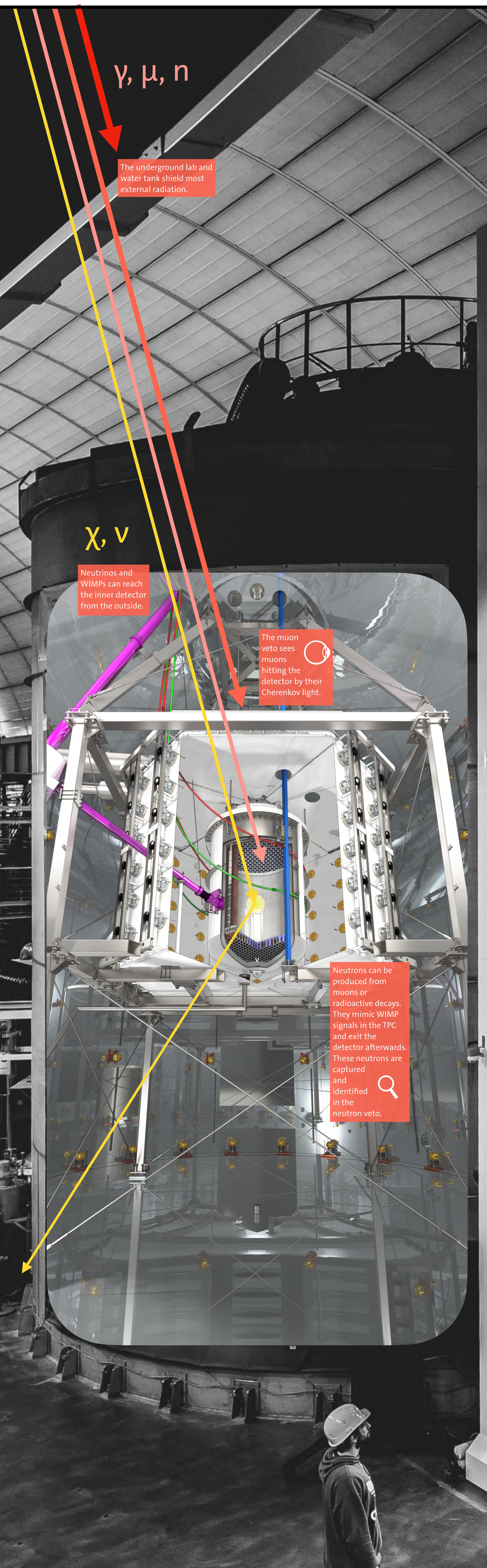
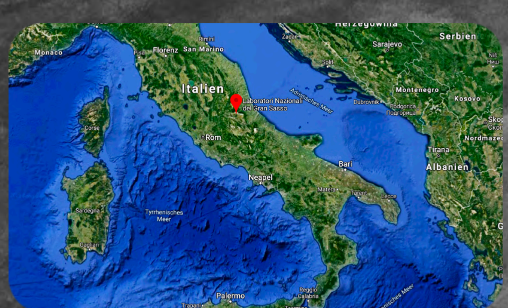
Dark Matter Search with XENONnT

Giovanni Volta & Christian Wittweg – Astroparticle Physics Group of Prof. Laura Baudis
Physik Institut – lbaudis@physik.uzh.ch

XENON

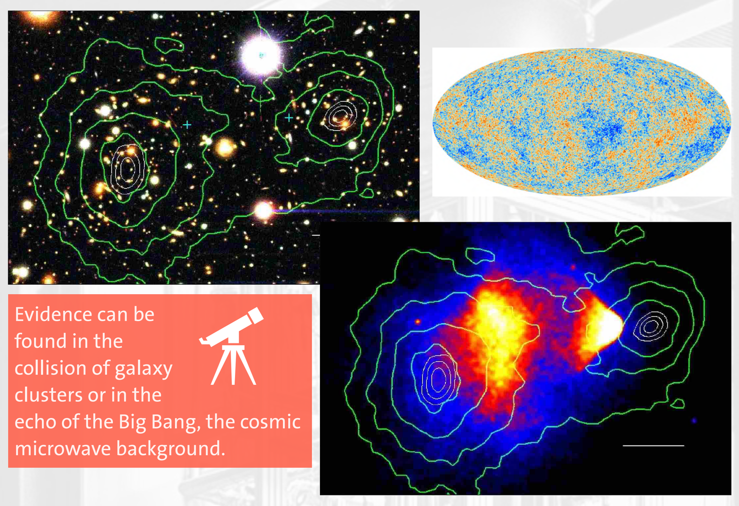
University of Zurich[UZH]





Laboratori Nazionali del Gran Sasso is XENONnT's home.

What is dark matter?

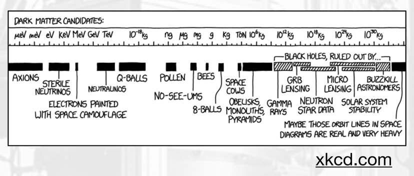


Evidence can be found in the collision of galaxy clusters or in the echo of the Big Bang, the cosmic microwave background.

Nobody knows! Nobody has ever measured it directly! We have only seen its gravitational effects.

It could be:

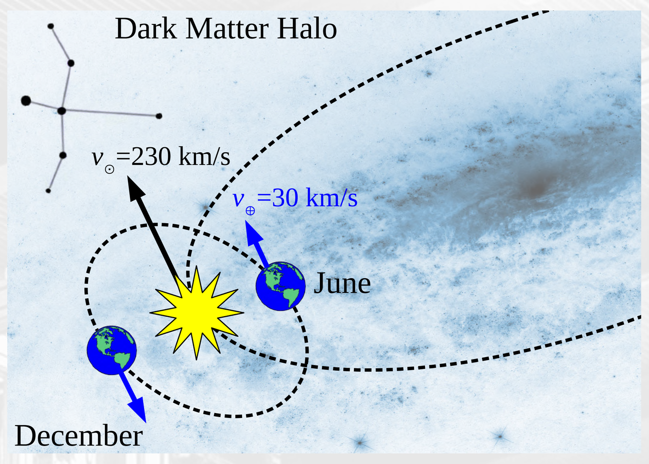
- Massive.
- Non-relativistic.
- Neutral and weakly interacting.



xkcd.com

Candidates are new fundamental particles such as axions or WIMPs (Weakly Interacting Massive Particles).

How would we detect dark matter directly?

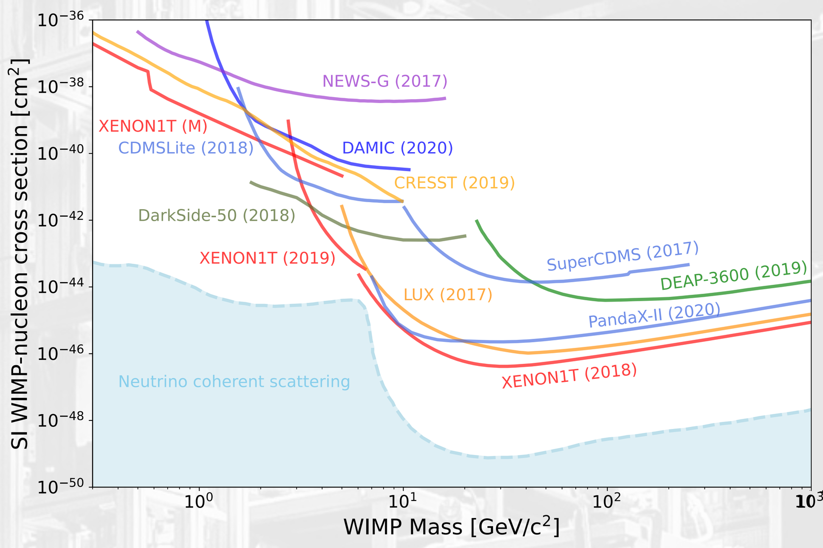


Dark matter would have been produced in the early Universe, hence it must be everywhere. Moving through the galaxy together with the Sun, the Earth is in a WIMP headwind, hence the WIMPs come to us. We just have to catch them in a detector – XENONnT.

WIMP interactions will be exceedingly rare, as they mostly pass through matter unaffected. We will only see them if we shield our experiment from cosmic rays and external radioactivity. Detectors are:

- Deep underground.
- Quiet, i.e. intrinsically radiopure.
- As big as possible.
- Sensitive to single photons.

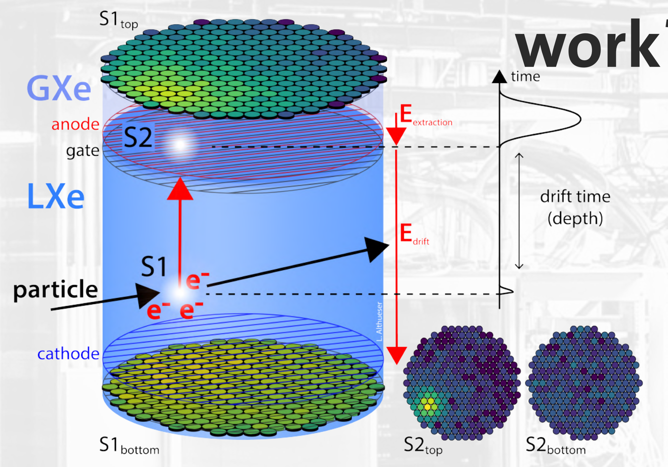
We check every screw for radioactivity before building the detector.



We aim to measure the tiny amount of energy from a WIMP interaction with an atomic nucleus. If we do not observe any events, the interaction strength is lower than the sensitivity of our detector. In this case we can set an upper limit.

At some point neutrinos start to mimic WIMP signals!

How does XENONnT work?

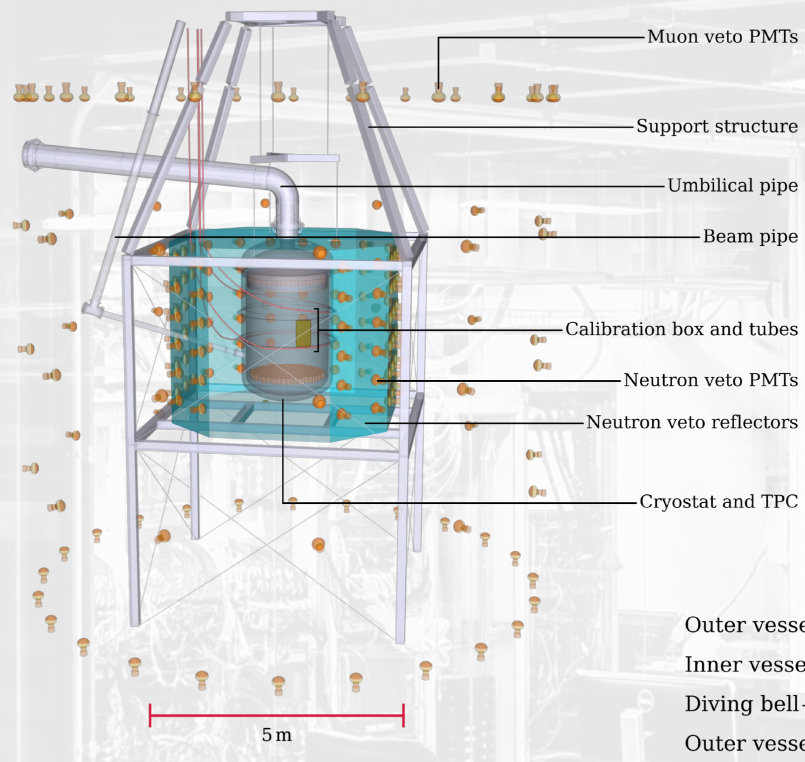


XENONnT is a dual-phase time projection chamber: filled with liquid xenon and a thin gas layer at the top. An energy deposition from a particle produces a prompt light (S1) and a delayed charge (S2) signal. These are measured with photomultipler tubes. From S1 and S2 we reconstruct the position, energy and type of the interaction.

The position reconstruction allows us to use the outer layers of the detector as its own radiation shield.

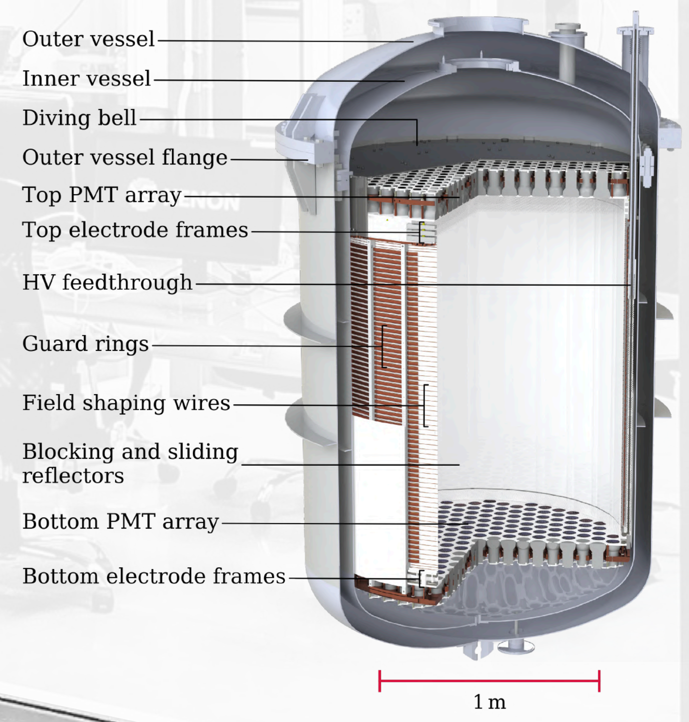
Three nested detectors:

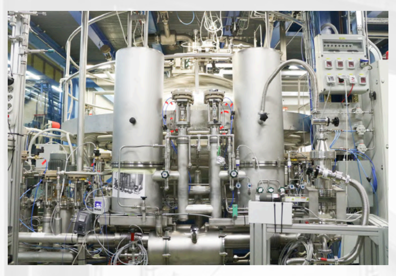
- The water tank contains 700 t of ultrapure water and doubles as a muon veto with 84 PMTs.
- An optically separate volume with 120 PMTs checks if neutrons escape the TPC. For this we will add Gadolinium salt to the water.
- The TPC sits at the center of this assembly with its calibration systems that allow us to deploy radioactive sources.



The XENONnT TPC:

- 5.9 tonnes of xenon.
- 494 PMTs in two hexagonal arrays.
- PTFE reflectors.
- Two sets of concentric field-shaping rings.
- Wire electrodes for applying electric fields.





Liquid xenon purification:

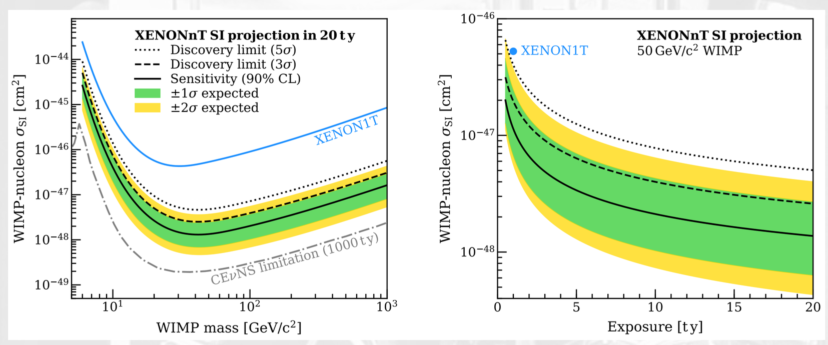
- Loss of S2 electrons by their attachment to impurities in xenon.
- Usually, experiments purify the xenon gas, but this is slow.
- Purify the liquid directly with 350 kg per hour.
- Achieve more than 90 % survival probability for electrons from the bottom of the detector.

Radon distillation:

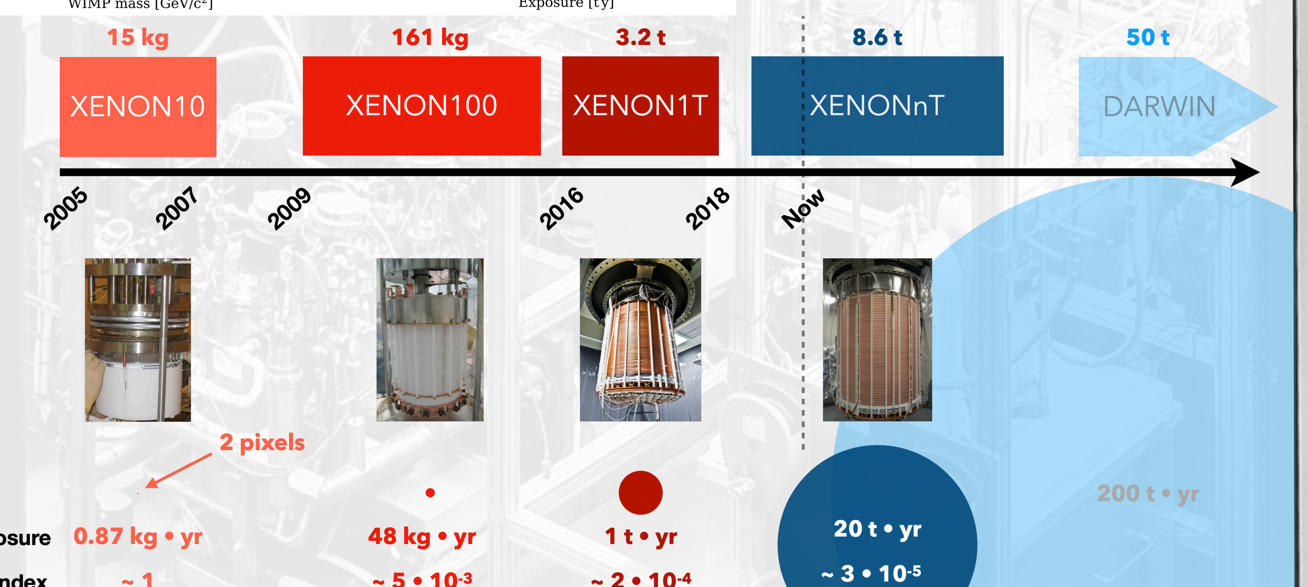
- Radon is continuously emanated from all materials.
- It is removed by cryogenic distillation.
- Lowest ever radon background in a xenon TPC: 2 μBq/kg.

By distillation we also reach sub-ppt (10^{-12}) levels of krypton.

Where do we go from here?

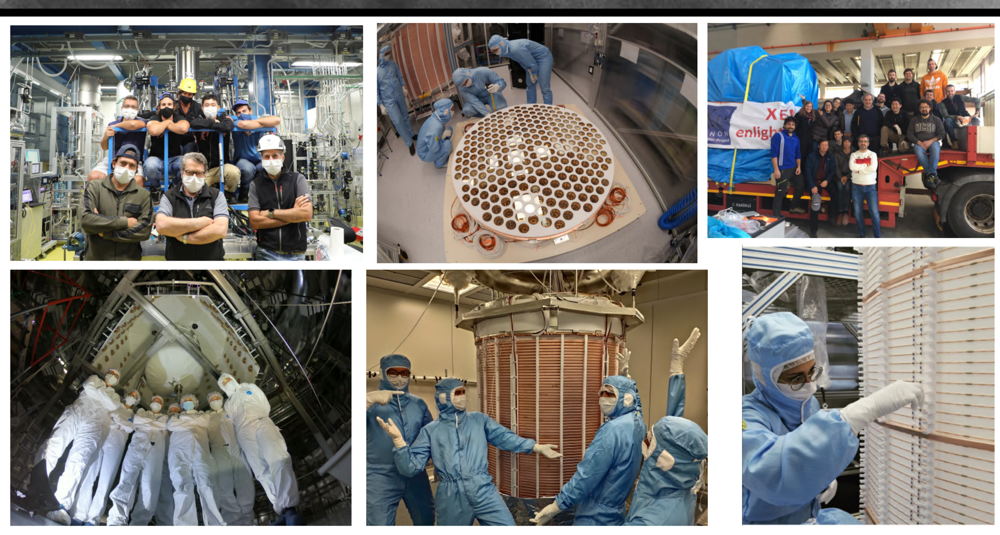


- Discover WIMPs or improve existing limits by a factor 10.
- Check for solar axions or axion-like particles.
- Conduct other physics searches such as for neutrinoless double-β decay, nucleon disappearance, ...



DARWIN:

- Scale up the detector to a total of 50 t xenon mass.
- Reduce backgrounds further such that neutrinos become the dominant and irreducible background.



The XENON collaboration:
170 scientists
27 institutions
12 countries