DEVELOPMENT OF POSITRON ANNIHILATION SPECTROSCOPY AT THE LEPTA FACILITY

I.N. Meshkov[#,1], E.V. Ahmanova, V.I. Hilinov, O.S. Orlov, A.A. Sidorin, Joint Institute for Nuclear Research, Dubna, Moscow region, Russian Federation
M.K. Eseev, Joint Institute for Nuclear Research, Dubna, Moscow region, Russian Federation and Northern (Arctic) Federal University, Arkhangelsk, Russian Federation
P. Horodek, K. Siemek, Joint Institute for Nuclear Research, Dubna, Moscow region, Russian Federation and Institute of Nuclear Physics of the Polish Academy of Sciences, Cracow, Poland
A.G. Kobets, Joint Institute for Nuclear Research, Dubna, Moscow region, Russian Federation and Institute of Electrophysics and Radiation Technologies NAS of Ukraine, Kharkov, Ukraine
[1]also at Saint Peterburg University, Saint Petersburg, Russian Federation

Abstract

The report aims to present the status of the development of the LEPTA facility for further enhancement of the positron annihilation spectroscopy (PAS) method application at the LEPTA facility. The research in solid state physics performed currently is based on slow monochromatic positron flux from the injector and Doppler PAS.

The new positron transfer channel being under construction at the LEPTA allows us to develop more advanced PAS method – so called "Positron Annihilation life-time spectroscopy" (PALS). It will enrich significantly the research program at the LEPTA. PAS method is sensitive to microdefects in solids. A pair of gamma quanta, born as a result of positron-electron annihilation carries information about the density of the defects that have the size less than 10 nm and are located at the depth from the surface of the material depending on the positron energy.

New monochromatic positron source construction supplied with the autonomous cooling system with emitter-source of the activity of 30 mCi (iThemba LABS production) and new positron transfer channel are presented in report.

DESIGN AND CONSTRUCTION OF THE TRANSFER CHANNEL

The new positron transfer channel (Fig. 1, 2) has been assembled at the LEPTA facility. It allows us to develop the advanced PAS method — so called «Positron Annihilation Life-time Spectroscopy» (PALS).

Positron lifetime spectroscopy measures the elapsed time between the implantation of the positron into the material and the emission of annihilation radiation. When positrons are trapped in open-volume defects, such as in vacancies and their agglomerates, the positron lifetime increases with respect to the defect-free sample. This is due to the locally reduced electron density of the defect. This method allow to determine defect concentration and its type.

#meshkov@jinr.ru

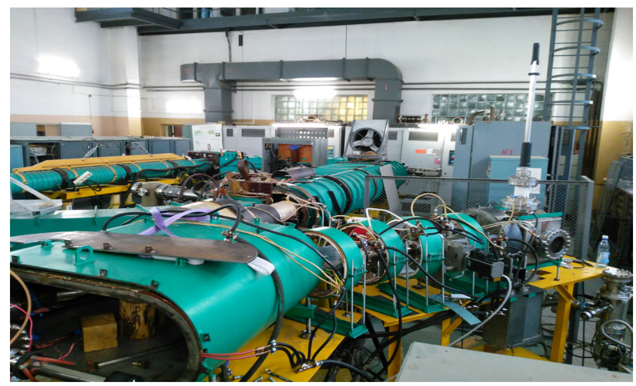

Figure 1: Positron transfer channel.

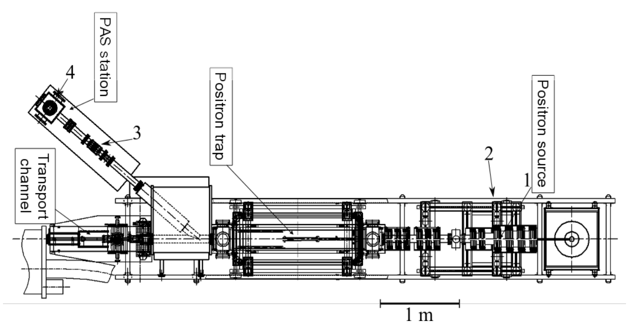

Figure 2: Scheme of the positron transfer channel.

The channel comprises four parts: cryogenic positron source equipped with closed loop LHe supply system (Fig. 3, pos. 1), pulsed voltage gap (Fig. 3, pos. 2), electrostatic acceleration gap (Fig 3, pos. 3), and the target box (Fig 3, pos. 4) containing samples to be studied by PALS method.

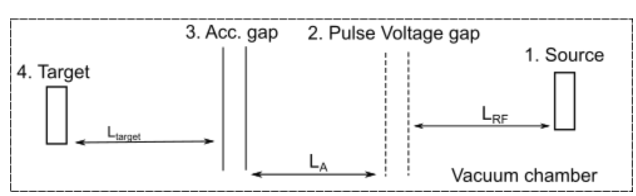

Figure 3: Scheme of the PALS method, with formation of the ordered positron flux: 1. Cryogenic positron source (Fig. 3); 2. Pulsed voltage gap; 3. Acceleration gap (electrostatic field); 4. Target — a sample for PAS studies.

ISBN 978-3-95450-181-6

The implemented method allows us to scan simply the sample in depth. Depending on the energy applied to the sample changes the depth where the positron annihilates, it gives the possibility to scan the sample thickness (Fig. 4).

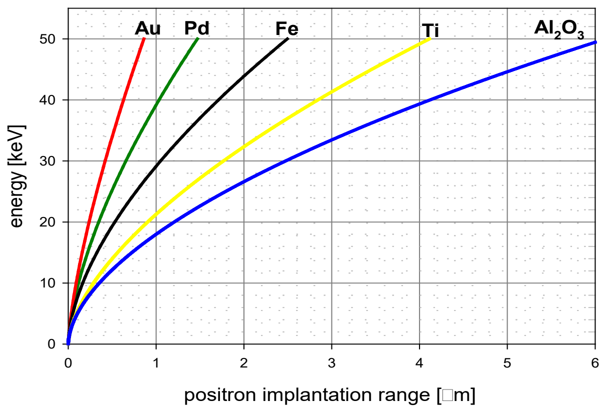

Figure 4: Dependency of positron energy on mean positron implantation depth.

In mid-November there was a beam of slow positrons at the exit of the positron channel (Fig. 5). The positron beam parameters are shown in Table 1.

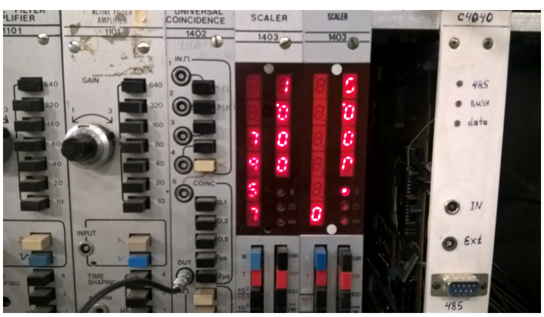

Figure 5: Positron counts at the transfer channel exit.

Table 1: General Parameters of Positron Beam

Feature	Value
Activity of ^{22}Na tablet	30 mCi
Moderator	Frozen Ne (7K) at 10^{-8}
Longitudinal magnetic	100 Gs
Vacuum conditions	10^{-6} Pa
Intensity	10^{6} e^{+}/s
Energy range	50 eV ÷ 35 keV
Diameter of the flux	3 mm

CALCULATION FOR THE TRANSFER CHANNEL

Было проведено математическое моделирование поведения позитронов в канале для PALS метода. Были определены параметры элементов канала вывода.

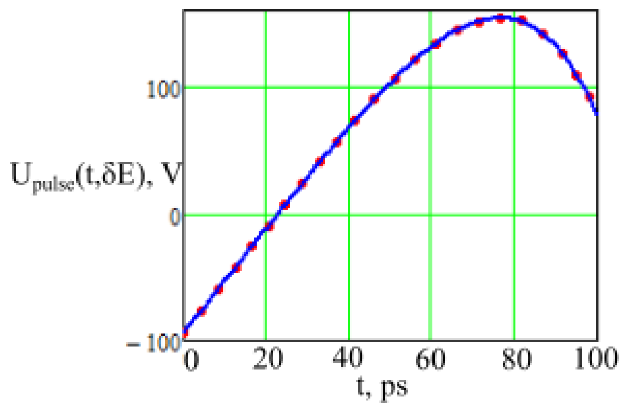

Figure 6: The pulsed voltage vs time. e+ average energy: 950 eV e+ energy spread: ⋯ 0; − 1.0 eV.

Figure 6 shows the voltage pulse in Voltage Pulse Gap (Fig. 3 Pos. 2) required to obtain the minimum time delays of arrival on target of the two positrons with various initial energies (Fig. 7).

The voltage pulse form V(t) (Fig. 6) is chosen as a result of numerical simulation for generation of an equidistant positron flux.

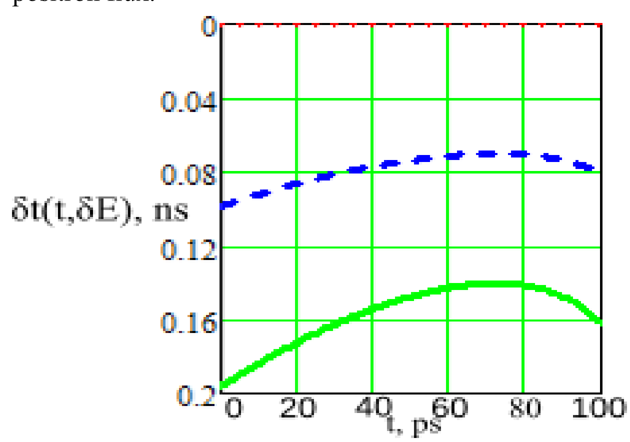

Figure 7: The difference of arrival time at the target of two positrons having different start energy eV: ••• 0; − − − 0.5; − 1.0.

New monochromatic positron source on the closed loop LHe system is based on 22Na isotope tablet of the activity of 30 mCi (iThemba LABS SAR) and cryocooler of the Sumitimo Co production. Presently the source is assembled, cooled down to 5.3 K and tested (Fig. 8). The positron flux of 10^{6} e^{+}/s is routinely generated. The flux was transported through the transfer channel in November 2016 (Fig. 5).

ISBN 978-3-95450-181-6

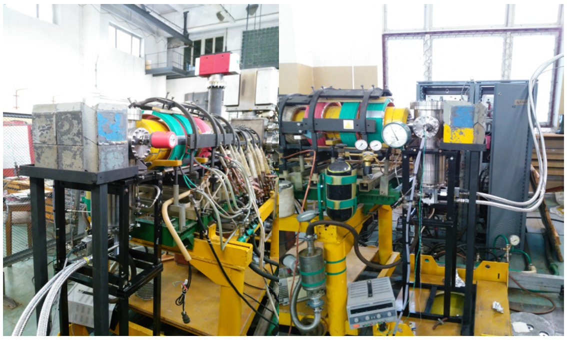

Figure 8: The autonomous cooling system.

PLANS

The next stage is experiments with a positron beam pass along the transport channel using the method of Doppler. Design and creation elements for the PALS system.

ISBN 978-3-95450-181-6