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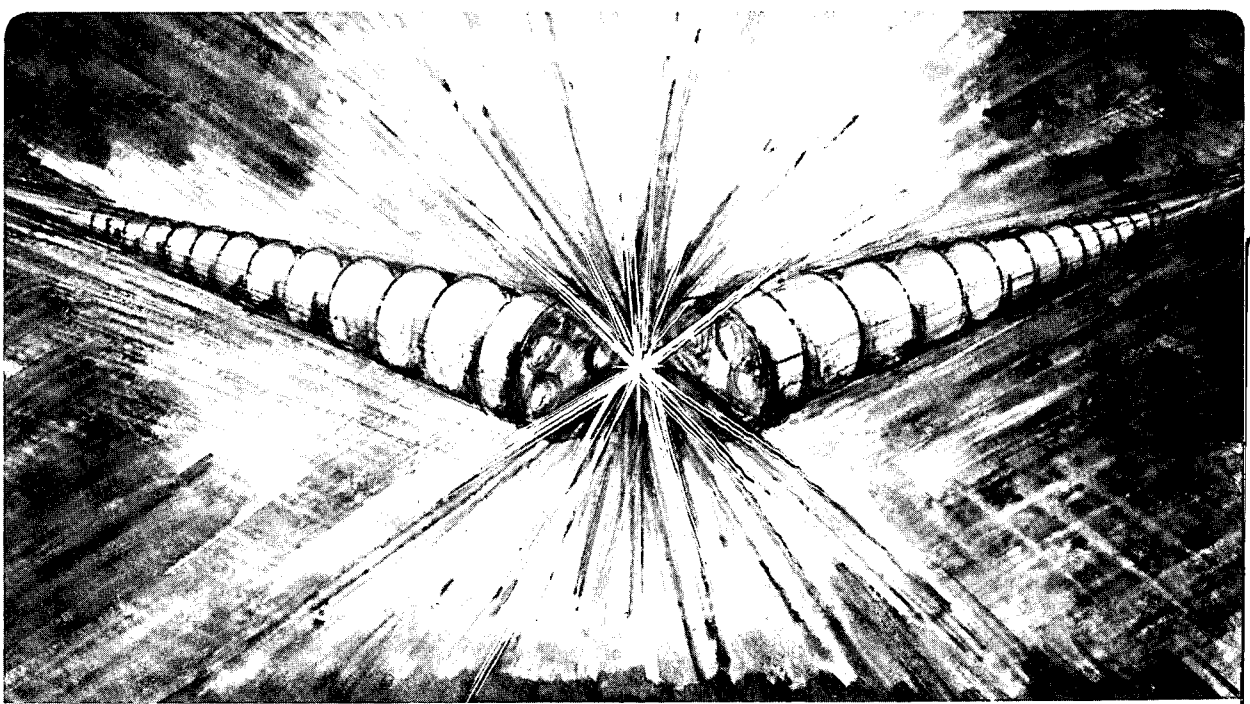
User's Guide for New ABCI Version 6.2 (Azimuthal Beam Cavity Interaction)

Y.H. Chin

November 1992



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User's Guide for New ABCI Version 6.2 (Azimuthal Beam Cavity Interaction)*

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Abstract

ABCI described here is a computer program which solves the Maxwell equations directly in the time domain when a Gaussian beam goes through an axi-symmetrical structure on or off axis. Many new features have been implemented in this version of ABCI, including the "moving mesh" and Napoly's method of calculation of wake potentials. The mesh is now generated only for the part of the structure inside a window, and moves together with the window frame. This moving mesh option drastically reduces the number of mesh points, and therefore allows calculation of wake potentials in very long structures and/or for very short bunches. In terms of Napoly's integration method, the calculation of transverse and longitudinal wake potentials in a structure such as a collimator, where parts of the cavity material come down below the beam pipe radius, can be carried out now correctly with beam pipes of short length at both ends. For the monopole wake potential, ABCI can be applied even to structures with unequal beam pipe radii. A newly installed mesh generator performs automatic circular and elliptical connections of input points just as TBCI does. In addition to the conventional method, ABCI permits the input of the structure geometry by giving the increments of coordinates from the previous positions. In this method, one can use the repetition commands to repeat input blocks when the same structure repeats many times. Plots of a cavity shape and wake potentials can be obtained in the form of a Top Drawer file. ABCI is available as a source code in the CERN IBM VM/CMS system.

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I. Introduction

The first version (version 2.0) of ABCI (Azimuthal Beam Cavity Interaction) [1] was written in 1984, however, its manual was published only in 1988. It was a computer program which solved the Maxwell equations directly in the time domain when a Gaussian beam passed through an axi-symmetrical structure on or off axis. It used the FIT method [2] to discretize the Maxwell equations, similar to TBCI [3]. However, in addition to some internal differences, it was preferable to TBCI mainly due to capability to change dimensions of arrays to make a larger mesh if necessary (which could not be done in TBCI which was only distributed in the compiled form), and the possibility of different mesh sizes in r- and z-directions. Furthermore, one could input the mesh sizes rather than the number of mesh lines, and could use `CONTINUE` cards to calculate with different bunch lengths and/or mode numbers (m=0 or 1) in a single job. In this program, the beam was assumed to be hollow, with surface charges azimuthally distributed either in an uniform or sinusoidal way. In the first version of ABCI, the radius of the hollow beam was always chosen to be equal to that of a beam pipe so that no fields were brought with it into the structure of concern. The wake fields were integrated at the radius of the beam pipe, which made long beam pipes unnecessary and reduced the range of integration to the gap of the structure. The program was compact, and simply structured so that users could easily change important parameters such as an array size for the number of mesh points, and modify the program for their special needs. Since the main body of the program was small, relatively large arrays could be allocated to mesh points in a limited memory space. Furthermore, permitting unequal mesh sizes in the axial and radial directions helped to reduce the number of mesh points.

However, if one tried to apply the program to long structures and/or very short bunches, the total number of mesh points easily becomes of the order of many hundred thousands or more. For example, the recently proposed "stagger-tuned" structure for the NLC of SLAC [4] consists of a disc loaded wave guide with a large number of cells with slightly different dimensions of the order of μm or less. In order to correctly represent such tiny differences, many million mesh points would be needed.

Not all of these mesh points are simultaneously necessary at each time step for the calculation of fields. If we are only interested in the wake potentials not too far behind the beam, the fields need to be calculated only in the area called, "window". The window is defined by the area of the structure which starts at the head of the bunch and ends at the last longitudinal coordinate in the bunch frame (which is often the tail of the bunch) up to which we want to know the wake potentials. The fields in front of the bunch are always zero. The fields behind the window can never catch up with the window, which is moving forward with the speed of light, and thus do not affect the fields inside the window. Since the calculation is confined to the area inside the window, the "mesh" is needed only for this

frame and moves together with it. One of main new features of ABCI is the implementation of this "moving mesh" in lieu of the conventional static mesh. Since the window is usually much smaller than the total structure, the number of mesh points can be drastically reduced. In addition, since the window length is determined only by the last longitudinal coordinate of the wake potentials, the number of mesh points does not change as the structure length increases.

Another main new feature of ABCI is the implementation of "Napoly's integration method" of fields to calculate wake potentials [5]. The conventional integration method at the radius of the beam pipe breaks down when a part of the structure comes down below it, or when the radii of the two beam pipes at both ends are unequal. One can avoid that the integration conture intersects the structure by moving it closer to the axis. However, then a very long outgoing beam pipe becomes necessary to allow the fields to catch up with the beam far behind the structure. Napoly's integration method is a solution to this classical problem (the integration along the structure surface was already described by Gluckstern and Neri in 1985 [6]). It eliminates the contribution from the outgoing beam pipe, and puts the integration conture back to the finite length over the gap of the structure. For the monopole (longitudinal) wake potential case, this method permits a structure with unequal beam radii at both ends. For the dipole (transverse and longitudinal) wake potential case, the beam pipe radii must be equal. The integration conture can be deformed to three straight lines ("Napoly-Zotter conture" [7]), which can be chosen by the user within certain limits.

In addition to these two new main features mentioned above, ABCI has a completely new mesh generator, which permits circular and elliptical inputs just as TBCI. The program allows variable radial mesh sizes for different radial intervals for the better fitting of mesh and reducing the total number of mesh points. In addition to the conventional method of inputting the shape of the structure by giving the absolute coordinates of points, users can now input the structure by giving the increments of coordinates from the previous positions (incremental input). In this method, one can use repetition commands to repeat input blocks which saves time and labor when the same structure repeats many times. The new ABCI also has better plotting facilities. It can show on a separate page each the input and actual shape of a cavity used for calculation, the wake potentials, and finally the Fourier transforms of the wake potentials. ABCI creates a "Top Drawer" file [8] for the corresponding figures. By this method, ABCI's graphical output becomes independent of computers and graphic devices. One can easily import/export the graphical output to other computers, and/or edit it if desired.

The standard output of ABCI contains the printout of all input parameters, an optional printout of the shape of a structure, numerical values of the wake potentials and their graphical representation on line printer, and finally the loss factors. When the drawing routines are called, the Top Drawer input data will be written to a separate file. In the

following section, we will explain the definitions of the input variables and how to interpret the output, referring to examples for test jobs.

II. Input Variables

Two sample input data, one with the conventional input method of the cavity geometry, and another with the incremental input method of the cavity geometry, are given in Figs. 1 and 2, respectively. They consist of one head line, eight **NAMELIST** formats, the input of a structure geometry, `CONTINUE` and `STOP` cards. The input format is essentially compatible to that of TBCI so that one can use the same input data for both programs with only slight changes. An example of an exec file to run ABCI on the CERN IBM VM/CMS system is shown in Fig. 3.

We list all input variables with brief explanations, their units or formats, default values, and array sizes in what follows.

NAMELIST	`&FILE`	defines different ways of running the program.
`LSAV`	logical*1 (default=F)	Save the intermediate results when the CPU time is expired. A file for saving has to be allocated when `LSAV` is true. The logical device number assigned to this file must be 1.
`ITEST`	(default=0)	When `ITEST=0`, ABCI computes wake fields. When `ITEST=1`, ABCI does not calculate any fields, but generates meshes for a structure to see if the input data are correct.
`LREC`	logical*1 (default=F)	Recovery from a previous unfinished job, and restart of calculation. The file, which was created when `LSAV` command was executed, has to be declared for recovery. The logical device number assigned to this file must be 2.
`LCPUTM`	logical*1 (default=F)	Activates the subroutine which monitors the remaining CPU time. If `LSAV` is true, `LCPUTM` becomes automatically true. When `LCPUTM=.TRUE.` and the calculation is not yet completed by the time `TMAX-TSOS` or the

		remaining CPU time is less than TSOS, ABCI stops the calculation and prints out the intermediate results on printer. To save them on a file, LSAV must be true.
TSOS	seconds (default=5.)	CPU time devoted to saving the intermediate results on a file.
TMAX	seconds (default=3600.)	CPU time limit for a batch job. It is required to be specified when a subroutine such as TIMEL of the CERN library that returns the remaining CPU time is not available.

TITLE FORMAT(A72)

The title of the run which may be printed as header of the program. If you do not want a title, leave it blank, but never eliminate the line.

NAMELIST	&BOUN	defines the boundary conditions at both ends of the structure. They are dummies for compatibility with TBCI. The boundary conditions at the ends are always "open".
IZL	dummy	The boundary condition at the leftmost mesh line.
IZR	dummy	The boundary condition at the rightmost mesh line.

NAMELIST &MESH defines mesh sizes for the r-and z-directions.

One can specify either the number of mesh lines or the mesh sizes.

DDR	meter array up to NF=20	Mesh sizes in the r-direction. This is actually an array. Different mesh sizes can be used for radial intervals defined by RMARK. For example,

		"DDR=0.02, 0.01, RMARK=0.1, 0.2" means that the mesh sizes are 0.02m from r=0.0m to r=0.1m, and 0.01m from r=0.1m to r=0.2m.
DDZ	meter	Mesh size in the z-direction. Only one mesh size can be used in the z-direction.
NR		Number of mesh lines in the r-direction. NR=(Total radius of the structure)/DDR+1. If this input method is chosen, only one mesh size can be used in the r-direction.
NZ		Number of mesh lines in the z direction. NZ=(Total length of the structure)/DDZ+1.
RMARK	meter array up to NF=20	The r coordinates which define intervals where different radial mesh sizes are applied. Between RMARK(I) and RMARK(I+1), the radial mesh size is DDR(I). If no value is specified, RMARK(1) is automatically set to be the total radius of the structure.
RAD	meter	The total radius of the structure. This is a dummy variable for compatibility with TBCI. ABCI finds out the total radius by itself.
RZ	meter array up to NVR=100	The values of variables RZi (i=1,100) which may be used in the subsequent input of the cavity geometry. The values can be specified either as RZ=v1,v2,...,vn or as RZ(1)=v1, RZ(2)=v2,...,RZ(n)=vn. If the values are specified, but not used in the input of the cavity geometry, they are ignored. One can use -RZi in the meaning of -vi in the cavity geometry input.

There are two ways to input the shape of the structure. One way is to give the absolute coordinates of the (r,z) points to be connected (the conventional input). Another way is to give the increments of coordinates (δr, δz) from the previous positions (the incremental input). The former and the latter cases are signaled by the keywords #(##)CAVITYSHAPE and @(@@)CAVITYSHAPE, respectively, for full (right half for the symmetrical case) input of structure shape. Each line contains the radial and the longitudinal coordinates. Subsequent input points can be connected by either a straight line, a circle or an ellipse, to produce a

closed polygon which should be clockwise oriented.

A straight line is specified by giving a pair of coordinates to be connected in the subsequent two lines. A circular connection between points is made when an additional line is inserted between them. This line contains two numbers, i.e., the "indicator" and the radius of the circle with a sign. The first one indicates whether the shorter part (indicator=-1., or CS) or the longer part (indicator=-2., or CL) of the full circle should be taken. The curve can be either convex (radius < 0) or concave (radius > 0) with the respect to the inner area of the polygon. The absolute value of the radius will be used as the radius of the circle.

r1, z1
indicator, radius
r2, z2

The ellipse in the input can have only one orientation, with the axis parallel to r and z. The elliptical connection is made when two lines are inserted between two points to be connected. The first line contains two numbers, i.e., the indicator and a dummy. The first one indicates whether the shorter part (indicator=-3., or ES) or the longer part (indicator=-4., or EL) of the full ellipse should be used. The second one is a dummy argument and its content is ignored. The second line specifies the center of the ellipse, (rm,zm). Unlike the circular case, ABCI does not calculate the center of the ellipse by itself.

r1, z1
indicator, dummy
rm, zm
r2, z2

When the incremental input method is used, one must use CS,CL,ES, and EL instead of the corresponding negative numbers. Otherwise, ABCI interprets these numbers as the decrements of coordinates.

Any number of comments can be inserted between the first line for the origin and the last one for the origin. They must be started by the percentage symbol, "%", at the first column.

When the incremental input method is used, one can use the repetition commands ">" and "<" to repeat input blocks which are started and ended by the data cards containing the ">" and "<" symbols, respectively. The number of desirable repetitions can be specified by a number following ">" symbol. A blank, 0, and 1 mean no repetition.

The input of cavity shape geometry is a completely free format. Two numbers can be separated by blanks, a comma, or their combinations. The followings are all legal:

0.01, 0.1E-1
> 2
0.2D-1 -RZ1
0.03 , 0.03

The following is an example of the conventional input method of the structure shape:

```
#CAVITYSHAPE (##CAVITYSHAPE)
```

`0.0`	Dummy number. Keep it always zero.
`0.0 0.0`	The first point of the polygon. Should be always `0.0, 0.0`.
`r1 z1`	
`r2 z2`	Straight line connection
`-1.0 -0.1`	Short circle, concave connection, radius=0.1m
`% This is a comment`	It must be started with % at the first column.
`r3 z3`	
`EL 0.0`	Long ellipse
`rm1 zm1`	Center of the ellipse
`r4 z4`	
`% Another comment.`	
`RZ1 z5`	Variable RZ1 whose value must be given in `&MESH`
`r6 RZ2`	Variable RZ2 whose value must be given in `&MESH`
`.....`	
`.....`	
`0.0 0.0`	The last point of polygon (= the first one).
`9999. 9999.`	End of input for `#(##)CAVITYSHAPE`.

The following is an example of the incremental input method of the structure shape:

```
@CAVITYSHAPE (@@CAVITYSHAPE)
```

`0.0`	Dummy number. Keep it always zero.
`0.0 0.0`	The first point of the polygon. Should be always `0.0, 0.0`.
δ`r1` δ`z1`	
δ`r2` δ`z2`	Straight line connection
`CL 0.1`	Long circle, convex connection, radius=0.1m
`% This is a comment.`	It must be started with % at the first column.

δr3 δz3	
ES 0.0	Short ellipse
δrm δzm	The center of the ellipse
δr3 δz3	
> 2	Repeat twice the input block closed by ">" and "<".
RZ1 δz4	Variable RZ1 whose value must be given in &MESH
δr5 -RZ2	Variable RZ2 whose value must be given in &MESH
<	End of the input block to be repeated
.....	
.....	
0.0 0.0	The last point of polygon. Leave it 0.0, 0.0. ABCI calculates the correct last longitudinal decrement to come back to the origin and replaces the second zero by the correct value.
9999. 9999.	End of input for @(@@)CAVITYSHAPE.

NAMELIST	&BEAM	defines beam parameters and charge distributions.
MROT		Azimuthal mode number, i.e., MROT=0 for monopole fields or MROT=1 for dipole fields.
SIG	meter	One standard deviation of bunch length
ISIG	(default=5)	Number of standard deviations used for a Gaussian bunch.
RDRIVE	(default= beam pipe radius)	The radius of the driving hollow beam. The beam pipe radius is found by ABCI. If the beam pipe radii at both ends are unequal, the default value will be the smallest of them. If the cavity material comes down below the beam pipe radii, the default value will be the radial coordinate of the cavity material closest to the beam axis.

NAMELIST &TIME

MT	(default=3) up to 10	Number of time steps for a beam to move from one cell to another. (It will be automatically changed to MT=4 when LCHIN=.TRUE. and MROT=1).

NAMELIST	&WAKE	specifies the calculation of wake potentials.
UBT	meter (defaults=10*SIG)	The last longitudinal coordinate relative to the head of the beam, up to which the wake potentials are calculated. This parameter defines the window length.
LCFRON	logical*1 (default=T)	Window suppressing calculation of fields in front of the bunch.
LCBACK	logical*1 (default=T)	Window suppressing calculation of fields behind the bunch.
LCHIN	logical*1 (default=F)	When LCHIN=.TRUE., wake potentials for MROT=1 case are calculated by means of Chin's method. The beam moves continuously, and wake fields are sampled at equal time steps. When LCHIN=.FALSE., the beam jumps to next cell every MT time steps.
LNAPOLY	logical*1 (default=F)	When LNAPOLY=.TRUE., the Napoly method of wake potential calculation is used for both MROT=0 and MROT=1 cases. If the beam pipe radii at both ends are unequal, or the cavity material comes down below the beam pipe radii, one must use the Napoly method. If LNAPOLY is yet false, ABCI changes it to LNAPOLY=.TRUE., and finds an appropriate integration conture (its validity should still be checked by the user). The integration conture can be specified by the user, using ZCF, ZCT and RWAK. For MROT=1 case, unequal beam radii are not allowed

		(ABCI will skip the calculation in that case). For more details, see the Appendix.
ZCF	meter	The z-coordinate in the cavity frame at which the Napoly-Zotter integration conture shirts from r=the radius of the left beam pipe to r=RWAK. See Fig. 4.
ZCT	meter	The z-coordinate in the cavity frame at which the Napoly-Zotter integration conture shifts from r=RWAK to the radius of the right beam pipe. See Fig. 4.
RWAK	meter	The r-coordinate in the cavity frame where the Napoly-Zotter integration conture runs horizontally between z=ZCF and z=ZCT. See Fig. 4.

NAMELIST	&PLOT	controls the plot of results in the form of Top Drawer input file. The logical device number assigned to this file must be 9.
LCAVIN	logical*1 (default=F)	Plot cavity shape input.
LCAVUS	logical*1 (default=F)	Plot cavity shape actually used.
LPLW	logical*1 (default=F)	Plot wake potentials.
LFFT	logical*1 (default=F)	Calculate the Fourier transforms of all wake potentials and plot them.
LFFTL	logical*1 (default=F)	Calculate the Fourier transform of the longitudinal wake potential and plot it.
LFFTA	logical*1 (default=F)	Calculate the Fourier transform of the azimuthal wake potential and plot it.
LFFTT	logical*1 (default=F)	Calculate the Fourier transform of the transverse wake potential and plot it.
CUTOFF	GHz (default= 0.5*c/DDZ)	The cutoff frequency for plots of the Fourier transforms of wake potentials.

NAMELIST	&PRIN	controls the printout of results.
LPRW	logical*1 (default=F)	Print numerical values of wake potentials on line printer.
LMATPR	logical*1 (default=F)	Print cavity shape actually used on line printer.

The calculation can be continued for another set of input parameters if one puts

```
CONTINUE
```

card behind **NAMELIST** &PRIN. Then **NAMELIST** &MESH, &BEAM, &WAKE, &PLOT and &PRIN formats can follow. Only the changed parameters need to be specified. The calculation can be again continued by putting CONTINUE card after them, followed by another set of **NAMELIST** formats. The program stops when the command card

```
STOP
```

is detected.

III. Output of ABCI

The outputs for the test inputs given by Figs. 1 and 2 are shown in Figs. 5 and 6, respectively. We will briefly explain how to interpret the output for the reader's convenience. The beginning of the output is signalled by the title of the program followed by the date, time and the version number of ABCI. All the input variables are printed with short explanations of their definitions and with their units. Next follows the printout of the actually used cavity shape. Then a normalized line-printer plot of the wake potentials, the scaling and the loss factors are printed. The transverse wake is calculated from the longitudinal one using the Panofsky-Wentzel relationship. If LPRW=.TRUE., numerical values of the wake potentials are printed as a function of distance from the bunch head. If any flag of **NAMELIST** &PLOT is true, a Top Drawer input file for the corresponding plots are created in a file called fn TOPDRAW, where fn is the file name of your input data. In order to view plots, you must execute a local Top Drawer command on this file.

In a batch job, if the specified CPU time was not enough to complete the calculation and LCPUTM is true, the last time step computed will be printed and a warning message will be issued. Wake potentials and loss factors will also be printed (and plotted), however, they should not be believed. If LSAV is true, the intermediate results of the computation will be stored in a file specified by the user. The logical device number assigned to this file must be 1. In order to recover the intermediate results from the file using LREC command, the same file must be assigned to the logical device number 2.

IV. How To Run ABCI

If you are a user of the CERN IBM VM/CMS, you must have access to the LEPTH disk, where you will find a copy of the files: ABCI FORTRAN (source code), ABCI EXEC (EXEC file for executing ABCI), ABCI HELPCMS file and two sample data files SAMPLE1 ABCI and SAMPLE2 ABCI. The content of the ABCI EXEC file is shown in Fig. 3 for the reader's convenience. In order to run the program, you must have a data file on the A-disk, called fn ABCI. (For test purposes, you can copy the SAMPLE1 ABCI and SAMPLE2 ABCI files from the LEPTH disk). Then type in:

```
ABCI fn
```

The results will be on the file fn RESULTS on your A-disk. The Top Drawer input data will appear on the file fn TOPDRAW on your A-disk, if any flag in `&PLOT` is true. If the specified CPU time was not enough to complete the calculation and `LCPUTM` is true, the intermediate results are dumped onto the file fn ABCSAVE on your A-disk.

V. How To Install ABCI into Other Computers

ABCI has been written in the standard Fortran 77. Since it creates a Top Drawer input file, rather than plots figures by itself, it contains no drawing routines. It is written to be self-sufficient, except it calls a few external routines from the CERN library. They are related to the date and time of job execution and the job cpu time, and serve merely as accessories for the convenience of users. They are:

`TIMEX(T)`	returns execution time in seconds used so far.
`TIMEL(T)`	returns execution time remaining in seconds until time limit.
`TIMEST(T)`	initializes the time operation.
`DATIMH(DATE,TIME)`	returns the current calender date and time.

All these routines are collected together in the subroutines, `CPUTIM`, `CPULFT` and `DATIME`, at the end of ABCI. If the IMSL packages are available, they can be substituted by the corresponding IMSL subroutines, `CTIME`, `TDATE` and `DTIME`. See the instructions there for how to alternate the routines between the CERN and IMSL libraries.

The array sizes are preset by the `PARAMETER` commands. They are:

`NMESH`	The maximum number of mesh points in the window.
`NWN`	The maximum number of wake potential points.
`NBP`	The maximum number of lines for the structure geometry input.
`NVAR`	The maximum number of variables, `RZi`, used in the geometry input.

NF	The maximum number of different radial mesh sizes.
NRN	The maximum number of radial mesh lines.
NSP	The maximum number of intersections between the structure and the mesh in the connection of two subsequent points.
NHIT	For internal use. Keep it comparable to NMESH.

They can be changed easily. See the instructions at the head of ABCI source code.

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Appendix: Napoly's Integration Method

We consider a ring-shaped beam with the radius b moving in the z-direction with the speed of light c. It has a longitudinal line charge density, $\lambda(s)$, and surface charges which are azimuthally distributed in an uniform or sinusoidal way. The longitudinal current density $\mathbf{J}$ produced by the beam is expressed in the general form as

$$\mathbf{J} = \frac{c\lambda(z-ct)}{\pi b} \sum_{m=0}^{\infty} \cos m\phi \cdot \delta(r-b) \cdot \kappa_m, \tag{1}$$

where ϕ is the azimuthal angle, and the parameter κ_m is defined by

$$\begin{aligned} \kappa_m &= 1/2 \quad \text{m=0} && (2) \\ &= 1 \quad \text{m=0.} && (3) \end{aligned}$$

The line charge density is normalized such that

$$\int_{-\infty}^{\infty} \lambda(s) ds = 1. \tag{4}$$

The electromagnetic fields excited by the beam have also sinusoidal azimuthal angle dependency. They can be written as

$$\begin{aligned} E_r(r,\phi,z,t) &= E_r^{(m)}(r,z,t)\cos m\phi, \\ E_\phi(r,\phi,z,t) &= E_\phi^{(m)}(r,z,t)\sin m\phi, \\ E_z(r,\phi,z,t) &= E_z^{(m)}(r,z,t)\cos m\phi, \\ H_r(r,\phi,z,t) &= H_r^{(m)}(r,z,t)\sin m\phi, \\ H_\phi(r,\phi,z,t) &= H_\phi^{(m)}(r,z,t)\cos m\phi, \\ H_z(r,\phi,z,t) &= H_z^{(m)}(r,z,t)\sin m\phi. \end{aligned} \tag{5}$$

Monopole wake potential

The monopole (longitudinal) wake potential is defined by

$$W_z^{(0)}(r,s) = -\int_{-\infty}^{\infty} E_z^{(0)}(r,z,\bar{t})\, dz, \tag{6}$$

where

$$\bar{t} = (z+s)/(\beta c), \tag{7}$$

and βc is the velocity of the beam. For $\beta = 1$, the result of the integral in Eq. (6) does not depend on r:

$$W_z^{(0)}(r,s) = W_z^{(0)}(s). \tag{8}$$

Napoly [5] has demonstrated the above integral is equivalent to the following integral for a structure of any shape:

$$\begin{aligned} W_z^{(0)}(s) &= -\int_{-\infty}^{z_1} E_z^{(0)}(a_{in},z,\bar{t})dz - \int_{a_{in}}^{r_m}[E_r^{(0)}(r,z_1,\bar{t}) + Z_0 H_\phi^{(0)}(r,z_1,\bar{t})]dr \\ &\quad -\int_{z_1}^{z_2} E_z^{(0)}(r_m,z,\bar{t})dz - \int_{r_m}^{a_{out}}[E_r^{(0)}(r,z_2,\bar{t}) + Z_0 H_\phi^{(0)}(r,z_2,\bar{t})]dr \\ &\quad -\int_{z_2}^{\infty} E_z^{(0)}(a_{out},z,\bar{t})dz - \frac{1}{2\pi\epsilon_0}\ln(\frac{a_{out}}{a_{in}})\cdot\lambda(s), \end{aligned} \tag{9}$$

where the fields $E_z^{(0)}$, $E_r^{(0)}$, and $H_\phi^{(0)}$ include only the radiated fields, the solutions of homogenous Maxwell equations. Here, a_{in} and a_{out} are the radii of the incoming and outgoing beam pipes, respectively, and Z_0 and ϵ_0 are the impedance and the permittivity of the vacuum, respectively. The integration conture (Napoly-Zotter conture [7]) is shown in Fig. 4. The last term on the RHS of Eq. (9),

$$\frac{1}{2\pi\epsilon_0}\ln(\frac{a_{out}}{a_{in}})\cdot\lambda(s), \tag{10}$$

comes from the difference of potential energies of the electromagnetic fields surrounding the beam in the two beam pipes at both ends. This term is referred as "`LOG. TERM`" in output of ABCI, when Napoly's method is used for calculation of the longitudinal wake potential.

Dipole wake potential

For a structure with equal radii of the two beam pipes ($a_{in} = a_{out} = a$), the formula (9) for the monopole wake potential can be extended to the longitudinal wake potential of m=1 case. The result is

$$\begin{aligned} W_z^{(1)}(r,s) &= -\frac{r}{2a}\int_{\partial C}\{[E_z^{(1)}\cdot(\frac{a}{r'}+\frac{r'}{a}) - Z_0 H_z^{(1)}\cdot(\frac{a}{r'}-\frac{r'}{a})]dz \\ &\quad +[(E_r^{(1)}+Z_0 H_\phi^{(1)})\cdot(\frac{a}{r'}+\frac{r'}{a}) + (E_\phi^{(1)} - Z_0 H_r^{(1)})\cdot(\frac{a}{r'}-\frac{r'}{a})]dr'\}, \end{aligned} \tag{11}$$

where the integration conture ∂C denotes the Napoly-Zotter conture. The transverse wake potential $W_t^{(1)}$ can be calculated from $W_z^{(1)}$ using the Panofsky-Wenzel theorem as

$$W_t^{(1)}(r,s) = \int_0^s \frac{\partial}{\partial r} W_z^{(1)}(r,s)ds. \tag{12}$$

The result is independent of r:

$$W_t^{(1)}(r,s) = W_t^{(1)}(s). \tag{13}$$

```
 &FILE  LSAV=.F., ITEST=0, LREC=.F.  &END
 SAMPLE INPUT #1  A SIMPLE CAVITY STRUCTURE
 &BOUN  IZL=3, IZR=3  &END
 &MESH  DDR=.005, DDZ=.005  &END
 ##CAVITYSHAPE
0.
0.000 0.000
0.210 0.000
0.210 0.115
0.180 0.135
0.130 0.135
0.070 0.095
-1., 0.009
0.060 0.097
0.060 0.150
0.000 0.150
0.000 0.000
9999. 9999.
 &BEAM  SIG=0.020, MROT=0  &END
 &TIME  MT=3  &END
 &WAKE  &END
 &PLOT  LCAVIN=.T., LCAVUS=.T., LPLW=.T.  &END
 &PRIN  LMATPR=.T.  &END
CONTINUE
 &BEAM  SIG=0.030, MROT=1  &END
 &PLOT  LCAVIN=.F., LCAVUS=.F., LPLW=.T.  &END
CONTINUE
 &MESH  DDR=.005, 0.0075, 0.005, 0.0075, DDZ=.005,
      RMARK=.070, 0.1300, 0.180, 0.2100  &END
 &BEAM  SIG=0.020, MROT=0  &END
 &WAKE  UBT=2.0  &END
 &PLOT  LCAVIN=.F., LCAVUS=.T., LPLW=.T., LFFTL=.T., CUTOFF=2.5  &END
STOP
```

Figure 1: Sample Input #1.

```
 &FILE  LSAV=.F., ITEST=0, LREC=.F.  &END
 SAMPLE INPUT #2  A COLLIMATOR-LIKE STRUCTURE WITH DOUBLE TEETH
 &BOUN  IZL=3, IZR=3  &END
 &MESH  DDR=.002, DDZ=.002, RZ=0.010, 0.030  &END
 @CAVITYSHAPE
0.
0.000 0.000
0.030 0.000
0.000 0.030
0.010 0.000
ES, 0.0000
0.000 0.010
0.020 0.000
> 2
ES, 0.0000
-.020 0.000
0.000 0.010
-.020 0.000
CS, 0.010
0.000 0.020
0.020 0.000
ES, 0.0000
0.000 0.010
0.020 0.000
<
ES, 0.0000
-.020 0.000
0.000 0.010
-RZ1  0.000
0.000 0.030
-RZ2  0.000
0.000 0.000
9999. 9999.
 &BEAM  SIG=0.020, MROT=0  &END
 &TIME  MT=3 &END
 &WAKE  LNAPOLY=.T.  &END
 &PLOT  LCAVIN=.T., LCAVUS=.T., LPLW=.T.  &END
 &PRIN  LMATPR=.T.  &END
CONTINUE
 &BEAM  SIG=0.020, MROT=1  &END
CONTINUE
 &MESH  DDR=.002, DDZ=.002, RZ=0.025, 0.015  &END
 &BEAM  SIG=0.020, MROT=0  &END
 &WAKE  LNAPOLY=.T., ZCF=0.020, ZCT=0.15, RWAK=0.010  &END
 &PLOT  LCAVIN=.T., LCAVUS=.F., LPLW=.T.  &END
STOP
```

Figure 2: Sample Input #2.

```
/* RUNNING ABCI VERSION 6.1 OCTOBER 1992 */
arg fn  .
'EXEC CERNLIB NAGLIB GENLIB'
'FILEDEF 5 DISK' fn 'DATA A (PERM'
'FILEDEF 6 DISK' fn 'RESULTS A (PERM'
'FI 1 DISK' fn 'ABCSAVE  A4 (RECFM VBS LRECL 32756 BLKSIZE 12000 PERM'
'FI 2 DISK' fn 'ABCSAVE  A4 (RECFM VBS LRECL 32756 BLKSIZE 12000 PERM'
'FILEDEF 9 DISK' fn 'TOPDRAW A (PERM'
/* 'EXEC VFORT ABCI (NOSOURCE NOMAP NOPRINT GO' */
'LOAD ABCP (NOAUTO CLEAR'
'START * NOXUFLOW'
exit
```

Figure 3: ABCI EXEC file to run ABCI.

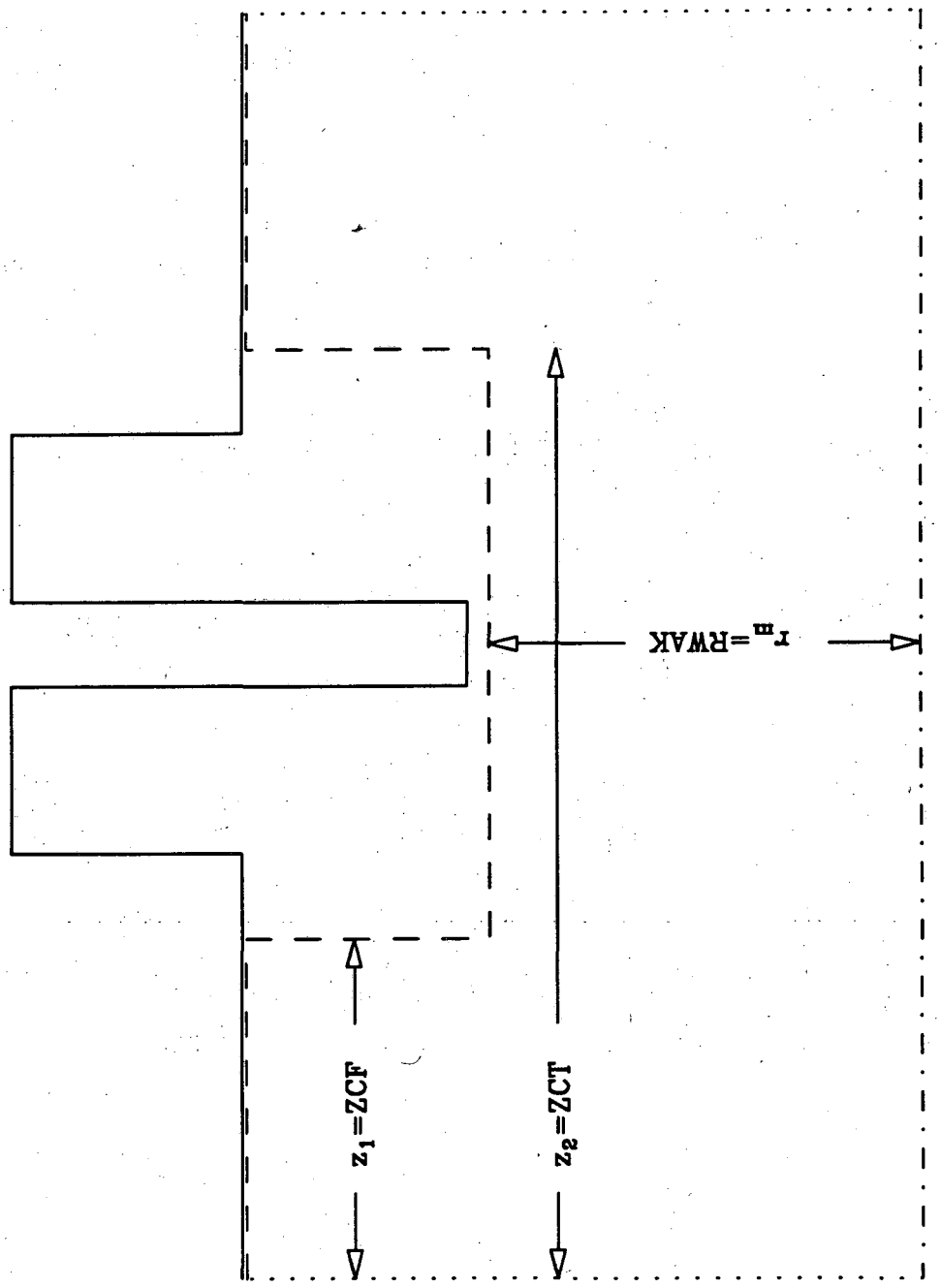
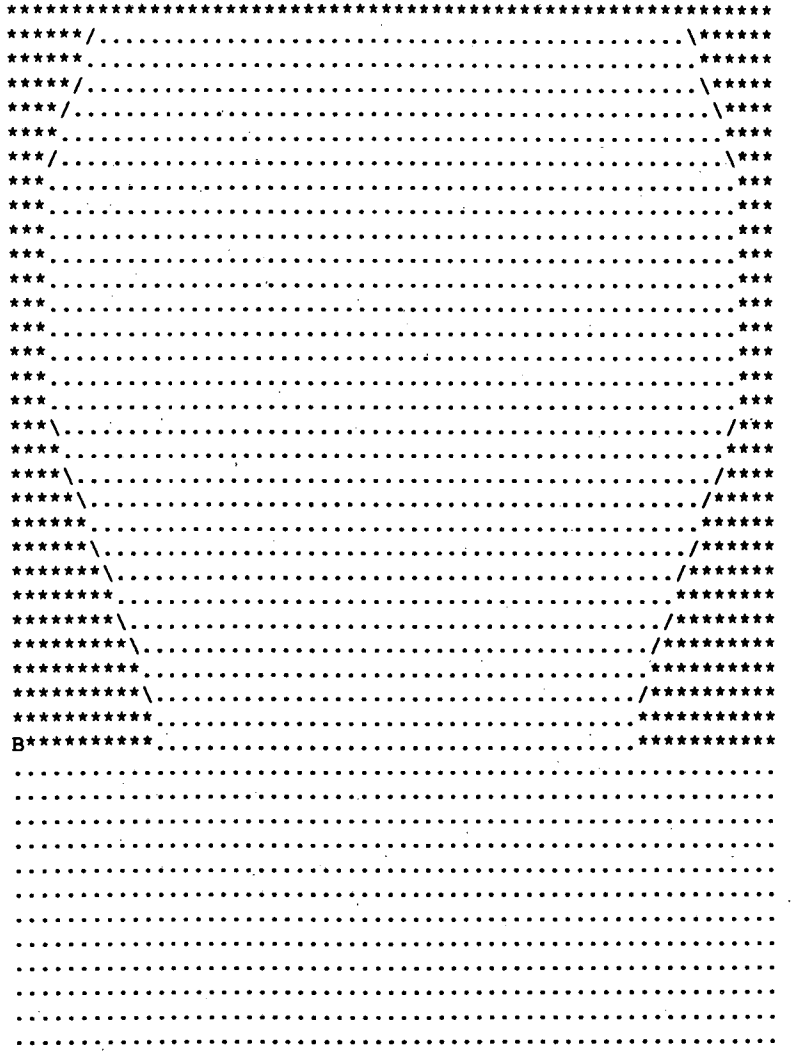


Figure 4: Napoly-Zotter Conture.

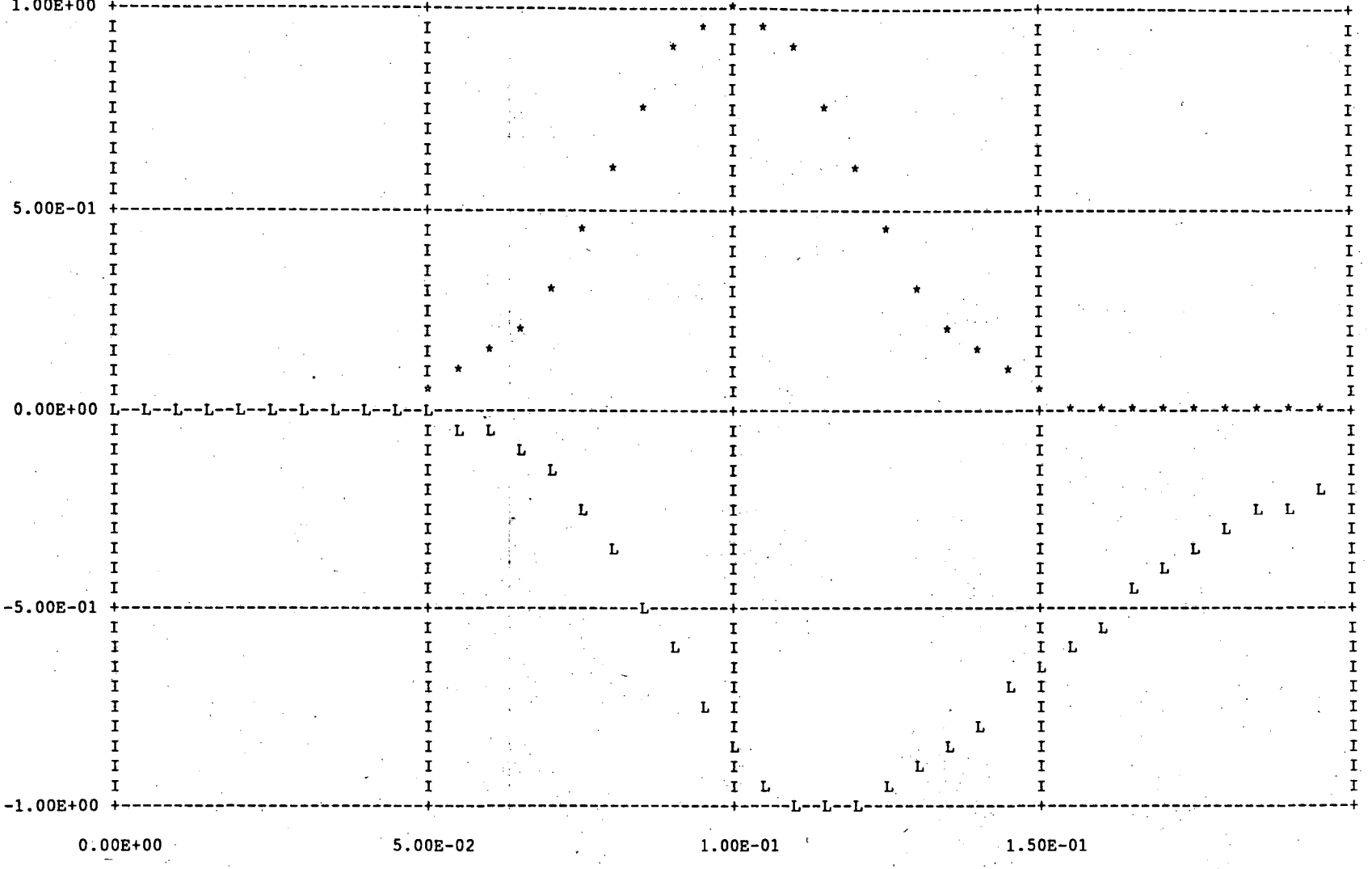
```
**************************************************************************
*                                                                        *
*                                ABCI                                    *
*                                                                        *
* Azimuthal Beam Cavity Interaction in a cylindrically symmetric structure *
*                                                                        *
*  SAMPLE INPUT #1  A SIMPLE CAVITY STRUCTURE                            *
*                                                                        *
*     DATE:30/10/92   TIME:01.00.53      VERSION 6.2,  OCTOBER   1992    *
*                                                                        *
**************************************************************************


$FILE:
SAVE FIELDS INTO FILE  (LSAV)  :  F
RECOVER FROM FILE      (LREC)  :  F
CPUTIME MONITOR ACTIVE (LCPUTM):  F

$BOUN:
BOUNDARY CONDITIONS     LEFT   : OPEN
BOUNDARY CONDITIONS     RIGHT  : OPEN

$MESH:
NUMBER OF MESH LINES IN R      : NR   =      43
NUMBER OF MESH LINES IN Z      : NZ   =      60
NUMBER OF MESH POINTS          : NP   =    1892
TOTAL RADIUS OF THE STRUCTURE  : RAD  =  0.21000     (M)
TOTAL LENGTH OF THE STRUCTURE  : ZL   =  0.30000     (M)
STEP SIZE IN R                 : DDR  =  0.50000E-02(M)
STEP SIZE IN Z                 : DDZ  =  0.50000E-02(M)

#CAVITYSHAPE (##CAVITYSHAPE) :  HALF CELL INPUT

INPUT:       (R, Z)                    (IR, IZ)
(   0.00000E+00  0.00000E+00 )  (       1      1 )
(   0.21000      0.00000E+00 )  (      43      1 )
(   0.21000      0.11500     )  (      43     24 )
(   0.18000      0.13500     )  (      37     28 )
(   0.13000      0.13500     )  (      27     28 )
(   0.70000E-01  0.95000E-01 )  (      15     20 )
CONNECTED BY A CONCAVE CIRCLE, IKIND=-1,  RADIUS=  0.90000E-02
(   0.60000E-01  0.97000E-01 )  (      13     20 ) ---> (   0.60000E-01  0.95000E-01 )
(   0.60000E-01  0.15000     )  (      13     30 )
(   0.00000E+00  0.15000     )  (       1     31 )
(   0.00000E+00  0.00000E+00 )  (       1      1 )

$BEAM:
SIGMA OF THE GAUSSIAN BUNCH    : SIG  =  0.20000E-01(M)
NUMBER OF STAND.DEV. USED      : ISIG = +/-  5
RADIAL BEAM OFFSET AT          :RDRIVE=  0.60000E-01(M)
MODE NUMBER (MONOPOLE/DIPOLE)  : MROT =      0

$WAKE:
RADIAL WAKE OFFSET        (LEFT)   AT  R   =  0.60000E-01(M)
WAKE    BETWEEN THE BUNCH  COORDINATES UBF =  0.00000E+00(M)
                                   AND UBT =  0.20000     (M)
```

```
WINDOW FOR FRONT                (LCFRON)  :  T
WINDOW FOR BACK                 (LCBACK)  :  T
CHIN WAKE INTEGRATION METHOD    (LCHIN )  :  F
NAPOLY WAKE INTEGRATION METHOD  (LNAPOLY) :  F
NUMBER OF WAKE POTENTIAL POINTS: NW   =      40

$TIME:
TIME STEPS TO BE PROCESSED     : NT   =    300
NUMBER OF TIME STEPS/MESH STEP : MT   =      3
VELOCITY OF THE BUNCH / C      : BETA =   1.0000
TIME-STEP VALUE                : DT   =  0.55594E-11(S)
TIME FOR A PARTICLE TO PASS    : PT   =  0.10007E-08(S)

$PLOT:
PLOT OF CAVITY SHAPE INPUT      (LCAVIN)  :  T
PLOT OF CAVITY SHAPE USED       (LCAVUS)  :  T
PLOT OF WAKE POTENTIALS         (LPLW)    :  T
PLOT OF FFT OF WAKE POTENTIALS  (LFFT)    :  F
PLOT OF FFT OF AZIMUTHAL WAKE   (LFFTA)   :  F
PLOT OF FFT OF TRANSVERSE WAKE  (LFFTT)   :  F
PLOT OF FFT OF LONGITUDINAL WAKE (LFFTL)  :  F
CUTOFF FREQUENCY FOR FFT PLOT  :CUTOFF=   29.979    (GHZ)

$PRINT:
PRINTOUT OF CAVITY SHAPE USED   (LMATPR)  :  T
PRINTOUT OF THE FIELDS          (LPRW)    :  F
```

CAVITY SHAPE
.=VACUUM ; \,/=TRIANGULAR FILLED MESH CELL ; *=FULL METAL ; B=BEAM

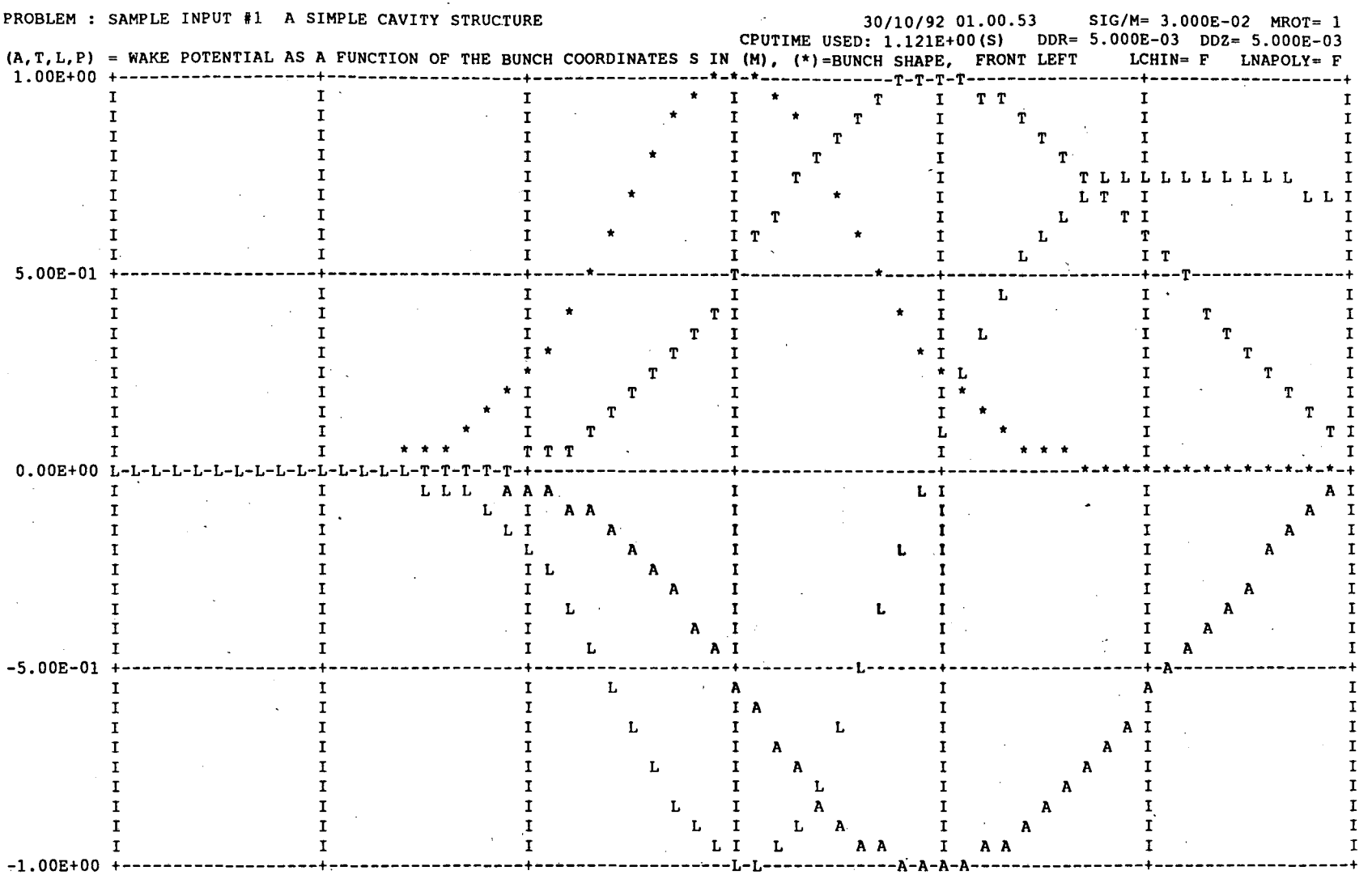


PROBLEM : SAMPLE INPUT #1 A SIMPLE CAVITY STRUCTURE 30/10/92 01.00.53 SIG/M= 2.000E-02 MROT= 0
CPUTIME USED: 4.826E-01(S) DDR= 5.000E-03 DDZ= 5.000E-03
(A,T,L,P) = WAKE POTENTIAL AS A FUNCTION OF THE BUNCH COORDINATES S IN (M), (*)=BUNCH SHAPE, FRONT LEFT LCHIN= F LNAPOLY= F



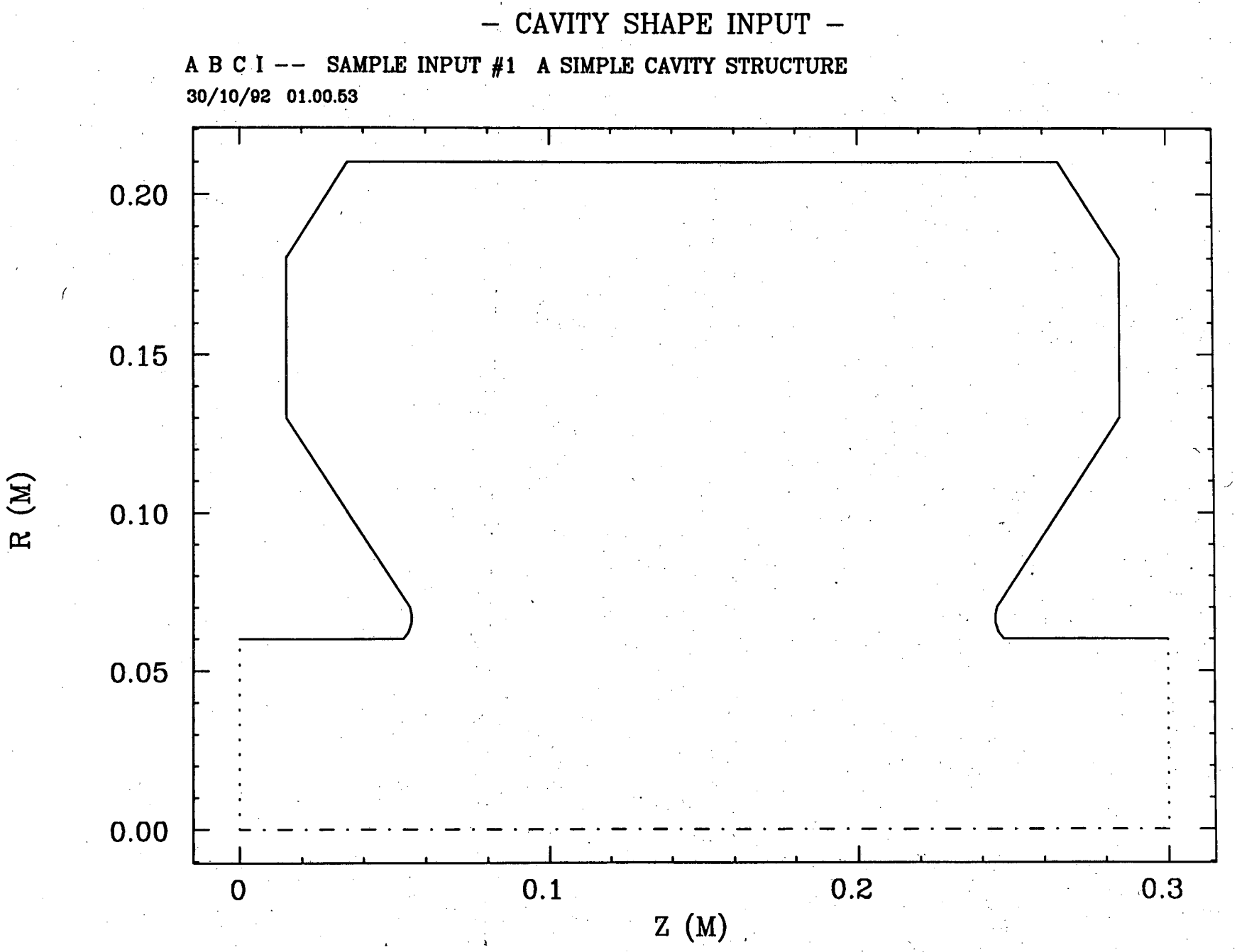
LINE CHARGE DENSITY MINMAX= 7.434E-05/ 1.995E+01AS/M, SCALE= 1.995E+01AS/M, PASSING AT R= 6.000E-02M
LONGITUDINAL WAKE MINMAX=-3.910E+11/ 0.000E+00 V , SCALE= 3.910E+11V , INTEGRATED AT R= 6.000E-02M , OR 3.910E+11 V/M**0

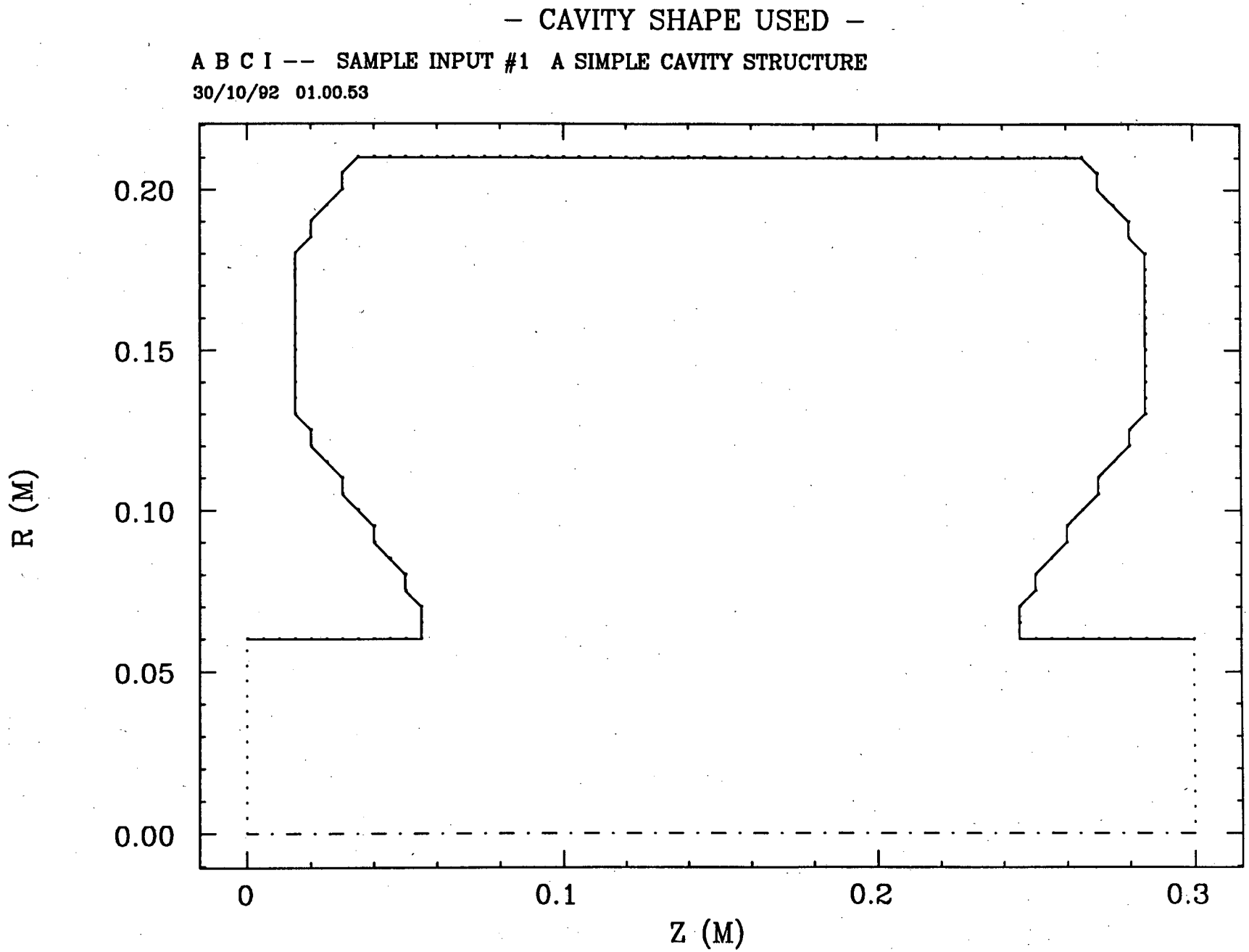
INTEGRATED LONGITUDINAL WAKE * CHARGE DENSITY = -2.785E+11 VAS , OR -2.785E+11 V/AS/M**0

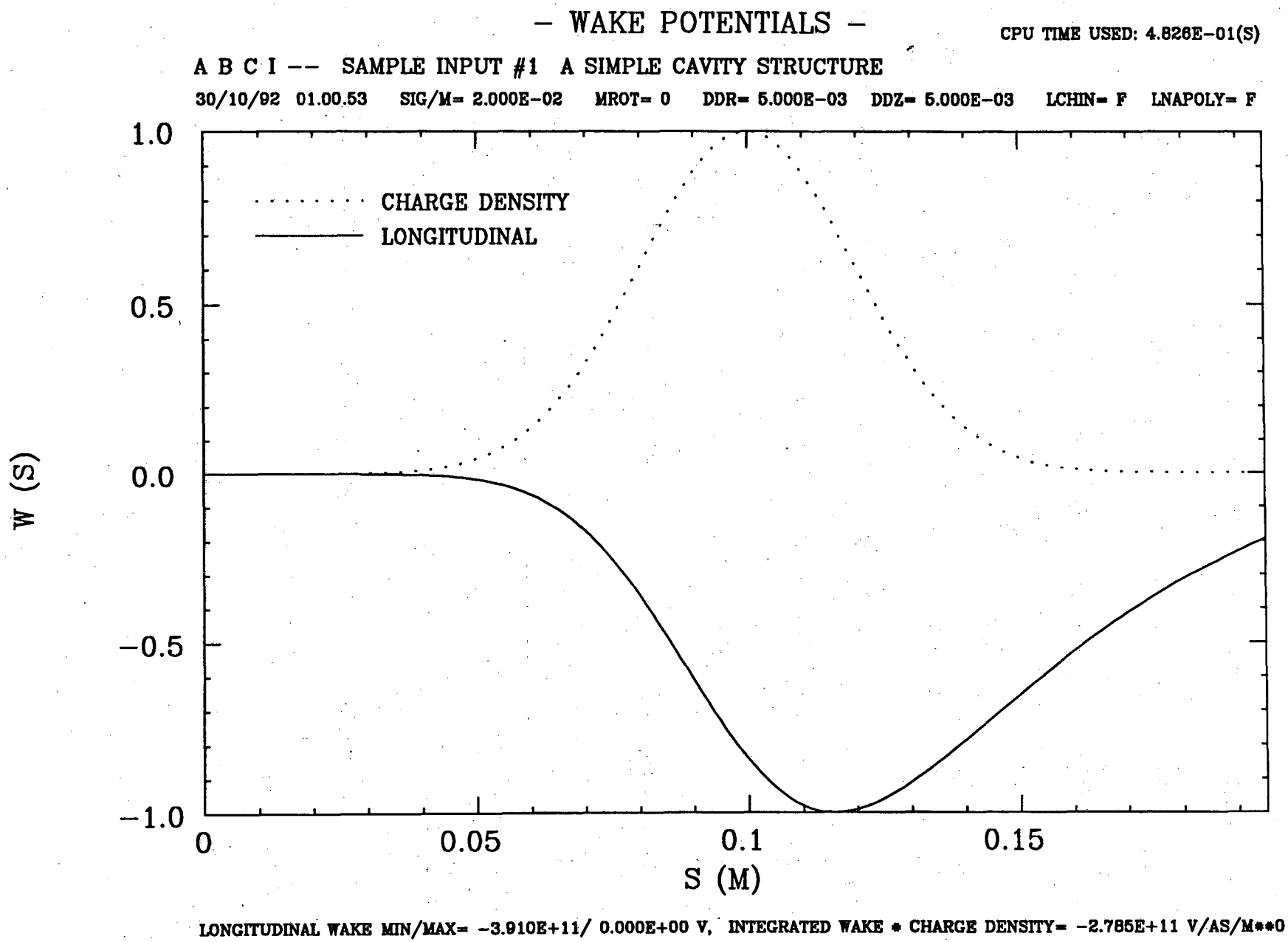


LINE CHARGE DENSITY MINMAX= 4.956E-05/ 1.330E+01AS/M, SCALE= 1.330E+01AS/M, PASSING AT R= 6.000E-02M
AZIMUTHAL WAKE MINMAX=-3.465E+11/ 2.452E+09 V , SCALE= 3.465E+11V , INTEGRATED AT R= 6.000E-02M , OR 5.775E+12 V/M**1
TRANSVERSE WAKE MINMAX= 0.000E+00/ 3.471E+11 V , SCALE= 3.471E+11V , INTEGRATED AT R= 6.000E-02M , OR 5.786E+12 V/M**1
LONGITUDINAL WAKE MINMAX=-3.251E+11/ 2.478E+11 V , SCALE= 3.251E+11V , INTEGRATED AT R= 6.000E-02M , OR 9.030E+13 V/M**2

INTEGRATED AZIMUTHAL WAKE * CHARGE DENSITY = -1.852E+11 VAS , OR -3.086E+12 V/AS/M**1
INTEGRATED TRANSVERSE WAKE * CHARGE DENSITY = 1.765E+11 VAS , OR 2.941E+12 V/AS/M**1
INTEGRATED LONGITUDINAL WAKE * CHARGE DENSITY = -2.076E+11 VAS , OR -5.767E+13 V/AS/M**2


– CAVITY SHAPE INPUT –
A B C I -- SAMPLE INPUT #1 A SIMPLE CAVITY STRUCTURE
30/10/92 01.00.53
0.20
0.15
0.10
0.05
0.00
R (M)
0
0.1
0.2
0.3
Z (M)


- CAVITY SHAPE USED -
A B C I -- SAMPLE INPUT #1 A SIMPLE CAVITY STRUCTURE
30/10/92 01.00.53
0.20
0.15
0.10
0.05
0.00
R (M)
0
0.1
0.2
0.3
Z (M)

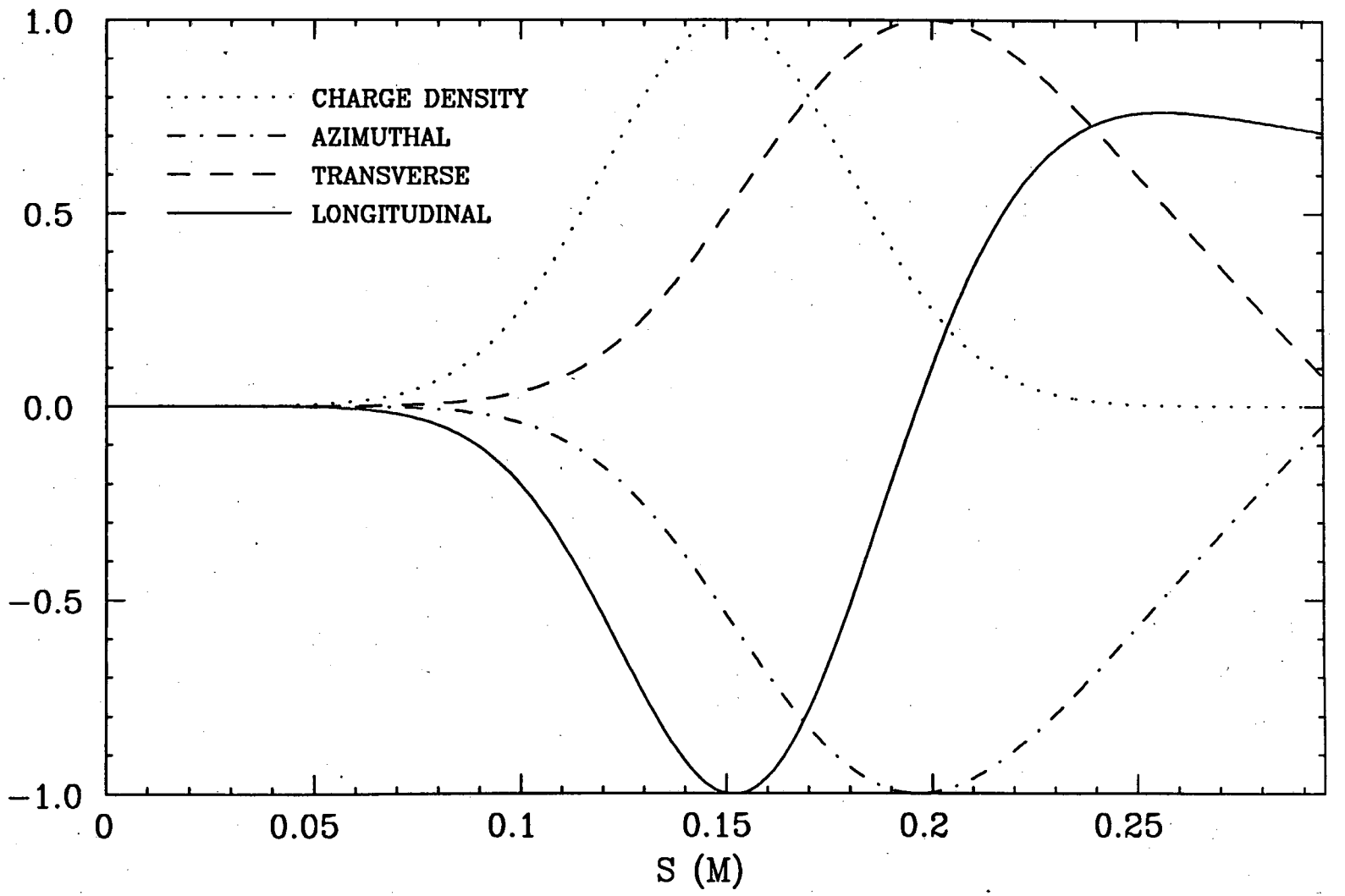

– WAKE POTENTIALS –
CPU TIME USED: 4.826E-01(S)
A B C I -- SAMPLE INPUT #1 A SIMPLE CAVITY STRUCTURE
30/10/92 01.00.53 SIG/M= 2.000E-02 MROT= 0 DDR= 5.000E-03 DDZ= 5.000E-03 LCHIN= F LNAPOLY= F
CHARGE DENSITY
LONGITUDINAL
1.0
0.5
0.0
−0.5
−1.0
W (S)
0
0.05
0.1
0.15
S (M)
LONGITUDINAL WAKE MIN/MAX= −3.910E+11/ 0.000E+00 V, INTEGRATED WAKE * CHARGE DENSITY= −2.785E+11 V/AS/M**0

– WAKE POTENTIALS –

CPU TIME USED: 1.121E+00(S)

A B C I -- SAMPLE INPUT #1 A SIMPLE CAVITY STRUCTURE

30/10/92 01.00.53 SIG/M= 3.000E-02 MROT= 1 DDR= 5.000E-03 DDZ= 5.000E-03 LCHIN= F LNAPOLY= F



AZIMUTHAL WAKE MIN/MAX= −3.465E+11/ 2.452E+09 V, INTEGRATED WAKE * CHARGE DENSITY= −3.086E+12 V/AS/M**1

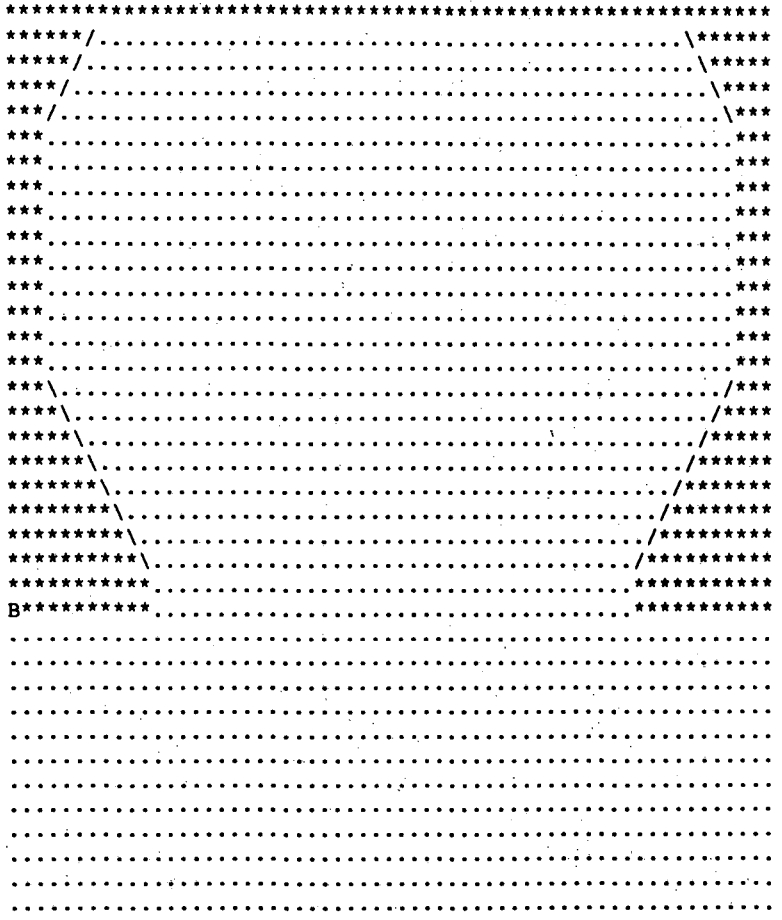
TRANSVERSE WAKE MIN/MAX= 0.000E+00/ 3.471E+11 V, INTEGRATED WAKE * CHARGE DENSITY= 2.941E+12 V/AS/M**1

LONGITUDINAL WAKE MIN/MAX= −3.251E+11/ 2.478E+11 V, INTEGRATED WAKE * CHARGE DENSITY= −5.767E+13 V/AS/M**2

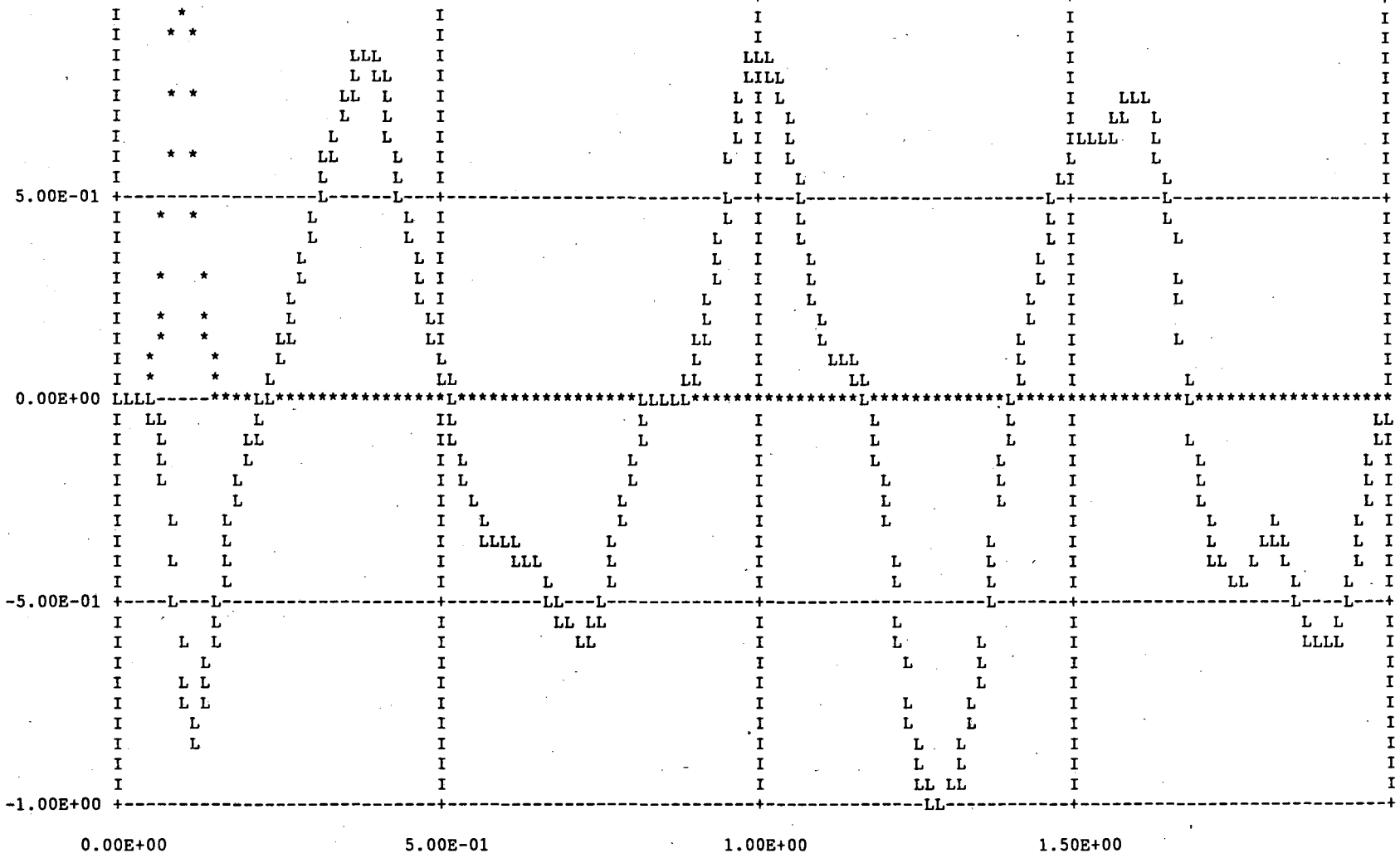
```
*************************************************************************
*                                                                       *
*                          ABCI   3RD RUN                               *
*                                                                       *
*   DATE:30/10/92   TIME:01.00.55      VERSION 6.2,  OCTOBER   1992     *
*                                                                       *
*************************************************************************


$FILE:
SAVE FIELDS INTO FILE  (LSAV)  :  F
RECOVER FROM FILE      (LREC)  :  F
CPUTIME MONITOR ACTIVE (LCPUTM):  F

$BOUN:
BOUNDARY CONDITIONS     LEFT   : OPEN
BOUNDARY CONDITIONS     RIGHT  : OPEN

$MESH:
NUMBER OF MESH LINES IN R      : NR   =      37
NUMBER OF MESH LINES IN Z      : NZ   =      60
NUMBER OF MESH POINTS          : NP   =    2220
TOTAL RADIUS OF THE STRUCTURE  : RAD  =  0.21000    (M)
TOTAL LENGTH OF THE STRUCTURE  : ZL   =  0.30000    (M)
STEP SIZE IN R                 : DDR  =  0.50000E-02(M)  FROM R=  0.00000E+00  TO R=  0.70000E-01
STEP SIZE IN R                 : DDR  =  0.75000E-02(M)  FROM R=  0.70000E-01  TO R=  0.13000
STEP SIZE IN R                 : DDR  =  0.50000E-02(M)  FROM R=  0.13000      TO R=  0.18000
STEP SIZE IN R                 : DDR  =  0.75000E-02(M)  FROM R=  0.18000      TO R=  0.21000
STEP SIZE IN Z                 : DDZ  =  0.50000E-02(M)

#CAVITYSHAPE (##CAVITYSHAPE) :  HALF CELL INPUT

INPUT:       (R, Z)                    (IR, IZ)
(   0.00000E+00  0.00000E+00 )  (       1      1 )
(   0.21000      0.00000E+00 )  (      37      1 )
(   0.21000      0.11500     )  (      37     24 )
(   0.18000      0.13500     )  (      33     28 )
(   0.13000      0.13500     )  (      23     28 )
(   0.70000E-01  0.95000E-01 )  (      15     20 )
CONNECTED BY A CONCAVE CIRCLE, IKIND=-1,  RADIUS=  0.90000E-02
(   0.60000E-01  0.97000E-01 )  (      13     20 ) ---> (   0.60000E-01  0.95000E-01 )
(   0.60000E-01  0.15000     )  (      13     30 )
(   0.00000E+00  0.15000     )  (       1     31 )
(   0.00000E+00  0.00000E+00 )  (       1      1 )

$BEAM:
SIGMA OF THE GAUSSIAN BUNCH    : SIG  =  0.20000E-01(M)
NUMBER OF STAND.DEV. USED      : ISIG = +/-  5
RADIAL BEAM OFFSET AT          :RDRIVE=  0.60000E-01(M)
MODE NUMBER (MONOPOLE/DIPOLE)  : MROT =      0

$WAKE:
RADIAL WAKE OFFSET        (LEFT)   AT  R   =  0.60000E-01(M)
WAKE    BETWEEN THE BUNCH  COORDINATES UBF =  0.00000E+00(M)
                                   AND UBT =   2.0000    (M)
WINDOW FOR FRONT                  (LCFRON)  :  T
```

```
WINDOW FOR BACK                    (LCBACK)   :  T
CHIN WAKE INTEGRATION METHOD       (LCHIN )   :  F
NAPOLY WAKE INTEGRATION METHOD     (LNAPOLY)  :  F
NUMBER OF WAKE POTENTIAL POINTS: NW    =      400

$TIME:
TIME STEPS TO BE PROCESSED      : NT    =   1380
NUMBER OF TIME STEPS/MESH STEP  : MT    =      3
VELOCITY OF THE BUNCH / C       : BETA  =   1.0000
TIME-STEP VALUE                 : DT    =  0.55594E-11(S)
TIME FOR A PARTICLE TO PASS     : PT    =  0.10007E-08(S)

$PLOT:
PLOT OF CAVITY SHAPE INPUT         (LCAVIN)   :  F
PLOT OF CAVITY SHAPE USED          (LCAVUS)   :  T
PLOT OF WAKE POTENTIALS            (LPLW)     :  T
PLOT OF FFT OF WAKE POTENTIALS     (LFFT)     :  F
PLOT OF FFT OF AZIMUTHAL WAKE      (LFFTA)    :  F
PLOT OF FFT OF TRANSVERSE WAKE     (LFFTT)    :  F
PLOT OF FFT OF LONGITUDINAL WAKE   (LFFTL)    :  T
CUTOFF FREQUENCY FOR FFT PLOT   :CUTOFF=    2.5000     (GHZ)

$PRINT:
PRINTOUT OF CAVITY SHAPE USED      (LMATPR)   :  T
PRINTOUT OF THE FIELDS             (LPRW)     :  F
```

CAVITY SHAPE
.=VACUUM ; \,/=TRIANGULAR FILLED MESH CELL ; *=FULL METAL ; B=BEAM

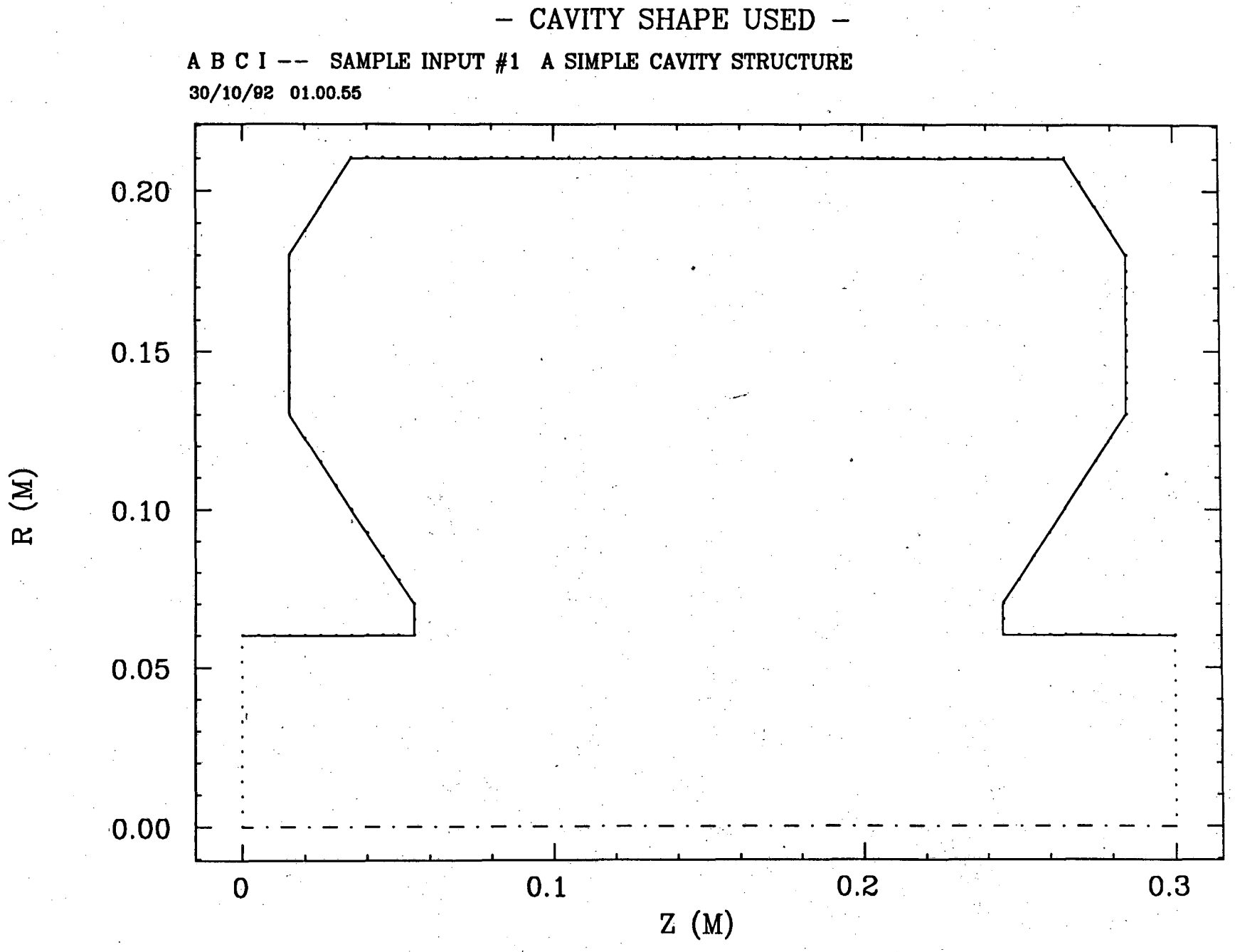


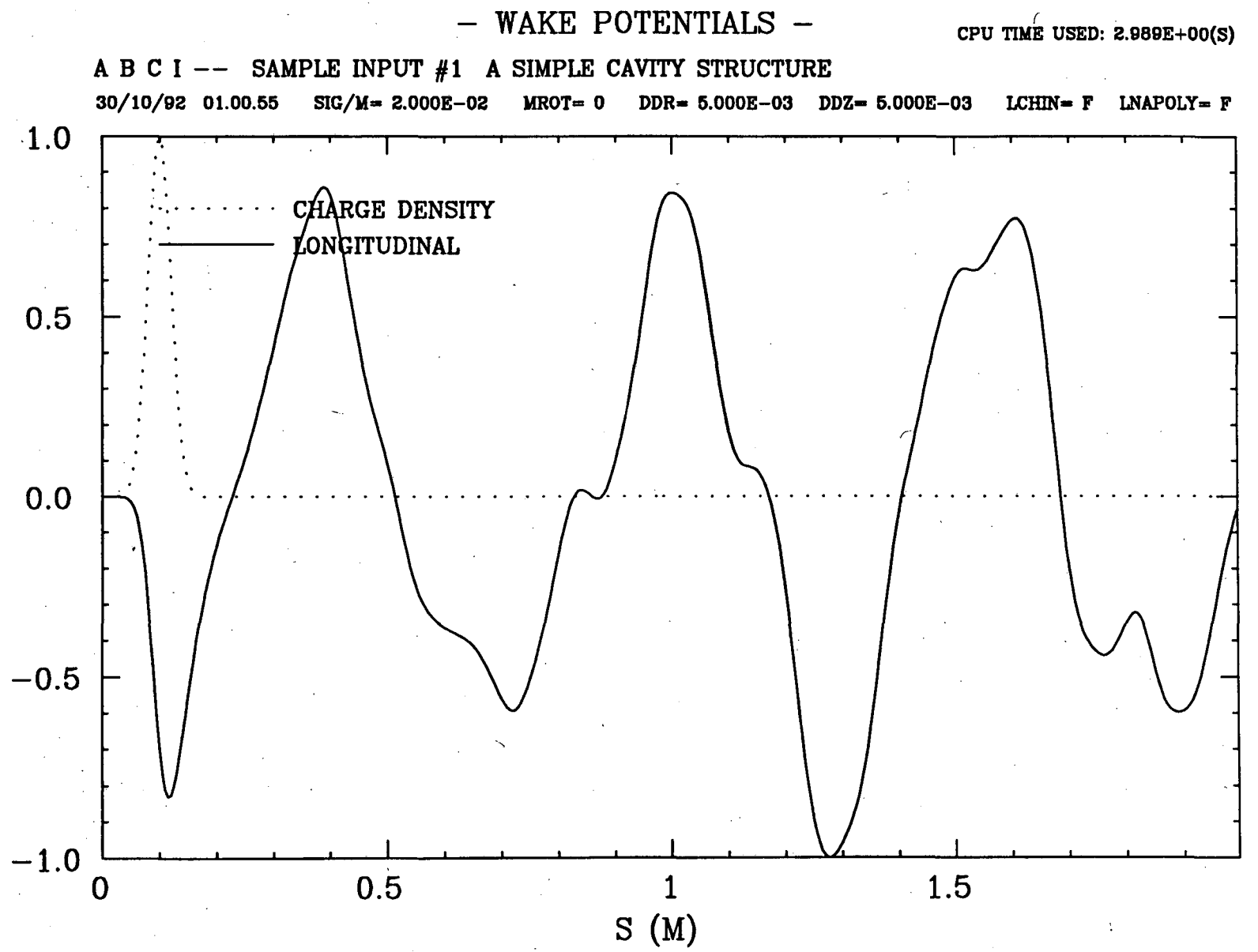
PROBLEM : SAMPLE INPUT #1 A SIMPLE CAVITY STRUCTURE 30/10/92 01.00.55 SIG/M= 2.000E-02 MROT= 0
CPUTIME USED: 2.989E+00(S) DDR= 5.000E-03 DDZ= 5.000E-03
(A,T,L,P) = WAKE POTENTIAL AS A FUNCTION OF THE BUNCH COORDINATES S IN (M), (*)=BUNCH SHAPE, FRONT LEFT LCHIN= F LNAPOLY= F

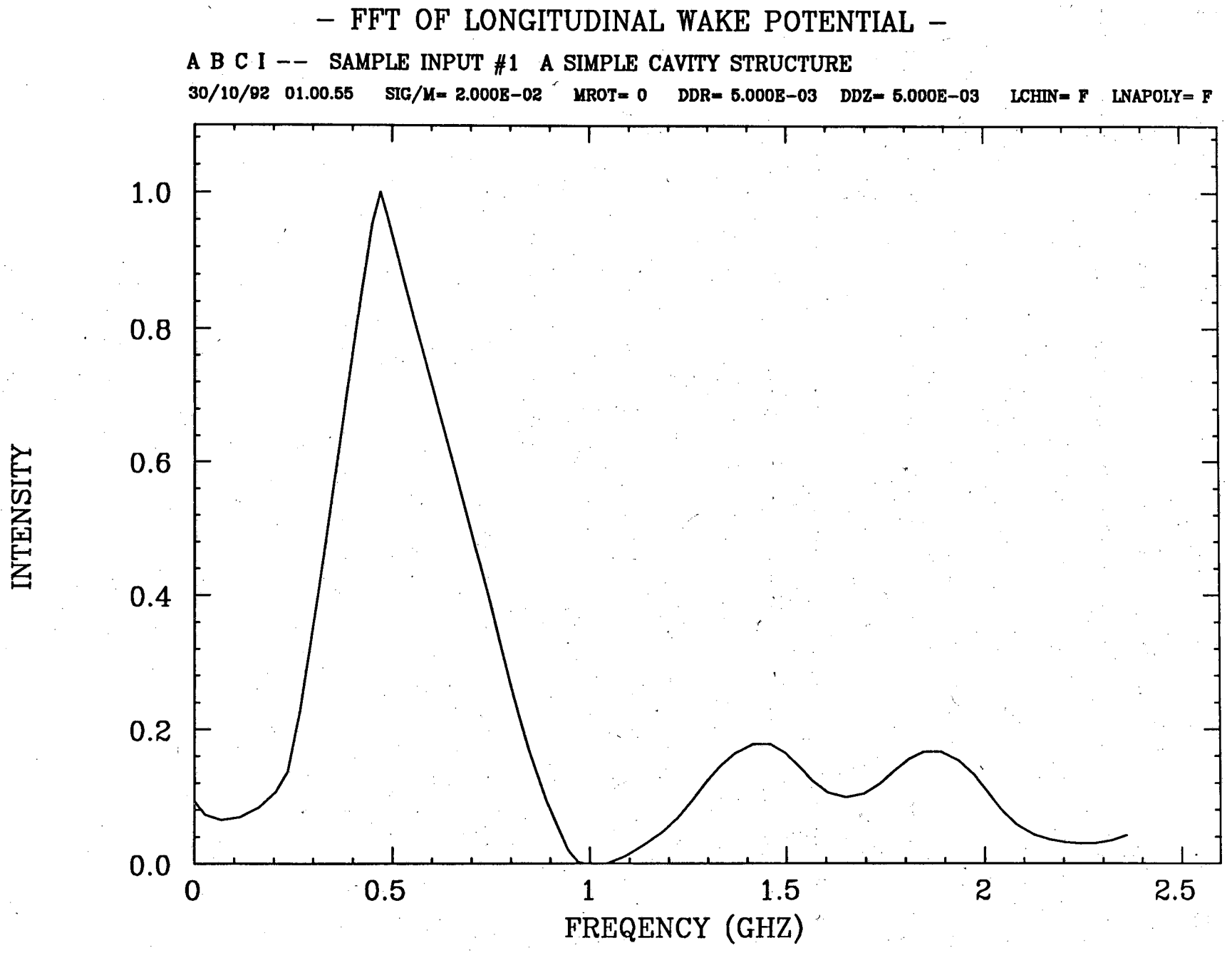


LINE CHARGE DENSITY MINMAX= 0.000E+00/ 1.995E+01AS/M, SCALE= 1.995E+01AS/M, PASSING AT R= 6.000E-02M
LONGITUDINAL WAKE MINMAX=-4.786E+11/ 4.104E+11 V , SCALE= 4.786E+11V , INTEGRATED AT R= 6.000E-02M , OR 4.786E+11 V/M**0

INTEGRATED LONGITUDINAL WAKE * CHARGE DENSITY = -2.821E+11 VAS , OR -2.821E+11 V/AS/M**0


- CAVITY SHAPE USED -
A B C I -- SAMPLE INPUT #1 A SIMPLE CAVITY STRUCTURE
30/10/92 01.00.55
0.20
0.15
0.10
0.05
0.00
R (M)
0
0.1
0.2
0.3
Z (M)

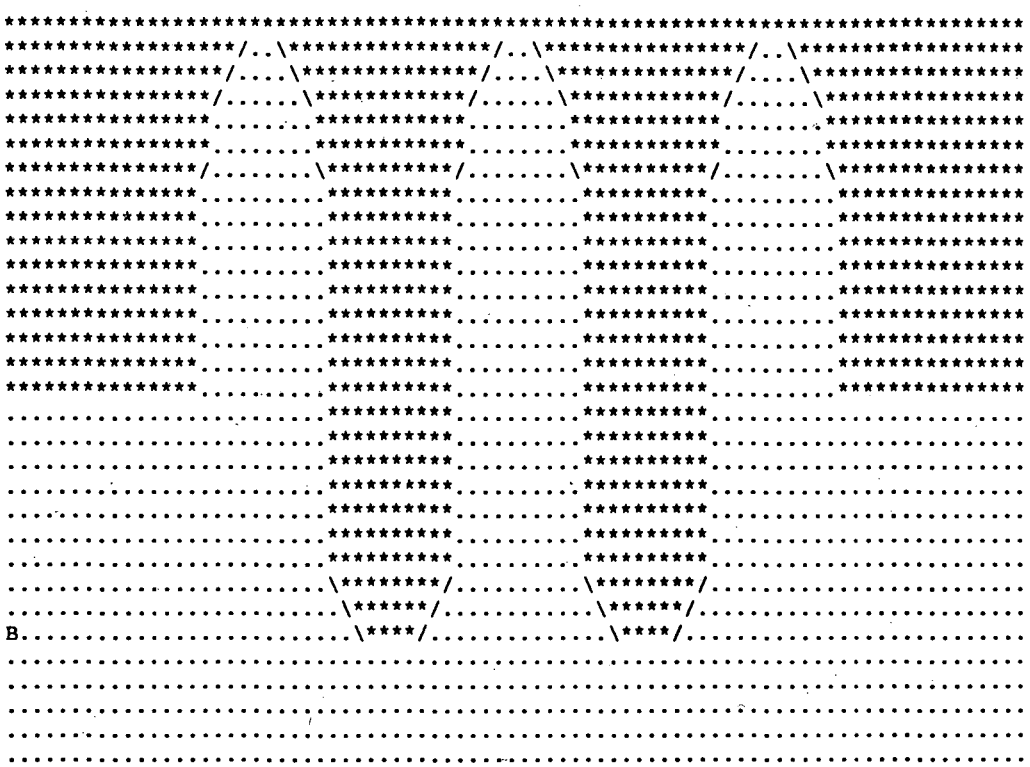

- WAKE POTENTIALS -
CPU TIME USED: 2.989E+00(S)
A B C I -- SAMPLE INPUT #1 A SIMPLE CAVITY STRUCTURE
30/10/92 01.00.55 SIG/M= 2.000E-02 MROT= 0 DDR= 5.000E-03 DDZ= 5.000E-03 LCHIN= F LNAPOLY= F
CHARGE DENSITY
LONGITUDINAL
1.0
0.5
0.0
-0.5
-1.0
0
0.5
1
1.5
S (M)
W (S)
LONGITUDINAL WAKE MIN/MAX= -4.786E+11/ 4.104E+11 V, INTEGRATED WAKE * CHARGE DENSITY= -2.821E+11 V/AS/M**0


– FFT OF LONGITUDINAL WAKE POTENTIAL –
A B C I -- SAMPLE INPUT #1 A SIMPLE CAVITY STRUCTURE
30/10/92 01.00.55 SIG/M= 2.000E-02 MROT= 0 DDR= 5.000E-03 DDZ= 5.000E-03 LCHIN= F LNAPOLY= F
INTENSITY
1.0
0.8
0.6
0.4
0.2
0.0
0
0.5
1
1.5
2
2.5
FREQENCY (GHZ)

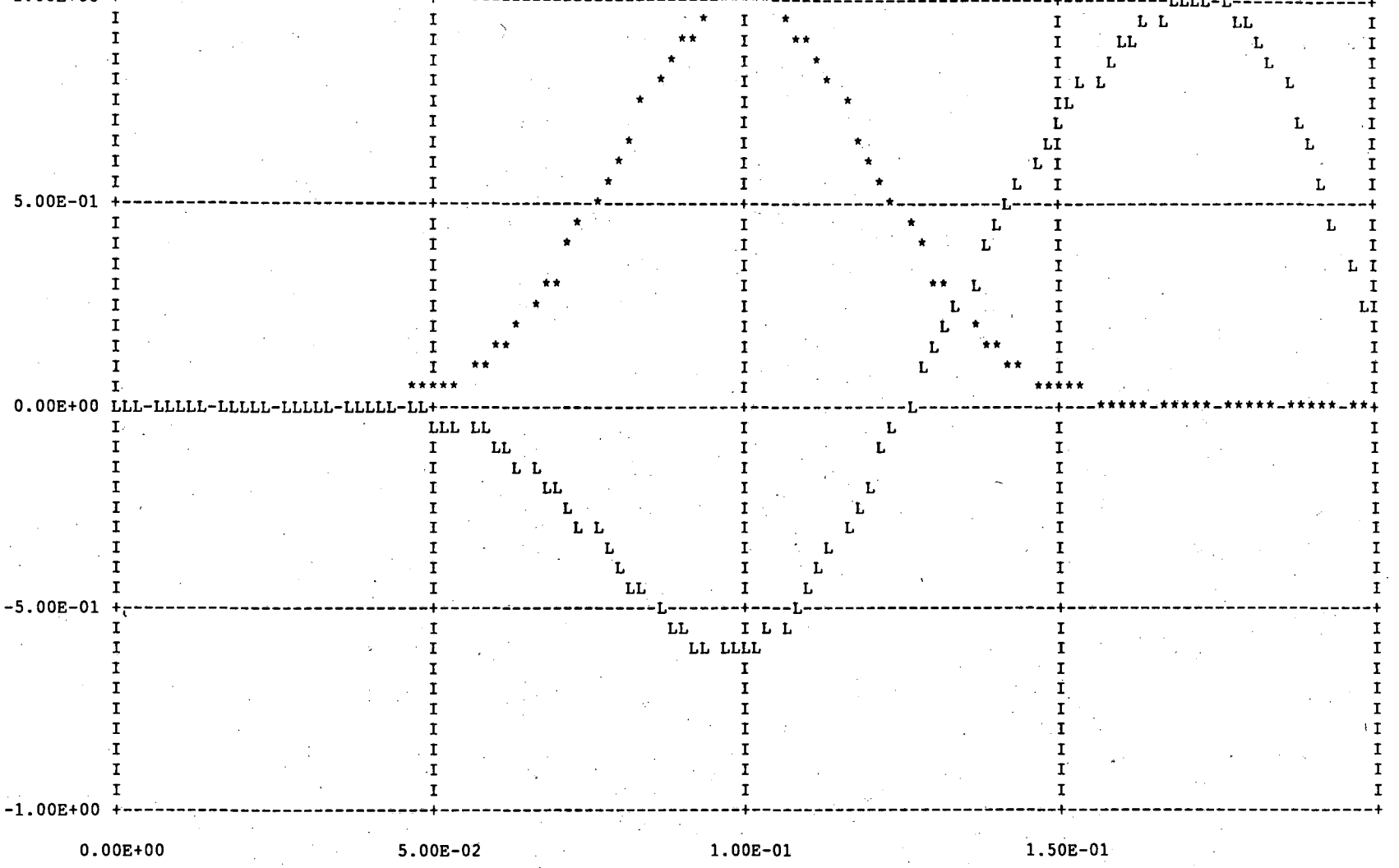
```
**************************************************************************
*                                                                        *
*                                ABCI                                    *
*                                                                        *
* Azimuthal Beam Cavity Interaction in a cylindrically symmetric structure *
*                                                                        *
*  SAMPLE INPUT #2  A COLLIMATOR-LIKE STRUCTURE WITH DOUBLE TEETH        *
*                                                                        *
*     DATE:30/10/92   TIME:01.01.08      VERSION 6.2,  OCTOBER   1992    *
*                                                                        *
**************************************************************************


$FILE:
SAVE FIELDS INTO FILE  (LSAV)  :  F
RECOVER FROM FILE      (LREC)  :  F
CPUTIME MONITOR ACTIVE (LCPUTM):  F

$BOUN:
BOUNDARY CONDITIONS     LEFT   : OPEN
BOUNDARY CONDITIONS     RIGHT  : OPEN

$MESH:
NUMBER OF MESH LINES IN R       : NR   =      31
NUMBER OF MESH LINES IN Z       : NZ   =      80
NUMBER OF MESH POINTS           : NP   =    2480
TOTAL RADIUS OF THE STRUCTURE   : RAD  =  0.60000E-01(M)
TOTAL LENGTH OF THE STRUCTURE   : ZL   =  0.16000    (M)
STEP SIZE IN R                  : DDR  =  0.20000E-02(M)
STEP SIZE IN Z                  : DDZ  =  0.20000E-02(M)
STRUCTURE INPUT VARIABLE        : RZ  1=  0.10000E-01(M)
STRUCTURE INPUT VARIABLE        : RZ  2=  0.30000E-01(M)

@CAVITYSHAPE (@@CAVITYSHAPE) :  FULL CELL INPUT

INPUT:       (R, Z)                    (IR, IZ)
(  0.00000E+00  0.00000E+00 )  (       1      1 )
(  0.30000E-01  0.00000E+00 )  (      16      1 ) ---> (  0.30000E-01  0.00000E+00 )
(  0.00000E+00  0.30000E-01 )  (      16     16 ) ---> (  0.30000E-01  0.30000E-01 )
(  0.10000E-01  0.00000E+00 )  (      21     16 ) ---> (  0.40000E-01  0.30000E-01 )
CONNECTED BY AN ELLIPSE,       IKIND=-3,  (RM, ZM)=     (  0.40000E-01  0.40000E-01 )
(  0.20000E-01  0.00000E+00 )  (      31     21 ) ---> (  0.60000E-01  0.40000E-01 )
CONNECTED BY AN ELLIPSE,       IKIND=-3,  (RM, ZM)=     (  0.40000E-01  0.40000E-01 )
(  0.00000E+00  0.10000E-01 )  (      21     26 ) ---> (  0.40000E-01  0.50000E-01 )
( -0.20000E-01  0.00000E+00 )  (      11     26 ) ---> (  0.20000E-01  0.50000E-01 )
CONNECTED BY A CONCAVE CIRCLE, IKIND=-1,  RADIUS=  0.10000E-01
(  0.00000E+00  0.20000E-01 )  (      11     36 ) ---> (  0.20000E-01  0.70000E-01 )
(  0.20000E-01  0.00000E+00 )  (      21     36 ) ---> (  0.40000E-01  0.70000E-01 )
CONNECTED BY AN ELLIPSE,       IKIND=-3,  (RM, ZM)=     (  0.40000E-01  0.80000E-01 )
(  0.20000E-01  0.00000E+00 )  (      31     41 ) ---> (  0.60000E-01  0.80000E-01 )
CONNECTED BY AN ELLIPSE,       IKIND=-3,  (RM, ZM)=     (  0.40000E-01  0.80000E-01 )
(  0.00000E+00  0.10000E-01 )  (      21     46 ) ---> (  0.40000E-01  0.90000E-01 )
( -0.20000E-01  0.00000E+00 )  (      11     46 ) ---> (  0.20000E-01  0.90000E-01 )
CONNECTED BY A CONCAVE CIRCLE, IKIND=-1,  RADIUS=  0.10000E-01
(  0.00000E+00  0.20000E-01 )  (      11     56 ) ---> (  0.20000E-01  0.11000     )
(  0.20000E-01  0.00000E+00 )  (      21     56 ) ---> (  0.40000E-01  0.11000     )
```

```
CONNECTED BY AN ELLIPSE,       IKIND=-3,  (RM, ZM)=     (   0.40000E-01  0.12000     )
(   0.20000E-01  0.00000E+00 )  (      31      61 ) ---> (   0.60000E-01  0.12000     )
CONNECTED BY AN ELLIPSE,       IKIND=-3,  (RM, ZM)=     (   0.40000E-01  0.12000     )
(   0.00000E+00  0.10000E-01 )  (      21      66 ) ---> (   0.40000E-01  0.13000     )
(     -RZ  1     0.00000E+00 )  (      16      66 ) ---> (   0.30000E-01  0.13000     )
(   0.00000E+00  0.30000E-01 )  (      16      80 ) ---> (   0.30000E-01  0.16000     )
(     -RZ  2     0.00000E+00 )  (       1      81 ) ---> (   0.00000E+00  0.16000     )
(   0.00000E+00 -0.16000     )  (       1       1 ) ---> (   0.00000E+00  0.00000E+00 )

$BEAM:
SIGMA OF THE GAUSSIAN BUNCH    : SIG  =  0.20000E-01(M)
NUMBER OF STAND.DEV. USED      : ISIG = +/-  5
RADIAL BEAM OFFSET AT          :RDRIVE=  0.10000E-01(M)
MODE NUMBER (MONOPOLE/DIPOLE)  : MROT =      0

$WAKE:
RADIAL WAKE OFFSET       (LEFT)   AT  R   =  0.30000E-01(M)
WAKE    BETWEEN THE BUNCH  COORDINATES UBF =  0.00000E+00(M)
                                   AND UBT =  0.20000    (M)
WINDOW FOR FRONT                (LCFRON)  :  T
WINDOW FOR BACK                 (LCBACK)  :  T
CHIN WAKE INTEGRATION METHOD    (LCHIN )  :  F
NAPOLY WAKE INTEGRATION METHOD  (LNAPOLY) :  T
NUMBER OF WAKE POTENTIAL POINTS: NW   =     100

$TIME:
TIME STEPS TO BE PROCESSED     : NT   =    540
NUMBER OF TIME STEPS/MESH STEP : MT   =      3
VELOCITY OF THE BUNCH / C      : BETA =   1.0000
TIME-STEP VALUE                : DT   =  0.22238E-11(S)
TIME FOR A PARTICLE TO PASS    : PT   =  0.53370E-09(S)

$PLOT:
PLOT OF CAVITY SHAPE INPUT       (LCAVIN)  :  T
PLOT OF CAVITY SHAPE USED        (LCAVUS)  :  T
PLOT OF WAKE POTENTIALS          (LPLW)    :  T
PLOT OF FFT OF WAKE POTENTIALS   (LFFT)    :  F
PLOT OF FFT OF AZIMUTHAL WAKE    (LFFTA)   :  F
PLOT OF FFT OF TRANSVERSE WAKE   (LFFTT)   :  F
PLOT OF FFT OF LONGITUDINAL WAKE (LFFTL)   :  F
CUTOFF FREQUENCY FOR FFT PLOT  :CUTOFF=   74.948    (GHZ)

$PRINT:
PRINTOUT OF CAVITY SHAPE USED    (LMATPR)  :  T
PRINTOUT OF THE FIELDS           (LPRW)    :  F

*** WARNING *** YOU DID NOT FULLY SPECIFY THE INTEGRATION CONTURE DESPITE OF LNAPOLY=T.
*** ABCI CHOOSES THE FOLLOWING CONTURE; ***
ZCF=  0.26000E-01(M)    ZCT=  0.13400    (M)    AND RWAK=  0.10000E-01(M)
YOU SHOULD STILL CHECK IF THIS CONTURE IS VALID OR NOT.

*** CAUTION *** YOU MUST NOW USE NAPOLY INTEGRATION FOR CALCULATION OF THE WAKE POTENTIALS.
YOUR CASE: LNAPOLY= T
IF LNAPOLY=F, ABCI NOW CHANGES IT TO LNAPOLY=T.
CHECK IF THE CONTURE IS VALID.
```

CAVITY SHAPE
.=VACUUM ; \,/=TRIANGULAR FILLED MESH CELL ; *=FULL METAL ; B=BEAM

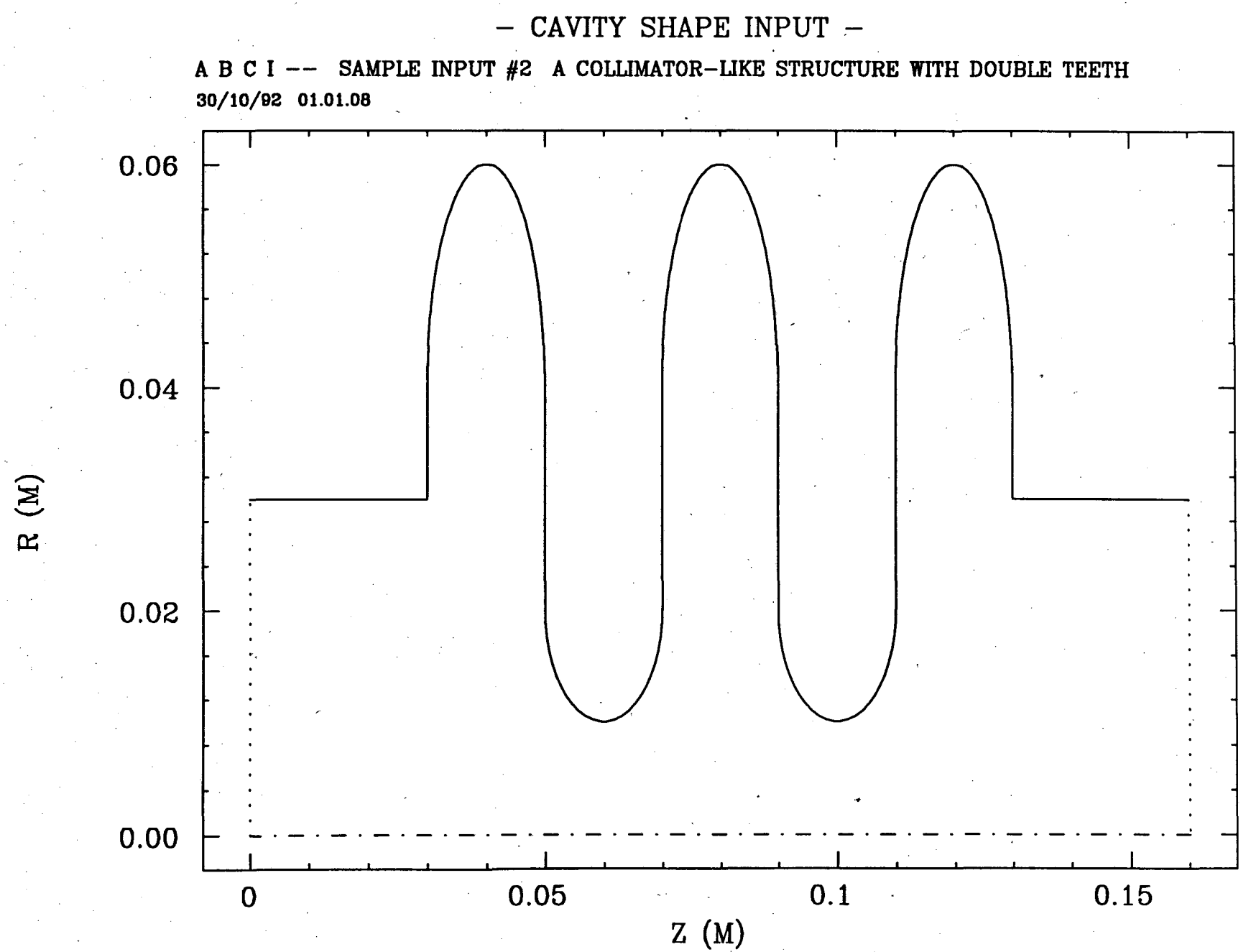


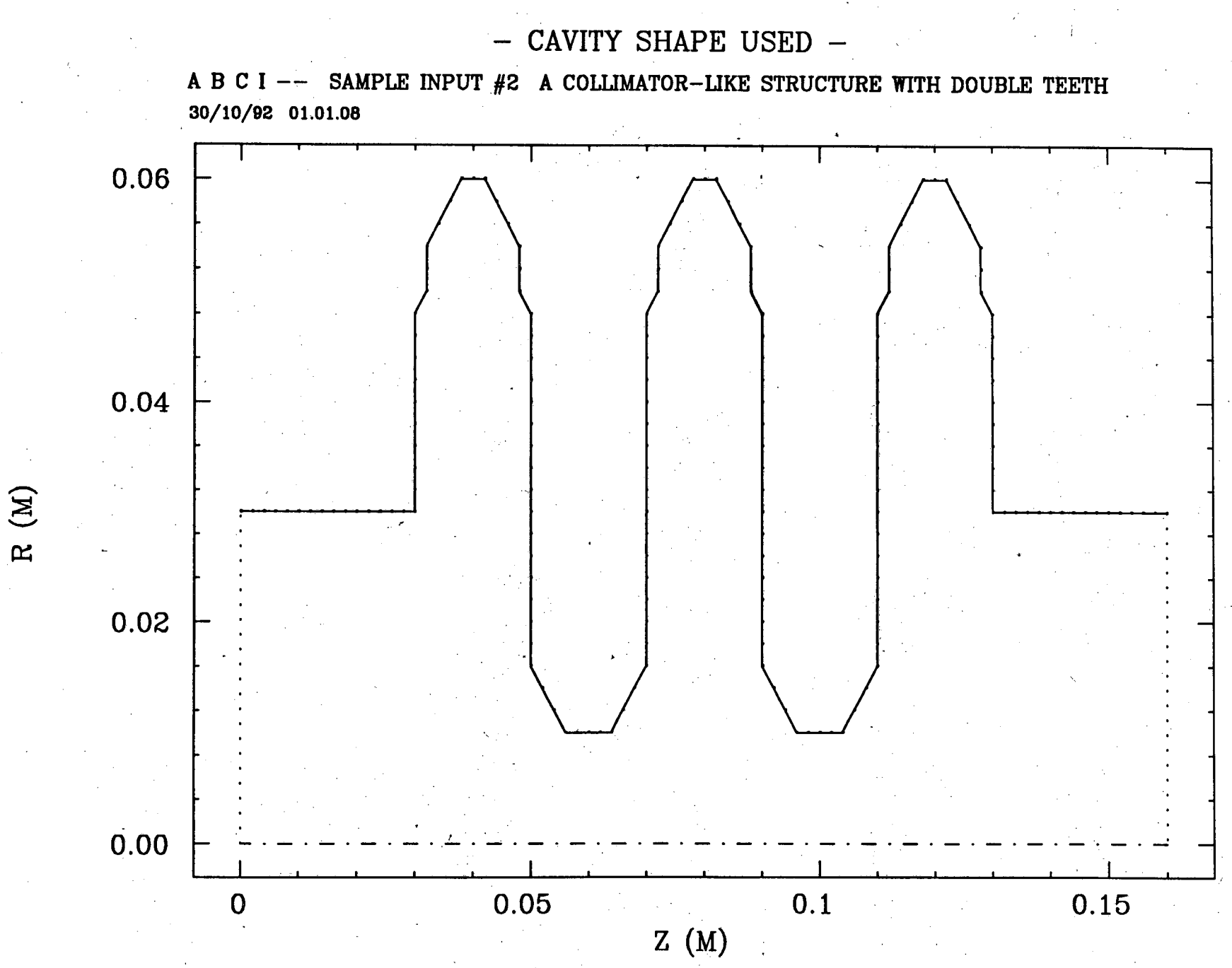
PROBLEM : SAMPLE INPUT #2 A COLLIMATOR-LIKE STRUCTURE WITH DOUBLE TEETH 30/10/92 01.01.08 SIG/M= 2.000E-02 MROT= 0
CPUTIME USED: 8.671E-01(S) DDR= 2.000E-03 DDZ= 2.000E-03
(A,T,L,P) = WAKE POTENTIAL AS A FUNCTION OF THE BUNCH COORDINATES S IN (M), (*)=BUNCH SHAPE, FRONT LEFT LCHIN= F LNAPOLY= T

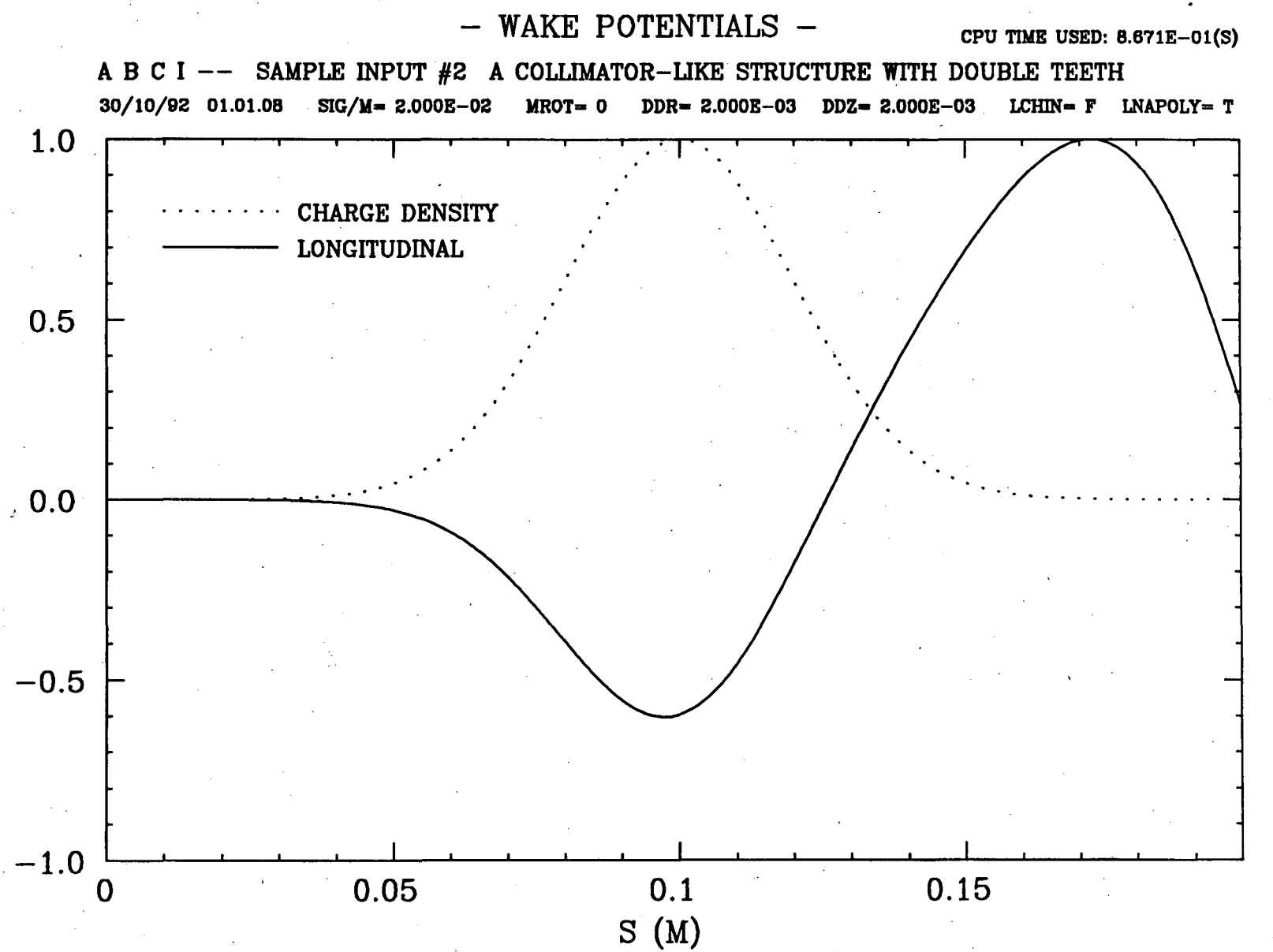


LINE CHARGE DENSITY MINMAX= 7.434E-05/ 1.995E+01AS/M, SCALE= 1.995E+01AS/M, PASSING AT R= 1.000E-02M
LONGITUDINAL WAKE MINMAX=-7.098E+11/ 1.176E+12 V , SCALE= 1.176E+12V , INTEGRATED AT R= 3.000E-02M , OR 1.176E+12 V/M**0

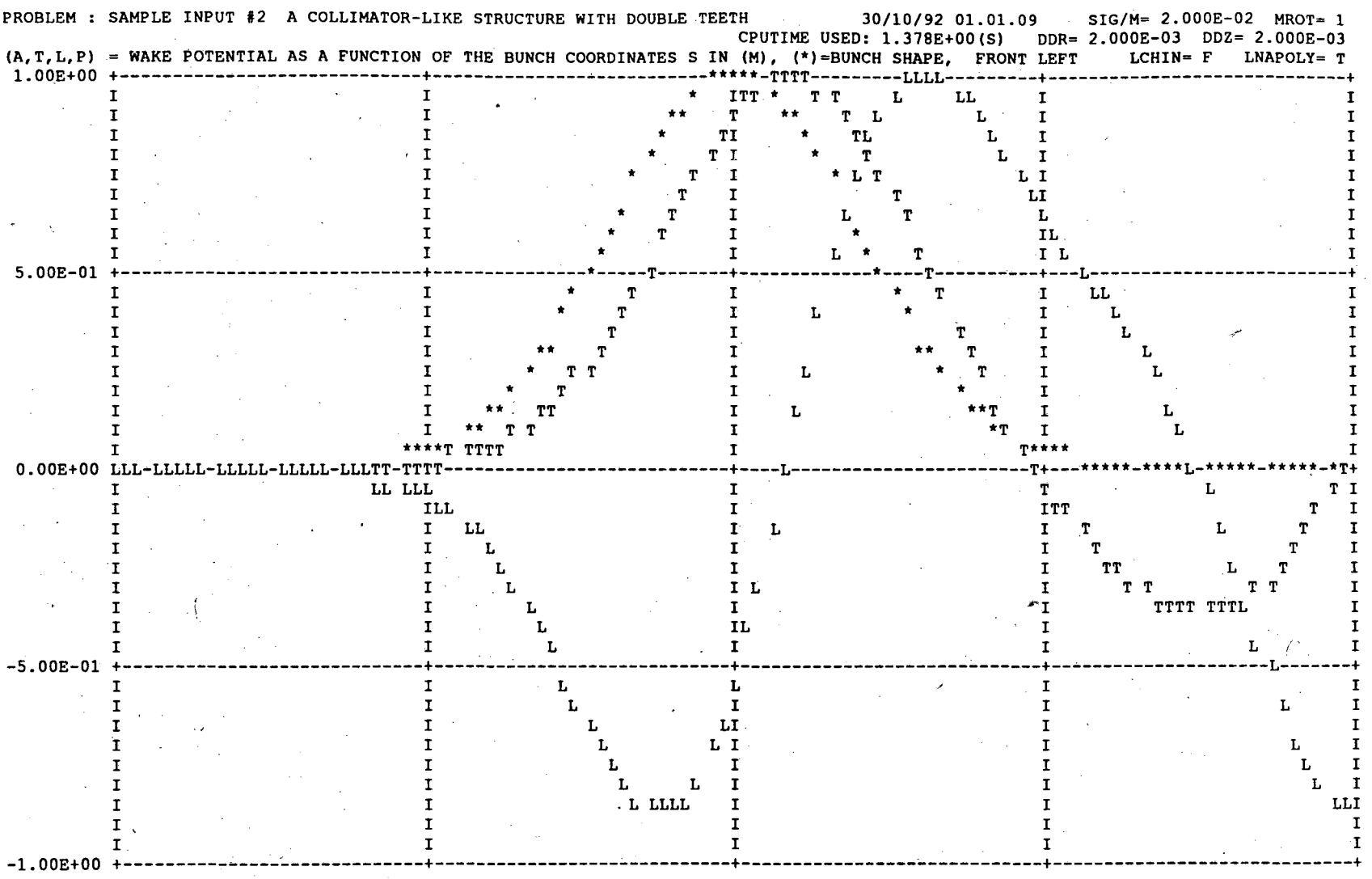
INTEGRATED LONGITUDINAL WAKE * CHARGE DENSITY = -4.171E+11 VAS , OR -4.171E+11 V/AS/M**0


– CAVITY SHAPE INPUT –
A B C I -- SAMPLE INPUT #2 A COLLIMATOR-LIKE STRUCTURE WITH DOUBLE TEETH
30/10/92 01.01.08
0.06
0.04
0.02
0.00
R (M)
0
0.05
0.1
0.15
Z (M)


- CAVITY SHAPE USED -
A B C I -- SAMPLE INPUT #2 A COLLIMATOR-LIKE STRUCTURE WITH DOUBLE TEETH
30/10/92 01.01.08
0.06
0.04
0.02
0.00
R (M)
0
0.05
0.1
0.15
Z (M)

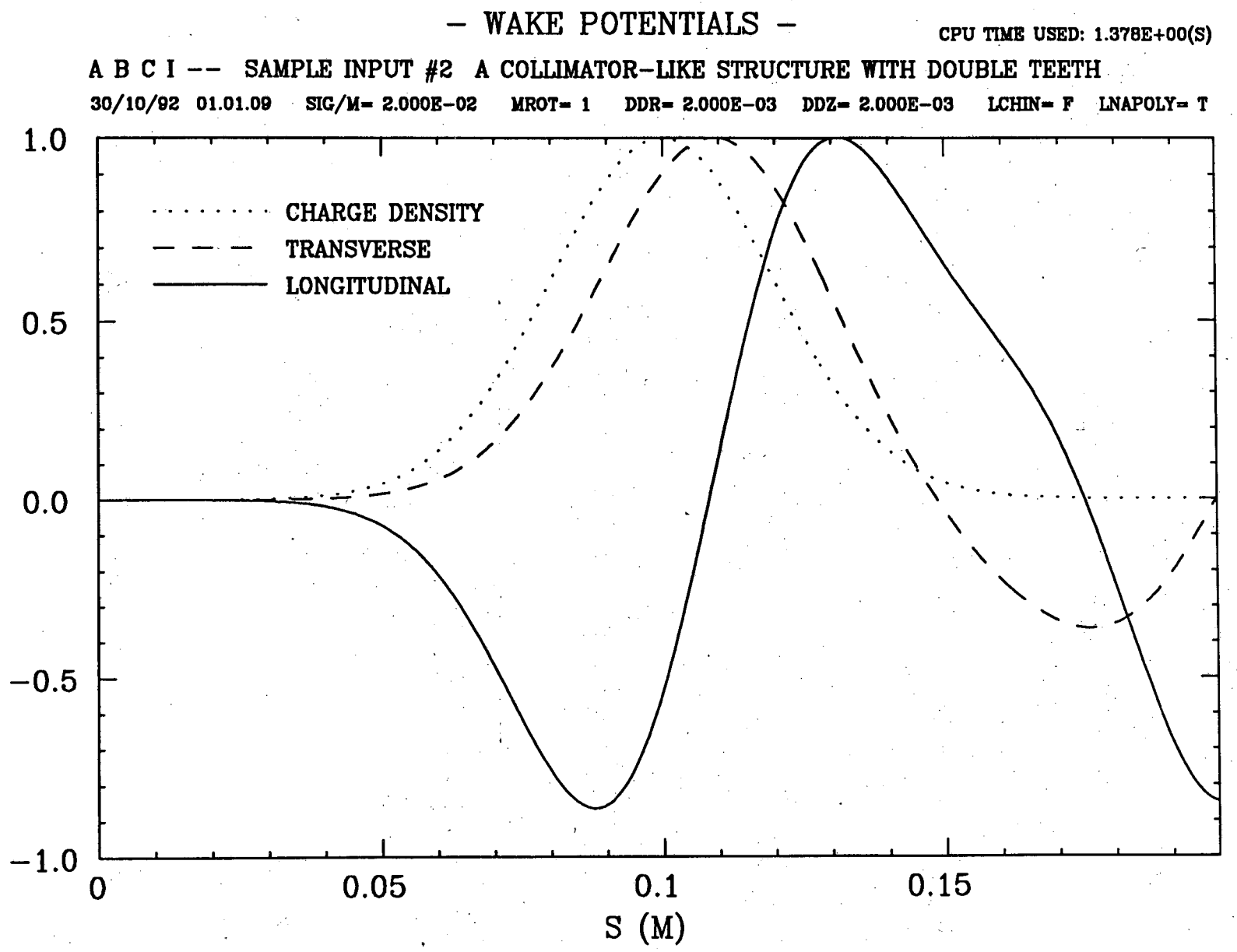

- WAKE POTENTIALS -
CPU TIME USED: 8.671E-01(S)
A B C I -- SAMPLE INPUT #2 A COLLIMATOR-LIKE STRUCTURE WITH DOUBLE TEETH
30/10/92 01.01.08 SIG/M= 2.000E-02 MROT= 0 DDR= 2.000E-03 DDZ= 2.000E-03 LCHIN= F LNAPOLY= T
CHARGE DENSITY
LONGITUDINAL
1.0
0.5
0.0
-0.5
-1.0
W (S)
0
0.05
0.1
0.15
S (M)
LONGITUDINAL WAKE MIN/MAX= -7.098E+11/ 1.176E+12 V, INTEGRATED WAKE * CHARGE DENSITY= -4.171E+11 V/AS/M**0

```
**************************************************************************
*                                                                        *
*                            ABCI   2ND RUN                              *
*                                                                        *
*   DATE:30/10/92   TIME:01.01.09      VERSION 6.2,  OCTOBER   1992      *
*                                                                        *
**************************************************************************

*** WARNING *** YOU DID NOT FULLY SPECIFY THE INTEGRATION CONTURE DESPITE OF LNAPOLY=T.
*** ABCI CHOOSES THE FOLLOWING CONTURE: ***
ZCF=  0.26000E-01(M)     ZCT=  0.13400     (M)    AND RWAK=  0.10000E-01(M)
YOU SHOULD STILL CHECK IF THIS CONTURE IS VALID OR NOT.

*** CAUTION *** YOU MUST NOW USE NAPOLY INTEGRATION FOR CALCULATION OF THE WAKE POTENTIALS.
YOUR CASE: LNAPOLY= T
IF LNAPOLY=F, ABCI NOW CHANGES IT TO LNAPOLY=T.
CHECK IF THE CONTURE IS VALID.
```



LINE CHARGE DENSITY MINMAX= 7.434E-05/ 1.995E+01AS/M, SCALE= 1.995E+01AS/M, PASSING AT R= 1.000E-02M
TRANSVERSE WAKE MINMAX=-3.653E+11/ 1.004E+12 V , SCALE= 1.004E+12V , INTEGRATED AT R= 3.000E-02M , OR 1.004E+14 V/M**1
LONGITUDINAL WAKE MINMAX=-8.888E+11/ 1.026E+12 V , SCALE= 1.026E+12V , INTEGRATED AT R= 3.000E-02M , OR 3.421E+15 V/M**2

INTEGRATED TRANSVERSE WAKE * CHARGE DENSITY = 6.739E+11 VAS , OR 6.739E+13 V/AS/M**1
INTEGRATED LONGITUDINAL WAKE * CHARGE DENSITY = -1.829E+11 VAS , OR -6.095E+14 V/AS/M**2

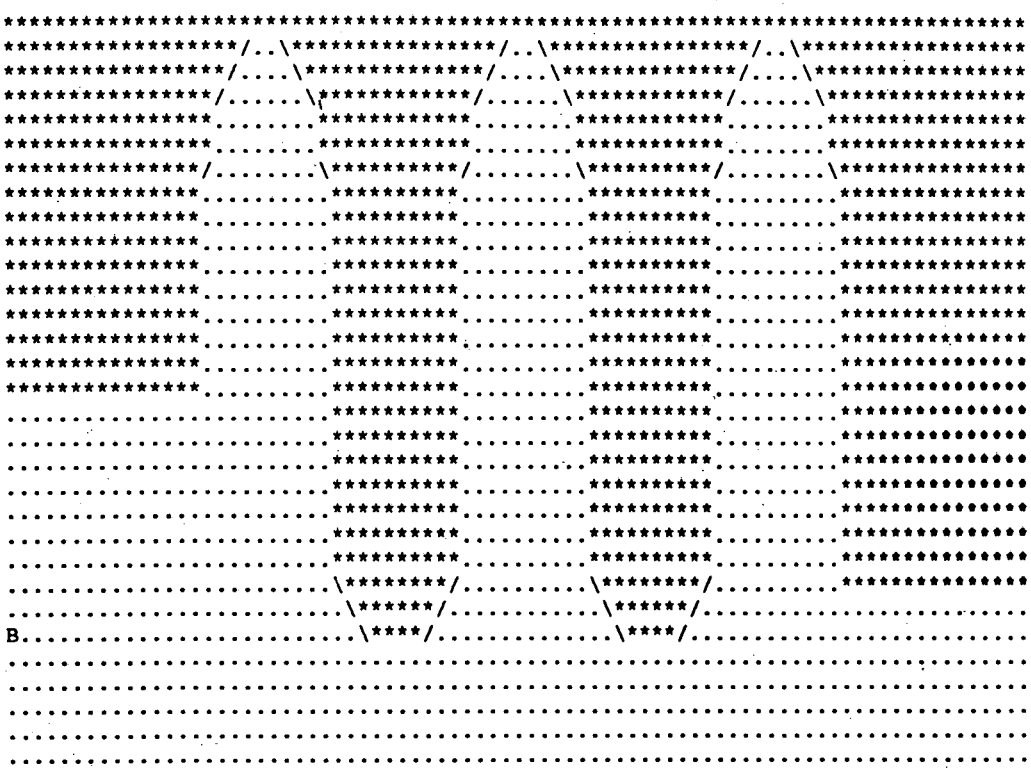


TRANSVERSE WAKE MIN/MAX= 0.000E+00/ 0.000E+00 V, INTEGRATED WAKE * CHARGE DENSITY= 6.739E+13 V/AS/M**1
LONGITUDINAL WAKE MIN/MAX= -8.888E+11/ 1.026E+12 V, INTEGRATED WAKE * CHARGE DENSITY= -6.095E+14 V/AS/M**2

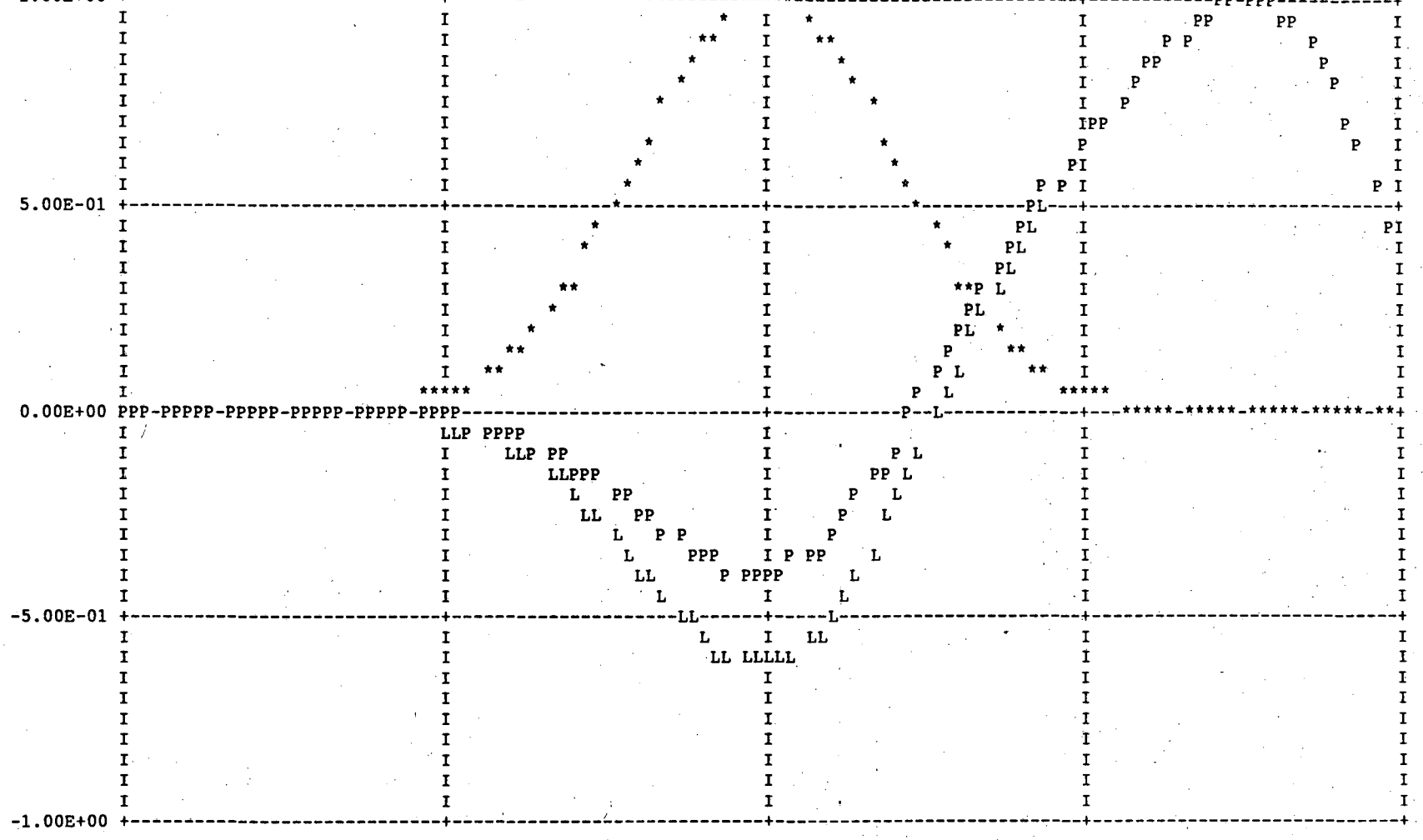
```
**************************************************************************
*                                                                        *
*                            ABCI   3RD RUN                              *
*                                                                        *
*   DATE:30/10/92   TIME:01.01.10      VERSION 6.2,  OCTOBER   1992      *
*                                                                        *
**************************************************************************


$FILE:
SAVE FIELDS INTO FILE  (LSAV)  :  F
RECOVER FROM FILE      (LREC)  :  F
CPUTIME MONITOR ACTIVE (LCPUTM):  F

$BOUN:
BOUNDARY CONDITIONS     LEFT   : OPEN
BOUNDARY CONDITIONS     RIGHT  : OPEN

$MESH:
NUMBER OF MESH LINES IN R       : NR   =      31
NUMBER OF MESH LINES IN Z       : NZ   =      80
NUMBER OF MESH POINTS           : NP   =    2480
TOTAL RADIUS OF THE STRUCTURE   : RAD  =  0.60000E-01(M)
TOTAL LENGTH OF THE STRUCTURE   : ZL   =  0.16000    (M)
STEP SIZE IN R                  : DDR  =  0.20000E-02(M)
STEP SIZE IN Z                  : DDZ  =  0.20000E-02(M)
STRUCTURE INPUT VARIABLE        : RZ  1=  0.25000E-01(M)
STRUCTURE INPUT VARIABLE        : RZ  2=  0.15000E-01(M)

@CAVITYSHAPE (@@CAVITYSHAPE) :  FULL CELL INPUT

INPUT:       (R, Z)                    (IR, IZ)
(   0.00000E+00  0.00000E+00 )  (       1      1 )
(   0.30000E-01  0.00000E+00 )  (      16      1 ) ---> (   0.30000E-01  0.00000E+00 )
(   0.00000E+00  0.30000E-01 )  (      16     16 ) ---> (   0.30000E-01  0.30000E-01 )
(   0.10000E-01  0.00000E+00 )  (      21     16 ) ---> (   0.40000E-01  0.30000E-01 )
CONNECTED BY AN ELLIPSE,       IKIND=-3,  (RM, ZM)=      (   0.40000E-01  0.40000E-01 )
(   0.20000E-01  0.00000E+00 )  (      31     21 ) ---> (   0.60000E-01  0.40000E-01 )
CONNECTED BY AN ELLIPSE,       IKIND=-3,  (RM, ZM)=      (   0.40000E-01  0.40000E-01 )
(   0.00000E+00  0.10000E-01 )  (      21     26 ) ---> (   0.40000E-01  0.50000E-01 )
(  -0.20000E-01  0.00000E+00 )  (      11     26 ) ---> (   0.20000E-01  0.50000E-01 )
CONNECTED BY A CONCAVE CIRCLE, IKIND=-1,  RADIUS=  0.10000E-01
(   0.00000E+00  0.20000E-01 )  (      11     36 ) ---> (   0.20000E-01  0.70000E-01 )
(   0.20000E-01  0.00000E+00 )  (      21     36 ) ---> (   0.40000E-01  0.70000E-01 )
CONNECTED BY AN ELLIPSE,       IKIND=-3,  (RM, ZM)=      (   0.40000E-01  0.80000E-01 )
(   0.20000E-01  0.00000E+00 )  (      31     41 ) ---> (   0.60000E-01  0.80000E-01 )
CONNECTED BY AN ELLIPSE,       IKIND=-3,  (RM, ZM)=      (   0.40000E-01  0.80000E-01 )
(   0.00000E+00  0.10000E-01 )  (      21     46 ) ---> (   0.40000E-01  0.90000E-01 )
(  -0.20000E-01  0.00000E+00 )  (      11     46 ) ---> (   0.20000E-01  0.90000E-01 )
CONNECTED BY A CONCAVE CIRCLE, IKIND=-1,  RADIUS=  0.10000E-01
(   0.00000E+00  0.20000E-01 )  (      11     56 ) ---> (   0.20000E-01  0.11000     )
(   0.20000E-01  0.00000E+00 )  (      21     56 ) ---> (   0.40000E-01  0.11000     )
CONNECTED BY AN ELLIPSE,       IKIND=-3,  (RM, ZM)=      (   0.40000E-01  0.12000     )
(   0.20000E-01  0.00000E+00 )  (      31     61 ) ---> (   0.60000E-01  0.12000     )
CONNECTED BY AN ELLIPSE,       IKIND=-3,  (RM, ZM)=      (   0.40000E-01  0.12000     )
(   0.00000E+00  0.10000E-01 )  (      21     66 ) ---> (   0.40000E-01  0.13000     )
```

```
(     -RZ  1      0.00000E+00 )  (       8      66 ) ---> (   0.15000E-01  0.13000     ) ---> (   0.14000E-01  0.13000     )
(   0.00000E+00   0.30000E-01 )  (       8      80 ) ---> (   0.15000E-01  0.16000     ) ---> (   0.14000E-01  0.16000     )
(     -RZ  2      0.00000E+00 )  (       1      81 ) ---> (   0.00000E+00  0.16000     )
(   0.00000E+00  -0.16000     )  (       1       1 ) ---> (   0.00000E+00  0.00000E+00 )

$BEAM:
SIGMA OF THE GAUSSIAN BUNCH     : SIG  =  0.20000E-01(M)
NUMBER OF STAND.DEV. USED       : ISIG = +/-  5
RADIAL BEAM OFFSET AT           :RDRIVE=  0.10000E-01(M)
MODE NUMBER (MONOPOLE/DIPOLE)   : MROT =      0

$WAKE:
RADIAL WAKE OFFSET        (LEFT)   AT  R   =  0.30000E-01(M)
                          (RIGHT)  AND R   =  0.14000E-01(M)
WAKE    BETWEEN THE BUNCH  COORDINATES UBF =  0.00000E+00(M)
                                   AND UBT =  0.20000    (M)
WINDOW FOR FRONT                 (LCFRON)  :  T
WINDOW FOR BACK                  (LCBACK)  :  T
CHIN WAKE INTEGRATION METHOD     (LCHIN )  :  F
NAPOLY WAKE INTEGRATION METHOD   (LNAPOLY) :  T
STARTING Z FOR INTEGRAL AT RWAK: ZCF  =  0.20000E-01(M)
LAST Z FOR INTEGRAL AT RWAK     : ZCT  =  0.15000    (M)
RADIAL OFFSET FOR WAKE INTEGRAL: RWAK =  0.10000E-01(M)
NUMBER OF WAKE POTENTIAL POINTS: NW   =     100

$TIME:
TIME STEPS TO BE PROCESSED      : NT   =    540
NUMBER OF TIME STEPS/MESH STEP  : MT   =      3
VELOCITY OF THE BUNCH / C       : BETA =  1.0000
TIME-STEP VALUE                 : DT   =  0.22238E-11(S)
TIME FOR A PARTICLE TO PASS     : PT   =  0.53370E-09(S)

$PLOT:
PLOT OF CAVITY SHAPE INPUT       (LCAVIN)  :  T
PLOT OF CAVITY SHAPE USED        (LCAVUS)  :  F
PLOT OF WAKE POTENTIALS          (LPLW)    :  T
PLOT OF FFT OF WAKE POTENTIALS   (LFFT)    :  F
PLOT OF FFT OF AZIMUTHAL WAKE    (LFFTA)   :  F
PLOT OF FFT OF TRANSVERSE WAKE   (LFFTT)   :  F
PLOT OF FFT OF LONGITUDINAL WAKE (LFFTL)   :  F
CUTOFF FREQUENCY FOR FFT PLOT  :CUTOFF=   74.948    (GHZ)

$PRINT:
PRINTOUT OF CAVITY SHAPE USED    (LMATPR)  :  T
PRINTOUT OF THE FIELDS           (LPRW)    :  F


*** CAUTION *** YOU MUST NOW USE NAPOLY INTEGRATION FOR CALCULATION OF THE WAKE POTENTIALS.
YOUR CASE: LNAPOLY= T
IF LNAPOLY=F, ABCI NOW CHANGES IT TO LNAPOLY=T.
CHECK IF THE CONTURE IS VALID.
```

CAVITY SHAPE
.=VACUUM ; \,/=TRIANGULAR FILLED MESH CELL ; *=FULL METAL ; B=BEAM

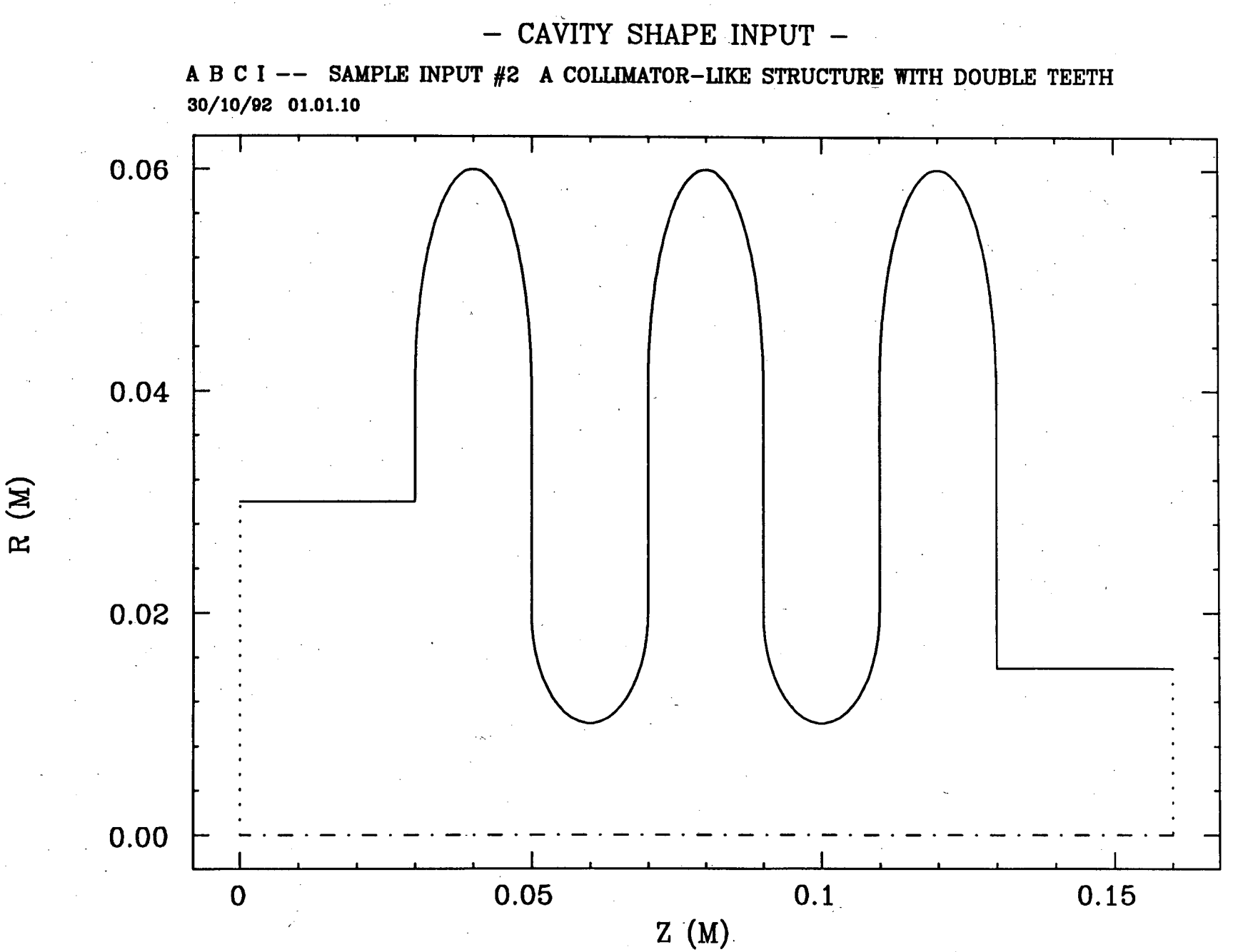


PROBLEM : SAMPLE INPUT #2 A COLLIMATOR-LIKE STRUCTURE WITH DOUBLE TEETH 30/10/92 01.01.10 SIG/M= 2.000E-02 MROT= 0
CPUTIME USED: 8.311E-01(S) DDR= 2.000E-03 DDZ= 2.000E-03
(A,T,L,P) = WAKE POTENTIAL AS A FUNCTION OF THE BUNCH COORDINATES S IN (M), (*)=BUNCH SHAPE, FRONT LEFT LCHIN= F LNAPOLY= T



LINE CHARGE DENSITY MINMAX= 7.434E-05/ 1.995E+01AS/M, SCALE= 1.995E+01AS/M, PASSING AT R= 1.000E-02M
LONGITUDINAL WAKE MINMAX=-7.600E+11/ 1.235E+12 V , SCALE= 1.235E+12V , INTEGRATED AT R= 3.000E-02M , OR 1.235E+12 V/M**0
WAKE WITH LOG. TERM MINMAX=-4.881E+11/ 1.235E+12 V , SCALE= 1.235E+12V , INTEGRATED AT R= 3.000E-02M , OR 1.235E+12 V/M**0

INTEGRATED LONGITUDINAL WAKE * CHARGE DENSITY = -4.512E+11 VAS , OR -4.512E+11 V/AS/M**0
WITH LOG. TERM DUE TO UNEQUAL BEAM PIPE RADII = -2.579E+11 VAS , OR -2.579E+11 V/AS/M**0

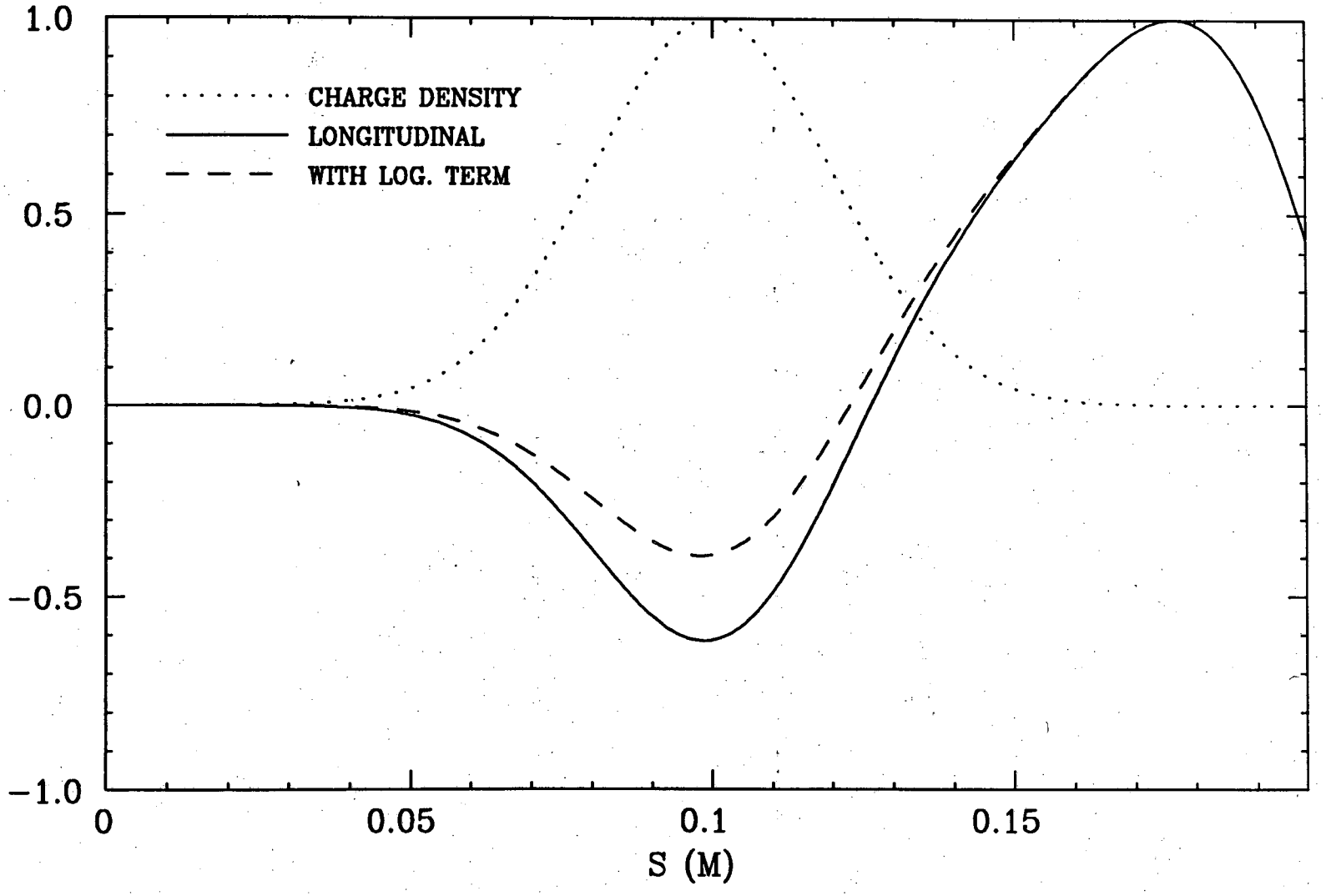

- CAVITY SHAPE INPUT -
A B C I -- SAMPLE INPUT #2 A COLLIMATOR-LIKE STRUCTURE WITH DOUBLE TEETH
30/10/92 01.01.10
0.06
0.04
0.02
0.00
R (M)
0
0.05
0.1
0.15
Z (M)

– WAKE POTENTIALS –

CPU TIME USED: 8.311E-01(S)

A B C I -- SAMPLE INPUT #2 A COLLIMATOR-LIKE STRUCTURE WITH DOUBLE TEETH

30/10/92 01.01.10 SIG/M= 2.000E-02 MROT= 0 DDR= 2.000E-03 DDZ= 2.000E-03 LCHIN= F LNAPOLY= T



LONGITUDINAL WAKE MIN/MAX= −7.600E+11/ 1.235E+12 V, INTEGRATED WAKE * CHARGE DENSITY= −4.512E+11 V/AS/M**0

LONGITUDINAL WAKE MIN/MAX= −4.881E+11/ 1.235E+12 V, INTEGRATED WAKE * CHARGE DENSITY= −2.579E+11 V/AS/M**0

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