

R&D Physique des particules (DRD)

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- Contexte
- ECFA Détecteurs R&D Roadmap
- Projets DRD
- Timescale

Inputs

- FCC week, Londres, 06/2023
- FCC physics workshop, Cracow, 01/2023
- Plenary ECFA, CERN, 11/2022
- 2nd DRD Calorimetry community meeting, CERN, 04/2023

Historique

- Réunion orientée vers projets physique des particules (ECFA)
 - En particulier collisionneurs mais pas seulement (voir plus loin)
- Plusieurs discussions au Labo sur les futurs projets R&D
 - Biennale 2022
 - Table ronde projets R&D : Petit embarqué, mécanique, Silicium pour accélérateurs, IA
 - Projet FCC : Implication souhaitée dans calorimeter électromagnétique argon liquide
 - Réunion 'Prospectives techniques' (03/2023)
 - Réunions du vendredi
 - Projet FCC avec discussion sur faisabilité CALICE/Argon liquide
- En parallèle, montée en puissance des projets DRD (ECFA)
 - Discussions en Réunions de Coordination
- -> Discussion (Marco, Didier, LP)
 - Suggestion d'organiser $\frac{1}{2}$ journée d'information sur futurs projets R&D

ECFA R&D Roadmap CERN-ESU-017 (12/2021)

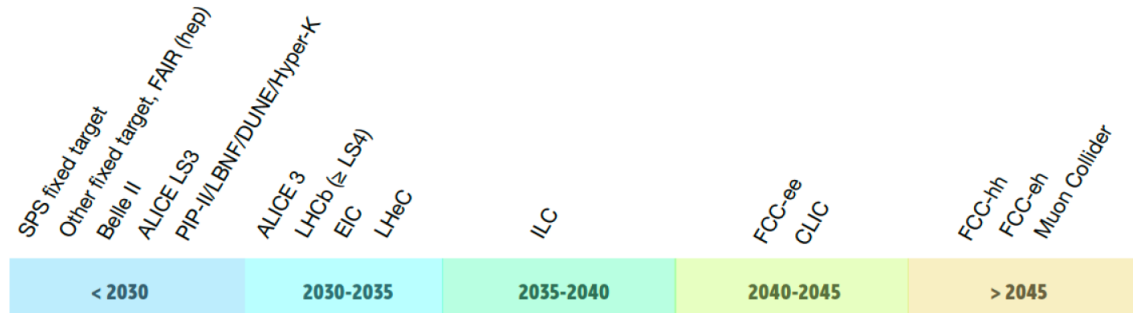
Moteur : Stratégie Européenne pour la Physique des Particules (2020)

physics programme in the near and long term”. The particle physics programme mentioned here is taken to consist of the projects listed in the Deliberation Document of the European Particle Physics Strategy Update (EPPSU) [Ch0-2] as either “*High-priority future initiatives*” or “*Other essential scientific activities for particle physics*”. The dif-

Mot-clé : Particules fondamentales

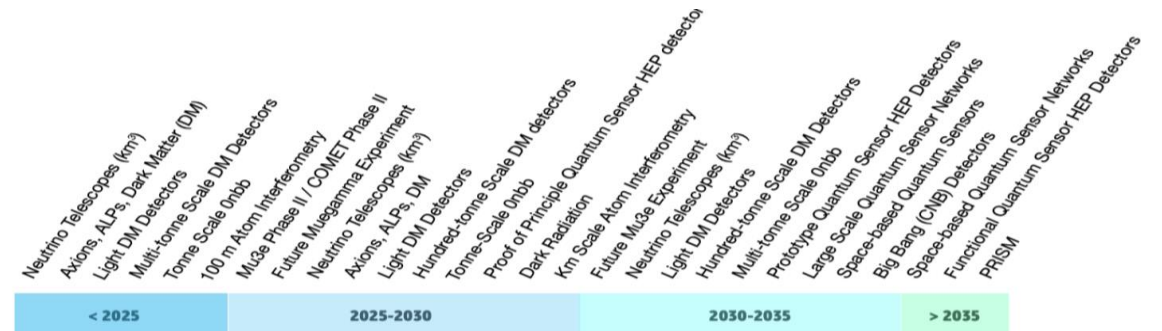
In the ECFA Detector R&D Roadmap the focus has been on facilities targeting the properties and interactions of fundamental particles (including those that are undiscovered but theoretically motivated). It is appreciated that a number of particles increas-

Facilités : Grands accélérateurs / Petits accélérateurs / Non-Acc



- Detector improvements required for full exploitation of the HL-LHC (R&D still needed for the next LHC Long Shutdown, LS3, upgrades and for experiment upgrades beyond then) including studies of flavour physics and quark-gluon plasma (where the latter topic also interfaces with nuclear physics);
- R&D for long baseline neutrino detectors (including aspects targeting astro-particle physics measurements) and supporting projects such as those at the CERN Neutrino Platform;
- Technology developments needed for detectors at e^+e^- Higgs-EW-Top factories in all possible accelerator manifestations including instantaneous luminosities at 91.2 GeV of up to $5 \times 10^{36} \text{ cm}^{-2} \text{ s}^{-1}$ and energies up to the TeV range;
- The long-term R&D programme for detectors at a future 100 TeV hadron collider with integrated luminosities targeted up to 30 ab^{-1} and 1000 multiple interactions for 25 ns bunch crossing interval;
- Specific long-term detector technology R&D requirements of a muon collider operating at 10 TeV and with a luminosity of the order of $10^{35} \text{ cm}^{-2} \text{ s}^{-1}$;
- Detector developments for accelerator-based studies of rare processes, DM candidates and high precision measurements (including strong interaction physics) at both storage rings and fixed target facilities, interfacing also with atomic and nuclear physics;
- R&D for optimal exploitation of dedicated collider experiments studying the partonic structure of the proton and nuclei as well as interface areas with nuclear physics;
- The very broad detector R&D areas for non-accelerator-based experiments, including dark matter searches (including axion searches), reactor neutrino experiments and rare decay processes, also considering neutrino observatories and other interface areas with astro-particle physics.

Axes R&D



Organisation projets DRD : Tracks

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Gaseous	<p>DRDT 1.1 Improve time and spatial resolution for gaseous detectors with long-term stability</p> <p>DRDT 1.2 Achieve tracking in gaseous detectors with dE/dx and dN/dx capability in large volumes with very low material budget and different read-out schemes</p> <p>DRDT 1.3 Develop environmentally friendly gaseous detectors for very large areas with high-rate capability</p> <p>DRDT 1.4 Achieve high sensitivity in both low and high-pressure TPCs</p>
Liquid	<p>DRDT 2.1 Develop readout technology to increase spatial and energy resolution for liquid detectors</p> <p>DRDT 2.2 Advance noise reduction in liquid detectors to lower signal energy thresholds</p> <p>DRDT 2.3 Improve the material properties of target and detector components in liquid detectors</p> <p>DRDT 2.4 Realise liquid detector technologies scalable for integration in large systems</p>
Solid state	<p>DRDT 3.1 Achieve full integration of sensing and microelectronics in monolithic CMOS pixel sensors</p> <p>DRDT 3.2 Develop solid state sensors with 4D-capabilities for tracking and calorimetry</p> <p>DRDT 3.3 Extend capabilities of solid state sensors to operate at extreme fluences</p> <p>DRDT 3.4 Develop full 3D-interconnection technologies for solid state devices in particle physics</p>
PID and Photon	<p>DRDT 4.1 Enhance the timing resolution and spectral range of photon detectors</p> <p>DRDT 4.2 Develop photosensors for extreme environments</p> <p>DRDT 4.3 Develop RICH and imaging detectors with low mass and high resolution timing</p> <p>DRDT 4.4 Develop compact high performance time-of-flight detectors</p>
Quantum	<p>DRDT 5.1 Promote the development of advanced quantum sensing technologies</p> <p>DRDT 5.2 Investigate and adapt state-of-the-art developments in quantum technologies to particle physics</p> <p>DRDT 5.3 Establish the necessary frameworks and mechanisms to allow exploration of emerging technologies</p> <p>DRDT 5.4 Develop and provide advanced enabling capabilities and infrastructure</p>

Talk Luca

Talk Giovanni

- The most urgent R&D topics in each Task Force area are identified as **Detector R&D Themes**.
- The **timeframe illustration for requirements in each DRDT area, in both the brochure and the main document, are based on the more detailed information and charts in the individual chapters.**

Calorimetry	<p>DRDT 6.1 Develop radiation-hard calorimeters with enhanced electromagnetic energy and timing resolution</p> <p>DRDT 6.2 Develop high-granular calorimeters with multi-dimensional readout for optimised use of particle flow methods</p> <p>DRDT 6.3 Develop calorimeters for extreme radiation, rate and pile-up environments</p>
Electronics	<p>DRDT 7.1 Advance technologies to deal with greatly increased data density</p> <p>DRDT 7.2 Develop technologies for increased intelligence on the detector</p> <p>DRDT 7.3 Develop technologies in support of 4D- and 5D-techniques</p> <p>DRDT 7.4 Develop novel technologies to cope with extreme environments and required longevity</p> <p>DRDT 7.5 Evaluate and adapt to emerging electronics and data processing technologies</p>
Integration	<p>DRDT 8.1 Develop novel magnet systems</p> <p>DRDT 8.2 Develop improved technologies and systems for cooling</p> <p>DRDT 8.3 Adapt novel materials to achieve ultralight, stable and high precision mechanical structures. Develop Machine Detector Interfaces.</p> <p>DRDT 8.4 Adapt and advance state-of-the-art systems in monitoring including environmental, radiation and beam aspects</p>
Training	<p>DCT 1 Establish and maintain a European coordinated programme for training in instrumentation</p> <p>DCT 2 Develop a master's degree programme in instrumentation</p>

Talks Rémi, LP

Talk Francesco

Organisation projects DRD : Working Groups

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DRDs in a Nutshell

DRD1 - Gaseous Detectors

- **WG1** : technologies MPGDs, RPC, Wires, TPC, DCH
- **WG2** : applications (Muon systems, Inner & Central Tracking with PID, Calorimetry, Photo-detectors, Timing, TPC for rare event searches)
- **WG3** : gas and material studies
- **WG4** : modelling and simulation
- **WG5** : electronic
- **WG6** : production & technology transfer
- **WG7** : common test facilities
- **WG8** : knowledge transfer

Draft - June

DRD2 - Liquid Detectors

- **WG1** : charge readout
- **WG2** : light readout
- **WG3** : target properties

Draft - June

DRD3 - Solid State Detectors

- **WG1** : Monolithic CMOS sensors
- **WG2** : sensors for tracking and calorimetry (Hybrid, LGADs)
- **WG3** : radiation damage and ultrahigh fluence
- **WG4** : simulation
- **WG5** : characterization techniques, facilities
- **WG6** : non silicon based detectors
- **WG7** : Interconnect and device fabrication
- **WG8** : dissemination and outreach

Draft - June

DRD5 - Quantum and Emerging Technologies

- **WG1** : clocks, clock networks
- **WG2** : kinetic detector
- **WG3** : superconducting spin based sensors
- **WG4** : optomechanical sensors
- **WG5** : atoms, molecules, ions, interferometry
- **WG6** : meta materials 0-1-2D materials

DRD4 - Photon Detectors & PID

- **WG1** : photodetector (SiPM, SPADs, PMT/MCP-PMT, Gas)
- **WG2** : particle ID (RICH/DIRC/TOP,TORCH/ToF)
- **WG3** : technologies (radiators, optical elements, readout, cooling, software)
- **WG4** : emerging technologies (novel materials and concepts...)

Draft - June

September 1st community workshop
Final proposal January 2024

DRD6 - Calorimeters

- **WG1** : full integrated sampling calorimeters
- **WG2** : liquified Noble Gas calorimeters
- **WG3** : optical calorimeters
- **WG4** : transversal activities

Draft - June

DRD7 - Electronics

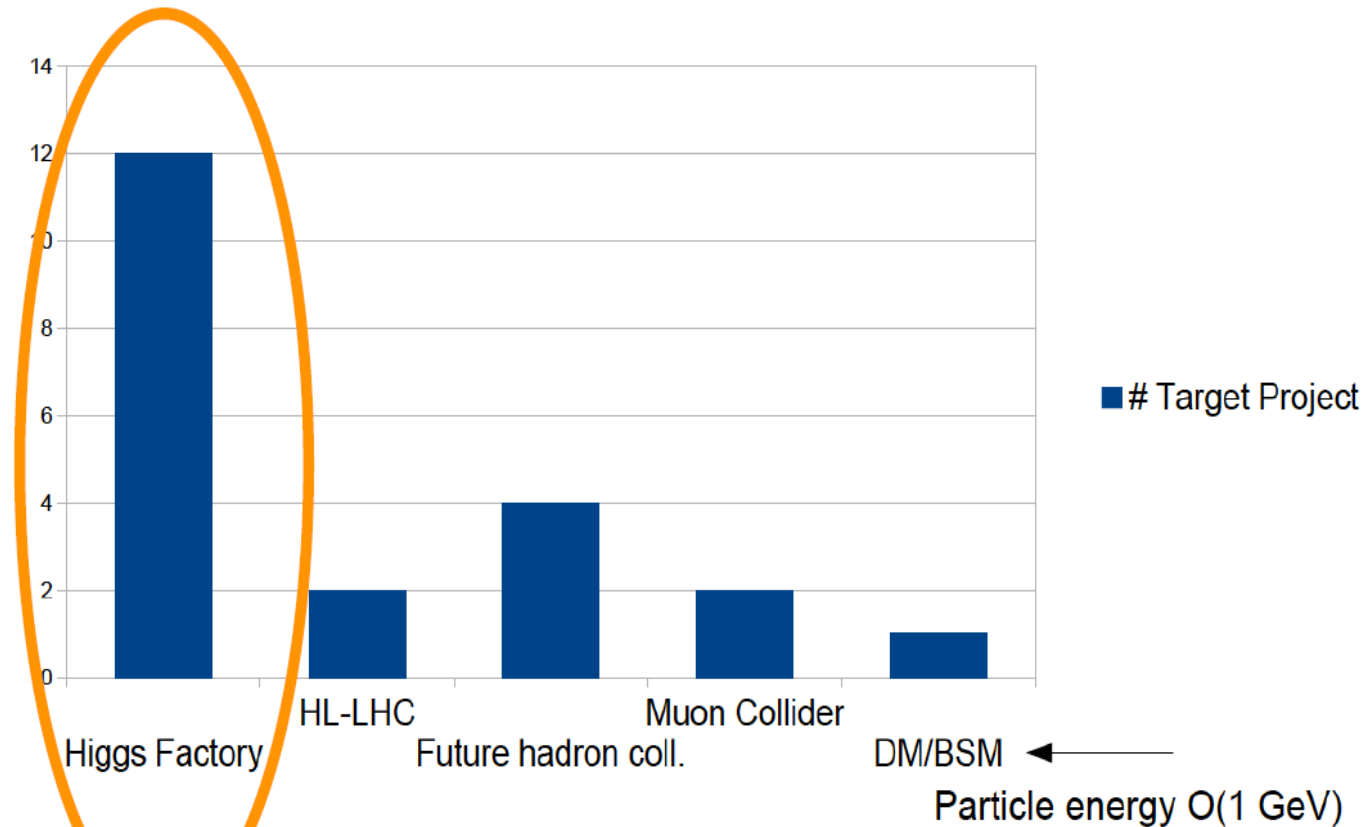
- **WG1** : data density and power efficiency
- **WG2** : intelligence on the detector
- **WG3** : 4D and 5D techniques
- **WG4** : extreme environments
- **WG5** : backend systems and cots
- **WG6** : complex imaging ASICs and technologies

Now collecting expressions of interest
September 2nd community workshop
Final proposal - December

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ECFA WG3: Topical Work... and Vertexing

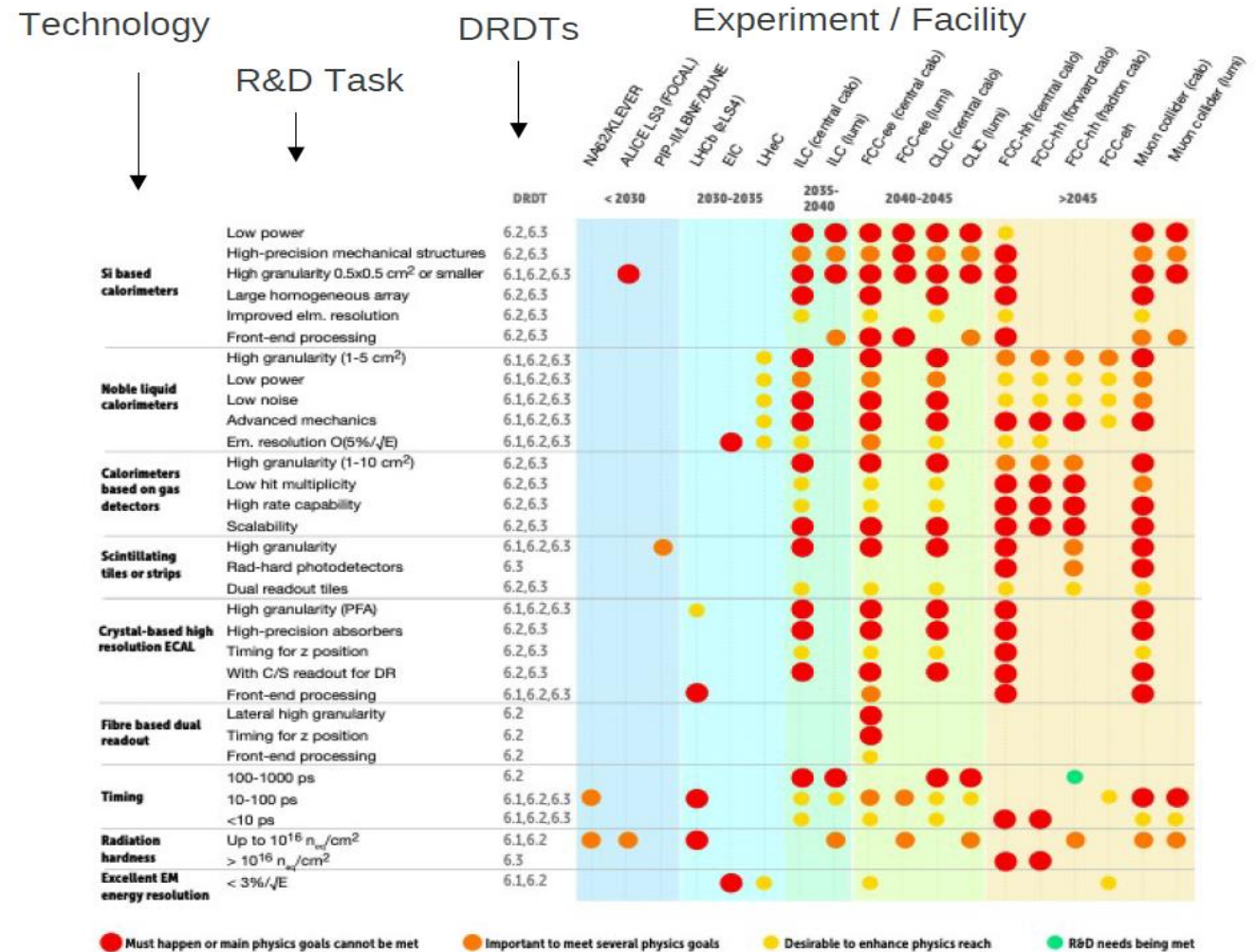
Projets futurs couverts par DRD (Exemple Calorimétrie DRD6)



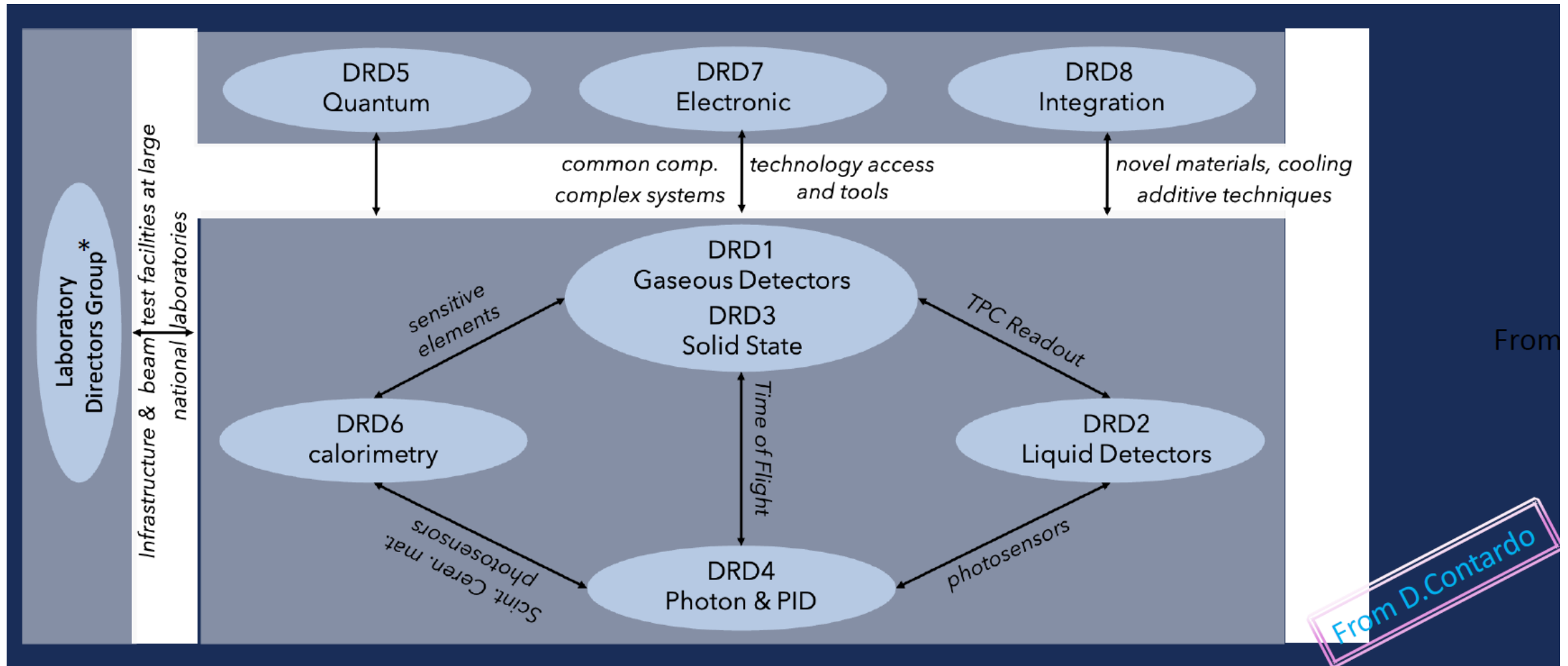
- En majorité, projets pour future usine à Higgs (FCC-ee, C3, ILC, CEPC)
- Aussi autres collisionneurs (FCC-hh, Muon Collider)
- Aussi Matière Noire/BSM

DRD : Tâches vs Projets (exemple Calorimétrie DRD6)

- Key technologies and requirements identified in roadmap
 - Si based calorimeters
 - Liquid Noble Gas calorimeters
 - Calorimeters based on gas detectors
 - Scintillating tiles and strips
 - Crystal based high-resolution ECal.s
 - Fibre-based dual readout
- R&D should in particular enable
 - Precision timing
 - Radiation hardness
 - High granularity
- R&D Tasks grouped into
 - Must happen
 - Important
 - Desirable
 - Already met



Interplay entre différents DRD (exemple DRD3/DRD1)



Detecteurs: R&D collaborations

RD1 SPACAL
RD3 LAr calo
RD50 Silicium
RD53 Silicium

Follow the successful model of R&D collaborations for the LHC

- funding in place since ~1986, R&D collaborations established in 1990
- Aim at **few large DRD collaborations**, to keep it manageable

Take full account of existing, successful and well managed R&D coll.

- Integrate with CERN EP R&D, AIDAInnova, RDxy, CALICE,...

Community-driven approach, supported by ECFA Roadmap Task Forces

- invite proposals, moderate process, timeline 1-2 years

Reasonably dimensioned review process (ECFA and CERN)

- addressing needs of future experiments is important criterion
- worldwide perspective

R&D Détecteurs: Revue & Approbation

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

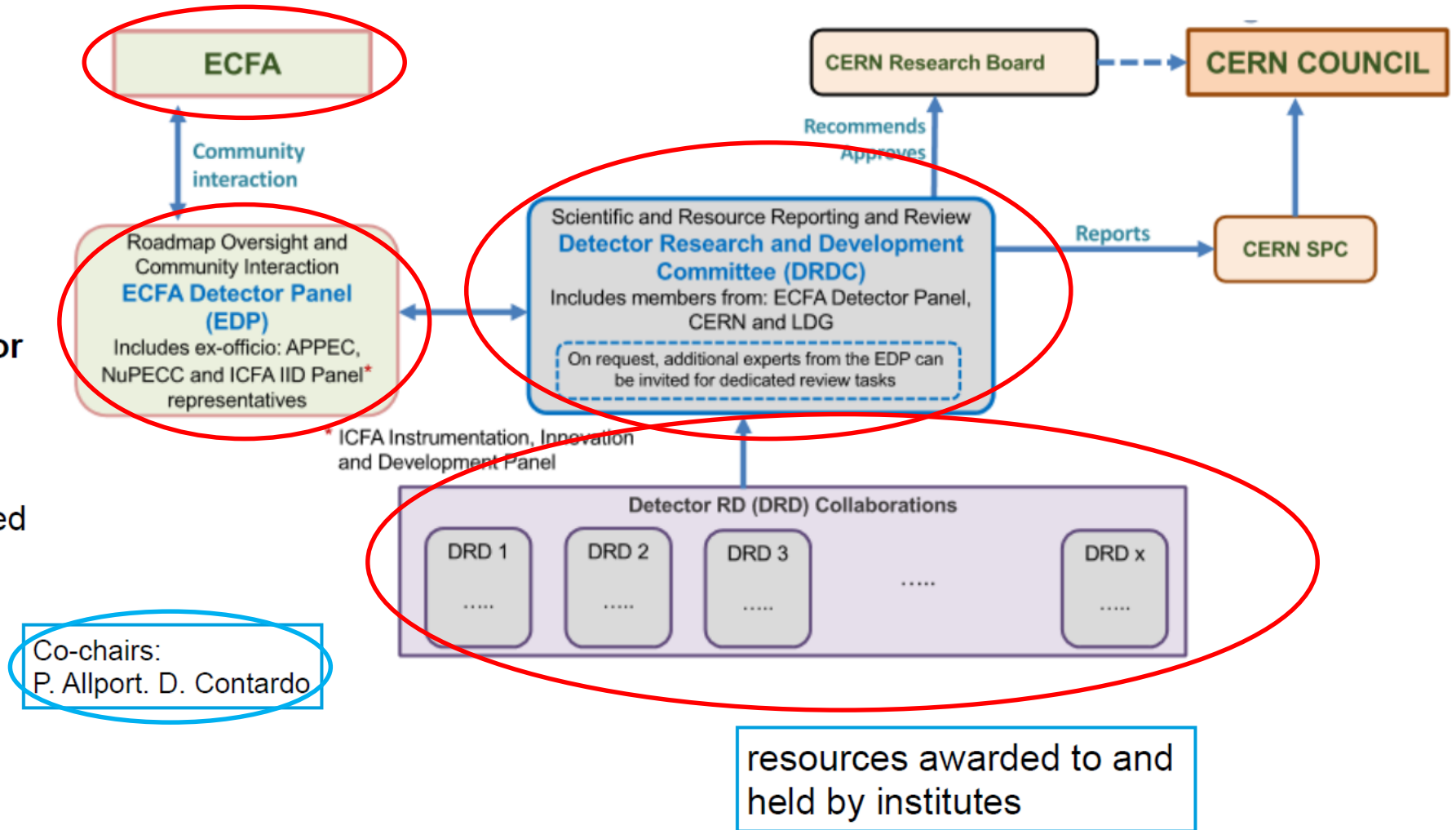
- yearly follow-up
- report via SPC to Council

Assisted by the ECFA Detector Panel (EDP):

- the scope, R&D goals, and milestones should be vetted against the vision encapsulated in the Roadmap.
- EDP exists, hosted at DESY: <http://cds.cern.ch/record/2211641/files/>

Funding Agency involvement via a dedicated Resources Review Board

- once every two years



R&D Détecteurs: Implementation timeline

Goal: Transition to new scheme during 2023

- approval of LHC-oriented RD50 (silicon), RD51 (gas detector) collaborations expires Dec 2023

Major Steps:

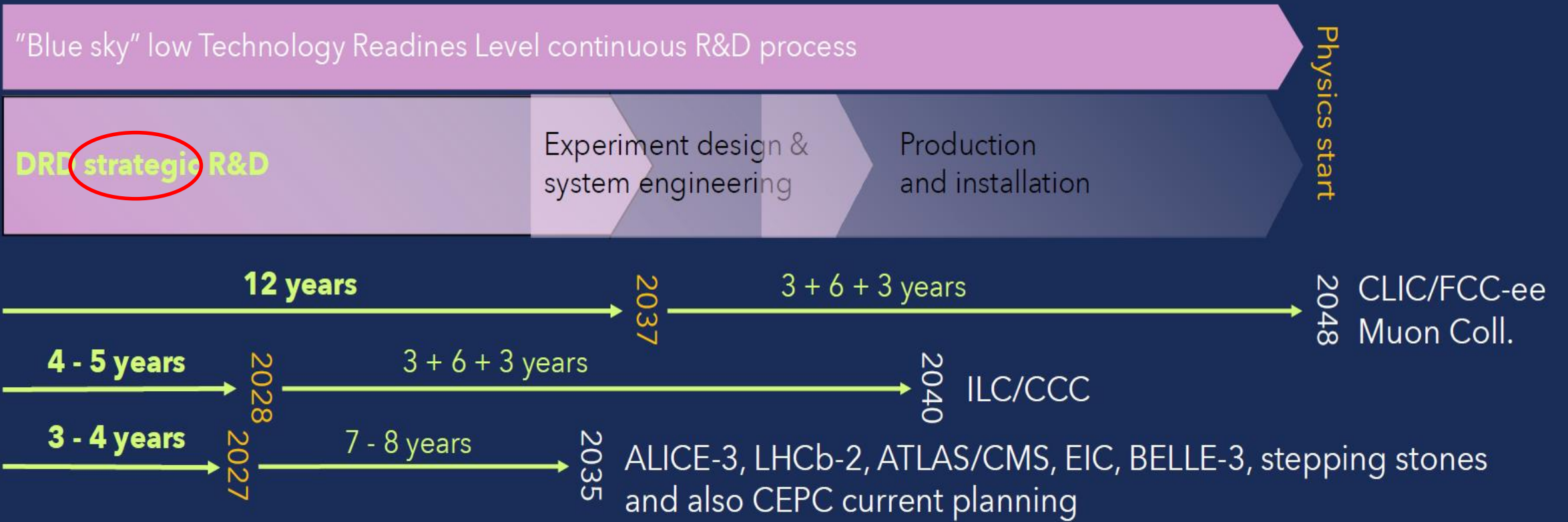
- **community input** (via existing R&D bodies where possible) by **Q1 2023**
 - To get involved, register at <https://indico.cern.ch/event/957057/page/27294-implementation-of-the-ecfa-detector-rd-roadmap>
- Work Package **structure** (Tasks, Participants, Resources, Deliverables, Milestones) by **spring 2023**
- In parallel, **DRDC** mandate and membership defined
- Written **proposals**, based on ECFA Detector Roadmap, by **mid 2023**
 - do not repeat roadmap; concrete plans, deliverables, resource-loaded (not a wish list) for **period 2024-2030**
 - aim at 20 pages per each of 9 the DRDs (or not much more)
- **Review** (by DRDC, assisted by EDP) in **fall 23**, approval by **end 2023**
- R&D collaborations **operational**, “Grant Agreements” (**MoU** signatures) through **2024**

Challenge

- funding not exactly known - but cost projections should be backed by Funding Agencies
- interaction with Agencies needed in parallel to proposal preparation

Futurs projets & Timescale DRD

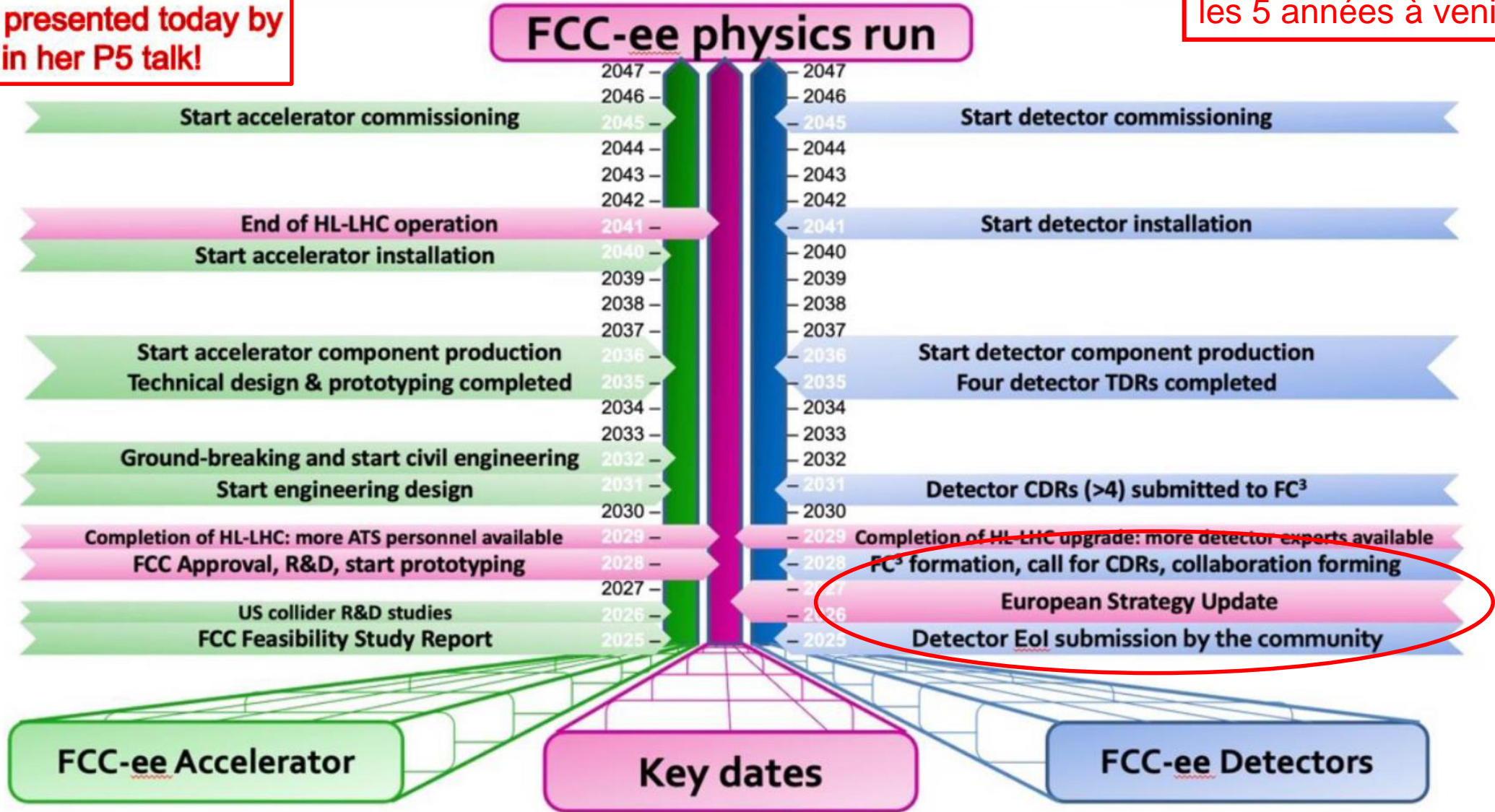
DRD collaborations active Jan. 2024



Timeline FCC-ee

Échéances cruciales wrt Détecteurs dans les 5 années à venir

Version presented today by Fabiola in her P5 talk!



Aujourd'hui

R&D pour la physique des particules (DRD ECFA)

mercredi 28 juin 2023, 14:00 → 17:00 Europe/Paris

Amphi Charpak (LPNHE)

Luc Poggioli (LPNHE Paris)

Description Lien zoom : <https://cern.zoom.us/j/3489975764?pwd=MmmtSYXgzWDI3QVFqaGR6NWlWaU1xdz09>

- | | | | | |
|-------|---------|--|-------|---|
| 14:00 | → 14:10 | Introduction
Orateur: Marco Zito (LPNHE) | 🕒 10m | ✎ |
| 14:10 | → 14:30 | Situation générale
Orateur: Luc Poggioli (LPNHE Paris) | 🕒 20m | ✎ |
| 14:30 | → 14:50 | DRD3 : Détecteurs silicium
Orateur: Giovanni Calderini (LPNHE Paris) | 🕒 20m | ✎ |
| 14:50 | → 15:10 | DRD6 : Calorimétrie silicium
Orateur: Dr Rémi CORNAT (LPNHE, Sorbonne Université - CNRS/IN2P3) | 🕒 20m | ✎ |
| 15:10 | → 15:30 | DRD6 : Calorimétrie liquides nobles
Orateur: Luc Poggioli (LPNHE Paris) | 🕒 20m | ✎ |
| 15:30 | → 15:50 | DRD7 : Electronique
Orateur: Francesco Crescioli (LPNHE) | 🕒 20m | ✎ |
| 15:50 | → 16:10 | DRD2 : Détecteurs liquides
Orateur: Luca Scotto Lavina (LPNHE Paris) | 🕒 20m | ✎ |
| 16:10 | → 16:55 | Discussion | 🕒 45m | ✎ |

Backup

ECFA R&D Roadmap (2)

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

Also 8 page synopsis document:

<https://cds.cern.ch/record/2784893/files/Synopsis%20of%20the%20ECFA%20Detector%20R&D%20Roadmap.pdf>

THE 2021 ECFA DETECTOR
RESEARCH AND DEVELOPMENT ROADMAP

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

European Strategy Update

ECFA
European Committee
for Future Accelerators

18th November 2022

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European Strategy Update

ECFA
European Committee
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18th November 2022

ECFA R&D Roadmap (3)

ECFA

European Committee for Future Accelerators



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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 Brenner⁴¹, Niels van Bakel⁹, Claire Gwenlan¹⁷, Jeff Wiener², Robert Appleby⁴²
(*Expert Members*)

Detector R&D Roadmap Process Group

**Process from May 2020 to December 2021 involved: 67 authors;
12 expert Input Session speakers; ECFA National Contacts;
Correspondents to the Task Force surveys; 121 Symposia presenters;
1359 Symposia attendees and 44 APOD* TF topic specific contacts.**

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

Panel coordinators: Phil Allport⁴³ (*Chair*), Silvia Dalla Torre⁴⁴, Manfred Krammer²,
Felix Sefkow¹⁹, Ian Shipsey¹⁷

Ex-officio Panel members: Karl Jakobs⁴⁵ (*Current ECFA Chair*),
Jorgen D'Hondt⁴⁶ (*Previous ECFA Chair*), Lenny Rivkin⁴⁷ (*LDG Representative*)

Scientific Secretary: Susanne Kuehn²

*** Advisory Panel with
Other Disciplines
(see back up slides)**

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, Bern, 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

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³² MPP, Munich, 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

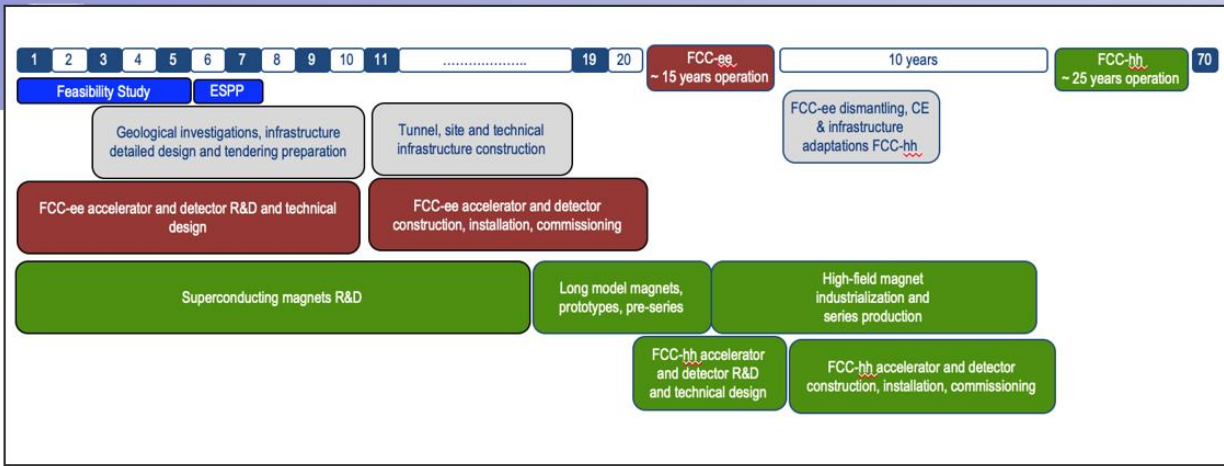
⁴⁴ INFN Sezione di Trieste, Trieste, Italy

⁴⁵ Albert-Ludwigs-Universität Freiburg, Freiburg, Germany

⁴⁶ IHE, Vrije Universiteit Brussel, Brussels, Belgium

⁴⁷ ETH Lausanne and PSI, Villigen, Switzerland

Timescale Grands Projets (eg FCC-ee)



FCC estimated timeline

F. Gianotti
London 06/2023

← **Technical schedule:**
FCC-ee could start physics operation in **2040 or earlier**



← **“Realistic” schedule** takes into account:

- past experience in building colliders at CERN
- approval timeline: ESPP, Council decision
- that HL-LHC will run until ~ 2041

→ **ANY future collider at CERN cannot start physics operation before ~ 2045** (but construction will proceed in parallel to HL-LHC operation)

1st stage collider, FCC-ee: electron-positron collisions 90-360 GeV
Construction: 2033-2045 → Physics operation: 2048-2063

2nd stage collider, FCC-hh: proton-proton collisions at ≥ 100 TeV
Construction: 2058-2070 → Physics operation: ~ 2070-2095

Care should be taken when comparing to other proposed facilities, for which in some cases only the (optimistic) technical schedule is shown