Developments towards high resolution laser spectroscopy of ^{235m}U

A. Raggio[1], L. E. Reed[2], J. Warbinek[3,4], I. Pohjalainen[1,3], I. D. Moore[1], Ch. E. Düllmann[2,3,4], M. Block[2,3,4] and the IGISOL group

[1]Department of Physics, University of Jyväskylä, Finland
[2]Department Chemie - Standort TRIGA, Johannes Gutenberg-Universität Mainz, Germany
[3]GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany
[4]Helmholtz institute Mainz, Mainz, Germany

MOTIVATION

The measurement of hyperfine structures and isotope shifts with high-resolution laser spectroscopy offers access to fundamental nuclear structure properties including spins, mean-square charge radii and electromagnetic moments. Within the LISA [1] framework, a new measurement campaign has been started on uranium by means of collinear laser spectroscopy at the IGISOL facility. The final aim is the study of the second lowest lying isomeric state in the nuclear landscape, the 76-eV isomer in ^{235}U. The state is populated directly with a 71% branching ratio by the ^{239}Pu alpha decay and has a lifetime of 26 minutes.

ALPHA RECOIL SOURCE DEVELOPMENT

To generate an isomeric beam a set of 27 molecular plated [2] ^{239}Pu alpha recoil sources have been produced at Mainz university (JGU) and are currently under characterization to select the optimal one in terms of rate of recoiling ^{235m}U

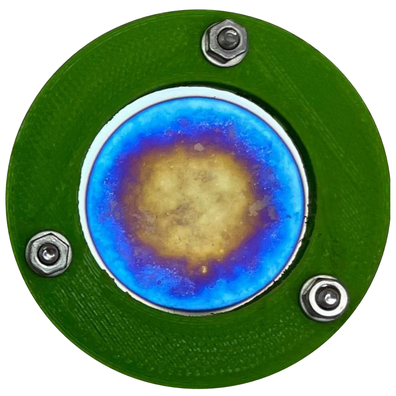

Fig. 1: Picture of a 22 mm diameter ^{239}Pu source on a 3D printed support.

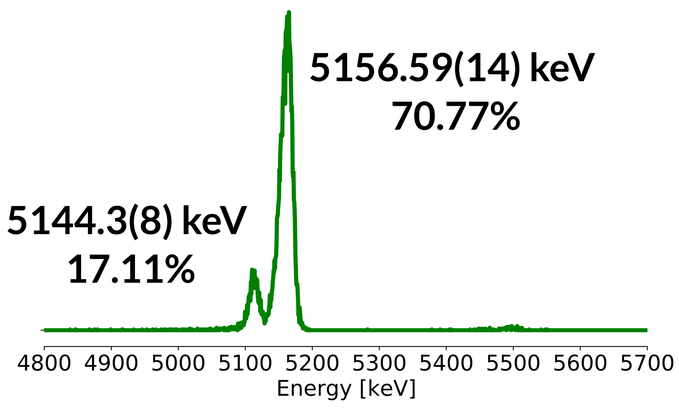

Fig. 2: Source alpha spectra. The two main alpha lines are marked.

Sources characterization :
- Alpha spectrometry
- Gamma spectrometry
- Rutherford Back Scattering (RBS)
- TOF-Elastic Recoil Detection Analysis (ERDA)

ACTINIDE GAS CELL

The sources will be used in the actinide gas cell [3] where the recoils are stopped in a buffer gas (He) and are extracted and guided to the IGISOL beamline for laser spectroscopy studies.

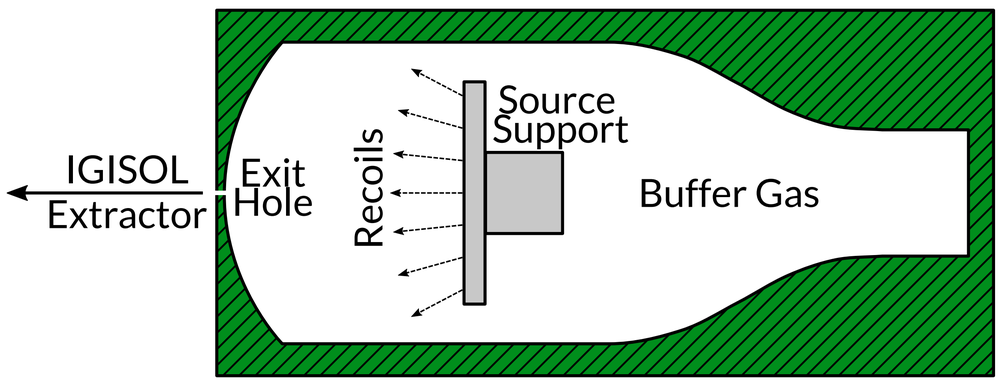

Fig. 3: Schematic representation of the actinide gas cell with an alpha recoil source installed

REFERENCES

[1] LISA – Laser Ionization and Spectroscopy of Actinides, <https://lisa-itn.web.cern.ch/>
[2] Vascon, A., et al., NIM A, 696 (2012): 180–191.
[3] Pohjalainen, I. et al., Nucl. Instr. Meth. Phys. Res. Sect. B, 376 (2016) 233-239.
[4] De Groote, R. P. et al. Nucl. Instr. Meth. Phys. Res. Sect. B, 463 (2020) 437-440.

Joliot Curie International school
Saint Pierre D'Oleron, France
October 3-8, 2021

COLLINEAR LASER SPECTROSCOPY

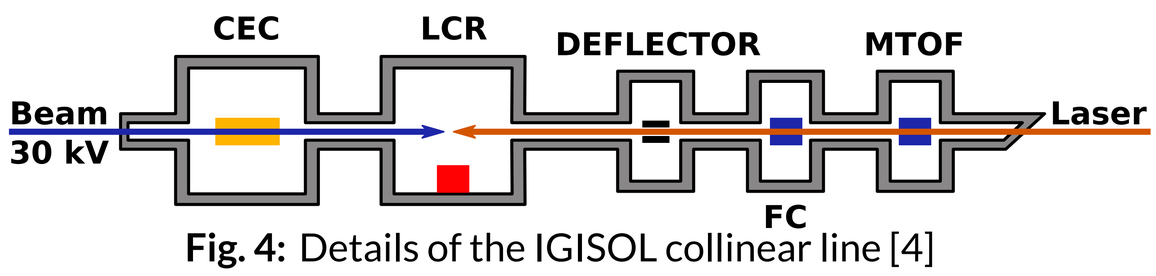

Fig. 4: Details of the IGISOL collinear line [4]

Detection of laser induced fluorescence allows the measurement of isotope shift and hyperfine structures.

GROUND STATE TEMPLATE

Using an electric discharge source placed in the IGISOL target chamber more than 10 ionic transitions have been studied in the three natural uranium isotopes : 234 (0.0054%), 235 (0.72%) and 238 (99.27%)

ISOTOPE SHIFT

$$\delta\nu_i^{A,A'} = M_i \frac{A' - A}{A'A} + F_i \delta\langle r^2\rangle^{A,A'}$$

M_i and F_i are the mass and the field shift constants

HYPERFINE SPLITTING

$$\Delta E_{\text{hfs}} = \frac{1}{2} A_{\text{hfs}} C + B_{\text{hfs}} \frac{\frac{3}{2} C(C+1) - 2I(I+1)J(J+1)}{2I(2I-1)2J(2J-1)}$$

$$C = F(F+1) - I(I+1) - J(J+1)$$

A_{hfs} and B_{hfs} are the dipole and quadrupole coupling constants

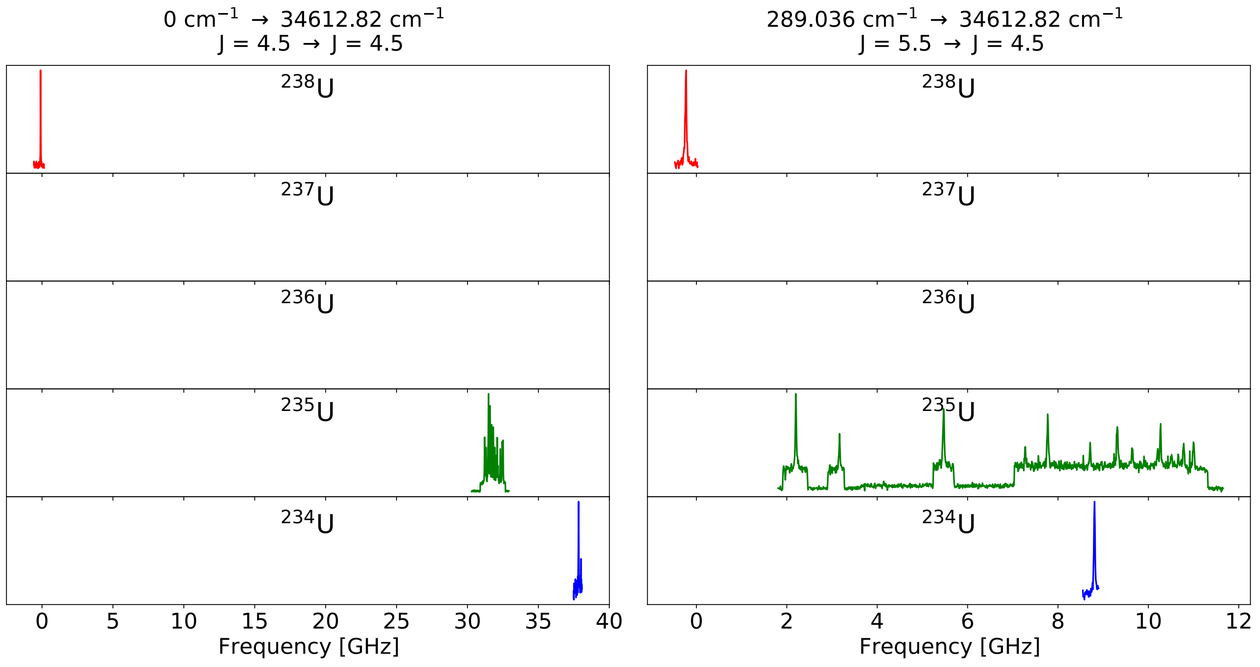

Fig. 5: Isotope shift representation for the three natural U isotopes in the 288.91 nm and 291.34 nm transitions

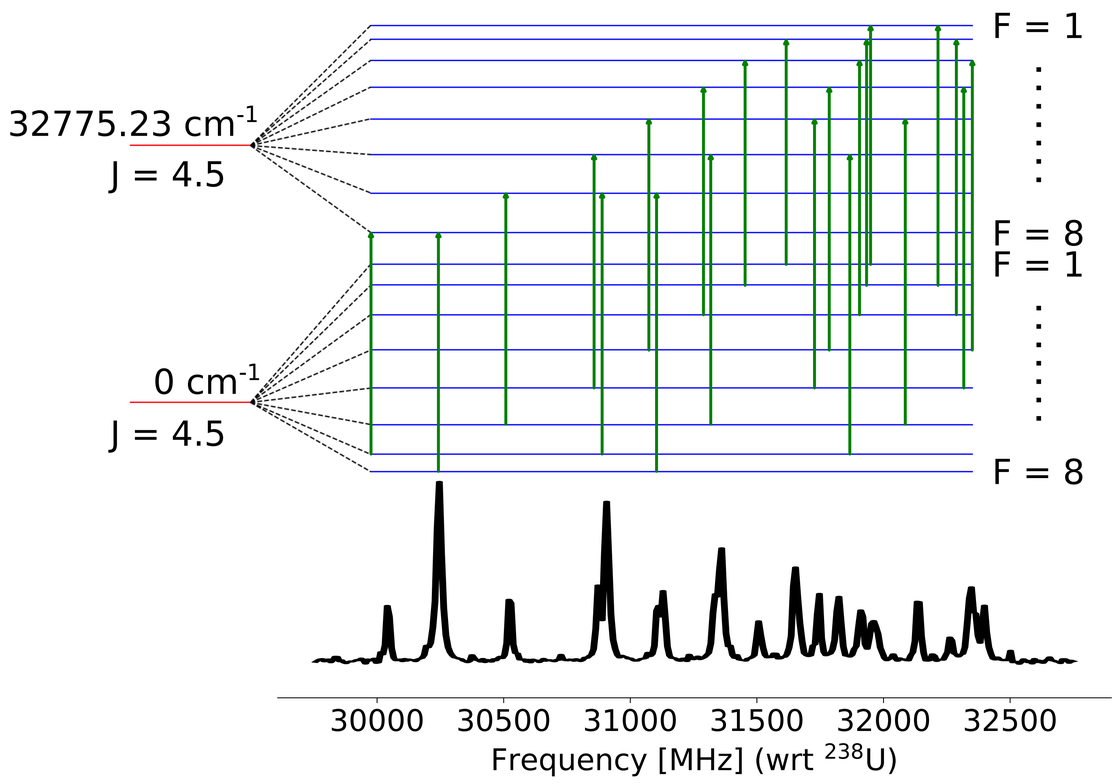

Fig. 6: ^{235}U hyperfine structure of the 305.02 nm transition

This Marie Sklodowska-Curie Action (MSCA) Innovative Training Network (ITN) receives funding from the European Union H2020 Framework Programme under grant agreement no. 861198.