# 2.7 Dark Matter
## Dark Matter Experiments

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**With the ongoing construction of a new detector, it is an exciting time for the Nikhef direct-detection dark matter group. The Nikhef group was one of the first to install a large subsystem in the XENON1T experimental area in Hall B of the Gran Sasso laboratory (LNGS) in Italy. Meanwhile, XENON100 is still taking data with various calibration sources to further study the performance of this well-running detector and data analysis is ongoing. There was also a local success: the XAMS dual-phase xenon time projection chamber (TPC) that we built at Nikhef over the past two years, saw first signals in May 2014.**

More globally, a number of experiments (*i.e.* CRESST, CoGeNT, CDMS-Si) that previously showed possible hints of having detected low-mass weakly interacting massive particles (WIMPs) either excluded or retracted their detection claims. The dark matter race is still very much ongoing.

***XENON100 Data Analysis***

While the focus of the XENON collaboration has clearly shifted to the construction of the XENON1T experiment, the XENON100 experiment continues to take data and results are being analysed. Early in 2014, we completed a 150 day lifetime dark matter science run. The analysis of these (still blinded) data is ongoing and will be combined with the earlier 225 day exposure

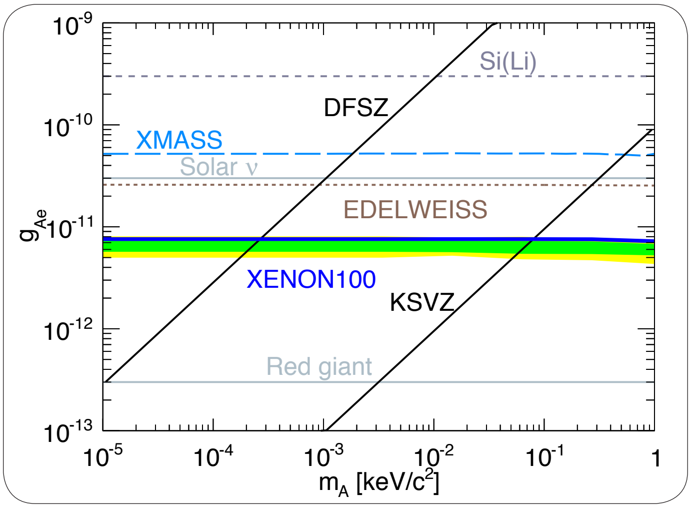


*Figure 1. The XENON100 limit (90% CL) on the axion-electron coupling constant vs solar axion mass (blue line). The expected sensitivity is shown by the green/yellow bands (1σ/2σ). Two benchmark axion models, DFSZ and KSVZ, are represented by grey lines. Within these models, XENON100 excludes axion masses above 0.3 eV/c$^2$ and 80 eV/c$^2$, respectively.*

data set. The ultra-low background of XENON100 has enabled us to study interactions different from the 'standard' WIMP-nucleus analysis, even without background rejection. We performed a sensitive search for solar axion and galactic axion-like-particle (ALP) interactions with electrons using the previous 225 day data-set, see Fig. 1. This result is the most stringent limit for the axion-electron coupling constant for solar axions with masses below 1 keV, and for galactic ALPs with masses below 10 keV.

Since longer dark matter running using XENON100 will not provide additional dark matter sensitivity, we have switched to running with various calibration sources. Of these, the ongoing multi-month run with a $^{88}$Y-Be neutron source is most important. This source provides nuclear recoils similar to those of a few-GeV WIMP, and it is the first time that this kind of measurement is performed in a liquid xenon detector. It is an essential tool to give a deeper insight into the sensitivity for low-mass WIMPs. Meanwhile, the analysis at Nikhef has concentrated on the so-called S2-only analysis in XENON100, primarily aimed at setting competitive limits for low-mass WIMPs. This analysis sacrifices event-by-event particle identification for a much lower energy threshold. The analysis is advancing rapidly and results are expected soon.

***XENON1T Construction***

The construction of XENON1T has made rapid progress in 2014. The experiment has started to dominate the experimental hall in the LNGS laboratory, see Fig. 2. All major items, such as the water tank, cryostat and support structure, cryogenics and purification plant, xenon storage and recovery system etc. have been delivered underground and their integration is ongoing. Nikhef was responsible for the vibration-free cryostat support structure which was delivered and installed in a three-week-long campaign in May. We are presently finalizing the design of the calibration system (to be built by others). The automated system will deliver radioactive sources inside the water tank, externally to the cryostat. The signals from the radioactive source are essential to understanding the performance of the heart of XENON1T, the TPC.

The Nikhef team is also responsible for the trigger and event builder as part of the data acquisition group. This software will allow continuous readout of the XENON1T detector, implementing the trigger entirely in software. A lot of progress was made during 2014, moving from an early prototype to an almost final system. The full DAQ system will be tested and commissioned on the XENON100 experiment in Spring 2015 before moving it to XENON1T. Since the number of photomultiplier (PMT) channels in XENON100 and XENON1T is very similar,

*Figure 2. View of XENON1T inside the water Cherenkov muon veto. The inner cryostat vessel, which will house the TPC, is hanging from the cryostat support structure. The large pipe will carry all the cryogen and signal lines from the cryostat to the support building outside of the water tank.*

the XENON100 test will allow exercising the DAQ already before the XENON1T TPC is ready.

Finally, the Nikhef team has also started to develop the data processor and analyser. With this set of tools all the necessary actions to convert the PMT signals into physical quantities that are stored for further analysis are performed, including peak-finding, gain and signal corrections, event position reconstruction etc. It was written with flexibility and software sustainability in mind.

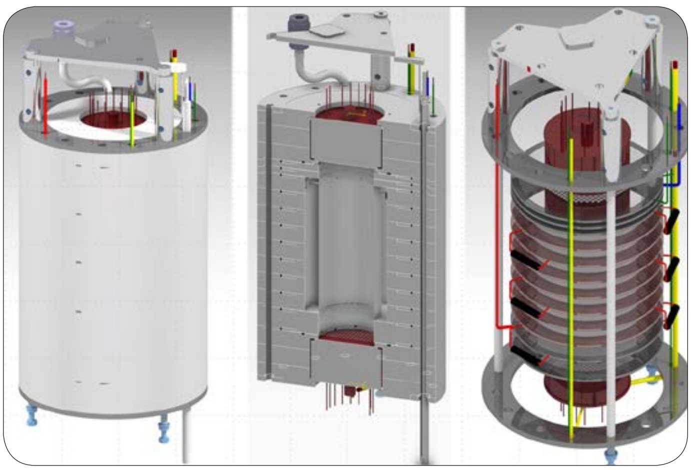

*Figure 3. Illustration of the XAMS dual-phase xenon TPC. The setup consists of two PMTs and a variety of meshes and electrodes to maintain an electric field. The xenon in the TPC is cooled and purified using external equipment.*

While the data processor was written for XENON1T, it is fully configurable and is able to also analyse XENON100 data and data from smaller setups, such as XAMS. The data processor has been benchmarked against the present XENON100 processor and found to have very similar performance and efficiency.

The Dark Matter group activities position us to have a leading role in the first XENON1T dark matter analysis. The XENON1T detector is expected to start data-taking in Fall 2015.

***XAMS R&D at Nikhef***

More locally at the Nikhef institute, the Dark Matter group finished and successfully operated a small dual-phase xenon TPC called XAMS. We designed and built the TPC during the first half of the year, see Figs. 3 and 4. The XAMS detector has an active mass of about 0.5 kg and it was operated during a few weeks in the summer using radioactive sources. We saw the tell-tale sign of 'electron drift' indicating high purity of the xenon. We are presently replacing the readout system and expect to start full commissioning soon.

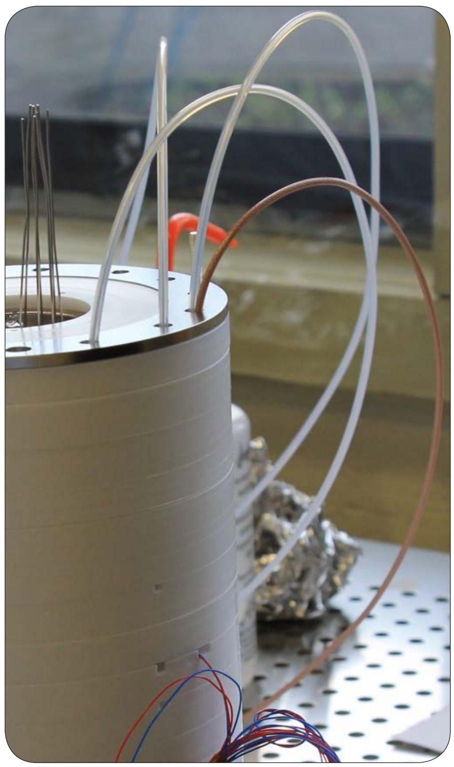

*Figure 4. The fully assembled XAMS TPC.*