EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

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

Spectroscopy of the low lying states of Neutron Rich Iodine nucleus

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Abstract

We intend to carry out the decay spectroscopy of Tellurium nuclei and to measure the lifetime and quadrupole moments for the low lying states of Iodine nuclei using the neutron rich Te beams from ISOLDE facility. As a first experiment we aim at the N = 81 isotope of Iodine which is obtained from the decay of ^{134}Te having a half life of 42 minutes. The measurement of decay half lives and $\gamma-\gamma$ coincidence will be carried out by using HPGe detector. For the measurement of lifetimes we will use both the slope methods as well as the Mirror Symmetric Centroid Difference Techniques. For the measurement of quadrupole moments, the Te nuclei will be implanted in the Te metal matrix with the incoming energy of the ^{134}Te beam. We will use the perturbed angular correlation technique to measure the quadrupole interaction frequency ω_Q for extracting the quadrupole moments of the excited states of Iodine. The hexagonal structure of Te matrix will provide the required electric field gradient (V_{zz}) in our measurement. This electric field gradient provided by the Te metal matrix can be estimated by using the known quadrupole moment of the first excited state of ^{132}I. The $LaBr_3$ (Ce) detectors will be required for the measurement of lifetime and quadrupole moment. The present proposal aims at understanding procedures for implementing a detailed program of research.

Requested shifts: 12 shifts

Introduction and Motivation

The knowledge about the single particle structure around the exotic doubly closed nuclei is one of the very important physics interests that are being greatly explored in recent times. This will help the physicist calibrate the nuclear shell model that explains the magic gaps away from the beta stability line. The ^{132}Sn, the heaviest neutron rich doubly closed shell nucleus, has attained an utmost importance until very recently [1]. Both theoretical and experimental studies are being carried out to explain the 2^+ excitation and the B(E2) values of the even-even nuclei around this doubly magic nucleus [2-5].

The odd-odd nuclei which are few nucleons away from the discussed shell closure carries importance for being studied both experimentally and theoretically. This is mainly because the study provides the understanding on the proton neutron residual interaction around the Z = 50 and N = 82 shell closure. The systematic study of the nuclei with proton particles and neutron holes, compared to the shell closure configuration of ^{132}Sn, is also very important to establish the validity of the shell closure of ^{132}Sn. The measurement of lifetime and transition moments of these nuclei can give direct evidence to the associated single particle/collective nuclear structure of these nuclei. The experimental data on the nuclei in this region are limited in number mainly because of the difficulty in their population. For the neutron rich isotopes of Z = 53 Iodine, there are not much experimental data existing in literature.

We have already initiated the study of lifetime and transition moments of low lying states of Iodine nuclei by in beam and off-beam decay spectroscopy at VECC, Kolkata [6,7]. However, most of the neutron rich Te nuclei are not accessible from the fusion evaporation type of reaction. The fission reaction produces this nuclei but even after chemical separation it becomes difficult to get rid of the contamination from neighbouring isotopes in the energy spectrum taken with $LaBr_3$(Ce) detector, which is required for the measurement lifetime less than a few tens of ns. Hence, using the ISOLDE facility we would like to study the Iodine isotopes from the decay of Te nuclei which are not possible to produce with a larger cross section and with required isotopic purity using the facilities available in India. This proposal describes the experimental study for the low lying structure of neutron rich odd-odd iodine nucleus with N = 81. The spectroscopy for low lying states of ^{134}I will be performed from the decay of ^{134}Te along with the measurement of lifetime and quadrupole moment for these states. The study will add meaningful information on the structure around the double shell closure of ^{132}Sn and will also add data to the systematics of low lying states of Iodine nuclei that has been taken up.

The low lying states of ^{134}I has been studied mainly from the decay of ^{134}Te, produced from the fission of Uranium and shows a complicated structure with a higher level density compared to the neighbouring ^{132}Sb. A three proton particle and one neutron hole structure has been proposed for these low lying states with a large configuration mixing [8]. One 3.8 min, 8^- isomer has been identified in the nucleus from the decay measurements [9]. Recently, the high spin members of the nucleus have been observed in the nucleus from the fission of ^{252}Cf source [10]. The study shows the levels excited beyond the 8^- isomeric state and the findings matches well with the shell model calculation on ^{134}I [11], considering the particle hole configuration with respect to the ^{132}Sn core. The 79 keV level of ^{134}Te is known to have a lifetime of 1.62 ns as measured by the electron –gamma coincidence by V. Berg and A. Hgglund [12] and from the same work the limits are given for the lifetimes of 180.8 and 210.5 keV levels.

We have attempted the lifetime measurement of the 79 keV state from the decay of ^{134}Te, produced from the fission of ^{238}U(α, f) reaction and using two $LaBr_3$(Ce) detectors at Variable Energy Cyclotron Centre, Kolkata. A very short irradiation (~ 2 hrs) and the chemical separation of active Te nuclei were carried out. However, the population of neighbouring Te nuclei of similar half-lives has made the spectrum very complicated as shown in figure 1. The preliminary analysis on the lifetime measurement of 79 keV level shows a slope in the right side of the TAC spectrum, as shown in figure 2. An approximate lifetime of 0.3 ns is estimated from this data with a poor statistics. While analysing the data, it has been realized that it is very difficult to study the decay of ^{134}Te nucleus ($t_{1/2}$ ~ 42 mins) using the fission reaction as such reaction produces also the neighbouring Te isotopes with similar half lives. It is never possible to get rid of these contaminations even with efficient chemical separation techniques. It is thus important to study the decay of ^{134}Te without any background of neighbouring Te isotopes and thus with the clean production of ^{134}Te, which is possible only at a facility like ISOLDE.

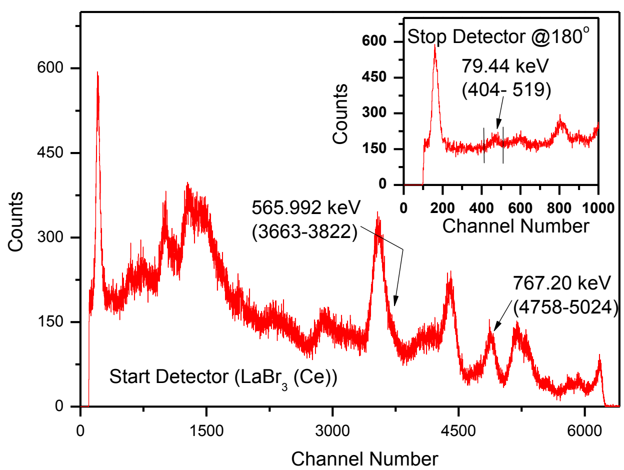

Figure 1: The energy spectrum obtained in the uranium fission experiment after separation of Te activity. The inset shows the zoomed spectrum around the 79 keV line of ^{134}I. A large number of transitions are observed to be coming from the other Te activities.

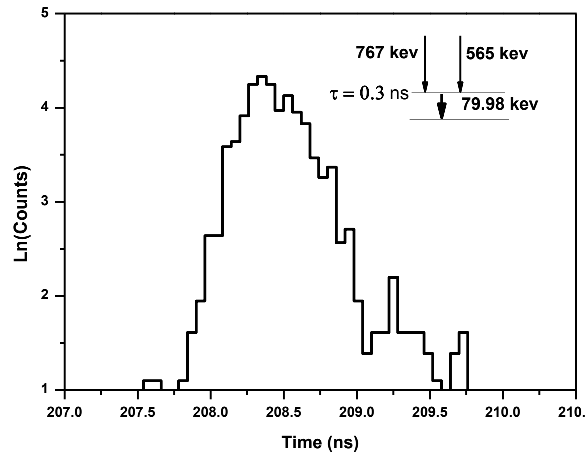

Figure 2: The lifetime of 79 keV state obtained from the coincidence of 79 keV and (767+565) keV transitions.

Important Aspects regarding the proposed measurement:

Comparing the situation of experimental measurement in neighbouring ^{132}I, for the life-time of the 49 keV level we see that there are at least three measurements [13,14,15] which are widely different and finally it has become decisive with the ISOLDE experiment [15]. We also recently re-measured it [7] and our result is consistent with the ISOLDE measurement. Hence on the same line the measurement of the life-time of the 79 keV level of ^{134}I is required to be confirmed. The 767-79 keV or the 565-79 keV cascade, which is measurable with $LaBr_3$ detector, can be used for the lifetime measurement of the 79 keV level. Again the quadrupole moment (Q) has been measured for the 49 keV state of ^{132}I, by doping ^{132}Te in Te matrix [16]. The quadrupole frequency is significant (~200 Mrad/s) in Te matrix. Q value for the

49 keV state is 0.23 b. To measure the Q for 79 keV state of ^{134}Te, the nucleus is proposed to be doped in Te matrix. This can be accomplished by directly implanting ^{134}Te beam on Te metal target (which can be kept at higher temperature say at ~300^{o}C for annealing). TDPAC will be followed to measure the quadrupole frequency from which one can get the Q value by comparing with that for ^{132}I in Te matrix[16]. The anisotropy is expected to be similar in both the systems. This measurement can be performed using the DIGIPAC system available at ISOLDE.

Coming to the measurement of lifetimes for the 181, 210 keV levels the assignment of the life-times are not unambiguous. As the expected level lifetimes are of the order of tens of ps, we will use both the slope methods as well as the Mirror Symmetric Centroid Difference Techniques [17] using the $LaBr_3$ (Ce) detectors, which have been proved to be an efficient tool to measure lifetimes down to few ps [18]. The calibration of prompt time curve will be made using the ^{60}Co and ^{152}Eu sources. As for better time resolution the data needs to be taken with 8K ADCs and in 8K channel to maintain low TPC. Hence the DIGIPAC system might not be useful for this purpose. Hence we propose to carry out this measurement with a separate $LaBr_3$ system as described in Ref. [18]. We will carry our $LaBr_3$ detectors assembled with PMT and the 8K ADC with the controller and the local group will arrange the required electronics and the offline sources like ^{152}Eu and ^{60}Co.

In addition, we propose to carry out the measurements of decay half lives and g-g coincidence using two HPGe detectors.

Proposal summary

We propose to carry out the decay spectroscopy of ^{134}Te ($\tau_{1/2}$ = 42 mins) and to measure the lifetime and quadrupole moments for the low lying states of ^{134}I using the ^{134}Te beam from ISOLDE facility. Two HPGe detectors for the measurement of γ–singles and γ–γ coincidence will be required. For the measurement of lifetimes and quadrupole moment of the 79 keV state the conventional Perturbed Angular correlation technique will be used and the measurement will be done using the DIGIPAC system. For the measurements of the lifetimes for the other excited levels we will use both the slope methods as well as the Mirror Symmetric Centroid Difference Techniques [18]. For the calibration of prompt time we will take data with ^{60}Co and ^{152}Eu source before starting the real run.

Summary of requested shifts:

We intend to take twelve shifts of beam time in total. Each irradiation will be of one hour duration with a gap of three hours between the consecutive irradiations.

A source calibration time will be required before the experiment depending on the strength of the used sources like ^{152}Eu and ^{60}Co.

Target, Ion Source and Instruments:

Target Unit: UCx

Ion source : VADIS plasma ion source

Note : The expected isobaric contamination(A~ 132) and possible oxides and/or flourides from a plasma ion source will not be a problem for the experiment.

Instruments :

1. Two HPGe detector with electronics and DAQ for γ singles and γ-γ coincidence measurements.
2. DIGIPAC system.
3. Two HVPS units for biasing PMT (upto 2500 V), Two CFDs, Two spectroscopy amplifiers, Four-Five ns delay units, One NIM Bin, One TAC, One CAMAC Crate and One Computer with Scientific Linux. We will carry LaBr3 detectors with PMT assembly, CAMAC controller and ADC.

References:

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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)*

PLEASE NOTE: The SSP GLM chamber will be probably replaced for physics runs in 2014, although this is not yet certain. Safety files will be updated in due course. Furthermore, building 115 has been demolished to be replaced by a new building 508. Many of the installations in B.508 for solid state physics will be essentially the same as in building 115, but the safety files will again be updated once the building has been completed.

Part of the	Availability	Design and manufacturing
SSP-GLM chamber	☒ Existing	☒ To be used without any modification
Existing equipment on the solid state labs in building 115	☒ Existing	☒ To be used without any modification ☐ To be modified
- 6 detector PAC standard setups - annealing furnaces - glove boxes	☐ New	☐ Standard equipment supplied by a manufacturer ☐ CERN/collaboration responsible for the design and/or manufacturing

HAZARDS GENERATED BY THE EXPERIMENT

(if using fixed installation) Hazards named in the document relevant for the fixed SSP-GLM chamber and building 115 installations.

Additional hazards:

Hazards	*SSP-GLM*	*Building 115*	*[Part 3 of the experiment/equipment]*
Thermodynamic and fluidic			
Pressure	[pressure][Bar], [volume][l]		
Vacuum	10-6 mbar at SSP chamber 10 during collections		
Temperature	295 K room temperature collections		
Heat transfer	-		
Thermal properties of materials	-		
Cryogenic fluid		Liquid nitrogen, 1 Bar, few litres used during the PAC measurements on appropriate dewar	

Electrical and electromagnetic			
Electricity	[voltage] [V], [current][A]		
Static electricity			
Magnetic field	[magnetic field] [T]		
Batteries	☐		
Capacitors	☐		
Ionizing radiation			
Target material	[material]		
Beam particle type (e, p, ions, etc)			
Beam intensity			
Beam energy			
Cooling liquids	[liquid]		
Gases	[gas]		
Calibration sources:	☐		
• Open source	☒ Produced at ISOLDE: ^{134}Te	Sources to be measured at 115	
• Sealed source	☒	60Co and 152Eu are needed as the calibration sources for the centroid shift measurement	
• Isotope	^{134}Te		
• Activity	(MAX) ~2MBq		
Use of activated material:	none		
• Description	☐		
• Dose rate on contact and in 10 cm distance	[dose][mSV]		
• Isotope			
• Activity			
Non-ionizing radiation			
Laser	none		
UV light	none		
Microwaves (300MHz-30 GHz)	none		
Radiofrequency (1-300MHz)	none		
Chemical			
Toxic	[chemical agent], [quantity]		
Harmful		Hydrochloric acid (ICSC: 0163) , in quantities less than few centilitres per chemical. From this acid solution Te will be precipitated as Te metal by sodium sulphite.	
CMR (carcinogens, mutagens and substances toxic to reproduction)	[chemical agent], [quantity]		
Corrosive	[chemical agent], [quantity]		
Irritant	[chemical agent], [quantity]		
Flammable	[chemical agent], [quantity]		
Oxidizing	[chemical agent], [quantity]		
Explosiveness	[chemical agent], [quantity]		
Asphyxiant	[chemical agent], [quantity]		
Dangerous for the environment	[chemical agent], [quantity]		
Mechanical			
Physical impact or mechanical energy (moving	[none]		

parts)			
Mechanical properties (Sharp, rough, slippery)	[none]		
Vibration	[none]		
Vehicles and Means of Transport	[none]		
Noise			
Frequency	[frequency],[Hz] Ambient noise at the ISOLDE Hall, building 170		
Intensity	Ambient noise at the ISOLDE Hall, building 170		
Physical			
Confined spaces	[none]		
High workplaces	[none]		
Access to high workplaces	[none]		
Obstructions in passageways	[none]		
Manual handling	All samples and sample holders are manually handled either by long tweezers to insert and extract the sample holder into and out of the SSP implantation chamber at GLM, or when manipulating the samples and sample holders inside glove boxes or fume houses on building 115 r-007	All samples and sample holders are manually handled either by long tweezers to insert and extract the sample holder into and out of the SSP implantation chamber at GLM, or when manipulating the samples and sample holders inside glove boxes or fume houses on building 115 r-007	
Poor ergonomics	[none]		

0.1 Hazard identification

3.2 Average electrical power requirements (excluding fixed ISOLDE-installation mentioned above): *(make a rough estimate of the total power consumption of the additional equipment used in the experiment)*

There is no additional equipment with relevant power consumption on these small-scale experiments.