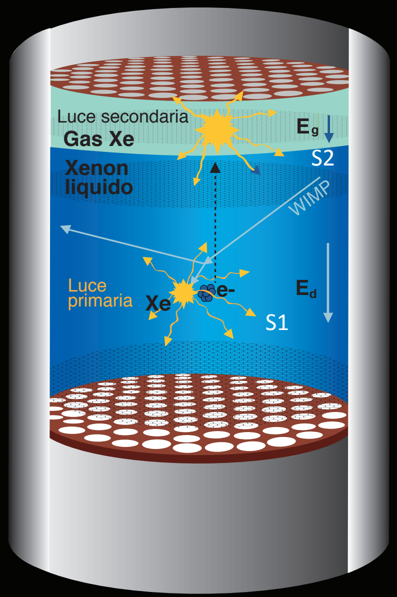
DETECTION PRINCIPLE

A possible WIMP interaction in the xenon liquid target generates a prompt flash of scintillation light which is recorded by 494 photomultipliers arranged in two arrays: one is mounted in the upper section of the TPC where the gaseous xenon is located, the other one in the lower section, in the liquid xenon.

The active dark matter target, defined by a cylinder with 1.5 m height and 1.3 m diameter, is delimited by highly-reflective PTFE panels.
Wire electrodes close the cylindrical target from above and below and are used to establish an electric field which prevents the ionization electrons to recombine with parent nuclei and drifts them towards the upper end of the detector.
Massive copper electrodes surrounding the cylindrical target ensure that the electric field lines are perfectly straight. Thus allowing electrons to move through the liquid xenon at a speed of about 1 mm/µs. Once they arrive at the interface between the liquid and the gaseous xenon, a suited electric field extracts them from the liquid into the gas phase.
By scattering off the xenon atoms they produce a scintillation signal which is proportional to the number of electrons. These particular type of detectors, which exploit the two phases of the xenon (liquid and gaseous), are referred to as dual-phase time projection chambers.



The XENONnT Detector Schematic

This light signal is once more recorded by the photomultiplier arrays. The combination between the primary and secondary light signals allows a three-dimensional reconstruction of the interaction vertex as well as the selection of events occurring in the central core of the target. The background events, produced by the detector's components, once measured in the outer part of the detector can be excluded, thus reducing the background at minimal level.
The ratio of the two signals is further used to distinguish background events, due to photons and electrons, from a possible dark matter signal interacting with the xenon nuclei.

The XENONnT Detector during Assembly (Left) and Design (Right).

XENON COLLABORATION: 28 INSTITUTIONS AND MORE THAN 170 PHYSICISTS

XENONnT

enlightening the dark

Astrophysical observations provide ample evidence for the existence of an invisible even though dominant mass component in the observable universe, from the scales of galaxies up to the largest cosmological structures.

After many decades of increasingly precise astrophysical observations, we have unequivocal evidence that the majority of the material that forms galaxies, clusters of galaxies and the largest observed structures in the Universe, is non-luminous, or dark (it does not emit or absorb light). Even the precise measurements of the cosmic microwave background radiation and of the abundance of light elements in the Universe, lead to the same result.

According to the current cosmological model, dark matter makes 85% of the total mass of the Universe. The residual mass is the ordinary matter, which we are made of.

Uncovering the nature of this dark matter component is one of the most outstanding challenges in physics today.

The dark matter could be made of a new, yet undiscovered particle, such as a weakly interacting massive particle (WIMP). One way to observe WIMPs is to search for their collisions with atomic nuclei in ultra low-background detectors placed deep underground.

Discovering WIMPs would enlighten two of the outstanding problems of modern physics - the matter composition of our Universe and the existence of new physics beyond the Standard Model. We infer that a few millions of WIMPs are passing through a human body every second, without any interaction.

Nonetheless we can search for WIMPs rare interactions with a variety of experiments on Earth, which are sensitive to the tiny energy deposited in collisions of WIMPs with atoms in a low background detector.

The XENONnT experiment, at the Gran Sasso Underground Laboratory, uses liquid xenon to search for these elusive collisions.

XENONnT

The XENONnT experiment is a low-background time projection chamber (TPC), filled with ultra-pure xenon as active detection medium to search for dark matter interactions. The xenon is used in both liquid and gaseous forms. This detector technology offers particularly attractive prospects for dark matter detection due to its excellent capability of rejecting events that are not induced by dark matter interactions and which are therefore called "background" events, as well as its scalability to large mass detectors.

Liquid xenon is an efficient scintillator, i.e. it emits light if a particle hits a xenon atom, and it can also be ionized easily. This allows the simultaneous measurement of a scintillation light and an ionization charge signal for every interaction. Liquid xenon time projection chambers have demonstrated remarkable success in recent years and are currently leading the race towards the direct detection of dark matter.

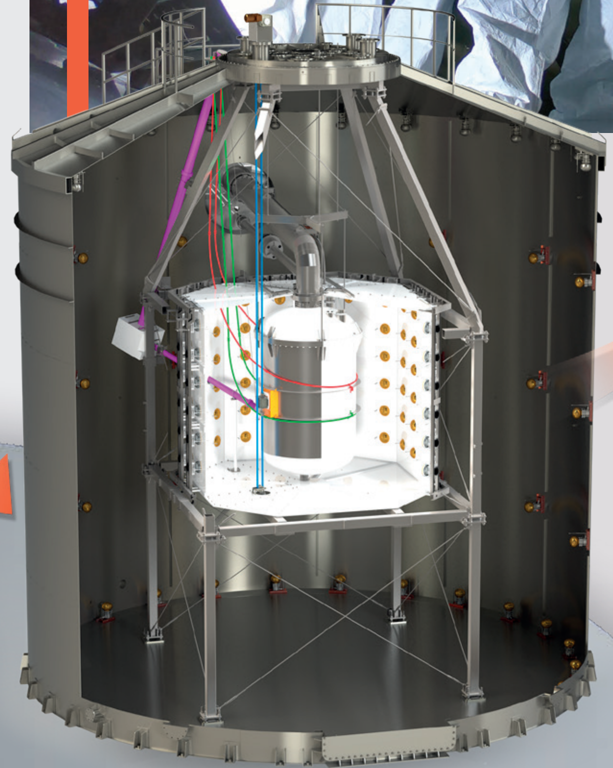
The xenon is intrinsically radio-pure, shields radiation very efficiently due to its high density, nearly 3 times the one of water, and is sensitive to low-energy interactions.

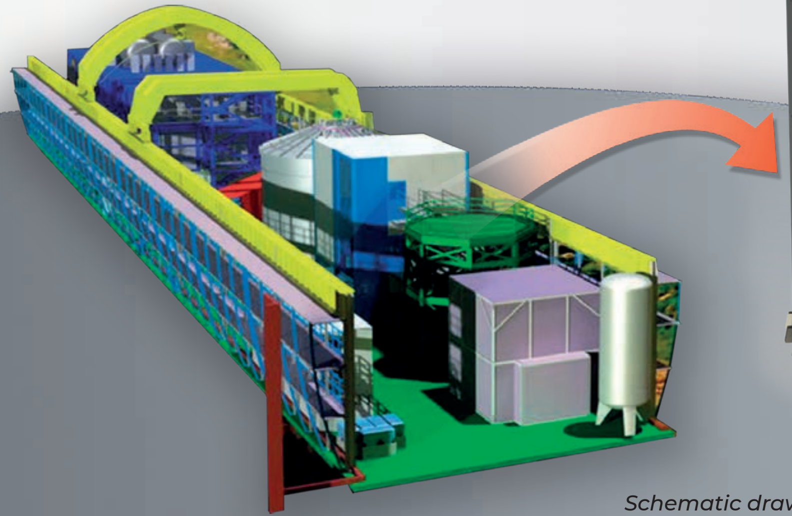
The XENON project, initiated at the Columbia University, follows a phased approach, with detector masses ranging from tens to thousands of kilograms of liquid xenon.
In the current phase, the XENONnT detector uses a total of about 8.5 t of ultrapure xenon, out of which 5.9 t are instrumented with 494 novel photomultiplier tubes (light detectors) as sensitive sensors for the xenon scintillation light. This inner part of the instrument, the dark matter target, is surrounded by the remaining xenon, acting as radiation shield.

In order to have an ultra-low background detector, all materials and components were selected according to the lowest possible intrinsic radioactivity.

The xenon is a noble element that has gaseous form at room temperature and pressure, and liquefies at -108° C. It is present in Earth's atmosphere with a very tiny concentration, 0.0000087 % by volume.

THE LIQUID XENON IS ENCLOSED IN A CRYOSTAT, WHICH IS MADE OF TWO CONCENTRIC VESSELS MANUFACTURED WITH SPECIALLY SELECTED STAINLESS STEEL WITH A VERY LOW INTRINSIC RADIOACTIVITY. THE EMPTY AREA BETWEEN THE TWO CONCENTRIC VESSELS IS NECESSARY TO THERMALLY INSULATE THE INNER VESSEL FROM THE ENVIRONMENT.
THE CRYOSTAT ALSO ACCOMMODATES THE ACTIVE DETECTOR, THE TIME PROJECTION CHAMBER WHOSE SIGNALS ARE RECORDED BY PHOTOMULTIPLIER TUBES ARRANGED IN TWO ARRAYS, INSTALLED ABOVE AND BELOW THE SENSITIVE XENON TARGET.





Schematic drawing of Hall B of the LNGS, where XENONnT is located.

The required measurements were conducted with instruments installed in the LNGS laboratory and at other institutions involved in the experiment. These devices have world-leading sensitivities.

In order to further improve the natural screening capability of the 1400 m of rock overburden provided by the Gran Sasso massif against cosmic ray muons, the cryostat is installed inside a cylindrical tank with 9.6 m diameter and 10 m height where 84 photomultipliers are installed. The tank contains 700 m^3 of de-ionized water, that reduces the ambient radioactivity to negligible levels. A charged particle passing through the water is able to produce a flash light (Cherenkov radiation) which is detected by the photomultipliers.

In the middle of the water tank it is installed a neutron detector. Neutrons are the main source of background; in fact, interacting with xenon, they produce a signal very similar to the WIMPs' one.

The XENONnT experimental facilities underground in Hall B.

The neutron detector consists of a structure around the cryostat bounded by high-reflective panels and 120 photomultipliers tubes, which allow to detect the light emitted by the interaction of the neutrons as well as to exclude the events from the data analysis. This additional instrumentation allows to increase the sensitivity of the experiment to WIMPs.

Aside the XENONnT experiment a three-level structure is located, hosting all ancillary devices necessary to the functioning of the experiment. The cryogenic system, liquefying the xenon gas, is installed on the top floor, as well as the purification system, which continually recirculates the xenon through special filters. This system removes impurities from the liquid xenon at a level of one atom of impurity per ten billion of xenon atoms.

The counting room, computing and control infrastructure are located at the middle floor of the building.

The bottom floor hosts the custom storage system of the precious stock of xenon. This device can store up the full amount of xenon (8.5 t) in safe conditions in state of matter, gas, liquid and even solid. In case of an emergency situation, it allows to recover the xenon from the cryostat in few hours. At the same floor there is a 5m high distillation column, which removes from the xenon minute amounts of krypton (one atom per ten thousand billions of Xe atoms) able to produce unexpected events. A similar distillation column is installed at the top floor to remove Radon atoms, another important potential contaminant.