

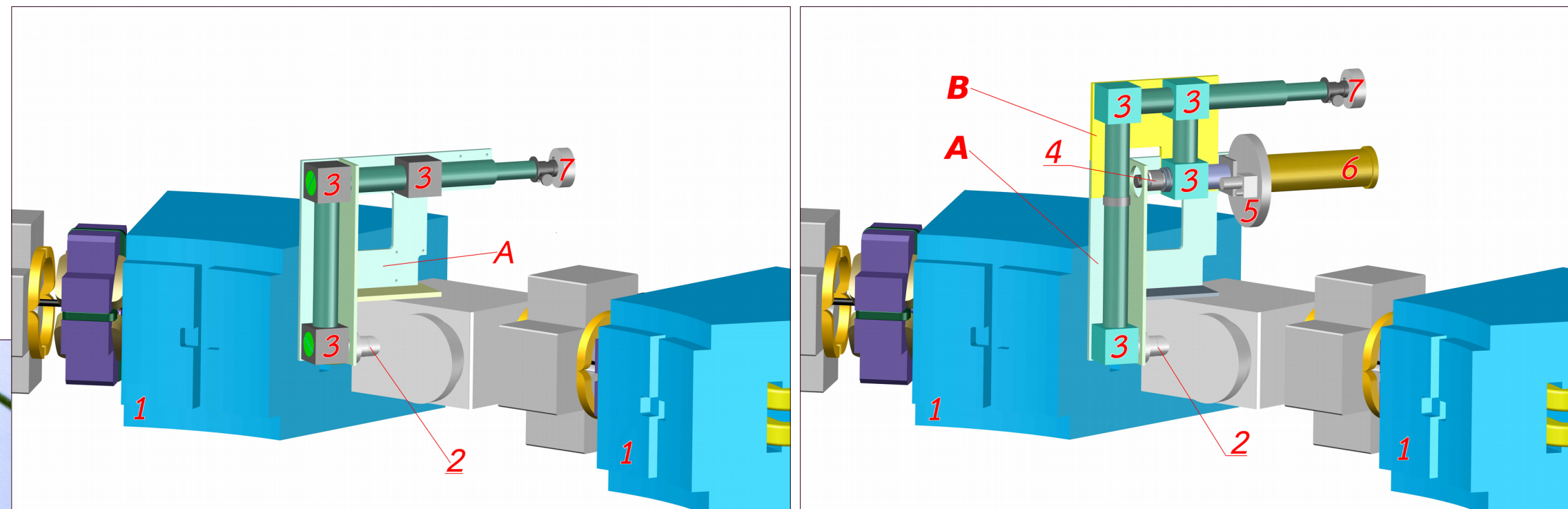
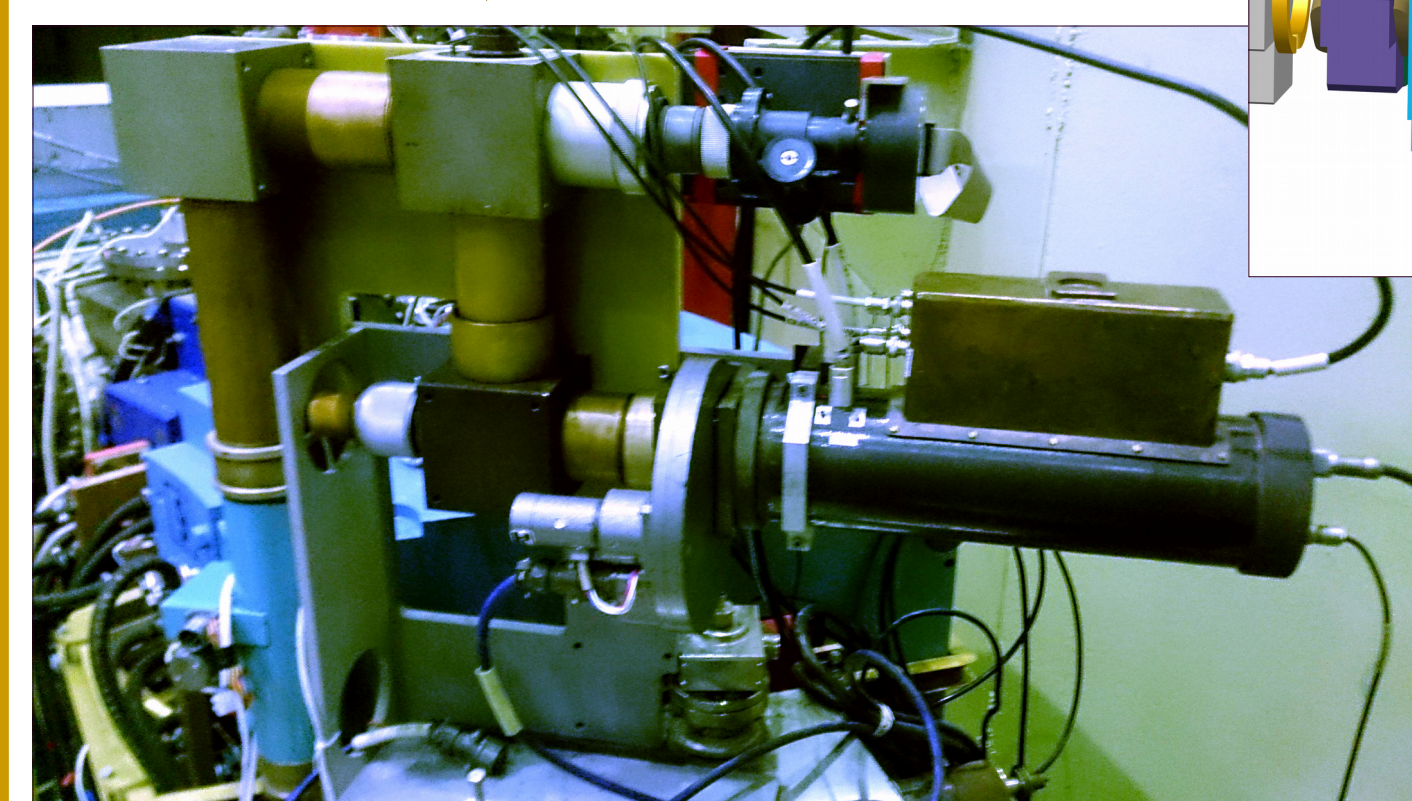
INTRODUCTION

The longitudinal beam profile measurement system based on optical dissector was upgraded at booster synchrotron BEP during VEPP-2000 collider complex 2017/2018 data taking run. New RF cavity of 13-th harmonic was installed during the booster upgrade in 2013-2015 to increase top energy to 1 GeV. The complex work on synchrotron radiation output modernization was performed, and measurement system was commissioned. The system was tested and calibrated, the resolution was studied. The bunch length dependence was measured for different RF cavity voltages while beam current changes and compared with the potential well distortion model. Good agreement with theory proved system operability. In addition the results of bunch length current dependence obtained by dissector at VEPP-2000 collider were compared with streak-camera measurements being in a good agreement. The synchrotron tune dependence on RF cavity voltage was measured both at BEP and VEPP.

OPTICAL PATH MODERNIZATION AT THE BEP

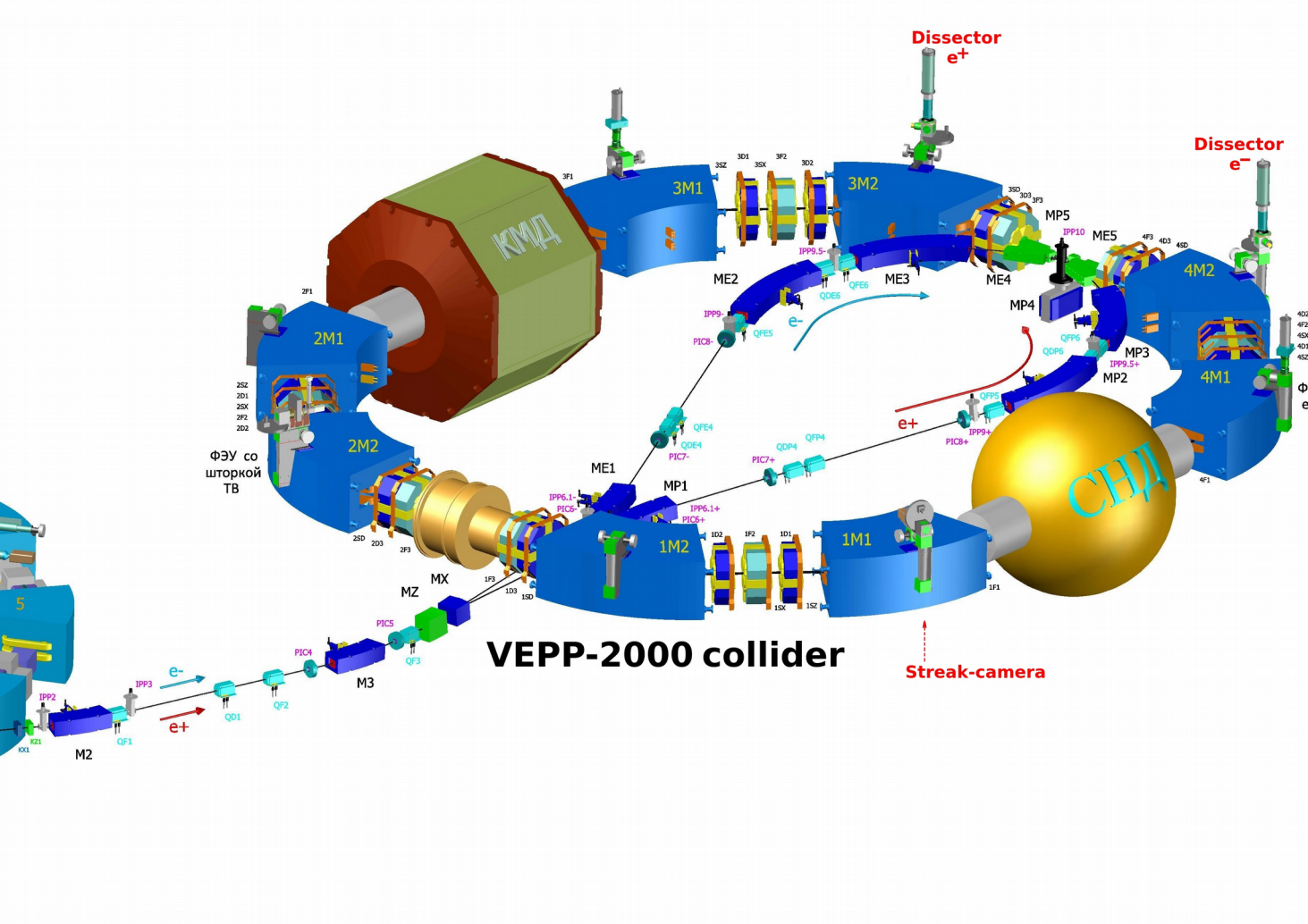
The task of modernization concludes in to save current beam transverse position monitor (CCD-camera) functional. For realization it and duplicating light of synchrotron radiation semitransparent mirror was setted in optical table tract (yellow part of table and mirrors at the **concept** figure was added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

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 nA) in the BEP.



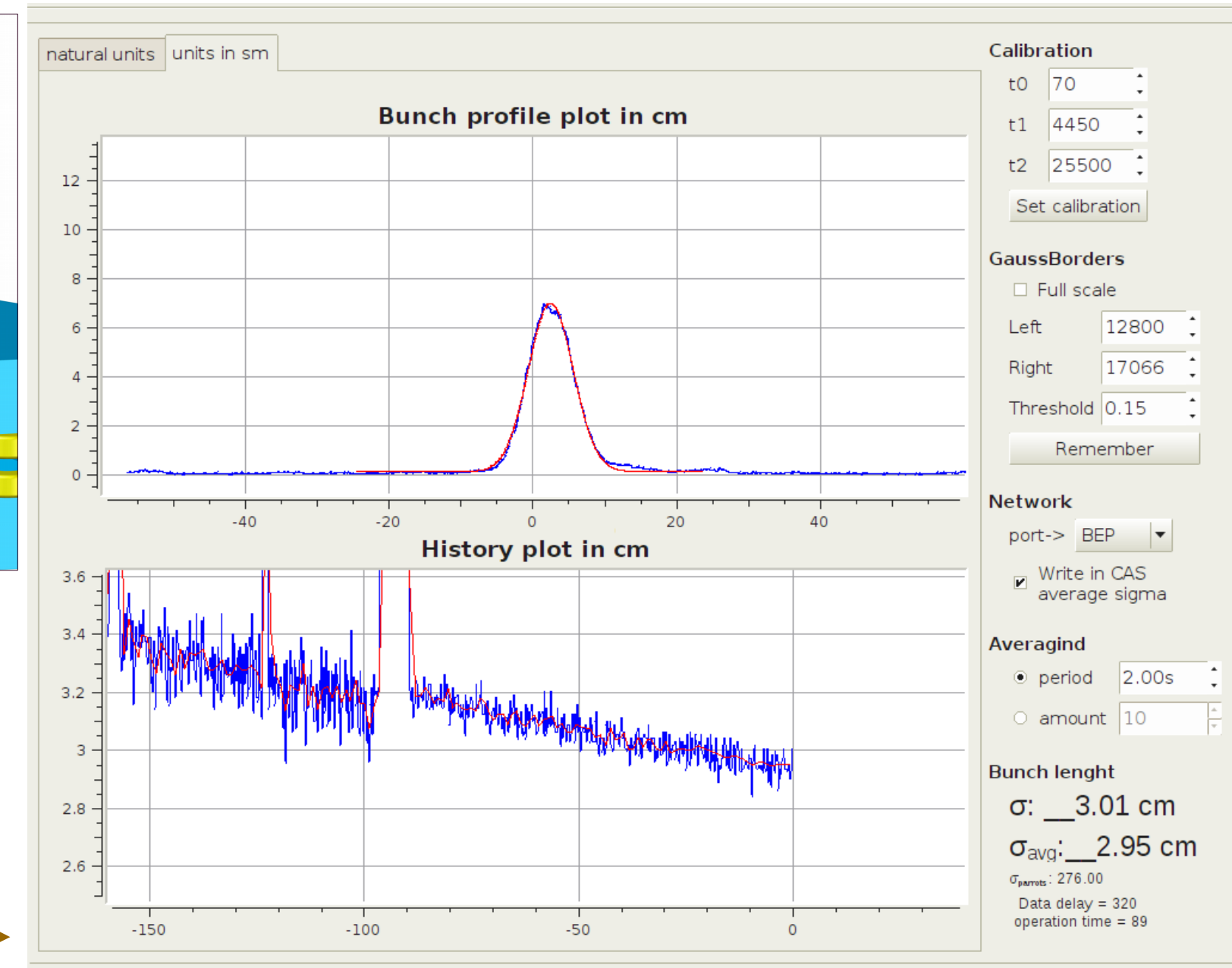
Concept: optical table before modernization and after modernization.
1— bending magnet, 2— sync. rad. output, 3— cubes with moving mirrors,
4— calibration light source, 5— light filters, 6— dissector, 7— CCD-camera.
A — existed surface of table, B — added surface.

Developed application for measurements where examples of longitudinal bunch profile in the BEP and history of bunch length measurements are showed.



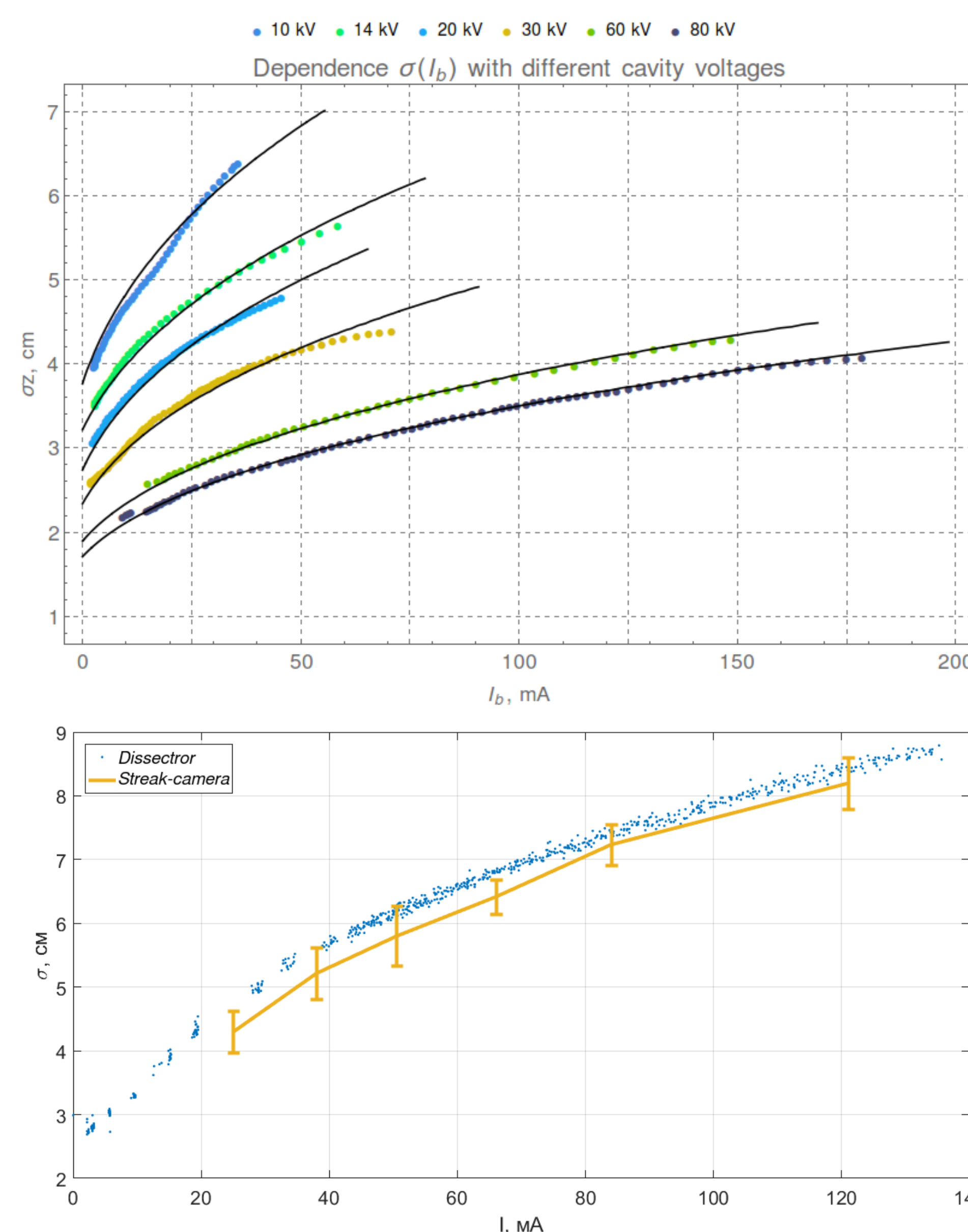
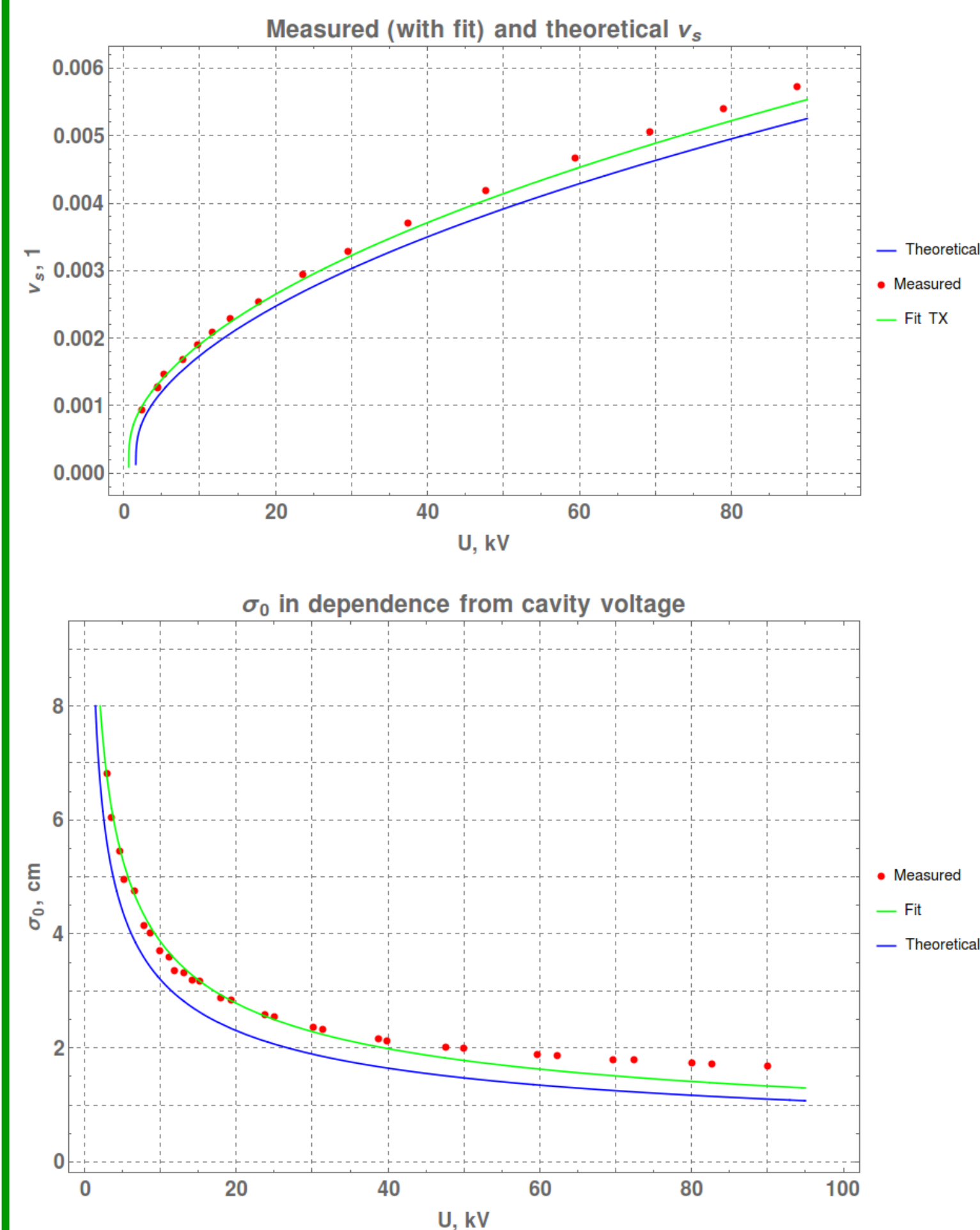
Parameter	Symbol	Value
Circumference	Π	2235 cm
Revolution frequency	f_0	13.4145 MHz
Momentum compaction factor	α_p	0.0576
Energy spread	$\frac{\sigma_E}{E}$	$7.3 \cdot 10^{-4}$
Energy lose per turnover	W	69 keV
Harmonic of cavity	h	13
Bending radius	r_0	128 cm
Maximum cavity voltage	U_{max}	110 kV
Synchrotron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

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



MEASUREMENTS

Normalized synchrotron frequency and bunch length at "null" bunch intensity versus RF cavity voltage at the BEP.



Bunch lengthening

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:

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

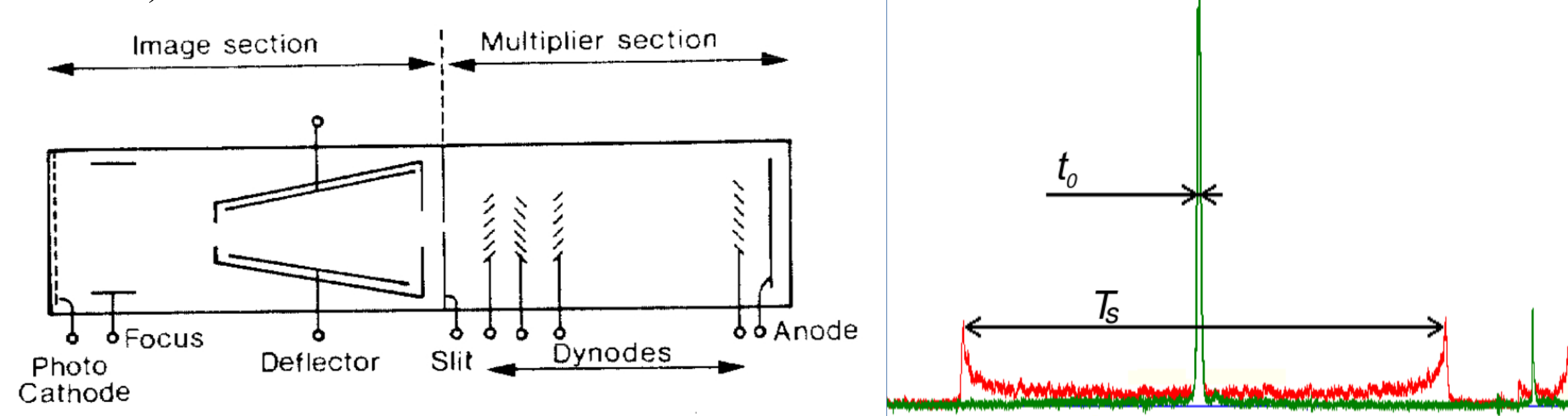
where U_0 - amplitude of RF-cavity voltage, ϕ_s - stationary phase of particle motion in RF cavity, σ_0 is bunch length at "null" bunch intensity, h - harmonic of revolution frequency which is frequency of RF-cavity processing, R - average accelerator radius, I_b - bunch intensity. $\text{Im} \left(\frac{Z}{n}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

Bunch length dependences on its intensity has been measured by dissector with different RF cavity voltages in BEP.

Also this dependence has been measured in VEPP-2000 collider and has been compared with results by streak-camera.

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. For dissector installed at the BEP resolution is 26 ps (or 0.8 cm in spacial dimension).



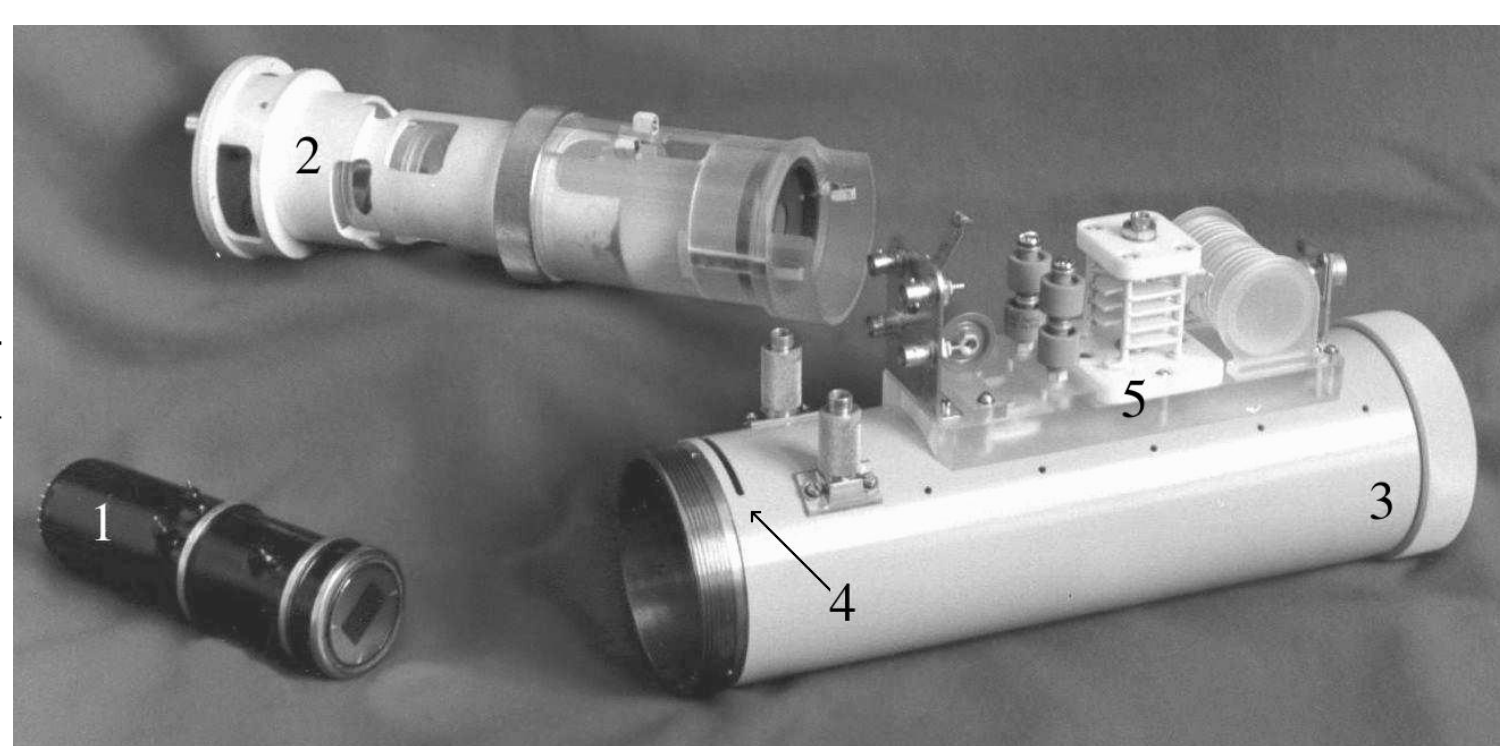
Calibration of dissector is implemented by calibration source of permanent light. Scaling factor and estimation of resolution can be found.

$$\text{Final formula of input pulse duration is: } \Delta l = \frac{D\sqrt{t^2 - t_0^2}}{q T_s}$$

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.

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



CONCLUSION

In work season 2017-2018 the longitudinal beam profile diagnostic get comprehensive development. Dissector has been installed at the BEP. Two more identical dissectors has been set to VEPP-2000 collider. All dissectors has been calibrated. For using them the special software has been developed. After that these systems has been commissioned by operators of complex VEPP-2000. Also the streak-camera has been installed at VEPP-2000 collider. Joint measurements of bunch length by dissector and streak-camera at the VEPP-2000 collider and comprehensive measurements of bunch length in the BEP in model of potential well distortion have been done.

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