EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

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

[title: Experimental investigation of decay properties of neutron deficient $^{116-118}$Ba isotopes and test of ^{114,115}Ba beam counts]

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Abstract

We propose to study decay of neutron deficient isotopes $^{116\text{-}118}$Ba using Double sided Silicon Strip Detector (DSSSD). In addition to that we may use gamma detectors as MINIBALL collaboration is willing to support us. To make accurate study of proton and alpha decay branching ratios and cluster activities of $^{116\text{-}118}$Ba are of special interest. In addition to that we propose beam development of $^{114\text{-}115}$Ba to determine the yield for future prospect.

Requested shifts: [21] shifts**, (split into 2 phases)**

1. Physics Motivation:

The nuclei in the mass region A~110-120 near proton drip line are enriched with a large variety of structural information. This mass region is being predicted as “a new island of cluster” by several theoreticians [1-2]. Over the last 20 years several theoretical and experimental research work have been published on the cluster decay in this medium mass region. In most of the theoretical papers the results have been deduced by comparing to the actinide region where the first cluster structure was observed [3] [4]. Beta delayed proton and alpha emission as well as heavier exotic clusters are expected to be observed in this mass region [5] [6]. Observation of cluster emission can give interesting structural information of the nuclei in various ways. Recently, it was shown that the behaviour of the symmetry energy in low energy heavy-ion collisions can only be explained if the formation of clusters is consistently taken into account [7]. The appearance of nuclear clusters in matter below saturation density leads to an increase of the binding energy of symmetric nuclear matter, so that e.g. the symmetry energy gets a finite value at zero density [8]. Also in astrophysical environments the formation of clusters, respectively nuclei, plays a crucial role [9]. The experimental evidence in this respect is scarce although the existence of several theoretical predictions. The Barium isotopes ($^{114\text{-}118}$Ba), belong to this mass region, are interesting cases to study as these isotopes are very close to the proton drip line. Although a large number of predictions, on cluster decay from these nuclei, have been done in recent years [5] [6], most of them are not in agreement with each other nor with experimental results. For example, A. Gugliemetti [10], showed emission of ^{12}C from ^{114}Ba, on the other hand the same author [11] confirmed the non observation of ^{12}C from ^{114}Ba two years later. In general the spectroscopy data of these isotopes are scarce. Since ISOLDE can produce beams of the light Barium isotopes, we propose here to make an accurate study of alpha and p emission; branching ratios and cluster activities of $^{116-118}$Ba. As a further support of this region being prone to delayed-alpha emission was reported in the only nucleus at intermediate and high mass that has a beta-delayed alpha branch of more than 1% is ^{110}I. In a recent article [12] on decay studies of exotic nuclei M.Pfutzner and K. Riisager have mentioned some of the challenging aspects for such decay as well.

We would, further, like to propose beam development of ^{114,115}Ba to determine the yield for future prospect. However, considering similar procedure like Cs isotopes, as done by earlier group [13], $^{118-116}$Ba should have sufficient yield to study the delayed proton and alpha branches from these isotopes and search for exotic clusters by studying proton and alpha co-relation. Delayed proton and alpha were measured for neutron deficient Cs isotopes at ISOLDE [14]. But as it is evident for Ba isotopes, the detailed study is yet to do. There have been attempts to perform these measurements [13] but due to experimental limitation it was never completed. ^{117}Ba is the interesting case for delayed particle emission. An older measurements [14 and ref there in] reported a branching ratio for delayed protons is around 13(3) % and delayed alphas (according to NUBASE) is around 2 x10^{-4}. Though (nndc.bnl.gov) refers proton decay >0% for this isotope.

Experimental Procedure:

We propose to measure the exotic decay mode of $^{118-116}$Ba. Since the life time of these isotopes are rather long (5.5s to 0.45 s), we propose to use a tape transport system together with a 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. These detectors will be calibrated using standard alpha source and online produced known activity. Further, either a number of HpGe or LaBr3 detectors will be placed to detect gamma-rays. Earlier several decay studies were performed with Ge detectors in collaboration MINIBALL collaboration and MINIBALL collaborators are willing to support the experiment.

Details of the requested beam time:

We need beam time in two phases. In first phase, for beam purity and events checking (for $^{114-115}$Ba) 3 shifts are required and in 2nd phase, for decay studies of $^{116-118}$Ba, 18 shifts are required. So, altogether 21 shifts are required.
It will be very helpful if we get both the beam shifts in 2012 as PhD student, Ms Jayati Ray has already joined in this year and her thesis topic will be related to these measurements.

Decay studies of ^{118}Ba ($t_{1/2}$~ 5.5 s):

In the literature details of delayed proton and alpha decay is not available. Only indication of delayed proton is there. Considering similar situation like ^{118}Cs, one may consider

Yield of ^{118}Ba beam : 10^5 p/sec

Proton and alpha decay: ~$2x10^{-5}$ alpha decay/sec

: ~proton decay $4x10^{-4}$/sec

No. of shifts required: 6

6 shifts ^{118}Ba: 3.5 $x10^5$ events alpha

Considering 30% solid-angle coverage of detector alpha events in all detectors ~10^5

Decay studies of ^{117}Ba ($t_{1/2}$~ 1.75sec)

Yield of ^{117}Ba beam : 10^4 p/sec

(Proton and alpha decay not known accurately)

>0% (according to NuDat of nndc.bnl.gov. However according to an old measurement [14 and ref therein] proton decay is 13%)

alpha decay $2x10^{-4}$/sec

No. of shifts required: 6

Considering 30% solid-angle coverage of detector alpha events in all detectors ~10^5

Decay studies of ^{116}Ba ($t_{1/2}$~ 1.36sec)

Yield of ^{116}Ba beam : 10^4 p/sec

(3% proton decay

No alpha decay reported (considering $2x10^{-4}$/sec)

No. of shifts required: 6

Considering 30% solid-angle coverage of detector alpha events in all detectors ~10^5

Beam development of ^{114}Ba and ^{115}Ba:

No. of shifts required: 3 for checking beam purity and yield

^{115}Ba

>15% proton decay, no alpha decay has been reported

^{114}Ba

Delayed proton : 20.00 %
Delayed alpha: 0.90 %
Delayed ^{12}C < 0.0034 %

Fig.1a. Partial decay scheme of A~116

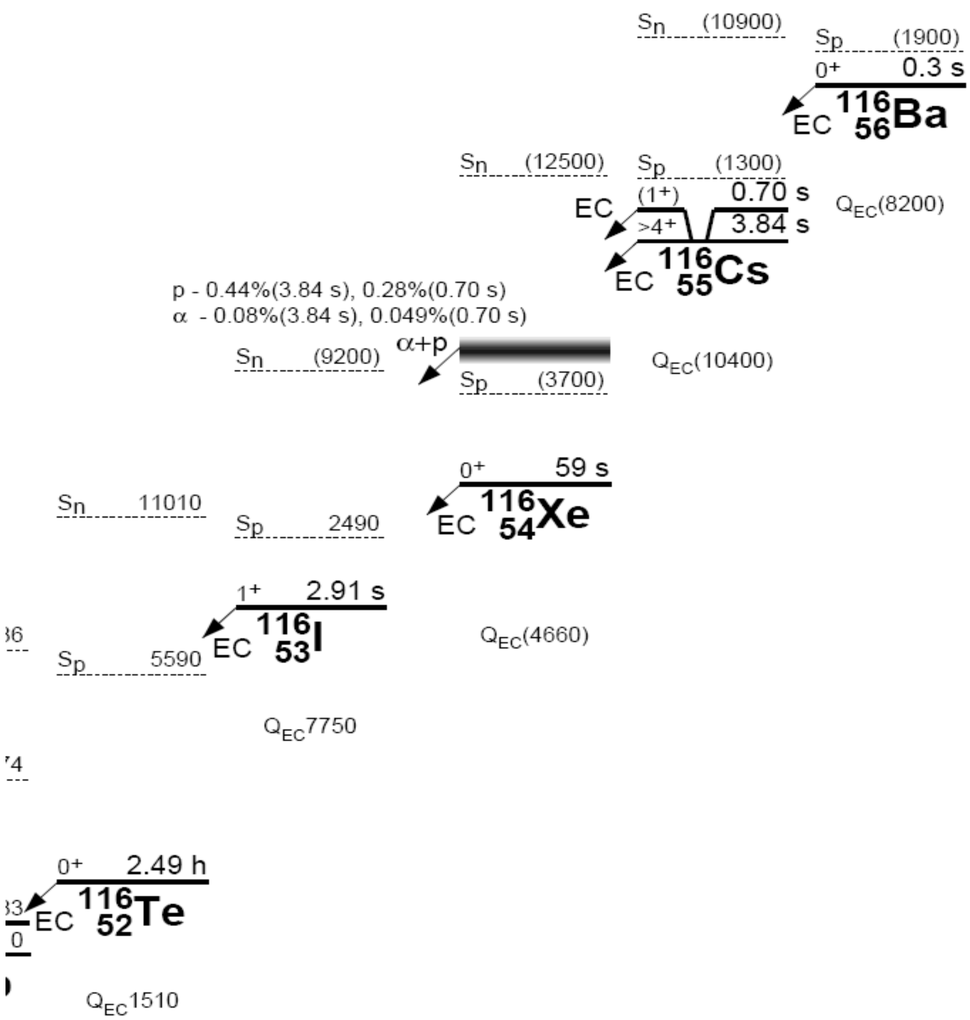


Fig.1.b Partical decay scheme of A~118

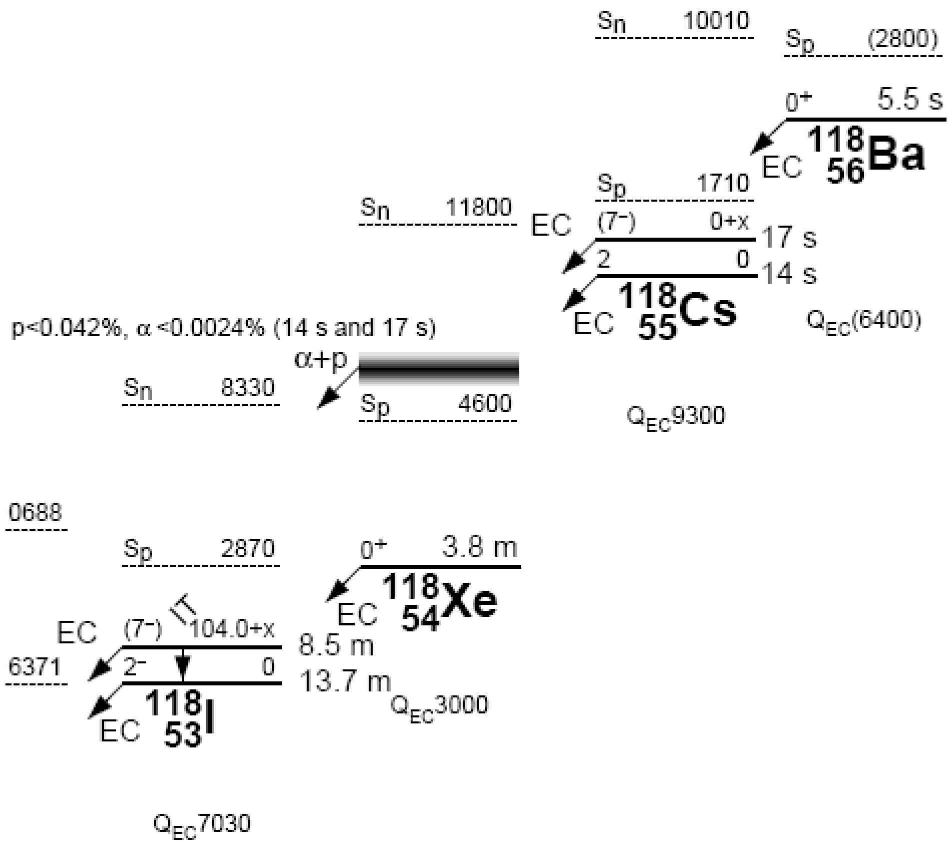
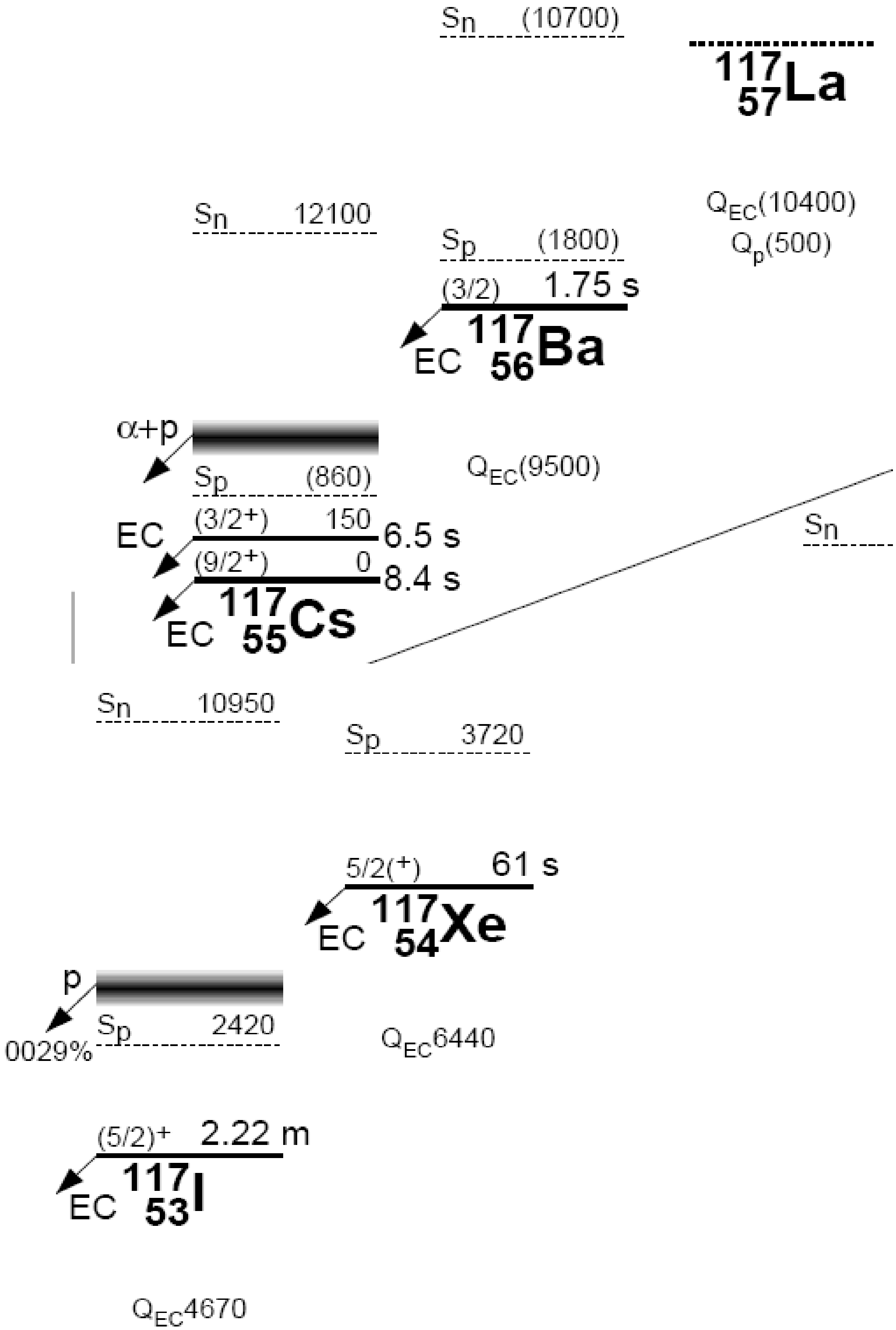


Fig.1c. Partial decay scheme of A~117



Sn (10700)
117 57 La
Sn 12100
QEC(10400)
Qp(500)
Sp (1800)
(3/2) 1.75 s
EC 117 56 Ba
α+p
Sp (860)
QEC(9500)
EC
(3/2+) 150 6.5 s
(9/2+) 0 8.4 s
Sn
EC 117 55 Cs
Sn 10950
Sp 3720
5/2(+) 61 s
EC 117 54 Xe
p
Sp 2420
0029%
QEC6440
(5/2)+ 2.22 m
EC 117 53 I
QEC4670

Summary of requested shifts:

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Appendix

DESCRIPTION OF THE PROPOSED EXPERIMENT

The experimental setup comprises: *(name the fixed-ISOLDE installations, as well as flexible elements of the experiment)*

Part of the Choose an item.	Availability	Design and manufacturing
Delayed proton and delayed alpha measurements	☐ Existing	☐ To be used without any modification ☐ To be modified
	☒ New	☐ Standard equipment supplied by a manufacturer ☒/collaboration responsible for the design and/or manufacturing
[insert lines if needed]		

HAZARDS GENERATED BY THE EXPERIMENT

(if using fixed installation) Hazards named in the document relevant for the fixed [COLLAPS, CRIS, ISOLTRAP, MINIBALL + only CD, MINIBALL + T-REX, NICOLE, SSP-GLM chamber, SSP-GHM chamber, or WITCH] installation.

Additional hazards:

Hazards	*[Part 1 of the experiment/equipment]*	*[Part 2 of the experiment/equipment]*	*[Part 3 of the experiment/equipment]*
Thermodynamic and fluidic			
Pressure	-		
Vacuum	Standard ISOLDE		

	vacuum		
Temperature	-		
Heat transfer	-		
Thermal properties of materials	-		
Cryogenic fluid	LN_2 cooling of HPGe detectors		
Electrical and electromagnetic			
Electricity	3 kV (HPGe detectors)		
Static electricity	-		
Magnetic field	-		
Batteries	☐ -		
Capacitors	☐ -		
Ionizing radiation			
Target material	-		
Beam particle type (e, p, ions, etc)	$^{114,115,116,117,118}Ba$		
Beam intensity	10^5		
Beam energy	-		
Cooling liquids	LN_2		
Gases	-		
Calibration sources:	☒		
• Open source	☐		
• Sealed source	☒ [ISO standard]		
• Isotope	^{152}Eu, ^{133}Ba, ^{241}Am and ^{60}Co		
• Activity	all the sources <40 kBq		
Use of activated material:			
• Description	☐		
• Dose rate on contact and in 10 cm distance	-		
• Isotope			
• Activity			
Non-ionizing radiation			
Laser			
UV light			
Microwaves (300MHz-30 GHz)			
Radiofrequency (1-			

300MHz)			
Chemical			
Toxic	Pb shielding of HPGe detectors		
Harmful	-		
CMR (carcinogens, mutagens and substances toxic to reproduction)	-		
Corrosive	-		
Irritant	-		
Flammable	-		
Oxidizing	-		
Explosiveness	-		
Asphyxiant	-		
Dangerous for the environment	-		
Mechanical			
Physical impact or mechanical energy (moving parts)	-		
Mechanical properties (Sharp, rough, slippery)	-		
Vibration	-		
Vehicles and Means of Transport	-		
Noise			
Frequency	-		
Intensity			
Physical			
Confined spaces	-		
High workplaces	-		
Access to high workplaces	-		
Obstructions in passageways	-		
Manual handling	-		
Poor ergonomics	-		

3.1 Hazard identification

Negligible.