EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

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

IS545: Experimental investigation of decay properties of neutron deficient $^{116-118}$Ba isotopes and test of $^{112-115\mathrm{Ba}}$ beam counts

J. Ray[1], P. Bhattacharya[1], A. Becerril[2], Y. Blumenfeld[3], M. J.G. Borge[2], S.Chakraborty[1], T. E. Cocolios[3], L.M.Fraile[3], H.O.U. Fynbo[4],. B. Jonson[5], J.Cederkall[6], J. Kurcewicz[3], U. Köster[7], S. Mandal[8], B.Mukherjee[9], E. Nacher[2], T. Nilsson[5], G. Nyman[5] , K. Riisager[4], A. Rahaman[1], P. Reiter[10], T. Sinha[1], T. Stora[3], P.J. Woods[11], F. Zocca[3]

[1]Saha Institute Of Nuclear Physics, Kolkata, India
[2]Inst. de Estructura de la Materia, CSIC, Serrano 113 bis, E-28006 Madrid, Spain
[3]ISOLDE, CERN, Switzerland
[4]Dept. of Physics and Astronomy, Aarhus Univ., DK-8000 Aarhus C, Denmark
[5]Fundamental Fysik, Chalmers Tekniska Hogskola, S-41296 Goteborg, Sweden
[6]Physics Department, University of Lund, Sweden
[7]IIL, Grenoble, France
[8]University Of New Delhi, New Delhi, India
[9]Viswa Bharati University, Santiniketan, India
[10]Institut fuer Kernphysik, Universitaet zu Koeln, D-50937, Koeln
[11]University Of Edinburgh, Edinburgh, United Kingdom

Spokesperson: Ushasi Datta Pramanik ushasi.dattapramanik@saha.ac.in
Co-spokesperson: Olof Tengblad olof.tengblad@csic.es
Local Contact: Magdalena Kowalska magdalena.kowalska@cern.ch

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Abstract

[text …We propose to study decay of neutron deficient isotopes $^{116-118}{}_{1}$Ba using Double sided Silicon Strip Detector (DSSSD). To study delayed-proton and alpha decay branching ratios of $^{116-118}$ Ba are of special interest because of their vicinity to the proton drip line. The nuclear life-times and properties of the proton unstable states of Cs isotopes, populated through decay of $^{116-118}$ Ba isotopes will be measured. In addition to that we propose beam development of $^{112-115}$ Ba to study exotic decay properties of these neutron deficient nuclei and to search for super-allowed a- decay in future.…]

Remaining shifts: 22 (twenty-two)

1. Motivation, experimental setup/technique

Study of the exotic decay properties of nuclei near the proton drip line is at the frontier of todays nuclear physics [1][2][3]. The nuclei in the mass region A~110-120 near the proton drip line exhibit a rich variety of structural information. Several theoretical approaches predict exotic structure and exotic decay modes, in particular cluster decay, for the Ba isotopes [4][5]. Experimental verification of these predictions is lacking today. Moreover decay studies of these isotopes have been rarely undertaken, although their decay properties would provide very important structural information in particular concerning the coupling to continuum states occurring near the proton drip line. Beta delayed proton as well as beta-delayed alpha emission are expected to be observed [7], further, also cluster emission might be present in this region that would yield additional structural information. Also in astrophysical environments the formation of clusters, respectively nuclei, plays a crucial role [8].

We would like to initiate a programme in order to in detail study the properties of neutron deficient Ba isotopes. In a first step we would like to measure their delayed-alpha and delayed-p decay and branching ratios. We would, further, like to propose beam development of ^{112,113,114,115}Ba to determine the yield for future prospects.

Physics Motivation:

The light Ba isotopes of this mass region have been populated using fusion- evaporation reaction only. Decay study of these isotopes using the ISOL method will itself be very interesting. Due to the lack of experimental data, clear idea about the decay properties as well as any structural information of these isotopes is rare. Particularly β-decay of even-even nuclei will populate states of odd-odd nuclei; hence the experimental information can provide useful information regarding pair correlation close to the proton drip-line. By means the delayed-proton information, i.e. its energy spectra and coincidence measurements with EM-radiation, one can obtain structural information of the parent nuclei that can be compared to theoretical models. The electron capture or β^+-decay could produce proton unstable (proton separation energies of ^{116}Cs and ^{117}Cs are 700 KeV and 740 KeV respectively) states of the daughter nuclei $^{116-118}$Cs and the life-times can measured of these nuclear states though proton-x-ray coincidence [9]. In this region it would also be interesting to look for α-decay transition, which might be possible according to several predictions. It is of our particular interest to search the following α-decay chain ^{112}Ba → ^{108}Xe → ^{104}Te → ^{100}Sn in the future. In addition to that exotic cluster decay is another interesting part for our experimental investigation. In this respect accurate beam count information is essential for future experimental studies.

Experimental Procedure :

We will measure the exotic decay mode of $^{118-116}$Ba. We will use a compact particle detection system consisting of four 60-μm-thick, double-sided silicon strip detectors (DSSSD), each backed by a 1.5-mm-thick, un segmented silicon detector. The detectors are to be placed at 5 cm distance from the collection point in a rectangular configuration, whereby a solid-angle coverage of >30% can be achieved with an angular resolution of 3^0. The detector thicknesses are chosen such that the most energetic α particles (~8.5MeV) are completely stopped in the DSSSD. The delayed proton will be detected by the thick PAD Si-detectors placed behind the DSSSDs. Further, two HpGe-detectors (high resolution) and 4x $LaBr_3$ detectors (high efficiency) will be placed to optimize the gamma-ray detection.

[1] P. J. Woods; Annual Review of Nuclear and Particle Science, Vol. 47: 541-590
[2] M. Pfutzner , K.Riisager et al, arXiv:1111.0482v1 [nucl-ex] 2 Nov 2011
[3] Blank, B., and M. Płoszajczak, 2008, Rep. Prog. Phys. 71,046301
[4] W. Greiner, M. Ivascu, D.N. Poenaru and A. Sandulescu, Treatise on Heavy Ion Science,in: D.A. Bromley, Editor, Plenum, New York (1989), p. 641
[5] D.N. Poenaru, et.al. Atomic Data Nuclear Data Tables, 48(1991), p. 231
[7] C. Qi, Phys. Rev. C 80, 044326 (2009)
[8] S. B. Rüster, M. Hempel, and J. Schaffner-Bielich, Phys. Rev. C 73, 035804 (2006)

2. Status Report:

The experiment IS545 was scheduled on September, 2012 just before the shutdown. New LaC_2 target was developed and used to produce neutron-deficient Ba isotopes. Since Cs isotopes was produced more (order of magnitude) than Ba isotope with similar mass number. So Fluorination was used to separate Ba from Cs. However due to serious problem of target , Ba yield was negligible and proper measurements could not be done. See more details below.

Accepted isotopes: $^{116\text{-}118}$Ba.

Performed studies: Initially, we tried to focus on exotic beam of ^{119}Ba, but as it was informed by target people, that number of ^{119}Ba beam was 1 event/sec which is several order of magnitude lower than expected according to earlier literature. So for checking the details of the beam, we set mass on GPS on A=115 and implanted on our C foil at experimental chamber which was surrounded by DSSDs and Pad detectors. Outside the chamber, we placed two **HpGe detectors and two LaBr3 detectors.** Fig. 1 shows the experimental setup during experiment IS545 on Sept., 2012. We did some preliminary analysis of that data. Fig.2, shows the gamma spectrum of HpGe detector during implantation of exotic beam on foil. Clearly, we could see the beam contained mainly, 115In (isomeric state, Ex=336 KeV), 115Te, 115Sb.

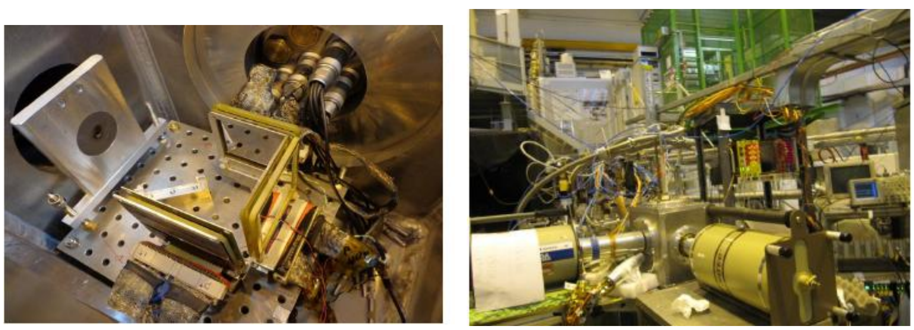
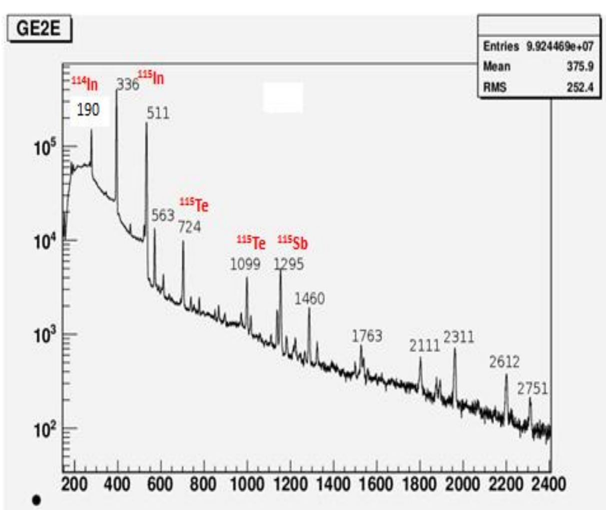


Fig.1. Experimental setup of IS545 , Sept, 2012, ISOLDE, CERN



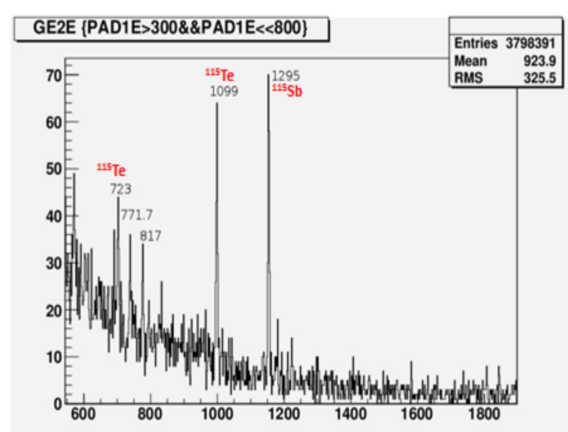


Fig.2. Gamma spectra of HpGe during experiment IS545 , Sept, 2012, ISOLDE, CERN. Left one is without beta gated, right one is after beta gated.

Future plans

Future plans with available shifts:

(i) Envisaged measurements and requested isotopes

We want to perform the experiment with similar setup but modified detector systems. Such as, now we have 152 mm long LaBr3 which we want to use for better high energy gamma efficiency. If possible , we shall use CdTe detector for X-ray in addition to DSSD Si detectors and Pad detectors of above mentioned thickness.

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

No experimental result has been reported yet.

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

isotope	yield (/uC)	target – ion source	Shifts (8h)
$^{115,116,118}Ba$			6 +6+6shifts
$^{112-114}Ba$			4 shifts

Total shifts: 22

3. References:

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4. Appendix

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Publications

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Theses [including link to CDS]

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