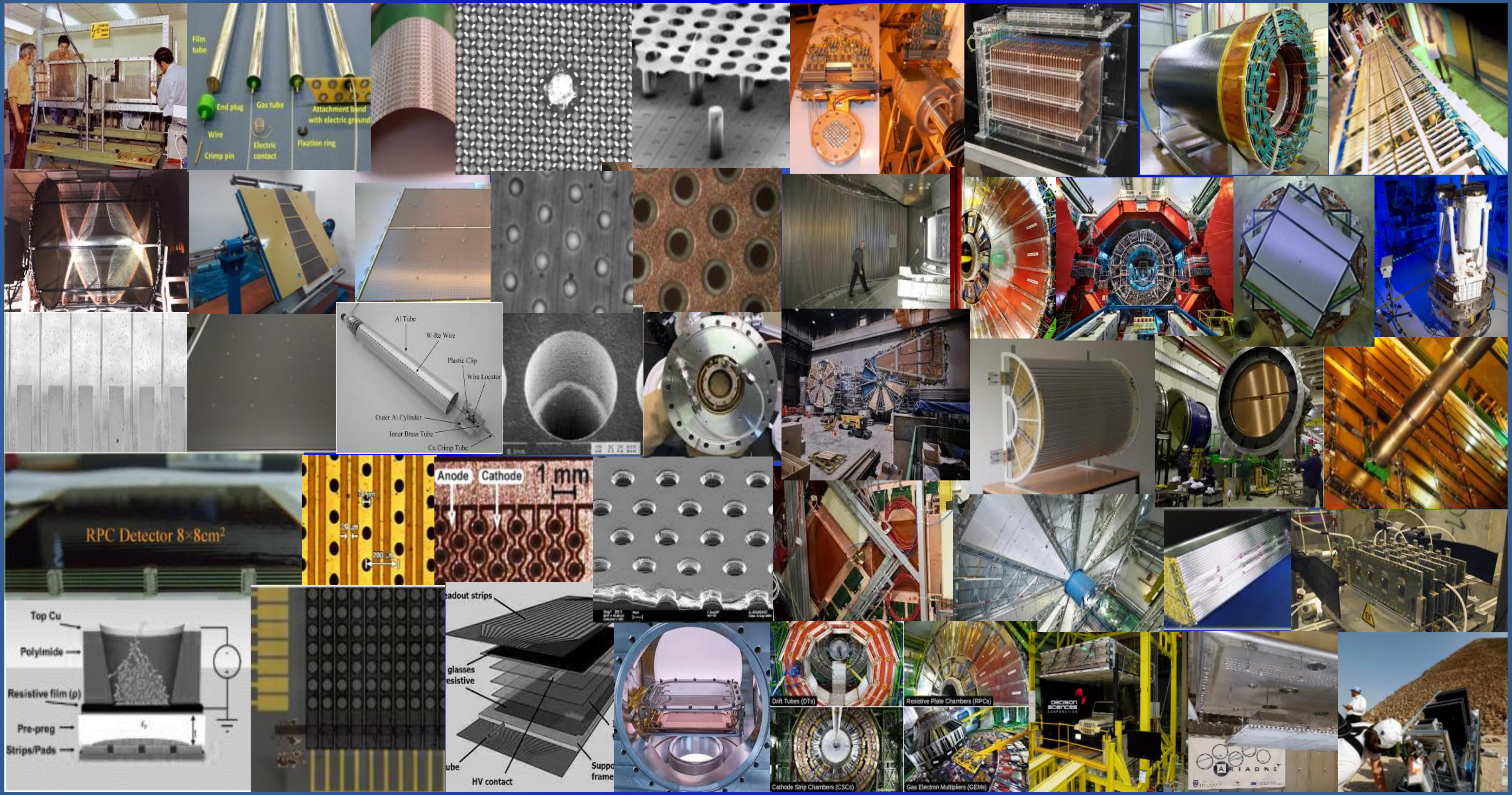
ECFA Detector R&D Roadmap and CERN - DRD1 Collaboration

Maxim Titov, CEA Saclay, Irfu, France

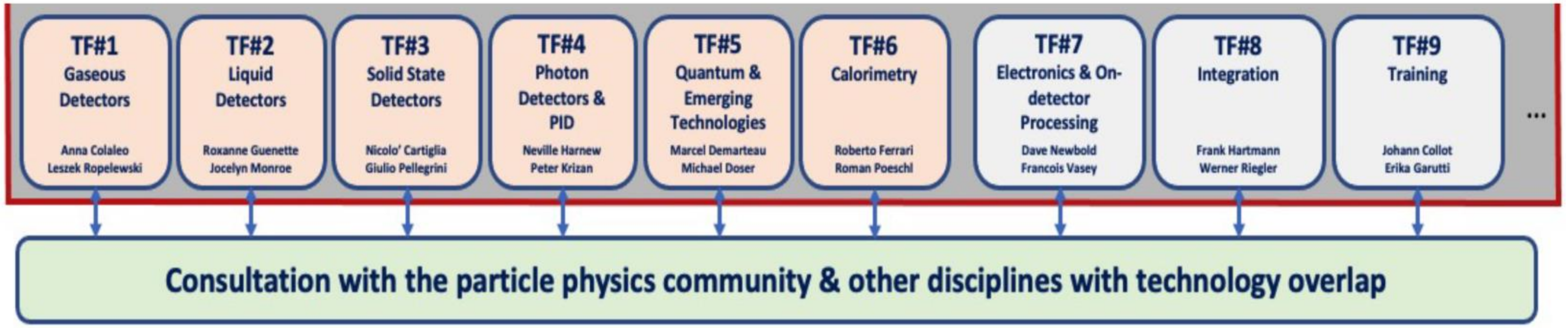


CERN - Ukraine 2024: "Past - Present – Future" Conference,
Kyiv, Ukraine, May 28-29, 2024

ECFA Detector R&D Roadmap & Implementation plan

2021: ECFA released full roadmap (200 pages) and synopsis (~10 pages) based on a community-driven effort DOI: 10.17181/CERN.XDPL.W2EX

- **Overview of future facilities (EIC, ILC, CLIC, FCC-ee/hh, Muon collider) or major upgrades (ALICE, Belle-II, LHC-b,…) and their timelines**
- **Ten "General Strategic Recommendations" (full list in backup slides)**
- **Nine Technology domains with Task Forces areas**
  - **Most urgent R&D topics in each domain: Detector R&D Themes (DRDTs)**



TF#1 Gaseous Detectors
Anna Colaleo
Leszek Ropelewski

TF#2 Liquid Detectors
Roxanne Guenette
Jocelyn Monroe

TF#3 Solid State Detectors
Nicolo' Cartiglia
Giulio Pellegrini

TF#4 Photon Detectors & PID
Neville Harnew
Peter Krizan

TF#5 Quantum & Emerging Technologies
Marcel Demarteau
Michael Doser

TF#6 Calorimetry
Roberto Ferrari
Roman Poeschl

TF#7 Electronics & On-detector Processing
Dave Newbold
Francois Vasey

TF#8 Integration
Frank Hartmann
Werner Riegler

TF#9 Training
Johann Collot
Erika Garutti

…

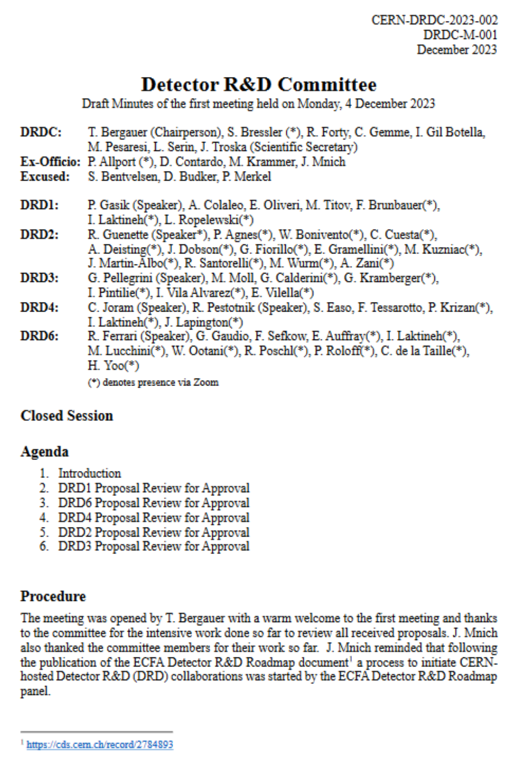
Consultation with the particle physics community & other disciplines with technology overlap

- **Implementation plan: Approved by CERN SPC and Council in fall 2022 (CERN/SPC/1190 ; CERN/3679)**
  - **CERN to host DRD collaborations**
  - **DRD interface to CERN through DRDC**
  - **DRD interface to ECFA via ECFA Detector panel: https://ecfa-dp.desy.de**

P. Sphicas, ECFA Chair, CERN-UA Conference, May 28: https://indico.cern.ch/event/1395415/contributions/5929907/attachments/2864969/5016019/2024-05-27-ECFA-Report-Ukraine.pdf

CERN RB approval & DRDC recommendation and guidelines in view of the first review and next steps

DRDC Meeting
(December 4, 20023)



CERN-DRDC-2023-002
DRDC-M-001
December 2023

Detector R&D Committee

Draft Minutes of the first meeting held on Monday, 4 December 2023

DRDC: T. Bergauer (Chairperson), S. Bressler (*), R. Forty, C. Gemme, I. Gil Botella, M. Pesaresi, L. Serin, J. Troska (Scientific Secretary)
Ex-Officio: P. Allport (*), D. Contardo, M. Krammer, J. Mnich
Excused: S. Bentvelsen, D. Budker, P. Merkel

DRD1: P. Gasik (Speaker), A. Colaleo, E. Oliveri, M. Titov, F. Brunbauer(*), I. Laktineh(*), L. Ropelewski(*)
DRD2: R. Guenette (Speaker*), P. Agnes(*), W. Bonivento(*), C. Cuesta(*), A. Deisting(*), J. Dobson(*), G. Fiorillo(*), E. Gramellini(*), M. Kuzniac(*), J. Martin-Albo(*), R. Santorelli(*), M. Wurm(*), A. Zani(*)
DRD3: G. Pellegrini (Speaker), M. Moll, G. Calderini(*), G. Kramberger(*), I. Pintilie(*), I. Vila Alvarez(*), E. Vilella(*)
DRD4: C. Joram (Speaker), R. Pestotnik (Speaker), S. Easo, F. Tessarotto, P. Krizan(*), I. Laktineh(*), J. Lapington(*)
DRD6: R. Ferrari (Speaker), G. Gaudio, F. Sefkow, E. Auffray(*), I. Laktineh(*), M. Lucchini(*), W. Ootani(*), R. Poschl(*), P. Roloff(*), C. de la Taille(*), H. Yoo(*)
(*) denotes presence via Zoom

Closed Session

Agenda

1. Introduction
2. DRD1 Proposal Review for Approval
3. DRD6 Proposal Review for Approval
4. DRD4 Proposal Review for Approval
5. DRD2 Proposal Review for Approval
6. DRD3 Proposal Review for Approval

Procedure

The meeting was opened by T. Bergauer with a warm welcome to the first meeting and thanks to the committee for the intensive work done so far to review all received proposals. J. Mnich also thanked the committee members for their work so far. J. Mnich reminded that following the publication of the ECFA Detector R&D Roadmap document[1] a process to initiate CERN-hosted Detector R&D (DRD) collaborations was started by the ECFA Detector R&D Roadmap panel.

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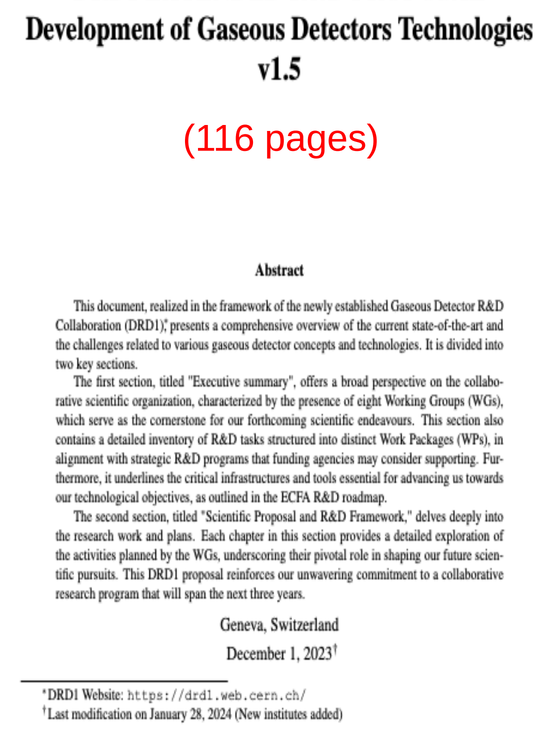
[1] https://cds.cern.ch/record/2784893

DRDC Minutes: https://cds.cern.ch/record/2883179?ln=en

CERN RB Approval
(December 6, 2023)

Five proposals for new Detector R&D collaborations ***were recommended for approval by the DRDC: DRD1 (Gaseous detectors), DRD2 (Liquid detectors), DRD3 (Solid-state detectors), DRD4 (Photon detectors and particle identification), and DRD6 (Calorimetry).*** *The Research Board approved DRD1, DRD2, DRD4 and DRD6 for an initial period of three years. The proposals for DRD4 and DRD6 can now be made public, while the final versions of those for DRD1 and DRD2 that had been provided very recently will be further reviewed by the DRDC in the coming weeks before being made public. The Research Board preliminarily approved DRD3 so that work towards establishing the collaboration can progress, on condition that the new collaboration structure be established in a timely fashion following the guidelines provided by the DRDC, and the new management appointed; approval of DRD3 will be reviewed at the next Research Board meeting in March 2024, on the basis of an updated proposal.*

DRD1 Proposal in CDS
(January 9, 2024)



DRD1 EXTENDED R&D PROPOSAL
Development of Gaseous Detectors Technologies
v1.5

(116 pages)

Abstract

This document, realized in the framework of the newly established Gaseous Detector R&D Collaboration (DRD1)[*] presents a comprehensive overview of the current state-of-the-art and the challenges related to various gaseous detector concepts and technologies. It is divided into two key sections.

The first section, titled "Executive summary", offers a broad perspective on the collaborative scientific organization, characterized by the presence of eight Working Groups (WGs), which serve as the cornerstone for our forthcoming scientific endeavours. This section also contains a detailed inventory of R&D tasks structured into distinct Work Packages (WPs), in alignment with strategic R&D programs that funding agencies may consider supporting. Furthermore, it underlines the critical infrastructures and tools essential for advancing us towards our technological objectives, as outlined in the ECFA R&D roadmap.

The second section, titled "Scientific Proposal and R&D Framework," delves deeply into the research work and plans. Each chapter in this section provides a detailed exploration of the activities planned by the WGs, underscoring their pivotal role in shaping our future scientific pursuits. This DRD1 proposal reinforces our unwavering commitment to a collaborative research program that will span the next three years.

Geneva, Switzerland

December 1, 2023[†]

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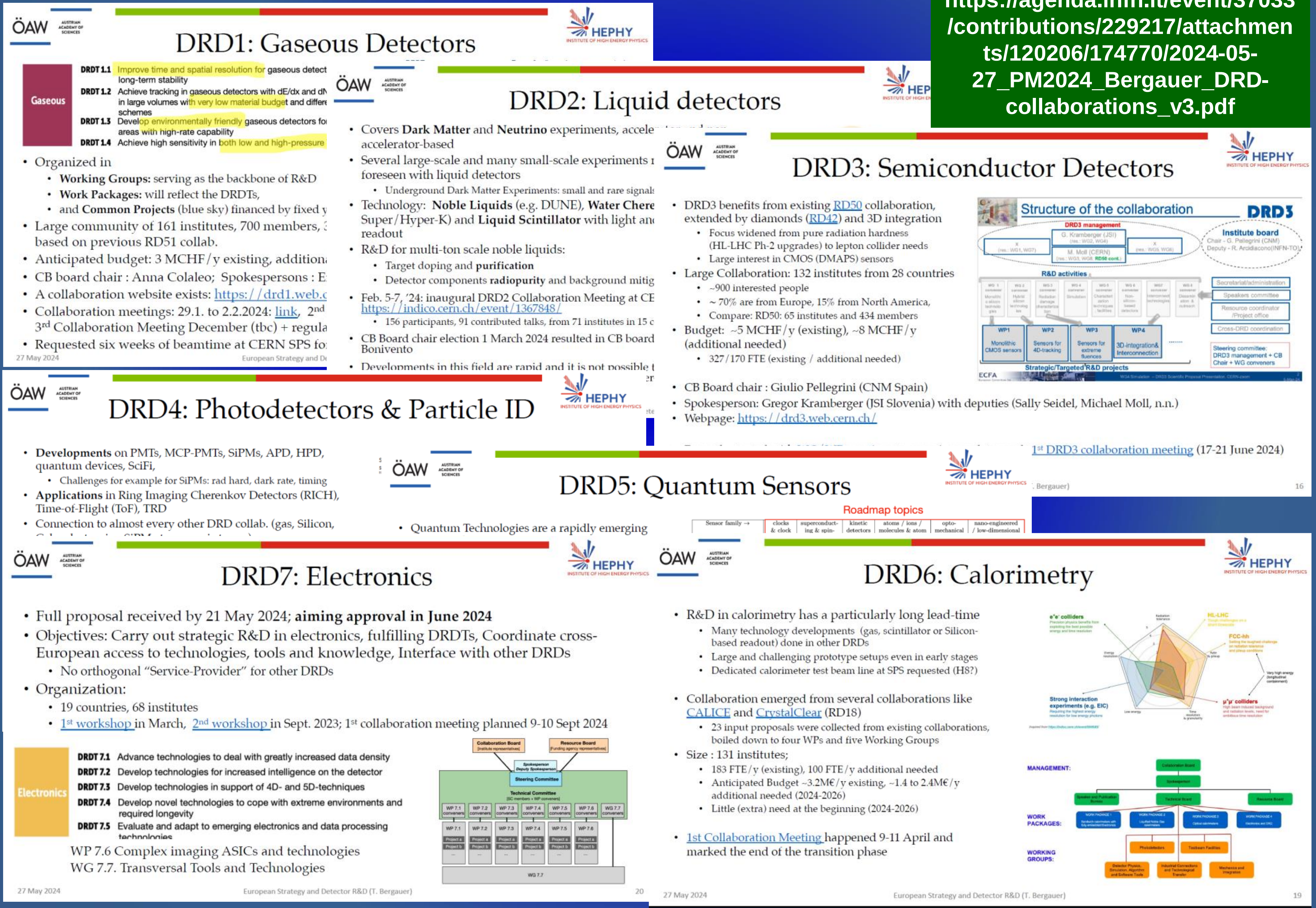
[*] DRD1 Website: `https://drd1.web.cern.ch/`
[†] Last modification on January 28, 2024 (New institutes added)

https://cds.cern.ch/record/2885937

Overview of DRD Collaborations in Europe

T. Bergauer, DRDC Chair, 2024
Elba Conference:
https://agenda.infn.it/event/37033/contributions/229217/attachments/120206/174770/2024-05-27_PM2024_Bergauer_DRD-collaborations_v3.pdf



DRD1: Gaseous Detectors

Gaseous

DRDT 1.1 Improve time and spatial resolution for gaseous detect
long-term stability
DRDT 1.2 Achieve tracking in gaseous detectors with dE/dx and dN
in large volumes with very low material budget and differe
schemes
DRDT 1.3 Develop environmentally friendly gaseous detectors fo
areas with high-rate capability
DRDT 1.4 Achieve high sensitivity in both low and high-pressure

- Organized in
  - **Working Groups:** serving as the backbone of R&D
  - **Work Packages:** will reflect the DRDTs,
  - and **Common Projects** (blue sky) financed by fixed y
- Large community of 161 institutes, 700 members, 3
  based on previous RD51 collab.
- Anticipated budget: 3 MCHF/y existing, addition
- CB board chair : Anna Colaleo; Spokespersons : E
- A collaboration website exists: https://drd1.web.c
- Collaboration meetings: 29.1. to 2.2.2024: link, 2nd
  3rd Collaboration Meeting December (tbc) + regula
- Requested six weeks of beamtime at CERN SPS fo

27 May 2024 European Strategy and De

DRD2: Liquid detectors

- Covers **Dark Matter** and **Neutrino** experiments, accele
  accelerator-based
- Several large-scale and many small-scale experiments
  foreseen with liquid detectors
  - Underground Dark Matter Experiments: small and rare signal
- Technology: **Noble Liquids** (e.g. DUNE), **Water Chere**
  Super/Hyper-K) and **Liquid Scintillator** with light an
  readout
- R&D for multi-ton scale noble liquids:
  - Target doping and **purification**
  - Detector components **radiopurity** and background mitig
- Feb. 5-7, '24: inaugural DRD2 Collaboration Meeting at CE
  https://indico.cern.ch/event/1367848/
  - 156 participants, 91 contributed talks, from 71 institutes in 15 c
- CB Board chair election 1 March 2024 resulted in CB board
  Bonivento
- Developments in this field are rapid and it is not possible t

DRD3: Semiconductor Detectors

- DRD3 benefits from existing RD50 collaboration, extended by diamonds (RD42) and 3D integration
  - Focus widened from pure radiation hardness (HL-LHC Ph-2 upgrades) to lepton collider needs
  - Large interest in CMOS (DMAPS) sensors
- Large Collaboration: 132 institutes from 28 countries
  - ~900 interested people
  - ~ 70% are from Europe, 15% from North America,
  - Compare: RD50: 65 institutes and 434 members
- Budget: ~5 MCHF/y (existing), ~8 MCHF/y (additional needed)
  - 327/170 FTE (existing / additional needed)

Structure of the collaboration **DRD3**

- CB Board chair : Giulio Pellegrini (CNM Spain)
- Spokesperson: Gregor Kramberger (JSI Slovenia) with deputies (Sally Seidel, Michael Moll, n.n.)
- Webpage: https://drd3.web.cern.ch/

1st DRD3 collaboration meeting (17-21 June 2024)

Bergauer) 16

DRD4: Photodetectors & Particle ID

- **Developments** on PMTs, MCP-PMTs, SiPMs, APD, HPD, quantum devices, SciFi,
  - Challenges for example for SiPMs: rad hard, dark rate, timing
- **Applications** in Ring Imaging Cherenkov Detectors (RICH), Time-of-Flight (ToF), TRD
- Connection to almost every other DRD collab. (gas, Silicon,

DRD5: Quantum Sensors

- Quantum Technologies are a rapidly emerging

Roadmap topics

Sensor family →	clocks & clock	superconduct-ing & spin-	kinetic detectors	atoms / ions / molecules & atom	opto-mechanical	nano-engineered / low-dimensional

DRD7: Electronics

- Full proposal received by 21 May 2024; **aiming approval in June 2024**
- Objectives: Carry out strategic R&D in electronics, fulfilling DRDTs, Coordinate cross-European access to technologies, tools and knowledge, Interface with other DRDs
  - No orthogonal "Service-Provider" for other DRDs
- Organization:
  - 19 countries, 68 institutes
  - 1st workshop in March, 2nd workshop in Sept. 2023; 1st collaboration meeting planned 9-10 Sept 2024

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

WP 7.6 Complex imaging ASICs and technologies
WG 7.7. Transversal Tools and Technologies

27 May 2024 European Strategy and Detector R&D (T. Bergauer) 20

DRD6: Calorimetry

- R&D in calorimetry has a particularly long lead-time
  - Many technology developments (gas, scintillator or Silicon-based readout) done in other DRDs
  - Large and challenging prototype setups even in early stages
  - Dedicated calorimeter test beam line at SPS requested (H8?)
- Collaboration emerged from several collaborations like CALICE and CrystalClear (RD18)
  - 23 input proposals were collected from existing collaborations, boiled down to four WPs and five Working Groups
- Size : 131 institutes;
  - 183 FTE/y (existing), 100 FTE/y additional needed
  - Anticipated Budget ~3.2M€/y existing, ~1.4 to 2.4M€/y additional needed (2024-2026)
  - Little (extra) need at the beginning (2024-2026)
- 1st Collaboration Meeting happened 9-11 April and marked the end of the transition phase

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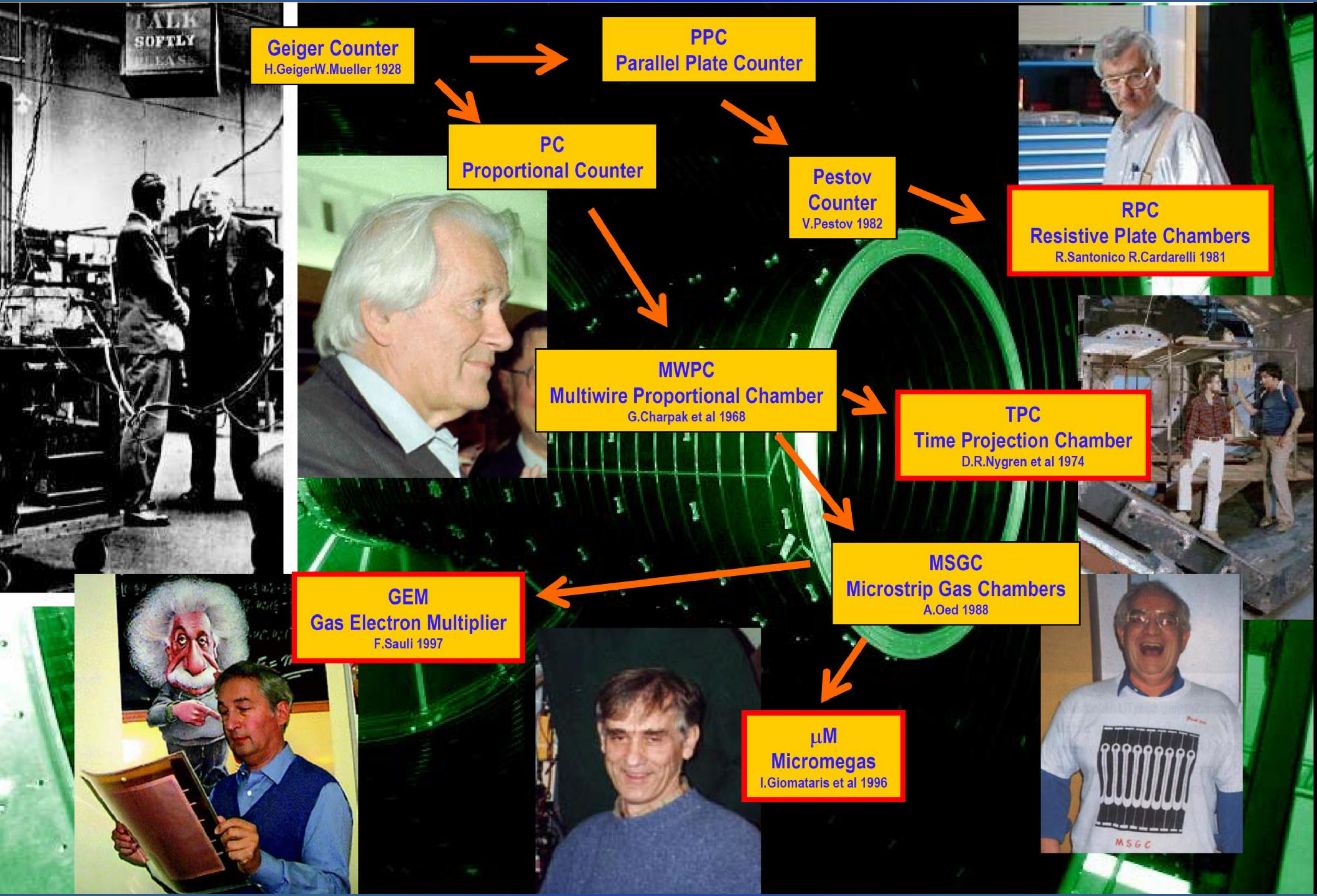
Gas-Based Detectors: A Brief History



Geiger Counter
H.GeigerW.Mueller 1928

PPC
Parallel Plate Counter

PC
Proportional Counter

Pestov Counter
V.Pestov 1982

RPC
Resistive Plate Chambers
R.Santonico R.Cardarelli 1981

MWPC
Multiwire Proportional Chamber
G.Charpak et al 1968

TPC
Time Projection Chamber
D.R.Nygren et al 1974

MSGC
Microstrip Gas Chambers
A.Oed 1988

GEM
Gas Electron Multiplier
F.Sauli 1997

μM
Micromegas
I.Giomataris et al 1996

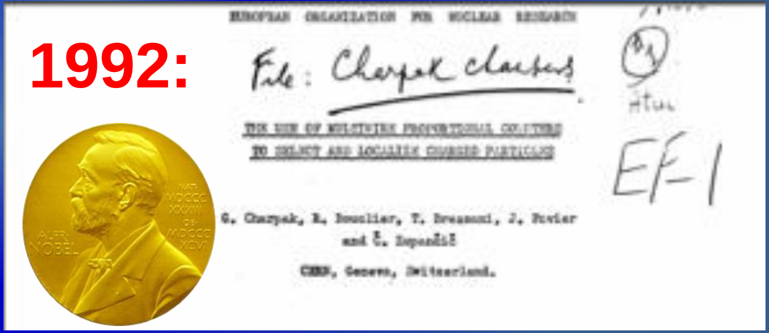
1968: MWPC – Revolutionising the Way Particle Physics is Done

G. Charpak, F. Sauli and J.C. Santiard

Before MWPC: Detecting particles was a mainly a manual, tedious and labour intensive job – unsuited for rare particle decays

1968: George Charpak developed the MultiWire Proportional Chamber, (MWPC), which revolutionized particle detection & HEP, ***and marked transition from Manual to Electronics era***

1992:



EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

File: Charpak chambers

EF-1

THE USE OF MULTIWIRE PROPORTIONAL COUNTERS TO SELECT AND LOCALIZE CHARGED PARTICLES

G. Charpak, R. Bouclier, T. Bressani, J. Favier and Č. Zupančič

CERN, Geneva, Switzerland.

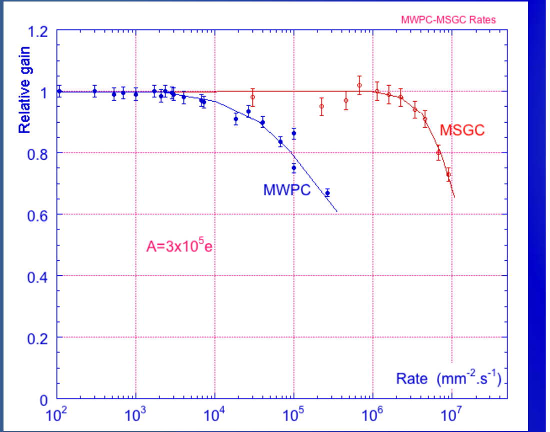
"Image" & "Logic (electronics)" tradition combined into the "Electronics Image" detectors during the 1970ies

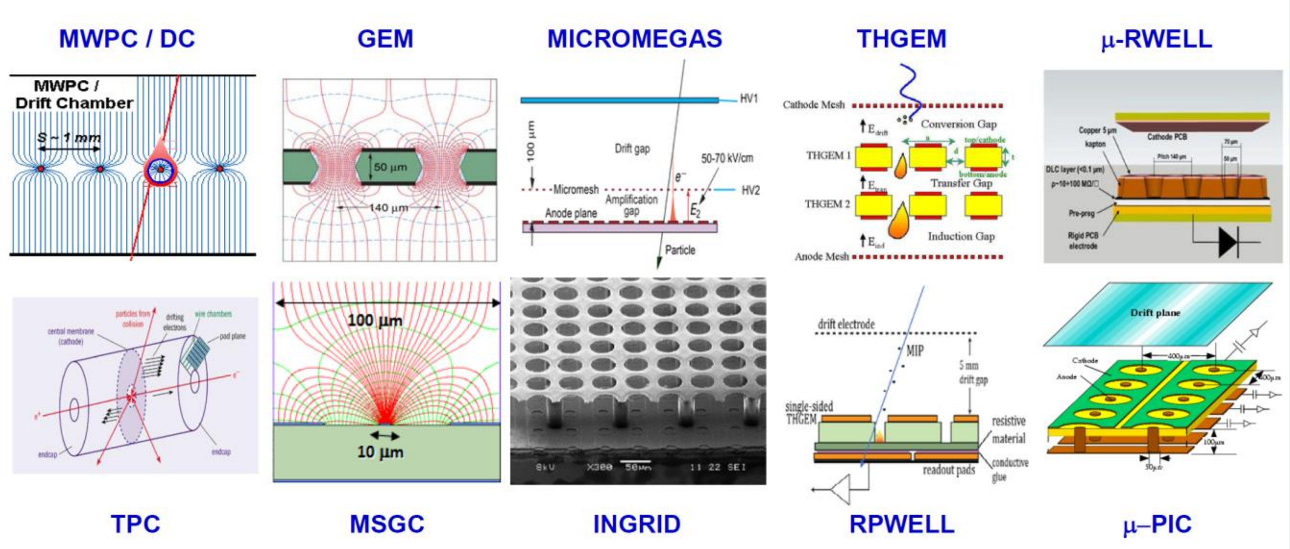
Gaseous Detectors: From Wire/Drift Chamber → Time Projection Chamber (TPC) → Micro-Pattern Gas Detectors

Primary choice for large-area coverage with low material-budget (+ dE/dx measurement)

1990’s: Industrial advances in photolithography has favoured the invention of novel micro-structured gas amplification devices (MSGC, GEM, Micromegas, …)

Rate Capability:
MWPC vs MSGC





Examples of Gaseous Detectors for Future Colliders:

HL-LHC Upgrades: Tracking (ALICE TPC/MPGD); Muon Systems: RPC, CSC, MDT, TGC, GEM, Micromegas;
Future Hadron Colliders: FCC-hh Muon System (MPGD - OK, rates are comparable with HL-LHC)
Future Lepton Colliders: Tracking (FCC-ee / CepC - Drift Chambers; ILC / CePC - TPC with MPGD readout)
Calorimetry (ILC, CepC – RPC or MPGD), Muon Systems (OK)

Future Election-Ion Collider: Tracking (GEM, μWELL; TPC/MPGD), RICH (THGEM), TRD (GEM)

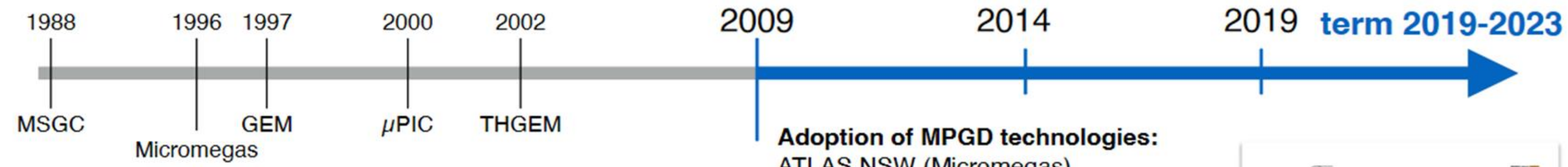
Legacy of the CERN-RD51 Collaboration: 2008-2023

***RD51* CERN-based *"TECHNOLOGY - DRIVEN R&D COLLABORATION"* was established to advance MPGD concepts and associated electronics readout systems**

RD51 community: ~ 90 institutes, 500 members

RD51

renewed for 3rd term 2019-2023



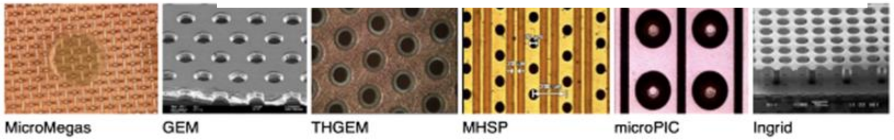
2008:

CERN-LHCC-2008-011 (LHCC-P-001)
RD51 2008-001
28 July 2008

R & D Proposal

Development of Micro-Pattern Gas Detectors Technologies

Editors: Matteo Alfonsi (CERN), Alain Bellerive (Carleton University), Amos Breskin (Weizmann Institute), Erik Van der Bij (CERN), Michael Campbell (CERN), Mar Capeans (CERN), Paul Colas (CEA Saclay), Silvia Dalla Torre (INFN Trieste), Klaus Desch (Bonn University), Ioannis Giomataris (CEA Saclay), Harry van der Graaf (NIKHEF), Lucie Linssen (CERN), Rui de Oliveira (CERN), Vladimir Peskov (St Etienne), Werner Riegler (CERN), Leszek Ropelewski (CERN), Fabio Sauli (TERA Foundation), Frank Simon (MPI Munchen), Hans Taureg (CERN), Maxim Titov (CEA Saclay), Andy White (University of Texas), Rob Veenhof (CERN)



Adoption of MPGD technologies:
ATLAS NSW (Micromegas)
CMS forward tracking update (GEM)
COMPASS RICH upgrade (hybrid MPGD)
ALICE TPC upgrade (GEM)
KLOE2 & BESIII (GEM)
LBNO-DEMO (THGEM)
T2K/ND280 TPC (Micromegas)
n-detection at ESS (GEM)
Muon radiography (Micromegas)

RD51 Spokespersons:
L. Ropelewski (2008-2022)
M. Titov (2008-2015, 2023)
S. Dalla Torre (2016-2022)
E. Oliveri (2023)

2018:

May 2018

arXiv:1806.09955v1 [physics.ins-det] 26 Jun 2018

R&D PROPOSAL
RD51 EXTENSION BEYOND 2018

EDITORS:
S. Dalla Torre (INFN Trieste), E. Oliveri (CERN), L. Ropelewski (CERN), M. Titov (CEA Saclay)

Abstract

arXiv:1806.09955

- ✓ ***Many of the MPGD Technologies were introduced before the RD51 was founded***
- ✓ ***With more techniques becoming available, new detection concepts were introduced and the existing ones were substantially improved during the RD51 period (2008-2023)***
- ✓ ***Beyond 2023, RD51 served as a nuclei for the new DRD1 ("all gas detectors") collaboration, anchored at CERN, as part of the ECFA Detector R&D Roadmap***

Legacy of the CERN-RD51 Collaboration:“RD51” Model

The success of the RD51 is related to the “RD51 model” inperforming R&D: combination of generic and focused R&D with bottom-up decision processes, full sharing of experience, “know-how”, and common infrastructure, which allows to build community with continuity and institutional memory and enhances the training of younger generation instrumentalists.

Scientific organisation in 7 working groups

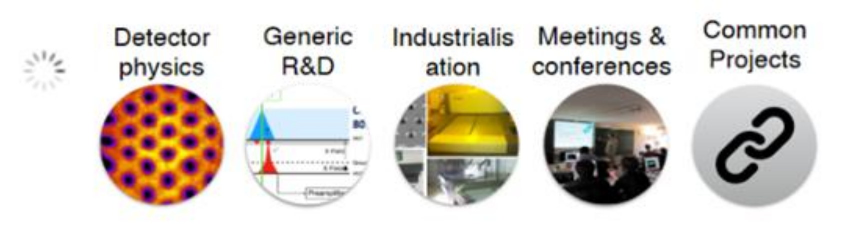
- **WG1:** New structures and technologies
- **WG2:** Detector physics and performance
- **WG3:** Training and dissemination
- **WG4:** Software & Simulation Tools
- **WG5:** Readout Electronics (RD51 SRS)
- **WG6:** MPGD Production & Industrialization
- **WG7:** Common test facilities

Community and Expertize (RD51 Scientific Network)

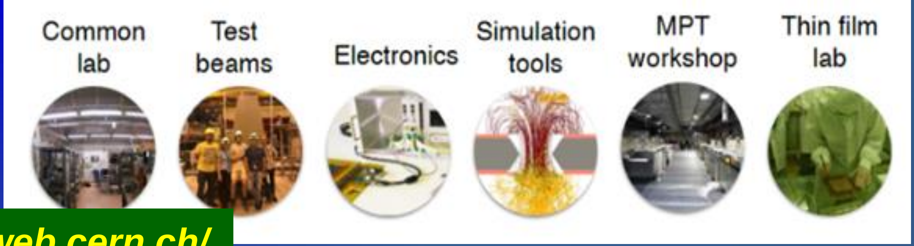
RD51:

3 MAJOR ASSETS

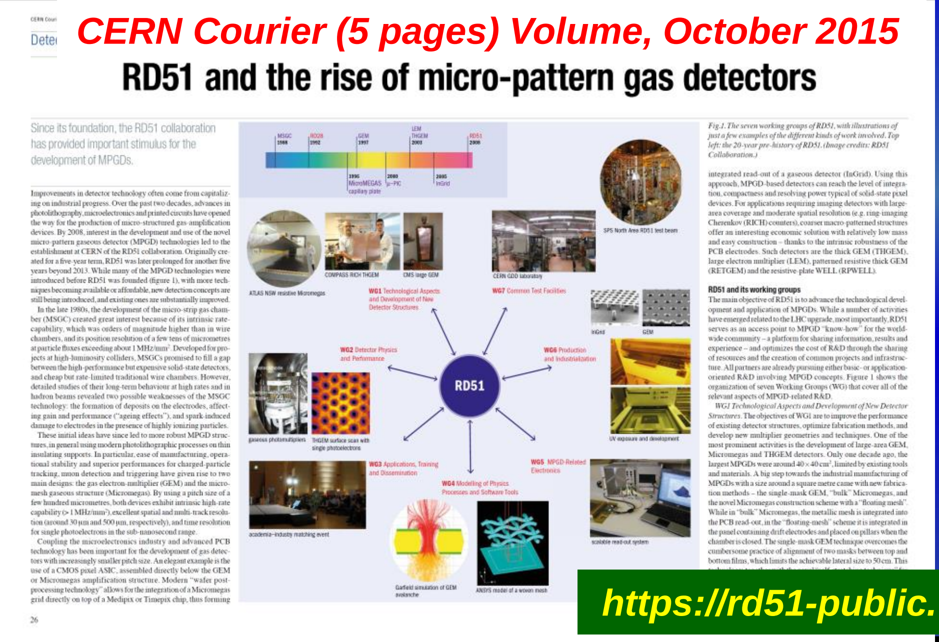
MPGD Technology Development & Dissemination



R&D Tools, Facilities and Infrastructure



CERN Courier (5 pages) Volume, October 2015



RD51 and the rise of micro-pattern gas detectors

Since its foundation, the RD51 collaboration has provided important stimulus for the development of MPGDs.

Improvements in detector technology often come from capitalizing on industrial progress. Over the past two decades, advances in photolithography, microelectronics and printed circuits have opened the way for the production of micro-structured gas-amplification devices. By 2008, interest in the development and use of the novel micro-pattern gaseous detector (MPGD) technologies led to the establishment at CERN of the RD51 collaboration. Originally created for a five-year term, RD51 was later prolonged for another five years beyond 2013. While many of the MPGD technologies were introduced before RD51 was founded (figure 1), with more techniques becoming available or affordable, new detection concepts are still being introduced, and existing ones are substantially improved.

In the late 1980s, the development of the micro-strip gas chamber (MSGC) created great interest because of its intrinsic rate-capability, which was orders of magnitude higher than in wire chambers, and its position resolution of a few tens of micrometres at particle fluxes exceeding about 1 MHz/mm^2. Developed for projects at high-luminosity colliders, MSGCs promised to fill a gap between the high-performance but expensive solid-state detectors, and cheap but rate-limited traditional wire chambers. However, detailed studies of their long-term behaviour at high rates and in hadron beams revealed two possible weaknesses of the MSGC technology: the formation of deposits on the electrodes, affecting gain and performance (“ageing effects”), and spark-induced damage to electrodes in the presence of highly ionizing particles.

These initial ideas have since led to more robust MPGD structures, in general using modern photolithographic processes on thin insulating supports. In particular, ease of manufacturing, operational stability and superior performances for charged-particle tracking, muon detection and triggering have given rise to two main designs: the gas electron-multiplier (GEM) and the micro-mesh gaseous structure (Micromegas). By using a pitch size of a few hundred micrometres, both devices exhibit intrinsic high-rate capability (> 1 MHz/mm^2), excellent spatial and multi-track resolution (around 30 μm and 500 μm, respectively), and time resolution for single photoelectrons in the sub-nanosecond range.

Coupling the microelectronics industry and advanced PCB technology has been important for the development of gas detectors with increasingly smaller pitch size. An elegant example is the use of a CMOS pixel ASIC, assembled directly below the GEM or Micromegas amplification structure. Modern “wafer post-processing technology” allows for the integration of a Micromegas grid directly on top of a Medipix or Timepix chip, thus forming integrated read-out of a gaseous detector (InGrid). Using this approach, MPGD-based detectors can reach the level of integration, compactness and resolving power typical of solid-state pixel devices. For applications requiring imaging detectors with large-area coverage and moderate spatial resolution (e.g. ring-imaging Cherenkov (RICH) counters), coarser macro-patterned structures offer an interesting economic solution with relatively low mass and easy construction – thanks to the intrinsic robustness of the PCB electrodes. Such detectors are the thick GEM (THGEM), large electron multiplier (LEM), patterned resistive thick GEM (RETGEM) and the resistive-plate WELL (RPWELL).

Fig.1. The seven working groups of RD51, with illustrations of just a few examples of the different kinds of work involved. Top left: the 20-year pre-history of RD51. (Image credits: RD51 Collaboration.)

RD51 and its working groups

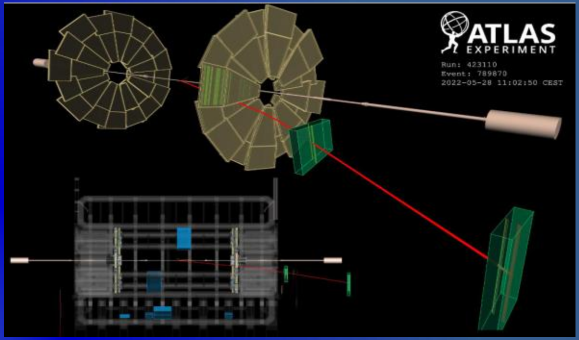
The main objective of RD51 is to advance the technological development and application of MPGDs. While a number of activities have emerged related to the LHC upgrade, most importantly, RD51 serves as an access point to MPGD “know-how” for the world-wide community – a platform for sharing information, results and experience – and optimizes the cost of R&D through the sharing of resources and the creation of common projects and infrastructure. All partners are already pursuing either basic- or application-oriented R&D involving MPGD concepts. Figure 1 shows the organization of seven Working Groups (WG) that cover all of the relevant aspects of MPGD-related R&D.

WG1 Technological Aspects and Development of New Detector Structures. The objectives of WG1 are to improve the performance of existing detector structures, optimize fabrication methods, and develop new multiplier geometries and techniques. One of the most prominent activities is the development of large-area GEM, Micromegas and THGEM detectors. Only one decade ago, the largest MPGDs were around 40 × 40 cm^2, limited by existing tools and materials. A big step towards the industrial manufacturing of MPGDs with a size around a square metre came with new fabrication methods – the single-mask GEM, “bulk” Micromegas, and the novel Micromegas construction scheme with a “floating mesh”. While in “bulk” Micromegas, the metallic mesh is integrated into the PCB read-out, in the “floating-mesh” scheme it is integrated in the panel containing drift electrodes and placed on pillars when the chamber is closed. The single-mask GEM technique overcomes the cumbersome practice of alignment of two masks between top and bottom films, which limits the achievable lateral size to 50 cm. This

https://rd51-public.web.cern.ch/

CERN Detector Seminars in 2022: LS2 Upgrades

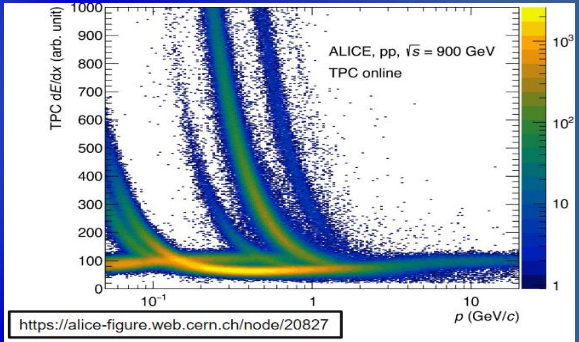
Major MPGDs developments for ATLAS, CMS, ALICE upgrades, towards establishing technology goals and technical requirements, and addressing engineering and integration challenges … and first results from Run 3 !!!



"The New Small Wheel project of ATLAS"

by Theodoros Vafeiadis (17 Jun 2022)

https://indico.cern.ch/event/1168778/

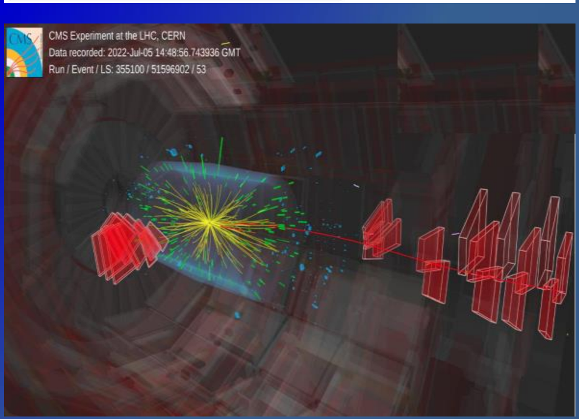


https://alice-figure.web.cern.ch/node/20827

"Continuous data taking with the upgraded ALICE GEM-TPC"

by Robert Helmut Munzer (24 Jun 2022),

https://indico.cern.ch/event/1172978/



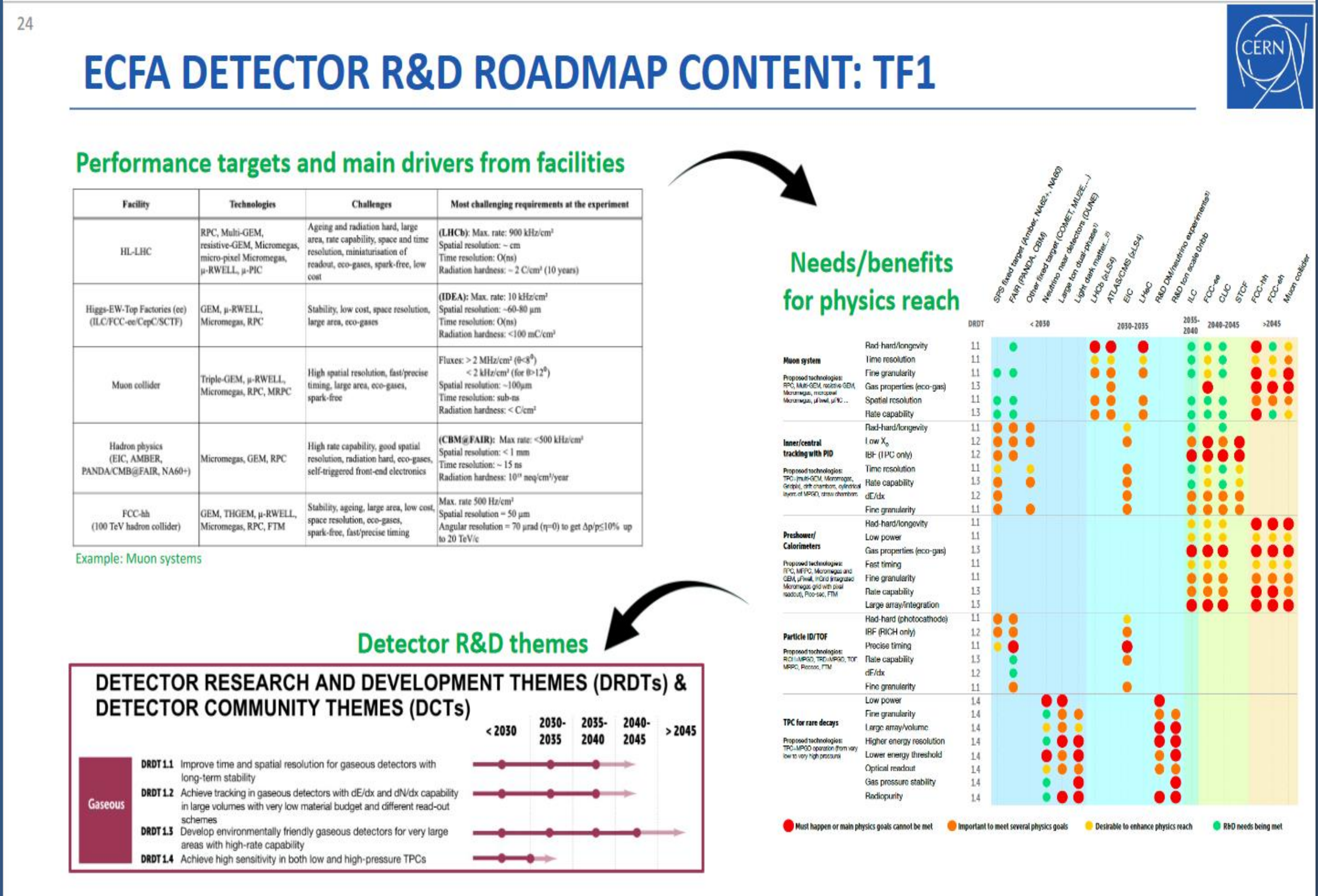
"The GEM detectors within the CMS Experiment"

Michele Bianco (08 Jul 2022)

https://indico.cern.ch/event/1175363/

All three major LHC upgrades, incorporating MPGDs, started their R&D in close contact with RD51, using dedicated setups at GDD-RD51 Laboratory

Gaseous Detectors: DRD1 Successor and Extension of RD51



ECFA DETECTOR R&D ROADMAP CONTENT: TF1

Performance targets and main drivers from facilities

Facility	Technologies	Challenges	Most challenging requirements at the experiment
HL-LHC	RPC, Multi-GEM, resistive-GEM, Micromegas, micro-pixel Micromegas, μ-RWELL, μ-PIC	Ageing and radiation hard, large area, rate capability, space and time resolution, miniaturisation of readout, eco-gases, spark-free, low cost	**(LHCb)**: Max. rate: 900 kHz/cm² Spatial resolution: ~ cm Time resolution: O(ns) Radiation hardness: ~ 2 C/cm² (10 years)
Higgs-EW-Top Factories (ee) (ILC/FCC-ee/CepC/SCTF)	GEM, μ-RWELL, Micromegas, RPC	Stability, low cost, space resolution, large area, eco-gases	**(IDEA):** Max. rate: 10 kHz/cm² Spatial resolution: ~60-80 μm Time resolution: O(ns) Radiation hardness: <100 mC/cm²
Muon collider	Triple-GEM, μ-RWELL, Micromegas, RPC, MRPC	High spatial resolution, fast/precise timing, large area, eco-gases, spark-free	Fluxes: > 2 MHz/cm² ($\theta<8^0$) < 2 kHz/cm² (for $\theta>12^0$) Spatial resolution: ~100μm Time resolution: sub-ns Radiation hardness: < C/cm²
Hadron physics (EIC, AMBER, PANDA/CMB@FAIR, NA60+)	Micromegas, GEM, RPC	High rate capability, good spatial resolution, radiation hard, eco-gases, self-triggered front-end electronics	**(CBM@FAIR):** Max rate: <500 kHz/cm² Spatial resolution: < 1 mm Time resolution: ~ 15 ns Radiation hardness: 10^{13} neq/cm²/year
FCC-hh (100 TeV hadron collider)	GEM, THGEM, μ-RWELL, Micromegas, RPC, FTM	Stability, ageing, large area, low cost, space resolution, eco-gases, spark-free, fast/precise timing	Max. rate 500 Hz/cm² Spatial resolution = 50 μm Angular resolution = 70 μrad (η=0) to get $\Delta p/p \leq 10\%$ up to 20 TeV/c

Example: Muon systems

Needs/benefits for physics reach

DRDT

< 2030: SPS fixed target (Amber, NA62+, NA60); FAIR (PANDA, CBM); Other fixed target (COMET, MUZE...); Neutrino near detectors (DUNE); Large ton dual-phase¹⁾; Light dark matter...²⁾

2030-2035: LHCb (≥LS4); ATLAS/CMS (≥LS4); EIC; LHeC; R&D DM/neutrino experiments³⁾; R&D ton scale 0nbb

2035-2040: ILC

2040-2045: FCC-ee; CLIC; STCF

>2045: FCC-hh; FCC-eh; Muon collider

		DRDT
Muon system Proposed technologies: RPC, Multi-GEM, resistive GEM, Micromegas, micropixel Micromegas, μRwell, μPIC ...	Rad-hard/longevity	1.1
	Time resolution	1.1
	Fine granularity	1.1
	Gas properties (eco-gas)	1.3
	Spatial resolution	1.1
	Rate capability	1.3
Inner/central tracking with PID Proposed technologies: TPC+(multi-GEM, Micromegas, Gridpix), drift chambers, cylindrical layers of MPGD, straw chambers	Rad-hard/longevity	1.1
	Low X_0	1.2
	IBF (TPC only)	1.2
	Time resolution	1.1
	Rate capability	1.3
	dE/dx	1.2
	Fine granularity	1.1
Preshower/ Calorimeters Proposed technologies: RPC, MRPC, Micromegas and GEM, μRwell, InGrid (integrated Micromegas grid with pixel readout), Pico-sec, FTM	Rad-hard/longevity	1.1
	Low power	1.1
	Gas properties (eco-gas)	1.3
	Fast timing	1.1
	Fine granularity	1.1
	Rate capability	1.3
	Large array/integration	1.3
Particle ID/TOF Proposed technologies: RICH+MPGD, TRD+MPGD, TOF: MRPC, Picosec, FTM	Rad-hard (photocathode)	1.1
	IBF (RICH only)	1.2
	Precise timing	1.1
	Rate capability	1.3
	dE/dx	1.2
	Fine granularity	1.1
TPC for rare decays Proposed technologies: TPC+MPGD operation (from very low to very high pressure)	Low power	1.4
	Fine granularity	1.4
	Large array/volume	1.4
	Higher energy resolution	1.4
	Lower energy threshold	1.4
	Optical readout	1.4
	Gas pressure stability	1.4
	Radiopurity	1.4

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

Detector R&D themes

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

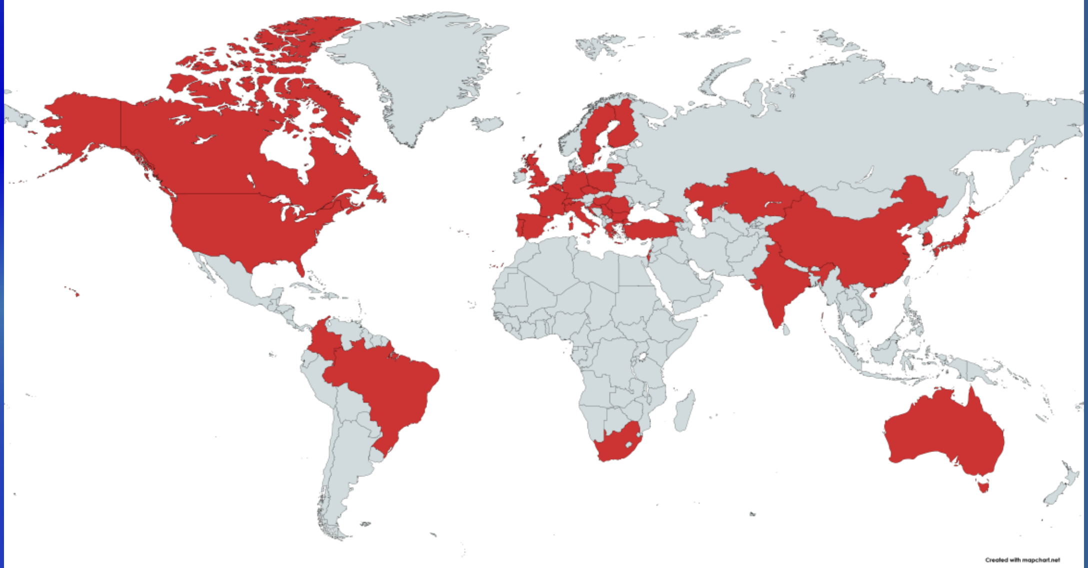
DRDT 1.2 Achieve tracking in gaseous detectors with dE/dx and dN/dx capability in large volumes with very low material budget and different read-out schemes

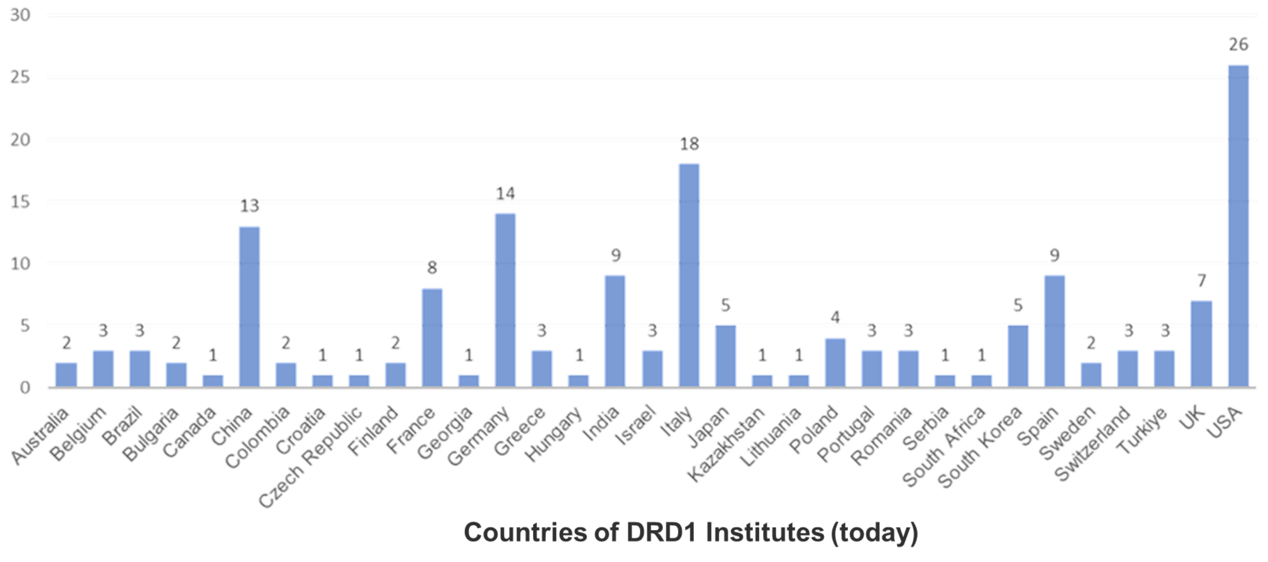
DRDT 1.3 Develop environmentally friendly gaseous detectors for very large areas with high-rate capability

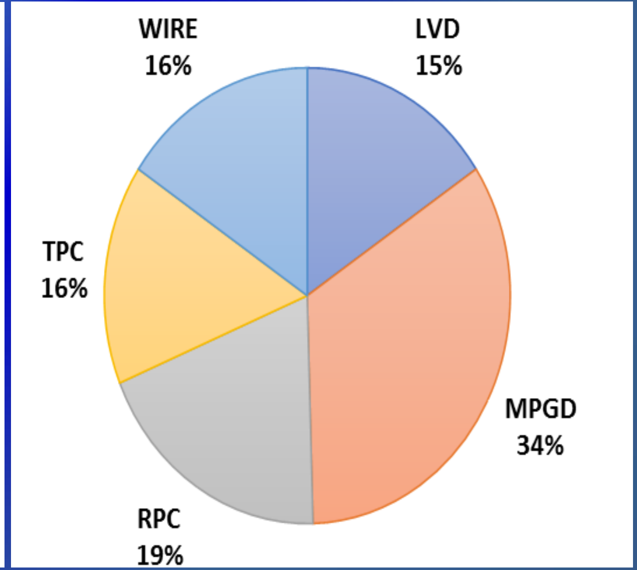
DRDT 1.4 Achieve high sensitivity in both low and high-pressure TPCs

DRD1 Collaboration: Large & Diversified Community

- ***161 Institutes***
- ***5 Industrial, Semi-Industrial and Research Foundations***
- ***33 Countries***
- ***More than 700 members***



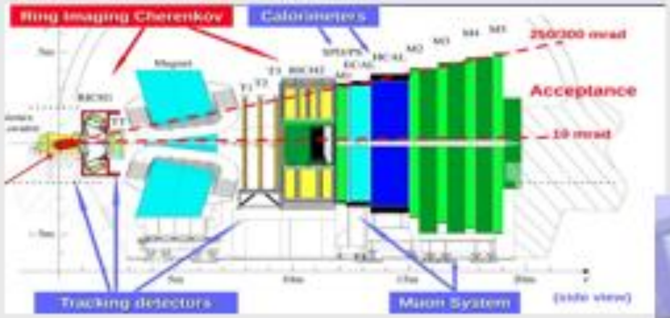




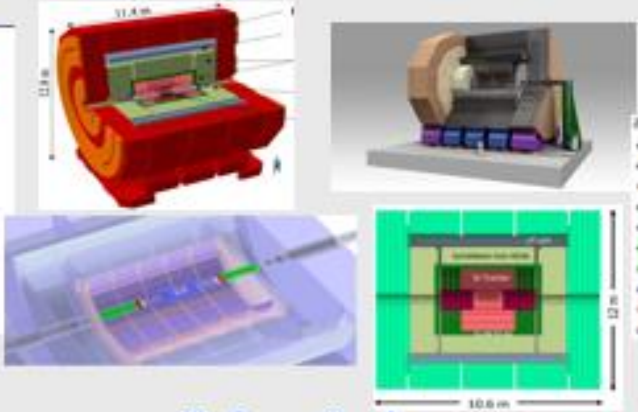
Steps Towards Long-Term Detector R&D Program

Main target projects of Gaseous Detector R&D

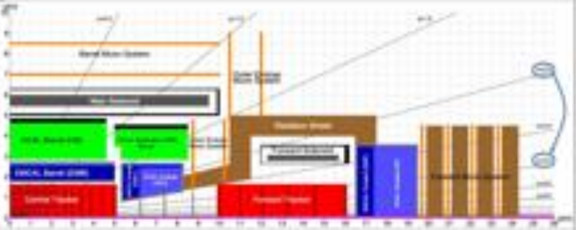
HL-LHC after LS4



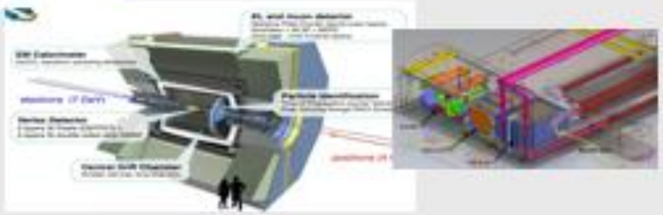
Higgs Factories



Future hadron colliders (FCC-hh/eh colliders)

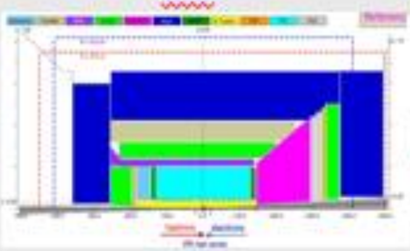


SuperKEKB, DUNE ND

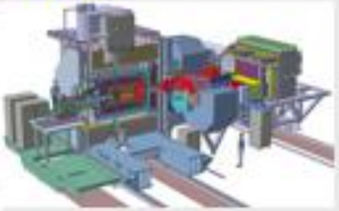


Hadron physics

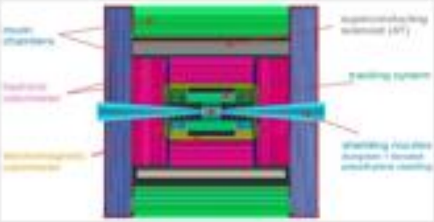
EiC



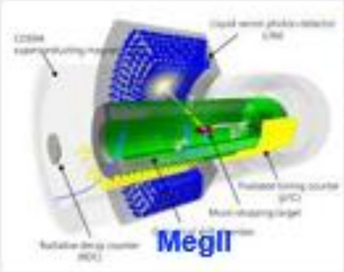
PANDA



Muon Collider



Rare event search, fixed target (LFV, Kaon physics)



MegII

HIKE

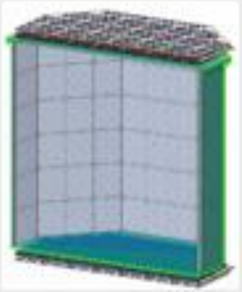
MU2E

DM, solar axions, ββ0ν-decay, neutrino, nuclear, astroparicle

MIGDAL

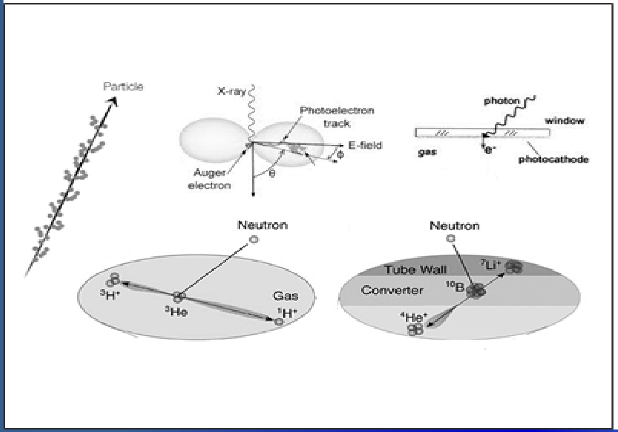
Darksphere

Cygnus

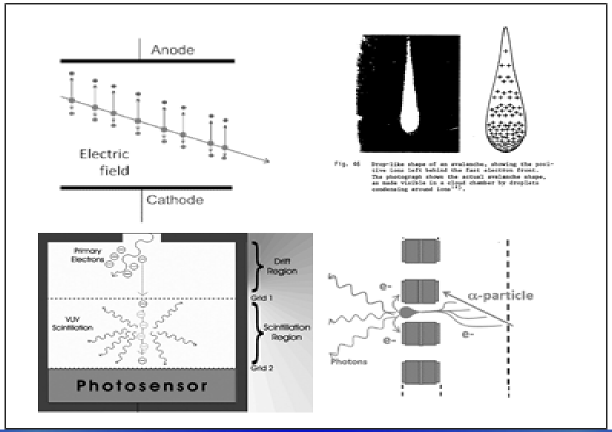


Gaseous Detector R&D: Common Issues

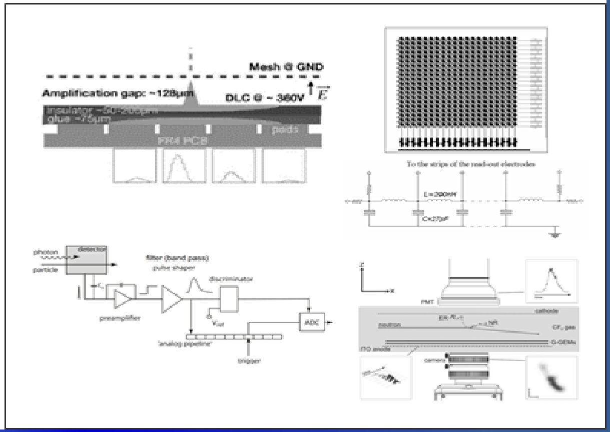
Ionization



charge drifting and amplification



readout

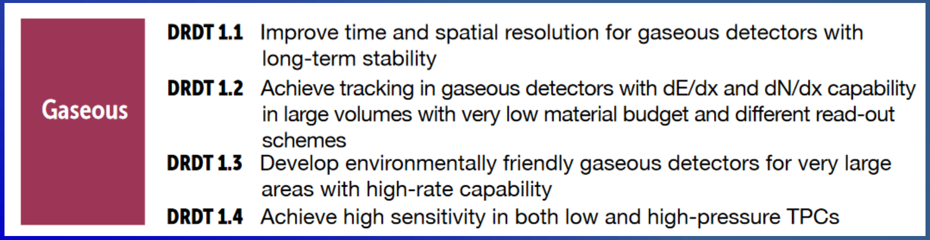


Despite the different R&D requirements, there is potential for overlapping in many aspects, allowing for a larger community of gaseous detectors to benefit. The most straightforward example is the classic ageing issues, but many others can be mentioned:

- **MPGD- the main challenges remain large areas, high rates, precise timing capabilities, and stable discharge-free operation**
- **RPC - focus stays on improving high-rate and precise timing capabilities, uniform detector response, and mechanical compactness.**
- **Straw tubes- requirements include extended length and smaller diameter, low material budget, and operation in a highly challenging radiation environment.**
- **Large-volume Drift chamber with a reduced material budget in a high-rate environment requires searching for new materials. Avalanche-induced Ion Back Flow (IBF) remains the primary challenge for TPC applications in future facilities.**

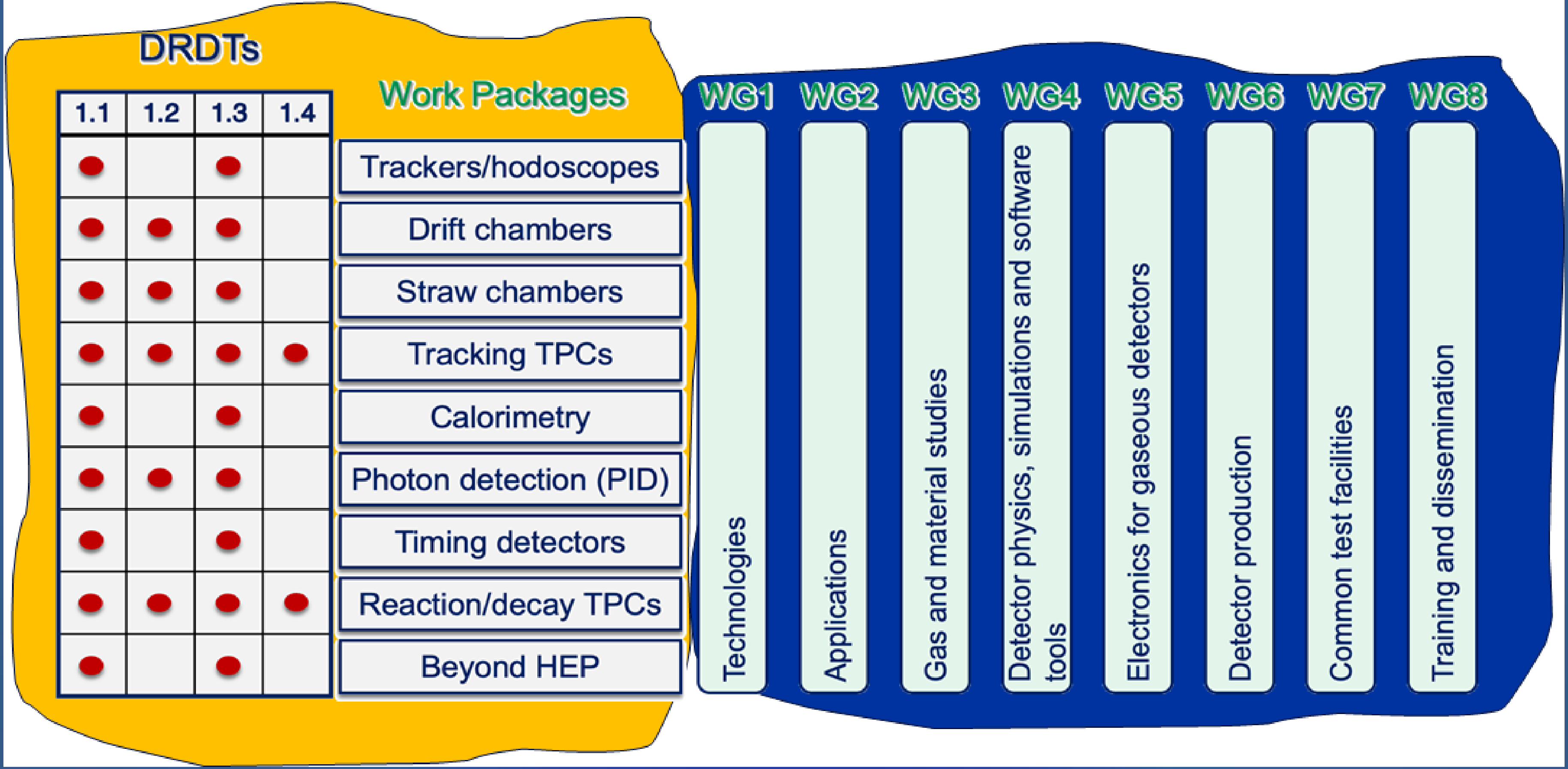
DRD1 Scientific Organization

ECFA Detector R&D Roadmap and General Recommendations are addressed with a scientific organization based on:



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

- ✓ **R&D Framework & Working Groups (RD51 Legacy)** → Distributed R&D Activities with Centralized Facilities.
- ✓ **Work Packages** → Strategic R&D and Long -Term Funding (Funding Agency)



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

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

DRD1 Organization and Management

Approved during the Collaboration Board with Consensus

COLLABORATION BOARD

RESOURCE BOARD

MANAGEMENT BOARD

SPOKESPERSONS

SCIENTIFIC COORDINATION BOARD
(Working Groups, Work Packages, DRDs Liaisons, Common Projects

Simlar to the RD51 Structure + SCB

- DRD1 spokespersons and CB chair candidates, CV, statements and open presentations: https://indico.cern.ch/event/1352912/

- Wide consolations and nominations from whole community (about 160 institutes)
- Election procedure discussed & approved by the DRD1 Implementation Team and DRD1 CB
- About 110 instates casted votes:

Elections Results (2024 -2025)

- **2 Spokespersons: Eraldo Oliveri, Maxim Titov**
  CB Chair: Anna Colaleo

✓ **DRD1 implementation and organization: Community Driven with key role played by the Implementation Team (about 50 persons)**

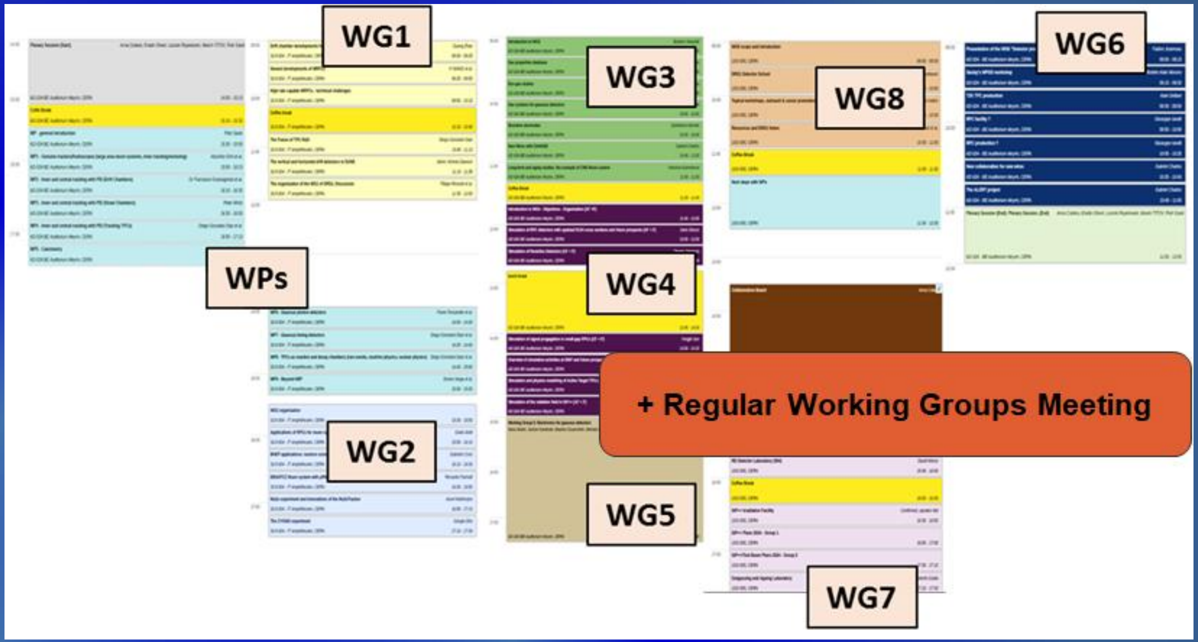
✓ **DRD1 Management Elections and Organization approved by CB. All roles will be approved by DRD1 Meting in June 2024**

✓ **DRD1 Activities started**

✓ **Prompt actions required to preserve and enhance the current momentum in the community**

DRD1 Collaboration & Future Events: JOIN US !!!

1st DRD Collaboration Meeting Agenda (Jan. 29 – Feb. 2)



1st Collaboration Meeting
Jan. 29-Feb. 2 (CERN):
https://indico.cern.ch/event/1360282/

2nd Collaboration Meeting
June 17-21 (CERN):
https://indico.cern.ch/event/1413681/

3rd Collaboration Meeting
December 9-13 (CERN)

More information on DRD1- related issues:

- Symposium of Task Force 1: https://indico.cern.ch/event/999799/
- ECFA Detector R&D Roadmap (chapter 1): https://cds.cern.ch/record/2784893
- DRD1 Proposal: https://cds.cern.ch/record/2885937
- DRD1 Website: https://drd1.web.cern.ch/
- Working Groups: https://drd1.web.cern.ch/working-groups
- Work Packages: https://drd1.web.cern.ch/wp

2024 Gaseous Detector Conferences & Schools:

- RPC2024 Conference, Santiago, 9-13 September: https://indico.cern.ch/event/1354736
- MPGD2024 Conference, Hefei, 14-18 October: https://mpgd2024.aconf.org
- DRD1 Gaseous Detector School, Nov. 27 – Dec. 6: https://indico.cern.ch/e/drd1school2024