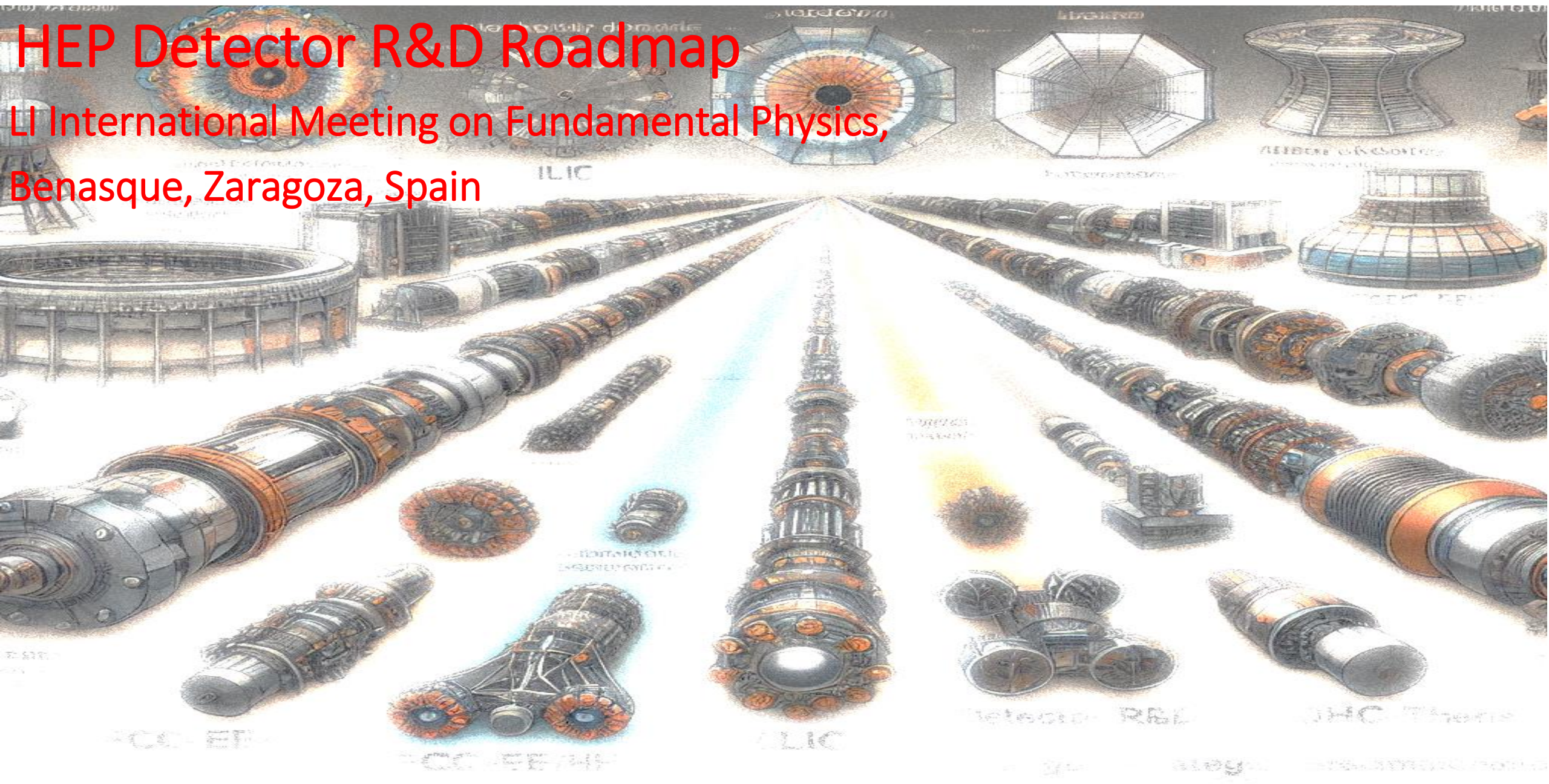
HEP Detector R&D Roadmap

LI International Meeting on Fundamental Physics,

Benasque, Zaragoza, Spain



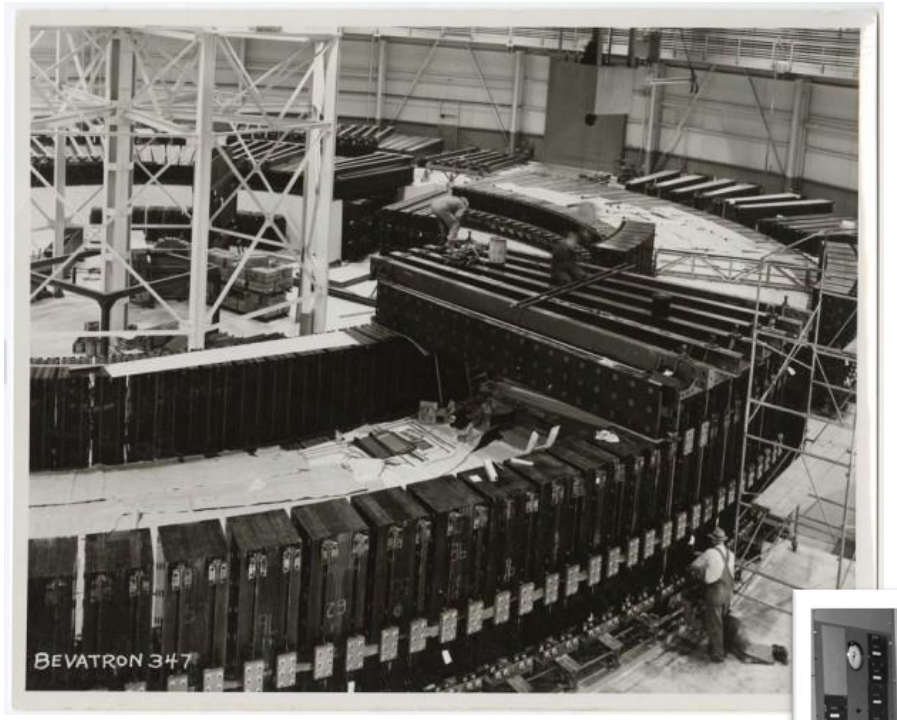
Iván Vila Álvarez
Instituto de Física de Cantabria (CSIC-UC)

Outline

- The motivation for a Detector R&D roadmap.
- The European Strategy on Detector R&D.
- The DRDs Collaborations at a glance.
- CPAN R&D network on detectors and instrumentation.
- Summary

What is it so important to define a Dectector R&D roadmap?

- The first particle discovered in a large accelerator was the antiproton, discovered in **1955** at the **Bevatron accelerator** at Lawrence Berkeley National Laboratory. physics discoveries.
- A first nobel prize: **Emilio Segrè** and **Owen Chamberlain**



Since then … accelerators dominated the fundamental physics discoveries.

- **Summary of Nobel Prizes Linked to Colliders:**
  - **1959**: Antiproton discovery at the Bevatron.
  - **1976**: Charm quark (J/ψ) discovery at Brookhaven ISR (indirectly linked to accelerator advancements).
  - **1984**: W and Z bosons discovery at CERN's SPS.
  - **2008**: Theoretical contributions to CP violation and symmetry breaking (tested in colliders).
  - **2013**: Higgs boson discovery at CERN's LHC.
  - Surprisingly, the **discovery of the bottom quark in 1977,** the **top quark in 1995 and the gluon in 1979** never received a Nobel Prize.

The Evolution of Flagship Colliders (1950s–Present)

1950s:

Bevatron (Approved 1949, Operational 1954) First to produce high-energy particles, leading to the discovery of the antiproton.

1960s:

CERN Proton Synchrotron (PS) (Approved 1953, Operational 1959)
First European accelerator to reach multi-GeV energies.

Brookhaven Alternating Gradient Synchrotron (AGS) (Approved 1952, Operational 1960) Key discoveries include the muon neutrino and CP violation in kaons.

1970s:

CERN Intersecting Storage Rings (ISR) (Approved 1965, Operational 1971)
First hadron collider, proton-proton collisions.

Fermilab Main Ring (Approved 1967, Operational 1972)
Important for early high-energy fixed-target experiments.

DESY Positron-Electron Tandem Ring Accelerator (Approved 1974, Operational 1978) Discovery of the gluon in 1979

1980s:

CERN Super Proton Synchrotron (SPS) (Approved 1971, Operational 1976, Collider Mode 1981)
Enabled discovery of the W and Z bosons.

SLAC Linear Collider (SLC) (Approved 1983, Operational 1989)
First linear electron-positron collider, focused on precision electroweak measurements.

1990s:

CERN Large Electron-Positron Collider (LEP) (Approved 1981, Operational 1989 Precision tests of the Standard Model.

Fermilab Tevatron (Approved 1972, Collider Mode 1983). Led to the discovery of the top quark.

2000s:

Large Hadron Collider (LHC) (Approved 1994, Operational 2008)
The world's most powerful collider, discovery of the Higgs boson.

2010s:

High-Luminosity Large Hadron Collider (HL-LHC) (Approved 2016, Operational 2029 for precision Higgs measurements and searches beyond the Standard Model.

In the recent past, the next flagship accelerator defined the detector R&D topics (LHC the main motivation)

RD-1	SPACAL	Scintillating Fibre Calorimetry at the LHC	R&D	20-09-1990	Finished
RD-10	RADHARD	A St.to Improve the Radiat.Hardness of Gas.Detect.for Use at Very-H Luminosities	R&D	04-04-1991	Finished
RD-11	EAST	Embedded Architectures for Second-level Triggering in LHC Experiments (EAST)	R&D	04-04-1991	Finished
RD-12	TTC	Timing, Trigger and Control Systems for LHC Detectors	R&D	04-04-1991	Finished
RD-13	LHCTB	A Scalable Data Taking System at a Test Beam for.LHC	R&D	04-04-1991	Finished
RD-14	XENON	Noble Liquid (Xenon or Krypton) Totally Active Calorimetry	R&D	04-04-1991	Finished
RD-15	PPC	The Prism Plastic Calorimeter (PPC)	R&D	04-04-1991	Finished
RD-16	FERMI	A digital Front-End and Readout MIcrosystem for calorimetry at LHC	R&D	04-04-1991	Finished
RD-17	FAROS	Ultrafast Readout of Scintill.Fibres Us.Upgr.Position-Sensitive Photomultipliers	R&D	04-04-1991	Finished
RD-18	CRYSTAL CLEAR	R&D on scintillation materials for novel ionizing radiation detectors for High Energy Physics, medical imaging and industrial applications	R&D	04-04-1991	In-Progre
RD-19	PIXEL	Development of Hybrid and Monolithic Silicon Micropattern Detectors	R&D	27-06-1991	Finished
RD-2	SITP	Study of a Tracking/Preshower Detector for the LHC	R&D	20-09-1990	Finished
RD-20	SI TRACKER	Dev.of High Resolution Si Strip Detectors for Exp.at High Luminosity at the LHC	R&D	27-06-1991	Finished
RD-3	ACCORDION	Liquid Argon Calorimetry with LHC-Performance Specifications	R&D	20-09-1990	Finished
RD-4	DOPANTS	Study of Liquid Argon Dopants for LHC Hadron Calorimetry	R&D	20-09-1990	Finished
RD-5	LHC-MUONS	St.of Muon Triggers & Momentum Rec.in a Str.Magn.Field x a Muon Detector at LHC	R&D	07-02-1991	Finished
RD-6	TRD-TRACKER	Integr.High-Rate Transition Radiation Detector & Tracking Chamber for the LHC	R&D	07-02-1991	Finished
RD-7	FITRACK	Central Tracking Detector Based on Scintillating Fibres	R&D	07-02-1991	Finished
RD-8	GAASWORKS	Development of GaAs Detectors for Physics at the LHC	R&D	07-02-1991	Finished
RD-9	SOI	A Demonstrator Analog Signal Process.Circuit in a Radiation Hard SOI-CMOS Techn.	R&D	07-02-1991	Finished
RD21	COLLIDER-BEAUTY	R&D for Collider Beauty Physics at the LHC	R&D	28-11-1991	Finished
RD22		Test of Beam Extr.by Crystal Chann.at the SPS:First Step tow.a LHC Extr.Beam	R&D	28-11-1991	Finished
RD23	OPTOELECTRONICS	Optoelectronic Analogue Signal Transfer for LHC Detectors	R&D	06-02-1992	Finished
RD24	SCI	Application of the Scalable Coherent Interface to Data Acquisition at LHC	R&D	06-02-1992	Finished
RD25	LFC	Continuing Studies on Lead/Scintillating Fibres Calorimetry (LFC)	R&D	16-04-1992	Finished
RD26	CSIRICH	Development of a Large Area Advanced Fast RICH Detector for Particle Identification at the Large Hadron Collider Operated with Heavy Ions	R&D	16-04-1992	Finished
RD27		First-Level Trigger Systems for LHC Experiments	R&D	30-06-1992	Finished
RD28	GAS MICROSTRIPS	Dev.of Gas Micro-Strip Chambers for Radiation Det.& Tracking at High Rates	R&D	30-06-1992	Finished
RD29	DMILL	A Mixed Analog-Digital Radiation Hard Technology for High Energy Physics Electronics: DMILL (Durci Mixte sur Isolant Logico-Lineaire)	R&D	30-06-1992	Finished
RD30	OPTICAL TRIGGER	St.of Impact-Par.Opt.Discrim.to be used x Beauty Sch in Fixed-Tgt Mode at LHC	R&D	26-11-1992	Finished
RD31	NEBULAS	NEBULAS.br H-P.Data-Dr.Event-Build.Arch.bas.on Asynchr.Self-R.Pack.-Switch.Netw.	R&D	26-11-1992	Finished
RD32	ALICE TPC	Dev.of a Time Projec.Chamber w.High Two Tr.Resol.Cap.x Exp.at Heavy Ion Collid.	R&D	26-11-1992	Finished
RD33	TGT	Study of a Novel Concept for a Liquid Argon Calorimeter The "Thin gap Turbine" (TGT)	R&D	11-02-1993	Finished
RD34	TILECAL	Constr.& Perf.of an Iron-Scintill.Hadron Calorim.w.Longitudinal Tile Configurat.	R&D	15-04-1993	Finished
RD35	SICAL	A Silicon Hadron Calorim. Module Op.in a Strong Magn.F.w.VLSI Readout for LHC	R&D	17-06-1993	Finished
RD36		Shashlik Calorimetry.br - A Combined Shashlik + Preshower Detector for LHC	R&D	25-11-1993	Finished
RD37		Very Forward Hadron Calorimetry at the LHC Using Parallel Plate Chambers	R&D	10-02-1994	Finished
RD38	CICERO	CICERO:Ctrl Inf.syst.Conc.b.on Enc.R-T.Obj.St.on Gen.Ctrl Syst.x Lge Sc.LHC Exp.	R&D	10-02-1994	Finished
RD39	SMSD	Cryogenic Tracking Detectors	R&D	10-02-1994	Finished
RD40	Q-CAL	Development of Quartz Fiber Calorimetry	R&D	21-04-1994	Finished
RD41	MOOSE	Object Oriented Approach to Software Development for LHC Experiments	R&D	16-06-1994	Finished
RD42		Development of Diamond Tracking Detectors for High Luminosity Experiments at the LHC	R&D	22-09-1994	In-Progress
RD43	BHCAL	Proposal for Research & Develop.of a Hadron Calorimeter for High Magnetic Fields	R&D	22-09-1994	Finished
RD44	GEANT4	GEANT 4: an Object-Oriented toolkit for simulation in HEP	R&D	24-11-1994	Finished
RD45		A Persistent Object Manager for HEP	R&D	09-02-1995	Finished
RD46		High Resolution Tracking Devices Based on Capillaries Filled with Liquid Scintillator	R&D	15-06-1995	Finished
RD47		High Energy Physics Processing using Commodity components (HEP PC)	R&D	08-02-1996	Finished
RD48	ROSE	Radiation Hardening of Silicon Detectors	R&D	13-06-1996	Finished
RD49	RADTOL	Studying Radiation Tolerant ICs for LHC	R&D	12-06-1997	Finished
RD50		Development of Radiation Hard Semiconductor Devices for Very High Luminosity Colliders	R&D	30-05-2002	In-Progress
RD51		Development of Micro-Pattern Gas Detectors Technologies	R&D	05-12-2008	In-Progress
RD52		Dual-Readout Calorimetry for High-Quality Energy Measurements	R&D	31-08-2011	Finished
RD53		Development of pixel readout integrated circuits for extreme rate and radiation	R&D	28-08-2013	In-Progress

R&D Collaborations at CERN many of then addressing the LHC and HL-LHC needs

2020s:

?

The Answer

The Detector R&D colaboraciones (DRDs)

focused R&D collaboration that help guide and coordinate the development of advanced detector technologies. They ensure that the necessary innovations are ready for upcoming high-energy physics experiments

(to be fully operational in 2024)

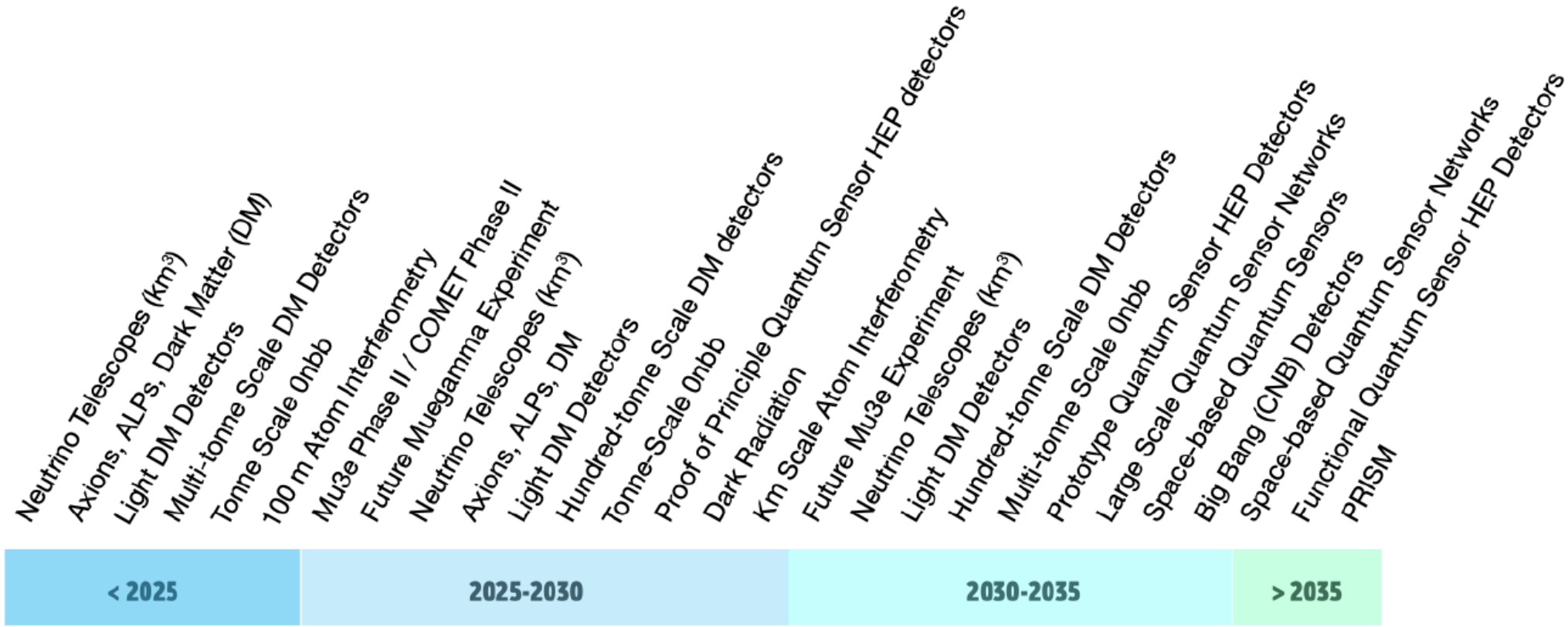
The European strategy for Detector R&D

- In 2021, the European Committee for Future Accelerators (released an extensive report (200 pages):
  - Comprehensive overview of prospective facilities (EIC, ILC, CLIC, FCC-ee/hh, Muon collider) and major upgrades (ALICE, Belle-II, LHC-b, etc.), along with their projected timelines.
  - Detailed examination of nine technology domains (Task Force areas).
  - Identification of the most pressing R&D priorities within each Task Force area.
  - Ten "General Strategic Recommendations."

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

Earliest feasible start date for future colliders and…

… non Accelerator too



DRD Jargon 101: DRD Themes (DRDT) for each Taskforce

- **Detector Readiness Matrix:** a framework used to evaluate the maturity of different detector technologies, for integration into particle physics experiments
- A **Detector R&D Theme (DRDT)** is a specific, high-priority research and development topic identified within each task force domain of the ECFA Detector R&D roadmap.
- DRDTs represent the most urgent technological challenges and opportunities that need to be addressed to advance particle detector technologies for future experiments.

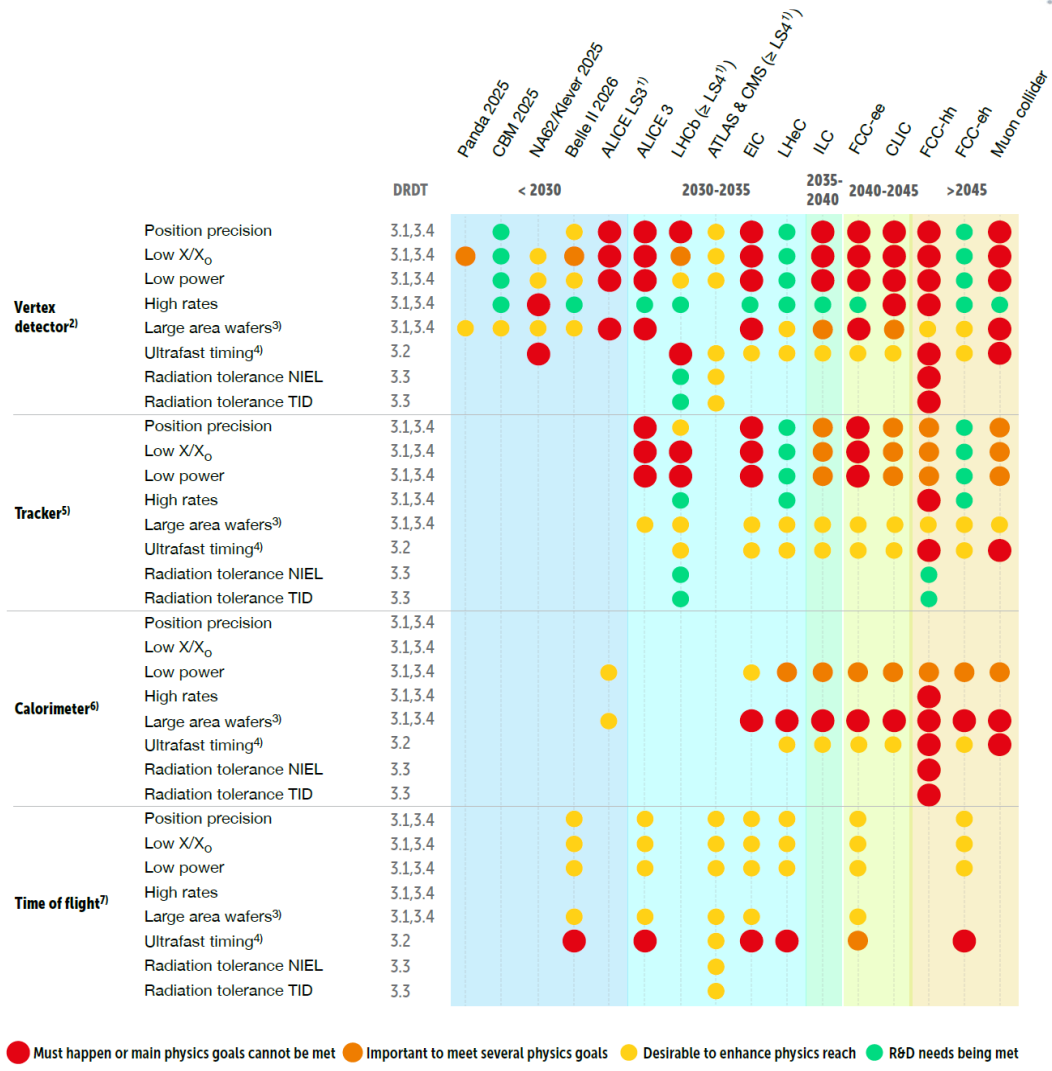
Solid state

DRDT 3.1 Achieve full integration of sensing and microelectronics in monolithi CMOS pixel sensors

DRDT 3.2 Develop solid state sensors with 4D-capabilities for tracking and calorimetry

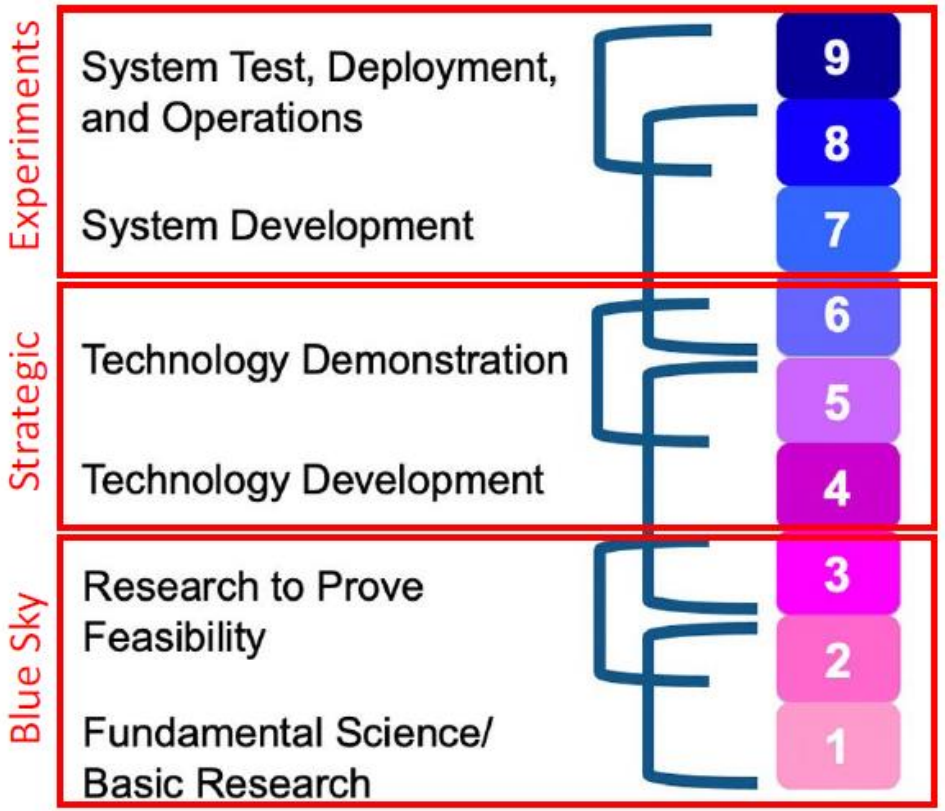
DRDT 3.3 Extend capabilities of solid state sensors to operate at extreme fluences

DRDT 3.4 Develop full 3D-interconnection technologies for solid state devices in particle physics



DRD Jagon 101: Strategic and Blue Sky R&D

- **Strategic R&D towards necessary technologies to build future facilities and experiments**
  - Addresses the DRDTs in ECFA roadmap by defining suitable deliverables and milestones
  - Technology Readiness Levels (TRL) 3-6
  - Backed up by strategic funding, agreed with funding agencies (MoUs)
- **Exploratory "blue-sky" R&D towards new developments.**
  - Address TRL 1-3
  - Possibly financed by common fund + institute contributions (RD50/51 scheme)



Detector R&D Collaborations

Targeting mostly HEP

Targeting "smaller experiments", e.g. rare event searches, DM

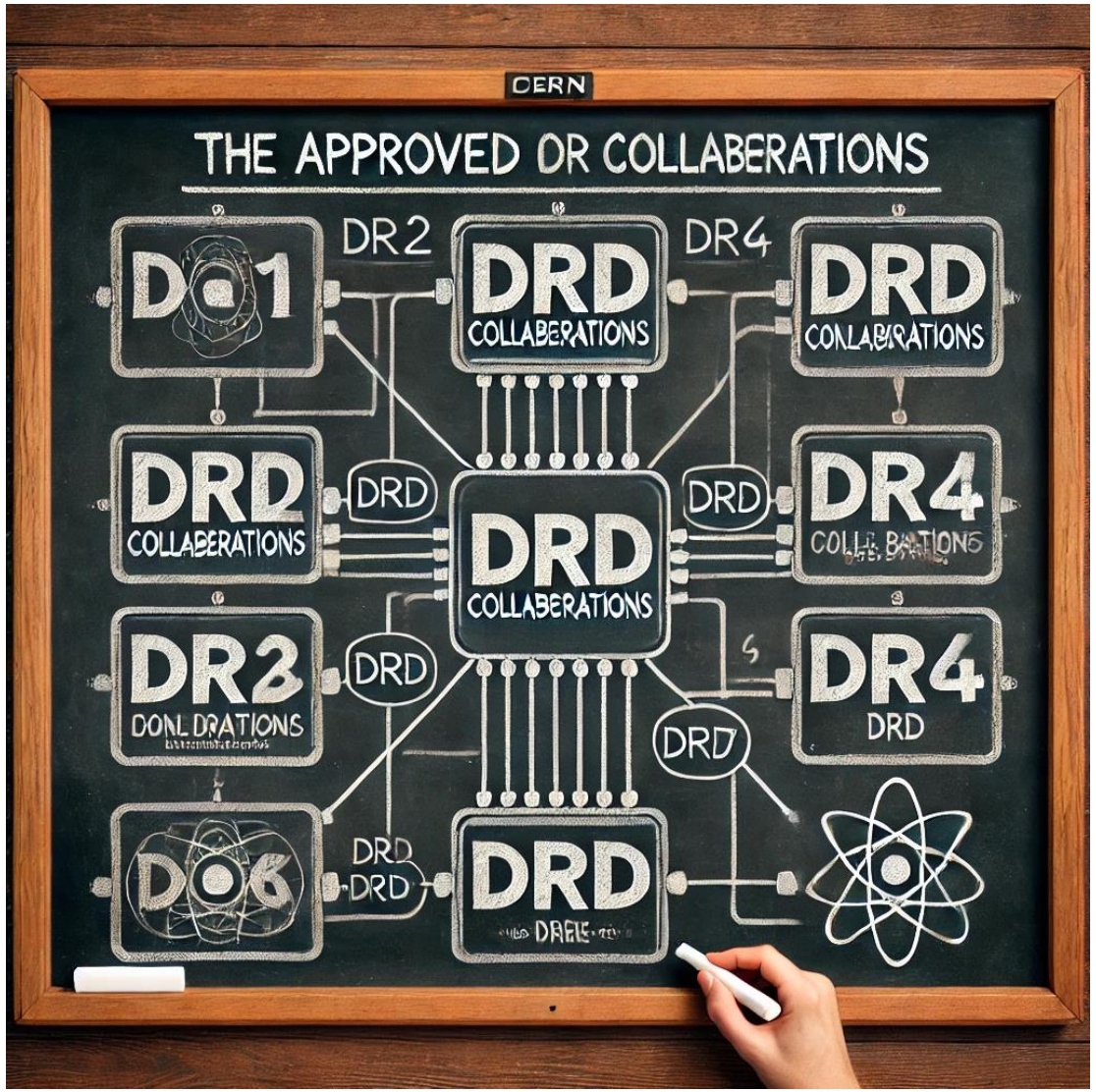
- Gaseous Detectors (DRD1)
- Semiconductor Detectors (DRD3)
- Calorimetry (DRD6)
- Photodetectors & Particle ID (DRD4)
- Liquid Detectors (DRD2)

- Quantum Sensors (DRD5)

Orthogonal topics necessary for all activities

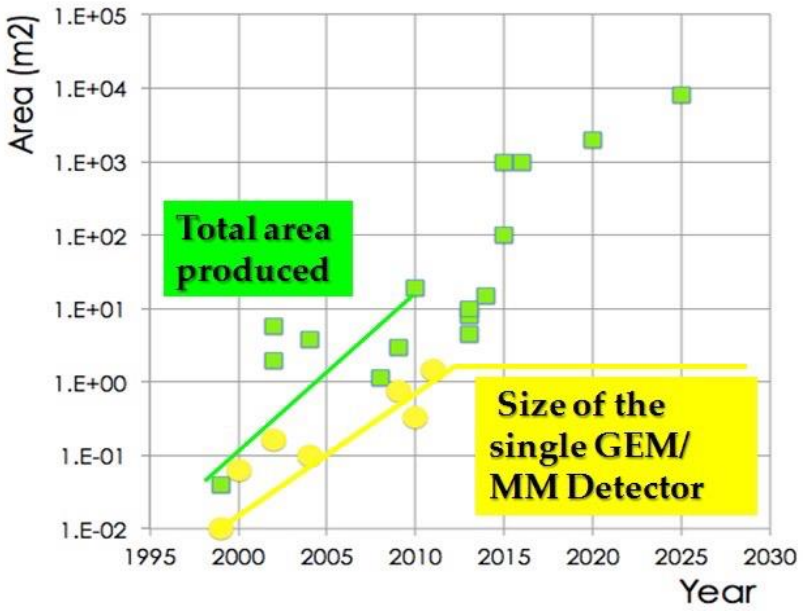
- Electronics (DRD7)
- *Integration (TF8)*
- *Training (TF9)*

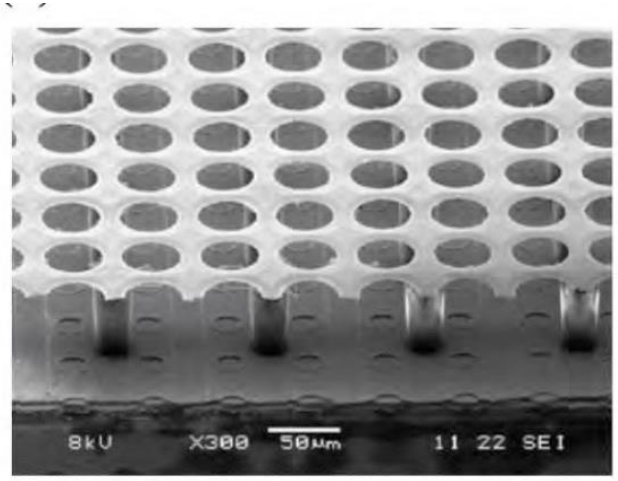
Currently approved DRD collaboration

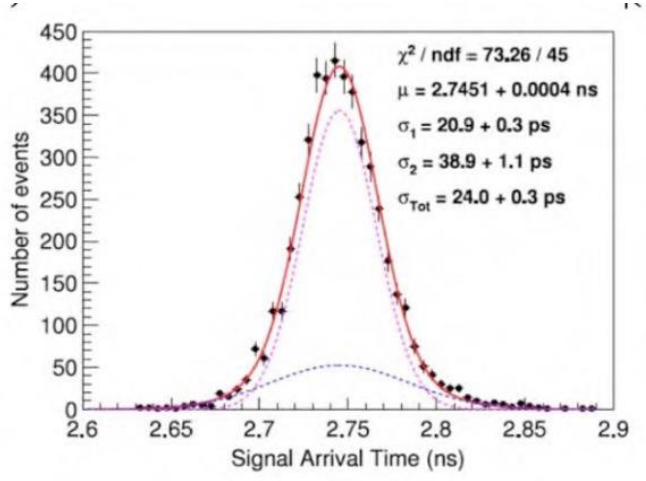


Gaseous detectors: current status

- **Large Areas:**
  - Systems developed for LHC experiments led to unprecedented large systems, mostly based on MPGDs
- **Fast Timing:**
  - Fast timing with Multi-Gap RPCs: achieved ~60ps time resolution (ALICE TOF Detector, Z.Liu)
  - Micromegas with timing (PICOSEC concept): 25ps
- **Eco-friendly gas mixtures**
  - 92% of emissions at CERN are related to LHC experiments
  -







PICOSEC: NIMA903 (2018) 317

Gaseous detectors: DRD1

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

RD51 successor, 118 institutes

DRDTs

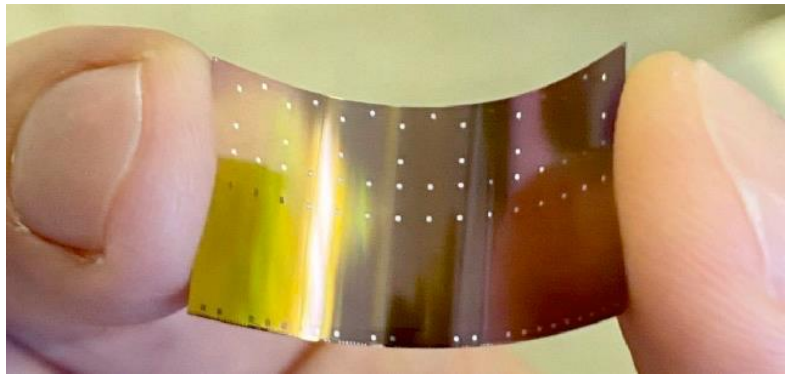
1.1	1.2	1.3	1.4	Work Packages
●	●	●		Trackers/hodoscopes
●	●	●		Drift chambers
●	●	●		Straw chambers
●	●	●	●	Tracking TPCs
●		●		Calorimetry
●	●	●		Photon detection (PID)
●		●		Timing detectors
●	●	●	●	Reaction/decay TPCs
●		●		Beyond HEP

Forum for discussion on common topics

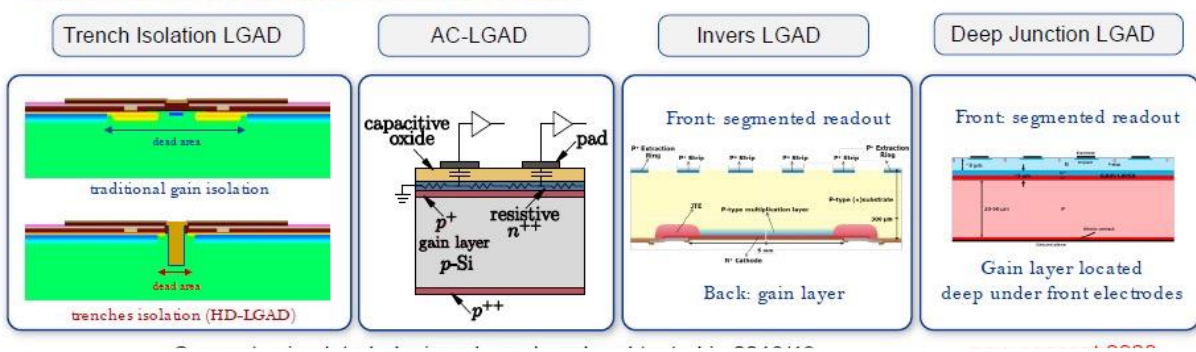
- WG1 Technologies
- WG2 Applications
- WG3 Gas and material studies
- WG4 Detector physics, simulations and software tools
- WG5 Electronics for gaseous detectors
- WG6 Detector production
- WG7 Common test facilities
- WG8 Training and dissemination

Semiconductor detectors: DRD3

- CMOS Monolithic sensors: combining sensing and readout elements
  - Sensor development becomes chip development, but typically with modifications to standard process, e.g. Towerjazz 180 nm
  - Overlap with DRD7 electronics
- 4D Tracking/ToF: Timing using LGAD sensors
  - Suppression of pile-ups
  - Foundries CNM, FBK, HPK
  - Timing performance (~ 25 ps for 50 µm sensors)
- Radiation hardness
  - Wide bandgap material (SiC, GaN)



CMOS MAPS for ALICE ITS3 (Run 4)
(LOI: CERN-LHCC-2019-018, M. Mager)

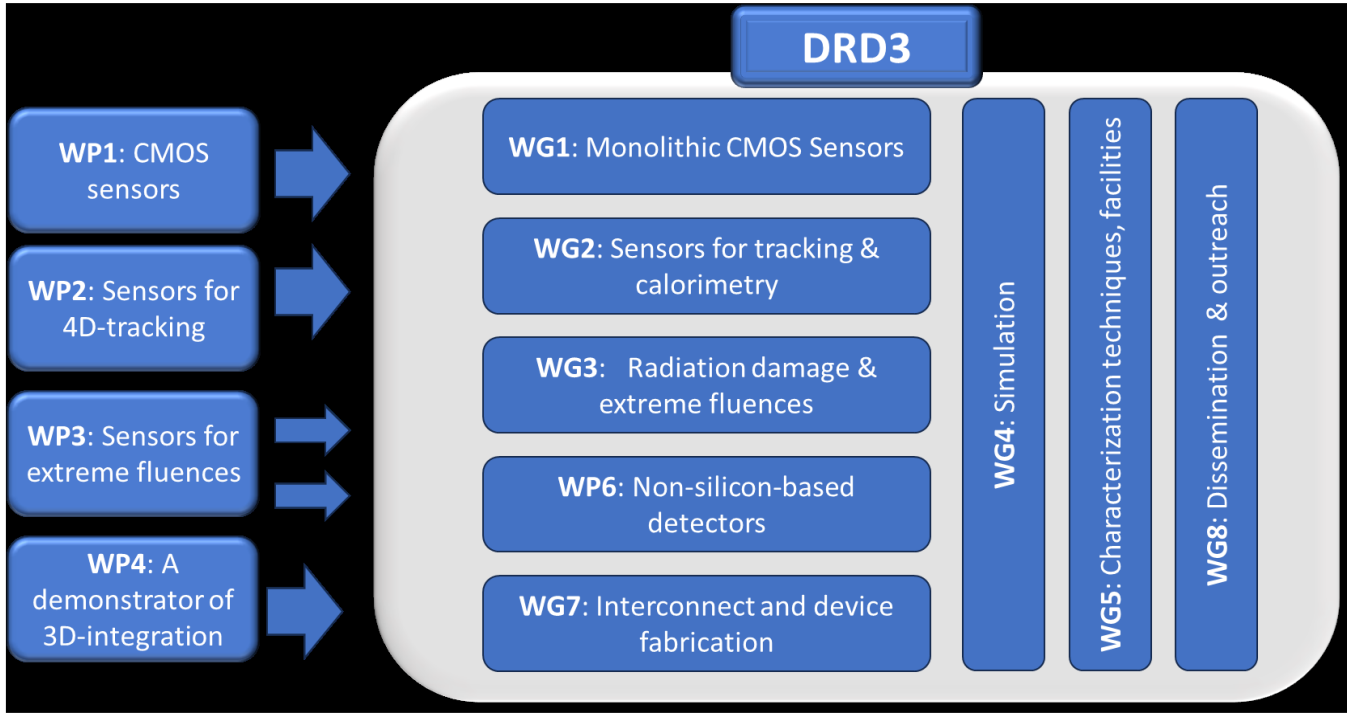


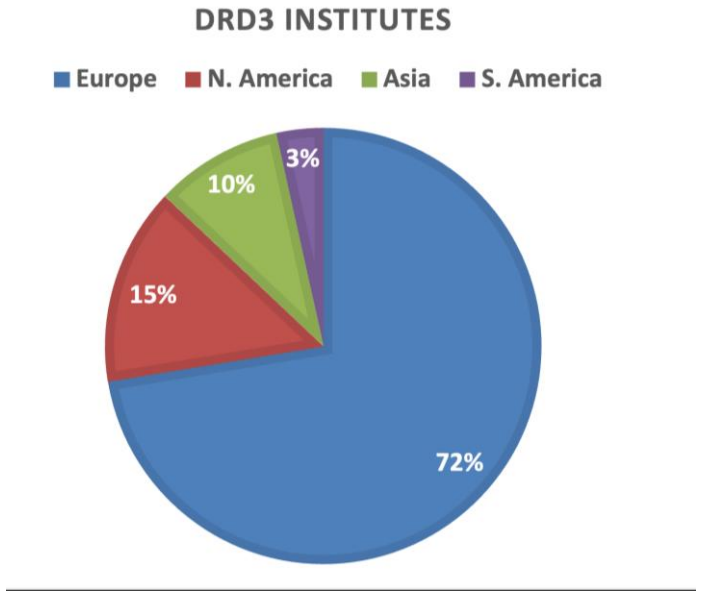
Semiconductor detectors: DRD3

- ~129 institutes, 28 countries, ~900 interested people
- Merging RD50 and RD42 collaborations

Solid state

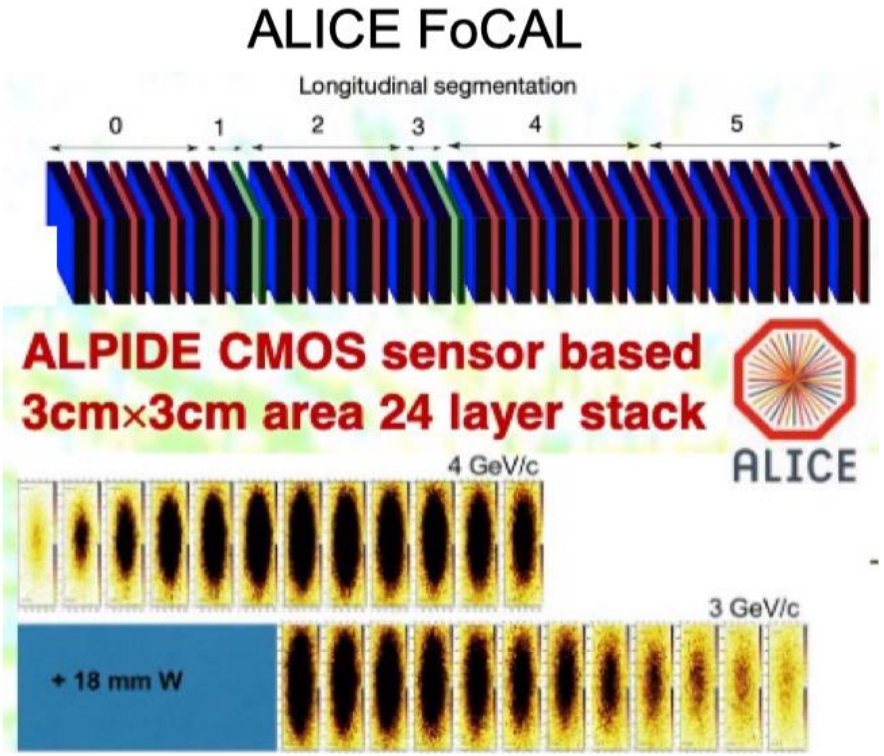
DRDT 3.1 Achieve full integration of sensing and microelectronics in monolithic CMOS pixel sensors
DRDT 3.2 Develop solid state sensors with 4D-capabilities for tracking and calorimetry
DRDT 3.3 Extend capabilities of solid state sensors to operate at extreme fluences
DRDT 3.4 Develop full 3D-interconnection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





Calorimetry

- R&D in calorimetry has a particularly long lead-time due:
  - Many technology developments (gas, scintillator or Silicon-based readout)
  - Large and challenging prototype setups even in early stages.



Calorimetry

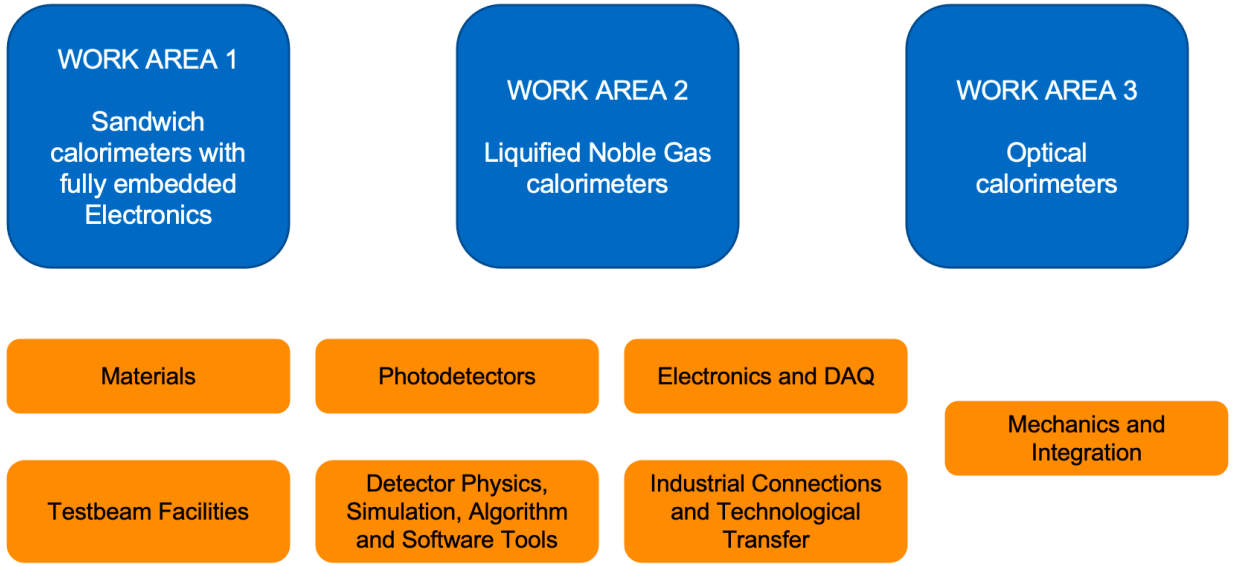
DRDT 6.1 Develop radiation-hard calorimeters with enhanced electromagnetic energy and timing resolution

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

Calorimetry: DRD6

- Collaboration emerged from CALICE and CrystalClear (RD18)
- Light-weight organization structure:
  - organized in three Work Areas
  - Several projects for different target application and calorimeter types
  - Several transversal activities



Target applications : e+e- collider FCC-hh Muon collider other

Calorimeter types : Electromagnetic Hadronic Electromagnetic + Hadronic

Project maturity : +++ exists a large prototype ++ exists a small prototype + at level of proof of principle

WA1		WA2		WA3	
SiW Ecal	(+) ++	EM LAr Calo	+	EM HGCAL	+
DECAL	++			EM MAXICC	+
Highly compact calorimeter	+			EM CRILIN	+
Sc Ecal	++			EM GRAINITA	+
AHCAL	+++			EM SPACAL (LHCb Phase 2)	++
ScintGlassHCAL	+			EM RADICAL	+
T-DHCAL	+++			EM + HAD DRCAL	(+)++
MGPD-HCAL	+			HAD TILECAL	+
ADRIANO3	++				

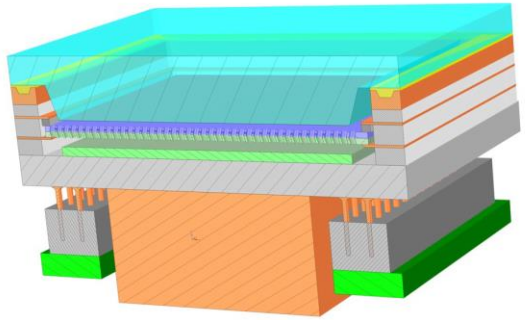
Photodetection and Particle ID: DRD4

- Particle Identification (PID) essential to identify decays when heavy flavor are present
- Developments on **MCP-PMTs, SiPMs, Vacuum and gaseous** photon detectors
- Applications in **Ring Imaging Cherenkov Detectors (RICH), Time-of-Flight (ToF), TRD**
- Challenges for example for SiPMs: the high dark count rate and moderate radiation hardness prevented their use in RICH detectors where single photon detector required at low noise, but also new ideas emerge (e.g. backside illumination)

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

(b)

MCP with 64 x 64 anode pads (Photek)



R&D to develop an MCP with integrated Timepix4 chip (55 x 55 μm^2 pixels)

Photodetection and Particle ID: DRD4

- About 50 institutes
- 36 EU + 6 US, 2 China, 2 Japan, 2 Australia, 1 S.Korea, 1 Armenia
- 7 industrial partners
  Connection to almost every other DRD collaboration (gas, Silicon, calo, electronics, SiPM at cryogenic temp.)

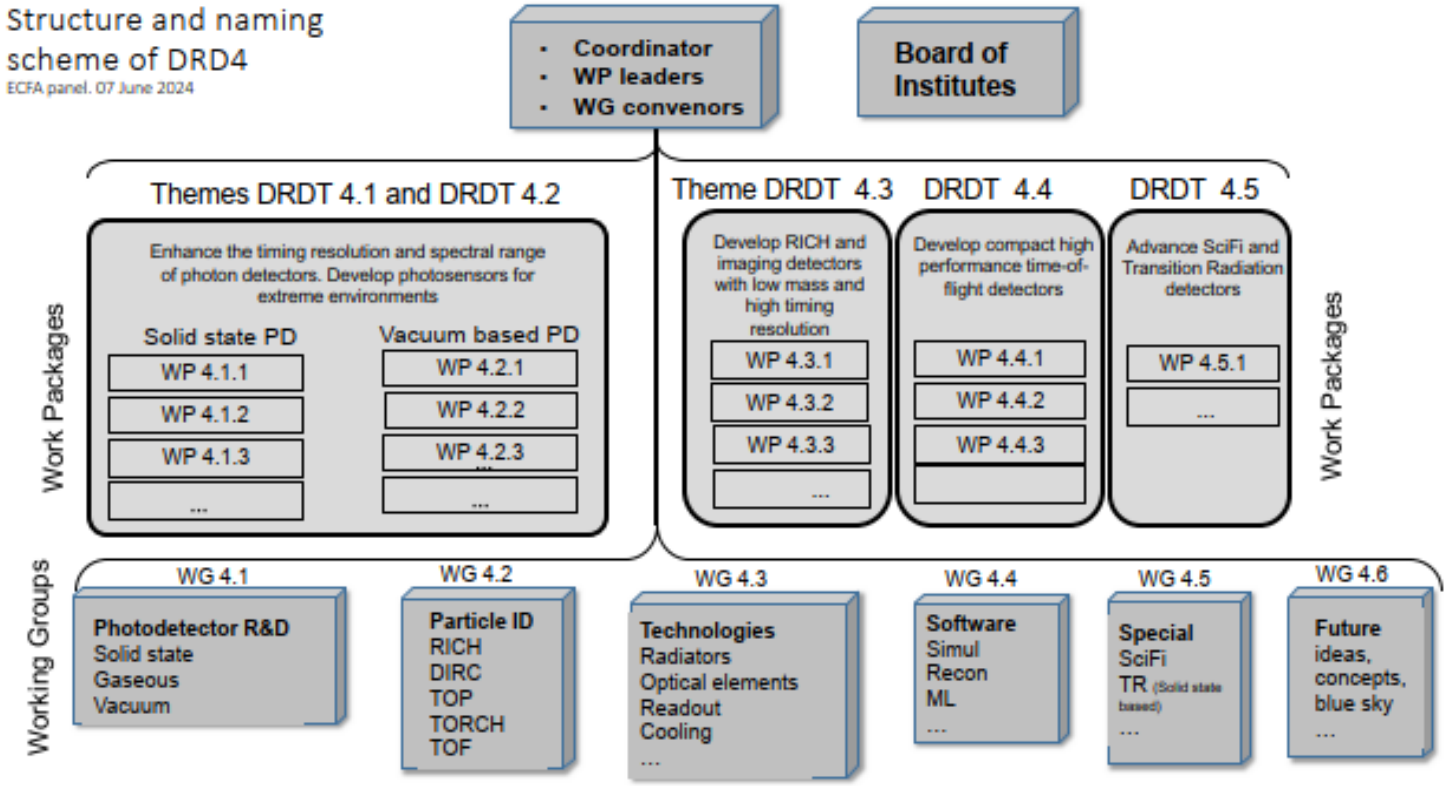
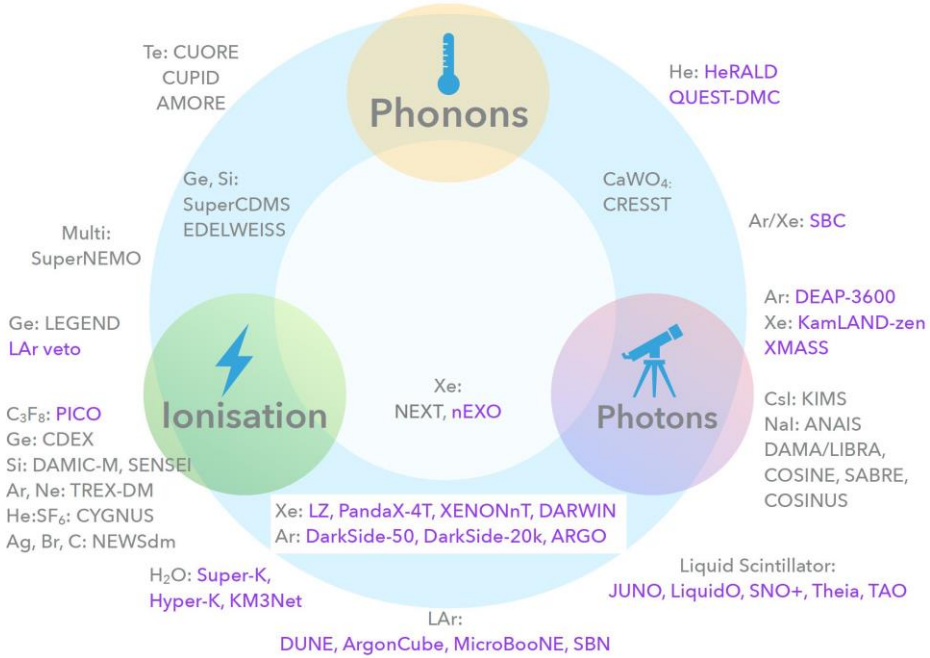


Figure 1: Organigram of DRD4 collaboration.

Liquid detectors: DRD2

- Covers Dark Matter and Neutrino experiments, accelerator and non-accelerator-based
- Several large-scale and many small-scale experiments running or foreseen with liquid detectors
- Technology: Noble Liquids (e.g. DUNE), Water Cherenkov (e.g. Super/Hyper-K) and Liquid Scintillator with light and ionization readout
- Underground Dark Matter Experiments – small and rare signals, R&D for multi-ton scale noble liquids:
  - Target doping and purification
  - Detector components radiopurity and background mitigation



Liquid

DRDT 2.1 Develop readout technology to increase spatial and energy resolution for liquid detectors

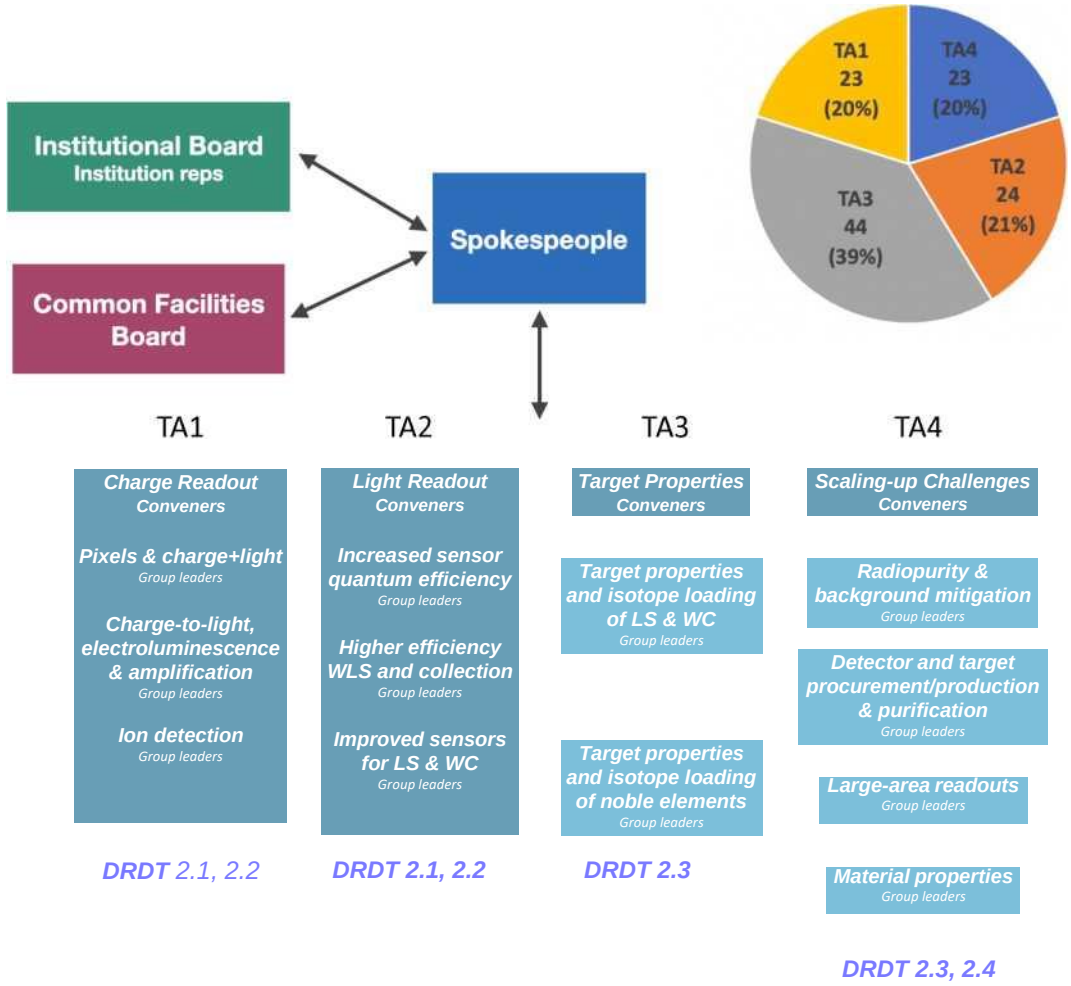
DRDT 2.2 Advance noise reduction in liquid detectors to lower signal energy thresholds

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

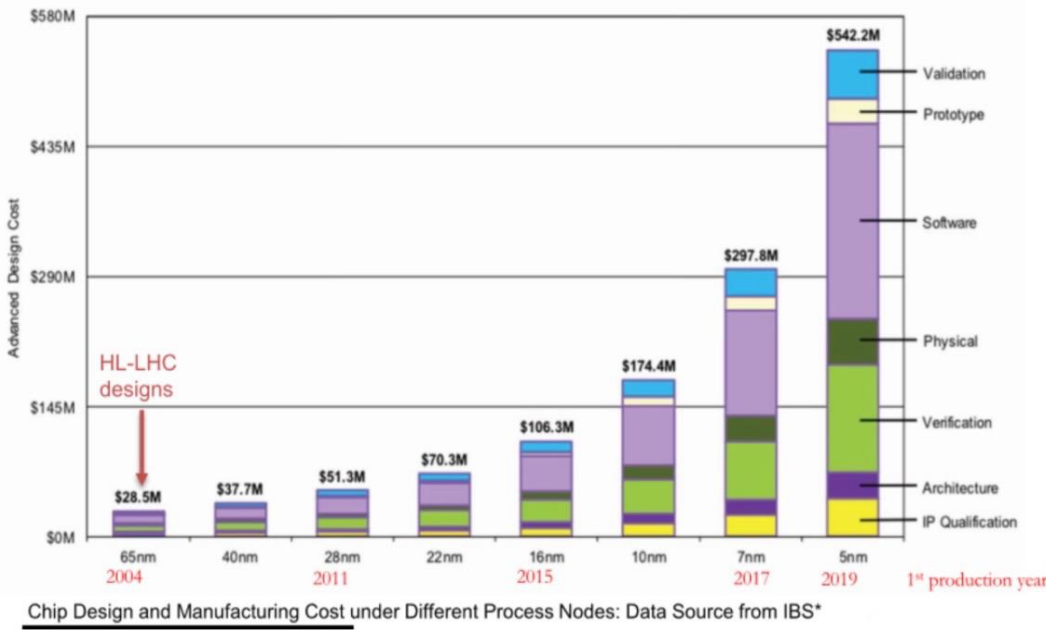
Liquid Detectors: DRD4

- DRD2 proposal, divided in four Technology Areas (TA), well aligned to DRDTs
- DRD2 Collaboration from 114 institutes in 15 countries
- Significant US contribution (1/ 4)
- Liaisons to DRD1,4 and 7
- list of companies associated to different TA is included



Electronic Systems: DRD7

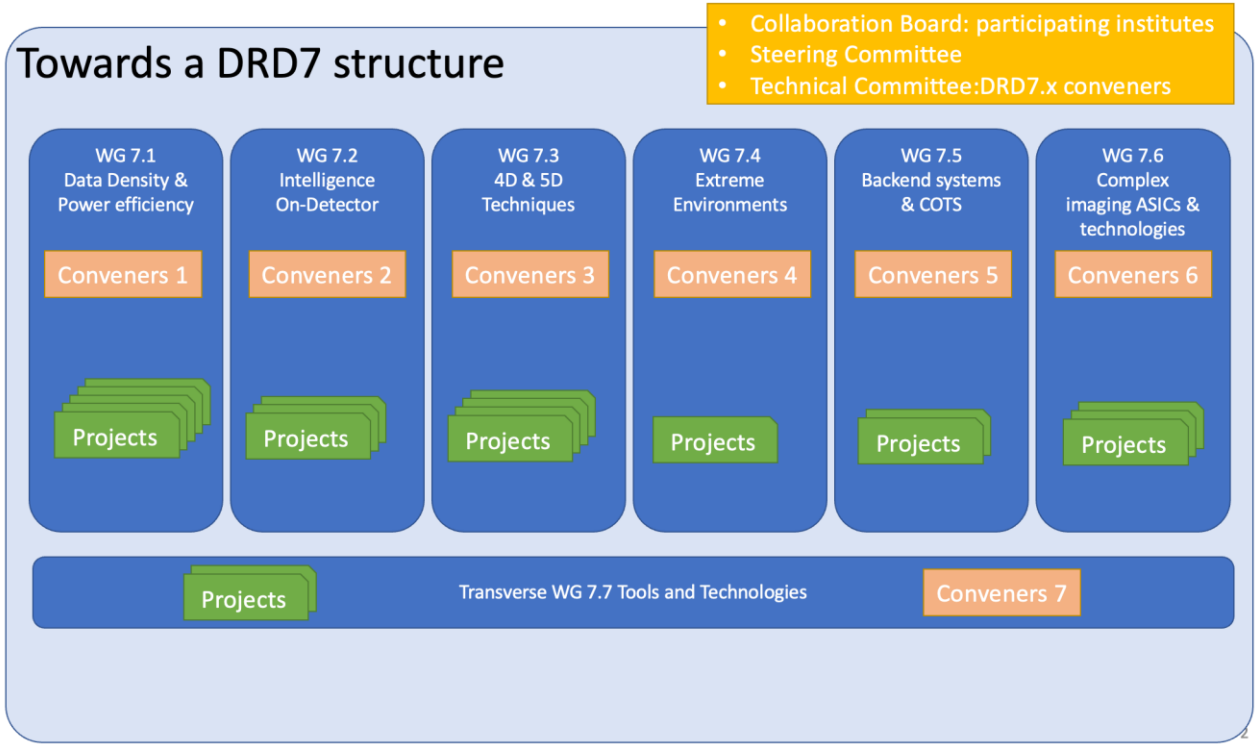
- All new techniques (Precision timing, ultra-high granularity and improved signal resolution) need more sophisticated data handling, processing, complexity and power.
  - Requires exploiting the latest advances in commercial microelectronics and high-speed links.
  - Additional HEP requirements: Radiation and magnetic fields (niche and low volume market only)
- Core topic: ASIC development
  - Community now looks into 28 nm CMOS nodes for the future and dedicated 130 /110/65 nm technologies for monolithic pixels (DRD3 overlap!)
  - Each new node imposes significantly higher funds necessary
  - Legal topics (NDAs, design sharing agreements, software licenses,..)
  - Organization of multi-project wafer runs
- Strategic developments necessary for systems to be used in large-scale experiments, with synergy across many domains (e.g. DC-DC powering, FMC boards like FC7, GLIB)
  - All DRD collaborations have demands in electronics, from ASICs specific to certain detector technologies to small-scale readout systems
  - expert persons needed to be members of both, original DRD collaboration and electronics (see Annex B in this document)



Chip Design and Manufacturing Cost under Different Process Nodes: Data Source from IBS*

Electronics Systems: DRD7

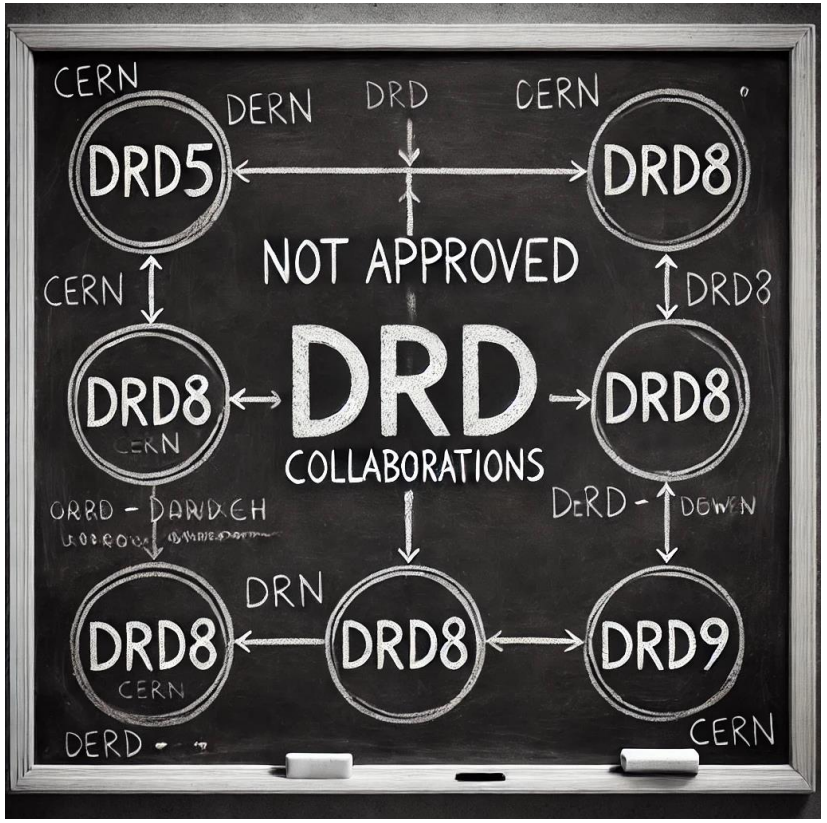
- Organization:
  - 50 Institutes, 18 countries
  - Six Development areas (WG)
- 16 projects in a bottom-up approach, but ensured that all are above certain threshold and fit the WGs



Electronics

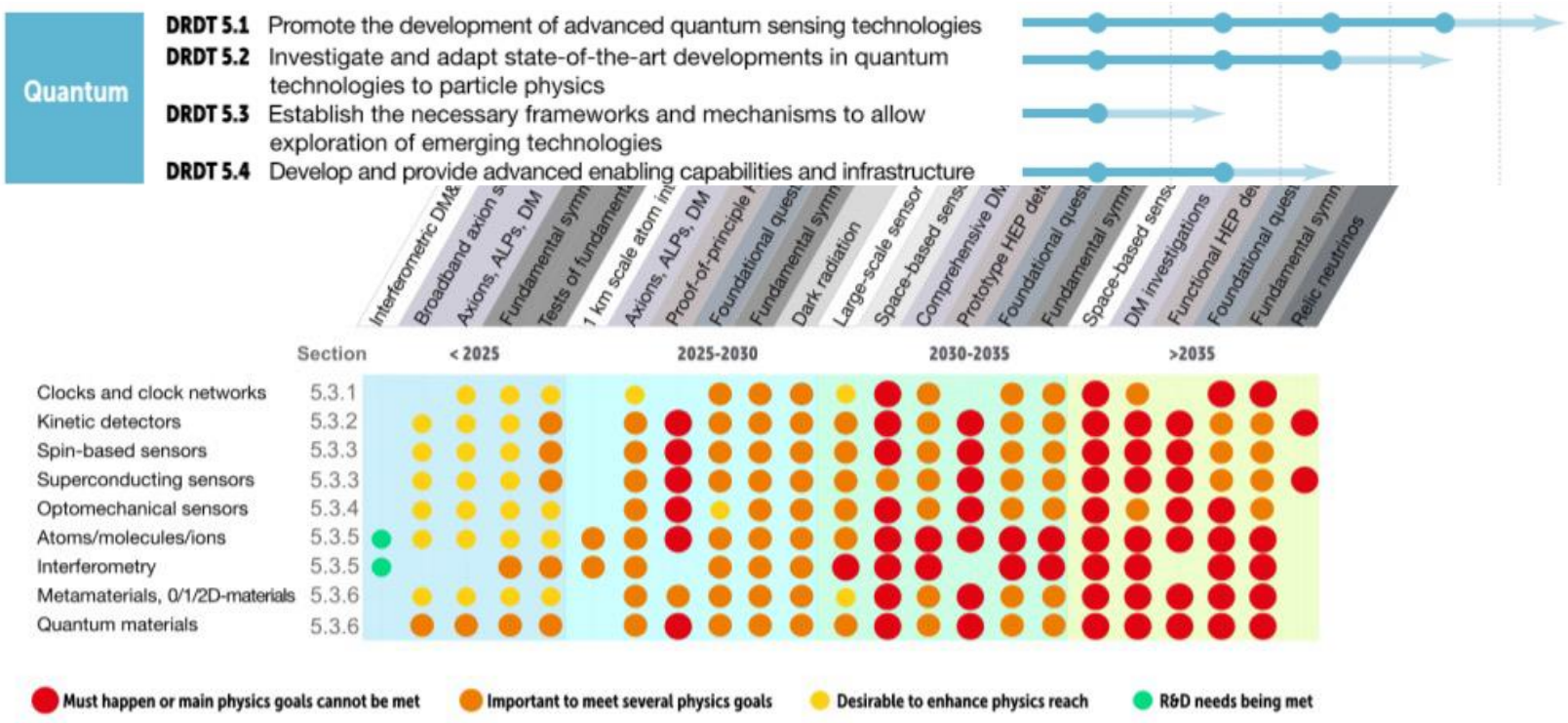
DRDT 7.1 Advance technologies to deal with greatly increased data density
DRDT 7.2 Develop technologies for increased intelligence on the detector
DRDT 7.3 Develop technologies in support of 4D- and 5D-techniques
DRDT 7.4 Develop novel technologies to cope with extreme environments and required longevity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

Not approved (yet) collaborations



Quantum sensors: DRD5

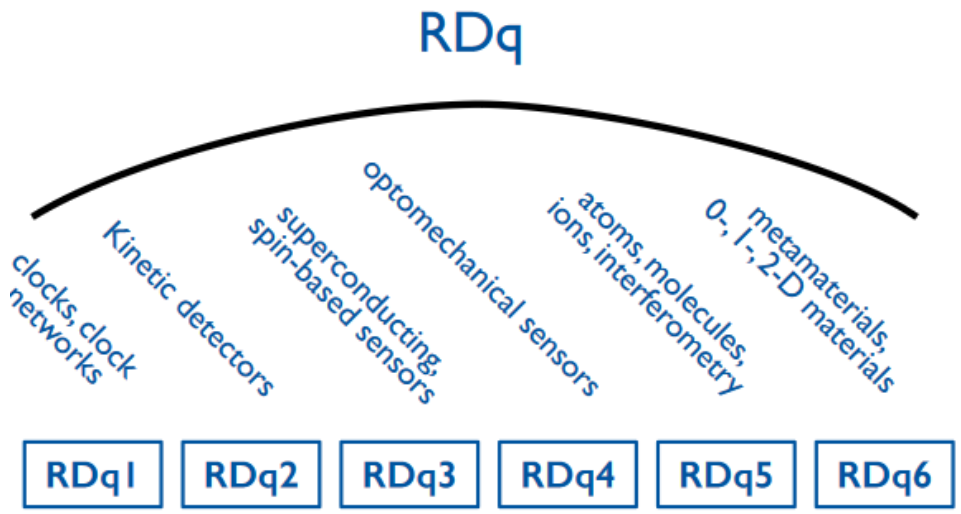
- Quantum Technologies are a rapidly emerging area of technology development to study fundamental physics
  - Targeting Gravitational Wave, Axion, DM detection
  - development of HEP detectors on the long term
- Many different sensor and technologies being investigated: clocks and clock networks, kinetic detectors, spin-based, superconducting, optomechanical sensors, atoms / molecules/ ions, interferometry, ...

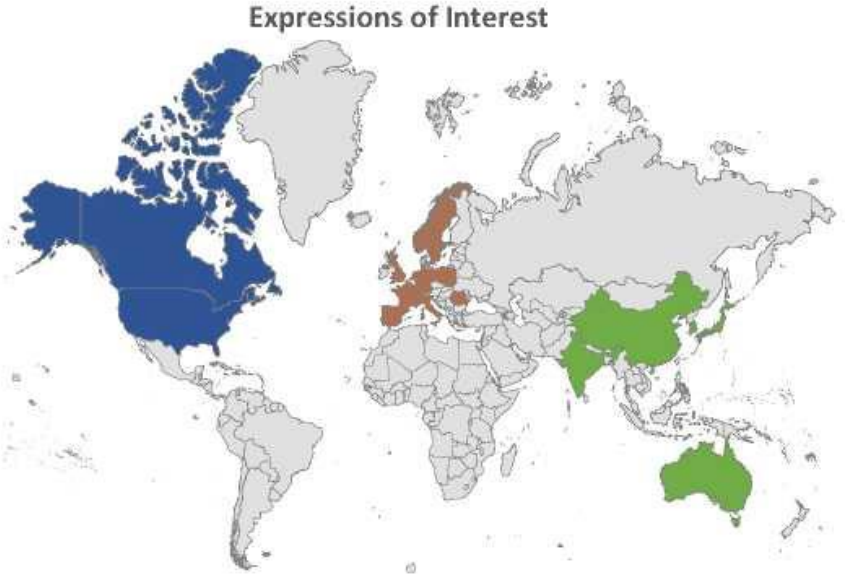


Quantum sensors: DRD5

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

- 40 institutes in 15 countries:
  - 25 proposed contributions





Task force 7: Integration

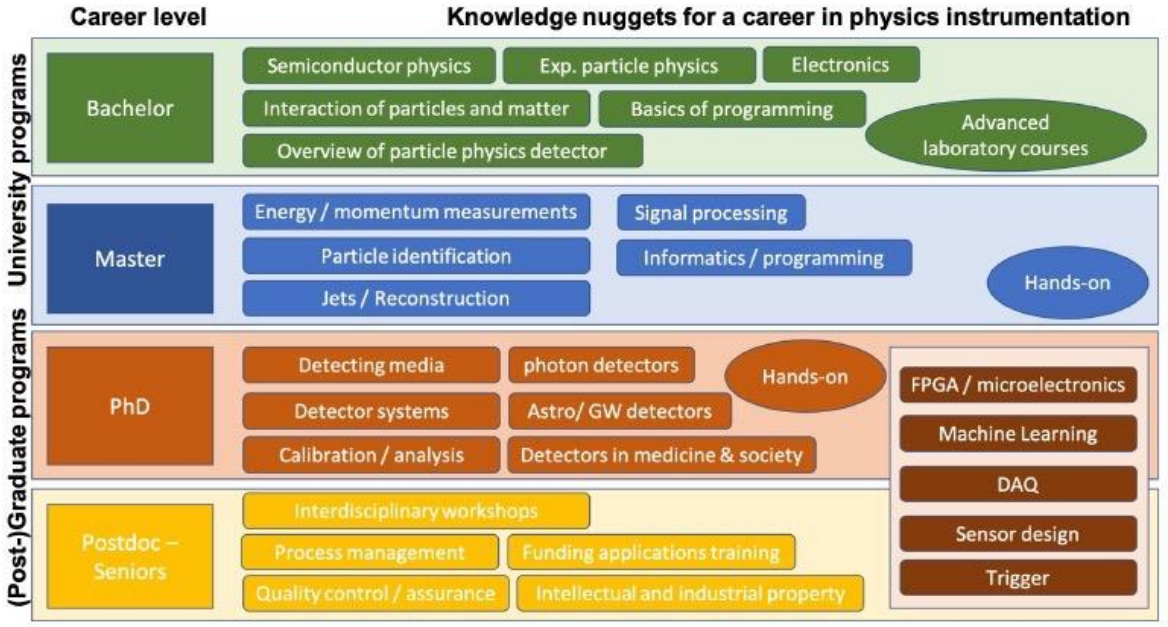
- Target: Mechanical support and structures, cooling, magnets and management of radiation environment
- DRDTs are quite diverse
- Some topics are very closely connected to the genuine DRDs, where the technology is developed (e.g. DRDT 8.3)
- No DRD collaboration has been proposed yet, but 16 institutions replied favourably to a community survey

- Topics:
- Gas cooling development
- Single- and two-phase liquid cooling R&D
- Humidity control
- Temperature control
- Thermal management
- hermal performance verification
- Thermal interface materials and expansion differences
- Pipe materials, pipe connection techniques and fittings
- Choices and characterisation of construction materials
- 3D printing
- Radiation and mechanics: Materials and issues like access constraints
- FEA and its comparison to real objects
- Structure design and optimisation
- Application of machine learning for design issues

Task Force 9: Training

- A structured training program shall support
- the scientists in their career
- Increase participation of young scientists, in particular graduate students, in leading-edge instrumentation R&D, and foster growth of future HEP instrumentation experts who can compete for permanent positions
- Establish a master's degree curriculum
- TF9 Training will not become a DRD collaboration, but an ECFA Training Panel has been founded to pursue these activities

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

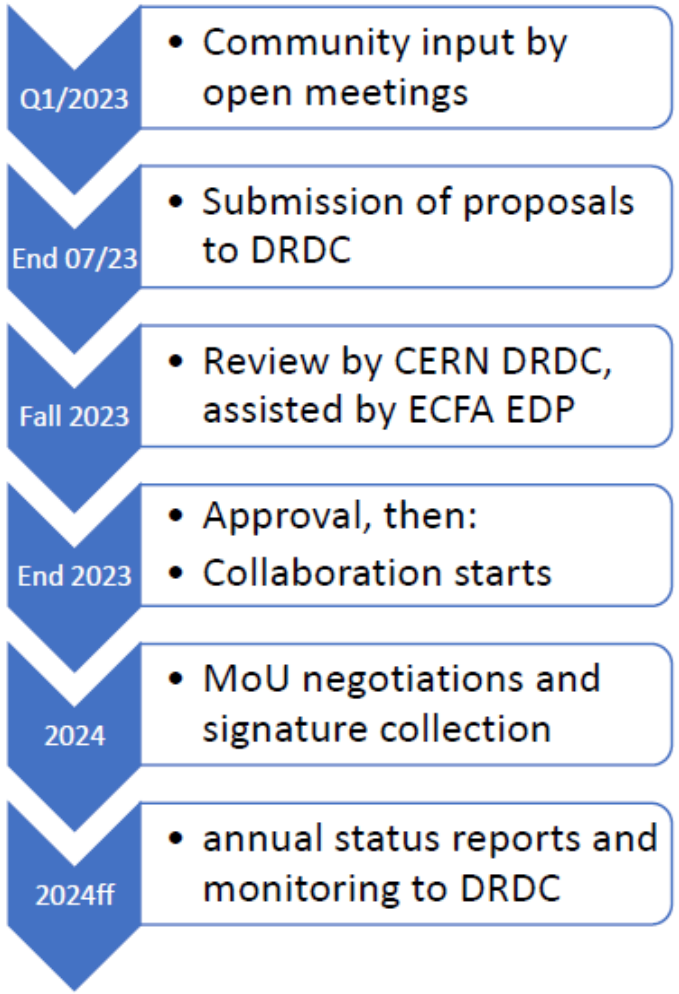


General Strategic Recommendations

- The General Strategic Recommendations (GSR) topics are:
  - GSR 1: Supporting R&D facilities (test beams, large-scale generic prototyping and irradiation)
  - 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

Approval and Reviewing : DRDC Committee

- New committee at CERN on the same level as SPSC and LHCC:
  - Reviewed submitted DRD proposals
  - Monitoring the progress of each DRD collaboration by requesting
  - Annual status reports
- Assisted by ECFA detector Paned



We are not alone…

– In parallel, the US HEP community, at the 2022 Coordinating Panel for Advanced Detectors (CPAD) annual workshop launched a network of US Detector R&D Collaborations.

RDC	Topic
1	Noble Element Detectors
2	Photodetectors
3	Solid State Tracking
4	Readout and ASICs
5	Trigger and DAQ

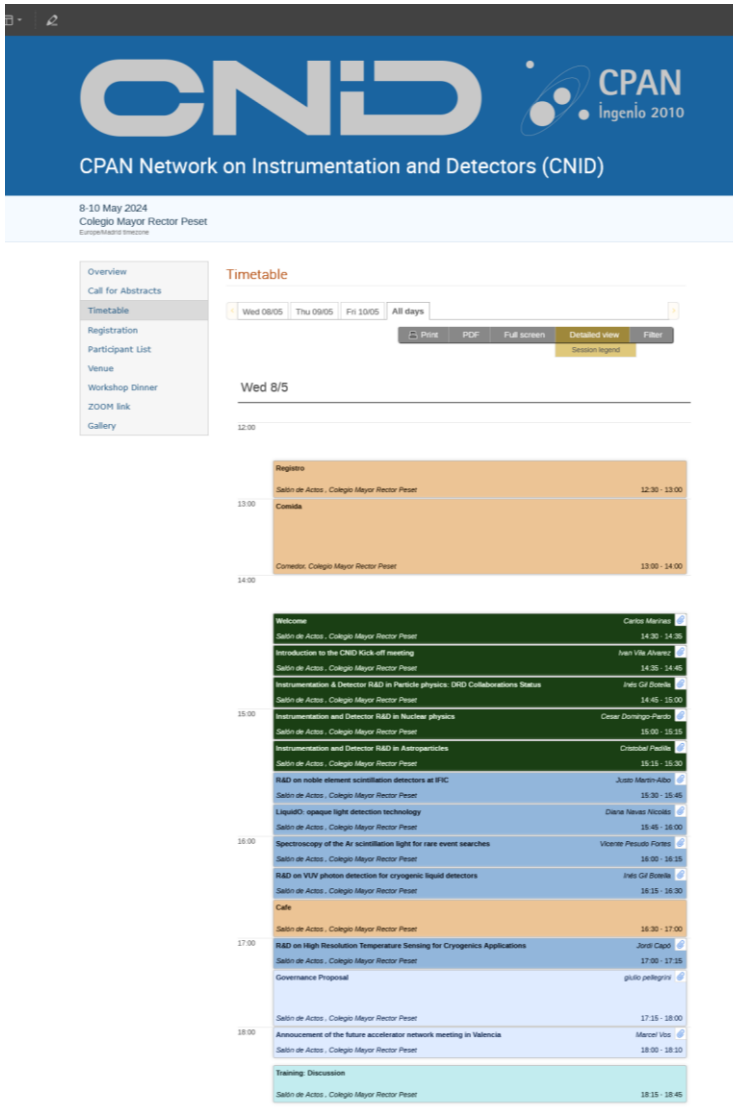
RDC	Topic
6	Gaseous Detectors
7	Low-Background Detectors (incl. CCDs)
8	Quantum and superconducting Detectors
9	Calorimetry
10	Detector Mechanics
11	Fast Timing

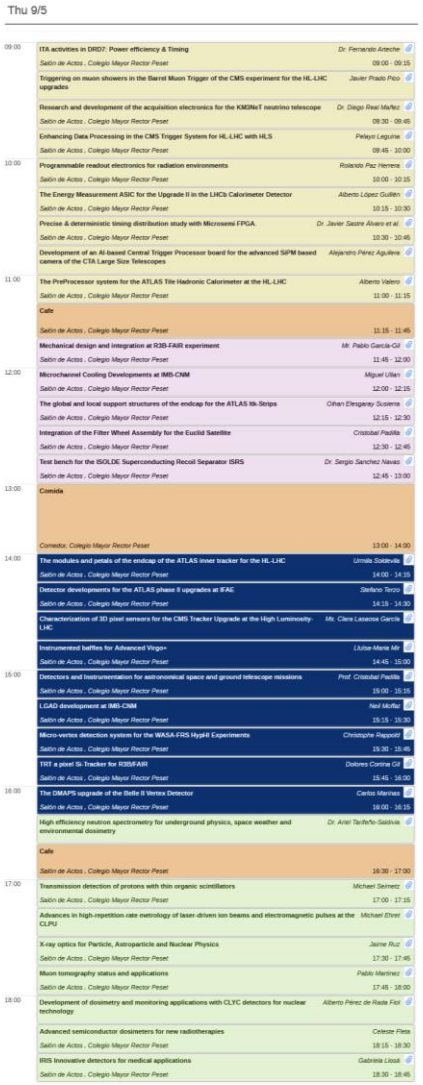
In Spain: CPAN network on Instrumentation and Detectors

- Proposal for a network on Instrumentation and Detectors, XV CPAN Days, October 2023, Santander (spin-off of a previous meeting in February 2023 at IMB-CNM). https://indico.cern.ch/event/1283224/contributions/5612901/
- Goals:
  - Building a Community of Experts in Instrumentation and Detectors.
  - Platform for sharing and exchanging knowledge, technologies, practices, and research findings in instrumentation across different fields and disciplines ➔ Annual Workshop
  - Promoting collaboration among groups that may lead to joint research projects.
  - Representing the community to influence and advise scientific leadership (as in case of the DRD collaborations or the coming update of European Strategy for Particle Physics).
  - Capacity development: training activities ➔ Schools, courses, and/or topical mini-workshops.
  - Recognition of excellence ➔ Awards for students

CPAN NETWORK ON INSTRUMENTATION AND DETECTORS

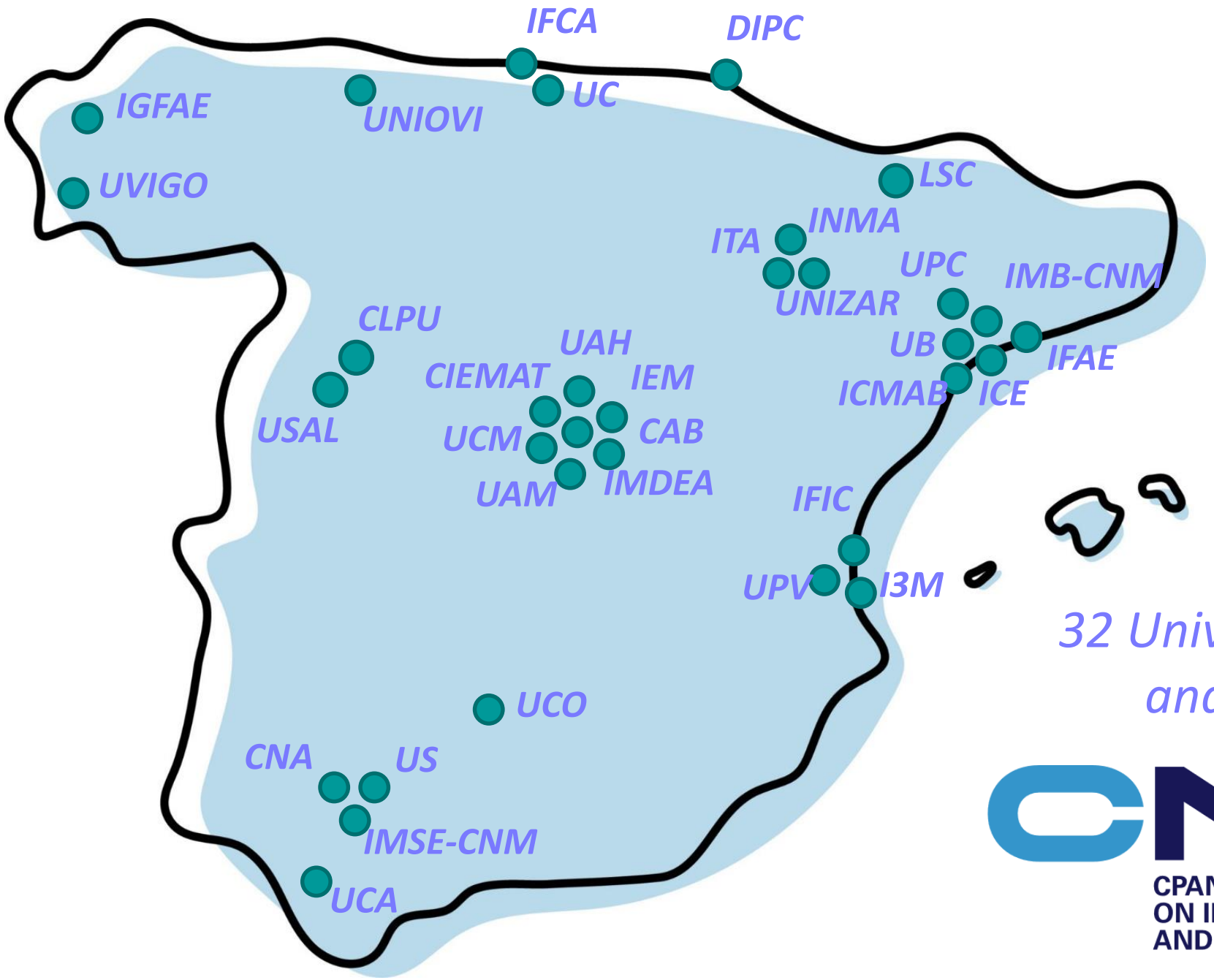
CNID: Kick-off meeing in Valencia





80 participants
67 contributions

https://indico.ific.uv.es/event/7477/overview



32 University centers and Institutes

CPAN NETWORK ON INSTRUMENTATION AND DETECTORS

Working Groups and coordinators

- **WG1 Gaseous detectors:** Yassid Ayyad (IGFAE) + Cristina Fernández (Ciemat)
- **WG2 Liquid detectors:** Clara Cuesta (Ciemat) + Justo Martín (IFIC)
- **WG3 Solid state:** Sebastian Grinstein IFAE) + Carlos Mariñas (IFIC) + Teresa Kurtukian (IEM)
- **WG4 Calorimetry:** Mary-Cruz Fouz (Ciemat) + Héctor Alvarez-Pol (IGFAE)
- **WG5 Quantum/Superconductor sensors:** Gemma Rius (IMB-CNM) + Igor García Irastorza IUNIZAR)
- **WG6 Electronics:** Santiago Folgeras (UNIOVI) + Fernando Arteche (ITA) + Diego Real (IFIC)
- **WG7 Mechanics & Integration:** Cristobal Padilla (IFAE) + Enrique Casarejos (UV)
- **WG8 Applications:** Carlos Guerrero (US) + Gabriela Llosá (IFIC)
- **WG9 Scintillators and photodetectors:** Luis Mario Fraile (UCM) + David Gascon (UB)
- **WG10 Characterization Techniques:** Carmen Jiménez (CNA) + Jordi Duarte Campderrós (IFCA)
- **WG11 Training:** to de appointed (dependent of the institution leading the school organization)
- **WG12 Low-Background experiments:** Susana Cebrián (UNIZAR) + Francesc Monrabal (DIPC) + Roberto Santorelli (CIEMAT)
- **Coordinator:** Iván Vila (IFCA); **Deputy Coordinators:** Cesar Domingo (IFIC) + Inés Gil (Ciemat)

Several conveners are also playing coordinating roles in the DRD WG and WP
MC. Fouz (deputy spoke DRD6), I. Gil (DRDC member), G. Pellegrini (Chair DRD3)

Summary

- The ECFA Roadmap defined the **strategic detector R&D themes** that should address enable the future HEP experiments.
- To implement the strategic detector R&D, Detector R&D Collaborations (DRD) at CERN on the relevant tecnological domains have started in 2024 (a few are still under creation).
- The Spanish network on instrumentation (CNID) shall be a tool to promote the participation of the HEP Spanish groups in the strategic R&D projects at the DRDs, increase the awareness of the community and, fostering inter-group collaboration to increase the impact of their activities.