LEPTA - THE FACILITY FOR FUNDAMENTAL AND APPLIED RESEARCH

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Abstract

The project of the Low Energy Positron Toroidal Accumulator (LEPTA) is under development at JINR. The LEPTA facility is a small positron storage ring equipped with the electron coolin system. The project positron energy is of 2 – 10 keV. The main goal of the facility is to generate an intense flux of positronium atoms – the bound state of electron and positron.

Storage ring of LEPTA facility was commissioned in September 2004 and is under development up to now. The positron injector has been constructed in 2005 ÷ 2010, and beam transfer channel – in 2011. By the end of August 2011 experiments on injection into the ring of electrons and positrons stored in the trap have been started. The recent results are presented here.

LEPTA POSITRON INJECTOR

Positron injector consist of cryogenic slow positron source, positron trap and positron transfer channel (Figure 1).

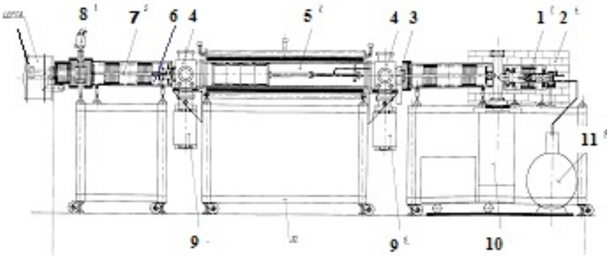

Figure 1: The positron injector. 1 – positron source 22Na, 2 – radioactive shield, 3 – vacuum valve, 4 – vacuum chamber for pumping out and diagnostic tools, 5 – positron trap, 6 – vacuum isolator, 7 – positron vacuum channel, 8 – vacuum "shatter", 9 – ion pump, 10 – turbo pump, 11 – liquid He vessel.

The solid neon is uses as a moderator in the positron source. The positrons lose energy passing thought neon layer and wide energy spectrum of 22Na the thin line of slow positrons is formed.

From the source slow positrons move to the positron trap. We use so called Penning-Malnberg-Surko (PMS) trap. The trap consists of the solenoids, of the vacuum chamber and of the electrodes which form static electric field (Figure 2).

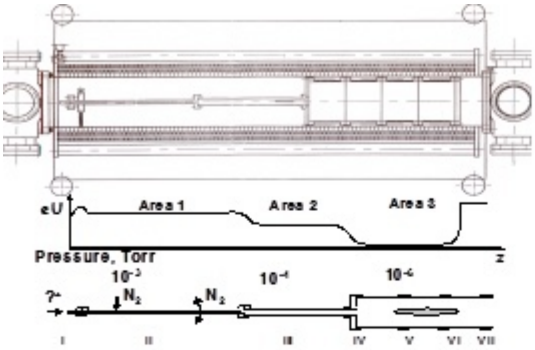

Figure 2: Assembly drawing of the positron trap (upper picture), potential and pressure distributions along the electrode system.

The trap of the LEPTA facility has the traditional geometry of the PMS trap [2]. In 2014, the trap pumping speed was significantly enhanced by implementation of turbo-molecular and cryogenic pumps. The choice of the potentials distribution on the electrodes 1-8 and pressure of the buffer gas (high-purity molecular nitrogen) is critical. At optimal allocation of potentials and pressure positrons, "jumping" on the atomic and molecular levels, very quickly overcome the energy region where the probability of annihilation is maximal (the so-called Ore gap [1]).

Rotating electrical field (RW) is generated in the electrode 4, cut into 4 sectors, which have permanent and (in pairs) alternative potentials. This method allows us to compress bunch and to increase number of particles in the bunch. The accumulation process is well described by the dependence of the number of accumulated particles N_{trap} on accumulation time at fixed values of the efficiency of the particle capture ε, the flux of the injected positrons $\dot{N}$ and the lifetime of the trapped particles τ:

$$N_{trap}(t) = \varepsilon \dot{N} \tau \left(1 - e^{\frac{t}{\tau}} \right) \Rightarrow \begin{cases} \varepsilon \dot{N} \tau, t << \tau \\ \varepsilon \dot{N} \tau, t >> \tau \end{cases} \qquad (1)$$

At known flux $\dot{N}$ the, first of the asymptotics in formula (1) allows us to determine the value of the efficiency ε, and the second asymptotics - the value of the τ. Both these values are dependent of buffer gas pressure: ε is increases, τ is decreases but their product increases up to some optimal value of gas pressure. Experimental results are presented in the Table 1.

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Table 1: Dependence of Storage Process Parameters on Buffer Gas Pressure

P, 10^{-6} Torr	**τ, sec RW off/RW**	**ε, % RW off/RW**	**ε × τ, % × sec**
1.5	4,1/10,5	2,3/2,1	9,43/22,05
2	4/9,5	3/2,9	12/27,55
2.5	3,7/9	4,3/3,6	15,91/32,4
4	3,9/8	6,7/6,4	26,13/51,2

Basically new results were obtained in measurements of the "RW spectra", i.e. dependencies of N_{trap} , ε and τ on the frequency of the RW field. For the first time in a unified approach the different modes of the low and high intensities of the injected particle flux and accumulated bunch has been investigated, new low frequency resonances of the RW field causing significant increase in the number of accumulated particles has been found (Fig. 3). The "anti-resonance" at low (of the order of tens of Hz) frequency of the RW field when the rotation of the field leads to the complete destruction of accumulated bunch have been discovered.

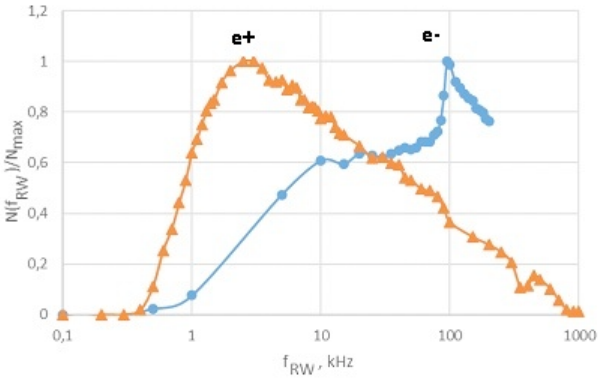

Figure 3: The resonant dependence of the stored particles' number (normalized) – positrons and electrons – on the RW-field frequency (kHz).

We think that RW-field mechanism is rather simple [3]. Charged particle rotates in the RW-field along the circular orbit of the radius

$$R_{RW} = cE_{RW}/B\omega_{RW} \gg \rho_L. \qquad (2)$$

Here E_{RW} and ω_{RW} are the amplitude and frequency of the RW-field, B is the trap magnetic field, c – the speed of light, ρ_L – the particle Larmor radius. After reflection from potential barrier the particle escapes from RW-field and travel along the trap magnetic field until it reaches the exit potential barrier. Reflected on it the particle returns into RW field at certain phase of the field rotation.

When traveling in the trap the particle rotates around the trap axis in the crossed fields B and Er – radial component of the electric fields of the trap electrodes and the bunch space charge ("magnetron rotation"). In the RW-field the particle has time to move along a short arc of the circular orbit. If after traveling in the trap it returns into RW-field at optimal phase of RW-field and "magnetron rotation" it will continue its way in the same direction as in the previous "round". When traveling ("bouncing") in the trap the particle loses its energy in the collisions with the buffer gas atoms (the "frictional cooling" again!). As result, the length of the arcs is decreasing and finally the particle does not penetrate into RW-field that is overlapped with the potential barrier of the sectioned electrode. And the particle looks as a small Larmor circle.

With the increase of the intensity, the azimuthal drift in crossed fields of the bunch space charge and longitudinal magnetic field plays the decisive role and increases the resonant frequency (Figure 4).

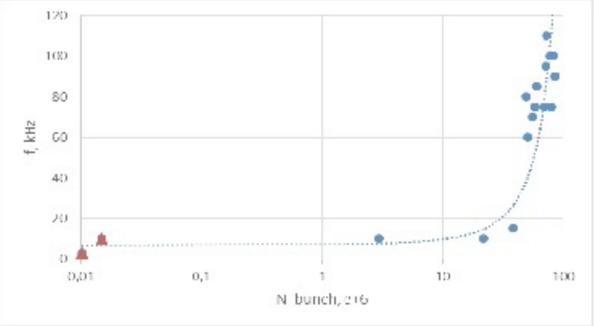

Figure 4: Dependence resonant frequency of RW-field vs number of particles in the stored bunch.

THE POSITRON ANNIHILATION SPECTROSCOPY

Another application of LEPTA positron injector is Positron Annihilation Spectroscopy (PAS). The method of the doppler broadening of the annihilation gamma line have been developed. This method allow us to study defects concentration in the matter depending of depth. The laboratory for the samples preparation has been equipped with the different tools (sendblast apparatus, vacuum oven and press).

Positron Injector Development

Now positron injector is under development. The main problems we have: deficit of liquid helium, low vacuum conditions and low intensity of slow positron flux.

We have bought cryocooler and designed and constructed the new cryogenic source (Figure 5).

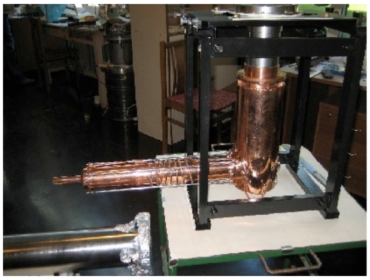

Figure 5: The new cryogenic source.

It allow us to have closed loop of the positron source cooling. Also we designed new channel for PAS (Figure 6).

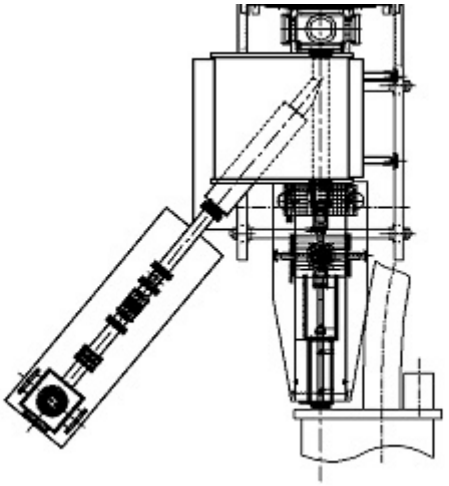

Figure 6: The new PAS channel drawing.

Now all elements of vacuum system and some elements of magnetic system are fabricated.

CONCLUDING REMARKS

The development of the LEPTA project is approaching the stage of experiments with circulating positron beam. The development of positron injector will allow us to study materials separately from investigations of storage process in the trap.

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