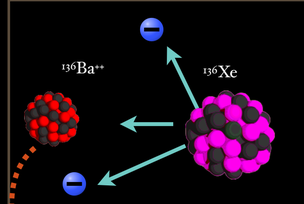
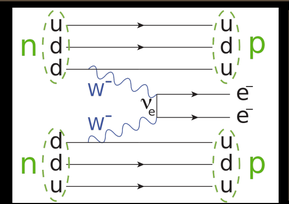
Barium capture and identification through bi-color molecular sensors and Two-Photon Absorption microscopy

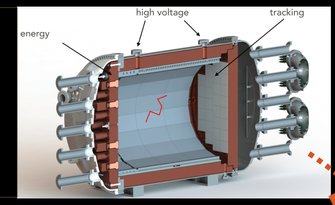
Pablo Herrero-Gómez on behalf of the NEXT collaboration.





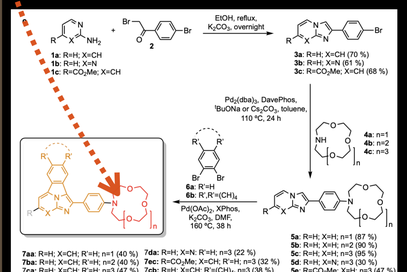
The NEXT collaboration seeks the neutrino less double beta decay $^{136}Xe \rightarrow ^{136} Ba^{2+} + 2e^-$, as an unambiguous proof of the Majorana nature of neutrinos. The detection of the daughter atom in the decay, Ba^{2+} would constitute a positive evidence of the reaction occurrence, since no other known radioactive decay produces such ion in coincidence with two electrons. I will show recent results towards the identification of a single barium ion in pressure gas obtained by the SABAT/NEXT group. See also poster #150 by Katherine Woodruff, UTA.

More information available in I. Rivilla et al. Nature in press, to be published in June 2020 (pre-print: arXiv:1909.02782)



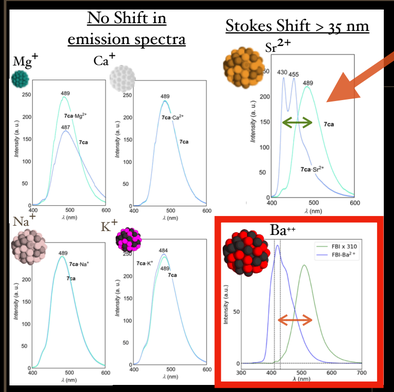
Upgrade

Synthesis of a Fluorescent Bicolor Indicator (FBI)



- Crown-ether size tailored for Ba^{++} capture.
- Fluorophore structure designed to maximise Stokes shift.

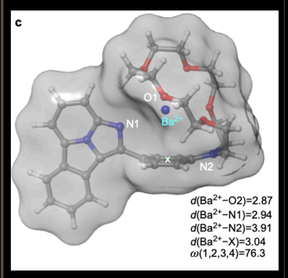
High ion selectivity



- Binding restricted by cation radius.
- Aside of Ba^{2+}, only Sr^{2+} would be captured but it is an irrelevant BG source in NEXT.
- Large discrimination factor $F = (2.5 \pm 0.6) \times 10^4$
- and binding constant: $K_a = 5.26 \times 10^4\ M^{-1}$

Due to

DFT simulations: capture in gas



- Flexible structure folded on the last phenyl group.
- Ba^{2+} ion interacts with phenyl and N_1 atom.
- Highly exergonic for Ba^{2+} & $Ba(ClO_4)_2$:

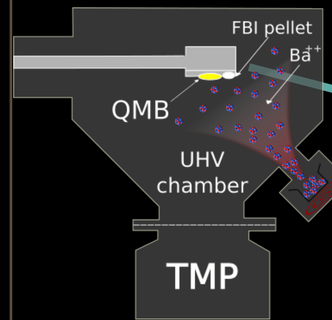
$\Delta G_{rxn} = -44.1$ kcal/mol

Even higher affinity in HPGXe:

$\Delta G_{rxn} = -197.4$ kcal/mol.

➡ Ba·Xe_8^{2+} clusters formation and release of 8 Xe atoms when FBI captures it.

arXiv: 1804.01169

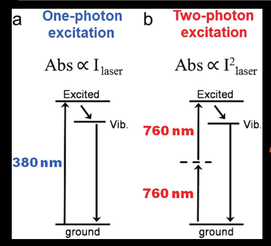


First observation of Ba^{2+} chelation by fluorescent indicators in dry medium (vacuum)

- **Solid phase support**: Silica pellets compressed together with FBI.
- Evaporate $Ba(ClO_4)_2$ over the pellet in a UHV chamber.
- Calibrate deposition thickness with quartz micro-balance (QMB).

FBI molecules capture Ba^{++} in vacuum.

Two-Photon Absorption (2PA)



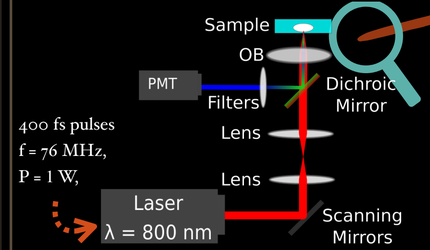
2nd order process

Order $\delta \approx 10^{-50}$ cm^{-4} s/photon

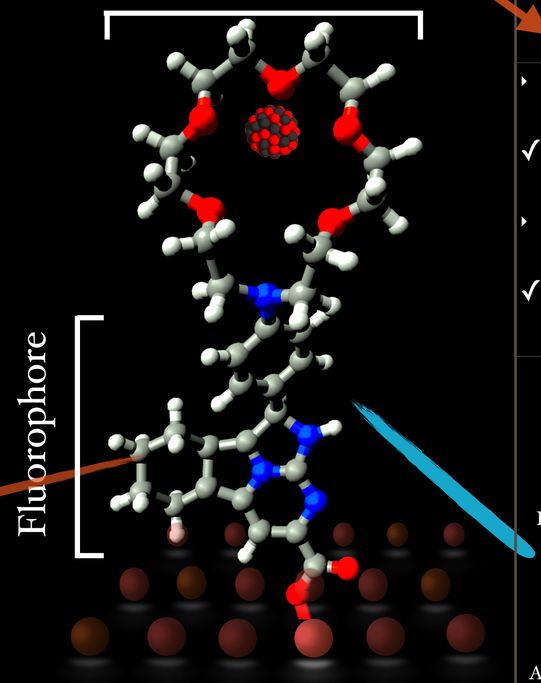
Dominant over SPA at high light intensity.

+ $N_\gamma \approx 10^{30}$ photons/(s · cm^2) s per pulse.

= Autofocus in the emitters and background discrimination.



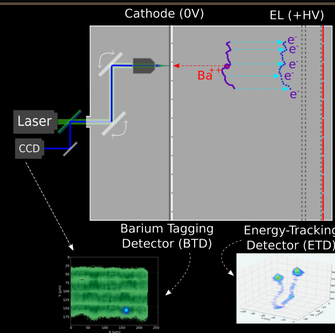
Catcher: crown ether



Towards a sensor for Ba^{++} tagging

1. Detect barycenter of two electrons with ETD.
2. Trigger laser while Ba^{2+} drifts towards cathode.
3. Lower cathode voltage for 1 ms to let Ba^{2+} pass.
4. Ba^{2+} is captured by FBI in a tiled sensor.
5. Scan sensor repeatedly. Achievable SNR ≈ 20.
6. Obtain delayed coincidence signal.

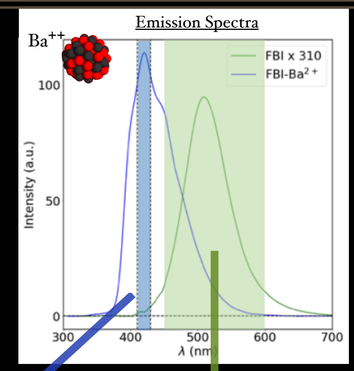
Aim for $0\nu2\beta$ w.rt $2\nu2\beta$ SNR ≈ 10

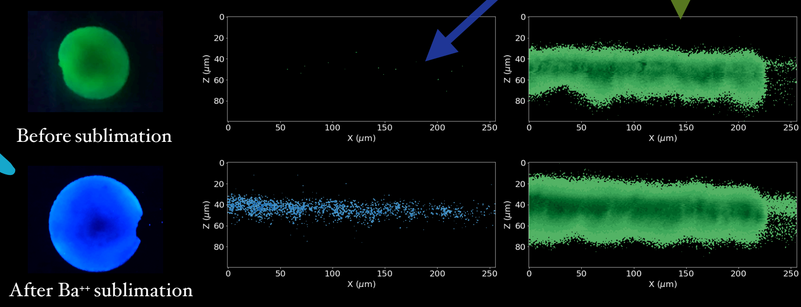


(See also poster #150 by K. Woodruff, UTA for a approach based on RF carpets)

2PA Detection Results

- Use high-pass green filter ($\lambda \geq 450$ nm) for **unchelated emission.**
- ✓ Control sample with no barium shows no chelated signal.
- Use band pass blue filter ($\lambda = 420 \pm 10$ nm) for **chelated emission**
- ✓ Sample with barium evaporated in vacuum emits intenselv in blue.





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