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New photosensor readout for noble gas electroluminescence

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The current generation of noble liquid dark matter detectors is limited by the radioactivity coming from detector materials, mostly from the specially radio-clean PMTs.Alternative large area avalanche photodiodes (LAAPDs), e.g. EXO, have low gain, small area, insensitiveness to low scintillation levels and high cost per unit of area. Large area hybrid vacuum PMTs, such as SIGHT, may be used as an alternative to PMTs. However, problems related with vacuum sealing and high voltages are limiting factors, adding up to the low interest shown by Hamamatsu in developing such devices. In addition, the large dimensions that are sought to be developed for SIGHT, for competitiveness, limit the spatial resolution that could be obtained for the event interaction position.An alternative to PMTs will be, indeed, SiPMs. The NEXT Collaboration has proven the potential of aSiPM 2D-readout plane for Xe EL. A 2D pattern of SiPM, 1mm^2 active area and 10 mm pitch, coated with PTB for wavelength shifting, was used to readout the EL in a 10-bar HPXe TPC. The 10% photosensor area coverage was shown to be sufficient, but a compromise has to be made with the energy resolution and position resolution that could be achieved with such a readout plane of small area coverage lowSiPM density.

For Xe-EL readout, an alternative to PMTs and to large area-coverage highSiPMdensity, can be a GPM. Standard GPM uses a CsI photocathode coating the "front"surface of a THGEM, which is the first photoelectron multiplier element; photoelectrons are focused into the holes and forwarded to subsequent amplification stages, a cascade of 2 or 3 THGEMsthat is used for photoelectron signal amplification through electron avalanche.The final signal is collected in the pixelated anode readout. GPMs allow for large-area coverage with high detection efficiency and high filling factor. In GPMs, the use of THGEMs and of total voltages that can reach few kV are needed to attain maximum gains above 10^5, which are required for efficient single photoelectron detection. In addition, the use of FR4 in THGEMs, with high intrinsic radioactivity, and the need for having the "hot"electronics close to the anode electrodes for the charge readout,hampers its use in dark matter searches. These critical issues still need to be solved in GPMs.

The GPM to be developedsubstitutesfor the electron multiplier cascade used for photoelectron signal amplification. Instead, a 2D SiPM plane, will be used to readout the scintillation produced in the photoelectron avalanches in the first element. This allows a much simpler device with only one micropattern element, instead of a cascade of a few elements. A Micro-Hole and Strip Plate, etched on kapton for radiopurity's sake, will be used substituting for the THGEM, since the former achieves higher photon output than the latter. The additional gainreached with the SiPMs provides signals with large amplitude and large signal to noise ratio. The large photon output of the charge avalanches and the small distances from the SIPMs to the scintillation region allow the use of a low coverage area, i.e. low SiPM density, with signals well above the dark current noise in several neighbor SiPMs and, thus, an easy measurement of both the signal amplitude its 2D-position. The kapton foils, the SIPMs, the GPM fused silica window and the GPM metal case can be obtained with reduced radioactivity levels.Also important, is the feasibility of 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 allow for an area coverage similar toor better than that of PMTs.On the other hand, the quantum efficiency of CsI is ~25% (in vacuum) and, with a photoelectron extraction & collection efficiency into the holes of 60%-80%, the photon detection efficiency may be lower than that achieved withPMTs.

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