ADVANCE IN THE LEPTA PROJECT*

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Abstract

The Low Energy Positron Toroidal Accumulator (LEPTA) at JINR is close to be commissioned with circulating positron beam. The LEPTA facility is a small positron storage ring equipped with the electron cooling system and positron injector. The maximum positron energy is of 10 keV. The main goal of the project is generation of intensive flux of Positronium (Ps) atoms - the bound state of electron and positron, and setting up experiments on Ps in-flight. The report presents an advance in the project: up-grade of LEPTA ring magnetic system, status of the construction of positron transfer channel, and the electron cooling system, first results of low energy positron beam formation with ^{22}Na radioactive positron source of radioactivity of 25 mCi.

LEPTA RING DEVELOPMENT

The Low Energy Particle Toroidal Accumulator (LEPTA) is designed for studies of particle beam dynamics in a storage ring with longitudinal magnetic field focusing (so called "stellatron"), application of circulating electron beam to electron cooling of antiprotons and ions in adjoining storage electron cooling of positrons and positronium in-flight generation.

For the first time a circulating electron beam was obtained in the LEPTA ring in September 2004 [1]. First experience of the LEPTA operation demonstrated main advantage of the focusing system with longitudinal magnetic field: long life-time of the circulating beam of low energy electrons. At average pressure in the ring of 10^{-8} Torr the life-time of 4 keV electron beam of about 20 ms was achieved that is by 2 orders of magnitude longer than in usual strong focusing system. However, experiments showed a decrease of the beam life-time at increase of electron energy. So, at the beam energy of 10 keV the life time was not longer than 0.1 ms. The possible reasons of this effect are the magnetic inhomogeneity and resonant behaviors of the focusing system.

Magnetic and Vacuum System Improvements

During March-May 2009 new measurements of the longitudinal magnetic field at solenoids connections were performed. According to the measurement results water cooled correction coils have been fabricated and mounted. As result, the inhomogeneity has been decreased down to $\Delta B/B \leq 0,02$ (Fig.1).

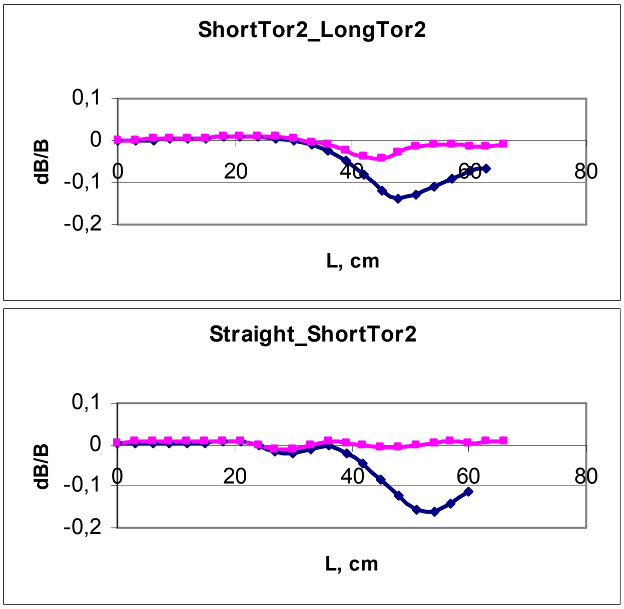

Figure 1: Magnetic field distribution along the toroidal solenoid axis.

The new water cooled helical quadrupole lens was designed and fabricated (Fig.2) that allowed us to improve significantly the vacuum conditions in the straight section.

Figure 2: The water cooled helical qudrupole.

To improve vacuum condition the evaporating titanium getter pumps manufactured at Budker INP have been mounted at the entrance and the exit of the straight section (Fig.3). First run of the pumps showed the average pressure decrease down to $5 \cdot 10^{-9}$ Tor at least.

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Figure 3: The evaporating getter pump.

Testing after Upgrading

After all the improvements and modifications the ring has been reassembled, the electron beam circulation has been obtained again and its life time has been remeasured. Typical life time dependence on electron energy, $\tau_e(E_e)$, has two slopes (Fig.4). The left one, where τ_e increases with Ee, is defined by electron scattering on residual gas. The right slope, descending with Ee, relates to violation of electron motion adiabaticity on inhomogeneities of solenoid magnetic field.

The curves 1 and 2 were obtained in 2005, whereas the curves 3, 4 and the point 5 have been measured in June 2008. The curve 6 was measured in August 2009, after all modifications of the ring described above. One can see significant increase of the electron life time. Of the main importance is the increase of the life time (comparing with the values of the year 2005, 2008) in the energy range above 4 keV by 6÷10 times. It proves the necessity of a further improvement of the solenoid field homogeneity.

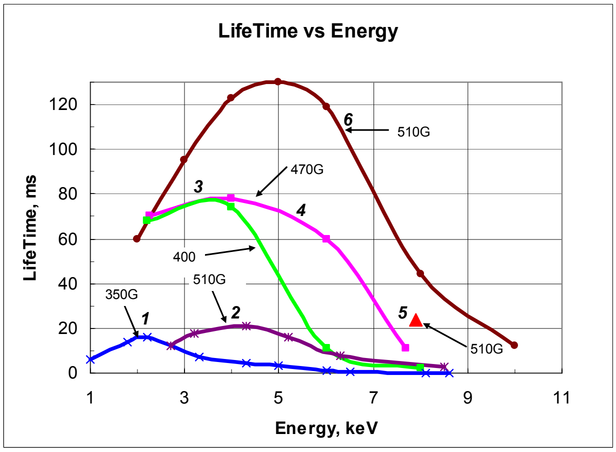

Figure 4: LifeTime vs electron energy.

An essential influence of magnetic field quality on τ_e value is demonstrated in Fig.5: the lifetime of 8 keV electrons increases significantly with correction coil current enhancement.

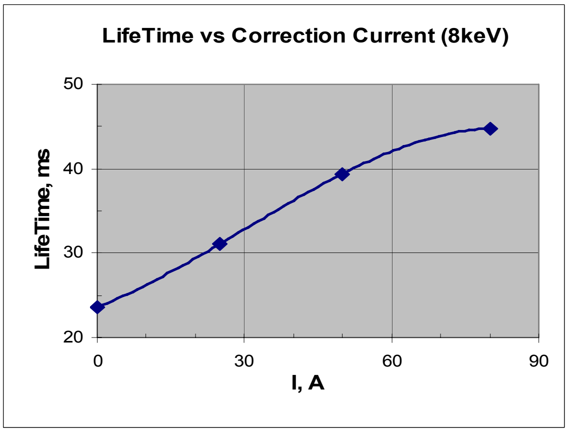

Figure 5: Lifetime vs correction coil current at electron energy of 8 keV.

Electron Cooling System Construction

The manufacturing of the system for generation, transportation and energy recovering of single pass electron beam has been completed at the beginning of the current year. Test of the electron beam transportation from the gun to collector was done in pulsed mode of the gun operation. The regime of the transportation system corresponded to the design one.

Positron Transfer Channel

The channel is aimed to transport positrons extracted from the trap of the injector (see below) and accelerate them up to 10 keV (maximum) in electrostatic field in the gap between the trap and the channel entrance. The designing of the channel elements is completed, their manufacturing is in progress.

TEST OF THE NEW POSITRON SOURCE

The slow monochromatic positron flux is formed from broad spectrum of positrons from radioactive isotope ^{22}Na (Fig.6). The positrons with energy up to 0,54 MeV are moderated to the energy of few eV in the solid neon [2]. The neon is frozen on the copper cone surface where capsule with isotope is located (Fig.7).

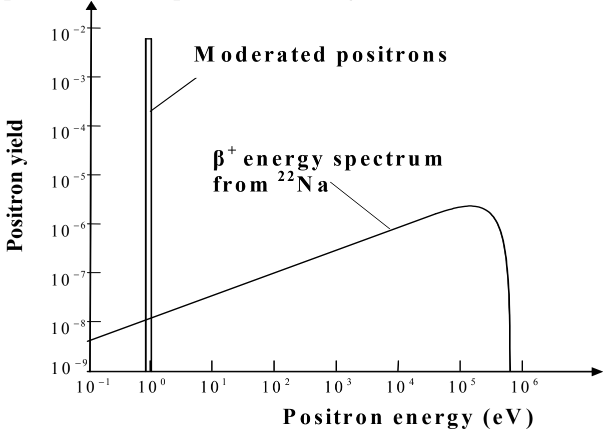

Figure 6: Positron spectrum from radioactive isotope ^{22}Na and moderated one.

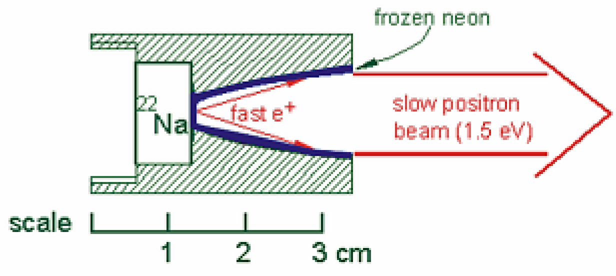

Figure 7: Positron moderation principle.

^{22}Na positron source of activity of 25mCi for LEPTA facility has been donated by iThemba LABS (RSA) and transferred to JINR in Febrary 2008. After completion of the very long procedure of formalities it was mounted in the LEPTA injector and tested (Fig.8).

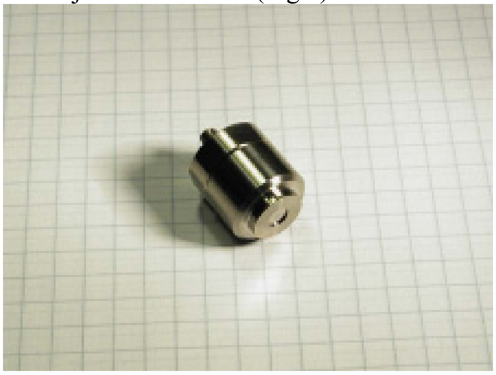

Figure 8: The positron source of iThemba Labs production.

To detect slow positron flux we used microchannel plate (MCP) detector and scintillater detector both working by coincidence scheme and independently. Efficiency of both detectors and maximum flux of slow positrons have been determined by standard method of analysis of a coincidence scheme counts. Integral spectra of slow positrons were measured with MCP and electrostatic analyzer - a short drift tube suspended at variable positive potential. The fitting of the experimental results are presented (Fig. 9).

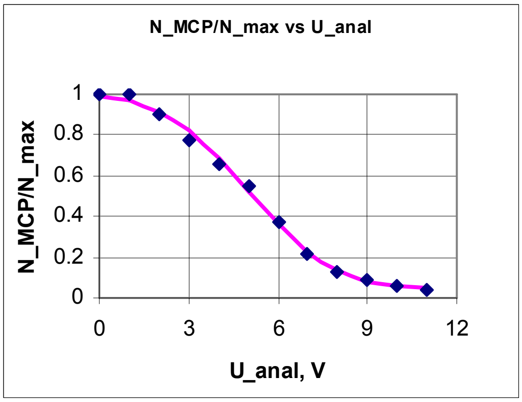

Figure 9: Gaussian fitting of positron energy spectrum curve measured at T = 7,35 K, d = 10 mcm, $(dN/dE)_{max}$ = 5.5 eV, spectrum width σ = 2.3 eV.

Maximum flux of slow positrons determined by standard method for coincidence scheme was equal:

$$N_{max} \approx 1.5 \cdot 10^5 \text{ positrons/ sec.}$$

THE POSITRON TRAP

When slow positron beam is formed, it enters the Penning-Malmberg trap where the positron cloud is accumulated [3]. The trap is a device which uses static electric and magnetic fields to confine charged particles using the principle of buffer gas trapping. The confinement time for particles in the Penning-Malmberg traps can be easily extended into hours allowing for unprecedented measurement accuracy. Such devices have been used to measure the properties of atoms and fundamental particles, to capture antimatter, to ascertain reaction rate constants and in the study of fluid dynamics. The JINR positron trap (Fig. 10) was constructed to store slow positrons and inject positron bunch into the LEPTA ring.

The research of the accumulation process was carried out using electron flux. For this purpose the test electron gun allowing to emit $dN/dt = 1*10^6$ electrons per second with energy 50 eV and spectrum width of a few eV was made. These parameters correspond to slow monochromatic positron beam which we expect from a radioactive source at activity of 50 mCi.

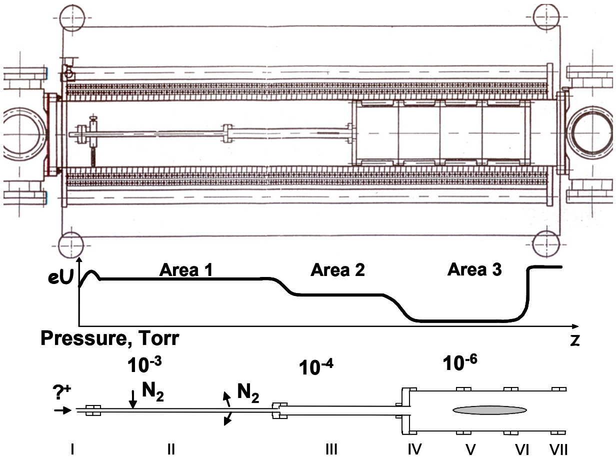

Figure 10: Assembly drawing of the positron trap (upper picture), potential and pressure distributions along the electrode system.

Electron accumulation in the trap with application of rotating electrical field [4] was studied during December 2006 and repeated in July 2009. One of the trap electrodes (Fig. 10, electrode IV) consists of four isolated segments, which are connected with sine voltage generator of amplitude *A* and frequency *f* (Fig.11). The phases of the voltage applied to each segment are shifted by 90^0 one to another one that forms rotating transverse electric field.

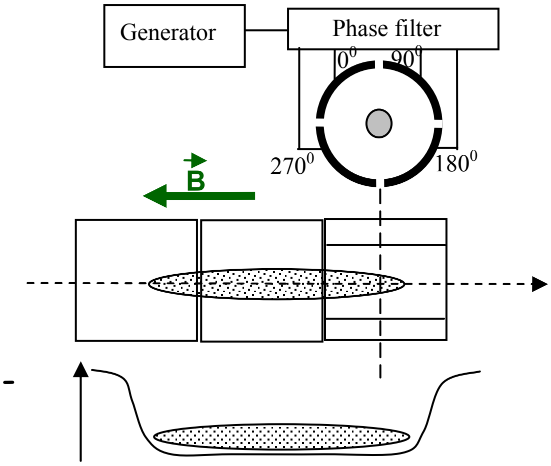

Figure 11: The rotating electrical field method.

The dependence of the accumulated electron number *N(t)* on accumulation time has been measured at different conditions (Fig.12). The curve 1 presents the function *N(t)* after optimization of distribution of pressure and electrode potentials. The curve 2 presents *N(t)* after optimization of the transverse correction magnetic field. The rotating field is OFF in both cases. The curve 3 gives *N(t)* after optimization of frequency and amplitude of the rotating electric field. The optimum frequency of rotation has been found equal to 650 кHz at the amplitude of 1V.

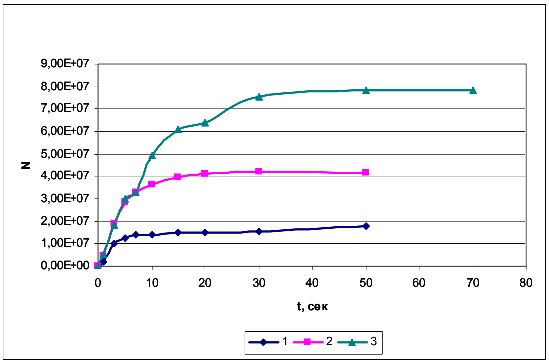

Figure 12: The trapped electron number as a function of storage time

CONCLUDING REMARKS

The development of the LEPTA project is approaching the stage of experiments with circulating positron beam. All main elements of the ring and the injector are ready and have been tested. The positron transfer channel is expected to be commissioned by the end of this year, that will allow us to start the experiments with positrons.

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