R&D Physique des particules (DRD)

L. Poggioli

- 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 collisonneurs 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 ½ journée d'information sur futurs projets R&D

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

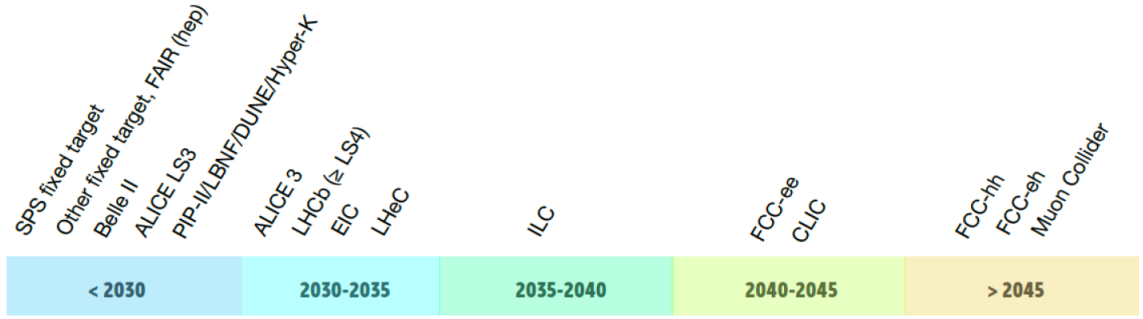
Moteur : Stratégie Européenne pour la Physique des Particules (2020)

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

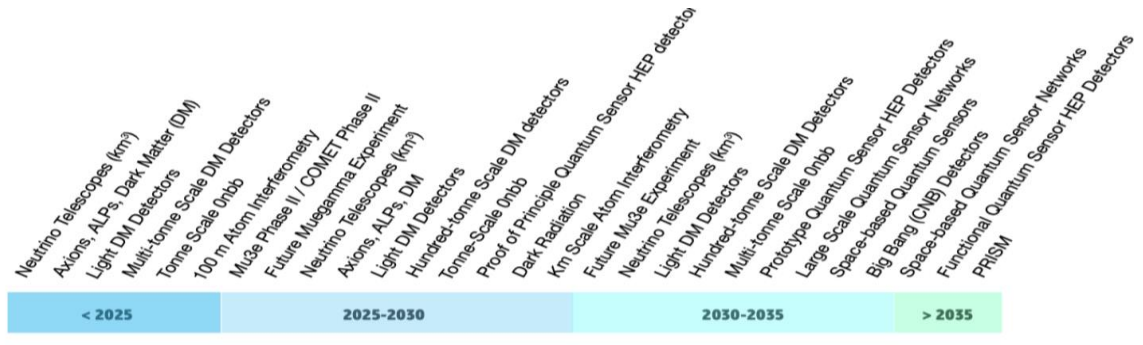
In the ECFA Detector R&D Roadmap the focus has been on facilities targeting the properties and interactions of fundamental particles (including those that are undiscovered but theoretically motivated). It is appreciated that a number of particles increas-

Facilités : Grands accélérateurs /Petits accélérateurs/Non-Acc



Axes R&D

- 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 $5\times10^{36}\,cm^{-2}s^{-1}$ 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 $10^{35}\,cm^{-2}s^{-1}$;
- 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.



Organisation projets DRD : Tracks

Talk Luca

Talk Giovanni

Gaseous

- **DRDT 1.1** Improve time and spatial resolution for gaseous detectors with long-term stability
- **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
- **DRDT 1.3** Develop environmentally friendly gaseous detectors for very large areas with high-rate capability
- **DRDT 1.4** Achieve high sensitivity in both low and high-pressure TPCs

Liquid

- **DRDT 2.1** Develop readout technology to increase spatial and energy resolution for liquid detectors
- **DRDT 2.2** Advance noise reduction in liquid detectors to lower signal energy thresholds
- **DRDT 2.3** Improve the material properties of target and detector components in liquid detectors
- **DRDT 2.4** Realise liquid detector technologies scalable for integration in large systems

Solid state

- **DRDT 3.1** Achieve full integration of sensing and microelectronics in monolithic CMOS pixel sensors
- **DRDT 3.2** Develop solid state sensors with 4D-capabilities for tracking and calorimetry
- **DRDT 3.3** Extend capabilities of solid state sensors to operate at extreme fluences
- **DRDT 3.4** Develop full 3D-interconnection technologies for solid state devices in particle physics

PID and Photon

- **DRDT 4.1** Enhance the timing resolution and spectral range of photon detectors
- **DRDT 4.2** Develop photosensors for extreme environments
- **DRDT 4.3** Develop RICH and imaging detectors with low mass and high resolution timing
- **DRDT 4.4** Develop compact high performance time-of-flight detectors

Quantum

- **DRDT 5.1** Promote the development of advanced quantum sensing technologies
- **DRDT 5.2** Investigate and adapt state-of-the-art developments in quantum technologies to particle physics
- **DRDT 5.3** Establish the necessary frameworks and mechanisms to allow exploration of emerging technologies
- **DRDT 5.4** Develop and provide advanced enabling capabilities and infrastructure

- **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.**

Talks Rémi, LP

Talk Francesco

Calorimetry

- **DRDT 6.1** Develop radiation-hard calorimeters with enhanced electromagnetic energy and timing resolution
- **DRDT 6.2** Develop high-granular calorimeters with multi-dimensional readout for optimised use of particle flow methods
- **DRDT 6.3** Develop calorimeters for extreme radiation, rate and pile-up environments

Electronics

- **DRDT 7.1** Advance technologies to deal with greatly increased data density
- **DRDT 7.2** Develop technologies for increased intelligence on the detector
- **DRDT 7.3** Develop technologies in support of 4D- and 5D-techniques
- **DRDT 7.4** Develop novel technologies to cope with extreme environments and required longevity
- **DRDT 7.5** Evaluate and adapt to emerging electronics and data processing technologies

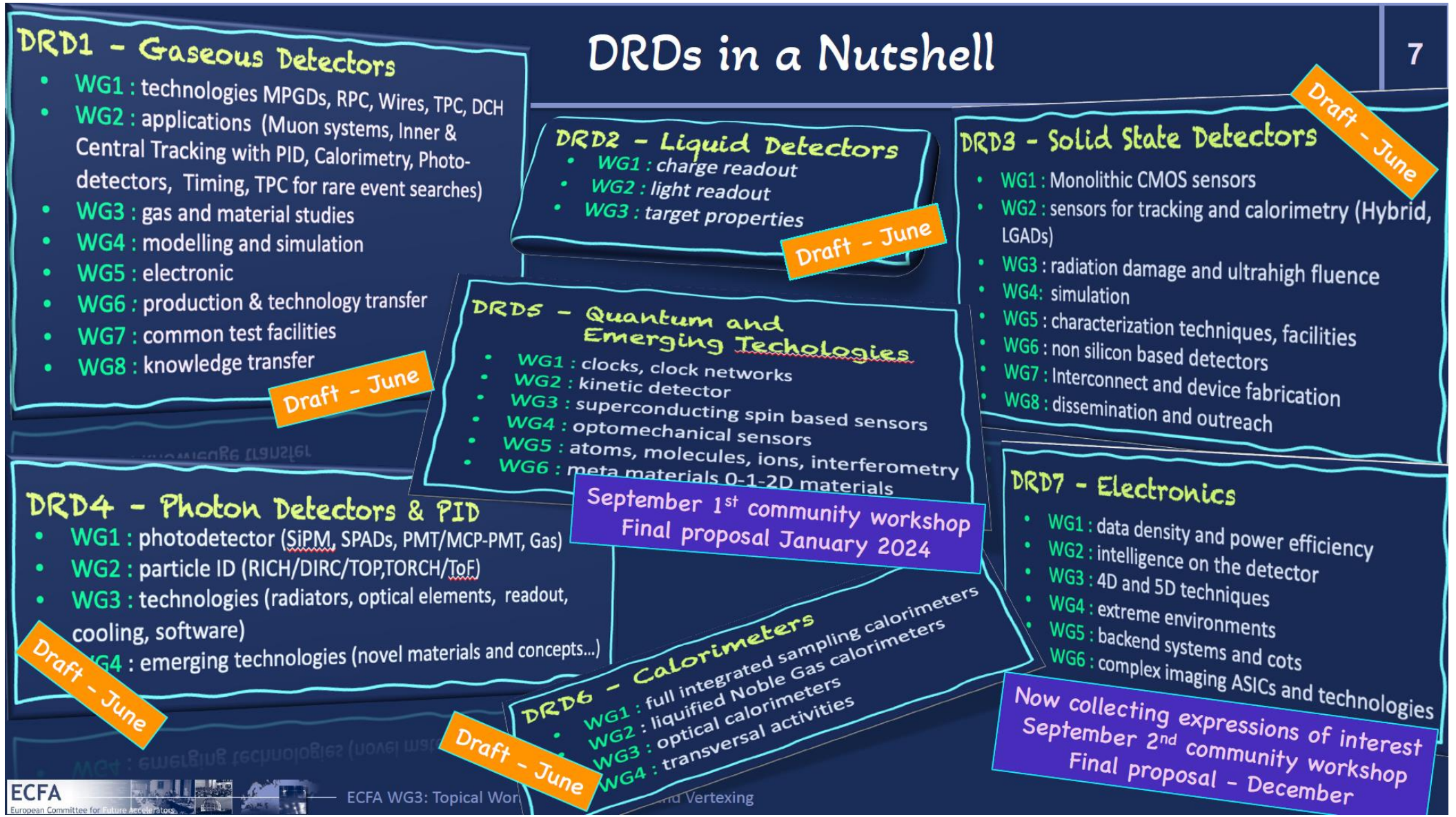
Integration

- **DRDT 8.1** Develop novel magnet systems
- **DRDT 8.2** Develop improved technologies and systems for cooling
- **DRDT 8.3** Adapt novel materials to achieve ultralight, stable and high precision mechanical structures. Develop Machine Detector Interfaces.
- **DRDT 8.4** Adapt and advance state-of-the-art systems in monitoring including environmental, radiation and beam aspects

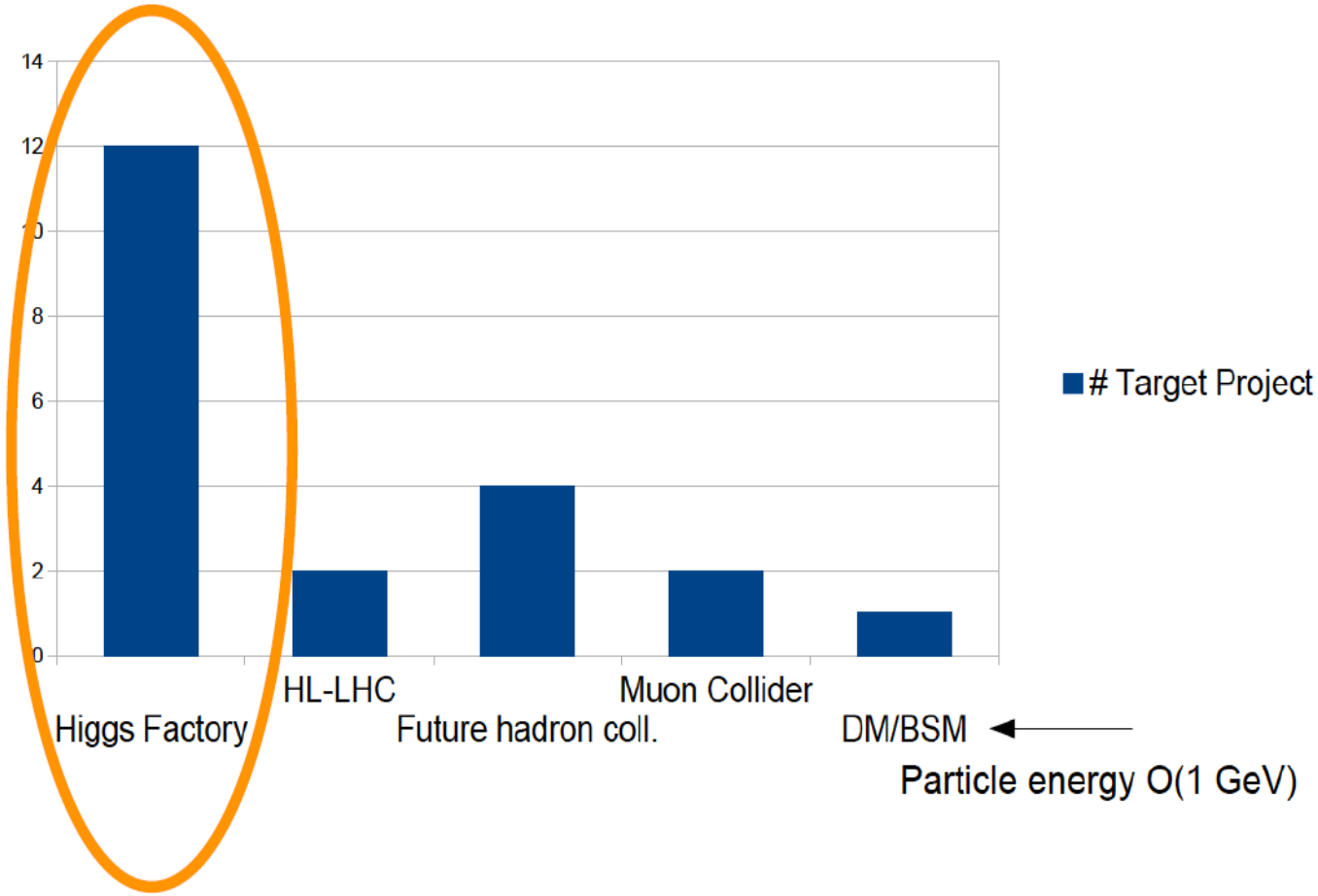
Training

- **DCT 1** Establish and maintain a European coordinated programme for training in instrumentation
- **DCT 2** Develop a master's degree programme in instrumentation

Organisation projets DRD : Working Groups



Projets futurs couverts par DRD (Exemple Calorimétrie DRD6)



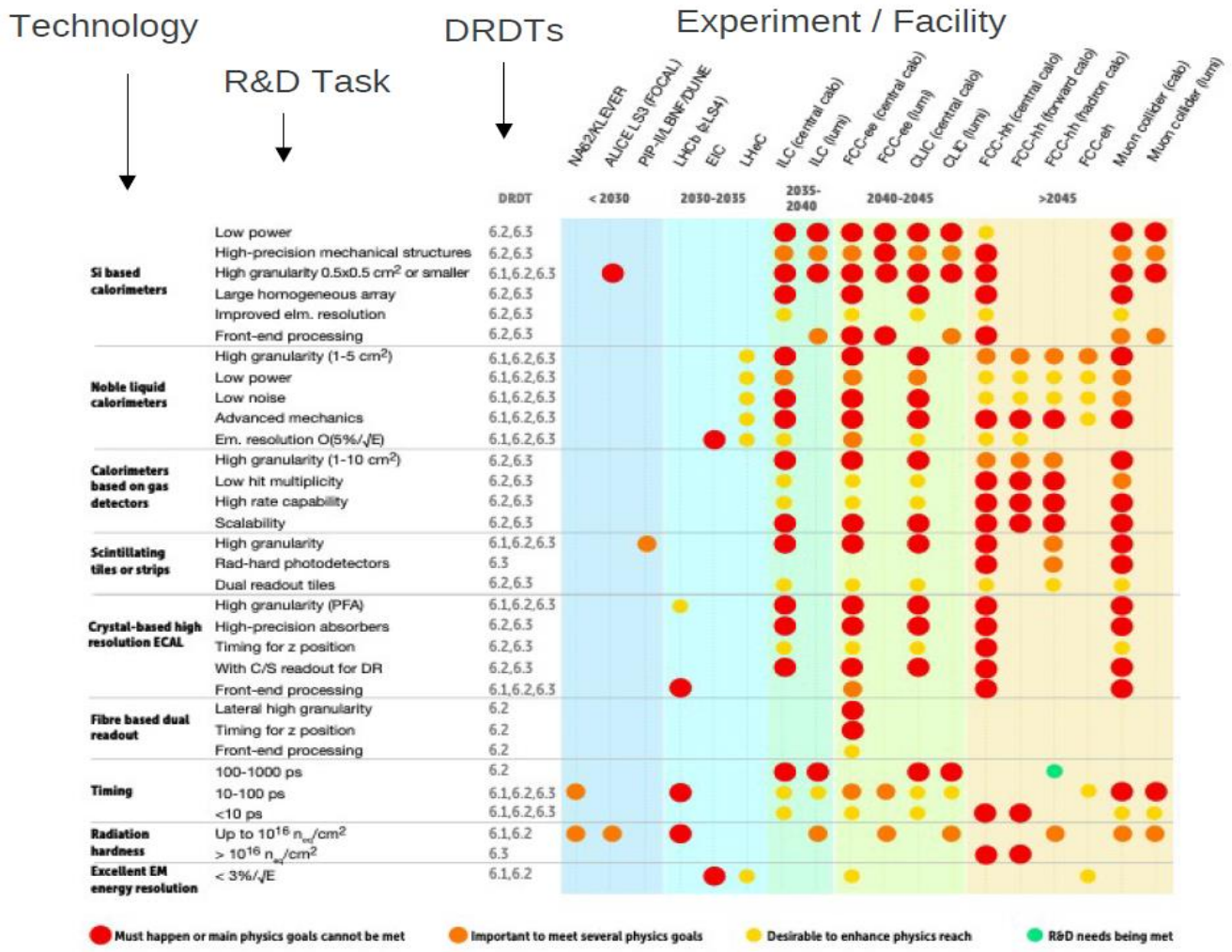
- En majorité, projets pour future usine à Higgs (FCC-ee, C3, ILC, CEPC)
- Aussi autres collisionneurs (FCC-hh, Muon Collider
- Aussi Matière Noire/BSM

DRD : Tâches vs Projets (exemple Calorimétrie DRD6)

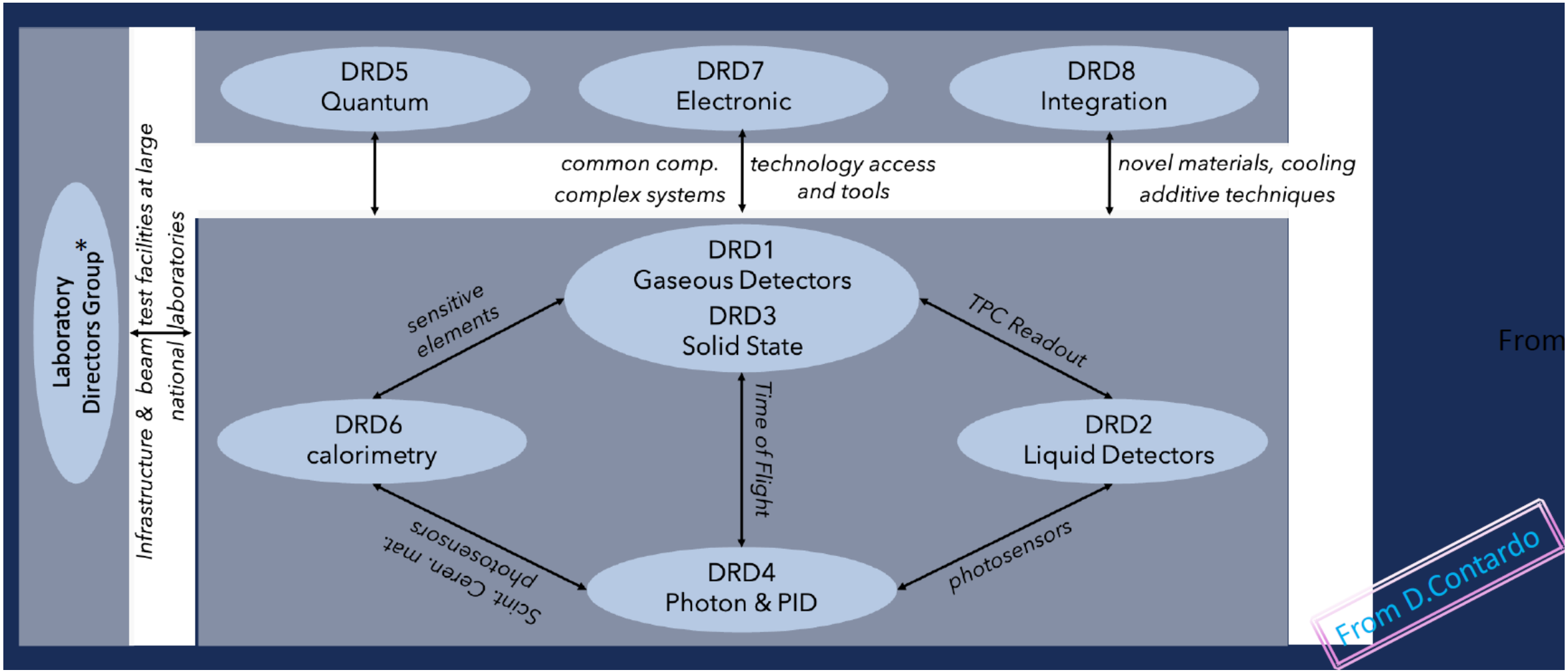
- Key technologies and requirements identified in roadmap
  - Si based calorimeters
  - Liquid Noble Gas calorimeters
  - Calorimeters based on gas detectors
  - Scintillating tiles and strips
  - Crystal based high-resolution ECal.s
  - Fibre-based dual readout

- 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)

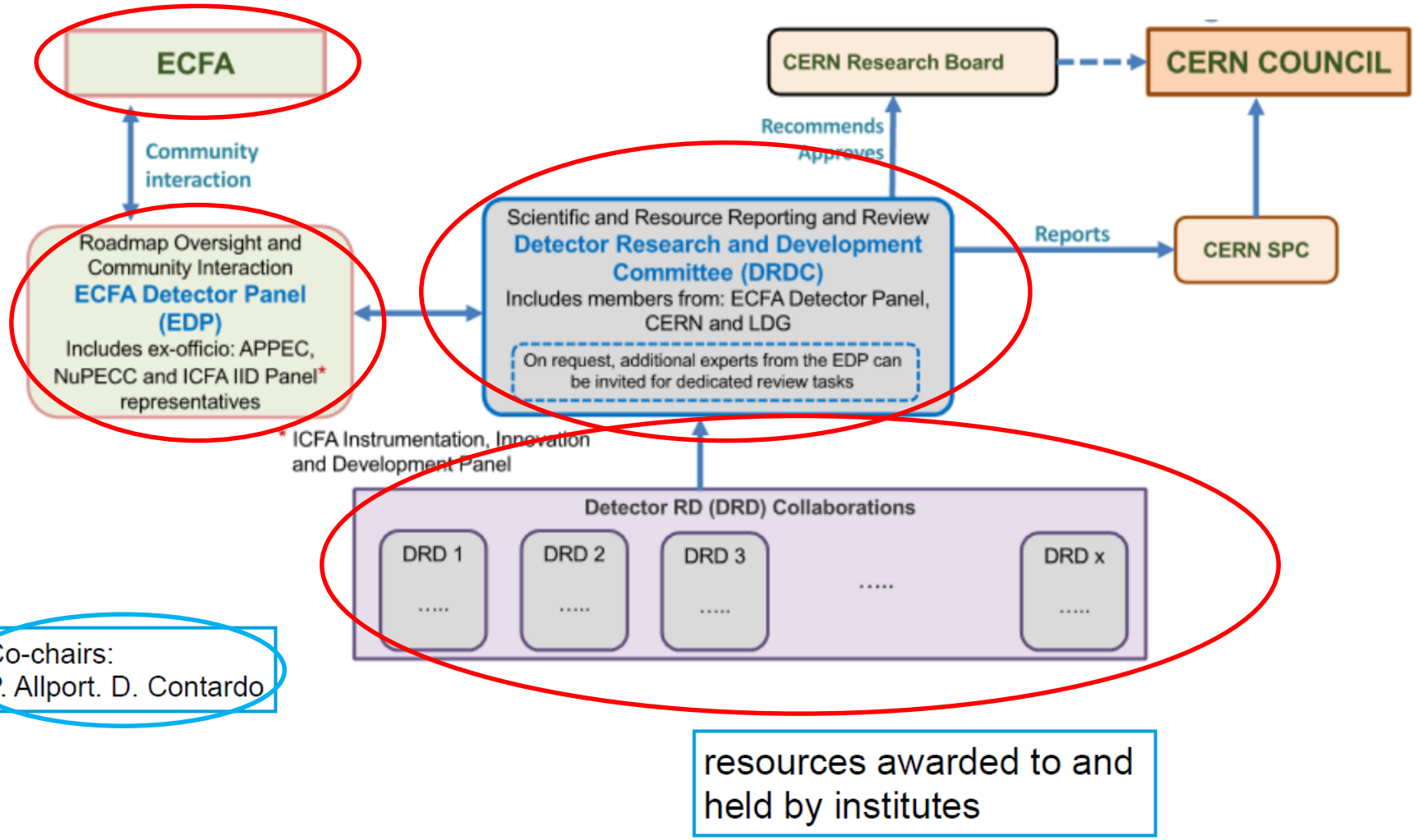
- yearly follow-up
- report via SPC to Council

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

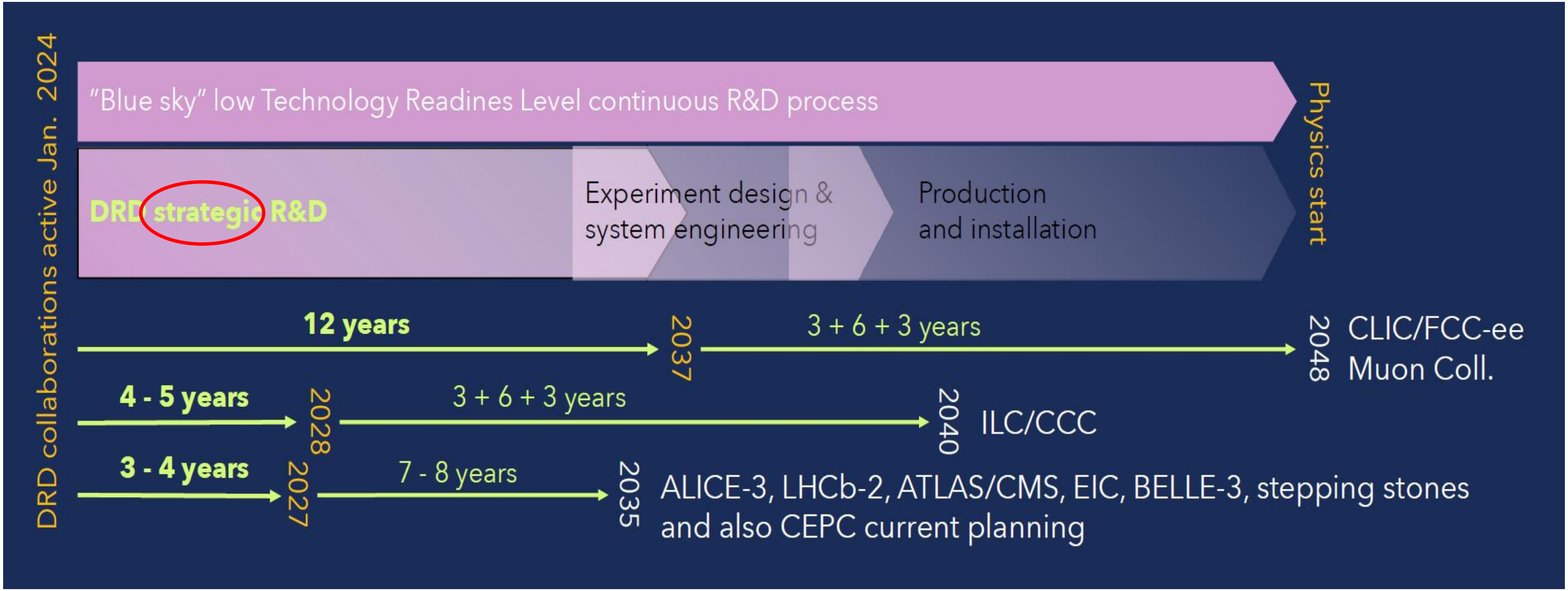
Major Steps:

- **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

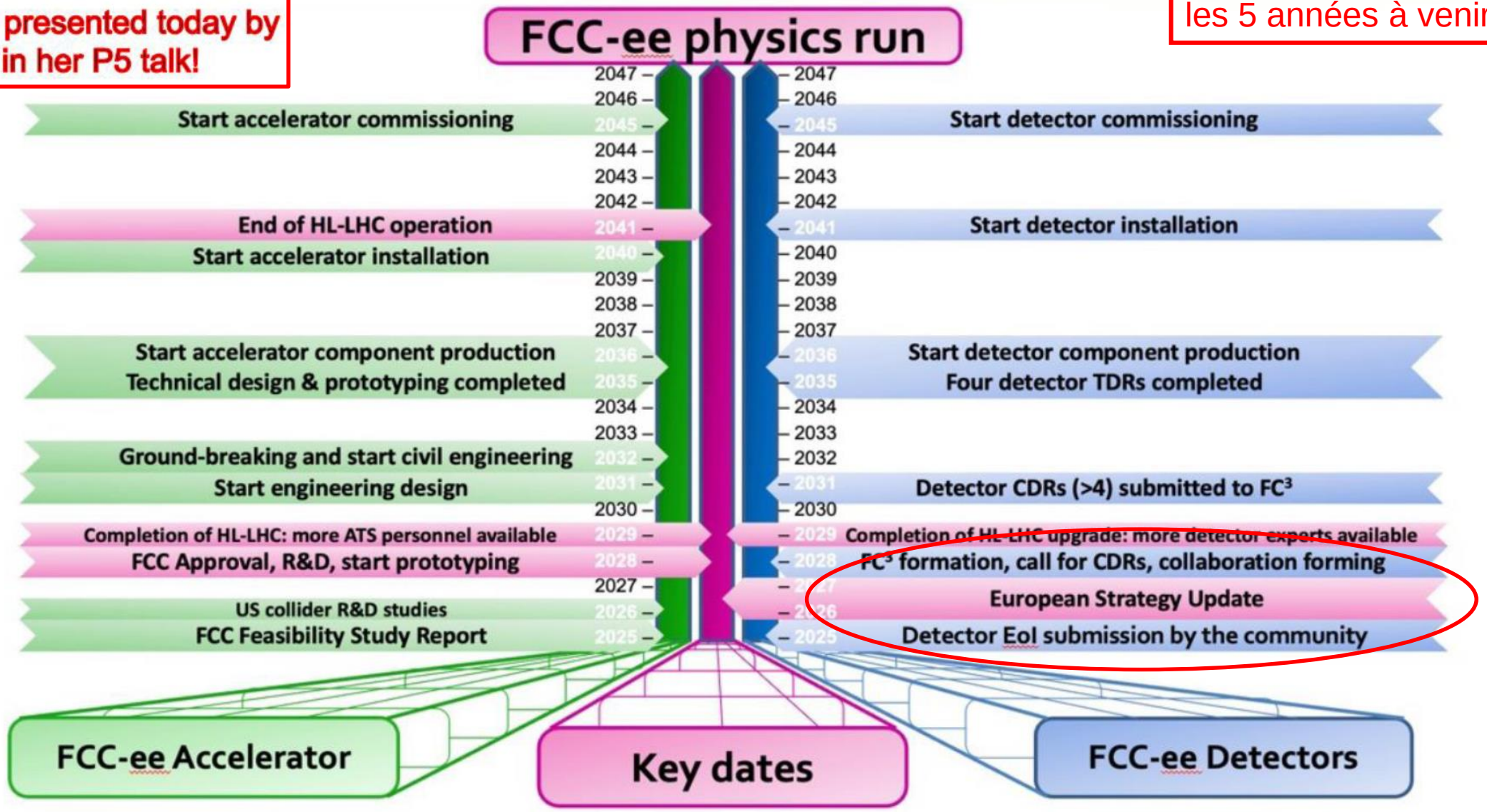
Futurs projets & Timescale DRD



Timeline FCC-ee

Version presented today by Fabiola in her P5 talk!

Échéances cruciales wrt Détecteurs dans les 5 années à venir



Aujourd'hui

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

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

Amphi Charpak (LPNHE)

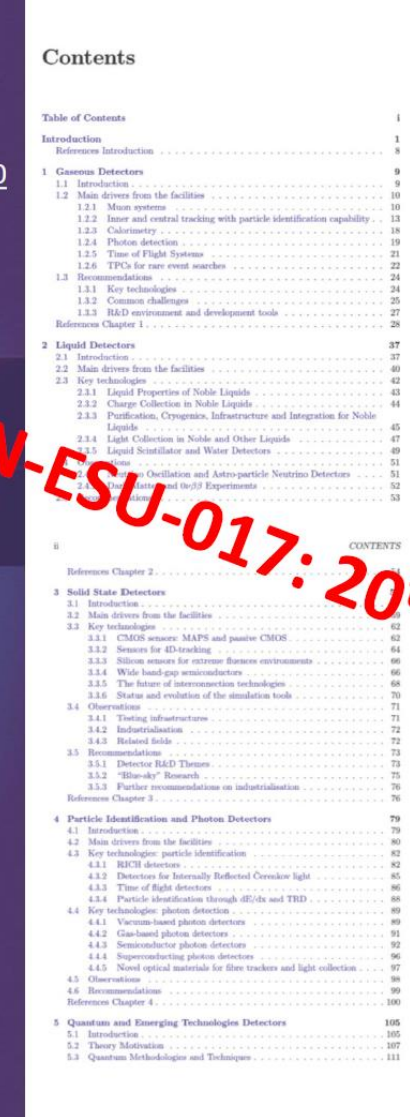
Luc Poggioli (LPNHE Paris)

Description Lien zoom : https://cern.zoom.us/j/3489975764?pwd=MmtSYXgzWDI3QVFqaGR6NWlWaU1xdz09

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)


Contents

CERN-ESU-017: 20th December 2021

ECFA R&D Roadmap (3)

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.

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 Colaleo[1], Leszek Ropelewski[2] *(Conveners)* Klaus Dehmelt[3], Barbara Liberti[4], Maxim Titov[5], Joao Veloso[6] *(Expert Members)*

Task Force 2 Liquid Detectors: Roxanne Guenette[7], Jocelyn Monroe[8] *(Conveners)* Auke-Pieter Colijn[9,10], Antonio Ereditato[11,12,28], Inés Gil Botella[13], Manfred Lindner[14] *(Expert Members)*

Task Force 3 Solid State Detectors: Nicolo Cartiglia[15], Giulio Pellegrini[16] *(Conveners)* Daniela Bortoletto[17], Didier Contardo[18], Ingrid-Maria Gregor[19,20] Gregor Kramberger[21], Heinz Pernegger[2] *(Expert Members)*

Task Force 4 Particle Identification and Photon Detectors: Neville Harnew[17], Peter Krizan[21] *(Conveners)* Ichiro Adachi[22], Eugenio Nappi[1] Christian Joram[2], Hans-Christian Schultz-Coulon[23] *(Expert Members)*

Task Force 5 Quantum and Emerging Technologies: Marcel Demarteau[24], Michael Doser[2] *(Conveners)* Caterina Braggio[25], Andy Geraci[26], Peter Graham[27], Anna Grasselino[28], John March Russell[17], Stafford Withington[29] *(Expert Members)*

Task Force 6 Calorimetry: Roberto Ferrari[30], Roman Pöschl[31] *(Conveners)* Martin Aleksa[2], Dave Barney[2], Frank Simon[32], Tommaso Tabarelli de Fatis[33] *(Expert Members)*

Task Force 7 Electronics: Dave Newbold[34], Francois Vasey[2] *(Conveners)* Niko Neufeld[2], Valerio Re[30] Christophe de la Taille[35], Marc Weber[36] *(Expert Members)*

Task Force 8 Integration: Frank Hartmann[36], Werner Riegler[2] *(Conveners)* Corrado Gargiulo[2], Filippo Resnati[2], Herman Ten Kate[37], Bart Verlaat[2], Marcel Vos[38] *(Expert Members)*

Task Force 9 Training: Johann Collot[39], Erika Garutti[40] *(Conveners)* Richard Brenner[41], Niels van Bakel[9] Claire Gwenlan[17], Jeff Wiener[2], Robert Appleby[42] *(Expert Members)*

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

Panel coordinators: Phil Allport[43] *(Chair)*, Silvia Dalla Torre[44], Manfred Krammer[2], Felix Sefkow[19], Ian Shipsey[17]

Ex-officio Panel members: Karl Jakobs[45] *(Current ECFA Chair)*, Jorgen D'Hondt[46] *(Previous ECFA Chair)*, Lenny Rivkin[47] *(LDG Representative)*

Scientific Secretary: Susanne Kuehn[2]

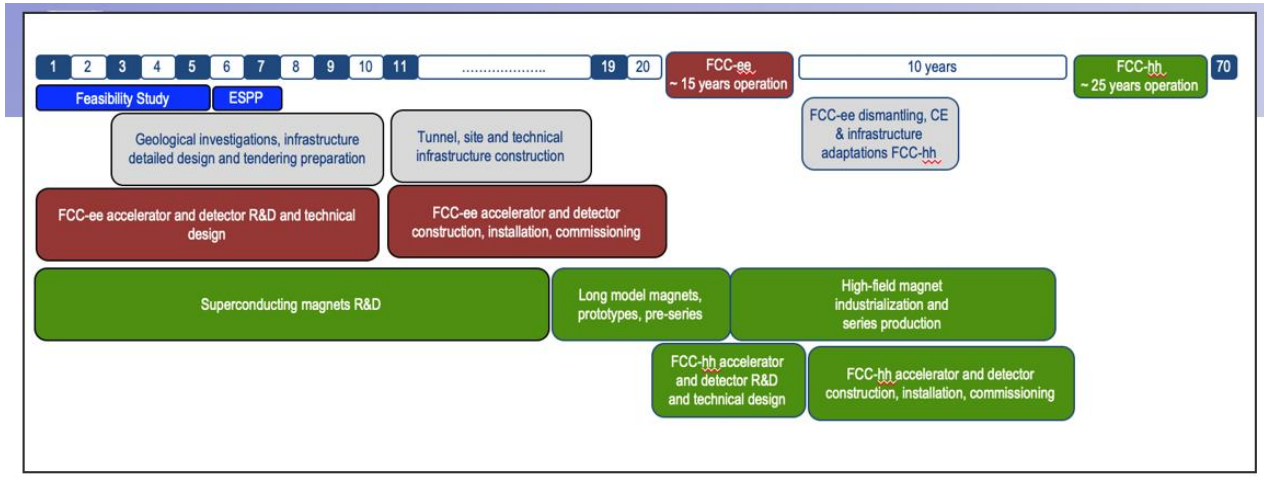
* **Advisory Panel with Other Disciplines (see back up slides)**

[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 NetherlandsYale
[11] University, New Heaven, 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, FranceMPP
[32] 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] Universit è 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-Universit ät Freiburg, Freiburg, Germany
[46] IIHE, Vrije Universiteit Brussel, Brussels, Belgium
[47] ETH Lausanne and PSI, Villigen, Switzerland

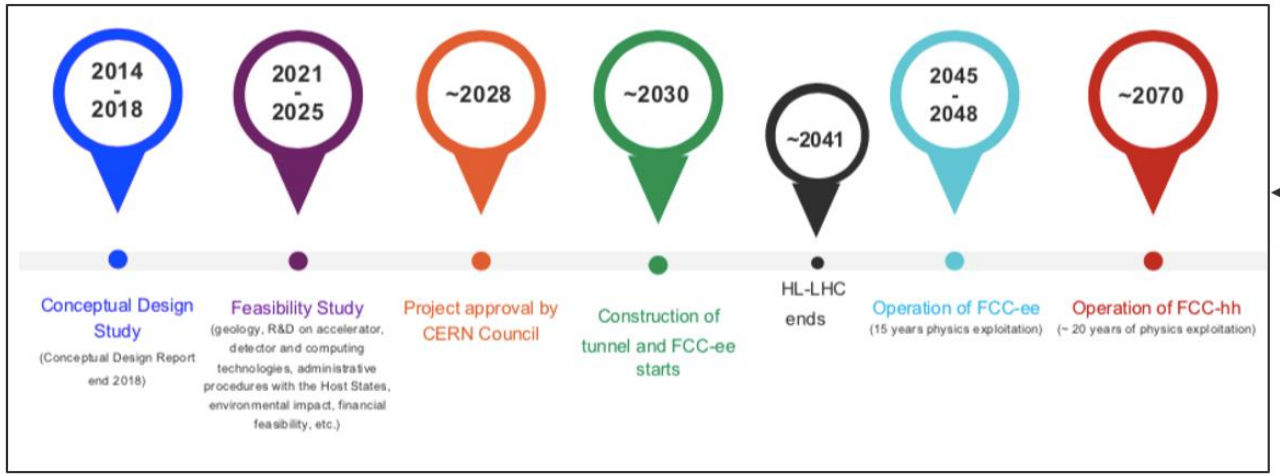
Timescale Grands Projets (eg FCC-ee)

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

3