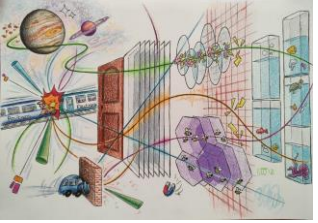


DRD3 status and plans

DRD3 Proposal team: D. Bortoletto, D. Contardo, E. Vilella, H. Pernegger, N. Cartiglia, C. Gemme, A. Macchiolo, M. Mikuz, M. Moll, I. Pintilie, S. Seidel, M. Bomben, G. Kramberger, A. Morozzi, F. Moscatelli, J. Schwandt, S. Spannagel, D. Dannheim, M. Fernandez, Garcia, M. Jaksic, I. Vila, T. Bergauer, T. Koffas, A. Oh, G. Pelligrini, X. Shi, G. Calderini, D. Dannheim, T. Fritzsch, F. Hugging

DETECTOR RESEARCH AND DEVELOPMENT THEMES (DRDTs) & DETECTOR COMMUNITY THEMES (DCTs)

From 01.01.2024

- The roadmap identified several R&D themes
- Critical to achieve the scientific programme in the ESPP (European Strategy for Particle Physics)
- Derived from the technological challenges that need to be overcome for the scientific potential of the future facilities

DRD3

Gaseous

- **DRDT 1.1** Improve time and spatial resolution for gaseous detectors with long-term stability
- **DRDT 1.2** Achieve tracking in gaseous detectors with dE/dx and dN/dx capability in large volumes with very low material budget and different read-out schemes
- **DRDT 1.3** Develop environmentally friendly gaseous detectors for very large areas with high-rate capability
- **DRDT 1.4** Achieve high sensitivity in both low and high-pressure TPCs

Liquid

- **DRDT 2.1** Develop readout technology to increase spatial and energy resolution for liquid detectors
- **DRDT 2.2** Advance noise reduction in liquid detectors to lower signal energy thresholds
- **DRDT 2.3** Improve the material properties of target and detector components in liquid detectors
- **DRDT 2.4** Realise liquid detector technologies scalable for integration in large systems

Solid state

- **DRDT 3.1** Achieve full integration of sensing and microelectronics in monolithic CMOS pixel sensors
- **DRDT 3.2** Develop solid state sensors with 4D-capabilities for tracking and calorimetry
- **DRDT 3.3** Extend capabilities of solid state sensors to operate at extreme fluences
- **DRDT 3.4** Develop full 3D-interconnection technologies for solid state devices in particle physics

PID and Photon

- **DRDT 4.1** Enhance the timing resolution and spectral range of photon detectors
- **DRDT 4.2** Develop photosensors for extreme environments
- **DRDT 4.3** Develop RICH and imaging detectors with low mass and high resolution timing
- **DRDT 4.4** Develop compact high performance time-of-flight detectors

Quantum

- **DRDT 5.1** Promote the development of advanced quantum sensing technologies
- **DRDT 5.2** Investigate and adapt state-of-the-art developments in quantum technologies to particle physics
- **DRDT 5.3** Establish the necessary frameworks and mechanisms to allow exploration of emerging technologies
- **DRDT 5.4** Develop and provide advanced enabling capabilities and infrastructure

Calorimetry

- **DRDT 6.1** Develop radiation-hard calorimeters with enhanced electromagnetic energy and timing resolution
- **DRDT 6.2** Develop high-granular calorimeters with multi-dimensional readout for optimised use of particle flow methods
- **DRDT 6.3** Develop calorimeters for extreme radiation, rate and pile-up environments

Electronics

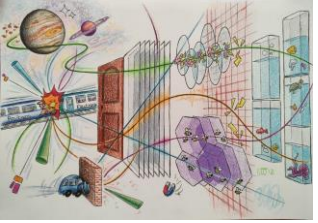
- **DRDT7.1** Advance technologies to deal with greatly increased data density
- **DRDT7.2** Develop technologies for increased intelligence on the detector
- **DRDT7.3** Develop technologies in support of 4D- and 5D-techniques
- **DRDT7.4** Develop novel technologies to cope with extreme environments and required longevity
- **DRDT7.5** Evaluate and adapt to emerging electronics and data processing technologies

Integration

- **DRDT 8.1** Develop novel magnet systems
- **DRDT 8.2** Develop improved technologies and systems for cooling
- **DRDT 8.3** Adapt novel materials to achieve ultralight, stable and high precision mechanical structures. Develop Machine Detector Interfaces.
- **DRDT 8.4** Adapt and advance state-of-the-art systems in monitoring including environmental, radiation and beam aspects

Training

- **DCT 1** Establish and maintain a European coordinated programme for training in instrumentation
- **DCT 2** Develop a master's degree programme in instrumentation



Coverage of ECFA DRDTs (& GSRs)

Within the ECFA roadmap
4 Detector R&D Themes (DRDTs)
have been identified for the
Solid State Detectors in particle physics.

- We are covering all ECFA DRDTs
- Additional WGs were added to cover simulations, facilities and dissemination corresponding to General Strategic Recommendations (GSRs) in the ECFA roadmap

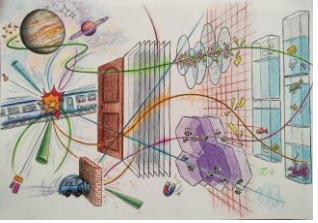
DRDT3.1. Achieve full integration of sensing and microelectronics in **monolithic CMOS** pixel sensors

DRDT3.2. Develop solid state sensors with **4D-capabilities for tracking and calorimetry**

DRDT3.3. Extend capabilities of solid state sensors to operate at **extreme fluences**

DRDT3.4. Develop full **3D-interconnection technologies** for solid state devices in particle physics.

- WG1: Monolithic CMOS Sensors
- WG2: Sensors for Tracking & Calorimetry
- WG3: Radiation damage & extreme fluences
- WG4: Simulation
- WG5: Characterization techniques, facilities
- WG6 Non-silicon based detectors
- WG7: Interconnect and device fabrication
- WG8: Dissemination and outreach



Coverage of ECFA DRDTs (& GSRs) DRD3

Within the ECFA roadmap
4 Detector R&D Themes (DRDTs)
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DRDT3.1. Achieve full integration of sensing and microelectronics in **monolithic CMOS** pixel sensors

DRDT3.2. Develop solid state sensors with **4D-capabilities for tracking and calorimetry**

DRDT3.3. Extend capabilities of solid state sensors to operate at **extreme fluences**

DRDT3.4. Develop full **3D-interconnection technologies** for solid state devices in particle physics.

DRD3

WG1: Monolithic CMOS Sensors

WG2: Sensors for Tracking & Calorimetry

WG3: Radiation damage & extreme fluences

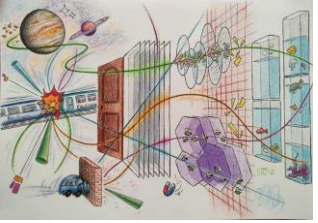
WG6: Non-silicon based detectors

WG7: Interconnect and device fabrication

WG4: Simulation

WG5: Characterization techniques, facilities

WG8: Dissemination and outreach



Timeline

DRD3

22-23 March 2023
DRD3 community meeting: To gather inputs from the community + to propose a way forward (milestones & deliverables)

June 2023
Circulate DRD3 for feedback from the community

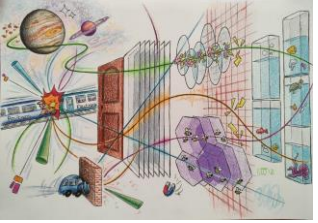
July 2023
Submit DRD3 proposal document to DRDC

We are here

December 2022
DRD3 proposal team formed to lead the preparation of the DRD3 proposal + questionnaires sent out to the community

16 March 2023
Latest day to be included in the first questionnaires evaluation (as presented in the DRD3 community workshop)
88 replies by then, **~100 replies as of today**

April-May 2023
DRD3 proposal developed based on the detector roadmap and community interest:
Final questionnaires evaluation + further meetings and discussions with experts (~20 pages)



Timeline going forward

DRD3

June 2023
Circulate DRD3 for feedback from the community

July 2023
Formation of the “electoral / administrative” Collaboration Board (1 rep. with voting right per institute)

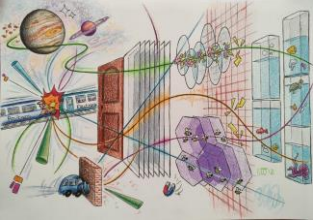
2024
Start of DRD3 collaboration: collection of MoU signatures + DRD3 kick-off workshop

We are here

July 2023
Submit DRD3 proposal document to DRDC including estimates of the resources needed

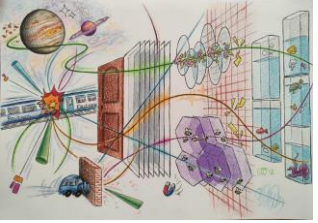
Q4 2023
Following the review and revision (if required) of the proposal, the DRDC recommends the formal establishment of the DRD3 collaboration + formal approval by the CERN Research board

Q4 2023
WG conveners will be elected (how many per WG and voting procedure to be agreed);
Collaboration Board Chair and spokespersons appointed



Working groups and technical proposal

- **Proposal document until < 2027**
  - The proposal details deliverables for the first R&D phase up to 2027, and it highlights the R&D path from 2028-on
    - Strategic R&D with stepping stones developments for ALICE-3, LHCb-2, EIC, Belle-3, ATLAS, CMS and HGCAL (DRD6)
    - Followed by developments for ILC, CLIC, FCC-ee, MC lepton colliders
    - And then for FCC-hh on the longer term

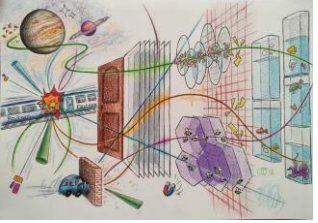


DRD3 proposal team: **members**

- DRD3 proposal core team:
  - to foster and guide a community-driven bottom-up process towards the **DRD3 proposal** and the formation of the **DRD3 collaboration** (survey, community wide workshop, proposal document and constitutional workshop)
  - formed in consensus between ECFA Roadmap TF3 conveners & RD50 management
  - regular meetings since October 2022

  Giovanni Calderini, Nicolo Cartiglia, Gianluigi Casse, Gregor Kramberger, Michael Moll, Giulio Pellegrini, Ioana Pintilie, Ivan Vila Alvarez, Eva Vilella

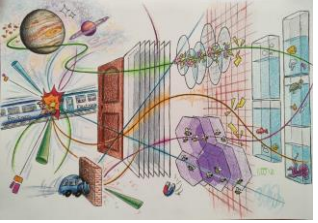
- Team extended with further experts to organize individual research lines
  - WG1: Monolithic CMOS Sensors
    D. Bortoletto, D. Contardo, E. Vilella, H. Pernegger
  - WG2: Sensors for Tracking & Calorimetry
    N. Cartiglia, C. Gemme, A. Macchiolo
  - WG3: Radiation damage & ultrahigh fluences
    - M. Mikuz, M. Moll, I. Pintilie, S. Seidel
  - WG4: Simulation
    - M. Bomben, G. Kramberger, A. Morozzi, F. Moscatelli, J. Schwandt, S. Spannagel
  - WG5: Characterization techniques, facilities
    - D. Dannheim, M. Fernandez Garcia, M. Jakšić, I. Vila
  - WG6 Non-silicon based detectors
    - T. Bergauer, T. Koffas, A. Oh, G. Pelligrini, X. Shi
  - WG7: Interconnect and device fabrication
    - G. Calderini, D. Dannheim, T. Fritzsch, F. Hügging
  - WG8: Dissemination and outreach
    - N. Cartiglia et al.



Working groups and technical proposal

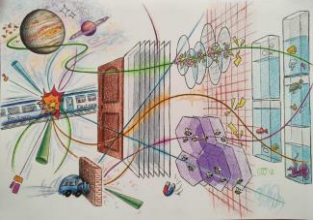
DRD3

- **WG 3.1: Monolithic CMOS sensors**
  - Spatial resolution towards 3 µm (including stitching)
  - Timing resolution towards 20 ps
  - Readout architectures towards 100 MHz/cm^2, 1 GHz/cm^2 with 3D stacked monolithic sensors
  - Radiation tolerance towards 10E16 n_{eq}/cm^2 NIEL and 500 Mrad
  - Common areas with other DRDs (interconnection, integration, non-silicon materials and simulation + characterisation)
- **WG 3.2: Sensors for tracking and calorimetry**
  - Spatial and temporal resolutions at extreme radiation levels
    - Reduction of pixel cell size for 3D sensors
    - 3D sensors with a temporal resolution of about 50 ps
  - Spatial and temporal resolutions at low radiation levels and low material and power budgets
    - LGAD sensors with very high fill factor and an excellent spatial and temporal resolution
    - LGAD sensors for Time of Flight applications
- **WG 3.3: Radiation damage and extreme fluence operation**
  - Build up data sets on radiation induced defect formation in WBG materials
  - Develop silicon radiation damage models based on measured point and cluster defects
  - Provide measurements and detector radiation damage models for radiation levels faced in HL-LHC operation
  - Measure and model the properties of silicon and WBG sensors in the fluence range 10E16 to 10E18 n_{eq}/cm^2



Working groups and technical proposal

- **WG 3.4: Simulation**
  - Flexible CMOS simulation of 65 nm to test design variations
  - Implementation of newly measured semiconductor properties into TCAD and MC simulation tools
  - Definition of benchmark for the validation of the radiation damage models with measurements and benchmark different models
  - Developing of bulk and surface model for 10E16 n_{eq}/cm^2 to 10E17 n_{eq}/cm^2 NIEL
  - Collate solutions from different MC tools and develop algorithms to include adaptive electric and weighting fields
- **WG 3.5: Measurement and characterization techniques**
  - Development of new semiconductor characterization techniques is a priority for future detector developments
  - These techniques should enable high-resolution imaging and defect spectroscopy of semiconductor materials, as well as advanced characterization of charge transport properties
  - The Two Photon Absorption – TCT setup, Caribou DAQ system and the Ion Beam testing and irradiation facility at RBI have been identified as good examples and further improvements are being proposed
- **WG 3.6: Wide bandgap and innovative sensor materials**
  - 3D diamond detectors, cages/interconnects, base length 25 µm, impact ionisation
  - Fabrication of large area SiC and GaN detectors, improve material quality and reduce defect levels
  - Improve tracking capabilities of WBG materials
  - Apply graphene and/or other 2D materials in radiation detectors, understand signal formation



Working groups and technical proposal

- **WG 3.7: Sensor interconnection techniques**
  - Yield consolidation for fast interconnections
  - Demonstration of small pitch (< 30 µm) pixel interconnections
  - Demonstration of radiation hardness and thermomechanical constraints
  - Development of maskless post-processing for commonly-used interconnection technologies
  - Bring part of the commonly-used interconnection technologies to specialised academic groups
  - Develop device-to-wafer interconnection technologies
  - Develop wafer-to-wafer in presently advanced interconnection technologies
  - Develop VIAS in multi-tier sensor/front-end assemblies
  - Develop connection techniques for post-processed devices
- **WG 3.8: Outreach and dissemination**
  - Disseminating knowledge on solid-state detectors to people working in high energy physics
  - Disseminating knowledge on solid-state detectors to high-school students and the general public
    - Design and set-up of the DRD3 website
    - Collection of the outreach material
    - Set-up and organize schools and exchange programs
    - Set-up of the DRD3 conference committee