AIDAinnova:
general, activity in Genova

C. Gemme *(INFN Genova)*

Gr1 - Genova

28 May 2020

Inputs:

- Talks by Nadia Pastrone e Paolo Giacomelli, CSN1 February 2020;
- Submitted proposal

History

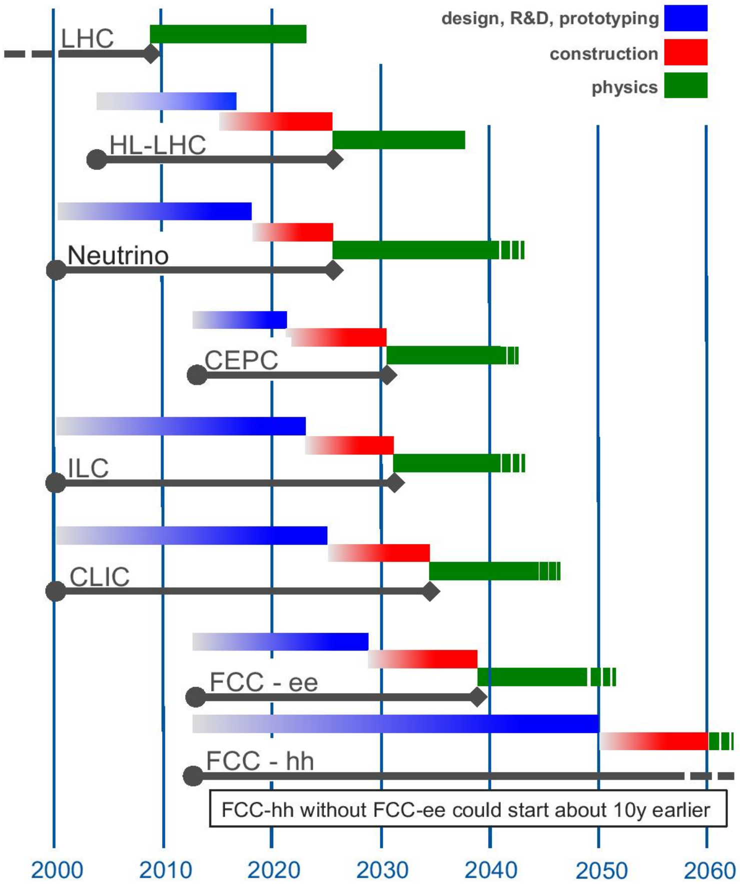
- FP6: EUDET: 2006-2010
  - Detector development for linear collider
- FP7: AIDA: 2011-2014
  - Detector development for LHC upgrades and linear colliders
  - Project-specific work packages
- FP8: AIDA-2020 started in May 2015
  - Common LC and LHC work packages
  - New communities: large cryogenic neutrino experiments, new topics
  - New innovation measures, with industry
- All projects have a strong leverage on **matching funds**

- AIDA2020 – completed on April 30, 2020. Genova had contributions in CMOS and Interconnections WPs.
  - Darbo local responsible
  - Gemme, Rovani staff partecipants
  - Funding for Andrea Gaudiello, Alessio Volpe, Alessandro Lapertosa

Strategy

- European strategy for particle physics
  - Process led by CERN Council
  - Input from global community
- Updates 2012-13, 2019-20

- Future projects have many detector R&D issues in common
- European Calls initiatives unique in creating coherence at European level
  - Closely follow European Strategy



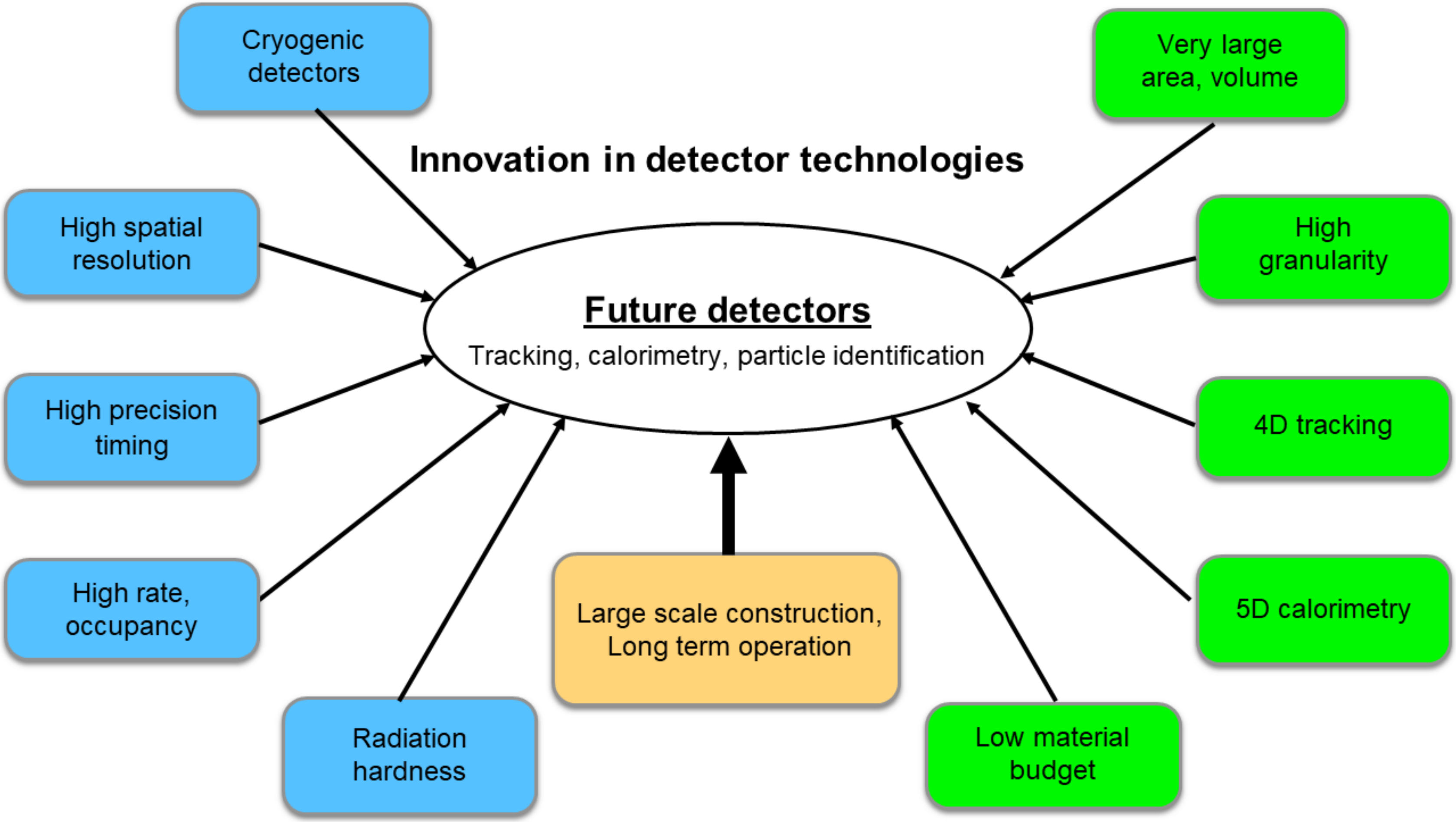
The new proposal

- H2020-INFRAINNOV-2019-2020: INFRAINNOV-04-2020: Innovation pilots
  - Innovation in light source technologies
  - **Innovation in detector technologies**
  - Innovation in accelerator technologies
- Starting from **160 EoIs** collected in early summer 2019, Proposal submitted on May 13th 2020

Overall objectives

- **To explore applications of novel technologies** such as integrated CMOS sensors, additive manufacturing or machine learning, and to assess their performance for the challenging needs of future or upgraded HEP experiments
- **To strengthen the synergies between different projects and communities**, with **added value** such as optimal use of modern concepts in **common software frameworks and common prototyping** using latest technologies for microelectronics.
- **To increase the efficiency and quality of the beam test and irradiation facilities** by supporting their upgrades and improvements through dedicated Innovation Activities
- **To render European Industry ready for large series production** of HEP detectors

Technology challenges



Innovation in detector technologies

Future detectors

Tracking, calorimetry, particle identification

Cryogenic detectors

High spatial resolution

High precision timing

High rate, occupancy

Radiation hardness

Large scale construction, Long term operation

Low material budget

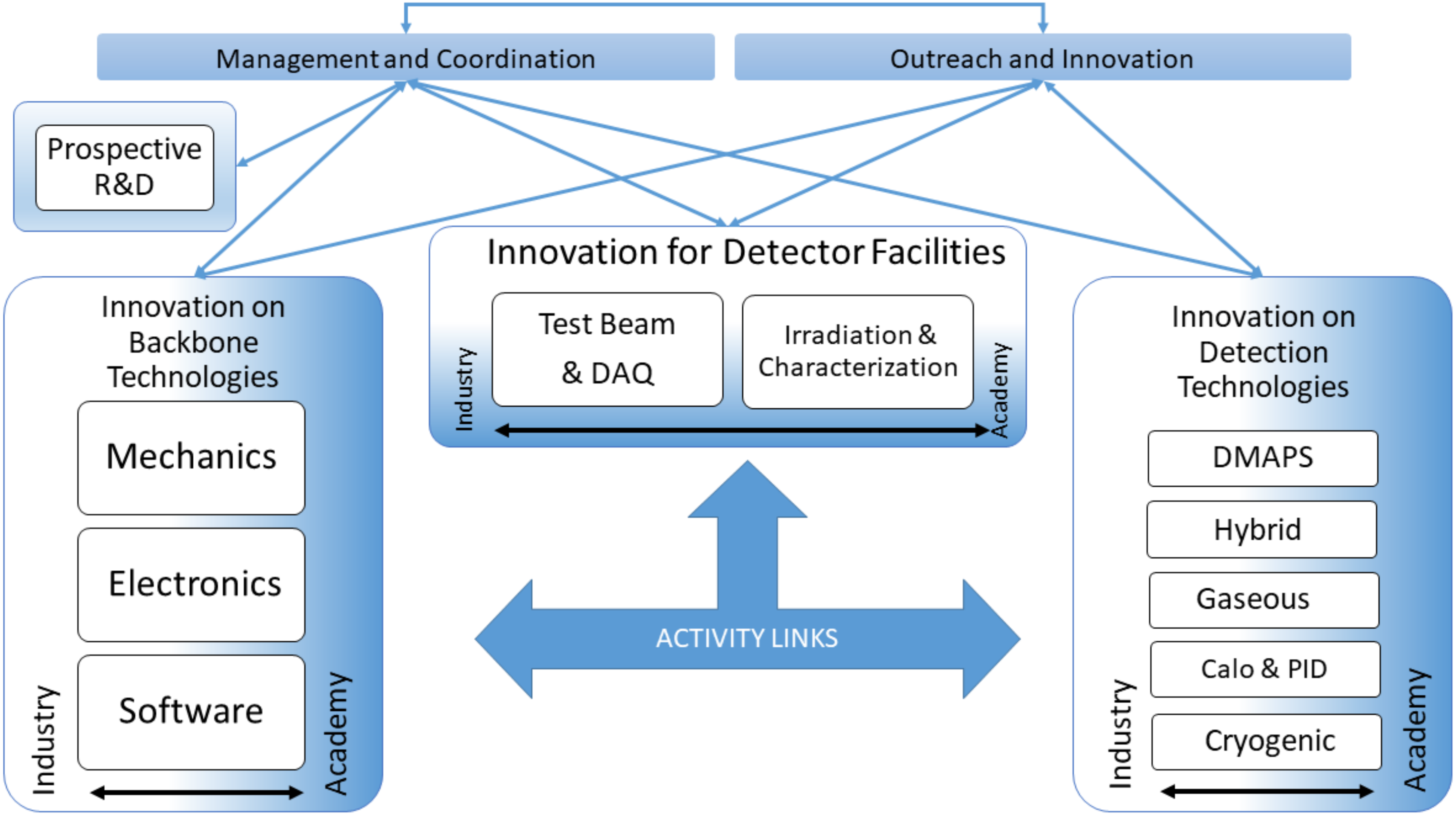
5D calorimetry

4D tracking

High granularity

Very large area, volume

Work Package structure and interactions



Management and Coordination

Outreach and Innovation

Prospective R&D

Innovation for Detector Facilities

- Test Beam & DAQ
- Irradiation & Characterization

Industry ↔ Academy

Innovation on Backbone Technologies

- Mechanics
- Electronics
- Software

Industry ↔ Academy

Innovation on Detection Technologies

- DMAPS
- Hybrid
- Gaseous
- Calo & PID
- Cryogenic

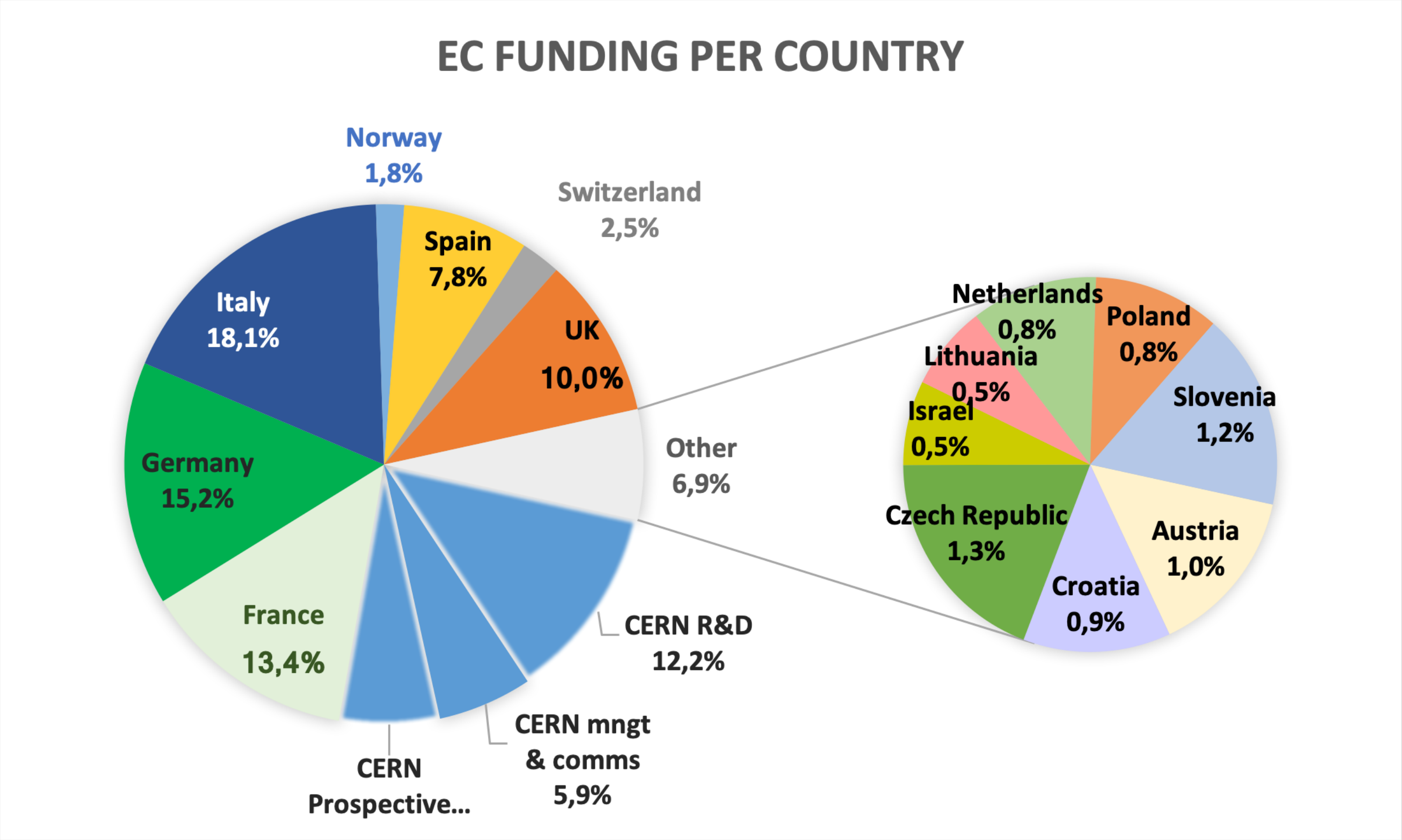
Industry ↔ Academy

ACTIVITY LINKS

Resources

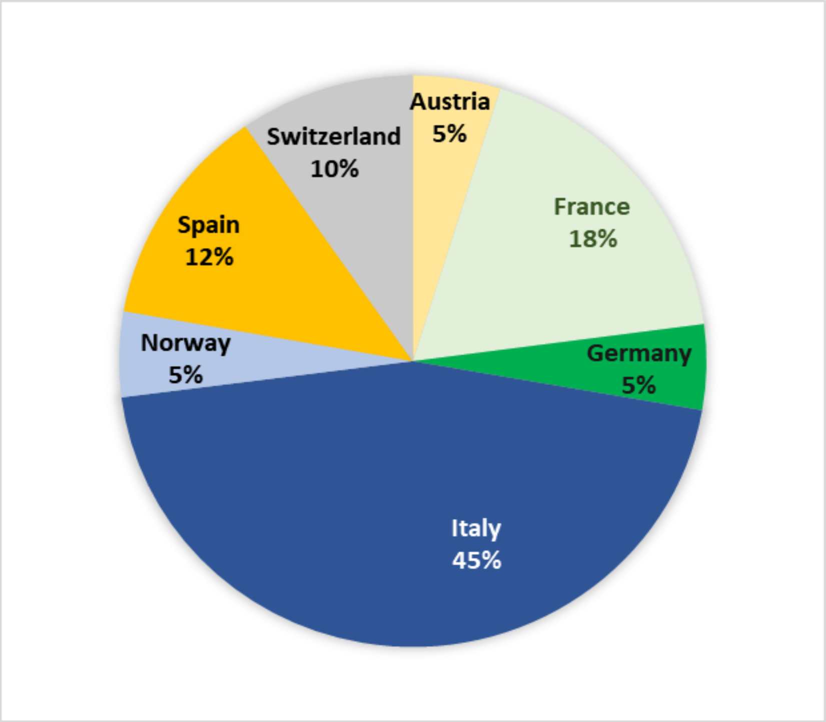
- Full costs budget AIDAinnova = ~ 30 M€
- EC contribution = 10 M€

→ Difference are Matching funds



EC funding for Industry+RTOs

- Italy is by far the largest beneficiary for Industry+RTOs!
  - FBK, CAEN, ELTOS



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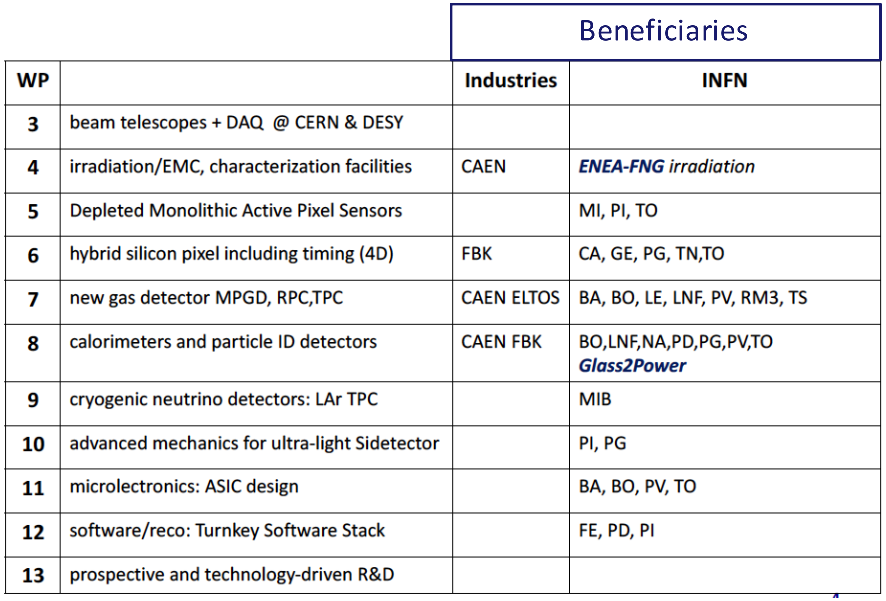
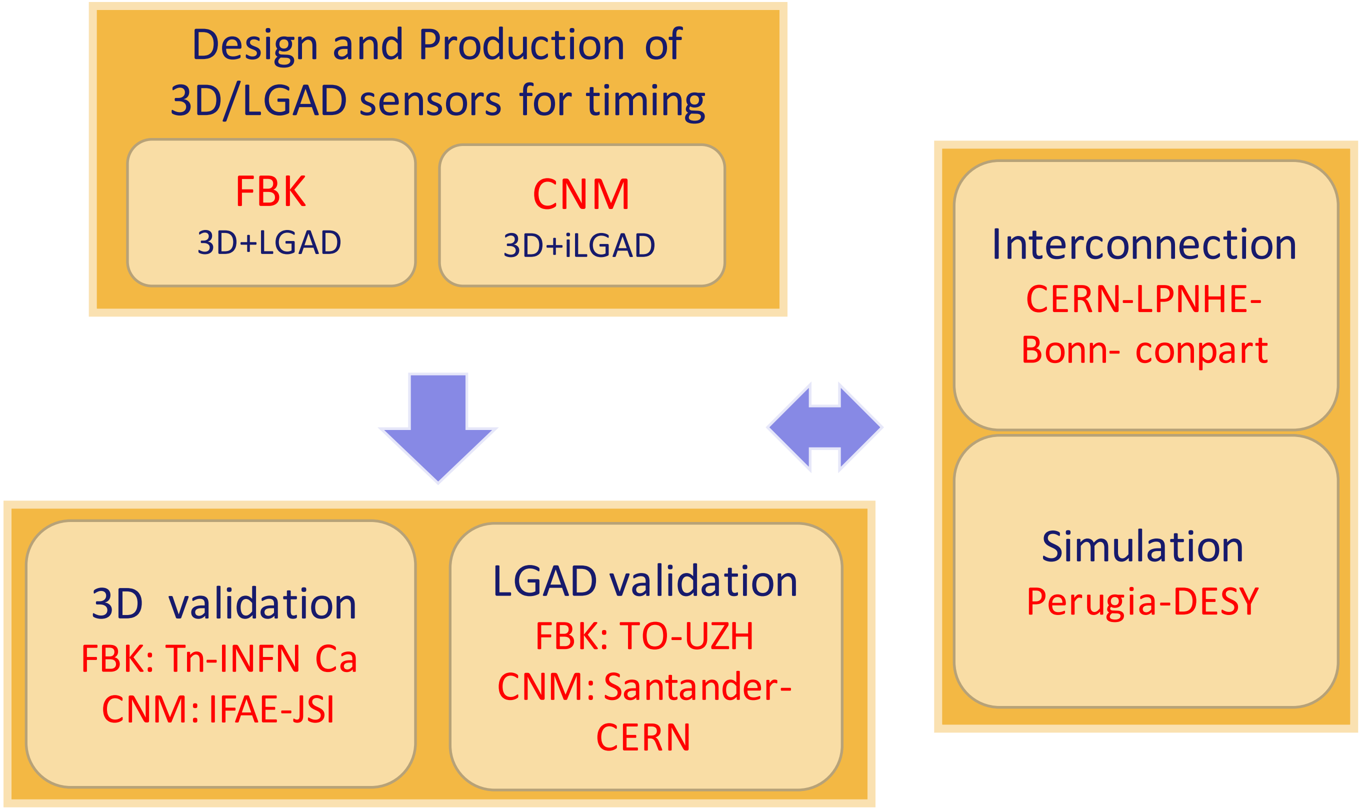


		Beneficiaries	
WP		**Industries**	**INFN**
3	beam telescopes + DAQ @ CERN & DESY		
4	irradiation/EMC, characterization facilities	CAEN	***ENEA-FNG*** *irradiation*
5	Depleted Monolithic Active Pixel Sensors		MI, PI, TO
6	hybrid silicon pixel including timing (4D)	FBK	CA, GE, PG, TN,TO
7	new gas detector MPGD, RPC,TPC	CAEN ELTOS	BA, BO, LE, LNF, PV, RM3, TS
8	calorimeters and particle ID detectors	CAEN FBK	BO,LNF,NA,PD,PG,PV,TO ***Glass2Power***
9	cryogenic neutrino detectors: LAr TPC		MIB
10	advanced mechanics for ultra-light Sidetector		PI, PG
11	microlectronics: ASIC design		BA, BO, PV, TO
12	software/reco: Turnkey Software Stack		FE, PD, PI
13	prospective and technology-driven R&D		

Budget for ~2y postdoc/site

- INFN Scientific contact: Nadia Pastrone (To)
- The members of the Project Management Team and the Steering Committee will be approved by the Governing Board.
  - P. Giacomelli (Bo) in PMT
- 4 WP coordinators:
  - C.Gemme (GE, WP6), S.Dalla Torre (TS,WP7), R. Ferrari (PV, WP8), A.Rivetti (TO, WP11)

WP6 overview



Design and Production of 3D/LGAD sensors for timing

FBK
3D+LGAD

CNM
3D+iLGAD

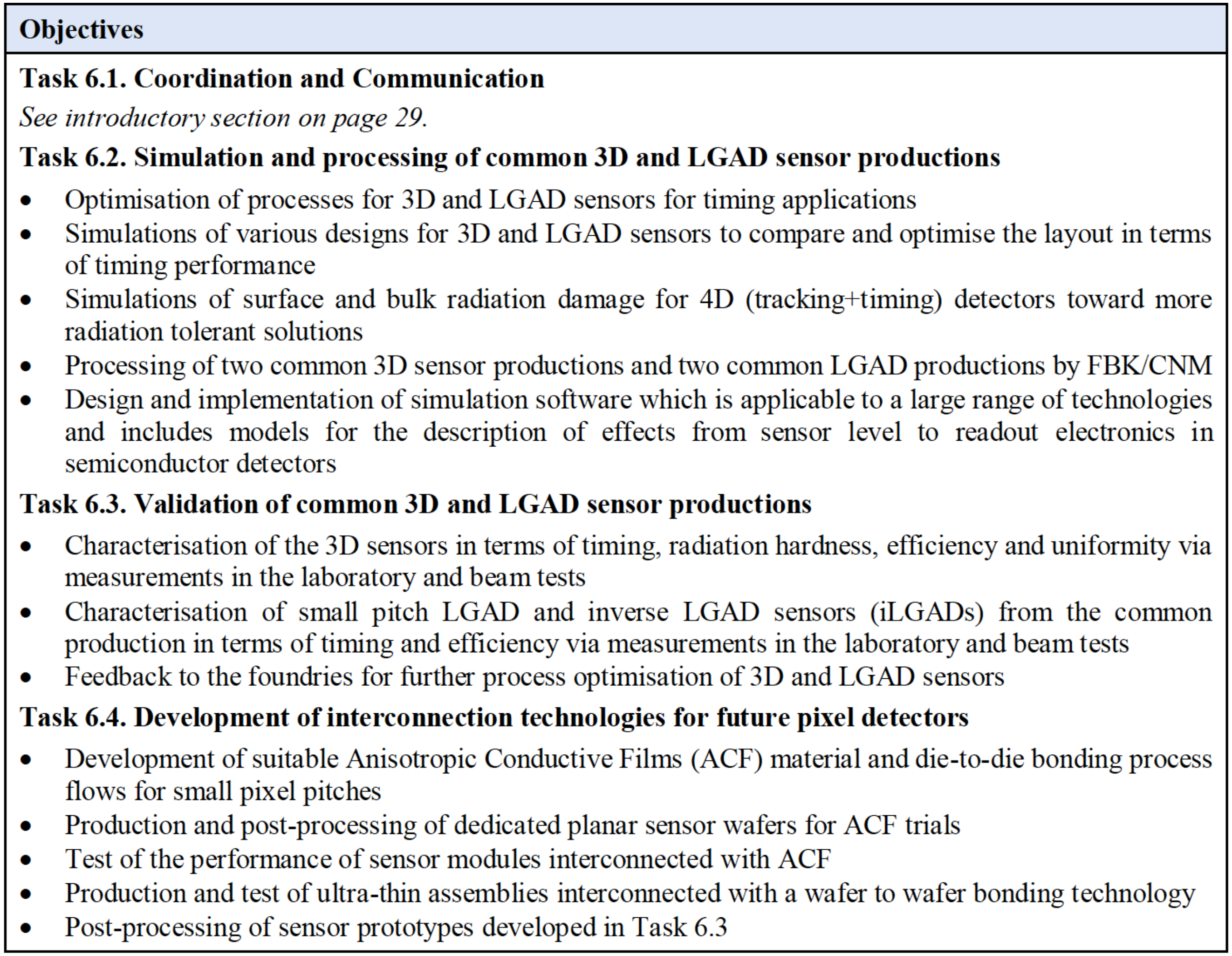
3D validation
FBK: Tn-INFN Ca
CNM: IFAE-JSI

LGAD validation
FBK: TO-UZH
CNM: Santander-CERN

Interconnection
CERN-LPNHE-Bonn- conpart

Simulation
Perugia-DESY

Tasks



Objectives

Task 6.1. Coordination and Communication

See introductory section on page 29.

Task 6.2. Simulation and processing of common 3D and LGAD sensor productions

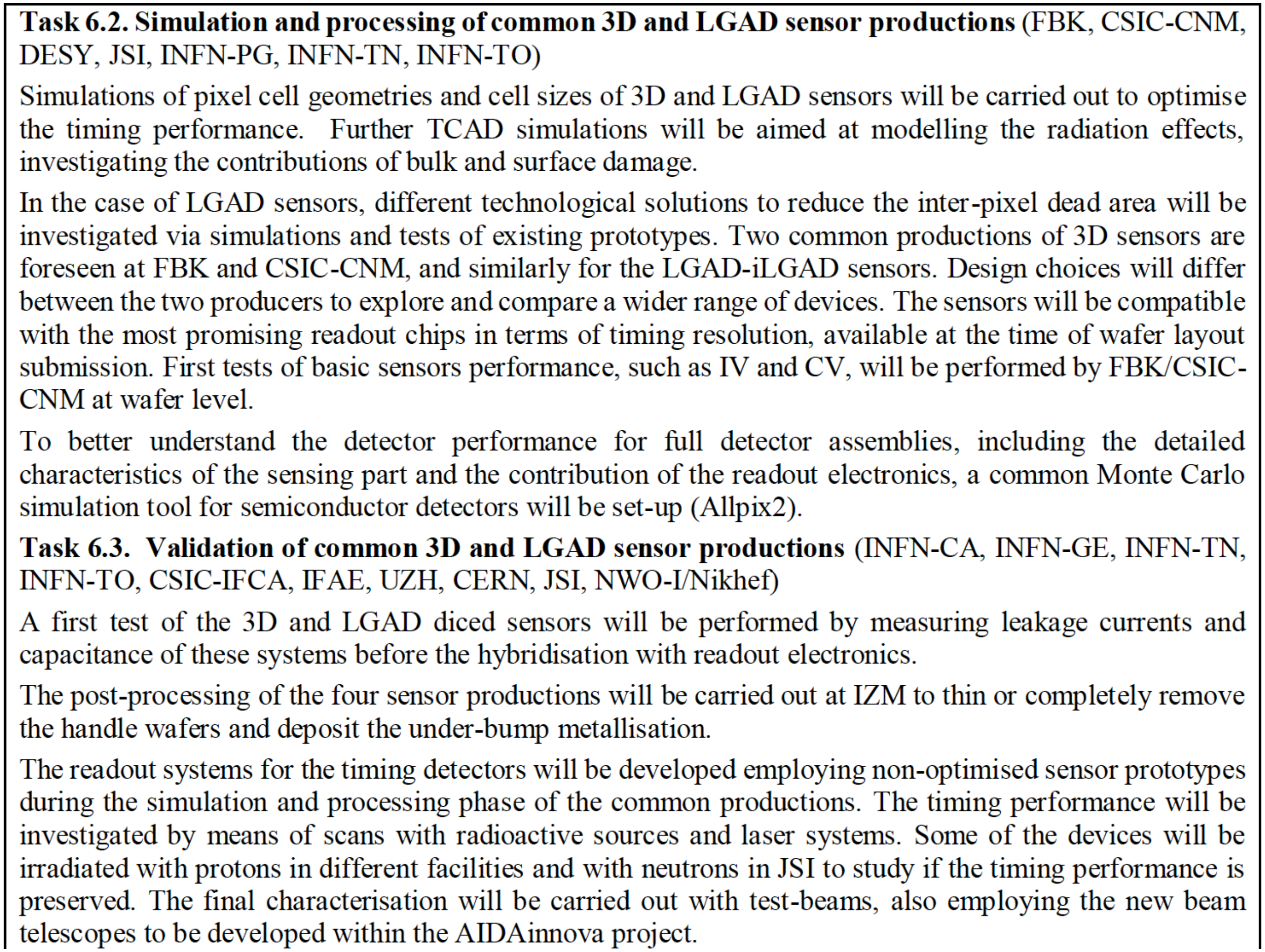
- Optimisation of processes for 3D and LGAD sensors for timing applications
- Simulations of various designs for 3D and LGAD sensors to compare and optimise the layout in terms of timing performance
- Simulations of surface and bulk radiation damage for 4D (tracking+timing) detectors toward more radiation tolerant solutions
- Processing of two common 3D sensor productions and two common LGAD productions by FBK/CNM
- Design and implementation of simulation software which is applicable to a large range of technologies and includes models for the description of effects from sensor level to readout electronics in semiconductor detectors

Task 6.3. Validation of common 3D and LGAD sensor productions

- Characterisation of the 3D sensors in terms of timing, radiation hardness, efficiency and uniformity via measurements in the laboratory and beam tests
- Characterisation of small pitch LGAD and inverse LGAD sensors (iLGADs) from the common production in terms of timing and efficiency via measurements in the laboratory and beam tests
- Feedback to the foundries for further process optimisation of 3D and LGAD sensors

Task 6.4. Development of interconnection technologies for future pixel detectors

- Development of suitable Anisotropic Conductive Films (ACF) material and die-to-die bonding process flows for small pixel pitches
- Production and post-processing of dedicated planar sensor wafers for ACF trials
- Test of the performance of sensor modules interconnected with ACF
- Production and test of ultra-thin assemblies interconnected with a wafer to wafer bonding technology
- Post-processing of sensor prototypes developed in Task 6.3



Task 6.2. Simulation and processing of common 3D and LGAD sensor productions (FBK, CSIC-CNM, DESY, JSI, INFN-PG, INFN-TN, INFN-TO)

Simulations of pixel cell geometries and cell sizes of 3D and LGAD sensors will be carried out to optimise the timing performance. Further TCAD simulations will be aimed at modelling the radiation effects, investigating the contributions of bulk and surface damage.

In the case of LGAD sensors, different technological solutions to reduce the inter-pixel dead area will be investigated via simulations and tests of existing prototypes. Two common productions of 3D sensors are foreseen at FBK and CSIC-CNM, and similarly for the LGAD-iLGAD sensors. Design choices will differ between the two producers to explore and compare a wider range of devices. The sensors will be compatible with the most promising readout chips in terms of timing resolution, available at the time of wafer layout submission. First tests of basic sensors performance, such as IV and CV, will be performed by FBK/CSIC-CNM at wafer level.

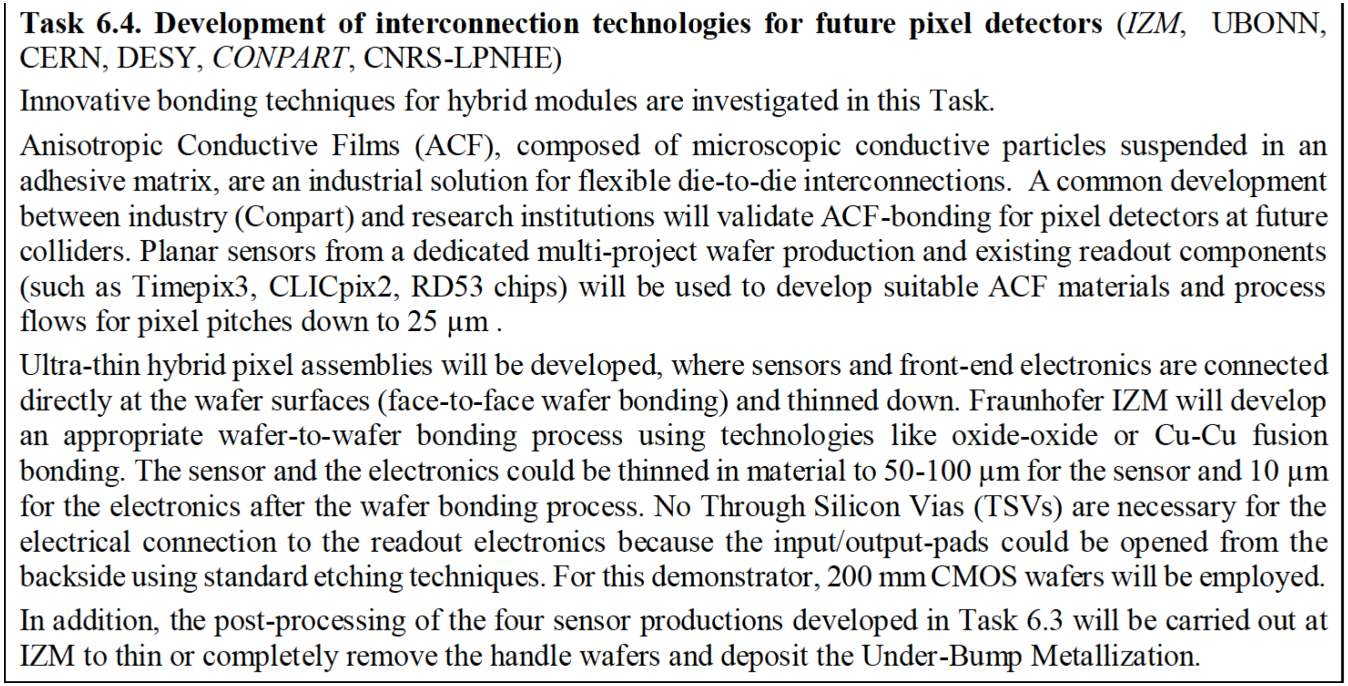
To better understand the detector performance for full detector assemblies, including the detailed characteristics of the sensing part and the contribution of the readout electronics, a common Monte Carlo simulation tool for semiconductor detectors will be set-up (Allpix2).

Task 6.3. Validation of common 3D and LGAD sensor productions (INFN-CA, INFN-GE, INFN-TN, INFN-TO, CSIC-IFCA, IFAE, UZH, CERN, JSI, NWO-I/Nikhef)

A first test of the 3D and LGAD diced sensors will be performed by measuring leakage currents and capacitance of these systems before the hybridisation with readout electronics.

The post-processing of the four sensor productions will be carried out at IZM to thin or completely remove the handle wafers and deposit the under-bump metallisation.

The readout systems for the timing detectors will be developed employing non-optimised sensor prototypes during the simulation and processing phase of the common productions. The timing performance will be investigated by means of scans with radioactive sources and laser systems. Some of the devices will be irradiated with protons in different facilities and with neutrons in JSI to study if the timing performance is preserved. The final characterisation will be carried out with test-beams, also employing the new beam telescopes to be developed within the AIDAinnova project.



Task 6.4. Development of interconnection technologies for future pixel detectors (*IZM*, UBONN, CERN, DESY, *CONPART*, CNRS-LPNHE)

Innovative bonding techniques for hybrid modules are investigated in this Task.

Anisotropic Conductive Films (ACF), composed of microscopic conductive particles suspended in an adhesive matrix, are an industrial solution for flexible die-to-die interconnections. A common development between industry (Conpart) and research institutions will validate ACF-bonding for pixel detectors at future colliders. Planar sensors from a dedicated multi-project wafer production and existing readout components (such as Timepix3, CLICpix2, RD53 chips) will be used to develop suitable ACF materials and process flows for pixel pitches down to 25 µm .

Ultra-thin hybrid pixel assemblies will be developed, where sensors and front-end electronics are connected directly at the wafer surfaces (face-to-face wafer bonding) and thinned down. Fraunhofer IZM will develop an appropriate wafer-to-wafer bonding process using technologies like oxide-oxide or Cu-Cu fusion bonding. The sensor and the electronics could be thinned in material to 50-100 µm for the sensor and 10 µm for the electronics after the wafer bonding process. No Through Silicon Vias (TSVs) are necessary for the electrical connection to the readout electronics because the input/output-pads could be opened from the backside using standard etching techniques. For this demonstrator, 200 mm CMOS wafers will be employed.

In addition, the post-processing of the four sensor productions developed in Task 6.3 will be carried out at IZM to thin or completely remove the handle wafers and deposit the Under-Bump Metallization.

Conclusions

- **Proposal** submitted on May 13, 2020
  - Results should be known 5 months after the deadline
  - We might have "rumours" after 4 months
  - If approved, **AIDAinnova could start on February-March 2021**
- Genova will participate to **WP6**, where we have responsibility and historical connections (both ATLAS and CMS groups)
- Although not funded, **INFN researchers may participate to the WPs and contribute**.

- Italian news:
  - **Subscribe to the CERN mailing list AIDAinnova-INFN** for the italian group, created by Nadia.
  - Italian meeting in week June 8th to be settled: https://doodle.com/poll/af688fyv37em72ty to discuss common activities and approach to funding request to INFN in 2021.
  - Nadia: ” Se per favore mi aiutate a contattare tutti i vari gruppi vorrei aver pronta presto una lista dei responsabili dei vari task e dei contatti anche a livello di sezione. “

Spares

Tasks updates

Task 1.2 Design and process optimization for 3D and LGAD sensors for timing **(EoI 3,69,31,44)**

Responsible institutes: CNM, FBK

- Development of the production process for 3D and LGAD pixel sensors optimized for timing:
  - 3D sensors with double-sided process to be developed at CNM on thick substrates, optimized for timing and high radiation fluences
  - 3D sensors with optimized cell design for timing (e.g. hexagonal geometry, trench electrodes, charge multiplication by design) to be developed at FBK
  - LGAD with small pitch (down to $55x55\ \mu m^2$) for 4D tracking
    - Optimization of the current design for gain termination to reduce inter-pixel distance
    - Pixels with trench isolation at FBK
    - Inverse-LGADs (iLGADs) at CNM

Deliverables:

- Two 3D productions with different geometrical characteristics for timing
- LGAD pixels with optimized gain termination design or trench isolation (FBK)
- iLGAD with uniform gain and small pixels at CNM

Tasks updates

Measurements and validation of 3D sensors for timing **(EoI 3,69,163,128)**

Responsible institutes for the FBK production: Uni Trento INFN Cagliari

Responsible institutes for the CNM production: IFAE – Ljubljana

- Coordination of the post-processing of the pixel sensors and flip-chipping to read-out electronics
- Extensive electrical characterisation of the 3D sensors in terms of timing, radiation hardness and efficiency via measurements in the lab and beam tests
- Feedback to the foundries for process optimisation

Measurements and validation of LGAD sensors **(EoI 31,44,72,131, 107)**

Responsible institutes for the FBK production: Torino -Uni Zurich

Responsible institutes for the CNM production: Santander -CERN

- Testing of the prototypes presently available to identify the most promising technology for a common LGAD and iLGAD productions in order to achieve small pitches with reduced inactive areas
- Validation of LGAD and iLGAD sensors with small pitches of the common production for timing applications
- Feedback to foundries for further process optimization

Deliverables for 1.3 and 1.4:

- Characterization of 3D and LGAD and iLGAD pixel sensors in terms of timing
- Technological recommendation for future productions
- Irradiations of the produced devices

Tasks

Task 1.6 Interconnections **(EoI 99, 47)** **Responsible institutes: CERN, LPNHE, Beneficiary company: Conpart (Norway)**

- Test of Anisotropic Conductive Films (ACF) for interconnection of hybrid detectors
- Prototyping and production of hybrid assemblies with ACF
- Investigate interconnection efficiency down to a pitch of 25 μm

Deliverables:

- ACF material and process parameters for hybrid pixel assemblies (e.g. Timepix4 and CLICpix2)

ACF – Anisotropic Conductive Film

μ-particle bonding

4 mvicente@cern.ch – 28/04/20

- Multiple μ-particle for connecting the pixels
  - 3 μm polymer spheres Ni-Au plated are embedded in an adhesive film, creating an anisotropic connection (only vertically) between the sensor and RO ASIC pixels
    - μ-particles under the elevated metalized contact pads* gets **deformed during bonding,** establishing the electrical contact
      - *ENEPIG maskless process used. More on slide 8

Timepix pixel matrix w/ ACF

ACF particle deformation