PS/HI/Note 96-04
28 February 1996

PATH 1.0
PC version, adaptation and new features

A. Ster

Abstract

PATH is a charged particle beam transport simulation program package originally developed at the Accelerator Technology Division, Los Alamos National Laboratory and adapted to personal computer at the Hadron Injection group, CERN-PS, Geneva, together with new features. The new additions include multi-charge effect and magnetic field aberration calculations. A description of the program package and the recently developed procedures is presented.

1 Introduction

The first parts of the report (programs, files, execution & helps) are, for the sake of completeness, based on the introductory help file supplied with the original PATH[1] programs. For the PC version, PATH 1.0, (in the following referenced as PATH) the help files have been slightly modified in order to include the information concerning the changes and the new developments that are highlighted here in the second parts. This manual corresponds to the adapted and extended version of PATH the whole documentation of which is available from the PS/HI program library.

PATH is ray tracing program package with space charge and with the latest developments, multi-charge and magnetic field aberration. It consists of four compatible computer programs that can be used to simulate charged particle beam transport systems and a new auxiliary program that can be used to transform the generated beam data to portable ASCII text format.

2 Programs

The five separate programs belonging to PATH are as follows:

- BEAMGEN
  A beam generator program that uses a random number generator to create a beam file of up to 5000 6-D particle coordinates. Four distributions are available, including uniform, gaussian, k-v, and binominal.

- TRAVEL
  The beam TRAVEL program, a modified version of TURTLE [2], transports the particle beam through a series of transport elements. There are the usual elements such as drifts, quadrupoles, and bending magnets, and several extra options such as space charge (both 2-D and 3-D), buncher cavity, accelerator column, and both DC and RF linac accelerating gaps. It features multi-charge and magnetic field aberrations, too. Some elements are to third order.

- PLOT
  This program can generate histograms and plots at the desired locations along the beam line. This program can produce graphics with the output from BEAMGEN, TRAVEL or LINAC.

- LINAC
  The linac program is a modified version of PARMILA [3] that generates output for the PLOT program. In addition, LINAC generates a linear accelerator line comprised of quadrupoles, drifts, and accelerating gaps that can be used as beam line elements in TRAVEL. The program simulates an Alvarez linear accelerator.

- BEAMTXT
  A program that can create ASCII-text files with 6-D particle co-ordinates coming from the beam data output of BEAMGEN, TRAVEL or LINAC. The converted data are separated according to the different charge states.

3 Location

The program files and the supplementary ones have been placed in the program library under the directory PATH\VERS.100 which is further divided into subdirectories as follows:

Subdirectory	*Content*
\BIN	Executable program files
\EXAMPLE	Example input files
\HELP	Documentation
\SRC	Source files

4 Files

Both TRAVEL and LINAC can use the same beam data file, either that generated by BEAMGEN or the beam data files generated as output by the two programs themselves. A listing of the input and output files for each program is as follows.

Program	*Input Files Required*	*Output Files Generated*
BEAMGEN	beamgen.in	beam.dat
TRAVEL	beam.dat travel.in	beamt.dat rays.dat (for PLOT) travel.out (summary)
LINAC	beam.dat linac.in	beaml.dat line.dat (for TRAVEL) rays.dat (for PLOT) linac.out (summary
PLOT	*.dat	
BEAMTXT	*.dat	beamx.dat

Note that the beam files (beam.dat, beamt.dat and beaml.dat) are the same in format and may be used as the input beam in either LINAC or TRAVEL. The PLOT and the BEAMTXT programs will also accept a beam file in lieu of rays.dat. The "beam" files and the "rays" files are binary; examples of the two input files, "travel.in" and "linac.in" can be found in the HELP and EXAMPLES packages.

5 Execution & help

Each of the five programs may be run separately by typing the name of the desired program. There is a help file for each of the five programs, accessible from the HELP package.

Filename	
_README.1ST	Help for PATH (Intro: Programs, Files, Execution)
BEAMGEN.HLP	Help for BEAMGEN (Beam Generator)
TRAVEL.HLP	Help for TRAVEL (Transport Elements)
PLOT.HLP	Help for PLOT Program
LINAC.HLP	Help for LINAC (PARMILA) Program
BEAMTXT.HLP	Help for BEAMTXT (ASCII file Converter)
XPATH.HLP	Help for PATH (Special info)

6 New features

Two major developments have been added to PATH. The first one can take into account multi-charge states in particle beams, which allows for studying space charge effects in more details. The second improvement can calculate magnetic field aberration effects seen in measurement data but not reproducible in the earlier simulations.

6.1 Multi-charges

Usually particle beams are composed of different charge states and this fact is now taken into account in PATH. The modifications have affected all the programs and the "beam" files whose structure has accordingly changed. The extra specifications are entered in the input file of BEAMGEN. Here is an example for the additional parameter lines in "beamgen.in" :

```
3                       ;line#2 number of charge states
24    25    26          ;line#3 charge states
0.25  0.5   0.25        ;line#4 charge fractions
```

The different charge states are randomly cast among the particles according to the fractional specification. Their reference energies are the same if line#2 is negative, otherwise proportional with the charges. The new beam files contain the extra charge parameter for each particle.

6.2 Magnetic field aberrations

In simple beam transport simulations magnetic fields are "ideal" and are usually defined via three parameters, the constant field strength (B), the effective length (L) and the aperture (R). The new additional procedure applied in TRAVEL extends the meaning of B by allowing to replace it with any general field map. In the latter case the program integrates the equations of motion step-by-step. This method can reproduce aberrations quite well [4]. The following example input files show the two ways of the parameter specifications for TRAVEL.

"travel.in" example#1:

```
3.0     0.0175                          "DRIF";
19.0    0.135  1.535                    "SOLE";
3.0     0.245                           "DRIF";
19.0    0.135  1.735                    "SOLE";
3.0     0.15                            "DRIF";
SENTINEL
```

"travel.in" example#2:

```
3.0     0.0175                          "DRIF";
19.0    0.135  'FIELD.SOL' 0.1411       "SOLE";
3.0     0.245                           "DRIF";
19.0    0.135  'FIELD.SOL' 0.1582       "SOLE";
3.0     0.15                            "DRIF";
SENTINEL
```

where the first column is the transport element type (also in " "), the second one is its length in meter, the third one is the (solenoid) field strength in KGauss. In Example#2 the third parameter is a map filename in stead. The fourth parameter can rescale the field supplied in that file.

References

1. J. Farrel, *PATH - A Lumped Element Beam Transport Simulation Program with Space Charge. Lecture Notes in Physics, W. Busse and R. Zelazny, Eds.* (Springer-Verlag, Berlin, New York 1984), pp. 267-272.

2. D.C. Carey, *TURTLE (Trace Unlimited Rays Through Lumped Elements) - A computer program for simulating charged particle beam transport systems*, Fermi National Accelerator Laboratory report NAL-64 (May 1978).

3. *PARMILA (Phase And Radial Motion in Ion Linear Accelerator)*, Los Alamos Accelerator Code Group, Los Alamos National Laboratory.

4. A. Lombardi & A. Ster, *Magnetic field aberration simulations*, PS/HI/Note 96-02