Imaging of single Ba atoms and ions in solid xenon for barium tagging in nEXO

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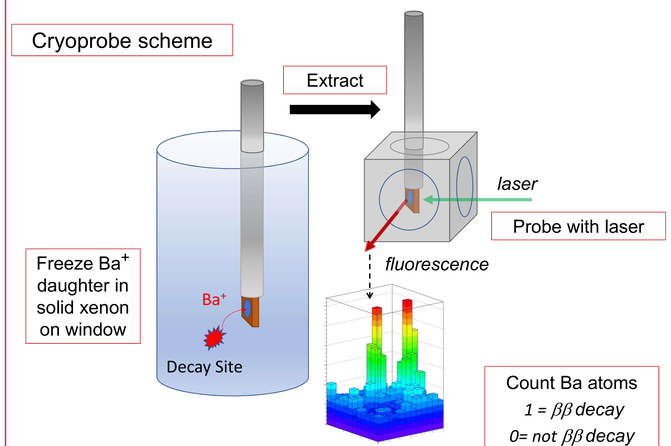
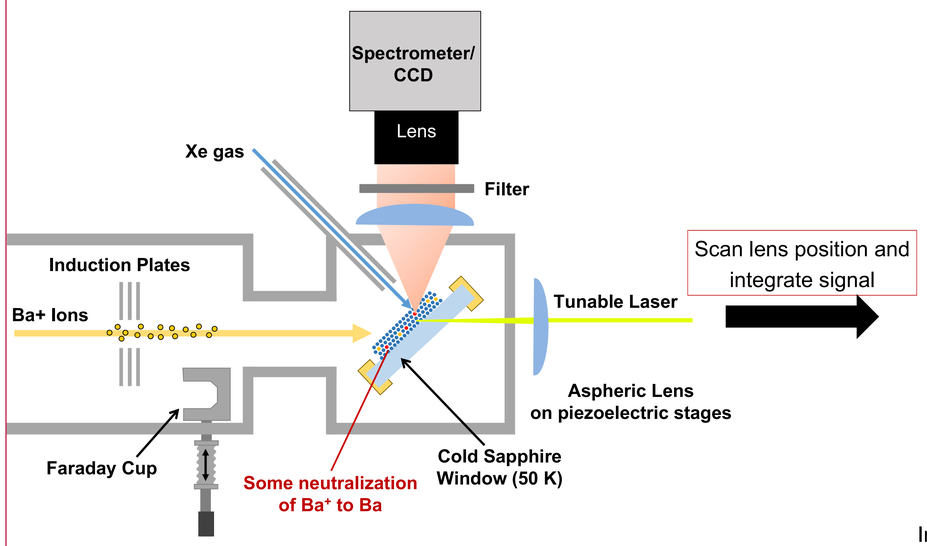
Introduction

$$^{136}Xe \rightarrow {}^{136}Ba^{++} + 2e^{-}$$

Barium tagging gives potential to eliminate all but 2νββ backgrounds in neutrinoless double beta decay experiments.



Test Apparatus



Scan lens position and integrate signal

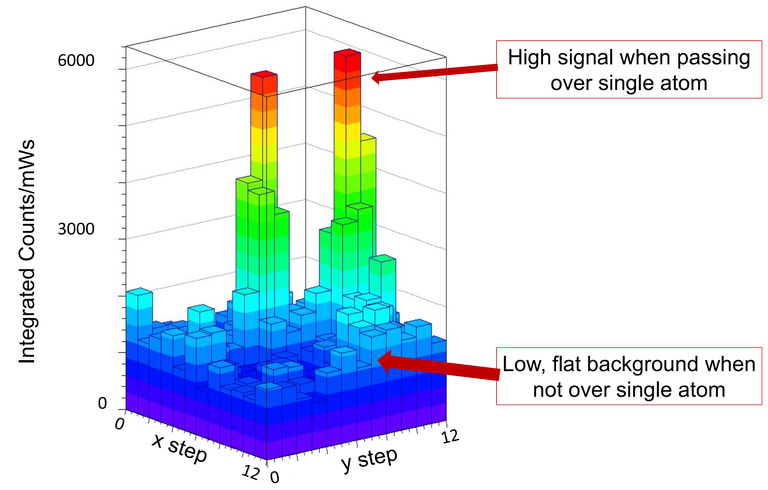
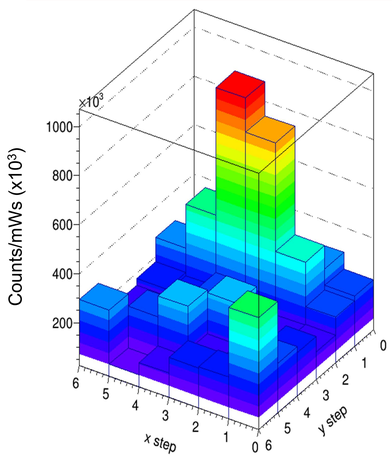


Image of two barium atoms in the single vacancy matrix site.[1]

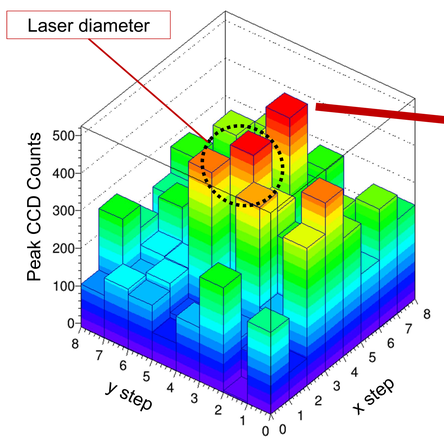
Results

Single Ba neutral image in 7-vacancy site

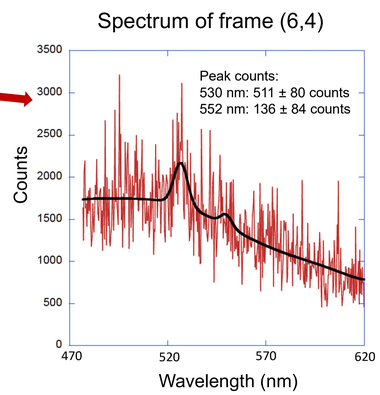


First image of a single Ba atom in the 7-vacancy xenon matrix site.

Preliminary low density Ba^{+} scan

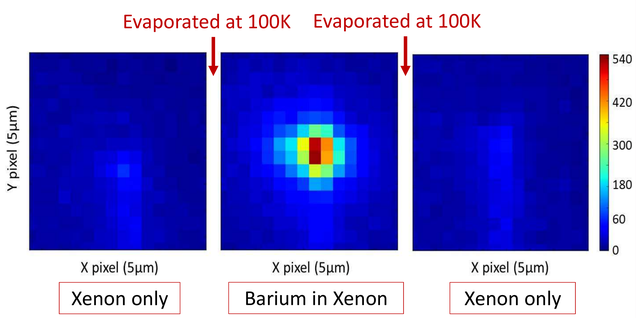


Scan image of Ba^{+} deposit looking at 530 nm Ba^{+} emission, with ~4 Ba^{+} ions deposited in entire scan area.



Spectrum of single frame of scan image.

Erasure of Deposits



Fluorescent signal is only observed when barium is deposited. We detect no signal from any Ba impurities on the surface, and even when depositing 7000 ions in solid xenon, the signal is gone on a successive xenon-only deposit.

Conclusion

Counting of single barium atoms in two solid xenon matrix sites has been demonstrated to the single atom level. Preliminary data shows promise for counting single Ba^{+} ions in solid xenon.

This technique has no sensitivity to any barium that we do not deposit, and no detectable barium is left on deposit erasure.

Citations

[1]C. Chambers et al., Imaging individual barium atoms in solid xenon for barium tagging in nEXO. *Nature* **569,** 203–207 (2019)