

ECFA Detector Roadmap and Implementation

1st ECFA Higgs Factory Workshop
October 06, 2022

And
CALICE Collaboration Meeting
October 12, 2022

Felix Sefkow
DESY

heavily based on or directly using
slides by Phil Allport and Karl Jakobs



Outline

This Talk

Reminder: Roadmap Process and Outcome

Implementation plan:

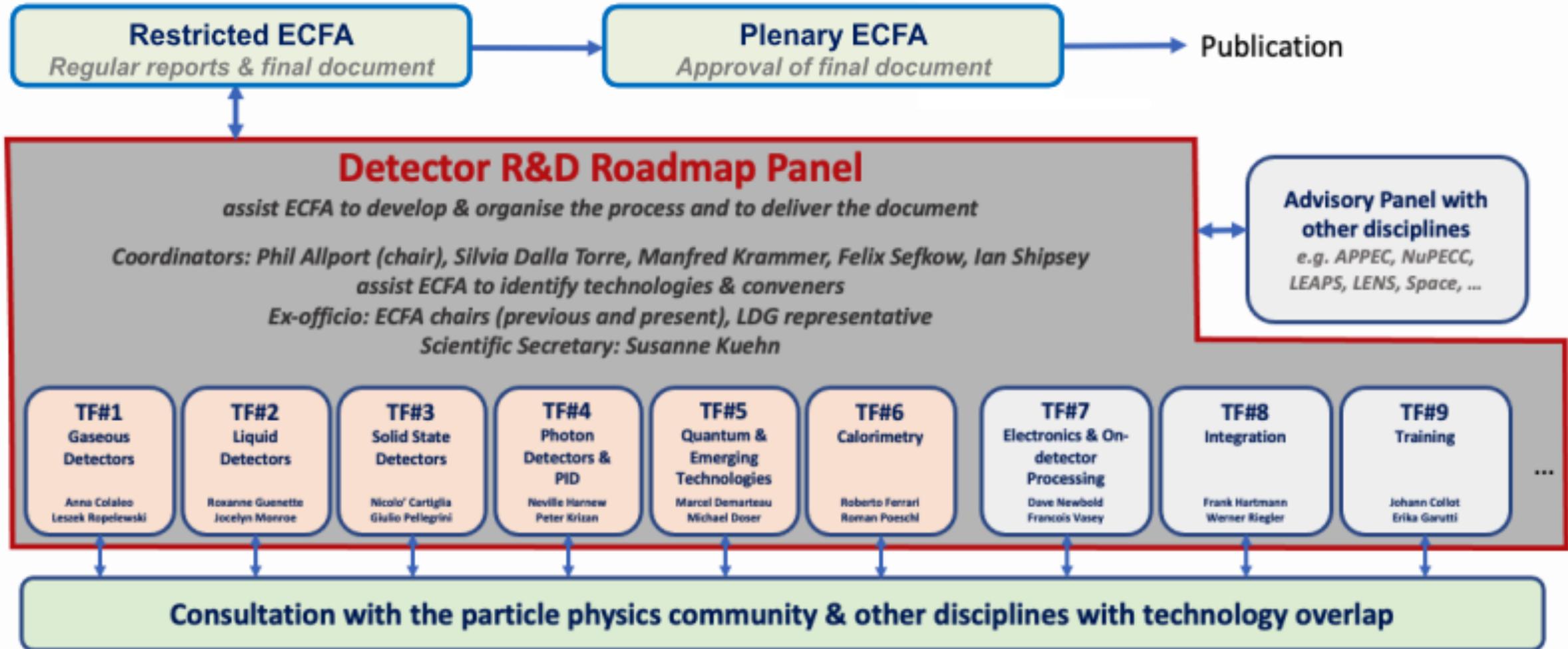
General approach

First feedback

Timeline

Role of ECFA studies and Detector Concepts

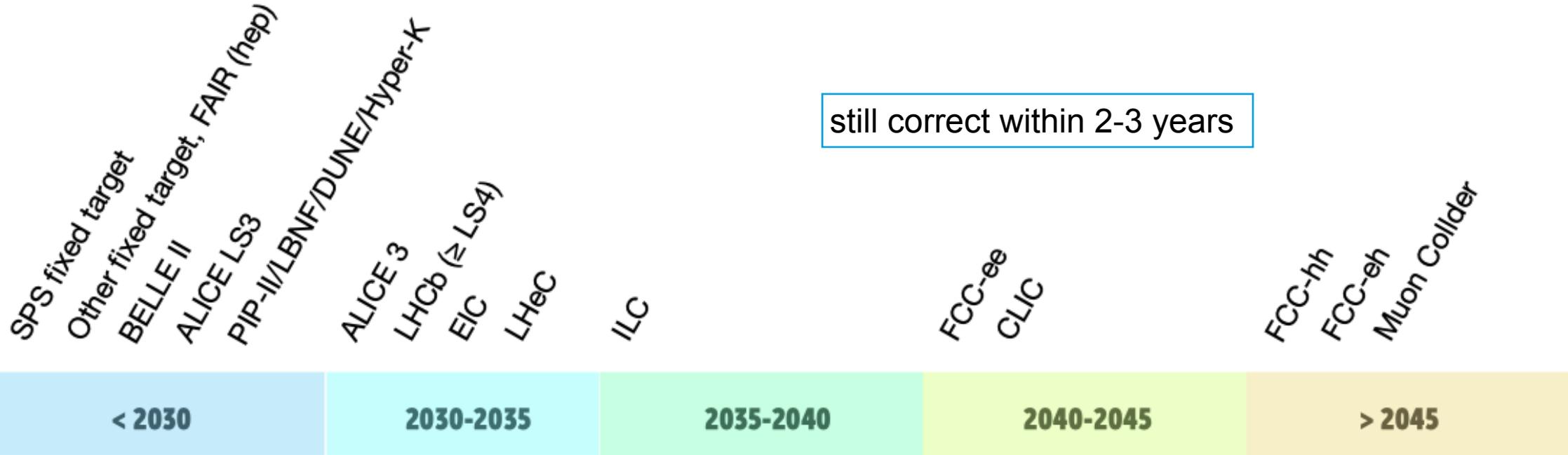
Roadmap Reminder



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

Future Projects Timeline (Accelerator Roadmap)

Accelerator Roadmap - as seen by the Lab Directors Group



The dates shown in the diagram have 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.

How Much Time Do We Need?

“Random” Examples - and NOT from the start of the R&D

Nuclear Instruments and Methods in Physics Research A309 (1991) 438–449
North-Holland

t0 -17y

**NUCLEAR
INSTRUMENTS
& METHODS
IN PHYSICS
RESEARCH**
Section A

Performance of a liquid argon electromagnetic calorimeter with an “accordion” geometry

RD3 Collaboration

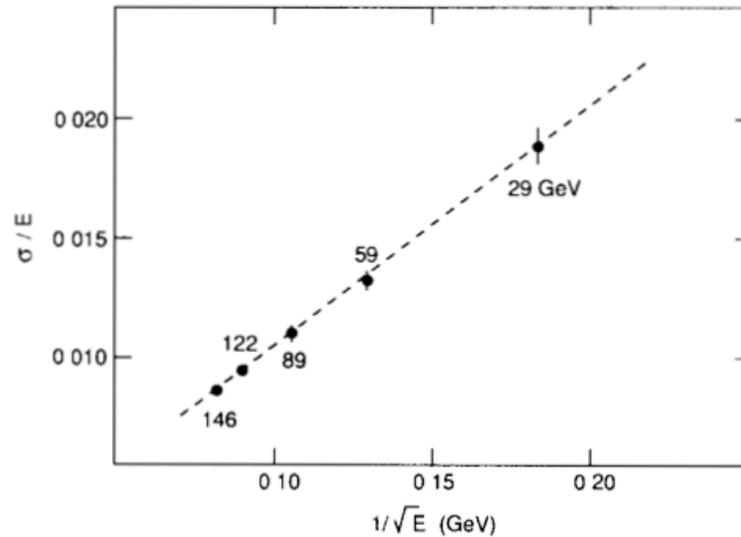
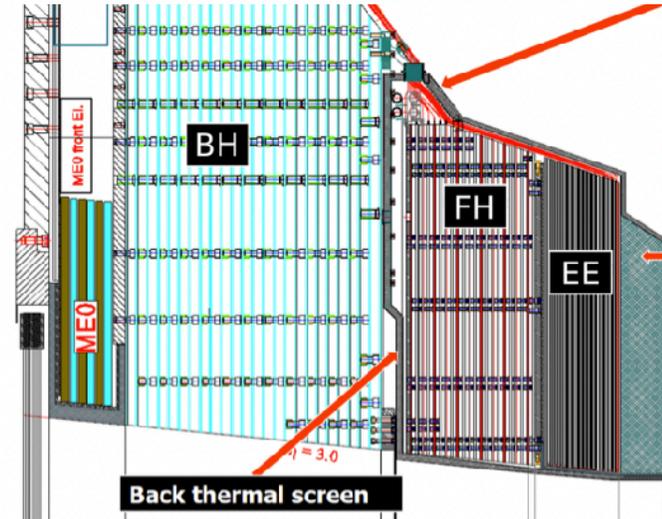


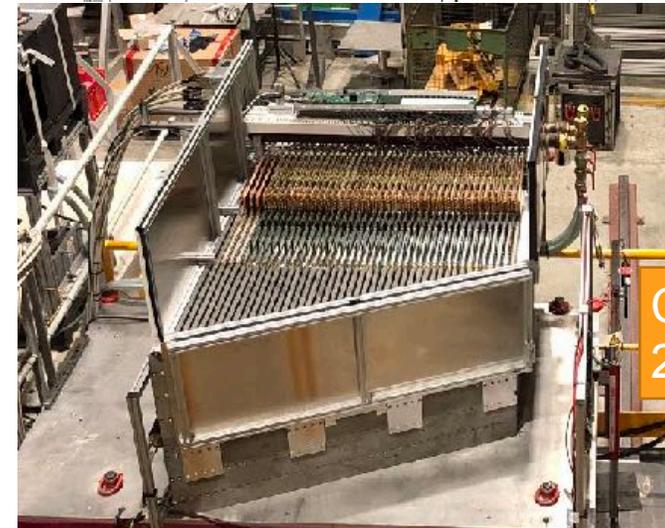
Fig. 6. Energy resolution of the prototype at different electron energies. The dashed line is a linear fit to the experimental points.



CERN-LHCC-2015-10
LHCC-P-008
CMS-TDR-15-02
ISBN 978-92-9083-417-5
1 June 2015



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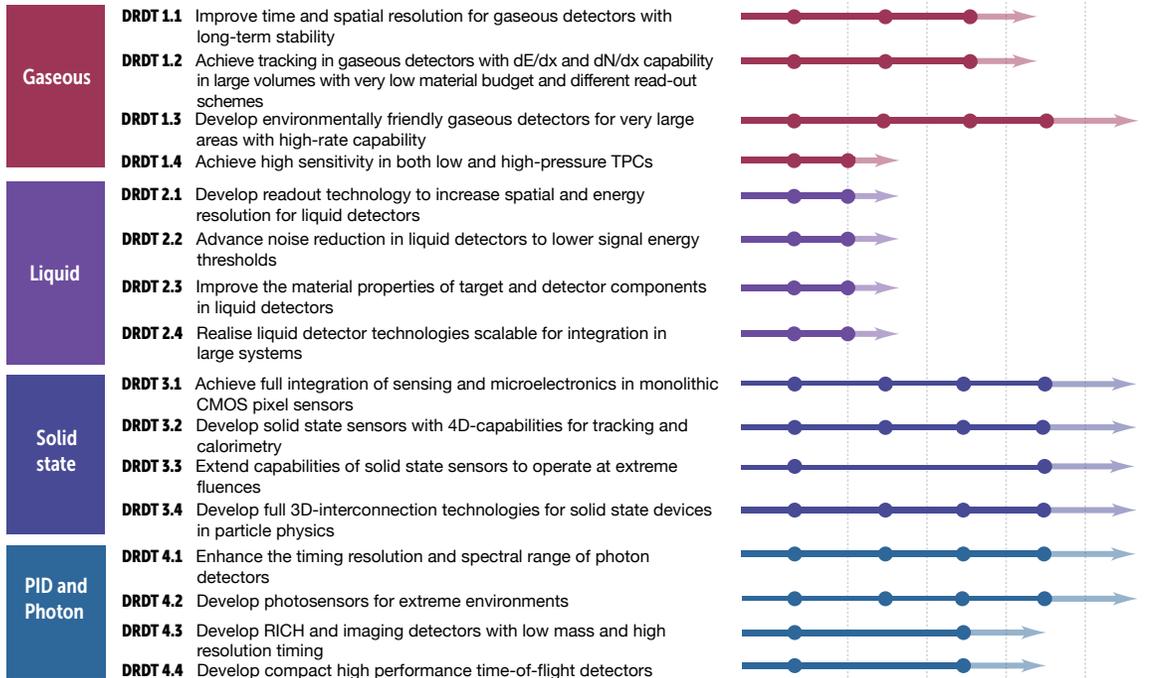
CALICE
2006-2018

ECFA Detector Roadmap Summary

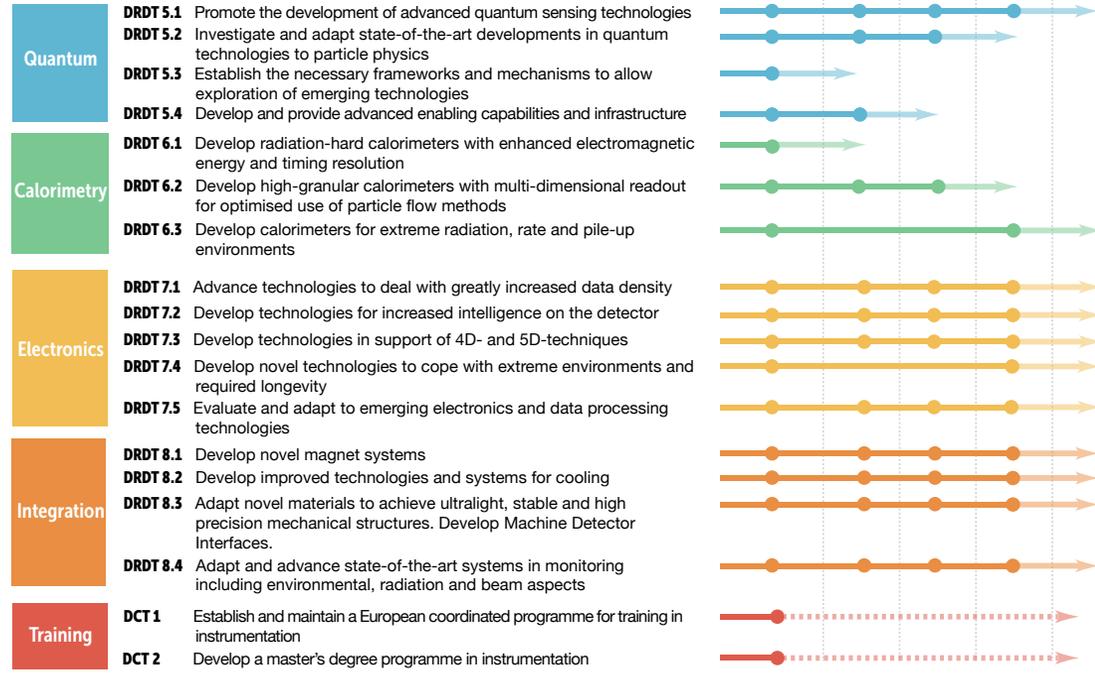
Relating Technology R&D to Major Drivers from Facilities



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



Dates when R&D finished and real engineering & construction can start

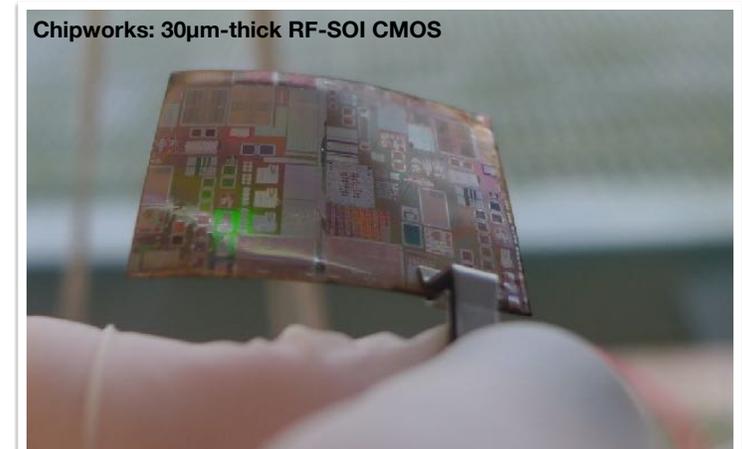
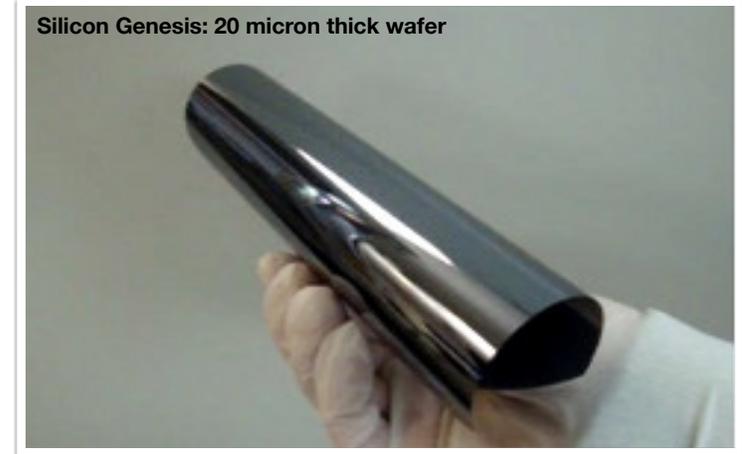
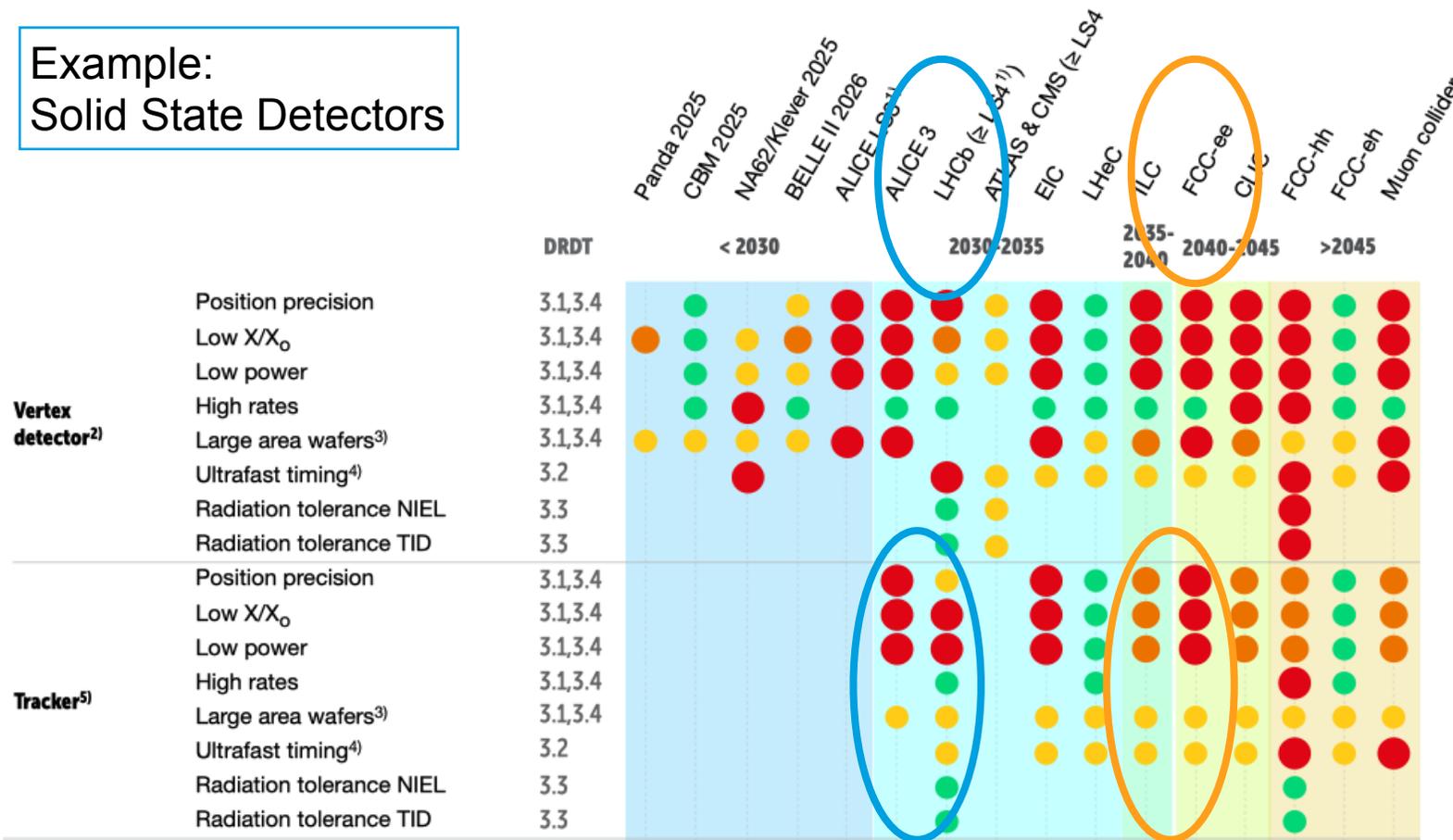


Detector R&D Themes (DRDTs) and Detector Community Themes (DCTs). Here, except in the DCT case, the final dot position represents the target date for completion of the R&D required by the latest known future facility/experiment for which an R&D programme would still be needed in that area. The time from that dot to the end of the arrow represents the further time to be anticipated for experiment-specific prototyping, procurement, construction, installation and commissioning. Earlier dots represent the time-frame of intermediate "stepping stone" projects where dates for the corresponding facilities/experiments are known. (Note that R&D for Liquid Detectors will be needed far into the future, however the DRDT lines for these end in the period 2030-35 because developments in that field are rapid and it is not possible today to reasonably estimate the dates for projects requiring longer-term R&D. Similarly, dotted lines for the DCT case indicate that beyond the initial programmes, the activities will need to be sustained going forward in support of the instrumentation R&D activities).

Synergies, Stepping Stones, R&D collaborations

Looking Across the Fence, and Beyond Tomorrow

Example:
Solid State Detectors



Magnus Mager (CERN) | ALICE ITS3 | CERN detector seminar | 24.09.2021 | 9

● Must happen or main physics goals cannot be met ● Important to meet several physics goals ● Desirable to enhance physics reach ● R&D needs being met

Detector Roadmap: Strategic Recommendations

General Needs of the Field

- 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

R&D
Collaborations

Capture many of the guiding principles of AIDA projects

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.

approved by ECFA
and presented to Council
end of 2021



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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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.com>
<https://indico.cern.ch/e/ECFA-DetectorRDRoadmap>
<https://ecfa.web.cern.ch/>

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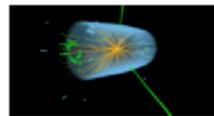
ECFA
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for Future Accelerators

8 page synopsis brochure also prepared for less specialist audience
<https://cds.cern.ch/record/2784893>

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.



3D visualization of a simulated Higgs boson decay into two photons as simulated 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



Interior view of a particle detector showing complex internal structures. (© CERN)



Aerial view of a particle detector showing its circular structure. (© 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 programmes, working in synergy with neighbouring fields and with a view to potential industrial applications.



Aerial view of a particle detector showing its circular structure. (© CERN)

Identifying the Tools

"It is vital to build on Europe's world-leading capabilities in sensor technologies for particle detection."

The figure opposite illustrates the "Detector R&D Themes" (DRDTs) and "Detector Community Themes" (DCTs) identified in the roadmap process, grouped according to the areas addressed by the nine task forces set up by ECFA to develop a strategy for future detector R&D priorities. All the themes are critical to achieving the science programme outlined in the ESPP and are derived from the technological challenges that need to be overcome for the scientific potential of the future facilities and projects listed in the ESPP to be realised. It is important to ensure that, for each of the future facilities mentioned in the ESPP, detector readiness should not be the limiting factor in terms of when the facility in question can be realised. In many cases, less demanding developments are required for experiments scheduled in the medium term, which can then act as "stepping stones" (illustrated by the in-between dots) towards achieving the final specifications.



Illustration of microelectronics circuitry integrated with a detecting medium as a single monolithic active detector. (© ALICE collaboration)

The R&D priorities are outlined for the key detector types: those based on gaseous, liquid or solid sensing materials; along with those required for sensing aspects specific to photon detection, particle identification (PID) or energy measurement (calorimetry). In addition, quantum sensors are already offering radically new opportunities to particle physics, and their further development will widen their applicability to the field. Sophisticated read-out technologies are essential to all detector types and are often the limiting factor when very large numbers of channels are to be instrumented, especially given the ever more demanding sensitivity and robustness required for operation in the extreme conditions of many particle physics experiments. Unique advanced engineering solutions are needed to complement all these detector developments and, as with accelerators, the field drives many aspects of progress in magnet technology. Last but not least, environmental sustainability is a central requirement for all future research and innovation activities.



Real Science Institute (RSI) detector facility for delivering high-precision technology with beams of accelerated protons (Proton Therapy). (© Scansite/Scansite Photography/RSI)

Given the vital importance of expertise in a wide range of cutting-edge technologies, the Detector R&D Roadmap also contains specific recommendations in terms of training, Detector Community Themes with emphasis on providing better coordination between the many different training schemes available across Europe, and exploring mechanisms to establish a core syllabus for a Masters qualification in particle physics instrumentation that brings together the crucial elements from the large number of diverse existing courses. Given the uneven access to training in the area of instrumentation in all regions of the world, a key focus is to greatly improve the industry of future programmes, workshops and schools, encouraging the widest possible diversity of participants.



Detector classroom facility for detector R&D testing and assembly targeting EIC operations, future collider facilities and medical applications. (© SLAC, University of Birmingham)

While defining the priorities within particle physics, as outlined above, the ECFA Detector R&D Roadmap also emphasises the vital importance of benefiting from synergies with adjacent research fields, knowledge institutions and high-technology industries.



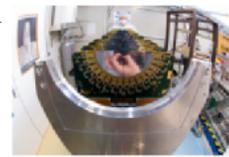
Students and young scientists working on the construction of prototype detector modules. (© CERN)

SYNOPSIS OF THE 2021 ECFA DETECTOR RESEARCH AND DEVELOPMENT ROADMAP

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



ECFA
European Committee
for Future Accelerators



Neutrino Detector (ND) of the LHC experiment allowing after the particle beams to be measured with precision. (© CERN)



Invention of solid scintillator crystals (over three times the density of conventional glass) that the high-granularity electromagnetic calorimeter of the ALICE experiment during percent scale energy measurements. (© CERN)



ProtonDRAC: First hundred cubic metre volume prototype Liquid Argon Neutron Detector being constructed at CERN. (© CERN)

Roadmap Implementation

Implementation of the 2021 ECFA Detector R&D Roadmap

*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, managements of existing RD Collaborations, SPC and Council, and with Funding Agencies
- Open presentation at the July Plenary ECFA meeting by Phil Allport <https://indico.cern.ch/event/1172215/>
- Document describing the proposed implementation plan was sent to SPC and Council (attached to the agenda page)

endorsed by Council last week



Implementation of the ECFA Detector R&D Roadmap

In a Nutshell

European Strategy stresses importance of a strong focus on instrumentation

- Relevant R&D issues must be addressed **in time**
- Common R&D lines with near- and mid-term projects - exploit **synergies and stepping stones**

Successful completion of High-Luminosity LHC must remain key focus

- start up the process now, but only gradually ramp-up
- larger involvement of many groups only after phase II construction completed

Offer long-term perspectives for instrumentation physicists / engineers

Two components

- Establishment of **R&D collaborations** anchored at CERN
- Implementation of General Strategic Recommendations

R&D Collaborations

Reloaded.

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

- call for proposals, moderate process, timeline 1-2 years

Reasonably dimensioned review process (ECFA and CERN)

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

ECFA Higgs factory study WG 3 established: MC Fouz, G.Marchiori, FS

- as a forum for the interplay between physics and detector studies and R&D efforts
- This is also relying on functional detector concepts

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

Review and Approval Process

Lightweight and commensurate with effort

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

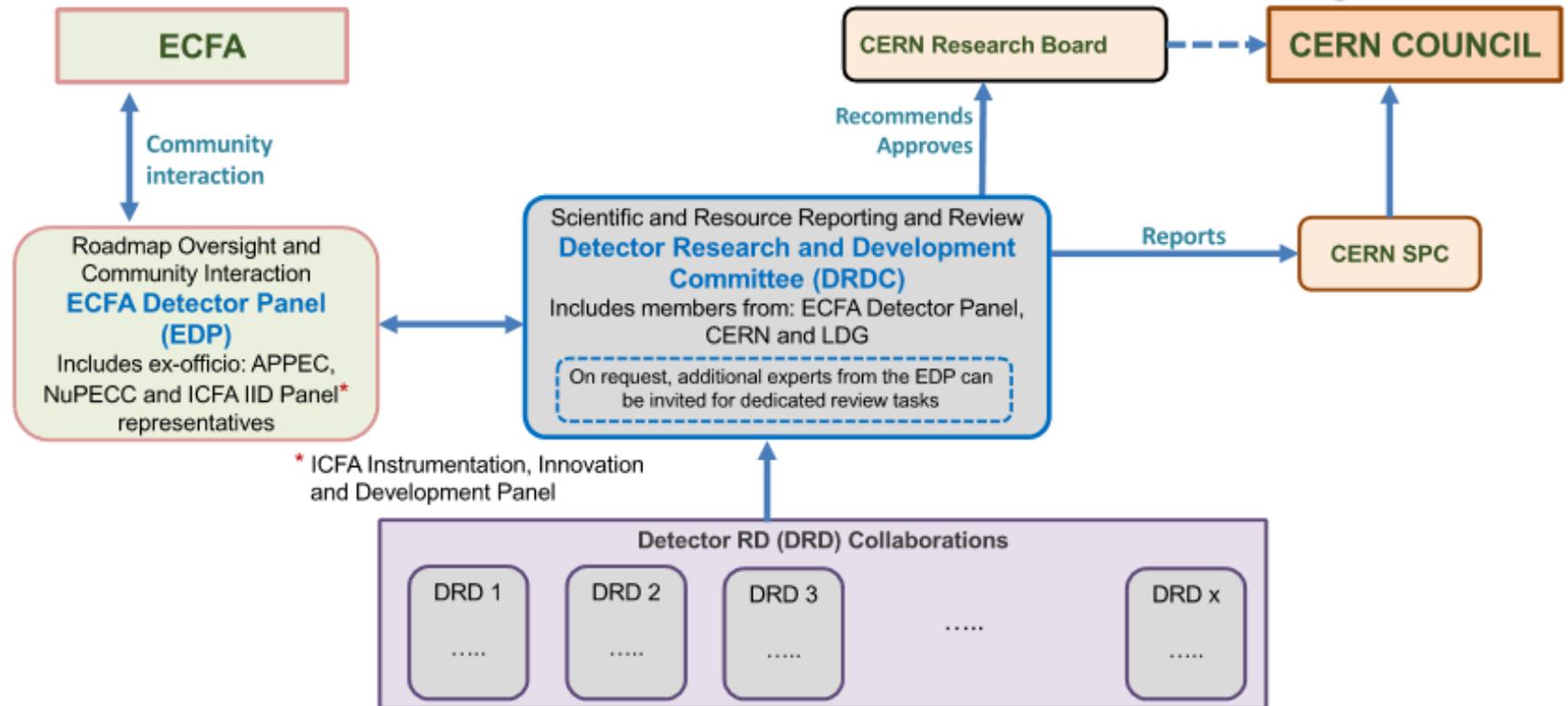
- yearly follow-up
- report via SPC to Council

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



* ICFA Instrumentation, Innovation and Development Panel

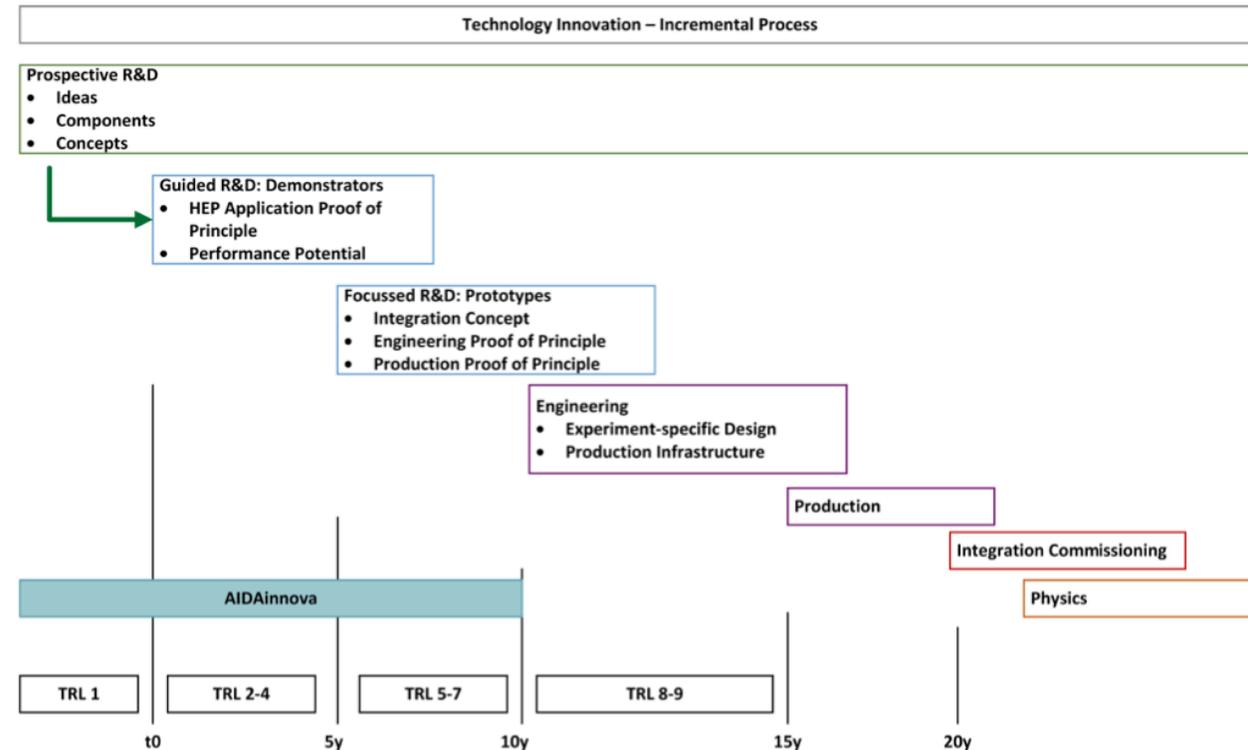
resources awarded to and held by institutes

Categories of R&D

And Sources of Funding

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) **vision**
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) **focus**
3. "Blue-sky" R&D
(competitive, short-term responsive grants, nationally organised) **agility**

Transitions Blue-sky → Strategic → Specific expected
Cross-fertilisation desired



Status of implementation:

- Discussions with existing RD50 and RD51 Collaborations (semiconductor and gaseous detectors, respectively) have been held (July, follow-up in September), on how the transition can be realised
- Consensus by all that new structure is needed and should be in place when HL-LHC detector construction is completed (**HL-LHC deliverables have to be prioritised by many / all institutes**);
 - Start-up of DRD Collaborations: January 2024 (also linked to end of approval of RD50/51 in Dec. 2023)
 - Ramp-up of the proposed resources (personnel, money) through 2025
 - Steady state by 2026
- Same start-up dates targeted for most of the DRD collaborations in the other areas
- Setting up: bottom-up approach involving the full community; (**→ timeline on separate slide**)

To be coordinated by the **ECFA Task Force leaders with strong participation of existing RD managements**
(**First meeting with full Roadmap Panel (TF leaders) was held on 23 August**)
- ECFA will accompany this process
(**regular meetings to discuss progress and upcoming issues every 6-8 weeks;**
RD50/51 management, CALICE management invited, together with Joachim Mnich and Manfred Krammer)

Further Feedback

And Progress

TF1: Gas

- see RD51, to integrate RPCs and large volumes

TF2: Liquids

- support and welcome the opportunity to realise a structures program

TF3: Silicon

- see RD50

TF4: PID and Photodetectors

- on boards, sub-structure to reflect 2 different areas

TF5: Quantum and Emerging

- needs more work, identify strategic targets in view of European Strategy for Particle Physics

TF6: Calorimeter

- constructive attitude of CALICE and other communities

Transverse activities TF7 and TF8

- discussions with CERN EP and LDG

TF7: Electronics

- contacted big labs on ASICs and off-detector electronics

TF8: Integration

- initiative on detector magnets and micro-channel cooling
- substructure likely

TF9: Training

- dedicated ECFA Panel proposed

Suggested Implementation Timeline

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

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

Through 2024, collection of MoU signatures



In short

In AIDA Terminology - with a Grain of Salt

Similarities to AIDA process

- concrete plans, deliverables, resource-loaded (not a wish list)

Differences

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

Steps:

- community input (via existing R&D bodies where possible) by **~end of 2022**
- Work Package structure (Tasks, Participants, Resources, Deliverables, Milestones) by **spring 2023**
- Written proposal by **mid 2023**
 - do not repeat roadmap
 - aim at 20 pages per each of 9 the DRDs (or not much more)
- Review in **fall 23**
- “Grant Agreements” (MoU) in **2024**

Role of Detector Concepts

In the ECFA Study and in the Roadmap Implementation

Primary goal of the detector WG is to demonstrate, as input to the next EPPSU, that detectors can be built that match the precision physics potential of future Higgs factories

- The level of realism of such demonstrations should be comparable between different Higgs factory proposals

The other main goal is to provide guidance for coherent detector R&D efforts to address the priority requirements of Higgs factory experiments

- And to support their funding requests

Software is the underlying tissue

- Detector models for performance evaluation, physics benchmarking and optimisation studies
- Validation and proof of feasibility from R&D

But some Engineering advice and inspiration is also needed:

- Rate, occupancy and bandwidth estimates
- Powering and cooling requirements
- Mechanical constraints

Indispensable ingredient to strategic detector R&D

Support for detector concepts
(software development,
engineering advice)
not part of DRD funding
(in the past: big labs)

ECFA Study WG3 Plans

For the next year

The Roadmap implementation process with its ambitious timescale challenges the detector R&D community

- Meetings, proposals, coordination - heavy load
- Resources for actual work are still at a very low level, and progress moderate

Main priority of WG3 is to support this process

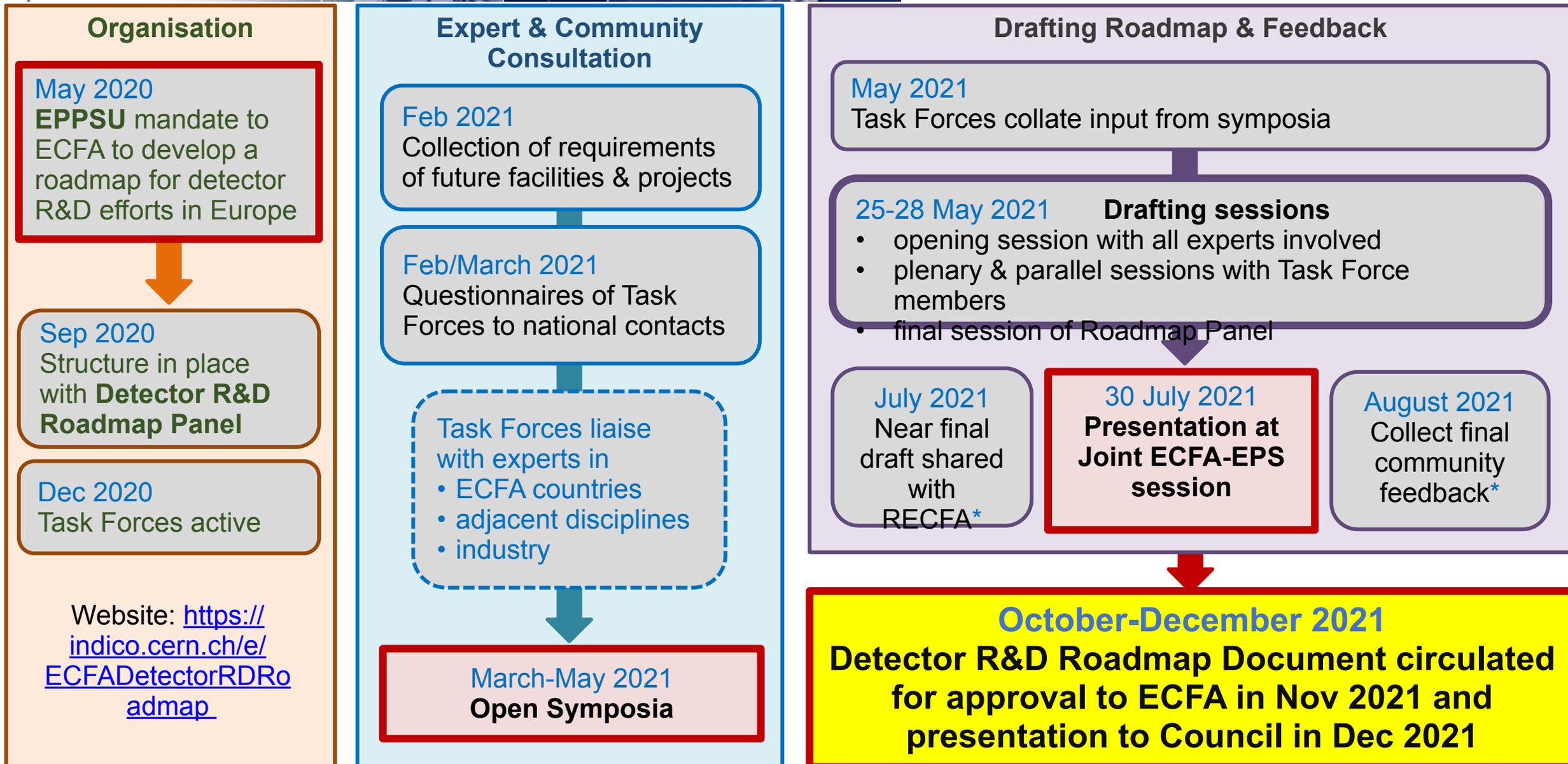
- provide input on detector requirements
- provide a forum for feedback on R&D plans
- help R&D groups to convincingly make their case for a strategic R&D program
- make sure that Higgs factories well represented among other targets of DRDs

Plan a series of workshops

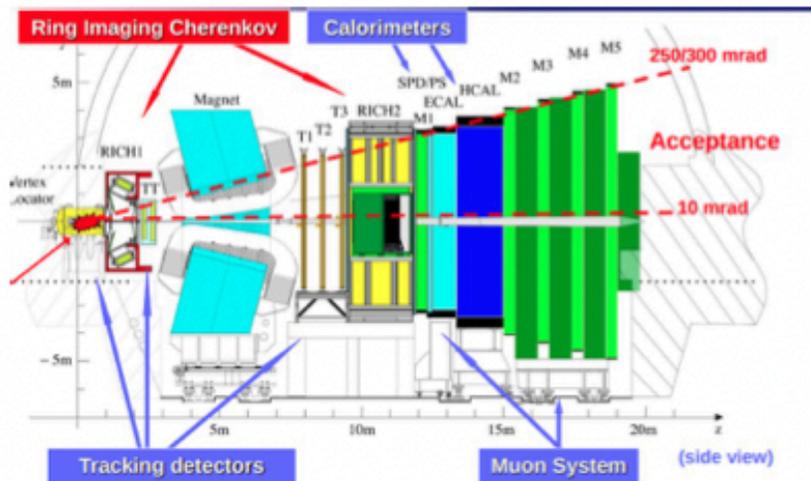
- Tracking and Vertexing for Higgs factories (TF1, TF3)
- Calorimetry and Particle ID for Higgs factories (TF4, TF6)
- Electronics and integration (TF7, TF8) separate or interleaved, t.b.d.

Will also be discussed in individual projects (ILC, FCC), but keep global view and ensure coherence here

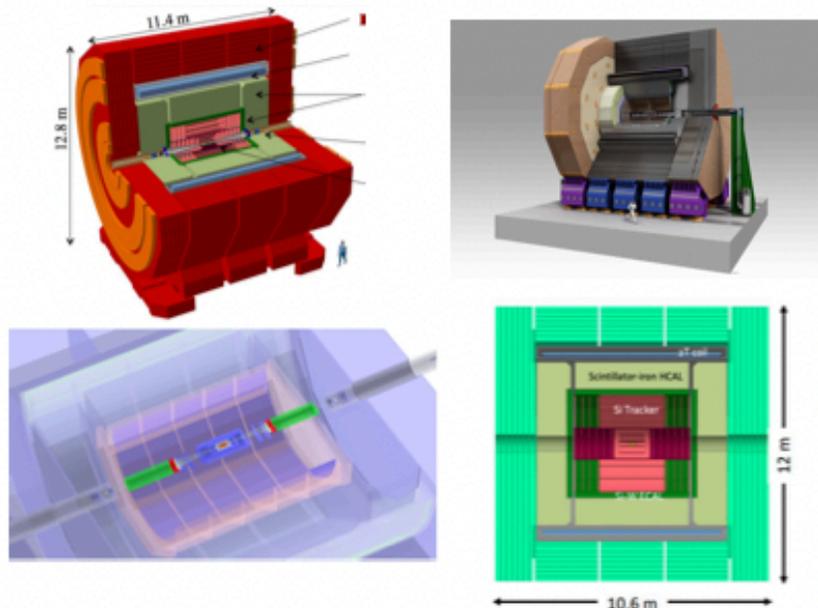
Back-up



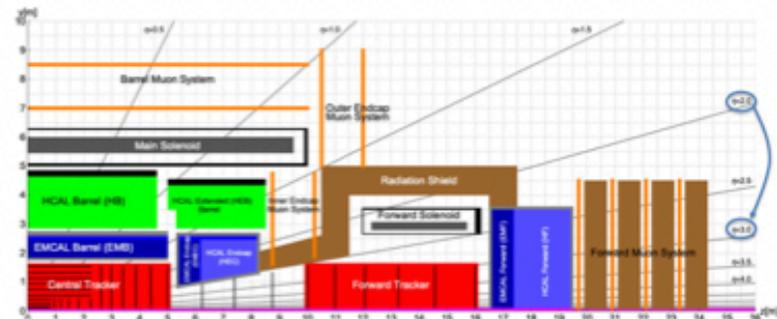
HL-LHC after LS4



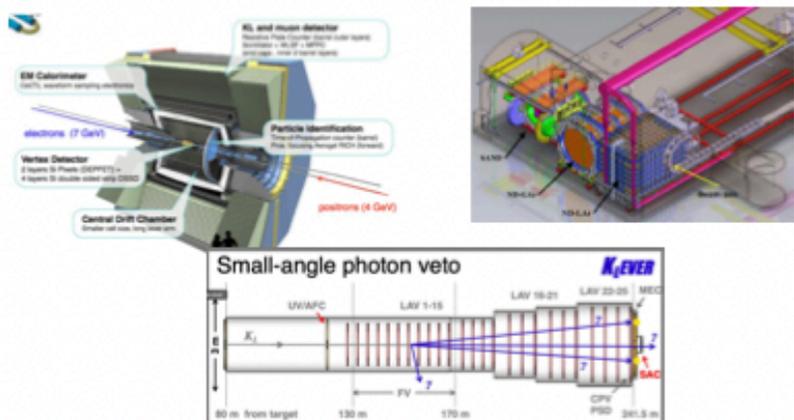
Higgs Factories



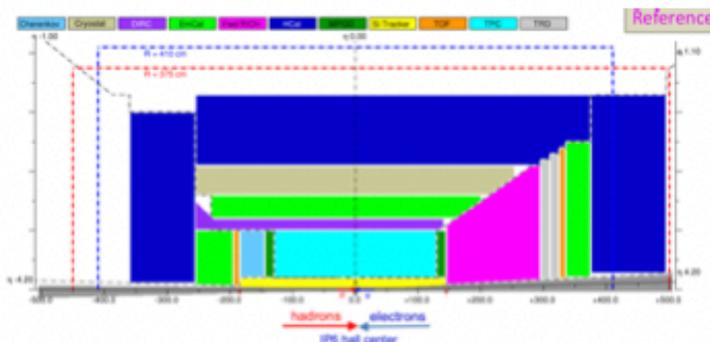
Future hadron colliders (including eh colliders)



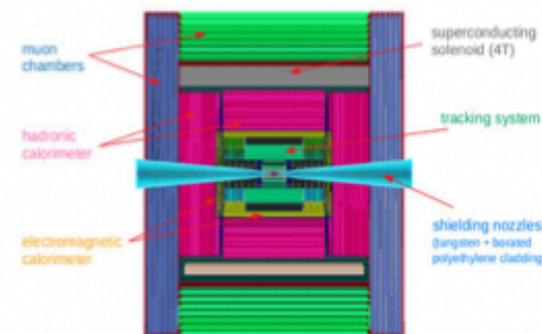
SuperKEKB, DUNE ND and Fixed Target



EiC



Muon Collider



Calorimeter Symposium

Orthogonal Views

Lessons learned: calorimeter upgrade R&D for HL-LHC & by Calice

Speaker: David Barney (CERN)

ECFA_TF6_LessonsL...

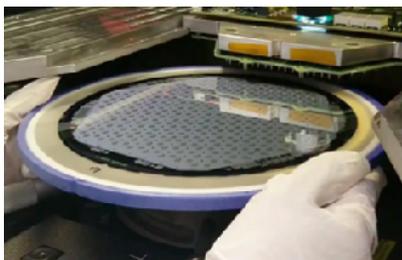
ECFA_TF6_LessonsL...

Precision timing and their applications in calorimetry

Speaker: Nural Akchurin (Texas Tech University (US))

ECFA_PrecisionTimi...

ECFA_PrecisionTimi...



Si based highly and ultra-highly granular calorimeters

Speaker: Vincent Boudry (LLR – CNRS, École polytechnique, Institut P)

ECFA_TF6_SiHGCalo...

ECFA_TF6_SiHGCalo...

ECFA_TF6_SiHGCalo...



Future Noble Liquid Systems

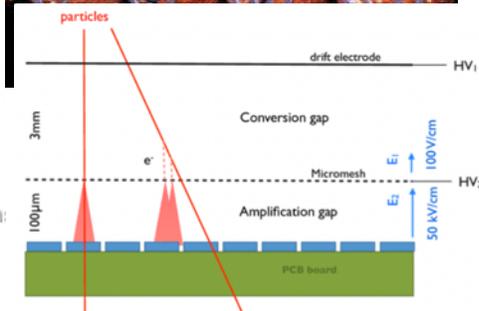
Speaker: Briec Francois (CERN)

ECFA_TF6_NobleLiq...

Gaseous calorimeters

Speaker: Maria Fouz Iglesias (Centro de Investigaciones Energéticas)

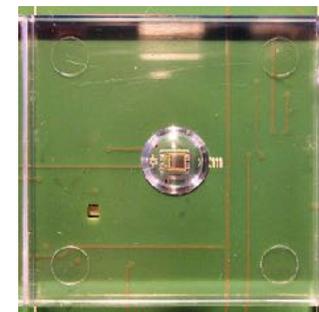
ECFATF6_GaseousD...



Tile and strip calorimeters

Speaker: Katja Kruger (Deutsches Elektronen-Synchrotron (DE))

TF6_Tiles_strips_v2...



Crystal calorimetry

Speaker: Marco Toliman Lucchini (Princeton)

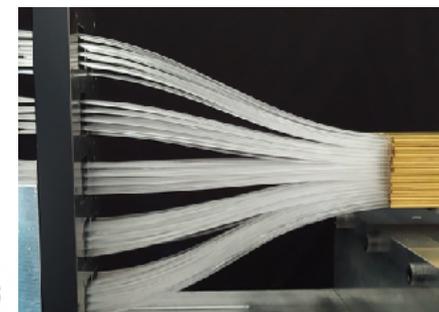
2021_05_07_ECFA_T...



R&D for Dual-Readout fibre-sampling calorimetry

Speakers: Gabriella Gaudio (INFN-Pavia), Gabriella Gaudio (CERN)

20210407_DualRead...



Compact and high performant readout systems

Speaker: André David (CERN)

20210507 ECFA TF6 ...

Symposia shed light along the technological direction
<https://indico.cern.ch/event/999820/>

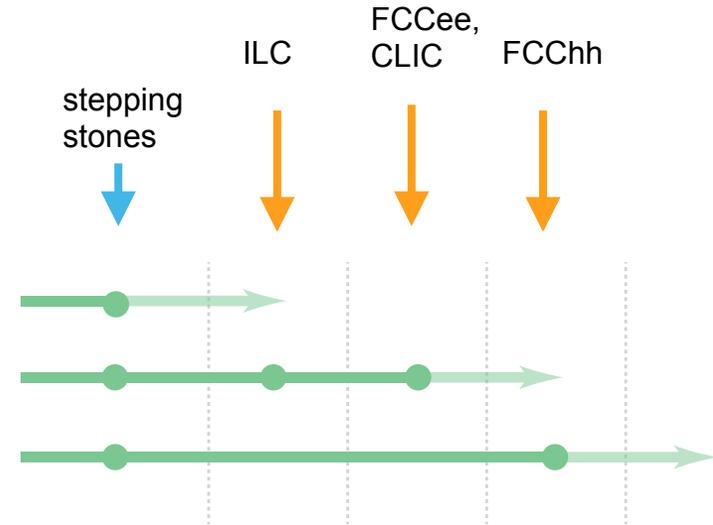
ECFA Detector Roadmap Summary: TF6

Relating Technology R&D to Major Drivers from Facilities

Example:
Calorimeters

Calorimetry

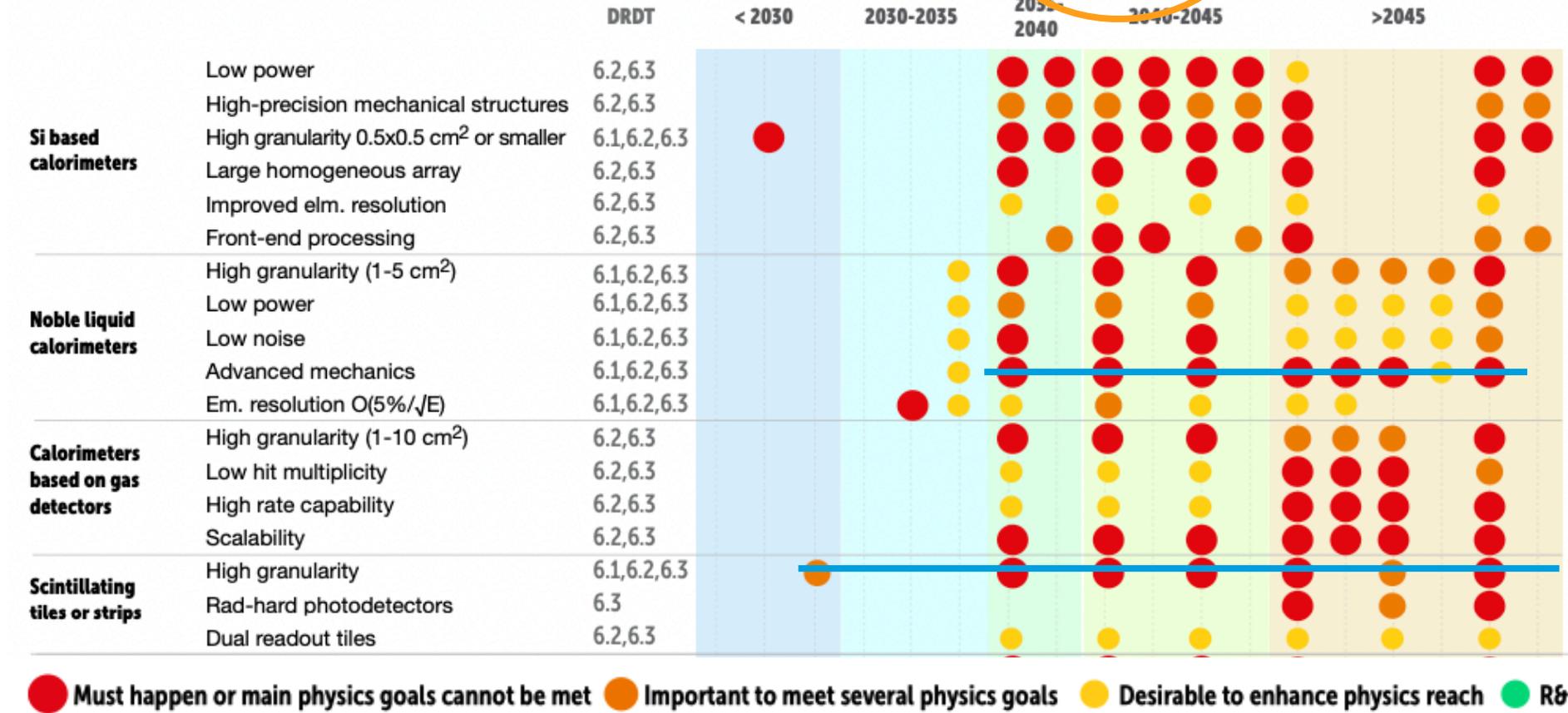
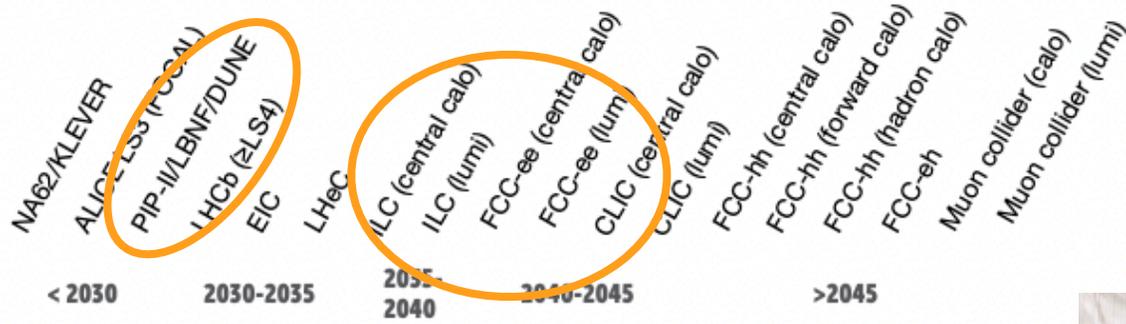
- DRDT 6.1** Develop radiation-hard calorimeters with enhanced electromagnetic energy and timing resolution
- DRDT 6.2** Develop high-granular calorimeters with multi-dimensional readout for optimised use of particle flow methods
- DRDT 6.3** Develop calorimeters for extreme radiation, rate and pile-up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



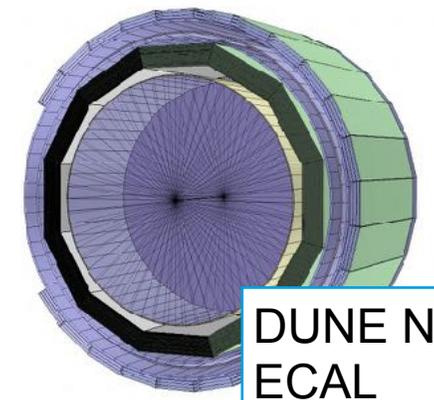
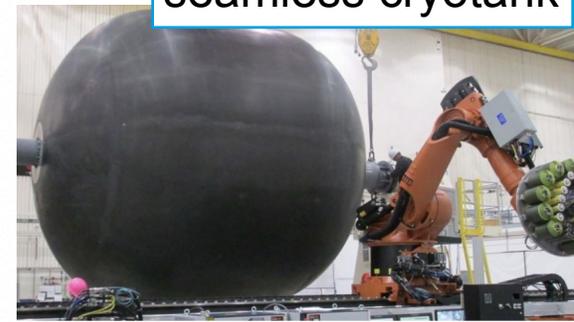
Synergies, Stepping Stones, R&D collaborations

Looking Across the Fence, and Beyond Tomorrow

Example:
Calorimeters



NASA
seamless cryotank



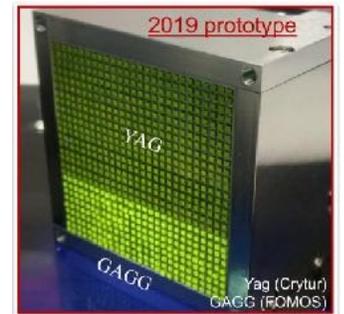
DUNE ND
ECAL

● Must happen or main physics goals cannot be met ● Important to meet several physics goals ● Desirable to enhance physics reach ● R&D needs being met

Synergies, Stepping Stones, R&D collaborations

Looking Across the Fence, and Beyond Tomorrow

Example:
Calorimeters



Fast timing
SPACAL

● Must happen or main physics goals cannot be met ● Important to meet several physics goals ● Desirable to enhance physics reach ● R&D needs being met

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.

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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.

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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.

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Recruiting, salaries

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Open Access publications

- **The detector roadmap depicts a rich landscape of connected R&D activities**
- **It exhibits synergies between parallel activities targeted at different future projects at different facilities**
- **Opportunities appear where near-term projects with less demanding conditions may serve as stepping stones for a strategic R&D targeting more aggressive requirements**
- **General strategic recommendations capture the needs of an evolving field with central importance for our future ambitions**

AIDAinnova focusses on Strategic R&D in the pre-TDR phase

- Technology Readiness Levels 2-7
- Not yet experiment-specific: potential to unfold synergies

Include some prospective R&D

- competitive call at start of project
- “Blue Sky”, quantum sensors,...

Targeted applications

- Higgs Factories
- ALICE, LHCb LS3 pre-TDR, ATLAS & CMS LS4
- Accelerator-based neutrino experiments
- and others

