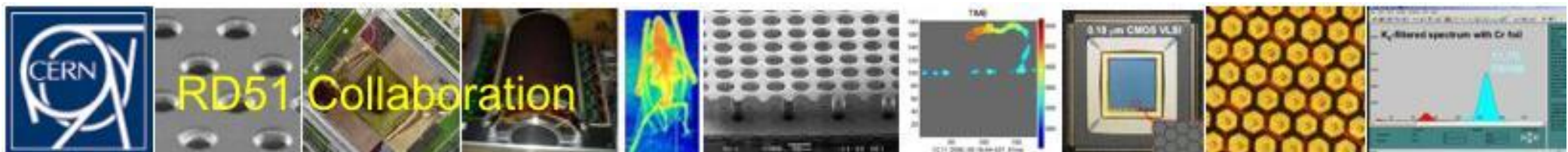


RD51

143rd LHCC Meeting

Eraldo Oliveri CERN EP DT GDD

on behalf of the RD51 Collaboration



Outline

- Collaboration Overview
- RD51 R&D Framework
 - Scientific Cultural Reference, Knowledge Transfer and Dissemination, Common Projects
 - Common Tools
 - Common Facilities and Infrastructures
- MPGD Technologies and Dissemination
- Summary

Remarks

It's **PAST YEAR UPDATE..** If not mentioned or explicit

Slightly **CERN BIASED..** Because of speaker and because we are @ LHCC

For sure **NOT EXHAUSTIVE...** apologize to my colleagues

Collaboration Overview

Collaboration Overview: Extension 2019-2023

RD51 R&D environment

3rd five-Year term

People – core service; generic and support R&D group

Community:

- open information and experience exchange
- organization of the conferences, meetings, workshops, schools, lectures, trainings, AIMEs
- contribution to the development, maintenance and user support of the infrastructure, electronics and software tools
- education of the new generation of instrumental physicists

Common infrastructure – R&D lab and test beam facilities

Electronics support: dedicated to Detector R&D

Software & simulation tools for detector physics

Diversified Resources

- CERN
- Collaborating institutions and projects contributions
- Industry
- EU projects
- Project synergies

Generic R&D

- Moving performance to the limits
- Developing new concepts and applications
- Support grants to explore innovative ideas

Project Oriented R&D

- R&D support to the projects and experiments
- Access to the R&D environment

Interdisciplinary CERN wide Instrumentation R&D

- Access to CERN and external facilities :
- MPT
- Thin Film Deposition
- Mechanics, designer office, 3D printing
- Metrology
- Nano Lab (EPFL)
- Industry (strategic partnership) and TT
- ...

CERN/LHCC-2018-018
LHCC-134
May 2018

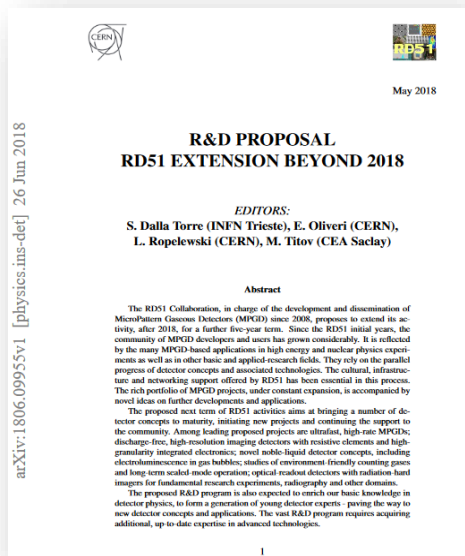
LARGE HADRON COLLIDER COMMITTEE

s of the one-hundredth-and-thirty-fourth meeting held on
Wednesday and Thursday, 30-31 May 2018

velopment of Micro-Pattern Gas Detectors Technologies

s an established collaboration with the aim to develop Micro-Pattern Gas
r (MPGD) technologies, to support experiments using this technology, and
aminate the technology within particle physics and in other fields. The
ration is well organised into seven working groups covering activities from
tector structures and electronics, to modelling, test facility management
ustrialisation.

- The collaboration has achieved major progress in MPGD technologies, some of which have already been picked up by experiments: ALICE TPC readout, ATLAS NSW, CMS GE1/1 forward detectors, Compass RHICH detector. The committee congratulated the collaboration for its progress since the last review session.
- A prolongation request for 5 years has been submitted to the present session of the LHCC. Apart from the support of the ongoing projects, the proposal included plans to explore new materials and technologies to achieve ever better resolution in space and time and open the door to new use cases both in HEP and elsewhere.
- The LHCC recommends granting RD51 the 5-year extension requested, including CERN support at the level currently provided. Progress will be reviewed every year by the LHCC. The LHCC considers the working mode of RD51, with a small but focussed core team and corresponding infrastructure at CERN, attracting contributions and bright ideas to be explored from collaborators around the world, to be an excellent setup. The LHCC notes that the CERN contribution to RD51 as listed in the proposal is crucial for the collaboration, and strongly encourages CERN to maintain its support of RD51.



<https://arxiv.org/pdf/1806.09955.pdf>

Reminder

Collaboration Overview: Objectives and Achievements

Advance the technological development and application of MicroPattern Gas Detectors (MPGDs) and contribute to the dissemination of these technologies.

Development

Exploit existing technologies

Large size single-mask GEMs
Resistive Micromegas

Develop novel technologies

μ PIC, μ R-WELL, GRIDPIX

Dissemination

High-Energy Physics

ALICE, ATLAS, CMS, Compass, KLOE, BESIII

Fundamental research beyond HEP

LBNO-DEMO, active-target TPCs

Beyond fundamental research

Muon radiography, n-detection, X-ray radiographies

Tools and facilities

Common infrastructures

(GDD lab, common test beam)

Electronics

(Scalable Readout System SRS, instrumentation)

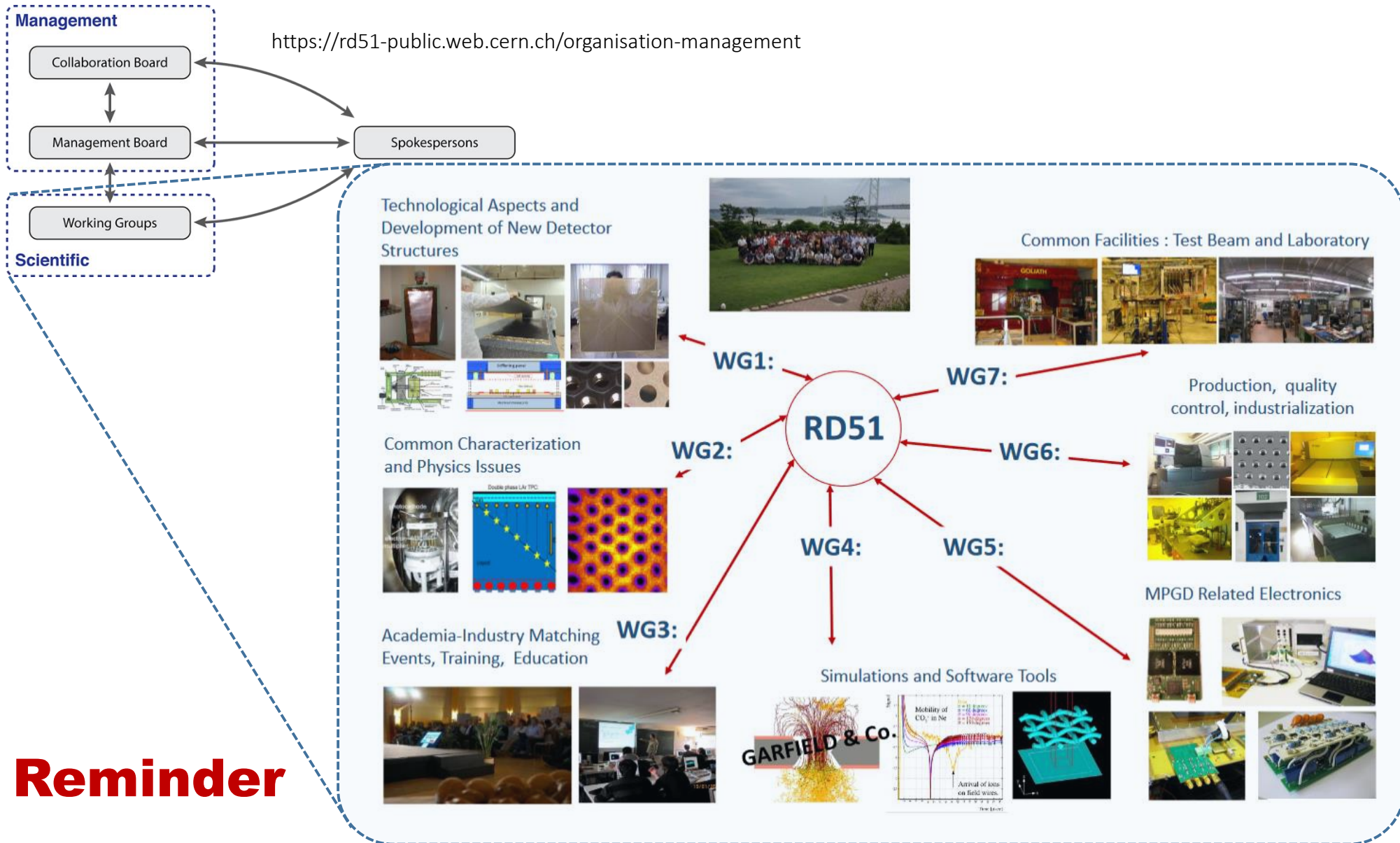
Simulation

(Garfield, Magboltz, Degrad, neBEM)

Reminder

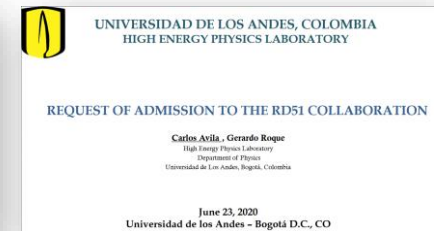
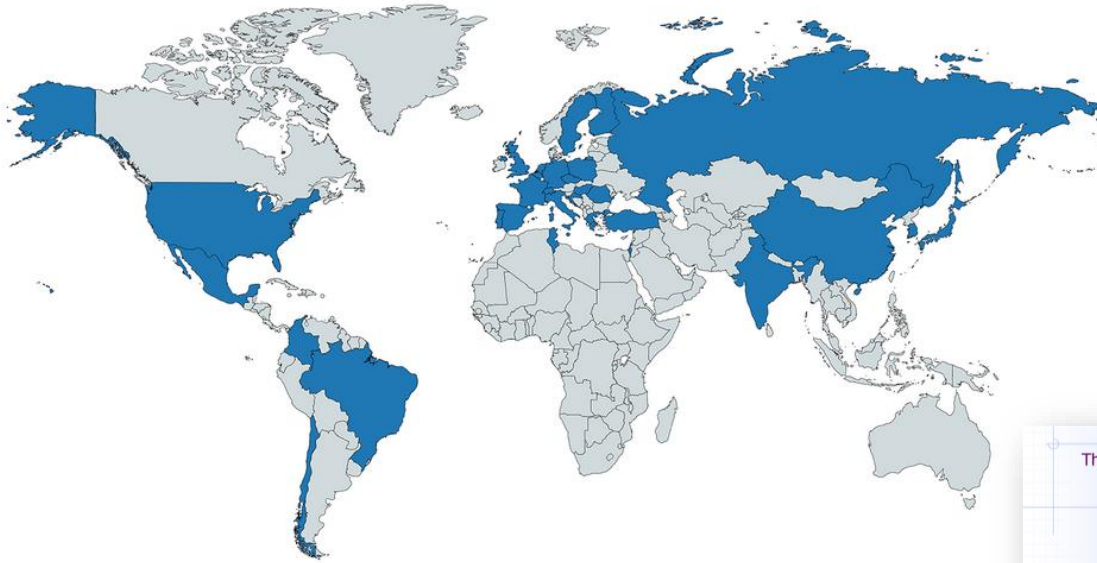
F. Brunbauer, RD51Development of MicroPattern Gaseous Detector Technologies @ EP R&D Day - Getting started
https://indico.cern.ch/event/842794/contributions/3589907/attachments/1932549/3201341/RD51_EP-RD.pdf

Collaboration Overview: Working Groups



Collaboration Overview: Teams

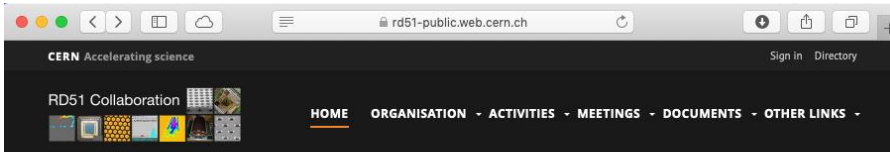
~450 Participants from 89 Institutes from 31 Countries



Past year new memberships



More info in the **re-designed** RD51 Web page



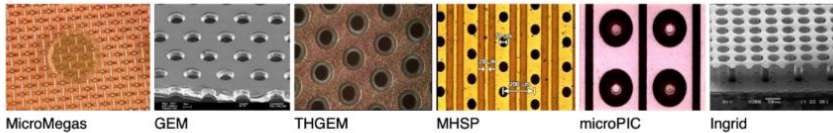
RD51 collaboration

Development of Micro-Pattern Gas Detectors Technologies

The proposed R&D collaboration, RD51, aims at facilitating the development of advanced gas-avalanche detector technologies and associated electronic-readout systems, for applications in basic and applied research. **The main objective of the R&D programme is to advance technological development and application of Micropattern Gas Detectors.**

The invention of Micro-Pattern Gas Detectors (MPGD), in particular the Gas Electron Multiplier (GEM), the Micro-Mesh Gaseous Structure (Micromegas), and more recently other micro pattern detector schemes, offers the potential to develop new gaseous detectors with unprecedented spatial resolution, high rate capability, large sensitive area, operational stability and radiation hardness. In some applications, requiring very large-area coverage with moderate spatial resolutions, more coarse Macro-patterned detectors, e.g. Thick-GEMs (THGEM) or patterned resistive-plate devices could offer an interesting and economic solution. The design of the new micro-pattern devices appears suitable for industrial production. In addition, the availability of highly integrated amplification and readout electronics allows for the design of gas-detector systems with channel densities comparable to that of modern silicon detectors. Modern wafer post-processing allows for the integration of gas-amplification structures directly on top of a pixelized readout chip. Thanks to these recent developments, particle detection through the *ionization of gas* has large fields of application in future particle, nuclear and astro-particle physics experiments with and without accelerators.

The RD51 collaboration involves ~ 450 authors, 75 Universities and Research Laboratories from 25 countries in Europe, America, Asia and Africa. All partners are already actively pursuing either basic- or application-oriented R&D involving a variety of MPGD concepts. The collaboration established common goals, like experimental and simulation tools, characterization concepts and methods, common infrastructures at test beams and irradiation facilities, and methods and infrastructures for MPGD production.



F. Brunbauer

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

General overview

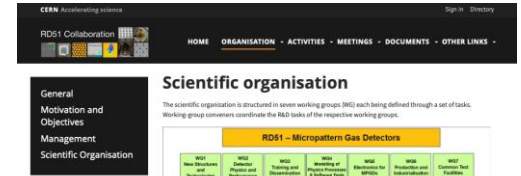
- Objectives
- Organisation
- Management
- Working Groups
- Common Projects

Meetings and conferences

- Collaboration Meetings & Mini Weeks
- MPGD conferences
- Workshops, Schools & Training Sessions

Documents

- RD51 Proposal
- MoU
- LHCC/Research Board
- Conference Contributions
- RD51 Notes



Working Group Convener

WG1	Paul Collin (CEA Saclay), Filippo Rosati (CERN)
WG2	Florian Brunbauer (CERN), Francisco Garcia (Heidelberg Institute of Physical)
WG3	Fabrizio Martin (CERN), Jaou Woods (University of Astoria)
WG4	Rik Veenhof (CERN), Oskar Sahn (Duisburg University), Piet Verwilligen (Universiteit a MNL, Bari)



RD51 Collaboration Meetings

- RD51 Collaboration Meeting, [rome](#), 04-22-28 June 2020
- RD51 Collaboration Meeting, [CERN](#), 24-30 October 2018
- RD51 Collaboration Meeting, [La Rochelle, France](#), 8-9 May 2017 in conjunction with MPGD2017 conference
- RD51 Collaboration Meeting, [CERN](#), 18-17 September 2016
- RD51 Collaboration Meeting and "MPGD Stability" workshop, [TUM, Munich, Germany](#), 18-22 June 2016
- RD51 Collaboration Meeting, [CERN](#), 02-18 September 2015
- RD51 Collaboration Meeting, [Bologna, Italy](#), 16-20 Oct 2015 in conjunction with MPGD2015 Conference
- RD51 Collaboration Meeting and "MPGD Applications Beyond Fundamental Science" workshop, [Austria, Austria](#), 02-16 September 2015
- RD51 Collaboration Meeting, [CERN](#), 01-11 March 2015
- RD51 Collaboration Meeting, [Trieste, Italy](#), 14-17 October 2014 in conjunction with MPGD2014 conference
- RD51 Collaboration Meeting, [HEP, CERN, Padova, Italy](#), 21-26 October 2014
- RD51 Collaboration Meeting, [CERN](#), 7-7 February 2014
- RD51 Collaboration Meeting, [CERN](#), 18-17 October 2013
- RD51 Collaboration Meeting, [Caracas, South Africa](#), 2013 in conjunction with MPGD2013 conference
- RD51 Collaboration Meeting, [Geneva, Switzerland](#), 24-28 September 2012
- RD51 Collaboration Meeting, [CERN](#), 18-22 February 2012
- RD51 Collaboration Meeting, [Aachen, Germany](#), 18-22 September 2011 in conjunction with MPGD2011 conference
- RD51 Collaboration Meeting, [CERN](#), 13-18 April 2011
- RD51 Collaboration Meeting, [Paris, Italy](#), October 1-16, 2010
- RD51 Collaboration Meeting, [Peking, Vietnam](#), 16-21 Oct 2010
- RD51 Collaboration Meeting, [CERN](#), November 22-29, 2009
- RD51 Collaboration Meeting, [McMasters, Canada](#), June 16-17, 2009 in conjunction with MPGD2009 conference
- RD51 Collaboration Meeting, [Paris, October 15-16, 2008](#)
- 1st RD51 Collaboration Meeting (NORKE), [April 16-18, 2008](#)
- Micro-pattern Gas Detectors, [Towards an R&D Collaboration](#), CERN, September 13-14, 2007



RD51 Proposal, MoU and Documents

- RD51 Proposal
- RD51 Proposal (Public 2008)
- Request for participation to the LHCC 2013
- Request for participation to the LHCC 2018
- Memorandum of Understanding (MoU)
- Memorandum of Understanding (MoU) April 2009
- Annex 1: [List of Institutes in the RD51 Collaboration and Names of their Representatives to the Funding Agencies \(May 2009\)](#)
- Annex 2: [Management and other service positions within the RD51 Collaboration and the names of the currently holding them \(June 2008\)](#)
- Annex 7: [Intellectual Property \(ascribed to the RD51 Collaboration\) \(October 2011\)](#)

Past year invited “RD51 review talks” & “RD51 IN invited review contributions”

CERN EP R&D Day

EP R&D Day - Getting started
Thursday, 24 Oct 2019, 09:00 → 18:15 Europe/Zurich
503/1-001 - Council Chamber (CERN)

Description CERN's Experimental Physics department has defined a strategic R&D programme on Technologies for future experiments. Funded for an initial period of 5 years, the activity will start in 2020. In this event we'll review the final work plans and prepare the steps to get started.

We invited a number of guest speakers to hear about detector R&D plans in the US, in the CALICE collaboration, the AIDA++ initiative and the CERN R&D collaborations RD18, RD50, and RD51.

RD51
Development of MicroPattern Gaseous Detector Technologies

Florian M. Brunbauer
on behalf of the RD51 collaboration
EP R&D Day, October 24, 2019

https://indico.cern.ch/event/842794/contributions/3589907/attachments/1932549/3201341/RD51_EP-RD.pdf

INSTR20

INSTR20: Instrumentation for Colliding Beam Physics

Budker Institute of Nuclear Physics, and Novosibirsk State University, Novosibirsk, Russia
24 - 28 February, 2020

UNIVERSITY OF VIRGINIA

INSTR20
Review on the R&D Activities within the RD51 Collaboration

Kondo Gnanvo
on Behalf of the RD51 Collaboration

https://indico.inp.nsk.su/event/20/contributions/795/attachments/524/609/INSTR20_KG_20200228.pdf

INSTR20

arXiv: 2006.08239, submitted to JINST

Next Frontiers in Particle Physics Detectors: INSTR2020 Summary and a Look into the Future

Maxim Titov
*Commissariat à l'Énergie Atomique et Énergies Alternatives (CEA) Saclay, DAP / DAPF / DAPF-SP
21193 Orfèvre State Circle, France
E-mail: maxim.titov@cea.fr

ABSTRACT: The physics goals of high luminosity particle accelerators, from LHC to HL-LHC and to the next generation of lepton colliders, have set quite stringent constraints on the future needs at the Instrumentation Frontier. Many technologies are reaching their sensitivity limit and new approaches need to be developed to overcome the currently unsolvable technological challenges. The detrimental effect of the material budget and power consumption represents a very serious concern for a high-precision silicon vertex and tracking detectors. One of the most promising areas is CMOS sensors offering low mass and potentially radiation-hard technology for the future proton-proton and electron-positron colliders, intensity frontier and heavy-ion experiments. MPGDs have become a well-established technique in the fertile field of gaseous detectors; these will remain the primary choice whenever the large-area coverage with low material budget is required. Vacuum tube technology is inherently fast and new developments include advances in microchannel plates for photomultipliers with a potential for a picosecond-time resolution in large systems. Several novel concepts of picosecond-timing detectors will have numerous powerful applications in particle identification, pile-up rejection and event reconstruction, and serve numerous scientific goals. The story of modern calorimetry is a textbook example of physics research driving the development of an experimental method. Silicon photomultipliers have seen a rapid progress in the last decade, becoming the standard solution for scintillator-based devices. The integration of advanced electronics and data transmission functionalities plays an increasingly important role and needs to be addressed. Bringing the modern algorithmic advances from the field of machine learning from offline applications to online operations and trigger systems is another major challenge. The innovations spanned by future projects in particle physics, ranging from four years to many decades, constitute a challenge in itself, in addition to the complexity and diversity of the required accelerator and detector R&D. This paper summarizes advances and recent trends in the instrumentation technologies for particle physics experiments, largely based on the presentations given at the International Conference “Instrumentation for Colliding Beam Physics” (INSTR-20), held at BINP Novosibirsk, Russia, from 24 to 28 February, 2020.

KEYWORDS: future particle physics; detector instrumentation; trends; advances; challenges; research infrastructure

Not really fair...

Figure 4. The seven working groups of RD51 Collaborations “Development of MicroPattern Gaseous Detector Technologies”, consisting of more than 30 institutes world-wide, with illustrations of a few examples of the different kinds of work involved. (19-16)

The Worldwide LHC Computing Grid (WLCG) was established in 2005 to address a major computing challenge for the particle physics community: today it includes resources from more than 170 sites in 42 countries with ~ 2 million jobs per day. The WLCG was developed for the LHC experiments, but the Belle II, LHCb, DUNE and the linear collider detector studies use the same infrastructure. The challenges to face were (and still are): to keep operating the system reliably enough with significantly less effort, to evolve towards more, more open and flexible computing models, and to provide the software and the resources needed by the LHC experiments. In terms of data processing, the rate of advances in hardware performance has slowed in recent years.

<https://arxiv.org/ftp/arxiv/papers/2006/2006.08239.pdf>

RD51 model and achievements in the Instrumentation review talk of INSTR20

... by... M. Titov

RD51 Contribution to International Scientific Studies

Input to the European Particle Physics Strategy Update 2018-2020

1 November 2018 to 19 December 2018

Development of the Micro-Pattern Gaseous Detector Technologies: an overview of the CERN-RD51 Collaboration

Not scheduled

1m

Development of the Micro-Pattern Gaseous Detector Technologies: an overview of the CERN-RD51 Collaboration

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

Representing the RD51 Collaboration

EPPSU

e-mail addresses:
Silvia.DallaTorre@ts.infn.it, Eraldo.Oliveri@cern.ch, Leszek.Ropelewski@cern.ch, Maxim.Titov@cea.fr

New Technologies For Discovery

A report of the 2018 DPF Coordinating Panel for Advanced Detectors (CPAD) Community Workshop

atXiv:1908.00194v2 [physics.ins-det] 10 Aug 2019

Z. Ahmed,¹ A. Apyrayan,² M. Artuso,³ P. Barry,⁴ E. Bickel,⁵ F. Blazczyk,⁶ T. Bone,⁷ D. Braga,⁸ S.A. Chafelouis,⁹ A. Chatterjee,¹⁰ A. Chawarha,¹¹ H. M. Cho,¹² S. Dalla Torre,¹³ M. Demaria,¹⁴ D. Desjardins,¹⁵ M. Dieffenthaler,¹⁶ A. Drogosz,¹⁷ F. Fakhri,¹⁸ C. Gee,¹⁹ S. Habib,²⁰ G. Haller,²¹ J. Hogan,²² B.J.P. Jones,²³ M. Garcia-Sciveres,²⁴ G. Giacomin,²⁵ K. Gilmore,²⁶ G.K. Giovanetti,²⁷ D. Glazovskii,²⁸ S. Glezer,²⁹ A.H. Golden,³⁰ S. Gollapinni,³¹ C. Graco,³² R. Guenther,³³ D. Gutsche,³⁴ U. Heintz,³⁵ S.A. Hertel,³⁶ N. R. Huxford,³⁷ S. Koloszewski,³⁸ T. Kowczak,³⁹ F. Leonard,⁴⁰ R. Lipson,⁴¹ M. Liu,⁴² J.F. Low,⁴³ P. Madigan,⁴⁴ S. Malik,⁴⁵ J. Mates,⁴⁶ Y. Mei,⁴⁷ P. Merkel,⁴⁸ T. Mohayaee,⁴⁹ A. Nonaka,⁵⁰ E. Oliveri,⁵¹ K. Palladino,⁵² E. Pantic,⁵³ A. Para,⁵⁴ K. Parys,⁵⁵ M. Pyke,⁵⁶ P. Rieder,⁵⁷ L. Ropelewski,⁵⁸ R. Russek,⁵⁹ M. Schieber-Smith,⁶⁰ I. Shipsey,⁶¹ K. Schullberg,⁶² B. A. Schumm,⁶³ A. Slosser,⁶⁴ W. Smith,⁶⁵ B. Surov,⁶⁶ A. O. Suslikov,⁶⁷ A. Suzuki,⁶⁸ M. Szydagis,⁶⁹ D. Temples,⁷⁰ J. Thorn,⁷¹ M. Titov,⁷² L. Tornikova,⁷³ E. Usai,⁷⁴ R. Van Berg,⁷⁵ V. Velas,⁷⁶ D.W. Whittington,⁷⁷ L. Winslow,⁷⁸ T. Wongjittakul,⁷⁹ Q. Xiang,⁸⁰ J. Xia,⁸¹ Z.F. You,⁸² A. Zaid,⁸³ J. Zhang,⁸⁴ R.Y. Zhu.⁸⁵

CPAD

Document for the US BRN (Basic Research Needs) in preparation based on CPAD report "New Technologies For Discovery": Progress of MPGDs and RD51 model <https://arxiv.org/abs/1908.00194>

2020 European Strategy Update for Particle Physics

- ✓ Update of the European Strategy for Particle Physics: <https://indico.cern.ch/event/931825/contributions/3915933/attachments/2061059/3457287/CERN-ESU-013.pdf>
- ✓ Deliberation Document on the 2020 update of the European Strategy for Particle Physics: <https://indico.cern.ch/event/931825/contributions/3915933/attachments/2061059/3457286/CERN-ESU-014.pdf>

Letter of Interest for the Snowmass 2021

Development of the Micro-Pattern Gaseous Detector Technologies: an overview of the CERN-RD51 Collaboration

Representing the RD51 Collaboration

Contact persons: S. Dalla Torre (INFN Trieste), Klaus Dehmelt (Stony Brook University), E. Oliveri (CERN), L. Ropelewski (CERN), M. Titov (CEA Saclay), A. White (University of Texas, Arlington)

Silvia.DallaTorre@ts.infn.it, klaus.dehmelt@stonybrook.edu, Eraldo.Oliveri@cern.ch, Leszek.Ropelewski@cern.ch, Maxim.Titov@cea.fr, awhite@uta.edu

Abstract:

RD51 is a well-established collaboration with the aim to develop Micro-Pattern Gaseous Detector (MPGD) technologies, to support experiments using this technology, and to disseminate the technology within particle physics and in other fields. Originally created for a five-year term in 2008 [1], RD51 was extended for a third five years term beyond 2018 [2]. The rich portfolio of MPGD projects, under constant expansion, is accompanied by novel ideas for further developments and applications. The cultural, infrastructure and networking support offered by RD51 has been essential in this process: this effort will continue thanks to the RD51 extension. Also in the next years, a collaborative R&D phase and the right environment will have a strong impact on project-oriented activities - similarly to the current scenario where three of the major upgrades for the LHC experiments benefited from the RD51 framework. The vast R&D program requires acquiring additional, up-to-date expertise in advanced technologies; it is also expected to generate young detector generations.

SNOWMASS21

performing R&D: combination of generic and purpose-built technologies, full sharing of "know-how", information, common infrastructures. This model to be continued and can be exported to other detector domains.

<https://www.snowmass21.org/docs/files/summaries/IF/SNOWMASS21-IF5-IF9-EF0-EF0-168.pdf>

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.*

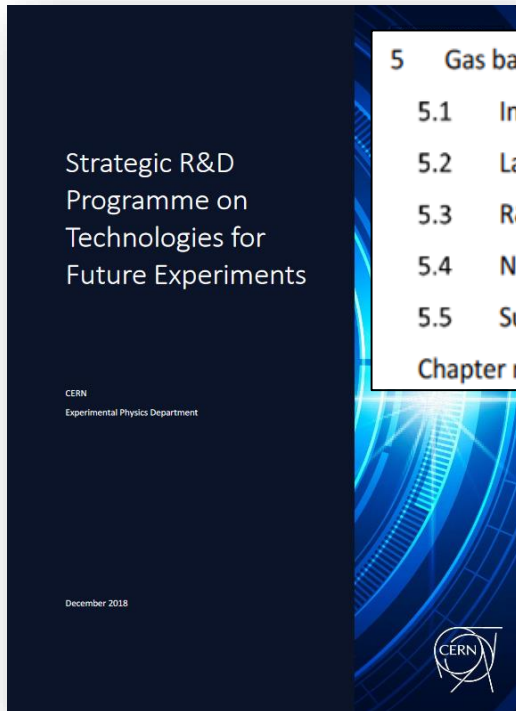
Strategy Document

Instrumentation R&D critical for present and future endeavours

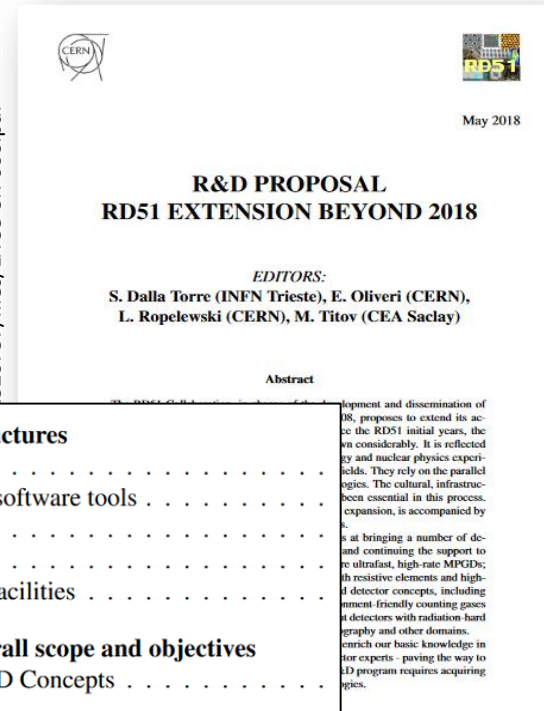
- Delivering the near and long-term future research programme requires advances in instrumentation through focused and transformational R&D
- There is a clear need to strengthen existing R&D collaborative structures and to create new ones, and to foster an environment that stimulates innovation and collaboration with industry
- The National Laboratories and research institutes in Europe play a central role by providing access to dedicated infrastructures and test facilities, specialised expertise and user support
- A roadmap should be developed by the community (ECFA's role) taking into account progress with emerging technologies in adjacent fields

Deliberation Document

Synergies with the strategic **EP R&D program**



5	Gas based detectors (WP2)
5.1	Introduction and overview
5.2	Large area gaseous detector systems
5.3	R&D Framework and Tools
5.4	Novel technologies
5.5	Summary
	Chapter references



3	RD51 Legacy, Expertize and Infrastructures
3.1	Community and Expertise
3.2	Detector physics, simulations and software tools
3.3	Electronics
3.4	Workshops
3.5	Common space and common test facilities
4	RD51 extension beyond 2018: the overall scope and objectives
4.1	R&D Program on Advanced MPGD Concepts
4.2	Support and Infrastructures

<https://ep-dep.web.cern.ch/sites/ep-dep.web.cern.ch/files/CERN-OPEN-2018-006.pdf>

EP R&D will cover **research activities of the CERN GDD team** in the field of interest of RD51. **Beneficial and bidirectional support** between the EP program and the Collaboration.

However personnel allocation for the maintenance, operation and consolidation of tools (electronics, simulation) and facilities (laboratory, test-beam, workshops) is not covered by the EP RD program. In the past this support was covered by the white paper – now partially by EP-DT-DD GDD human resources and operational budget.

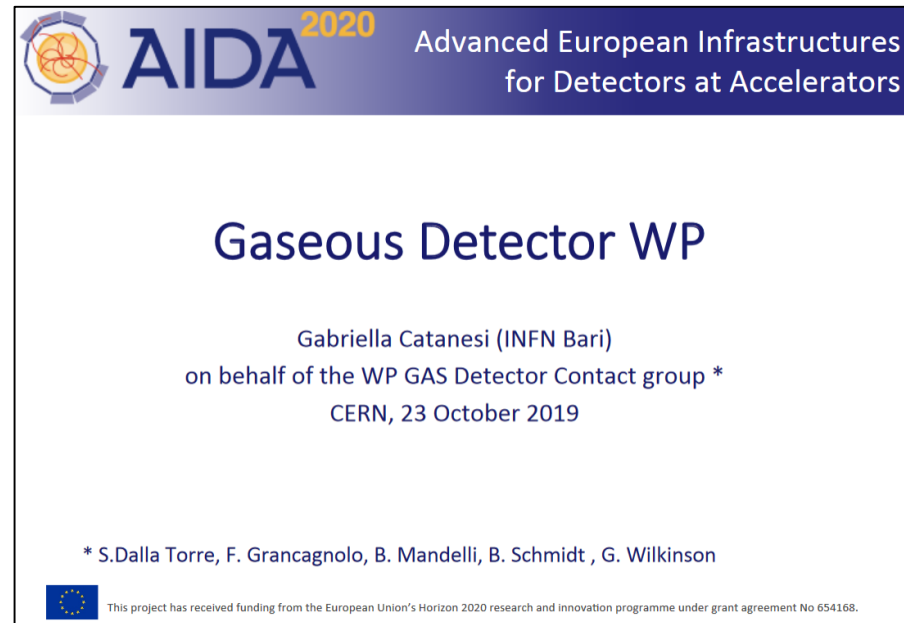
Synergies with the **AIDA**innova program



- R&D on MPGD for future colliders and their industrialization
- Large volume gas detectors for future colliders and neutrino beams
- Innovative developments on PID Cherenkov technologies

AIDAinnova submitted
on 17 March 2020

Number of EoI (Expressions of Interest) submitted and related to MPGDs: **18 over a total of 159;**



<https://indico.cern.ch/event/838461/contributions/3608124/attachments/1931843/3199838/AIDA-2020-WP-GAS-Gabriella-V3.pdf>

10 core activities linked to RD51 selected

2 suggested for Blue Sky R&D

**1 included in in DAQ and test beam WP
for RD51 common tools (SRS/VMM)**

RD51 R&D Framework

- Scientific Cultural Reference, Knowledge Transfer and Dissemination
- Common Projects
- Common Tools
 - Modelling and Simulation
 - Electronics for MPGDs
- Common Facilities and Infrastructures
 - EP-DT Gas Detector Development (GDD) laboratory
 - Semi Permanent Test Beam Installation
- EP-DT MPT workshop

Past year **“Enriched”** meetings

- RD51 Collaboration Meeting (CM), 21-23 October 2019, CERN, <https://indico.cern.ch/event/843711/>
- RD51 Mini-Week & **DLC workshop**, 10-13 February 2020, CERN, <https://indico.cern.ch/event/872501>

Remote RD51 CM & **Lectures**, 22-26 June 2020, remote-only by Vidyo, <https://indico.cern.ch/event/911950/>

- RD51 CM & **topical workshop on New Horizons in TPC** **5-9 October 2020** <https://indico.cern.ch/event/889369/>

RD51 Internal Notes

The screenshot shows the RD51 Internal Notes interface. On the left, there's a sidebar with filters for 'Public', 'Private', and 'Documents'. The main area displays a list of notes with columns for 'Year', 'Title', and 'Author'. A note titled 'RD51-NOTE-2020-003 - Measurements of the charging up effect in Gas Electron Multipliers' is highlighted. To the right, a detailed view of this note is shown, including an abstract and a list of authors.

COMING SOON

5-9 October 2020

Remote



MPGD2019

Proceeding recently published:

<https://iopscience.iop.org/issue/1742-6596/1498/1>

More than 150 participants, more than 100 contributions, more than 50 peer-reviewed papers
 Major contribution and support from RD51
 RD51 in the conference committees
 RD51 promoting and supporting young speakers for review talks

MPGD 2021 @ Weizmann, MPGD 2023 @ USTC

02/09/2020

Workshops, Lectures, ...

DLC workshop (Feb. 2020)

-> Discussion about the possibility of enlarging existing production capabilities with a DLC coater at CERN



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

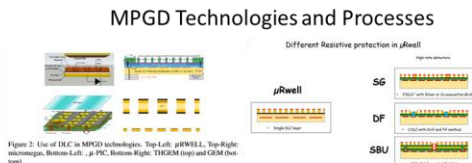
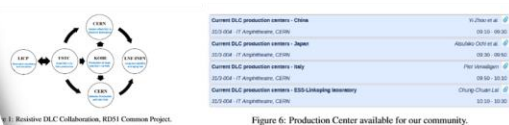


Figure 2: Use of DLC in MIPGD technologies. Top Left: μ RWELL, Top-Right: micromegas, Bottom-Left: μ -PC, Bottom-Right: THORM (logs) and GEM (cross-section)

Existing Research & Production Framework



Proposal for a machine at the CERN MPT workshop



RD51 Lectures (June 2020)



Five lecture sessions organized by R. Veenhof

One example: (Incredible) Remote Hands-on... by Josh Renner...

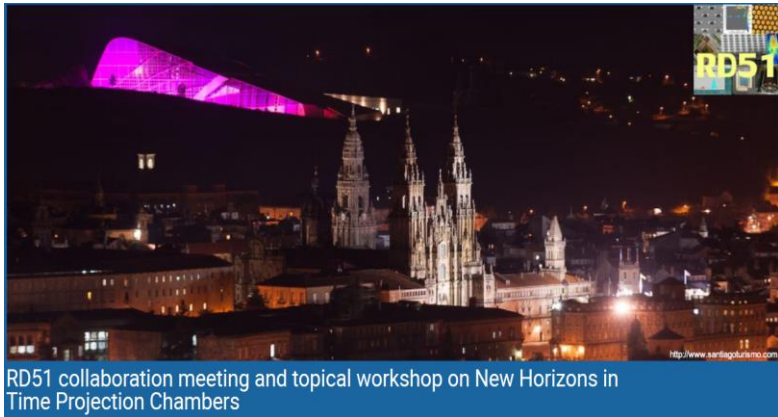
<https://indico.cern.ch/event/911950/>

Hands-on Open Source finite elements
Speakers: Josh Renner (CERN), CSC, Josthu Renner (CERN)

Simulations in Garfield++ with open source finite element calculations
The finite element method can be used to compute a numerical solution for the electrical potential in a detector using given the geometry and applied voltages. The main steps are:
1. Define the geometry
2. Mesh the geometry (discretize the space over which the geometry is defined)

Country	Count of Country
China	4
Czechia	1
Finland	1
France	7
Germany	1
India	9
Italy	4
Portugal	2
Spain	1
Switzerland	23
Turkey	1
United Kingdom	1
United States	3
TOTAL	58

RD51 collaboration meeting and Topical workshop on New Horizons in Time Projection Chambers (October 2020)



Organising committee

The meeting is organized by:

- D. González-Díaz (NEXT/DUNE), chair
- J. Benlliure (FAIR/LaserPET)
- D. Cortina (FAIR)
- A. Gallas (LHCb)
- J. A. Garzón Heydt (HADES)
- A. Saa-Hernández (NEXT/DUNE)
- M. Seco (technical support)



not only RD51
not only MPGD

A topical workshop on "New Horizons in Time Projection Chambers" will take place in parallel to the RD51 Collaboration Meeting, from Monday to Friday

The purpose of this workshop is to discuss upcoming developments and applications of TPCs, in relation with the current state of the art of this technological field. By bringing together specialists from the fields of direct Dark Matter detection and other Rare Event searches, Neutrino physics, Nuclear and Particle physics, and applied research, we are certain to bring a vibrant and inspiring atmosphere to the meeting.

<https://indico.cern.ch/event/889369>

Charge-based Scintillation-based Electroluminescent Active Targets Next-generation accelerator-based	Overview on electron transport Overview on scintillation Overview on ion transport Ion backflow mitigation Space-charge distortions
High pressure Low pressure Dual Phase	Dosimetry Medical applications
Charge amplification Charge-sharing Resistive-protection techniques Optical amplification and photodetectors Ion detection FE Electronics	New ideas Unusual geometries

Everyone is invited ("profiting" from the remote format) to follow and contribute

Common Projects

SUPPORTING “BLUESKY” IDEAS and RESEARCHES NOT DIRECTLY LINKED TO PROJECT THAT COULD HAVE DIFFICULTIES TO BE SUPPORTED ELSEWHERE

Active Projects

- **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 minimum number of participating institutes in the common project is 3, and **at least 3 institutes should be regular member of RD51 collaboration.**

Discharge Consortium in quest for Spark-Less-Avalanche-Microstructures, 2019, P. Gasik

Pixelated resistive bulk Micromegas with integrated electronics, 2019, F. Petrucci

Resistive materials and resistive-MPGD concepts & technologies, 2019, S. Bressler

Modular & General purpose Ultra Low Mass GEM Based Beam Monitors, 2018, G. Croci

DLC based electrodes for future resistive MPGDs, 2018, Y. Zhou

Study of negative ion mobility and ion diffusion for Negative Ion TPCs, 2018, A. Cortez

As well a tool for:

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

Clustering groups around new ideas

RD51 PICOSEC-MicroMegas Collaboration

- CEA Saclay (France): D. Desforge, I. Giomataris, T. Gustavsson, C. Guyot, F.J. Iguaiz, M. Kebbiri, P. Legou, O. Maillard, T. Papaevangelou, M. Pomorski, R. Schwemling, L. Sohl.
- CERN (Switzerland): J. Bortfeldt, F. Brunbauer, C. David, J. Frachi, M. Lupberger, H. Müller, E. Oliveri, F. Resnati, L. Ropelewski, T. Schneider, R. Thüner, M. van Stenis, R. Veenhof, S. White¹.
- USTC (China): J. Liu, B. Qi, X. Wang, Z. Zhang, Y. Zhou.
- AUTH (Greece): K. Kordas, I. Maniatis, I. Manthos, V. Ntaouris, K. Paraschou, D. Sampsonidis, S.E. Tzamarias.
- NCSR (Greece): G. Fanourakis.
- NTUA (Greece): Y. Tsiolitis.
- LIP (Portugal): M. Gallinaro.
- HIP (Finland): F. García.
- IGFAE (Spain): D. González-Díaz.

1) Now at Synchrotron Soleil, 91192 Gif sur Yvette, France
2) Also RD51 & USTC University
3) Also University of Virginia

VC12019, 20/2/2019

K. Ntoulas - RD51-PICOSEC

35

https://indico.cern.ch/event/716539/contributions/3246636/attachments/1798790/2933615/Kordas_PICOSEC_VC12019.pdf

2015 RD51 CP

Clustering groups working on the same fields to increase the impact

Resistive DLC collaboration

DLC Common project (2018-)

- UCP on the basis of theoretical calculation and simulation, give USTC team a guidance of the work
- USTC produce different bare DLC foils with different surface resistivity and also DLC foils with Copper coating (DLC-Cu)
- Kobe University produce large size DLC & DLC-Cu foils in order to study the reproducibility of the process turned on small prototypes and the uniformity of the surface resistivity of the DLC
- CERN study the behavior and changes of DLC properties under manufacturing processes foreseen for MPGD construction (i.e. µRREL, resistive GEM and TRGEM)
- INFN study stability of bare DLC properties under current drawing on bench (in irradiation)
- CERN produce detectors with DLC foils
- INFN perform aging and spark test of DLC based detectors (with different substrates)

https://indico.cern.ch/event/761832/contributions/3236762/attachments/1765980/2867435/DLC_CP_2018_181205_v2.pdf

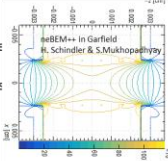
2018 RD51 CP

Modelling and simulation

neBEM interface available in Garfield++

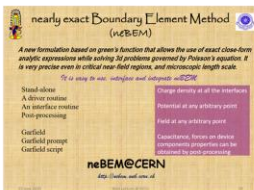


-----Original Message-----
From: Heinrich Schindler <Heinrich.Schindler@cern.ch>
Sent: Friday, July 17, 2020 3:27 PM
To: garfield-users (Users of Garfield detector : <garfield-users@cern.ch>
Cc: supratikmukhopadhyay.sinp@gmail.com
Subject: Garfield++/neBEM interface



Dear colleagues,
 we are happy to announce that a working version of the neBEM interface is now available in the master branch of Garfield++, including a number of examples illustrating its use:
<https://gitlab.cern.ch/garfield/garfieldpp/-/tree/master/Examples/neBEM>
<http://garfieldpp.web.cern.ch/garfieldpp/examples/nebem/>

Please note that we had to add GSL (<https://www.gnu.org/software/gsl/>) as an additional prerequisite to build the project.
 We hope that you will find the tool useful for your applications and are looking forward to your feedback.
 There is still some room for improvement (in particular in terms of performance optimisation); if you have any suggestions please do let us know.
 Best regards,
Supratik, Rob, Heinrich



https://indico.cern.ch/event/911950/contributions/3898133/attachments/2062186/3459881/BE_Mlectu_reRD51_Supratik.pdf

Garfield++ and delayed weighting fields in the calculation of the induced signal

Implementing delayed weighting fields in GARFIELD++

NB.. RD50, not RD51...
 IMPACT on several communities, not only MPGD

J. Hasenbichler, W. Riegler, H. Schindler, A. Wang

RD50 Workshop, 13 June 2019

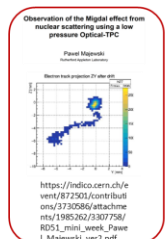
R&D framework and tools cross technologies and can boost synergies

- Summary and outlook
- GARFIELD++ is a toolkit that can be used for the detailed simulation of silicon sensors.
 - We have implemented the calculation of induced signals in resistive geometries based on the delayed weighting field formalism.
 - Some optimisation in terms of speed and accuracy remains to be done.
 - As a next step, apply the method to realistic devices.



New EP-RD PHD students working on this field of research with the goal of testing realistic devices and clustering groups of our community

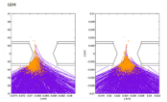
Garfield++ & modelling the photon production



Several research lines (2019) interested in MPGD readout optically.
 Large interest in the photon production processes..

Previous studies (2010) implemented and available in our modelling framework

Electroluminescence
<http://garfieldpp.web.cern.ch/garfieldpp/examples/electroluminescence/>



Collaboration grants collaborative developments and sharing of "common tools" developed by individual groups but made available for everyone, even after several years...

Source files
 • The program `example3` calculates the number of VUV production in a uniform electric field.
 Contact
 Carlos Oliveira (carlosoliveira.cas@cern.ch)

Modelling Ions

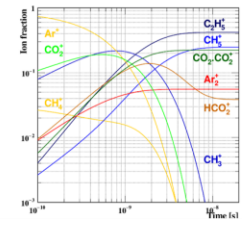
Simulating ion motion

▶ Lines found in most Garfield++ avalanche programs:

// Load the ion mobilities.
 gas->LoadIonMobility("als/cern.ch/user/rjrd/GemGain/Charge/mob_Ar_Ar+");

Evolution in Ar-CO₂-CH₄ (90-7-3)

- ▶ Initial ions: Ar⁺, CO₂⁺, CH₄⁺, Ar₂⁺, CO₂⁺, CO₂CO₂⁺, CH₄⁺, HCO₂⁺, CH₂⁺, CH₃⁺, HCO₂⁺, HCO₃⁺, CH₂CO⁺, CH₃⁺, C₂H₅⁺



▶ What do they do ?

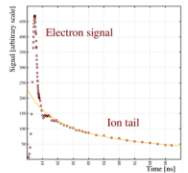
▶ Why are they often inappropriate ?

▶ Detectors like Micromegas and wire chambers get their signal mostly from ion motion.

- ▶ Hence we better know the basics of ions:
 - which ions are produced in the avalanche ?
 - which ions generate the signal ?
 - how fast do the ions move ?
 - are they subject to diffusion ?

Atlas TRT signals

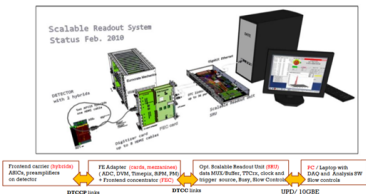
- ▶ Data: Xe-CO₂-CF₄ 70/10/20
- ▶ Straw tube V_d=1530 V
- ▶ r_d = 15 μm, r_g = 2 mm
- ▶ Fit: 1/(t+t₀)



[Data from POSITIVE ANATOMICAL CONTOURING]

<https://indico.cern.ch/event/911950/contributions/3898152/attachments/2063565/3463197/ions-mu.jui>

Focused on: Scalable Readout System (SRS) & BNL VMM3a



- Interface of the RD51 SRS with the BNL VMM3a FE ASIC
 - Overview
 - Production and procurement
 - Laboratory and beam measurements
 - RD51 Sub-working group WG5.1 focused on SRS/VMM

H. Muller

https://indico.cern.ch/event/843711/contributions/3613180/attachments/1931440/3199037/New_SRS_Hardware_.pdf

Logically following the large (more than expected) success of the RD51 SRS/APV25 developments where the system has been used for:

- generic R&D (several lab. and beam campaign, not only RD51 test beam),
- medium and large scale experiments (e.g. PRAD@JLAB),
- LHC upgrades (e.g. R&D for ATLAS mm NSW, QA for CMS GEM)

“Remarkable” laboratory tests

Past year results using proto-systems:
Laboratory (x-ray) Measurements

Fluorescence Processes

Fig. 1. Illustration of different fluorescence processes of an Fe K α photon γ with a gas atom. (a) Shows a single electron, the liberation of a photoelectron (h ν) followed by the emission of one or more Auger electrons (h ν) close to the initial interaction. (b) Shows another type of single electron, the liberation of a photoelectron followed by the emission of a fluorescence photon γ , which triggers the detector. (c) Shows a double electron process in which the fluorescence photon does not escape the detector, but interacts in the gas volume liberating another photoelectron (h ν).

Drift velocities measurement

Fig. 9. Electron drift velocity as a function of the electric drift field for ArCO₂ (90/90). 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 $\pm 1\sigma$ of the error function from the fit of (1).

Imaging (high rate)

Fig. 4. Energy spectra, showing the total measured X-ray spectrum and the spectrum of the double cluster events for 10⁷ Fe at E₀ = 3.581V/cm, D0 = 700 at E₀ = 1.271V/cm and for copper at E₀ = 1.254V/cm.

Space resolution

Fig. 5. Space resolution as a function of the position. The plot compares the results of a simulation with 'No Hardware Features' and 'Neighbouring Logic'. The resolution is $\sigma_{\text{total}} = 193 \mu\text{m}$ and $\sigma_{\text{neighbouring}} = 164 \mu\text{m}$.

Sauli's bat

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>

<https://indico.inp.nsk.su/event/20/contributions/809/attachments/553/638/mstr20-lucian-scharenberg.pdf>

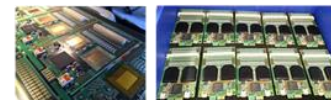
Hardware available soon for the community

Production

Successful pre-production using CERN facilities



Large involvement in design, pilot production and debugging from SRS Technology



First large production totally outside CERN



Passive cooling and DVMM card

<https://www.srstechology.ch/>

Firs fully commercial production done via SRS-Technology spin-off.

New and large production ongoing.

CERN support needed to integrate it in CERN store (as it is for SRS/APV25)

Scalable Readout System (SRS) and VMM3a (BNL) ASIC WG5.1 sub-working group

Synchronise activities and developments related to RD51's Scalable Readout System and its integration of the VMM3a ASIC Group people and institutes who are interested in next-generation readout electronics for MPGDs and exchange on developments and research interests:

- Common developments on firmware, software and hardware (improvement of existing SRS hardware, development of auxiliary devices and components)
- Provide the developments from the community to the community!
- Coordination of hardware production and testing with CERN KT Spin-Off: SRS Technology

Clustering RD51 member for common developments

Supported by RD51 + individual RD51 groups + AIDA2020 resources. Included in AIDAInnova (DAQ and test beam WP)

Firmware

Software

Testing SW/HW, procedures

VMM3a/SRS Developer Meeting

Calendar

VMM3a/SRS Developer Meeting

Calendar

154/R-007 GDD Laboratory



EP-DT-DD Gas Detector Development (GDD) lab

Common facility at CERN for the collaboration to perform detector R&D (design, mounting, testing and measuring). Technical (detector, electronics, instrumentation,..) and scientific (meetings, links, collaboration,..) support. Support during the RD51 test beam campaign. Access to technical CERN facilities. Close to Micro Pattern Technology Workshop and Thin Film and Glass laboratory. **Vital and important support from CERN (EP-DT) on maintenance and operation.**

- Expertize and links
- Equipment
- Close to MPT workshop
- Close to North Area Test beam



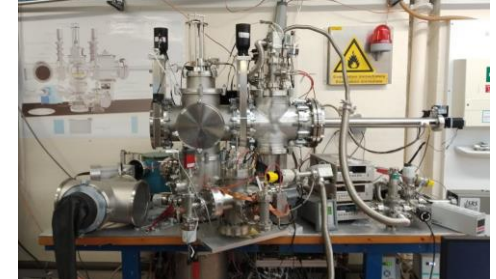
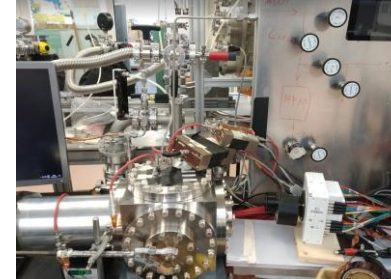
Clean Room



Irradiation



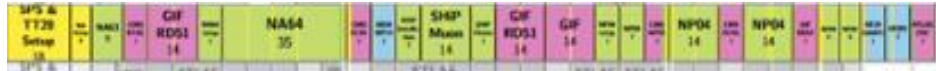
Charge and Optical readout



UV photocathode
characterization

Semi Permanent Test Beam Installation (H4A)

About three periods of two weeks each per year with more than 10 setup running in total. Since few years beam time shared with GIF++



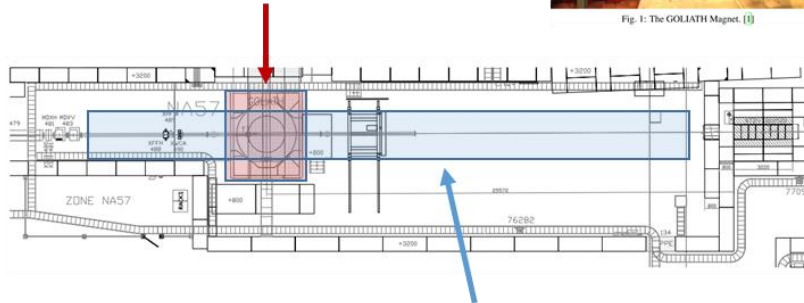
H4 it's a very Crowded Line, but..

GOLIATH magnet (1.5T, about 3Tm, Opening: about 1m height and 2.4m wide)

<https://cds.cern.ch/record/2310483/files/CERN-ACC-NOTE-2018-0028.pdf>



Fig. 1: The GOLIATH Magnet. [1]



SPACE to allows the operation of several setup in parallel



SERVICES (gas, power, signals, supports) organized in several years of works done together with the North Area teams.

Efforts from SPS to give us beam time recognized and appreciated.

Upgrading the common infrastructures (tracker)

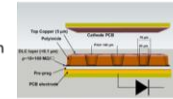
A new tracker out of several new developments

New FE ASICs: VMM3A (BNL)



<https://cds.cern.ch/record/2309951/files/ATL-MUON-PROC-2018-003.pdf>

New Development on MPGD technologies

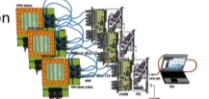


<https://arxiv.org/pdf/1903.11017.pdf>

New Detector Technology: μ RWELL

New Developments on multichannel readout ASICs: VMM3A

New Development on MPGD multichannel Readout System: SRS/VMM interface



<https://doi.org/10.1016/j.nima.2018.06.046>

New Interface (VMM3) for the SRS

One example of an existing common tracker: micromegas & SRS/APV25



Important investment (about 40kCHF in total) of resources from the collaboration.

New common tracker available

Additional Support may come from AIDAInnova test beam and DAQ WP

Waiting for the beam to be back...

CERN MPT Workshop

Secured future of the MPGD technologies development

R&D

Several ongoing R&D lines (here resistive layers and detectors based on DLC as one example)

DT Training Seminars

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

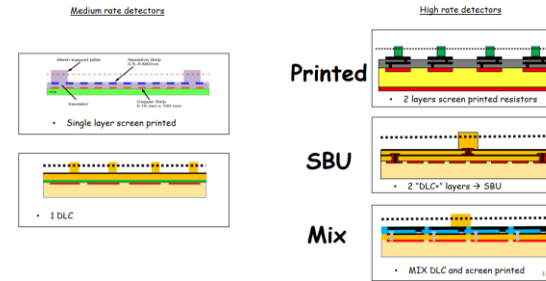
by Alexis Rodrigues (CERN), Antonio Teixeira (CERN), Olivier Pizzirusso (CERN), Rui De Oliveira (CERN)

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

32/1-A24 (CERN)



Different Resistive protection approach with Micro-Megas



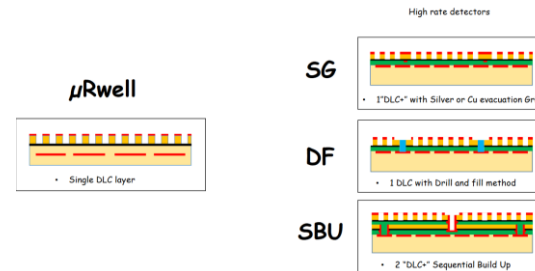
https://indico.cern.ch/event/872501/contributions/3723342/attachments/1986258/3309780/Processes_and_problems.pdf

In synergy with:

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

- UV exposure up to 2.2m x 1.4m
 - Resist developers, stripper, etcher, dryer up to 1.2m width
 - GEM electro etch up to 2m
 - GEM polyimide etch up to 2m
 - Ovens up to 2.2m x 1.4m
 - Laminator up to 1.2m
- **GEM up to about (2x0.5)m², mm up to (2x1)m²**

Different Resistive protection in μ Rwell



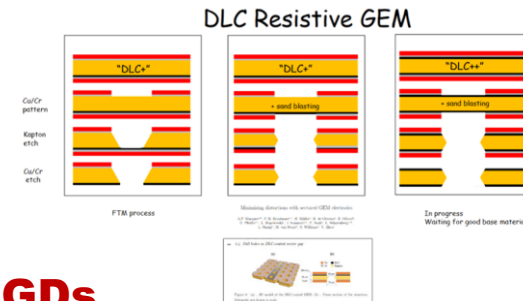
DLC Community Contributions from RD51 Common Project



<https://indico.cern.ch/event/872501/contributions/3723338/attachments/1985981/3509025/DLC%20community%20contributions%20from%20RD51%20common%20project-TV.pdf>

Almost all families of MPGD produced...

GEM, THGEM, MM-THGEM, Micromegas, mRWELL, RPWELL, DLC with MPGDs, ...



Production



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

GEM production for ALICE GEM TPC and CMS GE1/1



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

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.

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 ...

Industrialization

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

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 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 x 30cm 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

GEM Licenses signed by:

- Mecharonix, 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

MicroMegs Technology(contacts):

- ELTOS S.p.A. (Italy)
- TRIANGLE LABS(USA, Nevada)
- SOMACIS (Italy, Castelfidardo)
- ELVIA (France, CHOLET)

MICROMEAS industrialization status (today):

ELVIA

- Bulk MM detectors are routinely produced with size up to 50x50cm²
- production for ATLAS NSW started

ELTOS

- Several small-size 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

Some lessons learned:

- Industrialization possible if large **involvement** from **large project**
- Important to **involve the industrial partner from the beginning** (see μ RWELL with ELTOS, Techtra already in initial R&D phase)

RD51 is a framework

to support and advance technological developments and applications of Micro Pattern Gas Detectors

where

each member group, with its own identity, will perform its own research (a few examples in the next slides)

MPGD technologies and Dissemination

Past Year Highlights from RD51 Working Groups Activities

Material from: P. Colas (CEA Saclay), F. Resnati (CERN), F. Brunbauer (CERN), F. Garcia (Helsinki Institute of Physics), R. Veenhof (CERN), O. Sahin (Uludag University), P. Verwilligen (Universita e INFN, Bari)

@ CERN, LHC upgrades

(June 2020 RD51 CM)

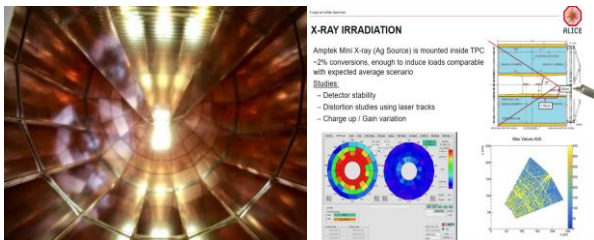
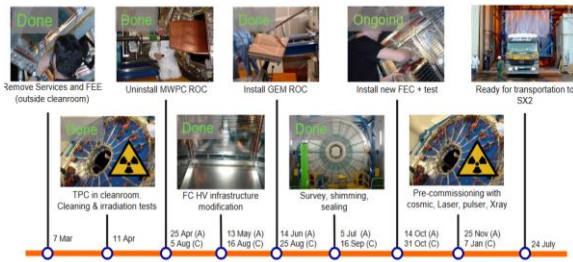
THE UPGRADE OF THE ALICE TPC

Robert Muenzer
RD 51 Week
23.06.2020

LARGE HADRON COLLIDER EXPERIMENT



TPC UPGRADE SEQUENCE



https://indico.cern.ch/event/911950/contributions/3876016/attachments/2061878/3459117/2020_06_18_ALICE_TPC_2.pdf

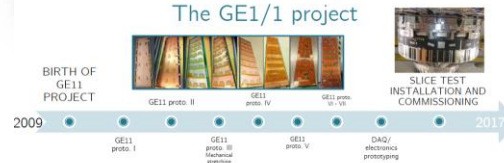
RD51 Mini-Week, 22-26 June 2020

Update on GE11 construction and commissioning

Federica Simone¹ on behalf of the GEM group

¹University and INFN Bari, Italy

RD51 Mini-Week, 22-26 June 2020

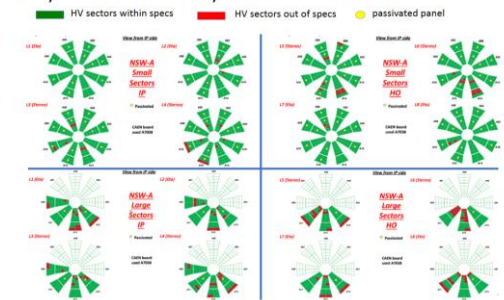


https://indico.cern.ch/event/911950/contributions/3876019/attachments/2061863/3458939/fsimone_GE11status_RD51.pdf

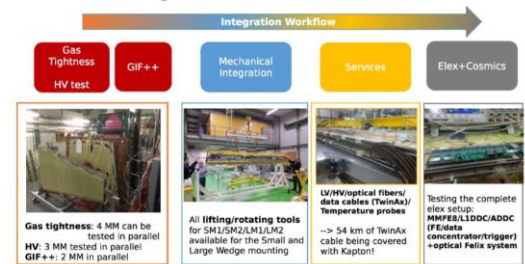
MICROMEGAS production status

M. Antonelli LNF-INFN for the ATLAS collaboration (nSW Team)

Summary on HV-stability for NSW-A chambers



NSW MM integration activities



https://indico.cern.ch/event/911950/contributions/3876018/attachments/2062109/3459460/MMstatus_RD51.pdf

@ CERN, beyond LHC

MPGD 2019

The MPGD-Based Photon Detectors for the upgrade of COMPASS RICH-1 and beyond

S. Dalla Torre
INFN - TRIESTE
on behalf of the COMPASS RICH group

SUMMARIZING ...

- MPGD-based photon detectors ACCOMPLISH THEIR MISSION in COMPASS RICH-1
 - From preliminary characterization exercises: stable gain, large gain, good number of detected photoelectrons
- Technological achievement - for the **FIRST TIME**:
 - single photon detection is accomplished by MPGDs
 - THGEMs used in an experiment
 - First resistive MM used in an experiment
 - For the first time MPGD gain > 10k in an experiment
- MPGD-based photon detectors have a **mission in the future of hadron physics**

[https://indico.cern.ch/event/757322/contributions/3384483/attachment/1838733/3013796/dallatorre_MPGD2019.pdf](https://indico.cern.ch/event/757322/contributions/3384483/attachments/1838733/3013796/dallatorre_MPGD2019.pdf)

Oct. 2019 RD51 CM

Commissioning of ProtoDUNE-DP (NP02) & LEM Development

Edoardo Mazzucato CEA/INFN/DPHP

Installation of CRPs inside the NP02 cryostat (Jan. - Feb. 2019)

Event Gallery

So far > 130 TB and > 10⁶ triggers

Horizontal muon track
 $E_{LEM} = 31 \text{ kV/cm}$ $P = 1010 \text{ mbar}$

Electromagnetic shower + two muon decays
 $E_{LEM} = 31 \text{ kV/cm}$ $P = 1010 \text{ mbar}$

Multiple hadronic interactions in a shower
 $E_{LEM} = 32 \text{ kV/cm}$ $P = 1010 \text{ mbar}$

Waveform for ch. 1170
Low noise 1 ADC=900 e⁻
Charge \propto to integral of waveform

https://indico.cern.ch/event/843711/contributions/3575916/attachments/1930481/3197221/edoardo_2019_10_22.pdf

@ CERN, new proposals

μ -RWELL for the upgrade of Muon Apparatus @ LHCb

Detector requirements:

- Rate > 1 MHz/cm² on detector single gap (innermost region)
- Rate per electronic channel up to 700 MHz
- Max input capacitance (double gap) $\leq 100 \text{ pF}$
- Efficiency (double gap) > 97% within a BX (25 ns)
- Long-term stability up to 2C/cm² accumulated charge in 10 y of operation (M2R1 with detector operated at G = 4000)
- Pad cluster size < 1.2 (innermost region: pad size $3 \times 8 \text{ mm}^2$)

Detector size:

- R1-R2: 288 detectors, size 30×25 to $74 \times 31 \text{ cm}^2$, 45 m² det. active area \rightarrow high rate
- R3: 384 detectors, size 120×25 to $149 \times 31 \text{ cm}^2$, 145 m² det. active area \rightarrow low rate
- R4: 1536 detectors, size 120×25 to $149 \times 31 \text{ cm}^2$, 582 m² det. active area \rightarrow 831 m² DLG

Proposed solution:

The μ -RWELL composed of two elements: the μ -RWELL_PCB & the cathode

The μ -RWELL_PCB is realized by coupling:

- a WELL patterned Apical® foil acting as amplification stage
- a resistive layer for discharge suppression w/ surface resistivity $\sim 50 \div 100 \text{ M}\Omega/\square$
- a standard readout PCB with pad readout

https://indico.cern.ch/event/872501/contributions/3723333/attachments/1986092/3309414/Resistive_MPGDs-RD51-mini-week-Feb-2020.pdf

GEM stack optimization for GE21 and MEO (cross-talk studies, discharge mitigation)

Jeremie A. MERLIN
RD51 Collaboration Meeting
June 24, 2020

https://indico.cern.ch/event/911950/contributions/3879507/attachments/2062838/3460906/JMerlin_Xtalk_18052020_V2.pdf

New GEM Tracking Detectors for COMPASS++/AMBER

Karl Jonathan Flöethner*, Christian Honisch, Michael Höfgen, Michael Lupberger, Emorfili Torzimpasoglou, Markus Ball, Bernhart Ketzler
Helmholtz-Institut für Strahlen- und Kernphysik
University of Bonn

AG Ketzler

UNIVERSITÄT BONN

*floethner@hiskp.uni-bonn.de

https://indico.cern.ch/event/911950/contributions/3910311/attachments/2062117/3459474/Floethner-CompassGEM-RD51-2020_06_23.pdf

+ ...

Micromegas: fast and precise timing

PICOSEC detection concept

Precise timing with Micromegas

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

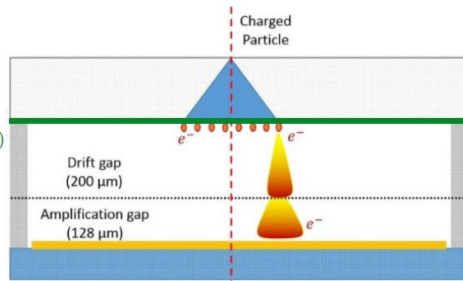
J. Bortfeldt et. al. (RD51-PICOSEC collaboration), Nuclear. Inst. & Methods A 903 (2018) 317-325

Cherenkov radiator
(3 mm MgF₂)

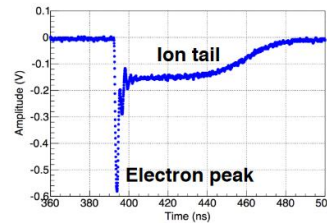
Photocathode
(3 nm Cr + 18 nm CsI)

Drift gap
(Pre-amplification)

Micromegas
(Amplification)



Gas mixture: 80% Ne + 10% C₂H₆ + 10% CF₄
(COMPASS gas)

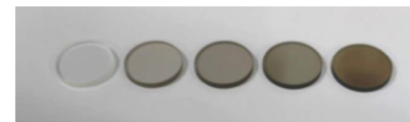
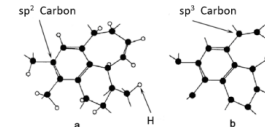


- **Signal with two distinct components:**
- Electron peak: fast (≈ 0.5 ns)
- Ion tail: slow (≈ 100 ns)

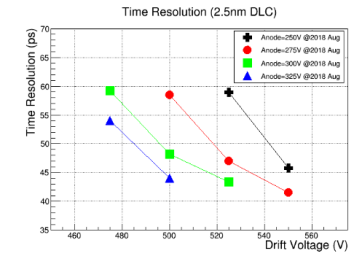
Photocathodes: DLC

Diamond-like carbon (DLC) is a robust material which may also be used as photocathode.

First beam tests show ≈ 3.5 pe/ μmion and 40-45 ps achievable time resolution



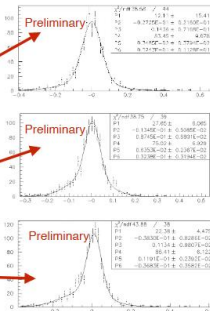
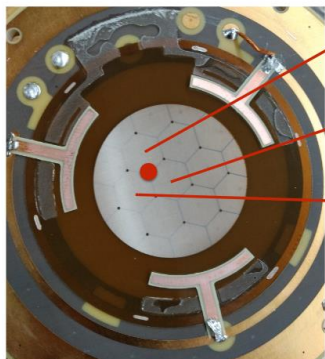
<https://indico.cern.ch/event/709870/contributions/3020982/attachments/1672821/2684487>



<https://indico.inp.nsk.su/event/20/contributions/925/attachments/541/626/PicoSecINSTR20.pdf>

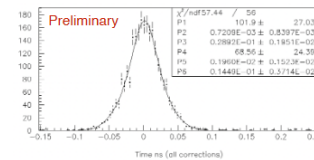
Large-area coverage

Scaling up multi-channel PICOSEC



Multiple pads hit:
70 ps / 86 ps / 81ps timing resolution
Combined: 31 ps timing resolution

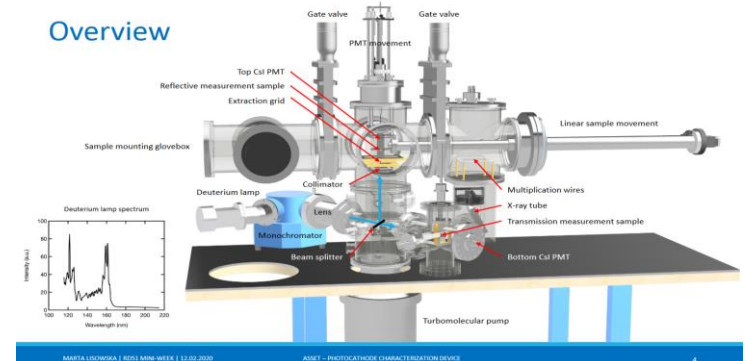
28



Single pad hit:
25 ps timing resolution for all pads

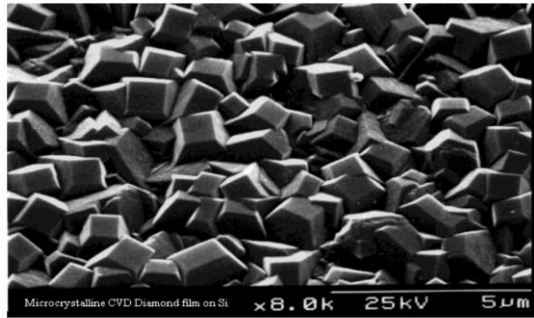
<https://indico.cern.ch/event/716539/contributions/3248636/>

Overview



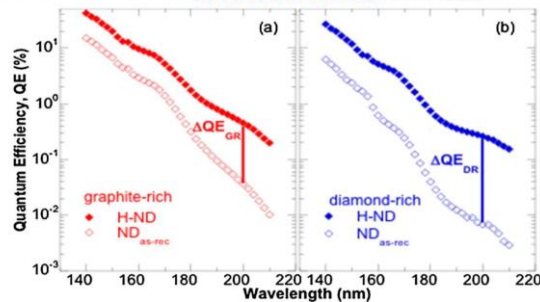
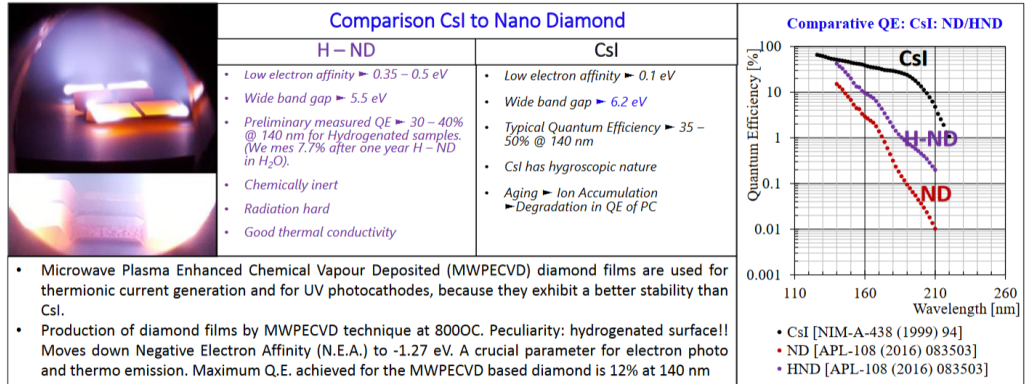
https://indico.cern.ch/event/872501/contributions/3726017/attachments/1985809/3308869/Marta_Lisowska_-_RD51_Mini_Week_-_Asset_photocathode_characterisation_device.pdf

Photocathodes: in timing (previous slide) and RICH



RD51 Mini-Week 10 -13 Feb. 2020 at CERN - A. Valentini

Why and which Nano Diamond



G. Cicala et al. Colloids and Surfaces A - April 2017

RD51 Mini-Week 10 -13 Feb. 2020 at CERN - A. Valentini

Pulsed spray thin film coating setup: No of Shots determine the coating thickness

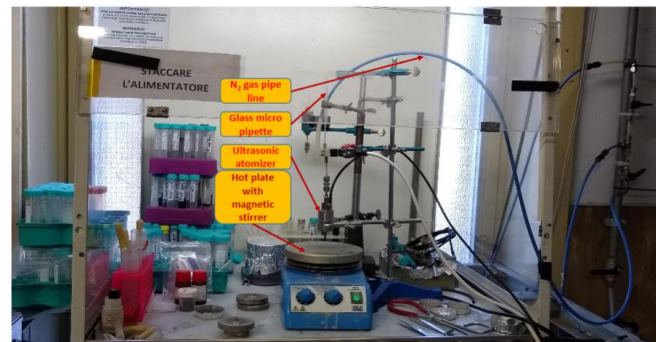


Figure : The pulsed spray technique for thin film coating, equipped with an ultrasonic atomizer and with a heater at INFN Bari, Italy

11/02/2020

Triloki (On behalf of INFN Trieste & INFN Bari collaboration)

Preliminary results of ND Photocathode coupled to THGEMs

S. Dasgupta and Triloki
On Behalf of a INFN, Trieste & INFN, Bari collaboration

Outline

- Motivation
- QE Setup in Bari
- QE measurement in Bari
- ASSET @ CERN
- Preliminary measurement with ASSET
- Conclusion

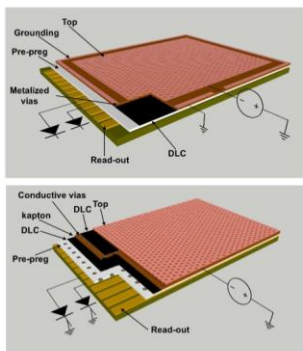
13/02/2020

Triloki (On behalf of INFN Trieste & INFN Bari collaboration)

https://indico.cern.ch/event/872501/contributions/3740114/attachments/1984715/3306637/RD51_Miniweek_Valentini.pdf

https://indico.cern.ch/event/872501/contributions/3728175/attachments/1985788/3308781/Triloki_NanoDiamond_RD51_20200212.pdf

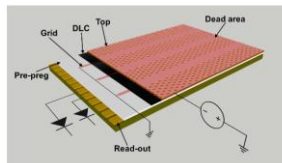
μRWELL: High Rate Layouts



SRL: 2-D current evacuation scheme based on a single resistive layer with a conductive grounding all around the perimeter of the active area.

DRL: 3-D current evacuation scheme based on two stacked resistive layers connected through a matrix of conductive vias and grounded through a second matrix of vias to the underlying readout electrodes (Rui).

Detector parameters (II)



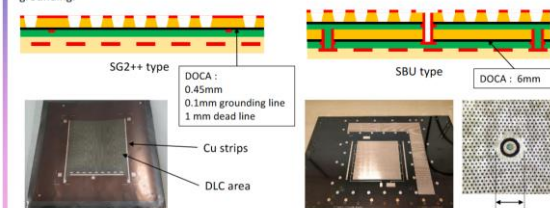
SG: 2-D current evacuation scheme based on a single resistive layer with a suitable conductive grounding grid realized on the DLC layer.

Since the presence of the conductive grid on the DLC can induce instabilities to the detector due to the discharge occurring over the DLC surface, a small dead zone in the amplification stage (a no-hole area) must be introduced.

This current evacuation scheme, besides the surface resistivity of the DLC, is then characterized by the *pitch* of the conductive grid and the *DOCA*, correlated with the *dead_zone* ($dead_zone = 2 \times DOCA + line_width$). The SG is a very simple HR layout allowing an easy TT to industry.

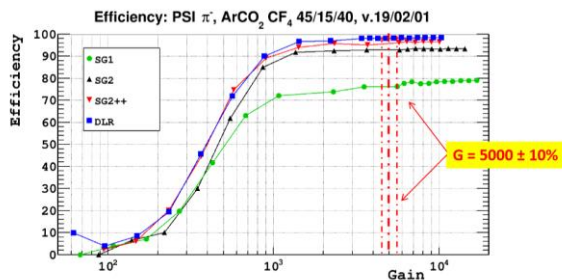
High-rate layouts of μRWELL

- SG2++ type** (Cu grid): The copper clad on the DLC is etched to conductive grounding lines by photolithography.
- SBU type** (Sequential Build Up): Current evacuation achieved by two stacked DLC layers. Matrix of conductive vias manufactured with SBU technology are used to connect DLC layer and grounding.



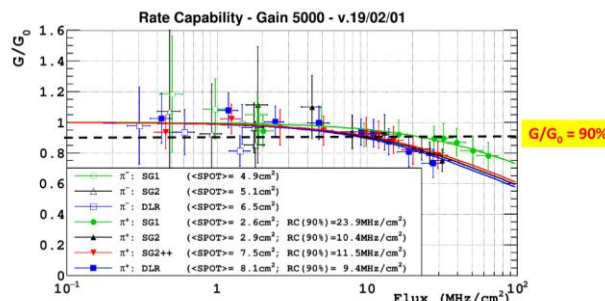
Copper-coated DLC needed to make conductive grounding lines and vias.

HR layouts performance: efficiency



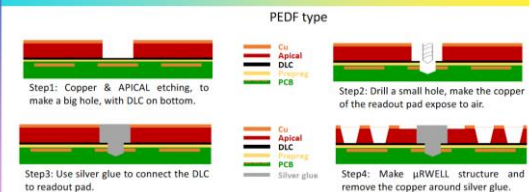
The **DRL prototype** reaches a **full tracking efficiency > 98%** (NO DEAD ZONE). The **SG1, SG2 and SG2++** show lower efficiency (76% -94% - 9%) BUT **higher than their geometrical acceptance** (66% - 90% - 95% respectively), thanks to the **efficient electron collection mechanism that reduces the effective dead zone**.

HR layouts performance: rate capability



A gain drop of 10 % is largely acceptable since does not affect the detection efficiency (see previous slide).

Novel idea (PEDF type)



Advantages:

- No copper-coated DLC needed, better resistivity control;
- No alignment problems even goes to large area;
- Larger contact area between DLC and silver glue, improving the connection.

Detector plan:

- A small-pad readout μRWELL with sensitive area of 5cm X 5cm was designed;
- If it is OK for small pad, then we will use this method to make a large area μRWELL;

https://indico.cern.ch/event/911950/contributions/3912037/attachments/2064317/3464019/RD51_report_USTC_You_Guofeng.pdf

GEM and Optical Readout, TPC

CYGNO PROJECT

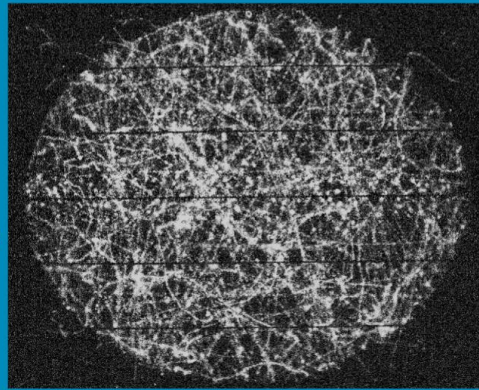
The aim of CYGNO project is the development and realisation of a **GEM-based Optically Readout Time Projection Chamber** for the study of rare events with energy releases in the **range 1-100 keV**.

Expected performance is:

- High **detection efficiency** down to **1 keV**;
- **Directionality** at **10 keV**;
- Background **rejection below 10 keV**;

Main ideas of the technology are:

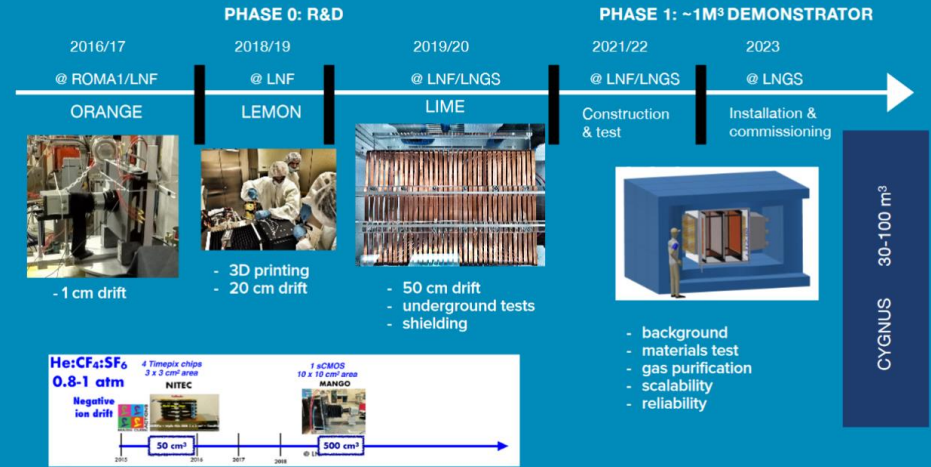
- **He/CF₄** based gas target (atmospheric pressure);
- **GEM** amplification stage;
- **Combined optical readout** CMOS + PMT;



D. Pinci - INFN Roma - RD51 Coll. Meet.

2

PROJECT PHASES

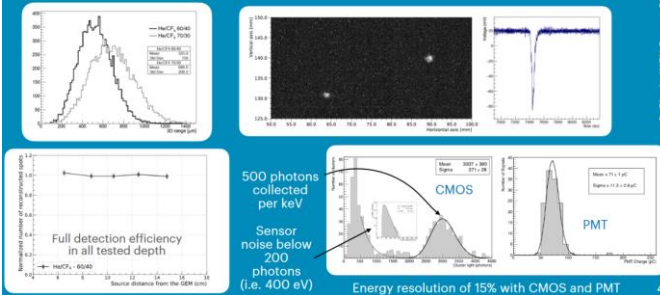


D. Pinci - INFN Roma - RD51 Coll. Meet.

3

PERFORMANCE WITH ⁵⁵FE: SPOT SIGNALS

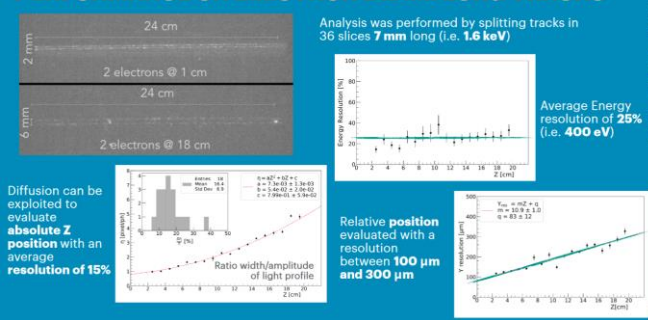
5.9 keV photons from ⁵⁵Fe source were used to test detection efficiency and light yield.



D. Pinci - INFN Roma - RD51 Coll. Meet.

4

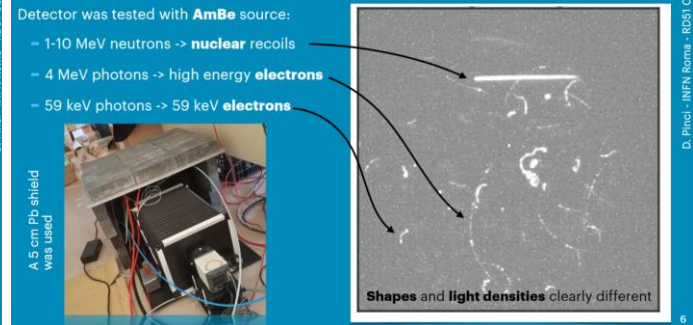
PERFORMANCE ON ELECTRON BEAM: LONG TRACKS



D. Pinci - INFN Roma - RD51 Coll. Meet.

5

PERFORMANCE WITH NUCLEAR RECOILS

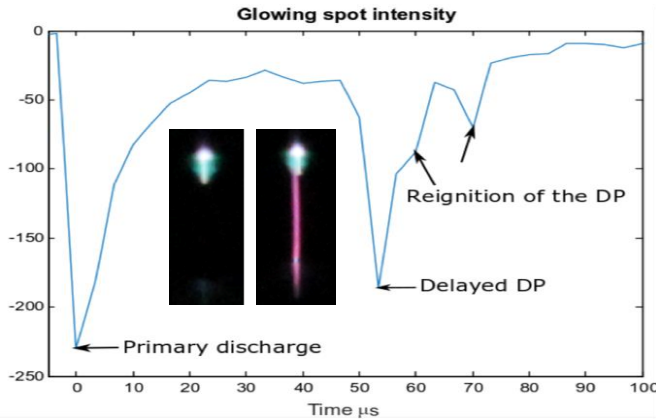


D. Pinci - INFN Roma - RD51 Coll. Meet.

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https://indico.cern.ch/event/911950/contributions/3879503/attachments/2062895/3461258/pinci_CYGNO_RD51.pdf

GEM and discharge studies

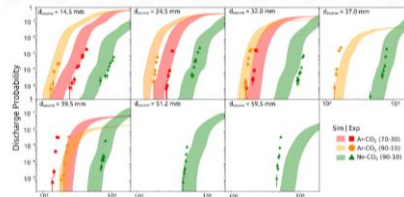


Correlation of electronic discharge signals with **high speed optical images** show sustained glow (thermionic emission) before secondary discharge

https://indico.cern.ch/event/757322/contributions/3396497/attachments/1839679/3015585/MPGD_delayed_DP.pdf

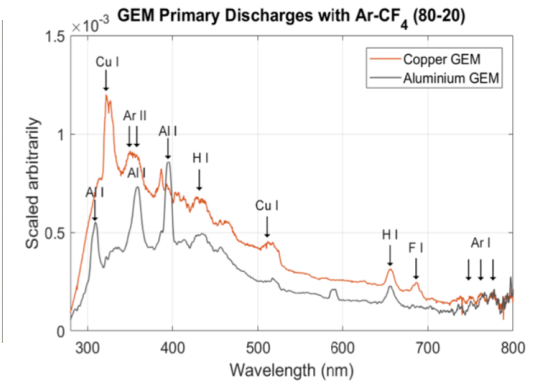
Charge density limits for discharge formation in THGEM structures: measurement and simulations

Lukas Lautner, L. Fabbietti, P. Gasik, A. Mathis, B. Ulukutlu, T. Klemenz, T. Waldmann
Dense and Strange Hadronic Matter Group
Technical University of Munich
RD51 Collaboration Meeting 2020



- Fairly good agreement between simulation and measurement
- Same Model used for GEMs & THGEMs & different gas mixtures

https://indico.cern.ch/event/911950/contributions/3911479/attachments/2063733/3462814/RD51_LukasLautner_25062020.pdf



Spectroscopic discharges studies of different GEM electrode materials (Cu, Al, Mo) show evaporation of metal and varying secondary discharge probability

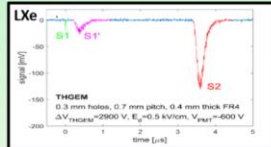
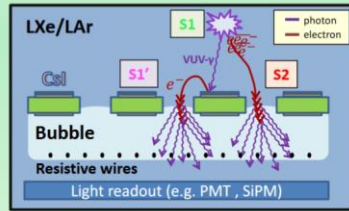
https://indico.cern.ch/event/843711/contributions/3571064/attachments/1930670/3197610/RD51_collaboration_meeting19_Berkin_U.pdf

THGEM & cryogenic: Gas Amplification in Trapped Bubbles

The concept – LHM physics

Radiation-induced electroluminescence from a bubble trapped in noble liquid

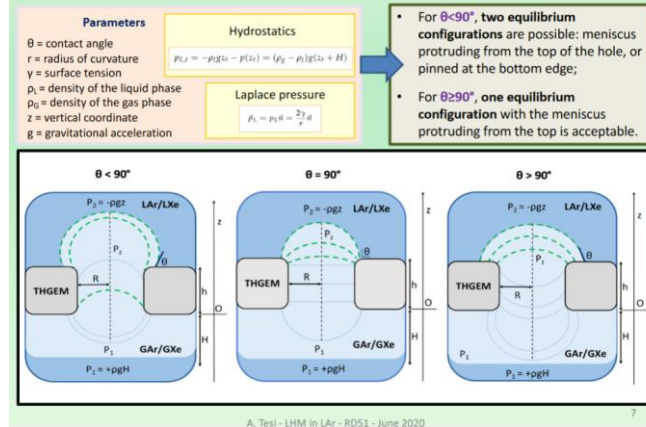
- **S1** – Primary scintillation light due to de-excitation;
- **S1'** – Electroluminescence induced by a single photoelectron extracted from the photocathode;
- **S2** – Electroluminescence induced by ionization electrons extracted from the liquid and transferred into the gaseous phase towards the THGEM bottom.



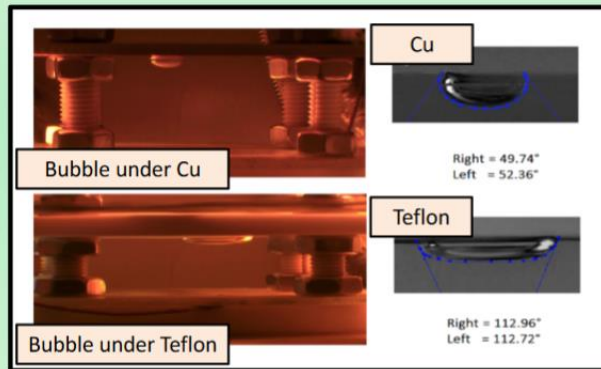
Note that, if E_p is implemented, electrons can travel through the bubble reaching the wires.

L. Arzi et al. 2015 *JINST* 10 P08015 [arXiv:1505.02316]
E. Erdal et al. 2015 *JINST* 10 P11002 [arXiv:1509.02354]

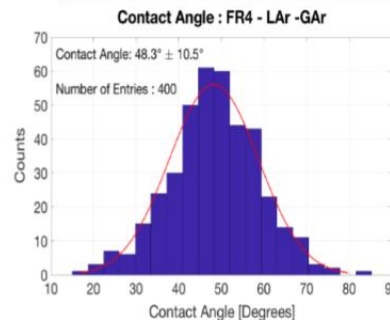
Theoretical Model



Contact Angle Measurements



FR4 – Example of fitted distribution



Material	Measured θ	Behaviour
Copper	$45.5^\circ \pm 8.5^\circ$	Argon-philic
FR4	$48.3^\circ \pm 10.5^\circ$	Argon-philic
Teflon	$108^\circ \pm 6.5^\circ$	Argon-phobic
Kapton	$59.3^\circ \pm 9.3^\circ$	Argon-philic

Results of the characterizations

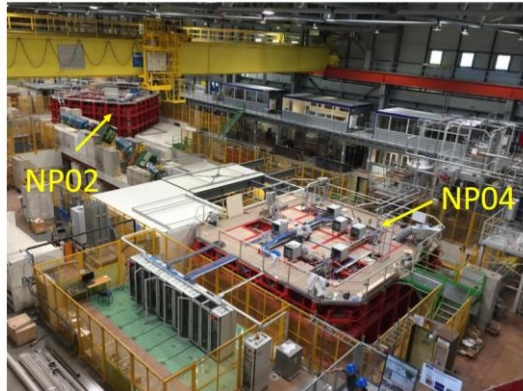
- 1000 frames/sample;
- Image selection and reconstruction using "DropSnake" – at the end: 400 points/sample;
- Fit of the resulting distribution → dynamical contact angle!!

A. Tesi - LHM in LAr - RD51 - June 2020

THGEM & cryogenic: NP02 - Dual Phase Proto Dune

ProtoDUNEs @ CERN EHN1

- Two large (> 700 t) LArTPC prototypes built at the CERN Neutrino Platform.
- LAr technologies for the future DUNE 10kt v FD modules in U.S.A.:
 - ProtoDUNE-SP or NP04 (single phase) in operation since Sept. 2018.
 - ProtoDUNE-DP or NP02 (dual phase) in commissioning phase since Aug. 2019.



22/10/2019

RD51 Collaboration Meeting

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Installation of CRPs inside the NP02 cryostat

(Jan. – Feb. 2019)



22/10/2019

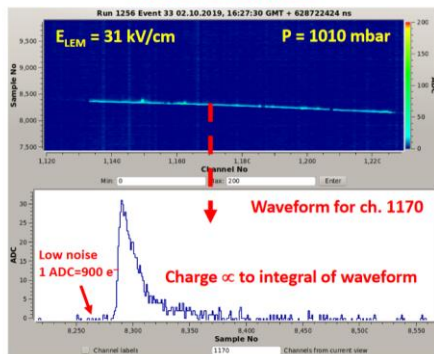
RD51 Collaboration Meeting

4

Event Gallery

So far > 130 TB and > 10⁶ triggers

Horizontal muon track

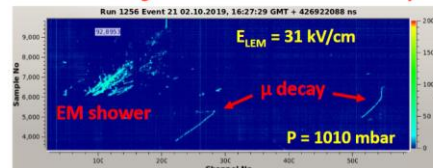


22/10/2019

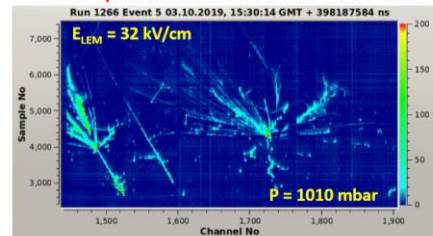
RD51 Collaboration Meeting

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Electromagnetic shower + two muon decays

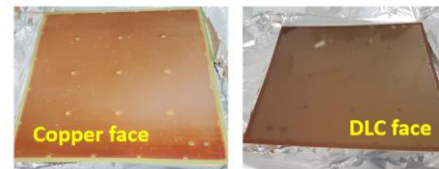


Multiple hadronic interactions in a shower



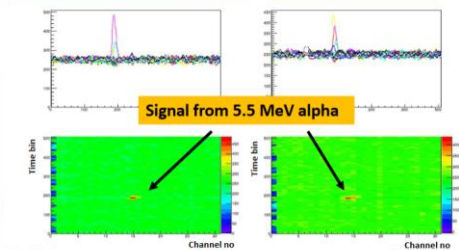
Resistive LEM

- Resistive 50x50 cm² LEM prototype made at CERN:
 - copper side facing readout anode
 - DLC on 50 μm APICAL polyimide film
 - same geometry as CFR-35 (ProtoDUNE-DP)
 - no rims, no gold plating on copper face.
- Tests in progress at CEA/Irfu.



22/10/2019

RD51 Collaboration Meeting



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Summary and conclusions

Summary (1/3)

- In the Third five-year Term (2019-2023), new membership applications in the past year (8), almost 90 institutes in total as of today.
- Contributions to international scientific studies (e.g. EPPSU, CPAD, Snowmass21)
- Good synergy with the CERN EP RD program. Well represented in AIDAInnova.
- Updated information at the new RD51 website: <https://rd51-public.web.cern.ch/>

• **RD51 R&D Framework**

- Several collaboration events (meeting, workshop, lectures) in spite of pandemic
- Upgrades of modelling and simulation tools (neBEM, DWF in Garfield++) and studies (photons, ions).
- New SRS/VMM3a era started in the context of Electronics for MPGD.
- Upgrades in GDD laboratory (charge/optical/photocathode) supported by CERN group R&D Activities.
- Test beam: Waiting for the beam – upgrade of infrastructure (one additional common tracker).
- MPT workshop, new facility fully functional, involved in new R&D (e.g. DLC, possibility to upgrade with new machine), excellent results in production for experiment (e.g. ALICE & CMS GEM), support to the industrialization processes (need of large projects, need to interact with industry in R&D).

Summary (2/3)

MPGD Technologies

- New developments (μ RWELL, RPWELL, M(M)-THGEM,..) and consolidation of the existing (GEM, THGEM, micromegas, μ PIC,..) MPGD technologies.
- Large interest in resistive layers for spark quenching and charge dispersion. DLC coating very attractive for its properties (resistivity, stability) and production processes.
- Groups clustering around photocathodes (RICH and timing). Some new lines of research on Carbon/Diamond based PC.
- Groups clustering around new materials (glass, ceramic, DLC, graphene,..) and novel manufacturing techniques (3D printing, laser,..).
- Groups clustering around Optically readout MPGD (DM searches as first).

MPGD Dissemination

- LHC (ALICE TPC, CMS GEM, ATLAS NSW mm) and beyond (COMPASS RICH) upgrades at CERN done or on the way to be completed.
- Several new proposal for future HEP (LHCb, CMS,..) and beyond (COMPASS, EIC..) experiments.
- All experimental needs: tracking, calorimetry, muon, PID, TOF,..
- Several applications beyond basic research: medical, cultural heritage, muon tomography, astrophysics, fusion plasma imaging,...

Summary (3/3)



- RD51 requests support from CERN at existing level.
 - Access to the CERN RD51 common facilities
 - Gaseous Detectors Development(GDD) laboratory
 - semi-permanent setup at the SPS H4 test beamline
 - Collaborative access to the:
 - the Micro Pattern Technology Workshop (EP-DT-EF MPT)
 - the Thin Film and Glass Laboratory (EP-DT-EF TFG)
 - Modelling and simulation: access to central computing resources for MPGD simulations
 - Electronics for MPGDs: access to laboratory and CERN services
 - Access to CERN technical facilities
 - Office space and administrative support.

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Maintenance and Operation

RD51 underlines the importance of CERN core groups and of the present support received by EP-DT... and consequently advice to have it implemented and reinforced in future CERN human resources allocation plans.

EXTRA

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Consolidating the future

Possible upgrade of the CERN MPT workshop with a new DLC coater machine. Scientifically supported by RD51 MB and several individual RD51 groups.

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Facilitating the R&D

CERN support to facilitate the access to the SRS/VMM3a systems for CERN users (KT, Procurement Office, CERN store), as done in the past for SRS/APV25

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Thanks!