

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Proposal to the ISOLDE and Neutron Time-of-Flight Committee

Clarification Letter to the INTC related to INTC-2014-062,
P-426

Measurement of the β asymmetry parameter in ^{35}Ar decay with
a laser polarized beam.

January 15, 2015

Ph. Velten¹, M.L. Bissell¹, C. Couratin¹, P. Finlay¹, R.F. Garcia Ruiz¹, L. Hayen¹, G. Neyens¹, M. Perkowski¹, W. Gins¹, N. Severijns¹, E. Wursten¹, G. Ban², X. Flécharde², E. Liénard², G. Quéméner², O. Naviliat-Cuncic³, A. Gottberg⁴, L. K. Grob⁴, M. Kowalska⁴, S. Malbrunot-Ettenauer⁴, M. Stachura⁴, Th. Bastin⁵, R. Glover⁵, J. Billowes⁶, K.T. Flanagan⁶, T.E. Cocolios⁶, D. Zákoucký⁷, D. Yordanov⁸, P. Delahaye⁹, R. Neugart¹⁰, W. Nörtershäuser^{10,11}

¹*Instituut voor Kern- en Stralingsfysica, KU Leuven, 3001 Leuven, Belgium*

²*LPC Caen, ENSICAEN, Université de Caen, CNRS/IN2P3, F-14050 Caen, France*

³*Michigan State University, 640 S. Shaw Lane, East Lansing, MI 48824-1321, USA*

⁴*Physics Department, CERN, CH-1211 Geneva 23, Switzerland*

⁵*Institut de Physique Nucléaire, Atomique et de Spectroscopie, Université de Liège, 4000 Liège, Belgium*

⁶*School of Physics and Astronomy, The University of Manchester, Manchester M13 9PL, UK*

⁷*Nuclear Physics Institute, Academy of Sciences of the Czech Republic, 250 68 Rez, Czech Republic*

⁸*Institut de Physique Nucléaire Orsay, CNRS/IN2P3, F-91406 Orsay, France*

⁹*GANIL, B.P. 5027, F-14021 Caen Cedex, France*

¹⁰*Institut für Kernchemie, Universität Mainz, D-55128 Mainz, Germany*

¹¹*Institut für Kernphysik, TU Darmstadt, D-64289 Darmstadt, Germany*

Spokesperson: Ph. Velten, philippe.velten@fys.kuleuven.be
Local contact person: M.L. Bissell, mark.lloyd.bissell@cern.ch



1 Introduction

The purpose of this letter is to address the comments/issues raised by the INTC referees regarding the INTC-2014-062, P-426 proposal.

The first comment concerned the choice of crystals for the ^{35}Ar implantation tests of the first phase of the project. This first step is necessary to find the best suited crystal to implant and maintain the polarization long enough to measure the experimental asymmetry of its β decay in conditions compatible with the high precision goal pursued by the proposed experiment. It is a well known fact that there are few physics guidelines to determine which material is the best to implant a given element, and the trial and error experimental method has to be employed. Published results are very scarce, especially for elements that could be compared to the ^{35}Ar case study.

The second comment of the committee concerns the use of a pulsed beam and time resolved detection. Here we emphasize that this has always been our intention for all measurements to be conducted in the context of this proposal.

2 Considerations regarding the choice of crystals for polarized ^{35}Ar implantation tests.

At TRIUMF-ISAC, Rob Kiefl and his team have built up a vast database about the relaxation of nuclear polarization in a wide range of host materials. However, the vast majority of their work has been on ^8Li [1, 2, 3] and is not transferable to ^{35}Ar due to substantial differences in both chemical and nuclear properties of both elements. Firstly the valence state, atomic radius and electronegativity of the probe strongly influence the implantation site and state. Secondly the relaxation can even be isotope dependent as the relaxation depends on the scale of the magnetic moment and the electrostatic quadrupole moment. Although much studied in solid-state research, to the best of our knowledge the accurate prediction of relaxation times for a given probe-host combination remains illusive. Despite this, a range of well established guidelines and previous experience can be drawn upon when selecting possible combinations.

Following the experience of Rob Kiefl and in line with our findings in literature (cf.[4], i.e. the ref.[21] in our proposal) a magnetic field of about 1 T or more and preferably also temperatures below 20 K to quench any relaxation from low frequency dynamics either magnetic or quadrupolar in nature, are desirable.

Further, a cubic insulator with a large band gap seems to be a good choice since there should then be no Korringa relaxation (as is the case in metals) and the sites are all cubic. One should also try to avoid paramagnetic defects being created in the implantation process and for Ar to avoid that some small fraction of it ends up as Ar^+ which is paramagnetic. In the latter case there may be two-component relaxation. A good option would be (simple) cubic metals, such as e.g. Au, in which case there is no question about the charge state, all the sites are cubic and the Korringa relaxation is linear in temperature so will be very small at low temperature.

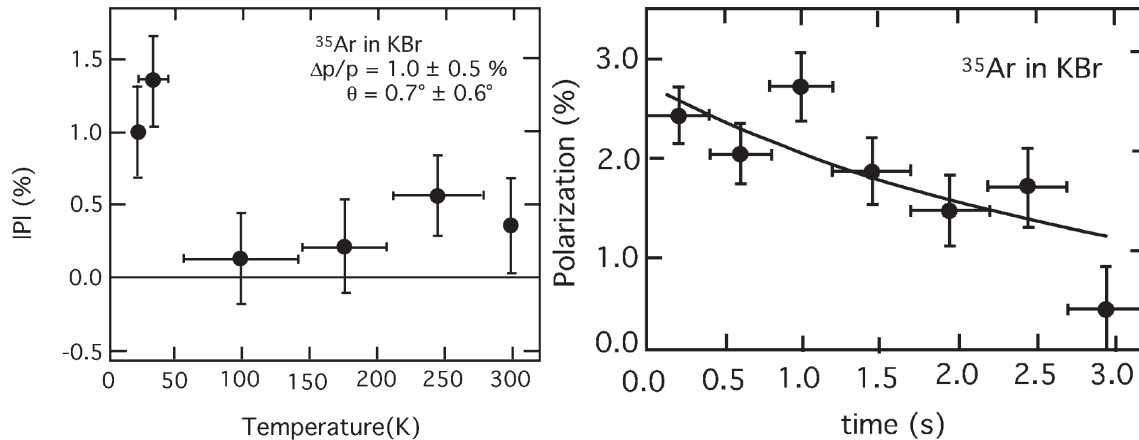


Figure 1: (Left) Polarization of ^{35}Ar in KBr as a function of temperature. (Right) Polarization of ^{35}Ar in KBr as a function of time at a temperature of 20 K, corresponding to a relaxation time of $T_1 = (3.4 + 1.50.78)$ s. The ^{35}Ar was produced in the fragmentation reaction $^{36}\text{Ar} + ^9\text{Be} \rightarrow ^{35}\text{Ar} + \text{X}$ and observed at an ejection angle of $0.7(6)^\circ$, leading to a nuclear polarization of about 1.5% [4].

As mentioned already, ^{35}Ar has already been implanted and its polarization studied in KBr (see fig.1).

Following from the request of the committee to perform additional literature surveys we identified one other promising candidate. Wikner *et al.* [5] reported nuclear quadrupole relaxation times T_1 of 5.2(5) s for ^{35}Cl in NaCl and 8.5(9) s for ^{35}Cl in KCl, each time at 298 K. Since ^{35}Cl and ^{35}Ar have the same spin-parity of $3/2^+$ and both the magnetic and quadrupolar moments are very close as well ($+0.82 \mu_N$ and -0.082 b for ^{35}Cl , and $+0.63 \mu_N$ and -0.084 b for ^{35}Ar) these relaxation times are most likely good estimates for ^{35}Ar . Thus our previous proposal of NaCl has been further supported and we would now add KCl to our preferential list of test host materials.

Finally our preferred list of host materials to test online has evolved to the following :

KBr, Si, NaCl, NaF, KCl and Au

3 Measuring the β assymetry in a time differential mode with a pulsed beam

It should be emphasized that all measurements proposed within the context of P-426 not only benefit from time correlated detection but absolutely require it.

The first major objective of INTC-2014-062, P-426 is the measurement of the relaxation time for the various candidate crystals and this type of measurement can only be conducted by utilising the time dependent information. In fact, for the crystal tests at the COLLAPS setup, it is foreseen to implant only 10 ms of the released ^{35}Ar per proton pulse and subsequently record the asymmetry as a function of time.

One could argue that bunching the beam with ISCOOL would reduce the time uncertainty on the final relaxation times obtained although we feel that the small improvement would not justify the undue additional technical complication and loss of versatility in scheduling unless the precise knowledge of these relaxation times was requested by the solid state community. The production rates are such that at COLLAPS, the scintillation detectors would be at the limit of saturation so no potential gain in signal by bunching rather than chopping can either be expected or required.

Our second objective of comparing the polarisation enhancement obtainable with laser and near-resonant collisional re-ionization at the VITO beamline could also only be conducted with bunched beam from ISCOOL, due to the duty cycle losses that would otherwise be incurred in pulsed laser re-ionization.

In conclusion, we thank the committee for recognising the importance of recording time correlated data and note that this was already our plan for all shifts requested within the framework of this proposal.

References

- [1] Morris GD, *et al. Phys. Rev. Lett.* **93** 157601 (2004)
- [2] Fan I, *et al. Physica B* **404** 5 (2009) pp. 906-909
- [3] Mansour AI, *et al. Physica B* **404** 5 (2009) pp. 910-913
- [4] Matsuta K, *et al. Nuc. Phys. A* **701** 383c (2002)
- [5] Wikner EG, *et al. Phys. Rev.* **118** 631 (1960)
- [6] Ramos J, *et al. Nucl. Inst. Meth. B* **320** 83-88 (2014)