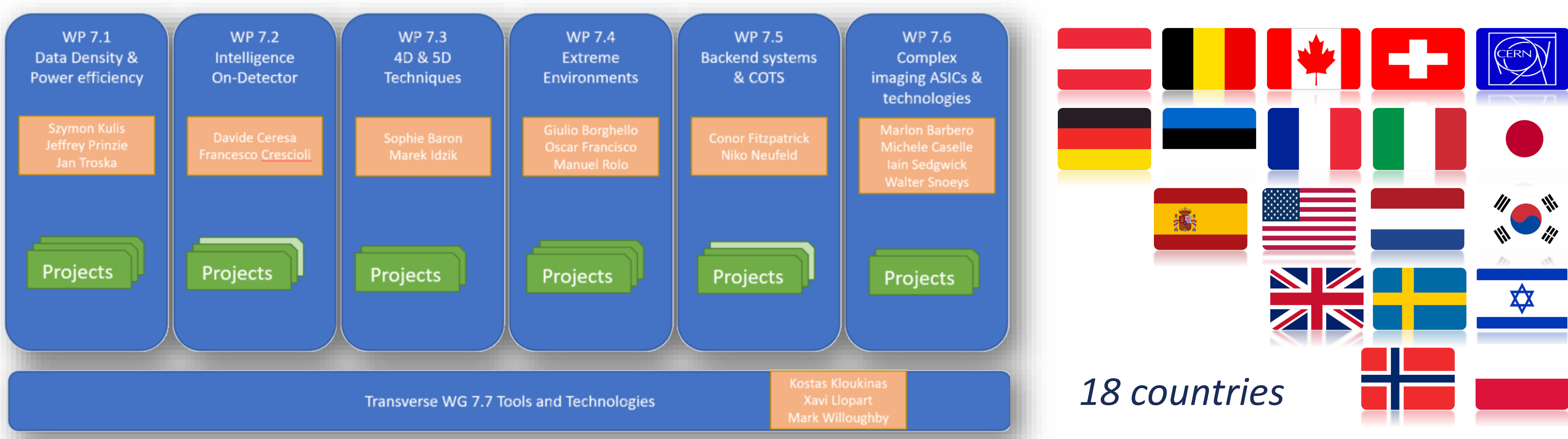
DRD 7.6b
Shared Access to 3D Integration
Status and Plans

Hoang Vu Nguyen

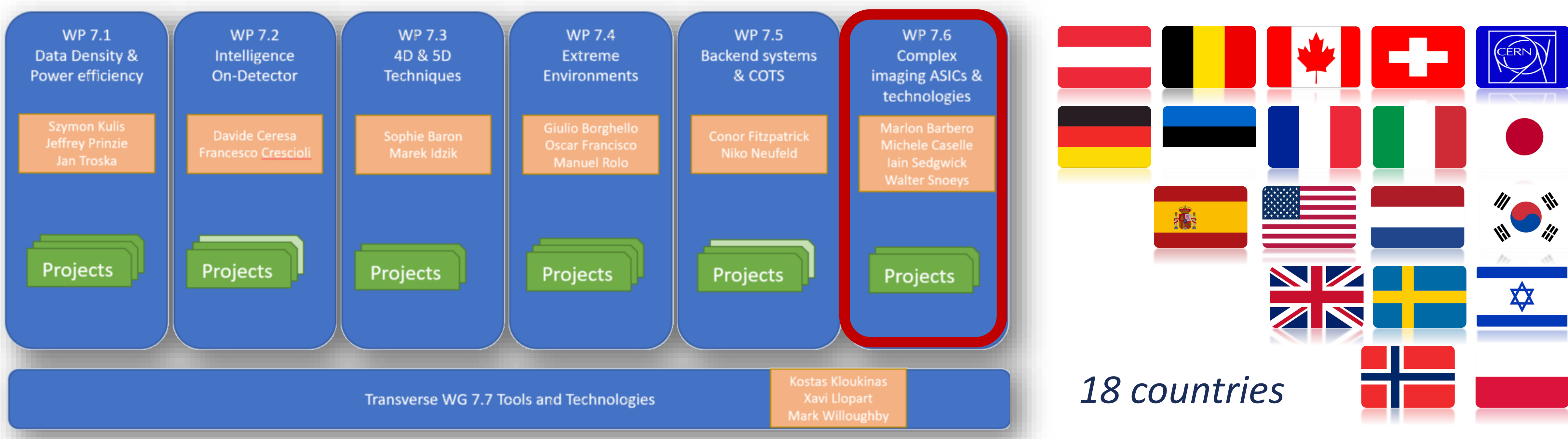
Contact persons: M. Caselle, L. Andricek, S. Charlebois

ECFA DRD7 – Worldwide Collaboration



- 68 Universities & research centers involved (currently)
- Research area: Data Density, Power efficiency, Intelligent On-Detector, 4D & 5D techniques, Backed electronics/systems and COTS (Commercial-Off-The-Shelf), complex imaging ASICs & 3D-technologies
- 15 confirmed projects cover a wide range of novel detector technologies

ECFA DRD7 – Worldwide Collaboration



- 68 Universities & research centers involved (currently)
- Research area: Data Density, Power efficiency, Intelligent On-Detector, 4D & 5D techniques, Backed electronics/systems and COTS (Commercial-Off-The-Shelf), complex imaging ASICs & 3D-technologies
- 15 confirmed projects cover a wide range of novel detector technologies

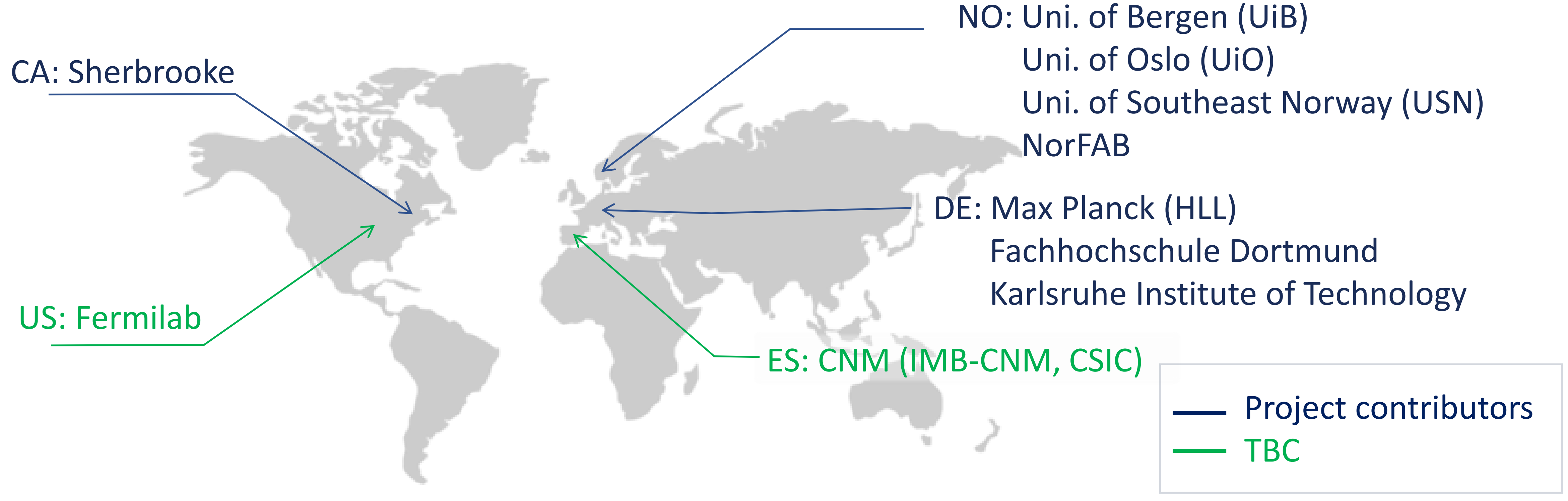
DRD7.6 – Complex imaging ASICs and technologies

- Working Group 6 deals with complex technologies merging multiple functionalities such as sensor and processing, multi-tier (2.5D and 3D) assemblies

- **Project 7.6a**
  - This project aims to provide common access to advanced imaging technologies through the organization of common fabrication runs. These are initially envisaged for the TowerJazz 180 nm, TPSCo 65 nm and the LFoundry 110 nm CMOS imaging technologies

- **Project 7.6b**
  - This project aims to develop essential technologies for both 2.5D and 3D integration that can be quickly transposed to wafer-to-wafer 3D integration for a wide range of future particle physics applications, ranging from low-temperature neutrino detectors to high-radiation environment HL-HLC pixel detectors

Evolution of the collaboration within 7.6b project



- CNM and Fermilab have expressed interest in joining. 10 institutes, 5 large national labs with well-renowned experience in interconnection technology and detector production

Work Topics and Areas of Contribution

- Provide access to TSV technology
  - MPG HLL , KIT
- Provide access to RDL technology
  - MPG HLL, KIT
- Provide access to small-pitch 2D-bonding process including maskless (ACF/ACP)
  - Norway, MPG HLL, KIT
- Provide access to chiplet/2.5D integration
  - FH Dortmund, MPG-HLL, KIT, Norway, Sherbrooke
- Provide access to W2W, C2W by industrial partners
  - Sherbrooke, Norway, MPG-HLL
- Integration of Photonic IC on the detector (→ with DRD 7.1)
  - Sherbrooke, KIT

Interplay between DRD7.6b and DRD3-WG7

In agreement with Giovani Calderini

DRD 7.6b Development of fundamental integration technologies (i.e. 2D, 2.5D and 3D) mainly for electronics interconnections:

- Maskless connection (in-house ACF/ACP)
- Bump-bonding by solder (in-house/industrial)
- TSVs and RDL for 2.5D and chiplet
- 3D integration (die- and wafer- levels)
- Provides access to industrial wafer-level 3D integration
- Provides the integration of SiPh chip and optical fibers on detector module

DRD3 mainly for sensor-to-FE and more experiment-oriented

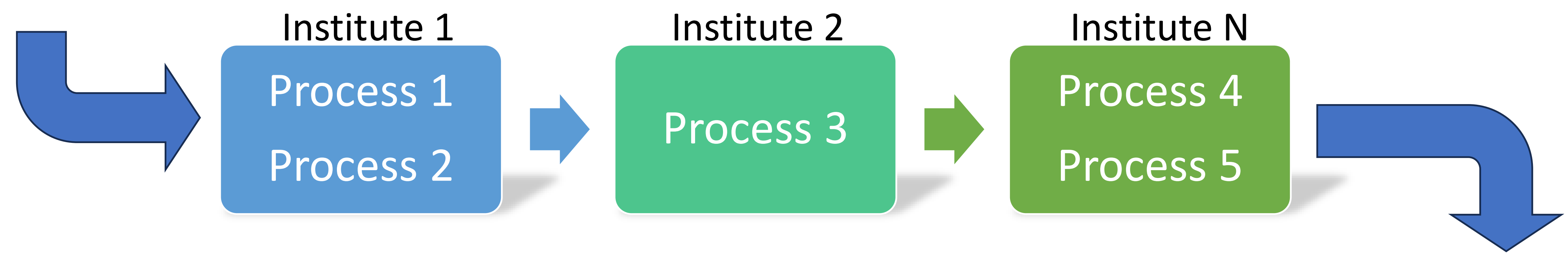
Examples of ongoing projects and collaborative work:

- TimeSpot hybridisation with conductive adhesives (Cagliari, Geneva U, CERN EP R&D)
- Timepix3 hybridisation with conductive adhesives (Geneva U, CERN EP R&D, Medipix)
- 100µPET (Geneva U, EPFL, HUG Geneva)
- MALTA (CERN EP R&D, Geneva U)
- ALICE ITS3 wafer-scale bent modules (Bari, Trieste, with other ALICE institutes)
- Timepix4 TSV bonding with ACF/ACP (Geneva U, CERN Medipix) and many others

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

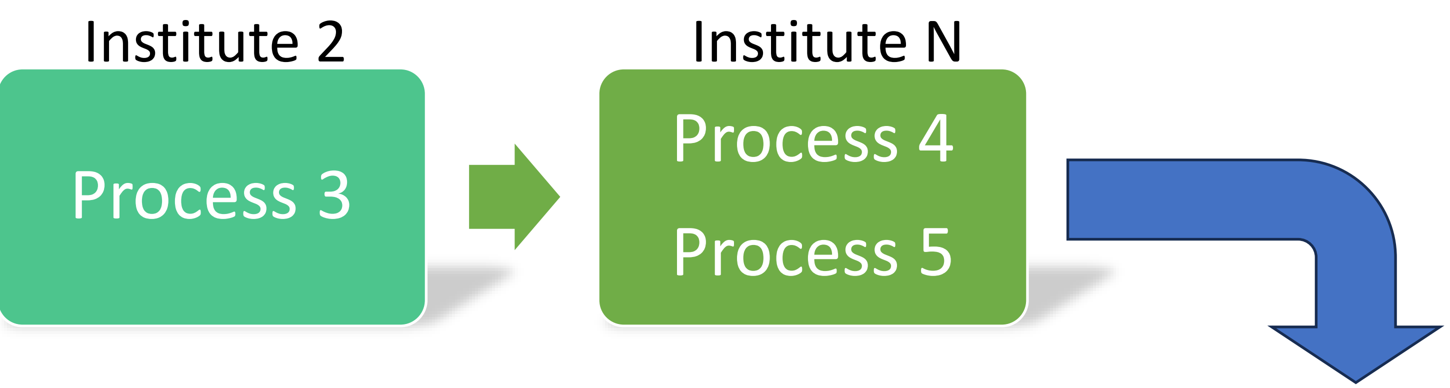
To community
(institute/experiment)

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)

Key parameters, are:
- Interface between institutes/processes
- Redundancy
- Complementary
- Development of new processes that are not currently in place

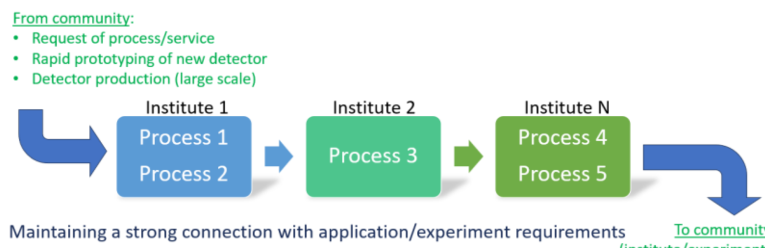


Maintaining a strong connection with application/experiment requirements

To community (institute/experiment)

Pathfinder project

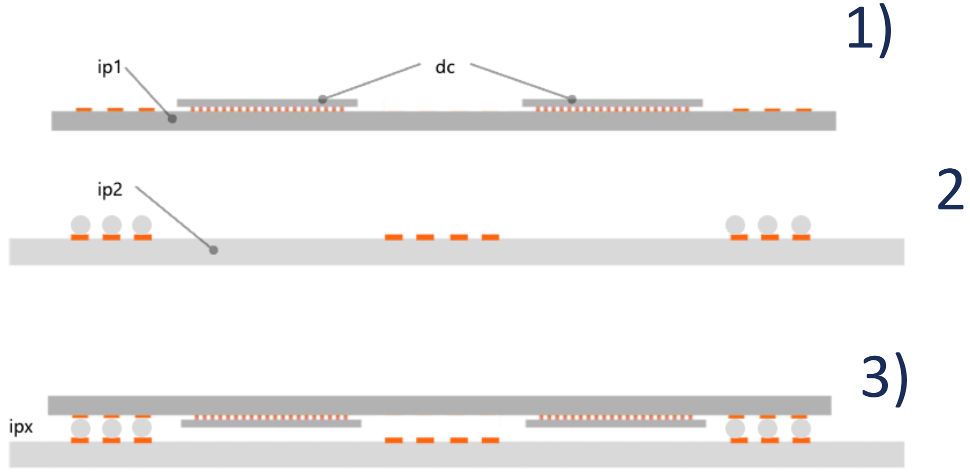
- **Validate and implement distributed production workflows** – Ensure all production steps are proven and effectively exercised.



- **Define interfaces across institutes and laboratories –** Develop clear and standardized communication channels, processes, and operational protocols to ensure seamless collaboration and integration.
- **Identify potential incompatibilities** – Detect mismatches in processes, technologies, or tools early in the workflow.
- **Develop and implement solutions** – Address incompatibilities with efficient and practical resolutions to maintain production consistency.

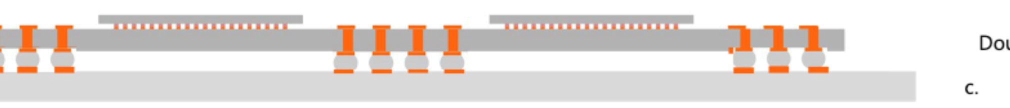
Pilot Heterogeneous Integration Project (Pilot HI project)

1. **Interposer 1 – "ip1"**
   - single sided metal Al/Cu
   - bumped dummy chips with Al/Cu - "dc"
   - small, high melting solder bumps, or Sn cap for SLID
   - thinned to ~100 µm
   - bump bond or SLID dummy chips to ip1
2. **Interposer 2 – "ip2"**
   - single sided metal Al/Cu
   - big, low melting solder bumps (Au-stud)
3. **flip and assemble ip1 and ip2 - "ipx"**
4. **Evaluate daisy chains, process characterization ....**
5. **TSVs and back side RDL**



First demonstrator

Second demonstrator



Next steps and enable technologies

- ***Heterogenous 3D-ASIC integration:*** the combination of TSV, RDL technologies, along with already existing in-house packaging technologies, will allow for a rapid transition towards the implementation of **3D-ASIC integration at the level of a single assembly (**e.g. Multi-Project Wafer)

Monolithic sensor (TJ, TPSco, LFoundry)

Digital memory + processing (65/28nm TSMC, UMC, etc.)

- ***Integration of SiPh chip and optical fibers on detector module:*** establish the necessary process steps to ensure the long-term availability of the integration of silicon photonics (SiPh) chip with state-of-the-art monolithic/hybrid detector module

One/multi RDL layers for signals routing

Hybrid MAPS

PIC

Optical fiber packaging (edge or grating couples) by automated/semi-automated procedure

Source: Karsten Hansen (DESY)

Progress report

- Infrastructures / machineries
- Technical

Three new machines from Oxford Instruments Plasma Technology

Installed and in operation

Courtesy: Mathias Wegner

ICP-PECVD
SiO_2, Si_3N_4

ICP-RIE 1
DRIE, SiO_2

ICP-RIE 2
Nb, Al, …

KIT-IMS clean room

Three new machines from Oxford Instruments Plasma Technology

Installed and in operation

Courtesy: Mathias Wegner

ICP-RIE 1
DRIE, SiO2

ICP-RIE 2
Nb, Al, …

TSVs on 4” Si-wafer
preliminary results

∅ = 200 µm

525 µm

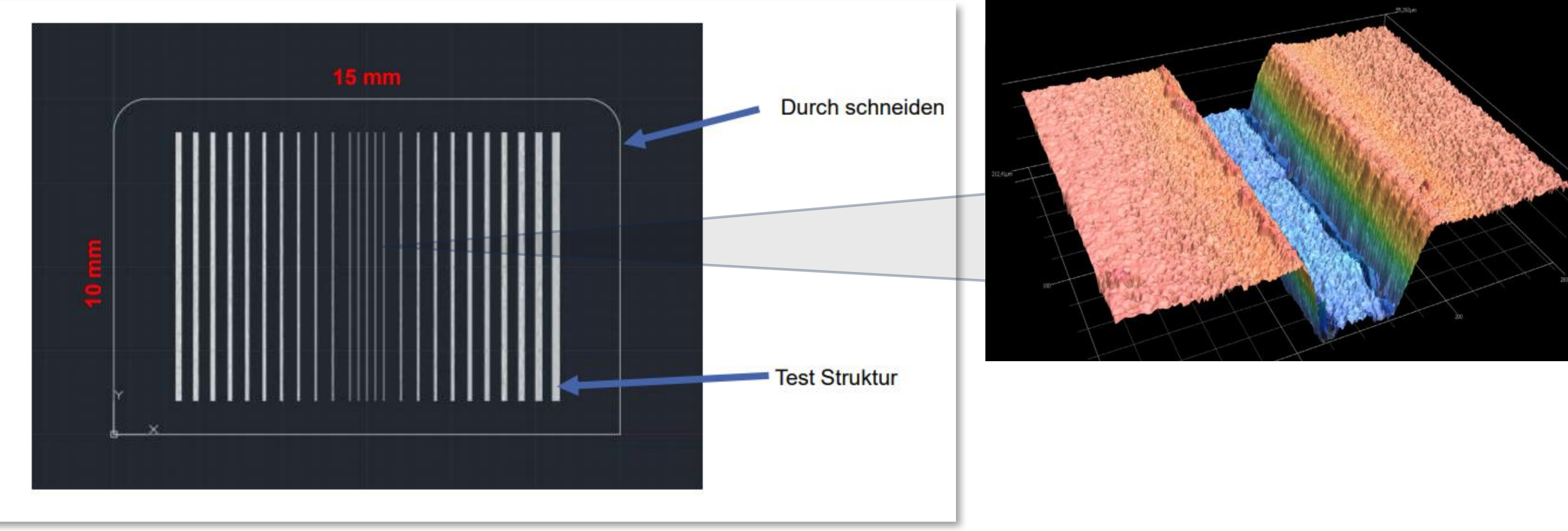
Laser drilled through silicon vias, maskless process for wafer and single die

Laser machine DR2000 from Photonic System

Courtesy: Felix Steiner and Thoms Blank

To be installed at KIT

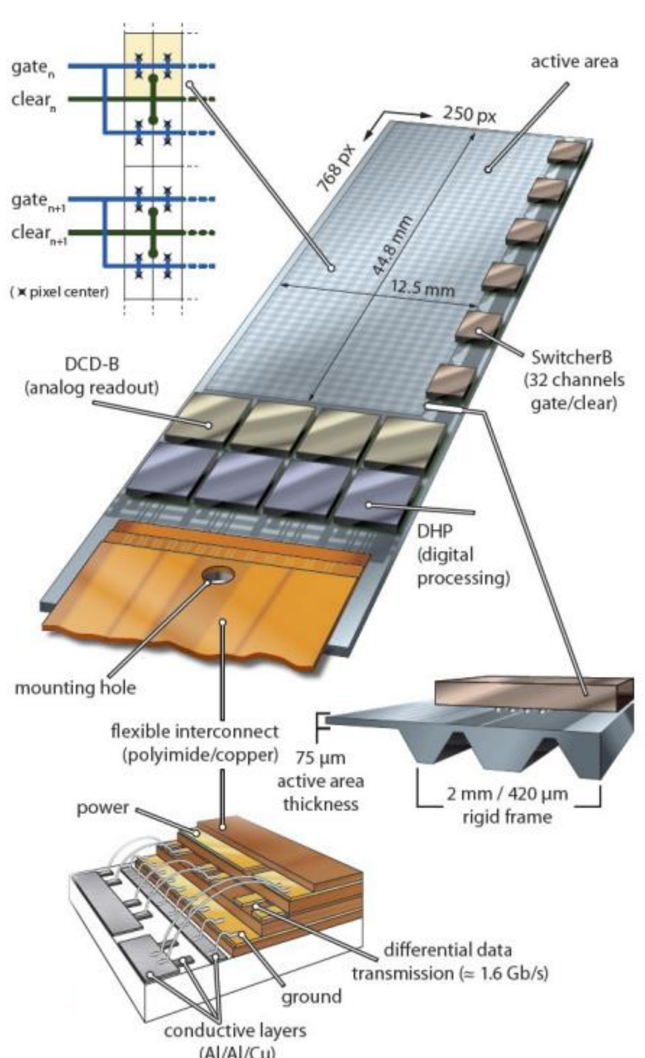
- Laser spot diameter: 20 µm
- Suitable for Si, glass, PCB
- Very large working area: 610 x 520 mm^2



Strip structure 15 to 20 µm spacing

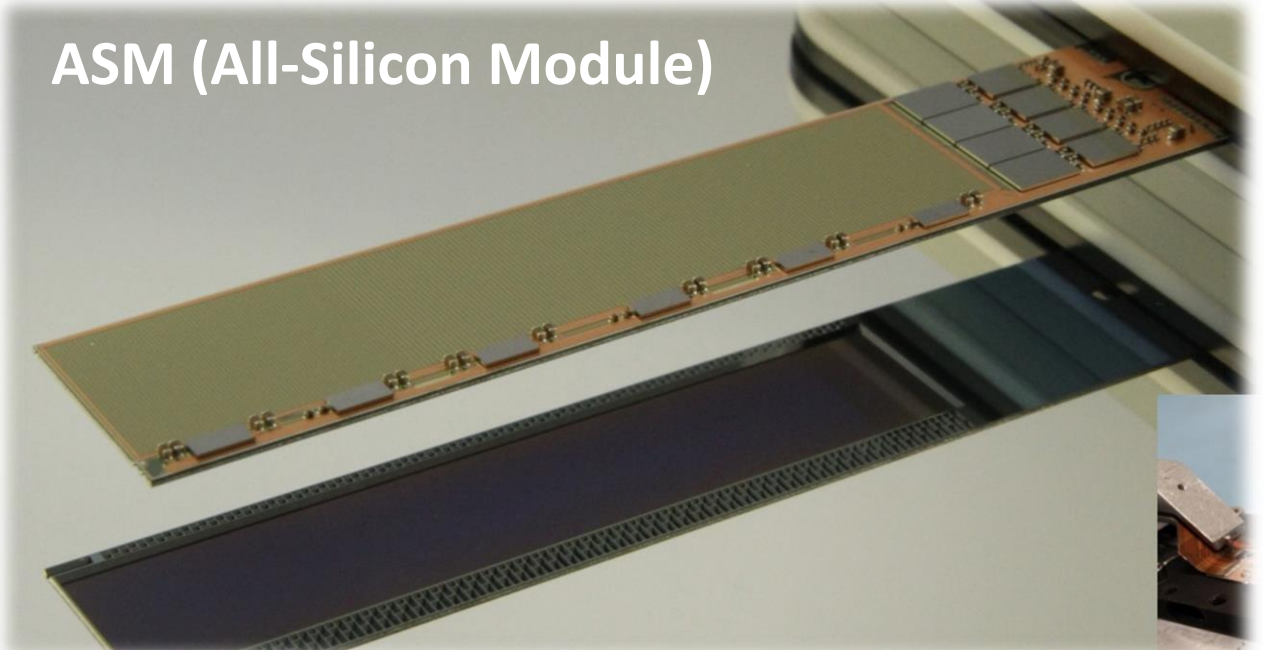
The DEPFET all-silicon module for Belle II PXD

Courtesy: Ladislav Andricek



Technology readiness level at MPG HLL

- Sensor employed as active interposer
- Routing based BCB/Cu RDL on sensor (up to 3 metal layers)
- ASICs bump-bonded on sensor (as a chiplet architecture)
- μ-channels cooling by DRIE and direct bonding (optionally)



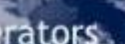
Conclusions

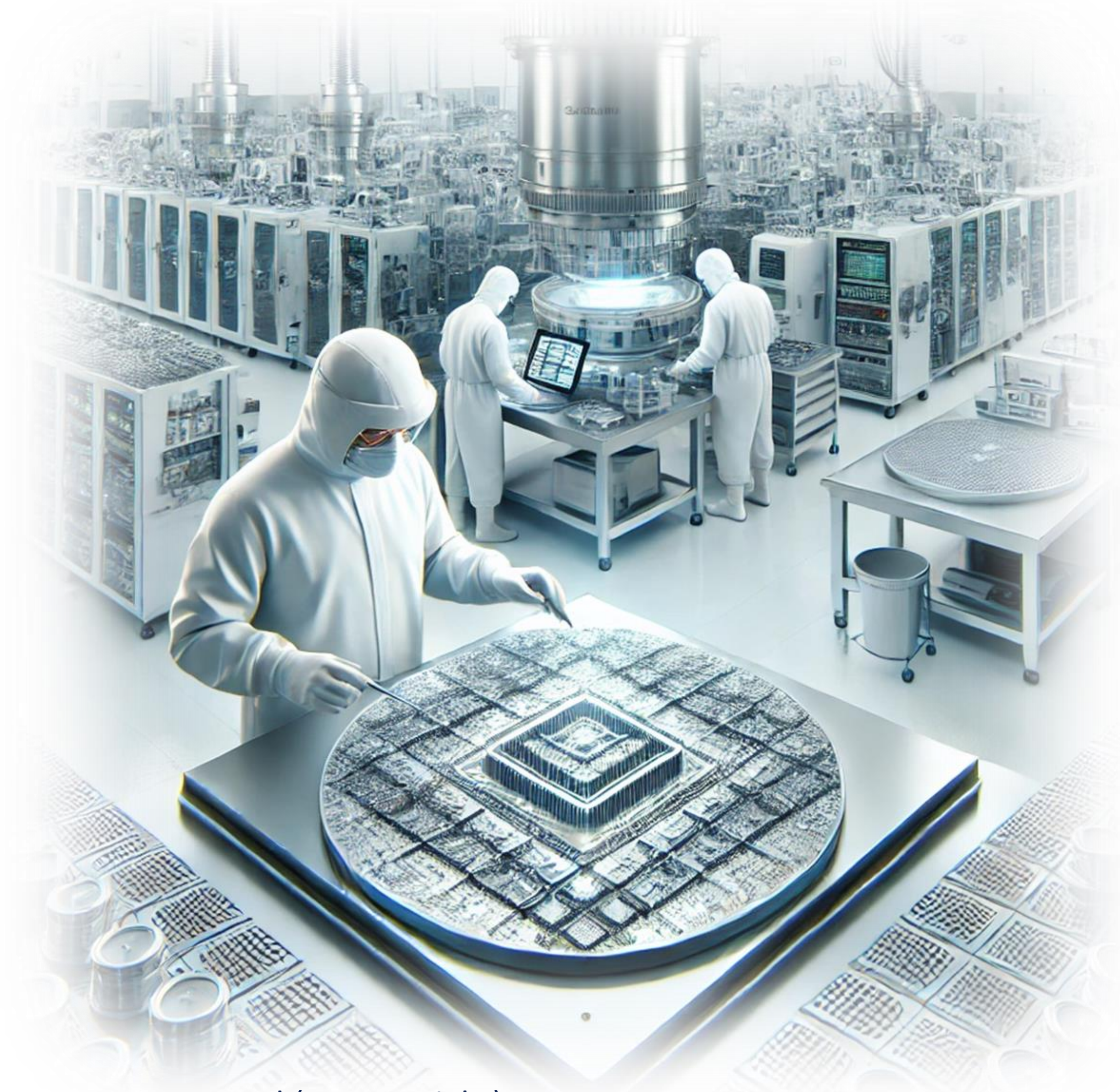
- Key objective of DRD 7.6b is to **establish a distributed detector laboratory,** enabling cost-effective access to 3D and advanced integration technologies for the detector community

- Current technologies at a **readiness level** within the DRD 7.6b community, include: wafer dicing/singulation, metal deposition/UBM, bumping deposition, flip-chipping, wire- and tab-bonding, and many others

- **Near-term milestones**, include development of Through-Silicon Vias (TSV) and multi-layer Redistribution Layers (RDL) on both front and back sides, integration of advanced silicon photonics and optical packaging directly on detector modules

- Connection between **DRD 7.6b and DRD3 – WG7** is vital, DRD7.6b is open to support projects within DRD3, define the technology roadmap based on the requirements coming from HEP experiments




AI generated (no copyright)

Thank you very much for your attention

Backup slides

Heterogenous 3D-ASIC integration

- The combination of TSV, RDL technologies, along with already existing in-house packaging technologies, will allow for a rapid transition towards the implementation of **3D-ASIC integration at the level of a single assembly (**e.g. Multi-Project Wafer)

Monolithic sensor
(TJ, TPSco, LFoundry)
Digital memory + processing
(65/28nm TSMC, UMC, etc.)
High-density intercon.
TVS
RDL
UBM/bumping deposition

- Roadmap
  - Production of dummy structures (Si) with one/two metals for connection testing
  - *Establish* the process steps and procedures for 3D-ASIC integration
  - Perform comprehensive *mechanical & electrical characterization* of TSV/RDL processes
  - *Extraction of equivalent circuit*, layout design rules /PDK (optionally)

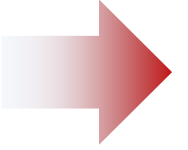
Integration of SiPh chip and optical fibers on detector module

- Establish the necessary process steps to ensure the long-term availability of the integration of silicon photonics (SiPh) chip with state-of-the-art monolithic/hybrid detector module

One/multi RDL layers for signals routing

Bump-bonding /interconnections

Optical fiber packaging (edge or grating couples) by automated/semi-automated procedure



Synergy with DRD7.1a

DRD7.6 – Complex imaging ASICs and technologies

- Working Group 6 deals with complex technologies merging multiple functionalities such as sensor and processing, multi-tier (2.5D and 3D) assemblies

- **Project 7.6a**
  - This project aims to provide common access to advanced imaging technologies through the organization of common fabrication runs. These are initially envisaged for the TowerJazz 180 nm, TPSCo 65 nm and the LFoundry 110 nm CMOS imaging technologies

Tightly connected

- **Project 7.6b**
  - This project aims to develop essential technologies for both 2.5D and 3D integration that can be quickly transposed to wafer-to-wafer 3D integration for a wide range of future particle physics applications, ranging from low-temperature neutrino detectors to high-radiation environment HL-HLC pixel detectors

Laser drilled through silicon vias, maskless process for wafer and single die

Laser machine DR2000 from Photonic System

Courtesy: Felix Steiner and Thoms Blank

er: 20 µm
ss, PCB
g area: 610 x 520 mm²

Laser drilled TSVs (preliminary results)