EXTREME ENVIRONMENT AND LONGEVITY

7.4b: RADIATION HARDNESS

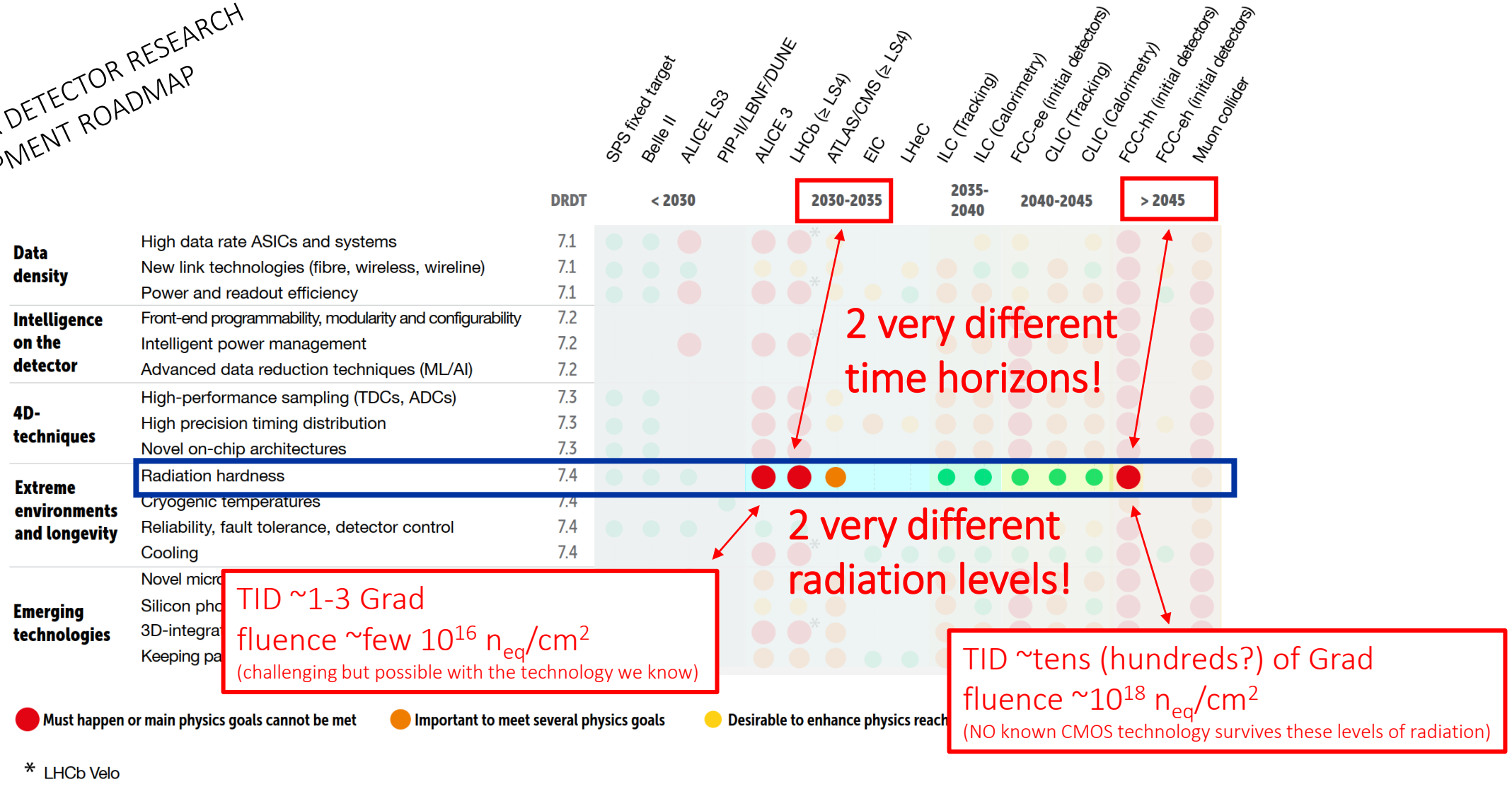
IMPLEMENTING DRD7:

AN R&D COLLABORATION ON ELECTRONICS AND ON-DETECTOR PROCESSING

2nd WORKSHOP

Giulio Borghello
giulio.borghello@cern.ch

THE 2021 ECFA DETECTOR RESEARCH AND DEVELOPMENT ROADMAP



EDRRP Group. *The 2021 ECFA detector research and development roadmap*. Tech. Rep. CERN-ESU-017, Geneva, 2020. (https://cds.cern.ch/record/2784893)

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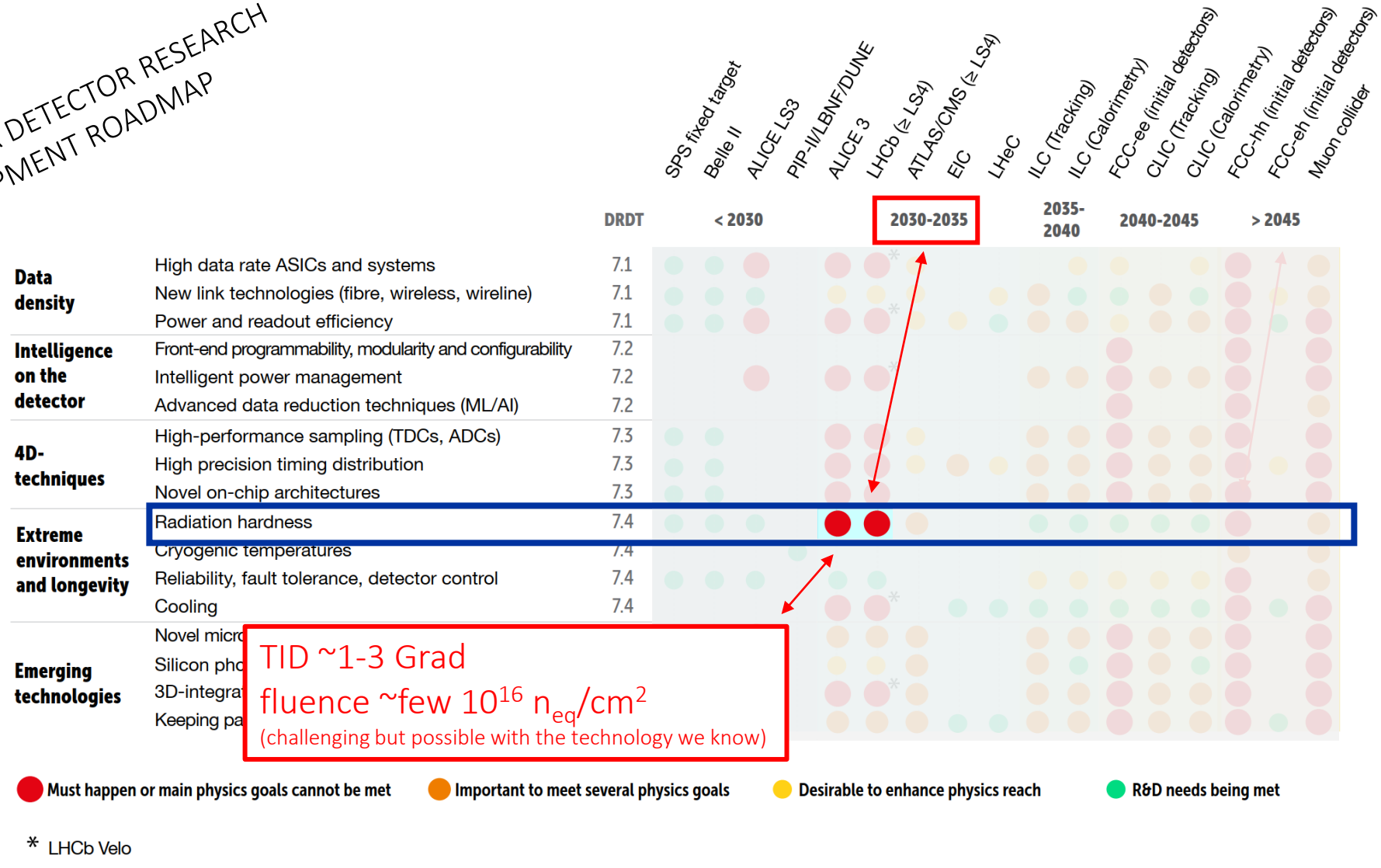

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first studies on 65nm CMOS technology: **2012** → (> 10 years) → chip production in 65nm for HL-LHC: **now**

[S. Bonacini et al 2012 JINST 7 P01015]

chips ready for **2030 - 2035** → the study on radiation effects should have already been started…

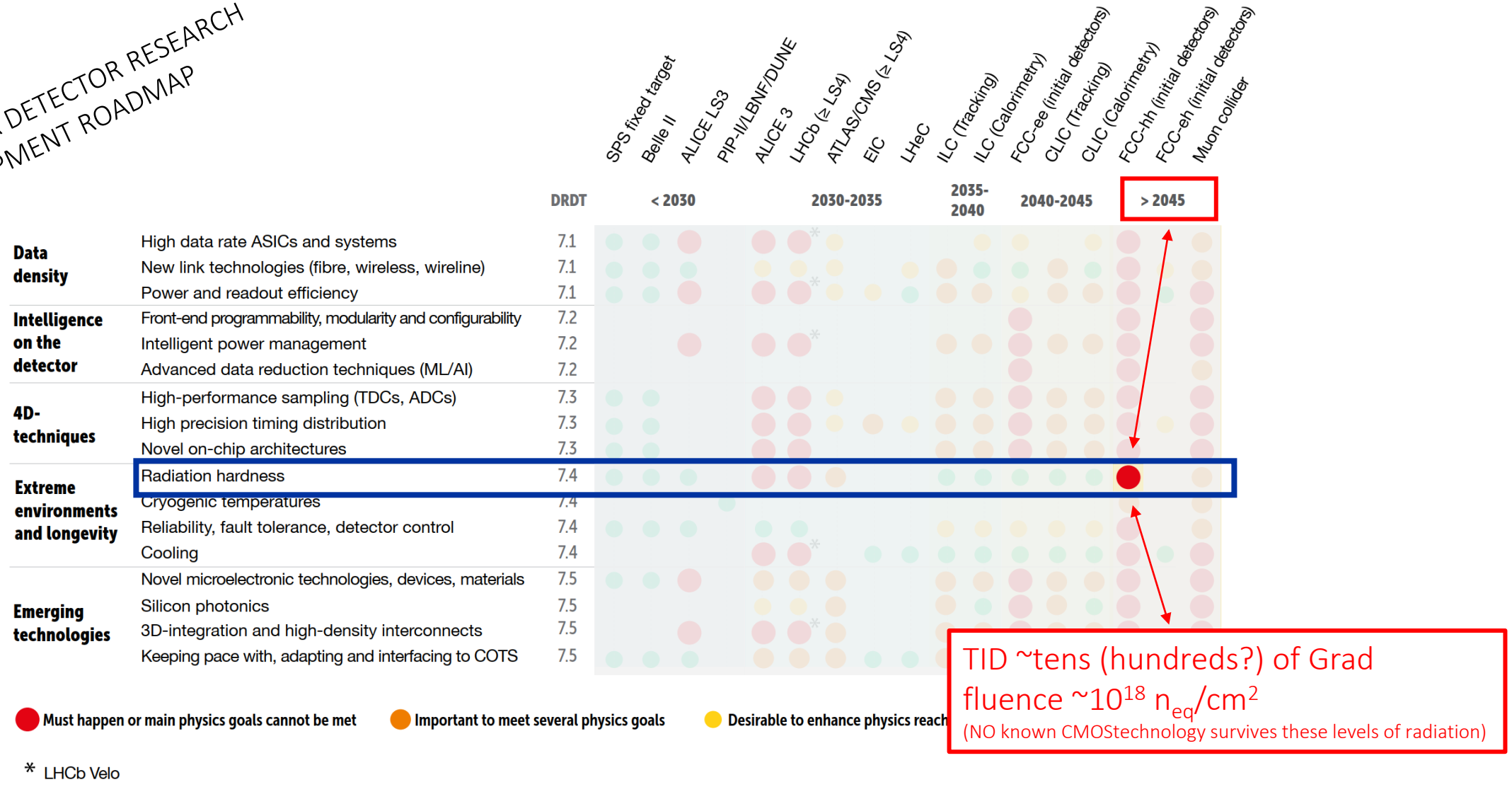
… and it was!

⇩

TID tests on **28nm CMOS** technology started in 2014!
TID tests on **65nm** imaging technology for **monolithic** started in 2022!
DCDC GaN, iPOL, etc…

research on commercial CMOS technologies is essential!

THE 2021 ECFA DETECTOR RESEARCH AND DEVELOPMENT ROADMAP



TID ~tens (hundreds?) of Grad
fluence ~10^{18} n_{eq}/cm^2
(NO known CMOStechnology survives these levels of radiation)

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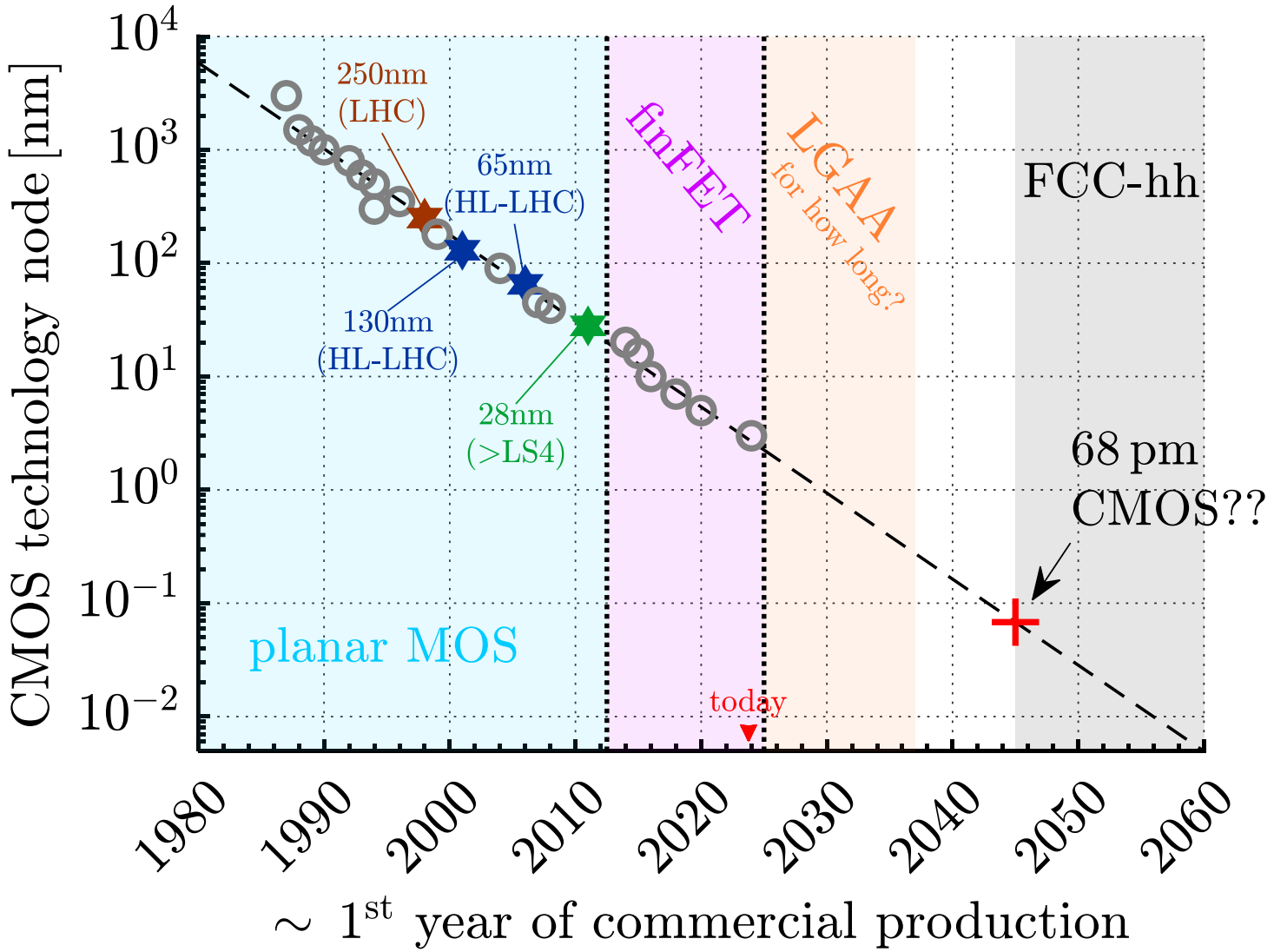

data from:
https://www.tsmc.com/english/dedicatedFoundry/technology/logic/l_3nm
https://irds.ieee.org/editions/2022/more-moore

7.4.b: EXTREME ENVIRONMENT AND LONGEVITY - RADIATION HARDNESS

Project: radiation resistance of advanced CMOS nodes

CERN EP-R&D WP5.1 [CH]

TU Graz [AU]

INFN PAVIA + [IT]

CPPM [FR]

EP-R&D WP5.1

- vast experience on radiation-effects on CMOS technology (250nm, 130nm, 65nm, 40nm 28nm, 22FDSOI)

- 28nm:
  - 2 ASICs to study TID and DD effects at transistor level
  - 1 ASIC to study TID effects on ring-oscillator
  - 1 ASIC to study SEE (SEU, MBU, SET, SEL)

- 2 X-ray machines (AsteriX and ObeliX)

- Resources: 1 student + 1 part time staff (~1.5 FTE)

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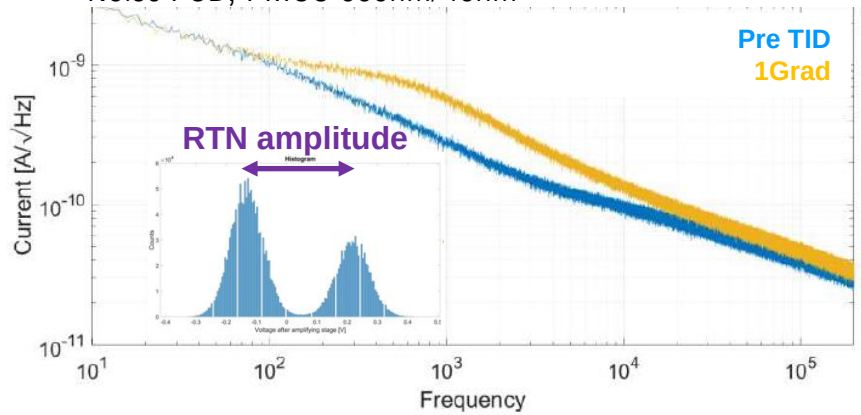
	[AU]	
+	[IT]	
	[FR]	

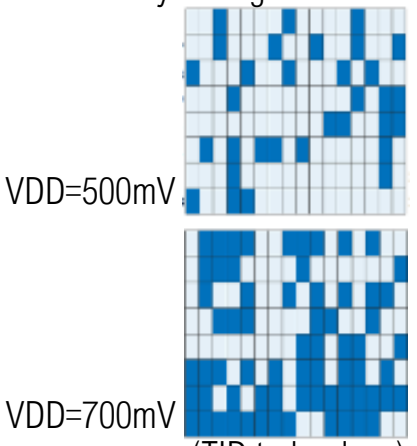
Graz University of Technology – Institute of Electronics

Infrastructure	X-ray irradiator, parameter analyzers, noise measurement, vector network analyzers	
Personnel	1 FTE till 2025	To be requested: 1.5 FTE 2025-2028
Budget	40k EUR till 2025	To be requested: 150k EUR

A) 28nm HPC+
Noise PSD, PMOS 600nm/40nm



B) 40nm CMOS
RTN density vs power supply
8 x 16 array of ring oscillators



(TID to be done)

Current focus:

- 28nm and 40nm → HKMG planar CMOS
- Single MOSFET DC, 1/f, RTN
- Variability in noise and radiation effects especially in small transistors
- Defect density evaluation

Future plans (funding request):

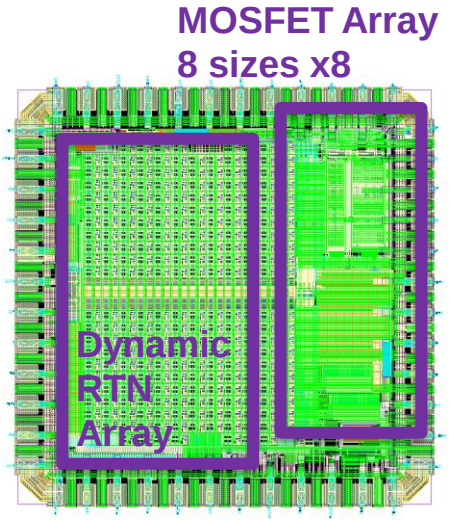
- Merge internal radhard and power electronics and RF activities

C)

28nm CMOS HPC+ January 2023 mini@sic run

Test structures for TID characterization:

- MOSFET array with leakage current compensated onchip MUX
- Defect density in dynamic characterization



SIRENS
Austrian Science Fund (FWF): P 33387-N

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+	[IT]	
	[FR]	

PiHEX project

- Starting at the end of **Sept 2023** will be focused on the design and radiation hardness qualification of **28 nm CMOS analog front-end channels** for **pixel sensors** for high energy physics and photon science applications
- **Two research units** involved: University of Bergamo/ INFN Pavia and University of Padova
- Duration : **2 years**
- Funded by **Italian Ministry for University and Research**
- **~ 2.7 FTE**
- The research group at **University of Bergamo / INFN Pavia** has a wide experience in the design of readout electronics for semiconductor detectors. The research interests are focused on low-noise, rad-hard analog front-ends as well as on mixed-signal multichannel readout systems. The research activities are also focused on the study of noise and radiation effects in electronic devices. Radiation hardness studies have been pursued in different nanoscale CMOS technologies.
- The Department of Information Engineering at the **University of Padova** has developed a significant expertise in the field of radiation effects on electronic components in the last twenty years. The RREACT (Reliability and Radiation Effects on Advanced Components and Technologies) group has been strongly involved in the characterization of the effects of the space, terrestrial and high-energy physics environments in electronic components. The devices studied in the framework of several Italian and European projects in collaboration with industrial and academic partners range from FinFETs and small circuits to full-size commercial non-volatile memories and complex microprocessors and FPGAs.

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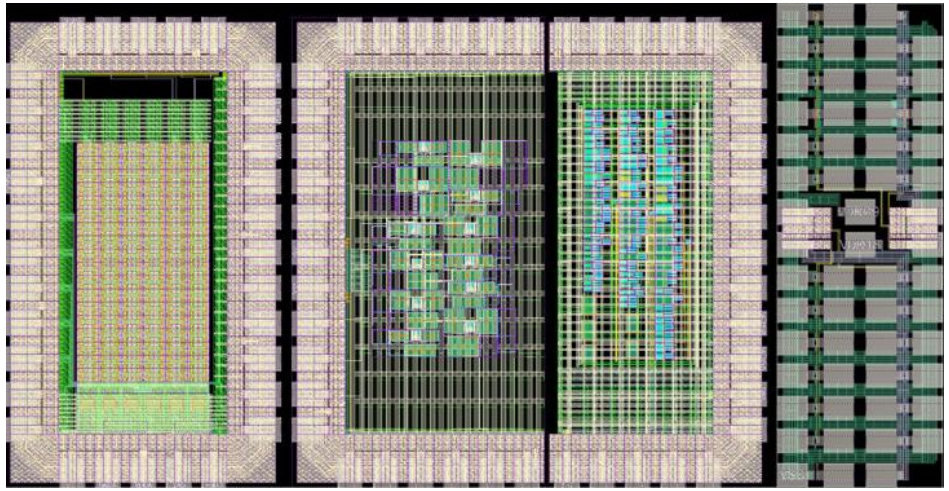
CPPM	[FR]	

CPPM activities

- R&D axis around hybrid pixels for 4D tracking
  - Time measurement with a resolution better than 50ps
  - Good spatial resolution → pixel size : 25µm × 25µm
  - Advanced CMOS process : 28 nm and more advanced
  - Tests of radiation tolerance of the technology and the pixel chip
- This R&D is financed by the IN2P3 master project DEPHY
- Mini@sic of 2 mm x 1 mm submitted
  - Received from the Fab June 2023
- Different structures implemented :
  - Small pixel matrix: Fast charge amplifier
  - SET Testing structures
  - Ring oscillators for the TID tolerance testing
  - Device array for TID tolerance testing



- Test set-up is under preparation
- Functional tests → Q4-2023
- Irradiation test (TID + SEE) → Q1-2024
- Resources :
  - 2 people working part-time on the project
  - PhD student can join us from the next year
  - Plan to devote ~0.3 FTE/year to DRD7.4.b activities

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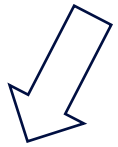
TU Graz	[AU]	1 FTE till 2025 + 1.5 FTE to be requested
Università degli Studi di Bergamo, INFN Pavia + Università degli Studi di Pavia	[IT]	~ 2.7 FTE till ~2025
CPPM Centre de Physique des Particules de Marseille	[FR]	~ 0.3 FTE/year

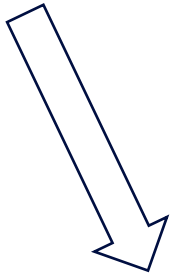
7.4.b: EXTREME ENVIRONMENT AND LONGEVITY - RADIATION HARDNESS

Project: radiation resistance of advanced CMOS nodes

More specific projects are expected to form around:



Specific nodes (e.g., 7nm finfets, 3nm LGAA, etc.)



Specific effects (e.g., low-dose-rates at ultra-high-doses, NIEL scaling, noise, etc.)

Other possible projects:

- “new” or different technologies (e.g., GaN, InGaAs, etc.)
- facilities (how to irradiate to tens of Grad in a reasonable amount of time)
- qualification (how to qualify chips for ultra-high doses)

difficulties: technology accessibility, facility accessibility

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Total Ionizing Dose effects in heterojunction bipolar transistor (HBT) - SiGe technologies for HEP experiments

Karlsruher Institut für Technologie

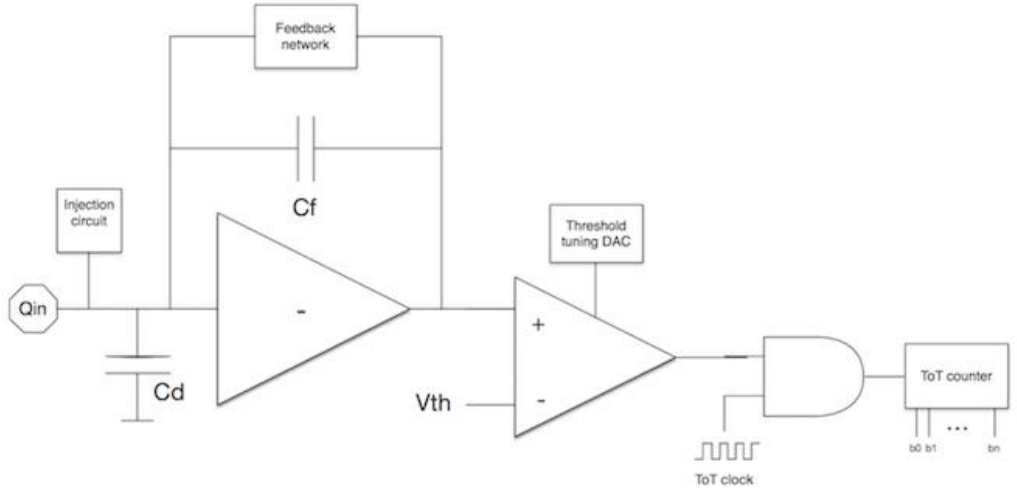
difficulties: technology accessibility, facility accessibility

BACKUP SLIDES

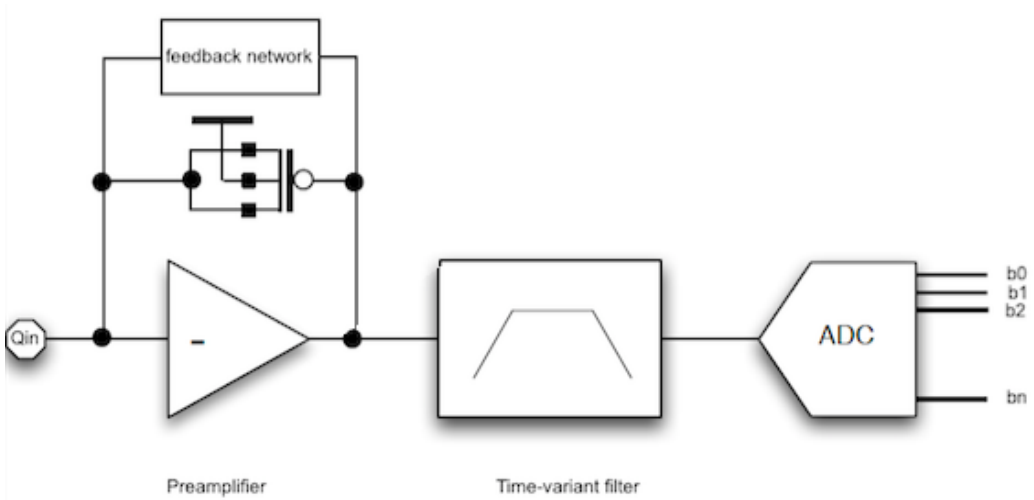
PiHEX project

- The project is focused on the development of **analog front-end channels in 28 nm CMOS for the readout of pixel sensors**, meeting a set of challenging requirements, including extreme radiation tolerance, high spatial resolution, very wide dynamic range and low threshold operation

- **Two front-end channels** will be developed (HEP and FEL front-ends), optimized for high energy physics experiments and photon science applications



HEP front-end



FEL front-end