# DEVELOPMENT OF THE POSITRON INJECTOR FOR LEPTA FACILITY

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## *Abstract*

An injector of the low energy positrons for the accumulator LEPTA has being assembled at JINR. The injector is based on $^{22}$Na radioactive source. Positrons from the source are moderated in the solid neon. The cryogenic source of slow positrons has been tested with a isotope $^{22}$Na of the initial activity of 0.8 MBk. The continuous slow positron beam with average energy of 1.2 eV, width of a spectrum 1 eV has been obtained. The achieved moderator efficiency is about 1 %.

The accumulation process in the positron trap was investigated with electron flux. The life time of the electrons in the trap, $\tau_{life} \geq 80$ s and capture efficiency ε ~0.4 have been obtained. The maximum number of the accumulated particle was $N_{exper} = 2 \cdot 10^8$ at the initial flux of $5 \cdot 10^6$ electrons per sec.

## THE POSITRON INJECTOR

The pulse positron injector of low energy positrons for accumulator LEPTA has been constructed at JINR [1-2]. One turn injection is used in LEPTA. The injection pulse duration is 300 ns at energy of circulating positrons in accumulator equal 10 kVe. The period of the injection pulses, determined the beam life time in the accumulator, is 10 ÷ 100 seconds. The peculiarity of the accumulator LEPTA is small value of the momentum spread of the circulating positrons - $\Delta p/p < 10^{-3}$. The demand positron intensity per pulse is $10^8$ [3]. The positron injector consists of the cryogenic source of slow monochromatic positrons, the transportation channel, the positron trap and the injection channel (see Fig. 1).

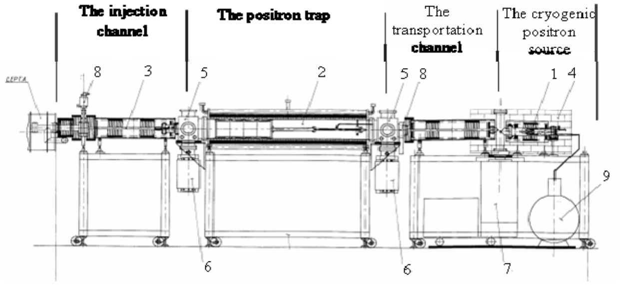

Figure 1: Positron injector. 1 - positron source $^{22}$Na, 2 - positron trap, 3 - vacuum insulator, 4 - radioactive protection shield, 5 - vacuum chamber for pumping out and diagnostic tools, 6 - ion pump, 7 - turbo pump 8 - the vacuum valve, 9 - LHe reservoir.

All sections of the injector are located in the longitudinal magnetic field created by system of solenoids. The continuous beam of slow monochromatic positrons from the cryogenic positron source passes trough the transport channel and accumulates at the trap. After the accumulation process has finished the positron extracted from the trap by electric pulse and injected to the accumulator LEPTA. Positrons are accelerated up to the energy 10 kVe at the injection process. The parameters of the injector are given in the table 1 [3].

Table 1: Design parameters of the positron injector.

| | |
|---|---|
| Length, *m* | 6,2 |
| Positron injection energy, *keV* | 2÷10.0 |
| Longitudinal magnetic field, *G* | 400 |
| Longitudinal magnetic field in the trap, *G* | 1500 |
| Residual gas pressure, *Tor* | $1 \cdot 10^{-9}$ |
| Beam radius, *cm* | 0.5 |
| Accumulation time, *s* | 100 |
| Injection pulse duration, ns | 300 |
| Number of positrons in injection pulse | $1 \cdot 10^8$ |
| Positron momentum spread | $1 \cdot 10^{-4}$ |

## THE CRYOGENIC POSITRON SOURCE

The slow monochromatic positron flux is formed at c from broad spectrum of positrons from radioactive isotope $^{22}$Na (see Fig. 2). The positrons with energy up to 0.54 MVe are moderated to the room temperature in the solid neon. The neon is frozen onto a copper substrate were capsule with isotope is located (see Fig. 3) [4].

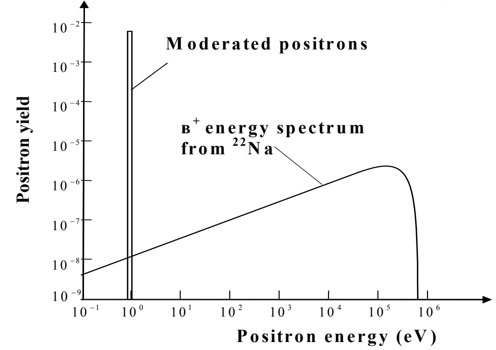

Figure.2: Positron spectrum from radioactive isotope $^{22}$Na and moderated one.

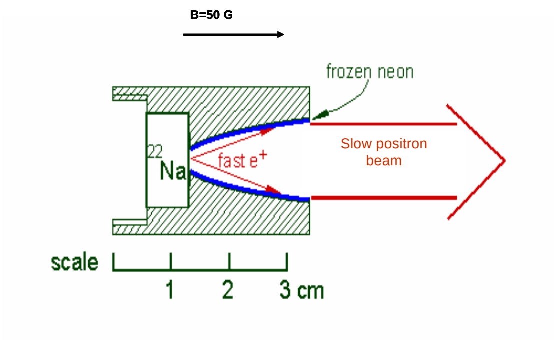

Figure 3: Slow positron getting principle.

The cryogenic source of slow positrons has been tested with the test isotope $^{22}$Na of the initial activity of 0.8 MBk. The continuous slow positron beam with average energy of 1.2 eV and the spectrum width of 1 eV has been obtained. The achieved moderator efficiency is about 1 % [5].

## THE POSITRON TRAP

The continuous beam of slow monochromatic positrons passes trough the transport channel and accumulates in the trap. The positron trap is a cylindrical vacuum chamber of 2 m long and inner diameter of 250 mm, located inside a solenoid (see Fig. 4).

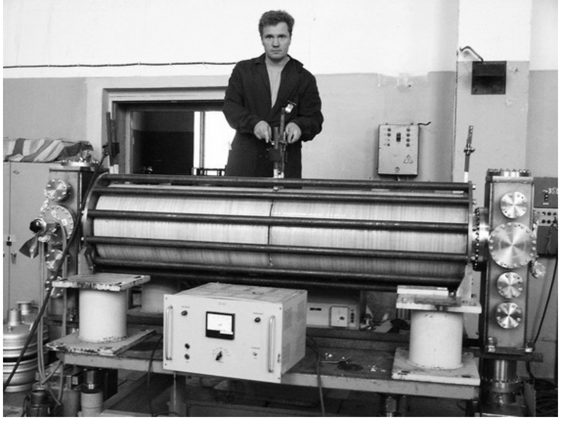

Figure 4: Positron trap.

The solenoid forms the longitudinal magnetic field up to 1.5 kGs. There is a set of eight electrically isolated aluminum electrodes within cylindrical vacuum chamber (see Fig. 5).

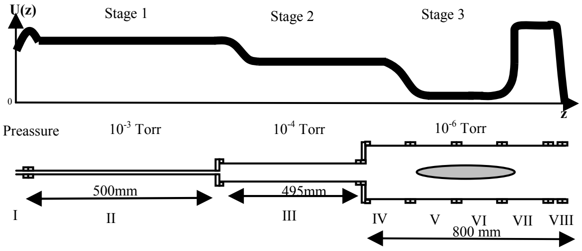

Figure 5: The scheme of the electrodes (I – VIII), potential distribution on the vacuum chamber axe and buffer gas pressure distribution inside the electrodes.

To each electrode its own potential is applied. The potential distribution confines the positrons in the axial direction after the initial trapping. The longitudinal magnetic field provides the radial confinement. The physical dimensions of the electrodes are designed to allow a pressure gradient to be developed along their length. The buffer gas (nitrogen) is introduced inside the electrode II and is pumped out through the vacuum chambers. The pressure along the array can be adjusted to obtain the optimal trapping of the positrons. Typically a pressure in the region of $10^{-3}$ Torr is sufficient within electrode II, falling to $10^{-6}$ Torr within the final stages. A steadily falling trapping potential is also applied along the array in order to accumulate the trapped positrons in the region of electrodes V - VII. The buffer gas pressure and potential applied to the electrodes play critical role in effectively of the accumulation process. On the stages 1-2 (see Fig.5) the high pressure of the buffer gas provides effective capture while low pressure on the stage 3 allows to achieve long life time of the positrons [6]. The electrode arrangement inside the vacuum chamber is set freely enough. The overlapping of axes of electrical and magnetic fields is provided with imposing of an transverse magnetic field $B_\perp$ on all length of the solenoid of the trap. The transverse magnetic field provides shifting the beam in horizontal and vertical directions on 2 cm. The correction field value is selected on affectivity of the accumulation process. Because of absence of the positron source of required activity the research of the accumulation process was carried out using electron flux. For this purpose the test electron gun allowing to emit $dN/dt = 5 \cdot 10^6$ 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 25 mCi.

To increase the particles life time the "rotating wall" method was applied during accumulation process [7]. One of the trap electrodes in the stage 3 consists of four isolated segments (see Fig. 6), 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 $90^0$ one to another one that forms rotating transverse electric field.

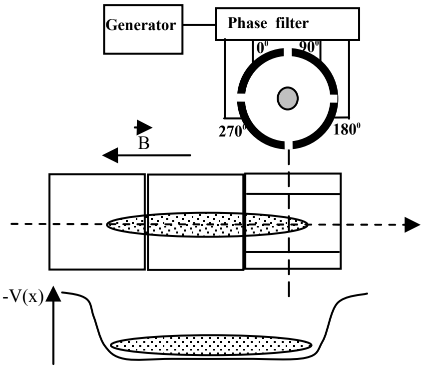

Figure 6: One electrode of the trap is placed under combined alternative and permanent potentials.

The dependence of the of accumulated electron number *N(t)* on the accumulation time has been measured at different conditions (see Fig. 7). The curve 1 presents the function *N(t)* after optimization of the bugger gas pressure and the electrode potentials distributions. 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. The optimum frequency of rotation field has been found equal to 650 KHz at the amplitude of 1V.

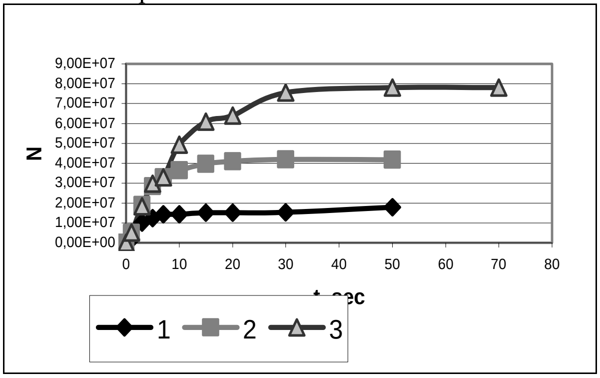

Fig.7: Total trapped charge as a function of filling time (the explanations in the text)

In a result of the experiments the total number of accumulated electrons is $N_{max} = 2 \cdot 10^8$. The achieved capture efficiency is of 0.4, the electron life time $\tau_{\text{life}} \geq 80$ s. The time of extraction of the particles from the trap did not exceed 500 ns, that allow to catch 60 % of the accumulated particles.

## CONCLUDING REMARK

The experimental testing of the injector elements – of the cryogenic positron source and the positron trap – has shown that the injector project parameters can be achieved at the positron source activity of 25 mCi and the injector will be able to deliver up to $10^8$ positrons per pulse at periodicity of injection in the accumulator less the 100 seconds. The next step of the experimental program is the test of the cryogenic source and positron trap using the source of such an activity that we have got recently.

## REFERENCES

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