DRD7: Status and Plans

Electronics and On-Detector Processing

2025 European Edition of the International Workshop on the Circular Electron-Positron Collider (CEPC)

Barcelona, 17 June 2025

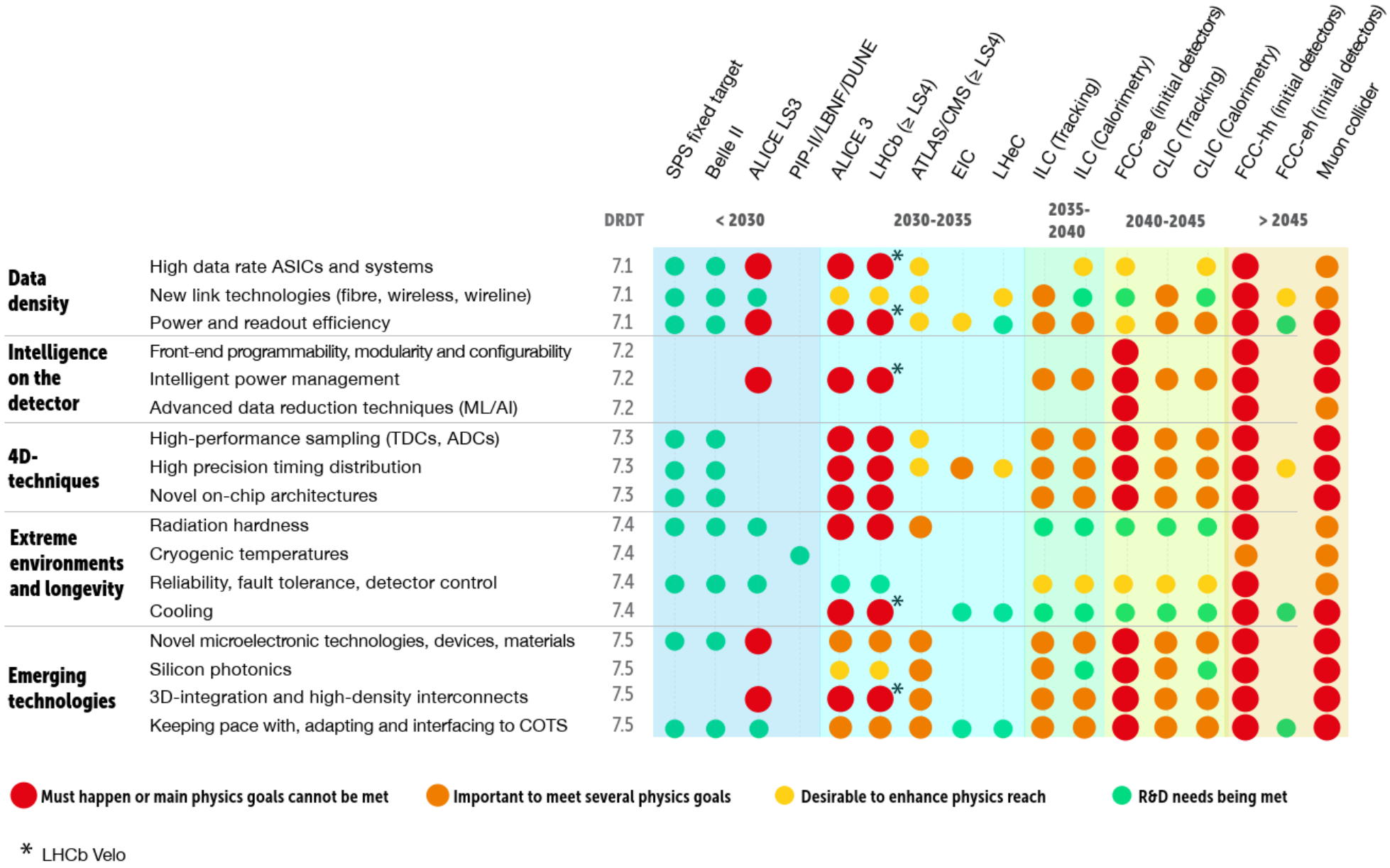
David Gascon (ICCUB)

for the DRD7 Collaboration

ECFA Detector Roadmap

- Progresses in Particle Physics require to push the boundary of detector technologies beyond the state-of-art
- **Electronics** is vital to almost **all detector systems**, and modern technologies offer **tremendous opportunities**, for example:
  - Transmission speeds **≥100 Gbps**
  - Extremely **high integration densities**
  - Very high performance **FPGA**s
  - Advanced **interconnection technologies**
- The exploitation of these technologies must face an increase of:
  - the **complexity** of the projects
  - the required **financial** and **human** resources
- Considerations at the base of the ECFA Detector R&D Roadmap

ECFA Detector Roadmap (2)



DRD7 Collaboration

https://cds.cern.ch/record/2901965/

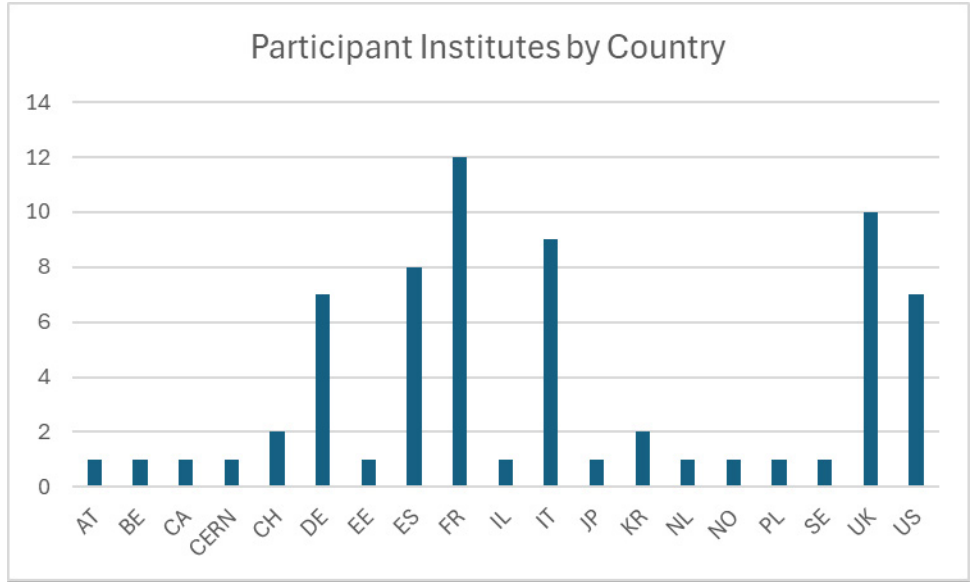
DRD 7: Proposal for an R&D Collaboration on: Electronics and On-Detector Processing

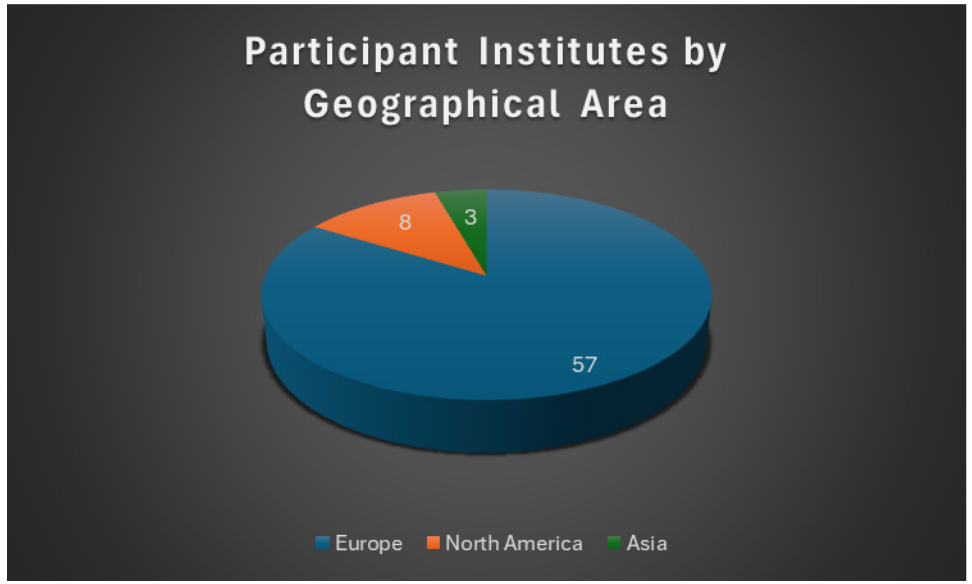
The DRD7 Collaboration

May 21, 2024

Jerome Baudot[1], Marcus French[2], Ruud Kluit[3], Angelo Rivetti[4], Frank Simon[5,*], Francois Vasey[6,*]
(**DRD7 Steering Committee**)

Marlon Barbero[7], Sophie Baron[6] , Giulio Borghello[6] , Michele Caselle[5], Davide Ceresa[6] , Francesco Crescioli[8], Manuel Da Rocha Rolo[4], Oscar Augusto De Aguiar Francisco[9], Conor Fitzpatrick[9], Marek Idzik[10], Kostas Kloukinas[6] , Szymon Kulis[6] , Xavi Llopart Cudie[6] , Niko Neufeld[6] , Jeffrey Prinzie[11] , Iain Sedgwick[2], Walter Snoeys[6] , Jan Troska[6] , Mark Willoughby[2]
(**DRD7 Work Package Conveners**)





Collaboration Proposal approved by DRDC on June 5th 2024

- 67 **Institutes** from 19 **countries**
- 6 **Work Packages**, fitting with the ECFA Detector R&D Roadmap objectives
  - 15 **Projects** (deliverables)
- 1 Transversal **Working Group** on *Tools and Technologies*

Since then, formal collaboration forming process has progressed.

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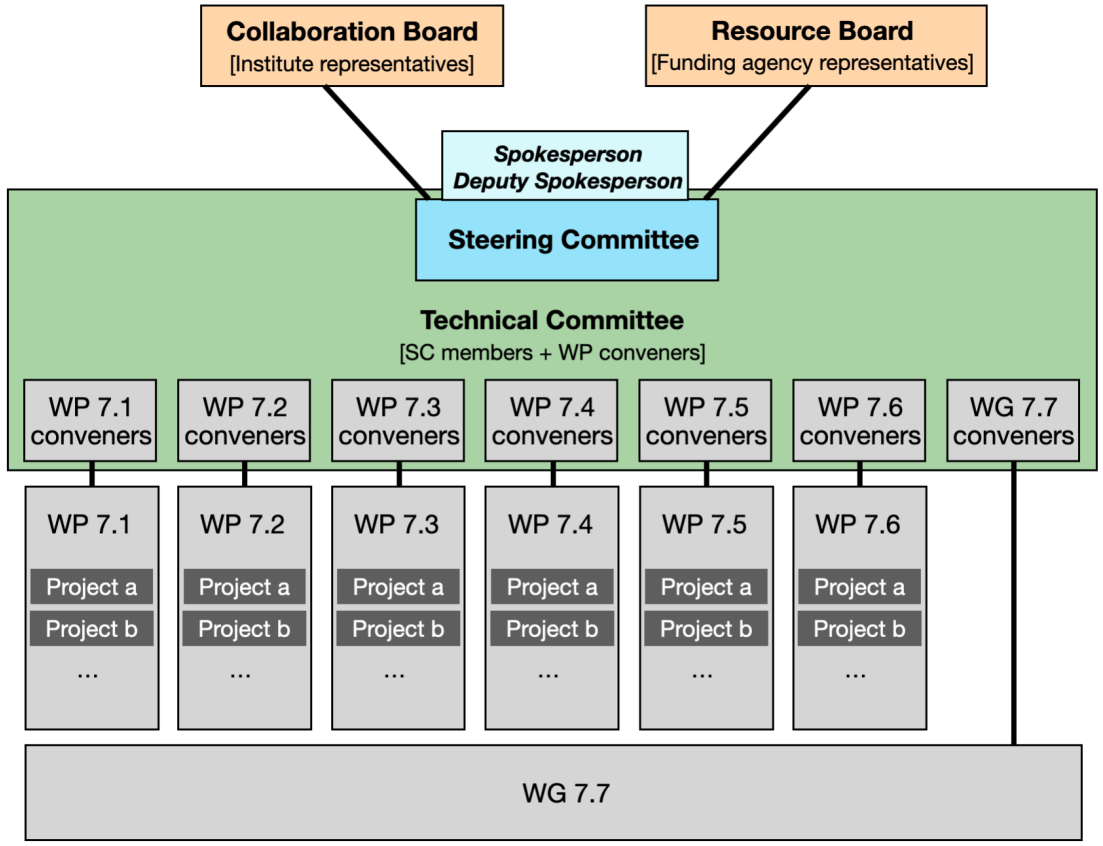

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DRD7 Projects

Data density	High data rate ASICs and systems New link technologies (fibre, wireless, wireline) Power and readout efficiency
Intelligence on the detector	Front-end programmability, modularity and configurability Intelligent power management Advanced data reduction techniques (ML/AI)
4D-techniques	High-performance sampling (TDCs, ADCs) High precision timing distribution Novel on-chip architectures
Extreme environments and longevity	Radiation hardness Cryogenic temperatures Reliability, fault tolerance, detector control Cooling
Emerging technologies	Novel microelectronic technologies, devices, materials Silicon photonics 3D-integration and high-density interconnects Keeping pace with, adapting and interfacing to COTS

Must happen or main physics goals cannot be met Important to meet several physics goals Desirable to enhance physics reach Novel needs being met

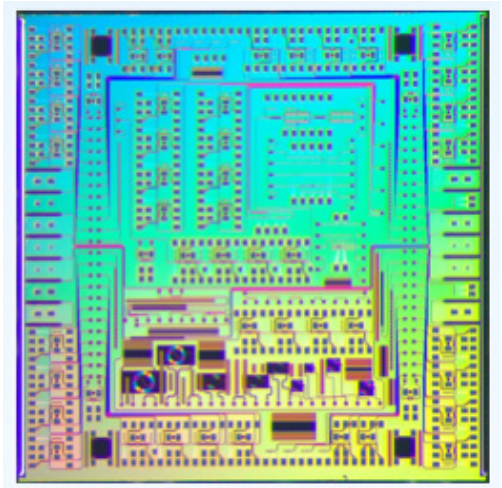
* LHCb Velo

- 7.1 Data density and power efficiency
  - 7.1a Silicon photonics transceivers
  - 7.1b Powering next generation detector systems
  - 7.1c Wireless allowing data and power transmission
- 7.2 Intelligence on detector
  - 7.2a Virtual Electronic System Prototyping
  - 7.2b Radiation Tolerant RISC-V SoC
- 7.3 4D and 5D techniques
  - 7.3a High Performance ADCs and TDCs
  - 7.3b Characterizing and calibrating sources impacting time measurements
  - 7.3c Timing distribution techniques
- 7.4 Extreme environnements
  - 7.4a: Modelling and development of cryogenics PDKs and IPs
  - 7.4b Radiation resistance of advanced CMOS nodes
  - 7.4c Cooling and cooling plates
- 7.5 Back-end system and COTS
  - 7.5a: DAQOverflow
  - 7.5b: From front-end to back-end with 100 GbE
- 7.6 Complex imaging ASICs and technologies
  - 7.6a: Common access to selected imaging technologies
  - 7.6b: Shared access to 3D integration

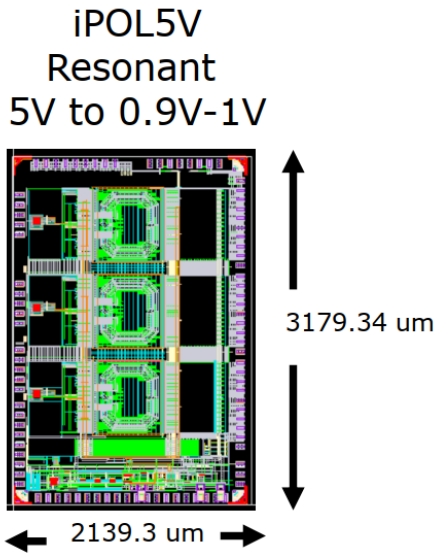
WP 7.1: Data density and power efficiency

- **Novel link technologies** must be developed to cope with these higher data rates, including radiation-hard optical links, wireline, wireless, and free-space optics
- **Efficient** power **distribution**, power **converters** and **regulator devices**, and protection circuits are required to minimise detector mass and heating.
- Development of **low TRL** approaches that may have **disruptive** and **far-reaching** goals

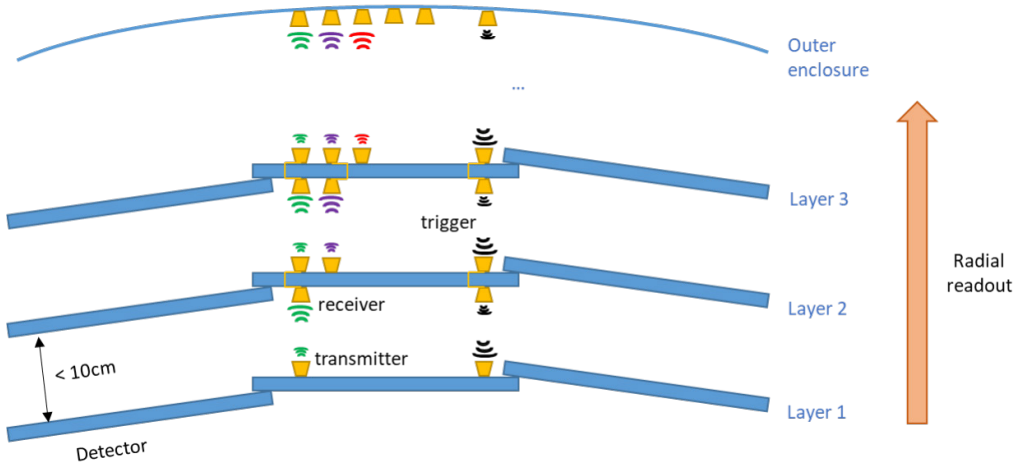
High-speed optical transceivers based on Silicon Photonics technology (up to 100 Gb/s)



Power distribution schemes and their voltage/current regulators and converters



Wireless technology based on a millimeter wave and Free Space Optics



- Conveners: *Szymon Kulis* [CERN], *Jeffrey Prinzie* [KU Leuven], *Jan Troska* [CERN]

WP 7.2: Intelligence on detector

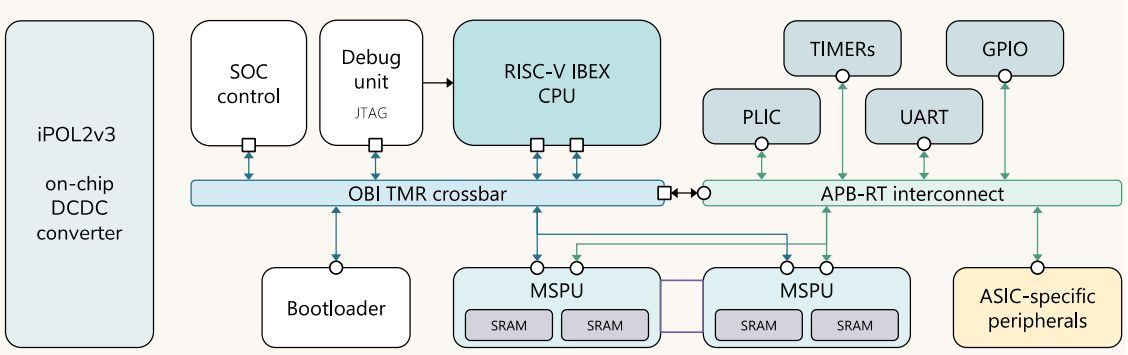
Front-end **programmability, modularity and configurability** must be vastly enhanced in order to allow fewer, more versatile front-end electronics to be developed.

- Manage **complexity** by increasing **flexibility** and **re-usability**
- Radiation-tolerant **processors** and **programmable logic** elements with **common interfaces** and **protocols** will allow re-use of shared developments.

High level system modelling will provide a robust specification and verification framework for the design phase

- **Reduce risks** and **optimize performance** exploiting **simulation** tools and computing power

Radiation-hardened SoC based on the RISC-V ISA standard



Frameworks for signal generation in detector elements, digitization and signal processing, data readout architecture, operating as a complete toolchains

- Conveners: *Davide Ceresa* [CERN], *Francesco Crescioli* [LPNHE]

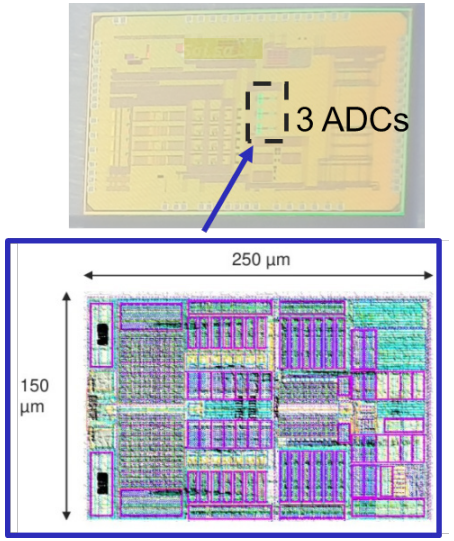
WP 7.3: 4D and 5D techniques

Combine **high spatial resolution** (μm-level) and **high timing resolution** (10s ps level) in a single 4D tracking device.

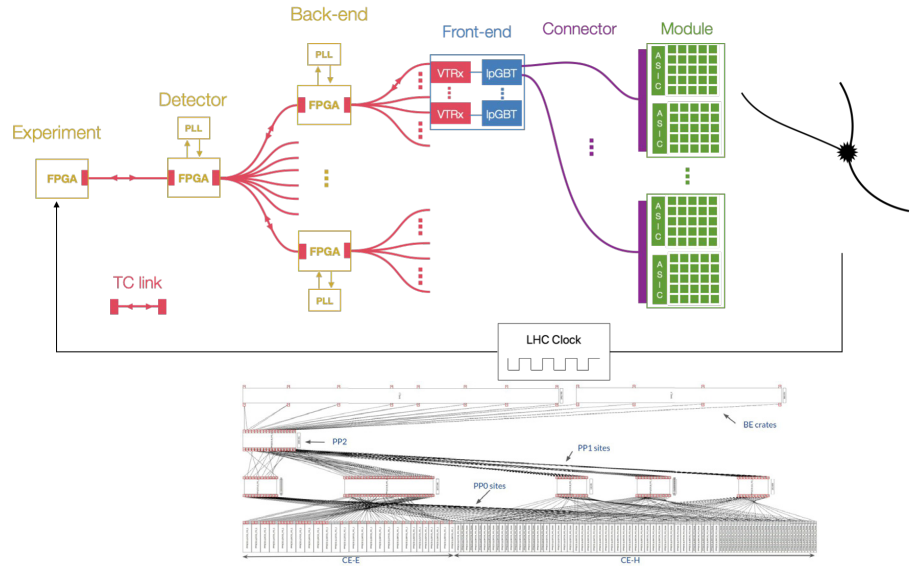
Combine 4D with accurate measurements of the **energy deposited** in the sensor providing 5D-capability.

- Developing IP blocks to improve the noise-speed-resolution trade-offs in advanced technologies with **low supply voltage** and **high transistor density**.
- Unprecedented precision required for the distribution of frequency and time references.

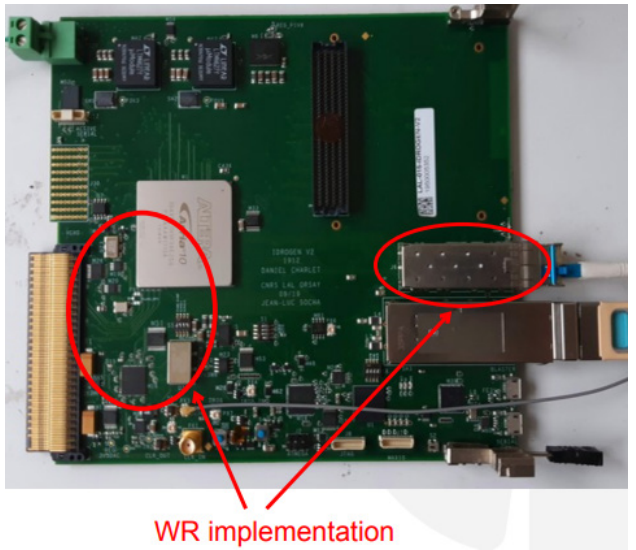
Ultra-low power high performance TDC and ADC blocks for use in future particle physics experiments



Data-driven calibration strategies for the time measurements in detectors requiring high precision timing



Strategies to optimize and assess ultimate precision and determinism of timing distribution systems for future detectors



- Conveners: *Sophie Baron* [CERN], *Marek Idzik* [Krakow]

WP 7.4: Extreme environments

Cryogenic detectors offer high **sensitivity** and **resolution** (for instance for future neutrino dark matter experiments) but are **challenging** for the design and operation of microelectronics.

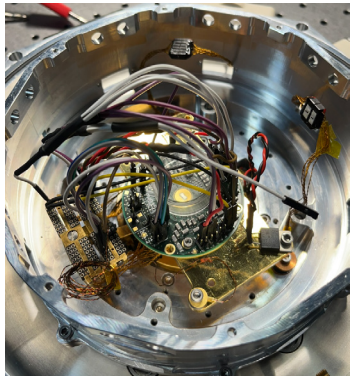
- Foundries often lack **reliable characterization** and **modelling** of their ASIC technologies at low temperature

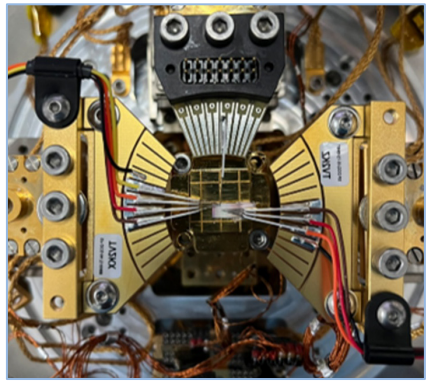
Future particle physics experiments, particularly at energy-frontier colliders, will face **extreme particle fluences**.

- Radiation **qualification** of new technologies is **critical** and **complex**

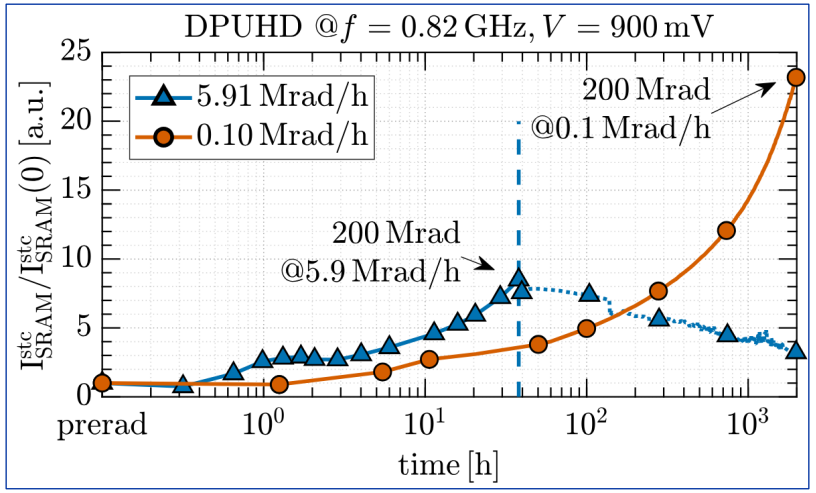
Low temperature operation requires novel techniques at the **interface** between **electronics** and **cooling** systems

Modelling and development of cryogenics PDKs and IPs design

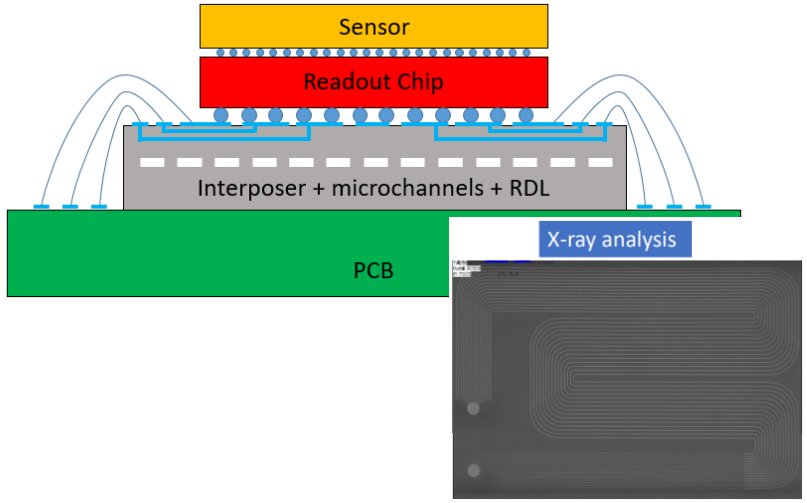




Report on developments and progress in the study of radiation effects in advanced CMOS technologies for HEP applications



Next generation cooling plates for front-end electronics



- Conveners: *Giulio Borghello* [CERN], *Manuel Da Rocha Rolo* [INFN TO], *Oscar A. De Aguiar* [Manchester]

WP 7.5: Back-end systems and COTS

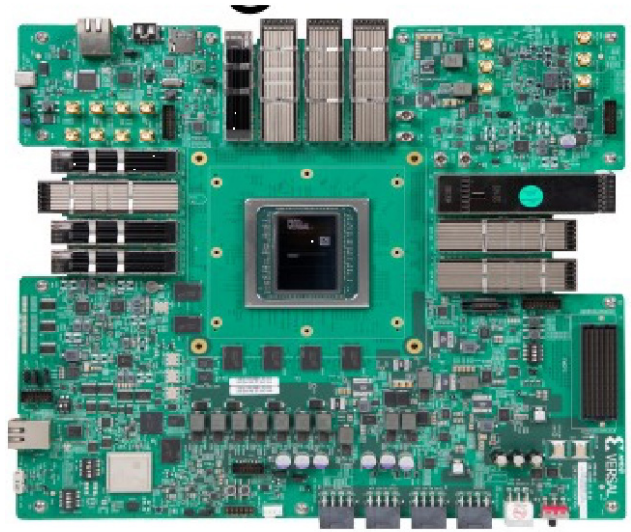
Commercial off-the-shelf (COTS) **components** for **computing** (CPUs, GPUs, FPGAs, AI- accelerators) and **networking** are evolving rapidly driven by Data Center applications

- keeping the pace for future DAQ systems is both important and challenging

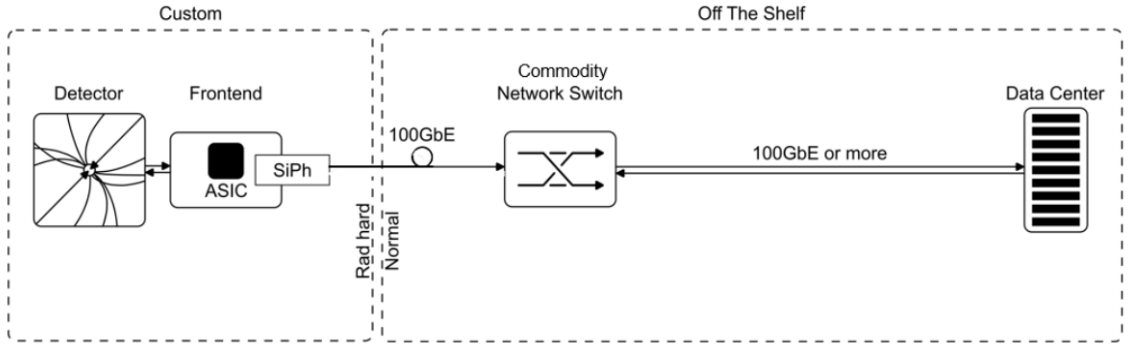
With more and more intelligence on detector, **direct connection** between the **front-end** and **COTS** component is an option to explore:

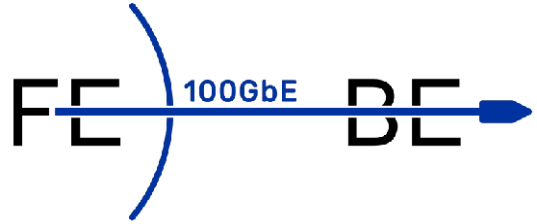
- different solutions explored for 100 GbE from front-end to back-end

DAQOverflow: Benchmarking of heterogeneous COTS architectures & tools and algorithms



Full 100Gb Ethernet-based solutions for Data Readout-links from Front-End to DAQ





- Conveners: *Conor Fitzpatrick* [Manchester], *Niko Neufeld* [CERN]

WP 7.6: Complex imaging ASICs and technologies

Increase the **integration** level of **sensor** and **front-end** electronics

CMOS Imaging Sensor (CIS) platforms are suitable technologies for **monolithic active pixel sensors**

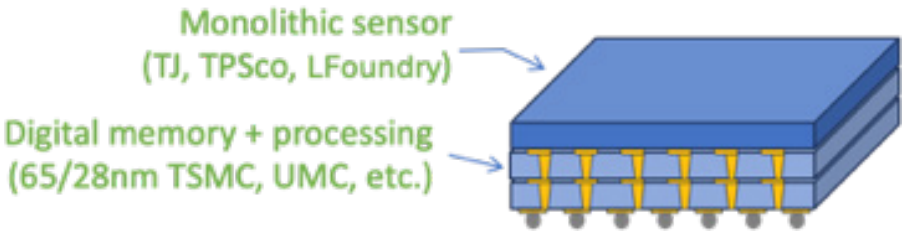
- Difficult to access CIS sensor technologies through standard MPWs

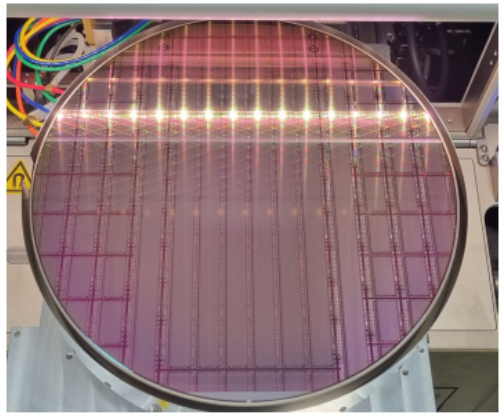
3D integration is powerful in expanding further the FE system capabilities,

- but challenging with **high initial barrier**

Strong connections with DRD3 activities

Organization of common submission to selected processes:
TPSCo 65 nm, TowerJazz 180 nm, LFoundry 110 nm

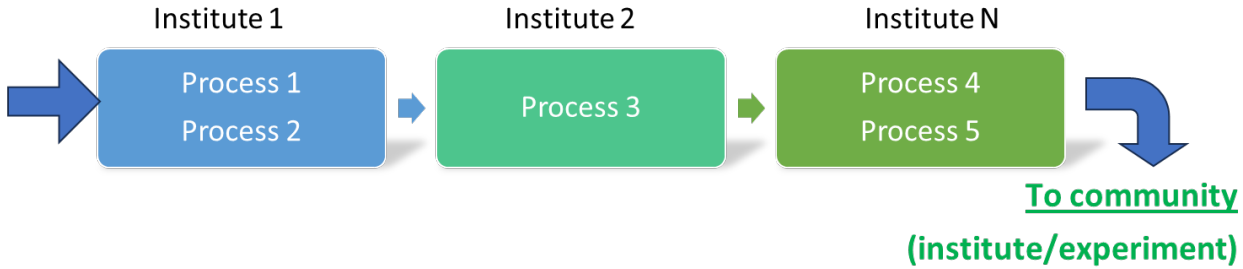




Common access to 2.5 and 3D integration: provide a distributed international laboratory operating as a hub-service for the community

From community:

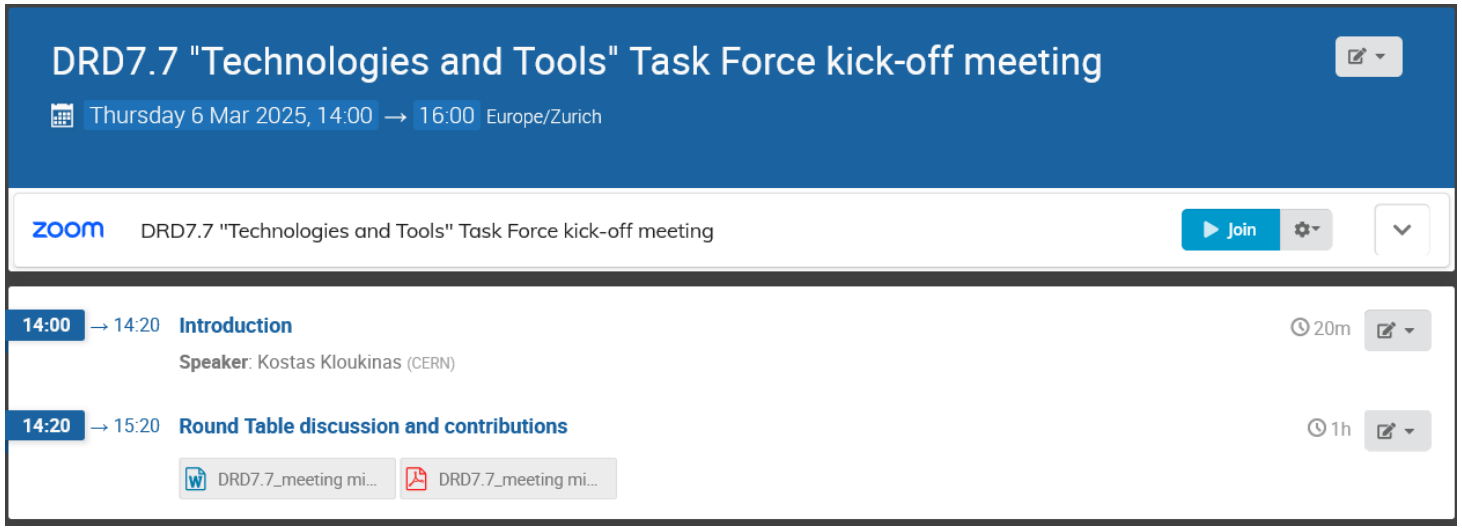
- **Request of process/service**
- **Rapid prototyping of new detector**
- **Detector production (large scale)**



- Conveners: *Marlon Barbero* [CPPM], *Michele Caselle* [KIT], *Ian Sedgwick* [STFC RAL], *Walter Snoeys* [CERN]

WG 7.7: Tools and Technologies

- Effective support of technologies and tools to the HEP community is both essential and demanding
- Models adopted in the past might not allow to keep the pace
- A task force has been established to discuss new cooperative models
- Initial mandate: *To propose an implementation solution for a hub-based structure for ASICs developments.*
- Kick-off meeting on March 6, regular meetings ongoing



- Conveners: *Kostas Kloukinas* [CERN], *Xavi Llopart Cudie* [CERN], *Mark Willoughby* [STFC RAL]

DRD7 next steps

- The **MoU annexes** related to the **existing projects** are under **finalization**
  - **received applications by new institutes** to join these projects: these will be circulated to the Collaboration and the Funding Agencies
  - together with the final version of the annexes **R&D projects** will anyhow continue to evolve and will be **regularly updated** with new contributions

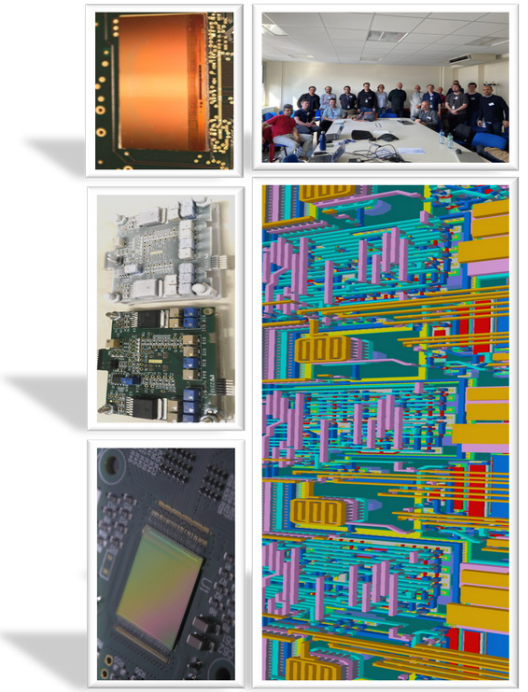
- If you would like to know more:
  - Check the DRD7 website: **https://drd7.web.cern.ch/**
  - CDS and Indico material being populated

Annual DRD7 workshop: 22–26 Sept 2025 @ CERN
https://indico.cern.ch/event/1556239

Thanks for your attention

Thanks to the organizers for giving the DRD7 Collaboration the opportunity to advertise its activities

DRD7 COLLABORATION



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