DRD7 3rd workshop closeout

A. Rivetti - INFN

On behalf of the DRD7 steering committee*

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To start with….

- This was the first workshop after the official DRD7 approval on June 5!
- From project proposal to project implementation
- Workshop organised along DRD7 philosophy: keep the formal part as light as possible and concentrate on scientific and technical challenges
- More than 100 participants

- Many thanks to all the WP conveners to put together a very stimulating program!

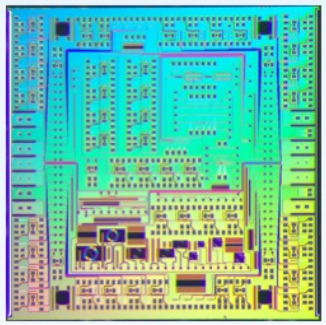
DRD7: a project-based R&D on electronics

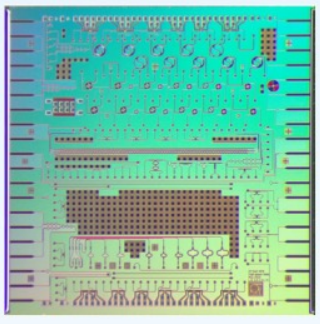
		DRDT
Data density	High data rate ASICs and systems	7.1
	New link technologies (fibre, wireless, wireline)	7.1
	Power and readout efficiency	7.1
Intelligence on the detector	Front-end programmability, modularity and configurability	7.2
	Intelligent power management	7.2
	Advanced data reduction techniques (ML/AI)	7.2
4D-techniques	High-performance sampling (TDCs, ADCs)	7.3
	High precision timing distribution	7.3
	Novel on-chip architectures	7.3
Extreme environments and longevity	Radiation hardness	7.4
	Cryogenic temperatures	7.4
	Reliability, fault tolerance, detector control	7.4
	Cooling	7.4
Emerging technologies	Novel microelectronic technologies, devices, materials	7.5
	Silicon photonics	7.5
	3D-integration and high-density interconnects	7.5
	Keeping pace with, adapting and interfacing to COTS	7.5

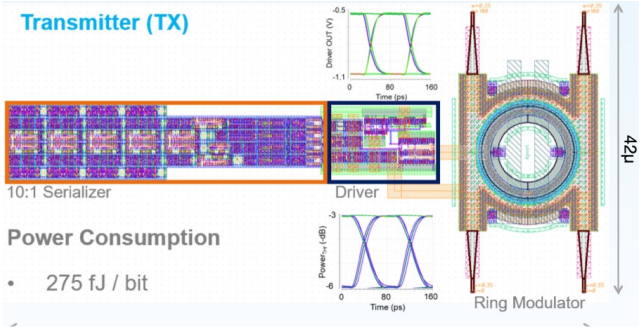
Some (very personal) highlights

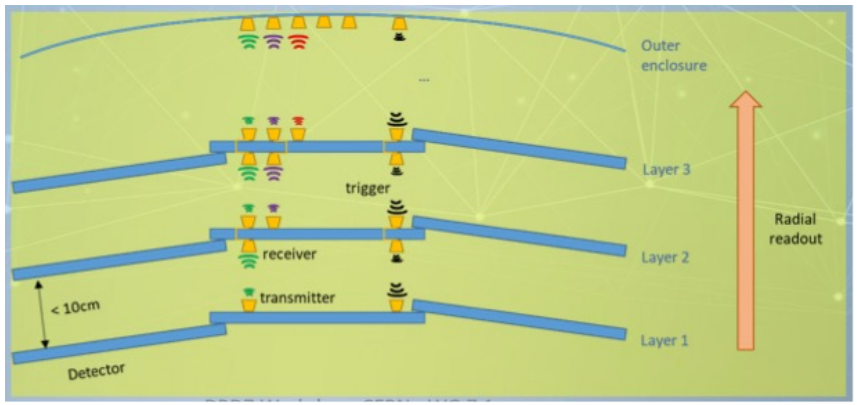
Toward 100 Gb/s link…and beyond

Performance Target	100 Gb/s per fibre optical readout with 2.5 Gb/s control optical link operating at a BER of 10^{-12}. Radiation tolerance up to 1×10^{16} particles/cm^2 and 10 MGy and power consumption of 250 mW. Cryogenic temperature operation for some lower-speed variants.



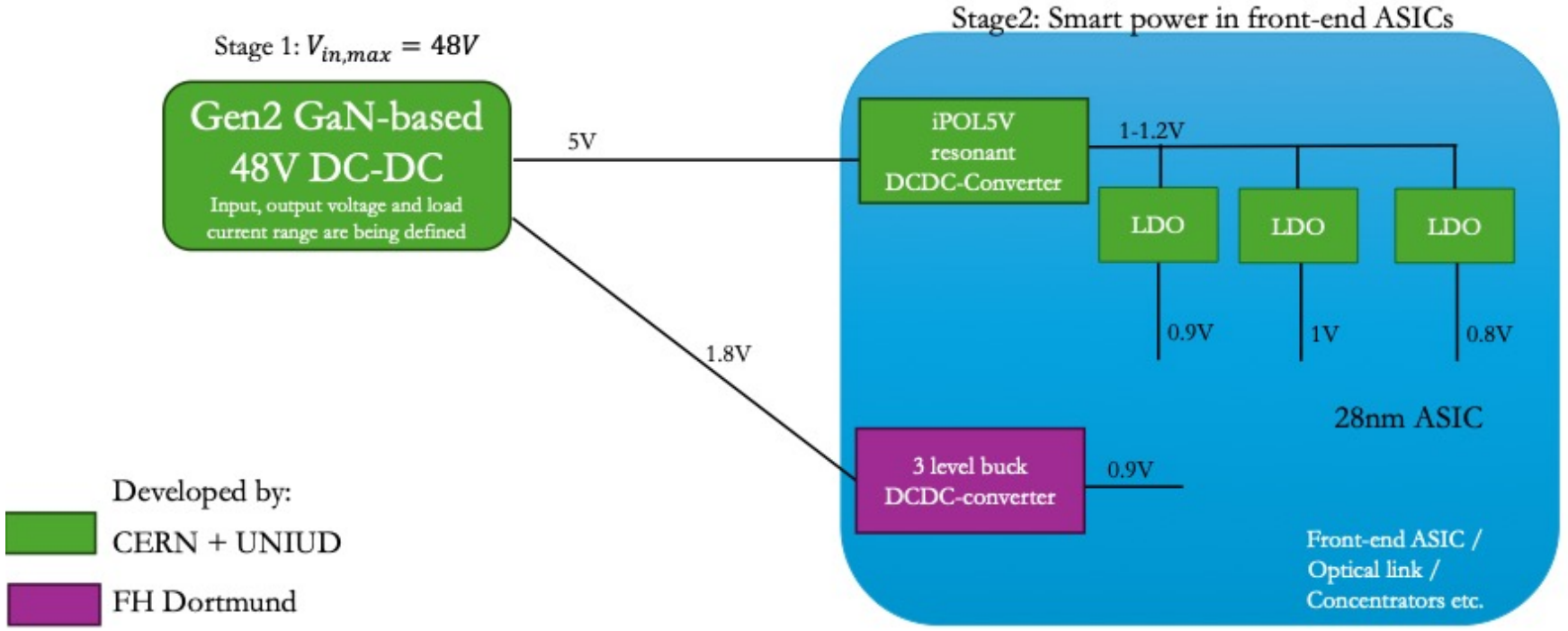




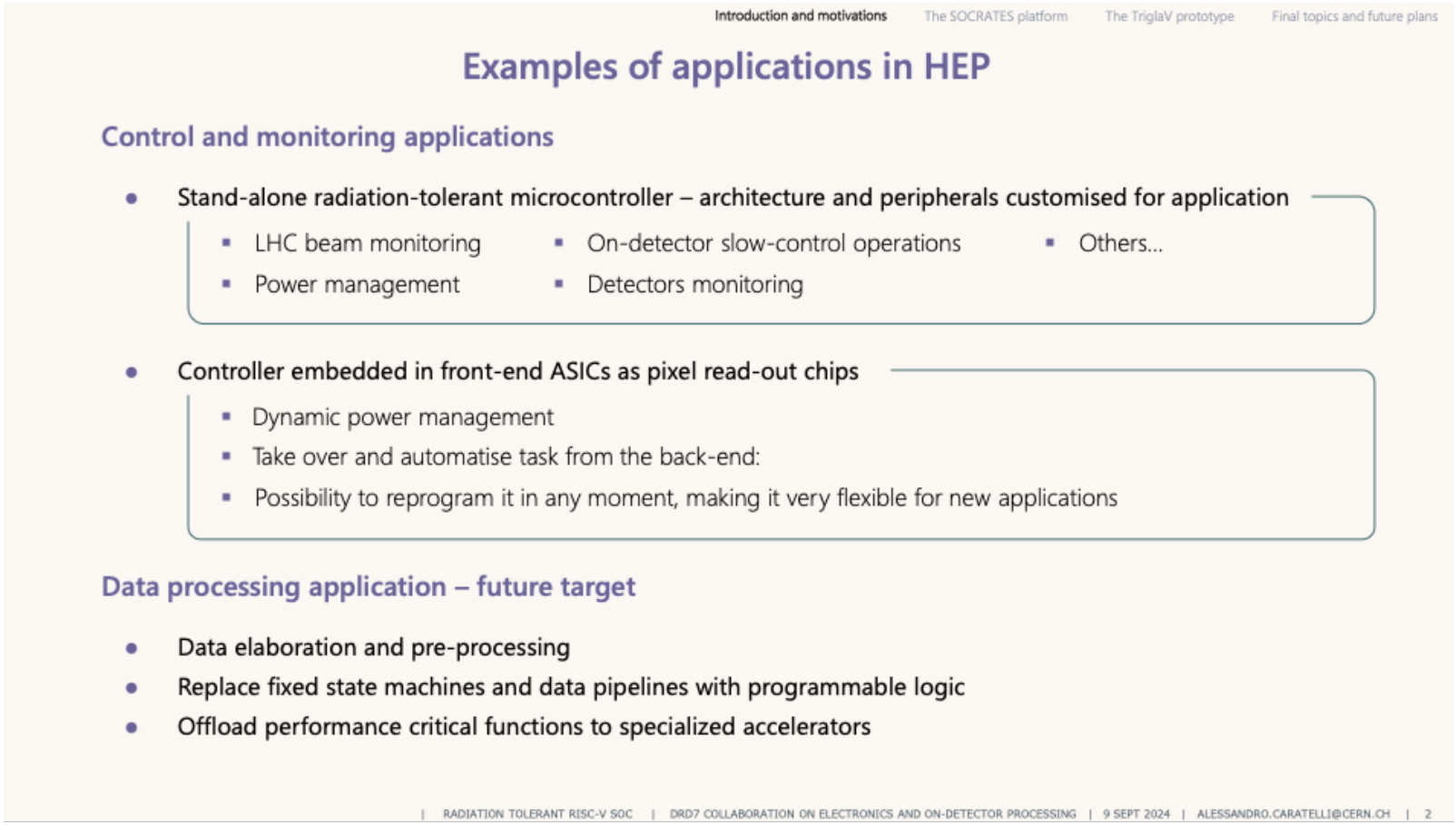


Beyond current mirror bias…

WP 7.1b: parallel power (DCDC)



More standardization



Introduction and motivations | The SOCRATES platform | The TriglaV prototype | Final topics and future plans

Examples of applications in HEP

Control and monitoring applications

- Stand-alone radiation-tolerant microcontroller – architecture and peripherals customised for application
  - LHC beam monitoring
  - Power management
  - On-detector slow-control operations
  - Detectors monitoring
  - Others…
- Controller embedded in front-end ASICs as pixel read-out chips
  - Dynamic power management
  - Take over and automatise task from the back-end:
  - Possibility to reprogram it in any moment, making it very flexible for new applications

Data processing application – future target

- Data elaboration and pre-processing
- Replace fixed state machines and data pipelines with programmable logic
- Offload performance critical functions to specialized accelerators

| RADIATION TOLERANT RISC-V SOC | DRD7 COLLABORATION ON ELECTRONICS AND ON-DETECTOR PROCESSING | 9 SEPT 2024 | ALESSANDRO.CARATELLI@CERN.CH | 2

- **How much intelligence on the front-end?**

Physical design on reliable specs

…or avoid excessive safety factors and duplications!

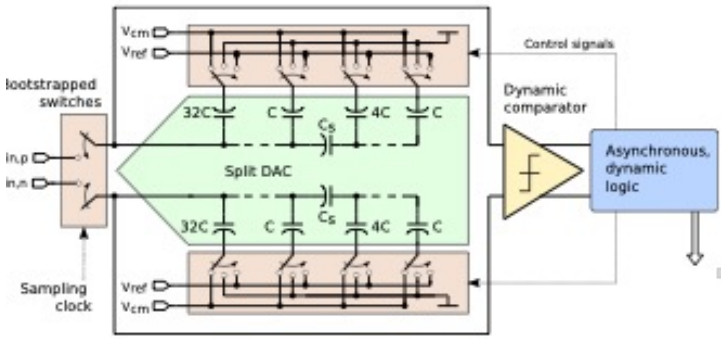
Virtual Electronic System Prototyping (WP7.2c)

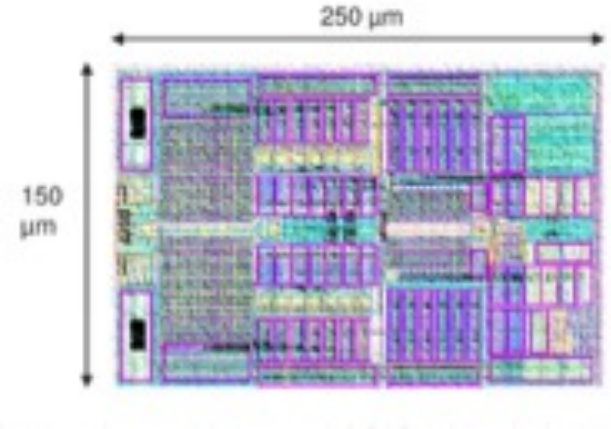
Project Description	Develop frameworks for high-level simulation of particle detectors. **Topics:** **1-** Signal generation in detector elements **2-** Digitization and Signal Processing **3-** Data readout architecture Topics 1. and 3. aim to create independent frameworks that can be used as a single toolchain. Topic 2. will be better defined during the project and might converge in one of the two frameworks or represent a third framework of the chain. Duration 3-4 years.
Innovative/strategic vision	Develop a toolchain for virtual prototyping to: **1-** model detector at high-level **2-** perform architectural studies **3-** provide a reference model for the verification
Performance Target	**Topic 1:** Cluster multiplicity: 1-10 Position resolution: $<10\ \mu m$ Time resolution: 10 ps to 100 ns **Topic 2:** to be defined in M7.2c.2 **Topic 3:** Accuracy: Event/Cycle-level Speed: hundred thousand transactions per second Scalability: readout components library Verification: integrate in verification environment User-Friendly: docs & support for user-only roles

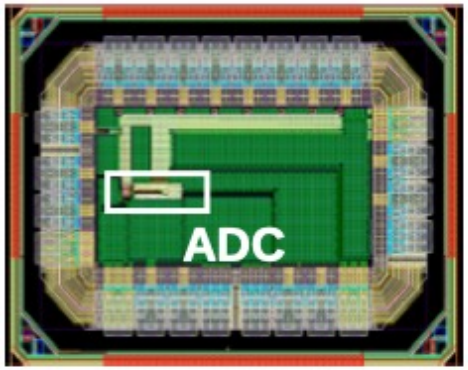
Multi-disciplinary, cross-WP content	**Detector Technologies:** support various detector technolog **Particle Physics Models:** integration of comprehensive particle physics models **Geometric Configurations:** ability to define and customiz the geometry **Data Formats:** support for common data formats **Monte Carlo Techniques:** implementation of Monte Carlo methods for simulating particle interactions and energy depositions, **Electronics Simulation:** accurate modeling of the readout electronics **Readout Architectures:** support triggered and data-driven systems
Contributors	CERN FR: IPHC Strasbourg *USER:* PSI (CH), UK Cons., INFN Cagliari (IT)

High performance IPs

- Many interesting developments going on
- How to we manage sharing of IPs
- Encourage even closer collaborations







Even more precise timing…

Project Target

- This project aims to study and propose strategies to optimize and assess ultimate precision and determinism of timing distribution systems for future detectors:

Assess phase stability and determinism of COTS and Systems used in HEP	All kinds of FPGAs	Systems (White Rabbit)
Develop FPGA-agnostic solutions to enforce clock stability	Generic hardware and gateware solutions to mitigate FPGA behaviours	Protocols allowing direct clock extraction
Connection with 7.3b1	Support stability tests implementation in HGTD detector slice	Investigation: online time reconstruction on hardware platform

Going to the extremes: very cold

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DRD7.4.a - summary and outlook

- Silicon foundries are providing (e.g. Skywater 90nm) or planning to provide access (e.g. GF 22FDX) to cryo-PDKs.
- Fermilab, EPFL, FZJ have ongoing funding and a solid track record (instrumentation, facilities, competences) for the development of cryo-PDKs, including test-chip design, characterisation down to 40 mK and cryo-PDK development in a collaborative effort involving industry partners.
  - ➢ To do: Cryogenic noise measurements, study radiation hardness at cold, AI/ML* based PDK development
- For DRD7.4a, other partners (UK, INFN, others) are expected to provide support and contribute to die-level and wafer-level device characterisation.
- Involvement of industry for model library is related to funding availability. Choice of EKV or BSIM models to be done.
- Choice of target technology for the DRD7.4a project needs to happen at the beginning of 2025: TSMC 28nm is baseline
  - ➢ A dedicated consortium agreement to define the distribution and licensing conditions of the DRD7.4a cryo-PDK will probably be needed.

* https://hsc.fnal.gov/archives/2024/slides/fermilab-slides-24-0010-ebd.pdf

DRD7 3rd Workshop | DRD7.4.a Device modelling and Development of Cryogenic CMOS PDKs and IP | 9-10 September 2024, CERN | 20

Going to the extremes: radiation

- **Irradiation in more realistic conditions**
- **Radiation-aware PDK**

DRD7: AN R&D COLLABORATION ON ELECTRONICS AND ON-DETECTOR PROCESSING

CERN EP-R&D WP5.1

low-dose-rate tests on 28nm CMOS technology

H-4

ELDRS in a con

G. Borghello[1], G. T
K. Kloukinas[1]
1. CERN (Switzerlan

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SRAMs, and singl
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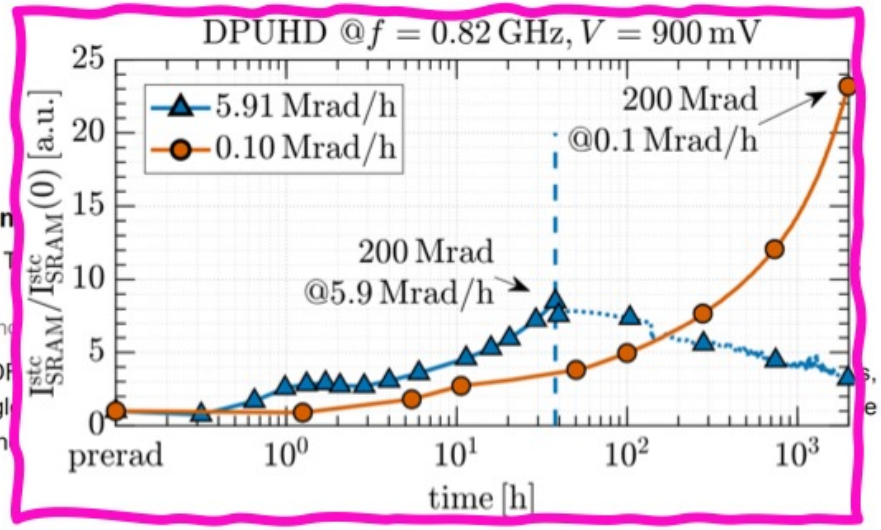


2024/09/10

10

Going to the extremes

- How we combine both?

Electronics needs cooling

Conclusion (1/2)

- Ceramics
  - It has also the potential to include electronic features
  - Fully validated initial prototypes in the coming years to high pressure, leak tightness and cooling performance in the following years
  - LHCb VELO Upgrade 2 as benchmark requirements (High pressure, CO_2 evaporative cooling)
- Metal 3D printing
  - X-ray tomography indicates issue with the fill factor
  - Distortion observed created a choke point
  - New run printed
    - focus on improving distortion and fill factor and investigation of electropolishing (material reduction/easier integration?)
- Microchannel cooling and active interconnection developments (CNM, DESY, IFIC)
  - Aiming to bring more functionalities to the cooling plate
    - Redistribution layer could be an interesting solution for ASICs with through-silicon vias
  - CMOS compatible process to integrate the cooling to the sensor

Electronics needs cooling

Conclusion (2/2)

- Microchannel cooling manufacturing via thermocompression (CPPM)
  - Main motivation to reduce the manufacturing cost
    - Very promising results “hyperbar” chamber (resistance to high pressure)
  - Techniques developed can be also explored for integration (chips and connecturization)

- DRD7/8: Cooling and cooling plates
  - *“Mechanics”* in DRD8 and *“Electronics”* in DRD7
  - First version of the draft by end of September in the DRD8
  - Request for descoped DRD7 proposal afterwards

Trigger and DAQ

Summary

- 7.5a is aiming for common TDAQ development with COTs.
  - Mainly focus on trigger with various platforms.
  - Also generic development for fundamental purpose.

- Our collaboration will be based on the sharing of technical knowledge of
  - Software/firmware framework
  - Hardware device
  - Using git repository, or even hand-on workshop in the future

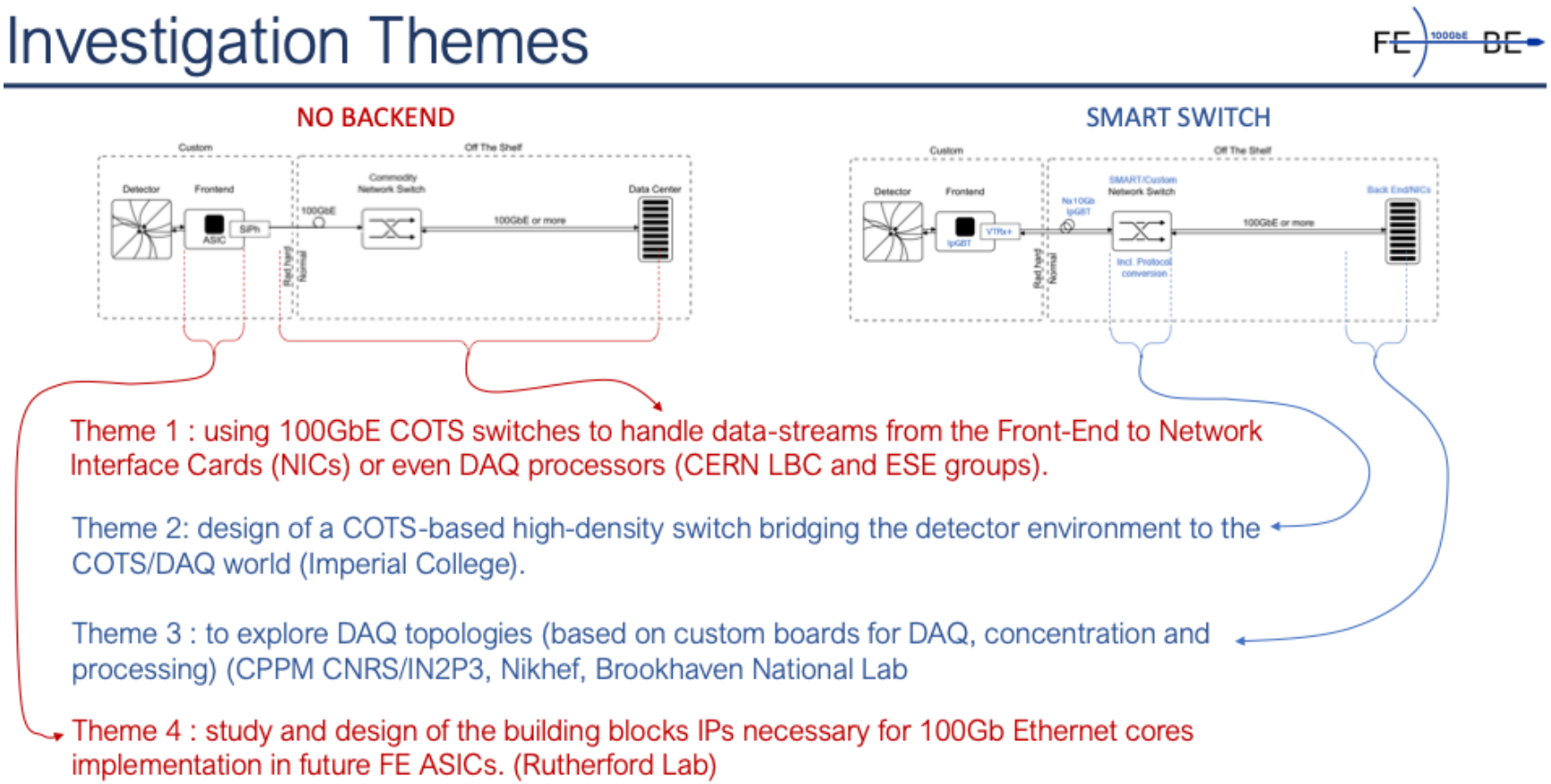
- Present activities:
  - PI: Alex Keshavarzi (Manchester), Yun-Tsung lai (KEK IPNS)
  - Monthly meeting on the first Friday of every month
  - Mailing list:
    ECFA-DRD7-WG7_5-Contributors@cern.ch
    ECFA-DRD7-WG7_5-Observers@cern.ch

- If you are interested in relevant research works and would like to join us, please do not hesitate to let us know!

FPGA, GPU, ML, HLS

Front-End to Back-End @ 100 Gb/s

Investigation Themes



- **Evolutionary, visionary…transformative!**

CMOS technologies for sensors

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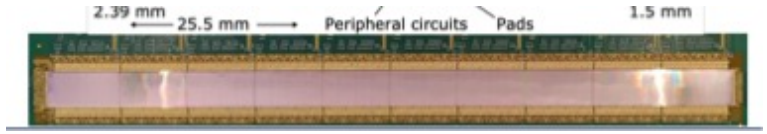
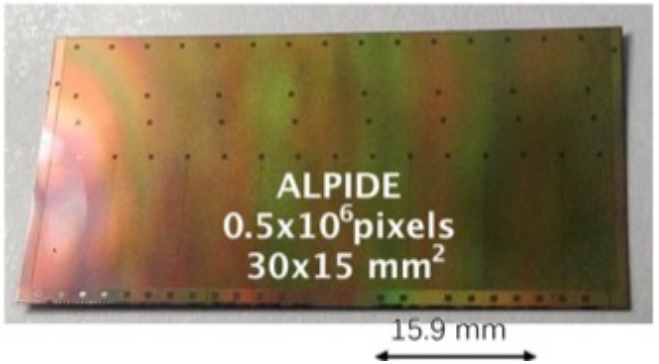
DRD7.6

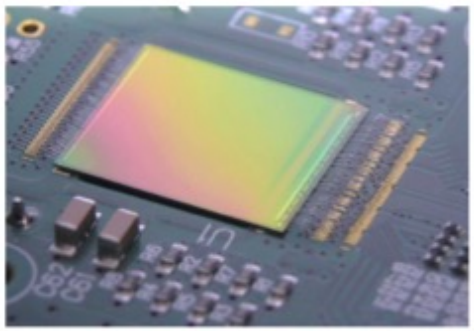
Project Name	Common Access to Selected Imaging Technologies (WP7.6a)
Project Description	Provide common access and centralized support for selected CMOS imaging technologies, including specific IP development to accelerate the design effort. Duration 3 years, expected to be extended.
Innovative/strategic vision	Potential of monolithic technologies, confirmed by successful ALICE ITS2 tracker and the widespread community interest. Efficient and affordable technology access requires concentration of the resources in the community.
Performance Target	Organize common runs and efficient and cost-effective access to selected technologies.
Multi-disciplinary, cross-WP content	Concerns several detectors types, calorimeters, tracking, etc. Serves other DRDs like DRD3 and DRD6, experiments and projects in HEP. Strong connection with 7.6b (e.g. 3D integration of chiplets). Requires expertise in analog and digital IC design, device design and technology, and significant testing effort.
Contributors	CH: CERN FR: IN2P3: CPPM, IPHC, IP2I + others IT: INFN(TO, TIFPA, MI, BO, PD, PV, PG, PI) NL: NIKHEF NO: UiB, UiO and USN UK: STFC US: TBC, SLAC already doing effort

Technologies targeted initially: TPSCo 65nm ISC, TJ 180nm, LF 110nm IS

DRD7.6 – Complex Imaging ASICs and Technologies







Shared access to 3D integration

DRD7.6

Shared Access to 3D Integration

Proposed Milestones and Deliverables

- M7.6b.1 (M18) Establish TSVs process on active/passive interposer, wafer/single die
- M7.6b.2 (M24) Establish RDL process and back-side metallization on real CMOS sensors and custom-designed silicon interposer

- D7.6b.1 (M30) Delivery of report summarising the integration of SiPh on detector by 2.5D interposer/chiplet technologies (→ with DRD 7.1)
- D7.6b.2 (M30) Delivery of a report on W2W bonding by industrial partners
- D7.6b.3 (M36) Deliver documentation of the process for the common use

Shared access to 3D integration

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DRD7.6

Shared Access to 3D Integration

International Distributed Detector Laboratory

- Establish a distributed laboratory that operates as a hub-service for the community
- Each institute highly specialized in one or more technological processes

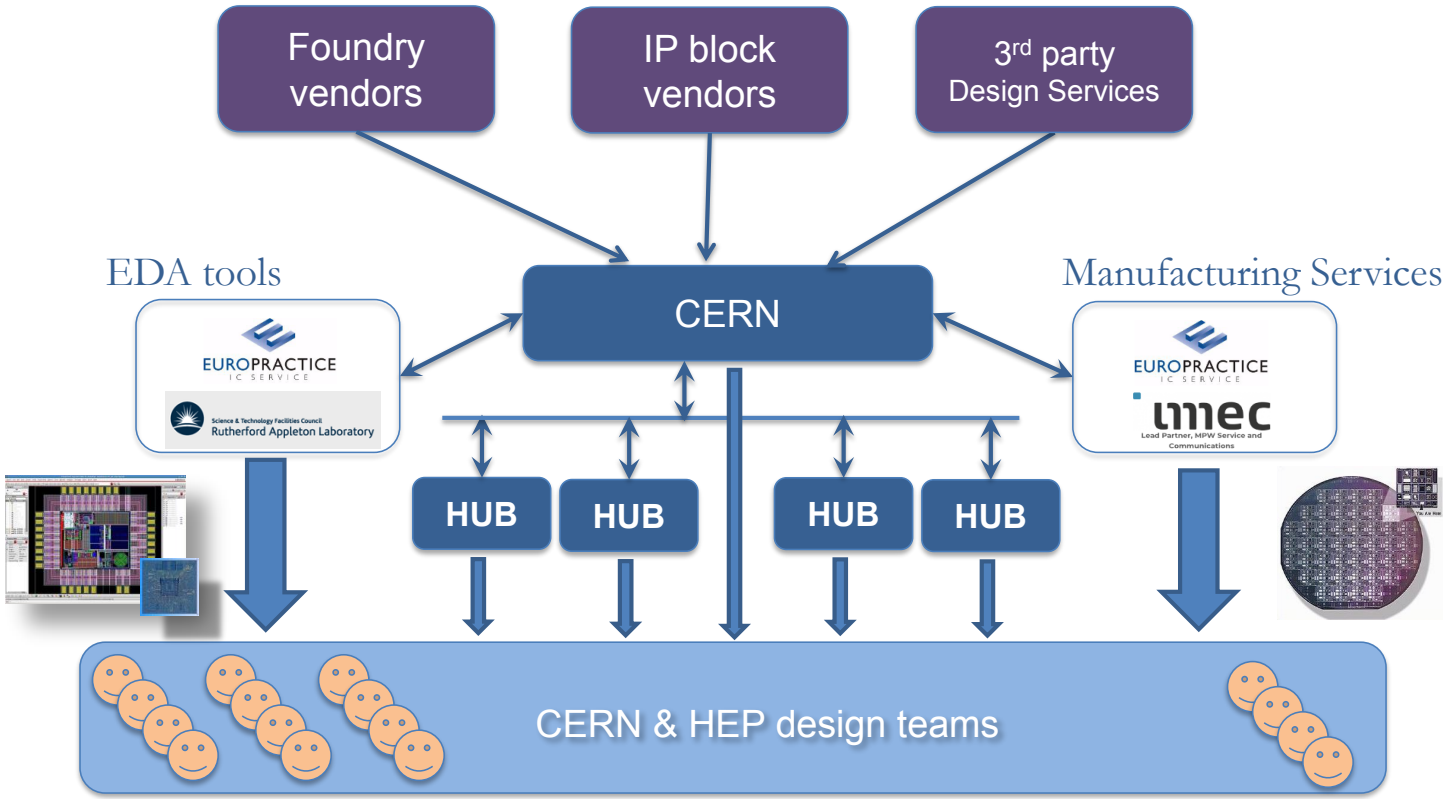
From community:
- Request of process/service
- Rapid prototyping of new detector
- Detector production (large scale)

Maintaining a strong connection with application/experiment requirements

To community (institute/experiment)

Maximizing efficiency

HUB based support service



Last, but not least…

- **We have a website: do not forget to populate it!**

Last, but not least…

- **Do not forget to cast your ballots for the CB chair election!**

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Actions

I would like to organize the next steps if elected

- CB meeting in October
  - discussion of collaboration rules
    - organize offline vote on major items submitted to the board
  - approval of CB Chair Deputy
  - (Resource Coordinator)
- CB meeting in November
  - approval of text of the collaboration rules
    - need enough time for the draft to be circulated and commented
  - start of the process of nomination for Steering Committee/Spokepersons
  - *open a competition for the DRD7 logo* ☺
  - (set up of the Resource Board)
- Elections in December/January, depending on the outcome of the nomination process
- CB meeting late January/beginning of February
  - endorsement of appointments by the governance (WP coordinators, deputies…)

Here we are…

See you at the next workshop!