

## THE PARTICLE TRACKING CODE PARMELA \*

Lloyd Young and James Billen  
 Los Alamos National Laboratory, Los Alamos, NM 87545, USA

### Abstract

The name PARMELA came from the phrase “Phase And Radial Motion in Electron Linear Accelerators,” which described its earliest applications[1]. However, a decade ago, the code’s capabilities were expanded to track particles of any mass and charge. A more recent addition was the ability to track particles of three different masses and any charge simultaneously. PARMELA uses time as the independent variable. PARMELA is a simulation code, and does not design a linac or beam transport channel. PARMELA can use electromagnetic fields calculated by other codes. These fields can be RF electromagnetic, static magnetic, or electrostatic. Both 2D cylindrically symmetric and fully 3D field maps can be used for all three types. The RF fields are confined to the rf cavity elements that describe standing-wave or traveling-wave structures. The static fields are treated as a background field that is superimposed over drift spaces and rf cavity elements. PARMELA includes options for selecting either 2D or 3D space-charge effects. The code’s input file can supply data for most common beam-line components and accelerator structures. This paper describes some of the capabilities of PARMELA and a few examples of PARMELA simulations.

### INTRODUCTION

Parmela takes a collection of particles and follows their path through a “beam line”. The path a particle takes is influenced by electromagnetic fields including the self-fields. The self-fields are usually called “space charge” and are caused by the charge on the particles. Gravity is ignored. The electromagnetic fields are described by a control file called the input file or by files containing a field map generated by another code. The “beam line” is described in the input file by a series of keywords. The beam line is made up of a series of elements. The keywords associated with the elements are followed by a series of parameters that describe the element. For example, the keyword “DRIFT” is followed by 3 numbers that represent the length of the element, the radial clear aperture, and a flag that tells PARMELA if you want to write the particle coordinates into an output file at the end of the “DRIFT” element. All keywords that represent elements have these same parameters as the first three followed by additional parameters that depend on the type of element.

To make the collection of particles visible, a second code call PARGRAF reads the output files produced by PARMELA and displays them in various formats. A

simple control file and tabs on the graphics display control the action of PARGRAF. PARGRAF can generate hard copy or graphic files with a choice of formats.

### THE INPUT FILE

The first line of the input file uses the keyword “RUN” that is followed by several parameters describing some basic parameters of the accelerator; namely, frequency, starting position and energy of the reference particle. Figure 1 shows an example of a Parmela input file with the various types of keywords. The mass of up to 3 particle types can also be defined on the run line. The default mass is 0.5110034 MeV which represents an electron. The optional keyword “TITLE” is followed by text on the next line that may be a description of the beam line. “TITLE” and its following line of text may be placed anywhere in the input file. The keyword “INPUT” generates the distribution of particles. In this case the particles are electrons because the run line does not have a

```
run 1 2 2856. -.00113 1.e-5
title
PHOTOCATHODE RF GUN + SLAC Linac.
INPUT 9 9999 9. .1 30. 5 0 3 5
Cathode 0 1 1 0 -.5
poisson 0.00 0.5 0 0 0 0 1
ecompl0.po7
CELL 2.625 1. 1 0. 63.75 1 5 -1
cfield 1
atfnn.t7
cell 2.625 1. 1 180. 63.75 1 5 1
cell 5.2464 1. 1 180. 32.05 2 5 -1
drift 10.0 5 1
drift 10.0 5 1
cell 5.2464 0.9547 1 90.0 4.7452 2 5 1 2856.
cfield 2
slac1.t7
trwave 1.75 0.9547 1 0.0 10.6289 1 5 2856. 1 -5 5 .666667 84
trwave 3.50012 1.311 1 0.0 10.6289 1 5. 2856. 1
...
trwave 3.50012 0.955 1 0.0 10.6289 1 5. 2856. 1
trwcfld 1
slac2.t7
slac2b.t7
adjust 4 7 7 120 7
adjust 4 8 97 120 9
zout 1000 30 0 80 .8
OUTPUT 5
scheff 2.86 .33 3 20 1000 0 0 7 1.5 0
start 39. 1. 330 1 10
continue 15 1500 1 3
end
```

Figure 1 Example of PARMELA input file.

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mass specified. Figure 2 shows a snap shot of the fields in the first 100 cm of the linac described in the above input file. This figure is produced by “TABLPLOT” from a text file written by PARMELA. The TABLPLOT program and it’s companion QUIKPLOT are general purpose window plotting codes distributed with both PARMELA and the Poission Superfish code distribution[2]. This file is produced by the “ZOUT” line that calls for a snap shot of the fields every 30 degrees of the master clock.

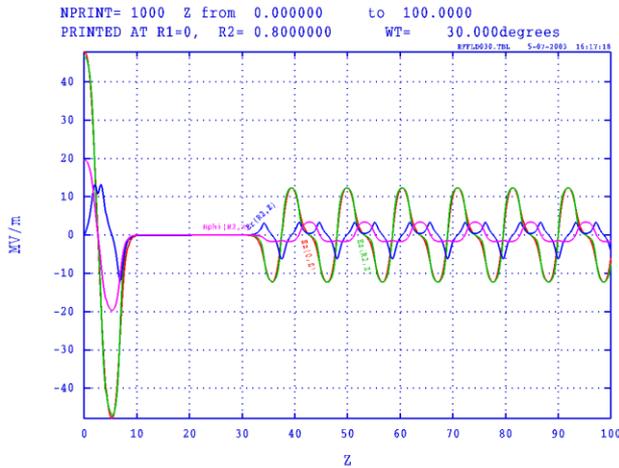


Figure 2: Plot of fields with master clock at 30 degrees.

### PARGRAF

Pargraf is the graphics code that uses the coordinates of the particles that PARMELA writes to two output files. One file is the particle coordinates at the end of each

```

subnum 8
output 2 1 1 500
optcon 11 12 0 340 10 0 5 1 200 1
begin
subnum 7
output 2 1 1 500
optcon 2 0. 1 0 0 0 0 0
begin
subnum 5
output 2 1 1 2000
optcon -1. 1.0 8 1. 2 1. 2 200 0
begin
end
    
```

Figure 3: Sample control for PARGRAF.

element for which the input file requests output. The other file contains the particle coordinates at the end of a time step. The time steps at which output is desired is set on the appropriate “START”, “CONTINUE”, or “RESTART” lines. A sample control file for PARGRAF appears in Figure 3. One of the pictures PARGRAF generates with this control file is shown in Figure 4.

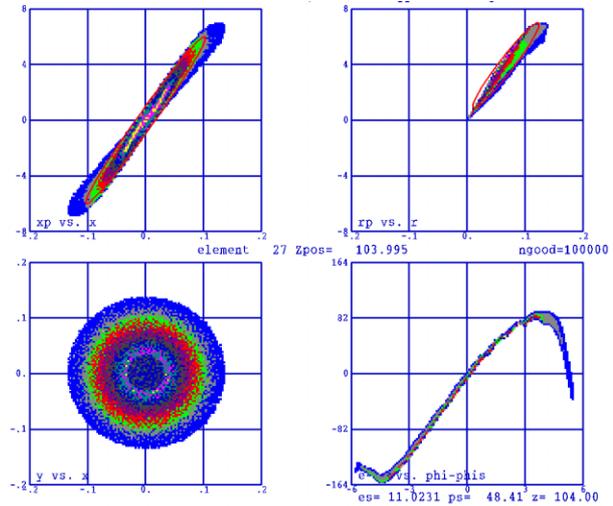


Figure 4: Sample picture from Pargraf.

### NEW FEATURES IN PARMELA V3.XX

- Unlimited number of particles. But in practice the number of particles is limited to about two million because of memory limitations.
- 3D space-charge routine. Invoke by using the SPCH3D line.
- 3-D field maps can now be used with the CFIELD line that reads in electromagnetic field maps for use by a CELL line.
- Coherent synchrotron radiation (CSR) calculation is available for use with SCHEFF and SPCH3D
- Unlimited number of cell types.
- Nearly unlimited number of elements. The limit is 2708 elements. This limit will increase when PARMELA is compiled with the Lahey LF95 compiler[3].
- Unlimited numbers of mesh intervals in cell fields maps. In 2D field maps, only, the number of intervals must be the same in all 2D field maps.
- Unlimited number of traveling-wave accelerators.
- Field maps are available for traveling-wave accelerators.
- Drift-tube-linac cell; RF field maps overlap quadrupole fields.
- 3D electrostatic and 3D static magnetic field maps can be read in with the POISSON line.
- The default extension on the PARMELA input file is “.acc”. In windows, PARMELA can be invoked by double clicking on the input file.
- An optional TABLPLOT file of time-step-data can be generated.

Figure 5 shows an example of a TABLPLOT file of time-step-data from running the PARMELA input file in Figure 1. PARMELA creates the optional time-step-data as input for TABLPLOT if the keyword TimeStepEmittance appears in the initialization file LANL.INI and if this keyword specifies the name of a TABLPLOT input file in the form filename.TBL. If this

keyword is present (and has a value other than None), then Parmela will write the Time-Step-data file. The Data in this file includes the following columns:

- T(deg) Time step in degrees
- Z(cm) Reference particle position
- Xun(mm-mrad) Un-normalized rms X-Xp emittance
- Yun(mm-mrad) Un-normalized rms Y-Yp emittance
- Zun(mm-mrad) Un-normalized rms Z-Zp emittance
- Xn(mm-mrad) Normalized rms X-Xp emittance
- Yn(mm-mrad) Normalized rms Y-Yp emittance
- Zn(mm-mrad) Normalized rms Z-Zp emittance
- Xrms(mm) Rms beam size in X direction
- Yrms(mm) Rms beam size in Y direction
- Zrmz(mm) Rms beam size in Z direction
- <kE>(MeV) Average energy
- Del-Erms Rms energy spread

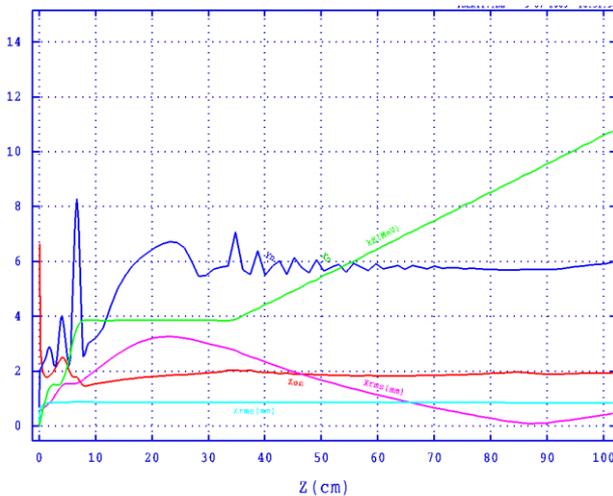


Figure 5: Example plot of data in TABLPLOT file produced by PARMELA

## NEW FEATURES IN PARGRAF V 3.XX

- Higher resolution graphics in Windows.
- Mouse control.
- Pull-down menus.
- More hard copy options.
- More information in the output file.
- Display the previous screen (Back up).
- Skip current SUBNUM series.
- Slice emittance calculations.
- LANL.INI file controls some initial display options (Background, Movie, Slice).
- The default extension of the PARGRAF control file is “.pgf”. When the user double clicks on a control file with this extension, PARGRAF will open the file and plot the data requested.

## PARMELA DOCUMENTATION

The PARMELA installation comes with a Microsoft Word document containing the Parmela documentation. This documentation is currently 116 pages long. Highlighted links are used extensively in this document to conveniently move to the location in the file of interest.

## ACKNOWLEDGMENTS

The authors of PARMELA version 3 wishes to acknowledge the extremely important contribution of Kenneth R. Crandall, who wrote the original version of PARMELA in 1980. He introduced the use of time (or phase angle) as the independent variable, which is retained in the present version. Even after retiring from Los Alamos National Laboratory in the mid 1980s, Ken Crandall contributed to the further development of PARMELA. Working as a consultant, he wrote new sections of the code for a traveling-wave accelerator tank and a wiggler element.

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## REFERENCES

- [1] L. M. Young, “PARMELA,” Los Alamos National Laboratory report LA-UR-96-1835 (Revised April 22, 2003).
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- [3] Lahey Computer Systems, Inc. 865 Tahoe Blvd. Box 6091 Incline Village NV 89450
- [4] <http://laacg1.lanl.gov/>