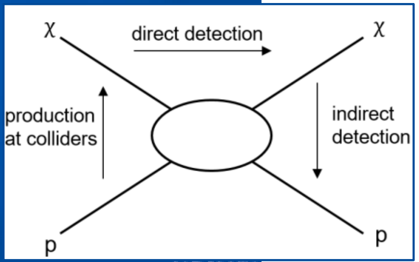
DARWIN – a next generation liquid xenon experiment for dark matter and neutrino physics

Julia Dierle
on behalf of the DARWIN collaboration



La Thuile 2021, Les Rencontres de Physique de la Vallée d’Aoste
09.03.2021

Astroparticle Physics
Physikalisches Institut
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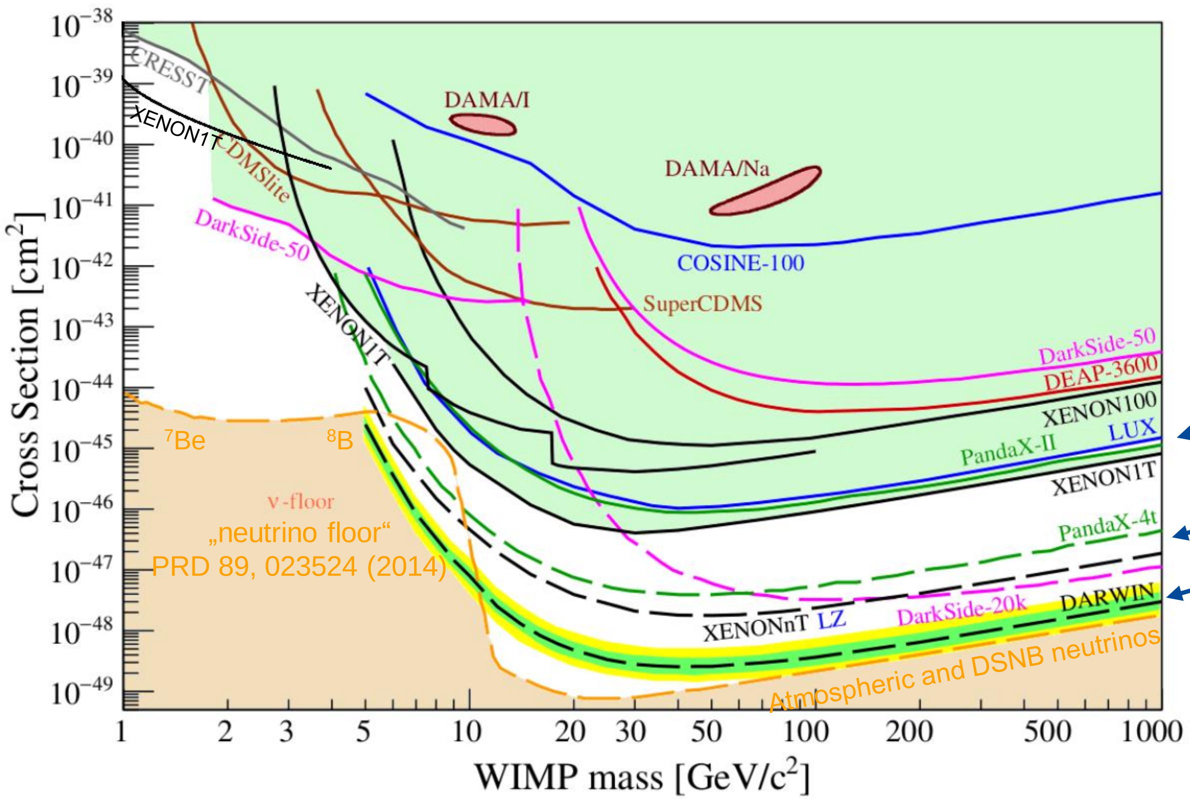
The WIMP landscape

- best WIMP exclusion limits above ~ 110 MeV/c² by active target experiments with liquid xenon
- **DARWIN**, with its 40 t target mass, aims to reach a sensitivity **down to the irreducible Coherent Neutrino-Nucleus Scattering (CNNS) background**



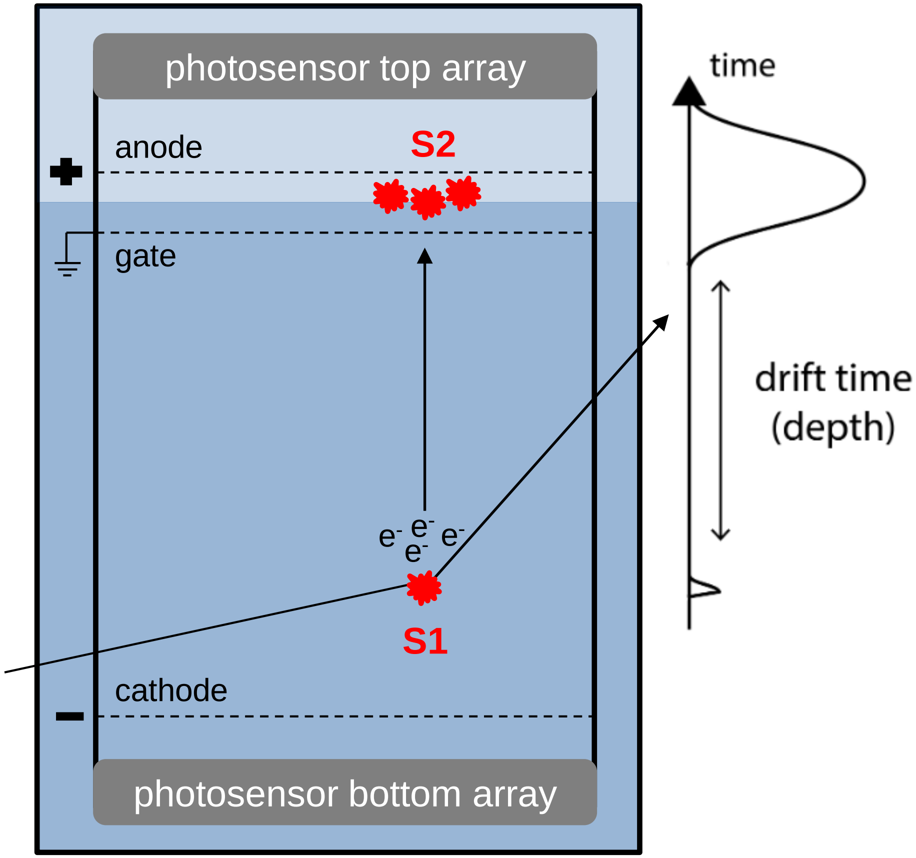
current limits

near future sensitivity

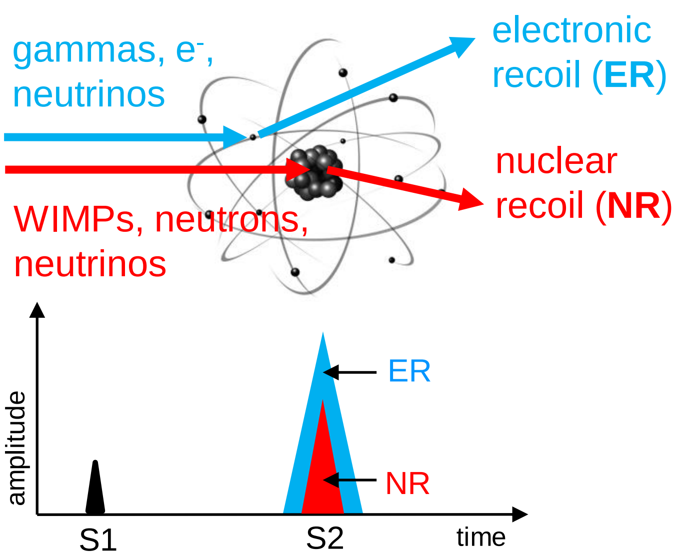
DARWIN's sensitivity

Dual-phase xenon TPC

S1: prompt scintillation light
S2: delayed scintillation light proportional to the charge



- 3D position recontruction via
  - S1 light distribution (x-y)
  - charge drift time (z)
  → target fiducialization
- S2/S1 ratio for particle identification
  → ER/NR discrimination

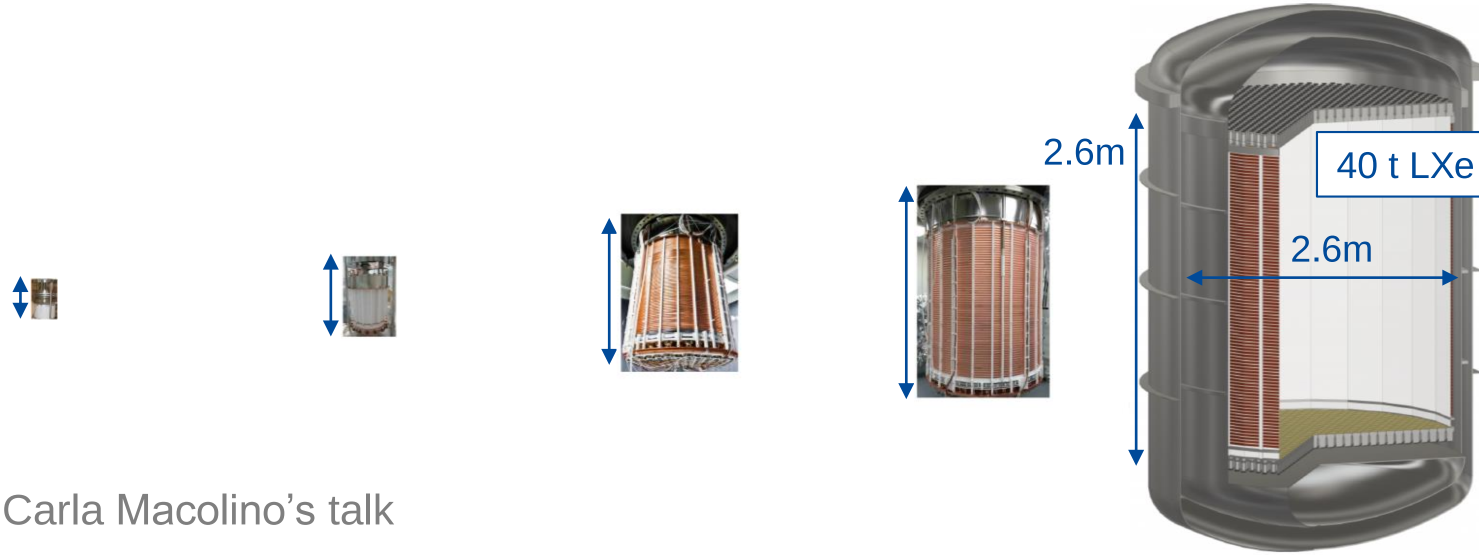


- single vs. multiple interactions
- energy reconstruction

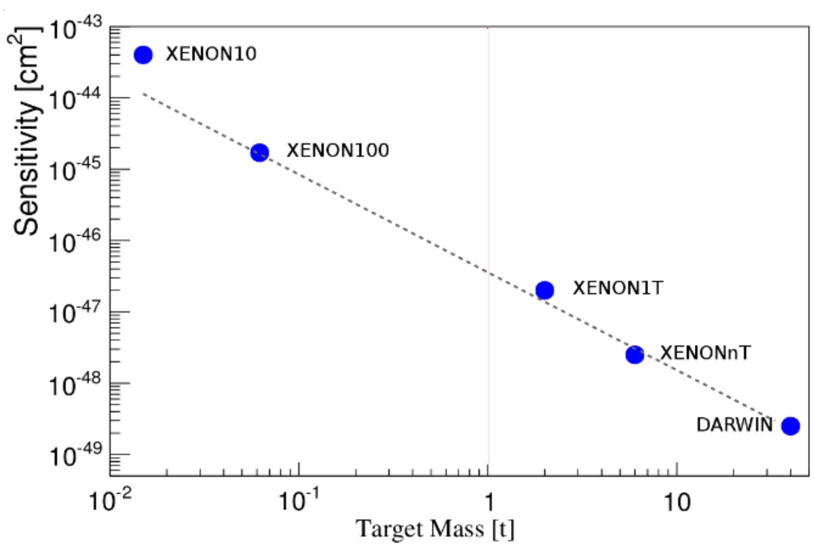
Dual-phase xenon TPC evolution at LNGS

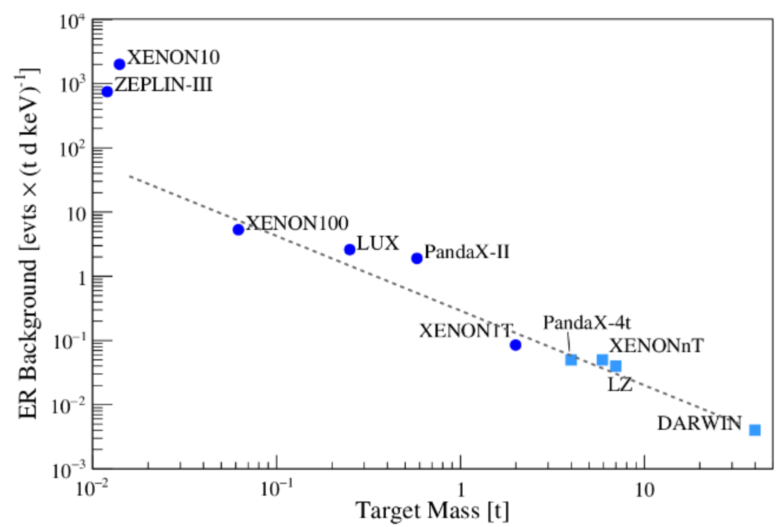
DARWIN

XENON10 XENON100 XENON1T XENONnT DARWIN



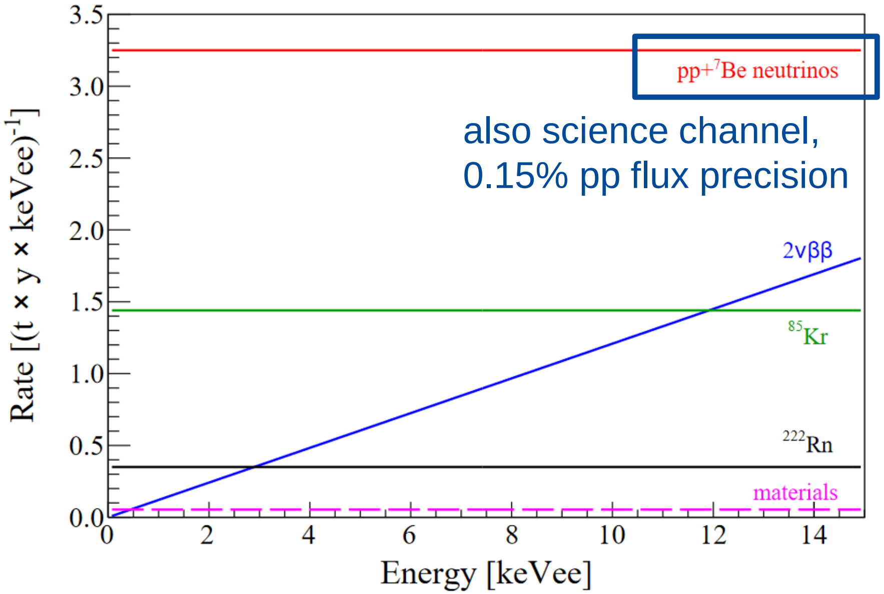
see also Carla Macolino's talk

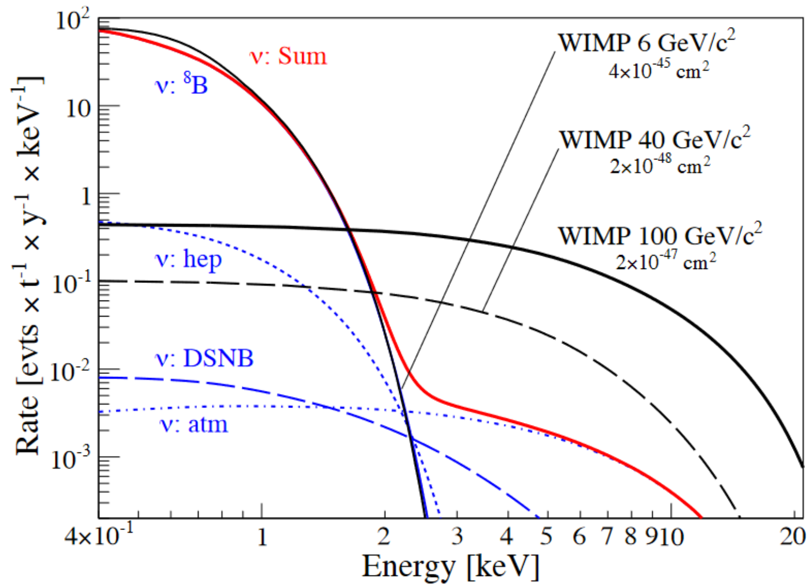




DARWIN's background sources [JCAP 10, 016 (2015)]

DARWIN





Electronic recoils (ER):

- pp and ^{7}Be neutrinos
- xenon intrinsic background
- external β and γ background

Nuclear recoils (NR):

- CNNS of high E solar neutrinos
- radiogenic neutrons from (α,n) reactions and spontaneous fission
- muon-induced neutrons

Goal: ER and NR background have to be dominated by neutrino-induced events

The DARWIN collaboration

Columbia RPI London Nikhef Muenster Hamburg Stockholm Mainz Dresden MPIK, Heidelberg Heidelberg

Chicago KIT

Purdue Freiburg

UCSD Tokyo

Alabama Nagoya

Rice Kobe

Coimbra

Subatech LPNHE IJCLab Zurich Bologna L'Aquila LNGS Napoli Weizmann Belgrade NYUAD

about 180 members @DarwinObserv www.darwin-observatory.org

DARWIN's science channels

DARWIN

JCAP 10, 016 (2015)

Direct dark matter detection

Eur. Phys. J. C 80, 9 (2020)

Neutrinoless double beta decay of ^{136}Xe

Eur. Phys. J. C 80, 12 (2020)

Low-energy solar neutrinos

this talk

DARWIN

Coherent neutrino nucleus scattering

Solar axions

low background, low energy threshold, large target mass detector

Supernova neutrinos

PRD89, 013011 (2014)
PRD94, 103009 (2016)

Galactic ALPS, dark photons

JCAP 1611 (2016) 017

DARWIN's science channels

JCAP 10, 016 (2015)

Direct dark matter detection

Eur. Phys. J. C 80, 9 (2020)

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Why looking for dark matter?
27% is composed of dark matter, not detected yet, explaining the large-scale structures and galaxies

Coherent neutrino nucleus scattering

low background, low energy threshold, large target mass detector

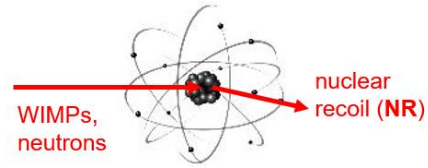
Supernova neutrinos

Galactic ALPS, dark photons

PRD89, 013011 (2014)
PRD94, 103009 (2016)

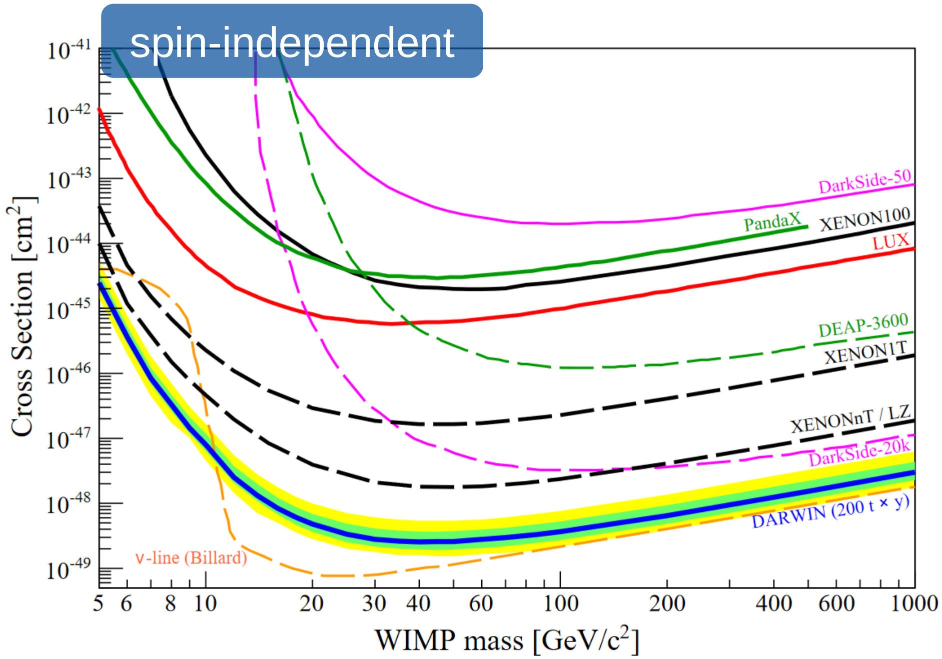
JCAP 1611 (2016) 017

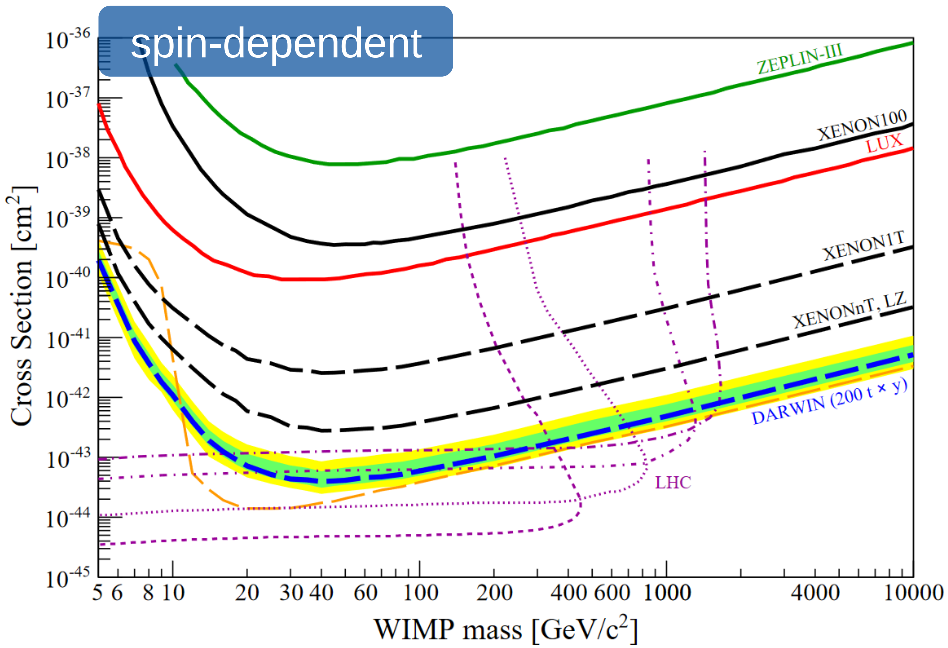
WIMP sensitivity [JCAP 10, 016 (2015)]



DARWIN

Assumption: 200 t x yr exposure





→ minimum of 2.5 x 10^{-49} cm² at 40 GeV/c²

→ complementary to LHC searches

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DARWIN's science channels

JCAP 10, 016 (2015)

Direct dark
matter detection

Eur. Phys. J. C 80, 9 (2020)

Neutrinoless
double beta
decay of ^{136}Xe

Eur. Phys. J. C 80, 12 (2020)

Low-energy
solar neutrinos

DARWIN

C
neut
s

Why looking for 0νββ?
probing neutrino's nature, lepton
number violation, Majorana nature

energy threshold,
ss detector

Solar axions

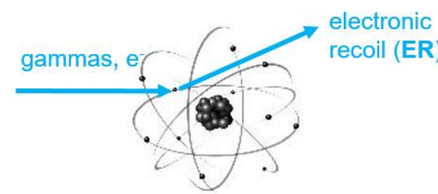
Supernova
neutrinos

Galactic ALPS,
dark photons

PRD89, 013011 (2014)
PRD94, 103009 (2016)

JCAP 1611 (2016) 017

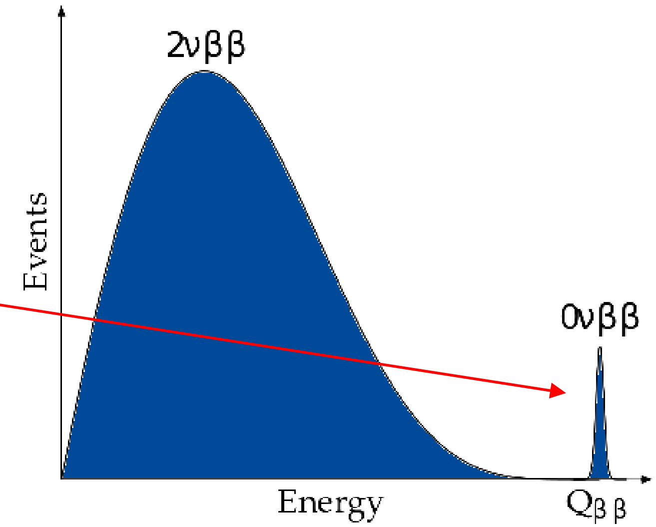
$0\nu\beta\beta$ decay in DARWIN [Eur. Phys. J. C 80, 9 (2020)]

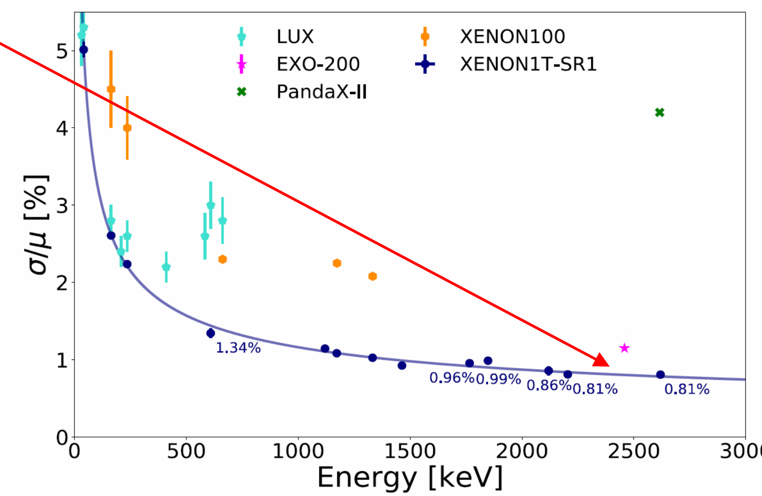


- ^{136}Xe is an excellent candidate:
  $^{136}Xe \rightarrow {}^{136}Ba + 2e^- + \cancel{2\bar{\nu}_e}$
  - abundance of 8.9% in ^{nat}Xe
    → DARWIN will contain **> 3.5 t of ^{136}Xe**
  - $Q_{\beta\beta}$ = 2.458 MeV (above the WIMP ROI)

- expected **energy resolution of < 1% at $Q_{\beta\beta}$** (demonstrated by XENON1T)

- ultra-low background environment



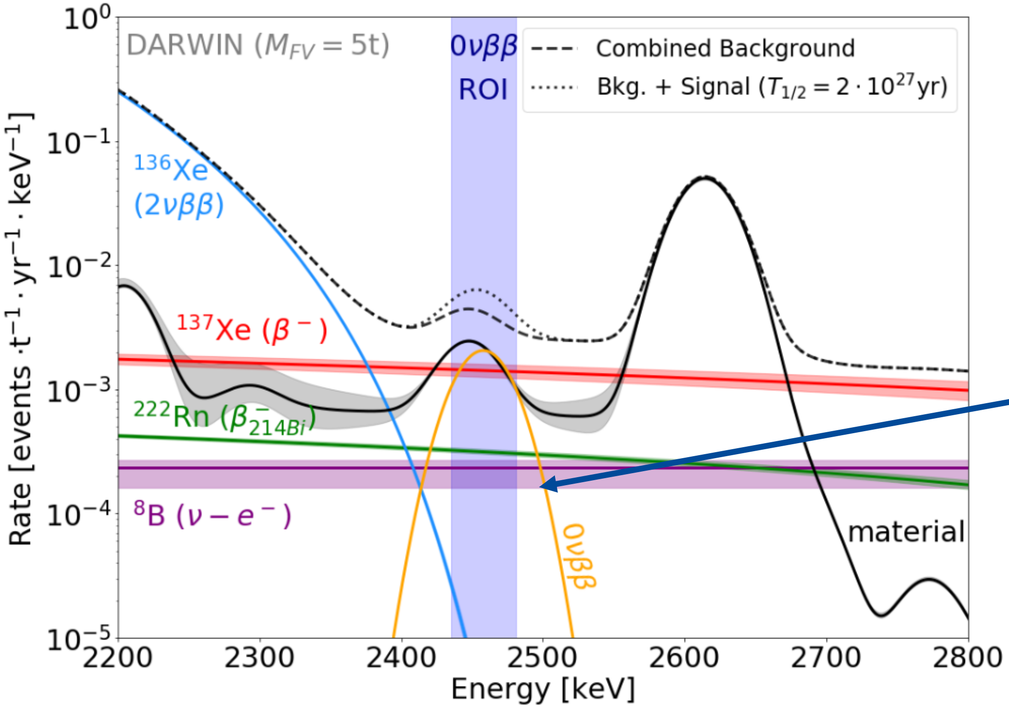


XENON collaboration,
Eur. Phys. J. C 80 (2020) 9

Background simulations [Eur. Phys. J. C 80, 9 (2020)]

- simulations with Geant4, implementing a realistic detector model with assuming already measured activities/ upper limits of materials
- optimization of the fiducial volume: background rejection vs. signal strength

Background rates for 5 t fiducial mass:



→ expected background of **0.91 events/yr** in $0\nu\beta\beta$ energy ROI [2435, 2481] keV

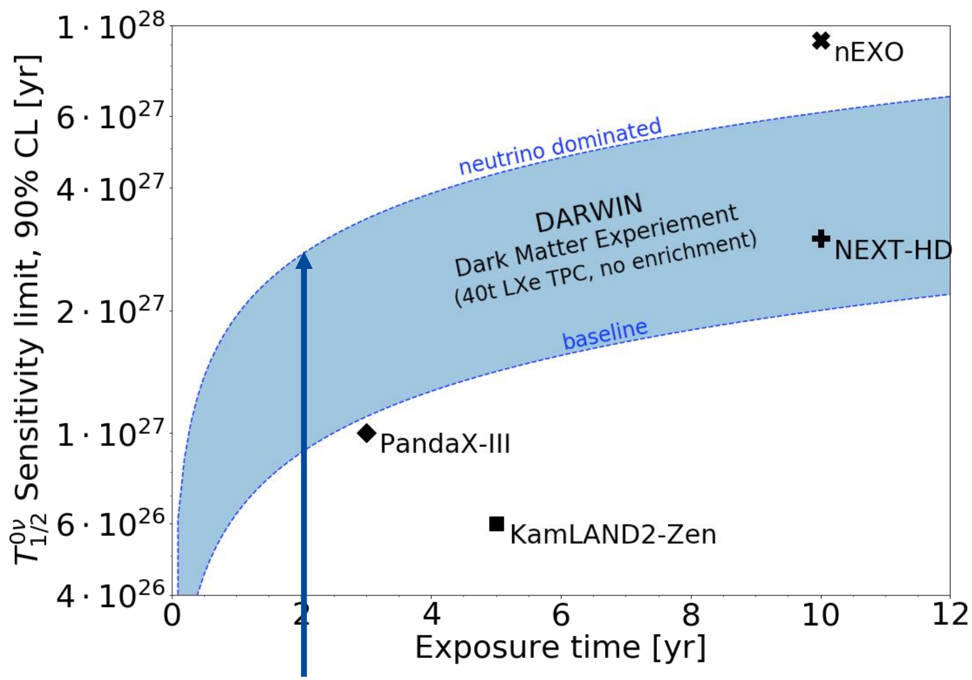
hypothetical signal strength of 0.5 events/yr, corresponding to $T_{1/2} = 2 \times 10^{27}$ yr

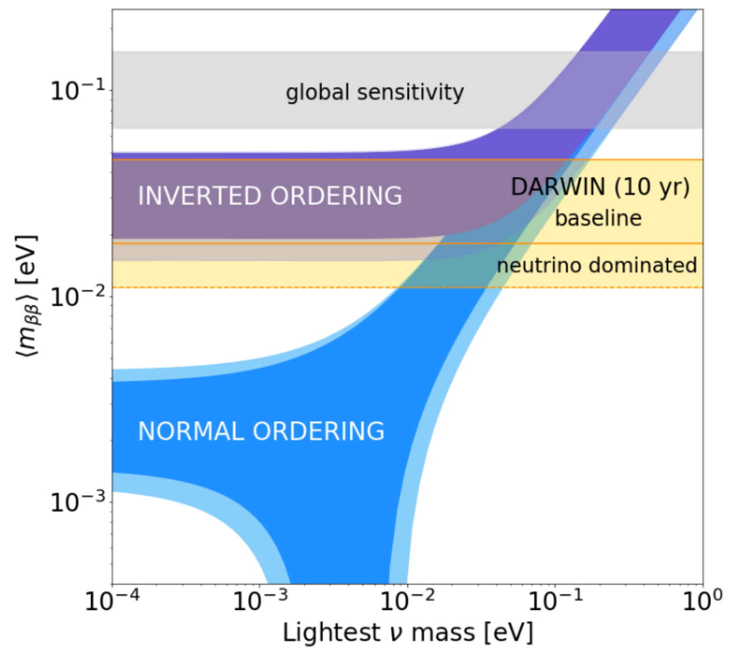
Expected sensitivity [Eur. Phys. J. C 80, 9 (2020)]

Profile likelihood analysis:

DARWIN will reach a sensitivity of 2.4 × 10^{27} yr for a 5 t × 10 yr exposure (90% C.L.)

Median discovery potential: 1.1 × 10^{27} yr at 3σ





with improvements (e.g., deeper lab, cleaner materials, …)

Outlook

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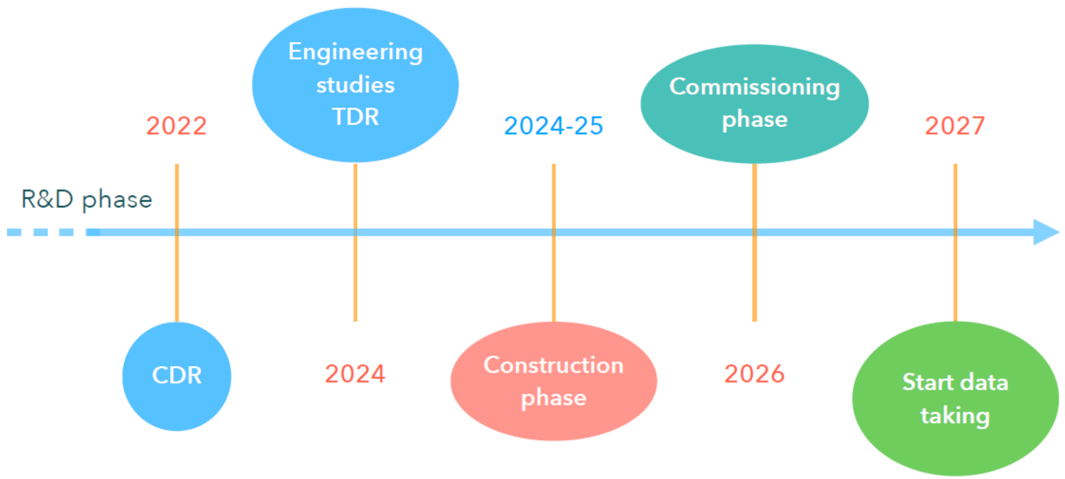
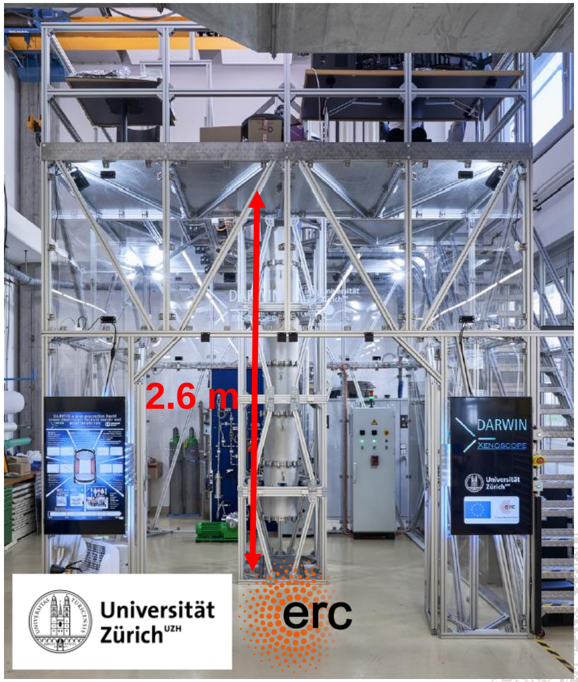
DARWIN

- DARWIN will be **much more than the ultimate LXe-based dark matter detector**
  → large detector with ultra-low backgrounds, very good energy resolution, low energy threshold

- R&D programs are in progress, working towards a CDR





DARWIN DEMONSTRATORS

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