DEVELOPMENT OF LONGITUDINAL BEAM PROFILE DIAGNOSTICS FOR BEAM-BEAM EFFECTS STUDY AT VEPP-2000

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Introduction

The VEPP-2000 is a collider complex which mean parts are electron-positron booster BEP and collider VEPP-2000 with two detectors CMD-3 and SND [1]. After modernization BEP energy range began to be from 200 MeV to 1 GeV. It and BEP parameters are described in [2]. The experiments at the collider VEPP-2000 has become possible in this energy range without acceleration.

To achieve luminosity project value 10^{32} $cm^{-1}s^{-1}$ the comprehensive beam monitoring system is required. There was no longitudinal beam distribution monitoring system.
Its observation gave more full understanding of colliding beams nature.

VEPP-2000 collider complex

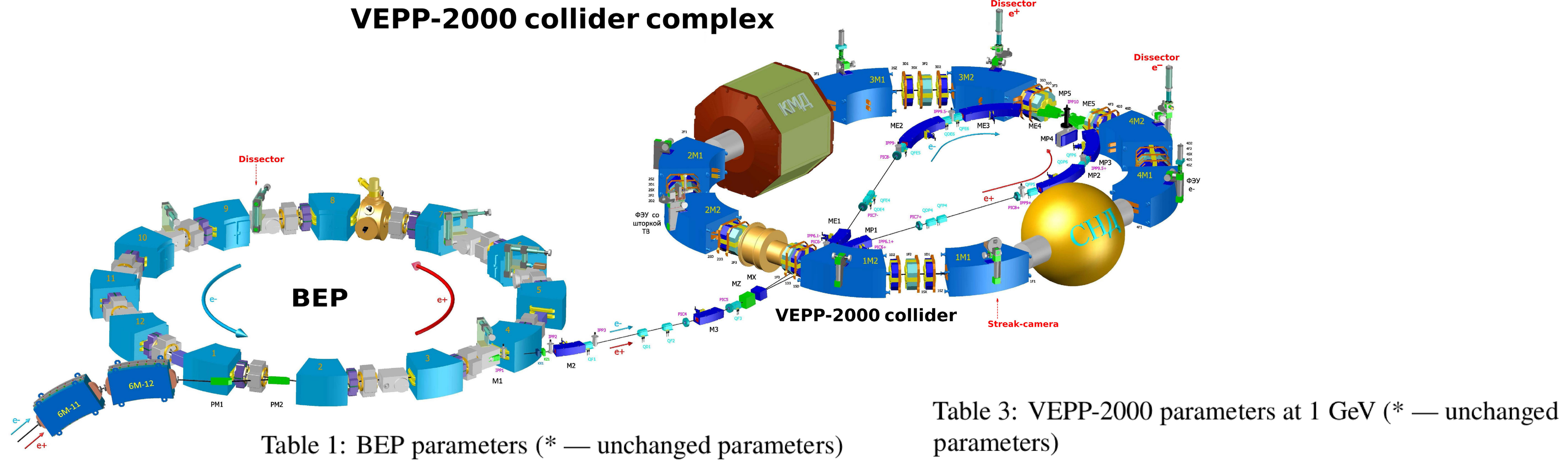


Table 1: BEP parameters (* — unchanged parameters)

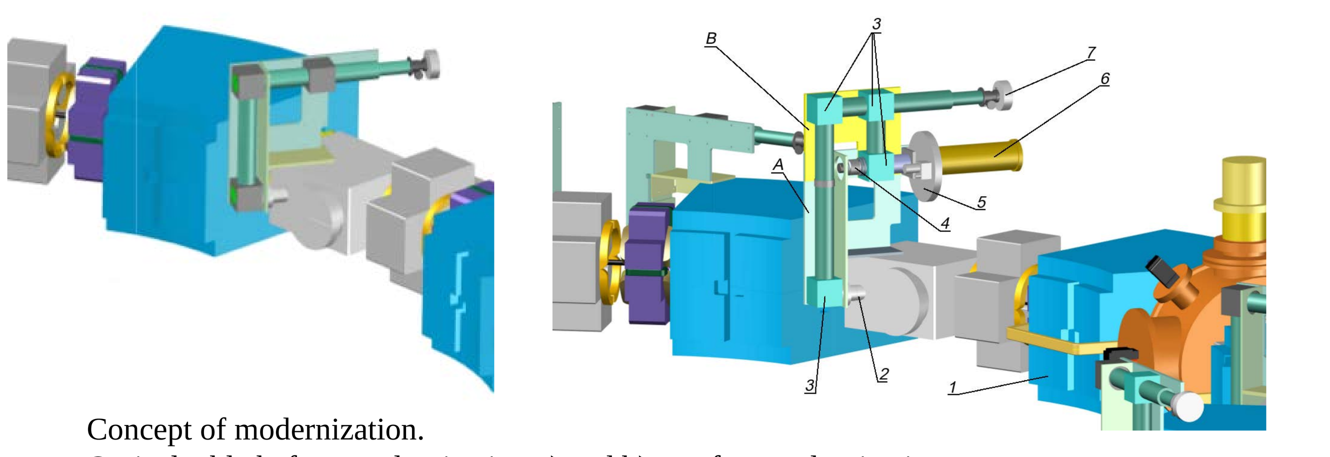
Parameter	Symbol	Value
Circumference	Π	2235 cm
Revolution frequency	f_0	13.4145 MHz
Momentum compaction factor	α_p	0.0576
Energy spread	$\frac{\sigma_E}{E}$	$7.3 \cdot 10^{-4}$
Energy lose per turnover	W	69 keV
Harmonic of cavity	h	13
Bending radius	r_0	128 cm
Maximum cavity voltage	U_{max}	110 kV
Synchrotron frequency (normalized at f_0)	ν_s	0.0032

Table 3: VEPP-2000 parameters at 1 GeV (* — unchanged parameters)

Parameter	Symbol	Value
Circumference	Π	2439 cm
Revolution frequency	f_0	12.2925 MHz
Momentum compaction factor	α_p	0.0359
Energy spread	$\frac{\sigma_E}{E}$	$7.1 \cdot 10^{-4}$
Energy lose per turnover	W	63.2 keV
Harmonic of cavity	h	14
Bending radius	r_0	140 cm
Maximum cavity voltage	U_{max}	100 kV
Synchrotron frequency (normalized at f_0)	ν_s	0.0025

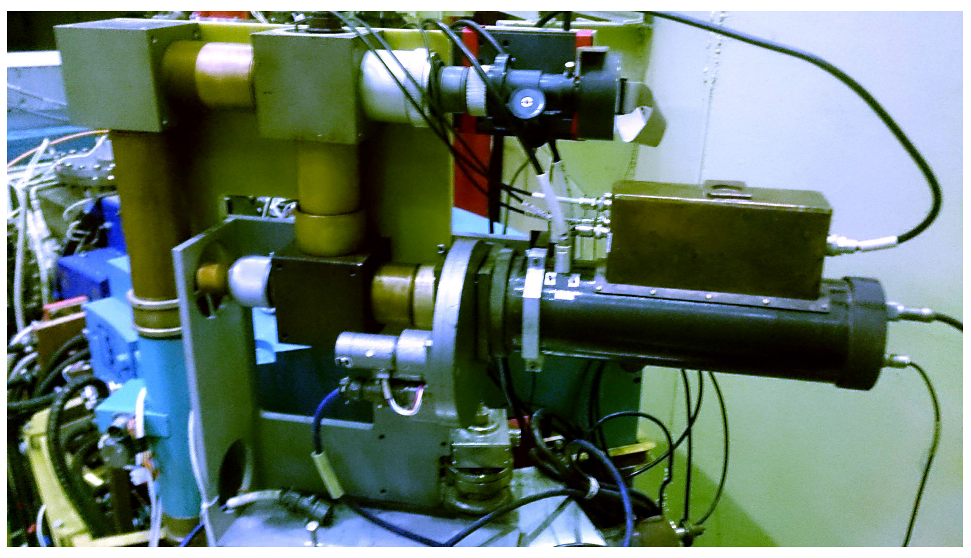
Optical path modernization at the BEP

The task of modernization conclude in to save current beam transverse position monitor (CCD-camera) functional. For realization it and duplicating light of synchrotron radiation semitransparent mirror was setted in optical table tract. Yellow part of table and mirrors at the figure is added in the modernization.



Concept of modernization.
Optical table before modernization a) and b) — after modernization.
1— bending magnet, 2— sync. rad. output, 3— cubes with moving mirrors,
4— calibration light source, 5— light filters, 6— dissector, 7— CCD-camera.

After preliminary alignment the optical table with both devices was installed to BEP synchrotron radiation output and the final tuning was completed with very low intensity beam (around 100 mkA) in the BEP.



Beam length

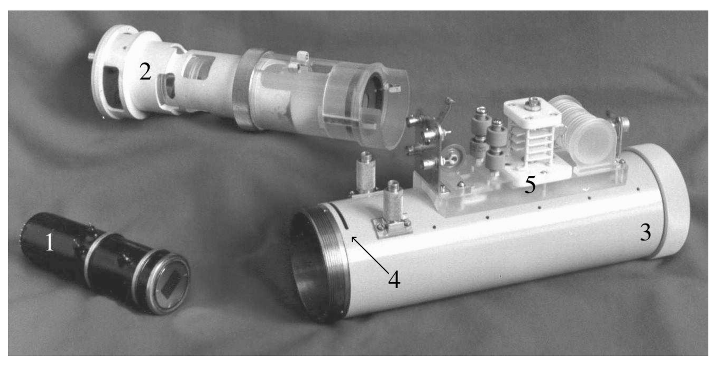
For dissector testing the model of potential well distortion has been selected. The nature of this process is in process of introduction between bunches and accelerator vacuum chamber and all its components (RF-cavity, bellows and other). In this model it was considered that energy spread change insignificantly versus beam intensity.
Distribution of bunch charge is Gaussian for electron-positron accelerators. The bunch length is dispersion of this distribution and is defined in [6] by following formula:

$$\left(\frac{\sigma}{\sigma_0}\right)^3+\left(\frac{\sigma}{\sigma_0}\right) = -A\cdot Im\left(\frac{Z}{n}\right)_{\text{eff}},\quad A=\frac{(2\pi R)^3 I_b}{3h\sigma_0^3 U_0 cos\phi_s}$$

where U_0 - amplitude of RF-cavity voltage, φ_s - stationary phase of particle motion in RF-cavity, σ_0 is bunch length ot "null" bunch intensity, h – harmonic of revolution frequency which is frequency of RF-cavity processing, R – average accelerator radius, I_b – bunch intensity. $Im\left(\frac{Z}{n}\right)_{\text{eff}}$ - is the imaginary part of total impedance of accelerator vacuum tube.

DISSECTOR

Dissector is a optical stroboscopic device. One of the way of applying it is registration longitudinal distribution of beam charge in a circular accelerators where the beam motion is strictly periodical. The synchrotron radiation light
from beam is focused and pointed at the dissector photo-cathode by optical table systems of mirrors and lenses.
For dissector installed at the BEP resolution is 26 ps (or 0.8 cm in spacial dimension).



Dissector device components:
1 - dissector LI-602,
2 - adapter of dissector,
3 - shielding shell,
4 - slit for alignment final short-focus lens,
5 - oscillatory RF-circuit.

Dissector layout

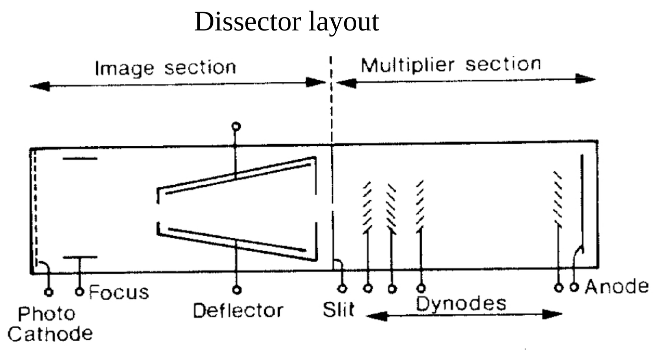
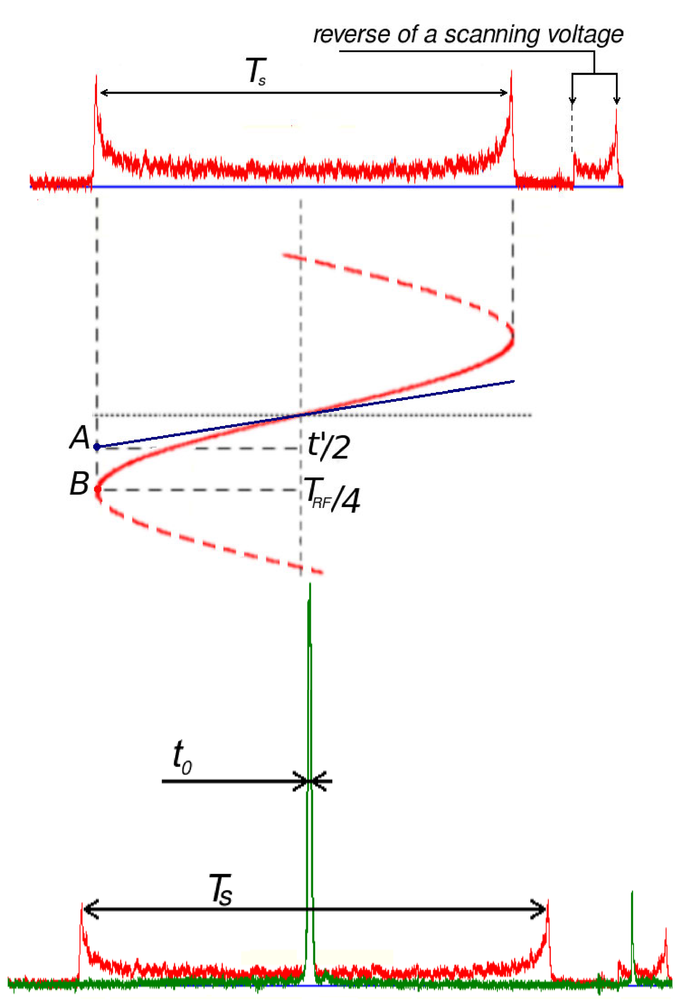


Table 2: LI-602 parameters)

Parameter	Value
Voltage slit — photo-cathode	10 kV
Voltage slit — focusing electrode	10 ± 1 kV
Max. voltage at deflection plates	2.5 kV
Max. spectrum sensitivity	440 – 470 nm
Multiplier voltage	−1.5 — −2.0 kV
Slit width	50 mkm

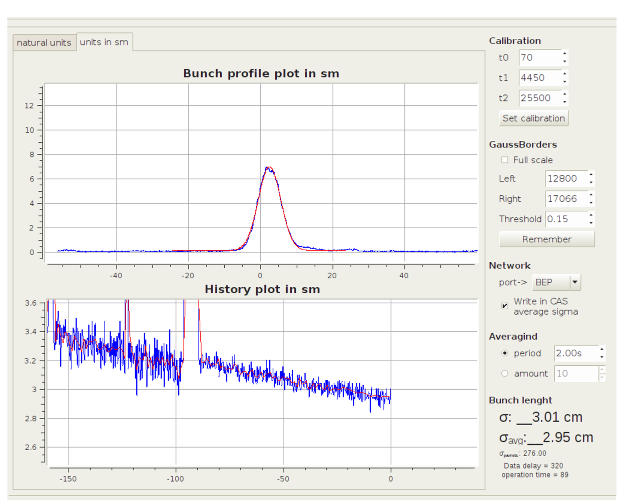
Photo-electrons beam can be deflected by electrostatic fields between pare of deflection plates. Sum of two voltages are applied to the plates. One of them is sinusoidal **RF sweep** voltage and other is scan voltage. RF sweep voltage forms photo-electron image which duplicates temporal distribution of synchrotron radiation light pulse created by circulated beam in accelerator. **Scan** voltage slowly shifts the image across the slit consistently cutting different narrow part of image from turn to turn of beam.



Calibration of dissector is implemented by calibration source of permanent light. Scaling factor and estimation of resolution can be found.

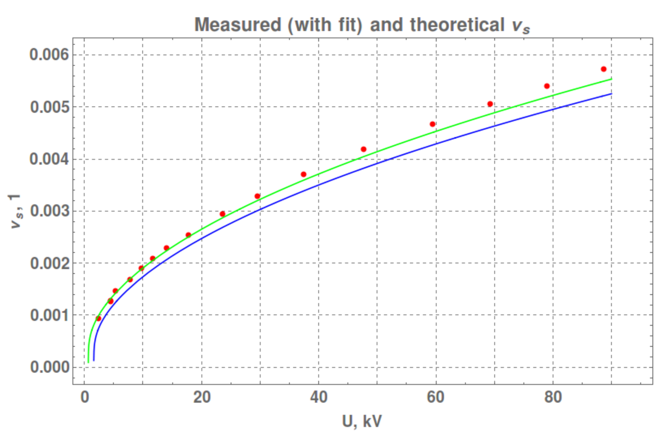
Final formula of input pulse duration is:

$$\Delta l = \frac{D}{q}\frac{\sqrt{t^2-t_0^2}}{T_s}$$

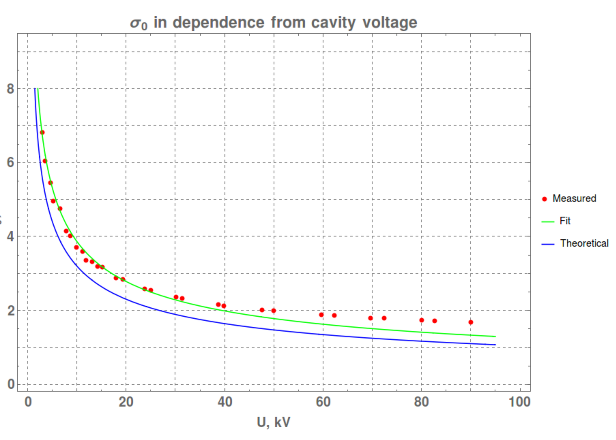


Results

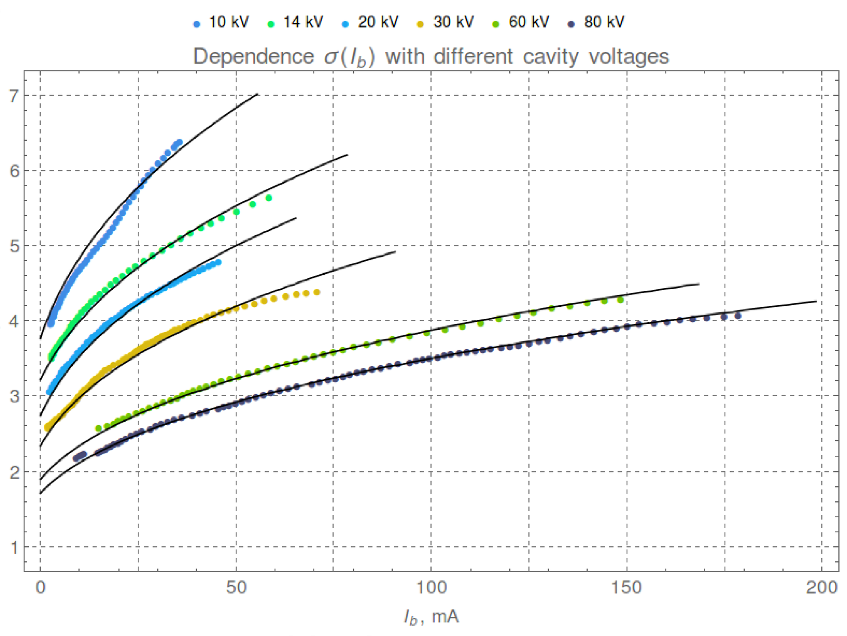
- Measurements at the BEP with using dissector



Normalized synchrotron frequency with low intensity of bunch versus RF-cavity voltage.

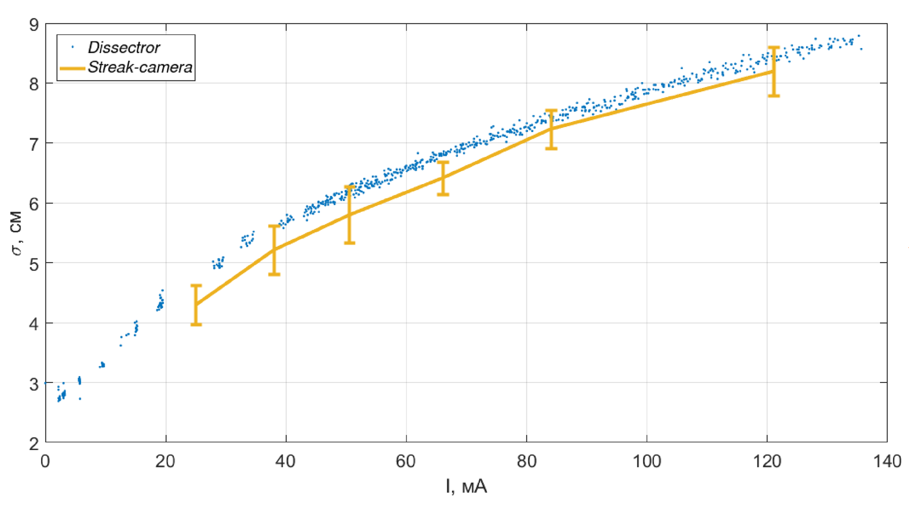


bunch length at "null" intensity (< 100 mkA) versus RF-cavity voltage



Bunch length versus its intensity with different values of RF-cavity voltage

- Measurements at the VEPP-2000 with using streak-camera and dissector



Streak-camera is useful for observing of dynamical processes through making single-turn snapshot of bunch charge profile in plane ZS (longitudinal and vertical coordinates). The distributions of charge can be obtained by snapshot post-processing.

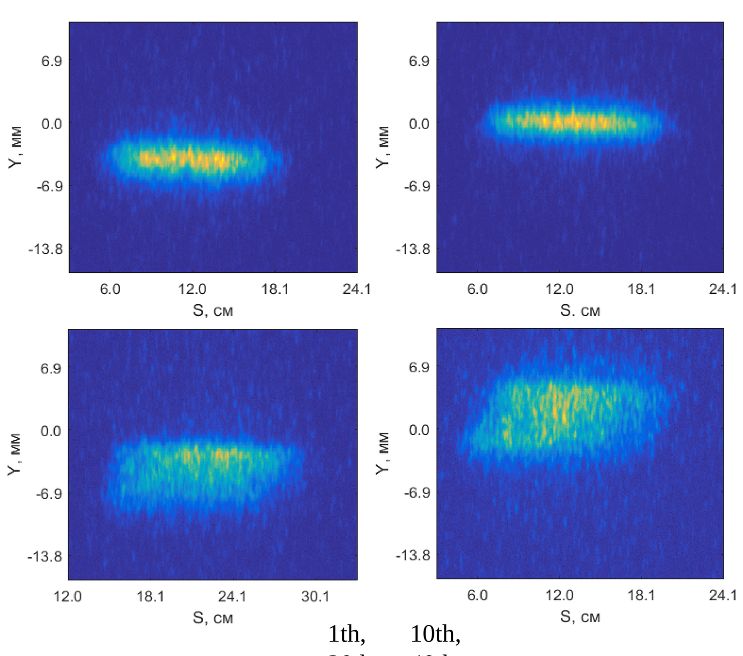
Bunch length versus its intensity has been measured by dissector and streak-camera in conjunction. Good agreement takes place.

The number of measurements was made for the observation of the injection processes for the single bunch and for colliding bunches over subsequent 20-80 turns. Unexpected results have been obtained at snapshots with different combination of conditions. The snapshots of electron bunch have been made at different turn after injection from the BEP and different intensities of electron and positron bunches (Ie⁻ and Ie⁺).

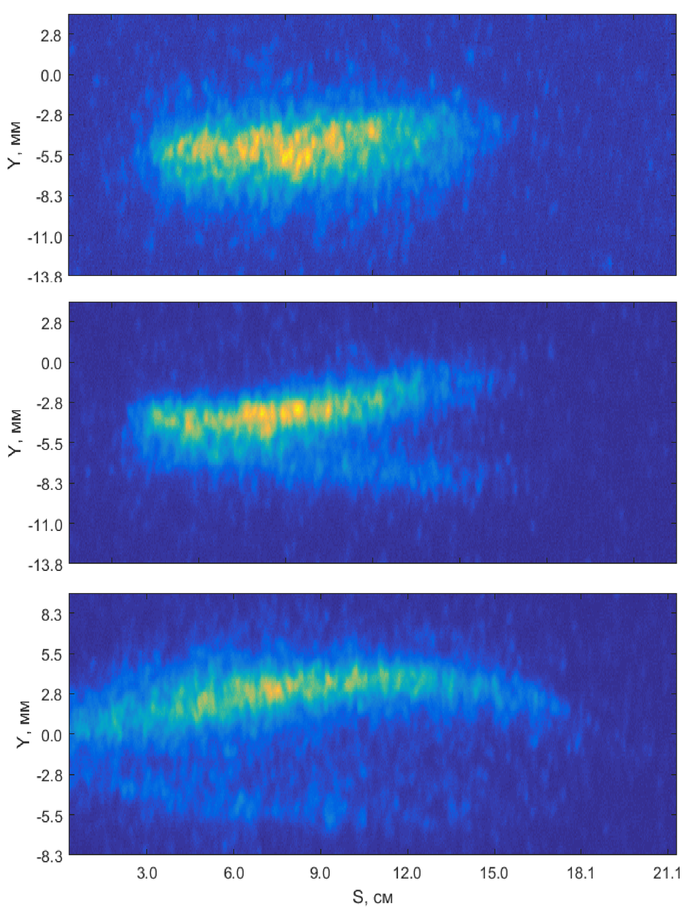
(left series of figure) Single electron bunch

(middle series of figure) Injection of the electrons when the positron bunch circulated

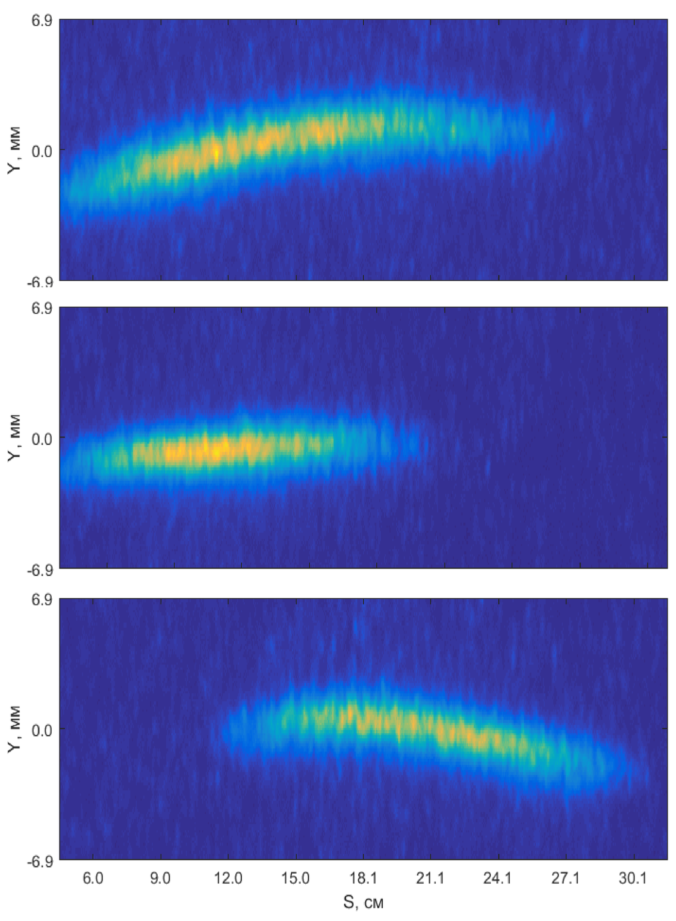
(right series of figure) Injection of the positrons when the electron bunch has circulated



1th, 10th, 20th, 40th, turns
I = 40 mA



20th turn, Ie⁻ = 30 mA, Ie⁺ = 70 mA,
40th turn, Ie⁻ = 30 mA, Ie⁺ = 66 mA,
60th turn, Ie⁻ = 30 mA, Ie⁺ = 64 mA.



40th turn, Ie⁻ = 66 mA, Ie⁺ = 45 mA,
60th turn, Ie⁻ = 44 mA, Ie⁺ = 40 mA,
80th turn, Ie⁻ = 50 mA, Ie⁺ = 40 mA.