T 22: Search for Dark Matter 1

Time: Monday 16:15–18:20 Location: T-H35

Group Report T 22.1 Mon 16:15 T-H35

Current status of the XENONnT Dark Matter Search Experiment — •Luisa Hötzsch — Max-Planck-Institut für Kernphysik, Heidelberg — on behalf of the XENON Collaboration

The XENON experiments are among the most sensitive dark matter (DM) detectors, utilizing the concept of dual-phase xenon time projection chambers (TPCs) for the direct detection of weakly interacting massive particles (WIMPs). The XENON1T detector, which utilized a total of 3.2 tonnes of xenon target, was able to set the most stringent limits on the WIMP-nucleon spin-independent cross section for WIMP masses above $6\,\mathrm{GeV/c^2}$, with a minimum of $4.1 \times 10^{-47}\,\mathrm{cm}^2$ at $30\,\mathrm{GeV/c^2}$.

The latest iteration in the XENON experiment series is the XENONnT detector, which is currently running at the INFN Gran Sasso National Laboratory in Italy. With a total of 8.4 tonnes of xenon, it is projected to improve the sensitivity to WIMP dark matter by another order of magnitude. In addition, due to its further background reduction by a factor of approximately 6, XENONnT is expected to be able to clarify the nature of an electronic recoil event excess observed in XENON1T.

In this talk, I will give an overview of the XENONnT detector and its subsystems, and present the current status of the experiment.

T 22.2 Mon 16:35 T-H35

Light signal correction for the XENONnT experiment — •Johanna Jakob for the XENON-Collaboration — Institut für Kernphysik - WWU, Münster, Germany

XENONnT, the latest stage of the XENON dark matter project, is currently taking science data with the science goals to detect WIMP-nucleus scattering and to search for other rare events. The detector is a dual-phase time projection chamber (TPC) filled with 8.5 tonnes of liquid xenon. The detector side walls reflect scintillation light caused by energy deposition in the detector, which is registered at the top and bottom by photomultiplier arrays. Free electrons, additionally created by the energy deposition in the detector, are drifted to the gaseous phase at the top of the detector where they create a second scintillation light pulse by electroluminescence. Both the light as well as the charge signal allow to perform a 3-dimensional position reconstruction of the recorded events.

This talk focuses on the light signal reconstruction, which requires a correction of the position dependent light collection efficiency and the understanding of the effects of the non-uniform electric drift field. Based on calibration data with several internal sources, light collection efficiency maps are derived and applied to the light signals.

This work is supported by BMBF under contract 05A20PM1 and by DFG within the Research Training Group GRK-2149.

T 22.3 Mon 16:50 T-H35

Energy calibration of the XENONnT Experiment — •Henning Schulze Eissing for the XENON-Collaboration — Institut für Kernphysik - WWU, Münster, Deutschland

The XENON Dark Matter Project uses a dual phase time projection chamber filled with liquid xenon to search for Dark Matter in the form of weakly interacting massive particles (WIMPs). The current iteration, the XENONnT experiment with 8.5 t of xenon, is taking science data and will also allow the investigation of other science topics due to its extremely low background especially for low energies.

The energy deposition as well as the three-dimensional location of an event in the detector is reconstructed using fast scintillation light signal and a delayed charge signal. The latter is converted into a light signal by electroluminescence in the gaseous xenon phase above the liquid. The size of the primary scintillation light and of the charge signal are anticorrelated. This talk will outline the energy calibration of the XENONnT experiment using several mono-energetic gamma sources that can be found in the background data as well as in dedicated calibration data using external and internal sources.

This work is supported by BMBF under contract 05A20PM1 und by DFG within the Research Training Group GRK-2149.

T 22.4 Mon 17:05 T-H35

Calibration of XENONnT with tagged neutrons in its TPC and water Cherenkov neutron veto — •Daniel Wenz — Institut für Physik & Exzellenzcluster PRISMA+, Johannes Gutenberg-Universität Mainz, 55099 Mainz, Germany

For more than a decade, liquid xenon (LXe) time projection chambers (TPC) have been playing a key role in the direct search for WIMP dark matter and other rare events. In 2018, XENON1T set the most stringent limits for WIMP-nucleon couplings for masses above 6 GeV/c2. Building on this success, an even larger LXe TPC called XENONnT was built, which features a ~3-times larger target mass of 5.9 t. The experiment reuses much of the existing infrastructure of XENON1T, which has been augmented by additional sub-systems. One of these new systems is a water Cherenkov neutron veto encapsulating the TPC cryostat. Neutrons are capable of mimicking WIMP signals by undergoing a single-scatter nuclear recoil inside the TPC and escaping the TPC cryostat. The neutron veto system has the goal to reduce the intrinsic nuclear-recoil background by serving as an active veto for those neutrons.

In 2021, XENONnT successfully finished commissioning and started science data taking. In this talk, we will present the first results of XENONnT*s nuclear recoil calibration as well as the calibration of the neutron-veto tagging efficiency, using coincident gammas and neutrons from an Americium-Beryllium source.

T 22.5 Mon 17:20 T-H35

Towards an automated krypton assay in xenon at the ppq level — •Robert Hammann, Hardy Simgen, and Steffen Form — Max-Planck Institut für Kernphysik, Heidelberg, Germany

The beta-decaying isotope ^{85}Kr is one of the main internal background sources of liquid xenon (LXe) detectors. With purification techniques, it is possible to reduce the concentration of krypton in xenon below 100 ppq (parts per quadrillion). To model the background contribution of the remaining ^{85}Kr, it is crucial for low-background experiments such as XENONnT to precisely quantify the concentration of krypton in the detector material. The rare gas mass spectrometer (RGMS) at MPIK Heidelberg can meet this requirement by measuring the krypton concentration of an extracted xenon sample in two steps: First, krypton is separated from the bulk of xenon using a cryogenic gas chromatographic system. Then, the amount of krypton is analyzed using a mass spectrometer. A fully automatic rare gas mass spectrometer (AutoRGMS) is envisaged for the krypton assay of future low-background LXe detectors. This instrument will considerably facilitate the time-consuming measurement procedure, thus enabling a more frequent krypton monitoring. In addition, larger adsorption traps with a novel adsorbent will be employed, which makes the system sensitive to lower krypton concentrations. A proof of concept was demonstrated with a test setup of an automated gas chromatographic system in which stable conditions were maintained for more than 10 hours during the separation process. Moreover, the setup was used to test individual components and to find a working point for AutoRGMS.

T 22.6 Mon 17:35 T-H35

Radon removal system of the XENONnT experiment — •Denny Schulte, Henning Schulze Eissing, Philipp Schulte, Christian Huhmann, and Christian Weinheimer — WWU Münster

A novel high flux radon removal system has been built for the dark matter experiment XENONnT reducing the dominant electron recoil background produced by Rn-222 and its progenies. Continuous emanation from detector components and its half-life of 3.8 days leads to a homogenous distribution of the Rn-222 within the detector system before it decays. Our radon removal method is based on the vapor pressure difference of xenon and radon. We built a cryogenic distillation column with a throughput of 200 slpm to exchange the liquid xenon mass of 8.5 tonnes within one mean lifetime of Rn-222 in order to decrease the radon concentration by a factor 2. An additional extraction flow of 25 slpm from the xenon gas phase at the top of the XENONnT detector, where some specific radon sources were identified, demonstrated to provide an additonal radon reduction factor of nearly 2. Both reduction methods aim for reaching for the first time a radon activity concentration of 1 μBq/kg in a xenon-based dark matter experiment. To provide the enormous cooling power of more than 3 kW at about -100°C we use a heat-pump concept with custom-built, radon-free xenon compressors and heat exchangers.

This talk will focus on the principle, construction and commissioning measurements of the radon removal system.

The project is funded by BMBF under contract 05A20PM1.

T 22.7 Mon 17:50 T-H35

Coating techniques for radon mitigation in liquid xenon detectors — •Mona Piotter, Hardy Simgen, and Florian Jörg — Max-Planck-Institut für Kernphysik, Heidelberg

Searching for rare events like dark matter interaction or neutrinoless double beta decay using liquid xenon detectors, requires a low radon background. Radon, which is part of the uranium and thorium decay chain, can continuously emanate from the detector materials. Current attempts to lower the radon induced background include the selection of radio-pure materials, techniques allowing to actively remove radon from xenon, as well as data selection criteria. However, next generation experiments will require even lower radon levels which likely can not be achieved by employing those methods alone. A new technique to stop radon emanation based on surface coatings has been investigated. This requires a tight and radium-free layer. We have developed a electrodeposited copper coating and present here the promising results. During the development, we systematically investigated the coating parameters with the short-lived ^{220}Rn emanating from tungsten rods or stainless steel plates. After this preliminary tests we applied the coating to a suitable ^{222}Rn emanating stainless steel source, which has a longer half-life. It was produced at the CERN facility ISOLDE by implanting ^{226}Ra in stainless steel plates. In the talk we present the results of the first coating of that sample.

T 22.8 Mon 18:05 T-H35

S1-based position reconstruction in dual phase time projection chambers — •Jaron Grigat — Albert-Ludwigs-Universität, Freiburg, Deutschland

Most particle interactions inside liquid xenon dual phase time projection chambers (LXe-TPCs) create two light signals. Besides the prompt scintillation light (S1), electrons from the interaction site are drifted in an electric field to the gas phase of the TPC. There, they create a delayed proportional scintillation signal (S2). Normally, the position in the x-y-plane is reconstructed from the hit pattern of the S2 signal on the top photosensor array. The depth of the interaction can be calculated from the time delay between S1 and S2. In this talk, we explore the possibility to reconstruct the 3D position by only looking at the S1 signal using machine learning techniques. We discuss possible applications of this additional information and show how this method can help us to characterize the electric field inside the XENONnT TPC.