CPAD workshop 2022
Stony Brook University
November 29 - December 02

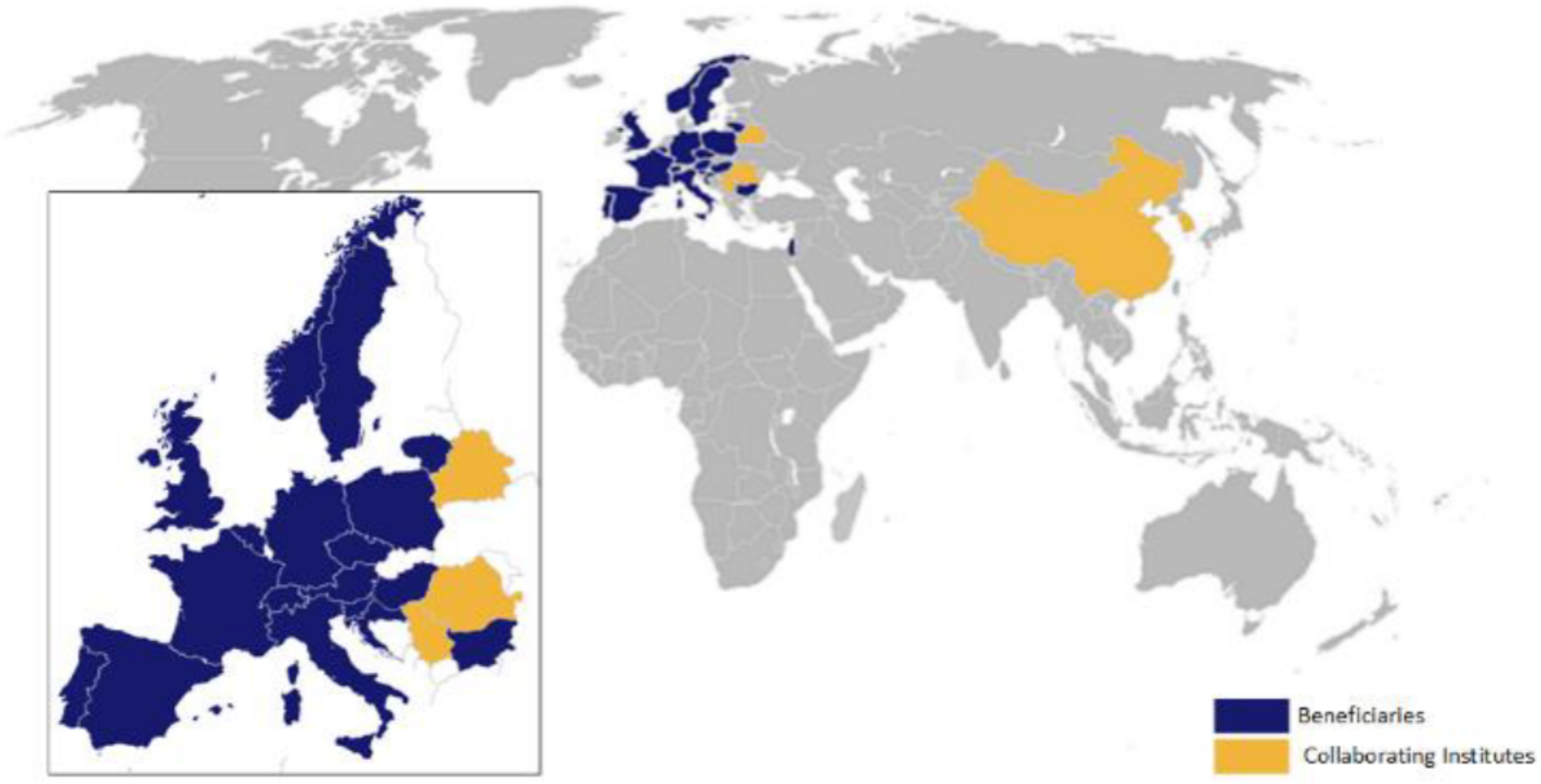
# AIDAinnova
## an overview

P. Giacomelli (INFN Bologna)
INFN Bologna
AIDAinnova Scientific coordinator

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 101004761.

**AIDAinnova** is the **largest** European program on R&D for detectors for High Energy Physics (HEP)

- Collaborative framework
- Infrastructure: common interest
- 15 countries
- 45 beneficiaries
  - 34 academic + 11 industrial and RTOs
  - + 10 associated partners
- Coordinated by CERN
- EC contribution **10.0 M€**
- Total budget **~26 M€** (co-funding of **~16 M€)**
- Activities:
  - Joint Research & Networking activity
- Website: [https://aidainnova.web.cern.ch](https://aidainnova.web.cern.ch)




Participants bring in complementary competences and a balanced coverage of projects.

# EU-funded detector R&D projects

- **FP6: EUDET: 2006-2010**
  - Detector development for linear collider
- **FP7: AIDA: 2011-2014**
  - Detector development for LHC upgrades and linear colliders
  - Project-specific work packages
- **FP8: AIDA-2020: 2015-2020**
  - Common LC and LHC work packages
  - New communities: large cryogenic neutrino experiments, new topics
  - New innovation measures, with industry

Increasing level of integration

**All had a strong leverage on matching funds from national sources, typically a factor of 3**

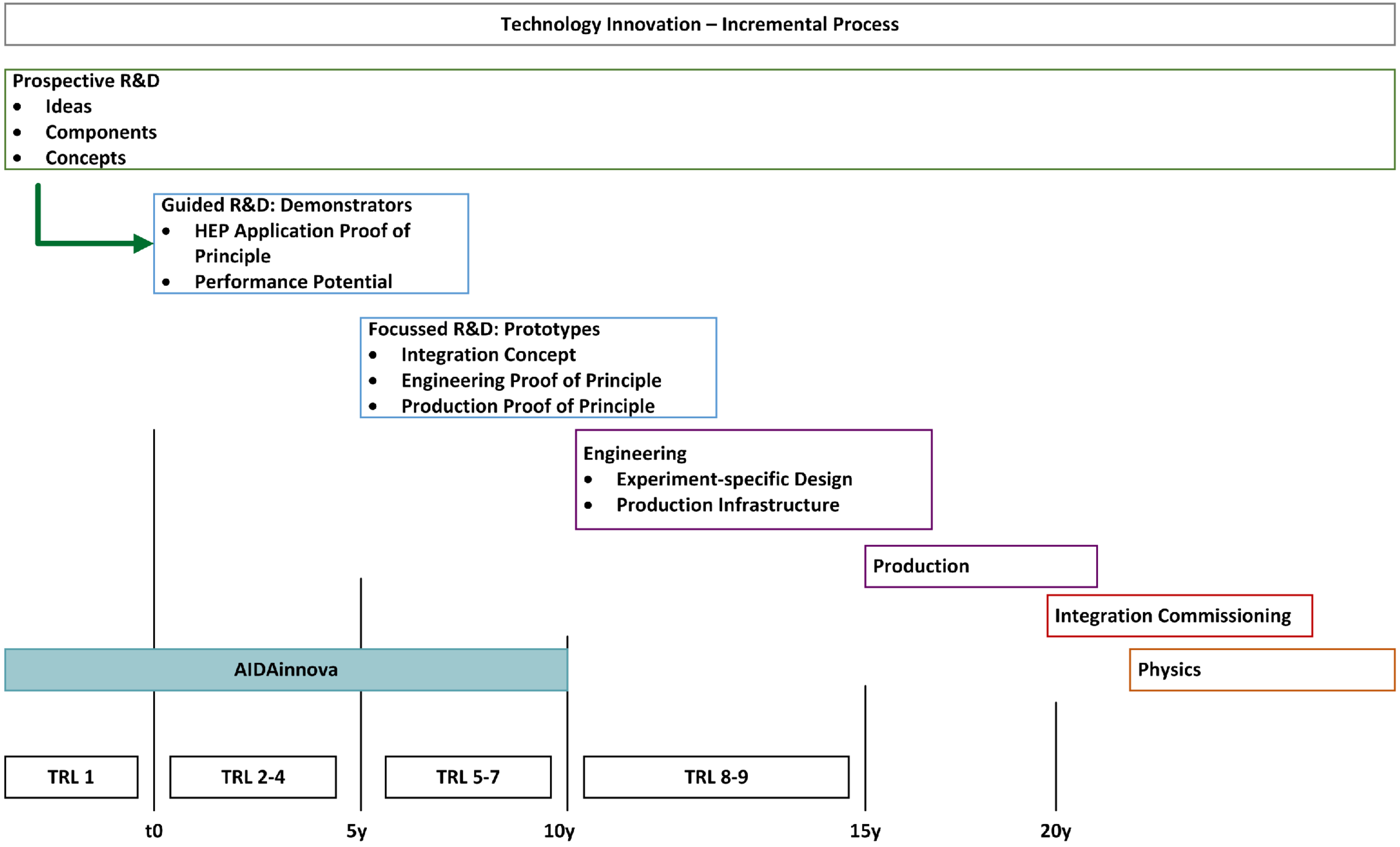
# AIDAinnova scope

**AIDAinnova focuses on Strategic R&D in the pre-TDR phase**

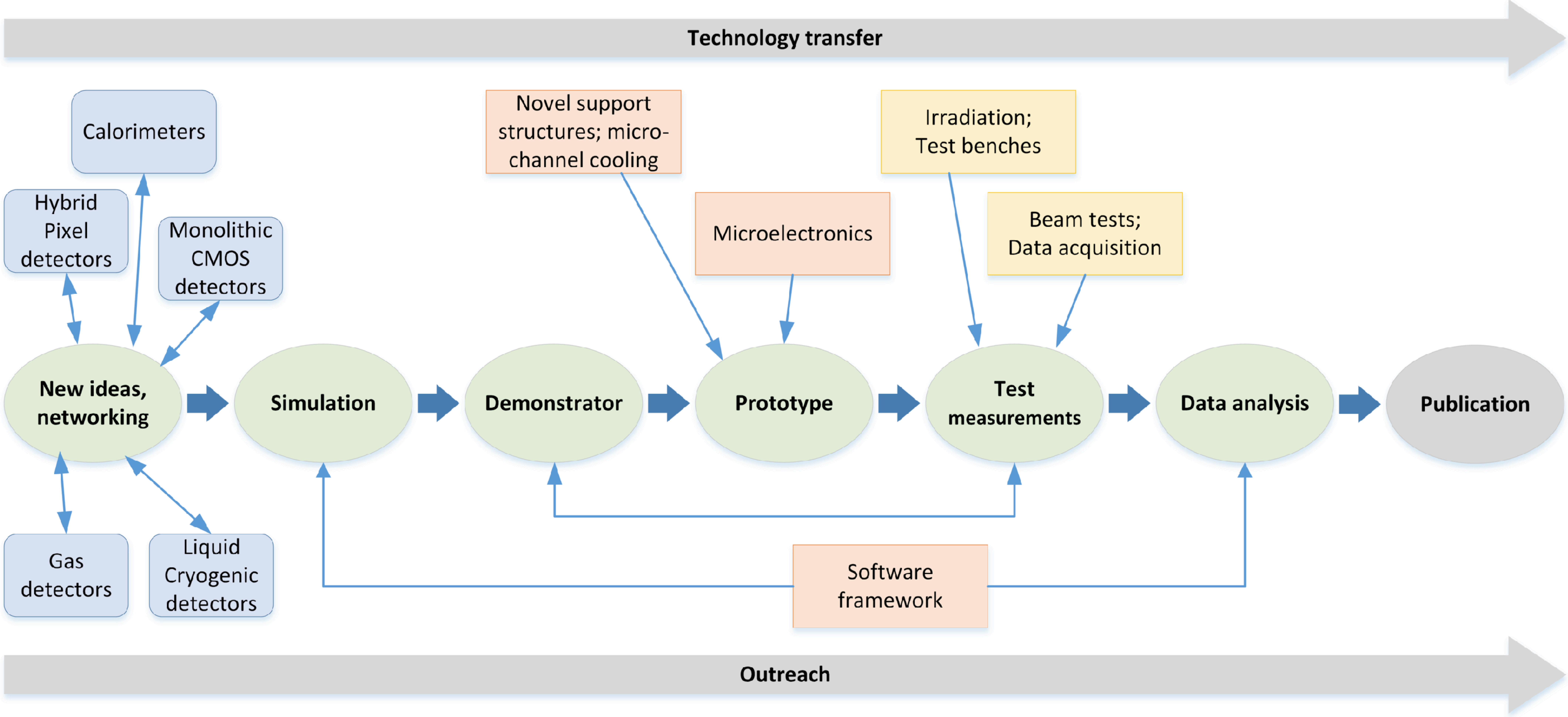
- Technology Readiness Levels 2-7
- Not yet experiment-specific: potential to unfold synergies
- **Include some prospective R&D**
- Competitive call at start of project
- “Blue Sky”, quantum sensors,…

**Targeted applications**

- Higgs Factories
- ALICE LS3, LHCb LS4 pre-TDR, ATLAS & CMS LS4
- Accelerator-based neutrino experiments
- and others…



# AIDAinnova activities




- Technology transfer to and from industrial partners happens throughout the development cycle
- Same is true for outreach

# AIDAinnova structure

- 13 Work Packages (WPs)
  - 2 Administration WPs
  - 10 Scientific WPs
  - 1 "Blue-sky" WP
- 2 coordinators/WP

- WP1: **Project management and coordination**
- WP2: **Communication, Education and Innovation**
- WP3: **Test beam and infrastructure**
- WP4: **Upgrade of Irradiation and Characterization Facilities**
- WP5: **Depleted Monolithic Active Pixel Sensors**
- WP6: **Hybrid pixels sensors for 4D Tracking and Interconnection Technologies**
- WP7: **Gaseous detectors for frontier science**
- WP8: **Calorimeters and Particle Identification detectors**
- WP9: **Cryogenic neutrino detectors**
- WP10: **Advanced mechanics for tracking and vertex detectors**
- WP11: **Microelectronics**
- WP12: **Software**
- WP13: **Prospective and Technology-driven Detector R&D**

# AIDAinnova structure

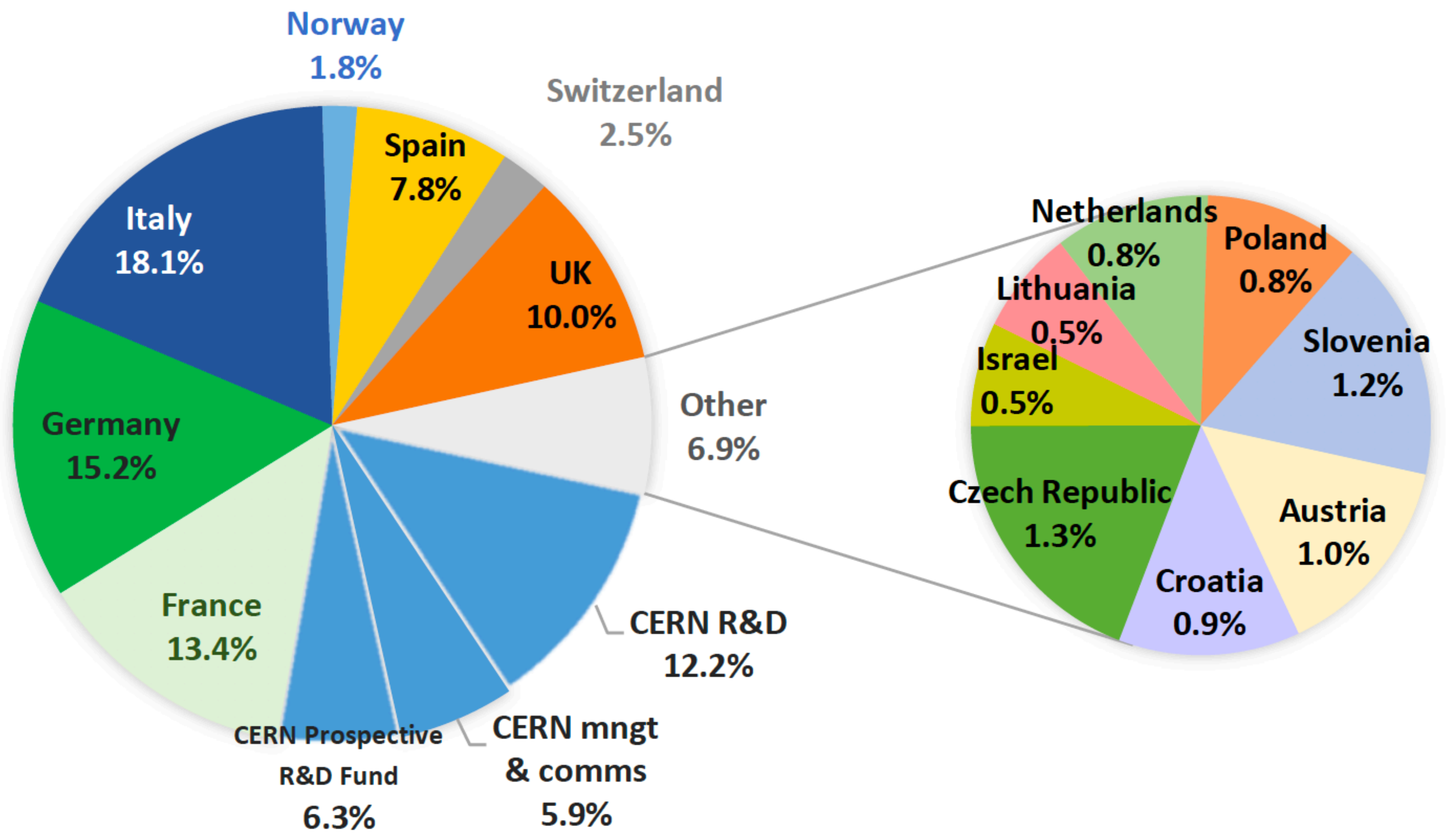
- **Advanced R&D and infrastructure** for detectors at future colliders
  - Lepton colliders
    - Circular
    - Linear
  - Hadron colliders
- **Novel detector technologies** for large-scale particle physics experiments
- **Innovative software** solutions (ML, etc.) for future detectors
  - Triggering
  - Tracking
  - Calorimetry
- Extended neutrino WP with also short baseline neutrino detectors
- **Joint R&D** programmes with **industrial beneficiaries**
- “Blue sky” R&D (competitive allocation after start of project) higher risk projects

# AIDAinnova budget

Full costs budget AIDAinnova = **~ 26 M€**

EC contribution = **10 M€**

## EC FUNDING PER COUNTRY



# AIDAinnova Management Team

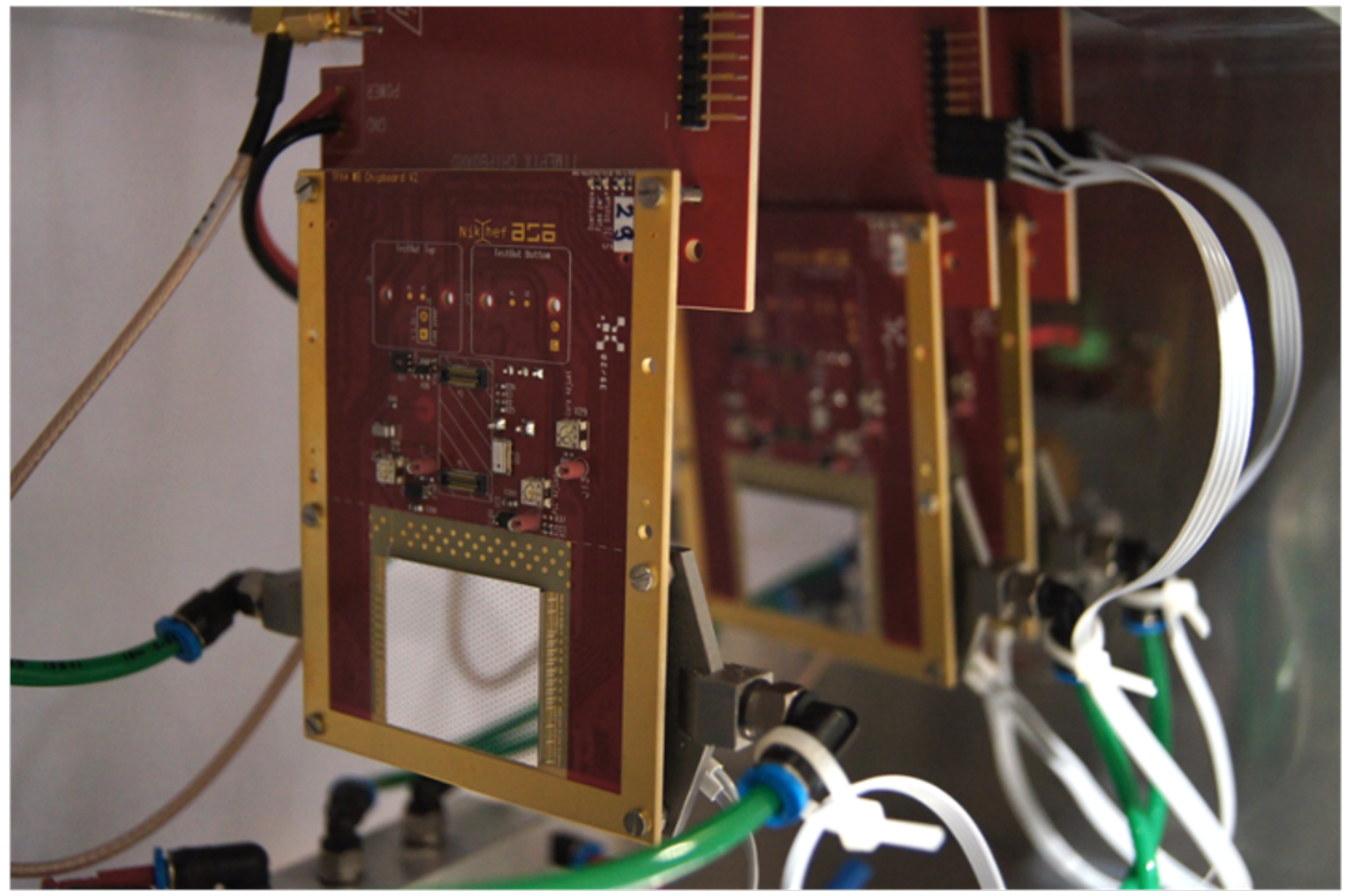
Paolo
Giacomelli
Scientific
Coordinator

Daniela
Bortoletto
Deputy Scientific
Coordinator

Giovanni
Calderini
Deputy Scientific
Coordinator

# Highlights of WP3: test beam and DAQ

- Mass production of 30 TLUs at DESY.
- Many lessons learnt on prototype to production process
- Delivered to users.
- Now working pn picosecond TLU.



Beam test of Timepix4 sensors:

- Test DAQ.
- Test plane-to-plane synchronisation.
- Gain experience with Timepix4.

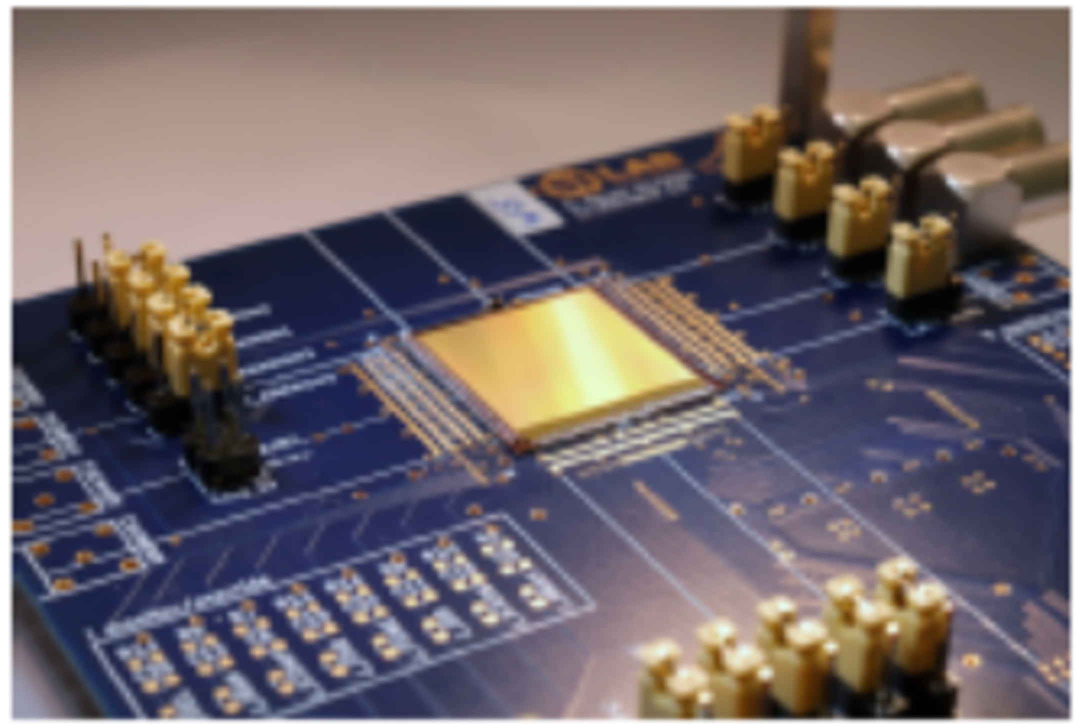

- Common readout board for silicon detector testing developed.
- VMM3 board for gas detectors also making good progress.

- Also telescopes are working well and upgrades planned.
- EUDAQ2 software upgraded to picosecond timing and monitoring being improved.

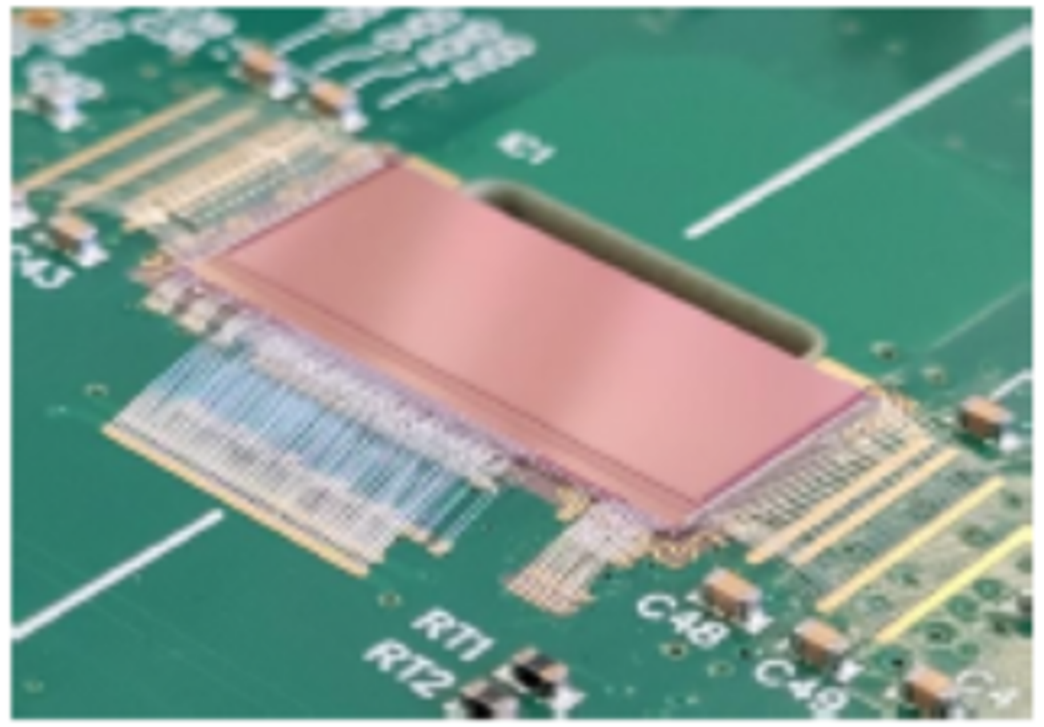
WP3 is well on track; good progress and expect upcoming milestones to be met.

# WP5 Depleted Monolithic Active Pixel Sensors

- Aim is to advance DMAPS, specially towards high granularity and radiation hardness
  - Also exploring timing resolution
- Link to deployment at experiment if possible
  - Example: of Belle II and ALICE upgrade

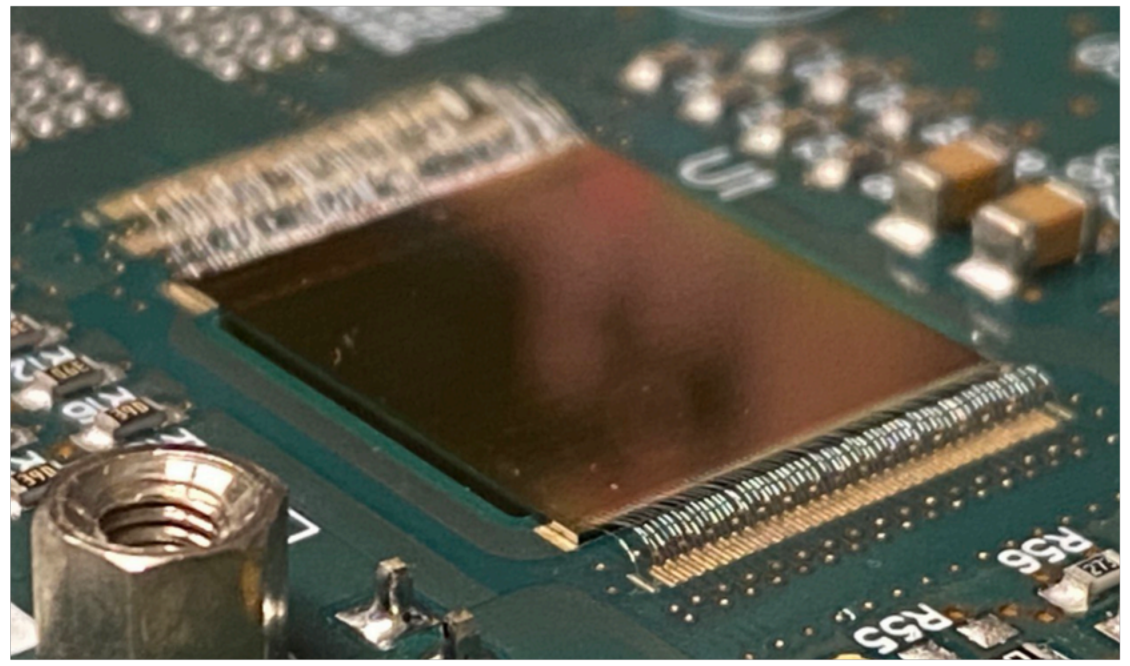


TJ Monopix 2:
2x2 $cm^2$ with 33x33 $\mu m^2$

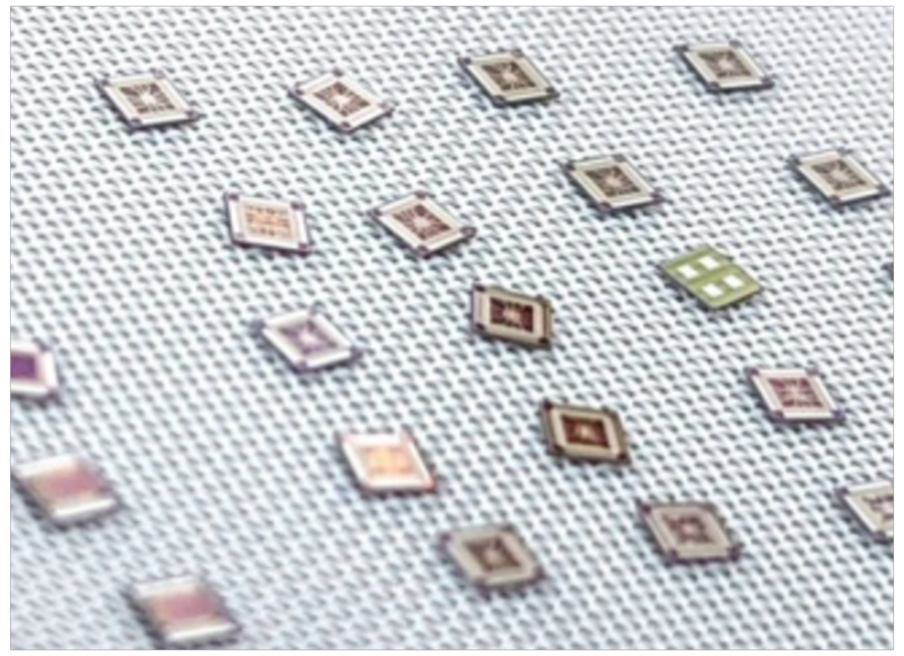


MALTA 2: 2x1 $cm^2$
with 34.6x34.6 $\mu m^2$

- First **milestone** reached:
  - Fabricated first batch of high granularity prototypes
- In fact, all activities produced first devices
  - Intense characterization effort starting



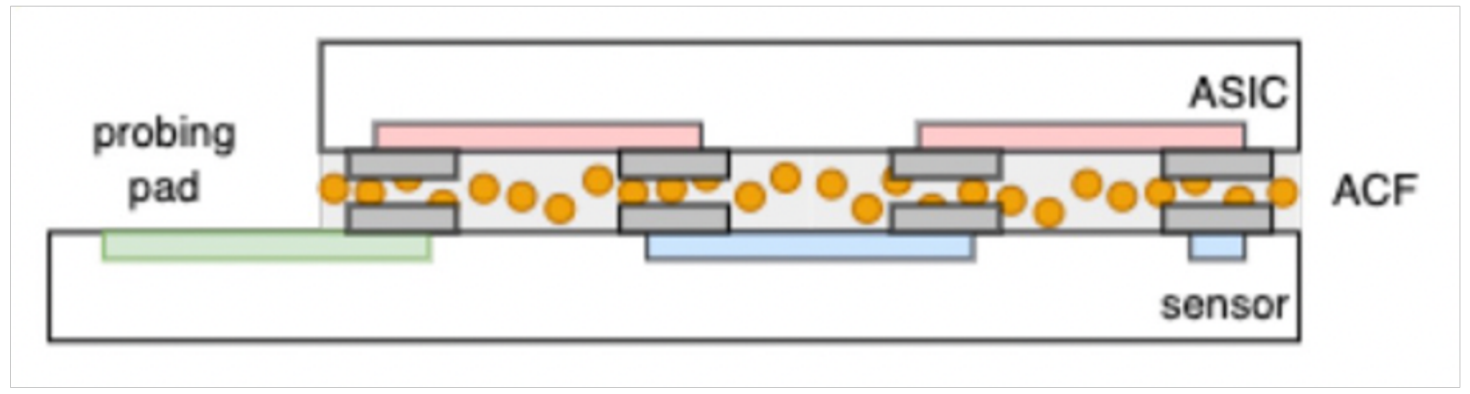
ARCADIA MD1:
1.3x1.3 $cm^2$ with 25x25 $\mu m^2$



TPSCo 65 nm:
test structures

# WP6: hybrid pixel sensors for 4D tracking and interconnection technologies

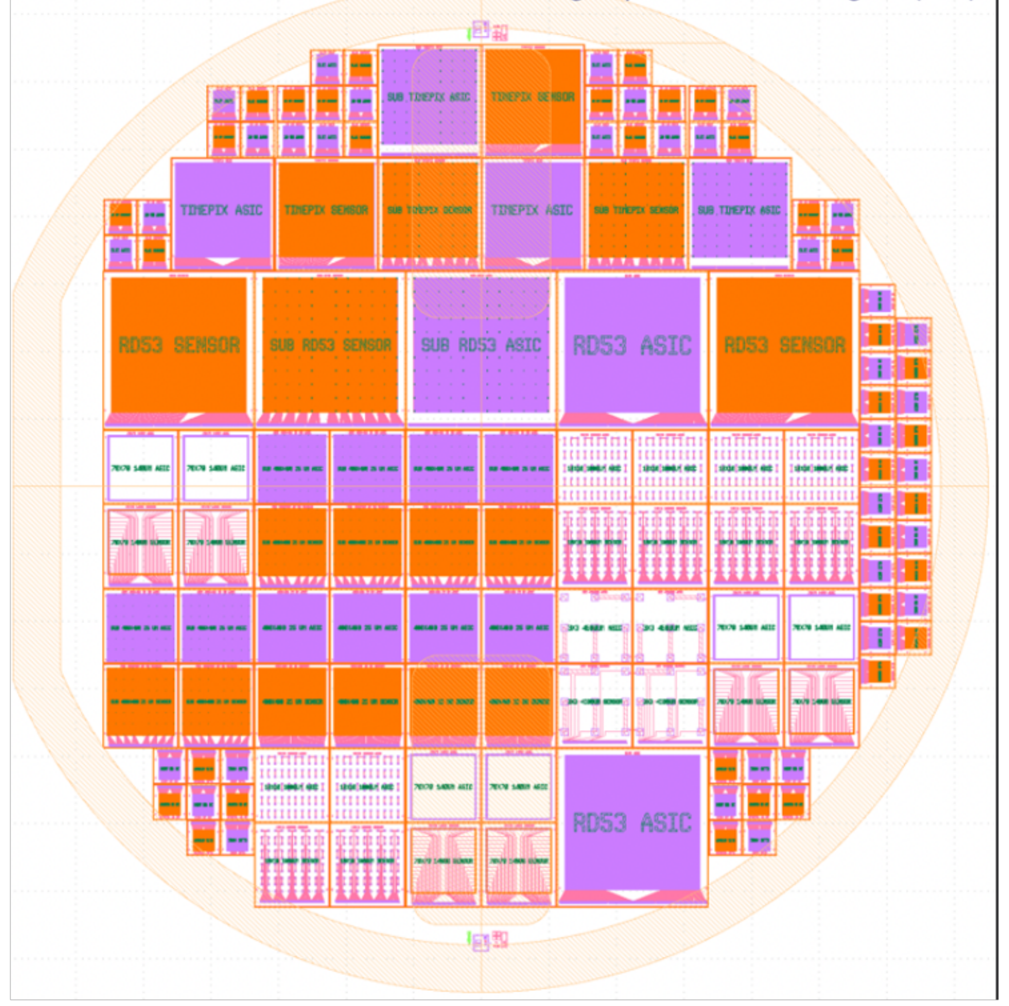
Anysotropic conductive films (ACF)





Pixel sensors with different sizes/pitches/geometries from AIDA-2020 planar active-edge production

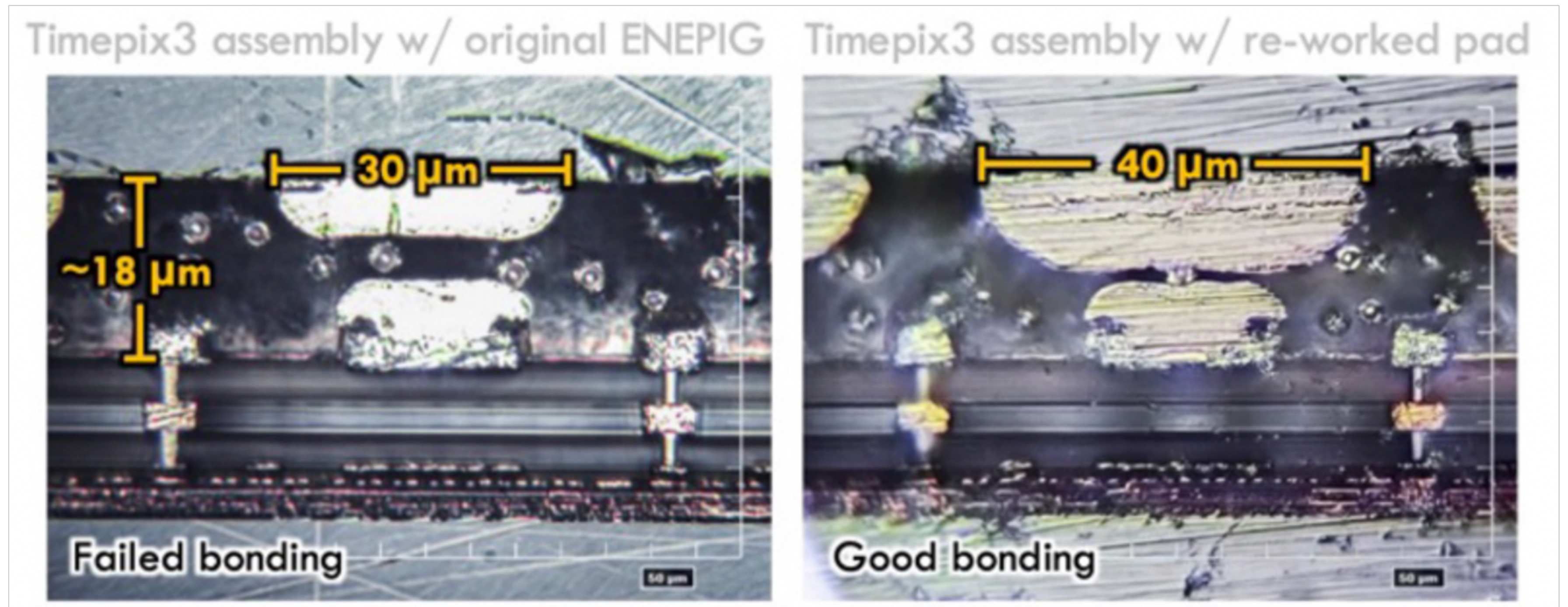
Design by Matteo Centis Vignali (FBK)




Dedicated production of conductive chain devices to precisely characterise interconnections

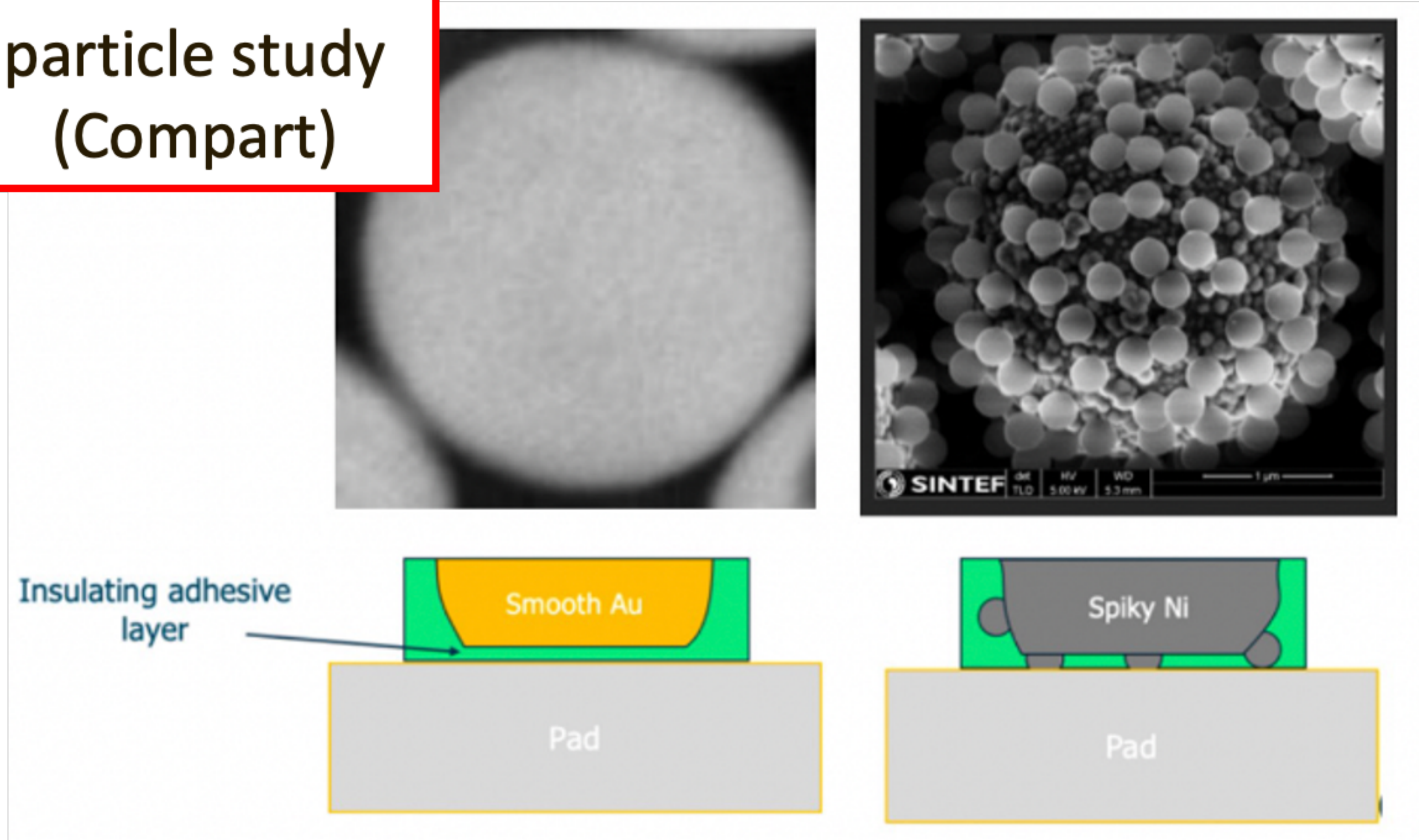
ENIG process optimization

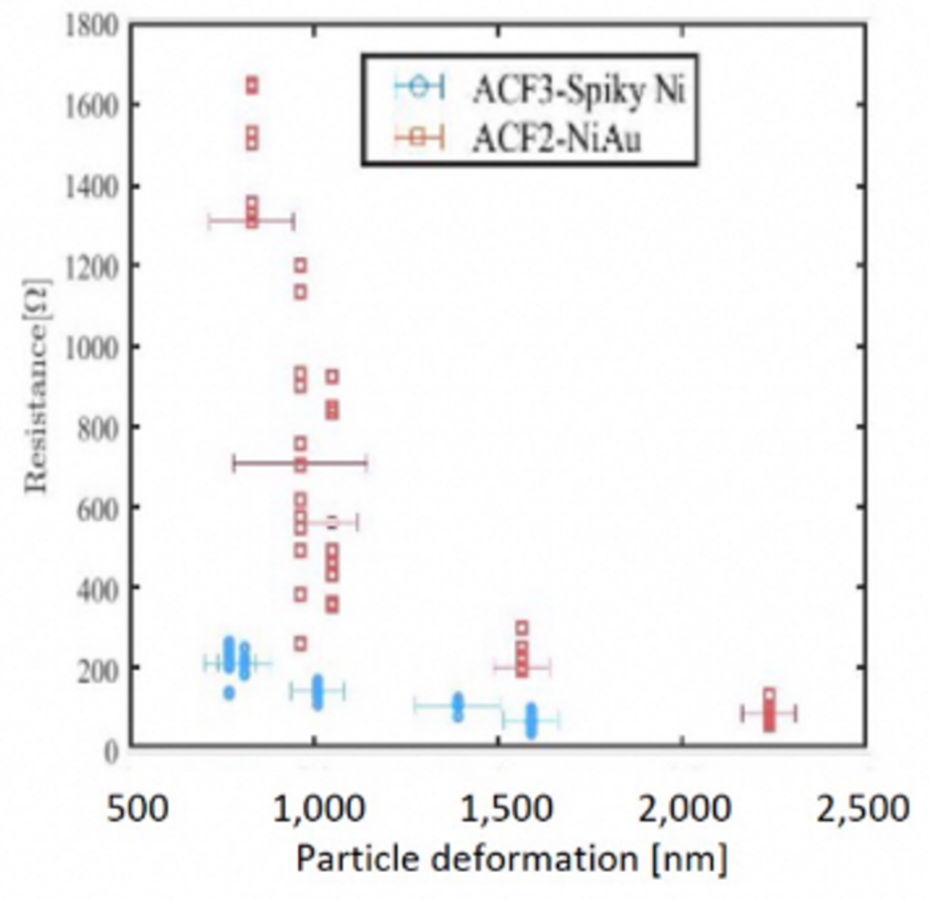
Contact quality
- Uniformity control
- Reproducibility




Very nice example of in-house process, allows die-level

Conductive particle study (Compart)



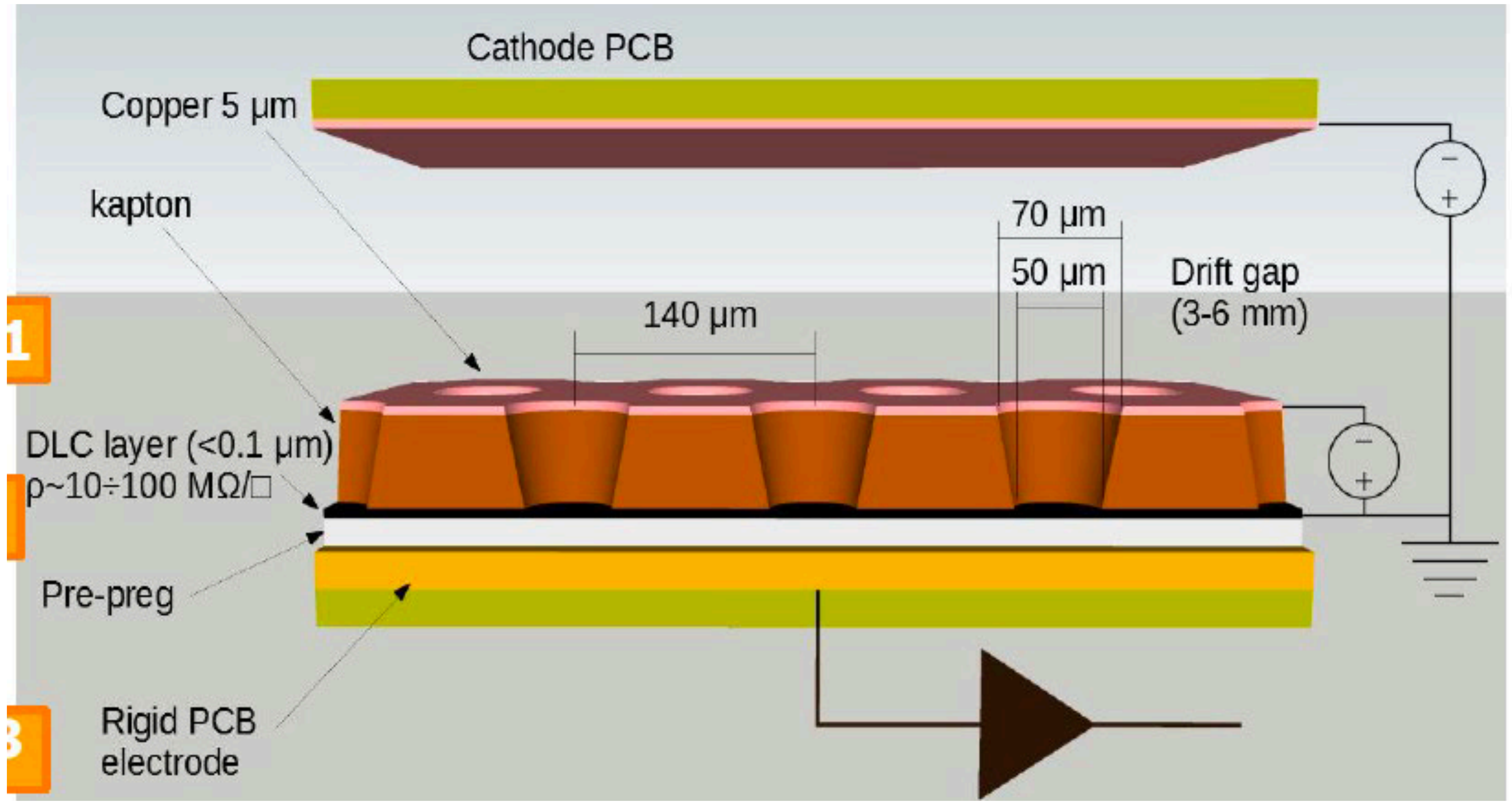
# WP7: Gas detectors

| SECTOR | TASK | | APPLICATIONS |
|---|---|---|---|
| RPC | 7.2.1 | MRPCs for fast timing | CBM, SoLID, SHiP, ALICE upgrade, Muography |
| | 7.2.2 | Shower development in SDHCAL | e+ e- colliders and more |
| | 7.2.3 | Eco-friendly gas mixtures for RPCs | LHC exp.s and all RPC applications |
| MPGD technologies | 7.3.1 | Resistive electrodes for MPGDs | resistve MMs, GEMs for time time resol., μR-WELL |
| | 7.3.2 | Industrial Engineering of high-rate μR-WELL | large size μR-WELL systems (LHBc, EIC, …) |
| Large volume gaseous detectors | 7.4.1 | Electronics for cluster counting | drift chambers for e+ e- colliders |
| | 7.4.2 | High P gas TPC for ν-physics | ν-physics (T2K, HyperK, NOvA, Duve) |
| PID | 7.5.1 | PDs for h-PID at high momenta | EIC, circular e+e-, more RICH implementations |

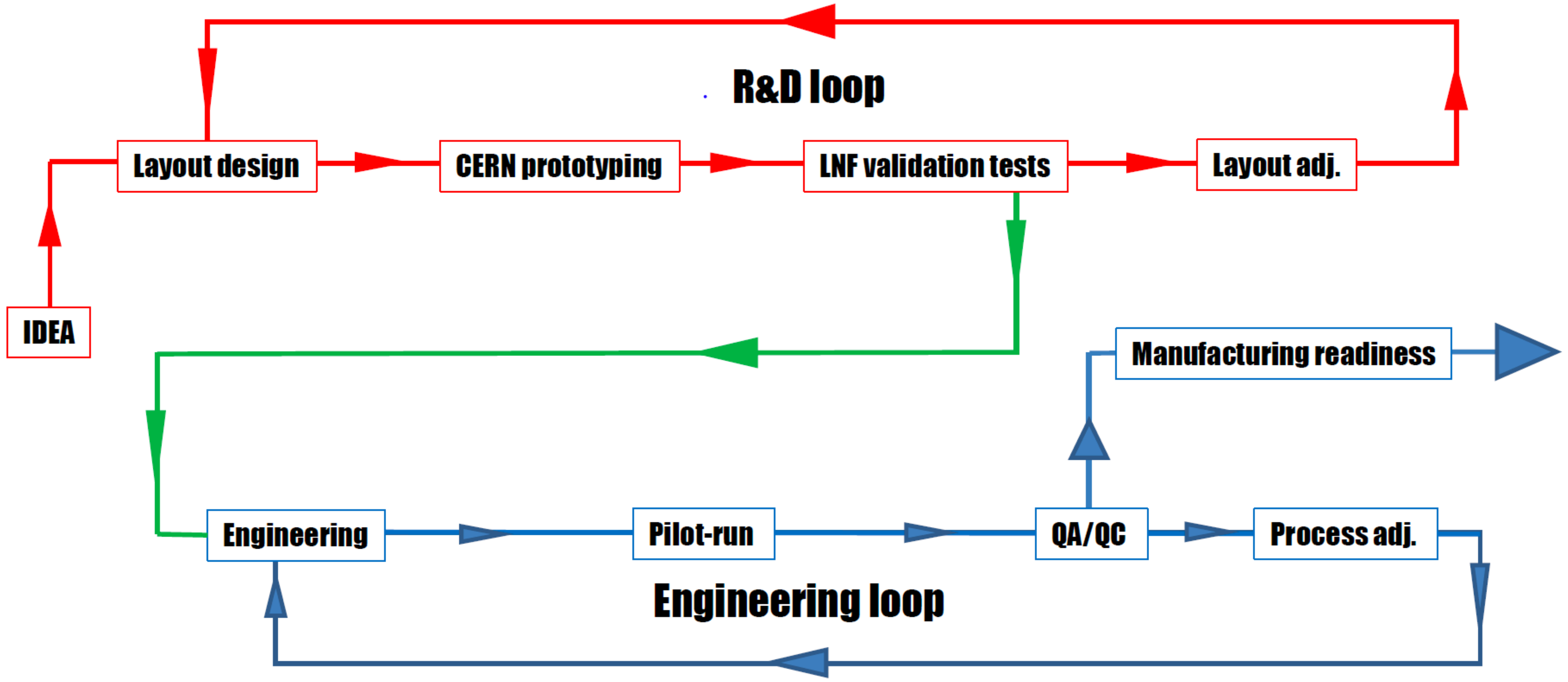
**Activity robustly progressing:**

**The several envisaged applications will profit of the progress in the gaseous detector sector by AIDAinnova WP7**

# WP7: Industrial engineering of µRWELL




## The road-map: R&D + Engineering




## Operative meetings

**21 Sept. 2021 - joint INFN-ELTOS-CERN meeting**
- **standardizing manufacturing procedures of µ-RWELL layout**

**1-3 Dec. 2021 - CERN-INFN meeting**
- status of the **R&D on the High Rate layout**
- **measurement with high intensity X-ray beam**
- **2D layout** based on the **readout of a segmented amplification stag**

**7–10 Dec. 2021 – 1st test batch in ELTOS**
- **DLC patterning**
- **PCB planarizing tests**

**7–8 Mar. 2022 - 2nd test batch in ELTOS**
- **PCB planarizing tests**
- **Kapton DLCed foil coupling with PCB-readout**

**28 Mar. 2022 - joint INFN-ELTOS-CERN meeting**
- **discussion with Rui about the results obtained**

# WP8: calorimeters

Task 8.1. Coordination and Communication - Roberto Ferrari, Katja Krüger, Roman Pöschl

Task 8.2. Towards next generation highly granular calorimeters

8.2.1 Integration aspects of highly granular calorimeters – Vincent Boudry
DESY, CNRS-IJCLab, CNRS-LLR, CNRS-LPNHE, JGU, CERN, TAU, FZU

8.2.2 Future Liquid Noble Gas Calorimeters – Jana Faltova
CERN, CNRS-IJCLab, CUNI

Task 8.3. Innovative calorimeters with optical readout

8.3.1 Crystal detectors – Etiennette Auffray Hillemanns
CERN, FZU, VU, INFN-PG, INFN-LNF, INFN-TO (→ GLASSTOPOWER)

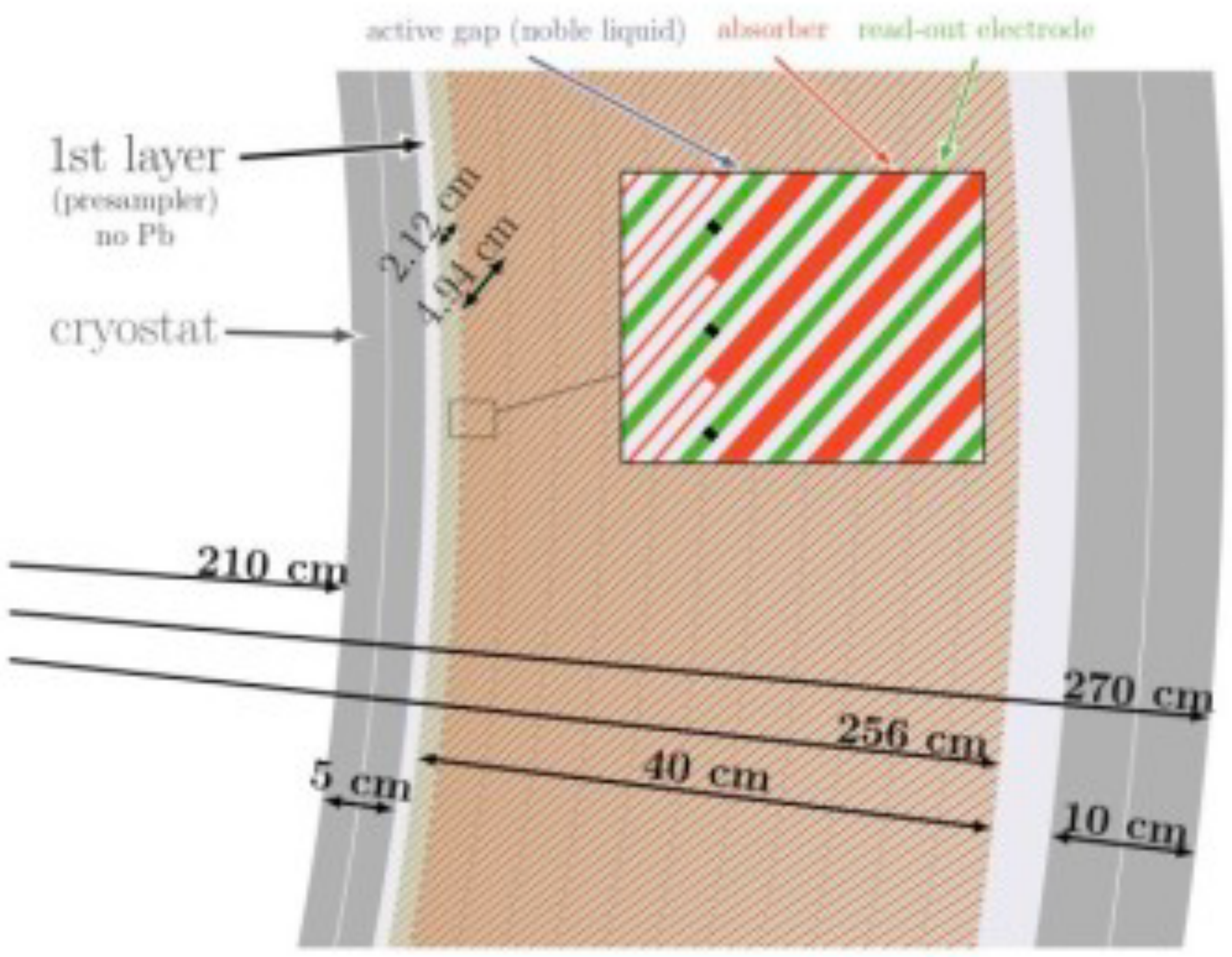
8.3.2 Large area scintillator detectors - Frank Simon
MPP-MPG, DESY, INFN-BO, INFN-LNF, JGU

Task 8.4. Innovative solid-state light sensors and highly granular dual-readout fibre-sampling calorimetry

8.4.1 Innovative SiPMs and future applications in PID detectors – Rok Pestotnik
JSI, INFN-PD, INFN-TO, CERN, FBK, UiB, FZU (→ FOTON)

8.4.2 Development of highly-granular dual-readout fibre-sampling calorimeters – Romualdo Santoro
INFN-PV, INFN-MI, INFN-PI, INFN-BO, UOS, CAEN

- **Electromagnetic calorimeter for FCC-ee**
- **1536 absorbers in 2π, inclined by ~50.4º, |z| ≤ 2 m along the beam axis**
  - Sandwich of 2 mm Pb absorber – active gap – 1.2 mm readout PCB – active gap
  - 19 - 22 $X_0$ reached after 40 cm with LAr as active material



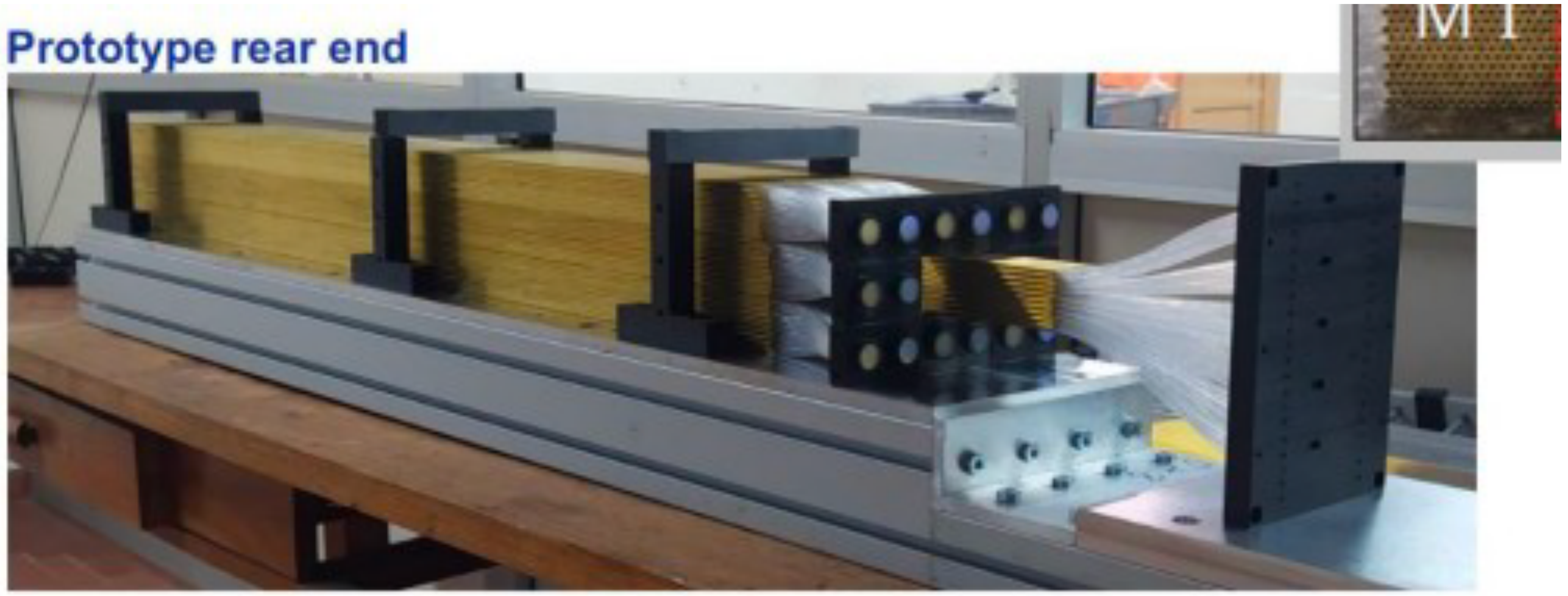

**High granularity achieved by usage of straight multilayer readout**

- **New calorimeter concepts have to optimize electronics noise (crucial for e+e- colliders)**
- Two approaches
  – **Warm electronics**: ATLAS EM-calorimeter like:
    - **Advantages:** Maintainability of front-end electronics (no active components inside the cryostat), upgradeability, possibility to adapt calorimeter to new requirements (e.g. as for HL-LHC upgrade )
    - **Disadvantages:** Long transmission lines (attenuation, noise), high-density signal feedthroughs

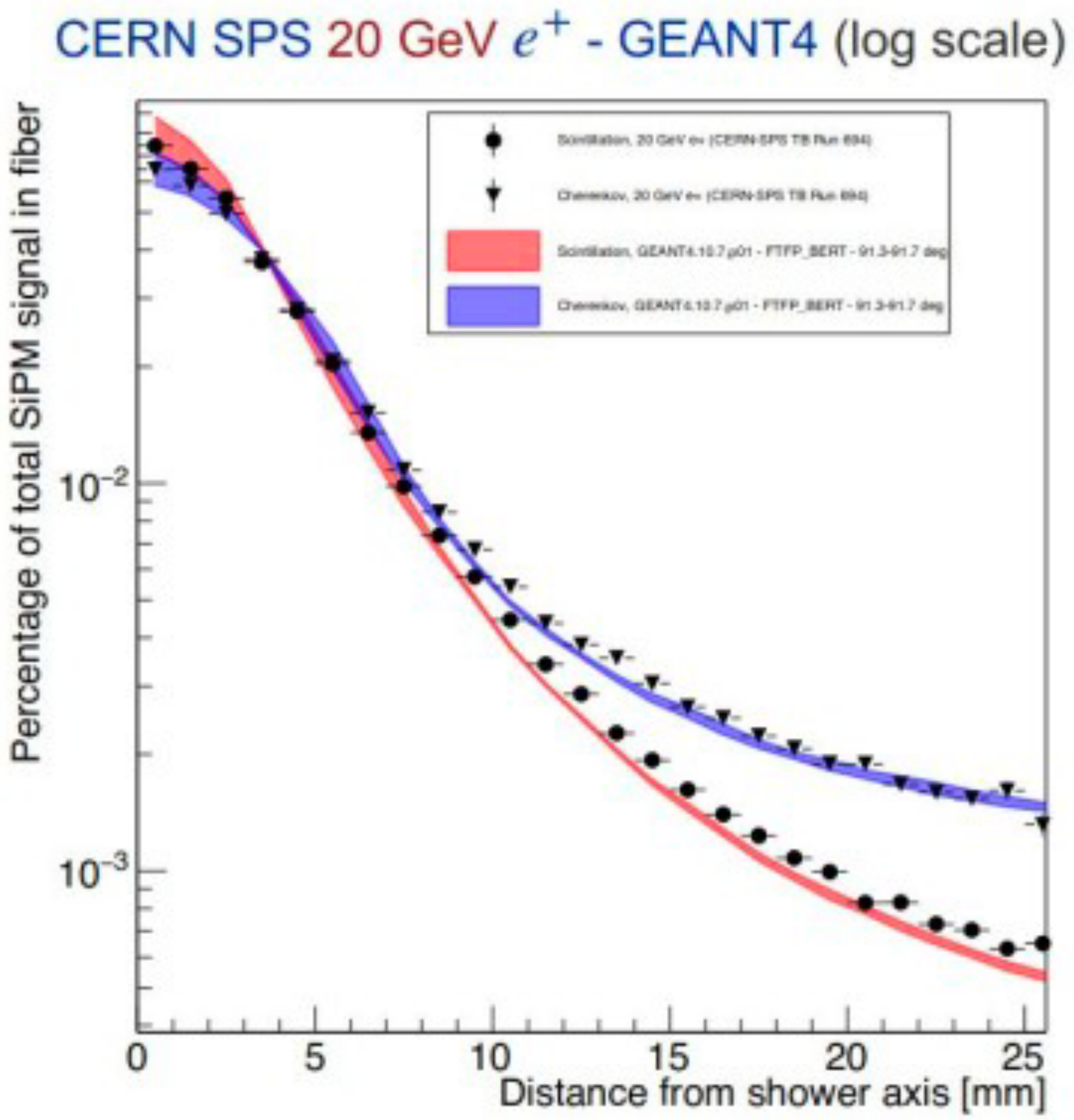
  – **Cold electronics**: ATLAS HEC-calorimeter or DUNE like:
    - **Advantages:** Much shorter transmission lines, cold preamplifiers have less serial noise, one optical fibre can carry signal of 100’s of channels
    - **Disadvantages:** No possibility to repair or upgrade

## Highly-granular dual-readout fibre-sampling calorimeters

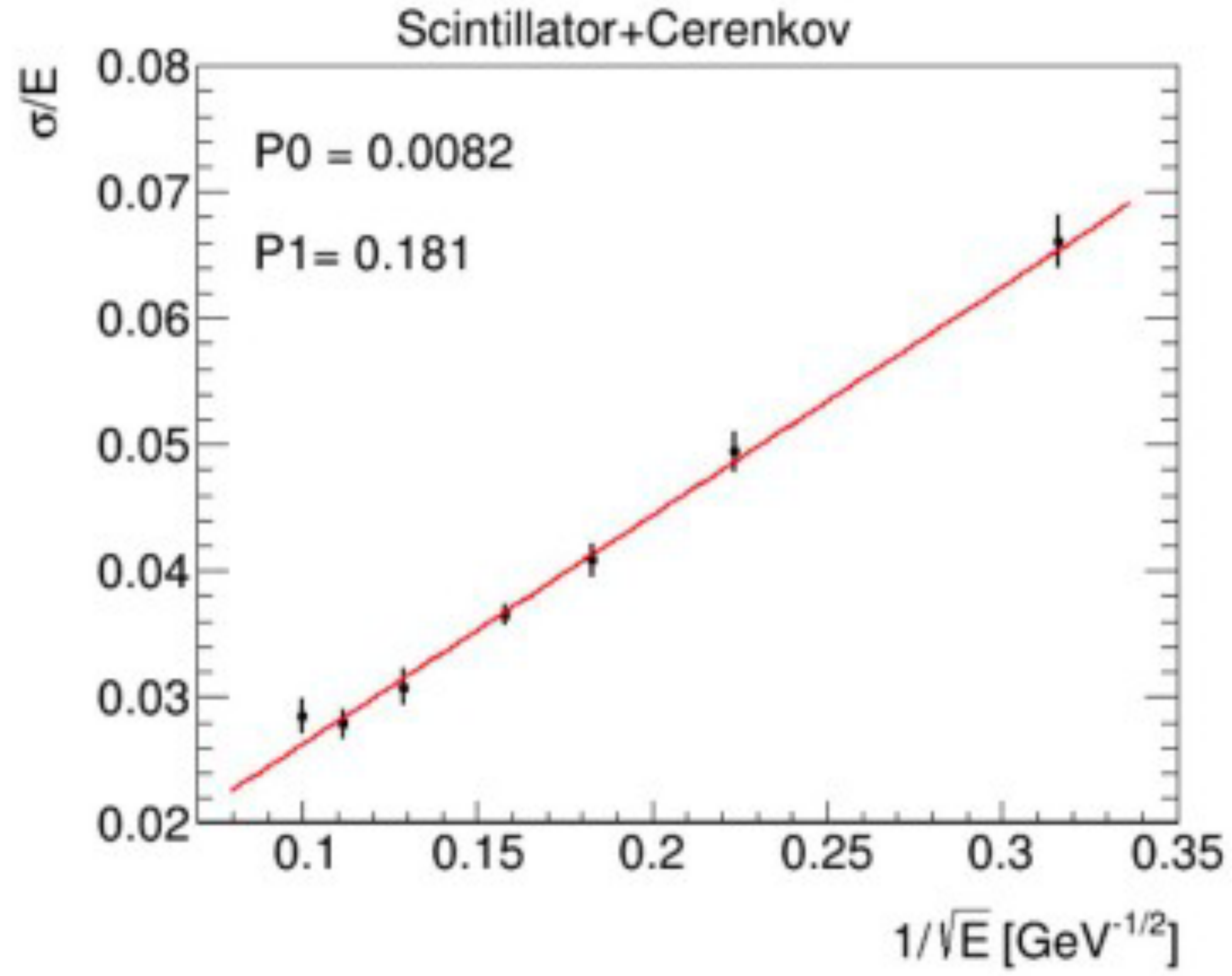
new (em) prototype (9 3x3 cm² towers) tested both at DESY and SPS
highly granular core (tower 0) w/ SiPMs




shower profile



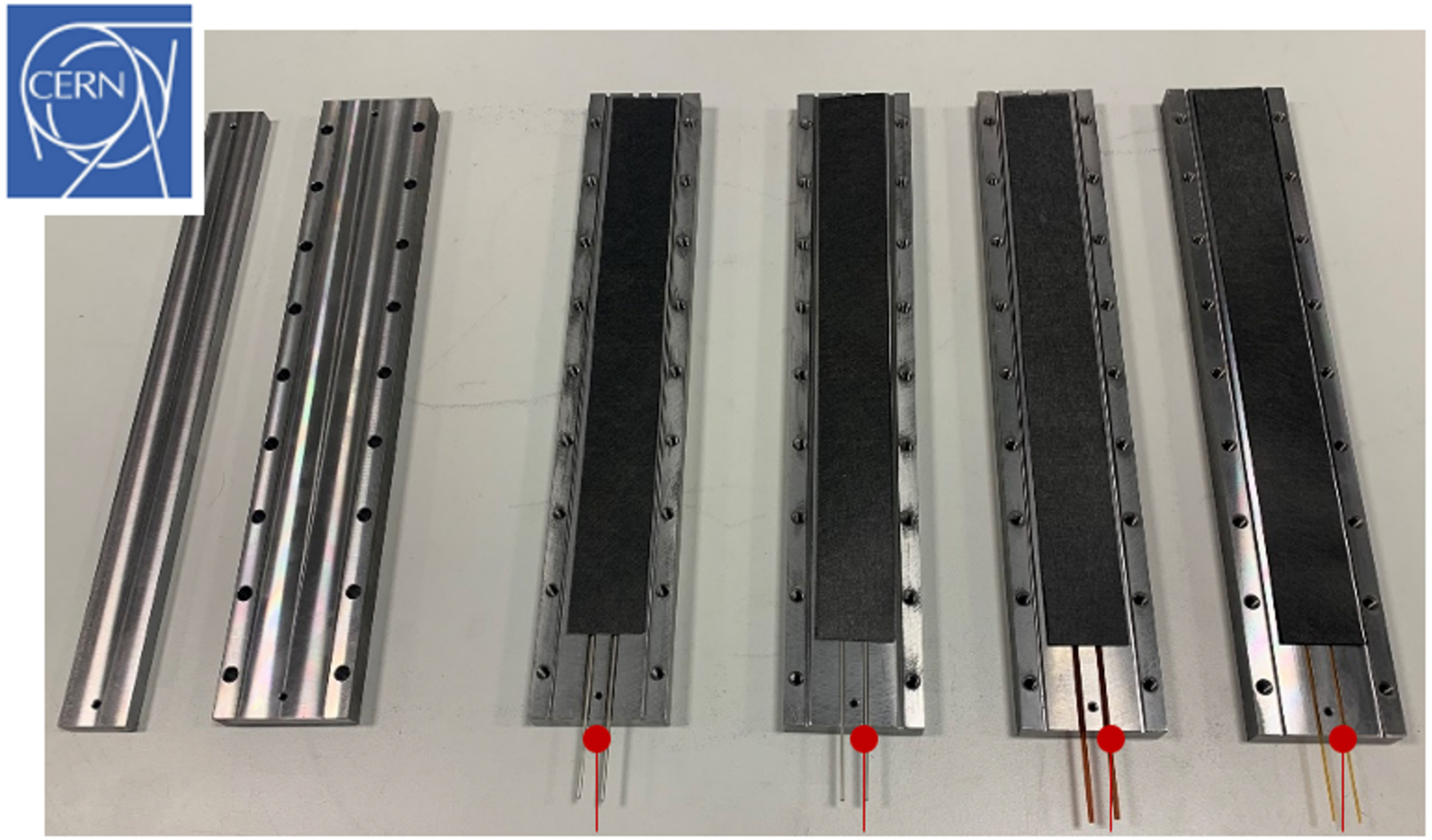

experimental resolution



# WP10: Advanced mechanics

## Ultra light structures

- **Carbon Cold Plate (CP) with embedded Kapton pipes**

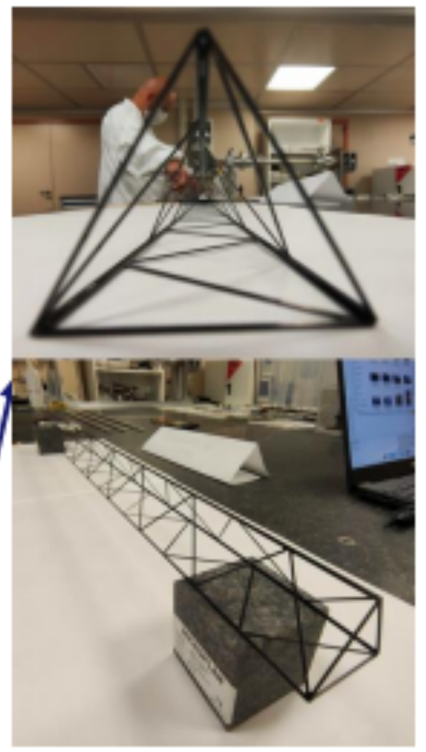




704 mm length truss for Belle 2 VTX upgrade
Total weight 5.8g, max sag 3-400um

INFN Pisa

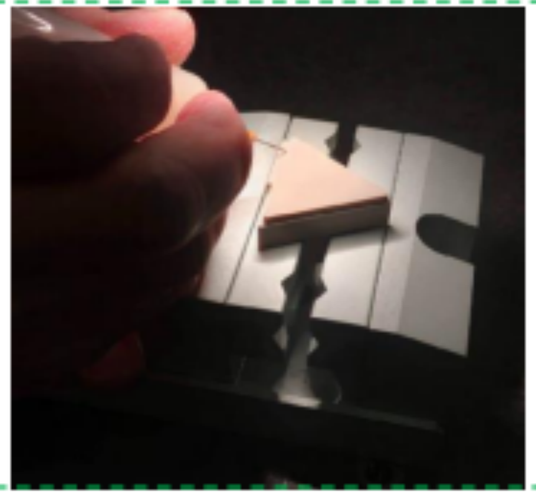
# WP10: ultralight CF ladders

INFN PISA



The total weight of the **704 mm** length carbon fiber truss is about 5.8 g.

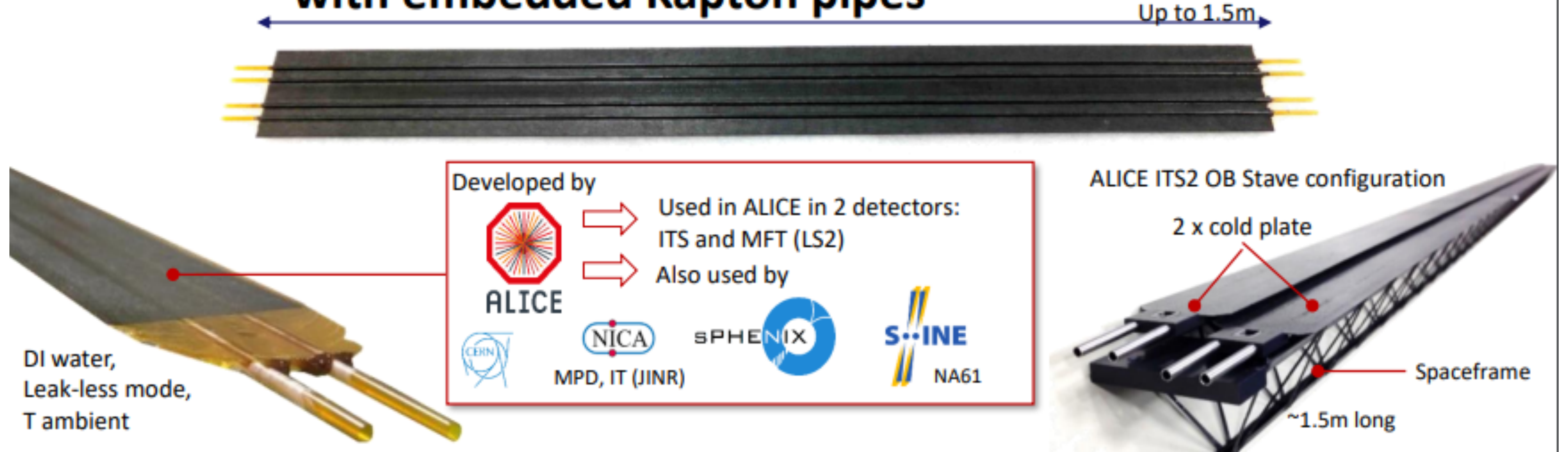
The glue accounts for 0.36 g (~6 %).



The weight of the peek end pieces is around **9.7 g each**

**oVTX L5 Mechanical structure prototype**

- **Carbon Cold Plate (CP) with embedded Kapton pipes**

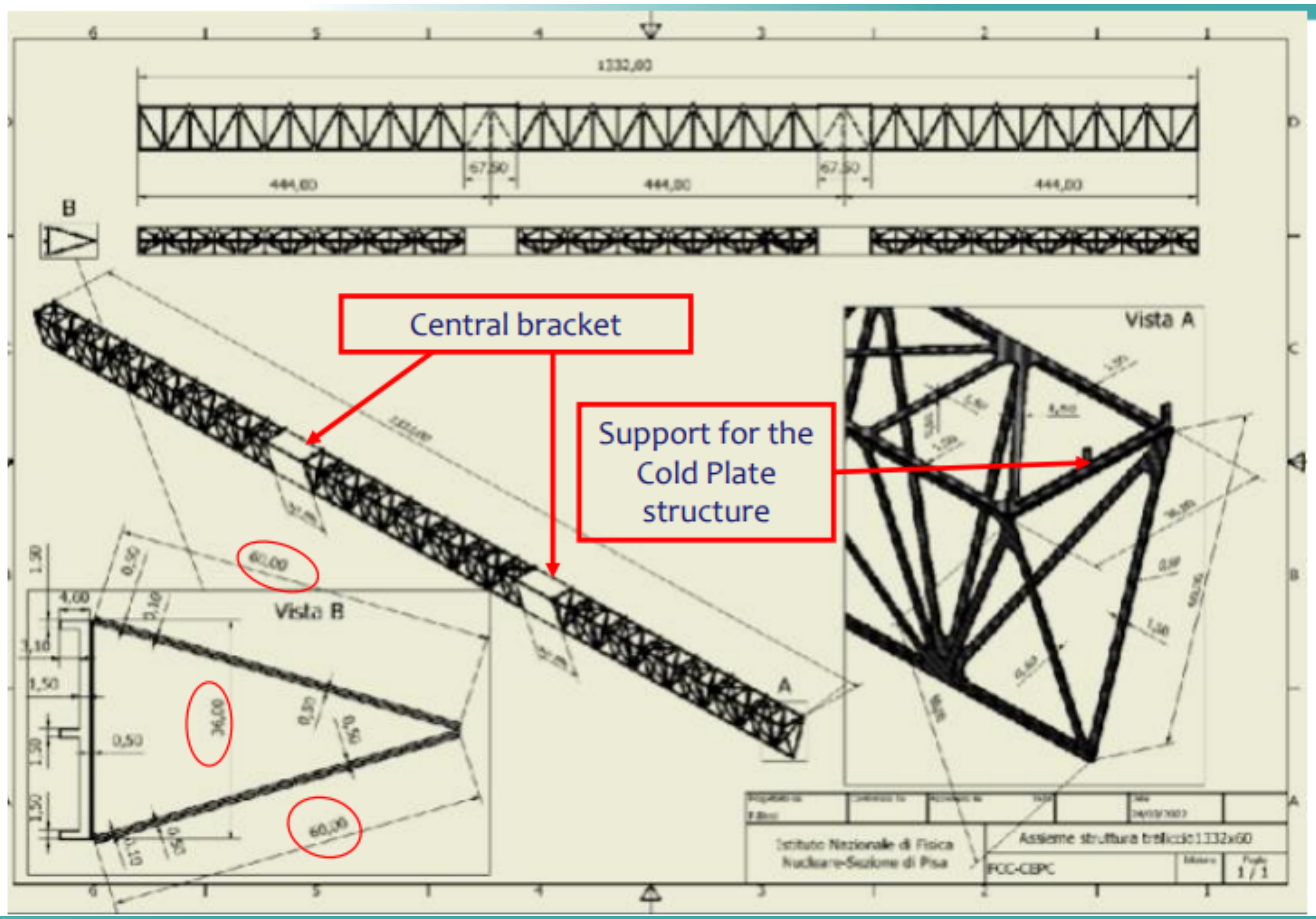



**Purpose:**

- Compatible with **high-pressure liquid coolants**: **Two-phase $CO_2$** refrigerant and new coolants (Krypton,…).
- Produce extended Carbon CP to **cover large surfaces**: understand their potentialities and limitations (considering minimum bending radius, pressure drop and pressure resistance limitations).

Collaboration between CERN and Workshape (composite company).

Long Stave realized gluing together the three 3single structures realized on the long gluing mask



# WP11

- **Task 11.2. Exploratory study of advanced CMOS (28 nm)**
  - AGH: propose to study ADCs and PLLs and participate to next LPGBT
  - CPPM: test vehicles for SEU/SET and TID studies (Expected submission Q3 2022)
  - Ubonn: study FPGA implementation for next generation chips and digital blocks
  - INFN PV: work started with FALAPHEL INFN project, propose to further study analog front-ends and IP blocks (Expected submission Summer 2022)

**Urgent need of 3-way NDA with TSMC and CERN**

**Indispensable to share expertise and blocks**

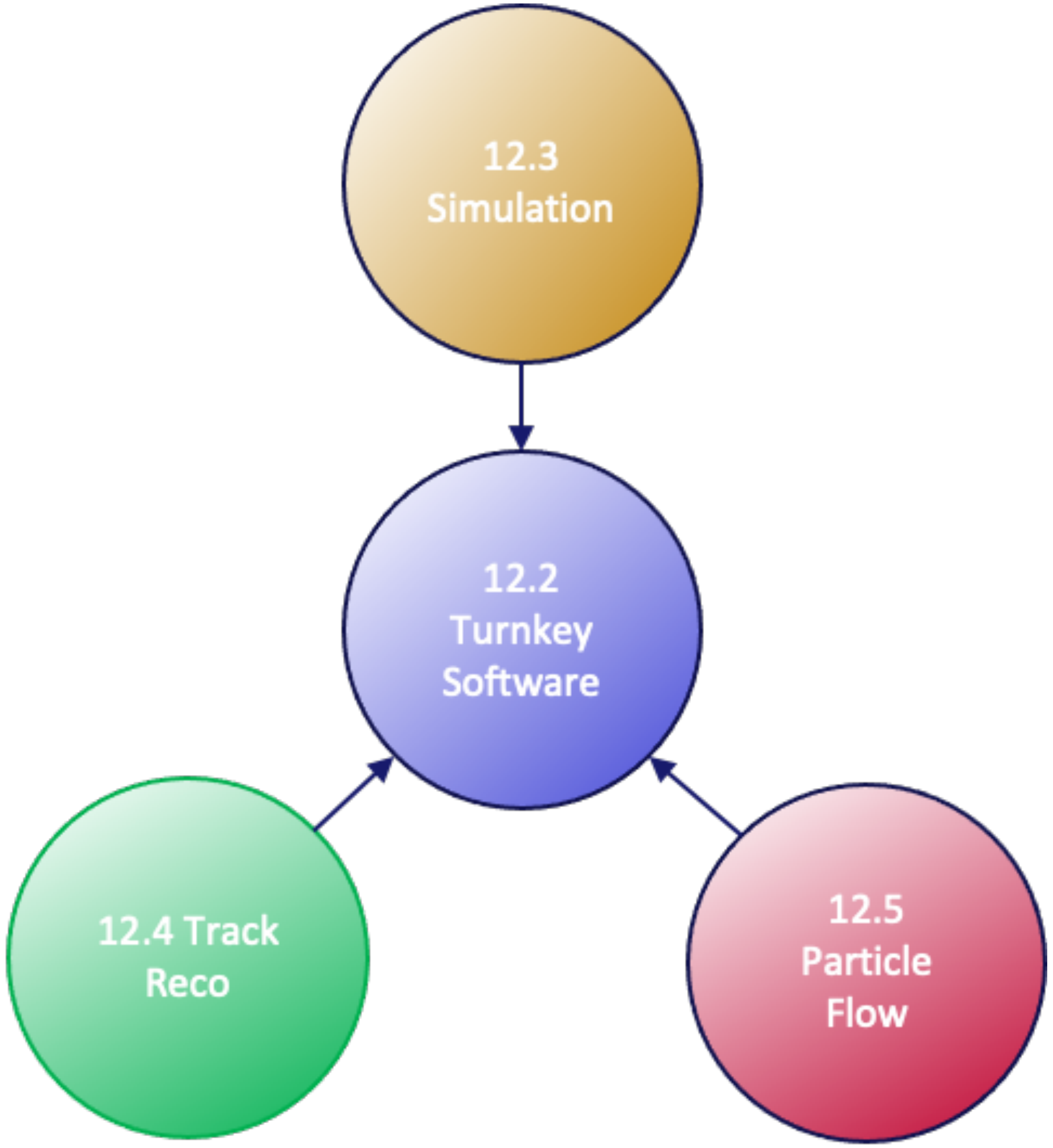
- **Task 11.3. Networking and ASICs for other WPs (65/130 nm)**
- AGH: FLAME/FLAXE readout ASIC for LUMICAL, TDC developments (10 ps)
- CNRS IP2I: plan to do cryogenic tests on low dropout regulator prototype
- CNRS OMEGA: AC LGADs timing chip readout in 130 nm submitted
- DESY/Heidelberg: study of SiPM tilebaords with KLAUS5/6 readout
- INFN BA/PV: MPGD 32ch readout ASIC in 130n 12b ADC + 100ps TDC, dual polarity, variable peaking time.
- INFN BO/LNF/TO: uRwell readout chip, based on TIGER chip. Test uRwell chambers with APV and TIGER. Design dedicated chip in 130n end 2022.
- INFN TO: engineering run in UMC110n for timing detectors
- WEEROC: SiPM readout/LIROC timing results.

**Propose to share an engineering run (end 2022) to get larger quantities of chips and equip detectors**

**Still open to additional detector requests…**

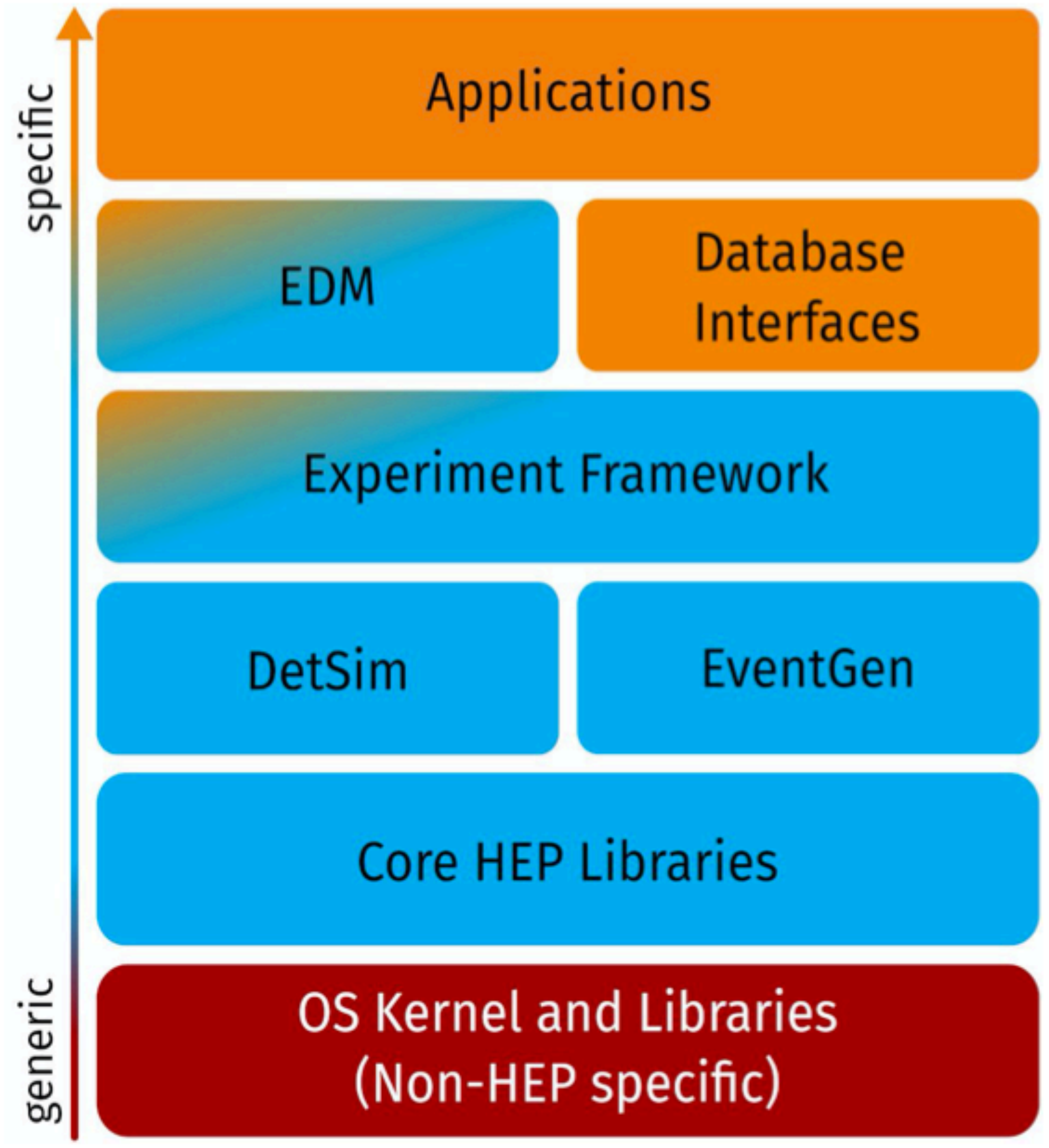
# WP12: structure

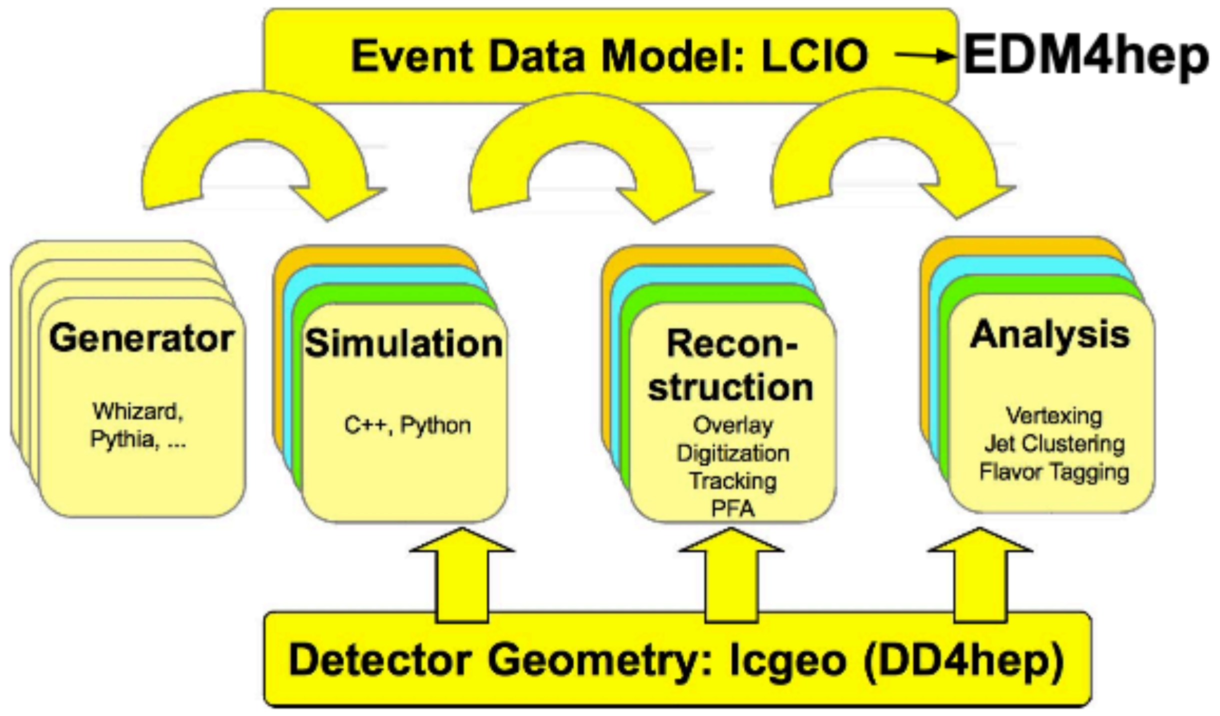
- Simulation
  - Fast simulation of calorimeters
  - Adopt and develop the latest techniques in parametric and machine learning approaches
- Track Reconstruction
  - Advanced tracking tools for speed and physics performance, ACTS
  - ML based track reconstruction toolkit for triple-GEM and u-RWELL detectors
- Particle Flow
  - Continue to develop state of the art algorithms for neutrino and linear colliders: PandoraPFA, APRIL
  - Develop PF for dual readout calorimeters
- Turnkey Software
  - Integrate software into a working and validated stack
  - Flexibility to rapidly prototype different detector options
  - Management of heterogeneous resources



# WP12: turnkey software

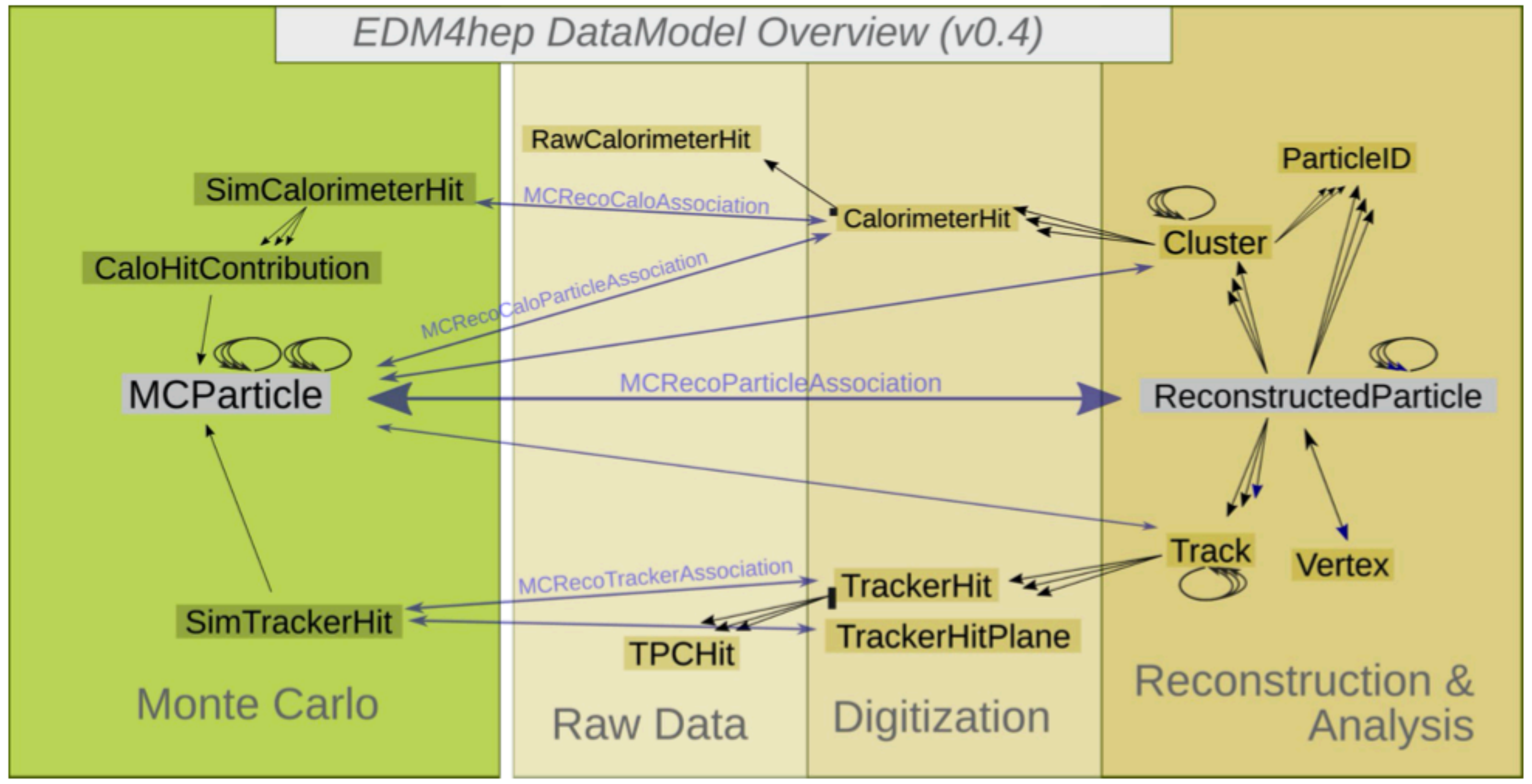
- Key4HEP: turnkey software stack for all future collider projects
- Take existing tools where possible
  - A lot of existing software from the shared **iLCSoft** developed by ILC and CLIC
- All major players involved: CEPC, CLIC, FCC, ILC, EIC
- Provide a complete data processing framework
  - Shared components reduce overhead for all users
- Supported by HSF, CERN EP R&D and AIDAinnova

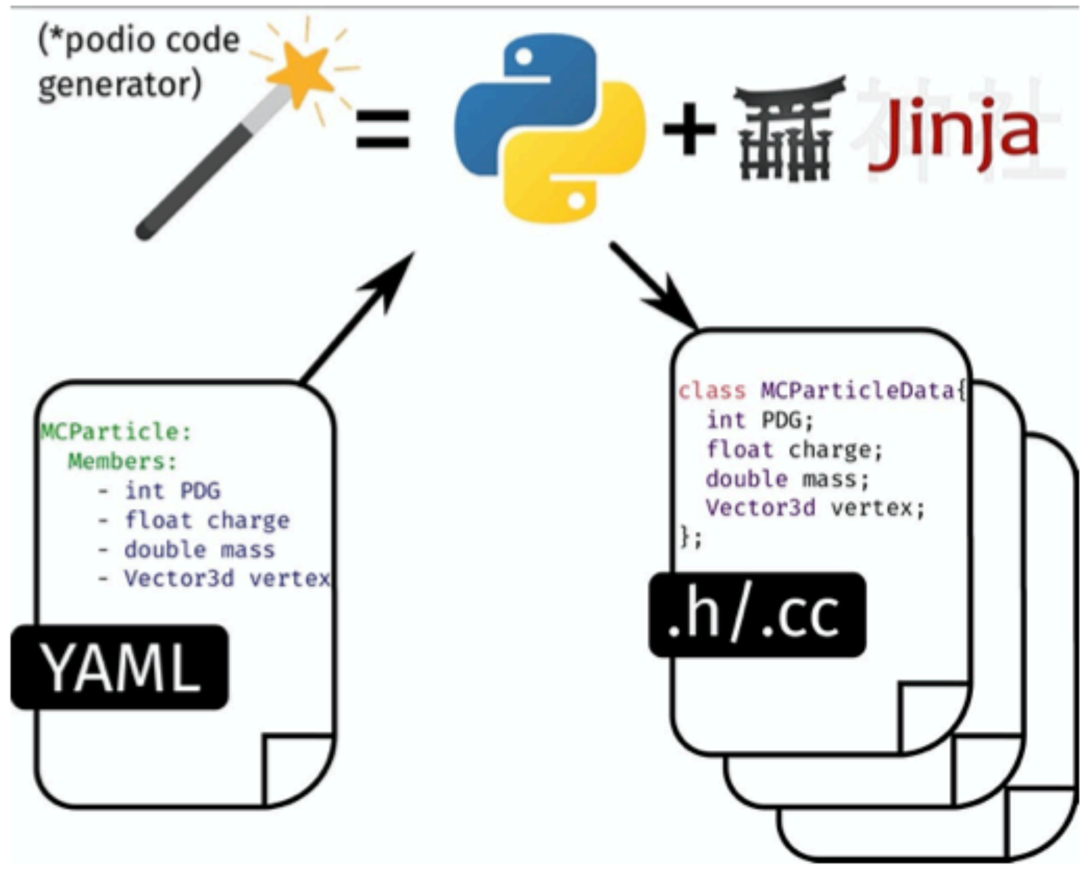


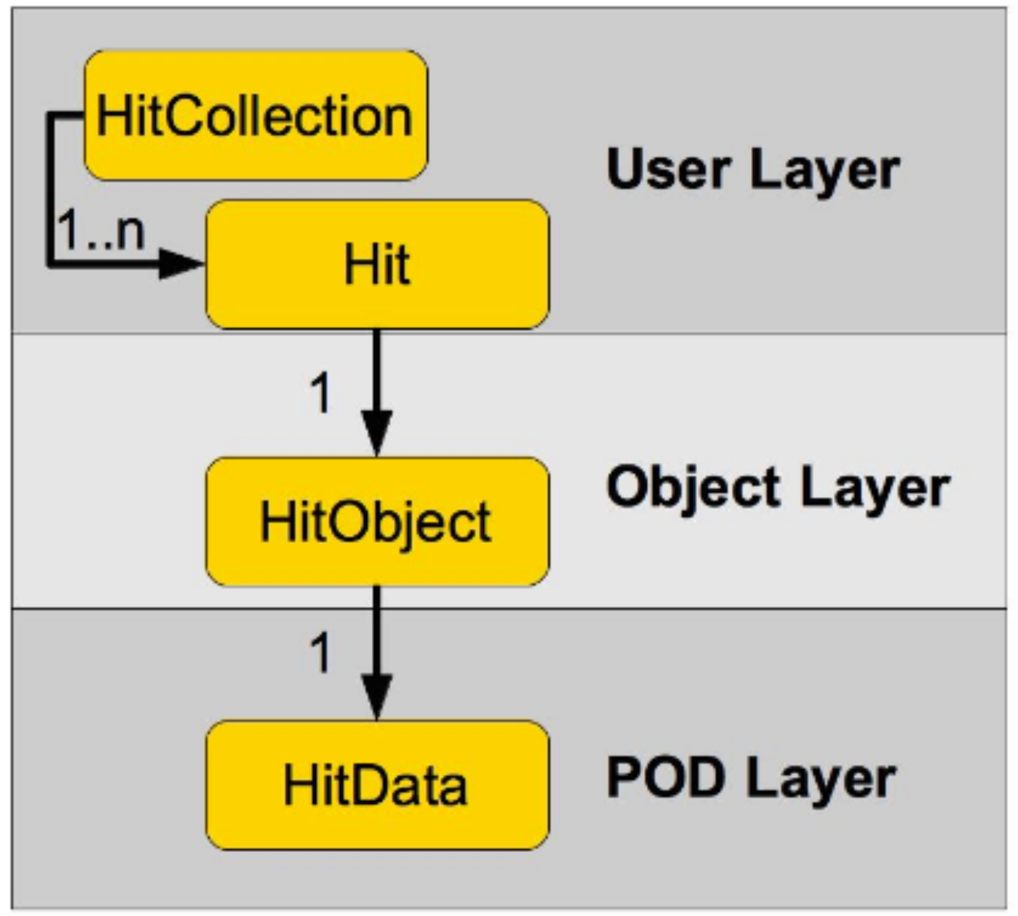



# WP12: turnkey software

- **EDM4hep** defines the common language for all **Key4hep** components to communicate
  - Heavily inspired by **LCIO** successfully shared by ILC and CLIC
  - Additional novel ideas from fcc-edm
- Generated by the **PODIO** EDM toolkit
  - *Main functionality exists*
  - *Aiming for prod. Release v1.0*
  - *Need schema evolution, event frames and thread safety ....*



# WP13: Prospective and Technology-driven R&D

Prospective and Technology-driven Detector R&D: → support blue-sky research

Call for proposals in 2021: 550 kEUR in total (+25% overheads), 2-4 projects, 3-year projects, small consortia, require modest matching funds.

Received 15 proposals (novel semiconductor detectors - 6, rad hard silicon – 3, gaseous detectors – 2, light detection ar scintillators - 3, DAQ - 1)

Selection: committee a combination of WP conveners and external experts: Felix Sefkow, Daniela Bortoletto, Paolo Giacomelli, Peter Križan, Christophe de la Taille, Christian Joram, Kevin Einsweiler, Niko Neufeld, Bernhard Ketzer. Two phases, second phase with interviews.

Selected 4 projects:

- **Thin Silicon Sensors for Extreme Fluences**
- **The Silicon Electron Multiplier, a new approach to charge multiplication in solid state detectors**
- **Development of fine-sampling calorimeters with nanocomposite scintillating materials**
- **Wireless Data Transfer for High-Energy Physics Applications**

# EURO-LABS project

EURO-LABS — EUROPEAN LABORATORIES FOR ACCELERATOR BASED SCIENCES

**Governing Board (GB)**
*One representative from each beneficiary of the project*

**WP1**
**Management team (MT)**
*Scientific coordinator*
*3 Deputy coordinators*
*Project coordinator*

**Steering Committee (SC)**
*Scientific coordinator*
*3 Deputy coordinators*
*Project coordinator*
*Work Package coordinators*

***Integrated access***
***Service improvements***

**WP2**
**Access for Physics**
*Stable Ion beams*
*Radioactive Ion beams*
*Neutron beams*
*Theoretical support*
*Service improvements*

**WP3**
**Access for Accelerators**
*Material testing*
*Technology infrastructures*
*Electron beams*
*Applications*

**WP4**
**Access for Detectors**
*Test beams*
*Detector characterization*
*Irradiation facilities*
*Service improvements*

**WP5**
**Open, Diverse and Inclusive Science**
*Diversity and dissemination*
*Open data*
*Machine learning*
*Training*

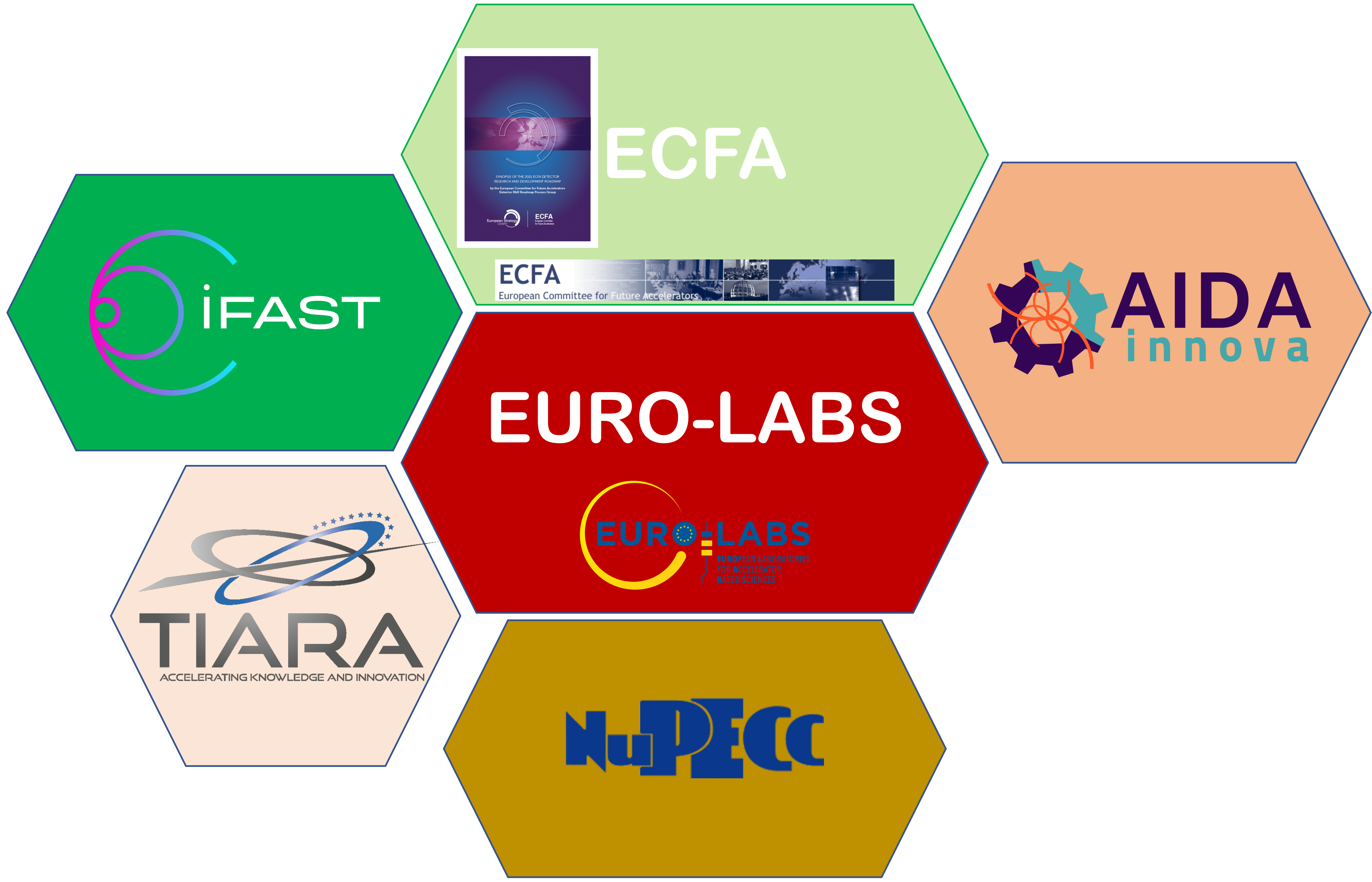
***Sharing Knowledge and Technology in an Open, Diverse and Inclusive manner***

EURO-LABS is a project that mostly provides funding for Transnational Access (TA) to Research Infrastructures (RI).
For us this means test beams and irradiation facilities.

Total EURO-LABS EU funding: **~15 M€**

- **Start of the Project: 01/09/2022**
- **Duration: 01/09/2022 - 31/08/2026**
- **Budget for WP4: ~3.2 M€**

**First EU project that brings together Nuclear Physics, HEP Accelerators and HEP Detectors**

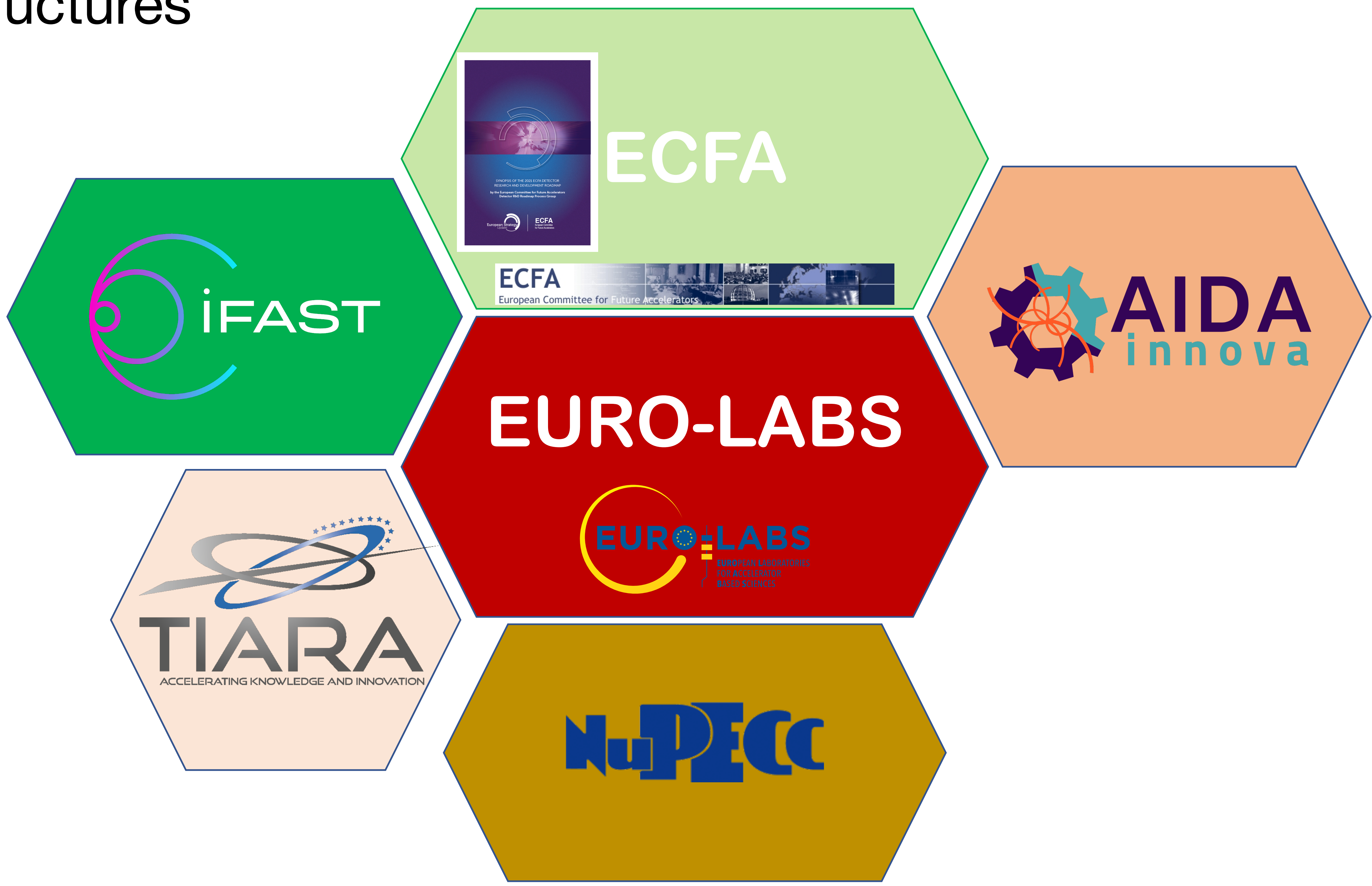



**EURO-LABS** [presentation at  ECFA plenary meeting]

**EURO-LABS** website: https://web.infn.it/EURO-LABS/

**EURO-LABS offers**

- Reimbursement of travel expenses to many of the Research Infrastructures
- Reimbursement of lodging expenses at RIs
- Support at the laboratories hosting the RI
- Service improvements for future research and training of new users

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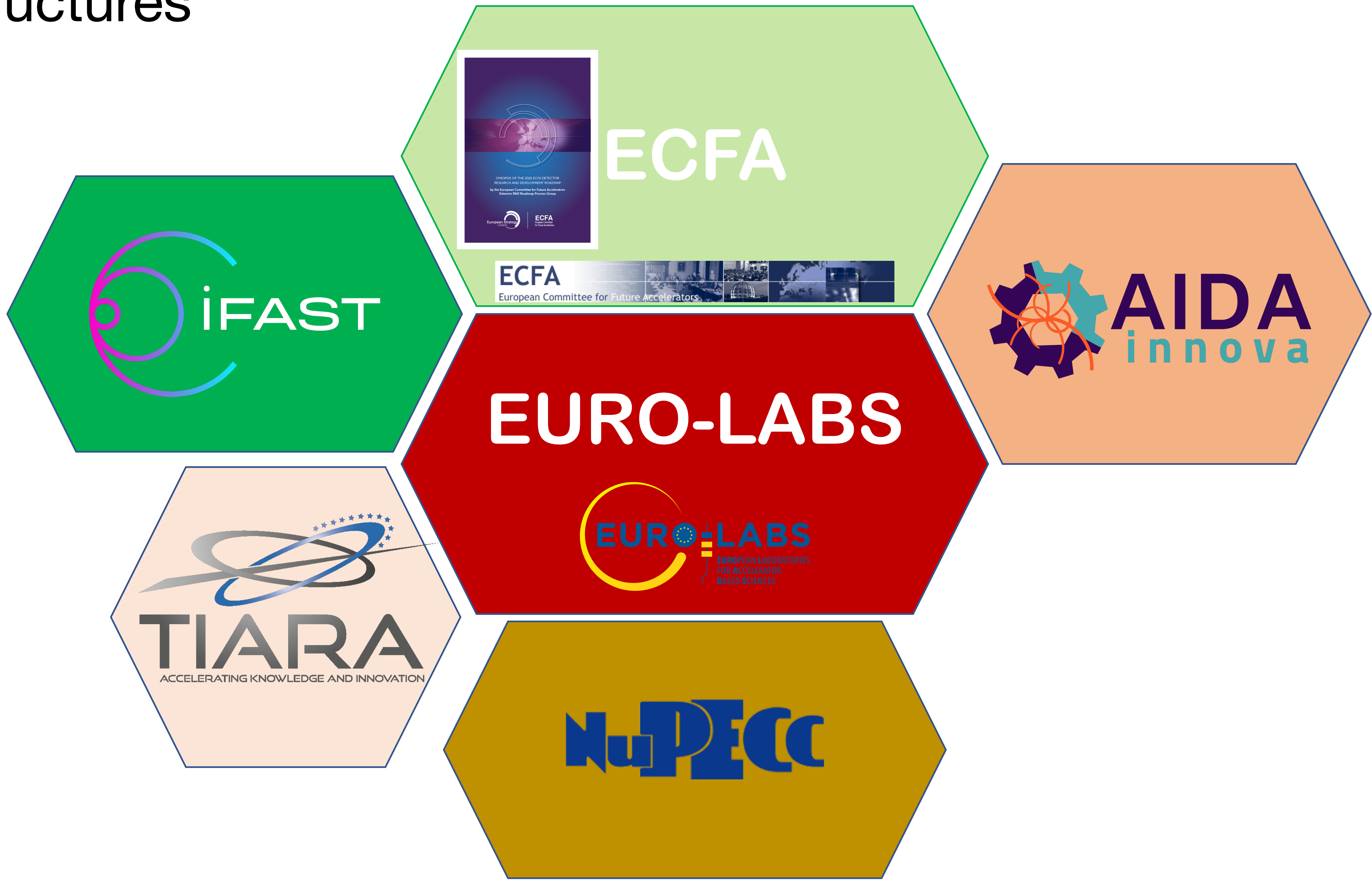


**Who can apply to EURO-LABS TA**

- European research groups
- Non-EU research groups up to 20% of the overall budget
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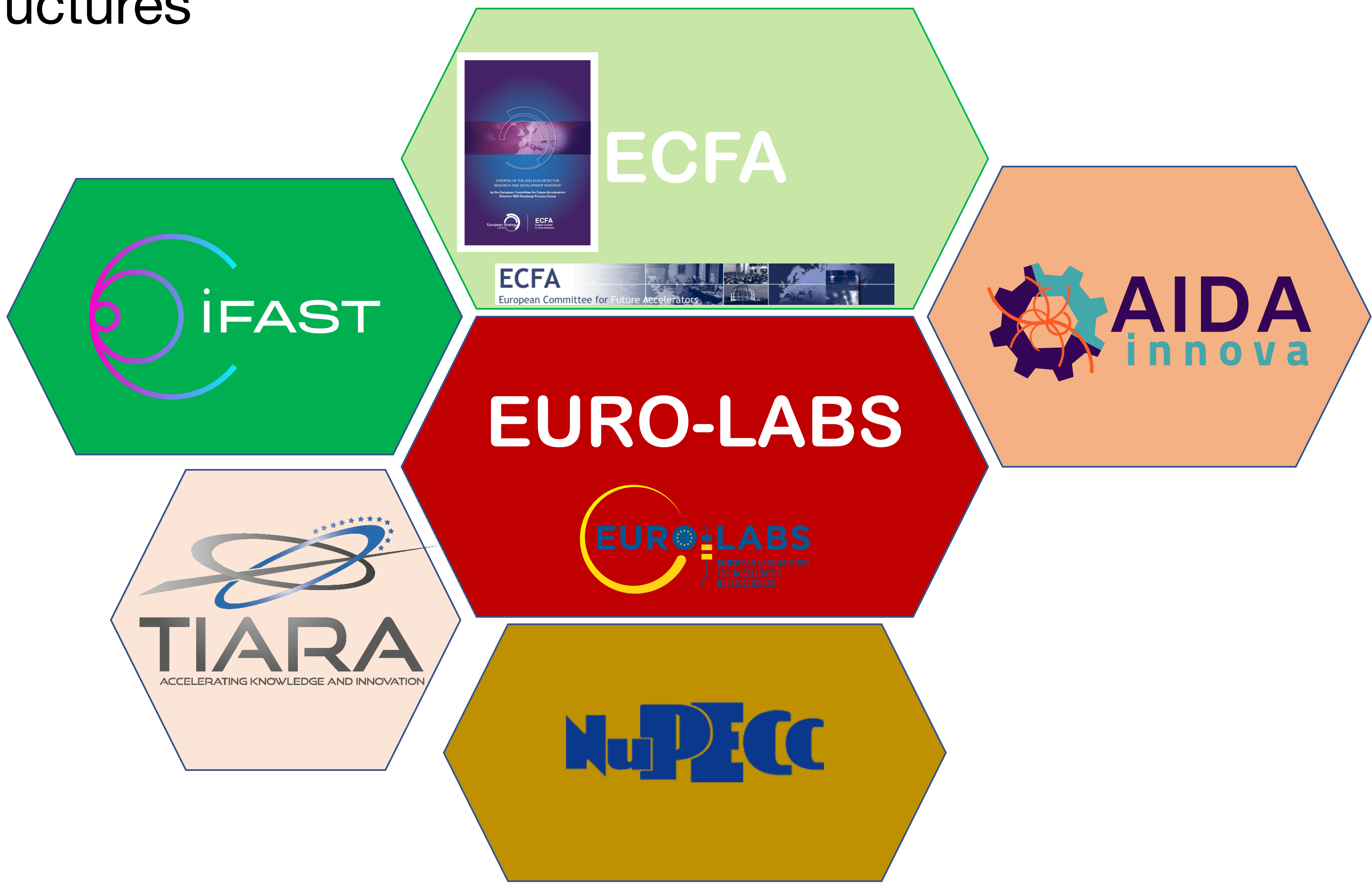


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**How to apply**:

- Application Procedure: https://web.infn.it/EURO-LABS/how-to-apply-for-transnational-access/

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# EURO-LABS Research Infrastructures

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  - US colleagues  are eligible for funding
- **Would be delighted to have increased collaboration with US colleagues**

# Backup

# Genesis of AIDAinnova

**Consultation with the community**

- Call for Expressions of Interest in May 2019
- Overwhelming response: 162 EoIs

**Structuring the Input: Topic Convenors***

- Reports at 1st Open Meeting September 4, 2019

**Proposal Structure, Work Package definition**

- Presented at 2nd Open Meeting October 23, 2019

**Deadline March 17, 2020** (postponed to May 14)

- proposal was submitted within deadline, and resubmitted with minor improvements

**Approval November 3, 2020**

- Prepare Grant Agreement, Consortium Agreement

**Start: April 1, 2021**

**CERN-EU Office:**

**Livia Lapadatescu**
**Sabrina El Jacoubi**
Coralie Hunsicker
Laëtitia Veyrat

**Hard and intense work by many people!**

**Proposal Preparation Team:**

**Felix Sefkow (DESY)**
AIDA-2020 Scientific Coordinator
**Daniela Bortoletto (U Oxford)**
AIDA-2020 Deputy Coordinator
**Giovanni Calderini (LPNHE Paris)**
AIDA-2020 Governance Board Chair
**Paolo Giacomelli (INFN Bologna)**
AIDA-2020 Deputy Coordinator
**Svetlomir Stavrev (CERN)**
AIDA-2020 Administrative Coord.
**Anne Dabrowski (CERN)**
CERN representative in the PPT
**Thomas Bergauer (HEPHY Vienna)**
**Lucie Linssen (CERN)**
**Ivan Vila Alvarez (CSIC Santander)**
**Morgan Wascko (IC London)**

# WP5 Depleted Monolithic Active Pixel Sensors

- Sensor spatial resolution
  - Key requirement for Higgs factories: $\sigma_{sp} \lesssim 3$ µm
  - ALICE-ITS3 ~5 µm, Belle II 5-10 µm

⇐ critical benefit of 65nm for task 5.2

- Detection layer with material budget: 0.05 to 0.15 % $X_0$
  - Achieved through large stitched & curved sensors
    - Key requirement for ALICE-ITS3, strong interest for Higgs factories
  - Low power <<100 mW/cm$^2$, compatible with air-cooling
    - Important for Higgs factories & ALICE-ITS3

⇐ possible with other techno BUT attractive in 65nm due to 12" wafer size

⇐ benefit of 65nm, critical for task 5.2

- Hit rate and time resolution (highly dependent on experiment)
  - Few 10 MHz/cm$^2$/s for Higgs-factories
  - > 100 MHz/cm$^2$/s for Belle II
  - Time resolution ~ns for CLIC
  - Specific for PID or 4D tracking: time resolution in 10-100ps range

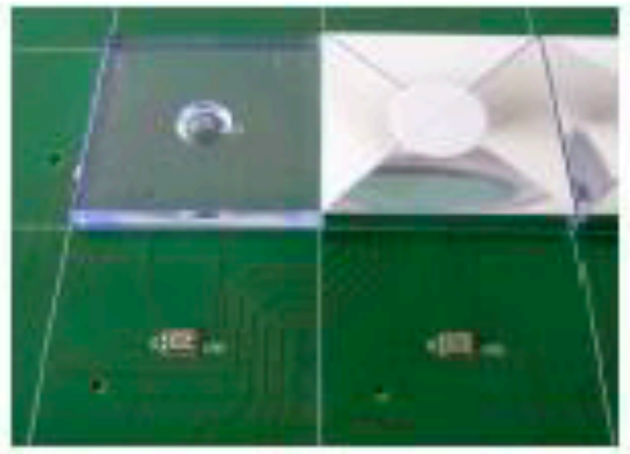
⇐ benefit of 65nm, critical for task 5.3

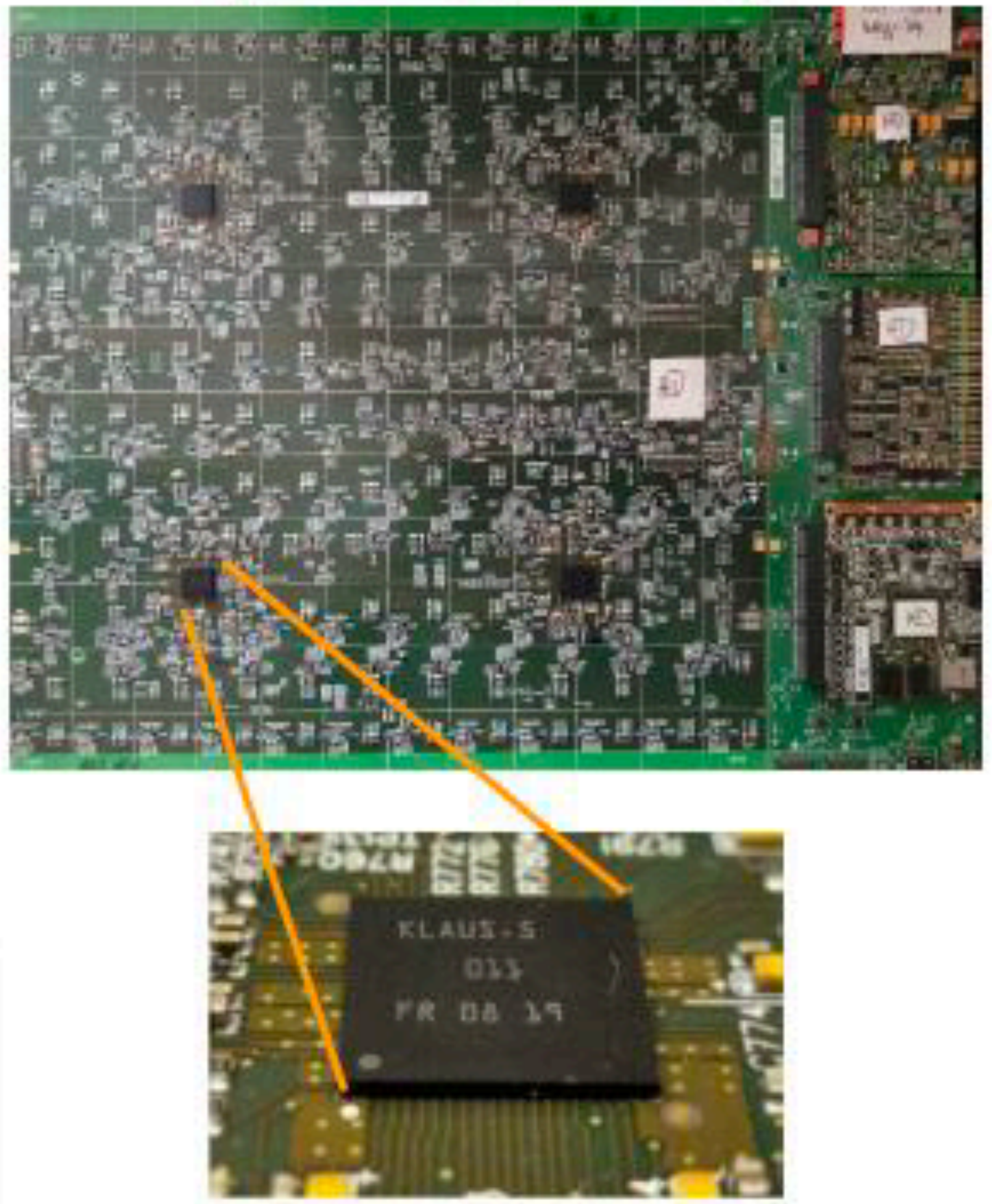
- Radiation tolerance to NIEL fluence
  - Up to $10^{12}$ $n_{eq(1MeV)}$/cm$^2$ for task 5.2
  - Mimimum $10^{15}$ $n_{eq(1MeV)}$/cm$^2$ and beyond for task 5.3

⇐ 65nm tolerance to be checked, critical for task 5.3

# WP11

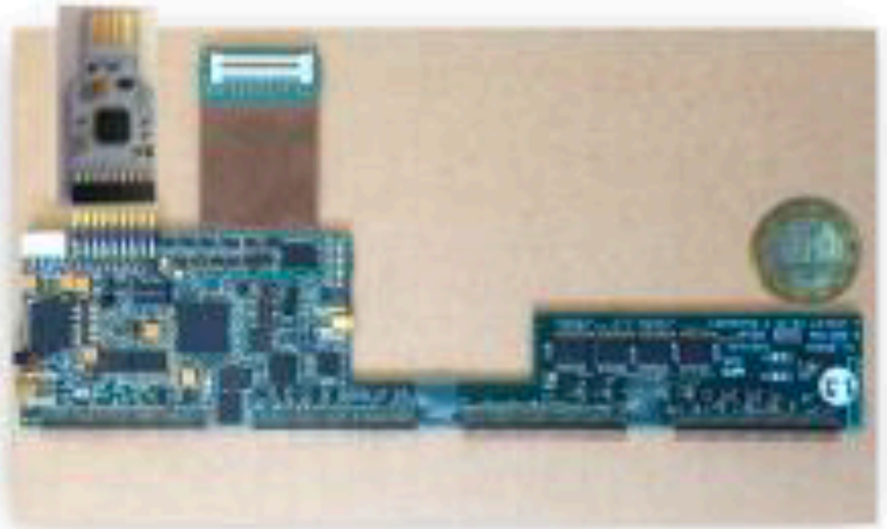
## DESY in WP11 (and WP8)





- Development of a highly granular SiPM-on-tile calorimeter
  - Originally for the hadron calorimeter of a detector at a linear electron-positron collider
  - baseline or option for a detector at any future - linear or circular - Higgs factory
  - Technology has been adopted for the CMS calorimeter endcap upgrade (HGCAL)
  - Technology is under discussion for ECAL of DUNE Near Detector

- Future R&D in AIDAinnova:
  - Improved timing: readout electronics for KLauS ASICs
    - First version in AIDA2020 for KLauS5
  - Homogenized readout electronics with ECAL for pulsed and continuous operation (WP8)



# EURO-LABS project

The EUROpean Laboratories for Accelerator Based Sciences (**EURO-LABS**) project aims to provide unified Transnational Access to leading research infrastructures across Europe. Taking over from previously running independent programmes (**ENSAR2**, **AIDAinnova**, **I.FAST**) it brings together the nuclear physics, the high-energy accelerator, and the high-energy detector R&D communities.

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With **33 partners** (**25 beneficiaries** and **8 associated partners**) from European and non-EU countries, EURO-LABS forms a large network of laboratories and institutes ranging from modest sized test infrastructures to large-scale ESFRI facilities such as SPIRAL2. Within this large network, EURO-LABS will **ensure diversity** and **actively support researchers** from **different nationalities, gender, age, grade,** and **variety** of **professional expertise**.

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At the **kick-off meeting**, held in **Bologna** from the **3rd to 5th October**, presentations offered a detailed overview of the research infrastructures and facilities providing particle and ion beams at energies from meV to GeV.