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The LUX Experiment

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Abstract

We present the status and prospects of the LUX experiment, which employs approximately 300 kg of two-phase xenon to search for WIMP dark matter interactions. The LUX detector was commissioned at the surface laboratory of the Sanford Underground Research Facility in Lead, SD, between December 2011 and February 2012 and the detector has been operating underground since January, 2013. These proceedings review the results of the commissioning run as well as the status of underground data-taking through the summer of 2013.

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Liquid xenon detectors, Dark matter, WIMP, Direct detection

The LUX experiment is a two-phase xenon time projection chamber (TPC) employing approximately 300 kg of liquid xenon to search for the elastic scattering of weakly interactive massive particles (WIMPs) off of the xenon nuclei. The design of the LUX detector is described at length in Ref. [1]. The cylindrical LUX TPC reads out both the light and charge signals from electronic and nuclear recoils through the primary scintillation signal in the liquid xenon (S1) and a secondary scintillation signal (S2) produced by electrolumenescence of the electrons drifted out of the liquid xenon and into the gaseous xenon through a series of applied electric fields. We use the ratio of inferred charge to light signals to separate nuclear and electronic recoils.

The LUX detector is located at the 4850' level of the Sanford Underground Research Facility (SURF, which is equivalent to 4.3 km.w.e. shielding. The muon flux in the Davis campus, the underground hall where the experiment is sited, is reduced by a factor of 10^7 relative to the surface. The TPC is shielded from external backgrounds by a 300 ton water shield that reduces the external gamma flux by 10^9 and the external neutron flux by 10^3. Combined with external shielding, the self-shielding of the liquid xenon target gives an inner volume of approximately 100 kg that is expected to have very few single-scatter background events.

The LUX cryostat is passively cooled with liquid nitrogen thermosyphons [2]. The scintillation signals in the TPC are read out by 122 Hamamatsu R8778 2.2" PMTs, evenly split between the top and bottom of the target, and the scintillation light is reflected along the length of the detector by 12 PTFE reflector panels. The xenon is constantly circulated and purified with a heated zirconium getter, with the full volume of xenon in the detector processed once per day. A series of five electric field grids arranged along the length of the cylinder apply the field to drift electrons through the xenon, the field to extract electrons out of the liquid, and the field to cause the electrons to electrolumenescence, in addition to a top and bottom grid to electrically shield the PMT arrays.

Several methods of calibration are used to determine the electronic and nuclear responses in the liquid xenon target. Internal sources are preferred when possible, due to the self-shielding nature of the xenon. We use ^{83m}Kr and tritium sources introduced through the xenon gas handling system for the light and electronic recoil responses, respectively. Our external neutron calibration relies on ^{241}AmBe and ^{252}Cf, in addition to a planned DD neutron generator calibration.

The LUX detector was assembled and commissioned at a surface laboratory at SURF while the Davis campus was being outfitted in preparation for underground deployment of the detector. The surface commissioning collected data between between December 2011 and February 2012 was used to study the purification of the xenon, as measured by the electron drift length, and the light collection properties of the TPC [3]. The surface data was also used to tune the simulation of the LUX detector response [4] in preparation for the WIMP search. Reconstruction algorithms to determine the $x - y$ event position were developed and tested [5], providing resolution of approximately 7 mm for high-energy events.

The detector was transported underground July 11-12, 2012 and underground operation began at the end of 2012, with gas phase data collected in January 2013. The xenon was liquified in mid-February 2013 and data-taking commenced in March 2013.

The background model to be used in the WIMP search was developed by tuning simulation to data for both single and multiple scatters above 100 keVee, which is well outside the LUX WIMP search region of approximately 1-5 keVee. The predicted background rates from the SOLO screening of the PMTs, superinsulation, and plastic thermal insulation were compared with the observed rates and the best fit values were used to determine the background model.

A number of radon daughters have been observed in the data originating from both the ^{238}U and ^{232}Th decay chains. Two of these represent potential backgrounds to our WIMP search: the β decay of ^{214}Pb, which is unaccompanied by a coincident γ and would populate the electronic recoil background, and the α decay from the ^{210}Po, which can create an (α,n) reaction on the fluorine of the PTFE, which could contribute events in the nuclear recoil WIMP signal region.

We observe seven distinct radon and radon-daughter lines, all of which are distributed through the bulk of the TPC with the exception of the ^{210}Po, which is on the surfaces of the walls and cathode, as expected due to the plate-out of the ^{210}Pb on surfaces during construction when the PTFE and other detector surfaces were exposed to air without any radon mitigation or controls. The α decays of ^{222}Rn are observed at a rate of 20 mHz. This rate is approximately stable throughout underground operation.

We observe 3 mHz rate of α decays of ^{220}Rn and ^{216}Po that show localization in the first quadrant of the detector in the $x - y$ plane, suggesting that these originate from thoriated welds inadvertently introduced into the plumbing system. The observed ^{220}Rn rate disappears completely when circulation is stopped, strengthening this hypothesis.

Based on the observed radon (daughter) decay rates, we predict 0.02 n/day from (α,n) on fluorine, compared with 1.2 n/day expected from the PMTs. We also obtain an 90% CL upper limit of 8.3 mBq on the β from the ^{214}Pb decay, corresponding to 0.23 mdru$_{ee}$. This rate is approximately 10% of our background rate expected due to detector materials.

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