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First Optical Observation of Negative Ion Drift at Atmospheric Pressure

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Negative Ion Drift (NID) offers a powerful solution to the intrinsic diffusion limitations of large gaseous Time Projection Chambers, enabling near-thermal diffusion without the need for magnetic fields and providing additional timing information through multi-species ion transport, which allows precise fiducialization along the drift direction. We will report the first optical observation of Negative Ion Drift at surface pressure in a He:CF₄:SF₆ gas mixture, using a triple-GEM optical TPC equipped with PMT and sCMOS readout. Clear experimental signatures of NID are demonstrated through both imaging and time-domain observables. While sCMOS images reveal reduced diffusion compared to electron drift, a novel dedicated analysis of PMT waveforms, exhibiting millisecond-scale time extensions characteristic of negative ion transport, clearly revealed the presence of minority carriers in He:CF₄:SF₆. From the drift-distance dependence of the PMT waveform time extension, we directly measure a difference in mobility between the dominant and minority ion populations, with the latter drifting approximately 30% faster than the main component. To our knowledge, this is the first time Negative Ion Drift is observed through a PMT. These findings demonstrate the viability of optical NID TPCs at (near) atmospheric pressure and establish PMT waveform timing as a powerful and readout-agnostic probe of negative ion transport. The approach opens new prospects for large-volume, low-diffusion detectors in directional dark matter searches and rare-event experiments.

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