



PBO LabTM 3.0

(Particle Beam Optics Laboratory 3.0)

**User Manual Supplement:
PARMILA-2 Application Module**

**A PBO Lab Module Created with the
OASIS Module Builder Technology**

***Release Draft A
(incomplete)***

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PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module

PBO Lab™ 3.0 User Manual Supplement: PARMILA-2 Application Module
A PBO Lab Module Created with the OASIS™ Module Builder Technology
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Table of Contents

Chapter and Subject	Page
1. Getting Started	1
Getting Started	3
Overview	3
Installing the PARMILA-2 Module	4
Summary of Command Structure	6
Summary of Supported Pieces	9
2. The PARMILA Command Menus	11
PARMILA-2 Commands Menu	13
PARMILA-2 Module I/O	17
PARMILA-LinGraf Commands Menu	18
PARMILA-Plots Commands Menu	24
PARMILA-T3D-file Commands Menu	30
3. PARMILA-2 Supported Pieces	35
PARMILA-2 Supported Pieces	37
Drift Tube Linac (DTL) Piece	39
Couple Cavity Linac (CCL) Piece	49
Couple Cavity Drift Tube Linac (CCDTL) Piece	63
SuperConducting Linac Overview	65
Missing Segments SuperConducting Linac (SC1) Piece	67
Grouped Segments SuperConducting Linac (SC2) Piece	77
Specialized PARMILA-2 Optics Pieces	85
PARMILA-2 Parameter Pieces	tbd
PARMILA-2 Command Pieces	tbd
4. PARMILA-2 Tools	tbd
Auxiliary Input	tbd
Search Tools & List Windows	tbd
PARMILA-LinGraf	tbd
PARMILA-Plots	tbd
PARMILA-2 Module Options	tbd



PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module

Appendix. PARMILA-2 Documentationtbd



List of Principal Figures and Tables

Figure Number and Abbreviated Caption	Page
Figure 1. Move the PARMILA 2 folder and the PARMILA-2.omod file.....	4
Figure 2. Tutorial menu of PBO-Lab Document contains a Register selection	5
Figure 3. Document Window showing the PARMILA-2 Commands submenu.....	6
Figure 4. PBO Lab Pieces supported by the PARMILA-2 Module	9
Figure 5. A "cmd.exe" window opens following Write and Run 'input.LIN' command ..	14
Figure 6. The primary results are given in the file 'Parmila.out'	15
Figure 7. The Main Input File after Write and View 'input.LIN'	16
Table 1. Summary of main I/O files used by PBO Lab PARMILA 2 Modules	17
Figure 8. PBO Lab selection of the "PARMILA-Lingraf Command Pieces" item	19
Figure 9. The PARMILA-Lingraf Command Pieces window	19
Figure 10. A newly created Piece will appear in the Work Space	20
Figure 11. The "Lingraf Graphics Request" Piece window	21
Figure 12. The Lingraf graphics following command "Write and Run 'ingraf.lgf' "	22
Figure 13. PARMILA-Lingraf window that displays the 'LgrafOut.txt ' data file	23
Figure 14. The 'ingraf.lgf' window following "Write and View 'ingraf.lgf' "	24
Figure 15. Windows file dialog opens following "Write and Run 'input.temp' "	25
Figure 16. The window displaying the 'part_dtl.TXT' file	26
Figure 17. Transverse phase space plots following "Write and Run 'input.temp' "	26
Figure 18. Longitudinal phase space plot following "Write and Run 'input.temp' "	27
Figure 19. Plot Options for the PARMILA-Plots (or PARMILA-2) Module	28
Figure 20. <i>Built-in</i> plots are part of both PARMILA-Plots and PARMILA-2.....	28
Figure 21. Example of an additional built-in plot display	29
Figure 22. Example of a 'Tr3Din.pbop' file	31
Figure 23. Example of a Subline created with the PARMILA-T3D-file Module.....	32
Figure 24. Details of interior Subline for the example illustrated in Figure 23	32
Figure 25. Result of using the TRACE 3-D Module for the Subline	33
Figure 26. TRANSPORT Module beam simulation for the Subline	33
Figure 27. Window listing Palette Bar Pieces supported by PARMILA-2	37
Figure 28. RF Field tab panel for a DTL Piece	39
Figure 29. Layout of a drift tube linac (DTL) from Appendix Figure III-3	40
Figure 30. Geometry cell table for a drift tube linac (DTL) in 'Parmila.out'	41
Figure 31. Quads tab panel for a DTL Piece	41
Figure 32. Meaningful options for the Quad Sequence Start Point	43
Figure 33. Field Ramp tab panel for a DTL Piece.....	44



List of Principal Figures and Tables (continued)

Figure Number and Abbreviated Caption	Page
Figure 34. Geometry tab panel for a DTL Piece.....	46
Figure 35. Example of a DTL "Design Line" with Changes and SuperFish Data	47
Figure 36. RF Field tab panel for a CCL Piece.....	49
Figure 37. Layout of a coupled cavity linac (CCL), from Appendix Figure III-5	50
Figure 38. Quads tab panel for a CCL Piece	50
Figure 39. CCL quadrupole Lattice Type determines other quad parameters	51
Figure 40. Field Ramp tab panel for a CCL Piece	52
Figure 41. Phase Ramp tab panel for a CCL Piece	54
Figure 42. Geometry tab panel for a CCL Piece	55
Figure 43. Example of a CCL "Design Line" that includes SuperFish Data	56
Figure 44. The Main Input File for the example "SNS-CCL-1st-8-cells.pbol"	57
Figure 45. The Main Output File for the example "SNS-CCL-1st-8-cells.pbol"	58
Figure 46. Lingraf profile plots for the example "SNS-CCL-1st-8-cells.pbol"	59
Figure 47. "SNS-CCL-1st-8-cells.pbol" Particle distribution data	59
Figure 48. Phase space scatter plots for "SNS-CCL-1st-8-cells.pbol"	60
Figure 49. TRACE 3-D calculation for equivalent "SNS-CCL-1st-8-cells.pbol"	61
Figure 50. Geometry tab panel of a CCDTL has 1 more than parameter CCL	63
Figure 51. Layout of a CCDTL, from Appendix Figure III-4	64
Figure 52. Superconducting (SC) layout, from Appendix Figure III-6	65
Figure 53. RF Field tab panel for a SC1 Piece	67
Figure 54. Missing segment SC linac (SC1), from Appendix Figure III-7	69
Figure 55. Quads tab panel for a SC1 Piece	69
Figure 56. Segment Layouts tab panel for a SC1 Piece	70
Figure 57. Geometry tab panel for a SC1 Piece	72
Figure 58. Document Window for "SC1 MissingCavity 700 MHz.pbol" example	73
Figure 59. A 'Parmila.out' file for "SC1 MissingCavity 700 MHz.pbol" example	75
Figure 60. RF Field tab panel for a SC2 Piece	77
Figure 61. Layout for SC2 with quadrupole doublets from Appendix Figure III-8....	78
Figure 62. Layout for SC2 with quadrupole singlets from Appendix Figure III-9	79
Figure 63. Quads & Segments tab panel for SC2 Piece	80
Figure 64. Segment Layouts tab panel for SC2 Piece	81
Figure 67. Specialized optics elements used by the PARMILA-2 Module	85

PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module





PBO Lab™

1. Getting Started

**User Manual:
Supplement:
PARMILA-2
Application
Module**



PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module

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1. Getting Started

The PARMILA-2 Module for PBO Lab is based upon the Open Architecture Software Integration System (OASIS™) Module Builder. The OASIS Module Builder is used to create Application Modules for the Particle Beam Optics Laboratory (PBO Lab™) software. This User Manual Supplement describes the use of the PARMILA-2 Module with the PBO Lab framework. Refer to the PBO Lab User Manual (Basic Package) for general information on the PBO Lab user interface.

This PBO Lab 3.0 User Manual Supplement describes the PARMILA-2 Module. Features specific to the PARMILA-2 Module are discussed here. The main (Basic Package) PBO Lab User Manual provides general information on the PBO Lab user interface.

Overview

The PARMILA-2 Module is available commercially as a PBO Lab Module. The PARMILA 2 executable physics program is included with the PBO Lab PARMILA-2 Module under the terms of a license agreement with the Los Alamos National Laboratory. This Section of the User Manual Supplement provides an introduction to the Module. The installation of the PARMILA-2 Module is described, a summary of the PARMILA-2 Module command structure is presented, and the PBO Lab Pieces supported by the PARMILA-2 Module are listed.

PBO Lab provides an intuitive, interactive, user friendly, graphic interface customized to the needs of the accelerator community. A number of Application Modules have been developed for PBO Lab. The OASIS Module Builder extends the utility of the PBO Lab software by allowing researchers to create their own Application Module for PBO Lab. The PARMILA-2 Module was created with the OASIS Module Builder.

Section 2 of the User Manual Supplement describes the Commands submenu for the PARMILA-2 Module. Section 3 describes the PARMILA-2 Module Optics, Parameter and Command Pieces. Section 4 summarizes the Auxiliary Input, List Windows and PARMILA-2 Options available to the user. Section 5 presents an example of carrying out PARMILA-2 computations and presents some example results. The Appendix provides copies of PARMILA-2 documentation, included as part of this User Manual Supplement under the license agreement with the Los Alamos National Laboratory.

The PARMILA 2 code is included with the PBO Lab PARMILA-2 Module under the terms of a license agreement with the Los Alamos National Laboratory (LANL).



Installing the PARMILA-2 Module

The PARMILA-2 Module consists of two parts:

1. The OASIS Module Specification Document, and
2. The PARMILA 2 physics program.

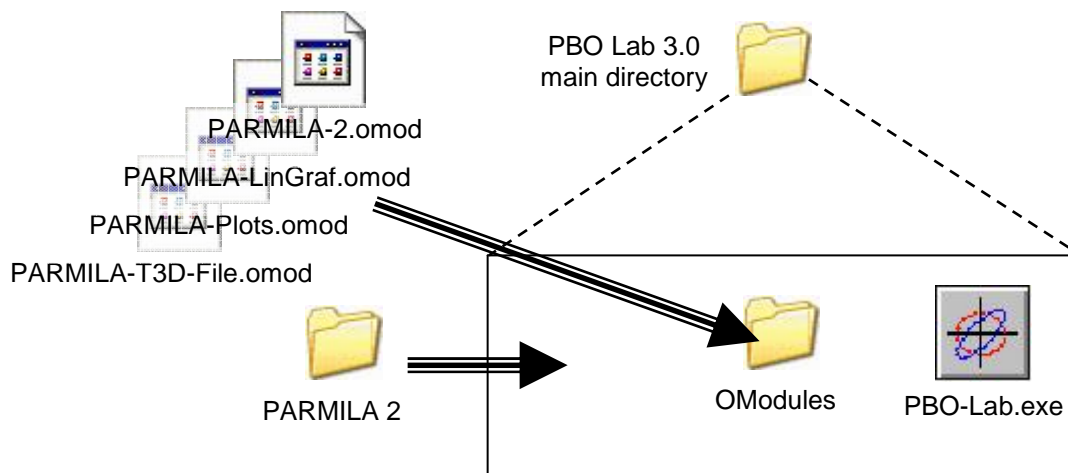
The OASIS Module Specification Document is a file with extension .omod and has the name OASIS-PARMILA-2. The PARMILA 2 physics program has several executable files with .exe extension and certain other files. To install the PARMILA-2 Module these files need to be moved (or copied) to specific locations on your computer's hard drive.

You will need to have PBO Lab 3.0 (or later) in order to utilize the PARMILA-2 Module. If you do not already have PBO Lab 3.0 installed on your computer, you will need to install it first. Follow the installation instructions that accompanied your PBO Lab 3.0 software. If you already have PBO Lab 3.0 installed on your computer, you will not need to reinstall it.

1. Move (or copy) the *files* with extension ".omod" to the folder (directory) named "OModules" inside the folder (directory) where the PBO Lab 3.0 (or later) executable application is installed.

2. Move (or copy) the *folder* "PARMILA 2" to the folder (directory) where the PBO Lab 3.0 (or later) executable application is installed.

Figure 1 shows the locations for these components. Other files in the main directory are not illustrated.



There will be many other files and folders (directories) appearing in the main PBO Lab directory. These are not shown in Figure 1.

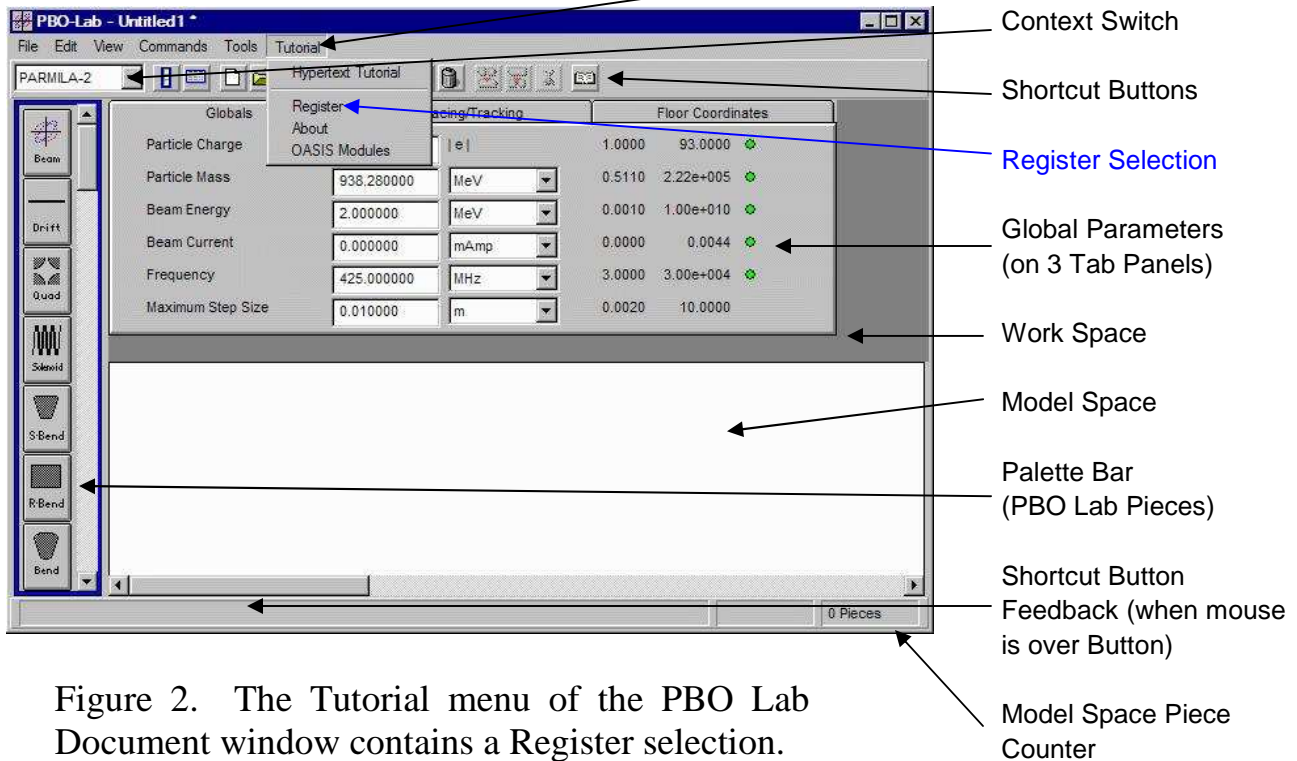
Figure 1. Move the PARMILA 2 folder to the main PBO Lab folder, and the OASIS-PARMILA-2.omod file to the OModules folder, respectively.

PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module



To access the PARMILA-2 Module you will need to have a user license number for PBO Lab 3.0 (or later) and a CD-Key *enabled for OASIS Modules*. The user license number and CD-Key are included in the documentation shipped with the PBO Lab software or Module upgrade. The license number and CD-Key need to be entered into the PBO Lab Registration window after installation of the PBO Lab software. If you are installing PBO Lab for the first time, follow the instructions in the PBO Lab User Manual (Basic Package). If you are adding the PARMILA-2 Module to an existing PBO Lab installation, you will need to update your CD Key. To do this, start PBO Lab in the (default) Single Model Mode. You should see a PBO Lab Document Window like that illustrated in Figure 2. Under the Tutorial menu of the Document Window select the Register choice. A PBO Lab Registration window will open. Enter your CD Key and other data as necessary.

You will need to have PBO Lab 3.0 or later in order to utilize the OASIS PARMILA-2 Module. (OASIS will not work properly with PBO Lab 2 or earlier.)





PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module

The PBO Lab PARMILA-2 Module installation CD contains two folders:

PARMILA OModules
PARMILA 2

The PARMILA OModules folder on the CD contains the following Module files:

PARMILA-2.omod
PARMILA-LinGraf.omod
PARMILA-Plots.omod
PARMILA-T3D-File.omod

Each of these OModule supports different capabilities of the PBO Lab PARMILA 2 application. The corresponding libraries for the computation engines of each of the OModules are located in the PARMILA 2 folder on the CD, which contains the following files:

PARMILA.EXE
Lingraf.exe
readdst.exe
T3Din.dll

You may wish to install certain optional items from the PARMILA-2 installation CD. A PDF version of this user manual is contained in the Manuals folder on the CD. Drag this folder from the CD to the same directory (folder) on your hard drive where PBO Lab is installed. Some PBO Lab files for running example PARMILA-2 problems are contained in the Examples folder installed in the PBO Lab main directory. Other examples may be in a folder on the CD, but not automatically installed.

Summary of Command Structure

A brief summary of the PARMILA-2 command structure is presented here. Individual PARMILA-2 commands are described in more detail in the following Sections of this Supplement. Figure 3 illustrates a PBO Lab Document window with the PARMILA-2 Commands submenu selected in the PBO Lab Command Menu.

Command submenus for installed Application Modules are accessed from the PBO Lab Commands Menu in the Document Window

Commands submenu for the PARMILA-2 Module

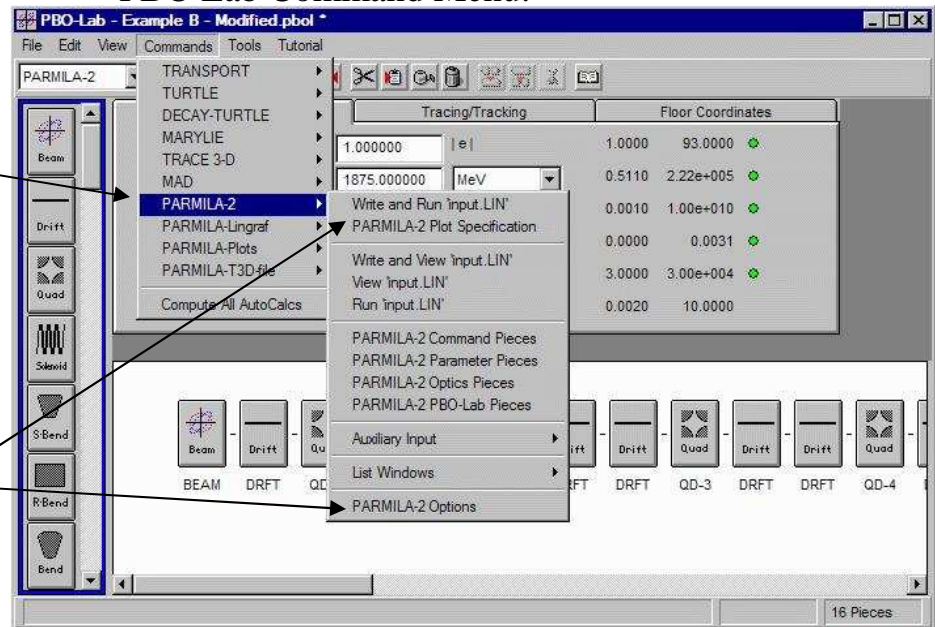


Figure 3. PBO Lab Document Window showing the PARMILA-2 Module Commands submenu.

PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module



The PBO Lab Document window illustrated in Figure 3 also shows the entries on the Commands menu for the other PARMILA Modules:

- PARMILA-Lingraf
- PARMILA-Plots
- PARMILA-T3D-file

The Command Menu shown in Figure 3 also includes six other installed PBO Lab Application Modules: TRANSPORT, TURTLE, DECAY-TURTLE, MARYLIE, TRACE 3-D, and MAD.

The PARMILA-2 Commands submenu is shown in the side-bar with the corresponding Manual Sections that describe the entries in more detail. The command structure for the PARMILA-Lingraf, PARMILA-Plots and PARMILA-T3D-file Modules are also discussed in later Manual Sections.

The Command Menu in the PBO Lab Document Window contains submenus for any installed Application Modules. The full PARMILA application has four separate Modules, and each of these has as a corresponding Commands submenu. The structure of each of these submenus is similar.

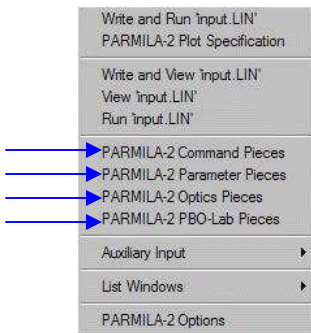
The PARMILA-2 Commands submenu is separated into six groups. The first two groups contain commands for generating I/O for the PARMILA-2 Module, and for running the computation engine. The Main Input File for the PARMILA-2 Module is named "input.LIN" and most of the commands operate via that file. These commands are described in Section 2 of this Supplement.

PARMILA-2 Module
Commands submenu.
Manual Section:

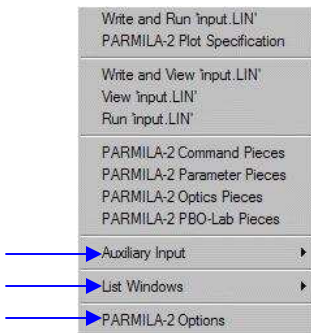
Write and Run 'input.LIN'	
PARMILA-2 Plot Specification	2
Write and View 'input.LIN'	
View 'input.LIN'	2
Run 'input.LIN'	2
PARMILA-2 Command Pieces	
PARMILA-2 Parameter Pieces	3
PARMILA-2 Optics Pieces	3
PARMILA-2 PBO-Lab Pieces	3
Auxiliary Input	▶ 4
List Windows	▶ 4
PARMILA-2 Options	4



PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module



PARMILA-2 Module Commands submenu has four (4) Piece creation commands.



Auxiliary Input, List Windows and Options for the PARMILA-2 Module are also accessed from the Commands submenu.

The next group of commands in the PARMILA-2 Commands submenu focuses on the different types of beamline elements (Pieces) that are supported by the PARMILA-2 Module. The PARMILA-2 Module utilizes each of the four Piece types listed in the menu. These Piece creation commands are discussed in Section 3 of this Supplement.

The next command group contains a submenu for PARMILA-2 Auxiliary Input. There are two items in the Auxiliary Input submenu that can be used to add additional text directly to the PARMILA-2 Main Input File (input.LIN). One is for "Header Instructions" to follow the Header Section of the Main Input File, and the other is for "Footer Instructions" to precede the Footer Section of the Main Input File. These are described in Section 4 of this Supplement.

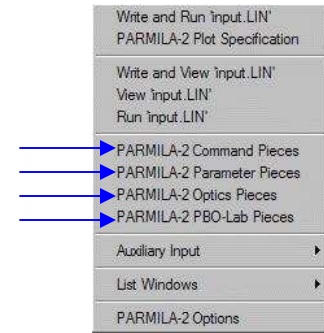
The PARMILA-2 List Windows are used to compile results from different types of parameter and labeling searches over a beamline model. These commands are also described in Section 4 of this Supplement. Although these commands are not utilized directly by the PARMILA-2 Module, they provide information on parameters utilized by other PBO Lab Modules.

The final entry on the Commands submenu is used to open the PARMILA-2 Options window. Section 4 of this Supplement illustrates the Options window and discusses the PARMILA-2 Options.



Summary of Supported Pieces

A summary of the Pieces supported by the PARMILA-2 Module is given here. The different types of Pieces include (a) PBO Lab "Palette Bar" optics elements that are supported by PARMILA-2 and by most other PBO Lab Application Modules, as well as (b) custom Command, Parameter and Optics Pieces developed specifically for the PARMILA-2 Module. Figure 4 lists (a) all of the Palette Bar Pieces that are supported by the PARMILA-2 Module. These include certain complex Pieces (e.g. DTL, CCL) unique to PARMILA. Section 3 of this Supplement describes (b) the PARMILA-2 specific Pieces including Command Pieces, Parameter Pieces and Optics Pieces that can be used by the PARMILA-2 Application Module. These Pieces implement specific PARMILA-2 instructions and are intended for use with the PARMILA-2 Module only. (Other PBO Lab Modules ignore these Pieces.) They are described more fully in Section 3 of this Supplement.



Lists of the various Pieces supported by the PARMILA-2 Module can be accessed by the corresponding entries on the PARMILA-2 Commands submenu.

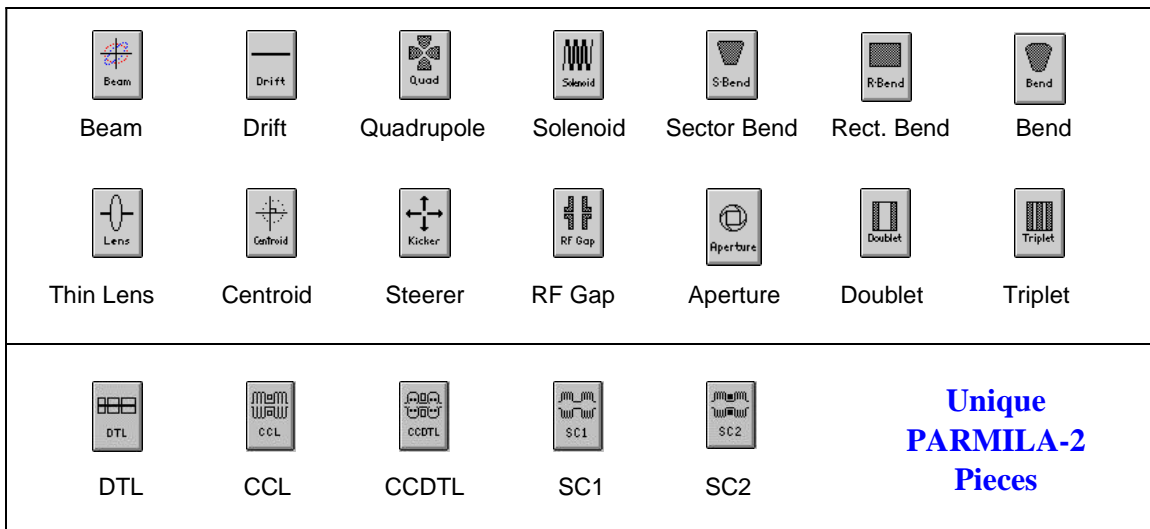


Figure 4. PBO Lab Palette Bar Pieces supported by the PARMILA-2 Module.



PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module

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PBO Lab™

2. The PARMILA Command Menus

**User Manual:
Supplement:
PARMILA-2
Application
Module**



PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module

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2. The PARMILA Command Menus

There are four Command menus associated with the PBO Lab PARMILA Module, corresponding to the four executable components of the Module:

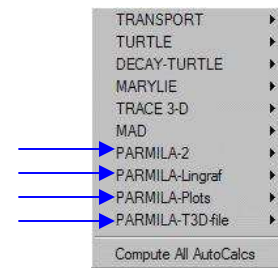
PARMILA.EXE
Lingraf.exe
readdst.exe
T3Din.dll

Each of the Commands Menus associated with these components have a similar appearance in the PBO Lab graphic interface, but their functionality is customized to the capabilities of each executable.

PARMILA-2 Commands Menu

A summary of the PARMILA-2 Module command structure was given in Section 1 and illustrated in Figure 3. This Section will describe the six groups of commands in the PARMILA-2 submenu shown in the side-bar at the lower right, concentrating on the first two ("Write" & "Run") groups. Section 3 provides additional details on the four items of the third ("Pieces") group, while Section 4 discusses additional features of the last three groups (Auxiliary Input, List Windows and PARMILA-2 Options).

The first group of commands provides a general command to execute the PARMILA.EXE computation engine. The "Write and Run 'input.LIN' " item is generally the most frequently used command. When selected, the "Write and Run 'input.LIN' " command will write the PARMILA-2 Main Input File (input.LIN) for the beamline in the Document Window and then run the PARMILA.EXE executable with that input. During execution, a "cmd.exe" window will open and provide some feedback on the progress. Upon completion of the run, the "cmd.exe" window will close, and another window opens to display the PARMILA-2 results.



The four (4) PARMILA Module Commands Menus are associated with the four (4) executable components of the PBO Lab PARMILA-2 Module.

When other PBO Lab Modules are installed, they will also have items on the Commands menu. For example, the above illustration has Modules for TRANSPORT, TURTLE, DECAY-TURTLE, MARYLIE, TRACE 3-D and MAD installed.

The Compute All AutoCalcs item on the Commands menu is used to update interdependent data in PBO Lab models after certain types of calculations. An example is illustrated in connection with the PARMILA-T3D-file Commands.

Manual Section:

Write and Run 'input.LIN'	2
PARMILA-2 Plot Specification	2
Write and View 'input.LIN'	2
View 'input.LIN'	2
Run 'input.LIN'	2
PARMILA-2 Command Pieces	3
PARMILA-2 Parameter Pieces	3
PARMILA-2 Optics Pieces	3
PARMILA-2 PBO-Lab Pieces	3
Auxiliary Input	4
List Windows	4
PARMILA-2 Options	4


The PARMILA-2 Module Commands submenu contains six groups of items.



PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module

Figure 5 illustrates an example of the cmd.exe window that opens following a "Write and Run 'input.LIN' " command. The illustration is for the example file "SNS DTL Tank 1.pbol" that is included in the Examples/PARMILA folder located in the PBO-Lab main directory (the Examples folder is installed when PBO Lab is installed).

The "cmd.exe" update window provides brief feedback during a PARMILA.exe calculation. The current location of the dynamics calculation is displayed and is updated as each step of the calculation is completed. The window closes upon completion of the PARMILA.exe computations.



```
C:\OASIS\PARMILA 2\PARMILA.exe
Program: C:\OASIS\PARMILA 2\PARMILA.exe
Structure 1 dynamics, DTL cell 23
```

Figure 5. A PARMILA.exe ("cmd.exe") window will open, perhaps only briefly, upon execution of the Write and Run 'input.LIN' command.

The example used for the illustrations of Figures 5-6 is contained in the PBO Lab file:

SNS DTL Tank 1.pbol

You may wish to open that example to see the results on your computer.

The window illustrated in Figure 5 provides some feedback on the progress of the PARMILA.exe execution, and closes immediately following the completion of the PARMILA calculations. Depending upon the speed of your computer and the size of the problem you are running, the "cmd.exe" window may open and then close very quickly. The illustration shown in Figure 5 indicates that the PARMILA calculations were taking place in DTL cell number 23 of Structure 1, in the example "SNS DTL Tank 1.pbol" when the "screen shot" was taken of the "cmd.exe" window.

PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module



After the PARMILA.exe computations are complete, a PBO Lab window will automatically open to display the results of the calculations, which are recorded in 'Parmila.out' (the PARMILA Main Output File). Figure 6 illustrates the 'Parmila.out' window after running the example file "SNS DTL Tank 1.pbol".

The 'Parmila.out' window opens following completion of a PARMILA calculation. Use the scroll bar to access data lower in the file.

```
Los Alamos National Laboratory Parmila - Ion Linac Design Code
Program Parmila written by Harunori Takeda

This program is provided as a service to the accelerator community by the Los Alamos Accelerator Code Group (LAACG).
(c) Copyright 1985-2004, by the Regents of the University of California.

This software is produced under U. S. Government contract W-7405-ENG-36 by Los Alamos National Laboratory, which is
operated by the University of California for the U. S. Department of Energy. Neither the Government nor the University
makes any warranty, express or implied, or assumes any liability or responsibility for its use, or represents that use
of this software would not infringe privately owned rights.
Unpublished - rights reserved under Copyright Laws of the United States.

Program Parmila 2.35  released 7-25-2005

Parmila starting at 07-08-2008  11:30:49
Parmila input file: input.lin
No LANL INI file found.
First random number (using system clock) for linac error studies = 0.850394462774602240

Lines that start with "LIN:" are from file input.lin:
LIN: RUN  1 1

*****
SNS DTL TANK 1 RUN ON 07/08/08 11:30:49
*****

LIN: LINAC  2.500000  402.500000  56.000000  939.301400  -1.000000
Maximum number of Particles:  50000
```

Figure 6. The primary results of each PARMILA calculation are given in the file 'Parmila.out' displayed automatically after a "Write and Run 'input.LIN' " command.

When selected, the "Write and Run 'input.LIN'" command will write the PARMILA-2 Main Input File (input.LIN) for the beamline in the Document Window and then run the PARMILA.EXE executable with that input. During execution, a cmd.exe window will open (Figure 5) and then close when the PARMILA calculations are completed. Upon completion of the run, the Main Output File 'Parmila.out' window will open to display the primary results of the computations.

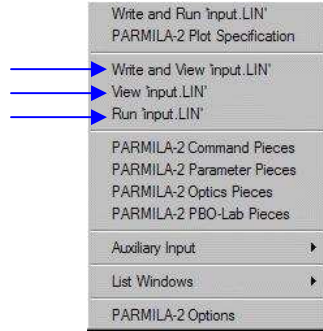
The next item on the commands menu, PARMILA-2 Plot Specification, is used in conjunction with a particle distribution file that PARMILA can create. Discussion of that capability appears in Section 3.

A given PARMILA calculation may utilize auxiliary input files in addition to 'input.LIN'. For example, the "SNS DTL Tank 1.pbol" model uses the SuperFish data file "SF Data File DTL." PARMILA will also generate other output files in addition to 'Parmila.out.' These various input and output files are discussed in Section 3 where the Command Pieces utilizing them are described.

NOTE: Execution of the command "Write and Run 'input.LIN' " will overwrite any existing 'input.LIN' file.



PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module



The second group of items on the PARMILA-2 Commands menu may be used to examine the Main Input File 'input.LIN'.

The sequence of events that occurs with the "Write and Run 'input.LIN'" command can be divided into separate steps by utilizing the second group of commands on the PARMILA-2 Commands menu. The second group of commands in the Commands Menu provides individual commands to Write, View and Run the PARMILA-2 Main Input File. The "Write and View 'input.LIN'" command will cause a new Main Input File to be written and opened for viewing. Figure 7 illustrates the window that is automatically opened following this command for the 'input.LIN' created for the model in the file "SNS DTL Tank 1.pbol".

Use scroll bars to access different parts of the text window.

```
RUN 1 1
TITLE
SNS DTL TANK 1 RUN ON 07/31/08 06:27:46
: *** PARMILA OASIS MODULE VERSION 2.2.0.3 FOR PBO LAB 3.0 ***
: LINAC: W0, FBUNCH, IBEAM, MC^2, NQ
LINAC 2.500000 402.500000 56.000000 939.301400 -1.000000
: ***** END OF THE INPUT.LIN HEADER SECTION *****
: *** USER AUXILLARY HEADER INPUT WILL APPEAR HERE ***
: ***** START OF THE INPUT.LIN LATTICE SECTION *****
FULLWALLPOWER
POWER
STARTPHASE -45.000000
INPUT -8 1000 2.371911 96.567733 0.001582
          -1.022037 29.001170 0.001490
          -0.028191 57.577889 0.001764
          0.000 0.000 0.000 0.000 0.000 0.000
: ***** START OF NEW STRUCTURE - PBO LAB PARMILA-2 MODULE *****
: STRUCTURE ID,NLAST, FO, FSF, DELTAPHI
STRUCTURE 3 60 402.500000 402.500000 0.0
TITLE
SNS_DTL_TANK
: DLT: NTANK,NC, PHIS, EO(MEV/M), CTILT, EO-MAX, DZ, DPHI,
DTL 1 -60 -45.000000 1.130000 0.004070 3.800000 0.000000 0.000000 3.0
          5 5 11 0.000000 1.250000 0.000000 0 0.000000 0 1 1 2 0
: 2ND ROW: LAT,QSTART,QENDS, DZE, RB1, RB2, NNR, PMAX, -0-, NBL, RAMPT, DELN, NS,
CHANGE 14 2.490000 3700.000000 101.100000 3700.000000
CHANGE 16 3700.000000 1.000000
SFDATA
: SNS LINAC, 402.5 MHZ, BORE = 1.25, DTL
: BETA T TP S SP G/BL Z E/EO
0.070000 0.563010 0.099403 0.572469 0.022447 0.170421 49.8612 1.00000
0.072500 0.581612 0.096563 0.566283 0.025463 0.167853 50.4299 1.00000
```

Figure 7. The Main Input File for the beamline on the Model Space is displayed automatically after the "Write and View 'input.LIN'" command is selected.



PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module

The "View 'input.LIN' " command is used to open the existing Main Input File 'input.LIN'. A window like that illustrated in Figure 7 opens when this command is executed. The existing 'input.LIN' file is not overwritten; it is simply opened for viewing.

The "Run 'input.LIN' " command is used to call the PARMILA-2 executable for the existing Main Input File 'input.LIN'. The existing 'input.LIN' file is not overwritten when the "Run 'input.LIN' " command is executed. The existing 'input.LIN' is run using the PARMILA.exe program. The "cmd.exe" window (Figure 5) will open and close (perhaps quickly), and then the Main Output File 'Parmila.out' (Figure 6) will open to display the results of the run.

PARMILA-2 Module I/O

Whenever the PARMILA-2 executable is run there may be additional output files generated. Which files are generated will depend upon the PARMILA-2 Command and/or Parameter Pieces used in the beamline model. Those Pieces are discussed in Section 3. Some of the files that PARMILA-2 generates are used by other parts of the PBO Lab PARMILA-2 Module: PARMILA-LinGraf, PARMILA-Plots or PARMILA-T3D-file. The next few pages describe the use of those. Table 1 summarizes the various I/O files that may be generated by a PARMILA-2 execution.

The PARMILA-2 Main Input File 'input.LIN' is divided into three primary sections:

- Header Section*
- Lattice Section*
- Footer Section*

The Header Section for 'input.LIN' is comprised of the first eight (8) lines of the example illustrated in Figure 7. PBO-Lab Global Parameters are included in the Header, as well as other required PARMILA inputs at the top of the file. Several comment lines, which start with a semicolon (;) are also incorporated to assist in interpreting the file.

The Lattice Section begins with line nine (9) of the example illustrated in Figure 7. The Lattice Section contains most of the detailed input for PARMILA, and is defined by the PARMILA-2 Pieces on the Model Space of the PBO Lab Document Window. Those Pieces are discussed in Section 3.

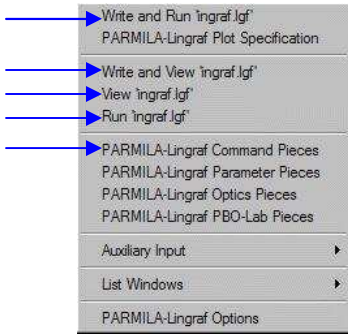
Table 1. Summary of main I/O files used by the PBO Lab PARMILA 2 Modules.

File Name	Description	Written By	Used By
input.LIN	PARMILA Main Input File	PBO-Lab PARMILA-2 Module	Parmila.exe
Parmila.out	PARMILA Main Output File	Parmila.exe	PBO-Lab View Menu
parmila.plt	LinGraf binary data file	Parmila.exe	Lingraf.exe
ingraf.lgf	LinGraf Main Input File	PBO-Lab PARMILA-LinGraf Module	Lingraf.exe
Lgrafout.txt	LinGraf Main Output File	Lingraf.exe	PBO-Lab View Menu
part_dtl.dst	distribution binary data file	Parmila.exe	readdst.exe
part_dtl.txt	distribution text data file	readdst.exe	PBO-Lab PARMILA-2 Plots
Tr3Din.t3d	lattice description file	Parmila.exe	PBO-Lab PARMILA-T3D-file
Tr3Din.pbop	PBO-Lab object model file	PBO-Lab PARMILA-T3D-file	PBO-Lab Edit Menu



PARMILA-Lingraf Commands Menu

The layout of the PARMILA-Lingraf commands menu is similar to that of the PARMILA-2 commands menu except that several of the items are not currently used. The illustration in the sidebar to the left indicates the command entries that are used by the PARMILA-Lingraf module.



PARMILA-Lingraf only uses those command items identified above with a blue arrow (→). The other command entries are not used by PARMILA-Lingraf.

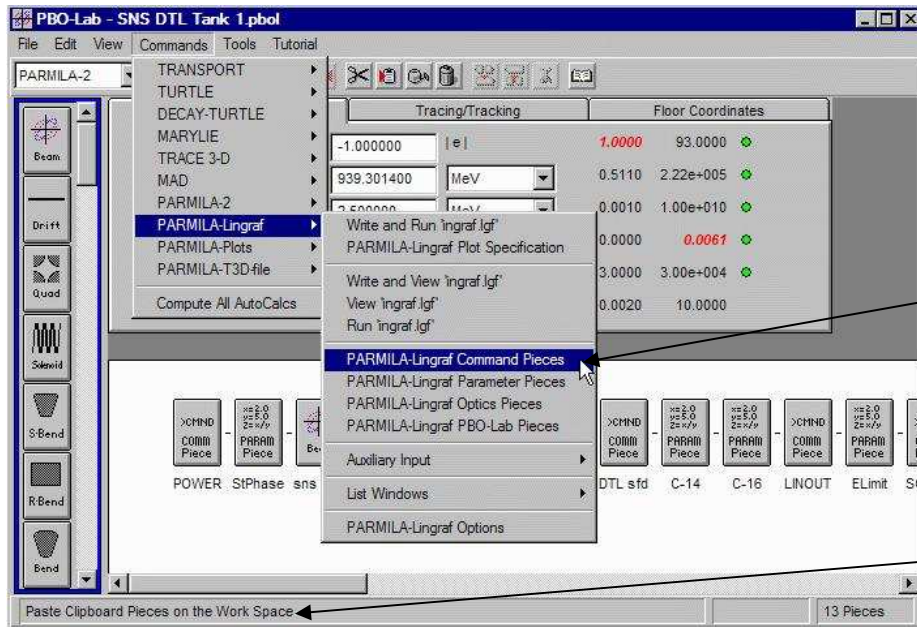
The "Write and Run 'ingraf.lgf' " command functions is used in a manner similar to that of the "Write and Run 'input.LIN' " command for the PARMILA.EXE executable. That is, when "Write and Run 'ingraf.lgf'" is selected the Main Input File ('ingraf.lgf') for Lingraf.exe is written, Lingraf.exe is called to run that input file, and then a window opens to illustrate the results. There are two principal differences:

- The output from a Lingraf.exe run can be a *graphics display*, a text file ('Lgrafout.txt'), or *both*, and
- Only PARMILA-Lingraf Command Pieces are used to prepare the Main Input File 'ingraf.lgf'.

An example will illustrate how to use the PARMILA-Lingraf part of the PBO Lab PARMILA 2 Module. The example will use the PBO Lab file "SNS DTL Tank 1.pbol" included in the /Examples/Parmila/ folder (directory) created when PBO-Lab 3.0 is installed CD.

A step-by-step example is used here to illustrate how to set up and use the PARMILA-Lingraf Module to create a graphics display for a simple drift tube linac (DTL) example. Additional PARMILA-Lingraf capabilities are described in Section 4.

Step 1 is to open the "SNS DTL Tank 1.pbol" file in PBO Lab and execute the PARMILA-2 "Write and Run 'input.LIN'" command. This step writes the necessary binary data file (parmila.plt) needed by Lingraf. Step 2 is to select the "PARMILA-Lingraf Command Pieces" item from the PARMILA-Lingraf commands submenu. This procedure is illustrated in Figure 8, and results in the opening of the PARMILA-Lingraf Command Pieces window illustrated in Figure 9.

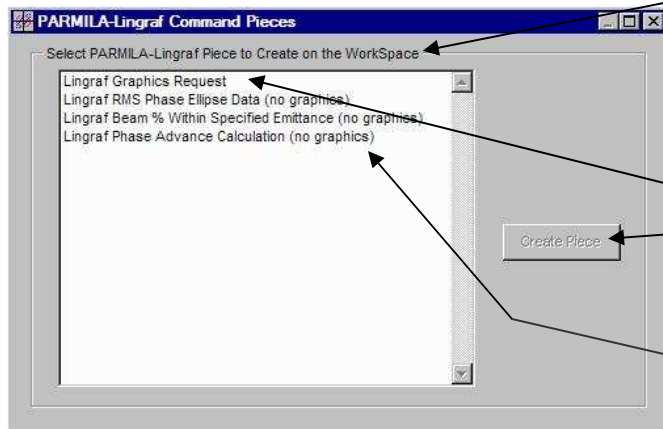


Selecting the "PARMILA-Lingraf Command Pieces" item will open a window listing the available Lingraf Command Pieces. That window is illustrated in Figure 9.

When a Lingraf Command Piece is selected (from Figure 9 list) the new Command Piece will appear in the lower left region of the Work Space.

Figure 8. PBO Lab Document Window for the example file "SNS DTL Tank 1.pbol" showing the selection of the "PARMILA-Lingraf Command Pieces" item from the PARMILA-Lingraf commands submenu.

When a Lingraf Command Piece is selected, and the Create Piece button pushed, the new Piece will appear in the lower left region of the Work Space.



Select a Lingraf Command Piece to activate the Create Piece button.

Available Lingraf Command Pieces cover all of the PARMILA-2 Lingraf capabilities including non-graphic (text) output to the file 'Lgrafout.txt'.

Figure 9. The PARMILA-Lingraf Command Pieces window lists all of the Command Pieces used by the PARMILA-Lingraf module to write the file 'ingraf.lgf'.

One PARMILA-Lingraf Command Piece is used for requesting graphics output from Lingraf; the others produce text output to a file named 'Lgrafout.txt'.

Lingraf also supports other programs such as PARMTEQ. Only PARMILA-2 applicable Lingraf commands are in the PARMILA-Lingraf Command Pieces window (Figure 9).



PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module

The step-by-step example described here is for the initial creation of a Lingraf graphics display. Once a PARMILA-Lingraf Command Piece is setup, it may be saved with the PBO-Lab Document (.pbol file) for future use.

Step 3 in initially setting up a Lingraf run involves selecting a Lingraf Command Piece from the list that appears in the PARMILA-Lingraf Command Pieces window (Figure 9). For illustrating a graphics display, select the Piece named "Lingraf Graphics Request." The "Create Piece" button appearing in the right side of the window (Figure 9) will become active. Push (mouse click on) the "Create Piece" button. A new Piece will appear on the Work Space of the Document window. The location of the newly created Piece is illustrated in Figure 10.

Newly Created Pieces Appear in the Lower Right of the Work Space, Partially Under the Global Parameter Pane

Hide/Show the Global Parameters Button

Drag or Move (Shift-Drag) the Newly Created Piece to the Beamline on the Model Space

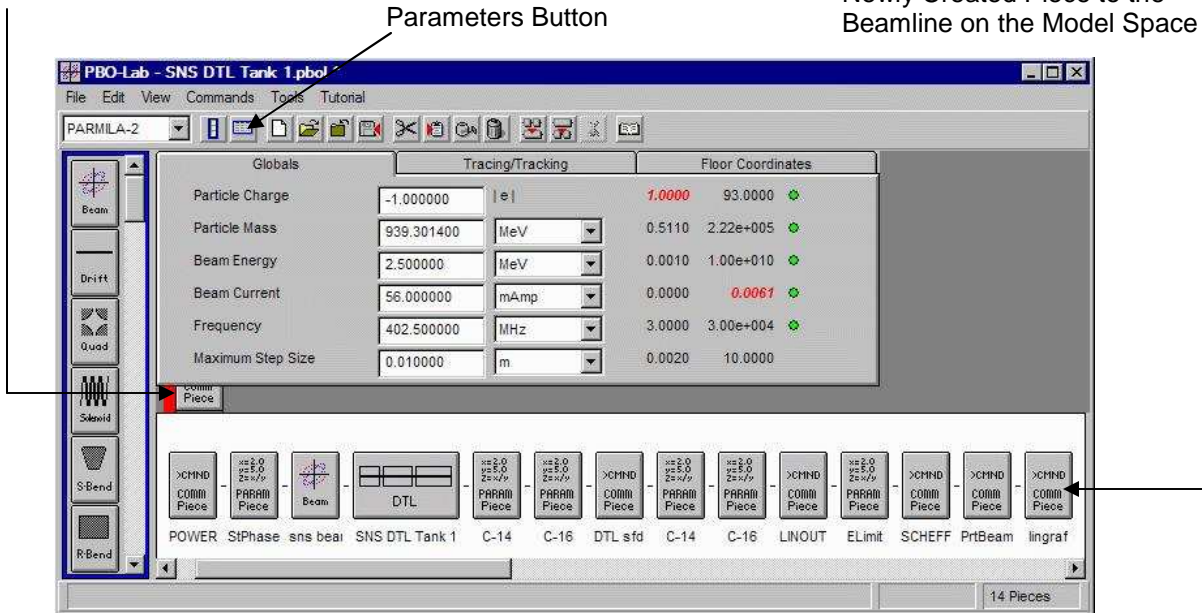


Figure 10. A newly created Piece will appear in the lower left part of the Work Space of a PBO Lab Document window, below (and partially covered by) the Global Parameter Pane. For convenience, the Globals hide/show toggle button may be used to hide (and later, show) the Global Parameter Pane.

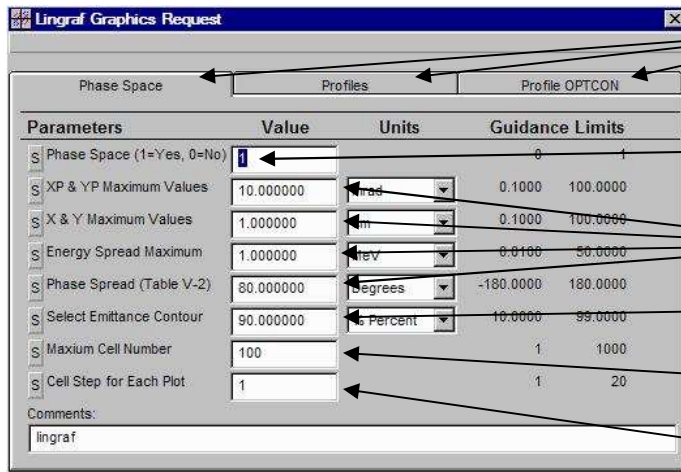
Figure 10 also illustrates Step 4: Drag the new Piece to the Model Space. The location in the beamline of the "Lingraf Graphics Request" Piece is not important; the PBO Lab PARMILA-Lingraf Module will correctly assign the necessary data when preparing the Lingraf Main Input File 'ingraf.lgf'.

PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module



Step 5 is to open the Piece window for the "Lingraf Graphics Request" Piece. Double-click the "Lingraf Graphics Request" Piece that is located in the beamline on the Model Space. Figure 11 illustrates the "Lingraf Graphics Request" Piece window.

A PARMILA-Lingraf Command Piece may be copied and pasted to another PBO Lab Document, and graphically manipulated like any other PBO Lab Piece.



Tabs Setup Different Graphics Data Specifications

Set the 'Phase Space' Setup Parameter to 1 (Yes) to Create a Display of Phase Ellipses

Scale Settings for Displays

Emittance Contour % Spec

Phase Ellipses Displayed Through This Cell

Phase Ellipses Displayed For Each Cell Step

Figure 11. The "Lingraf Graphics Request" Piece window used for setting up Lingraf graphics data.

Step 6 is to enter a "1" into the "Value" field for the "Phase Space (1=Yes, 0=No)" parameter. As the parameter name indicates, the value "1" corresponds to saying "Yes" create the phase space displays. The other data may be edited as desired. For the example to be run here, no other parameter value modifications are necessary.

The parameter "Phase Spread (Table V-2)" shown in Figure 11 controls the specific layout of the Lingraf graphics window. Negative and zero Value entries result in different phase plane displays. Details are described further in Section 4.

Step 7 is the last step: Select the "Write and Run 'ingraf.lgf' " item on the PARMILA-Lingraf Command Menu. A "cmd.exe" window (similar to that shown in Figure 5) will open and close, and then a Lingraf graphics window will open. For the "SNS DTL Tank 1.pbol" example illustrated here, the Lingraf graphics window should be similar to that shown in Figure 12.



PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module

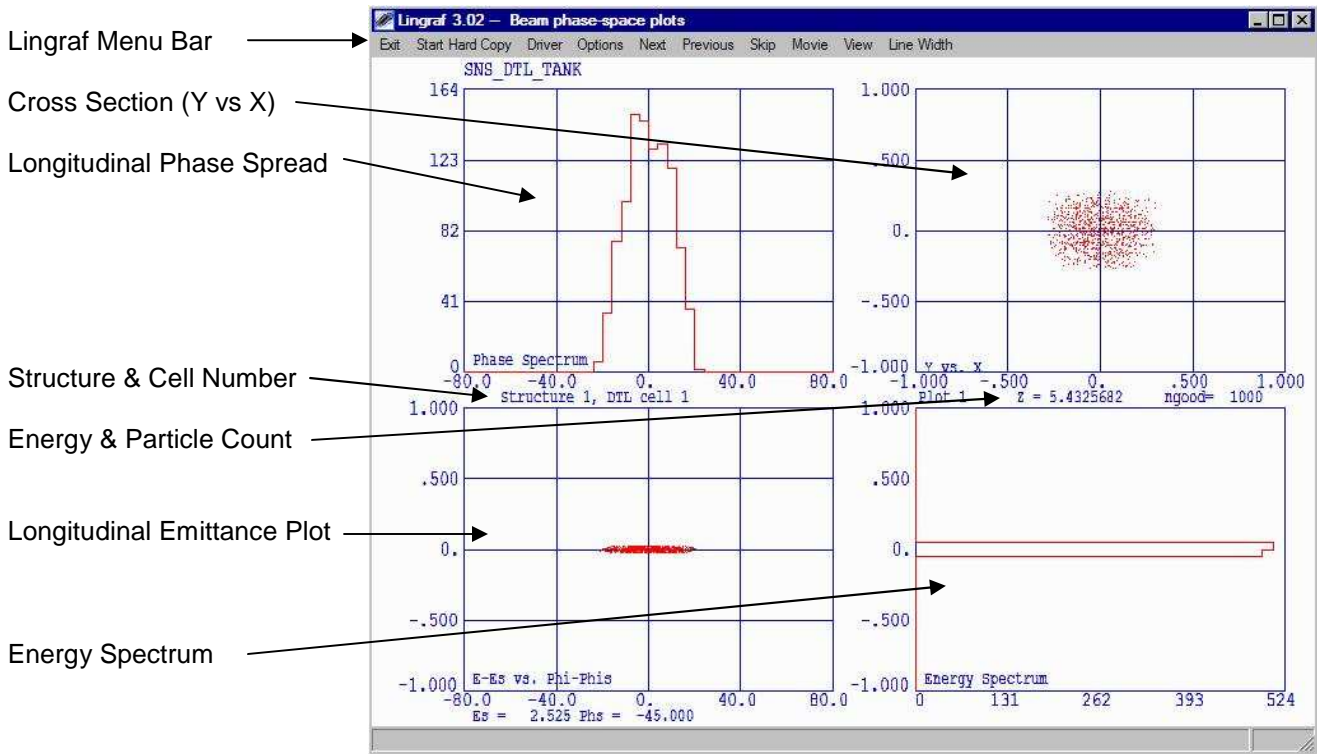


Figure 12. The Lingraf graphics window following selection of the command "Write and Run 'ingraf.lgf'".

The 'LgrafOut.text' file may, or may not, have data in it, depending upon the specific parameter values set in the Lingraf Graphics Request Command Piece. The example shown in Figure 13 is for the parameters illustrated in Figure 11, using the "SNS DTL Tank 1.pbol" example.

Additional information on the Lingraf graphics window is provided in Section 4 of this user manual. When the Lingraf graphics window is closed, a window opens that displays the LgrafOut.txt file. Figure 13 illustrates an example of the LgrafOut.txt window for the "SNS DTL Tank 1.pbol" example.

Lingraf offers several options for graphics displays and the text output of calculated results. All of these use the binary data file 'parmila.plt'. The 'parmila.plt' file is written to the PBO Lab main directory whenever a PARMILA-2 command is executed with an appropriate "PrtBeam" (print beam) PARMILA-2 Command Piece included in the beamline on the Model Space.



```

LgrafOut.txt
File Edit Font

Program Lingraf

(c) Copyright 1985-2005, by the Regents of the University of California.
This software was produced under U. S. Government contract W-7405-ENG-36
by Los Alamos National Laboratory, which is operated by the University
of California for the U. S. Department of Energy. Neither the Government
nor the University makes any warranty, express or implied, or assumes
any liability or responsibility for its use, or represents that use of
this software would not infringe privately owned rights.
Unpublished - rights reserved under Copyright Laws of the United States.

Program Lingraf 3.02 released 7-26-2005

No LANL.INI file found.
Input file: C:\NOASIS\lingraf.lgf 8-13-2008 15:12:04
Plot file: C:\NOASIS\Parmila.plt 8-12-2008 8:16:50

*****
SNS_DTL_TANK
*****

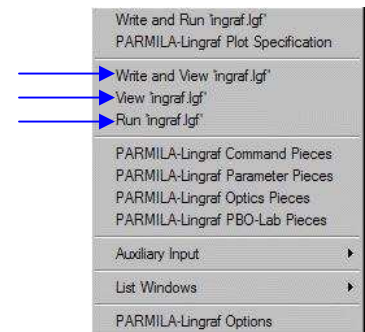
LGF:  : *** LINGRAF INPUT FILE FOR SNS DTL TANK 1 STARTING WITH 1000 PARTICLES. ***
LGF:  : *** CREATED WITH PBO-LAB PARMILA-LINGRAF ***
LGF:  : *** VERSION NUMBER 0.9.1.8 ON 08/13/08 15:12:02. ***
LGF: SUBNUM 7
LGF: OUTPUT 2 1 1.000000E+000 1.000000E+001 8.000000E+001 1.000000E+000 1 100 1
LGF: OPTCON 9.000000E+001
LGF: BEGIN
LGF: SUBNUM 9
LGF: OUTPUT 2 1 0 1 3 5 1 300 1
LGF: OPTCON 300 3 1.000000E+000 2 1.000000E+000 2 9.000000E+001 1
LGF: BEGIN
subnum 7 Unnormalized longitudinal emittance
OUTPUT 2 line parameters:
P1 = 1.0
P2 = 10.0
P3 = 80.0
P4 = 1.0
The column headings are:
plot: plot number corresponding to this line
ngood: number of good particles remaining
zrms: rms unnormalized longitudinal emittance (deg MeV)
z90: unnormalized emittance containing 90% of the beam (deg MeV)
z100: unnormalized emittance containing 100% of the beam (deg MeV)
dPhi_av: phase centroid of the distribution (degrees)
dW_av: energy centroid of the distribution (keV)
alphaz: ellipse alpha in the Z phase plane (dimensionless)
betaz: ellipse beta in the Z phase plane (deg/keV)
Z: longitudinal position at the end of the cell (cm)
W: average beam energy at the end of the cell (MeV)

```

cell	plot	ngood	zrms	z90	z100	dPhi_av	dW_av	alphaz	betaz	Z	W
1	1	1000	0.1175	0.4919	0.6678	0.0012	-0.052	0.014	0.753	5.4326	2.5253
2	2	1000	0.1186	0.4965	0.7385	0.0064	-0.118	0.042	0.742	10.8927	2.5515
3	3	1000	0.1201	0.4959	0.8244	0.0153	-0.158	0.069	0.733	16.3821	2.5784
4	4	1000	0.1213	0.5031	0.8796	0.0280	-0.237	0.080	0.728	21.9031	2.6063

Figure 13. PARMILA-Lingraf window, that displays the 'LgrafOut.txt' data file contents, upon completion of a "Write and Run 'ingraf.lgf'" command.

The three commands "Write and View 'ingraf.lgf'," "View 'input.LIN'," and "Run 'input.LIN'" are used to work with PARMILA-Lingraf Main Input File ('ingraf.lgf') directly. These commands may be helpful if there is a desire to edit the 'ingraf.lgf' file directly, or to examine the details of that file prior to running the Lingraf.exe executable. For the "SNS DTL Tank 1.pbol" example, with the "Lingraf Graphics Request" Piece added, and using the parameter values of Figure 11, the "Write and View 'ingraf.lgf'" will open the 'ingraf.lgf' file window shown in Figure 14.



The 'ingraf.lgf' file maybe examined or edited directly using the 2nd command group.



PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module

```

ingraf.lgf
File Edit Font
: *** LINGRAF INPUT FILE FOR SNS DTL TANK 1 STARTING WITH 1000 PARTICLES. ***
: *** CREATED WITH PBO-LAB PARMILA-LINGRAF ***
: *** VERSION NUMBER 0.9.1.8 ON 08/14/08 10:55:26. ***
SUBNUM 7
OUTPUT 2 1 1.000000E+000 1.000000E+001 8.000000E+001 1.000000E+000 1 100 1
OPTCON 9.000000E+001
BEGIN
:SUBNUM 9
:OUTPUT 2 1 0 1 3 5 1 300 1
:OPTCON 300 3 1.000000E+000 2 1.000000E+000 2 9.000000E+001 1
:BEGIN
END

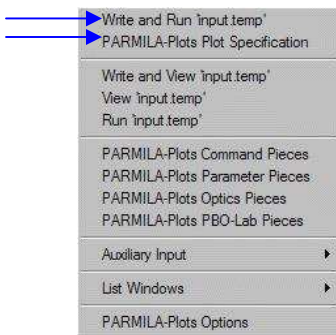
```

Figure 14. The 'ingraf.lgf' file window that opens following the command "Write and View 'ingraf.lgf'".

This completes the introductory discussion of the PARMILA-Lingraf Commands Menu. The PBO Lab file "SNS DTL Tank 1.pbol" was utilized to illustrate an example of the use of Lingraf. Further capabilities of the PARMILA-Lingraf Module are described in Section 4. The remainder of Section 3 summarizes the Command Menus for the PARMILA-Plots and PARMILA-T3D-file parts of the PBO Lab PARMILA 2 Module.

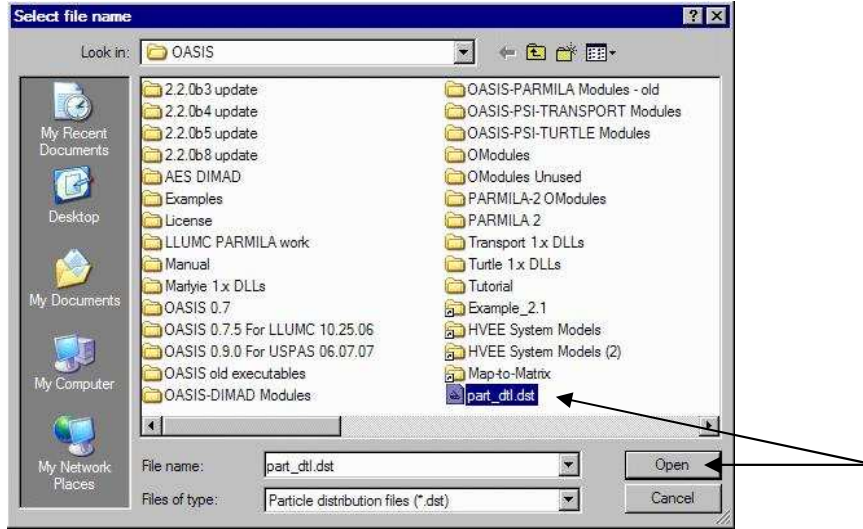
PARMILA-Plots Commands Menu

The layout of the PARMILA-Plots commands menu is similar to that of the PARMILA-2 and PARMILA-Lingraf command menus. However, only two of the command items are used. The illustration in the sidebar to the left indicates the command entries that are used by the PARMILA-Plots module.



PARMILA-Plots utilizes the command items identified with blue arrows (→). The other command entries are not used by PARMILA-Plots.

The PARMILA-Plots command a "Write and Run 'input.temp' " is used to create a text file version of the particle distribution binary data written by PARMILA-2 to the file 'part_dtl.dst'. When the command is selected, the executable "readdst.exe" opens a Windows file selection dialog. An example is illustrated in Figure 15. Select the file named 'part_dtl.dst' and then use to Open button to have that file read by "readdst.exe" executable.



The folder items appearing in the Windows file open dialog (Figure 15) will depend upon the details of your PBO-Lab installation. The file named 'part_dtl.dst' should be among the items displayed. Only files ending with the extension '.dst' can be opened and read by the "readdst.exe" executable.

Select the binary data file named 'part_dtl.dst' to activate the "Open" button. Then select the "Open" button to convert the binary data in the file 'part_dtl.dst' to a text file ('part_dtl.TXT').

Figure 15. A Windows file selection dialog opens following the selection of the PARMILA-Plots command "Write and Run 'input.temp' ". Select the file named 'part_dtl.dst' and push the "Open" button.

Once the "Open" button (Figure 15) has been selected, the executable "readdst.exe" will read the binary data in the file, and then write a text version of the data to a file named 'part_dtl.TXT'. A window will automatically open to display the 'part_dtl.TXT' file following the completion of the data conversion. Figure 16 illustrates the window for the data generated with the PBO Lab example file "SNS DTL Tank 1.pbol".

Three representative PBO Lab Plot Windows will also open following the completion of the "readdst.exe" execution. The three Plot Windows are scatter plots for the X-X', Y-Y' and Energy-Phase phase space planes. Figure 17 illustrates the transverse phase space (X-X', Y-Y') plots for the PBO Lab example file "SNS DTL Tank 1.pbol". Figure 18 shows the longitudinal phase space (Energy-Phase) plot for the same example.



PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module

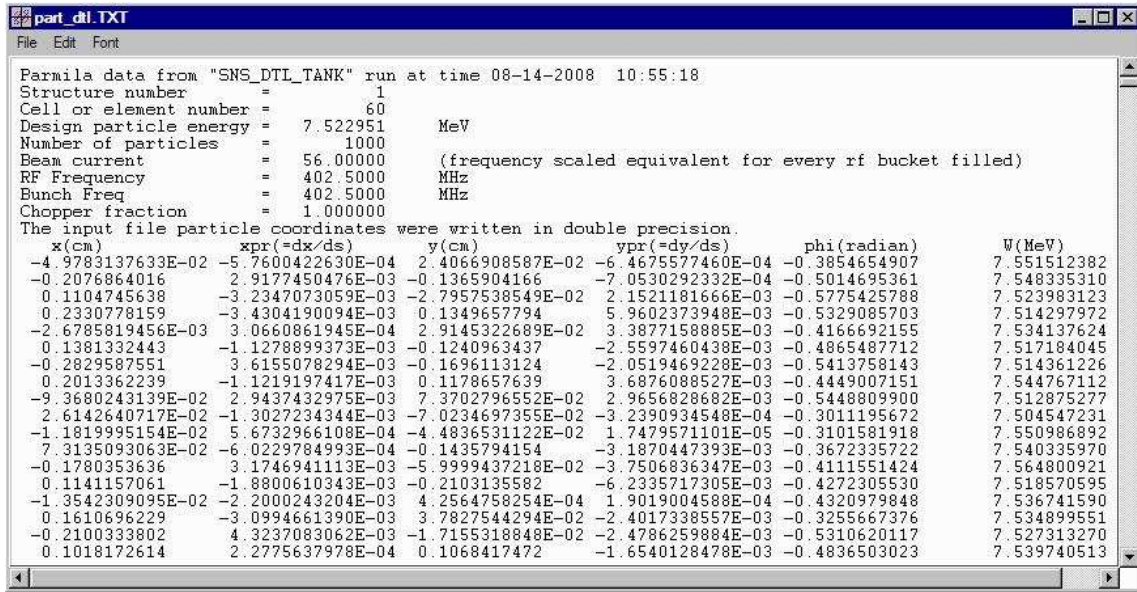


Figure 16. The window displaying the 'part_dtl.TXT' file that opens following the conversion of the 'part_dtl.dst' file by the 'part_dtl.dst' program. The data in this file is used by the PARMILA-Plots module for various graphics displays.

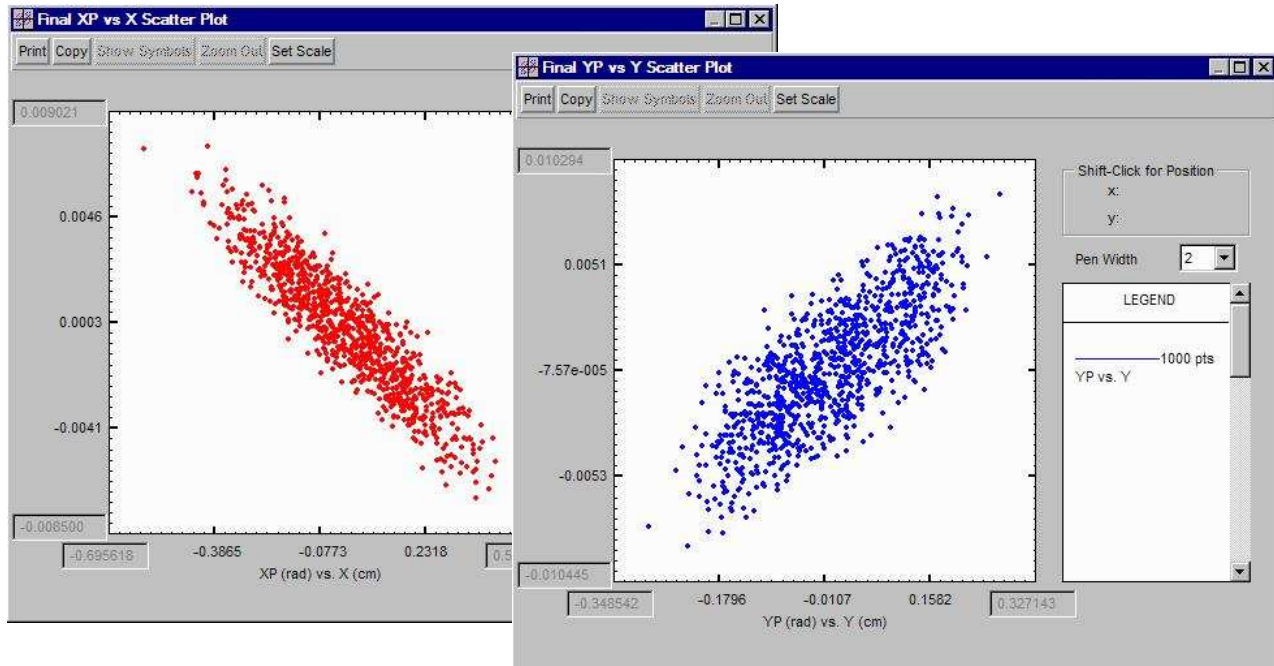
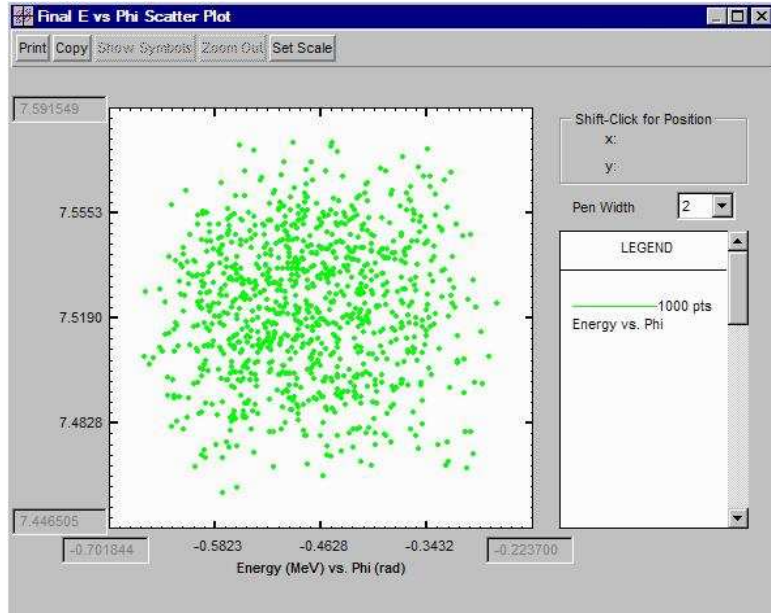


Figure 17. Default transverse phase space plots displayed following completion of the PARMILA-Plots command "Write and Run 'input.temp'".



The examples shown in Figures 17 and 18 have used the Pen Width selector to increase the point size of the data displayed. All other settings are default values, which include the PBO Lab Plot Window automatic scale settings to assure that all data will appear in the Figures.

Figure 18. Default longitudinal phase space plot that is displayed following completion of the PARMILA-Plots command "Write and Run 'input.temp'".

Figures 17 and 18 illustrate the three *default* PBO Lab Plot Windows that open following the completion of the "readdst.exe" execution. Many other *built-in* plot options are available as part of the PARMILA-Plots and PARMILA-2 Modules. These other plot options are accessed using the "PARMILA-Plots Plot Specification" command *or* the "PARMILA-2 Plot Specification" command. Figure 19 illustrates the list of Plot Specifications that are available for these commands. Both the "PARMILA-Plots Plot Specification" and the "PARMILA-2 Plot Specification" commands provide similar selections. Figure 20 shows the selection of these two commands, both of which lead to a Plot Specifications list similar to the list shown in Figure 19.

The Plot Windows that open following the execution of the PARMILA-Plots command "Write and Run 'input.temp' ", or with any Plot Window opened through a "PARMILA-Plots Plot Specification" or a "PARMILA-2 Plot Specification" command, support all of the interactive capabilities of the PBO Lab Plot Windows. The scales may be changed (Set Scale button), the point size adjusted (Pen Width selector), the display printed (Print button) or copied (Copy button) for use in another document, etc. See the PBO Lab Basic Package User Manual for more information.



PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module

Select a plot option to activate the "Plot Selection" button.

Use the "Plot Selection" button to display the selected plot option.

Type	Description	Data File Name	Open
Scatter	Final Energy vs Phase	part_dtl.TXT	Manual
Scatter	Final Beam energy Profile	part_dtl.TXT	Manual
Histogram	Final Beam phase Profile	part_dtl.TXT	Manual
Histogram	Final Beam x Profile	part_dtl.TXT	Manual
Histogram	Final Beam xp Profile	part_dtl.TXT	Manual
Scatter	Final Beam x' vs x	part_dtl.TXT	Manual
Histogram	Final Beam y Profile	part_dtl.TXT	Manual
Scatter	Final Beam y' vs x	part_dtl.TXT	Manual
Histogram	Final Beam yp Profile	part_dtl.TXT	Manual
Scatter	Final Beam y' vs x'	part_dtl.TXT	Manual
Scatter	Final Beam y' vs y	part_dtl.TXT	Manual

Figure 19. Plot Options available for the PARMILA-Plots (or PARMILA-2) Module using the command "PARMILA-Plots Plot Specification" (or "PARMILA-2 Plot Specification").

Figure 20. Several *built-in* plot options are available as part of both the PARMILA-Plots Module and the PARMILA-2 Module.

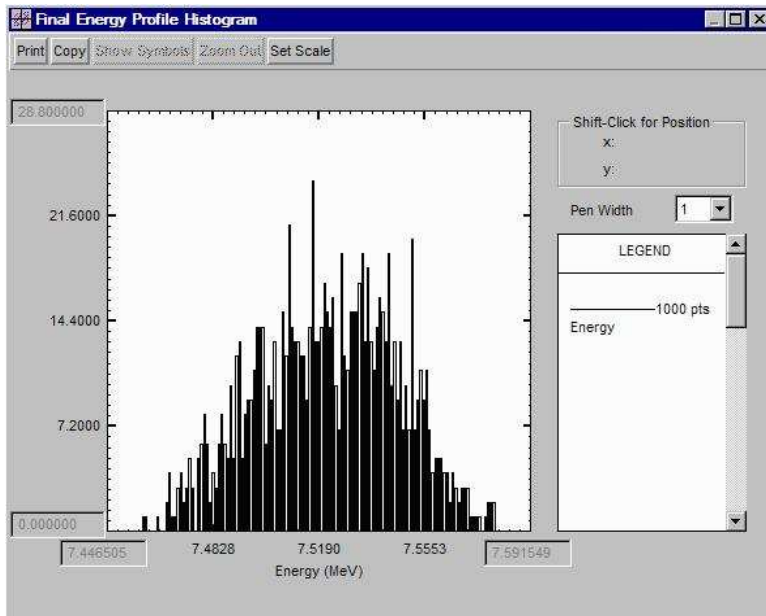
Plot Specification commands of both the PARMILA-2 and PARMILA-Plots utilize the same 'part_dtl.TXT' data file. The "readdst.exe" executable needs to be run (Write and Run 'input.temp') whenever a new binary distribution file (part_dtl.dst) has been created by PARMILA-2.

Figure 20 illustrates the virtual equivalence of accessing the Plot Specifications from either the PARMILA-2 or PARMILA-Plots command menus. However, it needs to be remembered that the PARMILA-Plots command "Write and Run 'input.temp' " *must be selected at least one time* after executing a PARMILA -2 "Write and Run 'input.LIN' " command.

PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module



An example of a built-in Plot Option is shown in Figure 21. The illustration is the histogram plot displayed using the "Final Beam energy Profile" PARMILA-2 Plot Option (see Figure 19) for the PBO Lab example file "SNS DTL Tank 1.pbol".



The built-in PARMILA-2 Plot Options have displays that support all of the interactive capabilities of the PBO Lab Plot Windows. The scales may be changed (Set Scale button), the point size adjusted (Pen Width selector), the display printed (Print button) or copied (Copy button) for use in another document, etc. See the PBO Lab Basic Package User Manual for more information.

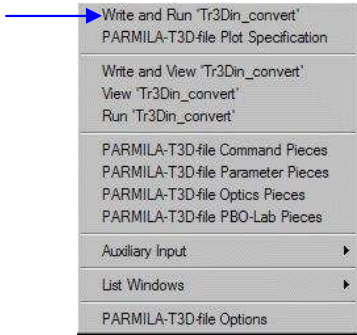
Figure 21. Example of an additional built-in plot display available in the PBO Lab PARMILA-2 Module.

In addition to the *built-in* plot options available as part of the PARMILA-Plots and PARMILA-2 Modules, users may create *customized* Plot Windows using the PBO Lab 3.0 Tools menu. The use of these tools is described in the PBO Lab Basic Package User Manual.



PARMILA-T3D-file Commands Menu

The PARMILA-T3D-file Module is used to create a *basic element* PBO-Lab Subline Model that is equivalent to the PARMILA-2 beamline that is on the PBO Lab Model Space. The equivalent *basic element* PBO-Lab Subline Model may be used to simulate the PARMILA-2 generated design *using any other* PBO Lab Application Module such as TRANSPORT, TURTLE, TRACE 3-D or MARYLIE.



PARMILA-T3D-file utilizes the one command item identified with the blue arrow (→). Selection of this command results in the creation of a PBO Lab object model file called 'Tr3Din.pbop'.

The layout of the PARMILA-T3D-file commands menu is parallels that of other PARMILA-2 command menus. However, only one of the items is used, the "Write and Run 'Tr3Din_convert' " command. This command operates on the PARMILA 2 generated file named 'Tr3Din.t3d'. The data in the 'Tr3Din.t3d' file provides a TRACE 3-D type lattice description of the beamline. That lattice description is converted into a PBO Lab object model representation of the beamline when the "Write and Run 'Tr3Din_convert' " command is executed.



The PARMILA-T3D-file Module also utilizes the PBO Lab Edit menu to import the PBO Lab object model file called 'Tr3Din.pbop'.

The PBO Lab model created by the PARMILA-TD-file Module is written to a file named 'Tr3Din.pbop' which can then be read by PBO Lab. If the command is successfully completed, a text file window will open and display the PBO Lab object model data in the file 'Tr3Din.pbop'. An example of this file is illustrated in Figure 22. The file is displayed for information purposes only in order to signify completion of the the "Write and Run 'Tr3Din_convert' " command.

Use the Edit menu of the Document Window to select the item "Import Pieces (.pbop)." This will open a standard Windows file selection dialog similar to that illustrated previously in Figure 15. Navigate to the file named 'Tr3Din.pbop' and select 'Open'.



```

Tr3Din.pbop
File Edit Font
////////////////////////////////////
"PBO-Lab, G.H. Gillespie Associates"
"Version"2.12

"Subline"                318
"Component"              301
"ConstraintAttach"       1
"END"
////////////////////////////////////

"Component"  5 { "piece" "" "Quad" ( "comment" "Quad Comment" "Q  5" )( "real" "Effective Ls
"Component"  6 { "piece" "" "Drift" ( "comment" "Drift Comment" "D  6" )( "real" "Effective
"Component"  7 { "piece" "" "RF Gap" ( "comment" "RF Gap Comment" "G  7" )( "real" "Effectiv
"Component"  8 { "piece" "" "Drift" ( "comment" "Drift Comment" "D  8" )( "real" "Effective
"Component"  9 { "piece" "" "Quad" ( "comment" "Quad Comment" "Q  9" )( "real" "Effective Ls
"Component" 10 { "piece" "" "Quad" ( "comment" "Quad Comment" "Q 10" )( "real" "Effective Ls
"Component" 11 { "piece" "" "Drift" ( "comment" "Drift Comment" "D 11" )( "real" "Effective
"Component" 12 { "piece" "" "RF Gap" ( "comment" "RF Gap Comment" "G 12" )( "real" "Effective
"Component" 13 { "piece" "" "Drift" ( "comment" "Drift Comment" "D 13" )( "real" "Effective
"Component" 14 { "piece" "" "Quad" ( "comment" "Quad Comment" "Q 14" )( "real" "Effective Ls
"Component" 15 { "piece" "" "Quad" ( "comment" "Quad Comment" "Q 15" )( "real" "Effective Ls
"Component" 16 { "piece" "" "Drift" ( "comment" "Drift Comment" "D 16" )( "real" "Effective
"Component" 17 { "piece" "" "RF Gap" ( "comment" "RF Gap Comment" "G 17" )( "real" "Effective
"Component" 18 { "piece" "" "Drift" ( "comment" "Drift Comment" "D 18" )( "real" "Effective
"Component" 19 { "piece" "" "Quad" ( "comment" "Quad Comment" "Q 19" )( "real" "Effective Ls
"Component" 20 { "piece" "" "Quad" ( "comment" "Quad Comment" "Q 20" )( "real" "Effective Ls
"Component" 21 { "piece" "" "Drift" ( "comment" "Drift Comment" "D 21" )( "real" "Effective
"Component" 22 { "piece" "" "RF Gap" ( "comment" "RF Gap Comment" "G 22" )( "real" "Effective
    
```

Figure 22. Example of a 'Tr3Din.pbop' file that opens after the completion of the "Write and Run 'Tr3Din_convert'" command. The example is for "SNS DTL Tank 1.pbol".

When the file named 'Tr3Din.pbop' has been imported a Subline will appear on the Work Space of the Document Window. This Subline Piece will appear in the lower left corner of the Work Space, similar to that illustrated previously in Figure 10. The newly created Subline can be moved to the Model Space for use with other PBO Lab Modules.



After the importation of a 'Tr3Din.pbop' file, a Subline with the individual Piece data will in lower part of the Work Space.

Depending upon the size of the PARMILA linac from which it was created, the Subline imported from the 'Tr3Din.pbop' file will included *nested* Sublines. Double-clicking the Subline will open a window similar to that shown in Figure 23, which illustrates the first level of nesting. Double-clicking on one of the interior (nested) Sublines will open a window that displays the details of that Subline. Figure 24 illustrates the details for the second Subline of Figure 23.



The imported Subline can be dragged to the Model Space for use in other PBO Lab Modules.



PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module

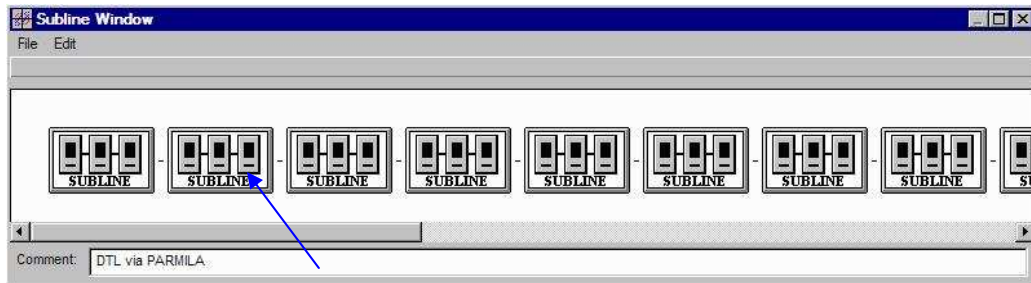


Figure 23. Example of a Subline created with the PARMILA-T3D-file Module. The example is for "SNS DTL Tank 1.pbol". Double-clicking the 2nd Subline in this window will open a view of the details of the 2nd Subline, as shown in Figure 24.

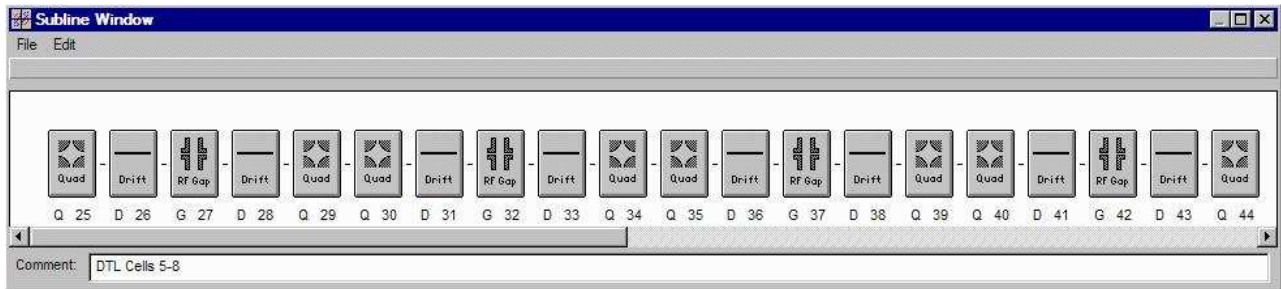
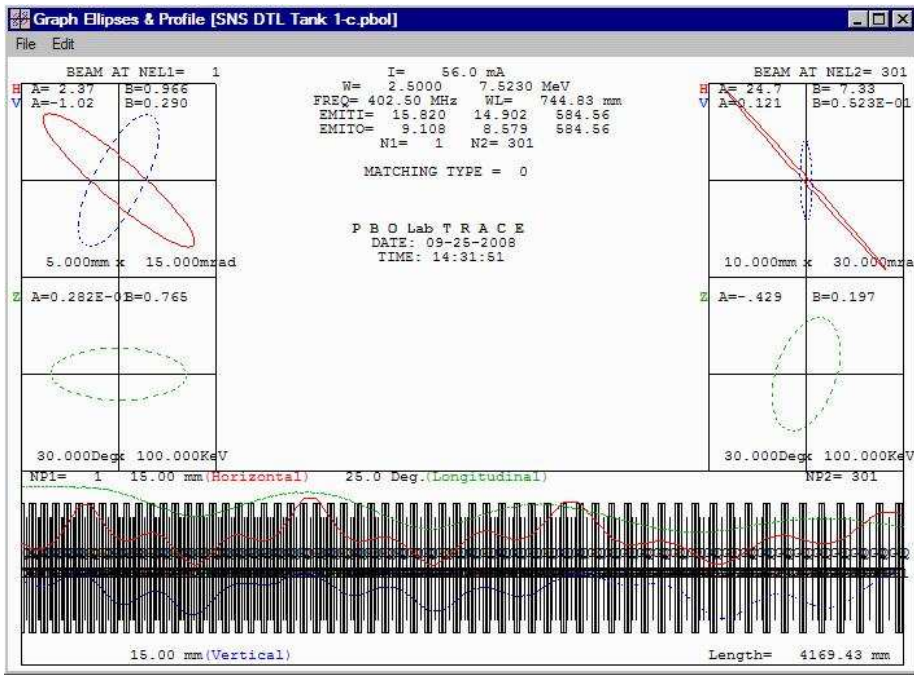


Figure 24. Details of the second interior Subline for the example illustrated in Figure 23. The individual Pieces comprising the first four cells of the PARMILA design for the example "SNS DTL Tank 1.pbol" drift tube linac.

Any Subline created with the PARMILA-T3D-file Module can be used with other PBO Lab Modules. Figure 25 illustrates a TRACE 3-D Module simulation of the Subline example of Figures 23 and 24. Figure 26 shows a TRANSPORT Module simulation for the same Subline.



The use of equivalent Sublines, for PARMILA-2 generated beamline designs, allows the easy comparison of results for different modeling and simulation codes.

Different simulation codes employ different physics models. Comparing results from different codes can help to identify issues that may need further study.

Figure 25. Result of using the Graph Beam Line command of the TRACE 3-D Module for the Subline illustrated in Figures 23 and 24.

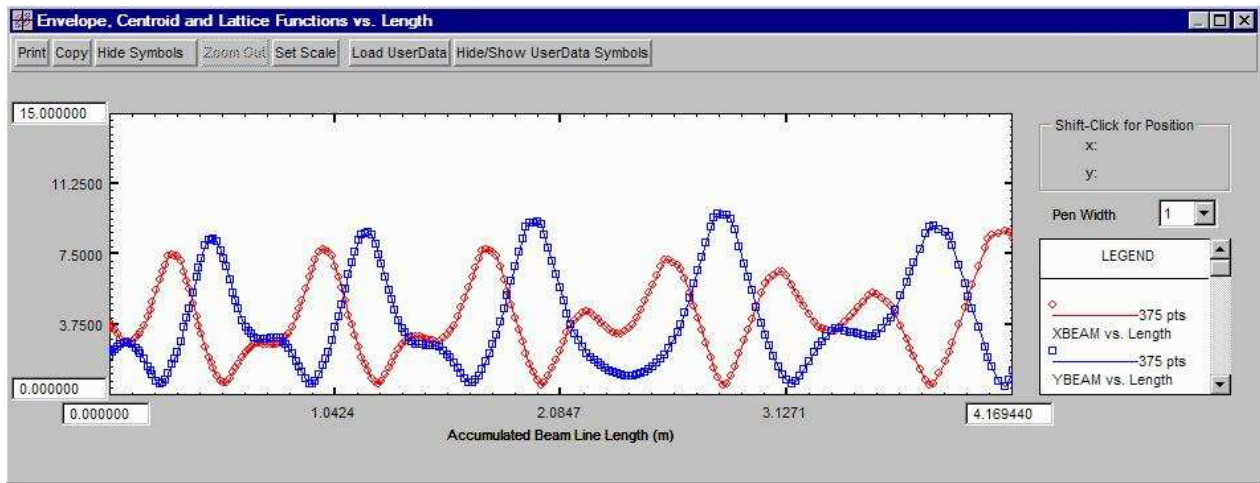


Figure 26. Example of a TRANSPORT Module beam envelope simulation for the Subline illustrated in Figures 23 and 24.



PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module

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PBO Lab™

3. PARMILA-2 Supported Pieces

**User Manual:
Supplement:
PARMILA-2
Application
Module**



PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module

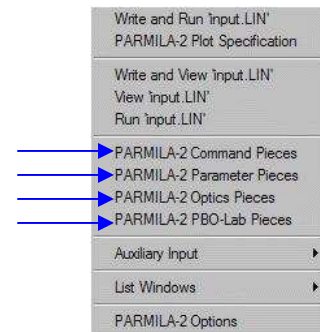
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3. PARMILA-2 Supported Pieces

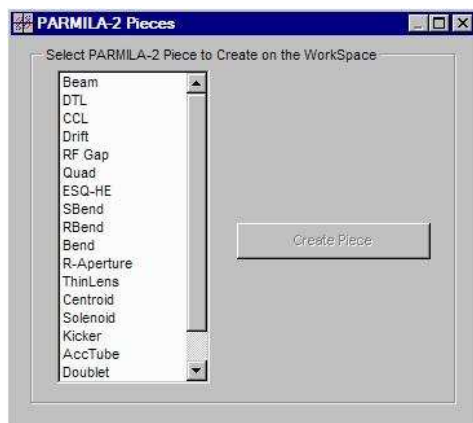
A summary of the Pieces appearing on the PBO Lab Palette Bar that are supported by the PARMILA-2 Module was presented in Section 1, Getting Started. Those Pieces include common transport elements as well as specialized Pieces used for the complex accelerator structures that PARMILA-2 can be used to design. All of the PARMILA-2 Pieces may be accessed using four items appearing on the PARMILA-2 Commands menu:

- PARMILA-2 Command Pieces
- PARMILA-2 Parameter Pieces
- PARMILA-2 Optics Pieces
- PARMILA-2 PBO-Lab Pieces



Pieces supported by the PARMILA-2 Module can be accessed from entries on the Commands submenu.

For example, selecting the menu item "PARMILA-2 PBO-Lab Pieces" opens the window illustrated in Figure 27. Pieces listed in the window can be selected and then created using the Create Piece button. The list can also be used to determine which PBO Lab Palette Pieces are supported by the PARMILA-2 Module.

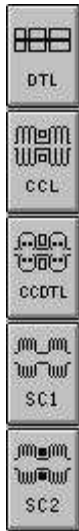


The PARMILA-2 Piece window can be used to confirm whether or not a PBO Lab Palette Piece is supported in the PARMILA-2 Module.

Figure 27. The PARMILA-2 Pieces window lists all of the PBO Lab Palette Bar Pieces used by the PARMILA-2 Module.



PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module



PARMILA-2 can be used to design several complex linear accelerator components. Each of these complex components is represented by a Piece on PBO Lab Palette Bar of the PARMILA-2 Module.

Each occurrence of a PBO Lab DTL, CCL, CCDTL, SC1 or SC2 Piece in the Model Space creates one STRUCTURE section in the PARMILA-2 input.LIN file.

Many of the PBO Lab Pieces for describing transport lines (drifts, quadrupoles, bends, etc.) are supported by the PARMILA-2 Module. The set up of transfer lines, and the selection of parameters for the individual Pieces in a transfer line, follow the standard PBO Lab procedures used for any PBO Lab Optics Application Module. A special "TRANSPORT STRUCTURE" PARMILA-2 Command Piece, described later in this manual (in the PARMILA-2 Command Piece section), is used to define the start of a transfer segment. Otherwise the set up of a transfer section is similar to that for any other PBO Lab Module.

The PARMILA-2 Module has five (5) unique Pieces that are used for both the design and simulation of linear accelerators. These Pieces include:

- DTL for Drift Tube Linac
- CCL for Coupled Cavity Linac
- CCDTL for Coupled Cavity Drift Tube Linac
- SC1 for Missing Quad Superconducting Linac
- SC2 for Grouped Quad Superconducting Linac

The accelerator structures used for these of types of linacs included radiofrequency cavities for acceleration and longitudinal focusing, with magnetic quadrupole lenses for transverse focusing. These structures are "complex" when compared to individual particle optics elements such as a radiofrequency gap or one magnetic quadrupole. One of the main capabilities of PARMILA 2 is that it generates *designs* for these complex structures starting with a set of user-specified goals or objectives. The PBO Lab Pieces for these complex structures have been developed to aid the user in setting up these design goals.



Drift Tube Linac (DTL) Piece

The DTL Piece is used to set up the main parameters for either *designing* or *simulating* a drift tube linac. The parameters are grouped into four (4) categories:

- RF Field
- Quads
- Field Ramp
- Geometry

The Piece Window for the DTL Piece has one tab panel for each of these parameter groups. The RF Field tab panel appears in front when a DTL Piece window is opened. Figure 28 illustrates the tab panel for the RF Field parameters.

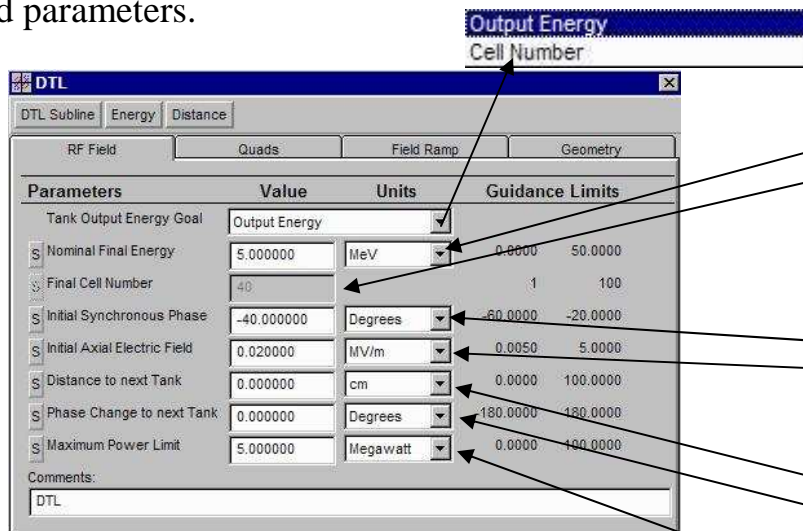
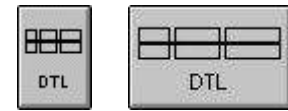


Figure 28. RF Field tab panel for a DTL Piece.

The RF Field parameters for a DTL Piece provide the top level field and output energy design objectives for one drift tube linac tank. Each tank of a multiple-tank drift tube linear accelerator is represented by separate DTL Piece. A key parameter used in designing a DLT tank is the final energy goal for the tank. This can be specified as *either* a "Nominal Final Energy" *or* a "Final Cell Number" goal. PBO Lab automatically formats the input for these two options.



DTL Piece

The DTL Piece is part of the PARMILA 2 Module. An equivalent Subline can be created with the PARMILA 2 Module that can then be used for other PBO Lab Modules.

Use one DTL Piece for each tank of a multiple-tank drift tube linac.

Tank Output Energy Goal is a primary design objective: that goal can be specified as *either*:

- Nominal Final Energy, or
- Final Cell Number

The RF Field tab is used for setting the starting (Initial) values for the radiofrequency (RF) phase and amplitude:

- Synchronous Phase, and
- Axial Electric Field

Two parameters are related to the tank following this one:

- Distance to Next Tank, and
- Phase Change to Next Tank

A Maximum Power Limit goal for the tank may also be specified. If set to zero, it is ignored.

The parameters on the RF Field tab page correspond to the following parameter numbers in Table IV-4 of the Appendix:
2, 3, 4, 7, 8, 19.

The tank number (parameter 1 of Appendix Table IV-4) is automatically set by the PBO Lab PARMILA 2 Module.



Cell	V	Beta	Lc	SL1(N)	g	SL2(N+1)	dg	Lq	G	E0	Phi	Z
initial	2.5000	0.07281				2.2551		3.5000	-3.7000			0.0000
1	2.5253	0.07318	5.4326	2.2676	0.9099	2.2673	0.0062	3.5000	0.0000	1.1300	-45.0000	5.4326
2	2.5515	0.07356	5.4601	2.2801	0.9128	2.2802	0.0064	3.5000	3.7000	1.1550	-45.0000	10.8927
3	2.5784	0.07394	5.4894	2.2933	0.9158	2.2942	0.0066	3.5000	3.7000	1.1802	-44.9388	16.3821
4	2.6063	0.07434	5.5210	2.3077	0.9191	2.3075	0.0067	3.5000	0.0000	1.2055	-44.7158	21.9031
5	2.6352	0.07475	5.5510	2.3214	0.9222	2.3212	0.0069	3.5000	-3.7000	1.2310	-44.4887	27.4541
6	2.6651	0.07517	5.5820	2.3354	0.9254	2.3351	0.0071	3.5000	-3.7000	1.2566	-44.2571	33.0362
7	2.6961	0.07560	5.6139	2.3498	0.9289	2.3495	0.0073	3.5000	0.0000	1.2823	-44.0211	38.6500
8	2.7282	0.07605	5.6467	2.3646	0.9326	2.3643	0.0075	3.5000	3.7000	1.3082	-43.7807	44.2967
9	2.7614	0.07651	5.6804	2.3798	0.9364	2.3795	0.0077	3.5000	3.7000	1.3343	-43.5359	49.9772
10	2.7957	0.07698	5.7152	2.3954	0.9403	2.3951	0.0080	3.5000	0.0000	1.3605	-43.2867	55.6924
11	2.8313	0.07747	5.7509	2.4115	0.9443	2.4112	0.0082	3.5000	-3.7000	1.3869	-43.0332	61.4433
12	2.8681	0.07797	5.7877	2.4280	0.9485	2.4276	0.0084	3.5000	-3.7000	1.4134	-42.7755	67.2310
13	2.9062	0.07848	5.8255	2.4448	0.9531	2.4444	0.0086	3.5000	0.0000	1.4401	-42.5134	73.0565
14	2.9457	0.07901	5.8644	2.4622	0.9578	2.4618	0.0089	3.5000	3.7000	1.4670	-42.2472	78.9209
15	2.9865	0.07955	5.9044	2.4800	0.9626	2.4796	0.0091	3.5000	3.7000	1.4940	-41.9769	84.8252
16	3.0288	0.08011	5.9455	2.4983	0.9675	2.4979	0.0093	3.5000	0.0000	1.5213	-41.7024	90.7707
17	3.0726	0.08069	5.9877	2.5171	0.9728	2.5165	0.0096	3.5000	-3.7000	1.5487	-41.4238	96.7584
18	3.1179	0.08128	6.0311	2.5362	0.9783	2.5357	0.0099	3.5000	-3.7000	1.5764	-41.1413	102.7895
19	3.1648	0.08188	6.0757	2.5560	0.9840	2.5555	0.0101	3.5000	0.0000	1.6042	-40.8548	108.8652
20	3.2133	0.08250	6.1215	2.5762	0.9898	2.5757	0.0104	3.5000	3.7000	1.6322	-40.5645	114.9867
21	3.2636	0.08314	6.1686	2.5970	0.9960	2.5963	0.0107	3.5000	3.7000	1.6605	-40.2704	121.1553
22	3.3156	0.08380	6.2170	2.6181	1.0026	2.6175	0.0109	3.5000	0.0000	1.6890	-39.9726	127.3723
23	3.3695	0.08448	6.2666	2.6399	1.0093	2.6392	0.0112	3.5000	-3.7000	1.7177	-39.6712	133.6389
24	3.4253	0.08517	6.3176	2.6622	1.0161	2.6614	0.0115	3.5000	-3.7000	1.7466	-39.3663	139.9565
25	3.4830	0.08588	6.3700	2.6850	1.0235	2.6842	0.0118	3.5000	0.0000	1.7758	-39.0578	146.3265
26	3.5428	0.08661	6.4237	2.7084	1.0311	2.7076	0.0121	3.5000	3.7000	1.8052	-38.7461	152.7502

Figure 30. Geometry cell table for a drift tube linac (DTL) in the file 'Parmila.out'.

The Quads tab panel of the DTL Piece window is used for specifying the top level design goals for the magnetic quadrupoles used for transverse focusing in a DTL. Figure 31 illustrates the tab panel for the quadrupole parameters.

The DTL geometry cell table (Figure 30) gives the design values for the DTL parameters illustrated in Figure 29. The Parmila.out file also provides a text description of these parameters immediately before the cell table data.

DTL Subline Energy Distance

RF Field Quads Field Ramp Geometry

Parameters	Value	Units	Guidance Limits
Constant Term in Quad Eq.	2.310000		0.0000 5.0000
Linear Term in Quad Eq.	7.000000		0.0000 10.0000
Length of Quad Magnets	Use Fixed Length		
Effective Quad Length	0.500000	Lambda	0.1000 0.7500
Ratio of Quad/Cell Length	0.500000		0.1000 0.7500
Quad Sequencing	FD Lattice		
Quad Sequence Start Point	1 - First Quad Focusing		
Quad at Tank Entrance	Full Length Quadrupole		
Quad at Tank Exit	Full Length Quadrupole		

Annotations:

- Coefficients C_0 and C_1 in the Quadrupole Gradient Formula
- Use Fixed Length
- Use Length Ratio
- Specify Quad Fixed Length or Quad Length / Cell Length
- Quadrupole Lattice Options:
 - FD Lattice
 - FFDD Lattice
 - FODD Lattice
 - FFFDDDD Lattice
 - FFODDD Lattice
- Entrance, Exit Quad Geometry

Figure 31. Quads tab panel for a DTL Piece.

PARMILA 2 uses a formula for estimating the gradients (B') of the magnet quadrupoles inside the drift tubes. The first 2 parameters of the Quad tab are coefficients in this formula. The Quad Formula is given on the next page.

The parameters on the Quads tab page correspond to the following parameter numbers in Table IV-4 of the Appendix: 9, 10, 11, 12, 13, 14



PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module

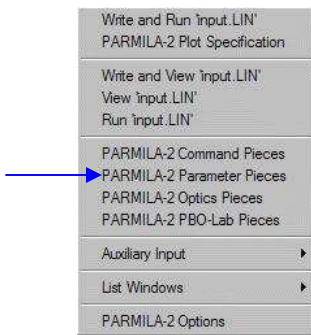
$$\text{Quad Formula: } B' = [L_c/(2L_q)] [\gamma/(c\beta)] \{ C_0 (mc^2)/(q\lambda^2) + C_1 (\pi E_0 T \sin \phi_s)/(\lambda \beta \gamma^3) \}$$

The Quad Formula is given in the PARMILA 2 documentation (Appendix) but is also repeated here for clarity. The values of C_0 and C_1 are the first two parameters appearing in the Quad tab panel of the DTL Piece Window. In the Quad Formula, the speed of light is given by c . The particle mass (m), particle charge (q), and radiofrequency wavelength (λ) are determined by the corresponding Global Parameters (see Figure 10). The other parameters in the Quad Formula (L_c , L_q , β , γ , E_0 , T , ϕ_s) are computed by PARMILA-2 for each cell of the DTL.



Choices for specifying the DTL Length of Quad Magnets

The Length of Quad Magnets, L_q , determines the ratio $[L_c/(2L_q)]$ where L_c is the cell length. In Figure 29, the length $L_c = L_N$ for cell N , and the length $L_q = 2DQ_N$ for cell N . Two primary options are available for specifying the design goals for L_q : "Use Fixed Length" (in cm) or "Use Length Ratio". When the "Use Fixed Length" choice is selected, the "Effective Quad Length" parameter is utilized for entering the design goal value. The value may be entered using any of several PBO Lab choices for units, and the "Effective Quad Length" in cm will be written to the PARMILA-2 input file ('input.Lin'). The value of $[L_c/(2L_q)]$ will then be computed for each cell. When the "Use Length Ratio" choice is selected, the goal value is set in the "Ratio of Quad/Cell Length" parameter field. This choice effectively sets a fixed goal for $[L_c/(2L_q)]$ that is independent of the cell number.



Goals for the DTL quadrupole gradients and lengths can be further modified using certain change options implemented through PBO Lab PARMILA-2 Parameter Pieces.

The top level goals for the quadrupole lengths and gradients can be modified with the use of *Change* lines in the PARMILA-2 input file 'input.Lin'. Change lines are implemented using PARMILA-2 Parameter Pieces. The PARMILA-2 Parameter Pieces are described later in this section.



PARMILA-2 offers five basic options for the quadrupole lattice structure. The "Quad Sequence" parameter is used to select these options. The options are designated by the polarity sequence of the quadrupoles inside a sequential set of drift tubes. The sequence contains a combination of "F" (for focusing in the x direction) and "D" (for defocusing) quadrupole specifications, and may also contain "O" specifications for an empty drift tubes (no quadrupole inside).

For a specific "Quad Sequence" selection an additional parameter is used to specify how the sequence starts. The "Quad Sequence Start Point" parameter determines the initial quad polarity at the start of the DTL tank. Not all start point options are meaningful for every choice of quadrupole sequence. Figure 32 illustrates the "Quad Sequence Start Point" options that are appropriate for each Quad Sequence selection.

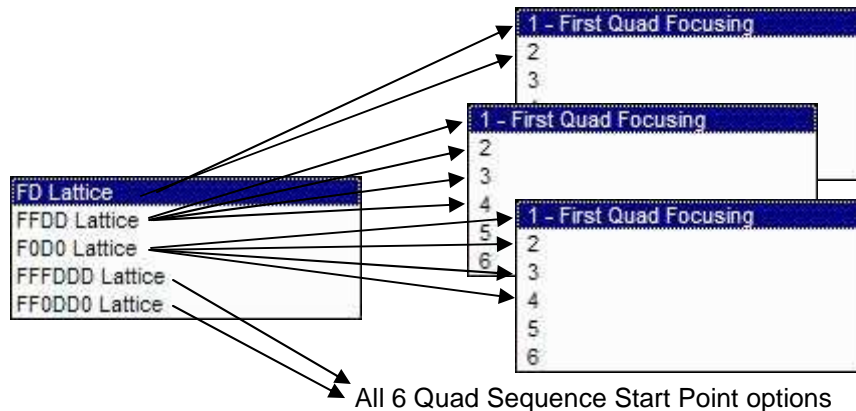


Figure 32. Meaningful options for the "Quad Sequence Start Point" are tied to the choice of "Quad Sequence".

The initial (entrance) and final (exit) quadrupole length can each be specified as either a "Half Length Quadrupole" or as a "Full Length Quadrupole". The "Half Length Quadrupole" choice is useful when only half of a quadrupole is physically located within a DTL tank. A matching half quadrupole may be included in an adjacent TRANSPORT line.

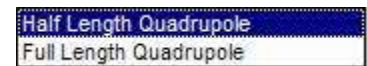


Five Quad Sequence options are available for the DTL quadrupole lattice. F means focusing in the x, or horizontal, direction.



Quad Sequence Start Point options depend upon the selection for Quad Sequence.

The first "n" Quad Sequence Start Point options are available for a given Quad Sequence selection, where "n" is the number of symbols (F, D or O) in the lattice description. For example, there are four symbols in the FODD lattice description, so n=4. Thus the first 4 choices for Quad Sequence Start Point are meaningful for a FODD lattice.



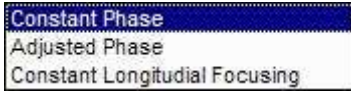
Two choices are available for specifying the Quad at Tank Entrance or the Quad at Tank Exit.



PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module

The Field Ramp tab panel of the DTL Piece window is used for setting selected design goals for the variations in the accelerating field and/or synchronous phase. Figure 33 illustrates the Field Ramp tab panel.

A Linear Ramp in Eo has Three Options for the Phase:



Field-tilt Coefficient specifies the Linear Ramp in Eo

Maximum Value for Eo

Eo Ramp Starting Location

Start Cell for Phase Ramp

Start Cell for Phase Ramp

Limit to Phase Ramp

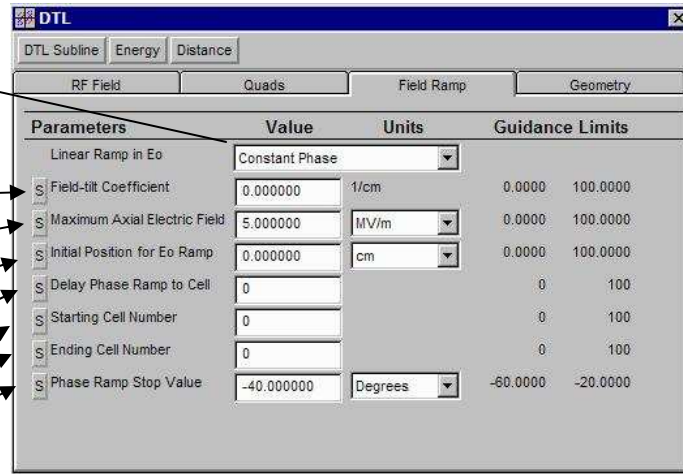


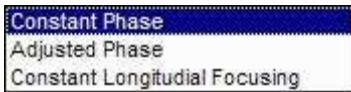
Figure 33. Field Ramp tab panel for a DTL Piece.

The parameters on the Field Ramp tab page correspond to the following parameter numbers in Table IV-4 of the Appendix:

22, 5, 6, 15, 23, 24, 25, 26

The starting values for the axial accelerating field and synchronous phase are given by the "Initial Axial Electric Field" and "Initial Synchronous Phase" parameters on RF Field tab panel (see Figure 28). Specifying a zero "Field-tilt Coefficient" (default value) corresponds to a flat field, i.e. no ramp is used. For this "no ramp" case, the other parameters on the Field Ramp tab panel are not significant and will be ignored by PARMILA 2.

If the "Field-tilt Coefficient" is non-zero, then the DTL design goals will include a field ramp, and the other parameters on the Field Ramp tab panel will be significant. The "Linear Ramp in Eo" selection on the Field Ramp tab panel is used to specify the *RampType*. The first choice corresponds to a "Constant Phase", while the second choice corresponds to an "Adjusted Phase" that maintains a fixed width (in cm) of the zero-current separatrix. The third choice corresponds to "Constant Longitudinal Focusing". This also maintains a fixed width for the zero-current separatrix, but adjusts the field ramp as well (no longer linear).



PARMILA 2 has 3 RampType choices.



When the *RampType* is set to "Constant Phase", the "Field-tilt Coefficient", C_{Tilt} , and "Initial Position for E_o Ramp", Δz_E , are used to compute the axial accelerating field at each cell location from the formula given in the PARMILA 2 documentation (Appendix):

$$E_{o,cell} = E_o [1.0 + C_{Tilt}(z_{cell} - \Delta z_E)] \text{ for } z_{cell} > \Delta z_E$$

The "Initial Axial Electric Field", E_o , is the value entered in the RF Field tab panel (see Figure 28). The value of z_{cell} is the (approximate) location of the center of the cell (e.g. at the location between L_N and L_{N+1} illustrated in Figure 29). The ramp is continued to the end of the tank, unless $E_{o,cell} = E_{o,max}$ where $E_{o,max}$ is the "Maximum Axial Electric Field". The ramp is then terminated, and $E_{o,cell}$ is held constant. The phase of the RF, ϕ_s , is held constant to the "Initial Synchronous Phase" throughout the tank.

The Constant Phase choice for RampType uses a linear accelerating field ramp. The distance z starts at zero at the beginning of each DTL tank.

When the *RampType* is set to "Adjusted Phase", a ramp similar to that for "Constant Phase" is utilized, except that the effective value of $\Delta z_E = z_{NStart}$ where N_{Start} is the "Starting Cell Number". The ramp is continued until $z_{cell} = z_{NEnd}$ where N_{End} is the "Ending Cell Number", unless $E_{o,cell} = E_{o,max}$. The ramp is then terminated, and $E_{o,cell}$ is held constant. The phase of the RF, ϕ_s , is adjusted throughout the tank so that the (zero-current) separatrix is held approximately constant in length (cm). The adjustment of ϕ_s continues throughout the tank unless either $z_{cell} = z_{NEnd}$ or $\phi_s = \phi_{s,Max}$ occurs, where $\phi_{s,Max}$ is the "Phase Ramp Stop Value". The phase of the RF is then held constant through the remainder of the tank.

The Adjusted Phase choice for RampType also uses a linear accelerating field ramp.

For a *RampType* set to "Constant Longitudinal Focusing", both axial electric field and the synchronous phase are adjusted throughout the tank. See the PARMILA 2 documentation (Appendix) for a description of this choice.

The Constant Longitudinal Focusing RampType option adjusts both the accelerating field and synchronous phase.



PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module

The last tab of the DTL Piece window is the Geometry tab, illustrated in Figure 34.

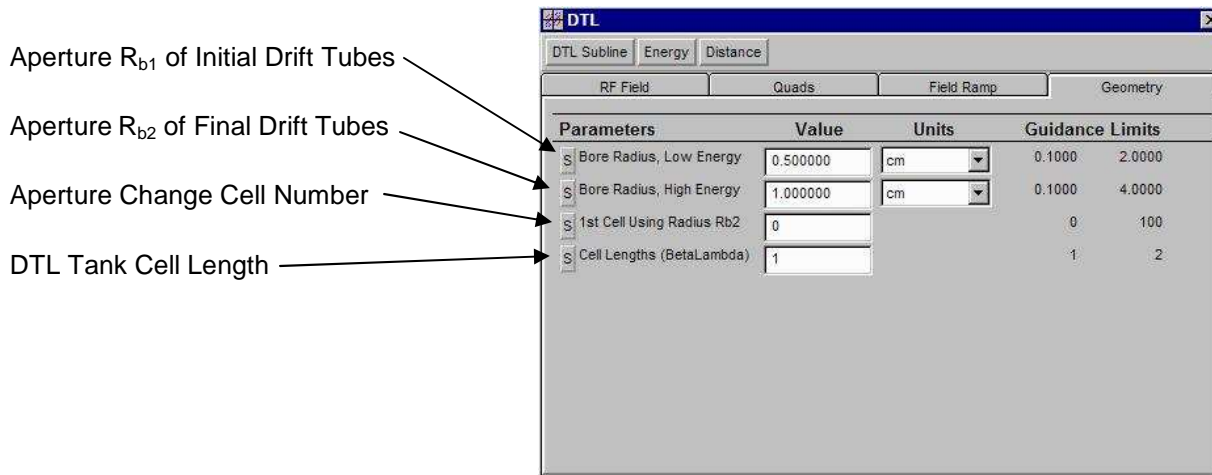


Figure 34. Geometry tab panel for a DTL Piece.

The parameters on the Geometry tab correspond to the following parameter numbers in Table IV-4 of the Appendix:

16, 17, 18, 21

The DTL parameters in the Geometry tab are used to set design goals for the bore radii (apertures) of the drift tubes, and to specify the cell length in terms of $\beta\lambda$. Two drift drift tube apertures, R_{b1} and R_{b2} , can be set: one for the drift tubes at the beginning of the tank ("Bore Radius, Low Energy") and the other for the drift tubes near the exit of the tank ("Bore Radius, High Energy"). The transition from the "low energy" to the "high energy" bore radius occurs at cell number N_{NBR} given by the "1st Cell Using Radius Rb2" parameter.

The overall length of one DTL cell (L_N in Figure 29) is an integer multiple of $\beta\lambda$. The default value for this multiple is 1. The "Cell Lengths (BetaLambda)" parameter is used to set a different value for the multiple.

PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module



In addition to the data contained in the DTL Piece, other parameters are utilized by PARMILA 2 in completing the design and/or simulation of a drift tube linac tank. Important among these is the use of SuperFish data. Several PARMILA-2 Command (COMM) Pieces are available for linking in SuperFish data. These are described in the discussion of the PARMILA-2 COMM Pieces later in this Section. Figure 35 illustrates a representative PBO Lab DTL "Design Line" that includes a DLT SuperFish Data Piece labeled "DLT sfd".

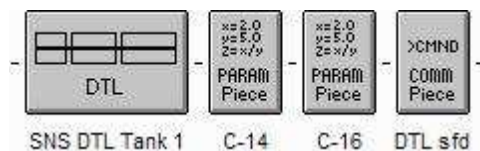
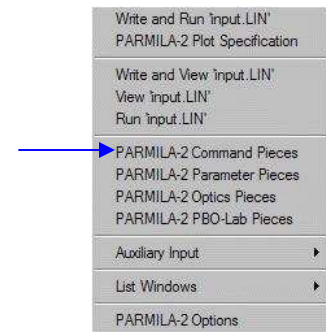


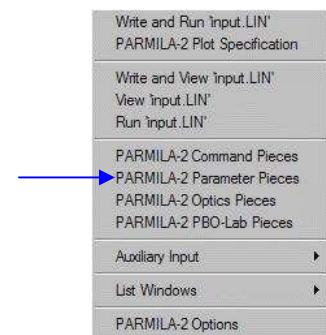
Figure 35. Example of a DTL "Design Line" that includes two Change lines and SuperFish Data

Many of the goal parameters for the design of a DTL tank, setup with the DTL Piece illustrated in Figures 28, 31, 33, and 34, may be adjusted or "fine-tuned" before PARMILA 2 completes the design. This "tweaking" of the design goals is accomplished with the use of *Changes*. Changes are implemented using PARMILA-2 Parameter (PARAM) Pieces that are *located between the DTL Piece and the SuperFish data COMM Piece*. The PARMILA-2 PARAM Pieces are described later in this Section. Figure 35 illustrates an example where Change types 14 (C-14) and 16 (C-14) are to be incorporated into the design. Change types 14 and 16 specify objectives for the magnetic quadrupole gradients, overriding the magnetic gradient goals set using the DTL Piece Quad tab (Figure 31). (Other parameters on the Quad tab, such as "Quad Sequencing", are not changed by C-14 or C-16). Note that Change Pieces located *after* the DLT sfd Piece do not modify the design objectives, but post-modify the PARMILA 2 created design for *simulations*.

SuperFish is a program that solves for the electromagnetic fields inside a radiofrequency (RF) cavity. SuperFish can output data for use with PARMILA 2.



SuperFish Data (sfd) Pieces are included in the PARMILA-2 Command Pieces, accessed from the corresponding item on the PARMILA-2 commands menu.



Change Pieces are included in the PARMILA-2 Parameter Pieces, accessed from the corresponding item of the PARMILA-2 commands menu.

Change Pieces after the SuperFish Data Piece have a different significance, and are discussed in the PARMILA-2 PARAM Piece section.



PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module

Several PARMILA-2 examples for a drift tube linac have been used for illustration earlier in this manual. See Figures 5, 6, 12, 13, 14, 16, 17, 18, 21, and 30.

PBO Lab can also be used to create equivalent object models of a DTL for computation with other optics codes. See Figures 25 and 26.

Figure 7 shows the first several lines the 'input.LIN' file that is written for a DTL example file ("SNS DTL Tank 1.pbol"). Illustrations from parts of the corresponding 'Parmila.out' file are shown in Figure 6 and Figure 30. Samples of Lingraf results for the same DTL example were also illustrated previously, in Figures 12, 13 and 14. The final particle distribution text file ('part_dtl.txt') that can be created after running the example file "SNS DTL Tank 1.pbol" is shown in Figure 16. Representative scatter plots of that same DTL data are illustrated in Figures 17, 18 and 21.

Examples of the creation and use of equivalent PBO Lab object models for a DTL were also illustrated previously. Figure 25 shows a PBO Lab TRACE 3-D Module calculation, and Figure 26 shows a PBO Lab TRANSPORT Module calculation, for the same "SNS DTL Tank 1.pbol" example, using an equivalent PBO Lab object model of the drift tube linac created with PARMILA-T3D-file Module.

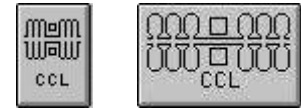


Coupled Cavity Linac (CCL) Piece

The CCL Piece is used to set up parameters for designing a coupled cavity linac. Similar to the DTL Piece, the parameters for the CCL Piece are grouped into five (5) categories:

- RF Field
- Quads
- Field Ramp
- Phase Ramp
- Geometry

The Piece Window for the CCL Piece has one tab panel for each of these parameter groups. The RF Field tab panel appears in front when a CCL Piece window is opened. Figure CCL-1 illustrates the tab panel for the RF Field parameters.



CCL Piece

Each CCL Piece represents one STRUCTURE section in the PARMILA 2 input file input.LIN.

Use one CCL Piece for each coupled cavity section of a multiple-section CCL structure.

The CCL Piece is part of the PARMILA 2 Module. An equivalent Subline can be created with the PARMILA 2 Module that can be used with other PBO Lab Modules.

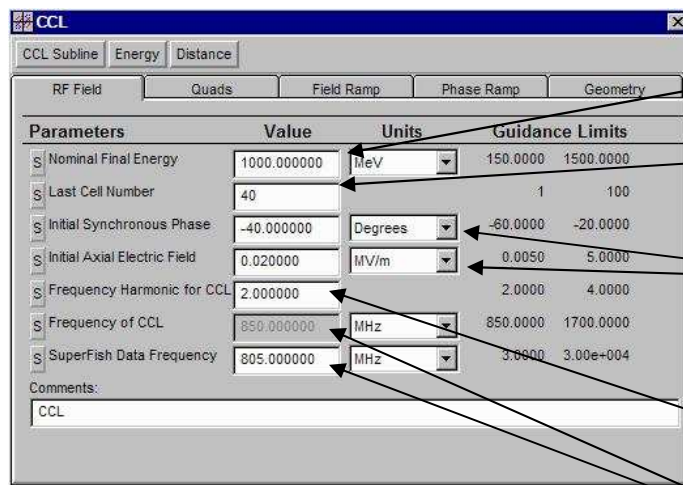


Figure 36. RF Field tab panel for a CCL Piece.

The RF Field parameters for a CCL Piece provide the top level field and output energy design objectives for one coupled cavity section. Each CCL Piece defines one PARMILA 2 CCL structure. Several parameters on the RF Field tab panel are used for a CCL Structure line in the PARMILA-2 Main Input File (input.LIN).

Nominal Final Energy is a primary design objective

Last Cell Number will be the final cell actually used in CCL

The RF Field tab is used for setting the starting (Initial) values for the radiofrequency (RF) phase and amplitude: Synchronous Phase, and Axial Electric Field

Frequency Harmonic for CCL is a multiple of the (Document Window) Global Frequency

If SuperFish Data Frequency is different from the Frequency of CCL, PARMILA 2 will scale the SuperFish data.

The parameters on the RF Field tab page correspond to the following parameter numbers in Table IV-7 of the Appendix:

- 1, 2, 3



PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module

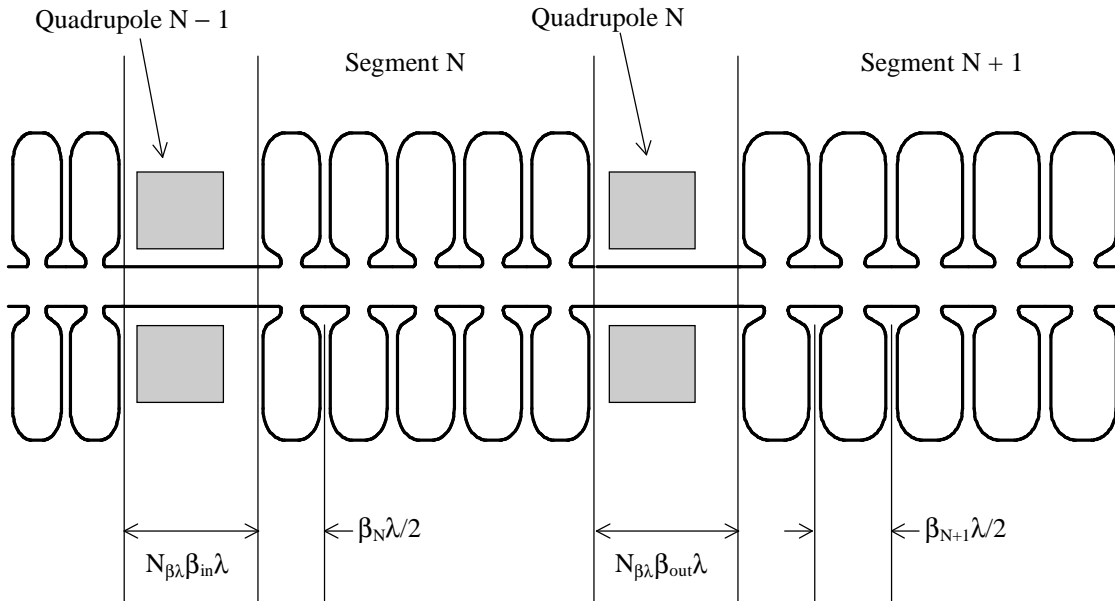


Figure 37. Layout of a coupled cavity linac (CCL), not to scale, from Appendix Figure III-5. This example has 5 cavities per segment.

The structure number for each CCL is automatically set by the PBO Lab PARMILA 2 Module.

The number of cells per segment is same for a given CCL structure, and is set using the Geometry tab panel (see Figure 42).

Figure 37 illustrates the layout for a CCL. Each CCL structure consists of one or more ("N") segments. Each segment consists of several equal length cavities, or cells. The length of the cells is given by $\beta_N \lambda / 2$, where β_N is average (geometrical) relativistic velocity of the particles in segment N. The quadrupole parameters for a CCL structure are specified using the Quads tab panel, shown in Figure 38.

Segment quad parameters:

Magnetic-Field Gradient

Effective Quad Length

Twice the $\beta\lambda$ Distance

Between Segments (integer)

Quadrupole Lattice Options

(see next page, Figure 39)

The parameters on the Quads tab page correspond to the following parameter numbers in Table IV-7 of the Appendix:

6, 7, 5, 11, 12, 8, 13, 10, 9

Parameters	Value	Units	Guidance Limits
Magnetic-Field Gradient	0.300000	kG/cm	-4.2700 4.2700
Effective Quad Length	2.000000	cm	1.0000 10.0000
2x Segment Space	2	$\beta\lambda$	1 8
Lattice Type	Singlet Quads		
Distance Between Quads	10.000000	cm	5.0000 127.9446
Sequencing for Singlet	FDFD Lattice		
Polarity for Doublets	x - First Quad Focusing x		
Quad at Tank Entrance	Half Length Singlet		
Magnet Locations	Start of Space		
Shift Location from End	0.100000	cm	0.0000 17.6349

Figure 38. Quads tab panel for a CCL Piece.



The Lattice Type parameter on the CCL Quads tab panel is used to specify whether the "Quadrupole_N" gray areas illustrated in Figure 37 are to be *singlet* or *doublet* lenses. This parameter determines which of the following quadrupole parameters are meaningful:

- Distance Between Quads
- Sequencing for Singlet
- Polarity for Doublets
- Quad at Tank Entrance

Figure 39 shows the relationship to the choice of Lattice Type.

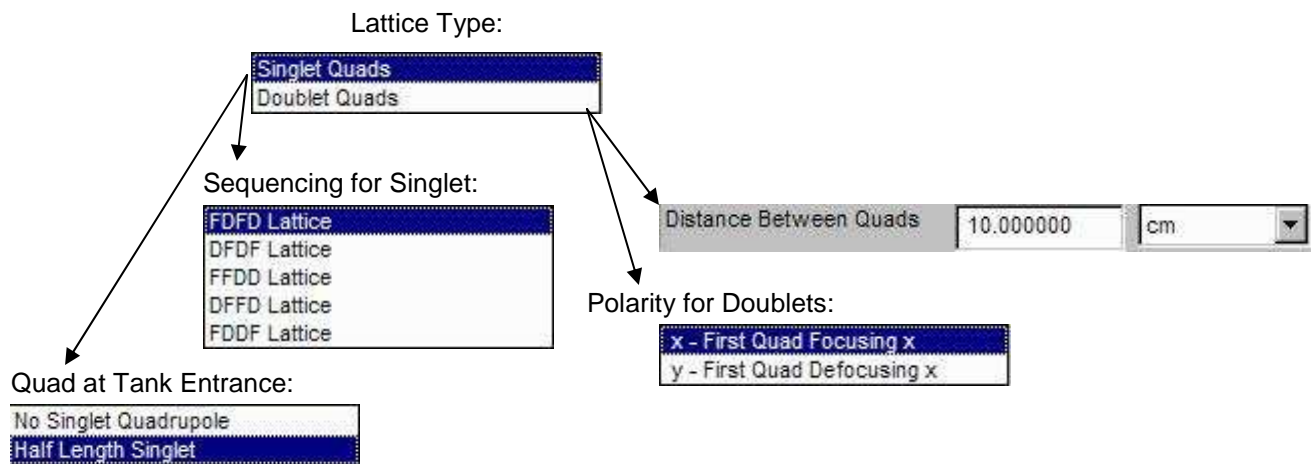
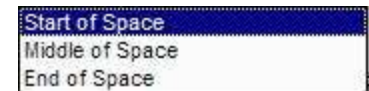


Figure 39. CCL choice for the quadrupole Lattice Type determines the meaningful options for other quad parameters.

For a given choice of "Lattice Type" only the related parameters shown in Figure 39 will be used by PARMILA 2 for the design. The parameters related to other choice of "Lattice Type" are ignored.

Another quad parameter is available for adjustment is for the "Magnet Locations". The "Magnet Locations" parameter is applicable to *both* the "Singlet Quads" and the "Doublet Quads" selection for "Lattice Type". The "Magnet Locations" parameter refers to the position within the space between adjacent segments (see Figure 39, which illustrates the "Magnet Locations" default "Start of Space").



Three choices are available for specifying the Magnet Locations in the space between two adjacent CCL segments.



PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module

The distance set in the Shift Location from End field is used to create a "QuadLocs" (keyword) entry in the PARMILA-2 input.LIN file. See Section IV.A.25 of the Appendix.

One final quad parameter that can be used for additional adjustment is "Shift Location from End". This parameter shifts the location of all CCL quadrupole magnets by a fixed distance. The distance is always taken as positive. If the "Magnet Locations" parameter is set to "Start of Space" (see previous page) a non-zero entry for the "Shift Location from End" will result in all quadrupoles being moved *downstream* by the entered distance. If the "Magnet Locations" parameter is set to "End of Space" then a non-zero entry for the "Shift Location from End" will result in all quadrupoles being moved *upstream* by the entered distance. The distance entry is *ignored* for the "Middle of Space" selection.

The parameters on the Field Ramp tab page correspond to the keywords "SetBetaRamp" and "EORamp" in Section IV.A.15 of the Appendix.

Accelerating electric field and synchronous phase ramps may be used with each CCL structure. The parameters for these ramps are set on separate tab pages of the CCL Piece window. Figure 40 shows the Field Ramp tab panel.

Field Ramp Choices

Field Ramp selection will activate ramp parameters:

- Acceleration Ramp Rate
- or Fixed Field Step Size

Maximum Axial Electric Field

Start Cell for Field Ramp

End Cell for Field Ramp

Choice for Applying Ramp

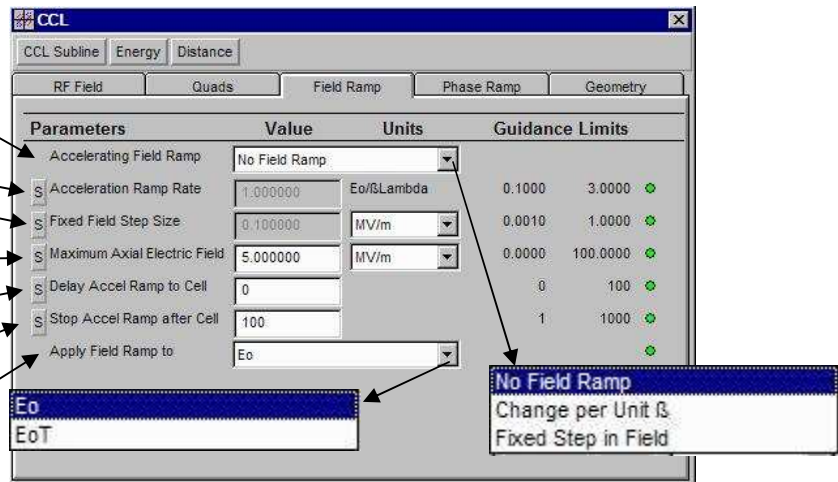


Figure 40. Field Ramp tab panel for a CCL Piece.

The default setting for the "Accelerating Field Ramp" is "No Field Ramp". However, two basic types of "Accelerating Field Ramp" can be applied to a given CCL Piece: "Change per Unit β " and "Fixed Step in Field".



PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module

The "Fixed Step in Field" selection uses the "Fixed Field Step Size" ($E_{o,Step}$) to incrementally increase the axial electric field (E_o). The starting value of E_o is set by the axial electric field at the cell number set by "Delay Accel Ramp to Cell" parameter. This may, or may not, correspond to the "Initial Axial Electric Field" value set in the RF Field tab panel of the CCL Piece (see Figure 36), depending on whether the "Apply Field Ramp to" option is set to "Eo" or "EoT". If "EoT" is set, then a PARMILA-2 *ETFixed* keyword is used (see sidebar).

When using the "Change per Unit β " selection, the "Acceleration Ramp Rate" R_E is used to try to ramp the electric field $E_o(\beta)$, as a linear function of β ($=v/c$):

$$E_o(\beta) = E_o + R_E (\beta - \beta_o)$$

The starting value of E_o is set according to the same criteria described above for the "Fixed Step in Field" selection. The relativistic velocity corresponding to E_o is β_o .

For either "Accelerating Field Ramp" option (i.e. other than "No Field Ramp") the axial electric field ramp is continued until either (a) the cell number assigned in "Stop Accel Ramp after Cell" is reached or (b) the "Maximum Axial Electric Field" value is attained. The accelerating field is then maintained at a constant value, or adjusted, according to the selection of the "Apply Field Ramp to" option ("Eo" or "EoT").

The synchronous phase of the CCL may also be ramped. Figure 41 illustrates the Phase Ramp tab panel of the CCL Piece Window. Each of the parameters appearing on the Phase Ramp tab panel (Figure 41) is similar to one of the parameters on the Field Ramp tab panel (Figure 40).

The Apply Field Ramp to option EoT is used to add an "ETFixed" keyword line to CLL PARMILA-2 description (in the 'input.LIN' file). When the EoT option is selected, then the starting value of E_o for the acceleration ramp is set by the (constant) value of EoT at the Delay Accel Ramp to Cell number. See Section IV.A.8 of the Appendix for additional information.

Some adjustment of the Acceleration Ramp Rate R_E may be needed in order to achieve a particular final value for the axial electric field. See the discussion in Section IV.A.15 of the Appendix for additional information.

The six parameters on the CCL Phase Ramp tab panel are similar to the first six parameters of the CCL Field Ramp tab panel.



PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module

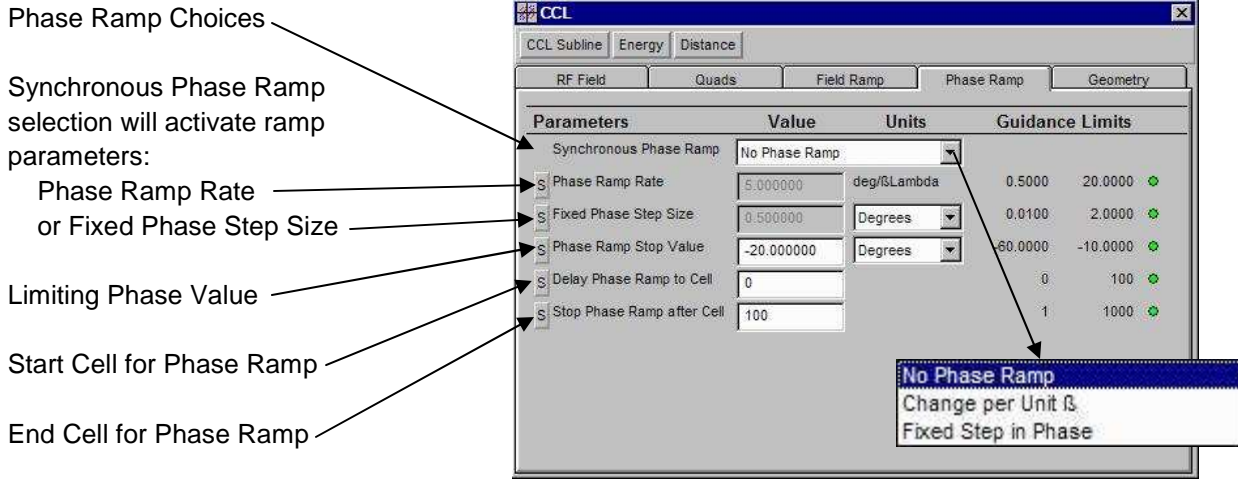


Figure 41. Phase Ramp tab panel for a CCL Piece.

The "Synchronous Phase Ramp" switch is used to select the type of ramp to be applied, with "No Phase Ramp" being the default. The other options are: "Change per Unit β " and "Fixed Step in Phase". If one of these options is selected, then the corresponding numerical input field becomes active: "Phase Ramp Rate" (in degrees/ β) or "Fixed Phase Step Size" (in Degrees or other units choice).

The parameters on the Field Ramp tab page are used to write a "PhaseRamp" keyword line to the 'input.LIN' file for the CCL. The "PhaseRamp" keyword line is discussed in Section IV.A.15 of the Appendix.

For either choice of the "Synchronous Phase Ramp" (other than "No Phase Ramp") the remaining three parameters impose certain limits on the phase ramp. The phase begins at the cell number given by the "Delay Phase Ramp to Cell" entry. The phase ramp is continued until either (a) the limiting value specified for the "Phase Ramp Stop Value" is attained or (b) the cell number given by "Stop Phase Ramp after Cell" entry is reached. The synchronous phase is then held constant through the remainder of the CCL structure.

Various layout and dimensional parameters for the CCL are set using the Geometry tab panel. The Geometry tab panel of the CCL Piece Window is illustrated in Figure 42.

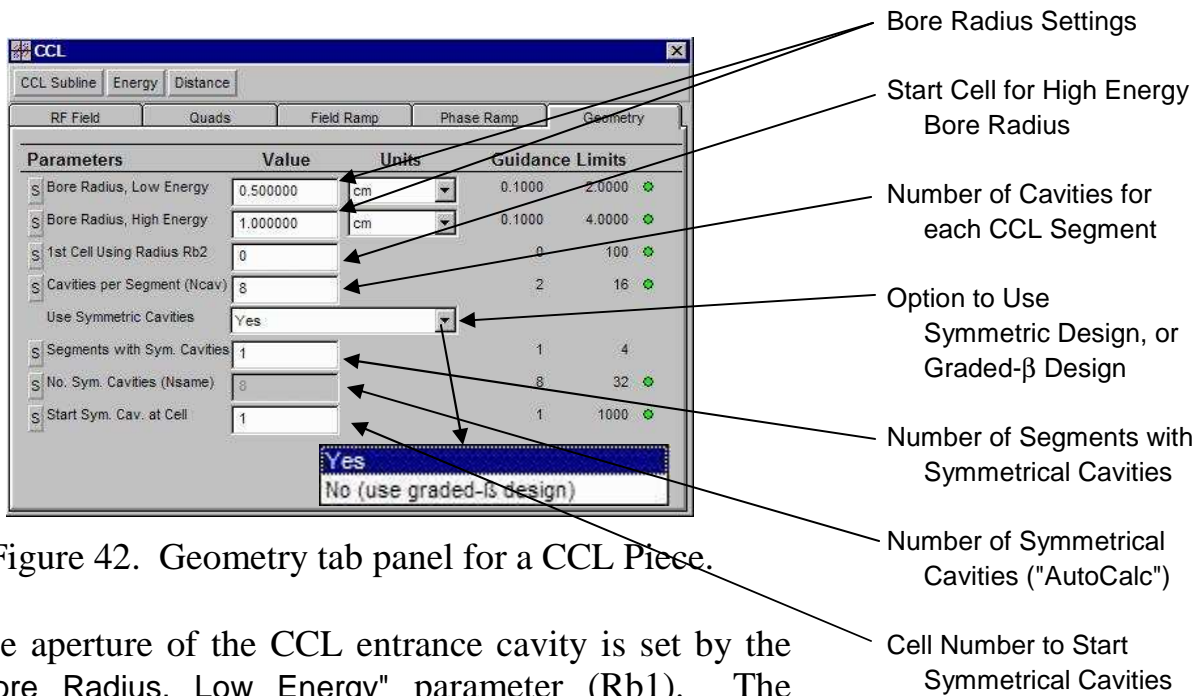


Figure 42. Geometry tab panel for a CCL Piece.

The aperture of the CCL entrance cavity is set by the "Bore Radius, Low Energy" parameter (Rb1). The aperture may be changed further down the structure by using the "Bore Radius, High Energy" parameter (Rb2). The change in aperture will occur at the cell number given by the "1st Cell Using Radius Rb2" entry. These parameters are not used for the CCL design, but are utilized for beam dynamics simulations.

The number of cavities for each CCL segment is set by the "Cavities per Segment (Ncav)" entry. This number is a constant for a given CCL tank (i.e. one PARMILA-2 CCL Structure). Figure 37 illustrates an example with 5 cavities per segment.

The CCL may use a *graded-β* design where the length of each cavity is adjusted to a computed geometric β for the cell. Each cavity thus has a different length. It may be more convenient (e.g. for easier fabrication) to use cavities of equal length. This type of CCL structure is referred to as a *symmetric* design. The "Use Symmetric Cavities" popup is used to select the type of design desired. The default setting "Yes" is for a *symmetric* design.

The 3 parameters specifying the bore radii are used to create a "Bore" keyword line in the 'input.LIN' file for the CCL structure. The "Bore" keyword line is only used in the beam dynamics simulation and is discussed in Section IV.B.18 of the Appendix.

The Yes choice of the Use Symmetric Cavities switch on the Geometry tab panel adds a "SymDesign" keyword line to the 'input.LIN' file for that CCL structure. The "SymDesign" keyword line is discussed in Section IV.A.10 of the Appendix.



PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module

The "SymDesign" keyword line in the 'input.LIN' file for the CCL structure use two parameters from the Geometry tab panel: No. Sym. Cavities (Nsame) and Start Sym. Cav. at Cell.

The No. Sym. Cavities (Nsame) parameter is an "Autocalc" parameter, meaning that it is automatically calculated from other parameters. Specifically:
No. Sym. Cavities (Nsame) = [Segments with Sym. Cavities] × [Cavities per Segment (Ncav)]

When the (default) "Yes" setting for "Use Symmetric Cavities" popup switch is selected, the three remaining parameters are utilized. The "No, use graded- β " setting does not utilize the three parameters following the switch, and those parameters are all inactive for that switch setting.

Similar to the DTL, the CCL design goals may be adjusted, or fine-tuned, using *Changes*. Changes are implemented using PARMILA-2 Parameter (PARAM) Pieces. In addition, there are other specialized modifications related to the external quadrupoles of the CCL. These are also implemented with PARMILA-2 Parameter (PARAM) Pieces.

One important Piece for the CCL design is a SuperFish data Piece. Several PARMILA-2 Command (COMM) Pieces are available for linking in SuperFish data. These are described in the discussion of the PARMILA-2 COMM Pieces later in this Section. Figure 43 illustrates a representative PBO Lab CCL "Design Line" that includes a CCL SuperFish Data Piece labeled "CCL sfd".

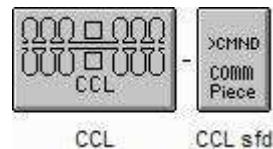


Figure 43. Example of a CCL "Design Line" that includes SuperFish Data

The PBO Lab file named "SNS-CCL-1st-8-cells.pbol" provides an example of using PARMILA-2 to design a CCL and then simulate its performance. The example file is located in the Examples/Parmila directory installed with PBO Lab 3.

PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module



Figure 44 shows the first several lines the 'input.LIN' file that is written for the CCL example file ("SNS-CCL-1st-8-cells.pbol"). This example is for an 8-cell symmetric cavity design. The example includes a Field Ramp but no Phase Ramp.

It can helpful to set options on a CCL Piece and then use the "Write and View 'input.LIN' " PARMILA-2 Command to see how the settings impact the 'input.LIN' file.

```
input.LIN
File Edit Font
RUN 11
TITLE
SNS-CCL-1ST-8-CELLS RUN ON 03/28/09 00:24:48
: *** PARMILA OASIS MODULE VERSION 2.2.0.6 FOR PBO LAB 3.0 ***
: LINAC: W0, FBUNCH, IBEAM, MC^2, NQ
: LINAC 97.905100 402.500000 110.800000 938.280000 1.000000
: ***** END OF THE INPUT LIN HEADER SECTION *****
: *** USER AUXILLARY HEADER INPUT WILL APPEAR HERE ***
: ***** START OF THE INPUT LIN LATTICE SECTION *****
STARTPHASE -30.000000
INPUT -8 1000 0.033890 101.100000 0.000281
      0.031500 489.750000 0.000419
      0.254940 1295.169050 0.002204
      0.000 0.000 0.000 0.000 0.000 0.000
: ***** START OF NEW STRUCTURE - PBO LAB PARMILA-2 MODULE *****
: STRUCTURE ID,NLAST, F0, FSF, DELTAPI
STRUCTURE 3 40 850.000000 805.000000 0.0
:CCL: WF(MEV), PHIS, EO(MEV/M), NCAV, N-BL, GRAD(G/CM), LQUAD,Q-SEQ,-LOC,-ENTRY, LATTICE, DDS, POLARITY
CCL 198.000000 -30.442000 2.512700 8 2.000000 7498.100000 3.000000 1010 1 1 1 10.000000 1

SYMDESIGN 8 1

SETBETARAMP 1 0.000000 56.000000 0 56
EORAMP 40.400000 4.800000
:PHASERAMP 5.000000 -20.000000 0.500000
ETFIXED :FIELD RAMP (IF SPECIFIED ABOVE) APPLIED TO EOT

BORE 1.505000 1000 1.505000

DELTABL 16 0.001520 0 -0.005000
SFDAQ
: SNS LINAC, 805.0 MHZ, BORE = 1.5, EXTERNAL CCL
: BETA T TP S SP G/BL Z E/E0 TAVE DZCTR
0.370000 0.878092 0.035918 0.365335 0.047523 0.104994 40.3866 1.000003 0.878092 0.020142
0.380000 0.881154 0.035107 0.361685 0.047356 0.107941 41.3521 0.999996 0.881154 0.018358
0.390000 0.883925 0.034372 0.358408 0.047210 0.110890 42.3849 0.999998 0.883925 0.016764
0.400000 0.886479 0.033691 0.355413 0.047075 0.113829 43.3729 0.999999 0.886479 0.015303
0.410000 0.888728 0.033092 0.352831 0.046969 0.116777 44.3392 1.000004 0.888728 0.014018
0.420000 0.890766 0.032548 0.350556 0.046883 0.119727 45.2815 1.000000 0.890766 0.012843
0.430000 0.892549 0.032074 0.348642 0.046823 0.122668 46.1897 0.999997 0.892549 0.011807
0.440000 0.894117 0.031658 0.347048 0.046789 0.125615 47.0846 1.000002 0.894117 0.010877
```

Figure 44. The Main Input (input.LIN) for the example "SNS-CCL-1st-8-cells.pbol" after executing the command "Write and View 'input.LIN' ".

The 'input.LIN' file illustrated in Figure 44 shows, near the bottom of the Figure, the beginning of the SuperFish Data (following the SFDAQ entry) for this example.



PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module

The reader should note that the design for the example is contains more than 8 cells. The design goal for the Last Cell Number parameter (see Figure 36) is actually set to 40 in this example.

Figure 45 shows a section of the corresponding 'Parmila.out' file for the example "SNS-CCL-1st-8-cells.pbol". The portion of the output displayed (accessed by adjusting the scroll bar on the right side of the window) shows the design details for the first few cells.

Quadrupole gradient = -7.4981 kG/cm
The column headings are:

W: Energy of the synchronous or design particle at the end of the cell in MeV
Beta: Velocity of the synchronous or design particle at the end of the cell
Lc: Cell length in cm
T: Transit-time factor cosine integral with reference position at electrical center
T': Derivative of T with respect to wave number
S: Transit-time factor sine integral (average magnitude of upstream and downstream halves)
S': Derivative of S with respect to wave number
Lq: Quadrupole magnet length in cm
G: Quadrupole gradient in kG/cm
E0d: Design value of E0 for a DTL cell or an entire cavity or segment in MV/m
E0: Average axial electric field for the cell in MV/m (used in energy-gain calculation)
Phi: Phase of the reference particle at the center of the gap in degrees
Phid: Synchronous phase or design phase for symmetric segments in degrees
Z: Distance to end of cell (or center of magnet) from the beam-entrance end wall in cm

Cell	W	Beta	Lc	T	T'	S	S'	Lq	G	E0d	E0	Phi	Phid	Z
initial	97.9051	0.42432						1.500	-7.4981					28.4310
1	98.0489	0.42458	7.5014	0.8917	0.0323	0.3495	0.0469	0.000	0.0000	2.5127	2.5127	-31.125	-30.442	35.9325
2	98.1944	0.42486	7.5014	0.8959	0.0313	0.3468	0.0471	0.000	0.0000	2.5127	2.5127	-30.487	-30.442	43.4339
3	98.3403	0.42513	7.5014	0.8959	0.0313	0.3468	0.0471	0.000	0.0000	2.5127	2.5127	-30.262	-30.442	50.9353
4	98.4863	0.42540	7.5014	0.8959	0.0313	0.3468	0.0471	0.000	0.0000	2.5127	2.5127	-30.152	-30.442	58.4367
5	98.6323	0.42567	7.5014	0.8959	0.0313	0.3468	0.0471	0.000	0.0000	2.5127	2.5127	-30.157	-30.442	65.9382
6	98.7781	0.42594	7.5014	0.8959	0.0313	0.3468	0.0471	0.000	0.0000	2.5127	2.5127	-30.277	-30.442	73.4396
7	98.9236	0.42621	7.5014	0.8959	0.0313	0.3468	0.0471	0.000	0.0000	2.5127	2.5127	-30.511	-30.442	80.9410
8	99.0684	0.42648	7.5014	0.8917	0.0323	0.3495	0.0469	0.000	0.0000	2.5127	2.5127	-30.566	-30.442	88.4424
	99.0684	0.42648	30.0829					3.000	7.4981					89.9424
9	99.2256	0.42677	7.5411	0.8921	0.0322	0.3491	0.0468	0.000	0.0000	2.7320	2.7320	-31.148	-30.442	126.0664
10	99.3847	0.42706	7.5411	0.8962	0.0313	0.3464	0.0471	0.000	0.0000	2.7320	2.7320	-30.490	-30.442	133.6075
11	99.5441	0.42736	7.5411	0.8962	0.0313	0.3464	0.0471	0.000	0.0000	2.7320	2.7320	-30.248	-30.442	141.1486

Figure 45. The Main Output File ('Parmila.out') for the example "SNS-CCL-1st-8-cells.pbol" after executing the command "Write and Run 'input.LIN'".

A representative Lingraf plot for the same "SNS-CCL-1st-8-cells.pbol" example is shown in Figure 46. The plot runs through 40 cells.

PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module

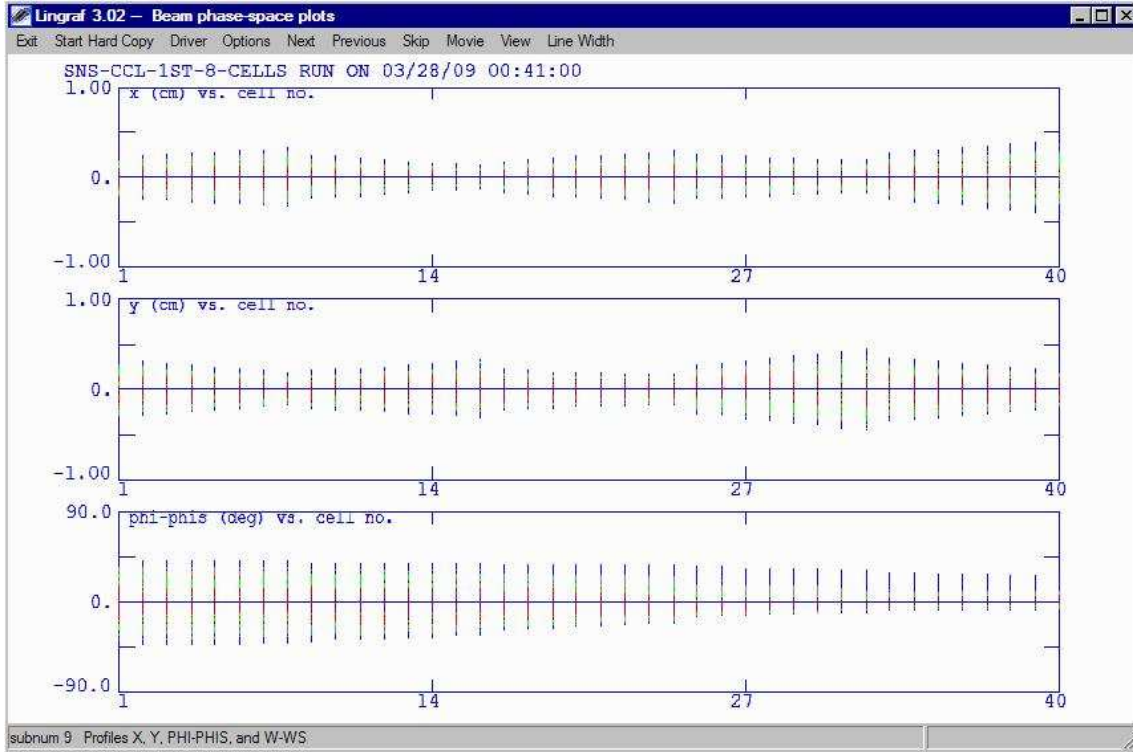


Figure 46. Lingraf profile plots for the example "SNS-CCL-1st-8-cells.pbol." Note that this example actually has 40 cells in the design.

The final particle distribution text file ('part_dtl.txt') created for the example file "SNS-CCL-1st-8-cells.pbol" is shown in Figure 47.

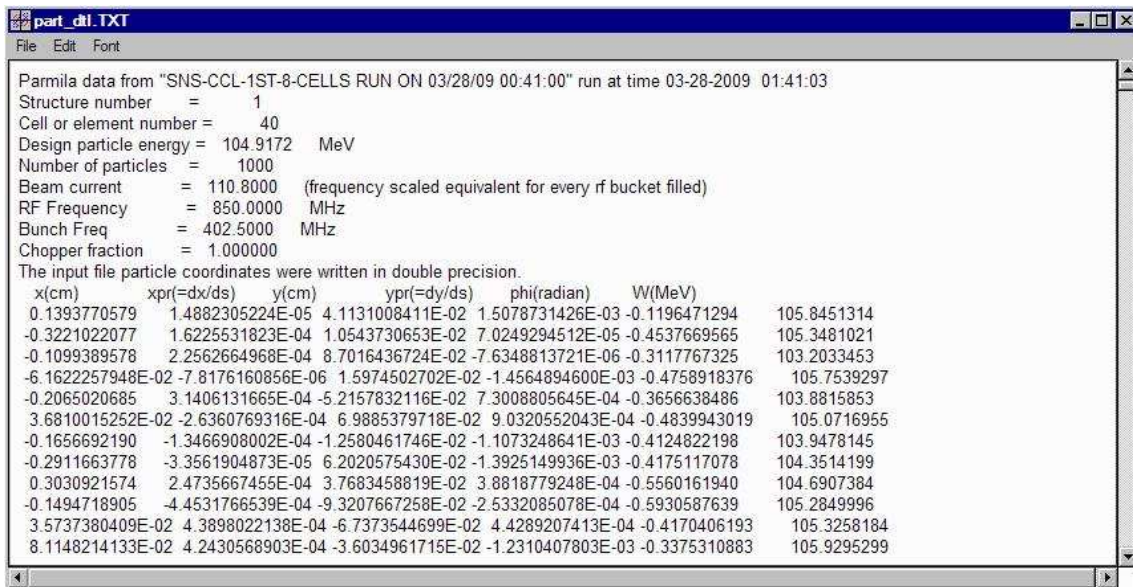


Figure 47. "SNS-CCL-1st-8-cells.pbol" Particle distribution data example after running the PARMILA-Plots command "Write and Run 'input.temp'".



PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module

Representative scatter plots at the exit of the CCL, utilizing the data in the 'part_dtl.txt' file, are illustrated in Figure 48.

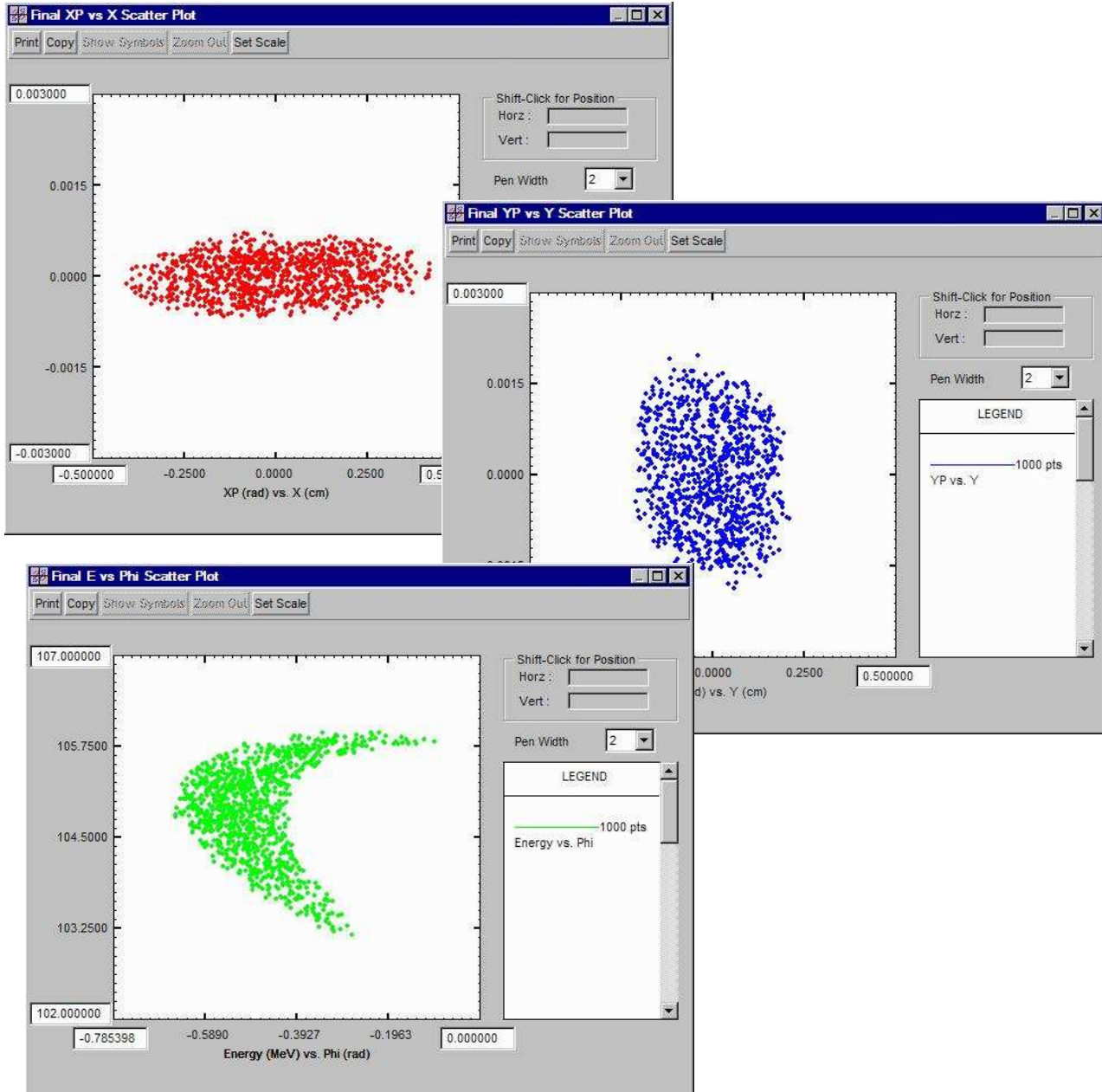


Figure 48. Phase space scatter plots for the example "SNS-CCL-1st-8-cells.pbol": (a) horizontal phase space (upper), (b) vertical phase space (middle), and (c) longitudinal phase space (lower).

PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module



Similar to the DTL, an equivalent PBO Lab object models for a CCDTL can be created for use with other PBO Lab Modules. The PARMILA-T3D-file Module is utilized for this purpose. The procedure is outlined in Section 2 of this manual: an equivalent *basic element* PBO-Lab Subline Model is created using, the "Write and Run 'Tr3Din_convert' " command of the PARMILA-T3D-file Module.

The CCL Piece is unique to the PARMILA 2 Module, and is ignored by other (non-PARMILA) PBO Lab Modules. However, an equivalent PBO Lab Subline can be created with the PARMILA-T3D-file Module. The equivalent Subline can then be used with other PBO Lab Modules, such as TRACE 3-D and TRANSPORT.

Figure 49 shows a PBO Lab TRACE 3-D Module calculation for the "SNS-CCL-1st-8-cells.pbol" example, using the equivalent PBO Lab object model of the coupled cavity linac created with PARMILA-T3D-file Module.

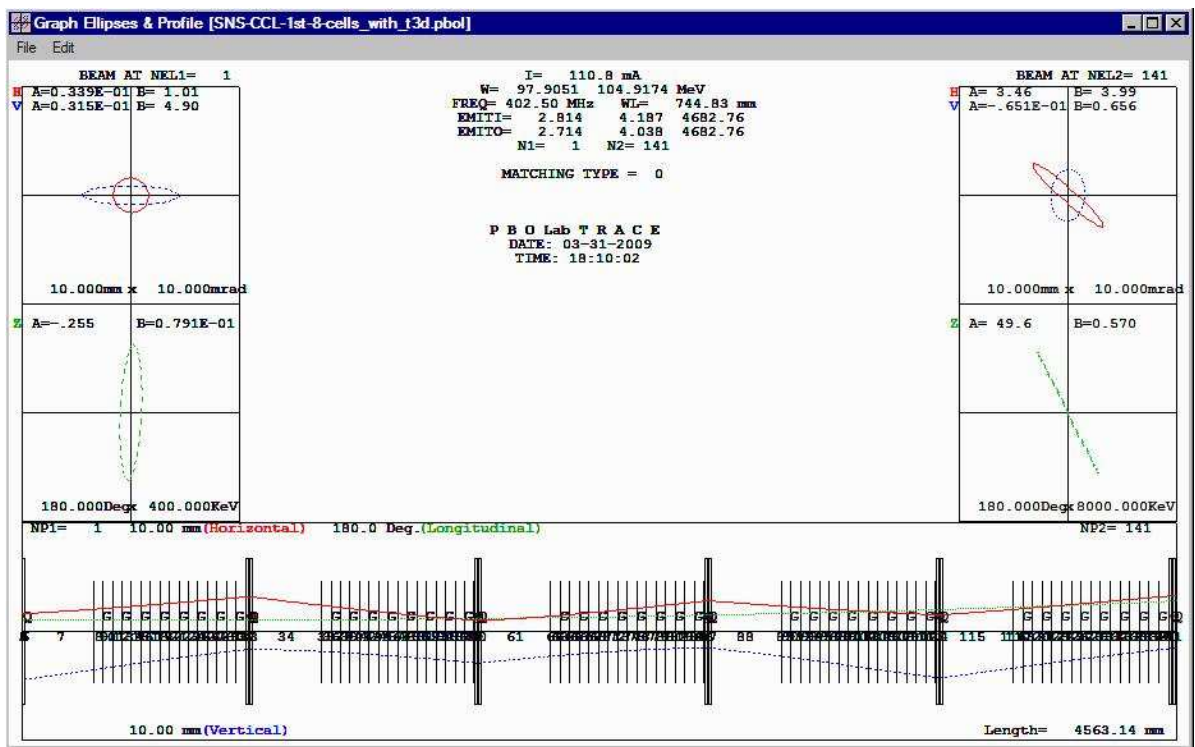


Figure 49. TRACE 3-D calculation using the PBO Lab equivalent object model for the example "SNS-CCL-1st-8-cells.pbol".



PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module

The output energy (W) from the TRACE 3-D calculation (104.9174 MeV) and the TRACE 3-D beamline length (4563.14 mm) are in agreement with the corresponding data from the 'Parmila.out' file *after 40 cells*. The following lines, copied from further down in the 'Parmila.out' file shown in Figure 45, give the values (underlines added) needed to compare to the TRACE 3-D results:

40	<u>104.9172</u>	0.43707	7.6810	0.8934	0.0318	0.3478	0.0468	0.000	0.0000	3.5059	3.5059	-30.740	-30.442	<u>453.3147</u>
	104.9172	0.43707	30.8301			<u>3.000</u>	7.4981				454.8147			
41	105.1422	0.43747	7.7354	0.8939	0.0317	0.3473	0.0468	0.000	0.0000	3.8074	3.8074	-31.257	-30.442	491.8802

Note: For a standalone CCL example such as this one, a PARMILA-T3D-file command Write and View 'Tr3Din_convert' should be run, in order to look at the frequency appearing at the top of the file Tr3Din_convert. That frequency (in MHz) should correspond to the Frequency of CCL (see Figure 36). If it does not, then change the value in the Tr3Din_convert file, and save that file. Then use the PARMILA-T3D-file command named Run 'Tr3Din_convert' to execute the new Tr3Din_convert file that was saved with the corrected frequency. The remaining procedures, to create the equivalent subline from the 'Tr3Din.pbop' file, are the same as described in Section 2.

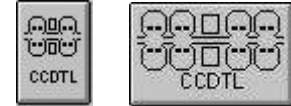
The first entry is the cell number (40 and 41 selected from the 'Parmila.out' file). The second entry (underlined) is the beam energy *after* the cell. For cell 40 this is 104.9172 MeV, in agreement with the TRACE 3-D result to within 2 parts in 10^6 (or 0.0002 %). The last number in a cell line (e.g. those that start with 40 or 41) is the distance (in cm) from the start of the CCL to the *end* of the corresponding cell. For cell 40 this is 453.3147 cm (underlined). Information on the quadrupoles between CCL cavities is given in abbreviated lines between cell lines. The length of the quadrupole space after cell 40 is 3.000 cm (underlined). Adding this quadrupole space to the to distance to the exit of cell 40 gives the corresponding beamline length through that quadrupole space: 456.3147 cm. This is also within 2 parts in 10^6 of the TRACE 3-D calculation.



Coupled Cavity Drift Tube Linac (CCDTL)

The CCDTL Piece is used to set up parameters for designing a coupled cavity drift tube linac. The parameters describing a CCDTL are nearly identical to those used to describe a CCL. Similar to the CCL Piece, the parameters for the CCDTL Piece are grouped into five (5) categories:

- RF Field
- Quads
- Field Ramp
- Phase Ramp
- Geometry



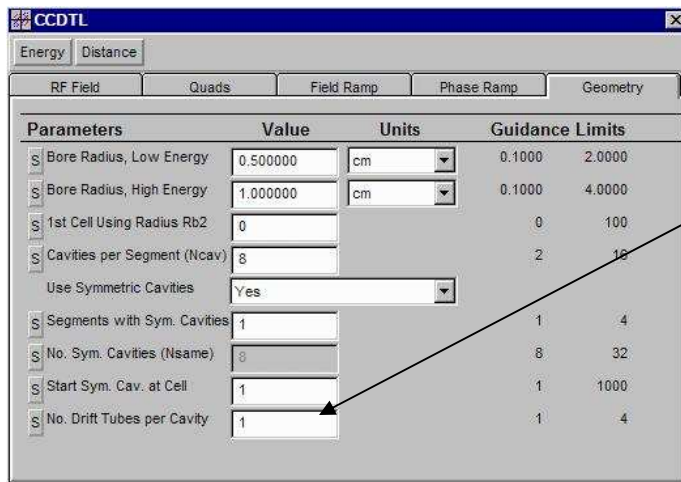
CCDTL Piece

Each CCDTL Piece represents one STRUCTURE section in the PARMILA 2 input file "input.LIN"

Similar to the CCL, the Piece Window for the CCDTL Piece has one tab panel for each of these parameter groups. The parameters have the same basic meaning as for the CCL and users may refer to CCL Figures 36 and 38-41 for additional information. The CCDTL has one more parameter than the CCL: the number of drift tubes per cavity. This parameter is set on the Geometry tab panel of the CCDTL which is illustrated in Figure 50.

Use one CCDTL Piece for each coupled cavity structure of a multi-structure CCDTL.

The parameters on the various tab pages of the CCDTL Piece Window include all of the parameters given in Table IV-8 of the Appendix. Similar to the CCL Piece, other parameters also appear on the tab pages.



The Number of Drift Tubes per Cavity is the only extra parameter for a CCDTL that is not on a CCL Piece.

Figure 50. Geometry tab panel of a CCDTL Piece has 1 more parameter than the Geometry tab of a CCL Piece.

Figure 51 shows an example of a CCDTL with 2 drift tubes per cavity.



PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module

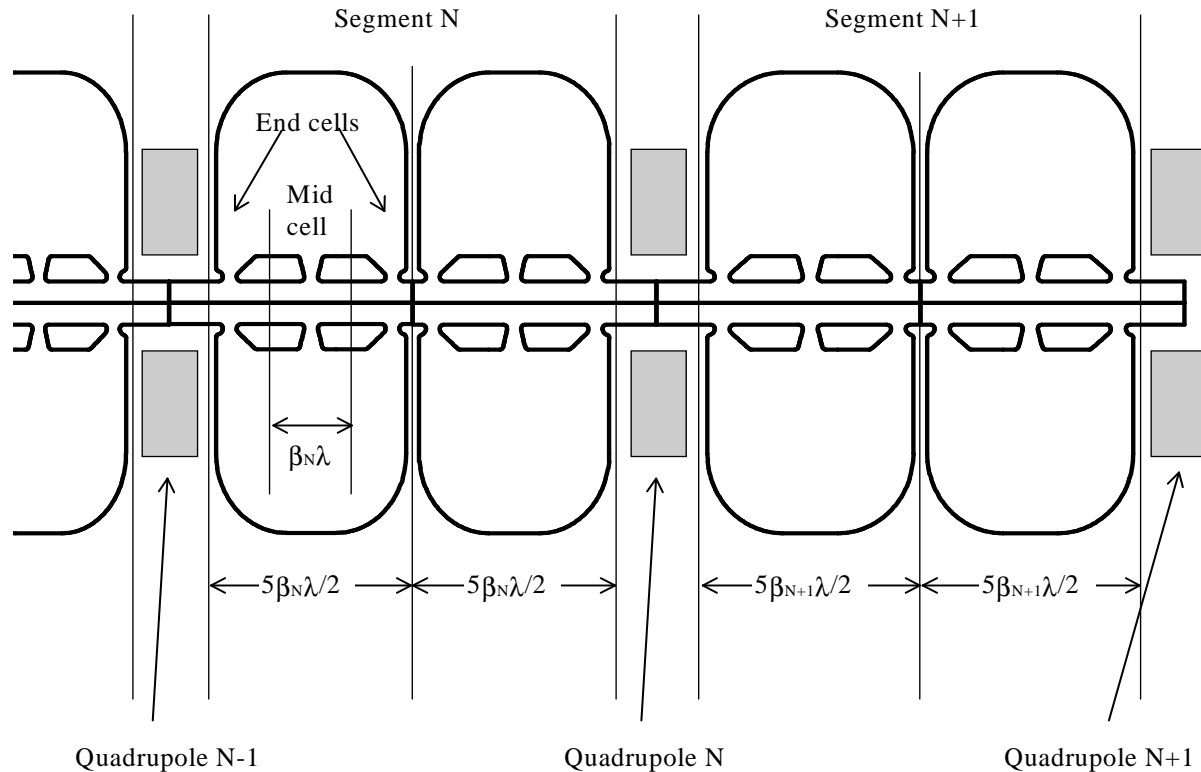


Figure 51. Layout of a coupled cavity drift tube linac (CCDTL), not to scale, from Appendix Figure III-4. This example has 2 cavities per segment

The CCDTL Piece is part of the PARMILA-2 Module. An equivalent PBO Lab Subline can be created with the PARMILA-T3D-file Module. That equivalent Subline can then be used with other PBO Lab Modules, such as TRACE 3-D and TRANSPORT. The procedures and steps for using PBO Lab to create the equivalent subline are similar to those summarized in Section 2.

Figure 51, taken from the Appendix attached to this manual, shows the general layout for a coupled cavity drift tube linac. This example has two cavities per segment, and two drift tubes per cavity. The drawing indicates that singlet quadrupoles are used between each segment.

An example of with a CCDTL structure is included in the Examples/Parmila folder of the PBO Lab software installation. The file is named:

"100 MeV LINAC through CCDTL.pbol"

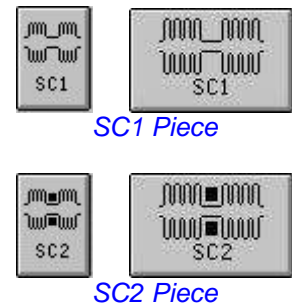
In addition to the CCDTL, the first 20 MeV of the accelerator in this example is composed of the two DTL tanks. A DTL to CCDTL matching section is also included in the example.



Superconducting Linac Overview

Superconducting (SC) linear accelerators differ in several respects from the drift tube linac (DTL), coupled cavity linac (CCL) and coupled cavity drift tube linac (CCDTL) accelerator structures. PARMILA-2 divides an SC accelerator into structures. Each SC structure of a linac corresponds to one PBO Lab SC Piece. Typically one SC structure can accelerate a beam by several hundred MeV so that only a few PBO Lab SC Pieces are needed to model the complete superconducting portion of a linac.

Each SC structure is divided into segments, which are sometimes referred to as *cavities* in the literature. Each segment is comprised of a fixed number of cells. The individual cells of an SC structure (i.e. all segments of the structure) all have the same length. This cell length is defined in terms of " $\beta_g \lambda / 2$ " for the structure, where β_g is the physical or *geometric* β for the structure and λ is the radiofrequency wavelength for the structure. Figure 52 illustrates a basic SC structure modeled by PARMILA-2.



Each SC Piece, either SC1 or SC2, represents a STRUCTURE section in the PARMILA 2 input file "input.LIN".

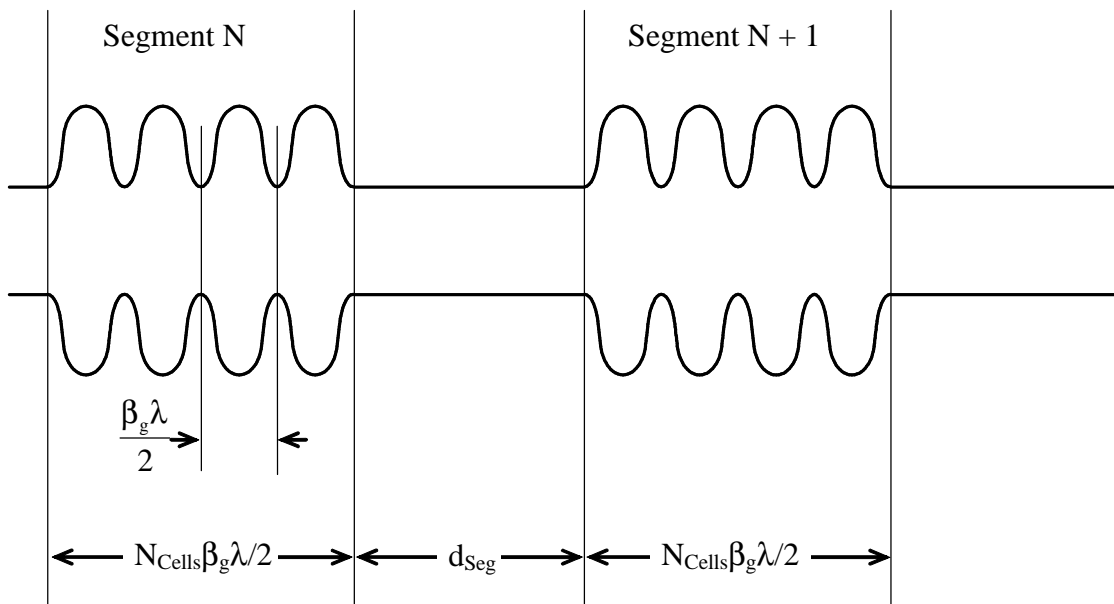


Figure 52. Superconducting (SC) layout consisting of multiple segments and N_{Cells} per segment, not to scale, from Appendix Figure III-6.



PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module

Hierarchy of PARMILA 2 objects used for modeling superconducting structures:

- **STRUCTURE**

A STRUCTURE is composed of one or more LAYOUTS. The number of LAYOUTS is specified by the user.

- **LAYOUT**

One LAYOUT is composed of a number of SEGMENTS. The number of SEGMENTS is computed by PARMILA 2 for each LAYOUT.

- **SEGMENT**

Each SEGMENT contains a fixed number of CELLS. This number is the same for all of the LAYOUTS within a STRUCTURE. The number of CELLS per SEGMENT for a STRUCTURE is specified by the user.

- **CELL**

Each CELL contains detailed information regarding RF fields and physical dimensions.

PARMILA 2 utilizes quadrupole magnets for transverse beam focusing. The quad LATTICE determines the x and y focusing properties for each STRUCTURE.

The SC1 and SC2 structures are described in separate sections of this User Manual.

The example SC structure illustrated in Figure 52 has 4 cells per segment ($N_{\text{Cells}}=4$). The distance between each segment is denoted by d_{Seg} . Focussing magnets (not shown in Figure 53) are located between segments.

PARMILA 2 further divides each structure into a number of *layouts*. Certain details of the segments within a given layout may be specified, such as the value of d_{Seg} , the energy gain goal for each segment, and other parameters discussed later. While some design details for each layout can be independently specified, the physical *cavity* structures are the same for each layout. In particular, the values of N_{Cells} and β_g are the same for all segments and layouts within a structure.

Two general classes of SC structures, referred to as SC1 and SC2, can be designed and/or modeled by the PBO Lab PARMILA-2 Module. Each of these is described in separate sections of this User Manual, but the brief overviews below may be helpful.

SC1 has singlet quadrupole magnets located *within* the space d_{Seg} . However, the primary characteristic of the SC1 structure is that the one segment in the structure does not contain a cavity. This is referred to as a *missing segments* superconducting linac. The linac designer (PBO Lab PARMILA-2 user) can specify which segment is missing

The SC2 type of structure has *extra space* between specific segments (not illustrated in Figure 53) in order to accommodate larger focusing magnets. Either quadrupole singlets or doublets can be used within the extra space. This is referred to as a *grouped segments* superconducting linac. Whenever a magnet is located between two segments, the extra space introduces a region larger than d_{Seg} between those segments.



Missing Segments Superconducting (SC1) Linac Piece

The missing segments superconducting (SC1) linac structure of PARMILA 2 refers to a superconducting structure where there is an acceleration segment (cavity) not present (i.e. "missing") in each layout (see Figure 54). The parameters for the SC1 Piece are grouped into four (4) categories:

- RF Field
- Quads
- Segment Layouts
- Geometry

The Piece Window for the SC1 Piece has one tab panel for each of these parameter groups. The RF Field tab panel appears in front when a SC1 Piece window is opened. Figure 54 illustrates the tab panel for the RF Field parameters.



SC1 Piece

Each SC1 Piece represents one **STRUCTURE** section in the PARMILA 2 input file "input.LIN"

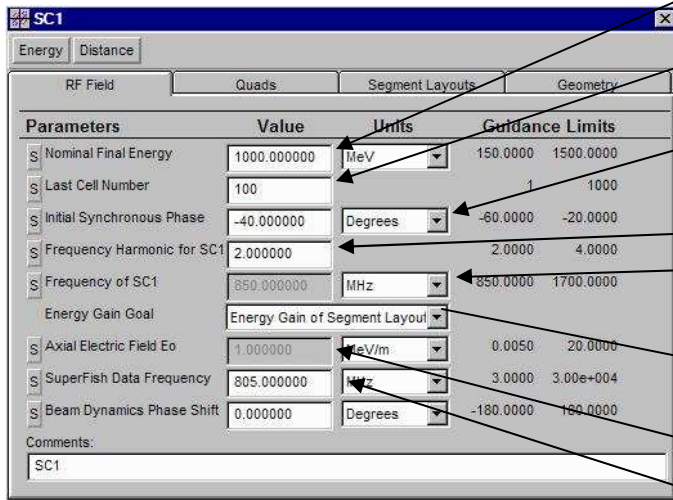


Figure 53. RF Field tab panel for a SC1 Piece.

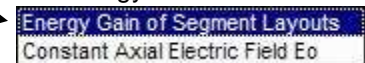
Nominal Final Energy should be larger than design objective.

Last Cell Number will be the final cell actually used in SC1.

The RF Field tab is used to set the Initial Synchronous Phase.

Frequency Harmonic for SC1 is a multiple of the (Document Window) Global Frequency. This sets the Frequency of SC1.

Two options are available for the Energy Gain Goal:



The Axial Electric Field value is used if the Energy Gain Goal is Constant Axial Electric Field Eo

Many of the parameters on the RF Field tab of the SC1 Piece window are the same as those appearing on the RF Field tab panel of the CCL Piece window (see Figure 36).

SuperFish Data Frequency may be different from the Frequency of SC1 and PARMILA 2 will scale the SuperFish data.



PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module

The Nominal Final Energy and Initial Synchronous Phase parameters on the RF Field tab page of the SC1 Piece correspond to the following parameter numbers in Table IV-9 of the Appendix: 1, 2

The RF Field parameters Last Cell Number, Frequency of SC1, and SuperFish Data Frequency of the SC1 Piece specify the corresponding data for the SC1 Structure line appearing in the PARMILA 2 input file "input.LIN".

The popup switch Energy Gain Goal on the RF Field tab of the SC1 Piece determines whether or not to use a "ConstESuper" keyword line in the PARMILA 2 input file "input.LIN". When the popup switch option is set to Constant Axial Electric Field Eo, then the "ConstESuper" keyword line is utilized, and the value for the Axial Electric Field Eo parameter specifies the data for that keyword line.

Quadrupoles are located between all general segments (cavities) of the SC1 Structure, including the so-called "missing" segments. There will actually be 2 quadrupoles, of opposite polarity, located in the special region that contains the "missing" segment. Or, equivalently, there will be (a) one quadrupole located after the segment that precedes the missing segment space and (b) another quadrupole, of opposite polarity, before the segment that follows the missing segment location.

The parameters in the SC1 Piece window, whose names are the same as those appearing on the on the CCL Piece window, may be understood to play the same basic role in the SC1 design process as the corresponding parameters of the CCL. However, the SC1 Piece does not have a parameter for specifying the initial axial electric field. The SC1 utilizes "Segment Layouts" in the design of the structure, and the axial electric field is determined by the details (primarily the "Energy Gain per Segment", see Figure 56) of the "Segment Layouts". The "Energy Gain Goal" popup switch illustrated in Figure 53 has its default setting to use those energy gains.

An "override" of the "Segment Layouts" specifications can be used to replace *all* axial electric fields in the entire *Structure* with a constant value. The "Energy Gain Goal" popup option "Constant Axial Electric Field Eo" is used to select this override. The "Axial Electric Field Eo" parameter value field is then used to input the desired constant value of the axial field.

An example illustrating *one Layout* of a missing segment superconducting linac (SC1) structure is shown in Figure 54. Specifying the details for individual "Segment Layouts" is described in detail further below. Note that there is one quadrupole located between every segment. For the SC1 this is a property of the entire Structure. That is, a quadrupole magnet is located between every Segment of every Layout of one SC1 Structure. The "Quads" tab panel of the SC1 Piece window is used to specify details for the quadrupole lattice. Figure 55 illustrates the SC1 Piece window "Quads" tab panel.

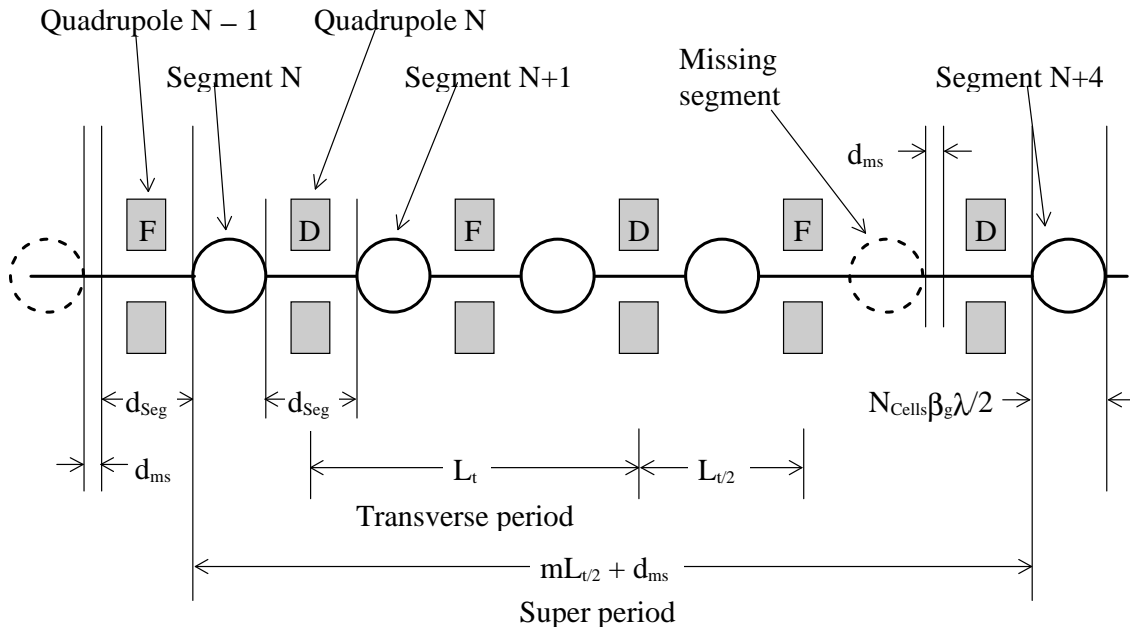


Figure 54. Layout for a missing segment superconducting linac (SC1), not to scale, from Appendix Figure III-7. This example has 1 missing segment every 4 segments.

Structure quad parameters:
 Magnetic-Field Gradient
 Effective Quad Length

The quadrupole lattice options include selections for setting:
 Sequencing of Polarities
 Magnet Locations
 Quad at Structure Start

*The parameters on the SC1 Quads tab page correspond to the following parameter numbers in Table IV-9 of the Appendix:
 5, 6, 7, 8, 9*

Only a singlet quadrupole lattice can be used with a PARMILA 2 SC1 Structure. The SC2 Structure supports both singlet and doublet lattice configurations.

Figure 55. Quads tab panel for a SC1 Piece.

The first two parameters on the "Quads" tab panel determine the quadrupole gradient and effective length for the entire SC1 Structure. The popup parameters ("Sequencing of Polarities", "Magnet Locations", "Quad at Tank Entrance") have the same choices as available for a CCL using *singlet* quadrupoles (see Figure 39).



PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module

Each SC1 Piece can support from 1 to 10 *Segment Layouts*. (At least one is required.) Figure 54 illustrates *one* Segment Layout, and the example layout shown has 1 missing segment, for every 4 segments. The "Segment Layouts" tab panel of the SC1 Piece window is used to set most of the other parameters illustrated in Figure 54. The SC1 "Segment Layouts" tab panel is shown in Figure 56.

Number of Layouts must be at least 1 and not more than 10

All *Layouts* for an SC1 Piece will have the *same* Number of Cells per Segment

The Individual Segment Layout switch *selects* input fields for the next 6 parameters:

Use this Layout

Starting Velocity (v/c)

Energy Gain per Segment

Distance Between Segments

Missing Segment Number m

Shift Missing Segment

Each Segment Layout to be used, i.e. each Layout number less than or equal 'Number of Layouts' entered, must have 'Use this Layout' set to "Yes"

Parameters	Value	Units	Guidance Limits
S Number of Layouts	1		1 10
S Number of Cells per Segment	10		1 100
Individual Segment Layouts	Segment Layout 1 Parameters		
Use this Layout	Yes		
S Starting Velocity (v/c)	0.500000	β	0.2000 0.9990
S Energy Gain per Segment	2.000000	MeV	0.0100 10.0000
S Distance Between Segments	100.000000	cm	30.0000 300.0000
S Missing Segment Number m	3		2 10
S Shift Missing Segment	0.000000	cm	0.0000 10.0000

PARMILA 2 superconducting structure hierarchy:

- **STRUCTURE**

A *STRUCTURE* is comprised of a Number of Layouts

- **LAYOUT**

One *LAYOUT* is composed of a number of *SEGMENTS*. The number is computed by *PARMILA 2* for each *LAYOUT*.

- **SEGMENT**

Each *SEGMENT* in a *LAYOUT* contains the fixed Number of Cells per Segment

Figure 56. Segment Layouts tab panel for a SC1 Piece.

The SC1 "Segment Layouts" tab panel, illustrated in Figure 56, can be conceptually separated into 2 parts. The upper part contains the two parameter input fields for "Number of Layouts" and "Number of Cells per Segment". These two parameters are the same for all Segments in each Layout. The sidebar to the left contains a summary of the superconducting structure hierarchy determined by the values of the parameters.

PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module



The "Number of Layouts" must be at least 1 (otherwise no SC1 structure exists). Similarly, the number of "Number of Cells per Segment" must also be at least 1.

The second part, of the conceptual division of the SC1 "Segment Layouts" tab panel, contains the popup switch "Individual Segment Layouts" and the remainder of the parameters on the tab. The "Individual Segment Layouts" popup switch has ten (10) positions, corresponding to the (maximum) possible "Number of Layouts". For *each* of the 10 switch positions, the popup switch "Use this Layout" and the five parameter input fields immediately below are individually set.

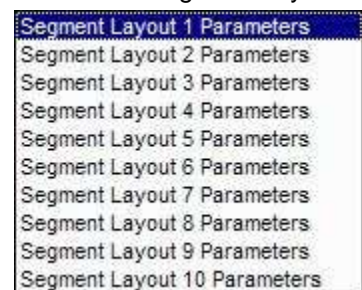
Parameters only need to be entered for the "Number of Layouts" specified. For example, if the "Number of Layouts" is set to "2", then values are only needed for the "Segment Layout 1 Parameters" and "Segment Layout 2 Parameters". (Values for "Segment Layout 3 Parameters" through "Segment Layout 10 Parameters" will not be used by the PARMILA-2 Module.) It is important that the popup switch "Use this Layout" be set to "Yes" for both Layout 1 and Layout 2. Only Layout 1 has a default of "Yes", all other Layouts have "No" as their default setting. The sidebar to the right provides a summary of the PARMILA 2 superconducting structure hierarchy for the example of 2 Layouts.

Each Layout has five (5) parameters that determine the SC1 design: "Starting Velocity (v/c)", "Energy Gain per Segment", "Distance Between Segments", "Missing Segment Number m" and "Shift Missing Segment". One of these parameters, "Starting Velocity (v/c)", should be increasing from one Layout to the next. The others may, or may not, be unique to each Layout. In the SC1 basic design all Layouts will have the same singlet quadrupole focusing characteristics as specified on the Quads tab panel (Figure 55).

Individual Layout parameters:
Starting Velocity (v/c)
Energy Gain per Segment
Distance Between Segments
Missing Segment Number
and
Shift Missing Segment
correspond to the following five parameter numbers in Table IV-9 of the Appendix:
10, 11, 12, 13, 14

One set of these five parameters is needed for each Layout, up to the Number of Layouts specified. Each set is entered by selecting a different position of the popup switch:

Individual Segment Layouts



Example for a superconducting structure hierarchy:

- **STRUCTURE**
Number of Layouts = 2

- **LAYOUT**
Enter parameter values for:
Segment Layout 1 Parameters
Segment Layout 2 Parameters
The number of Segments for Layout 1 and Layout 2 will be computed by PARMILA 2.

- **SEGMENT**
All Segments in Layout 1 and Layout 2 will contain the same
Number of Cells per Segment

- **CELLS**
Detailed cell parameters will be computed by PARMILA 2 for all Segments in Layout 1 and Layout 2.



PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module

Design: The number of Segments, and hence total number of cells, is computed by PARMILA 2 so that the SC1 structure achieves the Nominal Final Energy specified on the RF Field tab page (Figure 53).

Simulation: In beam dynamics simulations, computations are carried out only through the cell number specified for the Last Cell Number on the RF Field tab page (Figure 53).

When setting up the design goals for a SC1 Structure, it is important to specify a "Nominal Final Energy" (see Figure 53) that is high enough to allow PARMILA 2 to determine the design *beyond* the "Maximum Cell Number" desired for the actual Structure. As the preceding discussion of the superconducting structure hierarchy suggests, this may not be known *a priori* at the beginning of the design process. Users should anticipate the need for some iteration of the design.

The last tab panel of the SC1 Piece window is the Geometry tab. The SC1 Geometry tab panel is illustrated in Figure 57.

Aperture R_{b1} of Initial SC1 Cells
Aperture R_{b2} of Final SC1 Cells
Aperture Change Cell Number

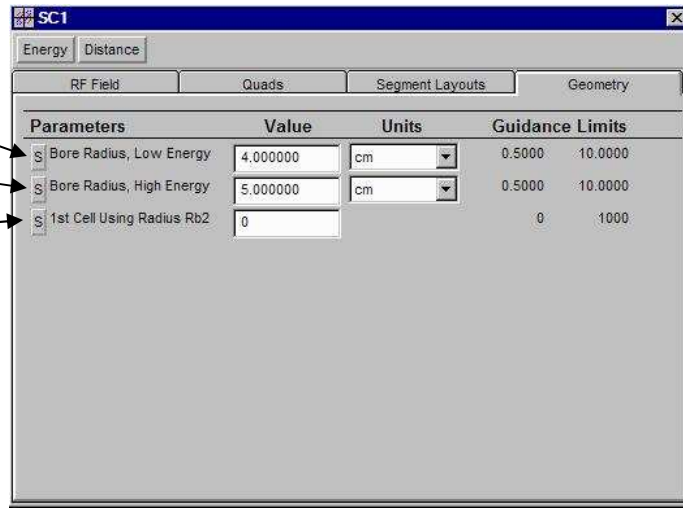


Figure 57. Geometry tab panel for a SC1 Piece.

The parameters on the Geometry tab provide the data for each SC1 "Bore" keyword line in the PARMILA 2 input file "input.LIN". Section IV.B.18 of the Appendix discusses the "Bore" keyword data.

The three parameters on the Geometry tab panel of the SC1 Piece window are used for PARMILA 2 beam simulations. The parameters play a role for each SC1 structure similar to the corresponding parameters of the DTL (Figure 34) and the CCL (Figure 44). If only one value for the bore radius is desired, set the desired value in the "Bore Radius, Low Energy" data field, and then set the integer parameter "1st Cell Using Radius Rb2" to "0" (default value). Any entry in the "Bore Radius, High Energy" data field will then be ignored.

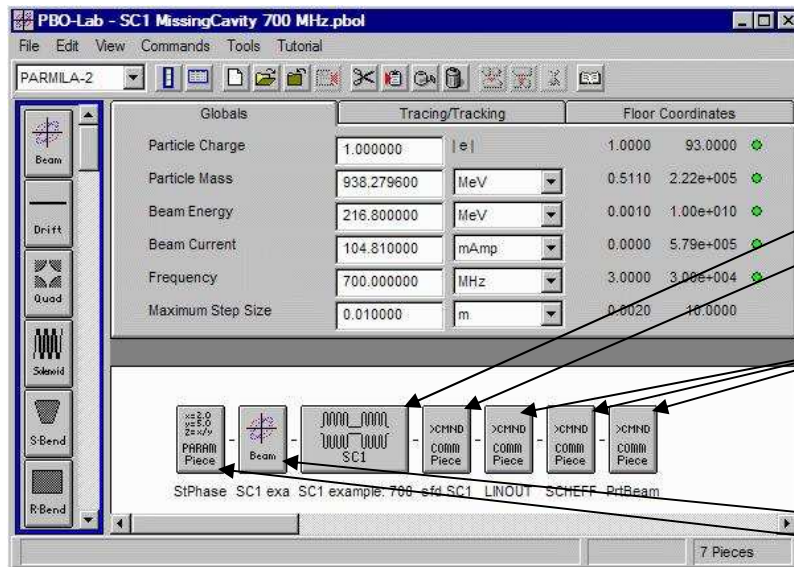
PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module



All PARMILA 2 radiofrequency *Structures* require a block of SuperFish data in order to carry out a design or simulation. Figure 58 illustrates a PBO Lab Document Window with a representative set of Pieces used for a carrying out a SC1 design and simulation.

The PBO Lab file "SC1 MissingCavity 700 MHz.pbol" is located in the PBO Lab installation folder:

Examples/Parmila



SC1 "Design Line" is Composed of 2 Pieces:

SC1 Piece - "SC1 example ..."

COMM Piece - "sfd SC1"

Other PARMILA-2 COMM Pieces provide data for output ("LINOUT", "PrtBeam") and space charge meshing ("SCHEFF").

Initial Beam Parameters are provided through:

Beam Piece - "SC1 exa..."

PARAM Piece - "StPhase"

Figure 58. PBO Lab Document Window for the "SC1 MissingCavity 700 MHz.pbol" example.

The PBO Lab file named "SC1 MissingCavity 700 MHz.pbol" provides an example of using PARMILA-2 to design a SC1 missing cavity type of structure, and then simulate its performance. This file is located in the Examples/Parmila directory installed with PBO Lab 3.

The SC1 Piece and the COMM Piece immediately following it in Figure 58 comprise the SC1 "Design Line" for the example. These two Pieces represent a minimal Design Line which incorporates the required SuperFish data through the COMM Piece labeled "SC1 sfd", but has no other Pieces that effect the design of the SC1. The other Pieces are utilized for the beam dynamics simulation and specifying various design or simulation outputs.



PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module

Similar to the DTL, CCL and CCDTL structures, various options are available to override (or replace) the basic SC1 design goals with other criteria. For example, the specification of individual quadrupole parameters can be imposed upon the design and simulation of an SC1 structure. The set up of these additional conditions utilizes various PARMILA-2 Parameter (PARAM) and Command (COMM) Pieces, similar to the examples illustrated for the DTL Piece (see Figure 35). The PARMILA-2 Parameter (PARAM) and Command (COMM) Pieces are described in a later Section of this manual.

Figure 59 illustrates part of the design section of the 'Parmila.out' file for the "SC1 MissingCavity 700 MHz.pbol" example. This SC1 example has 1 Layout, 5 cells per Segment, with every 4th Segment "missing" ($m=3$). The quadrupole Lattice is a DFDF type, meaning that the first *full-length* quadrupole (located after the 1st Segment) is defocusing (D) in the horizontal, or x, direction. There is an initial *half-length* quadrupole at the Structure entrance (before the 1st Segment) which has the opposite polarity.



```

Parmila.out
File Edit Font
Superconducting cavity design details
EO ramped linearly with beta starting at cell 1
LIN: LINOUT 1
RF structure and beam-dynamics parameters
RF structure of length 4130.7378 cm contains 90 cells
Total RF power including beam and structure = 12.4468 MW
Cavity frequency = 700.0 MHz, wavelength = 42.827494 cm
Center of preceding quadrupole magnet occurs at Z = 0.0 cm
Total length for the preceding quadrupole magnet including drift to first cavity = 101.476 cm
Preceding doublet center to the start of the first cavity = 50.738 cm
Quadrupole magnet half length = 15.25 cm
Quadrupole gradient = 0.64 kG/cm
The column headings are:
W: Energy of the synchronous or design particle at the end of the cell in MeV
Beta: Velocity of the synchronous or design particle at the end of the cell
Lc: Cell length in cm
T: Transit-time factor cosine integral with reference position at electrical center
T': Derivative of T with respect to wave number
S: Transit-time factor sine integral (average magnitude of upstream and downstream half)
S': Derivative of S with respect to wave number
Lq: Quadrupole magnet length in cm
G: Quadrupole gradient in kG/cm
EOd: Design value of EO for the entire cavity or segment in MV/m
EO: Average axial electric field for the cell in MV/m (used in energy-gain calculation)
Phi: Phase of the reference particle at the center of the gap in degrees
Phid: Synchronous phase or design phase for symmetric segments in degrees
Z: Distance to end of cell (or center of magnet) from the beam-entrance end wall in cm
Phir: Relative drive phase for the cavity in degrees

```

Cell	W	Beta	Lc	T	T'	S	S'	Lq	G
initial	216.8000	0.58323						15.250	0.6400
1	216.8674	0.58330	13.7048	0.5293	0.1690	0.2981	0.0213	0.000	0.0000
2	217.4511	0.58387	13.7048	0.7400	0.1233	0.2703	0.0481	0.000	0.0000
3	218.1961	0.58459	13.7048	0.7405	0.1234	0.2701	0.0482	0.000	0.0000
4	219.0337	0.58541	13.7048	0.7409	0.1234	0.2699	0.0483	0.000	0.0000
5	219.6000	0.58596	13.7048	0.5317	0.1698	0.2979	0.0214	0.000	0.0000
	219.6000	0.58596	101.4760					30.500	-0.6400
6	219.6862	0.58604	13.7048	0.5323	0.1700	0.2978	0.0214	0.000	0.0000
7	220.2724	0.58661	13.7048	0.7422	0.1236	0.2694	0.0486	0.000	0.0000
8	221.0079	0.58731	13.7048	0.7426	0.1236	0.2692	0.0487	0.000	0.0000
9	221.8319	0.58811	13.7048	0.7430	0.1237	0.2691	0.0489	0.000	0.0000
10	222.4000	0.58865	13.7048	0.5346	0.1709	0.2976	0.0214	0.000	0.0000
	222.4000	0.58865	101.4760					30.500	0.6400
11	222.5041	0.58875	13.7048	0.5352	0.1711	0.2975	0.0214	0.000	0.0000
12	223.0928	0.58931	13.7048	0.7443	0.1238	0.2686	0.0492	0.000	0.0000
13	223.8196	0.59000	13.7048	0.7447	0.1239	0.2684	0.0493	0.000	0.0000
14	224.6306	0.59077	13.7048	0.7452	0.1239	0.2682	0.0494	0.000	0.0000
15	225.2000	0.59131	13.7048	0.5375	0.1719	0.2973	0.0216	0.000	0.0000
	225.2000	0.59131	101.4760					30.500	-0.6400
	225.2000	0.59131	101.4760					30.500	0.6400
16	225.3214	0.59143	13.7048	0.5381	0.1721	0.2973	0.0217	0.000	0.0000
17	225.9124	0.59198	13.7048	0.7464	0.1241	0.2678	0.0497	0.000	0.0000
18	226.6310	0.59266	13.7048	0.7468	0.1241	0.2676	0.0498	0.000	0.0000
19	227.4297	0.59341	13.7048	0.7472	0.1242	0.2674	0.0499	0.000	0.0000
20	228.0000	0.59394	13.7048	0.5403	0.1729	0.2970	0.0221	0.000	0.0000

Figure 59. A portion of the 'Parmila.out' file, following completion of the menu command "Write and Run 'input.LIN' ", for the example file "SC1 MissingCavity 700 MHz.pbol".



PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module

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Grouped Segments Superconducting (SC2) Linac Piece

The second type of superconducting structure available in PARMILA 2 is referred to as the grouped segments superconducting (SC2) linac structure. This type of superconducting structure has quadrupoles located between groups of segments and differs in several ways from the SC1 structure. For example, either singlet or doublet quadrupole lattices can be used with SC2 structures. The parameters for the SC2 Piece are grouped into four (4) categories:

- RF Field
- Quads & Segments
- Segment Layouts
- Geometry

The Piece Window for the SC2 Piece has one tab panel for each of these parameter groups. The RF Field tab panel appears in front when a SC2 Piece window is opened. Figure 60 illustrates the tab panel for the RF Field parameters, which is identical to that of the SC1.

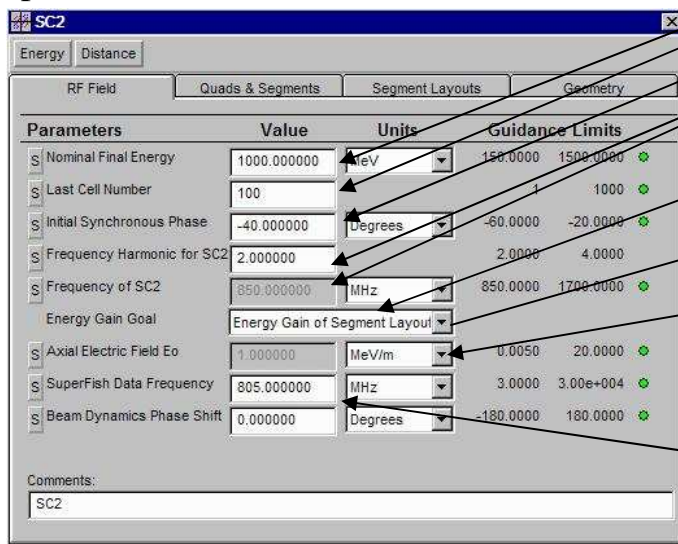


Figure 60. RF Field tab panel for a SC2 Piece.



SC2 Piece

Both singlet and doublet quadrupole lattices can be used with a PARMILA 2 SC2 Structure.

Nominal Final Energy should be larger than design objective

Last Cell Number will be the final cell actually used in SC2.

Initial Synchronous Phase

Frequency Harmonic for SC2 is a multiple of the (Document Window) Global Frequency, and sets Frequency of SC2

Two options are available for the Energy Gain Goal:



The Axial Electric Field value is used if the Energy Gain Goal is Constant Axial Electric Field Eo

SuperFish Data Frequency may be different from the Frequency of SC2; PARMILA 2 will scale data



PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module

The Nominal Final Energy and Initial Synchronous Phase parameters on the RF Field tab page of the SC2 Piece correspond to the following parameter numbers in Table IV-10 of the Appendix:
1, 2

The parameters Last Cell Number, Frequency of SC2, SuperFish Data Frequency, and Beam Dynamics Phase Shift specify the corresponding data for the SC2 Structure line appearing in the PARMILA 2 input file "input.LIN".

The SC2 Structure supports both doublet (Figure 61) and singlet (Figure 62) lattice configurations.

The RF Field tab panel for the SC2 Piece window is the same as the RF Field tab panel of the SC1 Piece (Figure 53). The discussion following Figure 53 is applicable to the SC2 Structure as well. A few summary items of that discussion are included in the sidebars of the next few pages, but users may wish to review the SC1 discussion in more detail.

The SC2 Structure can be designed using either a quadrupole doublet or a quadrupole singlet focusing Lattice. Figure 61 illustrates an example of one Layout for a SC2 with doublet quads after every 3 segments. Figure 62 shows a similar Layout example for a SC2 Structure that uses singlet quads after every 3 segments. The transverse quadrupole Lattice period for the singlet Lattice is generally longer than for a doublet Lattice. General properties of each SC2 Layout and Lattice are specified with parameters on the Quads & Segments tab panel, illustrated in Figure 63.

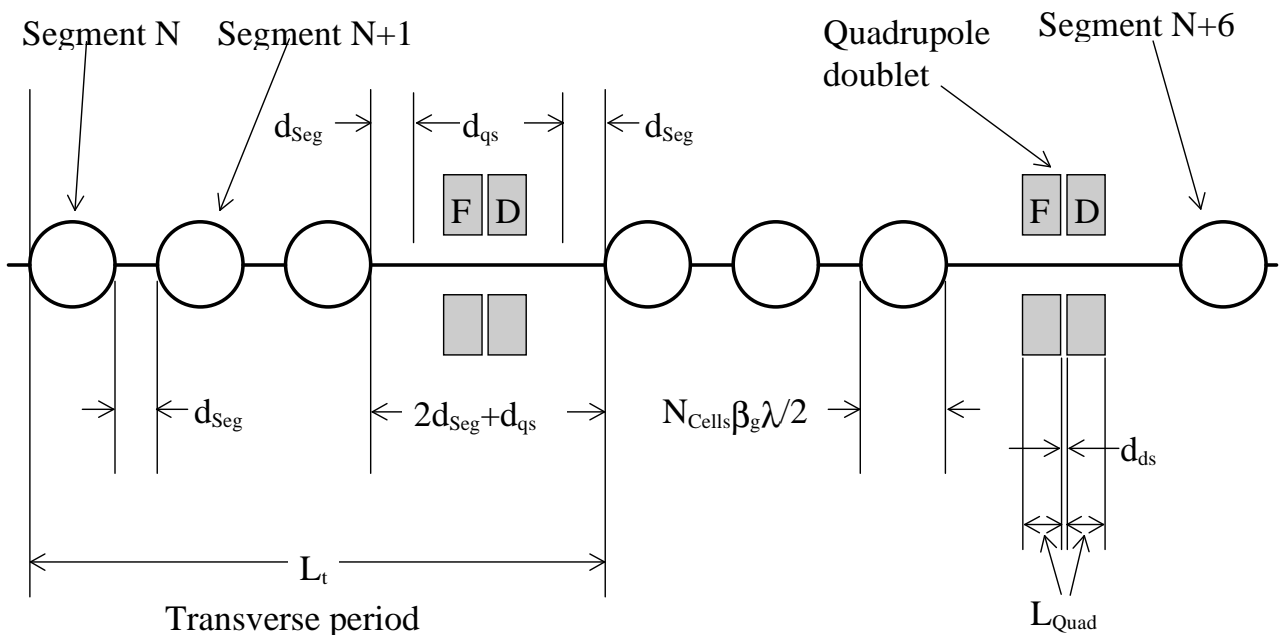


Figure 61. Layout for a grouped segment superconducting linac (SC2) using quadrupole doublet focusing, not to scale, from Appendix Figure III-8.

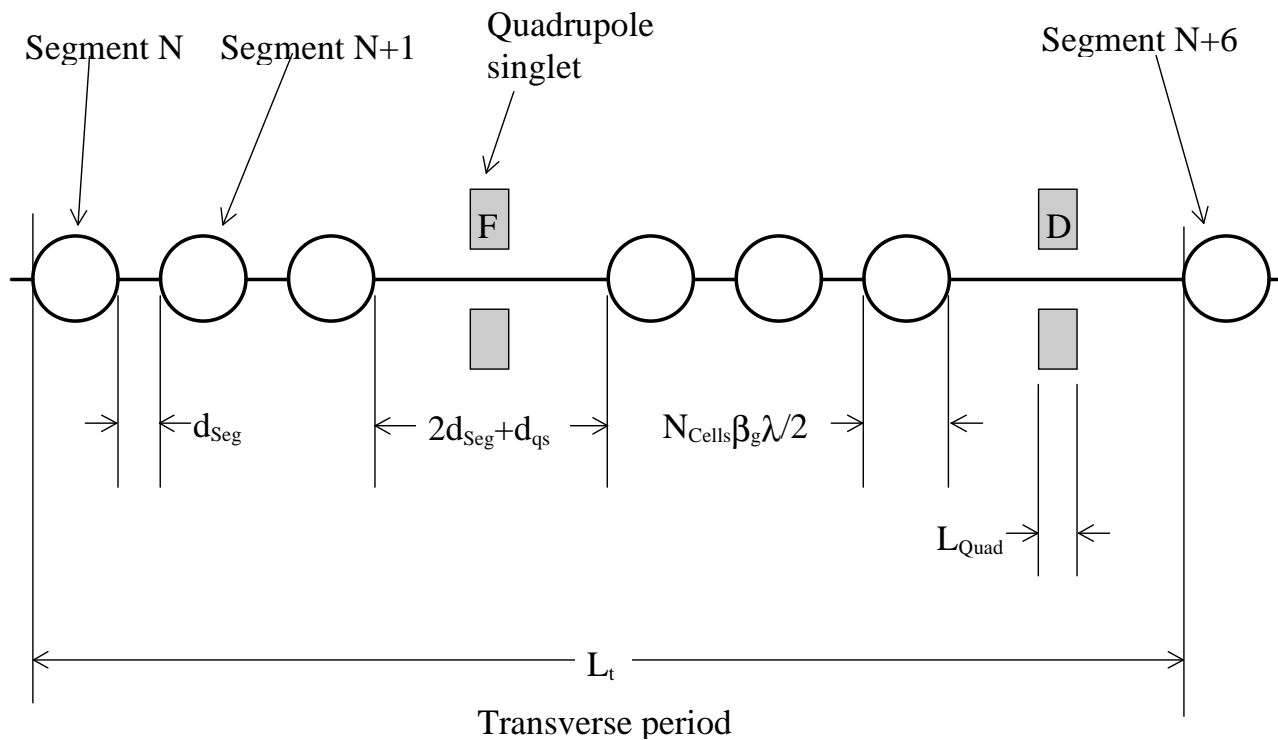


Figure 62. Layout for a grouped segment superconducting linac (SC2) using quadrupole singlet focusing, not to scale, from Appendix Figure III-9.

Figure 63 shows the Quads & Segments tab panel for the SC2 Piece window. The SC2 structure hierarchy follows the same pattern as for the SC1. A primary difference is that the quadrupole details (gradient, length) are specified for each Layout in an SC2, rather than for the whole Structure as in the case of an SC1. The Quads & Segments tab panel reflects this difference - only the top-level Structure inputs are on the Quads & Segments tab panel.

The "Lattice Type" popup switch is used to specify whether the SC2 Structure will use "Singlet Quads" or "Doublet Quads". If a doublet type lattice is selected, then the "Polarity for Doublets" popup switch assigns the polarity for the first quad in each doublet. The "Polarity for Doublets" setting is ignored if a singlet type lattice is selected. A half-length entrance quad may be included using the "Quad at Tank Entrance" popup switch.

PARMILA 2 superconducting structure hierarchy:

- **STRUCTURE**
A STRUCTURE is comprised of a Number of Layouts.
- **LAYOUT**
One LAYOUT is composed of a number of SEGMENTS. The number is computed by PARMILA 2 for each LAYOUT.
- **SEGMENT**
Each SEGMENT in a LAYOUT contains the fixed Number of Cells per Segment.
- **CELLS**
Detailed cell parameters will be computed by PARMILA 2.



PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module

Lattice Type determines quad arrangement for Structure

Polarity for Doublets only applies if Doublet Quads is selected for the Lattice Type

Quad at Tank Entrance has 2 possible choices

Number of Layouts must be at least 1 and not more than 10

All Layouts for an SC2 Piece will have the same Number of Cells per Segment

Parameters	Value	Units	Guidance Limits
Lattice Type	Singlet Quads		
Polarity for Doublets	x - First Quad Focusing x		✓
Quad at Tank Entrance	Half Length Quadrupole		✓
Number of Segment Layout and Cells per Segment			
S Number of Layouts	1		1 10 ✓
S Number of Cells per Segment	10		1 100 ✓

Figure 63. Quads & Segments tab panel for SC2 Piece.

The parameters on the SC2 Quads & Segment tab page (except Polarity for Doublets) correspond to the following parameter numbers in Table IV-10 of the Appendix: 5, 6, 3, 4

The Polarity for Doublets is utilized in conjunction with parameters on the Segment Layouts tab page of the SC2 Piece window (Figure 64).

The parameters selected on the Quad & Segments tab panel will impact the use of certain parameters on the Segment Layouts tab panel.

The remaining 2 top-level SC2 Structure parameters appearing on the Quads & Segments tab panel determine the "Number of Layouts" and the "Number of Cells per Segment". These parameters are identical to the parameters with the same names that appear at the top of the SC1 Segment Layouts tab panel (Figure 56). Their functionality is also the same for SC2 Structures.

The Segment Layouts tab panel for the SC2 Piece is illustrated in Figure 64. Five of the first six parameters appearing on the SC2 Segment Layouts tab panel are the same as the parameters of the same name that also appear on the SC1 Segment Layouts tab panel (Figure 56). The first two are the popup switches: "Individual Segment Layouts" and "Use this Layout". These switches are used in the same manner as those of the SC1 Piece: Set the "Use this Layout" popup switch to "Yes" for each layout number that is to be used. For example, if the "Number of Layouts" is set to 4, then the switch needs to be set to "Yes" for "Segment Layout 1 Parameters", "Segment Layout 2 Parameters", "Segment Layout 3 Parameters" and "Segment Layout 4 Parameters".



Segment Layout 1 Parameters
 Segment Layout 2 Parameters
 Segment Layout 3 Parameters
 Segment Layout 4 Parameters
 Segment Layout 5 Parameters
 Segment Layout 6 Parameters
 Segment Layout 7 Parameters
 Segment Layout 8 Parameters
 Segment Layout 9 Parameters
 Segment Layout 10 Parameters

Yes
No

Each Segment Layout to be used, i.e. each Layout number less than or equal to the 'Number of Layouts' entered on the Quads & Segments tab, must have 'Use this Layout' set to "Yes"

Segment Layout 'x' Parameters switch *selects* input fields for the next 11 parameters for Layout number 'x':

- Use this Layout
- Starting Velocity (v/c)
- Energy Gain per Segment
- Segs Between Quad Spaces
- Distance Between Segments
- Space for Quadrupoles
- Magnetic-Field Gradient
- Effective Quad Length
- Magnet Locations
- Sequencing for Singlet
- Distance Between Quads

Figure 64. Segment Layouts tab panel for SC2 Piece.

The next SC2 two parameters on the Segment Layouts tab panel, "Starting Velocity (v/c)" and "Energy Gain per Segment", are also the same as the corresponding parameters on the SC1 Segment Layouts tab panel. Values for these should be entered for each setting of the "Individual Segment Layouts" switch for a layout number that is to be used in the SC2 design. The value for the "Starting Velocity (v/c)" should be an increasing function of the layout number.

The SC2 parameter "Distance Between Segments" also has the same characteristics as the corresponding SC1 parameter, but the integer parameter "Segs Between Quad Spaces" is unique to the SC2 Piece. Figures 61 and 62 illustrate examples where the "Segs Between Quad Spaces" are equal to 3.

Individual Layout parameters:
 Starting Velocity (v/c)
 Energy Gain per Segment
 Segs Between Quad Spaces
 Distance Between Segments
 and
 Space for Quadrupoles
correspond to the following five parameter numbers in Table IV-10 of the Appendix:
 7, 8, 9, 10 11

Individual Layout parameters:
 Magnetic-Field Gradient
 Effective Quad Length
 and
 Magnet Locations
are used for both Singlet Quad *and* Doublet Quad *choices of the SC2 Lattice Type selection (Figure 63). The usage of the remaining parameters depends upon the Lattice Type.*



PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module

Individual Layout parameter:

Sequencing for Singlet
is only used for the Singlet
Quad choice of the SC2
Lattice Type selection.

Individual Layout parameter:

Distance Between Quads
is only used for the Doublet
Quad choice of the SC2
Lattice Type selection.

The Polarity for Doublets
appearing on the SC2 Quads
& Segments tab panel (Figure
63) is also utilized with the
PARMILA 2 'QuadDoublet'
keyword line in the input file
"input.LIN".

The 'QuadSinglet' keyword line
is discussed in Section IV.A.21
of the Appendix.

The 'QuadDoublet' keyword
line is discussed in Section
IV.A.22 of the Appendix.

The remaining five SC2 Segment Layouts tab panel parameters are associated with the magnetic quadrupole lattice to be used for a given layout. Unlike the SC1 Structure, where the quadrupole lattice is the same for all layouts, the SC2 Structure can be used for layouts in which the parameters of the lattice quadrupoles are different in each layout.

The "Space for Quadrupoles" defines the physical length of the additional space between segments within which the quadrupoles (singlets or doublets) are located. The "Space for Quadrupoles" is the distance indicated by d_{qs} in Figures 61 and 62.

The SC2 Segment Layouts tab panel parameters discussed to this point all appear in the main PARMILA 2 input file "input.LIN" following the PARMILA 2 keyword "SC2". The remainder of the parameters on the SC2 Segment Layouts tab panel, which give the details of the quadrupole lattice parameters, will appear after one of two other possible keywords: "QuadSinglet" or "QuadDoublet". The PBO Lab PARMILA-2 Module keeps track of all parameter settings, and writes all necessary and sufficient data in the correct order to the PARMILA 2 input file "input.LIN".

Note that for a doublet lattice, the value for the "Space for Quadrupoles" should be greater than *twice* the "Effective Quad Length" *plus* the "Distance Between Quads". For a singlet lattice, the "Space for Quadrupoles" need only be greater than the "Effective Quad Length". The Guidance Limits for the "Space for Quadrupoles" parameters reflect these requirements.



The SC2 Geometry tab panel is the same as the corresponding SC1 Geometry tab panel (Figure 57). The three parameters on the Geometry tab panel of the SC2 Piece window are used for PARMILA 2 beam dynamics simulations. The parameters play a role for each SC2 structure similar to the corresponding parameters of the DTL (Figure 34) and the CCL (Figure 44). If only one value for the bore radius is desired, set the desired value in the "Bore Radius, Low Energy" data field, and then set the integer parameter "1st Cell Using Radius Rb2" to "0" (default value). Any entry in the "Bore Radius, High Energy" data field will then be ignored.

The parameters on the Geometry tab provide the data for each SC2 "Bore" keyword line in the PARMILA 2 input file "input.LIN". Section IV.B.18 of the Appendix discusses the "Bore" keyword data.



PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module

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Specialized PARMILA-2 Optics Pieces

The PARMILA 2 code has a few specialized optics elements that are not found in most other optics codes. These include the PARMILA 2 funnel and chopper elements. These specialized, or custom, optics elements are accessed using the PARMILA-2 Optics Pieces submenu on the PARMILA-2 commands menu. Selection of the PARMILA-2 Optics Pieces menu item opens the window illustrated in Figure 67.

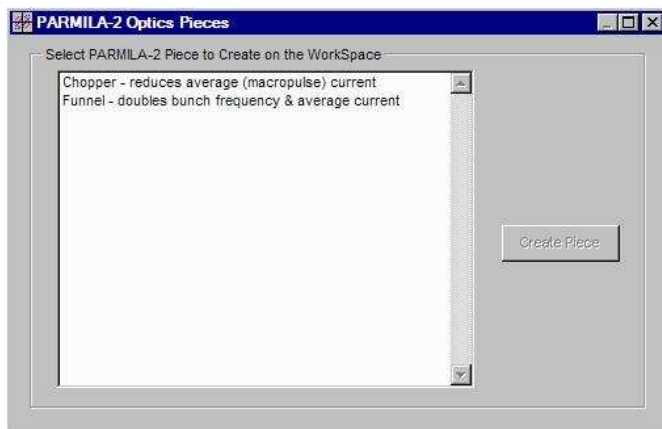
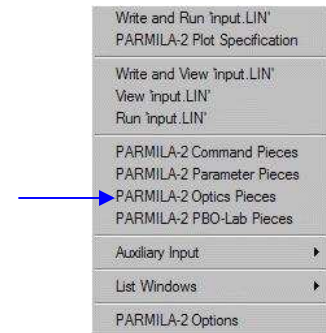


Figure 67. The PARMILA-2 Optics Pieces window lists all of the specialized optics elements used by the PARMILA-2 Module.

The PARMILA 2 funnel and chopper elements do not include any external fields in their physics models. They only impact the beam simulation *indirectly*, through affects introduced by space charge.



Specialized optics elements utilized by the PARMILA-2 Module are accessed from the PARMILA-2 Optics Pieces menu. These specialized Optics Pieces are only used by the PARMILA-2 Module, they are ignored by other PBO Lab Optics Modules.

Note: Some or all of the specialized PARMILA-2 Optics Pieces may be incorporated into the Palette Bar in future releases of PBO Lab.



PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module

Table 2. Summary of output files created by Parmila.exe.
(to be completed)

File Name	Description	PARMILA-2 Command	Comment
Parmila.out	PARMILA Main Output File	Write and Run 'input.LIN'	Always written
Design.out	Beam Dynamic Design Detail	Write and Run 'input.LIN'	Use LINOUT Command Piece
Beam.out		Write and Run 'input.LIN'	Use PrtBeam Command Piece
E0prof.out		Write and Run 'input.LIN'	
Quad.out		Write and Run 'input.LIN'	
QuadErrs.out		Write and Run 'input.LIN'	
QuadPos.out		Write and Run 'input.LIN'	
WallPwr.out		Write and Run 'input.LIN'	Use POWER Command Piece
parmila.plt	LinGraf binary data file	Write and Run 'input.LIN'	Use PrtBeam Command Piece



PBO Lab™

Appendix "Parmila 2" LA-UR-98-4478

**User Manual:
Supplement:
PARMILA-2
Application
Module**



PBO Lab 3.0 User Manual Supplement: PARMILA-2 Module

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