# Development of the Positron Injector for LEPTA Facility

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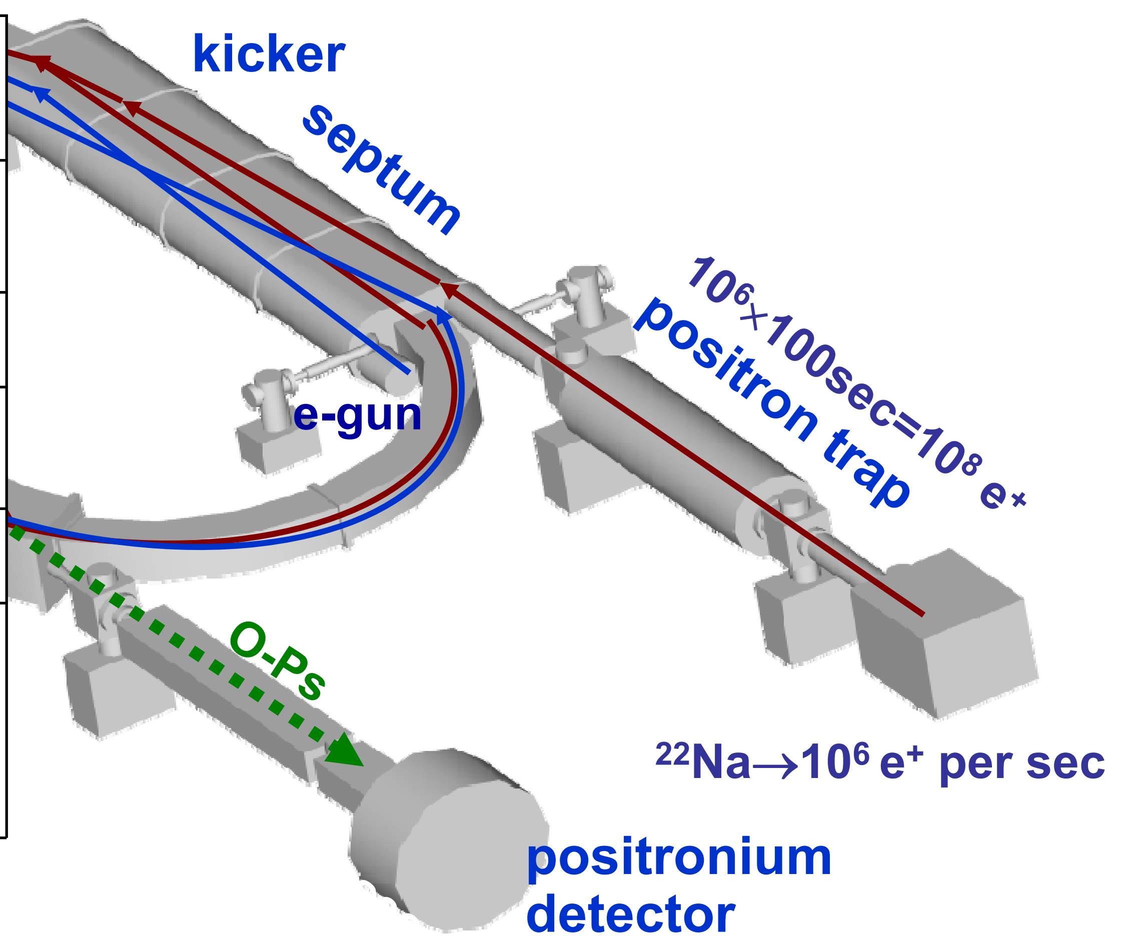
# Contents

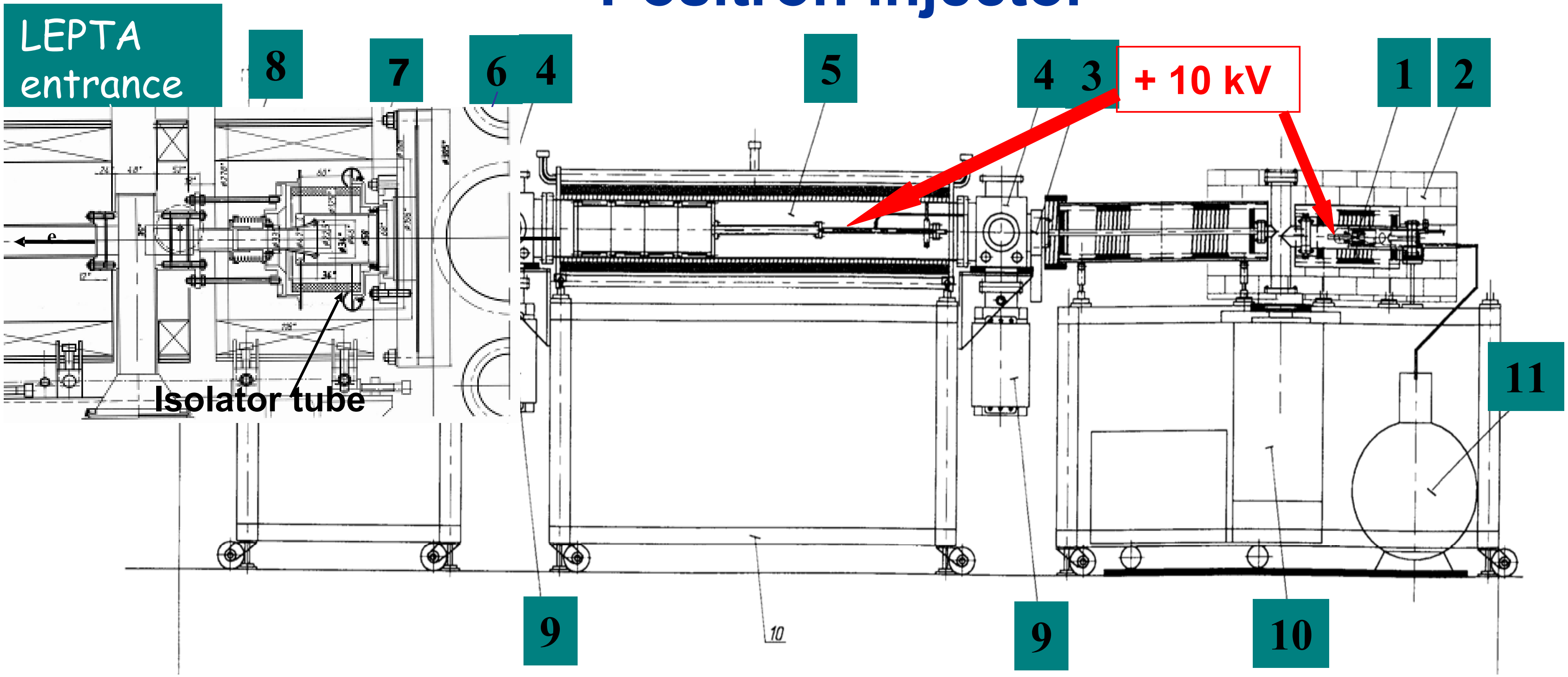
# 1. Positron injector (design and main parameters)

## LEPTA Facility

| Project parameters of the positron beam | |
|---|---|
| Injection duration | 300 ns |
| energy | 2 - 10 KeV |
| Injection periodicity | 10 ÷ 100 s |
| $\Delta p/p$ | $< 10^{-3}$ |
| Positron number per pulse | $1*10^8$ |



# Positron injector

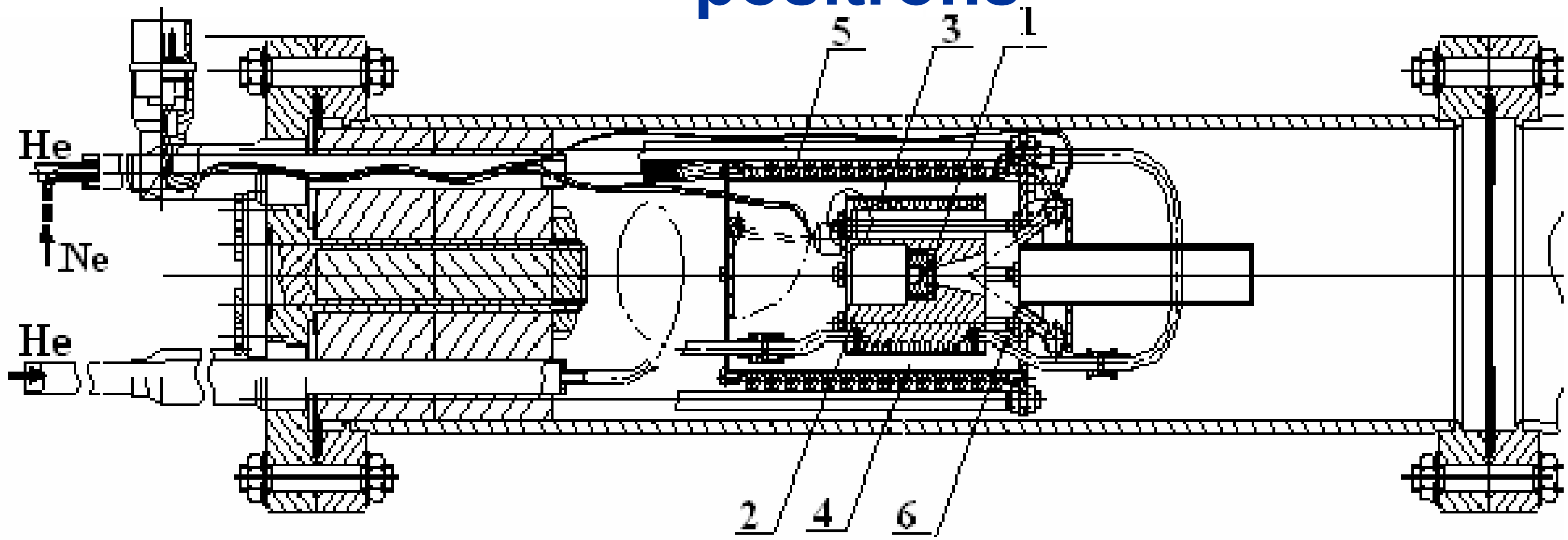



**1 - positron source $^{22}$Na, 2 - radioactive protection shield, 3 - vacuum valve, 4 - vacuum chamber for pumping out and diagnostic tools, 5 - positron trap, 6 - vacuum isolator, 7 - positron vacuum channel, 8 - vacuum “shutter” (fast valve), 9 - ion pump, 10 - turbopump, 11 - LHe vessel.**

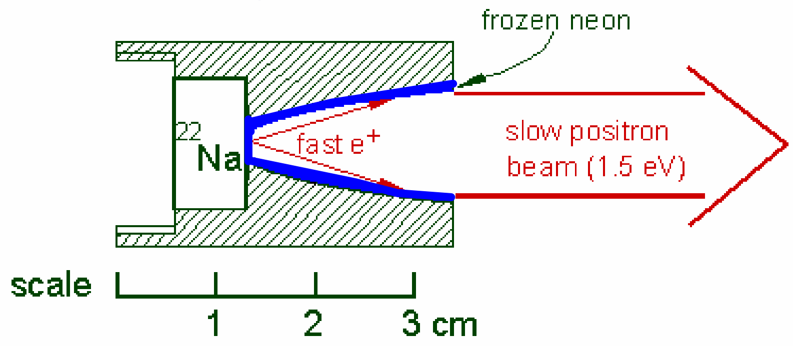
# Design parameters of the positron injector

| | |
|---|---|
| Length, *m* | 6,2 |
| Positron injection energy, *keV* | 2.0 ÷ 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 | $1{\cdot}10^{-4}$ |

# 2. The cryogenic source of slow monochromatic positrons

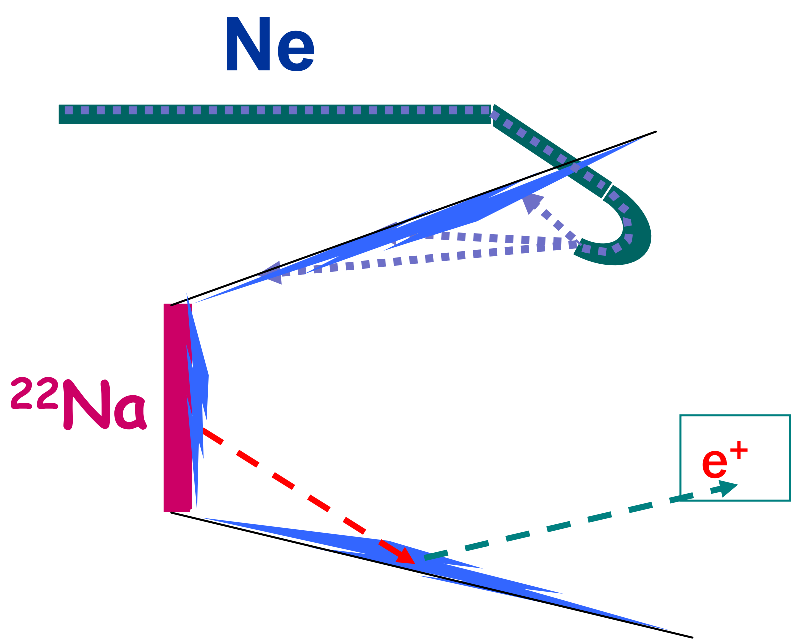



**The cryogenic source. 1-cupper subscribe with isotope $^{22}$Na , 2- cupper cylinder, 3- cryogenic heat exchanger of the cupper cylinder, 4 – thermal shield , 5- cryogenic heat exchanger of the thermal shield , 6- nozzles.**

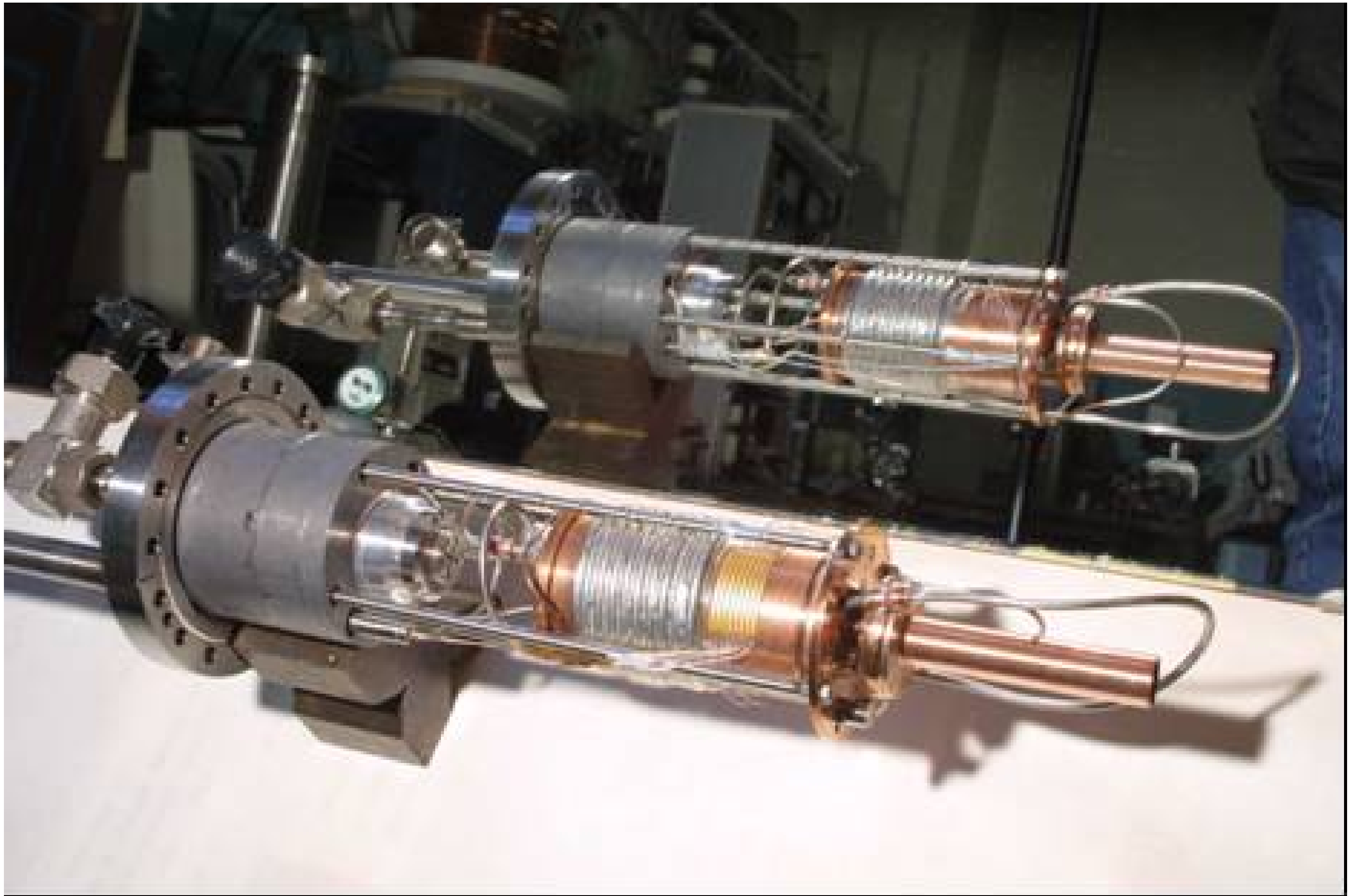


# The Cryogenic Moderator of Positrons

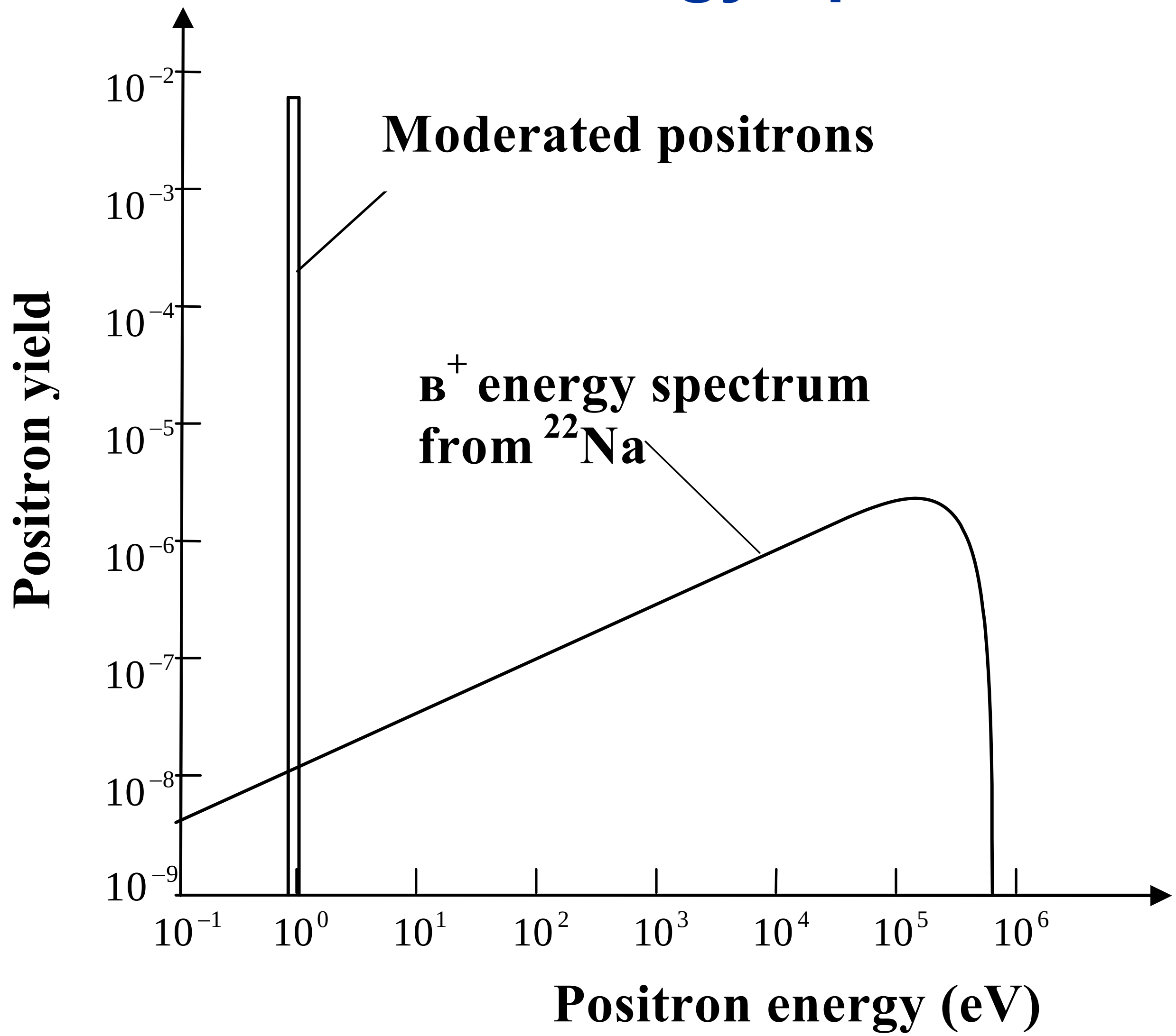
T ~ 5 K



## 2. The cryogenic source of slow monochromatic positrons (Contnd)



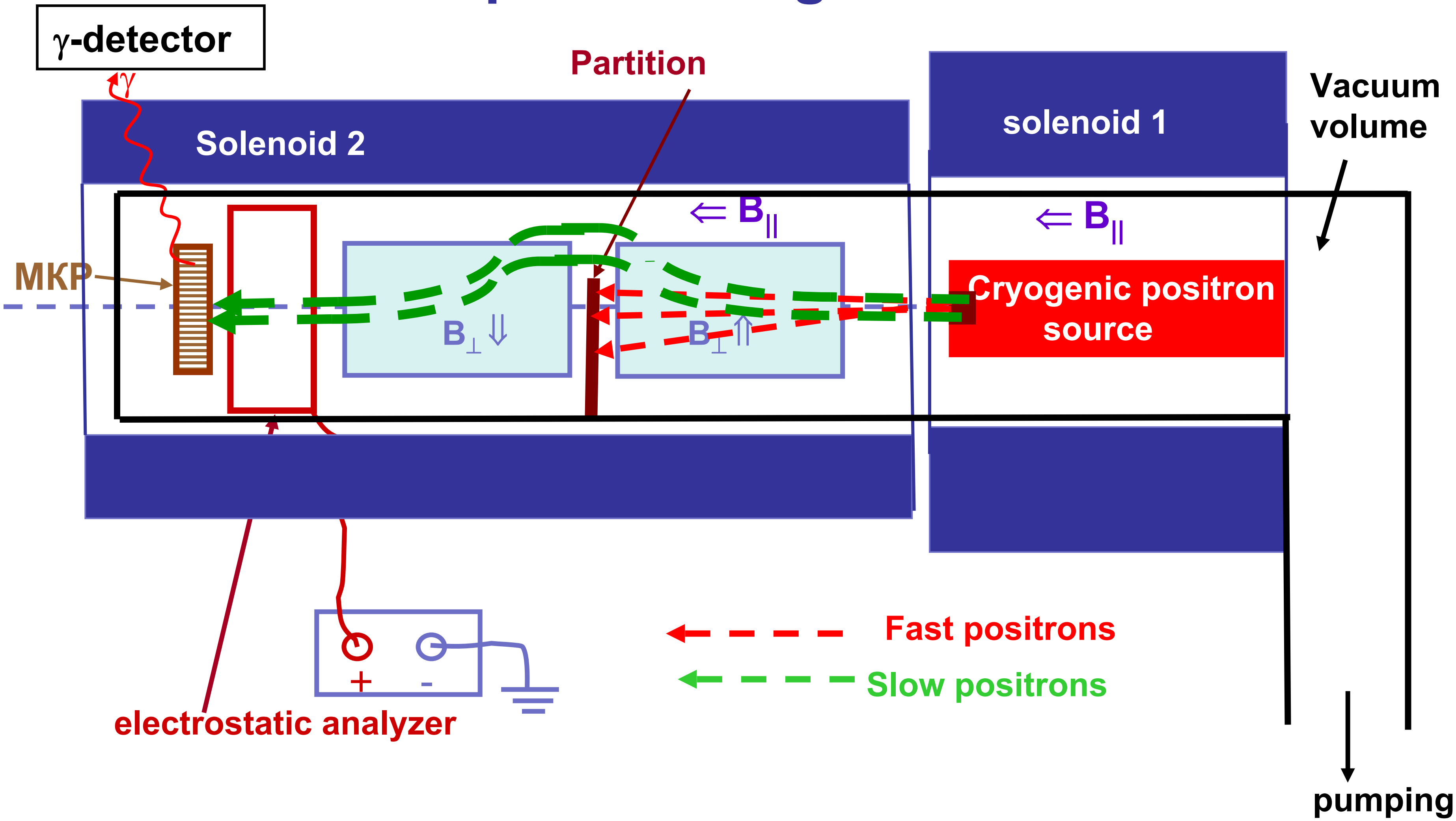
# Positron Energy Spectrum



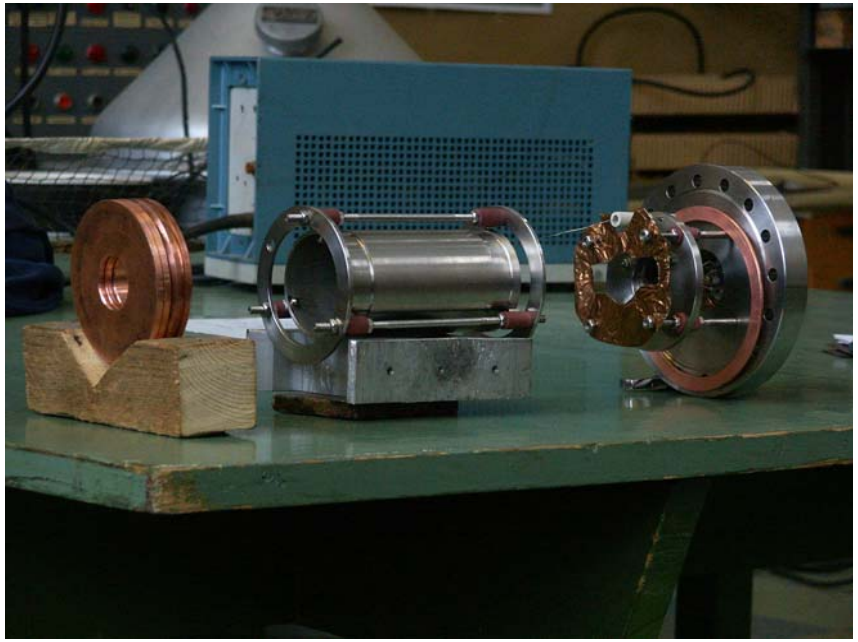
## 2. The cryogenic source of slow monochromatic positrons (Contnd)

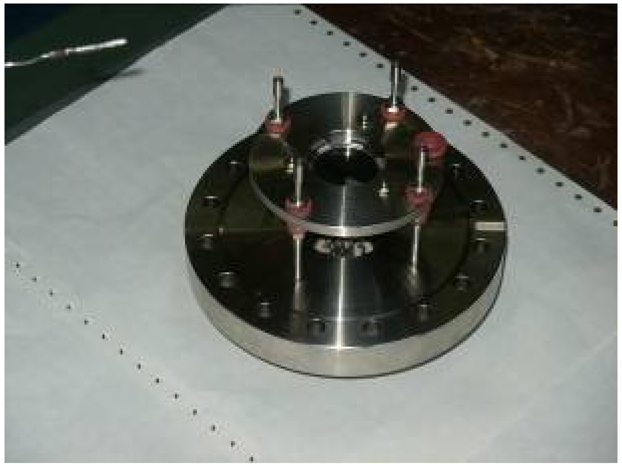
**The stand "Positron source"**

# The slow positron registration scheme

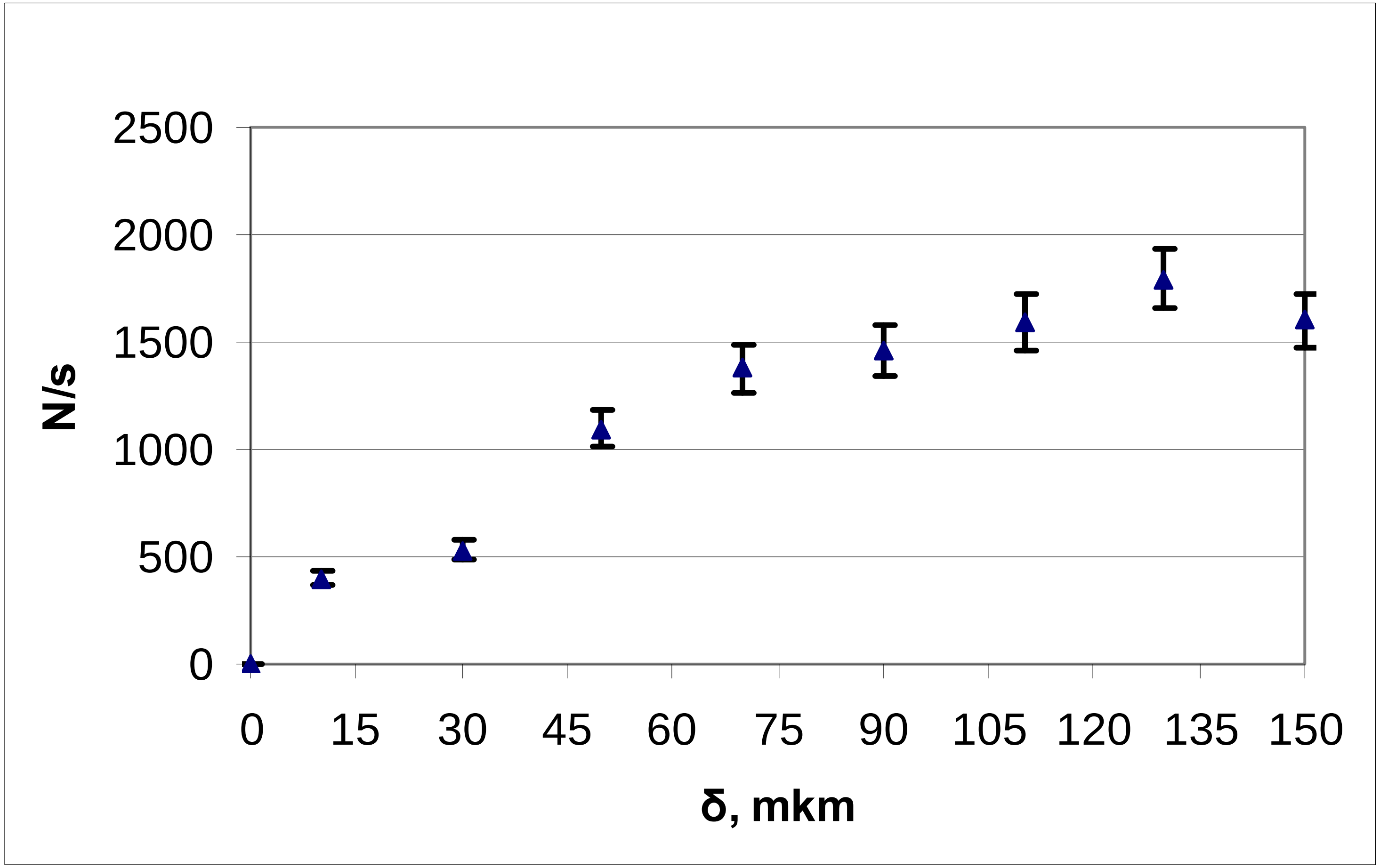


# The elements of registration system

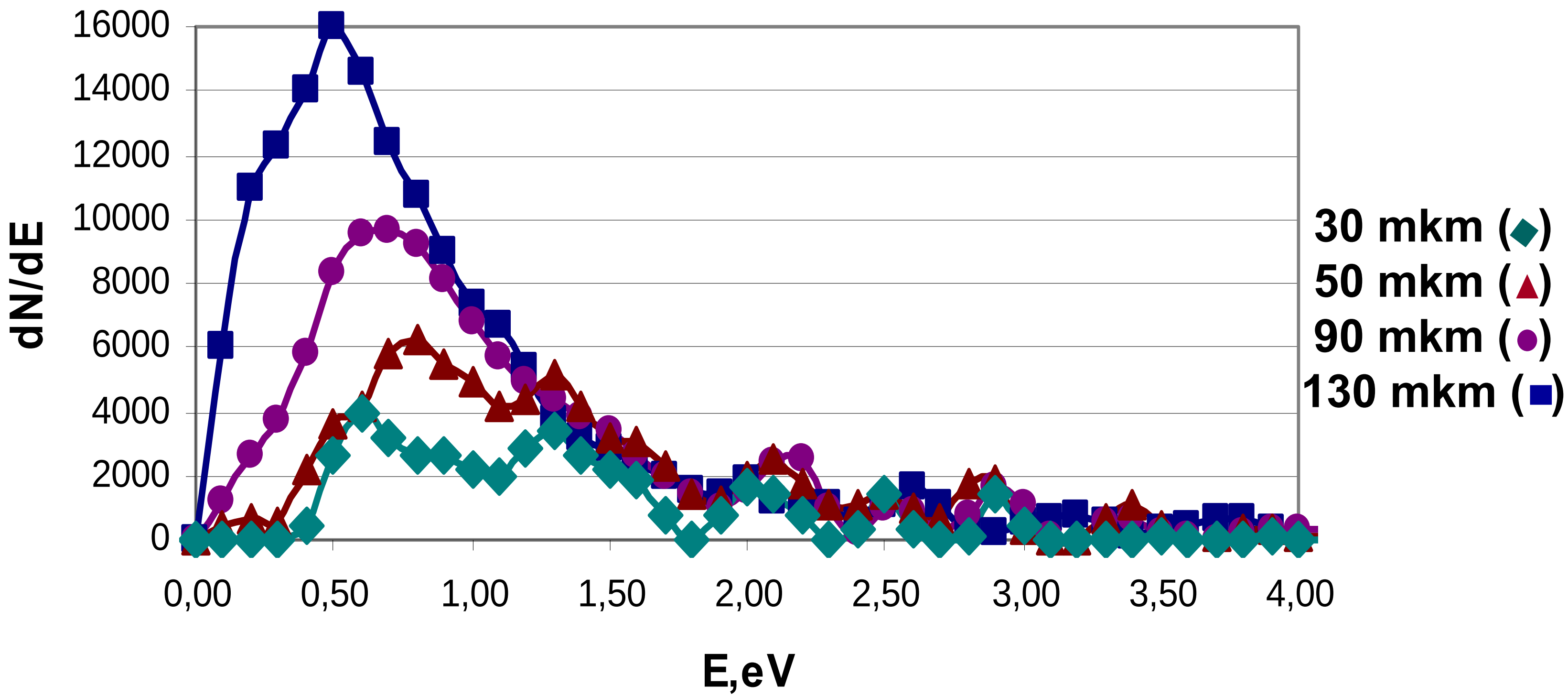




# Slow Positron Yield vs Frozen Neon Thickness



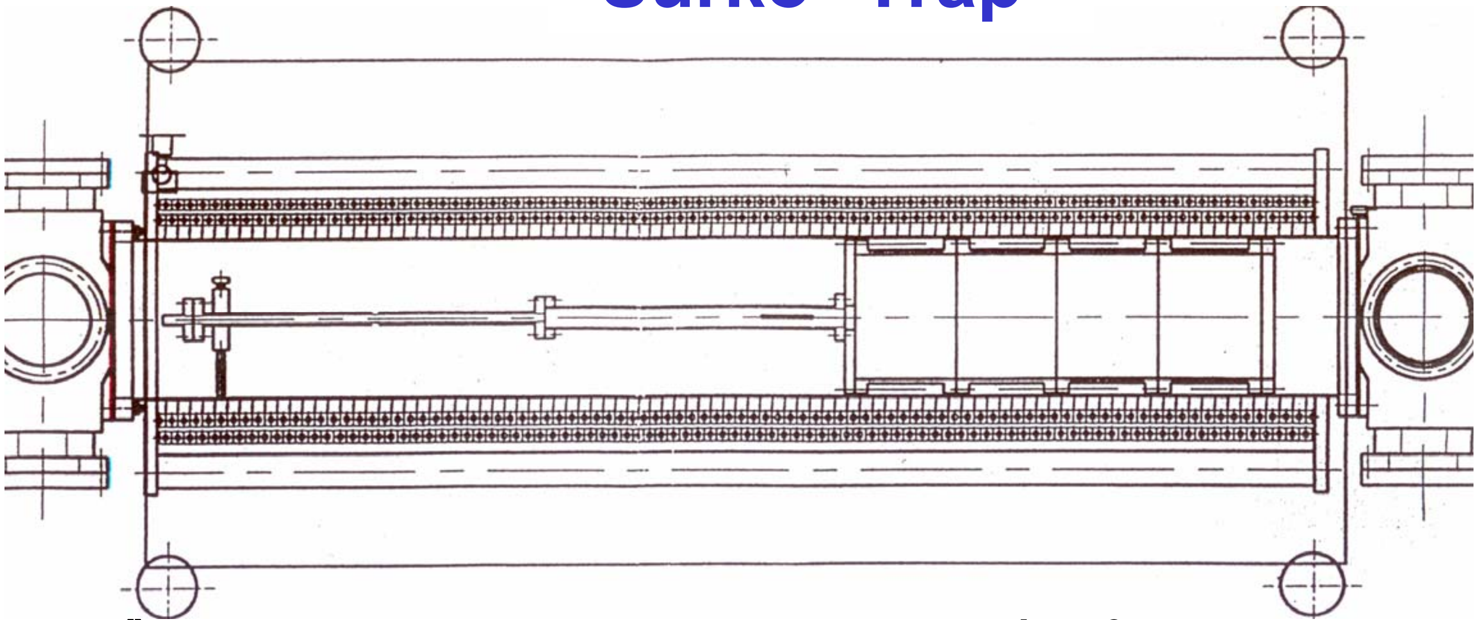
# Slow Positron Spectrum vs Frozen Neon Thickness

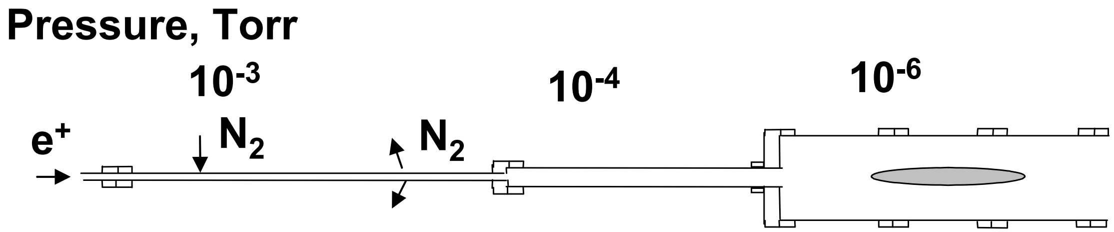


**The positron spectrum at the e+ flux of $5.8 \times 10^3$ positrons per sec of the average energy of 1.2 eV at the width of 1 eV has been obtained. The moderator efficiency is 1%.**

# 3. Positron trap

## “Surko” Trap



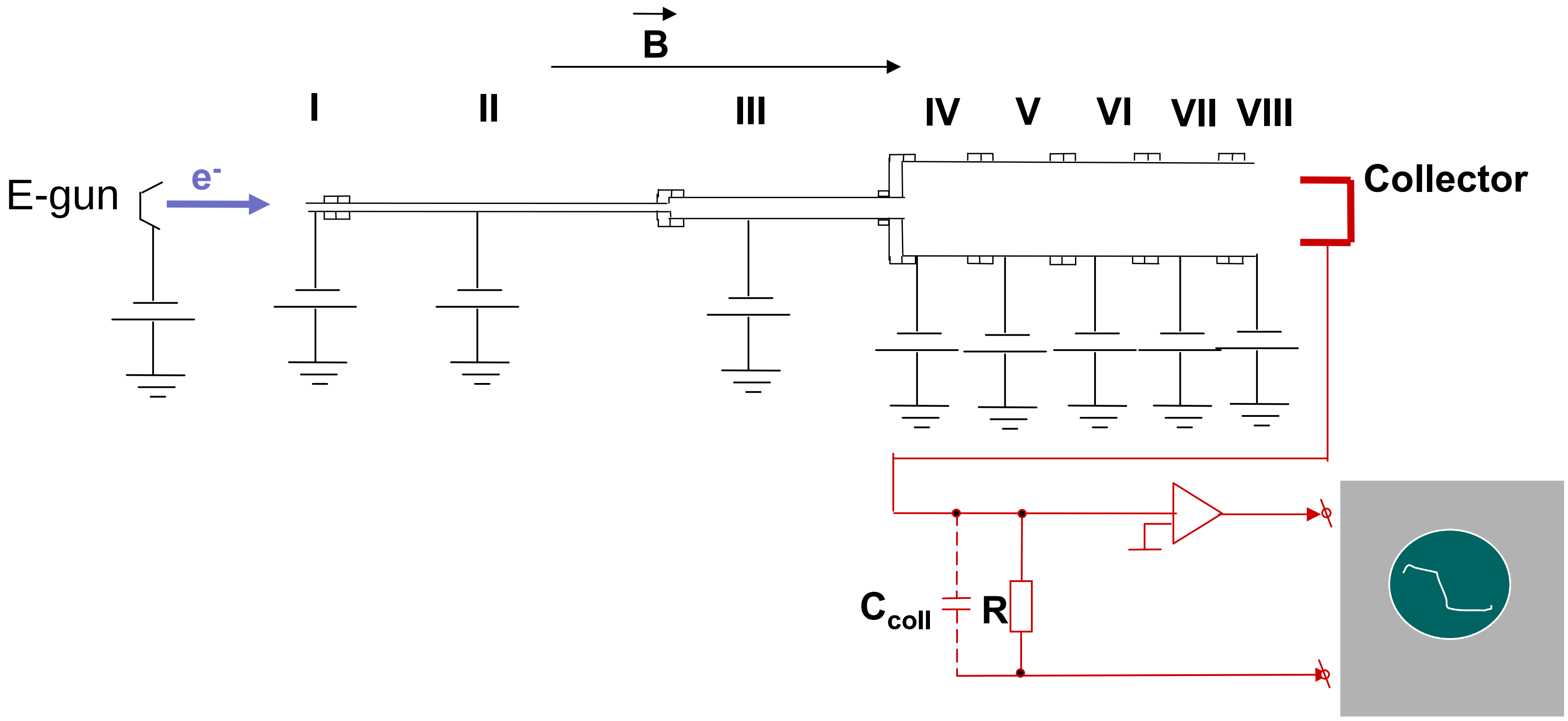
# The trap dimensions


Set of electrodes

| Electrode | Inner diameter (mm) | Length (mm) |
|---|---|---|
| 1 | 12 | 50 |
| 2 | 12.7 | 500 |
| 3 | 30 | 495 |
| 4 | 200 | 160 |
| 5 | 200 | 160 |
| 6 | 200 | 160 |
| 7 | 200 | 160 |
| 8 | 200 | 20 |

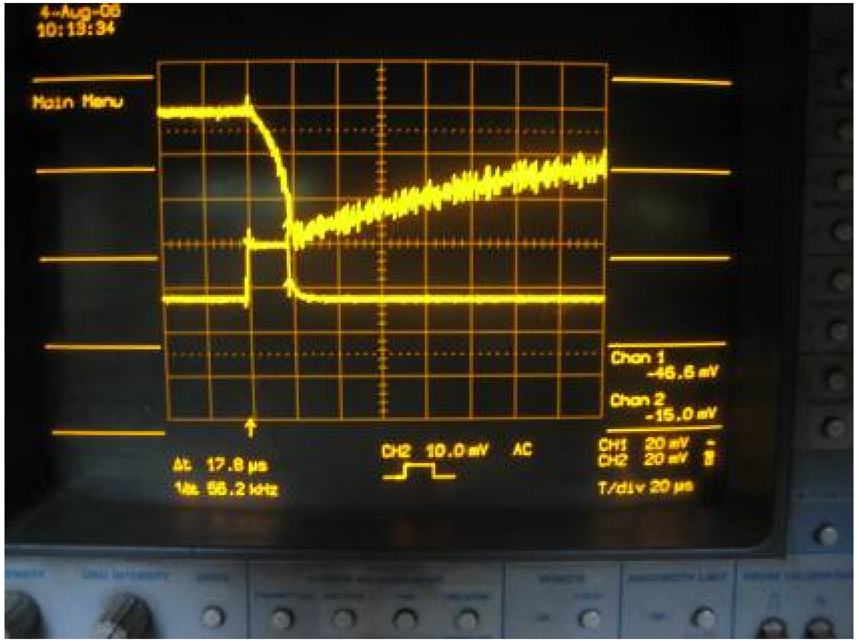
# Assembled positron trap

# Testing the trap with electrons



## 3. Positron trap (Contnd)

**The test electron gun current has been chosen corresponding to dN/dt = 5*$10^6$ electrons/sec (0.7 pA electron current) of the energy of 50 eV and spectrum width of a few eV. These parameters correspond to the positron beam which we expect from a radioactive source of an activity of 25 mCi.**



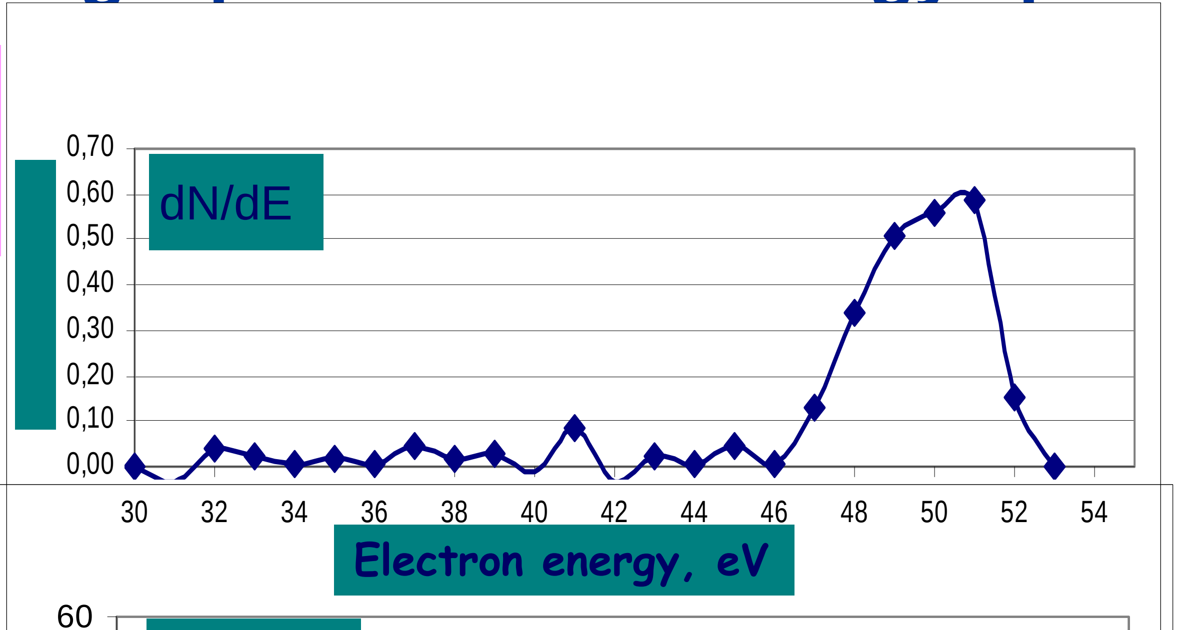

Single pass electron beam trough the trap to the collector. Trap has been opened in pulse mode

Stored electrons extracted to the collector

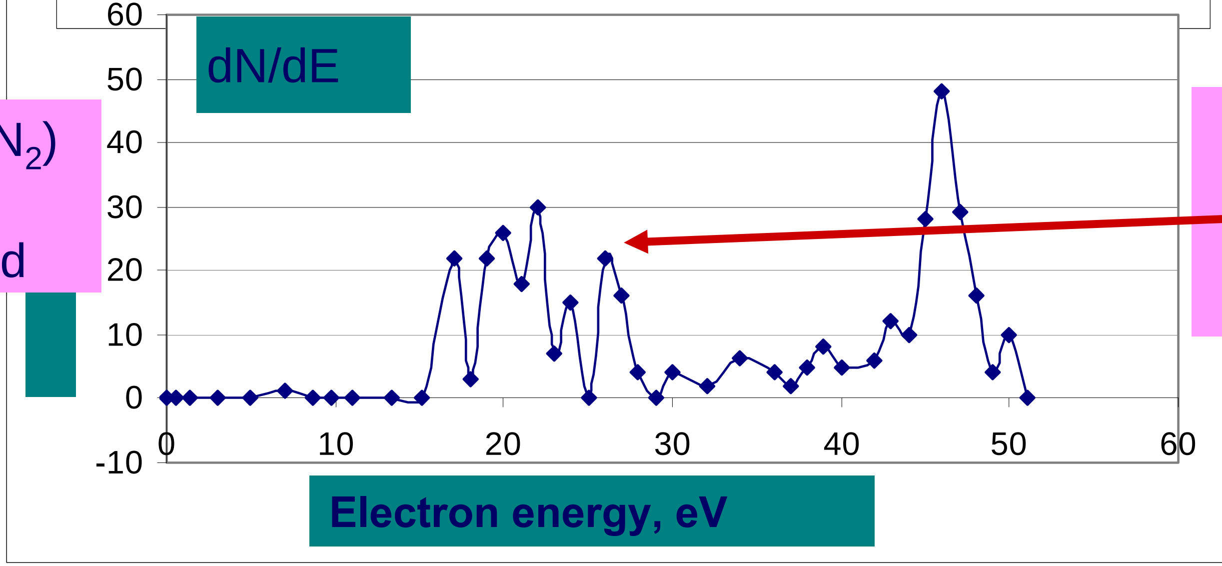
$\int I_e(t) \cdot dt$ – upper signal, $I(t)$ – lower signal,

# Single pass electron energy spectrum

No buffer gas

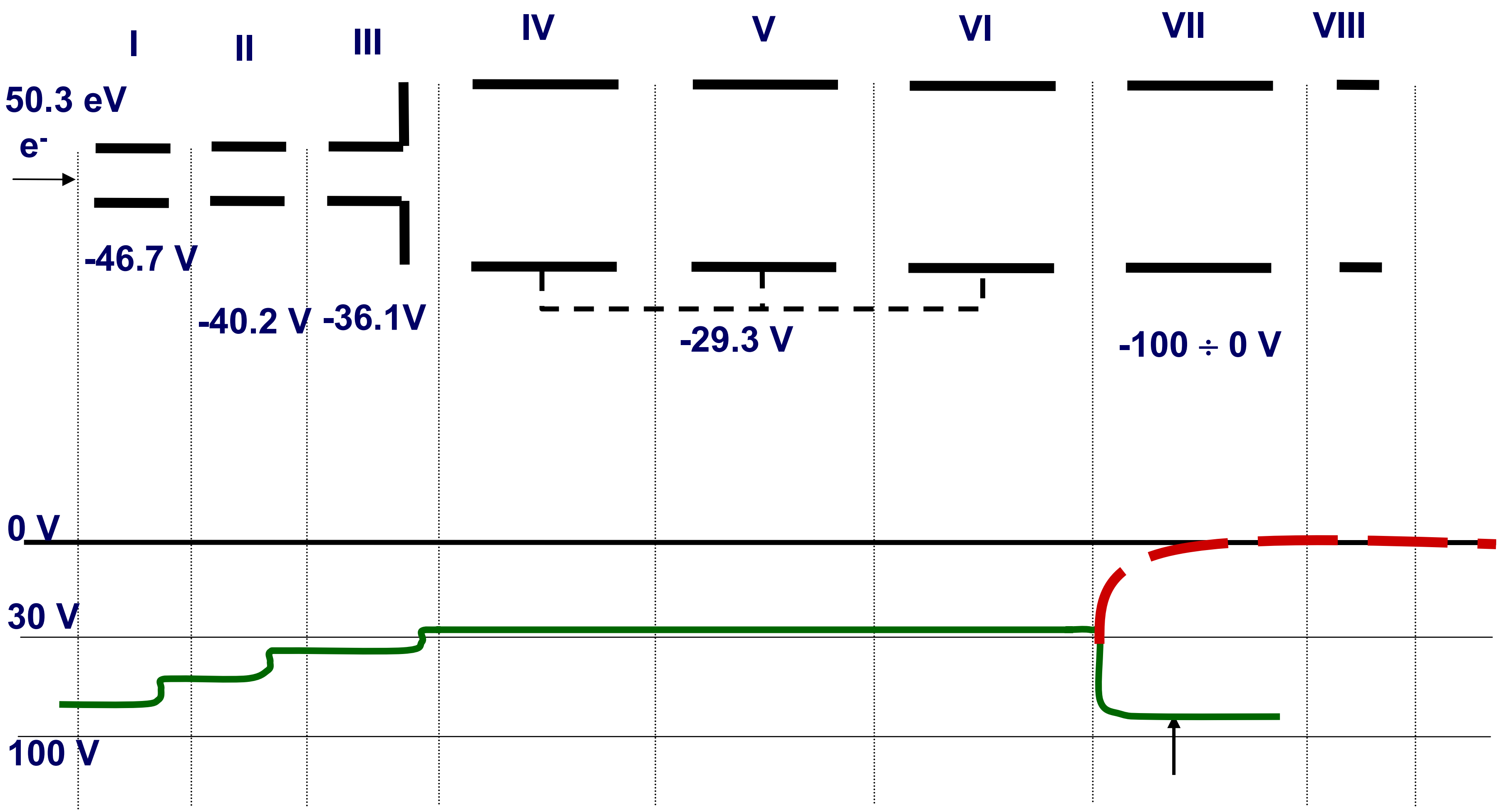



Buffer gas ($N_2$) pressure is optimized

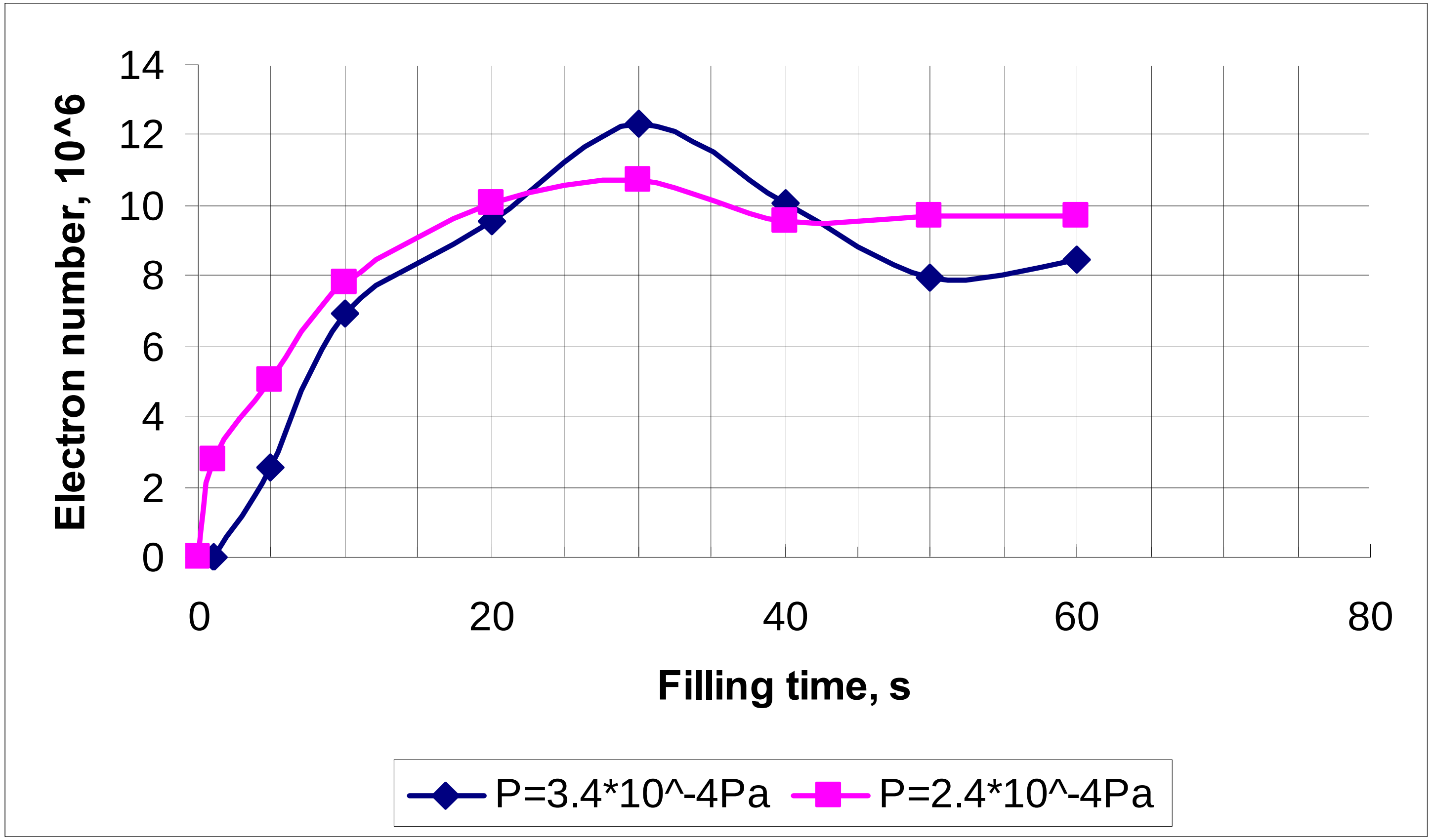



Frank-Hertz peaks appear!

# Electron storage studies



# Typical storage functions



# Data Analysis

Electron storage equation
$$\frac{dN_{trap}}{dt} = \varepsilon \dot{N} - \frac{N_{trap}}{\tau_{life}}$$

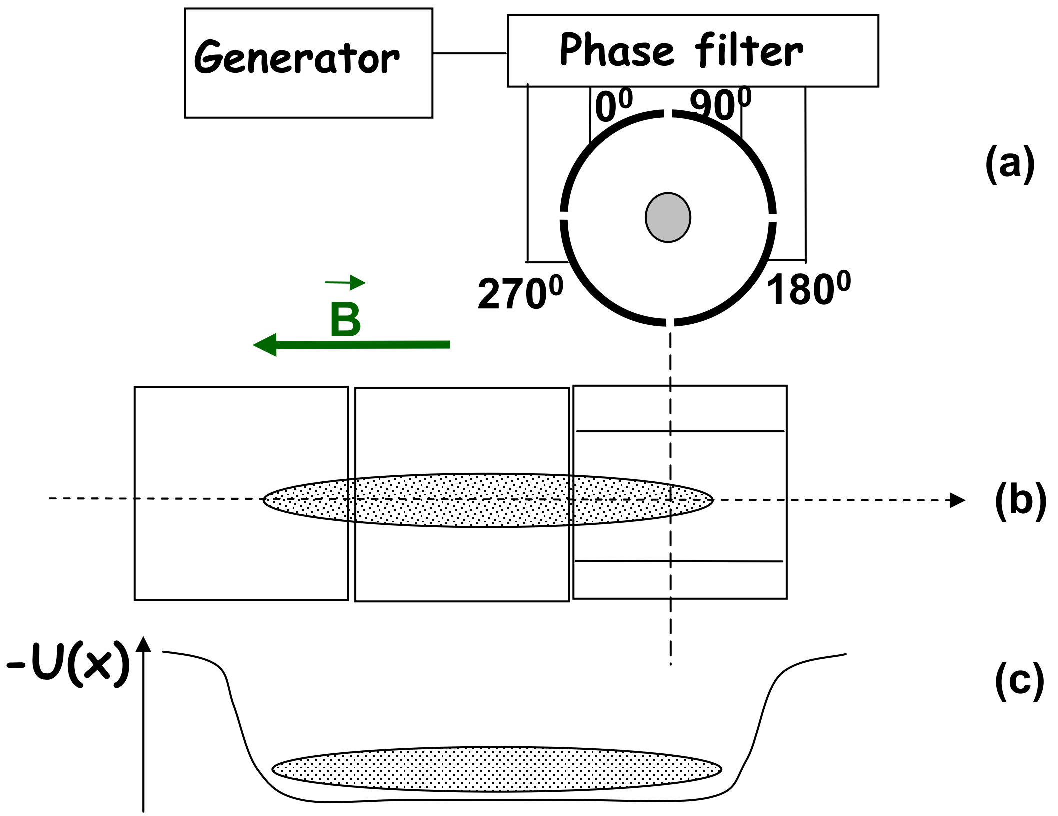
$N_{trap}$ – electron number stored in the trap, $\varepsilon$ – storage efficiency,
$\tau_{life}$ - electron life time in the trap.

It gives:
$$N(t) = \varepsilon \dot{N} \tau_{life} (1 - e^{-t/\tau_{life}})$$

Two asymptotes:
$$N(t) = \begin{cases} \varepsilon N t, & t \ll \tau_{life}, \\ \varepsilon N \tau_{life}, & t \to \infty. \end{cases}$$

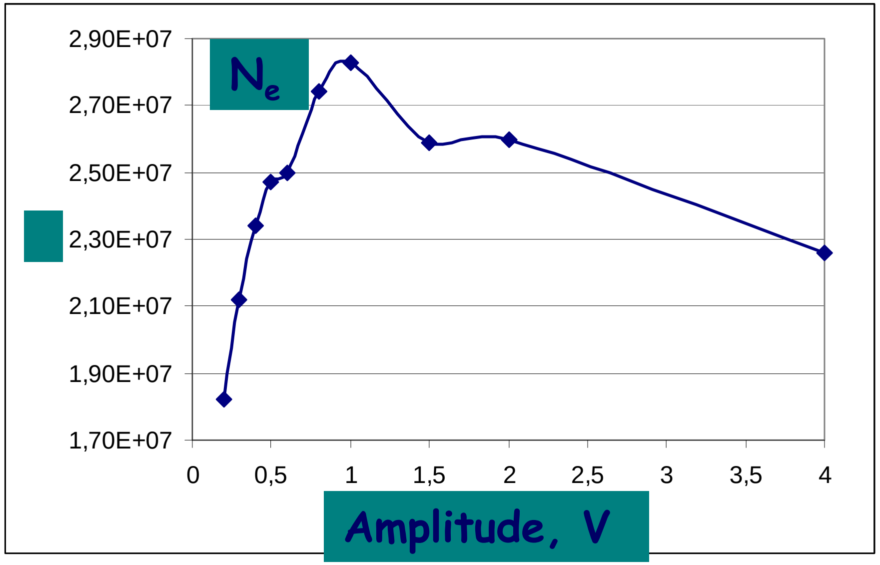
At $(dN_e/dt)_{entrance} = 4.5 \cdot 10^6\ s^{-1}$ from the Fig. in the previous slide we find: $\varepsilon = 0.18$, $\tau_{life} = 12.5$ c

# Rotating Electric Field Method

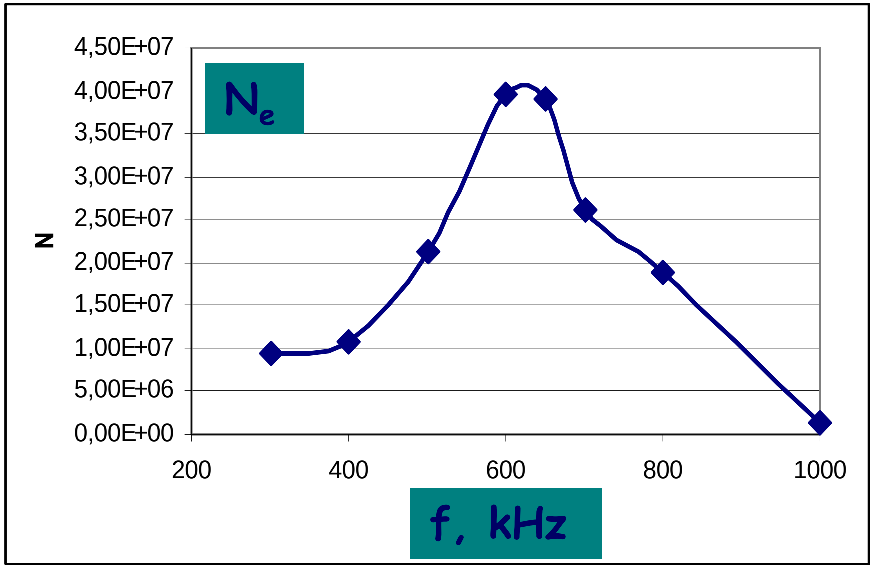



**One electrode is placed under combined alternative + permanent potentials (Fig.a, b, c).**

# Rotating Electric Field Method (Contnd)




**Stored electron number vs amplitude of the rotating field**

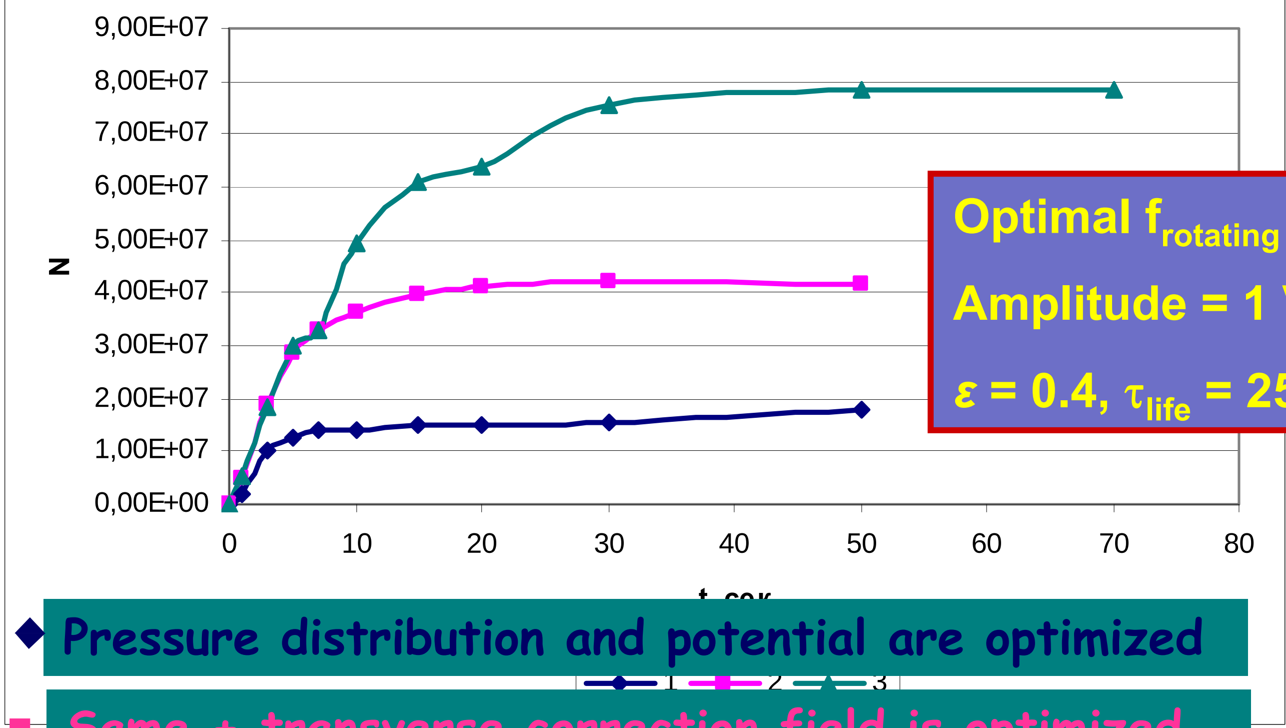



**Stored electron number vs frequency of the rotating field**

**Direction of the field rotation – opposite to electron drift in crossed B-field and e-field of electron space charge!**

# Rotating Electric Field Method (Contnd)

Stored electron number vs time



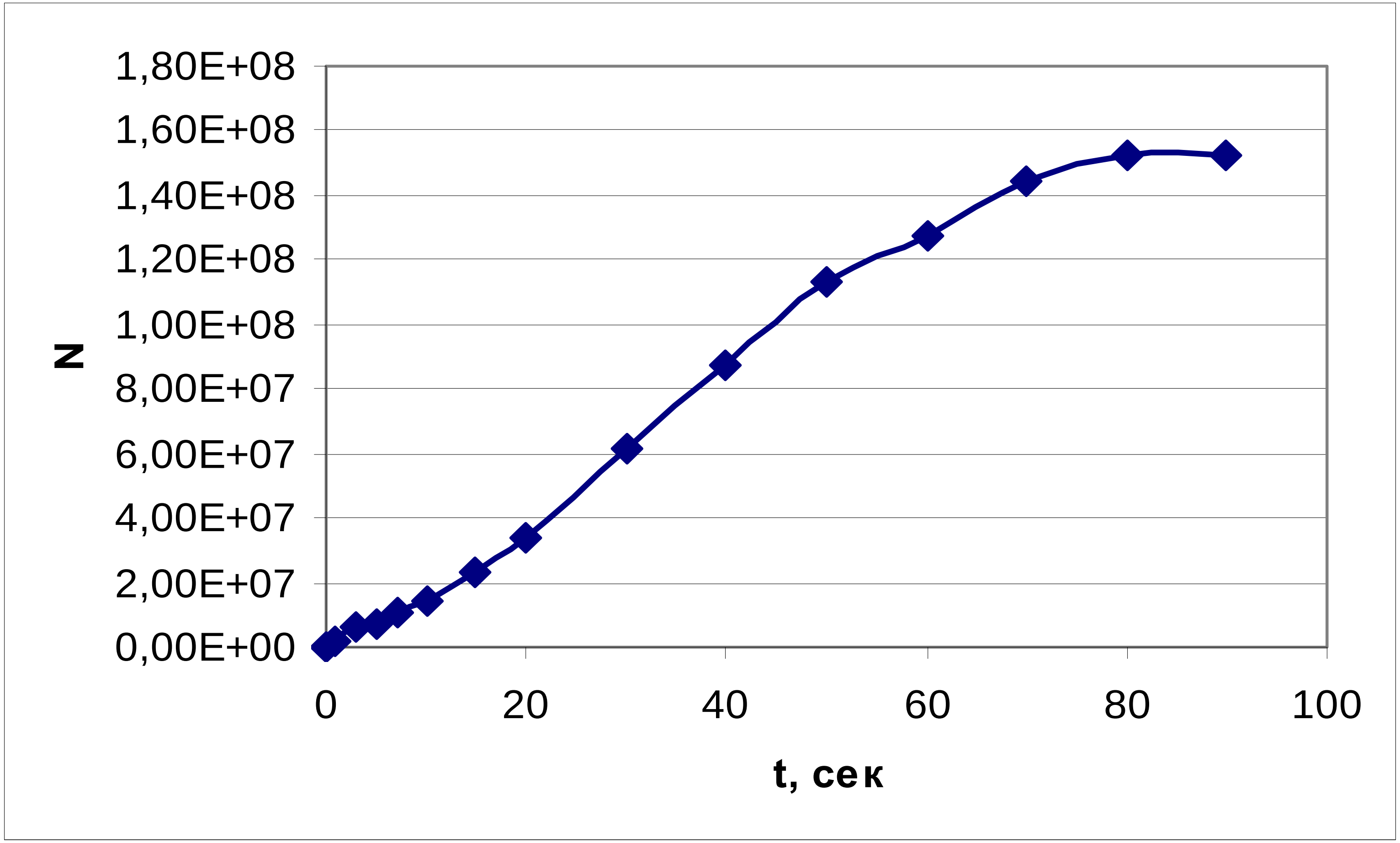

Optimal $f_{rotating}$ = 650 kHz,

Amplitude = 1 V,

$\varepsilon$ = 0.4, $\tau_{life}$ = 25 s

- ◆ Pressure distribution and potential are optimized
- ■ Same + transverse correction field is optimized
- ▲ Same + rotating field is ON and optimized

## Stored electron number vs time (B=1.2kGs)



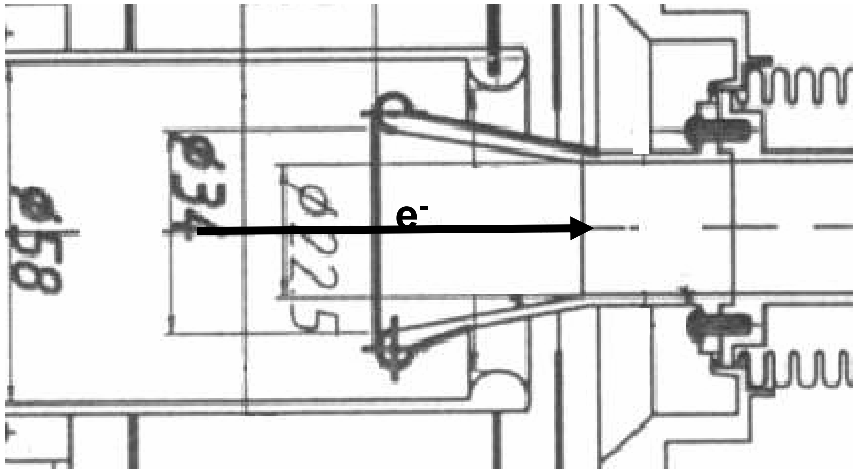

**$\tau_{life} \geq$ 80 s,**
**$N_{max}$=1,5·10$^{8}$, ($N_0$= 5·10$^{6}$ e$^{-}$/c)**

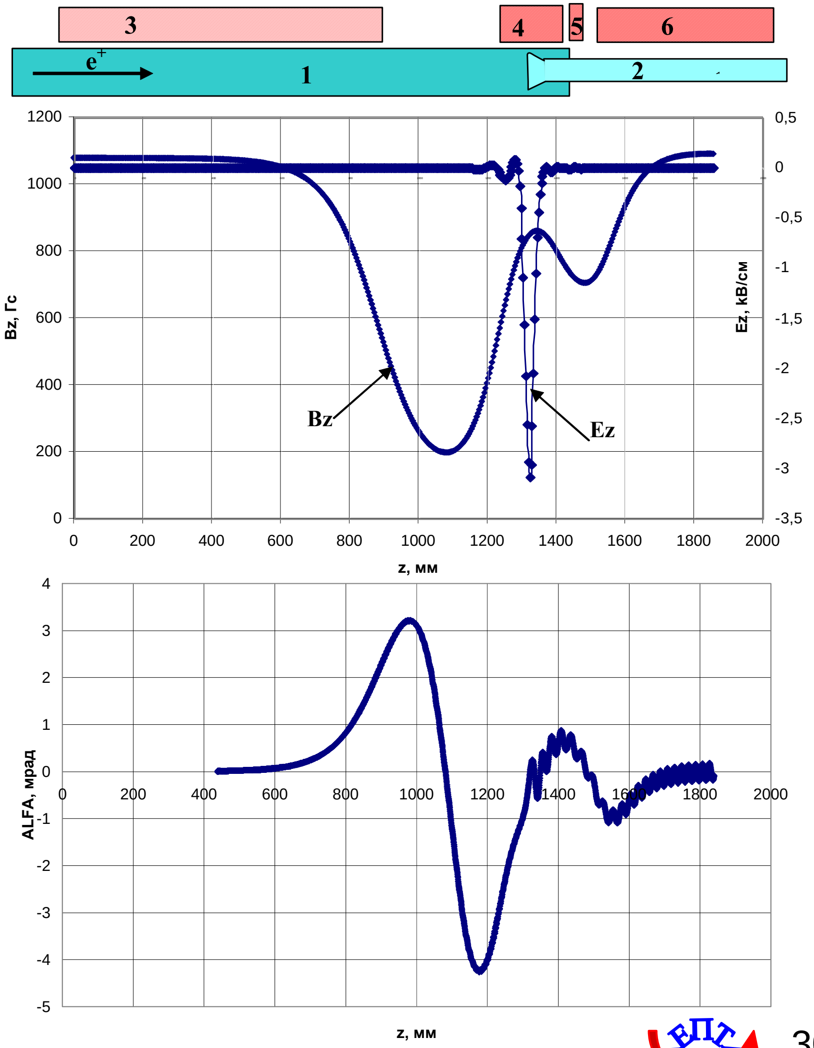
# Particle Extraction from The Trap


$$V_{coll} = \frac{1}{C}\int I(t)\,dt$$

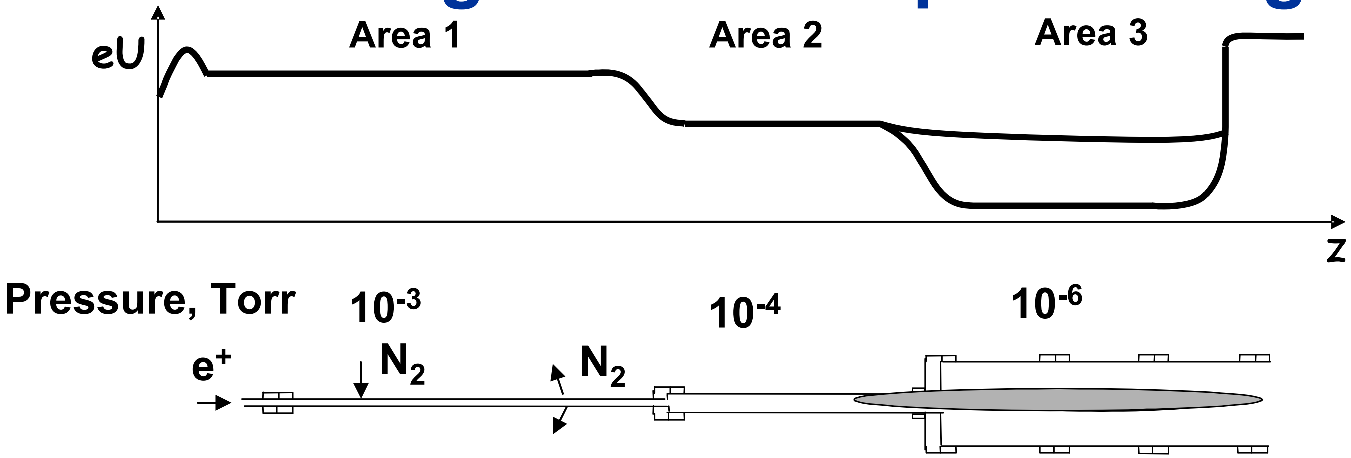
**Extracted bunch duration is about 500 ns**

# Particle Extraction from The Trap (Contnd)



# Particle storage and “the space charge limit”




**Estimated bunch intensity when the trap opens:**

$$\Delta U = \frac{eN}{L} \cdot \left(1 + 2 \cdot ln \frac{b}{a}\right)$$

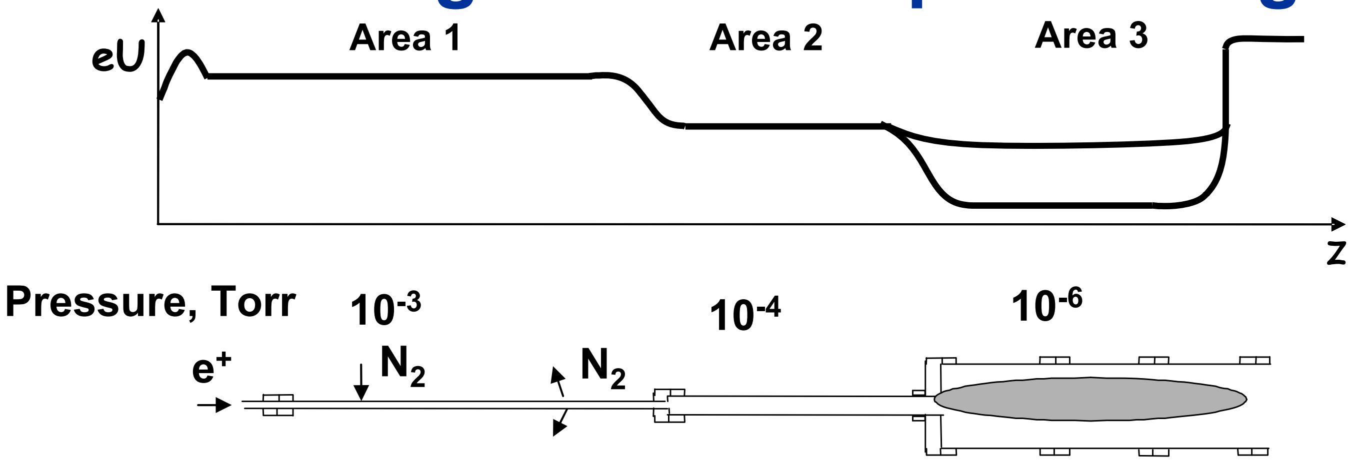
N – particle number in the bunch, L – the bunch length, a, b – the radii of the bunch and the tube in the Area 2.

For N = $3 \cdot 10^8$, a = 1 mm, b = 15 mm, L = 250 mm we find

$\Delta U$ = 11.1 V

## 3. Positron trap (Contnd)

# Particle storage and “the space charge limit”



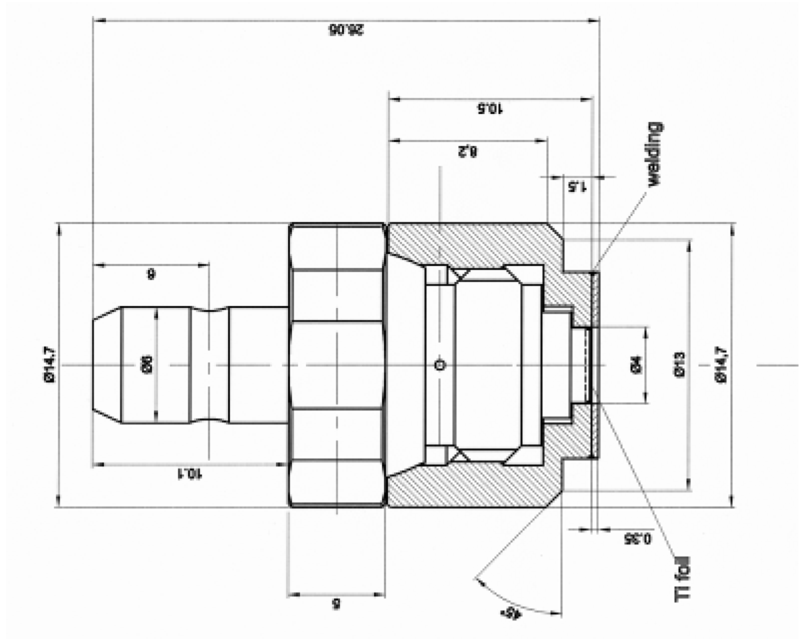

**Experimental proves:**

1) “Leak” current was measured and it was found on the electrode in the Area #2 !

2) “Dynamical control” of the Area #2 potential allows us to increase the particle number in the bunch ~ by 2 times!

# 4. Status and nearest plans

## New positron source from South Africa



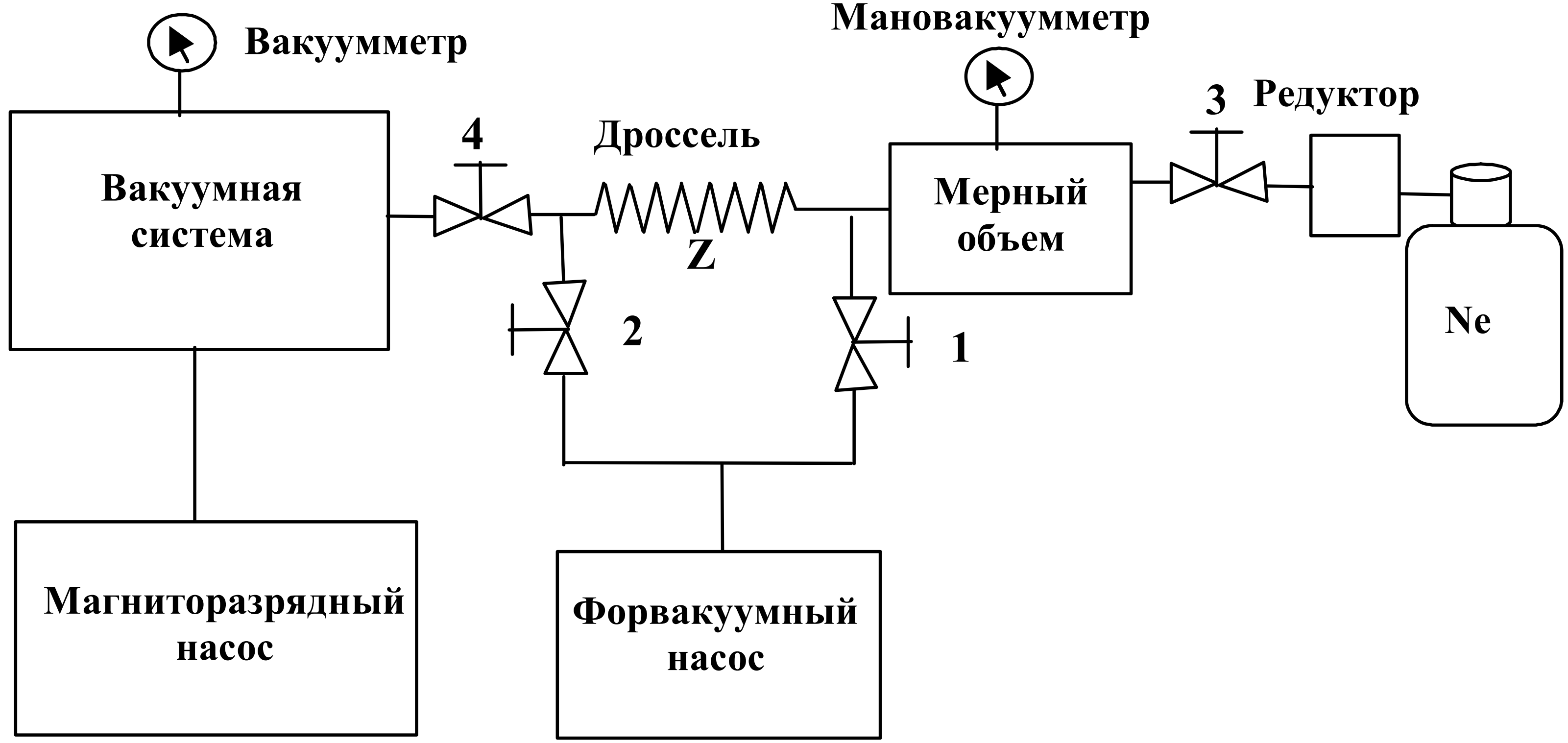

**New positron source activity of 25 mCi for LEPTA facility has been donated by iThemba LABS (South Africa)**

# The positron injector under assembling


**Our great thanks to iThemba Labs and personally to Dr. Lowry Conradie for donation of the $e^+$ source that enables us to reach the main goal of the LEPTA project – Ps generation in flight.**

***Thank you for attention***

# Линия напуска неона в систему



# Расчет толщины слоя намороженного замедлителя

$$\delta = \frac{V_{Ne}}{K \times S}\varepsilon$$

$$V_{Ne} = \frac{\Delta P}{P_{atm}}V$$

**Эффективность конденсации**

$$\varepsilon = (1 - \frac{\dot{n}'_{Ne}}{\dot{n}_{Ne}})100\,\%$$

$$\dot{n}_{Ne} = \frac{V_{Ne}P_{atm}}{\Delta t}$$

$$\dot{n}'_{Ne} = ДP_0 \cdot U$$

**Объем неона, испаряемого в единицу времени**

$$\dot{V}_{Ne} = \frac{\dot{n}''_{Ne}}{P_{atm}}$$

$$\dot{n}''_{Ne} = \delta PU$$

**$\varepsilon$ = 99,9%**

**$T_{исп}$(10 мкм) = 4 · $10^6$ с**