STATUS OF THE LEPTA PROJECT*

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Abstract

The Low Energy Positron Toroidal Accumulator (LEPTA) is under commissioning at JINR. The LEPTA facility is a small positron storage ring equipped with the electron cooling system. The project positron energy is of 4-10 keV. The main goal of the facility is to generate an intense flow of positronium atoms–the bound state of electron and positron. The focusing system of the LEPTA ring after solenoidal magnetic field remeasurement and correction has been tested with pulsed electron beam by elements. Some resonant effects of beam focusing have been observed.

The experiments aiming to increase the life time of the circulating electron beam and test the electron cooling elector beam are in progress. Construction of the pulsed injector of the low energy positrons is close to the completion.

The injector is based on ^{22}Na radioactive isotope and consists of the cryogenic positron source (CPS), the positron trap and the acceleration section. In the CPS positrons from the ^{22}Na tablet are moderated in the solid neon and transported into the trap, where they are accumulated during about 80 seconds. Then accumulated positrons are extracted by the pulsed electric field and accelerated in electrostatic field up to required energy (the injector as a whole is suspended at a positive potential that corresponds to required positron energy in the range of 4-10 keV). In injection pulse duration is about 300 nsec. The CPS has been tested at the low activity of isotope ^{22}Na tablet (100 MBq). The continuous positron beam with average energy of 1.2 eV and spectrum width of 1 eV has been obtained. The achieved moderation efficiency is about 1 %, that exceeds the level known from literature. The accumulation process in the positron trap was studied with electron flux. The life time of the electrons in the trap is 80 s and capture efficiency is about 0.4. The maximum number of the accumulated particles is $2\cdot10^8$ at the initial flux of $5\cdot10^6$ electrons per second.

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]. Experience of the LEPTA operation demonstrated main advantage of the focusing system using longitudinal magnetic field: long life-time of the circulating beam in a low energy range. At average pressure on the ring orbit of about 10^{-8} Torr the life-time of 4 keV electron beam of about 20 ms was achieved that is about 2 orders of magnitude longer than in usual strong focusing system. However, experiments showed a decrease of the beam life-time at increase of its 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 field errors and resonant behaviors of the beam focusing.

Magnetic System Improvements

The first experiments were performed without correction coils at junctions of solenoid sections of different cross-section. Moreover, the initial design of reverse current bars didn't provide the necessary distribution of the current between bars that led to an additional imperfection of the magnetic field. During testing of the straight section the electron beam didn't pass through the vacuum chamber due to influence of the magnetic fields of the reverse bars, and they were disconnected from the power supply. Therefore the whole magnetic system of the LEPTA ring was assembled without the reverse current bars, as result a magnetization of magnetic shields took a place.

To improve the magnetic field quality the LEPTA was disassembled at the end of 2005. The longitudinal magnetic field was measured on the axis of the magnetic system with Hole probe. The measured imperfections of the magnetic field were on the level of about 20% at the junctions of solenoids (Figure 1). On the basis of the measurement results the correction coils were designed using SAM program. After installation of the coils the homogeneity of the magnetic filed was achieved on the level of 2.5%.

During the disassembling of the LEPTA ring the design of the reverse current bars was improved. The using of the reverse bars permitted to improve reproducibility of experimental results.

The LEPTA injection system consists of septum windings and electric kicker located inside a septum solenoid. The injection system testing with an electron beam showed that the magnetic axis doesn't coincide with the geometry axis of the vacuum chamber. The vacuum chamber diameter in the septum windings is 50 mm and one needs a high precise adjustment of the septum winding position inside the septum solenoid. In the initial design the possibility of the septum winding displacement was restricted. The horizontal size of the septum windings was decreased by 36 mm that permitted to shift them by

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25 mm in the vertical direction and to adjust the vacuum chamber axis with necessary accuracy.

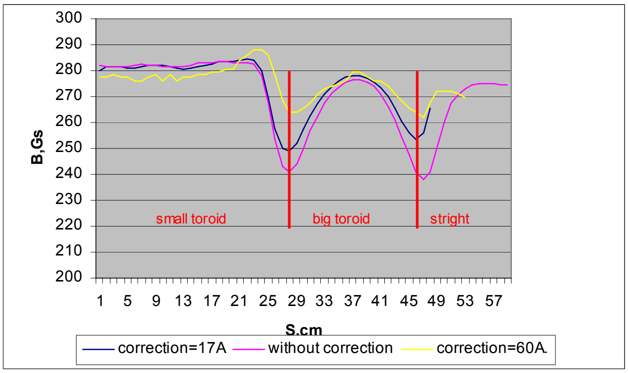

Figure 1: Magnetic field distribution along the toroidal solenoid axis at different currents of the correction coils. The design current is 60 A.

Upgrade of Diagnostic System

The Lepta diagnostic system was sufficiently modified. To adjust the beam orbit inside helical quadrupole (the optic element providing long term stability of the circulating beam) with more high precision an additional pick-up station was installed at the exit of the straight section. After crossing the straight section the electron beam can be directed into the especially installed luminescence screen. The diaphragm system at the septum entrance was made over to pick-up station.

The focusing system of the LEPTA ring after corrections of the magnetic field has been tested with pulsed electron beam by elements. For the adjustment of the beam orbit the luminescent screen was used. In front of the luminescence screen the diaphragm with 0.5 mm hole was installed. During the tests the resonance behavior of the electron gun optics was investigated. Figure 2 shows the dependence of the magnetic field on the electron energy corresponding to minimum beam spot size on the luminescent screen.

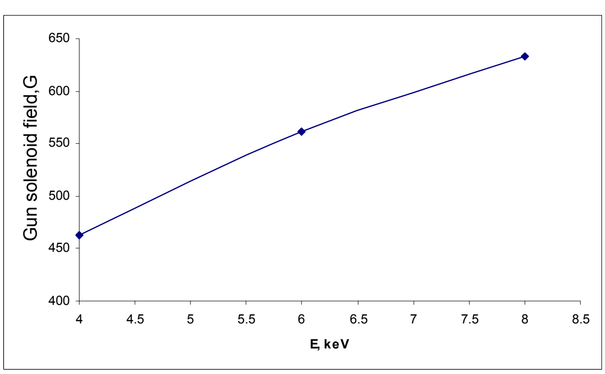

Figure 2: Dependence of Resonant Magnetic Field Value in Gun Solenoid on Electron Energy.

TEST OF THE CPS

Positrons emitted from radioactive source ^{22}Na have a very broad energy spectrum up to 0,5 MeV. To generate monochromatic beam of slow positrons the solid neon as moderator is used [2]. When positron pass trough the moderator the part of the broad energy spectrum are slowed down to thermal speeds. A small longitudinal magnetic field is used for transport of continuous beam of slow positrons (fig.3).

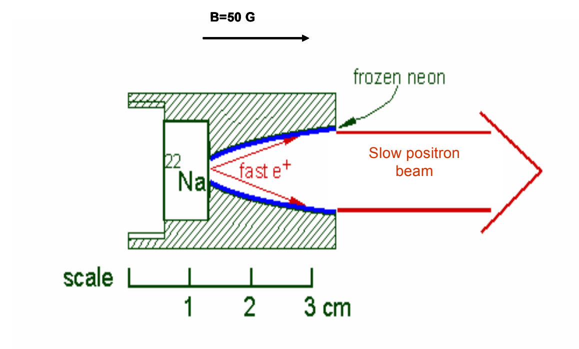

Figure 3: Slow positron getting principle.

The cryogenic source of slow positrons has been developed and made at JINR (Fig.4).

For realization of experiments with a cryogenic positron source a stand was constructed. The positron source is located in the vacuum chamber pumped to the pressure 4*10^{-8} Torr.

The stand includes neon and liquid helium lines. The slow positron beam flux is detected by a microchannel plate (MCP).

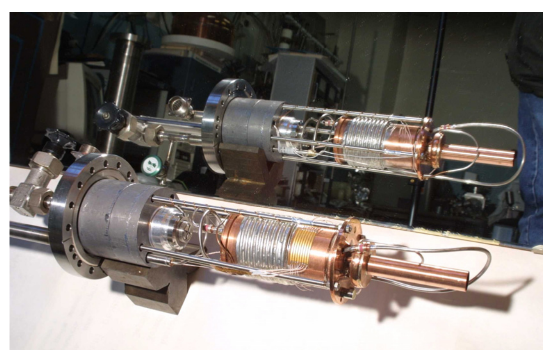

Figure 4: The cryogenic source of slow positrons.

During experiments with a test isotope ^{22}Na of activity 100 µCi, the frosting of neon was carried out on a substrate and cone. The dependence of the slow positron output on the thickness of the moderator was investigated (Fig,5). Dependence of slow positron spectrum on the thickness of the moderator was measured (Fig.6).

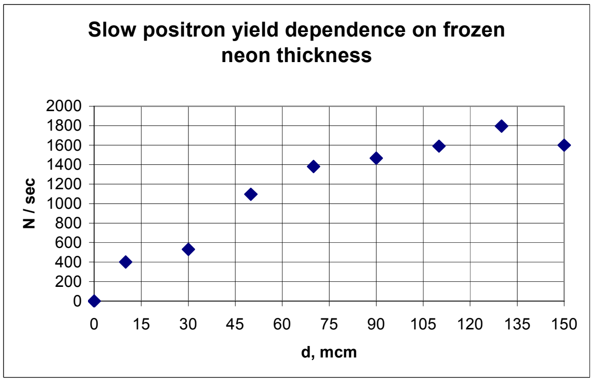

Figure 5: Slow positron yield vs moderator thickness.

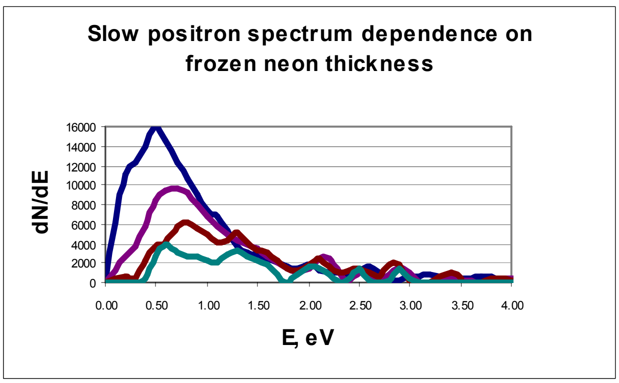

Figure 6: Slow positron spectrum vs moderator thickness.

The continuous slow positron beam at intensity of $1.75*10^3$ positrons per second has been obtained. The average energy is 1.2 eV, width of a spectrum is 1 eV. The achieved moderator efficiency is 1 %, that exceeds the level known from literature.

THE POSITRON TRAP

When slow positron beam has been formed, it enters to Penning-Malmberg trap were the positron cloud is accumulated [3]. The Penning-Malmberg 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 Penning-Malmberg traps can easily extend 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. 7) was constructed to 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 distribution 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.

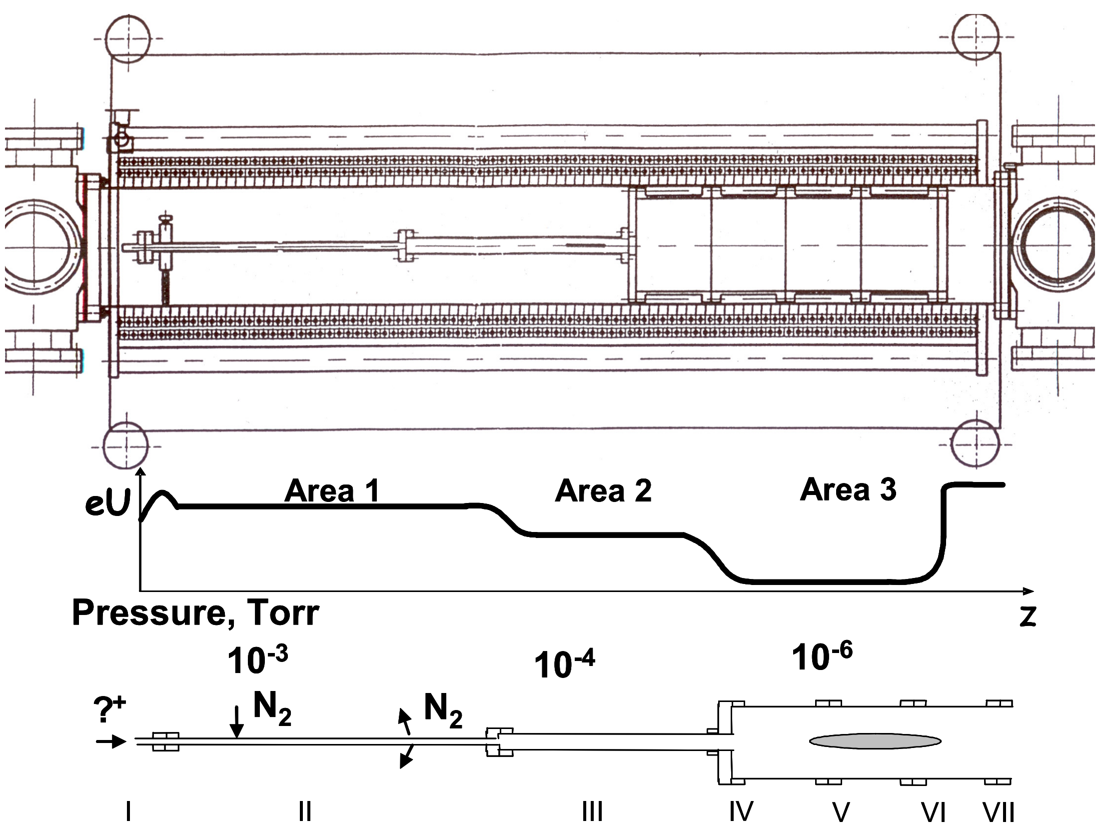

Figure 7: Assembly drawing of the positron trap (upper picture), potential and pressure distributions along the electrode system.

Electron accumulation in the trap with application of rotating electrical field was studied during December 2006. One of the trap electrodes (electrode 2) consists of four isolated segments (Fig. 1), which are connected with sine voltage generator of amplitude *A* and frequency *f.* The phases of the voltage applied to each segment are shifted by 900 one to another one that forms rotating transverse electric field

The dependence *N(t)* of the of accumulated electron number on accumulation time has been measured at different conditions (Fig.8). 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 kHz at the amplitude of 1V

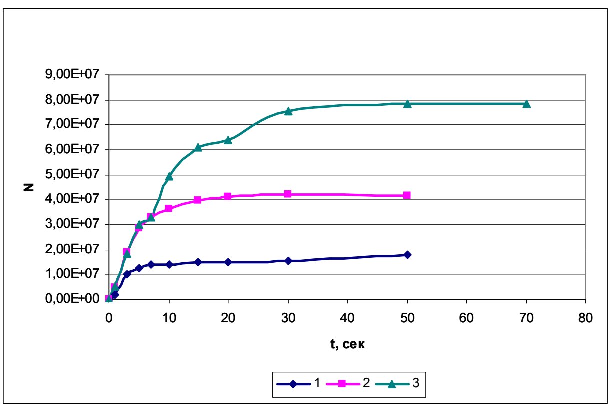

Figure 8: The total trapped charge as a function of filling time.

CONCLUDING REMARK

In the nearest future we plan to provide

1. Test of the LEPTA ring with improvement magnetic field
2. Test and tuning of electron cooling system with continuous electron beam
3. Assembling of the positron injector.

After receiving of ^{22}Na source from iThemba Labs (RSA) (expected in October 2007) the electron cooling of positrons and positromium generation will be realized.

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