LEPTA PROJECT: TOWARDS POSITRONS

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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 was 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 electron and positron injection into the ring have been started. The recent results are presented here.

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.

Vacuum system improvements

In old design the distance between kicker plates was off 32 mm that limited the aperture. New kicker design allows us to increase aperture up to 120 mm.

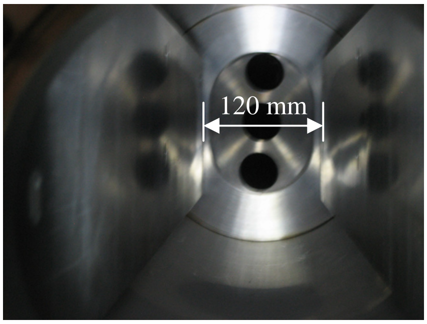

Figure 1: The new kicker

Testing after upgrading

Typical life time dependence on electron energy, τ_e(Ee), has two slopes (Fig.2). 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. The point 7 (2011) is result of the regime optimization and vacuum improvement.

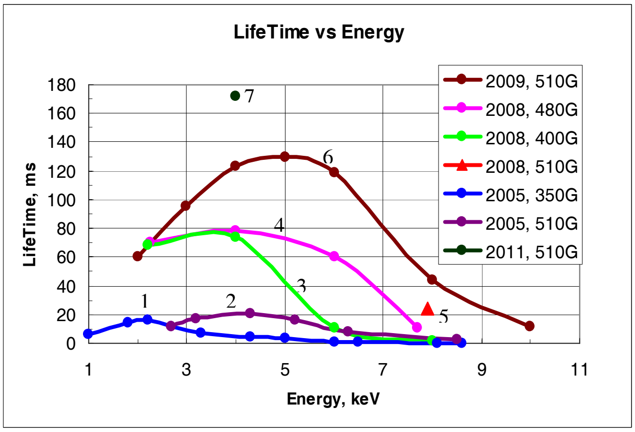

Figure 2: LifeTime vs electron energy.

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Electron cooling system construction

The manufacturing of the system for generation, transportation and energy recovering of single pass electron beam has been completed. Test of the electron beam transportation from the gun to the collector begun in pulsed mode and continued in DC mode of the gun operation. Result is in Table 1.

Table 1. Parameters of electron cooling system

Electron energy	Current		
	Ie, mA	ΔIe, uA	ΔIe/Ie
3	20	230	0,011
5	50	290	0,006
7	64	620	0,01
8,7	105	430	0,004

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 and manufacturing of the channel elements was completed in 2010. В 2011 году была изготовлена магнитная система канала и инжектор позитронов был присоединен к накопительному кольцу (Fig. 3).

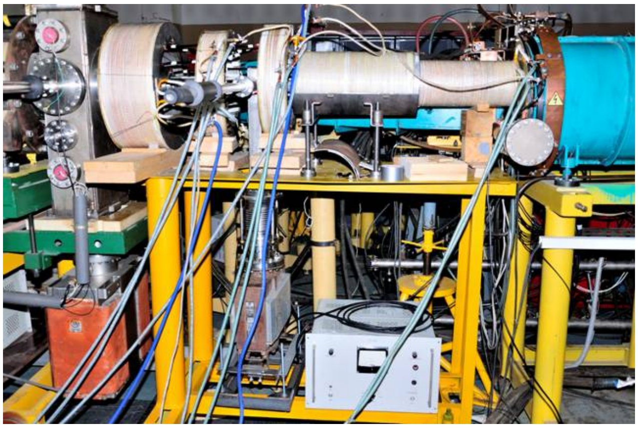

Figure 3. The transfer channel.

THE POSITRON TRAP

When slow positron beam is formed, it enters the Penning-Malmberg trap where the positron cloud is accumulated [2]. 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. 4) 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.

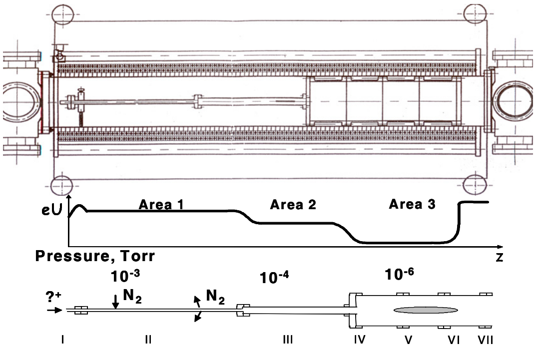

Figure 4: Assembly drawing of the positron trap (upper picture), potential and pressure distributions along the electrode system.

Electron accumulation in the trap with application of rotating electrical field so called "rotating wall" (RW)[3], was studied with electrons during December 2006 and repeated with electrons and positrons in July 2011. The test electron beam shrinking was observed when RW parameters were optimized (Fig.5).

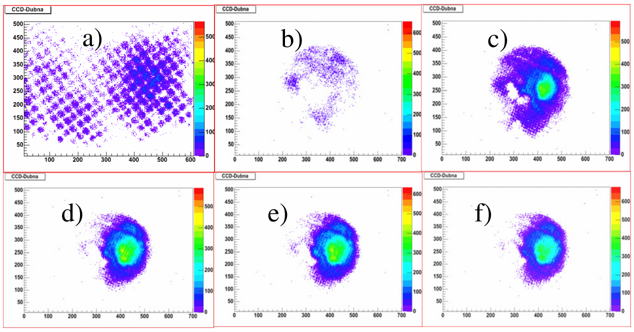

Figure 5: Profiles of the stored test electron beam at different storage time: a) 30s, RF Off; b) 15s, RF On; c) 20s, RF On; d) 30s, RF On; e) 40s, RF On; f) 90s, RF On.

THE POSITRON INJECTOR

In summer 2010 the slow positron source and the trap have been assembled. The first attempts of slow positron storage were performed (Fig.6) and stored positrons were extracted to the collector.

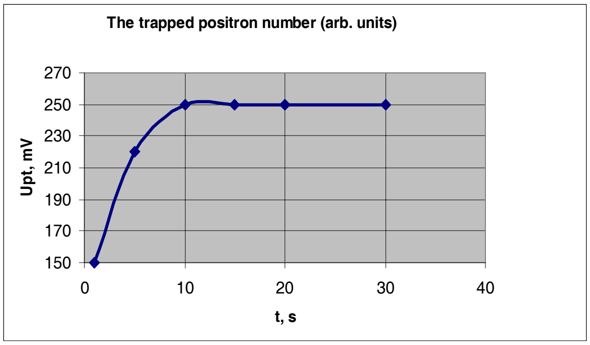

Figure 6: The trapped positron number vs storage time.

Upt is the amplitude of the signal from the phototube (PT), RW amplitude is equal to 0.5 V.

Manufacturing and assembling of the transfer channel from injector to the ring were completed by the end of July 2011. The test of the channel was performed in August 2011, first with test electron beam and later with positrons. Test electron gun was installed at the entrance of positron trap (Fig.7).

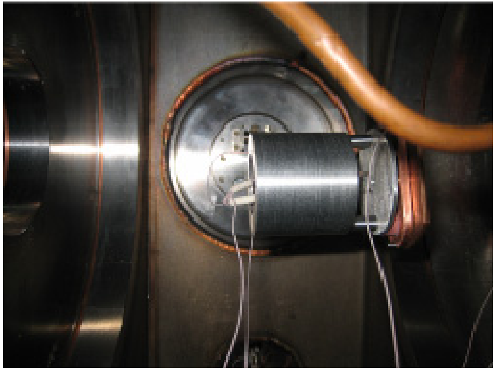

Figure 7. The test electron gun.

The ring was disassembled and luminescent screen was placed inside the kicker chamber. The beam images of electron beams both from the test gun and electron gun of the electron cooling system were obtained on the screen (Fig.8). After that positrons were injected into the ring at facility parameters optimized with electron beam.

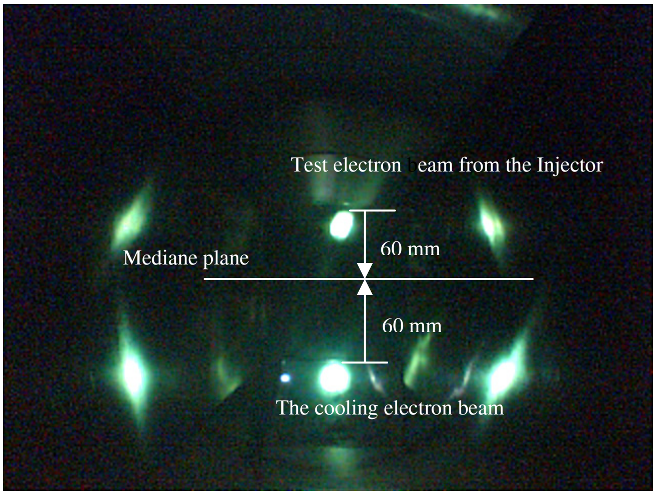

Figure 8. Two beams on luminescence screen.

The registration of positron transportation through the channel and septum section of the ring to the luminescence screen was performed with NaI scintillation counter in counting mode.

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.

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