# AN IMPEDANCE DATA BASE PROGRAM FOR LEP2 AND THE LHC

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*Abstract*

The development of an impedance data base program was motivated by the changing impedance budgets in the LEP and LHC machines and the resulting need to recalculate the instability thresholds for different parameters. For LEP, the changes are implied by the LEP2 upgrade and for the LHC, the impedance data for most items is still being calculated and continues to change as the geometries of the impedance components converge to a final design. In both cases, feedback from the impedance calculations is desirable. A central data base that allows a semi-automatic recalculation of the impedance data once the geometry of an item changes facilitates such a feedback. The development of the program was guided by four goals. First, the data base program should collect the impedance information in a central place and in a standard format allowing easy access. Second, it should provide procedures for estimating the impact of the impedance on the beam dynamics. Third, the program should provide a user friendly graphical interface to the data base and all external programs that are used for calculating the impedance data. Fourth, it should store the input files for the external programs allowing a semi-automatic recalculation of the impedance data once the geometry of an item changes.

## 1 INTRODUCTION

Collecting not only the impedance data but also the input files for the programs that were used for calculating it and all data necessary for calculating stability threshold currents, greatly facilitates the recalculation of the threshold currents if the parameters change. For LEPII, for example, the transverse mode coupling instability is expected to limit the maximum current in the machine. As the number of installed impedance components and the optics functions in the machine will change during the upgrade of LEP from 1996 to 1998 it is desirable to provide all the information required for estimating the instability threshold current in the data base and to provide an estimate for any stage of the upgrade. Furthermore, an interface of the data base to ABCI [2] allowed an automatic recalculation of all wake-potentials for different bunch length. The batch-job handling and the data acquisition of the final results is done automatically by the ZBASE program.

For the LHC, most of the impedance items are still in the design process and feedback from the impedance calculations is desirable at this stage. A central data base that allows a semi-automatic recalculation of the impedance data once the geometry of an item changes facilitates such a feedback. Having all the data and input files of the
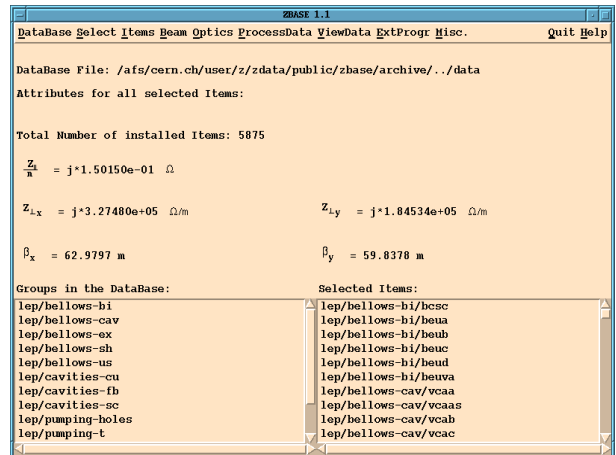


Figure 1: *The graphical user interface for the **ZBASE** program showing the net impedance attributes for all LEP* **items** *but the RF-cavities.*

impedance items in a central place and in a standard format also facilitates the exchange of information between the different groups and laboratories who are involved in the design process.

## 2 REALIZATION OF THE DATA BASE

The data base program is written in the Tcl-Tk scripting language to provide portability between different Unix platforms and to facilitate the programming of a graphical user interface. The program, all sub-programs and all data reside on an afs-file system. In this way the data can be accessed from any machine with an afs-mount which facilitates the exchange of information between the different laboratories which participate in the design/analysis of the impedance components. Fig. 1 shows the main graphical user interface for the data base.

The interface allows the user to select different beam and optics parameters (e.q. LEP or LHC), to select different impedance items for further processing, to modify the number of installed items in the machine, or to change and add items to the data base. For example, Fig. 2 shows the interface for selecting and modifying the beam parameters.

## 3 ORGANISATION OF THE DATA BASE

All data resides on an afs-file system under one common directory. Directly under this directory is a log-file and a file containing the default beam properties. The impedance data is hierarchically organised in four different levels of

| Machine: | lhc |
|---|---|
| Particle Type: | protons |
| Number of Bunches: | 2835 |
| Number of Particles/ Bunch: | 1.0e11 |
| Long. Beam Sigma at Low Energy [m] | 0.13 |
| Long. Beam Sigma at Top Energy [m] | 0.075 |
| Gamma at Low Energy: | 479.6 |
| Gamma at Top Energy: | 7460.6 |
| Relative Energy Spread: | 1.0e-3 |
| Slippage Factor: | 3.45e-4 |
| Revolution Frequency [Hz]: | 11.2458e3 |
| Synchrotron Frequency at Low Energy [Hz]: | 62.0 |
| Synchrotron Frequency at Top Energy [Hz]: | 21.0 |

Figure 2: *Listing of the default parameters for the LHC machine in the ZBASE data base.*

sub-directories:

$$data/machine/group/item/mode/data-files. \quad (1)$$

The machine sub-directory corresponds to a machine for which the data base contains entries. This directory also contains entries for the different optics and beam parameters which are available for the machine. Each group sub-directory contains a certain class of impedance items (e.q. bellows or cavities) and the third sub-directory specifies a single impedance item. Here, each item sub-directory in the ZBASE program corresponds to one element in the Oracle data base. This allows a straight forward link between the Oracle data base and the ZBASE program. Fig. 3 shows an example listing of the items in the data base. The fourth sub-directory specifies the mode, e.g. longitudinal or transverse, for which the impedance data entries are calculated. Such a hierarchical directory structure allows an access of the impedance data without the graphical user interface.

## 4  DATA TYPES

The impedance data entries consist of six different types of data:

- First, there is one file which contains some basic information on the impedance item (item attributes). It contains comments, the number of items in the machine, the average betatron function values at the location of the items in the machine and the low frequency inductance of the item.

- The second type of data are the higher-order-mode entries.

- The third data type are the loss factors related to an impedance item for different bunch lengths.

- Fourth, the data base program stores wake potentials.

List of selected Items

Export                                    Quit

| # Items | Name | Comment Line |
|---|---|---|
| 8 | lep/bellows-bi/bcsc | Bellows at beam instrumentation: BCSC. |
| 1 | lep/bellows-bi/beua | Bellows at beam instrumentation: BEUA |
| 1 | lep/bellows-bi/beuc | Bellows at beam instrumentation: BEUC |
| 1 | lep/bellows-bi/beud | Bellows at beam instrumentation: BEUD |
| 4 | lep/bellows-bi/beuva | Bellows at beam instrumentation: BEUVA. |
| 1 | lep/bellows-bi/bueb | Bellows at beam instrumentation: BUEB. |
| 40 | lep/bellows-cav/vcaa | Belloas at Cu-Cavities: VCAA. |
| 168 | lep/bellows-cav/vcaas | Bellows at Superconducting Cavities: VCAAS. |
| 232 | lep/bellows-cav/vcab | Bellows at the Cu-Cavities: VCAB. |
| 8 | lep/bellows-cav/vcac | Bellows at the Feedback Cavity: VCAC. |
| 60 | lep/bellows-cav/vksc | Bellows at superconducting cavities: VKSC. |
| 4 | lep/bellows-ex/aleph | Bellows at beam instrumentation: BCSC |
| 4 | lep/bellows-ex/delphi | LEP bellows at the DELPHI experiments. |
| 2 | lep/bellows-ex/l31 | LEP bellows at the L3 experiment (type1). |
| 2 | lep/bellows-ex/l32 | LEP bellows at the L3 experiments (type 2). |
| 4 | lep/bellows-ex/opal | LEP bellows at the OPAL experiments. |
| 1 | lep/bellows-sh/vbb2b | Shielded Bellow: VBB2B. |
| 2705 | lep/bellows-sh/vbba | Shielded Bellow: VBBA. |
| 35 | lep/bellows-sh/vbbb | Shielded Bellow: VBBB. |
| 2 | lep/bellows-sh/vbbe | Shielded Bellows: VBBE. |
| 2 | lep/bellows-sh/vbbp | Shielded Bellows: VBBP |
| 14 | lep/bellows-sh/vbia | Shielded Bellows: VBIA. |
| 2 | lep/bellows-sh/vbib | Shielded Bellows: VBIB. |
| 8 | lep/bellows-us/vbb2c | Unshielded Bellows: VBB2C. |
| 48 | lep/bellows-us/vbbc | Unshielded Bellows: VBBC. |
| 5 | lep/bellows-us/vbbd | Unshielded Bellows: VBBD. |
| 2 | lep/bellows-us/vbbik | Unshielded Bellow: VBHK. |
| 6 | lep/bellows-us/vbd2a | Unshielded Bellows: VBD2A. |
| 2 | lep/bellows-us/vbd2b | Unshielded Bellows: VBD2B. |
| 8 | lep/bellows-us/vbd2f | Unshielded Bellows: VBD2F. |
| 8 | lep/bellows-us/vbd2g | Unshielded Bellows: VBD2G. |
| 6 | lep/bellows-us/vbd2h | Unshielded Bellows: VBD2H. |
| 4 | lep/bellows-us/vbd2i | Unshielded Bellows: VBD2I. |
| 141 | lep/bellows-us/vbda | Unshielded Bellows: VBDA |
| 2 | lep/bellows-us/vbdb | Unshielded Bellows: VBDB |
| 2 | lep/bellows-us/vbz2c | Unshielded Bellows: VBZ2C. |
| 68 | lep/bellows-us/vbza | Unshielded Bellows: VBZA. |
| 23 | lep/bellows-us/vbzb | Unshielded Bellows: VBZB. |
| 600 | lep/cavities-cu/aas | Normal conducting Cu-cavity: 1 Cell of a 5 cell module: AAS. |
| 4 | lep/cavities-fb/azfc | Feedback Cavity (1 GHz Petra Cavity): AZFC. |
| 20 | lep/cavities-sc/ascl | Superconducting RF-Module: 4 Cavities with 4 Cells and 2 Tapers: ASCR. |
| 20 | lep/cavities-sc/ascr | Superconducting RF-Module: 4 Cavities with 4 Cells and 2 Tapers: ASCR. |
| 1 | lep/cavities-sc/asnl | Superconducting RF-Module: 4 Cavities with 4 Cells and 2 Tapers: ASNL. |
| 0 | lep/cavities-sc/asnr | Superconducting RF-Modules: 4 Cavities with 4 Cells and 2 Tapers: ASNR. |
| 0 | lep/pumping-holes/vc | Sum of all Vacuum Chambers: 751392 holes per item. |
| 4 | lep/pumping-holes/vcb2a | Chamber VCB2A: 440 holes per item. |
| 1624 | lep/pumping-holes/vcba | Chamber VCBA: 440 holes per item. |
| 0 | lep/pumping-holes/vcbb | Chamber VCBB: 439 holes per item. |
| 2 | lep/pumping-holes/vcbv | Chamber VCBV: 440 holes per item. |
| 1 | lep/pumping-holes/vcd2d | Chamber VCD2D: 154 holes per item. |
| 7 | lep/pumping-holes/vcd2e | Chamber VCD2E: 186 holes per item. |

Figure 3: *Listing of the number of installed items in the* **ZBASE** *data base.*

- Fifth, the program stores the input files and some of the output files of the programs that were used for calculating the impedance data. All input and output files have a prefix that specifies the program that is associated with the files.

- Sixth, the program stores the location of the items in the machine.

## 5  PROCESSING DATA

One of the goals for the ZBASE data base program in addition to storing impedance information is evaluating the net effect of the impedance on the beam dynamics. For example, it provides not only the HOM parameters for the impedance items but also some estimates for the corresponding multi-bunch instability rise times. To this end, ZBASE distinguishes between primary and secondary data:

- The primary data describes all information directly associated with the geometry of an item. This would include the inductance, the loss factors and the HOM parameters for example.

- The secondary data describes all information not directly associated with an item. This includes for example the betatron functions and the beam parameters.

During startup the program searches the directories in the data base for secondary data and stores the values in internal arrays. The entries of these arrays can be modified
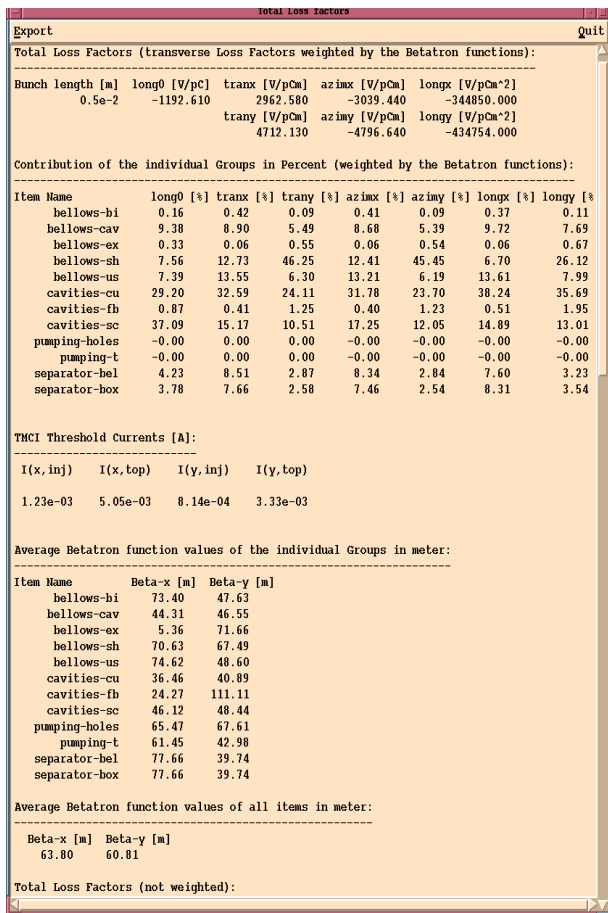
```
┌─────────────────────────────────────── Total Loss Factors ──────────────────────────┐
│ Export                                                                          Quit │
├──────────────────────────────────────────────────────────────────────────────────────┤
│ Total Loss Factors (transverse Loss Factors weighted by the Betatron functions):       │
│ ------------------------------------------------------------------------------------   │
│                                                                                        │
│ Bunch length [m]  long0 [V/pC]  tranx [V/pCm]  azimx [V/pCm]  longx [V/pCm^2]          │
│       0.5e-2         -1192.610      2962.580      -3039.440       -344850.000          │
│                                   trany [V/pCm]  azimy [V/pCm]  longy [V/pCm^2]        │
│                                      4712.130      -4796.640       -434754.000          │
│                                                                                        │
│ Contribution of the individual Groups in Percent (weighted by the Betatron functions): │
│ ------------------------------------------------------------------------------------   │
│ Item Name        long0 [%]  tranx [%]  trany [%]  azimx [%]  azimy [%]  longx [%]  longy [%  │
│    bellows-bi      0.16      0.42      0.09      0.41      0.09      0.37      0.11   │
│    bellows-cav     9.38      8.90      5.49      8.68      5.39      9.72      7.69   │
│    bellows-ex      0.33      0.06      0.55      0.06      0.54      0.06      0.67   │
│    bellows-sh      7.56     12.73     46.25     12.41     45.45      6.70     26.12   │
│    bellows-us      7.39     13.55      6.30     13.21      6.19     13.61      7.99   │
│    cavities-cu    29.20     32.59     24.11     31.78     23.70     38.24     35.69   │
│    cavities-fb     0.87      0.41      1.25      0.40      1.23      0.51      1.95   │
│    cavities-sc    37.09     15.17     10.51     17.25     12.05     14.89     13.01   │
│   pumping-holes   -0.00      0.00      0.00     -0.00     -0.00     -0.00     -0.00   │
│     pumping-t     -0.00      0.00      0.00     -0.00     -0.00     -0.00     -0.00   │
│   separator-bel    4.23      8.51      2.87      8.34      2.84      7.60      3.23   │
│   separator-box    3.78      7.66      2.58      7.46      2.54      8.31      3.54   │
│                                                                                        │
│                                                                                        │
│ TMCI Threshold Currents [A]:                                                           │
│ ---------------------------                                                            │
│  I(x,inj)    I(x,top)    I(y,inj)    I(y,top)                                          │
│                                                                                        │
│ 1.23e-3     5.05e-03    8.14e-04    3.33e-03                                           │
│                                                                                        │
│ Average Betatron function values of the individual Groups in meter:                    │
│ ------------------------------------------------------------------                     │
│ Item Name        Beta-x [m]  Beta-y [m]                                                │
│    bellows-bi      73.40      47.63                                                    │
│    bellows-cav     44.31      46.55                                                    │
│    bellows-ex       5.36      71.66                                                    │
│    bellows-sh      70.63      67.49                                                    │
│    bellows-us      74.62      48.60                                                    │
│    cavities-cu     36.46      40.89                                                    │
│    cavities-fb     24.27     111.11                                                    │
│    cavities-sc     46.12      48.44                                                    │
│   pumping-holes    65.47      67.61                                                    │
│     pumping-t      61.45      42.98                                                    │
│   separator-bel    77.66      39.74                                                    │
│   separator-box    77.66      39.74                                                    │
│                                                                                        │
│ Average Betatron function values of all items in meter:                                │
│ -------------------------------------------------------                                │
│   Beta-x [m]  Beta-y [m]                                                               │
│     63.80      60.81                                                                   │
│                                                                                        │
│ Total Loss Factors (not weighted):                                                     │
└──────────────────────────────────────────────────────────────────────────────────────┘
```

Figure 4: *The net lossfactors and estimates for the transverse-mode-coupling instability (tmci) threshold currents for the LEP impedance data.*

by any user. In order to process impedance data, the user must first select items from the data base. All selected item names are again stored in an array. When the program processes the impedance data it first goes through this name array and reads the required primary data for each item from the files in the data base. The required secondary data is read from the internal arrays. For example, the graphical user interface in Fig. 1 shows the processed attributes of all the LEP impedance items but the RF-cavities. Fig. 4 shows an example for the lossfactors with an estimate for the transverse mode coupling instability.

## 6  PROGRAM INTERFACES

Currently ZBASE offers graphical user interfaces and example input files to ABCI, URMEL, MAD and MAFIA [3][5][4]. The interfaces allow the user to select and modify input files from the data base or any other directory and manage the job handling on the CERN-SP batch computer system. For example, the ABCI interface of the ZBASE program can resubmit a selected range of items from the data base, automatically collect the final results of the calculations and update the data base accordingly. The job-submision and job-handling is done by the data base program. In this way it is easy to recalculate the loss factors and wakepotentials for different bunch length and mesh sizes for a large number of impedance items. The Tcl-Tk scripting language allows the creation of additional interfaces for any other program which is of interest for an impedance analysis.

## 7  SUMMARY

The main aim of the ZBASE impedance data base is to provide the impedance data of one or more machines in a standard format and in a central place which is accessible to everybody. The program is written in the Tcl-Tk scripting language to provide portability between different Unix platforms and to facilitate the installation of additional procedures and interfaces to external programs which evaluate the impact of the machine impedance on the beam dynamics. By collecting not only the impedance data but also the input files for the programs that were used for calculating the impedance data and providing graphical user interfaces for the programs that were used for the impedance calculations, greatly facilitates the recalculation of the impedance data if the parameters change. The current data base contains impedance data for LEP and LHC. However, the data base could easily be extended to other machines like the SPS for example.

## 8  REFERENCES

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[4] R. Klatt, F. Krawczyk, W.R. Novender, C. Palm, T. Weiland (DESY), B. Steffen (Julich,Forschungszentrum), T. Barts, M.J. Browman, R. Cooper, C.T. Mottershead, G. Rodenz, S.G. Wipf 'MAFIA - A THREE-DIMENSIONAL ELECTROMAGNETIC CAD SYSTEM FOR MAGNETS, RF STRUCTURES, AND TRANSIENT WAKE FIELD CALCULATIONS', DESY M-86-07, August 1986

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