The Detector and Accelerator R&D Roadmaps to Future Colliders

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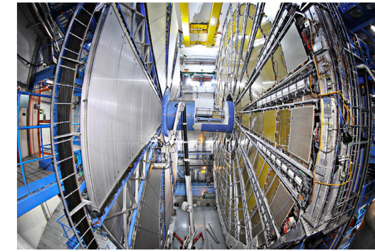
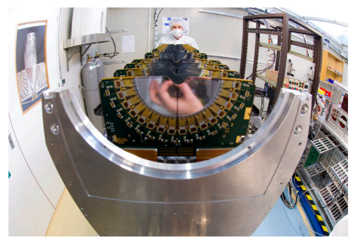
I. Detector R&D Roadmap

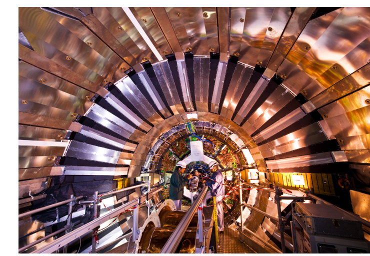
Insertion of lead-tungstate crystals (over three times the density of conventional glasses) into the high granularity electromagnetic calorimeter of the ALICE detector giving percent scale energy measurements. (© CERN)



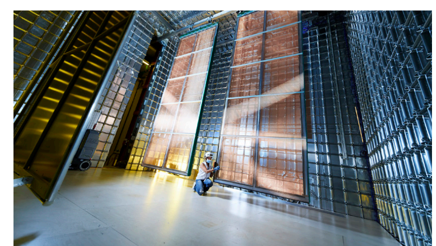
ATLAS gas detector based muon spectrometer, which covers a total area the size of a football field and measures the paths of the muons that pass through it to an accuracy of better than a tenth of a millimetre. (© CERN)



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



Installation of the CMS Central Tracking Detector with 10 million read-out channels and using silicon detectors covering an area of over 200 m^2. (© CERN)



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

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Update of the European Strategy for Particle Physics

4. Other essential scientific activities for particle physics

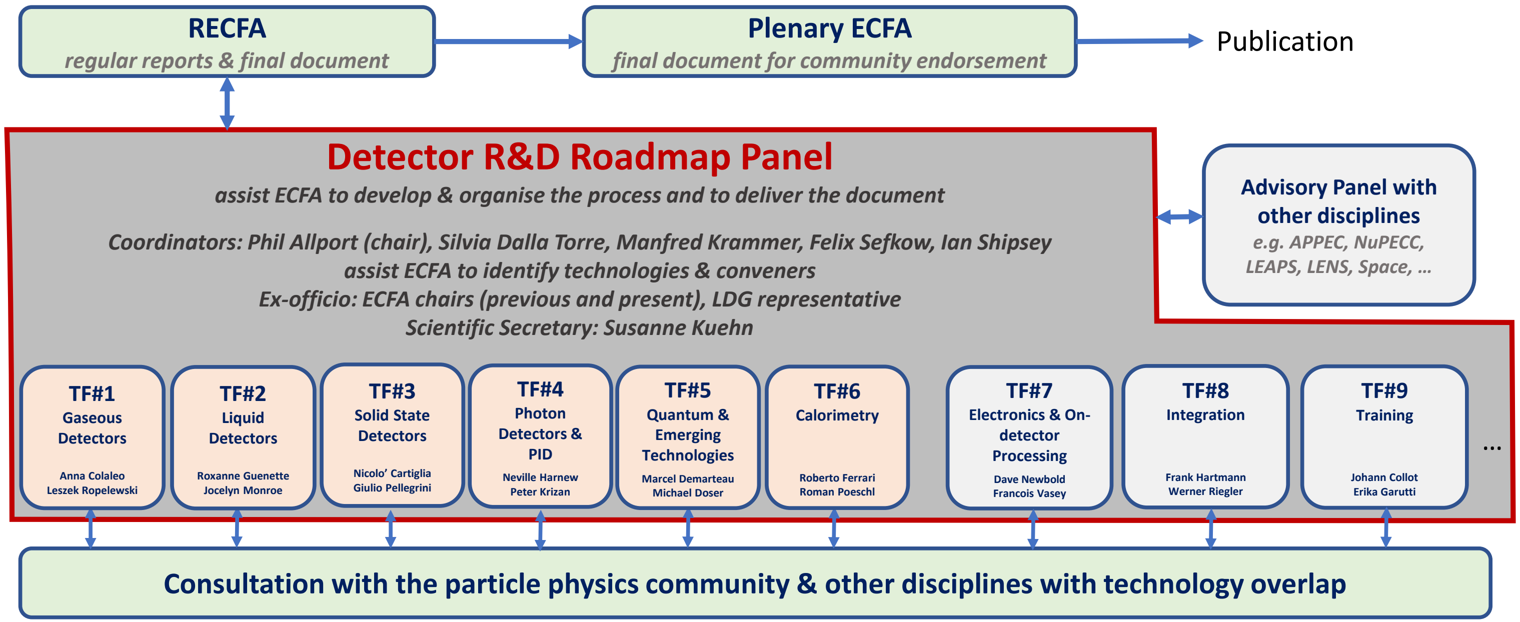
…

*c) The **success of particle physics experiments relies on innovative instrumentation and state-of-the-art infrastructures.** To prepare and realise future experimental research programmes, the community must **maintain a strong focus on instrumentation**. **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.***

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 roadmap should identify and describe a diversified detector R&D portfolio that has the largest potential to enhance the performance of the particle physics programme in the near and long term. …

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)*

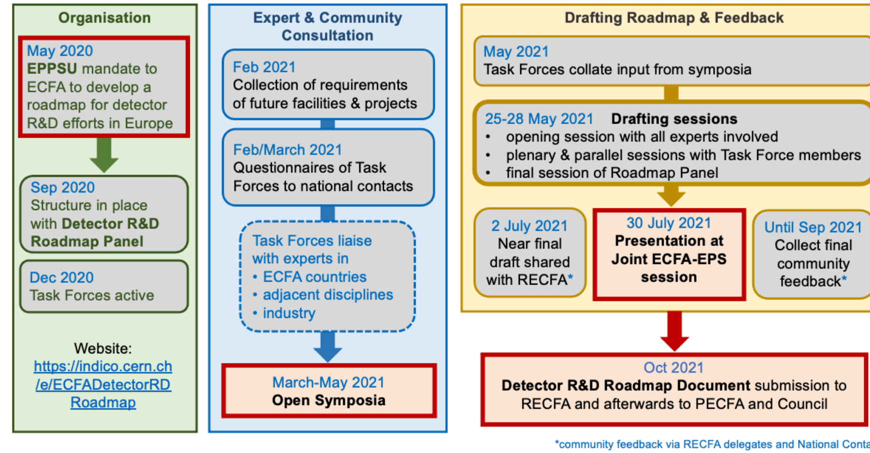
Information on the full process: [ECFA Detector R&D Roadmap]

The Detector R&D Roadmap Process

- Expert and Community consultation phase completed in May 2021; major input at Open Symposia
- **Roadmap Document approved by Plenary ECFA on 18th November 2021**

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

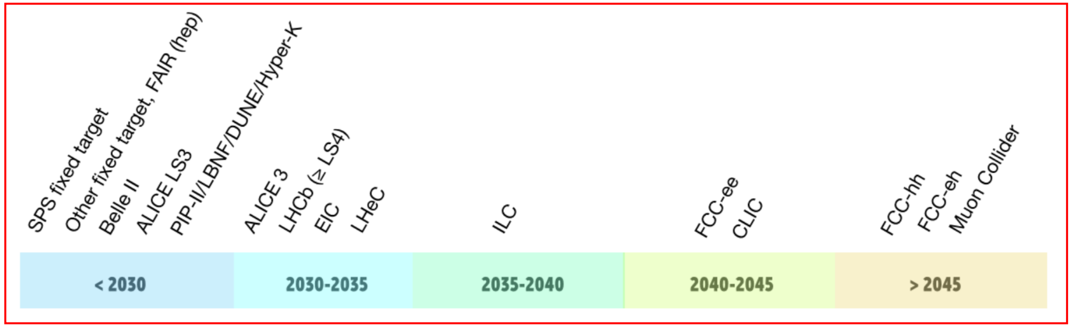
- Presentation to CERN Council in Dec 2021



- **Principles**
  For the **earliest feasible start dates** of the proposed facilities in the EPPSU:
  - Basic detector R&D should not be the time-limiting step
    (started sufficiently early and prioritised correctly to meet the needs of the long-term programme in its global context)
  - Outcomes of the R&D should provide the necessary information on the feasibility and cost of future deliverables

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.

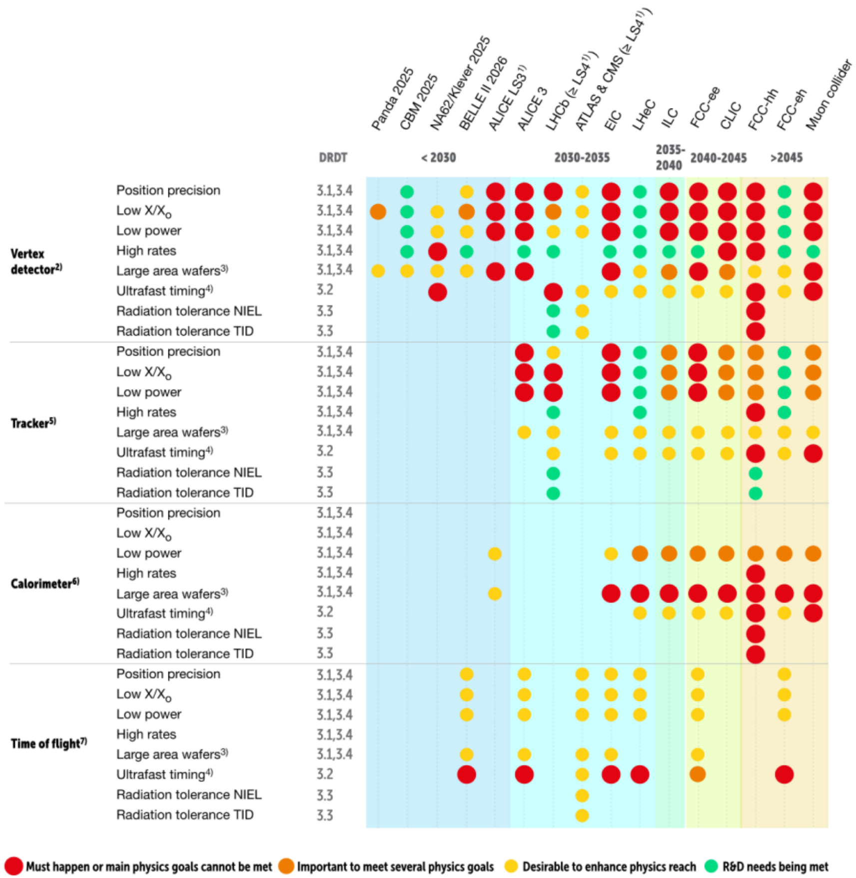
- Task Forces have identified a set of detector R&D areas which are required if the physics programmes of experiments at these facilities are not to be compromised

  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

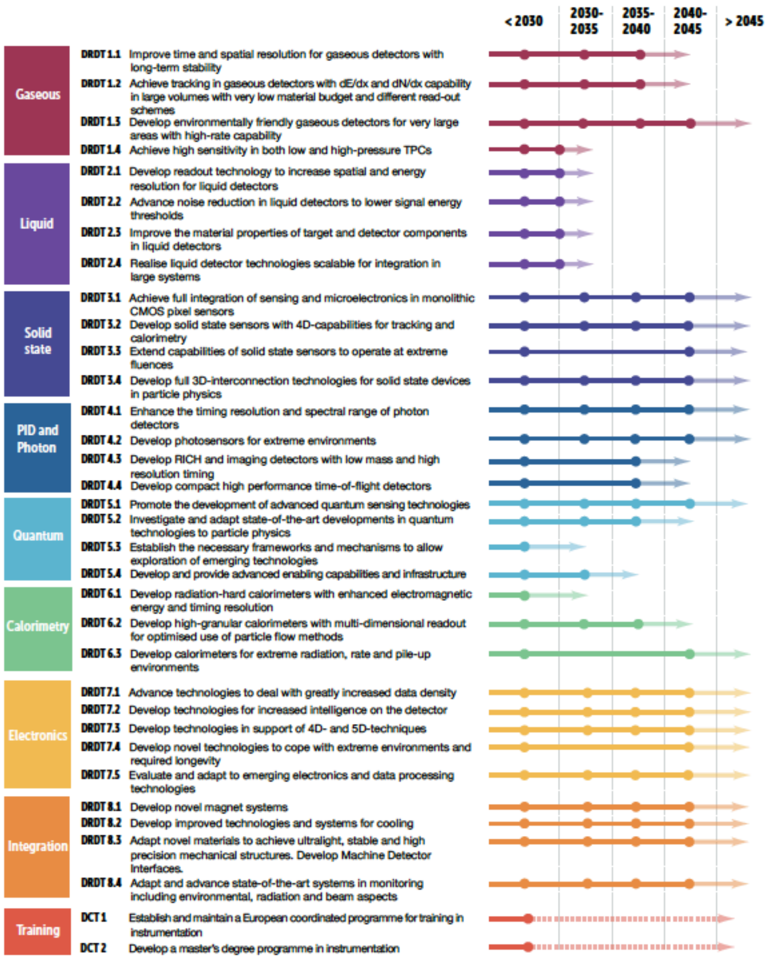
- In addition to the Detector R&D Themes **General Strategic Recommendations** are made

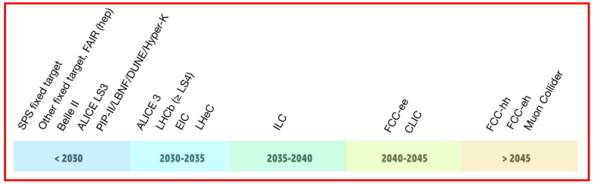
Detector R&D Roadmap: Example of Solid State Detectors (TF 3)



- 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.

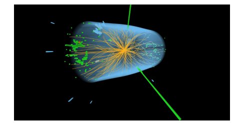
Give the area greater visibility and voice at a European level to make the case for the additional resources needed for Europe to maintain a leading role in particle physics with all the associated scientific and societal benefits that will flow from this.

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."

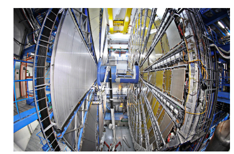
The field of particle physics builds on the major scientific revolutions of the 20th century, particularly on the experimental discoveries and theoretical developments which culminated in the Nobel Prize-winning discovery of the Higgs boson at CERN in 2012. The ambitions for the field going forward are 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.



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

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.

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)



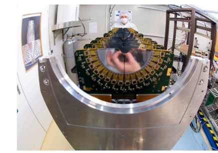
ATLAS gas detector based muon spectrometer, which covers a total area the size of a football field and measures the paths of the muons that pass through it to an accuracy of better than a tenth of a millimetre. (© CERN)

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."

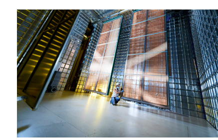


Vertex Locator (VELO) of the LHCb experiment allowing short lived particle lifetimes to be measured with precision of a twentieth of a picosecond. (© CERN)

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)

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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/
- Aim to get "sign-off" by SPC and Council in Sept. 2022 meetings

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

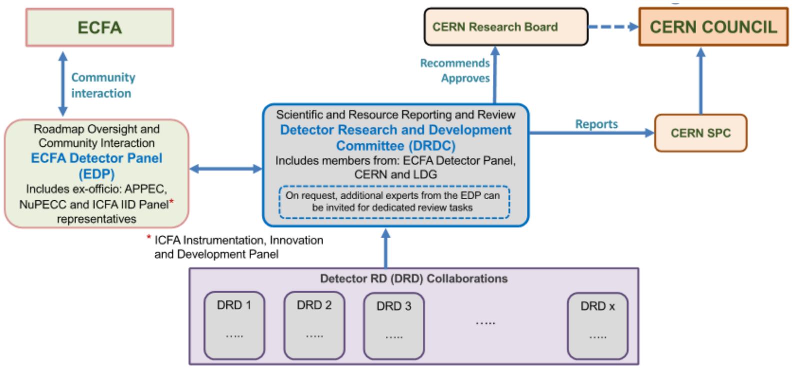
- **Taking full account of existing, well-managed and successful ongoing R&D collaborations and other existing activities**
  (RD50, RD51, …, CERN EP R&D programme, EU-funded initiatives, collaborations exploring particular technology areas for future colliders)

- 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

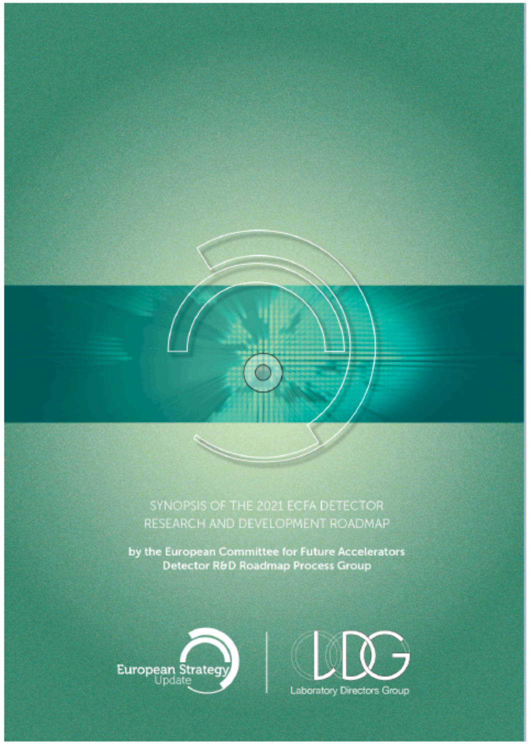
2. Funding Agency involvement via a dedicated Resources Review Board (~once every two years)

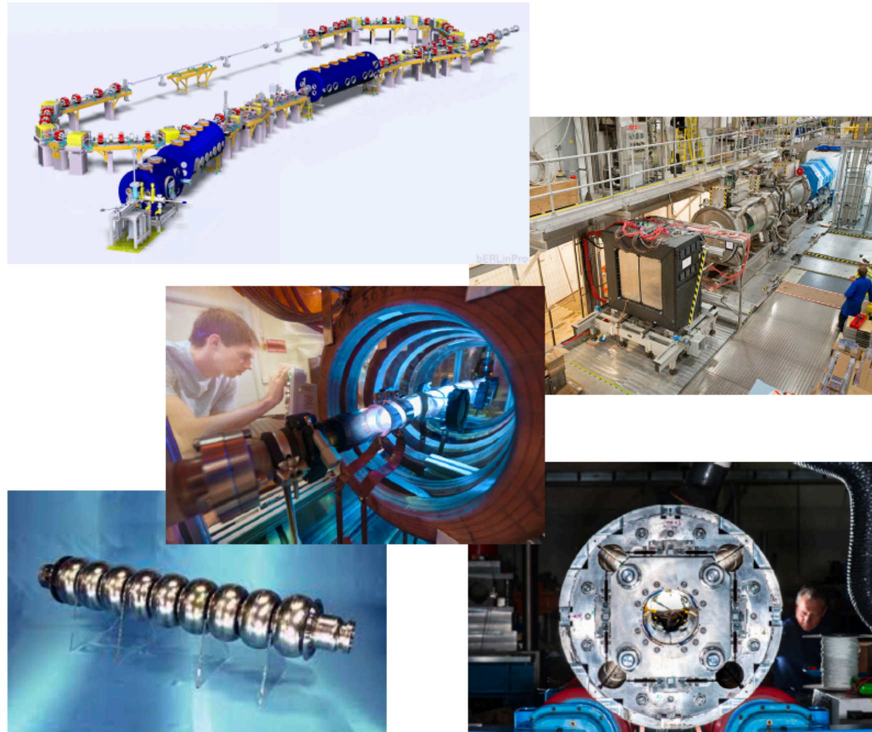
3. Yearly follow-up by DRDC → report to SPC → Council

- 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

II. Accelerator R&D Roadmap





https://arxiv.org/abs/2201.07895

Update of the European Strategy for Particle Physics (cont.)

B. Innovative accelerator technology underpins the physics reach of high-energy and high-intensity colliders. It is It is also a powerful driver for many accelerator-based fields of science and industry. The technologies under consideration include **high-field magnets, high-temperature superconductors, plasma wakefield acceleration and other high-gradient accelerating structures, bright muon beams, energy recovery linacs.**

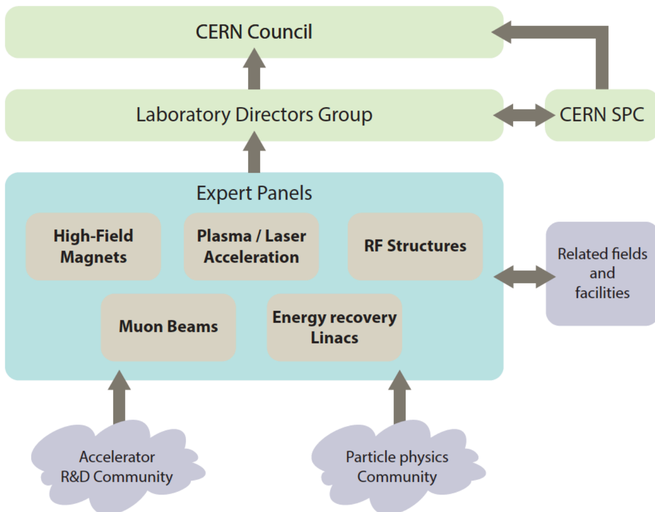
The European particle physics community must intensify accelerator R&D and sustain it with adequate resources. A roadmap should prioritise the technology, taking into account synergies with international partners and other communities such as photon and neutron sources, fusion energy and industry. Deliverables for this decade should be defined in a timely fashion and coordinated among CERN and national laboratories and institutes.

Lab Directory Group (LDG) has been mandated to develop this roadmap

LDG: European "Lab Directors Group" (10 labs)
- CERN, CIEMAT, DESY, IRFU, IJCLab, Nikhef, LNF, LNGS, PSI, STFC-RAL
- Lab-to-lab communications with a view to address together the ESPP issues
- Current chairperson: Dave Newbold (STFC-RAL)

Deliberation Document:
" … This roadmap should be established as soon as possible in close coordination between the National Laboratories and CERN."

The Accelerator R&D Roadmap Process



Work of panels was to answer key questions

(first in outline, followed by a plan to get answers at the next ESPPU)

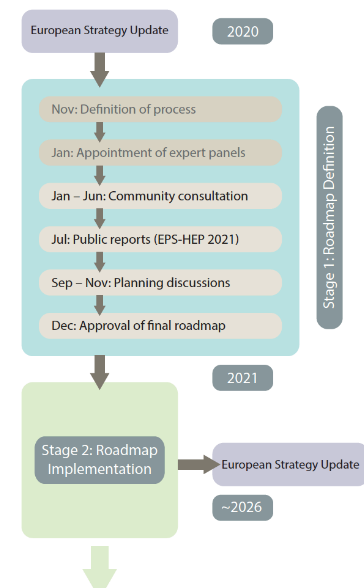
- *What R&D remains to be done towards future facilities?*
- *What are the priorities?*
- *How long might it take?*
- *How much will it cost?*
- *What different options and trade-offs exist?*
- *What are the dependencies or conflicts between activities?*

Expert panel chairs

Magnets: P. Vedrine (IRFU)
Plasma: R. Assmann (DESY)
RF: S. Bousson (IJCLab)
Muons: D. Schulte (CERN)
ERL: M. Klein (Liverpool)

Goal: provide the evidence allowing future decision-making by the field

(focus on the first five to ten years and the next two strategy updates)



The Accelerator R&D Roadmap Process

Planning:

- The scale of resources across accelerator R&D areas varies substantially
- Some areas are “mature”, some are just ramping up now
- Panels were asked to consider three potential resource scenarios
    - *Nominal: what can be done with today’s rate of investment?*
    - *Minimal: What is required at a minimum to keep the R&D in play?*
    - *Aspirational: how fast could one go with additional investments?*

Breakdown of the work into R&D tasks:

- Each with a well-defined scope, duration and cost (similar to the Detector R&D Themes)
- Could form the basis of future prioritisation and planning

However, no recommendations for overall funding level or priorities given

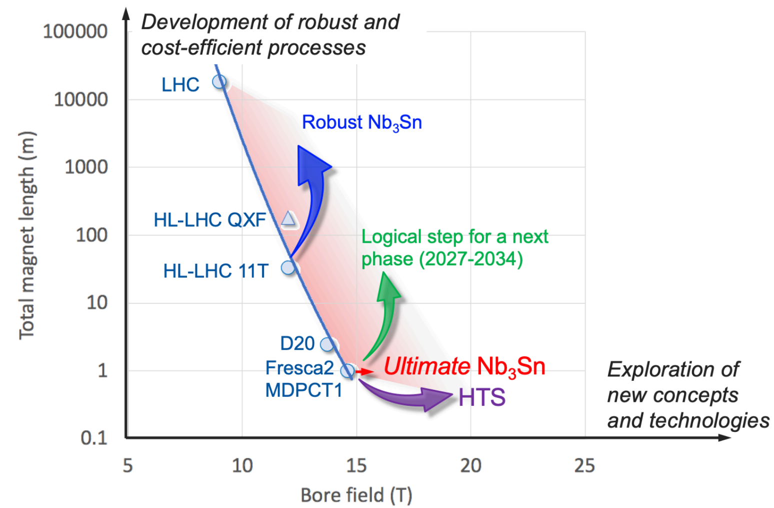
LDG: Judgement can only be made taking into account all the other tasks ahead of us;
Top-down roadmap must be matched by bottom-up commitments

High-field Superconducting Magnets

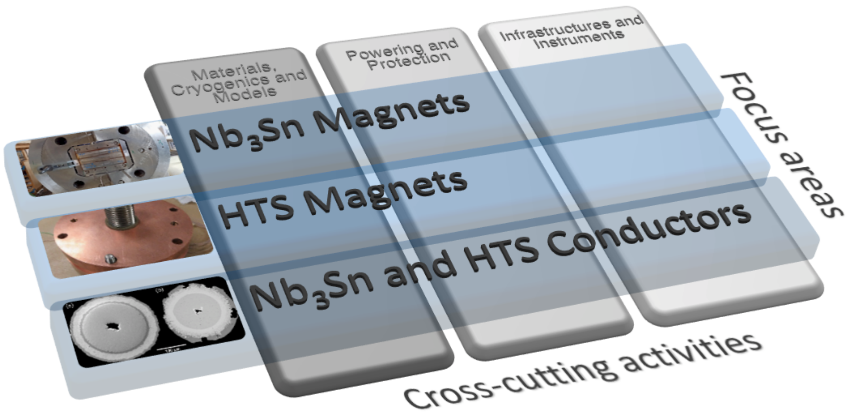
- Key technology for future accelerators (hadron colliders, muon colliders, neutrino beams, …)
- To reach the required field strength of 16 – 20 T for FCC_hh, new technologies have to be **established and brought into industrial production**
  (Present candidates: Nb_3Sn and High-Temperature Superconductors (HTS), …)

Accelerator Roadmap:

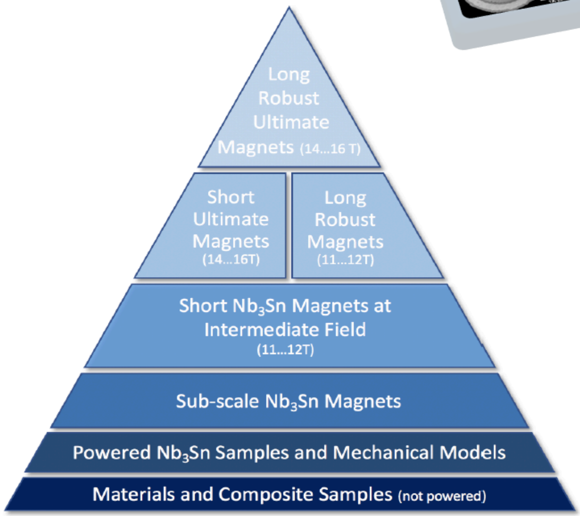
- Encompass Nb_3Sn and HTS (REBCO) developments
  - Demonstrate Nb_3Sn magnet technology for large-scale deployment
  - Demonstrate the suitability of HTS for accelerator magnet applications
- "Vertically integrated" approach to R&D
  - Development of all aspects from conductors to cables to magnets to systems
  - Emphases: full system optimisation, fast turnaround for R&D, modelling

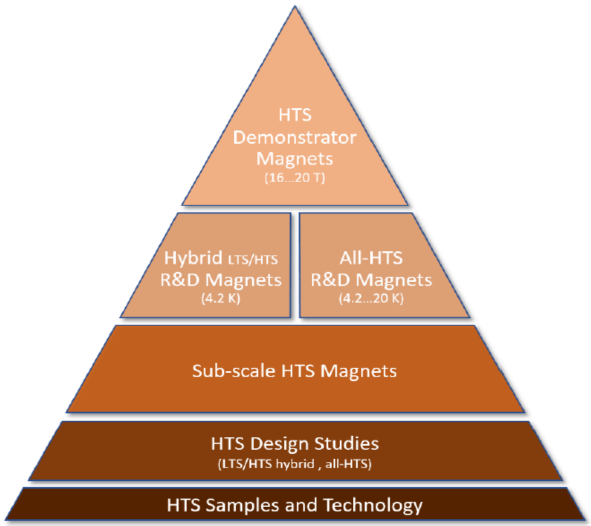


High-field Superconducting Magnets

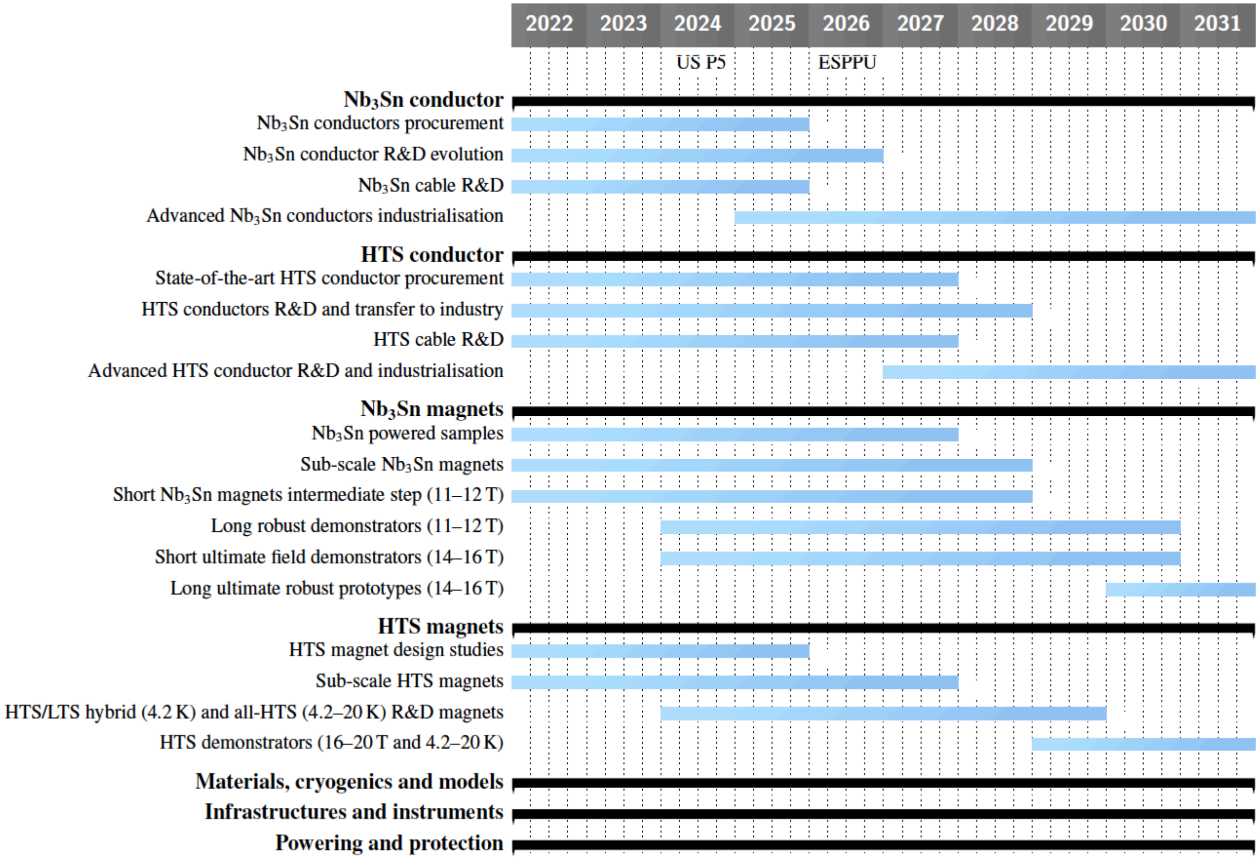


Schematic representations of the structure of the proposed programme and innovation/technology pyramids





High-field Superconducting Magnets



Indicative timeline of High-Field Magnet R&D activities

High-gradient Radio Frequency (RF) structures

- The next generation of particle accelerators will likely still be based on RF technology, however, with more challenging operational parameters → RF R&D programme needed

- Scope of the Roadmap programme covers:
  - Superconducting RF
  - Normal conducting RF
  - Ancillary systems (RF sources, couplers, tuners, control systems)

- Main objectives:
  - Efficiency and optimisation of the system (energy consumption)
  - Efficient industrialisation for assembly and tuning
  - Diagnostics and rapid feedback mechanisms
  - Development of sources, material and structures for new wavebands

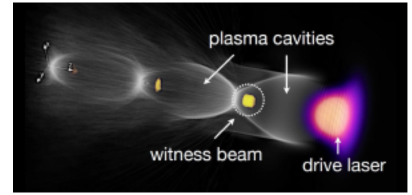
- Significant overlap between the R&D required for energy-recovery linacs (ERLs) and muon colliders
  → synergies should be used

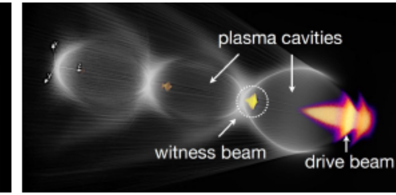
Tasks	Begin	End	Description
RF.SRF.BKNb	2022	2026	Superconducting RF: bulk Nb
RF.SRF.FE	2022	2026	Superconducting RF: field emission
RF.SRF.ThF	2022	2026	Superconducting RF: thin film
RF.SRF.INF	2022	2026	Superconducting RF: infrastructure
RF.SRF.FPC	2022	2026	Superconducting RF: power couplers
RF.SRF			**Total of superconducting RF**
RF.NC.GEN	2022	2026	Normal conducting RF: general NC studies
RF.NC.MAN	2022	2026	Normal conducting RF: NC manufacturing techniques
RF.NC.HF	2022	2026	Normal conducting RF: mm wave & high frequency
RF.NC			**Total of normal conducting RF**
RF.HP.HE	2022	2026	High-power RF: high-efficiency klystron & solid state
RF.HP.HF	2022	2026	High-power RF: mm-wave & gyro devices
RF.HP.TUN	2022	2026	High-power RF: reduced RF power needs (tuners)
RF.HP.AI	2022	2026	AI and machine learning
RF.HP			**Total of high-power RF**
RF.TS.NCRF	2022	2026	NC RF test stands
RF.TS.MAT	2022	2026	Test stand: new materials
RF.TS.BEAM	2022	2026	Beam test
RF.TS.SRF	2022	2026	Test stand: SRF Horizontal cryostat
RF.TS			**Total for test stand**

Research tasks for RF structures

High-gradient Plasma and Laser Acceleration

- Novel high-gradient accelerators have demonstrated acceleration of electrons and positrons with E-field strength of 1 to >100 GeV/m

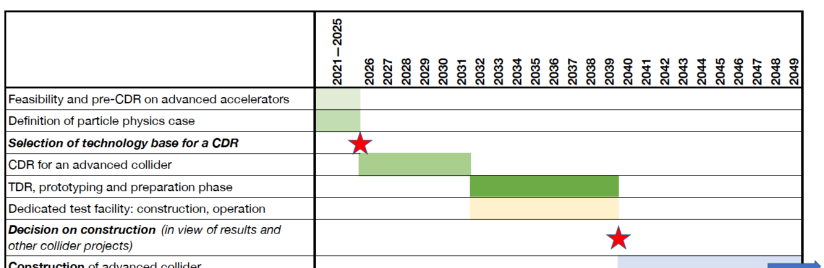


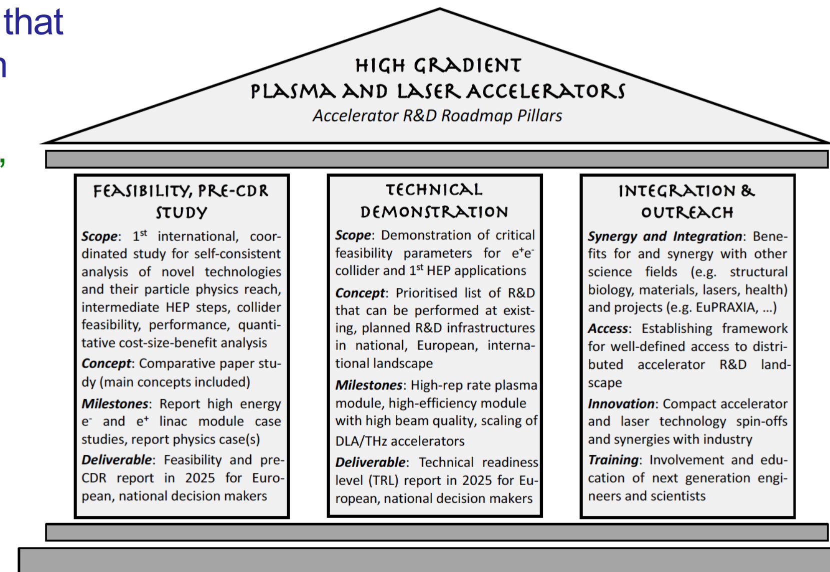


- Potential for significant reduction is size and, perhaps, cost of future accelerators, however, feasibility of a collider based on plasma acceleration remains to be proven
  Key challenges: acceleration of bunch charge sufficient to reach high luminosity, emittance preservation, staged designs of multiple structures

- Panel proposes a plasma and laser accelerator R&D roadmap that should be implemented and delivered in a three pillar approach

  By next strategy: A feasibility and pre-conceptual design report, i.e. evaluate the potential and performance reach for colliders, plus four experimental demonstrations



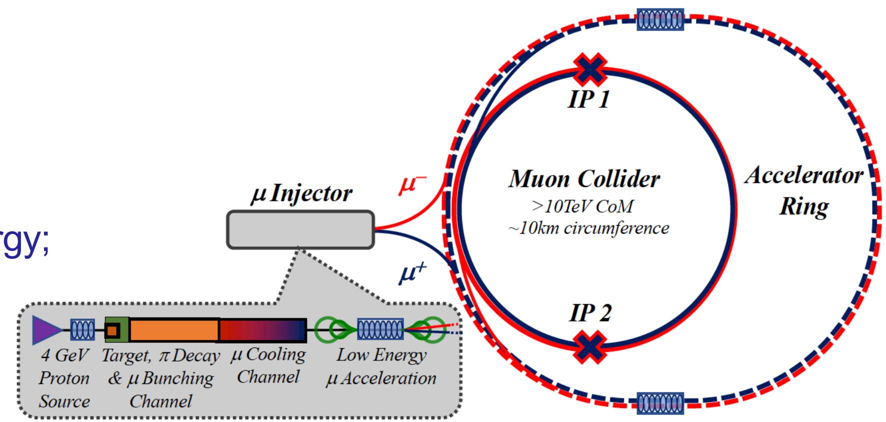


Muon Collider

- Potentially interesting path to realise high-energy lepton colliders, however, the muon-collider technology must overcome several significant challenges

- Advantages: - luminosity / beam power improves with energy;
  - compact collider

- Challenges: muon brightness, ionisation cooling, neutrino radiation, magnets & RF, machine detector interface, beam background…



Significant progress over the past years, but still a lot to demonstrate

- **Roadmap Objectives**: again focussed on the "plausibility case"

  → Examine the key technical barriers and cost drivers before the next strategy update

  → Planning towards a muon beam demonstrator

Energy-Recovery Linacs (ERL)

- Basic idea: recycling the kinetic energy of a used beam for accelerating a newly injected beam
  → reduced power consumption, high injector brightness, beam dump at injection energy

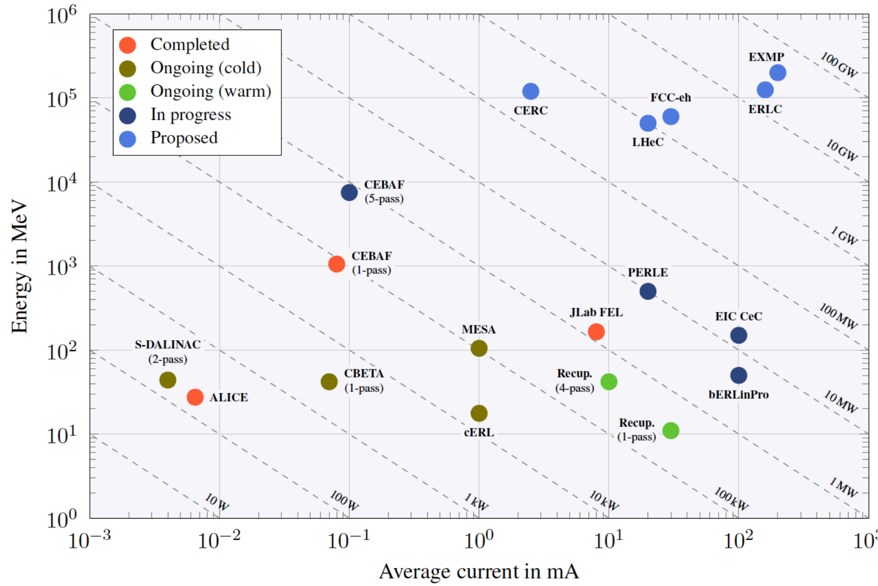
- Fundamental principles or ERLs have been successfully demonstrated worldwide during the past decades

- **Roadmap Objectives:**

  - Support and exploit the ongoing facility programmes

  - Focussed technical R&D into key technologies
    (high-current electron sources, high-power superconducting RF technology, …)

  - Development or upgrade of European facilities for the mid-2020s

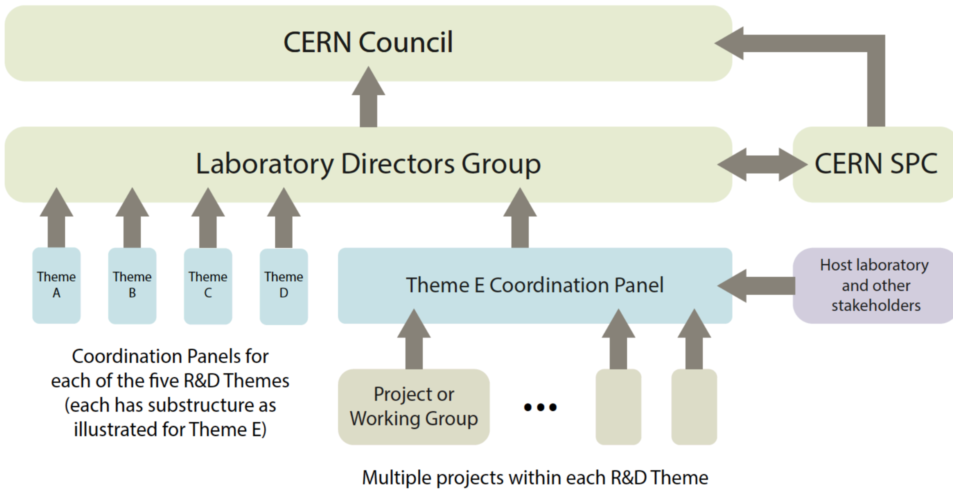


This programme is relevant to both absolute performance and sustainability of future machine

General Recommendations (Accelerator Roadmap)

1. The Roadmap is the **consensus view of the community** (but many detailed planning decisions yet to come)
2. Governance structures should be put in place, spanning the R&D programmes;
   CERN Council is the ultimate decision-making body
3. Maintain a broad front → at least the minimal programme in each area
4. Retain the capability for blue skies R&D
5. Continuity of funding is more important than maximal funding
6. Sustainability is now a driving factor; plan in light of this
7. Early science output (and impact) from the R&D is highly desirable
8. Need to work with industry closely, and in ways that they can accommodate
9. Close and organised cooperation between major labs internationally is needed to facilitate the programme
10. Trained people are the lifeblood and future of the field – ensure the supply

Implementation: Coordination Structure of the Accelerator R&D



For more details, see talk by
Dave Newbold at July Plenary ECFA:

https://indico.cern.ch/event/1172215/

- Intended to be light-weight, causing minimal disruption / delay to existing R&D projects
- Must provide a coherent route for a community-driven planning in “ramping-up” areas
- Coordination panels now have leadership in all cases; formed with a view to setting down the initial R&D plans by the end of the year.

Coordination panel chairs

Magnets: M. Lamont (CERN), P. Vedrine (IRFU)
Plasma: W. Leemans (DESY), Rajeev Patahill (RAL)
RF: G. Bisoffi (INFN-LNL), t.b.d.
Muons: S. Stapnes (Oslo), D. Schulte (CERN)
ERL: J. D’Hondt (Brussels), M. Klein (Liverpool)

Summary

- The Detector and Accelerator R&D Roadmaps have been prepared by large teams of internationally recognised leaders in the respective areas with access to a much wider pool of other instrumentation experts

  Detector Roadmap: https://cds.cern.ch/record/2784893
  Accelerator Roadmap: https://arxiv.org/abs/2201.07895

- They are based on wide community consultations with very broad participation

- In the Dec. 2021 CERN Council session ECFA and LDG were mandated to work out implementation plans

- Work is converging, hope to get endorsement of the SPC and CERN Council in September

- Next ECFA tasks: work on implementation of other General Strategic Recommendations;
  Work has started, for some items close collaborations with Lab Director Group is needed

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

- Status of Working Group activities
- Discussion of future plans
- Interaction between theory and experiments
- "Public Talk" on importance of future e^+e^- collider / new era
  Speaker: Hitoshi Murayama
  + panel discussion
  (involving Fabiola Gianotti, ..)

Registration is open!

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

Broad participation is highly welcome!

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

European Committee for Future Accelerators

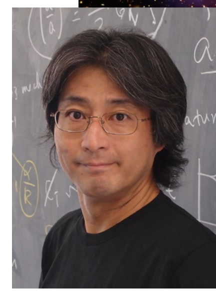
Does the World need a new particle collider – and why?

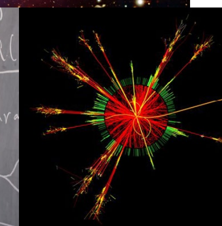
Public talk and round table discussion

The Higgs boson: particle superhero and tour guide to new particles

The Higgs boson, discovered at the world's largest particle collider LHC ten years ago, is a very special particle. We need to study it in great detail to answer key questions of physics. The Higgs boson may have been a superhero that saved us from complete annihilation and it can be the portal to a new world of particles with possible links to dark matter and dark energy.

This lecture by the Japanese-American scientist Hitoshi Murayama is aimed at the general public. Murayama discusses the fascinating exploration of a future particle physics era with the help of a new collider. It is followed by a round-table discussion about the need for a new collider, the discoveries that could be made and the different options that are on the table. Panelists include the renowned physicists J. Butterworth (U. College London), F. Canelli (U. of Zurich), F. Gianotti (CERN), B. Heinemann (DESY), K. Jakobs (U. of Freiburg), H. Murayama (UC Berkeley and IPMU) and J. Thaler (MIT).





Prof. Dr. Hitoshi Murayama

- **Berkeley Center for Theoretical Physics**
  University of California, USA
- **Lawrence Berkeley National Laboratory**
  Berkeley, USA
- **Kavli IPMU, University of Tokyo**
  Kashiwa, Japan

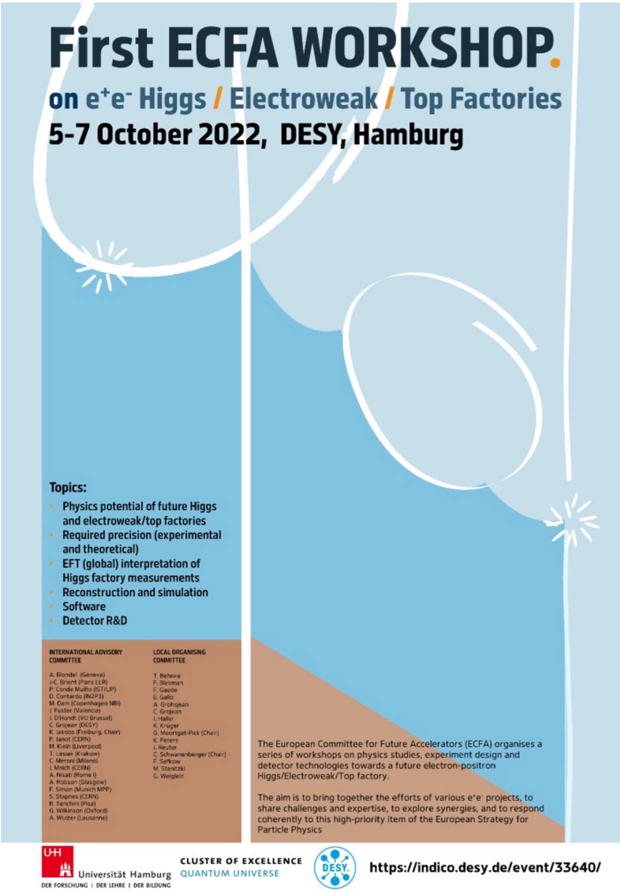
October 6, 19:30 h
DESY main auditorium
https://desy.de/youtube

Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

CLUSTER OF EXCELLENCE
QUANTUM UNIVERSE

DESY.

Poster and Web page



Poster and web page: www.desy.de/ecfa2022

The 2022 meeting of the ECFA study on physics and experiments at e+e- Higgs/EW/Top Factories will take place in Hamburg at the **campus of the DESY laboratory** from **October 5 to 7, 2022**.

This meeting is intended to be an **in-person meeting**.

The registration fee is 165 € until **<u>September 15 2022</u>**, and 200 € thereafter.

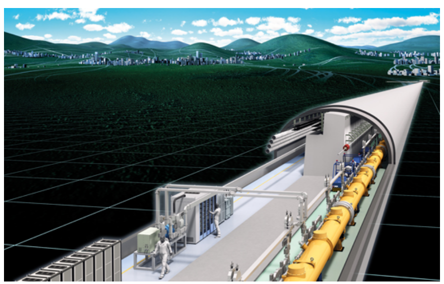
The central entry point of the ECFA study is accessible through this link.

Abstract submission is possible; talks (and posters) will be selected, in addition to those assigned by the conveners

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



CEPC

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.

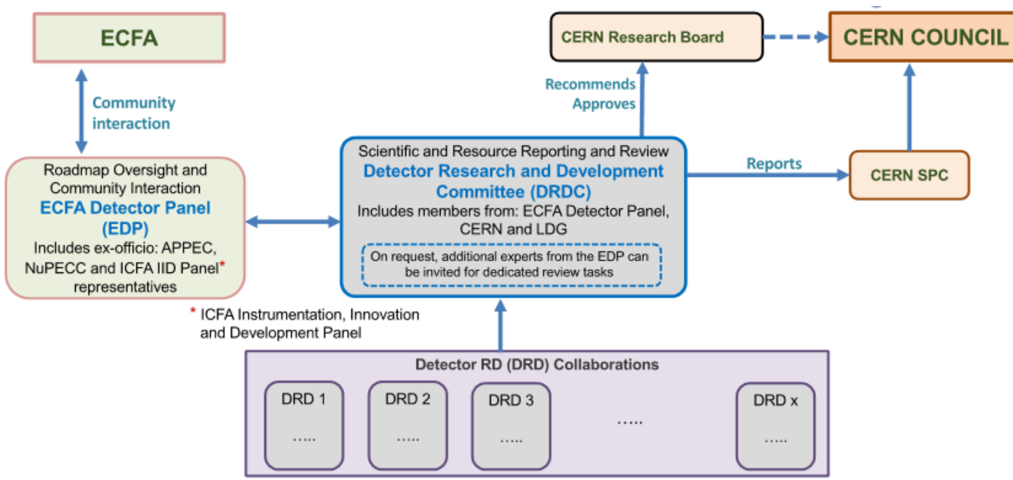
GSR 10 – Open Science

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.

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 Extended 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

Additional Comments

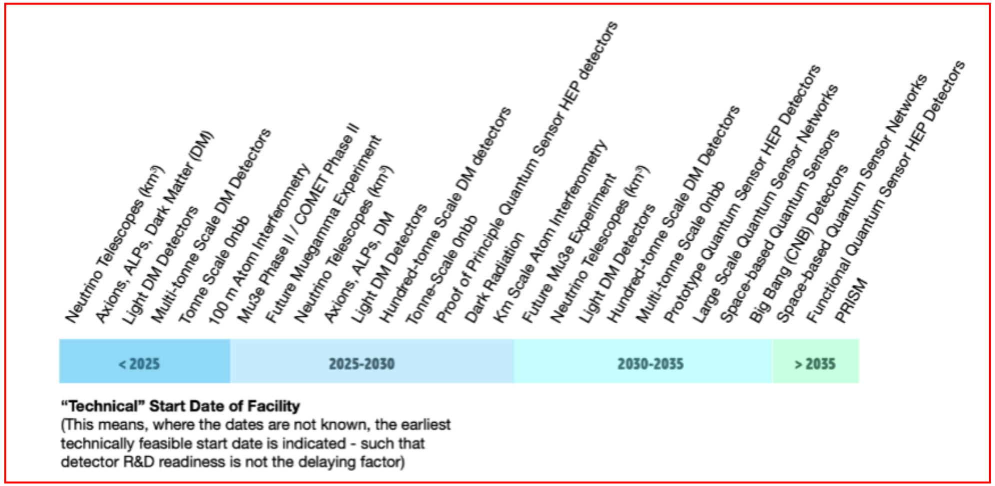
→ **Three areas of Detector R&D:**

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)

Timeline for representative* non-accelerator-based experiments



*Not intended to be an exhaustive list

- Focus has been on facilities targeting the properties and interactions of fundamental particles.

- It is noted that a number of particles increasingly play the role of cosmic messengers for phenomena happening far beyond our own galaxy which provides some of the exciting science opportunities in the neighbouring field of astroparticle physics, but the demanding detector requirements specific to this area are not generally within the scope

Indicative cost of the Accelerator R&D programme