EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

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

Experiment IS586
Embedding of ^{163}Ho and ^{166m}Ho in the energy absorbers of low temperature metallic magnetic calorimeters

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Abstract

The analysis of calorimetrically measured ^{163}Ho electron capture spectra is a very promising tool to investigate the effective electron neutrino mass. A suitable method to embed the ^{163}Ho source in the detectors is ion-implantation. In the last years we have demonstrated that the ion-implantation of ^{163}Ho in micro-fabricated low temperature metallic magnetic detector chips is a reliable and efficient process. The ^{163}Ho electron capture spectra obtained with these implanted detector are the most precise with an energy resolution of ΔE_{FWHM} smaller than 5 eV. In fall 2013 we have proposed to perform ^{163}Ho ion-implantation processed at ISOLDE on new chips with metallic magnetic calorimeter arrays. The ^{163}Ho implantation we have performed in 2014 onto two chips allowed our group to perform a very important measurement. This could also be regarded as the first step of the, at that time, early stage ECHo collaboration. We proposed also to perform an ion-implantation of ^{166m}Ho in a few detectors with an activity per pixel of less than 1 Bq. With these detectors we will study the energy deposition in the small volume of the metallic magnetic calorimeters due to decay of ^{166m}Ho for background studies. At the date of starting the LS2 our experiment has still 6 shifts left over 9. We discuss motivations why we would like to keep the left-over shifts for the ISOLDE running period after LS2.

Keywords: ^{163}Ho, electron neutrino mass, metallic magnetic calorimeters, ^{166m}Ho

Introduction

The determination of the absolute scale of neutrino masses would solve one of the most important open questions in Physics [1]. The analysis of the end point region of calorimetrically measured ^{163}Ho spectra represents a very promising approach to achieve this goal [2 - 5]. ^{163}Ho decays through electron capture and due to the very small energy available for this process $Q_{EC} = (2.833 \pm 0.030 \pm 0.015)$ keV [6], the smallest among all the know nuclides undergoing this decay, it is the best nuclide to achieve this goal.

The ^{163}Ho implantation shift which we have performed in the last years at ISOLDE have represented very important milestones for the success of the R&D towards the ECHo experiment [3]. The very first implantation test permitted to demonstrate the feasibility of the experiment [7 - 10]. On top of that the implantations performed in the framework of the IS586 experiment allowed us to work out advantages of off-line implantation in terms of reduced background [11 - 12].

Within the first phase of the ECHo experiment, Prof. Dr. Wendt's group from Johannes Gutenberg University in Mainz joined the collaboration. He offered to optimize the RISIKO mass separator facility at Mainz University for ^{163}Ho selection. Meanwhile Prof. Dr. Wendt's group has achieved a very high efficiency in Ho ionization, mass separation and post-focalization of the beam [13 - 14]. An ionization efficiency of about 70% was achieved which is extremely important to reduce losses at the source site. A good suppression of neighboring masses of $m/\Delta m$ larger than 400 is of utmost importance for reducing the implantation of other Ho isotopes, in particular of ^{166m}Ho, a nuclide undergoing beta decay with a half-life of about 1200 years, which would lead to background events in the spectrum. The third aspect for which RISIKO was optimized is the post-focalization of the beam, reaching a beam size with about 700 µm diameter FWHM, which plays an important role to reduce the geometrical losses due to the very small size of the detectors.
Several chips have been processed in Mainz and we could perform very important measurements with those.

The RISIKO facility at JGU Mainz, even though already 30 years old, performs rather reliably and will be continuously optimized for the requirements of the ECHo experiment. At the same time, we believe that the possibility to keep the remaining 6 shifts at ISOLDE would represent a very useful option as independent second facility for efficient and selective ^{163}Ho implantation into ECHo detector arrays. We consider to transfer the gained knowledge from the optimization of the RISIKO facility to be applied also at the RILIS facility and to similarly reach at ISOLDE the necessary performances to fulfil the requirements for the implantation onto ECHo detector chips. ISOLDE could here offer some very helpful advantages, i.e. the advantage of having permission to handle significantly higher radioactivity levels than RISIKO.

Other mass separator facilities known to us, as e.g. CERN MEDICIS cannot be used immediately for the implantation of ^{163}Ho in the ECHo detector arrays due to aspects like the relatively large beam size of 3 to 5 mm diameter and missing post focalization options.

Requested shifts: 6 shifts, (split into 2 runs over 3 years)

Summary of requested shifts:

Herewith we ask for **6 shifts** of **off-line** implantation of radioactive **^{163}Ho**. The targets will be prepared at the Nuclear Chemistry Institute of Mainz University.

- 6 shifts for implanting ^{163}Ho into micro-structured chips with typically 64 pixels on an area of about .5 mm times 10 mm.

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)*

Part of the Choose an item.	**Availability**	**Design and manufacturing**
[if relevant, name fixed ISOLDE installation: COLLAPS, CRIS, ISOLTRAP, MINIBALL + only CD, MINIBALL + T-REX, NICOLE, SSP-GLM chamber, SSP-GHM chamber, or WITCH]	☒ Existing	☒ To be used without any modification
[Part 1 of experiment/ equipment]	☐ Existing	☐ To be used without any modification ☐ To be modified
	☐ New	☐ Standard equipment supplied by a manufacturer ☐ CERN/collaboration responsible for the design and/or manufacturing
[Part 2 experiment/ equipment]	☐ Existing	☐ To be used without any modification ☐ To be modified
	☐ New	☐ Standard equipment supplied by a manufacturer ☐ CERN/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	[pressure][Bar], [volume][l]		
Vacuum			
Temperature	[temperature] [K]		
Heat transfer			
Thermal properties of materials			
Cryogenic fluid	[fluid], [pressure][Bar], [volume][l]		
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	☐		
• Sealed source	☐ [ISO standard]		
• Isotope			
• Activity			
Use of activated material:			
• Description	☐		
• Dose rate on contact and in 10 cm distance	[dose][mSV]		
• Isotope			
• Activity			
Non-ionizing radiation			
Laser			
UV light			
Microwaves (300MHz-30 GHz)			
Radiofrequency (1-300MHz)			
Chemical			
Toxic	[chemical agent], [quantity]		
Harmful	[chemical agent], [quantity]		
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 parts)	[location]		
Mechanical properties (Sharp, rough, slippery)	[location]		
Vibration	[location]		
Vehicles and Means of Transport	[location]		
Noise			
Frequency	[frequency],[Hz]		
Intensity			
Physical			
Confined spaces	[location]		
High workplaces	[location]		
Access to high workplaces	[location]		
Obstructions in passageways	[location]		
Manual handling	[location]		

Poor ergonomics	[location]		

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)*