PROCEEDINGS OF SCIENCE

XeLab: a test platform for xenon TPC instrumentation

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Xenon double phase TPCs have shown the best sensitivities for dark matter direct searches over a large parameter space. However difficulties in the construction large scale TPC have already arisen in the current detectors and will be even more challenging in the next generation one. Of critical importance are the construction of meter scale electrodes with negligible sagging and high optical transparency but also the control of instrumental background such as single electron emission. Xelab is a system equipped with a small double phase xenon TPC cooled with liquid nitrogen and a xenon recuperation module primarily designed for the test of innovative concept of floating electrodes but will also serve as a platform for instrumental development for xenon based TPC. We present the design and realisation of XeLab and the baseline of electrodes that we plan to test.

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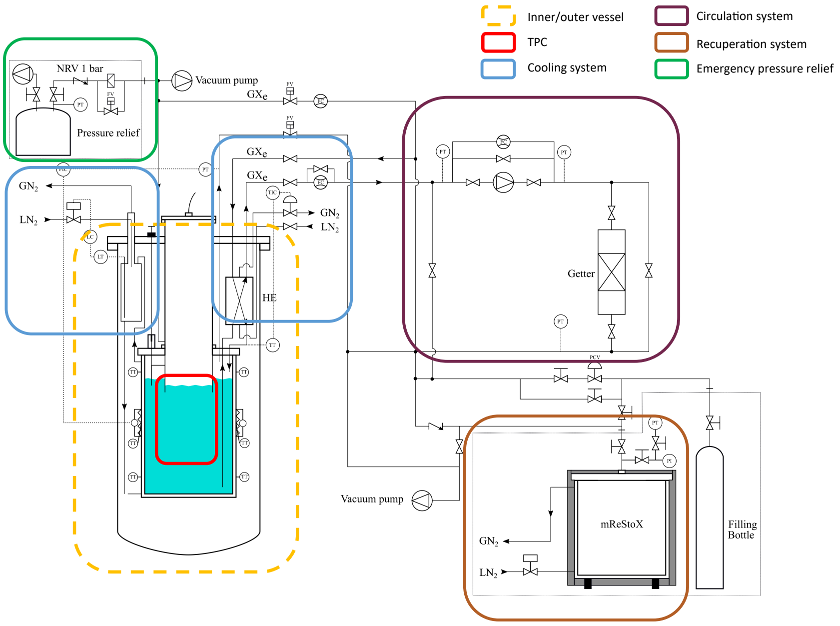

Figure 1: P&ID of Xelab facility

1. Motivation

The search for dark matter with liquid noble gas such as xenon has shown to be very effective for several reasons including the good amount of scintillation light, the low ionization energy $\approx 10eV$, large self shielding, the possibility to purify on line the active volume. Double phase liquid xenon TPC (Time Projection Chamber) for instance detect the light of primary scintillation S1 upon the interaction of a particle within the target material (liquid xenon) but also a secondary scintillation after the drifted electron are accelerated at the liquid gas interface by a large field. This large field is obtained thanks to two electrodes a few millimeters apart polarized with a large potential. Double phase LXE TPC have reached the best sensitivity in a large part of the spectrum for WIMP searches by always increasing the target mass. Current generation detector [2**?**] hold more than 8 tons of xenon in a cylindrical vessel of 1.3m diameter and 1.5m height. The next generation XLZD [3] is expected to have more than 50 tons be as large as 2.6m diameter. If the technique of the double phase TPC stays the same, the constraints due to the scale, in particular of the electrode, leads to many developments in that area. The groups at LPNHE and Subatech have developed a facility Xelab to host the first xenon double phase TPC in France in order to address some of the opened questions. The first study will be dedicated to the design of electrodes for the next generation experiment.

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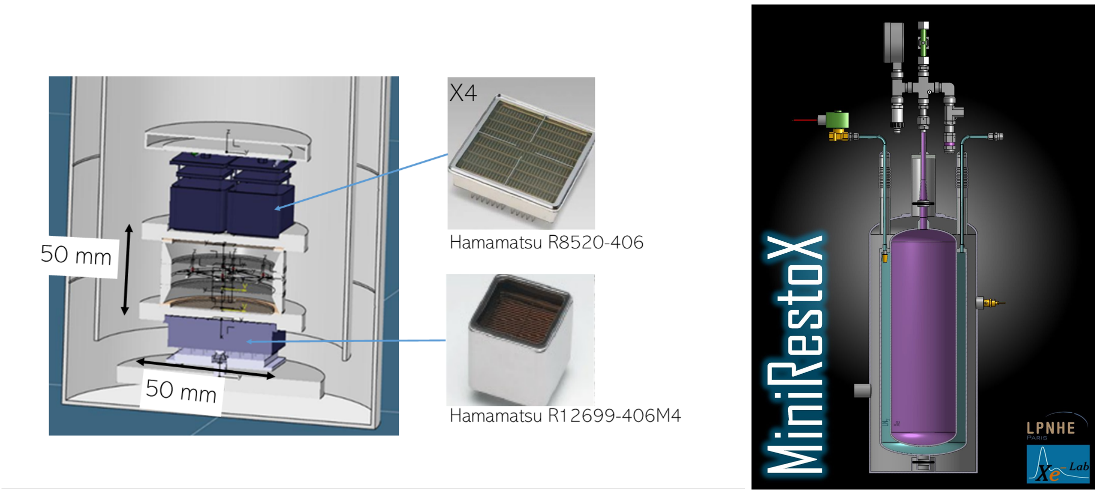

Figure 2: Enter Caption

2. Overall description of the cryogenic system

Xelab is a cryogenic facility that can host a double phase TPC, the P&ID (Piping and Instrumentation Diagram) is shown in the figure 1. It can be split into 6 parts connected to each other:

1. the outer and inner vessels: the outer vessel is maintained under low pressure and insure the thermal insulation. The inner vessel in cooled down by the cooling system and contains the liquified and gaseous xenon. The nominal quantity is 3L of xenon.
2. the TPC is under designed and can be placed and accessed from the top flange.
3. the cooling system : LN2 and GN2 are used to cool down and the inner vessel. The xenon liquefaction is carried out with an heat exchanger. See section 2.1.
4. the circulation system: is needed to get the xenon from the recuperation system and allows for the purification of the xenon. Note that the R&D that will be conducted with Xelab will not require a level of purity as stringent as for DM searched. The current purification system comprise a getter (SAES Microtorr - GPUS-200FEX04R00CA) to collect the electronegative impurities.
5. the recuperation system: is custom made and allows for the controlled recuperation and storage of xenon.
6. the pressure relief system: used only in case of emergency, can undergo the pressure of the 10kg of xenon at ambient temperature and pressure. It is not yet included in the system.

2.1 Cooling system

The cooling of the inner cryostat is based on the LN2 circulation. The laboratory building is supplied with a direct line of liquid nitrogen from the “Low Temperature Service” of the Sorbonne

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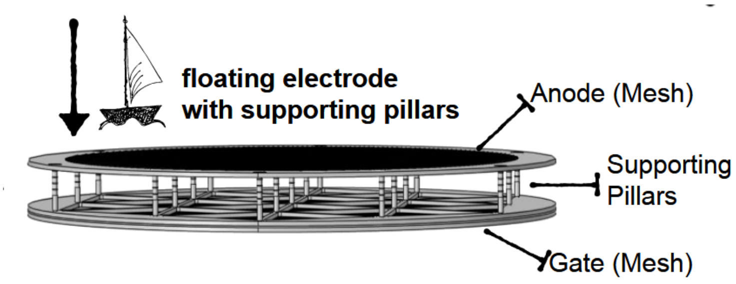

Figure 3: New design of gate and anode electrodes, bound together with the supporting pillars

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University where a LN2 is produced and stored in a 15 000 liters tank. The LN2 is circulated around a copper belt surrounding the inner vessel and the cooling power is controlled with heat resistors place directly in contact with the vessel. The xenon liquifying system use the vaporisation energy of the xenon circulating out to condense the gaseous one entering the vessel. The energetic losses during the process are compensated by an intake of LN2.

2.2 Recuperation systems

The mReStoX was designed to recuperate the xenon from the inner vessel when the operation with the TPC are stopped. As the the LN2 is circulated in the mReStoX, the xenon will be cryopumped and solidify in its volume in several hours. When the recuperation is finished, the xenon can be warmed up at room temperature as the mReStox is rated for pressure up to 75 bars.

2.3 The TPC

The current design of the TPC is shown in the figure 2 it will be cylindrical with 50mm height and 50mm diameter. It will be composed of 5 electrodes (cathode, gate and anode plus two screens for the PMTs) placed on a teflon frame. The light signals will be collected by an array of 4 PMTs (Hamamatsu R8520-406) at the top and a single PMT (Hamamatsu R12699-406M4) at the bottom[1].

3. System control and DAQ

The slow control system has two main goals, first to insure safety of people and recuperation of xenon and second to control and monitor the state of the cryogenic system. The first goal is insured with actuators directly fed with a sensor with no logic in between for the most crucial parts of the system. A second step of control is carried out by a PLC (programmable logic controller) which is programmed and can run some logic independently of a computer. The PLC used is an RevPi Connect S with one analog and one digital module. It is programmed with standard Codesys software and complies with industry standard while allowing some customization offered by the open source design of the Rasperry Pi. Lastly the monitoring is handled thanks to the "astro slow control" software suite [4] which allows for the communication with instrumentation devices such as the high voltage, the temperature and pressure sensors and allows the monitoring of several parameters as well as their display and alarms setting on them.

[1]this PMT is made of 4 cells whose signal can be separated in a later stage of the experiments if needed

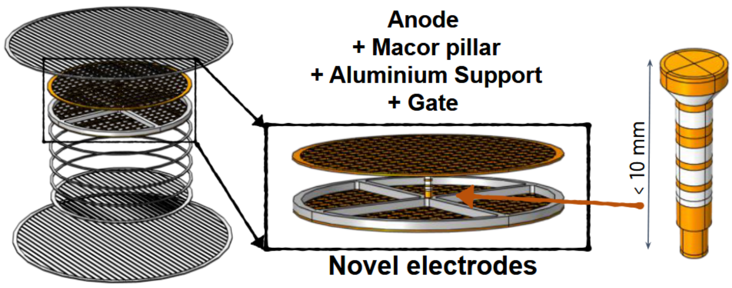

Figure 4: TPC electrodes as designed for testing in Xelab and close up on one pillar with alternating layer of conductive and isolating material.

The digitisation of the PMT signals is done with a CAEN V1720 (8 channels, 12 bits 250MS/s ADC board). The software used, based on the code XenoDAQ [5], allows the configuration of the ADC board and the data acquisition with option like a graphical interface, a zero length encoding to decrease the data throughput.

4. The floating electrodes

Concept The electrodes of current double phase TPC such as XENONnT are built with thin wires (200μm diameter). The gate electrode which insure the electron extraction from the liquid to gas phase is placed at only a few mm from the liquid interface and the anode a few mm above. They undergo electrostatic and gravitational force which can lead to sagging and in turn can worsen the spatial resolution. Furthermore, the tension on those wire is applied at room temperature while the actual operation of the TPC happens at the temperature of the liquid xenon (165K). To cope with such constraint, we propose a new electrode design with a rigid structure on which is sitting a mesh. The gate to anode distance is kept fixed with isolating pillars. The material of the pole needs to be well chosen to minimize the Archimedes force. The electrode structure will be also fixed to the sides of the TPC (so the electrode are not completely floating). The illustration of this design is shown the figure. 3.

Implementation The design of the electrode that will be tested in the Xelab TPC will contain only a single pole as shown in the figure. 4. The electric field of the TPC was simulated using COMSOL to verify its uniformity.
The mesh considered are stainless steel woven mesh of around 200μm diameter wires with optical transparency between 70 and 75% from the Gantois company. The pillar material will have to be undergo high electric field at low temperature. Several studies already exist in the literature and shown that specific ceramics such as Fe_2O_3/YSZ (yttria stabilized zirconia) [6] but also High Density PolyEthylene (HDPE) [7] can comply with the requirements.

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