Status of LEPTA project

Low Energy Positron Toroidal Accumulator

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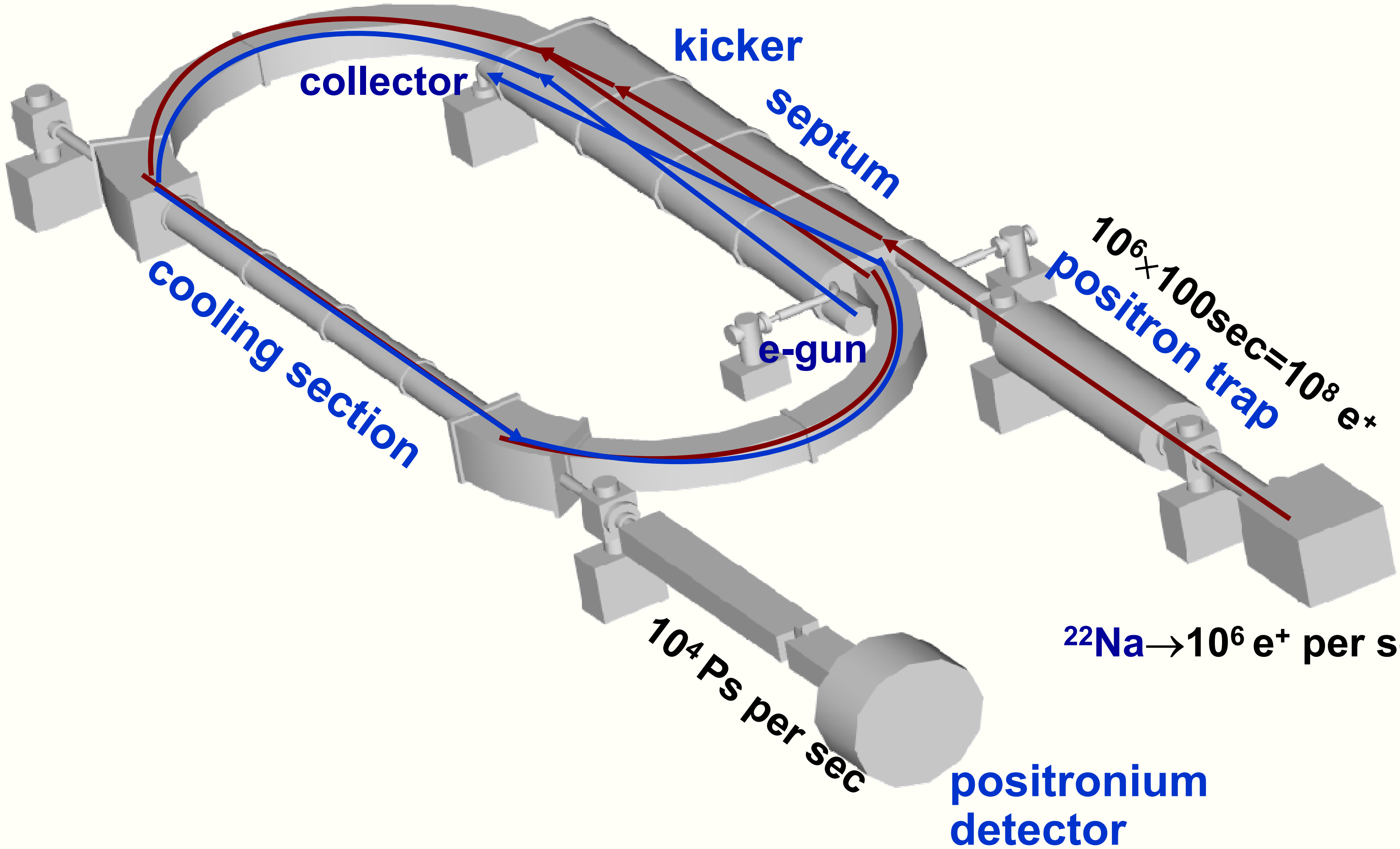
Goals of the LEPTA project

- Dynamics of coupling motion in the stellatron
- Electron cooling of positrons
- Positronium generation in flight
- Positronium physics
- Electron cooling with circulating electron beam
- Feasibility study of antihydrogen generation in flight

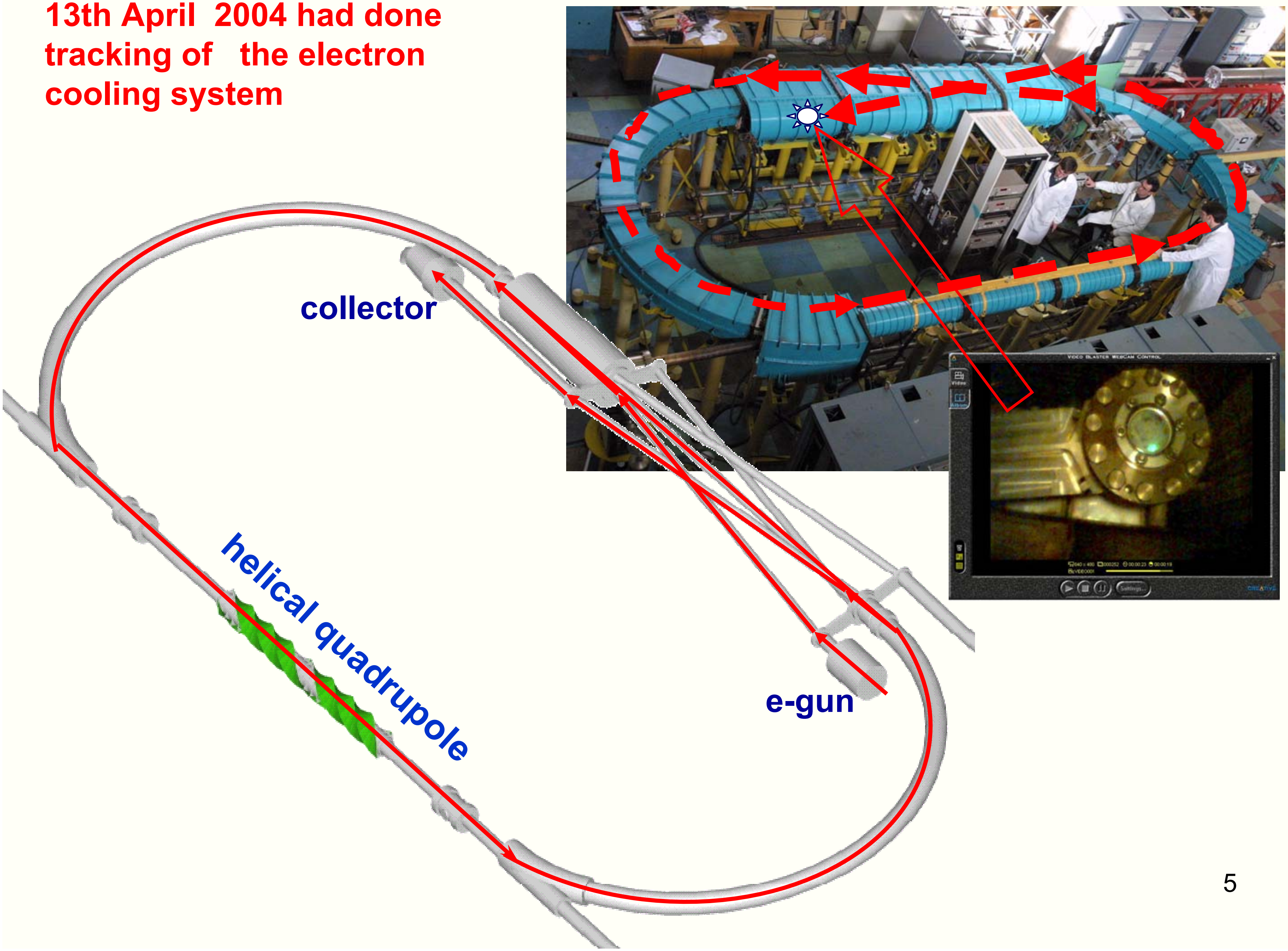
Design of the LEPTA



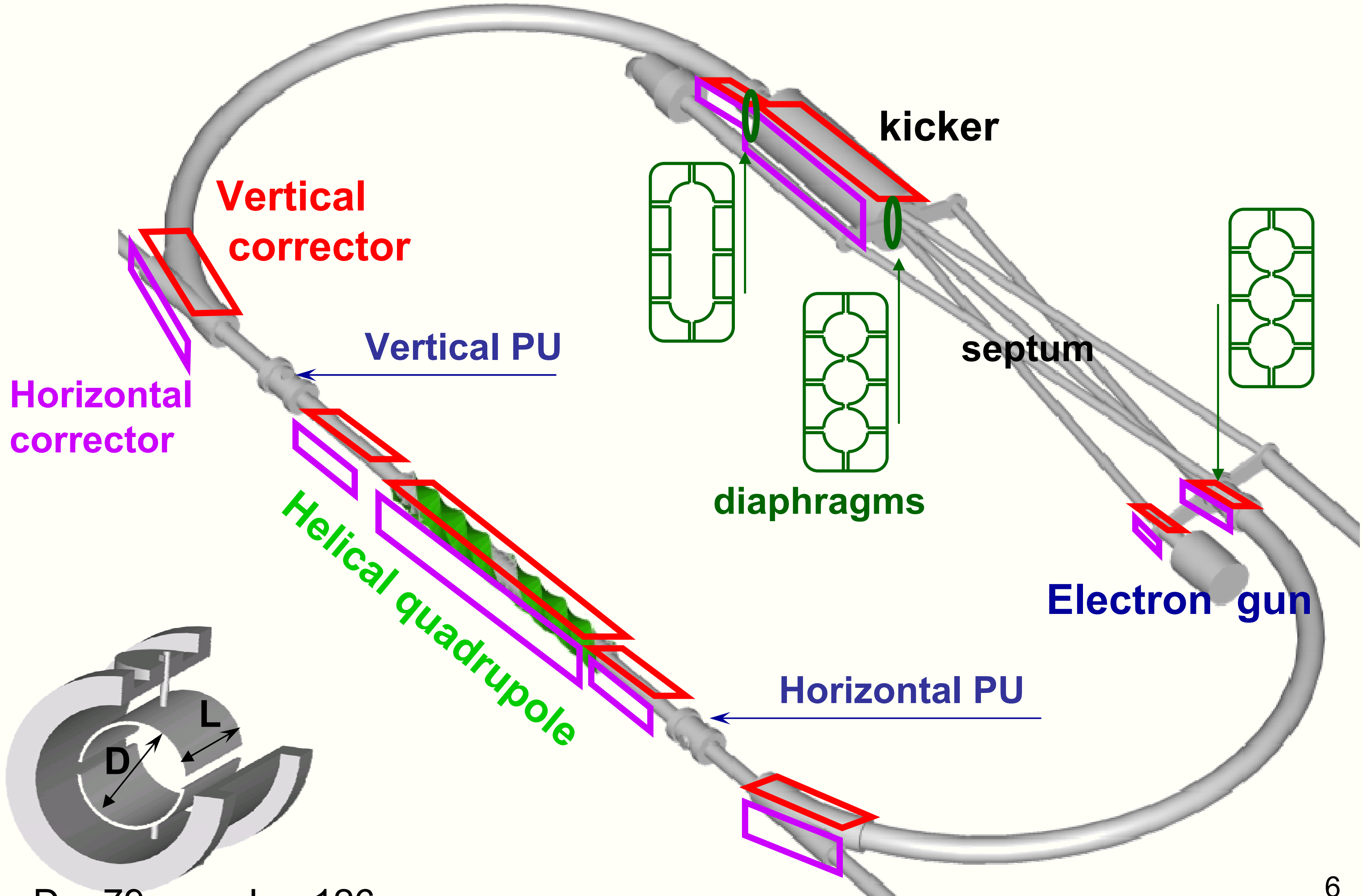
General parameters of the ring

Circumference , m	**17.2**
Particle energy, keV	**1 - 10**
Longitudinal magnetic field, G	**300 - 1000**
Radius of the toroidal solenoids, m	**1.45**
Helical quadrupole gradient, G/cm	**0 - 20**
Length of the helical quadrupole, m **and number of steps of the helix**	**1.6** **2**
Number of positrons in the ring	$1*10^{8}$
Residual gas pressure, Torr	$1*10^{-10}$
Design of positronium beam parameters	
Intensity, atom/s	$1\cdot10^{4}$
Angular spread, mrad	**1**
Velocity spread	$1\cdot10^{-4}$
Beam diameter at the exit of the ring, cm	**1.1**
Positronium decay length, m	**8.52**

13th April 2004 had done tracking of the electron cooling system



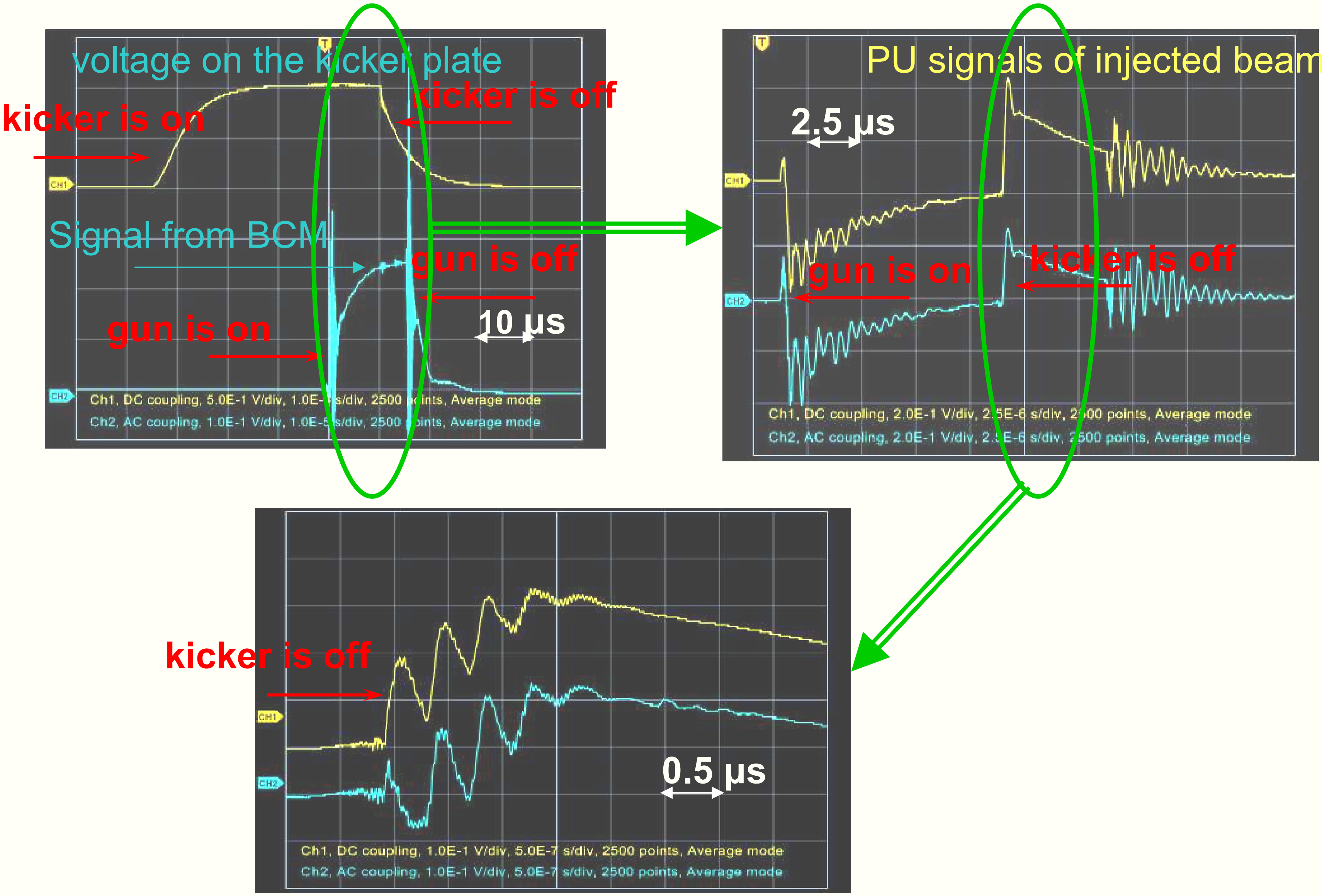
Beam diagnostic tools and correction coils disposition



D = 79 *mm*, L = 126 *mm*

Formation of closed orbit

in the case when the quadrupole is switched off



Helical quadrupole

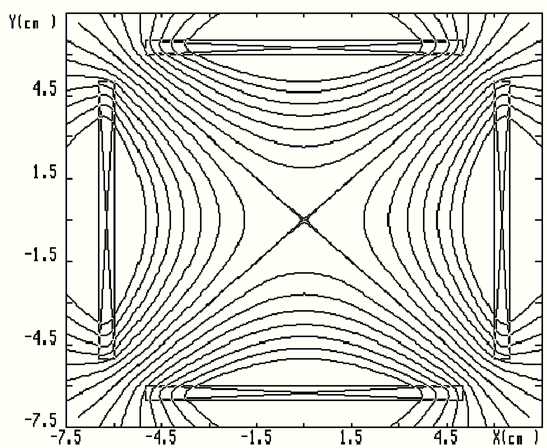
"stellarator windings"

Quadrupole Length L = 160 *cm*

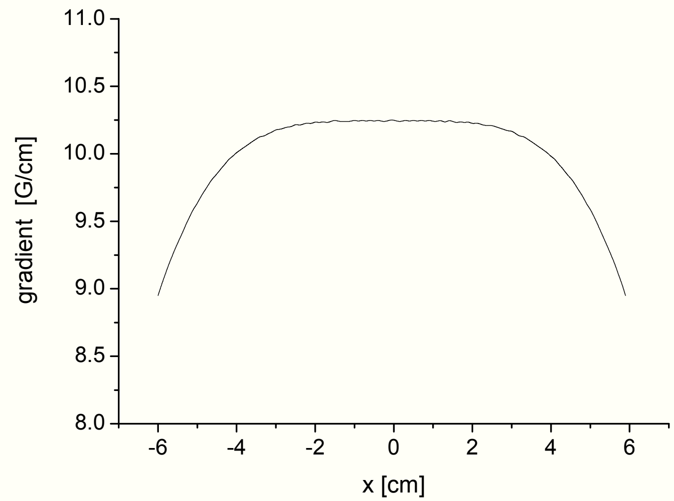
Helix step h = 80 *cm*

$$G = \frac{2\pi\ NI}{c \cdot d^2}$$

Cross section of the quadrupole is similar to Panofsky lens

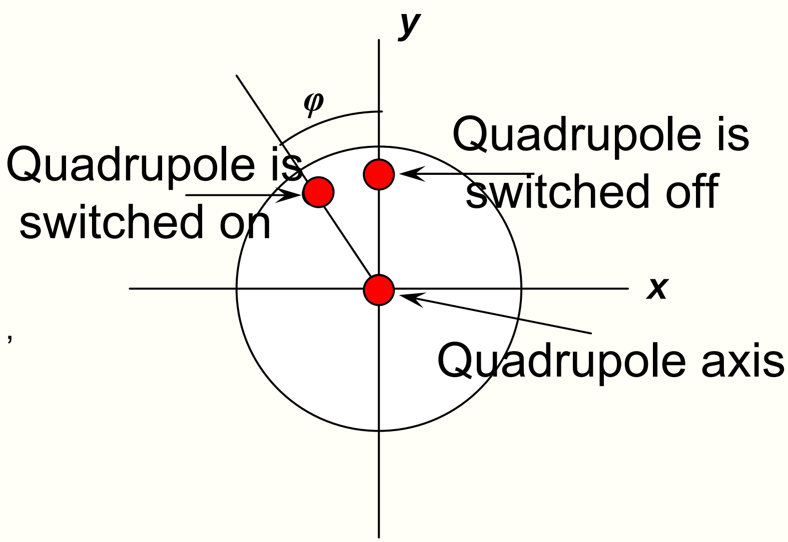


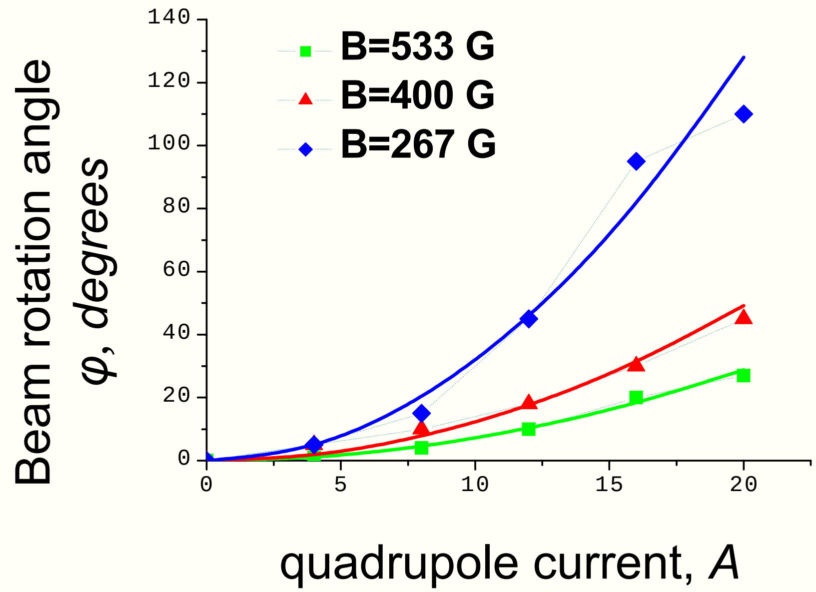
Uniform gradient magnetic field inside aperture



Test of the helical quadrupole

results at different magnetic fields





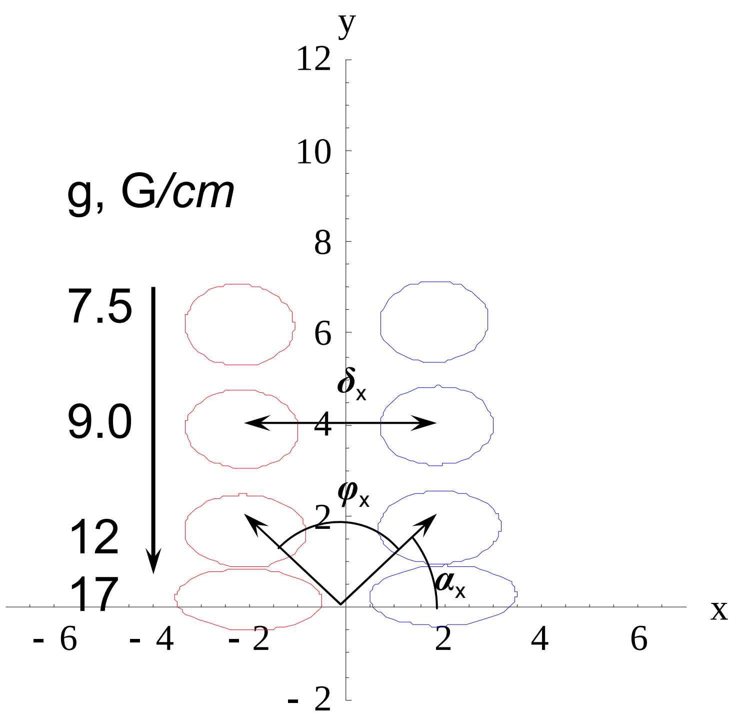
$$\varphi \approx Q_0 L$$

$$Q_0 \equiv \frac{G^2}{2kB_0^2}$$

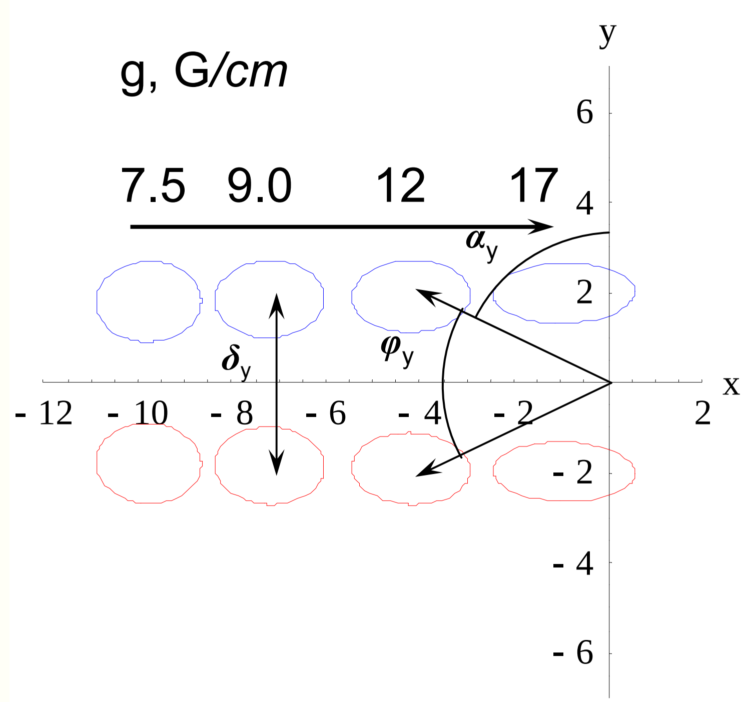
G – magnetic field gradient

k=2π/h *h – helix step*

one peculiarity
of the closed orbit formation in the focusing system with longitudinal magnetic field and helical quadrupole



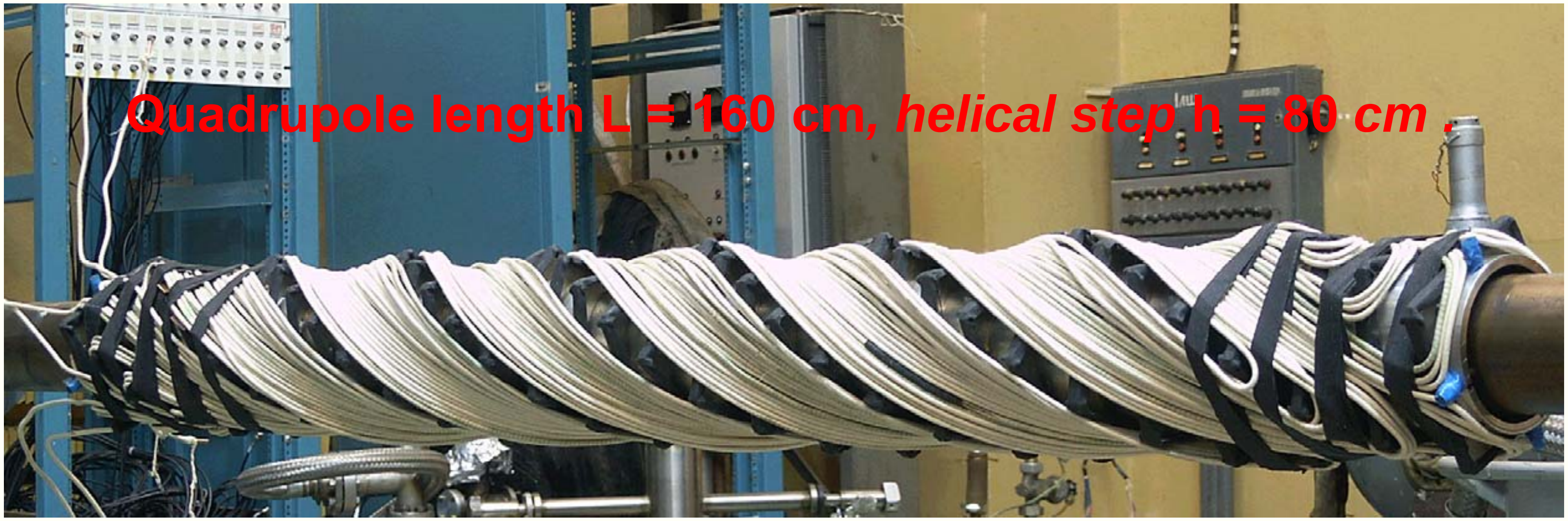
horizontal corrector → vertical displacement



vertical corrector → horizontal displacement

simulation results in drift approximation

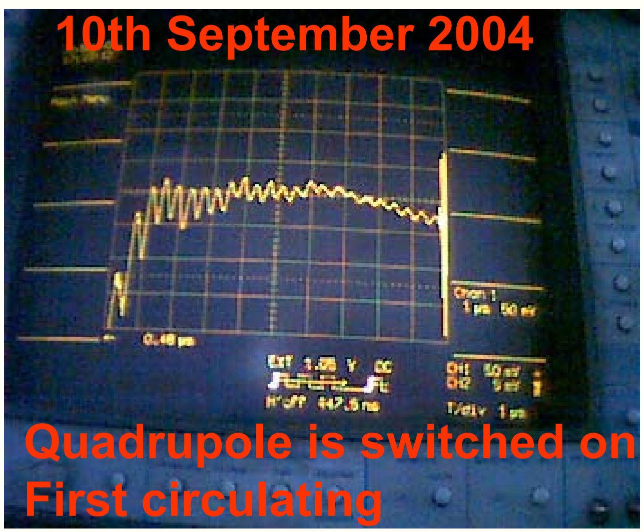
Quadrupole was upgraded



The design angle rotation was not suffusion for optimum machine setting.

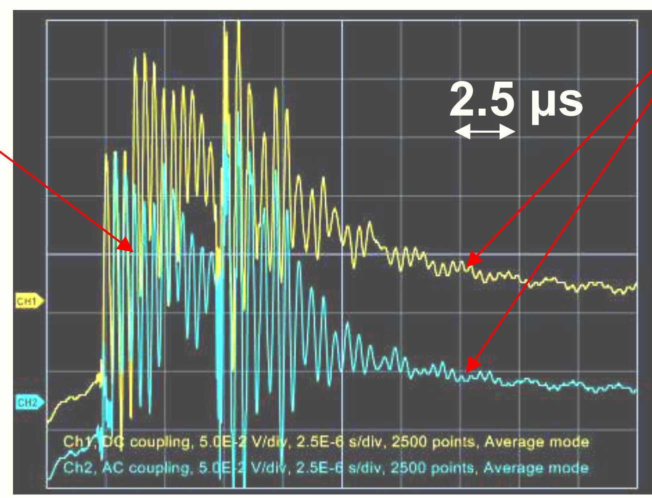
$$\varphi_{simulated} \leq 30^0$$

$$30^0 \leq \varphi_{experimental} < 180^0$$

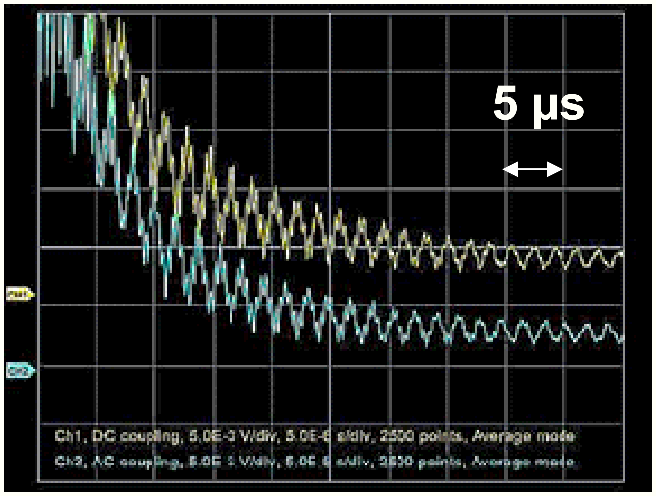


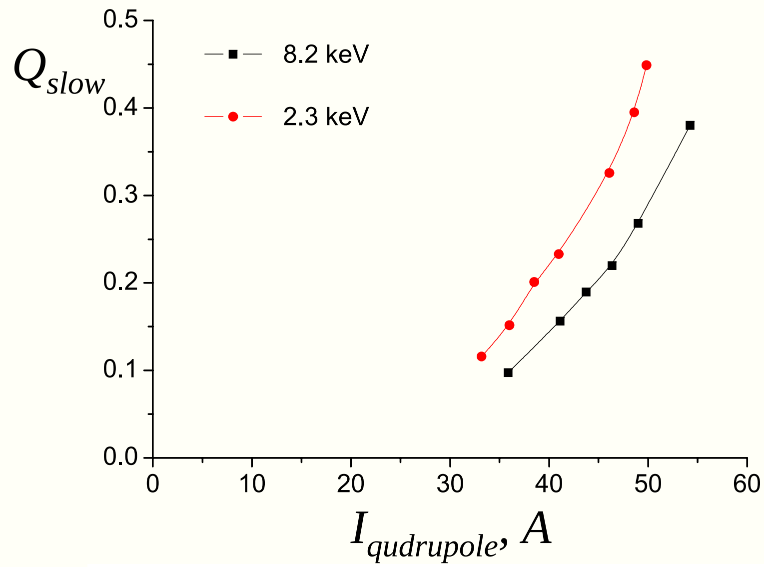
revolution frequency

slow mode frequency



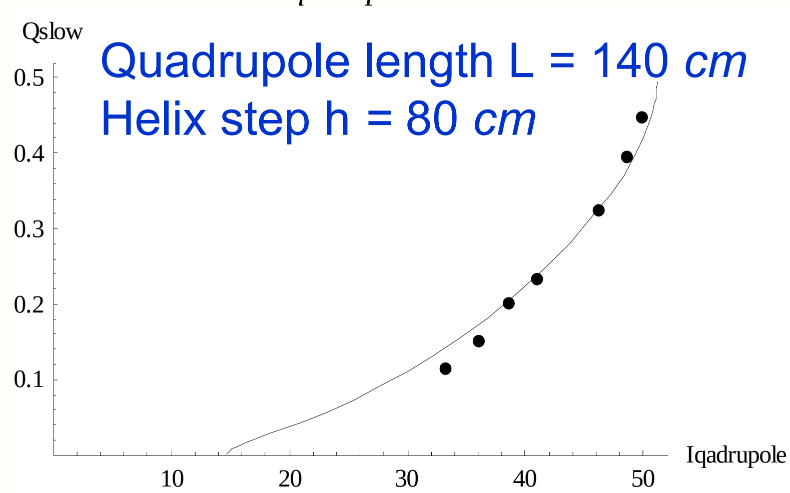
Betatrone tune of the slow mode



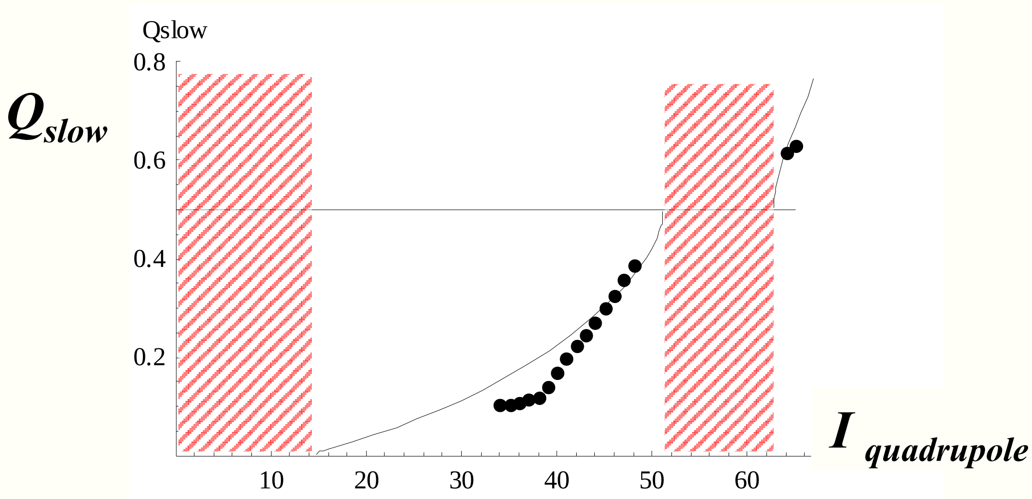


Fourier analysis

$$Q_{slow} = \frac{f_{slow}}{f_{revolution}}$$

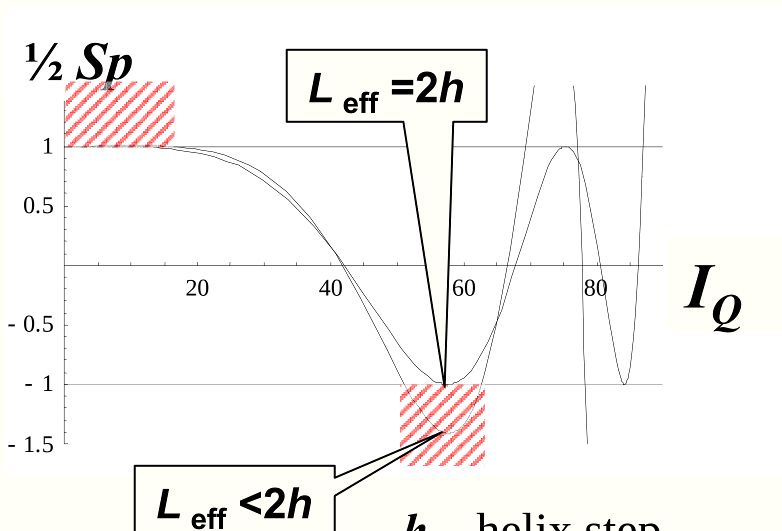


Betatrone tune was measured with excitation of the slow mode resonance using of the external sin signal applied to PU

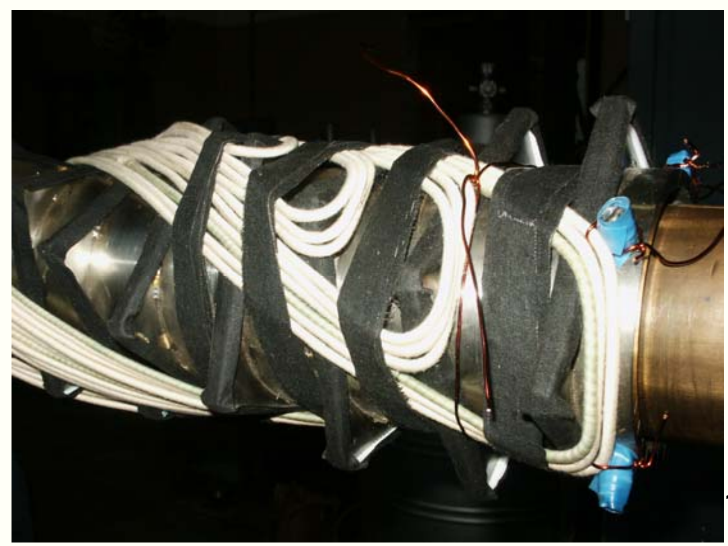


$$Q_{slow} = \arccos\left(\frac{1}{2}Sp\right)\frac{1}{2\pi}$$

adiabatic entrance and exit change of the effective length of the quad

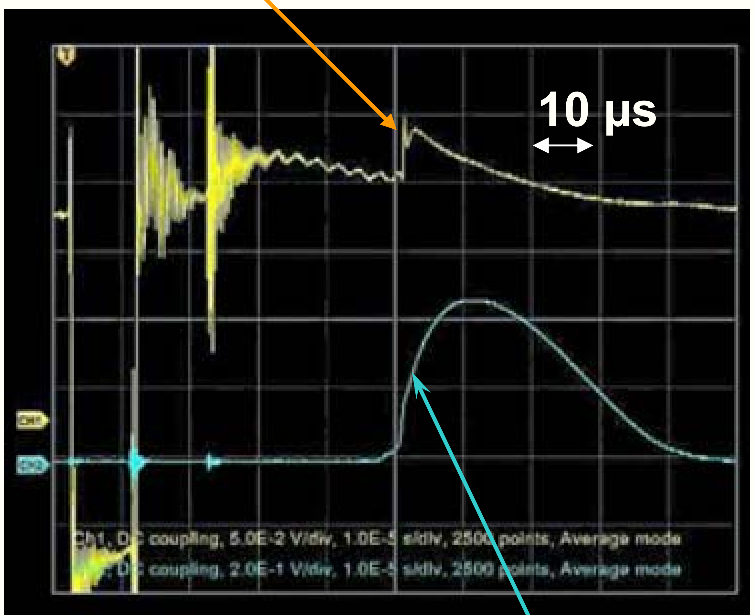


h – helix step

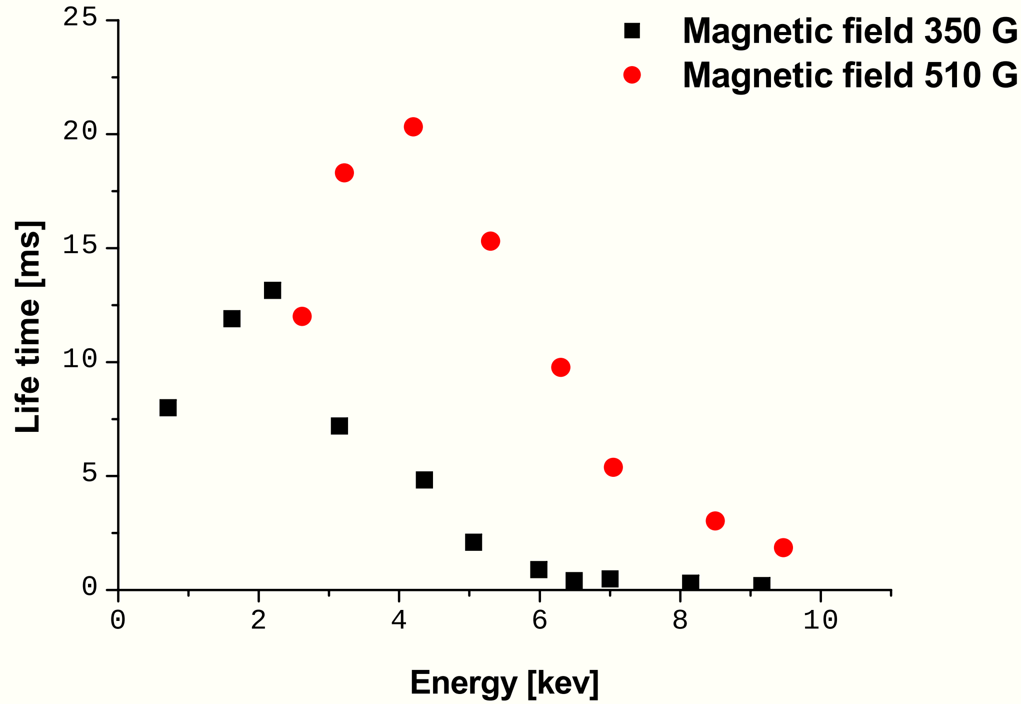


Beam life time

signal from PU



“Killer” pulse was
applied to the kicker plate



Lifetime vs Energy
Experimental results and theoretical fitting

Vacuum lifetime

$$\tau_{vacuum} = \frac{K}{P} \cdot \sqrt{\frac{\varepsilon}{mc^2}} \cdot \left(\frac{eBb}{mc^2}\right)^2$$

$K \approx 4000$ – numerical coefficient

ε - electron energy, c – the speed of light

P – residual gas pressure, nTorr, b – aperture

$$\tau_{total} = \left(\frac{1}{\tau_{vacuum}} + \frac{1}{\tau_B}\right)^{-1}$$

Magnetic field lifetime

$$\tau_B = \frac{1}{N_D} \cdot \frac{C}{c} \cdot \left(\frac{b}{a}\right)^2 \cdot \left(\frac{mc^2}{eBD}\right)^2 \cdot \sqrt{\frac{2\varepsilon}{mc^2}} \cdot \left(\frac{\Delta B}{B}\right)^{-2} \cdot \exp\left\{\frac{2eBD}{mc^2} \cdot \sqrt{\frac{mc^2}{\varepsilon}}\right\}$$

N_D – number of regions with perturbed magnetic field

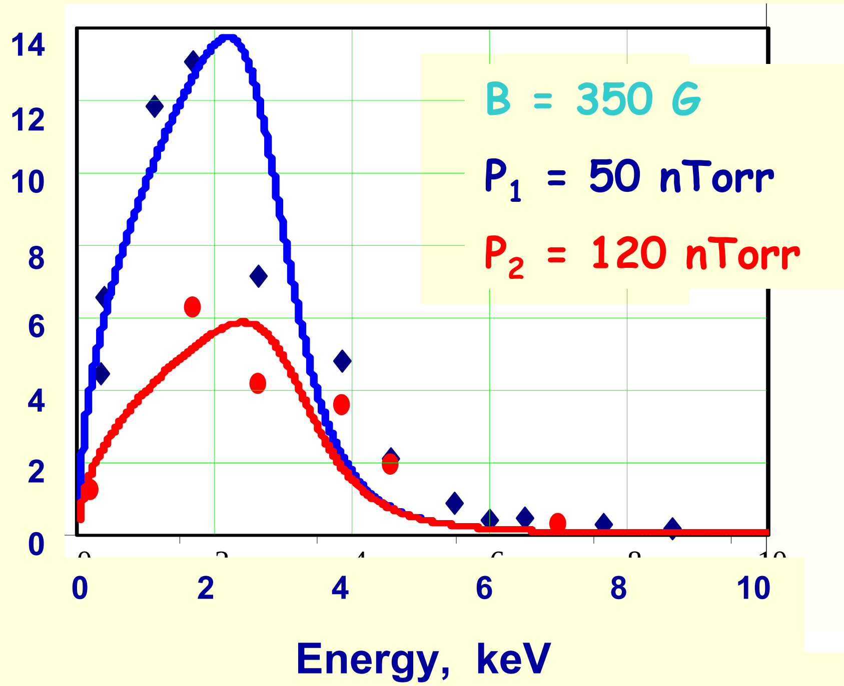
C – ring circumference, a – beam radius

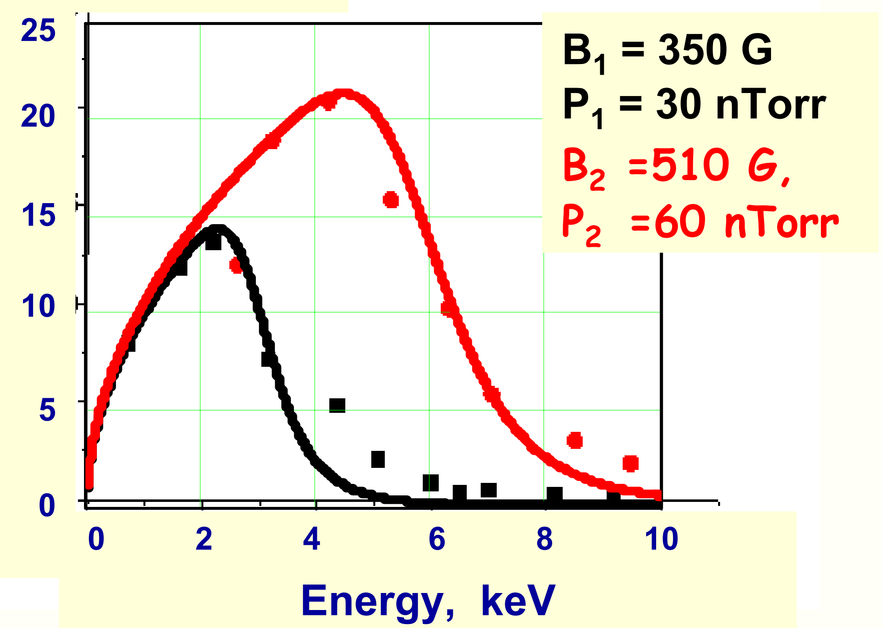
B – magnetic field, D – the length of the region with perturbed magnetic field

$\Delta B/B$ – the amplitude of the magnetic field perturbation

Experimental results and theoretical fitting

Lifetime vs Energy



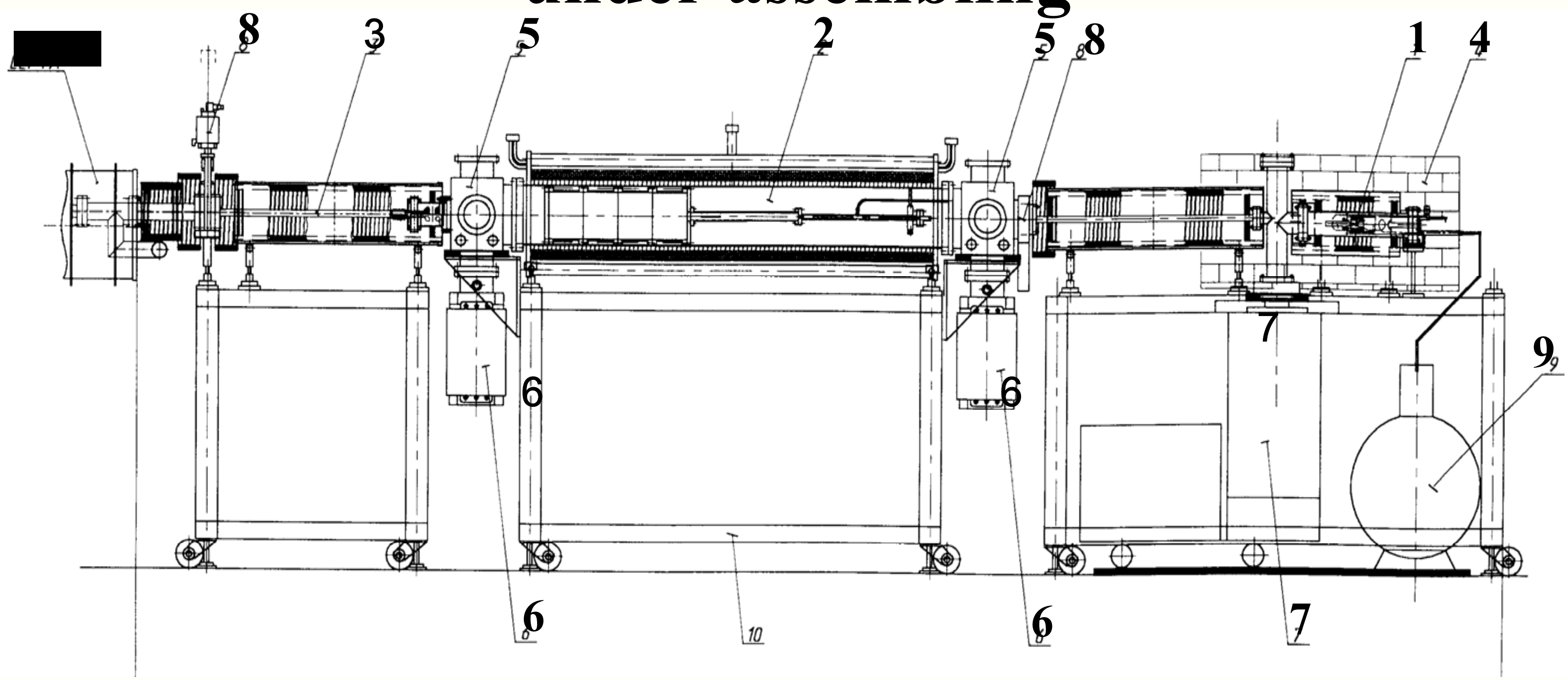


ΔB/B~20%

results of the LEPTA ring test with electron beam

Longitudinal magnetic field, *G*	**300 – 510**
Energy of the circulating beam, *keV*	**1- 10**
Current of the quadrupole, *A*	**32 – 57**
«Slow» betatron tune	**0.1 – 0.43**
Injection current, *mA*	**10**
Efficiency of injection	**0.5**
Number of circulating particles	**$3*10^{10}$**
Life time at 4 *keV, ms*	**22**
Residual gas pressure of, *Torr*	**$7*10^{-8}$**

The positron injector is under assembling

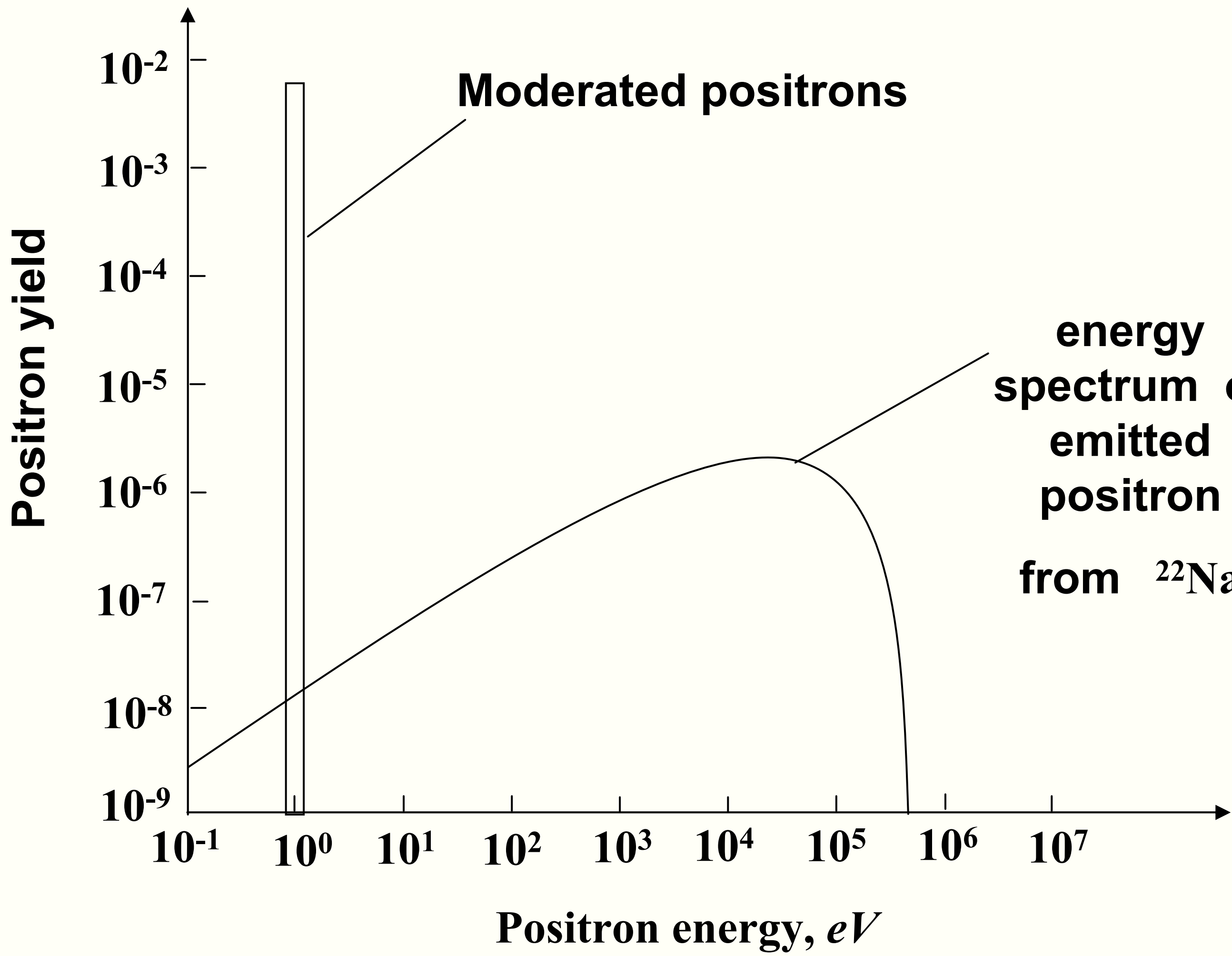


1-positron source ^{22}Na, 2-positron trap, 3-transport section to the ring, 4-radioactive protection shield, 5-vacuum chamber for pumping and diagnostics, 6-ion pump, 7-turbo molecular pump, 8-valve, 9-liquid helium

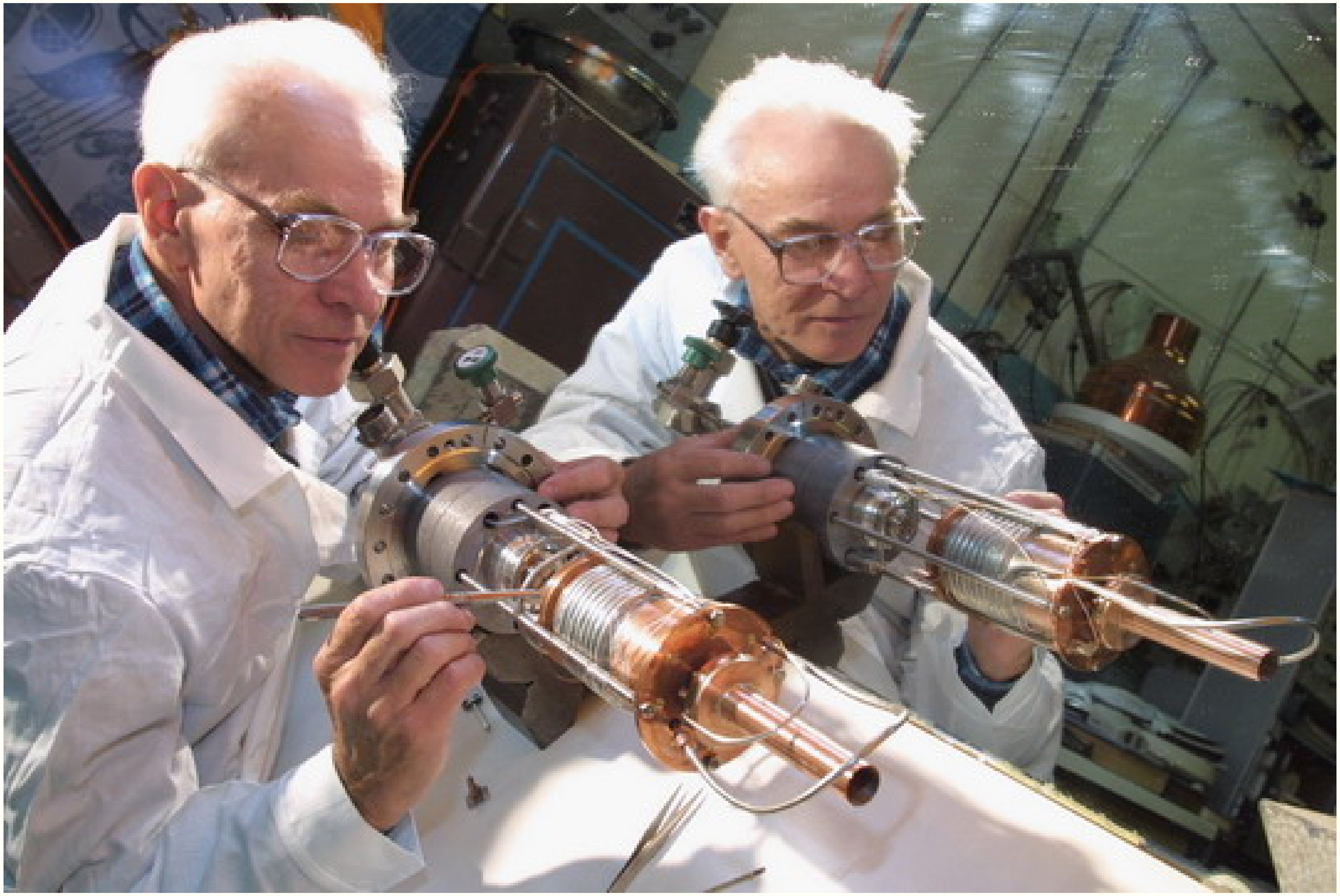
Design parameters of the positron injector

Length, *m*	6,2
Positron injection energy, *keV*	**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	$1 \cdot 10^{8}$
Momentum spread	$1 \cdot 10^{-4}$

Positron energy spectrum



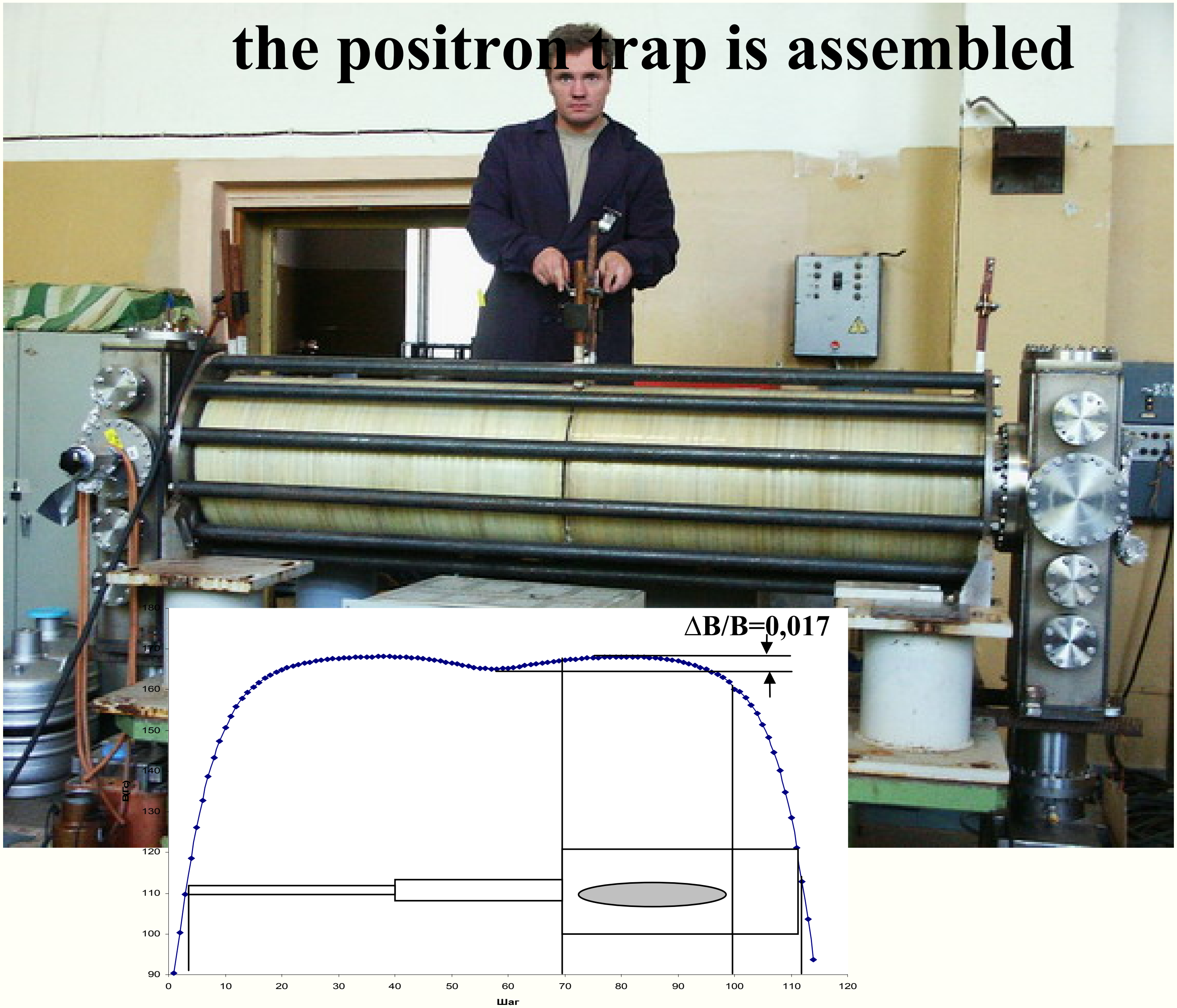
Positron source



Cryogenic test T = 6.9 K, moderator – frozen Ne

Assembling of the positron trap

Solenoid and vacuum chamber of the positron trap is assembled



Nearest plans

1 Improvement of magnetic field quality in LEPTA ring.

2 Test and tuning of electron cooling system with continuous beam.

3 Test of positron trap with electrons

4 Assembling of positron injector

5 Electron cooling of positrons and positromium generation

LEPTA team is very grateful to our colleagues who supported the project efficiently:

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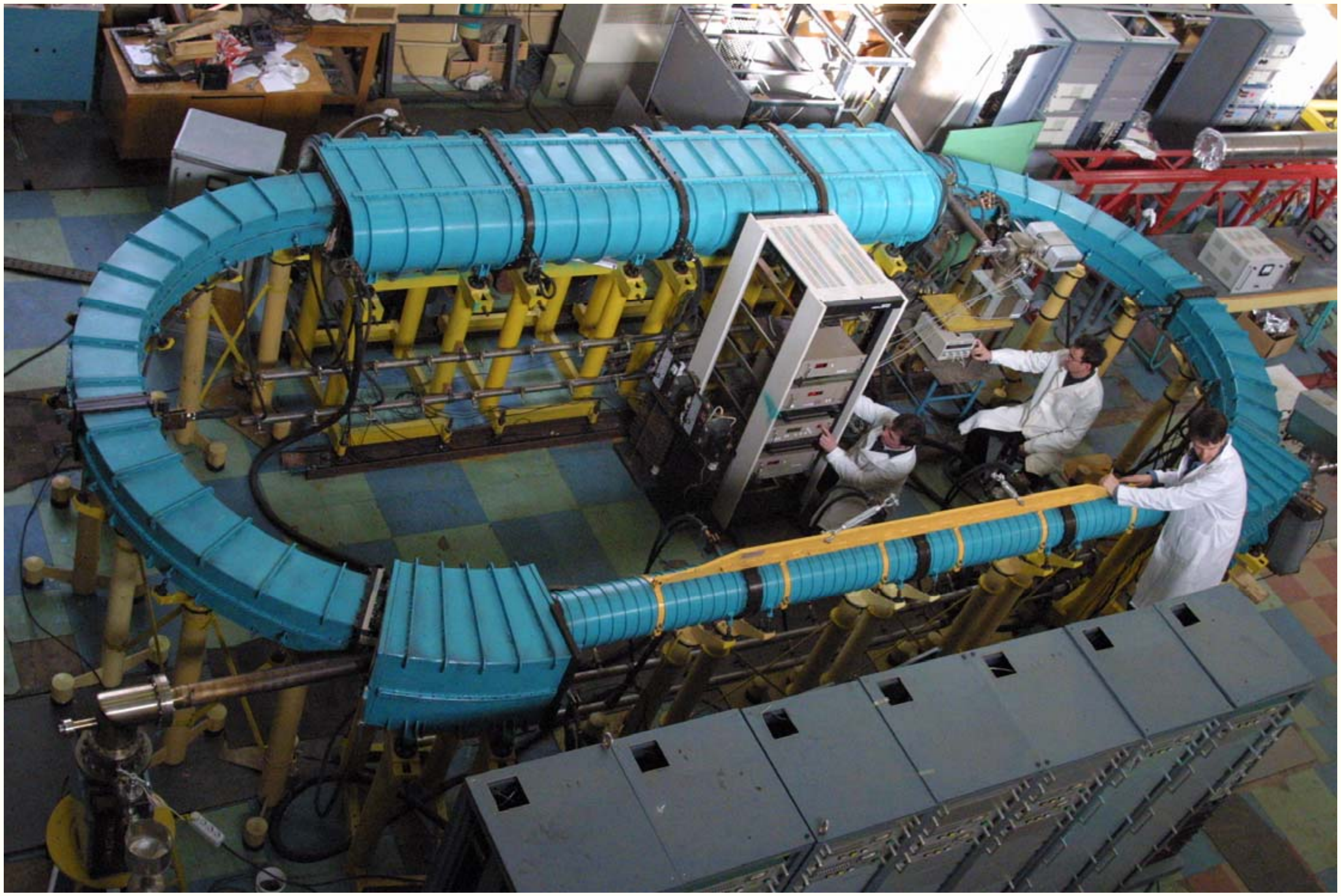
Rudolf Maier, Walter Oelert, Jurgen Dietrich, Hans Stockhorst, FZJ
Ilan Ben-Zvi, BNL
Takeshi Katayama, RIKEN
Akira Noda, Kyoto University

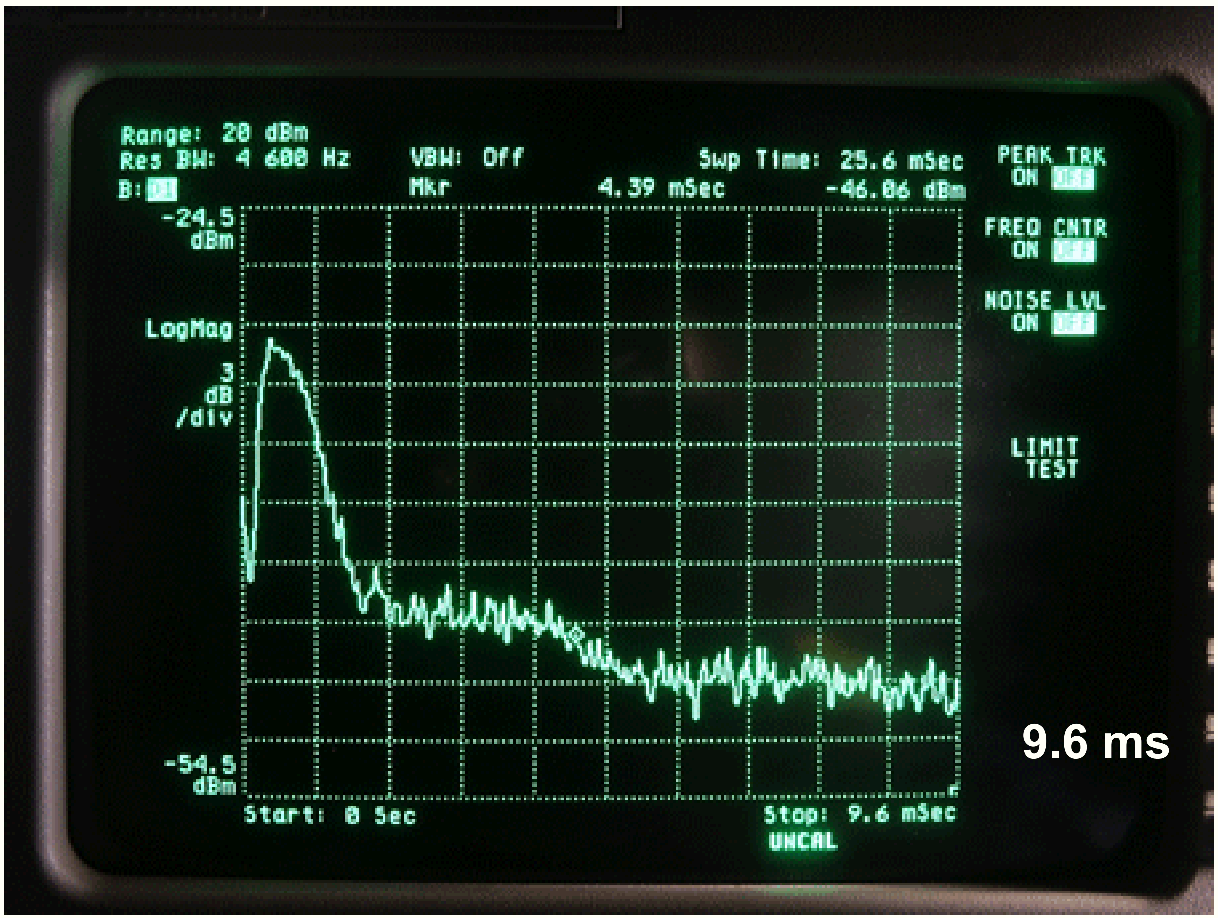
Thank you for your attention !

Assembling of the LEPTA ring is completed



Spectrum measurement

Beam energy 2.2 keV
Injection current 5 mA
Revolution frequency
corresponding to injection energy 1.58 MHz



Fourier amplitude of the signal from differential PU

$f = f_{revolution} - f_{slow}$

Self excitation frequency is 1.35 MHz

Beam excitation with external sinusoidal signal

(beam transfer function measurement)

Beam energy	**2.2 keV**
Injection current	**5 mA**
Revolution frequency corresponding to injection energy	**1.58 MHz**