Dark Matter Experiments
inauguration of XENON1T

Construction of the XENON1T Dark Matter detector in Hall B of the Gran Sasso laboratory (LNGS) in Italy was completed near the end of 2015. The Nikhef Dark Matter group played a leading role in the design and construction of several of its subsystems. The experiment is now moving into the commissioning phase, with first science data expected to arrive in early 2016 and our group is preparing for the analysis of this data. While the XENON1T construction was ongoing, the XENON collaboration also maintained the operation and data analysis of the XENON100 detector, resulting in a number of important publications. More locally, the Nikhef group has also commissioned XAMS, the dual-phase liquid xenon detector operating in Nikhef's cryo-lab. The analysis of the XAMS data has already given us insights into analyses improvements of the larger XENON detectors.

The XENON1T Dark Matter experiment is being commissioned in the underground Gran Sasso Laboratory in Italy. XENON1T, with a total xenon mass of 3.500 kg, is the third XENON experiment. It all began 10 years ago with a detector of just 15 kg mass. XENON1T is the follow-up of XENON100, the world's most sensitive Dark Matter detector until 2013.

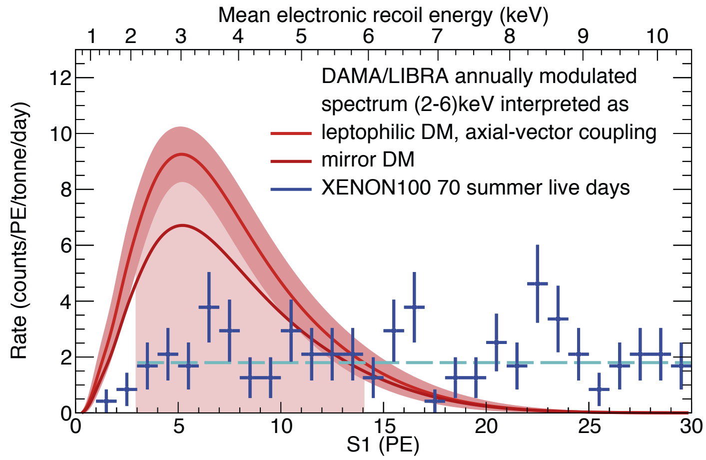


Figure 1. Contrasting XENON100 data with the claimed DAMA Dark Matter detection signal. The DAMA modulated spectrum, interpreted as WIMPs coupling to electrons through axial-vector interactions, is excluded at a 4.4 σ confidence level. A separate analysis searching for an annual modulation in XENON100 data, excludes the DAMA signal at 4.8 σ.

Management
prof.dr. M.P. Decowski

Effective 1 March 2015, **Patrick Decowski** was appointed professor of experimental astroparticle physics at the Faculty of Science of the University of Amsterdam.

The main priority of the XENON collaboration in the past year was completing the construction of the XENON1T experiment. Nevertheless, the smaller XENON100 experiment continues to take data and results are being analysed. This resulted in the publication, one of which in the journal *Science*, of two important analyses related to a Dark Matter detection claim by the DAMA collaboration. This claim is based on the observation of an annual modulation in the DAMA data. Since about a dozen Dark Matter experiments have excluded this signal as being due to WIMP-nucleus scattering, only an interpretation as WIMP-electron scattering was still viable. The XENON100 data has now excluded the observed DAMA modulation signal as being induced by WIMP-electron interactions, see Fig. 1. This result was further strengthened by an annual modulation analysis of XENON100 data, which included a generic search for modulation periods down to the week scale.

The Nikhef group also continues to be heavily involved in XENON100 data analysis. Our group led, and recently completed, the analysis of low-mass WIMP signals and we are also leading the analysis of the ^{88}YBe neutron source data. This latter analysis can provide essential information on the response of xenon detectors at very low nuclear recoil energies. Separately, our group is developing and testing various new algorithms on XENON100 data that will be used for XENON1T analyses. The collaboration is testing a number of novel calibration methods using the XENON100 detector that will also allow us to improve XENON1T data analysis.

Ready for data in 2016

The major event of the year was the completion of the XENON1T construction. This was celebrated with an inauguration event on 11 November. With all components installed, the collaboration is gearing up for a few months of detector commissioning before science data taking starts.

The Nikhef team is responsible for the trigger and event builder as part of the data acquisition group. Most of our on-site focus this year was the installation of the

DAQ system. This included a week-long testing phase on the running XENON100 experiment to identify any problems and exercise the full system. With the help of the Nikhef CT-group, we also installed and commissioned the 12 km-long underground-to-outside fiber network system and made Nikhef one of the best connected outside institutes to LNGS. All of this will ensure that we will be able to analyse data quickly once detector operation starts.

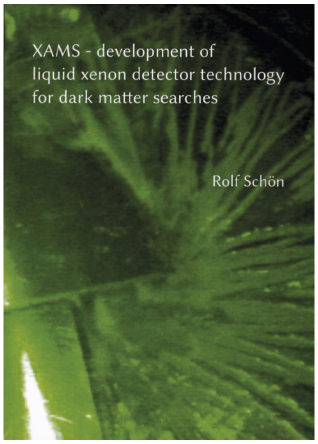
Another focus-area for our group has been the XENON data processing software, named *PAX*. Nikhef has initiated and led the development of *PAX*, and it has become the official XENON data processing software. *PAX* takes care of taking the raw PMT signals, applying all signal conditioning and processing steps, performing event position reconstruction etc. to finally provide ROOT-based output files to analysers. 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 Nikhef team has also recently organized workshops in both the US and Europe to prepare collaborators for XENON1T data analysis with *PAX*.

Our Dark Matter group activities positioned us well to have a leading role in the first XENON1T Dark Matter analysis and indeed one of our postdocs (Christopher Tunnell) has become one of two XENON1T analysis coordinators. His task will be to organize and lead the publication of the first XENON1T Dark Matter data analysis.

XAMS R&D at Nikhef

Over the past few years, we designed, built and operated XAMS, a small dual-phase xenon TPC at Nikhef. We improved several items this year, such as a better functioning xenon level-meter and a tagged ^{22}Na radioactive source. Data from this detector have already been used to benchmark our *PAX* data processing software, see Fig. 2. Based on XAMS data we have also developed a new PMT gain calibration procedure and will submit a paper describing this procedure shortly. We plan to apply this method to XENON1T data. This will allow us to have an alternative gain calibration and stability procedure for XENON1T, in addition to the standard LED-based gain calibration. Finally, after receiving the necessary permits, we are in the process of procuring a neutron source. The neutrons will allow us to see nuclear recoils in XAMS, the same signal as is expected from WIMP collisions and complements our γ-sources.

The Nikhef Dark Matter group is extremely dynamic with all group members participating in our three main experimental activities.



Rolf Schön
1 July 2015

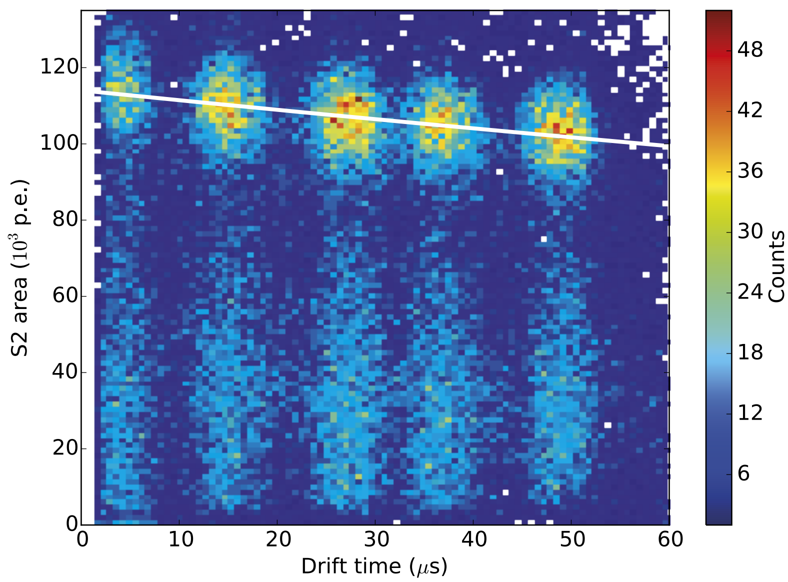
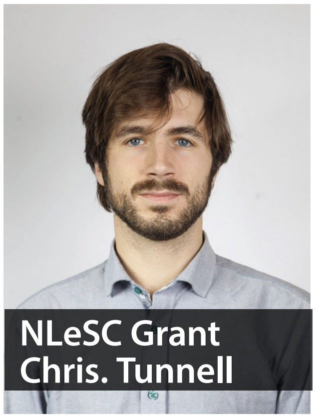


Figure 2. Data taken with a collimated ^{22}Na γ-source pointing at five different positions in the XAMS TPC. The density plot shows the S2-signal for the five different z-positions, corresponding to different drift times. The thick white line is a fit to the photo-peak. The decreasing S2-signal with increasing drift time is due to electron loss as they drift through the xenon liquid and corresponds to an electron life-time of (429 ± 29 µs.

Christopher Tunnell receives NLeSC Path-finding grant

Christopher Tunnell received a Path-finding grant from the Netherlands eScience Center (NLeSC) for his proposal *"Giving pandas a ROOT to chew on: Modern Big Data front and backends in the hunt for Dark Matter"*. The project will involve collaborating with one of their eScience engineers for one year. The Path-finding grants are intended to develop new lines of eScience research that may develop into bigger programs and projects.



NLeSC Grant
Chris. Tunnell

The completed XENON1T Time Projection Chamber (TPC) just before it was moved underground for installation in the cryostat.