The ECFA Roadmap process for PID and photon-detector R&D

RICH 2022
Edinburgh
12th September 2022

Neville Harnew
University of Oxford
With thanks to Peter Krizan

Some obvious introductory remarks

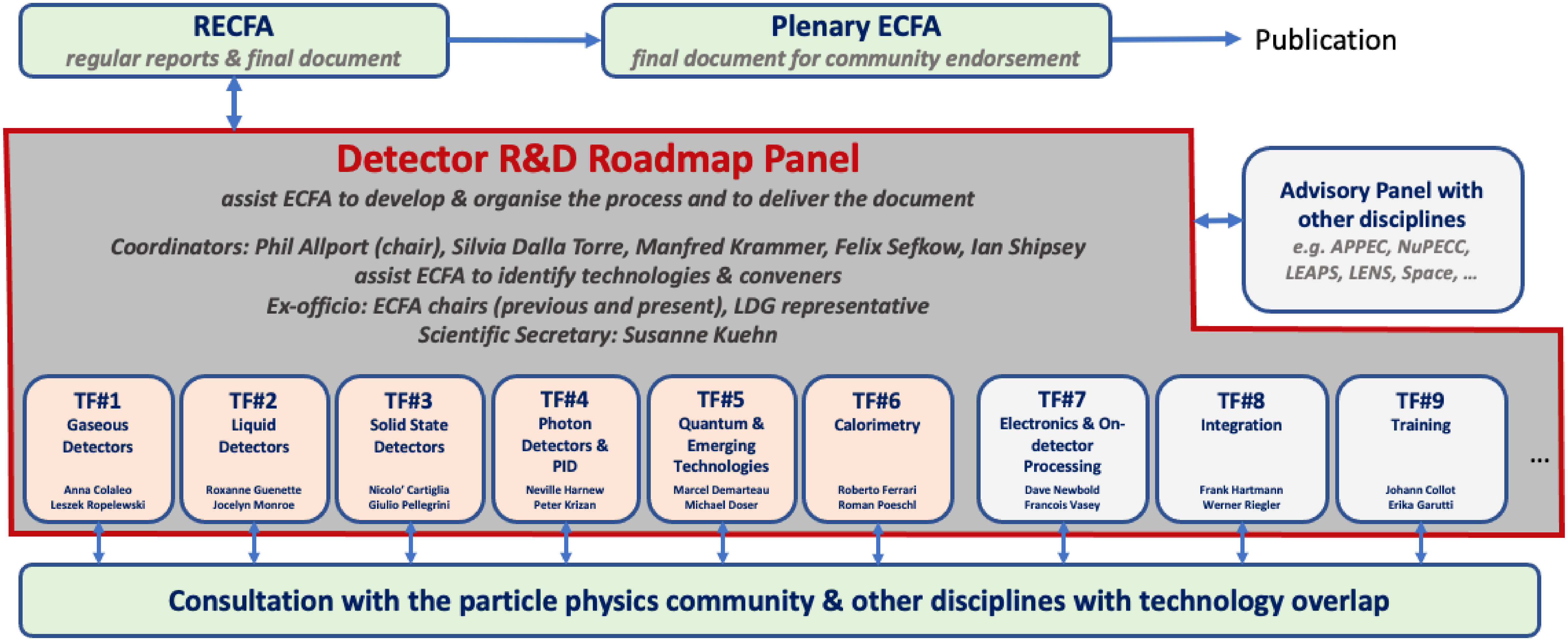
- PID methods have become an indispensable experimental tool, in particular for heavy flavour physics, heavy-ion collisions, electron & hadron experiments and particle astrophysics.
- RICH detectors have evolved to unprecedented levels of performance. This has allowed very efficient PID of charged particles and outstanding background rejection over a vast momentum range from a few 100 MeV/c up to several 100 GeV/c.
- The ever-growing demands of the future physics programme, from underground facilities to high luminosity colliders, require a new generation of PID detectors with separation power over 4-5 orders of magnitude in momentum.
- Advancement in photon detector technology is essential to address not only PID detectors but also *all* the science drivers of future high energy physics experiments → calorimeters, tracking, neutrino and dark-matter experiments; from ultra-high rates to extreme low-noise requirements, and for all particle astrophysics applications.

European particle physics R&D strategy

The terms of reference are here : https://europeanstrategyupdate.web.cern.ch/

- Organised by ECFA, a roadmap will be developed to balance the detector R&D efforts in Europe, taking into account progress with emerging technologies in adjacent fields.
- The roadmap will identify a diversified detector R&D portfolio with the aim to enhance the performance of the particle physics programme in the near and long term.
- The roadmap will identify detector R&D activities that require specialised infrastructures, tools and access to test facilities.
- The R&D roadmap will define activities that can be used to support research proposals at the European and national levels.

Organisation of Detector R&D Roadmap



https://indico.cern.ch/e/ECFADetectorRDRoadmap

TF4 Panel Members

- Ichiro Adachi (KEK)
- Neville Harnew (Oxford) Co-convener
- Christian Joram (CERN)
- Peter Krizan (Ljubljana) Co-convener
- Eugenio Nappi (INFN Bari)
- Hans-Christian Schultz-Coulon (KIP Heidelberg)

Facility input requirements

- As a kick-off to the process, on 21-22 Feb 2021, there were input sessions with 12 talks presenting the requirements of future facilities:

https://indico.cern.ch/event/957057/page/21634-input-from-future-facilities

- The facilities covered were the following, & the main drivers were discussed :
  - HL-LHC
  - Neutrino Long Baseline
  - Higgs-Top Factories (ee) FCC, ILC
  - High-energy hadron collider (ALICE3, FCC-eh/eA)
  - Muon collider
  - Storage rings & fixed target (Belle-II, Rare kaon, TauFV, Mu3e, etc)
  - Lepton-hadron collider, EIC, nuclear physics applications (eg GSI), Compass2
  - Non-accelerator including Particle Astro

09:00 → 09:25 **Introduction and facilities input**
Speakers: Neville Harnew (University of Oxford (GB)) , Philip Patrick Allport (University of Birmingham
Allport-Harnew-TF4-...

09:30 → 10:00 **RICH technology requirements & optical elements**
Speaker: Carmelo D'Ambrosio (CERN)
carmelo_2021_05_0...

10:10 → 10:35 **Radiator materials**
Speaker: Ichiro Adachi (KEK)
RadiatorMaterial-IA...

10:45 → 11:00 **Coffee break**

11:00 → 11:25 **DIRC technology requirements**
Speakers: Joachim Schwiening (GSI Helmholtzzentrum für Schwerionenforschung GmbH) , Jochen Sc
GmbH (DE))
20210506-ECFA-TF...

11:35 → 12:00 **Time of flight technologies**
Speaker: Roger Forty (CERN)
TOF technologies.pdf

12:10 → 12:35 **Gaseous detectors with photocathodes/ MPGDs**
Speaker: Fulvio Tessarotto (INFN Trieste)
tessarotto_ECFA_TF...

13:30 → 13:55 **MCP-PMT technologies**
Speaker: Kenji Inami (Nagoya university)
20210506MCP_ina...

14:05 → 14:30 **SiPMs technologies and timing**
Speaker: Samo Korpar (Jozef Stefan Institute (SI))
TF4-Korpar.pdf

14:40 → 15:05 **SiPMs - radiation hardness, low-temperature operation etc**
Speaker: Yuri Musienko (University of Notre Dame (US))
SiPMTs-rad-hard-ne...

15:15 → 15:30 **Coffee bre**

15:30 → 15:55 **Photomultiplier technologies**
Speaker: Razmik Mirzoyan (Max-Planck-Institute for Physics)
ECFA-Detector-R&D-...

16:05 → 16:30 **Superconducting devices overview**
Speaker: Sae Woo Nam (NIST)
TF4_Nam.pdf

16:40 → 17:05 **Overlapping technologies and summary**
Speaker: Peter Križan (Jožef Stefan Institute, Ljubljana)
ecfa2021-tf4sympo...

17:15 → 17:45 **Discussion session**

A symposium for TF4 was held on 6 May 2021 for community consultation and discussion : ~110 attendees

https:// indico.cern.ch/event/999817/

https://cds.cern.ch/record/2784893?ln=en

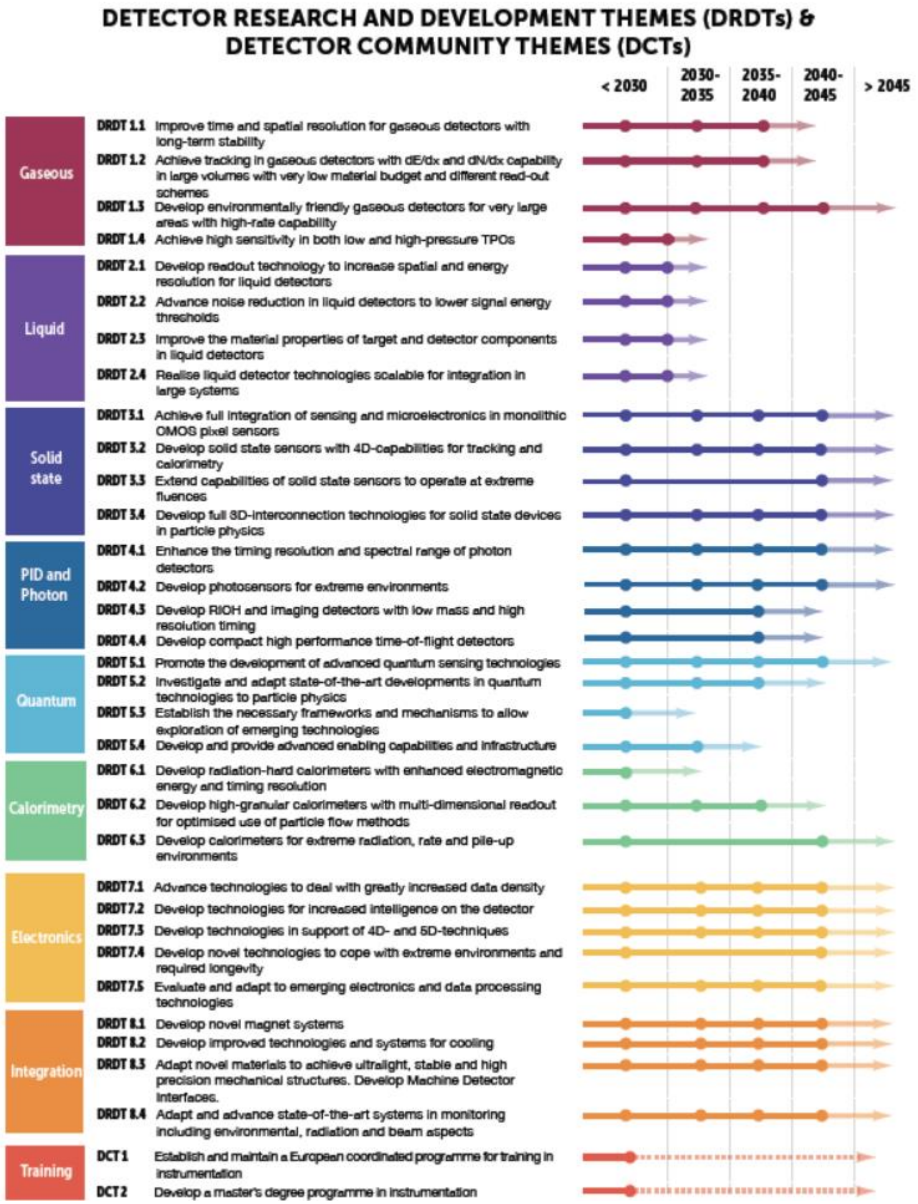
CERN-ESU-017 (Feb 2022)

Contents

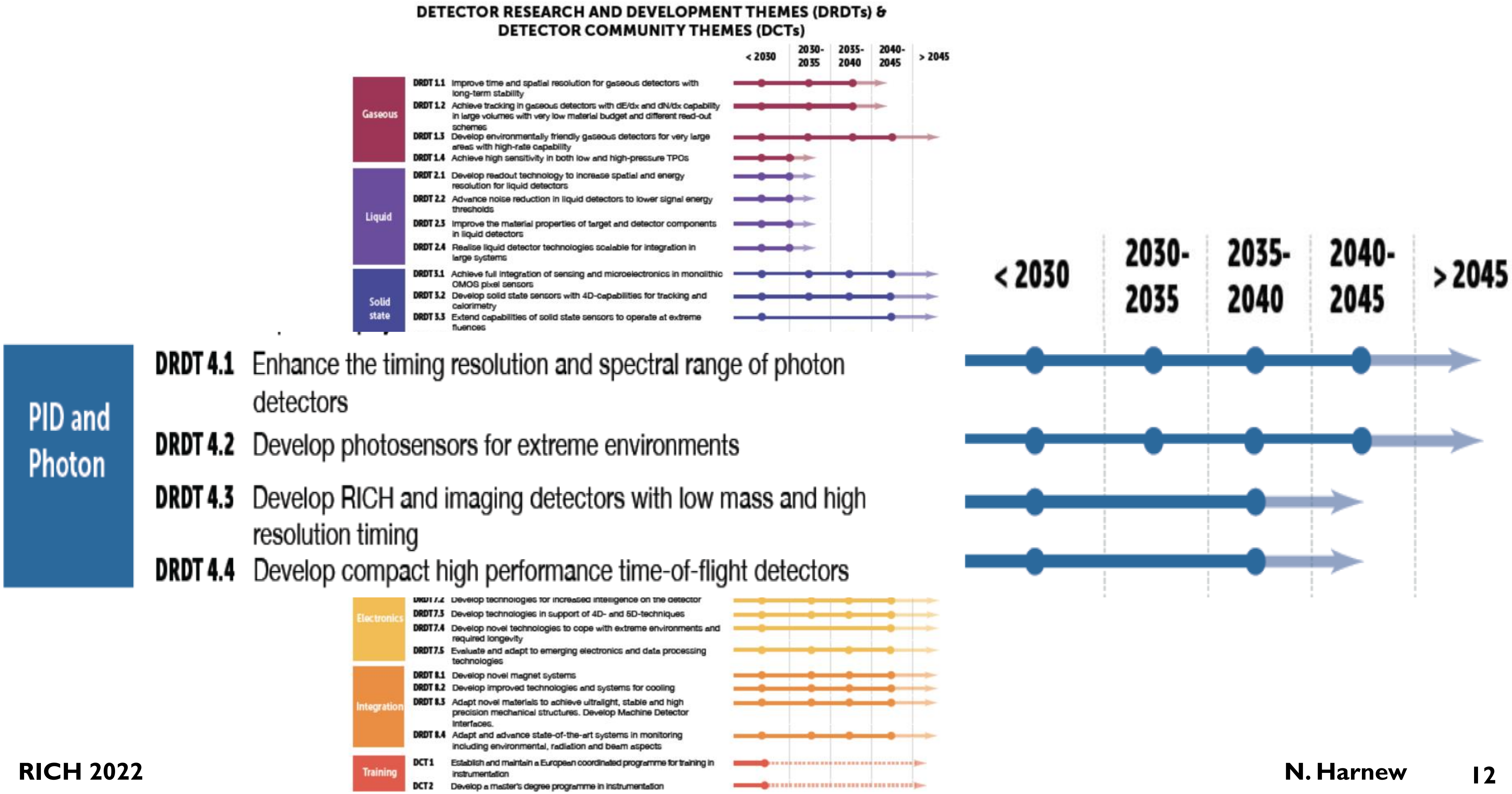
Large accelerator-based facility/experiment earliest feasible start dates

Smaller accelerator and non-accelerator-based experiments start dates

Detector Research and Development Themes (DRDTs)



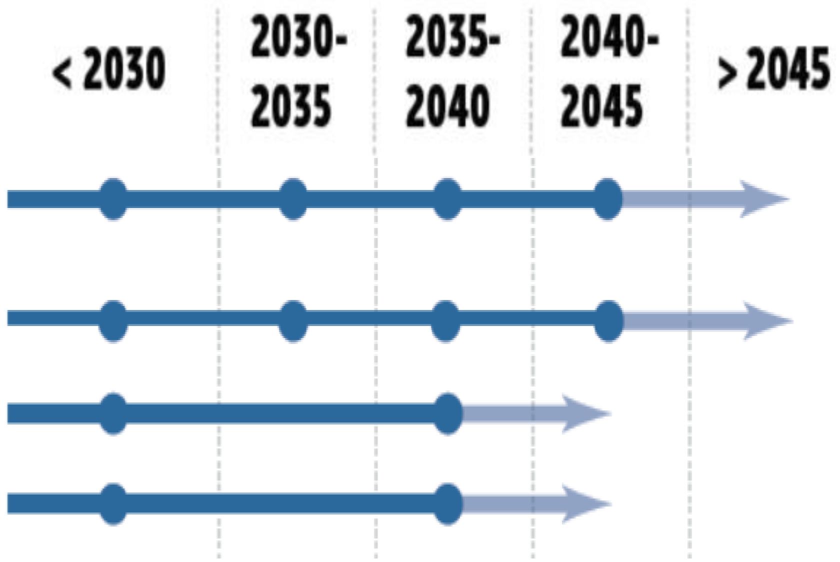
Detector Research and Development Themes (DRDTs)



Detector Research and Development Themes (DRDTs)

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



- Required for fast timing in Cerenkov and time of flight detectors, for operation with high particle fluxes and pile-up, and in extending the wavelength coverage of scintillation photons from noble gases and Cerenkov photons.
- Essential for operation in the high-radiation environments at the HL-LHC, Belle II Upgrade, EIC and FCC-hh; and similarly for cryogenic operation.
- Required for particle identication at HL-LHC, Belle II upgrade, EIC, and FCC-ee.
- As a complementary approach for particle identification at HL-LHC, EIC and FCC-ee.

RICH, DIRC and TOP (TOF) detector technologies

Facility requirements : Particle Identification

Projects	Timescale	RICH (high and low momentum PID)	Time of flight and DIRC	RPC technologies	TRD & dE/dx
Panda/CBM (Fair/GSI)	2025	✓	✓	✓	
NA62/KLEVER/TauFV	2025	✓	✓		
ALICE	2026-27 (LS3) – 2031 (LS4)	✓	✓	✓	✓
Belle-II	2026	✓	✓		
Neutrino long baseline	2027				
LHCb	2031 (LS4)	✓	✓		
ATLAS-CMS	2031 (LS4) - 2035 (LS5)				
Non accelerator & particle astro	--				
EIC	2031	✓	✓		
ILC	2035				
CLIC	2035				
FCC-ee	2040	✓	✓		✓
Muon-collider	> 2045				
FCC-hh	> 2050				

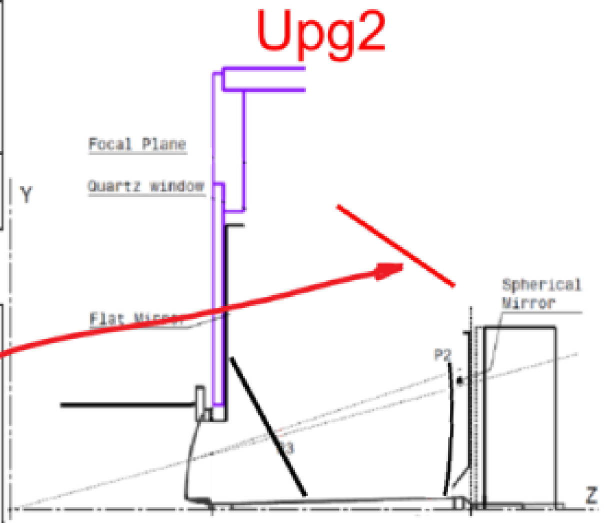
Extension of RICH designs

- The HL-LHC has possibly the most demanding requirements for the next generation of RICH detectors. Work in visible wavelength to reduce chromatic dispersion.
- Hermetic experiments (eg FCC-ee, EIC) need RICH detectors with a total length shorter than a meter.
  - Possibility of pressurizing noble gases to several bars to increase refractive index – innovative engineering solutions
  - Design of a compact RICH detectors working in the far UV region to improve photon yield
- The use of lightweight mirrors (CF technology), light collection systems, concentrators – smart optics design
- Timing absolutely crucial to the new generation of RICHes (<50 ps precision) for background rejection and vertex association.

eg. LHCb strawman design
- wide momentum coverage between 10 to 200 GeV/c
- ~0.3-0.5 mrad single photon angular resolution

Lumi = 10^{34} cm^{-2} s^{-1} ; Occupancy < 30%

Detector Version	RICH-1 Upg2
Avr. Phel. Yield	60 - 40
Single Photon Errors [mrad]	
Chromatic	0.24
Pixel	0.15
Emission Point	0.1
Track resolution	?
Overall	0.3



Reduce chromatic by choosing a photodetector with a "green-shifted" QE curve (and filter the shorter wavelengths)

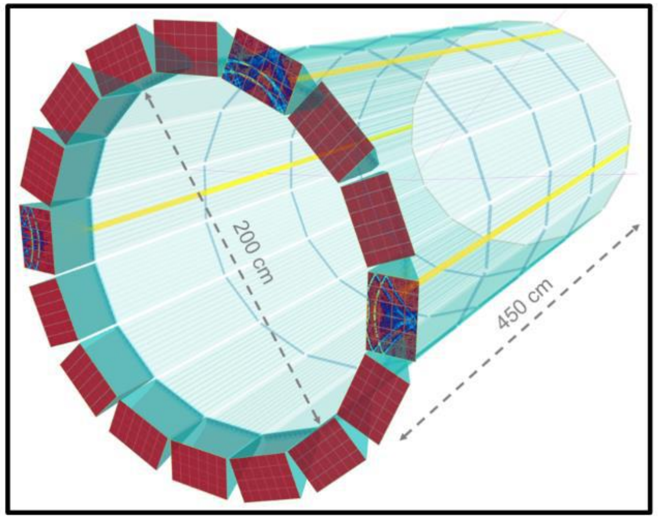
RICH technologies : key R&D areas

- Photon detectors and readout
  - Need large-area single-photon detectors capable of sustaining high counting rates (few MHz/cm^2), improved photon detection efficiency, a total ionizing dose up to a few Mrad, timing resolution of the order of few tens of ps. Granularities of mm-level pixel size.
  - Need to develop SiPMs and MCP-PMTs, solid photocathodes in micro-pattern gaseous detectors (MPGDs)
  - Rad-hard, low-consumption, picosecond-resolution, high-granularity front-end electronics
- Radiator materials
  - Gas radiators : to develop *green gases* as an alternative to fluorocarbons (C_4F_{10} or CF_4)
  - Liquid radiators with optical purity for large volumes (eg. Hyper-K)
  - Solid, crystal & aerogel radiators (tunable refractive index, larger tiles, higher photon yield, more production sites). Development of dual radiators.
  - Meta-materials, photonic crystals, capable to match the refractive indices needed to identify particles at low and high momentum.

DIRC and TOP detectors

- First pioneered by the BABAR collaboration and more recently by Belle II, extending the DIRC principle to measure Time of Propagation.
- Advantage of DIRC detectors is that they provide an extremely compact PID device. However current detectors are suitable only for low momentum PID up to 4-5 GeV/c.
- Applications are for flavour and heavy-ion physics, where PID is essential. e.g. Panda, Belle-II, EIC, Gluex and later HL-LHC drive the performance needs of DIRC detectors.
  - Example the hpDIRC (high performance DIRC) at the EIC
  - Need highly polished quartz bar radiators, light detection with MCP-PMTs for timing
  - DIRC detectors need to extend to 3 sigma pi/K separation @ 7-8 GeV/c (with TOP correction)

hpDIRC @ EIC



DIRC R&D requirements

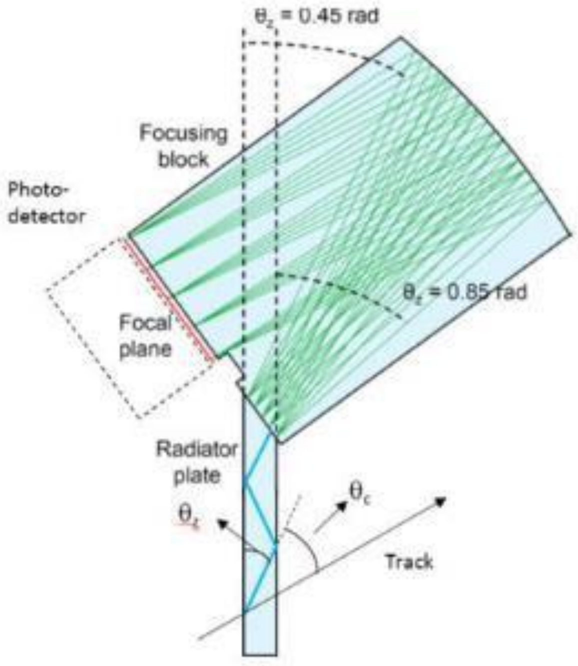
- R&D to make DIRC readout more compact, expand momentum reach, develop for endcap operation. Improvements in focusing designs, emphasizing spatial resolution.
- Decrease and mitigate RICH resolution terms: chromatic dispersion, multiple scattering.
- Develop quartz technology, surface quality is essential ((sub)-nm surface roughness) is a major cost driver, lower price.
- State of the art timing is also important (O(10)ps binning)
- Photon detection - fast timing performance is essential (ps level). SiPMs, MCP-PMTs. Improved photon detector granularity; radiation tolerance, lifetime, low noise, photon sensitivity.

TOF technologies

- TOF falls fast, provides only complimentary PID for high energy machines. Future applications, e.g. Panda/CBM, Na62/TauLV, ALICE, LHCb, ATLAS/CMS, EIC, FCC ...
- ToF methods
  - Scintillators to ~50ps. Gaseous detectors: multigap RPCs to <50ps with micro pattern gas detectors (MPGDs).
  - Silicon detectors : Low gain avalanche diodes (LGADs) important to the GPDs, FCC-hh etc, timing to10 ps.
  - Large area MCPs (to 15ps): LAPPDs. Instrumenting large area surfaces.
  - Cherenkov (DIRC)-based detectors eg. TORCH detector (LHCb, TauFV, kaon) with 3 sigma pi/K separation to 10 GeV/c at 10m.
- Future R&D challenges
  - State of the art timing ASIC compulsory (O(10)ps binning)
  - Quartz technology (as for DIRC)
  - Photon detection - fast timing performance essential (~10 ps level). SiPMs, MCP-PMTs LGADs.
  - R&D essential for timing (clock) distribution.

TORCH detector concept

- MCPs with high granularity (32 x 128 pixels over 2" active square area), aspire to withstanding integrated charges of ~50-100 Ccm^{-2} . SiPMs also an option.
- High resolution amp/discriminator/TDC readout chips with high channel count



Photon Detector Technologies

Facility requirements : Photon Detectors

Projects	Timescale	SiPM technology	MCP-PMT technology	Large diameter PMT technology	Scintillating fibres & new scintillating materials	CCDs & superconducting devices
Panda/CBM (Fair/GSI)	2025	✓	✓			
NA62/KLEVER/TauFV	2025	✓	✓			
ALICE	2026-27 (LS3) – 2031 (LS4)	✓	✓			
Belle-II	2026		✓			
Neutrino long baseline	2027	✓		✓	✓	
LHCb	2031 (LS4)	✓	✓		✓	
ATLAS-CMS	2031 (LS4) - 2035 (LS5)	✓				
Non accelerator & particle astro	--	✓		✓	✓	✓
EIC	2031	✓	✓		✓	
ILC	2035	✓			✓	
CLIC	2035	✓			✓	
FCC-ee	2040	✓	✓		✓	
Muon-collider	> 2045	✓				
FCC-hh	> 2050	✓				

Family of vacuum-based photodetectors

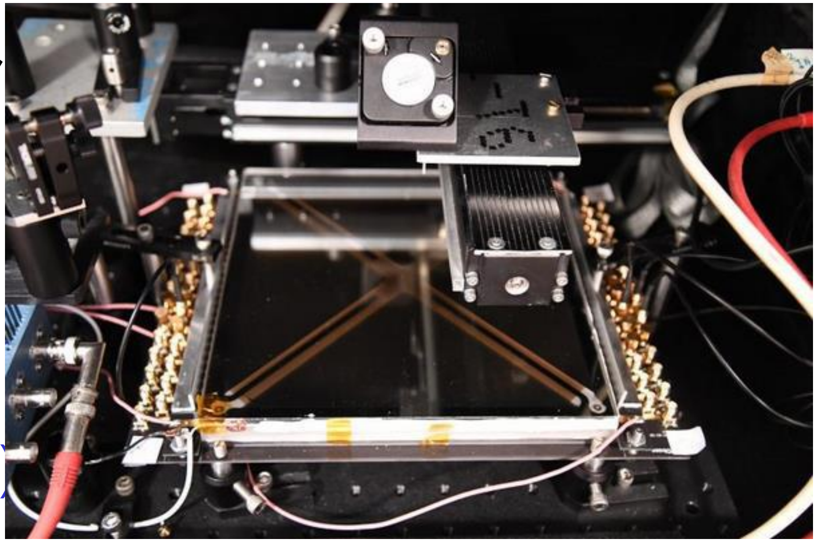
A number of photon detector types have evolved from the classic photomultiplier concept :

- Micro-channel plate detectors (MCP-PMTs)
  - Several suppliers : eg. LAPPD (large area) and Photonis/ Hamamatsu/ Photek (compact, tunable granularity) – see next slide
- Photo-multipliers (including large areas)
  - Improvements needed to increase radio-purity (factor 5-10), UV response & QE
- Multianode (MaPMTs)
- Hybrid avalanche photon detectors (HAPDs)
- Hybrid HPDs, V-SiPMT …. etc

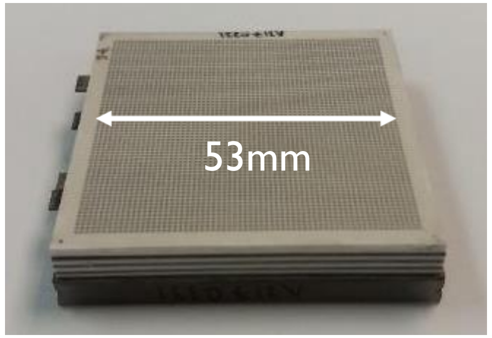
Microchannel plate PMTs

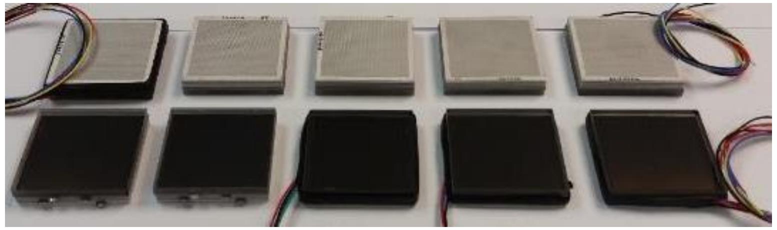
- MCP-PMTs proposed extensively for RICH detector and TOF
- State of the art currently ~20ps timing resolution
- R&D requirements
  - Large area coverage, cheaper cost for tiling large areas (LAPPD)
  - Customised granularity (for DIRC-type detectors, TOF) - 128 pixels over 2-inch tube size
  - Rate limitation around $10^5/cm^2$ - need to improve rate capabilities (>MHz)
  - Improved integrated charge capabilities (several factors above current state of the art ~20 C/cm^2)
  - Operating gain currently $10^6 – 10^7$. Electronics to facilitate operation at a ~few x 10^5 operation to reduce integrated charge
  - Improvements in QE, CCE need to come.

Testing of the LAPPD MCP



Photek 64x64 MCP-PMT





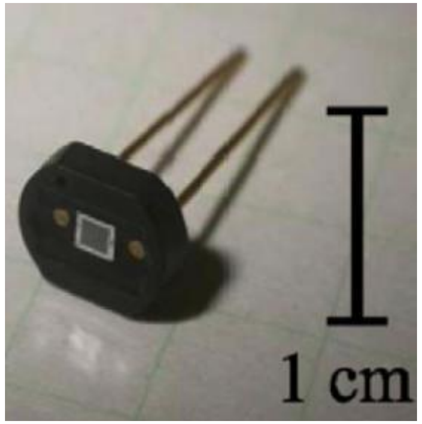
Gas-based photodetectors

- Gaseous Photon Detectors (GPDs) represent an effective solution for instrumenting large imaging surfaces (up to several square metres) in high magnetic felds.
- Need to develop GPDs based on Micro Pattern Gaseous Detector (MPGD) structures which allow photon conversions at few 10's of micron level.
  - Further R&D to improve the photocathode lifetime (GHz rates for EIC), the PDE, radiation hardness and time resolution in the few ps range (PICOSEC-Micromegas Detector Development); challenging extension to the visible spectral range.
- Search for UV-sensitive materials more radiation-hard and chemically inert than CsI.
  - Carbon based photocathodes
- Develop compact GPD systems with integrated electronics for imaging applications
  - InGrid - Micromegas integrated in a Timepix
- R&D for alternative hydrocarbon-free gas mixtures
- GPDs for cryogenic applications
  - Detection of both scintillator light and ionization

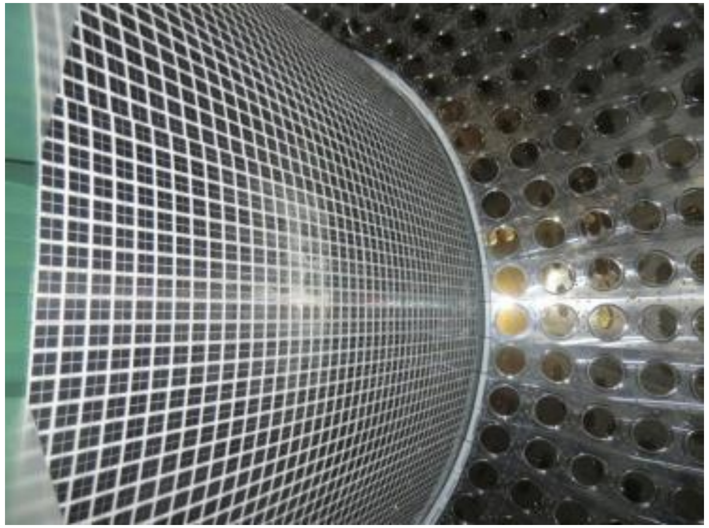
Radiation hard SiPMs : a key technology

- SiPMs are photosensors of choice for many applications – HL-LHC & FCC-hh mainly drive the HEP technology limits
- Important features are their compactness, low operation voltage, robustness to magnetic fields and reasonable price
- Timing, radiation tolerance, low backgrounds are key :
  - Wide applications for scintillating fibres, calorimeters, neutrinos and DM experiments (pulse shape discrimination), noble liquid detectors (eg MEG-II with LXe), gamma ray astronomy
  - SiPMs now becoming the detector of choice for RICH and DIRC-type detectors (LHCb, ALICE, EIC, FCC-ee etc).
    - High QE around 50-60% in the visible (350-600 nm)
    - However high dark count rates 10-100 kHz mm^{-2} at room temperature
    - Rad hardness : lose sensitivity to single photons at around 1×10^{11} n cm^{-2} eq.
    - Fast timing response – significantly below 100 ps
    - Small cell sizes which are tuneable

T2K SiPM



SiPM array of MEG II liquid Xe calorimeter



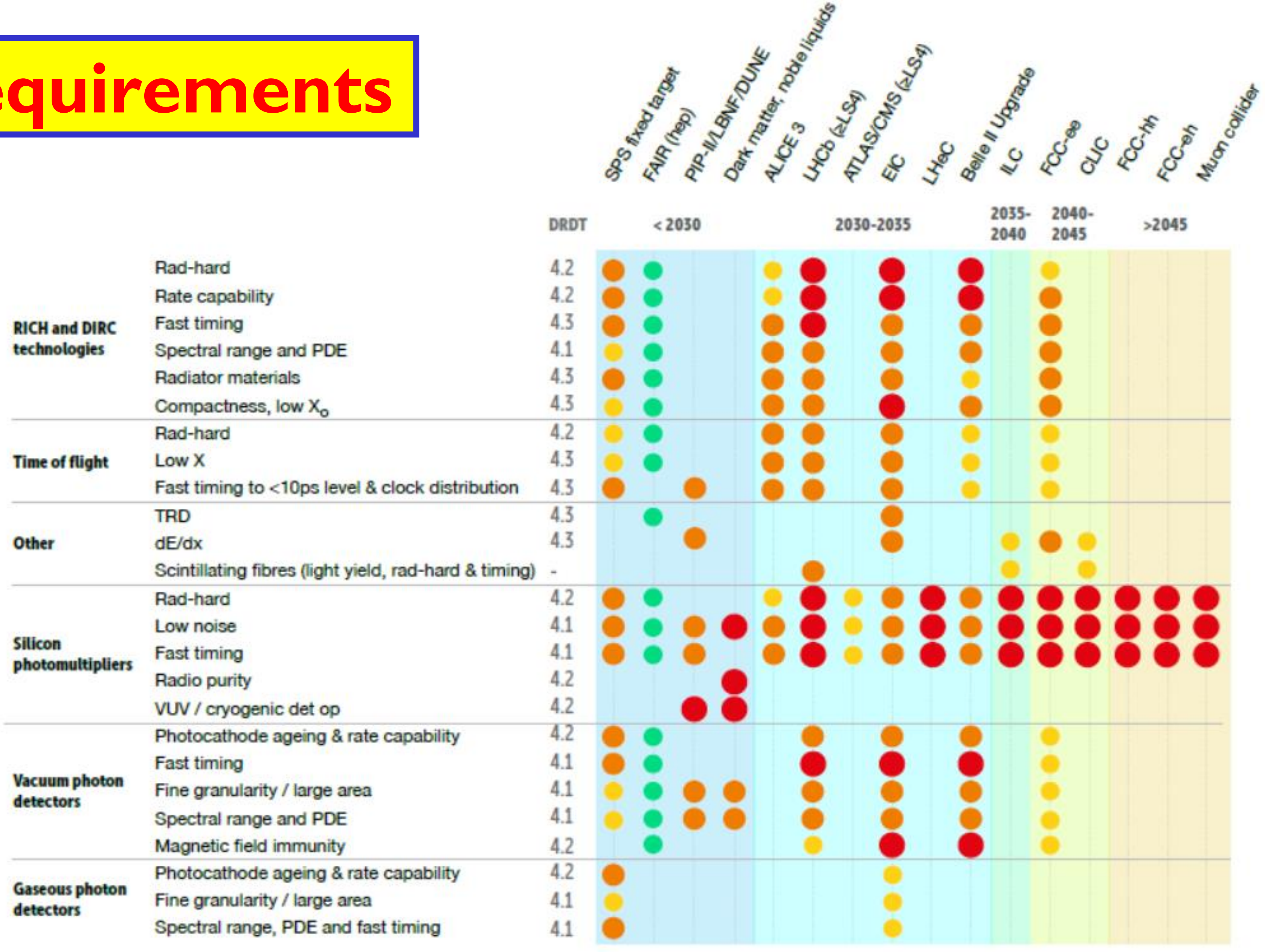
SiPMs : R&D technology requirements

- A non-exhaustive list – different applications, different requirements:
  - Improved radiation hardness (1×10^{14} n cm^{-2} eq @ CMS ; 10^{17}-10^{18}@ FCC-hh !)
  - Improved dark count rates towards 1 Hz mm^{-2} (driven by low light-level experiments) and reduced after pulsing
  - Improved timing characteristics (aspire to 10 ps or below for time resolution)
  - Increasing photon detection efficiency for single-photons : fill factor and spectral range into the UV & IR
  - Cryogenic operation of SiPMs : improved cooling systems (to reduce dark noise), @ -50 °C
  - Optimised SiPM systems - large-area integration with cooling
  - Optimised optical couplings. development of micro-lenses/filters.
  - New materials for SiPMTs (eg SiC, GaN, InGaN, AlGaN)
  - Improved dynamic range (driven by calorimetry)
  - Improved cross talk
  - Cheaper solutions for SiPMs (eg CMOS) for large area applications and high pixel density. Analogue vs. Digital
  - Improving pulse shape discrimination (neutrinos and non-accelerator); development of corresponding r/o electronics
  - High radioactive-purity for underground experiments, better than a few Bq/kg depending on material
  - Cell size, dynamic range, fill factor.

Summaries and recommendations

Summary of requirements

- A chart was produced showing the timeline of categories of experiments employing PID and photon detectors together with R&D tasks.
- The colour coding is linked to the potential impact on the physics programme of the experiment.
  - Red, largest dot : Must happen or main physics goals cannot be met;
  - Orange, large dot : Important to meet several physics goals;
  - Yellow, medium dot : desirable to enhance physics reach;
  - Green, small dot : R&D needs are being met;
  - Blank : no further R&D required or not applicable.



PDE stands for photon detector efficiency.

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

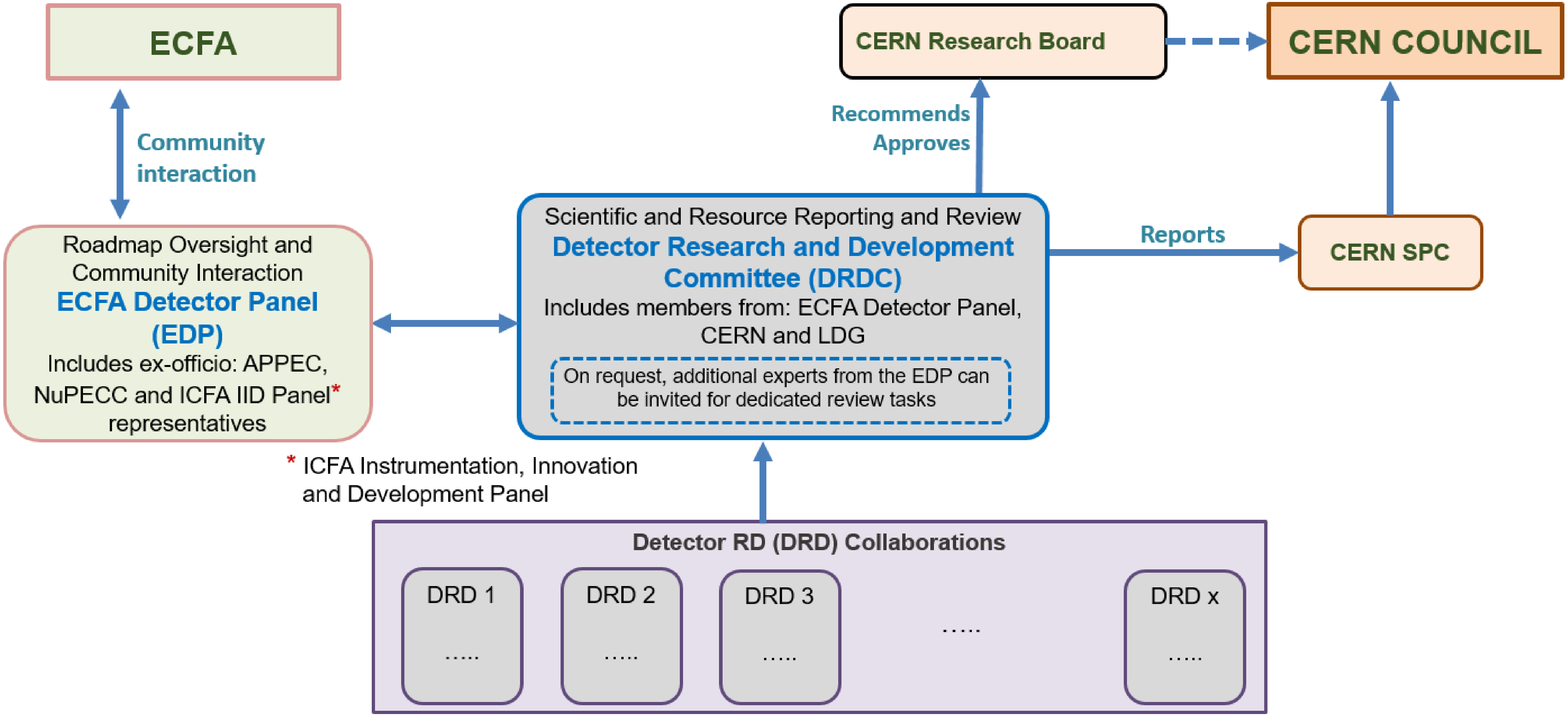
Some general observations

- Innovative photon sensors require development in specialized industrial companies. Close collaboration essential to ensure supply and lower cost, eg SiPMs. A close synergy needs to be developed.
- HEP has demanding requirements which result in highly qualified teams. Closer collaborations with other fields to transfer this expertise to be fostered.
- There will be benefits from interdisciplinary workshops including industrial companies, especially developing photon sensors. Small workshops can convey HEP needs to industry and to develop innovative ideas.
- R&D collaborations need to be created to ensure standardisation across research areas (see later).
- PID detectors are in general developed within research institutes. Important to develop a sustainable plan to recruit and train future instrumentalists to avoid generational gaps and maintaining technical facilities.

Summary of recommendations

- DRDT 4.1 : Enhance the timing resolution and spectral range of photon detectors
  - Next 5 years : Advances in SiPMs for fast timing, uv sensitivity and rad hardness. Light collection systems
  - MCP-PMTs improved QM, & collection efficiencies, granularity and large areas.
  - Next 10 years : Incremental improvements to gaseous photon detectors, granularity and fast timing.
- DRDT 4.2 : Develop photosensors for extreme environments
  - Next 5 years : Improve radiation tolerance of SiPMs. Radiation pure for cryo systems.
  - MCP-PMTs improve detector ageing and high-rate performance
  - Improve photocathode ageing and rate capability for gaseous detectors
  - Next 20 years : Further advances in SiPMT rad hadness a couple of orders of magnitude beyond 1×10^{14} n_{eq}/cm^2
- DRDT 4.3 : Develop RICH and imaging detectors with low mass and high timing resolution
  - Next 5 years : Picosecond timing, greenhouse-friendly radiator gases, cheaper quartz amd transparent aerogels
  - Next 10 years : Compact RICH systems with low X_0 (pressurised systems).
- DRDT 4.4 : Develop compact high performance time-of-flight detectors
  - Picosecond timimg, high granularity photosensors with long lifetime and high-rate capabilities
- Pursue "blue sky" R&D activities
  - Solid state photon detectors from novel materials
  - Cryogenic superconducting photosensors
  - Gaseous photon detectors for visible light
  - Metamaterials to give tune-able refractive indices

Provisional implementation organisation



Proposed implementation timeline

- **Starting now** : the R&D Roadmap Task Forces will organise open meetings to establish the scope and scale of the communities wishing to participate in the new DRD activities. DRD conveners and team of experts identified. Where the R&D area has a DRDT already in operation, these need to be involved from the beginning.
- **Q4 2022 :** Outline structure and review mechanisms agreed by CERN Council.
- **Through 2023** : mechanisms to be agreed with funding agencies, preparing for DRD collaboration funding requests.
- **By Spring 2023** : the DRDC mandate to be formally defined with CERN management; Core DRDC membership appointed.
- **Through early Summer 2023** : Conveners and experts prepare DRD proposals with work package structure which are then submitted.
- **Q4 2023** : DRD collaborations receive formal approval from CERN Research Board.
- **Q1 2024** : The new DRDs come into existence and operational for ongoing review of DRDs. R&D programmes underway.
- **Through 2024** : collection of MoU signatures to take place, with defined areas of interest per institute.
- **2024-2026 :** Ramp up of new strategic funding and R&D activities in parallel to completion of current deliverables.

SPARE SLIDES

Process and timeline

Organisation

May 2020
EPPSU mandate to ECFA to develop a roadmap for detector R&D efforts in Europe

Sep 2020
Structure in place with **Detector R&D Roadmap Panel**

Dec 2020
Task Forces active

Website:
https://indico.cern.ch/e/ECFADetectorRDRoadmap

Expert & Community Consultation

Feb 2021
Collection of requirements of future facilities & projects

Feb/March 2021
Questionnaires of Task Forces to national contacts

Task Forces liaise with experts in
- ECFA countries
- adjacent disciplines
- industry

March-May 2021
Open Symposia

Drafting Roadmap & Feedback

May 2021
Task Forces collate input from symposia

25-28 May 2021 **Drafting sessions**
- opening session with all experts involved
- plenary & parallel sessions with Task Force members
- final session of Roadmap Panel

July 2021
Near final draft shared with RECFA*

30 July 2021
Presentation at Joint ECFA-EPS session

Until Sep 2021
Collect final community feedback*

Oct 2021
Detector R&D Roadmap Document submission to RECFA and afterwards to PECFA and Council

*community feedback via RECFA delegates and National Contacts

Community Consultation

- A questionnaire was sent out to country representatives:
  - 1. Are there any missing items on the agenda?
  - 2. What aspects of R&D are ongoing in your country in the areas of Particle Identification and Photon Detector technologies for Particle Physics applications ?
  - 3. How do you feel the R&D work could be best facilitated, especially in the long term?
  - 4. Are there any blue skies topics (including developments for neighbouring fields) that you feel should get attention ?
- 9 replies (7 countries, 2 individuals). Very useful feedback.
- Responses have been posted on Google-drive. https://drive.google.com/drive/folders/1_502OP0-NEDqxQPvg940JsW8ITbo-5C3
- Industry has been invited to attend symposium → 3 contributions received.

PID with dE/dx, TRD

- dE/dx resolution around 5% is routinely reached, in excellent conditions and with accurate calibration. Possible improvements
  - dE/dx resolution ~ 5.4% $(LP)^{-0.37}$ with L length in m, P pressure in bar; the interest in the P term is renewed where excellent PID is needed together with a large mass of the gas (TPC-as-a-target). R&D topics: suitable gas mixtures for high-P operation, light pressure-containment vessels.
  - Cluster counting: dN_{cl}/dx resolution is potentially better than dE/dx (by a factor of 2). Cluster counting requires fast electronics and sophisticated counting algorithms, or alternative readout methods. It has the potential of being less dependent on other parameters. Cluster counting in time, cluster counting in space; R&D topics: wave-form sampling FEE with FPGA processing, 2D micropattern read-out.
- TRD: employed in several experiments, ATLAS, ALICE, AMS, CBM, EIC
  - Gas TRDs a mature instrument for PID at high energies. Due to the overlapping of the TR signal with the ionization, a precise knowledge (and simulation) of dE/dx is a must.
  - GEMs are making their way in the technique
  - An attempt has been made to improve cluster counting by means of a GridPix. Some improvement is possible, although not drastic. Potential improvement may be reached by differentiating the response to X-ray photons and to particle ionization→ Extensive R&D required!
  - TRD imaging (e.g., with Timepix3)? (for hadron PID at very high energies)

Superconducting photodetectors

- Single photon detection technologies with superconductors
- Superconducting detectors for UV-midIR photons
  - TES: Transition Edge Sensor
  - SNSPD: Superconducting Nanowire Single Photon Detector
  - MKID: Microwave Kinetic Inductance Detector
- Example: nanowire detectors for dark matter detection; dark photons
- Work in progress relevant to HEP applications

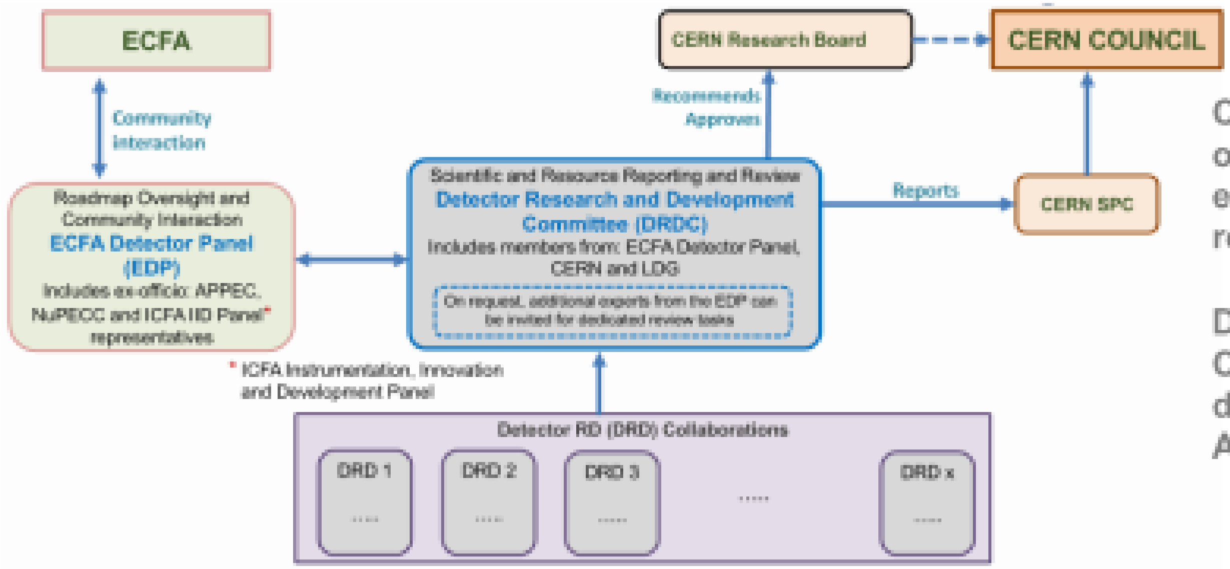
Novel optical materials for fiber trackers

- Scintillating fibres:
  - A cost-effective way of instrumenting large areas for charged particle tracking at relatively low material budget. With the availability of small-pitch SiPM arrays, high resolutions are possible (LHCb SciFi tracker upgrade)
- Further advances in the technology, e.g. for a second upgrade of the tracker envisaged for the High-Luminosity LHC:
  - Optimize photo-sensor and optical fibers need to be optimised for a higher light yield, allowing for smaller diameters and thus higher precision and improved radiation tolerance.
- Open issues:
  - Radiation tolerance, speed, emission spectrum
- Innovative materials: Nanostructured-Organo-silicon-Luminophores (NOL) scintillators:
  - Exhibit stronger and faster light output than presently achieved.
  - Decay time: NOL fibres are almost a factor 2 (6) faster than the best blue (green) standard fibres, which makes them very interesting for time critical applications
  - Radiation hardness (X-rays to a dose of 1 kGy): damage is as expected on a level comparable to reference fibres

Suggested Implementation Organisation

ECFA (through RECFA and PECFA) maintains broad links to the wider scientific community.

EDP engages with other scientific disciplines and also communities outside Europe through close links with the ICFA IID Panel.



CERN provides rigorous oversight through well-established and respected reviewing structures.

DRDs able to benefit from CERN recognition in dealings with Funding Agencies and corporations.

EDP:

- provides direct input, through appointed members to the DRDC, on DRD proposals in terms of Roadmap R&D priorities (DRDTs);
- assists, particularly via topic-specific expert members, with annually updated DRDC scientific progress reviews of DRDs;
- monitors overall implementation of ECFA detector roadmap/DRDTs;
- follows targets and achievements in light of evolving specifications from experiment concept groups as well as proto-collaborations for future facilities;
- helps plan for future updates to the Detector R&D Roadmap.

DRDC:

- provides financial, strategic and (with EDP) scientific oversight;
- evaluates initial DRD resources request with focus on required effort matching to pledges by participating institutes (including justification, given existing staff, infrastructures and funding streams);
- decides on recommending approval;
- conducts progress reviews on DRDs and produces a concise annual scientific summary encompassing the full detector R&D programme;
- be the single body that interacts for approvals, reporting etc with the existing CERN committee structure.

Status of implementation

- Discussions with existing RD50 and RD51 Collaborations (semiconductor and gaseous detectors, respectively) are ongoing, 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); Since both collaborations are only approved until end of 2023, a "natural" date for start-up of the new DRD collaborations seems to be 1. January 2024
- Setting up of new DRD collaborations should be done in a bottom-up approach involving the full community: To be coordinated by the ECFA Task Force leaders with strong participation of existing RD managements
- CERN DRD Collaborations are open to all institutes (world-wide) to participate!
- Aim:
  - Ramp-up of the proposed resources (personnel, money) through 2025
  - Steady state by 2026

Suggested Implementation Timeline

- Assuming the new DRDs need to come into existence by the start of 2024, the Detector R&D Roadmap Task Forces will need to start organising open meetings to establish the scope and scale of the communities wishing to participate in the corresponding new DRD activities from Autumn of this year.

  (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.)

- Through 2023, mechanisms will need to be agreed with funding agencies, in parallel to the below, for country specific DRD collaboration funding requests for Strategic R&D and for developing the associated MoUs.
- By Spring 2023, the DRDC mandate would need to be formally defined and agreed with CERN management; Core DRDC membership appointed; and EDP mandate plus membership updated to reflect additional roles.
- To allow sufficient time for reviewing and iteration, DRD proposals will need to be submitted by early Summer 2023.
- Formal approval should be given by the CERN Research Board in Autumn 2023.
- New structures operational and new R&D programmes underway from beginning 2024.
- Through 2024, collection of MoU signatures will need to take place, with defined areas of interest per institute.
- Ramp up of new strategic funding and R&D activities 2024-2026 in parallel to completion of current deliverables.

Suggested Implementation Timeline

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

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

Through 2024, collection of MoU signatures in parallel to defining areas of interest per institute.

Suggested Implementation Timeline

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Through 2024, collection of MoU signatures in parallel to defining areas of interest per institute.

Suggestion: *DRD Proposal Teams*

(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.)

- **Through TFs identify key players and stakeholders in the wider international community interested in pursuing DRDT topics identified in the Roadmap. Where current relevant detector R&D collaborations exist, their managements need to be involved from the beginning of this process.**

The stakeholders to then be contacted should include:

- – representation of those engaged in near-term programmes where these are clear "stepping stones" towards the longer-term ambitions;
- – those engaged in establishing detector concepts for the main longer-term experimental programmes advocated in the European Strategy for Particle Physics;
- – proponents of other facilities beyond the immediate horizon that are also supported in the European Strategy;
- – were relevant, the primary contacts to other existing funded international detector R&D programmes (including EU and CERN supported activities).

- **Helped by this wider grouping, one or more community workshops should be organised to gather input on how the relevant communities would best see a strategic R&D programme organised and discuss the proposed structure with the ECFA R&D Roadmap Coordinators.**
- **It is suggested that "DRD Proposal Teams" to lead the preparation of more detailed DRD proposals should be identified as a result of this process.**