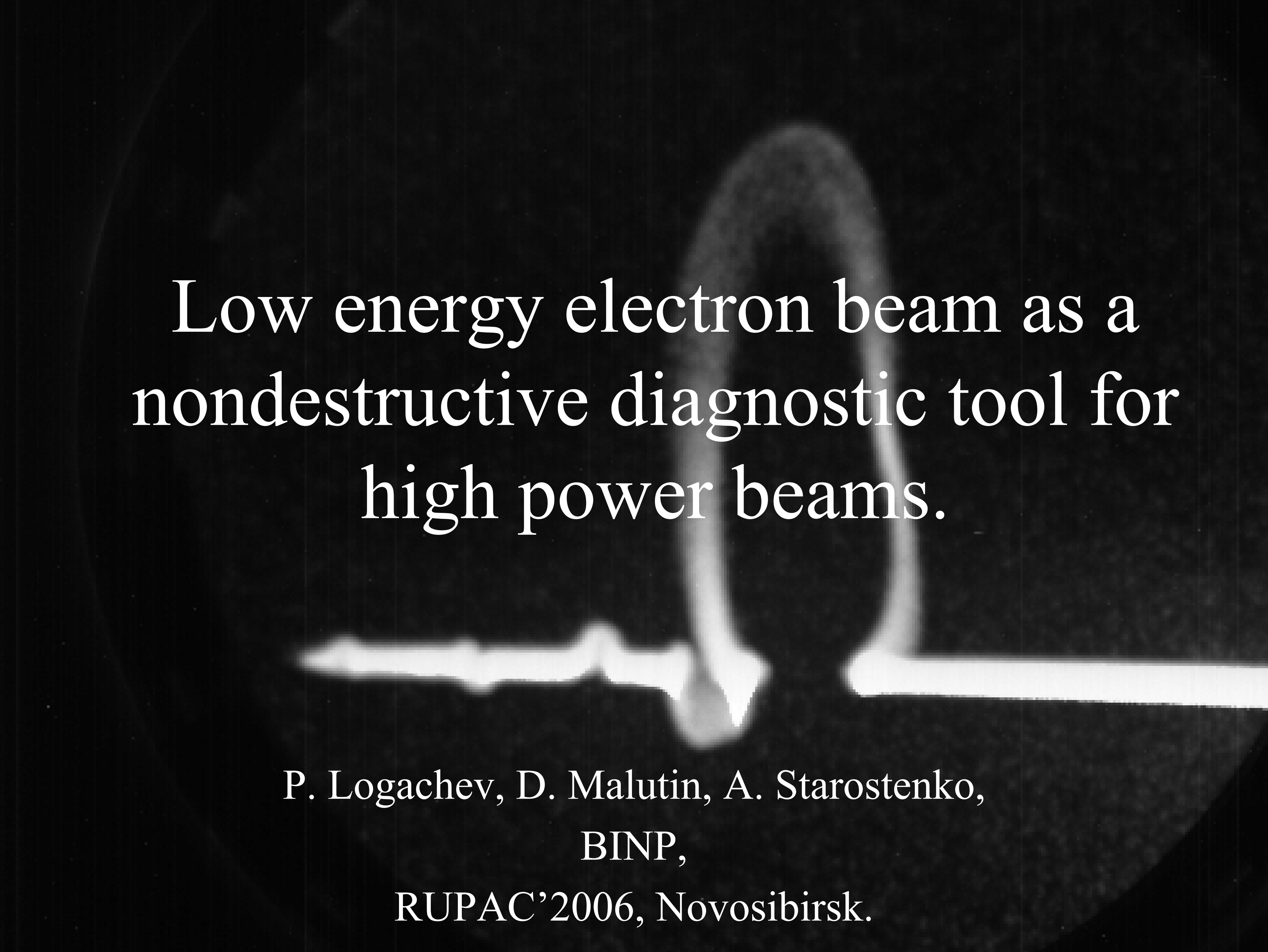
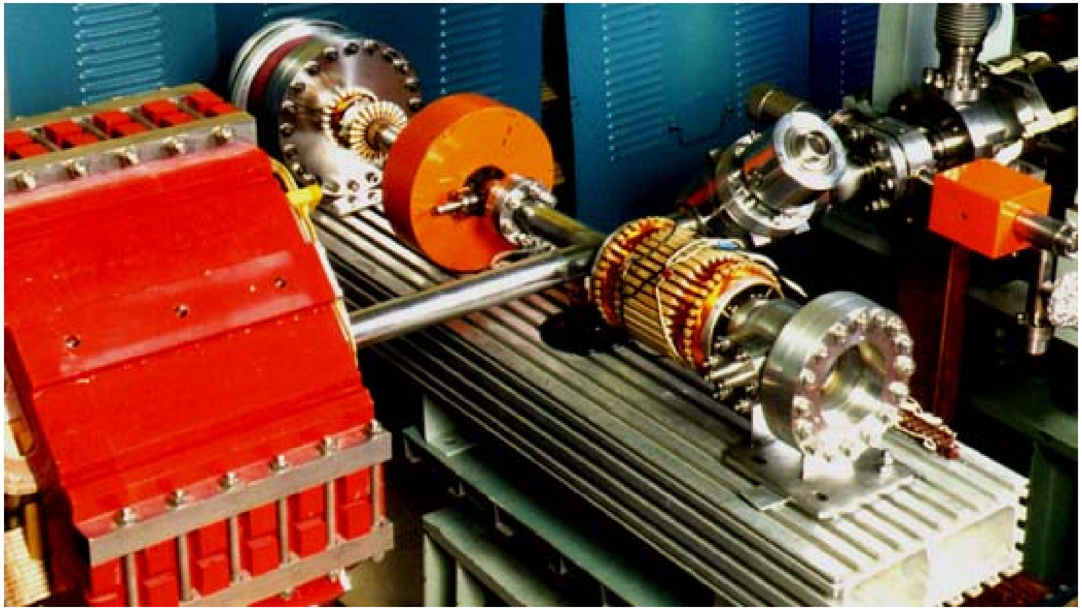


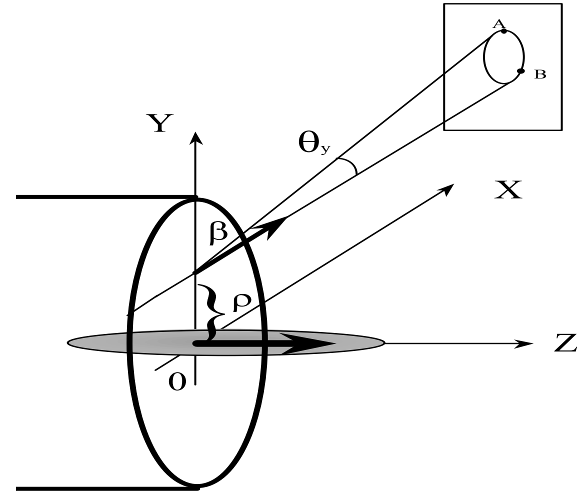
Low energy electron beam as a nondestructive diagnostic tool for high power beams.

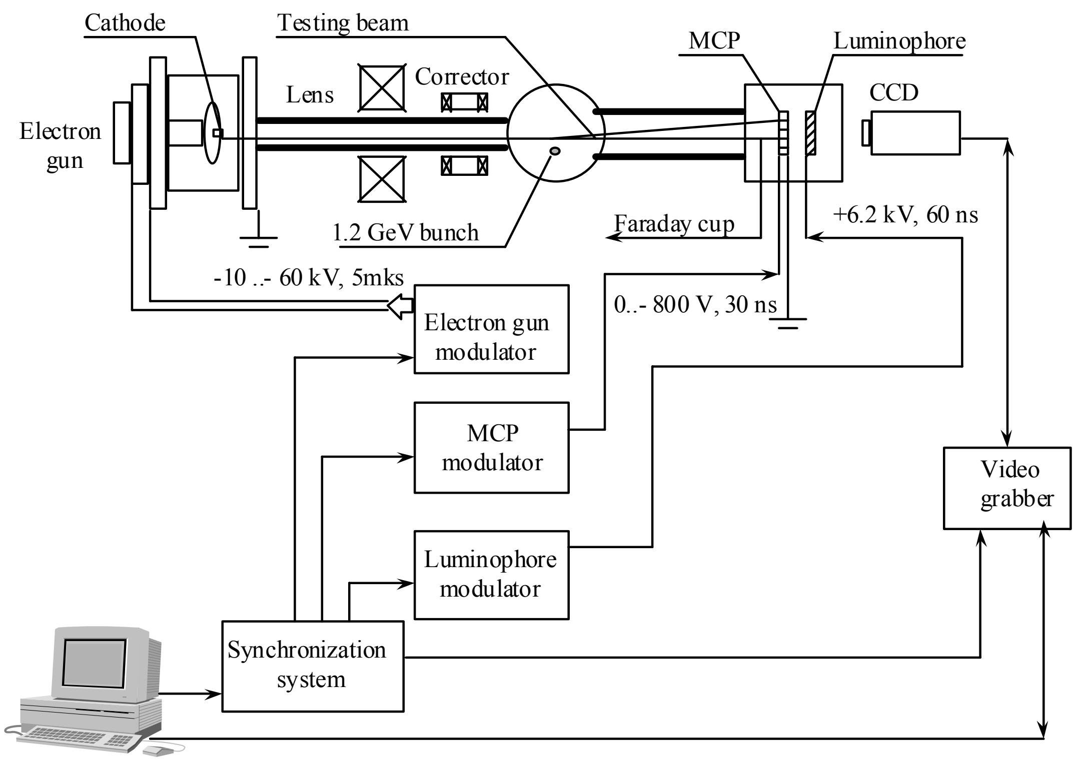
P. Logachev, D. Malutin, A. Starostenko,
BINP,
RUPAC’2006, Novosibirsk.

Electron beam probe for RF linacs.

- Beam structure monitoring.
- Wake-fields monitoring.
- Monitoring of the bunch tilt.
- Bunch-to-bunch position monitoring.







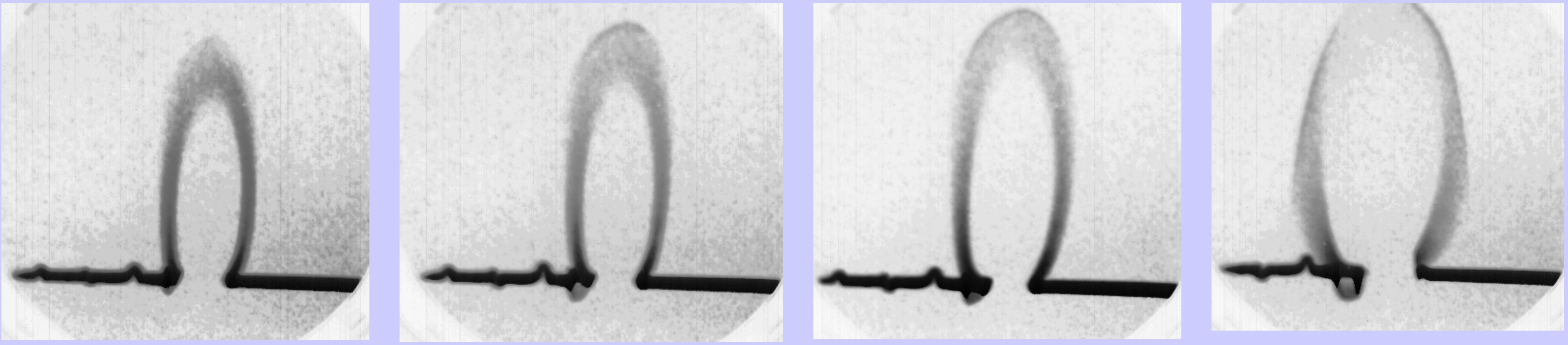
Electron Beam Probe

- basic idea
- scheme
- EBP at VEPP-5 injector linac

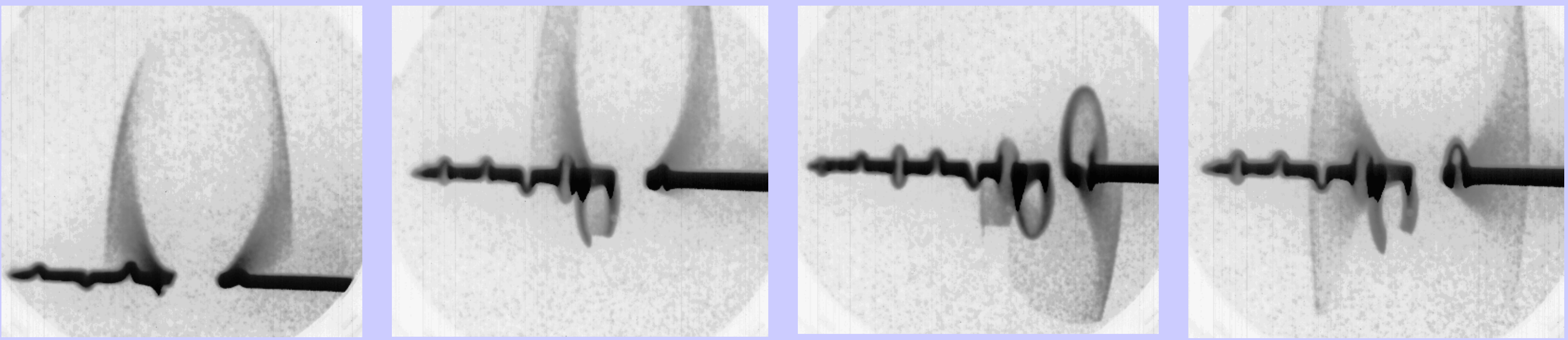
EBP is routinely used for tuning the beam at the VEPP-5 injector linac

longitudinal distribution of beam density, transverse position of its center of mass, even wake fields observation, single and multibunch regime

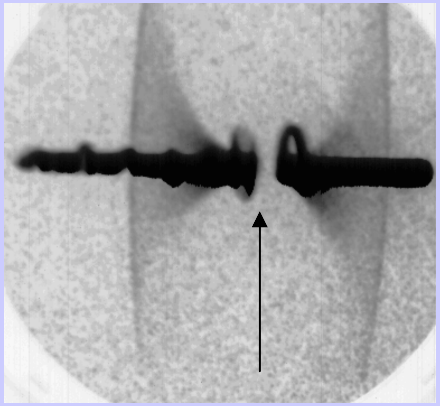
Single bunch regime



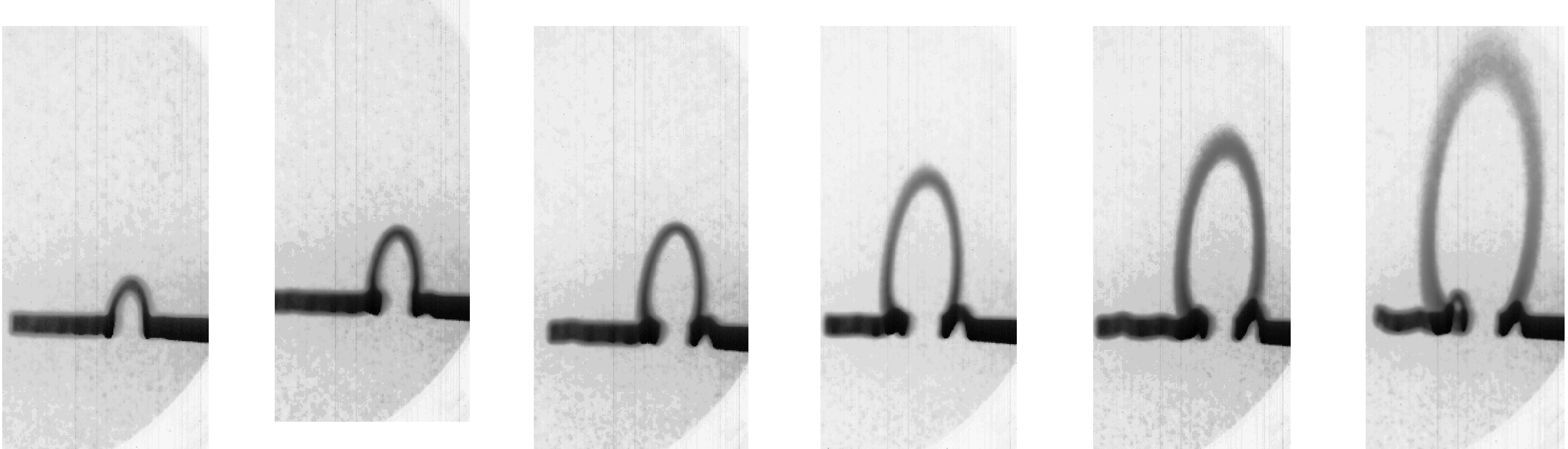
Offset parameter goes down->



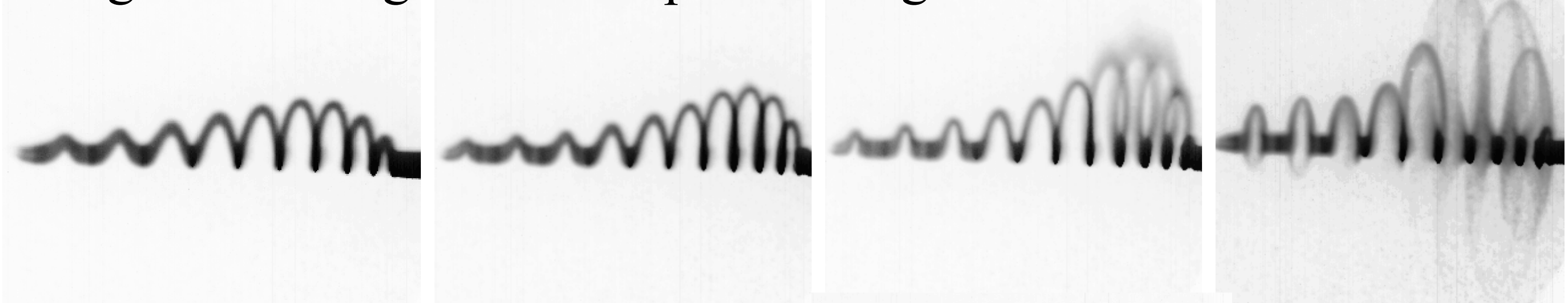
Examples of signals from EBP



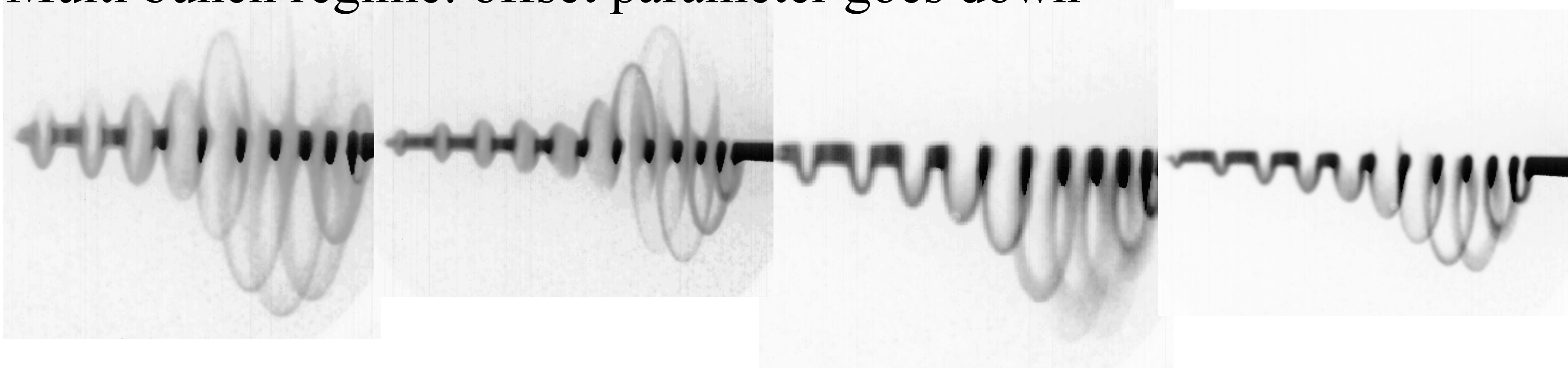
Collision with intense bunch



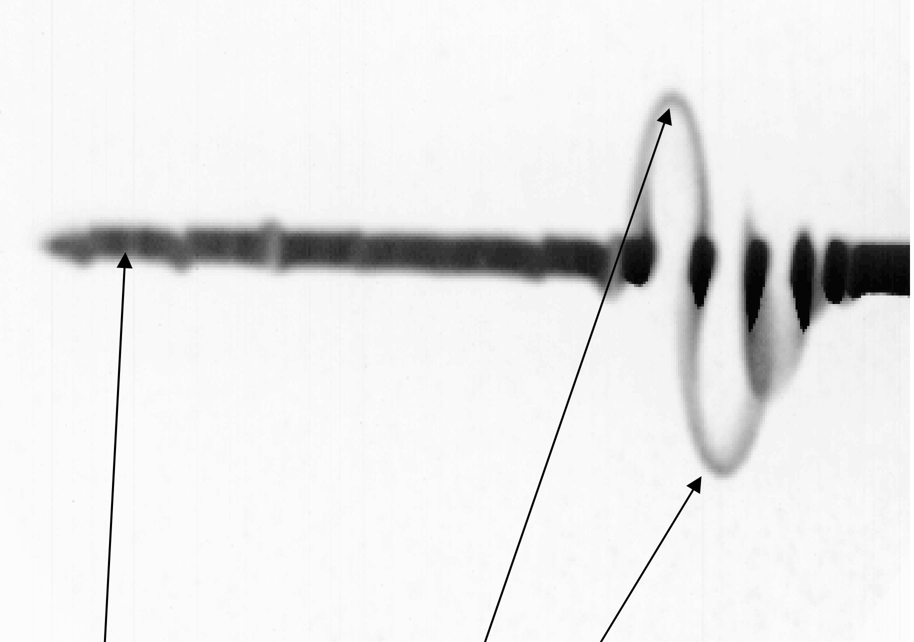
Single bunch regime: offset parameter goes down ->

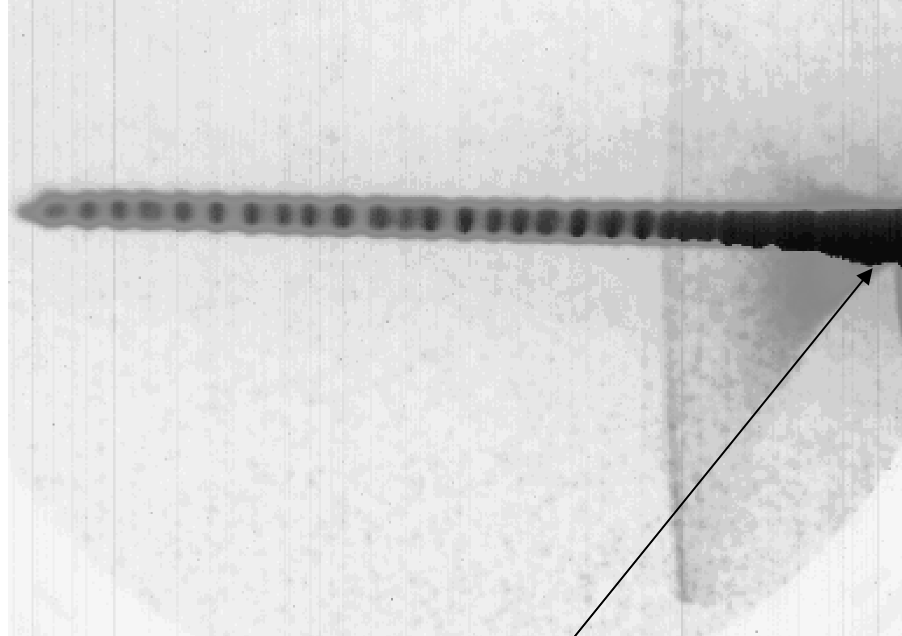


Multi bunch regime: offset parameter goes down ->



Pictures with wakes

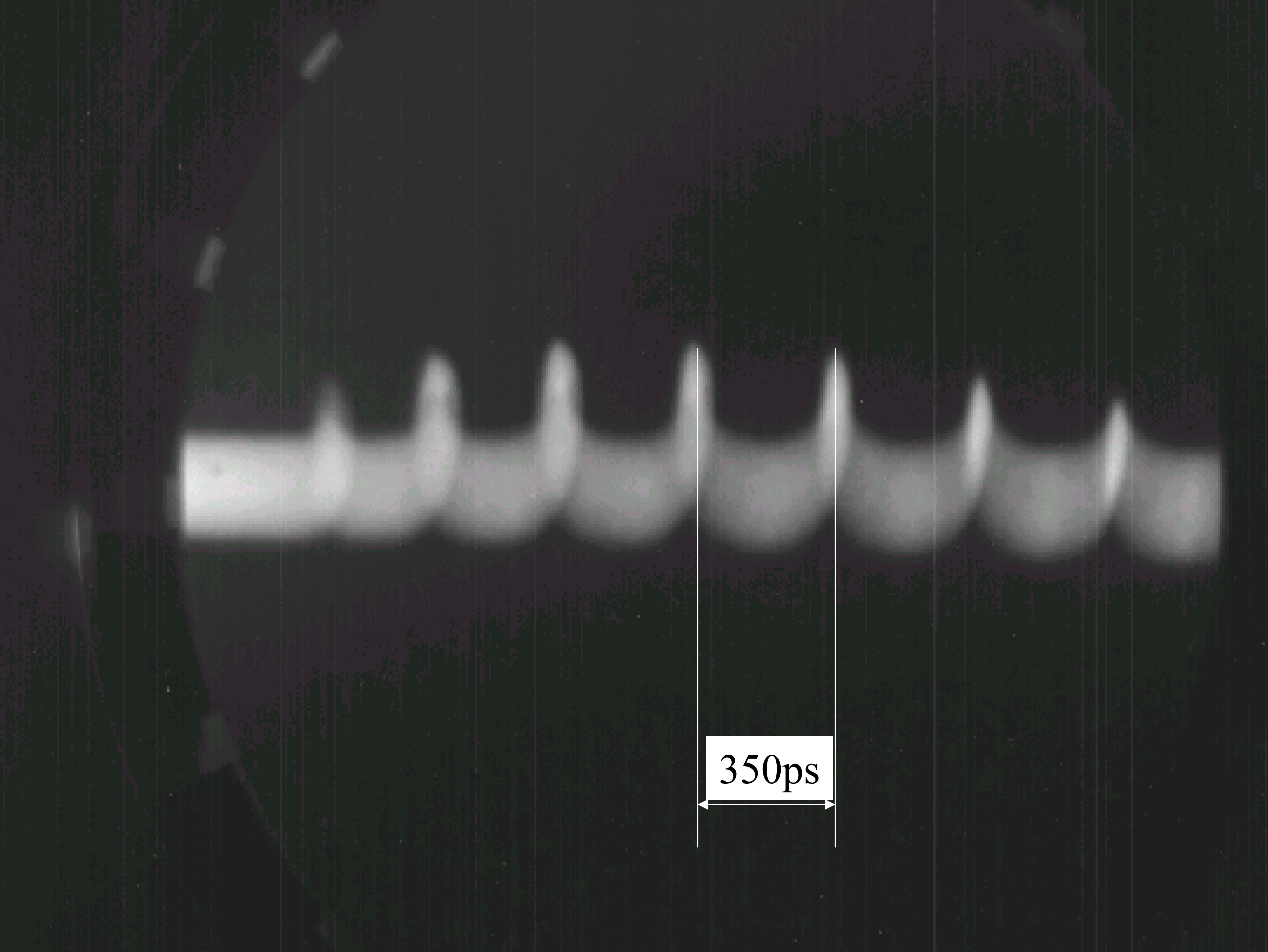


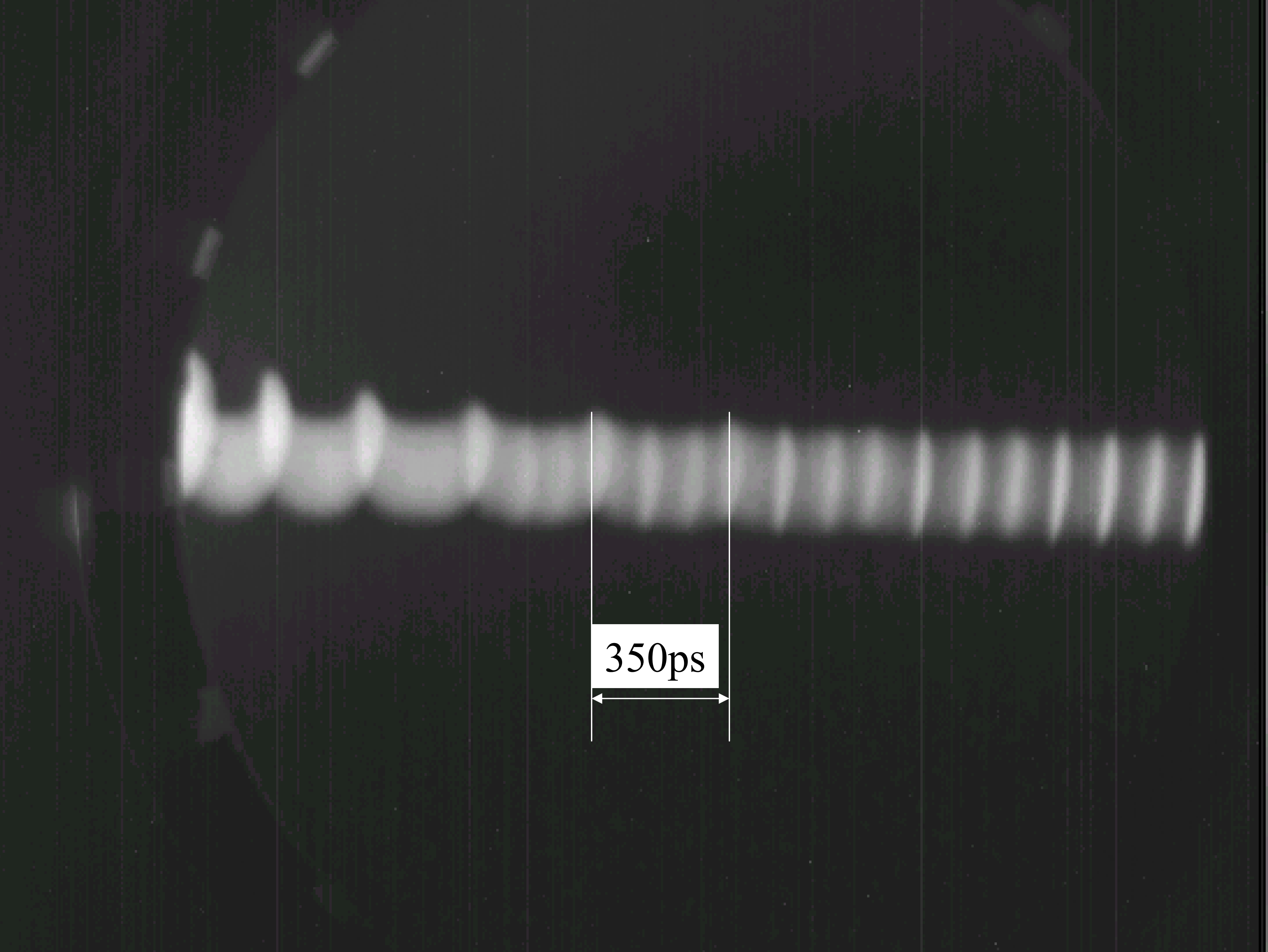


Two bunches

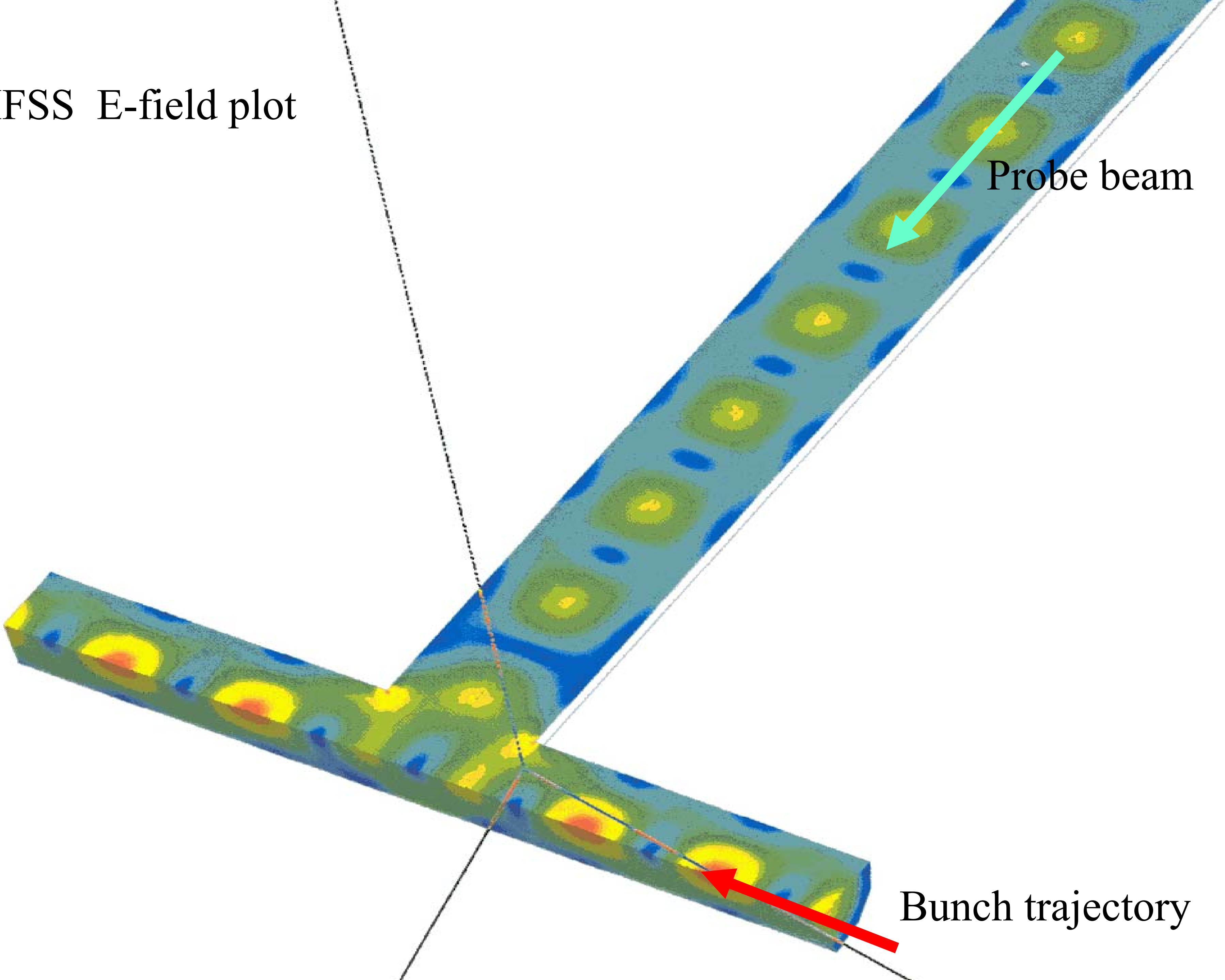
Collision with single bunch

Wakes start to appear


350ps

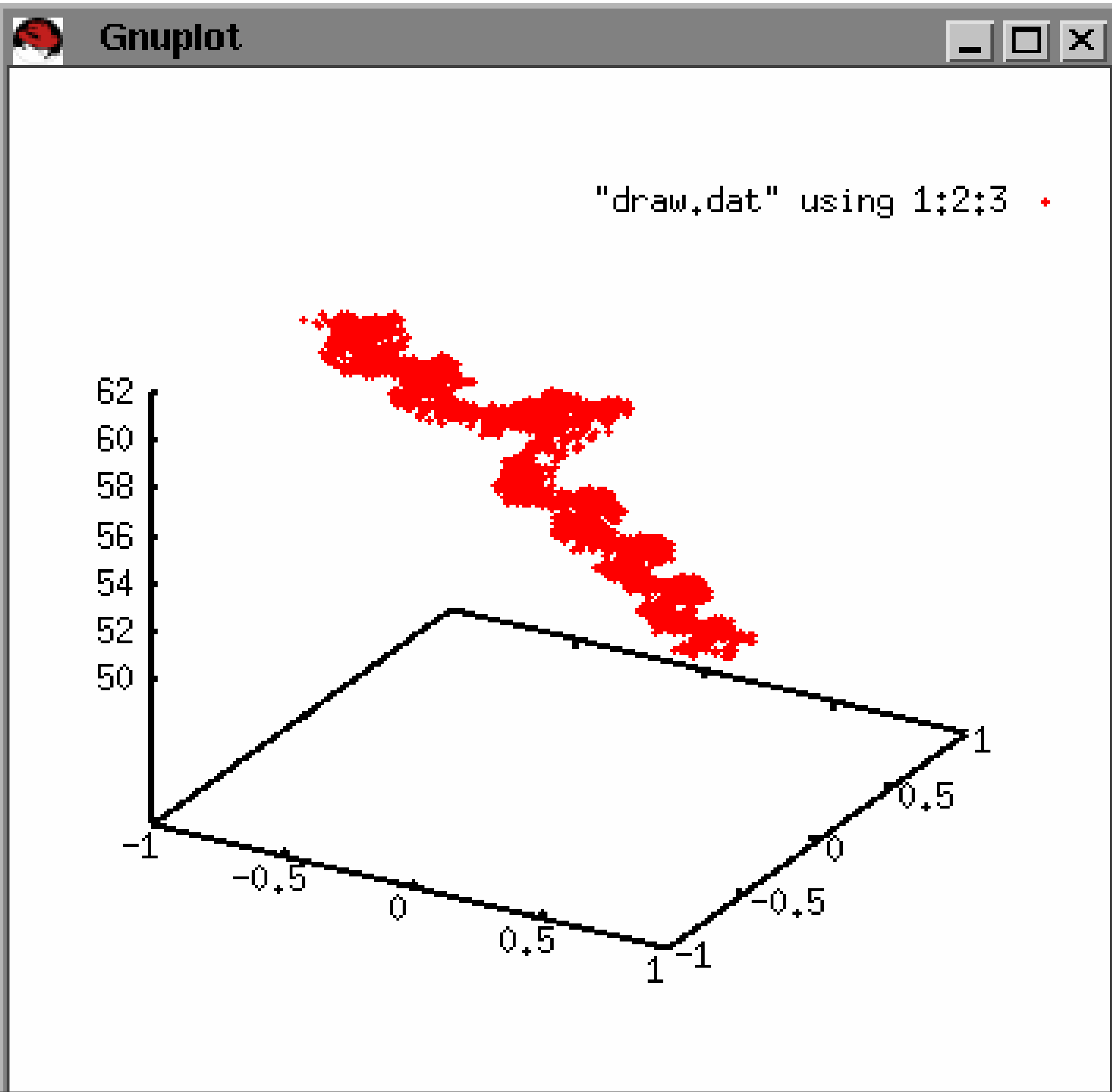

350ps

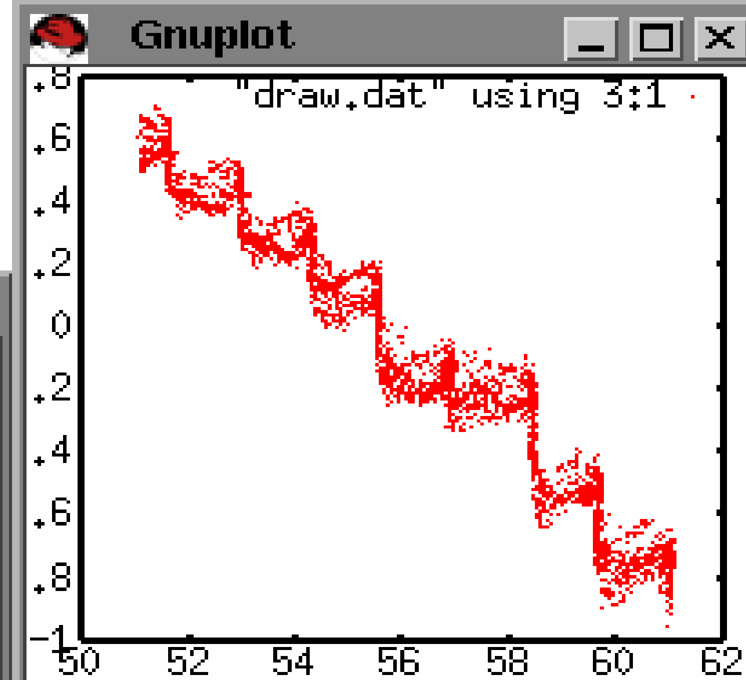
HFSS E-field plot

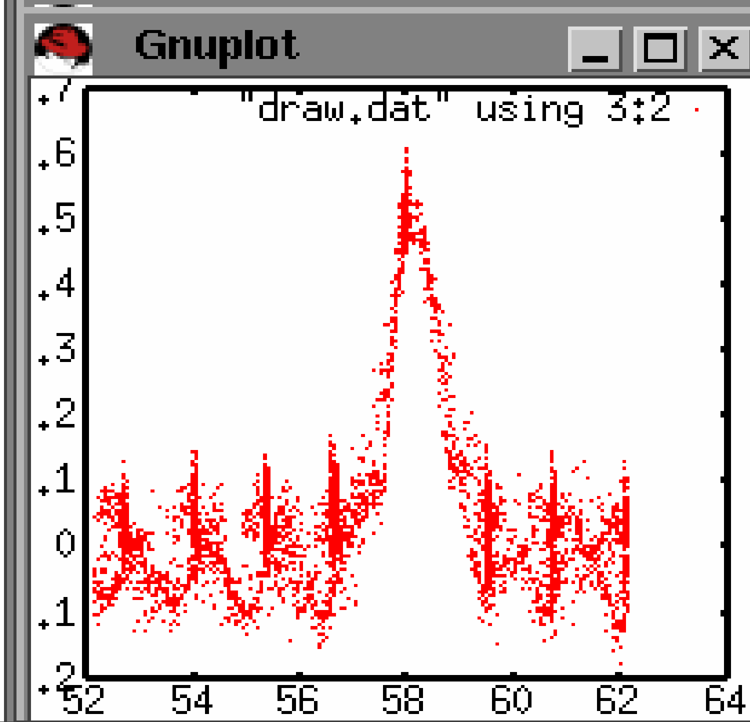


$W_{pb} = 36keV$

E wake = 0.05*E bunch

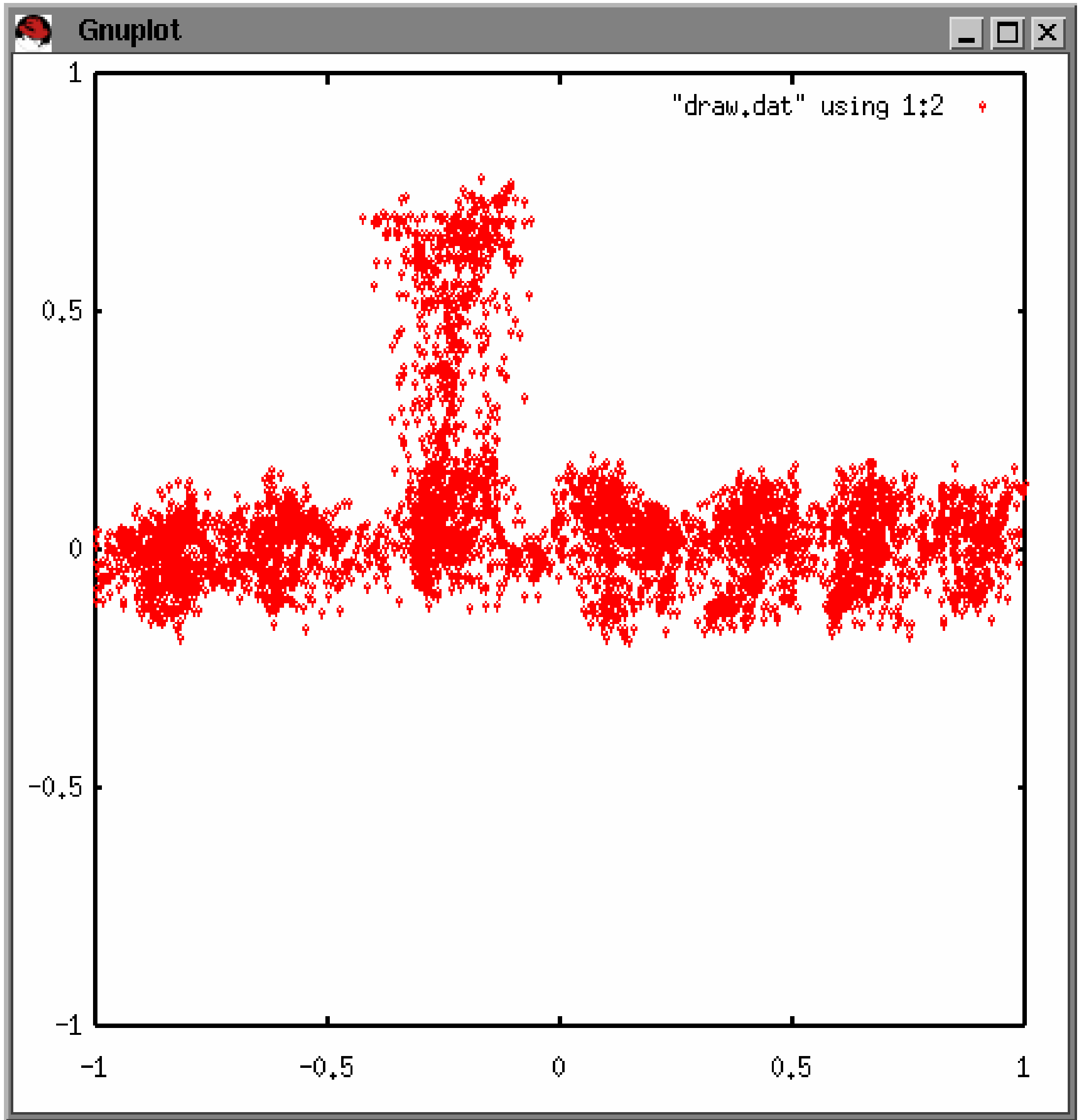


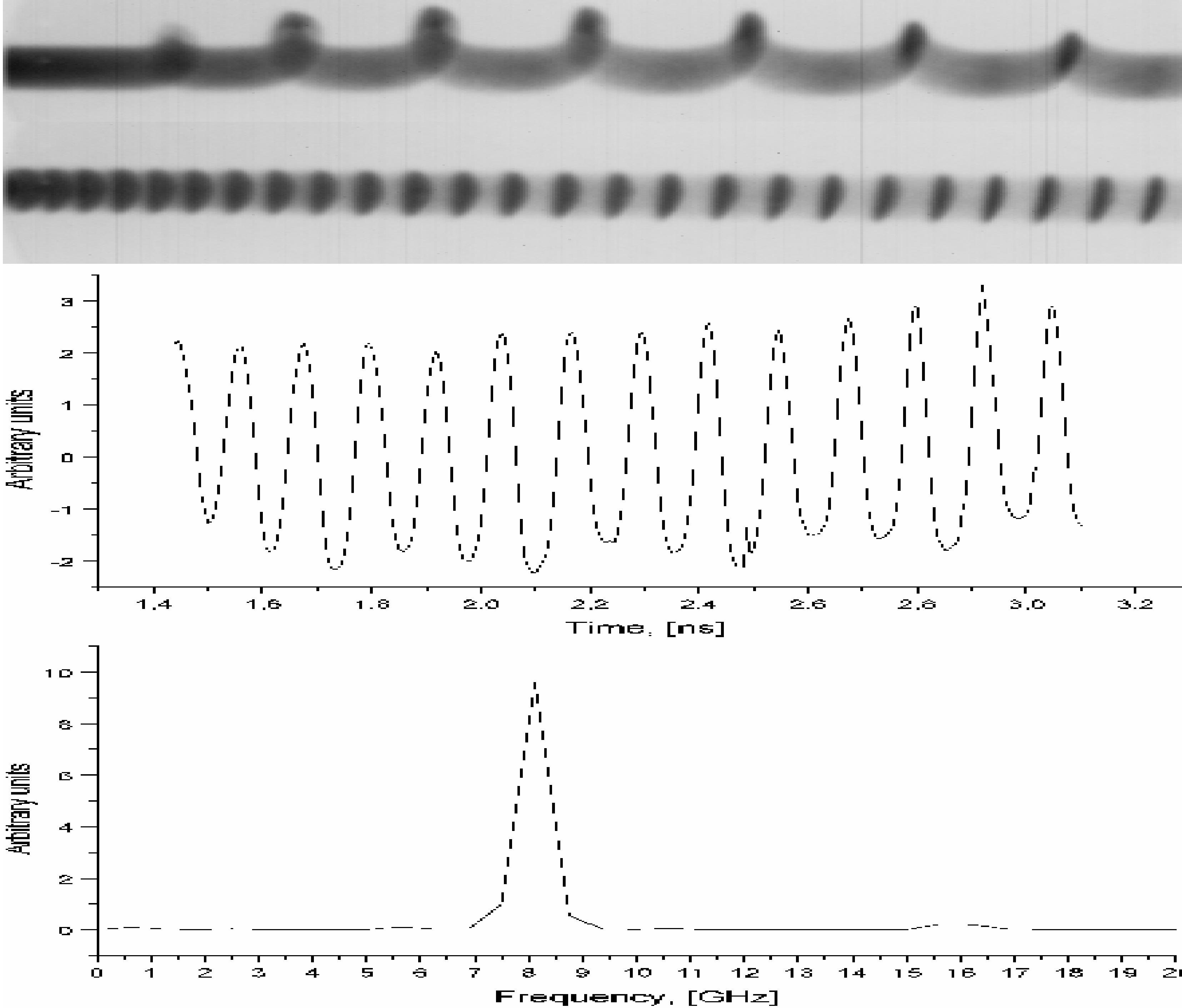




$W_{pb} = 36keV$

E wake = 0.05*E bunch,   E bunch = 50 kV/cm.



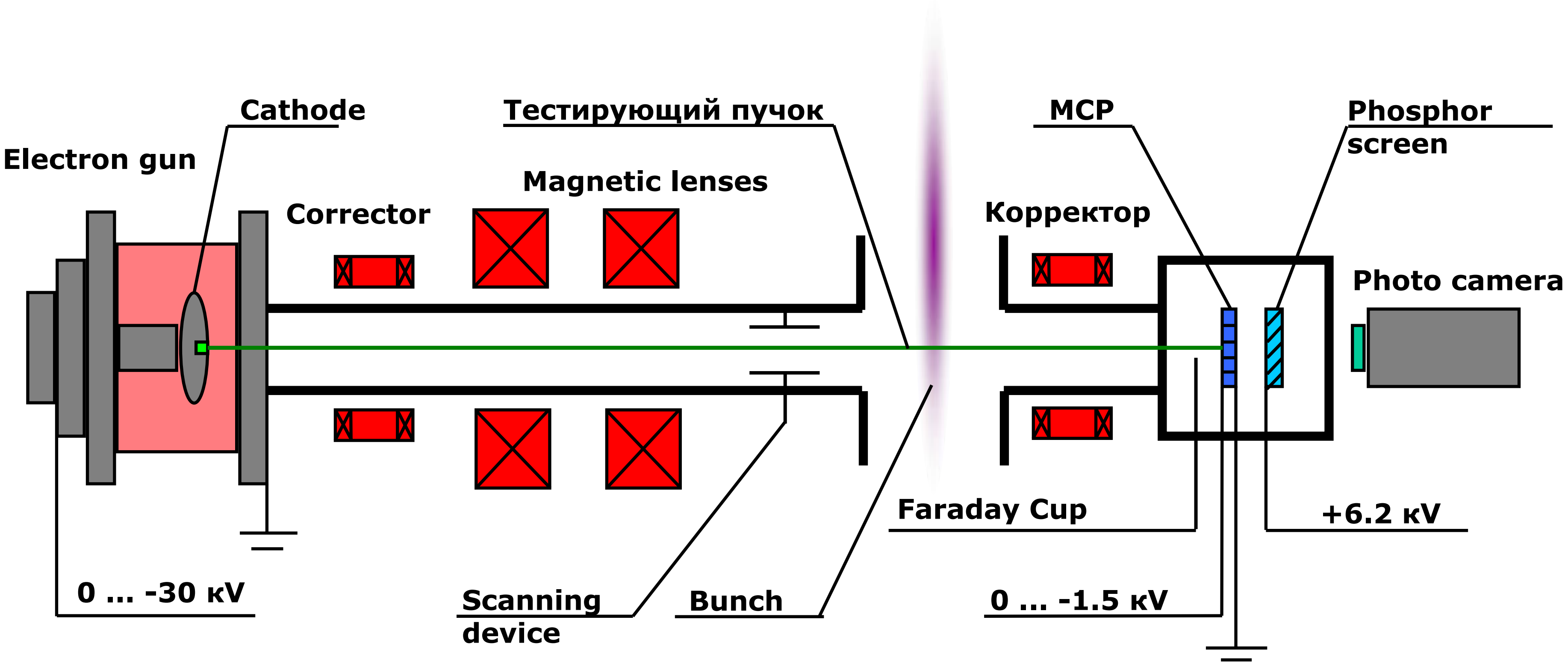


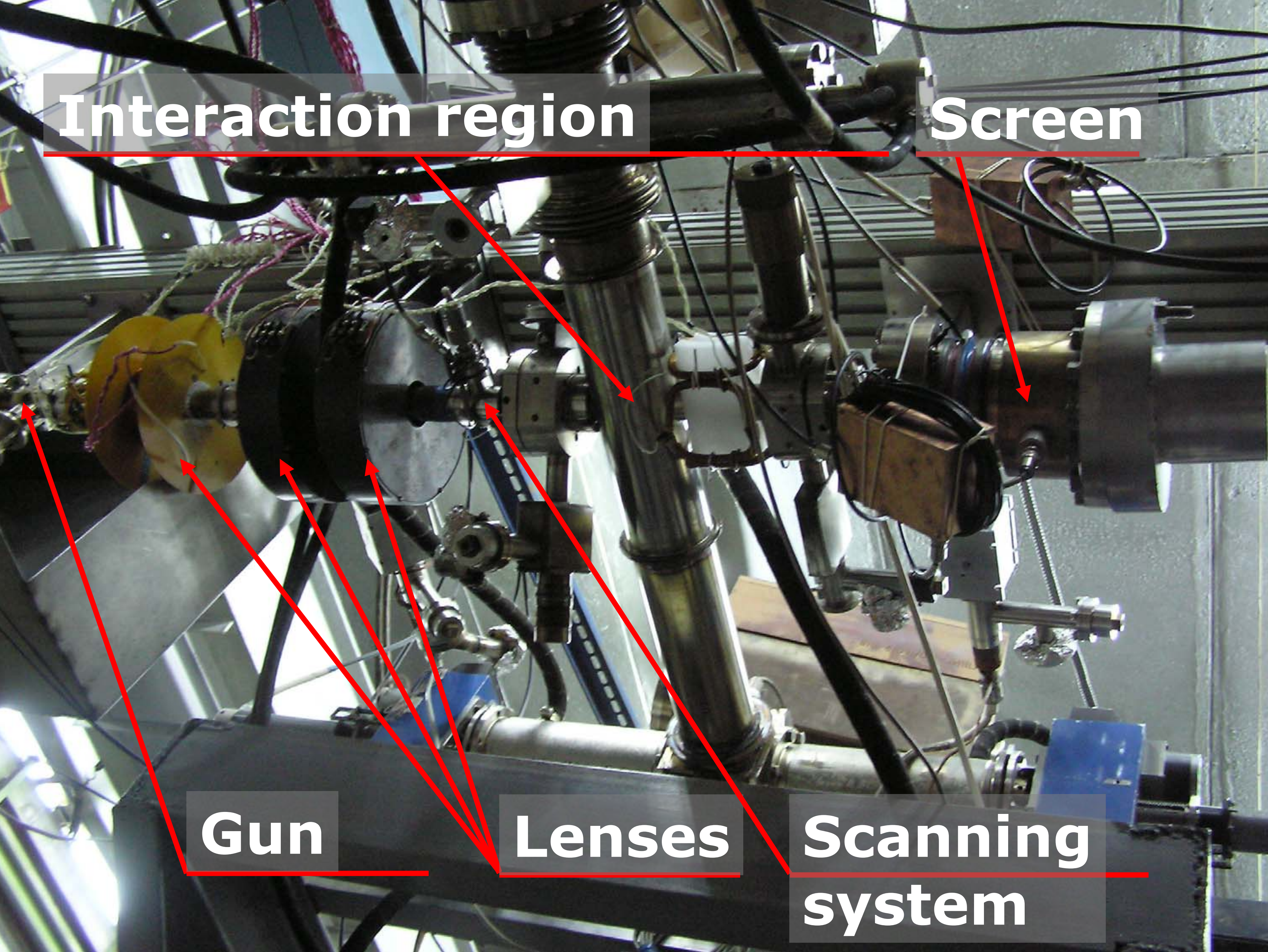
Arbitrary units
3
2
1
0
-1
-2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
Time, [ns]
Arbitrary units
10
8
6
4
2
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Frequency, [GHz]

Electron beam probe for circular collider.

- Bunch length measurement.
- Bunch position monitor.
- Measurement of bunch tilt.

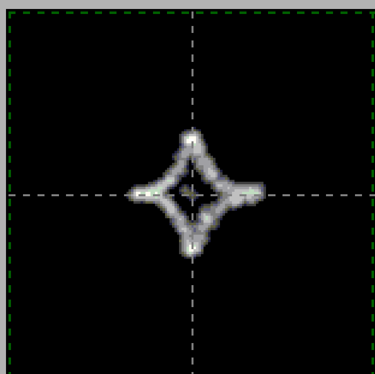
Scheme of VEPP-4 electron beam probe.



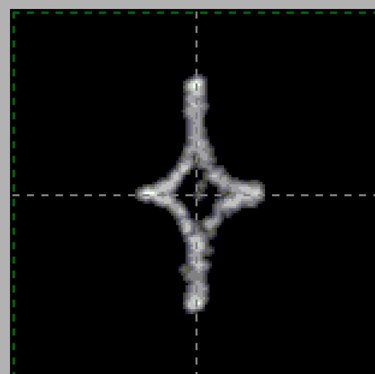

Interaction region
Screen
Gun
Lenses
Scanning system

Simulation for VEPP-4

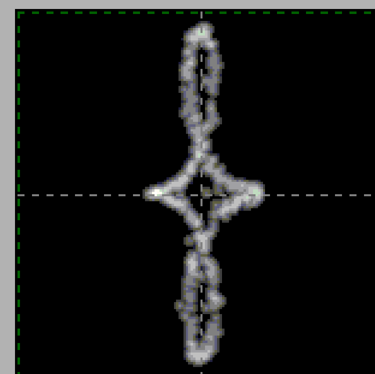
Longitudinal bunch sigma - 4 cm, transverse bunch sigma - 0.001см.



$Ne=7{,}6\cdot10^9$



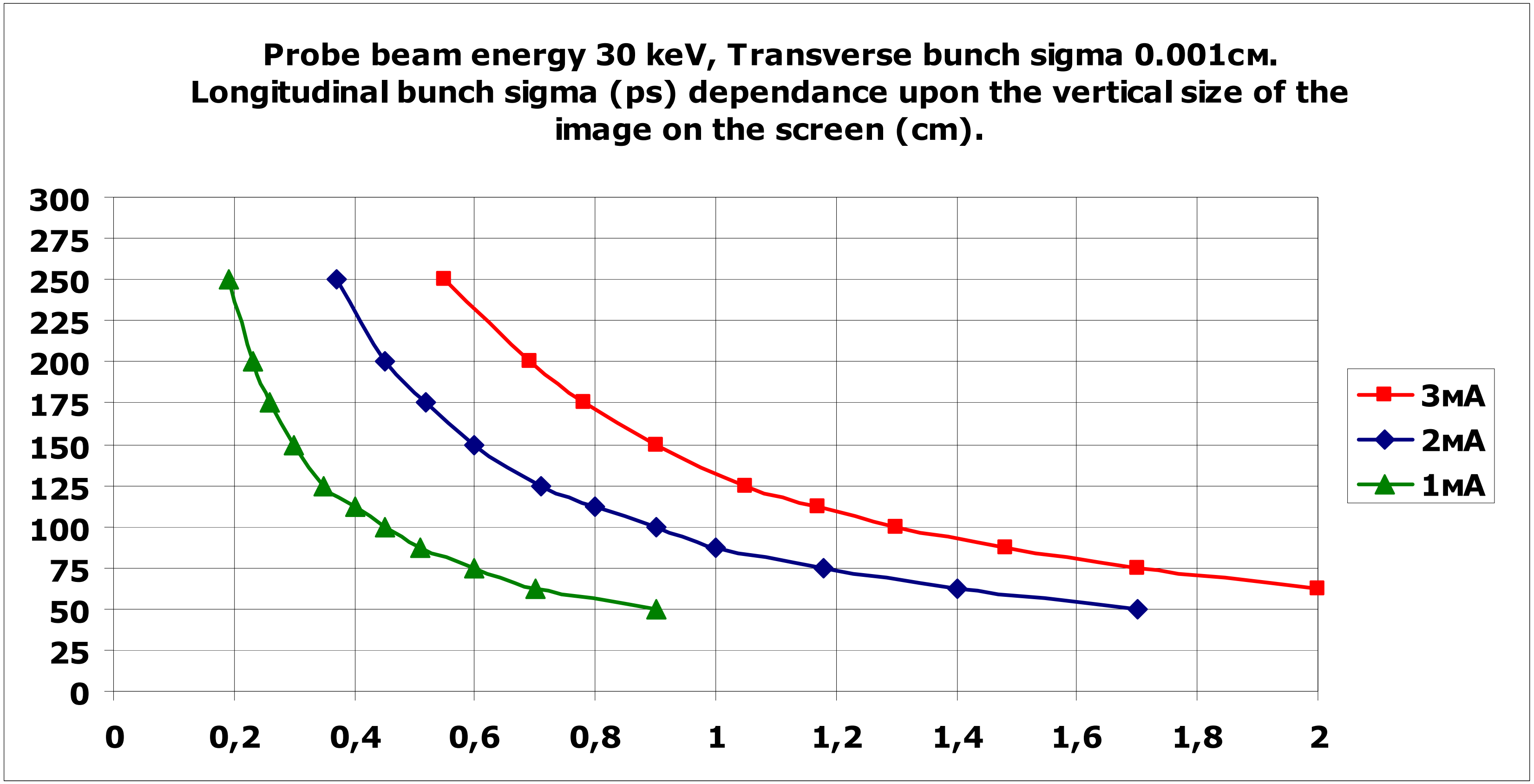
$Ne=14{,}2\cdot10^9$



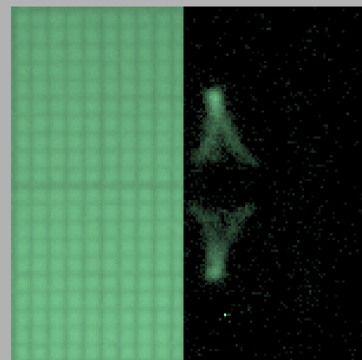
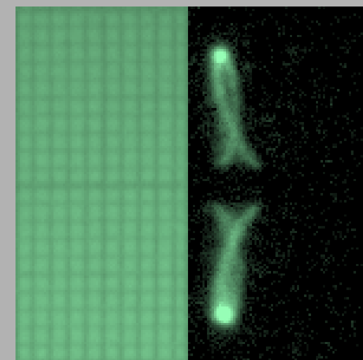
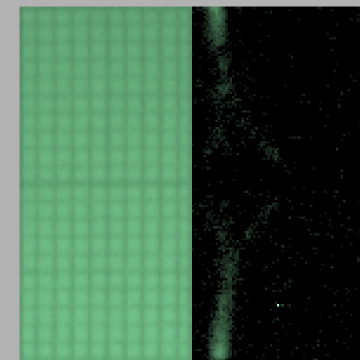
$Ne=22{,}8\cdot10^9$

Screen size 2x2 cm.

Simulation results



Experimental results from VEPP-4

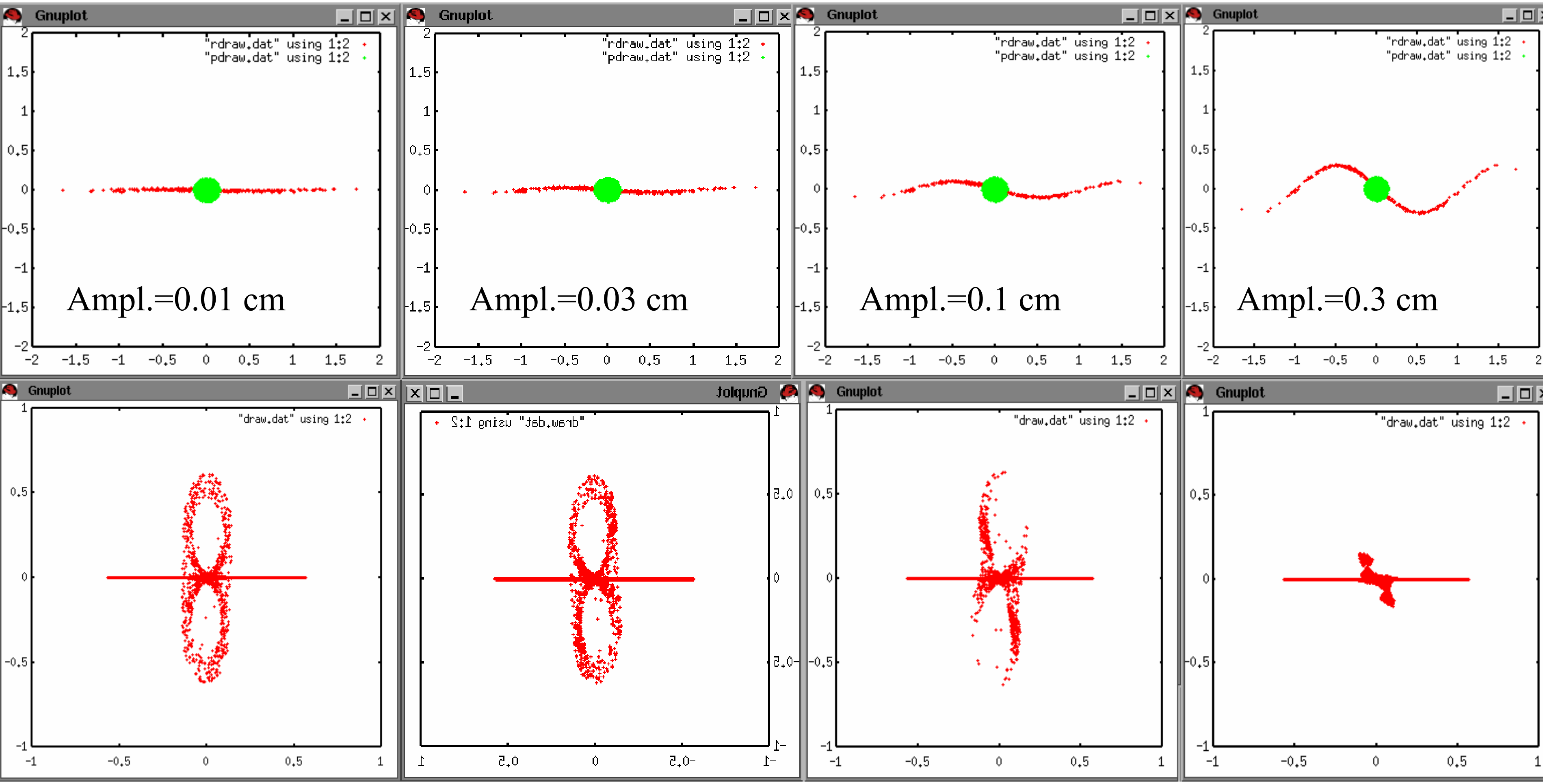
Image on the screen			
Number of e^- in the bunch	$7{,}6 \cdot 10^9$	$14{,}2 \cdot 10^9$	$22{,}8 \cdot 10^9$
Vertical size of the loop	0.5 см	0.8 см	1.0 см
Bunch current duration	87.5 ps	110 ps	130 ps
Bunch length	2.6 см	3.3 см	3.9 см

Electron Beam Probe
for nondestructive diagnostics

of the ILC bunch tilt

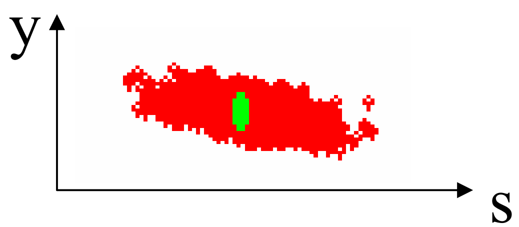
for better control of the
ILC beam emittance

Comparisons with simulations help to understand EBP signal



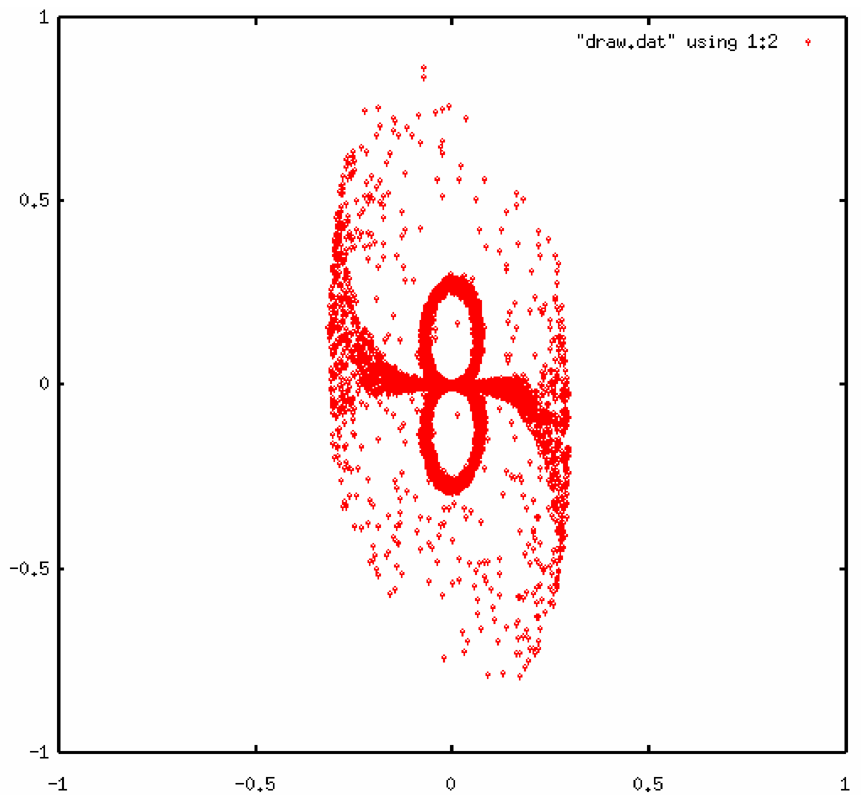
$$\sigma_l = 6mm \quad \sigma_r = 0.1mm \quad N_e = 3.0 \cdot 10^9 \quad W_{pb} = 50keV$$

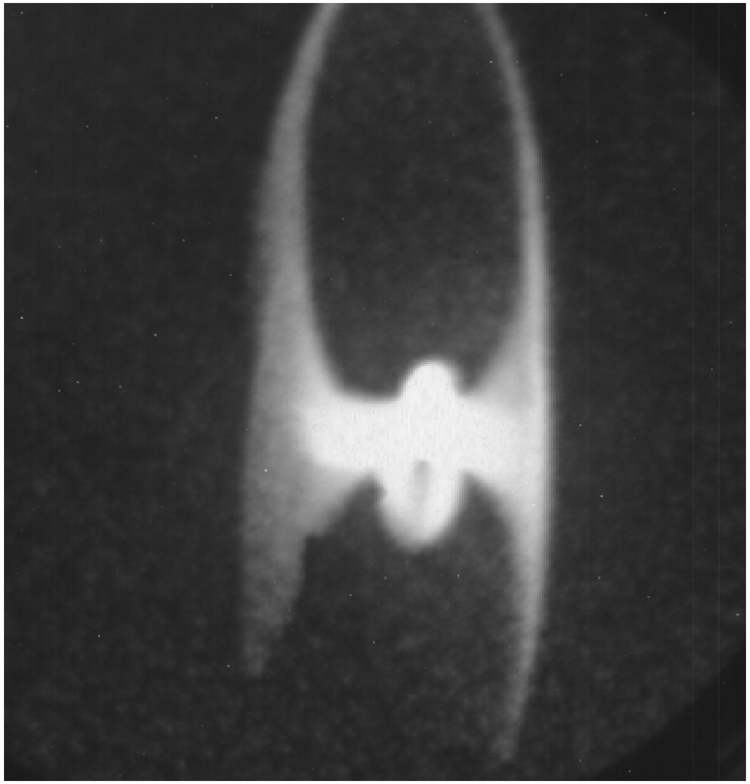
Tilt in the ILC beam



will result in asymmetry

which is easy to measure or to minimize





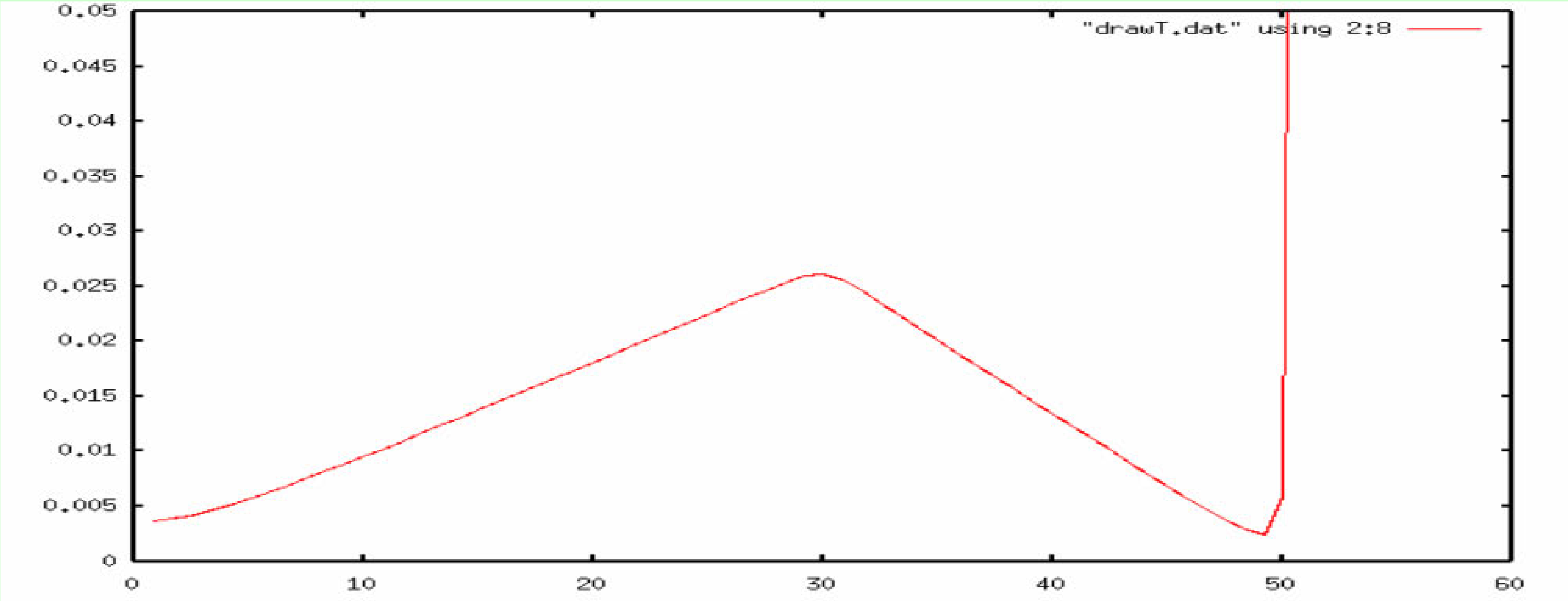
EBP simulation assumptions for ILC

Pulsed current density in 200 kV electron gun is about 20 A/cm^2.

Collimating diaphragm diameter of 0.1 mm => about 2 mA of probe beam current.

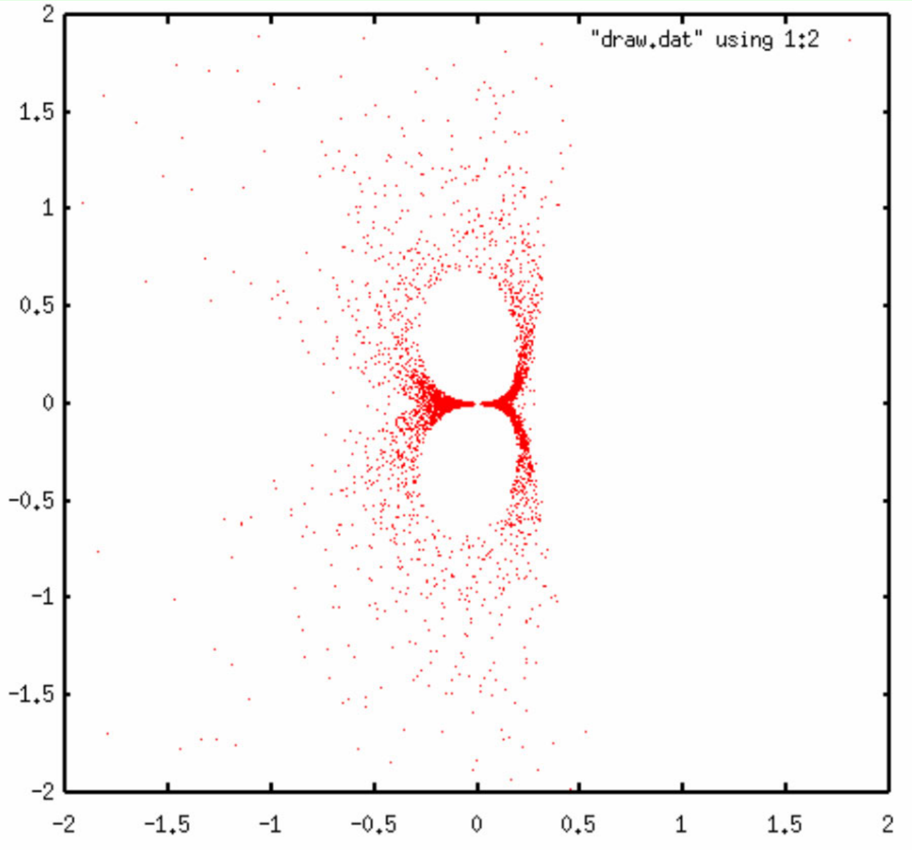
It gives for 0.1 mm ILC bunch length (0.5 ps at v=0.7c) 6000 electrons in the close vicinity of ILC bunch.

These electrons will form the image (MCP operates in the single electron regime).

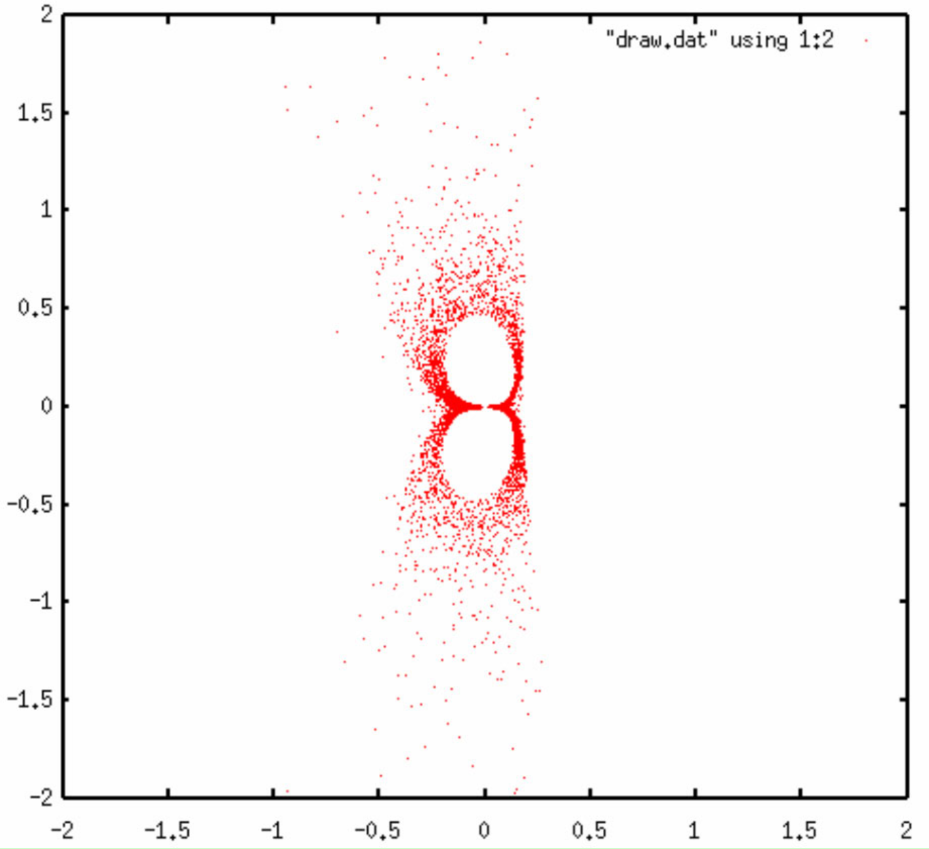


The probe beam envelope from the gun exit to the screen (horizontal axis (cm)), interaction point is placed 2 cm before the screen. The vertical axis gives the RMS transverse probe beam size in cm (probe beam is round).

EBP for ILC bunch tilt control



EBP signal, ideal bunch, no "banana" distortion



Bunch with symmetrical tilt:
bunch head up (5 microns) in Y
bunch tail down (5 microns) in Y (at 1sigma z)

The intensity asymmetry between upper left and down left branches of the loops reflects the displacement of the bunch tail.
Asymmetry in the right branches reflects the bunch head displacement.
The right down branch is more intense – it means the bunch head displaced up.

ILC bunch parameters: σ_z =0.1 mm, σ_y =1 μm, σ_x =20 μm, N =0.7*10^{10}

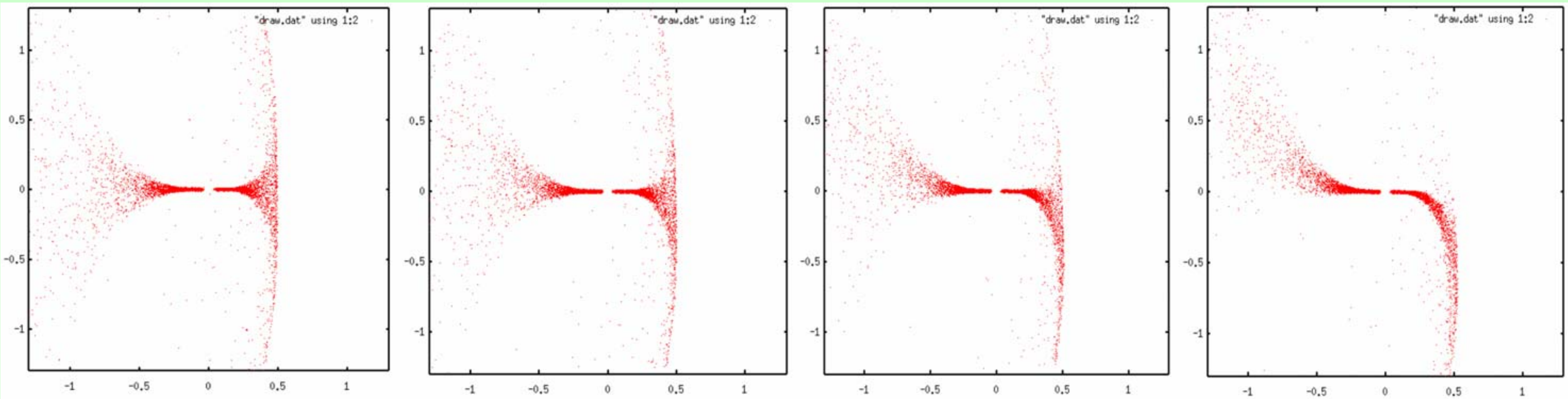
EBP: 200 keV, pulsed, beam current 2 mA, diameter at the gun exit is 0.1 mm, probe beam diameter in the interaction region is about 0.05 mm. Each dot on the screen, which paced 2 cm after the interaction point, corresponds to single electron (about 6000 electrons in the vicinity of ILC bunch).

EBP for ILC bunch tilt control

This mode of operation was successfully tested at S-band linac of VEPP-5 injector complex for the bunch length of 4 mm and 0.5mm transverse size

Simulation for typical ILC bunch parameters

δy = 1 µm **δy = 4 µm** **δy = 8 µm** **δy = 16 µm**



Screen images for increasing amplitude of the bunch tilt δy.

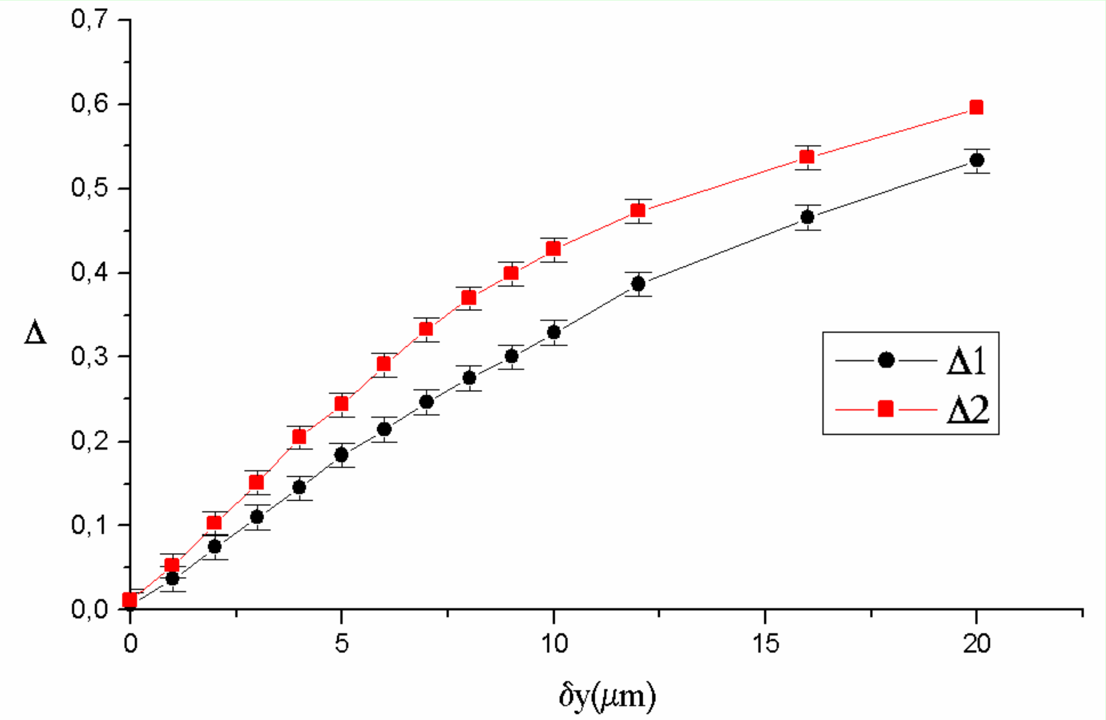
the bunch head is δy up at $+\sigma_z$ and the tail is δy down at $-\sigma_z$

The asymmetry monotonically increase with increase of beam tilt

ILC bunch parameters: $\sigma_z = 0.1$ mm, $\sigma_x = \sigma_y = 10$ µm, N $=0.7*10^{10}$

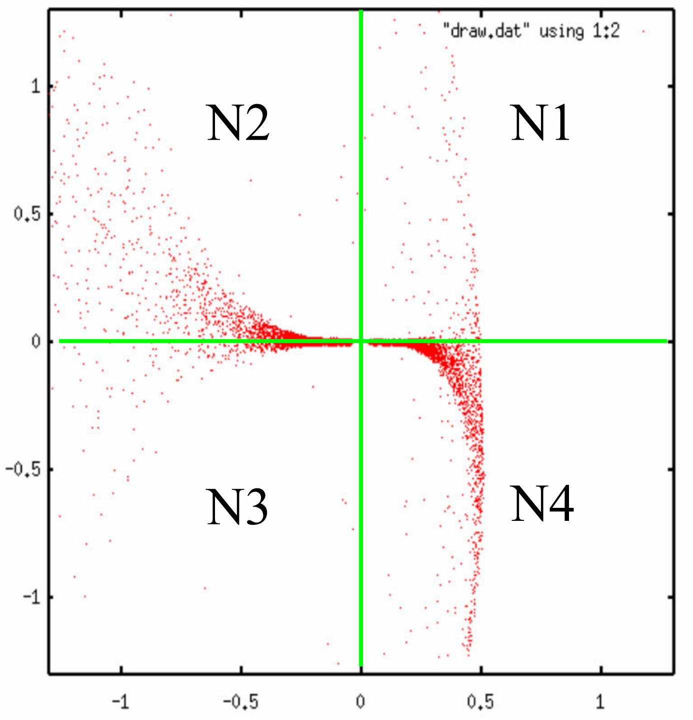
EBP: 200 keV, pulsed 2 mA, probe beam diameter in the interaction region is about 0.05 mm. About 6000 electrons in the vicinity of ILC bunch.

EBP for ILC bunch tilt control



The image asymmetry dependence on the bunch tilting amplitude

The error bars show the statistical error 1/sqrt(Nparticles), Nparticles=5000



Measure of asymmetry:

Δ1= (N4-N1)/(N4+N1)

Δ2 = (N2-N3)/(N2+N3)

In this example, the ILC single bunch tilting amplitude (or banana amplitude) can be measured starting from ~ 1 micron

ILC bunch parameters: $\sigma_z = 0.1$ mm, $\sigma_x = \sigma_y = 10$ μm, N =$0.7*10^{10}$

EBP: 200 keV, pulsed 2 mA, probe beam diameter in the interaction region is about 0.05 mm. About 6000 electrons in the vicinity of ILC bunch.

Conclusion

The EBP based bunch tilt monitor appears to be a useful tool for ILC emittance control

Suggestions:

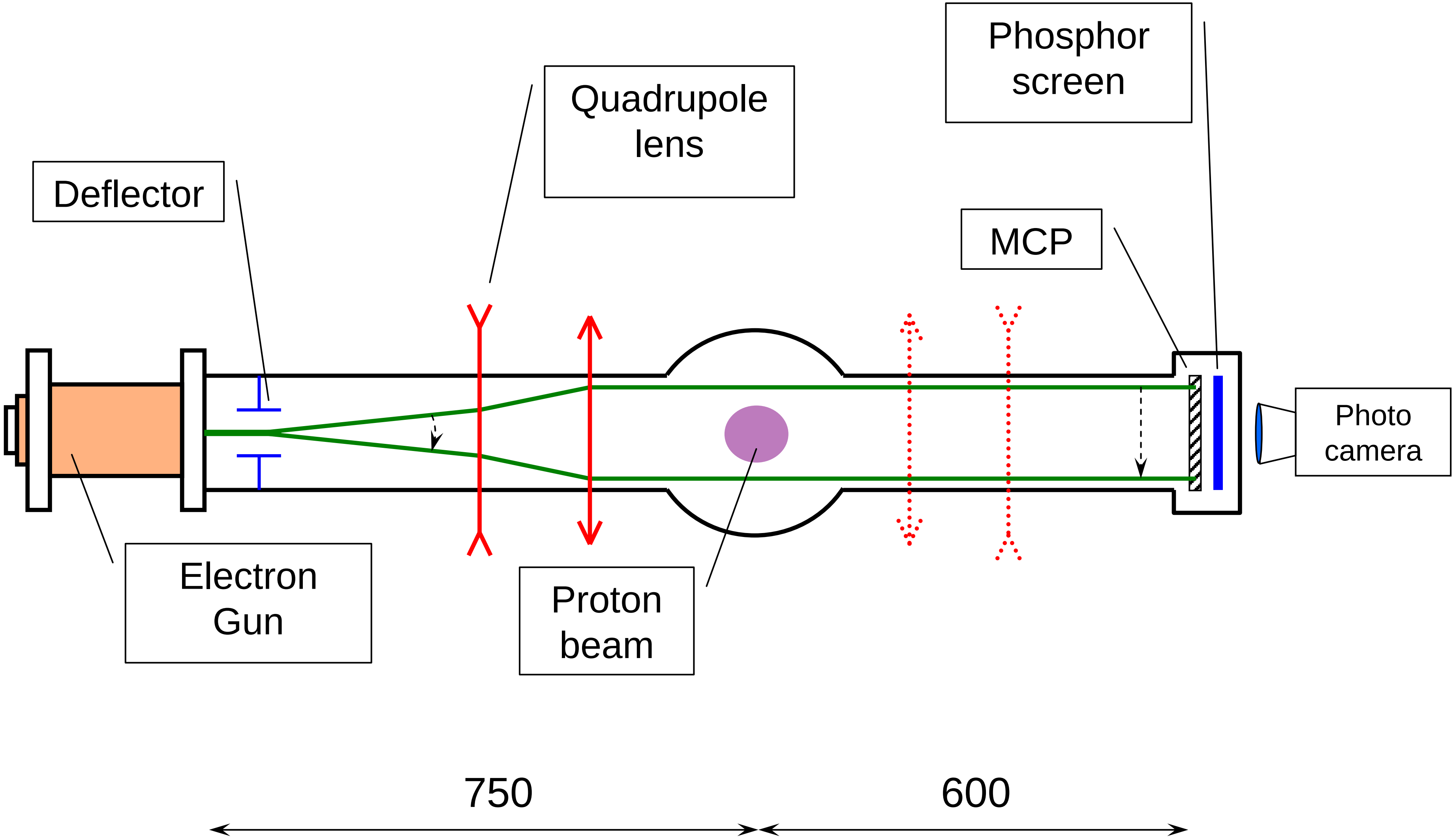
more simulation study

experimental test, e.g. at ATF

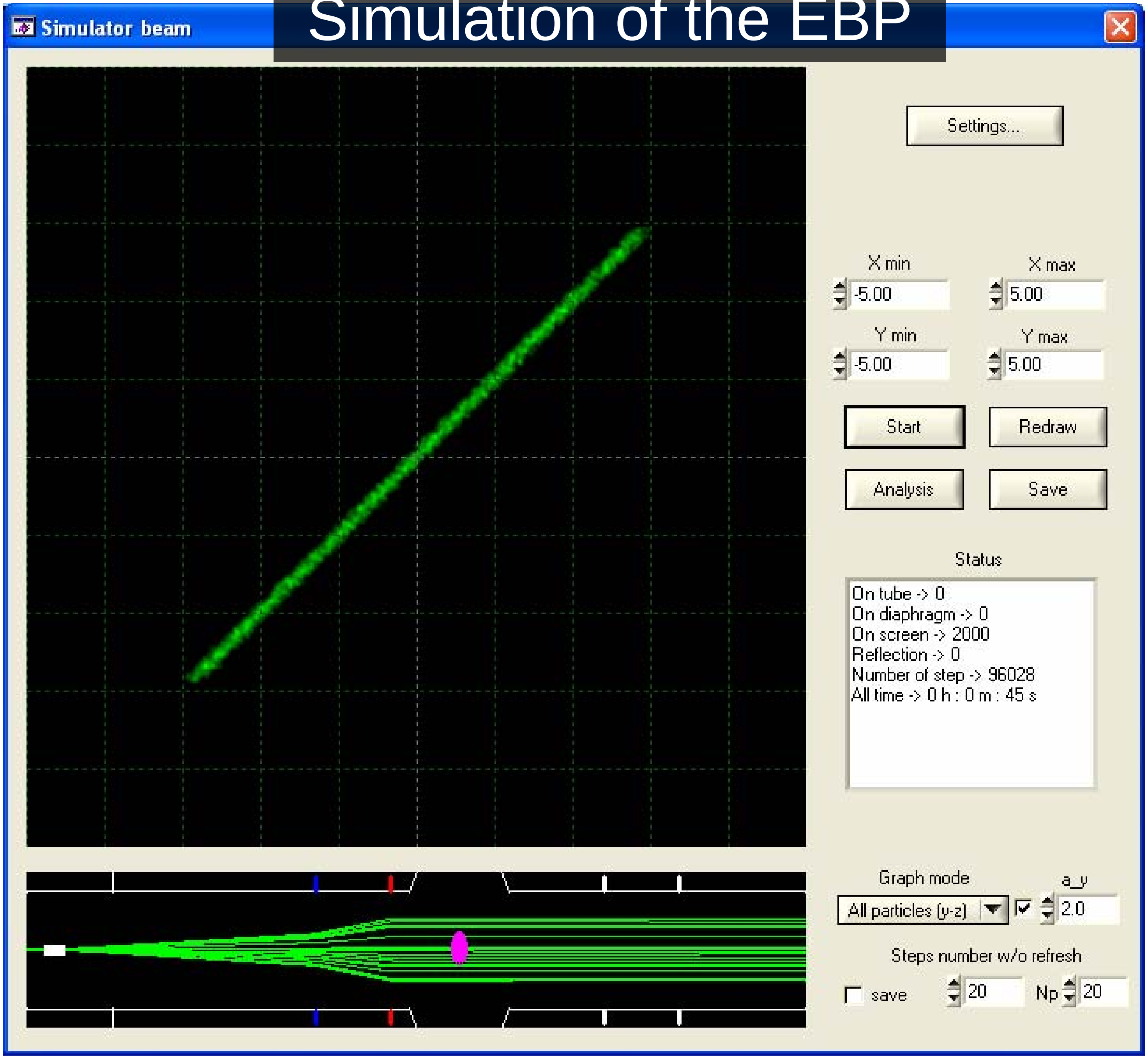
Electron beam probe as a profile monitor for intense proton beam.

- Beam profile scanning in 10 ns.
- Non destructing control during normal operation.
- Profile control on few different turns.

Layout of the proposed EBP for SNS accumulator ring



Simulation of the EBP



Probe beam:

Energy=75keV,

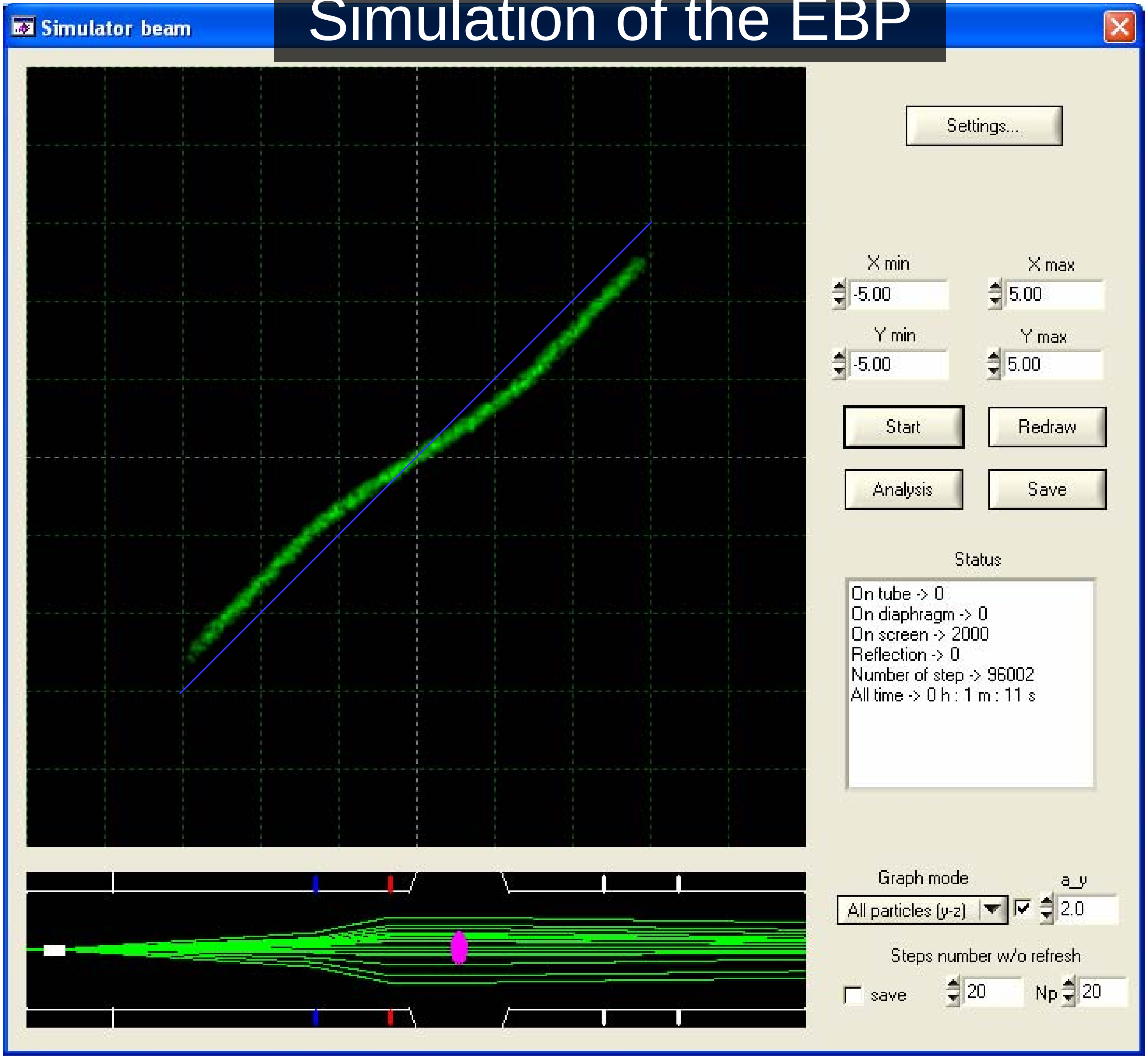
Scan.-parallel,

3rd ,4th quads - off

Proton beam:

OFF

Simulation of the EBP



Probe beam:

Energy=75keV,

Scan.-parallel,

3^{rd} ,4^{th} quads - off

Proton beam:

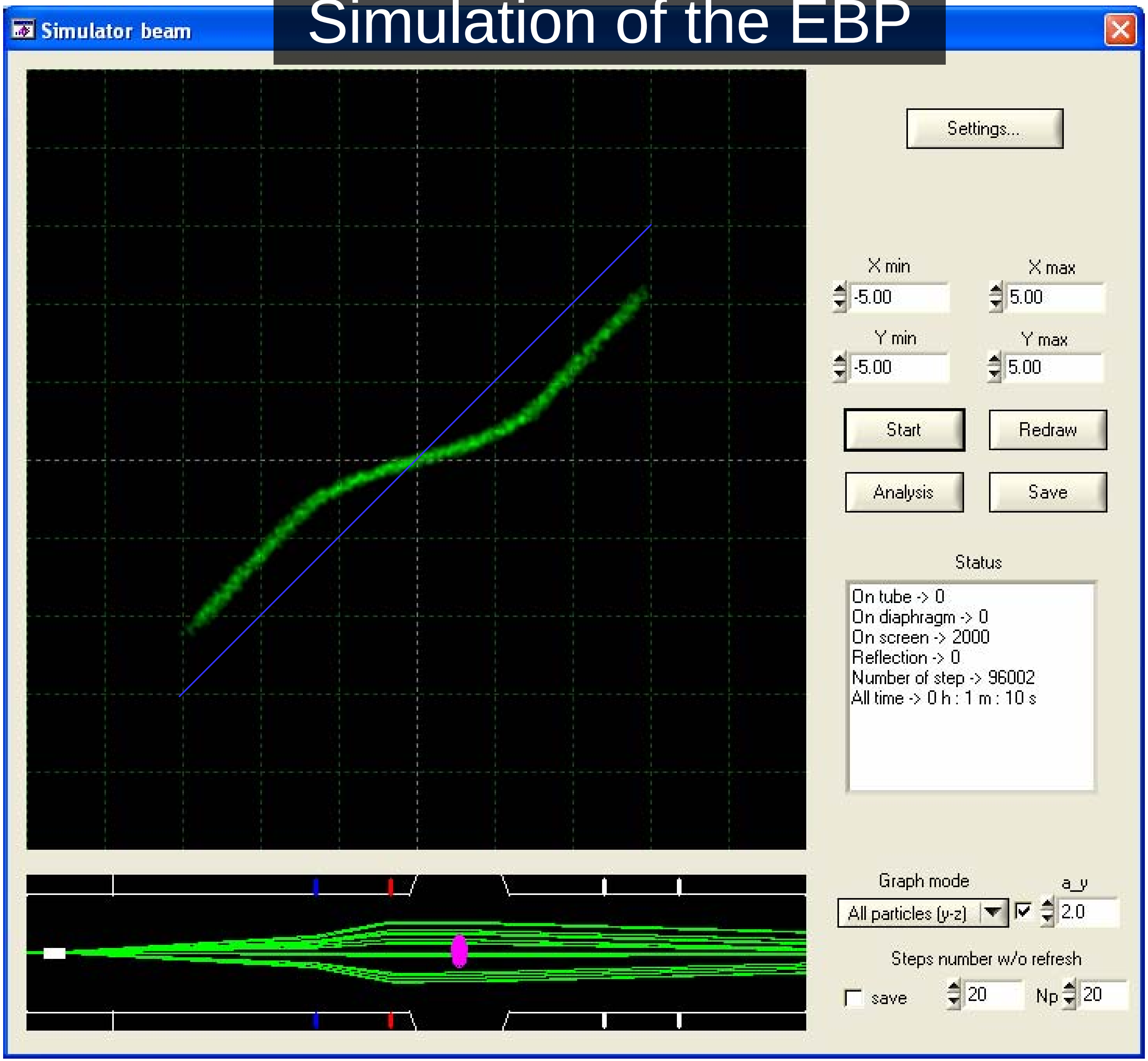
Energy=1GeV

Np=$\mathbf{1*10^{13}}$

Transverse size r=1.5cm

Round uniform transverse distribution

Simulation of the EBP



<u>Probe beam:</u>

Energy=75keV,

Scan.-parallel,

3rd ,4th quads - off

<u>Proton beam:</u>

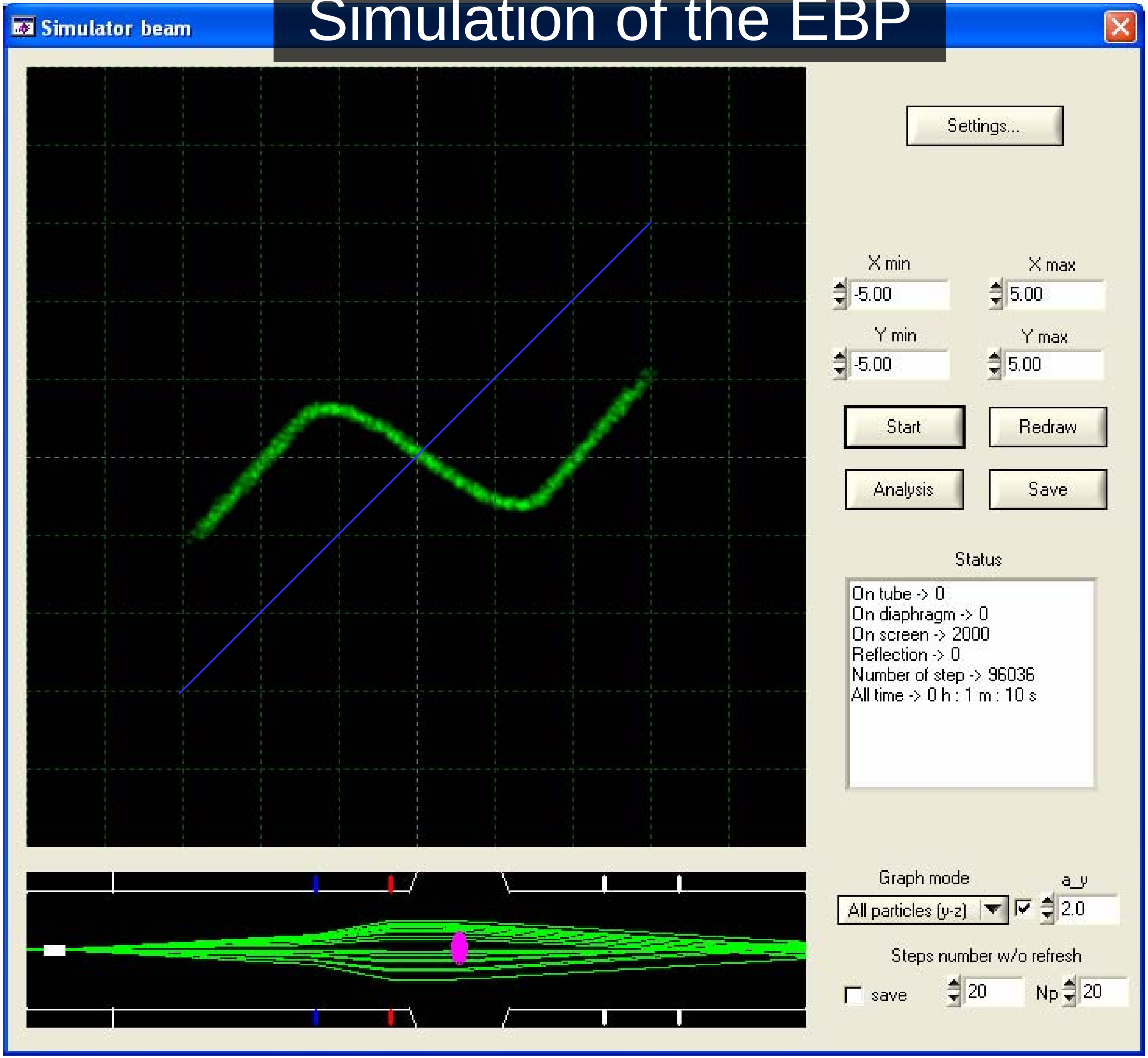
Energy=1GeV

Np=**2*10^13**

Transverse size r=1.5cm

Round uniform transverse distribution

Simulation of the EBP



Probe beam:

Energy=75keV,

Scan.-parallel,

3rd ,4th quads - off

Proton beam:

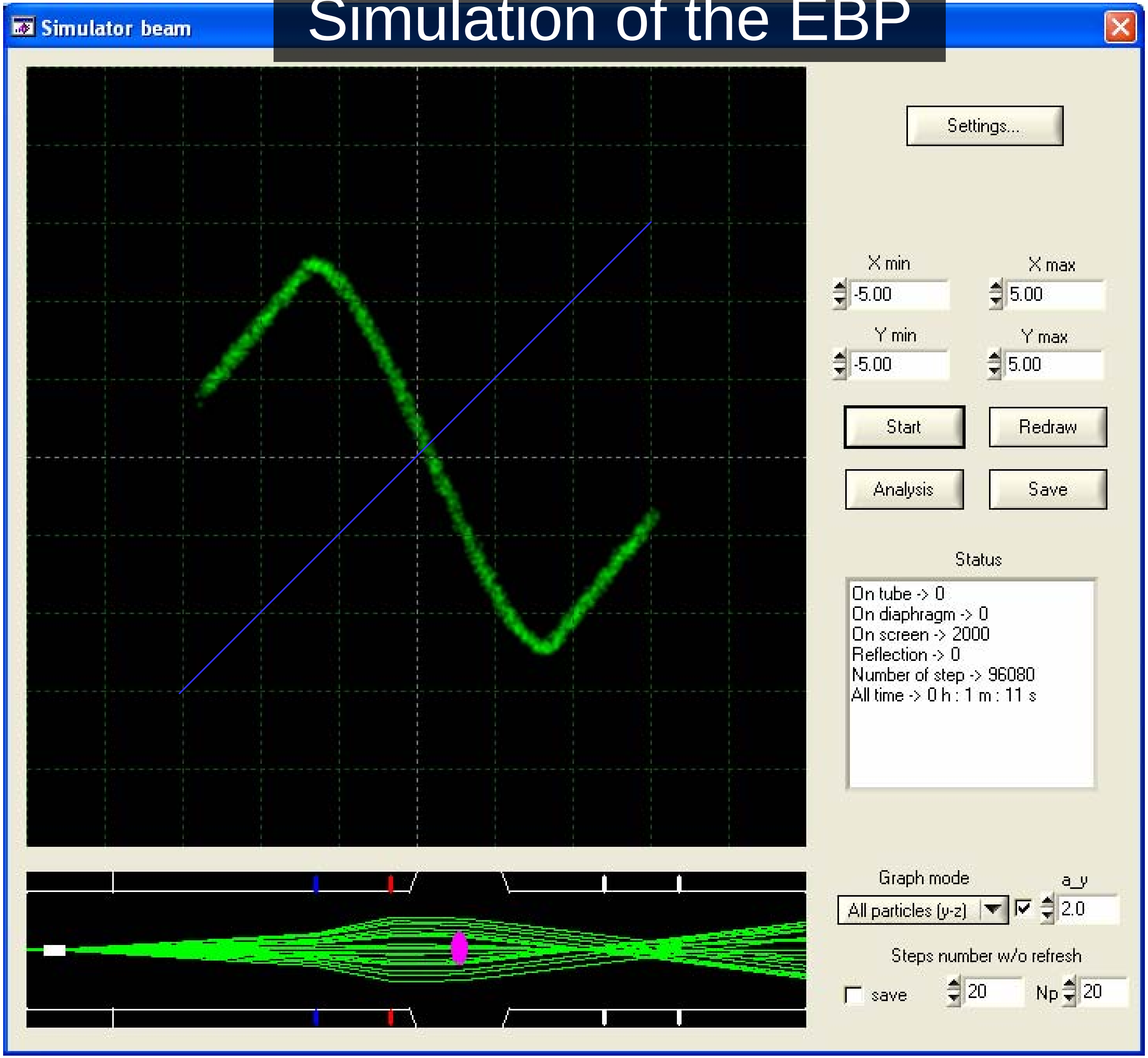
Energy=1GeV

Np=**5*10^{13}**

Transverse size r=1.5cm

Round uniform transverse distribution

Simulation of the EBP



Probe beam:

Energy=75keV,

Scan.-parallel,

3rd ,4th quads - off

Proton beam:

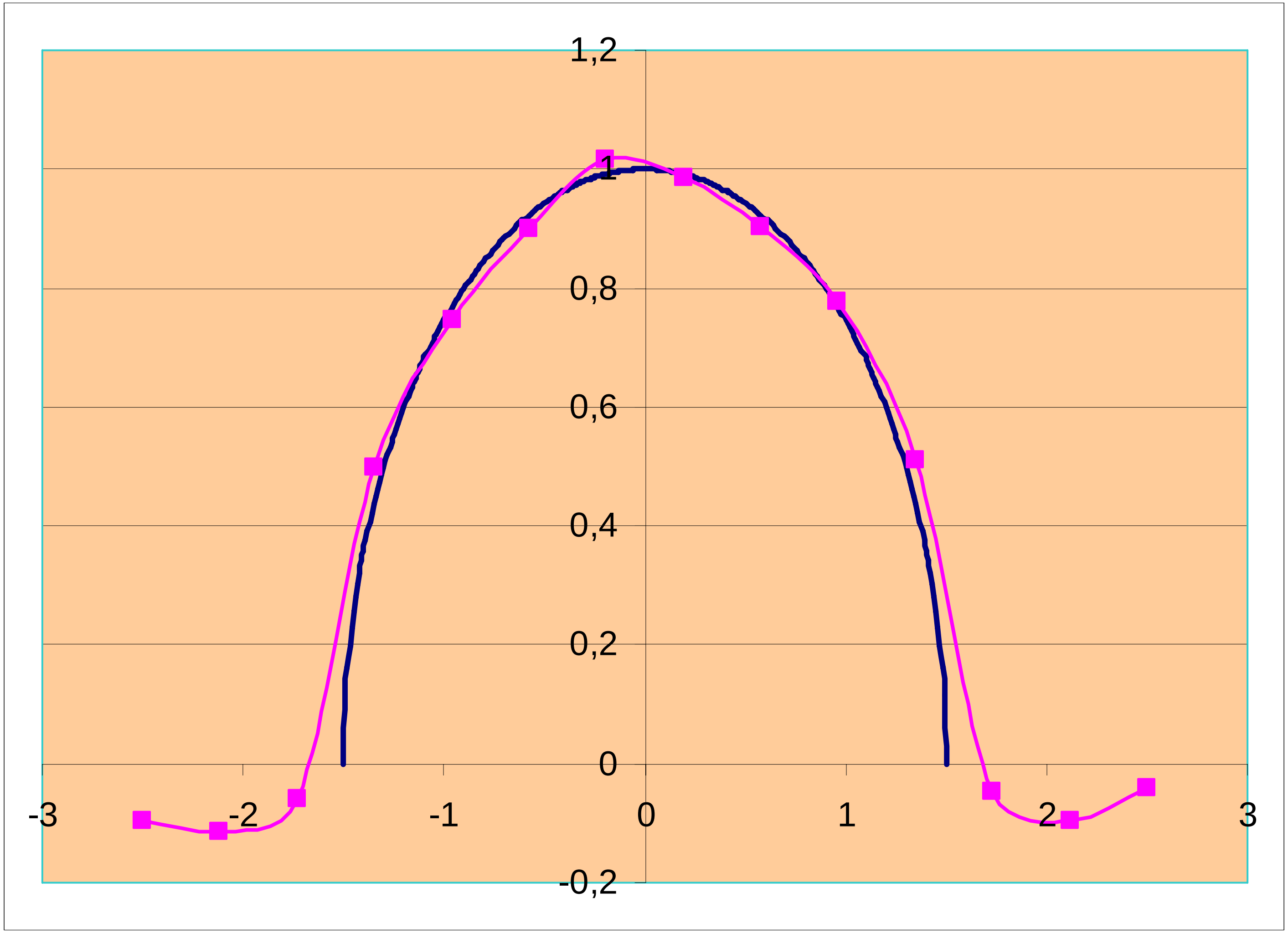
Energy=1GeV

Np=**1*10**^{14}

Transverse size r=1.5cm

Round uniform transverse distribution

Proton beam profile reconstruction



Blue line – integrated beam profile under the test,

Magenta + square – reconstructed profile

<u>Probe beam:</u>

Energy=75keV,

Scan.-parallel,

3rd ,4th quads - off

<u>Proton beam:</u>

Energy=1GeV

Np=**1*10**^{13}

Transverse size r=1.5cm

Round uniform transverse charge distribution