WP5: Gaseous detectors for calorimeters

Two key points were mentioned in the ECFA report on gaseous-detector calorimeters:

- Large area, thin and high rate detectors.
- Homogeneity : efficiency, resistivity (rate and cluster size)
- Timing and High-Rate GD

1.2.3 Calorimetry

R&D in particle-flow calorimetry is a major "paradigm shift" for high-resolution imaging calorimeters, which was originally an e^+e^- linear collider driven effort, but nowadays is highly relevant for HL-LHC upgrades and future facilities (see Chapter 6). Particle-flow hadronic calorimeters with alternating layers of absorbers and sampling elements, based on GDs, are considered for ILC, FCC-ee, EIC, FCC-hh and muon collider [Ch1-49].

The main differences between circular and linear e^+e^- colliders reside in the readout timing and the power pulsing, which if possible enables a larger effective density of the calorimeter and more compact particle showers. GD-based calorimeters with a typical cell size of $\mathcal{O}(1\,\mathrm{cm}^2)$, together with a large number of sampling layers ($\approx$50 to contain hadronic showers) imply a very large channel count ($\mathcal{O}$(10k) per m^2). This requires thin gas layers, which might affect signal amplification and timing resolution, and embedded electronics integrated in a very compact system. Moreover, production of high planarity, large-area PCBs for MPGDs and mechanical fabrication issues of very thin High Pressure Laminate RPCs represent additional challenges. Single-stage structures, based on RPC, resistive-plate WELL (RPWELL) and Micromegas also require a very uniform resistivity, gas gap thickness (down to micron level), and well-modelled gas distribution inside the detector volume in order to guarantee uniform response in terms of signal efficiency, rate capability and timing resolution. Last, but not least, hermetic calorimeters are usually extended down to small polar angles where beamstrahlung particles deposit several MGy of dose per year. Therefore, radiation hard gaseous detectors are needed.

Facility	Technologies	Challenges	Most challenging requirements at experiment
Higgs-EW-Top Factories (ee) (ILC/FCC-ee/CepC,/SCTF)	RPC, Micromegas and GEM, μ-RWELL, GridPix, PICOSEC, FTM	High granularity, excellent hit timing, large area detectors, stabiliy, uniform response, eco-gases	**(ILC)** Max. rate:1 kHz/cm² Granularity (~1 cm²) Radiation hardness: no Jet Energy resolution: 3-4 % Power-pulsing, self-triggering readout
Muon collider	RPC, Micromegas and GEM, μ-RWELL, GridPix, PICOSEC, FTM	High granularity, radiation hardness, excellent hit timing, stabiliy, uniform response, eco-gases	Granularity (~1cm²) Fat jet identification Time resolution= O(100ps) Energy resolution =(5%)/sqrt(E) for fat-jet High radiation hardness
Hadron physics (EIC)	RPC, Micromegas and GEM, μ-RWELL, GridPix, PICOSEC, FTM	High granularity, radiation hardness, excellent hit timing, stabiliy, uniform response, eco-gases	**(EIC option)** DHCAL

Figure 1.4: Main drivers for Calorimeters at future facilities. The most stringent requirements for the future R&D activities are quoted in the last column.

Digital or semi-digital hadronic calorimeters, based on one- or two-bits ADC [Ch1-50], were advanced within the CALICE collaboration [Ch1-51]. In a semi-digital hadronic calorimeter, the energy measurement relies on the approximate linear relationship between the particle energy and the number of associated hits and requires sampling elements with high detection efficiency and a low pad hit multiplicity per traversing particle. Glass RPC [Ch1-52], GEM, RPWELL [Ch1-53] and Micromegas [Ch1-54] have been studied as potential sensing elements for the ILC Semi-Digital Hadronic Calorimeter. Larger area RPC prototypes were subsequently built to verify the scalability of the fabrication process and to address engineering challenges. Ultra-fast picosecond-timing information with technologies like MRPC, PICOSEC and FTM can be used to resolve the development of hadron showers, resulting in a smaller "confusion term" and to improve jet energy resolution in hadronic calorimeters. The main challenges of the future R&D in the GD-based calorimetry is to ensure a uniform response over the large detector area (DRDT 1.1), and operation with eco-friendly gas mixtures (DRDT 1.3). Figure 1.4 summarises the main facilities, the proposed technologies to address the main challenges, and the most stringent conditions expected for calorimetry.

The related activities on calorimetry in DRD1 are dedicated to the active media while the system aspects and readout electronics belong to DRD6

Gaseous Detectors for calorimetry: (M)RPC, MicroMegas, RPWELL, µRWELL
Task1: Large area detectors
- Construction of large GD (.5 x .5, 1 X 1 m2 and then 2x1 m2)
  with precise timing and using low resistive materials and snew methods to increase the homogeneity
  and reduce the dead zones

Task2: **Homogeneity study**
Sub task2.1: resistivity map (after using adequate coating methods) in case of (M)RPC
Local cluster size measurement is the essential parameter to monitor
Subtask2.2: gas circulation study to ensure homogeneity of the gas renewal with possible
use of radioactive sources to validate in addition to efficiency
Sub task2.3: efficiency mapping as function of threshold, HV ..etc
Sub task2.4: timing mapping as function of threshold and HV.. Etc

Remarks:
-7 groups have shown interest to join this WP
-Electronics developed for (Calorimetry) in DRD6 will be used but until this is ready we propose to use the one developed for LHC (like petiroc for iRPC) or others. We will try to have the same electronics in future for the different technologies.
-Deliverables and milestones will be based on the tasks. For instance
D1: Characterization study of medium and large GD for future calorimeters