DRD 2: Liquid Detectors Implementation

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Barcelona

6 March 2023

Grouped targeted facilities/areas emerging from the EPPSU

1. Detector requirements for full exploitation of the HL-LHC (R&D still needed for LS3 upgrades and for experiment upgrades beyond then) including studies of flavour physics and quark-gluon plasma (where the latter topic also interfaces with nuclear physics).
2. **R&D for long baseline neutrino physics detectors** (including aspects targeting astro-particle physics measurements) and supporting experiments such as those at the CERN Neutrino Platform.
3. Technology developments needed for detectors at e^+e^- EW-Higgs-Top factories in all possible accelerator manifestations including instantaneous luminosities at 91.2GeV of up to $5\times10^{36}cm^{-2}s^{-1}$.
4. The long-term R&D programme for detectors at a future 100 TeV hadron collider with integrated luminosities targeted up to $30ab^{-1}$ and 1000 pile-up for 25ns BCO.
5. Specific long-term detector technology R&D requirements of a muon collider operating at 10 TeV and with a luminosity of the order of $10^{35}\,cm^{-2}\,s^{-1}$.
6. **Detector developments for accelerator-based studies of rare processes, DM candidates and high precision measurements** (including strong interaction physics) at both storage rings and fixed target facilities, interfacing also with atomic and nuclear physics.
7. R&D for optimal exploitation of dedicated collider experiments studying the partonic structure of the proton and nuclei as well as interface areas with nuclear physics.
8. The very broad **detector R&D areas for non-accelerator-based experiments**, including dark matter searches (including axion searches), reactor neutrino experiments, rare decay processes, neutrino observatories and other interface areas with astro-particle physics.

Grouped targeted facilities/areas emerging from the EPPSU

In addition, facilities and structures supporting detector development need to be evolved:

9. Facilities needed for detector evaluation, including test-beams and different types of irradiation sources, along with the advanced instrumentation required for these.
10. Infrastructures facilitating detector developments, including technological workshops and laboratories, as well as tools for the development of software and electronics.
11. Networking structures in order to ensure collaborative environments, to help in the education and training, for cross-fertilization between different technologically communities, and in view of relations with industry.

12. Overlaps with neighbouring fields and key specifications required for exploitation in other application areas
13. Opportunities for industrial partnership and technical developments needed for potential commercialisation

ECFA
European Committee for Future Accelerators

Organization to structure the consultation with the community

RECFA
regular reports & final document

Plenary ECFA
final document for community endorsement (aim by Summer 2021)

Publication

Detector R&D Roadmap Panel

assist ECFA to develop & organise the process and to deliver the document

Coordinators: Phil Allport (chair), Silvia Dalla Torre, Manfred Krammer, Felix Sefkow, Ian Shipsey
assist ECFA to identify technologies & conveners
Ex-officio: ECFA chair (outgoing & incoming), LDG chair
Scientific Secretary: Susanne Kuehn

Advisory Panel with other disciplines
APPEC, NuPECC, LEAPS, LENS, ESA

TF#1	TF#2	TF#3	TF#4	TF#5	TF#6	TF#7	TF#8	TF#9	...
Gaseous Detectors	Liquid Detectors	Solid State Detectors	Photon Detectors & PID	Quantum & Emerging Technologies	Calorimetry	Electronics & On-detector Processing	Integration	Training	
Anna Colaleo Leszek Ropelewski	Roxanne Guenette Jocelyn Monroe	Nicolo' Cartiglia Giulio Pellegrini	Neville Harnew Peter Krizan	Marcel Demarteau Michael Doser	Roberto Ferrari Roman Poeschl	Dave Newbold Francois Vasey	Frank Hartmann Werner Riegler	Johann Collot Erika Garutti	

Consultation with the particle physics community & other disciplines with technology overlap

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

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

May-June 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*

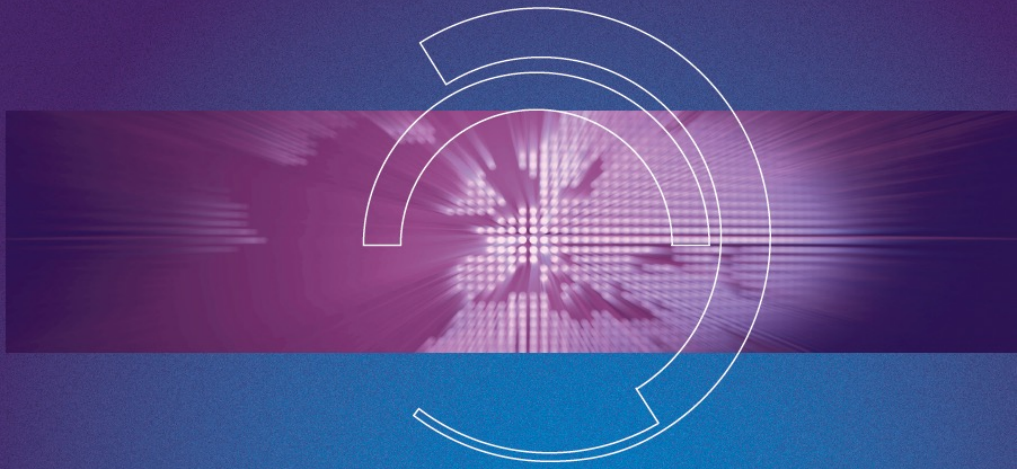
Oct 2021
Detector R&D Roadmap Document submission to RECFA and afterwards to PECFA and Council

*community feedback via RECFA delegates and National Contacts

Input from community: TF2

- Inputs from the community collected by a questionnaire in March 2021
- Liquid detector TF2 Symposium organized on April 9, 2021: https://indico.cern.ch/event/999815/
  - First part: Noble liquids (properties, charge collection, purification, cryogenics and infrastructure)
  - Second part: Any liquids (light collection, LSc and WC, readout)
  - Breakout rooms for discussion after each part + summary and recap of discussions
  - Highlights of novel ideas + summary and future directions

2021: ECFA Roadmap for Detector R&D



THE 2021 ECFA DETECTOR
RESEARCH AND DEVELOPMENT ROADMAP

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

European Strategy Update | ECFA European Committee for Future Accelerators

Approved by Plenary ECFA on 19th Nov 2021

Task Force convenors, Task Force expert members and Panel members of the ECFA Detector R&D Roadmap Process Group

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

Liquid Detectors

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

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

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

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

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

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

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

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

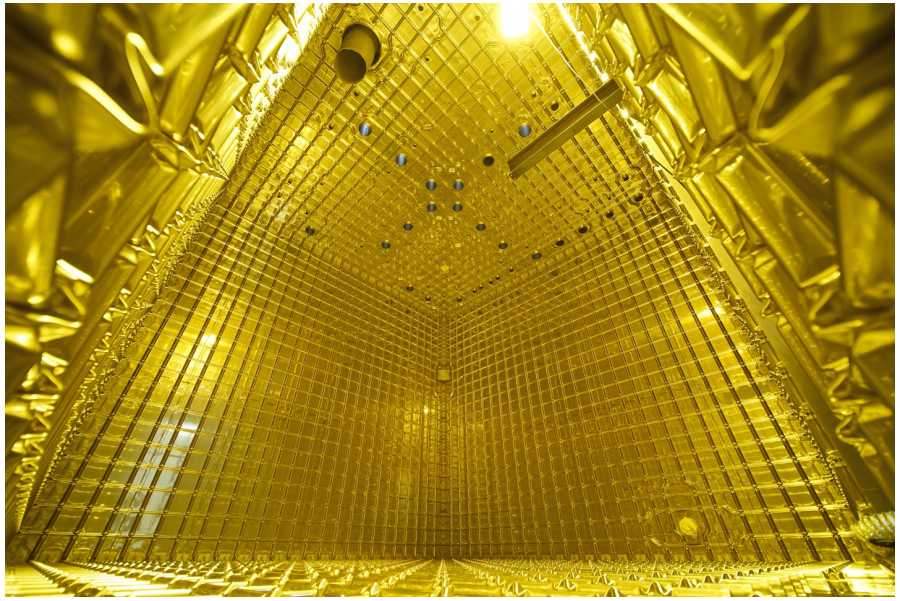
The Task Force Convenors join those listed below to compose the Detector R&D Roadmap Panel.

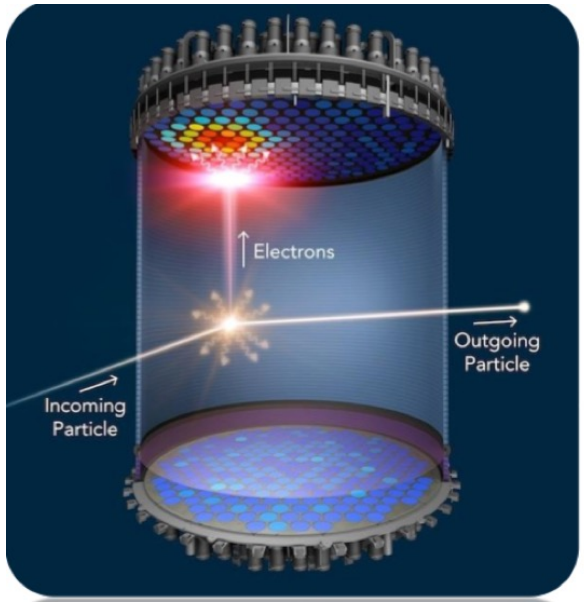
Panel coordinators: Phil Allport[43] *(Chair)*, Silvia Dalla Torre[44], Manfred Krammer[2],
Felix Sefkow[19], Ian Shipsey[17]

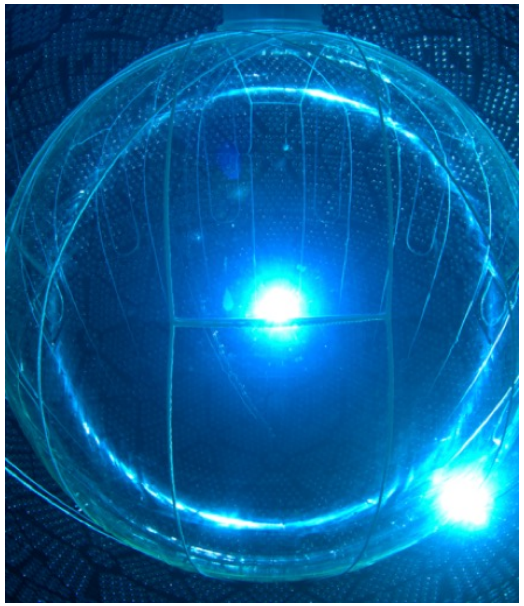
Ex-officio Panel members: Karl Jakobs[45] *(Current ECFA Chair)*,
Jorgen D'Hondt[46] *(Previous ECFA Chair)*, Lenny Rivkin[47] *(LDG Representative)*

Scientific Secretary: Susanne Kuehn[2]

TF2: Main physics drivers







NEUTRINO PHYSICS (acc & non-acc)

- Oscillation precision measurements
- Neutrino interactions
- Astrophysical neutrinos
- Reactor neutrinos …

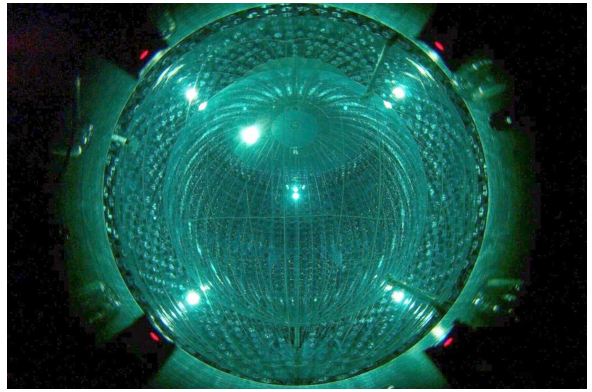
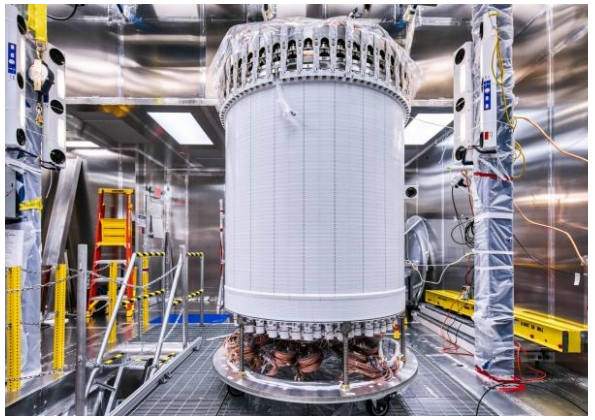
RARE PROCESSES (non-acc)

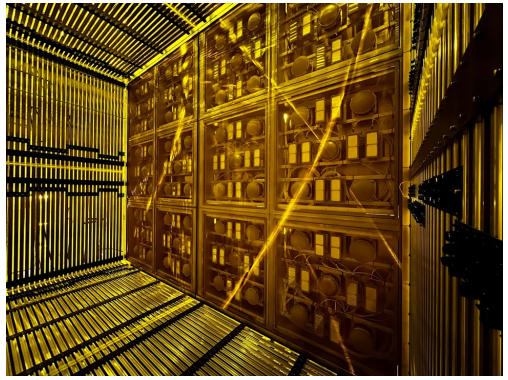
- Dark matter searches
- $0\nu\beta\beta$
- …

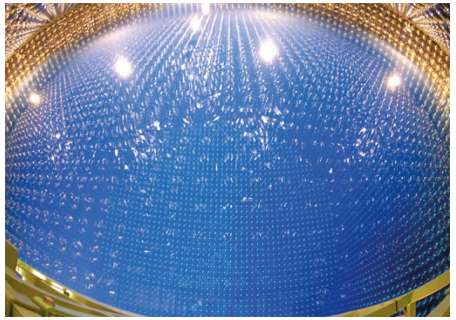
Main technologies

- **Liquid Noble Gas TPC:** ProtoDUNE, DUNE, SoLAr, SBN, LZ, XENON, DARWIN, DEAP-3600, DarkSide, Argo…
- **Liquid Scintillator:** Borexino, JUNO, THEIA, LiquidO, …
- **WC:** KM3NeT, IceCube, SK/HK, …

Large liquid active volumes (tons to kilotons) and large readout areas (thousand m^2)

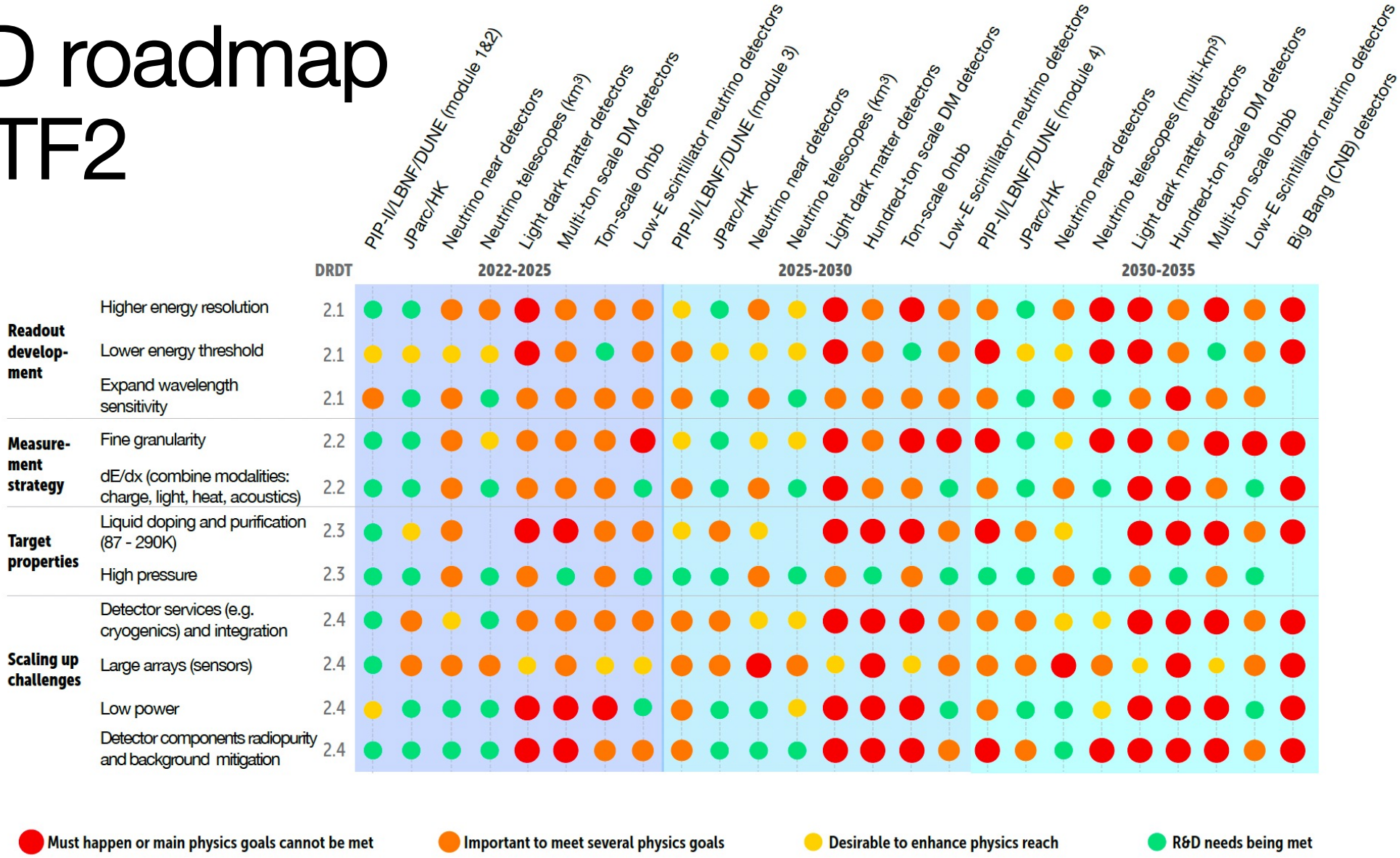




Liquid Detectors DRDTs

- **DRDT 2.1 - Develop readout technology to increase spatial and energy resolution for liquid detectors**. Developments should achieve readout of more highly pixellated detectors with greater photon collection capabilities. Advancing liquid detector readout technologies towards greater quantum efficiency while still offering much higher granularity is a further objective.
- **DRDT 2.2 - Advance noise reduction in liquid detectors to lower signal energy thresholds**. The expected performance of future liquid detectors requires R&D to achieve lower sensor and electronics noise, as well as developments to measure simultaneously more components of the energy partition: for example light, charge and heat.
- **DRDT 2.3 - Improve the material properties of target and detector components in liquid detectors**. The R&D on material properties for liquid detectors aim to improve the emission properties of the target, for example through doping of Xe in Ar, H in Xe, Gd in H20, and to achieve lower radiogenic backgrounds from the detector components, via target purification, material radioassay, and cryogenic distillation to change isotopic content.
- **DRDT 2.4 - Realise liquid detector technologies scalable for integration in large systems**. Dedicated developments should achieve applications of the previous DRDTs in future detectors ten to a hundred times larger, compared to the current state of the art, and allow coping with increased noise hit rates from detectors with sensor areas reaching 10, 100 and ultimately 1000 m2. This will have to proceed while addressing the step change in complexity, with decade-long construction, in underground or undersea environments, with handling of heat load, value engineering and industrial production.

R&D roadmap for TF2

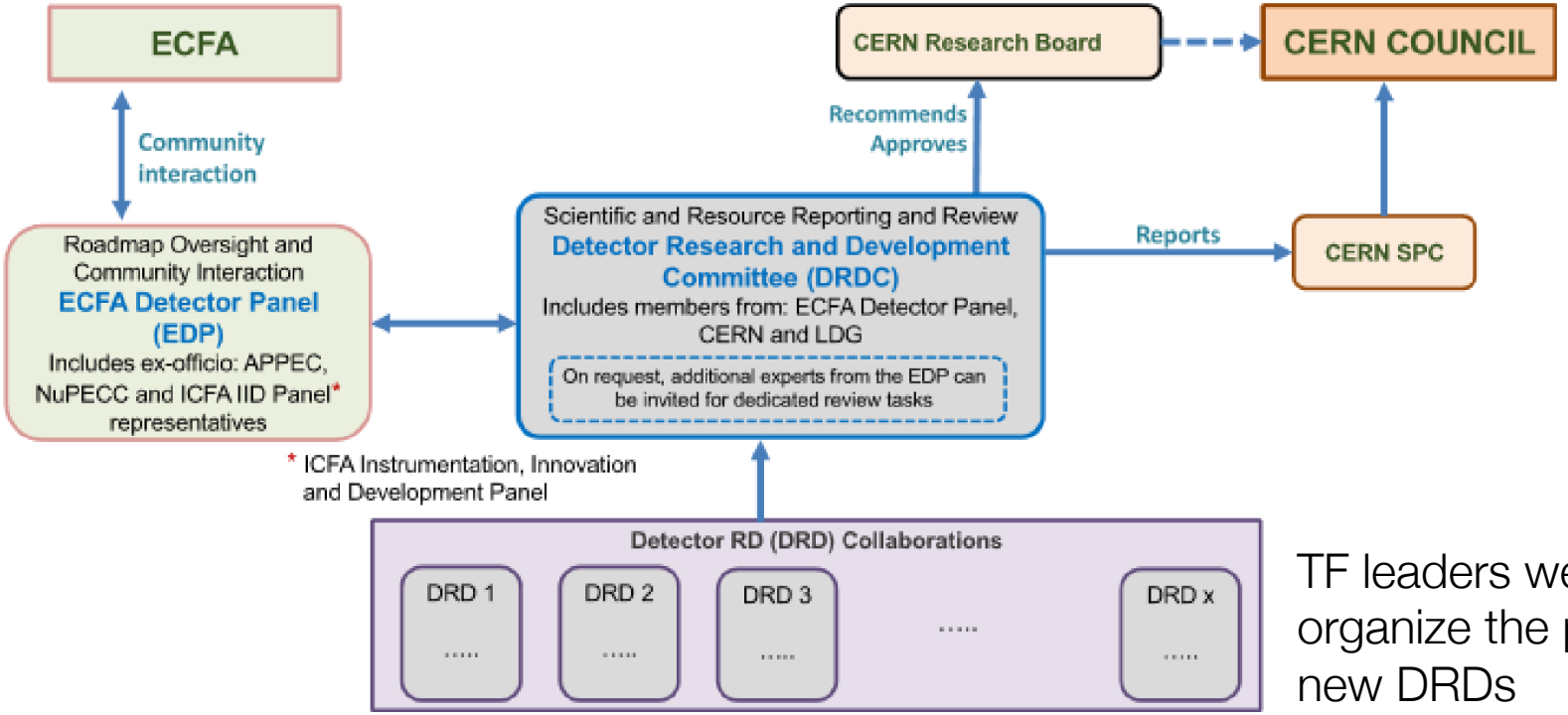


Implementation of the Detector R&D roadmap

An implementation plan was approved by the SPC and CERN Council in September 2022

ECFA Detector Panel

Co-chairs:	**Phil Allport (Birmingham)** **Didier Contardo (IP2I Lyon)**
Scientific secretary:	Doris Eckstein (DESY)
Gaseous Detectors:	Silvia Dalla Torre (Torino)
Liquid Detectors:	Inés Gil Botella (CIEMAT, Madrid)
Solid State Detectors:	Doris Eckstein (DESY) Phil Allport (Birmingham)
PID & Photon Detectors:	Roger Forty (CERN)
Quantum and emerging Technologies.:	Steven Hoekstra (Groningen)
Calorimetry:	Laurent Serin (IJCLab)
Electronics:	Valerio Re (Bergamo)
Ex Officio:	Karl Jakobs (ECFA Chair) Ian Shipsey (ICFA Detector Panel)
Observer for APPEC	Aldo Ianni (INFN, LNGS)
Observer for NuPECC	Eugenio Nappi (INFN, Unit of Bari)



TF leaders were asked to organize the proposals for the new DRDs

Current status of DRD 2 implementation

- A new survey was conducted as starting point for the DRD 2 implementation
- Group of experts (from France, Germany, Italy, Poland, Spain, UK + Canada, USA) meeting every 2 weeks preparing:
  - ✦ 20-page proposal following ECFA guidelines
    - Milestones, deliverables, test facilities and needed resources (FTEs and funding) per DRDT for next 3-5 years
    - Recruiting interested institutions
  - ✦ Online community workshop (18 or 20 April) to gather further input
- DRD 2 proposal submission to ECFA by early Summer 2023
- Fall 2023 review of proposals; end 2023 formal approval of DRDs by CERN Research Board

Current state of DRD 2 structure

WP 1: Charge Readout	WP 2: Light Readout	WP 3: Target Properties	WP 4: Scaling-up challenges
1.1: Pixels	2.1: Increased sensor QE	3.1: Purification	4.1: Material properties
1.2: Amplification	2.2: Higher efficiency WLS/collection	3.2: Doping & isotope loading	4.2: Radiopurity & bkg mitigation
1.3: Ion detection	2.3: Electronics, readout, integration for cryogenics	3.3: Optimization of light emission & transport	4.3: Detector & target procurement/production
1.4: Dual (charge + light)	2.4: Improved sensors for LS/Water	3.4: Microphysics & characterization	4.4 Large-area readout
1.5: Charge to light			

Current state of DRD 2 structure

SPAIN Leaders of WP

WP 1: Charge Readout	WP 2: Light Readout	WP 3: Target Properties	WP 4: Scaling-up challenges
1.1: Pixels	2.1: Increased sensor QE	3.1: Purification	4.1: Material properties
1.2: Amplification	2.2: Higher efficiency WLS/collection SPAIN	3.2: Doping & isotope loading	4.2: Radiopurity & bkg mitigation SPAIN
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