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Photon Induced Scintillation Amplifier - The PISA Concept

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Research at the frontier of particle physics often requires the search for phenomena of extremely low probability of occurrence, known as "rare events". One such search is for the hypothetical particles that may compose the mysterious dark matter (DM) of the Universe, such as Weakly Interacting Massive Particles (WIMPs) or axions. These low-energy events with faint probability of occurrence are buried under high levels of background events from environmental radiation, posing significant challenges for detection.

Currently, there are ongoing efforts worldwide to directly detect DM in terrestrial particle detectors using dual-phase gas/liquid xenon or argon. Xenon has emerged as a promising detection medium due to its high liquid density and moderate price, making it scalable for next-generation multi-ton experiments. However, the current generation of noble liquid DM detectors is limited by the radioactivity from the detector materials, particularly the photomultiplier tubes (PMTs) used for photon detection, which contribute to the background at approximately 80% level. PMTs also have limitations such as less than full active photocathode area and high cost per unit of area.

To address these challenges, we propose a simple concept as a new photosensor, called the Photon Induced Scintillation Amplifier (PISA) for photoelectron signal amplification in Gas Photomultipliers (GPMs). In PISA, the secondary scintillation produced in the charge avalanches that occur inside the holes of solely one micropattern electron multiplier is read out by silicon photomultipliers (SiPMs), instead of using a multi-element stack of micropattern electron multipliers.

We have shown that a large number of photons are produced in micropattern electron multipliers, enabling the use of a single microstructure. One electron may produce about 10ˆ5 and 10ˆ4 photons in the charge avalanches in xenon and argon, respectively. A Micro-Hole and Strip Plate (MHSP), etched on Kapton for radiopurity, can be used instead of the traditional GEM/THGEM, as it presents higher photon output. The large photon output in the final charge avalanche ensures single-photon sensitivity.

The PISA concept has several advantages, including improved radiopurity, as the materials used for the MHSP can be obtained with reduced radioactivity levels. It also allows for the deployment of remote "hot" electronics, as the high gains achieved in the SiPMs enable signal transmission over large distances without significant degradation. Moreover, the PISA is cost-effective compared to vacuum PMTs and allows for area coverage above 80%, maximizing photon detection efficiency.
PISA is also an alternative to read out the gas scintillation of Xe and Ar directly with SiPMs, because the area coverage can be less than 10% compared to the over 80% coverage when only SiMs are used, implying a much less number of SiPMs needed when the PISA is used.

In this presentation, we will provide detailed information on the PISA concept and present experimental results obtained with a first prototype equipped with a GEM or a MHSP, including the total number of scintillation photons produced in the charge avalanches and the number of photons per avalanche electron. The PISA concept represents a breakthrough in photon detection technology for low background Dark Matter detectors, with potential implications for the field of particle physics and our understanding of the nature of the Dark Universe.

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