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Electroluminescence yield of He-CF4-isobutane mixtures

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CYGNO is part of the CYGNUS international proto-collaboration for the development of a distributed Galactic Nuclear Recoil Observatory for directional Dark Matter search at low WIMP masses (1-10 GeV/c2) and coherent neutrino scattering measurement. CYGNO is developing a gaseous Time Projection Chamber (TPC), which will be hosted at Laboratori Nazionali del Gran Sasso, Italy. The CYGNO-TPC will rely on a triple Gas Electron Multiplier (GEM) stack for charge multiplication and electroluminescence (EL) production, operating at room temperature and atmospheric pressure. The EL will be collected with a high resolution scientific camera for particle identification and 2D track reconstruction, with the aim of discriminating nuclear recoils and their direction.

To probe the middle energy and mass range of WIMPs (GeV), having a low mass target is essential, hence He will be the main component of the CYGNO-TPC. The addition of CF_4 is also fundamental as it increases gas scintillation and sensitivity to Spin Dependent WIMP-Nucleon Coupling. To further improve the tracking capabilities of the gas mixture (such as electron diffusion and drift velocity), the addition of isobutane and other gases with high H-content is currently under consideration.

This work aims at determining how the addition of small percentages of isobutane to the He-CF_4 (60/40) base mixture influences the EL yield, charge gain and corresponding energy resolution. The detector, operated in continuous-flow mode, was irradiated with low-energy x-rays (5.9-keV) and a Large Area Avalanche Photodiode (LAAPD) was used to readout the EL produced in the avalanches of a single GEM. Increasing concentrations of isobutane, from 1% to 5%, were added to the base mixture of He-CF_4 (60/40), continuously flowing at 4 L/h.

Our results show that the number of avalanche electrons increases with the addition of isobutane, with a 2.7-fold increase for 5% isobutane content relatively to 0%. The energy resolution of the charge signals is independent of the isobutane content and around 12 % (FWHM) for all mixtures. The EL yield decreases with increasing concentration of isobutane. Although a 7.9-decrease in the number of EL photons emitted per avalanche electron was measured for 5% isobutane relative to 0%, there was only a 2.8-fold decrease in the total number of emitted EL photons. The energy resolution of the EL signals was around 20%, showing a slight degradation with increasing isobutane content, which we attribute to low statistics.

These results show that isobutane does not compromise the total amount of EL photons, while maintaining the energy resolution of the base mixture unchanged and is therefore a good option to study for possible applications in the CYGNO-TPC.

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