Report from the DRD Committee

Thomas Bergauer (HEPHY-OEAW Vienna)

17 November 2023

Previous Talks on this subject

- 110th [link] (July 2022) and 111th Plenary ECFA meeting (November 2022) [link]:
  Towards Detector R&D Collaborations - Update on Detector R&D Roadmap (Phil Allport)

- 112th Plenary ECFA meeting (July 2023) [link]:
  Report on ECFA Detector R&D Roadmap Implementation status (Felix Sefkow)

- 112th special ECFA-EPS session [link]:
  ECFA detector R&D roadmap (Didier Contardo)

Content

- First Part:
  - Updates on the process
  - Introduction to new DRD Committee: Mandate, Members, Timeline for approval
- Second Part:
  - Brief look at planned Detector R&D collaborations

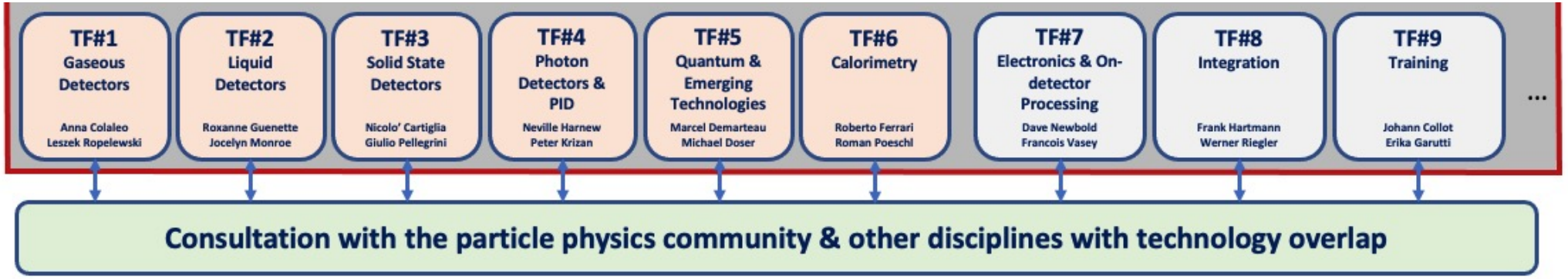
Disclaimer: I am from the Silicon community, and I will use this on several occasions as an example

ECFA Detector Roadmap

European Committee for Future Accelerators (ECFA) released in 2021 a full document (200 pages) and synopsis (~10 pages) with this content:

The full document can be referenced as DOI: 10.17181/CERN.XDPL.W2EX

- Overview of **future facilities** (EIC, ILC, CLIC, FCC-ee/hh, Muon collider) or major **upgrades** (ALICE, Belle-II, LHC-b,…) and its **timeline**
- **Nine Technology domains** based on **Task Forces** areas
  - The **most urgent R&D topics** in each Task Force area identified as **Detector R&D Themes** (DRDTs)
- Concludes with ten "**General Strategic Recommendations**"



R&D Topics and DRDTs

- The most urgent R&D topics in each Task Force area are identified by **Detector Readiness Matrix**
  - Tables with much more details exist in roadmap (contains also target numbers for different experimental needs, e.g. ALICE 3: 0.05% X/X_0 (per layer)

- **Detector R&D Themes (DRDTs)** were formulated as high-level deliverables

Solid state

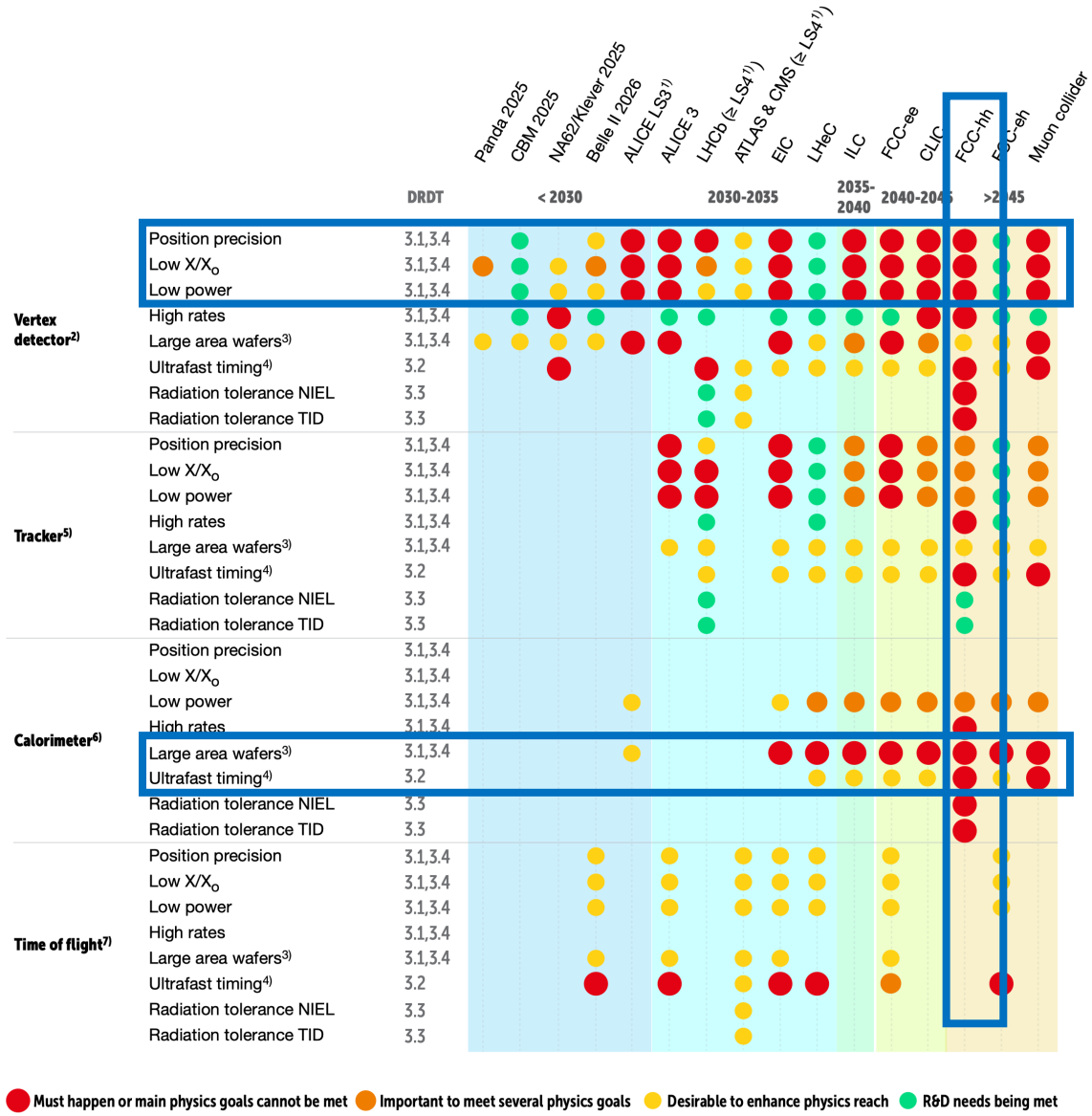
DRDT 3.1 Achieve full integration of sensing and microelectronics in monolithic CMOS pixel sensors

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

Semiconductor Example!

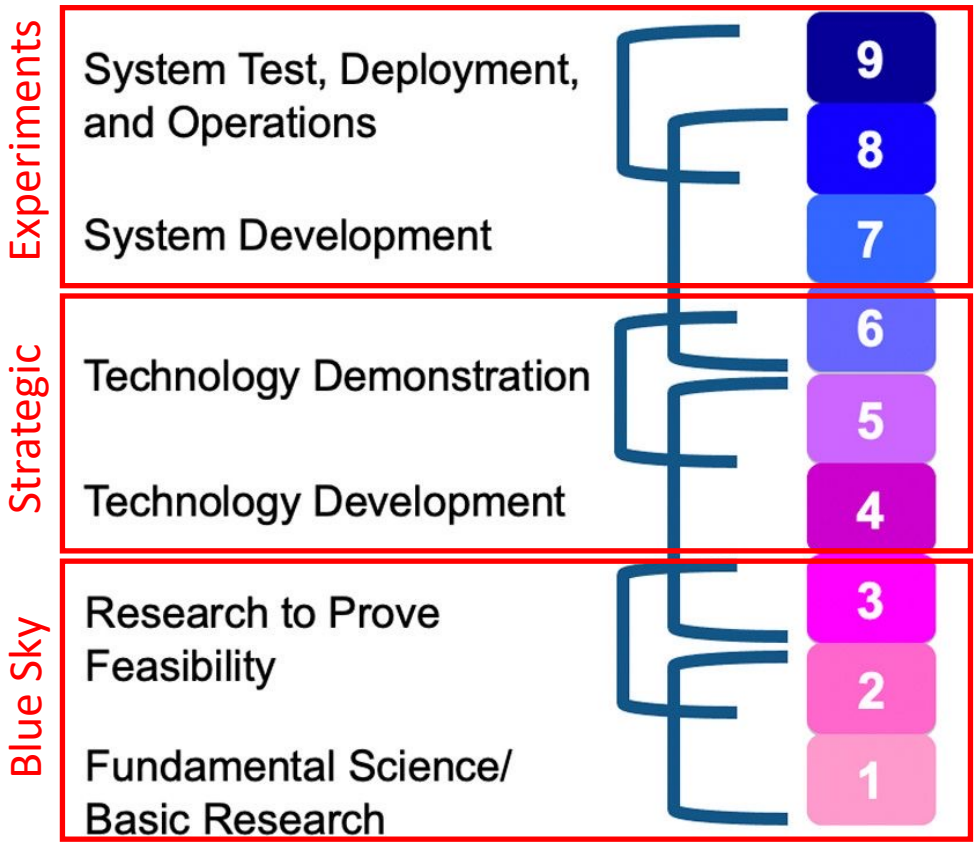


Strategic R&D vs. Blue Sky

Strategic R&D towards **necessary technologies to build future facilities** and experiments

- Addresses the DRDTs in ECFA roadmap by defining suitable deliverables and milestones
  - Technology Readiness Levels (TRL) 3-6
  - Backed up by **strategic funding**, agreed with funding agencies (MoUs)

- DRD collaborations should also contain a small "**blue-sky**" section (TRL 1-3)
  - Allow new developments to emerge
  - Possibly financed by common fund + institute contributions (RD50/51 scheme)

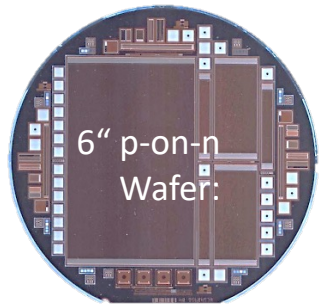


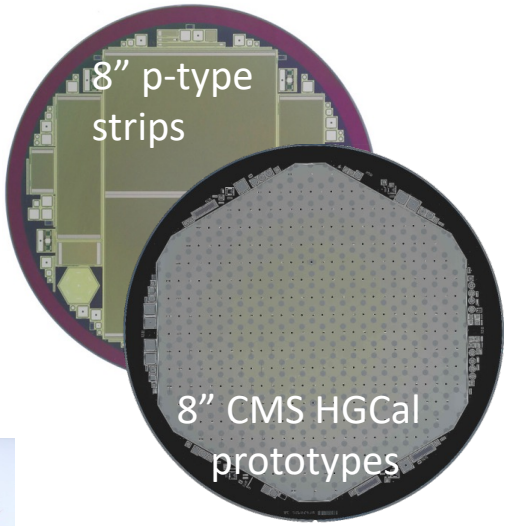
Example for the need of strategic funding

My group worked for almost a decade with European semiconductor industry to find a "second source" for large-area planar Si sensors

- Attracted a lot of attention
- Pushed HPK into developing 8" process
  → now being used for CMS HGCal
- Milestones:
  - 2009: re-produce 6" p-on-n strip sensors
  - 2015: First AC-coupled strip sensors on 8" wafers
  - 2016/17: production of first 8" hexagonal HGCal sensors
  - **2018: program stopped due to economic reasons**


Former CERN DG R. Heuer with Infineon manager and HEPHY staff

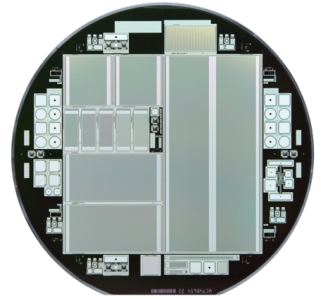




Reason for termination of program before series production:

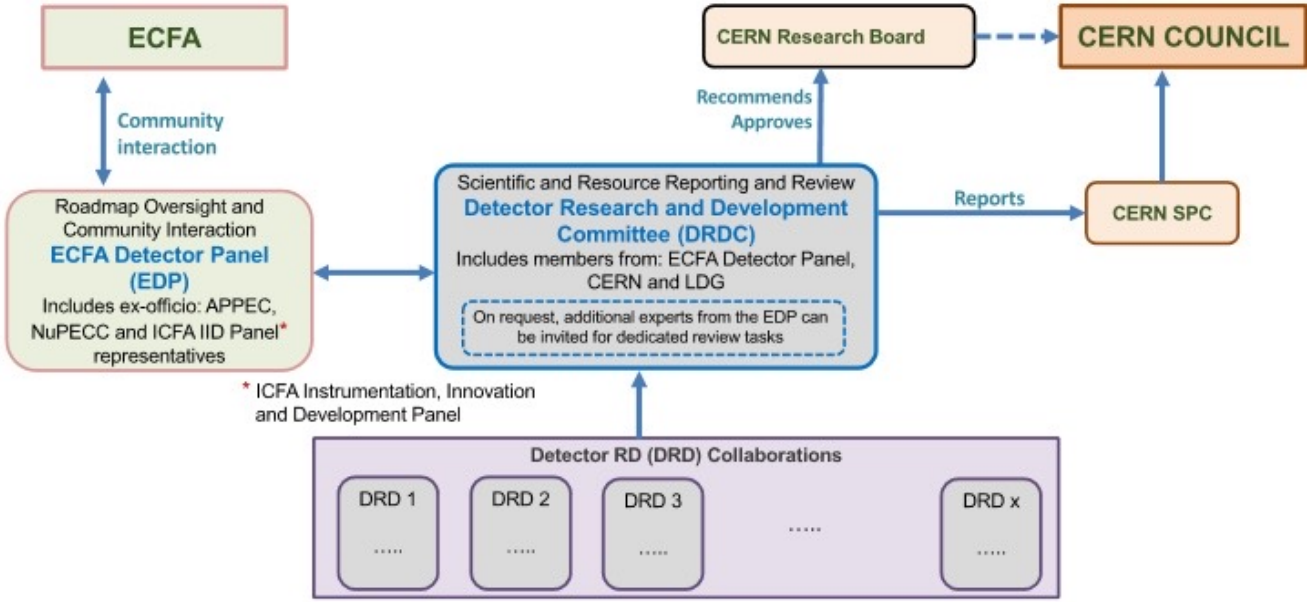
- O(10) more wafer runs (~150k€ each) would have been necessary to mature the technology
- Strategic R&D funding for R&D costs
  → reduction of series production costs

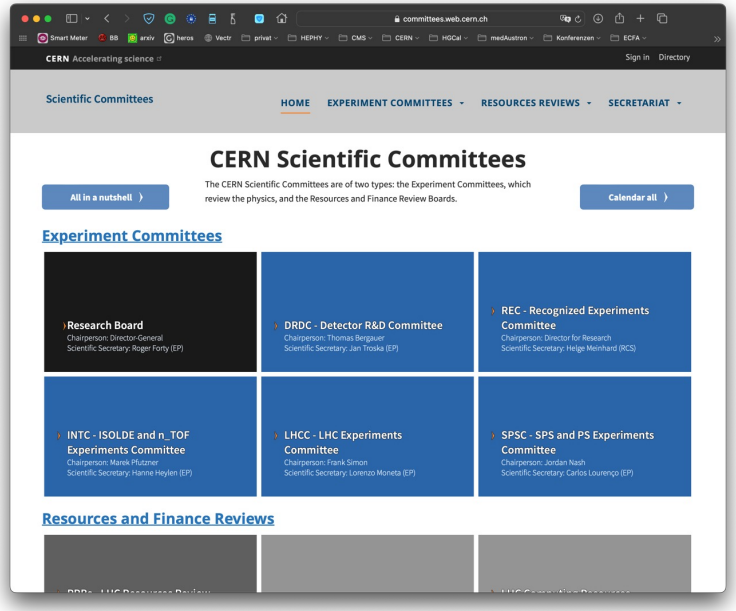

Infineon CEO together with HEPHY and CERN representatives



Roadmap implementation plan

- Approved by CERN SPC and Council in fall 2022 (CERN/SPC/1190 ; CERN/3679)
- Two bodies review and evaluate DRD proposals:
  - "New" DRD committee: http://committees.web.cern.ch/drdc established late summer / autumn this year
  - ECFA Detector Panel: https://ecfa-dp.desy.de
- Interaction between DRD collaborations and CERN **only through DRDC**





DRDC Mandate

- DRDC Tasks:
  - receiving and evaluating proposals for formal detector R&D collaborations
  - evaluating, on a regular basis, the progress and plans of the collaborations and projects approved by the RB
  - recommending corrective actions wherever they are deemed necessary
  - providing other recommendations to the RB relating to detector R&D
- DRDC Composition, Chair:
  - Nominated by CERN DRC
  - Members should include a representative of the Large Particle Physics Laboratory Directors' Group (LDG) and cross-membership with the ECFA Detector Panel (EDP).
  - Term: two years, renewable on two successive occasions for a maximum overall term of six years.
- DRDC Meetings:
  - At least two official meetings per year, before the RB meetings
  - Include an open session, where the proposals and progress reports are presented.

Committee Members

Detector R&D Committee (DRDC):

- ***Thomas Bergauer*** (HEPHY Vienna)
- Scientific secretary: *Jan Troska* (CERN)
- *Stan Bentvelsen* (NIKHEF, **LDG**)
- *Shikma Bressler* (Weizmann)
- *Dimitry Budker* (Mainz)
- ***Roger Forty*** (CERN)
- *Claudia Gemme* (INFN and U. Genoa)
- ***Inés Gil Botella*** (CIEMAT)
- *Petra Merkel* (Fermilab, US)
- *Mark Pesaresi* (Imperial College)
- ***Laurent Serin*** (IJCLab)
- Ex-officio: ***P. Allport***, ***D. Contardo*** (EDP)
- Ex-officio: CERN DRC, EP dep. head, KT head

ECFA Detector Panel (EDP):

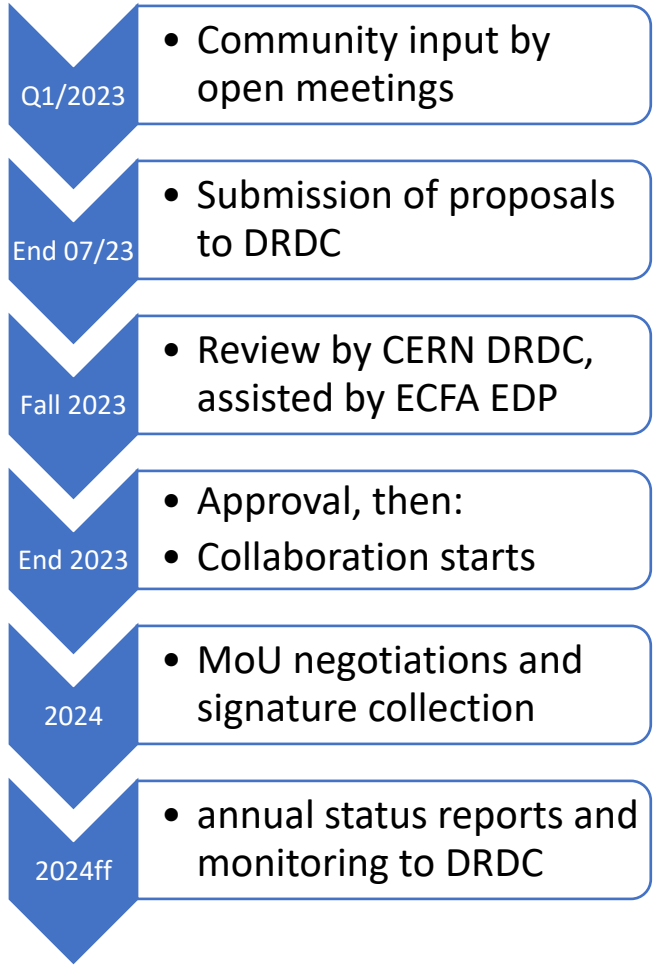
- Co-chairs: ***Phil Allport*** *(Birmingham)*, ***Didier Contardo*** *(Lyon)*
- Scientific secretary: *Doris Eckstein (DESY)*
- Gaseous Detectors: *Silvia Dalla Torre (Torino)*
- Liquid Detectors: ***Inés Gil Botella*** *(CIEMAT)*
- Solid State Detectors: *Doris Eckstein, Phil Allport*
- PID & Photon Detectors: ***Roger Forty*** *(CERN)*
- Quantum and emerging Technologies.: *Steven Hoekstra (Groningen)*
- Calorimetry: ***Laurent Serin*** *(IJCLab)*
- Electronics: *Valerio Re (Bergamo)*
- Ex Officio: *ECFA Chair (Karl Jakobs), ICFA Detector Panel (Ian Shipsey), DRDC chair (**Thomas Bergauer**), APPEC & NuPECC observers*

Names in bold in both committees

From ECFA Task forces and RD collaborations to DRD collaborations

Timeline:

- Review of DRD proposals by DRDC this fall:
  - Nine DRDC internal meetings so far discussing DRD proposals
  - Several meetings between DRDC and proponents of collabs.
  - Three iterations of each proposal received after suggestions from DRDC
- **Approval by the end of 2023**
  - 4th December: 1st official (but fully closed) DRDC meeting with presentations and discussions with each DRD proposal teams
  - 6th December: Official approval by CERN Research Board
- Once approved, DRD collaborations can start in 2024
  - Enables entry to CERN grey book, so that team leaders of each participating institute can be nominated and users registered
  - Collaborations will have kick-off meetings, elect spokespersons
  - MoU setup and collecting signatures from Funding Agencies
  - Later: Annual status reports to DRDC; monitoring of milestones and deliverables



Memorandum of Understanding

- All institutes of one DRD collaboration sign a “light-weight” MoU
  - Does not contain commitments on strategic funds
  - Defines Common Fund, if agreed by the respective DRD Collaboration
  - Covers IP topics, how to handle involvement of industr

  (In that case very similar as the current existing MoUs of RD50/51)
  - MoU Template will be provided by CERN (currently being negotiated with legal office, KT, DRC,..)
- Strategic funding will be agreed upon in annexes to this light-weight MoU
  - One Annex per Work Package, signed by the FAs of the institutes involved in the respective WP

Status in the US and elsewhere

- Result from US Snowmass process: recommendation to **create Detector R&D collaborations in the US**
  - Organized by CPAD (Coordinating Panel for Advanced Detectors) of the APS/DPF (one chairperson from CPAD is in DRDC)
  - They created 11 RDCs (R&D Collaborations) and appointed coordinators (see CPAD website)
  - Recently started to reach out to the community and work on detailed planning: CPAD workshop 7-11 Nov at SLAC
  - Overlap to DRDs through people/groups involved in both and liaisons

- **EU-funded programs** play an important role in enabling and supporting generic R&Ds, and fostering collaboration: AIDA/2020/innova, ATTRACT, ERC grants

RDC#	TOPIC
1	Noble Element Detectors
2	Photodetectors
3	Solid State Tracking
4	Readout and ASICs
5	Trigger and DAQ
6	Gaseous Detectors
7	Low-Background Detectors
8	Quantum and Superconducting Sensors
9	Calorimetry
10	Detector Mechanics
11	Fast Timing

Proposed Detector R&D collaborations

Highlights of scientific programs, organization and community contributions

Status of Proposed DRD Collabs.

Collab.	Topic	Initial Proposal Submission	Seeking approval	comment
DRD 1	Development of Gaseous Detectors	July 2023	Dec. 2023	Former RD51
DRD 2	Liquid Detectors	July 2023	Dec. 2023	
DRD 3	Solid State Detectors	3 Oct. 2023	Dec. 2023	Former RD50
DRD 4	Photon Detectors and Particle Identification Techniques	July 2023	Dec. 2023	
DRD 6	Calorimetry	July 2023	Dec. 2023	CALICE, CrystalClear
DRD 5	Quantum and Emerging Technologies		later	
DRD 7	R&D Collaboration for Electronic Systems	LoI submitted	later	
TF 8	Integration	-	later	Workshop on 6th Dec.

DRD1: Gaseous Detectors

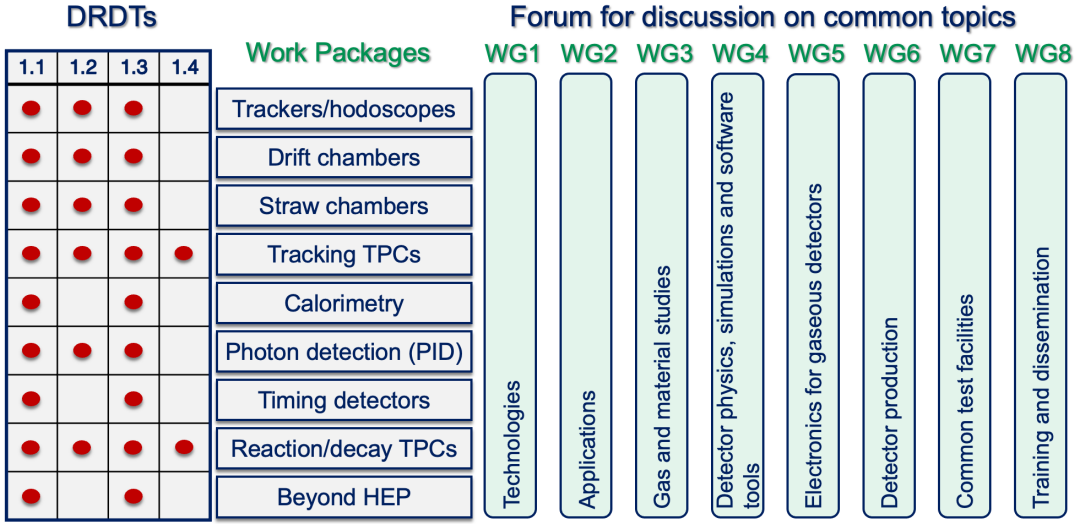
Gaseous

DRDT 1.1 Improve time and spatial resolution for gaseous detectors with long-term stability

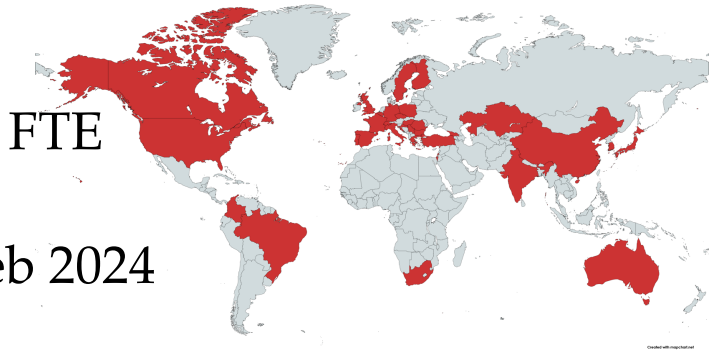
DRDT 1.2 Achieve tracking in gaseous detectors with dE/dx and dN/dx capability in large volumes with very low material budget and different read-out schemes

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

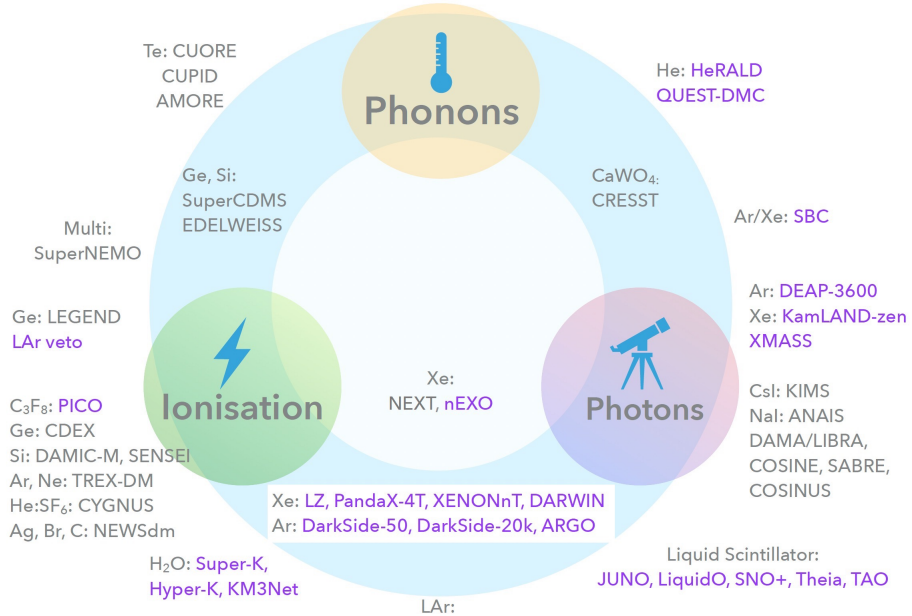


- Organized in
  - **Working Groups:** serving as the backbone of the proposed R&D environment and framework
  - **Work Packages:** will consolidate the activities of institutes with shared research interests in specific areas,
  - and **Common Projects** (blue sky) financed by fixed yearly fee (Common Fund)
- Large community of 160 institutes
- Budget: 3 MCHF/y existing, additional 3 MCHF/y requested, 270/100 FTE
- Community meeting: most recent June 23;
  next tentatively scheduled for Dec. 2023; DRD1 Kick-off meeting Jan-Feb 2024
- Web page: https://drd1.web.cern.ch/ (with proposal v1.4)

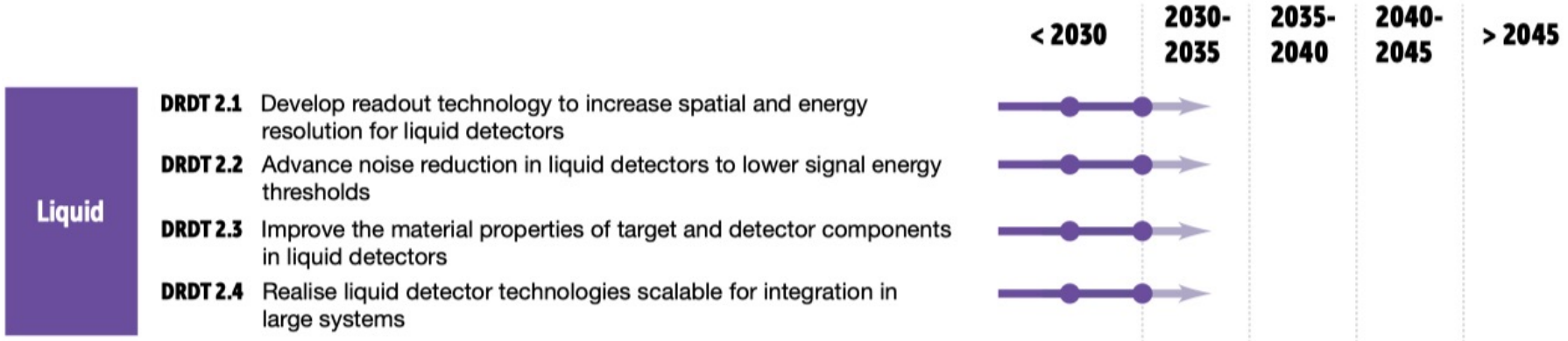


DRD2: Liquid detectors

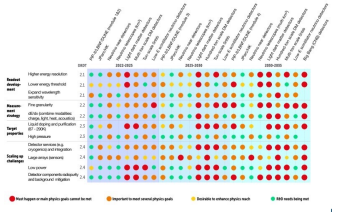
- Covers Dark Matter and Neutrino experiments, accelerator and non-accelerator-based
- Several large-scale and many small-scale experiments running or foreseen with liquid detectors
- Technology: Noble Liquids (e.g. DUNE), Water Cherenkov (e.g. Super/Hyper-K) and Liquid Scintillator with light and ionization readout
- Underground Dark Matter Experiments – small and rare signals R&D for multi-ton scale noble liquids:
  - Target doping and purification
  - Detector components radiopurity and background mitigation



[ECFA roadmap, Modified from L.Baudis]



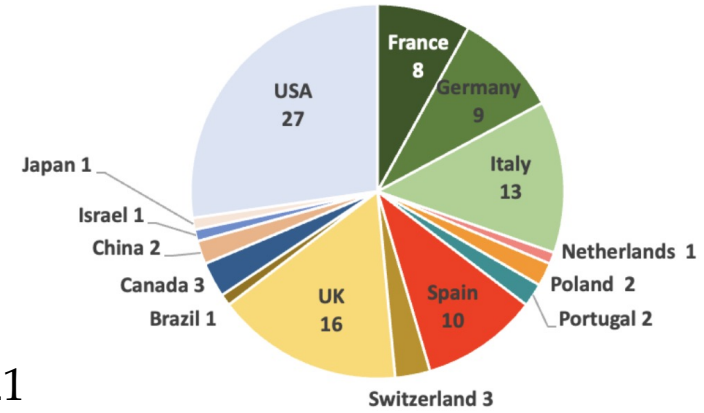
Note: Developments in this field are rapid and it is not possible today to reasonably estimate the dates for projects requiring longer-term R&D



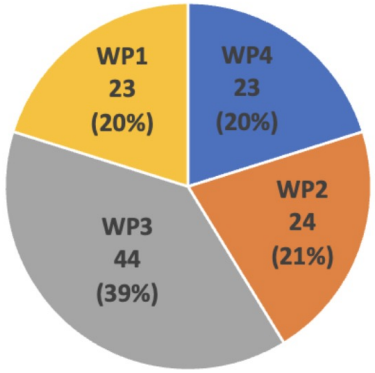
DRD2 Collaboration

- DRD2 proposal v4 almost final, divided in four WPs
  - Aligned but not identical to DRDTs
  - Based on 51 bottom-up projects
  - 150 participants in community meeting
  - Conveners: Roxanne Guenette, Jocelyn Monroe + 21 contributors
- DRD2 Collaboration from 114 institutes in 15 countries
  - Significant US contribution (>25%)
  - Nominated liaisons to DRD1,4 and 7
- Budget:
  - 2.6 / 7.8 M€/y (available / required)
  - 148.4/ 305.6 (available/required) FTE

Countries invovled in DRD2



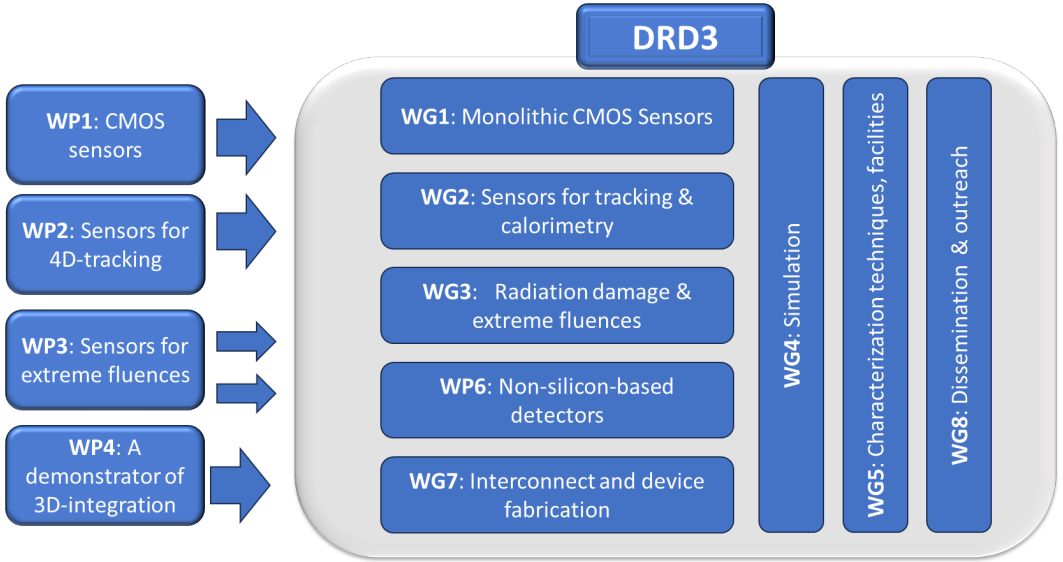
Number of insitutions per WP



WP1	WP2	WP3	WP4
Charge Readout Conveners	Light Readout Conveners	Target Properties Conveners	Scaling-up Challenges Conveners
Pixels & charge+light Group leaders	Increased sensor quantum efficiency Group leaders	Target properties and isotope loading of LS & WC Group leaders	Radiopurity & background mitigation Group leaders
Charge-to-light, electroluminescence & amplification Group leaders	Higher efficiency WLS and collection Group leaders		Detector and target procurement/production & purification Group leaders
Ion detection Group leaders	Improved sensors for LS & WC Group leaders	Target properties and isotope loading of noble elements Group leaders	Large-area readouts Group leaders
			Material properties Group leaders
DRDT 2.1, 2.2	DRDT 2.1, 2.2	DRDT 2.3	DRDT 2.3, 2.4

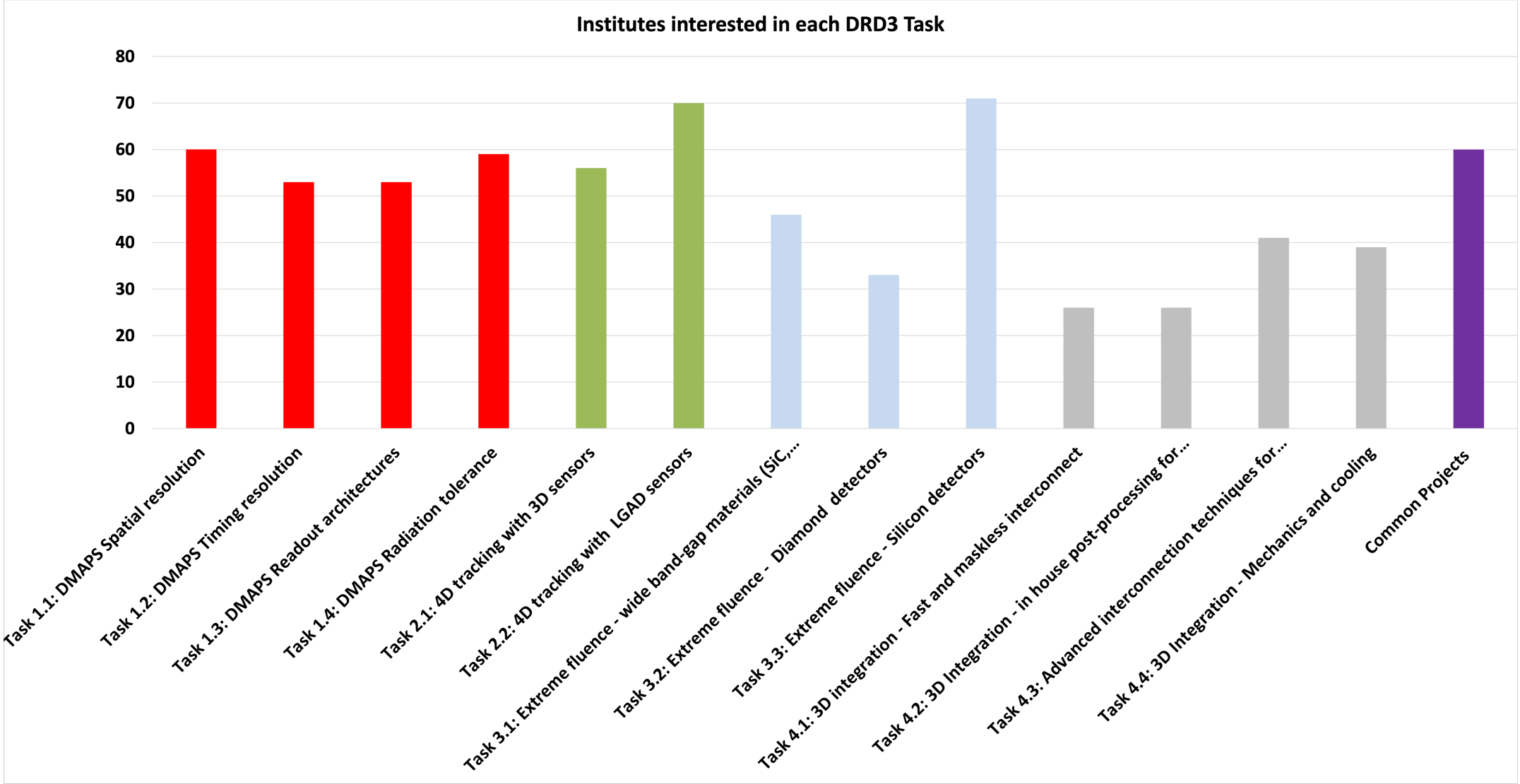
DRD3: Semiconductor Detectors

- DRD3 benefits from existing RD50 collaboration
  - Extended by diamonds (RD42) and 3D integration
- Organized in
  - Work Packages identical to DRDTs
  - Working Groups very similar to current RD50
  - Common projects (for blue-sky)
    (many still running from RD50)
- Large Collaboration: 129 institutes,
  28 countries, ~900 interested people
  - ~ 70% are from Europe, 15% from North America,
  - Compare: RD50: 65 institutes and 434 members
- Budget:
  - ~5 MCHF/y (existing), ~8 MCHF/y (requested)
  - 327 FTE (existing), 170 FTE (requested)



WP	Task	Title
1	1.1	DMAPS: spatial resolution
1	1.2	DMAPS: timing resolution
1	1.3	DMAPS: read-out architectures
1	1.4	DMAPS: radiation tolerance
2	2.1	4D tracking: 3D sensors
2	2.2	4D tracking: LGAD
3	3.1	Extreme fluence: wide band-gap materials (SiC, GaN)
3	3.2	Extreme fluence: diamond-based detectors
3	3.3	Extreme fluence: silicon detectors
4	4.1	3D Integration: fast and maskless interconnect
4	4.2	3D Integration: in house post-processing for hybridization
4	4.3	3D Integration: advanced interconnection techniques for detectors
4	4.4	3D Integration: mechanics and cooling

DRD3: Semiconductor Detectors

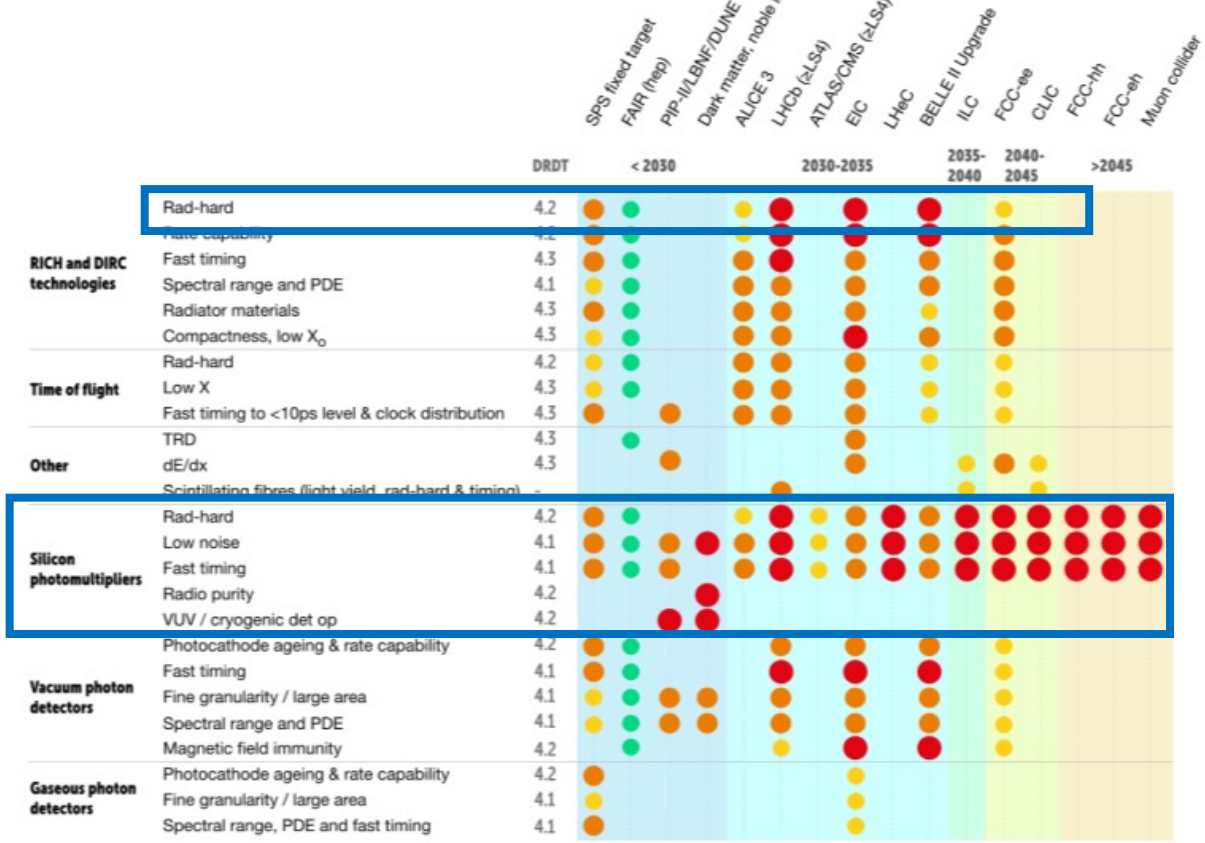


DRD4: Photodetectors & Particle ID

- Particle Identification (PID) essential to identify decays when heavy flavor are present

- **Developments** on PMTs, MCP-PMTs, SiPMs, APD, HPD, quantum devices, SciFi,
  - Challenges for example for SiPMs: rad hard, dark rate, timing
- **Applications** in Ring Imaging Cherenkov Detectors (RICH), Time-of-Flight (ToF), TRD

- Connection to almost every other DRD collab. (gas, Silicon, Calo, electronics, SiPM at cryogenic temp.)

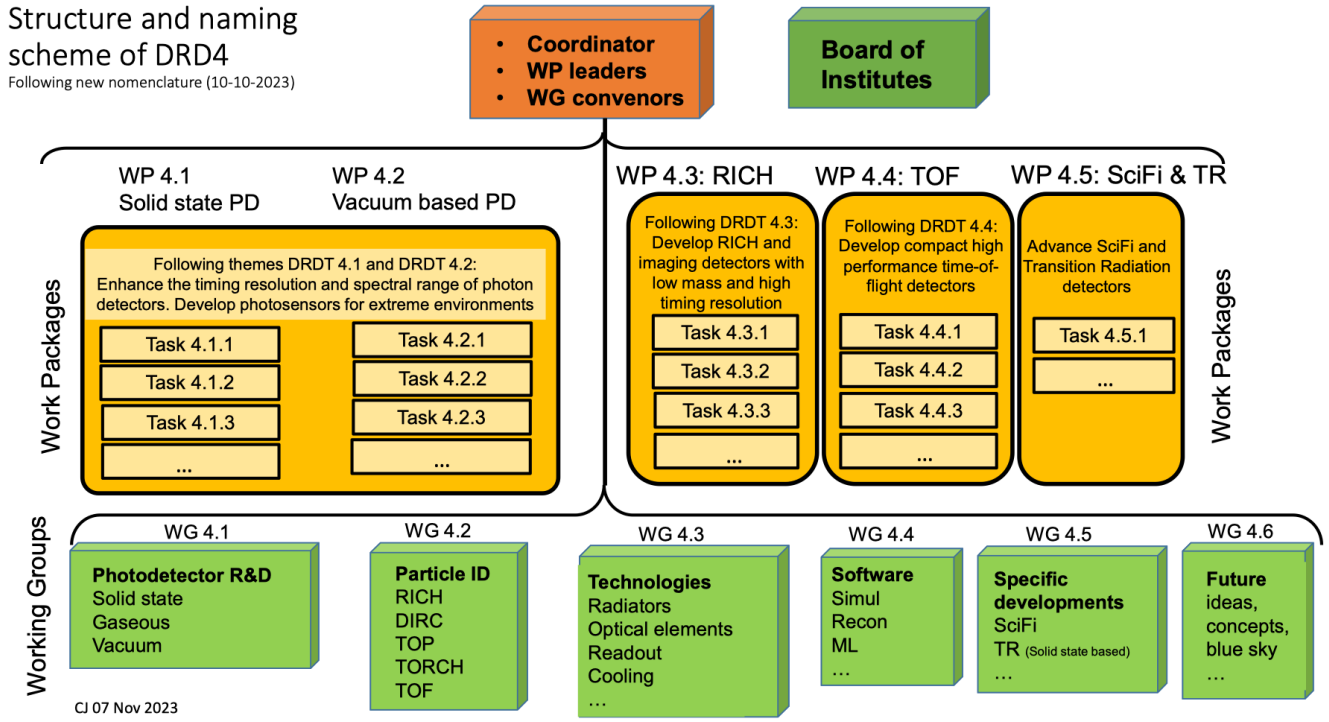


PID and Photon

- **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

DRD4: Photodetectors & Particle ID

- Collaboration currently led by Christian Joram (CERN) + Peter Krizan (Ljubljana) + team of 12 others
  - election of management when collaboration officially constituted in 2024
- 67 institutes + 7 industrial partners
  - EU + 6 US, 2 China, 2 Japan, 2 Australia, 1 S.Korea, 1 Armenia
- Budget
  - 100 FTE/y (avail), ~60 FTE/y (additional)
  - 1.5MCHF/y (avail.), 1.8MCHF/y (additional)



DRD6 Calorimetry

- Collaboration emerged from CALICE and CrystalClear (RD18)
  - 23 input proposals were collected from existing collaborations, boiled down to four WPs and five Working Groups
  - 110 institutes; 183 FTE/y (existing), 100 FTE/y requested
  - Budget ~3.2M€/y existing, ~1.4 to 2.4M€/y requested (2024-2026)

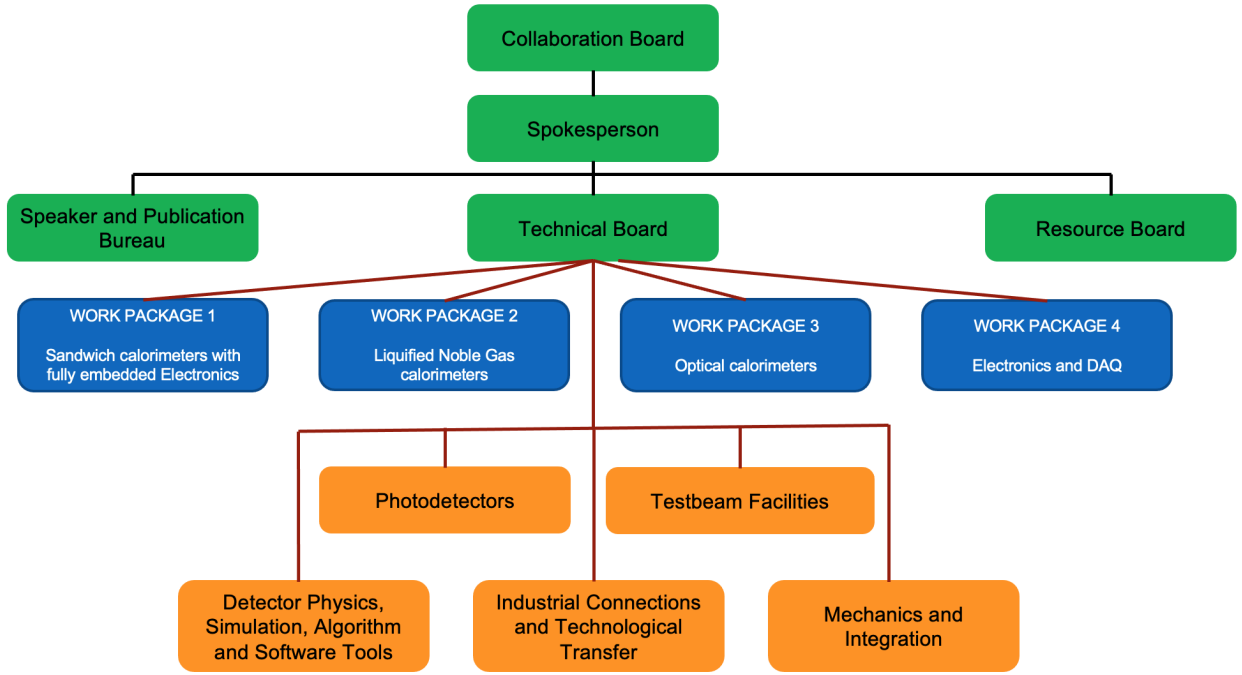
- R&D in calorimetry has a particularly long lead-time due
  - Many technology developments (gas, scintillator or Silicon-based readout) done in other DRDs
  - Large and challenging prototype setups even in early stages
  - Dedicated calorimeter test beam line requested

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

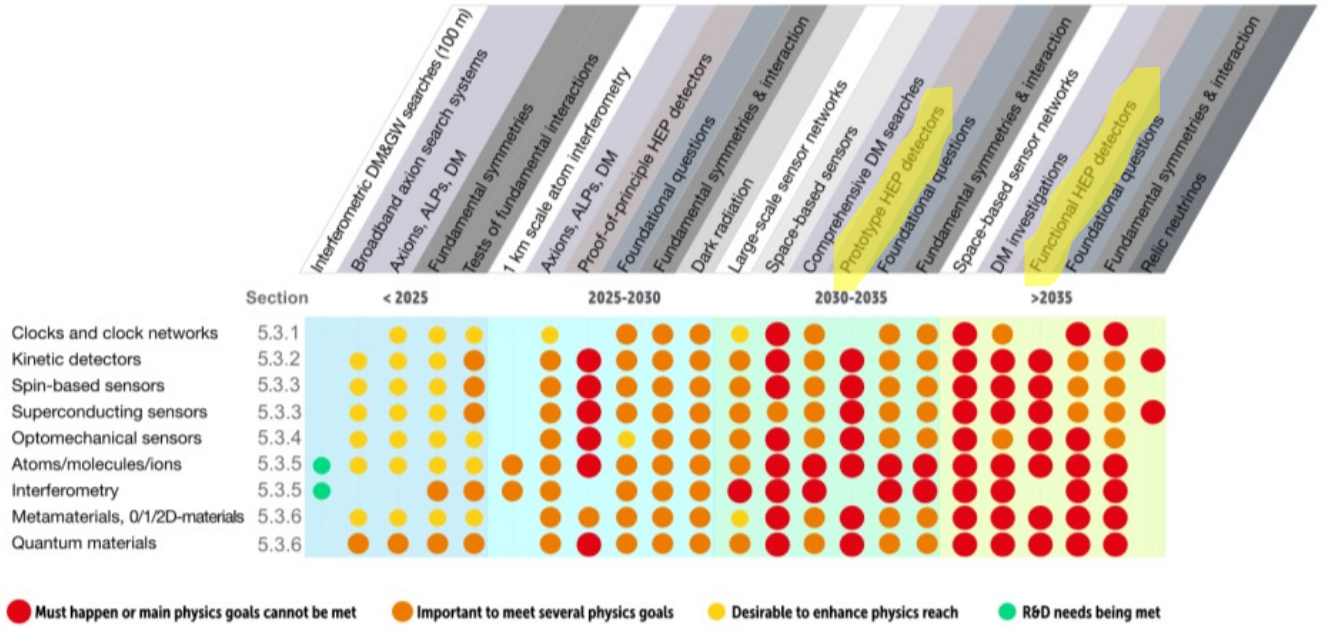


DRD5: Quantum Sensors

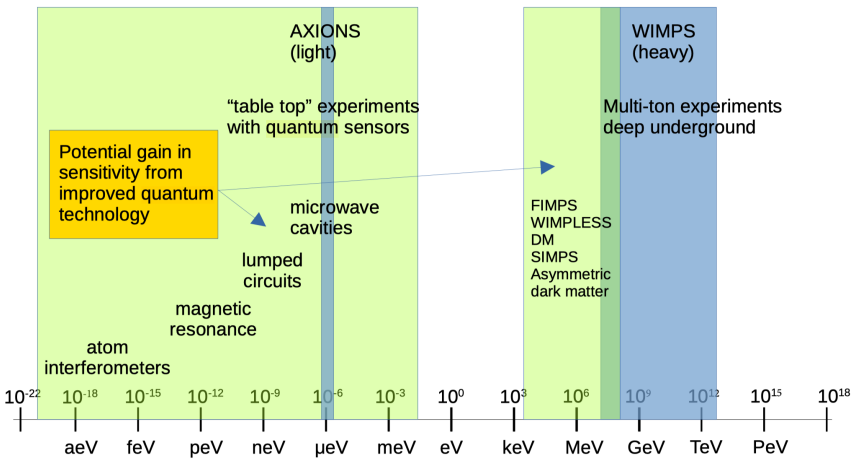
- Quantum Technologies are a **rapidly emerging area** of technology development to study fundamental physics
  - Targeting Gravitational Wave, Axion, DM detection
  - development of HEP detectors on the long term

- Many different sensor and technologies being investigated: clocks and clock networks, kinetic detectors, spin-based, superconducting, optomechanical sensors, atoms/molecules/ions, interferometry, …

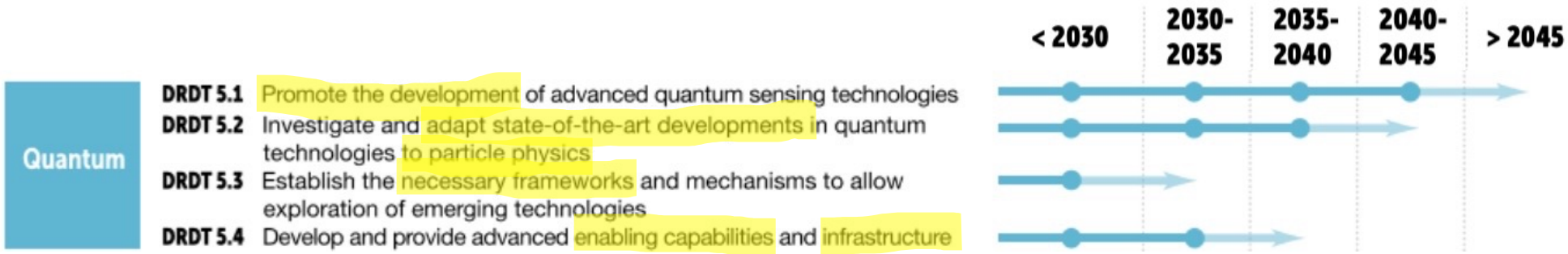
- Several initiatives started at CERN, DESY, UK,…



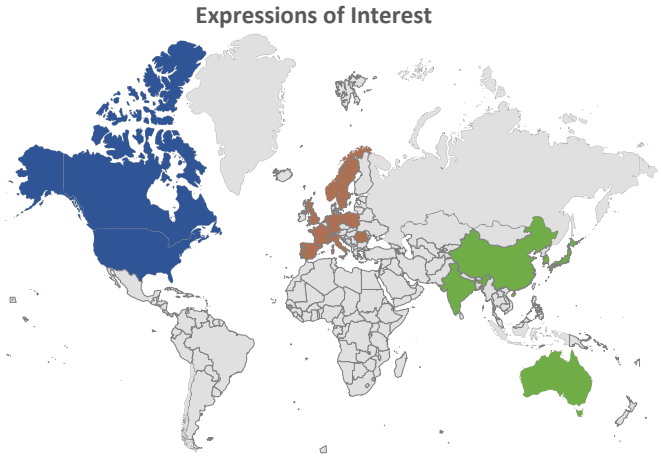
Example: potential mass ranges that quantum sensing approaches open up for Axion searches (from: ECFA roadmap)



DRD5 Collaboration



- 40 institutes in 15 countries
- 25 proposed contributions
- conveners: Marcel Demarteau, Michael Doser
- White Paper / LoI being submitted to DRDC
  - Information on personal web page of M. Doser

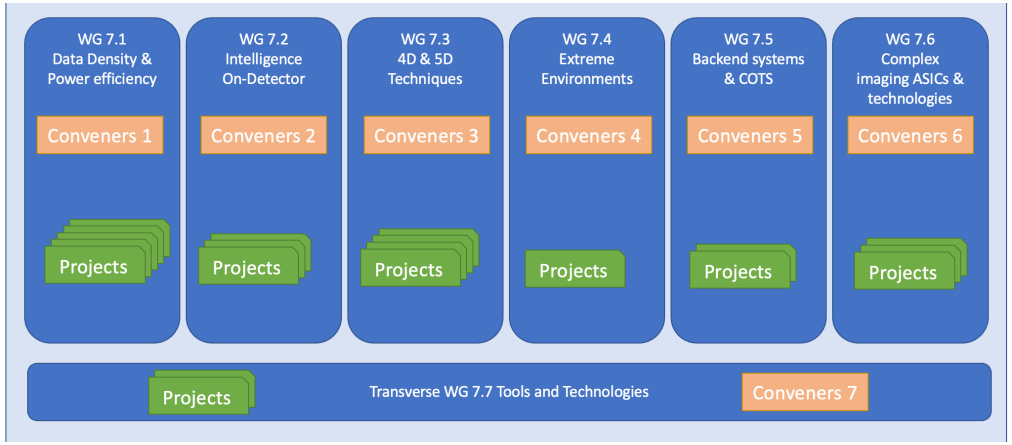


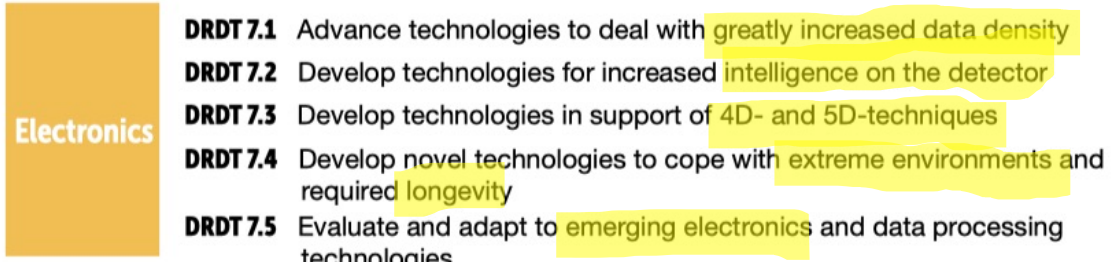
- A workshop to prepare the proposal for submission by the end of the year took place Oct. 2-4.

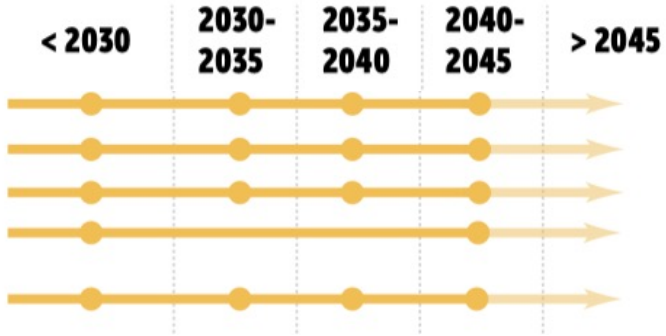
DRD7: Electronics

- LoI exists, full proposal to be submitted by the end of this year
  - To ensure no duplication and foster cooperation between different DRDs
  - NOT to understand the immediate needs of the other DRD collaborations
  - Develops strategic electronics (e.g. GLIB, FC7, FEAST DC-DC converter)
  - Single point of contact to foundries

- Organization:
  - Six (Seven) Development areas (WPs)
  - 50 Institutes, 18 countries
  - Steering committee: Jerome Baudot, Marcus French, Angelo Rivetti, Frank Simon, Francois Vasey + 20 WP coordinators
  - 1st workshop happened in March, 2nd workshop 25-27 September 2023







Projects in DRD7

16 projects in a bottom-up approach, but ensured that all are above certain threshold and fit the WGs

- 7.1a: Silicon Photonics Transceiver Development
- 7.1b: Powering Next Generation Detector Systems
- 7.1c: Wireless Allowing Data and Power Transmission

- 7.2a: eFPGA - Programmable Logic Array
- 7.2b: Radiation Tolerant RISC-V processor
- 7.2c: Virtual electronic system prototyping

- 7.3a: High performance TDC and ADC blocks at ultra-low power
- 7.3b-1: Data-driven impact studies and calibration strategies for time measurements
- 7.3b-2: Timing distribution techniques and systems

- 7.4a: Modeling and development of cryogenic CMOS PDKs
- 7.4b: Radiation resistance of advanced CMOS nodes
- 7.4c: Cooling and cooling plates

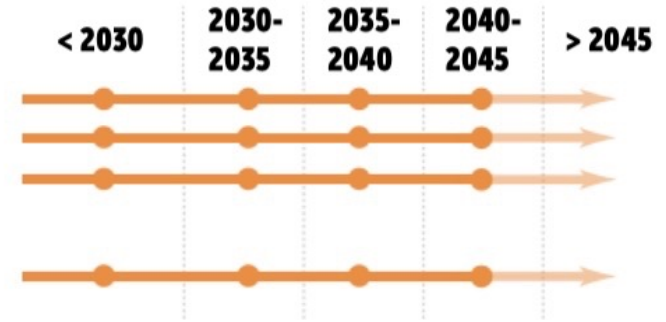
- 7.5.a COTS architectures, tools and IP
- 7.5b: No backend, full 100GbE solutions from FE to DAQ

- 7.6a: Common access to selected imaging technologies and IP blocks
- 7.6b: Common access to 3D and advanced integration

Task Force 8: Integration

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



- Target: Mechanical support and structures, cooling, magnets and management of radiation environment
  - DRDTs are quite diverse
  - Some topics are very closely connected to the genuine DRDs, where the technology is developed (e.g. DRDT 8.3)
- **No DRD collaboration has been proposed yet, but 16 institutions replied favourably to a community survey**
  - **Community Meeting on December 6, 2023**

Topics:

- Gas cooling development
- Single- and two-phase liquid cooling R&D
- Humidity control
- Temperature control
- Thermal management
- Thermal performance verification
- Thermal interface materials and expansion differences
- Pipe materials, pipe connection techniques and fittings
- Choices and characterisation of construction materials
- 3D printing
- Radiation and mechanics: Materials and issues like access constraints
- FEA and its comparison to real objects
- Structure design and optimisation
- Application of machine learning for design issues

Summary (1)

- **New Detector R&D (DRD) collaborations are being set up following the ECFA Detector roadmap to pave the way for the next decades.**
  - Main Goal: Instrumentation is not the limiting factor to meet the needs of the long-term particle physics program
  - Collaboration-building for communities that have not worked together before

- Submitted, currently being reviewed by DRDC: **Gas detectors** (DRD1), **liquid detectors** (DRD2), **semiconductor detectors** (DRD3), **photodetectors & particle ID** (DRD4), **calorimetry** (DRD6)
  - DRDC and CERN research board approval meetings 4th and 6th of December
  - The proposals will then be publicly accessible in the CERN CDS
- Proposal Submission later:
  - **Quantum sensors** (DRD5), **Electronics** (DRD7)
  - **Integration** (DRD8) to be decided

Summary (2)

- What might be missing at this point?
  - A coherent picture of **resources across all DRDs** so that funding agencies get the total demand
    - Discussions on national level started
    - Currently, the strategic funding listed in the proposal is just “wishful thinking”
  - Better **coordination between different DRDs** to **reduce duplications** and **synchronize activities**, especially for electronics (e.g. CMOS sensors)
  - Coordinated approach on how **to involve industry** (IP topics) and **non-European groups**

- **Proposal approval, collaborations kick-off, MoU signatures**

The End.

Acknowledgments: Phil Allport, Didier Contardo, Roger Forty, Susanne Kühn, Felix Sefkow, Laurent Serin, Maxim Titov and others

Links:

- DRD Committee
- Future CERN Indico Section of all DRD Collaborations
- Link to all TF/DRD community meetings and resources

Checklist for proposal evaluation

1. Check if the proposal format matches guidance document from EDP (tables, layout,..)
   - Document linked here and here (if not accessible at Indico)
2. Milestone and Deliverables match ECFA detector roadmap
3. Committed resources (FTE /funds) match the demand given by the scientific program
4. Collaboration structure exists (institution board, conference board, decision-making bodies,..)
5. Common fund and its usage (for small bottom-up projects, but also for administration?)
6. Overlap/transition from existing collaborations explained
   - DRD1/3: RD51/50: common projects, common fund
   - DRD6: Calice, CrystalClear
   - DRD5: CERN quantum initiative
7. Interconnections
   - Explanation of scientific topics which overlap with other DRDs, especially electronics
   - Liaisons nominated to other DRDs and the US DRC groups
   - Industry participation

Draft DRD Proposal Guidance

(16th February 2023)

Updated 29th June 2023 following discussion with DRDC Chair

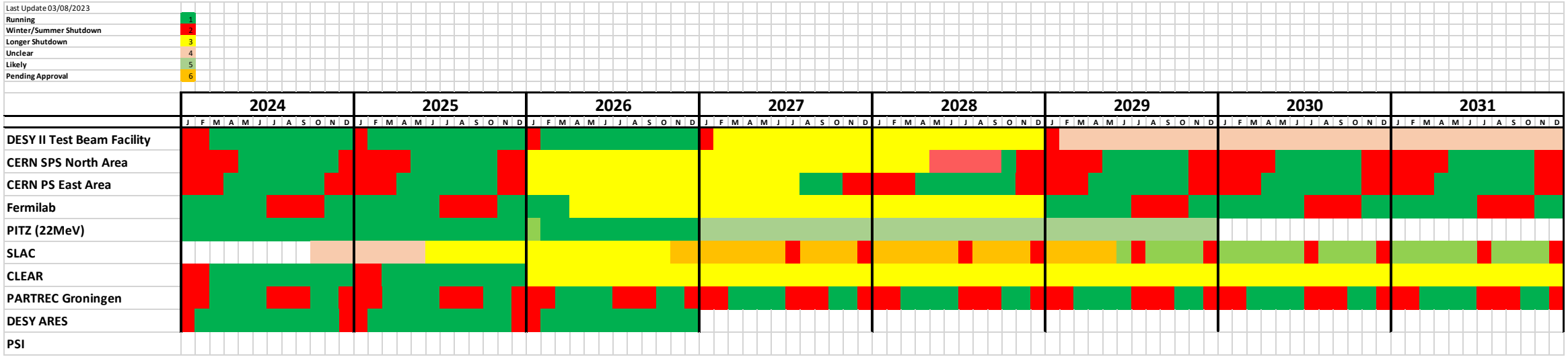
2. Main Proposal:

To keep the process manageable for both proponents and reviewers, it is recommended that the DRD proposal document should not exceed 20 pages, following a common outline template as suggested below:

- Introduction (objectives of the DRD collaboration)
- Planning technology area 1 (including a task/deliverable synoptic, resources and list of contributing institutes)
- …
- Planning technology area n (including a task/deliverable synoptic, resources and list of contributing institutes)
- Interfaces to other DRD proposals - including particularly the links to DRD7 as a transversal Detector R&D topic area
- Common simulation tools and test facilities
- Partnerships (industrial, other research areas, other applications)
- Networking and training
- Proposal for the collaboration structure
- Resources (as discussed below) both existing and anticipated
- Summary (high level planning synoptic by DRDT broken-down to sub-areas)

Beam test schedule

By coincidence, there is a lack of beam test possibilities in 2026-2028.
At CERN this is caused by LHC LS3 and the upgrade to HL-LHC

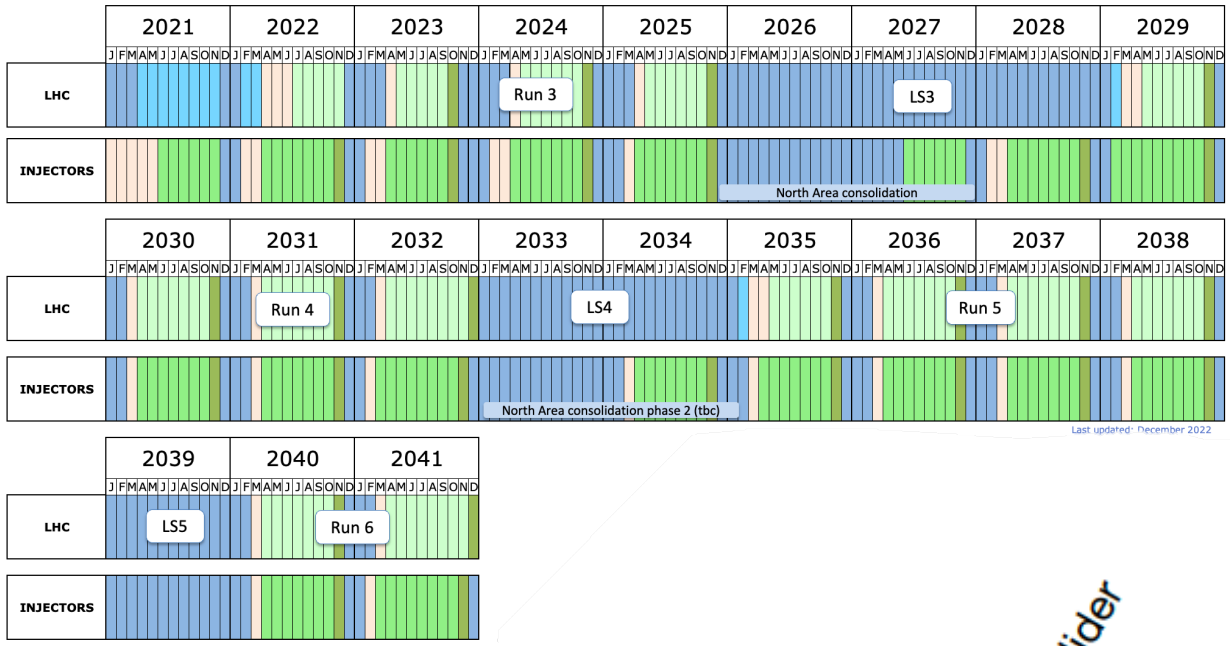


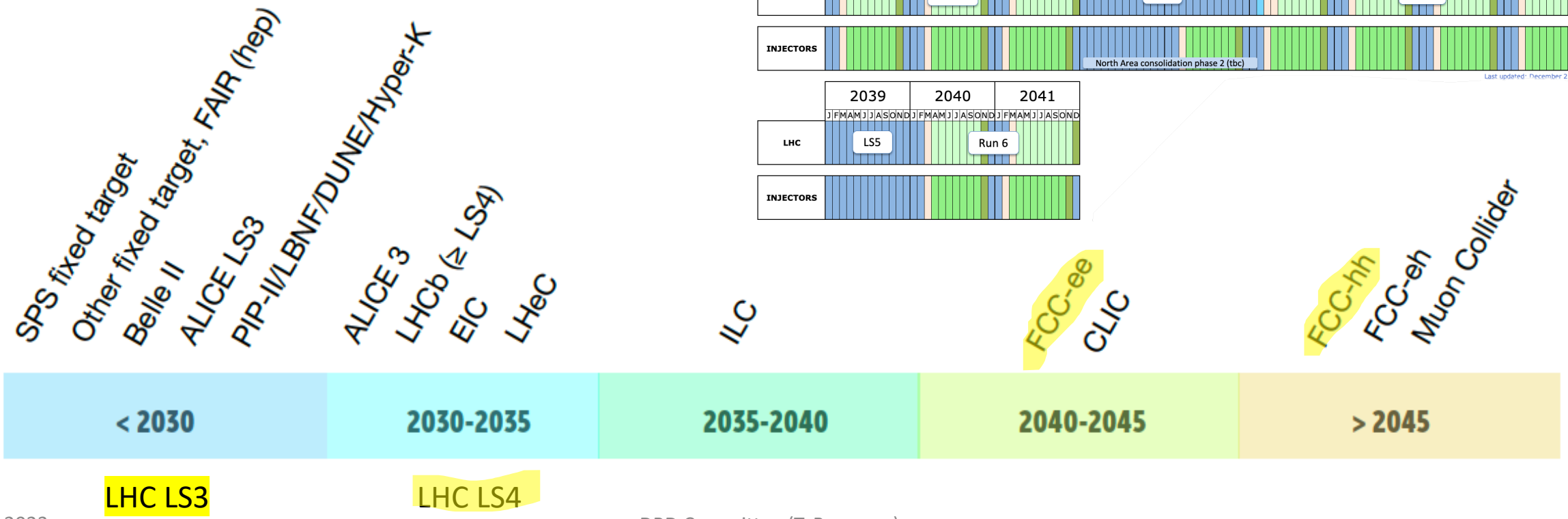
https://cern.ch/international-facilities

Future Large Experiments

- Five Time periods defined
  - In agreement with (HL)-LHC

(HL-)LHC timeline:





Future "Smaller" Experiments

- Different time periods as for large experiments: