Understanding delayed (spurious) emission mechanisms in dual-phase TPCs for Dark Matter searches

Mystery of dark matter. The presence of Dark Matter (DM) in the Universe is nowadays an established, yet still mysterious, paradigm: deciphering its essence is one of the most compelling tasks for fundamental physics today.

Dark Matter accounts for 23% of the mass-energy density of the observable universe (while ordinary matter accounts for only 4.6% and the remainder is attributed to dark energy). However, the exact nature of dark matter (and dark energy) is still unknown and its origin is at present one of the most important questions in physics. A currently favored hypothesis is that dark matter is composed of WIMPs, Weakly Interacting Massive Particles, which have so far remained undetected. A direct detection of a dark matter particle would be a clear sign of new physics beyond the Standard Model of particle physics, would greatly contribute to our understanding of the Universe, fundamental laws of physics and will guide the scientific community towards a more complete theory.

Direct searches for dark matter. Compelling astrophysical and cosmological evidence for the existence of dark matter (DM) has led to numerous direct detection DM experiments searching for particle candidates, including DarkSide, XENON, LZ, etc. These experiments rely on signals induced by elastic scattering of WIMPs on nuclei in noble liquid detectors sensitive to vacuum ultraviolet (VUV) scintillation or scintillation and ionization. Experiments relying on such detectors are leading today direct DM searches with the most stringent upper limits in the 1000 GeV WIMP mass range.

Importance of knowing the background. As a consequence of the rarity of the expected interaction, these experiments require that any backgrounds indistinguishable from the DM signal to be strictly controlled and minimized. As low-energy sensitivity improves, many detectors start to see a large number of not-well-identified low-energy events. The spectra of events observed in noble liquid detectors often rise sharply towards low energies with the number of these low-energy events being larger than the expected neutrino or dark matter interactions. The signals observed in this case are originated by single/few-electrons trapped under the gas-liquid interface that result in **delayed (spurious) scintillation emission events**. Understanding the underlying mechanisms responsible for these events while proposing methods to improve their rejection, **will set new limits on sub-GeV DM models**.

Project goals. This proposal aims to make key contributions to understand the underlying mechanisms that originate these backgrounds, namely delayed (spurious) scintillation emission originated by single/few-electrons trapped under the gas-liquid interface, while proposing methods to improve its suppression/rejection which will set new limits on sub-GeV DM models, through: **(i)** simulation of charge transport processes and scintillation production mechanisms in gas-liquid interfaces, **(ii)** R&D on novel amplification structures to minimize the effect of spurious emissions and **(iii)** study the scintillation originated in dual-phase TPCs, using traditional meshes and novel amplification structures.