

# EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

## Addendum to the ISOLDE and Neutron Time-of-Flight Committee

### IS530: Properties of low-lying intruder states in $^{34}\text{Al}$ and $^{34}\text{Si}$ sequentially populated in beta-decay of $^{34}\text{Mg}$

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F.Negoita<sup>1</sup>, S.Grévy<sup>2</sup>, R.Lica<sup>1</sup>, N.Marginean<sup>1</sup>, Ph.Desagne<sup>3</sup>, T.Stora<sup>4</sup>, C.Borcea<sup>1</sup>, R.Borcea<sup>1</sup>,  
S.Calinescu<sup>1</sup>, J.M.Daugas<sup>5</sup>, D.Filipescu<sup>1</sup>, I.Kuti<sup>8</sup>, L.Fraille<sup>9</sup>, S.Franchoo<sup>6</sup>, I.Gheorghe<sup>1</sup>,  
R.Marginean<sup>1</sup>, C.Mihai<sup>1</sup>, P.Mourface<sup>6</sup>, J.Mrazek<sup>7</sup>, A.Negret<sup>1</sup>, D.Pietreanu<sup>1</sup>, F.Rotaru<sup>1</sup>, T.Sava<sup>1</sup>,  
D.Sohler<sup>8</sup>, I.Stefan<sup>6</sup>, R.Suvaila<sup>1</sup>, S.Toma<sup>1</sup>

<sup>1</sup> IFIN-HH, Bucharest, Romania

<sup>2</sup> CENBG, Bordeaux, France

<sup>3</sup> IPHC, Strasbourg, France

<sup>4</sup> ISOLDE/CERN, Geneva, Switzerland

<sup>5</sup> CEA, DAM, DIF Arpajon, France

<sup>6</sup> IPN, Orsay, France

<sup>7</sup> NPI, AS CR, Rez, Czech Republic

<sup>8</sup> Atomki, Debrecen, Hungary

<sup>9</sup> Universidad Complutense, CEI Moncloa, E-28040 Madrid, Spain

Spokesperson(s): F.Negoita ([negoita@tandem.nipne.ro](mailto:negoita@tandem.nipne.ro)), S.Grévy ([grevy@in2p3.fr](mailto:grevy@in2p3.fr))

Local contact: T.Stora ([thierry.stora@cern.ch](mailto:thierry.stora@cern.ch))

### Abstract

The run of IS530 experiment scheduled in September 2012 was successful and many new results have been obtained. However, one of the goals of the experiment, namely the measurement of branching ratio of the  $2^+$  state transitions toward the two lower  $0^+$  states in  $^{34}\text{Si}$  has not been achieved. It will allow to extract the  $B(E2; 2^+ \rightarrow 0_2^+)$  using the known  $B(E2; 2^+ \rightarrow 0_1^+) = 85 \pm 33 \text{ e}^2 \text{fm}^4$  [1]. Together with measured  $\rho^2(E0) = 13.0 (0.9) \times 10^{-3}$  [2], this information is essential for understanding the shape coexistence between the spherical (closed shell configuration of double magic character) and deformed (based on  $2h\omega$  configurations) states. The statistics obtained for the transition  $2^+ \rightarrow 0_2^+$  expected at  $607 \pm 3 \text{ keV}$  [2] is few times lower than our estimate. Taking advantage of larger lifetime measured for  $^{34}\text{Mg}$  and various improvements of experimental set-up, as explained in the text, an increase of one order of magnitude is expected in the statistics.

**Requested shifts (in total): 15**

The present Addendum follows the status report INTC-SR-037.



## 1. Motivation, experimental setup and technique (to be used in the addendum)

The IS530 experiment was performed in September 2012. The beam intensity was comparable with ISOLDE database estimate and beam purity very high such that the LIST mode (giving anyway very low intensity) was not necessary. The main results of data analysis performed so far by two master students in Bucharest are the following:

- new beta-time for  $^{34}\text{Mg}$ :  $63\pm 1$  ms instead of  $20\pm 10$  ms [3]
- strong population of previously discovered (1+) isomer in  $^{34}\text{Al}$  and 10 new states above it such that a first level scheme of  $^{34}\text{Al}$  was established.
- surprisingly, no direct or indirect feeding was observed to the known  $4^-$  state in  $^{34}\text{Al}$ , raising the question of which of the two beta decaying states in  $^{34}\text{Al}$  is actually the ground state. Following this result, a mass measurement at ISOLTRAP was proposed and accepted by INTC for the two states
- the decay toward  $^{34}\text{Si}$  also revealed 2 new states in this nucleus
- the absence of neutron coincidences, despite the low neutron efficiency (0.1%), was clearly confirming the assignment of new transitions in  $^{34}\text{Al}$  and  $^{34}\text{Si}$  (just because transition with much lower intensities in  $^{33}\text{Al}$  and  $^{33}\text{Si}$  were indeed observed in coincidence with neutrons)
- relative intensities in the two beta-decay schemes were determined, while the absolute intensities are still to be worked out. Theoretical estimates for  $^{34}\text{Al}(1+)$  decay scheme presented in the proposal are in good agreement with measured data.

Completing the known picture of excitation energies and transition probabilities of lowest states in double magic  $^{34}\text{Si}$  nucleus is one of the most important goals of IS530 experiment. The feeding scheme of  $2^+$  state in  $^{34}\text{Si}$  starting from  $^{34}\text{Mg}$  is different from our initial assumption, mainly because the  $4^-$  state in  $^{34}\text{Al}$  is not at all populated. However the population of  $2^+$  states is not very far from our estimate for the corresponding number of  $^{34}\text{Mg}$  incident ions. A number of  $1.8\text{e}4$  counts were recorded in 3326 keV peak in beta-gamma coincidences spectrum for about  $1.3\text{e}7$  detected  $^{34}\text{Mg}$  beta decays.

The difficulty comes also from a very low branching, of order of  $10^{-3}$ , for the  $607\pm 3$  keV E2 transition compared to 3326 keV transition. In Figure 1 the measured gamma spectrum of clover detectors in coincidences with beta detectors is shown in red. There peaks are observed in the region of interest, the highest is 596 keV and corresponds to inelastic scattering of neutrons on Ge nuclei, known to be large and followed at 608 keV by a second peak of similar origin. To filter out, signals from the beta detector (fast plastic scintillator) were digitized and treated off-line to identify the second hit originating from  $e^+/e^-$  pair emitted in E0 transition. The method was successful as can be observed in the Figure 2 and allowed to gate the gamma spectrum on E0 transition with high efficiency. The resulting spectrum, in red in Figure 1, is clean by non-desired peaks but statistics the transition at  $607\pm 3$  keV is hardly seen from the remaining background. We mention that the spectrum in red was scaled by a factor of 0.038 for visualisation purposes.

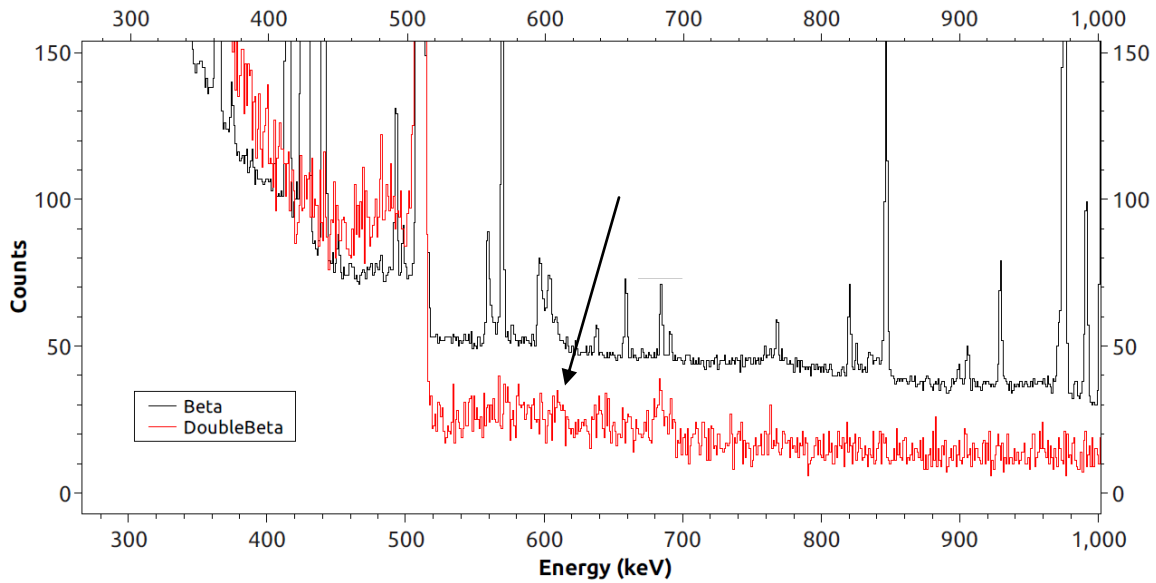


Figure 1. Gamma spectrum in black (multiplied by a factor of 0.038) is gated by coincidence with beta detector. The spectrum in red is conditioned by a double hit in the beta detector with time difference between the two hits in the range of [16, 205] ns (see Figure 2). The peak of interest at  $607 \pm 3$  keV is marked by an arrow.

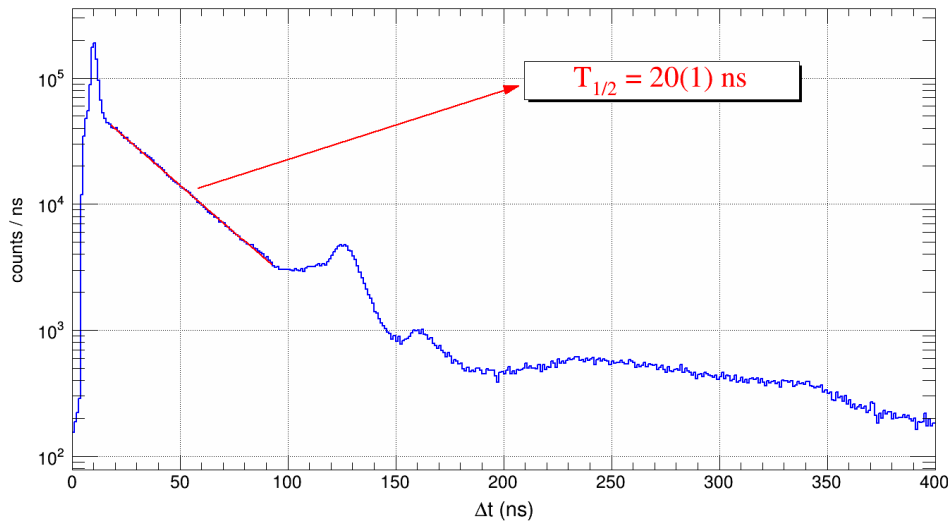


Figure 2. The time difference between two consecutive hits in the beta-detector. The known lifetime of  $T_{1/2} = 20$  ns of E0 transition in  $^{34}\text{Si}$  [2] is well reproduced by off-line analysis of recorded waveform of a single detector.

We propose to continue the measurement at new IDS (ISOLDE Decay Station) which design is following, in many respects, the IS530 set-up (same type of Ge clover detectors, same mechanical supporting structure and therefore same geometry). The implantation chamber will be the one already used in IS530 replacing the standard IDS chamber. Several optimizations will be made, as described in the next section, such that we estimate that in 15 shifts an increase of factor of 10 or more can be obtained in the statistics.

## 2. Addendum

The estimated increase in statistics will be obtained in the following conditions:

- The maximum yield of  $^{34}\text{Mg}$  measured during IS530 run in September 2012 was 140 ions/ $\mu\text{C}$ , as mentioned in database. However the yield was fluctuating, with mean value at 75% from maximum, during an actual measuring time of about 6 shifts. In the remaining 9 shifts from the total of 15 used shifts, the yield was very low or beam stopped for various technical problems. Working with the already commissioned set-up at ISOLDE Decay Station we expect to take full benefit of the requested 15 shifts (7 shift available and 8 shifts requested in addition) at the same mean yield achieved during previous run.
- Based on previous estimate of the  $^{34}\text{Mg}$  lifetime of  $20\pm 10$  ms, a beam gate of 50 ms open shortly after the proton bunch arrival has used. The offline analysis revealed that lifetime is  $63\pm 1$  ms. Therefore the increase of gate duration to 150-200 ms is expected to increase the number of implanted ions per pulse by a factor of 2-3.
- During the run in September 2013 there were used 3 Ge clover detectors, one coaxial Ge detector and 5  $\text{LaBr}_3$  detectors at forward angles. The coaxial detector was very noisy and will be replaced by a 4<sup>th</sup> clover at IDS. The  $\text{LaBr}_3$  detector was used to avoid interference with 596 keV background peak specific to Ge detector when neutron emission channels are present. The very good selection obtained with double hit method in beta detector eliminated completely this peak. Therefore a 5<sup>th</sup> clover detector will be accommodated at forward angle where is possible to decrease the distance to implantation point at less than 3 cm. Therefore we expect an increase in total gamma efficiency by another factor of 2-3.
- The fast plastic scintillator used as beta detector was design to assure a geometrical coverage of  $\sim 95\%$  of implantation point. In the same the thickness was kept at only 3-4 mm in order to reduce the absorption of low energy gamma rays. This lead to a complex form of the detector and, also to electronic noise that imposed a rather high threshold, lead to a beta efficiency of about 80% for high energy beta transitions decreasing to about 70% for beta transition of 2 MeV. The low energy gamma rays are no longer of interest and there we can improve the beta efficiency using a thick rectangular beta detector (with just one channel for tape passage and one channel for ions passage) read simultaneously by 2 photomultipliers. We expect thus an increase of beta efficiency close to the limit of geometrical coverage mentioned above. Moreover, the technique of identification of double hits in beta detectors described above, when applied simultaneously on the two waveforms from the two photomultipliers highly probably will eliminate the spurious maximum observed in left side of spectrum in Figure 2. If so, the condition of having de distance between hits larger than 16 ns will be relax to about 6-7 ns, recovering about 25% of E0 transition that are lost (due to halftime of 20 ns). Therefore the improvement in beta detector may increase further by a factor of 2 the statistic in the spectrum shown in Figure 2.

**Future plans with all requested shifts (including available shifts):**

- (i) Envisaged measurements and requested isotopes  
Measurements: continue beta-gamma decay measurements at new ISOLDE Decay Station.  
Requested isotopes:  $^{34}\text{Mg}$  at maximum possible intensity
  
- (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 (/uC)	target - ion source	Shifts (8h)
$^{34}\text{Mg}$	100	UCx	15

**Total shifts: 15**

**3. References:**

- [1] R.W.Ibbotson et al., Phys. Rev. Lett. 80, 2081 (1998).
- [2] F. Rotaru et al., Phys. Rev. Lett. 109, 092503 (2012).
- [3] M. Langevin et al., Nucl. Phys. A 414, 151 (1984).

**IS530 Publications :**

**Theses: S. Toma, Master Thesis, University Politenica of Bucharest, 2013**

**Workshops: R. Lica et al., presentation at ISOLDE workshop 25-28 Nov 2013.**