EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Proposal for the ISOLDE and neutron time-of-flight experiments committee

Obtaining empirical validation of shape-coexistence in the mass 70 region: Coulomb excitation of a radioactive beam of ^{70}Se

D.G. Jenkins, P.A. Butler, G.D. Jones, R-D. Herzberg, N. Amzal, M. Chartier, R.D. Page, N. Hammond, A. Andreyev
Oliver Lodge Laboratory, Department of Physics, University of Liverpool

J. Eberth, I. Stefanescu, N. Warr, D. Weisshaar
IKP Koeln

W. Korten, E.Bouchez, Ch. Thiesen, Y. LeCoz
CEA Saclay

T. Czosnyka, J. Iwanicki, P. Napiorkowski, M. Zielinska
Heavy Ion Laboratory, University of Warsaw

REX-ISOLDE collaboration

Abstract: We propose to study the Coulomb excitation of a radioactive beam of ^{70}Se at 2.2 MeV/u obtained from the REX-ISOLDE facility in order to determine the sign of the quadrupole moment and, hence, the sign of the quadrupole deformation. Calculations suggest a 33% sensitivity in Coulomb excitation yield for a nickel target depending on whether the nuclear shape is oblate or prolate. Such a determination would provide compelling evidence for the presence of oblate shapes in the vicinity of N=Z=34.

Spokespersons: D.G. Jenkins and P.A. Butler

Introduction:

While naïve expectations would lead one to believe that oblate and prolate shapes should be equally favoured in nuclear ground states, Bohr and Mottelson showed that higher order terms in the liquid drop model ensure that oblate shapes are relatively rare. Moreover, even where collective oblate rotation is manifested, prolate configurations with higher moments of inertia rapidly cross the oblate configuration and form the high spin yrast line. It is believed therefore that unusually favourable conditions are required for oblate shapes to be observed -- one such being around N=Z=34. Indeed in ^{68}Se a ground state rotational band has been observed which has a moment of inertia consistent with the expectation for collective oblate rotation [1]. This configuration is crossed around J=4 by a prolate configuration with considerably larger moment of inertia. The oblate minimum in ^{68}Se is more bound by 1.5 MeV. Adding additional neutrons might be expected to reduce the gap between the oblate and prolate configurations. However, the evidence is presently unclear. In ^{69}Se [2] a strongly coupled band is observed which has dipole mixing ratios consistent with that expected for oblate deformation. In ^{70}Se, the crossing between 'oblate' and prolate configurations is much smoother than in ^{68}Se. B(E2) values for the ground state band in ^{70}Se inferred from lifetime measurements indicate a strong reduction in collectivity for the 6+ - 4+ and notably the 8+ - 6+ transitions [3]. This was taken as a strong indication of a nuclear shape effect and destructive configuration mixing which destroys the collectivity.

We propose to study the Coulomb excitation of a radioactive beam of ^{70}Se and use the measured yield to determine the sign of the quadrupole moment for the first 2^+ state. The sign of the quadrupole moment will be used to infer the sign of the nuclear deformation. If we show that the yield is consistent with an oblate shape for ^{70}Se then by inference this will confirm the oblate deformation in ^{68}Se – claimed to be the most strongly deformed oblate shape in this region. More specifically, since the analogue 2^+ state in ^{70}Br lies within 12 keV of the 2^+ state in ^{70}Se, it would be safe to infer an oblate deformation for N=Z ^{70}Br also. Indeed, in a recent study of ^{70}Br [4] it was found that in order to reproduce the level scheme within a TQRM model it was necessary to invoke oblate deformation and a repulsive proton-neutron residual interaction. Our measurement would help to clarify the interpretation of shape changes and band crossings in this mass region and verify long-standing TRS predictions of co-existing minima.

Experimental Details

We intend to extract a radioactive beam of ^{70}Se from the ISOLDE source and accelerate it to 2.2 MeV/u using the REX-ISOLDE facility. The highest quoted beam current for ^{70}Se out of the source is 4 x 10^6 /mC. However, we note that this is uncertain to perhaps an order of magnitude, so we assume more conservatively a current of 1 x 10^6 /mC.
Assuming a transport efficiency of 1% and 2 mA initial beam current, we anticipate a useful ^{70}Se beam on target of 2 x 10^4 s^{-1}. In order to detect gamma rays originating from the de-excitation of the first 2^+ state in ^{70}Se, we will employ MINIBALL cluster detectors in a compact geometry.

We expect an absolute efficiency for the array of around 13 % for 1.333 MeV gamma-rays or around 18 % for the 945 keV transition of interest.

In order to reduce background, the beam will be dumped several metres downstream of the target. In addition, scattered beam particles will be detected by the Edinburgh Compact Disc (CD) detector consisting of four quadrants of DSSSD detectors. Coincidence with the CD detector can be used to cleanly select the Coulomb excitation events and will permit an event-by-event kinematic reconstruction.
We propose to use two different Coulomb excitation targets – nickel and silicon. Coulomb excitation targets of 1 mg/cm^2 will be appropriate as the extra yield from using a thicker target is negligible.
Our calculations suggest that the Coulomb excitation yield is relatively insensitive (<10 % sensitivity) to nuclear shape for a silicon target at the relevant beam energy, whereas for a nickel target the expected sensitivity to nuclear shape in the Coulomb excitation yield is around 33%, with a larger yield being expected for the oblate shape.
We will therefore obtain the following independent measurements:

- Coulomb excitation yield of ^{70}Se on a nickel target
- Coulomb excitation yield of ^{70}Se on a silicon target
- Coulomb excitation yield for nickel as an internal calibration of the efficiency
- Angular distribution information from the CD detector

With the available beam currents we should be able to measure the ^{70}Se yields to around 2-3 % accuracy in two days of running time. The lifetime of the first 2^+ state in ^{70}Se has previously been measured to be 1.5(3) ps [4].
Using the B(E2) value derived from this lifetime measurement along with the measured yields from this Coulomb excitation study, we would perform a least squares fit within the Coulomb excitation code GOSIA and obtain the sign of the quadrupole moment and, hence, infer the sign of the nuclear deformation.
We request four days of running time (two with each of the two targets – nickel and silicon) plus one day's set-up time.

Beam	Min. Intensity	Target Material	Ion Source	Shifts
^{70}Se	4 X 10^6	Zr oxide	Hot plasma	18

References

[1] S.M.Fischer et al., Phys Rev Lett 84, 4064 (2000)

[2] M.Wiosna et al., Phys Lett 200 B, 255 (1988)

[3] J.Heese et al., Nucl. Phys. A325, 45 (1986).

[4] D.G.Jenkins et al., Phys Rev C (submitted)