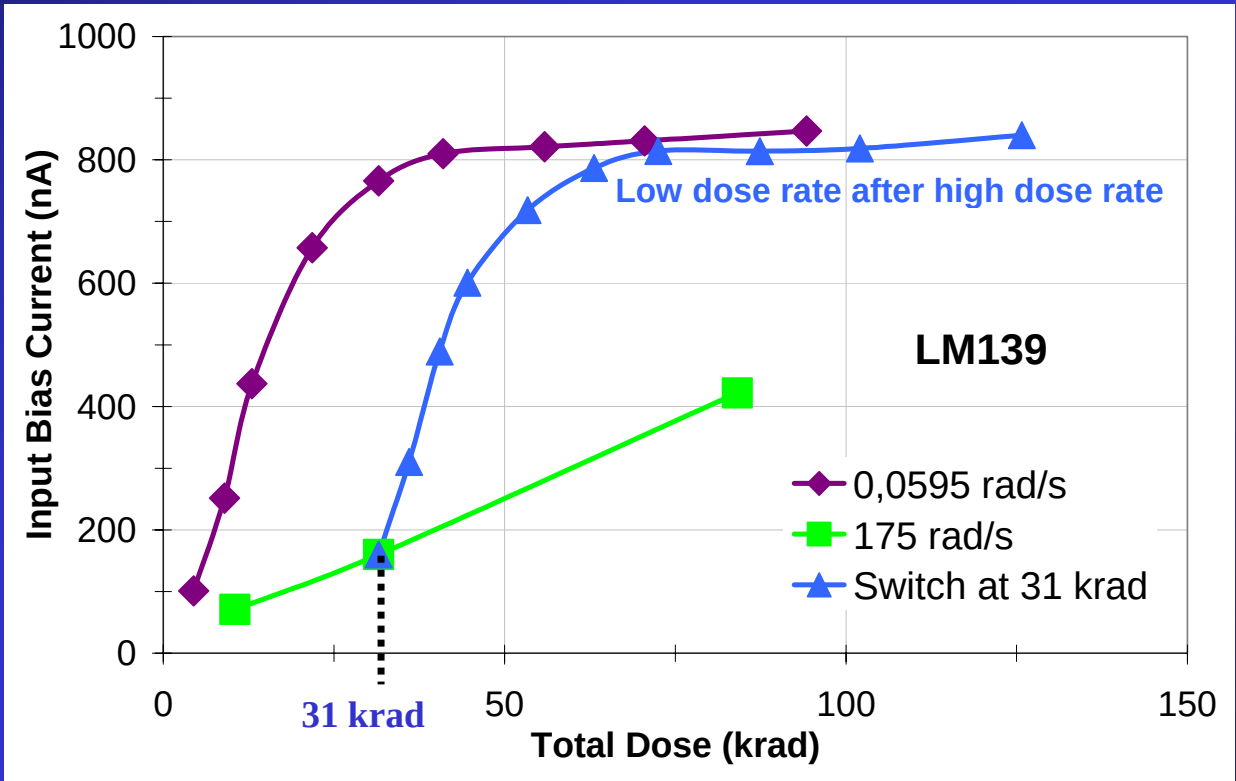
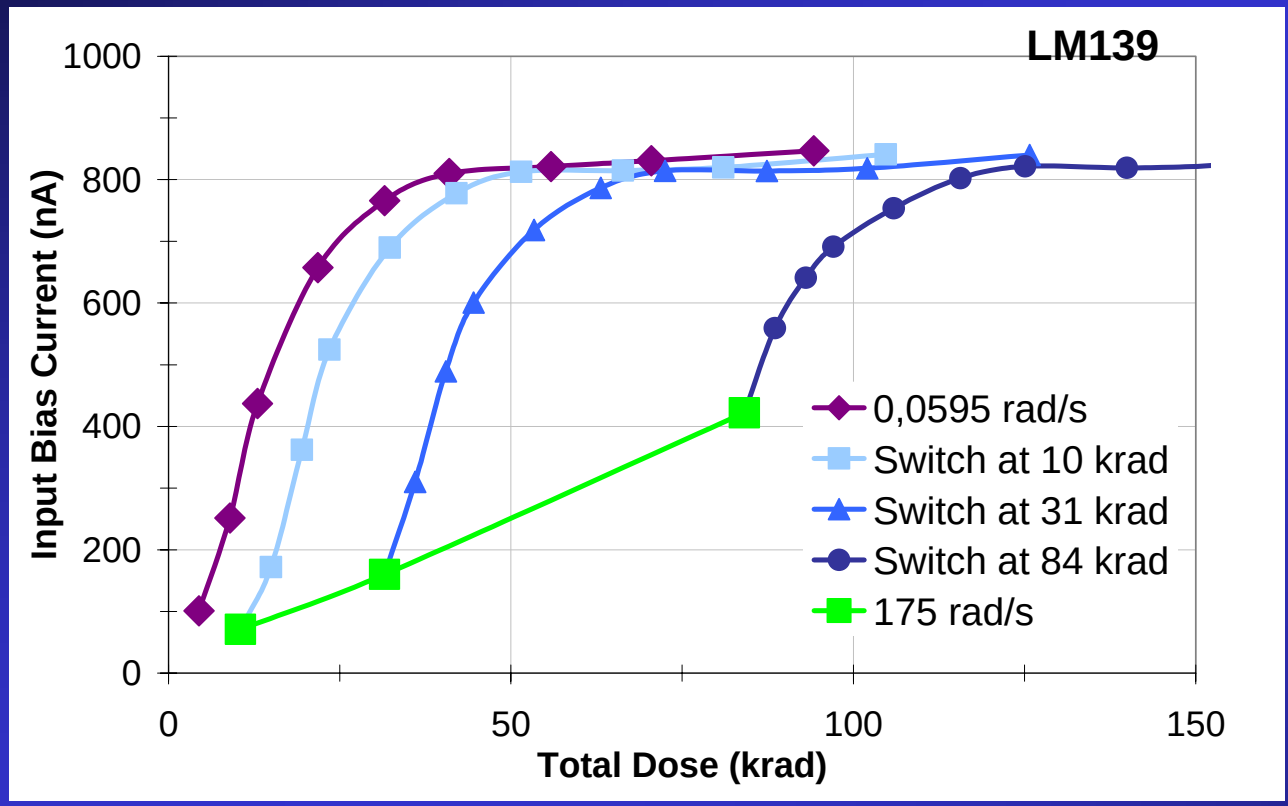
Switching Experiments

Switching Experiments = a two-steps irradiation process:

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

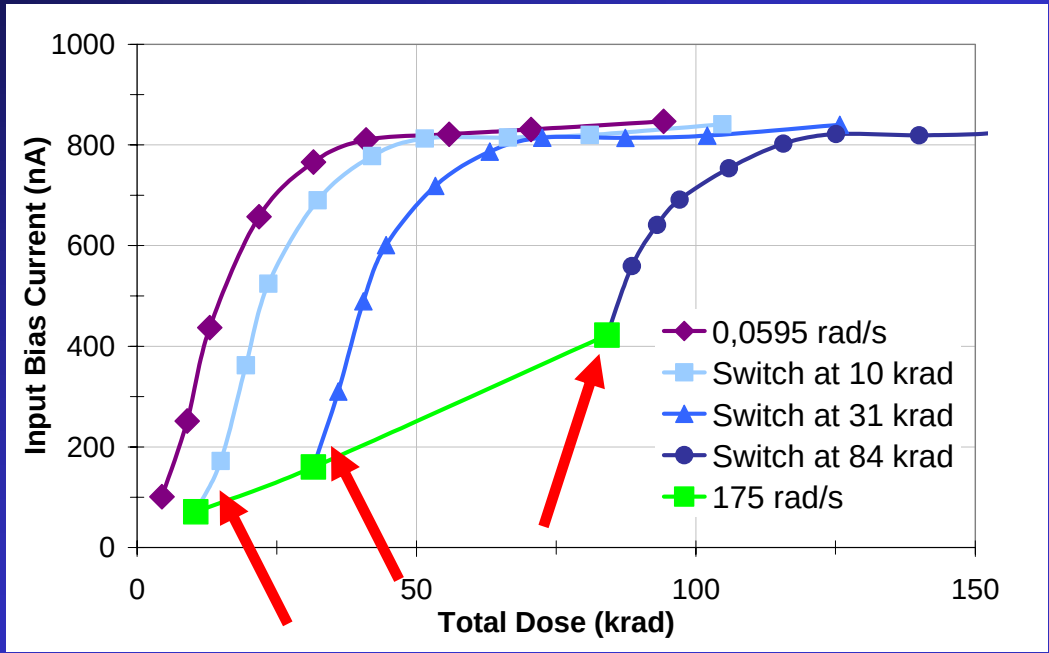


Switching Experiments



- ✓ Switched devices follow the same degradation rate than at low dose rate
- ✓ A shift remains

Switching Experiments



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

⇒ Validity of the already proposed physical Models ?

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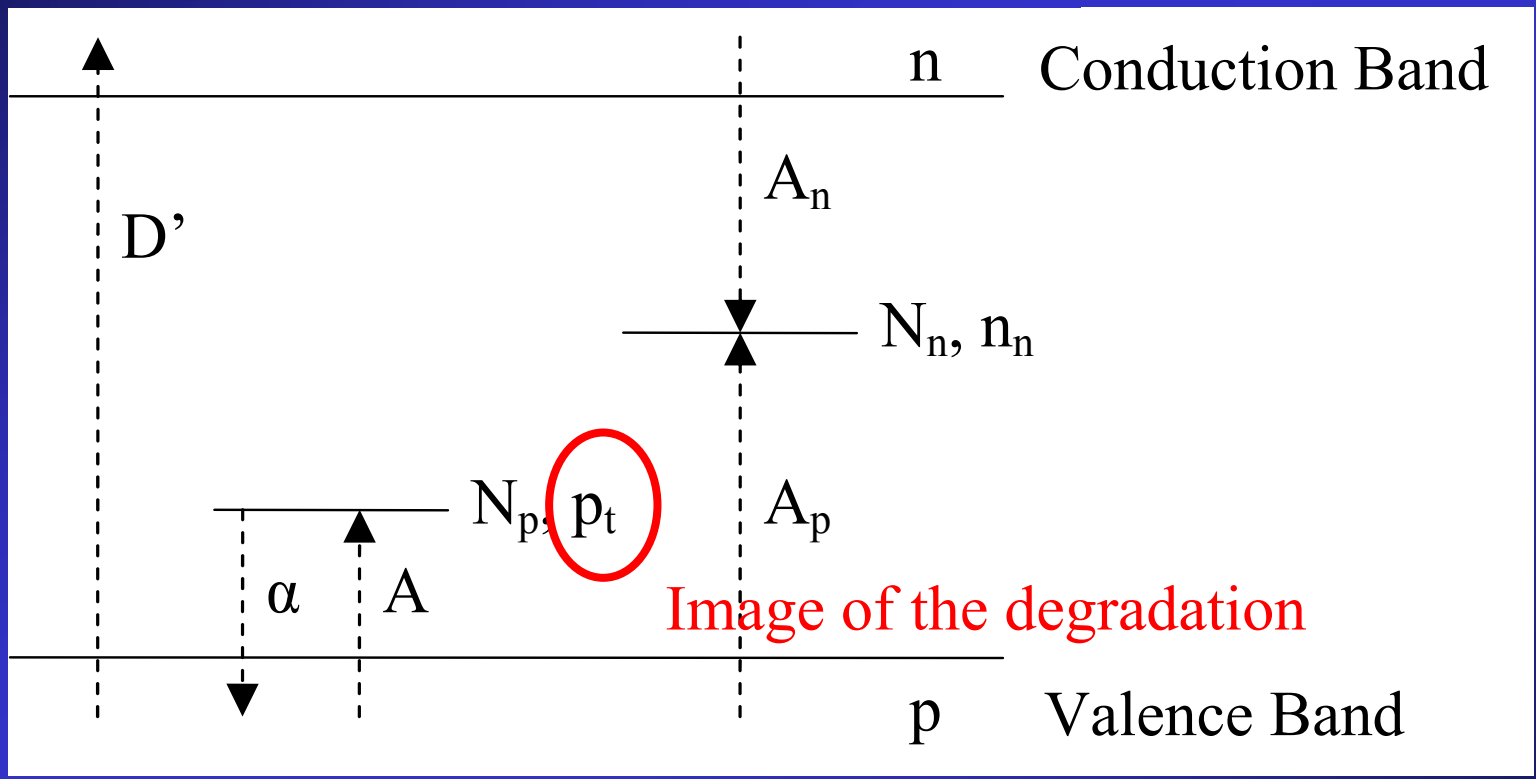
Basic Model

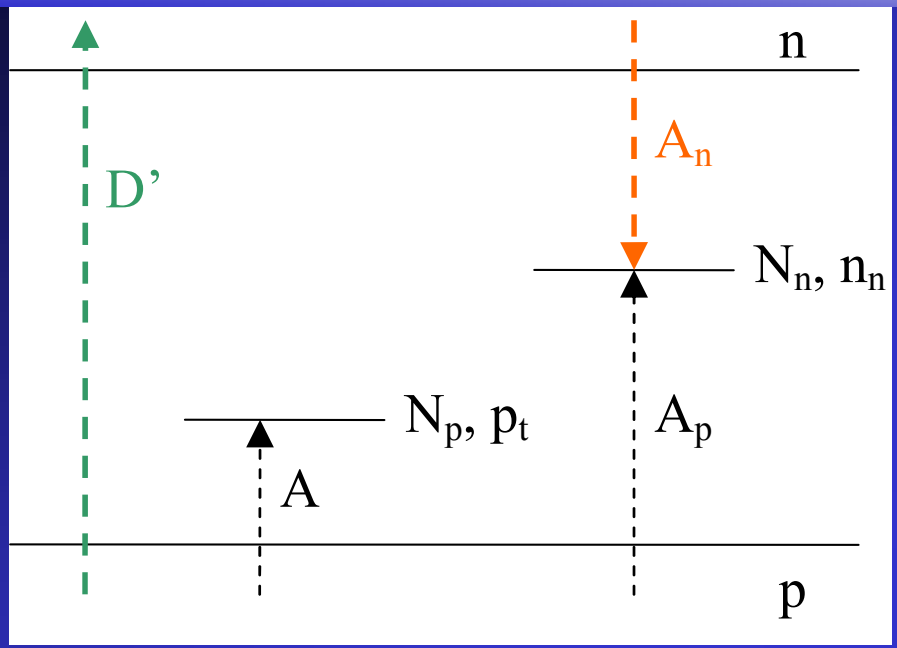
Energetic Diagram in the Oxide



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

BOCH – *Apl. Phys. Lett. (2006)*

Basic Model



- Ax : probabilities for a transition to occur
- N_X, : densities of traps
- n, p: densities of free carriers
- p_t, n_n: densities of trapped carriers
- D': Generation rate

$$\frac{dn}{dt} = D' - n.(N_n - n_n).A_n$$

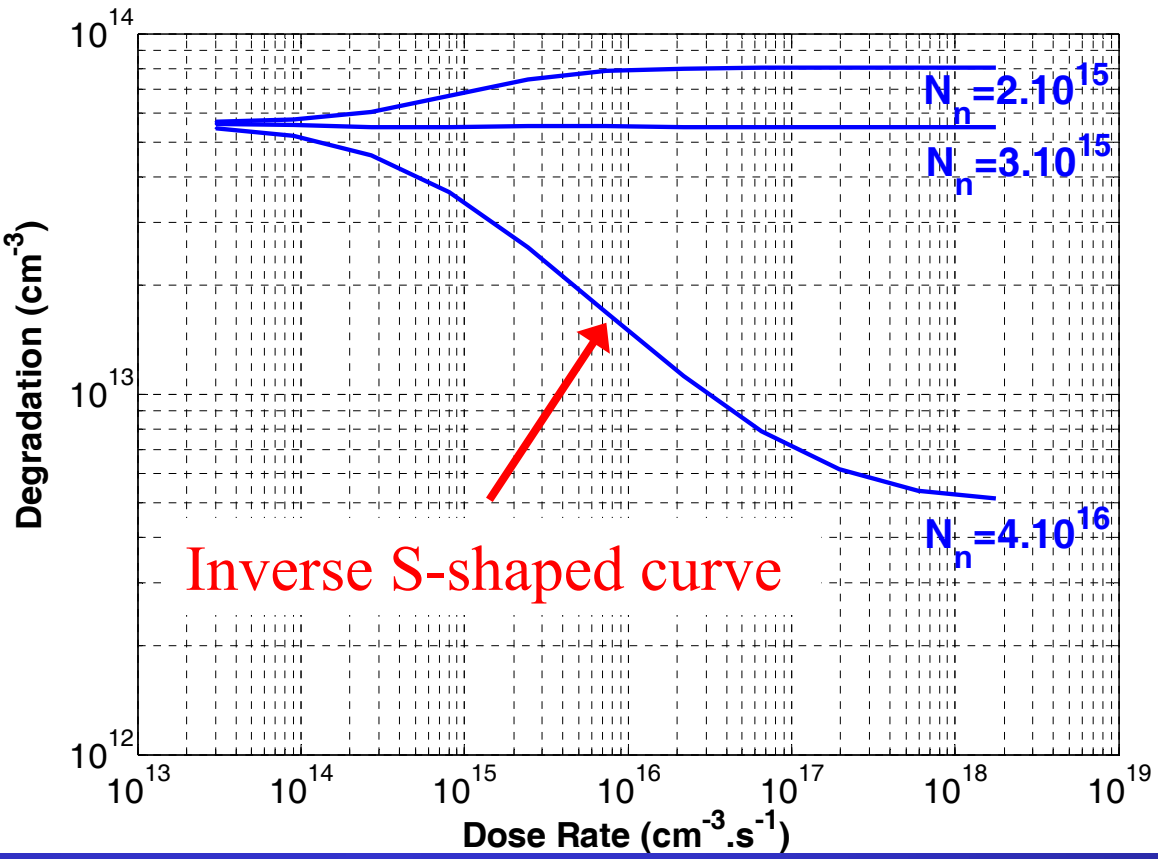
$$\frac{dp_t}{dt} = p.(N_p - p_t).A$$

$$\frac{dp}{dt} = D' - p.(N_p - p_t).A - A_p.p.n_n$$

$$\frac{dn_n}{dt} = n.(N_n - n_n).A_n - A_p.p.n_n$$

- ✓ Derived from Chen - *Phys Rev. B (1981):*
- ✓ Describes ELDRS in
  - ✓ TL materials
  - ✓ OSLs
  - ✓ Diamond, Quartz

Basic Model

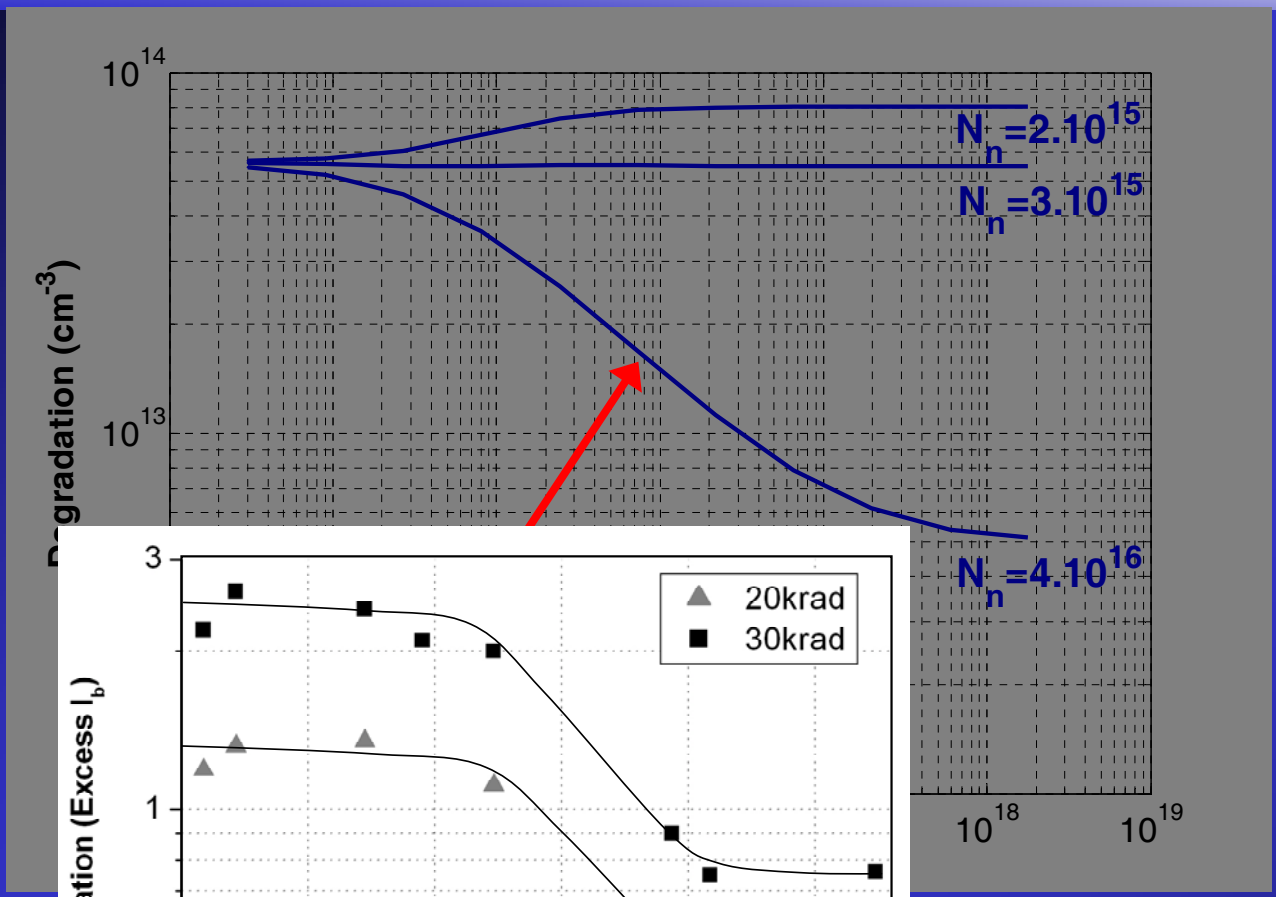


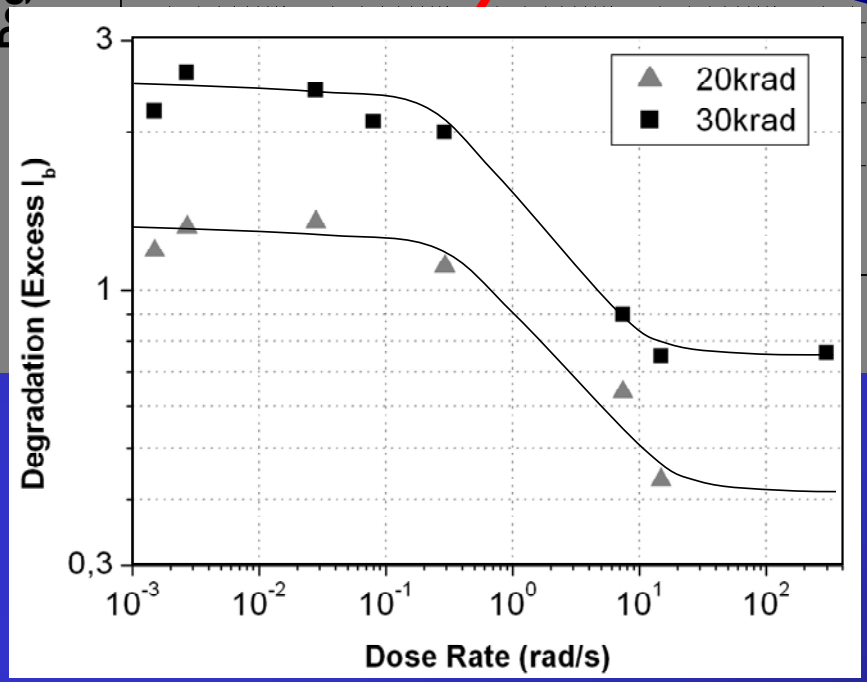
High oxide quality (Small N_h)

Low oxide quality (Large N_h)

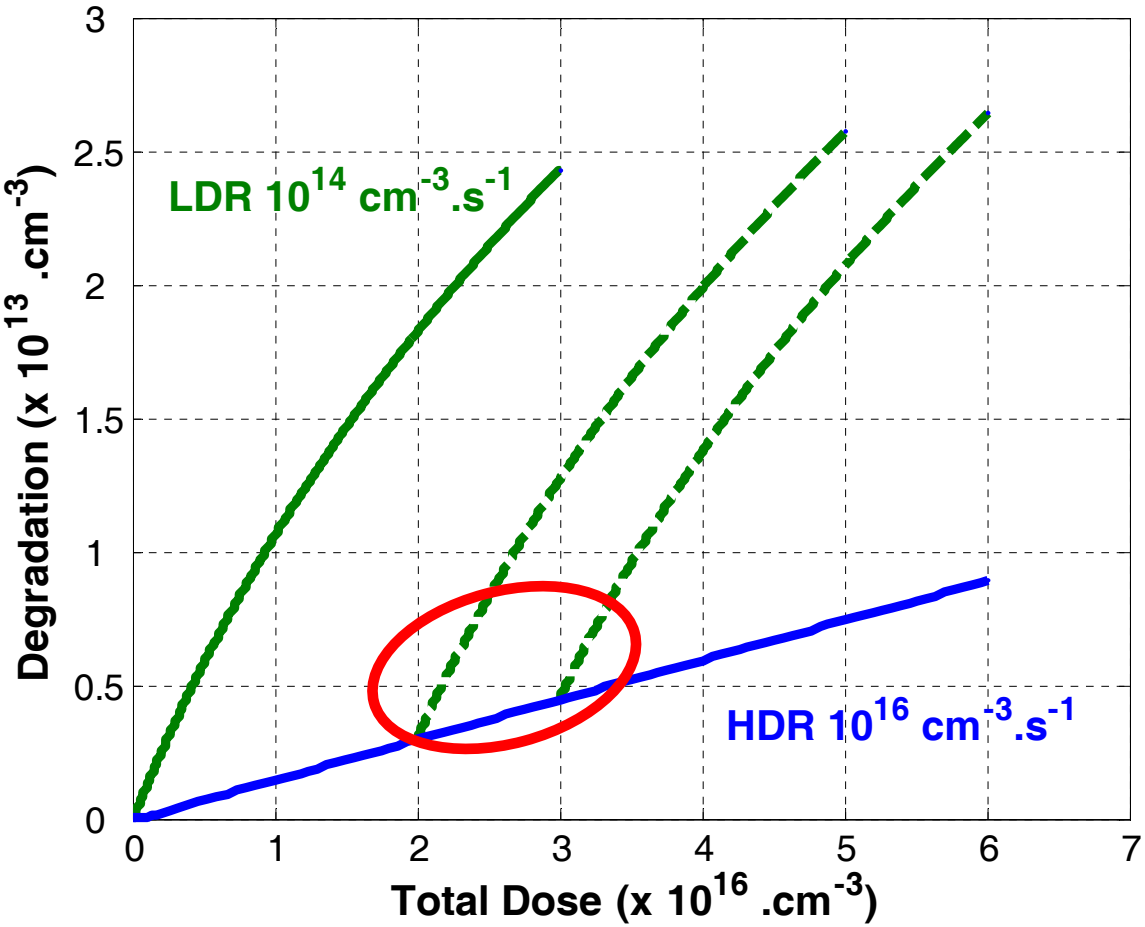
- ✓ The degradation depends of the oxide quality
- ✓ An inverse S-shaped curve is obtained for large Nh

Basic Model


10^{14}
10^{13}
$N_n=2.10^{15}$
$N_n=3.10^{15}$
$N_n=4.10^{16}$
10^{18}
10^{19}

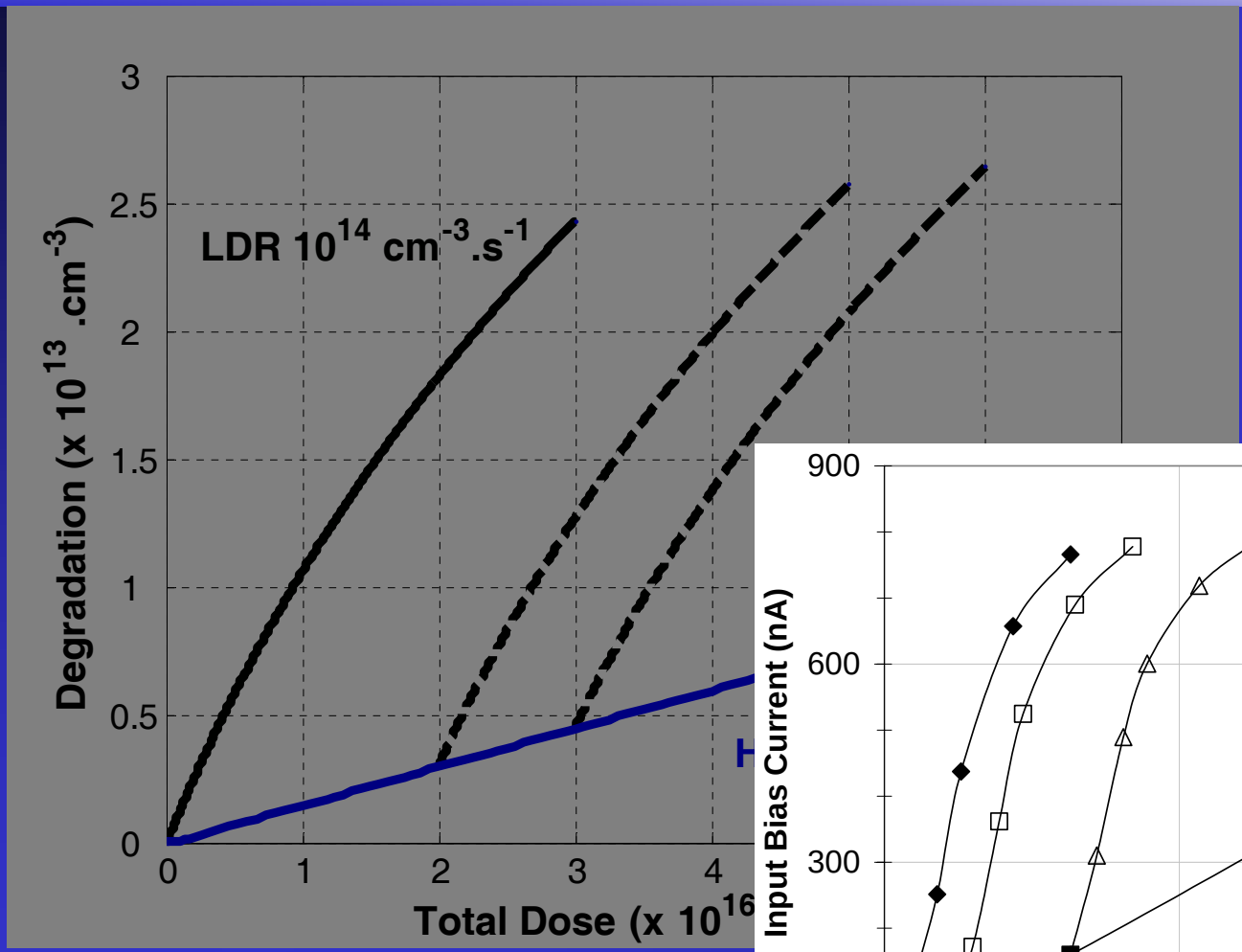

3
1
0,3
20krad
30krad
Degradation (Excess I_b)
10^{-3}
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
Dose Rate (rad/s)

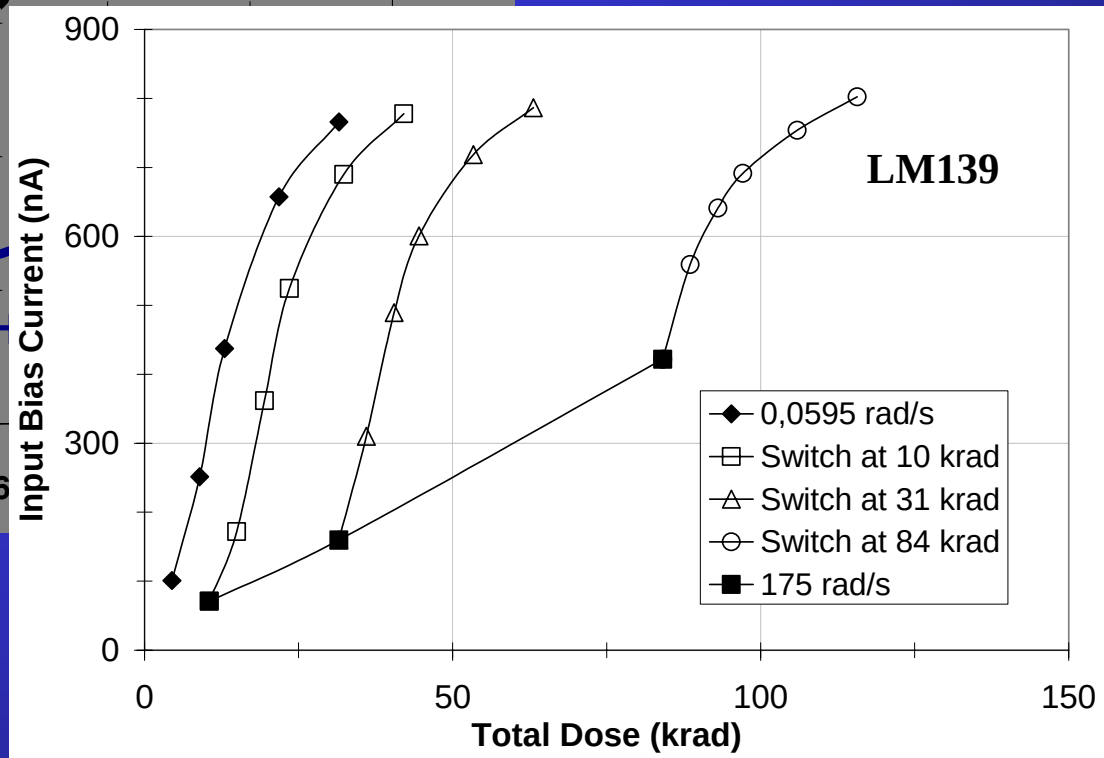
Basic Model



Sudden increase of the degradation just after the switch

Basic Model


LDR 10^{14} $cm^{-3}.s^{-1}$
Degradation (x 10^{13} $.cm^{-3}$)
Total Dose (x 10^{16}
0
0.5
1
1.5
2
2.5
3
0
1
2
3
4


LM139
Input Bias Current (nA)
Total Dose (krad)
0
300
600
900
0
50
100
150
0,0595 rad/s
Switch at 10 krad
Switch at 31 krad
Switch at 84 krad
175 rad/s

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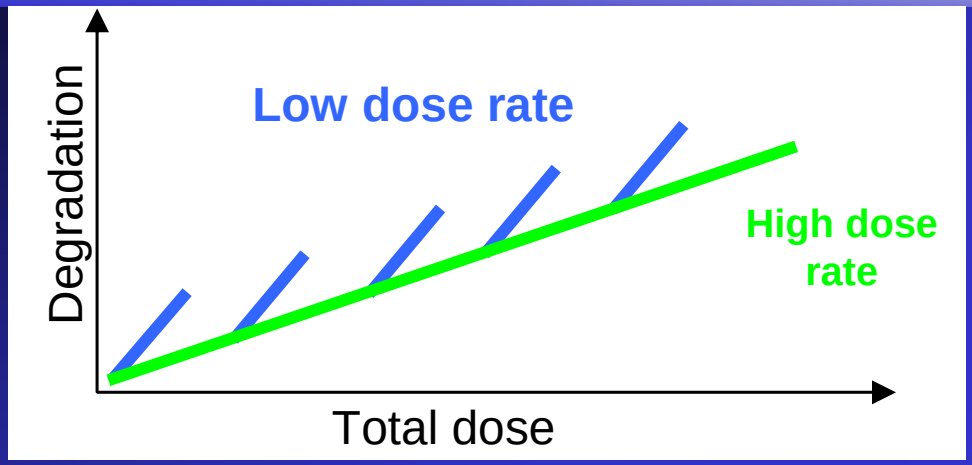
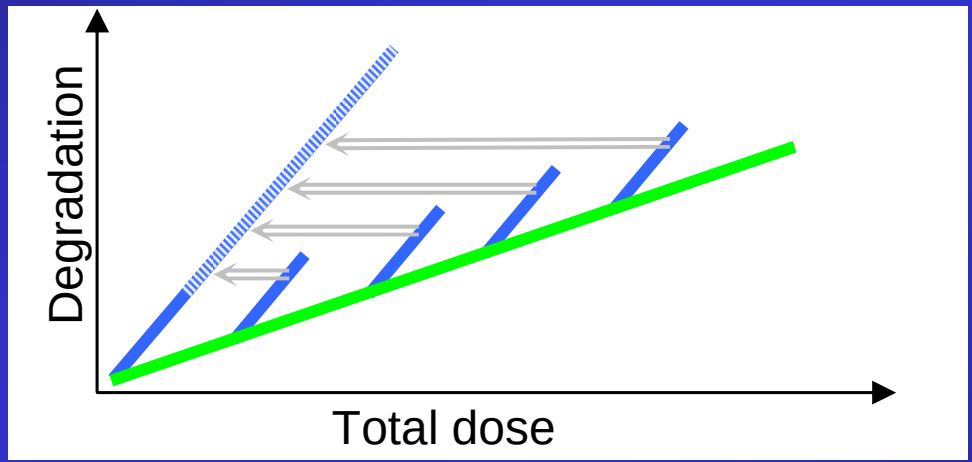
Estimation Method

Switching Experiment = 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.

Estimation Method





Perform Several switching experiments

Shift the low dose rate segments

Reconstruct the low dose rate curve

It saves time!

Estimation Method

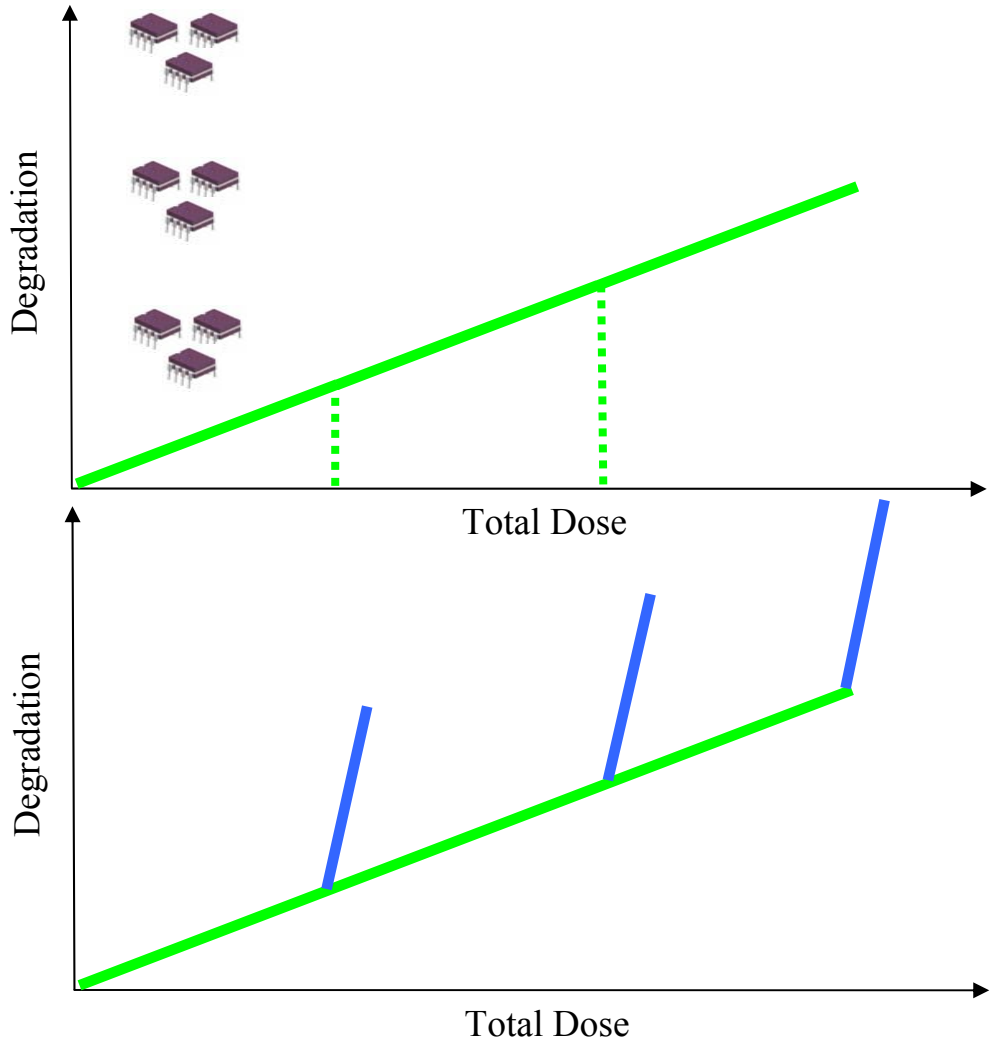
1. High dose rate

Three sets of devices

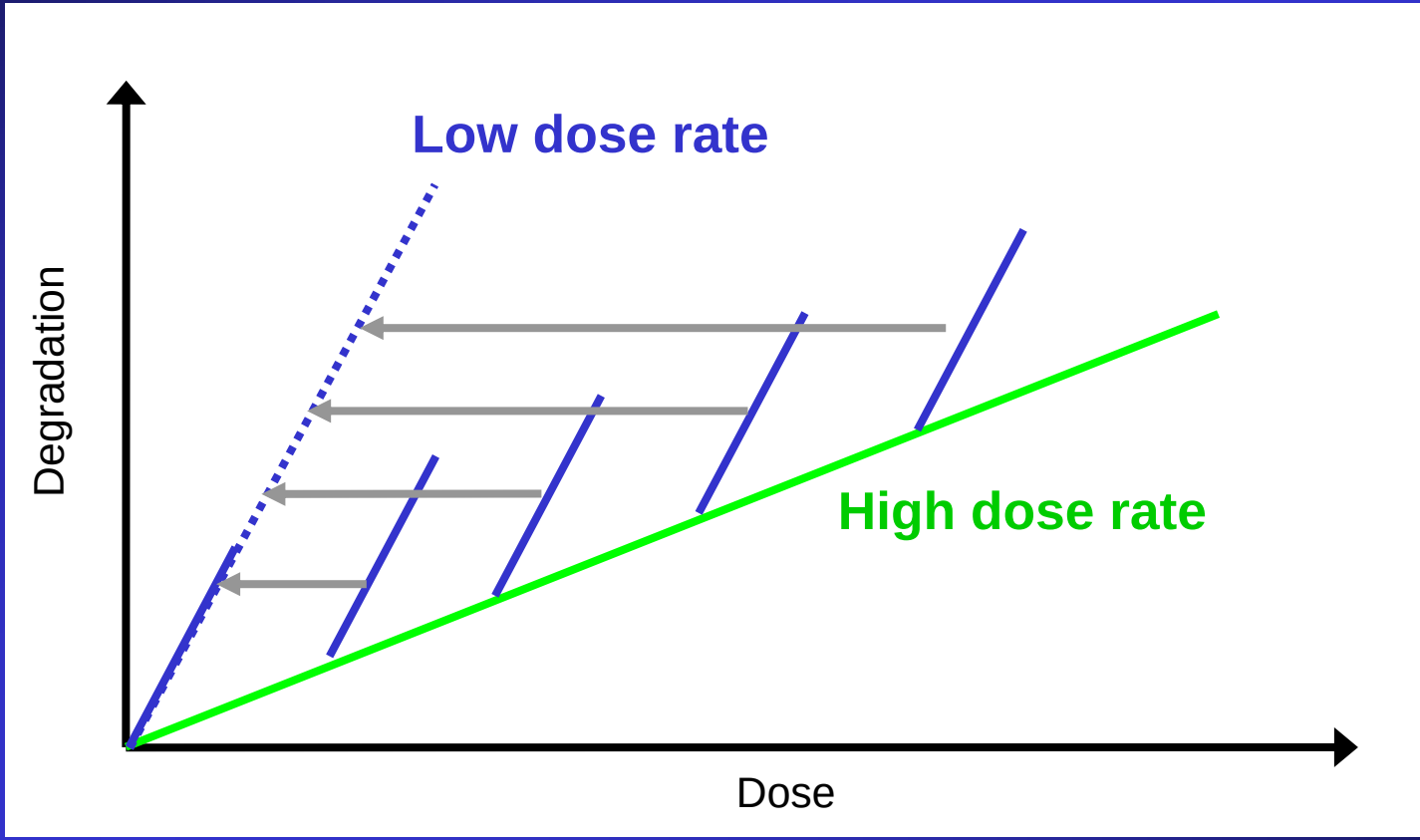
Three switches

2. Low dose rate

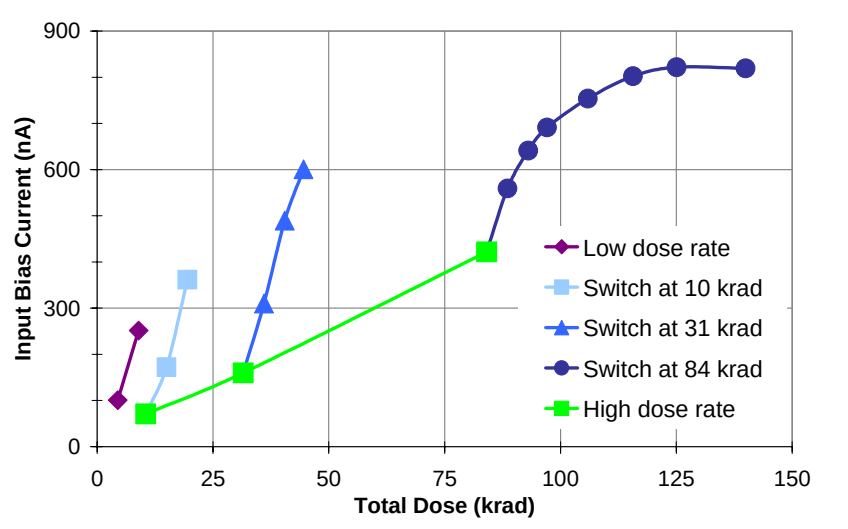
It saves time!

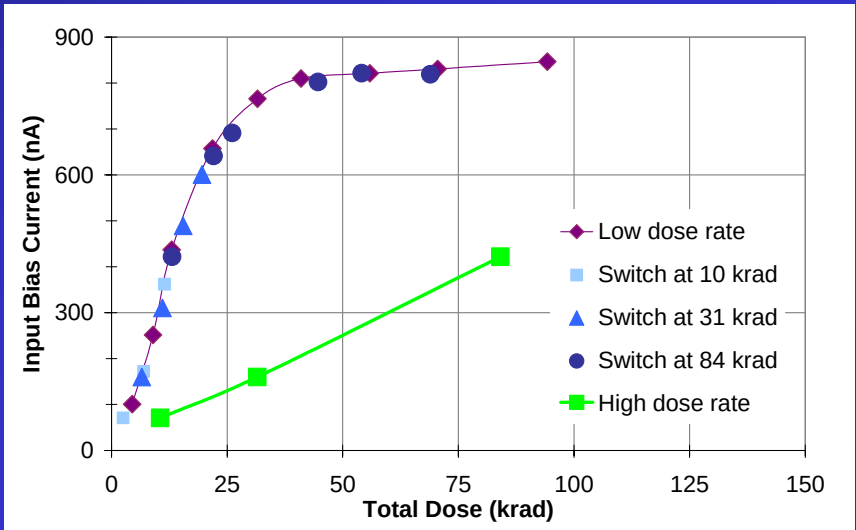


Estimation Method



LM139 Results





From four low dose rate segment lines:

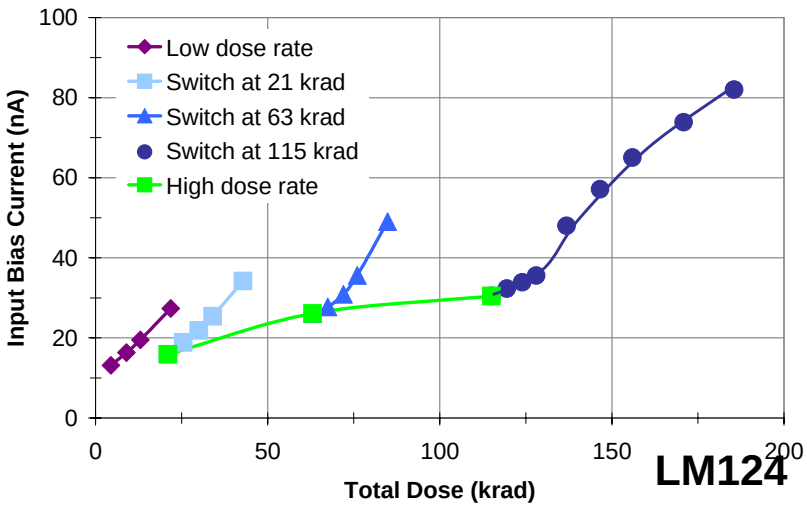
- one low dose rate
- three switching experiments

Good agreement between predictive and low dose rate curves

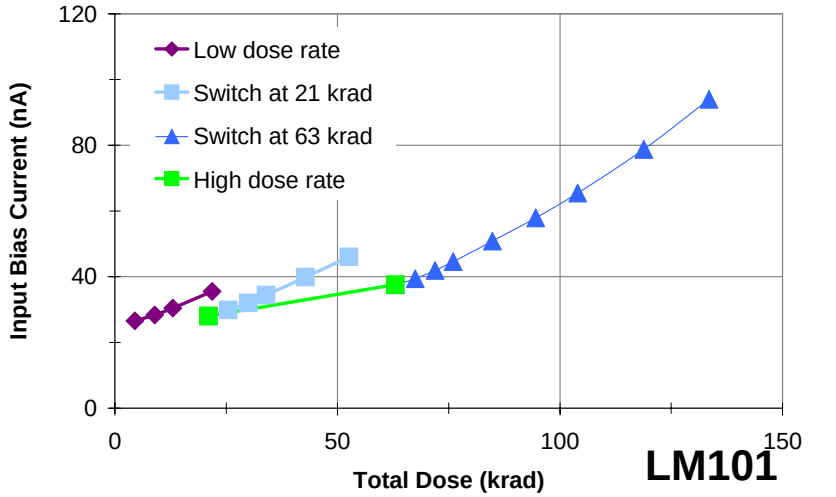
Decrease of the irradiation test time by a factor 3

BOCH – *Apl. Phys. Lett. (2006)*

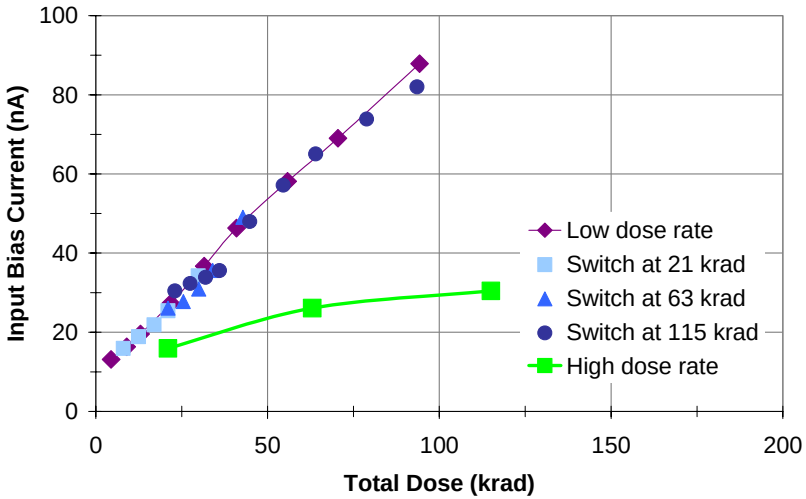
LM124 and LM101 Results

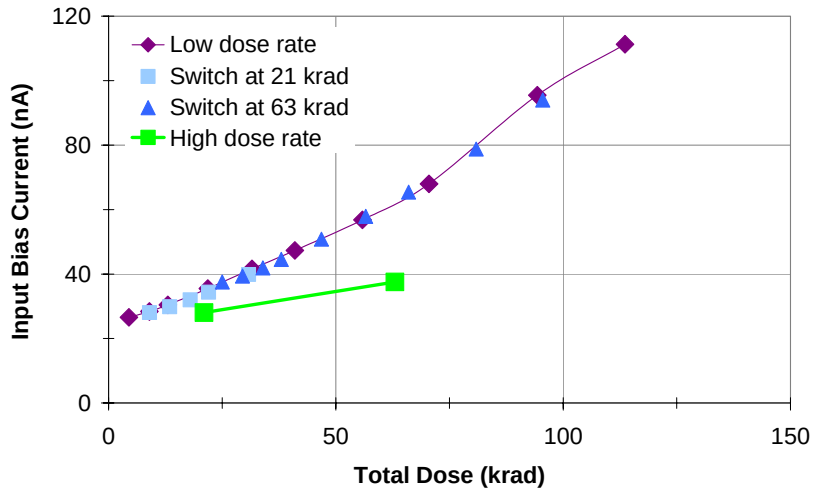


LM124



LM101





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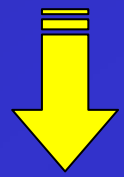
Future Works

To be willing to listen to industrial's needs.



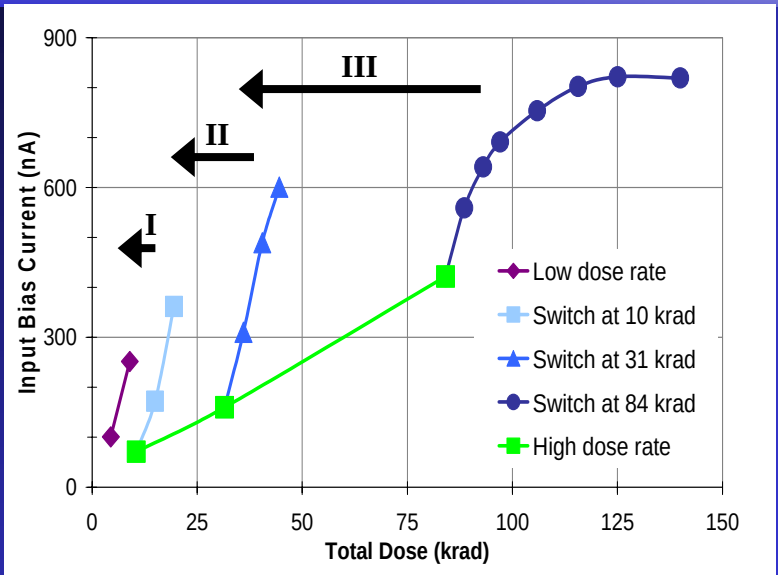
Provide a method for ELDRS testing.

Future Works

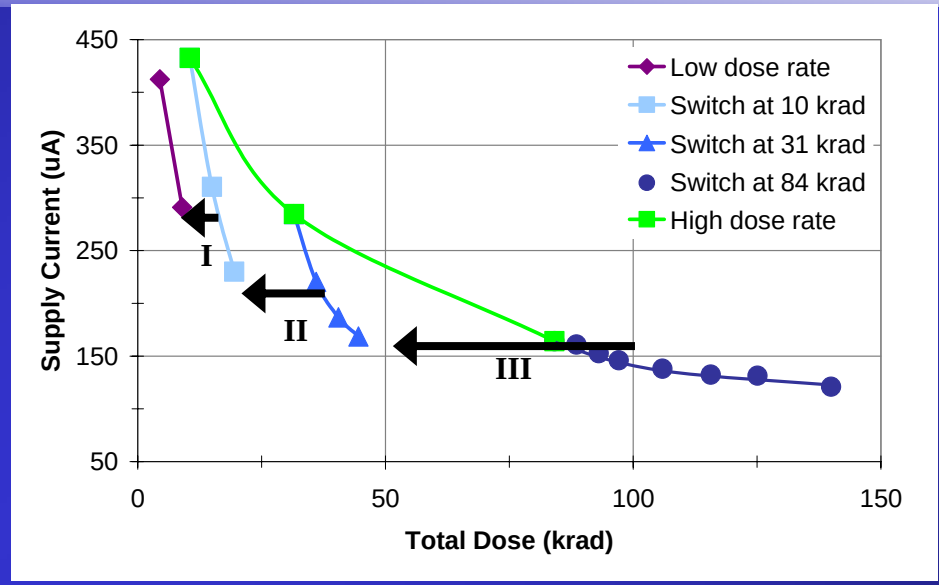
For example, we have to:

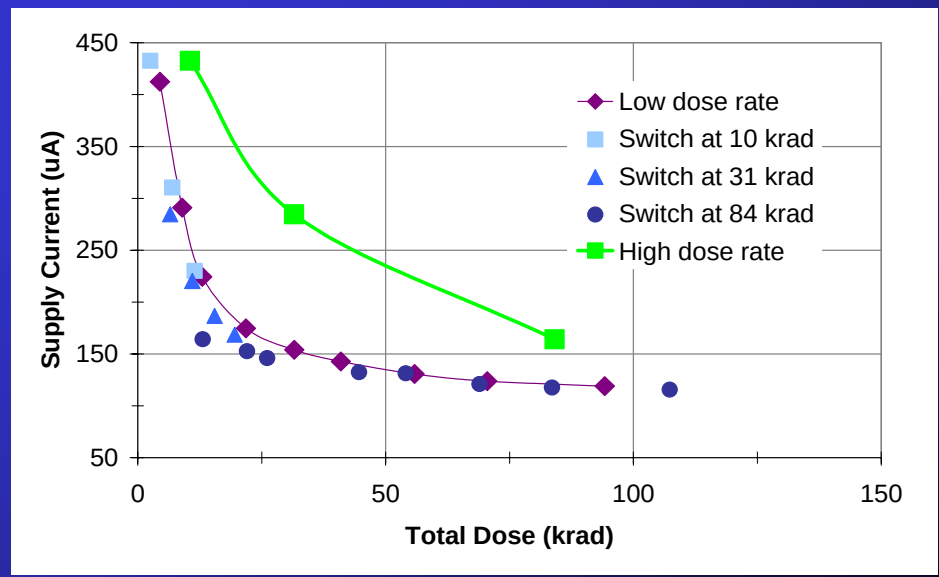
- take into account several electrical parameters
- reduce the number of devices sets
- …

LM139 Supply current

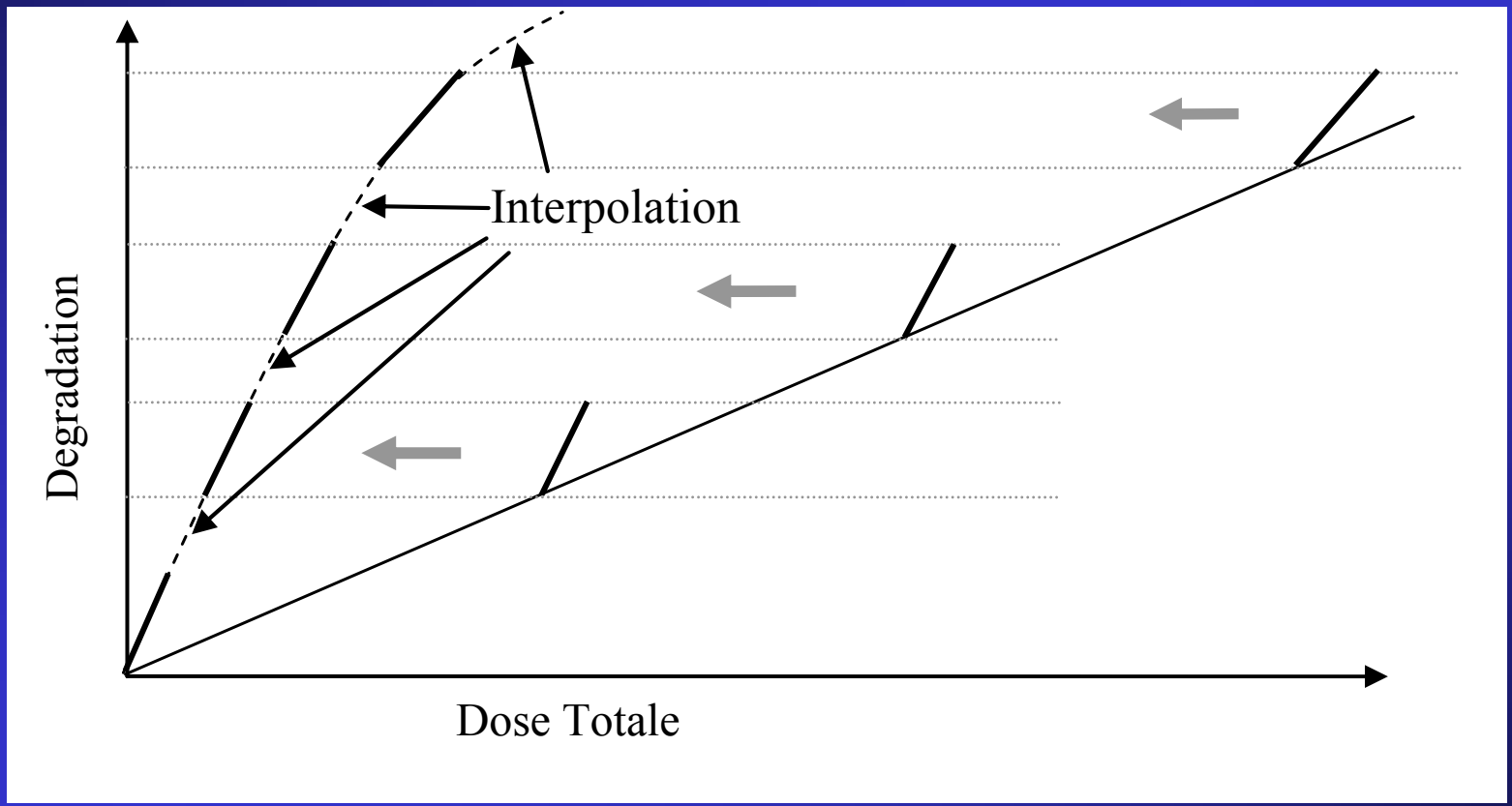


Shift values obtained from input bias current curve





Interpolation



Conclusion

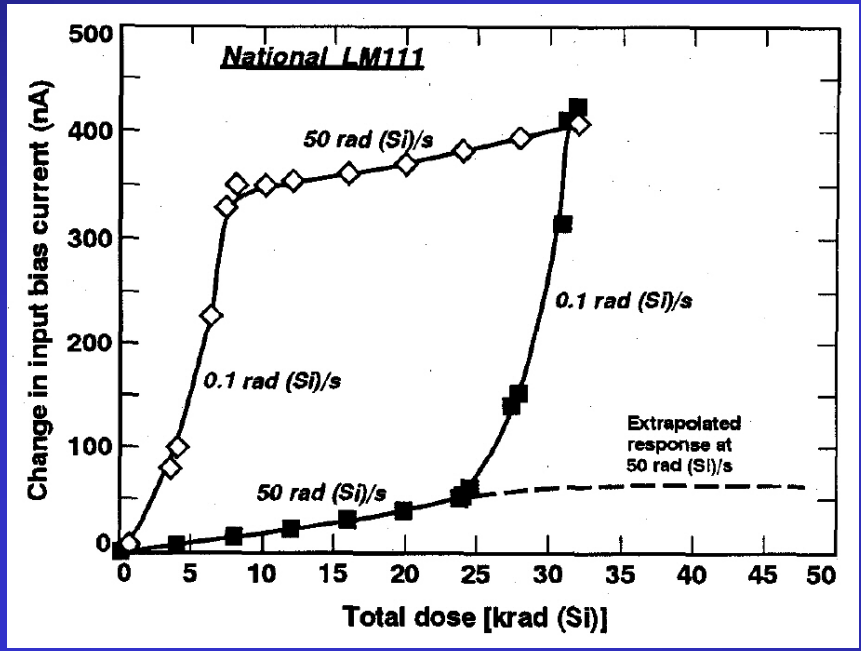
- For switching experiments:

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

- A new time-saving method has been proposed to predict low dose rate degradation:

✓A very good agreement with low dose rate curves.

- All the effects can be explained with the new physical model we have proposed.


National LM111
50 rad (Si)/s
0.1 rad (Si)/s
0.1 rad (Si)/s
50 rad (Si)/s
Extrapolated
response at
50 rad (Si)/s
Change in input bias current (nA)
Total dose [krad (Si)]
0
100
200
300
400
500
0
5
10
15
20
25
30
35
40
45
50