EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Status Report to the ISOLDE and Neutron Time-of-Flight Committee

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Total Absorption Spectroscopy Studies with the LUCRECIA setup

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Abstract

In beta decay, apart from quantities that characterize the global properties of the decay, as the Q value and the half-life, it is important to know the beta transition probability to each individual level in the daughter nucleus. This information is relevant for the understanding of the nuclear structure involved in the process (both the structure of the parent state and the daughter states) and can also be important for practical applications. In this document we report on the progress of our two active experiments, namely IS440 and IS539, devoted to the determination of the B(GT) distribution in light isotopes of Pb and Hg.

Experiments and remaining shifts: IS440 - 6 shifts, IS539 – 5.5 shifts

Experimental setup/technique

Because of the nature of beta decay, conventionally the information of feeding probability to a level is obtained indirectly from experiments using Ge detectors. The first step in the analysis of such experiments is the construction of the level scheme of the daughter nucleus from gamma coincidence relations. Then, once the level scheme is available, from the gamma intensity balance populating and de-exciting the levels, the beta probability is deduced. Due to the low efficiency of standard Ge setups used in such experiments the beta feeding can be incorrectly determined. This systematic error is known in the literature as the Pandemonium effect [Hardy].

The total absorption spectroscopy technique is widely accepted as the only one that can provide beta decay data free of the Pandemonium effect. The technique is based on the detection of the gamma cascades that follow the beta decay using highly efficient detectors (see for example [Rubio,Tain]). This experimental method along with the complex data analysis that it involves, have proved to be a invaluable tool in nuclear structure studies [Nacher,Poirier,Perez] as well as practical applications [Algora].

At ISOLDE a total absorption spectrometer (TAS) Lucrecia was installed in the framework of the Strasbourg – Madrid – Surrey - Valencia international collaboration. The Lucrecia TAS is one of the largest total absorption spectrometers available in the World. It is composed of one NaI mono-crystal of cylindrical shape of 38 cm diameter and 38 cm length, which is read by 8 photomultipliers. The detector has approximately 90 % efficiency for mono-energetic gamma rays in the range of 300 to 3000 keV, which implies an efficiency of almost 100 % for gamma cascades. The TAS setup can be combined with ancillary detectors: an X-ray detector to select the electron capture (EC) component of the decay or beta detectors for selecting coincidences with the betas. In many applications the EC component provides isotopically very clean decay data.

The Lucrecia detector has been used for nuclear structure studies in the A∼80 and A∼190 regions [Nacher,Poirier,Perez], in particular in an application related to the determination of the shape of the nucleus based on the measurement of the beta strength of the daughter. In the following we will present the status of the studies performed in the A∼190 region.

Status report for IS440

Title: Shape effects along the Z=82 line: study of the beta decay of ^{188,190,192}Pb using total absorption

Spokesperson: A. Algora, B. Rubio, W. Gelletly

Accepted isotopes: ^{188,190,192}Pb

Performed studies: The main goal of the proposal was to study the beta decay of ^{186,188,190,192}Pb isotopes using the total absorption technique. Theoretical calculations performed by Sarriguren et al. [Sarriguren, Moreno] showed that there are clear differences in the beta strength distribution in the daughter nuclei depending on the assumed deformation for the parent nucleus. This information can be used to infer the shape of the decaying state if combined with a proper measurement of the beta strength. Our idea was to study the feasibility of these studies in order to provide an additional method of study of nuclear shapes in this region of particular interest from the perspective of shape coexistence. This possibility was already studied in the A~80 region [Nacher, Poirier, Perez]. Concerning the experiment, TAS measurements were performed for the decay of ^{188,190,192}Pb isotopes. Half an hour test data was also taken on the decay of 186Pb to see the feasibility of this for a later study. The TAS data has been analyzed (^{188,190,192}Pb) and the results showed a spherical character of the studied nuclei (^{188,190,192}Pb) in their ground states in agreement with earlier results [DeWitte].

Future plans: Apart from the little information available in the literature**,** the analysis of the ^{188}Pb TAS decay showed that the high-resolution data of this nucleus is very incomplete. We request to use the still available 6 shifts for high-resolution studies that will allow us to perform a better analysis of the TAS data of the ^{188}Pb isotope, to obtain information on possible beta delayed particle emission of this decay and to prepare for a future TAS study of ^{186}Pb. For the beta decay of this last isotope nothing is presently known from high-resolution studies.

Future plans with <u>available</u> shifts:

(i) Envisaged measurements and requested isotopes

We propose to perform a high-resolution measurement of the decays of ^{186,188}Pb using a Ge setup, preferably using the planned ISOLDE Decay Station (IDS) setup in combination with a particle detection setup. This idea has been already put forward in the IDS collaboration meeting in order to organize it within the IDS measurement campaign. The reasons for these measurements are the following: nothing is known from the decay of ^{186}Pb (populated levels) and very little is known from the decay of ^{188}Pb. The TAS analysis performed already for ^{188}Pb and presented in the thesis of E. Estevez, can be improved if a better high-resolution study of this decay is available. In the future we would like to perform a TAS study of the decay of ^{186}Pb, of particular interest because of the shape coexistence phenomena [Andreyev], which requires high-resolution data for the analysis. For the continuation of the TAS studies of the Pb isotopes (^{186}Pb) a future addendum is planned.

(ii) Have these studies been performed in the meantime by another group?

Not to our knowledge

(ii) Number of shifts (based on newest yields) required for each isotope

isotope	**yield (/uC)**	**target – ion source**	**Shifts (8h)**
^{186}Pb	4.6E+04	UC_x - RILIS (Pb)	4
^{188}Pb	1.7E+06	UC_x - RILIS (Pb)	2

Total shifts: 6 shifts

Status report for IS539

Title: Shape effects in the vicinity of the Z=82 line: study of the beta decay of ^{182,184,186}Hg

Spokesperson: A. Algora, L. M. Fraile, E. Nácher

Accepted isotopes: ^{182,184,186}Hg

Performed studies: The experiment was aimed at the investigation of shape co-existence in the region of Hg/Pb nuclei by means of the study of the beta decay of the neutron-deficient ^{182,184,186}Hg nuclei via total absorption spectroscopy. The measurements of the Gamow-Teller strength distribution can be related to the shape of the ground state of the decaying Hg nuclei [Moreno] as in the Pb isotopes already mentioned. The experiment was successful in collecting sufficient data on ^{182}Hg and ^{186}Hg, including isotope selective X-ray coincidence gates. We measured one full shift of ^{184}Hg, but, given the fact that the analysis is based on complex coincidence conditions, it is difficult to evaluate the quality of these data at this stage. The measured data should allow for statistically significant results for at least two of the three nuclei. We are presently working in the preparation of the complex data for the analysis (sorting, gain-matching, calibrations, etc.).

Future plans: We would like to use the remaining shifts for the study of the beta delayed particle emission of the studied isotopes, simultaneously with a high-resolution gamma spectroscopy measurement. For that we would like to use the future available setups at the ISOLDE Decay Station (IDS), which can provide highly efficient setups for charge particle and gamma detection (see below).

In addition, once the analysis of the studied isotopes is in a more advanced status and we have theoretical calculations available for the odd-A Hg isotopes, an **addendum** is planned for the study of these cases. They are also of particular interest from the point of view of shape changes and shape coexistence. This addendum is not discussed here, since it will be presented at a later stage, once the preliminary analysis of the even isotopes is ready. The theoretical calculations are already in progress [J.M. Boillos & P. Sarriguren]. For the study of the odd-A Hg isotopes, such as 185Hg, we will require isomerically selected beams in order to selected the beta-decaying isomer. Ideally a combination of Pb molten metal target with RILIS ionization for Hg (efficiency of the order of 0.1%, NIM 2008) will be required for this purpose.

Future plans with <u>available</u> shifts:

(i) Envisaged measurements and requested isotopes

Beta delayed particle emission study of $^{182-186}$Hg using the future setups available at IDS. These studies can give us the opportunity to have a full picture of the beta strength distribution combined with the TAS results.

(ii) Have these studies been performed in the meantime by another group?

Not to our knowledge

(iii) Number of shifts (based on newest yields) required for each isotope

For these nuclides molten Pb target coupled to plasma ion source are better suited than UCx + RILIS. The quoted numbers are obtained by scaling up by a factor of 5 those reported in the ISOLDE DB for the SC with Pb Molten metal and MK6 [Stora]. In addition no isobaric contaminations, such as Tl, have been observed.

Taking into account that the production of the different isotopes is more than enough for our measurement, our limitation in activity is imposed by the maximum counting rate accepted by the Germanium detectors. The distribution of shifts has been then estimated assuming a beta-delayed alpha branch of 10^{-5} – 10^{-4}. We plan to use a high-efficient setup for beta-delayed particles based on the use of six DSSD telescopes in close geometry, covering 70% of solid angle, and a vacuum chamber designed to maximize the gamma-ray transmission and detection efficiency, namely the one designed for the approved experiment IS577.

isotope	yield (/uC)	target – ion source	Shifts (8h)
^{182}Hg	4.0E+07	Pb - VADIS	1.5
^{184}Hg	6.5E+08	Pb - VADIS	2.5
^{186}Hg	2.8E+09	Pb - VADIS	1.5

Total shifts: 5.5 shifts

References:

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Appendix

IS440:

Publications

E. Estevez, et al., Study of the beta decay of ^{190,192}Pb using the total absorption technique, to be submitted to Physics Letters B.

Theses

M. E. Estevez, PhD thesis, TAS measurements for neutrino physics and nuclear structure: study of the beta decays of ^{150}Er, ^{152,156}Yb and ^{188,190,192}Pb, Univ. of Valencia, 2012, Summa Cum Laude, supervisors A. Algora.

IS539:

Data has been taken only recently, and the data analysis is ongoing.