The RD51 Collaboration:
Development of Micro-Pattern Gas Detector Technologies

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Maxim Titov, CEA Saclay, France

OUTLINE:

• RD51 Highlights
• RD51 Collaboration Activities and Results
  Technology Achievements
  Detector Assembly Optimization, QA, Long Term Stability
  Electronics for MPGDs
  Software tools
  MPGD workshop upgrade & industrialization
  RD51 test beam facility

RD51 Plans and Outlook
RD51 Collaboration
The main objective of the R&D programme is to advance technological development of Micropattern Gas Detectors


• ~ 80 institutes
• ~ 450 people involved
• Representation (Europe, North America, Asia, South America, Africa)

“RD51 aims at facilitating the development of advanced gas-avalanche detector technologies and associated electronic-readout systems, for applications in basic and applied research”

RD51 contributes to the LHC upgrades, BUT, the most important is:
RD51 serves as an access point to MPGD “know-how” for the world-wide community

http://gifna.unizar.es/mpgd13/
Micro-Pattern Gas Detectors

- High Rate Capability
- High Gas Gain
- Good Space, Time and Energy Resolution
- Good Ageing Properties
- Ion Backflow and Photon Feedback Reduction
- Large Size
- Low Cost

Rate Capability Comparison for MWPC and MSGC
Consolidation of the Collaboration and MPGD community integration ( >80 Institutes, 450 members);

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);

Secured future of the MPGD technologies development through the TE MPE workshop upgrade and FP7 AIDA 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);

Infrastructure for common RD51 test beam and lab facilities (>20 user groups)
Technology Development Highlights
GEM Single Mask Technique

GEM Single Mask Process

- Standard double mask method limits max. size of the detector to 30x30 cm²
- Single mask technique reduces costs and production time
- Performance comparison (max. gain, stability, rate capability..) shows no difference

CMS high eta upgrade triple GEM prototype in the RD51 test beam facility

Time resolution 4 ns

ALICE triple GEM TPC end-cap module

KLOE2 inner tracker: 4 layers of triple cylindrical GEM detectors
Technology Development Highlights

Resistive MicroMegas

Bulk MicroMegas Process

- PCB
- Lamination
- Mesh deposit
- Lamination
- Development

Standard Bulk MicroMegas suffers from limited efficiency at high rates due to discharges induced dead time.

The resistive-strip protection concept

Efficiency measured in H6 pion beam (120 GeV/c); S3 is a non-resistive MM, R12 has resistive-strip protection.

Spatial resolution measured with an external Si telescope, shown is convoluted resolutions of Si telescope + extrapole (~30 μm) and MM with 250 μm strip pitch.

ATLAS small wheels upgrade project resistive MicroMegas prototype.
Technology Development Highlights
THGEM Surface Treatment

Polyurethane Treatment

Non-treated THGEM suffers from: limited max. gain, response non-uniformity and time instabilities

Polishing and Cleaning

COMPASS RICH photo-detector upgrade prototype
Technology Development Highlights

Pixel Readout Integration

Octoboard

Results of the tests of the GridPix type detector with TimePix chip readout with RD51 SRS mounted in LP TPC prototype for LC TPC application
Detector Assembly Optimization

Industrialization and Cost Reduction

Simplified Bulk MicroMegas & GEM NS2

ATLAS muon system MicroMegas upgrade assembly

CMS high eta project triple GEM detector assembled using self-stretching method
Quality Control

- Electrical rigidity
- Hole diameter uniformity in GEM
- Gap uniformity in MicroMegas
- THGEM thickness uniformity
- Final detector calibration and characterization protocols and infrastructure
Long Term Stability

- Classical gas detectors ageing detector
- Radiation hardness and activation of detector components
- Sustainability to neutrons and heavily ionizing particles induced discharges
- Exposure to X-Ray, Gamma, Neutron and Alpha Sources
- Monitoring infrastructure

Portable gas monitoring system for detector stability studies; to be used by LHCb and CMS upgrade of the muon system

Resistive MicroMegas stability performance under X-Ray irradiation

Discharge studies of the triple GEM detector exposed to the low energy neutron flux
Piggy Back – a novel method of the readout of the MPGD detectors using pixel chips; Electronics is completely separated from the detector volume.
Development of Scalable Readout System (SRS) for MPGDs

Development of a portable multi-channel readout system (2009-2012):

Scalable readout architecture: a few hundreds channels up to very large LHC systems (> 100 k ch.)

Project specific part (ASIC) + common acquisition hardware and software

Physical Overview of SRS:

- **Scalability** from small to large system
- **Common interface** for replacing the chip frontend
- **Integration** of proven and commercial solutions for a minimum of development
- **Default availability** of a very robust and supported DAQ software package

Frontend hybrids: based on APV25, VFAT, Beetle, VMMx and Timepix chips

ADC frontend adapter for APV and Beetle chips: ADC plugs into FEC to make a 6U readout unit for up to 2048 channels

FEC cards (common): Virtex-5 FPGA, Gb-Ethernet, DDR buffer, NIM and LVDS pulse I/O, High speed Interface connectors to frontend adapter cards
<table>
<thead>
<tr>
<th>#</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>ALICE EMCal Calorimeter upgrade, ORNL, SRS readout backend via DTCC links and 24 SRU’s, DATE Online system, being installed</td>
</tr>
<tr>
<td>2.</td>
<td>ATLAS upgrade CERN, MAMMA project NSW, μMEGAS, APV frontend SRS Eurocrates-SRU, MMDAQ Online, installed</td>
</tr>
<tr>
<td>3.</td>
<td>ATLAS upgrade Mainz, μMEGAS for MBTS, APV frontend- SRS Eurocrate, MMDAQ Online, waiting delivery</td>
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<tr>
<td>4.</td>
<td>ATLAS Muon upgrade R&amp;D, INFN Rome, APV frontend SRS Eurocrate, MMDAQ Online, delivered</td>
</tr>
<tr>
<td>5.</td>
<td>ATLAS Saclay, μMEGAS R&amp;D, APV frontend SRS Minicrate, MMDAQ Online, delivered</td>
</tr>
<tr>
<td>6.</td>
<td>NA62 CERN straw tracker upgrade with μMEGAS, APV frontend with SRS Minicrate, MMDAQ Online, delivered</td>
</tr>
<tr>
<td>7.</td>
<td>CMS upgrade CMS GEM collaboration CERN, Muon Endcaps, design of VFAT frontend digital readout SRS, ongoing with IFIN-HH</td>
</tr>
<tr>
<td>8.</td>
<td>TOTEM upgrade GEMs Baris testlab, OPTO-Rx card design, Minicrate, Eurocrate, SRU, DATE Online, delivered</td>
</tr>
<tr>
<td>9.</td>
<td>BNL GEM detectors, APV frontend-SRS Minicrate, RCDAQ Online, delivered</td>
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<tr>
<td>10.</td>
<td>Stony Brook GEM detector R&amp;D, APV frontend SRS Minicrate, RCDAQ Online, delivered</td>
</tr>
<tr>
<td>12.</td>
<td>Florida Inst Tech GEMs, Muon Tomografi for Homeland security, 15k channel SRS prototype Eurocrate, DATE Online, delivered</td>
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<td>13.</td>
<td>Géosciences Azur-CNRS-UNSA, Muon Tomography w.μMEGAS for geology, APV frontend SRS Eurocrate, Date Online, delivered</td>
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<tr>
<td>14.</td>
<td>GDD lab RDS1, CERN, R&amp;D for GEM and μMEGAS, APV frontend SRS Euro and Minicrates, DATE, Labview MMDAQ, delivered</td>
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<tr>
<td>15.</td>
<td>HIP, HELSINKI, characterization MPGAD detectors, APV frontend SRS Eurocrate, Date and Labview, delivered</td>
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<tr>
<td>16.</td>
<td>INFN Napoli, ATLAS. Development of SRS Hardware and Firmware, Labview, delivered</td>
</tr>
<tr>
<td>17.</td>
<td>Jefferson Lab, Virginia UVa upgrade GEM readout system, APV frontend SRS Eurocrate, DATE online, partially delivered</td>
</tr>
<tr>
<td>18.</td>
<td>Yale University, GEM development ALICE, APV frontend SRS Eurocrate, DATE Online, delivered</td>
</tr>
<tr>
<td>19.</td>
<td>NEXT Coll. small Xenon TPC with PM and Si PMs, SRS readout electronics co-development, SRS Eurocrate and SRU, DATE – Delivered</td>
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<td>20.</td>
<td>UNAM, MEXICO, MX, R&amp;D on THGEM, APV frontend SRS Minicrate, DATE Online, delivered</td>
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<td>21.</td>
<td>Radiation Laboratory, Nishina Center, RIKEN, APV frontend SRS Eurocrate, Online unknown, delivered</td>
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<td>22.</td>
<td>J-PARC /E16 experiment, GEM based tracking, APV frontend SRS Minicrate, Online Unknown, partially delivered</td>
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<td>23.</td>
<td>Jefferson Lab SHM spectrometer triple GEM, APV frontend SRS Eurocrate, DATE Online, waiting</td>
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<td>24.</td>
<td>Harward Univ. Physics, APV frontend SRS Minicrate, Online unknown, waiting</td>
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<td>25.</td>
<td>Tokyo Univ. ATLAS, APV frontend SRS Eurocrate, Online unknown, waiting</td>
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<tr>
<td>26.</td>
<td>WIS and Aveiro Univ. GEM validation, APV Frontend SRS Eurocrate, MMDAQ and Labview, being delivered</td>
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<td>27.</td>
<td>East Carolina University, Health Physics, APV frontend, SRS Eurocrate, Labview, waiting</td>
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<tr>
<td>28.</td>
<td>Munich LMU / ATLAS μMEGAS, APV frontend SRS Eurocrate –SRU, MMDAQ Online, partially delivered</td>
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<td>29.</td>
<td>NCSR Democritos ATHENS, APV frontend SRS Minicrate, Online unknown, waiting</td>
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<tr>
<td>30.</td>
<td>IFIN-HH-Bucharest new Detector lab, APV and VFAT frontend, SRS Eurocrate and SRU, Labview, delivered</td>
</tr>
<tr>
<td>31.</td>
<td>ATLAS NSW CERN, SRS-ATCA pilot system, MMDAQ Online, waiting</td>
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<tr>
<td>32.</td>
<td>ALICE FOCAL ORNL, SRS-ATCA pilot system, DATE Online, waiting</td>
</tr>
<tr>
<td>33.</td>
<td>NEXT Collaboration, SRS-ATCA pilot system, DATE Online, waiting</td>
</tr>
<tr>
<td>34.</td>
<td>Lunds Univ, ILC TPC, SRU for 24 channel DTCC link readout, Online unknown, delivered</td>
</tr>
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</table>
A main feature of SRS, apart from its scalability, portability and affordable cost (< 2 EUR/ channel), possible choice of the frontend ASIC (APV, VFAT, Beetle, VMMx, Timepix).

System was used for R&D for upgrades in ATLAS, CMS, ALICE ECAL and for SiPM readout
ELMA and EicSys GmbH, Germany started to rework the “SRS classic” system into the industry Advanced xTCA standard (ATCA), targeting larger experiments and commercial applications.

**SRS ATCA**—fully commercial SRS in certified ATCA Crates

1.) higher channel integration => reduce cost/channel for large systems
2.) certified crate standard
3.) replace DTCC cables by ATCA backplane
4.) start with 2-slot ATCA crate that can be read out via SRU

Delivery of the first ATCA SRS expected in June – July 2013
Towards a Complete SRS-Lab Equipment for MPGDs

- **AVD box**: active Voltage Divider with monitoring for GEMs (under test)
- **Remote I2C readout of AVD and CM via SRS**: in progress
- **CM box**: Current monitoring range 10 pA -100 µA (design status)
- **QSA frontend**: quad signal amplifier 2 GHz, factor 20, for MPGD’s (tb revised)
- **TPB trigger pickup box**: generates triggers from Meshes (working in several places)
- **I-GEM**: Anode current summing hybrid for GEMs (planned)
- **Shaper-Discriminator**: SRS card 50 OHM triggers from TPB (planned)
- **HGM**: SRS card, programmable High Voltage for mesh grounded MM (design status)

**Active Voltage Divider for GEM’s**

**High Voltage pAmmeter**

**Subrack 3U2**

**Hans Muller (CERN) et al.**
Development and Maintenance of Garfield++:
Garfield++ is a collection of classes for the detailed simulation of small-scale detectors.

Garfield++ contains:
- electron and photon transport using cross sections provided by Magboltz
- ionization processes in gases, provided by Heed and MIP
- ionization and electron transport in semi-conductors
- field calculations from finite elements, boundary elements, analytic methods

Simulation Improvements:
Transport:
- ion mobility and diffusion, measurement and modelling
- ongoing update of electron cross sections
- e-ion recombination process in Xe
- thermal motion

Photons:
- update in UV emission
- inclusion of IR production
- photon trapping and resulting excitation transport
- photon absorption in the gas (gas feedback)
- photon absorption in and electron emission from walls (feedback)
- photo cathodes
Applications:

- TPC GEM: ion backflow
- GEM: multiplication process and polyimide properties; charging up
- MicroMegas: timing and effects of resistive layers

ALICE TPC end-cap upgrade studies of rate dependence of the Ion Back Flow in GEM. Left: measurement; Right: Garfield++ simulation results
Demand for the Micro-Pattern Gas Detectors – LHC Upgrades

### About 1200m² of resistive bulk for small wheel muon stations of Atlas

<table>
<thead>
<tr>
<th>Sector</th>
<th>Nbr sectors</th>
<th>MM layer area (containing rectangle)</th>
<th>Total Nbr MM layers (w/o spares)</th>
<th>Total MM PCB area</th>
<th>Manufacturing plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td>8x2=16</td>
<td>From ~0.68m² (696x980) To ~1m² (1420x730)</td>
<td>512</td>
<td>0.88x512 = 450m²</td>
<td>1st sector 2014</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td>Completion 2016+2017</td>
</tr>
<tr>
<td></td>
<td>4x2=8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large</td>
<td>8x2=16</td>
<td>From ~0.96m² (1036x930) To ~1.9m² (2300x835)</td>
<td>512</td>
<td>1.5x512 = 768m²</td>
<td>1st sector 2014</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td>Completion 2016+2017</td>
</tr>
<tr>
<td></td>
<td>4x2=8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**1024 Micromegas layers**

### About 1000m² of GEM foils for stations 1 and 2 of CMS muon detector

216 triple GEM detectors

<table>
<thead>
<tr>
<th>Station</th>
<th>Nbr of modules</th>
<th>Module area (containing rectangle)</th>
<th>Total Nbr of modules (w/o spares)</th>
<th>Total GEM foil area (3ple GEMs)</th>
<th>Manufacturing plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>GE1/1</td>
<td>18x2=72</td>
<td>~0.43m² (440x990)</td>
<td>72</td>
<td>0.43x72x3 = 93m²</td>
<td>Prototypes 2013+2014 Completion 2016+2017</td>
</tr>
<tr>
<td>GE2/1</td>
<td>36x2=72 (long)</td>
<td>~2.4m² (1251x1911)</td>
<td>144</td>
<td>(2.4+1.6)x72x3 = 864m²</td>
<td>Prototypes 2013+2014 Completion 2016+2017</td>
</tr>
<tr>
<td></td>
<td>36x2=72 (short)</td>
<td>~1.6m² (1251x1281)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### About 130m² of GEM foils for Alice TPC upgrade

72 triple GEM detectors

<table>
<thead>
<tr>
<th>Module</th>
<th>Nbr of modules</th>
<th>Module area (containing rectangle)</th>
<th>Total Nbr of modules (w/o spares)</th>
<th>Total GEM foil area (3ple GEMs)</th>
<th>Manufacturing plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>IROC</td>
<td>18x2=36</td>
<td>~0.23m² (460x500)</td>
<td>36</td>
<td>0.23x36x3 = 25m²</td>
<td>Yr 2016</td>
</tr>
<tr>
<td>OROC</td>
<td>18x2=36</td>
<td>~1m² (880x1120)</td>
<td>36</td>
<td>1x36x3 = 108m²</td>
<td>Yr 2016</td>
</tr>
</tbody>
</table>

### About 57m² of GEM foils for LHCb muon upgrade

144 triple GEM detectors

<table>
<thead>
<tr>
<th>Module</th>
<th>Nbr of modules</th>
<th>Module area</th>
<th>Total Nbr of modules (w/o spares)</th>
<th>Total GEM foil area (3ple GEMs)</th>
<th>Manufacturing plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>M2-R1</td>
<td>48</td>
<td>~0.075m² (300x250)</td>
<td>48</td>
<td>0.075x48x3 = 11m²</td>
<td>Prototypes 2013+2014 Completion 2015+2016</td>
</tr>
<tr>
<td>M2-R2</td>
<td>96</td>
<td>~0.16m² (600x270)</td>
<td>96</td>
<td>0.16x96x3 = 46m²</td>
<td>Prototypes 2013+2014 Completion 2015+2016</td>
</tr>
</tbody>
</table>
RD51– MPGD Production

Currently CERN-MPGD workshop is the UNIQUE MPGD production facility (generic R&D, detector components production, quality control)

2008 RD51 Collaboration Survey:

<table>
<thead>
<tr>
<th>detector type</th>
<th>end 2008 capability</th>
<th>required future capability</th>
</tr>
</thead>
<tbody>
<tr>
<td>GEM</td>
<td>40 x 40</td>
<td>50 x 50</td>
</tr>
<tr>
<td>GEM, single mask</td>
<td>70 x 40</td>
<td>120 x 50</td>
</tr>
<tr>
<td>TGEM</td>
<td>70 x 50</td>
<td>200 x 100</td>
</tr>
<tr>
<td>RTGEM, serial graphics</td>
<td>20 x 10</td>
<td>100 x 50</td>
</tr>
<tr>
<td>RTGEM, Kapton</td>
<td>50 x 50</td>
<td>200 x 100</td>
</tr>
<tr>
<td>Micromegas, bulk</td>
<td>150 x 50</td>
<td>200 x 100</td>
</tr>
<tr>
<td>Micromegas, microbulk</td>
<td>10 x 10</td>
<td>30 x 30</td>
</tr>
<tr>
<td>MHSP</td>
<td>3 x 3</td>
<td>10 x 10</td>
</tr>
</tbody>
</table>

GEM:
- Continuous polyimide etcher
- Cu electroetch line

MicroMegas:
- Large laminator
- Large Cu etcher
- Large UV exposure unit
- Large resist developer
- Large resist stripper
- Large oven
- Large dryer

Upgrade of the workshop approved by CERN management (Nov. 2009):
Installation of the new infrastructure to fabricate 2x1m² Bulk MM and 2x0.5m² GEM

COMPLETED
MPGD Technology Industrialization

Technology Industrialization ➔ transfer “know-how” from CERN workshop to Industrial partners for MASS PRODUCTION

THGEM Technology – ELTOS S.p.A. (Italy), PRINT ELECTRONICS

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

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

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

• 2012-2013: Industrial test runs for GEM and MM in companies (Techtra, ELTOS, ELVIA)
• 2013: Two large area MMs (1*0.5 m²) are ordered in ELVIA for GEOAZUR Project (Tomography Densitometric Meas.); 4 more det. to be produced at CERN
2008-2013: > 20 RD51 groups participated;

3-beam telescopes
1 Bulk MM, 1 resistive MM and 1 triple-GEM with SRS readout

DT GDD lab infrastructure

Common RD51 infrastructure: 3 beam telescopes, services, DAQ, FEE
RD51 Future – beyond 2013

- Continuation of the R&D support for the experiments and LHC upgrades **WG1**
- Generic R&D (new structures, ideas, detector physics) – RD51 Common Projects **WG2**
  Development of new structures and consolidation of the existing structures
- Applications - organization of series of specialized workshops disseminating MPGD applications beyond fundamental physics – RD51, potential users and industry (e.g. dosimetry, neutron detection, medical physics, …) **WG3**
- Development and Maintenance of Software & Simulation Tools; basic studies & software support for the RD51 community **WG4**
- Development and Maintenance of the SRS Electronics; An extended support for the SRS including new developments and implementations of additional features **WG5**
- MPGD Industrialization and QA Control - GEM, MicroMegas, Thick GEM; Completion of the industrialization of main technologies **WG6**
- Maintenance and extension of the RD51 Lab and Test-Beam Infrastructure **WG7**
- MPGD Education and Training : organization of schools for students and newcomers & academic training **NEW WG**
In 2008 RD51 Collaboration was Approved for the 5-years term (MoU)

The Collaboration would like to ask LHCC for extension for the next 5 years and for continuation of limited support:

- Access to test beam facility (including the possibility to keep “semi permanent” setup)
- Access to CERN TE MPE Printed Circuit Workshop (similar to present availability level)
- Access to Silicon Bonding Laboratory
- Access to central computing resources for MPGD simulations.
- Limited amount of office space


## RD51 Collaboration – Working Groups

“Transverse organization” of MPGD activities in 7 Working Groups

### RD51 – Micropattern Gas Detectors

<table>
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<tr>
<th>Working Group</th>
<th>Objectives</th>
<th>Tasks</th>
</tr>
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<tbody>
<tr>
<td>WG1</td>
<td>Design optimization</td>
<td>Large Area MPGDs</td>
</tr>
<tr>
<td></td>
<td>Development of new geometries and techniques</td>
<td>Design Optimization New Geometries Fabrication</td>
</tr>
<tr>
<td>WG2</td>
<td>Common test standards</td>
<td>Common Test Standards</td>
</tr>
<tr>
<td></td>
<td>Characterization and understanding of physical phenomena in MPGD</td>
<td>Discharge Protection</td>
</tr>
<tr>
<td>WG3</td>
<td>Evaluation and optimization for specific applications</td>
<td>Ageing &amp; Radiation Hardness</td>
</tr>
<tr>
<td>WG4</td>
<td>Development of common software and documentation for MPGD simulations</td>
<td>Charging up and Rate Capability</td>
</tr>
<tr>
<td>WG5</td>
<td>Readout electronics optimization and integration with MPGD detectors</td>
<td>Study of Avalanche Statistics</td>
</tr>
<tr>
<td>WG6</td>
<td>Development of cost-effective technologies and industrialization</td>
<td>Electronics Modeling</td>
</tr>
<tr>
<td>WG7</td>
<td>Sharing of common infrastructure for detector characterization</td>
<td>Algorithms</td>
</tr>
</tbody>
</table>

- **Tracking and Triggering**
  - Photon Detection
  - Calorimetry
  - Cryogenic Detectors
  - X-Ray and Neutron Imaging
- **Simulation Improvements**
  - Astroparticle Physics Appl.
  - Medical Applications
- **Common Platform (Root, Geant4)**
- **FE electronics requirements definition**
  - General Purpose Pixel Chip
  - Large Area Systems with Pixel Readout
  - Portable Multi-Channel System
  - Discharge Protection Strategies
  - Common Production Facility
  - Testbeam Facility
  - Industrialization
  - Collaboration with Industrial Partners
  - Irradiation Facility
RD51 Collaboration Organization

**Consolidation around common projects:** large area MPGD R&D, CERN/MPGD production facility, common electronics developments, software tools, beam tests

WG1: large area Micromegas, GEM; THGEM R&D; MM resistive anode readout (discharge protection); design and detector assembly optimization; large area readout electrodes and electronics interface

WG2: double phase operation, radiation tolerance, discharge protection, rate effects, single-electron response, avalanche fluctuations, photo detection with THGEM and GridPix

WG3: applications beyond HEP, industrial applications (X-ray diffraction, homeland security)

WG4: development of the software tools; microtracking; neBEM field solver, electroluminescence simulation tool, Penning transfers, GEM charging up; MM transparency and signal development, MM discharges

WG5: scalable readout system; Timepix multi-chip MPGD readout

WG6: CERN MPGD Production Facility; industrialisation; TT Network (HEPTech)

WG7: RD51 test beam facility and GDD lab
RD51 Collaboration Notes

https://espace.cern.ch/test-RD51/RD51%20internal%20notes/Forms/AllItems.aspx

RD51 INTERNAL NOTES

2013


RD51-Note-2013-005 - "Summary of the results and further advances of the 2011 RD51 Common Project: MWPCs technology laboratory for training, development, fabrication, applications and innovation" (by R. Gutierrez)


RD51-Note-2013-003 - "Liquid noble gas detectors for low energy particle physics" (by V. Chepel, H. Araujo)

RD51-Note-2013-002 - "Proposal of the Micromegas/InGrid test program using low energy electrons from the versatile facility at Phil" (by D. Attie, A. Chaus, P. Colas, M. Titov, S. Barsuk, L. Burmistrov, A. Vaniola, H. Monard, O. Fedorchuk, O. Bezhlyko)


2012


RD51-Note-2012-010 - "Secondary Scintillation readout from GEM and THGEM with a large area avalanche photodiode" (by C.M.B. Monteiro, L.M.P. Fernandes, J.F.C.A. Veloso, J.M.F. dos Santos)


RD51 Notes: 6 in 2013
12 in 2012
17 in 2011
9 in 2010
7 in 2009
RD51 Collaboration Supported Projects

2012:

- R&D on large area GEMs for the ALICE TPC upgrade \( (GSI/\ Tyko/\ UNAM) \)
- High resolution UV scanner for MPGD applications \( (Wigner \ FCP/\ INFN \ Trieste/\ INFN \ Bari) \)
- Large-area THGEM detector evaluation with SRS electronics \( (Weizmann/\ Coimbra/\ Aveiro) \)

2011:

- Thin and high-pitch laser-etched mesh manufacturing and bulking \( (Saclay/\ CERN/\ Bari) \)
- Development of innovative resistive GEM alpha detectors for earthquakes prediction and homeland security \( (INFN \ Bari/\ UNAM, \ Mexico/\ INFN \ Padova/\ INFN \ Frascati) \)
- MPGDs technology laboratory for training, development, fabrication, applications and innovation \( (Universidad \ Antonio \ Nariño, \ Columbia/\ Brookhaven \ National \ Laboratory/\ Helsinki \ Institute \ of \ Physics/\ HEPTech/\ GSI \ Helmholtzzentrum) \)
- A low mass microbulk with real XY strips structure \( (NCSR \ Demokritos/\ Saclay/\ Laboratorio \ de \ Física \ Nuclear \ y \ Astropartículas, \ Universidad \ de \ Zaragoza/\ CERN) \)
Demand for the Micro-Pattern Gas Detectors

MPGD are mostly used/proposed for high-rate tracking and photodetectors

COMPASS Upgrade:
Micromegas and GEM detectors for high-rate tracking
Photon Detectors Using THGEM technology for RICH 1

KLOE2 Upgrade:
Large-area cylindrical GEMs for Inner Tracker

RHIC Upgrades:
GEM Tracking for STAR Experiment
GEM Tracking for PHENIX Experiment (+ drift micro-TPC);
development of Ring Imaging version of HBD for particle ID

Future JLAB Projects:
Thin-Curved Micromegas for JLAB/CLAS12
GEM Tracker for JLAB/Hall A High Luminosity (SBS) experiments

Future FAIR Facility:
GEM Tracker PANDA Experiment
GEM/Micromegas tracking in CBM Muon Chamber (MUCH)

Future Electron - Ion Collider Facility:
Tracking and particle ID detectors based on MPGD-technology
**HV monitoring board (VM)**

- Stabilize Voltages of GEM foils in high-rate applications
- Reduce noise by low impedance HV outputs
- Protect Voltages at GEM foils against shorts in other GEM foils
- Precision output of kilo-Volt levels by 1/2000 factor to DVM/oscilloscope
- Online readout via cable to SRS
- Include measurements of ambient temperature and humidity
- Planned 2nd step: add CM box for Picoampere readout in all lines

**Electronics inside AVD box**

**Principle inside AVD:**
- a.) use high-ohmic resistor divider to bias HV Transistors to obtain constant, low impedance output voltages
- b.) use GigaOHM dividers and instrumentation amplifiers for HV monitoring (static and dynamic down 10 ns)
- c.) static readout via remote I2C cable to SRS

I2C readout via LVDS cable to SRS

Analogue Outputs $U_{in}/2000$
(Banana plugs will be replaced by Coax type)
PicoAmp box (planned)

QSA Quad Signal Amplifier for MPGD’s

2.4 GHz preamplifiers of 4 neighboring detector channels.
Gain Vout/Vin = 20
⇒ Monitor detector signal dynamics below the millivoltage at full BW

Trigger pickup box

- Designed to pick up induced charge on grid or mesh
- Converts charge to voltage via our proprietary CSP amplifier
- 50 OHM fast signal for external shaper/discriminator

Types of signals on MM strip

- Typical electron–ion tail signal
  - 13mV/div 50 OHM 10ns/div

- Typical positively induced strip signal

- Typical discharge (large vertical scale)
  - 500 mV/div

QSA board to be revised to suppress ringing