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# Studies of the scintillation yield emitted from GEM avalanches in He-40%CF4 admixtures with few percent of ethane or propane

An optical Time-Projection Chamber (TPC) using a He-40%CF4 gas mixture has been proposed for directional Dark Matter (DM) searches. The motion of the Earth around the Sun results in an anisotropic angular distribution of the WIMP relative to the gas target and, thus, relative to the nuclear recoils induced by WIMP collisions with nuclei which, together with the Earth rotation, enables an unambiguous DM signal identification. The He light nuclei allow for long track lengths, resulting in improved determination of their direction and enables high sensitivity to the WIMP masses in the GeV and sub-GeV range.
In optical TPCs the primary ionization produced by the radiation interaction, e.g. nuclear recoils due to WIMP collisions, is amplified promoting in the gas target secondary scintillation produced by electron impact, e.g. promoting electron avalanches in GEMs. CF4 presents a high scintillation yield, both in the UV and in the visible regions, and its scintillation emission is well known. The 2D readout of the GEM scintillation by a pixelized photosensor, together with the time-profile of the arrival of the ionization electrons at the GEM plane, allows for the determination of the 3D ionization track topology.
The addition of lighter nuclei, hydrogen, would further improve the sensitivity for low mass WIMPs and will result in longer track lengths, increasing the directional sensitivity and particle identification, through dE/dx, thus improving background discrimination. The impact of adding few percent of isobutane or methane to He-40%CF4 on the mixture secondary scintillation, produced in electron avalanches, have been investigated. For isobutane, the average number of photons per avalanche electron is reduced by 90% as the concentration increases from 0 to 5%, due to quenching of the excited state species from He and CF4 excitations. Nevertheless, the average total number of photons produced in the avalanches only decreases by 35%, due to the simultaneous presence of Penning transfer from He excited atoms to isobutane molecules and to the reduction of the gas w-value, which increases the number of electrons in the avalanches and, thus, the total number of photons. This latter effect is present because the energy of the He excited states is higher than that of CF4 ionization. Methane addition does not present a strong quenching, but it also does not present Penning transfer. In overall, the addition of methane to the He-40%CF4 mixture results in improved electrical stability, allowing for higher GEM bias voltages, resulting in an increase in the maximum scintillation output.
In this work, we extend the studies to the addition of ethane and propane to the He-40%CF4 mixture, in an attempt that one of these molecules presents the advantages of both methane and isobutane: a weak quenching effect, as in methane mixtures, and the presence of Penning transfer, as in isobutane mixtures. Experimental results for the total scintillation yield produced in the electron avalanches and the yield per avalanche electron will be presented and discussed.

## Workshop topics

Sensor materials, device processing & technologies

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