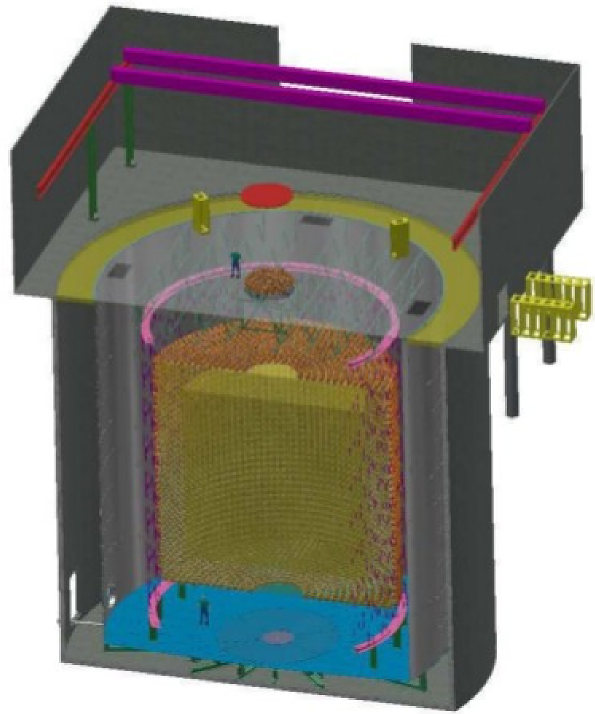
AIT Beyond NEO



Matthew Malek
(on behalf of the WATCHMAN Scientific Collaboration)

Boulby Feasibility Study Community Meeting
26th February 2021

Advanced Instrumentation Testbed

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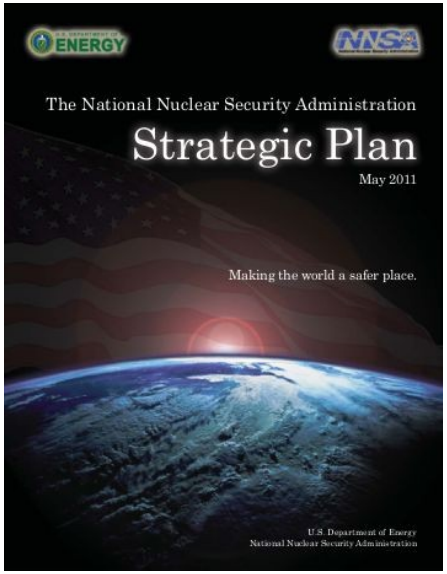


AIT evolved as an expansion from WATCHMAN, an applied antineutrino physics project to demonstrate remote monitoring of nuclear reactors for non-proliferation objectives.

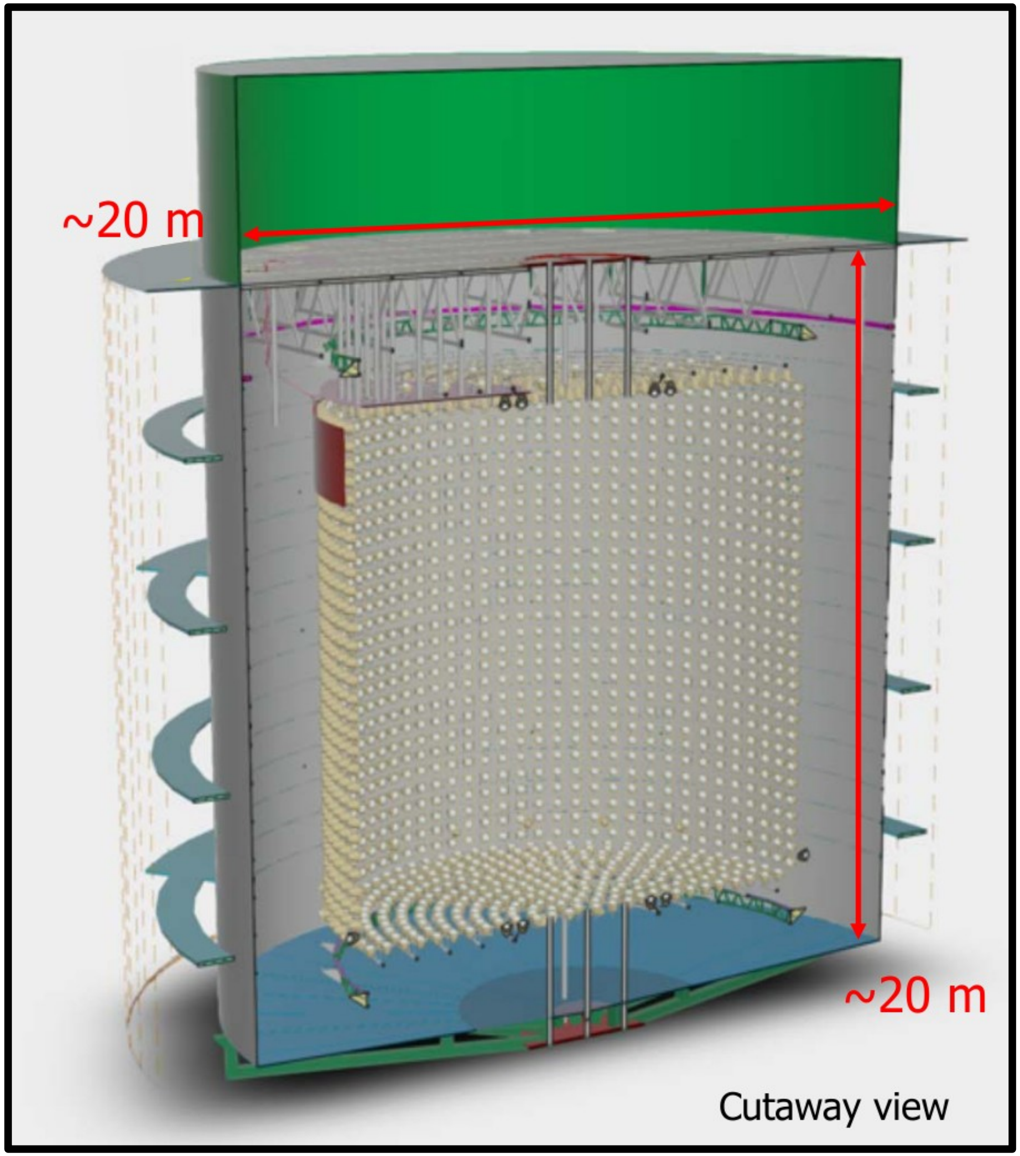
The primary sponsor is US National Nuclear Security Administration, Office of Defense Nuclear Nonproliferation.

Baseline design includes a cylindrical cavern measuring ~25m diameter, ~30m height, with clean room lab space, etc.

Neutrino Experiment One (NEO)

Baseline design includes:

- Kilotonne-scale fiducial mass
- 0.1% Gd-loaded water **or** water-based liquid scintillator
- ~3600 Hamamatsu 10" PMTs with:
  - High quantum efficiency (~30%)
  - Low radioactivity (esp. U and Th)
  - 20% photocathode coverage
- Active veto region (~1.5 metre)
- Located at 1100 metre level



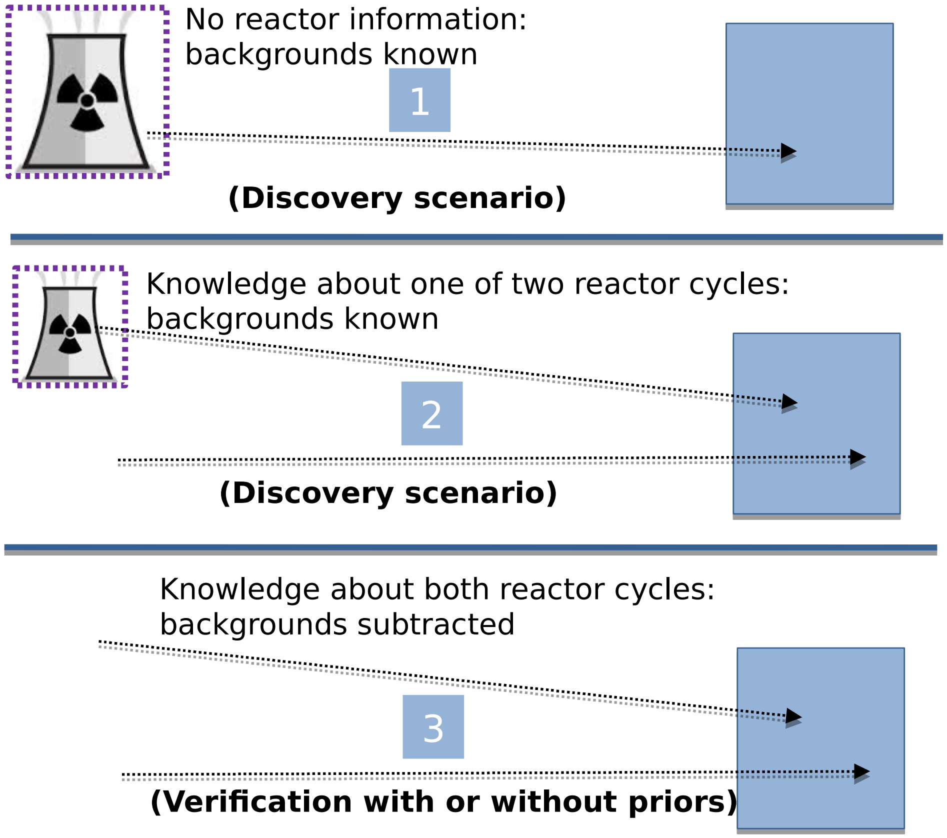
Non-Proliferation Scenarios

Discovery Scenarios (Project Goal 1):

- **Case 1:** Determine whether any reactor is present.
- **Case 2:** Knowing that one reactor is operating, determine that a second reactor has turned on.

Verification Scenario: (Project Goal 2)

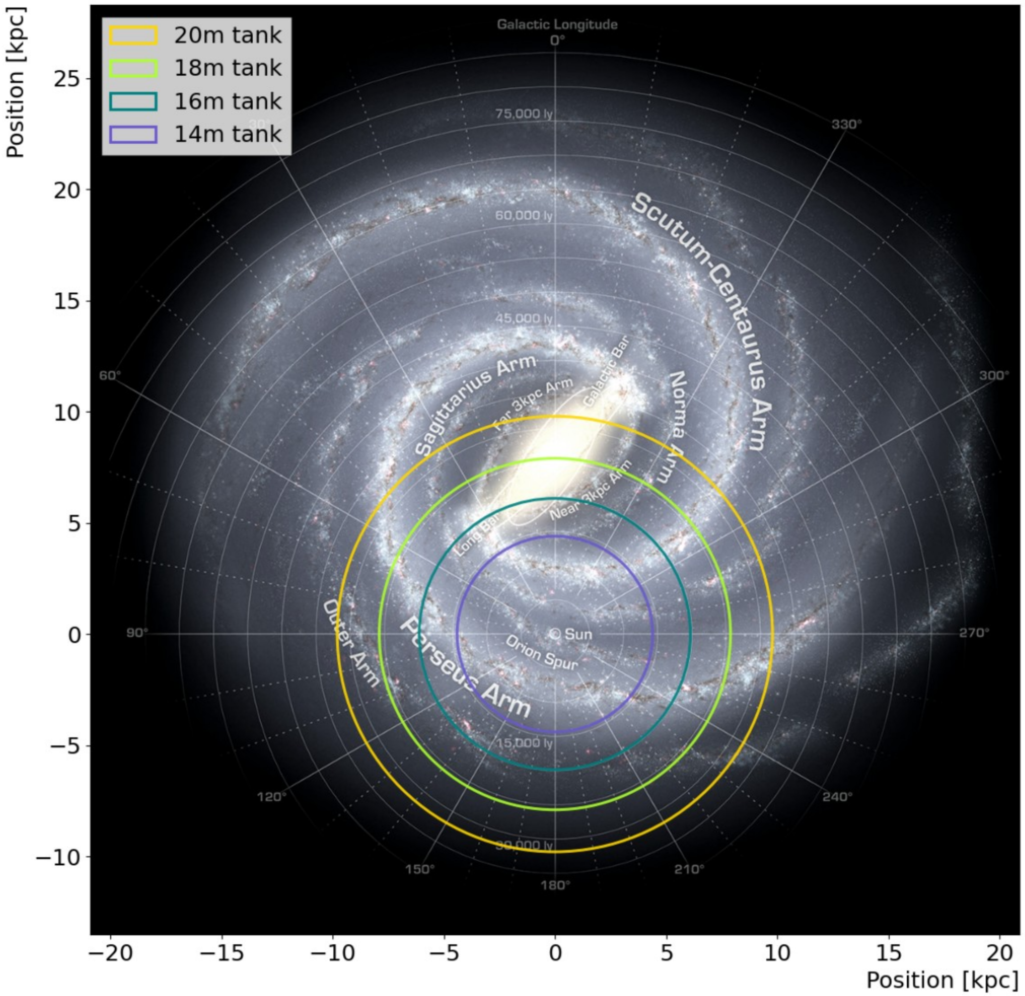
- **Case 3:** Confirm operational status <u>with or without prior knowledge</u> of both reactor cycles.

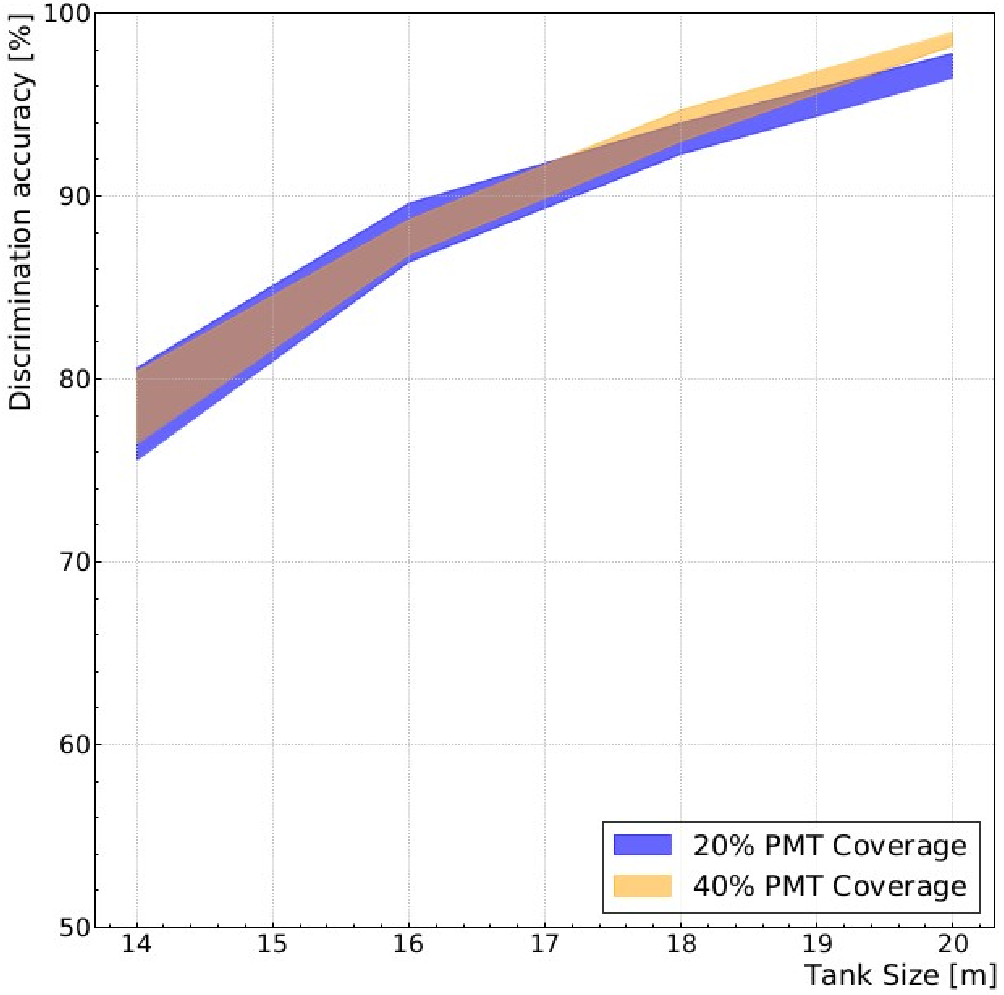


The baseline AIT design is rated for a minimum 15-year lifetime.
The NEO mission should be completed in 1 – 2 years of operation.

Thus, a sensitivity study was commissioned to show physics potential for AIT after the conclusion of NEO.

Supernova Model Discrimination





Supernova model discrimination using Gd-loaded water.
Left shows radius of 90% model discrimination, based on tank size.
Right shows sensitivity to canonical SN burst, also with tank size.

CNO-cycle Solar Neutrinos

With the first announcement of a CNO-cycle solar neutrino measurement last year, by Borexino, we have looked AIT sensitivity using water-based liquid scintillator (1% and 3%) as a target.

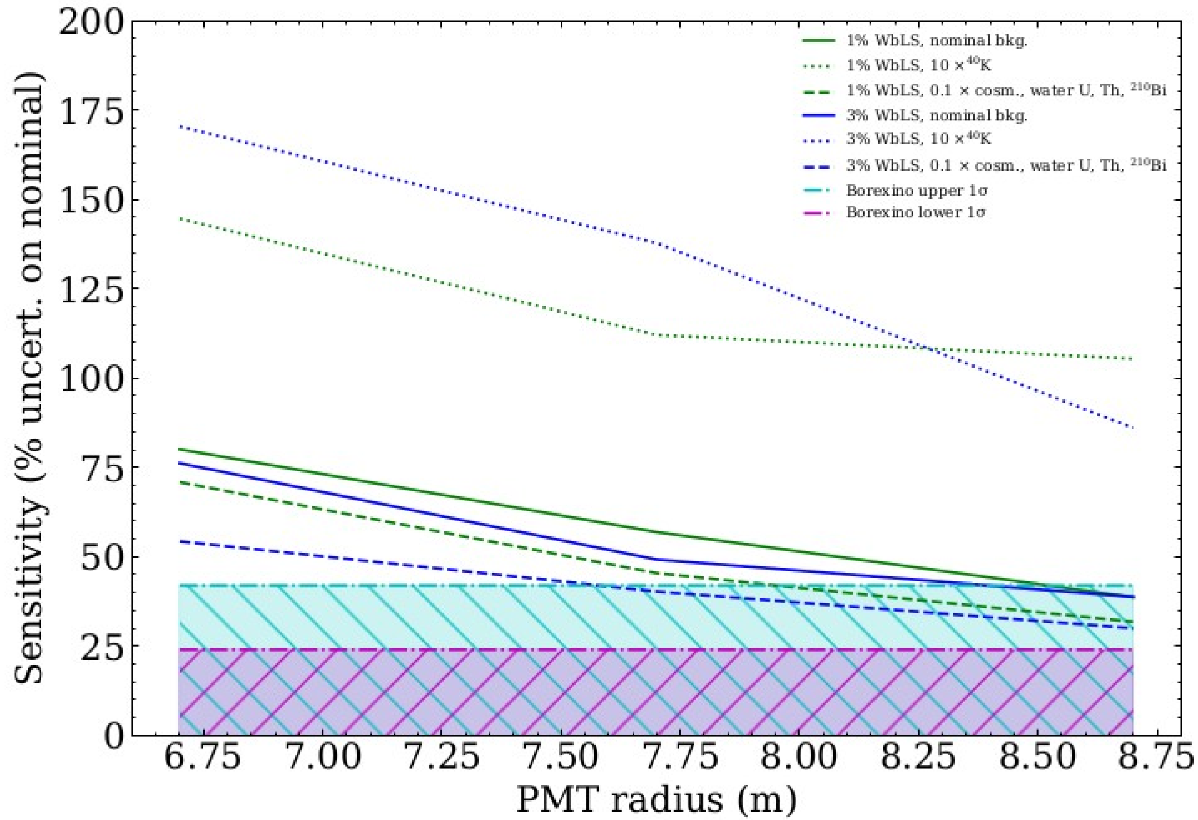
Relative to Borexino:

Advantages:

- (Much) bigger

Challenges:

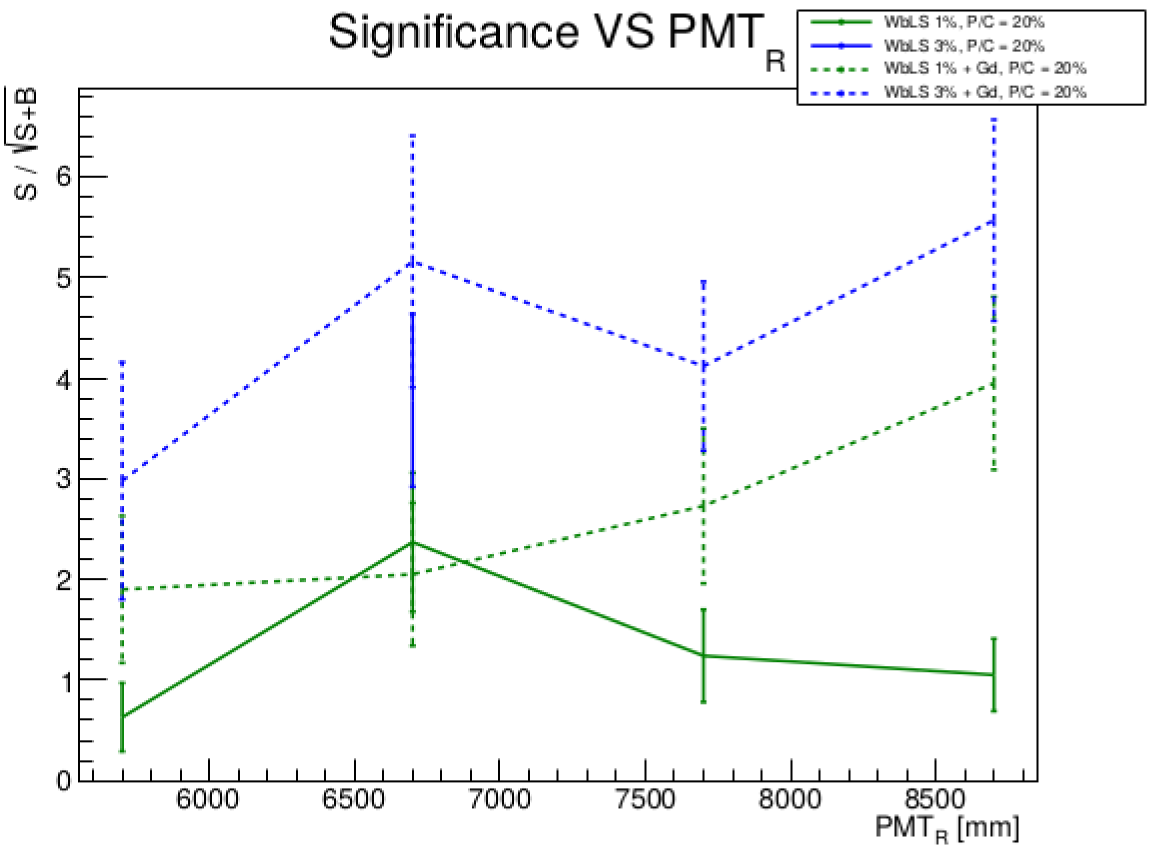
- Cleanliness
- (Much) lower light yield



Preliminary results show sensitivity equals Borexino in ~5 years. Possible to do better if we use pure scintillator (instead of WbLS).

Geo (anti) neutrinos

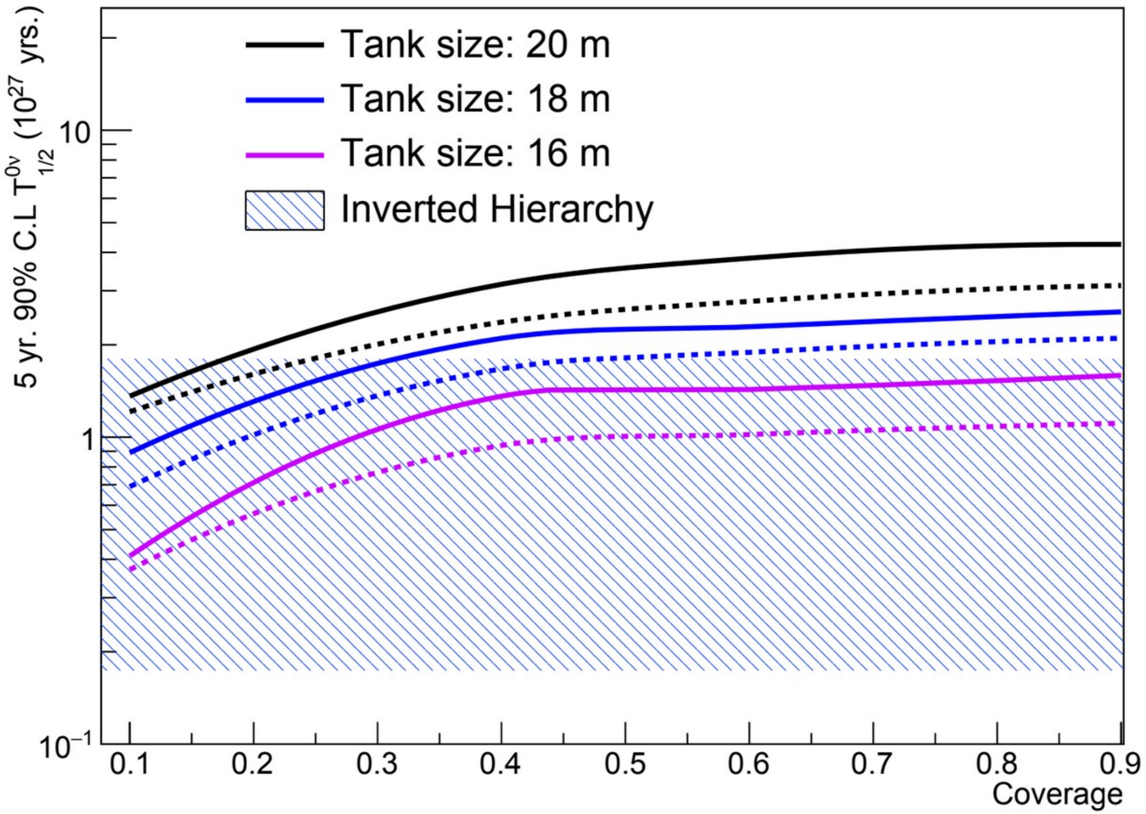
Fills considered with WbLS as well as Gd-loaded WbLS.
Results from a 10-year exposure are:



For baseline design, 3σ detection can be achieved in 5 years with a 3% WbLS fill and 20% photocoverage. Gd-loading improves this sensitivity (as does increased photocoverage).

Neutrinoless Double Beta Decay

This study used **pure liquid scintillator** (in inner vessel) not WbLS.
→ very much AIT beyond the scope of NEO



For baseline detector size (20m tank):
5 year exposure with LS can cover full inverted ordering region
Requires additional photocoverage (ideally 40%)

Additional Possibilities

Physics topics proposed but not yet studied include:

- Sensitivity to neutrino mass ordering from supernova burst
- Supernova pointing accuracy
- Sensitivity to supernova relic neutrinos (DSNB)
- Invisible neutron decay to three neutrinos

In addition, we have received expressions of interest for use of the AIT facility from outside of the existing WATCHMAN Scientific Collaboration, including from:

- DarkSide-LM (see earlier talk from Darren Price)
- CYGNUS

N.B. Current baseline AIT has been developed to 50% conceptual design level, and exceeds current project budget. At present, value engineering exercises are in progress, as well as investigating options for procuring additional funding.