Although the astrophysical and cosmological evidence for the existence of dark matter is highly compelling, none of the known fundamental particles are good dark matter candidates. This is, perhaps, one of our best indications for physics beyond the standard model. From the perspective of particle physics, both axions and weakly interacting massive particles (WIMPs) are well motivated dark matter candidates, and both are being pursued by direct observation experiments. Here we describe our group's efforts to shed light on the dark matter question within the context of the LUX and LZ experiments.

Our group played an important role in the LUX dark matter experiment, which aims to detect the coherent scattering of galactic WIMPs on xenon nuclei. LUX was a dual-phase liquid xenon time projection chamber (TPC) located in the Davis Cavern at the Sanford Underground Research Facility (SURF) in Lead, South Dakota. LUX has a sensitive target mass of 270 kg and has been collecting WIMP search data since March of this year. LUX reported its first physics results in November of 2013, and reported results from its complete dataset in July of 2016. LUX ultimately achieved a WIMP-nucleon cross section sensitivity of 1.1×10^{-46} cm^2 at 90% C.L. for a WIMP mass of 50 GeV. LUX is a collaboration among university and national lab groups in the US, the UK, and Portugal. It has been funded in the US by the Dept. of Energy and the NSF, and by university and private resources.

Our group's science focus has been on the flagship and world-leading spin-indepedent WIMP search of LUX. Our group has played a central role in the analysis of the LUX WIMP search data, with a particular aim toward understanding the detector's response to electron-recoil events, its most common background source. Our hardware and technical expertise is intended to complement and augment this science goal. In particular, we have specialized in the measurement, control, and manipulation of the purity of liquid xenon to further amplify and exploit this material's outstanding potential for dark matter detection in LUX and LZ. Specifically, our group has developed one-of-a-kind expertise in two related areas: calibration of the detector's electron recoil response with a tritium beta decay source; and highly-sensitive and automated xenon impurity detection via mass spectrometry, including real-time measurements of atmospheric impurities (O_2, N_2, Ar, CH_4) and noble gas impurities (Kr and Ar). Both the tritium calibration technique and the mass spectrometry technique were developed in our lab at Maryland, and both have played key roles in the collection and interpretation of LUX data and will continue to play key roles for LZ. In addition, within the last year and a half we have extended our radioactive noble gas expertise by developing a Maryland facility for sensitive radon emanation screening of detector materials. This is in preparation for the LZ experiment, where ^{222}Rn is expected to be a challenging electron-recoil background source due to the beta decay of its ^{214}Pb daughter.

Maryland group members that participated in LUX are the PI (Hall), graduate students Richard

Knoche (Ph.D. 2016), and Jon Balajthy (Ph.D. expected 2017). In addition, former graduate student Attila Dobi received his Ph.D. from Maryland in October of 2014 on LUX Run 3 data (thesis title: ‘Measurement of the electron recoil band of the LUX dark matter detector with a tritium calibration source’) and advanced to a prestigious Chamberlain fellowship at LBNL.

In recent years our group has developed unique methodology for the detection and monitoring of both electronegative and noble gas impurities in xenon gas. We separate impurities from the xenon gas sample with a liquid nitrogen cold trap and then observe and quantify them with a vacuum mass spectrometer (RGA). The method is sensitive to both oxygen and noble gas impurities including krypton, which is an important background source for dark matter searches. We first applied this technique to the EXO-200 double beta decay experiment, however since the summer of 2011 we have refined the method and applied it to great effect on LUX.

Our impurity screening for LUX proceeded in several stages. In the fall of 2012 we worked closely with collaborators at Case Western (Dan Akerib and Tom Shutt) to guarantee the successful removal of residual krypton contamination from the LUX xenon prior to the WIMP search run. Krypton is an important source of radioactive backgrounds due to the presence of the β-emitting isotope ^{85}Kr. Case Western removed the krypton using a chromatographic technique and periodically sent samples of the processed xenon to our lab in College Park for analysis. Our detection method is sensitive to krypton at the sub ppt-level, and the feedback provided by our monitoring of the LUX Kr removal program was crucial to its success. Also in 2012 we constructed an automated version of our mass spectrometry system which is integrated into the LUX xenon purification system. This allowed for daily monitoring of the LUX xenon during physics operations to insure that the krypton, oxygen, and other impurities concentrations are acceptable. This was the first application of this monitoring technique to a dark matter experiment, and the results illustrate the power of regular, systematic, and species-specific impurity monitoring. This data has been of fundamental importance for monitoring the operation of the LUX detector, and for insuring the high quality of the LUX data with respect to krypton and other types of impurities.

A second unique contribution made by our group was the development and implementation of an internal tritium calibration source that has allowed the LUX electron recoil band and detector threshold to be precisely characterized. We performed an initial tritium injection into LUX in August 2013, and the results were used to directly define the electron recoil band of LUX for its first WIMP search result. We subsequently made a second, larger injection into LUX in December of 2013 and analyzed the data, reporting the results in Phys.Rev. D93 (2016) no.7, 072009 (“Tritium calibration of the LUX dark matter experiment”). This technique has now been adopted by competing experiments in Europe and Asia.

LZ is a Generation-2 experiment that will replace LUX in the Davis cavern at SURF and will begin operating in the spring of 2020. LZ was selected for funding by the DoE and the UK science agency (STFC) in July of 2014, and passed its CD3 review in January of 2017. The PI of this proposal (Hall) is the Level 2 manager for xenon handling and purification (WBS 1.4), responsible for managing a $6.3 M budget, and the Maryland group has substantial deliverables within four WBS items at Level 3&4: 1.4.1 (xenon sampling and purity measurements, Level 3 manager is Hall, project budget of $479k), WBS 1.4.5 (xenon recirculation system, xenon gas purifier, project budget of $267k), WBS 1.10.2 (cleanliness and screening - radon emanation screening, project budget of $231k), and WBS 1.7.1.3 (tritium and ^{14}C calibration sources, Level 4 manager is Hall, project budget of $13k). Our group's project budget totals $990k. In November of 2016 Hall was elected to a two-year term as spokesperson of LZ.

The LZ target will consist of ten tonnes of xenon, of which seven tonnes are active and 5.6 tonnes are fiducial (about 50 times more than LUX). It will achieve an ultimate WIMP-nucleon cross section sensitivity of 2.5×10^{-48} cm^2 at 90% C.L. for a WIMP mass of 50 GeV.