A Xe-127 Calibration Source for Liquid Xe Experiments

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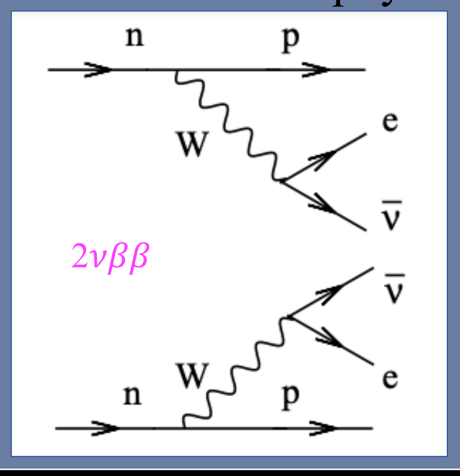
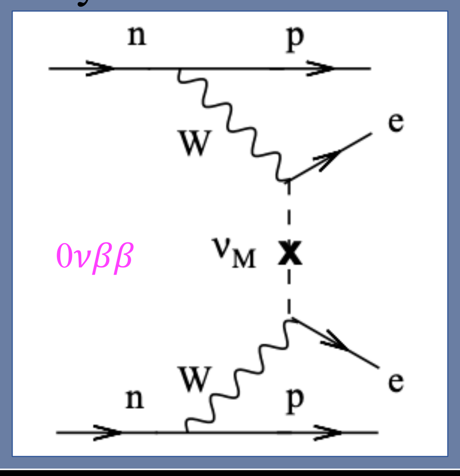
Searching for $0\nu\beta\beta$

The nEXO collaboration is searching for neutrinoless double beta decay ($0\nu\beta\beta$) using 5 tonnes of liquid xenon (LXe), enriched to 90% in Xe-136 [1].

Detection of $0\nu\beta\beta$ would be a lepton number violating process [2], which would indicate new physics from Beyond the Standard Model.





The LoLX R&D Detector at McGill

The Light-only Liquid Xenon (LoLX) experiment is designed to study the properties of light emission and transport in liquid xenon (LXe) using silicon photomultipliers (SiPMs).

- Focuses on **measuring and studying Cherenkov and scintillation light emission in LXe.**

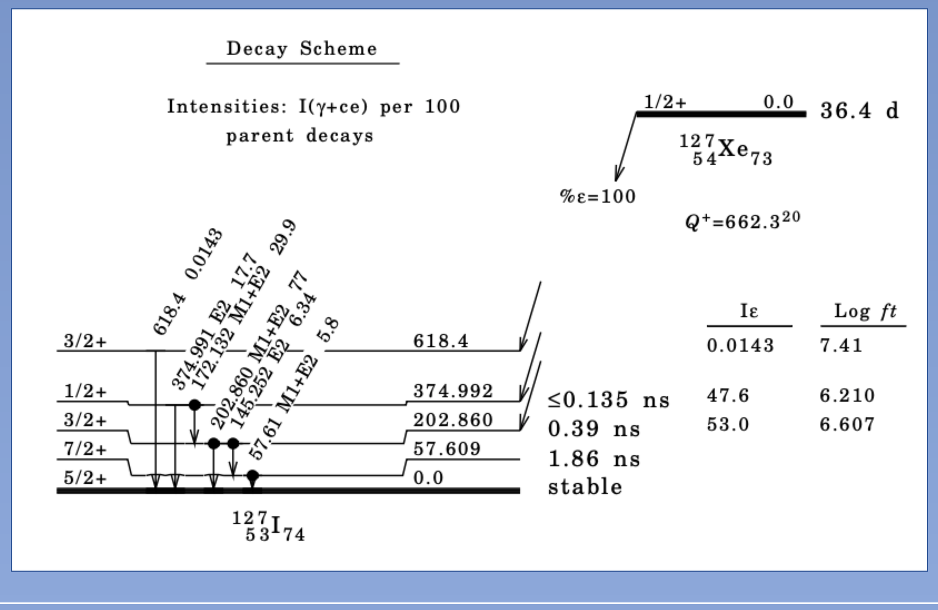
Currently investigating the performance and long-term behaviour of Hamamatsu VUV4 and FBK VUV-HD3 SiPMs, both of which are being considered for the nEXO collaboration.

Xe-127 as a Calibration Source

Xe-127 is an ideal calibration source as it has a relatively long half-life of 36.4 days and a Q-value of 662.3 keV [3] which is lower than the $0\nu\beta\beta$ Q-value of 2458.10 ± 0.31 keV.

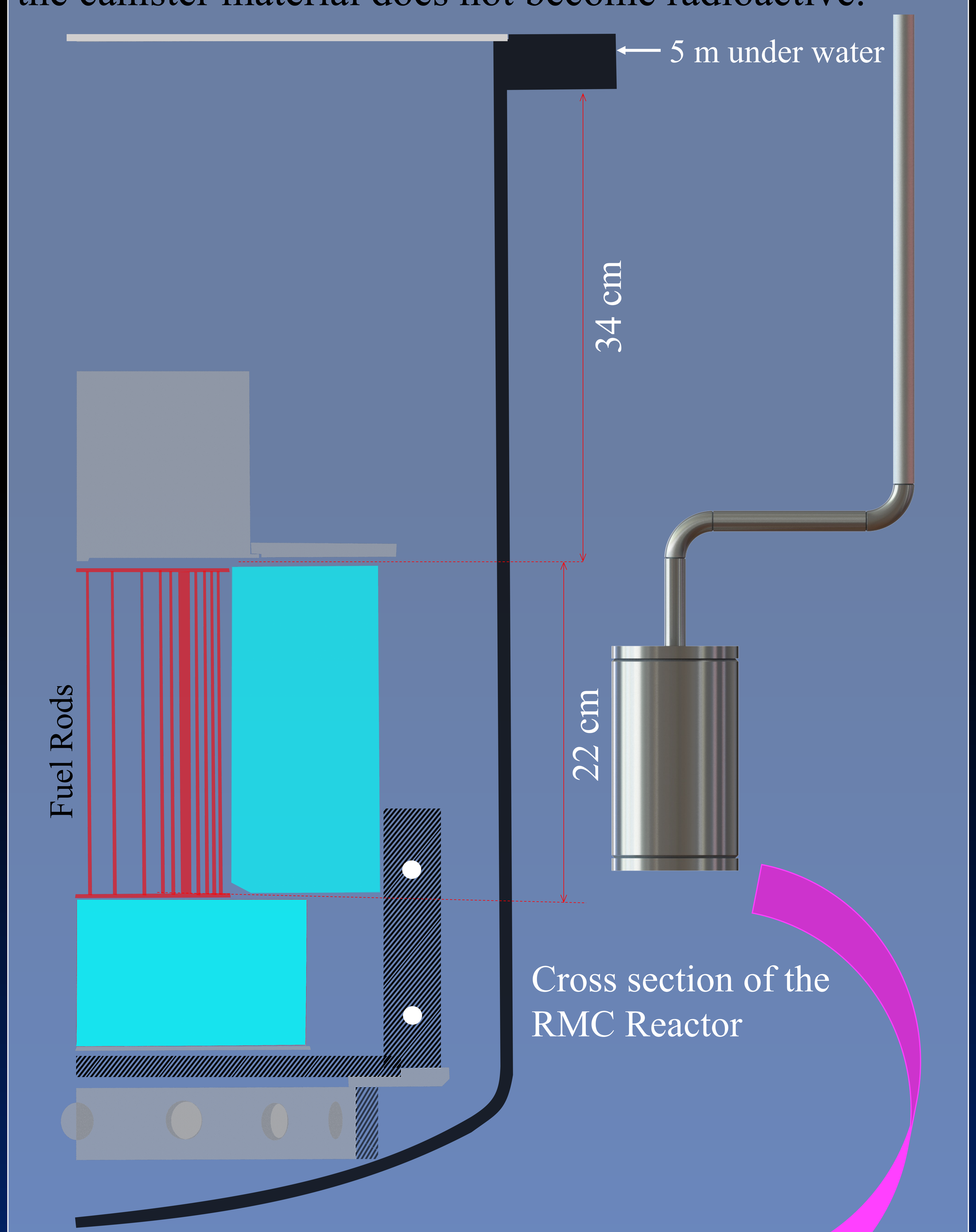
Xe-127 decays to I-127 via electron capture and releases either 263 keV or 408 keV of ionizing radiation [3].

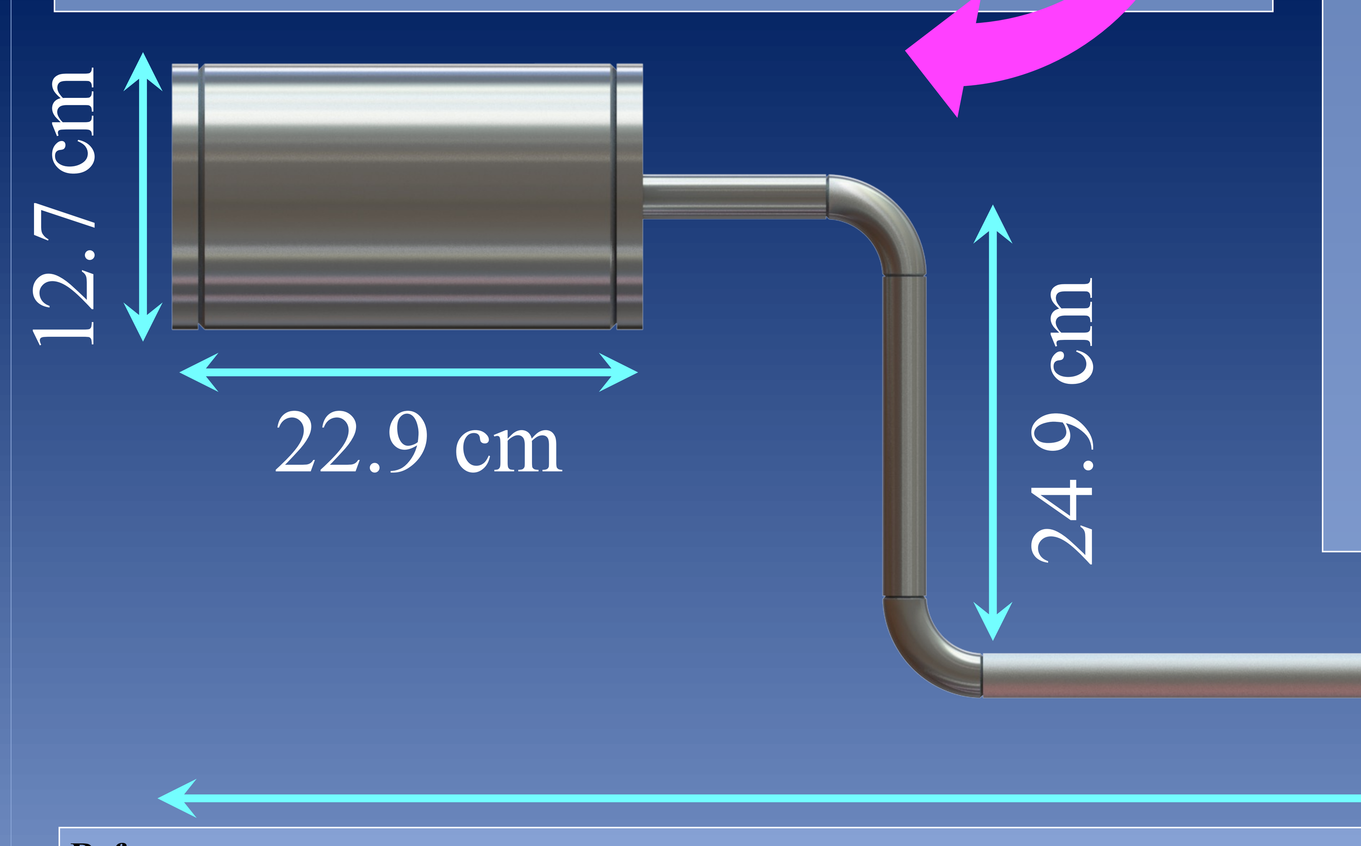
By augmenting the LXe with radioactive Xe-127, this ionizing radiation can be used for ***in-situ* calibration and performance characterization of SiPMs** while the detector is operational.



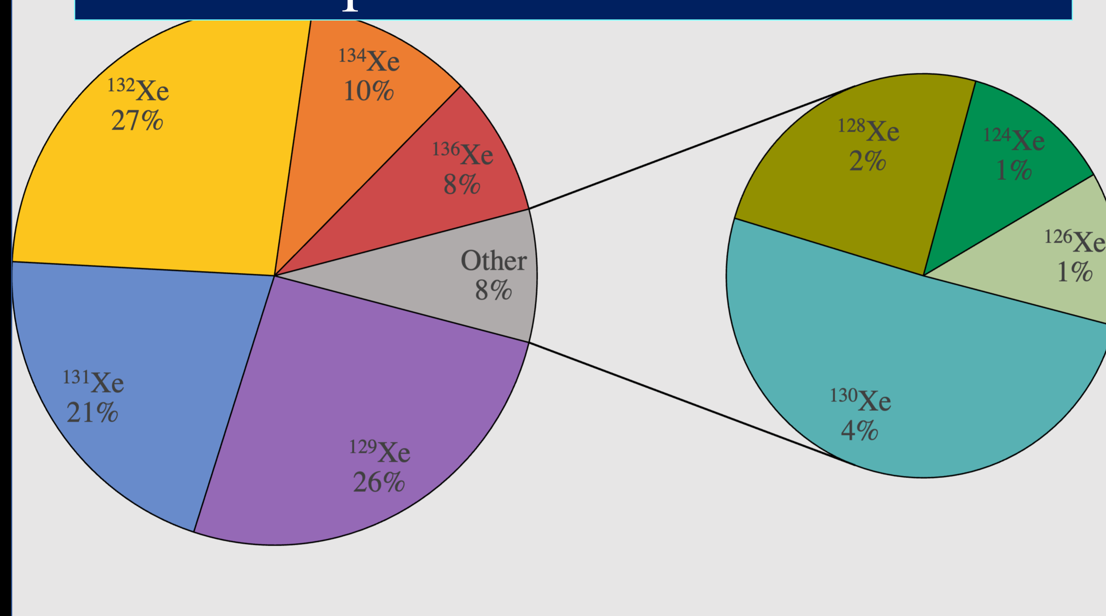
1 Design a Reactor-Safe Aluminum Canister

Design an Aluminum canister that will hold 17g of natural Xe and will meet the structural requirements of the SLOWPOKE-2 reactor at the Royal Military College (RMC) in Kingston, ON while ensuring that the canister material does not become radioactive.





Composition of Natural Xe

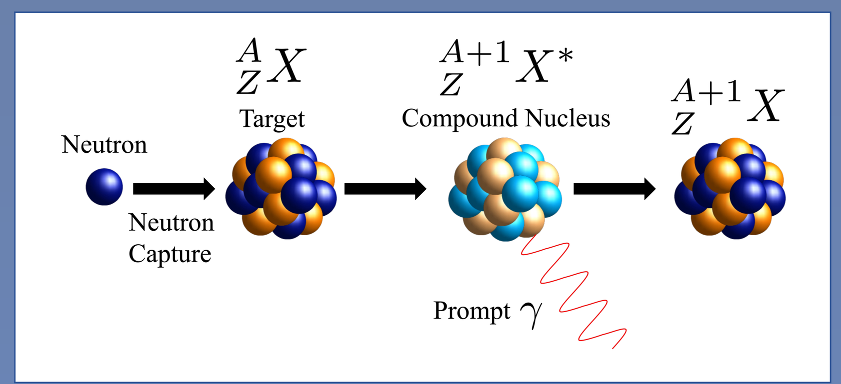


2 Perform the Theoretical Calculations

Calculate the expected radioisotope activities due to neutron activation after irradiating the natural Xe for ~170 minutes at a thermal neutron flux of 1.9×10^{10} neutrons/cm^{2}s.

Radioisotope	Half-life	Production Mode	Decay Chain
^{125}Xe	16.9 hours	^{124}Xe(n, γ)^{125}Xe	^{125}Xe $\xrightarrow[\beta^+ \text{(17 hrs)}]{}$ ^{125}I $\xrightarrow[\text{EC (55 d)}]{}$ ^{125}Te
^{127}Xe	36.3 days	^{126}Xe(n, γ)^{127}Xe	^{127}Xe $\xrightarrow[\text{EC (36 d)}]{}$ ^{127}I
^{129m}Xe	8.9 days	^{128}Xe(n, γ)^{129m}Xe	^{129m}Xe $\xrightarrow[\text{IT (9 d)}]{}$ ^{129}Xe
^{131m}Xe	11.9 days	^{130}Xe(n, γ)^{131m}Xe	^{131m}Xe $\xrightarrow[\text{IT (12 d)}]{}$ ^{131}Xe
^{133}Xe	5.2 days	^{132}Xe(n, γ)^{133}Xe	^{133}Xe $\xrightarrow[\beta^- \text{(5 d)}]{}$ ^{133}Cs
^{135}Xe	9.1 hours	^{134}Xe(n, γ)^{135}Xe	^{135}Xe $\xrightarrow[\beta^- \text{(9 hrs)}]{}$ ^{135}Cs $\xrightarrow[\beta^- (2.3\times10^6 \text{ y})]{}$ ^{135}Ba
^{137}Xe	3.8 minutes	^{136}Xe(n, γ)^{137}Xe	^{137}Xe $\xrightarrow[\beta^- \text{(4 min)}]{}$ ^{137}Cs $\xrightarrow[\beta^- \text{(30 y)}]{}$ ^{137}Ba

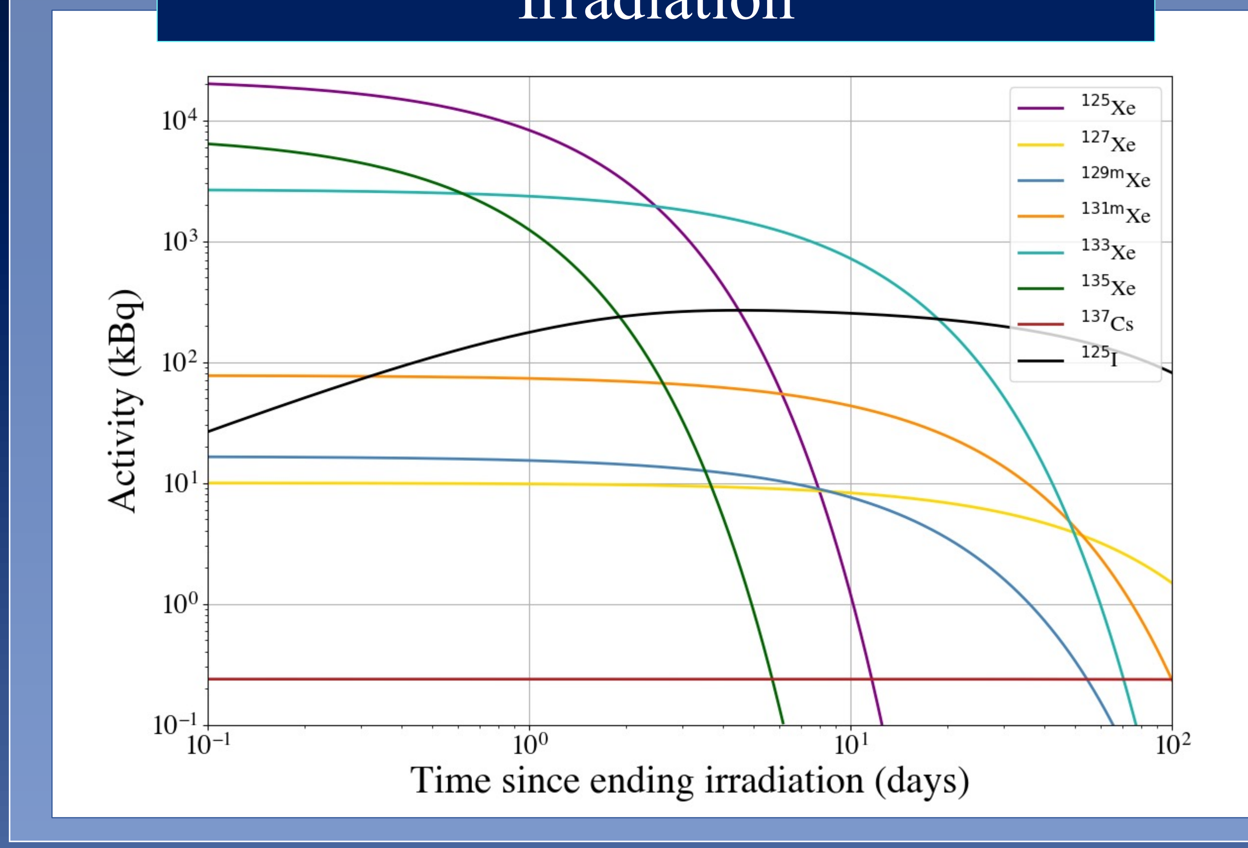
Xe-127 will be produced from the neutron capture on Xe-126.



3 Irradiate the Sample and Wait

Monitor how the radioisotopes' activity changes over a period of rest and from their decay chains **calculate the expected activity of their daughter isotopes**.

Radioisotope Activity After Ending Irradiation



4 Filter Xe Prior to Deployment

Large amounts of the Cs-137 should adhere to the inner surface of the canister [4], however the **gas should be purified prior to deployment**.

References:
[1] Adhikari, G. et al., 2021. Journal of Physics G: Nuclear and Particle Physics, 49
[2] F.T. Avignone III et al., Double Beta Decay, Majorana Neutrinos, and Neutrino Mass, arxiv:0708.1033v2 [nucl-ex] (2007)
[3] A. Hashizume, Nuclear Data Sheets 112, 1647 (2011).
[4] B.G. Lenardo et al., 2022. *JINST* **17** P07028

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