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

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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 on 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 enrich our basic knowledge in detector physics, to form a generation of young detector experts - paving the way to new detector concepts and applications.

RD51 and MPGD success is related to the RD51 model in performing R&D: combination of generic and focused R&D with bottom-top decision processes, full sharing of "know-how", information, common infrastructures. This model has to be continued and can be exported to other detector domains.

Recent advances in photolithography, microelectronics and printed circuits has favored the invention of novel micro-structured gas-amplification devices. Nowadays, a broad family of micro-pattern gaseous detector (MPGD) technologies are being developed/optimized, such as: Gas Electron Multiplier (GEM), Micro-Mesh Gaseous Structure (MM), THick GEMs (THGEM), also referred to in the literature as Large Electron Multipliers (LEM), Resistive Plate WELL (RPWELL), GEM-derived architecture (μ-RWELL), Micro-Pixel Gas Chamber (μ-PIC), and an integrated readout of gaseous detectors using solid-state pixel chips (InGrid). During the past 10 years, the deployment of MPGDs in high-energy and nuclear physics experiments has increased enormously, which indicates the degree of maturity of given technologies, the level of dissemination within the particle physics community and their reliability. Scaling up MPGD detectors, while preserving the typical properties of small prototypes, allowed their use in the upgrades of the LHC experiments (MM in combination with Thin Gap chambers in the ATLAS New Small Wheel, GEMs in the CMS Muon System and in the ALICE TPC). In addition, wire-chamber based photon detectors of COMPASS RICH-1 have been replaced by hybrid MPGDs - staggered THGEM and a MM multiplication stage with CsI photocathodes.

The consolidation of the better-established technologies has been accompanied with flourishing of novel ones, often specific to well-defined applications. Modern technologies have been also derived from MM and GEM concepts, hybrid approaches combining different elements in a single device, gaseous with non-gaseous detectors, as it is the case for optical read-out. MPGD hybridization, a strategy aiming to strengthen the detector performance, remains a valid asset for addressing future experimental challenges such as high granularity and precision picosecond-timing (e.g. PICOSEC-MM project). As a result, all flavours of MPGDs are in high demand for future applications in particle and nuclear physics, including cryogenic LAr/LXe detectors for neutrino physics and dark matter searches. Hence, industrial manufacturing became mandatory and remains a central issue to be solved. Better understanding of the physics processes, originating from experiment-validated model simulations, paved the road towards novel detection concepts. A clear direction for future developments is that of resistive materials and related detector architectures. Their usage improves detector stability, making possible a higher gain in a single multiplication layer, a remarkable advantage for assembly, mass production and cost. Diamond-like carbon (DLC) resistive layers are the key ingredients for increasing the rate capability of MPGDs, while minimizing the probability of destructive discharges.

Future developments call for novel materials as well as for new fabrication techniques. Contributions to the detector concepts are required for several domains: resistive materials, solid-state photon and neutron converters, innovative nanotechnology components. Material studies can contribute to requirements related to low out-gassing, radiation hardness, radio-purity, converter robustness and eco-friendly gases. The development of the next generation of MPGDs can largely profit of emerging technologies as those related to MicroElectroMechanical Systems (MEMS), sputtering, novel photoconverters, 3-D printing of amplifying structures and cooling circuits, etc. This activity will enlarge community expertise in the domains of nanotechnologies and material science, fields that are not exhaustively covered today and which might bring large potential for future applications. This is just a partial list of fascinating R&D lines that MPGDs will see in the years to come.

Nowadays, many intensive R&D activities and their diversified applications are pursued within the world-wide CERN-RD51 collaboration [3]. The collaboration is widely distributed in terms of institutes/countries. Initially in 2008, the participation was mainly limited to Europe and nearby countries. Over the years, the number of collaborating Institutes from other continents, like from USA and Asia has greatly increased - reinforcing the RD51 world-wide vocation and enhancing the geographical diversity and expertise of the MPGD community; today it comprises of almost of 90 institutes, 500 members in 30 countries. The US community has been for a long time engaged in the development and application of MPGDs; examples are LHC upgrades, JLAB experiments and FRIB facility, and the future US-based EIC program.

The main objective of the RD51 is to advance technological development and application of MPGDs and contribute to the dissemination of these technologies. It is a worldwide open scientific and technological forum on MPGDs, and RD51 has invested resources during these years in forming expertise, organizing common infrastructures and developing common research tools. The progress in various R&D projects has been made possible by open access to facilities and research tools. There is no similar detector R&D consortium, world-wide, relying on such freedom and diversity of research groups and their interests.

In addition to the support mechanisms and facilities tools, the RD51 portfolio is rich and diversified, including: maintenance and development of simulation software (e.g. Garfield ++) dedicated to gaseous detectors, development of SRS [4], a complete read-out chain designed to operate in a laboratory context, also expandable to large read-out systems, realization of affordable laboratory instruments dedicated to MPGD developments, and more. Micro Pattern Technology workshop at CERN is the center of excellence in MPGD production and the RD51 has contributed to the upgrade of its infrastructure. Last, but not least, the RD51 community has open access to the instrumentation, services and infrastructures of the large and well-equipped Gas Detector Development (GDD) laboratory at CERN, continuously hosting several parallel R&D activities. In addition, the common test beam infrastructure at the H4 test-beam area at SPS, available usually three times a year for RD51 collaboration members, allows several groups to investigate in parallel their R&D projects. RD51 underlines the importance of core groups at CERN (modelling and simulation, electronics, facilities and infrastructures, workshops) in terms of development, operation and maintenance and encourages that this should be considered, supported and implemented in future Detector R&D Roadmap.

Future RD51 activities aims at bringing a number of detector concepts to maturity, initiating new developments and continuing the support to the community in order to preserve and enrich the present scenario, including: networking activity, with focus on training and education, further development of dedicated simulation tools, advances in electronics tools, continuation of the collaborative interactions with strategic CERN workshops. *The RD51 collaboration and MPGD success is related to the RD51 model in performing R&D: combination of generic and focused R&D with bottom-up decision processes, full sharing of "know-how", information, common infrastructures. This model has to be continued and can be exported to other detector domains.*

References:

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