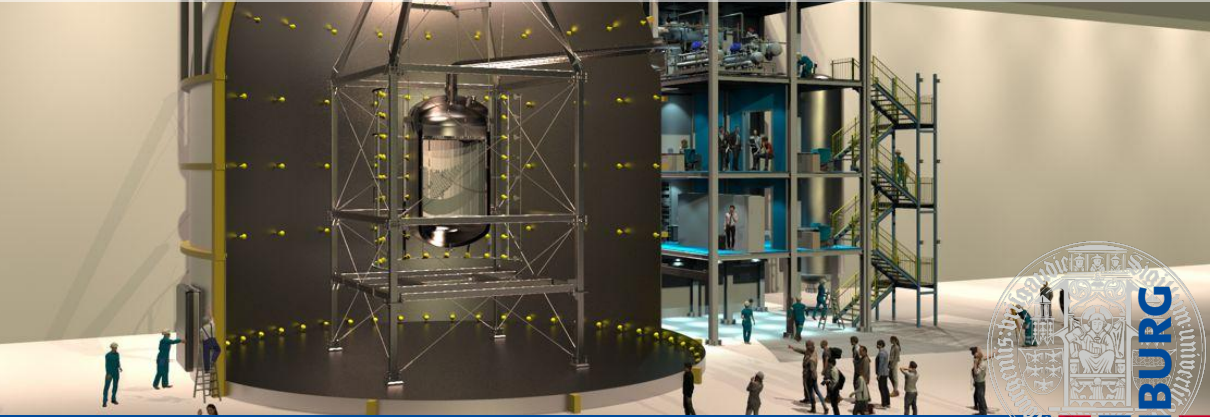
DARWIN

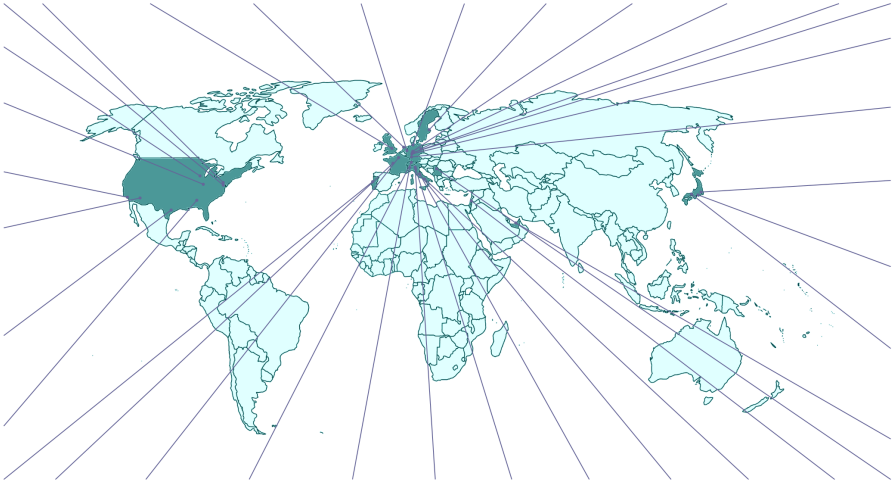
A Next-Generation Liquid Xenon Observatory for Dark Matter and Neutrino Physics



DANIEL BAUR - on behalf of the DARWIN collaboration

Lake Louise Winter Institute 2022

UNI FREIBURG



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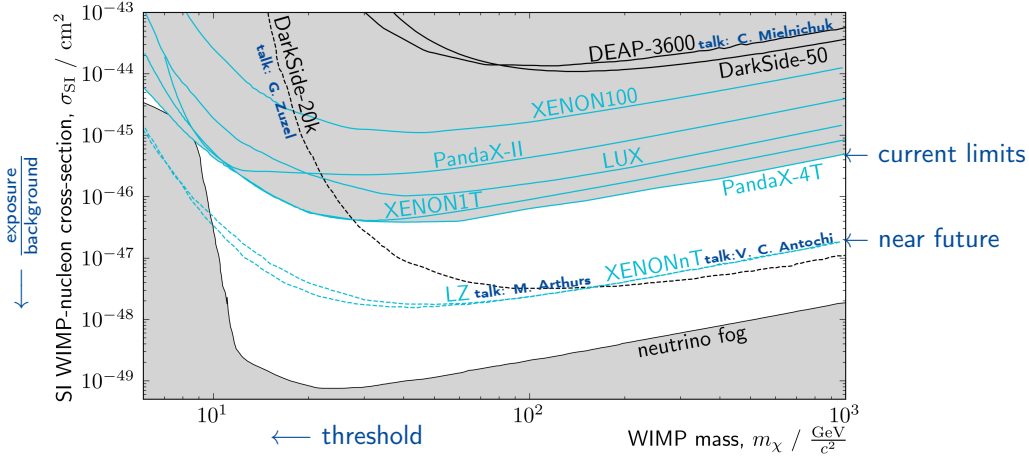
Belgrade

Motivation: WIMP Parameter Space

The WIMP search from $5\,\mathrm{GeV}$ to $1\,\mathrm{TeV}$ is dominated by modern noble gas (Xe, Ar) detectors:



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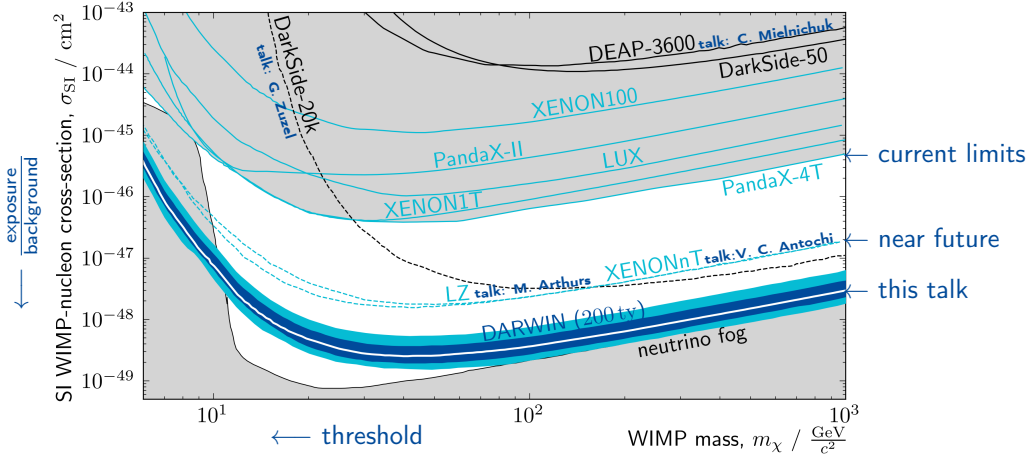
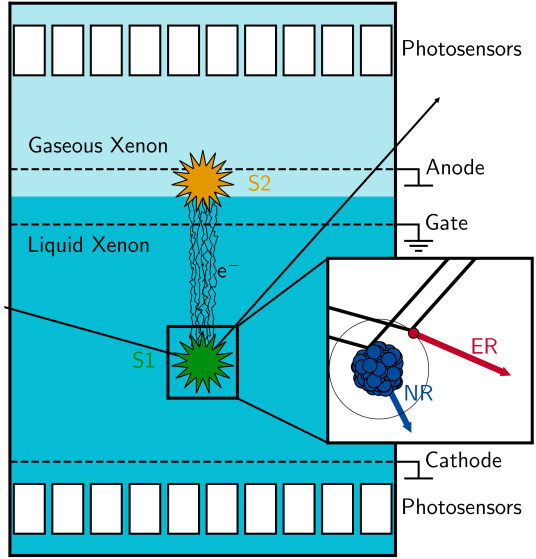


⇒ DARWIN sensitivity goal: background dominated by irreducible neutrino interactions

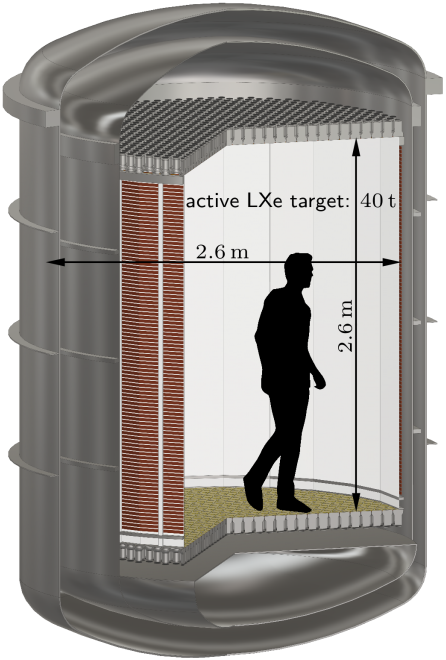
Detector Concept



Dual-Phase Xenon Time Projection Chamber

detection of prompt (S1) and delayed (S2) scintillation signals:

- energy reconstruction
- 3D position resolution → fiducialization, single-/multi-scatter
- $\frac{S2}{S1}$ → ER/NR discrimination



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DARWIN: Baseline TPC Design

commissioning after LZ/XENONnT:

- active liquid xenon target: $40\,\mathrm{t}$ ($50\,\mathrm{t}$ total)
- dimensions: $\varnothing = 2.6\,\mathrm{m}, h = 2.6\,\mathrm{m}$
- photosensors: ∼1800 3-inch PMTs
- n- and μ-veto: Gd-doped water

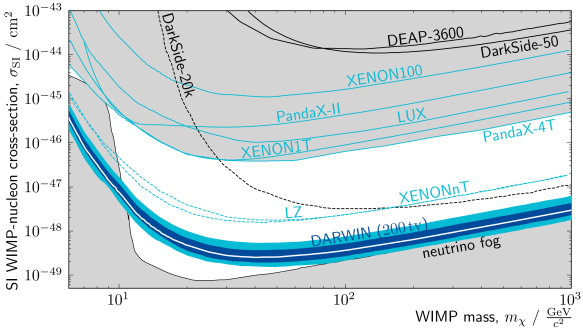
Direct Detection of WIMP Dark Matter

[JCAP 11 (2016) 017, JCAP 10 (2015) 016]

goal: explore the entire accessible WIMP parameter space

experimental challenges:

- background: $^{222}\mathrm{Rn} < 0.1\,\frac{\mu\mathrm{Bq}}{\mathrm{kg}}$, $^{\mathrm{nat}}\mathrm{Kr} < 0.1\,\mathrm{ppt}$
- threshold: light yield $> 8\,\frac{\mathrm{PE}}{\mathrm{keV}}$
- exposure: $200\,\mathrm{ty}$



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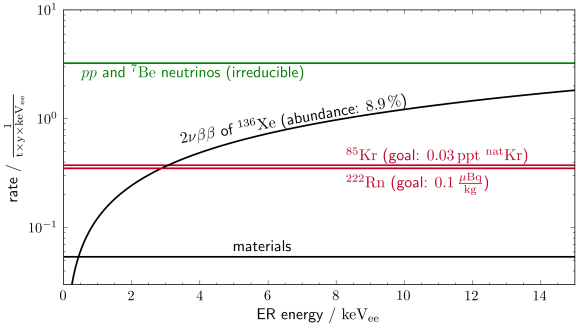

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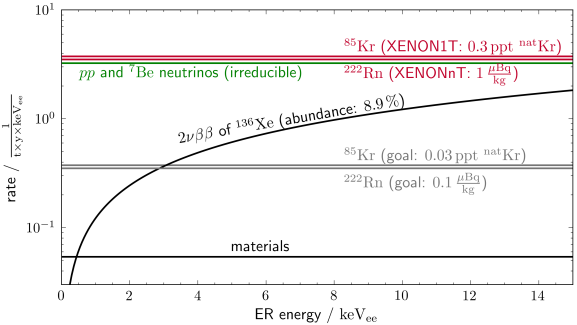
  - → $^{222}\mathrm{Rn}$ in XENONnT: $\sim 1\,\frac{\mu\mathrm{Bq}}{\mathrm{kg}}$ (goal)
  - → $^{\mathrm{nat}}\mathrm{Kr}$ in XENON1T: $\sim 0.3\,\mathrm{ppt}$ [EPJC 77 (2017) 275]
  - → discrimination: $99.98\,\%$ ER rejection, $30\,\%$ NR acc.
- threshold: light yield $> 8\,\frac{\mathrm{PE}}{\mathrm{keV}}$
- exposure: $200\,\mathrm{ty}$



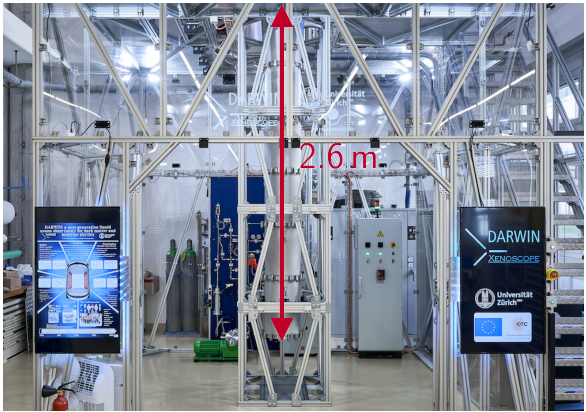
⇒ The above (and many more) critical topics require dedicated R&D campaigns.

R&D: Full-Scale Demonstrators

goal: test full-size detector subsystems under real conditions in LXe

full diameter: Pancake

full height: Xenoscope [JINST16 08052]



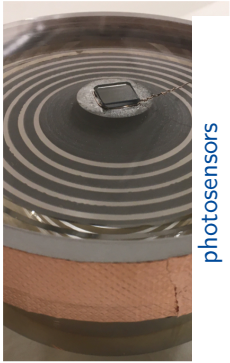
⟶ electrodes, photosensors, materials

⟶ electron drift over full height, purity

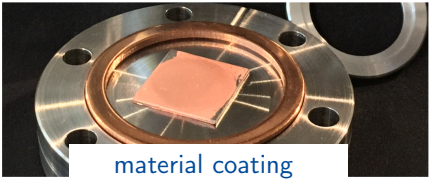
Active R&D Efforts

cryogenic distillation

alternative detector concepts



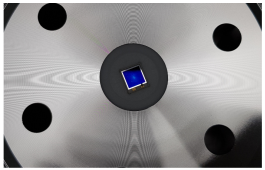
photosensors

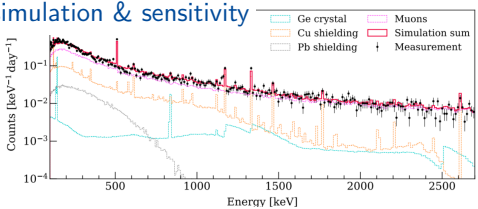


material coating

simulation & sensitivity

radiopurity assay





talk: M. Arthurs

The LZ and DARWIN/XENON collaborations will join forces to build and operate the next-generation LXe observatory.

→ **new and stronger collaboration:**

- first successful workshop, next planned
- Memorandum of Understanding signed
- important advance in xenon inventory

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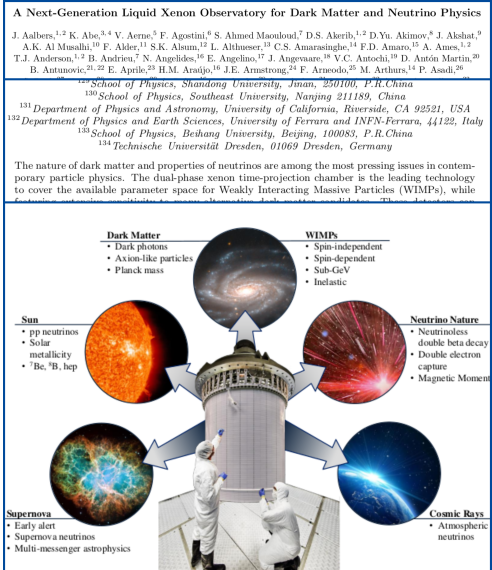
→ **new and stronger collaboration:**

- first successful workshop, next planned
- Memorandum of Understanding signed
- important advance in xenon inventory
- joint community whitepaper on G3 science
  [on the arXiv later this week]

600+ scientists, 130+ institutions (DARWIN, LZ, XENON, theory, ...)

lots of science channels...

1200+ references



A Next-Generation Liquid Xenon Observatory for Dark Matter and Neutrino Physics

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The nature of dark matter and properties of neutrinos are among the most pressing issues in contemporary particle physics. The dual-phase xenon time-projection chamber is the leading technology to cover the available parameter space for Weakly Interacting Massive Particles (WIMPs), while

Dark Matter
- Dark photons
- Axion-like particles
- Planck mass

WIMPs
- Spin-independent
- Spin-dependent
- Sub-GeV
- Inelastic

Sun
- pp neutrinos
- Solar metallicity
- ^{7}Be, ^{8}B, hep

Neutrino Nature
- Neutrinoless double beta decay
- Double electron capture
- Magnetic Moment

Supernova
- Early alert
- Supernova neutrinos
- Multi-messenger astrophysics

Cosmic Rays
- Atmospheric neutrinos

[1200] C. Zeitnitz, *Particle Physics Strategy in Germany*, https://indico.desy.de/indico/event/20166/contribution/6/material/slides/0.pdf (2018).
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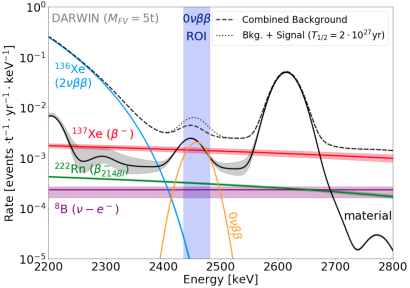
Neutrinoless Double Beta Decay of $^{136}\mathrm{Xe}$ [EPJC 80 (2020) 808]

prerequisites:

- candidate isotope: $> 3.5\,\mathrm{t}$ of $^{136}\mathrm{Xe}$
- energy resolution: $0.8\,\%$ at $Q_{0\nu\beta\beta} = 2.5\,\mathrm{MeV}$
  [EPJC 80 (2020) 785]
- low background: material-dominated



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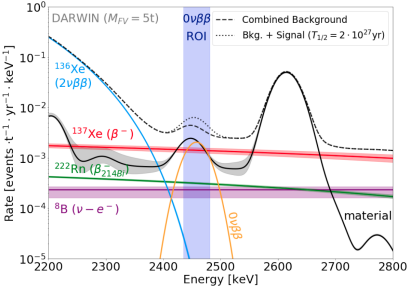
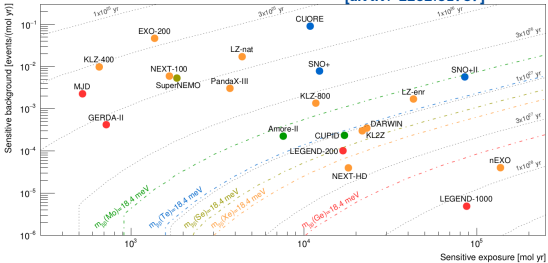


[arXiv: 2202.01787]



$\rightarrow$ $T^{0\nu}_{1/2} = 2.4 \cdot 10^{27}\,\mathrm{yr}$ ($5\,\mathrm{t} \times 10\,\mathrm{yr}$, $90\,\%$ C.L)

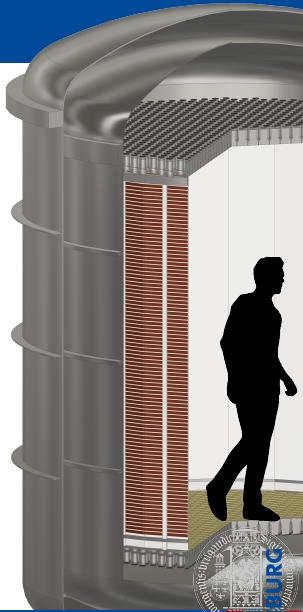
$\rightarrow$ assess effective Majorana mass ordering

$\rightarrow$ competitive without enrichment

Take Home Messages

DARWIN will be the next-generation liquid xenon observatory for dark matter and neutrino physics:

- goal: explore entire accessible WIMP parameter space
- ultra-low background, large target mass, low energy threshold
- active R&D: full-scale demonstrators, radon-mitigation, photosensors, ...
- future: DARWIN + LZ collaboration



Thank You for Your Attention!

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