IFCA R&D activities – short and long term plans

Iván Vila Álvarez
IFCA

Outline

- Participation of IFCA in DRD3 projects:
  - _TI-LGADs for 4D tracking and SiC-LGAD detectors.
- Future DRD3 project:
  - _A versatile monolithic CMOS pixel sensor proposed inside DRD3-WP1: concept
- PROTECT validation at DCPT:
  - _Plan for the multi-plane demonstrator: cosmic muons first, then a beam-current scan and reference pCT phantoms.
  - _Connection with DRD7

Current DRD3 projects — WP1 & WP2

Ref.	Project	Project leader	CB approval
WP1 — Monolithic CMOS sensors			
1.1	OCTOPUS — monolithic active pixel sensors for vertexing at future lepton colliders	S. Spannagel (DESY)	4.6.2025
1.2	CASSIA — CMOS Active SenSor with Internal Amplification	H. Pernegger (CERN) / T. Suligoj (FER)	29.9.2025
1.3	MALTA65 (listed in the WP structure, project sheet pending)	—	—
WP2 — Sensors for 4D tracking			
2.1	**Development of TI-LGADs for 4D Tracking** ◆ IFCA	A. Macchiolo (UZH)	4.6.2025
2.2	US–Japan development of ultra-fast-time low-mass tracking detectors	A. Tricoli (BNL)	4.6.2025
2.3	Novel silicon 3-D trench pixel detectors on 8-inch CMOS process	Manwen Liu (IMECAS)	4.6.2025
2.4	Very small pitch ultra-rad 3D sensors for 4D tracking at FBK	G. F. Dalla Betta (INFN-TN)	4.6.2025
2.5	LGAD-based timing tracker development for the future collider	Mei Zhao (IHEP)	4.6.2025

Current DRD3 projects — WP3 & WP4

Ref.	Project	Project leader	CB approval
WP3 — Sensors for extreme fluences			
3.1	Development of radiation-hard GaN devices for MIP detection	T. Koffas (Carleton)	4.6.2025
3.2	**SiC-LGAD Detectors** ◆ **IFCA**	Xin Shi (IHEP)	4.6.2025
3.3	Radiation hardness of 25 µm 3D diamond detectors and internal gain in diamond	A. Oh (Manchester)	4.6.2025
3.4	Radiation damage in Si PiN and LGAD sensors	I. Pintilie (NIMP) / M. Moll (CERN)	4.6.2025
WP4 — 3D integration and interconnections			
4.1	In-house plating, hybridisation and module-integration technologies for pixel detectors	D. Dannheim (CERN)	4.6.2025

Spanish landscape in these projects:

- IFCA (WP2.1, WP3.2)
- IMB-CNM (WP3.1, WP3.2 fabrication)
- CNA Seville (WP2.1, WP3.2 characterisation & irradiation)

Current DRD3 projects — TI-LGADs (WP2.1)

< 5 µm inter-pixel distance
before and after irradiation

30–40 ps time resolution
per hit

3×10^{15} neq/cm²
radiation-hardness target

50×50 µm² pixel pitch
on few-cm² read-out chips

Technology and starting point

- The JTE of standard LGADs leaves a ~40 µm gap with no multiplication between pads — incompatible with pixelated 4D devices.
- FBK replaces it by a narrow, shallow trench (TI-LGAD), already prototyped in two runs: RD50 (pad test structures) and AIDAinnova (pixel matrices up to 1×1 cm²), 45–55 µm thick.
- Demonstrated so far: better than 50 ps on 50×50 µm² pixels up to 1.5×10^{15} neq/cm² with IPD below 5 µm.
- Hit efficiency above 99 % at the CERN SPS beam test, 97 % after irradiation; spatial resolution ≈ 14.5 µm.

Goals of the project

- Push the radiation hardness to 3×10^{15} neq/cm² by optimising dose, energy and activation of the C and B implants of the gain layer.
- Keep the inter-pixel distance at a few microns before and after irradiation, through design and process optimisation.
- Reach a good yield on structures compatible with read-out chips of a few cm² at 50×50 µm² pitch, and 30–40 ps per hit.
- Prototype sensors for the ATLAS HGTD upgrade and a possible 4D-pixel CMS TEPX; explore TI-LGADs for particle identification in the outer tracker layers at FCC-ee.

D1.1 1st TI-LGAD batch 2025.1 → 2027.6 · D1.2 2nd batch, large area and full-scale ASICs 2027.6 → 2028.12
Sensors produced at FBK · 18 institutions · irradiation at JSI and KIT · hybridisation at CERN and IPE-KIT

Current DRD3 projects — SiC-LGADs (WP3.2)

1×10^{18} neq/cm²
irradiation target

10–50 avalanche gain
DC- and AC-coupled devices

28 institutions
14 countries, 10 funding agencies

3.2 · 3.3 DRDT
4D tracking + extreme fluences

Technology and motivation

– Wide-bandgap SiC is pulled by the power-device market, and its material quality is getting close to that of silicon.

– As in silicon LGADs, adding a gain layer amplifies the MIP signal; pixelated SiC-LGADs combine timing and position and could bring 4D tracking to the extreme-fluence region of future colliders.

– The project fabricates both DC- and AC-coupled pixelated SiC-LGADs, with SiC-PIN and Schottky devices as intermediate steps, and correlates the multiplication mechanism after high fluence with detector performance.

– Aligned with DRDT 3.2 (sensors for 4D tracking) and DRDT 3.3 (sensors for extreme fluences).

Work plan

Di.1 **11/2024 → 12/2025** SiC-PIN, AC SiC-PIN and Schottky device fabrication
Di.2 **6/2025 → 12/2026** DC- and AC-coupled SiC-LGADs, avalanche gain 10–50
Di.3 **6/2025 → 12/2025** Read-out board and ASICs
Di.4 **1/2026 → 12/2027** Characterisation: IV, CV, charge collection, timing, defects
Di.5 **1/2027 → 12/2027** Irradiation up to 1×10^{18} neq/cm²
Di.6 **1/2028 → 12/2028** Analysis of the defects left by the different irradiation types

Devices fabricated at IHEP with IMB-CNM, On semi and FBK· irradiation at JSI, HEPHY, FZU, NTUA and CNA
Read-out electronics from Manchester, NTUA, SCIPP and HEPHY · characterisation shared by 26 institutions

A future DRD3 project — MANTA

20–50 µm pixel pitch
set by the WP1 findings

10–100 ns time stamping
adjustable by slow control

≲ 30 ps TDC precision
digital precision, staged goal

40–100 mW/cm²
power saving → full bandwidth

Monolithic Asynchronous sensor for Next Tracker generAtion

- MAPS are proven trackers in STAR-HFT, ALICE-ITS2 and ALICE-MFT, but flavour physics, Higgs factories and heavy-ion experiments now ask for two orders of magnitude in time stamping while keeping ~50 µm of material and ~50 mW/cm².
- Designing a dedicated sensor per experiment is beyond the resources of the community, so MANTA proposes one common architecture, versatile enough to cover ALICE3, Belle II, CBM, FCC-ee and LHCb requirements.
- The most demanding performance comes with relaxed power constraints, so flexibility is bought by trading performance against power.
- A mid-size but scalable demonstrator in TPSCo 65 nm over the first 3–4 years, with two submissions, eases the later step to an experiment-specific sensor.

Where the versatility comes from

- DAC-based power sources tune the in-pixel pre-amplifier current through slow control, following the DPTS approach (10 nA to 5 µA).
- Bandwidth and depth of the on-chip buses and buffers are adapted, and unused resources can be disabled or clocked down.
- Optional blocks are switched on or off, for instance a sub-ns TDC at the end of column; time-over-threshold gives the time-walk correction.
- Asynchronous arbiter tree in the matrix instead of frame-based readout, already prototyped in the SPARC chiplet fabricated in 2026.
- Wide pitch (>30 µm) lowers power; the alternative groups small (<30 µm) collection diodes on a shared in-pixel front-end.

Proposed inside DRD3-WP1 — research goals RG2 (timing), RG3 (architecture) and RG4 (radiation tolerance)
Synergies with OCTOPUS and MALTA on the same TPSCo 65 nm process · sensor design reviewed by DRD7-WG6 (project 7.6.a)

A future DRD3 project — MANTA work plan

5 work packages
plus 3 working groups

2 ASIC submissions
MANTA-0 and MANTA-1

15 institutes
≈ 14.8 FTE pledged

M48 project span
from January 2025

Work packages

WP1 IPHC Sizeable-pitch pixels: multi-diode grouping on a common front-end, device simulation and test structures.

WP2 IP2I Front-end with adjustable power and timing, radiation tolerance to NIEL, prototyped in the MANTA-0 ASIC.

WP3 IPHC / GSI / LLR Fast versatile digital readout based on asynchronous logic; test of the SPARC chiplet.

WP4 demonstrator MANTA-1, a column-size prototype of about 2×1 cm^2 integrating all the design blocks.

WP5 test infrastructure Read-out system and analysis software, reusing standard tools such as Corryvreckan.

Working groups: WG1 ASIC design · WG2 simulation · WG3 tests

Deliverables in the MoU

D2.2 M24 Prototype design of the front-end options in a dedicated ASIC, MANTA-0.

D3.4 M24 Test and evaluation of the SPARC chiplet as read-out demonstrator.

D4.1 M30 Design of the main demonstrator sensor, MANTA-1, reviewed with DRD7-WG6.

D4.3 M48 Test and evaluation of MANTA-1.

Main risks

Under-performance of the demonstrator, mitigated by prioritising hit rate, radiation tolerance and the ToT time-walk correction, and by optional modules that can be turned off; and access to the TPSCo 65 nm process, mitigated by sharing IP blocks and fabrication runs with the other DRD3-WP1 projects.

IFCA Santander (I. Vila): 0.5 + 0.5 FTE in the test activities · 15 contributing institutes, 7.45 secured and 7.3 non-secured FTE
Equipment: ASIC design tool licences · foundry submission access · test systems · test-beam access

PROTECT — multi-plane validation plan at DCPT

multiple detector planes
HPK LGADs on ETROC2, White Rabbit

< 40 ps per plane
already shown in the CERN SPS run

3 validation phases
cosmics → beam → phantoms

2026 beam time at DCPT
clinical proton beam, Aarhus

Phase 0 · at IFCA

Cosmic-muon demonstrator

- The multi-plane stack runs self-triggered on a scintillator coincidence, with no beam and no external schedule.
- Plane-to-plane time offsets, White Rabbit synchronisation and geometrical alignment fixed on minimum-ionising tracks.
- Tracking efficiency, noise and threshold maps, and long unattended runs to prove stability before asking for beam time.

Phase 1 · at DCPT

Beam-current scan

- Clinical proton beam scanned over currents from single-proton counting up to nominal delivery.
- Occupancy, pile-up fraction and DAQ dead time measured plane by plane, to find where single-proton decorrelation breaks down.
- Time resolution and time-walk correction as a function of current, extending the PIN and SiC beam-structure studies.(PIN mode)

Phase 2 · at DCPT

Reference pCT phantoms

- phantom and inserts of known relative stopping power, plus a resolution phantom for the modulation transfer function.
- Full chain exercised: tracking, filtered backprojection and U-NET super-resolution, compared against the GEANT4 model.
- RSP accuracy and spatial resolution versus delivered dose — the measurements left open as D5.1 and D5.2.

Outlook

— Two complementary fronts, both on the characterisation side:
  _ TI-LGADs with FBK and SiC-LGADs with IHEP and IMB-CNM.
  _ Gradually phasing out the SiC HEP related activities.
  _ CNM and CAN involved in these two activities.

— MANTA would add a new front in monolithic CMOS.
  _ ITA also a member of the collaboration, opportunity for CNA and CNM.

— Signature of the MoU annexes and the open slots for deputy leadership as entry points for wider involvement.

— Beam time at DCPT in 2026 to close the PROTECT validation, with the cosmic-muon phase starting beforehand at IFCA.

—Final remark on ILGAD:
  _ Large area fine pitch pixelated Double-sided ILGAD became an on-the-shell 100% fill factor solution. Currently produced by FBK.
  _ No clear plan to produce Trench Isolated LGADs for timing