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Efficient noble gas purification using hot getters and gas circulation by convection

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Noble gas radiation detectors with optical readout are increasingly applied to astrophysics, particle physics and to x- and gamma ray imaging. They are based on the notable characteristic of responding to ionizing radiation interaction by producing both ionization and scintillation signals. In addition, another important asset of noble gases is the possibility to obtain the amplification of the primary ionization signals by promoting secondary scintillation in the gas, upon drifting the primary ionization electrons throughout the gas.
One of the well-known factors that strongly influences the detector performance is its purity (e.g. H2O, N2, O2, CO2 and hydrocarbons). The extremely large number of collisions that drifting electrons undergo with the gas atoms/molecules along their drift path may result in the loss of primary electrons to electronegative impurities, due to attachment, or in the loss of the electron energy through inelastic collisions with molecular impurities, due to excitation of rotational or vibrational states of the molecule, or else due to quenching of the noble gas excited atoms and/or excimers by the molecular impurities. All these effects contribute to the deterioration of the gas scintillation, imposing a stringent purity level of the gas. This purity level is more demanding for optical detectors than for detectors base on electron avalanche amplification and charge readout because the scintillation quenching and because the electric fields, thus the average drifting electron energy, in the former detectors are weaker. This is particularly significant if the secondary scintillation is achieved in the so-called proportional regime, where the electric fields are below the gas charge multiplication threshold.

In general, the detector volume is sealed, being the gas purity achieved and maintained by imposing gas circulation through hot non-evaporable getters.

Since 1989, in Coimbra, we developed a simple method for gas purification in our gas noble gas radiation detectors operated in sealed mode. We have used washer-shaped non-evaporable getters having a relatively low activation and operation temperatures. The getters fill a vertical tube inserted in the gas circulation loop, being the getter temperature maintained by heating tapes rolled up around the tube, on the outside. In this way, the gas circulation can be promoted by convection, since the gas column in the vertical arm of the loop containing the getters is heated up. We have applied this gas purification technique to gas chambers of few tenths of liters to few liters in volume. The effectiveness of the gas purification has been confirmed by the state-of-art energy resolutions achieved in our detectors and the fast recovery of the scintillation output when the gas circulation is reassumed after being stopped for some time. In addition, the experimental results obtained for the absolute EL Yield in Xe, Kr and Ar are similar to those obtained by other authors and by state-of-art simulations.

Nevertheless, through the years, our peers have questioned about the actual effectiveness of our purification method either in terms impurity content or in terms of electron attachment and scintillation quenching by impurities. A simple and easy evaluation of the impurity levels by means of mass spectrometry has been difficult since we are dealing with very low concentrations and large backgrounds at the Residual Gas Analyzer chamber.

In this work, we used waveform analysis of the primary and secondary scintillation pulses and we were able to evaluate the impact of the attachment and quenching by impurities in one of our detectors filled with pure Xe and estimate upper values for impurity content in the gas.

Primary authors: TEIXEIRA, J. M. R. (LIBPhys-UC, Department of Physics, Univesity of Coimbra, Portugal); HENRIQUES, C.A.O. (LIBPhys-UC, Department of Physics, Univesity of Coimbra, Portugal); SILVA, P. A. O. C. (LIBPhys-UC, Department of Physics, Univesity of Coimbra, Portugal); MANO, R. D. P. (LIBPhys-UC, Department of Physics, Univesity of Coimbra, Portugal); DOS SANTOS, J. M. F. (LIBPhys-UC, Department of Physics, Univesity of Coimbra, Portugal); MONTEIRO, C. M. B. (LIBPhys-UC, Department of Physics, Univesity of Coimbra, Portugal)

Presenter: TEIXEIRA, J. M. R. (LIBPhys-UC, Department of Physics, Univesity of Coimbra, Portugal)

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