Direct measurement of electric dipole moment in thorium-228

Author(s): M. M. R. Chishti[1], D. O'Donnell[1], G. Battaglia[2], M. Bowry[1], D. A. Jaroszynski[2], B. S. Nara Singh[1], M. Scheck[1], P. Spagnoletti[1], J. F. Smith[1]
Institution(s): [1]University of the West of Scotland, [2]University of Strathclyde
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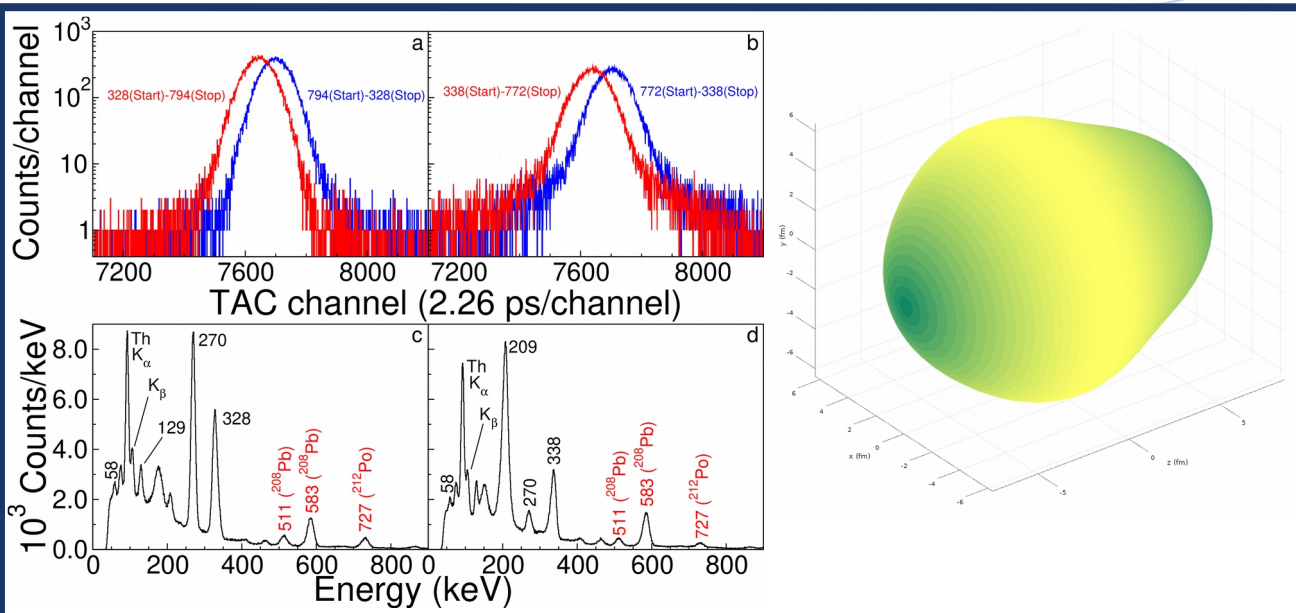
Abstract
Measurements of the mean lifetime of the low-energy $J^{\pi} = 1^-$ and $J^{\pi} = 3^-$ states in ^{228}Th have allowed for the electric dipole transition probabilities and the intrinsic dipole moment to be determined. The experimental results are compared with theoretical predictions which indicate that ^{228}Th may be the nucleus with the largest octupole deformation. This study indicates that the nuclei ^{229}Th and ^{229}Pa may be good candidates for the search for a permanent atomic electric dipole moment and physics beyond the Standard Model.



Project Description
A vanishingly small but non-zero permanent electric dipole moment (EDM) in the electron is predicted by the Standard Model of particle physics. A non-zero EDM may offer a solution to the matter-antimatter asymmetry observed in the Universe but the magnitude of the predicted EDM is too small. Octupole-deformed, or pear-shaped, atomic nuclei have been identified as potential candidates with which to search for an electron EDM since the non-uniform distribution of protons and neutrons induces a dipole moment [1]. It is predicted that the sensitivity to an electron EDM has a quadratic dependence on the octupole deformation parameter, β_3 [2]. It is possible to extract the β_3 value by measuring the mean lifetimes of the low-energy odd-parity states and comparing with theoretical predictions [3]. Lifetimes are measured following γ-ray spectroscopy using fast scintillating detectors in a lab at UWS.

Key Results, Conclusions and Impact
- $\tau(1^-) = 4(2)$ ps and $\tau(3^-) = 13(2)$ ps → $B(E1;1^- \rightarrow 0^+) = 8(6) \times 10^{-4}$ W.u.
- These values result in an intrinsic dipole moment of $D_0 = 0.16(8)$ efm
- Consistent with a significant octupole deformation or pear shape
- Excellent agreement with theoretical calculations in the literature suggesting $\beta_3 = 0.11(2)$ which is the largest reported to date
- This result means that odd-mass atomic nuclei in the vicinity of ^{228}Th may be the best candidates with which to search for a permanent EDM
- Currently, significant effort in this field is focused on octupole-deformed Rn and Ra nuclei but this study suggests that ^{229}Th and ^{229}Pa may be preferable

References
[1] Auerbach *et al*. PRL **76**, 4316 (1996)
[2] Spevak *et al*. PRC **56**, 1357 (1997)
[3] Robledo and Butler, PRC **88**, 051302 (2013)

More information can be found in the Nature Physics paper at https://rdcu.be/b4fga