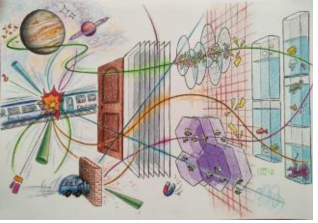
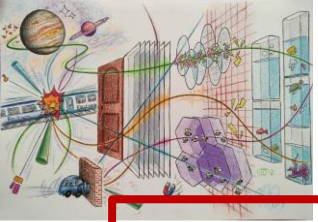


DRD3

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



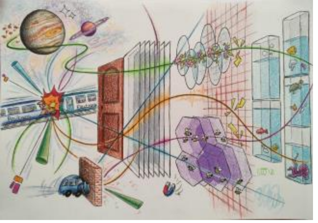
DETECTOR RESEARCH AND DEVELOPMENT THEMES (DRDTs) & DETECTOR COMMUNITY THEMES (DCTs)

DRD3

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

Theme	ID	Description
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 (DRD3)	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	DRDT 7.1	Advance technologies to deal with greatly increased data density
	DRDT 7.2	Develop technologies for increased intelligence on the detector
	DRDT 7.3	Develop technologies in support of 4D- and 5D-techniques
	DRDT 7.4	Develop novel technologies to cope with extreme environments and required longevity
	DRDT 7.5	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) DRD3

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

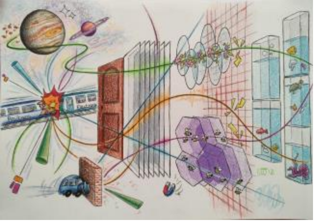
DRDT3.1. Achieve full integration of sensing and microelectronics in **monolithic CMOS** pixel sensors → WG1

DRDT3.2. Develop solid state sensors with **4D-capabilities for tracking and calorimetry** → WG2

DRDT3.3. Extend capabilities of solid state sensors to operate at **extreme fluences** → WG3, WG6

DRDT3.4. Develop full **3D-interconnection technologies** for solid state devices in particle physics. → WG7

- 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



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DRDT3.1. Achieve full integration of sensing and microelectronics in **monolithic CMOS** pixel sensors → **WG1:** Monolithic CMOS Sensors

DRDT3.2. Develop solid state sensors with **4D-capabilities for tracking and calorimetry** → **WG2: Sensors for Tracking & Calorimetry**

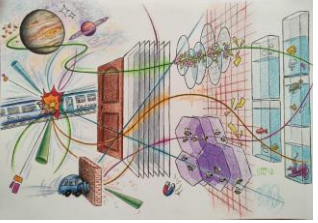
DRDT3.3. Extend capabilities of solid state sensors to operate at **extreme fluences** → **WG3: Radiation damage & extreme fluences**

WG6: Non-silicon based detectors

DRDT3.4. Develop full **3D-interconnection technologies** for solid state devices in particle physics. → **WG7: Interconnect and device fabrication**

DRD3

- **WG4:** Simulation
- **WG5:** Characterization techniques, facilities
- **WG8:** Dissemination and outreach



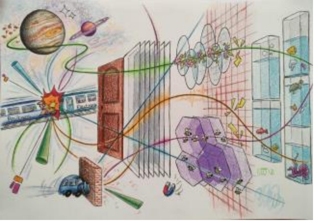
DRD3 proposal team: **members**

- 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.



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

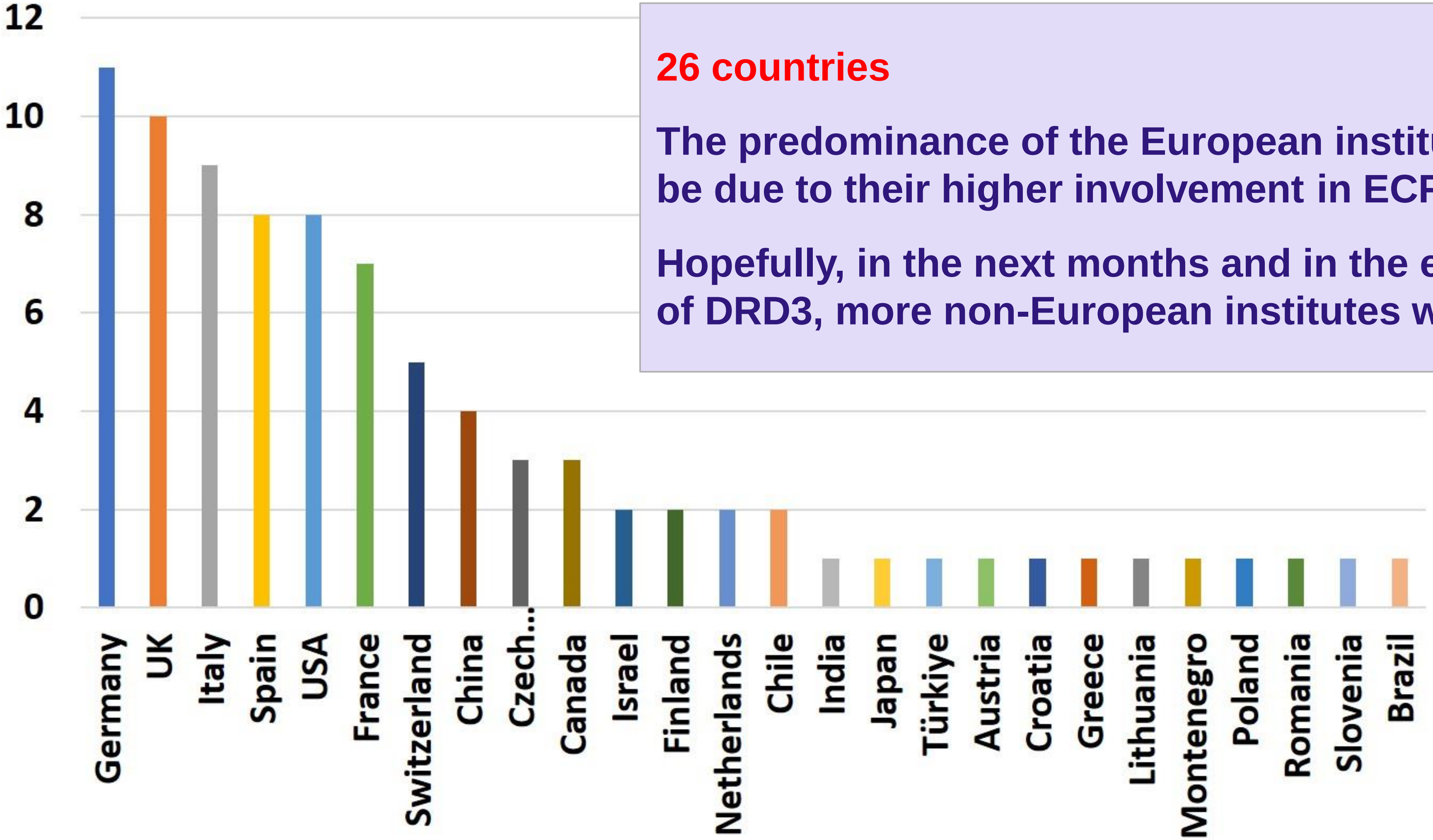
We are here

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)

Survey response: country

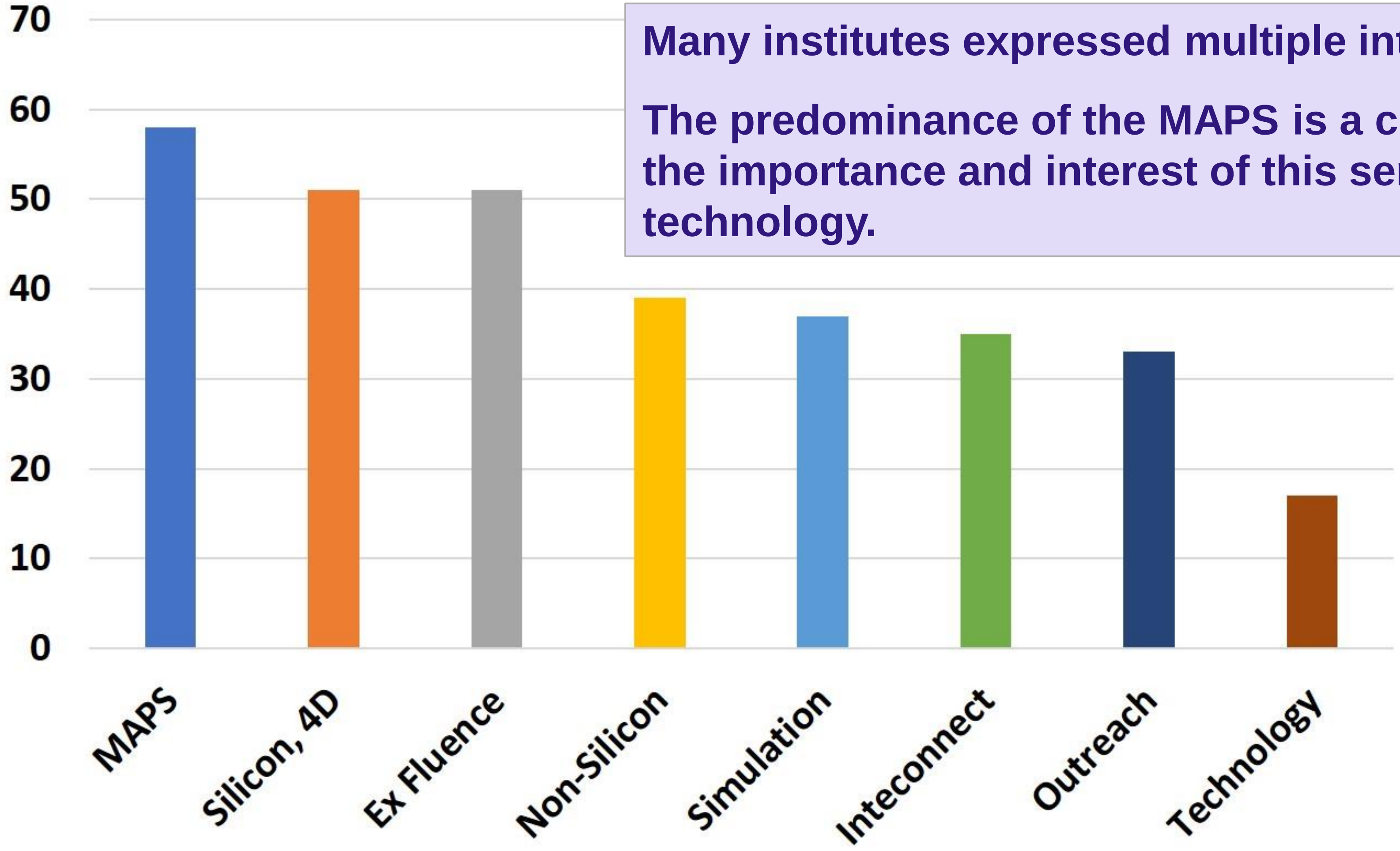


26 countries

The predominance of the European institutes might be due to their higher involvement in ECFA.

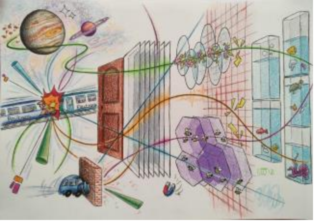
Hopefully, in the next months and in the early stage of DRD3, more non-European institutes will join.

Survey response: interests

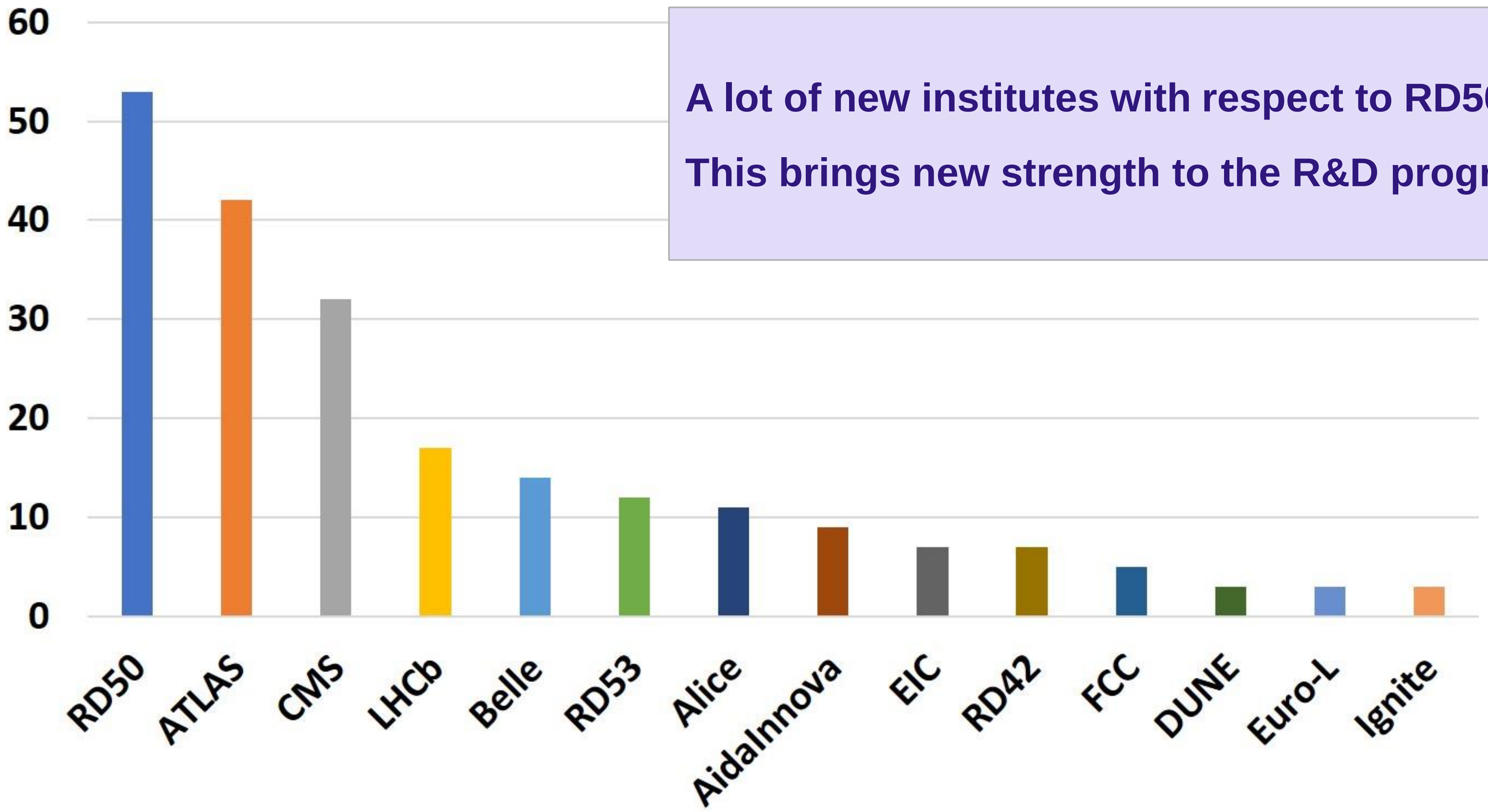


Many institutes expressed multiple interests.

The predominance of the MAPS is a clear sign of the importance and interest of this sensor technology.

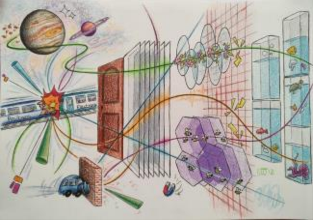


Survey response: experiments



A lot of new institutes with respect to RD50.

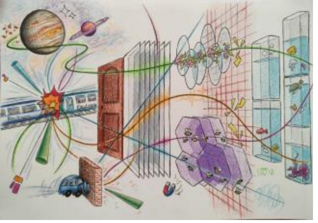
This brings new strength to the R&D program.



Technologies and work packages

DRD3

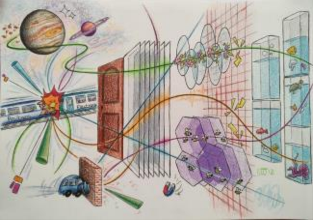
DRDT 3.1	CMOS sensors	DRDT 3.2	Sensors for 4D tracking
WP1.1	TPSCo 65 nm	WP2.1	3D sensors
WP1.2	TowerJazz 180 nm	WP2.2	LGADs
WP1.3	LFoundry 150 nm		
WP1.4	TSI 180 nm		
WP1.5	LFoundry 110 nm		
WP1.6	IHP 130 nm		
DRDT 3.3	**Sensors for extreme fluence**	**DRDT 3.4**	**Demonstrator for 3D-integration**
WP3.1	Wide bandgap (SiC, GaN)	WP4.1	
WP3.2	Diamond	WP4.2	
WP3.3	Silicon		



Working groups and technical proposal

DRD3

- **WG 3.1: Monolithic CMOS sensors**
  - Spatial resolution of 3 µm
  - Timing precision of 20 ps
  - Readout architectures for 100 MHz/cm^2
  - Radiation tolerance of 10E16 n_{eq}/cm^2 NIEL and 500 MRad
- **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



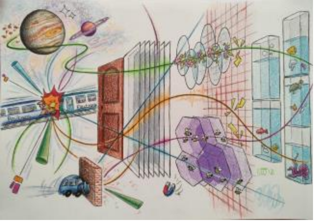
Working groups and technical proposal

DRD3

- **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

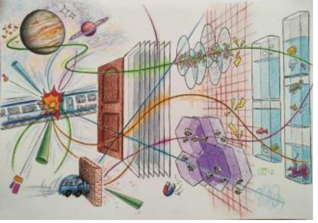


Working groups and technical proposal

DRD3

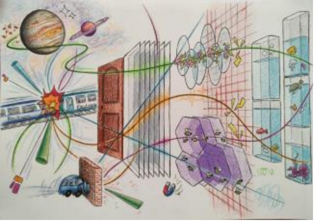
- **WG 3.7: Sensor interconnection techniques**
  - Yield consolidation for fast interconnections
  - Demonstration of small pitch (< 30 µm) pixel interconnections
  - Demonstration of radiation hardness and thermomechanical constraints
  - Development of maskless post-processing for commonly-used interconnection 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



Working groups and technical proposal

- **Proposal document until < 2027**
  - Strategic R&D aligned with “near time” experiments
  - Acknowledged this R&D is a stepping stone towards other experiments that are further down the line



Broad brush matrix starting point

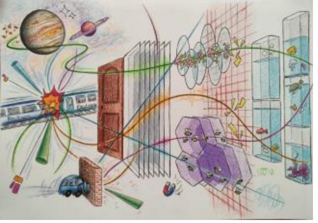
DRD3

Different detector requirements

Different environmental constraints

Strategic Projects	Tracking Vertex Detector (VD) Central Tracker (CT)	Timing Layer (TL) + Calorimeter
Heavy Ion	ALICE-3, EIC	ALICE-3 (LS4+), EIC
Flavour collider	BELLE-3	BELLE-3
Lepton collider	ILC, CLIC FCCee, Muon Collider	ILC, CLIC FCCee, Muon Collider
pp collider	LHCb-2, ATLAS, CMS FCC-hh	LHCb-2, ATLAS, CMS FCC-hh

Note: fixed target experiments in the shadow of colliders, to be consolidated (some high precision timing targets in NA62/Klever by 2025)



1^{st} R&D phase, up to 2028-2029

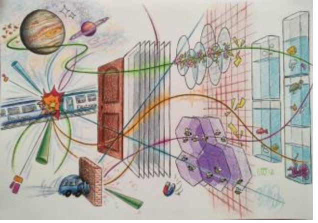
DRD3

Handle mandatory (independant) performance for strategic projects of 1^{st} half of 2030's

Ball park generic performance targets*
mandatory/desireable

Milestones	Tracking VD/CT	Timing Layer + Calorimeter
Heavy Ion	**M1** ultralight low power tracker pitch 10 - 30 µm @ O(100) MHz/cm^2, O(1) µs	**M2** O(20) ps (TL)
Flavour collider	ultralight low power tracker pitch 10 - 30 µm @ O(100) MHz/cm^2, O(1) ns	O(20) ps in (TL)
Lepton collider	e-e: ultralight low power tracker pitch down to <10 µm, @ O(100) MHz/cm^2 timing driven by power dissipation µ-µ: O(20) ps rates and irradiation tbc	O(10) ps in TL O(< 50) ps in calorimeter driven by power dissipation
pp collider	**M3** HL-LHC: 25-50 µm @ O(5) GHz/cm^2 5×10^{15} to 5×10^{16} neq/cm^2, 250 - 500 MRad timing O(<50) ps FCC-hh: < 10 - 20 µm @ 30 GHz/cm^2 4D tracking O(<10) ps up to O(10^{18}) neq/cm^2, up to O(50) GRad	**M4** HL-LHC: pitch O(<1) mm O(20) ps in TL, NIEL 5×10^{15} FCC-hh: 5D calorimeter O(<10) ps up to O(10^{18}) neq/cm^2, up to O(50) GRad

* ranges representative, ex. for VD and CT with more stringent constraints to be achieved in VD



2^{nd} R &D phase, up to 2034-2035

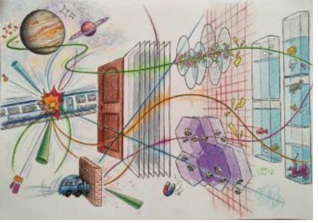
DRD3

Integration of 1^{st} R&D phase performance in full 4D devices for stategic progams of the 2040 decade

Ball park generic performance targets* mandatory/desireable

Milestones	Tracking VD/CT	Timing Layer + Calorimeter
Heavy Ion	**M1** ultralight low power tracker pitch 10 - 30 µm @ O(100) MHz/cm^2, O(1) µs	**M2** O(20) ps (TL)
Flavour collider	ultralight low power tracker pitch 10 - 30 µm @ O(100) MHz/cm^2, O(1) ns	O(20) ps in (TL)
Lepton collider	**M5** e-e: ultralight low power tracker pitch down to <10 µm, @ O(100) MHz/cm^2 timing driven by power dissipation µ-µ: O(20) ps rates and irradiation tbc	**M6** O(10) ps in TL O(< 50) ps in calorimeter driven by power dissipation
pp collider	**M3** HL-LHC: 25-50 µm @ O(5) GHz/cm^2 5x10^{15} to 5x10^{16} neq/cm^2, 250 - 500 MRad timing O(<50) ps	**M4** HL-LHC: pitch O(<1) mm O(20) ps in TL, NIEL 5x10^{15}
	M7 FCC-hh: < 10 - 20 µm @ 30 GHz/cm^2 4D tracking O(<10) ps up to O(10^{18}) neq/cm^2, up to O(50) GRad	**M8** FCC-hh: 5D calorimeter O(<10) ps up to O(10^{18}) neq/cm^2, up to O(50) GRad

* ranges representative, ex. for VD and CT with more stringent constraints to be achieved in VD

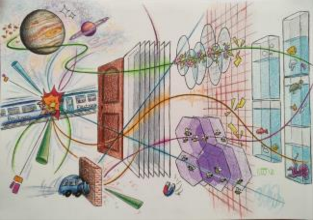


WG1 Monolithic CMOS sensors WPs

DRD3

WP	Technology
1.1	TPSCo 65 nm
1.2	TowerJazz 180 nm
1.3	LFoundry 150 nm
1.4	TSI 180 nm
1.5	LFoundry 110 nm
1.6	IHP 130 nm

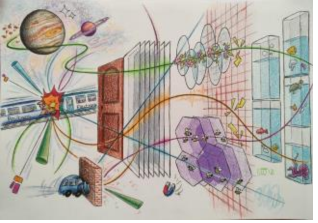
- Programme foresees several submissions (deliverables) per technology.
- Subject to availability of MPWs and shared ER submissions where MPWs are not possible.
- Synergies with DRD7 (timeline of 65 nm driven by DRD7, conversations onogoing).



WG1 Monolithic CMOS sensors WPs

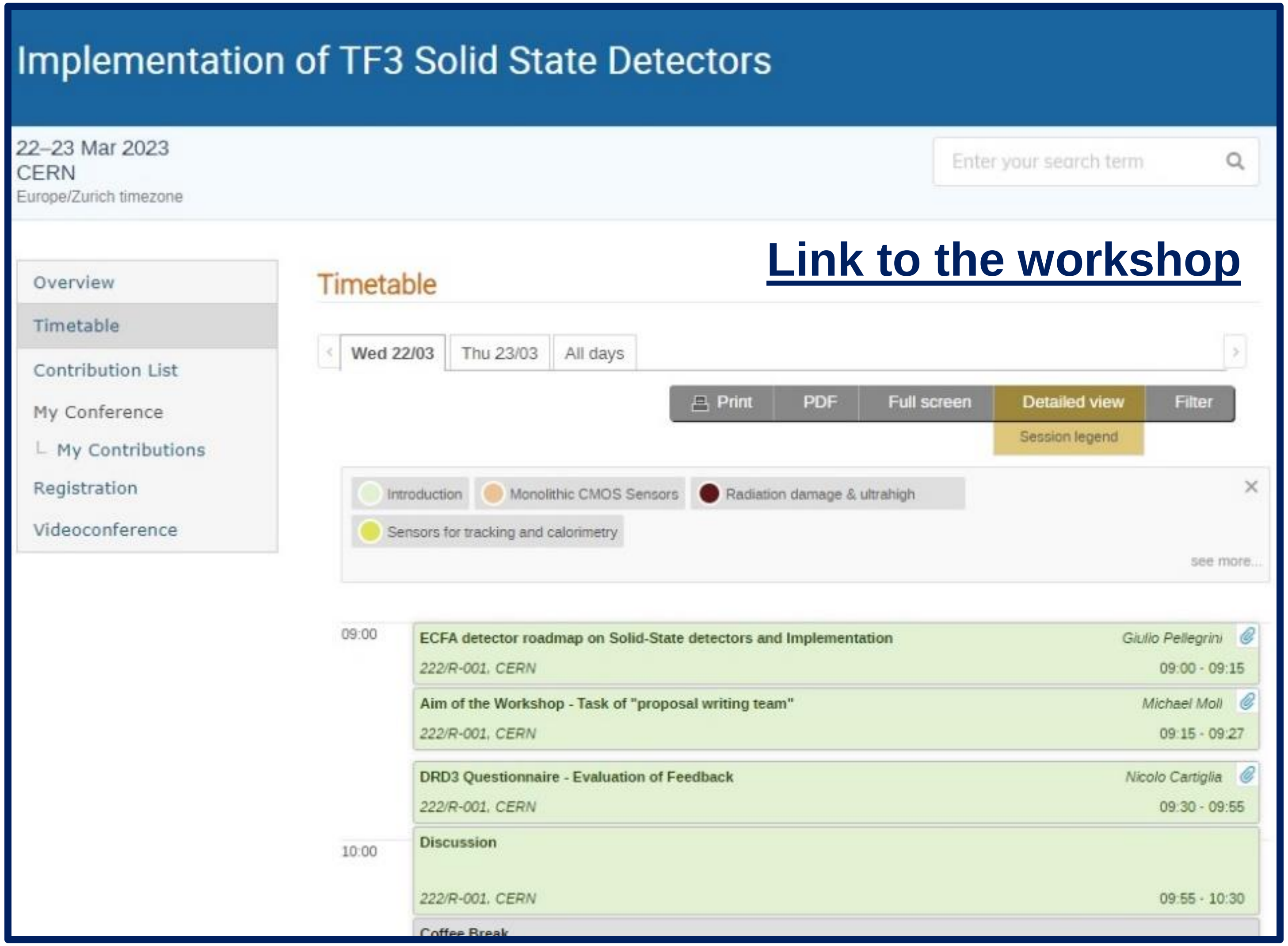
DRD3

- Many discussions with experts to define
  - Number of deliverables
  - What could be achieved with each deliverable
  - Detailed timeline
  - Cost
- Starting to converge…

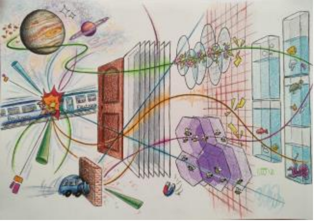


Full details about the proposed plan

DRD3



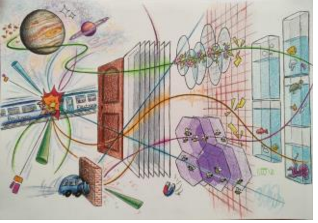
Link to the workshop



Areas of 'Detector R&D'

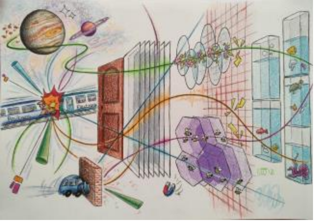
DRD3

- **Strategic R&D via DRD Collaborations**
  - Long-term strategic R&D lines
  - To address the high-priority items defined in the Roadmap via the DRDTs
- **'Blue-sky' R&D**
  - Competitive
  - Short-term responsive grants
  - Nationally organised
- **Experiment-specific R&D**
  - With very well defined detector specifications
  - Funded outside of the DRD programme, via experiments



Work Groups will take care of

- **Work package is a platform for addressing**
  - Strategic R&D to which funding agencies will commit (included in MoU)
- **Common projects**
  - Also generic R&D, blue sky
- **Collaboration with experiments**
  - With very well defined detector specifications
  - Funded outside of the DRD programme, via experiments



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