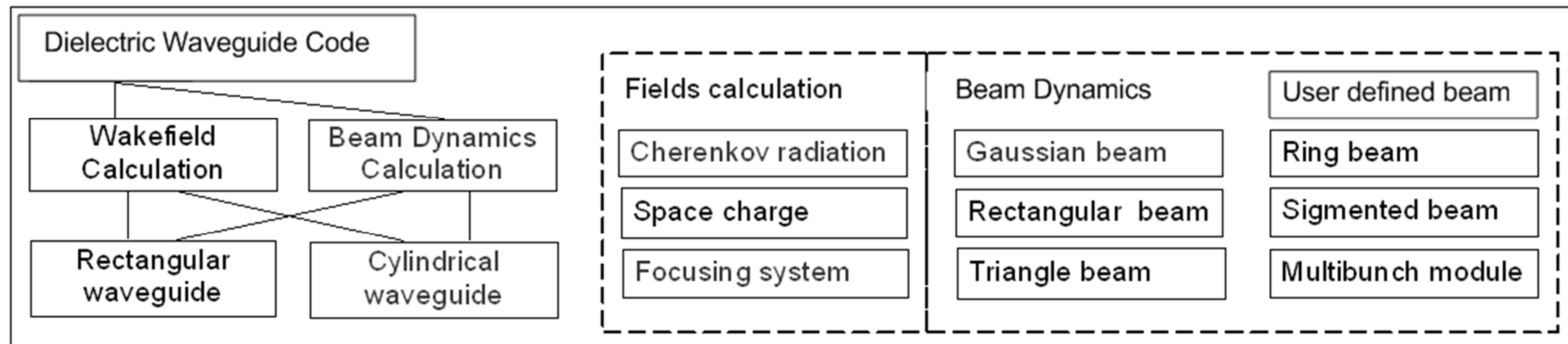


## Short description of “Dielectric Waveguide” code

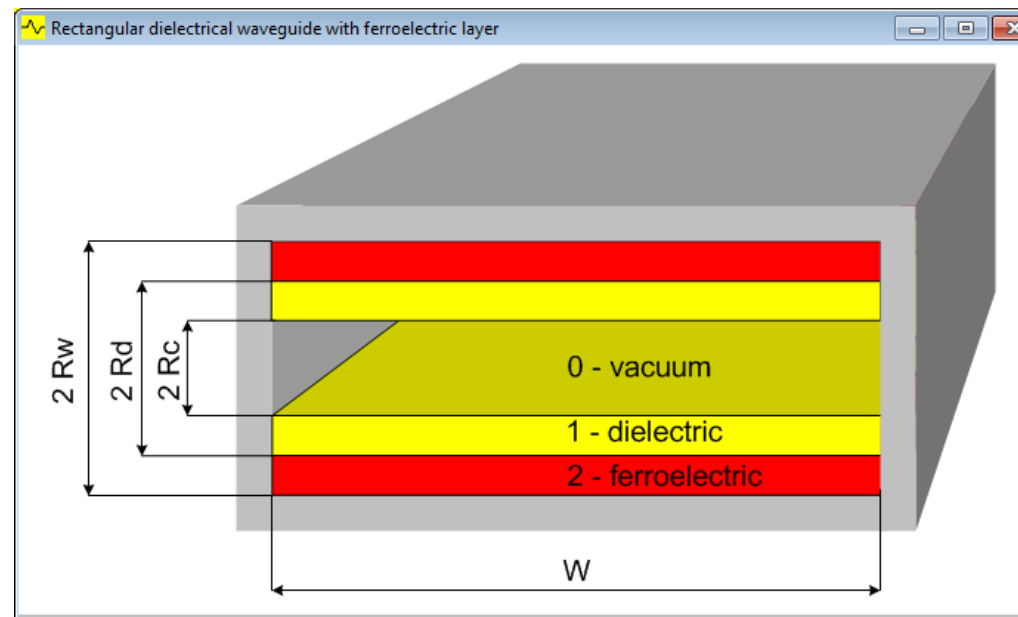
|                                     |           |
|-------------------------------------|-----------|
| 1. Introduction                     | <u>2</u>  |
| 2. Field calculation                | <u>4</u>  |
| 2.1. Main window                    | <u>4</u>  |
| 2.2. Bunch profiles                 | <u>9</u>  |
| 2.3. Menu of main window            | <u>11</u> |
| 3. Beam Dynamics module             | <u>13</u> |
| 3.1. Window of beam dynamics module | <u>13</u> |
| 3.2. Focusing System                | <u>19</u> |
| 4. Multibunch module                | <u>20</u> |

# 1. Introduction

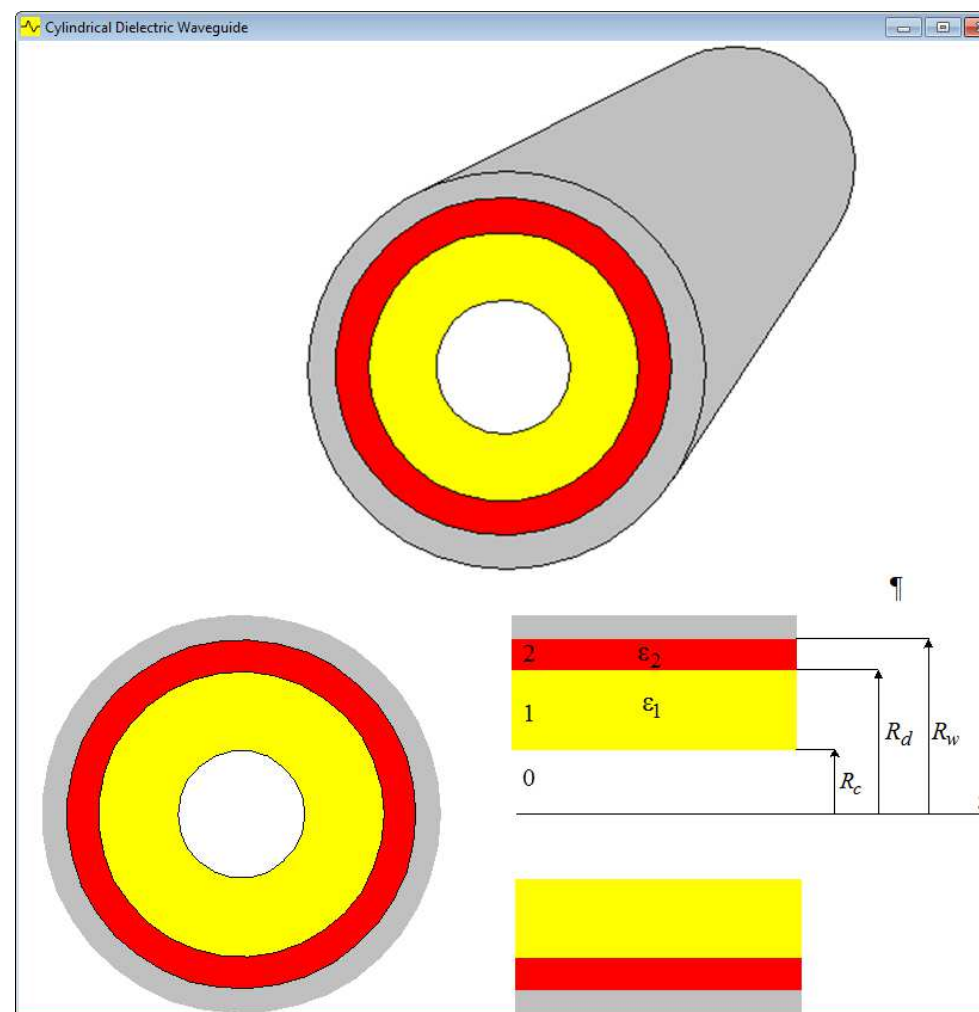
“Dielectric Waveguide” code is created for calculating Wakefield and Beam Dynamics in two layer dielectric waveguides with cylindrical and rectangular geometries (Pic.1-Pic.3)



Pic.1 Structure of code



Pic.2 Rectangular two-layer dielectric waveguide



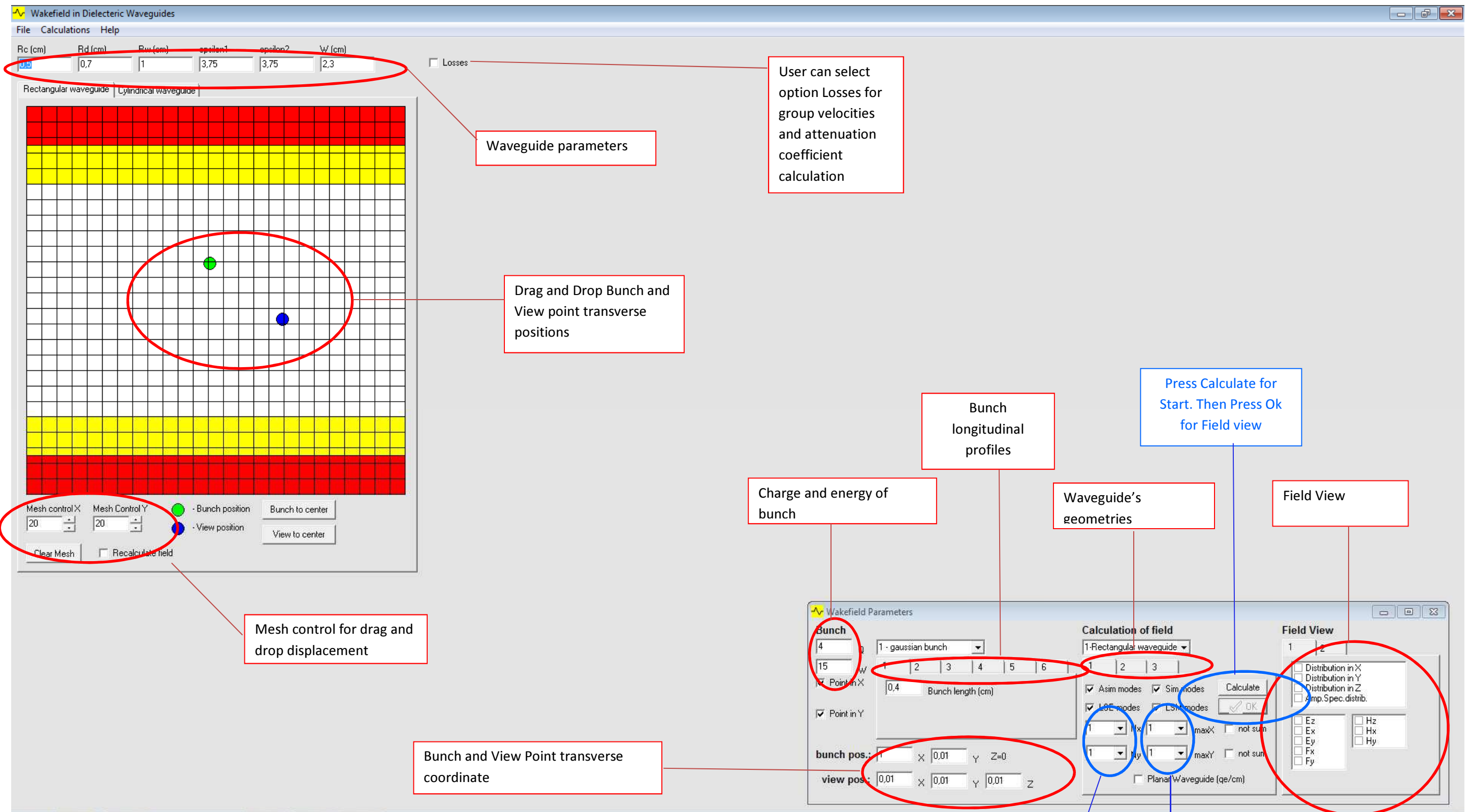
Pic.3 Cylindrical two-layer dielectric waveguide

## 2. Field Calculation

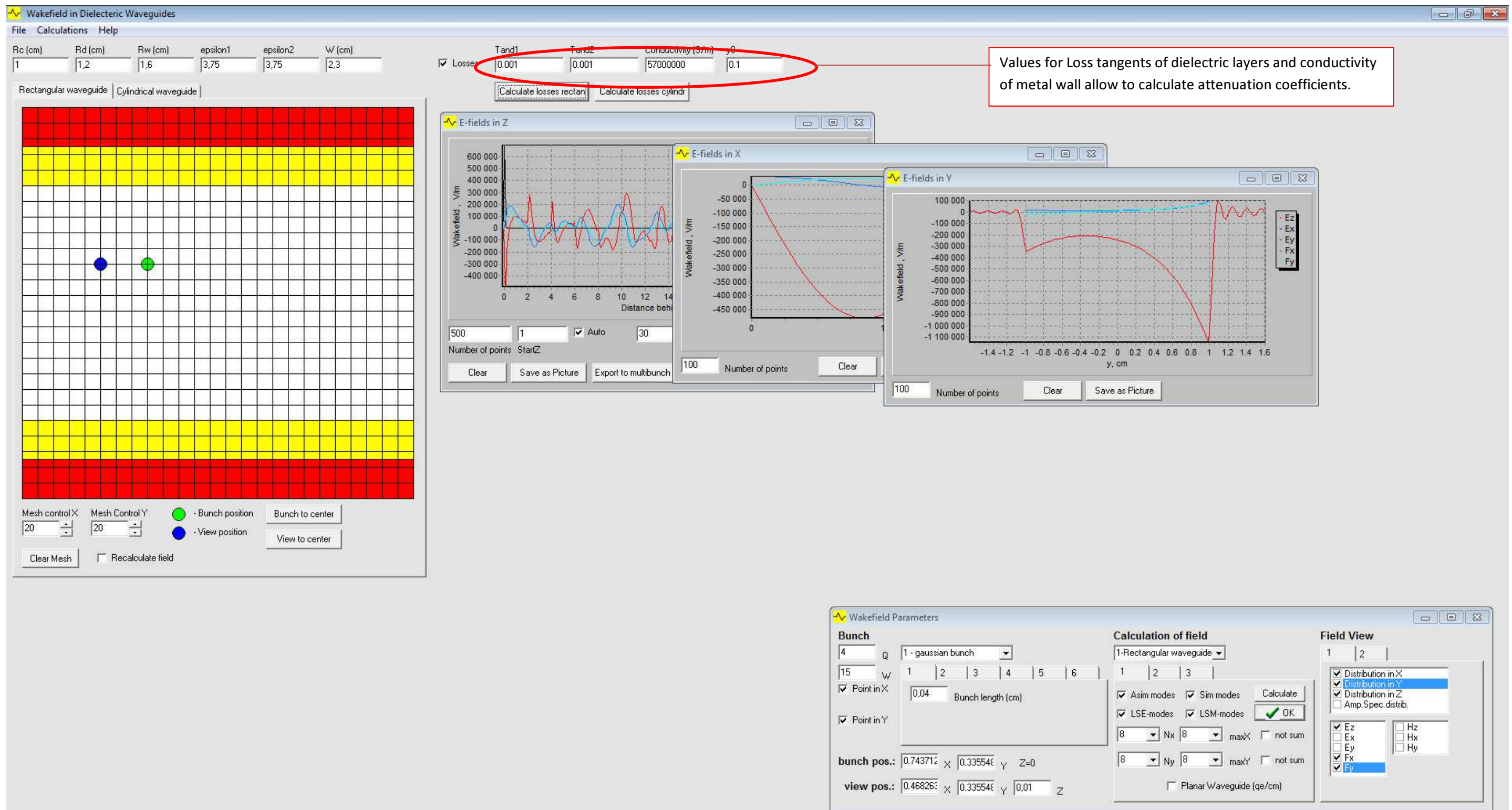
### 2.1. Main Window

When program start user see main window. User can choose type of waveguide, longitudinal profile of bunch, edit parameters of bunch, edit parameters of waveguides, select number of calculated modes, plot selected components of electromagnetic field. Calculation of wakefield is realized for transverse point bunch or transverse Gaussian bunch (options PointX and PointY). For rectangular geometry user have possibility to drag and drop transverse positions of bunch and view point.

First of all, user have to press button “Calculate” for Green function calculation. This button has to be pressed every time when geometry parameters are changed. After “Calculate” is clicked program start to solve dispersion equation and calculate frequencies, amplitudes of Green function in range limited by MaxY and MaxX numbers. For others actions (plot field for example) user press button “Ok”.



Pic. 4 Main Window for Rectangular waveguide



Values for Loss tangents of dielectric layers and conductivity of metal wall allow to calculate attenuation coefficients.

Pic. 5 Main Window with plots of electromagnetic field for Rectangular waveguide

Losses
  Tand1
  Tand2
  Conductivity (S/m)
  y0

FunctionAndTest

Clear

Modes in Cylindrical waveguide

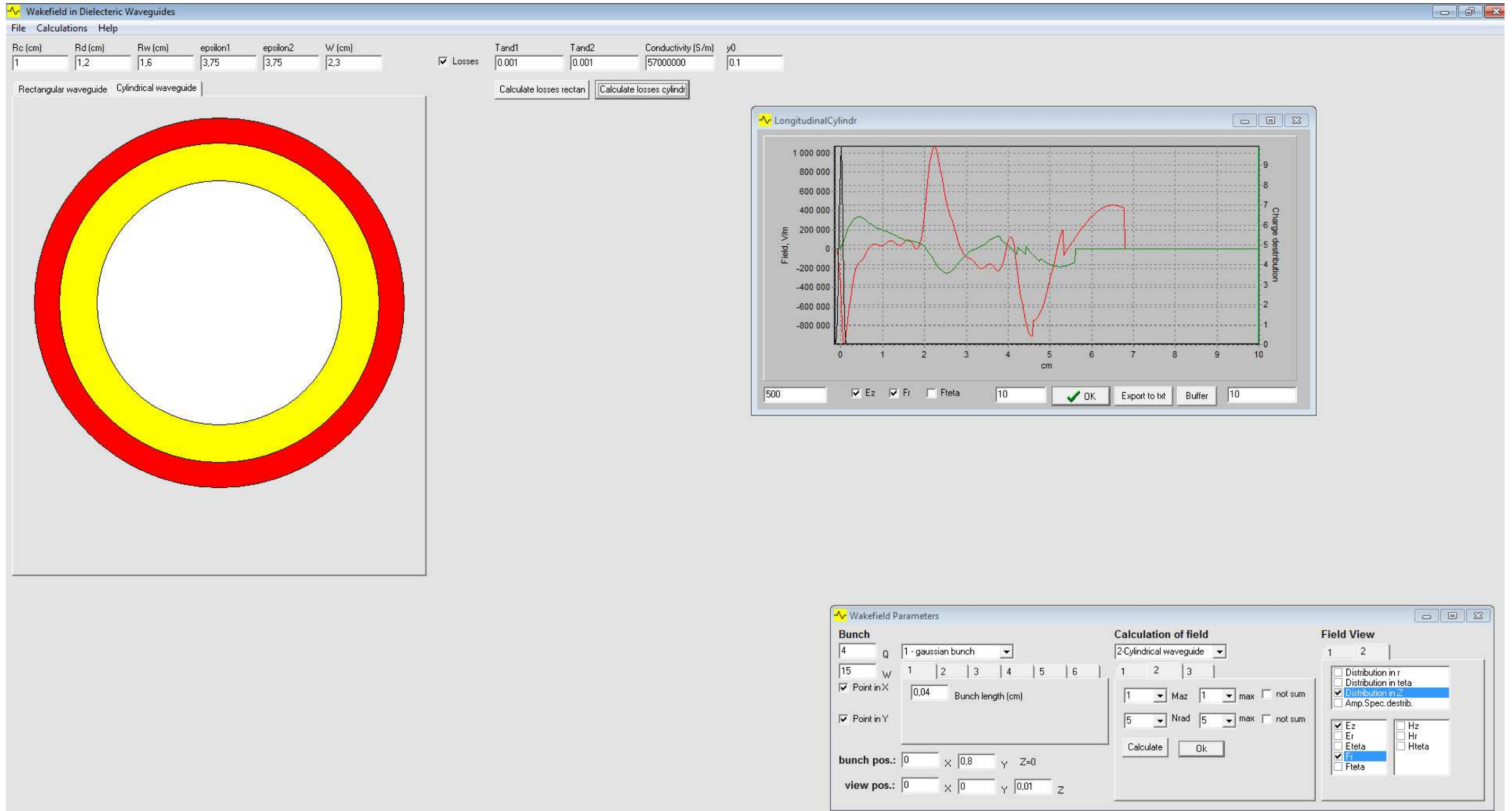
m = 0

| mode    | freq      | Vg/c      | Quality factor | Atten. coef | Norm. Shunt |
|---------|-----------|-----------|----------------|-------------|-------------|
| mode0,0 | 6.901E+00 | 3.089E-01 | 1.228E+03      | 1.907E-03   | 3.666E+03   |
| mode0,1 | 1.929E+01 | 4.540E-01 | 1.498E+03      | 2.972E-03   | 7.422E+02   |
| mode0,2 | 3.298E+01 | 5.282E-01 | 1.621E+03      | 4.035E-03   | 2.066E+02   |
| mode0,3 | 4.730E+01 | 5.584E-01 | 1.682E+03      | 5.276E-03   | 7.723E+01   |
| mode0,4 | 6.192E+01 | 5.711E-01 | 1.706E+03      | 6.659E-03   | 3.549E+01   |

m = 1

| mode    | freq      | Vg/c      | Quality factor | Atten. coef | Norm. Shunt |
|---------|-----------|-----------|----------------|-------------|-------------|
| mode1,0 | 5.937E+00 | 5.444E-01 | 1.290E+03      | 8.860E-04   | 8.674E+00   |
| mode1,1 | 9.997E+00 | 4.268E-01 | 1.047E+03      | 2.345E-03   | 1.266E+01   |
| mode1,2 | 1.914E+01 | 5.643E-01 | 1.625E+03      | 2.188E-03   | 4.745E+00   |
| mode1,3 | 2.367E+01 | 5.086E-01 | 1.035E+03      | 4.712E-03   | 2.495E+00   |
| mode1,4 | 3.297E+01 | 6.019E-01 | 1.804E+03      | 3.182E-03   | 1.608E+00   |

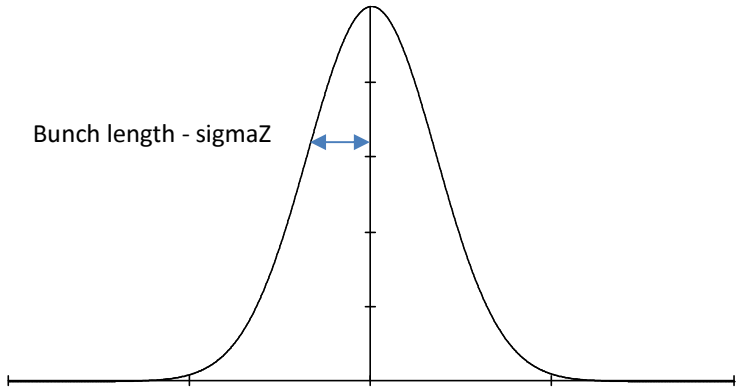
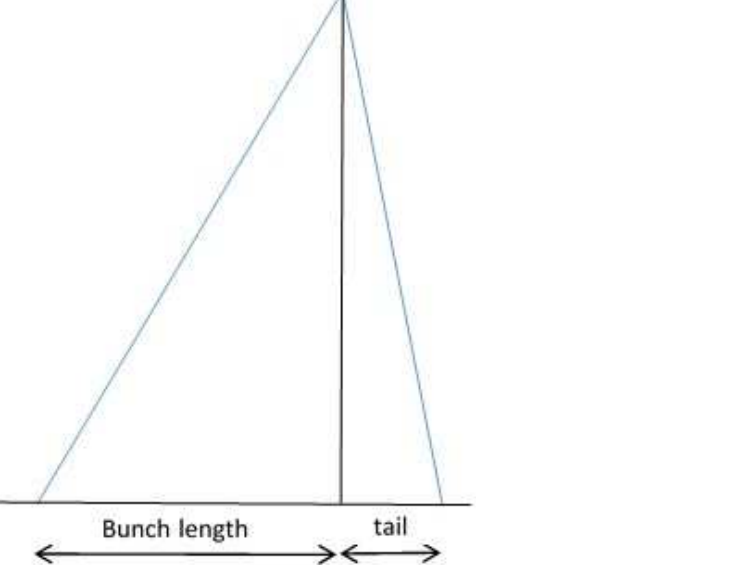
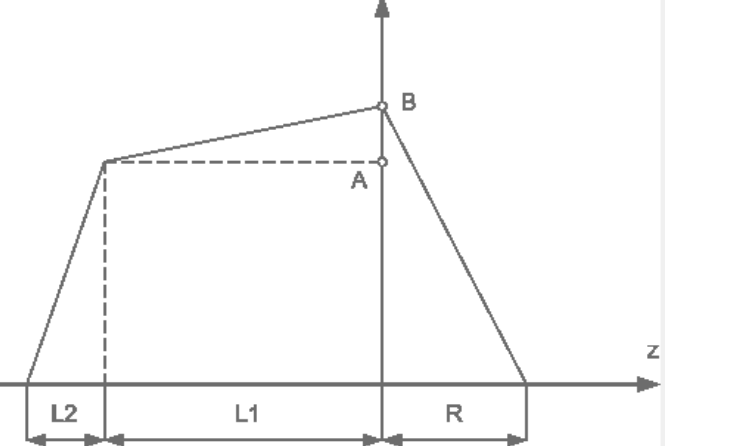
Pic. 6 Losses calculation



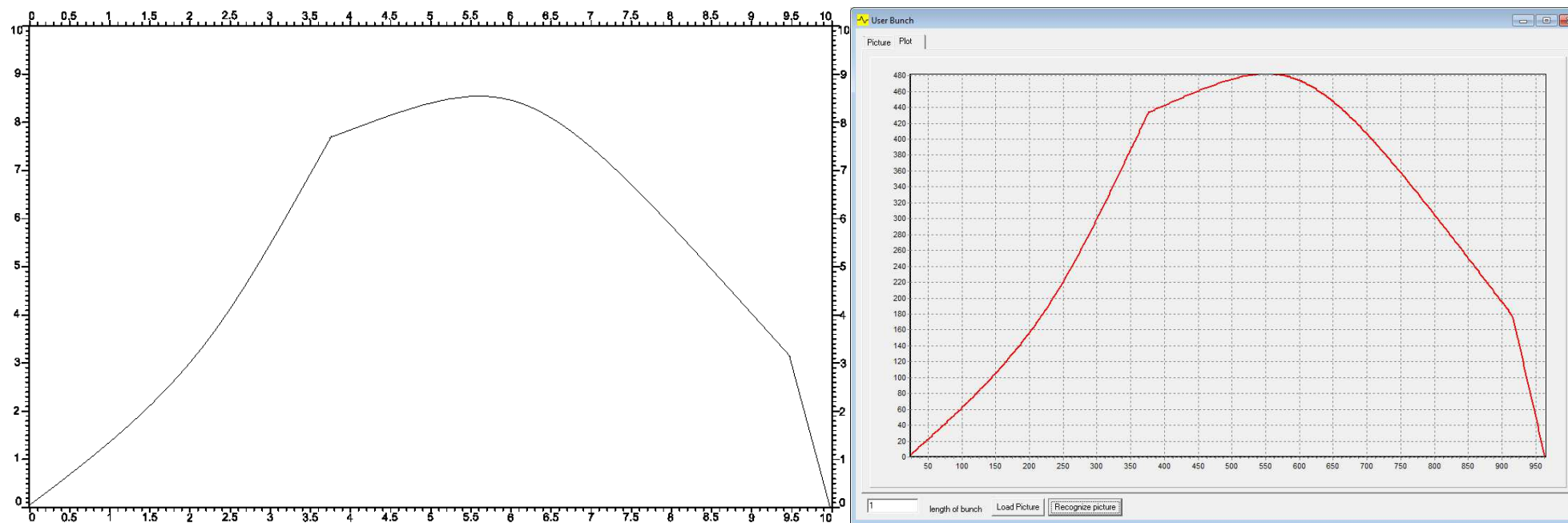
Pic. 7 Main Window with plots of electromagnetic field for Cylindrical waveguide



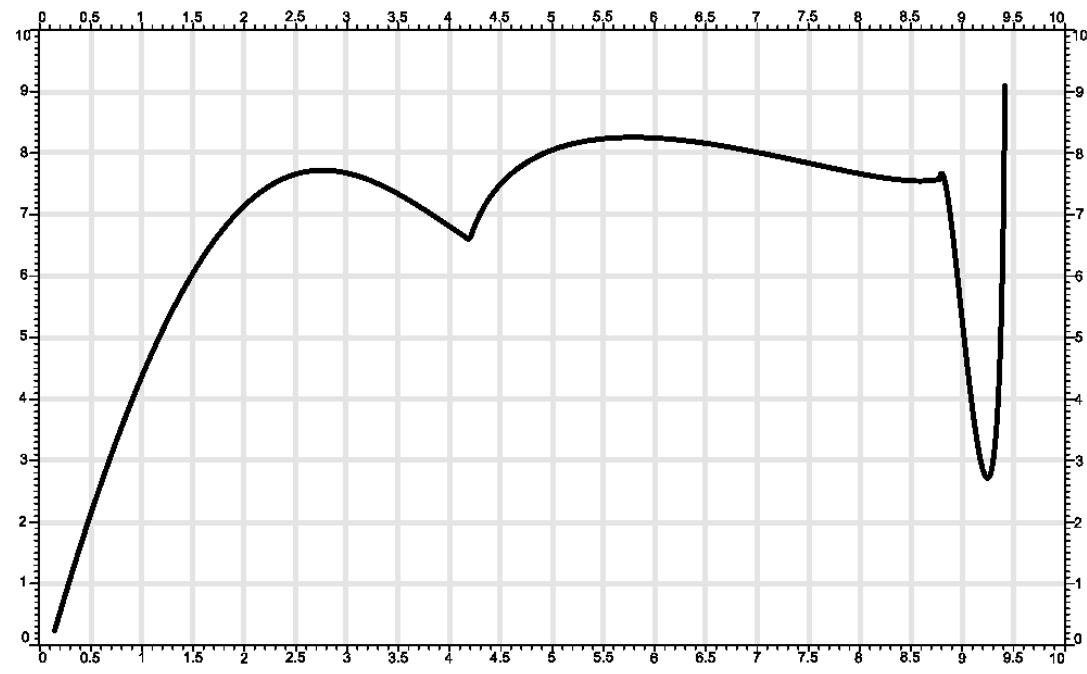
## 2.2. Bunch Profiles

|  |   |
|--|---|
| <p>1 - gaussian bunch</p> <p>1 2 3 4 5 6</p> <p>0,4 Bunch length (cm)</p>                                  |  <p>A Gaussian curve representing a bunch profile. A vertical line marks the center. A horizontal double-headed arrow below the curve, centered on the vertical line, is labeled "Bunch length - sigmaZ".</p>  |
| <p>2 - Triangle slope</p> <p>1 2 3 4 5 6</p> <p>1 Bunch length (cm)</p> <p>0.1 Bunch tail (cm)</p>         |  <p>A triangular profile with a vertical line from the peak to the base. The base is divided into two segments: "Bunch length" on the left and "tail" on the right, indicated by horizontal double-headed arrows.</p>   |
| <p>4 - Rectangular bunch</p> <p>1 2 3 4 5 6</p> <p>0.1 L1 0.8 A/B</p> <p>0.2 L2</p> <p>0.1 R See Bunch</p> |  <p>A trapezoidal profile on a horizontal z-axis. The base is divided into segments L2, L1, and R. A vertical line passes through the right side of the trapezoid, with points A and B marked on it. A dashed horizontal line connects the top-left corner to point A.</p> |
| <p>5 - User defined</p> <p>1 2 3 4 5 6</p> <p>User Bunch Edit</p> <p>0,4 length, cm 1 nC/cm</p>            | <p>See next Page</p>  |

### User bunch profile



Pic. 8 Recognizing picture (left) for creation user bunch profile in program (right)



Pic. 9 User can draw bunch profile in any Graphical program on template mesh

## 2.3. Menu of Main Window

Wakefield in Dielectric Waveguides

File Calculations Help

- Wakefield Parameters — Open window Wakefield Parameters if it closed
- Multibunch calculation — Run Multibunch Module (Click Link)
- 3D Beam Dynamics — Run Beam Dynamics Module
- Calculations of waveguide parameters — Run Module which allow to calculate waveguide's parameters (N4 in table 1)
- Calculation of spectrum — Run Module which allow to calculate Spectrum for Rectangular Waveguide (N1 in table 1)
- Plot of dispersion equations — Run Module which allow to plot dispersion equation of Rectangular Waveguide ((N2 in table 1))
- Loss Calculation
- Test
- Parameters variation — Run Module which allow to plot different dependences of field parameters from waveguide parameters (Under construction, N3 in table 1)

epsilon2  
3,75

Wakefield in Dielectric Waveguide

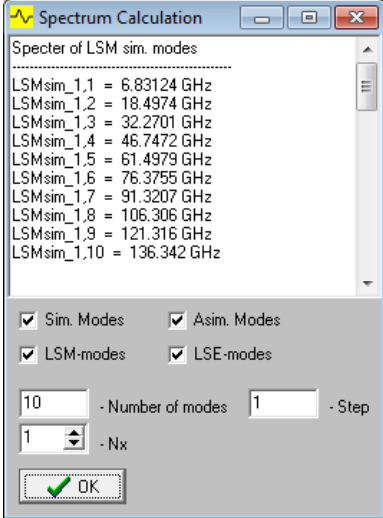
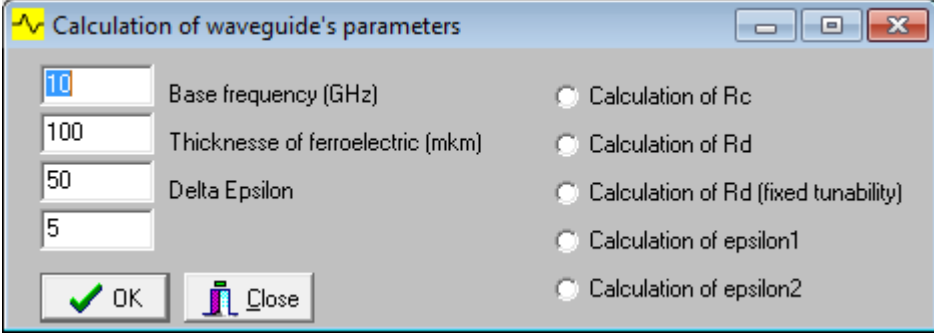
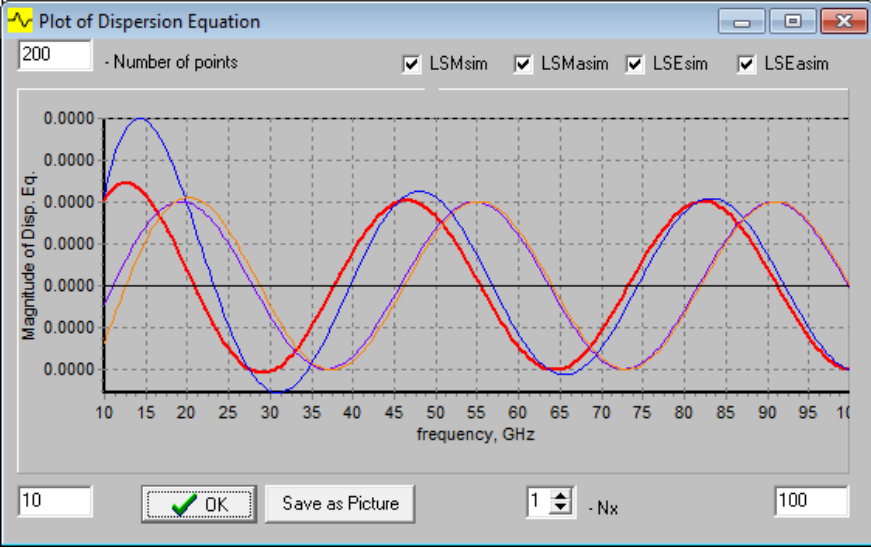
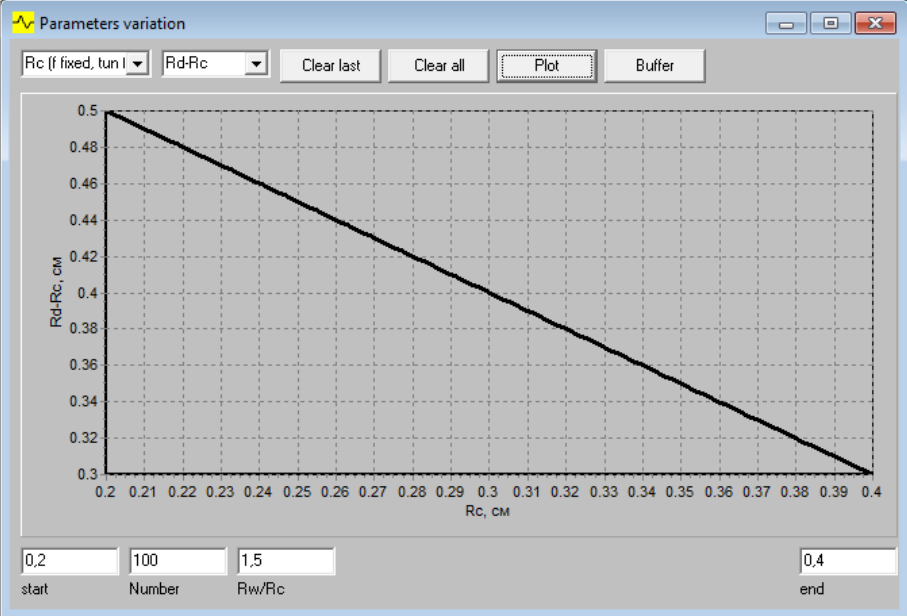
File Calculations Help

- Open Profile — Load all program values from file
- Save Profile — Save all program values from file
- Exit

Rw (cm)  
1

indrical wav

Table 1

|           |  |           |   |
|-----------|--|-----------|---|
| <p>1.</p> |    | <p>4.</p> |  |
| <p>2.</p> |   |           |   |
| <p>3.</p> |  |           |   |

### 3. Beam Dynamics module

This module consist algorithm for beam dynamics calculations according to macroparticle methods.

#### 3.1. Window of beam dynamics module

The screenshot shows the '3D Beam Dynamics' software interface. Key components are labeled as follows:

- Y-Z View:** A 3D plot showing the beam bunch distribution in the Y-Z plane. The Y-axis ranges from -0.5 to 0.5 cm, and the Z-axis ranges from -0.05 to 0.06 cm. The plot is titled 'Y-Z'.
- View Controls:** A row of buttons at the top left includes 'Y-Z', 'Y-X', 'Charge histogram', 'X-X', 'Y-Y', and 'Energy'. The 'Y-Z' button is highlighted.
- Time control:** A label pointing to the 'Time control' section of the control panel.
- Beam dynamics controls:** A label pointing to the main control panel at the bottom.
- Job List:** A panel on the right showing a list of tasks: 'results1', 'results2', 'results3', and 'results4'. 'results4' is selected.
- Parameters of current task:** A table on the right showing the parameters for the selected task 'results4'. The parameters and their values are:
 

| Parameter          | Value       |
|--------------------|-------------|
| Task name          | results4    |
| Rc, cm             | 0.5         |
| Rd, cm             | 0.87581437  |
| Rw, cm             | 0.88103076  |
| W, cm              | 2.3         |
| energy, MeV        | 150         |
| energy spread, MeV | 1           |
| Wglenght, cm       | 200         |
| Number of p.       | 500         |
| z0, cm             | 0           |
| epsilon1           | 3.75        |
| epsilon2           | 3.75        |
| Q, nC              | 4           |
| sigmaz, cm         | 0.02        |
| sigmax, cm         | 0.02        |
| sigmay, cm         | 0.02        |
| offsetx, cm        | 0.001       |
| offsety, cm        | 0           |
| RMSXX              | 0.000297732 |
| RMSYY              | 0.000653495 |
| start time, fs     | 0           |
| step time, fs      | 333         |
| save time, fs      | 3330        |
| end time, fs       | 6671000     |
| LSM_simNx          | 1           |
| LSM_simNy          | 1           |
| LSM_asimNx         | 1           |
| LSM_asimNy         | 1           |
| LSE_simNx          | 1           |
| LSE_simNy          | 1           |
| LSE_asimNx         | 1           |
| LSE_asimNy         | 1           |

Pic. 10 Window of Beam Dynamics Module

|  |  |
|--|--|
| <p>1) Single bunch generation</p>  |  |
| <p>2) Multibunch generation (See Pic.10)</p>   |  |
| <p>3) User can see beam dynamics and plot on same chart (Pic.11 )</p>  |  |
| <p>4) Panel for running beam dynamics. User can calculate dynamics by steps or run calculation on full time range. If user press "Run Job List" then calculation results will be saved in folder Data. Names of folders are names of tasks in Job List. There is code "BBU View" for watching these results.</p> |  |
| <p>5) Panel with calculation options. User can define energy spread in bunch, choose geometry of waveguide, switch on/off space charge calculation, Cherenkov field, focus system, longitudinal and transverse field.</p>  |  |

6) This panel is made for saving values of beam dynamics and for import/export data from others codes.

Single bunch | Multibunch | Acceleration in travel wave | Options | Save/Load | Bunch and Field | Run | Focus System

Load Profile

Export to PIT

Parmella

Save profile

Import from PIT

1 ▾

Load Bunch

Import from Parmella

7) This panel is for creating and editing of focus system (see Pic.12)

Single bunch | Multibunch | Acceleration in travel wave | Options | Save/Load | Bunch and Field | Run | Focus System

Gradient (T/cm)

0,03579

Number

6

Type of focusing

FODO

FDFD

Edit

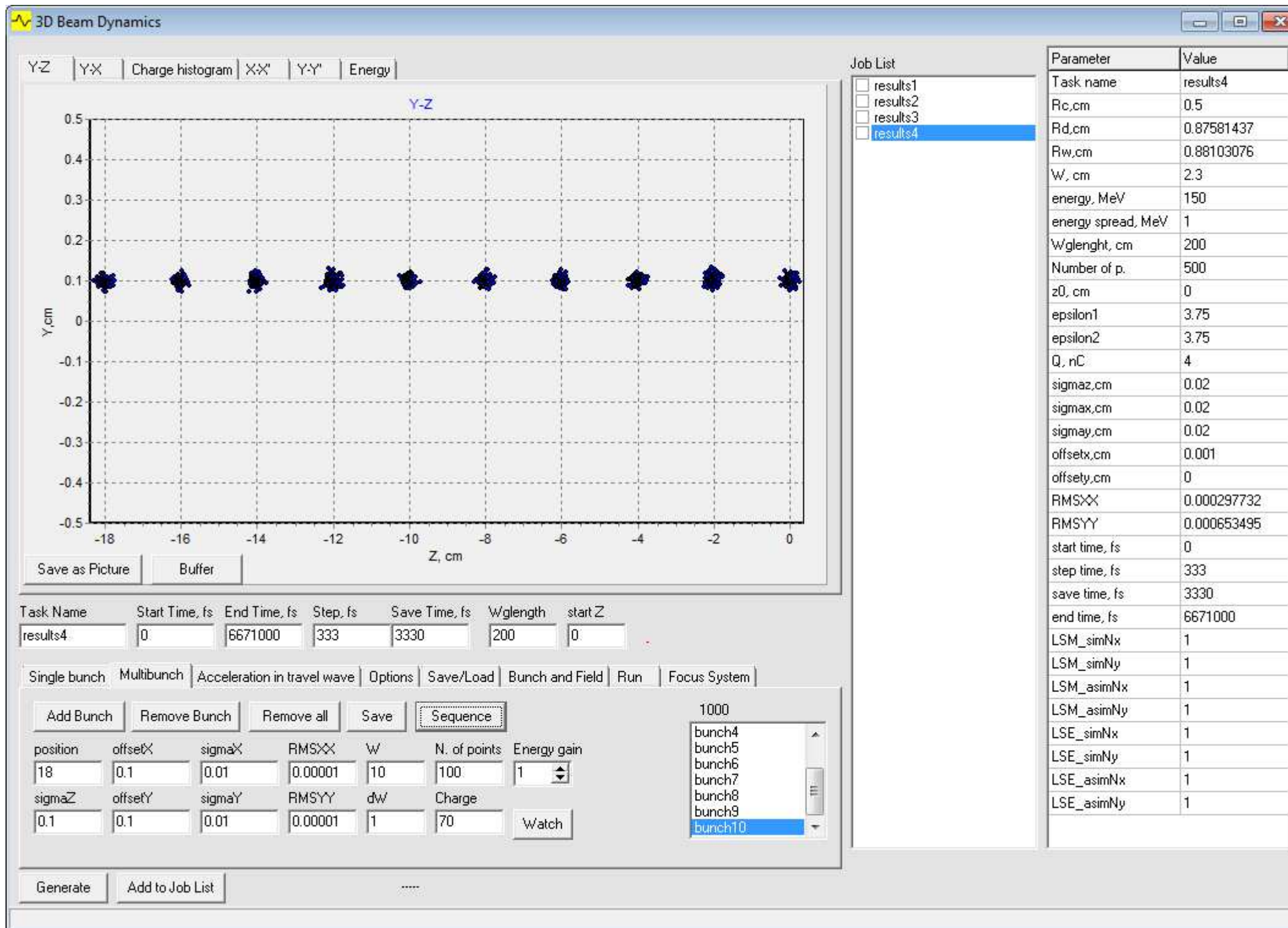
Period, cm

2

StartSign

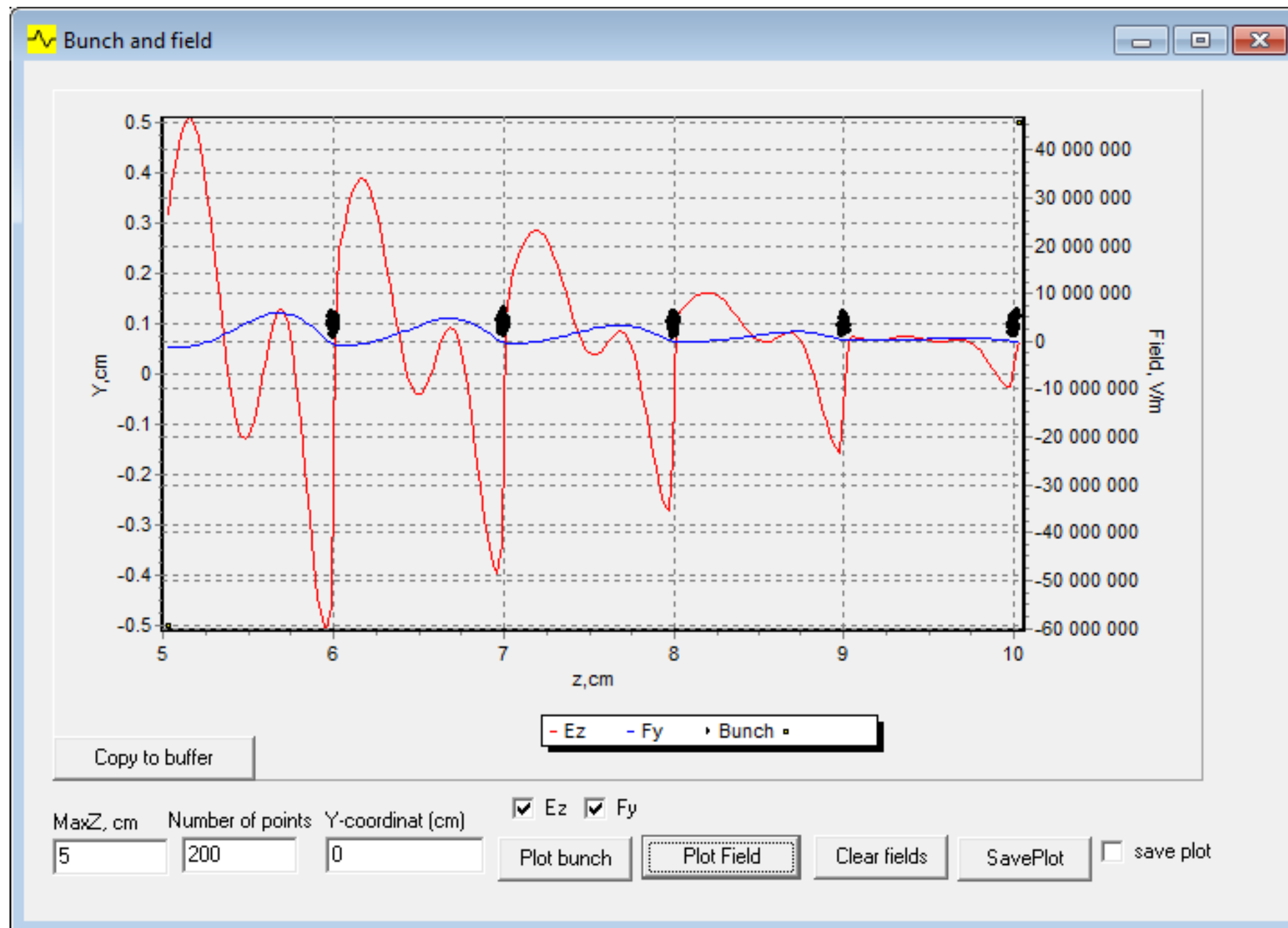
-1

User Defined System



Pic. 10 Window of Beam Dynamics Module for Multibunch mode

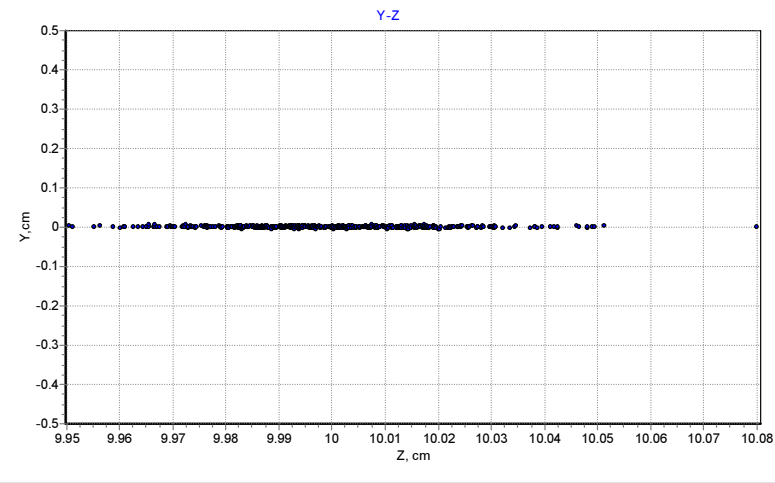




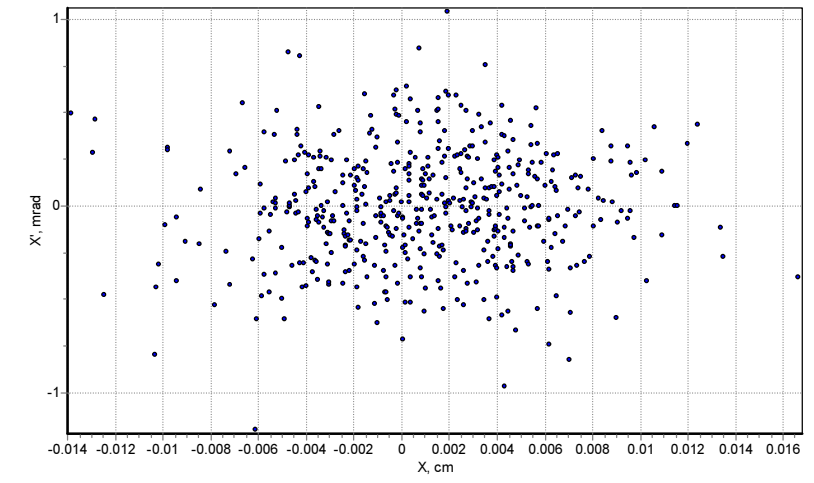
Pic. 11 Window with chart where bunches and field are presented.

# Bunch View controls

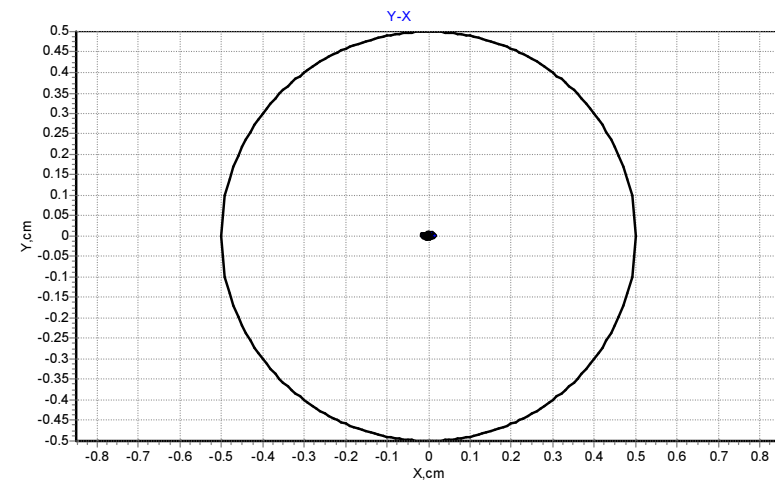
Longitudinal View of bunch



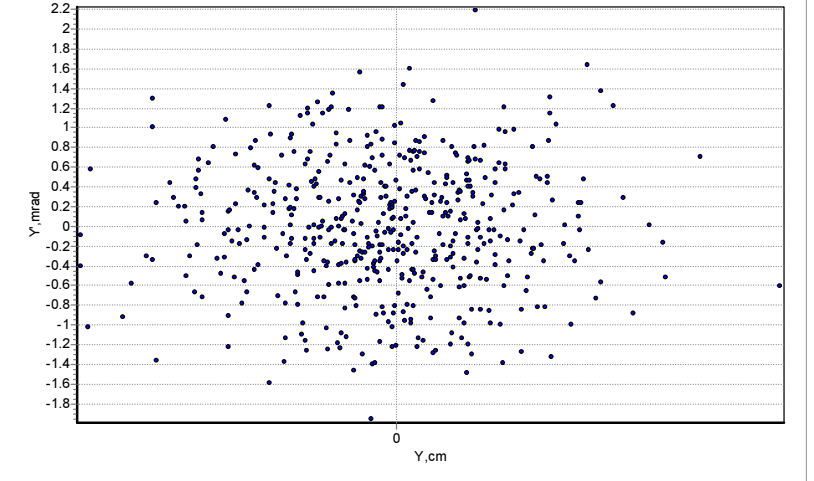
Phase space on X coordinate



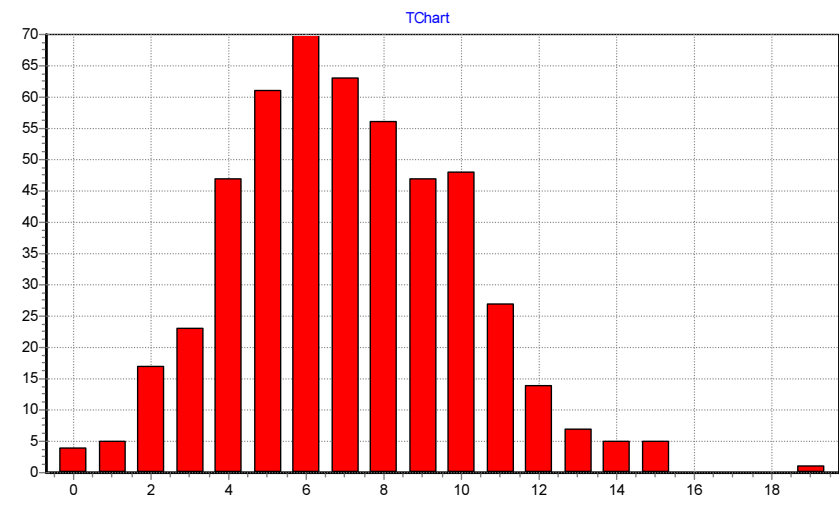
Transverse View of bunch



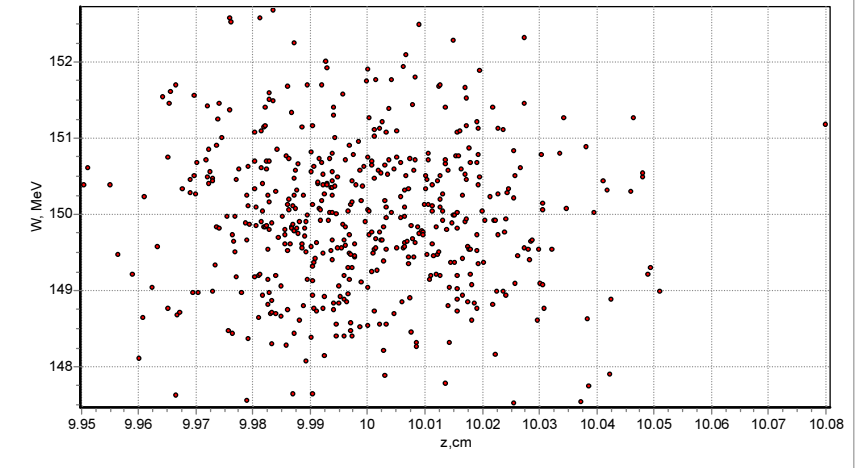
Phase space on Y coordinate



Charge histogram



Energy distribution in bunch



### 3.2. Focusing system

The screenshot shows the 'User Defined Focus System' window. It features a central plot area with three data series: a pink square wave, a red sine wave, and a blue sine wave. The plot is surrounded by control buttons like 'Clear Track', 'Clear FODO', and 'Copy to Buffer'. To the right, there is a 'Focus info' table and a 'Select cell' list. At the bottom, there are input fields for 'Number', 'Borders', 'Cell Field', and 'Cell control' parameters, along with 'ReBuild', 'Load', and 'Save' buttons.

**Callout Labels:**

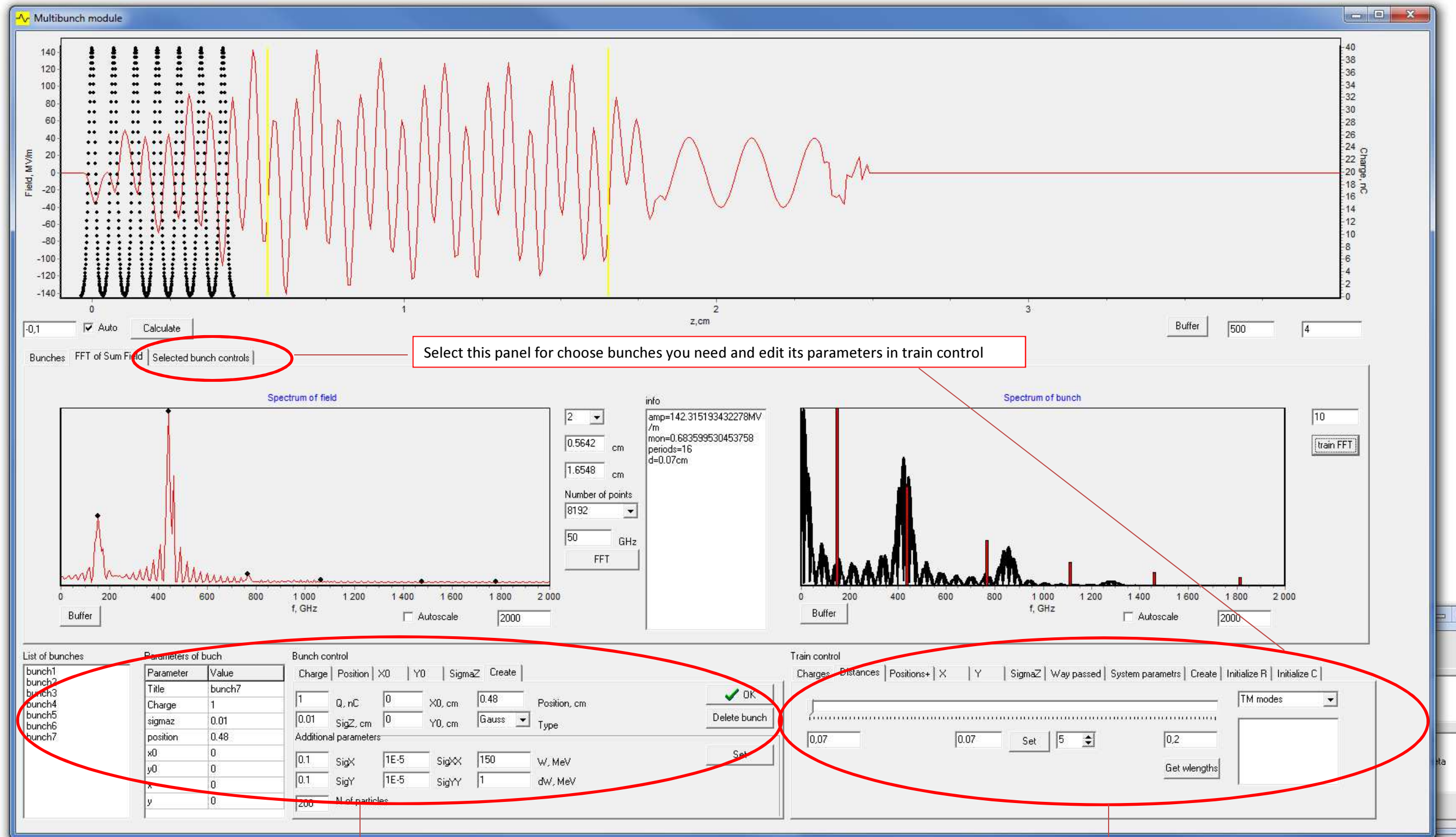
- Plot control
- Plot of Focusing system and borders
- Parameters of focusing system
- List of cells
- Panel for creating focusing system
- Current cell control. Cell chosen from List of cells
- Load and save focusing system

|           |            |
|-----------|------------|
| 6.750E+01 | 4.271E+00  |
| 7.250E+01 | 4.219E+00  |
| 7.750E+01 | 4.167E+00  |
| 8.250E+01 | -4.115E+00 |
| 8.750E+01 | 4.063E+00  |
| 9.250E+01 | -4.011E+00 |
| 9.750E+01 | 3.959E+00  |
| 1.025E+02 | -3.908E+00 |
| 1.075E+02 | 3.856E+00  |
| 1.125E+02 | -3.804E+00 |
| 1.175E+02 | 3.752E+00  |
| 1.225E+02 | -3.700E+00 |
| 1.275E+02 | 3.648E+00  |
| 1.325E+02 | -3.596E+00 |
| 1.375E+02 | 3.544E+00  |
| 1.425E+02 | -3.492E+00 |
| 1.475E+02 | 3.440E+00  |
| 1.525E+02 | -3.388E+00 |
| 1.575E+02 | 3.336E+00  |
| 1.625E+02 | -3.284E+00 |
| 1.675E+02 | 3.233E+00  |
| 1.725E+02 | -3.181E+00 |
| 1.775E+02 | 3.129E+00  |
| 1.825E+02 | -3.077E+00 |
| 1.875E+02 | 3.025E+00  |
| 1.925E+02 | -2.973E+00 |

Pic. 12 Window for focusing system control

## 4. Multibunch module

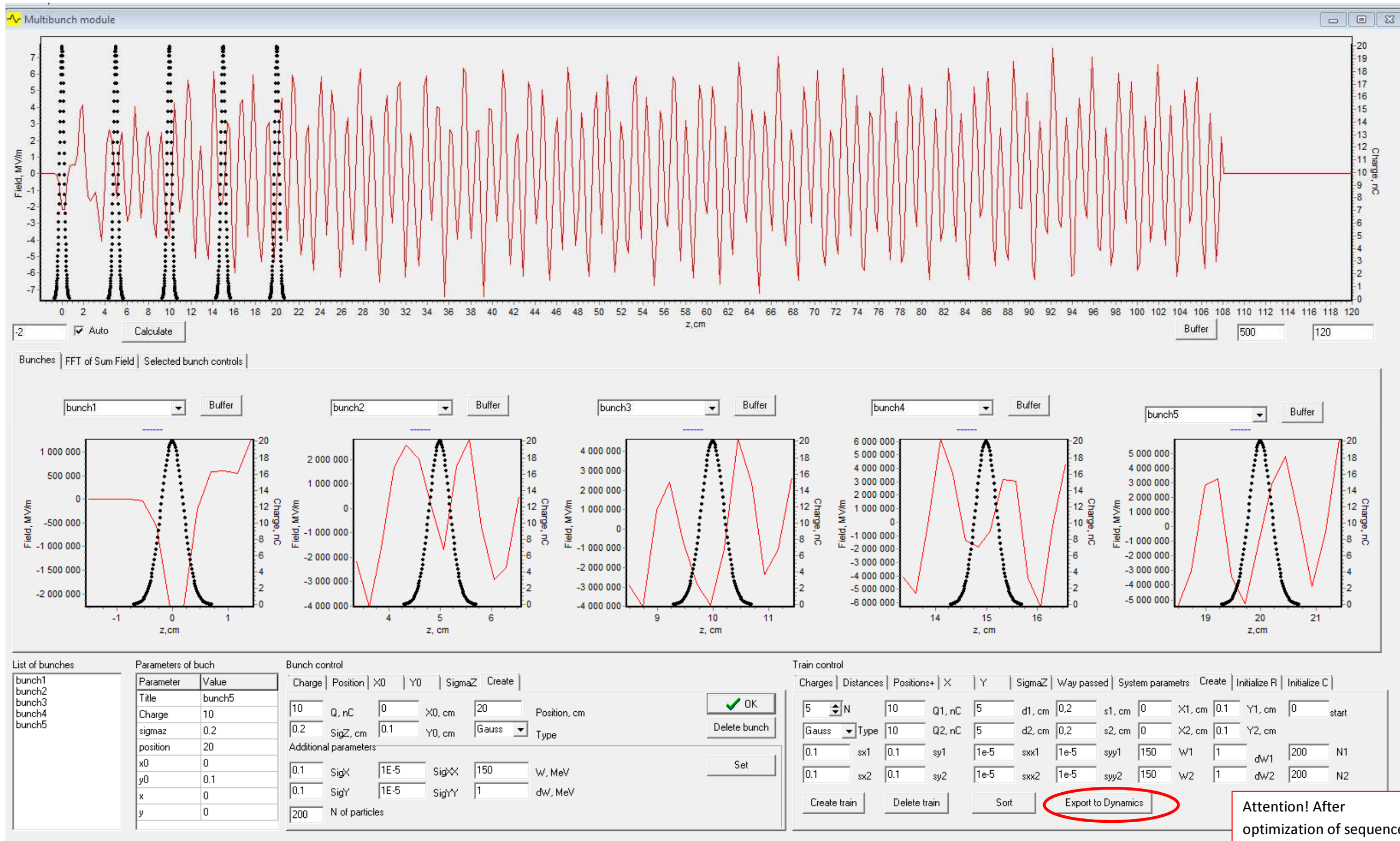
This module allows to calculate field created by sequence of bunches. User can create any numbers of bunches, control its parameters, watch bunches in selected windows, calculate spectrum of wakefield and export data tom beam dynamics Module. Start work with panels "Initialize". Then user can add bunch or train of bunches.



Selected bunch control

Train of bunches control

Pic. 13 Window for focusing system control



Pic. 14 Window of Multibunch module. User can see bunches in sequence or in different windows

Attention! After optimization of sequence user can calculate Beam Dynamics!