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Letter of Intent to the ISOLDE and Neutron Time-of-Flight Committee

Positron Annihilation Spectroscopy using a Digital PAC Spectrometer

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Abstract: Positron Annihilation Spectroscopy can be performed with a digital Perturbed Angular Correlation spectrometer without changes of the machine setup. This experiment will prove the possibility to extend this method for solid state science at ISOLDE.

Requested shifts: 4 shifts, parasitically

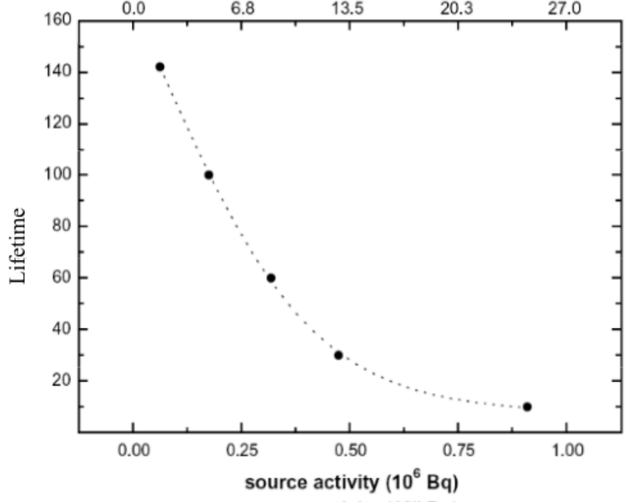

Figure 1: Optimal activity of positron source in comparison with lifetimes to be measured.

1 Introduction

Positron Annihilation Spectroscopy (PAS) is a technique sensitive to lattice imperfections which allows one to investigate e.g. vacancies in ionic crystals, plastically deformed semiconductors, or vacancies in thermal equilibrium in metals. Positrons are localized or trapped by open-volume defects. The lifetime of trapped positrons is correlated to the local electron density.

For the detection, the decay γ-quant of 1.275 MeV in coincidence with the annihilation γ-quant of 511 keV are detected in a very similar setup as used for Perturbed Angular Correlation (PAC). In a standard PAS setup, only two detectors are required, while a PAC setup has depending on its construction 4, 6 or more detectors. Currently an extension from a 4 to an 8-detector digital PAC setup is under development and expected to be finished during the winter period. Using a digital PAC spectrometer therefore improves the efficiency with its numbers of 180° pairs. Recording a PAS experiment in a digital PAC machine does not require any changes or modification to the spectrometer. However, a higher time resolution than usually needed for PAC is required.

With this experiment we want to test the usability of PAS in the existing digital PAC setup and extend the available solid state methods at ISOLDE.

2 Experimental

At the first stage, simple sandwich experiments will be performed: Two pellets or crystals of the material to be investigated will be fixed around a positron emitting source, allowing the positrons to penetrate into the crystal. The source can be made of ^{22}Na being implanted into 5 μm Aluminium foil with about 30-50 keV. The sandwich setup permits to reuse the source for many experiments.

A source with a higher activity accelerates the measurement, however, the signal to background ratio is decreasing. This leads to overlapping of longer lifetimes signals with the background signal. An optimal activity has been suggested by [1], see Figure 1. Three sources with different activities will be produced: 0.1, 0.3, 0.7 MBq which will allow to setup optimal conditions for the measurements.

Due to the long lifetime of ^{22}Na, measurements will be performed during the long shutdown time in 2013.

Sources can be more or less produced parasitically at any calibration time of other experiments when target beam is not needed, in parallel or at target cooling times.

3 Perspectives

Positron Annihilation Spectroscopy can be principally performed with a digital Perturbed Angular Correlation spectrometer without changes of the machine setup. With these experiments, we want to prove this possibility and extend the methods for solid state science at ISOLDE. When measurements are successful, high temperature PAS measurements, using the PAC furnace, will be performed under controlled atmospheres, implanting ^{22}Na directly into the samples.
The sources will be also useful for testing and improving time resolution of the digital PAC. As a side effect, these sources can be used for time calibration on standard PAC setups during busy measurement periods.

Summary of requested shifts: 4, Ti or UC_x unit.
Ti units have a high yield of 10^9 atoms/s and samples can be produced within 15 minutes. UC_x units have lower yields of about $3{\cdot}10^4$ atoms/s for ^{21}Na. No detailed values available for ^{22}Na yet.

References

[1] Thraenert, S., Hassan, E.M., Krause-Rehberg, R.; NIM B248 (**2006**) 336

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	Availability	Design and manufacturing
SSP-GLM chamber, SSP-GHM chamber	☒ 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 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
[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 experiment/ equipment]	[Part 2 of experiment/ equipment]	[Part 3 of 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	^{22}Na	^{22}Na	^{22}Na
• Number of atoms	$4{\cdot}10^{10}$	$1.2{\cdot}10^{11}$	$2.8{\cdot}10^{11}$
• Activity	0.1 MBq	0.3 MBq	0.7 MBq
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 (1-300 MHz)			
Chemical			
Toxic	[chemical agent], [quantity]		
Harmful	[chem. agent], [quant.]		
CMR (carcinogens, mutagens and substances toxic to reproduction)	[chem. agent], [quant.]		
Corrosive	[chem. agent], [quant.]		
Irritant	[chem. agent], [quant.]		
Flammable	[chem. agent], [quant.]		
Oxidizing	[chem. agent], [quant.]		
Explosiveness	[chem. agent], [quant.]		
Asphyxiant	[chem. agent], [quant.]		

Dangerous for the environment	[chem. agent], [quant.]		
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]		

Hazard identification:

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]