Micropattern gas detector technologies and applications

The work of the RD51 collaboration

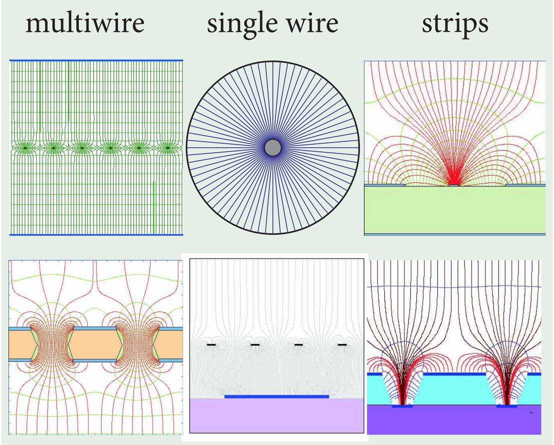
Serge Duarte Pinto, on behalf of the collaboration

Technologies

The working principle of all gas detectors is similar: radiation causes ionization in the gas, electrons and ions drift apart in an electric field, and the electrons create further electron-ion pairs in an avalanche process in a region with a strong electrostatic field. Gaseous detectors differ in how this strong field region is created; historically by thin wires, in recent years many planar structures have seen the light:

- Microstrip gas chamber (MSGC)
- Gas electron multiplier (GEM)
- Micromegas
- Thick GEM
- CMOS-based gas detectors

multiwire single wire strips



holes parallel plate grooves

Organization of the collaboration in working groups

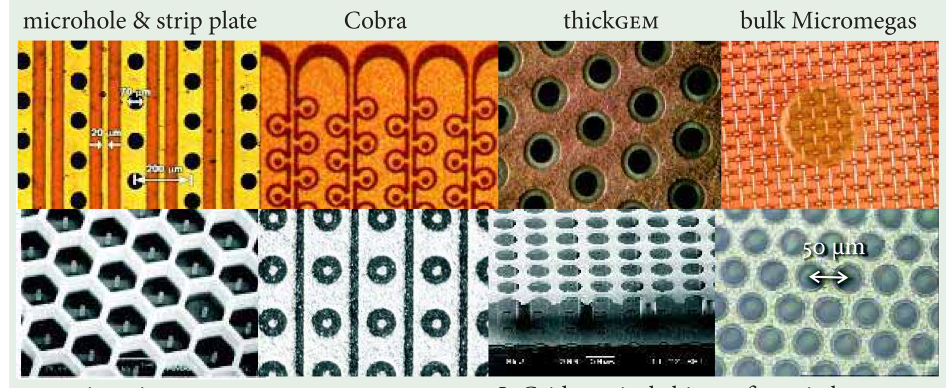
	WG1 MPGD technology & new structures	WG2 Characterization & physics issues	WG3 Applications	WG4 Software & simulation	WG5 Electronics	WG6 Production	WG7 Common test facilities
Objectives	Design optimization. Development of new geometries and techniques	Common test standards. Characterization of physical phenomena in MPGDs	Evaluation and optimization for specific applications	Development of common software and documentation for MPGDs	Readout electronics optimization and intergration with MPGDs	Development of cost-effective technologies and industrialization	Sharing of common infrastructure for detector characterization
Tasks	Large area MPGDs — Design optimization New geometries Fabrication — Development of rad-hard detectors — Development of portable detectors	Common test standards — Discharge protection — Aging and radiation hardness — Charding-up and rate capability — Avalanche statistics	Tracking and triggering — Photodetection — Calorimetry — Cryogenic det. — X-ray & neutron imaging — Astroparticle physics appl. — Medical appl. — Plasma diagn. Homeland sec.	Algorithms — Simulation improvements — Common platforms (ROOT, Geant4) — Electronics modeling	FE electronics requirements definition — General purpose pixel chip — Large area systems with pixel readout — Portable multi-channel system — Discharge protection strategies	Common production facility — Industrialization — Collaboration with industrial partners	Testbeam facility — Irradiation facility

Techniques

The techniques that enabled the advent of micropattern gas detectors come from the industry of microelectronics and printed circuits. Use of these advanced techniques and the base materials provided by industry allows reliable fabrication of very dense patterns, while keeping cost low. Many techniques exist or have been developed to pattern:

- Metal layers
  - Photolithography
  - Wet etching
  - Laser drilling
  - NC milling & drilling
  - Lamination of metallic meshes in insulating structures
- Insulators
  - Photoimageable polymers
  - Polyimide etching
  - Laser ablation
  - NC milling or drilling
- Resistors
  - Screen printing resistive paste
  - Spraying
  - Patterning with help of photoimageable polymers
  - Lamination of carbon-loaded polymer sheets
  - Doping

microhole & strip plate Cobra thickGEM bulk Micromegas



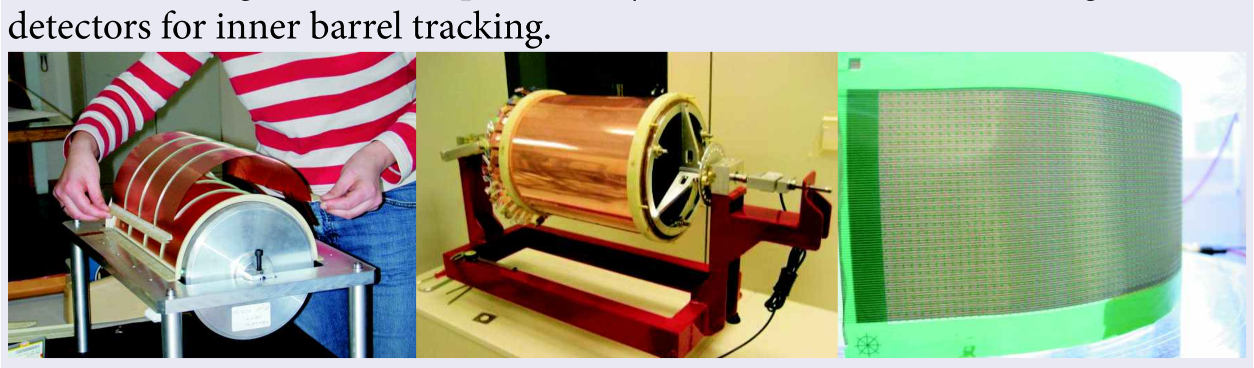
micropin array µ-PIC InGrid on pixel chip fine-pitch GEM

WG1: Technology & new structures

WG1 is concerned with the technology of MPGDs and the design of new structures. Examples are developments of techniques to make large area GEMs (*single-mask technique*) and Micromegas (*bulk Micromegas*).

single-mask GEM bulk Micromegas

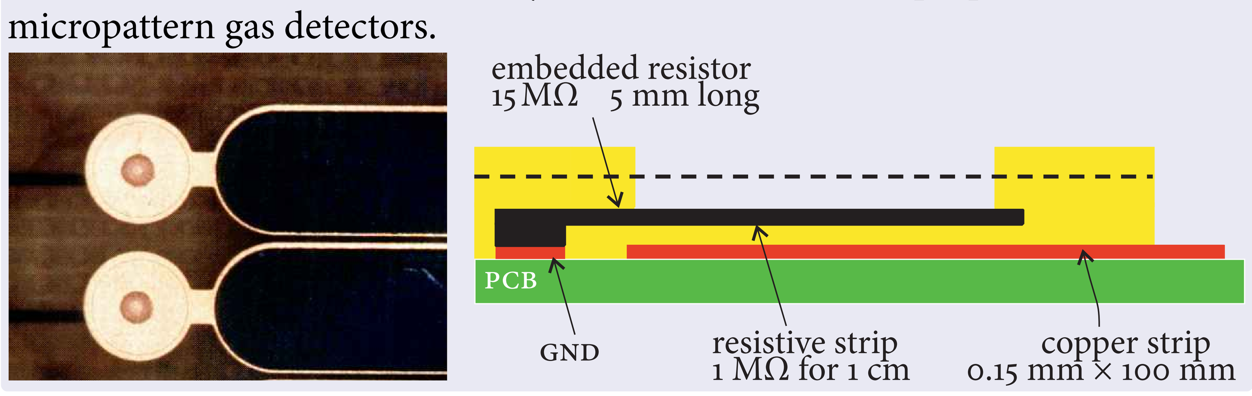
Also interesting is the development of cylindrical GEM and Micromegas detectors for inner barrel tracking.



cylindrical GEMs curved Micromegas

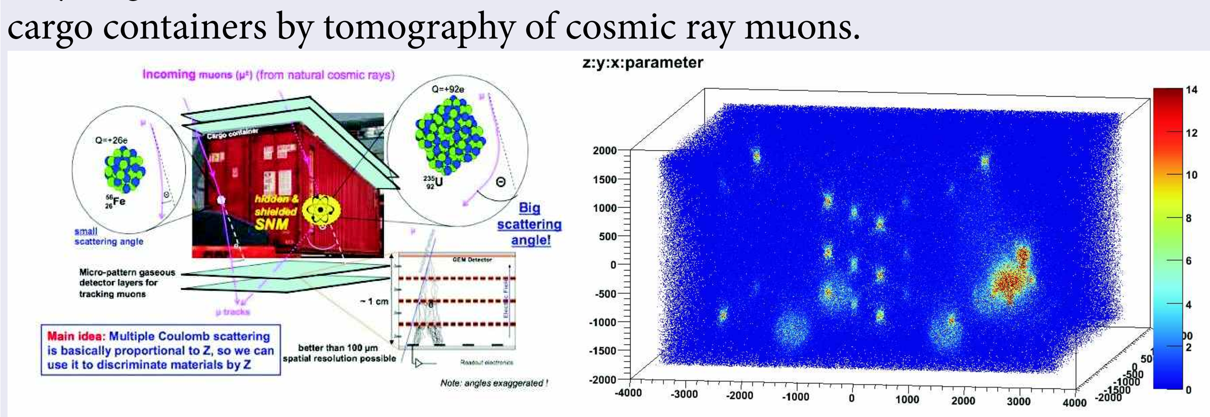
WG2: Physics issues & common characterization

The second working group deals with physics issues of MPGDs, such as discharges, charging of dielectric surfaces and aging. Also, common test standards are proposed to enable different groups to compare their results. Regular meetings have become a forum for exchanging results and for discussion about what are actually the most fundamental properties of micropattern gas detectors.

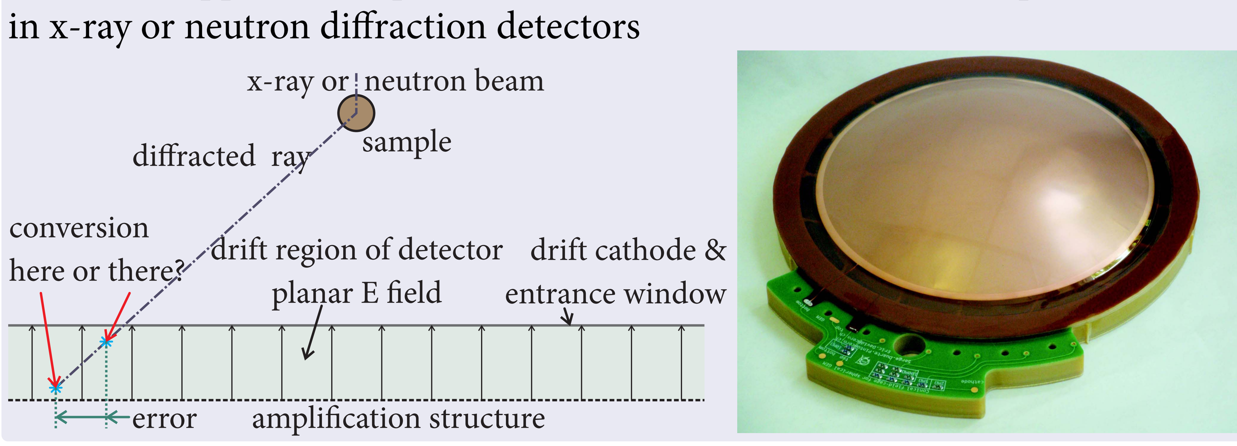


WG3: Applications

WG3 concentrates on the applications of MPGDs, and on how to optimize detectors for particular applications. Most technologies were born in high-energy physics, where there are still many applications. But these technologies are spreading into other domains: one project aims to construct very large area GEM chambers to detect nuclear fission materials or waste in cargo containers by tomography of cosmic ray muons.

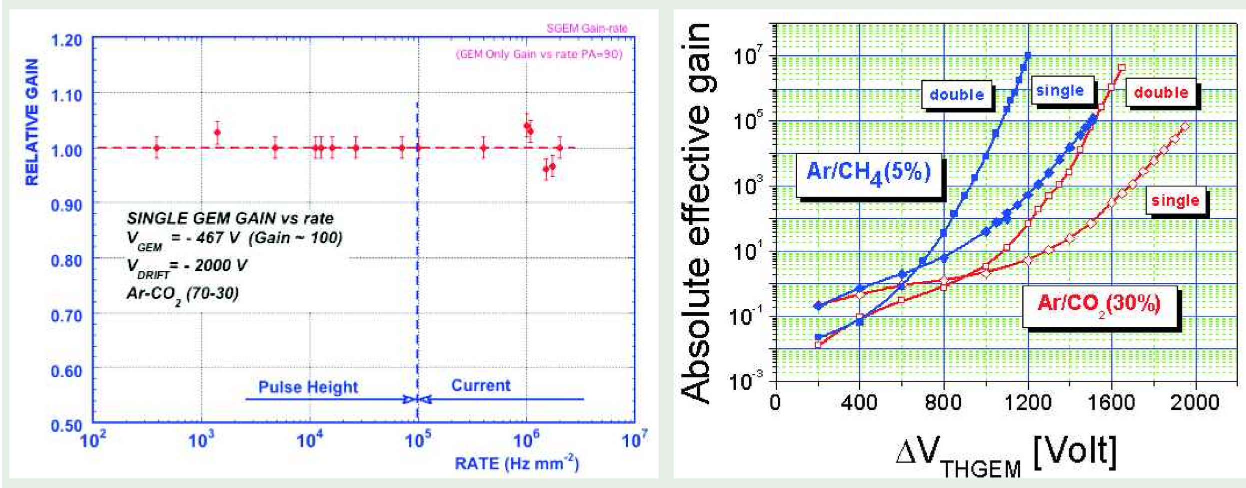


In another application, spherical GEMs are used to eliminate the parallax error in x-ray or neutron diffraction detectors

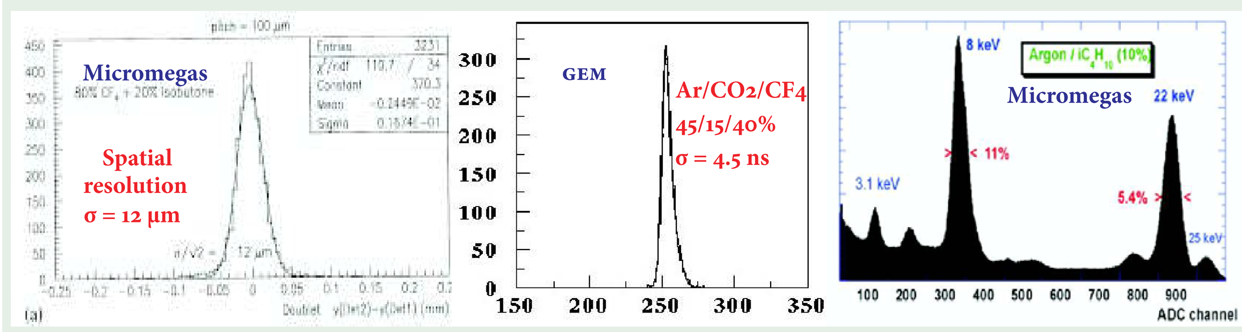


Performance

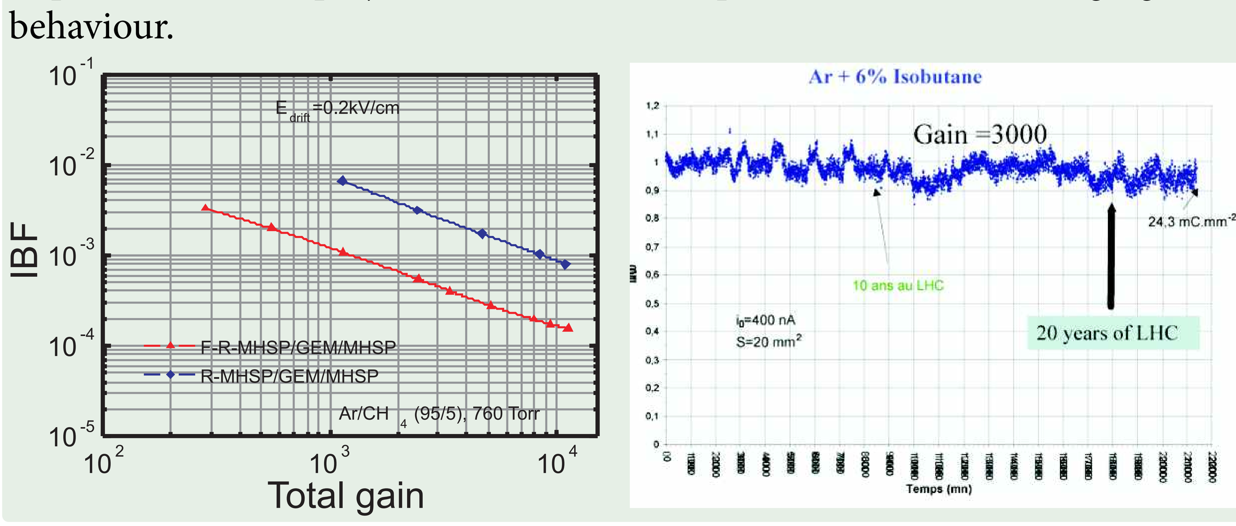
Depending on the application, the performance of MPGDs has different figures of merit. The first MPGDs were designed to obtain a high rate capability. Several MHz/mm² of charged particles are easily reached with, for instance, a triple GEM detector, without a measurable loss of gain and with negligible discharge probability.



Time, position and energy resolution are crucial figures for most applications. GEM-based detectors normally have a position resolution of about 50 μm, Micromegas can go down to ~ 12μm if equipped with a high density readout board. Time resolutions are of the order of few nanoseconds.



Further relevant performance aspects are ion feedback suppression, especially important for time projection chambers and photon detectors, and aging behaviour.



WG4: Software & simulation tools

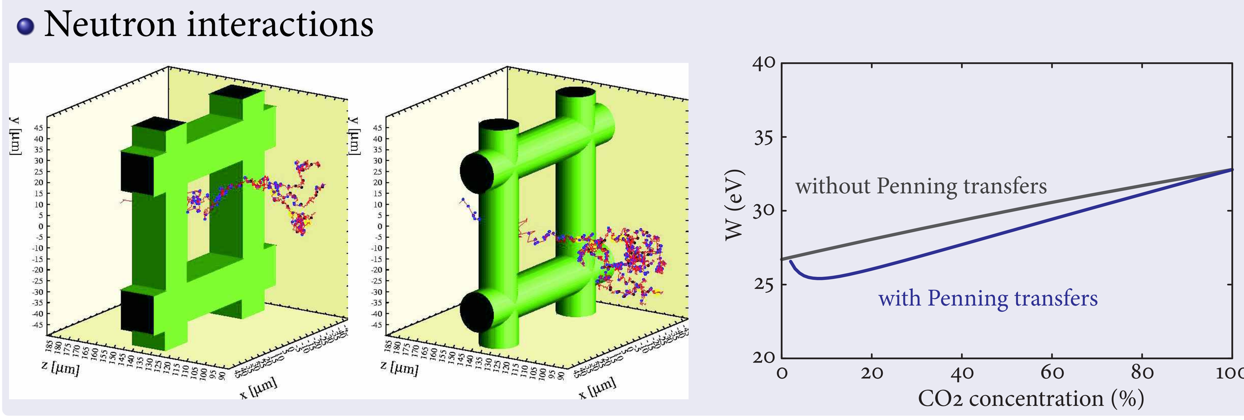
WG4 develops software tools and makes progress in the field of simulation.

- Electric & magnetic field simulation: neBEM (by S. Mukhopadhyay et al.)
- Ionization: Heed (by I. Smirnov)
- Cluster size distribution: MIP (by S. Biagi)
- Drift & diffusion: MagBoltz (by S. Biagi)
- Avalanches & photoproduction: Garfield (by R. Veenhof)

All these tools are interfaced with Garfield, which in turn can be used from Geant4.

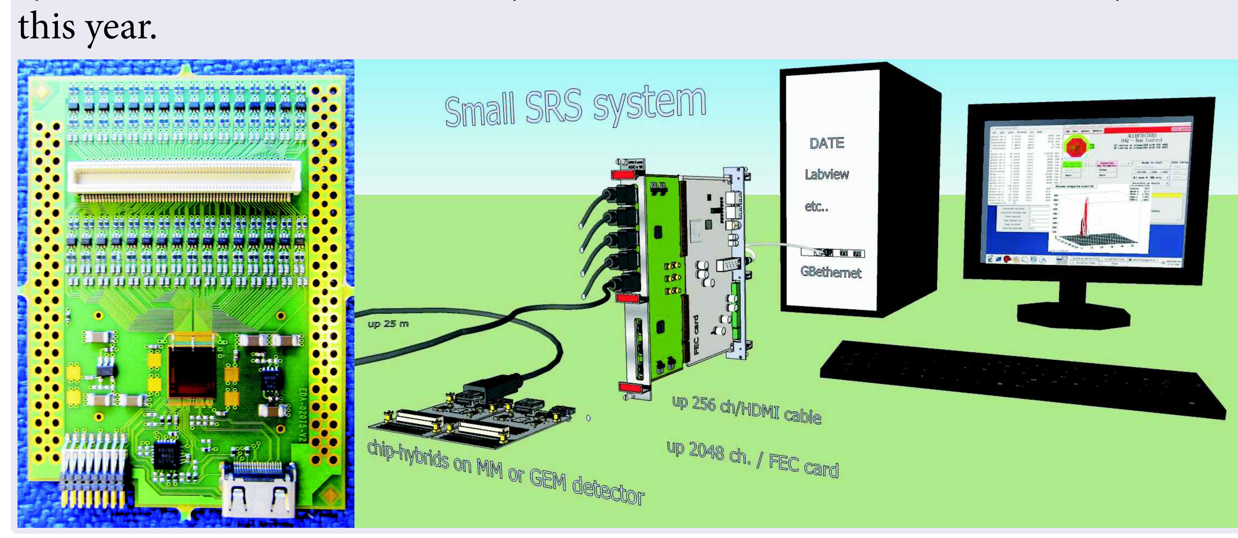
New developments include:

- Microscopic tracking & avalanche
- Penning & Jesse transfer mechanisms in ionization and avalanche simulations
- Neutron interactions



WG5: Electronics

Front-end electronics and data acquisition systems are discussed in WG5. Most notable accomplishment is the development of scalable modular acquisition system that can work with many different front-end ASICs, successfully tested this year.



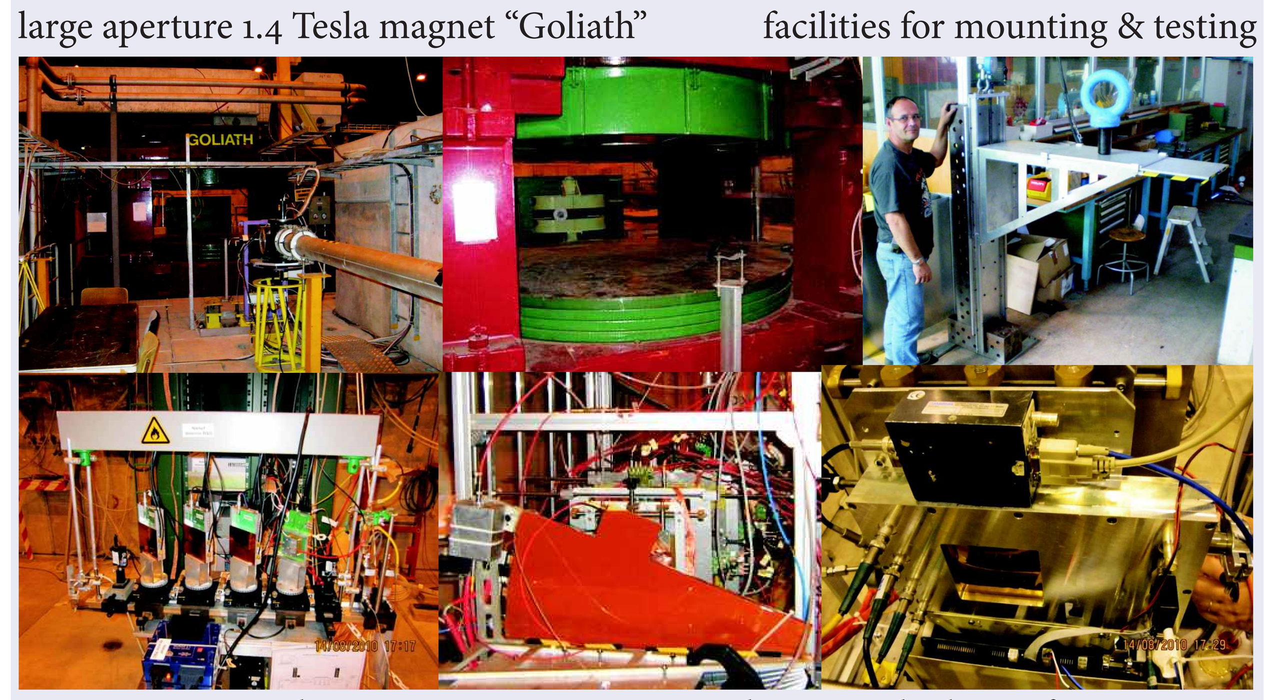
WG6: Production

WG6 deals with the production of MPGDs. Almost all MPGDs were first made in the CERN PCB workshop of Rui de Oliveira, and it remains an almost exclusive manufacturing site for most technologies. Hence, efforts in WG6 are aimed at plans for upgrading this workshop on the one hand, and industrial partnership and export of the technology and know-how on the other. Also, scenarios are developed for industrial scale production of some MPGDs (especially GEMs and Micromegas), in case a large experiment decides to implement them in their system.

WG7: common test facilities

WG7 coordinates the effort to set up a shared test infrastructure in the form of test beam and irradiation facilities. The test beam facility is equipped with supply and exhaust of gases, including flammable mixtures. Also a large 1.4 Tesla magnet is provided, and two beam telescope systems are available.

large aperture 1.4 Tesla magnet "Goliath" facilities for mounting & testing



GOSSIP/GridPix TOTEM T1 upgrade thickGEM for RICH

The irradiation facility will provide a strong gamma source combined with a 100 GeV muon test beam and is called GIF++.

Info & contacts

Public website: http://rd51-public.web.cern.ch/RD51-Public/

RD51 meetings:

- NIKHEF, Amsterdam, 16–19 April 2008.
- Paris, 13–15 October 2008.
- Kolympary, Crete, 16–17 June 2009.
- CERN, Geneva, 23–25 November 2009.
- Freiburg, Germany, 24–27 May 2010.
- Bari, Italy, 7–10 October 2010.
- CERN, Geneva, 13–15 April 2011.
- Kobe, Japan, 2–3 September 2011.

Interested? Contact one of the spokesmen:Leszek Ropelewski (Leszek.Ropelewski@cern.ch), Maxim Titov (maxim.titov@cea.fr), or the secretary of the management board: Hans Taureg (Hans.Taureg@cern.ch)