Cosmogenic background simulations for neutrinoless double beta decay with the DARWIN observatory at various underground sites

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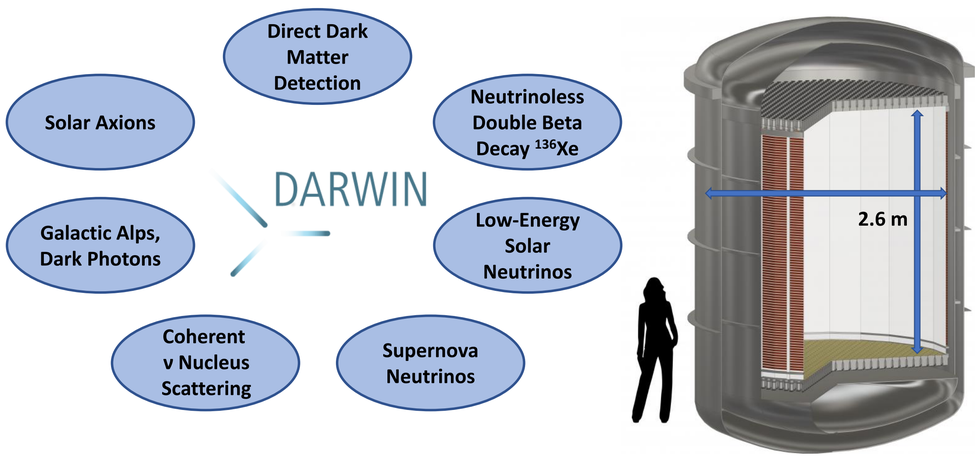
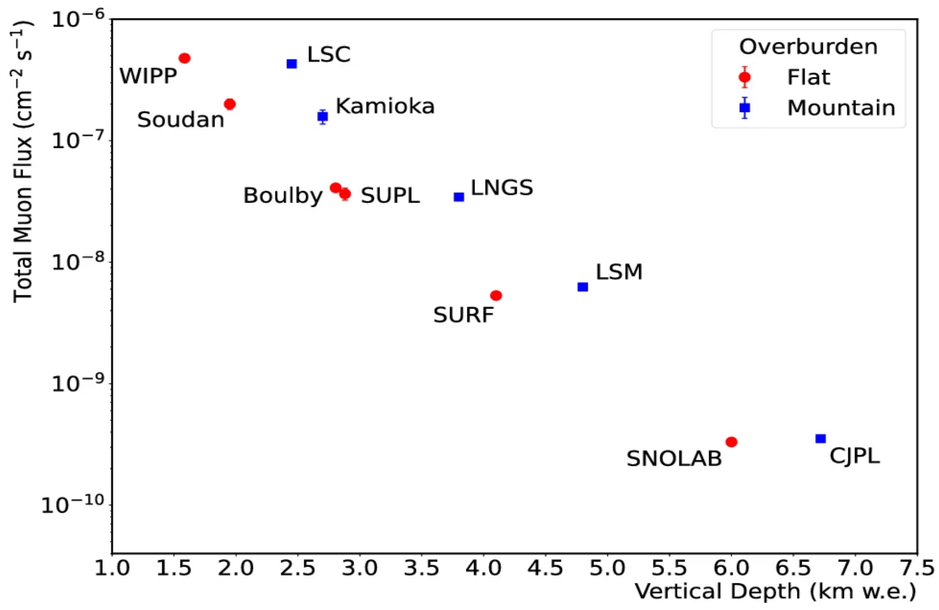
DARWIN – the next generation dark matter and neutrino observatory



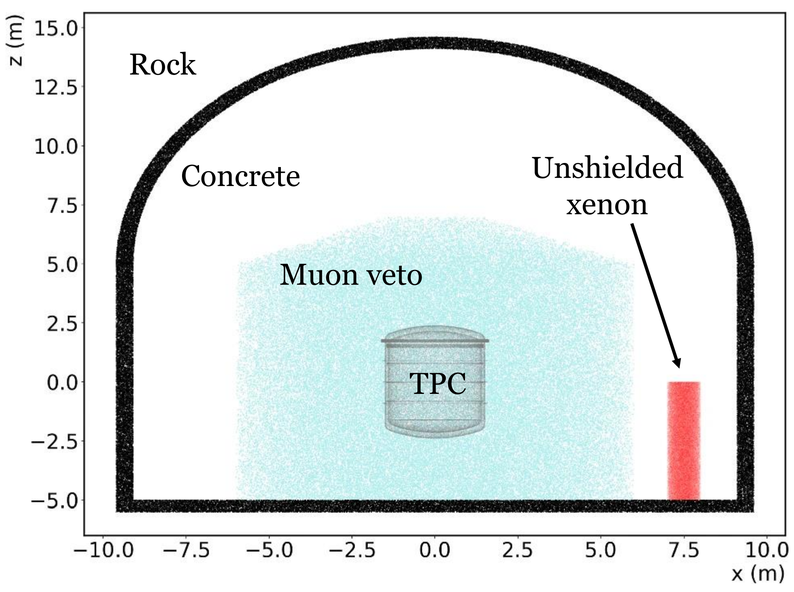
Dual-phase time projection chamber with 50 tonnes of liquid xenon (40 t active) to, among others, probe the WIMP phase space down to the neutrino fog.

Underground laboratories



Cosmic muons are a source of background that cannot be completely eliminated, but greatly diminished by placing the detector deep underground. In this work, we have considered Gran Sasso (LNGS), Laboratoire Souterrain de Modane (LSM), Sanford Underground Research Facility (SURF) and SNOLAB.

Geant4 simulations



To study the cosmogenic background we have performed simulations using the Geant4 toolkit. In our custom DARWIN simulation package it has been included:

- **Geometry.** Experimental hall, cryostat, TPC, vetos and xenon storage and circulation systems were implemented.
- **Muon generator.** The muon flux in the underground labs have been simulated using the MUSIC-MUSUN software (V. Kudryavtsev)
- **Physics lists.** We based our simulations on the *Shielding* list. To estimate systematics, we also simulated with the *ShieldingLEND* and *QGSP_BIC_HP* lists.

Shielding	Elastic model	NeutronHP	CHIPS	
	Inelastic model	NeutronHP	Bertini	FTFP
	Capture model	NeutronHP	nRadCapture	
ShieldingLEND	Elastic model	LEND	CHIPS	
	Inelastic model	LEND	Bertini	FTFP
	Capture model	LEND	nRadCapture	
QGSP_BIC_HP	Elastic model	NeutronHP	CHIPS	
	Inelastic model	NeutronHP	BIC	QGSP
	Capture model	NeutronHP	nRadCapture	

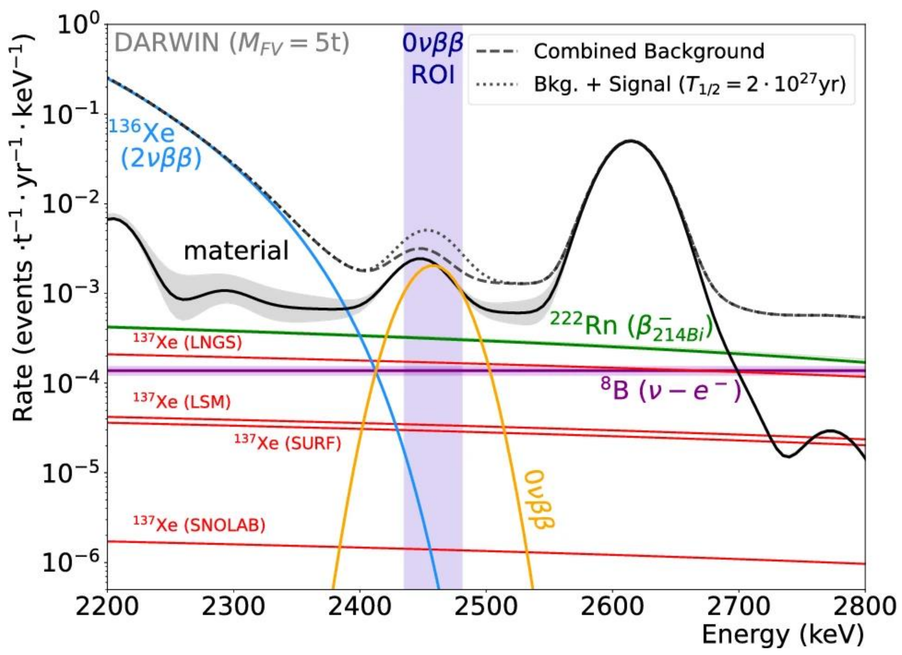
~ keV — 1 MeV — 1 GeV — 1 TeV

Background of the ^{136}Xe neutrinoless double beta decay

In DARWIN, there are several intrinsic background sources:

- Muon induced neutrons: ^{136}Xe (n,γ) ^{137}Xe, $^{137}\mathrm{Xe} \rightarrow {}^{137}\mathrm{Cs} + e^- + \overline{\nu}_e$ (Q_β = 4.1 MeV)
- ^{8}B solar neutrinos
- Two-neutrino double beta decay of ^{136}Xe
- ^{122}Rn in liquid xenon

Unstable isotopes present in the materials (decay chains of ^{238}U and ^{232}Th, ^{214}Bi, ^{208}Tl, ^{44}Sc or ^{44}Ti) introduce external background events.



The cosmogenic ^{137}Xe background for Gran Grasso is at the same level as the ^{8}B background and below it for the other locations

Other xenon isotopes, muon-induced spallation products and isotopes produced in the xenon storage system could also have a non-negligible impact on the background (ongoing study)

DARWIN/XLZD – the future of liquid xenon observatories

XENON, LUX-ZEPLIN and DARWIN joined forces to build a multi-ten-ton liquid xenon TPC (60 tonnes of active mass)

- Large scale demonstrators have been built: Xenoscope (Zurich) and Pancake (Freiburg)
- New sensitivity studies for the neutrinoless double beta decay ongoing

Visit us: https://xlzd.org https://darwin.physik.uzh.ch

References:
[1] DARWIN collaboration, M. Adrover et al., Cosmogenic background simulations for neutrinoless double beta decay with the DARWIN observatory at various underground sites , *EPJC* **84** (2024) P088.
[2] DARWIN collaboration, J. Aalbers et al., *DARWIN: towards the ultimate dark matter detector*, *JCAP* **11** (2016) 017.