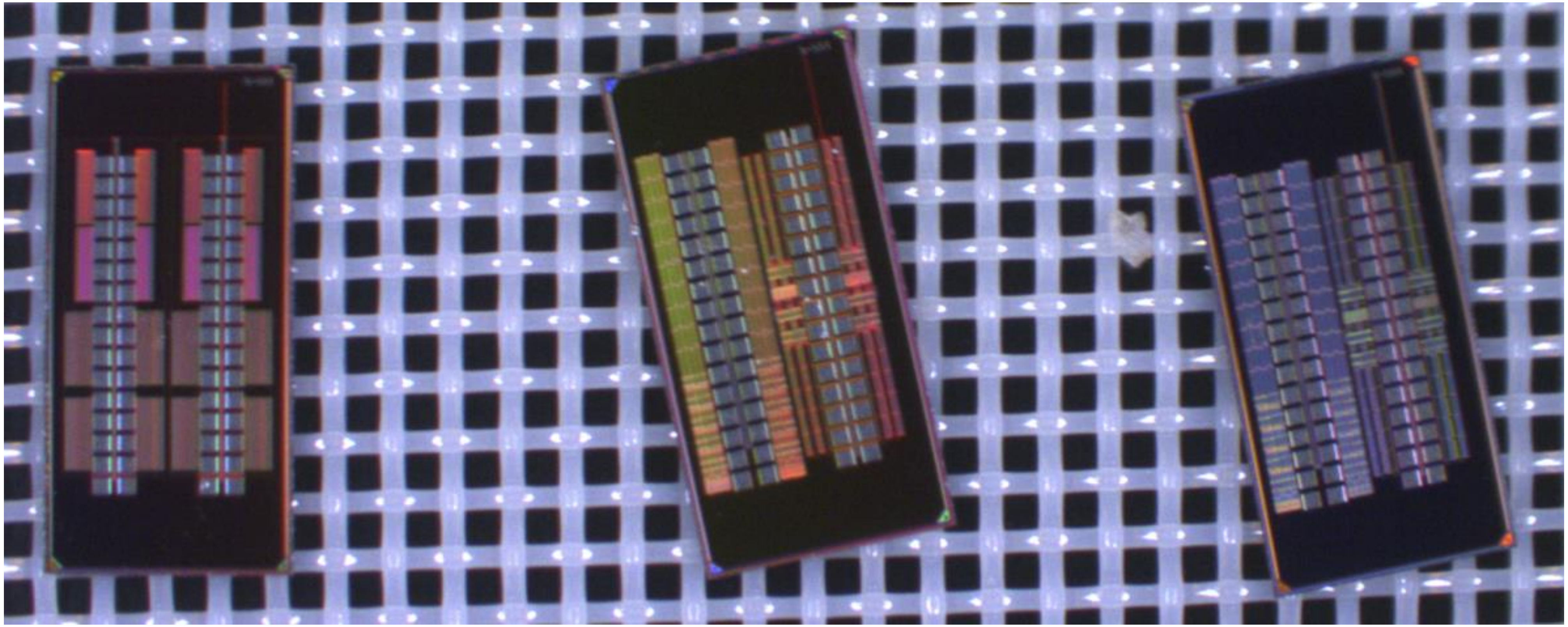
MEASUREMENTS

Transistor measurements

Giulio Borghello, Wenjing Deng, Ana Dorda Martin, Geun Hee Hong, Gennaro Termo



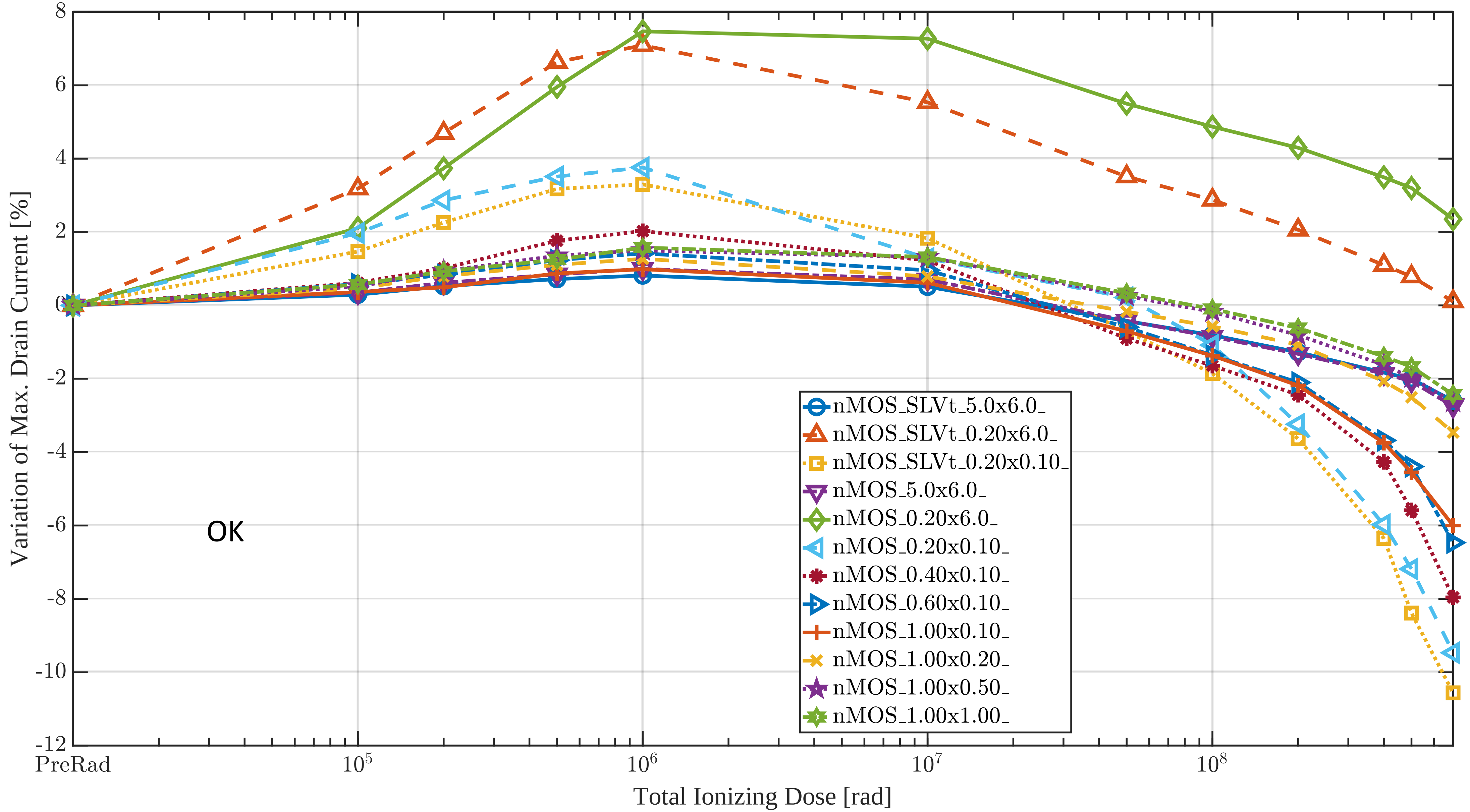
5 test chips

- 4 traditional transistor test structures with different transistor flavors
- 1 gate leakage test structure

1.2 NMOS transistor 10keV X-ray irradiation measurements

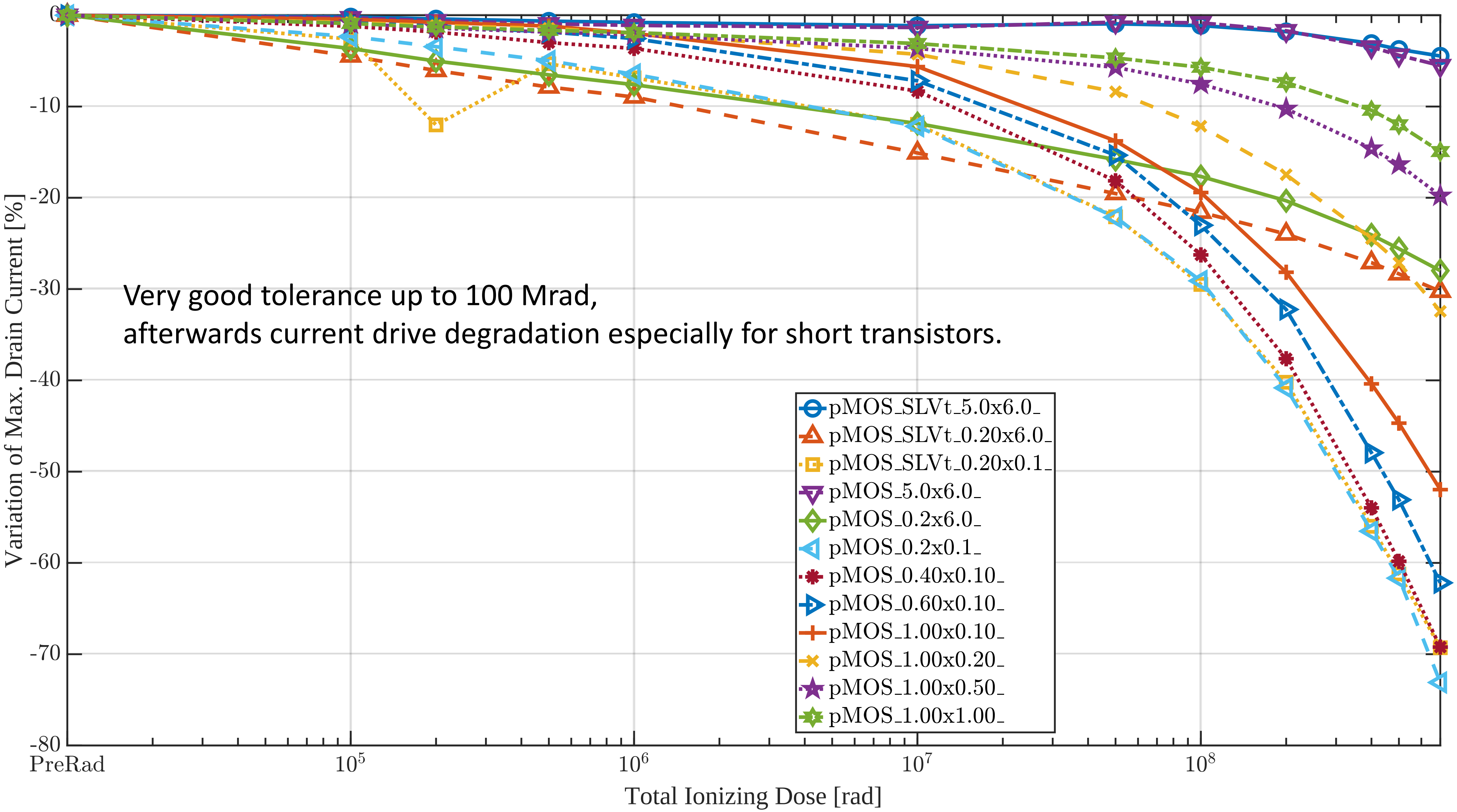
Giulio Borghello, Wenjing Deng, Ana Dorda Martin, Geun Hee Hong, Gennaro Termo

EP R&D



1.2 V PMOS transistor 10keV X-ray irradiation measurements

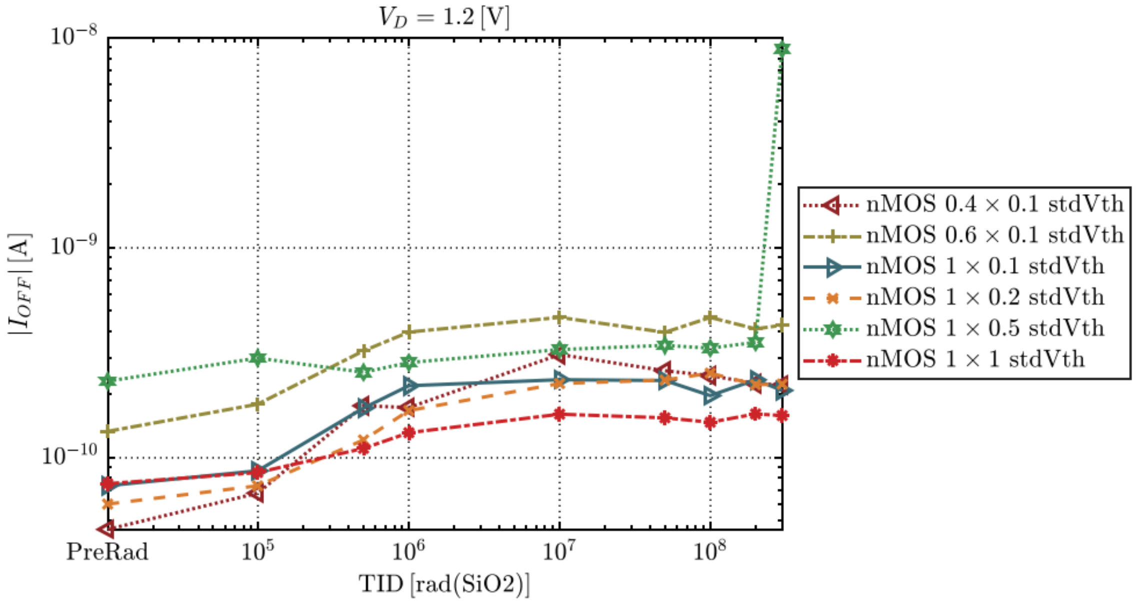
Giulio Borghello, Wenjing Deng, Ana Dorda Martin, Geun Hee Hong, Gennaro Termo

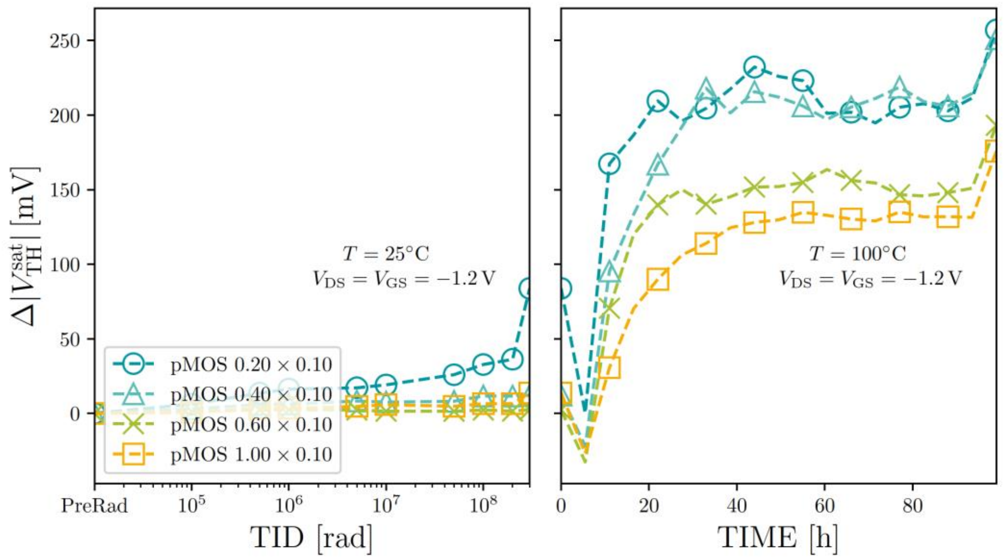


Very good tolerance up to 100 Mrad,
afterwards current drive degradation especially for short transistors.

Summary transistor 10keV X-ray irradiation measurements

Giulio Borghello, Wenjing Deng, Ana Dorda Martin, Geun Hee Hong, Gennaro Termo





Irradiation measurements

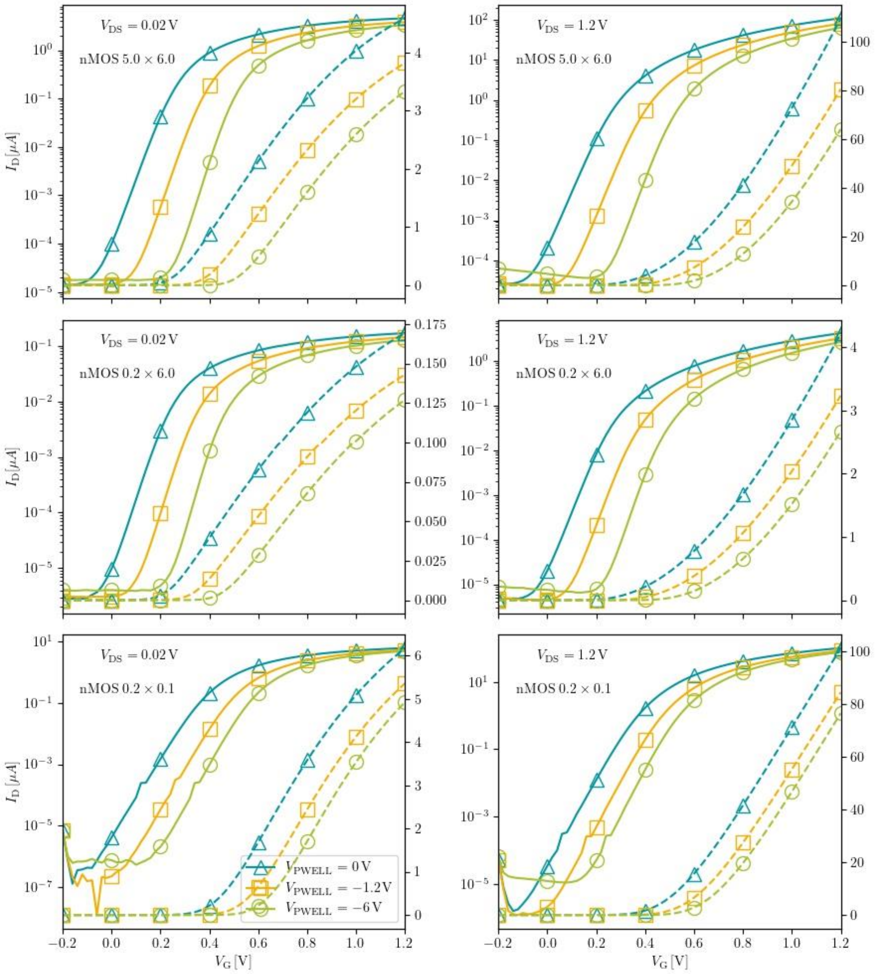
- 1.2 V NMOS transistors OK up to 1Grad, leakage increase less than an order of magnitude for W> 600nm
- 1.2 V PMOS transistors OK up to 100 Mrad, beyond severe current degradation especially for short transistors
- Thicker oxide transistors some what weaker, according to oxide thickness
- Special cases, eg ~ 200mV threshold shift during post-rad anneal for very narrow PMOS transistors
- In general in line with other 65 nm technologies

Special modeling study

- Observing deviation of Vth between model and experiment for reverse substrate biases larger than 1.2 V (not within ‘normal’ transistor operating range). Detailed study ongoing

Bulk bias measurements

Ana Dorda Martin

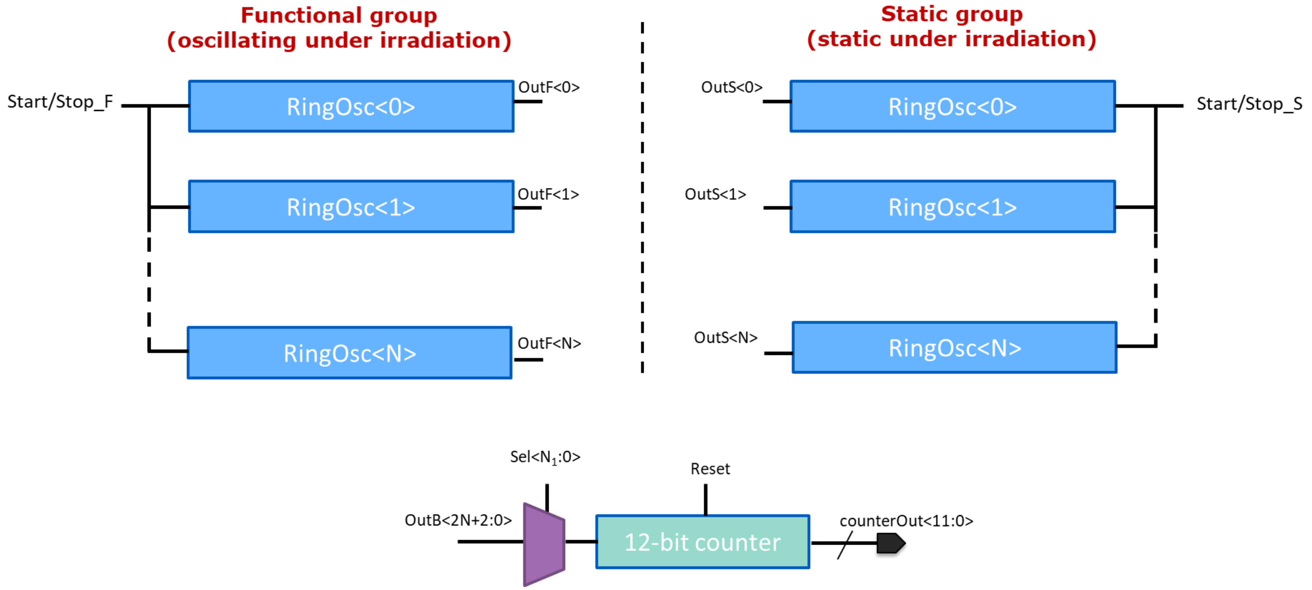


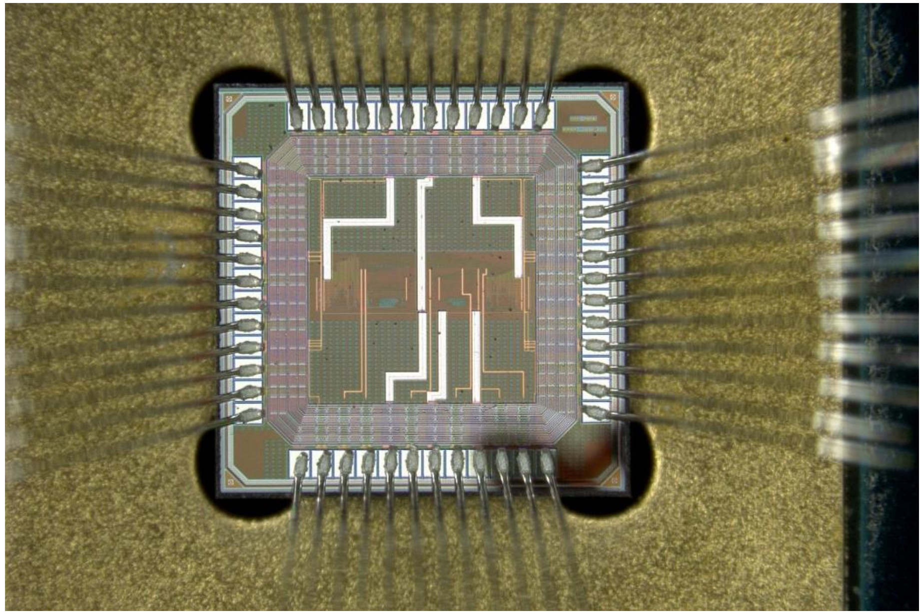
- Preliminary measurements of VTH shows a variation up to +260 mV (@ VPWELL = -6 V) with respect to nominal (@ VPWELL = 0 V).
- Relation with transistor size is under study.

Transistor	VPWELL [V]	|VTH_lin| [mV]	VAR_VTH_lin [mV]	|VTH_sat| [mV]	VAR_VTH_sat [mV]
nMOS_5.0x6.0	**0**	259.9	-	223.4	-
	-1.2	389.3	+129.4	354.7	+131.3
	-6	517.5	+257.6	487.1	+263.6
nMOS_0.20x6.0	**0**	224.6	-	181.8	-
	-1.2	339.1	+114.5	301.7	+119.9
	-6	456.8	+244.7	426.5	+244.7
nMOS_0.20x0.1	**0**	427.7	-	315.2	-
	-1.2	544.2	+116.4	413.7	+98.5
	-6	623.6	+195.9	483.2	+168

Ringoscillator measurements

CPPM: Pierre Barrillon, Marlon Barbero, Denis Fougeron, Alexandre Habib and Patrick Pangaud





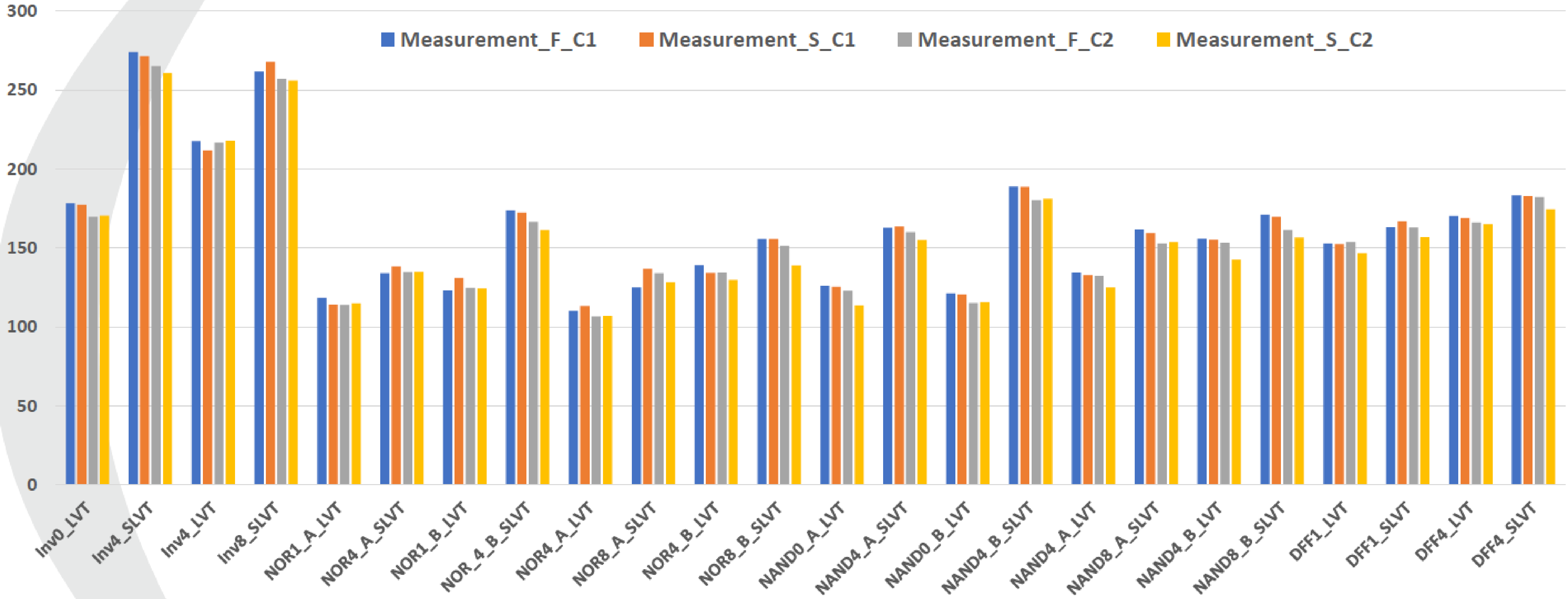
Low V_T		Super Low V_T	
Size Min	**Size+**	**Size Min**	**Size+**
INV0_LVT	**INV4_LVT**	**INV4_SLVT**	**INV8_SLVT**
NOR1_LVT_A	**NOR4_LVT_A**	**NOR4_SLVT_A**	**NOR8_SLVT_A**
NOR1_LVT_B	**NOR4_LVT_B**	**NOR4_SLVT_B**	**NOR8_SLVT_B**
NAND0_LVT_A	**NAND4_LVT_A**	**NAND4_SLVT_A**	**NAND4_SLVT_A**
NAND0_LVT_B	**NAND4_LVT_B**	**NAND4_SLVT_B**	**NAND4_SLVT_B**
DFF1_LVT	**DFF4_LVT**	**DFF1_SLVT**	**DFF4_SLVT**

- CPPM contributed to MLR1 with a Ring Oscillator test chip to characterize the standard cells of the TJ 65 nm technology.
- The chip contains 48 ring oscillator based on different standard cells.
- 2 banks of 24 Rows each with the purpose of testing two approaches while irradiating:
    - Functional: the oscillation is enabled
    - Static: the oscillation is disabled

Ringoscillator measurements

CPPM: Pierre Barrillon, Marlon Barbero, Denis Fougeron, Alexandre Habib and Patrick Pangaud

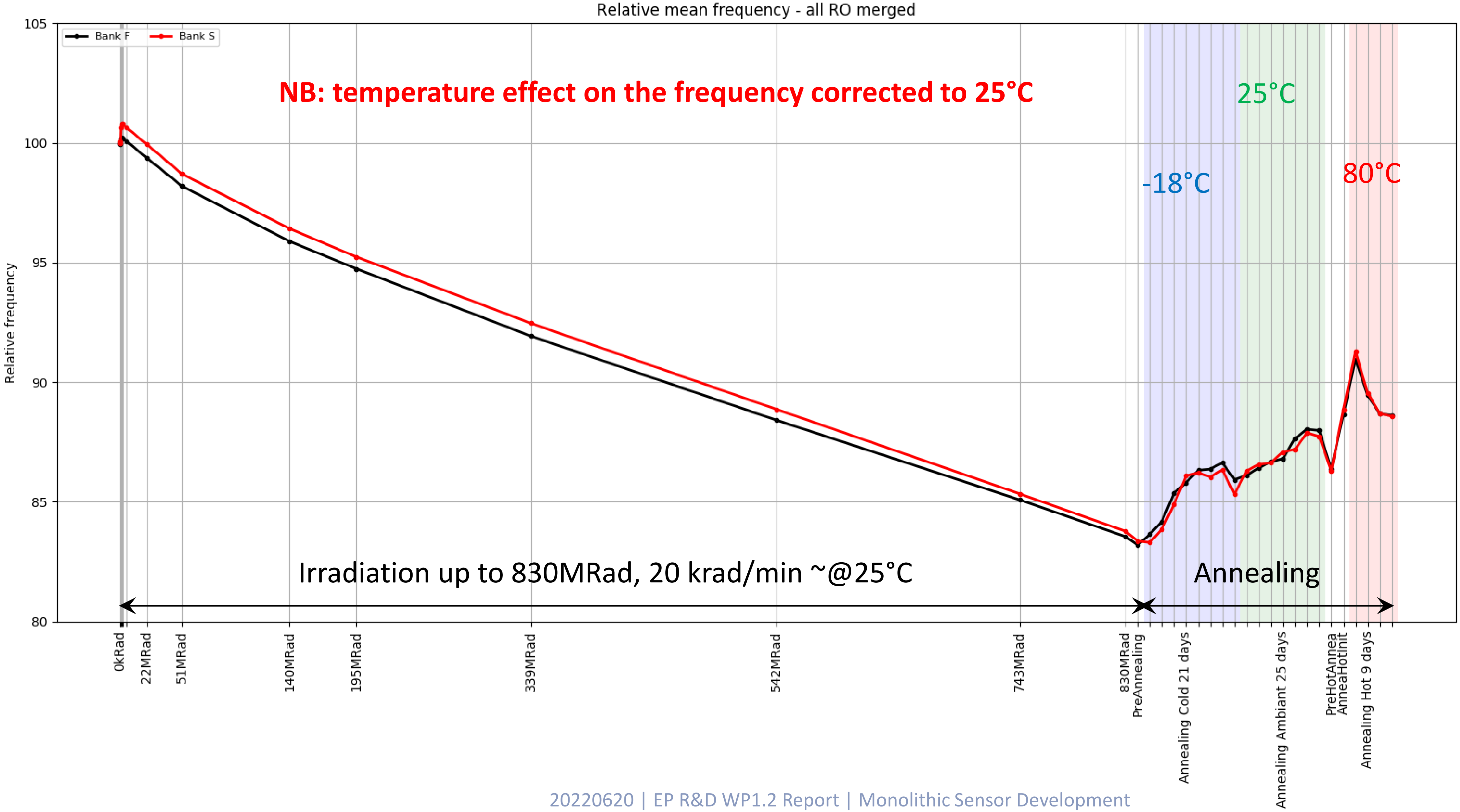
24 flavors oscillating in good agreement with simulations



The measurements are consistent between the 2 measured chips

Ringoscillator measurements, all averaged and merged

CPPM: Pierre Barrillon, Marlon Barbero, Denis Fougeron, Alexandre Habib and Patrick Pangaud



NB: temperature effect on the frequency corrected to 25°C

Irradiation up to 830MRad, 20 krad/min ~@25°C

Ringoscillator measurements, summary

CPPM: Pierre Barrillon, Marlon Barbero, Denis Fougeron, Alexandre Habib and Patrick Pangaud

48 ring oscillators have been irradiated for 4 weeks at 20 krad/min and a total dose of 830 Mrads

- The chip continued to work with no issues spotted
- No real difference between static (quiet during irradiation) and functional (oscillating during irradiation)

Oscillation frequency dropped during irradiation by 12 to 25 %

- Compatible with measurements on similar technologies (same node size)
- Smaller cells (lower transistor width W) seem more affected than bigger cells (higher W). Coherent with transistor measurements

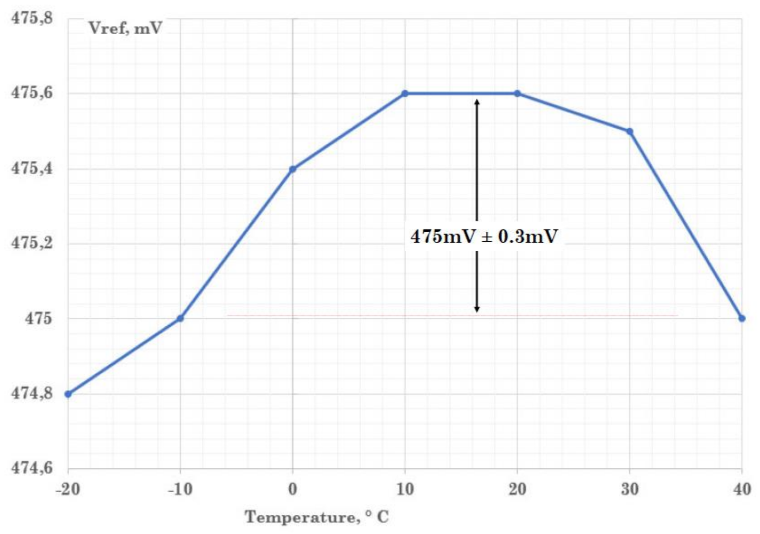
Annealing in progress, some effects observed

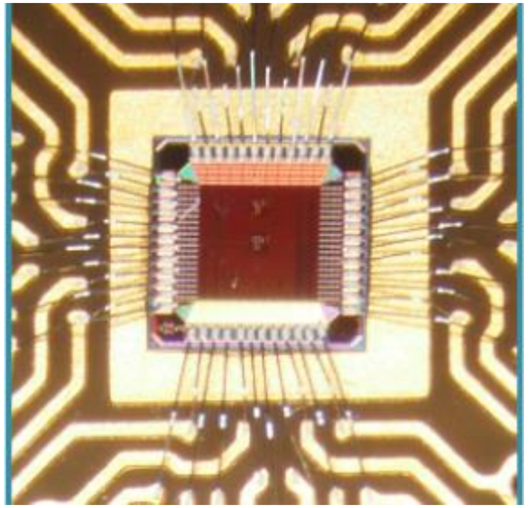
- Will do 2nd chip for consistency
- Results to be presented at TWEPP

IP Block measurements bandgap, T-sensor, VCO: all functional

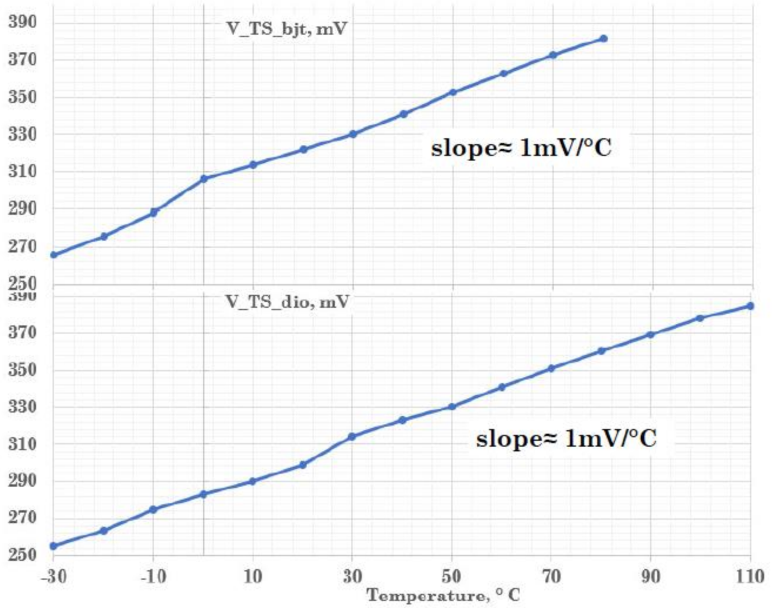
NIKHEF: V. Gromov, D. Gajanana, A. Yelkenci, A. Grelli, R. Kluit, M. Rossewij

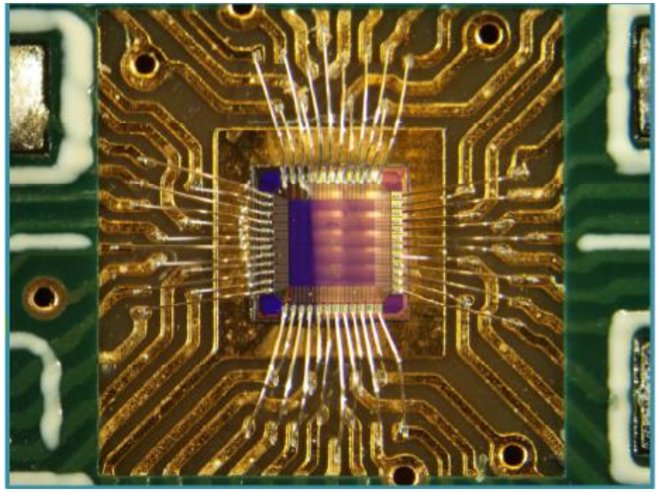
Bandgap



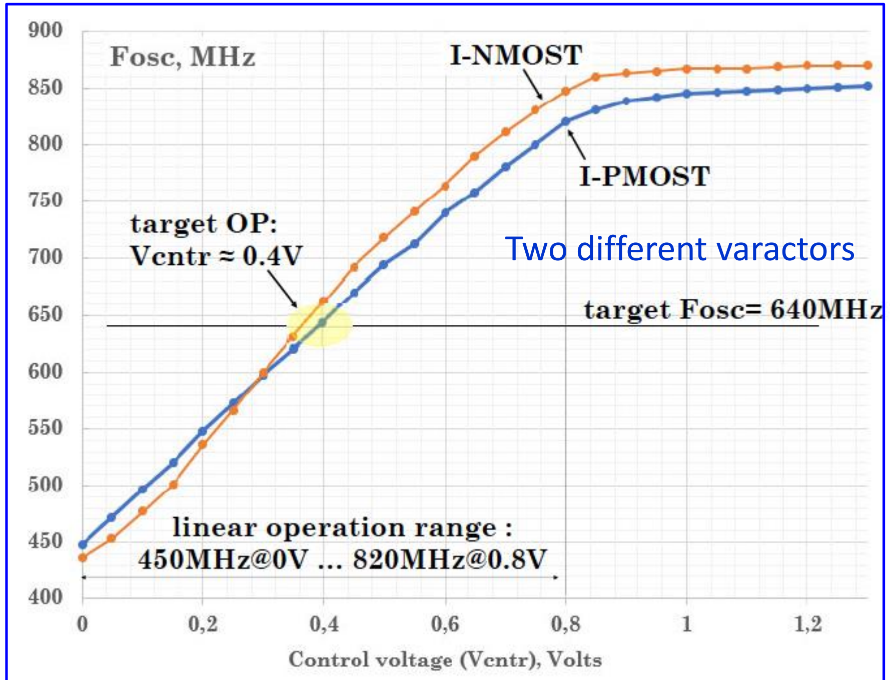


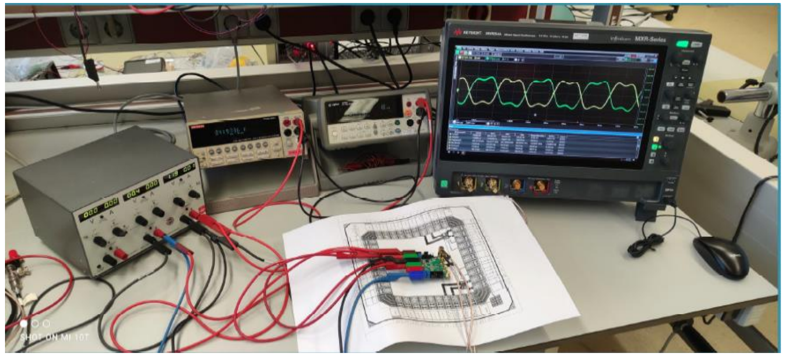
Temperature sensor





Voltage Controlled Oscillator (VCO)





IP Block measurements bandgap, T-sensor, VCO: irradiation results

NIKHEF: V. Gromov, D. Gajanana, A. Yelkenci, A. Grelli, R. Kluit, M. Rossewij

10 keV X-rays 6.5 Mrad/hour

Bandgap

- Standard process: BG 1, 2 24 hours -> 150 Mrad,
- Modified process BG 3, 4: 48 hours -> 300 Mrad

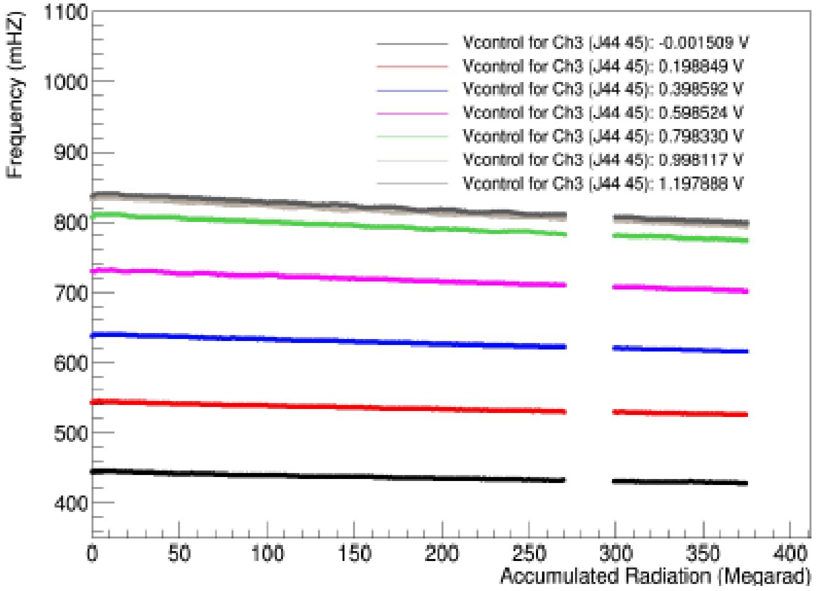
VCO

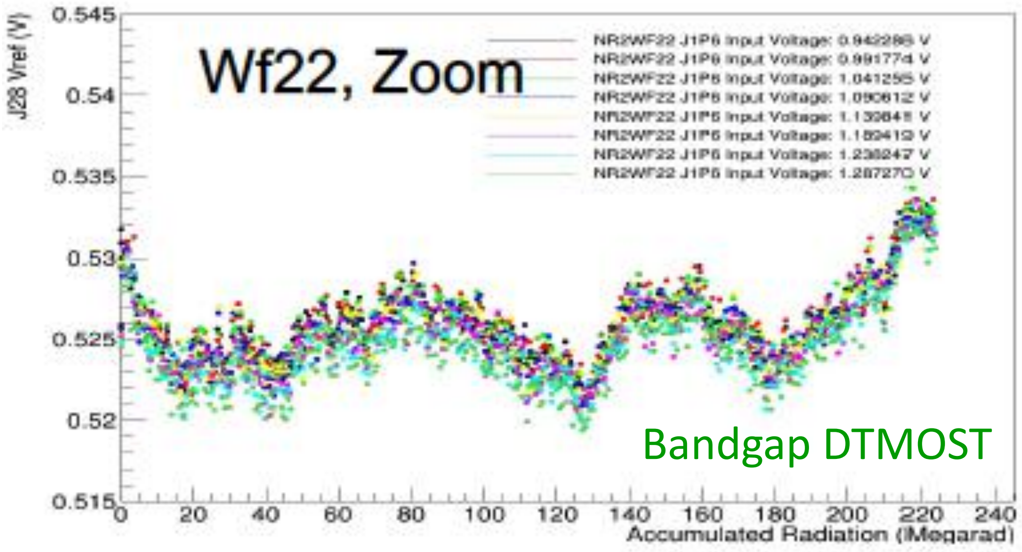
- Modified process 60hours -> 375 Mrad

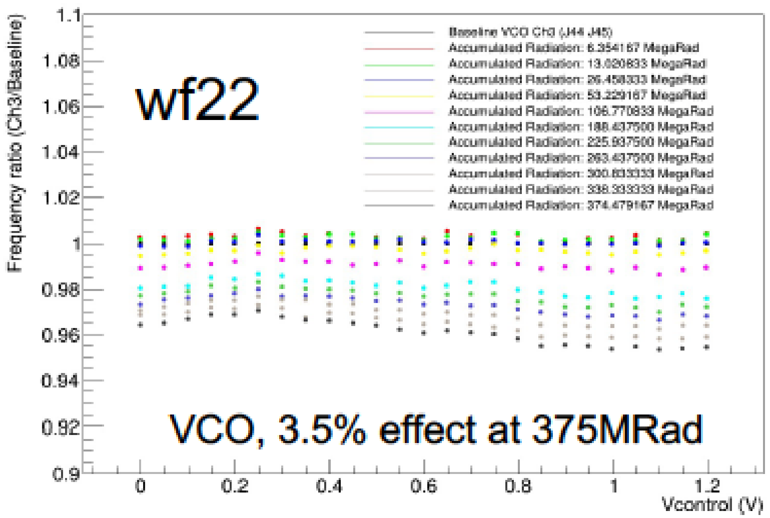
T-sensor

- Modified process 15 hours -> ~100 Mrad

VCO, 375MRad





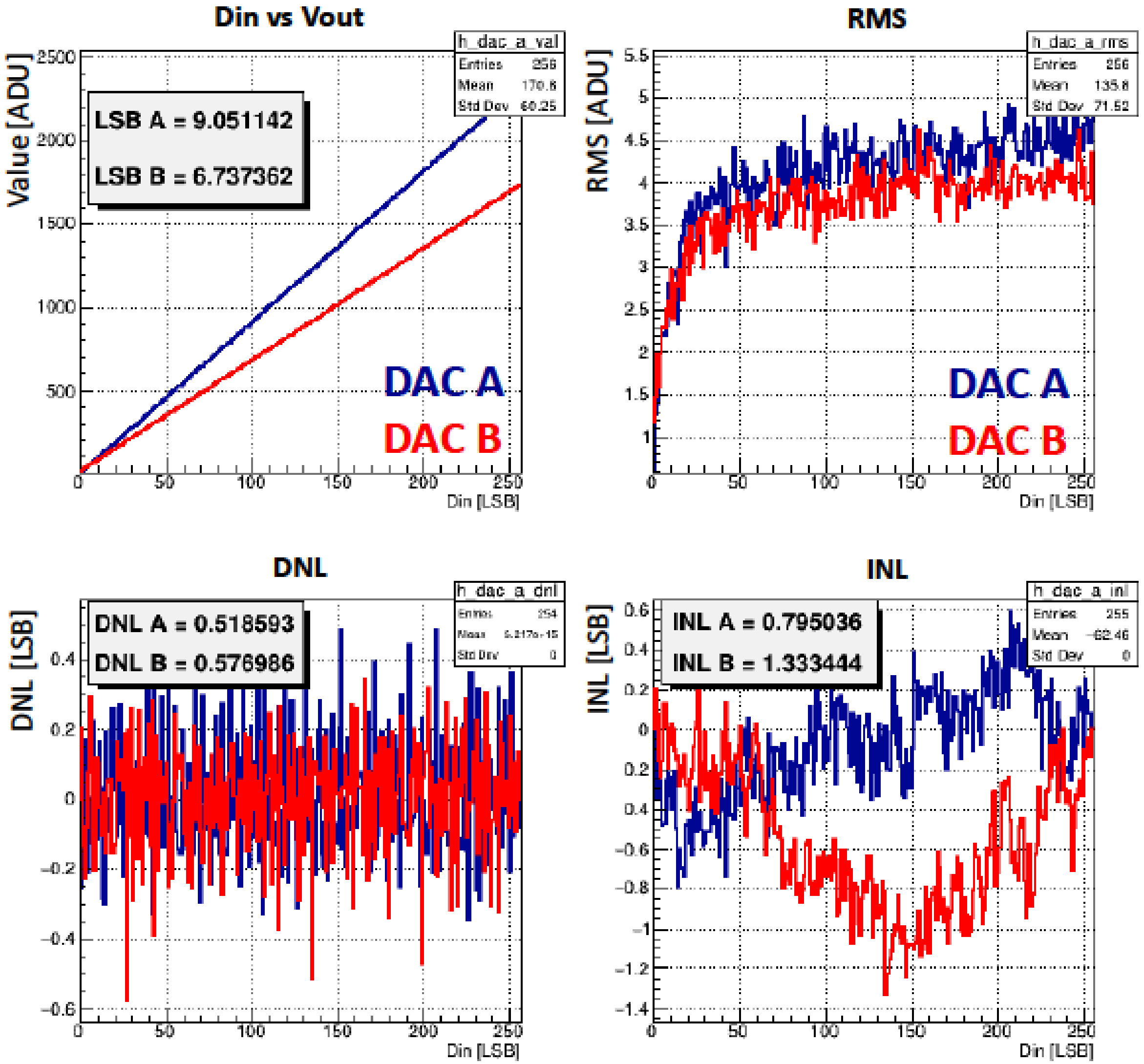


IP Block measurements DAC

IPHC: I. Valin, S. Bugiel, A. Dorokhov, C. Colledani, C. Hu et al.

	DAC A	DAC B
Resolution	8 bit	8 bit
LSB [nA]	40	40
Reference current [uA]	-0.8	-10.72
Power [uW] (*)	13	13
Area [um x um]	133x253	143x253

Both DACs fully functional



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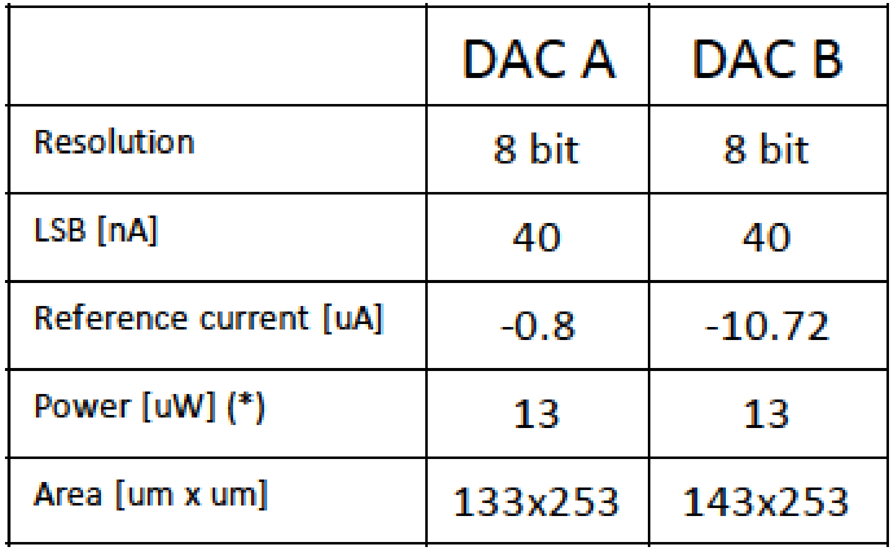

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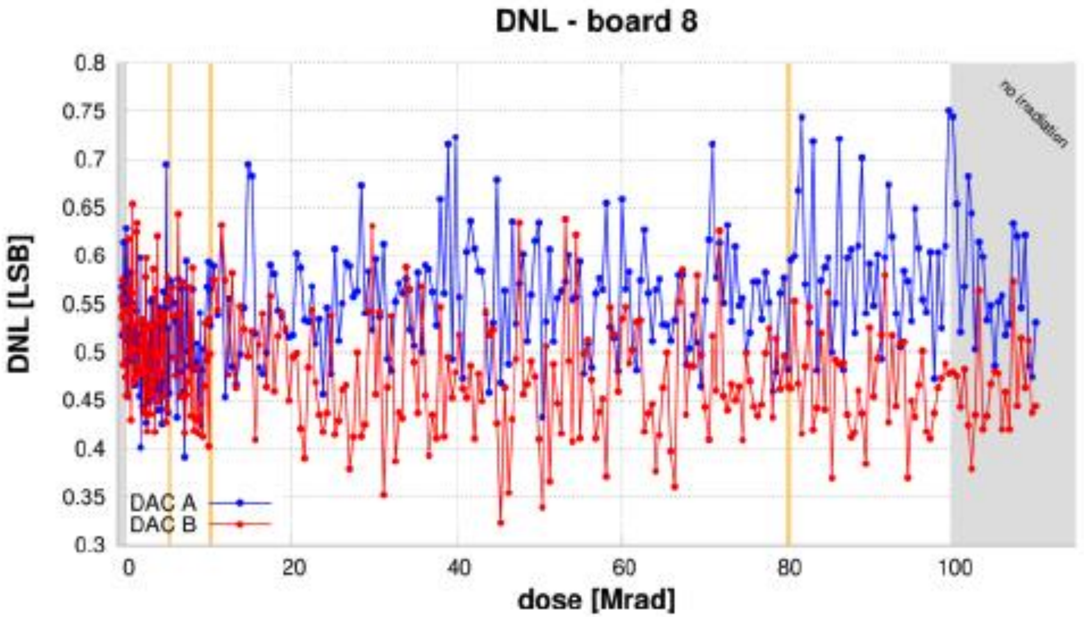

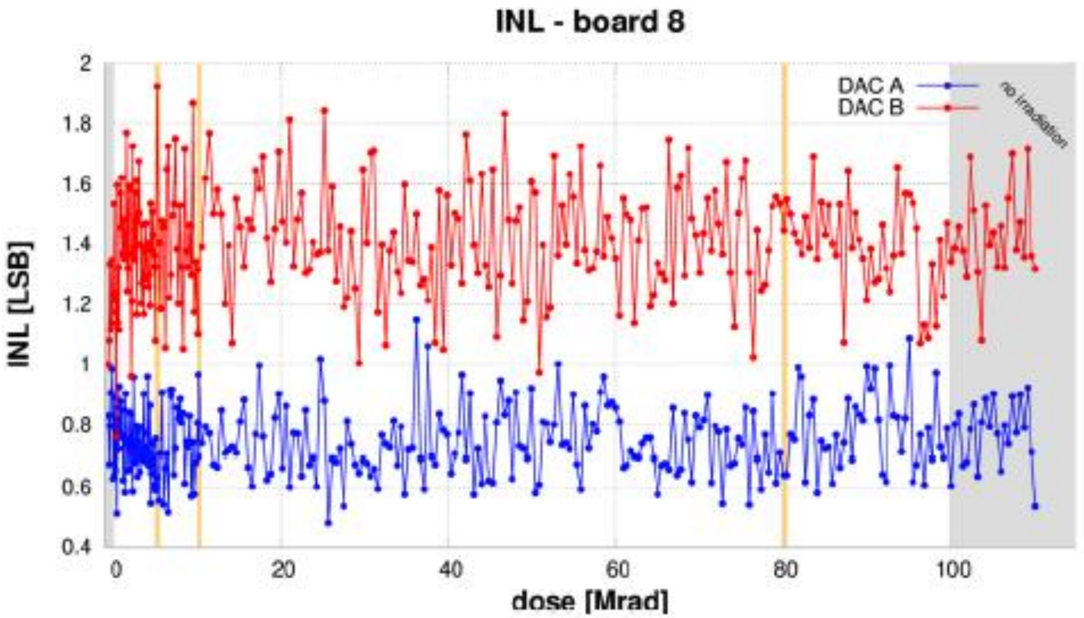

Both DACs remain functional after irradiation,
Irradiation up to 100 Mrad in this example

10 keV X-rays 6.5 Mrad/hour

Total Ionizing dose irradiation measurements

Transistor measurements in line with other 65 nm technologies

- Total ionizing dose tolerance very good up 1Grad for 1.2 V NMOS transistors, and up to 100 Mrad for PMOS transistors, after which significant drain current degradation sets in especially for short channel devices
- Higher voltage transistor radiation tolerance scales with gate oxide thickness
- In general no showstoppers, some more sensitivity with small W PMOS transistors

Leads to tested tolerance to in excess of 100 Mrad and well beyond for some sample circuits :

- Ring oscillators
- Bandgaps, temperature sensors, voltage controlled oscillators and DACs