Hellweg2D Interface Guide

To calculate beam dynamics in TW linacs you need to follow some simple steps, describing below.

1. INPUT file.

Program reads the initial data from text file «INPUT.txt» which must be in the same folder as the "Hellweg2D.exe" file. If the data was successfully read, you will see the correct numbers in the main window. If the data is not correct you can look through the «PARSER.txt» file to see what lines were successfully read. The example of an input file is presented in Figure1.1

```
OPTIONS COULOMB
SOLENOID 0.1     1        0
BEAM 90 180      EQ       0.05     0.0001   EQ
CURRENT 0.01     1000     1.00     1.192    0.002
POWER    25      2856 0.00

CELL 120         0.413    123.684 0.005550         0.163323
CELL 120         0.432    239.010 0.010804         0.123194
CELL 120         0.630    358.763 0.007940         0.114390
CELL 120         0.958    429.009 0.005722         0.112439
CELL 120         0.997    430.000 0.005506         0.112549
CELL 120         0.999    430.000 0.005489         0.112564
CELL 120         0.999    432.500 0.005546         0.112294
CELL 120         0.999    435.000 0.005599         0.112028
CELL 120         0.999    437.500 0.005653         0.111761

END
```

Fig. 1.1 INPUT.txt structure

Operators description:

- OPTIONS. This keyword defines extra modes that will be used in calculations.

COULOMB – defines a space charge influence. *Ex. OPTIONS COULOMB REVERSE*

- SOLENOID. This keyword sets the source of external longitudinal magnetic field. There are 3 parameters to define solenoid specification: magnetic field strength B[T]; solenoid length L[m]; longitudinal coordinate of the start of the solenoid Z_0[m]

Ex. SOLENOID 0.15 0.2 0.1

Custom magnetic field distribution can be imported from file. In this case you add the name of the file with magnetic field data after the keyword SOLENOID.

Ex. SOLENOID BFIELD.txt

The following input file format must be used: first column is z coordinate in [m], second is magnetic field in [Gs]. Z-coordinates can be outside the simulation domain.

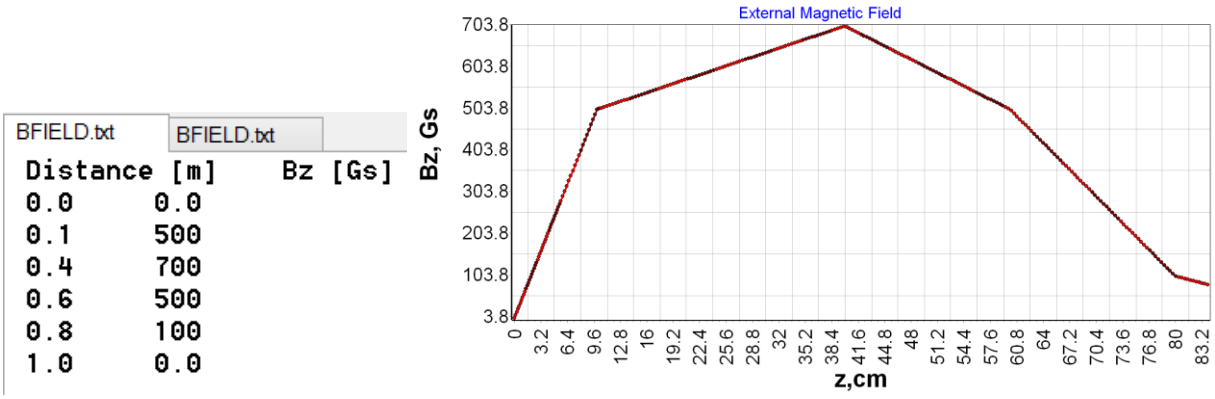


Fig. 1.2 BFIELD.txt file structure and imported field

- BEAM. Here is defined the initial distribution of particles in a longitudinal phase space. There are 6 parameters to be defined: average phase φ_0[grad]; type of particles phase distribution (NORM for normal distribution, EQ for uniform distribution); average energy W[MeV]; thickness of energy spectrum ΔW[MeV]; type of particles energy distribution (NORM for normal distribution, EQ for uniform distribution).

Ex. BEAM 90 20 EQ 0.8 0.1 NORM

- CURRENT. This keyword describes the initial parameter of an electron beam: beam pulse current I_0[A]; number of particles in beam N; Twiss parameters α, β[cm/rad], ε[cm/rad]

Ex. CURRENT 0.15 1000 2.2 2.8 0.004

The particles distribution in transverse phase space x-x' can be exported from the external file. In this case you add the name of file with x-vx data after the beam current value.

Ex. CURRENT 0.15 beam.txt

The following input file format must be used: first column is x coordinate in [m], second is transverse velocity in [m/s]. This is the format of exported particles from beam monitor in CST Particle Studio Tracking Solver.

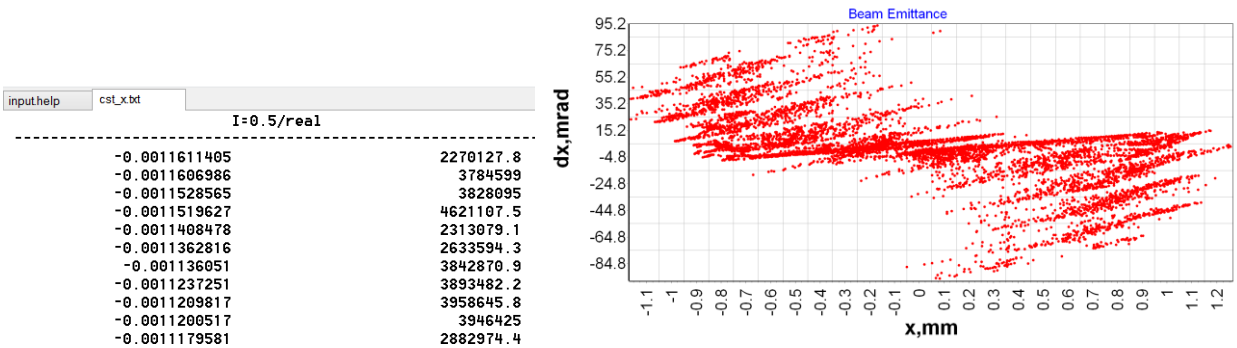


Fig. 1.3 cst_x.txt file structure and imported distribution

- POWER. Defines RF power input parameters: input pulse power P_0[MW]; operating frequency F_0[MHz]; phase shift from the reference phase $\Delta\varphi$[grad] (this parameter can be undefined – in this case it will be automatically assumed to be zero)

Ex. POWER 2.0 2856

Ex. COUPLER 4.5 5712 90

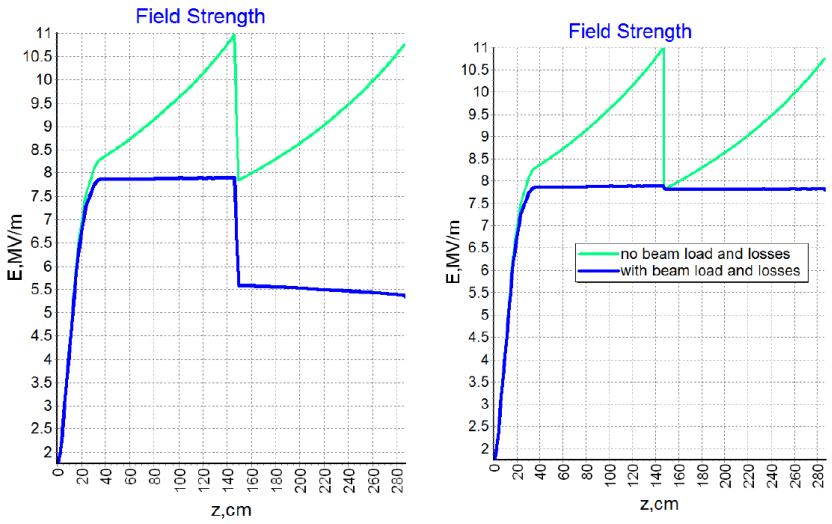
It possible to modulate extra RF power inputs by putting operator POWER before coupling CELL line (pic 1.4). This operation equates power counter to value defined in the POWER line (pic.1.5b)

```
OPTIONS          COULOMB
SOLENOID 0.09    0.5      0
BEAM 45 45       EQ       0.025    0.0000   EQ
CURRENT 0.075    1000     1.00     1.192    0.002

POWER    5.0     2856     0.00
CELL 120         0.420    82.500   0.004802          0.190819
CELL 120         0.475    92.000   0.003981          0.188993
CELL 120         0.525    110.000  0.003364          0.182546
                                  ...
CELL 120         0.999    514.875  0.007304          0.103506

POWER    5.0     2856     0.00
CELL 120         0.999    368.000  0.003984          0.120257
CELL 120         0.999    370.500  0.004052          0.119765
CELL 120         0.999    372.688  0.004138          0.119335
CELL 120         0.999    375.188  0.004237          0.118842
CELL 120         0.999    377.375  0.004323          0.118412
CELL 120         0.999    379.875  0.004421          0.117920
CELL 120         0.999    382.375  0.004477          0.117642
```

Fig. 1.4 Example of extra RF power input



a b

Fig.1.5 Longitudinal electrical field in linac (a – without extra POWER line; b- with extra POWER line)

- CELL. In this line 5 cells parameters are defined: phase shift per cell θ*grad+; relative phase speed β_{phase}; normalized value of electrical accelerating field intensity ; normalized attenuation factor $\alpha\lambda_{3/2}[m_{1/2}]$; normalized aperture radius a/λ (If last 2 parameters are not defined, program automatically recalculates it for DLS structure using tables. But in this case only modes π/2 and 2π/3 can be calculated)

Ex. CELL 120 0.999 380.0 0.01 0.12

Ex. CELL 90 0.8 200.0

-CELLS. Almost the same function as CELL, but this line defines N number of cells with equal parameters

Ex. CELLS 6 120 0.999 380.0 0.01 0.12

-DRIFT. You can define a drift tube using 2 parameters: length L[cm]; radius a[cm]. Optionally, it is possible to add the number of mesh points for drift element after the radius that will override the global mesh settings.

Ex. DRIFT 10.0 2.0

Ex. DRIFT 10.0 2.0 100

Please, note that the DRIFT element will terminate any power used before.

-SAVE. If this line is present, the code will export the live particle parameters (phase, energy, radius, azimuth and radial velocity) at position define in the INPUT to the defined file

Ex. CELLS 3 120 0.999 380.0

SAVE beam.log

DRIFT 10.0 2.0

In this example the particle parameters will be exported at the position between 3 cells and a drift. Multiple export commands are possible, but two SAVE lines at the same position will be overwritten.

It is possible to define the number of particles to be exported or the region of particles numbers after the name of file

Ex. SAVE beam.log 500

Ex. SAVE beam.log 1000 2000

In the first example, the first 500 particles will be exported. In the second one, only the particles with numbers from 1000 to 2000 will be exported. Lost particles are not exported.

Several flags are allowed to define the particular parameters to be exported. If no flags are defined, all parameters (except live status) will be exported. If at least one flag is set, only flagged parameters wil be exported.

LOST – export the lost or live status of the particle

PHASE – export the phase of the particle

ENERGY – export the energy of the particle

RADIUS – export the radius of the particle

AZIMUTH – export the azimuth of the particle

VX – export the radial velocity of the particle

The flags must be defined in any combination after the number of elements region or after the file name if the region is not defined.

Ex. SAVE beam.log LOST ENERGY

Ex. SAVE beam.log 500 ENERGY PHASE RADIUS

Ex. SAVE beam.log 500 2000 LOST RADIUS VX

COMMENTS. Any line with improper format will be ignored and not copied into the output file. To make a comment use '!' symbol in the beginning of the line

Ex. !This line is a comment

2. Simulation and post-processing results.

Program interface is presented in Figure 2.1

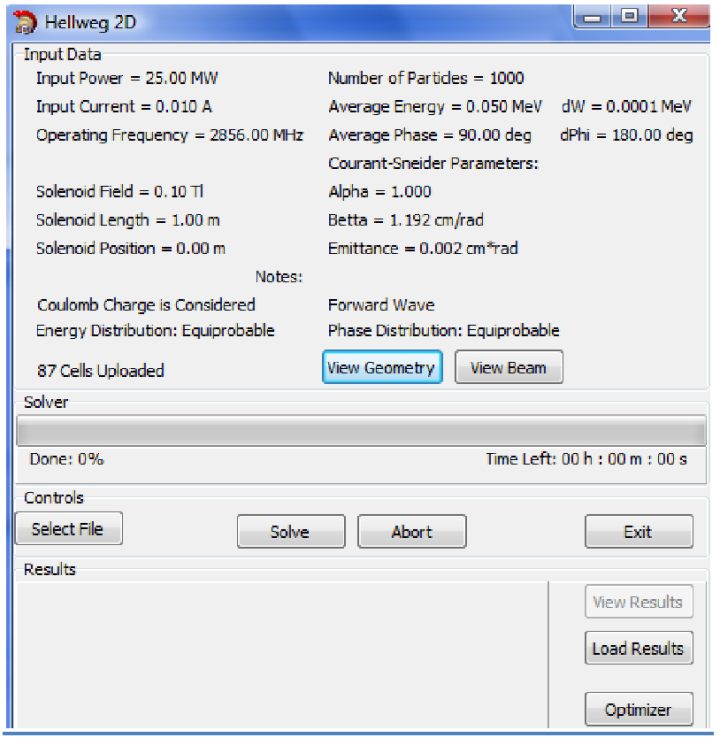


Fig. 2.1 Hellweg2D Interface

Hellweg2D automatically reads an input file and displays user defined parameters.

You can watch defined cells parameters on the graphs by pushing “View Geometry” and defined beam parameters on the graph by pushing ”View Beam”

After solving the problem (button “Solve”) «OUTPUT.txt» file is automatically generated. You can watch results of calculations in the Hellweg2D window (Fig.2.2) or you can find OUTPUT.TXT in program folder.

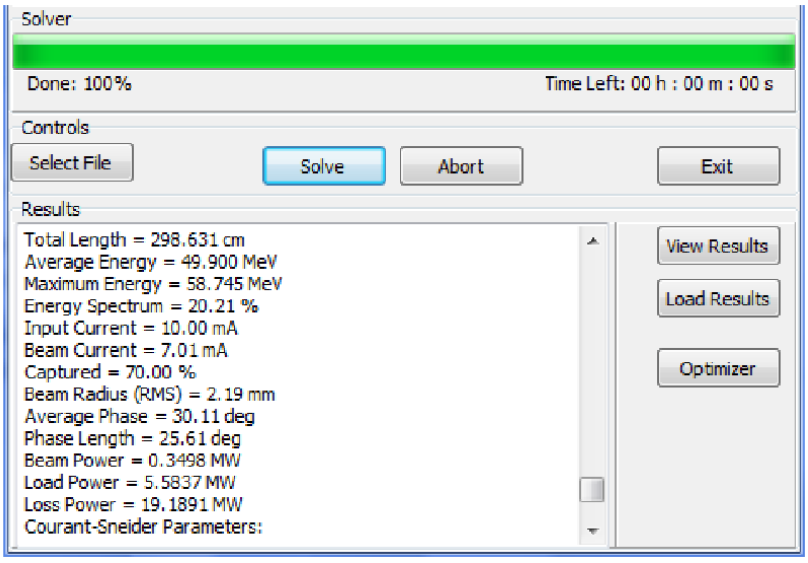


Fig. 2.2 Results of calculation

Button “View Result” lets user to watch graphical results such as Field vs. coordinate; phase space; energy spectrum, etc (Fig.2.3).

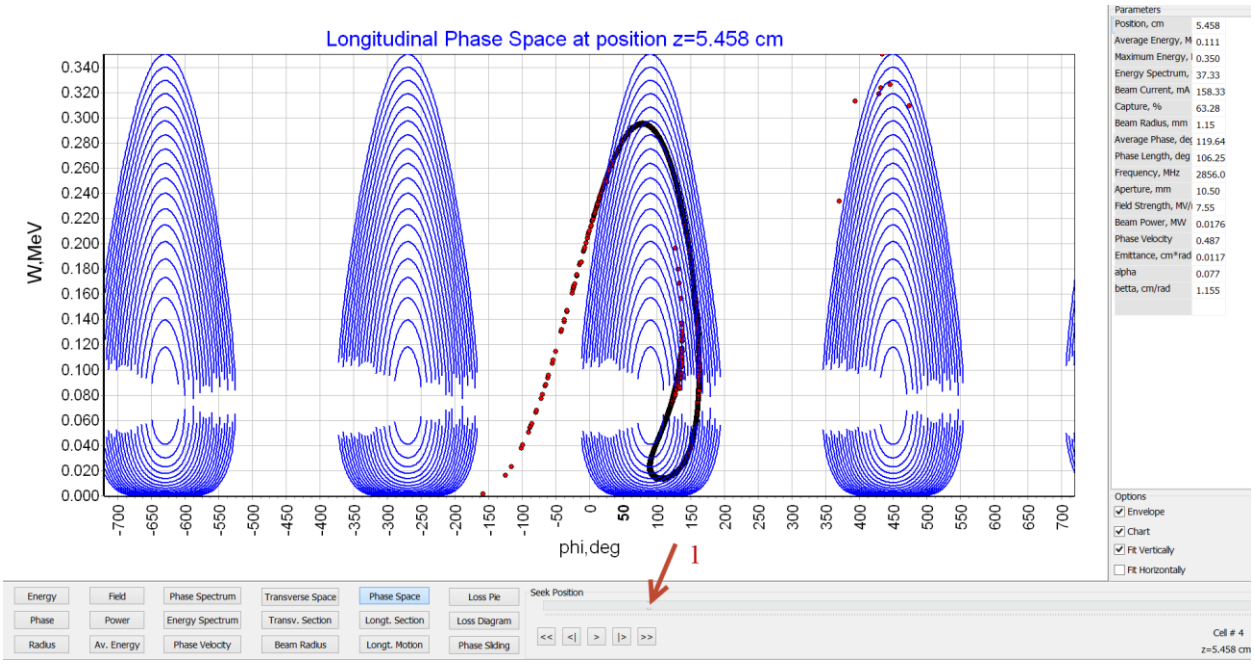


Fig 2.3 Graphical results

Using marker 1 (Fig. 2.3) user can watch beam parameters in any longitudinal coordinate

3. Optimizer.

Hellweg2D has a very convenient feature – Optimizer (Fig. 3.1)

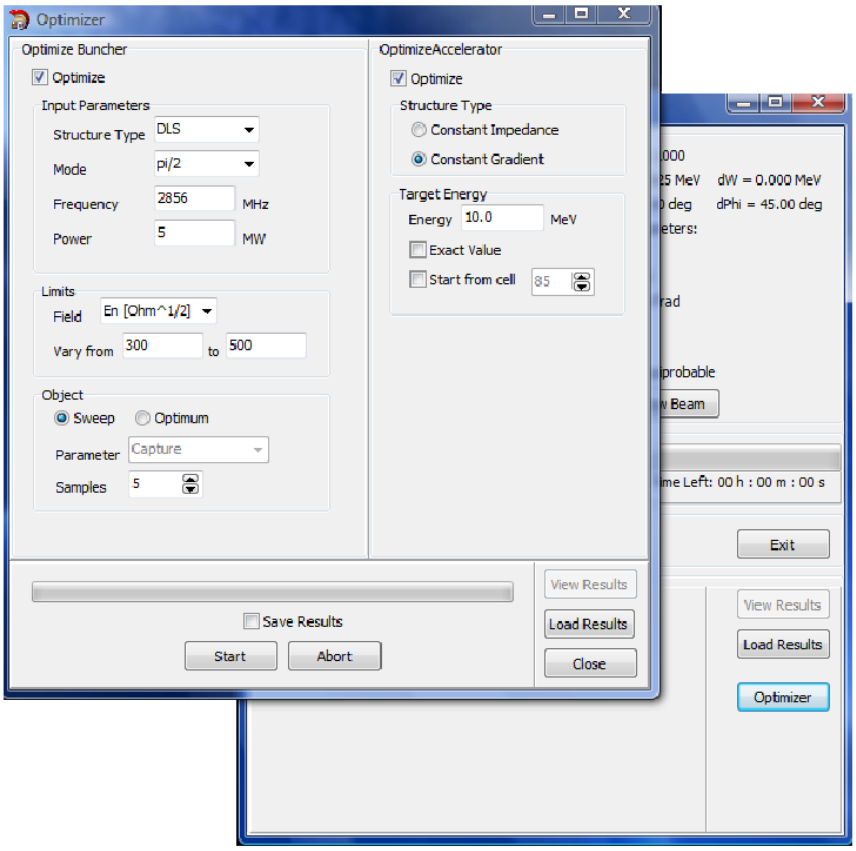


Fig. 3.1 Optimizer interface

This function can calculate DLS cells parameters (relative phase speed β_{phase}; normalized value of electrical accelerating field intensity ; normalized attenuation factor $\alpha\lambda_{3/2}[m_{1/2}]$; normalized aperture radius a/λ) using included tables to obtain the desired energy on the end of the accelerator without access to the INPUT file.

- Optimize Buncher. In this window user defines coupler parameters and desired buncher field parameters.

·*Input parameters:* Choice between π/2 and 2π/3 modes; operating frequency; input pulse power.

·*Limits:* It necessary to define allowable variations of the values of the accelerating electrical field on the end of the buncher. User can choose between 3 field dimensions: dimensionless field A; normalized electrical field ; absolute value of electrical field E [MV/m].

·*Object:* There are 2 algorithms to calculate buncher cells parameters: *Sweep* divides an interval defined in Limits for equal parts (Samples) and calculates field in them using table's data; *Optimum* chooses the best field value to obtain the best capture coefficient/energy spectrum/phase spectrum (Parameter).

- Optimize Accelerator. In this window user defines desired output parameters.

·*Structure type:* The choice between Constant Gradient or Constant Impedance structures. In the first case the optimizer will add the cells identical to the last one. In second case, it will adjust the aperture radius in order to maintain the same electrical field gradient.

·*Target Energy:* It is necessary to define desired output energy. Marker “Exact Value” varies beam current to obtain exact value of average beam energy.

Marker “Start from cell” is used when it is necessary to modulate accelerating structure after the already defined cells parameters in INPUT file (Optimize Buncher marker is switched off)

- Get Results. You can find results in the OUTPUT file in the Results folder

4. Configuration file.

Mesh parameters and interpolation parameters are defined in file Hellweg.ini which placed in program folder (Fig. 4.1)

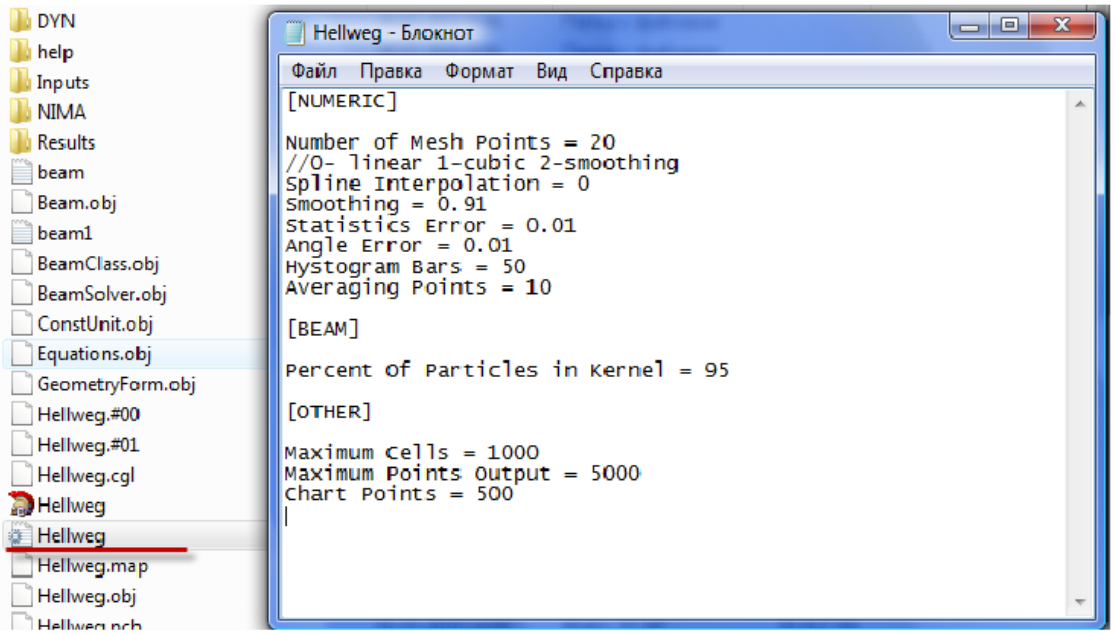
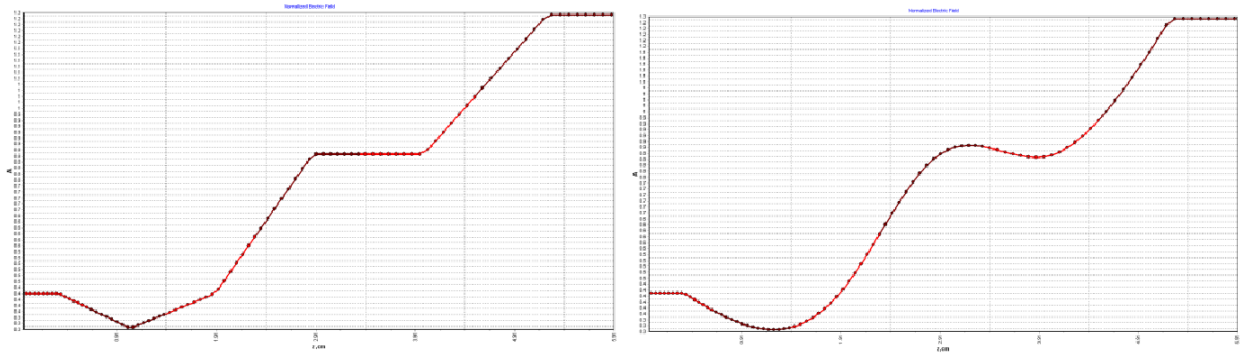


Fig. 4.1 Hellweg2D configuration file

- Number of mesh points. This value of mesh points will be used for accelerating field interpolation in cell. Please, note that the same number of points will be used for a single DRIFT element.

- Interpolation. Relative phase speed and value of accelerating electrical field are defined in the centers of cells. Then these values are interpolated for other mesh cells (Number of mesh points). In Figure 4.2 are presented 2 kinds of interpolations (linear and cubic). It is recommended to use linear interpolation to avoid nonphysical field oscillations. Smoothing spline can be used for example to obtain spectrum envelope.



a b

Fig. 4.2 Interpolation types (a-linear; b-cubic)

Thank you for using our program!

Have a good simulation time with Hellweg2D!