EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

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

IS525: Study of multi-neutron emission in the β-decay of ^{11}Li

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N. L. Achouri[1], A. Algora[2], M. Assié[3], M. J. G. Borge[4], R. Baeturia[5], F. Calvino[5], D. Cano Ott[6], F. Delaunay[1], C. Domingo[2], H. O. U. Fynbo[7], A. Garcia Rios[6], J. Gibelin[1], B. Gomez[5], A. Heinz[8], B. Jonson[8], B. Laurent[9], X. Ledoux[9], T. Martinez[6], F. M. Marqués[1], M. Mendoza[6], E. Nacher[4], T. Nilsson[8], G. Nyman[8], N. A. Orr[1], M. Parlog[1], A. Perea[4], K. Riisager[7], B. Rubio[2], C. Santos[6], M. Sénoville[10], N. de Séréville[3], J. L. Tain[2], O. Tengblad[4]

[1] LPC Caen, ENSICAEN, Université de Caen, CNRS/IN2P3, Caen, France
[2] IFIC, CSIC, University of Valencia, Spain
[3] IPN, 91406 Orsay, France
[4] IEM, CSIC, E-28006 Madrid, Spain
[5] Dept of Physics and Nuclear Engineering, UPC, E-08034 Barcelona, Spain
[6] CIEMAT, E-28040 Madrid, Spain
[7] Institut for Fysik og Astronomi, Aarhus University, DK-8000 Aarhus, Denmark
[8] Fundamental Fysik, Chalmers University of Technology, SE-41296 Göteborg, Sweden
[9] CEA, DAM, DIF, F-91297 Arpajon, France
[10] CEA Saclay, IRFU/SPhN, F-91191 Gif-sur-Yvette, France

Abstract

In this experiment a new investigation of neutron emission in the β-decay of ^{11}Li will be undertaken, with the main goal of directly measuring for the first time for any system two β-delayed neutrons in coincidence and determining their energy and angular correlations. This will be possible owing to the use of liquid scintillator detectors, capable of discriminating between neutrons and ambient γ and cosmic rays, coupled to a new digital electronics and acquisition system. In parallel, a considerably more refined picture of the single-neutron emission will be obtained. The setup and measurements presented here are for the most part unchanged compared to the original proposal. Minor changes concern the collection of the ^{11}Li ions (a foil rather than a tape) and an additional calibration beam (^{9}Li) to obtain a low energy neutron line (without any impact on the total requested beam time).

Remaining shifts: 19

1. Motivation, experimental setup/technique

Motivation:

The main goal of this experiment is to measure directly for the first time two β-delayed neutrons in coincidence and measure their energies and angles. An attempt was made some years ago by members of the present collaboration with ^{11}Li and the TONNERRE plastic scintillator array [1]. This measurement proved that such a detection would be possible only if the neutrons could be discriminated from the ambient gamma-rays and cosmic rays which cause random coincidences. Here we will use liquid scintillator neutron detectors that show excellent discrimination capabilities.

By analogy with two-proton decay, two-neutron decay could proceed via simultaneous rather than sequential emission. In the case of direct emission, the nature of correlations between the two neutron could be of considerable interest and serve as a probe of the configuration of the neutrons in the decaying state.

^{11}Li is a good candidate for such a first study as it is produced with a reasonable yield and has one of the highest known two-neutron emission probabilities (P_{2n}=4.2 %).

In addition to two-neutron detection, we will explore further the single-neutron decay, which is still unclear despite a number of studies (unresolved weak neutron transitions, uncertain branching ratios). With the proposed setup, we expect ten times more events than in the latest study [2] with a similar resolution, and similar statistics with an energy resolution twice better.

Setup:

^{11}Li ions will be collected on a C or Al foil, rather than on a tape, as the ^{9}Be, ^{10}Be and ^{11}Be daughters are stable, long-lived and populated with a low branching ratio, respectively, and will therefore not produce important background activity. The β-rays will be detected by a cylindrical thin plastic scintillator surrounding the collection point (efficiency ~80 %). 40 liquid scintillator modules (20 cm diameter × 5 cm thickness, ~40% intrinsic efficiency in the energy range of interest) will be used to detect the neutrons, discriminate them from the γ and cosmic-rays and measure the energy of the neutrons through their time-of-flight, the start being provided by the β-ray plastic detector. The neutron detectors will be arranged in two walls:

– 30 modules at 1.5 m (“near wall”) from the collection point, to detect two-neutron coincidence events,

– 10 modules at increased flight distance (~3 m) (“far wall”) for improved resolution, to explore β-1n decays.

γ-rays will be detected with a large volume Ge detector, in order to record β-γ and β-n-γ coincidences. In particular, feeding of the 320 keV γ-ray line in ^{11}Be, whose branching ratio is known, will be used for normalisation.

2. Status Report

Accepted isotopes:

Performed studies:

No beam taken yet.

The necessary neutron detectors exist and have been characterized.

The neutron-γ discrimination performance of one module coupled to the digital electronics developed at LPC Caen has been explored in details. The overall quality of the digital discrimination is excellent and is better than the one obtained using analogue electronics in similar conditions. Furthermore, the intrinsic efficiency and the cross-talk probabilities between two modules have been measured in the energy range of interest with monoenergetic neutrons [3].

Tests on the coincident detection of two neutrons with measurements of their energies and angles are currently being performed at the LPC Caen with 11 neutron detectors, a $LaBr_3$ detector for neutron time-of-flight start, digital electronics and DAQ, and a ^{252}Cf source.

3. Future plans

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

(i) Envisaged measurements and requested isotopes

In addition to 15 shifts with ^{11}Li for data collection (expected statistics detailed in the original proposal), we will use ^{9}Li (P_n=51 %) and ^{49}K (P_n=86 %) at a reduced intensity (~500 ions/s) for calibration of the setup (1 shift for each). ^{49}K emits 4 neutron lines in the range 1 to 2 MeV. ^{9}Li has one neutron line at 0.68 MeV, in addition to a continuum between ~0 and some 0.5 MeV.

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

No.

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

Isotope	yield (/μC)	target – ion source	Shifts (8h)
^{49}K	*	Ta foil target (intermediate thickness foils) – W surface ion source	1
^{9}Li	1.7×10^7	Ta foil target (intermediate thickness foils) – W surface ion source	1
^{11}Li	~5000	Ta foil target (intermediate thickness foils) – W surface ion source	15

Total shifts: 17 **

* The yield of ^{49}K with the same target-ion source system is not listed on the data base ; a yield of 10^5 ions/μC with a Ta target and 0.6 GeV protons from SC is listed for ^{48}K.

** Does not include additional 2 shifts, one at the beginning of the run for electronics tuning and one for the beam changeovers.

4. References:

[1] A. Buta et al., Nucl. Instr. and Meth. Phys. Res. A455 (2000) 412

[2] Y. Hirayama et al., Phys. Lett. B611 (2005) 239

[3] M. Sénoville, PhD Thesis, Université de Caen, december 2013

5. Appendix