DARWIN: an excellent environment to probe neutrino physics

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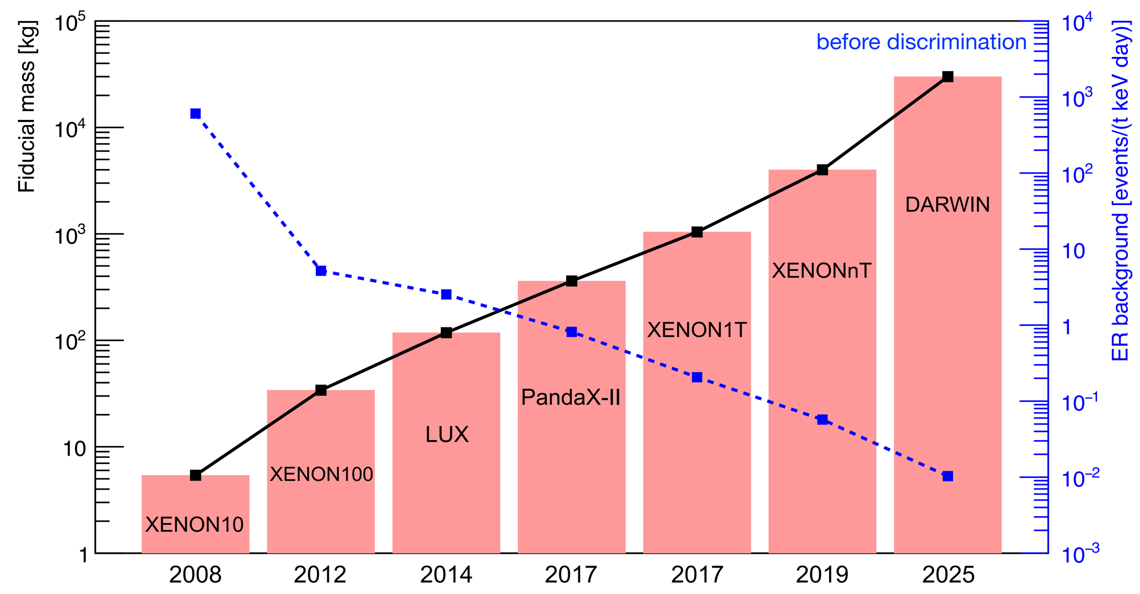
INTRODUCTION

The future of dark matter direct searches calls for the use of multi-ton scale detectors. In this context, DARWIN (DARk matter WImp search with liquid xenoN), with its 40 tons of active target, will be the ultimate xenon detector, able to explore the entire experimentally accessible parameter space for WIMPs. Furthermore, such a large detector, with its low energy threshold and ultra low background level, will be also a powerful tool to probe neutrino physics.

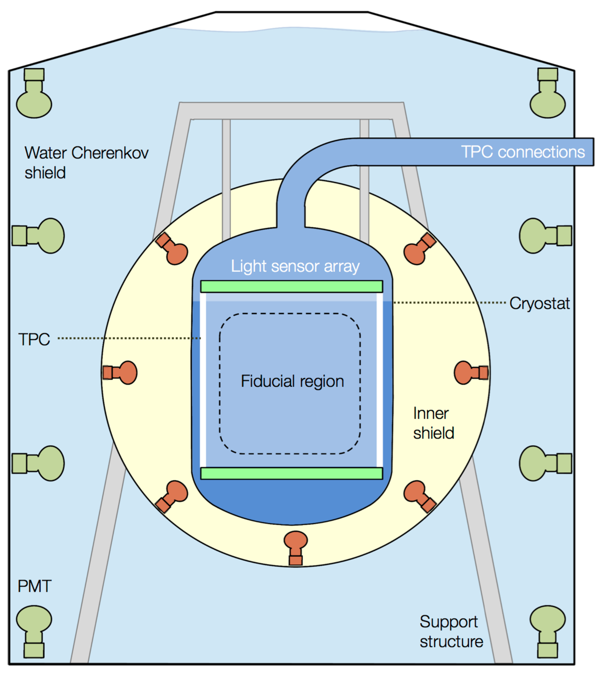
DARWIN will use a dual-phase liquid xenon (LXe) time projection chamber (TPC).

- Working principle**:** The prompt scintillation light (S1) and the delayed proportional scintillation light signal from the charge (S2) are measured**.**



Size and background evolution of dark matter detectors based on dual-phase LXe TPCs.

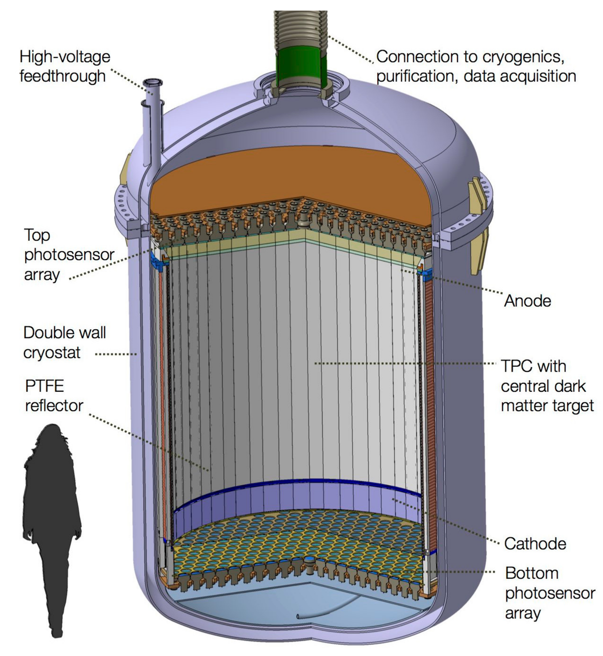
THE DARWIN PROJECT



Sketch of the DARWIN detector.

The main goal is the direct detection of WIMPs, probing masses in a wide range, and WIMP-nucleon cross sections until neutrino interactions become an irreducible background.

- Cylindrical dual-phase TPC: 2.6 m diameter and 2.6 m height.
- 50 t total (40 t active) of LXe.
- In the baseline scenario two arrays of PMTs (top and bottom).
- Other possible photosensors are under study.
- Low-background cryostat surrounded by concentric structures.
- Outer and inner shields filled with water and liquid scintillator respectively.
- Electron recoil background discrimination level of 99.98%.



Possible realization of DARWIN TPC inside the cryostat.

POTENTIAL NEUTRINO CHANNELS

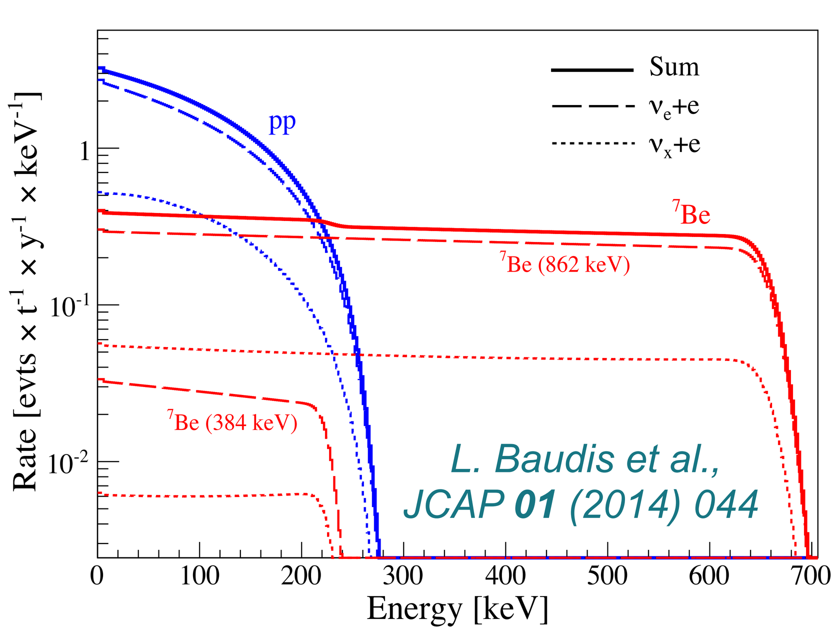
Solar neutrinos

Solar neutrinos are an important physics channel since a precise measurement of *pp*-neutrinos would test the main energy production mechanisms in the Sun.

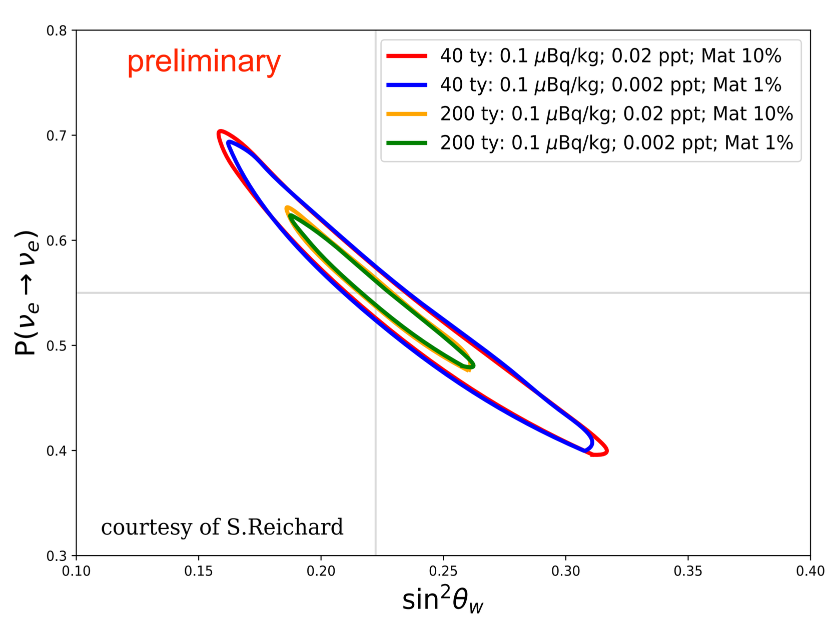
- *pp-* and ^{7}Be-neutrinos account for ~98% of the total neutrino flux predicted by the Standard Solar Model.
- Detection of low-energy solar neutrinos through elastic scattering:

$$\nu_x + e \longrightarrow \nu_x + e$$

- Assuming 30 t of fiducial volume, DARWIN will observe more than 2500 *pp*-neutrinos per year ⟶ Flux measurement with 2% statistical precision.
- The high statistics will lead also to test different neutrino properties, such as the electron neutrino survival probability (P_{ee}).
- The neutrino mixing angle will be measured below 300 keV.



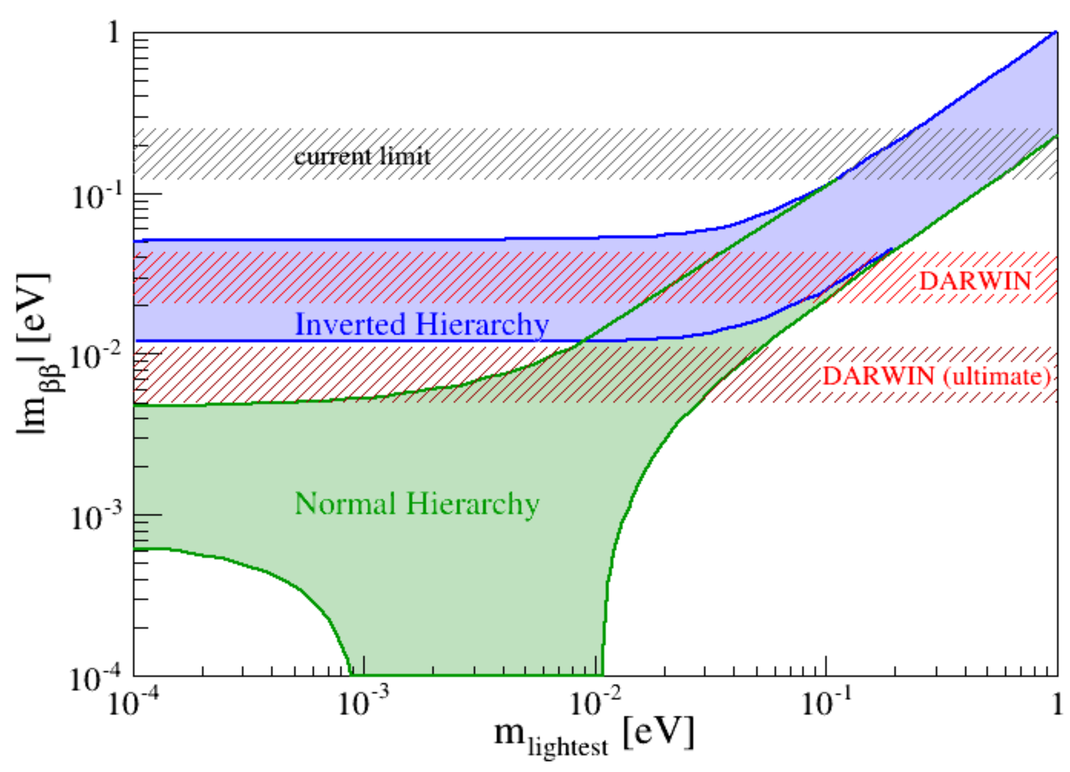
Rate of electron recoils in LXe.



Survival probability P_{ee} vs. mixing angle.

Neutrinoless double-beta decay

The nature of neutrinos is still unknown and the question about whether they are Majorana fermions is studied via the search of the neutrinoless double-beta decay $(0\nu\beta\beta)$.



Expected sensitivity for the effective Majorana neutrino mass.

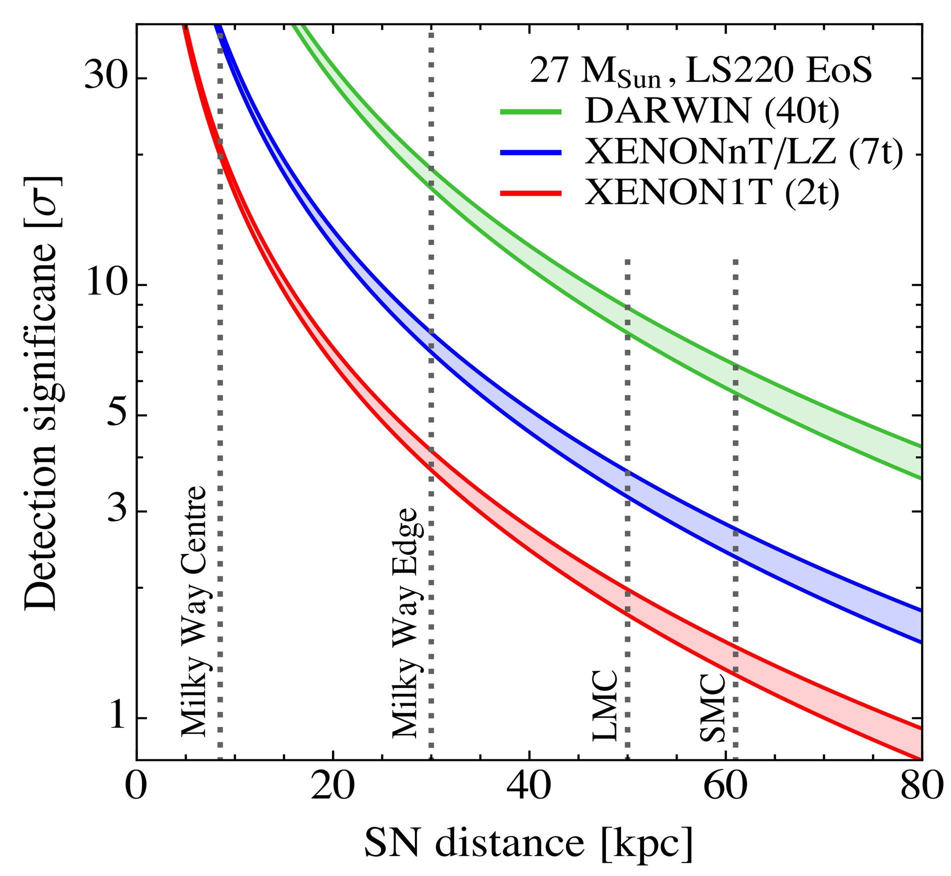
*DARWIN Collaboration, JCAP **1611** (2016) 017*

- ^{136}Xe is a good candidate: abundance of 8.9% in natural xenon and *Q*-value at 2.458 MeV (above the region of interest for WIMP searches).
- DARWIN will have more than 3.5 t of ^{136}Xe without isotopic enrichment and an ultra-low background environment: only ^{222}Rn, $2\nu\beta\beta$-decays and interactions of solar ^{8}B neutrinos.
- With an energy resolution of ~2%, DARWIN's sensitivity will become comparable to future dedicated experiments.
- $T_{1/2} > 10^{27}$ y for an exposure of 30 t × y (90%CL).

Coherent neutrino-nucleus scattering (CNNS)

DARWIN will be able to detect this process, which produces a nuclear recoil.

- The largest rate comes from the high-energy solar ^{8}B neutrinos. With a threshold of 1 keV, ~90 events/(t × y) are expected.
- Atmospheric neutrinos will produce ~3×10^{-3} events/(t × y).
- *Geo*-neutrinos will not produce nuclear recoils with enough energy to be observed above a threshold of 1 keV.
- All flavors of supernova (SN) neutrinos will be observed as well, providing additional information to dedicated experiments. DARWIN will detect SN bursts up to 65 kpc from Earth (5σ), observing ~700 events from a 27 $M_\odot$ SN progenitor at 10 kpc.



Detection significance as a function of the SN distance. The SN signal has been integrated over a window of 7 s.

*R. F. Lang et al., Phys. Rev. D **94** (2016) 103009*

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