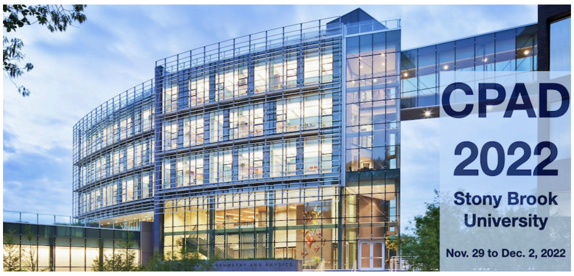

Contribution ID: **107** Type: **Contribution Talk**

The PISA concept: Photon Induced Scintillation Amplifier, an innovative high-gain photosensor for rare event detection

Wednesday, 30 November 2022 13:35 (20 minutes)

Research at the frontier of particle physics often requires the search for phenomena of extremely low probability of occurrence, the so called "rare events". Under this category falls the search for the hypothetical particles potentially composing the mysterious dark matter (DM) of the Universe, like e.g. the Weakly Interacting Massive Particles (WIMPs) or the axions. Being low energy events with faint probability of occurrence, they are buried under much higher levels of background events from environmental radiation. The task is challenging, relying heavily upon reducing background levels to extremely low rates. DM experiments are among the highest priorities in contemporary modern particle physics roadmaps and are typically carried out by large international collaborations. It could be that a breakthrough discovery in one or more of these searches may happen during the next decade. Such a discovery would have ground-breaking consequences for our knowledge of the foundations of particle physics and the nature of the Dark Universe.
There are currently a number of on-going efforts worldwide to directly detect DM in terrestrial particle detectors employing dual-phase gas/liquid xenon or argon. Xenon has in the last few years come to the forefront of the field as a powerful detection medium, with the best scalability prospects for the next generation of multi-ton scale experiments, e.g. DARWIN and MAX [e.g. 1,2], due to its high liquid density and moderate price.
However, the current generation of noble liquid DM detectors is limited by the radioactivity from the detector materials, mostly from the specially radio-clean photomultiplier tubes (PMTs), contributing to the background at ~ 80% level. Additionally, and despite of being the reference photosensors, PMTs have less than full active photocathode area, ~70%. Nevertheless, regarding the characteristically low rate and high background of these experiments, to effectively discriminate de recoiling events from the background it is crucial to have the highest possible photosensor gain and sensitiveness to single photon detection, being these the main reasons to use PMTs.
Large area avalanche photodiodes (LAAPDs), e.g. used by the EXO 200 experiment [3], have small gain (few hundreds, to be compared to the 10^6 of PMTs), small area (few cm^2, to be compared to the few tens of cm^2 of PMTs), insensitiveness to low scintillation levels and high cost per unit of area, limiting their application. In addition, SiPMs although presenting gains around 10^6, have too small active areas to be an alternative. On the other hand, large area hybrid vacuum PMTs are under development to be used as alternative to standard PMTs. Nevertheless, the problems related with vacuum sealing and with the applied high voltages are limiting factors. In addition, the large dimensions that are sought for competitiveness, limit the spatial resolution that could be obtained for the event interaction position.
However, the challenging goals of future multi-ton experiments motivate the development of new photon-detector concepts; these should not only be more affordable than PMTs, but must also allow for a significant improvement in detection sensitivity and background rejection.
We propose a simple concept, the Photon Induced Scintillation Amplifier (PISA), for photoelectron signal amplification in Gas Photomultipliers (GPMs) [4]. Instead of a multi-element stack of micropattern electron multipliers, reading out the charge avalanche produced by the photoelectrons inside the holes of the micropattern electron multipliers, in the PISA a true photon-multiplier is conceived: it is the secondary scintillation produced in the charge avalanches that take place inside the holes of the micropattern electron multiplier that will be read out by suitable photosensors, like SiPMs.
We have shown that a very large number of photons are produced in micropattern electron multipliers enabling the use of just one single multiplier [5]. One electron may produce about 10^5 and 10^4 photons in the THGEM avalanches in xenon and argon, respectively. A Micro-Hole and Strip Plate, etched on Kapton

for radiopurity sake, can be used instead of the GEM or THGEM cascade, since the former presents higher photon output. A large photon output in the final charge avalanche ensures the capability for single-photon sensitivity.

This will be a breakthrough also in terms of radiopurity, as the kapton foils, the SIPMs, the GPM fused silica window and the metal case can be obtained with reduced radioactivity levels and, also important is the feasibility to the deployment of remote "hot" electronics, since the large gains achieved in the SiPMs allow for signal transmission over large distances without significant degradation. In addition, the GPM will be cost effective in comparison with the vacuum PMTs and will allow for area coverage above 80% [4]. This higher coverage is important to maximize the photon detection efficiency, as the photoelectron collection efficiency in the gas can be made similar to that of the PMTs (~80%) but, on the other hand, the quantum efficiency of CsI is ~25% (in vacuum) at 175 nm (the CERN RD-26 nominal value), lower than the somewhat above 30% for the photocathode presently used in the PMTs of DM TPCs. The SiPMs can be distributed in a 2D array with a pitch suitable for the needed position resolution.

In this presentation we will show in detail the PISA concept, and experimental results meanwhile obtained for a first prototype, equipped with a GEM or a MHSP, are presented in terms of total number of scintillation photons produced in the charge avalanches, number of photons per avalanche electron and the optical gain, i.e. the number of photoelectrons produced in the photosensor per primary electron that originates a charge avalanche. These parameters will be presented for several scintillating gases/gas mixtures (e.g. based on Ne, CF4, CH4, N2, CO2) of interest for GPM operation, either at room temperature or for cryogenic operation.

[1] J Aalbers et al., JCAP 11 (2016) 017.
[2] DN McKinsey, J. Phys. Conference Series 718 (2016) UNSP 042039.
[3] JB Albert et al., Phys. Rev. C 92 (2015) 015503.
[4] L Arazi et al., JINST 12 (2017) P10020.
[5] CMB Monteiro et al., Phys. Lett. B 714 (2012) 18.

Primary authors: Dr BERNARDES MONTEIRO, Cristina M (LIBPhys-UC, Department of Physics, University of Coimbra, Portugal); Ms ROQUE, Rita J. da C. (LIBPhys-UC, Department of Physics, University of Coimbra, Portugal); Mr MANO, Rui D. P. (LIBPhys-UC, Department of Physics, University of Coimbra, Portugal)

Presenter: Dr BERNARDES MONTEIRO, Cristina M (LIBPhys-UC, Department of Physics, University of Coimbra, Portugal)

Session Classification: Cross Cutting Topics

Track Classification: WG8: Cross Cutting Topics