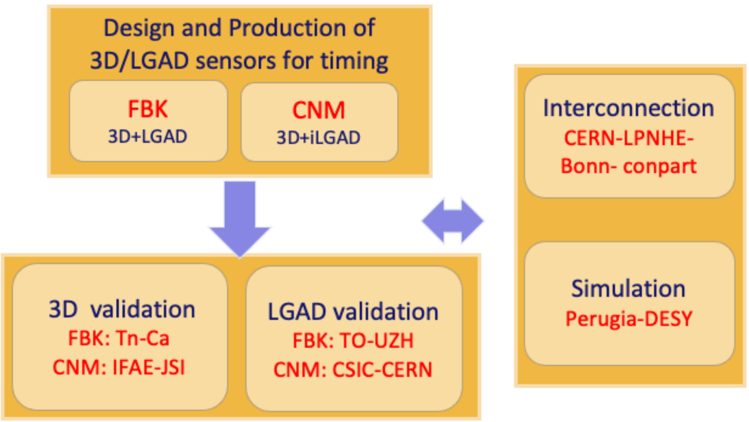
WP6 Overview

~ 25 EoIs received on the hybrid sensors. Grouped by Anna Macchiolo (Zurich), Giulio Pellegrini (IMB-CNM-CSIC) and CG according to the schema in 4 main areas:

Original scientific Proposal



Final Proposal

- 6.1 Coordination:
  - Genova (4Mo)
- 6.2 Simulation and processing:
  - FBK (17Mo) and INFN-PG (15 Mo)
- 6.3 Production Validation:
  - INFN-Tn (18Mo), INFN-Ca (21Mo), INFN-To (19Mo)
- 6.4 Interconnections: hybridization, Wafer-wafer and ACF
  - No Italian contributions

77Mo: 24 EC, 53 In-Kind.

~25% of the funding to the Productions of 3D and LGAD in FBK/CNM; ~ 35% in the interconnections funding; the rest in Simulation, Validation and Management.

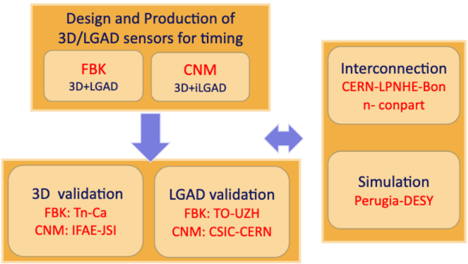
First meeting with WP6 stakeholders on Feb 25th, in preparation of first Steering in March. Most probably 1st WP6 meeting after the steering.

WP6 Overview

		PERCENTUALE [FTE]					WP6 [PM]		
tecnico: 3 keu/PM **ric/tecn: 4-6-7 keu/PM**	**Sede**	**2021**	**2022**	**2023**	**2024**	**Total**	**T6.1**	**T6.2**	**T6.3**
Sedi							**GE**	**PG**	**TN,CA,TO**
Responsabile							C.Gemme	F. Moscatelli	
Months TOT PROGETTO							**4**	**15**	**58**
COSTO personale (Mo*5kE [keu]							**20**	**75**	**290**
In- kind available Mo							**4.0**	**10.0**	**58.0**
In- kind Budget (Mo*real value)								**to be filled**	
nome									
Gemme Claudia	GE	0.1	0.1	0.1	0.1	4.8	4		1
Darbo Giovanni	GE	0.1				1.2			
Robutti Enrico	GE	0	0.1	0.1	0.1	3.6			
Adriano Lai	CA	0.1	0.2	0.2	0.2	8.4			8
Alessandro Cardini	CA	0.1	0.2	0.2	0.1	7.2			7
Sandro Cadeddu	CA	0.1	0.1	0.2	0.2	7.2			7
Andrea Contu	CA	0.1	0.1	0.1	0.1	4.8			5
Gian Mario Bilei	PG	0.1	0.2	0.2	0.2	8.4		6	1
Mauro Menichelli	PG	0.2	0.2	0.2	0.2	9.6		4	
Francesco Moscatelli	PG	0	0	0	0	0		0	
Daniele Passeri	PG	0	0	0	0	0		0	
Nicolo' Cartiglia per Torino	TO					0			14
Nadia Pastrone	TO	0.2	0.2	0.2	0.2	9.6			4
Gian-Franco Dalla Betta	TN	0	0	0	0	0			0
Irina Rashevskaia	TN	0.2	0.3	0.3	0.3	13.2			11
						78			

SPARES

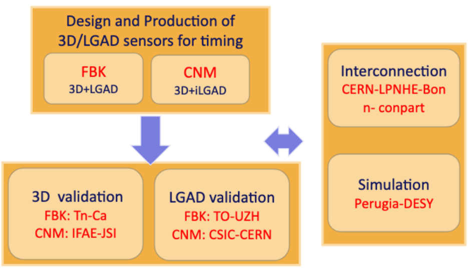
Objectives of the tasks



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

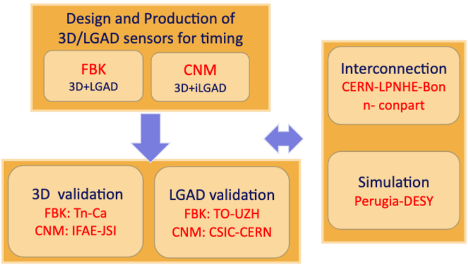
Objectives of the tasks



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

Objectives of the tasks



Task 6.4. Development of interconnection technologies for future pixel detectors (see spares slides)

- Post-processing of 3D and LGAD sensor prototypes
- 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

3D processing and validation

GF Dalla Betta - A. Lai

3D sensors already used in ATLAS IBL and planned for Phase-II for their high rad-hardness. The 3D solution has been demonstrated very beneficial also concerning time resolution (Kramberger 2019 ~60ps – columns, INFN TIMESPOT 2020 ~20ps – trenches). By simulation, trenches are expected to be even more rad-hard than columns.

- **Planned activities:** Design and production of new 3D geometries for enhanced timing and rad-hardness. Characterisation of performances in yield production, timing and rad-hardness. Matching with suitable front-end electronics, both discrete and integrated. Electronics is absolutely crucial at this level of timing performance of the sensors – especially low-power CMOS ASIC (see also the Timespot1 ASIC in 28-nm CMOS).
- **INFN role:** The R&D and results by the TIMESPOT project (ending in 2021) are a precious starting point about further developments on 3D pixels for timing. Expertise in simulation, design and testing is growing in various INFN sites.
- **Strong synergy** with silicon foundries (FBK and CNM). **Strong synergies** also with AIDAinnova WP on new ASIC developments and WP on dedicated simulations.

LGAD processing and validation

N. Cartiglia

Sensor design:

Two LGAD designs for small pitch sensors are established and proved to work:

- **Trench-isolated LGAD (TI-LGAD)** ~ 98-99% fill factor
- **Resistive AC-LGAD** ⇒ 100% fill factor

Both designs achieved ~ 35 ps timing resolution. Leveraging on these results, arrays of small pixels will be manufactured to test additional evolutions of both approaches in term of temporal and spatial resolutions. Specifically, TI-LGAD are deemed more radiation hard than AC-LGAD. This hypothesis needs verification.

Readout:

Discrete components boards: boards with up to 16 analog channels are presently completed and available. We foresee several designs evolution

ASIC: the new FAST ASIC will be used for testing small arrays. FAST, available in Torino, is an ASIC with 16 channels explicitly designed to read small pitch arrays of LGADs. The evolution of this chip, FAST2 is almost completed, submission Q3/2020

Testing:

Irradiation with neutrons and protons is planned. Beamtest campaigns at FERMILAB is programed, development of a in house beam test facility in Torino, using a 6 MeV medical LINAC is progressing. Warm and cold testing capabilities available

Simulation

F. Moscatelli, G. Bilei, D. Passeri

Calibration/extension of the previously developed simulation models

- Calibration/extension of the previously developed models ("Perugia model" and its recent upgrade) by comparing the simulation findings with measurements carried out on dedicated test structures as well on different classes of 3D and LGAD detectors.

Study the effect of surface and bulk radiation damage with reference to 4D (tracking+timing) detectors toward more radiation resistance solutions.

- The proposed activity will focus specifically on disentangling the effects of the two main radiation damage mechanisms, e.g. the surface damage due to ionizing effect and the bulk damage due to atomic displacement, with reference to 4D detectors toward more radiation resistance solutions.

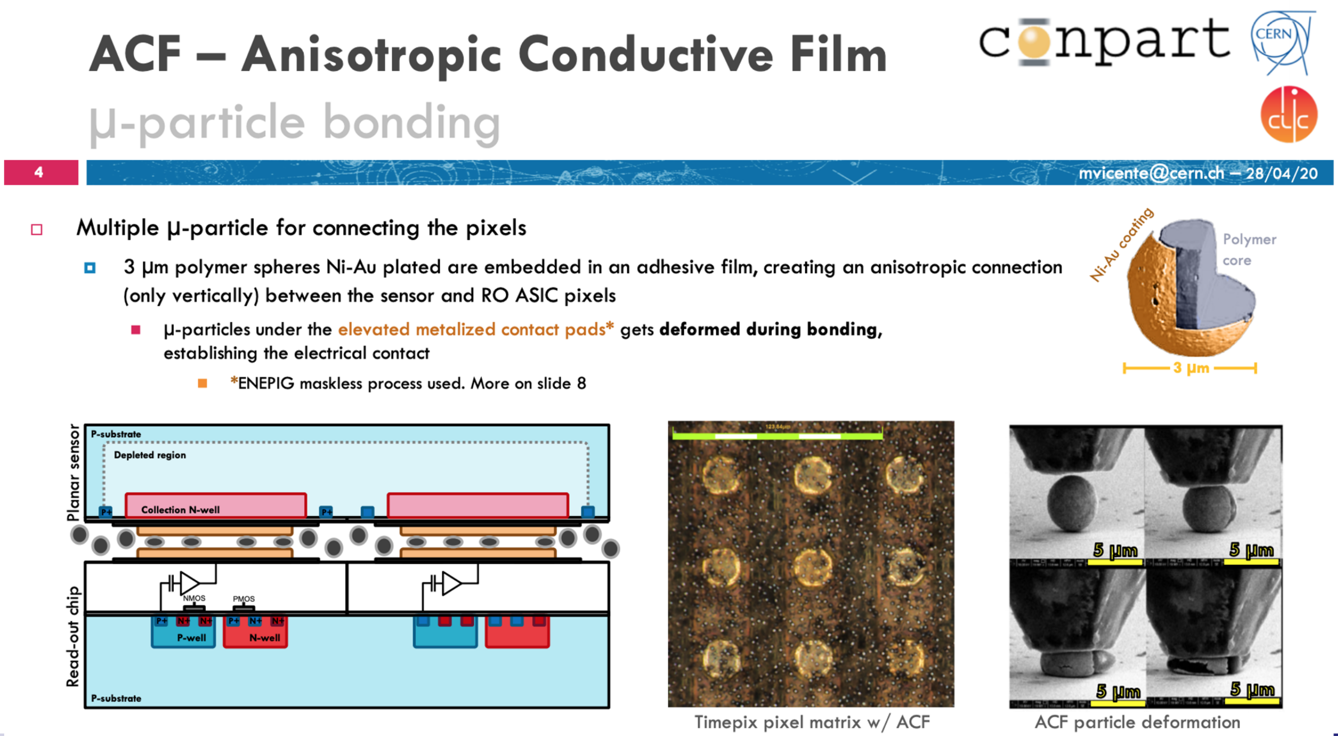
Deliverables:

- Simulation of timing performance of 3D and LGAD detectors after irradiation.
- TCAD Radiation damage modelling handbook

Interconnections - I

Responsible institutes: CERN, LPNHE, Beneficiary company: Conpart (Norway)

- 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.



Interconnections - II

Responsible institutes: Bonn, DESY (+IZM)

- 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.

Tasks Details

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.