R-I. “Lendület” innovative gaseous detector development

“Momentum” research team

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After the infrastructure developments of the previous years, the activities of the group were focused on detector development and detector physics research. This includes contributions to specific CERN experiments, such as the ALICE, NA61 and RD51. Relevant detector physics projects were financed by H2020 grants. In the field of cosmic muon imaging, novel methods and novel detector systems were established, leading to a Japanese-Hungarian utility patent.

Contributions to CERN Collaborations. — The group's participation, along with the Hungarian ALICE Group, is now clearly established within the Time Projection Chamber (TPC) Upgrade Collaboration. Budapest will be one of the two Advanced Quality Assurance testing sites, that is, half of the foils which will be built into the new ALICE TPC readout will pass through our lab. Within the framework of the NA61 Collaboration, new TPC-s will be built to capture the forward particles, highly relevant for neutrino factories. The RD51 Collaboration establishes the basis for R&D for gaseous detectors, and is correlated with the AIDA-2020 participation of the group.

Detector physics results. — The most relevant results of the group are related to detector physics, that is, the fundamental questions in the operation of gaseous detectors. Gas Electron Multipliers (GEM-s) are particularly interesting, both as a highly relevant Micro-Pattern Gaseous Detector (MPGD) type with very confined amplification region, and as a popular actual advanced detector technology (also used in the ALICE TPC Upgrade).

By understanding the cascaded steps in the multiplication process (Fig. 1, left), one can trace the energy resolution of GEM-s, dominated by avalanche fluctuations. The inverse of the energy resolution can be experimentally found to linearly increase with the inverse of the effective GEM gain (Fig. 1, right), to first order independently from absolute gain and from gas type.

A statistical calculation leads to an analytic formula for the effective gain fluctuations, as a function of the true avalanche fluctuation f (ratio of spread over mean) as well as transfer and collection parameters, which explicitly predicts the resolution dependence on the inverse of the effective gain G:

$$f_{all}^2 = (\frac{1+f^2}{c} - 1) + \frac{1}{G}(1 - t + F^2)$$

Ph.D. student

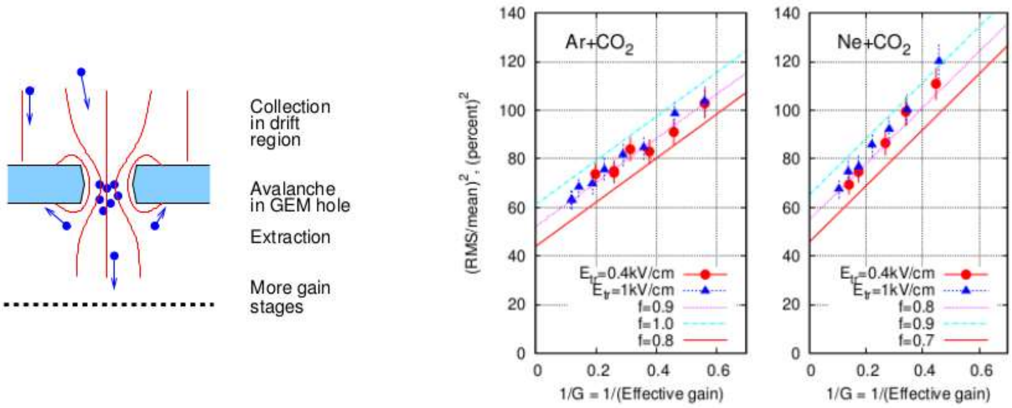

Figure 1. *Relevant cascaded processes in a GEM amplification stage (left panel), including collection, avalanche fluctuation and extraction before subsequent gain stages. Analytic calculation predicts that the inverse of the resolution (right panel) linearly depends on the inverse of the effective gain G.*

Even more interesting is to establish the *avalanche size distribution initiated by single electrons,* as this has been directly measured in various gases. Fig. 2 left panel shows a typical pulse height distribution for very low UV photon irradiation: if there is no photo-electrons induced, a sharp peak appears, whereas a single photo-electron distribution clearly departs from the noise peak. In this measurement, 2 or more photo-electrons (Poissonian) contribution is very small, thus making this measurement very clear for the first time.

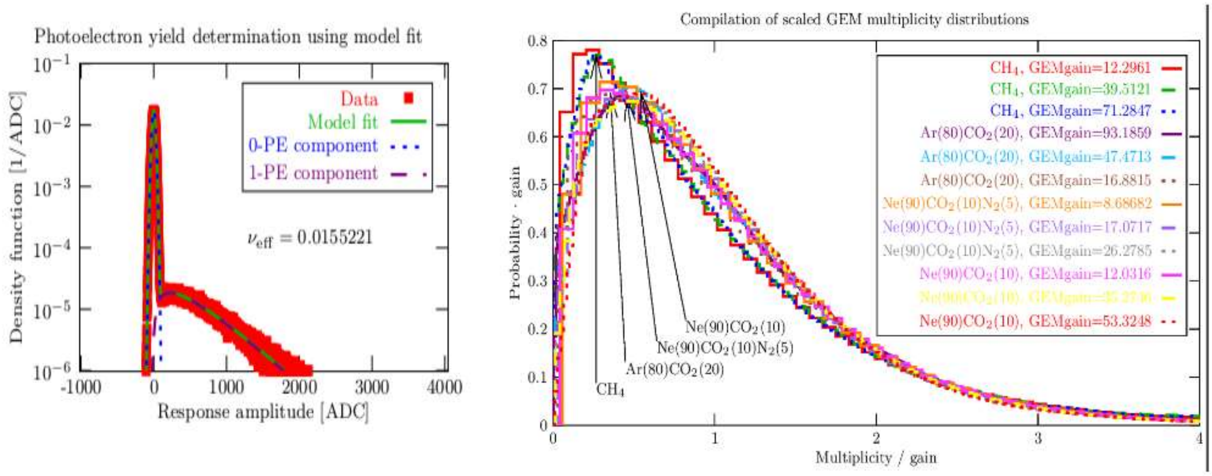

Figure 2. *Signal amplitude (left panel) from UV photons, showing typically 0 (sharp peak) and 1 photo-electron responses. The amplitude distribution clearly departs from the typical exponential distribution. For various gases, the signal amplitude (right panel) shows similar non-exponential feature, strongly depending on gas composition.*

On the right panel of Figure 2, the extracted single electron avalanche distributions are shown, normalized to a mean of 1, in different gases. There is a clear trend indicating that gases with higher ionization potential show stronger departure from a pure exponential distribution, observed regularly in Multi-Wire Proportional Chambers (MWPC).

Imaging with cosmic muons. — The application of cosmic muons for large scale imaging has been a research direction in the group in the previous years. Collaboration with the Novi Sad University (Serbia) has led to a novel imaging technique, which utilizes secondary emission. When cosmic particles, mainly muons, cross any material, a gamma photon (with energies from few keV up to few MeV) may be emitted coincidentally. Registering the particle trajectory along with the energy deposit in a gamma counter, one can visualize those tracks which were responsible for the emission: this possibility is demonstrated on the left panel of Figure 3. A key advantage of the approach in comparison to earlier techniques is that it is sensitive for low atomic number materials as well. The method may find its application in imaging where X-ray irradiation is undesirable.

An important application for cosmic muons detectors, developed in the last years by the group, is imaging the interior of volcanos. This direction was pursued by Japanese and various European groups. Given the fact that gaseous tracking detectors, and in our case, a specific type of an MWPC, are highly competitive with the traditional scintillators in terms of cost, weight and power consumption, a utility patent has been filed in Japan, owned jointly by Wigner RCP and Tokyo University, for the so called “Muography Observation Instrument”. A first prototype of the detector, installed at the Wigner campus, is shown on the right panel of Figure 3. The detector shows excellent long term performance, sustaining high efficiency at varying environmental conditions.

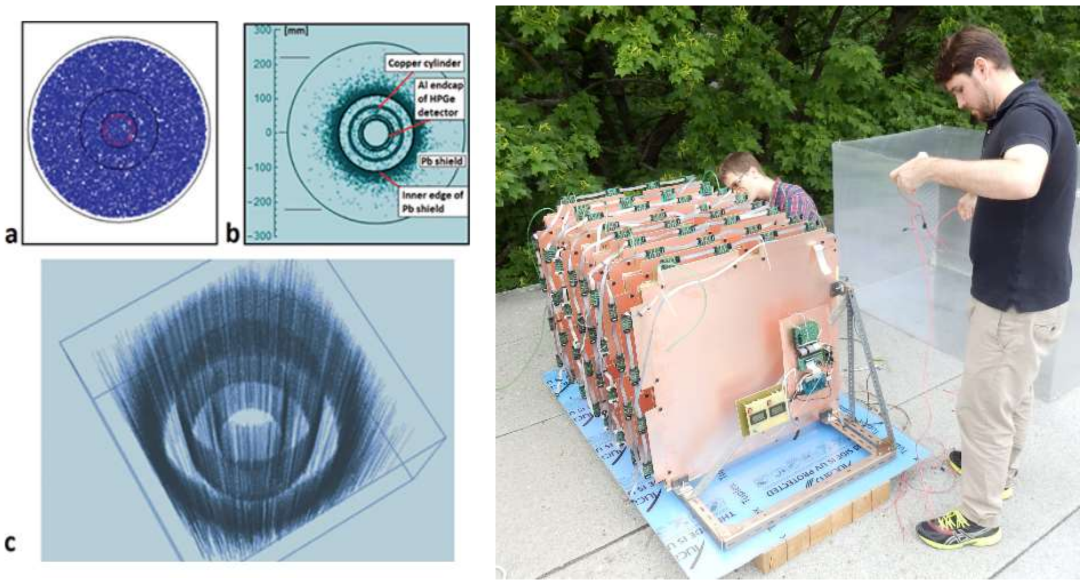

Figure 3. *A new imaging technique involving secondary emission can be used to visualize low atomic number materials: on the left panel, the middle ring appears for those tracks which had a coincident gamma photon in the HPGe detector. The right panel shows the prototype of a large size imaging system installed outdoor.*

Grants

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International cooperation

CERN NA61 Collaboration (A. László), CERN RD51 Collaboration (D. Varga), CERN ALICE TPC Upgrade Collaboration (D. Varga)

Earthquake Research Institute, Tokyo Uni., Muography for Volcano Monitoring (L. Oláh, D. Varga)

University of Novi Sad (Serbia), Novel Imaging Methods (L. Oláh, D. Varga)

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See also: R-B.1,R-B ALICE Collaboration, R-H NA49 Collaboration, R-H NA61 Collaboration