DARWIN

Universität Zürich[UZH]

PHYSIK INSTITUT
UNIVERSITÄT ZÜRICH

European Research Council
Established by the European Commission

DARWIN – a next-generation observatory for dark matter and neutrino physics

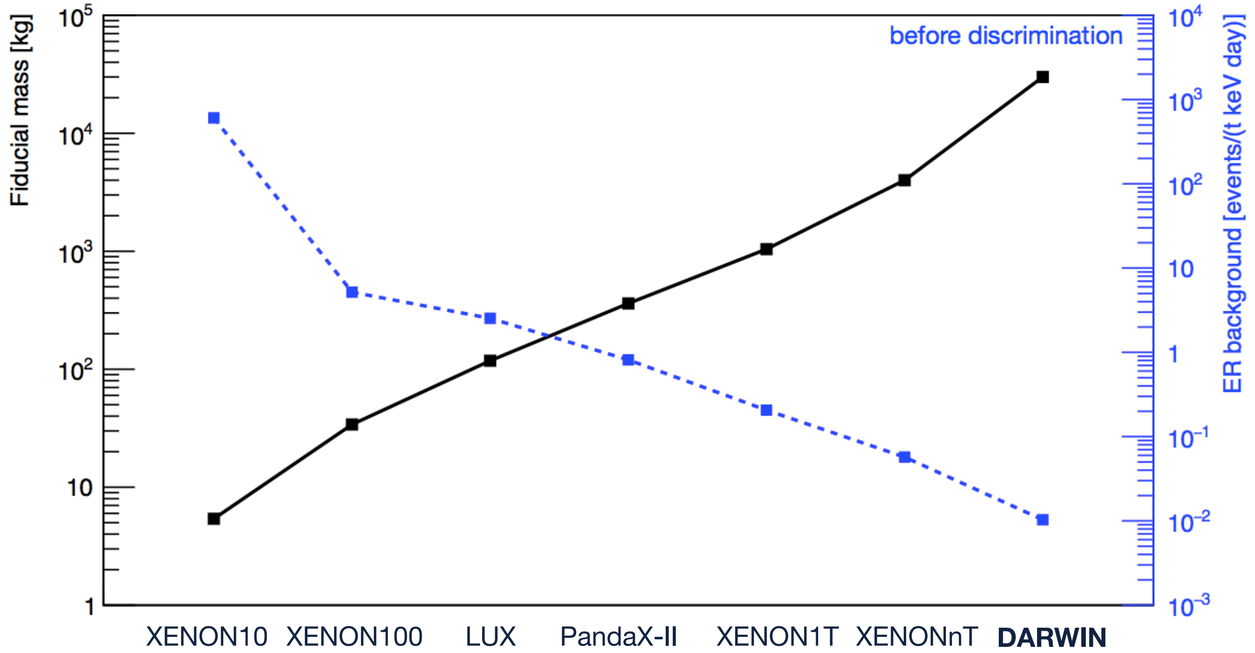
Kevin Thieme
University of Zurich

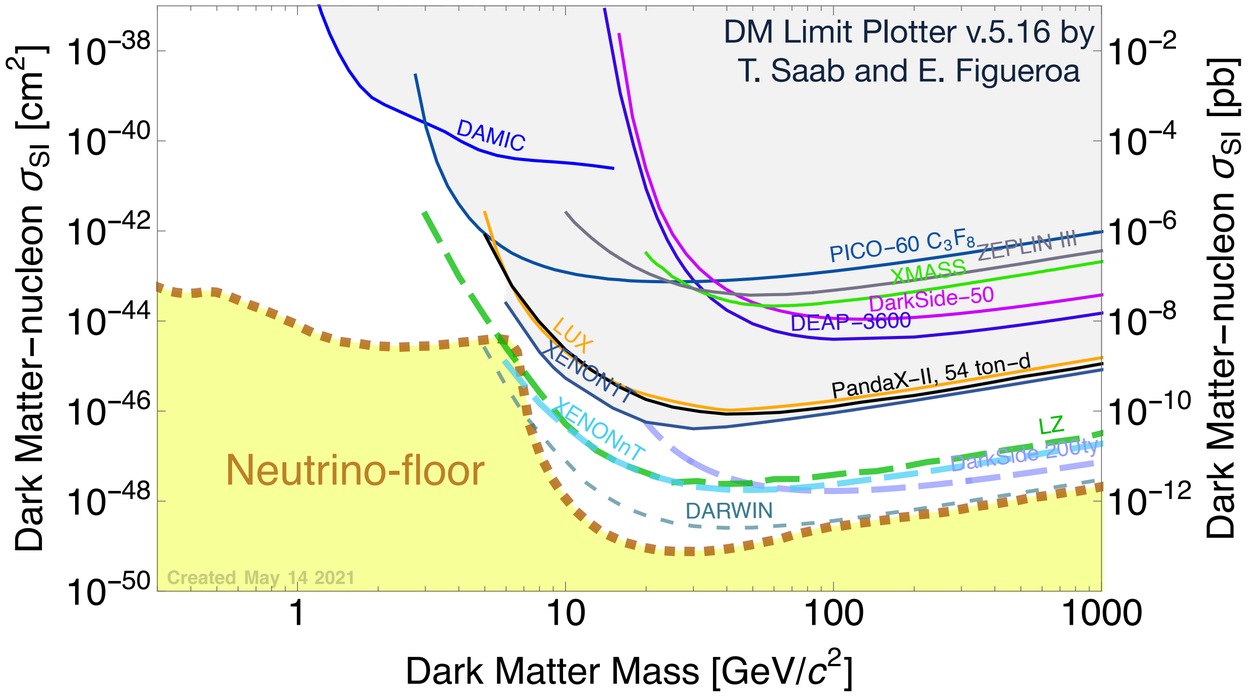
on behalf of the DARWIN collaboration

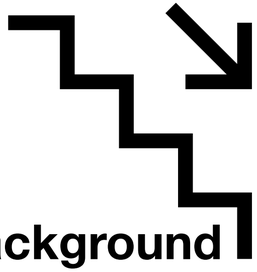
DARWIN Collaboration

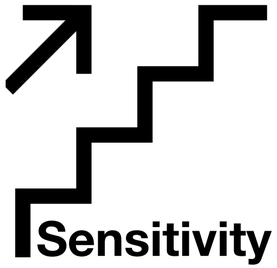
- Over 160 scientists
- 33 institutions
- 13 countries
- Large overlap with XENON Collaboration

Evolution from XENON10 to DARWIN



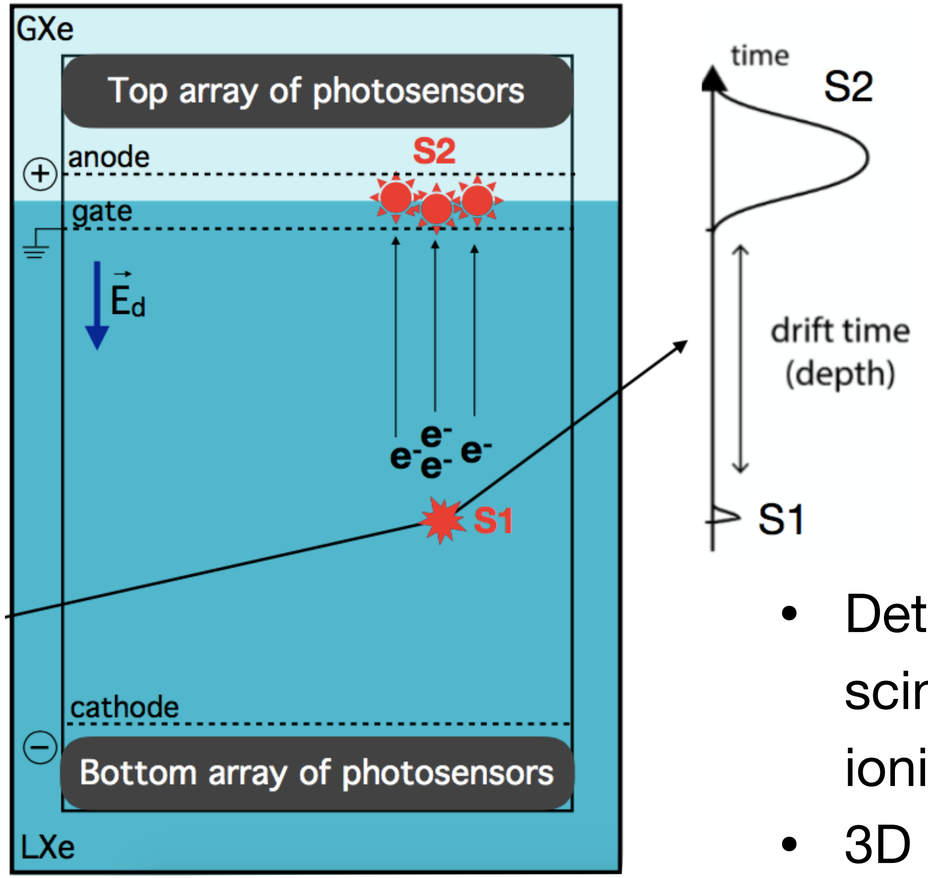


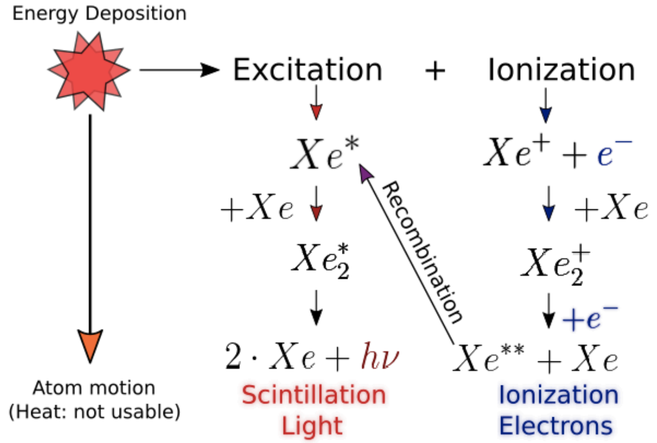


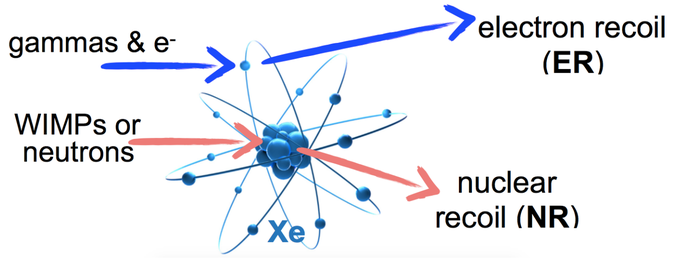


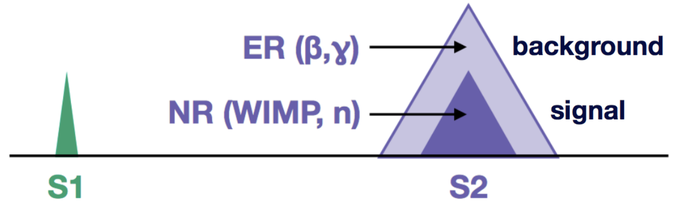
- Hunt for WIMPs from ~GeV to ~TeV led by liquid noble gas experiments
- DARWIN aims to push near-future sensitivities by an order of magnitude down to the irreducible CEνNS background

Dual-Phase Xenon Time Projection Chamber





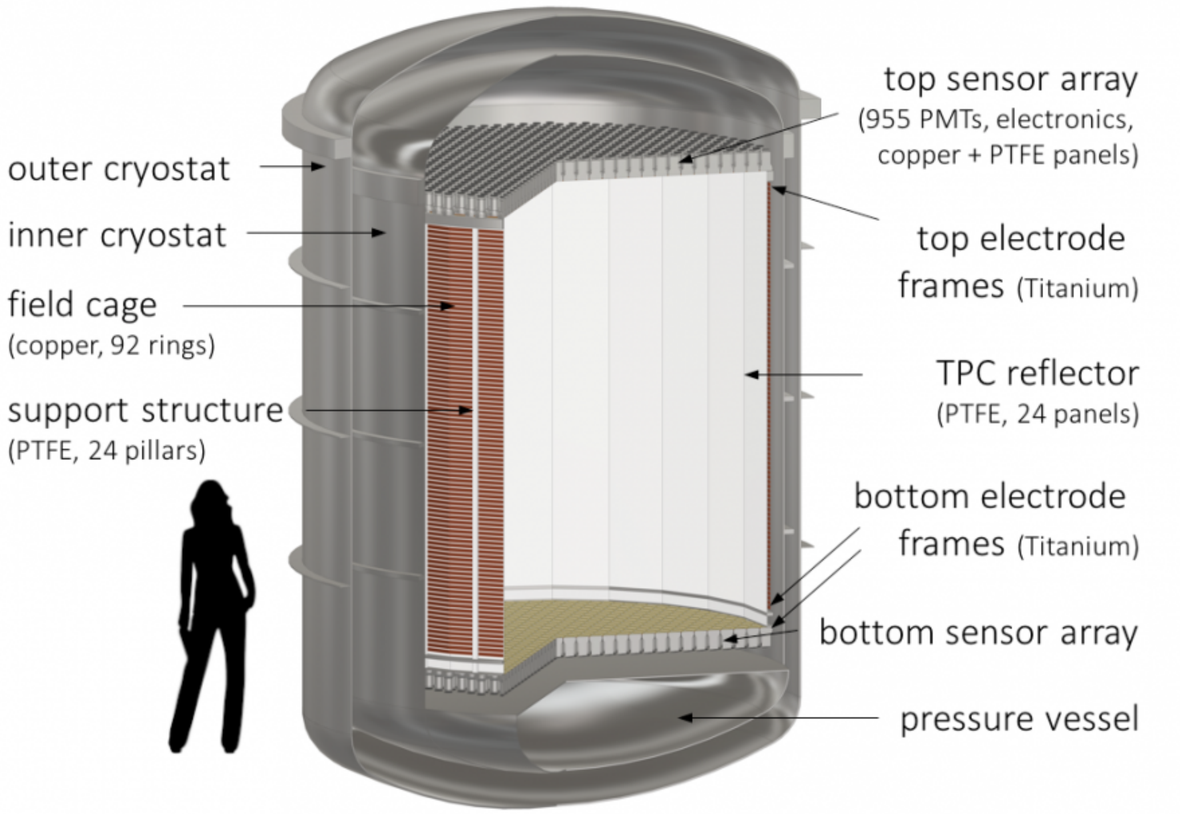




- Detection of prompt scintillation (S1) and delayed ionisation signal (S2)
- 3D position reconstruction

- ER/NR discrimination based on S1/S2 ratio

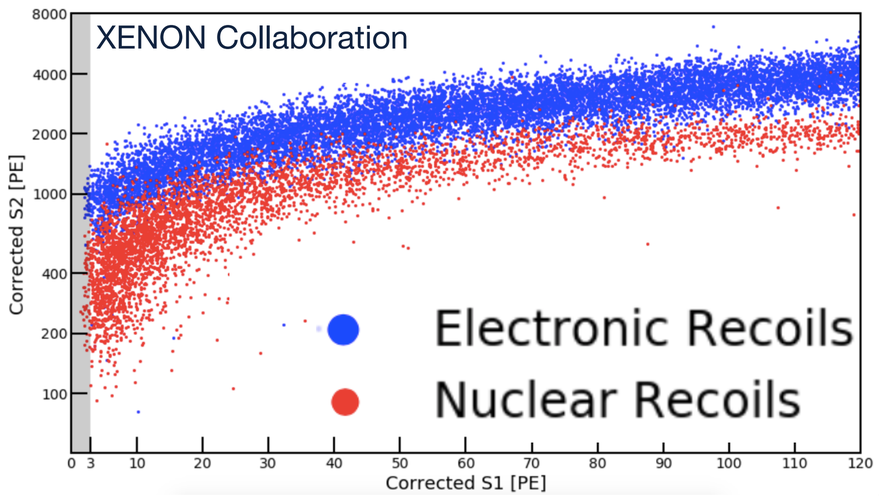
Baseline Design



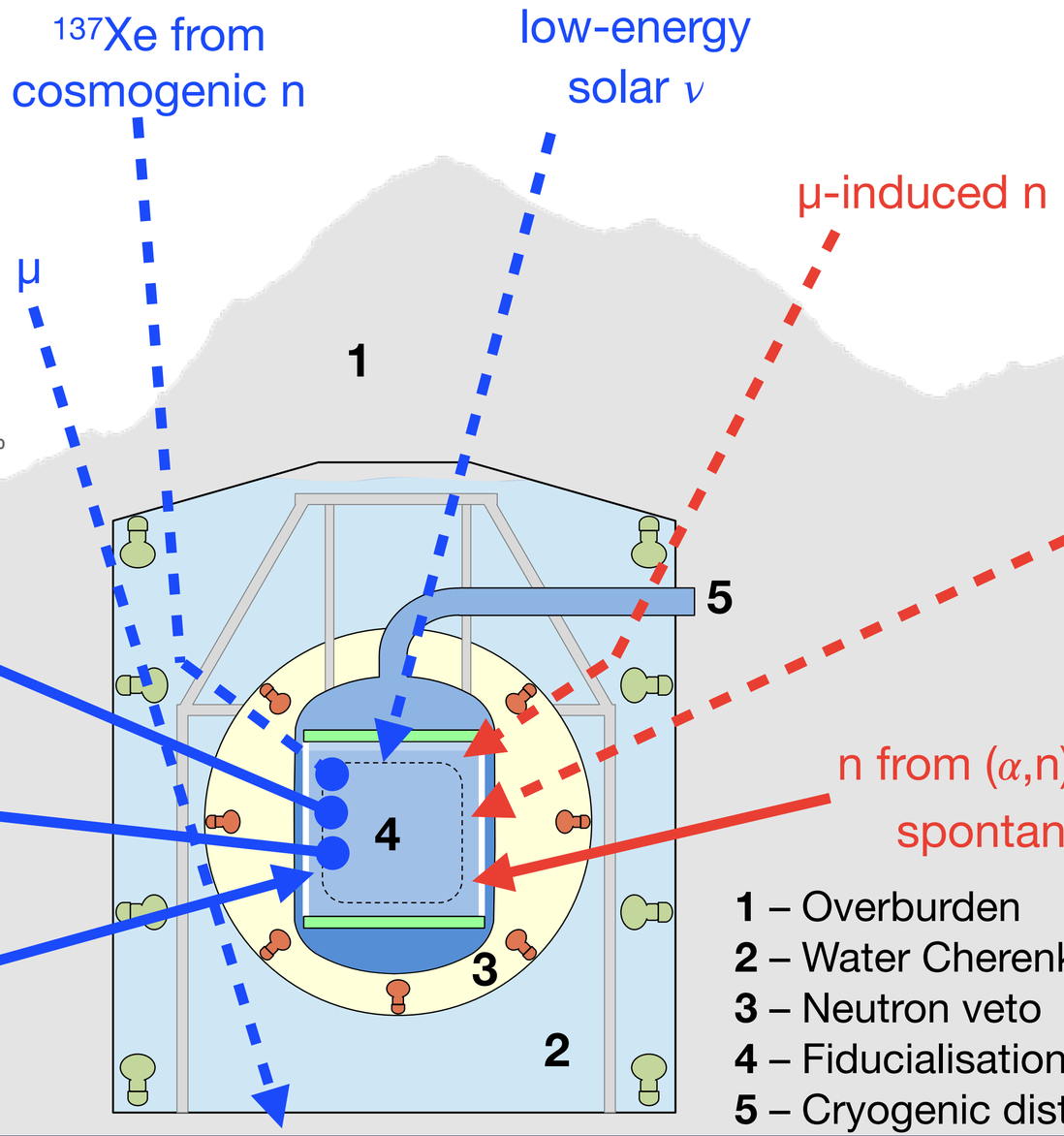
JCAP11 (2016) 017

- 2.6 m x 2.6 m dual phase TPC in a double-walled cryostat
- 50 t (40 t active) liquid xenon (LXe) target
- Top and bottom array of 3-inch PMTs
- Surrounded by highly reflective PTFE walls
- Drift field $\mathcal{O}(0.1)$ kV/cm
- Inner neutron veto
- Min.12 m $\times$ 12 m water Cherenkov shield and muon veto

Expected Events in DARWIN



…background to one, signal for another channel…

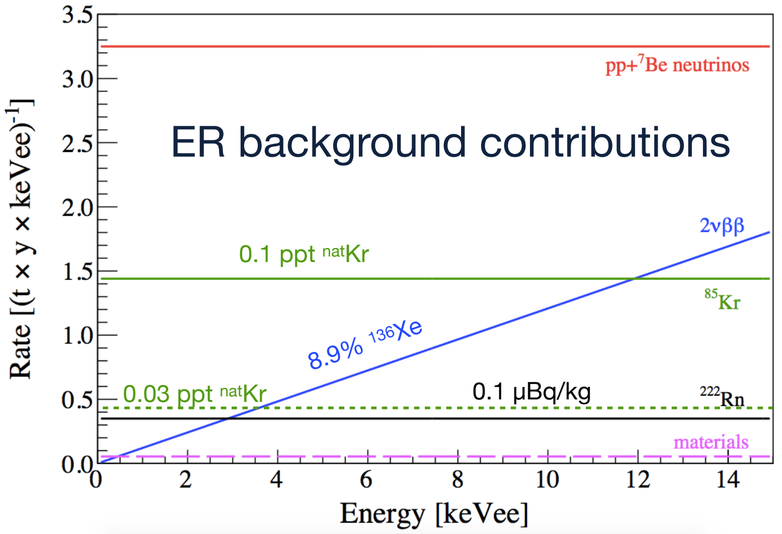


- - - cosmogenic
——— radiogenic
←——— external
●——— internal

1 – Overburden
2 – Water Cherenkov shield and muon veto
3 – Neutron veto
4 – Fiducialisation, LXe self-shielding, depletion?
5 – Cryogenic distillation and delayed re-feed

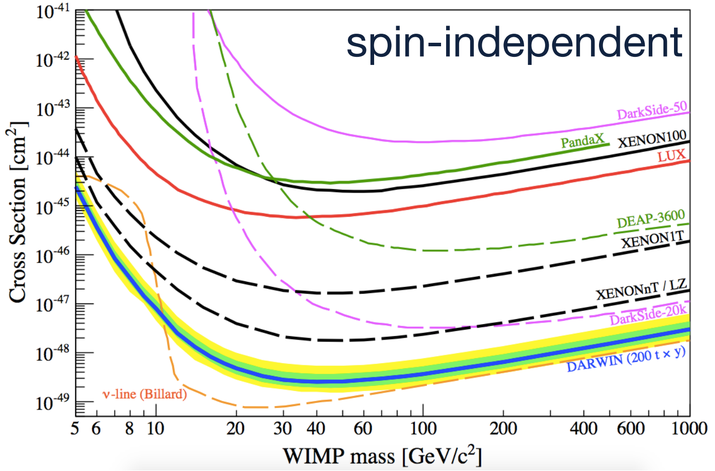
WIMP Dark Matter

- 30 t fiducial volume and 200 t x y exposure
- 99.98% ER rejection -> achieved by ZEPLIN-III ✓
  Phys. Rev. D 80 (2009) 052010
  at 30 % NR acceptance
- 0.1 ppt ^{nat}Kr -> XENON achieved 0.03 ppt in distillation test ✓
  Eur. Phys. J. C 77 (2017) 275
- 0.1 µBq/kg ^{222}Rn -> push by another order of magnitude
- 8 PE/keV light yield

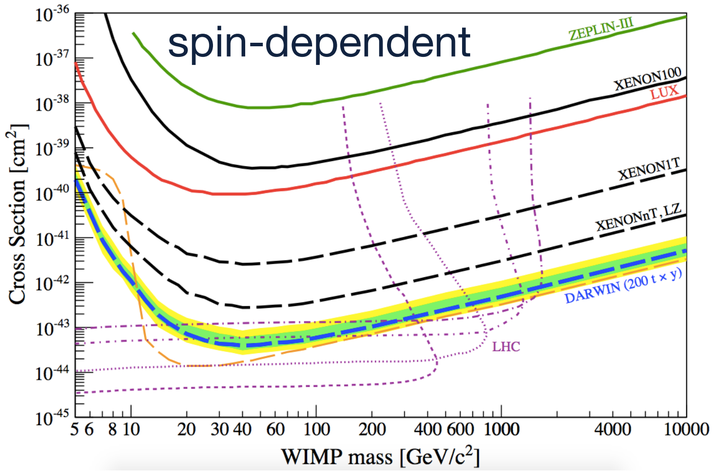


JCAP10 (2015) 016

JCAP11 (2016) 017



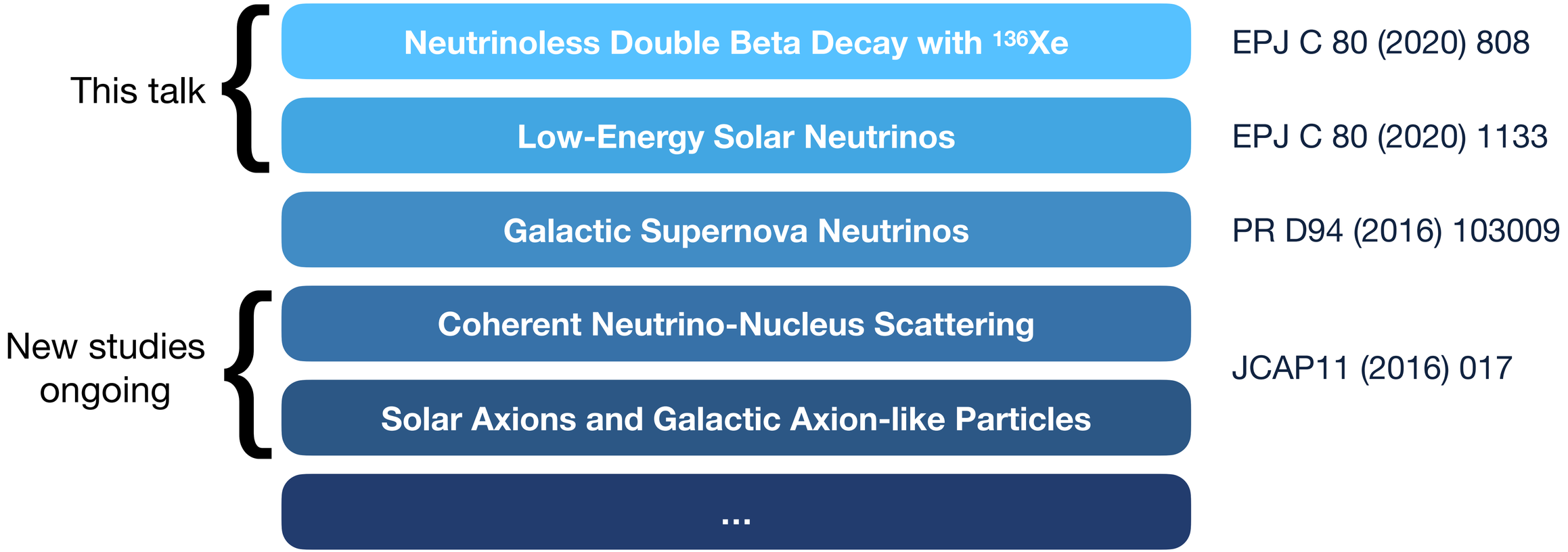
2.5 × 10^{-49} cm^2 at 40 GeV/c^2



complementary to 14 TeV LHC

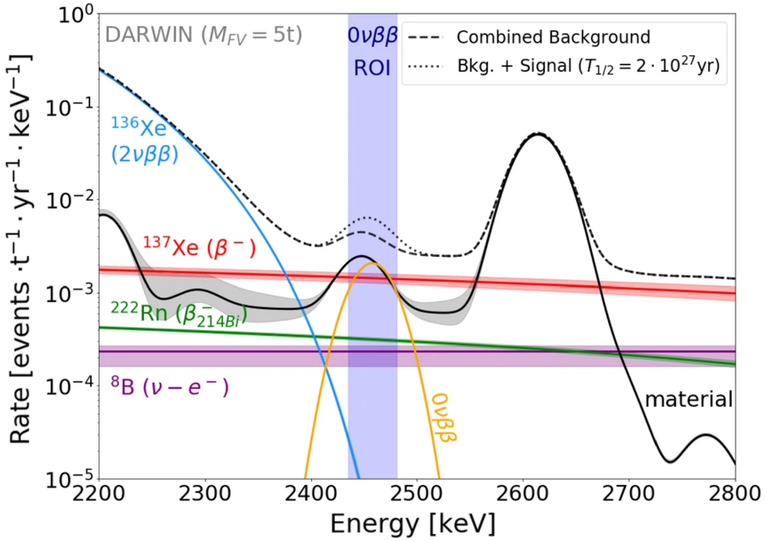
A Multipurpose Observatory

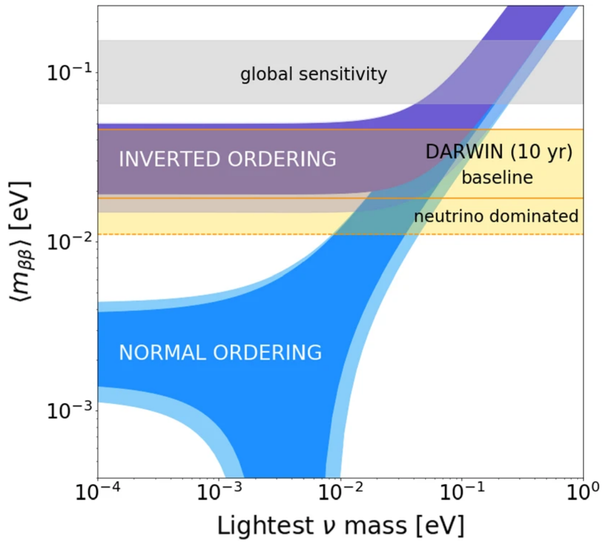
The large mass, low energy threshold and ultra-low background makes a variety of other channels accessible…

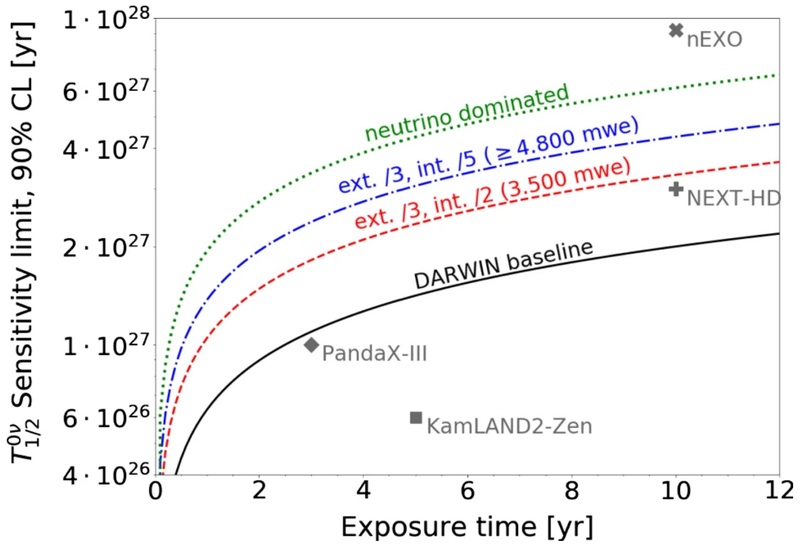


Neutrinoless Double Beta Decay

- Natural abundance of ^{136}Xe is 8.9% -> ~3.5 t active mass without enrichment
- Q-value is 2458 keV -> well above WIMP region
- Background from materials, ^{137}Xe, ^{222}Rn, solar ^{8}B ν, 2νββ of ^{136}Xe
- Optimised 5 t fiducial mass
- Sensitivity of baseline scenario after 10 y: $T_{1/2} = 2.4 \times 10^{27}$ y (90 % CL) -> 3σ discovery potential: 1.1×10^{27} y
- Will cover inverted hierarchy Majorana mass region
- Competitive to future dedicated experiments







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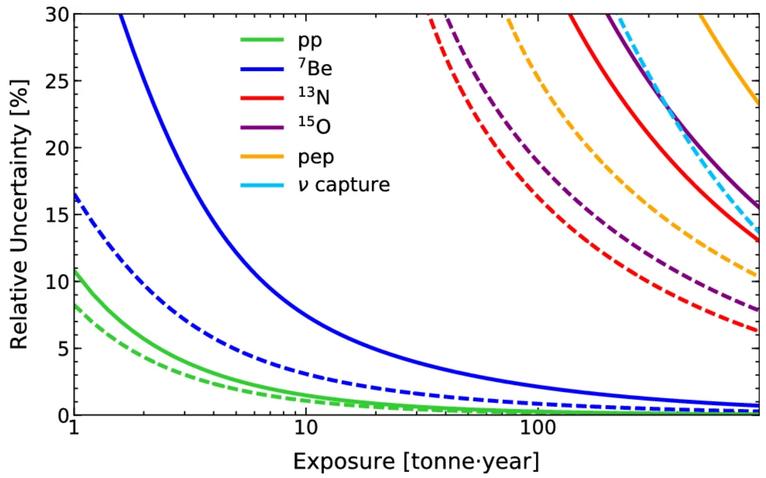
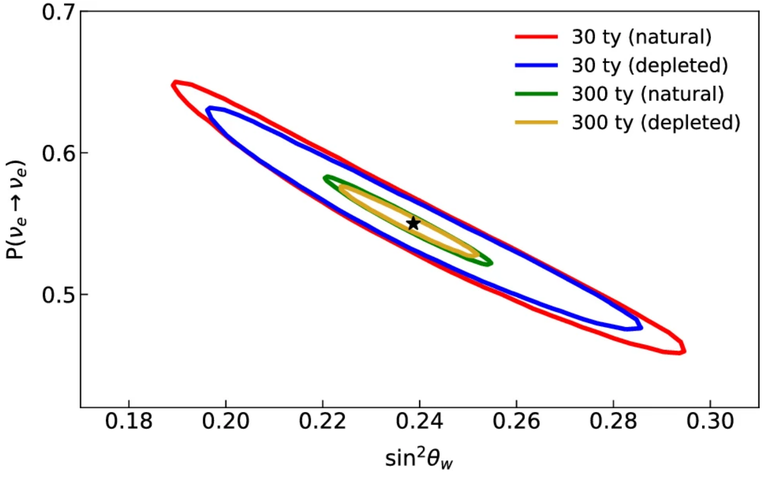
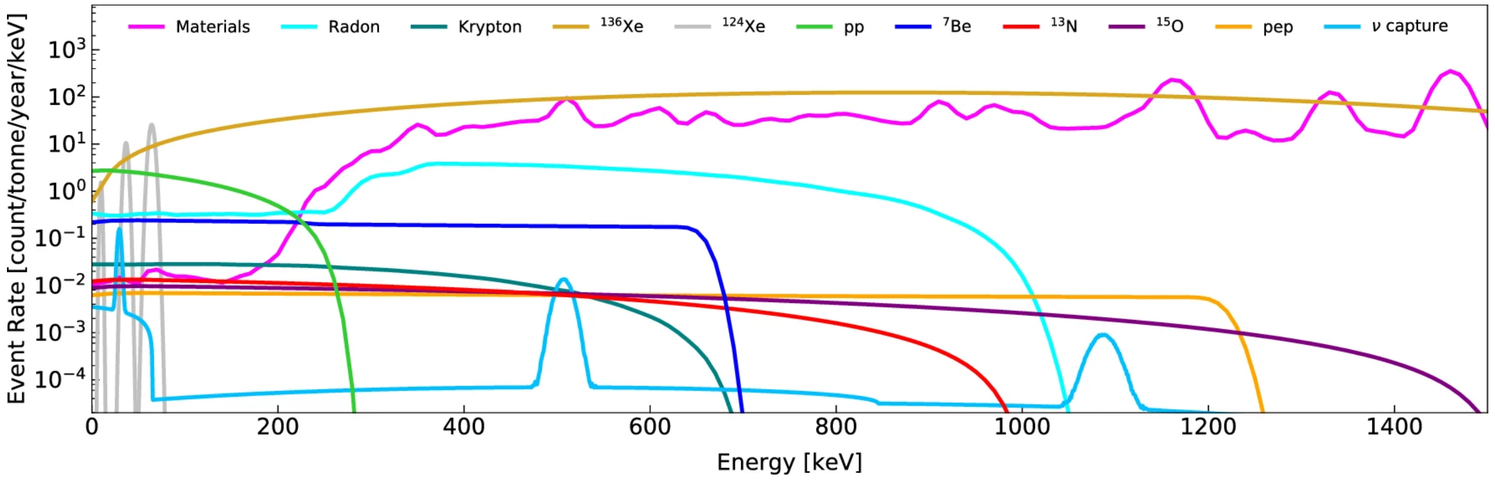
Low-Energy Solar Neutrinos

- pp and ^{7}Be neutrinos account for > 98% of solar neutrino flux (SSM)
- Detection via elastic electron scattering
- Background from $2\nu\beta\beta$ of ^{136}Xe, materials, ^{222}Rn, ^{85}Kr, DEC of ^{124}Xe
- 30 t fiducial volume
- High-precision pp (^{7}Be) flux measurement -> 0.15 % (1%) after 300 t x y
- Measurement of ν_e survival probability (4.0 % precision) and neutrino mixing angle (5.1 % precision) below 300 keV
- ^{13}N, ^{15}O within reach, but pep and ν-capture on ^{131}Xe requires depletion



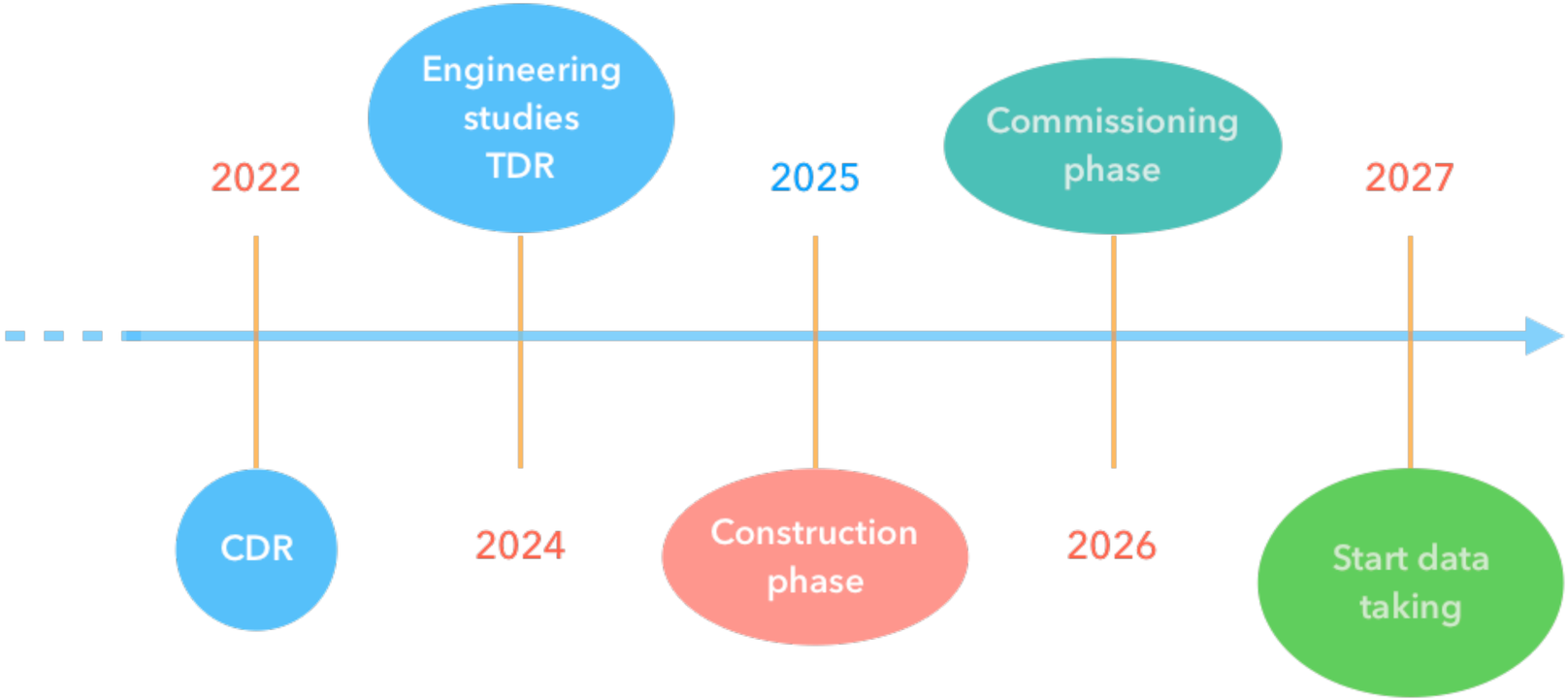




Eur. Phys. J. C 80 (2020) 1133

Status and Schedule

- Working towards CDR and TDR
- DARWIN is in the APPEC roadmap
- Letter of Intent submitted to LNGS in 2019 with positive feedback
- Supported by two ERC grants for R&D (Xenoscope @ Zurich CH, ULTIMATE @ Freiburg GER)



DARWIN-LZ Collaboration

- Future merger of DARWIN and LUX-ZEPLIN Collaborations

  -> new, stronger international collaboration

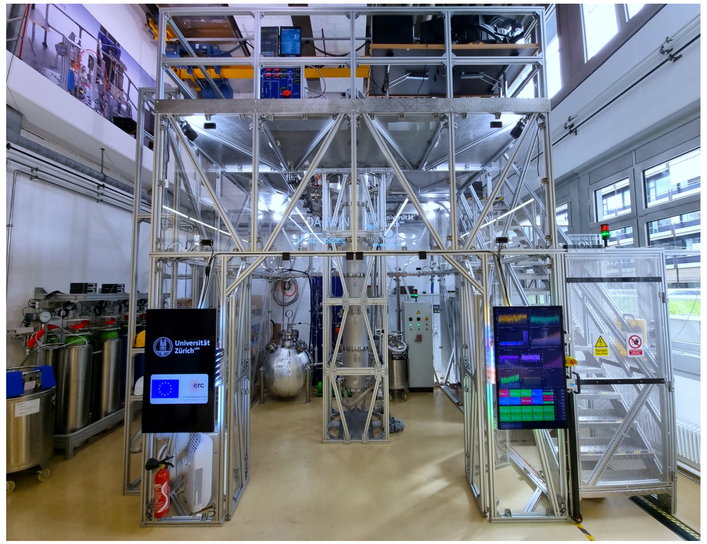
- Comes after XENONnT and LZ are done
- First joint and successful DARWIN LZ Meeting (26–27 April): https://indico.cern.ch/event/1028794/
- Memorandum of Understanding in progress

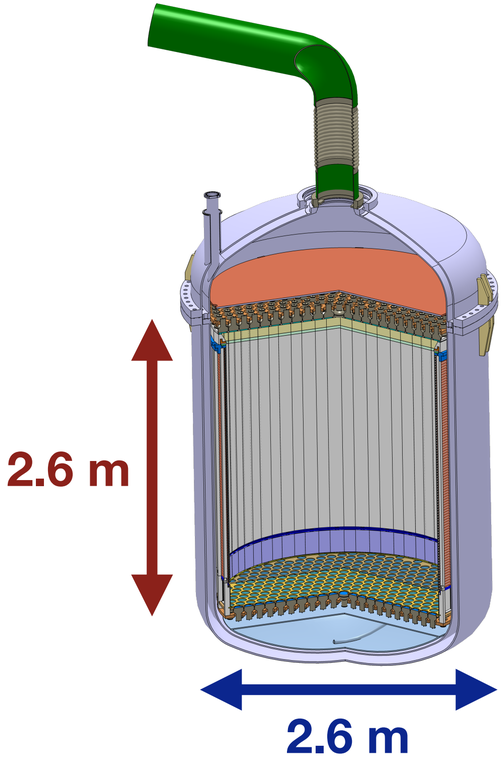
Ongoing R&D: Full-scale Demonstrators

➡ Test instrumentation and detector technology at DARWIN scale

arXiv:2105.13829

Full-Height





- Demonstrate 2.6 m electron drift and study purity requirements
- Test optical properties of xenon
- R&D on HV feedthrough

Full-Diameter

- Mechanical and electrical test of electrodes
- Test detector materials under cryogenic conditions
- Address sagging, shrinkage, uniform S2-amplification

Ongoing R&D (Selection)

Photosensors

- Alternative to 3-inch PMT 11410 from Hamamatsu
- Goal: Reduce background contribution, maximise light collection and position resolution, good SPE resolution
- Address dark count rate, readout, number of channels
- SiPM [1–4], Digital SiPM, ABALONE [5], VSiPMT [6], Liquid Hole Multipliers [7], 2-inch square PMTs, …

Material, Radon Background Mitigation and Screening

- Material coating to reduce radon emanation
- Low-background screening facilities [8–9] and radon emanation chamber

Detector Design

- Optimise established TPC design and consider alternatives
- Hermetic TPC for radon lock-out [10]
- Single Phase LXe TPC with S2-production on thin wires

[1–4] JINST 13 (2018) P10022, Nucl. Instrum. Meth. A 893 (2018) 117, Eur. Phys. J. C 80 (2020) 477, JINST 16 (2021) P03014

[5] arXiv:1703.04546

[6] Astropart. Phys. 67 (2015) 18

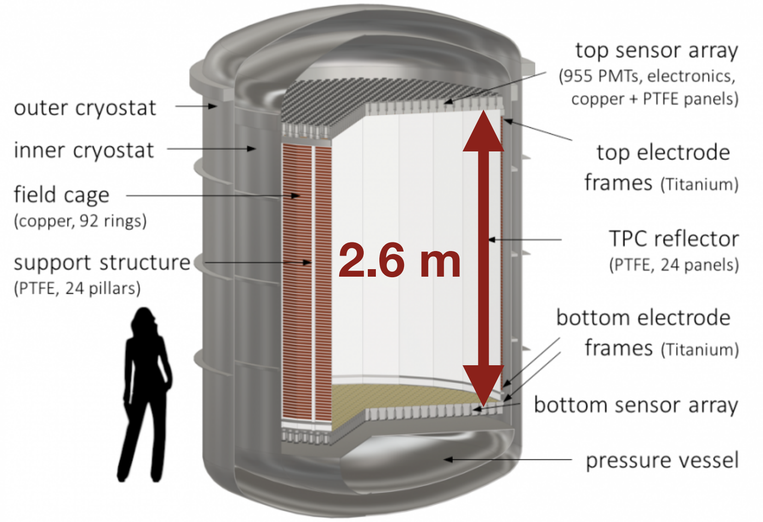
[7] JINST 15 (2020) C04002

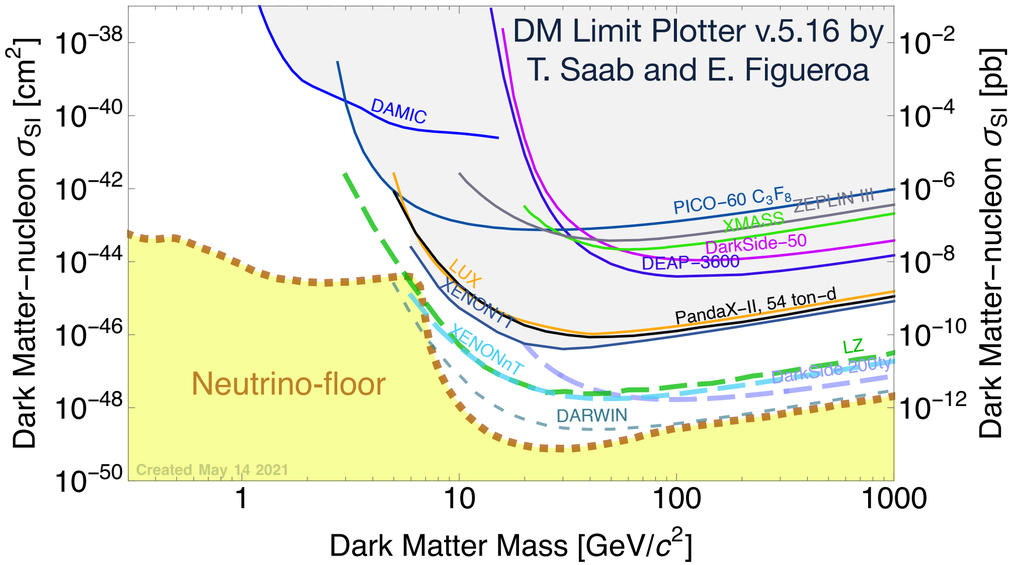
[8–9] JINST 6 (2011) P08010, JINST 11 (2016) P12017

[10] PTEP 2020 (2020) 11, 113H02

DARWIN Observatory – Summary

- **DARWIN** will be the **ultimate dark matter detector**, probing a wide mass range and WIMP-nucleon cross sections down to the irreducible background of coherent neutrino-nucleus interactions
- **Dual-phase TPC** with **50 t xenon** (40 t active) deep underground with neutron veto, water Cherenkov muon veto and shield
- The large mass, low-energy threshold and ultra-low background will open **a large variety of accessible physics channels:** WIMPs, 0νββ, low-energy solar neutrinos, galactic supernova neutrinos, CEvNS, solar axions and galactic ALPs
- Competitive **0νββ** half life sensitivity and high-precision measurements of the **low-energy solar neutrino fluxes**
- DARWIN is growing, currently 33 institutions from 13 countries
- Future merger with **LUX-ZEPLIN collaboration**
- R&D: 2 full-scale demonstrators, photosensors, detector design, background mitigation -> supported by two **ERC Grants**: Xenoscope (Zurich CH), ULTIMATE (Freiburg GER)





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