

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Letter of Intent to the ISOLDE and Neutron Time-of-Flight Committee
For the Long Shut Down #2 (LS2)

High Resolution Study of Neutron Interactions With ^7Be
(The “Primordial ^7Li Problem”)

May 31, 2017

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Abstract:

This letter of intent is an update for an INTC approved proposal INTC-P-411, May 24, 2014. Two weeks of beam time were already approved in the 47th meeting of the INTC, June 25-26, 2014. The approved time was not yet used for this project and we propose to use it during the CERN long shut down #2. A poor resolution measurement was successfully completed at the SARAF in Israel using electro-deposit ^7Be target and CR39 Nuclear Track Detectors (NTD). The results of the SARAF measurement with a thick target and poor resolution NTD, while tantalizing, call for repeating this measurement at the SARAF with high resolution using an implanted ^7Be target and a yet to be developed array of diamond detectors.

Requested shifts: NO PROTON REQUESTED

INTC already approved: 24 shifts, split into two runs for two targets, 12 shifts for each target.



1 Introduction

We proposed to the INTC modern measurements of the cross section of the ${}^7\text{Be}(n,\alpha)$ reaction at the Big Bang Nucleosynthesis (BBN) energies of 40-70 keV with neutron beams that mimic a quasi Maxwellian flux at the Soreq Applied Research Accelerator Facility (SARAF) in Israel. The neutron beams provided by the SARAF resembles the cosmological conditions during BBN. We attach in the appendix the approved proposal INTC-P-411, where we discuss the science of the proposed project. For these measurements two weeks of off-line beam time were approved for the production of two implanted ${}^7\text{Be}$ targets (300 mCi, with 10% 478 gamma-activity) at the ISOLDE facility at CERN. We attach in the appendix the minutes of the 47th meeting of the INTC. The current proposal will utilize a ${}^7\text{Be}$ sample that will be extracted from CERN Medics facility

A measurement of the ${}^7\text{Be}(n,\alpha)$ reaction was carried out at SARAF facility in Israel [1]. This measurement in the BBN window with neutron beams that mimic a quasi Maxwellian flux, together with the complementary measurement below the BBN window, at the n_TOF facility of CERN [2] and the Kyoto measurement [3] above the BBN window, allow us to tentatively deduce the modern reaction rate for the ${}^7\text{Be}(n,\alpha)$ reaction shown in Fig. 1.

We propose to improve the sensitivity of the SARAF measurement by a factor 10 and place the tentative results on firmer footings. We intend to do that by using a thin implanted target (thus good energy resolution of the outgoing alphas) and by using an array of high resolution detectors that will allow for measuring the two alpha-particles in coincidence. For example only an upper limit of $1.0 \mu\text{b}$ was obtained in the SARAF measurement of the cross section of the ${}^7\text{Be}(n,\gamma\alpha)$ reaction for the high energy alpha-particles (~ 8.4 MeV). As we discussed below the proposed sensitivity is for a cross section on $0.1 \mu\text{b}$. For the $E_\alpha = 1.5$ MeV the SARAF result was obtained with large uncertainty (35%). We are developing at the SARAF an array of high resolution diamond detectors that was proven to sustain the high neutron flux ($\sim 10^{10}$ n/sec) of the SARAF. This high resolution detector array together with the proposed implanted ${}^7\text{Be}$ target will result a high resolution measurement in the BBN window.

1.1 The Implanted ${}^7\text{Be}$ Targets

The ${}^7\text{Be}$ target we propose to use will be produced using current technologies. We propose to implant 7×10^{16} ${}^7\text{Be}$ atoms (300 mCi electron capture, 11 GBq, 30 mCi, 1.1 GBq of 478 keV gamma-activity) in 8 mm diameter, hence $1.4 \times 10^{17}/\text{cm}^2$ which is below the blister limit of $6 \times 10^{17}/\text{cm}^2$. Each target will require 3 days with an implantation current of 50 nAmp, hence we request 4 days for each implantation to allow for source down time. We note that ${}^7\text{Be}$ currents of up to 300 nAmp were achieved at ISOLDE, but we use the conservative value of 50 nAmp. We propose to use the laser ion source that was used in the past for producing ${}^7\text{Be}$ beams. The implanted ${}^7\text{Be}$ target will be prepared using a dedicated implantation chamber we constructed at the ISOLDE facility at CERN. The activity of the ${}^7\text{Be}$ implanted target is close to the allowed limit of 100LA for the

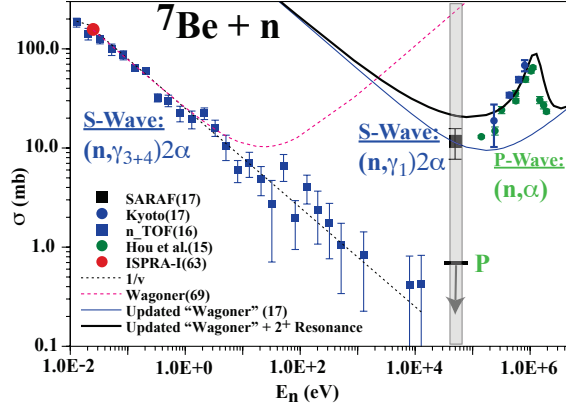


Figure 1: The cross section of the ${}^7\text{Be}(n,\alpha)$ and the ${}^7\text{Be}(n,\gamma\alpha)$ reactions measured in the BBN window at SARAF [1] and by the n_TOF collaboration [2] and in Kyoto [3].

implantations at ISOLDE (swiss class C lab for radiological risks). Hence the target removal and shipment to Israel will require special safety consideration. The ${}^7\text{Be}$ sample will be extracted from the CERN Medics facility in a form that will be suitable for the ISOLDE ion source.

1.2 Design Goal Sensitivity

A neutron beam intensity of $1.0 \times 10^{10}/\text{sec}$ and a ${}^7\text{Be}$ target of $1.0 \times 10^{17}/\text{cm}^2$ leads to a luminosity of $10^{27}\text{cm}^{-2}\text{sec}^{-1}$ hence an integrated luminosity of $28 \mu\text{b}^{-1}$ in one hour, leading to a goal sensitivity for measuring cross sections as low as $0.1 \mu\text{b}$. This design goal is a factor of 10 smaller than the upper limit measured at the SARAF for the high energy alpha-particles from the ${}^7\text{Be}(n,\alpha)$ reaction.

Summary of requested shifts:

No proton beams are requested. INTC already approved 24 shifts: 12 shifts are requested for producing each ${}^7\text{Be}$ implanted target, two targets require 24 shifts.

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Appendix

DESCRIPTION OF THE PROPOSED EXPERIMENT

The experimental setup comprises:

Implantation of ^7Be in a collection chamber in ILA1, SSP-GLM or SSP-GHM chamber.

Part of the	Availability	Design and manufacturing
Implantation of ^7Be in a collection chamber in ILA1, SSP-GLM or SSP-GHM chamber.	<input checked="" type="checkbox"/> Existing	<input checked="" type="checkbox"/> To be used without any modification

HAZARDS GENERATED BY THE EXPERIMENT (if using fixed installation:)

At most 15 GBq (478 keV gamma-ray activity) ^7Be sample from CERN Medics facility.

Proposal INTC-P-411, May 24, 2014

Minutes 47th meeting of the INTC, June 25-26, 2014.

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

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

Implanted ${}^7\text{Be}$ Targets For The Study of
Neutron Interactions With ${}^7\text{Be}$
(The “Primordial ${}^7\text{Li}$ Problem”)

May 26, 2014

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Abstract:

The disagreement of the predicted abundance of primordial ${}^7\text{Li}$ with the observed abundance is a longstanding problem in Big Bang Nucleosynthesis (BBN) theory (“Primordial ${}^7\text{Li}$ problem”). While BBN theory correctly predicts the relative abundances of ${}^2\text{H}/{}^1\text{H}$, ${}^3\text{He}/{}^1\text{H}$ and ${}^4\text{He}/{}^1\text{H}$ (that vary over four orders of magnitudes), but it over-predicts the relative abundance of primordial ${}^7\text{Li}/{}^1\text{H}$ by a factor of approximately 3-4 larger than observed (approximately 4-5 σ discrepancy). Primordial ${}^7\text{Li}$ is destroyed during the first 15 minutes primarily via the ${}^7\text{Li}(p,\alpha)$ reaction. Hence most of the primordial ${}^7\text{Li}$ is predicted as the result of the (later when atoms are formed) electron capture beta decay of the primordial ${}^7\text{Be}$ that is produced primarily in the ${}^3\text{He}(\alpha,\gamma){}^7\text{Be}$ reaction. We propose to investigate the direct destruction of ${}^7\text{Be}$ during (the first 15 minutes of) BBN via the ${}^7\text{Be}(n,\alpha)$ reaction to check whether this direct destruction of ${}^7\text{Be}$ competes with the ${}^7\text{Be}(n,p){}^7\text{Li}(p,\alpha)$ reaction chain. The rate of the ${}^7\text{Be}(n,\alpha)$ reaction at BBN energies relies on cross section of thermal neutron (only) measured in 1963 that was extrapolated to BBN energies for the first and last time by Wagoner in 1967.

We propose modern measurements of the cross section of the ${}^7\text{Be}(n,\alpha)$ reaction at the BBN energies of 20-100 keV with neutron beams that mimic a quasi Maxwellian flux at the new Soreq Applied Research Accelerator Facility (SARAF) in Israel. For these measurements two implanted ${}^7\text{Be}$ targets (30 mCi of 478 gamma-activity) are proposed to be prepared at the ISOLDE facility at CERN from a ${}^7\text{Be}$ sample that will be extracted from the water-cooling loop of the SINQ neutron spallation source at the Paul Scherrer Institute in Villigen, Switzerland.

Our experiment planned at the SARAF facility in Israel together with a complementary experiment proposed for the nTOF facility of CERN will measure the neutron interactions with ${}^7\text{Be}$ at all applicable energies [1].

For the measurements of neutron interactions with ${}^7\text{Be}$ at the SARAF in Israel we consider active charged particle detectors such as a twin-ionization chamber as well as plastic track detector (e.g. CR-39), requiring two separate ${}^7\text{Be}$ targets. In both cases before measuring the ${}^7\text{Be}(n,\alpha)$ reaction we plan to test the background and feasibility of the method by measuring the ${}^{10}\text{B}(n,\alpha){}^7\text{Li}$ reaction.

An implantation of ${}^{10}\text{B}$ in thin aluminum foil has been demonstrated using the off-line ion source at ISOLDE. For this purpose a new implantation chamber was constructed that we plan to also use for implanting ${}^7\text{Be}$. The implanted ${}^{10}\text{B}$ sample was tested using neutrons from the CERN intense Pu-Be neutron source and the ${}^{10}\text{B}(n,\alpha){}^7\text{Li}$ reaction.

Requested shifts: NO PROTON REQUESTED

24 shifts, split into two runs for two targets, 12 shifts for each target over two years.

1 Introduction

The theory of Big Bang Nucleosynthesis (BBN) was first introduced in the 1940s by George Gamow and since then it was successful in predicting the abundances of the primordial ^1H , ^2H , ^3He and ^4He that vary over four orders of magnitudes [2]. It also predicted correctly the number of neutrino types and allowed for accurate determination of the baryonic density in the Universe. This latest prediction gave credence to the concept of dark matter that was introduced by Fritz Zwicky already in the 1930s. Such cosmological observations brought on the era of precision cosmology [2] and allowed the study of fundamental physics beyond the scope of terrestrial laboratories. Recent accurate determination of the baryon density by the Wilkinson Microwave Anisotropy Probe (WMAP) [3], together with a measurement of the number of neutrino types, and several improvements of the nuclear data including neutron half-life and cross-sections of relevant nuclear reactions such as the $^3\text{He}(\alpha, \gamma)^7\text{Be}$ [4] reaction, allowed for precise model independent predictions by BBN theory of the abundance of primordial elements. These predictions agree quite well with new precise observation of primordial abundances, except for ^7Li as shown in Fig. 1. The discrepancy observed for ^7Li is coined the “Primordial ^7Li problem”.

The rate of the $^7\text{Be}(n, \alpha)$ reaction was first and last compiled by Wagoner et al. in 1967 [5] that extrapolated to high energies the cross section of the $^7\text{Be}(n, \alpha)$ measured at thermal energies [6]. In Serpico et al. [7] we find the following statement: “To our knowledge, evaluations for the rate of the $^7\text{Be}(n, \alpha)$ reaction have only been published in [5], without information on the sources of the data and error estimate. We did not find further analysis in subsequent compilations. For this reason we adopted Wagoners rate, assuming a factor of ten uncertainty, as he suggested as a typical conservative value. Within this allowed range, this reaction could play a non-negligible role in direct ^7Be destruction, so it would be fruitful to have a new experimental determination. Apart from the role of unknown or little known ^8Be resonances, it is however unlucky [unfortunate] that the used extrapolation may underestimate the rate by more than one order of magnitude, as this process mainly proceeds through a p-wave”. A compilation by our collaborator K.M. Nollett [1] of the various cross sections for the interaction of ^7Be with neutrons is shown in Fig. 2. Note that at 100 keV where the (n, α) reaction is compiled to be only a factor of 20 smaller than measured (n, p) reaction, the quoted uncertainty of a factor of 10 confirms Serpico’s statement of the possible relevance of the $^7\text{Be}(n, \alpha)$ reaction.

There is no proton-induced reaction with sufficiently large cross section to destroy the ^7Be during BBN. The destruction of ^7Be by interactions with deuterium was found [8] not to be responsible for destruction of ^7Be during BBN and the proposed unknown $d + ^7\text{Be}$ resonances were ruled out [9, 10] as the solution of “Primordial ^7Li problem”. The destruction of ^7Be by ^3He -induced reactions that was measured at the Weizmann Institute [11] does not yield a solution of the ^7Li problem either. Hence our measurement of the interaction of neutrons with ^7Be could be considered as the last attempt to reconcile the “Primordial ^7Li problem” using standard nuclear physics.

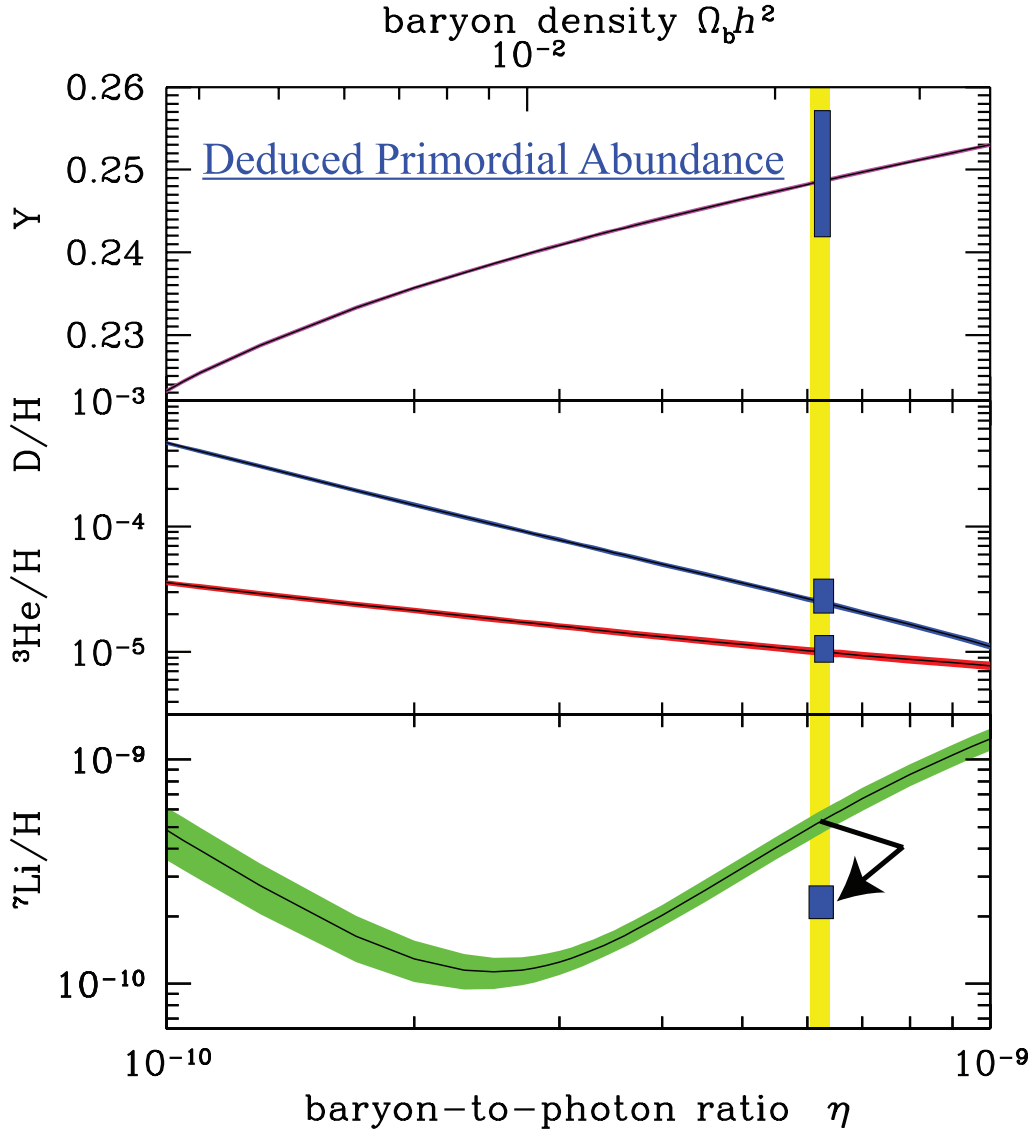


Figure 1: The primordial light element abundances of D, ${}^3\text{He}$, ${}^7\text{Li}$ (relative to the abundance of H), and the mass fraction of ${}^4\text{He}$ as a function of η . The thickness of the bands represents 1σ uncertainties in the calculated abundance. The yellow band corresponds to the WMAP baryon-to-photon ratio, η of $6.07(9)10^{-10}$. The observed abundances are shown by the blue bands and the discrepancy for ${}^7\text{Li}/\text{H}$ is indicated.

Kenneth M. Nollett, ANL, Private Communication, 2011

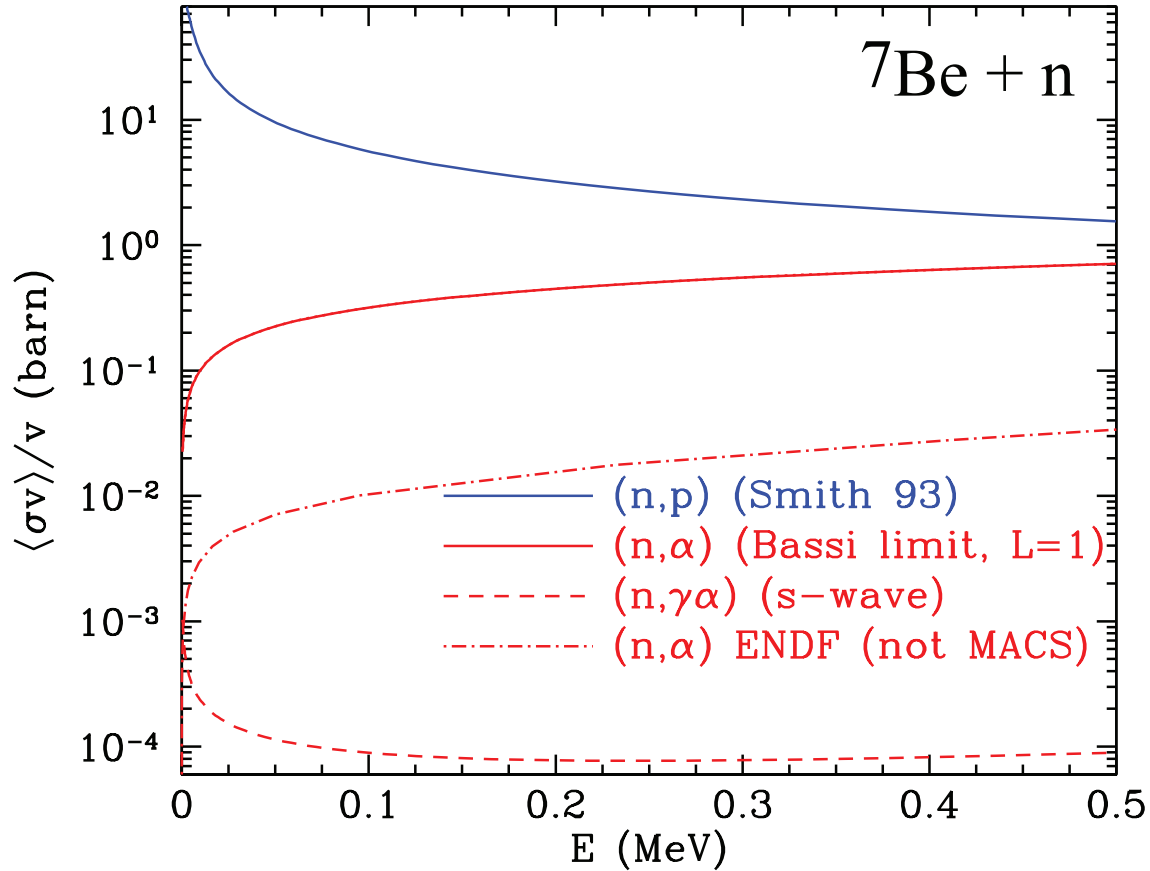


Figure 2: The cross sections of the interactions of neutrons with ${}^7\text{Be}$ as compiled by K.M. Nollett [1]. The (n,α) cross section is as extrapolated (from thermal neutrons energies) by Wagoner in 1967 for p-wave neutrons. Note at 100 keV the cross section of the (n,α) reaction is compiled to be only 20 times smaller than the measured (n,p) reaction, with a factor of 10 uncertainty [7].

2 The Proposed Measurements

We plan to initially measure the ratio of the cross section of ${}^7\text{Be}(n,\alpha)$ reaction and the previously measured ${}^7\text{Be}(n,p)$ reaction [12] using plastic CR-39 track detectors. Following this measurement we plan to measure the cross section of the ${}^7\text{Be}(n,\alpha)$ and the ${}^7\text{Be}(n,\gamma\alpha)$ reaction using charged particle detectors. Prior to measurements with a ${}^7\text{Be}$ target we plan to measure the ${}^{10}\text{B}(n,\alpha){}^7\text{Li}$ reaction in order to study the background and the response of the detector to the intense neutron beams. We propose here to produce at ISOLDE two implanted ${}^7\text{Be}$ targets (see below) for these measurements.

2.1 The Implanted ${}^7\text{Be}$ Targets

The ${}^7\text{Be}$ target we propose to use will be produced using current technologies. We propose to implant 7×10^{16} ${}^7\text{Be}$ atoms (300 mCi electron capture, 11 GBq, 30 mCi, 1.1 GBq of 478 keV gamma-activity) in 8 mm diameter, hence $1.4 \times 10^{17}/\text{cm}^2$ which is below the blister limit of $6 \times 10^{17}/\text{cm}^2$. Each target will require 3 days with an implantation current of 50 nAmp, hence we request 4 days for each implantation to allow for source down time. We note that ${}^7\text{Be}$ currents of up to 300 nAmp were achieved at ISOLDE, but we use the conservative value of 50 nAmp. A new ion source with high (20%) efficiency for the production of ${}^7\text{Be}$ [13] will be used for the implantation provided the purity will be satisfactory, otherwise we will use the laser ion source that was used in the past for producing ${}^7\text{Be}$ beams. The implanted ${}^7\text{Be}$ target will be prepared using a dedicated implantation chamber we constructed at the ISOLDE facility at CERN. The activity of the ${}^7\text{Be}$ implanted target is close to the allowed limit of 100LA for the implantations at ISOLDE (swiss class C lab for radiological risks). Hence the target removal and shipment to Israel will require special safety consideration.

The ${}^7\text{Be}$ sample will be extracted by the RadWasteAnalytics group from the water-cooling loop of the SINQ spallation neutron source at the Paul Scherrer Institute (PSI) in Villigen. A ${}^7\text{Be}$ radioactive sample of up to 200 GBq can be readily prepared by the RadWasteAnalytics group of the PSI. A ${}^7\text{Be}$ sample including tens of GBq has already been separated at the PSI and implantation of ${}^7\text{Be}$ was already performed at ISOLDE [14] for an experiment at the Weizmann Institute in Israel [15].

A ${}^{10}\text{B}$ implanted target was prepared by the student Christoph Seifferet at the ISOLDE facility using a dedicated implantation chamber that we constructed to use for the implantation of ${}^7\text{Be}$. The ${}^{10}\text{B}$ dose of 1.5×10^{16} was implanted with 3 mm diameter into a thin (1 μm thick) aluminum foil. The implanted ${}^{10}\text{B}$ target was tested using the strong Pu-Be neutron source available at CERN. The resulting 1.477 MeV alpha-particles from the ${}^{10}\text{B}(n,\alpha){}^7\text{Li}$ reaction is shown in Fig. 3.

2.2 The Neutron Beam and the SARAF Experiment

The neutron beams will be provided by the newly constructed Soreq Applied Research Accelerator Facility (SARAF) in Israel [16] using the Liquid Lithium Target (LiLiT) [17] that is already operating at the Soreq Nuclear Center in Israel. The neutron beams provided by the SARAF are very intense of the order of $10^{10}/\text{sec}$. A first measurement

Christoph Seiffert, ISOLDE off Line Ion Source, 2013

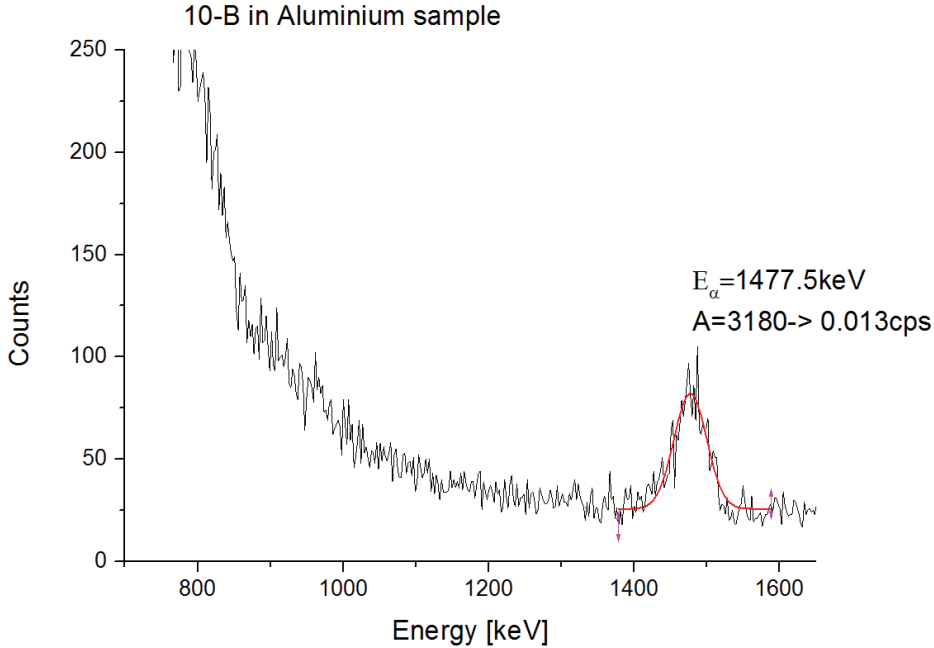


Figure 3: Alpha-particle from the $^{10}\text{B}(n,\alpha)^7\text{Li}$ reaction measured by Christoph Seiffert [1] with the ^{10}B implanted target produced at ISOLDE and the CERN Pu-Be source.

we plan to perform is of the ratio of the cross sections: $^7\text{Be}(n,p)/^7\text{Be}(n,\alpha)$ in order to test the rates published by Wagoner [5]. In this case one needs to compare the yield for proton peaks at 1.4 MeV from the (n,p) reaction with the alpha peak at 9.5 MeV from the (n, α) reaction. For this first measurement we propose to employ two plastic CR-39 track detector in a closed sandwich geometry that will allow for coincidence measurements of the two back-to-back alpha-particles.

CR-39 track detectors were already used by members of this collaboration [18]. In these measurements (with CR-39) of the $^{10}\text{B}(n,\alpha)^7\text{Li}$ reaction with neutrons produced by the $^7\text{Li}(p,n)$ reaction, the plastic track detectors were observed to be blind to the low energy (up to 120 keV) neutrons, indeed they are guaranteed to be insensitive to neutrons up to 200 KeV. They are also insensitive to the high flux of 10^{10} /sec 478 keV gamma-rays to which they are exposed from the $^7\text{Li}(p,p)^7\text{Li}^*(478)$ reaction (and the radioactive ^7Be target). We plan to repeat the measurements of the $^{10}\text{B}(n,\alpha)^7\text{Li}$ reaction at SARAF using CR-39 track detectors before using a ^7Be target.

Such CR-39 plastic track detectors were extensively used in the past for measuring coincidence between alpha-particles and ^7Li emanating from the $^{10}\text{B}(n,\alpha)^7\text{Li}$ reaction. Coincidence were determined by measuring tracks recorded within 8μ proximity in the two opposite CR-39 track detectors [19]. It was also demonstrated that CR-39 detectors can distinguish protons, alpha-particles and ^7Li using the track gray scale plotted against the major axis of the produced tracks [19, 20] as well as the ratio of the major and minor axis [21]. Differential etching was also used to accentuate the tracks [22]. Energy

resolution of 100 keV was reported [22] using CR-39 track recorders. We foresee no problem with the use of the plastic CR-39 track recorder to measure the ratio of the cross sections: ${}^7\text{Be}(n,p)/{}^7\text{Be}(n,\alpha)$ since such CR-39 were already used extensively to detect alpha-particles and ${}^7\text{Li}$ from the ${}^{10}\text{B}(n,\alpha){}^7\text{Li}$ reaction.

We also plan to detect the alpha particles with active charged-particle detectors (Si or gas ionization chamber). A detector consisting of twin ionization chambers having a common cathode (where the ${}^7\text{Be}$ target will be placed) can detect in coincidence the two alpha particles emitted on both sides. Such a detector was successfully used for detection of fission fragments [23, 24] and beta-delayed alpha emission of ${}^{16}\text{N}$ [25]. Before measuring the ${}^7\text{Be}(n,\alpha)$ reaction with the charged particle detectors we plan to test the background and feasibility of the method by measuring the ${}^{10}\text{B}(n,\alpha){}^7\text{Li}$ reaction.

2.3 Design Goal Sensitivity

A neutron beam intensity of $1.0 \times 10^9/\text{sec}$ and a ${}^7\text{Be}$ target of $1.0 \times 10^{17}/\text{cm}^2$ leads to a luminosity of $10^{26}\text{cm}^{-2}\text{sec}^{-1}$ hence an integrated luminosity of $2.8 \mu\text{b}^{-1}$ in one hour, leading to a goal sensitivity for measuring cross sections as low as $1 \mu\text{b}$.

Summary of requested shifts:

No proton beams are requested. We request 24 shifts: 12 shifts are requested for producing each ${}^7\text{Be}$ implanted target, two targets require 24 shifts.

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ISOLDE AND NEUTRON TIME-OF-FLIGHT
EXPERIMENTS COMMITTEE

Minutes of the 47th meeting of the INTC
held on Wednesday, June 25, and Thursday, June 26, 2014

OPEN SESSION Wednesday, June 25, 2014 at 13:00 in the Council Chamber.

The chairman of the INTC, Klaus Blaum, opened the meeting, presented all members of the committee and announced the agenda.

ISOLDE Status report (R.Catherall, M. Kowalska)

ISOLDE is getting ready to take the first protons. Multiple LS1 activities have taken place since the last INTC: installation of new robots and a new hot-cell to manipulate irradiated targets, civil engineering for the MEDICIS project, upgrade of the control software for the HRS magnet, modifications and realignment of ISCOOL- the cooler-buncher behind HRS. So far the biggest problems and delays were encountered with re-welding of water tubes after robot installations and the HRS separator vacuum leak which required removing one of the magnets. The offline target and ion-source activities included work on 11C beam, LaC target material, and RILIS schemes and alignment target unit. The activities on the critical path are: the final commissioning of the robots, stable beam through the ISCOOL, testing of the repaired tape station. The aim was to take the first protons as planned, on July 10 while spending 2 more weeks on ISCOOL commissioning.

The ISOLDE physics programme is planned to start at the end of July and run until December 15th. This corresponds to 20 weeks, 14 of which are already covered by the detailed schedule. 530 8-h shifts were requested for 2014 and about 260 have been scheduled so far. Two weeks of buffer time on HRS should allow no delays in physics in spite of machine problems. The new rules for obtaining a dosimeter and accessing ISOLDE were then discussed. Finally, the status of the laboratory and control-room building behind ISOLDE (b508) was presented – due a redesign of the cooling and ventilation system the building will be ready for users not in May but earliest in July, which will affect some of the physics.

HIE-ISOLDE Status Report (Y. Kadi)

For the HIE-ISOLDE project the main technical points were presented. Three out of four rf cavities tested recently performed according with or above specifications. The elements and activities with the status close to the original schedule are copper cavities, beam diagnostics, infrastructure in service buildings and inside ISOLDE. The elements delayed by a few months are the superconducting solenoid, beamline magnets and cryomodule components. The new baseline schedule is to have one cryomodule available for physics up to 4.5 MeV/ in autumn 2015 and to install the 2nd cryomodule during the 2015-16 shutdown. The resulting key issues in the next six months will be maintaining the present success rate for the cavity sputtering/processing protocol and maintaining the tight schedules of cryomodule assembly and cryogenic installation. The planning and activity monitoring are presently reviewed weekly. The

resources issues (highlighted by Risk Analysis) are being addressed and the budget is under control.

nTOF Status Report (E. Chiaveri)

nTOF is preparing for the first protons after LS1 in EAR1 and the first protons ever in EAR2. The LS1 activities in EAR1 included work on both beam collimators, renovation of the filter box, exchange of the vacuum window, modifications of the access system, and general consolidation. The works at EAR2 are also progressing well: most components and materials will be available for the end of June and the plan is to start with beam commissioning around mid-July. Then, a list of accepted and envisaged measurements for EAR1 and EAR2 was presented. Finally, the detailed planning for EAR2 was presented – the aim was to take the first protons before the end of July – this plan looked challenging, but feasible.

In the remaining part of the open session the following documents were presented (the order corresponds to the sequence of document submission, not presentation):

INTC-P-410, Search for beta-transitions with the lowest decay energy for a determination of the neutrino mass

INTC-P-411, Implanted ^7Be Targets For The Study of Neutron Interactions With ^7Be : (The “Primordial ^7Li Problem”)

INTC-P-413, Collinear resonance ionization spectroscopy of radium ions

INTC-P-414, Spectroscopy of the low lying states of neutron rich ^{134}I

INTC-P-415, Tackling the s-process stellar neutron density via the $^{147}\text{Pm}(n,\gamma)$ reaction

INTC-P-416, High accuracy measurement of the $^{235}\text{U}(n,f)$ reaction cross-section in the 10-30 keV neutron energy range

INTC-P-417, Measurement of $^7\text{Be}(n,\alpha)^4\text{He}$ and $^7\text{Be}(n,p)^7\text{Li}$ cross-sections for the Cosmological Lithium Problem

INTC-P-418, Measurement of the neutron capture cross-sections of ^{53}Mn at EAR-2

INTC-P-335-ADD-1, Measurement of the $^{44}\text{Ti}(\alpha,p)^{47}\text{V}$ reaction cross section, of relevance to gamma-ray observation of core collapse supernovae, using reclaimed ^{44}Ti from radioactive waste

CLOSED SESSION Thursday, June 26, 2014 at 9:00, room 60-6-015

Present: O. Aberle, N. Alahari, K. Blaum (chair), B. Blank, M. Block, M.G. Borge, W. Catford, R. Catherall, E. Chiaveri, J. Dobaczewski, M. Doser, Y. Kadi, E. McGlynn, M. Kowalska (secretary), Z. Salman, T. Stora, V. Vlachoudis, Ch. Weiss, H. Wilkens

Apologies: G. De Angelis, J. Vaagen

1. INTRODUCTION BY THE CHAIRMAN

The Chairman opened the meeting and welcomed all participants.

The replacement of Jan Vaagen, who will finish his mandate as INTC referee in December 2014, was discussed. Three candidates were selected and the chairman would contact them before the next INTC meeting.

The dates of the next INTC meetings were discussed and agreed:

Wednesday 11 - Thursday 12 February

Wednesday 1 - Thursday 2 July (during the meeting a date 1 week earlier was discussed, but it was moved to the present date after the meeting).

Wednesday 11 - Thursday 12 November.

The Chairman informed the members of the feedback from the last Research Board: all INTC recommendations were approved.

Finally, the minutes from the previous INTC meeting were approved without further changes.

2. STATUS OF ISOLDE AND HIE-ISOLDE

The Chairman acknowledged the reports and the progress presented by the ISOLDE technical and physics coordinators, and by the HIE-ISOLDE project leader.

The question was raised about the 2015/2016 shutdown and how its date would influence the low-energy and HIE-ISOLDE physics programmes. The stop of protons to ISOLDE in 2015 was not known at the time of the meeting, but because the HIE-ISOLDE physics programme should start in October 2015, it would be important to run until December 2015. These dates should be reflected in the call for beamtime requests to be sent by the ISOLDE Physics Coordinator in February.

Concerning the HIE-ISOLDE phase 2, the INTC supports the plan not to delay it. For phase 1 the required resources are presently available and, e.g. several cleanroom technicians have been hired for the project. Thanks to this some of the points identified in the risk assessment, namely those connected to the lack of manpower, are less critical. On the other hand, the risk of a long learning curve is still present.

3. STATUS OF N_TOF

The report by the n_TOF spokesperson and the progress presented in it were acknowledged.

There was a discussion concerning the planning of LS1 activities and how the start of EAR2 in July 2014 can be maintained. This is possible, because the time of detector installation has been shortened accordingly.

4. DISCUSSION ON THE SUBMITTED DOCUMENTS

The documents submitted to the open and closed session were discussed.

INTC-P-410, Search for beta-transitions with the lowest decay energy for a determination of the neutrino mass:

The proposal suggests performing high-precision Q value measurements of four nuclide pairs that are relevant in the context of the neutrino mass determination via microcalorimetric experiments studying their electron capture decay. The authors have performed a large survey and selected a number of the potentially most interesting nuclides that involve decays into excited states. The suggested Q value measurements will be performed with the ISOLTRAP setup.

The INTC considers the physics case very appealing and encourages the authors to pursue this activity. The ISOLTRAP collaboration has the necessary expertise to perform such experiments adequately. However, there are some issues to be considered. First of all, the experiment requires several (complicated) beams not yet available at ISOLDE. In addition, the authors want to apply the new PI-ICR technique at least for the “hard” cases. However, this technique has not yet been implemented at ISOLTRAP and a clear time line for the installation was not presented. The INTC encourages the collaboration to give priority to the implementation of the PI-ICR technique prior to performing these experiments since all measurements would profit from it. Nonetheless, the INTC recommend 6 shifts of online beam time for the ^{131}Cs case, which is already feasible using the conventional technique, and 6 online shifts for the development of the PI-ICR method. The INTC recommends the necessary beam development for the remaining cases.

12 out of 36 shifts were recommended for approval by the Research Board

INTC-P-411, Implanted ^7Be Targets For The Study of Neutron Interactions With ^7Be : (The “Primordial ^7Li Problem):

The astrophysical observations of the primordial Li in very old, metal poor halo stars are about a factor 3 lower than what is predicted by the standard Big Bang Nucleosynthesis (BBN) together with the baryon-to-photon ratio deduced from the cosmic microwave background. Neutron-induced reactions on ^7Be play a role in the production of ^7Li during the BBN and thus the scientific case of the proposal is very appealing.

The collaboration requests a production of a pure sample of long-lived ^7Be via mass separation at ISOLDE, using a chemically-separated target produced in PSI. The sample will be then used in SARAF, Israel, where a measurement of the maxwellian averaged cross section is planned using CR39 track etch detectors. This study will be complementary to the energy-resolved measurements planned at n_TOF within P-417.

The requirements for ISOLDE to produce a pure beam of ^7Be are well explained and the aimed activity (larger than in P-417) is within ISOLDE radioprotection limits. The committee welcomes the collaboration between the three facilities, PSI, ISOLDE and SARAF. However, the Committee requests that the ISOLDE spokesperson is informed once SARAF is ready, in order for the production of the source at ISOLDE to be scheduled.

24 out of 24 offline shifts were recommended for approval by the Research Board, once SARAF is ready

INTC-P-413, Collinear resonance ionization spectroscopy of radium ions:

This proposal aims to use two already-identified hyperfine transitions to measure magnetic moments and spectroscopic quadrupole moments across a range of radium isotopes. Transitions in the radium ions (not atoms) are envisaged because in this case the electric field gradient can be calculated better and also some experimental problems can be avoided. Whereas Pb (Z=82) and Fr (Z=87) and Po (Z=84) systematics for mean square charge radii are known from N=126

all the way down to $N=114$, Ra ($Z=88$) is known incompletely, only down to 120. The systematics including the sequence of spins reveal shape changes that are the primary interest here and there is tentative evidence that the departure from sphericity occurs closer to $N=126$. Different theoretical models exist and have a sensitivity such that the new observations can offer very useful constraints.

The beam time request includes a re-measurement for isotopes with $N=120-126$, which should bring new results for the quadrupole moments of two isotopes and define parameters used in fitting the data. The B-coefficient measured in Ra also has additional interest in relation to a planned atomic parity non-conservation experiment at KVI and to proposed Ra-based atomic.

The committee found the physics case interesting. The collaboration is encouraged to look for theory support for their studies and to contemplate also the studies of Rn isotopes. The shifts for RILIS development are not included explicitly in the recommended shifts.

14 out of 14 shifts were recommended for approval by the Research Board

INTC-P-414, Spectroscopy of the low lying states of neutron rich ^{134}I :

This proposal is resubmission of proposal P-403 (Oct 2013) and it addresses the nuclear structure around $Z=50$ and $N=82$. The focus on the odd ^{134}I , where it is proposed to improve the knowledge of the lifetimes, spins and parities, and transition quadrupole moments of several low lying excited states. Theoretical shell model calculations (with different cores) invert the 3^+ and 5^+ tentative assignments made many years ago. The committee still felt that there remained several questions concerning the feasibility of the studies and the presentation of the physics case was not very strong. It was namely not clear whether it is feasible to extract a meaningful PAC measurement in a solid Te metal since the EFG at the Te implantation site is not known in this system. Basing the estimates on calculated values of the EFG will not produce a reliable result. On the motivation side, it was not shown in a convincing way how a successful measurement will improve the understanding of the shell model interaction in the region around ^{132}Sn . The shell-model calculations are not expected to be precise within a few tens of keV and the clarification of the experimental situation at this level of precision, proposed here, may have a very limited impact of the shell-model parameters.

No shifts were recommended for approval by the Research Board

INTC-P-415, Tackling the s-process stellar neutron density via the $^{147}\text{Pm}(n,\gamma)$ reaction:

The time-of-flight measurement of neutron capture cross sections at the s-process branching ^{147}Pm proposed for EAR2 will improve the understanding of the physical conditions during the s-process nucleosynthesis, thanks to the determination of the maxwellian averaged cross section. The radioactive target of ^{147}Pm has been produced by neutron irradiation of the high flux reactor at ILL in the frame of the EC NeutAnadalus Project.

The technical concerns expressed by the committee were all addressed. The count rate estimate is based on the prior experience at EAR1 and on model cross sections that have some uncertainty. The results of the EAR2 commissioning concerning background conditions and resolution have to be taken into account in the preparation of this experiment. The background from the radioactive sample should be below the detection limit. Liquid scintillators will be used, which will be deuterated to reduce neutron sensitivity. The experiment was found interesting and feasible.

2.0×10^{18} protons at EAR2 were recommended for approval by the Research Board

INTC-P-416, High accuracy measurement of the $^{235}\text{U}(n,f)$ reaction cross-section in the 10-30 keV neutron energy range:

High accuracy measurement of the $^{235}\text{U}(n,f)$ reaction cross section in the 10-30 keV neutron energy range is proposed. It is motivated by a several percent difference at EAR1 between the "evaluated" neutron flux based on the average of Si and ^{10}B Micromegas detectors in comparison with the ^{235}U Micromegas and a ^{235}U fission chamber from PTB. Other experiments

on neutron capture of ^{235}U have also found a problem that could be related to the fission cross section.

The ^{235}U fission cross section is an important standard for thermal and fast neutron range above 150 keV. Therefore it would be interesting to investigate the possible anomaly, maybe even in a larger energy range up to 150 keV. To rule out unknown systematic issues a similar measurement is planned at IRMM, Gelina, and the results of both experiments should be combined to minimize remaining uncertainties. In the proposed experiments the experimental setup will be changed to observe the reference reactions on ^6Li and ^{10}B in both directions relative to the beam. Si detector stacks shall be put in the beam at EAR1. The results from these measurements should be taken into account for the proposal P-417, where a very similar setup is to be tested at EAR2.

1.5×10^{18} protons at EAR1 were recommended for approval by the Research Board

INTC-P-417, Measurement of $^7\text{Be}(n,\alpha)^4\text{He}$ and $^7\text{Be}(n,p)^7\text{Li}$ cross-sections for the Cosmological Lithium Problem:

The motivation of this proposal is the same as for P-411: to explain why the astrophysical observations of the primordial Li in very old, metal poor halo stars are lower than the predictions of the standard Big Bang Nucleosynthesis (BBN) and the baryon-to-photon ratio deduced from the cosmic microwave background. This scientific case is very appealing, although it was not fully clear, to what extent the additional measurement of $^7\text{Be}(n,p)^7\text{Li}$ can improve the previous results.

As in P-411, the ^7Be sample will be prepared in PSI and will be mass-separated at ISOLDE. It will be then used at n_TOF to perform measurements of $^7\text{Be}(n,\alpha)$ and $^7\text{Be}(n,p)$ reactions for 10 – 100 keV neutrons. For comparison, in P-411, where a measurement of the maxwellian averaged, cross section is planned at SARAF, Israel.

In a first step only beamtime for detector tests is applied for. A sandwich of ^7Be between two Si detectors shall be put in the neutron beam at EAR2. As a test case ^6Li or ^{10}B shall be used together with a sandwich of Si-detectors in the neutron beam.

The test of Si-detectors in the beam with ^6Li or ^{10}B deposits for neutron-fluence determination proposed here and at EAR1 (P-416) involve similar activities that should be combined and maybe already some test are possible during the commissioning stage. The requirements for ISOLDE to produce a pure beam of ^7Be are well explained and motivated and are recommended and so are the detector tests at n_TOF. A future addendum to the proposal should clearly discuss the results of these tests and the feasibility of the main experiment to measure the $^7\text{Be}(n,\alpha)$ cross section. Finally, the committee welcomes the close collaboration of the three facilities, PSI, ISOLDE, and n-TOF.

1.5×10^{18} protons at EAR2 and 3 offline shifts at ISOLDE are recommended for approval by the Research Board

INTC-P-418, Measurement of the $^{240}\text{Pu}(n,f)$ reaction cross-section at the CERN n_TOF facility EAR-2:

The precise measurement of the $^{240}\text{Pu}(n,f)$ cross section proposed here is of high priority for the development of future nuclear transmutation technologies. The time of flight measurement of the neutron induced fission of ^{240}Pu at EAR1 suffered from radiation damage in the Micromegas Fission chamber. The existing ^{240}Pu sample together with new reference samples to be made by IRMM, Geel, will be mounted in a detection chamber with new Micromegas anodes. The front electronics has been improved to reduce the disturbances by the gamma-flash. The experiment can be done at EAR2 within much shorter time than at EAR1 and will allow avoiding long-term radiation damage.

2.0×10^{18} protons at EAR2 were recommended for approval by the Research Board

INTC-CLL-015, Beta-delayed neutrons from oriented $^{137,139}\text{I}$ and $^{87,89}\text{Br}$ nuclei:

Following the proposal P-384 for beta-delayed neutron studies, the committee requested a Clarification Letter concerning the expected neutron background due to neutrons scattered from the NICOLE set-up.

The committee appreciates the performed simulations. However, the Committee felt that the simulation should also include a random gamma background (which could affect e.g. the spectrum from Fig. 4 of the CLL). This is because also a non negligible gamma background is expected, but there is no gamma neutron discrimination performed in VANDLE based on pulse-shape. Depending on the rate of random events the statistics required to reach the needed sensitivity will therefore strongly be affected. Nevertheless, the Committee welcomes the initiative to use the VANDLE detector at ISOLDE and encourages the first studies.

17 out of 17 shifts were recommended for approval by the Research Board

INTC-CLL-016, Measurement of the neutron capture cross-sections of ^{53}Mn at EAR-2:

Following the proposal P-408 aimed at studying neutron capture of ^{53}Mn at n_TOF, the committee asked the proponents for a more detailed scientific justification, for the clarification of the radioprotection aspects using the ISOLDE off-line or on-line mass separators, and for a more precise time estimation of use the on-line ISOLDE setup in off-line mode. In the letter of clarification the scientific justification has been elaborated. A measurement of the neutron-induced reactions on ^{53}Mn (mostly neutron capture) can be of importance for the understanding of the nucleosynthesis in supernova explosions. In core collapse supernova the production of ^{53}Mn shows sensitivity on the initial electron fraction before the explosion. Recent simulations indicate that in thermonuclear super nova Ia $^{53}\text{Mn}(n,\gamma)$ is an important channel which influences the production of e.g. ^{54}Fe . The proposed measurement can provide the first experimental data for the neutron capture on ^{53}Mn in the keV range. In addition the produced ^{53}Mn sample can be used in further experiments, e.g. half-life determination. The letter also provides a detailed discussion of the radiation safety aspects, in the context of the Swiss radiation protection ordinance, which confirms the conclusion of the INTC ISOLDE Technical Advisory Committee that the previously envisaged use of the offline ion-source test setup to perform the mass separation is not feasible. The use of the ISOLDE online mass separator is then presented in detail. The beamtime estimate is also lowered, following a too low ionization efficiency used in the original proposal. This leads to a request for 6 shifts of the ISOLDE online separation set-up in offline mode with no protons.

The proposers have answered in detail all the points raised by the INTC and the physics case appears convincing.

3.5×10^{18} protons at EAR2 and 6 offline shifts at ISOLDE were recommended for approval by the Research Board

INTC-P-335-ADD-1, Measurement of the $^{44}\text{Ti}(\alpha,p)^{47}\text{V}$ reaction cross section, of relevance to gamma-ray observation of core collapse supernovae, using reclaimed ^{44}Ti from radioactive waste:

This is an addendum to the proposal P-335 aiming at the determination of the $^{44}\text{Ti}(\alpha,p)^{47}\text{V}$ reaction cross section, of importance for the core collapse supernovae scenarios. This problem joins efforts by different communities using a wide range of techniques. It is important in such astrophysical problems to make an effort to remove nuclear physics related uncertainties. Thus a direct measurement of the reaction cross section is important.

The first measurement has been already performed at ISOLDE, using a ^{44}Ti produced at PSI, after mass separation with GPS and post-acceleration with REX-ISOLDE. The experiment suffered from technical difficulties at ISOLDE limiting the available beam intensity. Only an upper limit for the cross section at 4 MeV was obtained, inside the Gamow window. The result suggests that the cross section by the NON-SMOKER code is overestimated by a factor two resulting in a change of the ^{44}Ti production by about 30%. The addendum proposes to extend the

measurements and determine the cross section at 4 MeV and at three additional energies from 5-6 MeV.

The INTC considers the physics case to be important and supports a direct cross section measurement. A useful result was obtained in the first run despite the technical problems demonstrating the general feasibility of the experimental setup. However, some open questions remain concerning the addendum. The authors were rather short on relevant experimental detail like the energy calibration. Only part of information was provided in the oral presentation and could be obtained from the publication. It was not clear whether systematic errors were already included in the last measurement. The question whether the requested beam energies can be provided in the first stage of the HIE-ISOLDE was answered positively by the HIE-ISOLDE experts. It was not however clear which window thickness would be used and how the beam energy was determined in the first experiment and how it will be estimated now. There was also concern whether a beam intensity of 10^7 pps can be provided over the full time of the experiment. In addition, the cross section could be even further reduced more than a factor of two compared to the NON-SMOKER calculations, in which case it may not be possible to measure a cross section at all energies, in particular at 4 MeV. In addition, the motivation for the need of all four energies was not convincingly presented. Since the beam is long lived, there was also concern about the amount of activity deposited in the different elements of the accelerator. The first experiment revealed not to cause problems, but the presently requested integrated activity is much higher.

The physics motivation is very appealing, but before shift approval a clarification is requested, which should address the following points: (i) whether the presented results include systematic uncertainties and how was the energy of reacting ^{44}Ti nuclei determined (and what was the energy uncertainty), (ii) how will the beam energy be determined in the planned studies and what is its expected uncertainty, (iii) why are studies with four energies planned, (iv) detailed justification of the requested beamtime (efficiencies, cross-sections), (v) radioprotection aspects for the accelerator due much more collected ^{44}Ti .

A clarification letter was therefore requested before recommendation of the addendum to the Research Board

INTC-I-157, High precision mass measurements of odd-odd $T=1$ nuclides for the study of the Isobaric Multiplet Mass Equation:

This Letter of Intent proposes to perform mass measurements of several odd-odd $T=1$ nuclides for the investigation of discrepancies found by a global evaluation of the Isobaric Multiplet Mass Equation. The INTC appreciates the effort of a global evaluation of all IMME related data and the physics case in general is sound. It is certainly remarkable that the IMME approach works so well, but it fails in some cases, as might be expected in the proposed cases. However, even if the deviation would remain the impact of this finding is not evident, e.g. with respect to determining the isospin breaking. Therefore, at this point the INTC does not recommend the requested beam development. The proponents can consider coming back with a letter of intent or proposal focused on selected cases, where other physics motivation might be also present.

At this point the Letter of Intent was **not endorsed** by the Committee

INTC-I-158, Are ^{221}Rn and ^{223}Rn good candidates to search for an atomic EDM? Investigation of their low-energy nuclear level schemes following β decay of ^{221}At and ^{223}At :

The authors would like to continue their investigations of octupole deformation in the Rn and Ra region, in order to propose the best candidates for the measurement of CP violating permanent Electric Dipole Moments (EDM). This letter of intent proposes to focus on ^{221}Rn and ^{223}Rn and requests beam development of pure $^{221,223}\text{At}$ beams in order to study low lying parity doublets in the Rn following beta decay, as well as to investigate the feasibility of measuring the relevant energies, intensities and multipolarities and lifetimes using the new ISOLDE Decay

Station setup (IDS). The committee supports this measurement program and recommends the development of pure At beams.

The Letter of Intent and the beam development were **endorsed** by the Committee

5. A.O.B.

The mandate of Navin Alahari as referee was prolonged until July 2015.

For the November meeting the n_TOF spokesperson is asked to present an overview of the various detectors used at the facility.

It was also agreed that for the February meeting status reports from REX-ISOLDE experiments will be requested and no documents for HIE-ISOLDE will be accepted for this meeting.

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