Letter of Interest: **The IsoDAR (Isotope Decay At Rest) nu-e-bar source**

Primary Frontier: Neutrino Physics / Artificial Neutrino Sources **NF0**9
Additional Frontier: Accelerators / Technology – Targets, Sources **AF7**
Underground Facilities **UF**

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The IsoDAR experiment [1,2] will provide a highly sensitive search for sterile neutrinos, by placing a powerful source of electron antineutrinos in close proximity to a kiloton-scale liquid scintillator detector such as KamLAND. A compact cyclotron produces a 10 mA beam of 60 MeV protons [3] that strike a neutron-producing target. These neutrons are captured in a sleeve surrounding the target, consisting of a mixture of beryllium and highly-enriched (>99.99%) ^{7}Li. The ^{8}Li neutron-capture product decays within 1 second yielding a high endpoint-energy nu-e-bar that is detected via inverse-beta decay (IBD) in the detector. For the most-favored parameters for sterile neutrinos, the nu-e-bar oscillation pattern has maxima and minima within the volume of the detector, providing exquisite sensitivity for discovery of one or more sterile neutrinos through shape analysis.

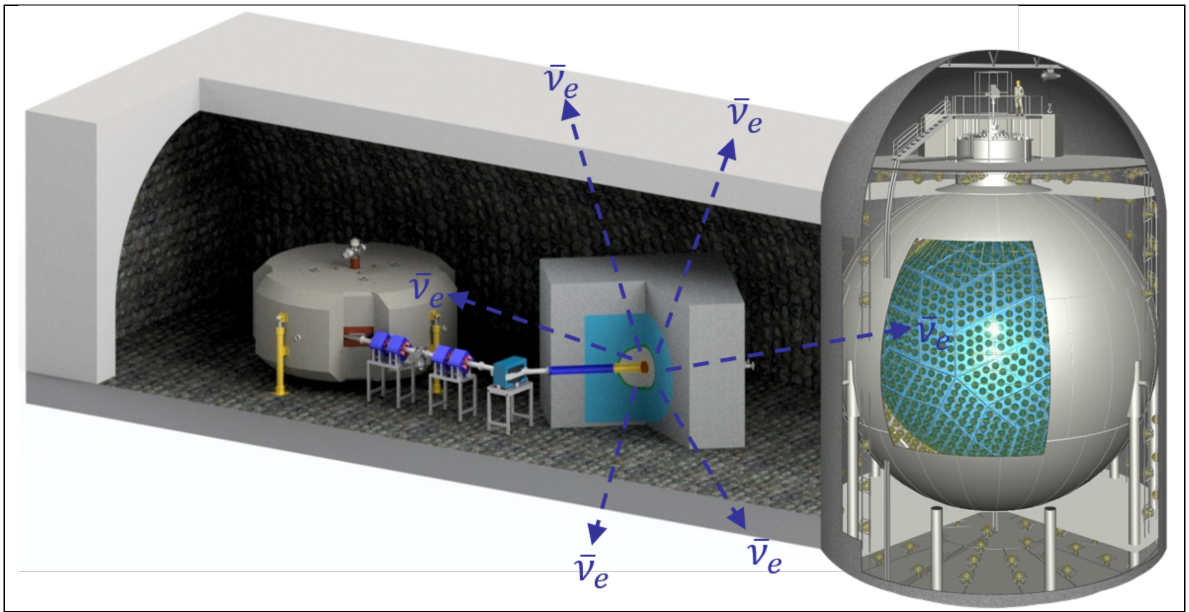

Fig. 1: Schematic of IsoDAR, showing (without full shielding) the cyclotron, transport line, and target system placed in close proximity to the kiloton KamLAND liquid scintillator detector.

THE NEUTRINO SOURCE:

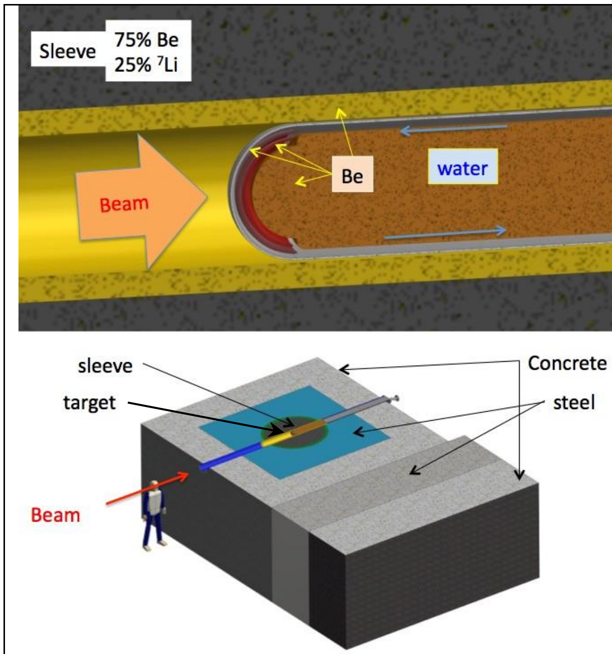

Fig. 2: Beam enters from left, is spread to uniformly strike the 20 cm diameter target of thin, nested beryllium hemispheres with flowing heavy water coolant between them. Beam range is 2.1 cm; it stops in the last water layer. 600 kW of beam power generates +10 K temperature rise in the water. Neutrons flood into the sleeve, are moderated, multiplied by the Be, and are captured by ^{7}Li to produce ^{8}Li, whose beta decay generates the desired antineutrinos. Shielding is 2 meters of steel surrounded by 2 meters of concrete. An additional 2 meters of steel and concrete in the direction of the detector keep the background from fast neutron events in the detector fiducial volume within acceptable limits.

Table 1: Performance of the IsoDAR system

Process	Material	Efficiency	Total yield in 5 yrs
Proton production	Compact cyclotron	10 mA, 60 MeV	8.8e24
Neutron production	Target: Be + D_2O 3 nested hemispheres	0.1 neutron/proton	8.8e23
Nu-e-bar production	Sleeve: 364 kilo ^{7}Li (>99.99%) 1089 kilo Be spheres (~3mm dia)	0.016 nu-e-bar/proton	1.4e23
Inverse Beta Decay (IBD) events	KamLAND (~1 kton liquid scintillator)	~6% solid angle	8.2e5

SHIELDING: IAEA regulations [4] state that any activity level of artificially-induced radioactivity greater than 0.1 Bq/gm must be contained in a Controlled Area. A requirement for IsoDAR is that at the end of the experiment, after all equipment and movable shielding has been removed, there must be no remaining controlled areas. Shielding requirements have been calculated based on this premise.

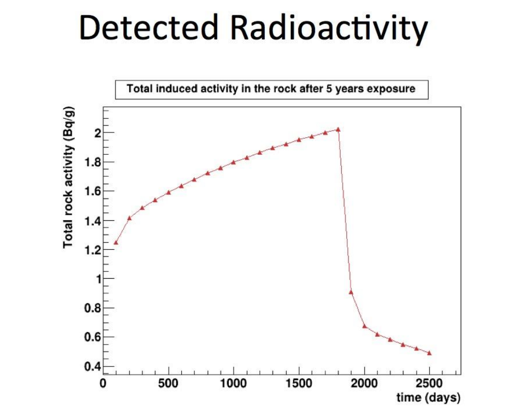

Fig.3: Example of buildup of activity in rock layers during the run, and subsequent decay when the beam is turned off after 5 years. Assay for release of Controlled Area is done after ~2 years of cooldown and dismantling. Long-lived activities followed are ^{60}Co, ^{22}Na, ^{152}Eu and ^{154}Eu. GEANT4 was used to evaluate rock activation and specify required shielding. 2 meters of steel and 2 meters of concrete were found to be adequate.

CONCLUSION: The designs for the IsoDAR cyclotron, target and shielding are mature, and meet all the requirements for a successful experiment that will unambiguously answer questions about the existence and properties of sterile neutrinos. We believe the concepts developed for this experiment—the ground-breaking high-current cyclotron, and the neutrino producing targets—can provide new paradigms for neutrino physics experiments in the future.

REFERENCES

[1] "Proposal for an Electron Antineutrino Disappearance Search Using High-Rate ^{8}Li Production and Decay," A. Bungau *et al.* [IsoDAR Collaboration], *Phys. Rev. Lett.* 109 141802 (2012).

[2] "IsoDAR@KamLAND: A Conceptual Design Report for the Technical Facility," M. Abs *et al.,* [IsoDAR Collaboration], arXiv:1511.0530v1 (2015).

[3] "High intensity cyclotrons for neutrino physics," D. Winklehner *et al.*, *Nucl. Instrum. Methods Phys. Res. Sect. Accel. Spectrometers Detect. Assoc. Equip.*, vol. 907, pp. 231–243, Nov. 2018, doi: 10.1016/j.nima.2018.07.036.

[4] "Radiation Safety Guide," IAEA Safety Standards Series, RS-G-1.7 (2004).