Gaseous Detectors R&D, where do we stand / where do we go

Eraldo Oliveri, EP-DT, GDD, CERN

RPC2024, Santiago De Compostela

Outline

- **Introduction to the DRDs Collaborations**
- **DRD1, the collaboration focusing on gaseous detector technologies**
- **Is it worth doing? Concrete examples of collaborative efforts and activities within the RD51 Collaboration. One example as well on DRD1 and Work Packages (strategic R&D).**

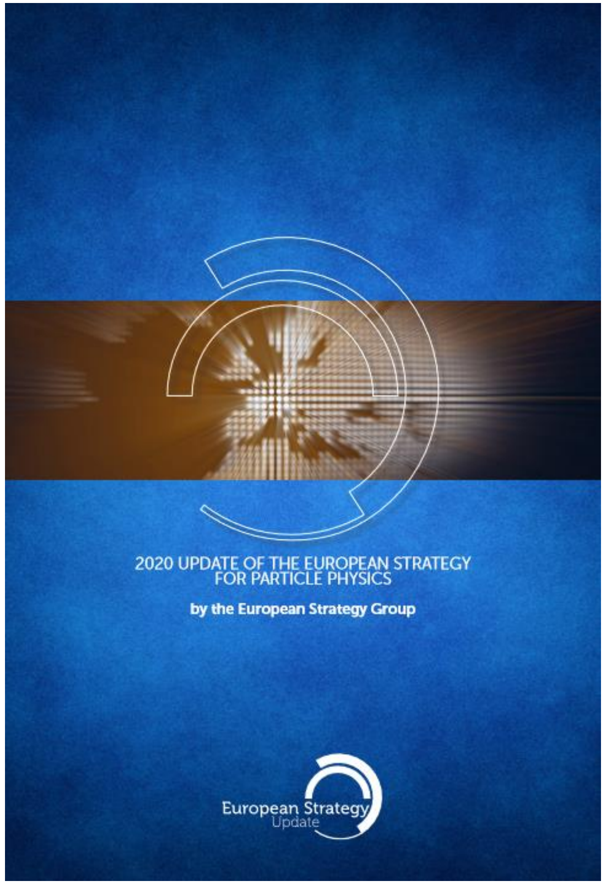
Introduction to the DRDs Collaborations

This section will contextualize the setting up of several new R&D collaborations on instrumentation, specifically the newly established DRDs, following the recommendations from the latest European Strategy Update for Particle Physics. Motivation behind these collaborations and the main aims they should focus on will be highlighted.

June 2020

European Strategy Update for Particle Physics (ESPPU)

https://europeanstrategyupdate.web.cern.ch/



https://cds.cern.ch/record/2721370/files/CERN-ESU-015-2020%20Update%20European%20Strategy.pdf

Record created 2020-06-19, last modified 2021-11-11

4

Other essential scientific activities for particle physics

C. The success of particle physics experiments relies on innovative instrumentation and state-of-the-art infrastructures. To prepare and realise future experimental research programmes, the community must maintain a strong focus on instrumentation. *Detector R&D programmes and associated infrastructures should be supported at CERN, national institutes, laboratories and universities.* ***Synergies between the needs of different scientific fields and industry should be identified and exploited to boost efficiency in the development process and increase opportunities for more technology transfer benefiting society at large. Collaborative platforms and consortia must be adequately supported to provide coherence in these R&D activities. The community should define a global detector R&D roadmap that should be used to support proposals at the European and national levels.***

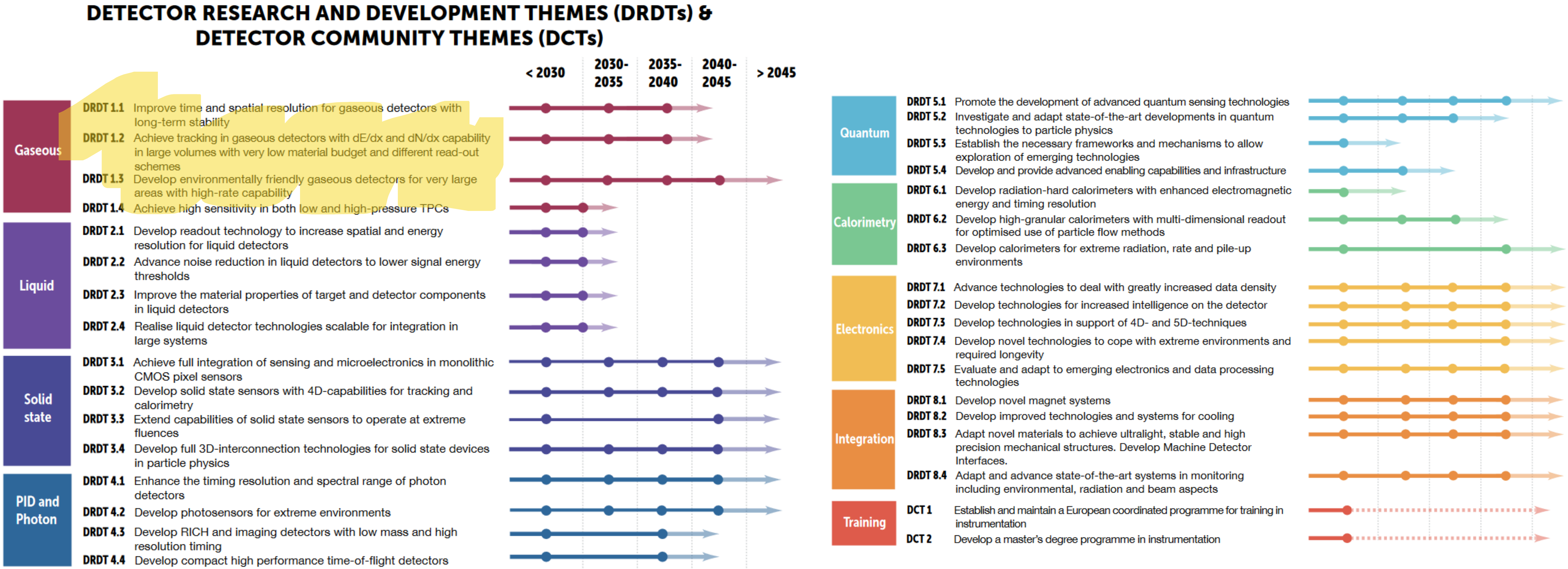
ECFA Detector R&D Roadmap Document

The links are here to the Synopsis and Full Document as presented to the Scientific Policy Committee and CERN Council in December 2021.

The Full Documents can be found on 10.17181/CERN.XDPL.W2EX

October 2021

ECFA Detector R&D Roadmap Document



https://cds.cern.ch/record/2784893/files/Synopsis%20of%20the%20ECFA%20Detector%20R&D%20Roadmap.pdf

General Strategic Recommendation

The report concludes with ten "General Strategic Recommendations" (GSRs). The aim of these is to propose mechanisms to achieve a greater coherence in detector R&D across Europe through better streamlining of local and national activities. Greater coordination will reduce duplication, improve effectiveness and give the area greater visibility. It will also give the field a greater voice at a European level to make the case for the additional resources needed for Europe to maintain a leading role in particle physics, with all the associated scientific and societal benefits that will flow from this.

The GSR topics covered by the detailed recommendations in the report are:

GSR 1 - Supporting R&D facilities
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

GSR 4 - International coordination and organisation of R&D activities

In some, but not all, areas of generic detector R&D, community-led collaborations provide vital fora for exchange of ideas and pooling of resources, thereby minimising duplication of effort. This ecosystem, which originally sprung from a CERN initiative around the challenges of detectors for the LHC and has evolved over three decades, has proved to be very effective and has also spawned a number of collaborations not linked to the original CERN structures. Within GSR 4, it is proposed to significantly refresh the structures and processes for the creation and peer-reviewing of such R&D collaborations, encouraging CERN and the other national laboratories to actively assist in catalysing this transformation

GSR 5 – Distributed R&D Activities with Centralized Facilities

A major concern for the future of several sensor R&D areas (particularly those linked to solid-state devices, microelectronics and on-detector data handling) is that R&D costs to exploit, adapt and further develop cutting-edge technologies are rising much faster than the rate of inflation. Although addressing the niche specifications of particle physics can provide an important vehicle for product development, the field remains by commercial standards a low volume market making it expensive. Increasingly, costs can only be met through a significant pooling of resources, particularly given the growing complexity and degree of specialisation required of those involved in the device design and the need to negotiate as a larger-scale organisation. GSR 5 proposes a solution to achieving the required critical mass through a network of national hubs which, while improving focus and cost-effectiveness, would still allow a vibrant research base in individual smaller institutes and university departments

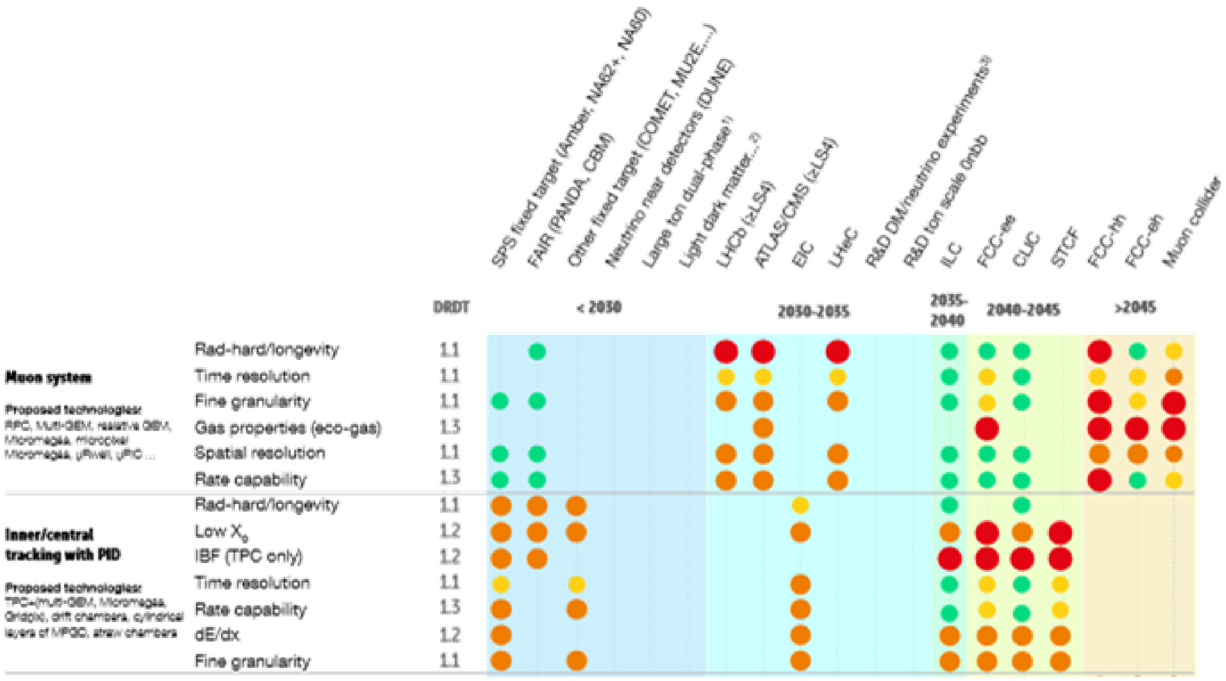
GSR 6 – Establish long-term strategic funding programs

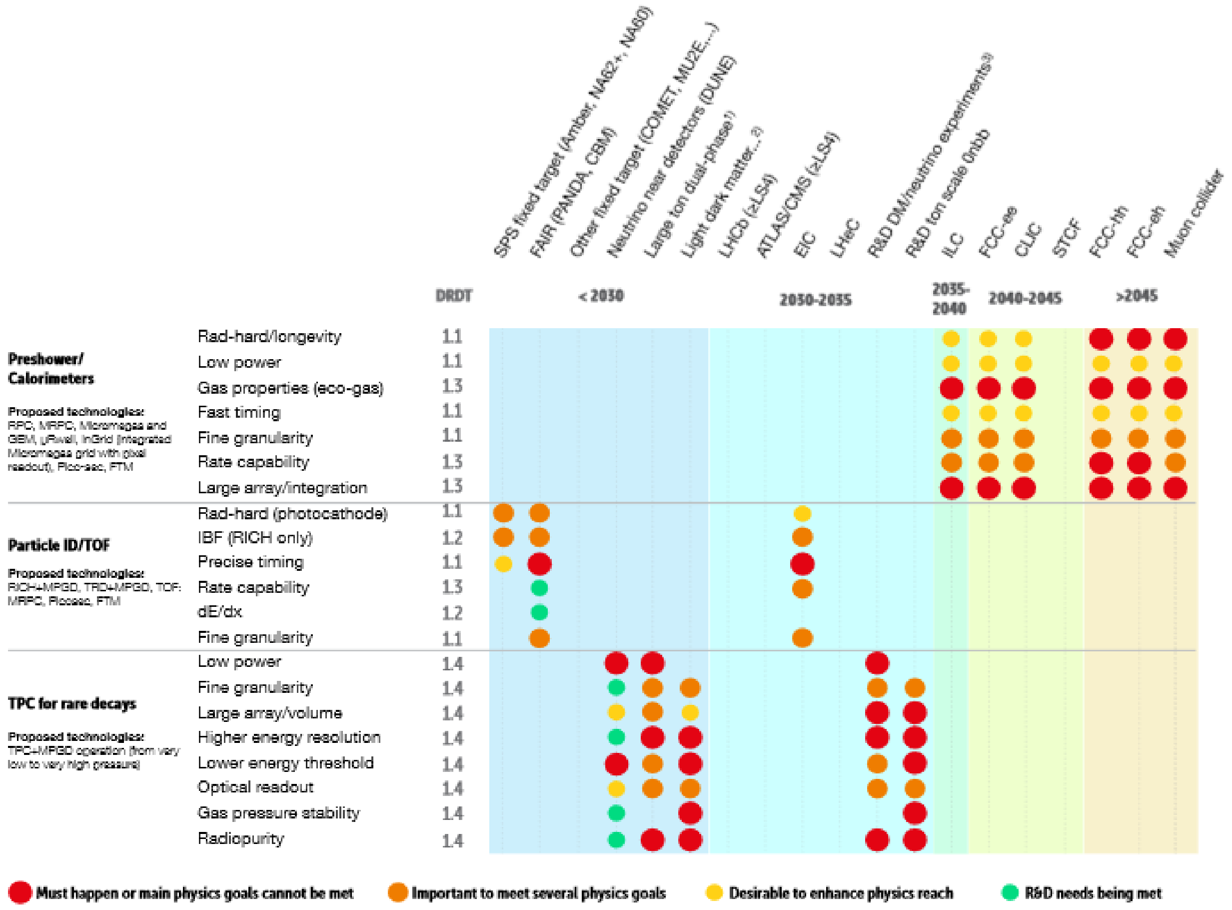
Linked to rising R&D costs, the need for a critical mass and the decadal timescales for strategic R&D investments needed for the ESPP programmes, there is an urgent need to augment the short-term funding mechanisms, suited for exploratory stages of the R&D cycle, with funding mechanisms better suited to long-term programmes as outlined in GSR 6. The scale of the technical challenges, the long planning horizons and the need to build serious relationships with industrial partners make sustained strategic investment a must, particularly if matching resources are to be leverage

The DRD1 Collaboration on gaseous detector technologies

This section will shift the focus to the DRD1 Collaboration, which encompasses a range of gaseous detector technologies, including Micro Pattern Gas Detectors (MPGD), Resistive Plate Chambers (RPC), and wire-based detectors. More than 160 institutes have shown interest in this collaboration, making it one of the largest and more diversified in terms of research activities.

Detector R&D Themes and Requirements from future experiments





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

https://cds.cern.ch/record/2784893/files/ECFA%20Detector%20R&D%20Roadmap.pdf

Requirements for future experiments at future facilities

Rate Capabilities	Up to several MHz/cm2
Spatial Resolution	Down to 50μm
Time Resolution	Down to few tens of ps
Radiation Hardness	up to 10^{13} $n_{eq}/cm^2/y$
Ageing	Up to C/cm2
Material Budget	<1% X/X0
Magnetic Field	Up to several Tesla
Gain	Larger than 10^5-10^6
dE/dx	Down to 10%
….	

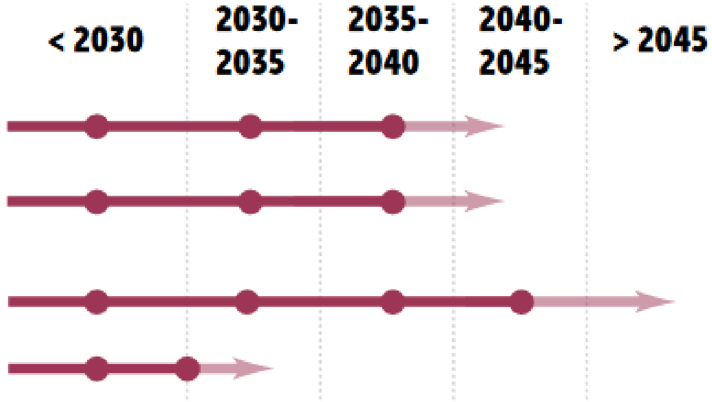
Extracted by ECFA Detector R&D Roadmap (detailed tables in backup) 10.17181/CERN.XDPL.W2EX

- **Muon Systems** (HL-LHC, ILC/FCC-ee/CepC/SCTF, Muon Collider, Hadron Physics, FCC-hh),
- **Inner and Central Tracking** (HL-LHC, ILC/FCC-ee/CepC/SCTF, Rare/Atomic/Nuclear Physics, Hadron Physics),
- **Preshower/Calorimeters** (ILC/FCC-ee/CepC/SCTF, Muon Collider, Hadron Physics),
- **Particle ID/TOF: RICH and TRD** (Hadron and Nuclear Physics, FCC-ee/CepC), **TOF** (Hadron and Nuclear Physics),
- **TPC for Rare Decays** (WIMP, Solar Axions, Nuclear Physics, Neutrino and neutrino-less double beta decay, DM)

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

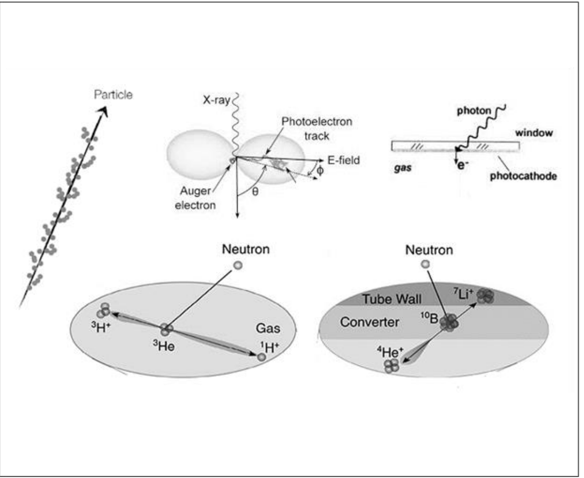
Gaseous

- **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

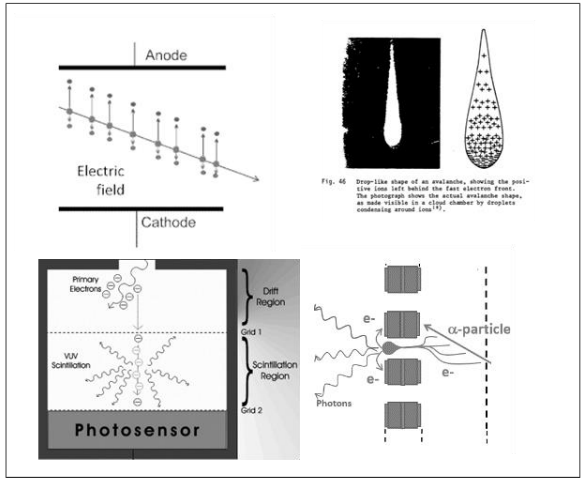


https://cds.cern.ch/record/2784893/files/Synopsis%20of%20the%20ECFA%20Detector%20R&D%20Roadmap.pdf

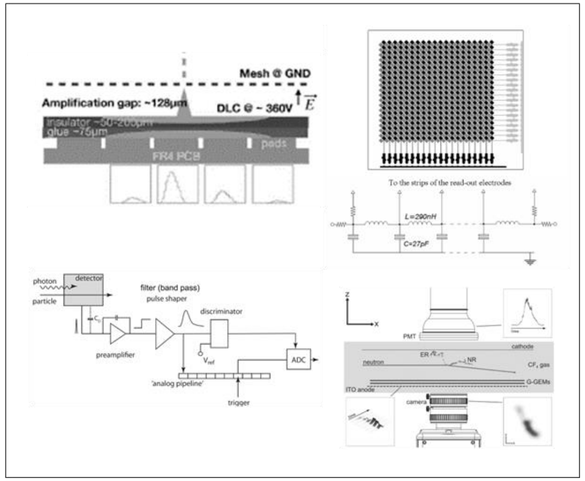
Ionization



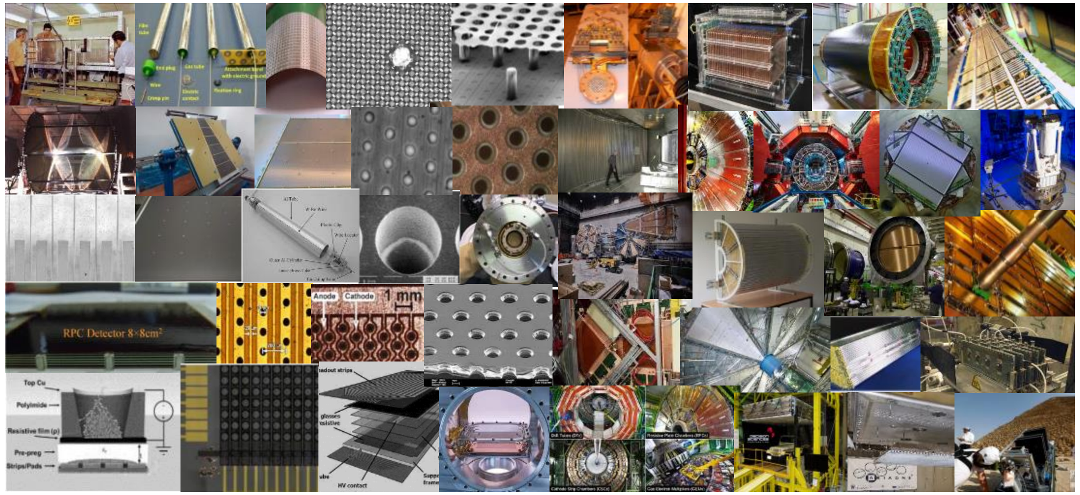
charge drifting and amplification



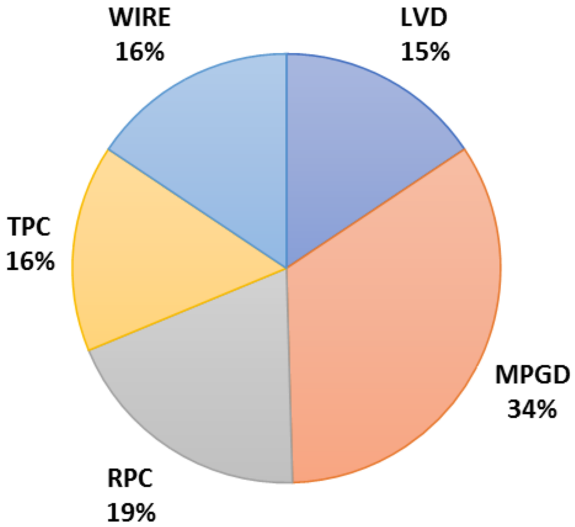
readout

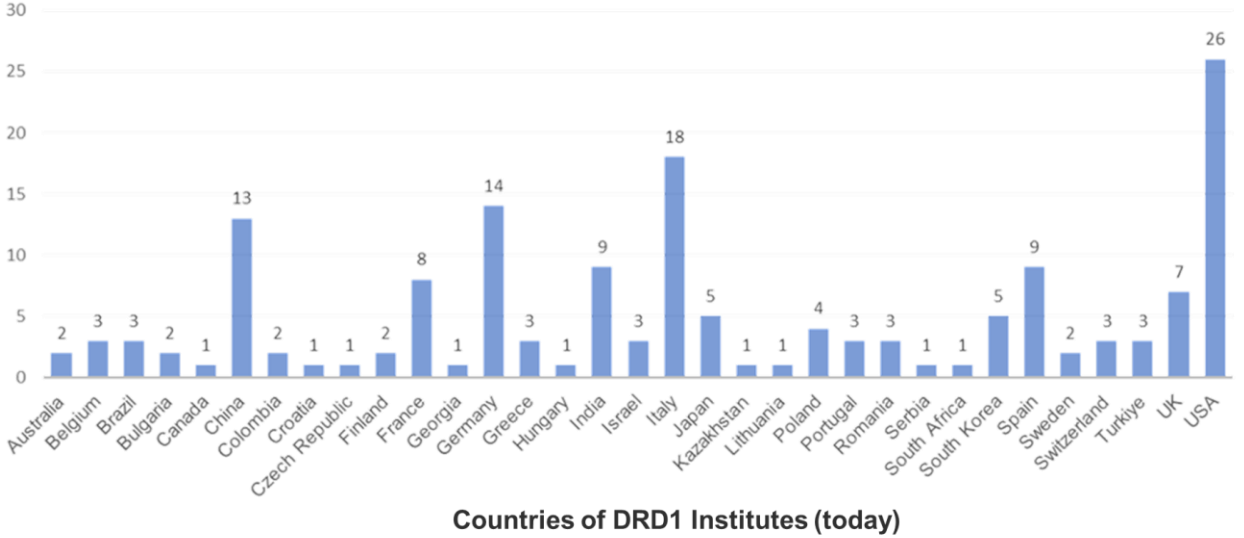


DRD1: A very large and diversified set of technologies and solution, a very large and diversified community



- More than 160 Institutes
- More than 30 Countries
- More than 700 members
- 5 Industrial, Semi-Industrial and Research Foundations





DRD1 Implementation Team (Bottom-up & Inclusive)

Task Force Conveners
Anna Colaleo, Leszek Ropelewski;

Implementation Team Florian Brunbauer , Silvia Dalla Torre , Klaus Dehmelt , Ingo Deppner , Esther Ferrer Ribas , Roberto Guida , Giuseppe Iaselli , Jochen Kaminski , Barbara Liberti , Beatrice Mandelli , Eraldo Oliveri , Marco Panareo , Francesco Renga , Hans Taureg , Fulvio Tessarotto , Maxim Titov , Joao Veloso , Peter Wintz

Proposal Review Team
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DRD4: F. Tessarotto
DRD5: F. Brunbauer
DRD6: I. Laktineh
DRD7: M. Bregant, S. Martoiu

US-CPAD: M. Titov, S. E. Vahsen
US-FCC/ILC: M. Hohlmann, G. Iakovidis, B. Zhou

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WG3: K. Dehmelt, B. A. Gonzalez, B. Mandelli, G. Morello, D, Piccolo, F. Renga, S. Roth, A. Pastore
WG4: M. Abbrescia, M. Borysova, P. Fonte, O. Sahin, R. Veenhof, P. Verwilligen
WG5: R. Cardarelli, M. Gouzevitch, J. Kaminski, M. Lupberger, H. Muller
WG6: G. Charles, R. De Oliveira, A. Delbart, G. Iaselli, F. Jeanneau, I. Laktineh
WG7: A. Ferretti, R. Guida, G. Iaselli, E. Oliveri, Y. Tsipolitis
WG8: E. Baracchini, F. Brunbauer, M. Iodice, B. Liberti, A Paoloni

Work Package Coordinators
Overall Coordination: P. Gasik
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WP2: N. De Filippis, F. Grancagnolo
WP3: P. Wintz
WP4: D. Gonzalez Diaz, E. Ferrer Ribas, F. I. Garcia Fuentes, P. Gasik, J. Kaminski
WP5: I. Laktineh
WP6: F. Brunbauer, S. S. Dasgupta, P. Gasik, F. Tessarotto
WP7: F. Brunbauer, I. Deppner, D. G. Diaz, I. Laktineh
WP8: D. G. Diaz, E. Ferrer Ribas, F. I. G. Fuentes, P. Gasik, J. Kaminski
WP9: J. Bortfeldt, G. Croci, D. Varga

More than 50 people, from different technologies, research fields and countries

Main goal: present how DRD1 is addressing the general recommendations (I)

GSR 5 – Distributed R&D Activities with Centralized Facilities

A major concern for the future of several sensor R&D areas (particularly those linked to solid-state devices, microelectronics and on-detector data handling) is that R&D costs to exploit, adapt and further develop cutting-edge technologies are rising much faster than the rate of inflation. Although addressing the niche specifications of particle physics can provide an important vehicle for product development, the field remains by commercial standards a low volume market making it expensive. Increasingly, costs can only be met through a significant pooling of resources, particularly given the growing complexity and degree of specialisation required of those involved in the device design and the need to negotiate as a larger-scale organisation. GSR 5 proposes a solution to achieving the required critical mass through a network of national hubs which, while improving focus and cost-effectiveness, would still allow a vibrant research base in individual smaller institutes and university departments

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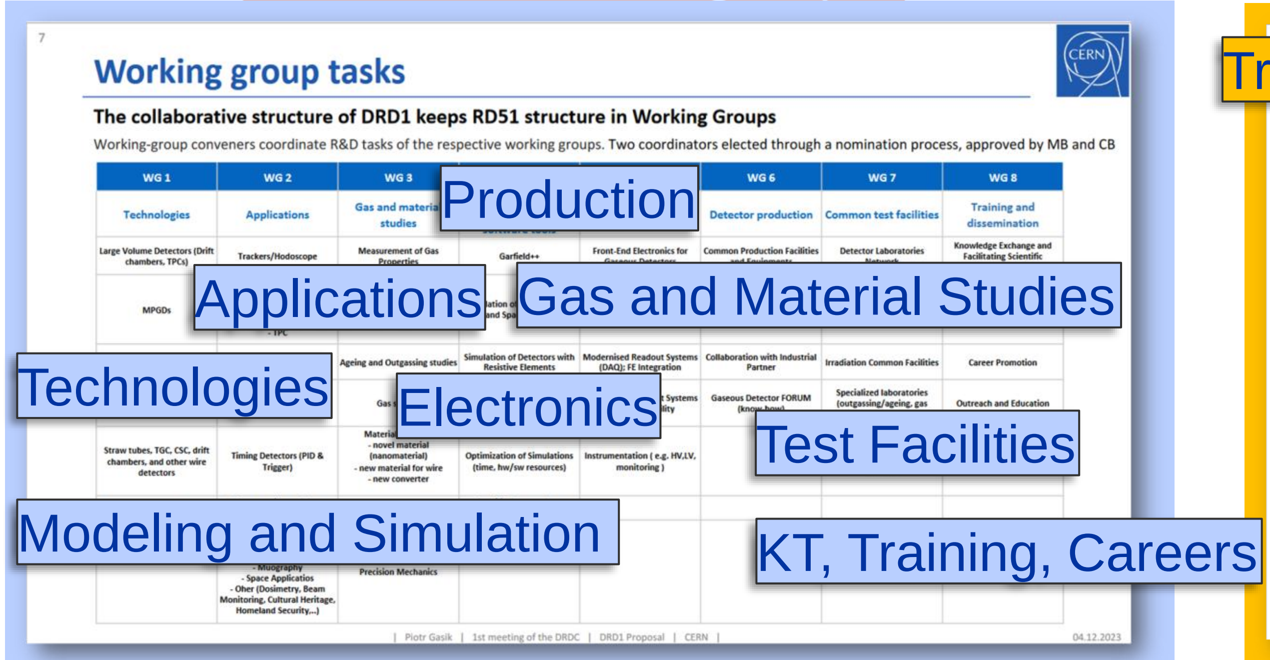
R&D Framework & Working Groups



P. Gasik, DRD1 Proposal: Development of Gaseous Detectors Technologies, **1st meeting of the DRDC** 4 Dec 2023, CERN

Main goal: present how DRD1 is addressing the general recommendations (II)

GSR 6 – Establish long-term strategic funding programs

Linked to rising R&D costs, the need for a critical mass and the decadal timescales for strategic R&D investments needed for the ESPP programmes, there is an urgent need to augment the short-term funding mechanisms, suited for exploratory stages of the R&D cycle, with funding mechanisms better suited to long-term programmes as outlined in GSR 6. The scale of the technical challenges, the long planning horizons and the need to build serious relationships with industrial partners make sustained strategic investment a must, particularly if matching resources are to be leverage

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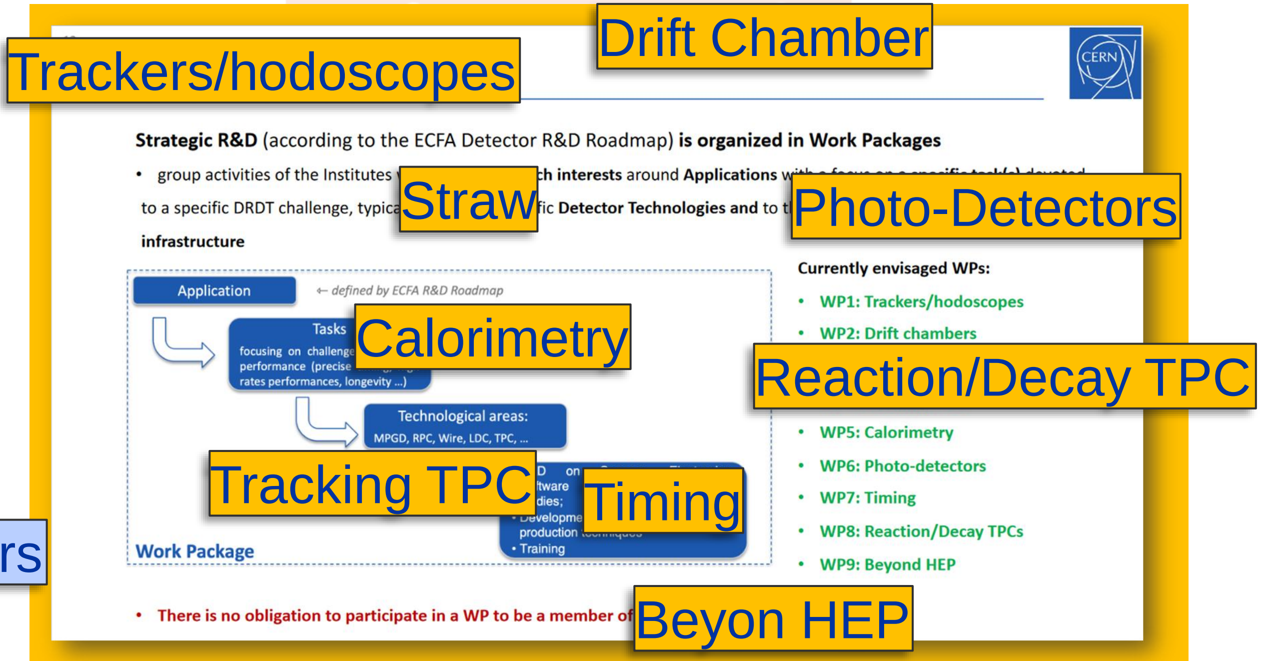
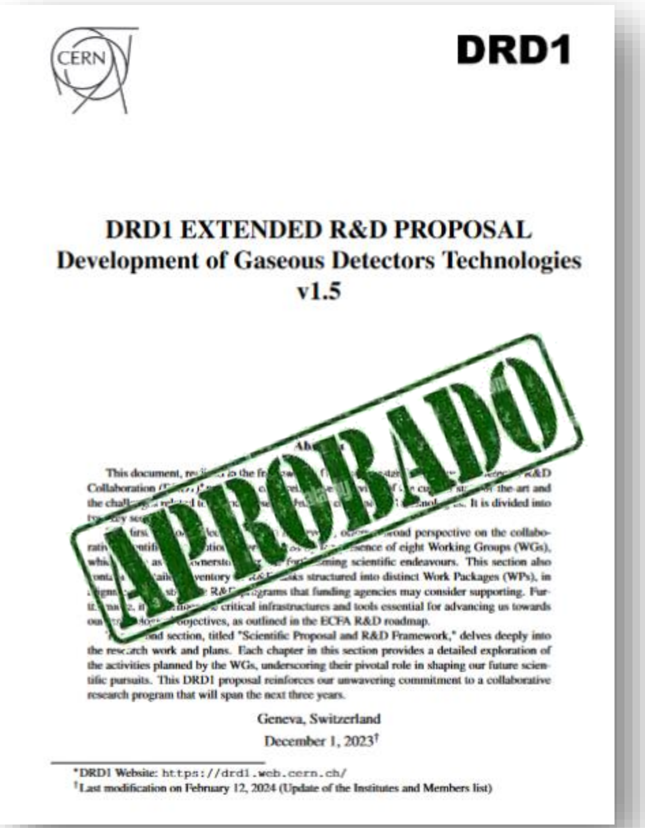
Strategic R&D & Work Packages



P. Gasik, DRD1 Proposal: Development of Gaseous Detectors Technologies, **1st meeting of the DRDC** 4 Dec 2023, CERN

R&D FRAMEWORK a simplified vision, reality is slightly more complex and mixed **STRATEGIC R&D PROJECTS**

DRD1 Proposal



https://cernbox.cern.ch/s/PP7BZroM3NYS2Vh

Scientific Organization

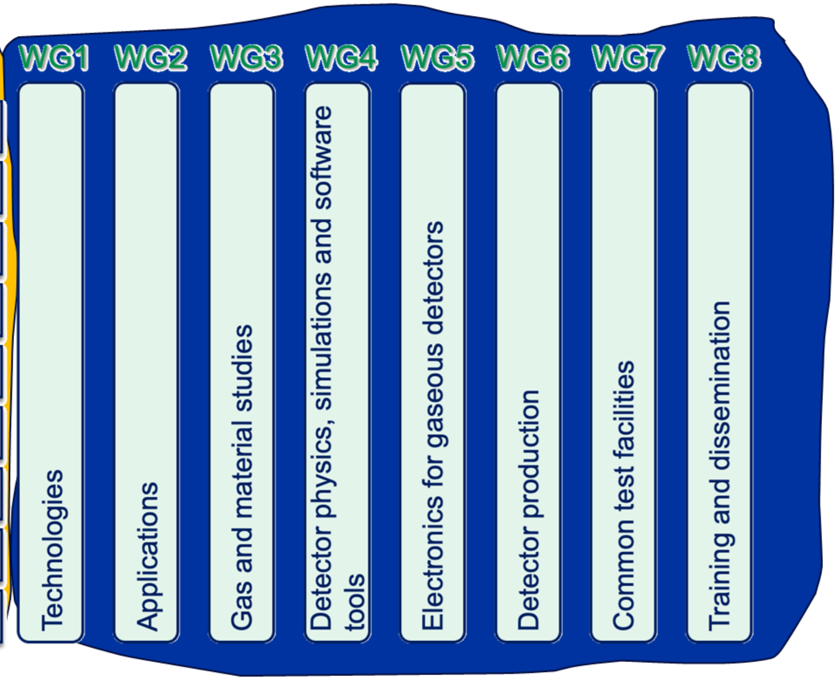
Strategic R&D and Long-Term Funding based on Work Packages → **GSR6** (but also GR5)

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

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

STRATEGIC R&D



R&D FRAMEWORK

R&D Framework based on Working Groups →**GSR5** (but also GR6)

Is it worth building all of this?

Intermezzo (personal thoughts)

It is not possible today to guarantee that all motivations/expectations behind the DRDs collaboration will be satisfied.

Nevertheless, I firmly believe that a **community-led collaboration is beneficial** no matter what and that, while **preserving (*) the freedom, dynamism, and independence of each group**, it will provide more resources (in terms of knowledge, scientific, and technical support) and better optimize their sharing to support the research activities of each member group.

(*) From ECFA Roadmap Recommendation: *supporting and valorise the vibrant research in individual smaller institutes and university departments*

This will work best of course if we will be open to sharing our developments and participating in common initiatives. Often, this creates a win-win situation, and it works.

A set of examples based on my experience of collaborative efforts within the RD51 Collaboration

The formation of DRD1 has benefited from the experience and heritage of the RD51 Collaboration, an international R&D initiative based at CERN that was dedicated to advancing MPGD technologies. A series of concrete examples of collaborative efforts and activities will be given.

In the next slides I will pick up a few examples of activities done within RD51. I will focus on activities that were enriching the R&D framework available to all the members of the collaboration.

The examples I will cover are connected to:

- **Modelling and Simulation** → Garfield++ & Co.
- **Electronics** → The Scalable Readout System
- **Production** → The MPT Workshop
- **Common test Facilities** → The Semipermanent Test Beam installation at the SPS

I will close this part with **Common Project**, an initiative a support of blues sky and generic R&D.

These common projects had the objective of:

- Clustering of groups
- Supporting basic research and blue-sky activities that may have difficulties to be funded as such
- Seeding long terms initiatives

Let’s start with Modeling and Simulation

RD51 supported directly the long-term clustering of developers and the training and formation of new generations. It additionally supported the clustering of research groups and valorize their contribution.

Garfield(++) & Co.

INTRODUCTION

- WHO I AM
  SUMMER STUDENT (C FABJAN)
  Rob VEENHOF / LEIDEN - NETHERLANDS
- WHAT I HAVE BEEN DOING
  WRITING A COMPUTER PROGRAM FOR
  DRIFT CHAMBER
  SIMULATION
- WHAT THE PROGRAM CAN DO
  - CALCULATE THE ELECTRIC FIELD AND POTENTIAL IN A DRIFT CHAMBER
  - PLOT ELECTRIC FIELD + POTENTIA
  - CALCULATE AND PLOT DRIFT LINES AS WELL AS EQUAL-ARRIVAL-TIME CONTOURS,
  - SIMULATE THE SIGNAL ON THE SENSE WIRES DUE TO A CHARGED PARTICLE GOING THROUGH THE DC.
  - WRITE THE SIGNAL ON A FILE THAT CAN BE USED AS INPUT FOR SCEPTRE.

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN/EF 86-10
2 June 1986

DRIFT CHAMBERS WITH CONTROLLED CHARGE COLLECTION GEOMETRY

FOR THE NA34/HELIOS EXPERIMENT

D. Bettoni[1], K.H. Dederichs[1], H. En'yo[1], C.W. Fabjan[1], F. Piuz[1], V. Radeka[3], G. Roiron[1], R. Roosen[1], A. Rudge[1], R.J. Veenhof[2], T.D. Williams[1] and W.J. Willis[1]

1 CERN, European Organization for Nuclear Research, Geneva, Switzerland
2 CERN summer student from Rijks Universiteit Leiden, Netherlands
3 Brookhaven National Laboratory, Upton , NY, USA

REFERENCES

[1] The HELIOS Collaboration, Proposal P189 to the SPSC, CERN/SPSC 83-51 (1983).

[2] D. Bettoni, B. Dolgoshein, C.W. Fabjan, H. Hofmann, J. Perez, F. Piuz, P. Queru, V. Radeka, E. Rosso, A. Rudge, D. Soria-Buil, J.P. Vanuxem, W.J. Willis, Nucl. Instr. and Meth. A236 (1985) 264-270.

[3] S. Bobkov, V. Cherniatin, B. Dolgoshein, G. Evgrafov, A. Kalinovsky, V. Kantserov, P. Nevsky, V. Sosnovtsev, A. Sumarokov, A. Zelenov, Nucl. Instr. and Meth. 226 (1984) 376-382.

[4] J. Va'vra, Nucl. Instr. and Meth. A244 (1986) 391-415.

[5] R.J. Veenhof, GARFIELD drift chamber simulation package, HELIOS note 114, (1984).

Garfield(++) & Co.

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

ELSEVIER Nuclear Instruments and Methods in Physics Research A 419 (1998) 726–730

GARFIELD, recent developments

Rob Veenhof[1]

[a] NIKHEF, Amsterdam, The Netherlands

Abstract

Various developments have taken place in GARFIELD over the last 2 years: the limitation to analytic potentials and 2-dimensional geometries is being lifted via interfaces with finite element programs such as [1]; detailed calculations of the electrostatic wire movements have been added; cluster generation has been enhanced considerably thanks to an interface with the Heed program [2] and considerable effort has been put into the improvement of signal calculations. I will illustrate these points with calculations carried out by the researchers for whom these extensions were made. © 1998 Published by Elsevier Science B.V. All rights reserved.

CERN | Consult | Writeups | Garfield

Garfield - simulation of gaseous detectors

Responsible at CERN:	Rob Veenhof	**Created:**	1 Sep 1984
Manual Type:	User Guide	**Last Update:**	7 Sep 2010
Version:	9	**Verified:**	7 Sep 2010
Author:	Rob Veenhof	**Valid until:**	further notice
Reference:	W5050	**Support Level:**	High

What Garfield does

Garfield is a computer program for the detailed simulation of two- and three-dimensional drift chambers.

https://garfield.web.cern.ch/garfield/

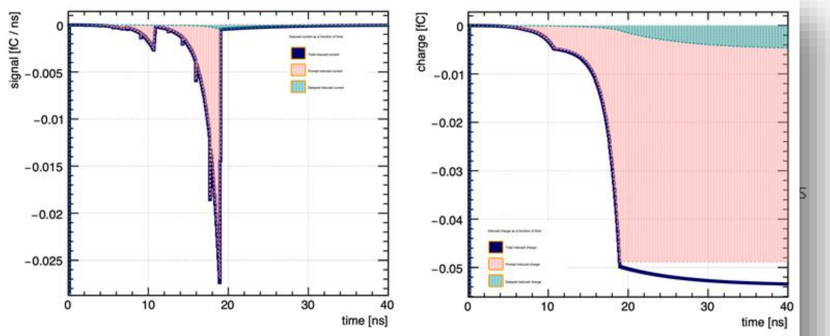
Today → Garfield++ (H. Schindler)
https://garfieldpp.web.cern.ch/garfieldpp/

The main differences are the more up-to-date treatment of electron transport, the possibility to simulate silicon sensors, and the user interface, which is based on ROOT.

Tutorials

First steps

- Simulating a drift tube: gas tables, analytic
- Simulating a GEM: finite element model, mi
- Simulating a silicon sensor: user-parameteri
- Simulating a Resistive Plate Chamber



A working example can be found in Examples/RPC.

References

[1] R. Santonico , R. Cardarelli, "Development of Resistive Plate Counters", Nucl. Instrum. Meth. 187 (1981).
[2] R. Santonico , R. Cardarelli, A. Di Biagio and A. Lucci,"Progress in Resistive Plate Counters", Nucl. Instrum. Meth. A 263 (1988).
[3] ATLAS, "ATLAS muon spectrometer: Technical design report", CERN-LHCC-97-22, ATLAS-TDR-10, (1997).
[4] S. Ramo, "Currents induced in electron motion", PROC. I
[5] W. Shockley, "Currents to Conductors Induced by a Movi
[6] W. Riegler, "Extended theorems for signal induction in p
[7] W. Riegler, "Electric fields, weighting fields, signals and
[8] W. Riegler and C. Lippmann and R. Veenhof, "Detector p

Contact

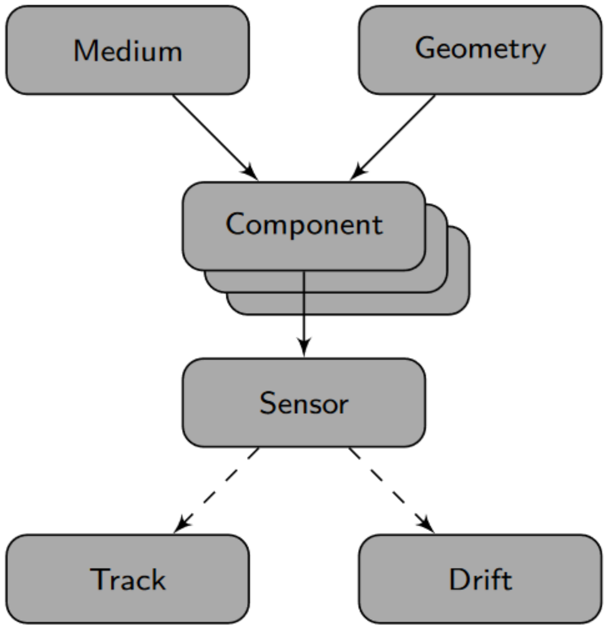
Djunes Janssens

Garfield(++) & Co. (I): Keeping together (and growing) the developers' team…

material properties
- gases (→ Magboltz)
- semiconductors

field calculation
- analytic
- field maps
- neBEM

detector description



primary ionisation
- Heed
- SRIM/TRIM
- Geant4

transport

charge transport
- microscopic
- MC integration
- RKF integration

Magboltz is being developed by Steve Biagi.

Heed was written by Igor Smirnov.

The authors of neBEM are Supratik Mukhopadhyay and Nayana Majumdar.

Authors

Garfield++ includes contributions from

- Ibrahim Alsamak,
- Kim Baraka,
- Stefano Caiazza,
- Asmund Folkestad,
- Egor Frolov,
- Jakob Haimberger,
- Kevin Heijhoff,
- Michał Jagielski,
- Djunes Janssens,
- Irina Kempf,
- Grigory Latyshev,
- Pere Mato Vila,
- Joseph McKenna,
- James Mott,
- Tom Neep,
- Lorenzo Neri,
- Shinsuke Ota,
- Dorothea Pfeiffer,
- Joshua Renner,
- Heinrich Schindler,
- Ali Sheharyar,
- Nicholi Shiell,
- Rob Veenhof,
- Ann Wang,
- Klaus Zenker.

Garfield++, Heinrich Schindler (CERN), https://indico.in2p3.fr/event/20627/contributions/94392/

Valorize the work of research groups: the Penning Transfer

Frans Michel Penning
(1894-1953)

Penning effect

- Ar* $3p^5 4s$ can transfer to iC_4H_{10}, C_3H_8 and C_2H_6;
  - two 4*s* are metastable, the two others live 2.6 ns and 8.6 ns;
- Ar* $3p^5 4p$ can also ionise CH_4;
  - 4*p* decays to 4*s* with a lifetime of 20-40 ns;
- Ar* $3p^5 3d$ can in addtion transfer to CO_2;
  - radiative 3*d* decays take ~3.5 ns, the others ~50 ns.
- Metastables: collision frequencies of Ar* in pure quencher are ~100 ps.

AGH University of Science and Technology

Kraków measurement setup

- Single anode, cylindrical counters:
  - r_{anode}: 10-50 µm;
  - $r_{cathode}$: 2 mm (Atlas TRT straws) to 26 mm;
  - p_{gas}: 50 hPa - 0.6 MPa;
  - in some cases, guard rings were added;
  - careful shielding to protect against noise.
  - pA-nA range; usually < 5 nA to avoid space charge;
  - ^{55}Fe, ^{109}Cd and ^{90}Sr sources.
- Available gases: Ar, Xe, Kr, (Ne,) i-C_5H_{12}, C_6H_{12}, C_2H_5OH, C_2H_6, H_2, N_2, CF_4, CO_2, O_2, DME.

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High-precision gas gain and energy transfer measurements in Ar–CO_2 mixtures

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[b] Faculty of Physics and Applied Computer Science, AGH University of Science and Technology, Kraków, Poland
[c] RD51 collaboration, CERN, Genève, Switzerland

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ABSTRACT
Ar–CO_2 is a Penning mixture since a fraction of the energy stored in Ar $3p^5 3d$ and higher excited states can be transferred to ionize CO_2 molecules. In the present work, concentration and pressure dependence of Penning transfer rate and photon feedback parameter in Ar–CO_2 mixtures have been investigated with recent systematic high-precision gas gain measurements which cover the range 1–50% CO_2 at 400, 800, 1200, 1800 hPa and gas gain from 1 to 5×10^5.

Özkan Şahin [a,*], Tadeusz Z. Kowalski [b], Rob Veenhof [a,c]
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[b] Faculty of Physics and Applied Computer Science, AGH University of Science and Technology, Kraków, Poland
[c] RD51 collaboration, CERN, Genève, Switzerland

Valorize the work of research groups: Cluster ions (and mobility)

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NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A
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A new experimental technique for positive ion drift velocity measurements in noble gases: Results for xenon ions in xenon

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[b]ESTG, Instituto Politécnico de Leiria, Morro do Lena—Alto Vieiro, 2411-901 Leiria, Portugal

Available online 13 May 2007

Abstract

A new technique is described for measuring the drift velocities and mobilities of noble gas ions in noble gases that makes use of a gaseous electron multiplier (GEM) and a UV flash lamp to produce the ions in a thin, well-defined, planar region. The drift velocities are determined from measurements of the transit time of the ions in crossing the drift space. We present experimental results for xenon ions in xenon. For these ions, the reduced mobility values measured at various pressures when $E/N \rightarrow 0$ fall within the interval $[0.70, 0.74]\,cm^2\,V^{-1}\,s^{-1}$. A discussion of the results concerning the existence of Xe^+, Xe_2^+, Xe_3^+, etc., ions is also made.

PACS: 51.20; 29.40.C; 51.10; 52.25.Fi

Keywords: Drift velocity; Xenon ions; Gas detectors; Ion mobility

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Cluster ions in gas-based detectors

ABSTRACT: Avalanches in gas-based detectors operating at atmospheric pressure and using Ar-CO_2 or Ne-CO_2 as drift medium produce in a first instance mainly Ar^+, Ne^+ and CO_2^+ ions. The noble gas ions transfer their charge to CO_2 in a few ns. A few ns later, the CO_2^+ ions have picked up CO_2 molecules, forming cluster ions, in particular $CO_2^+ \cdot (CO_2)_n$. Since the cluster ions are slower than the initial ions, the signals induced by ion motion are altered. The effect is shown to be present in constant-field detectors and TPC readout chambers, and is expected to affect devices such as Micromegas and drift tubes.

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Y. Kaya,[e] İ. Tapan[a] and R. Veenhof[f,a]

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[b]Department of Physics, Muş Alparslan University,
[c]Institut für Kernphysik, Goethe-Universität,
[d]Laboratório de Instrumentação e Física Experimental de Partículas ·
Departamento de Física, Faculdade de Ciências e Tecnologia,
Universidade de Coimbra,
[e]Department of Chemistry, Uludağ University,
[f]RD51 collaboration, CERN,

https://iopscience.iop.org/article/10.1088/1748-0221/10/07/P07004/pdf

4.1 Coimbra measurement

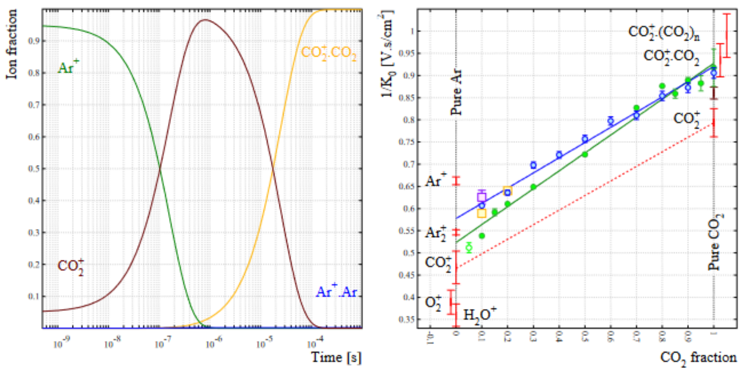
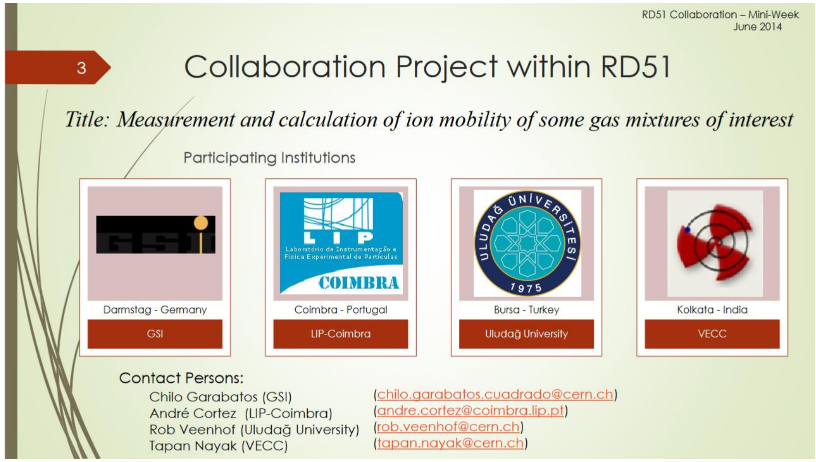


Figure 6. *Left*: ion and cluster count as function of time at $p = 1070$ Pa. Even if 95% of the initial ions are Ar^+ hardly any $Ar^+ \cdot Ar$ is produced because Ar^+ prefers to transfer its charge to CO_2^+ at low pressure. *Right*: Blanc plot for Ar-CO_2 mixtures. Blue points are measurements by G. Schultz et al. [68]; the blue line is a linear fit to this data; green points come from P.M.C.C. Encarnação et al. [19]; the green line is a linear fit for which the light green point is not taken into account (see text); the purple point was measured in ALICE with wet gas (section 4.4), and the orange points come from an ALICE prototype chamber ("Praktikum", section 4.3); red markers and error bars are mobilities for pure gases (section 3); the red line is the mobility expected for a CO_2^+ ion; the brown error bar is the weighted average from figure 3. TPC data reduced from 999 hPa and 25 °C.

Research Activity supported by the Collaboration via Common Projects (see following slides about Common Projects)



Electronics

Develop common electronics to support our R&D, offering more possibilities and improving the quality of our detector characterization.

Electronics for MPGDs: the RD51 Scalable Readout System

Working group 5

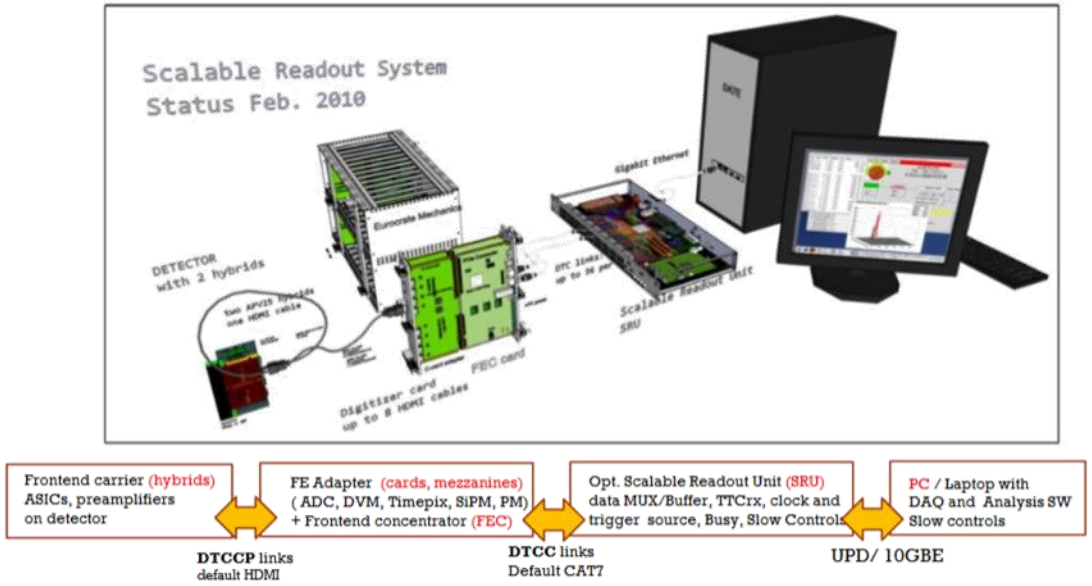
Electronics for MPGDs

Conveners: Hans Muller (CERN), Jochen Kaminski (Bonn University)

The availability of highly integrated electronics systems for the charge readout of high granularity MPGD systems poses a non-trivial problem to many of the modern MPGD applications. The specifications of such systems for the different fields of application will be collected. For the classical configuration of charge collecting pads or strips an easy-to-use portable readout solution will be developed. Ultimate granularity is achieved by using the inputs of a CMOS pixel readout chip directly as a charge collecting anode. The specifications of such a readout chip will be worked out and a common effort will be made towards a next-generation pixel chip for MPGD readout. The tasks are: (1) Definition of front end electronics requirements for MPGDs; (2) Development of general purpose pixel chip for active anode readout; (3) Development of large area detectors with pixel readout; (4) Development of portable multichannel data acquisition systems for detector studies; and (5) Discharge protection strategies.

WG5 tasks:

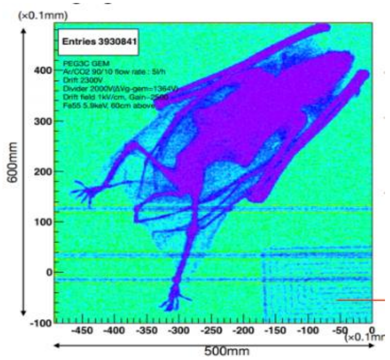
1. Definition of front end electronics requirements for MPGDs;
2. Development of general purpose pixel chip for active anode readout;
3. Development of large area detectors with pixel readout;
4. Development of portable multichannel data acquisition systems for detector studies;
5. Discharge protection strategies.



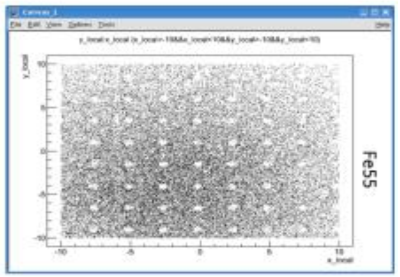
H. Muller, Scalable Readout System
https://indico.cern.ch/event/1360282/contributions/5786568/attachments/2790914/4867304/Scalable%20Readout%20System%20for%20DRD1.pdf

The experience with SRS/APV25

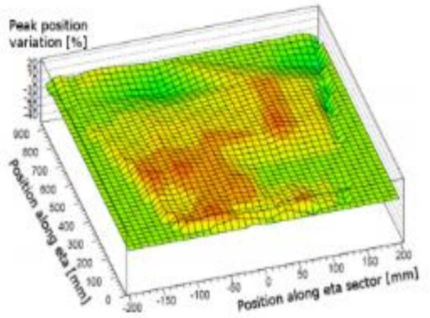
- Generic R&D (laboratory and test beam measurements)
- Support to project driven R&D (e.g. support to LHC upgrades such as ATLAS NSW/R&D and CMS GEM/QA)
- Small and Medium Scale experiments (e.g. PRAD@JLAB)



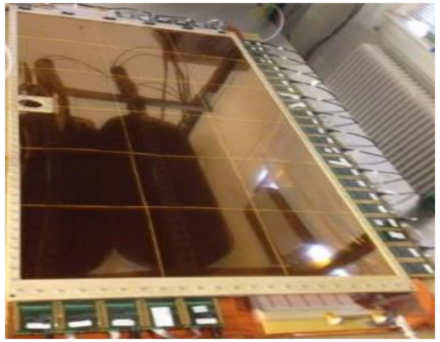
Detector Testing: X-Ray Imaging with GLASS GEM, Tokyo University



Detector Characterization: ATLAS NSW Resistive Micromegas Prototype

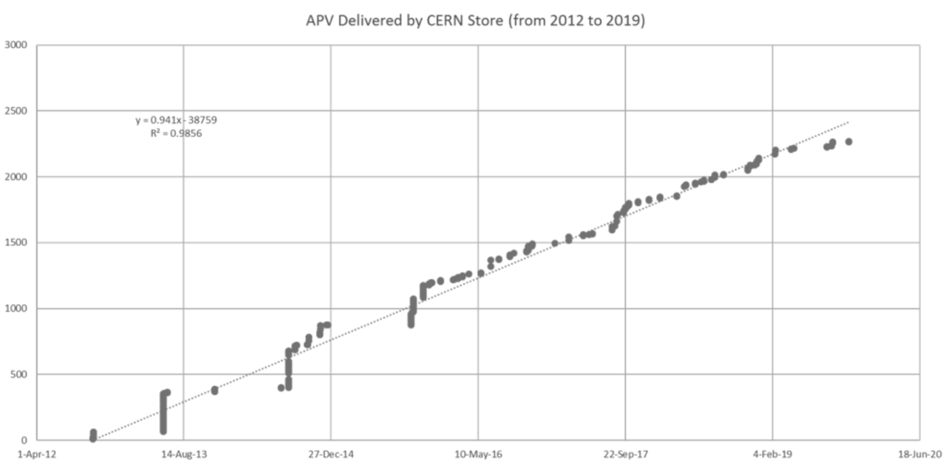


Quality Assurance: gain uniformity test of a Triple GEM, implemented in the CMS GEM QA



Triple GEM PRAD chambers covering an area of ~ 120 cm x 110cm with 2D strips readout readout via the SRS Electronics (36 APV cards per Chamber, 4608 Readout Channels)

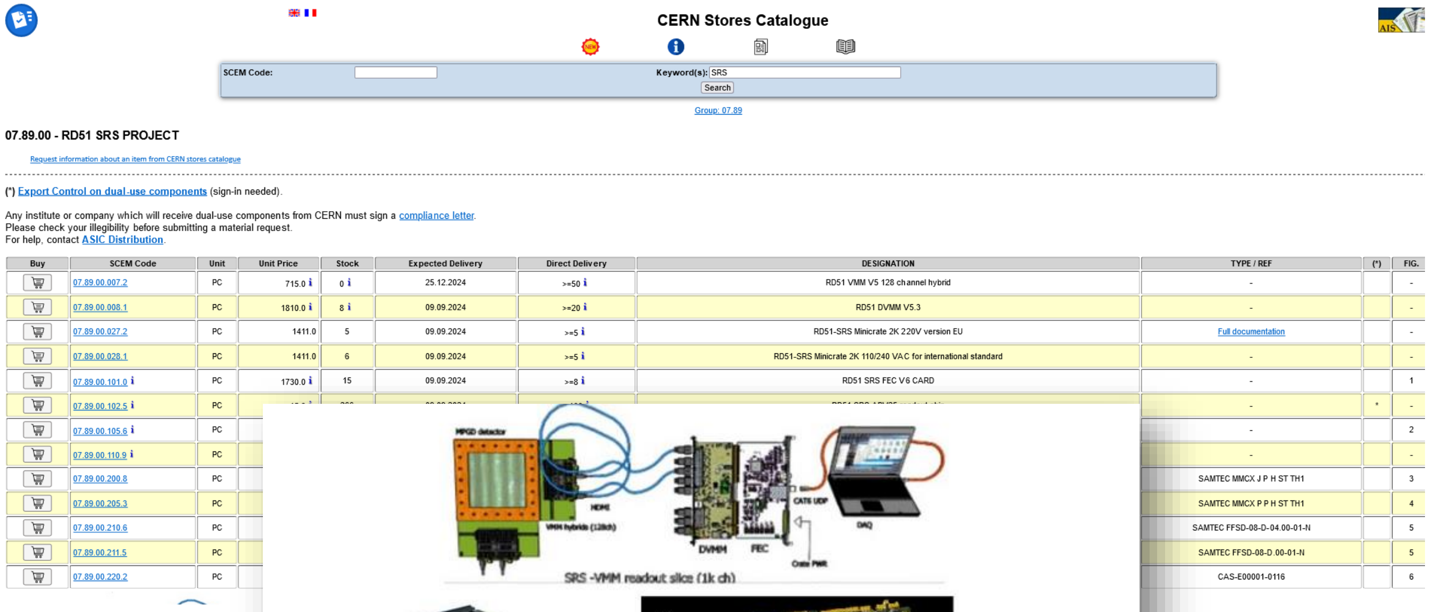
The experience with SRS/APV25 (CERN Store)



Total: about 2.4k hybrids (128 chs/hybrid)

About 350 hybrids/year

Including: large/medium/small size experiments and laboratory R&D activities.



CERN Stores Catalogue

SCEM Code: Keyword(s): SRS
Search

Group: 07.89

07.89.00 - RD51 SRS PROJECT

Request information about an item from CERN stores catalogue

(*) Export Control on dual-use components (sign-in needed).

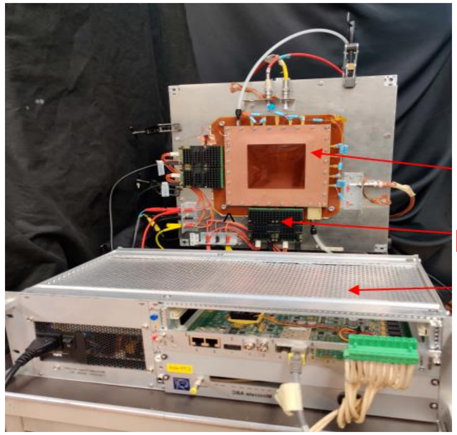
Any institute or company which will receive dual-use components from CERN must sign a compliance letter.
Please check your illegibility before submitting a material request.
For help, contact ASIC Distribution.

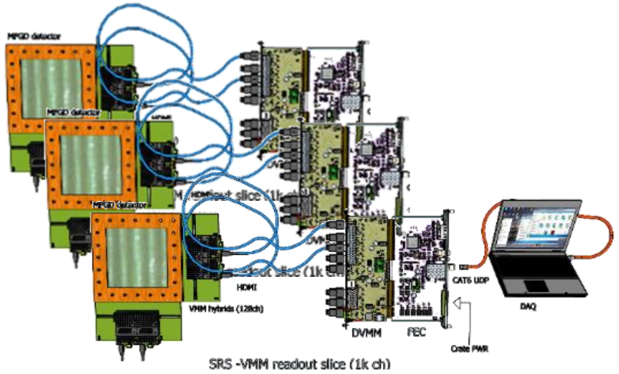
Buy	SCEM Code	Unit	Unit Price	Stock	Expected Delivery	Direct Delivery	DESIGNATION	TYPE / REF	(*)	FIG.
	07.89.00.007.2	PC	715.0 i	0 i	25.12.2024	>=50 i	RD51 VMM V5 128 channel hybrid	-		-
	07.89.00.008.1	PC	1810.0 i	8 i	09.09.2024	>=20 i	RD51 DVMM V5.3	-		-
	07.89.00.027.2	PC	1411.0	5	09.09.2024	>=5 i	RD51-SRS Minicrate 2K 220V version EU	Full documentation		-
	07.89.00.028.1	PC	1411.0	6	09.09.2024	>=5 i	RD51-SRS Minicrate 2K 110/240 VAC for international standard	-		-
	07.89.00.101.0 i	PC	1730.0 i	15	09.09.2024	>=8 i	RD51 SRS FEC V6 CARD	-		1
	07.89.00.102.5 i	PC	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	*	-
	07.89.00.105.6 i	PC	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-		2
	07.89.00.110.9 i	PC	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-		-
	07.89.00.200.8	PC	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	SAMTEC MMCX J P H ST TH1		3
	07.89.00.205.3	PC	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	SAMTEC MMCX P P H ST TH1		4
	07.89.00.210.6	PC	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	SAMTEC FFSD-08-D-04.00-01-N		5
	07.89.00.211.5	PC	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	SAMTEC FFSD-08-D.00-01-N		5
	07.89.00.220.2	PC	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	CAS-E00001-0116		6

The after-APV25: the BNL/ATLAS NSW VMM3a FE ASIC (I)

Large interest in the new FE ASIC: about 2500 VMM3a in the expression of interest.

		Wafer yield = 0.85		
	VMM hybrids 2019 (already available)	VMM hybrids by end 2020	Nr. VMM chips on wafer after	Nr. good VMM chips
	thing else gets calculated			
ESS	11	560	1318	1120
USTC		78	184	156
Bonn Univ. Physics		120	282	240
Mainz Univ, Physics		12	28	24
Mainz Univ, Physics		16	38	32
Budker	2	22	52	44
INFN		10	24	20
Univ. o. Tsukuba		50	118	100
GDD lab CERN	24	24	56	48
Peking Univ. HEP		50	118	100
LMU-HEP	8	8	19	16
LMU-Medphysics		48	113	96
ETH Zurich		40	0	0
CERN BE		18	42	36
Univ.o Virginia		8	19	16
Kobe Univ.		8	19	16
TUM Munich		0	0	0
LSBB Rustrel		160	376	320
Univ of Hawai		4	9	8
Universidad de Los Andes		16	38	32
Total VMM hybrids short term =	45			
Total VMM hybrids long term =		1252		
Total VMM ASICs (+10%) short term			2852	
Total VMM ASICs (+10%) long term			2852	2424
Total VMM wafers already in use =		already in use	4	
Total VMM wafers needed =				25





Supported by individual RD51 groups interested in the development (e.g., ESS), by RD51 common resources, and by AIDA2020 and AIDAinnova resources.

Access to wafers is provided through the collaboration (several wafers were purchased and redistributed to the community). The collaboration's investment is returned once the wafers have been used to produce hybrids.

The after-APV25: the BNL/ATLAS NSW VMM3a FE ASIC (II)

The community behind: WG5.1 sub-working group

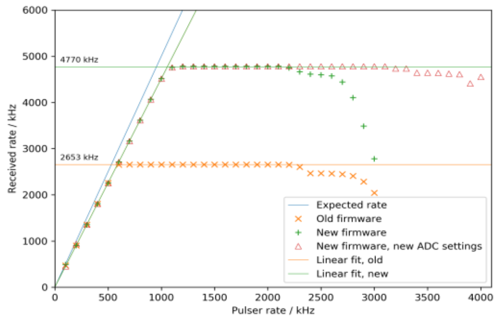
Synchronize activities and developments related to RD51's Scalable Readout System and the integration of the VMM3a ASIC.

Group together people and institutes interested in next-generation readout electronics for MPGDs and facilitate the exchange of developments and research interests.

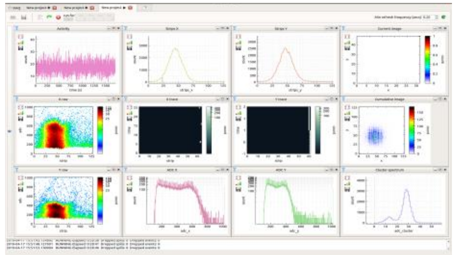
Collaborate on common developments in firmware, software, and hardware (including the improvement of existing SRS hardware and the development of auxiliary devices and components).

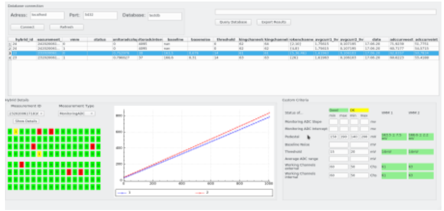
Provide the community's developments back to the community! Coordinate hardware production and testing with the CERN KT Spin-Off: SRS Technology.

Firmware

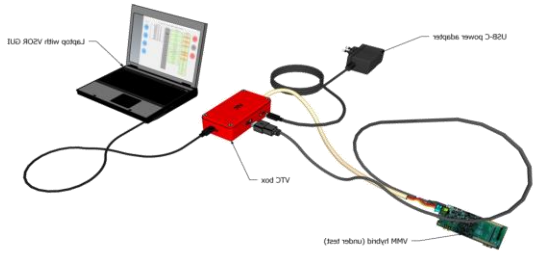


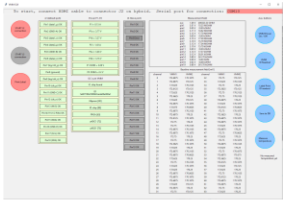
Software





Testing SW/HW, procedures





First measurements using the first proto-system: Laboratory (x-ray) Measurements

Fluorescence Processes

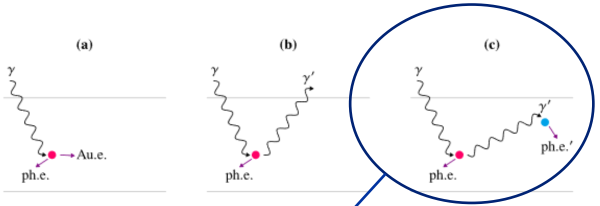
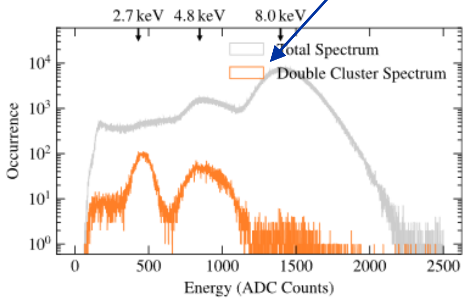


Fig. 1. Illustration of different interaction processes of an X-ray photon γ with a gas atom. (a) shows a single cluster event, the liberation of a photoelectron (ph.e.) followed by the emission of one or more Auger electrons (Au.e.) close to the initial interaction. (b) shows another type of single cluster event, the liberation of a photoelectron followed by the emission of a fluorescence photon γ', which escapes the detector. (c) shows a double cluster event, in which the fluorescence photon does not escape the detector, but interacts in the gas volume and liberates another photoelectron (ph.e.′).

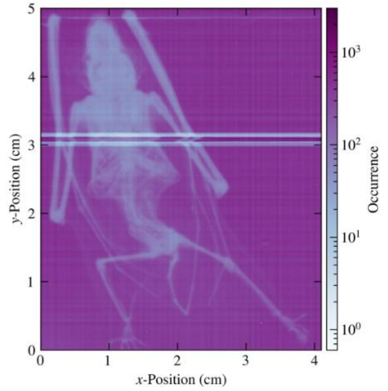


(c)

Fig. 4. Energy spectra, showing the total measured X-ray spectrum and the spectrum of the double cluster events for (a) ^{55}Fe at $E_d = 2.50$ kV/cm, (b) ^{55}Fe at $E_d = 1.25$ kV/cm and (c) copper at $E_d = 1.25$ kV/cm.

L. Scharenberg et al.: *Resolving soft X-ray absorption in energy, space and time in gaseous detectors using the VMM3a ASIC and the SRS,* Nucl. Instrum. Methods Phys. Res. A **977** (2020) 164310. https://doi.org/10.1016/j.nima.2020.164310

Imaging (high rate)



Sauli's bat

Drift velocities measurement

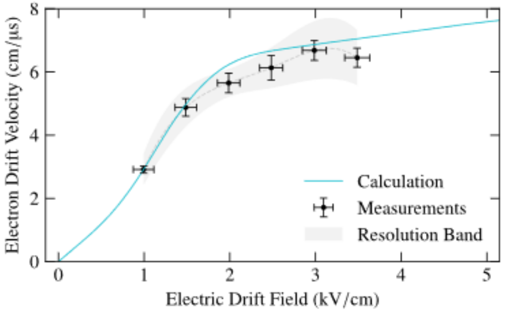
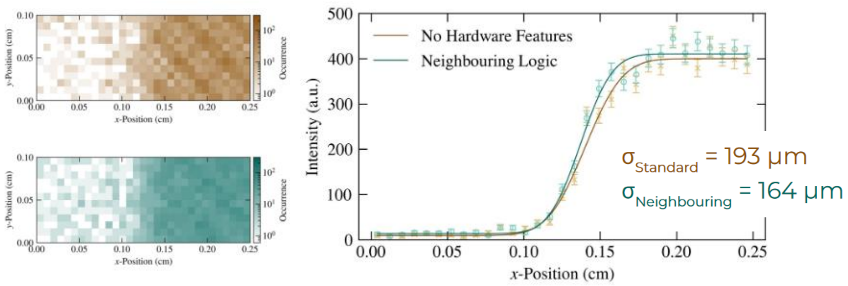


Fig. 9. Electron drift velocity as a function of the electric drift field for Ar/CO_2 (70/30%). The continuous line shows the results of a Magboltz calculation for NTP, while the points are measurements at ambient pressure and temperature. The grey area indicates standard deviation σ on μ of the error function from the fit of Eq. (1).

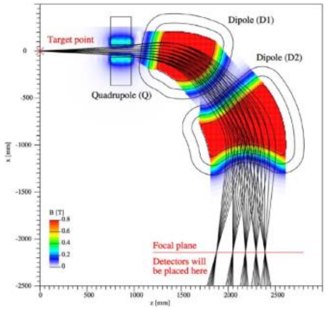
Space resolution

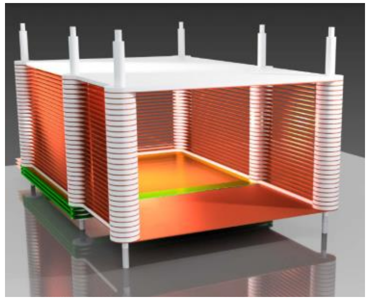


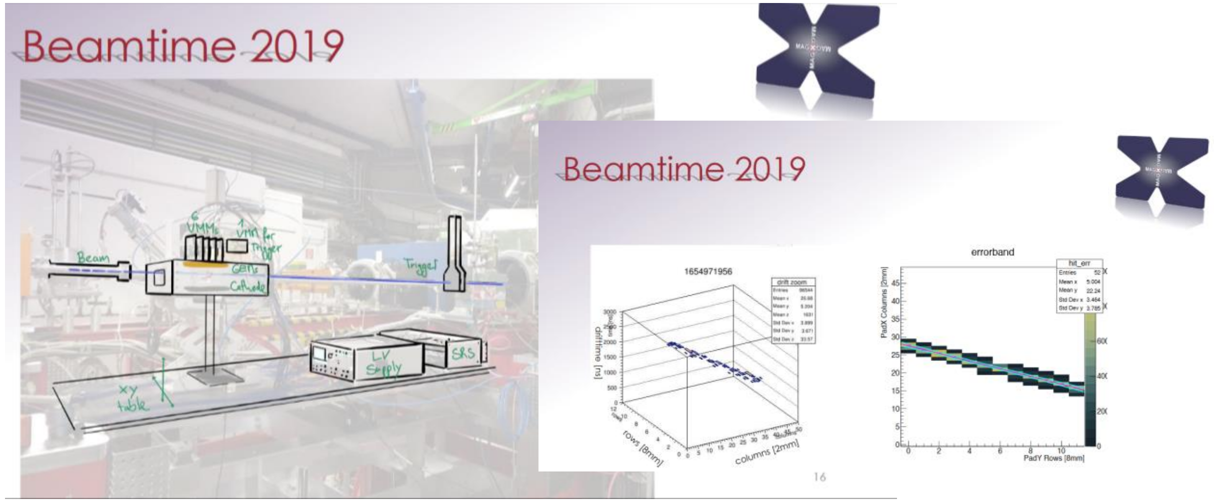
https://indico.inp.nsk.su/event/20/contributions/809/attachments/553/638/instr20-lucian-scharenberg.pdf

SRS/VMM3a in test beam

First measurements using the first proto-system: Beam Measurements (TPC@MAGIX)

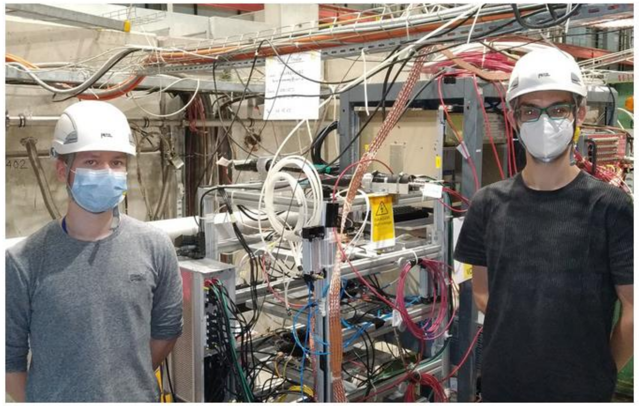






[MAGIXperiment @ MESA](https://indico.cern.ch/event/872501/contributions/3743007/attachments/1985085/3307389/2002_rd51_miniweek_guelker.pdf)
https://indico.cern.ch/event/872501/contributions/3743007/attachments/1985085/3307389/2002_rd51_miniweek_guelker.pdf

RD51 Telescope Readout


First characterisation study for front-end and data acquisition systems aimed at future micro-pattern gas detectors

By Lucian Scharenberg (CERN)

In summer 2021, several state-of-the-art detector instrumentations conducted full characterisation studies at SPS.

On Track, Nov. 2021
https://aidainnova.web.cern.ch/first-characterisation-study-front-end-and-data-acquisition-systems-aimed-future-micro-pattern-gas


AIDA innova — Technical Progress (2)

- **Several telescopes and DUTs operated:** RD51 telescope: 21 hybrids (2688chs), UNIANDES/GSI/DUBNA (1920 chs), LMU (1152 chs).

Oct. 21 Telescopes equipped with SRS/VMM3a prototype systems

- **Different detector technologies** read via VMM3a: **GEM, MM, Straw Tubes, Scintillators/PMT/NIM.**

https://indico.cern.ch/event/1104064/contributions/4785093/attachments/2417580/4137362/WP3_Task3_5_VMM3a_AIDAINNOVA_1st_annual_meeting_30Mar2022.pdf

Manufacturing, the CERN MPT workshop

Cost-effective, industrial technology solutions will be developed and transferred to industry. A common “production facility” based on the MPGD workshop at CERN will be developed and maintained and procedures for industrialization will be set up. The tasks are: (1) Development and maintenance of a common production facility; (2) MPGD production industrialization (quality control, cost-effective production, and large-volume production), (3) Collaboration with Industrial Partners.

ECFA
European Committee for Future Accelerators

CERN based infrastructure

MPT workshop @ CERN

MPGD Projects

•SBS tracker	GEM 600mm x 500mm
•ALICE TPC upgrade	GEM 600mm x 400mm
•CMS muon	GEM 1.2m x 450mm
•ATLAS NSW muon	Micromegas 2m x 1m
•COMPASS pixel Micromegas	GEM & Micromegas 500mm x 500mm
•BESIII	GEM 600mm x 400mm
•KLOE	GEM 700mm x 400mm
•SOLID	GEM 1.1m x 400mm
•CLAS 12	Micromegas 500mm x 500mm
•LSBB (geoscience)	Micromegas 1m x 500mm
•Prad	GEM 1.5m x 55cm
•CBM	GEM 1m x 450mm
•ASACUSA	Micromegas

•Most of them are still at the R&D phase but some are already in production:

•ATLAS NSW	1300 m2
•SBS Tracker	100 GEMs
•ALICE TPC upgrade	350 GEMs
•COMPASS pixel Micromegas	20 GEM + Micromegas
•BESIII	15 GEM
•CLAS 12	30 Micromegas
•CMS	450 GEM

New Capabilities

UV exposure unit limited to 2m x 0.6m → 2.2m x 1.4m

Resist developer limited to 0.6m width → 1.2m
Resist stripper "
Copper etcher "
Dryer "

GEM electro etch limited to 1m → 2m

GEM polyimide etch limited to 1m → 2m

Ovens limited to 1.5m x 0.6m → 2.2m x 1.4m

Laminator limited to 0.6m width → 1.2m

installation of the new infrastructure (to produce 2x1m^2 Bulk MM & 2x0.5m^2 GEM)

Construction of the new workshop's building

CERN

Engineering Department

EN-ICE/RS/se
18 December 2009

MEMORANDUM

To : S. Bertolucci

Cc : P. Bloch, R. De Oliveira, B. Magnin, L. Ropelewski, M. Titov, V. Vuillemin

From : R. Saban

Subject : Extending the present Fine Pitch Photolithography Workshop

The RD51 Collaboration approached EN-ICE with the request to extend the existing facilities in the Fine Pitch Photolithography Workshop for the construction of detector components with dimensions of up to 2m x 1m more than doubling the present limit (1.5m x 0.5m).

In order to continue the support at CERN to R&D on Micro-Pattern Gas Detector technology while the project for the construction of the new building for the workshop takes shape, we met on November 19th 2009 to review the different scenarios.

Three options were submitted to you: they are detailed in the document attached to this memorandum. We take note of your decision to fund Scenario 2, which allows limited R&D (longer development cycles) on large size MPGD and the associated large size read-out boards in building 102.

April 29th, 2021 ECFA Detector R&D Roadmap -TF1 Symposium – Gaseous Detectors 6

L. Ropelewski, Networking – collaborations, technology dissemination and training. https://indico.cern.ch/event/999799/contributions/4204424/attachments/2236130/3790095/Networking.pdf

MPT Workshop

DT Training Seminars

L'atelier Micro-Pattern Technology: Nouvelles et projets clés

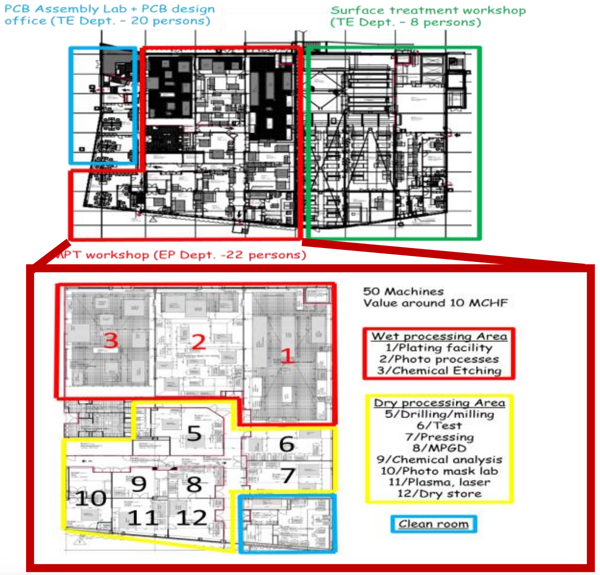
by Alexis Rodrigues (CERN), Antonio Teixeira (CERN), Olivier Pizzirusso (CERN), Rui De Oliveira (CERN)

Tuesday 16 Apr 2019, 11:00 → 12:00 Europe/Zurich

32/1-A24 (CERN)

https://indico.cern.ch/event/791893/

Almost all families of MPGD produced…
GEM, THGEM, MM-THGEM, Micromegas, mRWELL, RPWELL, DLC with MPGDs, …



MPT/Production: GEM as one example

https://ep-news.web.cern.ch/content/new-home-gem-detectors-cern

EP Newsletter of the EP department

A new home for GEM detectors at CERN

DT GEM detectors

Jun 19 2019

by Rui De Oliveira (CERN)

New Micro Pattern Technology (MPT) workshop (building 107) of CERN EP-DT [109]

https://indico.cern.ch/event/791893/

Several experiments
COMPASS, LHC-B, KLOE, CBM @FAIR, BM @ N, Phoenix TPC, SBS tracker, T2K, Compass tracker, Compass RICH, ILC TPC prototypes, ILC Calorimeter prototypes, ATLAS NSW …

GEM production for ALICE GEM TPC and CMS GE1/1

Fig. 3: GEM production team handling different type of GEMs

ALICE TPC and CMS GE1/1

More than 1400 GEMs produced in the EP/DT/MPT

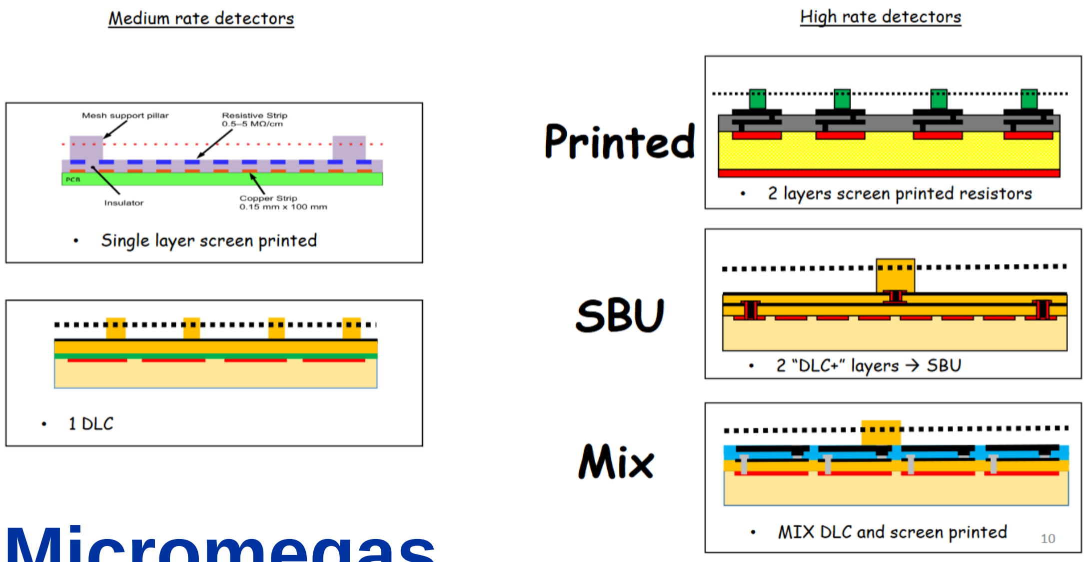
Production was spread over a period of 2 years and required the constant effort of a team of five people, up to seven at the peak of production.

The production yields of about 70% initially, reached 90% in average at the end of production, with peaks at 100% for some batches.

The deadlines fully respected.

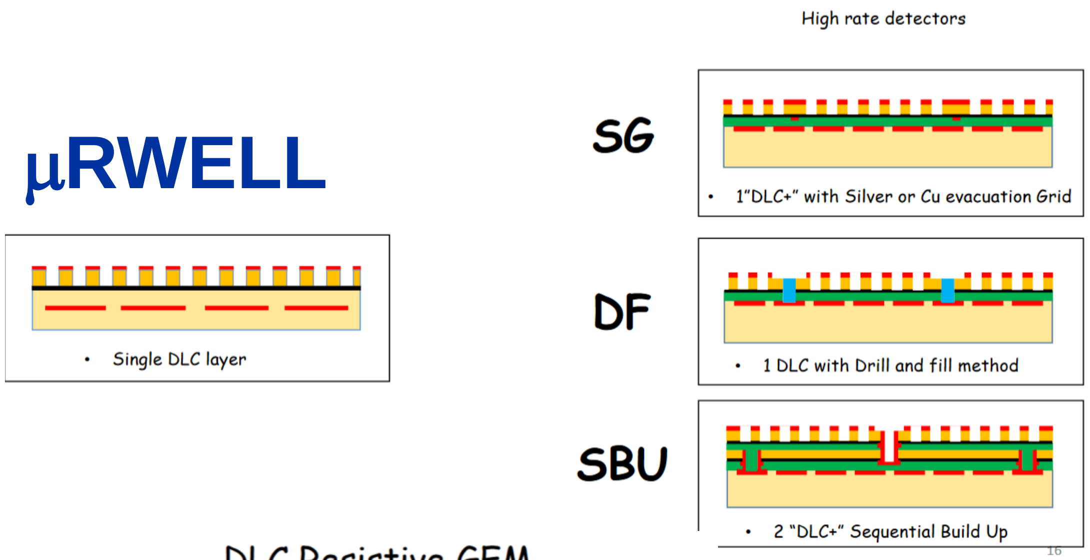
MPT/R&D: Resistive MPGD

Different Resistive protection approach with Micro-Megas

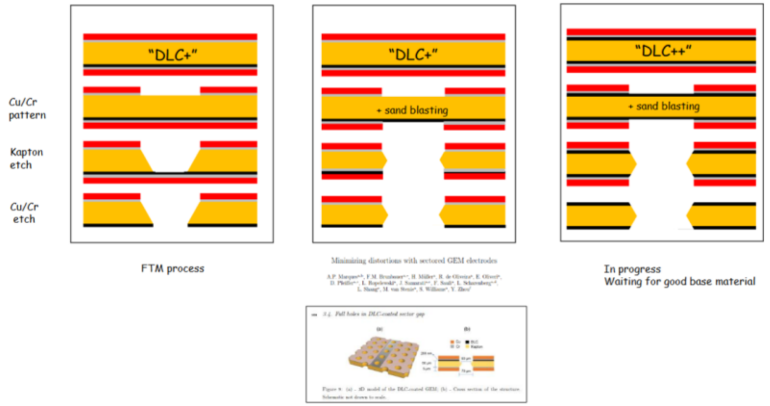


Micromegas

Different Resistive protection in µRwell



DLC Resistive GEM



GEM

Resistive MPGD Processes and problems, Rui de Oliveira, 12/02/2020 CERN RD51 mini-week
https://indico.cern.ch/event/872501/contributions/3723342/attachments/1986258/3309780/Processes_and_problems.pdf

MPT/Industrialization: Technology Transfer

- Crucial role of the MPT workshop.
- Quite stable (↑/↓) scenario
- Several companies involved in he past years. "Difficult" market.
- Long-lasting Effort

Some of the lessons learned:

- Industrialization possible if large involvement from large project
- Important to involve the industrial partner from the beginning (see µRWELL with ELTOS involved in initial R&D phase)

Technology Industrialization → transfer "know-how" from CERN workshop to industrial partners

GEM Technology (contacts)
- Mecharonix (Korea, Seoul)
- Tech-ETCH (USA, Boston)
- Scienergy (Japan, Tokyo)
- TECHTRA (Poland, Wroclaw

THGEM Technology (contacts):
- ELTOS S.p.A. (Italy),
- PRINT ELECTRONICS

GEM Licenses signed by:
- Mecharonics, 21/05/2013
- TECH-Etch, 06/03/2013
- China IAE, 10/01/2012
- SciEnergy, 06/04/2009
- Techtra, 09/02/2009
- CDT, 25/08/2008
- PGE, 09/07/2007

MicroMegas Technology(contacts):
- ELTOS S.p.A. (Italy)
- TRIANGLE LABS(USA, Nevada)
- SOMACIS (Italy, Castelfidarco)
- ELVIA (France, CHOLET)

GEM Industrialization Status (today):

TECH-ETCH
- Single Mask process fully understood. Many 10cm x 10cm produced and characterized.
- 40cm x 40cm GEM successfully produced
- CMS GE1/1 size of 1m x 0.5m started

TECHTRA
- Production Line Operational
- Stable process for 10cm x 10cm
- Single Mask process completely understood – 10cm x 10cm produced
- 30cm x30cm Single Mask Produced

MECARO
- 10cm x 10cm double mask produced and tested
- 30cm x 30cm double mask under evaluation @ CERN
- CMS GE1/1 size of 1m x 0.5m

MICROMEGAS industrialization status (today):

ELVIA
- Bulk MM detectors are routinely produced with size up to 50x50cm^2
- production for ATLAS NSW started

ELTOS
- Several small-zize Bulk MM detectors produced
- production for ATLAS NSW started

THGEM industrialization status (today):

ELTOS
- THGEM for COMPASS RICH upgrade (final polishing in house)
- LEMs for LBNO-DEMO

From 139th LHCC Meeting - OPEN Sessionhttps://indico.cern.ch/event/835603/

Common Test Facilities

The development of robust and efficient MPGDs entails the understanding of their fundamental properties and performance at several stages of their development. This implies a significant investment for detector test beam activities to perform the R&D needed, to test prototypes and to qualify final detector system designs, including integrated system tests.

Test beam At the SPS

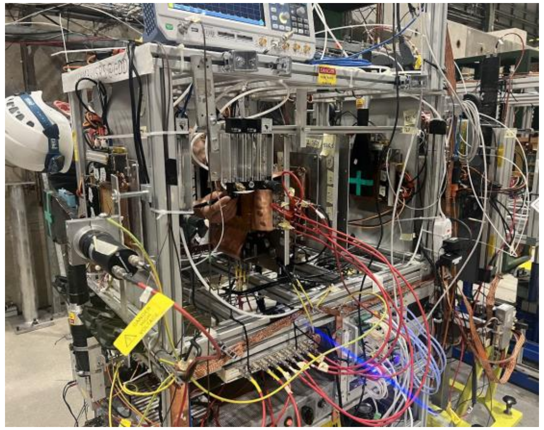
Common test facilities (WG7): three test beam campaigns in 2023.
Last RD51 test beam @ SPS in September (first one in June 2009, 15 years ago) - Links 1,2,3

Generic and Application driven R&D
Muon/Tracking: GEM, Micromegas, uRWELL, ugroove, TPC, Straw
Timing: PICOSEC micromegas/uRWELL
Calorimetry: MPGD DHCAL

Project Driven R&D & Commissioning
HL-LHC: CMS ME0
PBC: GEM (AMBER/COMPASS++)
e+e- collider : BESIII

FE electronics and DAQ
Tracking: TIGER-GEMROC, VMM3a-SRS, VFAT3
Timing: Custom Amplifiers, SAMPIC Digitizer, FASTIC

2023 SPS Test Beam Campaign



RD51 H4(PPE134) April-May 2023 Test Beam

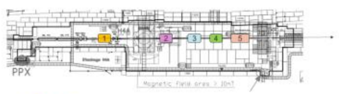
Mon. 24/04/2023 – Wed. 10/05/2023

Beam H4 – PPE134

Generic and Application driven R&D
Muon/Tracking: GEM and Straw
Timing: PICOSEC micromegas

Project Driven R&D
HL-LHC: CMS ME0

FE electronics and DAQ
TIGER-GEMROC
VMM3a-SRS
VFAT3

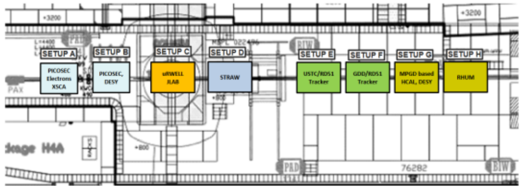


1 PICOSEC
2 STRAW (PARASITIC)
3 TWIN TPC
4 RD51 Tracker (VMM3a)
5 CMS GEM ME0

https://indico.cern.ch/event/1285182/contributions/5400569/subcontributions/426737/attachments/2645452/4578954/RD51-H4(PPE134)-Beam-AprilMay2023.pdf

5 setup

BEAM H4, PPE134 – INSTALLATION (RD51, 5-19 July)



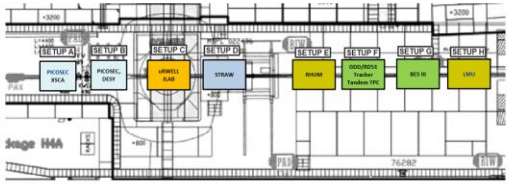
- SETUP A/B: PICOSEC [AUTH, CAE/IRFU, CERN-GDD, INFN PV, JLAB, RBI , USTC]
- SETUP C: JLAB uRWELL ← CANCELLED, late delivery of Detectors, POSTPONED TO AUGUST TB
- SETUP D: STRAW - PARASITIC
- SETUP E: USTC/RD51 Tracker
- SETUP F: CERN-GDD/RD51 Tracker
- SETUP G: MPGD based HCAL [INFN Ba-Na-LNF-RM3, WIS]
- SETUP H: RHUM [INFN Na-RM3]

Details on planned measurements (for most of them) here:
https://indico.cern.ch/event/1273825/sessions/488837/#20230621

https://indico.cern.ch/event/1308791/contributions/5505037/subcontributions/435868/attachments/2688816/4665508/RD51-July23-TestBeam-H4-SUMMARY.pdf

7 setup

BEAM H4, PPE134 – INSTALLATION (RD51, 23 August – 6 September)



- SETUP A, B: PICOSEC (F. Brunbauer, M. Lisowska)
- SETUP C: uRWELL JLAB (K. Gnanvo)
- SETUP D: STRAW (T. Enik, K. Kuznetsova) - PARASITIC
- SETUP E: RHUM (M. Iodice, G. Sekhniaidze)
- SETUP F: GDD/RD51 Tracker (K. Floethner) & TANDEM TPC (F. Garcia)
- SETUP G: BES III (R. Farinelli)
- SETUP H: LMU (R. Hertenberger)

https://indico.cern.ch/event/1316325/contributions/5537101/subcontributions/438352/attachments/2699124/4684615/RD51-Aug23-TestBeam-H4-SETUP.pdf

7 setup

ALICE TPC Upgrade with MPGD
Specific Requirements: End of the beam line (Shower)

ATLAS NSW Project (micromegas)
Specific Requirements: GOLIATH

CMS GEM Muon Upgrade : GEM Collaboration
Specific Requirements: One Tracker and APV/SRS & VFAT/TURBO readout

FRASCATI - Triple GEM in magnetic Field (BESIII and Ship experiment)
Specific Requirements: GOLIATH, Isobutane

WIS/Aveiro/Coimbra - Large single-stage THGEM detectors
Specific Requirements: One Tracker and APV/SRS readout

LAPP/UA/NCSR/IRFU – Resistive micromegas for calorimetry
Specific Requirements: End of the beam line (Showers)

LHC experiments Upgrades

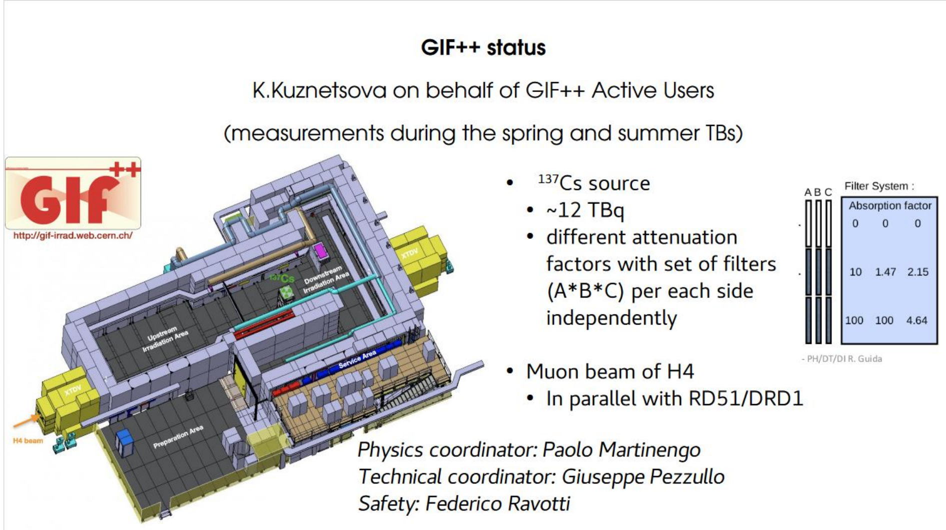
Project Driven R&D

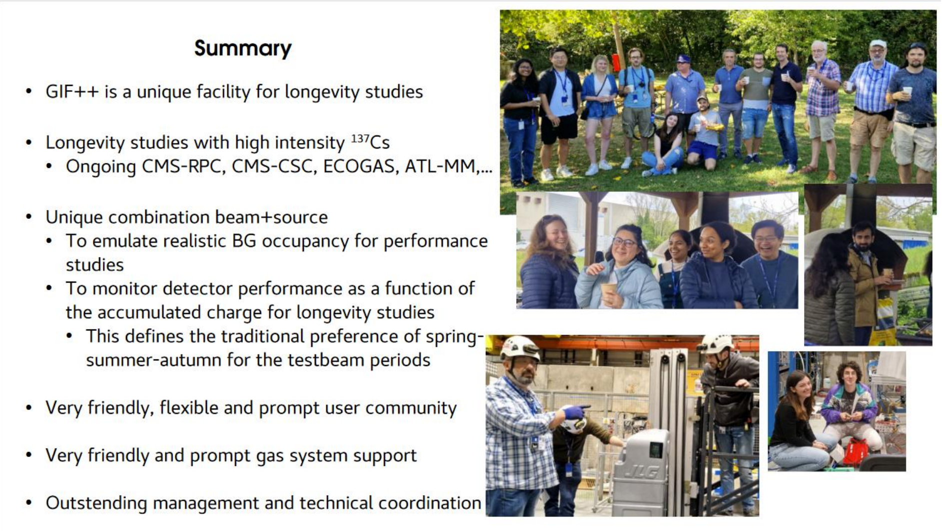
Generic R&D

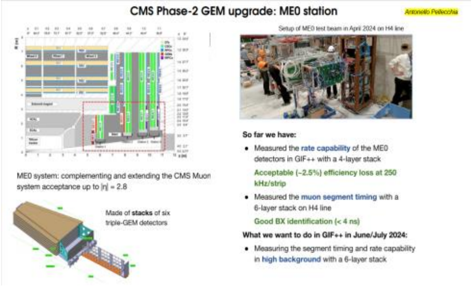
Application Driven R&D

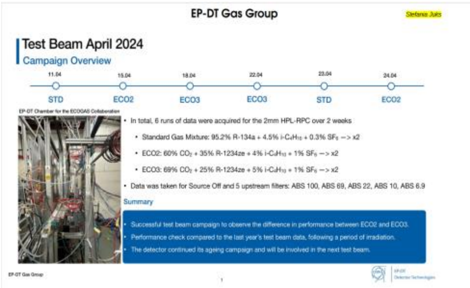
An almost unique opportunity of exchange between groups

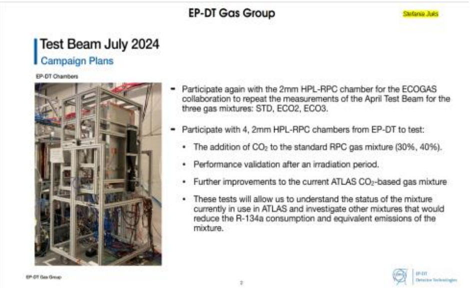
Similar experience as in GIF++
Katerina Kuznetsova, **GIF++ Status**
2nd DRD1 Collaboration Meeting
https://indico.cern.ch/event/1413681/contributions/6011529/

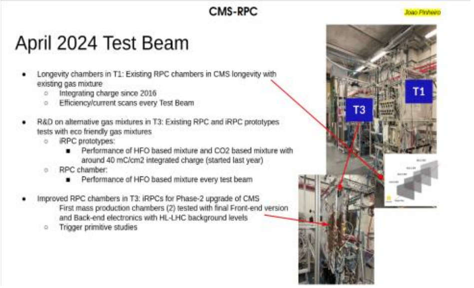


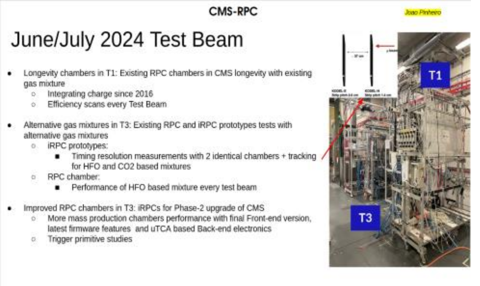


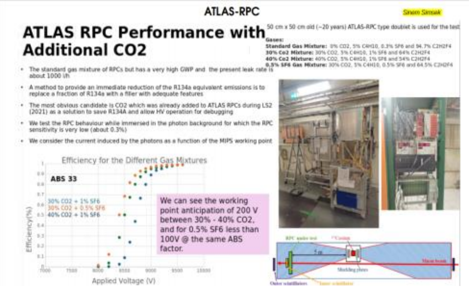


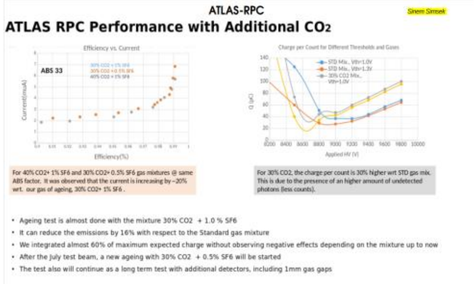


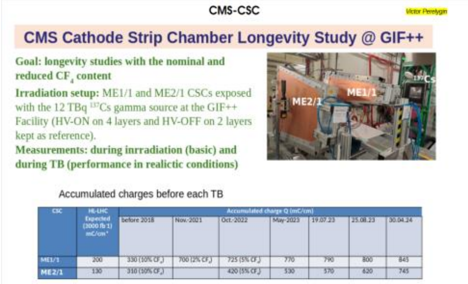


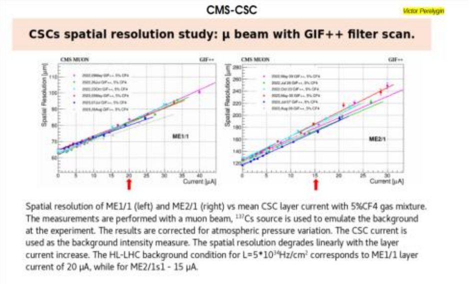












RD51 Common Projects

- Support to blue sky and to generic research activities of common interest
- Promoting the clustering of different research teams, acting as a seed for long-term collaborations and activities

Common Projects

- *The RD51 Common Project Funding is intended to support a project cost in the areas of common interest to theRD51/MPGD community*
  - *Technology R&D projects towards developments of novel techniques, improvements of existing technologies, characterization methods and dedicated tools;*
  - *Development and optimization of MPGDs for novel applications;*
  - *Improvement of the MPGD technology transfer to industry.*

- *The program will fund only generic projects – not ones related to experiments.*
- *Transversal collaborations among groups from different countries, experiments, physics areas of interest encouraged and supported by RD51*
- *Started since 2011, 24 projects are approved in these 12 years.*

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

Common Projects

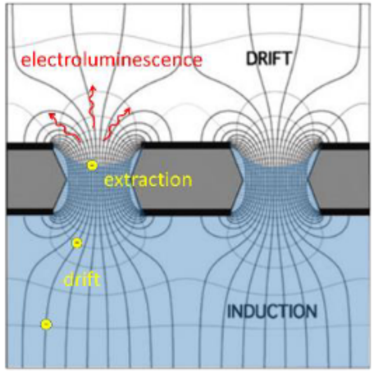
Year	Title	Contact person
2011	A low mass microbulk with real XY strips structure	Theo Geralis
	MPGDs technology laboratory for training, development, fabrication, applications and innovation	Rafael Gutierrez
	Thin and high-pitch laser-etched mesh manufacturing and bulking	Paul Colas
	Development of innovative resistive GEM alpha detectors for earthquakes	Guy Paic
	Large-area THGEM detector evaluation with SRS electronics	Amos Breskin
2012	R&D on large area GEMs for the ALICE TPC upgrade	Chilo Garabatos Cuadrado
	High resolution UV scanner for MPGD applications	Dezso Varga
2014	Measurement and calculation of ion mobility of some gas mixtures of interest	Chilo Garabatos
	Fast Timing for High-Rate Environments: A Micromegas Solution	Sebastian White
	Development of a novel Micro Pattern Gaseous Detector for Cosmic Ray Muon Tomography	Paolo Iengo
2016	Sampling Calorimetry with Resistive Anode MPGDs (SCREAM)	Maximilien Chedeville
	New Scintillating gases and structures for next-generation scintillation-based gaseous detector	Diego Gonzalez Diaz
2017	Development of modular multilayer GEM units	Alexander Milov
2018	Modular & General purpose Ultra Low Mass GEM Based Beam Monitors	Gabriele Croci
	DLC based electrodes for future resistive MPGDs	Yi Zhou
	Study of negative ion mobility and ion diffusion for Negative Ion TPCs	André Cortez
2019	Discharge Consortium in quest for Spark-Less-Avalanche-Microstructures	Piotr Gasik
	Pixelated resistive bulk Micromegas with integrated electronics	Fabrizio Petrucci
	Resistive materials and resistive-MPGD concepts & technologies	Shikma Bressler
2020	Optical readout studies for negative ion TPCs	Florian M. Brunbauer
	Large area high-granularity segmented mesh microbulk forfuture rare event searches	Javier Galan
2021	Comprehensive studies of the glass, ceramic- and kapton-THGEMs in high- and low-pressure TPCs	Pawel Majewski
	Development for Resistive MPGD Calorimeter with timing measurement	Piet Verwillligen
2022	Study of MPGD performance in liquefied noble gases	Vitaly Chepel

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

Blue Sky R&D: Study of MPGD performances in liquified noble gases

- Technology R&D projects towards developments of novel techniques, improvements of existing technologies, characterization methods and dedicated tools;
- Development and optimization of MPGDs for novel applications;
- Improvement of the MPGD technology transfer to industry

1. LIP-Coimbra, Vitaly Chepel, *vitaly@uc.pt*
2. Weizmann Institute of Science, Amos Breskin, *amos.breskin@weizmann.ac.il* and Shikma Bressler, *shikma.bressler@weizmann.ac.il*
3.. LIBPhys-University of Coimbra, Joaquim Marques Ferreira dos Santos, *jmf@uc.pt*, Fernando Domingues Amaro, *famaro@uc.pt* and Cristina Maria Bernardes Monteiro, *cristinam@uc.pt*



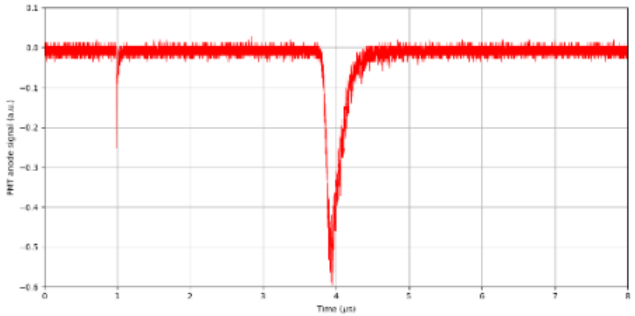
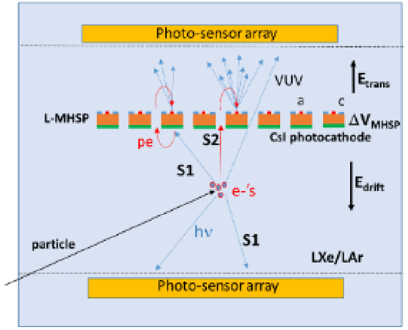


Figure 1. A double-phase TPC with a floating THGEM. (Left) – the principle; (Right) – preliminary results with a 0.4 mm thick THGEM, 0.3 mm holes and 1 mm pitch in liquid xenon. The ionization (in the liquid) is due to alpha-particles; the VUV photons are detected with a PMT. A fast pulse at t = 1 μs, corresponding to primary scintillation in the liquid, is followed by the secondary scintillation in gas.



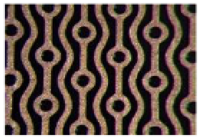
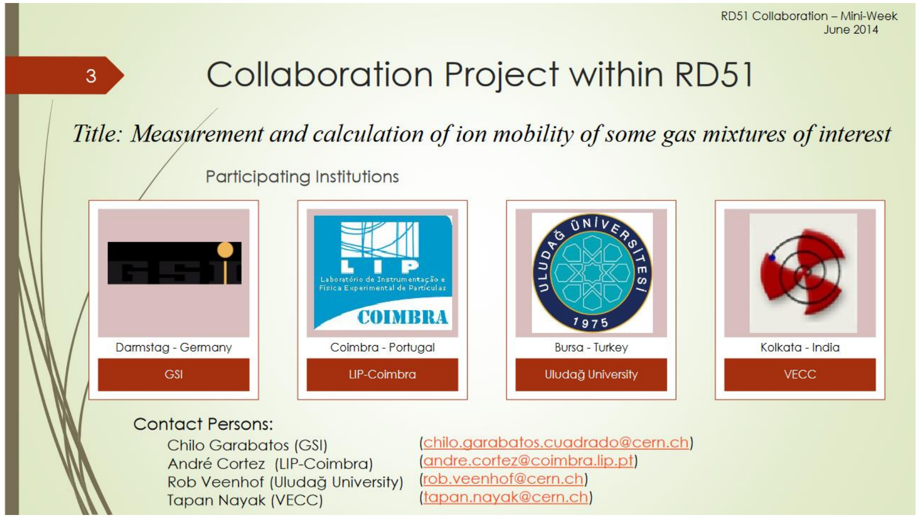


Figure 2. A single-phase TPC with a L-MHSP (or L-COBRA, shown) coated underneath with CsI. Ionization electrons and UV-induced photoelectrons from CsI are collected into the L-MHSP holes, and drift towards the anode strips. VUV photons emitted by EL + small avalanche near the strips, are detected by the top photo-sensors. Another fraction of S1 photons are detected by bottom photo-sensors.

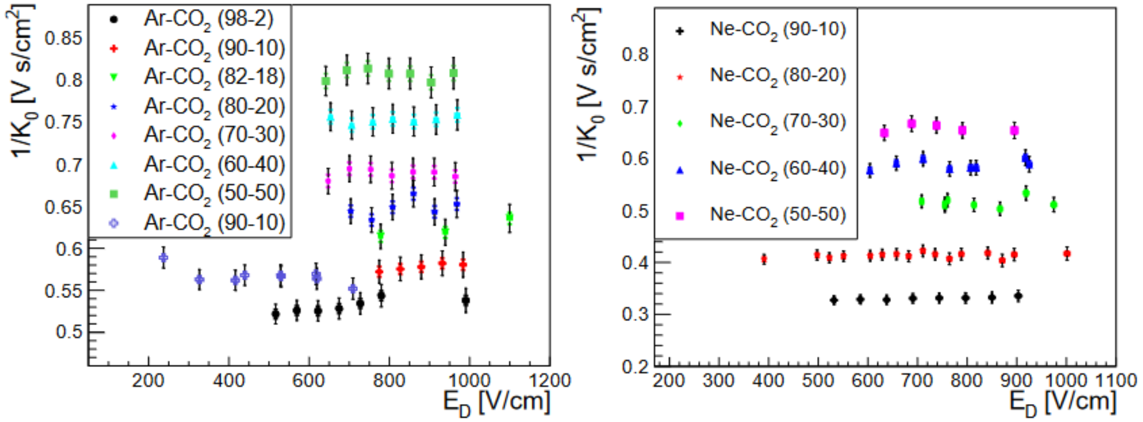
Fundamental measurements: Ion Mobility

Request for Project Funding from the RD51 Common Fund
- Date: *13.04.2014*-

Title of project: *Measurement and calculation of ion mobility of some gas mixtures of interest*
Contact person: *Chilo Garabatos, CERN, 165327, chilo.garabatos.cuadrado@cern.ch*
RD51 Institutes:
1. *GSI, contact person: Chilo Garabatos, chilo.garabatos.cuadrado@cern.ch*
2. *LIP Coimbra (Portugal), contact person: André Cortez, andre.cortez@coimbra.lip.pt*
3. *University of Bursa (Turkey), Rob Veenhof, rob.veenhof@cern.ch*
4. *VECC, Kolkata (India), Tapan Nayak, tapan.nayak@cern.ch*



Project description (Abstract, up to 100 words):
Data of ion mobility for mixtures of two and three gases is scarce, and is often replaced by educated guesses. On the other hand, the build up of positive space-charge in the large, ~90 m³, drift volume of the upgraded ALICE TPC determines the feasibility of a sufficient on-line correction of the track distortions for immediate data compression. The choice of the gas mixture thus hinges on the time it takes the ions to drift back to the central electrode. Therefore, an R&D program is proposed to measure the ion mobility of mixtures of Ar and Ne with CO_2, N_2 and or CF_4. This research should be completed with phenomenological understanding of the ion production and charge transfer processes.



(a) Ar-CO_2 mixtures (b) Ne-CO_2 mixtures

Figure 5: Inverse reduced ion mobility for Ar-CO_2 (Ne-CO_2, respectively) mixtures. All closed (open, respectively) points are measured with a drift length of 21.35 mm (25.31 mm, respectively). The water content in different measurements ranges from 34 ppm to 98 ppm (120 ppm to 180 ppm, respectively) for the Ar-CO_2 (Ne-CO_2, respectively) mixtures. The coloured error-bars represent the error due to the drift length uncertainty, while the black error bar represents the combined uncertainty of all other sources.

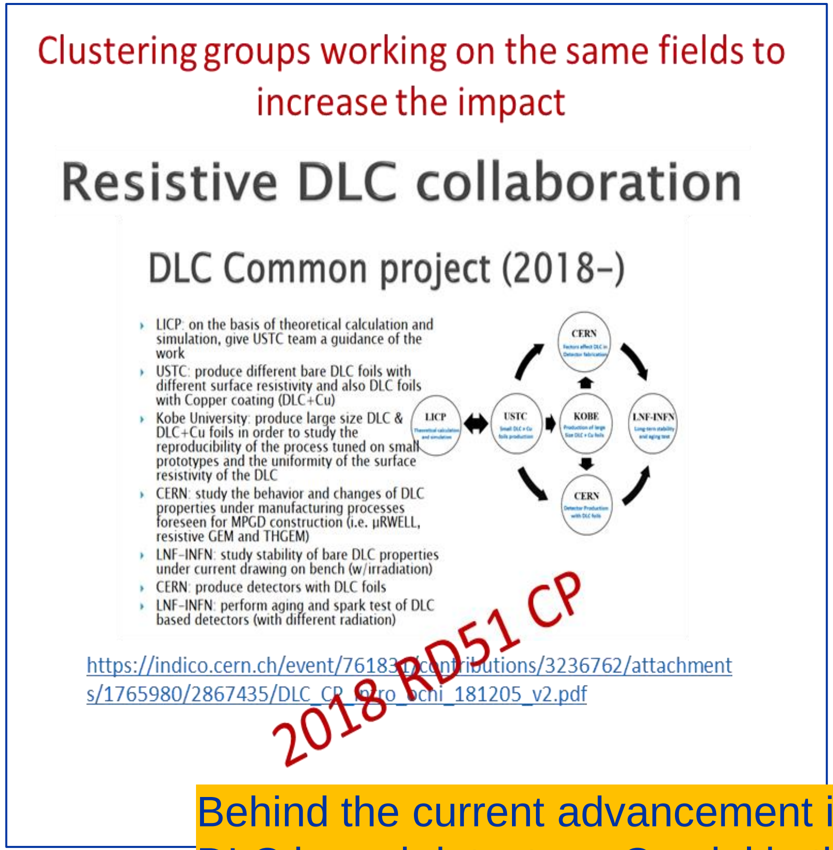
[ArXiv:1804.10288v2]

Clustering of groups and acting as a seed for potential long-term collaborations and activities.

As well a tool for:

- promoting collaboration between institutes
- promoting self-sustaining collaborations with large potential and impact

Running still today. Moving from Proof of principle to developments towrd potential applications. Part of DRD1 Work Package 7



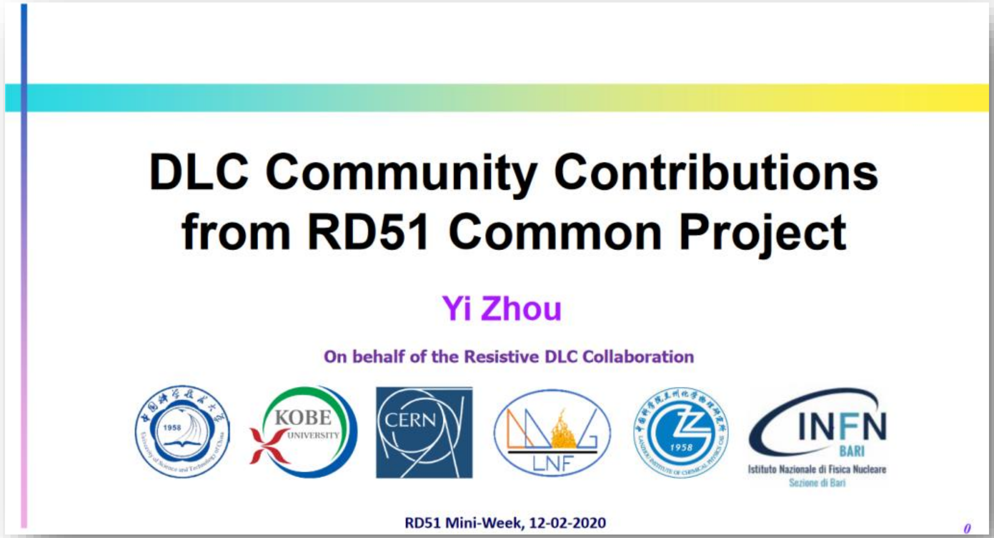
Behind the current advancement in DLC based detectors. Crucial in the purchase of the DLC magnetron sputtering machine by CERN/INFN

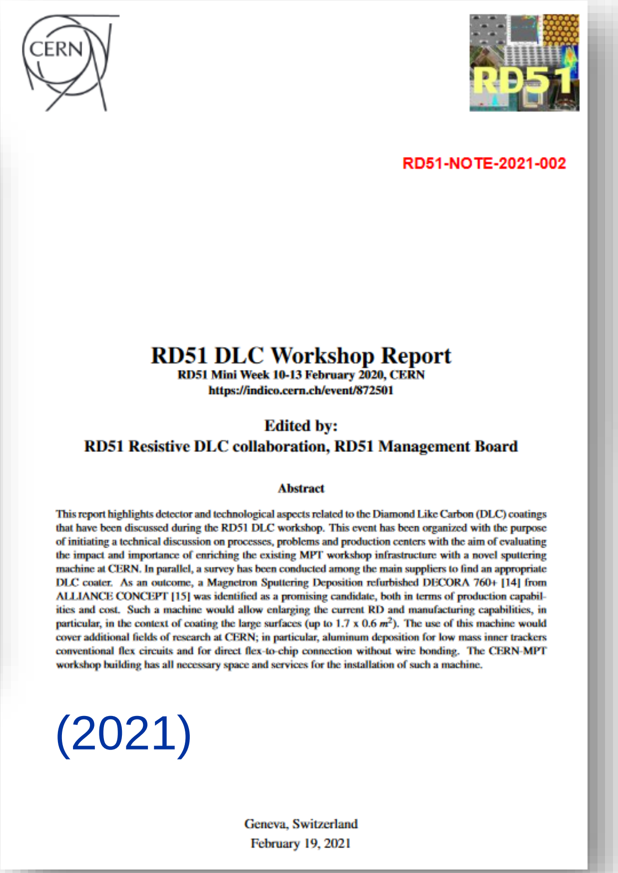
https://rd51-public.web.cern.ch/commonprojects

DLC Magnetron Sputtering Machine @ MPT

Production (WG6): DLC spattering machine @ CERN MPT workshop (resistive layers, photocathodes, thin coatings, CERN/INFN joint investment) https://indico.cern.ch/event/872501/attachments/1984404/4671553/RD51-NOTE-2021-002.pdf

(2018-2020)





CERN

RD51

RD51-NOTE-2021-002

RD51 DLC Workshop Report

RD51 Mini Week 10-13 February 2020, CERN

https://indico.cern.ch/event/872501

Edited by:

RD51 Resistive DLC collaboration, RD51 Management Board

Abstract

This report highlights detector and technological aspects related to the Diamond Like Carbon (DLC) coatings that have been discussed during the RD51 DLC workshop. This event has been organized with the purpose of initiating a technical discussion on processes, problems and production centers with the aim of evaluating the impact and importance of enriching the existing MPT workshop infrastructure with a novel sputtering machine at CERN. In parallel, a survey has been conducted among the main suppliers to find an appropriate DLC coater. As an outcome, a Magnetron Sputtering Deposition refurbished DECORA 760+ [14] from ALLIANCE CONCEPT [15] was identified as a promising candidate, both in terms of production capabilities and cost. Such a machine would allow enlarging the current RD and manufacturing capabilities, in particular, in the context of coating the large surfaces (up to 1.7 x 0.6 m^2). The use of this machine would cover additional fields of research at CERN; in particular, aluminum deposition for low mass inner trackers conventional flex circuits and for direct flex-to-chip connection without wire bonding. The CERN-MPT workshop building has all necessary space and services for the installation of such a machine.

Geneva, Switzerland

February 19, 2021

(2021)

COLLABORATION AGREEMENT

CONCERNING

THE ACQUISITION OF A MAGNETRON SPUTTERING DEPOSITION FACILITY

(THE "AGREEMENT")

BETWEEN: THE EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH ("CERN"), an Intergovernmental Organization having its seat at Geneva, Switzerland, duly represented by Manfred Krammer, Head of the Experimental Physics Departments,

AND: THE ISTITUTO NAZIONALE DI FISICA NUCLEARE ("INFN"), a public research body dedicated to fundamental research under the supervision of the Ministry of Education and Research of the Italian Republic, having its seat in Frascati (Rome), Italy, duly represented by Antonio Zoccoli, President,

Independent agreement between collaboration members (CERN/INFN)

Done in the context of the RD51 MoU, article 9.3

(2022-2023)

Work Packages (Is it worth doing?)

The way the DRDs want to address GSR 6 – Establish long-term strategic funding programs

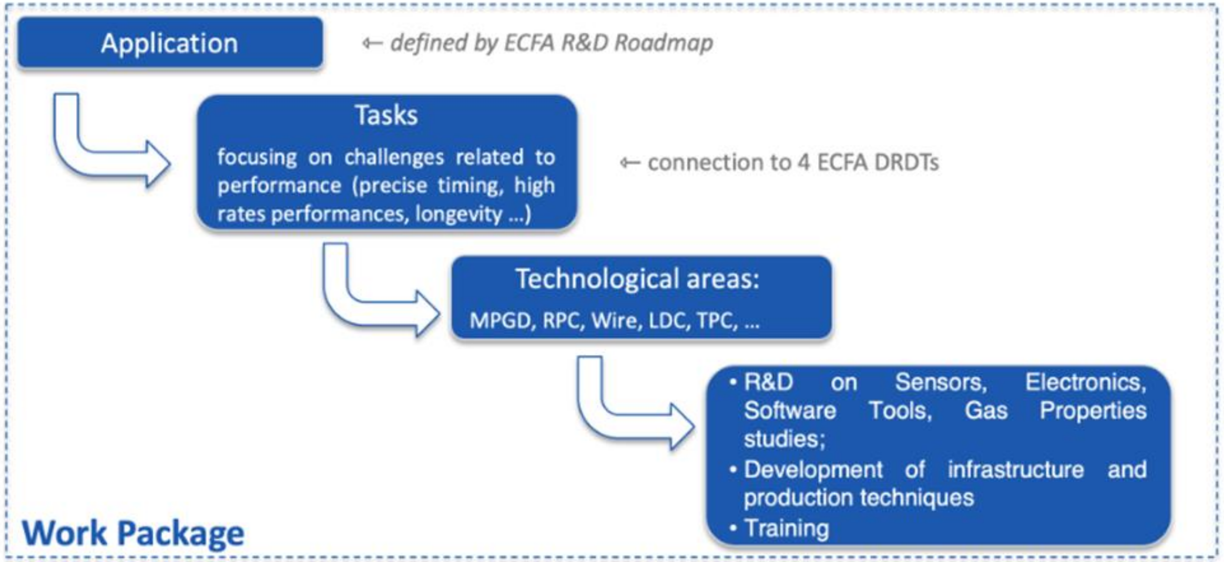
Linked to rising R&D costs, the need for a critical mass and the decadal timescales for strategic R&D investments needed for the ESPP programmes, there is an urgent need to augment the short-term funding mechanisms, suited for exploratory stages of the R&D cycle, with funding mechanisms better suited to long-term programmes as outlined in GSR 6. The scale of the technical challenges, the long planning horizons and the need to build serious relationships with industrial partners make sustained strategic investment a must, particularly if matching resources are to be leverage.

13

Work Packages

Strategic R&D (according to the ECFA Detector R&D Roadmap) **is organized in Work Packages**

- group activities of the Institutes with **shared research interests** around **Applications** with a focus on a **specific task(s)** devoted to a specific DRDT challenge, typically related to specific **Detector Technologies and** to the development of **specific tools or infrastructure**



Currently envisaged WPs:

- **WP1: Trackers/hodoscopes**
- **WP2: Drift chambers**
- **WP3: Straw chambers**
- **WP4: Tracking TPCs**
- **WP5: Calorimetry**
- **WP6: Photo-detectors**
- **WP7: Timing**
- **WP8: Reaction/Decay TPCs**
- **WP9: Beyond HEP**

- **There is no obligation to participate in a WP to be a member of DRD1.**

P. Gasik, DRD1 Proposal: Development of Gaseous Detectors Technologies, **1st meeting of the DRDC** 4 Dec 2023, CERN

Work Package 7

DESCRIPTION OF THE WORK PACKAGE

The project aims to cover strategic R&D towards the development of stable, robust and longest-running gaseous based detectors capable of offering precise timing (from tens of ps up to a few hundreds), good space resolution (from hundreds mm to mm), different readout granularities (from mm^2 to cm^2 size pads) and layouts, high rate capabilities (from hundreds of KHz to MHz per cm2), large gain (single electron sensitivity). and with a modularity that will allow to equip large area (several m^2) at practical costs. Sensitivity and response to charged particles and photon will be explored.

The long-term plans of this projects aims to match the requirements highlighted in the 2021 ECFA detector research and development roadmap. The relevant parts in terms of facilities requirements and recommendation are reported here. The proposed activities are covering the Detector Research and Development Themes DRDT 1.1 (Improve time and spatial resolution for gaseous detectors with long-term stability) and DRDT 1.3 (Develop environmentally friendly gaseous detectors for very large areas with high-rate capability).

This work package contains two projects:

- **WP7 Project A -** High-rate, high-granularity precise timing with MPGDs
- **WP7 Project B** - High-rate, large, precise timing (M)RPC

Nuclear Instruments and Methods in Physics Research A 374 (1996) 132-135

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

ELSEVIER

Letter to the Editor

A new type of resistive plate chamber: The multigap RPC

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Received 30 November 1995

Abstract

This Letter describes the multigap resistive plate chamber (RPC). The goal is to obtain a much improved time resolution, keeping the advantages of the wide gap RPC in comparison with the conventional narrow gap RPC (smaller dynamic range and thus lower charge per avalanche which gives higher rate capability and lower power dissipation in the gas gap).

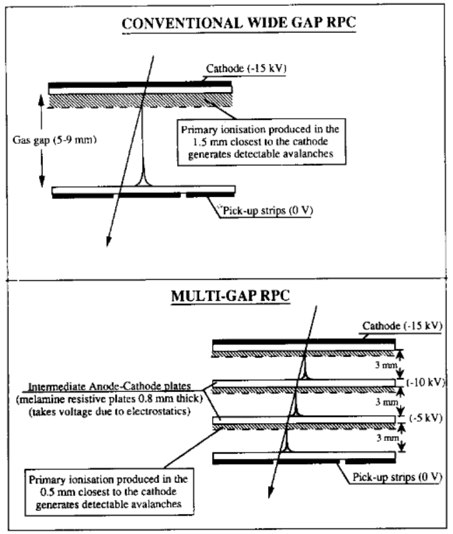

Fig. 1. Schematic diagram and principle of operation of multi-gap RPC compared to a conventional 9 mm single gap RPC.

Nuclear Inst. and Methods in Physics Research, A 903 (2018) 317–325

Contents lists available at ScienceDirect

Nuclear Inst. and Methods in Physics Research, A

journal homepage: www.elsevier.com/locate/nima

ELSEVIER

PICOSEC: Charged particle timing at sub-25 picosecond precision with a Micromegas based detector

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ARTICLE INFO

Keywords:
Picosecond timing
MPGD
Micromegas
Photocathodes
Timing algorithms

ABSTRACT

The prospect of pileup induced backgrounds at the High Luminosity LHC (HL-LHC) has stimulated intense interest in developing technologies for charged particle detection with accurate timing at high rates. The required accuracy follows directly from the nominal interaction distribution within a bunch crossing ($\sigma_z \sim 5$ cm, $\sigma_t \sim 170$ ps). A time resolution of the order of 20–30 ps would lead to significant reduction of these backgrounds. With this goal, we present a new detection concept called PICOSEC, which is based on a "two-stage" Micromegas detector coupled to a Cherenkov radiator and equipped with a photocathode. First results obtained with this new detector yield a time resolution of 24 ps for 150 GeV muons, and 76 ps for single photoelectrons.

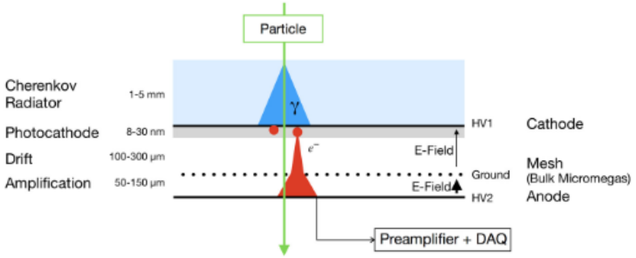


Fig. 1. The PICOSEC detection concept. The passage of a charged particle through the Cherenkov radiator produces UV photons, which are then absorbed at the photocathode and partially converted into electrons. These electrons are subsequently preamplified and then amplified in the two high-field drift stages, and induce a signal which is measured between the anode and the mesh.

WP7 Tasks

- T1: Optimize the amplification technology towards large-area detectors
- T2: Enhance timing performance
- T3: Enhance rate capability
- T4: Spatial resolution and readout granularity
- T5: Stability, robustness and longevity
- T6: Material studies
- T7: Gas studies for precise timing applications
- T8: Modelling and simulation of timing detectors
- T9: Readout electronics for precise timing
- T10: Precision mechanics and construction techniques
- T11: Common framework and test facilities for precise timing R&D

Tasks addressed by both MPGD and RPC/MRPC projects

#	Task	Performance Goal	DRD1 WGs	ECFA DRDT
T1	Optimize the amplification technology towards large-area detectors	- Uniformity over m^2 (time resolution, rate capability, efficiency)	WG1, WG2, WG3, WG4, WG5, WG6, WG7	1.1, 1.3
T2	Enhance timing performance	- Time resolution < 50 ps up to 30 kHz/cm^2		
T3	Enhance rate capability	- Time resolution < 200 ps up to 100-150 kHz/cm^2		
T4	Spatial resolution and readout granularity	- Spatial resolution of mm with low number of readout channels		
T5	Stability, robustness and longevity	- IBF <1% with <100 ps time resolution for single photoelectrons - Stable, high-gain operation		
T6	Material studies	- Radiation-hardness - Longevity		
T7	Gas studies for precise timing applications	- Eco-friendly mixtures - Recuperation - Ageing mitigation - CO_2-based mixture with geometrical quenching		
T8	Modelling and simulation of timing detectors	- Accurate modelling of charge transport and signal induction processes in precise timing detector geometries		
T9	Readout electronics for precise timing	- Low-noise FEE – High input capacitance – Large dynamic range – Fast rise time – Sensitivity to small charges - Multi-channel readout solution for timing detectors		
T10	Precision mechanics and construction techniques	- Precise mechanics (μm) over relatively large active areas (hundreds of cm^2)		
T11	Common framework and test facilities for precise timing R&D	- Test bench for precise timing studies		

RPC 2022
XVI Workshop on Resistive Plate Chambers and Related Detectors

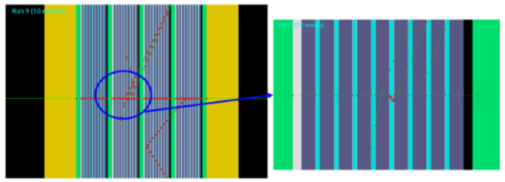
Tsinghua University

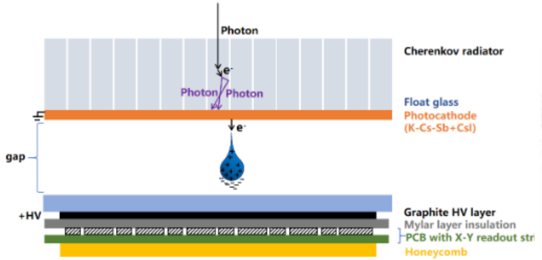
A new RPC

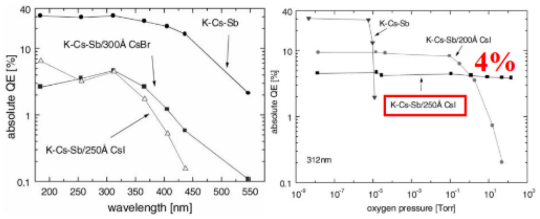
Radiation Physics and Detection Technology

Ultrathin, high efficiency, high time resolution RPC

- **Detection efficiency for γ (128μm gas gap)**
  - 1-chamber 1-gap ~ 0.2%
  - 1-chamber 8-gap ~ 1.5%
  - 4-chamber 32-gap ~ 6.3%







[A. Breskin et al. Israel 2000]

- **Performance indicators**
  - time resolution < 20ps， detection efficiency ~ 6.4%
  - sensitive area thickness < 3mm， energy resolution < 20%

10

Jianing Liu, Study of time resolution of MRPC for cosmic rays and 0.511MeV photons, XVI Workshop on Resistive Plate Chambers and Related Detectors ,26–30 Sept 2022, CERN

https://indico.cern.ch/event/1123140/contributions/5010269/

RPC 2024
Santiago de Compostela (Spain)

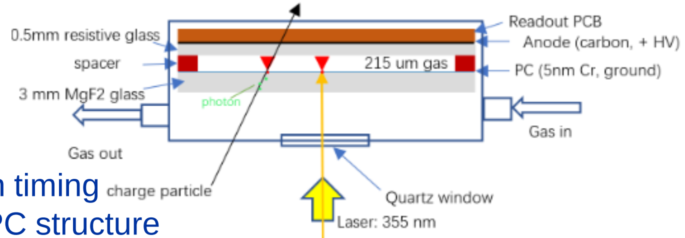


Figure 1: Schematic design of detector.

Yiding Zhao (USTC), A high rate and high timing gaseous photodetector prototype with RPC structure

https://indico.cern.ch/event/1354736/contributions/5986474/

A high rate and high timing photoelectric detector prototype with RPC structure

Yiding Zhao[a,b,1], D.Hu[a,b,1,*], M.Shao[a,b,**], Y.Zhou[a,b], S.Lv[a,b], Xiangqi Tian[a,b], Anqi Wang[a,b], Xueshen Lin[a,b], Hao Pang[a,b], Y.Sun[a,b]

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Abstract

To meet the needs of high counting rate and high time resolution in future high energy physics experiments, a prototype of gas photodetector with RPC structure was developed. Garfield++ simulated the detector's performance, and the single photoelectron performance of different mixed gases was tested with an ultraviolet laser. The detector uses a low resistivity ($\sim 1.4 \cdot 10^{10} \Omega \cdot cm$) float glass so that its rate capability is significantly higher than that of ordinary float glass($10^{12} \sim 10^{14} \Omega \cdot cm$), the laser test results show that in MRPC gas($R134a/iC_4H_{10}/SF_6(85/10/5)$), the single photoelectron time resolution is best to reach 20.3 ps at a gas gain of $7 \cdot 10^6$. Increasing the proportion of iC_4H_{10} can effectively reduce the probability of photon feedback, without changing the time resolution and maximum gain. In addition to being applied to high-precision time measurement scenarios (eg:T0, TOF), the detector can also quantitatively test the single photoelectron performance of different gases and will be used to find eco-friendly MRPC gases.

Keywords: gas photodetector, RPC, high time resolution, high-rate capability

https://arxiv.org/abs/2407.19720

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Nuclear Instruments and Methods in Physics Research A 533 (2004) 163–168
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH
Section A
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High rate (up to 10^5 Hz/cm^2), high position resolution (30 μm) photosensitive RPCs

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[b] *Physics Department, Royal Institute of Technology, Stockholm Physics Center, Stockholm 10691, Sweden*
[c] *Reagent Research Center, Moscow, Russia*
[d] *CERN, Geneva, Switzerland and Torino University, Torino, Italy*

Available online 25 July 2004

Abstract

In many applications there is a need for high position resolution VUV and UV imagers. For these applications we have developed and successfully tested 1D and 2D VUV imaging detectors based on microgap RPCs. Two versions of these detectors were extensively tested: one filled with photosensitive vapours and the other one with the GaAs cathode coated by a 400 nm thick CsI layer. The main feature of these detectors is the high position resolution—30 μm in digital form. Additionally, it is spark-protected and can operate at high counting rates (up to 10^5 Hz/cm^2). In this study the results in application for these detectors for spectroscopy are presented.

https://doi.org/10.1016/j.nima.2004.07.021

Summary and Conclusion (I)

- The requirements arising from future experiments at future facilities in the next decades have defined a series of **strategic R&D lines**.
- To facilitate exchange of ideas, resource pooling and effort sharing, the formation of international **community-led R&D collaborations** (DRDs), like the previously existing RD50 and RD51, has been strongly supported in Europe.
- DRD1 will focus on gaseous detectors and aims to offer a proper R&D framework to support both **strategic and generic, blue-sky, and technology-driven R&D**.
- Respect with RD51, DRD1 enlarged the scope covering on **all gaseous detector technologies**. This offers several opportunities for inspiration and cross-fertilization, synergies, cooperation, and complementarity between technologies.
- The core **R&D framework** of DRD1 is based on **Working Groups**, a very positive experience coming from the past RD51 experience.
- In addition, the required **strategic R&D** is organized into application-driven **Work Packages** that have been created in view of **long-term funding lines**. This is a new approach connected to the formation of DRDs, and it is in our interest to exploit it to the fullest.
- Even though it is still unclear what will be the impact on our R&D future funding**, the R&D framework that we can collaboratively build will undoubtedly support the quality of our research**.

Summary and Conclusion (II)

- A non exhaustive list of concrete examples of common activities done withing RD51 has been shown.

- The R&D framework created by the community and available to the community cover different fields, today we went through examples connected to:
  - Modelling and Simulation
  - Electronics
  - Manufacturing and production
  - Common test Facilities

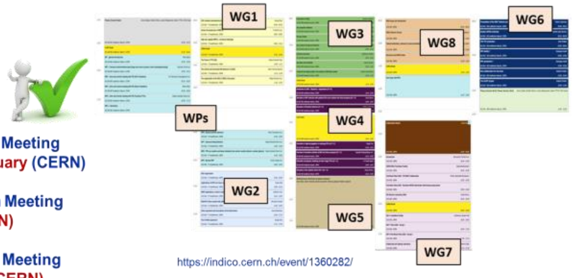
- The support of blues sky and generic R&D through Common Project has been presented emphasizing :
  - Clustering of groups
  - Basic research and blue-sky activities
  - Seed of long terms initiatives

- In the context of Work Packages, Work Package 7 on timing has been presented where RPC and MPGD technologies are addressing the needs of future experiments. This is a good example were having exchanges between groups and technologies can be beneficial to each research line.

Summary and Conclusion (III)

Despite formal aspect for DRD1 still to be completed (memorandum of understanding between members and CERN) the activities started….

DRD1 Collaboration Meetings (2024)



1st Collaboration Meeting
January 29-February (CERN)

2nd Collaboration Meeting
June 17-21 (CERN)

3rd Collaboration Meeting
December 9-13 (CERN)

https://indico.cern.ch/event/1360282/

Guideline/Target: Three Meetings per year, with one of the three outside CERN

+ Regular Working Groups Meeting

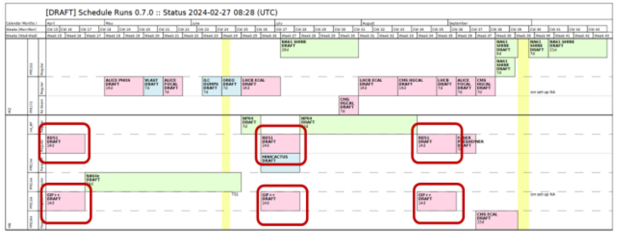
DRD1 Test Beams and Irradiation @ CERN (WG7)

DRD1 test beam at SPS H4 line (PPE134)

Dipanwita Banerjee (CERN),
https://indico.cern.ch/event/1360282/contributions/5768392/attachments/2791930/4868999/DRD1_H4.pdf

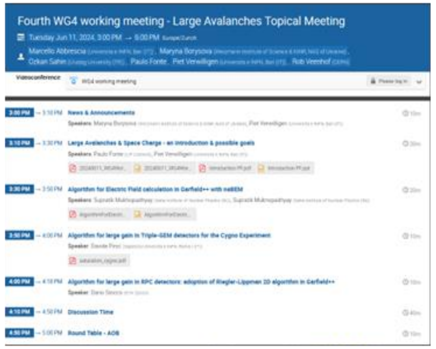
GIF++ Irradiation Facility & Test Beam (PPE154)

Martin R. Jaekel (CERN),
https://indico.cern.ch/event/1360282/contributions/5768396/attachments/2791702/4868978/2024_02%20GIF%20DRD1.pdf



https://ps-sps-coordination.web.cern.ch/

Topical Meeting on Large Avalanches (WG4)



https://indico.cern.ch/event/1420266/

Topical Workshop on Electronics (WG5)

https://indico.cern.ch/event/1413681/timetable

DRD1 Detector School (WG8)

Organising DRD1 Gaseous Detector School in 2024

- Single school for 2024, to be discussed for next years
- Regular (yearly) school targeted at students / young researchers / DRD1 community
- Based on previous school with **extension to other gas detector technologies**
- Similar format: lecture program open to community + lab exercises
- **Extended length** - 7-10 days?
- At CERN or other institute
- Planned for late 2024 - possibly connected to last DRD1 Collaboration Meeting this year

@ CERN

Follow-up of the RD51 Detector School

https://indico.cern.ch/event/1239595/

Extended to all gaseous detector technologies

https://indico.cern.ch/event/1360282/sessions/525034/attachments/2791402/4868283/DRD1%20WG8%20-%20Collaboration%20Jan%202024.pdf

Work Packages (WP1 as one example)

Activities of the DRD1 groups within the framework and tasks of the WPs have commenced, despite pending formal aspects (approvals, consultation with WP-FA,..)

https://drd1.web.cern.ch/

home.cern

backup

Detector Requirements at future facilities

Extracted by ECFA Detector R&D Roadmap 10.17181/CERN.XDPL.W2EX

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

Figure 1.2: Main drivers for the Muon Systems at future facilities. The most stringent requirements for the future R&D activities are quoted in the last column.

Facility	Technologies	Challenges	Most challenging requirements at the experiment
HL-LHC	MPGD	High spatial resolution, high rate/occupancy, radiation hardness, low mass	**LHCb option:** replace Scintillating Fibre tracker Spatial resolution:70 μm bending plane
Higgs-EW-Top Factories (ee) (ILC/FCC-ee/CepC/SCTF)	TPC+(multi-GEM, Micromegas, GridPix), Drift Chambers, Cylindrical layers of MPGD	Ultra-lightweight inner or central tracker, high spatial resolution, high rate/occupancy, radiation hardness, low mass, transparency, cluster counting, TPC continuous mode at high rate, (IBF x Gain) ~1	**Inner tracker (SCTF)** Fluxes: ≥10 kHz cm^{-2} s^{-1} Time resolution: 1 ns X/X0 = 1% Spatial resolution: ~100 μm **Central tracker (CepC)** Max. rate: >100 kHz/cm^2 Spatial resolution: ~100 μm Time resolution: ~ 100 ns dE/dx: <5% Particle separation with cluster counting at 2% level
Rare processes, atomic and nuclear physics (SPS Kaons: K^+ Phase, K-Phase, Mu2eII/COMET-II, ELENA)	TPC, straw tubes	High spatial resolution, occupancy, fast/precise timing, radiation hardness, low mass, Gd-deposited MPGD detectors	Max rate = 500 kHz/straw **(Mu2e II)**: Thinner straw material: 8 μm X/X0 ~ 0.02% per layer, X/X0 ~ 1% total **(COMET+)**: Diameter = 4.8 mm Trailing time resolution = 1 ns per track
Hadron and nuclear physics (EIC, AMBER, PANDA and CMB@FAIR, PRES MAINZ, NA60+	Micromegas, GEM, μ-RWELL, straw tubes	High spatial resolution, good timing, radiation hardness , tolerance to magnetic field	**(EIC)** Max rate = 100 kHz/cm^2 Spatial resolution ~50 μm X/X0 = 5% dE/dx=12%, continuos running

Figure 1.3: Main drivers for the Inner and Central tracking at future facilities. The most stringent requirements for the future R&D activities are quoted in the last column.

Facility	Technologies	Challenges	Most challenging requirements at experiment
Higgs-EW-Top Factories (ee) (ILC/FCC-ee/CepC,/SCTF)	RPC, Micromegas and GEM, μ-RWELL, GridPix, PICOSEC, FTM	High granularity, excellent hit timing, large area detectors, stabiliy, uniform response, eco-gases	**(ILC)** Max. rate:1 kHz/cm^2 Granularity (~1 cm^2) Radiation hardness: no Jet Energy resolution: 3-4 % Power-pulsing, self-triggering readout
Muon collider	RPC, Micromegas and GEM, μ-RWELL, GridPix, PICOSEC, FTM	High granularity, radiation hardness, excellent hit timing, stabiliy, uniform response, eco-gases	Granularity (~1cm^2) Fat jet identification Time resolution= O(100ps) Energy resolution =(5%)/sqrt(E) for fat-jet High radiation hardness
Hadron physics (EIC)	RPC, Micromegas and GEM, μ-RWELL, GridPix, PICOSEC, FTM	High granularity, radiation hardness, excellent hit timing, stabiliy, uniform response, eco-gases	**(EIC option)** DHCAL

Figure 1.4: Main drivers for Calorimeters at future facilities. The most stringent requirements for the future R&D activities are quoted in the last column.

Facility	Technologies	Challenges	Most challenging requirements at experiment
Hadron and nuclear physics (EIC, AMBER, PANDA and CMB@FAIR)	**Gaseous-RICH** with MPGD-based photon detector **TRD** with GEM or GridPix	- **RICH:** Compact, single photon detection, high gain, fine spatial and time resolution, eco-friendly gas radiator, high pressure; limited IBF, novel photoconverters - **TRD:** cluster counting technique, heavy gas for X-ray absorption, TRD photon -dE/dx separation.	**(EIC-gaseous RICH)** 1 meter of radiator gas High-gain: 10^5 - 10^6 Spatial resolution: O(1mm pitch) Time resolution (even with small signals) $\lesssim$ 1n Tolerance to magnetic field (1.5 - 3 T) Rad-hardness up to 10^{11} neq/cm^2 option: High Pressure-Rich: Ar @ 3.5 bar **(EIC-TRD)** compactness 10^{-2} rejection in 20-30 cm improved MIP/x-ray identification
Higgs-EW-Top Factories (ee) (FCC-ee/CepC)	**Gaseous-RICH** with MPGD-based photon detector	- **RICH:** Compact, single photon detection, high gain, fine spatial and time resolution, eco-friendly gas radiator, high pressure, limited IBF, novel photoconverters	**(Gaseous-RICH):** High-gain: 10^5 - 10^6 Spatial resolution O(1mm pitch) Time resolution (even with small signals) $\lesssim$ 1ns

Figure 1.5: Main drivers for the RICH and TRD. The most stringent requirements for the future R&D activities are quoted in the last column.

Facility	Technologies	Challenges	Most challenging requirements at experiment
Hadron and nuclear physics (CMB@FAIR, SOLID@JLAB, CEE@HIRFL-CSR)	MRPC, MPGD with precise timing (PICOSEC, FTM)	Rate capability, radiation hardness, large area detectors, new material, eco-gas, thinner structures, FEE, system time distribution	**(CMB)** Max Rate = 30 kHz/cm^2 Full system time resolution < 80 ps Occupancy < 5% Full system area = 120 m^2 ~100.000 channels, low power electronics

Figure 1.6: Main drivers for the TOF system. The most stringent requirements for the future R&D activities are quoted in the last column.

Facility	Technologies	Challenges	Most challenging requirements at experiment
WIMP search (DRIFT, MIMAC, CYGNUS, MIGDAL, TREX-DM)	-TPC w/ MWPC/MPGD at 20-130 mbar, charge readout -TPC w/ MPGD at 66 mb/1 bar, charge and optical readout -TPC w/ MPGD at 1-10 bar, charge readout	High granularity, high gain, low background, very low noise level and fast electronics, self trigger capability, gas optimization	**(CYGNUS)** Gain = $O(10^6)$ Spatial resolution = O(100 μm) Energy Threshold = 2 keVee Energy Resolution = 20% at 5.9 keVee Optical readout $He:SF_6$ or $He:CF_4$ at P = 1 bar
Solar axion helioscope (IAXO)	-TPC w/ pixelated Micromegas, GridPix, charge readout	High granularity, low background, radiopure electronics, self-trigger capability	High efficiency in ROI (0-10 keV) Spat. res = O(100 μm) Background: 10^{-7} c/keV/cm2 /s Xe at P = 1 bar B = 6 T
Low energy nuclear physics general purpose active target (AT-TPC, ACTAR)	-TPC+MM at 0.05- 3 bar, charge readout	Electronics with large dynamic range and flexible configuration. self-trigger capability, high pressure MPGD	(AT-TPC) B = 2 T P = 0.05-1 bar 3D-layout Generic target gases (H2, He, Ar, CO2. . .)
Neutrino physics and Neutrino-less double beta decay (DUNE-ND, NEXT, PANDAX-II)	-TPC+SiPM+PM: electroluminescence readout, -TPC+MM: charge readout	low background, energy resolution and topological rejection factors, scale to large volume, transparency and long drifting distance, high pressure, Ba++ tagging	**(NEXT)** P = 5-15 bar 3D-reconstruction of tracks through SiPM plane Energy resolution < 1% Ba++tagging
Neutrinos and DM search (Dune, DarkSide-20k, Argo, PandaX-4T, LZ, ARIADNE, Darwin)	- Dual-Phase TPC+MPGD	Large volume (uniform and stability response), ultra-low background, energy resolution, low energy thresholds, high granularity, charge extraction from liquid to gas, background rejection by prompt scintillation light -S1/ signal from the charge -S2 optimisation; Xenon and Argon storage and recuperation techniques	**(Darwin)** - 200 t x yr exposure - Drift/diameter: 2.6 m / 2.6 m - LXe Mass: 40 t - Particle discrimination by S1/S2 - Low-energy threshold of ~1 keVnr - Robust electrode design (up to 50kV) - Ultra-low intrinsic radioactivity materials - 222Rn: factor 100 reduction - (α,n) neutrons (from PTFE) - >99.98% Electron Recoil rejection at 30% Nuclear Recoil efficiency - High light yield (QE) ~ 8 PE/keV **(Darkside-20k /Argo)** - 200 t x yr exposure /Argo = 3000 t x yr) - Drift/diameter: 3.5 m / 3.5 m - LAr Mass: 51.7 t /Argo - 350 t - Particle discrimination by S1/S2 and pulse shape. - Low-energy threshold of ~0.5 keVnr - Highlander scintillation yield ~40 PE/KeV - Membrane cryostat like the ProtoDune - Low radioactivity argon in underground CO2 wells (UAr) with an activity 1400 times lower than atmospheric

Figure 1.7: Main drivers for TPCs used in rare event searches. The most stringent requirements for the future R&D activities are quoted in the last column.