Search for New Physics with XENONnT

Mariana Rajado Silva & Christian Wittweg – Astroparticle Physics Group of Prof. Laura Baudis

Physik Institut – lbaudis@physik.uzh.ch

γ, μ, n

χ, ν

A muon travelling through water emits characteristic Cherenkhov light. As a muon crosses the detector, the PMTs in the muon veto detect this radiation and are able to tag it. μ

A traversing muon or a radioactive decay can produce a neutron inside the TPC, which would mimic the WIMP signal. Thanks to the neutron veto, such neutrons are tagged as they exit the detector. n

What is dark matter?

Great question! No one really knows, as it has not been directly detected. Only its gravitational effects have been observed.

The cosmic microwave background or the phenomenon of gravitational lensing are examples of dark matter evidence.

It should be
- massive
- charge neutral
- weakly interacting

and make up 85% of matter in the Universe.

Most dark matter candidates are new fundamental particles, such as axions or WIMPs (Weakly Interacting Massive Particles). Within the XENON collaboration, we focus on the latter.

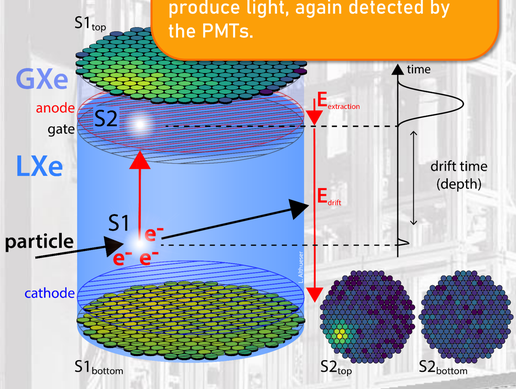
How does XENONnT work?

WIMPs, being weakly interacting, are likely to pass through matter without leaving any trace.

If one wants to detect a WIMP interaction, one should have a detector which is
- sufficiently large
- placed deep underground (shielded from external radioactivity)
- made of radiopure materials
- sensitive to single photons

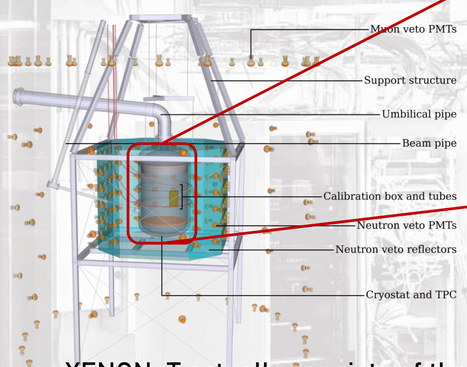
… and XENONnT ticks all these boxes.

The emitted light (S1) is detected by the PMTs at the top and bottom of the TPC. The released electrons (S2) are drifted upwards and extracted into the gas, where they produce light, again detected by the PMTs.



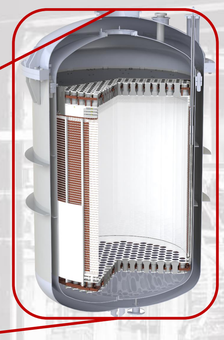
XENONnT is a time projection chamber (TPC) operated in dual phase (filled with liquid xenon, with a gas layer on top). The interaction of a particle with the xenon produces two detectable signals: prompt light (S1) and delayed charge (S2). These are read out by photomultiplier tubes (PMTs), allowing one to reconstruct:
- the position
- the energy
- & the type of interaction.

What is the XENONnT infrastructure like?



XENONnT actually consists of three nested detectors! The TPC is housed inside a vessel which serves as a neutron veto. This volume is further nested within a water tank: a Cherenkhov muon veto.

The XENONnT TPC in numbers:
- 1.5 m x 1.3 m ∅
- 494 PMTs
- 8.5 t of liquid xenon (5.9 t instrumented)
- 5 wire electrodes
- 2 sets of concentric field-shaping rings

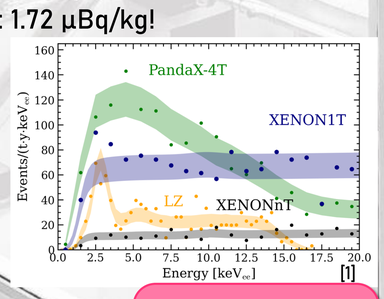


XENONnT also features a novel liquid purification system, in addition to the commonly used gas one. This allows for the purification of 350kg of liquid xenon per hour. Furthermore, cryogenic distillation of the xenon is also a used technique to reduce the inevitable radon background, which is continuously emanated from all detector surfaces.

Liquid xenon purification system (a) and radon distillation system (b). Purification is important because the S2 electrons can attach to impurities in the xenon and, therefore, be lost.

Which milestones have been reached?

XENONnT reached an electron lifetime of just above 10 ms, leading to a survival rate of over 90% for electrons produced at the bottom of the TPC!
Also, the cryogenic distillation of the xenon led XENONnT to have the lowest ever ^{222}Rn activity concentration in a xenon TPC: 1.72 μBq/kg!

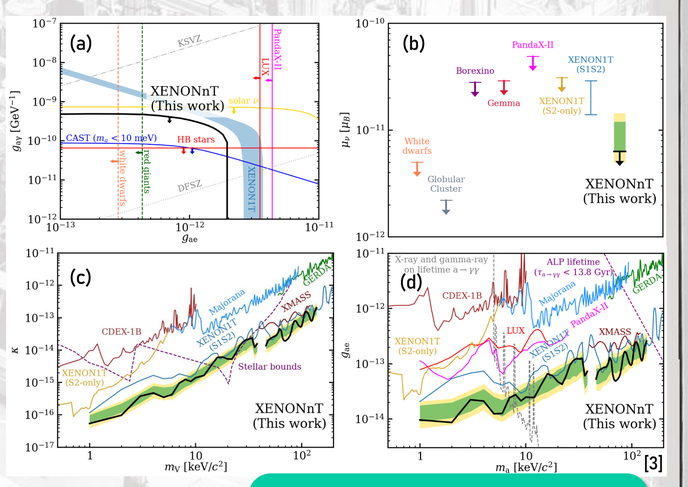


[1]

XENONnT has the lowest background level ever achieved in a dark matter experiment.

What other BSM physics channels can be probed?

Despite the focus of XENONnT on WIMPs (expected to produce nuclear recoils), the very low background conditions also allow for electronic recoil interactions to be probed. This opens up research possibilities for new science channels, such as:
- other dark matter candidates: axion-like particles (ALPs) or dark photons
- the half-life of 2νECEC of ^{124}Xe (confirming the result already obtained with XENON1T [2])
- an anomalous neutrino magnetic moment
- solar axions



[3]

Limits on solar axion couplings (a), the effective neutrino magnetic moment (b), and the mass of dark photons (c) and ALPs (d).

XENONnT is located deep underground in the Laboratori Nazionali del Gran Sasso, Italy.

[1] – PandaX Collaboration, PRL 129, 161804 (2022); XENON Collaboration, PRD 102, 072004 (2020); LZ Collaboration, arXiv: 2207.03764 (2022), XENON Collaboration, PRL 129, 161805 (2022)
[2] – XENON Collaboration, Nature, 568, p. 532–535 (2019)
[3] – XENON Collaboration, PRL 129, 161805 (2022)

The XENON collaboration:
~170 scientists
27 institutions
12 countries