The Future is Xenon!

Join our Canadian XLZD efforts!

Thomas Brunner

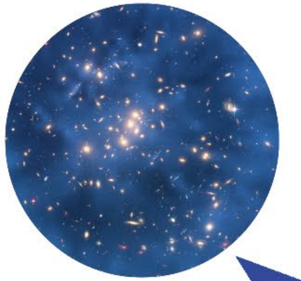
McGill University

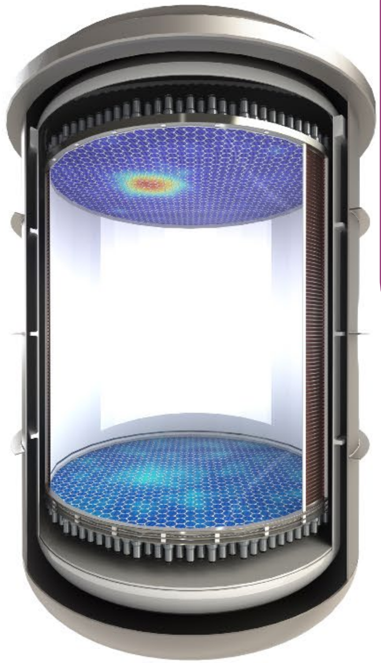
SNOLAB User Meeting

May 26, 2026

Multi-physics observatory

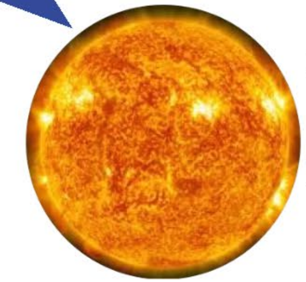
Dark Matter
WIMPs
Sub-GeV
Inelastic
Axion-like particles
Planck mass
Dark photons





Neutrino nature
Neutrinoless double beta decay
Neutrino magnetic moment
Double electron capture

Supernovae
Early alert
Supernova neutrinos
Multi-messenger astrophysics

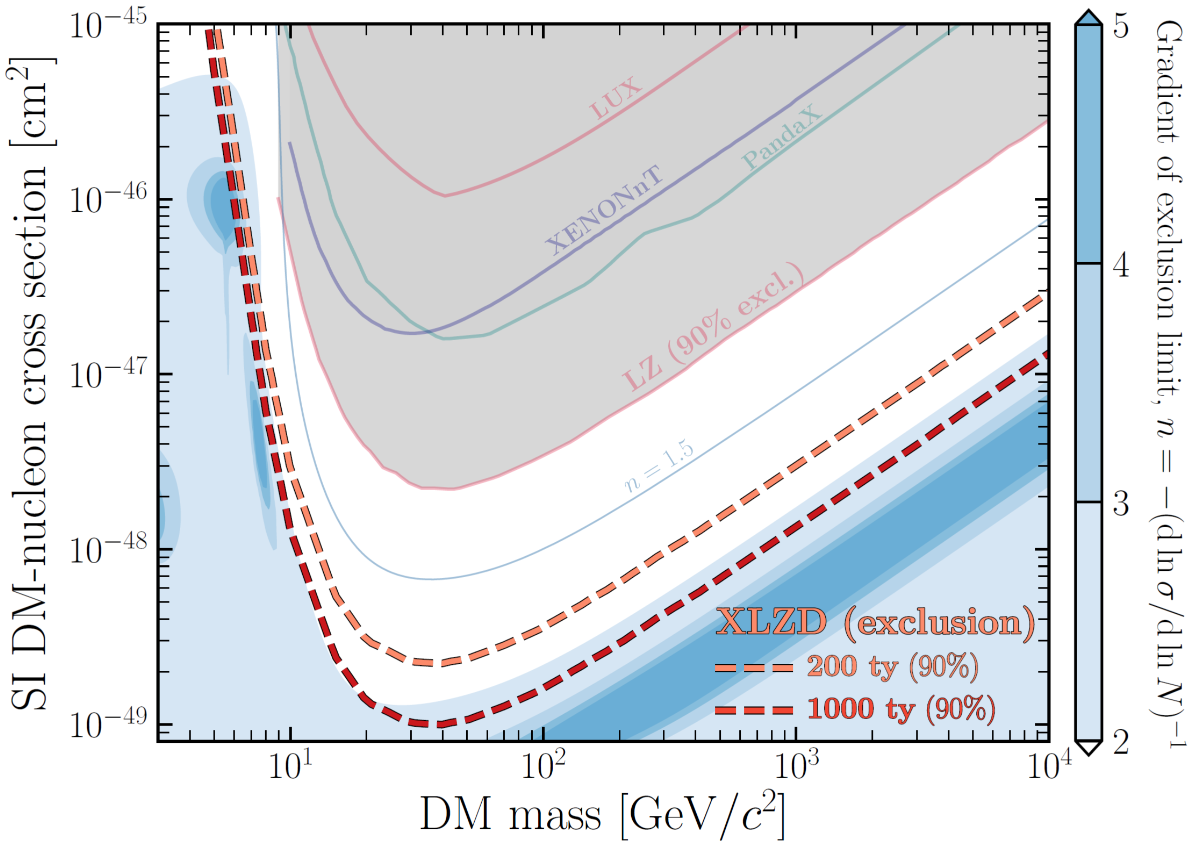


Sun
pp neutrinos
Solar metallicity
^{7}Be, ^{8}B, hep

Dark Matter: Where do we need to go?

- Three O(5 T) dual-phase TPCs currently operational:

  → demonstrated technology!
- PandaX upgrade to 20 T imminent.
- 1000 ty experiment has the potential to be the **ultimate WIMP dark matter** experiment → 60-80 T Xe target.
- Questions:
  - Can multiple experiments jointly maximize scientific reach?
  - How many experiments do we need for an unambiguous observation?



Quo Vadis 0νββ Search?

Current Limit

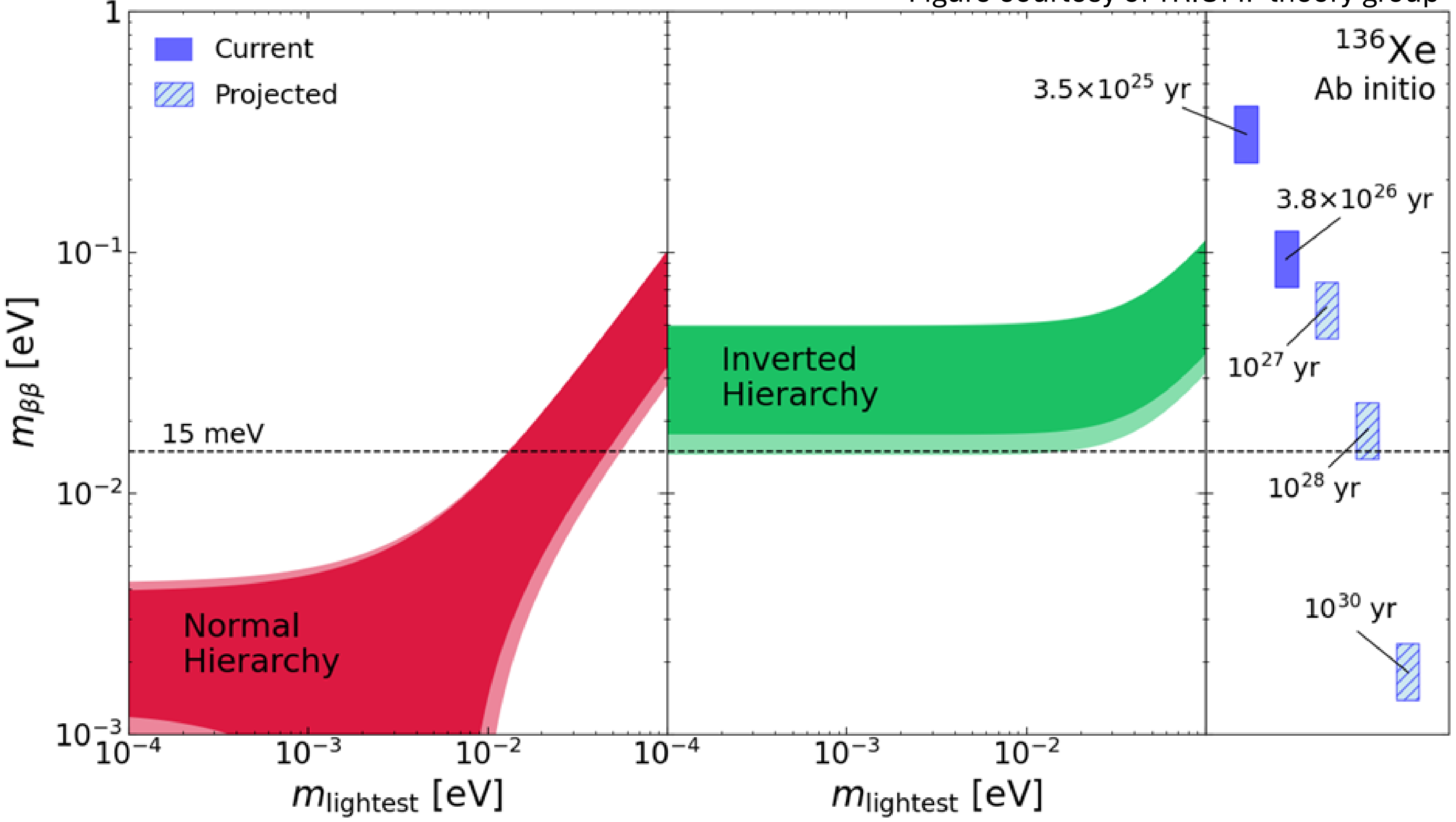
Next-Generation

We know how to do this technically, but funding unclear

Ultimate Experiment?

The ultimate goal in 0νββ of ~1 meV

Figure courtesy of TRIUMF theory group



Deeper Physics Reach

$$\left(T_{1/2}^{0\nu}\right)^{-1} = \frac{\langle m_{\beta\beta}\rangle^2}{m_e^2} G^{0\nu} g_A^4 |M^{0\nu}|^2$$

Phase space factor

Axial coupling, $g_A = 1.27$

NME

Disclaimer: Effective Majorana mass $\langle m_{\beta\beta}\rangle$ is an effective, albeit imperfect, metric to compare physics reach between isotopes and experiments.

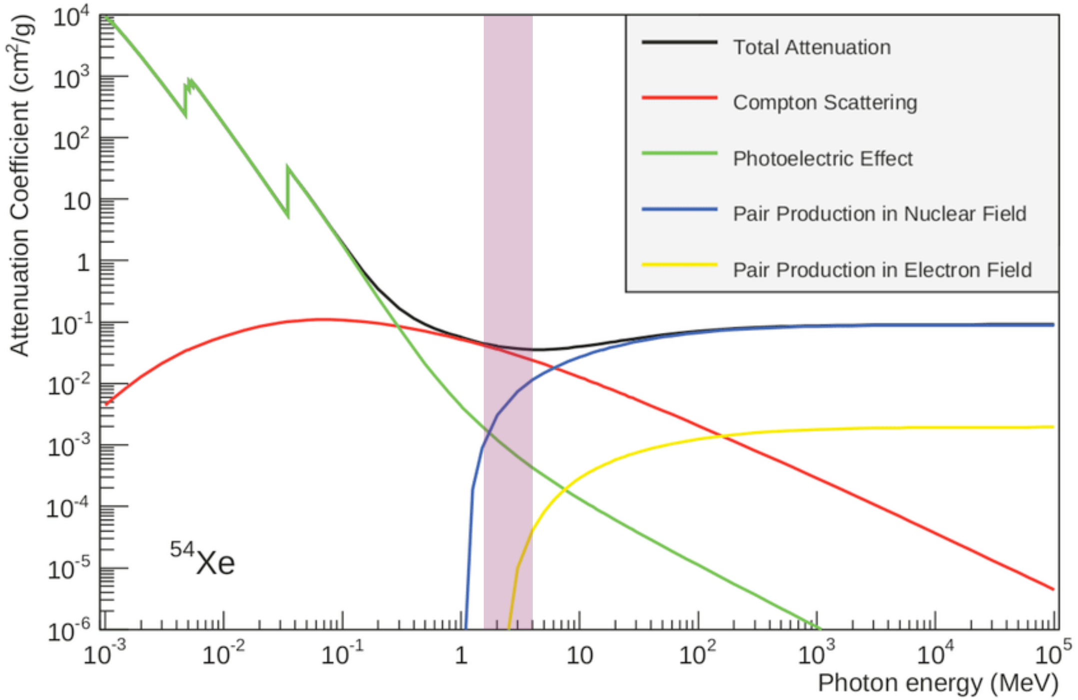
Quo Vadis 0νββ Search?

$Note\!: \sqrt[4]{10} = 1.78$

Background scenario*: $m_{\beta\beta} \propto \sqrt{1/T_{1/2}} \propto \sqrt{1/\epsilon}\left(\frac{b \cdot \Delta E}{M_{\beta\beta} \cdot t}\right)^{1/4}$

*with caveats, counting exp. only, not applicable to multi-parameter fits such as nEXO

BGND; Energy resolution; Mass of isotope



Background free scenario: $m_{\beta\beta} \propto \left(\frac{1}{\epsilon \cdot M_{\beta\beta} \cdot t}\right)^{1/2}$

Detector efficiency; Exposure

Two things to point out:

1) You want to maximize energy resolution and minimize backgrounds! **(but this is not all)**
2) **No matter your detector optimization, you need isotope mass!**

Strategy to reach 10^{28} years: More Isotope

- Ultimately, even a background free experiment is limited by exposure, i.e., by the number of atoms → **a global approach is ideal to procure sufficient Xe-136 for next-generation and future experiments.**

$$\frac{dN}{dt} = \frac{\ln(2)}{T_{1/2}} N = 0.693 \frac{N}{T_{1/2}}$$

^{136}Xe Rate at 10^{28} years:
~0.3 decays/tonne/yr

Mass required for 1 decay/year (average)

Half life [yr]	Atoms	^{76}Ge [t]	^{100}Mo [t]	^{130}Te [t]	^{136}Xe [t]
10^{27} years	1.4×10^{27}	0.18	0.24	0.31	0.32
10^{28} years	1.4×10^{28}	1.82	2.4	3.11	3.26
10^{29} years	1.4×10^{29}	18.2	24	31.1	32.6
10^{30} years	1.4×10^{30}	182	240	311	326

~10 decays/100g/s

0νββ search in ^{136}Xe

- Some of the most competitive 0νββ limits come from Xe experiments (90% CL):
  - PandaX-4T $T_{1/2} > 2.1 \times 10^{24}$ yr (44.6 kg x yr)
  - EXO-200 $T_{1/2} > 1.6 \times 10^{25}$ yr (32.5 kg x yr)
  - EXO-200 $T_{1/2} > 3.5 \times 10^{25}$ yr (234 kg x yr)
  - KamLAND-Zen $T_{1/2} > 3.8 \times 10^{26}$ yr (2.1 t x yr)
- Technical feasibility demonstrated for:
  - Dissolved in scintillator
  - Gas-phase TPC
  - Single-phase **liquid** TPC
  - Dual-phase **liquid** TPC

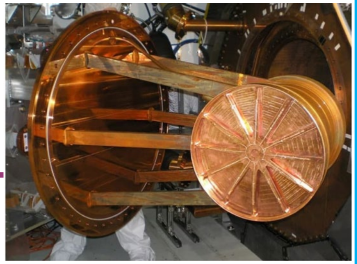
4 technologies!

- **Liquid noble TPC – a demonstrated technology at and beyond the tonne scale.**

0νββ results:
EXO-200: 1205.5608, 1906.02723
PandaX-4T: 2412.13979
KamLAND-Zen: 2406.11438

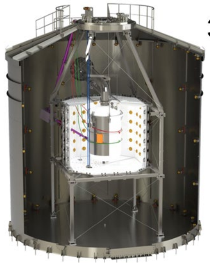
Past

EXO-200 (175 kg)



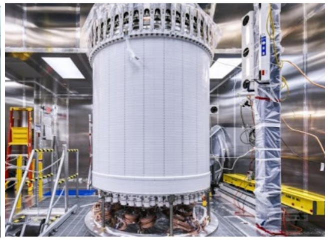
Current Generation

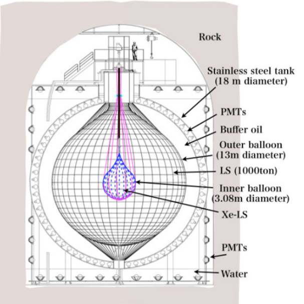
XENONnT (6 Tonne)



3.7 Tonne

LZ (7 Tonne)

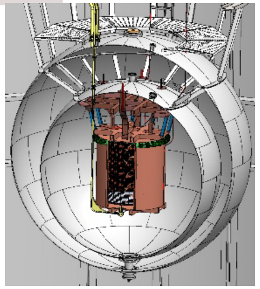




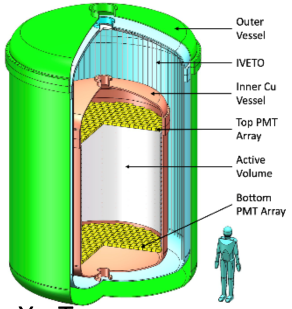
DarkSide-20k (70 Tonne underground Ar)

SBND (112 Tonne Ar)

Next Generation Concepts



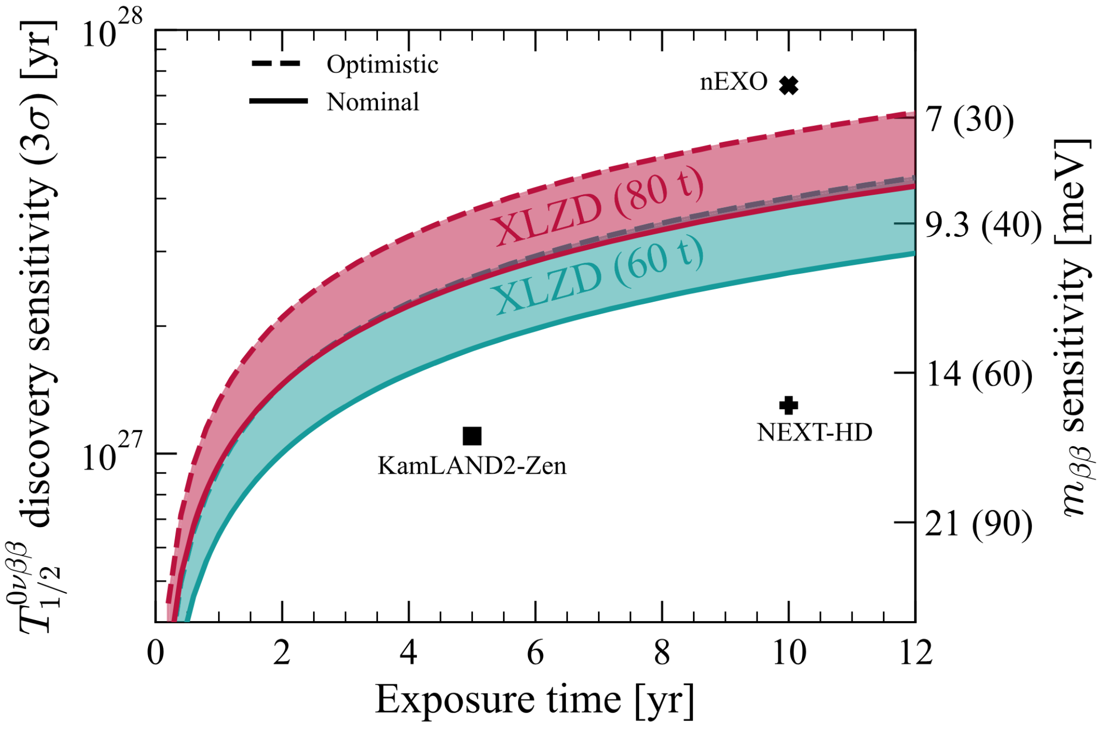
nEXO (5 Tonne)



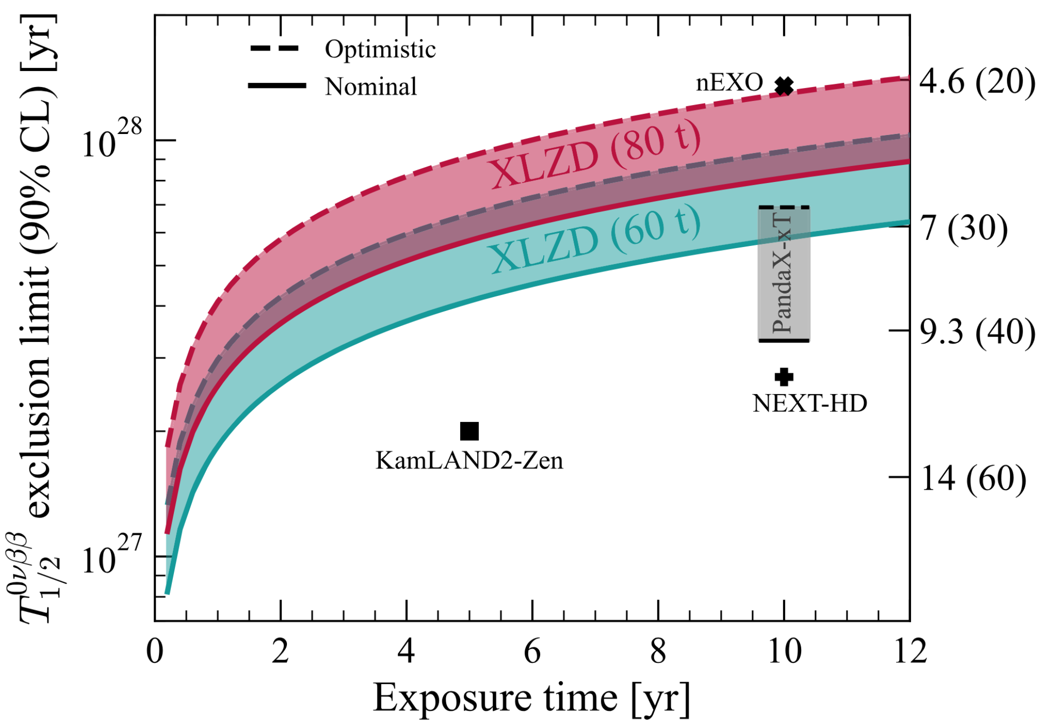
PandaX-xT (43 Tonne)

XLZD (60 Tonne)

Sensitivity Projections



J. Phys. G 52, 045102 (2025)



DM/MP

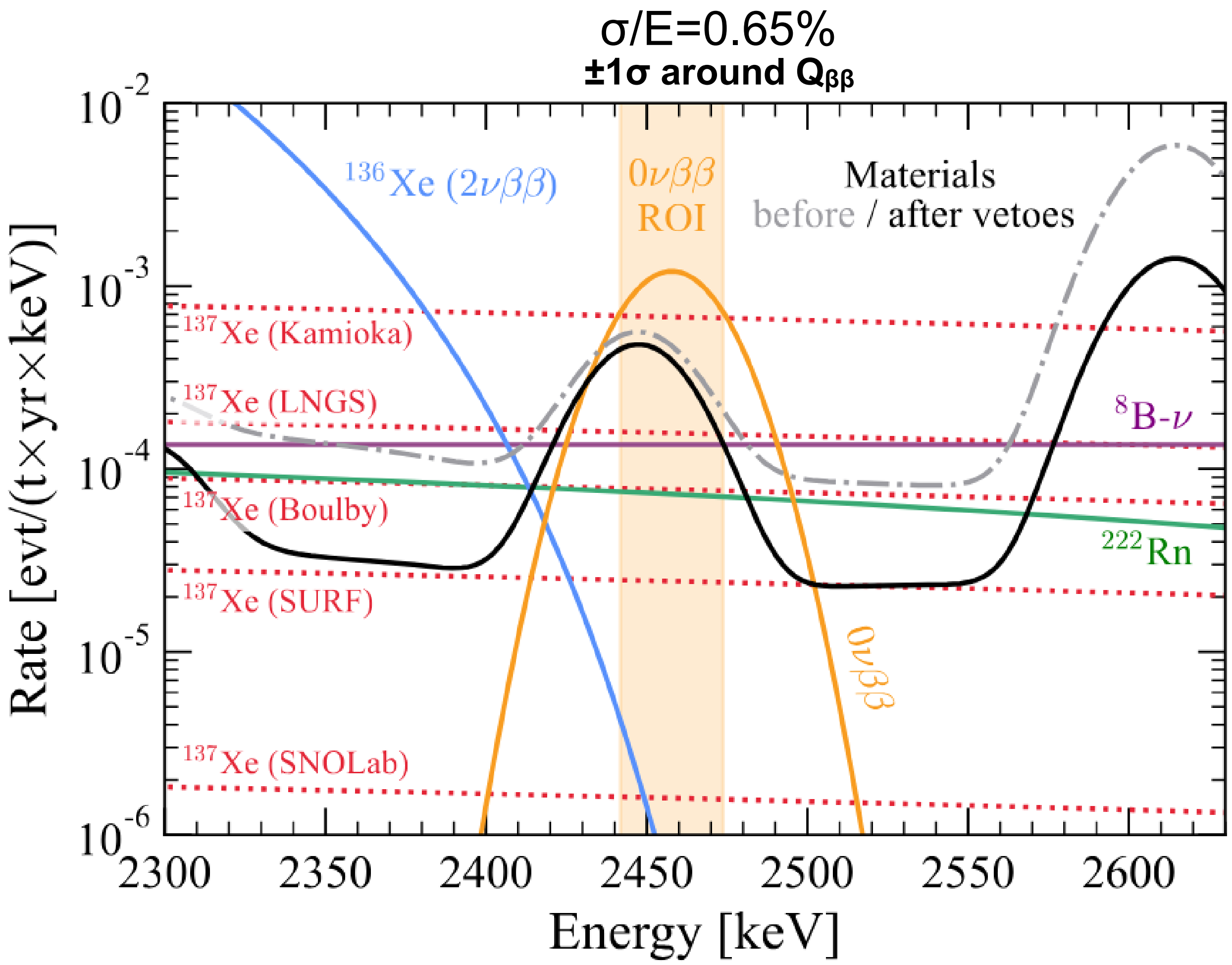
Experiment	Natural Xe	Xe-136 in detector
XLZD	60 t	5.3 t
XLZD	80 t	7.1 t
PandaX-xT	43 t	3.8 t

0νββ

Experiment	Xe-136 in detector
KL2Z	0.68 t
nEXO	3.4 t (90% enr.)
NEXT-HD	0.9 t*

Future-Safe Location

- ^{8}B-ν background ~ total xenon mass → enrichment agnostic.
- ^{222}Rn background depends on detector technology → enrichment agnostic.
- ^{137}Xe background scales with enrichment:
  - For natural xenon XLZD experiment, Boulby or deeper will result in subdominant ^{137}Xe bgnd.
  - For XLZD^{n+} with 90% ^{136}Xe, the ^{137}Xe rate will be a factor ~ 10 higher at all sites.

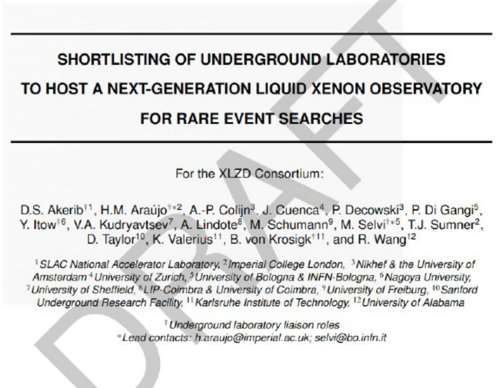


→ SNOLAB (and CJPL) are the only viable options for a forward-looking 0νββ program with XLZD

XLZD Siting

- Host laboratory to be selected in ~~2026~~
- Requirements
  - Minimal **lab-depth driven by 0νββ**
  - lab readiness and country commitment
  - space+accessibility → impacts design decisions
  - underground fabrication/staging if required
- Task-force compiled a detailed siting report
- **Boulby**, **LNGS, SNOLAB** and **SURF** are currently considered
- Discussions with laboratories ongoing

INTERIM REPORT



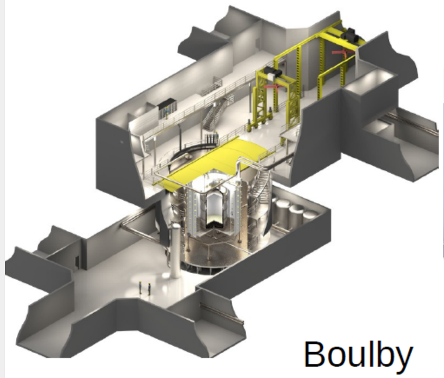
SHORTLISTING OF UNDERGROUND LABORATORIES
TO HOST A NEXT-GENERATION LIQUID XENON OBSERVATORY
FOR RARE EVENT SEARCHES

For the XLZD Consortium:

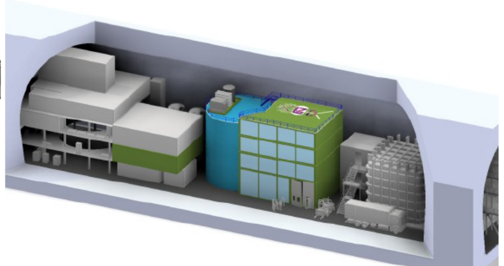
D.S. Akerib[†1], H.M. Araújo[†*2], A.-P. Colijn[3], J. Cuenca[4], P. Decowski[3], P. Di Gangi[5], Y. Itow[†6], V.A. Kudryavtsev[7], A. Lindote[8], M. Schumann[9], M. Selvi[†*5], T.J. Sumner[2], D. Taylor[10], K. Valerius[11], B. von Krosigk[†11], and R. Wang[12]

[1] SLAC National Accelerator Laboratory, [2] Imperial College London, [3] Nikhef & the University of Amsterdam [4] University of Zurich, [5] University of Bologna & INFN-Bologna, [6] Nagoya University, [7] University of Sheffield, [8] LIP-Coimbra & University of Coimbra, [9] University of Freiburg, [10] Sanford Underground Research Facility, [11] Karlsruhe Institute of Technology, [12] University of Alabama

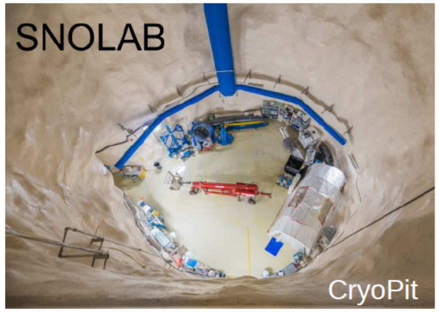
[†] Underground laboratory liaison roles
[*] Lead contacts: h.araujo@imperial.ac.uk; selvi@bo.infn.it



Boulby
new laboratory at 1300 mwe



LNGS
center of Hall C



universität freiburg M. Schumann – XLZD 27

SNOLAB is the best location:
- Future proof!
- Cryopit available!
- SNOLAB expertise!
- Scientific expertise!

XLZD is currently performing site reviews!

Ultimately the decision to site XLZD will be a political decision.

XLZD in Canada - Timeline

Time

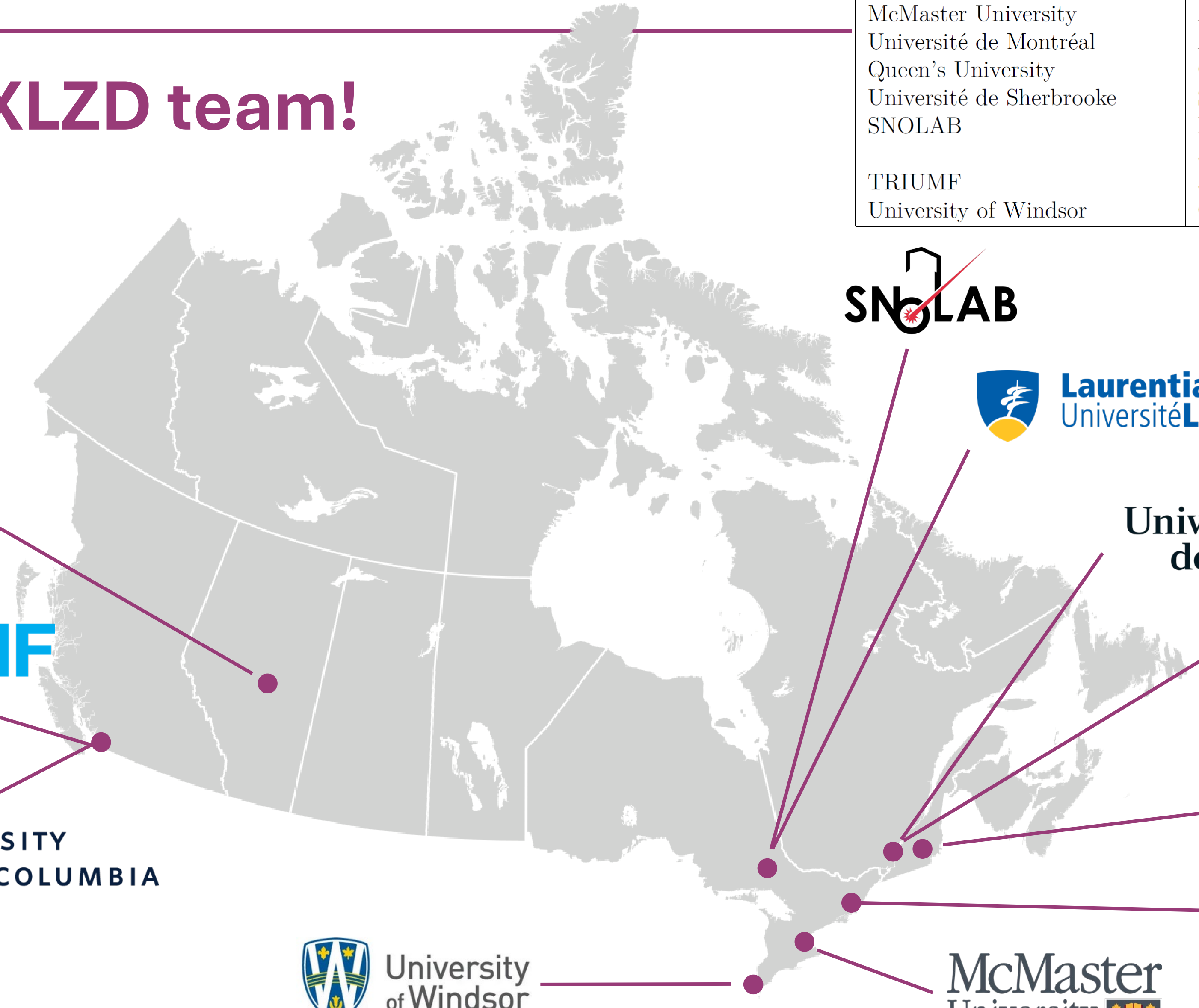
- We (Brunner, Cooley, McDonald, Noble, Smith) submitted a 2-page pitch to the Canadian government for it to make a bid to host XLZD (Nov. 2025). Federal investment is required to attract XLZD to Canada! → **Feedback from Minister Joly's office very positive!**
- **CFI made available CAN$1.2M to advance the XLZD concept at SNOLAB via MSI.**
- Canadian team to officially join XLZD → approved by XLZD IB on March 15, 2026
- Updated the Long Range Plan Committee on our Canadian efforts.
- XLZD Leadership and Canadian PIs met May 5-8, 2026, in Montreal to integrate Canadian scientists in XLZD→ Canadian scientists in each WBS.
- Define and agree upon XLZD-Canada bylaws → underway.
- Develop project, cost model, and governance for a scenario where XLZD is sited at SNOLAB.
- Team to apply for NSERC project funding for XLZD in the Fall of 2026.
- **Submit a CFI proposal to the IF 2027 round requesting support to advance Canadian technology to enhance XLZD's 0νββ sensitivity → planning started.**
- **Expand Canadian team and develop additional expertise.**

Continue engaging with the Canadian government to commit to host XLZD.

Canadian Team

Join the XLZD team!

Institution	PIs
University of Alberta	Carsten Krauss
University of British Columbia	Chloé Malbrunot†
Laurentian University	Christopher Jillings$^{\diamond}$
McGill University	Thomas Brunner, Katelin Schutz
McMaster University	Annika Lennarz†
Université de Montréal	Alan Robinson
Queen's University	Guillaume Giroux, Michela Lai, Stephen Sekula
Université de Sherbrooke	Serge Charlebois
SNOLAB	Erica Caden, Nasim Fatemighomi, Shaun Hall, Christopher Jillings, Christine Kraus
TRIUMF	Jason Holt, Annika Lennarz, Chloé Malbrunot, Fabrice Retière
University of Windsor	Caio Licciardi



- 11 institutions
- 18 PIs (others expressed interest)

Focused Canadian Efforts

XLZD Background Goals

Reduction of material γ-ray backgrounds by factor of 4-10 compared to LZ

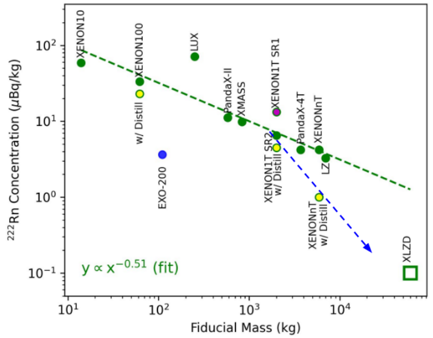
^{222}Rn concentration of <0.1 μBq/kg

^{85}Kr <0.03 ppt with monitoring and online distillation

- At these levels Rn and Kr are sub pp-ν ER rates

screening, low radioactivity materials, and active removal → on target

B. Mong, XeSAT 2026



^{214}Bi SS ROI Events in 8.2t of 60t TPC in 10 yrs with 4x reduction of LZ materials

Component	
TPC PMTs	0.61
PMT structures	0.33
Field-cage resistors	0 *
Internal sensors	0.14
PMT bases	0.24
Cryostat	0.51 ←
PMT cables	0.10
Field-cage rings	0.25
OD tank supports	0
OD foam	0
Skin PMTs	0.04
Other skin parts	0.03
Other components	0.88
Total	3.15

From: XLZD 0vBB Sensitivity (2025) J. Phys. G: Nucl. Part. Phys. 52 045102

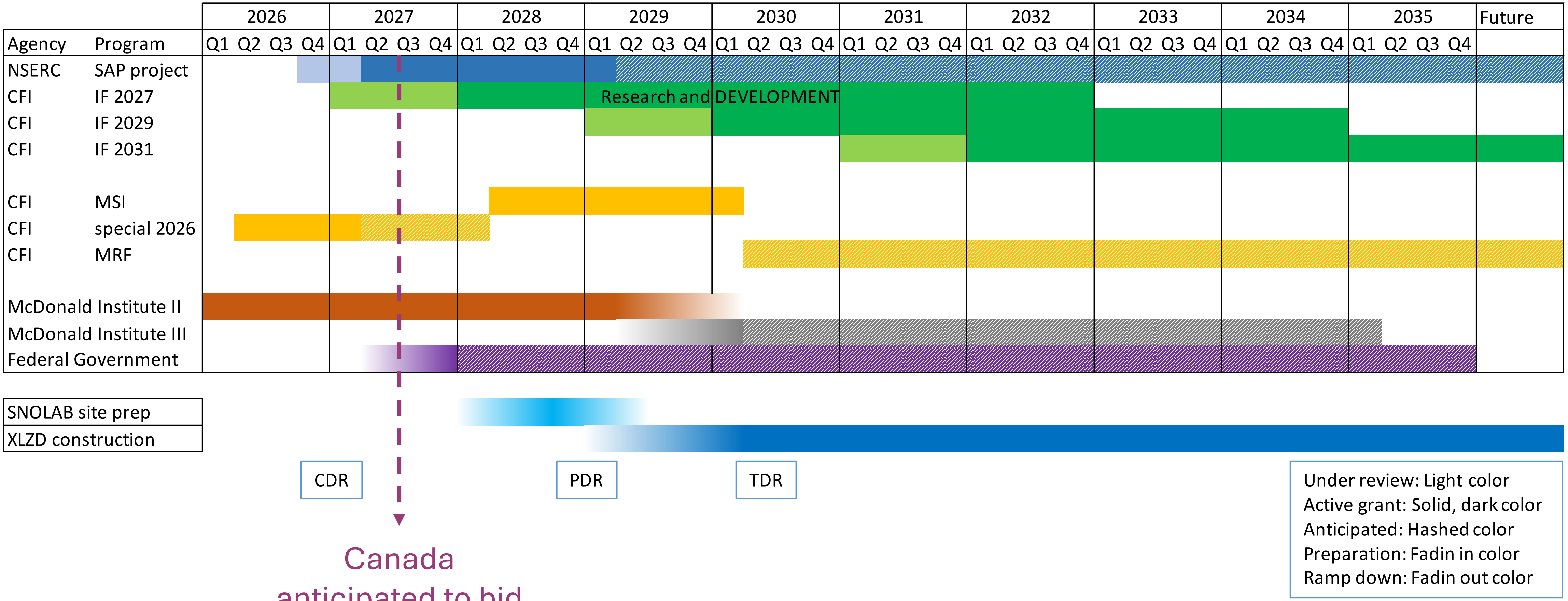
* Amorphous silicon resistors (2026) https://doi.org/10.1016/j.nima.2026.171547

Ultrapure Nickel (2026) https://doi.org/10.1016/j.nima.2026.171402

5

- Leveraging Canadian expertise to realize XLZD at SNOLAB.
- Identify in simulations detector components that could be improved to increase (0vββ) sensitivity.
- Advance Canadian technology to improve scientific reach of XLZD:
  - Photosensors
  - Radiopure Ni (CVD-Ni)
  - *[YOUR IDEA]*

Funding strategy and schedule



<u>Assumptions:</u>

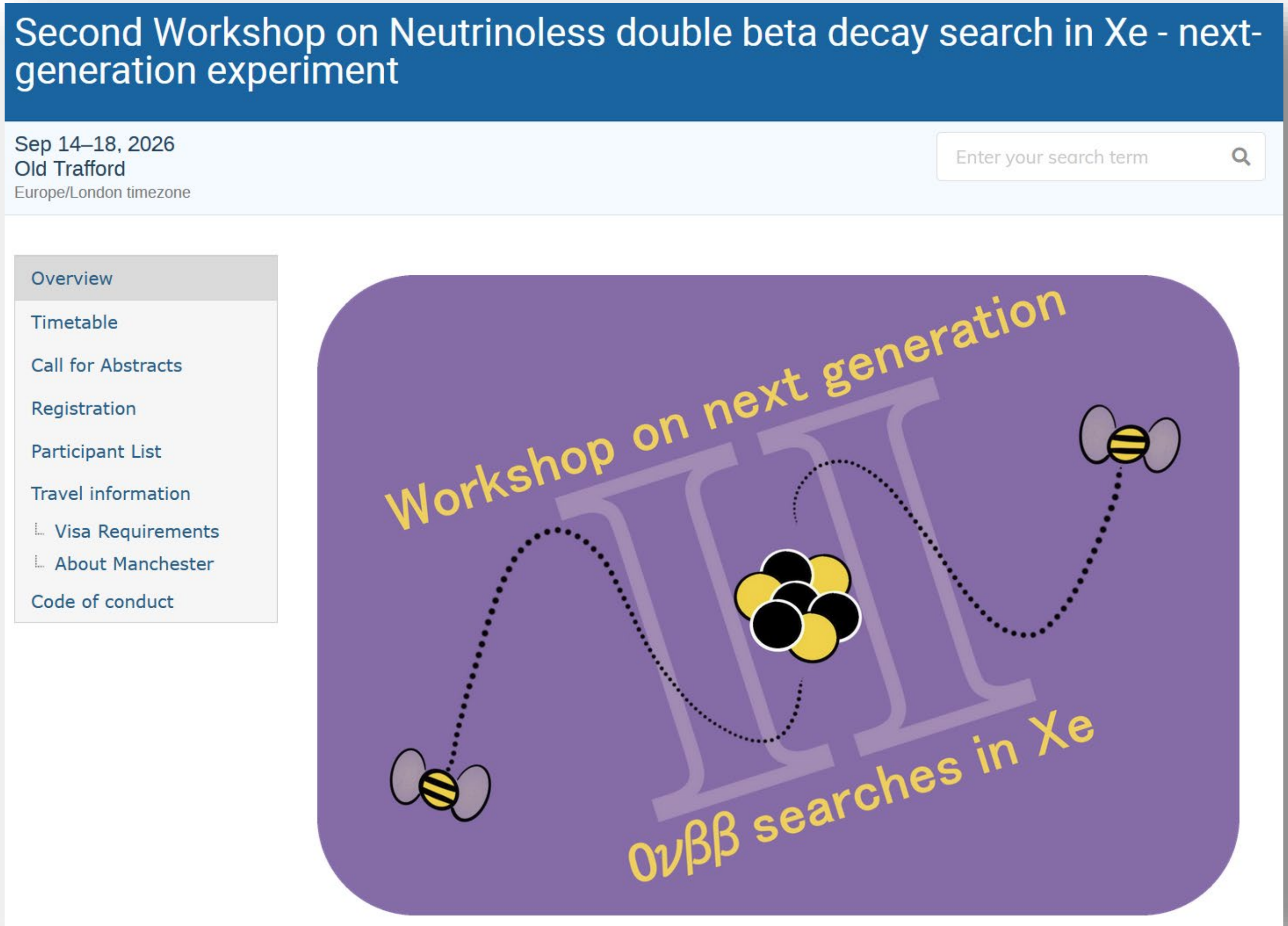
- XLZD located at SNOLAB
- Pre-construction cost partially supported by federal government.
- Construction cost supported by federal government.

Conclusion

- XLZD is the most promising next generation flagship experiment.
- XLZD aims for world-leading sensitivities in two mayor physics channels: $0\nu\beta\beta$ and Dark Matter

- A growing team of Xe-enthusiast is forming within Canada with the goal of realizing XLZD at SNOLAB.
- We are starting to develop plan and strategy → the time is now to get involved and join our efforts!

Advertisement: Join the discussion!



Join us Sept. 14-18, 2026 in Manchester:
https://indico.global/event/17139