The Measurements of the Longitudinal Beam Profile on the Preinjector VEPP-5.

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EPAC'04, 4-9 July, Lucerne.

The Budker Institute of Nuclear Physics

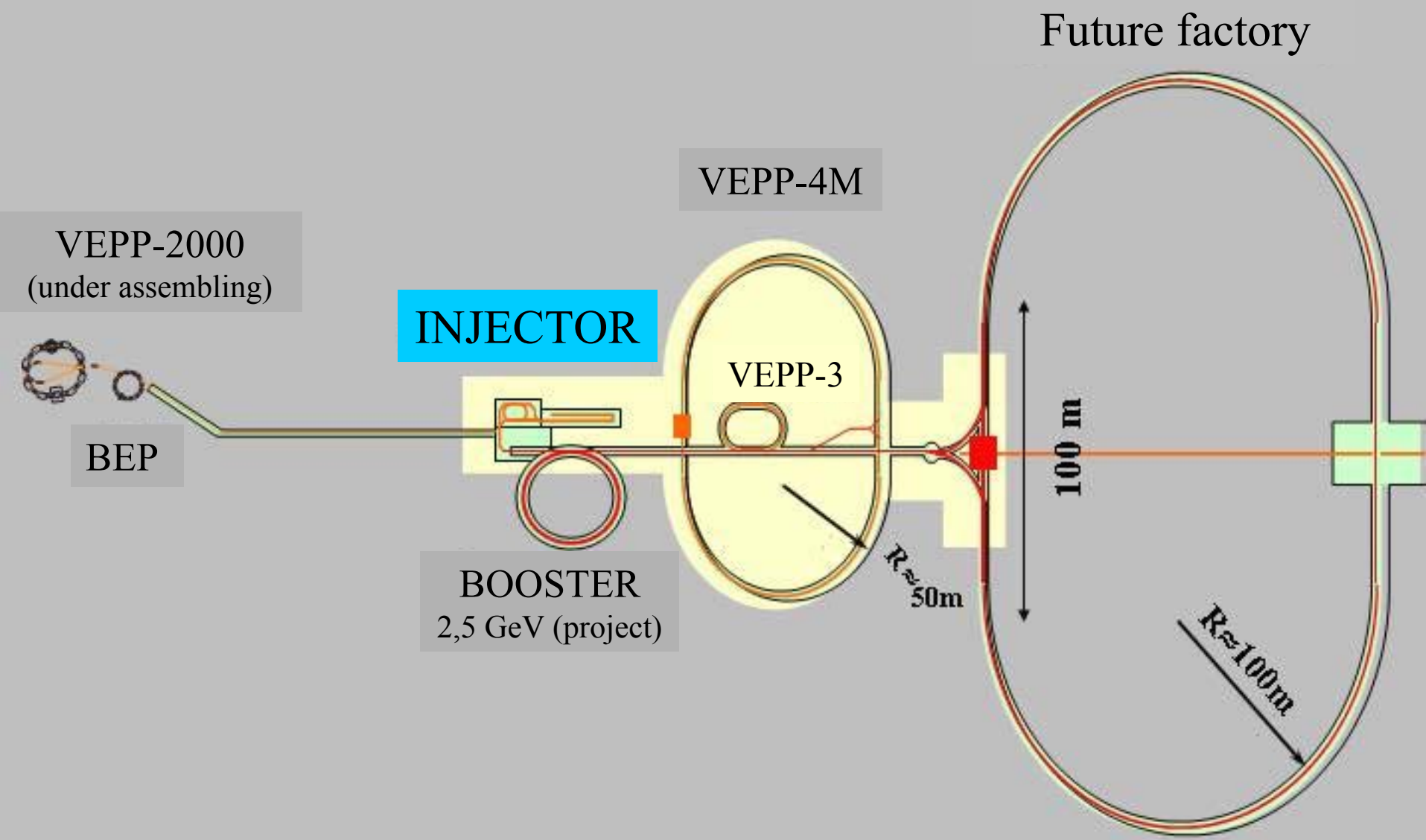
Guideline.

1. VEPP-5 forinjector and tasks

2. Electron beam probe:
   - idea
   - device
   - measurements

3. Streak camera:
   - limitations
   - RF cavity promise advantages
   - device and measurement
   - idea of spiral sweep

VEPP-5 COMPLEX (project)

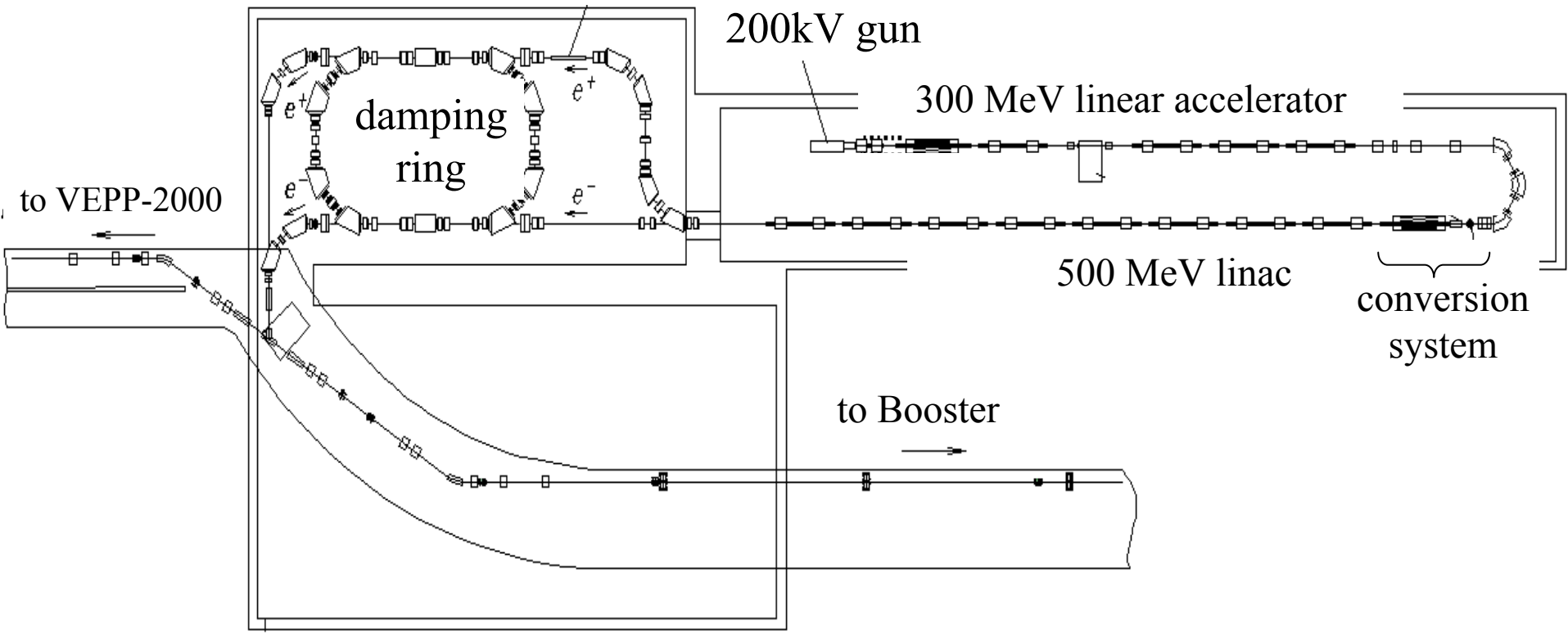


Positron conversion efficiency.

Project is 2-3 %.

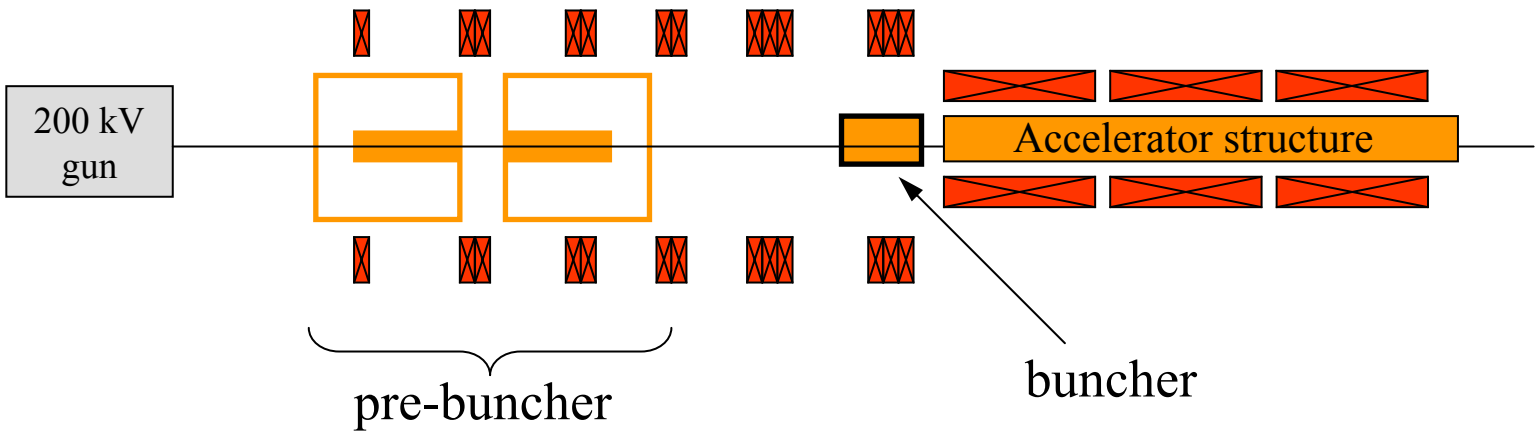
First result (May 2004) is 1% or 3×10^{8} per pulse or $1{,}5 \times 10^{10}$ per second.

The main part of work is for positrons production.

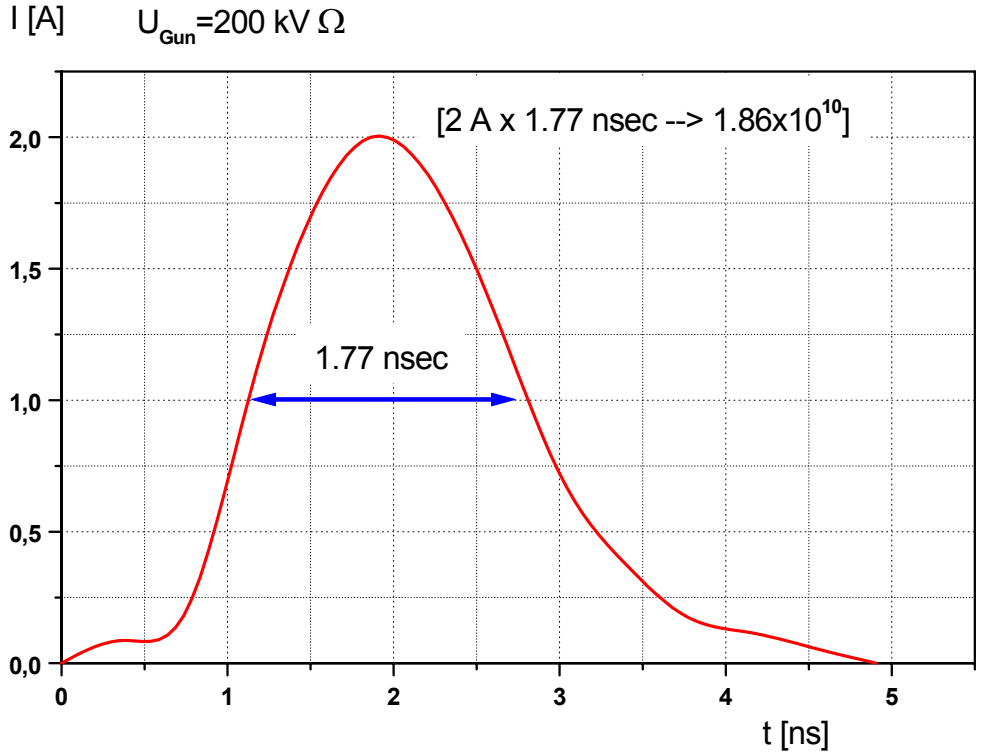


Layout of VEPP-5 forinjector.

Compression system.



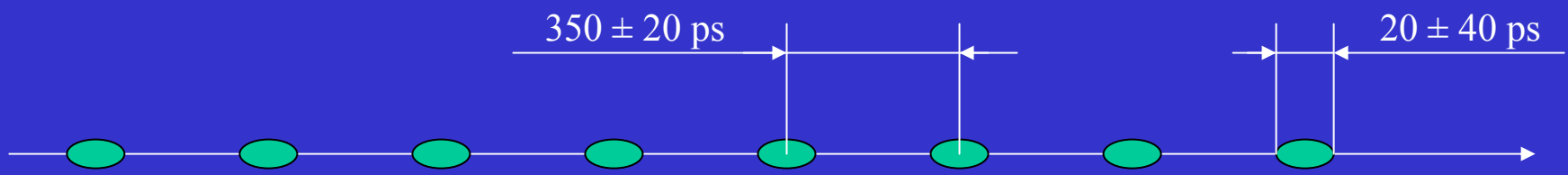
The compression system: two cavities that operate at the 16th RF Subharmonic (178.5 MHz) and RF buncher that operates at the main accelerator frequency (2856 MHz).



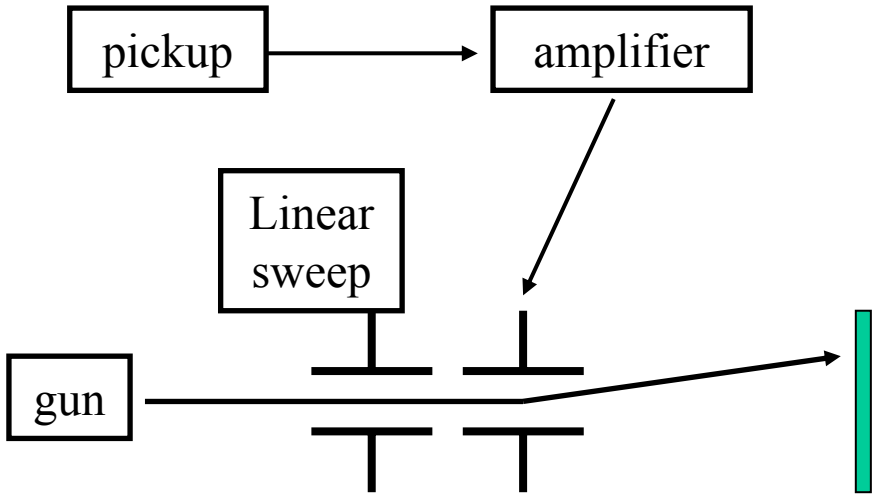
Current from 200 kV gun

Beam length at basis: 2-3 ns

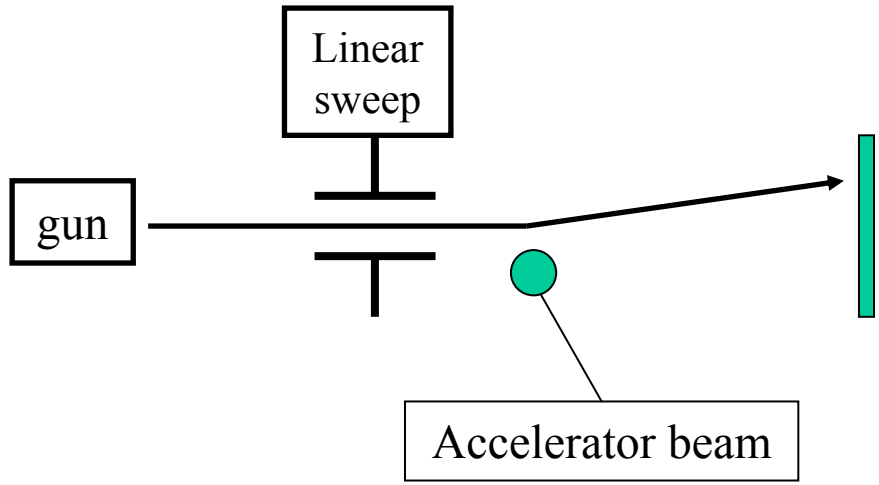
Linac frequency: 2856 MHz => T=350ps



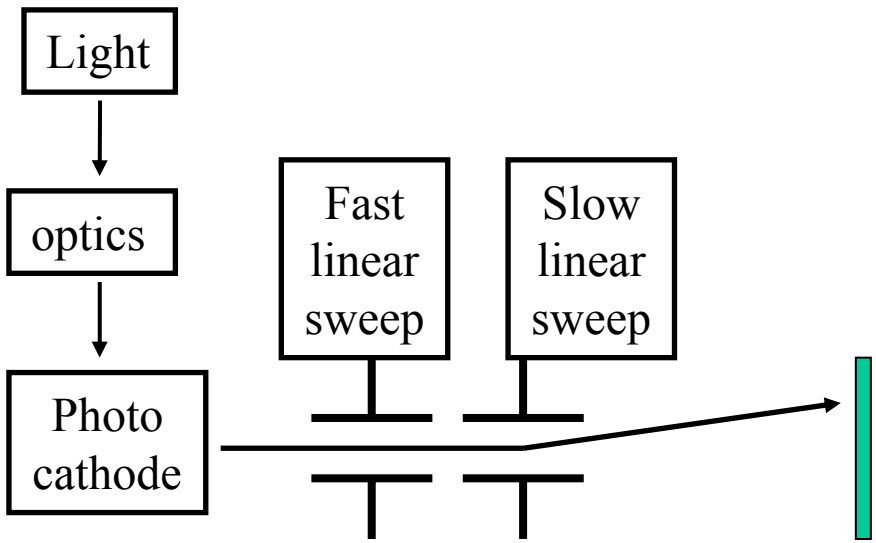
Oscilloscope



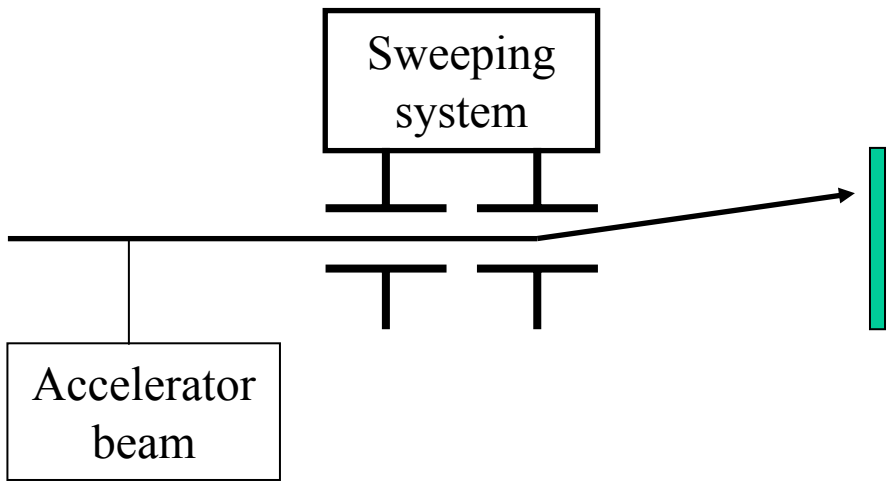
Electron beam probe



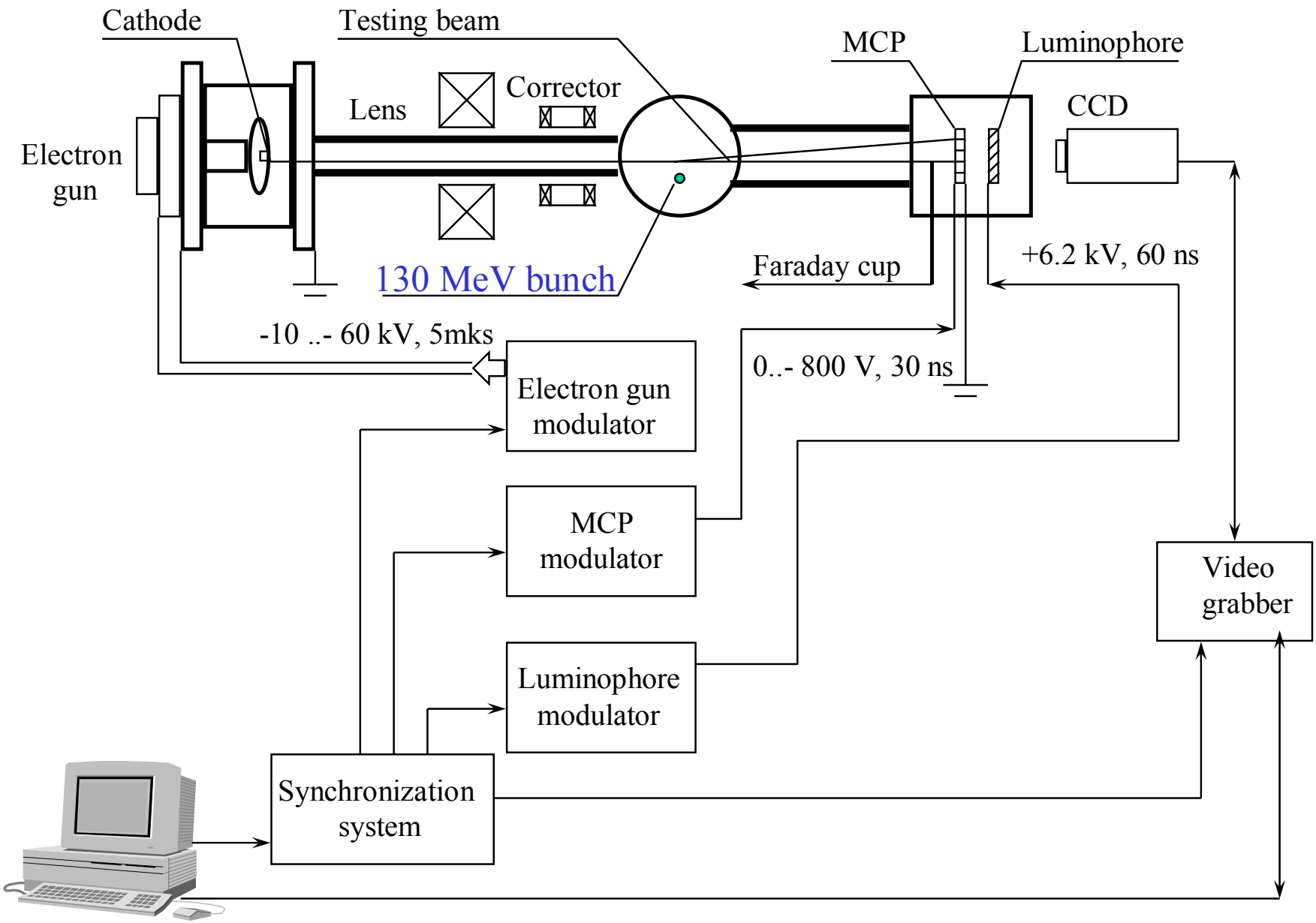
Streak camera

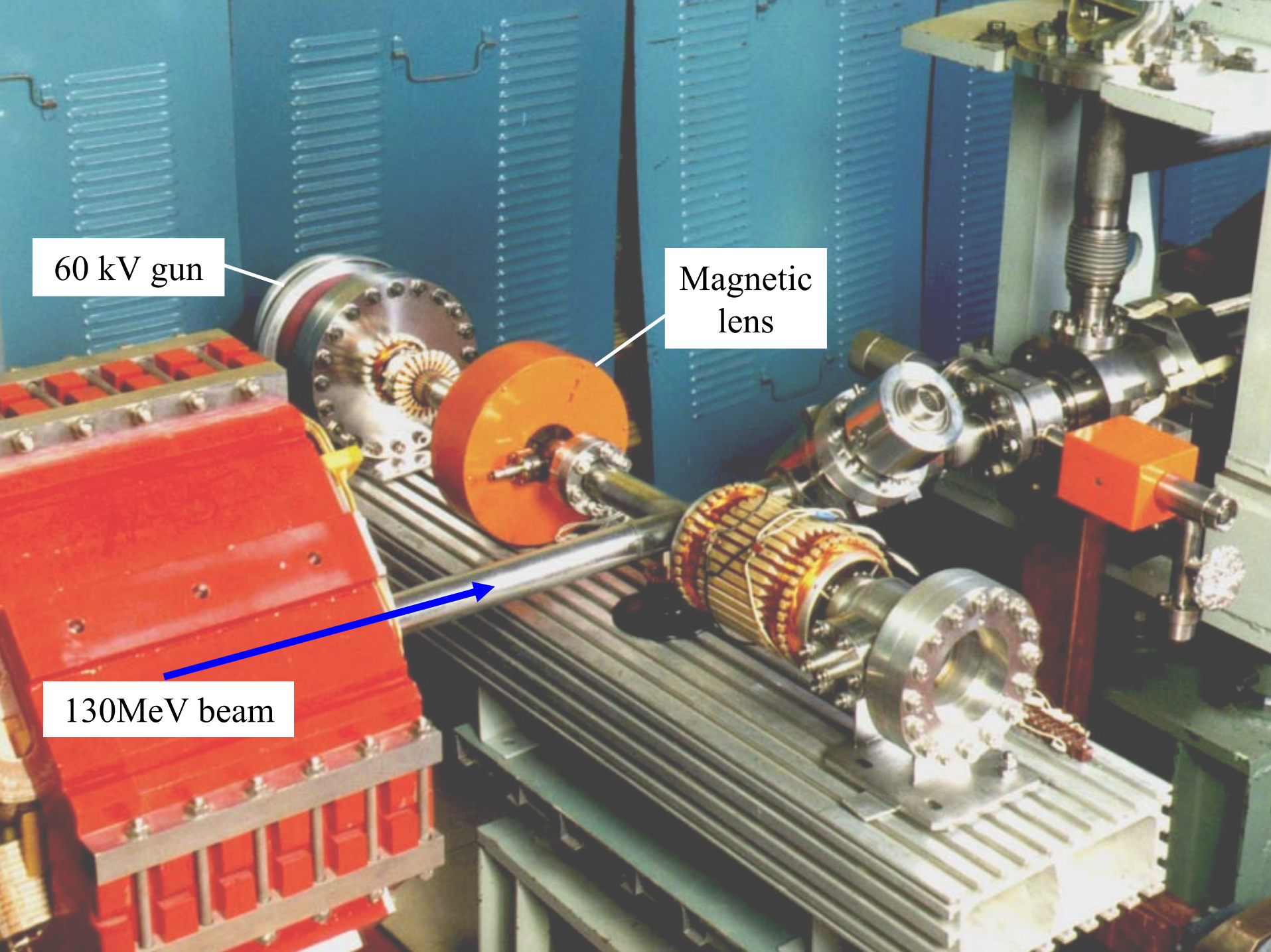


Deflector

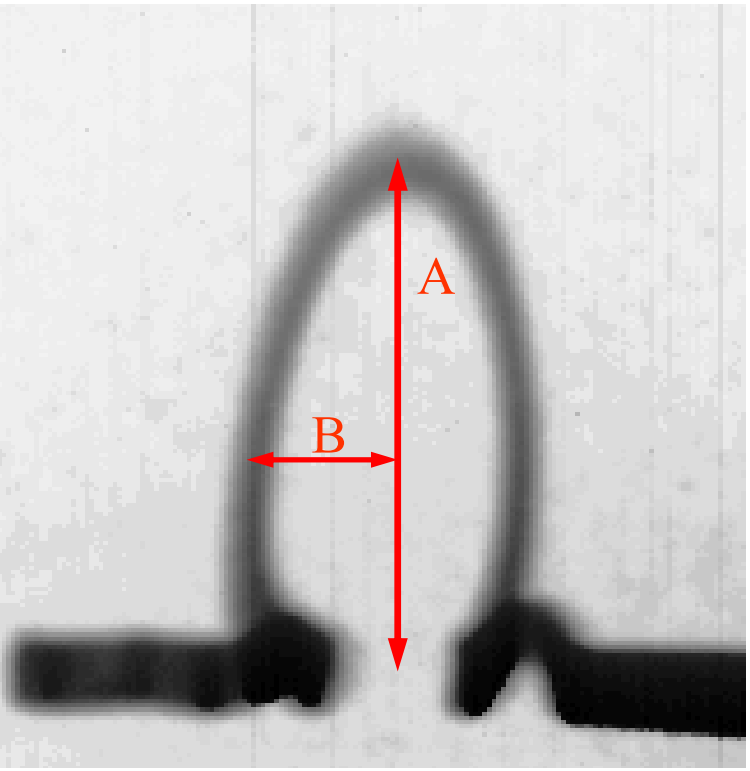


The scheme of electron beam probe




60 kV gun
Magnetic lens
130MeV beam

Single bunch regime

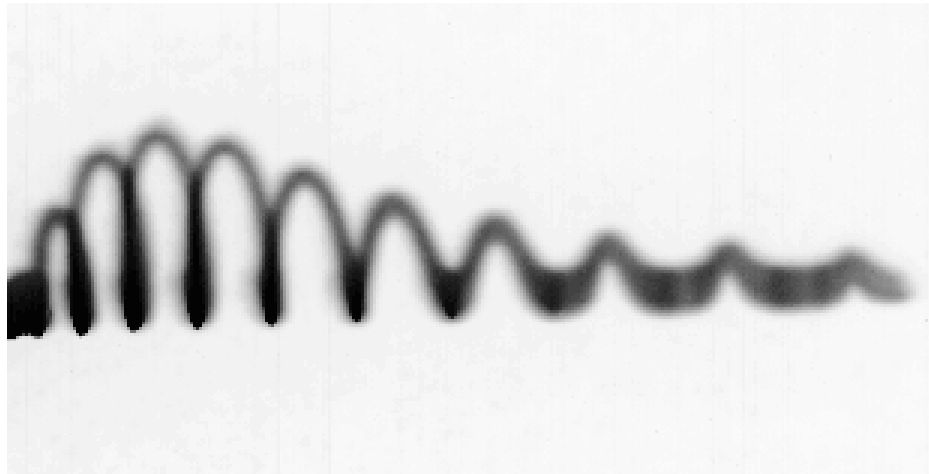


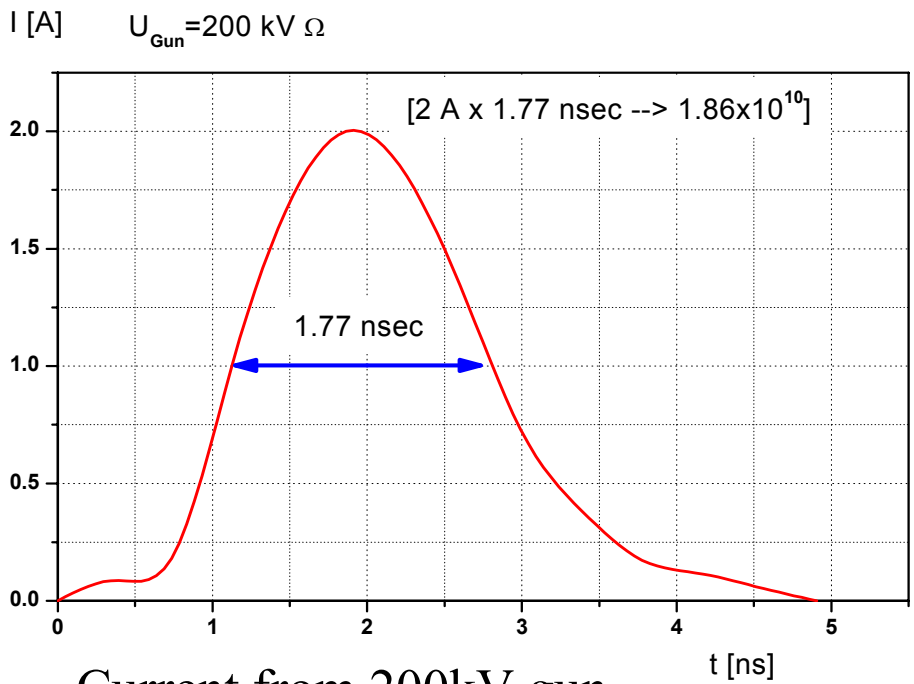
$$A \propto \frac{\rho \cdot I}{pc \cdot V}$$

$$B \propto \frac{\rho}{pc \cdot V} \cdot \frac{dI}{dt}$$

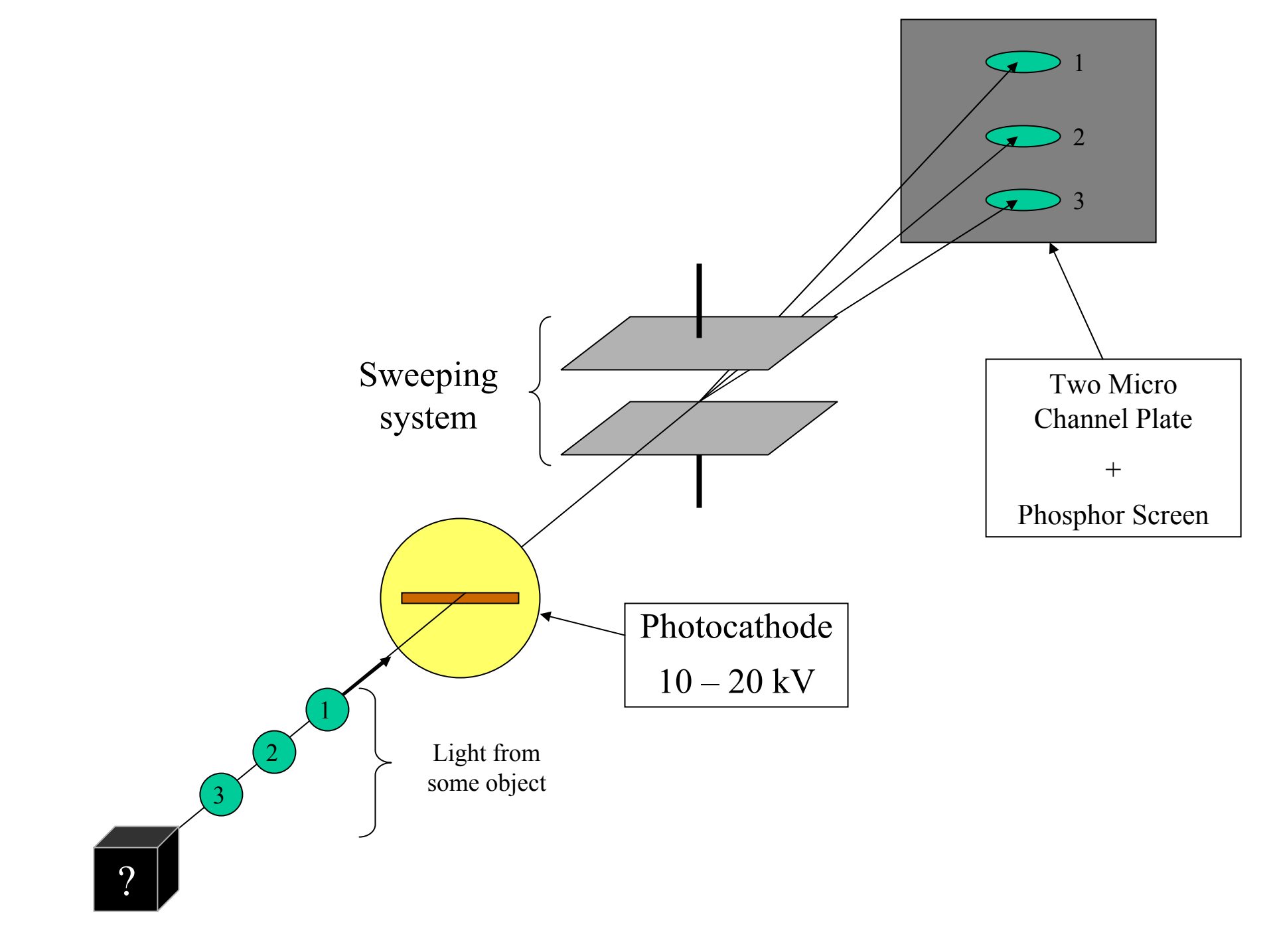
Multi bunch regime.

Pre-buncher system switch off.





Current from 200kV gun


1
2
3
Sweeping system
Two Micro Channel Plate
+
Phosphor Screen
Photocathode
10 – 20 kV
1
2
3
Light from some object
?

The main factors limited of time resolution is:

- velocity spread photoelectrons:
  (signal lengthening at photocathode)

$$\Delta t = \frac{m \Delta V_z}{eE}$$

- space-charge effect:
  (signal lengthening from photocathode
  to sweeping system)

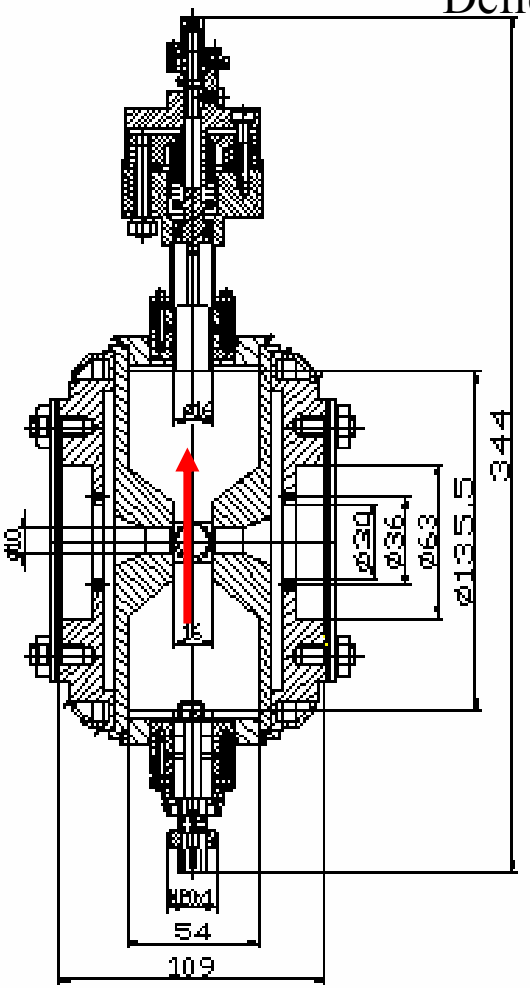
$$\Delta t \propto \frac{N}{V^3}$$

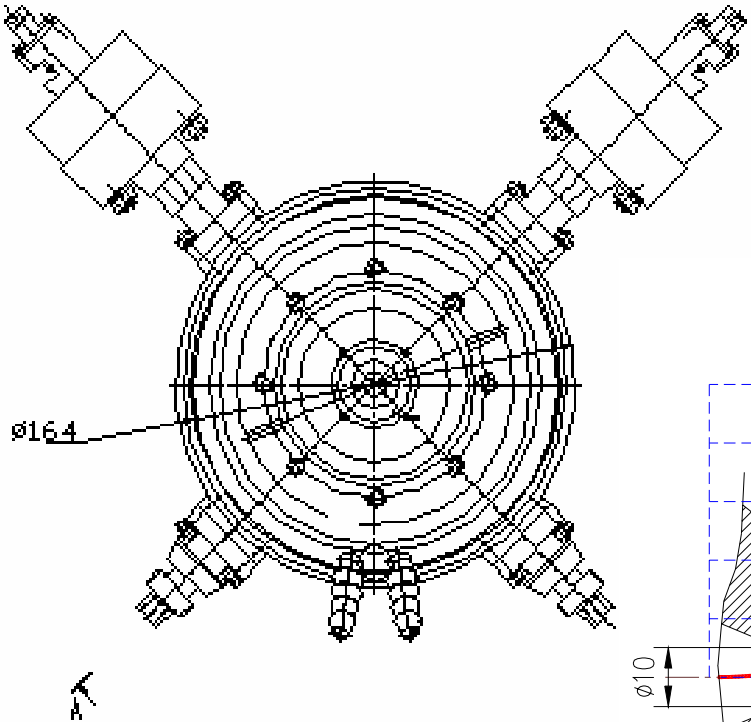
- statistical noise:

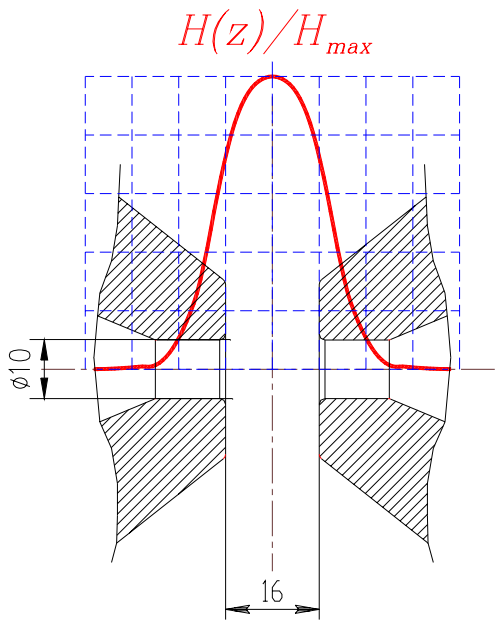
$$\propto \frac{1}{\sqrt{N}}$$

K.Scheidt, «Review of streak cameras for accelerators: features, applications and results», EPAC-2000.

Operating mode	TM_{110}
Resonant frequency	2856.0 ± 0.5 MHz
Unloaded quality factor	16000
Deflecting efficiency at 50 kV	$1.53\ 10^{-3}$ rad/$W^{1/2}$







The advantages of RF cavity using:

$Q \sim 10^4$ → increase eU up to 100 kV

↓

Space charge limitation is significantly reduced

↓ → Time resolution improvement

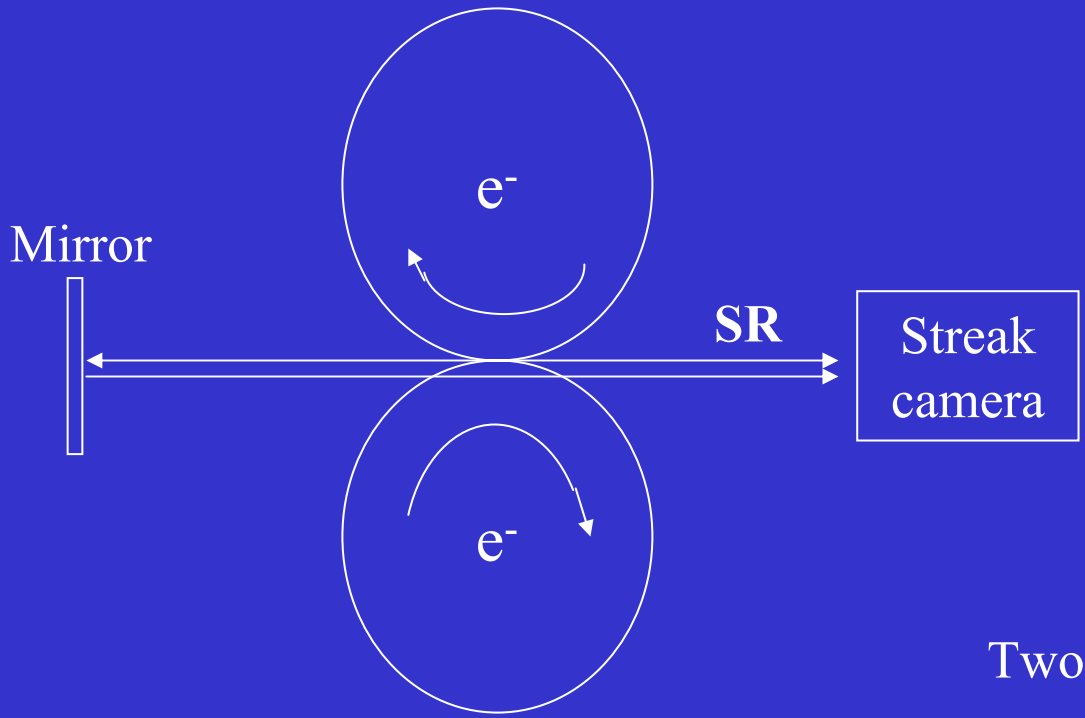
↓

Circle scanning
unique signal
up 350 ps
at $t_R < 1$ пс.
Synchro: 1 μs

→ **Trochoidal scanning**
will be discussed

← **Spiral scanning**
unique signal,
up to 10 ns
at $t_R \sim 1$ ps.
Synchro: ~ 1ns

VEP-1, 1965



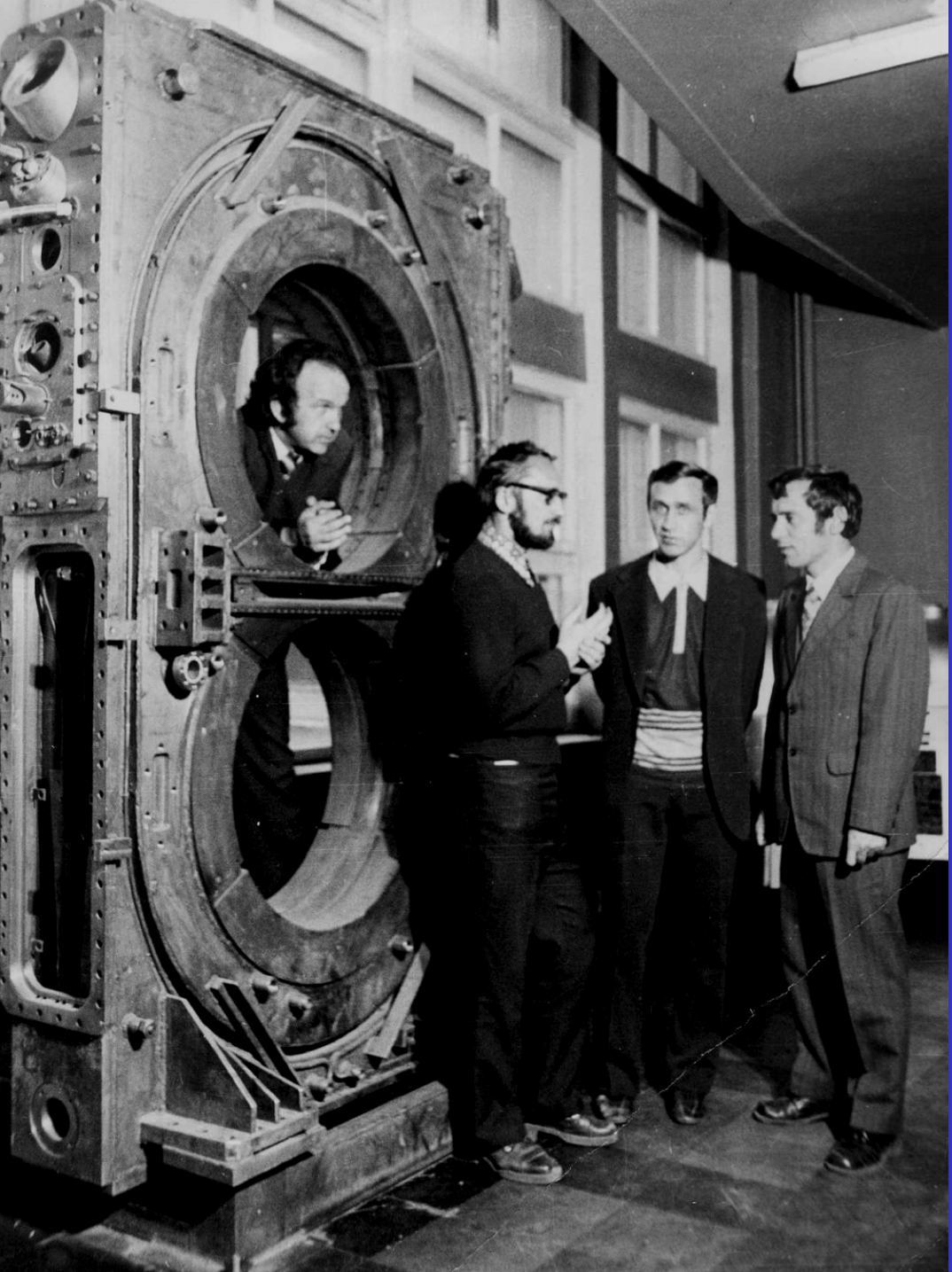
Bunch length was 10 cm.

The time resolution was 30ps.

Two pair of deflecting plates

provide circle scanning

on the main accelerator frequency.



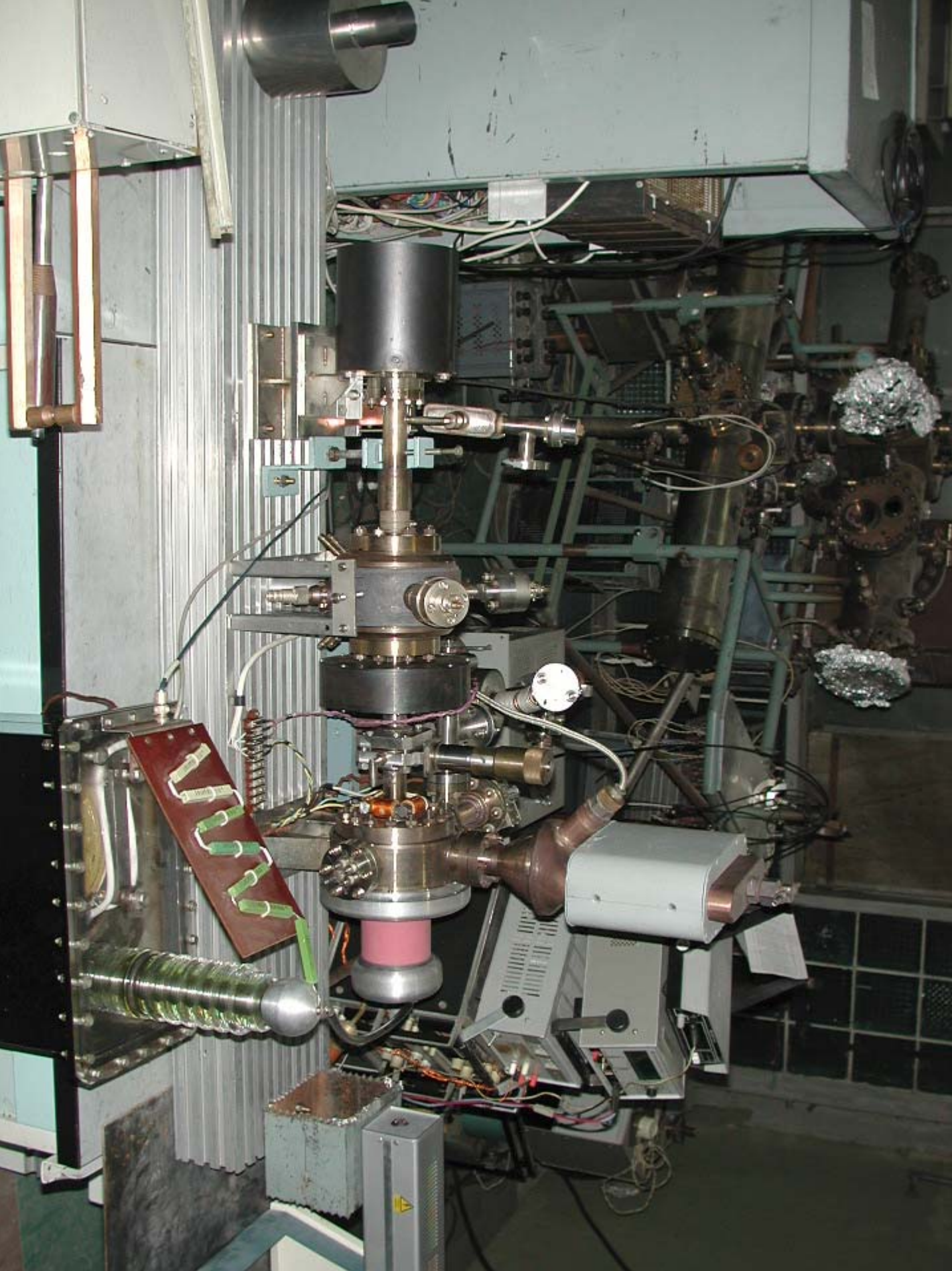
First mention about using streak camera on colliders:

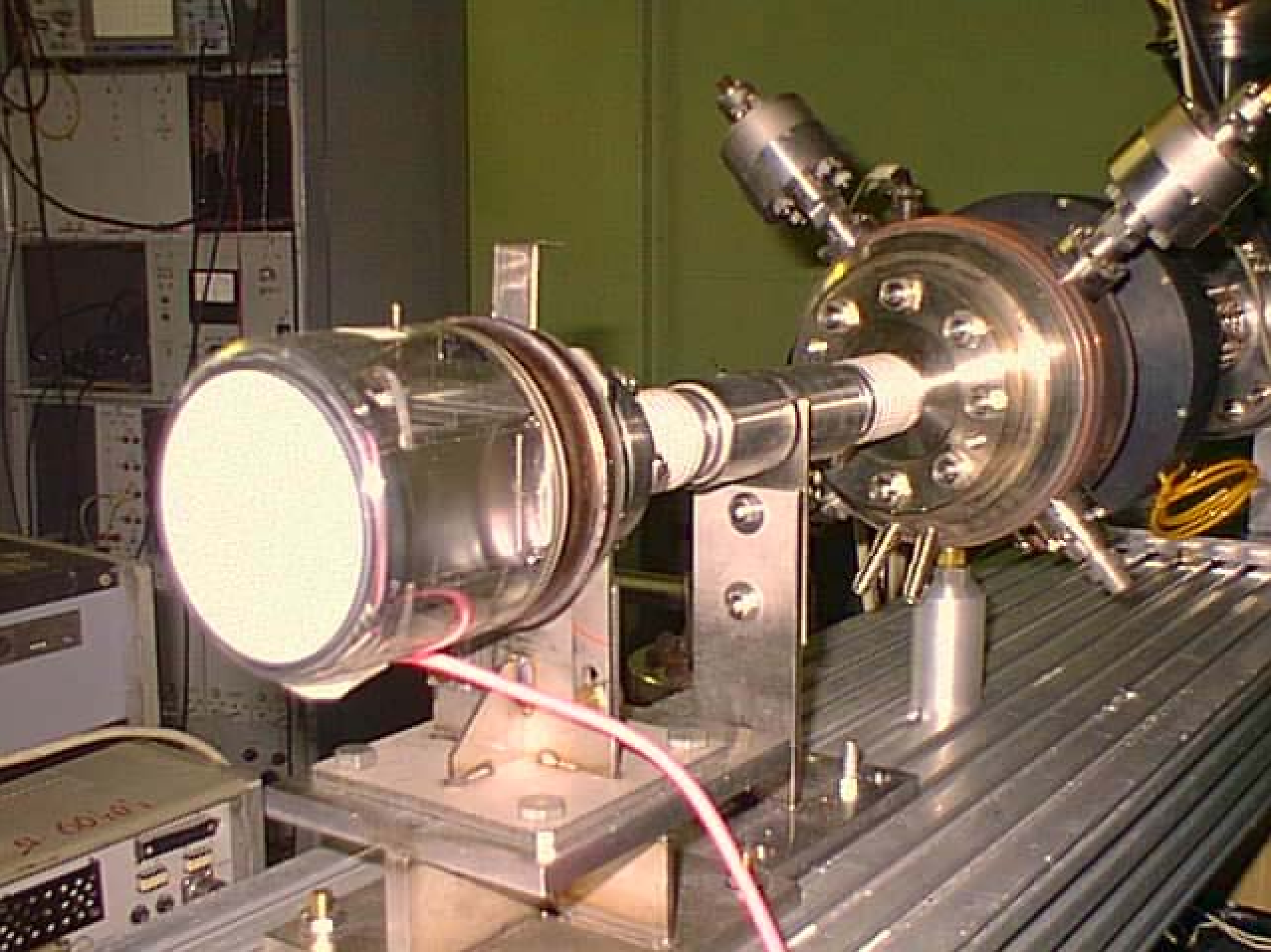
Journal «Atomic energy», 1965

E.I.Zinin, L.S.Korobeynikov, G.N.Kulipanov, B.L.Lazarenko, Yu.G.Matveev, S.G.Popov, A.N.Skrynsky, T.P.Starodubtseva, G.M.Tumaykin

«Control System of Electron Beam Parameters in Electron-Electron Storage Ring VEP-1 »

On the photo from left to right: G.N.Kulipanov, S.G.Popov, A.N.Skrynsky, G.M.Tumaykin





The valuation of photons number in visible range

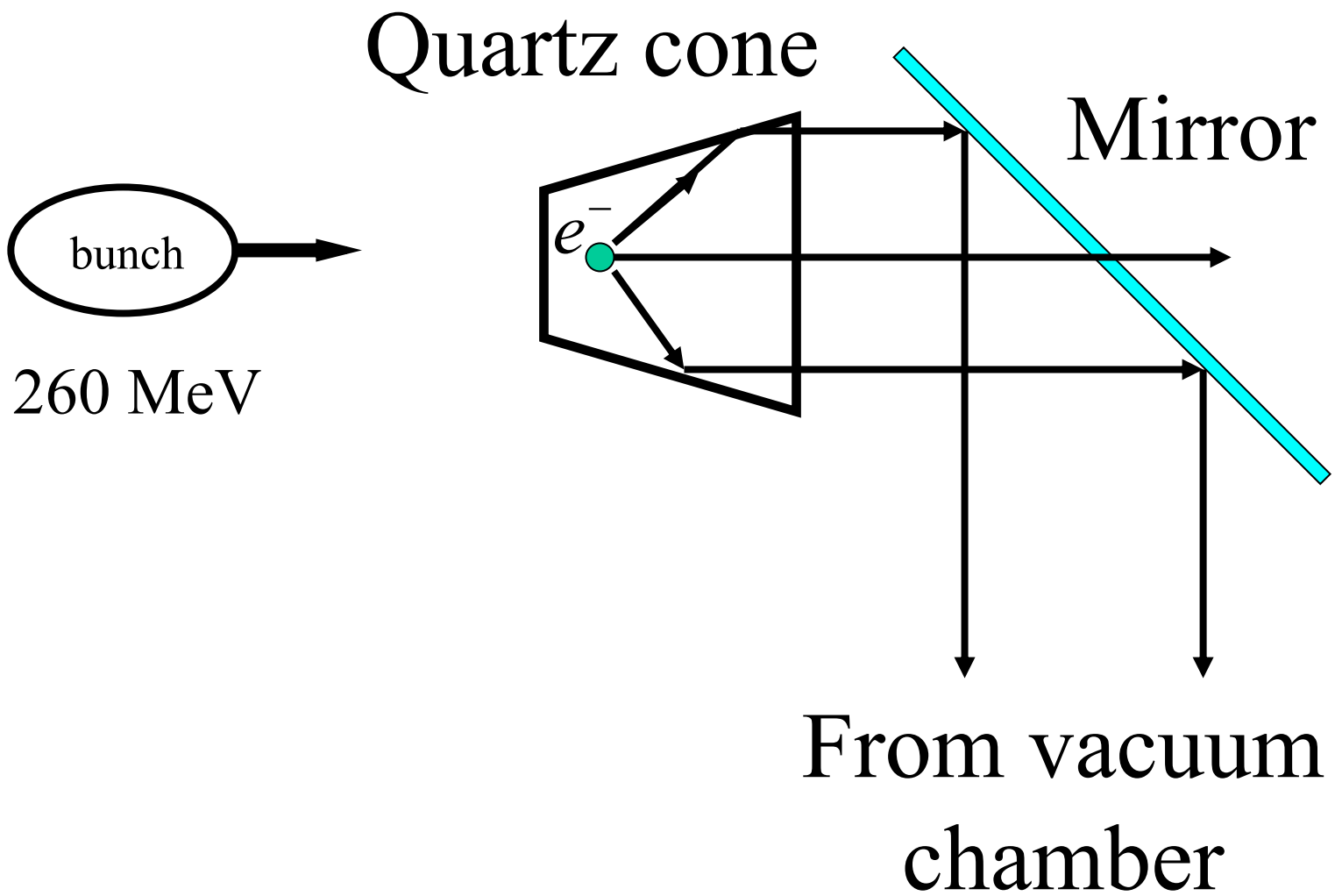
from beam with charge of $Ne = 10^{10}$ electrons

and energy E = 260МэВ

Cherenkov radiation: $Nch := Ne \cdot \alpha \cdot \frac{Lch}{c} \cdot \left(1 - \frac{1}{\varepsilon}\right) \cdot \Delta\omega$ $Nch = 1.6 \times 10^{12}$

Transition radition: $Ntr := Ne \cdot \frac{2 \cdot \alpha}{\pi} \cdot \ln(\gamma) \cdot \ln\left(\frac{\omega 1}{\omega 2}\right)$ $Ntr = 2 \times 10^{8}$

Synchrotron radiation: $Nsr := Ne \cdot \frac{4}{9} \cdot \alpha \cdot \gamma \cdot d\psi \cdot S\omega \cdot \frac{\Delta\omega}{\omega av}$ $Nsr = 9.2 \times 10^{7}$


Quartz cone
Mirror
bunch
e^-
260 MeV
From vacuum chamber

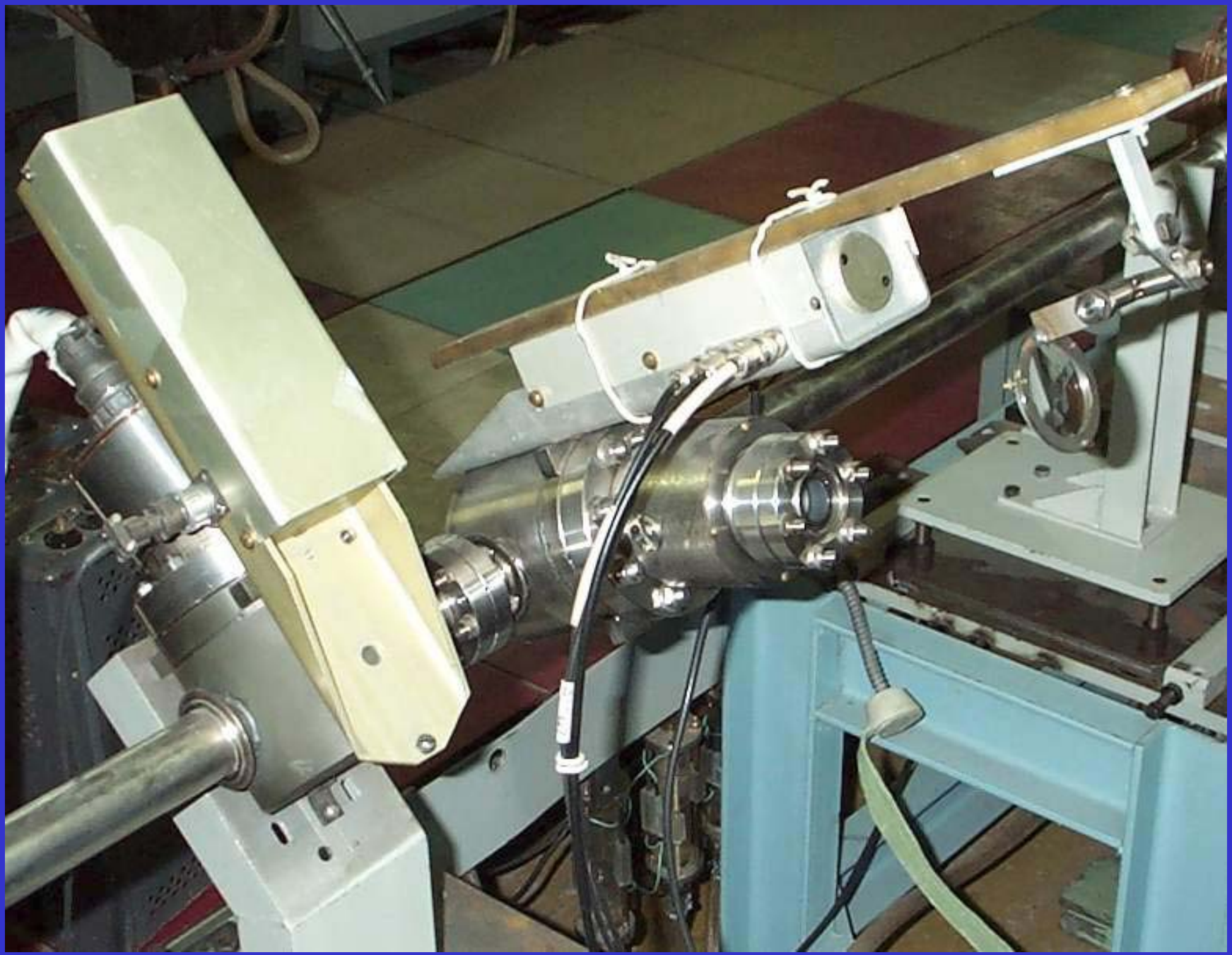
The experiment in search of the available glass.

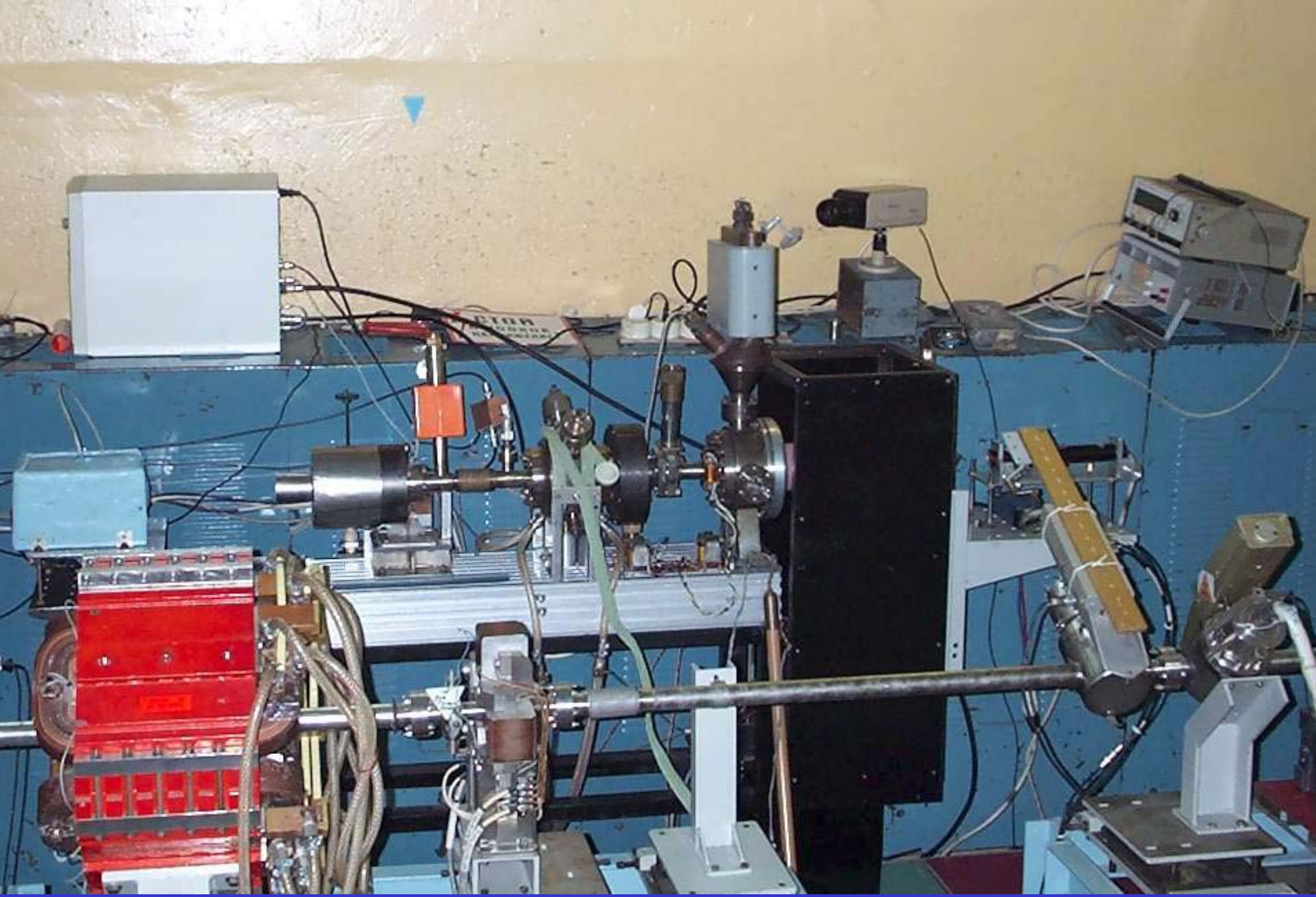
The cone must be created from material remained transparency under beam influence.

Institute of Chemical Kinetics and Combustion

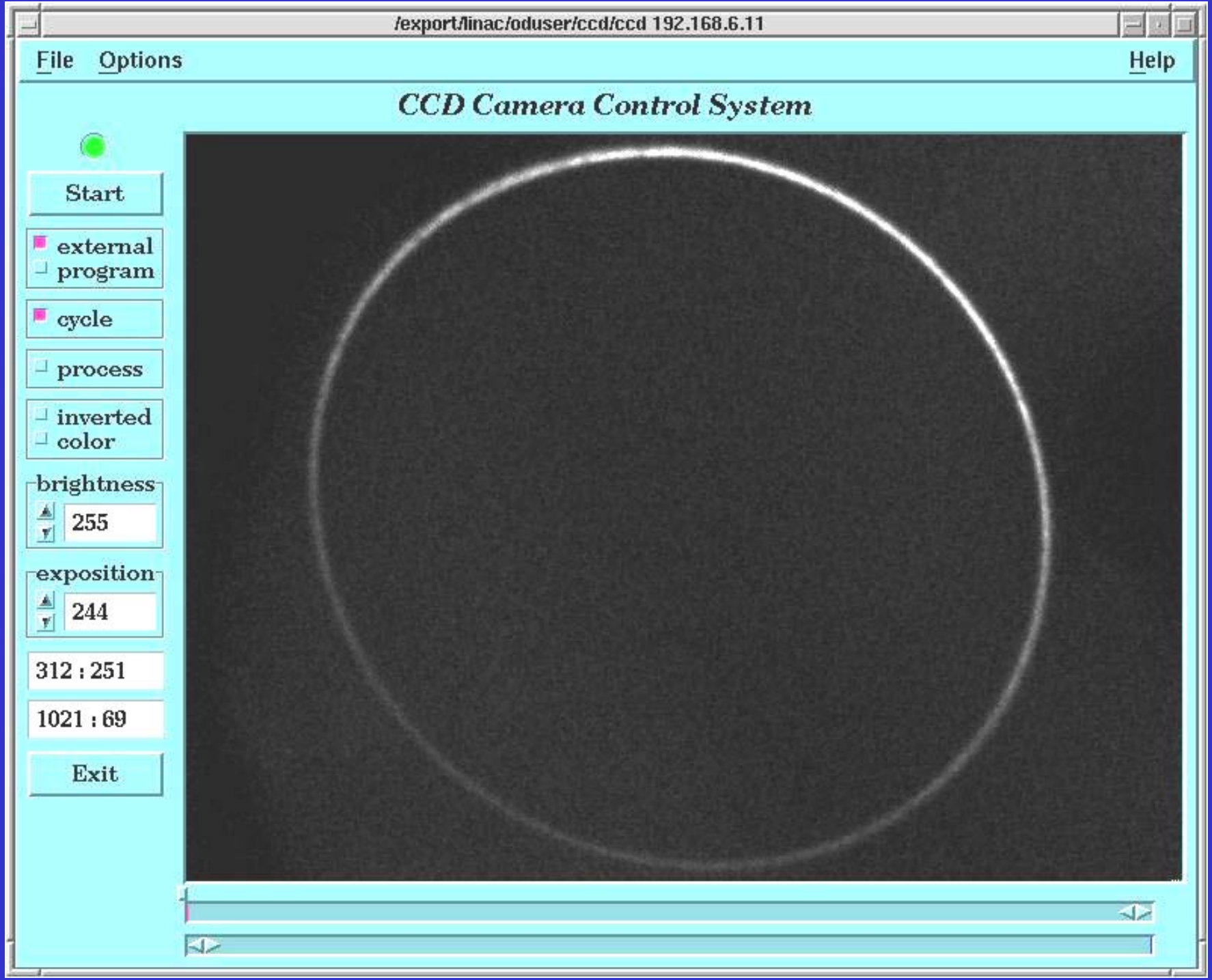
Energy	3 MeV
Pulse duration	3 μs
Current	50 μA
Charge per pulse	$1.6*10^{12}$

Samples of glass	Treatment time, minutes	f (Hz)	Total charge	Result
N 1	20	1.6	$3*10^{15}$	become black.
N 2	20	12.5	$2.4*10^{16}$	Lose transparency, split
N 3	22	1.6	$3.4*10^{15}$	Without change
	+19	+25	$+4.6*10^{16}$	transparent, split, hot ~ 80 C^{o}





On the preinjector VEPP-5.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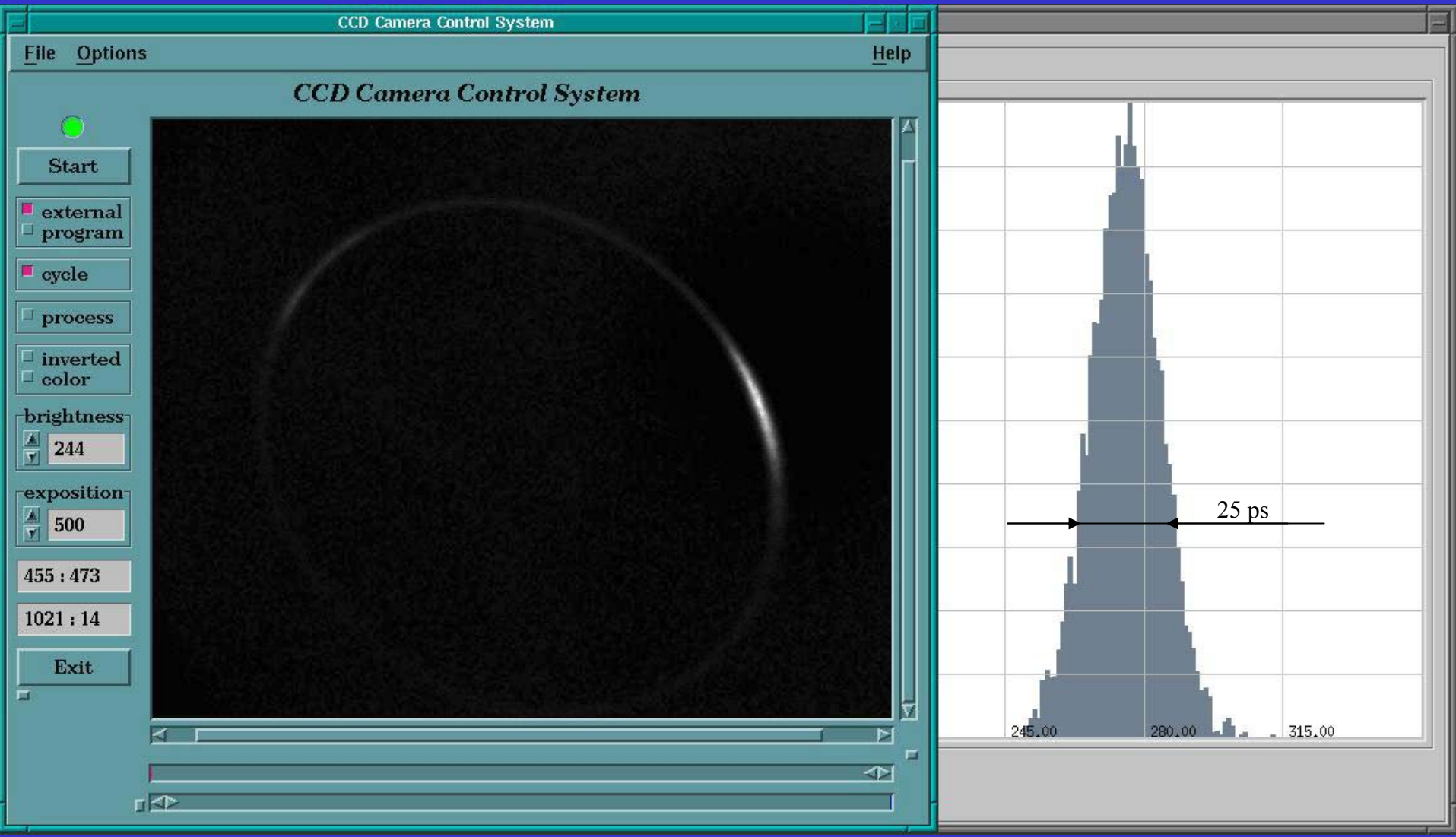
File
Options
Help
CCD Camera Control System
Start
external
program
cycle
process
inverted
color
brightness
255
exposition
244
312 : 251
1021 : 69
Exit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CCD Camera Control System
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color
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exposition
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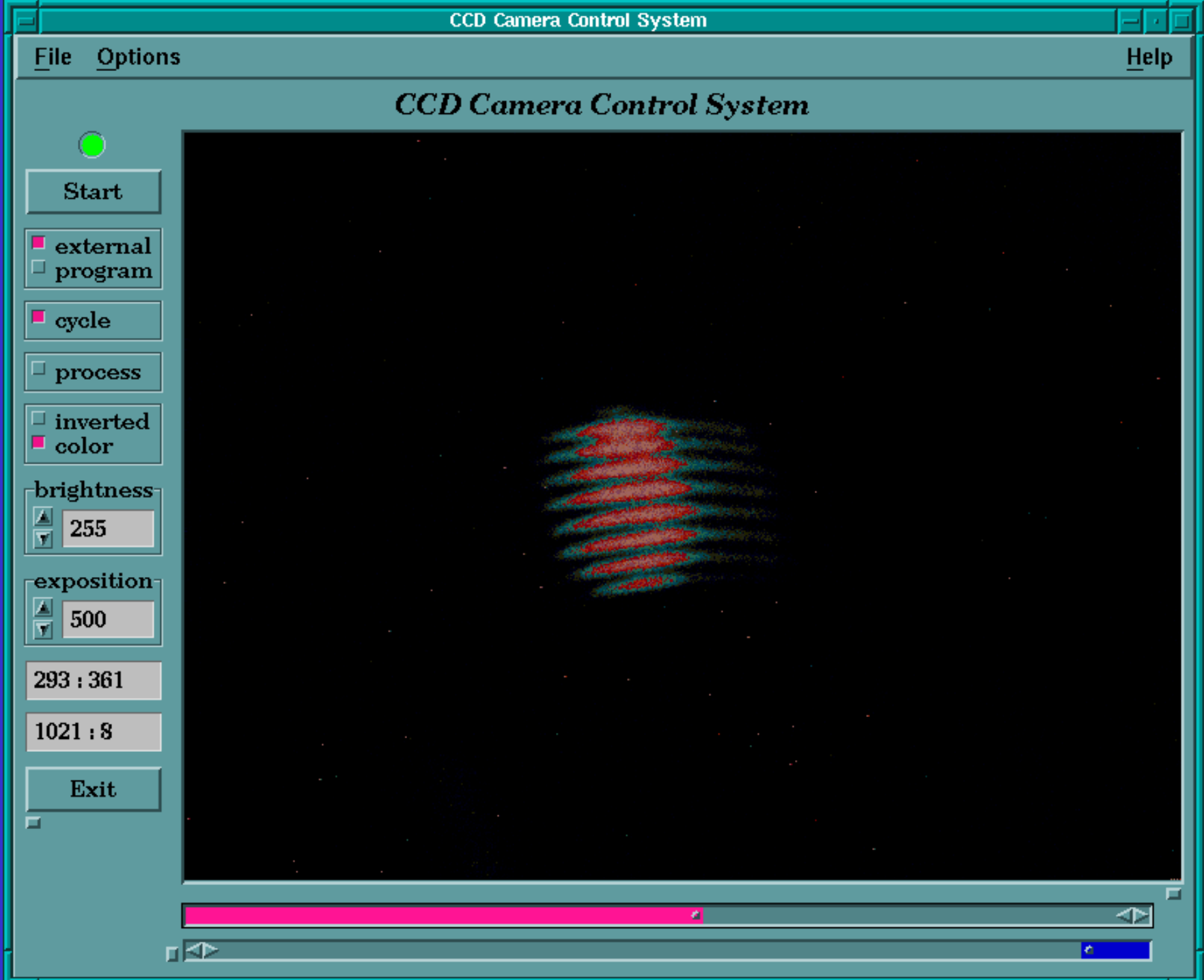
455 : 473
1021 : 14
Exit
25 ps
245.00
280.00
315.00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293 : 361
1021 : 8
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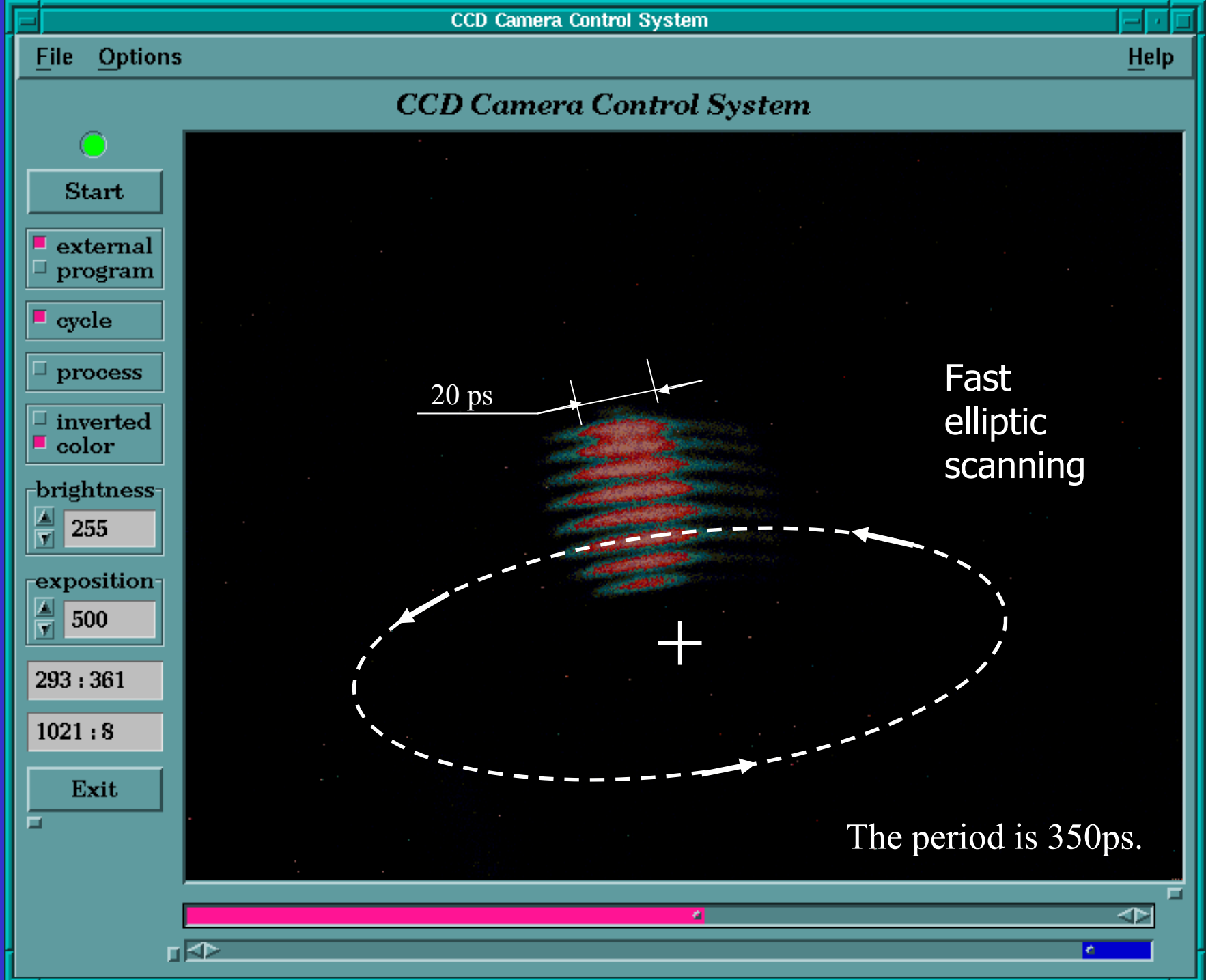
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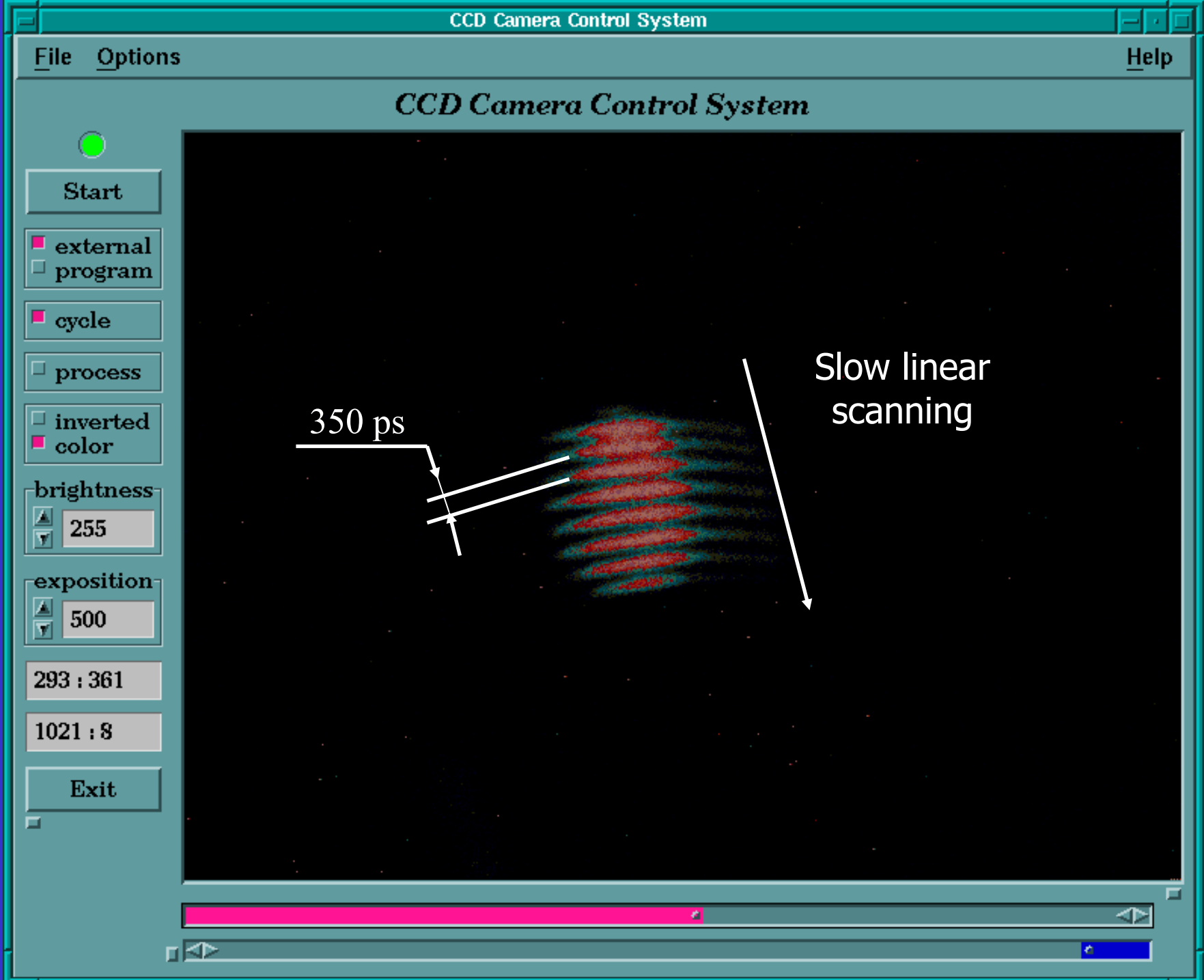
File
Options
Help
CCD Camera Control System
Start
external program
cycle
process
inverted color
brightness
255
exposition
500
293 : 361
1021 : 8
Exit
20 ps
Fast elliptic scanning
The period is 350ps.


CCD Camera Control System
File
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CCD Camera Control System
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external
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brightness
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exposition
500
293 : 361
1021 : 8
Exit
350 ps
Slow linear
scanning


/export/linac/oduser/ccd/ccd 192.168.6.11
File
Options
Help
CCD Camera Control System
Start
external
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brightness
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exposition
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312 : 251
1021 : 69
Exit


/export/linac/oduser/ccd/ccd 192.168.6.11
File
Options
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CCD Camera Control System
Start
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312 : 251
1021 : 69
Exit


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CCD Camera Control System
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312 : 251
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Exit


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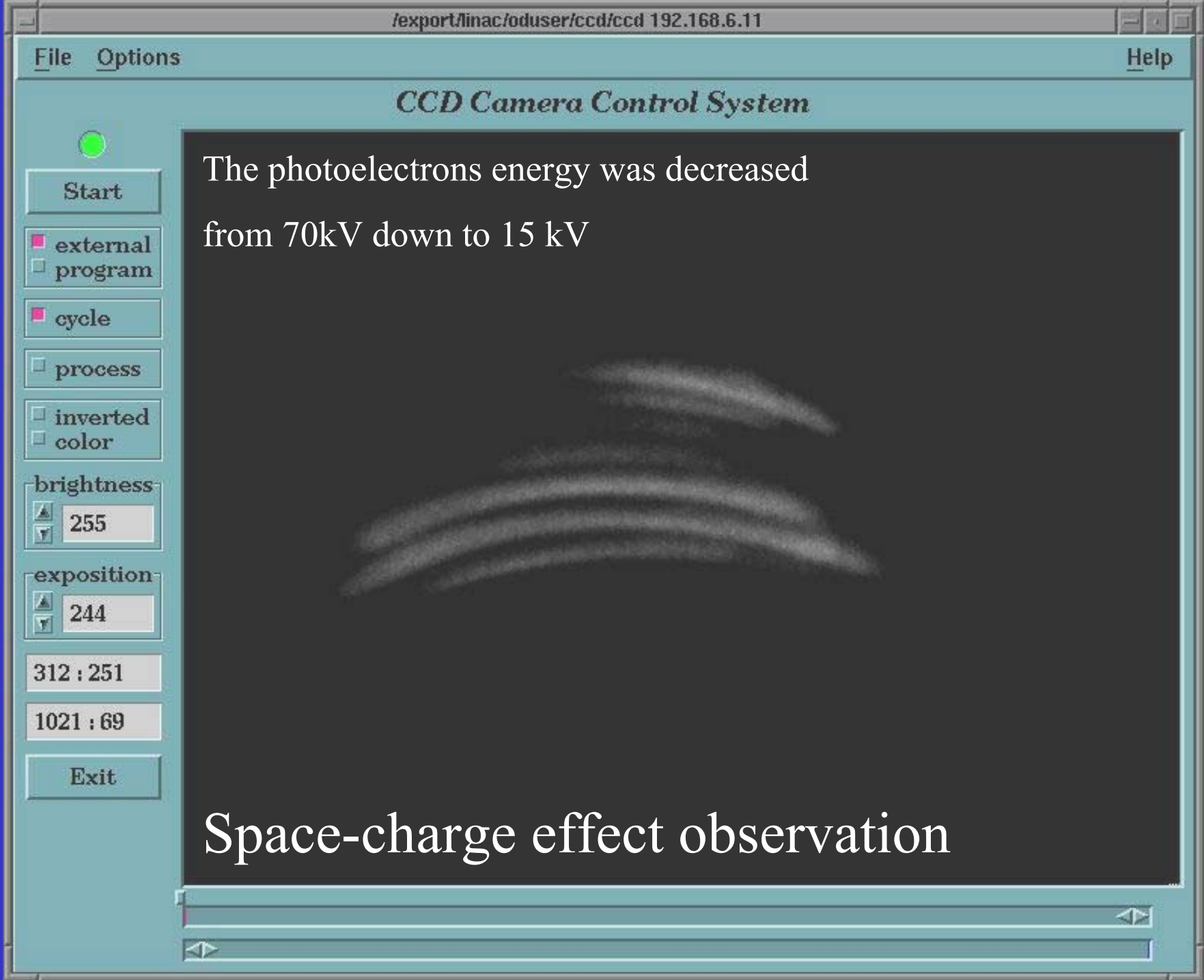
312 : 251
1021 : 69
Exit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File
Options
Help
CCD Camera Control System
Start
external
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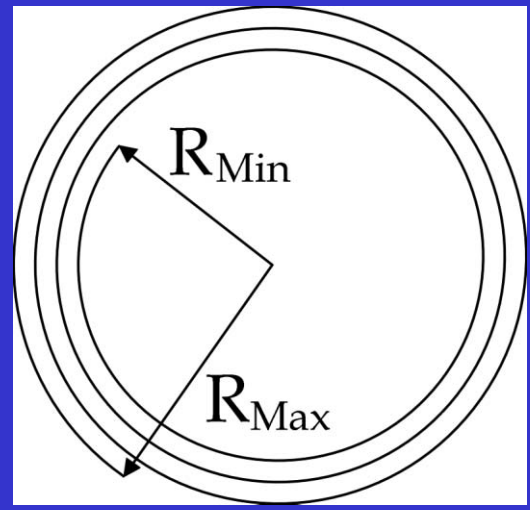
inverted
color
brightness
255
exposition
244
312 : 251
1021 : 69
Exit
The photoelectrons energy was decreased
from 70kV down to 15 kV
Space-charge effect observation

Spiral scanning.

One single light signal of several ten duration with picoseconds resolution on all duration



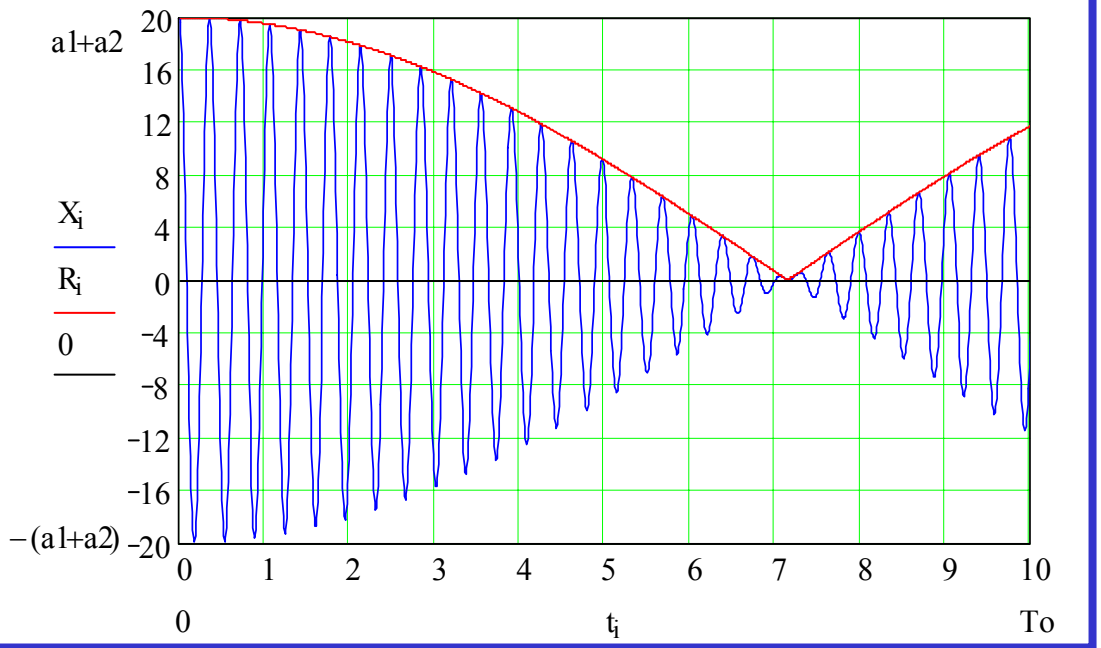
High quality RF cavity → It is not possible fast withdrawal of RF power

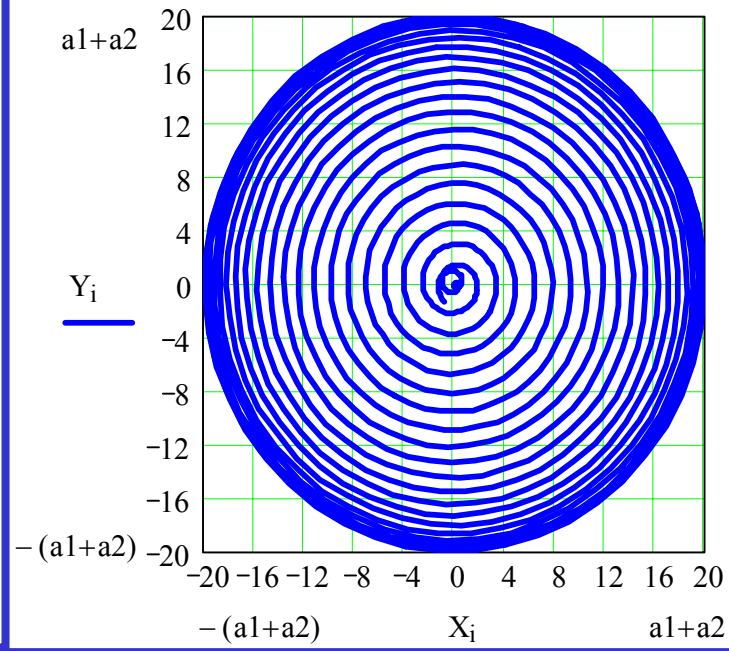
Decision:

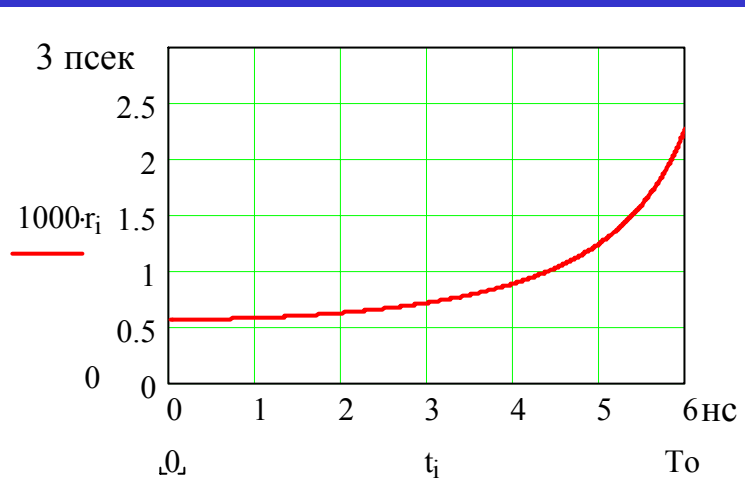
1) Two cavities with closely frequency

2) Fast withdrawal in other RF cavity with the same frequency

Two cavity with different frequency.





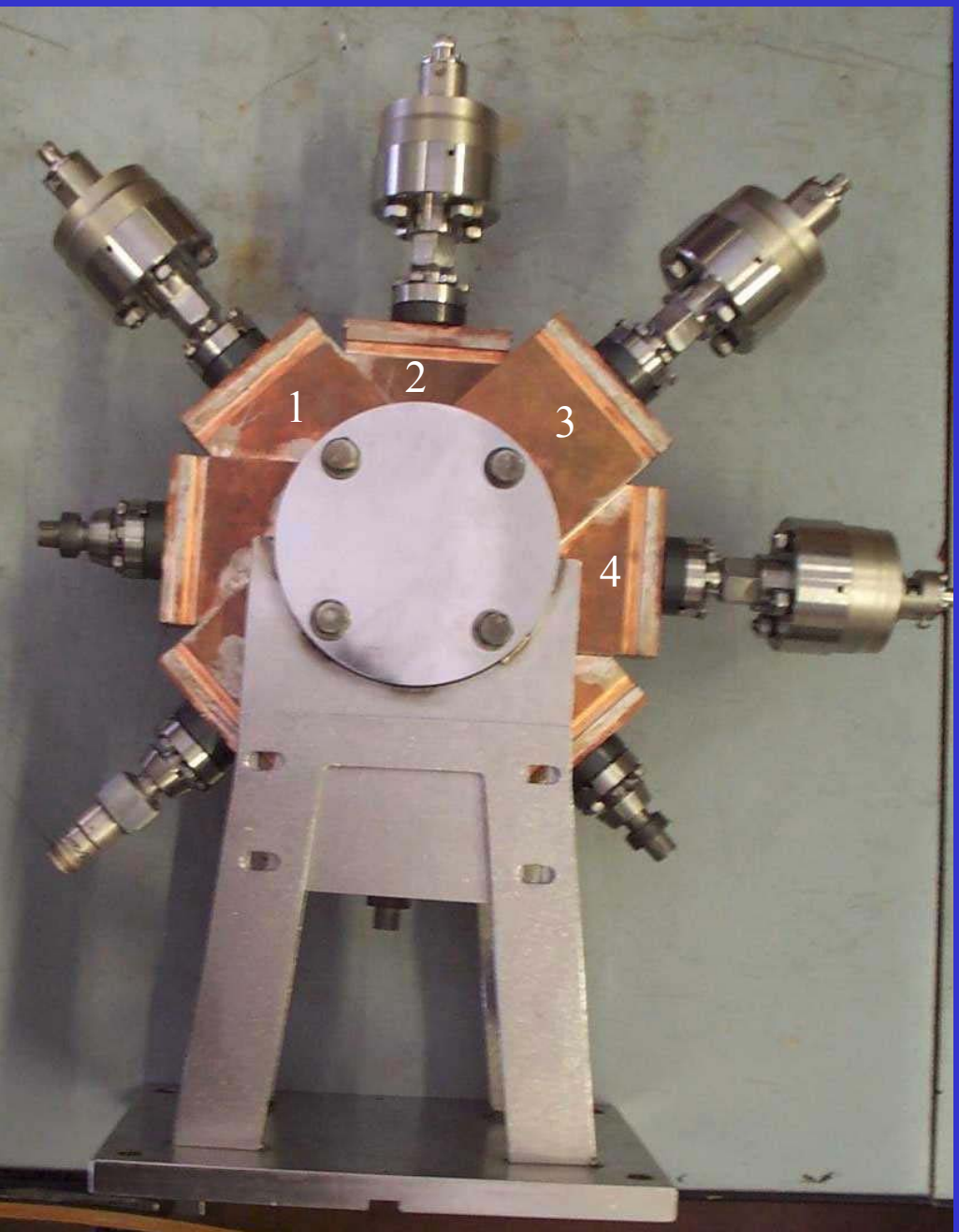


$$X_i := a1 \cdot \cos(\omega 1 \cdot t_i) + a2 \cdot \cos(\omega 2 \cdot t_i)$$

$$Y_i := a1 \cdot \sin(\omega 1 \cdot t_i) + a2 \cdot \sin(\omega 2 \cdot t_i)$$

$$R_i := \sqrt{(X_i)^2 + (Y_i)^2} \qquad r_i := T0 \cdot \frac{d}{2 \cdot \pi R_i}$$

Status of streak camera with spiral scanning



The assembling of 4 cavities has been produced.

$F1 = F3 = 2856 \pm 2$ МГц

$F2 = F4 = 2786 \pm 2$ МГц

$\Delta F = 70$ МГц

It is possible see one single light signal of 3 ns duration with time resolution better then 2 ps.

In this moment the production of RF amplifier on these frequencies is go on.

Thank you for attention.

Your questions, please.