



ECFA Detector R&D Roadmap

Status of Implementation Plans

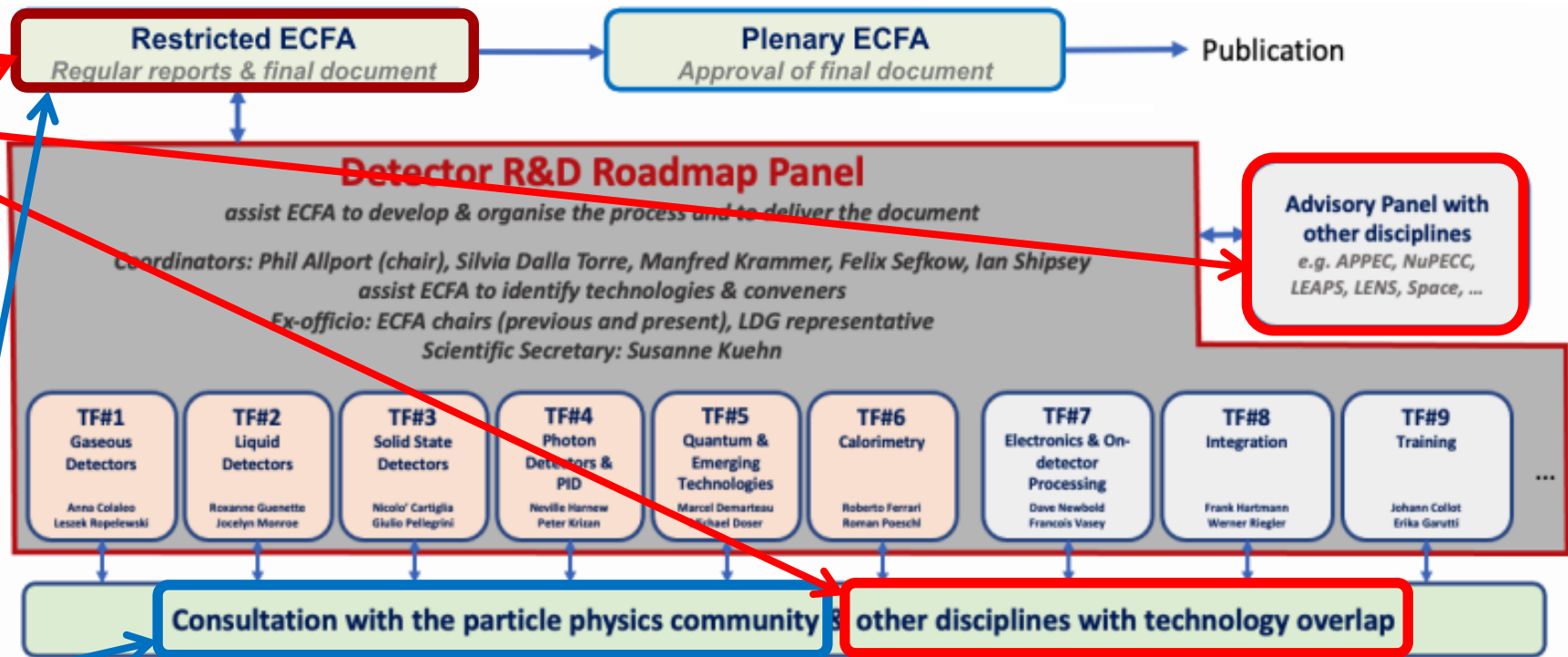
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(University of Birmingham)

On behalf of the ECFA Detector R&D Roadmap Panel Coordinators
(Phil Allport; Silvia Dalla Torre; Jorgen D'Hondt; Karl Jakobs;
Manfred Krammer; Susanne Kuehn; Felix Sefkow; Ian Shipsey)

*“Organised by ECFA, a roadmap should be developed by the community to balance the detector R&D efforts in Europe, taking into account progress with emerging technologies in adjacent fields” **

*“The community should define a global detector R&D roadmap that should be used to support proposals at the European and national levels” **



ECFA Detector R&D Roadmap Panel web pages at:
<https://indico.cern.ch/e/ECFADetectorRDRoadmap>

* 2020 European Particle Physics Strategy Update
<https://europeanstrategyupdate.web.cern.ch/>

(<https://cds.cern.ch/record/2784893>)



THE 2021 ECFA DETECTOR
RESEARCH AND DEVELOPMENT ROADMAP

The European Committee for Future Accelerators
Detector R&D Roadmap Process Group



ECFA
European Committee
for Future Accelerators

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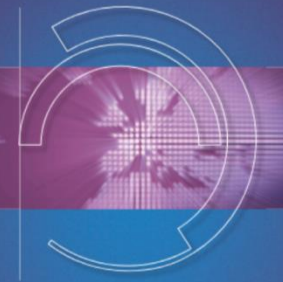
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We ought, in every instance, to submit our reasoning to the test of experiment, and never to search for truth but by the natural road of experiment and observation.

Antoine Lavoisier
Traité élémentaire de chimie, 1789



More information:

<https://europeanstrategy.cern>
<https://indico.cern.ch/e/ECFADetectorRDRoadmap>
<https://ecfa.web.cern.ch/>

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ECFA
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for Future Accelerators

Process involved: 67 authors; 12 expert Input Session speakers; ECFA National Contacts; respondents to the Task Force surveys; 121 Symposia presenters; 1359 Symposia attendees and 44 APOD TF topic specific contacts.

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<https://indico.cern.ch/e/ECFADetectorRDRoadmap>

The Task Force Convenors join those listed below to compose the Detector R&D Roadmap Panel.

Panel coordinators: Phil Allport⁴² (Chair), Silvia Dalla Torre⁴³, Manfred Kramer², Felix Sefkow¹⁸, Ian Shipsey¹⁶

Ex-officio Panel members: Karl Jakobs⁴⁴ (Current ECFA Chair), Jorgen D'Hondt⁴⁵ (Previous ECFA Chair), Lenny Rivkin⁴⁶ (LDG Representative)

Scientific Secretary: Susanne Kuehn²

ECFA Two Days of Input Sessions

Input Session speakers provided detailed specifications and continued giving support for the process ... particularly for checking if there were any unmet detector R&D needs for the ESPP identified programme which may have been overlooked in the symposia programmes.

Speaker	Presentation Topic
1 Chris Parkes	Detector R&D requirements for HL-LHC
2 Luciano Musa	Detector R&D requirements for strong interaction experiments at future colliders
3 Johannes Bernhard	Detector R&D requirements for strong interaction experiments at future colliders
4 Frank Simon	Detector R&D requirements for future linear high energy e+e- machines
5 Mogens Dam	Detector R&D requirements for future circular high energy e+e- machines
6 Martin Aleksa	Detector R&D requirements for future high-energy hadron colliders
7 Nadia Pastrone	Detector R&D requirements for muon colliders
8 Marzio Nessi	Detector R&D requirements for future short and long baseline neutrino experiments
9 Maarten De Jong	Detector R&D requirements for future astro-particle neutrino experiments
10 Laura Baudis	Detector R&D requirements for future dark matter experiments
11 Cristina Lazzeroni	Detector R&D requirements for future rare decay processes experiments
12 Alexandre Obertelli	Detector R&D requirements for future low energy experiments

ECFA Full-day Public Symposia

Two days of Input Sessions covered all the future facilities and topic areas identified in the ESPSU (see back-up). Following these were nine technology focussed full-day public symposia as the main fora to collect community input.

Task Force	1F7	1F8	1F2	1F5	1F3	1F1	1F9	1F4	1F6
Dates	20/01	30/01	06/02	12/02	21/02	28/02	06/03	13/03	20/03
Online seats	388 + 120 (booked)	154 + 17 (booked)	301 + 1 (booked)	220	504	338	305	207	201
No. of conceptual papers	230 + 123 (booked)	78 + 17 (booked)	138 + 5 (booked)	100	275	191	99	110	115

Common registration for the symposia had logged 1359 participants by the end of the last one. Received extensive feedback during symposia and after by email.

Surveys were also employed to receive direct inputs from individuals and via ECFA delegates or their National Contacts. APOD appointed experts consulted where needed by Task Force convenors for advice on developments in their disciplines.

Organisation name	Contact name
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NoPECC	Marek Lewkowicz (Chair)
LEAPS	Caterina Biacchi (Chair)
LENS	Helmuth Schuber (Chair)
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APPEC	1F11: Andrew Cooper (UK)
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Advisory Panel with Other Disciplines

- APPEC: Astro-Particle Physics European Consortium
- ESA: European Space Agency
- LEAPS: League of European Accelerator-based Photon Sources
- LENS: League of advanced European Neutron Sources
- NoPECC: Nuclear Physics European Collaboration Committee

- The most urgent R&D topics in each Task Force area are identified as **Detector R&D Themes**.
- The timeframes for activities in these areas are illustrated in this figure from both the brochure and the main document.
- **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.

→ See “Results of the 2021 ECFA Early-Career Researcher Survey on Training in Instrumentation” [ECFA ECR Panel arXiv:2107.05739](https://arxiv.org/abs/2107.05739)

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



It is not to be implied that further R&D is not needed but the schedule for future facilities in this area that need it are not currently defined

(<https://cds.cern.ch/record/2784893>)



In addition to the Detector R&D Themes described above and discussed in each chapter the following General Strategic Recommendations were made under the following headings.

- 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**

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.

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.

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.

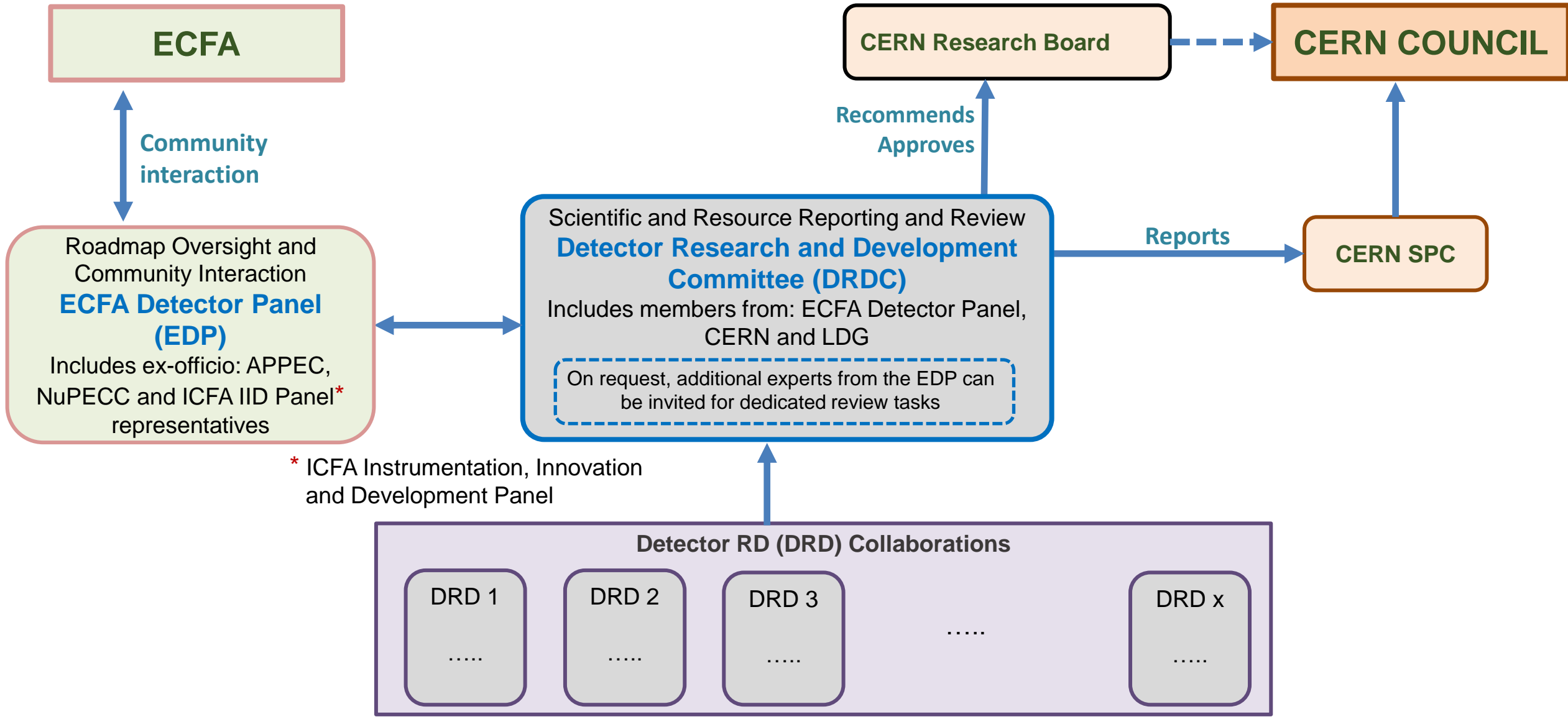
GSR 10 – Open Science

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 (SCOAP³) should explore ensuring similar access is available to instrumentation journals (including for conference proceedings) as to other particle physics publications.

- The initial proposals were worked out by the Coordination group and presented and discussed first with the scientific representatives of all 28 Member countries of ECFA in the Rome RECFA meeting of March 2022.
- The resulting scheme was further modified to reflect specific feedback from them and CERN management.
- Discussion have been going on in parallel with the leading Funding Agencies to understand what sort of new funding mechanisms and review structures might be acceptable to them.
- The proposed Detector and Accelerator implementation plans were presented to all Funding Agencies at the April 2022 Plenary RRB <https://indico.cern.ch/event/1133070/timetable/> by ECFA and LDG Chairs (Karl Jakobs and Dave Newbold).
- ECFA regards the first stage, that needs the longest lead-time, as being to work out funding structures that would meet the recommendations **GSR4**, **GSR5** and **GSR6** to define a long-term framework for strategic R&D detector funding in Europe.
- In discussions with the many Funding Agencies with their diverse funding and costing models it was realised that the only viable model to fund future R&D Collaborations to deliver programmes to sustain the multi-decadal requirements, identified as the the DRDTs in the Roadmap, was to utilise the existing understood framework for funding long-term investments in particle physics experiments at CERN.

- **Detector technology areas:** larger DRD collaborations should be considered, given: concerns about the review and administrative overheads with too many entities covering too fine-grained topics, the synergies that can be better exploited by larger organisations and the advantages of scale in terms of dealing with external bodies.
- It is proposed that DRD Collaborations should be anchored at CERN → CERN recognition; DRD label.
- **The new DRDs should take full account of existing, well-managed and successful ongoing R&D collaborations and other existing activities (current RDs, CERN EP R&D programme, EU-funded initiatives, collaborations exploring particular technology areas for future colliders, ...).**
- **The formation of the new DRD collaborations should clearly adopt a community-driven approach;**
 - propose this could be supported by existing ECFA Detector R&D Roadmap Task Forces;
 - existing CERN RDs, or other collaborations, covering several DRDT topics can help nucleate the process;
 - aim to initiate this year, with full process established over the coming year.
- Research topics, budget, milestones, etc., would have to be adapted as rolling grants for long-term R&D lines with flexibility for adapting to the changing international landscape and new R&D opportunities (for example coming from “blue-sky” R&D funded through resources outside those awarded for DRDT-specific strategic R&D).
- Many details are still under discussion, but it has been strongly recommended that the setting up of this proposed organisational structure proceeds immediately to enable it to produce concrete R&D plans to be presented during the 2022 September Council Week for final approval at the December Council Week.

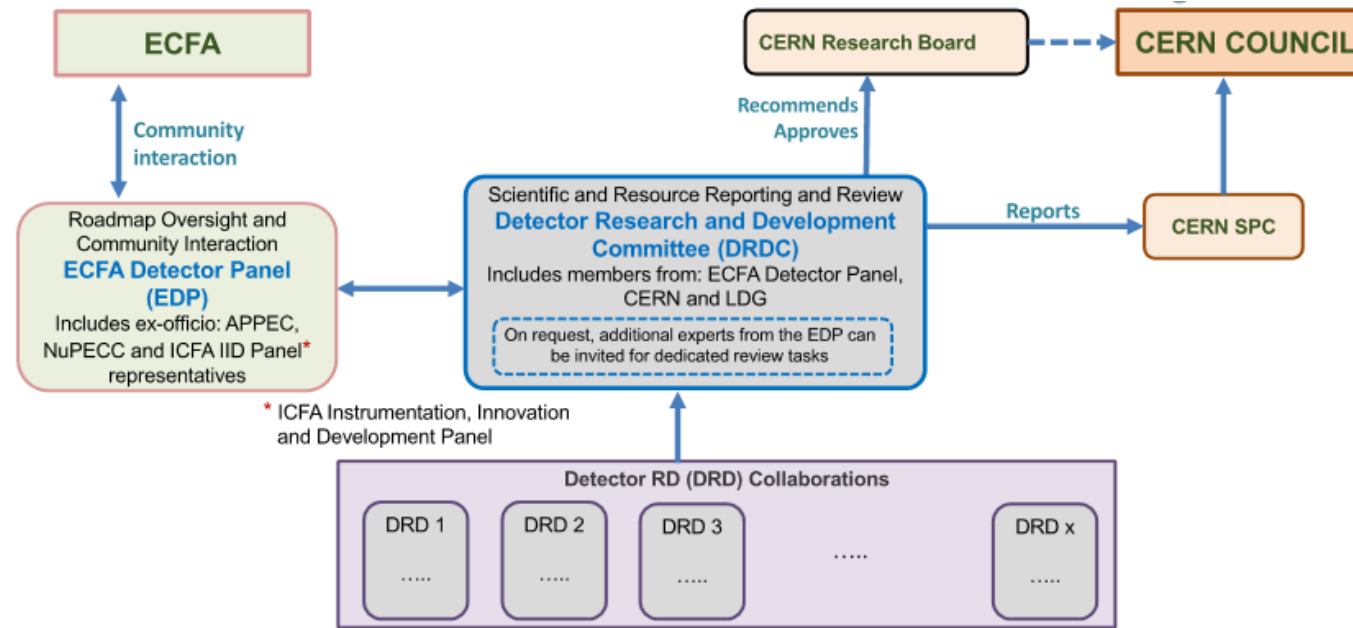
- **The aim is for DRDs to be up and running as entities by 2024 and to be ready for having a ramp up of the proposed resources awarded for “Strategic R&D” through 2025 to a steady state by 2026.**
- **The timescales are set by the necessity to prioritise HL-LHC deliverables and to allow a timely completion or transfer of existing funded R&D into this new framework.**
(Note existing CERN RD collaborations will need to put in proposals for continuation beyond the end of 2023.)
- **Strategic funding is here intended to be additional to continued funding opportunities to support of more exploratory Blue-Sky R&D through shorter-term “responsive mode” schemes (often nationally organised with broader peer review looking across applications in a range of scientific communities).**
- **Such funding should be expected to continue being sought by participating researchers where it is more appropriate for speculative ideas whose impact is much wider than that defined by the currently understood detector R&D needs of the future particle physics programme (as encapsulated in the DRDTs).**
- **As currently, highly Experiment Specific R&D is expected to be covered within the funding envelope for approved projects where detailed specifications call for a much more targeted approach.**
- **Mechanisms should be established to maximise flow of ideas and experience between these three different modes of R&D.**



* ICFA Instrumentation, Innovation and Development Panel

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.



- Assuming the new DRDs need to come into existence **by the start of 2024**, the Detector R&D Roadmap Task Forces will need to start organising open meetings to establish the scope and scale of the communities wishing to participate in the corresponding new DRD activities **from Autumn of this year**.
(Where the broad R&D topic area has one or more DRDs 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 much of the relevant community together around the proposed programmes.)
- **Through 2023**, mechanisms will need to be agreed with funding agencies, in parallel to the below, for country specific DRD collaboration funding requests for Strategic R&D and for developing the associated MoUs.
- **By Spring 2023**, the DRDC mandate would need to be formally defined and agreed with CERN management; Core DRDC membership appointed; and EDP mandate plus membership updated to reflect additional roles.
- To allow sufficient time for reviewing and iteration, DRD proposals will need to be submitted by **early Summer 2023**.
- Formal approval should be given by the CERN Research Board **in Autumn 2023**.
- New structures operational and new R&D programmes underway **from beginning 2024**.
- **Through 2024**, collection of MoU signatures will need to take place, with defined areas of interest per institute.
- Ramp up of new strategic funding and R&D activities **2024-2026** in parallel to completion of current deliverables.

- The ECFA Detector R&D Roadmap was prepared by a large team of internationally recognised leaders in this area with access to a much wider pool of other instrumentation experts.
- It was the product of wide community consultation with very broad participation.
- It was endorsed by RECFA and has been presented to the CERN Scientific Policy Committee and Council and been very well received, with the SPC congratulating the Roadmap Panel and endorsing the recommendations, **creating significant support and momentum for following up on its key recommendations.**
- ECFA has been mandated to propose mechanisms for implementing the Roadmap recommendations.
- A process of consultation with Funding Agencies, national scientific contacts (via RECFA), CERN committees and management around the aspects requiring the longest lead-times (those linked to new funding lines and structures linking in particular to the General Strategic Recommendations **GSR4, GSR5 and GSR6**) has been initiated.
- An overall framework needs to be agreed to secure longer-term R&D resources that also anticipates post-LHC and supports non-LHC programmes in a way that takes better advantage of the multiple synergies that exist across the many particle physics (and neighbouring discipline) detector development programmes – **otherwise a substantial community of experts and funding to support their activities will be lost to our community.**
- **We need everyone's help to pull the community together through the coming year to converge on the DRD organisation and proposals which can secure some of the resources that should start becoming available as the major HL-LHC deliverables begin to be completed and final integration gets underway in 2026.**

Back-up

European Particle Physics Strategy Update

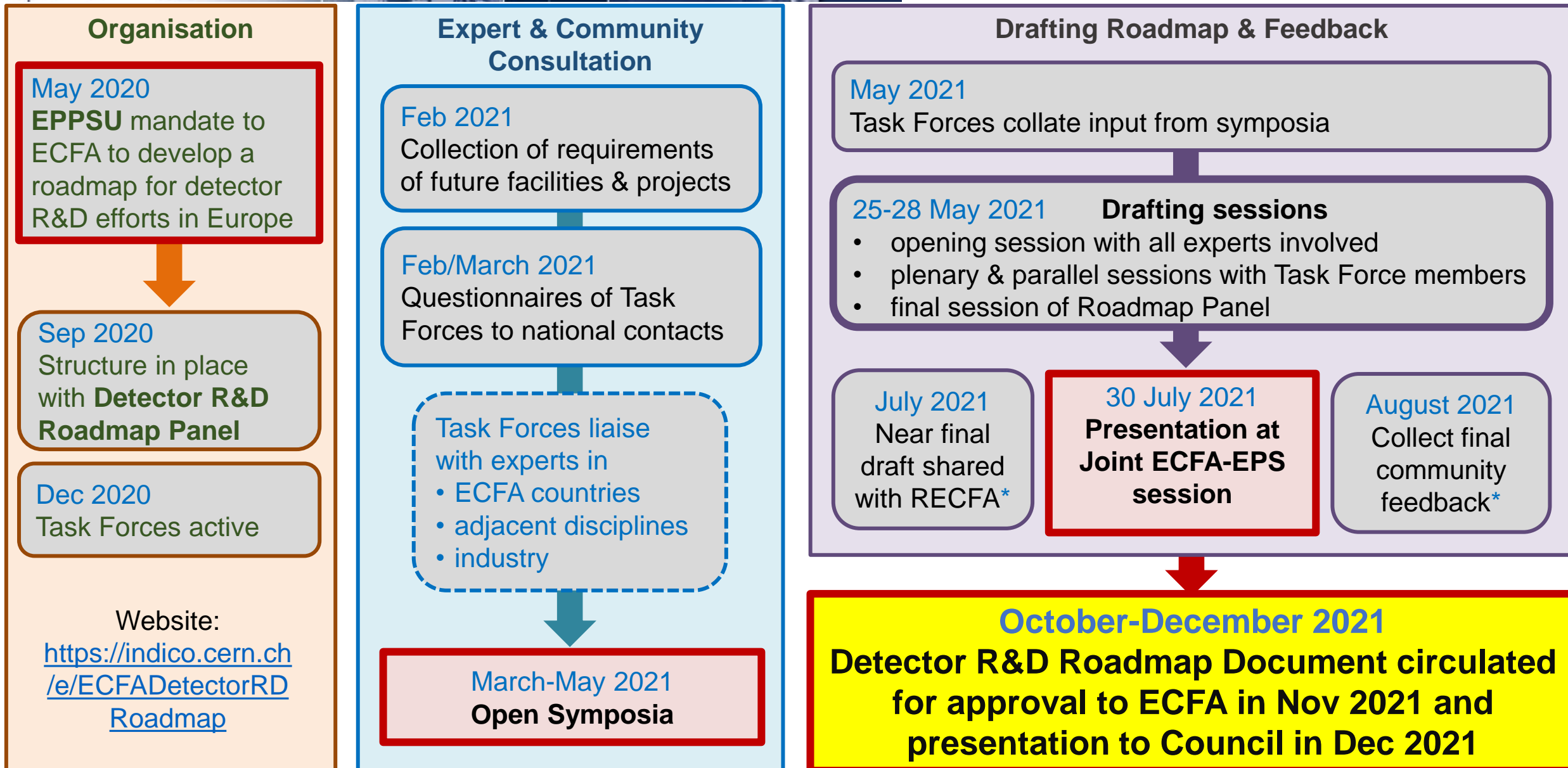
Main report: *“Recent initiatives with a view towards strategic R&D on detectors are being taken by CERN’s EP department and by the ECFA detector R&D panel, supported by EU-funded programmes such as AIDA and ATTRACT. Coordination of R&D activities is critical to maximise the scientific outcomes of these activities and to make the most efficient use of resources; as such, there is a clear need to strengthen existing R&D collaborative structures, and to create new ones, to address future experimental challenges of the field beyond the HL-LHC. Organised by ECFA, a roadmap should be developed by the community to balance the detector R&D efforts in Europe, taking into account progress with emerging technologies in adjacent fields.”*



Deliberation document: *“Detector R&D programmes and associated infrastructures should be supported at CERN, national institutes, laboratories and universities. Synergies between the needs of different scientific fields and industry should be identified and exploited to boost efficiency in the development process and increase opportunities for more technology transfer benefiting society at large. Collaborative platforms and consortia must be adequately supported to provide coherence in these R&D activities. The community should define a global detector R&D roadmap that should be used to support proposals at the European and national levels.”*

Extracted from the documents of 2020 EPPSU, <https://europeanstrategyupdate.web.cern.ch/>

More roadmap process details at: <https://indico.cern.ch/e/ECFADetectorRDRoadmap>



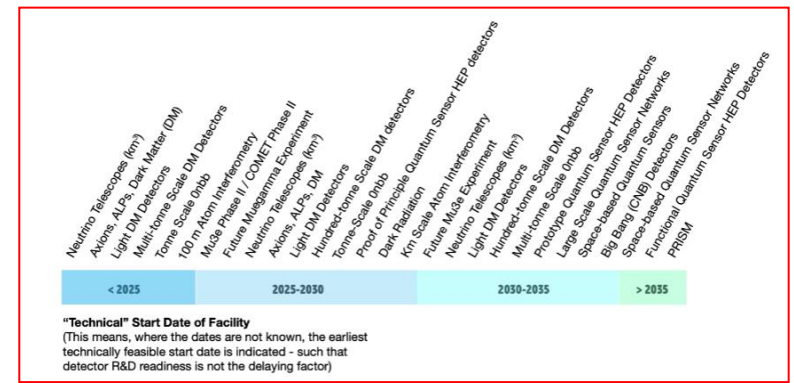
Roadmap process involved: 67 authors; 12 expert Input
 Session speakers; ECFA National Contacts; respondents to the
 Task Force surveys; 121 Symposia presenters; 1359 Symposia
 attendees as well as 44 APOD (Advisory Panel with Other
 Disciplines) Task Force topic specific contacts.

248 page report and 8 page synopsis document identifying
 the most urgent R&D topics or activities for meeting the
 EPPSU listed programme in the 9 Task Force Areas.

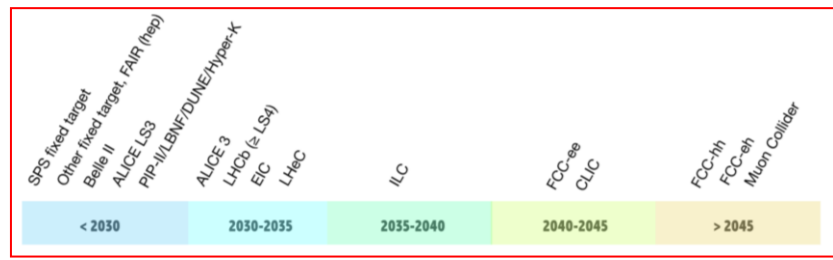
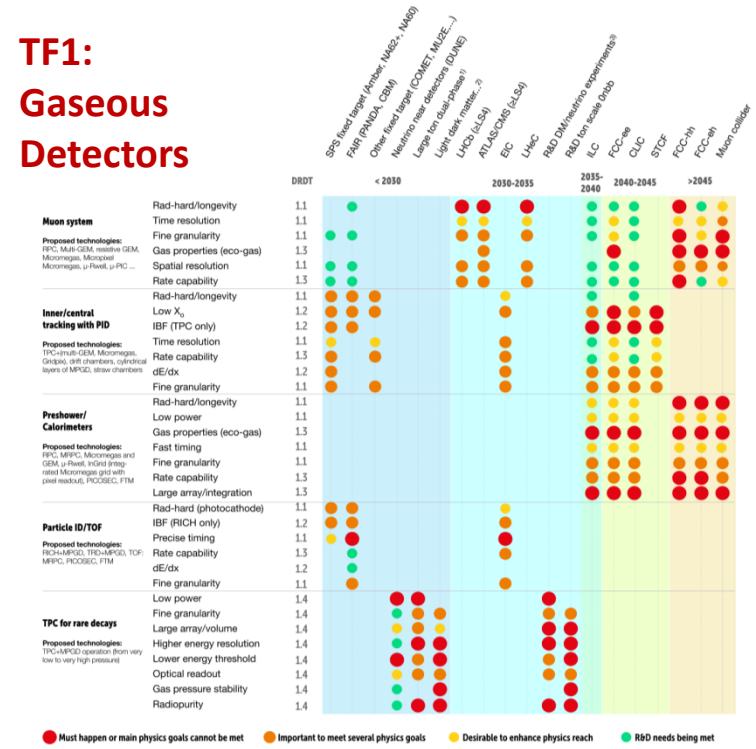


(<https://cds.cern.ch/record/2784893>)

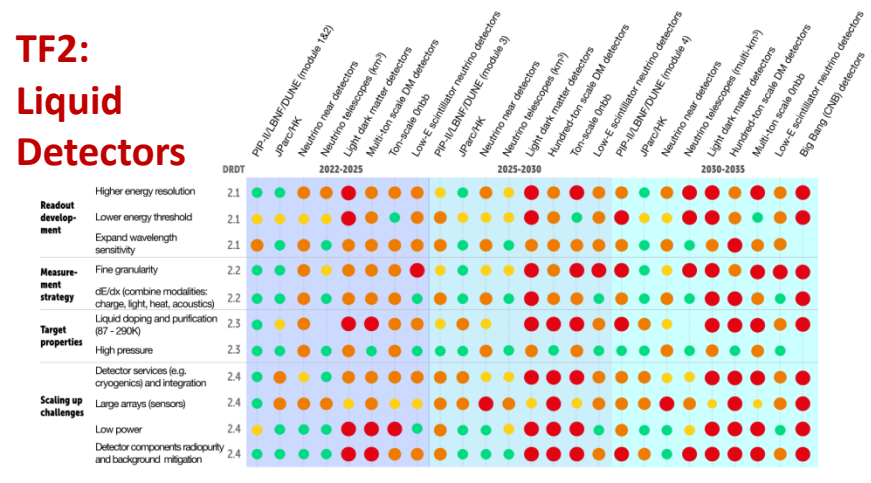
Example non-accelerator dates (not complete)



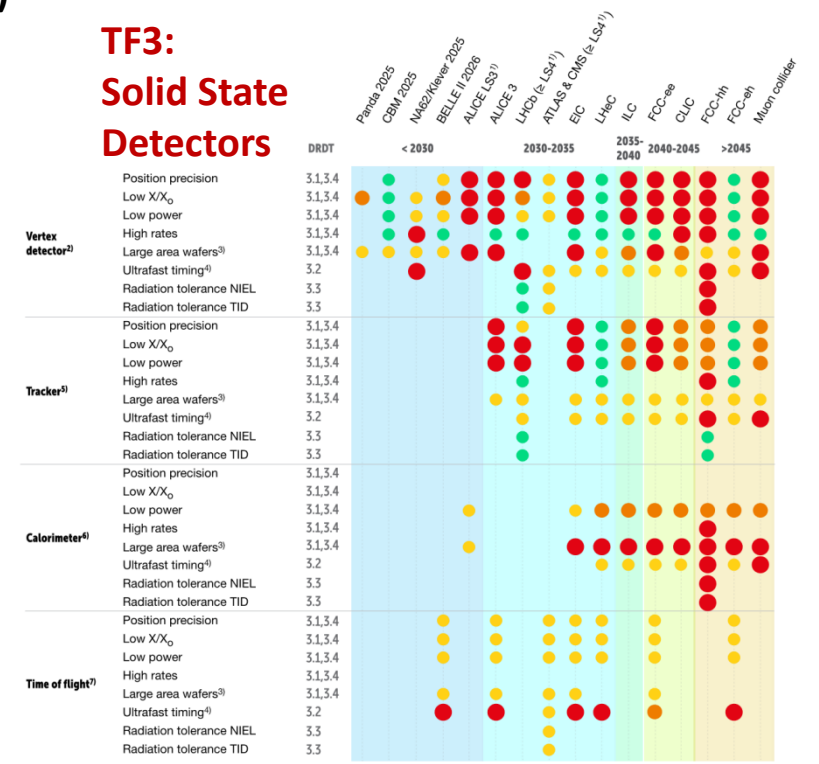
TF1: Gaseous Detectors



TF2: Liquid Detectors

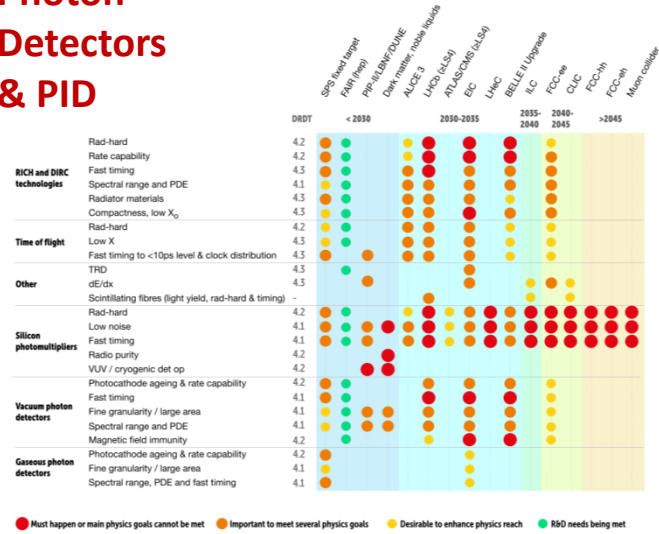


TF3: Solid State Detectors

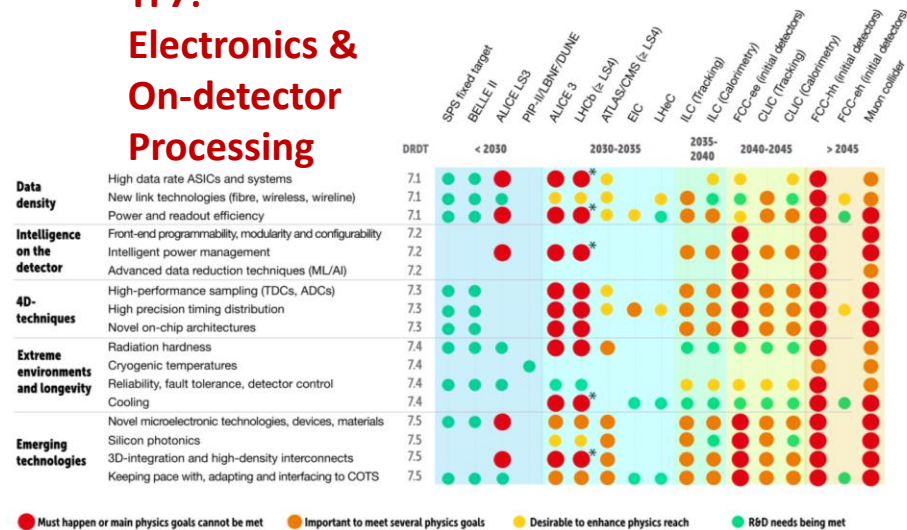


1) Large ion dual-phase (PandaX-II, LZ, DarkSide-20k, Argo 200k, APRIADNE, ...)
 2) Light dark matter, solar axion, Orino, rare nucleons and astro-particle reactions, Be tagging
 3) R&D for 100-ton scale dual-phase DM/neutrino experiments

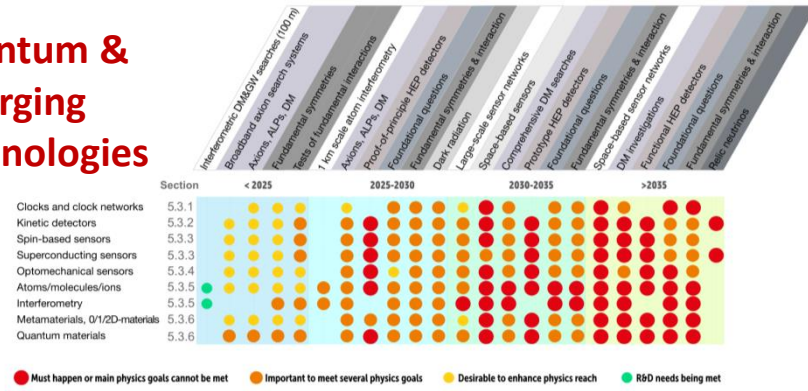
TF4: Photon Detectors & PID



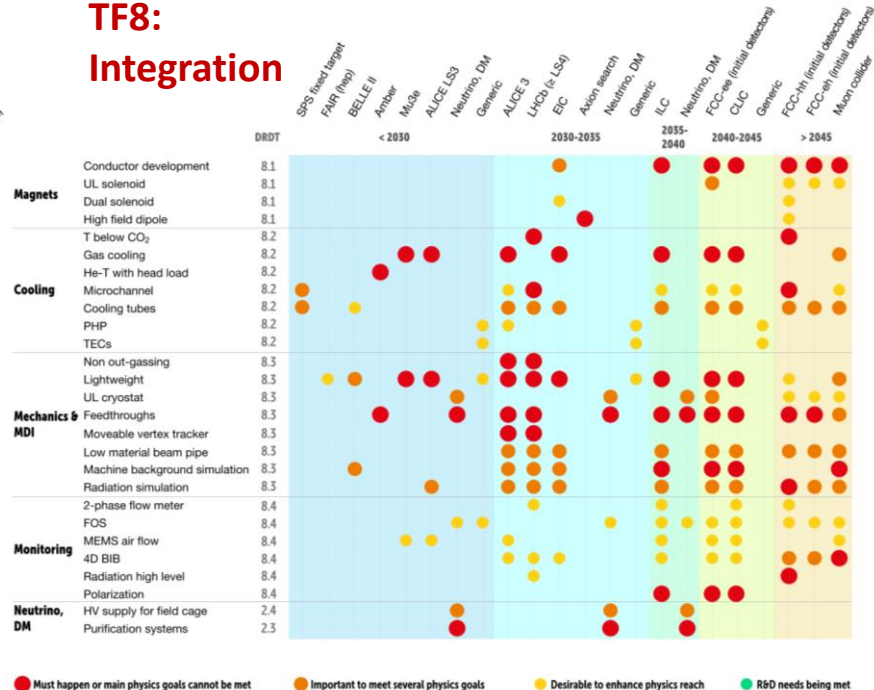
TF7: Electronics & On-detector Processing



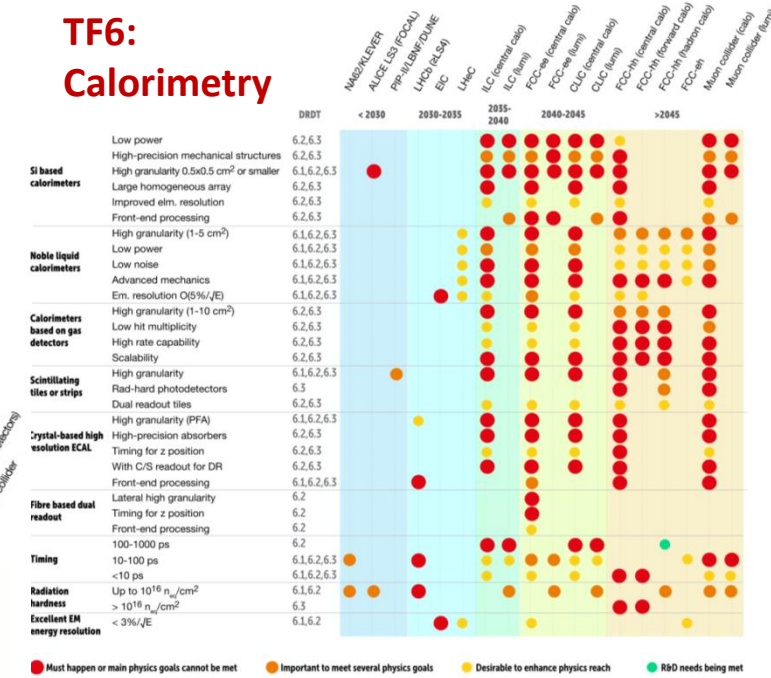
TF5: Quantum & Emerging Technologies



TF8: Integration



TF6: Calorimetry



* LHCb Velo

*Task Force convenors, Task Force expert members and Panel members
of the ECFA Detector R&D Roadmap Process Group*

Task Force 1 Gaseous Detectors: Anna Colaleo¹, Leszek Ropelewski² (*Convenors*)
Klaus Dehmelt³, Barbara Liberti⁴, Maxim Titov⁵, Joao Veloso⁶ (*Expert Members*)

Task Force 2 Liquid Detectors: Roxanne Guenette⁷, Jocelyn Monroe⁸ (*Convenors*)
Auke-Pieter Colijn^{9,10}, Antonio Ereditato^{11,12,28}, Inés Gil Botella¹³,
Manfred Lindner¹⁴ (*Expert Members*)

Task Force 3 Solid State Detectors: Nicolo Cartiglia¹⁵, Giulio Pellegrini¹⁶ (*Convenors*)
Daniela Bortoletto¹⁷, Didier Contardo¹⁸, Ingrid-Maria Gregor^{19,20}, Gregor Kramberger²¹,
Heinz Pernegger² (*Expert Members*)

Task Force 4 Particle Identification and Photon Detectors: Neville Harnew¹⁷,
Peter Krizan²¹ (*Convenors*)
Ichiro Adachi²², Eugenio Nappi¹, Christian Joram²,
Hans-Christian Schultz-Coulon²³ (*Expert Members*)

Task Force 5 Quantum and Emerging Technologies: Marcel Demarteau²⁴,
Michael Doser² (*Convenors*)
Caterina Braggio²⁵, Andy Geraci²⁶, Peter Graham²⁷, Anna Grasselino²⁸,
John March Russell¹⁷, Stafford Withington²⁹ (*Expert Members*)

Task Force 6 Calorimetry: Roberto Ferrari³⁰, Roman Pöschl³¹ (*Convenors*)
Martin Aleksa², Dave Barney², Frank Simon³²,
Tommaso Tabarelli de Fatis³³ (*Expert Members*)

Task Force 7 Electronics: Dave Newbold³⁴, Francois Vasey² (*Convenors*)
Niko Neufeld², Valerio Re³⁰, Christophe de la Taille³⁵, Marc Weber³⁶ (*Expert Members*)

Task Force 8 Integration: Frank Hartmann³⁶, Werner Riegler² (*Convenors*)
Corrado Gargiulo², Filippo Resnati², Herman Ten Kate³⁷, Bart Verlaet²,
Marcel Vos³⁸ (*Expert Members*)

Task Force 9 Training: Johann Collot³⁹, Erika Garutti⁴⁰ (*Convenors*)
Richard Bremner⁴¹, Niels van Bakel⁹, Claire Gwenlan¹⁷, Jeff Wiener², Robert Appleby⁴²
(*Expert Members*)

*The Task Force Convenors join those listed below to compose the Detector R&D Roadmap
Panel.*

Panel coordinators: Phil Allport⁴² (*Chair*), Silvia Dalla Torre⁴³, Manfred Krammer²,
Felix Sefkow¹⁸, Ian Shipsey¹⁶

Ex-officio Panel members: Karl Jakobs⁴⁴ (*Current ECFA Chair*),
Jorgen D'Hondt⁴⁵ (*Previous ECFA Chair*), Lenny Rivkin⁴⁶ (*LDG Representative*)

Scientific Secretary: Susanne Kuehn²

¹ University and INFN Sezione di Bari, Bari, Italy

² CERN, Geneva, Switzerland

³ Stony Brook University, New York, US

⁴ INFN Roma, Rome, Italy

⁵ IRFU/DPhP CEA Saclay, Saclay, France

⁶ Universidade de Aveiro, Aveiro, Portugal

⁷ Harvard University, Cambridge, US

⁸ Royal Holloway University of London, London, UK

⁹ Nikhef, Amsterdam, The Netherlands

¹⁰ University of Amsterdam, Amsterdam, The Netherlands

¹¹ Yale University, New Haven, US

¹² University of Bern, Berne, Switzerland

¹³ CIEMAT, Madrid, Spain

¹⁴ MPI Heidelberg, Heidelberg, Germany

¹⁵ INFN Sezione di Torino, Torino, Italy

¹⁶ IMB-CNM-CSIC, Barcelona, Spain

¹⁷ University of Oxford, Oxford, UK

¹⁸ CNRS/IN2P3-IP2I, Lyon, France

¹⁹ DESY, Hamburg, Germany

²⁰ University of Bonn, Bonn, Germany

²¹ University of Ljubljana and J. Stefan Institute, Ljubljana, Slovenia

²² KEK, Tsukuba, Japan

²³ Heidelberg University, Heidelberg, Germany

²⁴ ORNL, Oak Ridge, US

²⁵ INFN Sezione di Padova, Padova, Italy

²⁶ Northwestern University, Evanston, US

²⁷ Stanford University, Stanford, US

²⁸ FNAL, Batavia, US

²⁹ University of Cambridge, Cambridge, UK

³⁰ INFN Sezione di Pavia, Pavia, Italy

³¹ CNRS/IN2P3-LJClab, Orsay, France

³² MPP, Munich, Germany

³³ University of Milano-Bicocca and INFN Milano-Bicocca, Milano, Italy

³⁴ RAL, Didcot, UK

³⁵ CNRS/IN2P3-OMEGA, Palaiseau, France

³⁶ KIT, Karlsruhe, Germany

³⁷ University of Twente, Twente, Netherlands

³⁸ IFIC (UVEG/CSIC) Valencia, Valencia, Spain

³⁹ Université Grenoble Alpes, CNRS, Grenoble INP, LPSC-IN2P3, Grenoble, France

⁴⁰ University of Hamburg, Hamburg, Germany

⁴¹ University of Uppsala, Uppsala, Sweden

⁴² University of Manchester, Manchester, UK

⁴³ University of Birmingham, Birmingham, UK

⁴⁴ INFN Sezione di Trieste, Trieste, Italy

⁴⁵ Albert-Ludwigs-Universität Freiburg, Freiburg, Germany

⁴⁶ IHE, Vrije Universiteit Brussel, Brussels, Belgium

⁴⁷ ETH Lausanne and PSI, Villigen, Switzerland

Restricted ECFA Composition

<https://ecfa.web.cern.ch/restricted-ecfa>

Chair	Prof. Dr Karl Jakobs	Appointed Jan. 2021
Secretary	Prof. Patricia Conde Muino	Appointed July 2021
Members		
Austria	Dr Manfred Jeitler	Appointed Jan. 2018
Belgium	Prof. Nick van Remortel	Appointed July 2018
Bulgaria	Prof. Plamen Iaydjiev	Appointed Jan. 2016
Croatia	Prof. Mirko Planinic	Appointed July 2020
Cyprus	Prof. Panos Razis	Appointed Oct. 2017
Czech Republic	Dr Marek Tasevsky	Appointed Jan. 2019
Denmark	Prof. Mogens Dam	Appointed Jan. 2018
Finland	Dr Kati Lassila-Perini	Appointed Jan. 2018
France	Dr Jean-Claude Brient	Appointed Jan. 2020
Germany	Prof. Heiko Lacker	Appointed July 2021
Greece	Prof. Paris Sphicas	Appointed July 2018
Hungary	Dr Ferenc Siklér	Appointed Jan. 2021
Italy	Prof. Chiara Meroni	Appointed July 2020
Israel	Prof. Eilam Gross	Appointed Jan. 2018
Netherlands	Prof. Stan Bentvelsen	Appointed Jan. 2015
Norway	Prof. Alexander Read	Appointed Jan. 2018
Poland	Prof. Justyna Łagoda	Appointed Jan. 2021

Portugal	Prof. Patricia Condes Muino	Appointed July 2020
Romania	Dr Alexandru-Mario Bragadireanu	Appointed Jan. 2019
Serbia	Prof. Peter Adžic	Appointed July 2012
Slovakia	Dr Pavol Strženeč	Appointed May 2016
Slovenia	Prof. Marko Mikuž	Appointed July 2018
Spain	Prof. Celso Martinez	Appointed Jan. 2021
Sweden	Prof. David Milstead	Appointed Jan. 2018
Switzerland	Dr Mike Seidel	Appointed Jan. 2019
Turkey	Prof. Mehmet Zeyrek	Appointed July 2018
United-Kingdom	Prof. Max Klein	Appointed Jan. 2021
Ukraine	Prof. Mykola Shul'ga	Appointed July 2018
CERN	Dr Roger Forty	Appointed Sept. 2015
Ex-Officio Members		
CERN	Dr Fabiola Gianotti Prof. Joachim Mnich	Appointed Jan. 2016 Appointed Jan. 2021
LDG	Prof. Dave Newbold	Appointed Jan. 2021
Observers		
EPS-HEPP Board Chair	Prof. Thomas Gehrman	Appointed Sept. 2019
ApPEC Chair	Dr Andreas Haungs	Appointed Jan. 2021
NuPECC Chair	Prof. Marek Lewitowicz	Appointed March 2018
Russian Federation	Prof. Victor Matveev	Appointed Jan. 2007
Early Career Researchers (ECR)	Lydia Brenner	Appointed Feb. 2021

Input session of Future Facilities I

Friday 19 Feb 2021, 13:00 → 18:00 Europe/Zurich

- 13:00 → 13:30 **Detector R&D requirements for HL-LHC**
Speaker: Chris Parkes (University of Manchester (GB))
ECFA_RD_Parkes_1...
- 13:30 → 14:00 **Detector R&D requirements for strong interaction experiments at future colliders**
Speaker: Luciano Musa (CERN)
MUSA_ECFAJIS_20...
- 14:00 → 14:30 **Detector R&D requirements for strong interaction experiments at future fixed target facilities**
Speaker: Johannes Bernhard (CERN)
Detector R&D requir...
- 14:30 → 14:45 **Coffee-Tea Break**
- 14:45 → 15:15 **Detector R&D requirements for future linear high energy e+e- machines**
Speaker: Frank Simon (Max-Planck-Institut fuer Physik)
LC_DetRoadmapinp...
- 15:15 → 15:45 **Detector R&D requirements for future circular high energy e+e- machines**
Speaker: Mogens Dam (University of Copenhagen (DK))
ECFA_Detector_R&D...
- 15:45 → 16:15 **Detector R&D requirements for future high-energy hadron colliders**
Speaker: Martin Aleksa (CERN)
20210219-ECFA-Det...
- 16:15 → 16:35 **Detector R&D requirements for muon colliders**
Speaker: Nadia Pastrone (Universita e INFN Torino (IT))
MuonColliders_Dete...

Input session of Future Facilities II

Monday 22 Feb 2021, 14:00 → 18:00 Europe/Zurich

- 14:00 → 14:30 **Detector R&D requirements for future short and long baseline neutrino experiments**
Speaker: Marzio Nessi (CERN)
21-02-22-ECFA-Neut... 21-02-22-ECFA-Neut...
- 14:30 → 15:00 **Detector R&D requirements for future astro-particle neutrino experiments**
Speaker: Maarten De Jong (Riksfundatortje voor wetenschappelijk onderzoek (NL))
ECFA - Maarten de ... ECFA - Maarten de ...
- 15:00 → 15:30 **Detector R&D requirements for future dark matter experiments**
Speaker: Laura Baudis (University of Zurich)
baudis_ecfa_feb21...
- 15:30 → 15:40 **Coffee-Tea Break**
- 15:40 → 16:10 **Detector R&D requirements for future rare decay processes experiments**
Speakers: Cristina Lazzeroni (University of Birmingham (GB)), Cristina Lazzeroni (University of Birmingham (GB))
ECFA_Lazzeroni.pdf
- 16:10 → 16:40 **Detector R&D requirements for future low energy experiments**
Speaker: Dr Alexandre Obertelli (TU Delft)
ECFA_LowEnergyFa...

Input Session speakers provided detailed specifications and continued giving support for the process

... particularly for checking if there were any unmet detector R&D needs for the ESPP identified programme which may have been overlooked in the symposia programmes.

	Speaker	Presentation Topic
1	Chris Parkes	Detector R&D requirements for HL-LHC
2	Luciano Musa	Detector R&D requirements for strong interaction experiments at future colliders
3	Johannes Bernhard	Detector R&D requirements for strong interaction experiments at future colliders
4	Frank Simon	Detector R&D requirements for future linear high energy e+e- machines
5	Mogens Dam	Detector R&D requirements for future circular high energy e+e- machines
6	Martin Aleksa	Detector R&D requirements for future high-energy hadron colliders
7	Nadia Pastrone	Detector R&D requirements for muon colliders
8	Marzio Nessi	Detector R&D requirements for future short and long baseline neutrino experiments
9	Maarten De Jong	Detector R&D requirements for future astro-particle neutrino experiments
10	Laura Baudis	Detector R&D requirements for future dark matter experiments
11	Cristina Lazzeroni	Detector R&D requirements for future rare decay processes experiments
12	Alexandre Obertelli	Detector R&D requirements for future low energy experiments

Many thanks to all these key experts for their time and help with this process

Two days of Input Sessions covered all the future facilities and topic areas identified in the EPPSU (see back-up).

Following these were nine technology focussed full-day public symposia as the main fora to collect community input.

Task Force	TF7	TF8	TF2	TF5	TF3	TF1	TF9	TF4	TF6
Dates	25/3/21	31/3/21	9/4/21	12/4/21	23/4/21	29/4/21	30/4/21	6/5/21	7/5/21
Unique users	369 + 123 (webcast)	154 + 17 (webcast)	197 + 5 (webcast)	220	504	339	105	207	201
Max. number of concurrent viewers	230 + 123 (webcast)	76 + 17 (webcast)	130 + 5 (webcast)	100	275	191	59	110	115

Common registration for the symposia had logged **1359** participants by the end of the last one.

Received extensive feedback during symposia and after by email.

Surveys were also employed to receive direct inputs from individuals and via RECFA delegates or their National Contacts.

APOD appointed experts consulted where needed by Task Force convenors for advice on developments in their disciplines.

May 2021

- 07 May ECFA Detector R&D Roadmap Symposium of Task Force 6 Calorimetry
- 06 May ECFA Detector R&D Roadmap Symposium of Task Force 4 Photon Detectors and Particle Identification Detectors

April 2021

- 30 Apr ECFA Detector R&D Roadmap Symposium of Task Force 9 Training
- 29 Apr ECFA Detector R&D Roadmap Symposium of Task Force 1 Gaseous Detectors
- 23 Apr ECFA Detector R&D Roadmap Symposium of Task Force 3 Solid State Detectors
- 12 Apr ECFA Detector R&D Roadmap Symposium of Task Force 5 Quantum and Emerging Technologies
- 09 Apr ECFA Detector R&D Roadmap Symposium of Task Force 2 Liquid Detectors

March 2021

- 31 Mar ECFA Detector R&D Roadmap Symposium of Task Force 8 Integration
- 25 Mar ECFA Detector R&D Roadmap Symposium of Task Force 7 Electronics and On-detector Processing

Materials from past Symposia, Input Sessions and other components of the ECFA Detector R&D Roadmap Process can be found at <https://indico.cern.ch/e/ECFADetectorRDRoadmap>

Many thanks to the 121 presenters, the 1359 attendees and all who provided feedback

Organisation name	Contact name
APPEC	Andreas Haungs (Chair)
NuPECC	Marek Lewitowicz (Chair)
LEAPS	Caterina Biscari (Chair)
LENS	Helmut Schober (Chair)
ESA	Guenther Hasinger (Director of Science) Franco Ongaro (Director of Technology, Engineering and Quality)

APPEC: Astro-Particle Physics European Consortium
ESA: European Space Agency
LEAPS: League of European Accelerator-based Photon Sources
LENS: League of advanced European Neutron Sources
NuPECC: Nuclear Physics European Collaboration Committee

Named expert contacts		
APPEC	TF1	Jennifer L Raaf (Fermilab)
	TF2	Manfred Lindner (MPI Heidelberg)
	TF3	Fabrice Retiere (TRIUMF)
	TF4	Tina Pollmann (Nikhef)
	TF5	Harald Lück (Hannover)
	TF6	Federica Petricca (MPI Munich)
	TF7	Marc Weber (KIT)
	TF8	Aldo Ianni (LNGS)
	TF9	Katrin Link (APPEC)
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	TF4	Eugenio Nappi (INFN Bari) Jochen Schwiening
	TF5	: Christian Enns (Heidelberg),
	TF6	Thomas Peitzmann (Utrecht)
		Ulrike Thoma (Bonn)
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Many thanks to these experts for their advice and availability

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	TF4	
	TF5	Helmut Schober (ILL)
	TF6	
	TF7	Bruno Guerard (ILL)
	TF8	
	TF9	
ESA	TF1	Nick Nelms
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	TF3	Brian Shortt Nick Nelms Giovanni Santin Alessandra Constantino Mucio
	TF4	Brian Shortt Peter Verhoeve Sarah Wittig Nick Nelms Giovanni Santin Peter Verhoeve Sarah Wittig Nick Nelms
	TF5	Peter Verhoeve Sarah Wittig Nick Nelms
	TF6	Nick Nelms
	TF7	Joerg Ter Haar Christophe Honvault Nick Nelms Alessandra Constantino Mucio
	TF8	Massimo Braghin
	TF9	Christophe Honvault



- Draft circulated to RECFA, National Contacts and ECR on 2nd July with deadline for comments on 16th July
- Comments received from many of the RECFA members, observers and appointed National Contacts for the ECFA Detector R&D Roadmap process.
- Overwhelmingly positive and a number of countries had also organised a careful reading of the full draft with many detailed comments to each section - which were very helpful and have been implemented.
- A number of more general comments were discussed in greater detail on 21st July with a special sub-panel composed of RECFA members with reports back to RECFA and also to Plenary ECFA on 22nd July.
- The main messages contained here were presented to the particle physics community on 30th July at the ECFA Plenary Session of the EPS-HEP2021 Conference.
- **The document will need formal approval from ECFA on 19th November and will be presented as printed copies to CERN Council on 10th December.**
- **In parallel we have prepared an 8 page “synopsis” to accompany this, summarising the main conclusions which has been prepared with CERN IR-ECO in a more accessible language and style.**
- **Currently the 8 page document is printed and will be made available with the main document as both paper copies and pdf versions.**
- **The first print run of the main document is also completed but materials can only be made public once they have first been presented to CERN Council.**



<https://indico.cern.ch/event/957057/page/21633-mandate> (Panel Mandate document)

<https://indico.cern.ch/event/957057/page/21653-relevant-documents>

<https://home.cern/resources/brochure/cern/european-strategy-particle-physics>

<https://arxiv.org/abs/1910.11775> (Briefing Book)

https://science.osti.gov/-/media/hep/pdf/Reports/2020/DOE_Basic_Research_Needs_Study_on_High_Energy_Physics.pdf

<https://ep-dep.web.cern.ch/rd-experimental-technologies> (CERN EP R&D)

<https://aidainnova.web.cern.ch> (linking research infrastructures in detector development and testing)

<https://attract-eu.com/> (ATTRACT: linking to industry on detection and imaging technologies)

https://ecfa-dp.desy.de/public_documents/ (Some useful documents from the ECFA Detector Panel)