Hands-on session with 1D BEPS Codes
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The codes for today's hands-on session are in the directory:
new_beps1.source

Included are 3 main codes and supporting libraries:

- new_beps1.f, an unmagnetized electrostatic code
- new_bbeps1.f, a magnetized electromagnetic code
- new_dbeps1.f, a magnetized darwin code.

These are simple codes intended for teaching:

- Periodic, electrons only

The mathematical foundations for these codes is in the file:
UPICModels.pdf

Details about the codes themselves are in the file:
README1.txt

Generally, these codes are intended to run interactively. The preferred mode of operation is to use X11. This requires installation of a free graphics library called Ygl. The preferred compiler is gfortran, although other compilers should work.

To compile these codes, type: make

In addition, there are two post-processors, which performs time and frequency analysis of waves in the various models.

- spectrum1.f, for analyzing the potential
- vspectrum1.f, for analyzing the vector potential

To compile these codes, type: make -f spectrum1.make

It is also possible to run the codes in batch mode, producing post-script files which require some viewer to examine, such as Preview on the Macintosh. Details are in the README1.txt file.

Units:

These codes use dimensionless units, where distance is normalized to the size of the grid δ=Lx/Nx, and time to the plasma frequency $\omega_0 = \omega_{\mathrm{pe}}$. Thus:

$$\widetilde{x} = x/\delta \qquad \widetilde{t} = \omega_0 t \qquad \widetilde{\boldsymbol{v}} = \boldsymbol{v}/\delta\omega_0 \qquad \widetilde{q} = q/e \qquad \widetilde{m_e} = m/m_e$$

The grid spacing is then related to some other dimensionless parameter, typically the Debye length. Thus

$$\lambda_{De}/\delta = \frac{v_{the}}{\delta\omega_{pe}} = \widetilde{v}_{the}$$

The dimensionless thermal velocity is an input to the code. It is often set to 1, which makes the grid space equal to a Debye length. Further details about the units can be found in the UPICModels.pdf file.

There are 9 sample input files for the session:

input1.plasma
input1.test

input1.light
input1.weibel
input1.LR
input1.X

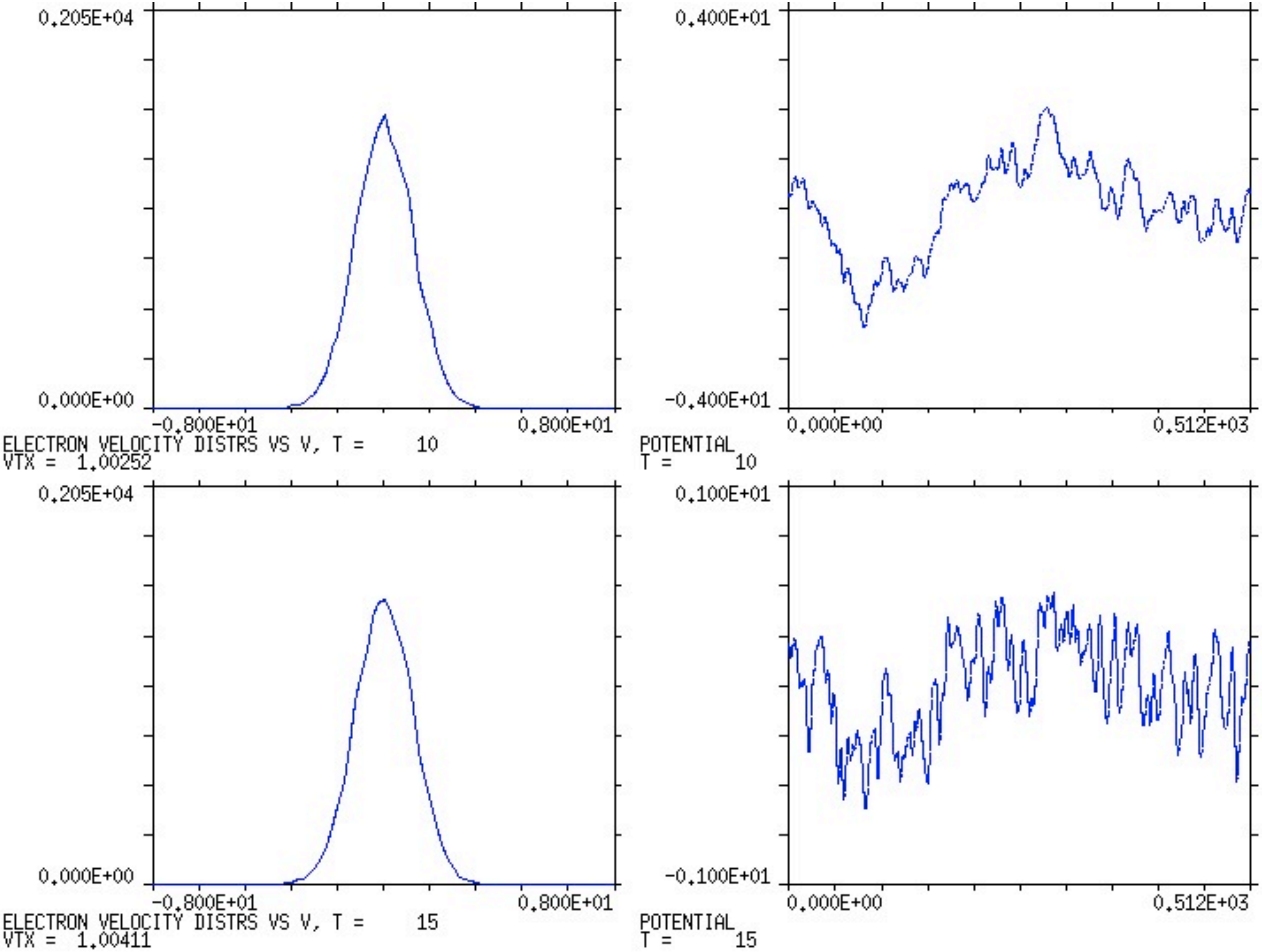
input1.darwin
input1.whistler
input1.dweibel

They are intended to be starting points for exploration.

The input to the codes are a namelist file, which must be called input1. Let's look at a typical input file for the electrostatic code.

```
&input1
IDRUN = 10
INDX =   9, NPX =   18432, NPXB = 0
INORDER = 1
NTW = 1, NTP = 5, NTV = 5
TEND = 1000.000, DT =   0.200
QME =  -1.000,  VTX =   1.000, VX0 =   0.000
AX = .912871
MODESXP = 40
NPLOT = 4
/
```

Start by copying input1.plasma into the file input1, by executing: cp input1.plasma input1. Then execute ./new_beps1


0.205E+04
0.000E+00
-0.800E+01
0.800E+01
ELECTRON VELOCITY DISTRS VS V, T = 10
VTX = 1.00252
0.400E+01
-0.400E+01
0.000E+00
0.512E+03
POTENTIAL
T = 10
0.205E+04
0.000E+00
-0.800E+01
0.800E+01
ELECTRON VELOCITY DISTRS VS V, T = 15
VTX = 1.00411
0.100E+01
-0.100E+01
0.000E+00
0.512E+03
POTENTIAL
T = 15

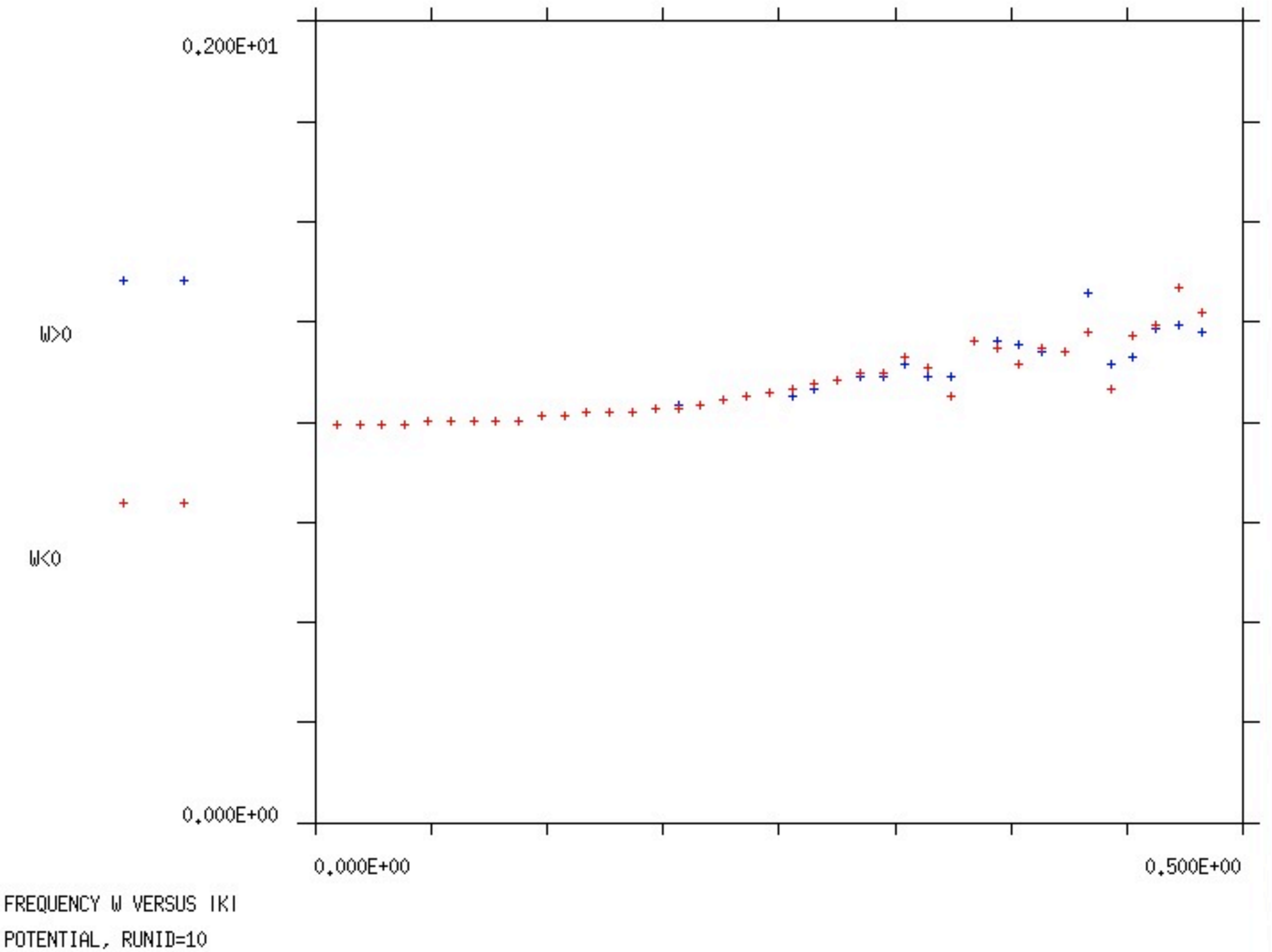
The input to the post-processors are usually entered interactively. Let's look at typical input for spectrum1:

```
&inspect1
BATCH = 1
DMETAF = '10'
LTS = 1, ITS = 1, NTS = 1000
KXMIN = 0, KXMAX = 39
NTD = 1000, NTC = 333
WMIN = 0.000, WMAX =   2.000, DW =   0.010
NPLOT = 4, NTR = 0
/
```

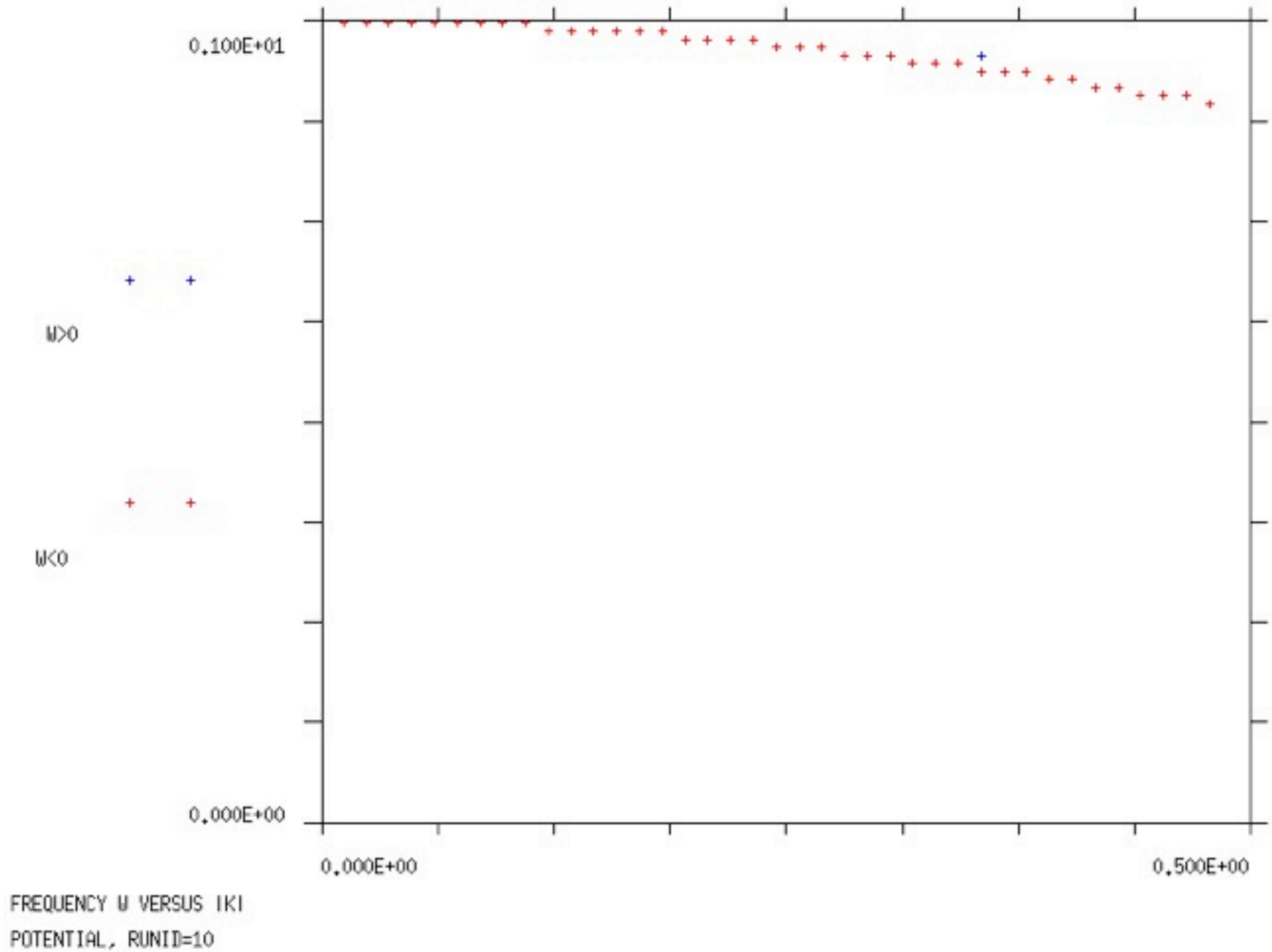
This input represents a plasma in thermal equilibrium, useful for looking at plasma waves.

Execute ./spectrum1

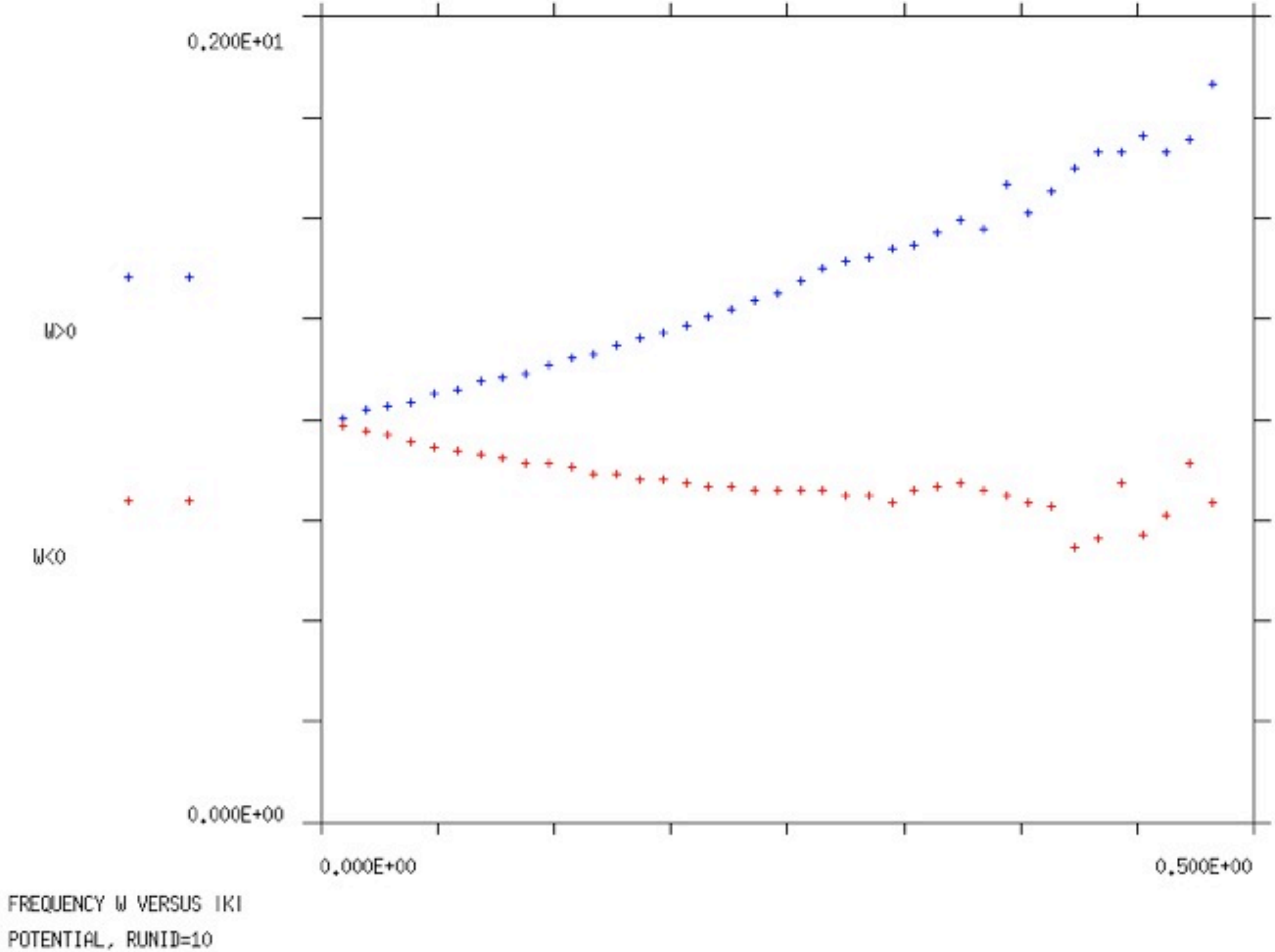
Enter 10 when prompted for the runid


0.200E+01
W>0
W<0
0.000E+00
0.000E+00
0.500E+00
FREQUENCY W VERSUS |K|
POTENTIAL, RUNID=10

Let's see what happens if we reduce the plasma temperature: set VTX = 0.2 and INORDER = 2



Let’s see what happens if we make the plasma drift: reset the original parameters, and set VX0 = 1.0

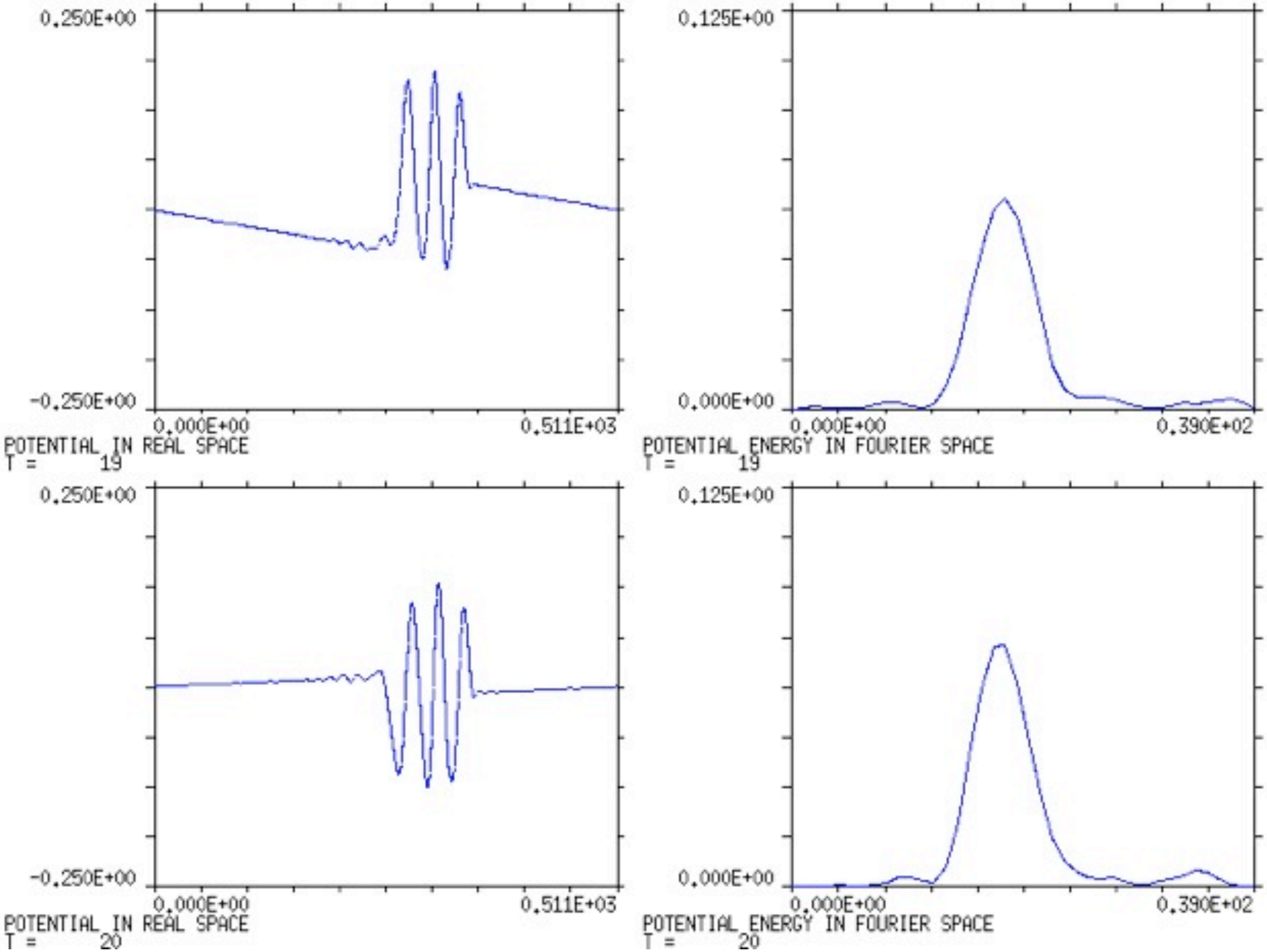


Now let us look at how a plasma responds to a test charge, by copying input1.test to input1, and executing ./new_beps1 We will add one beam particle, which is initially stationary.

```
&input1
IDRUN = 11
INDX =   9, NPX =   18432, NPXB = 1
INORDER = 1
NTW = 1, NTP = 5, NTV = 5
TEND = 100.000, DT =   0.200
QME =  -1.000,  VTX =   1.000, VX0 =   0.000
VTDX = 0.0, VDX = 0.0
AX = .912871
MODESXP = 40
NPLOT = 4
/
```

Now do a second run, where you change:
IDRUN=12 and VDX = 5.0

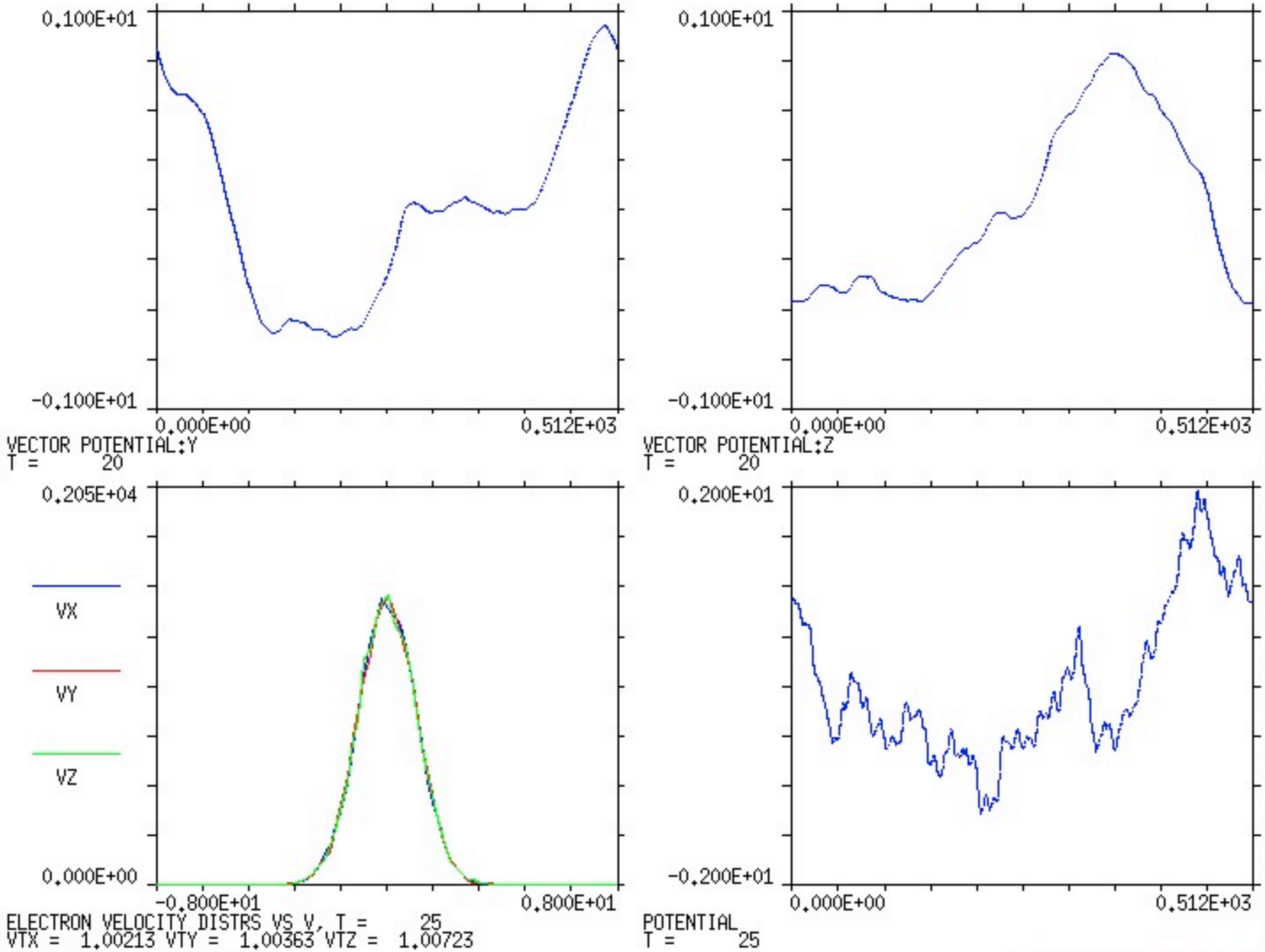
When you run the post-processor, enter 12/11 as the runid. This will display the differences between the two runs and you should see the wake created by the moving particle.



Let's look at a typical input file for the electromagnetic code:

```
&input1
IDRUN = 20
INDX =   9, NPX =   18432, NPXB = 0
INORDER = 1
NTW = 1, NTP = 5, NTV = 5, NTA = 5, NTE = 5
TEND = 500.000, DT =   0.0250, CI = 0.1
QME =  -1.000,  VTX =   1.000, VTY =   1.000, VTZ = 1.000
VX0 =   0.000, VY0 =   0.000, VZ0 =   0.000
AX = .912871
MODESXP = 40, MODESXA = 40, MODESXE = 40
NPLOT = 4
/
```

Start by copying input1.light into the file input1,
and executing ./new_bbeps1

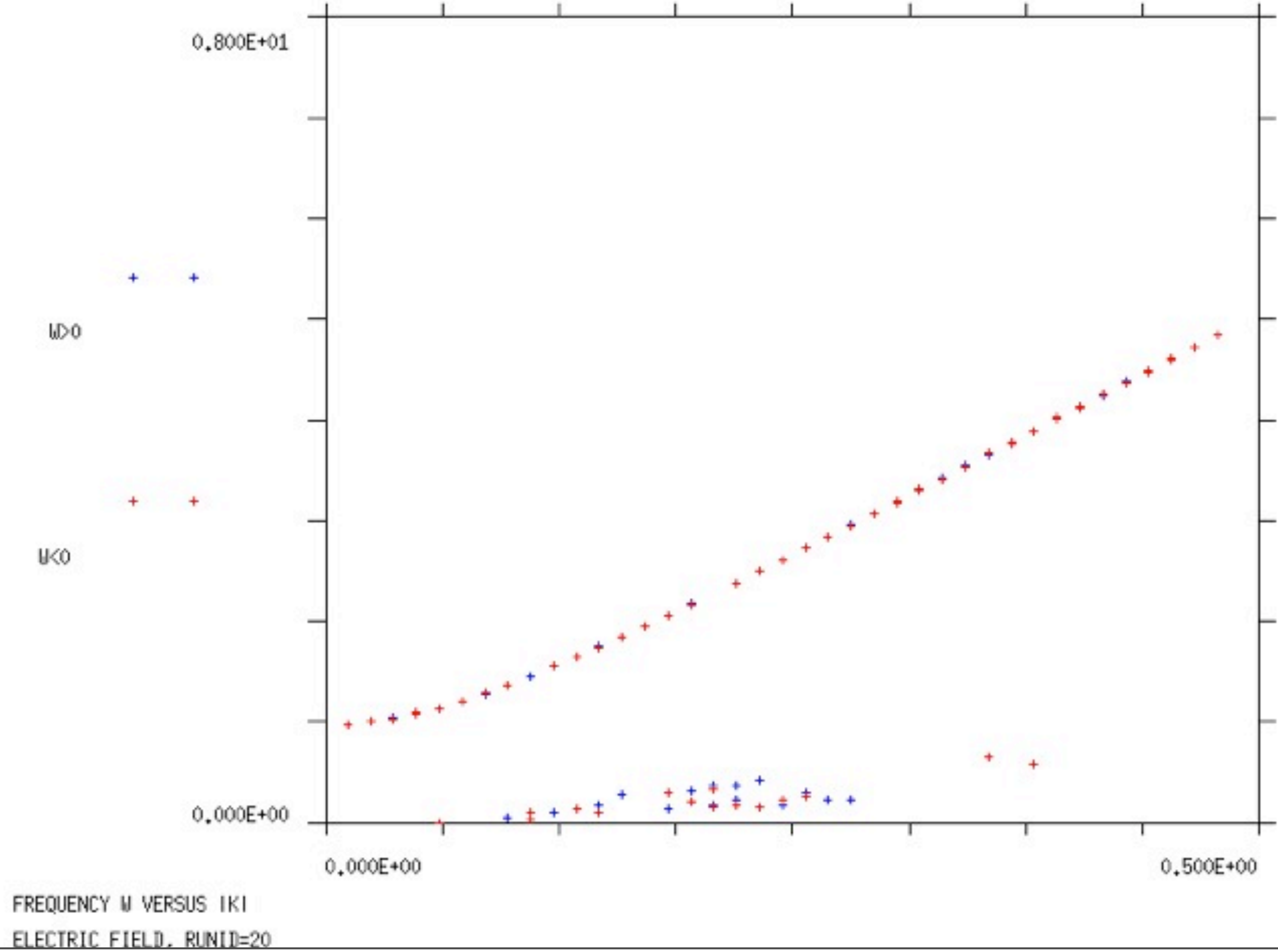


0.100E+01
-0.100E+01
0.000E+00
0.512E+03
VECTOR POTENTIAL:Y
T = 20
0.100E+01
-0.100E+01
0.000E+00
0.512E+03
VECTOR POTENTIAL:Z
T = 20
0.205E+04
0.000E+00
VX
VY
VZ
-0.800E+01
0.800E+01
ELECTRON VELOCITY DISTRS VS V, T = 25
VTX = 1.00213 VTY = 1.00363 VTZ = 1.00723
0.200E+01
-0.200E+01
0.000E+00
0.512E+03
POTENTIAL
T = 25

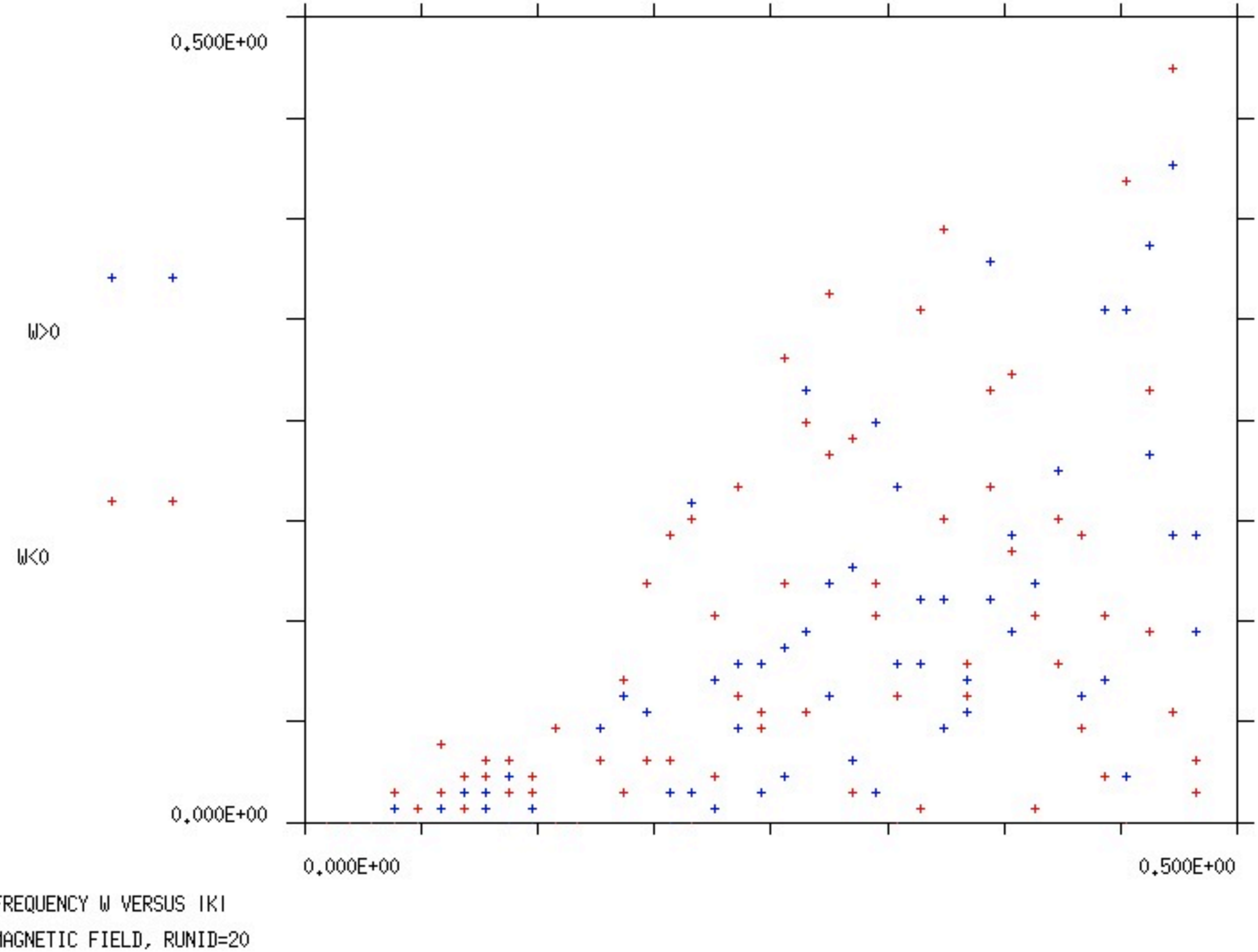
Execute ./vspectrum1

Enter 20 when prompted for the runid, then a for diagnostic type

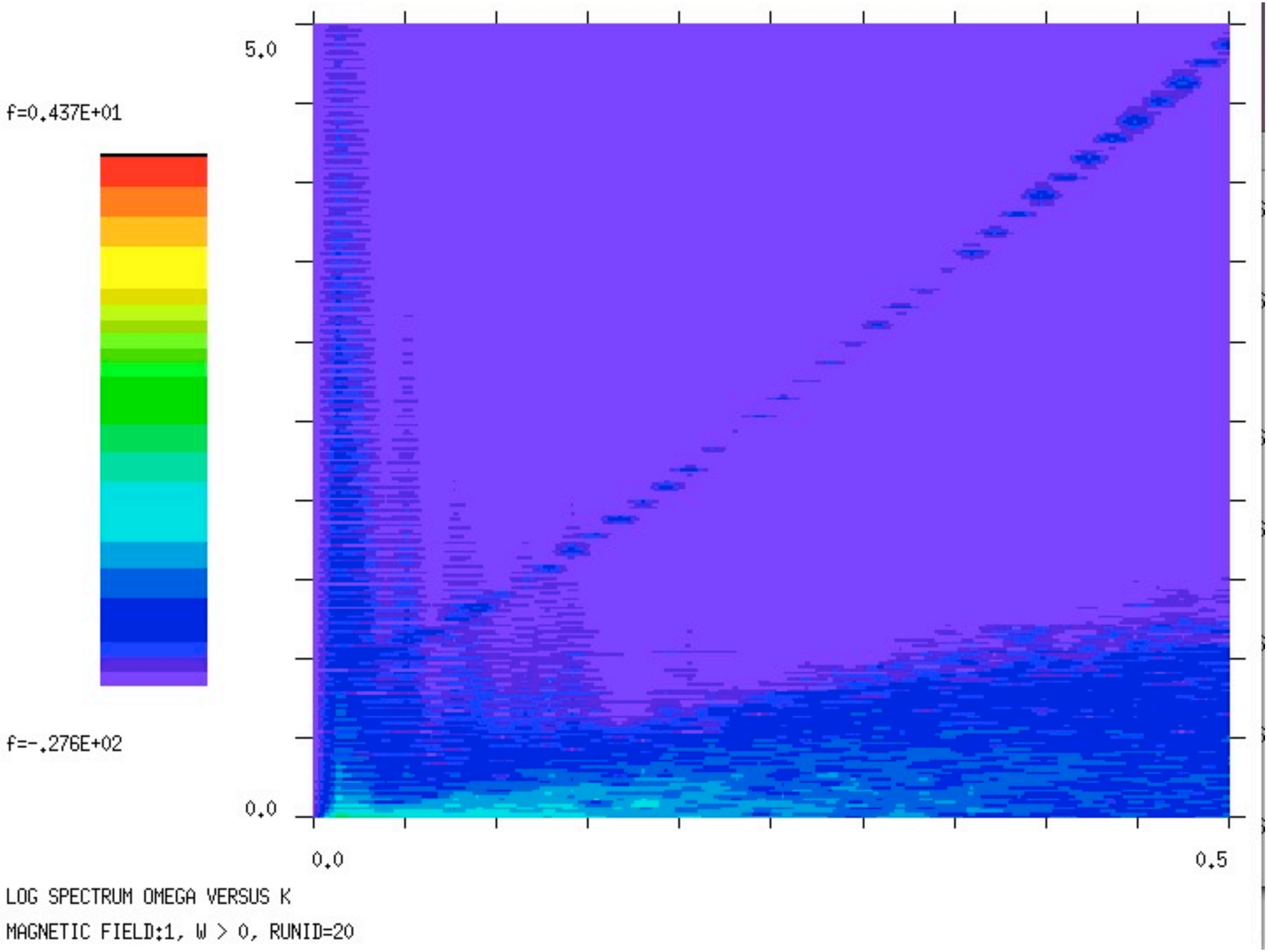
Examine the Electric field, NVF=2:



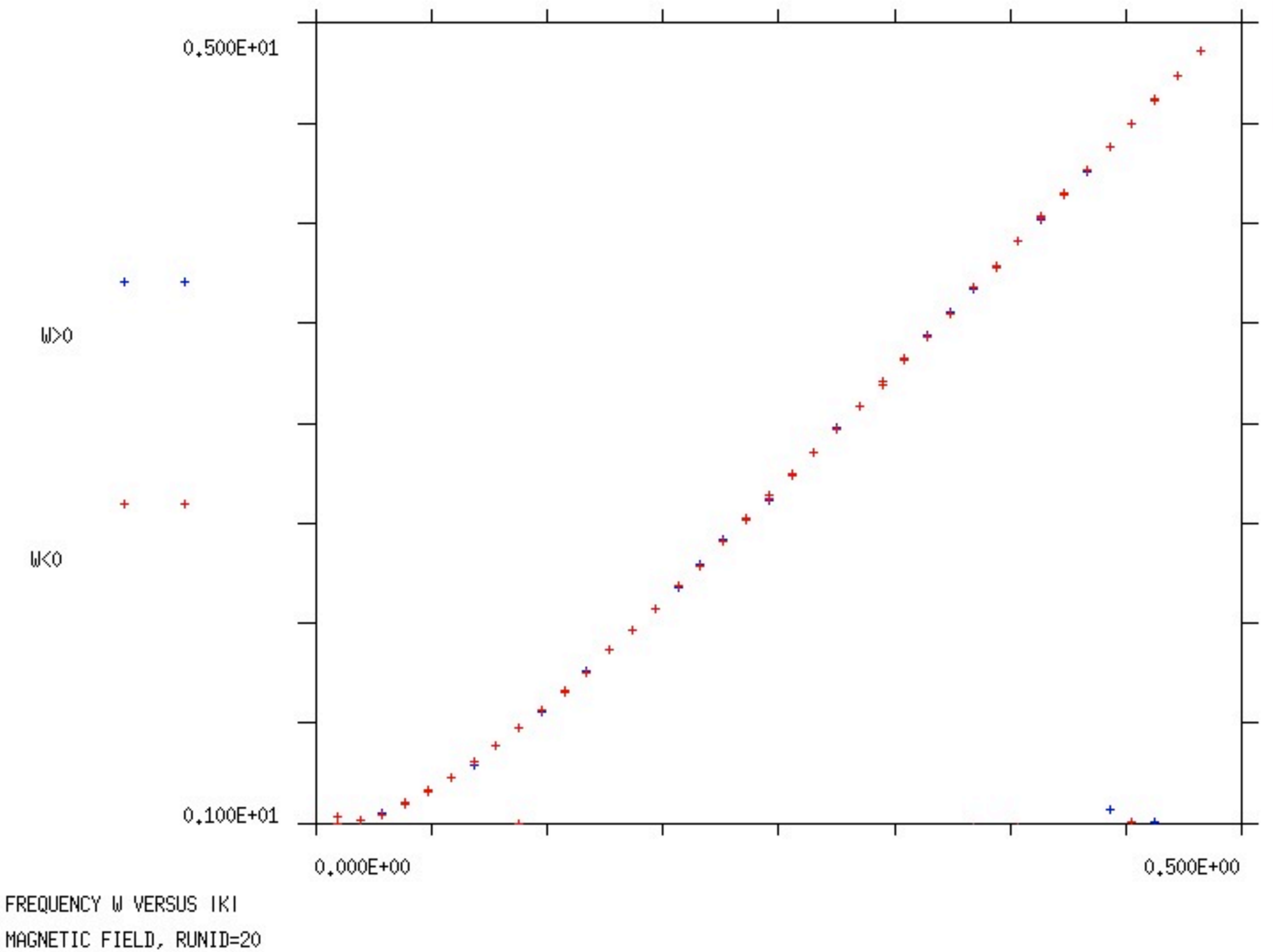
Examine the Magnetic field, NVF=3:



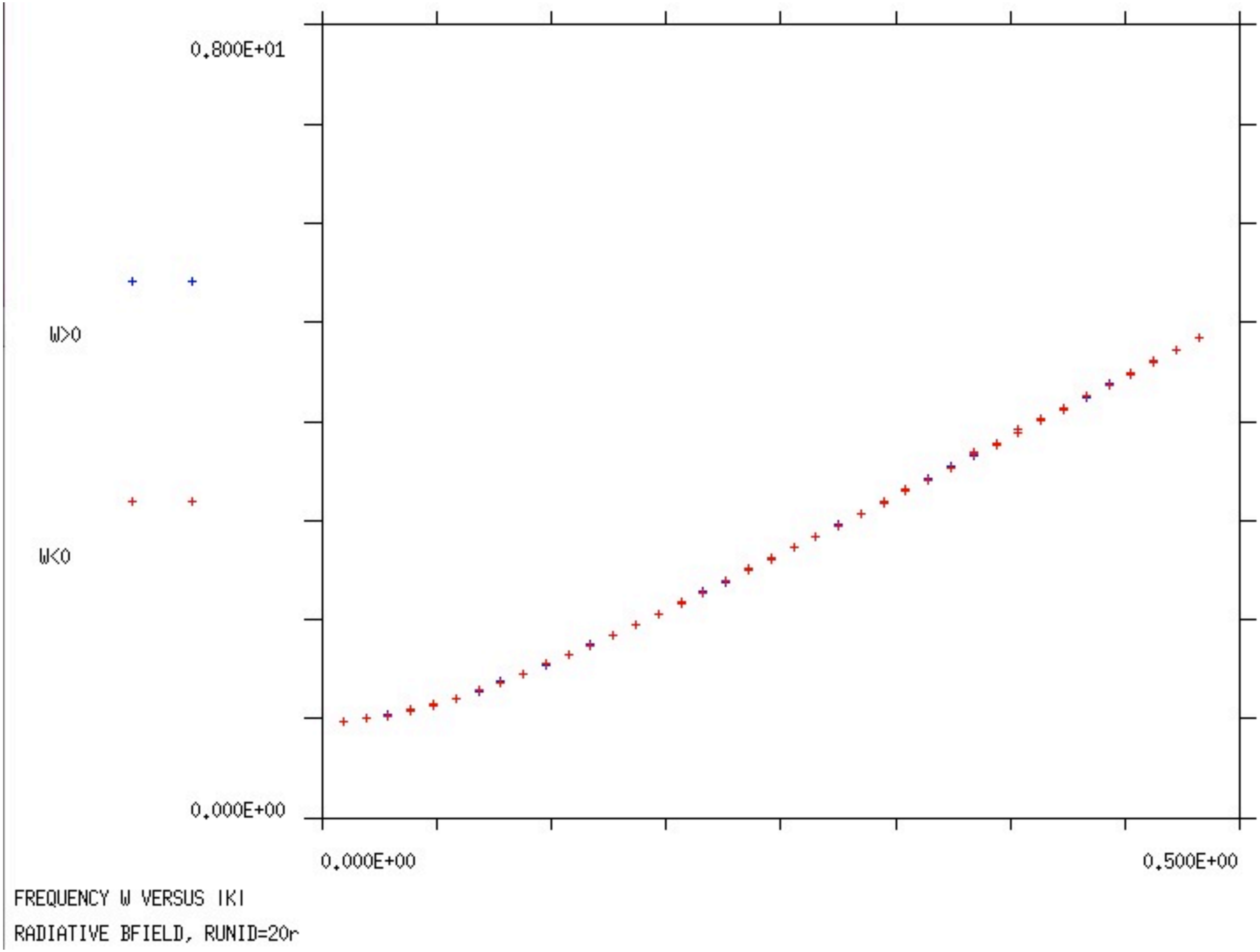
Examine the Magnetic field, NVF=3 and DMAP=1:



Examine the Magnetic field, NVF=3, exclude $0 < \omega < \omega_{\text{pe}}$:



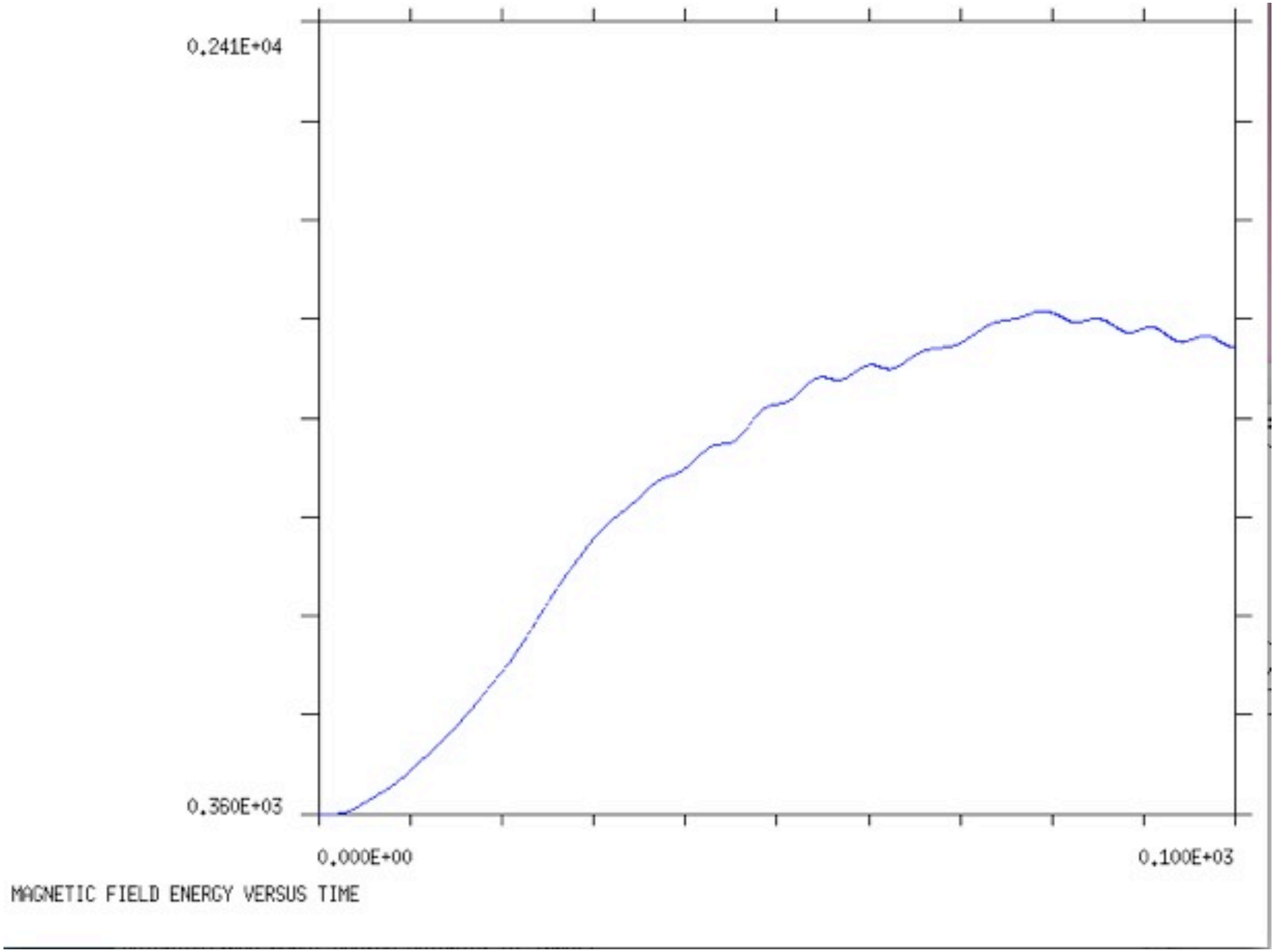
For diagnostic type e, examine the Radiative Magnetic field, NVF=3:



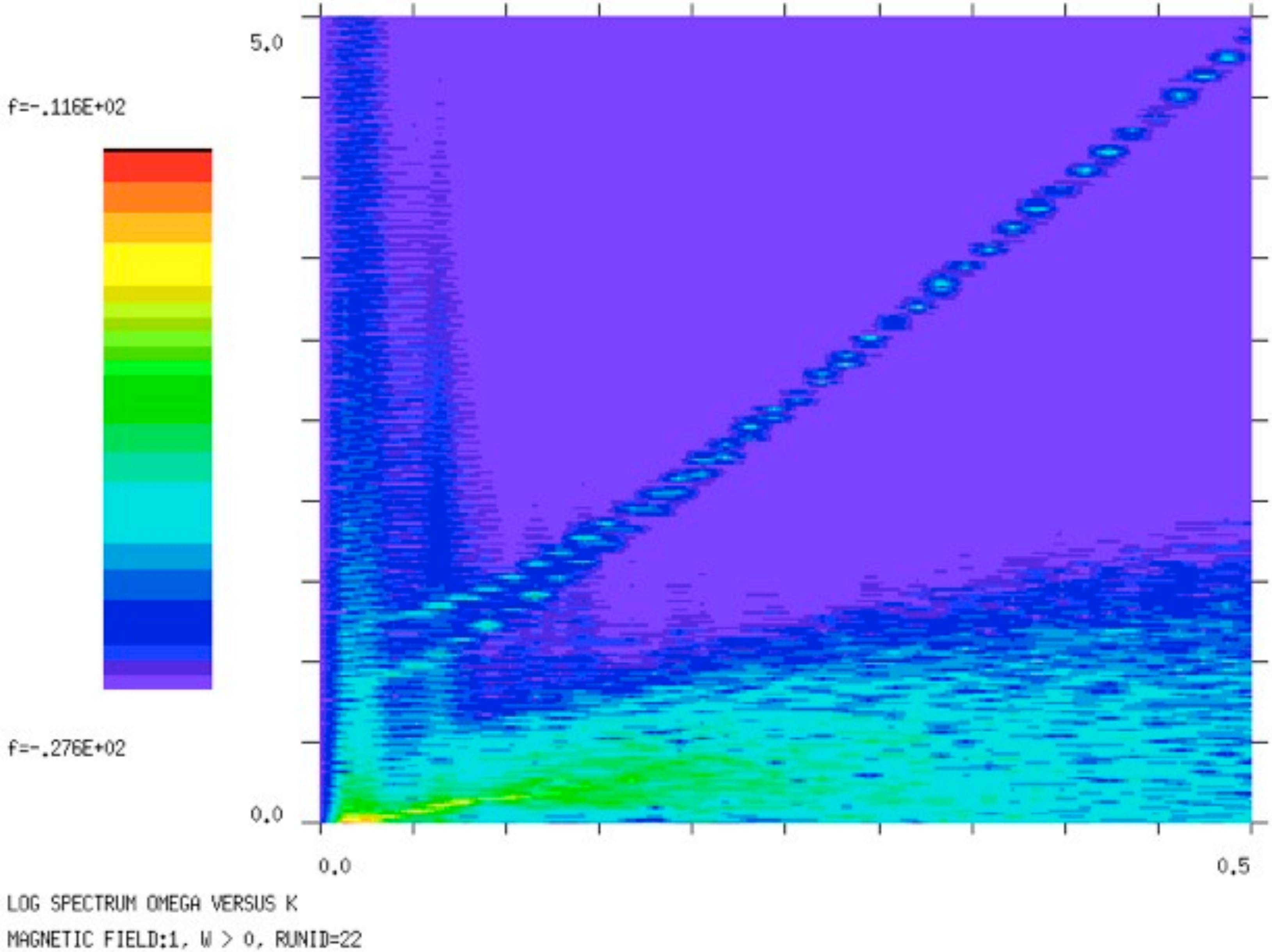
Let's see what happens if the temperature is anisotropic,
by copying input1.weibel to input1, and executing ./new_bbeps1

```
&input1
IDRUN = 21
INDX =   9, NPX =   18432, NPXB = 0
INORDER = 1
NTW = 1, NTP = 0, NTV = 40, NTA = 0, NTE = 0
TEND = 100.000, DT =   0.0250, CI = 0.1
QME =  -1.000,  VTX =   1.000, VTY =   2.000, VTZ = 1.000
VX0 =   0.000, VY0 =   0.000, VZ0 =   0.000
AX = .912871
MODESXP = 40, MODESXA = 40, MODESXE = 40
NPLOT = 4
/
```

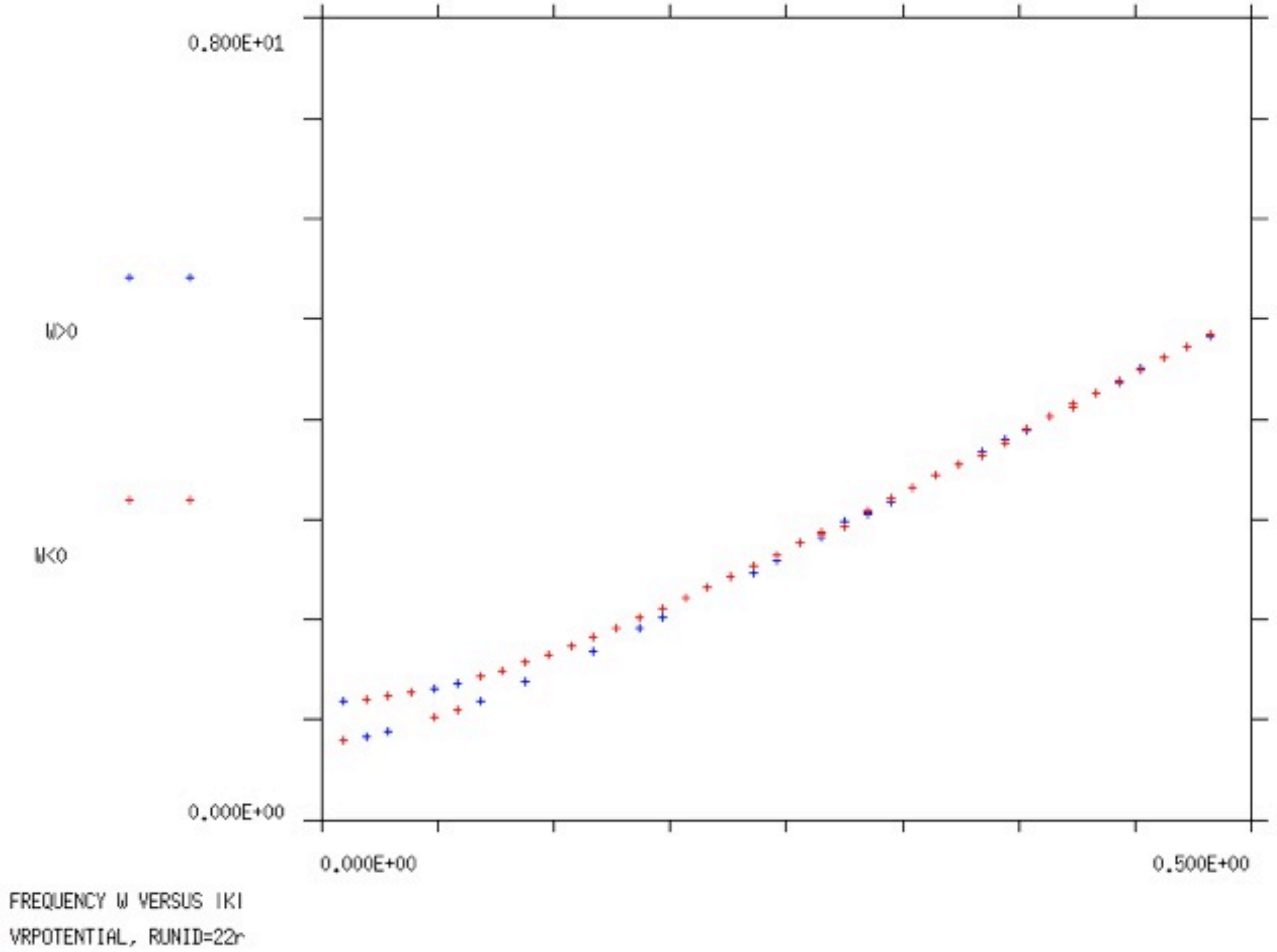
The final result: VTX=1.45, VTY = 1.65, VTZ = 1.04
and magnetic fields grows via weibel instability



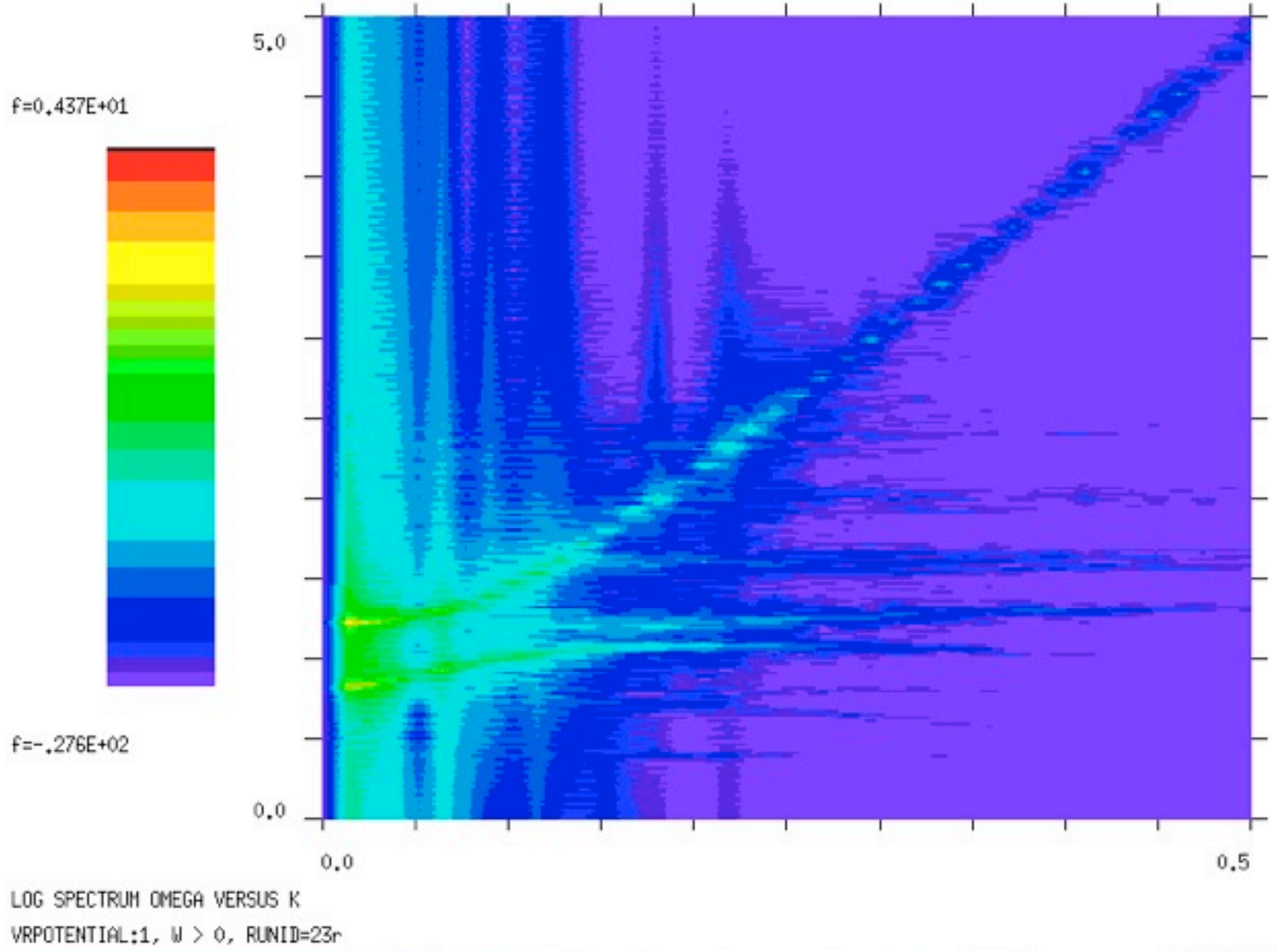
Let's look at waves in magnetized plasma, set OMX = 0.4 by copying input1.LR to input1, and executing ./new_bbeps1. To see LR waves and whistler waves, execute: ./vspectrum1



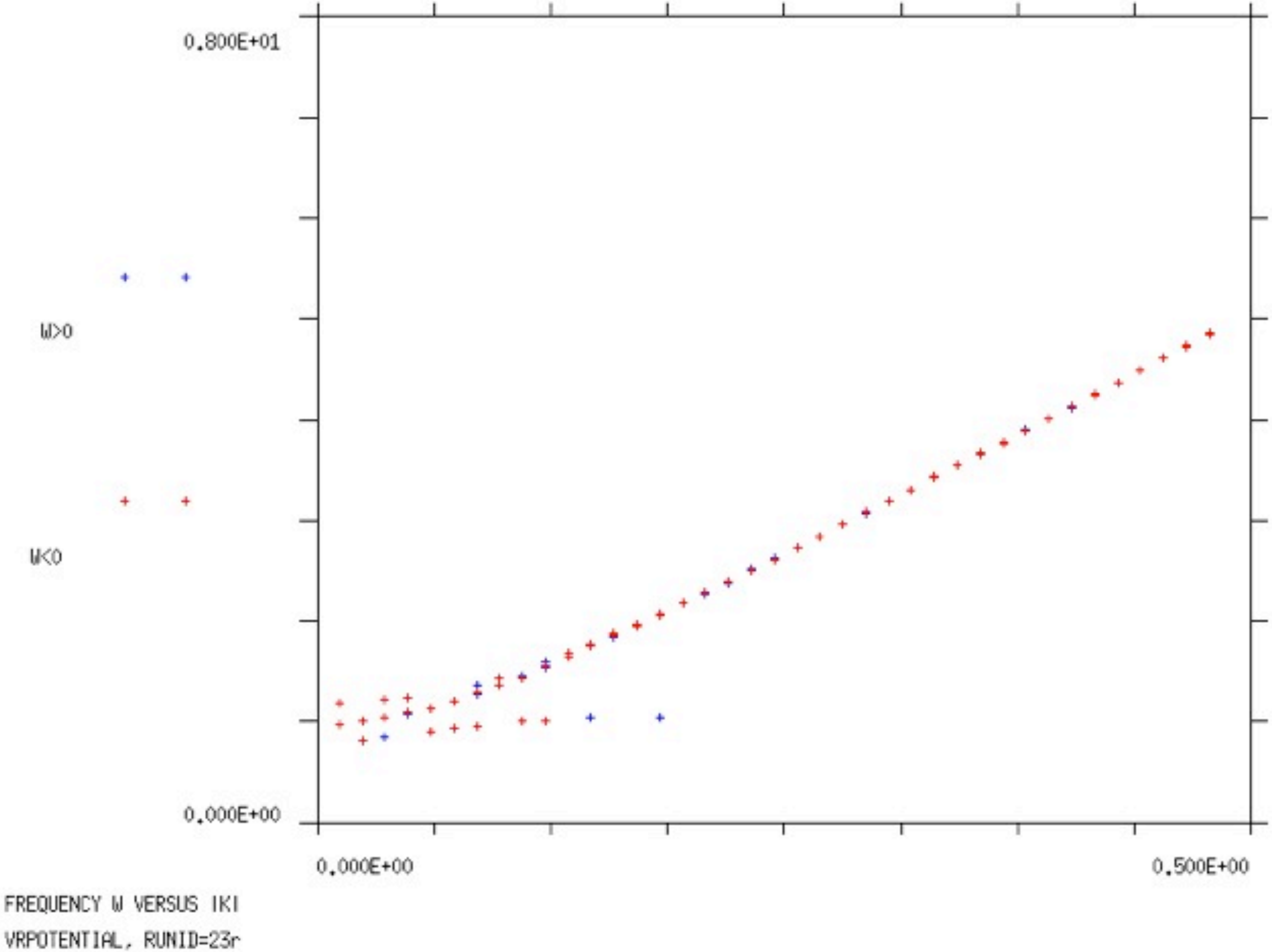
For diagnostic type e, Note LR waves are radiative, whistlers are not



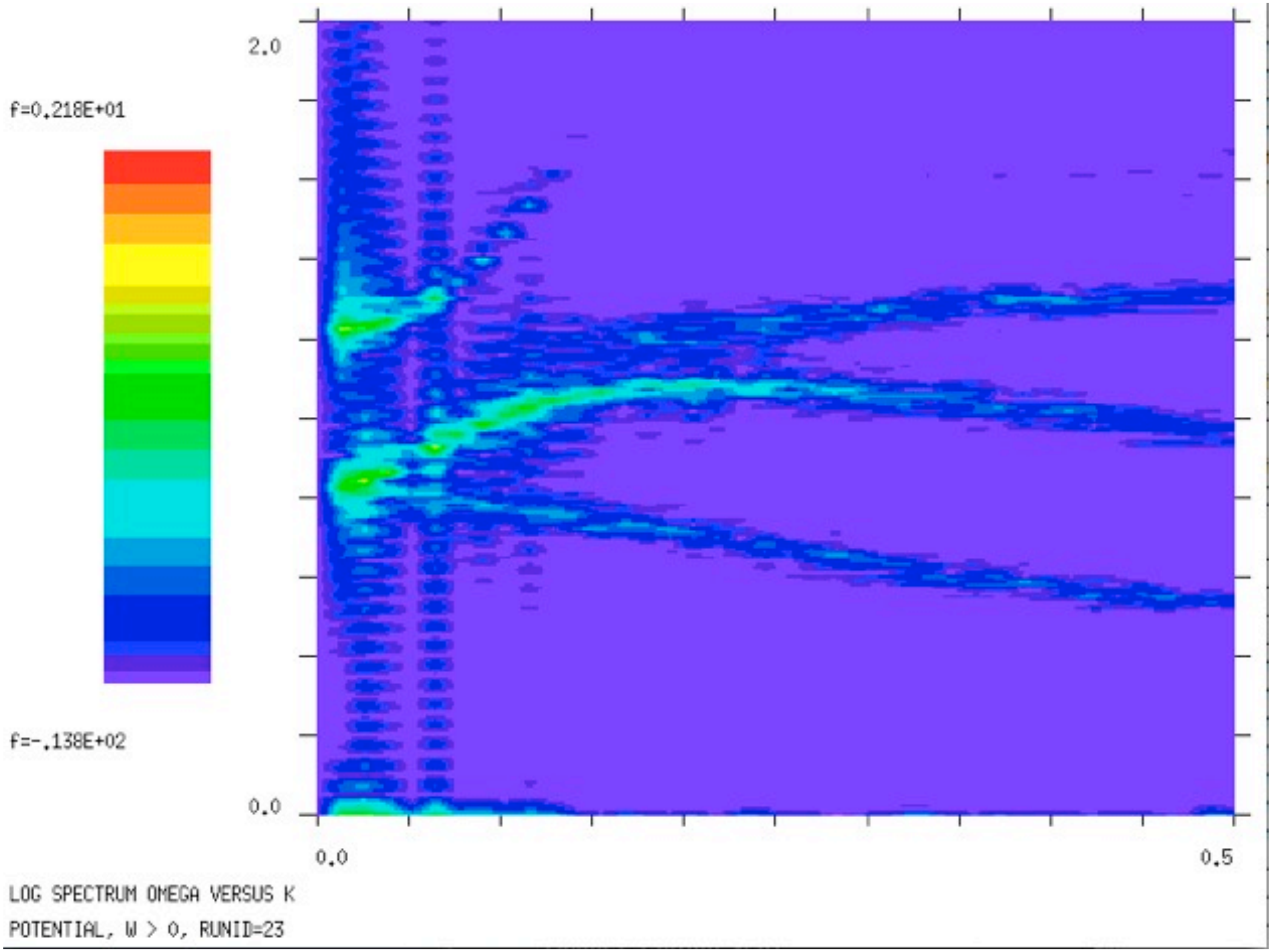
Let's look at more waves in magnetized plasma, set OMZ = 0.4 by copying input1.X to input1, and executing ./new_bbeps1. To see X waves, execute: ./vspectrum1, for diagnostic type e



Note Extraordinary (X) waves are radiative, but so are some of the Bernstein waves



To see Bernstein waves, execute: ./spectrum1
Bernstein waves are hybrid waves, partly EM and ES

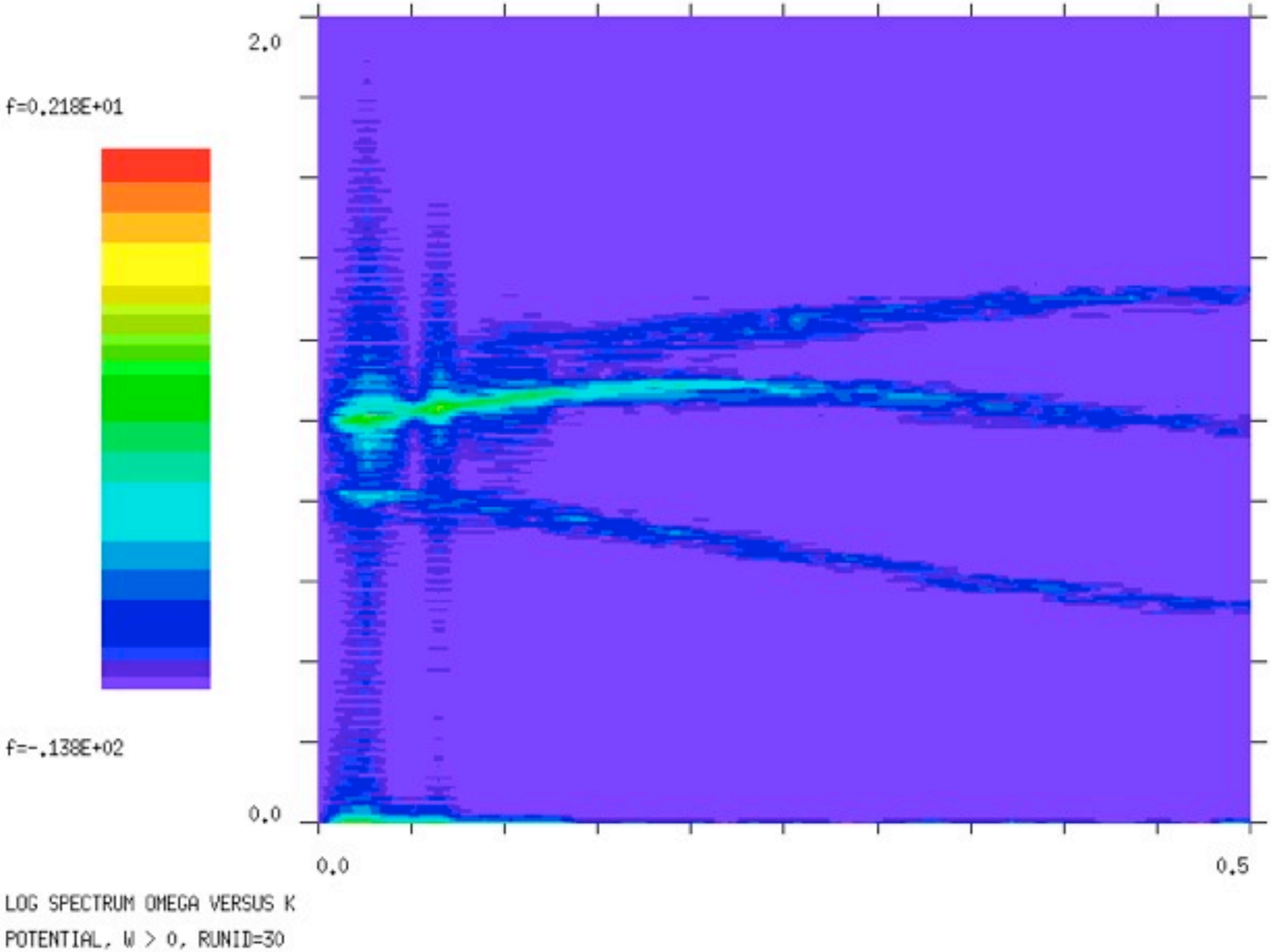


Let's look at a typical input file for the darwin code:

```
&input1
IDRUN = 30
INDX =   9, NPX =   18432, NPXB = 0
INORDER = 1
NTW = 1, NTP = 5, NTV = 5, NTA = 5
NDC = 2
OMX = 0.0, OMY = 0.0, OMZ = 0.4
TEND = 500.000, DT =   0.200, CI = 0.1
QME =  -1.000,  VTX =   1.000, VTY =   1.000, VTZ = 1.000
VX0 =   0.000, VY0 =   0.000, VZ0 =   0.000
AX = .912871
MODESXP = 40, MODESXA = 40
NPLOT = 0
/
```

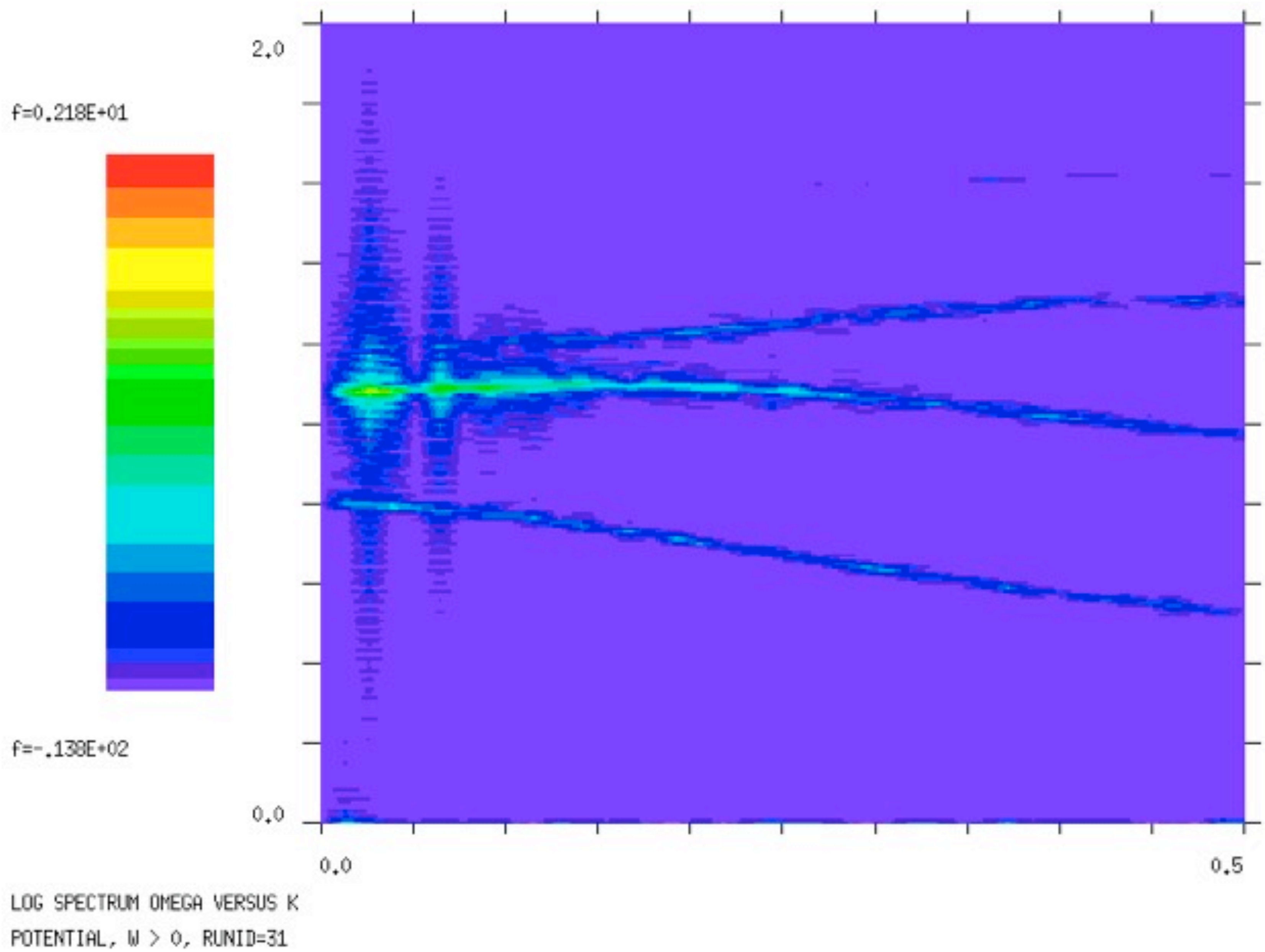
Start by copying input1.darwin into the file input1,
and executing: ./new_dbeps1

Longitudinal Waves perpendicular to $\mathbf{B}_0$, $\Omega_{ce}/\omega_{pe} = 0.4$, c = 10

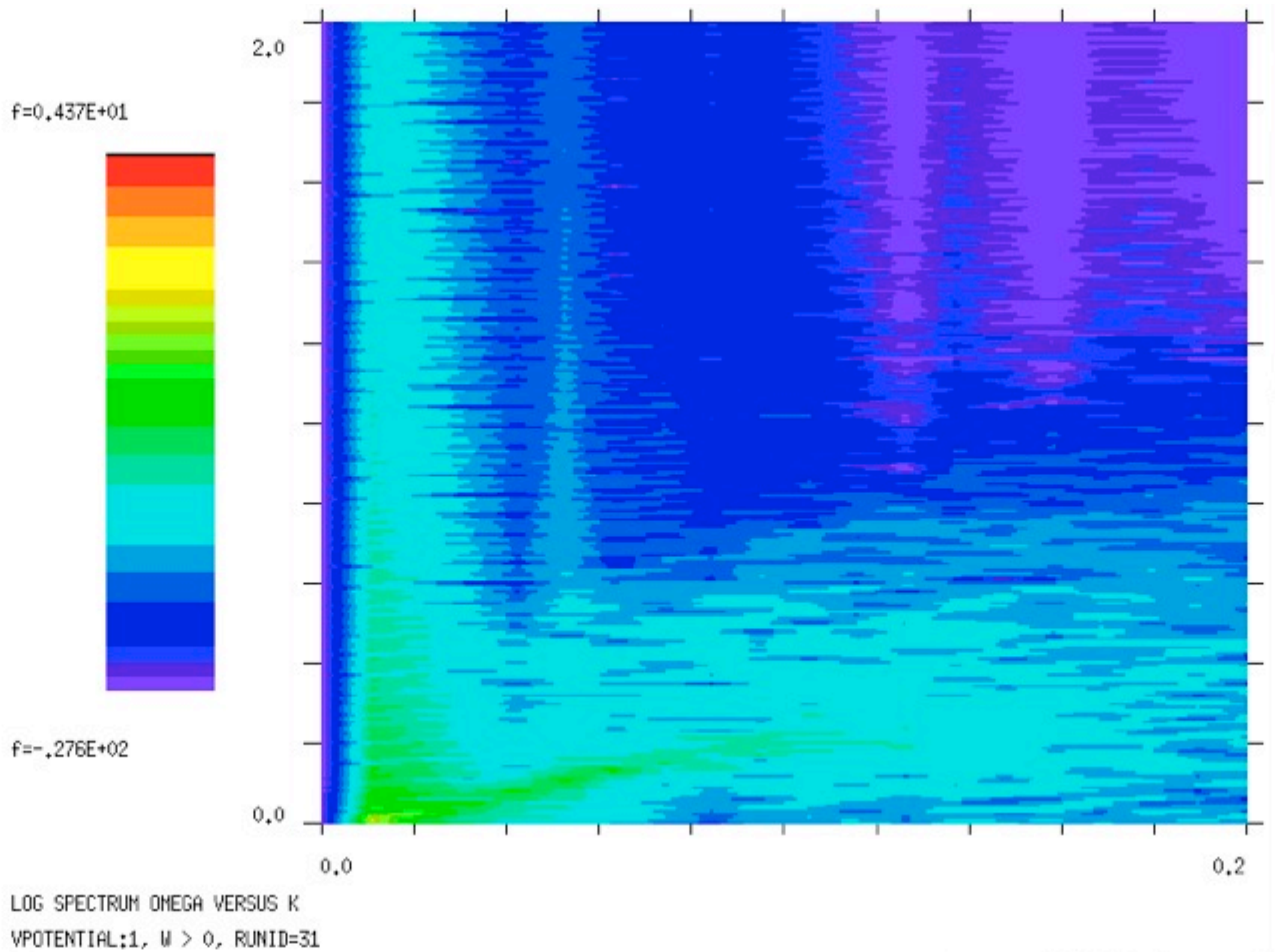


set CI = 0 (c = infinity)

Electrostatic (Bernstein) Waves perpendicular to $\mathbf{B}_0$, $\Omega_{ce}/\omega_{pe} = 0.4$

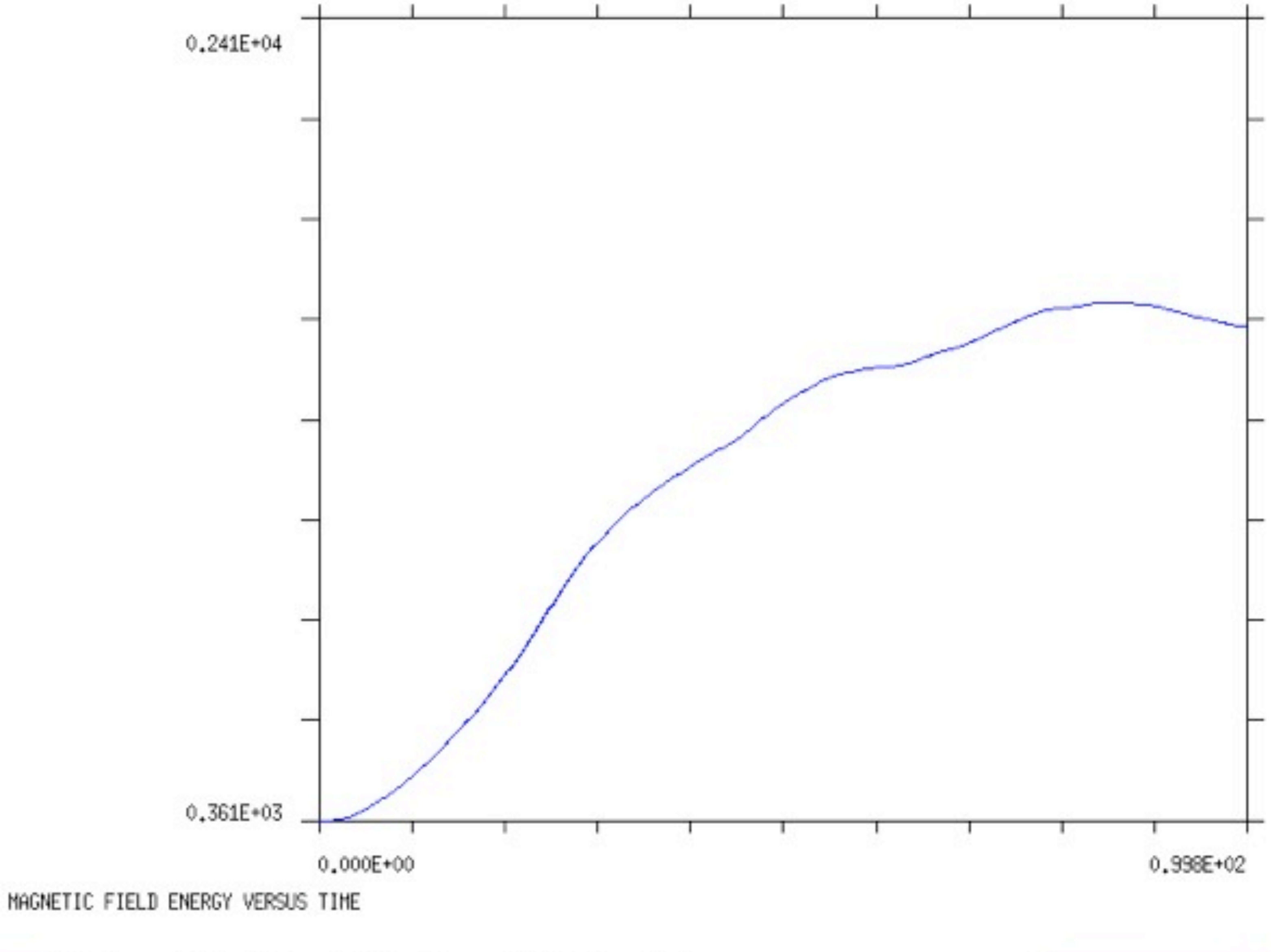


To see Whistler Waves Parallel to $\mathbf{B}_0$, $\Omega_{ce}/\omega_{pe} = 0.4$, c = 10:
copy input1.whistler, and execute: ./new_dbeps1
then ./vspectrum1



To see Weibel with Darwin code, copy input1.dweibel to input1, and execute: ./new_dbeps1

Note Darwin gives same result for weibel instability as the EM code



To compile codes with moving ions, type: make bounded

To see Ion Acoustic modes with ES code, copy input1.ions to input1, and execute: ./new_d0_beps1

Then, ./spectrum1, and select diagnostic type d