Negative ions as charge carriers in gas detectors

A.P.Marques[a,b], A.M.F. Trindade[a,b], J. Escada[a,b], F.I.G.M.Borges[a,b] and F.P. Santos[a,b,*]

- *Corresponding autor: filomena.santos@coimbra.lip.pt*

[a] LIP – Laboratório de Instrumentação e Física Experimental de Partículas,
[b] Departamento de Física da Universidade de Coimbra,

Abstract: Event tracking is a major requirement of large setups used in rare event and particle physics experiments that use gas detectors. It is based on the low diffusion of charge carriers produced by the incoming radiation event. Noble gas, with high electron diffusion, are commonly the detection medium of choice in many of these experiments, so solutions must be found. One of these is the use of negative ions as charge carriers and the concept, long known, has proved to work with electronegative gases as detection medium. This, however, will not work in many ongoing applications. Thus, we plan to investigate the possibility of using the electronegative gas as a trace additive to the main detection gas instead of detection medium. For this technique to work, a sequence of events with large efficiency must occur: electrons produced must attach to the additive, must form a stable ion, should be easily detached from the ion when convenient and should not reattach to the additive. The overall success of the approach depends on the maximization of the efficiencies of individual processes. Furthermore, the amplification stages usually required in gas detectors must keep their yields to a level compatible with the desired energy resolution.

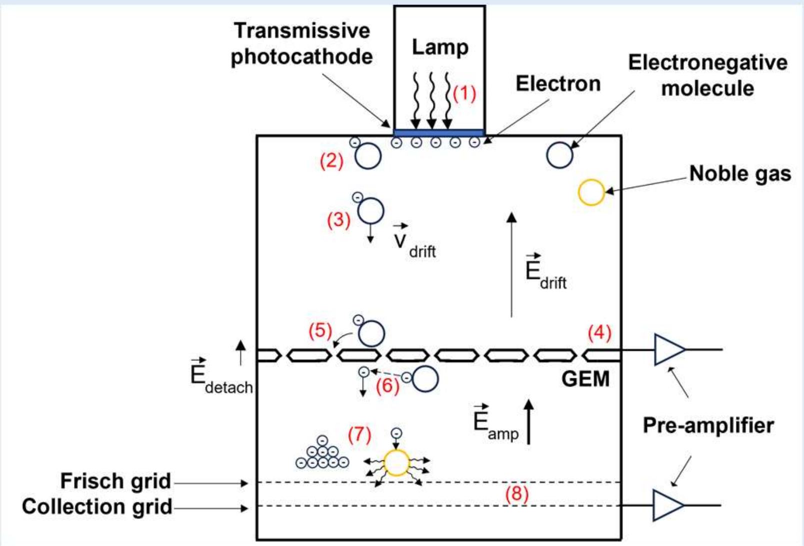

Figure 1. Scheme of a vertical cut of the newly developed experimental system

Description of elements highlighted on Figure 1:

1) Vacuum chamber containing xenon lamp
2) After being produced in the CsI transmissive photocathode, electrons quickly attach to electronegative additive molecules
3) Produced ions drift (with low diffusion) under the externally applied electric field
4) First check point: collecting the charge at this point at the unpolarized GEM allows to assess the efficiency of the attachment stage
5) Duly polarized, the GEM device triggers
6) the detachment of the electrons from the negative ion
7) Frisch grid to avoid charge induction during drift
8) Collection grid (second check point)

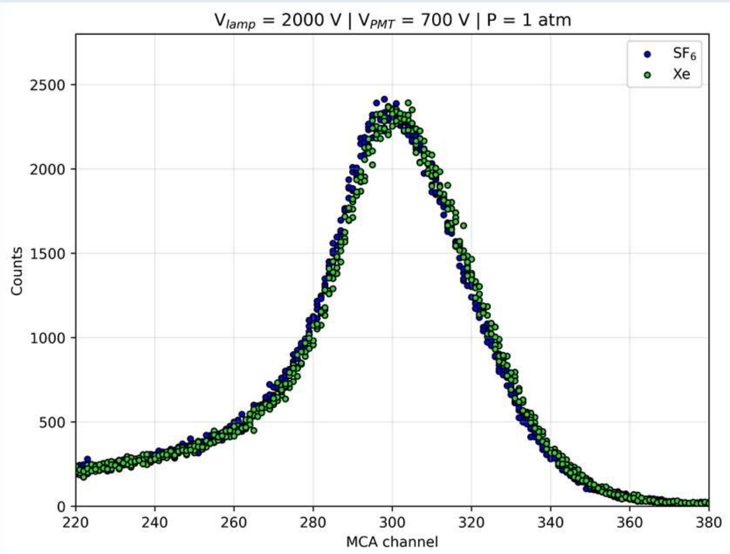

Figure 2. The transparency of SF_6 to Xe emission was checked with an available device that has a xenon lamp on the top and a VUV sensitive photomultiplier tube on the bottom. Within the sensitivity of our system there is no absorption of Xe VUV scintillation by SF_6 thus it configures a suitable electronegative additive to a xenon electroluminescent TPC.

After establishing the best working conditions for the events mentioned in Figure 1, assessment must be made of the effect of the additive on the efficiency of the usual amplification modes of gas detectors: charge multiplication or, in electroluminescent detectors, scintillation. The additive amount must be compatible with the energy resolution targeted. Experiments are being made in dedicated devices (proportional and gas proportional scintillation counter).

Conclusions: To improve event tracking in large gas detector setups, negative ions as charge carriers have been considered. The concept, long proposed, has worked in very specific conditions. To validate its wider use a thorough stepwise investigation is being carried out checking sequentially each of the steps involved and their best operating conditions. The main goal is to study xenon as the main gas and SF_6 as the additive, to be used in trace quantities, that is to determine the least amount of additive that can produces a workable charge diffusion (to be monitored). SF_6 is transparent to Xe VUV emission which makes a viable candidate. Effect of the additive in amplification modes will also be assessed and a good compromise between low diffusion and adequate energy resolution will be found.

Acknowledgments:
This work was supported by the RD51 Collaboration/CERN, through the common project CERN/FIS-INS/0013/2021. A.P.Marques was supported by a FCT PhD grant 2021.05576.BD.