An accelerator-driven Ba^+ ion source for a future neutrinoless double beta decay search in nEXO

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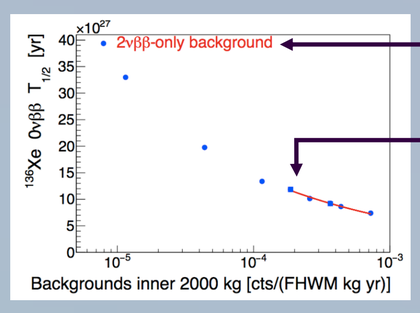
0νββ and nEXO

- nEXO is a proposed experiment to observe the hypothetical **neutrinoless double beta decay** (0νββ) in ^{136}Xe [1].
- 0νββ is a lepton-violating process and an observation would have implications on **physics beyond the Standard Model**.
- The rate of 0νββ ($T_{1/2}$) is related to the currently unknown effective neutrino mass.

Ba tagging for background rejection



If 100% Ba-tagging efficiency

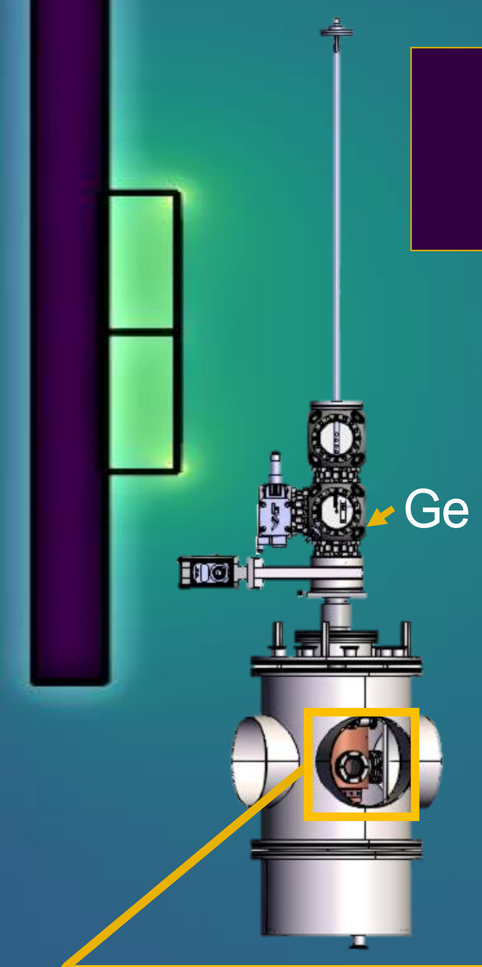
Projected nEXO sensitivity to 0νββ $T_{1/2}$ is 1.35×10^{28} years at 90% C.L. [2].

- The general methodology involves **extracting** the Xe volume in the vicinity of a potential ββ-decay event, followed by **separation** of the Ba^+ ion from the Xe and subsequent **identification**.

Ba extraction from LXe

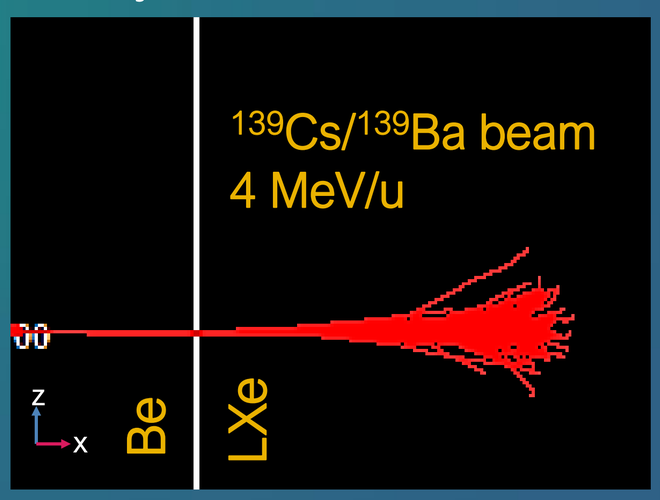
- There are two Ba-tagging extraction methods under development by the nEXO Collaboration.
- One method involves freezing the ion in Xe ice using a cryoprobe for spectroscopy [3], and the other approach features a capillary tube [4].
- Both methods will require a **Ba^+ ion source** to test efficiency.

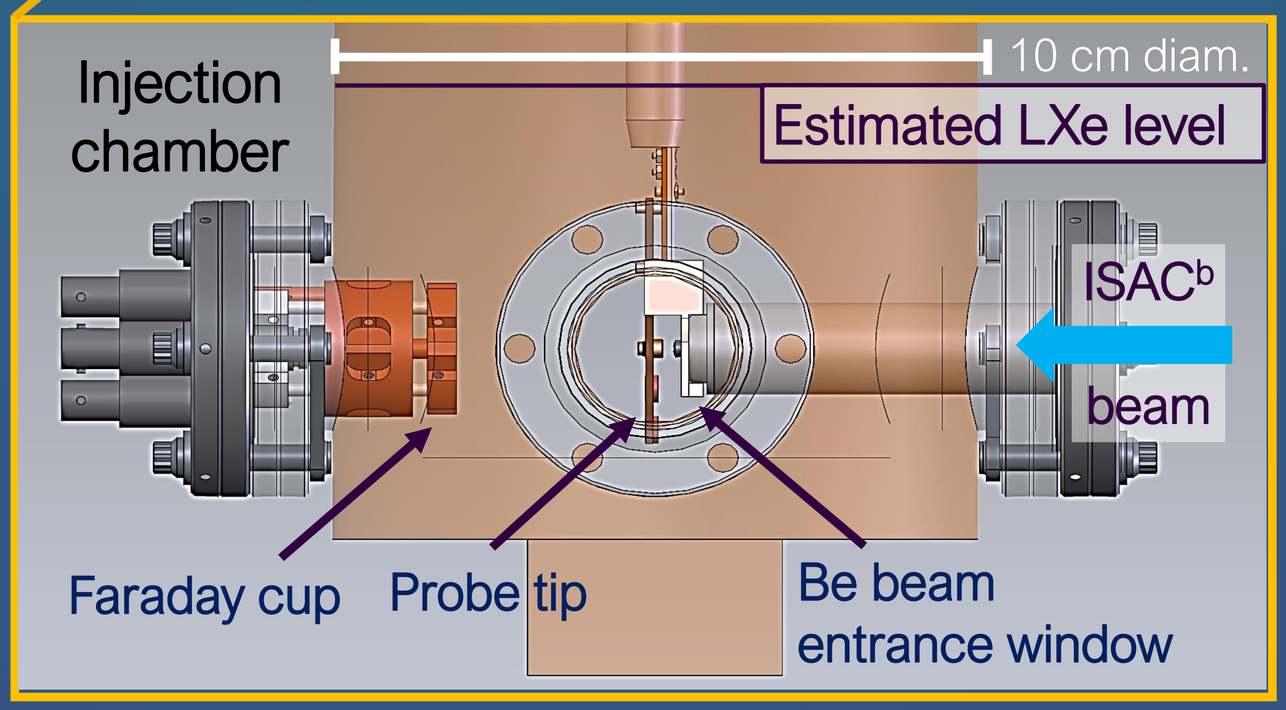
Goal: To build a Ba^+ source through achieving **Ba^+ ion extraction** from a known position in a LXe volume by "mimicking" 0νββ in LXe using the ^{139}Cs → ^{139}Ba β-decay via **radioactive ion beam** (RIB) implantation at TRIUMF.



1 Implant radioactive ions through a Be window, into liquid xenon.

Ion trajectories simulated with SRIM[a]

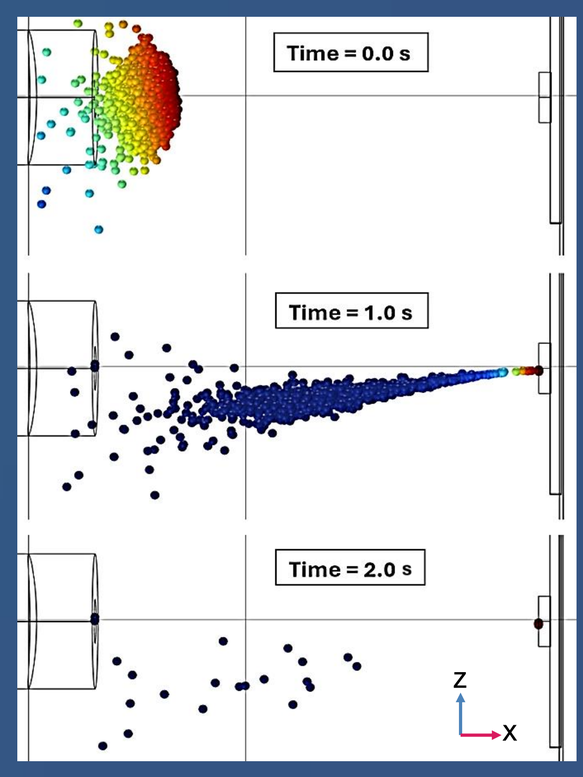




2 Electrostatically attract implanted ions onto biased probe tip.

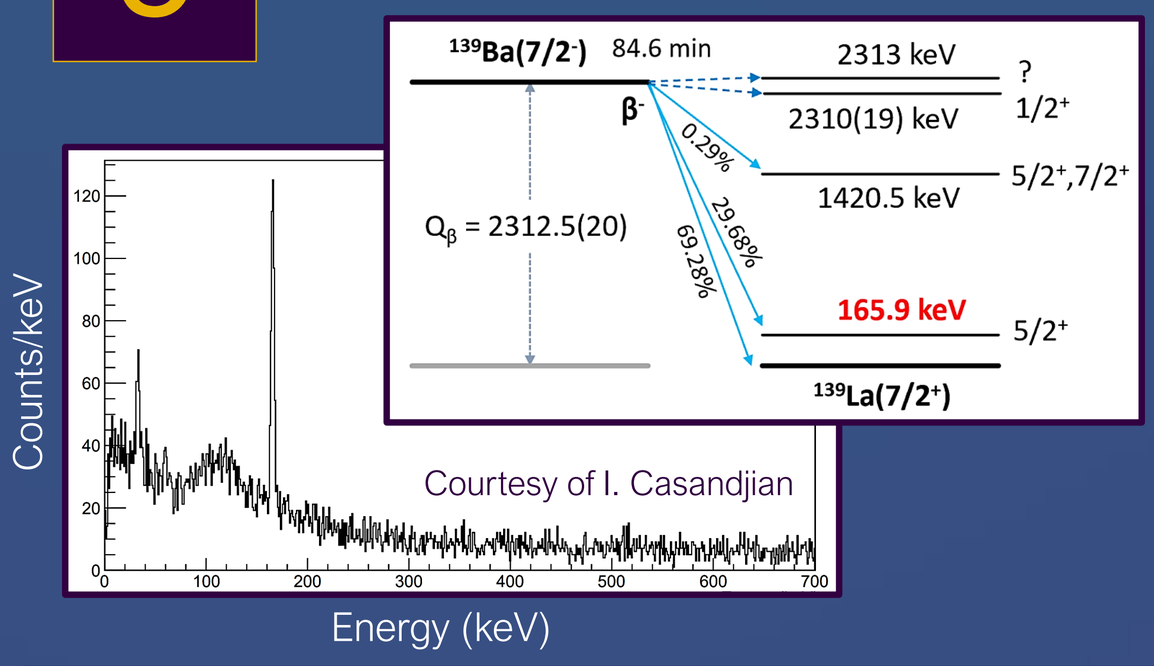
Building a COMSOL Multiphysics™ model

- A combination of fluid dynamics and particle tracing simulations inform optimal probe bias value, probe position and shape, and could benchmark future experimental data.
- An induced electric field **guides the ions** to the probe, governed by ion mobility μ in $\mathbf{v} = \mu\mathbf{E}$ [5].



- Simulations show that 15,000 $^{139}Ba^+$ ions in a GAr test medium at 1 atm require <5 s to collect on the probe with a -500 V probe bias. The findings are similar for LXe if implanting ions within 2 cm of probe, giving an idea of the required collection time.

3 Extract probe and identify collected Ba^+ ions via γ-spectroscopy.



4 Initial development will be using a GAr medium before moving to LXe for a full demonstration of the apparatus.

Status and Outlook: The simulation results suggest experimental feasibility. The experimental setup is currently being commissioned for accepting RIB in the near future.

The background image of this poster is the COMSOL-simulated electric field (V/m) used to guide the ions through the LXe medium, near the probe tip.

References

[1] nEXO Collaboration et al. nEXO Pre-Conceptual Design Report. 2018.
[2] J. B. Albert et al. Sensitivity and discovery potential of the proposed nEXO experiment 0νββ. Phys. Rev. C 97(6) (June 2018)
[3] C. Chambers et al. Imaging individual barium atoms in solid xenon for barium tagging in nEXO. Nature. 2018.
[4] D. Ray, R. Collister, H. Rasiwala et al. Ba-tagging for a nEXO upgrade and future 0νββ experiments: The Canadian approach. (In preparation).
[5] E. Bainglass et al. Mobility and clustering of barium ions and dications in high pressure xenon gas. Phys. Rev. A 97(6) (June 2018)

[a] The Stopping and Range of Ions in Matter software program
[b] Isotope Separator and Accelerator Facility at TRIUMF