

Xenoscope: Towards DARWIN – the Ultimate Dark Matter Detector



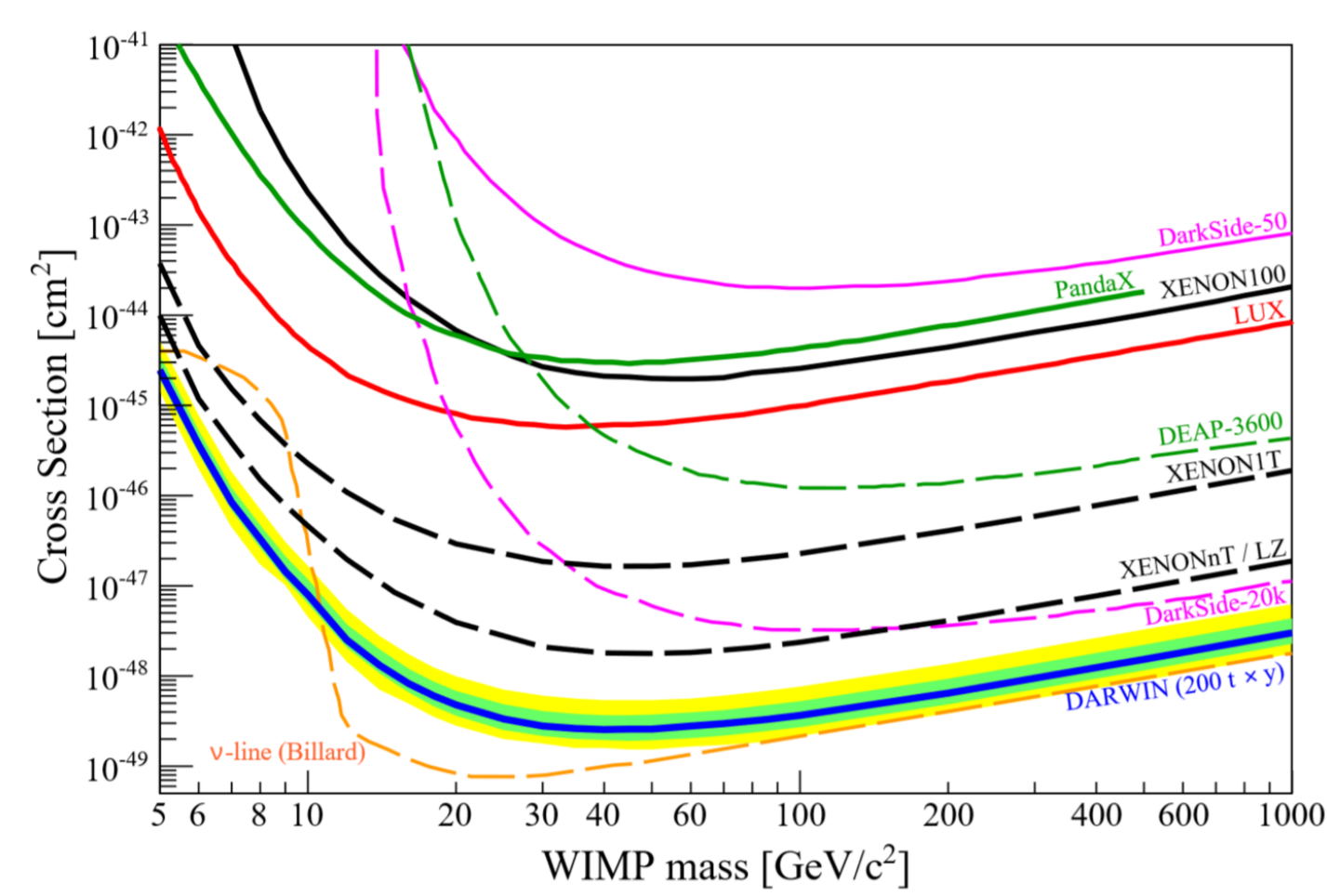
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DARk matter WImp search with liquid xenon

Xenoscope is a new ERC-granted project focused on essential, cutting-edge research towards DARWIN, a future astroparticle observatory in Europe.

DARWIN will be using a ~ 40 t target of liquid xenon for direct detection of dark matter particles in a sensitive time projection chamber (TPC). This detector will achieve an unprecedented sensitivity, probing the entire parameter space for WIMP masses above ~ 5 GeV/c². It will ultimately be limited by the

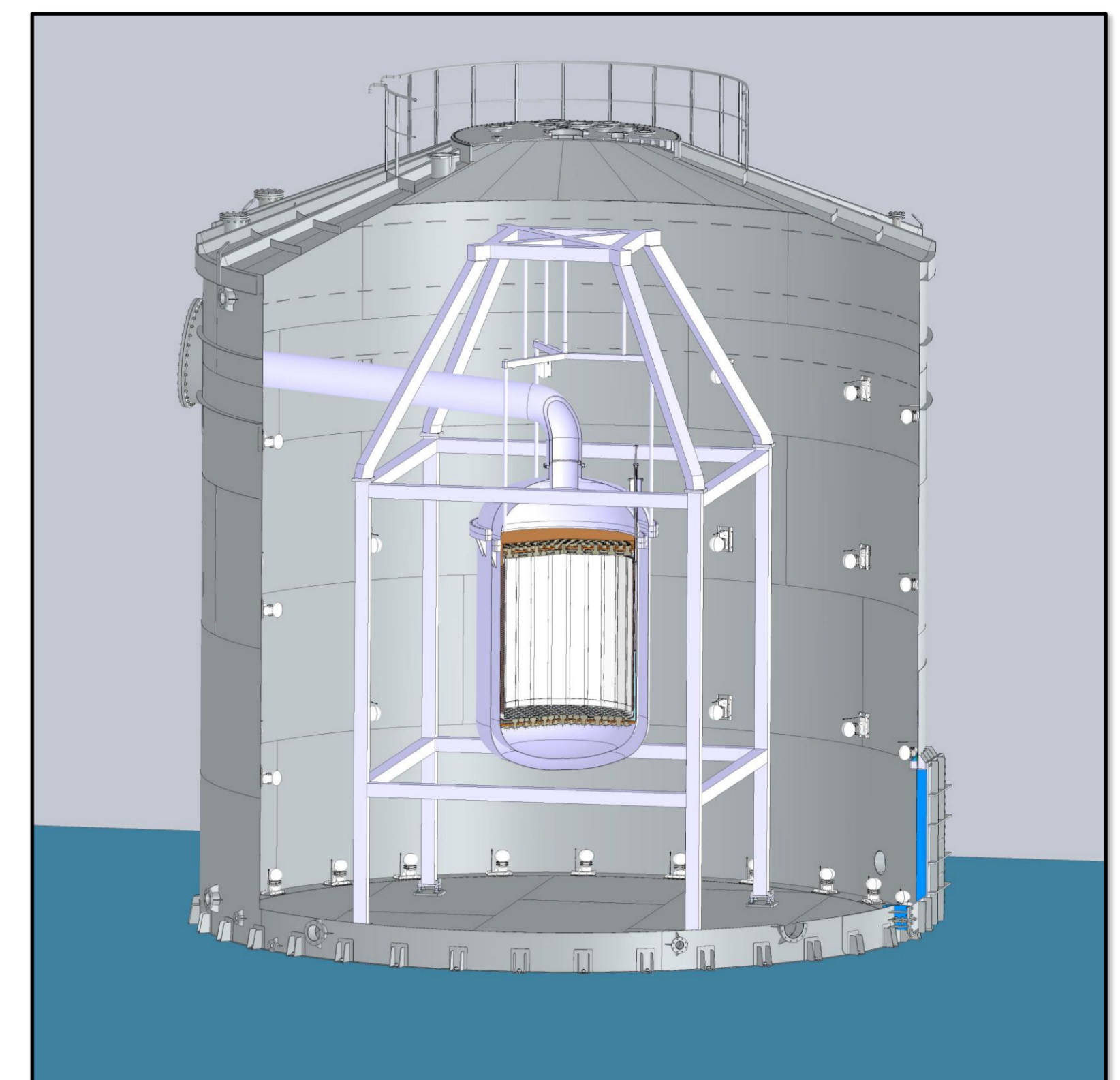


Spin-independent sensitivity projection for DARWIN

irreducible background of neutrino interactions (ν -line, dashed orange), making DARWIN the ultimate dark matter detector.

With a lower energy threshold than current neutrino experiments and its ultra-low background level, DARWIN will even be sensitive to low energy solar neutrinos (pp, ⁷Be), as well as to the neutrinoless double beta decay of ¹³⁶Xe, which has an abundance of 8.9% in natural Xe.

Other rare event searches with DARWIN will include the coherent neutrino scattering of ⁸B, galactic supernova neutrinos and the observation of axions and axion-like particles.



Possible realization of DARWIN

R&D challenges for DARWIN

Optimization of Light Readout

- Testing of state-of-the-art Photomultiplier Tubes (PMTs)
- Testing of novel, solid-state, VUV-sensitive Silicon Photomultiplier (SiPM) arrays
- 4 π photosensor coverage in a LXe TPC

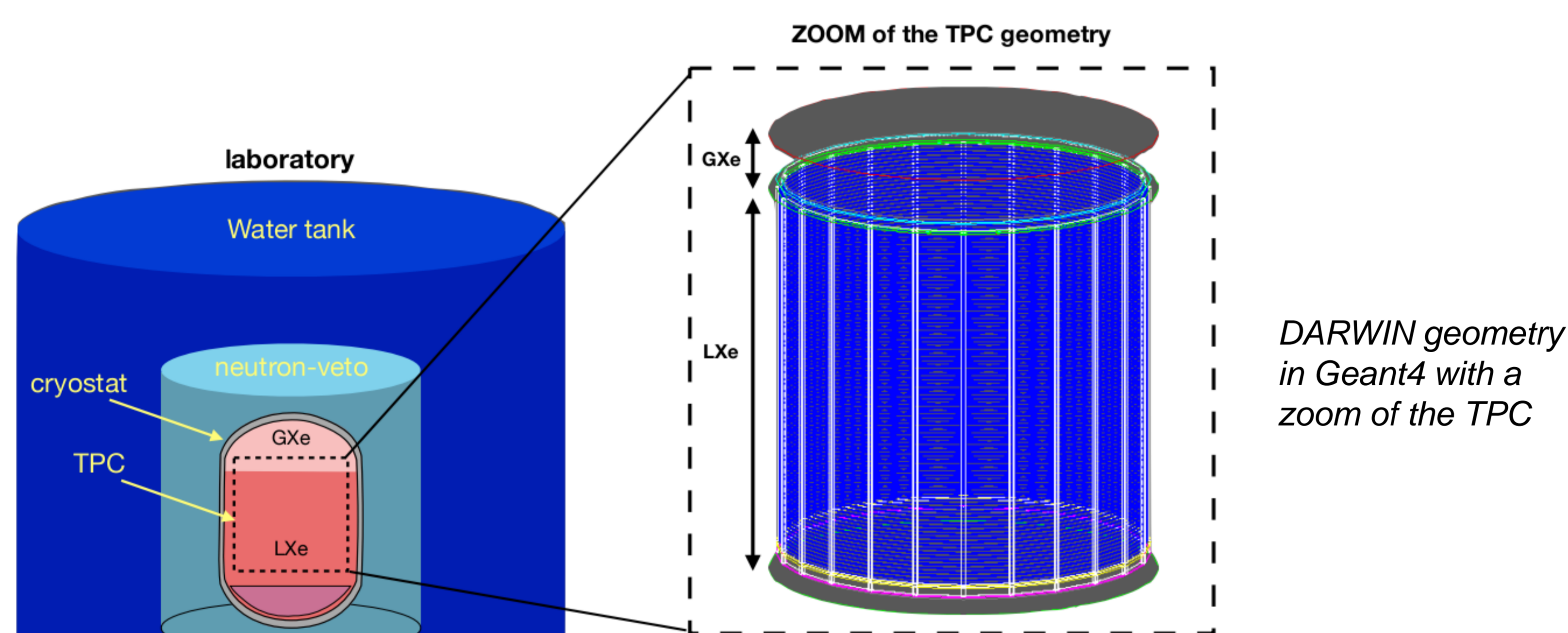
- Identification and characterization of low-radioactivity materials for photosensors and other components of the TPC.
- Determination of required dimensions and effectiveness of a water Cherenkov shield for muon-induced neutron background reduction.

Background Reduction Techniques

- Identification of materials with ultra-low radioactivity levels of radon.
- Study and modelling of short-lived, muon-induced isotopes at underground site.
- Improved nuclear vs. electronic recoil discrimination.

DARWIN Simulations in Geant4

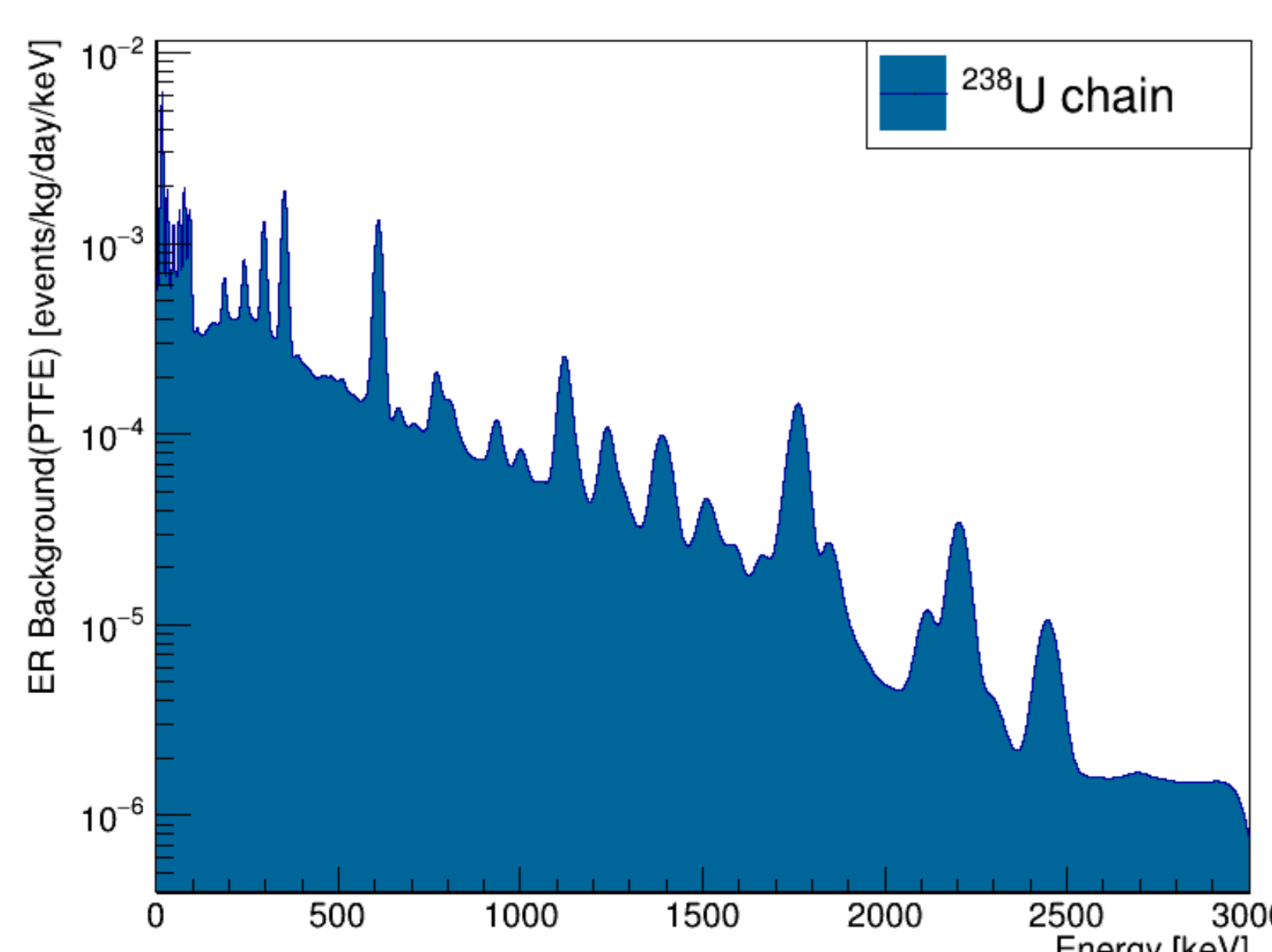
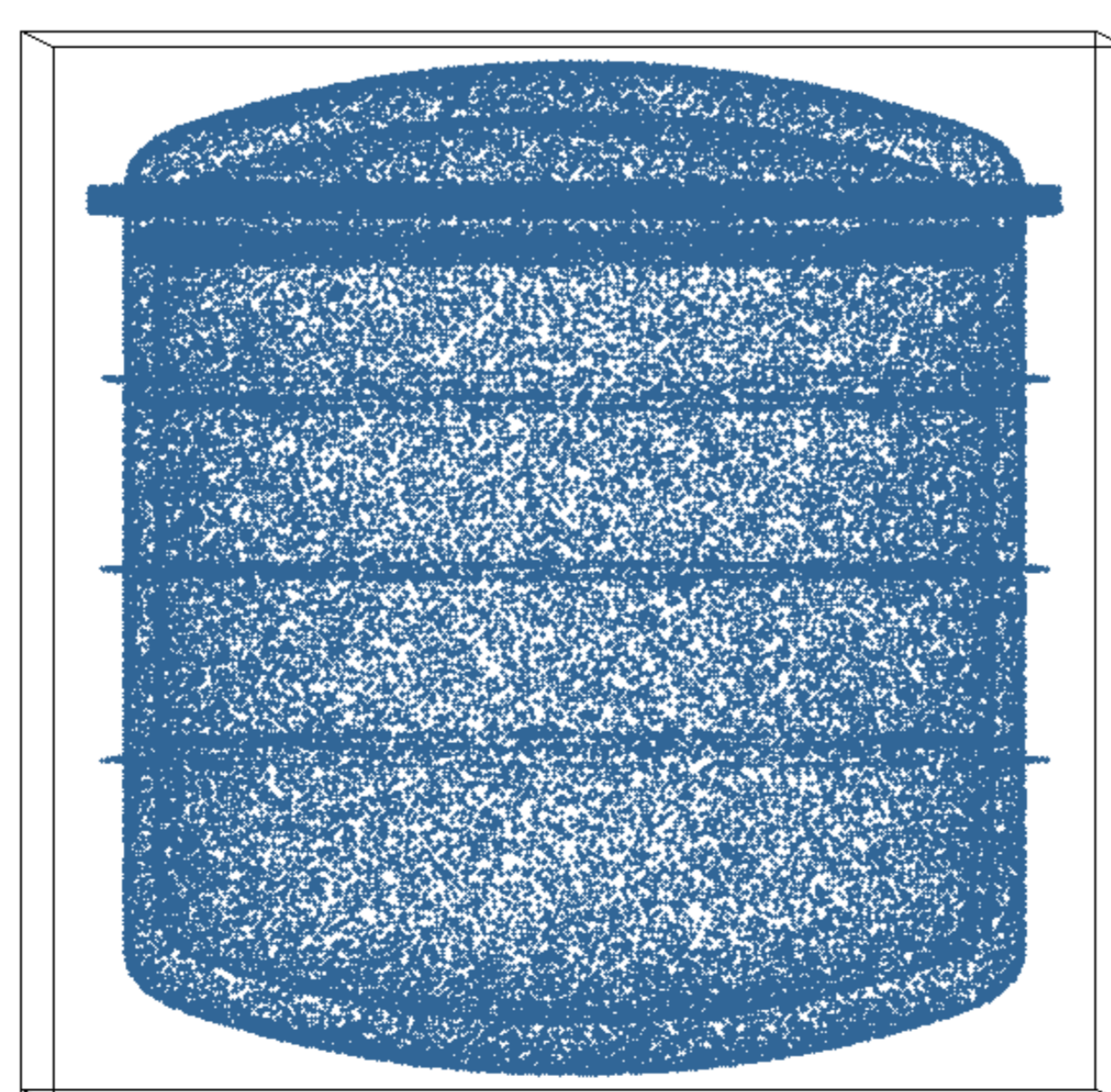
As a detector searching for rare events, DARWIN will require a detailed simulation campaign to identify and quantify all the possible backgrounds in the detector. This study is crucial in order to determine the sensitivity of DARWIN to the different physics channels.



Simulations will be also needed to determine the optimal dimensions of the TPC and the shielding structures as well as the best material for the cryostat.

One of the most complex elements implemented in Geant4 is the cryostat, a double walled, vacuum insulated vessel composed of a cylindrical body and a torispheric dome on top and bottom. The level of background inside the TPC will drastically depend on the material used to build the cryostat. Titanium and stainless steel are the materials under investigation.

Geant4 visualization of the DARWIN cryostat using geantinos



With Geant4 we can simulate the energy spectra of all the radioactive isotopes in the detector materials which are able to deposit energy within the sensitive detector, the LXe inside the TPC.

Energy spectrum of the ER background produced by the ²³⁸U chain from the PTFE

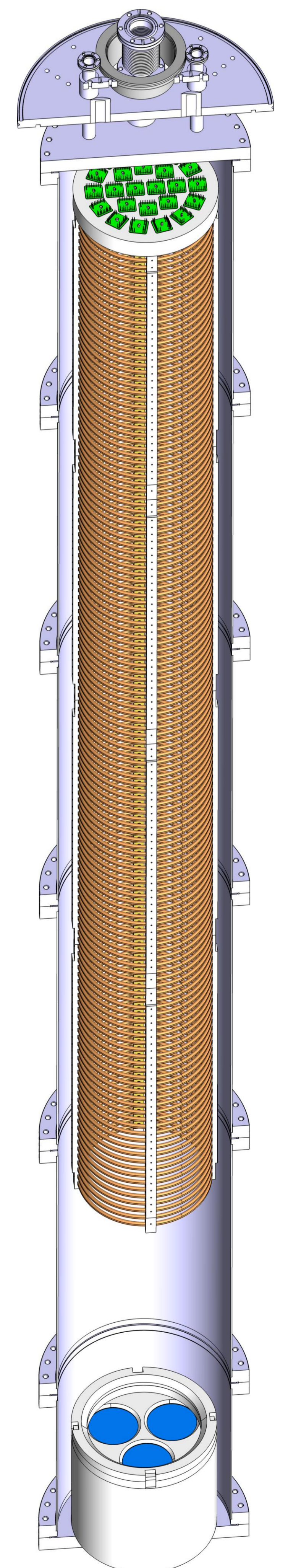
DARWIN Demonstrator

The main objective of the project is the demonstration of the electron drift over the full height of DARWIN. For this purpose, we are going to design, build and operate a TPC of 2.6 m height and 20 cm diameter filled with approximately 315 kg LXe. Our group will be the first to operate a LXe TPC with this height for which one of the indispensable requirements is a stable and uniform drift field of ~ 0.5 kV/cm.

In order to achieve the necessary free electron lifetime of several milliseconds to drift and extract the electrons into the gas phase, one of the main goals is to determine the required circulation and purification rate.

The current design involves two arrays of PMT's, three 3" PMT's on the bottom, and 24 1" PMT's on the top array. The low light collection efficiency caused by the geometry can be increased to 26% (39%) due to simulations by adding 10 (20) rings of SiPM arrays, each consisting of 30 modules (not shown in the CAD drawing on the right).

This will be the first demonstration of electron drift over 2.6 m in LXe and extraction into a vapour phase in a TPC



References:

- [1] DARWIN Collaboration (J. Aalbers et al.) JCAP 1611 (2016) 017, arXiv:1606.07001.
- [2] L. Baudis et al., arXiv:1712.08607.
- [3] <http://darwin.physik.uzh.ch/>
- [4] <http://www.physik.uzh.ch/en/groups/audis/Research/Xenoscope.html>

