DRD3

Introduction to WG2/WP2
Hybrid silicon technologies

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WG2 Scientific Proposal

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- Broad scope:

Sensors with 4D capabilities foreseen in many systems, from Time-of-Flight systems with only 1-2 layers of sensors with the best possible timing resolution to large 4D trackers with many layers.

- Challenges:
  - Hadron colliders: high radiation levels and high occupancies
  - Lepton colliders: requirement of low material budget and low power dissipation

WG2 research goals <2027	
	Description
RG 2.1	Reduction of pixel cell size for 3D sensors
RG 2.2	3D sensors for timing ($\leq 55 \times 55$ μm, < 50 ps)
RG 2.3	LGAD for 4D tracking < 10 μm, < 30 ps, wafer 6" and 8"
RG 2.4	LGAD for ToF (Large area, < 30 μm, < 30 ps)

Link to DRD3 scientific proposal

- Proposals for Work packages should be mainly focused on these DRD3 Research Themes
- Other technologies related to hybrid detectors and innovative ideas are welcome to be developed within WG2

ASICs for timing detectors

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ASICs for HL-LHC Timing detectors (pitch of 1.3 mm x 1.3 mm):
- ATLAS HGTD ALTIROC chip in 130 nm CMOS
- CMS ETROC chip for ETL in 65 nm CMOS

From the ECFA Roadmap: Technology Choice

❑ The selection and adoption of the 28nm CMOS technology as a “mainstream” process will ”fuel” the developments of ”near-future” experiments

- A few chips are being developed at the moment for 4D tracking:
  - Ignite and PicoPix, focused on LHCb VELO upgrade in 28 nm CMOS
  - EICROC for ePIC detector at EIC in 130 nm CMOS
  - Fermilab’s FCFD for 4D trackers in 65 nm CMOS
  - Etc.
- but nothing readily available here and now

WG2 can help to collect requirements for future ASICs and streamline efforts → link to DRD7

Proposed WG2 Structure

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•To kick off WG2 activities we propose a light-weight structure

In the next few months, we want to collect information on

- **Main application drivers** (e.g. HL-LHC, FCC, ILC/CLIC, Muon Collider etc.),
- **Research goals** and directions the community wants to pursue,
- Level of **needed vs available effort/person-power** for specific developments,
- Specific interests of various institutes in specific technological areas

• We encourage everyone with ideas for a possible WP to send us (the conveners) the proposal document (template available here), even if partially filled, by end of August, so that we can get an overview of the plans in the community to identify possible synergies

- The structure of WG2 will be reviewed in the future, after the initial months
- At the moment, we want to encourage the community to get an overview of all on-going activities before we compartmentalise into focused groups
- Cross-fertilisation among different R&D areas
- Boost cooperation spirit
- Encourage the formation of institute **clusters** around specific research goals

Proposed WG2 Organization

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- **No subgroups for the time-being**
  - Discussions open to the whole community, regardless of specific research interests
  - We may have dedicated meetings on specific technologies, specific Research Goals (RG) or WP to keep meetings focused

- **Appointment of Support Contacts and Liaisons:**
  - Advice WG2 members on available facilities, techniques, platforms, tools etc.
  - Provide bi-directional communication with other DRD3 Working Groups or DRDx groups
  - Provide technical support to community by linking with experts
  - Maintain support web pages
  - **Proposed Support/Liaison (to be nominated through this Google Survey)**
    1. Test-beam and Characterisation facilities → link to WG5
    2. Irradiation Coordination → link to WG3
    3. Interconnections → link to WG7
    4. Simulation → link to WG4
    5. Readout Systems → link to DRD7

Keep in touch

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- **Provide Feedback on this proposal with Convenors (Anna, Martin, Alessandro):**
  - drd3-wg2-conveners@cern.ch
- **Send Nominations for support/liaisons positions through this Survey within end of next week**
  - Anyone can nominate, self-nominations are also welcome
  - Early Career nominations are very much welcome
- **Subscribe to WG2 e-group for general communications/announcements:**
  - drd3-wg2-hybrid@cern.ch
  - Follow instructions here how to subscribe: https://drd3.web.cern.ch/egroups
- **Mattermost DRD3-WG2 channels**
  - https://mattermost.web.cern.ch/drd3-wg2/channels/wg2-community
    - To be used for general quick enquiries or lengthy discussions useful to the whole community, which may be difficult to manage by email. But let's keep traffic low
  - Specific channels on dedicated topics (to be implemented) - suggestions?
    - E.g. for support/coordination of irradiation campaigns, test-beams etc.

Additional slides

3D sensors – replacement of innermost pixel layers at HL-LHC

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Possible application for the replacement of the innermost pixel layer of ATLAS/CMS pixel systems

- Geometry for Phase-2: 50x50 μm^2 or 25x100 μm^2.

One replacement foreseen in Phase-3 where the use of 28 nm CMOS technology for the ASICs could allow for finer pixel sizes to improve hard scattering track reconstruction and pile-up rejection

3D sensors still the most promising candidate due to radiation resistance and low contribution to power dissipation

- ASIC pixel size possibly down to 30x30 μm^2 (No timing functionality included)

RG 2.1 Reduction of pixel cell size for 3D sensors.

– 2024-2025: 3D sensors test structures with pixel size smaller than the current 50 x 50 μm^2 or 25 x 100 μm^2

– 2026-2028: Large size 3D sensors with reduced pixel size.

– ≥ 2028: Expand the number of foundries capable of producing 3D sensors for HEP applications

3D sensors - timing at HL-LHC

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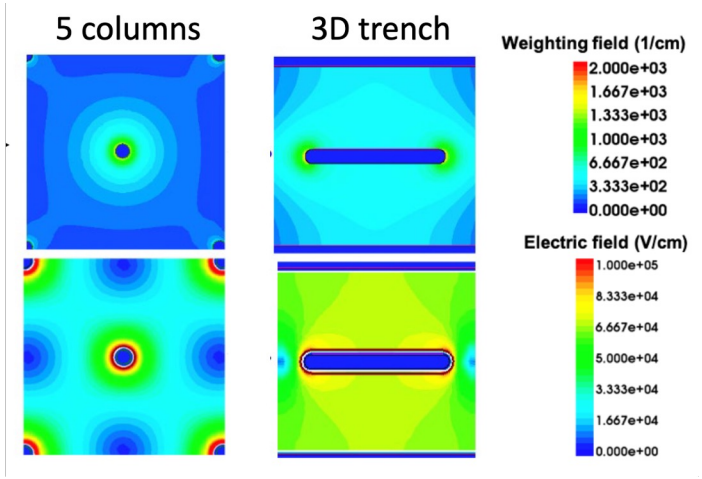

3D with advanced timing capabilities: possible application for replacing the present VELO vertex detector at LHCb (Upgrade-II).

Compare the performance in terms of timing properties and radiation hardness of columnar and trench 3D detectors

- **RG 2.2**: 3D sensors with a temporal resolution better than 50 ps.

– 2024-2025: Production of a small matrix with pitch equal to or less than 55 x 55 μm^2 to be connected with existing read-out ASICS

– 2026-2028: Production of large-size sensors (using the selected geometry from the R&D runs) and interconnection with custom-made read-out ASIC

LGAD sensors for 4D Tracking

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Demonstration of the feasibility of producing pixelated LGAD sensors to achieve a position resolution around 10 µm, with a timing resolution of the order of 30 ps before irradiation.

Possible application for the replacement of outer pixel layers or disks in the CMS/ATLAS pixel systems in Phase-3.

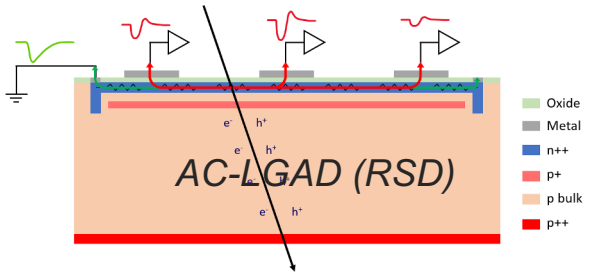
The requested radiation tolerance can be in the range of 3-5x10^{15} n_{eq}/cm^2.

RG 2.3: LGAD Sensors with very high fill factor, and an excellent spatial and temporal resolution

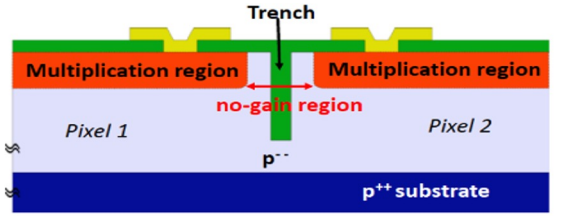
– 2024-2025: LGAD test structures of different technologies (TI-LGAD, iLGAD, AC-LGAD/RSD, DJ-LGAD), matching existing read-out ASICs

– 2026-2028: Large LGAD sensors based on the best-performing technology.

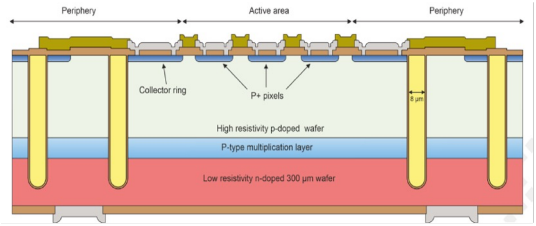
– 2025-2028: Investigation of radiation hardness of LGAD technology beyond 2.5 x10^{15} n_{eq}/cm^2



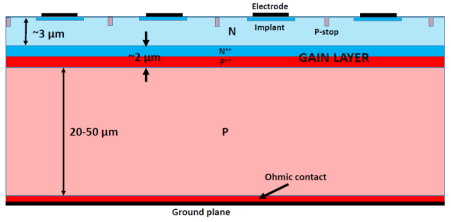
Trench Isolated LGAD



Inverse-LGAD (I-LGAD)



Deep junction LGAD



LGAD sensors for ToF applications

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- Demonstration of the feasibility of producing LGADs for particle identification (Time of Flight).
  - Possible applications at ALICE 3 (Run5), Belle2, Electron Ion collider (Tracking+TOF@ePIC) >2031) and Future Lepton collider (>2040).
  - In all these cases, larger surfaces (several m^2) have to be covered with respect to vertex detectors.
  - Yield and reproducibility of the process have to be demonstrated while radiation hardness is less of a problem in these experiments with respect to HL-LHC applications.
- In the case of the Electron Ion Collider, a spatial resolution around 30 μm and timing resolution better than 30 ps are required. An area up to 13 m^2 has to be instrumented. In case RSD are used, pad size of 0.5 mm could be implemented.
- For experiments at FCC-ee, a time of flight detector could be placed as the most external tracking layer (silicon wrapper), with a surface of around 100 m^2, time resolution better than 30 ps, and spatial resolution around 10 (90) μm (r-φ, z).

RG 2.4: LGAD sensors for Time-of-Flight applications
– 2024-2026: Production of LGAD sensors with large size for Tracking/Time-of-Flight applications to demonstrate yield and doping homogeneity. Study of spatial and temporal resolutions as a function of the pixel size.
– 2026-2028: LGAD structures with 4D capabilities produced with vendors capable of large-area productions to demonstrate the industrialization of the process.

Relationship with other WG

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Work Package		3.1 Monolithic CMOS sensors				3.2 4D Tracking		3.3 Extreme Fluence			3.4 Intercon.			
2.1	Reduction of pixel cell size for 3D sensors					X					X	X		X
2.2	3D sensors for timing ($\leq$ 55 $\times$ 55 um, $<$ 50 ps)					X					X	X		X
2.3	LGAD for 4D tracking $<$ 10 um, $<$ 30 ps, wafer 6" and 8"						X				X	X		X
2.4	LGAD for ToF (Large area, $<$ 30 um, $<$ 30 ps)						X				X	X		X