R&D PROPOSAL
RD51 EXTENSION BEYOND 2018

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Abstract

The RD51 Collaboration, in charge of the development and dissemination of Micropattern Gaseous Detectors (MPGD) since 2008, proposes to extend its activity, after 2018, for a further five-year term. Since the RD51 initial years, the community of MPGD developers and users has grown considerably. It is reflected by the many MPGD-based applications in high energy and nuclear physics experiments as well as in other basic and applied research fields. They rely on the parallel progress of detector concepts and associated technologies. The cultural, infrastructure and networking support offered by RD51 has been essential in this process.

The rich portfolio of MPGD projects, under constant expansion, is accompanied by novel ideas on further developments and applications.

The proposed next term of RD51 activities aims at bringing a number of detector concepts to maturity, initiating new projects and continuing the support to the community. Among leading proposed projects are ultrafast, high-rate MPGDs; discharge-free, high-resolution imaging detectors with resistive elements and high-granularity integrated electronics; novel noble-liquid detector concepts, including electroluminescence in gas bubbles; studies of environment-friendly counting gases and long-term sealed-mode operation; optical-readout detectors with radiation-hard imagers for fundamental research experiments and radiography and more.

The proposed R&D program is also expected to enrich our basic knowledge in detector physics, to form a generation of young detector experts - paving the way to new detector concepts and applications. The vast R&D program requires acquiring additional, up-to-date knowhow in advanced technologies.
The main objective is to advance MPGD technological development and associated electronic-readout systems, for applications in basic and applied research.”

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

- Large Scale R&D program to **advance MPGD Technologies**
- Access to **the MPGD “know-how”**
- Foster **Industrial Production**

- ~ 90 institutions
- ~ 500 members
- National and International Laboratories
- National **Institutes and Universities**
Recent reviews of Micro Pattern Gas Detector (MPGD) and RD51 collaboration

- High Rate Capability
- High Gain
- High Space Resolution
- Good Time Resolution
- Good Energy Resolution
- Excellent Radiation Hardness
- Good Ageing Properties
- Ion Backflow Reduction
- Photon Feedback Reduction
- Large Size
- Low Cost

Micro-pattern gaseous detector technologies and RD51 collaboration

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RD51 (well consolidated) Working Groups

Technological Aspects and Development of New Detector Structures

Common Characterization and Physics Issues

Academia-Industry Matching Events, Training, Education

Common Facilities: Test Beam and Laboratory

Production, quality control, industrialization

MPGD Related Electronics

Simulations and Software Tools

WG1: 

WG2: 

WG3: 

WG4: 

WG5: 

WG6: 

WG7: 

RD51
RD51 Achievements and Highlights

- Consolidation of the Collaboration and **MPGD community integration** (90 Institutes, ~500 members); Conferences, Meetings, Workshops, AIMEs, Schools, Lectures, Trainings

- Major progress in the MPGD technologies development in particular **large area GEM** (single mask), **MicroMegas** (resistive), **THGEM**; some picked up by experiments (including LHC upgrades);

  - **ALICE**, TPC read-out, ~500 m² of GEM foils
  - **ATLAS**, small wheels, 1200 m² to be instrumented
  - **CMS**, GE1/1 forward detectors, 250 m² of GEM foils
  - **COMPASS RICH**, 4.5 m² to be instrumented, single photon detection

- **Secured future** of the MPGD technologies development through the EP DT MPT workshop upgrade and FP7 AIDA & AIDA2020 contribution;

- Contacts with industry for large volume production, **MPGD industrialization and first industrial runs**;

- Major improvement of the **MPGD simulation software framework** for small structures allowing first applications;

- Development of common, scalable readout electronics (**SRS**) (many developers and > 50 user groups); **Production** (PRISMA company and availability through CERN store); **Industrialization** (re-design of SRS in ATCA in EISYS); SRS Technology CERN spin-off, APV and VMM interfacing.

- **Infrastructure** for common RD51 test beam and lab facilities (>20 user groups)
LHC Upgrades: Original R&D efforts emerged from RD51 activities. Today: production phase under the project effort, access to RD51 facilities (laboratory, test beam, workshops) and tools (simulation, electronics,...) to facilitate this particular phase.
Examples of CERN/LHC Upgrades

**CMS (GEM)**

**The CMS GEM project**

- Muon trigger at highest rate
- 2 or 3 GEMs
- 6 layers of Triple-GEM
- each chamber spans 20°
- Installation: L5 (2012-16)

**GE2/1**

- 1.5° x 2.45
- 18 modules super chambers per endcap, each chamber spans 20°
- Installation: LS2 (2018-19)

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**R&D: 6 generations of triple-GEMs**

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**Performances**

- Test with GEM-1 at the CERN Gamma Irradiation Facility (GIF)
  - Incidence rate: 30 kHz
  - Gas: CO$_2$/Ar (80:20)
  - Gas gain: 2 x 10$^4$
  - No gain drop after 16 months
  - No aging

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**Detector Concept**

**Large Area THGEMs**

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**Performance in Beam & FE Electronics**

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**Status of the Development of Large Area Photon Detectors based on THGEMs and Hybrid MPGD architectures for Cherenkov Imaging Applications**, C.A. Santos, Elba 2015

**COMPASS RICH-1 (THGEM+MM)**

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**Motivation**

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**Status Report of the Upgrade of the CMS muon system with triple-GEM detectors**, G. De Lentdecker, Elba 2015


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**LHC Upgrades**: Original R&D efforts emerged from RD51 activities. Today: production phase under the project effort, access to RD51 facilities (laboratory, test beam, workshops) and tools (simulation, electronics,...) to facilitate this particular phase.
Novel technologies, new ideas and applications.

Calorimetry with MPGD

Resistive Micromegs for Sampling Calorimetry

- Resistive Micromegas for Sampling Calorimetry
- Calorimetry at future collider will be based on Particle Flow (PF)
- Resistive Micromegas meets most of the technical and performance requirements (mm-size prototypes) ...
- but sparking might result from dense shower ionisation (e.g. nuclear recoils, EM shower core)
- spark suppression by means of resistive coatings

What resistive coating? Embedded resistive
- Allows charge evacuation from top to bottom
- no lateral charge dispersion
- maintain calorimeter imaging capability
- RC constant controlled with embedded R pattern

Green dot = R-pad contact, blue dot = RO-pad contact

Fast Timing

MicroMegas based:
(initial tests March/April 2015)
Ne-Ethane(10%) - 200 micron drift + 50 micron Micro Bulk

≈50 phe

36 picosecond rms on first try!!

Neutrons Detection

European Spallation Source (ESS)

New Large Area Thin Detectors

The µ-RWELL performance (I)

- The prototypes have been tested with $^{24}$Am source neutron moderated with PE Over 100 kHz
- We have just made it, and it is being tested now.

A. Ochi

New Materials (Glass GEM)

The Latest Results of Crystalized Glass GEM, Y. Mitsuia, RD51 miniweek (GDD/RD51 lab)

Resistive Material

- Resistive µ-PIC
- New version using carbon sputtering is being tested
- Resistive GEM
- The resistive electrodes are made by very thin (50 - 300nm) material
- It will improve the signal gain
- We have just made it, and it is being tested now.

A. Ochi
R&D Support to the projects and experiments

Effect of extreme operating conditions on the GEM detector components

Gating GEM
Ion back-flow at equal fields

**Ion back-flow reaches maximum at approx. same voltage** as for electron transparency

**Higher voltages** than for electrons to fully close gate

Very preliminary data with large error bars (not shown)!
IBF normalized to $\Delta V_{\text{GEM}} = 20$ V

Discharge studies ALICE/CMS

Graphene

Membrane opaque to ions and transparent to electrons:
- solution of the ion back-flow in gaseous detectors
- protective layer on photocathodes
- enhancement of electron emission

-99% (suspended) graphene tri-layer coverage

Ion density effects in multiGEM

ALICE TPC IBF

- Ion charges instantaneously modify the electric fields
- Transfer field modification: increase of the effective gain
- Ion distribution at the hole entrance: reduction of the amplification field

Measurement

Computation
Modelling of Physics Processes and Software Tools

**Single-electron spectra**
- Blue: Poisson + Gaussian noise fit; red: Monte Carlo (Magboltz), not fit!
- Ar 95% + CH$_2$ 5%, E=20.12 kV/cm
- Ne 95% + CH$_2$ 5%, E=26.25 kV/cm
- He 95% + CH$_2$ 5%, E=26.25 kV/cm

**Mesh transparency**
- Electron tracking requires improvement.

**High-precision data from AGH**
- Current reference is taken at the ionisation level.
- Main source of error: ~5%.

**Charging-up of a GEM**
- Gain changes as a result of the charge deposits.
- Electron tracking to be refined.

**Gas detector simulation: new areas**
- Discharges and Resistive layers.
- Ion diffusion.
- Refinement of ionisation esp. at low energy.
- Integration of boundary element methods.

**Fig. 5.** Fraction of measurable signal electrons dependence on the drift field for two mesh geometries, experimental data (normalized signal strength) and simulation prediction (non-loss electrons after drift and mesh transition).

[Fabian Kager et al. 10.1016/j.nima.2015.11.011]

**Ion distribution at the hole entrance: reduction of the amplification field**
The RD51 Scalable Readout System (SRS)

**SRS & APV25 FE chip**
Worldwide use in the RD51 community (>2000 hybrids)

**SRS+SiPM (NEXT TPC)**

**SRS-FEC+TOTEM DAQ**

**SRS+Timepix (LC-TPC) – Bonn/Desy**

Very appealing for the future: **VMM (NSW ATLAS FE chip)**

Baseline solution for RD51 SRS community.

**SRS: Different System**

**SRS for R&D on Detectors**

**SRS for experiments (ATCA)**

LHC experiments: from detector to counting room

**SRS for spatially distributed system (optical SRS)**

Interest and support from ESS (European Spallation Source) and ALICE FOCAL
EP-DT-DD GDD Laboratory available for the RD51 collaboration

Permanent installations (Today): ALICE, ATLAS, ESS
CMS moved roughly two years ago to T1FF, access to the lab for specific measurements
More than 15/20 groups per year coming to perform measurements

Clean Rooms
Mechanical and Electronic Workshop

Technical support
MPGD Detectors
Gas system and services
Readout electronics (std and custom RD51 SRS&APV)
Radioactive Sources
Interface with CERN services (RP, gas, metrology, irradiation facilities,...)
Semi permanent test beam in the SPS extraction Line

Examples of the test beam user teams

- CMS (GEM)
- WIS/A/C (WELL, THGEM)
- ATLAS NSW (mm)
- BESS III & SHIP (GEM)
- LAPP/DEM/IRFU (mm)
- ALICE TPC (GEM and mm)

Three periods of two weeks each per year
About fifteen-twenty users per year

Building 887 – EHN1
H4 (PPE134)

Goliath Magnet → Ship?

A warm and special thanks to the SPS, the North Area Facility and to all the people that supports our installations
Technology: MPGD Production @ CERN

MPGD Projects....

<table>
<thead>
<tr>
<th>Project</th>
<th>Technology</th>
<th>Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>SBS tracker</td>
<td>GEM</td>
<td>600mm x 500mm</td>
</tr>
<tr>
<td>ALICE TPC upgrade</td>
<td>GEM</td>
<td>600mm x 400mm</td>
</tr>
<tr>
<td>CMS muon</td>
<td>GEM</td>
<td>1.2m x 450mm</td>
</tr>
<tr>
<td>ATLAS NSW muon</td>
<td>Micromegas</td>
<td>2m x 1m</td>
</tr>
<tr>
<td>COMPASS pixel Micromegas</td>
<td>GEM &amp; Micromegas</td>
<td>500mm x 500mm</td>
</tr>
<tr>
<td>BESIII</td>
<td>GEM</td>
<td>600mm x 400mm</td>
</tr>
<tr>
<td>KLOE</td>
<td>GEM</td>
<td>700mm x 400mm</td>
</tr>
<tr>
<td>SOLID</td>
<td>GEM</td>
<td>1.1m x 400mm</td>
</tr>
<tr>
<td>CLAS 12</td>
<td>Micromegas</td>
<td>500mm x 500mm</td>
</tr>
<tr>
<td>LSBB (geoscience)</td>
<td>Micromegas</td>
<td>1m x 500mm</td>
</tr>
<tr>
<td>Prad</td>
<td>GEM</td>
<td>1.5m x 55cm</td>
</tr>
<tr>
<td>CBM</td>
<td>GEM</td>
<td>1m x 450mm</td>
</tr>
<tr>
<td>ASACUSA</td>
<td>Micromegas</td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Project</th>
<th>Technology</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATLAS NSW</td>
<td></td>
<td>1300 m²</td>
</tr>
<tr>
<td>SBS Tracker</td>
<td></td>
<td>100 GEMs</td>
</tr>
<tr>
<td>ALICE TPC upgrade</td>
<td></td>
<td>350 GEMs</td>
</tr>
<tr>
<td>COMPASS pixel Micromegas</td>
<td></td>
<td>20 GEM + Micromegas</td>
</tr>
<tr>
<td>BESIII</td>
<td></td>
<td>15 GEM</td>
</tr>
<tr>
<td>CLAS 12</td>
<td></td>
<td>30 Micromegas</td>
</tr>
<tr>
<td>CMS</td>
<td></td>
<td>450 GEM</td>
</tr>
</tbody>
</table>

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 fabricate 2x1m² Bulk MM & 2x0.5m² GEM) COMPLETED

Construction of the new workshop’s building:

Start: beginning 2012
End: end 2017
RD51 Future
R&D Environment

R&D Environment
Expertise, infrastructure and tools

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

Minimum infrastructure – R&D lab and test beam facilities

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

Interdisciplinary CERN wide Instrumentation R&D Infrastructure
Alternatively access to CERN and external facilities:
MPT
Thin Film Deposition
Mechanics, designer office, 3D printing
Metrology
...
Nano Lab (EPFL)
Industry (strategic partnership) and TT

Generic R&D support grants to explore innovative ideas

Detector R&D dedicated electronics support

Detector physics and simulation software tools support

Diversified Resources
CERN
Collaborating institutions and projects contributions
Industry
EU projects
Project synergies

Project Oriented R&D
R&D support to the projects and experiments

Access to the R&D environment

MPGD Generic R&D
Moving performance to the limits and developing new concepts and applications
RD51 Future
Flagship technologies – Resistive materials and architectures

The μ-RWELL performance (I)

The prototypes have been tested with \( \text{Ar:CO}_2 \sim 70/30 \) & \( \text{Ar:CH}_4 \sim 90/10 \) gas mixtures and characterized by measuring the gas gain, rate capability and discharge in current mode.

The devices have been irradiated with a collimated flux of 5.9 kJ in X-rays generated by a PW2217/20 Philips Tube.

The gain has been measured vs potential applied between the top of the electrode of the amplification stage and the resistive layer.

Resistive electrodes with DLC

- On beginning of 2013, we have developed resistive electrodes by DLC
  - Initially, it was developed for ATLAS MM resistive foils
  - Fine micro-patterning (nm order) available
    → applying it for u-PIC electrodes

The High Rate scheme (LHCb)

1. Copper layer 5 µm
   Kapton layer 50 µm
   DLC layer: 0.1 – 0.2 µm (10-200 ML of C)
2. 2nd resistive kapton layer with \( \sim 1 \text{cm}^2 \) “through via” density
   DLC-coated kapton base material
3. Insulating layer
   pads/strips readout on standard PCB
   “through via” for grounding
4. DLC-coated base material after copper and kapton chemical etching (WELL amplification stage)
RD51 Future
Flagship technologies – Fast and precise timing

Two Possibilities:
- Large 2 x 2 cm Trigger
- Small 5 mm circle Trigger

Resistive Picosec HFS Multipad

χ² / ndf = 73.26 / 45
Mean (ns) = 2.7451 ± 0.0004
Sigma1 (ps) = 20.9 ± 0.3
Sigma2 (ps) = 38.9 ± 1.1
Total sigma (ps) = 24.0 ± 0.3
RD51 Future
Flagship technologies – New materials and technologies

Prototyping: new techniques as 3D/Ink-Jet printing, etching and laser to create novel structures will speed up and enlarge the detector prototyping capabilities.

Innovative photocathodes by ND powder

Highly efficient and stable ultraviolet photocathode based on nanodiamond particles

2D strip anode

DRIE Plasma
Laser Drilling
Super InkJet Printer

2 layers of strips separated by insulating material
Bottom strips: 3mm wide at 6mm pitch
Top strips: 2mm wide at 6mm pitch
Signal feedthrough to the back for contacting
18kΩ resistance along track
2.7kΩ resistance through contact feedthrough

Ionisation chamber

Printed overnight with 0.1mm layer height and slow speed for high surface quality

Timelapse of printing
IR-image during printing
Finished print
RD51 Future
Flagship technologies – Hybrid detectors

InGrid & TimePix, the ultimate gaseous TPC
(H. Van Der Graaf)

256 x 256 pixels, 55 x 55 μm pitch, about 1.4x1.4 cm² sensitive area

F. Hartjes,
https://agenda.linearcollider.org/event/7795/contributions/40334/attachments/32507/49403/QUAD_development.pdf

A large TPC prototype for a linear collider detector P. Schade, J. Kaminski, NIMA, 628, 1, 1 February 2011, Pages 128-132

GEMPIX (F. Murtas et al.)

J. Kaminski,
https://indico.cern.ch/event/391665/contributions/1827282/attachments/1230061/1802690/GridPix.pdf
RD51 Future
Flagship technologies – **Hybrid detectors**
Phantom high speed camera - oTPC events almost SF
RD51 Request

RD51 proposes to extend its activities for further five-year term.

RD51 requests limited support from CERN facilities at existing level:

- access to the Gaseous Detectors Development (GDD) lab space, infrastructure and maintenance support;

- office space and administrative support;

- maintenance of the semi-permanent setup at the SPS H4 test beam line and, correspondingly, access to the beams over several time periods for a total of six weeks per year;

- continuation of the collaborative access to the:
  – the Micro Pattern Technology Workshop (EP-DT-EF MPT)
  – the Thin Film and Glass Laboratory (EP-DT-EF TFG);

- access to other CERN technical facilities, in particular:
  – Bond Laboratory (EP-DT-DD)
  – Electronics Assembly Workshop (TS-DEM-WS)
  – Materials, Metrology & Non Destructive Testing (EN-MME-MM)
  – Surface treatment, coating and chemical analysis (TE-VSC)
  – the central computing resources for MPGD simulations.