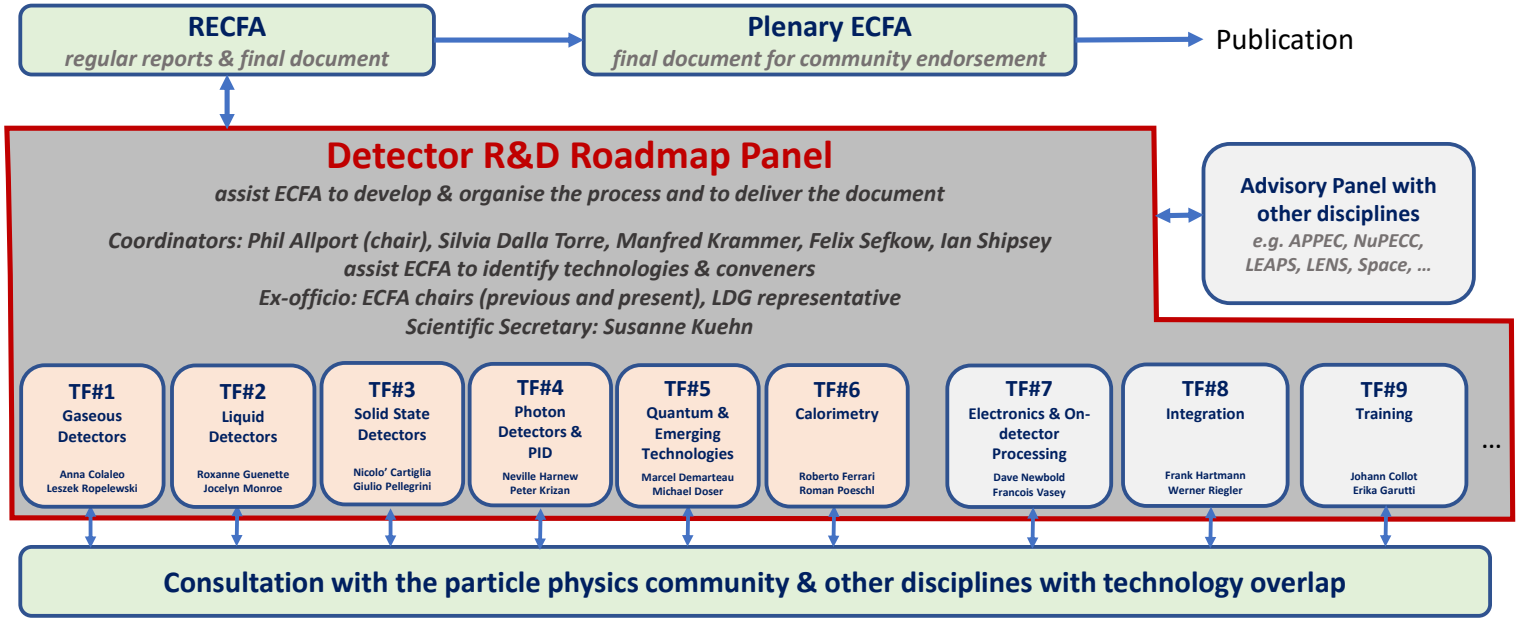
ECFA activities on Detector R&D and e^+e^- studies

Joint FCC France-Italy Workshop
Lyon, 21st November 2022

Karl Jakobs, ECFA Chair
University of Freiburg / Germany

ECFA
European Committee for Future Accelerators

The Detector R&D Roadmap Process



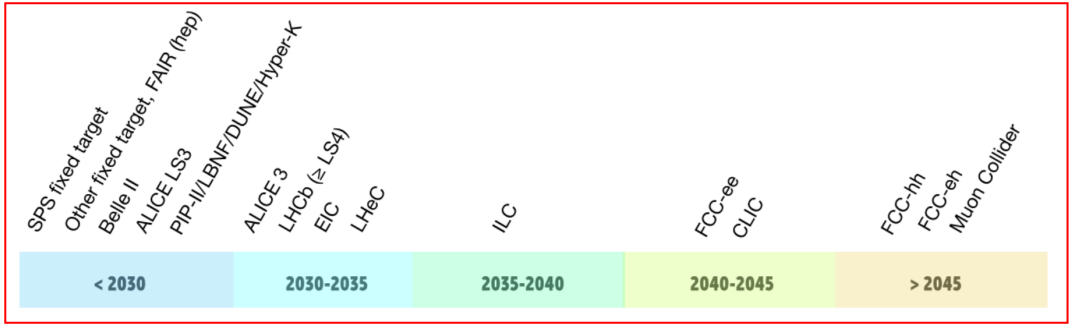
- ***Task forces*** *were composed of experts from the community covering key sub-topics in the relevant technology areas, including* ***two conveners*** *(who are part of the Roadmap Panel)*

- *Progress with emerging technologies in adjacent fields is provided through an* ***Advisory Panel with Other Disciplines*** *(→ expert contacts by Task Forces area)*

Information on the full process: [ECFA Detector R&D Roadmap]

The Detector R&D Roadmap

- Timeline of future accelerator facilities



The dates shown have deliberate low precision, and are intended to represent the **earliest 'feasible start date'** (where a schedule is not already defined), taking into account the necessary steps of approval, development and construction for machine and civil engineering.

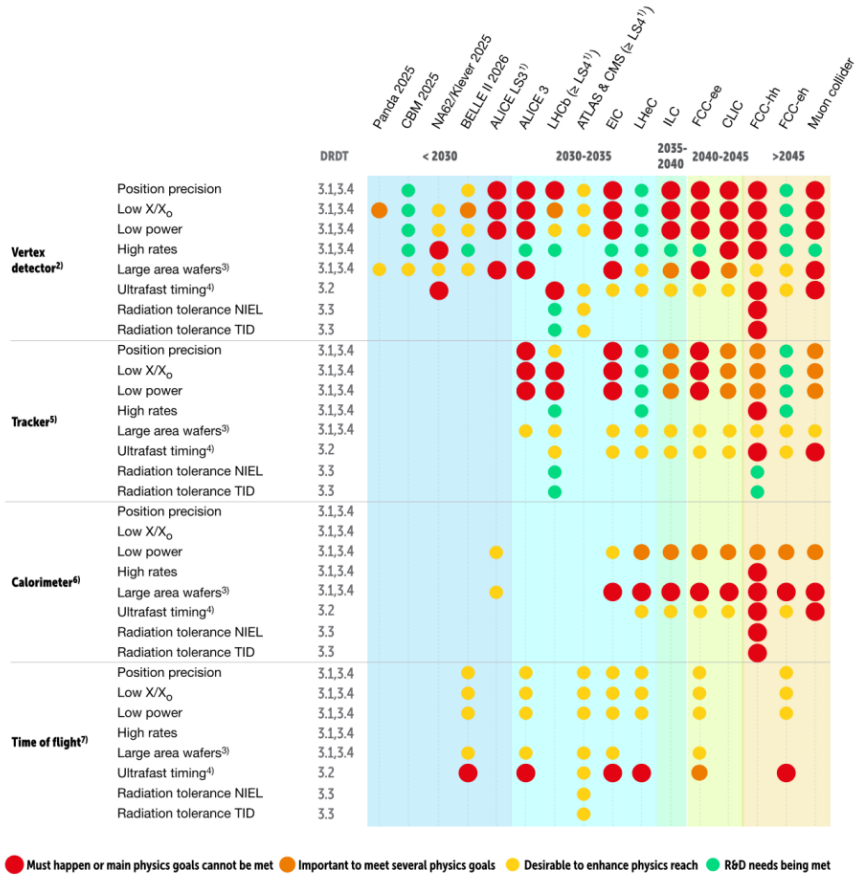
- Task Forces have identified a set of detector R&D areas which are required if the physics programmes of experiments at these facilities are not to be compromised

  The most important drivers for research in each technology area are defined as **"Detector R&D Themes" (DRDTs)**

- It is also noted that in many cases, the programme for a nearer-term facility helps enable the technologies needed for more demanding specifications later, providing **stepping stones** towards these

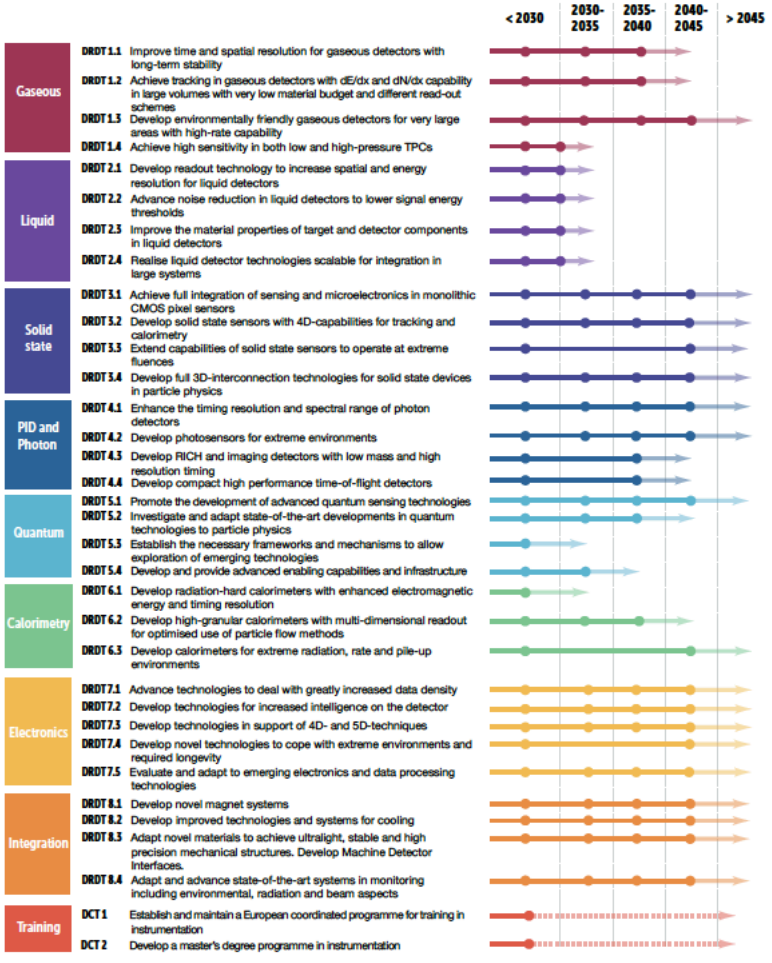
- In addition to the Detector R&D Themes **General Strategic Recommendations** are made

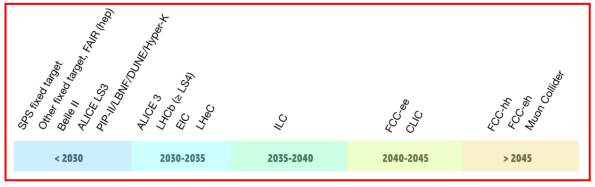
Detector R&D Roadmap: Example of Solid State Detectors (TF 3)



- For each technology these figures inform the development of the Detector R&D Roadmap with a view to set concrete target timelines for the readiness of the recommended R&D thematic programmes
- Ensure that the main physics goals of the updated strategy for particle physics do not risk being compromised by detector readiness

Detector R&D Roadmap: Detector R&D Themes (DRDTs)





- Stepping stones are shown to represent the R&D needs of facilities intermediate in time.
- The faded region acknowledges the typical time needed between the completion of the R&D phase and the readiness of an experiment at a given facility.
- Future beyond the end of the arrows is simply not yet defined, not that there is an expectation that R&D for the further future beyond that point will not be needed.

Detector R&D Roadmap: General Strategic Recommendations

GSR 1 - Supporting R&D facilities

GSR 2 - Engineering support for detector R&D

GSR 3 - Specific software for instrumentation

GSR 4 - International coordination and organisation of R&D activities

GSR 5 - Distributed R&D activities with centralised facilities

GSR 6 - Establish long-term strategic funding programmes

GSR 7 - Blue-sky R&D

GSR 8 - Attract, nurture, recognise and sustain the careers of R&D experts

GSR 9 - Industrial partnerships

GSR 10 - Open Science

see backup slides for details

Aim: Propose mechanisms to achieve a greater coherence across Europe to better streamline the local and national activities and make these more effective.

Give the area greater visibility and voice at a European level to make the case for the additional resources needed for Europe to maintain a leading role in particle physics with all the associated scientific and societal benefits that will flow from this.

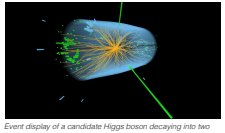
Synopsis Document:

_Building the Foundations

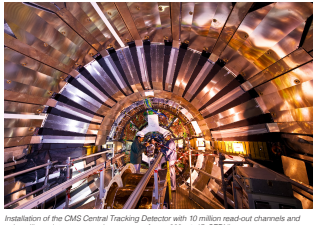
"Strong planning and appropriate investments in Research and Development (R&D) in relevant technologies are essential for the full potential, in terms of novel capabilities and discoveries, to be realised."

The field of particle physics builds on the major scientific revolutions of the 20th century, particularly on the experimental discoveries and theoretical developments which culminated in the Nobel Prize-winning discovery of the Higgs boson at CERN in 2012. The ambitions for the field going forward are set out from a European perspective in a global context in the European Strategy for Particle Physics (ESPP) which was updated in 2020. This strategy lays down a vision for the coming half-century, with a science programme which, in exploring matter and forces at the smallest scales and the Universe at earliest times, will continue to provide answers to questions once thought only to be amenable to philosophical speculation, and has the potential to reveal fundamentally new phenomena or forms of matter never observed before.

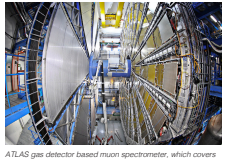
The ESPP recognises the huge advances in accelerator and detector technologies since the world's first hadron collider, the Intersecting Storage Rings, started operation at CERN 50 years ago. These advances have not only supported, and in turn benefited from, numerous other scientific disciplines but have spawned huge societal benefits through developments such as the World Wide Web, Magnetic Resonance Imaging, Positron Emission Tomography and 3D X-ray imaging.



Event display of a candidate Higgs boson decaying into two photons as recorded by the CMS experiment. (© CERN)



Installation of the CMS Central Tracking Detector with 10 million read-out channels and using silicon detectors covering an area of over 200 m². (© CERN)



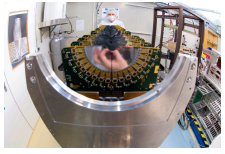
ATLAS gas detector based muon spectrometer, which covers a total area the size of a football field and measures the paths of the muons that pass through it to an accuracy of better than a tenth of a millimetre. (© CERN)

The far-reaching plans of the ESPP require similar progress over the coming decades in accelerator and detector capabilities to deliver its rich science programme. Strong planning and appropriate investments in Research and Development (R&D) on relevant technologies are essential for the full potential, in terms of novel capabilities and discoveries, to be realised.

The 2020 update of the ESPP called on the European Committee for Future Accelerators (ECFA) to develop a global Detector R&D Roadmap defining the backbone of detector R&D required to deploy the community's vision. This Roadmap aims to cover the needs of both the near-term and longer-term programme, working in synergy with neighbouring fields and with a view to potential industrial applications.

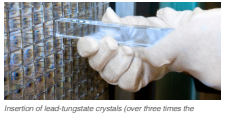
_Setting the Priorities

"To fully explore the properties of the Higgs boson and study many of the other deepest questions in physics necessitates the development of a roadmap for the required detector technologies."



Vertex Locator (VELO) of the LHCb experiment allowing short lived particle lifetimes to be measured with precision of a twentieth of a picosecond. (© CERN)

The highest priority laid down by the updated ESPP is for a future Higgs factory to thoroughly explore the properties of this completely new type of particle, which is seen as a key to a much deeper understanding of how the Universe works. Until the discovery of the Higgs boson, every known particle was either a "matter" or a "force" particle, describing the world in terms of fundamental entities and their interactions without being able to accommodate the fact that particles also have mass. In the ESPP, the vision for the future facilities to fully explore the properties of the Higgs boson and study many of the other deepest questions in physics necessitates the development of a roadmap for the required detector technologies (in much the same way as the LHC and its upgrades significantly guided R&D planning for previous decades). The ECFA Detector R&D Roadmap addresses this need whilst highlighting synergies with other projects on nearer timescales and showing how they are also embedded in the longer-term context.



Insertion of lead-tungstate crystals (over three times the density of conventional glasses) into the high granularity electromagnetic calorimeter of the ALICE detector giving percent scale energy measurements. (© CERN)

In the area of detector development, it is vital to build on Europe's world-leading capabilities in sensor technologies for particle detection, using gas and liquid-based or solid-state detectors, as well as energy measurement and particle identification. Also required are cutting-edge developments in bespoke microelectronics solutions, real-time data processing and advanced engineering. Adequate resourcing for such technology developments represents a vital component for future progress in experimental particle physics. Talented and committed people are another absolutely core requirement. They need to be enthused, engaged, educated, empowered and employed. The ECFA Detector R&D Roadmap brings forward concrete proposals for nurturing the scientists, engineers and technicians who will build the future facilities and for incentivising them by offering appropriate and rewarding career opportunities.

ProtoDUNE: three hundred cubic metre volume prototype Liquid Argon Neutrino Detector being constructed at CERN. (© CERN)

https://cds.cern.ch/record/2784893

Implementation

In December 2021, ECFA was invited by CERN Council to elaborate, in close contact with the SPC, funding agencies and relevant research organisations in Europe and beyond, a ***detailed implementation plan***

Likewise, the European Lab Director Group (LDG) was mandated to work out an implementation plan for the ***Accelerator R&D Roadmap***

- ECFA **Roadmap Coordination Group** has worked out a proposal
  (P. Allport, S. Dalla Torre, J. D'Hondt, K. Jakobs, M. Krammer, S. Kuehn, F. Sefkow and I. Shipsey)
- Discussed and iterated with RECFA, national contacts for detector R&D, CERN management, SPC and Council, and with Funding Agencies
- Open presentation at the July Plenary ECFA meeting by Phil Allport
  https://indico.cern.ch/event/1172215/
- "Sign-off" by SPC and Council in their Sept. 2022 meetings

From the Council's *"Summary of Conclusions"*

21. DETECTOR R&D ROADMAP IMPLEMENTATION PLAN
(Item 21 of the Agenda) (CERN/SPC/1190/RA-CERN/3679/RA)

The Council took note of document CERN/SPC/1190/RA-CERN/3679/RA, of the introductory remarks by the Chair of ECFA, Professor Jakobs, outlining the main changes made to the implementation plan since its presentation at the June Session, and of the report by the Chair of the Scientific Policy Committee, Professor Rivkin, on the Committee's discussion of the plan at its September 2022 meeting.

The Council further thanked ECFA for organising the development of the roadmap, warmly welcomed the implementation plan and encouraged ECFA to move forward with the implementation phase.

Proposed implementation plan

- It is proposed to organise long-term R&D efforts into **newly established Detector R&D (DRD) Collaborations**

  Detector technology areas: larger DRD collaborations should be considered
  (one for each of the six areas and an additional similar structure for some of the transversal topics)

- **DRD Collaborations should be anchored at CERN** → CERN recognition, DRD label

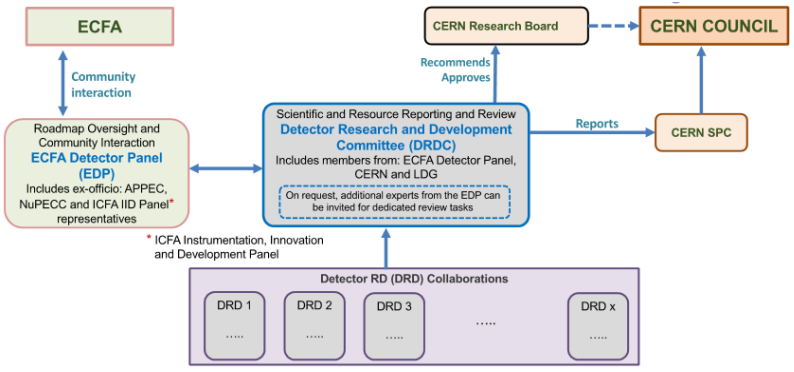
- **Taking full account of existing, well-managed and successful ongoing R&D collaborations and other existing activities**
  (RD50, RD51, …, CERN EP R&D programme, EU-funded initiatives, collaborations exploring particular technology areas for future colliders)

- The **formation of new DRD collaborations** should adopt a **community-driven approach**
  Supported by existing ECFA Detector R&D Roadmap Task Forces, with involvement of managements of existing R&D collaborations

- Aim for proposals in July 2023; New structure in place in January 2024;
  Ramp-up of resources during 2024/25, reaching a steady state in 2026

For more details: see talk by Phil Allport at plenary ECFA in July: https://indico.cern.ch/event/1172215/

Review and Approval Process



1. Scientific and Resource Reporting and Review by a Detector Research and Development Committee (DRDC)

   Assisted by the ECFA Detector Panel (EDP): the scope, R&D goals, and milestones should be vetted against the vision encapsulated in the Roadmap

2. Funding Agency involvement via a dedicated Resources Review Board (~once every two years)

3. Yearly follow-up by DRDC → report to SPC → Council

- As projects develop, **some aspects should be expected to transition into approved experiment-specific R&D** (outside the DRD programme)

- In addition, as stated in the General recommendations (GSR7) funding possibilities for **"Blue-sky" R&D** should be foreseen

Suggested Implementation Timeline

Through 2023, mechanisms will need to be agreed with funding agencies in parallel to the process below for country specific DRD collaboration funding requests for Strategic R&D and for developing the associated MoUs.

Q4 2022	Outline structure and review mechanisms agreed by CERN Council. Detector R&D Roadmap Task Forces organise **community meetings** to establish the scope and scale of community wishing to participate in the corresponding new DRD activity. (Where the broad R&D topic area has one or more DRDTs already covered by existing CERN RDs or other international collaborations these need to be fully involved from the very beginning and may be best placed to help bring the community together around the proposed programmes.)
Q1 2023	**DRDC mandate formally defined** and agreed with CERN management; Core DRDC membership appointed; and EDP mandate plus membership updated to reflect additional roles.
Q1-Q2 2023	**Develop the new DRD proposals** based of the detector roadmap and community interest in participation, including light-weight organisational structures and resource-loaded work plan for R&D programme start in 2024 and ramp up to a steady state in 2026.
Q3 2023	**Review of proposals by DRDC** leading to recommendations for formal establishment of the DRD collaborations.
Q4 2023	DRD Collaborations receive formal **approval from CERN Research Board**.
Q1 2024	New structures operational for ongoing review of DRDs and R&D programmes underway.

Through 2024, collection of MoU signatures

Next steps:

- **Community meetings** organised by Task Forces, involving managements of existing RD collaborations (where relevant)

  Call to sign up to the different Task Force areas was sent on 25th October (Phil Allport, Susanne Kühn):
  https://indico.cern.ch/event/957057/page/27294-implementation-of-the-ecfa-detector-rd-roadmap

  Goal: sort out interests of the community, set up a proposal-writing group with goal to prepare DRD proposals by end of July 2023

  You should get engaged in this process and present your interest in working in these DRDs!

- Process will be accompanied by the ECFA Roadmap Coordination Group;
  Regular meetings to follow up on progress in various areas and to address upcoming issues

  Guidelines for DRD Proposal writing are being prepared (will try to keep it light-weight)

- ECFA Detector Panel (EDP) has been re-activated, needs to be adapted to the new role;

  EDP mandate and composition have been updated (approved by ECFA last week)

Implementation of the ECFA Detector R&D Roadmap

After the publication of the ECFA Detector R&D Roadmap, CERN Council requested ECFA to develop the plan for its implementation.

The document approved by the SPC and CERN Council in September 2022 can be found at https://indico.cern.ch/event/1197445/contributions/5034860/attachments/2517863/4329123/spc-e-1190-c-e-3679-Implementation_Detector_Roadmap.pdf.

As proposed in the document, topic specific community meetings will now be held in the course of the coming months. To sign up for these and to register your interest in participating on the corresponding R&D Collaborations being developed please see the links below.

- TF1 Gaseous Detectors https://indico.cern.ch/event/1214405/
- TF2 Liquid Detectors https://indico.cern.ch/event/1214404/
- TF3 Solid State Detectors https://indico.cern.ch/event/1214410/
- TF4 Photon Detectors and PID https://indico.cern.ch/event/1214407/
- TF5 Quantum and Emerging Technologies https://indico.cern.ch/event/1214411/
- TF6 Calorimetry https://indico.cern.ch/event/1213733/
- TF7 Electronics and On-detector Processing https://indico.cern.ch/event/1214423/
- TF8 Integration https://indico.cern.ch/event/1214428/
- TF9 Training https://indico.cern.ch/event/1214429/

ECFA Detector Panel (EDP):

The ECFA Detector Panel (EDP) is a subcommittee of ECFA, hosted at DESY

So far: a committee to review detector development efforts for future projects

http://cds.cern.ch/record/2211641/files

Mandate:

- Direct input on DRD proposals, through the appointment of members to the DRDC;
- Assists, particularly via topic-specific expert members, in the conduct of annual DRDC reviews;
- Monitors the overall implementation of the ECFA detector roadmap follows up targets and achievements in the light of evolving specifications from experiment concept groups, as well as proto-collaborations for future facilities
- Helps plan for future updates to the Detector R&D Roadmap.

Composition:

Co-Chairs: **Phil Allport (Birmingham)**
Didier Contardo (IP2I Lyon)

Scientific Secretary: Doris Eckstein (DESY)

Gaseous Detectors:	Silvia Dalla Torre (Torino)
Liquid Detectors:	Inés Gil Botella (CIEMAT, Madrid)
Solid State Detectors:	Doris Eckstein (DESY)
PID & Photon Detectors:	Roger Forty (CERN)
Quantum and em Tech.	
Calorimetry:	Laurent Serin (IJCLab)
Electronics:	Valerio Re (Bergamo)
Ex Officio:	Karl Jakobs (ECFA Chair)
	Phil Allport (ECFA Roadmap)
	Ian Shipsey (ICFA Detector Panel)

Next steps (cont.)

- **DRDC Mandate and composition** need to be worked out

  → CERN management

- In each country / laboratory the DRD proposal process has to be discussed with the respective funding agencies;

  RECFA delegates and ECFA Roadmap National Contacts for Detectors should help to launch this process and to set up the right structures
  (most likely, it will be different from country to country)

- **Finally: ECFA – LDG working group to address some of the GSRs has been set up**
  (endorsed at ECFA meeting last week 17/18 Nov)

Detector R&D Roadmap: General Strategic Recommendations

GSR 1 - Supporting R&D facilities

GSR 2 - Engineering support for detector R&D

GSR 3 - Specific software for instrumentation

GSR 4 - International coordination and organisation of R&D activities

GSR 5 - Distributed R&D activities with centralised facilities

GSR 6 - Establish long-term strategic funding programmes

GSR 7 - Blue-sky R&D

GSR 8 - Attract, nurture, recognise and sustain the careers of R&D experts

GSR 9 - Industrial partnerships

GSR 10 - Open Science

ECFA-LDG Working Group:

- Address the implementation of GSRs (mainly on infrastructure, such as GSR1, GSR2, GSR3, GSR5, and GSR9)
- Needs a broad representation

  - Directors of large laboratories

  - ECFA Representation / community

    * Larger countries (Funding Agencies), universities
    * Representation of smaller European countries (not in LDG)

- Address various issues in sub-groups (status quo, what is available, what needs to be refurbished, new investments)
- Accompany the proposal-writing process, which will give direct input on requirements

Composition:

Co-Chairs:	**Stan Bentvelsen (Nikhef, LDG, ECFA)** **Marko Mikuz (Ljubljana)**
LDG members:	Joachim Mnich (CERN) 1-2 other LDG members
ECFA representation:	Rep. BMBF/universities Germany Rep. IN2P3/universities France Rep. INFN/universities Italy Rep. STFC/universities UK Rep. smaller countries
Ex Officio:	Karl Jakobs (ECFA Chair) Phil Allport (ECFA Roadmap) Dave Newbold (LDG Chair)

Plans for “TF9” on “Training”

First proposal, for feedback from RECFA and for discussion! (Phil Allport, Johann Callot, Erika Garutti, Karl Jakobs)

The conclusions of the detector R&D roadmap document (https://cds.cern.ch/record/2784893) explicitly stress the need to train and maintain a work force in instrumentation for particle physics, targeting, with the highest priority, graduate students and Early Career Researchers (ECR). One of the two “Detector Community Themes” (DCTs) that emerged from the deliberations of the training task force (TF9), calls for the **creation of a dedicated panel in this area under the auspices of ECFA**, in consultation with organisations or communities representing neighbouring disciplines and ICFA. The role of this coordination panel would primarily be to enhance the synergies between existing training programmes and stimulate the creation of complementary ones where relevant, in particular multidisciplinary schools or academia-industry-joined training programmes. The second equally important DCT sets out as a goal the creation of a European master's degree programme in HEP instrumentation, to also be a potential responsibility of this proposed panel to help coordinate.

During the roadmap process it realised that there was a mutual interest to also involve training in accelerators and to support cross-disciplinary activities with this area. As a result, the recommendations state that the same panel should also coordinate the synergies between HEP instrumentation and accelerator training provision.

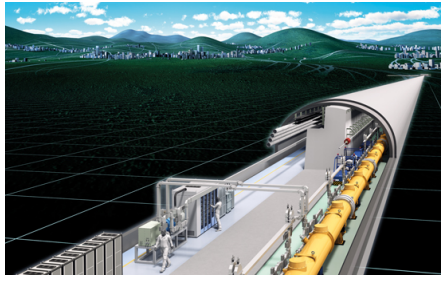
→ **ECFA Training Panel**

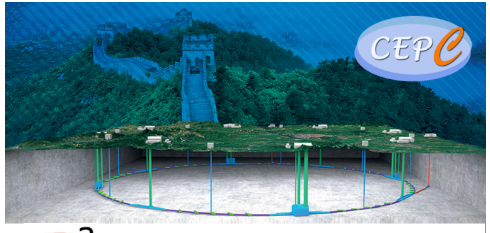
The membership of this panel could encompass that of the detector roadmap R&D TF9 group, plus one more expert on training in accelerators, plus a representative of ICFA, a representative of APPEC, a representative of NuPECC and a representative of the ECFA ECR Panel.

2. ECFA Study on Physics, Experiments and Detectors at a Future e^+e^- Factory

"ECFA recognizes the need for the experimental and theoretical communities involved in physics studies, experiment designs and detector technologies at future Higgs factories to gather. ***ECFA supports a series of workshops*** *with the aim to* ***share challenges and expertise, to explore synergies in their efforts*** *and to respond coherently to this priority in the European Strategy for Particle Physics (ESPP)."*

Goal: bring the entire e^+e^- Higgs factory effort together, foster cooperation across various projects; collaborative research programmes are to emerge





ECFA Working Groups

WG 1: Physics Potential
Convener: Juan Alcaraz (CIEMAT - Madrid), Jenny List (DESY), Fabio Maltoni (UC Louvain / Bologna) and Jorge de Blas (Granada)

WG 2: Physics Analysis Methods
Convener: Patrizia Azzi (INFN-Padova / CERN), Fulvio Piccinini (INFN Pavia) and Dirk Zerwas (IJCLab / DMLab)

WG 3: Detector R&D
Convener: Marie Cruz Fouz (CIEMAT - Madrid), Giovanni Marchiori (APC Paris) and Felix Sefkow (DESY)

Full information available here:

https://indico.cern.ch/event/1033941/

–> Rich programme of seminars, topical meetings, mini-workshops

June 2022
- 10 Jun ECFA Higgs Factory seminars: Precision physics in the e+e- -> WW region
- 07 Jun - 17 Jun Precision calculations for future e+e– colliders: targets and tools (FC CERN Unit Workshop)

May 2022
- 06 May ECFA Higgs Factory seminars: Higgs self-coupling
- 04 May - 05 May ECFA Higgs Factories: 1st Topical Meeting on Reconstruction

April 2022
- 08 Apr ECFA Higgs Factory seminars: Physics with light quarks

March 2022
- 04 Mar ECFA Higgs Factory seminars: Implications of (g-2)_mu for e+e- Higgs factories: an overview

February 2022
- 01 Feb - 02 Feb ECFA Higgs Factories: 1st Topical Meeting on Simulation

January 2022
- 12 Jan Focus Meeting: Beamstrahlung

November 2021
- 09 Nov - 10 Nov ECFA Higgs Factories: 1st Topical Meeting on Generators

WG1-SRCH: Direct searches (weakly-interacting, directly accessible particles)
May 2022 ECFA HF WG1: 1st Workshop of the WG1-SRCH group
Feb 2022 Brainstorming session

WG1-PREC: theoretical and experimental precision
July 2022 MiniWorkshop: parametric uncertainties: α_em
Mar 2022 MiniWorkshop: parametric uncertainties: α_s
Mar 2022 MiniWorkshop: high-precision measurements

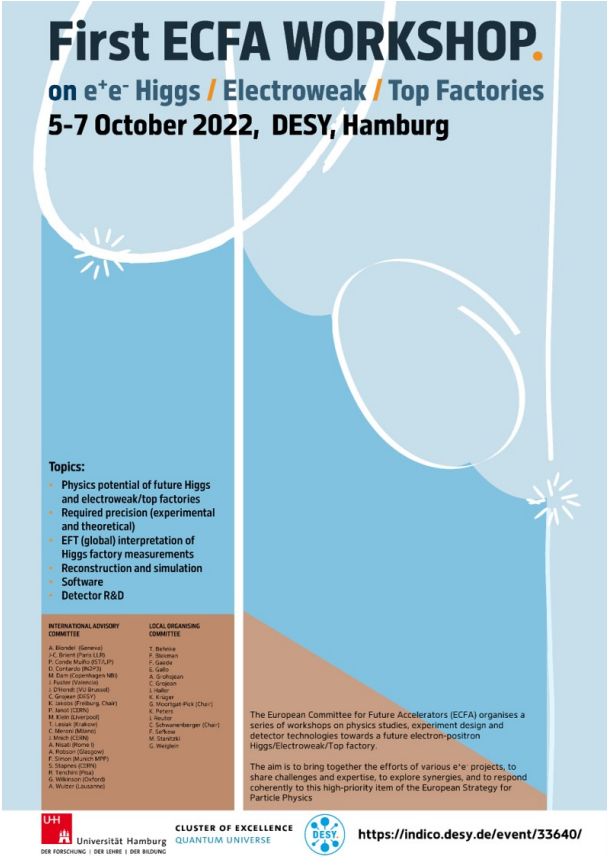
WG1-HTE: specific Higgs/Top/EW studies (+ connection w/ LHC)
Sept 2022 ECFA HTE meeting on Z pole physics
Apr 2022 1st Workshop of the Higgs/Top/EW group

WG1-HF: Heavy Flavour
June 22 1st Meeting

WG1-GLOB: global interpretations
Sept 2022 Analyses of concrete models
July 2022 Global interpretations in (SM)EFT and UV complete models

2022 ECFA e^+e^- Workshop in Hamburg 5 – 7 October 2022

https://indico.desy.de/event/33640/



2. ECFA workshop in Hamburg

- Hamburg, 5 – 7 October 2022 https://indico.desy.de/event/33640/
- 200 registrants in person and 145 online

- Plenary and parallel session organised by WG conveners
- Poster session on Thursday afternoon (16 posters)
- Public event on Thursday evening (not well attended from the outside)

Some impressions

- Positive developments on:

  - Experts across projects (ILC, FCC-ee, CLIC, CEPC) are connecting
  - Common approach to software framework (key4HEP) is agreed and many topics in simulation and reconstruction being actively worked on together
  - High-priority topics are emerging to focus the work and as good places for people to contribute

- However, despite the fact that the workshop was followed by ~200 people, the real work-force is still very small!

Reasons:
- Nearly all people busy with LHC, Phase-II upgrade or other HEP projects (e.g. Belle-II)
- Theory community not fully engaged yet
- LHC people not yet there (see bullet 1, above)
- US colleagues not yet there, we need to make efforts to include them in the post-Snowmass era
- Not sure that we have the full support of all e^+e^- project groups (ILC, FCC_ee, CLIC, CEPC, C^3 ..)
- Concrete e^+e^- project not yet approved!

Next steps / goals

- **It is essential for the field that there is a strong community and participation in e^+e^- studies**

- **Physics case** (Higgs, electroweak, top, flavour, … complementarity to LHC, e.g. EFT analysis, differential cross sections at high-p_T, …)

  → Updated science case (for us, but not only for us!)
  We need to present a clear physics case to the decision makers

- There are many **common topics on software, simulation, reconstruction**, ... → goes in right direction

- **Detector requirements need to be understood** (← Driven by Physics we want to do / can do)

- They have **implications on the Detector R&D**
  (define, sharpen R&D goals, make sure they can be reached in time when we need to have them)

Next steps / goals

- How can this be achieved?

  - Given unitarity, and shortage of person power, cooperation among the various projects is important

  - Try to get additional resources, discussion with Funding Agencies;
    ECFA will continue to raise this issue strongly at country visits

  - Allow postdocs / students to work part of their time (~20%) on such studies;

    This **calls for the support of the group leaders / PIs** …

Encouraging wider participation

In addition to this, the ECFA study is proposing a limited set of **"focus topics"**
(Still preliminary, under discussion!)

Use topics of active interest as a vehicle to:

- Engage more (new) people;
- Foster cooperation and connect people working on similar topics on different projects;
- Develop tools for use across projects *(e.g. reco algorithm / analysis technique / MC generator improvement / …)*

In addition:

- Lower threshold for participation in e^+e^- studies (e.g. repository of example analysis codes is suggested)

  → newcomers can get up to speed on e^+e^- / get some 'training' and make a significant contribution

Proposed 'focus topics' are not intended to map the physics programme comprehensively;

Instead: complete the current overall physics picture where it is (most) necessary!

Some examples of Focus Topics (still preliminary)

◆ Higgs at √s=240…250 GeV and 350 GeV

Many aspects are of course well-studied – focus on those that are less so, e.g. :

1. CP studies of Higgs couplings and SMEFT interpretation (most so far assume CP conservation)
–> can incorporate e.g. theory calculations / MC generators / reconstruction techniques (e.g. taus and q/qbar separation) / EFT interpretation / …

2. H->ss (addressed only recently – extend studies)
–> can incorporate e.g. reconstruction and PID challenges / SMEFT & BSM interpretation / …

◆ W/Z

3. W Couplings at WW threshold and 240..250 GeV / ~350 GeV
–> add full detector-level studies at 240GeV and go beyond 'standard TGCs' with CPV operators
–> can include theory predictions / MC generators / detector-level studies / …

4. W mass at threshold and continuum
–> ultimate precision on M_W?
–> can include theory predictions / MC generators / assessment/development of analysis and calibration methods to highlight aspects of detector performance requirements / …

5. 2-fermion production at Z pole
–> focus on channels with detector/reco challenges e.g. $e^+e^- \rightarrow$ bb, cc, ss, $\tau^+\tau^-$
–> can include theory predictions / MC generators / detector-level studies / interface to global interpretations / studies on tau polarisation / …

Aidan Robson, ECFA Plenary
https://indico.cern.ch/event/1212248/

Some examples of Focus Topics (still preliminary)

◆ Top

6. Full analysis of top threshold scan
–> can include updates to MC generators to reflect newest threshold calculations / polarisation & beam spectrum / reco/analysis / interface to global interpretations / …

7. threshold scan optimisation
–> can include backgrounds / polarisation / energy-step optimisation / parameter extraction / …

◆ Direct discovery potential

8. Weakly-coupled / light / long-lived particles
–> can include detector-level studies of "exotic" signatures: "kinks", "prongs", "V0" / detector requirements, reco/pattern recognition / interface to BSM interpretations / …

◆ Flavour

can e.g. focus on B mesons that are too heavy to be produced at Belle-II and final states that are difficult at LHCb:

9. $B_s \rightarrow D_s K$ at $\sqrt{s} = M_Z$

10. $B_s \rightarrow K^{0*}\tau^+\tau^-$

–> can include detector-level study with all backgrounds / dependency on reconstruction, vertexing, PID / global interpretations / ...

Aidan Robson, ECFA Plenary
https://indico.cern.ch/event/1212248/

Some examples of Focus Topics (still preliminary)

◆ Systematics

11. Luminosity measurement from low-angle Bhabha scattering
–> understand how to control with unprecedented precision
–> *can include theory and MC generators / detector-level sim. including backgrounds / measurement strategies / LumiCal detector requirements / …*

12. Measurement of b- and c-fragmentation functions / hadronisation

13. Measurement of gluon splitting to bb / cc
& interplay with separating h → gluons from h →bb/cc

–> understand how well these both can be constrained, as input to precision Higgs & EWK
–> *can include detector-level studies / new ideas in theoretical modelling / …*

Aidan Robson, ECFA Plenary
https://indico.cern.ch/event/1212248/

Timeline of ECFA Study

- The ECFA study will **provide key input** for the next update of the European Strategy for Particle Physics

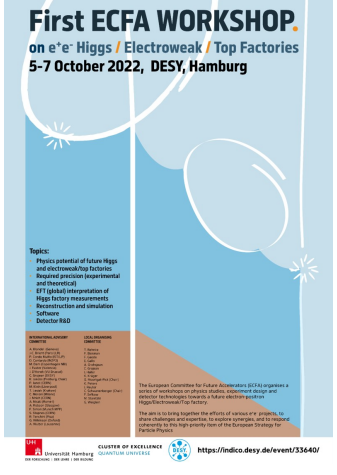
- Strategy at present planned for 2026 / 2027, with input to be submitted by end of 2025;
  e.g. FCC feasibility study report is scheduled for end 2025

  → Target **spring 2025 for ECFA study final report** (ECFA report, Yellow Book)

  Aspects of ECFA report should be available as input for individual reports of the projects (FCC_ee, CLIC)

- To match this timeline, we plan for **two additional ECFA workshops in 2023 and 2024**

  Calls for proposals will be made soon!



Summary

- The Detector R&D Roadmap has been prepared by large teams of internationally recognised leaders with access to a much wider pool of other instrumentation experts

  Detector Roadmap: https://cds.cern.ch/record/2784893

- Implementation plan based on CERN DRD Collaborations has been worked out by ECFA and was accepted by CERN Council in Sep 2022

  → Process for preparing DRD proposal started, interested groups should get engaged, in parallel discussions with funding agencies in the countries should take place

  Timeline: proposals by July 2023, approval process until end of 2023, start of DRDs in Jan. 2024, ramp-up throughout 2025/2026

- ECFA study on physics, experiments and detectors at a future e+e- factory has been set up, with target to provide key input to the next Strategy Update in 2026/2027

Work successfully started in several areas, however, more support from the community is vital!

You are welcome to join and actively contribute to both ECFA activities!

Looking forward to seeing the accelerator, detector and physics communities working together towards the new machines and experiments that will underwrite the future of our field.

Backup Slides

Detector R&D Roadmap: General Strategic Recommendations

GSR 1 - Supporting R&D facilities

It is recommended that the structures to provide **Europe-wide coordinated infrastructure in the areas of: test beams, large scale generic prototyping and irradiation be consolidated and enhanced to meet the needs of next generation experiments** with adequate centralised investment to avoid less cost-effective, more widely distributed, solutions, and to maintain a network structure for existing distributed facilities, e.g. for irradiation

GSR 2 - Engineering support for detector R&D

In response to ever more integrated detector concepts, requiring holistic design approaches and large component counts, the R&D should be supported with **adequate mechanical and electronics engineering resources**, to bring in expertise in state-of-the-art microelectronics as well as advanced materials and manufacturing techniques, to tackle generic integration challenges, and to maintain scalability of production and quality control from the earliest stages.

GSR 3 - Specific software for instrumentation

Across DRDTs and through adequate capital investments, the availability to the community of **state-of-the-art R&D-specific software packages must be maintained and continuously updated**. The expert development of these packages - for core software frameworks, but also for commonly used simulation and reconstruction tools - should continue to be highly recognised and valued and the community effort to support these needs to be organised at a European level.

GSR 4 - International coordination and organisation of R&D activities

With a view to creating a vibrant ecosystem for R&D, connecting and involving all partners, there is a **need to refresh the CERN RD programme structure and encourage new programmes for next generation detectors**, where CERN and the other national laboratories can assist as major catalysers for these. It is also recommended to revisit and streamline the process of creating and reviewing these programmes, with an extended framework to help share the associated load and increase involvement, while enhancing the visibility of the detector R&D community and easing communication with neighbouring disciplines, for example in cooperation with the ICFA Instrumentation Panel.

Detector R&D Roadmap: General Strategic Recommendations

GSR 5 - Distributed R&D activities with centralised facilities

Establish in the relevant R&D areas a distributed yet connected and supportive tier-ed system for R&D efforts across Europe. Keeping in mind the growing complexity, the specialisation required, the learning curve and the increased cost, consider more focused investment for those themes where leverage can be reached through centralisation at large institutions, while addressing the challenge that distributed resources remain accessible to researchers across Europe and through them also be available to help provide enhanced training opportunities.

GSR 6 - Establish long-term strategic funding programmes

Establish, additional to short-term funding programmes for the early proof of principle phase of R&D, also **long-term strategic funding programmes to sustain both research and development of the multi-decade DRDTs** in order for the technology to mature and to be able to deliver the experimental requirements. Beyond capital investments of single funding agencies, international collaboration and support at the EU level should be established. In general, the cost for R&D has increased, which further strengthens the vital need to make concerted investments.

GSR 7 – "Blue-sky" R&D

It is essential that **adequate resources be provided to support more speculative R&D** which can be riskier in terms of immediate benefits but can bring significant and potentially transformational returns if successful both to particle physics: unlocking new physics may only be possible by unlocking novel technologies in instrumentation, and to society. Innovative instrumentation research is one of the defining characteristics of the field of particle physics. "Blue-sky" developments in particle physics have often been of broader application and had immense societal benefit. Examples include: the development of the World Wide Web, Magnetic Resonance Imaging, Positron Emission Tomography and X-ray imaging for photon science.

Detector R&D Roadmap: General Strategic Recommendations

GSR 8 - Attract, nurture, recognise and sustain the careers of R&D experts

Innovation in instrumentation is essential to make progress in particle physics, and R&D experts are essential for innovation. It is recommended that ECFA, with the involvement and support of its Detector R&D Panel, continues the study of **recognition with a view to consolidate the route to an adequate number of positions with a sustained career in instrumentation R&D** to realise the strategic aspirations expressed in the EPPSU. It is suggested that ECFA should explore mechanisms to develop concrete proposals in this area and to find mechanisms to follow up on these in terms of their implementation. Consideration needs to be given to creating sufficiently attractive remuneration packages to retain those with key skills which typically command much higher salaries outside academic research. It should be emphasised that, in parallel, society benefits from the training particle physics provides because the knowledge and skills acquired are in high demand by industries in high-technology economies.

GSR 9 - Industrial partnerships

It is recommended to **identify promising areas for close collaboration between academic and industrial partners**, to create international frameworks for exchange on academic and industrial trends, drivers and needs, and to establish strategic and resources-loaded cooperation schemes on a European scale to intensify the collaboration with industry, in particular for developments in solid state sensors and micro-electronics.

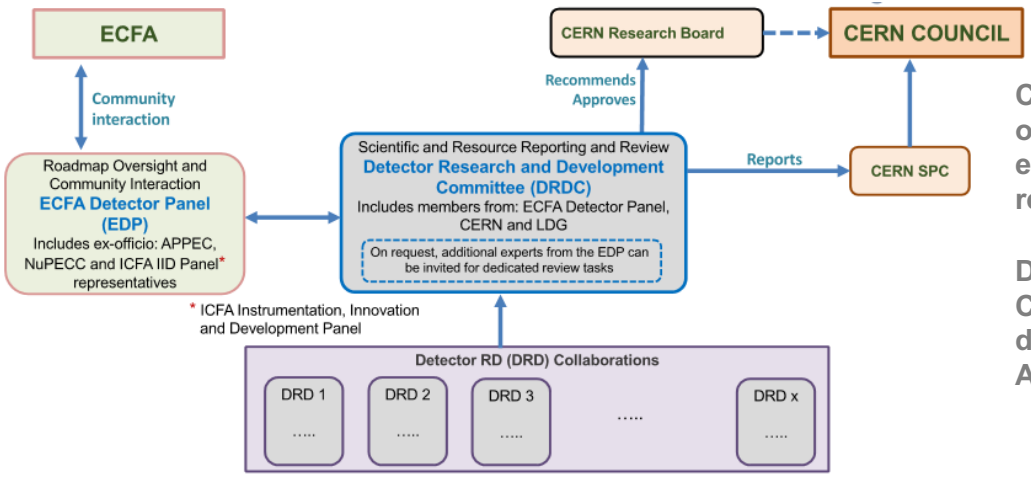
GSR 10 – Open Science

It is recommended that the concept of **Open Science be explicitly supported in the context of instrumentation**, taking account of the constraints of commercial confidentiality where these apply due to partnerships with industry. Specifically, for publicly-funded research the default, wherever possible, should be open access publication of results and it is proposed that the Sponsoring Consortium for Open Access Publishing in Particle Physics (SCOAP^3) should explore ensuring similar access is available to instrumentation journals (including for conference proceedings) as to other particle physics publications.

Suggested Implementation Organisation

ECFA (through RECFA and PECFA) maintains broad links to the wider scientific community.

EDP engages with other scientific disciplines and also communities outside Europe through close links with the ICFA IID Panel.



CERN provides rigorous oversight through well-established and respected reviewing structures.

DRDs able to benefit from CERN recognition in dealings with Funding Agencies and corporations.

EDP:

- provides direct input, through appointed members to the DRDC, on DRD proposals in terms of Roadmap R&D priorities (DRDTs);
- assists, particularly via topic-specific expert members, with annually updated DRDC scientific progress reviews of DRDs;
- monitors overall implementation of ECFA detector roadmap/DRDTs;
- follows targets and achievements in light of evolving specifications from experiment concept groups as well as proto-collaborations for future facilities;
- helps plan for future updates to the Detector R&D Roadmap.

DRDC:

- provides financial, strategic and (with EDP) scientific oversight;
- evaluates initial DRD resources request with focus on required effort matching to pledges by participating institutes (including justification, given existing staff, infrastructures and funding streams);
- decides on recommending approval;
- conducts progress reviews on DRDs and produces a concise annual scientific summary encompassing the full detector R&D programme;
- be the single body that interacts for approvals, reporting etc with the existing CERN committee structure.

Additional Comments

→ **Three areas of Detector R&D:**

1. Strategic R&D via DRD Collaborations (long-term strategic R&D lines)
   (address the high-priority items defined in the Roadmap via the DRDTs)

2. Experiment-specific R&D (with very well defined detector specifications)
   (funded outside of DRD programme, via experiments, usually not yet covered within the projected budgets for the final deliverables)

3. ”Blue-sky” R&D
   (competitive, short-term grants, nationally organised)