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TRISIM User's Guide

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Abstract

The computer program TRISIM simulates the effects of longitudinal and transverse wake potentials in circular accelerators. The main new feature of this code with respect to its predecessors SIMTRAC and HERSIM is the expansion of the particle distribution and of its first moment into a basis of linear, triangular-shaped interpolating functions. This approach permits improving the description of the particle distribution function, in particular near the instability thresholds, where it departs significantly from a Gaussian. At the same time, a reduction of the computer time required for wake potential calculation of up to one order of magnitude could be achieved, as well as a significant reduction of the memory requirements and of the number of precalculated wake tables. Some other features, like feedback system simulation and better graphics, have also been included. TRISIM is available as a standard FORTRAN-77 source code and currently runs on HP UNIX platforms.

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1 Introduction

Collective effects are responsible for a severe limitation of the bunch current in electron storage rings and have therefore to be studied carefully. For this purpose, the new simulation program TRISIM has been developed. As far as the description of the beam dynamics is concerned, the program uses the same formalism as HERSIM2 [1] which was derived from the predecessors SIMTRAC [2] (with a super-particle approach), and HERSIM [3] (using a development into Hermite polynomials). The main new feature of the code TRISIM is the expansion of the particle distribution and of its first moment into a basis of linear interpolating functions. The new program has been successfully tested on experimental data of LEP [4]: using improved estimates for the impedances, which are mainly caused by the RF cavities and the (shielded) bellows, it was possible to get quite good agreement with measurements in particular for the bunch lengthening effect and for the threshold of transverse mode coupling, which is limiting the single bunch current most severely. The code has also been used to study a new reactive feedback system [5] and to evaluate its effectiveness and sensitivity to errors, and to study and explain observations made in the LEP control room, such as synchro-betatron resonances and mode splitting at higher currents. A complete report describing the wakefield representation technique implemented in the program, and the results which have been obtained, is in preparation [6].

2 Input Variables

The input parameters, which must be provided in the file *trisim.inp*, are grouped in homogeneous classes, and for each class a namelist is defined. A list of all input variables with brief explanations, units, default values and array sizes is given in what follows.

Namelist BEAM : defines the beam parameters.

NAME	TYPE	UNIT	DESCRIPTION
E0	Real	eV	Operating Energy
BEAMIT	Real	A	Bunch current
SIGE0	Real	MeV	Natural RMS Energy spread
TAUEP	Real	s	Radiation damping time
TAUZ	Real	s	Vertical damping time
U0	Real	eV	Radiation loss (one turn)
XNU	Real		Vertical tune (one turn)
T0	Real	s	Revolution time
ALPHA2	Real		Second order momentum compaction
EMIT	Real	m	Beam emittance (see also COUPL)
COUPL	Real		If COUPL is not zero, vertical emittance E_z is computed from E_z = EMIT*COUPL/(1+COUPL)
ETAZ	Real		Momentum slip factor

Namelist TRACK: defines the tracking options.

NAME	TYPE	UNIT	DEFAULT	DESCRIPTION
N	Integer		500	Number of superparticles
NLOOP	Integer		2000	Number of turns to be tracked
INI	Integer		2	Distribution at start (see table)
SIGE1	Real	MeV		RMS energy spread at start
SIGT1	Real	ps		RMS bunch length at start
TBAR1	Real	ps		Bunch position at start with respect to the reference phase
SIGZ1	Real	m		RMS bunch height at start
SHINI	Real	sigz1	0.1	Vertical offset at start
ZPR1	Real			RMS vertical slope at start
HORIZ	Logical		False	Transverse motion in horiz plane

INI Value	Starting distribution
1	Load distribution from the file *trisim.rsav* (created with STORE)
2	Load random Gaussian distributions with user defined mean value and variance
3	Load exact gaussian longitudinal distribution with fixed offset
4	Load exact triangular longitudinal distribution with fixed offset

Namelist POST: defines the output options.

The output data is produced according to the following scheme: first, the user selects the turns at which the data will be *printed* (output to the *trisim.res* file) or *plotted* (output to the *trisim.hbook* file) by specifying the first, the frequency and the total number of output turns. Then he choses which data should be stored at the selected turns by switching on/off the correspondent flags.

NAME	TYPE	DEFAULT	DESCRIPTION
IPRSTA	Integer	0	Starting turn for printing
IPRFRE	Integer	200	Interval between print-outs
IPRNUM	Integer	100	Maximum number of print-outs
IPLSTA	Integer	0	Starting turn for plottings
IPLFRE	Integer	0	Interval between plottings
IPLNUM	Integer	0	Number of plottings
PRTURN	Logical	True	Mean values and standard deviations are printed at selected turns
PBUNCH	Logical	False	Save bunch configuration at selected turns
PWKPOT	Logical	False	Save wake potentials at selected turns
PLFEED	Logical	False	Save feedback data at selected turns
STORE	Logical	False	Store final bunch configuration for

			the restart option (see INI)
NAVRGE	Integer	200	Number of turns used to compute the averaged equilibrium values
IDELQ	Integer	1000	Number of turns used to compute the bunch oscillation modes

Namelist WAKE: defines the wake tables format.

The reference wakes required by the simulation program are the wake potentials of the basis triangular-shaped distribution, carrying a total charge of 1 Coulomb and travelling through the impedance with unit off-axis displacement. These wake potentials are usually computed by a mesh program, for example ABCI [7]. Alternatively, if a broad band resonator model of the impedance is available, the reference wakes can be obtained from the broad band resonator parameters; a simple program for the calculation of the transverse reference wakes from the broad band resonator parameters is provided with the TRISIM distribution kit. The half-width Δ of the basis function should be chosen in the range from $\Delta \approx \sigma_s/2$ to $\Delta \approx \sigma_s/4$, where σ_s is a typical value of the bunch length in the machine configuration of interest, and the length of the wake potential should correspond to about ten times the maximum σ_s of interest. The wake tables must be stored in the unformatted data files *tables/tripot.l0* (for the longitudinal m=0 wake) and *tables/tripot.t1* (for the transverse m=1 wake), as a sequence REAL*8 numbers starting at t=0. The required units are V/C for the longitudinal m=0 wake, and V/Cm for the transverse m=1 wake.

NAME	TYPE	UNIT	DEFAULT	DESCRIPTION
LWAK	Logical		True	Longitudinal wake switch on/off
TWAK	Logical		True	Transverse wake switch on/off
TRDEL	Real	s		Half width of the basis function
NPWT	Integer			Number of data points in TRDEL
NTRI	Integer			Length of the wake in units of TRDEL
PWKTAB	Logical		False	Save wake tables for plotting.

Namelist FBK: defines the feedback system settings.

NAME	TYPE	DEFAULT	DESCRIPTION
FEEDBK	Logical	False	Feedback system switch on/off
SHIRAT	Real		Detuning compensation factor
RELAX	Real	1.0	Feedback gain relaxation factor

Namelist RING: defines the elements placed around the ring.

The ring is envisioned as a circle, and the elements are input in the order of their (clockwise) polar angles corresponding to their locations along the circumference of the ring. The first

element should always be located at zero degree. The data relative to specific elements (from EVP to SEXTG) are input in a clockwise sequence starting at zero degree and including those elements only.

NAME	TYPE	UNIT	DESCRIPTION
NELE	Integer		Number of elements in the ring (Max 100)
LTYPE	Integer(100)		Element type (see table)
ALOC	Real(100)	DEG	Location of the elements in clockwise polar angle
BETAZE	Real(100)	m	Magnitude of the beta function at the elements
PHAD	Real(100)		Number of betatron oscillations between the first element and the present one
ALPHA	Real(100)		Momentum compaction between present and next element
CHROM	Real(100)		Chromaticity between present and next element
EVP	Real(100)	Volt	Peak voltage at the RF cavities
PHIS	Real(100)	DEG	Reference angle between beam and RF field
OMEGRF	Real(100)	Hertz	$2\ \pi$ times the RF frequency
XCELL	Integer(100)		Number of cells in the RF station
DISPA	Real(100)	m	Horizontal dispersion at sextupoles
SEXTG	Real(100)	m^{-2}	Sextupole strength

LTYPE Value	Element type
0	Resonant cavity
1	Sextupole magnet
3	Feedback pick-up
4	Feedback kicker

Namelist BLOAD: defines the beam loading data.

NAME	TYPE	UNIT	DESCRIPTION
ROBIN	Logical		Beam loading effects switch on/off
TFILL	Real	s	Filling time of the cavity
PSI	Real	DEG	Tuning angle
RSH	Real	Ω	Shunt impedance of the cavity
BETAC	Real		Cavity coupling coefficient
NBUNCH	Integer		Number of e^- bunches in the real machine, to be taken into account in the beam loading term

3 Output of TRISIM

TRISIM produces three output files, the first of them (*trisim.res*) is a text file reporting the input conditions, the evolution of the beam parameters during the tracking, the final equilibrium values and the error messages (if any). The information provided in *trisim.res* is self-explaining. The two other files (*trisim.hbook* and *trisim.pldat*) are used for plotting purposes with the HBOOK/PAW [8] package. A set of macros are provided with the program so that the more common postprocessing tasks can be easily performed without knowing the details of the package: just call paw or paw++ and enter the command "exec macroname" in the Command window; the result will appear in the Graphics window and the picture will be saved in the postscript file macroname.ps. A list of the available macros is provided in what follows, together with some example of the output they produce.

Macros for result presentation

- **restra.kumac:** Prints the run conditions and results and plots the vertical bunch width as a function of turn, and the transverse oscillation mode spectrum. Similar to *restra* are **feedbk.kumac**, which also prints the feedback settings, and **modtra.kumac**, with a bigger picture of the oscillation modes.
- **reslon.kumac:** Prints the run conditions and results and plots the position of the bunch center and the bunch length as a function of turn.

Macros for bunch motion visualization

- **tzraw.kumac:** for each of the selected turns, *tzraw* plots the particle distribution (as a t-z scatter plot) and the histograms of the charge density and the dipole moment vs time. Needs PBUNCH=T.
- **tzsmo.kumac:** for each of the selected turns, *tzsmo* prints the particle distribution (as a t-z smoothed contour plot) and the charge density and the dipole moment of the distribution as smoothed functions of time. Needs PBUNCH=T.
- **bmovie.kumac:** *bmovie* collects the selected turns in sequences of four and for each sequence puts the corresponding coutour plots of the particle distribution on the same page. Two versions are available, **bmovie_bw** with black and white line contours and **bmovie_cl** with filled colour levels. For the second case, the macro **pal.kumac** provides a suitable palette of colours. Needs PBUNCH=T.

Macros illustrating the distribution representation and the wake potential calculation

- **waklon.kumac:** for each of the selected turns, waklon produces a sequence of four plots on the same page with an histogram of the charge density vs time, its approximation in the basis of linear approximating functions, the longitudinal wake of a single basis function and the superposition producing the final longitudinal wake potential. Needs PBUNCH=T, PWKPOT=T and PWKTAB=T.
- **waktra.kumac:** for each of the selected turns, waktra produces a sequence of four plots on the same page with an histogram of the dipole moment vs time, its approximation in the basis of linear approximating functions, the transverse wake of a single basis function and the superposition producing the final transverse wake potential. Needs PBUNCH=T, PWKPOT=T and PWKTAB=T.

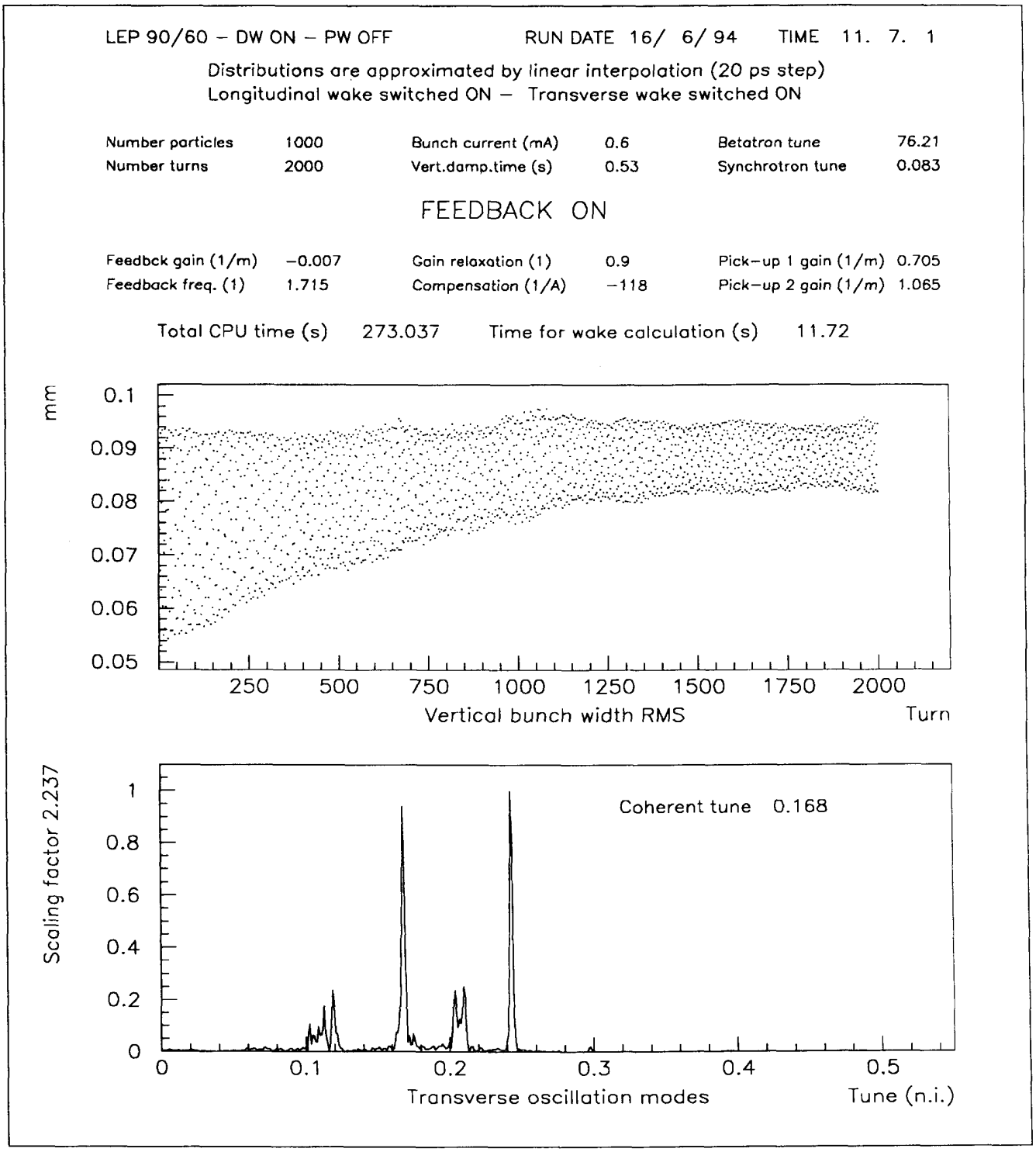

Figure 1: Example of the the output produced by the *feedbk* macro

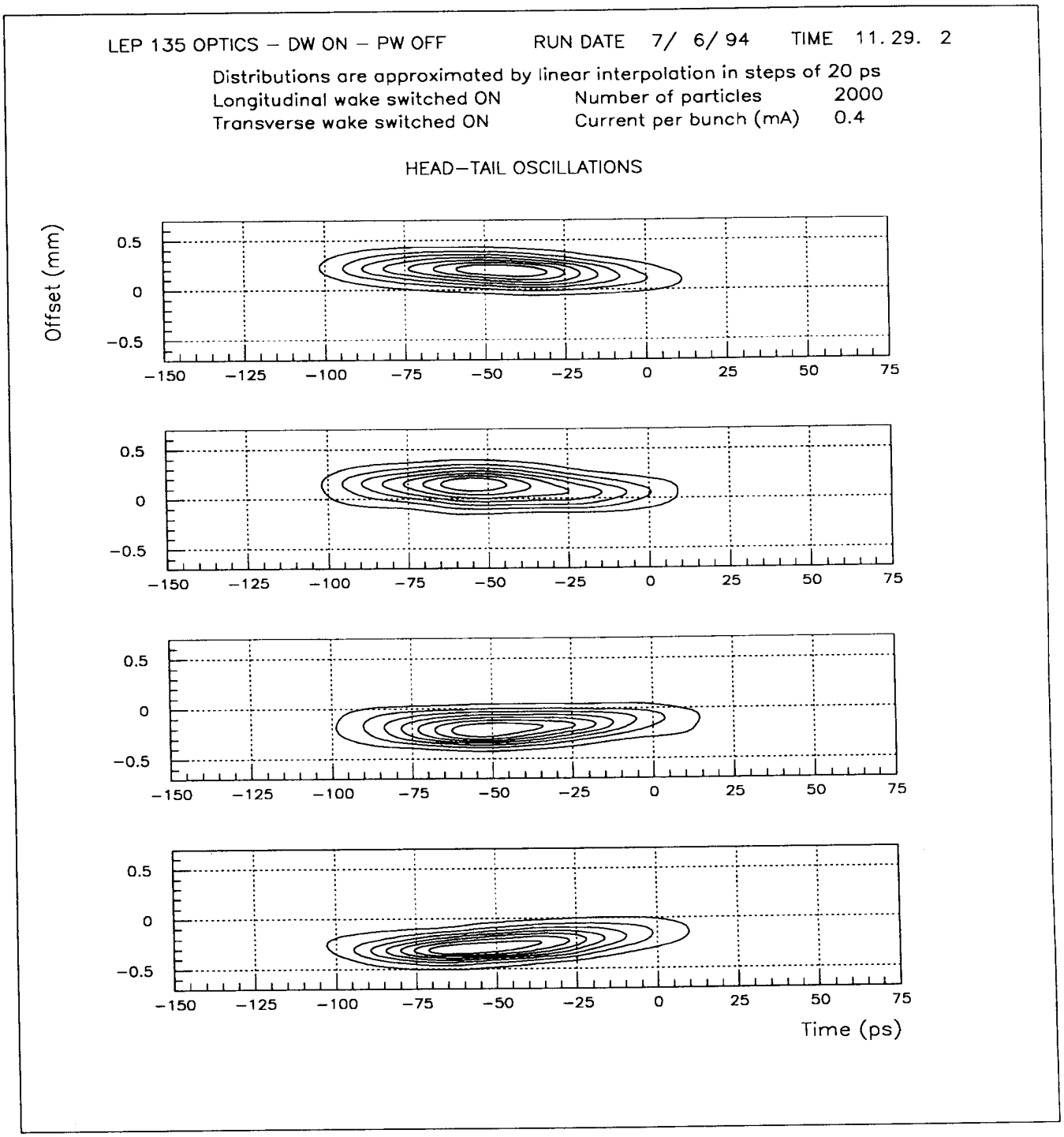

Figure 2: Example of the the output produced by the *bmovie* macro

4 Distribution kit

The distribution kit of TRISIM is organized in four directories:

- The **programs** directory contains the TRISIM code (source program and executable in the HP-UX system), as well as some utility programs for building the wake potential tables.
- The **leptab10** and **leptab20** directories contain the wake potential tables for the LEP machine, computed by ABCI [7] and corresponding to two choices of the basis function (10 ps and 20 ps half width).
- The **example** directory contains the setup file, an example input file and the corresponding results.
- The **paw** directory contains the postprocessing macros.

To receive the program, please contact the author at the E-mail address *sabbi@cernvm.cern.ch.*

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