Single Barium Atom Imaging in Solid Xenon

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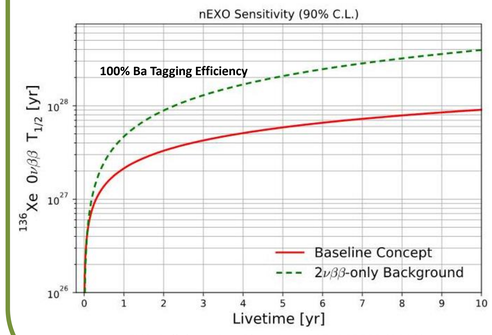
Neutrinoless Double Beta Decay in the nEXO Detector

Discovery would demonstrate:

- Neutrinos are Majorana Particles
- Lepton Number Violation

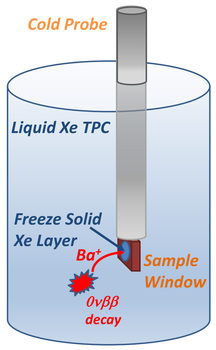
$$^{136}Xe \rightarrow {}^{136}Ba^{++} + 2e^{-}$$



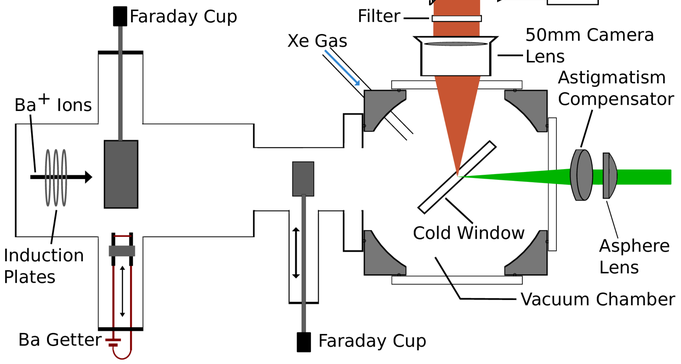
nEXO Collaboration *Phys. Rev. C* **97**, 065503 (2018)

- Locate the decay using TPC 3D position reconstruction
- Extract Ba daughter from liquid Xe TPC using a cryogenic probe
- Detect the Ba daughter in solid Xe

With Ba Tagging, we eliminate all but 2νββ backgrounds



Experimental Method



Deposition of Ba

1. Cool sapphire window to 50K
2. Inject Xe gas to form solid Xe layer
3. Pulse Ba^+ beam onto window
4. Stop Xe gas flow
5. Cool window to 10K

Detection of Ba Atoms

- Excite with dye laser at 572 nm
- Observe fluorescence at 619 nm
- Collect fluorescence photons with LN-cooled CCD
- Scan the laser with piezo-electric translation stages
- Evaporate sample at 100K

Intensity plot of integrated counts as a function of laser position

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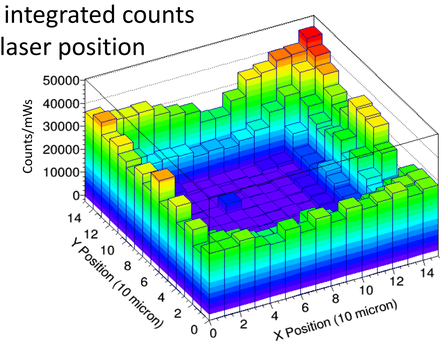
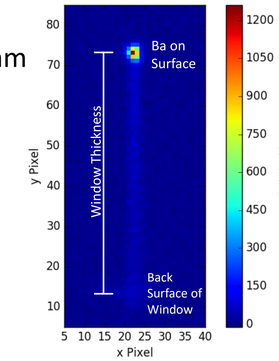


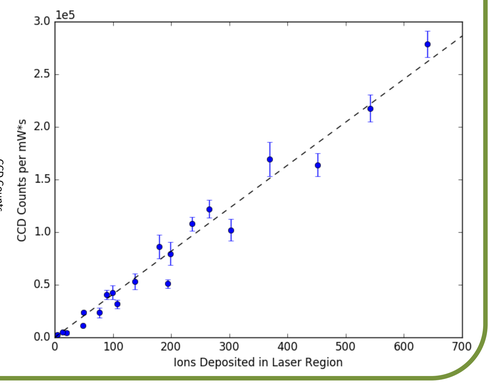
Background Suppression

- 532 nm laser rastered across sample (90μm × 90μm)
- Reduces surface background by a factor of 30

Barium Atom Fluorescence in Solid Xenon

- Fluorescence is observed at 619 nm
- Raw images are integrated and scaled by laser power
- Fluorescence signal is linear with number of ions deposited
- Fluorescence signal rate of 379 counts/mWs per ion





Imaging with Laser Scanning

- Weak background emission as laser approaches the Ba atom location
- Strong fluorescence signal when the laser is at the Ba atom location (x,y) = (4,7)
- Return to weak background level when the laser passes the Ba atom location

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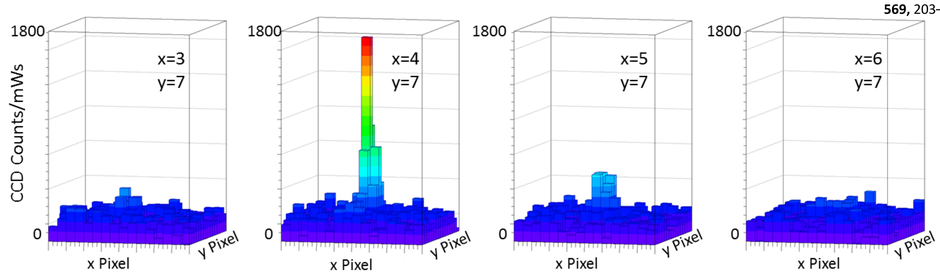
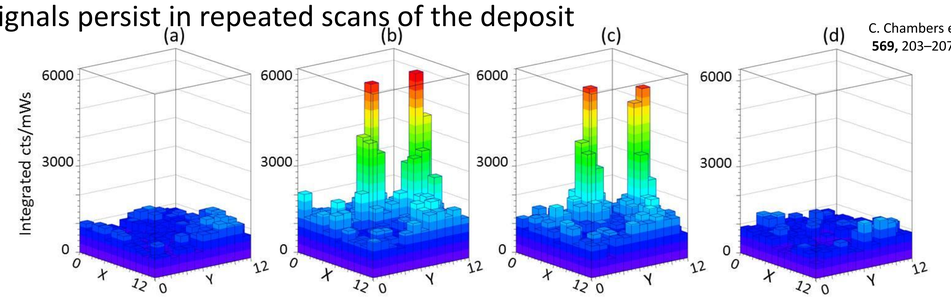
Raw Images



- Integrate each image, scale by laser power and plot as a function of laser position
- Ba atom signals persist in repeated scans of the deposit

Composite Images



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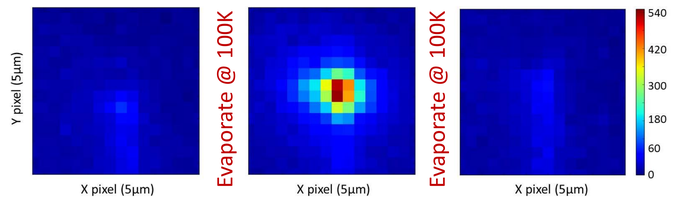
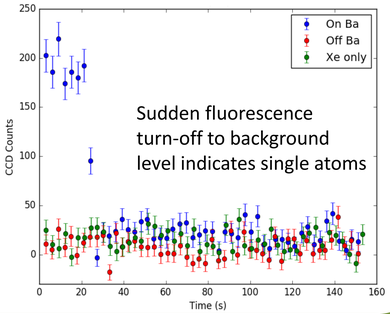
- Ba atoms emit for ~30 s to more than 300s
- No residual Ba observed after evaporating the sample even on large Ba deposits





Summary: First detection of single atoms in solid rare gas, a major step for Ba tagging in nEXO