ECFA Detector R&D Roadmap
Towards Detector R&D (DRD)Collaborations

With focus on Calorimetry

Roman Pöschl
TF6+ Task Force

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Felix Sefkow, Frank Simon

IAS@HKUST – February 2023

Many slides shown hereafter inspired by/stolen from talks by K. Jakobs, P. Allport and F. Sefkow

European Particle Physics Strategy Update

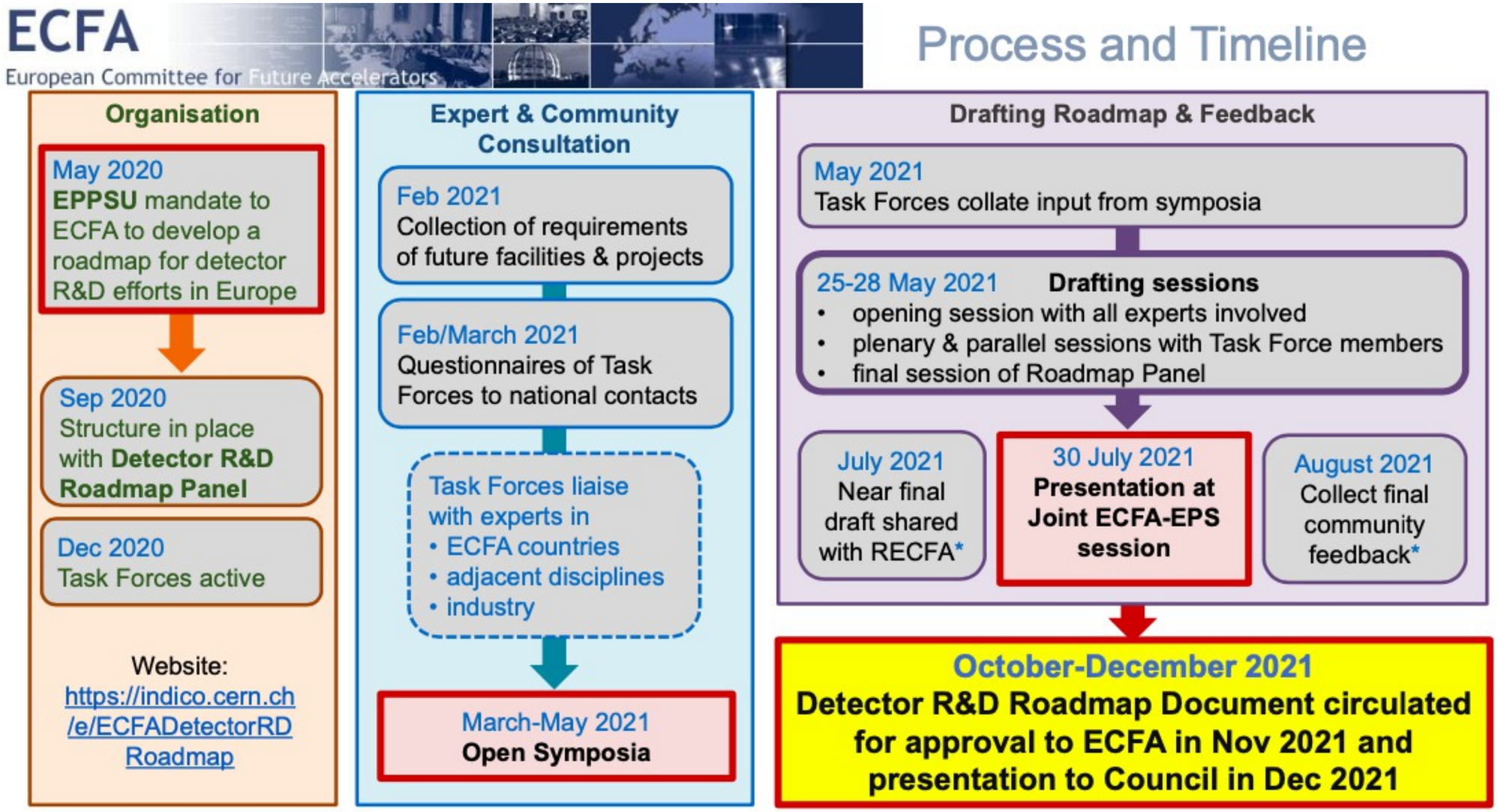
"Main report: ***"Recent initiatives with a view towards strategic R&D on detectors are being taken by CERN's EP department and by the ECFA detector R&D panel, supported by EU-funded programmes such as AIDA and ATTRACT. Coordination of R&D activities is critical to maximise the scientific outcomes of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

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

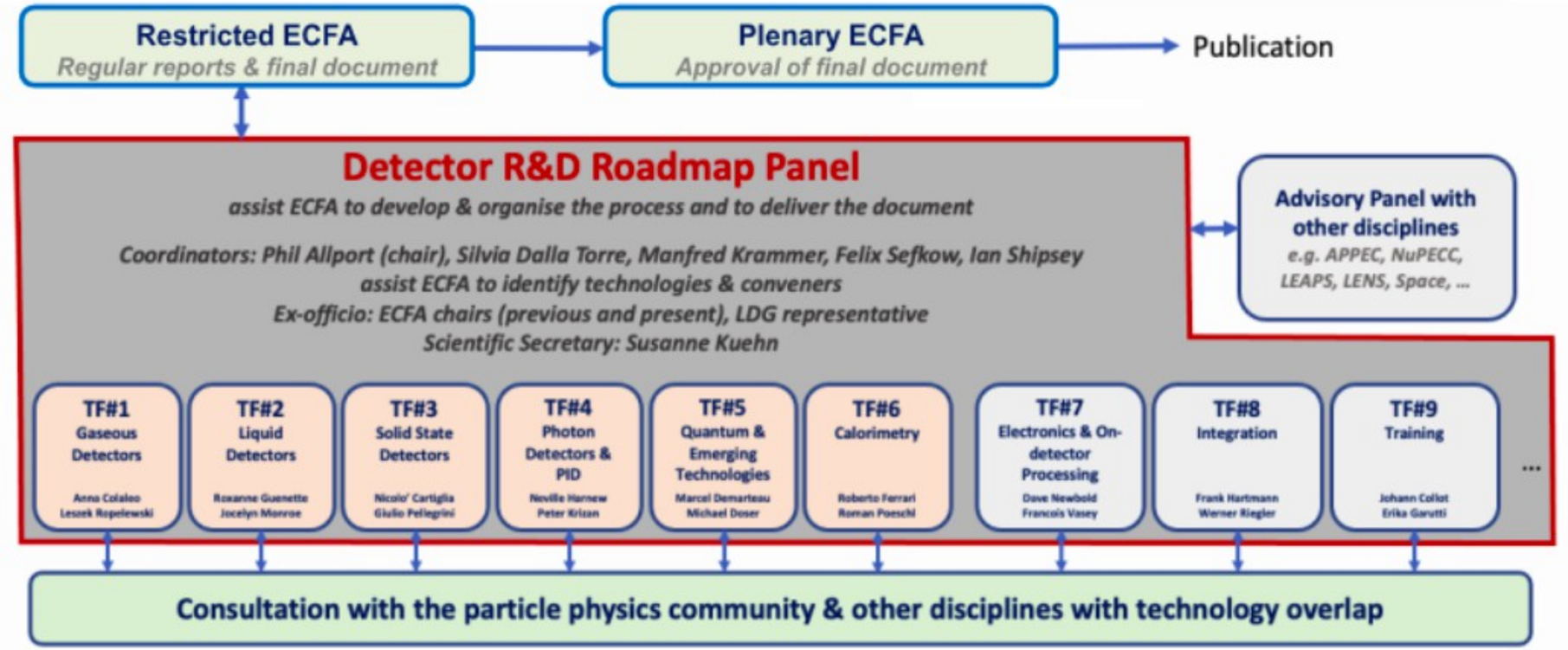
Extracted from the documents of the EPPSU 2020: https://europeanstrategyupdate.web.cern.ch/

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

Reminder on the roadmap process



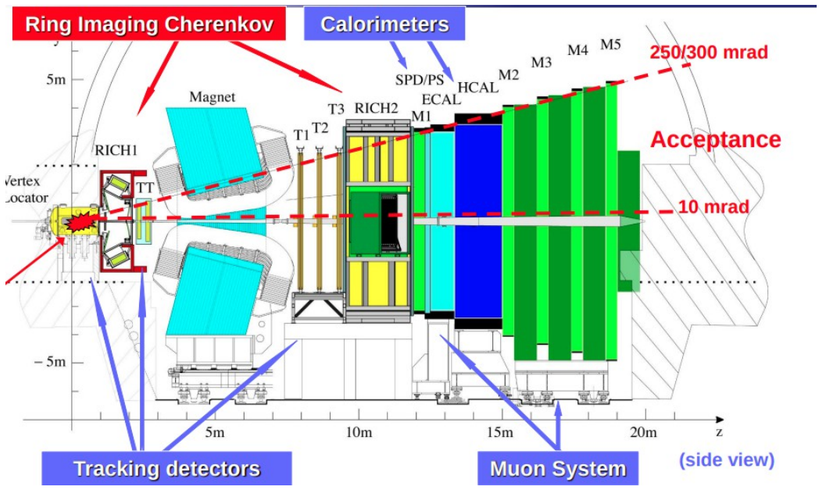
Roadmap process - Organisation



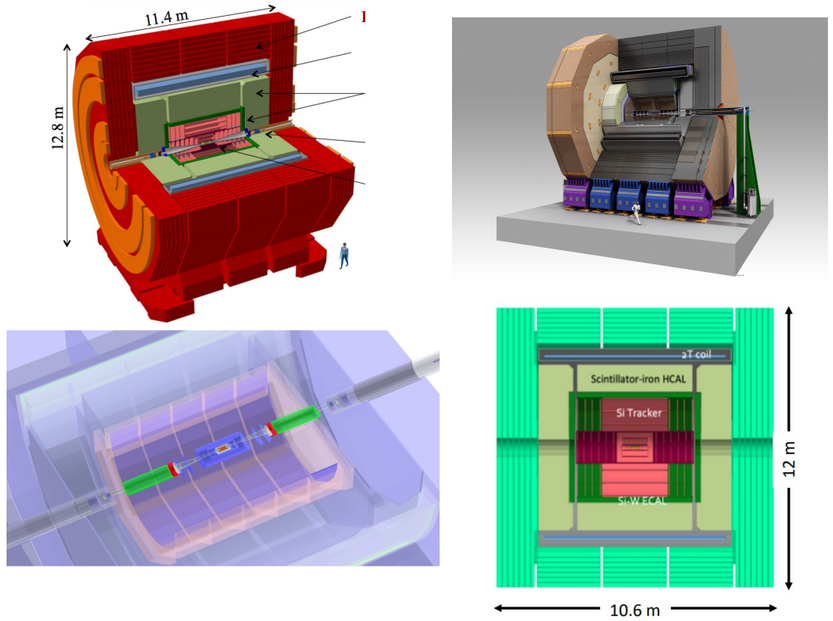
- 9 Taskforces including TF6 on Calorimetry
- Central events: Symposia
  - TF6 Symposium https://indico.cern.ch/event/999820/
- More on roadmap process https://indico.cern.ch/event/957057/

(Main) Target Projects of Detector R&D

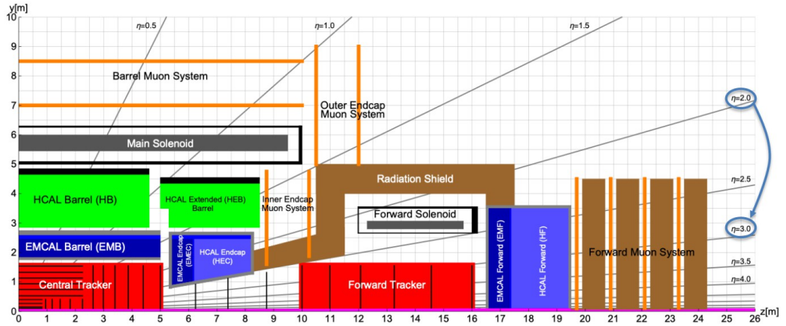
HL-LHC after LS4



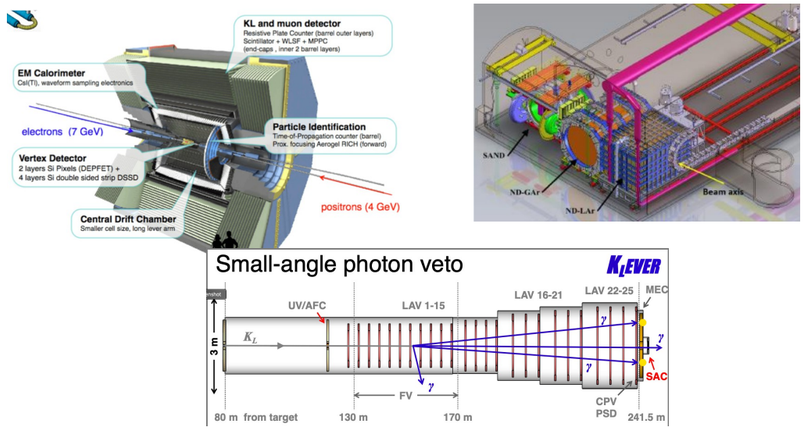
Higgs Factories



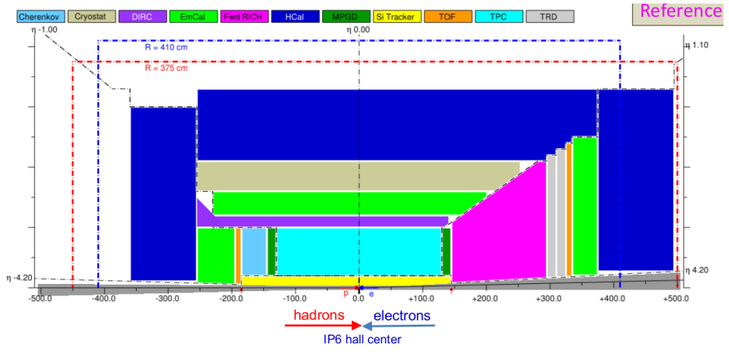
Future hadron colliders (including eh colliders)



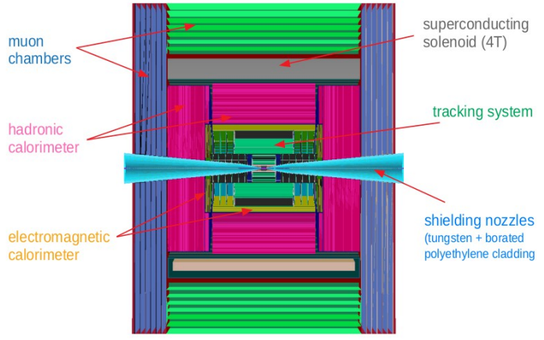
SuperKEKB, DUNE ND and Fixed Target



EiC



Muon Collider



Review Input Sessions – Overview Table

Project	~Earliest Start of data taking	Current Calorimeter options					
		Solid state	Scintilling tiles/strips	Crystals	Fibre based r/o (including DR)	Gaseous	Liquid Noble Gas
HL-LHC (>LS4)	2030			✔	✔		
SuperKEKb (>2030)	2030			✔			
ILC	2035	✔	✔			✔	
CLIC	2045	✔	✔				
CEPC	2035	✔	✔	✔	✔	✔	✔
FCC-ee	2045	✔	✔	✔	✔	✔	✔
EiC	2030		✔	✔	✔		
FCC-hh (eh)	>2050	✔	✔				✔
Muon Collider	> 2050	✔	✔	✔	✔	✔	
Fixed target	“continous”		✔	✔	✔		✔
Neutrino Exp.	2030		✔				(✔)

In most of the cases final choices have still to be made

The roadmap document(s)

- ECFA R&D Roadmap
  - CERN-ESU-017 https://cds.cern.ch/record/2784893
  - 248 pages full text and 8 page synopsis

- Endorsed by ECFA and presented to CERN Council in December 2021

The Roadmap has identified
  - General Strategic Recommendations (GSR)
  - Detector R&D Themes (DRDT) for each of the taskforce topics
  - Concrete R&D Tasks

- Timescale of projects as approved by European Lab Director Group (LDG)

Guiding principle: Project realisation must not be delayed by detectors

General Strategic Recommendations

GSR1- Supporting R&D facilities

GSR2- Engineering support for detector R&D

GSR3- Specific software for instrumentation

GSR4- International coordination and organisation of R&D activities

GSR5- Distributed R&D activities with centralised facilities

GSR6- Establish long-term strategic funding programmes

GSR7- 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

For completeness – All Detector R&D Themes

ECFA Detector Roadmap Summary

Relating Technology R&D to Major Drivers from Facilities

stepping stones, ILC, FCC, CLIC, FCC-hh µ-Coll.

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

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

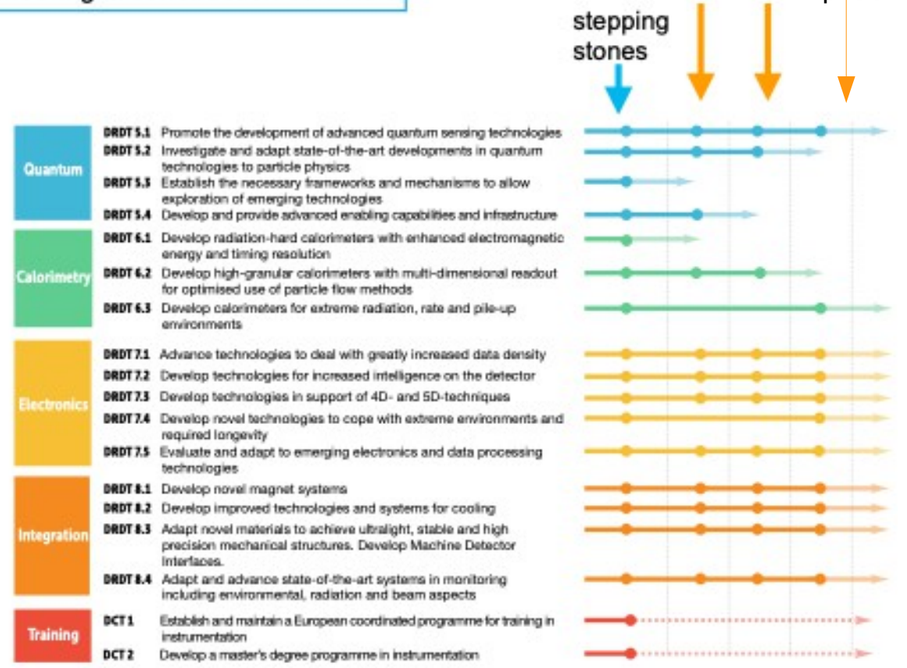
< 2030 | 2030-2035 | 2035-2040 | 2040-2045 | > 2045

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



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).

F. Sefkow, CALICE Meeting and ECFA Higgs/top/EW Factory Meeting

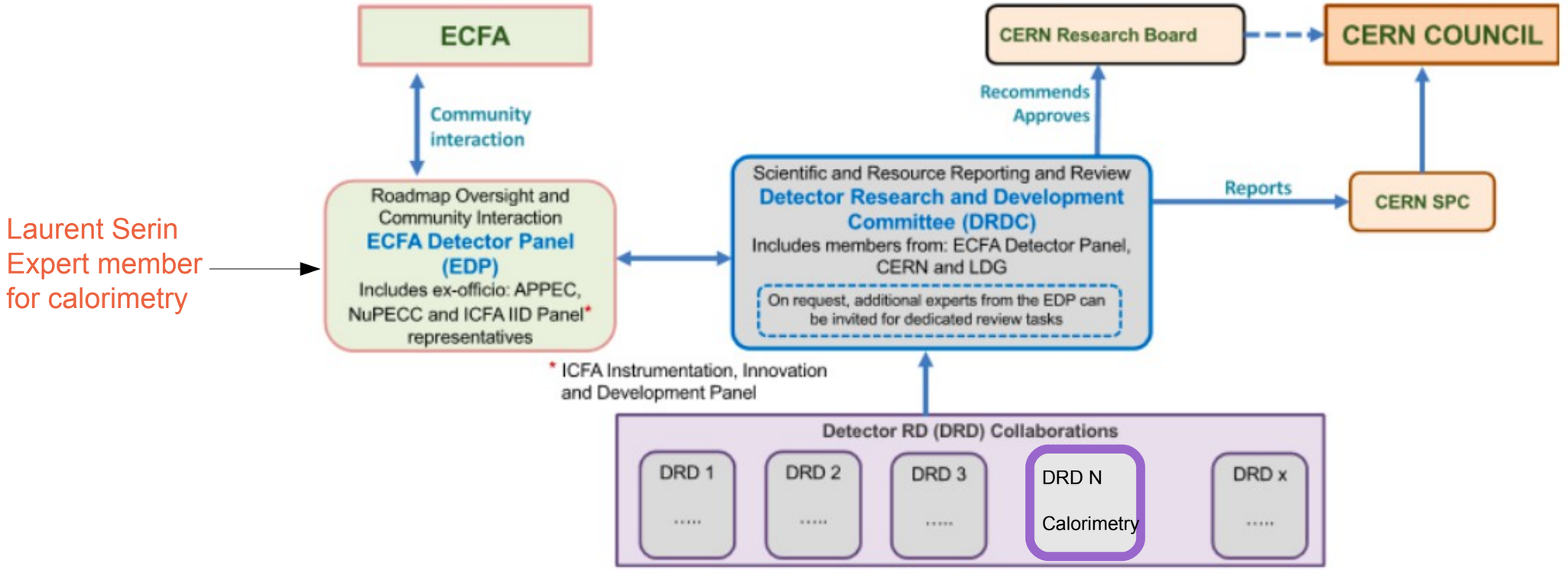
Developments in 2022

> *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***

K. Jakobs, ECFA Meeting, November 2022

- ECFA Roadmap Coordination group has worked out a proposal
  - P. Allport, S. Dalla Torre, J. D'Hondt, K. Jakobs, M. Krammer, S. Kühn, F. Sefkow and I. Shipsey
- Proposal went through discussions with RECFA, National ECFA Contacts, CERN SPS and Council as well as with existing R&D Collaborations
- Document sent to and endorsed by CERN Council in September 2022 (CERN/SPC/1190)
- Main outcomes are the organization of the Detector R&D in form of DRD Collaborations, the overall Organisation of the detector R&D and an outline of the way towards the formation of the DRD

Future Organisation of Detector R&D (in Europe)

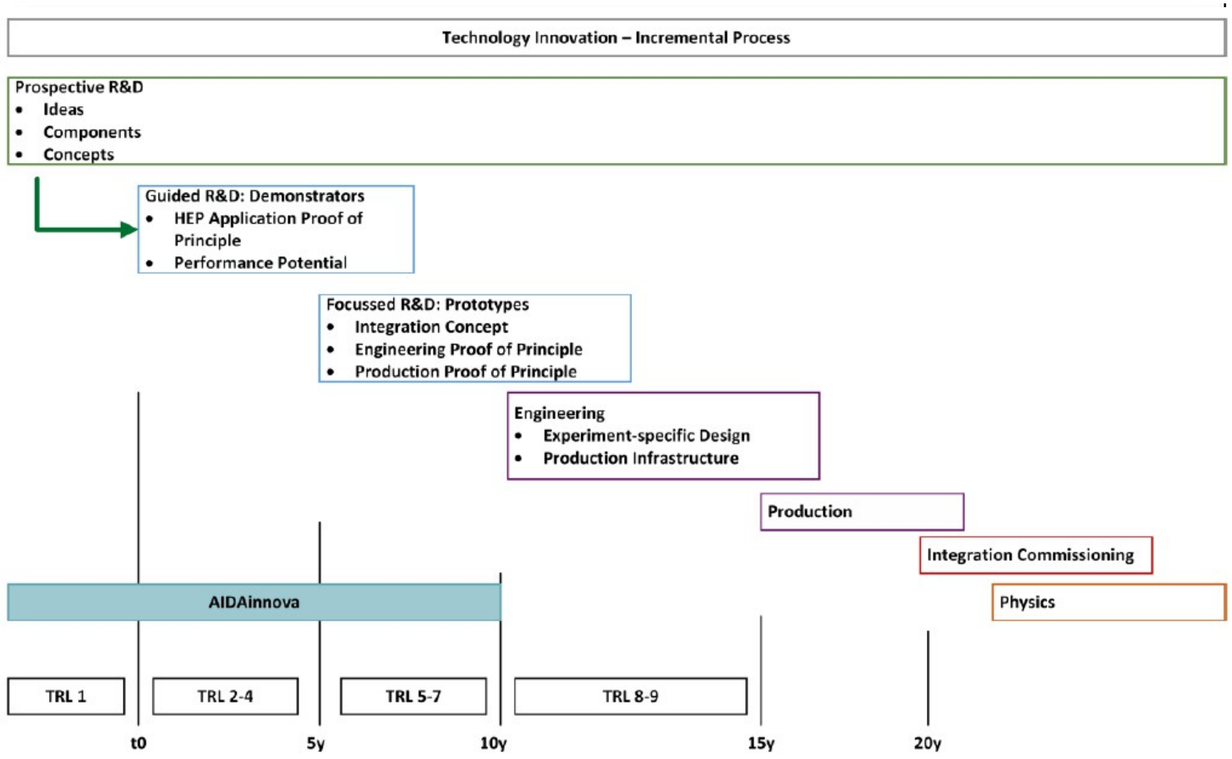


- DRD will have a CERN recognition but they **will not be** CERN Collaborations (“anchored at CERN”)
  - Significant participations by non-European groups is explicitly welcome and needed
- The progress and the R&D will be overseen by a DRDC that is assisted by ECFA
  - Availability and usage of resources, monitoring of progress, vetting agains Roadmap objectives
  - CERN Research Director is preparing setting up the DRDC
- The funding will come from national resources (plus eventually supranational projects)

Categories of R&D

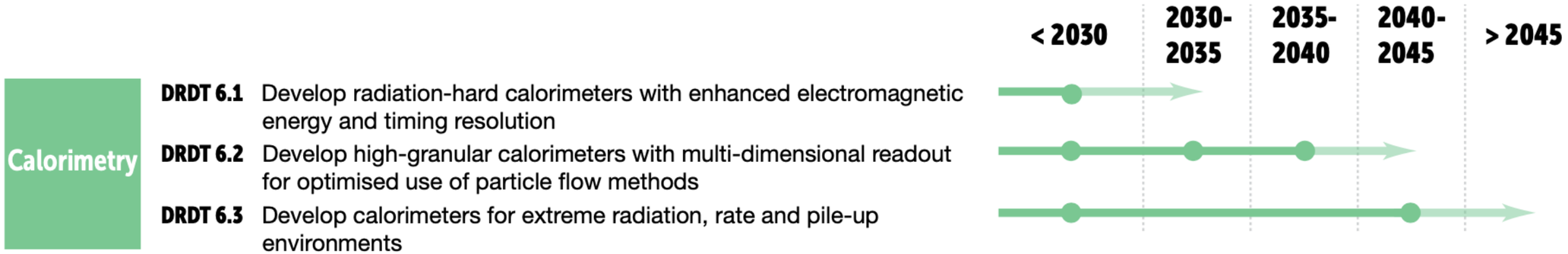
1. Strategic R&D via DRD Collaborations **vision**
   (long-term strategic R&D lines)
   (address the high-priority items defined in the Roadmap via the DRDTs)
2. Experiment-specific R&D **focus**
   (with very well defined detector specifications)
   (funded outside of DRD programme, via experiments, usually not yet covered within the projected budgets for the final deliverables)
3. "Blue-sky" R&D **agility**
   (competitive, short-term responsive grants, nationally organised)

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



F. Sefkow, CALICE Meeting and ECFA Higgs/top/EW Factory Meeting

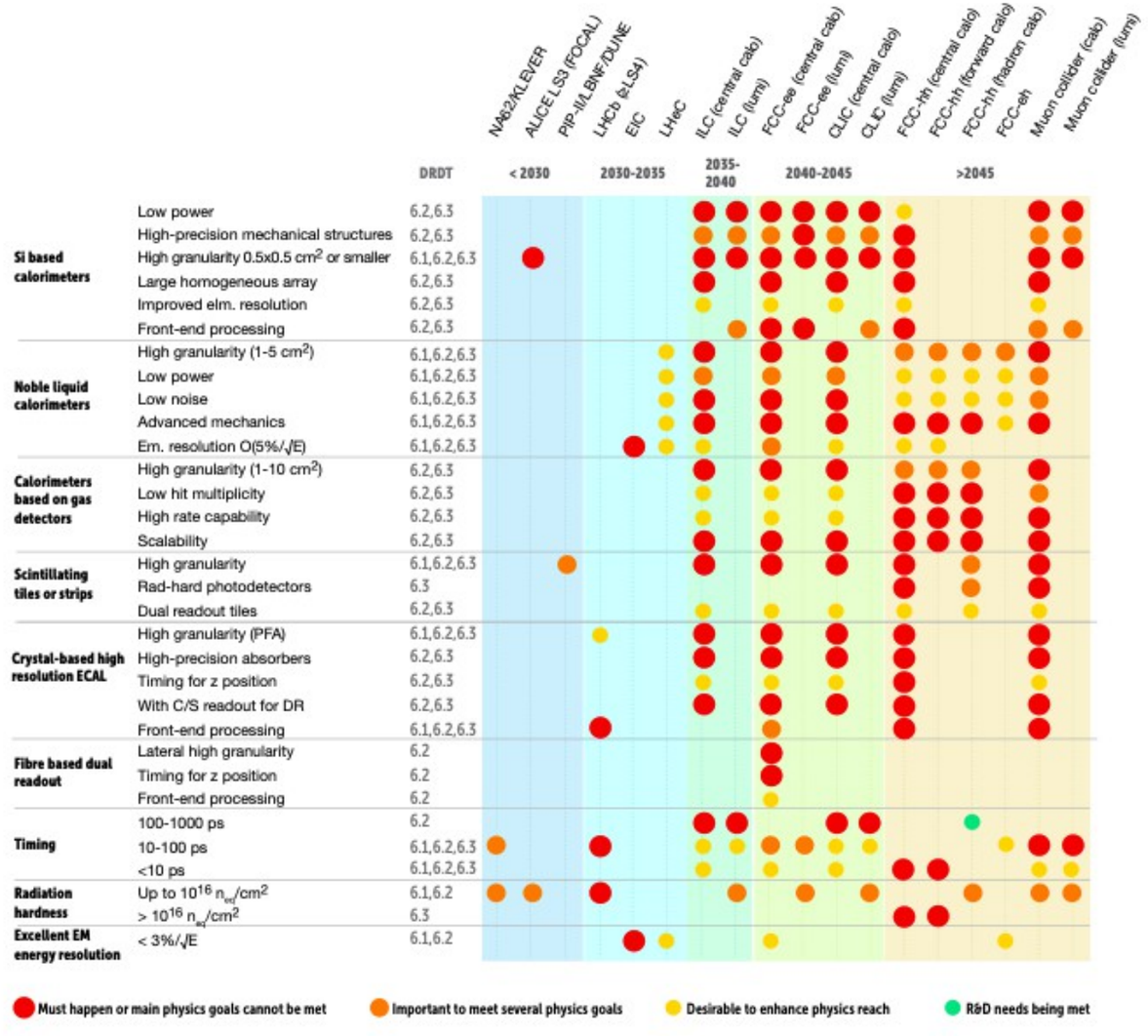
Future Facilities and DRDT for Calorimetry



- The DRDT and the provisional time scale of facilities set high-level boundary conditions
  - See next slide for detailed R&D tasks
- Both as well as the GSR should be taken into account when formulating the R&D proposal(s)

Identified Key Technologies and R&D Tasks

- Key technologies and requirements are identified in Roadmap
  - Si based Calorimeters
  - Noble Liquid Calorimeters
  - Calorimeters based on gas detectors
  - Scintillating tiles and strips
  - Crystal based high-resolution Ecals
  - Fibre based dual readout
- R&D should in particular enable
  - Precision timing
  - Radiation hardness
- R&D Tasks are grouped into
  - Must happen
  - Important
  - Desirable
  - Already met



Toward DRD – 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

K. Jakobs, ECFA Meeting November 2022

Towards DRD – Indico pages for implementation phase

- https://indico.cern.ch/category/12772/
  - Choose you favorite topic and register to get information on the progress

- Each community organises the implementation phase somewhat differently
  - There is no blueprint for what we are doing (at least for concerns detector R&D)

- Community Meetings DRD other than Calorimetry (known to me)
  - TF1/DRD Gaseous detectors: 1-3 Mars at CERN
  - TF3/DRD Solid State Detectors: 22-23 March at CERN
  - TF7/DRD Electronics and data processing: 14-15 March at CERN

Reminder on today's “eco system” for calorimetry

- European projects such as AIDAinnova and EURO-Labs
- CERN EP R&D Programme
- Existing collaborations (LHC Experiments, Belle II, DUNE, NA62, KLEVER, ...)
- R&D Collaborations and communities (CALICE, FCAL, CrystalClear, GranuLAr, CalVision ...)
- Detector concept groups (ILD, SiD, CLICdp, FCC Detector with LAr, IDEA, CEPC Detectors, EpiC, ...)

Towards Implementation of DRD Calorimetry

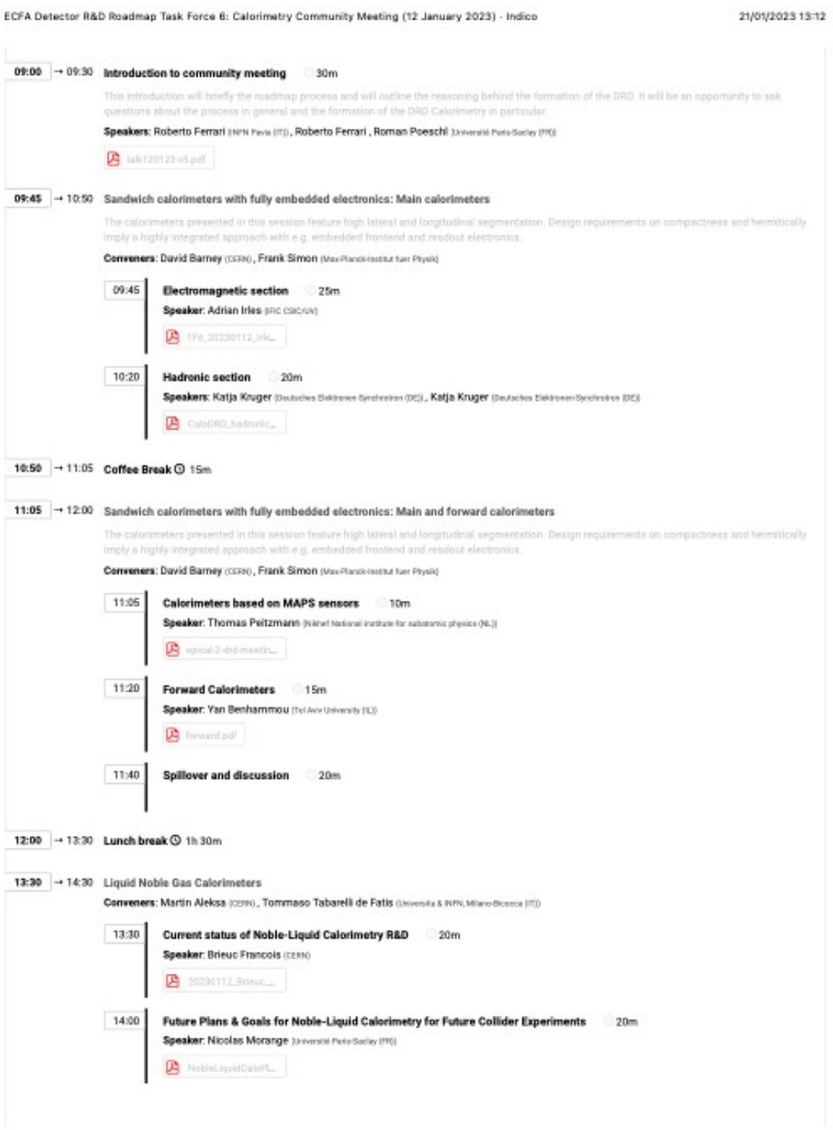
- **Entry point, "DRD Calo indico page": https://indico.cern.ch/category/12772/**
  - Information on important events and access to relevant documents
  - Note also the Q&A Doc
  - 204 people from four regions registered so far

- 1st Community Meeting 12/1/23
  - https://indico.cern.ch/event/1212696/
  - See also next slides

- Proposal phase until 1st of July 2023
  - **Input-proposals until latest 24th of March 2023**
    - Proposal team (see later) will get in contact with stakeholders and ask for input-proposals
    - Contact persons will be assigned for the different topics
  - 2nd Community Meeting 20th April
    - Presentation of input-proposals (w/o disclosing confidential information)
    - Presentation of a WP Structure of DRD Calorimetry
      - Guidance by existing R&D collaborations

  - Input-proposals will be condensed into a DRD on Calorimetry proposal until (around) 1st of June 2023
    - Further iteration with stakeholders, community and higher level bodies

DRD Calorimetry 1st Community Meeting



ECFA Detector R&D Roadmap Task Force 6: Calorimetry Community Meeting (12 January 2023) · Indico 21/01/2023 13:12

09:00 → 09:30 **Introduction to community meeting** 30m

This introduction will briefly the roadmap process and will outline the reasoning behind the formation of the DRD. It will be an opportunity to ask questions about the process in general and the formation of the DRD Calorimetry in particular.

Speakers: Roberto Ferrari (INFN Pavia (IT)), Roberto Ferrari , Roman Poeschl (Université Paris-Saclay (FR))

talk120123-v5.pdf

09:45 → 10:50 **Sandwich calorimeters with fully embedded electronics: Main calorimeters**

The calorimeters presented in this session feature high lateral and longitudinal segmentation. Design requirements on compactness and hermitically imply a highly integrated approach with e.g. embedded frontend and readout electronics.

Conveners: David Barney (CERN), Frank Simon (Max-Planck-Institut fuer Physik)

- **09:45** **Electromagnetic section** 25m
  Speaker: Adrian Irles (IFIC CSIC/UV)
  TF6_20230112_Irle...
- **10:20** **Hadronic section** 20m
  Speakers: Katja Kruger (Deutsches Elektronen Synchrotron (DE)), Katja Kruger (Deutsches Elektronen-Synchrotron (DE))
  CaloDRD_hadronic_...

10:50 → 11:05 **Coffee Break** 15m

11:05 → 12:00 **Sandwich calorimeters with fully embedded electronics: Main and forward calorimeters**

The calorimeters presented in this session feature high lateral and longitudinal segmentation. Design requirements on compactness and hermitically imply a highly integrated approach with e.g. embedded frontend and readout electronics.

Conveners: David Barney (CERN), Frank Simon (Max-Planck-Institut fuer Physik)

- **11:05** **Calorimeters based on MAPS sensors** 10m
  Speaker: Thomas Peitzmann (Nikhef National institute for subatomic physics (NL))
  epical-2-drd-meetin...
- **11:20** **Forward Calorimeters** 15m
  Speaker: Yan Benhammou (Tel Aviv University (IL))
  forward.pdf
- **11:40** **Spillover and discussion** 20m

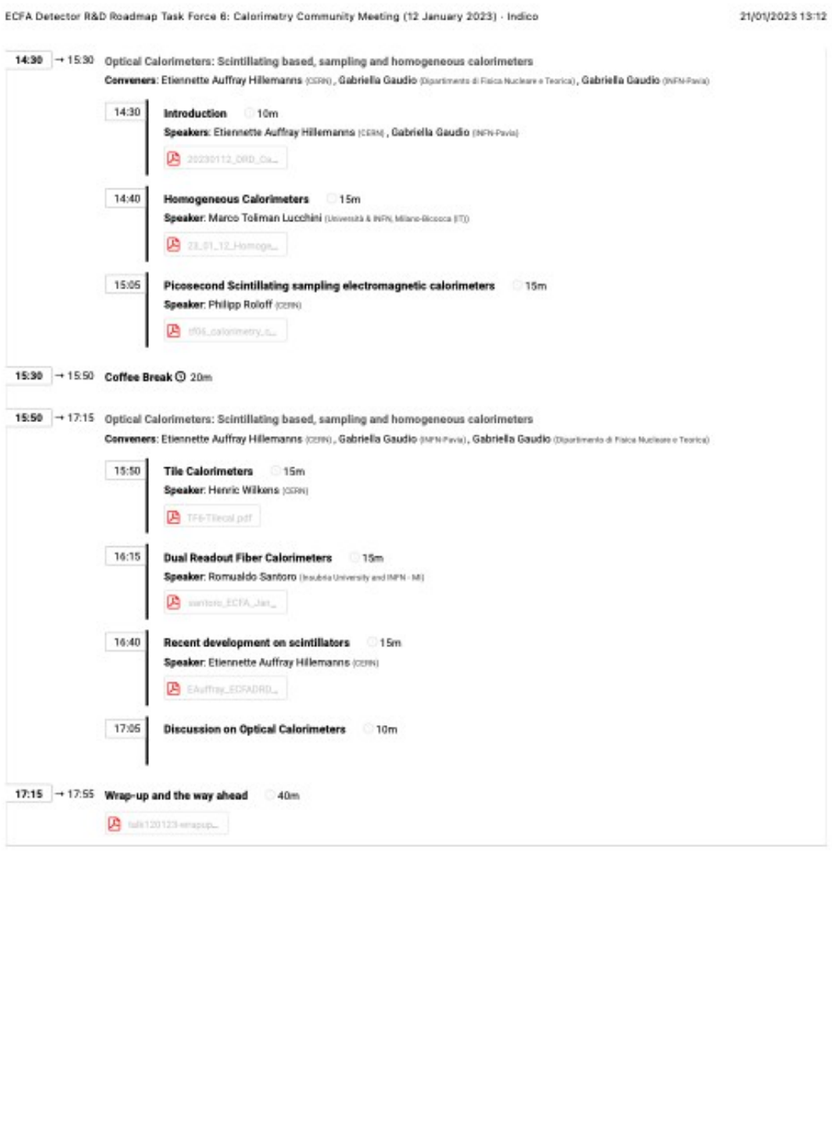
12:00 → 13:30 **Lunch break** 1h 30m

13:30 → 14:30 **Liquid Noble Gas Calorimeters**

Conveners: Martin Aleksa (CERN), Tommaso Tabarelli de Fatis (Università & INFN, Milano-Bicocca (IT))

- **13:30** **Current status of Noble-Liquid Calorimetry R&D** 20m
  Speaker: Brieuc Francois (CERN)
  20230112_Brieuc_...
- **14:00** **Future Plans & Goals for Noble-Liquid Calorimetry for Future Collider Experiments** 20m
  Speaker: Nicolas Morange (Université Paris-Saclay (FR))
  NobleLiquidCaloPL...

https://indico.cern.ch/event/1212696/?print=1 Page 2 of 3



ECFA Detector R&D Roadmap Task Force 6: Calorimetry Community Meeting (12 January 2023) · Indico 21/01/2023 13:12

14:30 → 15:30 **Optical Calorimeters: Scintillating based, sampling and homogeneous calorimeters**

Conveners: Etiennette Auffray Hillemanns (CERN), Gabriella Gaudio (Dipartimento di Fisica Nucleare e Teorica), Gabriella Gaudio (INFN-Pavia)

- **14:30** **Introduction** 10m
  Speakers: Etiennette Auffray Hillemanns (CERN), Gabriella Gaudio (INFN-Pavia)
  20230112_DRD_Ca...
- **14:40** **Homogeneous Calorimeters** 15m
  Speaker: Marco Toliman Lucchini (Università & INFN, Milano-Bicocca (IT))
  23_01_12_Homoge...
- **15:05** **Picosecond Scintillating sampling electromagnetic calorimeters** 15m
  Speaker: Philipp Roloff (CERN)
  tf06_calorimetry_s...

15:30 → 15:50 **Coffee Break** 20m

15:50 → 17:15 **Optical Calorimeters: Scintillating based, sampling and homogeneous calorimeters**

Conveners: Etiennette Auffray Hillemanns (CERN), Gabriella Gaudio (INFN-Pavia), Gabriella Gaudio (Dipartimento di Fisica Nucleare e Teorica)

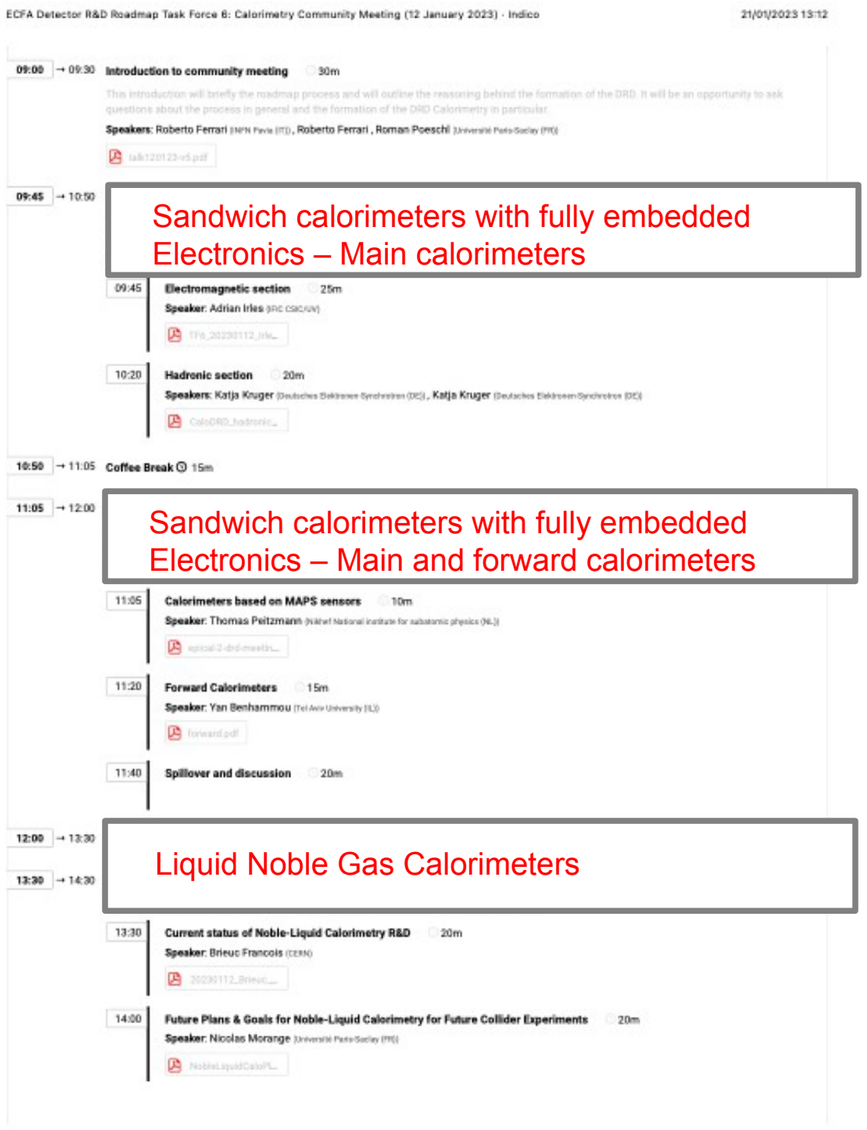
- **15:50** **Tile Calorimeters** 15m
  Speaker: Henric Wilkens (CERN)
  TF6-Tilecal.pdf
- **16:15** **Dual Readout Fiber Calorimeters** 15m
  Speaker: Romualdo Santoro (Insubria University and INFN - MI)
  santoro_ECFA_Jan_...
- **16:40** **Recent development on scintillators** 15m
  Speaker: Etiennette Auffray Hillemanns (CERN)
  EAuffray_ECFADRD_...
- **17:05** **Discussion on Optical Calorimeters** 10m

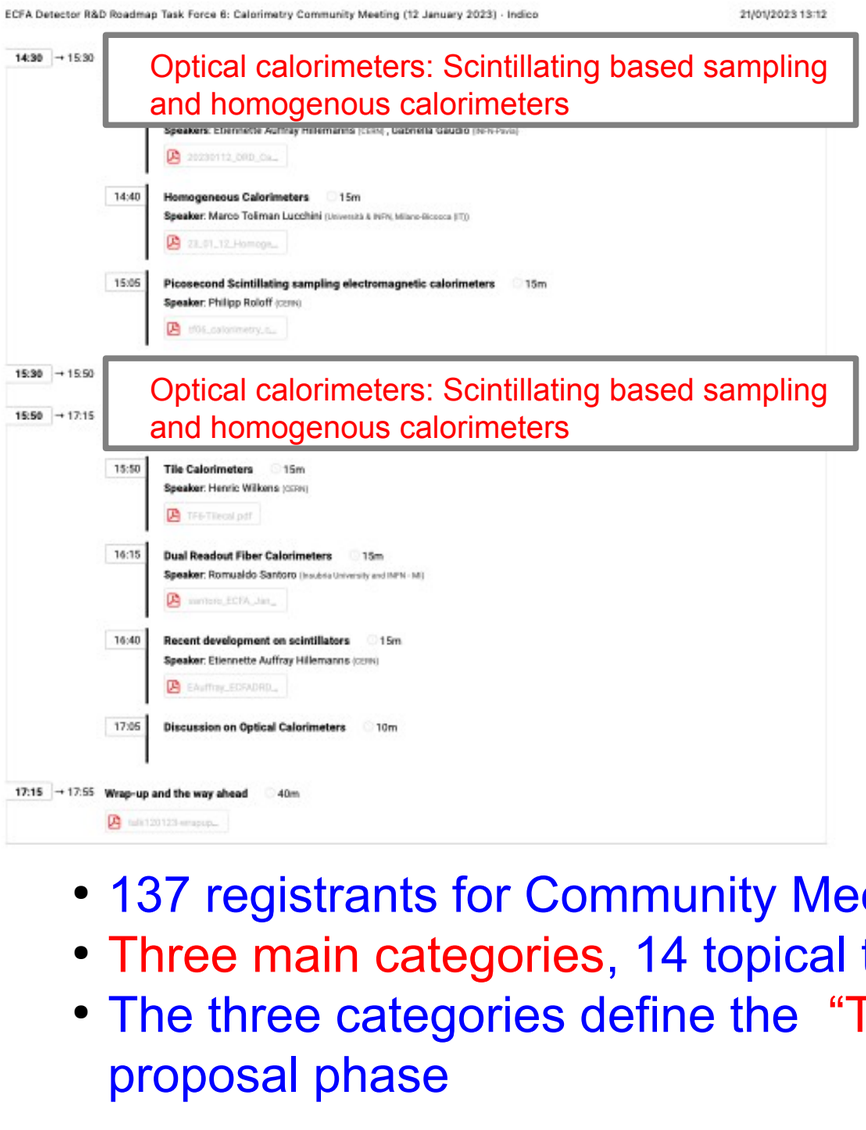
17:15 → 17:55 **Wrap-up and the way ahead** 40m

talk120123-wrapup...

https://indico.cern.ch/event/1212696/?print=1 Page 3 of 3

DRD Calorimetry 1st Community Meeting





- 137 registrants for Community Meeting
- Three main categories, 14 topical talks in total
- The three categories define the "Tracks" for the proposal phase

DRD Calorimetry 1st Community Meeting – Wrap-up I

Nice overview of ongoing calorimetry R&D -> very interesting and positive - not exhaustive (it could not be)

Very lively discussion!

Lots of open challenges over different time scales -> they depend on physics case and machine

Many common issues (not exhaustive):

- High granularity
- Timing -> from O(100) ps down to O(10) ps
- Sensors and readout electronics
- Connectors, mechanical integration, ...
- Infrastructures/facilities (beam test lines, ...)

Many different specific issues

Many synergies with (or dependence on) other TFs -> need transversal collaboration(s)

calorimeters are at the top and bottom of the chain

DRD Calorimetry 1st Community Meeting – Wrap-up II

The interest of the community looks excellent! More than 100 people participating

Way toward proposal:

- 2nd Community Meeting with focus on concrete proposals
  - TF6+ will contact stakeholders and will inform about progresses
  - In any case contact us directly or use Q&A File if you have questions/ideas

some (possible) driving lines

- learn from (i.e. build on top of) existing experiences of collaborative R&D
- think about building light and flexible MoU
- each collaboration will decide its own structure!

We should be able to formulate common goals and synergies

nothing is fixed

- must find the right way to combine/cope with national projects
- must find the right way to combine/cope with existing collaborations or activities

but all is up to us -> we drive the process

DRD Calorimetry – Room for collaboration I

... as indicated at 1st Community Meeting

New active materials:

- Fast, high-density, low-cost, scintillating materials ● Fast and rad-hard WLS fibres

Sensors + FE elx:

- Low x-talk, low-noise, low-power budget
- High granularity → high integration → embedded FE elx
- High-precision timing → from O(100) ps down to O(10) ps
- Radiation hardness
- Si/GaAs sensors: high integration, very-front-end integration, sensor bonding
- CMOS sensors: MAPS, digital SiPMs
- Photosensor architecture: MCP-PMTs, SiPMs, LGADs, ...,
- Photosensor performance: dynamic range, light yield, timing, UV sensitivity, ...
- ASICs: architecture, timing performance
- Components / connectors reliability
- High data rate → on-chip processing (DNN) for data selection and compression

DRD Calorimetry – Room for collaboration II

- Mechanics / production issues:
  - Services:

- Others:
  - Low-material budget
  - High mechanical precision
  - Industrialisation, engineering, scalability → relation w/ industry
  - High-density absorber
  - (e.g. W) production → (e.g.) 3D-printing
  - Cooling
  - Powering and control
  - Clock distribution for O(10) ps timing
  - Beam test infrastructure, setup & DAQ software (EUDAQ)
  - Beam line features + common beam requests
  - MC samples → common benchmarks
  - Software tools (DD4hep, EDM4hep, Key4hep, ...), event-data format (?)
  - Test benches, but also ... PFA and dual readout

add transversal package to cover overarching topics?

On the proposals

- Template for input-proposals
  - https://indico.cern.ch/event/1213733/timetable/#6-proposal-template
  - Oriented at guidelines set out by coordination team

- Input-proposals: Content
  - Brief description of R&D project including a reference to the roadmap
  - Where applicable a sketch of synergies inside and outside of DRD Calorimetry
  - “External needs” like test facilities, software framework etc.

- Input-proposals: Important Formalities
  - Set of tables on R&D projects with Milestones and Deliverables
  - A list of interested institutes associated with the R&D projects
    - This can be European and also non-European Groups
  - An overview on (eventually) existing and needed resources (confidential information)
    - Again, European and non-European resources
  - The length of these input-proposals should be of the order of 5-10 pages

- Proposal with plans and general overview on resources (20 pages per DRD)

Proposal Team – Current Composition

Track 1: Sandwich calorimeters with fully embedded Electronics – Main and forward calorimeters

Track conveners: Adrian Irles (IFIC, adrian.irles@ific.uv.es), Frank Simon (KIT, frank.simon@kit.edu)

Track 2: Liquified Noble Gas Calorimeters

Track Conveners: Martin Aleksa (CERN, martin.aleksa@cern.ch), Nicolas Morange (IJCLab, nicolas.morange@ijclab.in2p3.fr)

Track 3: Optical calorimeters: Scintillating based sampling and homogenous calorimeters

Track Conveners: Etiennette Auffray (CERN, etiennette.auffray@cern.ch), Gabriella Gaudio (INFN-Pavia, gabriella.gaudio@pv.infn.it), Macro Lucchini (University and INFN Milano-Bicocca, marco.toliman.lucchini@cern.ch), Philipp Roloff (CERN, philipp.roloff@cern.ch)

Track 4: Alternatives or transversal proposals.

Watched by entire proposal team

Final remarks

- This year will see the implementation of the ECFA Detector R&D Roadmap

- Formation of DRDs that conduct the strategic R&D formulated in the roadmap
  - DRD are expected to be in place in meanwhile less than one year from now!!

- The Implementation process builds upon confirmed panels and established detector R&D Communities
  - However, there is no real blueprint for what we are doing (at least what concerns Detector R&D)
  - Each DRD will decide on its own structure, likely starting from the experience of existing collaborations and working groups

- The proposal phase of DRD on Calorimetry has just been launched
  - Looking forward to your interesting proposals

Backup

Testbeam facilities – General remarks

- Let us first thank the beam test and radiation facilities operators and the lab and institute managements for the availability of the facilities

- The importance of beam tests during detector development cannot be overrated
  - Recent refurbishment of various beam test sites witness that this is recognised by the lab managements

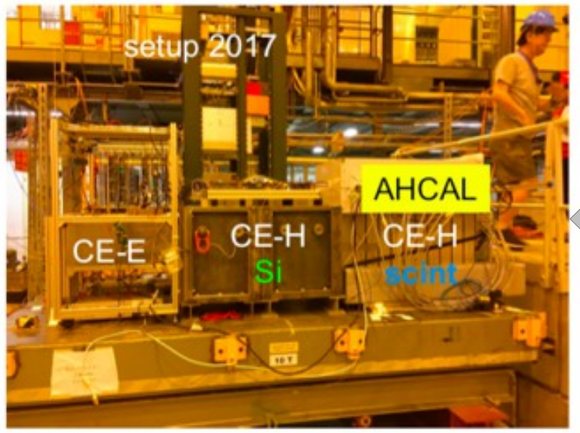
- Maybe more than other detectors calorimeters need a large variety of particle momenta, particle types and beam rates

- The portfolio of the EPPSU comprises projects supposed to run between now and 2080-2090
  - During all these decades we need versatile beam test and radiation facilities to accompany the R&D program
  - ... including competent staff to run these facilities (-> investment in accelerator and instrumentation experts)
  - CERN will continue to be the only side with real high energy beam
  - Maybe some steps can be executed with powerful computing, AI or whatever the future brings
  - However, it can never be desirable that the first beam a detector sees is the beam in the final experiment
    - Despite the fact that the return vessel of Apollo 11 has also never been tested before ;-)

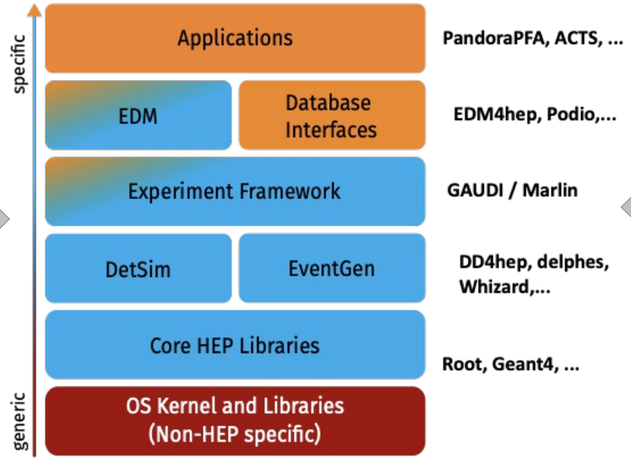
- A future hadron collider would require to make a test beam facility part of the LHC programme

Software

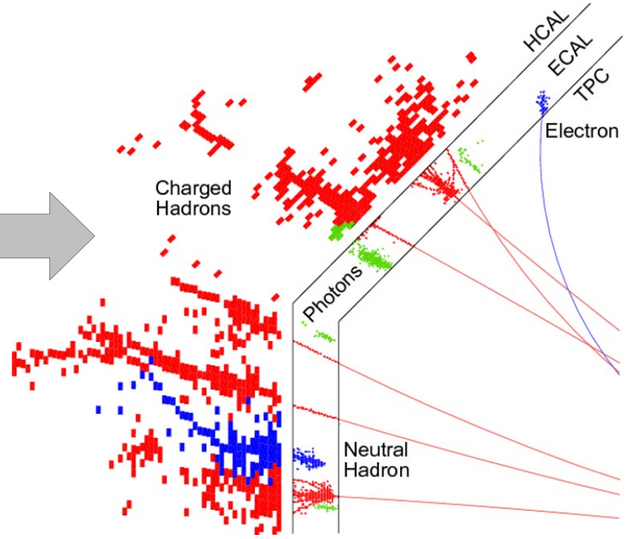
Beam test



Software framework



Detector/physics studies



- Software plays a central role in calorimeter development
- Validation of hadronic cascades in beam tests to guide full detector/full simulation studies
- In turn, realistic event reconstruction guides the technical choices
- It is important that Calorimeter R&D projects integrate into common software frameworks as Key4HEP
  - Better comparability of results
  - Facilitates porting of e.g. beam test results to full simulation studies
  - Facilitates switching between beam test studies and physics studies

Future projects – Some general considerations

- Detectors at future high energy lepton colliders
  - Relative benign environment in terms of radiation (well, maybe less true for Muon Collider)
  - Physics program span between Z-pole and few TeV
    - At same machine in case of LC
  - Consequences for detector design?
  - This is particularly important for calorimeters since calorimeters require significant human resources and material during construction and during maintenance

- Detectors at future hadron colliders
  - However,
    - Harsh radiation environments from the beginning
    - ... amplified by potential luminosity upgrades
  - Requires calorimeters that can stand severe conditions w/o degradation (or upgrades are priced in from the beginning)
  - Again calorimeters are huge and require sustained long term support

- Most other projects have constraints that are subsets of the above but in different combinations and on different time scales