Universität Zürich[UZH]

European Research Council
Established by the European Commission

DARWIN: a next-generation time projection chamber

Patricia Sanchez-Lucas, Universität Zürich

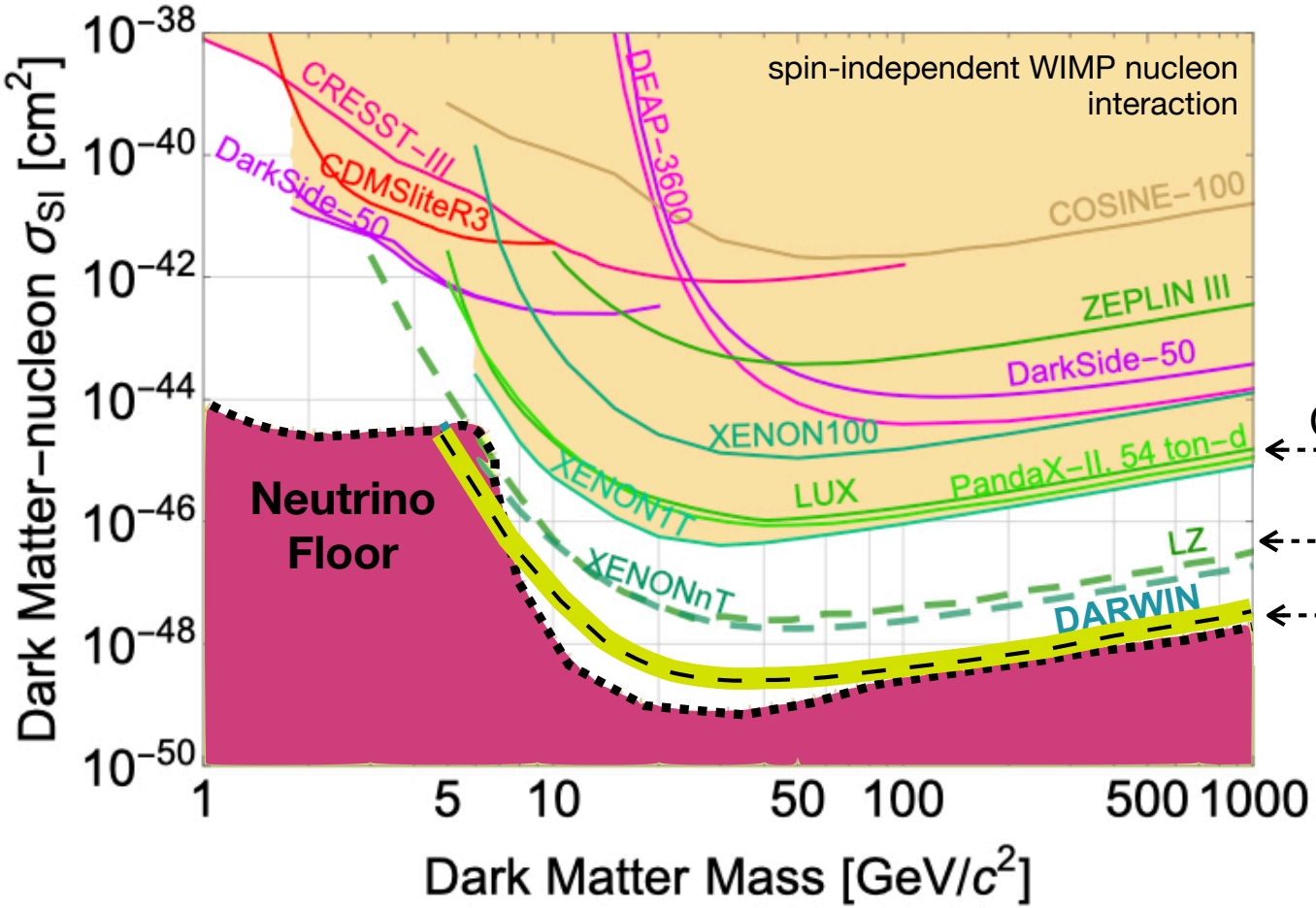
on behalf of the DARWIN Collaboration

KASHIWA DARK MATTER SYMPOSIUM 2021

30 November 2021

WIMP DETECTION LANDSCAPE TODAY

- The best sensitivity above 5 GeV/c^2 comes from experiments using liquid noble gases as a target (Xe, Ar). (heavy target and easy scalability)
- **DARWIN**, the ultimate liquid Xe WIMP detector, with **50t of total mass**, plans to increase 100-fold the current sensitivity.



Current Limits

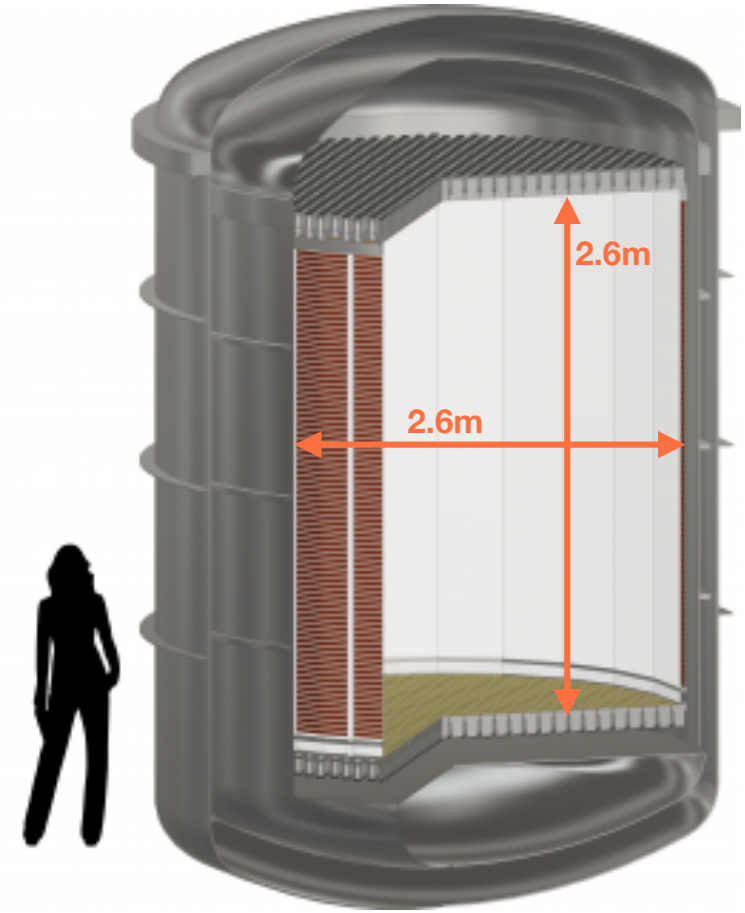
Near Future Sensitivity

DARWIN

sensitivity limited by the neutrino floor

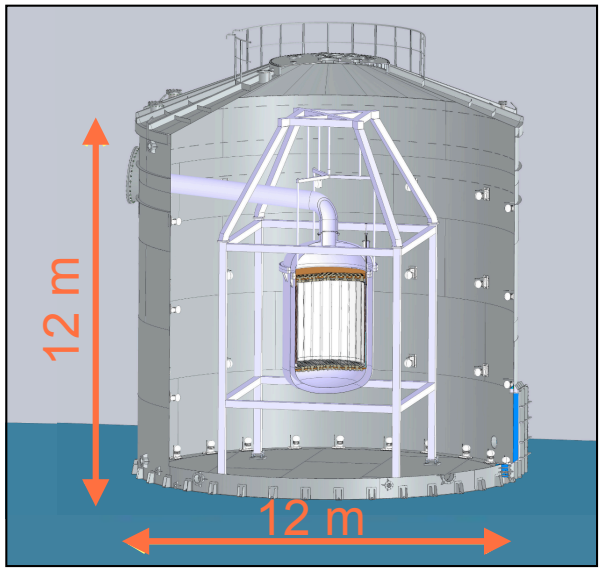
DARWIN BASELINE DESIGN

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



baseline design with PMTs but several alternatives under consideration

- Dual-phase Time Projection Chamber (TPC)
- 50t total (**40 t active**) of liquid xenon (LXe)
- Dimensions: **2.6 m diameter x 2.6 m height**
- Two arrays of photosensors (1800 PMTs of 3”)
- Low-background double-wall Ti cryostat
- PTFE reflector panels & copper shaping rings
- Outer shield with Gd doped water (veto μ & n)

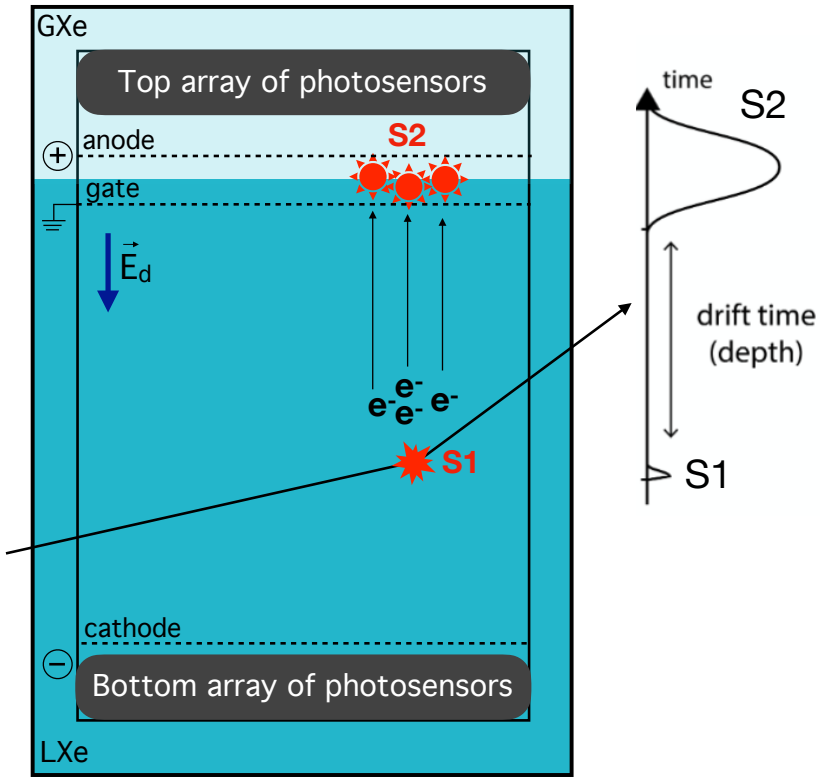


Possible realisation of the water tank

DUAL-PHASE XENON TPC

Dual phase TPC working principle

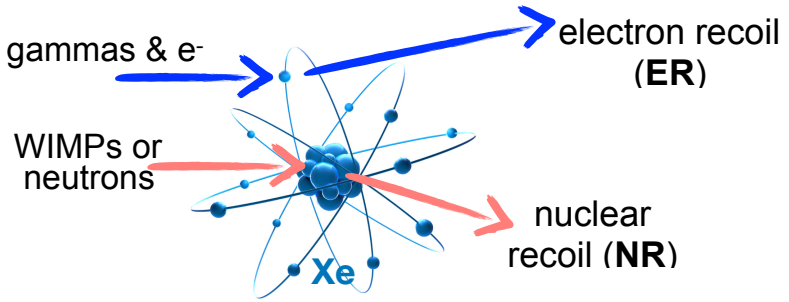
Detection of the scintillation **light** (**S1**) and the delayed scintillation light proportional to the **charge** (**S2**)



The dual-phase TPC allows for a 3D position and Energy reconstruction.

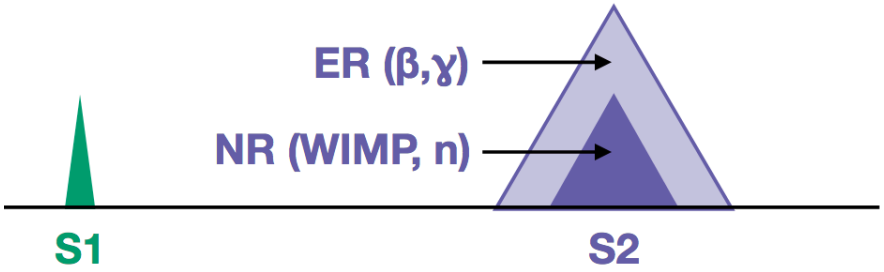
- (x-y) from S2 pattern, z from drift time
- Energy from S1 and S2

Particle interactions



Background discrimination

The ratio S2/S1 depends on the interacting particle.



DARWIN SCIENCE PROGRAMME

Ultra-low Background — **Large Mass** — **Low Energy Threshold**

DIRECT DETECTION OF DARK MATTER

SOLAR AXIONS

GALACTIC AXION-LIKE PARTICLES

BOSONIC SUPERWIMPs

COHERENT SOLAR NEUTRINO-NUCLEUS SCATTERS

NEUTRINOLESS DOUBLE-BETA DECAY ^{136}Xe

DARWIN Collaboration, EPJ C80, 808 (2020)

DARWIN

much more than a dark matter detector

LOW-ENERGY SOLAR NEUTRINOS

DARWIN Collaboration, EPJ C80, 1133 (2020)

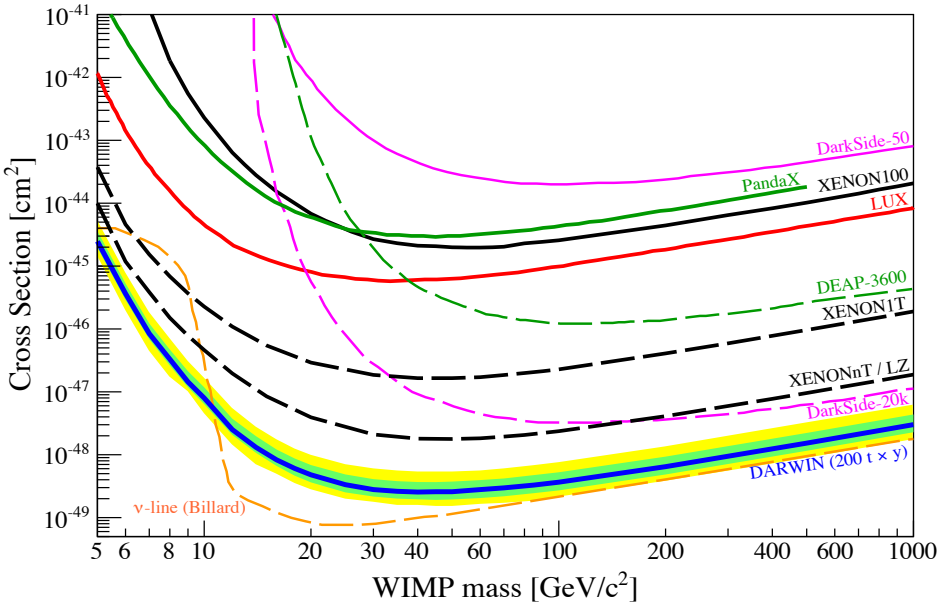
GALACTIC SUPERNOVA NEUTRINOS

SENSITIVITY TO WIMPS

Schumann et al.,
JCAP **1510** (2015) 016

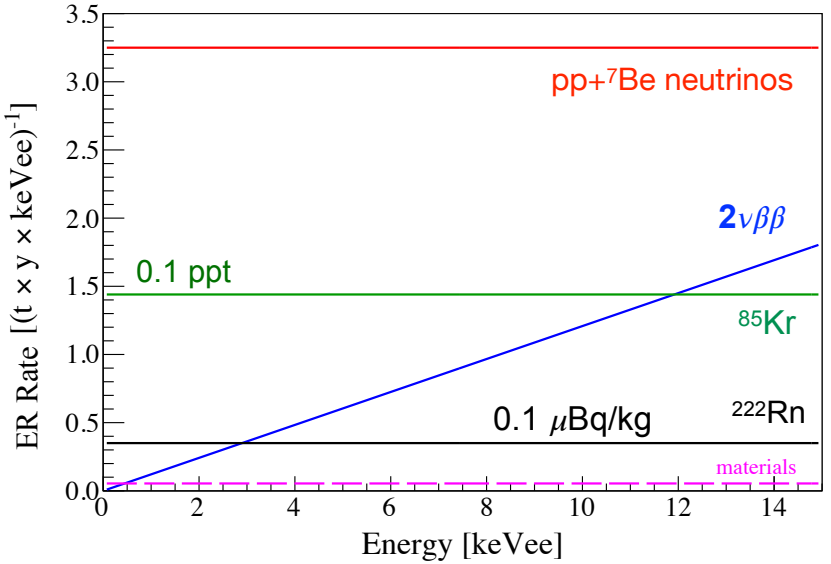
- Assumed exposure 200 t x y (30t FV)
- 99.98% ER rejection (30% NR acceptance)
- Combined (S1+S2) energy scale
- Energy window 5-35 keV_{NR}
- Light yield 8PE/keV

spin-independent interaction



minimum: 2.5x10^{-49} cm^2 at 40 GeV/c^2

Background Assumptions



before ER discrimination

Source	Rate [events/(t·y·keVxx)]
γ-rays materials	0.054
neutrons*	3.8×10^{-5}
intrinsic ^{85}Kr	1.44
intrinsic ^{222}Rn	0.35
2νββ of ^{136}Xe	0.73
pp- and ^{7}Be ν	3.25
CNNS*	0.0022

NR

ER = 5.824 events/(t · y · keV_{ee})

LOW ENERGY SOLAR NEUTRINOS

DARWIN Collaboration, Eur. Phys. J. C 80, 1133 (2020)

- pp- neutrinos are ~92% of the solar neutrino flux (SSM)
- Detection through neutrino-electron elastic scattering (ER)

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

- Real-time measurement of the neutrino flux:

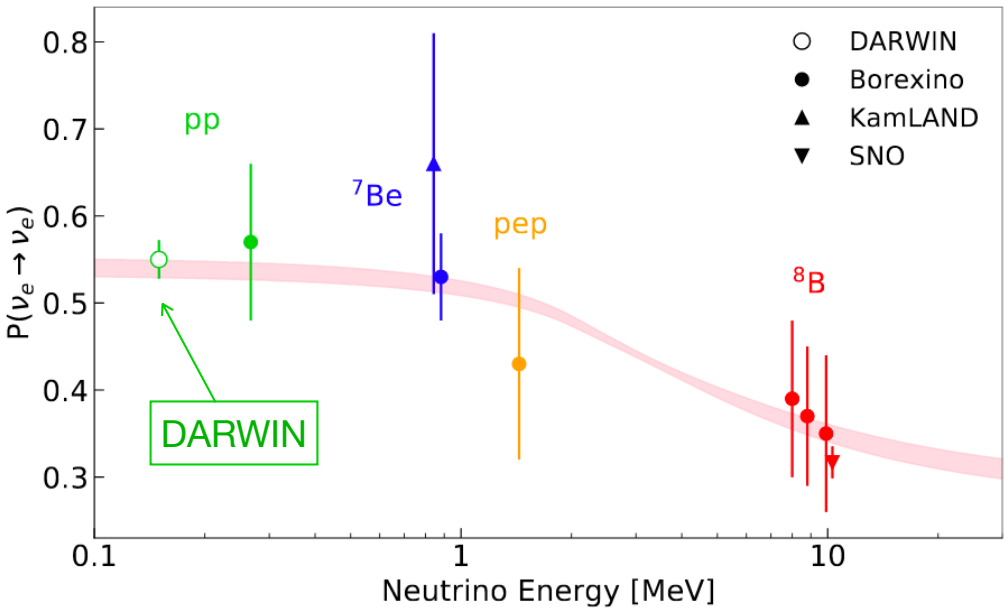
  pp-ν —— 365 events/(t x y)

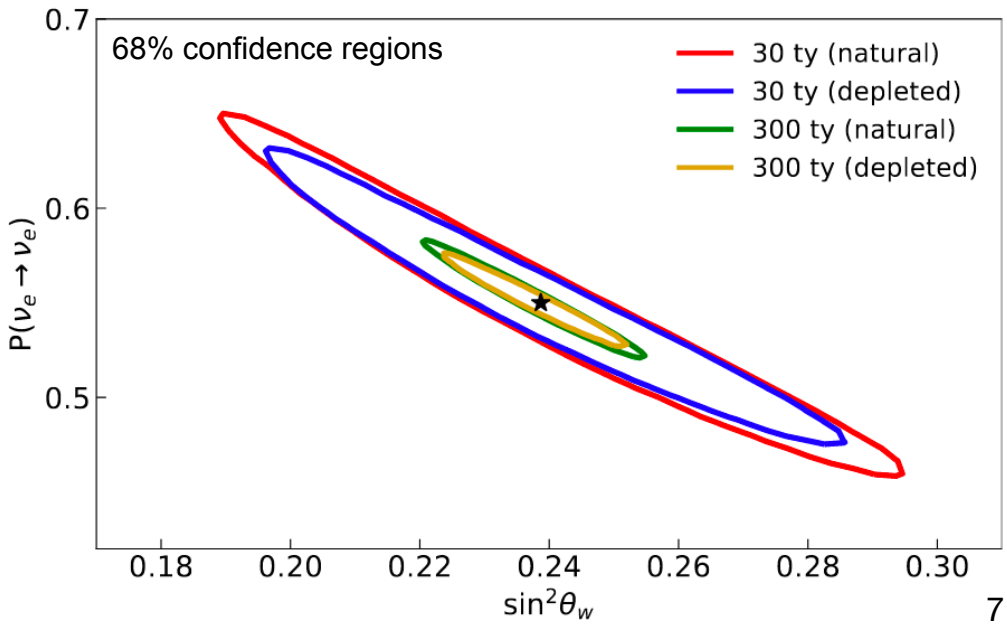
  ^{7}Be-ν —— 140 events/(t x y) (with 30t FV & above 1 keV$_{ee}$)

- Measurement of electron neutrino survival probability (P$_{ee}$) and the neutrino mixing angle below 300 keV.

neutrino fluxes high-Z SSM

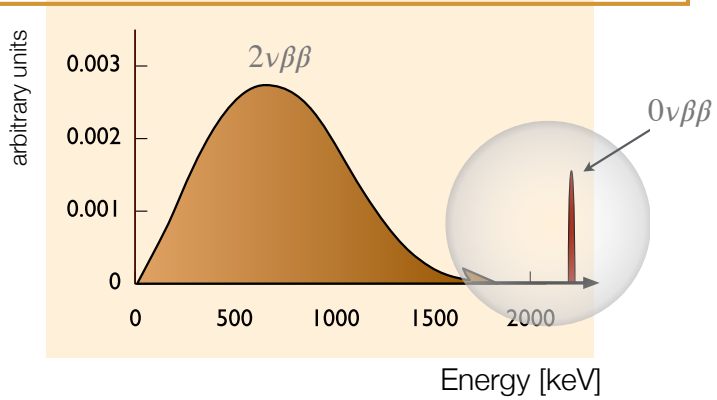
component	Φ[cm^{-2}s^{-1}]	P_{ee}
pp	$5.98 \cdot 10^{10}$	0.55
^{7}Be	$4.93 \cdot 10^{9}$	0.52
^{13}N	$2.78 \cdot 10^{8}$	0.52
^{15}O	$2.05 \cdot 10^{8}$	0.50
pep	$1.44 \cdot 10^{8}$	0.50





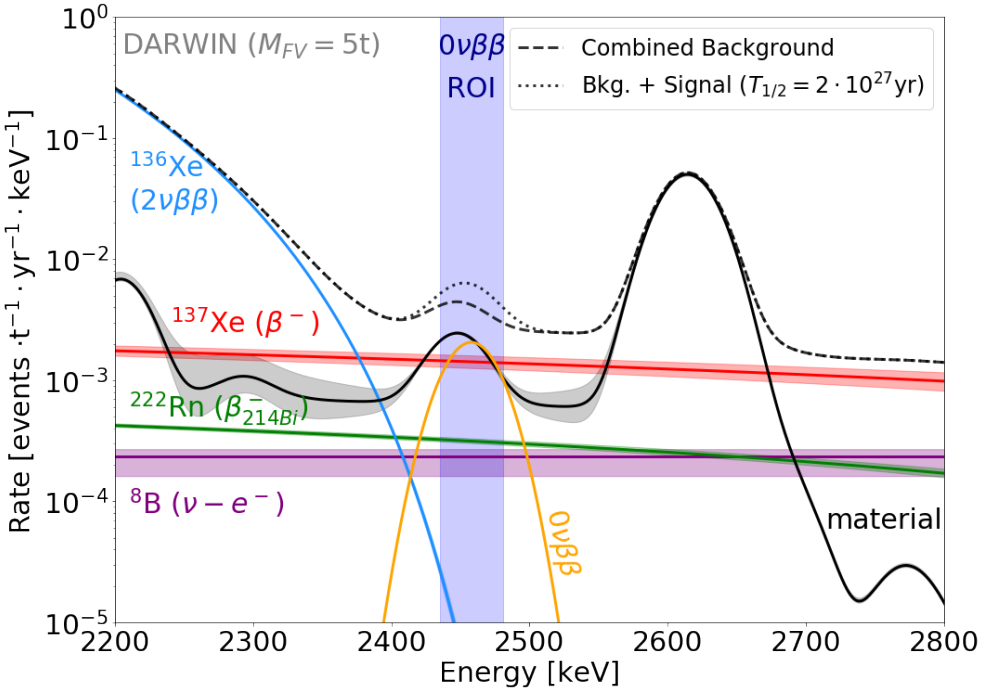
NEUTRINO LESS DOUBLE BETA DECAY

$$T^{0\nu}_{1/2} \propto a \cdot \epsilon \cdot \sqrt{\frac{M \cdot t}{B \cdot \Delta E}}$$



DARWIN Collaboration, Eur. Phys. J. C 80, 808 (2020)

Background Model & Signal



1. **Large mass of a candidate isotope**

   3.5 t of active ^{136}Xe (8.9% in natural Xe)

   - Q-value = 2.458 MeV

2. **Excellent energy resolution**

   resolution of ~0.8% at 2.5 MeV

   - As demonstrated by XENON1T
     Eur. Phys. J. C 80, 785 (2020)

3. **Ultra-low background**

   dominated by intrinsic backgrounds

0.91 background events per year in ROI

NEUTRINO LESS DOUBLE BETA DECAY

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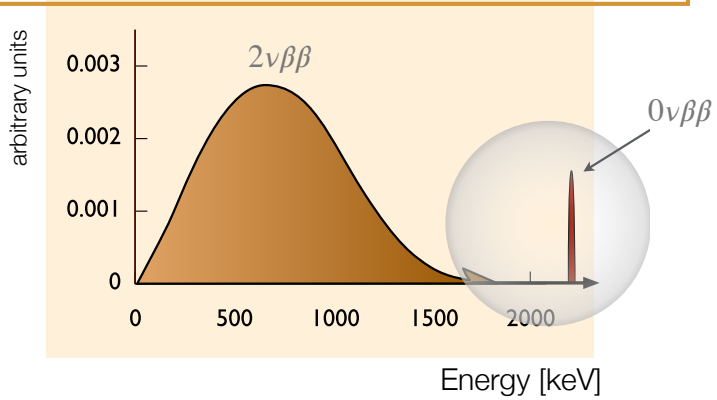
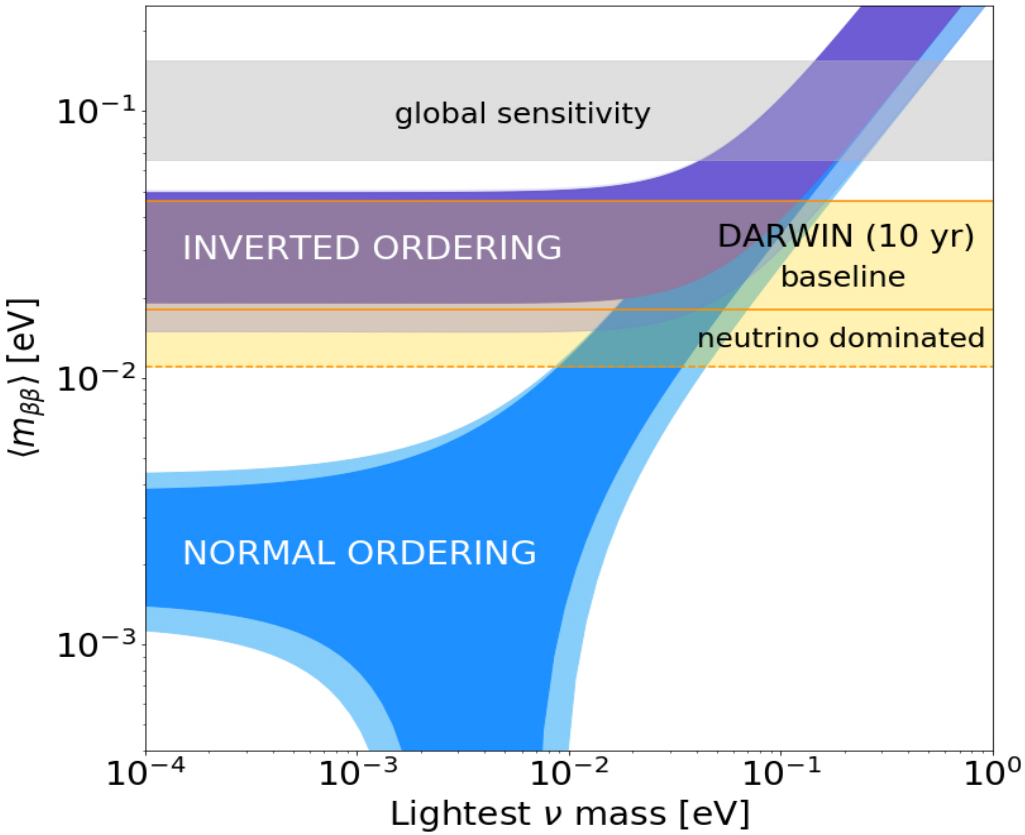


DARWIN Collaboration, Eur. Phys. J. C 80, 808 (2020)

DARWIN Sensitivity



DARWIN could reach a sensitivity of
2.4×10^{27} years (90%C.L)
for 50 t×y (baseline)

1. **Large mass of a candidate isotope**
   3.5 t of active ^{136}Xe (8.9% in natural Xe)
   - Q-value = 2.458 MeV

2. **Excellent energy resolution**
   resolution of ~0.8% at 2.5 MeV
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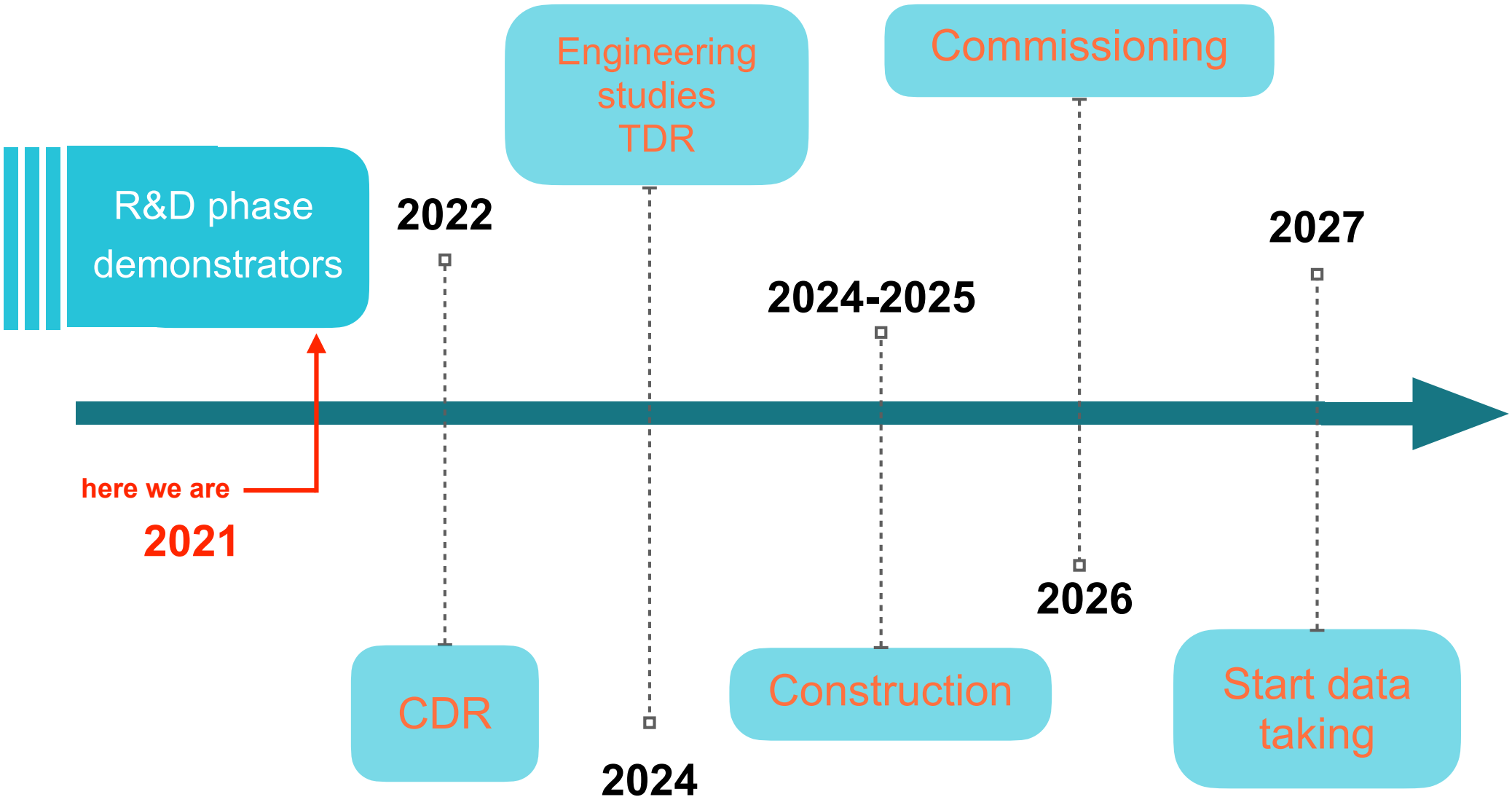
     Eur. Phys. J. C 80, 785 (2020)

3. **Ultra-low background**
   dominated by intrinsic backgrounds

OVERVIEW OF THE DARWIN COLLABORATION

- More than 170 members from 33 institutions in 11 countries and growing…

DARWIN TIME SCALE



★ 2019: LoI submission to LNGS, invited to submit a CDR

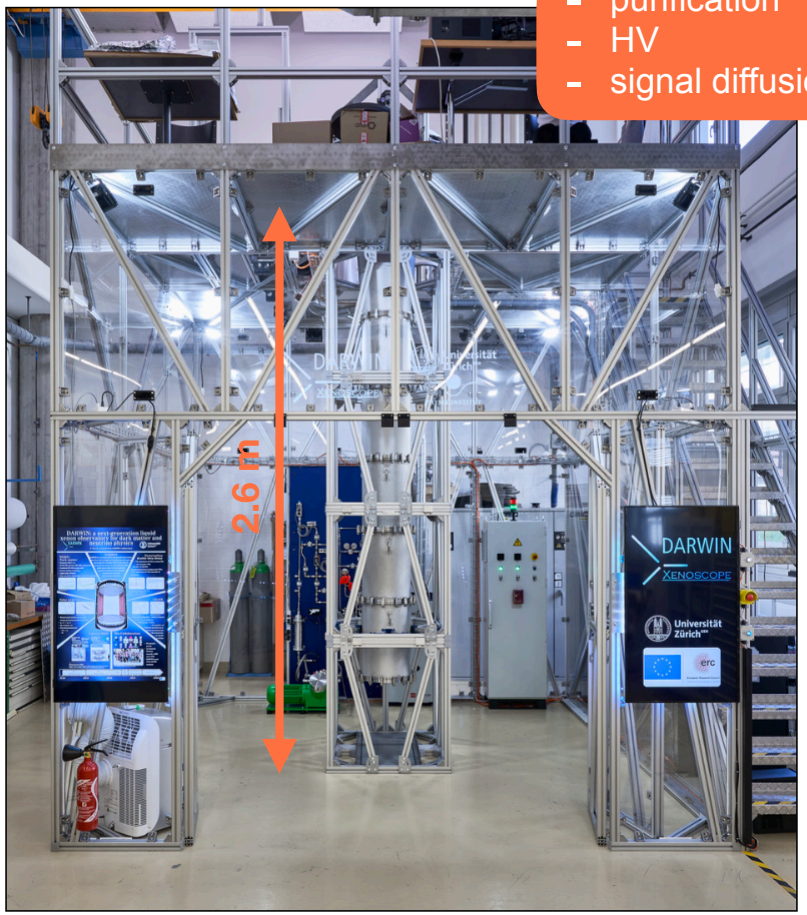
ONGOING R&D: DEMONSTRATORS

DARWIN full-length demonstrator

Universität Zürich[UZH]

The main goal is the demonstration of the electron drift over the full height of DARWIN

- purification
- HV
- signal diffusion



L. Baudis *et al* 2021 *JINST* **16** P08052

DARWIN full-(x,y) scale demonstrator

The main goal is to test components at real diameter under real conditions

- flatness of electrodes
- strength of the extraction field
- x-y homogeneity of the drift field

FUTURE: DARWIN-LZ COLLABORATION

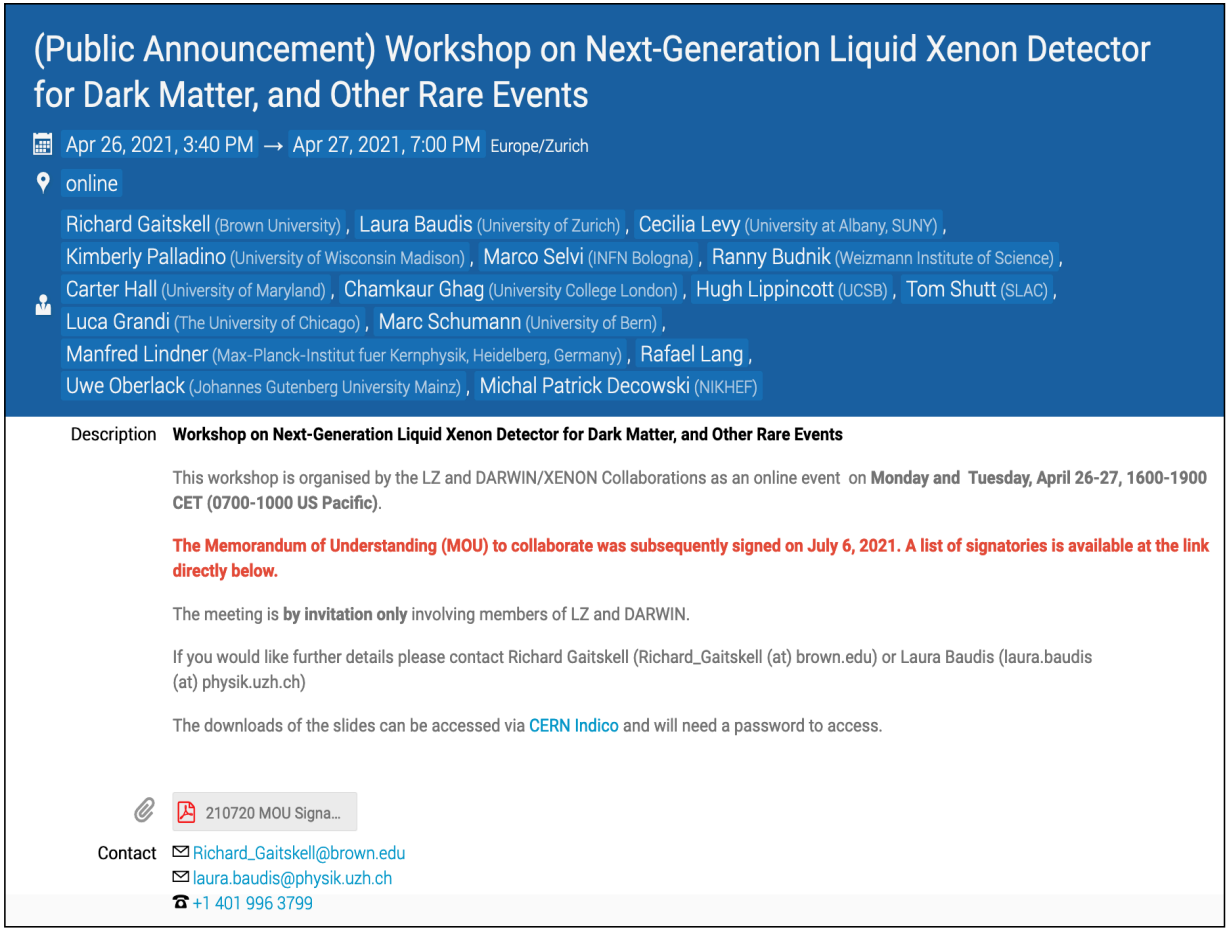
New Collaboration

Future merger of DARWIN and LZ collaborations to build/operate next-generation liquid xenon experiment

- ►new, stronger international collaboration
- ►comes after LZ and XENONnT are done

First steps ongoing

- ►very successful DARWIN-LZ meeting on April 26-27, 2021
- ►MoU signed on July 6, 2021 by 104 research group leaders from 16 countries



(Public Announcement) Workshop on Next-Generation Liquid Xenon Detector for Dark Matter, and Other Rare Events

Apr 26, 2021, 3:40 PM → Apr 27, 2021, 7:00 PM Europe/Zurich

online

Richard Gaitskell (Brown University), Laura Baudis (University of Zurich), Cecilia Levy (University at Albany, SUNY), Kimberly Palladino (University of Wisconsin Madison), Marco Selvi (INFN Bologna), Ranny Budnik (Weizmann Institute of Science), Carter Hall (University of Maryland), Chamkaur Ghag (University College London), Hugh Lippincott (UCSB), Tom Shutt (SLAC), Luca Grandi (The University of Chicago), Marc Schumann (University of Bern), Manfred Lindner (Max-Planck-Institut fuer Kernphysik, Heidelberg, Germany), Rafael Lang, Uwe Oberlack (Johannes Gutenberg University Mainz), Michal Patrick Decowski (NIKHEF)

Description **Workshop on Next-Generation Liquid Xenon Detector for Dark Matter, and Other Rare Events**

This workshop is organised by the LZ and DARWIN/XENON Collaborations as an online event on **Monday and Tuesday, April 26-27, 1600-1900 CET (0700-1000 US Pacific)**.

The Memorandum of Understanding (MOU) to collaborate was subsequently signed on July 6, 2021. A list of signatories is available at the link directly below.

The meeting is **by invitation only** involving members of LZ and DARWIN.

If you would like further details please contact Richard Gaitskell (Richard_Gaitskell (at) brown.edu) or Laura Baudis (laura.baudis (at) physik.uzh.ch)

The downloads of the slides can be accessed via CERN Indico and will need a password to access.

210720 MOU Signa...

Contact Richard_Gaitskell@brown.edu
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+1 401 996 3799

SUMMARY

- DARWIN observatory: excellent sensitivity for dark matter and neutrino physics
- The large mass (50t), low-energy threshold and ultra-low background, offer the possibility of **a broad physics programme:**
  - WIMP dark matter (sensitivity down to the neutrino floor)
  - Low energy solar neutrinos (1% precision in pp flux after 1 year of data)
  - Neutrinoless double-beta decay (half-life sensitivity of 2.4×10^{27} years)
  - and much more …
- DARWIN is a growing collaboration, currently **33 institutions from 13 countries**.
- R&D and prototypes in their way
  - CDR for the end of 2022
- Future DARWIN-LZ merger

Thank you for your attention!!