PPAP Community Meeting

Community submissions to

Strategy Update

Neutrino Physics

Collated by

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STFC Science Challenges and Neutrino Physics

Science and Technology Facilities Council

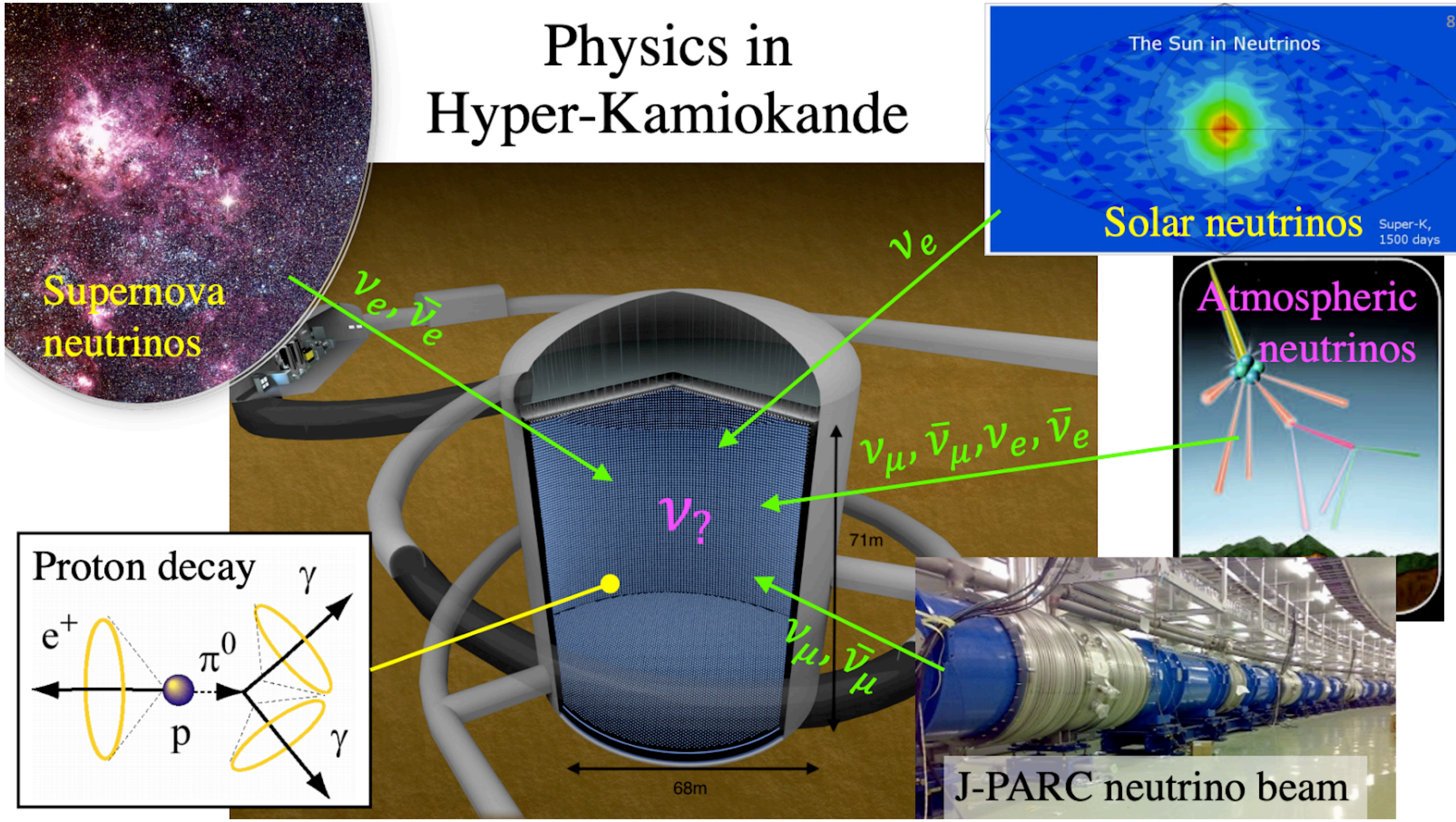
C:1. What are the fundamental particles and fields?	C:2. What are the fundamental laws and symmetries of physics?	C:3. What is the nature of space-time?
C:4. What is the nature of dark matter and dark energy?	C:5. How do quarks and gluons form hadrons?	C:6. What is the nature of nuclear matter?
C:7. Are there new phases of strongly interacting matter?	C:8. Why is there more matter than antimatter?	C:9. What will precision measurements of the Higgs boson reveal about the Universe?

Submitted Inputs

- HyperK (neutrino oscillations)
- LEGEND ($0\nu\beta\beta$)
- SNO+/future LS ($0\nu\beta\beta$)
- Not a comprehensive list by any means. Expect more in the future.

HyperK Mission

- Microscope for discovering properties of neutrinos
  - CP Violation
  - Neutrino mass ordering
- Neutrino telescope for observing the cosmos
- Proton decay



HyperK Overview

- 18 countries, > 80 institutions
- Beam upgrade, far-detector excavation, significant parts of far detector approved in Jan-2020 by Japanese government.
- Three Facilities: J-Parc, Near and Intermediate detectors, HyperK Far Detector
- Timeline:
  - Construction: Apr’21 – Mar’27.
  - Operational from 2027 for at least 20 years

HyperK. UK Groups.

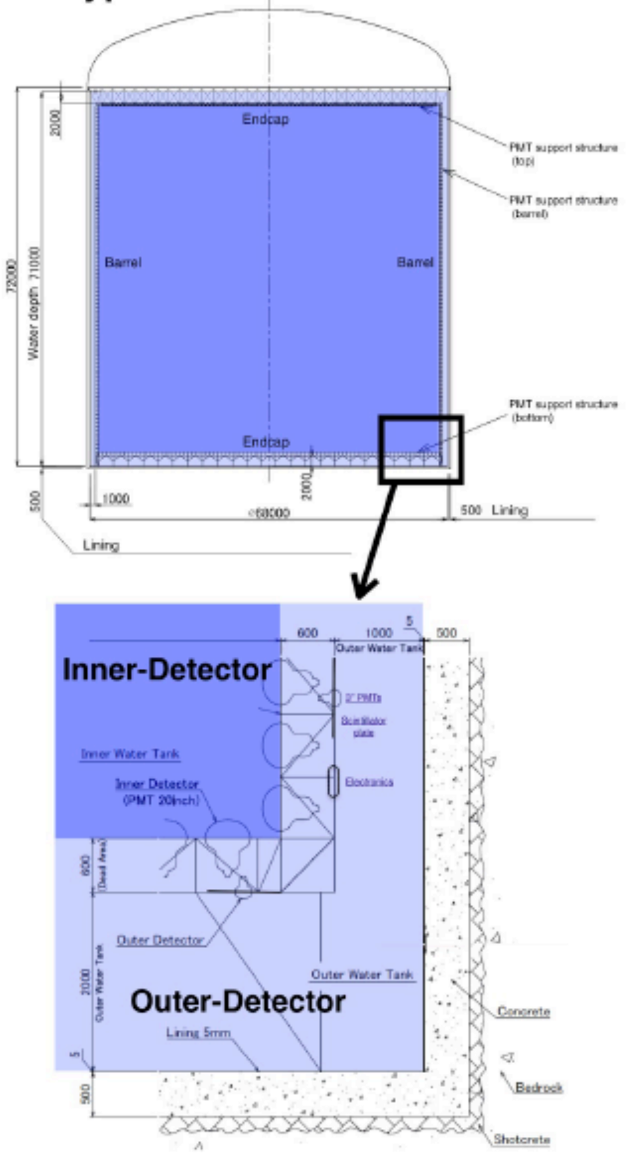
- University of Edinburgh
- University of Glasgow
- Imperial College London
- King’s College London
- Lancaster University
- University of Liverpool
- University of Oxford
- University of Sheffield
- STFC/RAL
- University of Warwick

- UK -- largest participating country after Japan
- Leadership positions (one of the two Project Leaders) building on high-profile roles in T2K and Super-Kamiokande collaborations

HyperK. UK Contribution

- Leverages investment in T2K and builds on expertise from SNO, MINOS, LHCb etc
- Leading UK involvement in critical areas:
  - Outer Detector for HyperK
  - DAQ and calibration for HyperK and IWCD
    - ToolDAQ
    - Light Injection calibration
  - Target for upgraded J-PARC beam
    - Leveraging expertise in high-power target design
    - Capable to sustain 1.3 MW
    - Increase **ν**-yield, reduce wrong sign background
  - Capital investment in UK industries to design, manufacture and assembly components

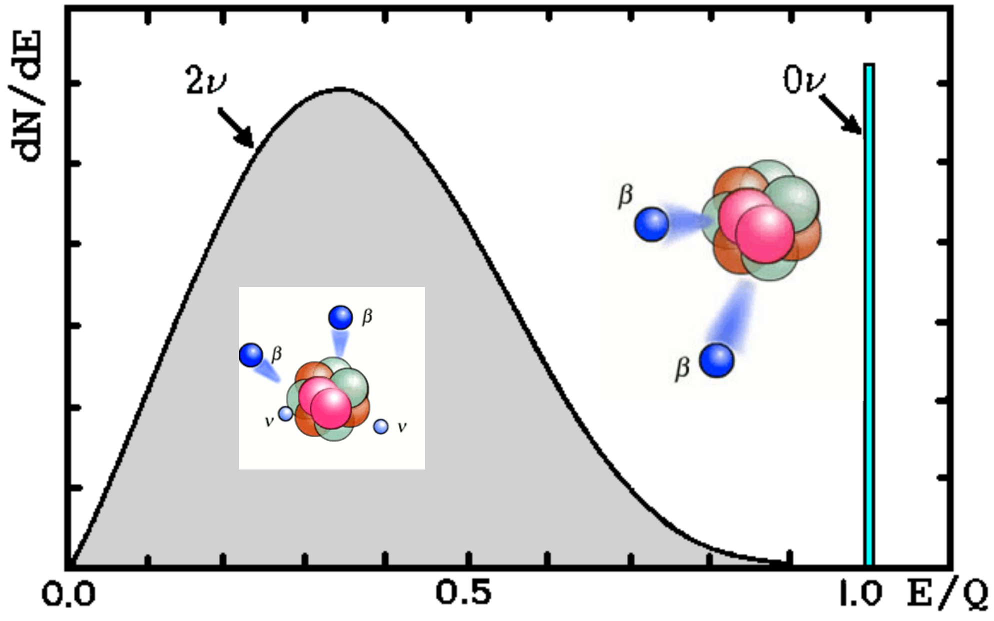
Cross section of
Hyper-Kamiokande detector



Neutrinoless Double Beta Decay

- $0\nu\beta\beta$ is only practical way to address Lepton Number Violation → Matter-antimatter asymmetry
- Access to absolute neutrino mass scale
  - Next-Gen: Inverted Ordering: I.O. ~20-50 meV
  - $Next^2$-Gen: Normal Ordering: N.O. ~1-10 meV

For SuperNEMO Exploitation: see M. Agostini's talk in the morning



Two submissions for longer term future : LEGEND and SNO+/LS

LEGEND

- UCL
- University of Liverpool (Nuclear and Particle)
- University of Warwick
- Lancaster University
- University of Manchester (Nuclear)

SNO+

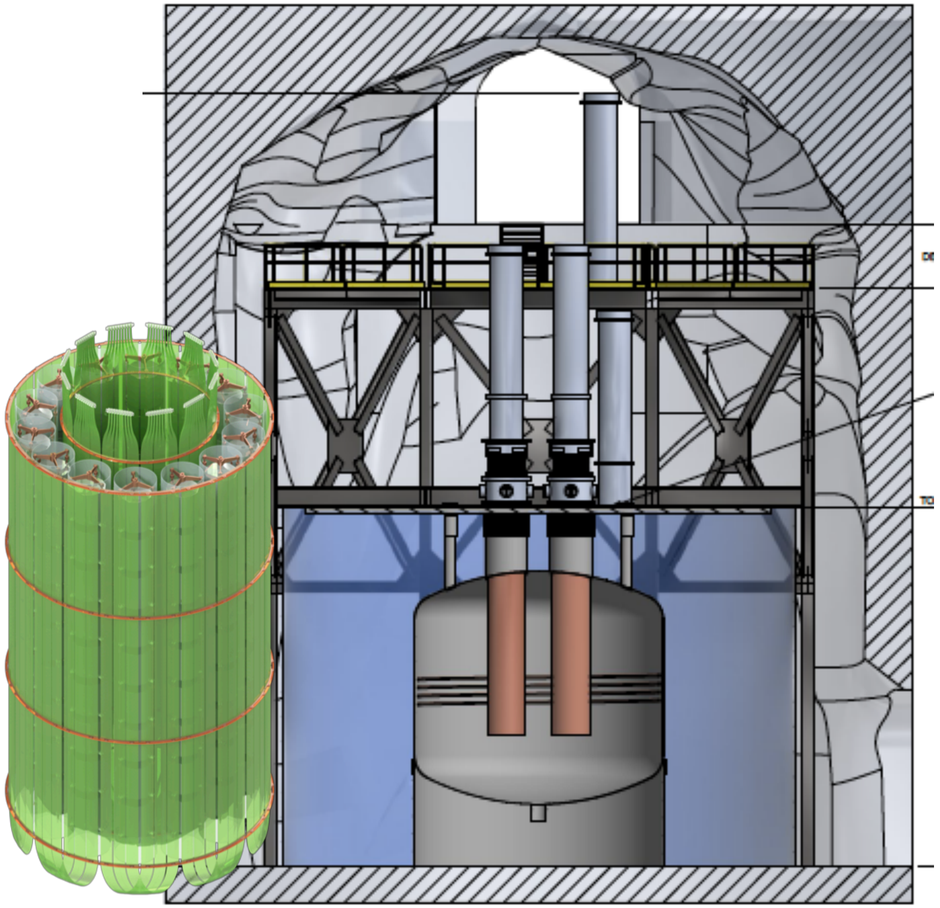
- University of Oxford
- University of Sussex
- King's College London
- Lancaster University
- University of Liverpool

LEGEND Overview

- HPGe detectors with particle ID in active LAr shield
- Best energy resolution and lowest background in ROI on the "market".
- Zero background concept, focus on discovery potential
- Phased approach from funded LEGEND-200 at LNGS to LEGEND-1000
- High technical readiness, low cost uncertainties
- Discovery potential (3**σ**): 10^{28} yr, 9-17 meV, fully covering inverted mass ordering

<u>LEGEND-1000:</u>

- 1000 kg of ^{76}Ge, staged via individual payloads
- Background goal <0.03 cts/(FWHM t yr),

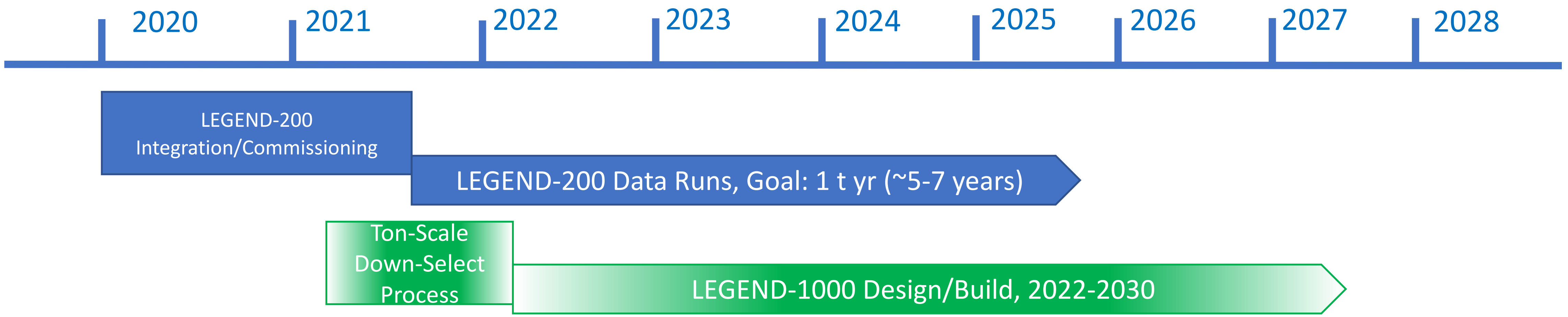


LEGEND UK Contributions and Timescale

- HPGe detector characterisation
- Novel HPGe detector development
- Radio-assays
- Software and Analysis
- Novel Scintillating materials (PEN)

- Founding members of collaboration
- Leadership roles (Analysis Coordinator, IB Chair, Steering Committee)

Leveraging UK investment in nuclear physics (e.g. Agata), Low-background expertise and infrastructure (e.g. Boulby), detector technologies, as well seed corn STFC Opportunities funding (£140k).



Earliest, and optimistic, LEGEND-1000 Data Start 2027/8

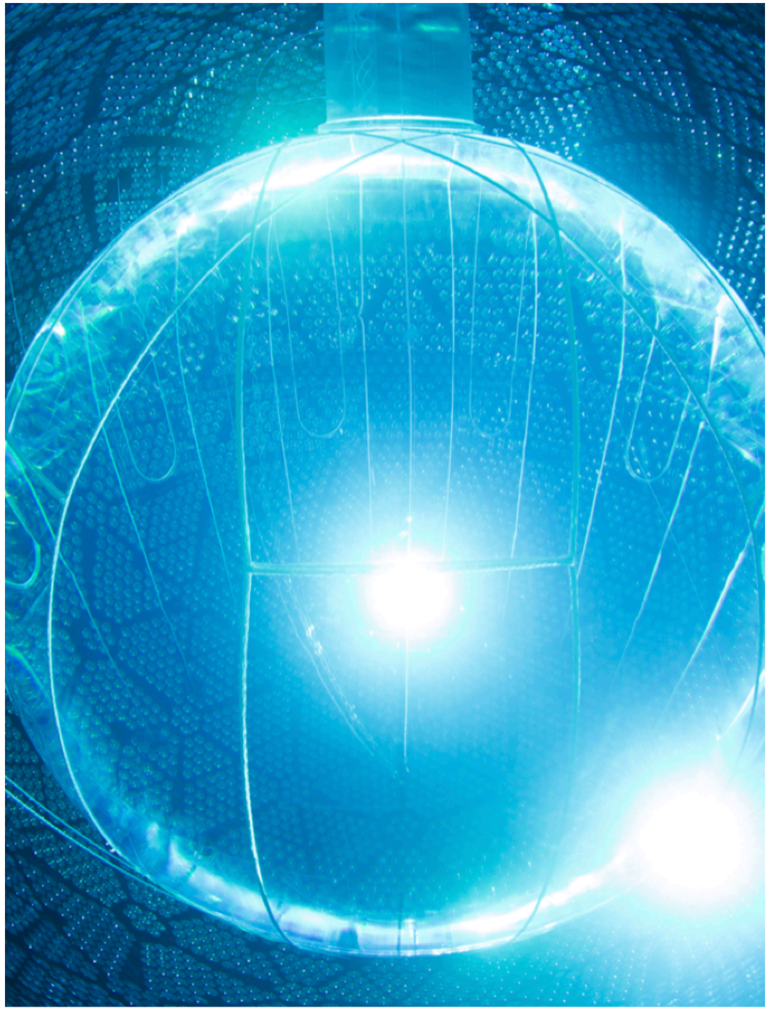
LEGEND. International Context and synergies

- Strong push by international community for at least 2(3) experiments with different isotopes and technologies.
- LEGEND is one of main contenders in US “down-select” (with nEXO, CUPID)
- LEGEND is one of main contenders in European programme (with CUPID, NEXT/DARWIN).

- Intrinsically interdisciplinary: Particle and Nuclear physics communities
- Low BG: Radio-assay and analysis/detector techniques directly applicable to Dark Matter
- LAr: synergy with low-background physics for DUNE
- Strong industrial connection with international HPGe producers: MIRION, ORTEC – environmental, nuclear industry, security.

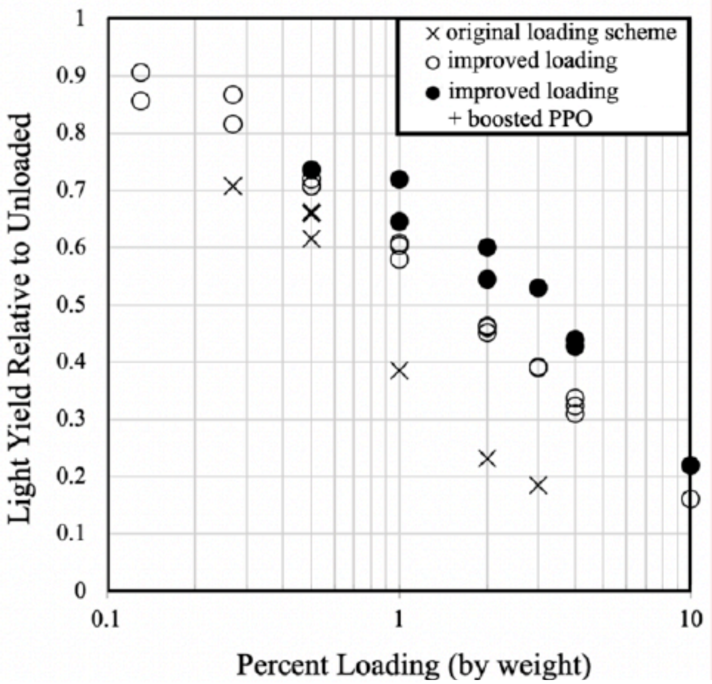
SNO+

- Using existing SNO infrastructure
- Loading natural Te ($\beta\beta$ isotope ^{130}Te) in 0.8 kT liquid scintillator
- Phased approach, from 0.5% loading up
- Scalability. Most economical $\beta\beta$ isotope (enrichment may not be needed)
- Other physics (e.g. solar and supernovae neutrinos)



SNO+/Future LS Strategy

- New promising Te loading technique in LAB scintillator
- Pathway from 0.5% to 2.5% loading ⇢ 6.7t of ^{130}Te in SNO+ volume at modest cost (~£10M for ^{nat}Te)
- SNO+ combines
  - Competitive sensitivity to probe I.O.
  - High isotope loading demonstration
  - Solar ν-background suppression with Cerenkov directionality



- Further future: loading in gigantic LS (e.g. JUNO, 20 kT). Potentially most economical scaling up to N.O. *if* backgrounds drastically reduced

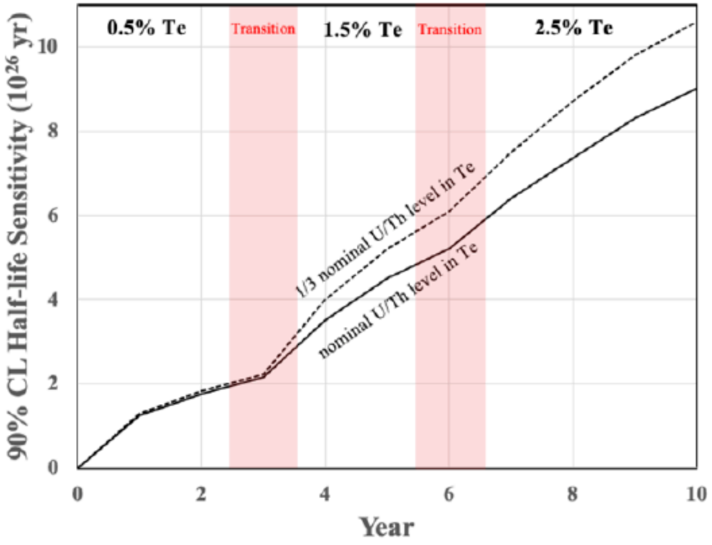


Fig 2: Phased loading scenario for SNO+

SNO+ Sensitivity, timeline and UK role

- Te loading concept originated in UK (S. Biller, Oxford)
- Leadership roles
  - Te-development, Calibration, Data Quality, Analysis, Background group
  - Science Board, Executive Committee, Finance Committee, Resource Committee
- High Loading: UK seeks to contribute £1.5M of expected £10M for Te in phased deployment over 10 years
- Timeline depends on success of enhanced loading