DARWIN: More than just the ultimate Dark Matter detector

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European Research Council

Established by the European Commission

Xenon: WIMP target of choice

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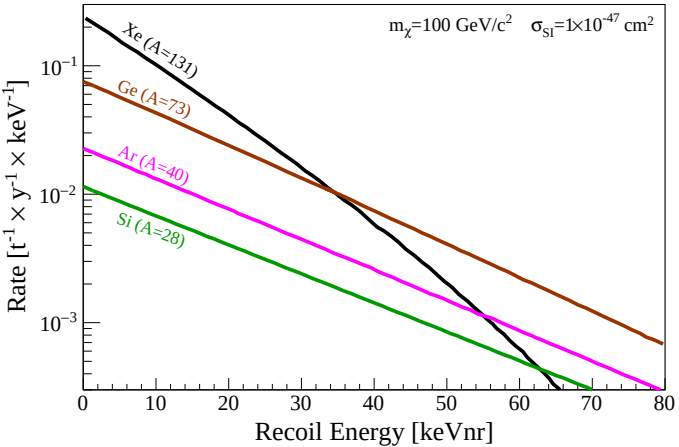
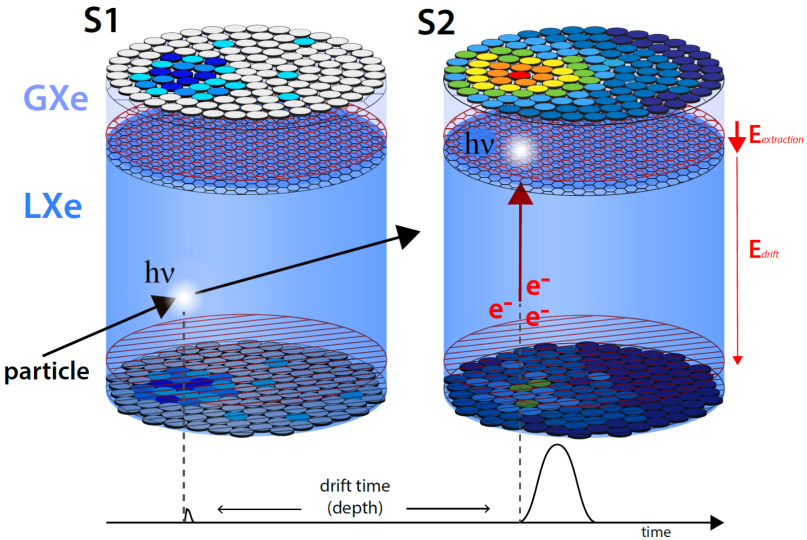
- Good density
- Good stopping power
- Good target for WIMPS $> 10\,\mathrm{GeV/c^2}$
- Good scintillation properties
- Very scalable
- No long-lived isotopes*
- "Easy" purification

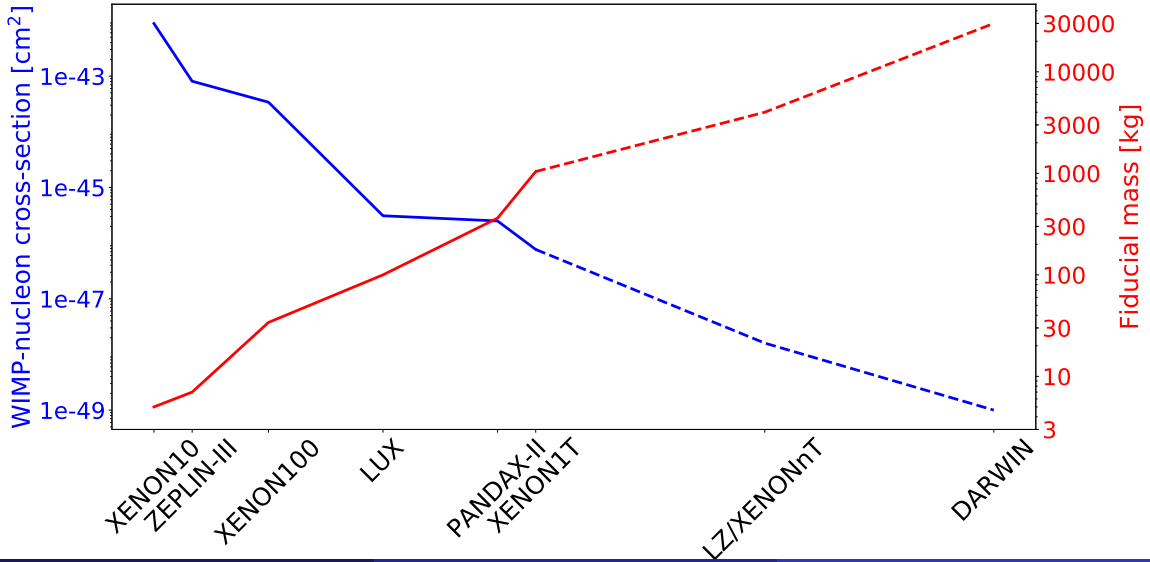


Dual-phase TPC: detector of choice

- 3D position reconstruction
- ER/NR discrimination via scintillation/ionization
- $\mathcal{O}(1)\,\mathrm{keV}$ threshold



A brief tour through history

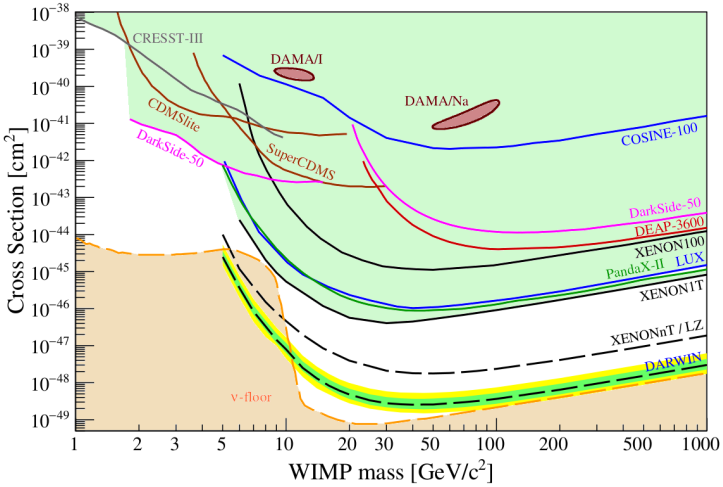


Next: 50 tonnes

DARWIN: a versatile, low-background, low-threshold, astroparticle physics observatory

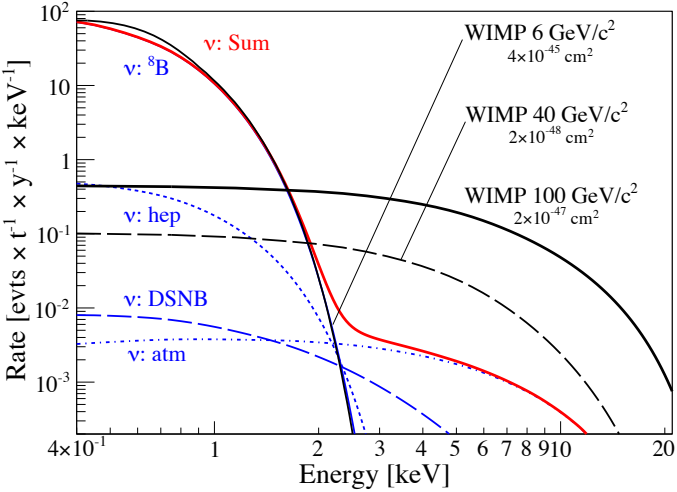
Main science channel:

- WIMP Dark Matter at the neutrino floor



Neutrinos: coherent scattering

- ^{8}B spectrum very similar to low-mass WIMPs
- Significant impact on sensitivity at low mass
- Possible science channel or calibration source



JCAP 11, 017 (2016)

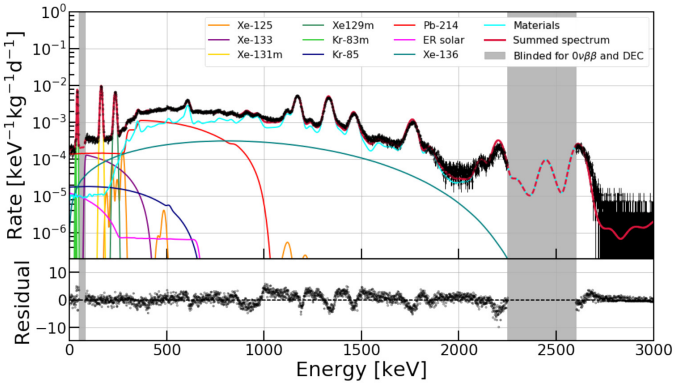
Backgrounds: fundamentally neutrino-limited

Electronic recoils:

- Solar-ν: $\sim 3.5\,(\mathrm{keV}\cdot\mathrm{tonne}\cdot\mathrm{yr})^{-1}$
- ^{222}Rn: $\sim 5\,(\mathrm{keV}\cdot\mathrm{yr}\cdot\mathrm{mBq})^{-1}$
- $^{85}\mathrm{Kr}/^{nat}\mathrm{Kr}$: $10^{-11}\,\mathrm{mol/mol}$
- Materials: $\mathcal{O}(10\,\mathrm{mBq/kg})$

Nuclear recoils:

- CNNS (^{8}B): $90\,(\mathrm{tonne}\cdot\mathrm{yr})^{-1}$ at $1\,\mathrm{keV}$ threshold, $0.1\,(\mathrm{tonne}\cdot\mathrm{yr})^{-1}$ at $3\,\mathrm{keV}$
- Cosmogenic neutrons
- Radiogenic neutrons ((α, n))



XENON1T background spectrum

Radon

Target: 0.1 $\mathrm{mBq/tonne}$; XENON1T: $\sim$ 10 $\mathrm{mBq/tonne}$

- Cleaner materials
- Distillation
- Independent xenon volumes
- Surface treatment
- Ion tracking

Dedicated radon column for XENONnT under construction

Eur.Phys.J. C77 (2017) no.5, 275

Materials

Clean materials are a requirement for any low-background search

- Emanation of ^{222}Rn
- Gamma backgrounds
- (α, n) neutrons

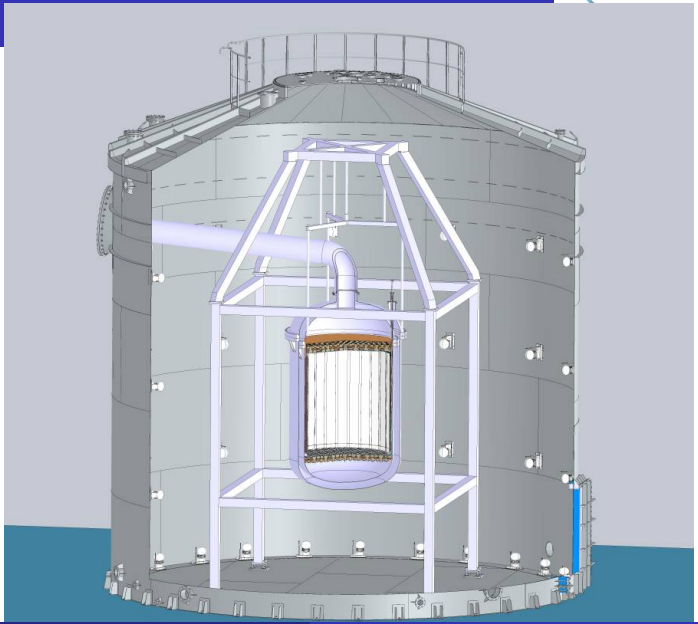
Screening is important!

GeMSE remote screening facility, Vue-des-Alpes, CH

arXiv 1606.03983

Nominal design

- 14 m water tank with Gd doping
- $\sim$ 3 m outer cryostat
- 2.6 m dual-phase TPC
- 50 tonne total, 40 tonne active
- $\sim$ 1800 PMTs (3″)



Science channels with DARWIN

ER background rate: $\sim 4\,(\mathrm{keV}\cdot\mathrm{tonne}\cdot\mathrm{yr})^{-1}$ (ν_{pp}-dominated)

Main science channels:

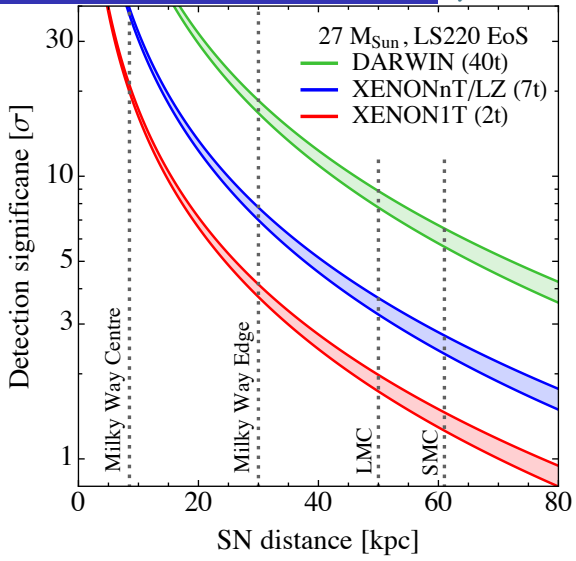
- WIMP Dark Matter
- Supernova neutrinos
- Solar neutrinos
- $0\nu\beta\beta$

Extra science channels:

- Axions/ALPs
- SD Dark Matter (n + p)
- Inelastic DM
- WIMP-π
- SuperWIMPs

Supernova neutrinos: coherent scattering

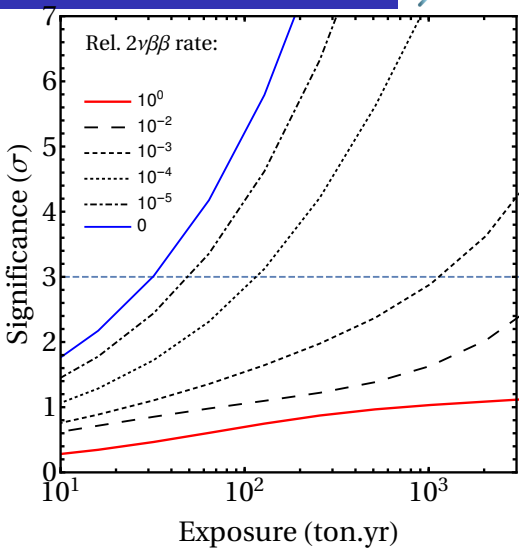
- Flavor-insensitive interaction
- $\mathcal{O}(20)\,\mathrm{events/tonne}$ at $10\,\mathrm{kpc}$
- Some sensitivity to different solar models
- Planned participation in SNEWS network



Phys.Rev. D94 (2016) no.10, 103009

Solar neutrinos: $\nu + e^- \rightarrow \nu + e^-$

- Realtime *pp* flux measurement at $\sim 1\%$ possible
- Some sensitivity to other solar neutrino channels
- ER background spectrum dominated by ^{136}Xe $2\nu\beta\beta$
- Sensitivity (esp. to CNO) improves significantly with depleted xenon



Neutrinoless double-beta decay

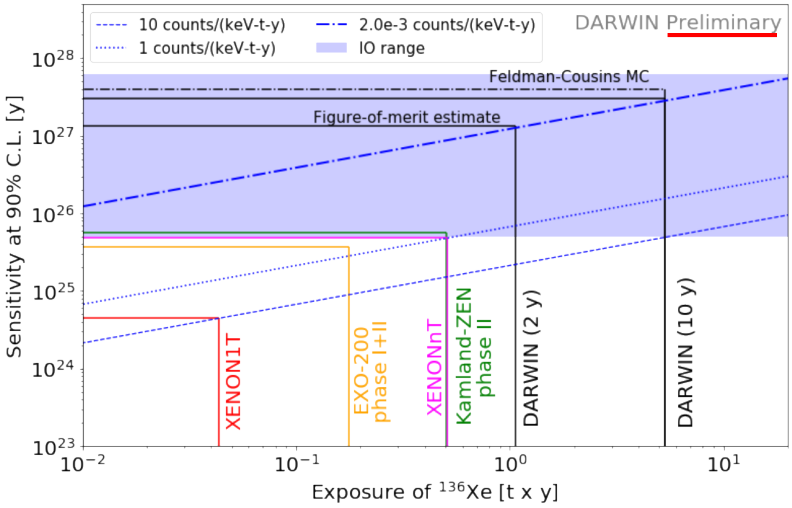
DARWIN

$^{136}\mathrm{Xe}/^{nat}\mathrm{Xe}$

$\sim 9\%$, $Q = 2458\,\mathrm{keV}$

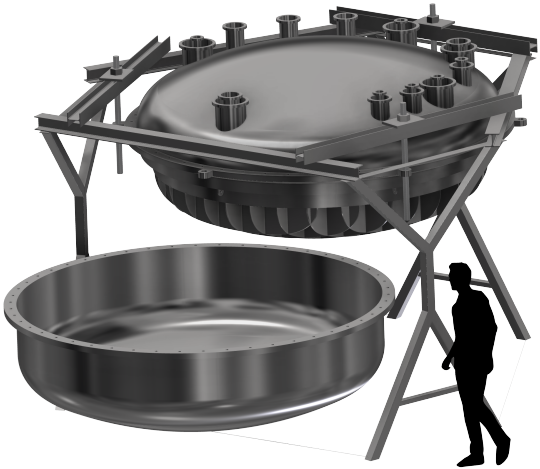
Main backgrounds:

- $^{214}\mathrm{Bi}$ ($2\,447.7\,\mathrm{keV}$ γ)
- $^{137}\mathrm{Xe}$ ($4.2\,\mathrm{MeV}$ β)



Full-scale demonstrators

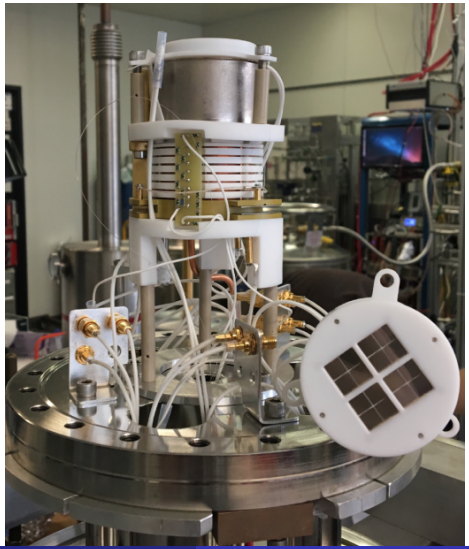
Freiburg: (x, y)



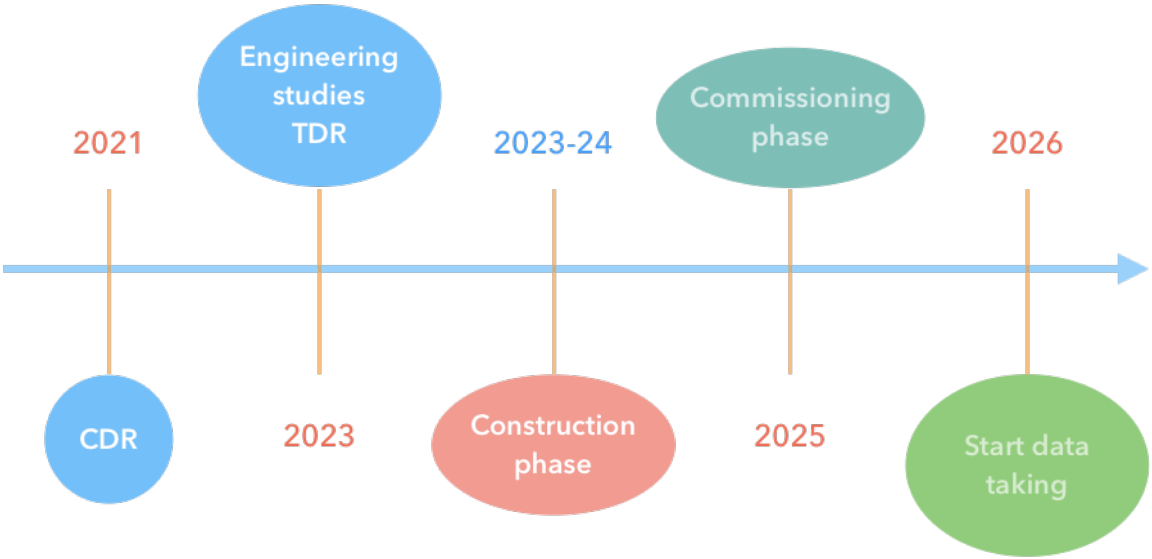
Zürich: z

Current R&D within DARWIN

- SiPMs vs PMTs:
  - \+ Improved radiopurity
  - \+ Better fill factor
  - \+ Great single-photon resolution
  - – Dark rate
- Single-phase amplification
  - Reduce effect of electrode sagging
  - Reduce material usage
- Radon emanation reduction techniques
  - Hermetically sealed inner volume



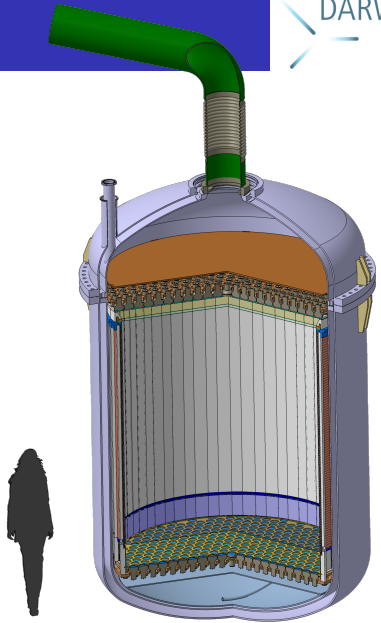
It's on the schedule



The Future

Upgrade from 8 to 50 tonnes not straightforward

- A variety of science channels, including:
  - WIMP dark matter
  - Solar neutrinos
  - Supernova neutrinos
  - Rare decays ($0\nu\beta\beta$, $2\nu\mathrm{EC}$, etc)
  - Axions/ALPs
  - Sterile neutrinos
  - Anything requiring an ultra-low background
- Stringent background requirements
- Detector design challenging
- `darwin-observatory.org`, @DarwinObserv



With help from

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- Kalsruhe Institute of Technology
- University of Zurich
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- Imperial College London
- INFN LNGS
- INFN Bologna
- Weizmann Institute of Science
- Nikhef, Amsterdam
- University of Coimbra
- Stockholm University
- Colombia University
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- Rice University
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- RPI
- NYU Abu Dhabi