EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Addendum to proposal P242 to the ISOLDE and Neutron Time-of-Flight Committee

SEARCH FOR NEW CANDIDATES FOR THE NEUTRINO-ORIENTED MASS DETERMINATION BY ELECTRON-CAPTURE

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Requested shifts: 5 shifts (1 run)

Introduction:

The determination of the neutrino mass from nuclear electron capture (EC) is an exciting alternative to β-decay experiments with ^{187}Re and tritium [1,2]. Unlike the β-decay experiments, in which nuclides with the smallest Q_{β}-value are preferred, the determination of the neutrino mass from EC nuclides requires the smallest total energy of the emitted neutrino. To date, the best candidate is ^{163}Ho with a decay energy of Q_{EC} = 2.56(2) keV [3]. However, there is a variety of other potential candidates with Q_{EC} below 100 keV and with expected very small total energy of the emitted neutrino [4,5]. The choice of the best candidate among them is hampered by imprecise knowledge of their Q_{EC} -values.

With the proposal P242 and the experiment IS473 we have initiated a search for potential candidates (besides ^{163}Ho) for a determination of the neutrino mass from EC by a determination of the Q_{EC}-values of the nuclides of interest [4]. The first two candidates we addressed were ^{194}Hg and ^{202}Pb.

Status report 2011:

The Q_{EC}-values of EC in ^{194}Hg and ^{202}Pb were proposed [4] to be determined by high precision Penning trap mass measurements of ^{194}Hg, ^{194}Au and ^{202}Pb,^{202}Tl with ISOLTRAP. Within the beam-time allocated to the experiment IS473 we have successfully completed three quarters of the program by having measured the masses of ^{194}Hg, ^{194}Au and ^{202}Pb with an accuracy of a few keV. An overview of ISOLTRAP beam times that were scheduled and performed in the framework of proposal P242 is given in Table 1.

Table 1: ISOLTRAP beam times scheduled for proposal P242.

Beam time	Dedicated for	Target/ion source	Remark
May 2008	^{202}Pb,^{202}Tl	UC$_x$/Hot plasma	canceled due to power failure
July 2008	^{194}Au	UC$_x$/RILIS	successful
August 2008	^{194}Hg	UC$_x$/Hot plasma	by-product of experiment IS461 successful
October 2008	^{202}Pb	UC$_x$/Hot plasma	successful
April 2009	^{194}Hg	UC$_x$/Hot plasma	unsuccessful no ^{194}Hg was seen
June 2011	^{202}Pb ^{202}Tl	UC$_x$/RILIS UC$_x$/Surface ionization	Direct measurement of the Q_{EC}-value. The Q_{EC}-value is measured with insufficient accuracy

The successful runs in July and August 2008 have enabled us to determine the Q_{EC}-value of ^{194}Hg. The resulting new Q_{EC}-value is 29(4) keV and substantially deviates from the AME2003 evaluated Q_{EC}-value of 69(14) keV. A thorough consideration of the data available in the literature on mass measurements of ^{194}Hg and ^{194}Au has led us to the conclusion that such a strong discrepancy between the AME2003 and our Q_{EC}-values originates in inaccurate experimental data for the ^{194}Au mass taken by AME2003 for the evaluation. The total energy of the neutrino emitted in EC in ^{194}Hg has thus been calculated to be 15(4) keV.

With the new value for the neutrino energy one can presently in principle determine the neutrino mass from EC in ^{194}Hg with an uncertainty of approximately 20 eV, which would be a tenfold improvement of the present limit. Nevertheless, it would still be much worse than the present limit on the antineutrino mass of 2 eV from the tritium experiments. Thus, it can be concluded that ^{194}Hg is not a suitable nuclide for the determination of the neutrino mass on the level of a few eV.

The new Q_{EC}-value of ^{194}Hg and all details associated with the measurement have been published in *Physics Letters B 693 (2010) 426.*

Addendum to proposal:

In June 2011 we attempted to perform a direct measurement of the Q_{EC}-value of EC in ^{202}Pb by measuring the cyclotron frequency ratio of ^{202}Pb/^{202}Tl by alternating between the parent and daughter nuclide in the same run. The RILIS ion source was used to create ^{202}Pb ions, whereas ^{202}Tl ions were expected to come out of RILIS due to surface ionization on the hot surfaces in RILIS. Unfortunately, the ionization rate of ^{202}Tl has turned out to be much lower than expected. This has resulted in the determination of the Q_{EC}-value of 51(20) keV with by far insufficient accuracy to draw a definite conclusion on the suitability of ^{202}Pb for the determination of the neutrino mass.

Since the mass of ^{202}Pb was successfully measured in October 2008 with an uncertainty of approximately 3 keV, it remains to only measure the mass of ^{202}Tl, which has not been measured in the meantime.

Beam time request:

Based on the experience acquired during the above-mentioned runs, we ask **for 5 more shifts** of on-line beam at ISOLDE to measure the mass of ^{202}Tl. We would like to perform the experiment in 2012 with the RILIS ion source and UC_x target. We expect the ^{202}Tl- yield of 10^5 ions/μC, which is sufficient for our experiment. It is sufficient to determine the Q-value of EC in ^{202}Pb with an uncertainty of approximately 3 keV in order to unambiguously state whether ^{202}Pb falls into the group of the good candidates. Thus, the mass of ^{202}Tl has to be measured with an uncertainty of 2 keV. The measurement is planned to be performed by alternating between the measurements of the cyclotron frequency of reference ^{133}Cs-ions and the measurements of the cyclotron frequency of ^{202}Tl. More than 20 such alternating one-hour measurements of the cyclotron frequencies of ^{202}Tl and ^{133}Cs are needed to acquire sufficient statistics. This corresponds to about 3 shifts of a pure measurement time. The mass measurements of ^{194}Hg, ^{194}Au and ^{202}Pb have shown that the pure measurement time constitutes at most two-thirds of the total beam-time. Thus, five shifts and the Ramsey scheme [6-8] for fast measurements appear to be realistic to measure the mass of ^{202}Tl with an uncertainty of few keV.

References:

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Appendix

DESCRIPTION OF THE PROPOSED EXPERIMENT

The experimental setup comprises: *ISOLDE and ISOLTRAP*

Part of the Choose an item.	Availability	Design and manufacturing
ISOLTRAP	☒ Existing	☒ To be used without any modification