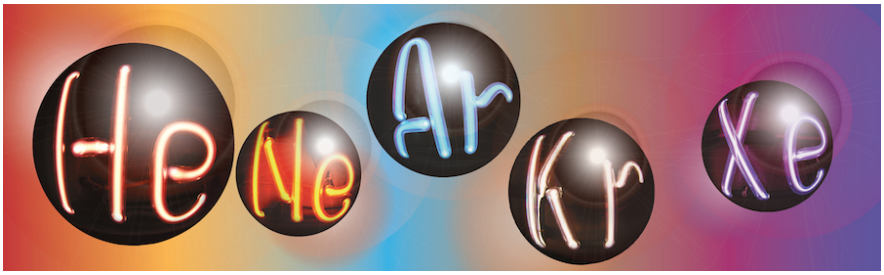

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Surface treatments to improve the detection efficiency of VUV-SiPMs

The high-efficiency detection of the VUV scintillation light of liquid Xenon (LXe) and Argon (LAr) is a key driver of science reach for detectors employing these media. Silicon photomultipliers (SiPMs) are becoming the photon detector of choice for a number of current and planned experiments, but photon detection efficiency (PDE) at VUV wavelengths remains limited. Current VUV SiPMs demonstrate PDE of ˜15% and 20-25% at 128nm (LAr) and 175nm (LXe) respectively - by comparison, the state-of-the-art VUV PMT achieves a PDE of 33% at 178nm and ˜30% at 128nm. PMTs therefore remain the baseline solution for large-scale LXe experiments, including XLZD, but replacement with SiPMs would significantly reduce radiogenic backgrounds and would improve sensitivity to neutrinoless double beta decay in Xe-136. Additionally, current-generation LAr detectors employ SiPMs combined with wavelength shifters to convert VUV photons to visible light. However, these also contribute to radiogenic backgrounds, and increase complexity due to the isotropic re-emission of the shifted light. An improved PDE at 128nm, permitting direct detection of LAr scintillation by SiPMs, could remove the need for wavelength shifting - this would represent a transformative reduction in cost and complexity for future large-scale LAr detectors.

We present recent work at TRIUMF to apply two technologies for improved VUV sensitivity to SiPMs: delta-doping and 'black silicon'. Various performance metrics of delta-doped digital SPAD array structures, produced by the University of Sherbrooke, have been studied, including PDE at wavelengths down to 140nm. This is the first demonstration of a delta-doped SPAD structure and of VUV responsivity in a digital SPAD array. We will also show results extending the measured quantum efficiency of black silicon photodiodes down to 115nm, investigating the suitability of this technology for deployment in LAr detectors. Additionally, we will present optical simulation work of the XLZD detector architecture. We demonstrate that, even with current technology, overall photon collection efficiency can be maintained or improved over an all-PMT baseline by incorporating SiPMs into the light readout system.

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