RADIATION HARDNESS

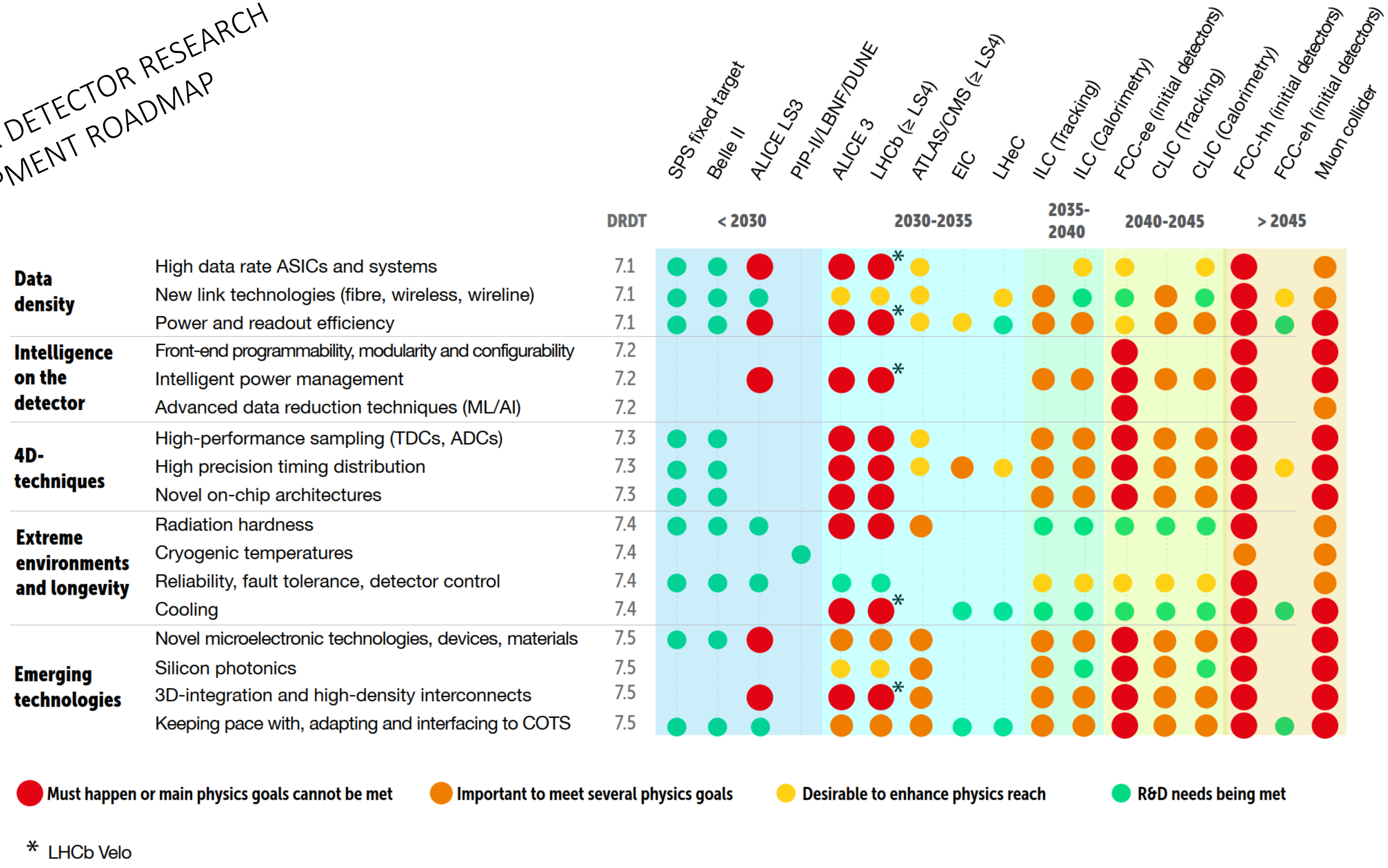
7.4: EXTREME ENVIRONMENT AND LONGEVITY

IMPLEMENTING DRD7:

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

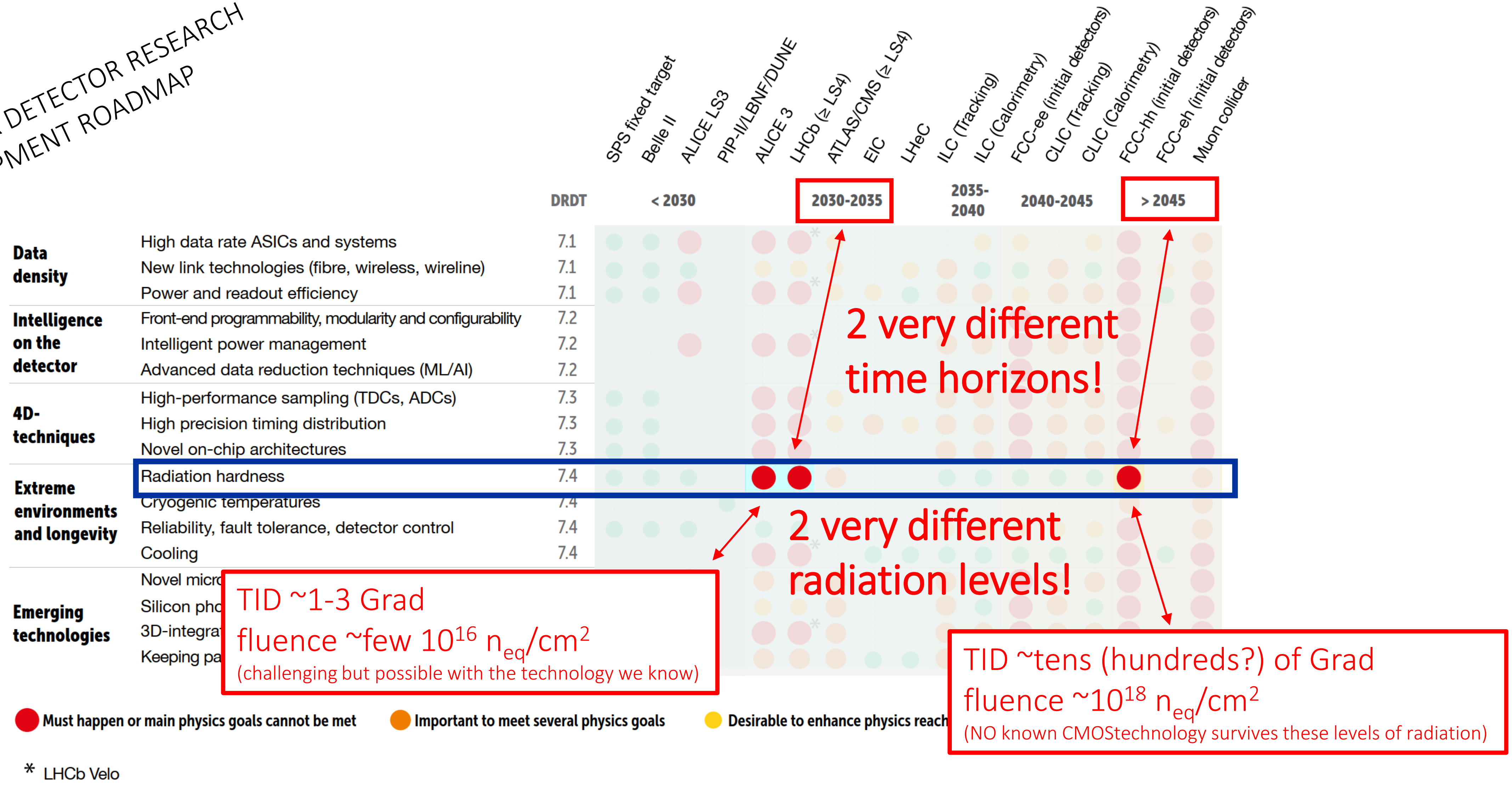
Giulio Borghello
giulio.borghello@cern.ch

THE 2021 ECFA DETECTOR RESEARCH AND DEVELOPMENT ROADMAP

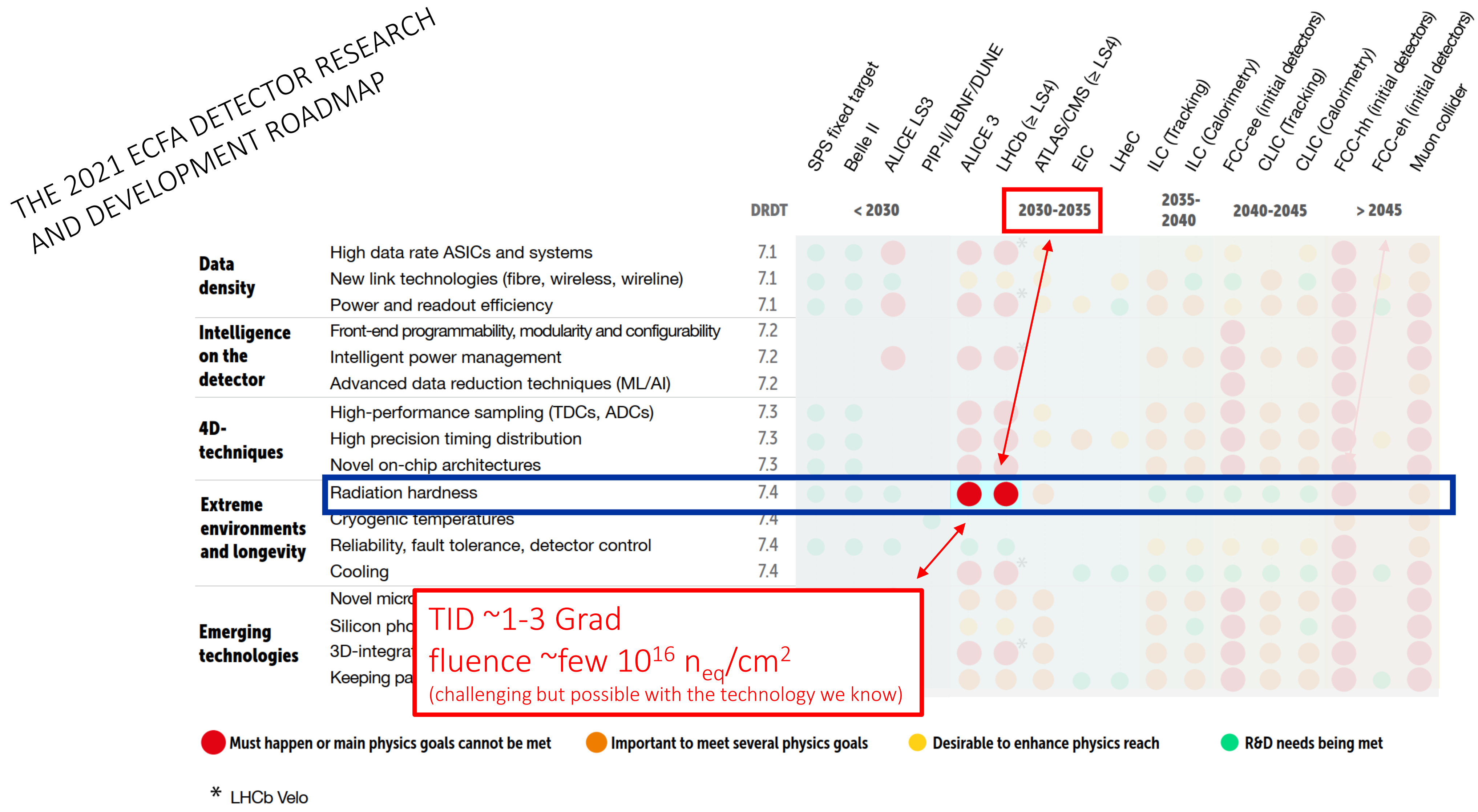


EDRRP Group. *The 2021 ECFA detector research and development roadmap*. Tech. Rep. CERN-ESU-017, Geneva, 2020. (https://cds.cern.ch/record/2784893)

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)



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

> 10 years

first studies on 65nm CMOS technology: **2012** → 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, ecc.. (see yesterday's presentation by Stefano Michelis)

research on commercial CMOS technologies is essential!

research on <u>commercial</u> CMOS technologies is essential!

(no control on the production process)

constantly investigate the radiation responses of new technologies

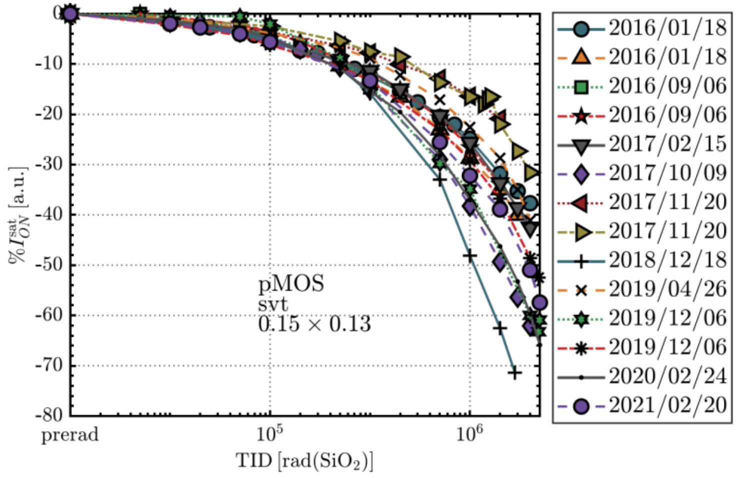
(the study of 28nm started before there was a specific project)

collaborations with institutes is vital!

Several studies on high-TID effects on 28nm CMOS done in collaboration with (or by) EPFL and University of Padova

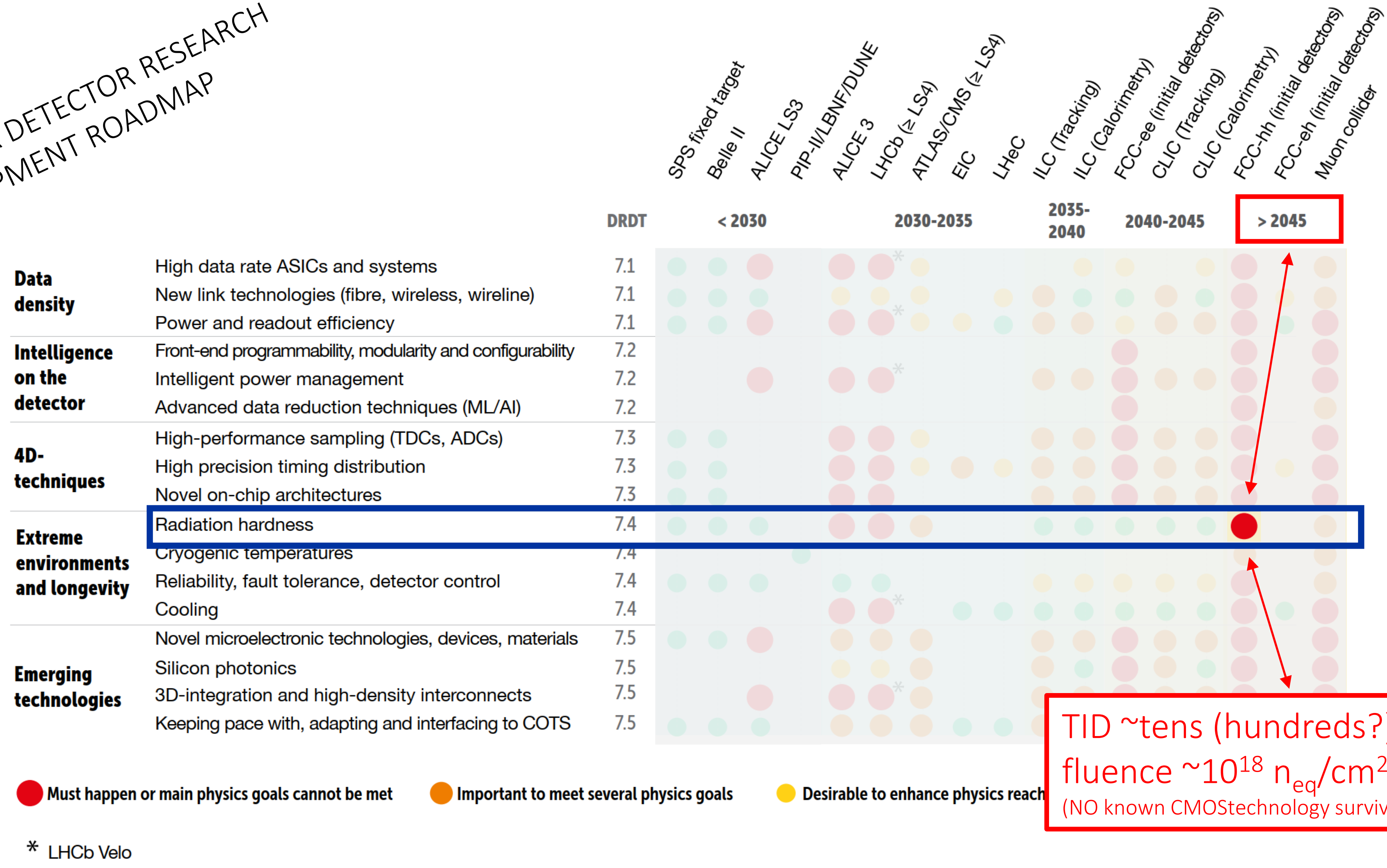
[1] Pezzotta, Alessandro, et al. "Impact of GigaRad Ionizing Dose on 28 nm bulk MOSFETs for future HL-LHC." *2016 46th European Solid-State Device Research Conference (ESSDERC)*. IEEE, 2016.
[2] Zhang, C-M., et al. "Total ionizing dose effects on analog performance of 28 nm bulk MOSFETs." *2017 47th European Solid-State Device Research Conference (ESSDERC)*. IEEE, 2017.
[3] Zhang, Chun-Min, et al. "Characterization and modeling of Gigarad-TID-induced drain leakage current of 28-nm bulk MOSFETs." *IEEE Transactions on Nuclear Science* 66.1 (2018): 38-47.
[4] Zhang, C-M., et al. "Mobility degradation of 28-nm bulk MOSFETs irradiated to ultrahigh total ionizing doses." *2018 IEEE International Conference on Integrated Circuits, Technologies and Applications (ICTA)*. IEEE, 2018.
[5] Zhang, Chun-Min, et al. "Bias dependence of total ionizing dose effects on 28-nm bulk MOSFETs." *2018 IEEE Nuclear Science Symposium and Medical Imaging Conference Proceedings (NSS/MIC)*. IEEE, 2018.
[6] Bonaldo, Stefano, et al. "Influence of halo implantations on the total ionizing dose response of 28-nm pMOSFETs irradiated to ultrahigh doses." *IEEE Transactions on Nuclear Science* 66.1 (2018): 82-90
[7] Bonaldo, Stefano, et al. "Ionizing-radiation response and low-frequency noise of 28-nm MOSFETs at ultrahigh doses." *IEEE Transactions on Nuclear Science* 67.7 (2020): 1302-1311..

monitor selected CMOS processes over time



Termo, G., et al. "Fab-to-fab and run-to-run variability in 130 nm and 65 nm CMOS technologies exposed to ultra-high TID." *JINST* 18.01 (2023)

THE 2021 ECFA DETECTOR RESEARCH AND DEVELOPMENT ROADMAP

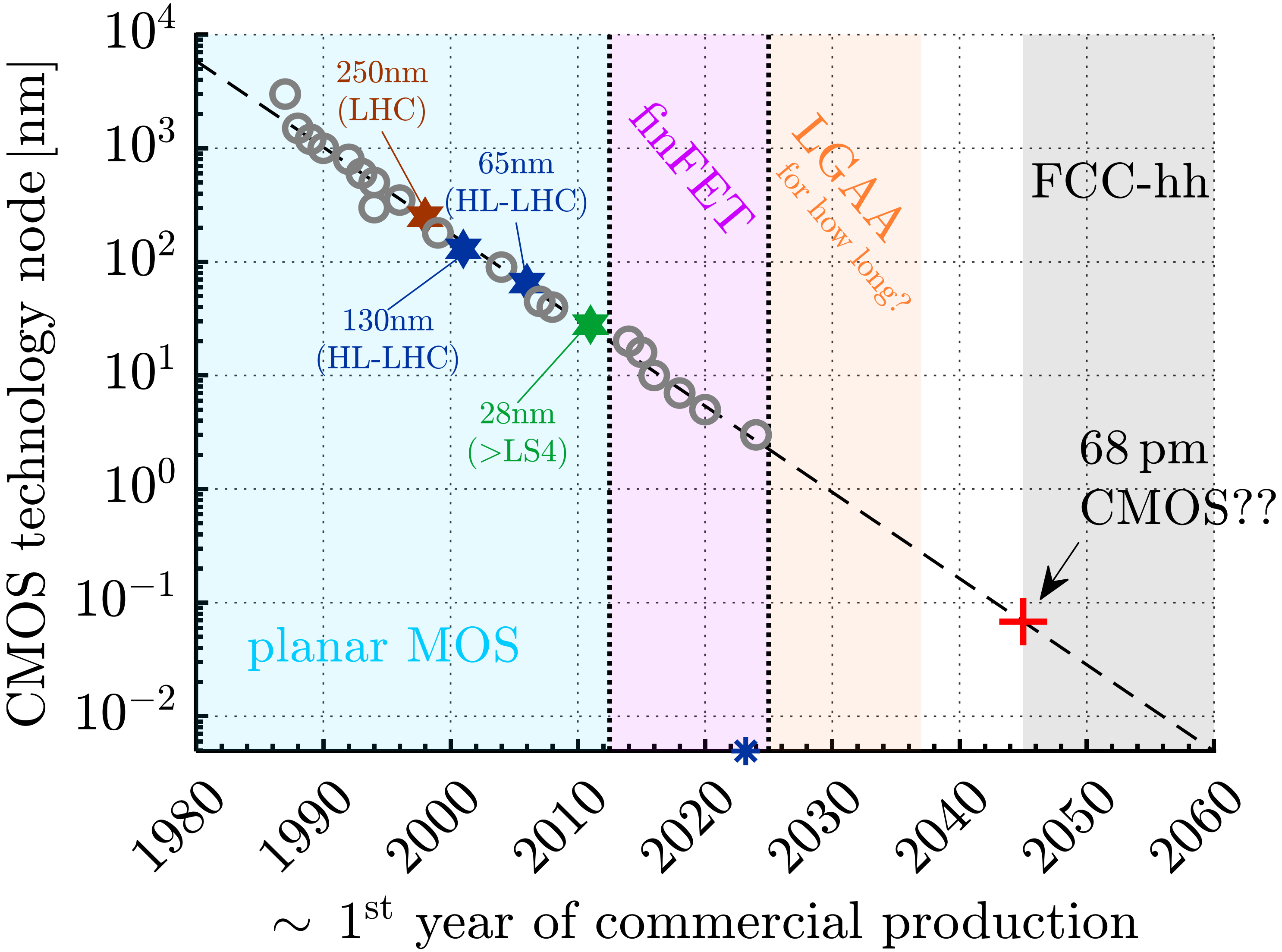


TID ~tens (hundreds?) of Grad

fluence ~10^{18} n_{eq}/cm^2

(NO known CMOStechnology survives these levels of radiation)

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



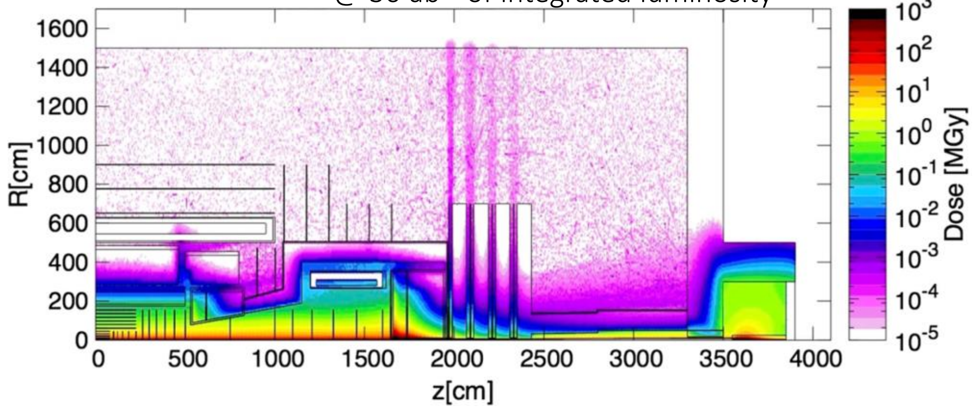
Is scaling necessarily good for radiation hardness?

See presentation by Stefano Bonaldo later.

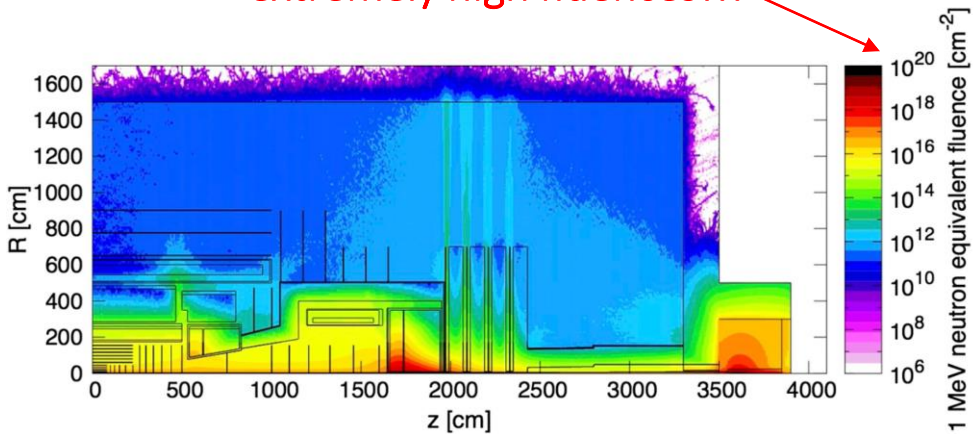
data from:
https://www.tsmc.com/english/dedicatedFoundry/technology/logic/l_3nm
https://irds.ieee.org/editions/2022/more-moore

100 Grad!!!

@ 30 ab^{-1} of integrated luminosity



extremely high fluences!!!



Abada, A., Abbrescia, M., AbdusSalam, S.S. *et al.* FCC-hh: The Hadron Collider. *Eur. Phys. J. Spec. Top.* **228**, 755–1107 (2019). https://doi.org/10.1140/epjst/e2019-900087-0

FCC-hh IS A REAL CHALLENGE

- no known CMOS technology survives these levels of TID
- dramatic fluence levels for optoelectronics, monolithics and power devices
- CMOS technologies are usually not sensitive to DD but we never tested them at these levels of fluence

TESTING WILL BE A KEY PROBLEM!

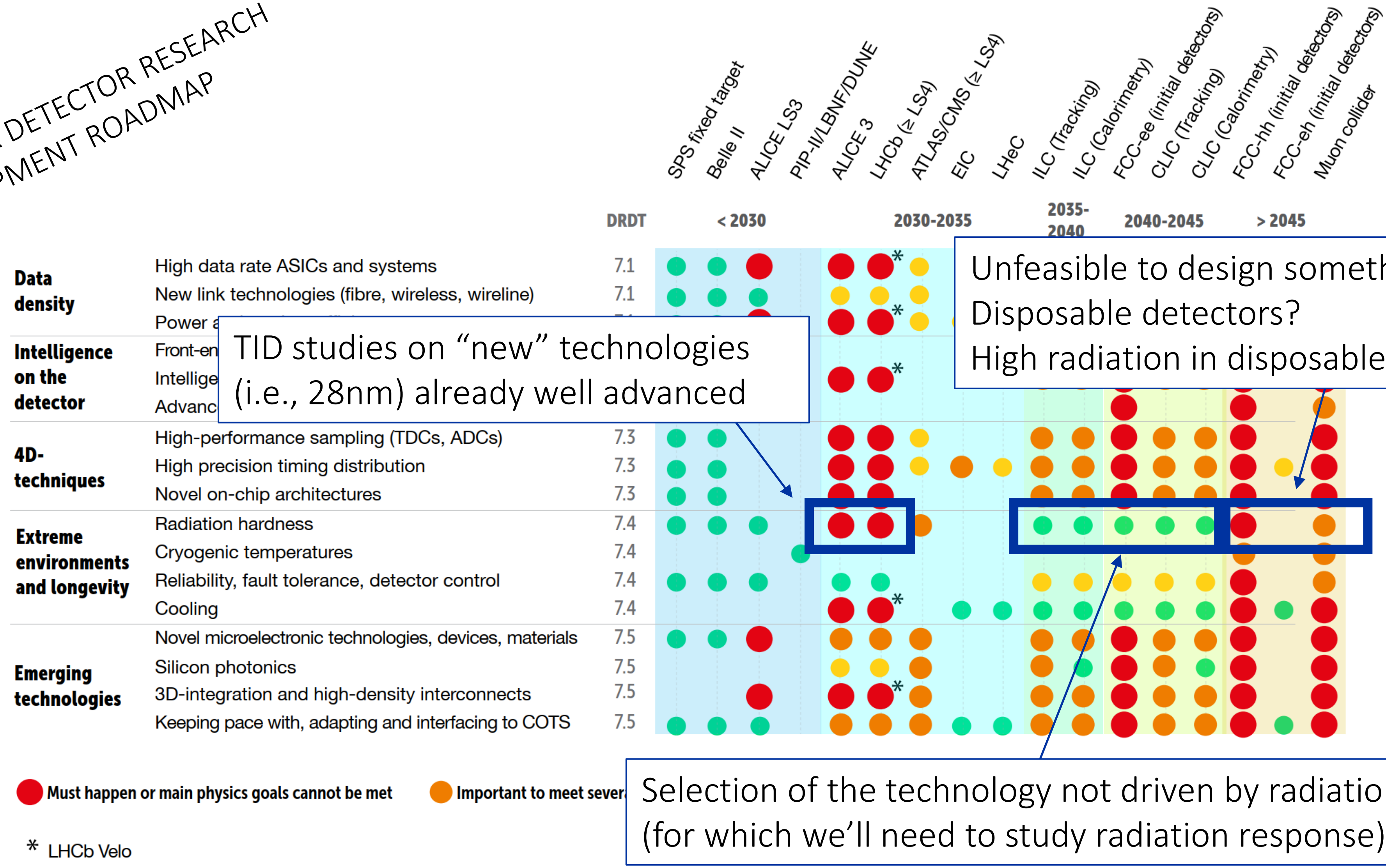
with EP-ESE-ME xray machine (1 chip at the time):

~10 Mrad/h -> 100 Grad in 417 days!!

extreme activation of chips!

- improve irradiation capabilities
- distribute tests among institutes
- simulations of radiation effects
- creative solutions

THE 2021 ECFA DETECTOR RESEARCH AND DEVELOPMENT ROADMAP



TID studies on "new" technologies (i.e., 28nm) already well advanced

Unfeasible to design something at >10 Grad?
Disposable detectors?
High radiation in disposable detectors?

Selection of the technology not driven by radiation (for which we'll need to study radiation response)

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