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Detector Research and Development collaborations

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Following endorsement of the update of the European Strategy for Particle Physics by the CERN council in 2020, ECFA was charged to prepare a Detector R&D roadmap and then to develop an organisation to execute it. This paper outlines the main steps that led to form new Detector Research and Development collaborations, it briefly describes the framework to host them at CERN and highlights the scientific programs and the work plan established by the participating institutes.

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1. Introduction

Initial thoughts for future detector R&D programs were discussed at the Granada Symposium in preparation of an update of the European Strategy for Particle Physics (ESPP) [1]. When the strategy [2] was endorsed by the CERN council in 2020, ECFA was entrusted to a step forward to prepare a roadmap of the Detector R&D needed to fulfil the requirements of the future strategic projects identified by the ESPP.

The roadmap was prepared under the umbrella of a dedicated ECFA panel as illustrated in figure 1. The document published in 2021 [3] considered two main classes of experiments, those at large accelerator facilities and those at small accelerator facilities, nuclear reactors and other non-accelerator experiments. Theses projects have different time scales, as well as different requirements, that where reflected in the definition and perimeters of the R&D areas covered by the six first Tasks Forces (TF) of the panel. The coverage of each TF is further discussed in section 3. In addition TF7, TF8 and TF9 respectively addressed transverse R&D aspects of electronics, integration and training.

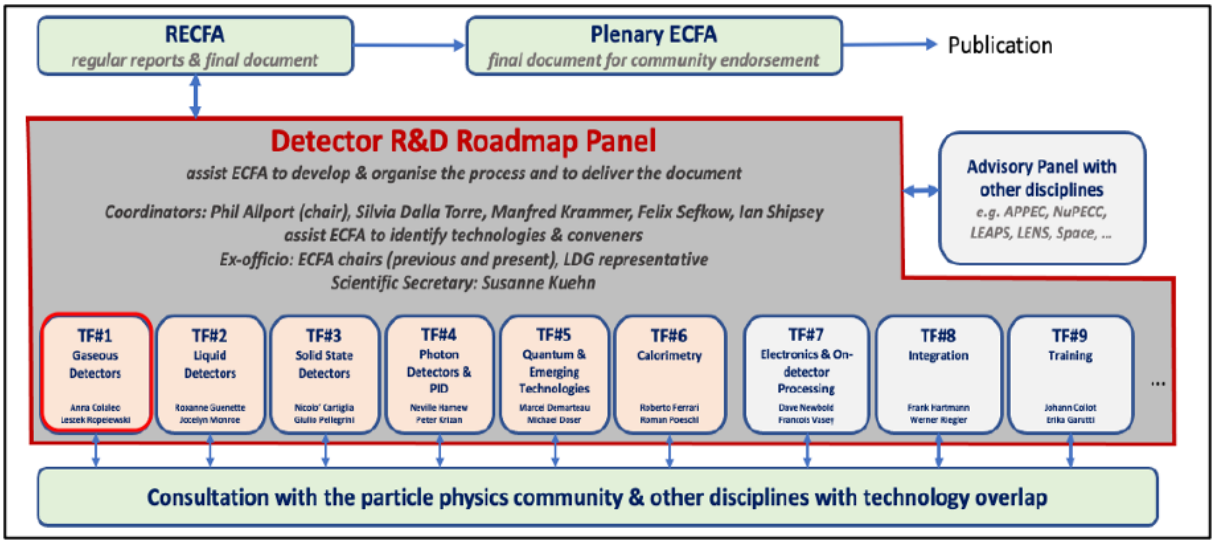

Figure 1: Organisation structure for preparation of the Detector R&D roadmap.

For each TF area, the roadmap identifies the performance requirements of future experiments and the technology options to use in different instrumental systems. On this basis, high level Detector Research and Development Themes (DRDT), that technologies should achieve to fulfil critical needs to the physics programs were established for each area. The roadmap concludes with ten Global Strategic Recommendations (GSR) of which GSR4 suggests "international coordination and organisation of the R&D activities" and GSR6 to "establish long term strategic funding program". Section 2 describes the framework to implement these recommendations, while section 3 outlines the scientific programs and organisation proposed by the DRD collaborations.

2. Framework for DRD collaborations

Forming Detector Research and Development (DRD) collaborations to execute the programme outlined in the ECFA detector R&D roadmap was endorsed by the CERN SPC and Council at their September 2022 meetings. The objectives of the collaborations and the framework to host them at CERN (fig. 2) were fully described in reference [4].

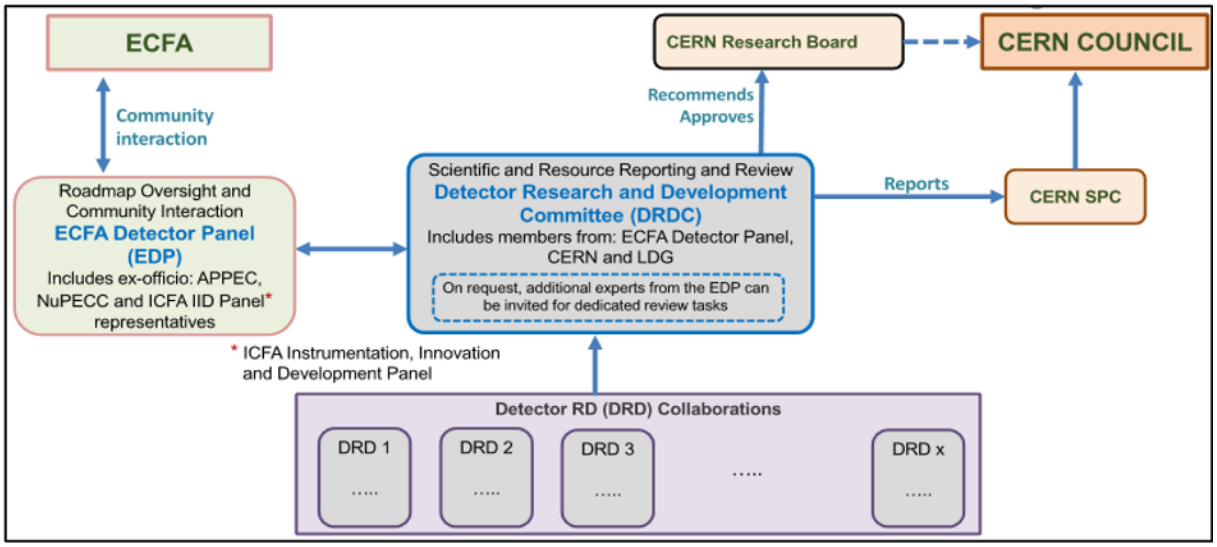

Figure 2: Framework to host DRD collaborations at CERN

The DRD collaboration activities will follow the general conditions of execution of an experiment at CERN and will be reviewed by a dedicated Detector Research and Development Committee (DRDC)[5]. The ECFA Detector Panel[6] will provide input to the DRDC in terms of roadmap priorities and potential updates according to the R&D progress and evolution of experiment concepts and requirements. To fulfil GSR6, the resource engagements of the participating funding agencies will be acknowledged by Memorandum of Undertandings (MoU). Usage of these resources will be reported at dedicated CERN Resource Review Board meetings.

Preparing the DRD proposals was assigned to the same ECFA Roadmap Panel and the TFs teams that served for the roadmap. In this process, the leaders of ongoing structured R&D programmes (CERN RDs, CALICE, AIDAInnova, etc.) were invited to facilitate the integration of existing communities and their activities into the new DRDs. To define the scientific programs and to propose a subsequent work organisation, the relevant communities were widely consulted through dedicated workshops and surveys that collected input from the institutes willing to contribute.

3. DRD scientific programs and collaboration organisations

The DRD proposals outline the program for developing generic technical solutions, from the demonstration that they could be used for a strategic project up to passing the developed technologies on to experiment collaborations for incorporation into their specific engineering designs[1]. At this

[1]The DRD programmes cover roughly the range TRL3 to TRL6 in the language of the Technology Readiness Level model developed by NASA[7]. The projects with a lower TRL are often referred to as "blue sky" R&D.

stage, the proposals focus on a first R&D phase of about 3 - 4 years, to cover the needs of earlier strategic projects and to prepare technology transitions towards longer-term applications. The scientific programmes are broken down by technology areas developed via Work Packages (WP) that set out performance deliverables and milestones to be achieved in technology demonstrators and/or in system prototypes.

Five proposals and two Letters of Intent (LoI) were released to the DRDC at the time of this conference and the review process is now on-going so that collaborations can become active by January 2024[2]. The proposals will become public by the end of 2023.

3.1 DRD1 proposal - Gaseous Detectors

DRD1 R&D areas are identified with the six main domain of applications: tracking hodscopes; inner and central tracking with Particle Identification (PID); calorimetry; photodetectors for PID; Timing detectors for PID; TPCs as reaction and decay chambers. These areas have well identified links to specific projects and to the DRDTs of the roadmap. The proposal develop a research program to covers the needs for these applications with appropriate technology options among MPGDs, RPCs, Wire Chambers, Large Drift Chambers and TPCs. DRD1 is expected to provide technical solutions for system studies in DRD2, DRD4 and DRD6. New material and electronics developments will happen in conjunction with DRD5 and DRD7. At this stage, about 120 institutes in 60 countries have expressed their interest to participate to the DRD1 collaboration.

3.2 DRD2 proposal - Liquid Detectors

DRD2 targets mostly the future experiments for Dark Matter, Neutrino physics and rare decays with large detector volumes using: Water Cerenkov, Noble Liquids and Liquid Scintillators. The proposal considers four R&D areas: charge readout; light readout; target properties; scaling-up challenges. The associated WPs involve several technology options for readout that will be provided by, or developed in synergy of specifications, with DRD1, DRD3 and DRD4. Similar links as for DRD1 exist with DRD5 and DRD7, with a specific aspect of operation at cryogenic temperature for electronic systems. At this stage, about 115 institutes in 15 countries have expressed their interest to participate to the DRD2 collaboration.

3.3 DRD3 proposal - Solid State Detectors

The DRD3 R&D areas are matched to the roadmap DRDTs, with a technology orientation: Monolithic CMOS sensor; Hybrid sensors in Low Gain Avalanche Detectors and 3D designs; radiation tolerant materials; 3D interconnection and integration. The associated WPs are aiming at delivering best technical solutions in each technology for application in 3D and 4D tracking, in Time of Flight (ToF) layers and for high granularity calorimeters. Complex electronics architecture for high density readout and high rates will be developed in conjunction with DRD7. At this stage, about 100 institutes in 30 countries have expressed their interest to participate to the DRD3 collaboration.

[2]The opportunity for an "integration" DRD8 collaboration covering detector mechanical structures, system integration and cooling devices is still being investigated with the relevant communities

3.4 DRD4 proposal - Photon Detectors and PID

The DRD4 program target mostly the measurement of small photon signals in light devices for application to PID in Ring Imaging CHerenkov (RICH) detectors or dedicate ToF layers. The R&D areas cover at the same time technolgy options and complete systems: photodetectors (solid state devices and vacuum photosensors); RICH systems (material and concepts); thin Cerenkov radiators for ToF PID layers; light-based device for tracking (scintillating fibers and solid state Transtion Radiator Detectors). Development perimeters and synergies with other DRDs are well identified with: DRD2 and DRD6 for photodetectors; DRD6 for scintillating and Cerenkov materials; DRD2 and DRD7 for low pressure and cryogenic temperature operation. At this stage, about 70 institutes in 19 countries have expressed their interest to participate to the DRD4 collaboration.

3.5 DRD5 LoI - Quantum sensors

The DRD5 field is relatively new to HEP, verging on low TRL, but it has demonstrated capabilities to enter into specific strategic projects. This topic is also of worldwide societal interest in a competitive development environment with vast and very diverse funding sources. At this stage, the DRD5 team is focusing on identifying development areas where the HEP collaborative model could apply. Six initial R&D areas have been identified: networks, signal and clock distribution; Exotic systems in traps and beams; Cryogenic systems; Theory; "Bulkification" of devices; Capability driven design. Specific technology WPs can be attached to these areas. With respect to other DRDs, DRD5 can also be considered as a transverse area, especially for what concerns new materials and concepts that can emerge for application in collider experiments. At this stage, collaboration building is ongoing. Considerations are given to organise the work in pools of competences and/or specific technical goals. A full proposal is expected early 2024.

3.6 DRD6 proposal - Calorimetry

The DRD6 R&D areas are identified with the the three major calorimeter concepts: sampling calorimeters with fully embedded electronics; liquified noble gas calorimeters; optical calorimeters. The WPs are focused on developing system prototypes in several combinations of system designs and sensitive components. The latter will be mostly developed in DRD1 and DRD3 for solid state and gaseous sensitive elements; and in conjunction with DRD2 and DRD4 for materials producing light and the associate photodectors, specific scintillating and Cerenkov material developments will be undertaken within DRD6. At this stage, about 110 institutes in 25 countries have expressed their interest to participate to the DRD6 collaboration with some consortia already existing around the three calorimetry concepts.

3.7 DRD7 LoI - Electronic Systems

DRD7 has identified seven R&D areas: data density and power efficiency; intelligence on detector; 4D and 5D techniques; extreme environments; back-end systems and cots; complex imaging ASICs and technologies. In the associated WPs new common standards, methodologies and IP components will be developed. DRD7 will also provide the community with access to tools and technologies, and to a framework to build expertise. The coordination with developments undertaken in other DRDs will be ensured through contact persons. Cross-participation of developers

is expected to prepare new generic components and to deploy them in specific DRD electronic systems. As for DRD5, the community building is ongoing, with considerations given to organise the work in in pools of competences and/or specific technical goals. A full proposal is expected by the end of 2023.

4. Next steps

In addition to the scientific program, the DRD proposals contain an evaluation of the manpower and funds needed to execute the WPs. This assessment is backed up by a survey of the resources available and requested at the institutes willing to contribute. The breakdown of these resources was provided confidentially to the DRDC to evaluate the feasibility of the proposed programs.

While the review process continues, DRD collaboration boards will be formed to prepare the DRD organisation structures and to fill the management positions. The resource MoUs for the first phase of the programs will then be prepared for release to funding agencies in 2024.

The ECFA roadmap implementation work will continue in order to address the other general strategic recommendations of the ECFA detector R&D roadmap, e.g. on infrastructure and training, involving the Laboratory Directors Group (LDG) and the new ECFA training panel.

References

[1] Physics Briefing Book: Input for the European Strategy for Particle Physics Update 2020. Technical report, CERN-ESU-004, Geneva, 2019, http://cds.cern.ch/record/2691414,.

[2] 2020 Update of the European Strategy for Particle Physics (Brochure). Technical report, CERN-ESU-015, Geneva, 2020, https://cds.cern.ch/record/2721370.

[3] The 2021 ECFA detector research and development roadmap. Technical report, CERN-ESU-017, Geneva, 2021, https://cds.cern.ch/record/2784893.

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[5] https://committees.web.cern.ch/drdc.

[6] https://ecfa-dp.desy.de/.

[7] https://www.nasa.gov/directorates/heo/scan/engineering/technology/technology_readiness_level.