**What is the detector:** [**http://arxiv.org/pdf/1211.3788v2.pdf**](http://arxiv.org/pdf/1211.3788v2.pdf)

The Large Underground Xenon detector (LUX) is a dual phase time projection chamber location in the Sanford Underground Research facility in South Dakota. The detector is a dodecagonal structure that uses 300 kg of liquid xenon as a target medium. Particle interactions in the liquid xenon produce ionized and excited state xenon atoms. Some of the electrons released in the ionization process recombine with the xenon ions, forming additional xenon excitons, while the rest are drifted to the liquid surface by an electric field. The xenon excitons return to the ground state with a characteristic time constant of 2.2 ns for the singlet state and 27 ns for the triplet state, producing scintillation light at ~175 nm in the processes. This scintillation light is referred to as the S1 signal. Electrons which make it to the liquid surface are accelerated through the gas above the liquid xenon by a stronger electric field, producing electroluminescent light which is referred to as the S2 signal.

Two arrays of 61 PMTs each are used to measure both the S1 and S2 light in the detector. The light response of each PMT in the top array is used to reconstruct the XY position of recoil events based on the intensity of the S2 signal, and the time difference between the S1 and S2 signal is used to reconstruct the depth of the recoil events. In this way, the LUX detector has three dimensional position reconstruction.

The LUX detector is an extremely low background environment due to the strong self shielding properties of liquid xenon and the lack of naturally occurring xenon radioisotopes. Any background events which do appear in the fiducial volume are reduced by over 99\% by using the ratio of the S1 and S2 signal as a form of nuclear recoil discrimination. Discrimination techniques in the LUX detector will be discussed more in section \ref{DiscrimSec}. In this section, we will discuss the detector internals, external support system, and the DAQ electronics used to read out the PMT signal.

**Detectors Internals:**

**Cryostat:**

LUX cryostat is shown in figure (Show figure 5 from <http://arxiv.org/pdf/1211.3788v2.pdf>).

An outer layer of titanium is used as a thermally insulating vessel to keep the inner cryostat cold.

An inner cryostat which holds the liquid xenon and detector internals is attached to the roof of the outer cryostat via three plastic hangers at the top of the outter cryostat.

Instrumentation cables and circulation system plumbing are fed through flex hoses at the top of the detector. Flexibility of the hoses is required to deal with thermal contraction of the plastic hangers.

**PMT arrays, PTFE structure, and Electric Field cage**

Inside the inner cryostat, a 5 cm thick copper block with a diameter of 55 cm is mounted directly on to the flange. This copper serves as a radiation shield and a temperature controller during detector operations. A similar copper structure is attached to the bottom of the inner cryostat and is used to displace xenon from the inactive volume in addition to the functions of the top radiation shield.

Two PMT arrays are used to collect light from the S1 and S2 signals in the detector. Each array contains 61 Hamamatsu R8778 PMTs which observe the active volume. These PMTs were specifically designed for operation in liquid xenon, with a typical quantum efficiency of 33% at the 175 nm wavelength of liquid xenon scintillation. The top PMT array is housed in a copper structure which is hung 15 cm below the upper radiation shield by six titanium straps. Reflective polytetrafluoroethylene (PTFE) trifoils cover the inner face of the copper housing to increase light collection efficiency in the detector. A similar structure is placed at the bottom of the detector to house the bottom PMT array.

Twelve PTFE panels hang from the top PMT support and are attached to the bottom PMT support. These panels are used to increase light collection efficiency in the detector, and serve as the support structure for the electric field cage in the detector. The field cage is made of five wire grids. Each grid is made of thing stainless streel wires and are 88-99% transparent at a normal angle of incidence. Stainless steel is known to be 57% reflective at xenon scintillation wavelength, further minimizing the optical footprint of the wire grids. The top grid is located 2 cm below the top PMT array. A stainless steel ring is used to string 50 micron diameter stainless steel wires spaced with a pitch of 1 cm. The voltage on the top grid is used to zero the electric field at the photocathodes of the top PMTs. The anode is placed 4 cm below the top grid. It is similar in design to the top grid, but uses 30 micro wires with 0.5 mm spacing. The gate grid, which uses 50 micron stainless steel wires with a pitch of 5 mm, is placed 1 cm below the anode grid. The position of the gate grid places it about 5 mm below the liquid xenon surface. These two grids work in tandem to produce a strong extraction field (5-6 kV/cm) that pulls charge out of the liquid xenon and into the gas, producing the S2 signal. The cathode grid is placed about 49.5 cm below the liquid surface. This grid uses 260 micron diameter stainless steel wires with a pitch of 5 mm, and works in tandem with the anode grid to produce a ~180 V/cm electric field which drifts charge from a particle interaction to the liquid surface. The bottom grid is the last of the five wire grids. It is located 4 cm below the cathode grid and 2 cm above the bottom PMT support, and uses 206 micron diameter stainless steel wires with a pitch of 1 cm. The bottom grid serves the similar purpose as the top grid – it is used to zero the field at the photocathodes of the bottom PMT arrays.

Fourty-eight copper field rings are spaced 1 cm apart inside of the PTFE panels to shape the drift field. These rings have thickness of 3.2 mm and a width of 12.7 mm. The spacing and thickness of the rings were chosen to shield the active region from the electric field produced by the cathode high voltage cable. The voltage of the field rings is set by a resistor chain that runs between the gate and the cathode grids. A pair of 0.875 GΩ resistors connect the top field ring to the gate grid, while a pair of 1.25 GΩ resistors connect the bottom field ring to the cathode grid. A pair of 1 GΩ resistors is used to connect each adjacent field ring.

**Cryogenics:**

Thermosyphon system is used to cool the detector internals to LXe temperatures (~175K)

Thermosyphon is a sealed tube will with a variable amount of gaseous nitrogen. Top of the thermosyphon is condenser which is immersed in a liquid nitrogen dewar. As nitrogen condenses gravity causes it to trickle down stainless steel plumbing to copper heat exchanger that are attached to various points in the inner cryostat. The condensed nitrogen evaporates when it hits the copper heat exchanger, removing heat from the detector. The evaporated nitrogen rises back up the stainless steel plumbing where it is once again condensed by the liquid nitrogen bath. In this way, the thermosyphons act in a continuous loop, transferring heat from the detector to the liquid nitrogen bath which the condenser is immersed in.

Two thermosyphons are attached to blocks of copper at the top and bottom of the inner cryostat and are used as the driving force to cool the detector from room temperature to 175K. Two more thermosyphons are attached to copper shielding around the inner inner vessel and are used to prevent any thermal gradients from building in the detector. Each copper evaporator is fitted with a 50-W heater and a thermometer for fine temperature control. Larger 750-W heaters are attached to the two primary thermosyphons to aid in detector warm up during liquid xenon recovery.

**Instrumentation:**

63 thermometers (40 inside, 23 in vacuum space)

Types: 100 Ohm thin film platinum resistance temperature detectors (RTDs)

Advantech Adam 6015 modules are used to read the output voltage of the RTDs

Calibration of the RTD readouts was performed prior to installation, as well as in situ at room temperature, with an accuracy of 170 mK for each RTD.

10 pressure sensors (7 inside, 3 vacuum space)

Look at SC + P&ID for types of gauges.. should be something like:

“Pressure read-out of the inner cryostat consists of three Ashcroft AST4900 sensors used by the automated recovery system, described in section (3.6), an InstruTech Hornet ion and convection gauge pair for vacuum readout, a Swagelok PGU-50-PC100-L4FSF manual pressure gauge, and a Setra model 759 capacitance manometer customized with range 0-5000 Torr rated at ±0.15% of readout.”

9 level sensors

Six parallel wire sensors (LS01,02,03,04,05, and 09)

Three parallel plate sensors (06,07,08?)

“Two varieties of liquid level sensor are deployed in LUX, as shown in Fig. 8. In the circulation plumbing, where unimpeded fluid flow is important, parallel-wire level sensors are used. Level sensors of this type are used to measure the liquid level in the main chamber, the weir, the condenser of the dual-phase heat exchanger, and the liquid return line that reintroduces liquid to the active region after circulation. These sensors consist of two parallel wires, mounted in compression-type connections, and designed to fit into standard Swagelok R fittings. Measuring the capacitance of each wire pair allows the length of the submerged portion of the wires to be determined. A different type of level sensor is used to measure the liquid xenon level in relation to the electric field grids. To achieve the level of accuracy required, three level sensors of a parallel-plate design were incorporated into the structure surrounding the active region between the gate and the anode grids. These sensors, spaced 120 degrees apart, surround the electron extraction region and provide a method to determine if the liquid surface is level with respect to the grids, thus ensuring a uniform extraction field.”

**External Support Systems:**

**Purification and Gas System (mention ACRS and APSS?)**

The xenon used in the LUX detector needs to be free of electronegative and molecular impurities that could attenuate charge and light. To achieve this goal LUX circulates the detector’s xenon through a gas system which includes a heated zirconium getter made by SAES. The getter removes all non-nobel gas impurities (?) with an efficiency of (?), but requires the xenon to be in gaseous form when operating.

A weir reservoir is used to maintain a constant liquid level at the top of the detector.

Excess liquid spills over the weir lip into a reservoir, where it enters the evaporator side of a two phase heat exchanger. In this side of the heat exchanger, xenon is pumped on by the external circulation system until it evaporates. The cooling effect of the evaporation is used to recondense xenon which is returning to the detector on the other side of the heat exchanger.

The gaseous xenon leaving the evaporator side of the heat exchanger passes through a concentric-tube heat exchanger which warms it to room temperature before circulating to the SAES getter.

The purified xenon continues on to a concentric-tube heat exchanger, where it is cooled before entering the condenser side of the two phase heat exchanger.

After condensing in the two phase heat exchanger the, now liquid, xenon enters the detector through the bottom radiation shield to ensure the supply of new xenon is at a consistent temperature.

A diaphragm pump which is capable of 50 SLPM (420 kg/day) is used to maintain a constant flow of xenon through the circulation system

**Gas Sampling System**

Copy Pasta – JUST FOR REFERENCE, REWRITE IN OWN WORDS: The xenon handling system is equipped with an integrated xenon gas purity assay system. A 0.5 liter sample of xenon gas can be collected from four critical locations in the system: the input to the getter, the output from the getter, the detector return line, and a conduit purge line. The gas samples are collected via plumbed-in stainless steel lines which connect the xenon system to the assay system. The impurity content of each sample is evaluated using the cold trap mass spectrometry method which is described in Refs. [20, 21]. This technique is sensitive to oxygen and nitrogen at a level of better than one part-per-billion, and can detect krypton at the part-per-trillion level. The mass spectrometer is periodically calibrated by collecting a sample of xenon gas from a specially prepared cylinder which contains xenon with a known impurity content. The assay system is used to monitor the effectiveness and performance of the getter, to monitor the purification process, and to confirm that the xenon gas system is leak tight.

**Water Tank and Veto System (Mentioned in section 8)**

**LN System and SRV?**

**Calibration Systems (Source tubes, Kr system, and tritium system)**

**Detector Electronics:**

**Things to add:**

**Example of recoil event in introduction**

**Background rejection description to introduction**

**Purity of detector materials in introduction**

**Xenon target description to cryostat section**

**Source tube description in detector externals section**

**Science results section?**