PowerTrace™ User Manual
with
TRACE 3-D Documentation

First Edition

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1. Introduction

PowerTrace™ is a graphical user interface shell which has been integrated to run with the accelerator beam dynamics code TRACE 3-D. The interface is based on the Shell for Particle Accelerator Related Codes (S.P.A.R.C.) software technology. This manual describes the operation and use of the PowerTrace interface with the TRACE 3-D program.

TRACE 3-D is a FORTRAN program maintained and distributed by the Los Alamos Accelerator Code Group.   TRACE 3-D is integrated with the PowerTrace software under a license agreement with the Los Alamos National Laboratory and the Regents of the University of California. A copy of the TRACE 3-D Documentation is included at the end of this manual and distributed with PowerTrace under the same license agreement.

PowerTrace Overview

PowerTrace is a Graphic User Interface (GUI) developed to work in conjunction with the TRACE 3-D program on PowerPCs under the Mac OS. Sections 2-3 of this User Manual describe the use of the PowerTrace GUI. Section 4 discusses the various matching options available in TRACE 3-D and Section 5 describes the PowerTrace commands used to run TRACE 3-D. Section 6 discusses User Preferences. Section 7 describes Customization of the PowerTrace application. Documentation for the TRACE 3-D program is included as an appendix to this User Manual. PowerTrace is based on the Shell for Particle Accelerator Related Codes (S.P.A.R.C.) software technology which provides a graphic interface customized to work with programs used for the design and analysis of particle optics systems and accelerators.

PowerTrace is a custom graphic user interface designed to work with the beam dynamics program TRACE 3-D. PowerTrace is fully integrated with the TRACE 3-D program and provides an easy to use standalone package on the PowerMac.

The PowerTrace software is distributed in both Standard and Professional packages. The Standard package contains the PowerTrace application only, while the Professional package includes the S.P.A.R.C. object code for the PowerTrace GUI and the TRACE 3-D FORTRAN source code used to build the PowerTrace application for the PowerMac. Professional users can compile and link a customized version of TRACE 3-D using templates provided for FORTRAN subroutines that are accessed through the GUI as Custom elements on the Palette Bar.

Professional users can compile and link a customized version of TRACE 3-D.

Several Custom elements that are not part of the original TRACE 3-D program have been developed and are also available as plug-in modules. The FORTRAN source code is also included with these modules.

The Electrostatic Palette provides a set of elements for a variety of electrostatic lenses and accelerator columns that have been developed including three einzel lenses, two electrostatic accelerating columns and three electrostatic prisms. These elements utilize the first-order R matrix formalism to compute changes to the beam (Sigma matrix), calculating the effective transfer

The Electrostatic Palette provides additional Custom elements to model electrostatic lenses and accelerator columns.

matrix in a series of longitudinal steps through the element, incorporating changes in the Beam Energy as a function of position in the electrostatic elements, as well as calculating fringe fields and retaining the space charge model for all elements.

A Traveling Wave Palette is also available for PowerTrace users who want to use TRACE 3-D for modeling traveling wave accelerators. This palette has been developed to allow incorporation of particle beam loading (current) effects on the accelerator gradient and the accelerator structure's beam focusing properties in a self-consistent manner.

The Traveling Wave Palette provides additional Custom elements to model traveling wave accelerators.

TRACE 3-D Overview

TRACE 3-D is a FORTRAN beam dynamics program maintained and distributed by the Los Alamos Accelerator Code Group. TRACE 3-D calculates the envelopes and phase-space ellipses of a bunched beam, including linear space-charge forces, through a beamline. TRACE 3-D also supports fourteen different types of fitting or beam-matching options. Matching options will vary the Initial Beam parameters for a matched beam in X,Y planes, Z plane, X,Y,Z planes (Upright) or in X,Y,Z planes. Fitting options will vary element parameters to fit a desired beam in X, in Y, or in the Z plane, in X,Y planes or in X,Y,Z planes. The Initial Beam can also be fit for a desired beam in X,Y,Z planes. In addition, TRACE 3-D can vary element parameters to fit desired R-Matrix or σ-Matrix elements, vary element parameters to fit for a round beam, or to fit for specified phase advances in selected phase planes.

The TRACE 3-D program calculates beam envelopes and phase-space ellipses in the transverse and longitudinal dimensions.

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2. Quick Start

This section is intended to provide users, who are familiar with both TRACE 3-D and the Macintosh operating system, with a brief introduction to PowerTrace that will get them up and running quickly. Not all features of the PowerTrace user interface are covered here and all users should (eventually) read the complete User Manual and TRACE 3-D Documentation.

Installing PowerTrace

The PowerTrace software is distributed in both Standard and Professional packages. The Standard PowerTrace package contains the application and some example beamline models. The Professional package also includes the S.P.A.R.C. object code for the PowerTrace GUI and the TRACE 3-D FORTRAN source code used to build the PowerTrace application for the PowerMac. Installation for the Professional package is discussed in Appendix B "Customizing PowerTrace".

The PowerTrace application disk contains the PowerTrace application and some example files, as illustrated in Figure 2-1.
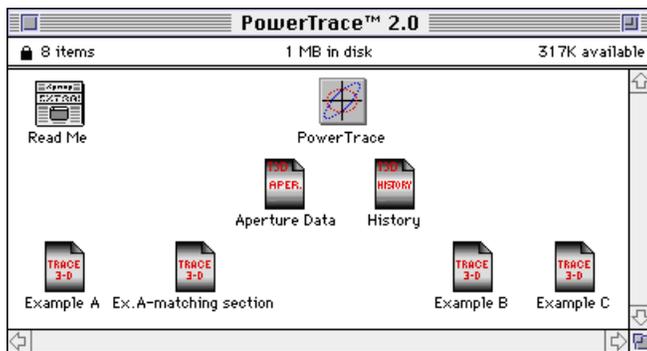
The PowerTrace application requires no special installation, simply drag the contents of the application disk to your hard drive.

Figure 2-1. PowerTrace Application Disk.

The PowerTrace application requires no special installation, simply insert the application disk into your computer's floppy disk drive and drag the contents to your hard drive. The application requires approximately 1 MB of disk space.

PowerTrace User Interface

The PowerTrace application may be opened by double clicking the application icon or on a PowerTrace Model file. Figure 2-2 below illustrates the principal parts of the PowerTrace application: the Menu Bar, Palette Bar and the different panes of the Document Window (the Global Parameter Pane, the Model Space Pane and the Work Space Pane), as well as the TRACE 3-D Graphic Output Window and Text Output Window. Figure 2-2 indicates the principal parts of the PowerTrace application with the "Example B" Model file which is distributed on the application disk.

Build a beamline model by Selecting Elements from Palette Bar and Dragging them to the Model Space Pane of the Document Window.
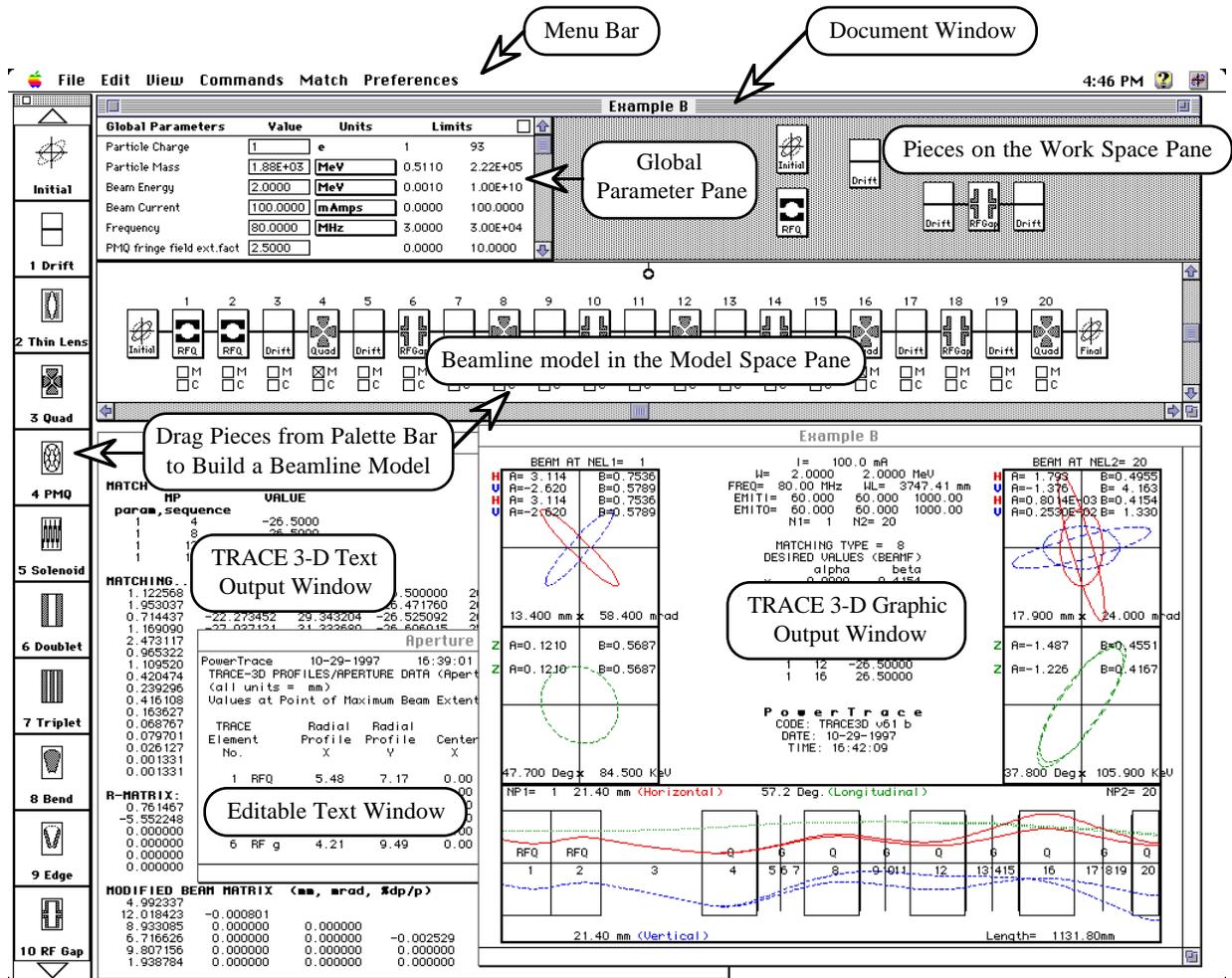
Figure 2-2   PowerTrace Screen Shot.

Running TRACE 3-D using PowerTrace is simple. A beamline model is defined by selecting elements from the Palette Bar and dragging them to the Model Space Pane of the Document Window. As many as six Document Windows may be opened at any one time. PowerTrace windows may be expanded horizontally and vertically, for example, to fit the size of the monitor you are using, so the screen may appear different than that shown in Figure 2-2. The Palette Bar will automatically expand to the height of your monitor. The output windows use a default size and placement. When resized and left open these windows will scale the output for the new size on the next execution of a TRACE 3-D command.

Input Parameters

PowerTrace uses four sets of input parameters. The user inputs are grouped by:

(1) Global Parameters,
(2) Piece Parameters,
(3) Matching Parameters and
(4) User Preferences.

Global Parameters

The Global Parameters are set in the scrollable Global Parameter Pane of each Document Window as illustrated in Figure 2-3. The Global Parameter Pane contains input parameters which are global to the beamline model such as the Particle Charge, Particle Mass, Beam Energy, Beam Current and Frequency, etc. Various unit options are available for several of the Global Parameters. Figure 2-3 illustrates the pop-up menu for inputting the Beam Energy in terms of the equivalent momentum units (in GeV/c).

The first step in building a PowerTrace beamline model is to review the Global Parameters and make changes as necessary.
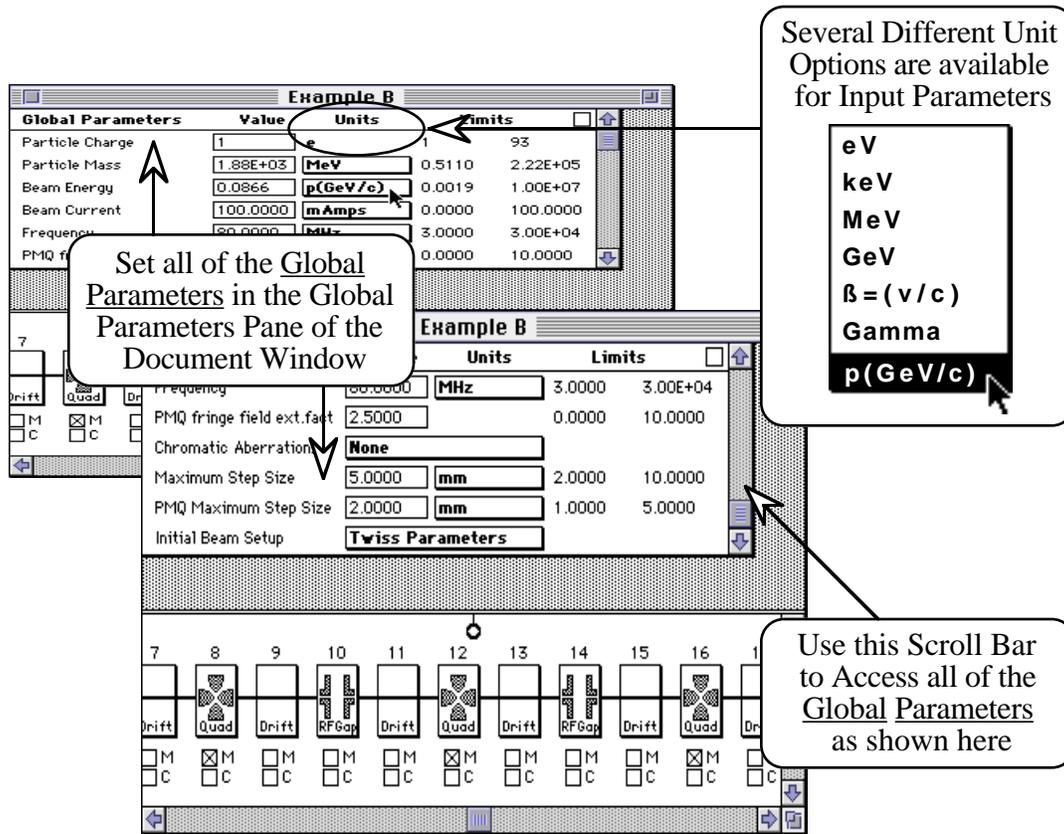
Figure 2-3.   PowerTrace Global Parameter Pane.

Table 2-1 lists the ten Global Parameters of PowerTrace and the corresponding TRACE 3-D parameters.

Table 2-1.   PowerTrace Global Parameters

#	Power Trace Global Parameters	TRACE 3-D
1	Particle Charge	Q
2	Particle Mass	ER
3	Beam Energy	W
4	Beam Current	XI
5	Frequency	FREQ
6	PMQ Fringe Field Extension Factor	PQEXT
7	Chromatic Aberrations	ICHROM
8	Maximum Step Size	SMAX
9	PMQ Max Step Size	PQSMAX
10	Initial Beam Setup	IBS

For definitions and discussion refer to subheadings 9.1 and 9.3 from Section 9 "Input Variables", of the TRACE 3-D Documentation.

Piece Parameters

The <u>Piece</u> <u>Parameters</u> define all of the elements in the beamline model including the initial beam emittances and Twiss parameters, and the final beam Twiss parameters. Double clicking on an individual piece in the beamline model, such as the "Initial" Emittance Piece in Figure 2-4, opens a Piece Window. All of the Piece Parameters for each of the beamline elements are input through Piece Windows of this type.
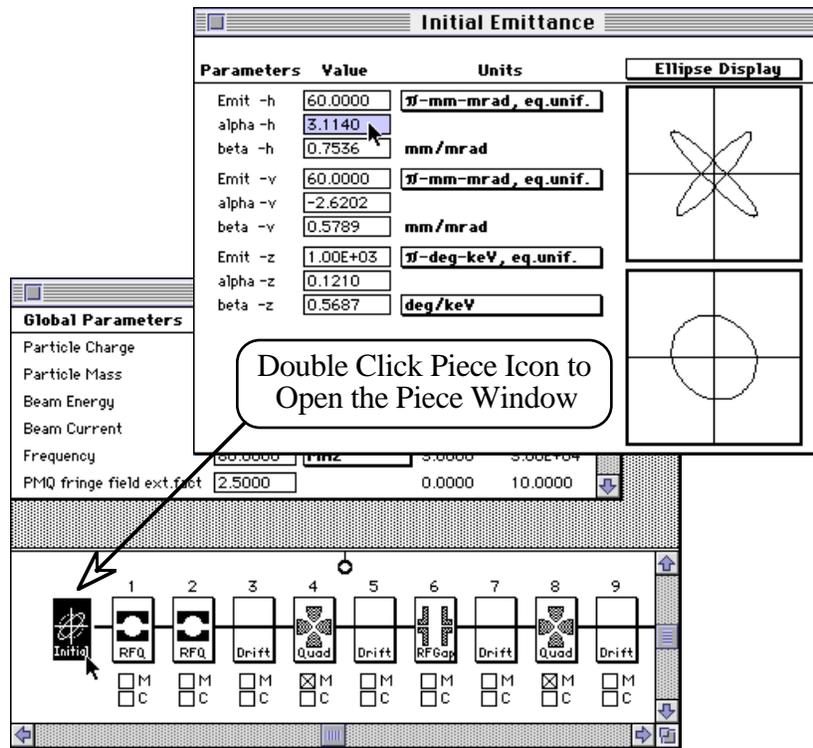
Figure 2-4.   Initial Emittance Piece Window.

The Initial Emittance Piece Window is used to input Initial Emittances (Emit) and Twiss Parameters (alpha & beta) for the Horizontal (h), Vertical (v) and Longitudinal (z) Planes. Both the Initial and Final elements are required in the beamline model to run TRACE 3-D. The **BEAMI(6)** and **EMITI(3)** data arrays are filled with the values from the Initial Emittance Piece parameters.

Refer to subheading 9.2 from Section 9 "Input Variables", of the TRACE 3-D Documentation.

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Type Codes for the Elements are Automatically Set. This Example Sets **NT(4)=3**

Element #4 Type:3 Quad

Element Parameters	Value	Units	Limits	
Magnetic-Field Gradient	-26.5000	T/m	-42.7000	42.7000
Effective Length	96.0000	mm	5.0000	163.9682
Horizontal Offset	0.0000	mm	-1.0000	1.0000
Vertical Offset	0.0000	mm	-1.0000	1.0000
Quad Misalignment	No Misalignment			

Each Piece has a Self Explanatory Piece Window for Inputting Element Parameters

Double Click Piece Icon to Open the Piece Window

Input Parameters for Selected Beamline Element. This Example Sets the Values for **A(I,4)** where **I=1 to 5**

Beam Current	100.0000	mAmps	0.0000	100.0000	
Frequency	80.0000	MHz	3.0000	3.00E+04	
PMQ fringe field ext.fact	2.5000		0.0000	10.0000	

1	2	3	4	5	6	7	8	9
Initial	RFQ	RFQ	Drift	Quad	Drift	RFGap	Drift	Quad	Drift

□M □C □M □C □M □C ☒M □C □M □C □M □C □M □C ☒M □C □M □C

Figure 2-5. Example of a Piece Parameter Window

Figure 2-5 shows an example of a typical PowerTrace Piece Window. There are defaults values set for every parameter. The arrays **NT(NELMAX)** and **A(5,NELMAX)** are defined when each Piece icon is dragged to the Model Space Pane, and the defaults are used to initially fill in the values for these arrays. Entering data in a Piece Window writes over the existing entry. The TRACE 3-D control parameters **N1** and **N2** are defined by the location of the "Initial" and "Final" Piece Icons in the PowerTrace beamline model. Once the Piece Parameters are input for all the elements of the desired beamline, including the Initial Emittance and Final Emittance parameters, then the PowerTrace beamline model is "complete" and you are ready to run TRACE 3-D commands such as "Graph".

Refer to subheadings 9.1 and 9.3 from Section 9 "Input Variables", of the TRACE 3-D Documentation.

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Matching Parameters

The matching capabilities of TRACE 3-D are among it's most useful features, and there are several different types of matching calculations possible. Each type of matching calculation in PowerTrace uses a unique and intuitive way to set up the problem. For example the "Final" Piece icon is also used to set the final Twiss Parameters **BEAMF(6)** for matching types 5-8 and 13. A complete discussion of PowerTrace matching is beyond the intent of this Quick Start Section and is covered in detail in Section 4 "Matching Options".

Refer to subheading 9.4 from Section 9 "Input Variables", of the TRACE 3-D Documentation.

User Preferences

The TRACE 3-D control parameters **NEL1**, **NEL2**, **NP1** and **NP2** are really <u>User</u> <u>Preferences</u> for controlling the display of output. PowerTrace sets default values for these parameters automatically. This automatic feature may be turned off in the Options dialog which is accessed from the <u>Preferences</u> Menu. The values may then be set explicitly in the Plot Control window, also accessed from the Preferences Menu. See Section 6 "User Preferences" for a complete discussion of all the PowerTrace User Preferences and Options.

Refer to subheading 9.3 from Section 9 "Input Variables", of the TRACE 3-D Documentation.

Running TRACE 3-D

The TRACE 3-D program is executed using a variety of commands in the PowerTrace <u>Commands</u> Menu illustrated in Figure 2-6. Most of the commands call the TRACE 3-D FORTRAN and correspond directly to the native TRACE 3-D commands defined in the TRACE 3-D Documentation. Many of the keyboard equivalents have been retained. For example, "Graph" is executed either by selecting the <u>Graph</u> <u>Beam</u> <u>Line</u> command or entering ⌘-G from the keyboard (press "G" while pressing the apple command "⌘" key). Some keyboard equivalents require the command and option keys to be pressed along with the TRACE 3-D equivalent. Figure 2-6 shows all of the PowerTrace commands and corresponding TRACE 3-D commands.

Refer to Section 10 "Description of Commands", of the T R A C E 3 - D Documentation.

PowerTrace commands are organized in four functional groups. The first group contains the standard commands for executing TRACE 3-D. The second group of commands are for matching operations. The third group contains data display commands and the last group includes some PowerTrace specific commands and miscellaneous TRACE 3-D commands.

PowerTrace Command	PowerTrace Key-Equivalent	TRACE 3-D Code	TRACE 3-D Command
Commands			
Graph Beam Line	⌘G	G	GRAPH
Trace on Background	⌘T	T	TRACE
Find Ellipses from Profile	⌘L	L	ELLIPSE
Plot Projections	⌘J	J	PROJECTIONS
Calculate Phase Advance	⌘F	F	PHASE
Exchange Beams	⌘≈ (⌘-Option-X)	X	EXCHANGE
Calculate Mismatch	⌘ø (⌘-Option-O)	O	MISMATCH
Perform Matching	⌘M	M	MATCH
Match Without Print	⌘N	N	MATCH
Match in Range (MT=7,8,9)	⌘U	U	USER
Show Match/Couple			-
Show Match Variables	⌘√ (⌘-Option-V)	V	VARIABLES
Restore Prematch Variables		!	UNMATCH
Show Beam Vectors	⌘B	B	BEAM
Show R Matrix	⌘R	R	R-MATRIX
Show Modified Sigma	⌘Z	Z	SIGMA
Show Phase & Energy	⌘Σ (⌘-Option-W)	W	φ-W
Show TRACE 3D Data	⌘π (⌘-Option-P)	P	PRINT
Load Return Data (31–>30)			-
PARMILA Units	⌘Ç (⌘-Option-K)	C	CONVERT
Help	▶		-
Reinitialize TRACE 3D	⌘E		-

Most of the PowerTrace Commands correspond directly to the native TRACE 3-D commands described in Section 10 of the TRACE 3-D Documentation.

Figure 2-6. PowerTrace Commands Menu.

This Quick Start Section of the User Manual is only intended to provide a brief overview of the PowerTrace application. The remainder of the User Manual provides more information on the material presented in the Quick Start Section, as well as other important subjects on the use of the PowerTrace application. All users are encouraged to read the entire User Manual.

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3. PowerTrace Interface

This section provides a description of the PowerTrace user interface and defines terms used to refer to different parts of the interface. It also provides an overview of the data structures and the transfer of data between the interface and TRACE 3-D. A functional description of each part of the PowerTrace interface is given in this section. Familiarity with the preceding Section "Quick Start" is assumed.

PowerTrace Application Screen

The PowerTrace application may be opened by double clicking the application icon or on a PowerTrace Model file. Figure 3-1 illustrates the application screen after launching PowerTrace. The principal parts of the PowerTrace application are the the Document Window, the Menu Bar and the floating Palette Bar. There is one Menu Bar and one Palette Bar for the application but up to six Document Windows may be open at any one time.

PowerTrace

PowerTrace application.

Example A   Example B

PowerTrace Model files.
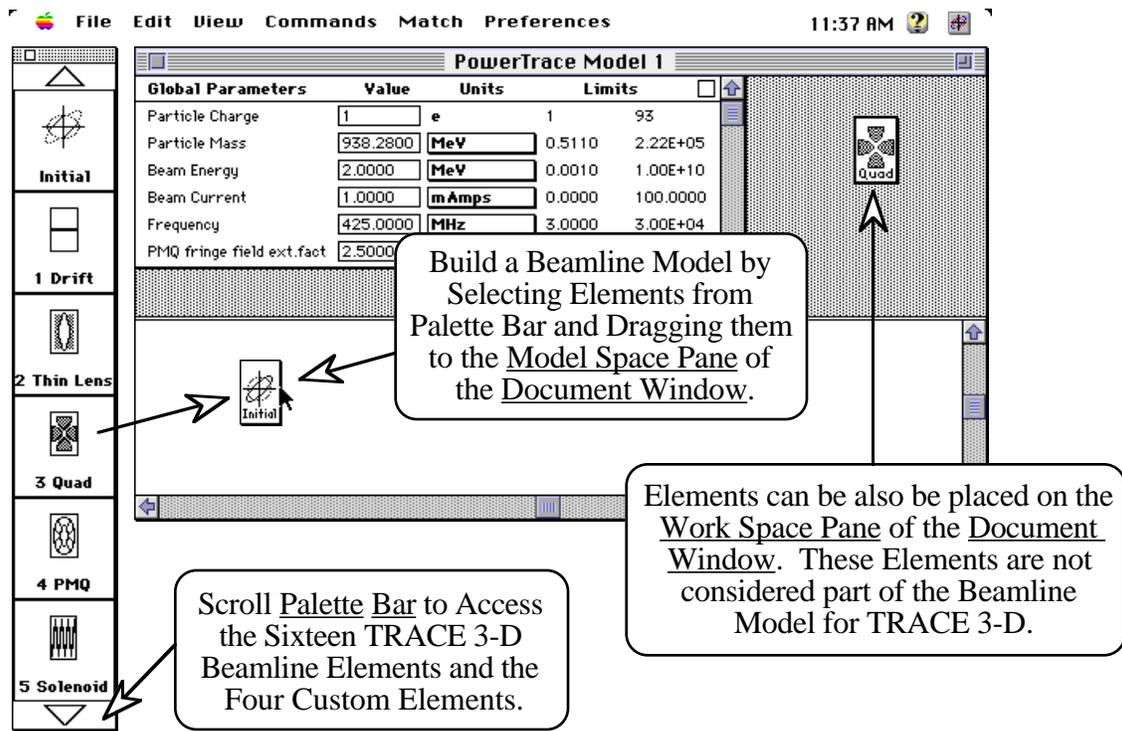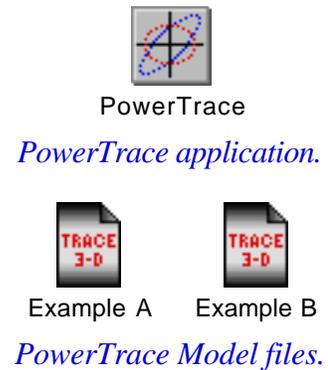
Figure 3-1   PowerTrace Application Screen.

The Palette Bar will automatically grow to fit the vertical size of your monitor and the Document Windows will grow to fit the horizontal size. The Palette Bar will float above all Document Windows. The Menus apply to the currently active Document Window.

Menu Bar

There are seven pull down menus in the PowerTrace Menu Bar. Several of these menus also have submenus. The first menu is the standard Apple (🍎) menu whose functions are established by the configuration of your operating system. This menu contains only one command which is controlled by the interface. This is the About PowerTrace command which brings up a window with information about the PowerTrace application. Figure 3-2 illustrates the next three pull down menus: File, Edit and View. These are discussed further below. The remaining Menus: Commands, Match, and Preferences are discussed in Sections 5, 4, and 6, respectively.

File		**Edit**		**View**	
New	⌘N	Cut	⌘X	Hide Palette	⌘P
Open	⌘O	Copy	⌘C		
Close	⌘W	Paste	⌘V	Hide Global Parameters	⌘H
		Delete			
Save	⌘S	Select All	⌘A	Show Tape 30	
Save As...				Show Tape 31	
				Show Aperture Data	
Import	▶			Show PARMILA Data	
Export	▶			Show History File	
				Clear History File	
Page SetUp					
Print Window				PowerTrace Model 1	
				√ PowerTrace Model 2	
Quit	⌘Q				
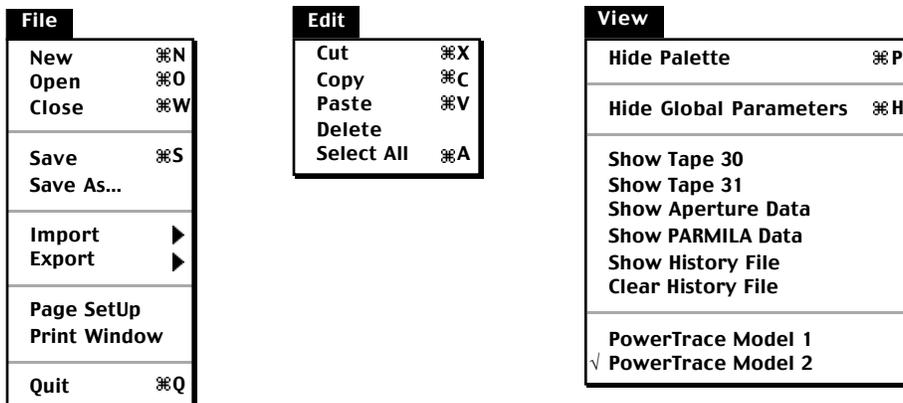
Figure 3-2. PowerTrace File, Edit and View Menus.

File Menu

The File menu (Figure 3-2) has ten commands. The New and Open... menu commands will create and activate a new PowerTrace Document Window. A currently active Document Window will remain open but will be deactivated. The New command creates an empty Document Window while the Open... command is used to open a previously saved model (defined by a Document Window). The Close command is used to close the currently active window.

The Save and Save As… commands are for saving the PowerTrace model as defined in the currently active Document Window. The Import and Export commands both have submenus for VAX and PC files. Import and Export are used to open and save TRACE 3-D models in the (ASCII text) format of the VAX and IBM-PC TRACE 3-D programs. These are used for exchanging TRACE 3-D input files with these platforms. The Page Setup and Print Window commands control printer configuration and printing. The final command in the File menu is Quit which closes all windows and quits the application.

The Import and Export commands are used for exchanging input files with VAX and IBM-PC TRACE 3-D programs.

All of the File commands are similar to other applications and follow standard Macintosh guidelines. Many bring up standard dialogs for defining file names, file locations (folders), etc. Commands which cannot be executed in a particular context are dimmed and are not accessible. Users unfamiliar with the Mac OS should consult their Macintosh documentation for additional information.

Edit Menu

The Edit menu (Figure 3-2) has five commands. These commands also follow standard Macintosh guidelines. The current selection determines what actions are taken with the Cut, Copy and Paste commands. For example the selection may be ASCII text, a numerical value, a graphic image, or Pieces in the Document Window. For numerical values, graphics or text information, the Cut command makes a copy of the selection and then deletes the selection. If a single Piece or group of Pieces is selected, the Cut command will delete the selection from the Document Window, and without changing the parameters, copy that selection to the clipboard for future pasting in the current Document Window or to another Document Window. The Copy command is also used to copy selected pieces, numerical values, graphics or text information to the clipboard, but without deleting the selection. The Copy command can be used to copy a PICT image of the TRACE 3-D output window to the clipboard.

When Pieces are copied the system clipboard is used to store a PICT image of the Piece icons. This image can pasted into a word processor or graphics application.

The Copy command can be used to copy a PICT image of the TRACE 3-D output window which can be pasted into a word processor or graphics application.

The clipboard image can then be pasted into a word processor or graphics application. The <u>Paste</u> command places the current contents of the clipboard (if valid PowerTrace Piece data) on the Work Space of the Document Window. See the discussion of the Document Window later in this Section for additional information. If text data is on the clipboard it can be pasted into the different text windows of PowerTrace. If numerical data is in the clipboard it can be pasted into parameter value fields. The <u>Delete</u> command deletes any selected Pieces from the Document Window, or deletes any selected text data, but does not place the selection on the clipboard. Deleted data is permanently removed. The <u>Select</u> <u>All</u> command is used to select the entire group of Pieces on the Model Space of the Document Window, or all of the information in a text window, for subsequent execution of Copy, Cut, Paste or Delete.

Select All can be used to select all of the beamline elements in the active Document Window.

View Menu

The <u>View</u> menu (Figure 3-2) has from eight to fourteen commands depending on how many Document Windows are open. The <u>Hide/Show</u> <u>Palette</u> command allows the user to show or hide the floating Palette Bar. The <u>Hide/Show</u> <u>Global</u> <u>Parameters</u> command lets the user show or hide the Global Parameter Pane of the currently active Document Window. The next two commands, <u>Show</u> <u>Tape</u> <u>30</u> and <u>Show</u> <u>Tape</u> <u>31</u> are used to view the TRACE 3-D input file (Tape 30) for the current Document Window and the return data file (Tape 31) if TRACE 3-D has been executed. These files are discussed later in the "Data Structures and Data Flow" subsection. The <u>Show</u> <u>Aperture</u> <u>Data</u> command is used to open a text window for the Aperture Data file generated by TRACE 3-D. The Aperture Data file is produced with the execution of various TRACE 3-D commands if the PowerTrace Option: "Generate Aperture File" is on. PowerTrace Options are discussed in Section 6 "User Preferences". The <u>Show</u> <u>PARMILA</u> <u>Data</u> command opens a text window for the PARMILA Data file generated by TRACE 3-D.

Hide the Global Parameter Pane to access more of the Work Space Pane.

View the TRACE 3-D input file with the Show Tape 30 command and if TRACE 3-D has been executed, use the Show Tape 31 command to view the return data file .

The Show Aperture Data command is used to open a text window for the Aperture Data file generated by TRACE 3-D if the PowerTrace Option: "Generate Aperture File" is on.

The PARMILA Data file is produced with the execution of the PARMILA Units command in the PowerTrace Commands menu. This file is discussed further in Section 5 "TRACE 3-D Commands". The Show History File command opens a text window for the PowerTrace History file. The History file is a listing of all the text based output generated by TRACE 3-D. The History file can be cleared with the next command in the View menu: Clear History File. The History file is discussed further in Section 5 "TRACE 3-D Commands".

Show PARMILA Data is used to review the output from the PARMILA Units command.

The History file is a cumulative listing of all text output that is generated with multiple runs of TRACE 3-D.

The remainder of the View menu lists the titles of all open PowerTrace Document Windows, with a check mark by the currently active document. Selecting one of these commands activates that Document Window and brings it to the front. As discussed above (and further below) several commands result in operations determined by the currently active Document Window. Only one Document Window is active at a time and it can be identified by the check mark in this menu.

Selecting a Document title from the View menu brings that Document Window to the front.

The functionality of the File, Edit and View menus are very similar to other Macintosh applications, while the Commands, Match and Preferences menus are customized for TRACE 3-D. These are discussed separately in Section 4 "Matching Section", Section 5 "TRACE 3-D Commands", and Section 6 "User Preferences".

Palette Bar

The PowerTrace Palette Bar contains Piece icons for each of the transport elements used to build a beamline model. The Palette Bar automatically fits the vertical size of your monitor so the number of piece icons visible depends on monitor size. There are scroll controls on the top and bottom of the Palette Bar to access all of the Piece icons. The title bar of the Palette Bar window can be used to drag the Palette to different locations on your screen. The Palette Bar is a floating window which means it will "float" to the front if a Document Window is placed over it.

Scroll controls on the top and bottom of the Palette Bar are used to access all of the available Piece icons.

Move the Palette Bar by Draging the Title Bar of the Window. The Palette Bar Window will float on top of PowerTrace Document Windows

Close Box Hides the Palette Bar. Use the Show Palette Command in the View Menu to Restore the Palette Bar

Drag Elements from the Palette Bar to the Model Space or Work Space Pane of the Document Window

Scroll the Palette Bar to Access all of the PowerTrace Elements

Initial

1 Drift

2 Thin Lens

3 Quad

4 PMQ

5 Solenoid

Figure 3-3. PowerTrace Palette Bar of Beamline Elements.

Figure 3-3 illustrates several different features of the Palette Bar. Piece icons are selected from the Palette Bar and dragged to either the Model Space Pane or the Work Space Pane of the Document Window. The Palette Bar contains twenty-two (22) different Piece icons, including sixteen (16) native TRACE 3-D elements, four (4) Custom element positions and two (2) Pieces for the "Initial" and "Final" beam phase space ellipse parameters. These elements are listed in Table 3.1. The PowerTrace Custom elements are discussed in Appendix B "Customizing PowerTrace".

Descriptions for the TRACE 3-D elements can be found in Sections 4, 5 and 6 of the TRACE 3-D Documentation.

Table 3-1. PowerTrace Beamline Elements.

Type Code	Piece Icon	Piece Type	Type Code	Piece Icon	Piece Type
-		Initial Beam (Twiss Parameters)	11		RFQ
1		Drift	12		Radio Frequency Cavity
2		Thin Lens	13		Tank
3		Quadrupole	14		Wiggler
4		Permanent Magnent Quadrupole	15		Rotate
5		Solenoid	16		Identical (Initially Undefined)
6		Doublet	-		Custom 17 (Open Slot for Custom Element)
7		Triplet	-		Custom 18 (Open Slot for Custom Element)
8		Bend	-		Custom 19 (Open Slot for Custom Element)
9		Edge	-		Custom 20 (Open Slot for Custom Element)
10		Radio Frequency Gap	-		Final Beam (Twiss Parameters)
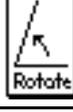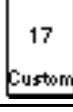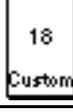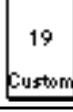
Document Window

The Document Window is divided into three areas
called panes. These three panes are the Global
Parameter Pane, the Model Space Pane and the Work
Space Pane. Figure 3-4 indicates the three principal
panes of the Document Window.
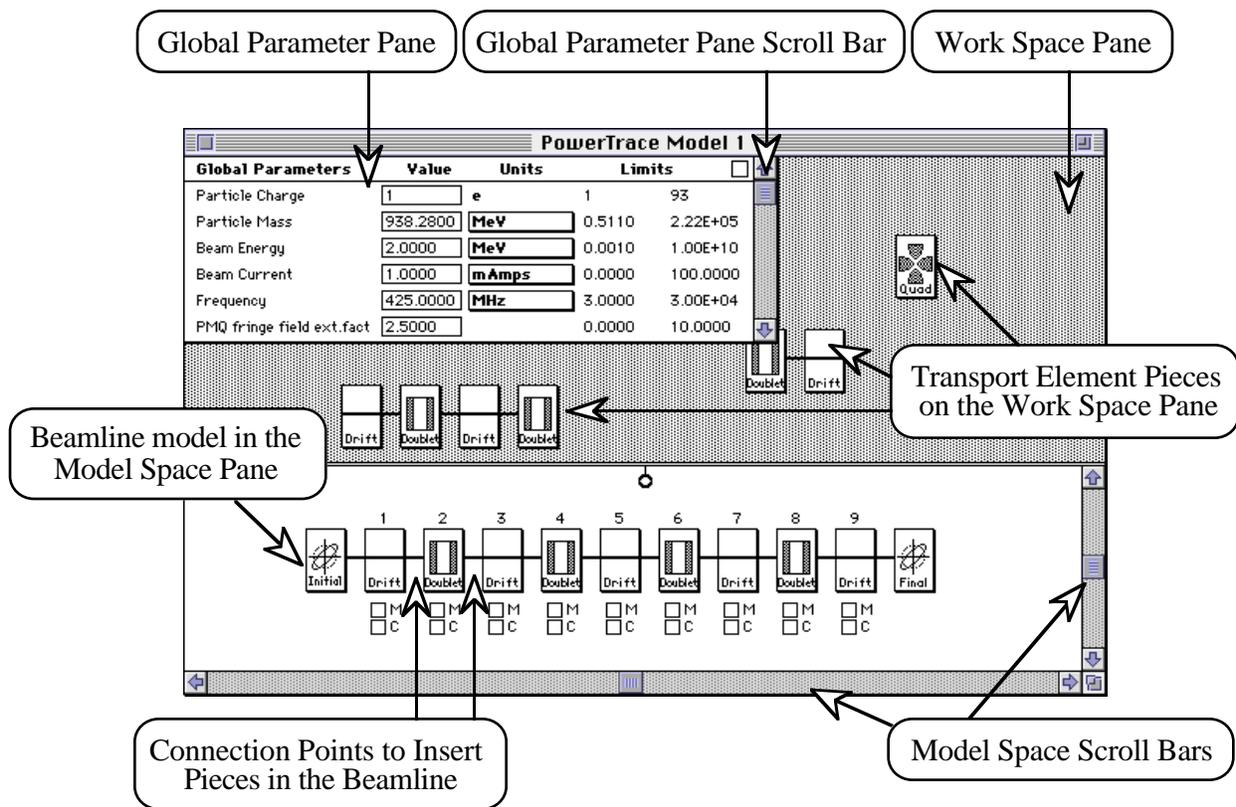
Figure 3-4. Principle Parts of the PowerTrace Document Window.

An important and unique feature of PowerTrace is that
multiple Document Windows, up to six, may be opened
at any one time. The user can set up multiple TRACE
3-D problems, including the ability to exchange
beamline Pieces or groups of Pieces between them, and
run TRACE 3-D for *any* of the models.

Global Parameter Pane

The Global Parameter Pane consists of the header region, the close box, the scroll bar and the Global Parameter Table. The header region is at the top of the pane and displays the title of the Global Parameters and the other fields which include the current Value, the Units, and the Limits (lower and upper). The close box, located in the upper *right* corner of the pane, hides the Global Parameter Pane from view. It is the same as selecting the Hide Global Parameters from the View menu. To view the Global Parameter Pane, once hidden, the user must select the Show Global Parameters from the View menu. The scroll bar on the Global Parameter Pane is used to access additional parameters in the Global Parameter Table.

Several Unit pop ups scale dynamically with particular Global Parameters.

Model Space Pane

A beam line to be modeled is built on the Model Space Pane of a Document Window.

The Model Space Pane of the Document Window is where the transport pieces are placed to construct a beamline model. The Pieces assembled on the Model Space constitute the beamline model whose data will be used to run TRACE 3-D. This model may be saved at anytime using the appropriate commands from the File menu.

Pieces are "dragged" from the Palette Bar to the Document Window. Pieces may be placed on either the Model Space or the Work Space in the Document Window. The first Piece that is "dragged" to the Model Space may be placed anywhere on the Model Space. Once the first Piece is placed, the following Piece "snaps" on to the end closest to where the Piece was "let go" when the mouse button was released. The Model Space Pane will automatically scroll to the end to which the Piece is placed if this end is not visible in the window.

Pieces are selected from the Palette Bar and dropped onto the Model Space.

Pieces may also be placed at connection points in the model which will insert the piece between two other pieces in the beamline. Connection points are represented by lines between pieces in the beamline model. To insert a Piece or group of Pieces, drag the selection over a connection point and release the mouse button. The *connection point will flash* while the mouse is directly over it. Releasing the mouse button inserts the selection in the beam line model at that point. Note that there can never be "loose" pieces in the Model Space. All pieces are either inserted at connection points or snapped to an end of the beamline model.
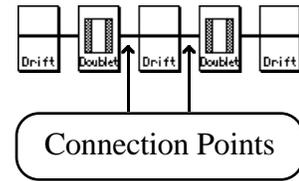
Pieces may be inserted into the beam line at connection points between pieces on the Model Space.

The two scroll bars of the Model Space Pane control the positioning of the beamline model with respect to the window (Figure 3-4). The Model Space Pane is large and can accommodate 300 beamline Pieces. However, if the intent is to build such a large model by starting at one end of the beamline, the user should scroll to near the corresponding end of the Model Space Pane, rather than starting near the center of the Model Space.

A Piece or a group of Pieces may be selected and dragged from the Model Space to the Work Space Pane. This action creates copies of the Piece(s) selected for placement on the Work Space. The original Pieces and the data associated with them are unaffected and remain on the Model Space. A Piece or group of Pieces may also be selected and copied, cut or deleted using the appropriate commands from the Edit menu. These actions are very similar to the standard Copy, Cut and Delete actions of many other applications. The <u>Delete</u> action removes the selected Pieces from the beamline model - information associated with the Pieces is <u>permanently</u> <u>lost</u>.
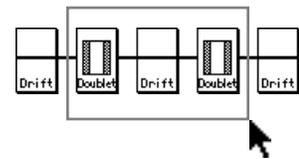
Drag a box around a group of Pieces in the beamline model to make a selection of multiple Pieces.

Dragging a selection of Pieces from the Model to the Work Space creates copies of the selected pieces.

The <u>Copy</u> action makes a copy of the Pieces and stores it on a PowerTrace internal "clipboard". The Pieces may be later pasted onto any PowerTrace Document Window (they will appear on the Work Space Pane). The original Pieces and the data associated with them are unaffected and remain on the Model Space.

A graphic image (PICT) of the selected beamline Piece(s) is also placed on the System clipboard. This image may then be pasted into other Macintosh applications, for example, in order to prepare a figure for publication.

Beam line information for copied or cut pieces is retained on the PowerTrace internal clipboard .

The Cut action is similar to the Copy action, except that the original Pieces and associated data are removed from the Model Space. Cut makes a copy of the Pieces and associated information and stores it the same as with Copy. The complete information is on the PowerTrace internal clipboard and the Pieces may be pasted onto any PowerTrace Document Window. A graphic image of the selected beamline Piece(s) is also placed on the System clipboard and may be pasted into other Macintosh applications.

In order for a PowerTrace model to be well-defined it *must* have an Initial and Final Piece in the beamline model. These need not be at the ends of the beamline, nor does the Initial Piece have to be before the Final Piece, nor do any parameter inputs have to be made, but the model will not be well-defined without them. Each model should only have one Initial and one Final Piece to avoid confusion. When saving a model, or updating parameters for passing to TRACE 3-D, or during other actions, PowerTrace will only retain the information on one Initial and one Final piece. (Which one PowerTrace encounters first depends upon the action being undertaken.) Of course, additional Initial and Final pieces, with or without other Pieces, may be placed on the Work Space.

The beamline model must have an Initial and Final Piece to run TRACE 3-D.

Work Space Pane

The Work Space Pane consists of the Work Space "window shade" and a Pull Ring. The Work Space window shade is not scrollable, but it can be raised or lowered, like a window shade, by dragging the Pull Ring. Double clicking the Ring will retract the shade completely.

The Work Space can be raised or lowered, like a window shade, by dragging the Pull Ring.

Additional Work Space area may be accessed by hiding the Global Parameters as illustrated in Figure 3-5. This may be done from the close box in the upper right hand corner of the Global Parameter Pane, or by selecting the Hide Global Parameters from the View menu.
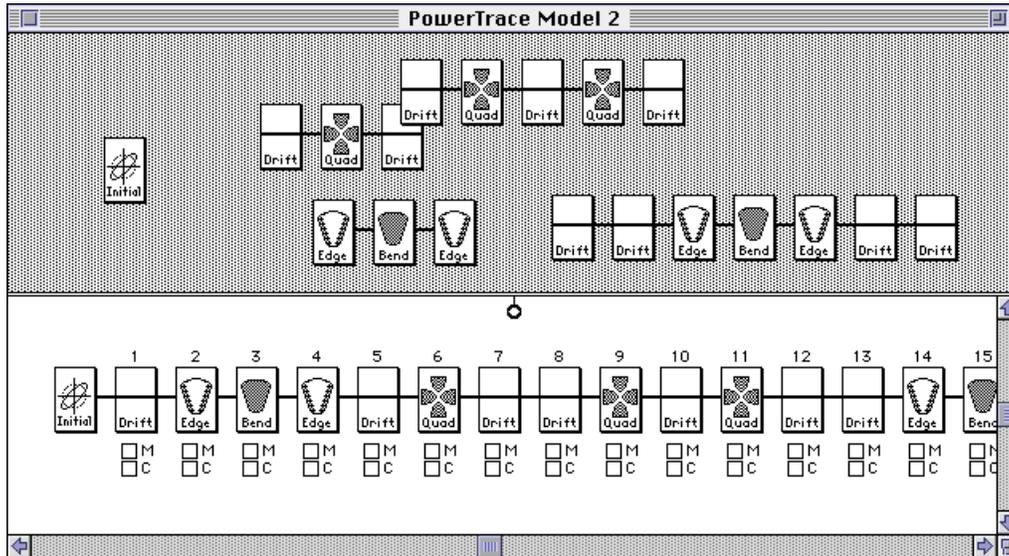
Figure 3-5. PowerTrace Document Window with the Global Parameter Pane Hidden.

Pieces may be placed on the Work Space either by dragging them from the Palette Bar or the Model Space. When a Piece, or a group of Pieces from the Model Space, is dragged to the Work Space it can be placed anywhere on the Work Space. Pieces are not grouped on the Work Space unless they were grouped *prior* to being placed on the Work Space. No Piece is snapped to, or inserted into, a model structure when placed on the Work Space. A group of Pieces placed on the Work Space will remain in their original configuration (i.e. same order in line) and cannot be separated. (Of course, they can be dragged to the Model Space, a subset selected, and then that subset placed on the Work Space.) A Piece or a group of Pieces may also be copied, cut or deleted from the Work Space with the same result as in the case of the Model Space (discussed above). There is only one internal PowerTrace clipboard so that any existing data on it will be erased when either Cut or Copy is executed.

When a Paste command is executed, the existing set of Pieces currently on the clipboard will appear on the Work Space. They may then be dragged to the beam line in the Model Space Pane.

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If Pieces or groups of Pieces have been previously copied or cut, from either the Work Space or the Model Space, they may be placed on the Work Space by *pasting* them from the internal PowerTrace clipboard. The <u>Paste</u> action is similar to that of other applications. However, the Work Space is the only location to which a previously cut or copied Piece, or group of Pieces, will be pasted. Pieces pasted to the Work Space may then be dragged to the Model Space. There may be many individual "loose" Pieces or groups of Pieces on the Work Space and they may be moved around and located on the Work Space as desired. These Work Space Pieces are *not* part of the beamline model and information associated with them is not retained when a model is saved (Save, Save As, or Export commands from the File menu). However, Global Parameters associated with the model are utilized for these Pieces, for example in displaying "smart units" for the input parameters and for the Ellipses in the Initial and Final Pieces. Similarly these Pieces are not used when a call to TRACE 3-D is made from the Command menu. Only the beamline model on the Model Space Pane of a Document Window is used to define TRACE 3-D input.

Selections on the Work Space are moved by dragging with the mouse.

Pieces on the Work Space are only temporary. The pieces on the Work Space are not saved with the Model file and are disposed when the Document Window is closed.

The Work Space can be used for several purposes, for example, to store a repeated set of Pieces which will be used several times in a beamline. Other uses include comparing alternative "prototype" beamlines. After defining a set of Pieces, the prototype beamline can be selected and dragged from the Model Space to the Work Space. An alternative set of parameters can be input to the Model Space beamline while a "backup" of the original is on the Work Space with the parameters unchanged. TRACE 3-D results for the new prototype can then be compared directly to the original. Other possibilities will suggest themselves as the user becomes familiar with the Work Space functions. The parameters of Pieces on the Work Space may be set independently of the beamline Pieces on the Model Space and are not affected by changes to the beamline model.

The Work Space is useful for temporarily storing Pieces. The Work Space is most helpful when used in conjunction with the Model Space.

Piece Windows and Data Tables

Parameter input for transport elements is done through the <u>Data</u> <u>Tables</u> in PowerTrace <u>Piece</u> <u>Windows</u>. Piece Windows are accessed by "double clicking" the mouse button while the cursor is on the desired transport element icon in the Document Window. Figure 3-6 illustrates a Piece Window for the Permanent Magnet Quadrupole (PMQ) element. Each Piece Window consists of a Title Bar with close box and a Data Table. The Data Table includes four fields of data: (1) a description of the Element Parameters, (2) a Value field for data entry of the numerical parameters, (3) a Units field which provides options through pop up menus and (4) a Limits field which gives lower and upper limits based on a expert system set of knowledge based rules.

Input parameters are edited using Data Tables. The Data Tables for each Piece are contained in the Piece Window.

Limits rules are discussed in the Appendix "Knowledge Base Rules for Input Parameters of TRACE 3-D". Element Parameters are defined in Section 5 of the TRACE 3-D Documentation.

The Piece Window Title Includes the Sequence Number of the Element in the Beamline and the Element Type Code

Element #3 Type:4 PMQ				
			Limits	
Element Parameters	**Value**	**Units**	**Match**	**Couple**
Max Mag-Field Gradient	130.0000	T/m	☑ M	☐ C
Physical Length of PMQ	37.0000	mm	☐ M	☐ C
Inner Radius	15.0000	mm	☐ M	☐ C
Outer Radius	1.0873	B-Lambda	☐ M	☐ C

Pop Up Menu Toggles between Limits Display or Match and Couple Selections

The Data Table Contains the Numerical Parameters for each Transport Element

Figure 3-6. Example of a PowerTrace Piece Window showing Match and Coupling Check Boxes for Piece Parameters.

Parameter Value Fields

Several features of the Piece Window Data Table are illustrated in Figures 3-6 and 3-7. All numerical data is entered into the Value fields of the Piece Window Data Table. Default values have been defined for all parameters and these are the initial values when a Piece icon is placed on the Model Space. When a new value is entered into a Value field the limits for that Piece Window are updated. (For some specialized Pieces that interface with the FORTRAN, such as the Initial and Final Pieces, certain data is not updated until the Piece Window is closed.)

After entering a numerical value, use the "Enter" key to accept that value or click outside of the Value Field.

Element #3 Type:4 PMQ

Element Parameters	Value	Units	Limits	
Max Mag-Field Gradient	130.0000	T/m	-98.9333	98.9333
Physical Length of PMQ	37.0000	mm	2.5000	62.2732
Inner Radius	15.0000	mm	1.0000	49.0000
Outer Radius	1.0873	B-Lambda	0.3480	3.2620
		mm		
		cm		
		m		
		inches		

Pop Up Menu Allows Selection of Units. These Can Include "Smart Units" Such As Displaying Any Length Dimensioned Parameter in Units of βλ

Lower and Upper "Limits" Based on Expert "Rules of Thumb" and Similar Considerations -- User is Alerted Visually if a Limit is Violated

Figure 3-7. Example of a PowerTrace Piece Window showing Expert Limits and Smart Units Functionality.

Unit Pop Ups

The user may select different units for a parameter by selecting the appropriate option from the Unit pop ups as illustrated in Figure 3-7. All unit conversions are done by the Piece Window and all numbers transferred to the data structure are in the default units, which are the same as the units used by TRACE 3-D.

Each Data Table provides users with options for the units of input parameters.

Several Unit pop ups include "smart units." These are units which scale dynamically with certain Global Parameters. For example, all parameters which have the dimensions of length include "β-Lambda" as a units option. The value of the β, the relativistic velocity parameter of the particle, is determined by the Global Parameter values for the Particle Energy and Mass, while the value of λ is set by the Radio Frequency Global Parameter.

Limits

Piece Windows also contain lower and upper "limits" for each parameter. These limits are not used to restrict the input, *any* parameter value may be entered and will be passed to TRACE 3-D via the PowerTrace data structure. The limits are intended to provide the user with estimates of a practical range for each parameter. A detailed description of individual limits calculations including relationships with other parameters for a given Piece and the Global Parameters is presented in the Appendix "Knowledge Base Rules for Input Parameters of TRACE 3-D".

Guidance limits are displayed for each Piece Parameter. However, the guidance limits are "soft", and any value for an input parameter may be used.

The limits calculations for Piece Parameters are described in the Appendix "Knowledge Base Rules for Input Parameters of TRACE 3-D".

Initial and Final Beam Pieces

There are two specialized Piece Windows for setting up the initial and final beam parameters used by TRACE 3-D. When the Twiss Parameters option for the Initial Beam Setup Global Parameter (TRACE 3-D **IBS** parameter) is selected then the initial emittances (**EMITI** array) and the initial Twiss parameters (**BEAMI** array) are set by the user in the special Initial Emittance Piece Window. As with other Piece Windows this window is opened by double clicking on the "Initial" Piece icon in the Model Space. This is illustrated in Figure 3-8. If the Sigma Matrix option is selected for the Initial Beam Setup Global Parameter then a specialized dialog (not shown) is opened via the Initial Piece. The final Twiss parameters (**BEAMF**, used for matching) are set via a similar Piece Window, opened by double clicking on a "Final" Piece icon. It is important to note that *both Initial and Final elements are needed for a PowerTrace*

Refer to subheading 9.2 and 9.3 from Section 9 "Input Variables" of the T R A C E 3 - D Documentation.

Both Initial and Final Pieces are required for a PowerTrace model to be well defined.

model to be well defined. The Initial and Final Piece Windows do not contain parameter Limits fields. Instead, a graphic display of the phase space ellipses is presented. This display uses the TRACE 3-D graphics scales and provides the user with a preview of how the ellipse plots will appear after executing a Graph Beam Line command. These windows can also be used to automatically set values for the TRACE 3-D graphics scales if the "Use Graphics Scaling" Option is selected. The Options are accessed from the Preferences menu and are discussed in Section 6 "User Preferences". If the Use Graphics Scaling Option is on (default case), the initial graphics scales (**XMI**, **XPMI**, **DPMI** and **DWMI**, which set values for the boundaries of the initial phase-space plots) are generated when the Initial Emittance window is opened.

Refer to subheading 9.5 from Section 9 "Input Variables" of the TRACE 3-D Documentation.
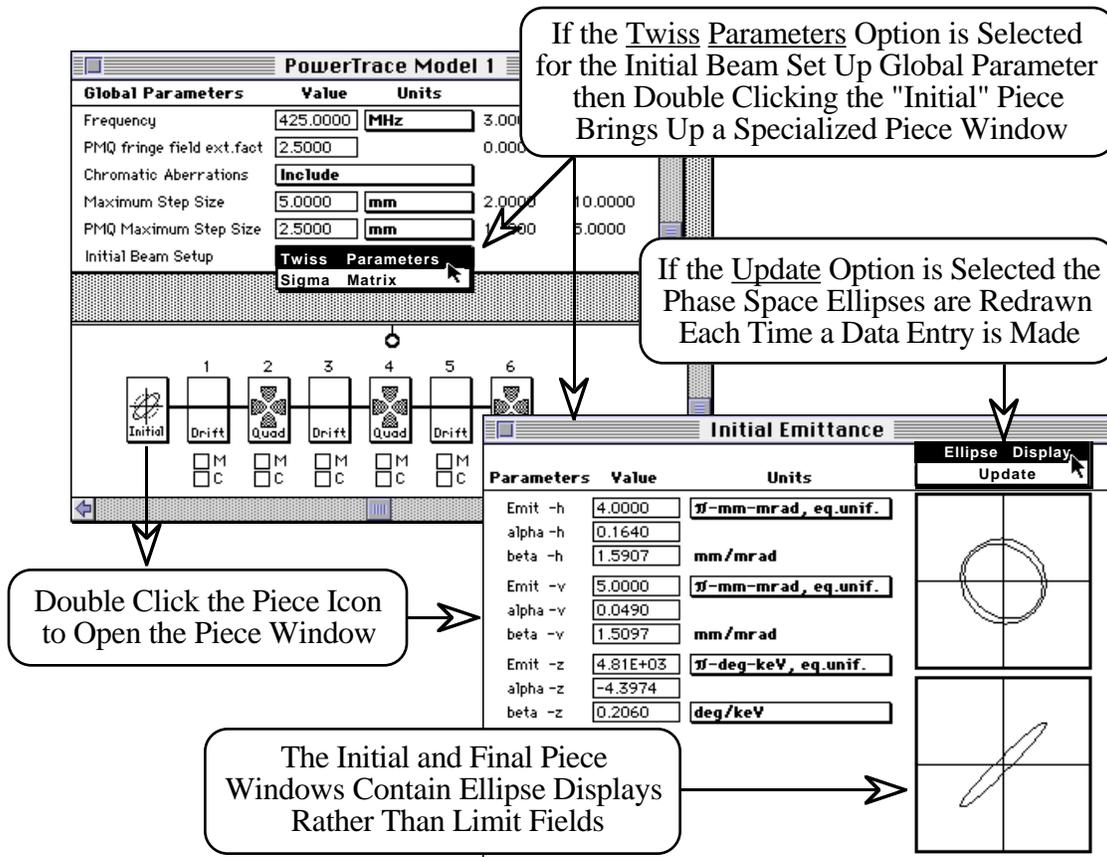
Figure 3-8. PowerTrace Document Window and Initial Beam Piece Window.

The following equations are used by PowerTrace to initially estimate values for the TRACE 3-D graphics scales:

$$\textbf{XMI} = \text{GraphScale1}*\text{SQRT}((\text{Beta}_h)*(\text{Emit}_h)),$$
$$\textbf{XPMI} = \text{GraphScale1}*\text{SQRT}((\text{Gamma}_h)*(\text{Emit}_h)),$$

where $\text{Gamma}_h = (1.0 + \text{Alpha}_h{**}2)/\text{Beta}_h$.

Emit_h, Alpha_h and Beta_h are the current values for these input parameters shown in the Initial Emittance window. This is repeated for the vertical plane, and the larger of the two values of XMI and XPMI are used. Similarly for the longitudinal plane

$$\textbf{DPMI} = \text{GraphScale3}*\text{SQRT}((\text{Beta}_z)*(\text{Emit}_z)),$$
and $\quad\textbf{DWMI} = \text{GraphScale3}*\text{SQRT}((\text{Gamma}_z)*(\text{Emit}_z)),$

where $\text{Gamma}_z = (1.0 + \text{Alpha}_z{**}2)/\text{Beta}_z,$

A similar scaling is done for the final graphics scales (**XMF**, **XPMF**, **DPMF** and **DWMF**, which set values for the boundaries of the final phase-space plots). In this case the output emittances are used (if Graph Beam Line or a comparable TRACE 3-D command has been run) unless they are zero (i.e. Graph Beam Line has not been run) and then the initial emittances are used. The profile and projection graphics scales are then set as

Refer to subheading 9.5 from Section 9 "Input Variables" of the TRACE 3-D Documentation.

$$\textbf{YM} = \text{GraphScale2}*\text{larger}(\text{XMI,XMF}),$$
$$\textbf{DPP} = \text{GraphScale4}*\text{larger}(\text{DPMI,DPMF}),$$
$$\textbf{XM} = \text{GraphScale2}*\text{larger}(\text{XMI,XMF}),$$
and $\quad\textbf{XPM} = \text{GraphScale4}*\text{larger}(\text{XPMI,XPMF}).$

The values for the GraphScale factors used by PowerTrace are:

GraphScale1 = 2.0	GraphScale2 = 1.2
GraphScale3 = 2.0	GraphScale4 = 1.2

This provides the user with an automatic initial set of graphics scales to be used in the TRACE 3-D graphic output. The graphics scales are passed to the interface data structure when the Initial or Final Piece windows are closed.

Data Structures and Data Flow

The PowerTrace interface is based on the Shell for Particle Accelerator Related Codes (S.P.A.R.C.) software technology written in the C programming language. It is designed to provide a common Graphical User Interface (GUI) for multiple applications. TRACE 3-D is a FORTRAN code which has been integrated with the PowerTrace GUI. This mixed language application uses specialized data structures developed for transferring data between S.P.A.R.C and the TRACE 3-D FORTRAN. There is a dynamic data exchange between PowerTrace and TRACE 3-D which is facilitated with data structures in both C and FORTRAN that are identical in size and reference a common block of memory. This block of memory is accessed from both PowerTrace and TRACE 3-D and is shown schematically in Figure 3-9.
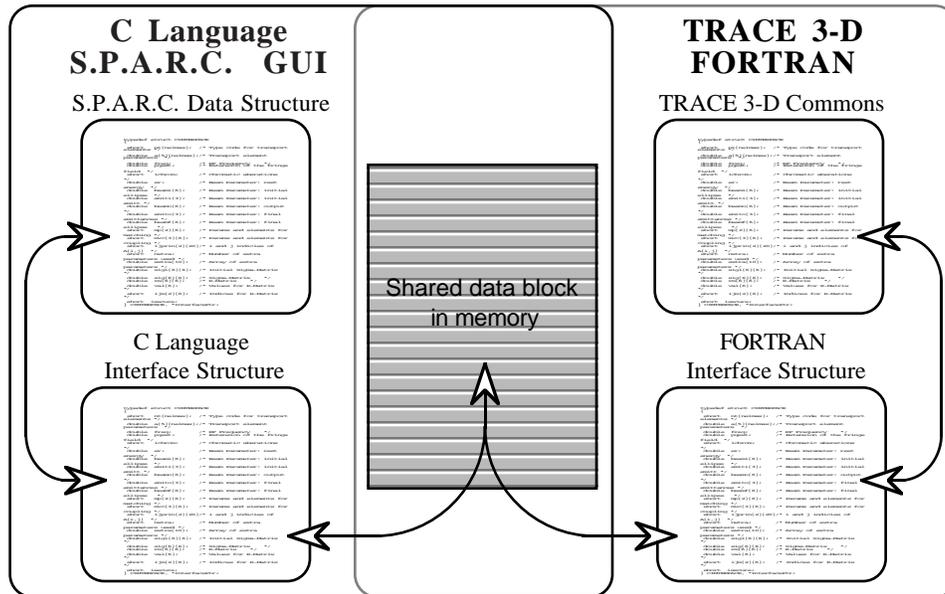
Figure 3-9. Mixed Language Data Interface.

As a beamline model is built all data defining the model is stored in the S.P.A.R.C. data structure. Certain actions, such as selection of a TRACE 3-D command from the Commands menu, initiates the mixed language interface to pass the model data to (or from) the FORTRAN.

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Although the data transfer is rapid and transparent to the user, it involves a few well defined steps. These are discussed here briefly since an understanding of this data flow can be capitalized upon to accomplish some things not normally done with TRACE 3-D.

The PowerTrace to TRACE 3-D interface data transfer involves the following steps.

(1.)   PowerTrace model data is passed to the C Language Interface Structure which stores data in the shared memory block. The C Language Interface Structure corrects for the different storage schemes of the two languages. The PowerTrace model data may be viewed in the FORTRAN text format of a TRACE 3-D input file by selecting Show Tape 30 from the View menu.

Figure 3-10 shows an example of the Tape 30 data in a PowerTrace editable text window.

(2.)   PowerTrace calls a (SPARC) FORTRAN interface routine, passing a pointer to the shared data block in memory. This defines the FORTRAN Interface Structure.

Refer to Section 9 "Input Variables" of the TRACE 3-D Documentation.

(3.)   The FORTRAN interface routine assigns data to the TRACE 3-D common blocks **TCOM** and **ITCOM** from the FORTRAN Interface Structure. The data as passed to FORTRAN, may be viewed using the Show TRACE 3-D Data command in the Commands menu.

At this point the original action (i.e. selecting a TRACE 3-D command) that initiated this data transfer is completed. Note that the PowerTrace model data is retained in the Data Tables independent of any actions within TRACE 3-D that alters the common block data.

(4.)   A FORTRAN interface return data routine assigns data from the TRACE 3-D commons **TCOM** and **ITCOM** to the shared memory block of the FORTRAN Interface Structure.

(5.)   A pointer to the shared memory block is returned from the FORTRAN Interface Structure to PowerTrace.

(6.)   The return data is assigned from the shared memory block to the C Interface Structure, correcting for the different storage schemes of the two languages. However, this return data is <u>not</u> automatically transferred to the Data Tables (except for matching, see below). The return data may be viewed in the text format of a TRACE 3-D FORTRAN input file by selecting <u>Show</u> <u>Tape</u> <u>31</u> from the View menu.

Figure 3-10 shows an example of the Tape 31 data in a PowerTrace editable text window.

All TRACE 3-D FORTRAN commons are maintained when control returns to PowerTrace. Variables in the **TCOM** and **ITCOM** commons are passed back and forth at each entry into, and return from, TRACE 3-D. This is because the user can modify this data in the Data Tables of PowerTrace, and TRACE 3-D can modify this data during execution of a user command.

TRACE 3-D can modify data during execution of a user command. This data is returned to the PowerTrace Interface with the Load Return Data command.

To transfer the return data ("Tape 31") to the Data Tables select the <u>Load</u> <u>Return</u> <u>Data</u> (Tape 31 → Tape 30) command from the Commands menu. PowerTrace will automatically update the Data Tables with the return data from TRACE 3-D after executing a match command (Perform Matching, Match Without Print, or Match in Range, see Section 5 "TRACE 3-D Commands"). However, this feature can be disabled with a PowerTrace Option. (see Section 6 "User Preferences"). No other TRACE 3-D command will automatically update the PowerTrace Data Tables from the TRACE 3-D return data.

Automatic update of return data from TRACE 3-D for matching commands can be turned on and off in the Options dialog.

TRACE 3-D can be reinitialized with the <u>Reinitialize</u> <u>Trace</u> <u>3-D</u> item in the Commands menu. This will reinitialize the TRACE 3-D **TCOM** and **ITCOM** common data. Note that most internal arrays, such as the **HOLD** array, are retained. This effectively allows the "fresh" restart of TRACE 3-D while maintaining the PowerTrace model data and certain FORTRAN internal data.

TRACE 3-D commons can be reinitialized using <u>Reinitialize</u> <u>Trace</u> <u>3-D</u> in the Commands menu.

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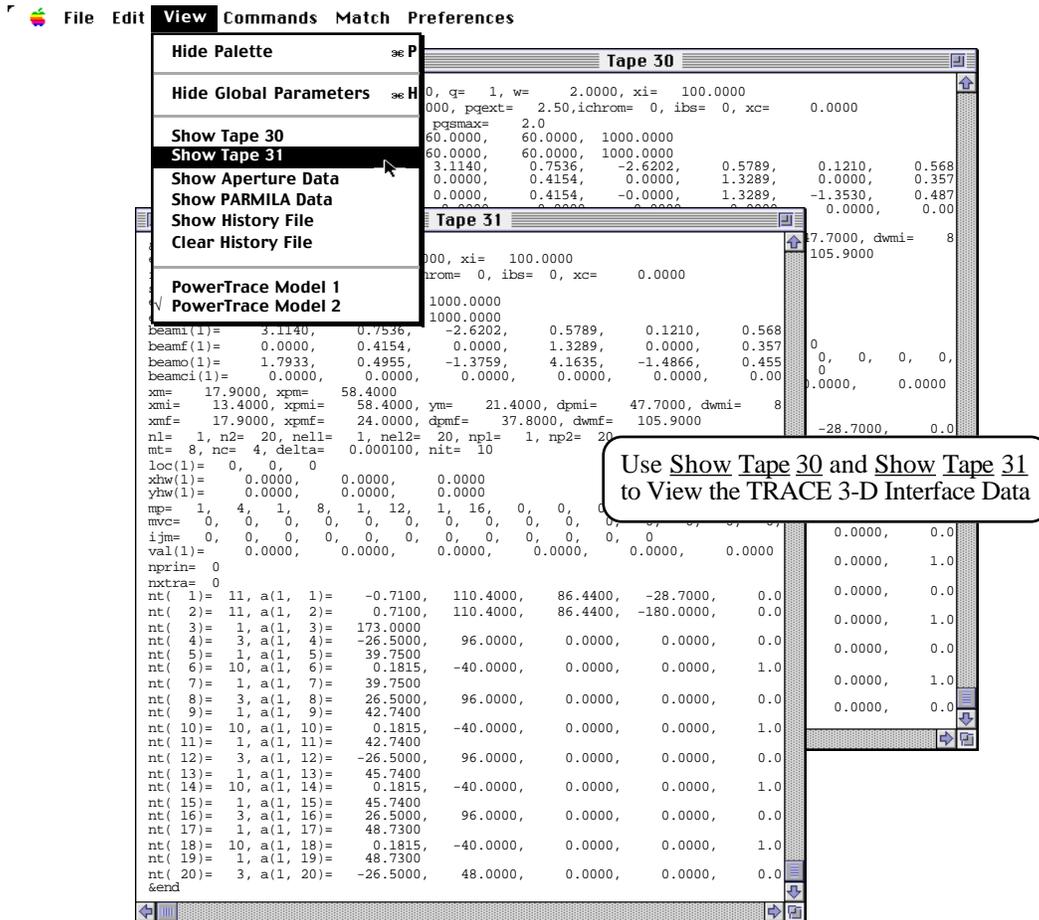
Figure 3-10. PowerTrace Text Windows Showing Input to TRACE 3-D (Tape 30) and Returned Data (Tape 31).

Several other PowerTrace actions initiate data transfers with TRACE 3-D. While this is transparent to the user and is unlikely to cause a problem, these actions are summarized here for information purposes. Opening either an Initial or Final Piece Window, by double clicking the Initial or Final Piece icons in a Document Window, calls certain TRACE 3-D subroutines which are used for displaying the emittance ellipses. This action will initiate the data transfer to TRACE 3-D.

Opening the Tape 30 window, by selecting Show Tape 30 under the View menu, can result in a call to the TRACE 3-D FORTRAN *when the window is closed* if the "Auto Update from Tape 30" Option is turned on. This option is discussed in Section 6 "User Preferences". Use of any of the Import commands under the File menu also results in a call to the TRACE 3-D FORTRAN and initiates the data transfer.

This Section provides a description of the PowerTrace user interface and defines terms used to refer to different parts of the interface. The following Section discusses the use of PowerTrace to implement the various matching options available in TRACE 3-D.

4. Matching Options

The matching capabilities of TRACE 3-D are among its most powerful features. This section discusses the use of PowerTrace to implement the various matching options available in TRACE 3-D. The set up of matching problems is the focus of this section. Actual match commands are discussed in the TRACE 3-D Commands section.

Matching Types

Several matching types are available in TRACE 3-D and these are listed in Table 4-1 below. The match type indicates the type of beam matching or transport fitting desired. Types 1-4 specify that matched Twiss parameters are to be found. Type 13 specifies that initial Twiss parameters are to be found to fit desired final Twiss parameters. Types 5-12 specify that values are to be found for selected element parameters to fit final Twiss parameters, or to fit selected R matrix or Sigma matrix elements. Type 14 specifies that values are to be found for selected element parameters to fit for desired phase advances in selected phase planes.

TRACE 3-D supports fourteen different types of beam matching and fitting.

Table 4-1. Types of Matching in TRACE 3-D

MT	Desired Values at End of Beamline
1	Vary initial beam for a matched beam in X,Y planes.
2	Vary initial beam for a matched beam in Z plane.
3	Vary initial beam for a matched beam in X,Y,Z planes (Upright).
4	Vary initial beam for a matched beam in X,Y,Z planes.
5	Vary element parameters to fit desired beam in X plane.
6	Vary element parameters to fit desired beam in Y plane.
7	Vary element parameters to fit desired beam in Z plane.
8	Vary element parameters to fit desired beam in X,Y planes.
9	Vary element parameters to fit desired beam in X,Y,Z planes.
10	Vary element parameters to fit desired R matrix elements.
11	Vary element parameters to fit desired Sigma matrix elements.
12	Vary element parameters to fit for round beam.
13	Vary initial beam to fit desired beam in X,Y,Z planes.
14	Vary element parameters to fit for specified phase advances in specified phase planes.

The PowerTrace Match menu is used to set the match type and to access other matching data. The match type is specified with the <u>Set</u> <u>Match</u> <u>Type</u> submenu as shown in Figure 4-1. For this discussion matching types can be divided into two groups: "Find Matched Twiss Parameters" and "Find Variables For Match". Match types 1-4 are used to find matched Twiss parameters, similarly match type 13 varies initial Twiss parameters to match for desired final Twiss parameters.

The match type is specified with the <u>Set</u> <u>Match</u> <u>Type</u> submenu in the Match menu.

Match types 5-12 are used to find variables for a match by varying element parameters (match variables) to fit for a desired beam or to fit for desired R matrix or Sigma matrix elements. The match type is determined by the TRACE 3-D match type parameter **MT**, which is set by the PowerTrace interface when an item in the Set Match Type submenu is selected.
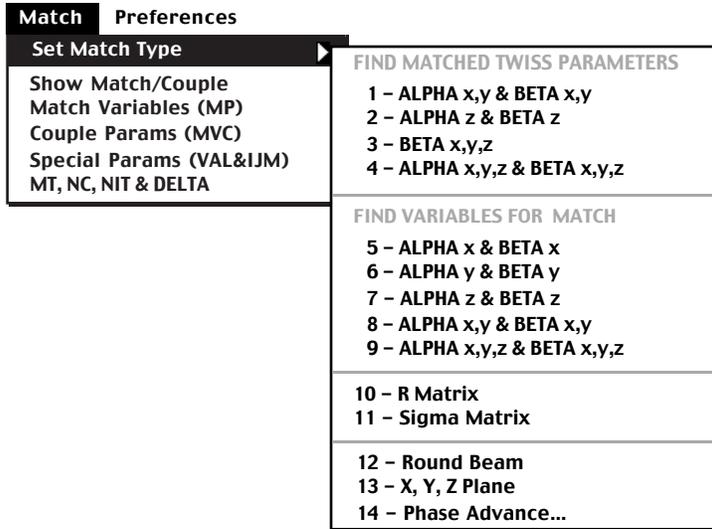
Match types are divided into two general groups: "Find Matched Twiss Parameters" and "Find Variables For Match".

Figure 4-1. PowerTrace Match Type Submenu.

The PowerTrace interface sets the number of matching conditions (**NC**) and has built in defaults for the number of iterations and convergence criteria (**NIT** and **DELTA**). The parameters **MT**, **NC**, **NIT** and **DELTA** may be viewed, and changed, by selecting the last item in the Match menu shown in Figure 4-2. This will bring up the "Match Parameters" window which displays the current values for these parameters.

Refer to subheading 9.4 from Section 9 "Input Variables" of the TRACE 3-D Documentation.
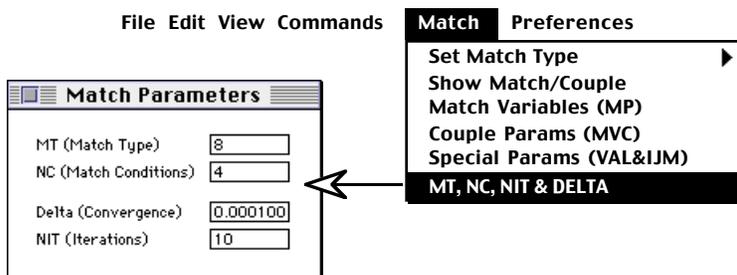
Figure 4-2. Match Parameters Window.

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Find Matched Twiss Parameters (Match Types 1-4)

Once a beamline is defined the only action necessary for setting up a matching problem to <u>Find</u> <u>Matched</u> <u>Twiss</u> <u>Parameters</u> (match types 1-4) is to select the match type in the Set Match Type submenu. Once the match type is specified, select the Perform Matching (or Match Without Print) item in the Commands menu to execute the TRACE 3-D matching procedure. These commands are discussed further in the Section 5 "TRACE 3-D Commands".

Setting up a problem to Find Matched Twiss Parameters (MT=1-4) only requires selection of the match type.

Find Variables For Match (Match Types 5-12 & 14)

Once a beamline is defined, match variables must be specified in order to <u>Find</u> <u>Variables</u> <u>For</u> <u>Match</u> (match types 5-12 & 14). These match types have been further divided in the Set Match Types submenu according to whether the objective is to adjust beamline element parameters to achieve (a) specified final values of certain Twiss parameters (match types 5-9), (b) specified values of selected R matrix elements (match type 10) or Sigma matrix elements (match type 11), (c) fit for a round beam (match type 12), or (d) fit for specified phase advances in selected phase planes (match type 14). As with match types 1-4, the match type parameter (**MT**) is set by the PowerTrace interface when the corresponding item is selected in the Set Match Type submenu. The value for **NC** is automatically set, as are the built in defaults for **NIT** and **DELTA**. These may viewed and edited in the "Match Parameters" window as discussed above. For match types 10 and 11 the value of **NC** is also set by PowerTrace based on the number of goal values specified for the R or Sigma matrix elements. Selection of goal values is discussed later in the subsection "Matching the R and σ Matrices".

Setting up a problem tto Find Variables For Match (MT=5-9) requires match variables to be specified.

Refer to subheading 9.4 from Section 9 "Input Variables", of the TRACE 3-D Documentation.

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Match Variables and Coupling Parameters

Beamline element parameters which are to be varied by TRACE 3-D (match variables) are specified from the Piece Windows of beamline elements. Each Piece Window has a "Match/Couple" option on the Limits pop-up menu. Selecting this option displays check boxes for each parameter which can legitimately be varied during matching. Checking a box in the Match column assigns that parameter to be a match variable. This is illustrated in Figure 4-3 for a PMQ Piece.

Match variables and Coupling parameters are set using the Match and Couple check boxes in individual Piece Windows.
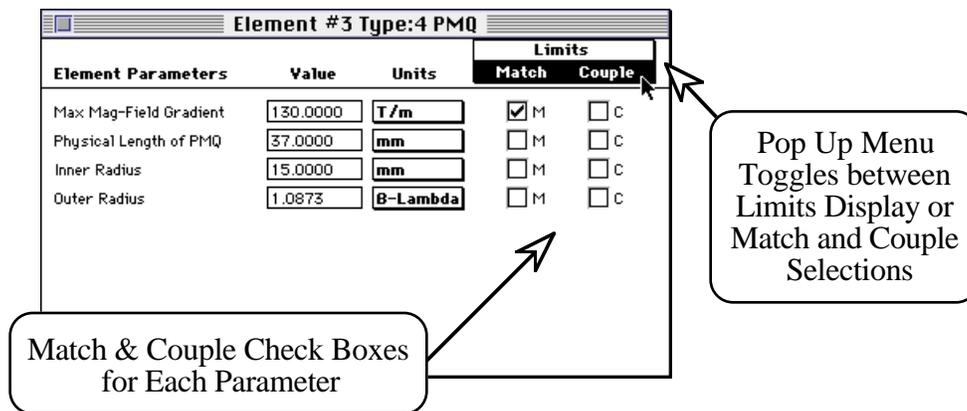
Figure 4-3.   Selecting Parameters for Matching or Coupling.

PowerTrace automatically sets up the **MP** and **MVC** arrays which are used by TRACE 3-D to define match variables and coupling parameters. When a Match or Couple box is checked in a Piece Window, the number of that parameter and the sequence of that element in the model are entered into the <u>first</u> <u>empty</u> <u>location</u> in the **MP** or **MVC** array. If new elements are added to the model, then the sequence values in the arrays are adjusted appropriately. If an element which has been chosen for matching and/or coupling is deleted from the model, then it is also deleted from the **MP** and/or **MVC** array. In this case the arrays are not reordered. The **MP** and/or **MVC** elements associated with the deleted element are set to zero, so that the order of any other conditions are preserved. The empty spots will be filled with any subsequent checking of matching or coupling boxes by the user.

PowerTrace automatically sets up the MP and MVC arrays when a Match or Couple box is checked in a Piece Window.

Refer to subheading 9.4 from Section 9 "Input Variables", of the TRACE 3-D Documentation.

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The order in which the coupling parameters are selected (i.e. when their Couple box is checked) is important since that determines the matching variable with which the parameter will be coupled. A special window is available to graphically display the status of the match and coupling selections and their order in the **MP** and **MVC** arrays. This window is opened with the Show Match/Couple item in the Match menu and an example is illustrated in Figure 4-4.

The order that coupling parameters are selected is important since that determines the matching variable with which the parameter will be coupled.

Figure 4-4. Example of the PowerTrace Window that Shows Match & Coupling Selections.

The contents of the **MP** and **MVC** arrays may also be displayed and edited directly in the Coupling Window and the Matching Window. These windows are accessed with the Match Variables (MP) and the Couple Params (MVC) items in the Match menu as illustrated in Figure 4-5.

The matching and coupling arrays can be changed directly by entering new data in these windows. The *coupling k* values are given by the **MVC(3,n)** entries in the Coupling Window. The *coupling k* value, in the **MVC** array is always defaulted to +1, but may be changed to -1 in the Coupling Window (Figure 4-5).

*The **MP** and **MVC** arrays may be edited directly in the Coupling and Matching Windows.*
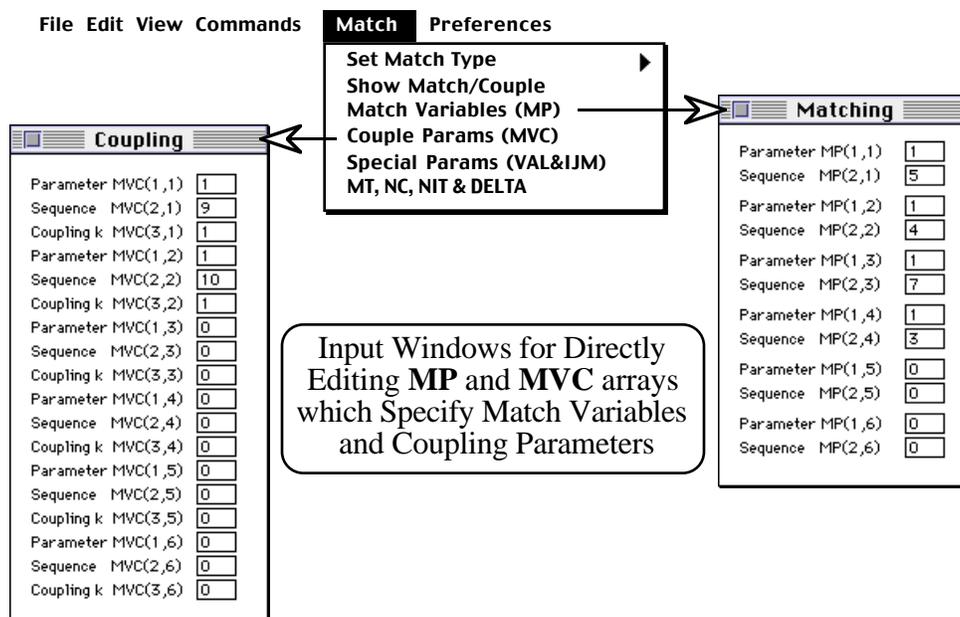
Figure 4-5. Input Windows for Directly Editing the TRACE 3-D Coupling and Matching Data.

Matching the R and σ Matrices (match types 10 & 11)

When the user selects either the R Matrix option (match type 10) or the Sigma Matrix option (match type 11) from the Set Match Type submenu, the Goal Selections dialog window appears for inputting the goal values for up to six (6) of these matrix elements. The process for making goal selections with these windows is the same for either matrix. The following discussion gives examples for Sigma matrix matching; any differences for R matrix matching are noted.

The Goal Selections dialog window is used to specify goal values for up to six R matrix or Sigma matrix elements.

When the R Matrix match type is selected, the Goal Selections dialog displays the current values for the TRACE 3-D 6x6 **RM** matrix. If the Sigma Matrix option (match type 11) is selected then the display gives the current values of the TRACE 3-D 6x6 (final beam) **SIGI** matrix (not the modified sigma matrix).

Refer to subheading 9.4 from Section 9 "Input Variables", of the TRACE 3-D Documentation.

Note that these initial matrices will be zero if appropriate TRACE 3-D commands have not been executed prior to the opening of this dialog. Running Graph Beam Line and the Load Return Data from the Commands menu will compute these matrices and provide initial values for these arrays based on the existing beamline model. The one-dimensional **VAL** and two-dimensional **IJM** arrays are needed by TRACE 3-D to perform the match for **MT** = 10 and 11. These arrays are set by PowerTrace when data is entered into the R matrix or Sigma matrix in the the Goal Selections dialog window.

Run Graph Beam Line and Load Return Data from the Commands menu to provide initial values for R and Sigma matrices based on the existing beamline model.

The Goal Selections dialog has two modes: the *Matrix mode* and the *VAL/IJM mode*. The user may switch between the two modes using the radio buttons in the lower left corner of the window. Figure 4-6 shows an example of both the *Matrix* mode used to set goal values for R Matrix matching and the *VAL/IJM* mode which displays **VAL** entries at **IJM** indices of the 6x6 matrix.

Select between Matrix mode and VAL/IJM mode with the radio buttons in the lower left corner of the Goal Selections Dialog.

The Goal Selections dialog is used to set the desired values for matrix elements (goal selections). Selecting a check box beside an element identifies it as a potential matching condition; values for the selected elements are the matrix elements which TRACE 3-D will try to match. PowerTrace automatically sets up the **VAL** and **IJM** arrays in both display modes when the user *adds* or *removes* goal selections by checking the boxes to the left of the value fields and pressing the Add to VAL & IJM or Remove from VAL & IJM button. None of the data input by the user is actually utilized until the add or remove button is pressed. The value for **NC** is automatically set by counting the goal selections entered by the user.

No data input occures in the Goal Selections dialog until the Add to VAL & IJM button is pressed.

To Match desired R or Sigma Matrix Elements, Check Matrix Elements (up to 6) and Enter Goal Values then Use the Add toVAL & IJM button

Run Graph Beam Line Followed by the Load Return Data Command in order to Get Initial Sigma or R Matrix Element Values

Sigma Matrix Goal Selections

☑ 32.0000	☐ 276.224	☐ 0.0000	☐ 0.0000	☐ 0.0000	☐ 0.0000
☐ 276.224	☐ 74.5138	☐ 0.0000	☐ 0.0000	☐ 0.0000	☐ 0.0000
☐ 0.0000	☐ 0.0000	☑ 32.0000	☐ 306.499	☐ 0.0000	☐ 0.0000
☐ 0.0000	☐ 0.0000	☐ 306.499	☐ 91.7428	☐ 0.0000	☐ 0.0000
☐ 0.0000	☐ 0.0000	☐ 0.0000	☐ 0.0000	☐ 1881.59	☐ 317.684
☐ 0.0000	☐ 0.0000	☐ 0.0000	☐ 0.0000	☐ 317.684	☐ 53.6432

◉ Sigma Matrix   [**Add to VAL & IJM**]   [OK]

○ VAL & IJM   [**Remove from VAL & IJM**]   [Cancel]

Matrix Mode Goal Selection for Sigma or R Matrix Matching

VAL/IJM Mode of the Goal Selections Dialog Shows the Current Matrix Element Goal Selections Used for R Matrix (**MT** = 10) and Sigma Matrix (**MT** = 11) Matching

VAL/IJM Mode Goal Selection for Sigma or R Matrix Matching

VAL, IJM Goal Selections

☐ 32.0000	☐	☐	☐	☐	☐
☐	☐	☐	☐	☐	☐
☐	☐	☐ 32.0000	☐	☐	☐
☐	☐	☐	☐	☐	☐
☐	☐	☐	☐	☐	☐
☐	☐	☐	☐	☐	☐

○ Sigma Matrix   [Add to VAL & IJM]   [OK]

◉ VAL & IJM   [Remove from VAL & IJM]   [Cancel]

Select Between Matrix and VAL/IJM Mode for Sigma or R Matrix Goal Selections

Figure 4-6.   Matrix Mode and VAL/IJM Mode of the Goal Selections Dialog for Sigma Matrix Matching.

While the current values of the R and Sigma matrices are used to initialize the data in this dialog, the actual **RM** and **SIGI** arrays in TRACE 3-D are not modified.

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To exit the Goal Selections dialog after accepting any matrix goal selections, use the OK button. To exit without saving modifications, use the Cancel button. If the Cancel button is used to exit the dialog then the **VAL** and **IJM** arrays will be restored to their contents before the dialog was opened.

The **VAL** and **IJM** array values may also be accessed directly in the Special Window which is opened with the Special Params (VAL&IJM) item in the Match menu as illustrated in Figure 4-7. This window allows direct modification of both the **VAL** and **IJM** arrays.

*The **VAL** and **IJM** arrays may be edited directly in the Special Window.*

Special Window for Directly Viewing and Editing the VAL and IJM Arrays Used for R Matrix (MT = 10) and Sigma Matrix (MT = 11) Matching
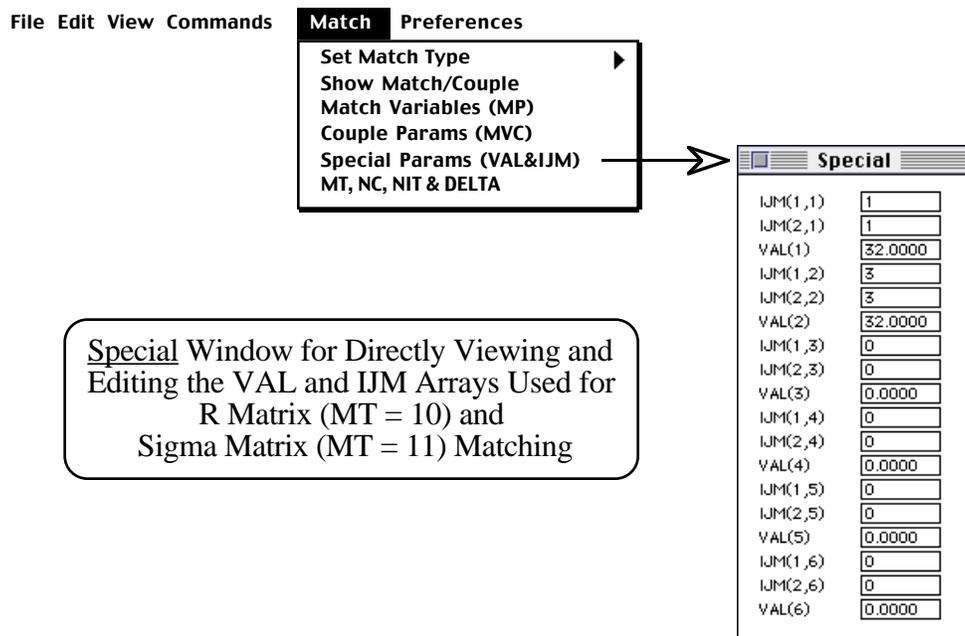
Figure 4-7. Special Window to Directly Edit the VAL & IJM Arrays.

Matching for Round Beam (match type 12)

Match Type 12 is used to vary element parameters to fit for a round beam (equal X and Y envelopes at the end of the beamline). Matching variables (beamline element parameters which are to be varied) must be specified as described for match types 5-11.

Match Type 12 is used to vary element parameters to fit for a round beam.

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Matching for X,Y,Z Planes (match type 13)

Match Type 13 is used to vary initial Twiss parameters (**BEAMI**) to fit a desired beam in X,Y,Z planes (**BEAMF**). The initial Twiss parameters in the Initial Piece Window will be varied by TRACE 3-D to fit a desired final beam which is specified in the Final Piece Window. Once the desired final Twiss parameters are specified the only action necessary for setting up a matching problem is to select the match type in the Set Match Type submenu. The Perform Matching command can then be executed to find the initial Twiss parameters that satisfy the desired final beam.

Match Type 13 is used to vary the initial beam to fit a desired final beam.

Matching for Phase Advance (match type 14)

Match Type 14 is used to vary element parameters to fit for specified phase advances.

Match Type 14 is used to vary element parameters to fit for specified phase advances in specified phase-space planes. Match variables (beamline element parameters which are to be varied) must be specified as described for match types 5-11. The desired phase-space planes and phase advances are set in the Match for Phase Advance Window illustrated in Figure 4-8. This window is automatically opened when the Phase Advance match type is selected in the Set Match Types submenu.

Select Phase Space Plane for matching and the desired Phase Advances
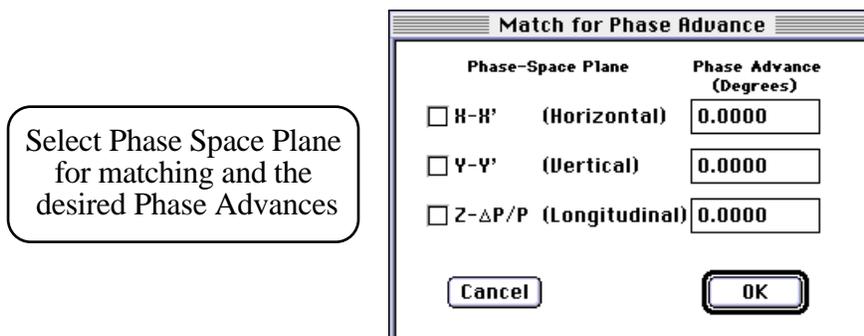
Figure 4-8. Match for Phase Advance Dialog.

This Section provides a description of the PowerTrace user interface for setting up various matching options available in TRACE 3-D. The following Section discusses the use of PowerTrace Commands to execute TRACE 3-D.

5. TRACE 3-D Commands

Running TRACE 3-D is accomplished directly from the PowerTrace interface. The TRACE 3-D FORTRAN is fully integrated with the PowerTrace application. This section discusses the Commands menu and the other PowerTrace components which interact directly with the TRACE 3-D FORTRAN.

The Commands Menu

The Commands menu illustrated in Figure 5-1, is used to execute TRACE 3-D commands. The majority of commands correspond directly to the native TRACE 3-D commands defined in the TRACE 3-D Documentation. The keyboard equivalents have been retained. For example, "Graph" is executed either by selecting the Graph Beam Line command or entering ⌘-G from the keyboard (press "G" while pressing the apple command "⌘" key). Some keyboard equivalents require the command and option keys to be pressed along with the TRACE 3-D equivalent. Keyboard equivalents requiring command-option are noted in Figure 2-6 which shows all of the PowerTrace commands and the corresponding TRACE 3-D commands.

PowerTrace Command	PowerTrace Key-Equivalent		TRACE 3-D Code	TRACE 3-D Command
Commands				
Graph Beam Line	⌘ G		G	GRAPH
Trace on Background	⌘ T		T	TRACE
Find Ellipses from Profile	⌘ L		L	ELLIPSE
Plot Projections	⌘ J		J	PROJECTIONS
Calculate Phase Advance	⌘ F		F	PHASE
Exchange Beams	⌘ ≈	(⌘-Option-X)	X	EXCHANGE
Calculate Mismatch	⌘ ø	(⌘-Option-O)	O	MISMATCH
Perform Matching	⌘ M		M	MATCH
Match Without Print	⌘ N		N	MATCH
Match in Range (MT=7,8,9)	⌘ U		U	USER
Show Match/Couple				-
Show Match Variables	⌘ ✓	(⌘-Option-V)	V	VARIABLES
Restore Prematch Variables			!	UNMATCH
Show Beam Vectors	⌘ B		B	BEAM
Show R Matrix	⌘ R		R	R-MATRIX
Show Modified Sigma	⌘ Z		Z	SIGMA
Show Phase & Energy	⌘ Σ	(⌘-Option-W)	W	φ-W
Show TRACE 3D Data	⌘ π	(⌘-Option-P)	P	PRINT
Load Return Data (31–>30)				-
PARMILA Units	⌘ ç	(⌘-Option-K)	C	CONVERT
Help	▶			-
Reinitialize TRACE 3D	⌘ E			-

Most of the PowerTrace Commands correspond directly to the native TRACE 3-D commands described in Section 10 of the TRACE 3-D Documentation.

Figure 5-1. PowerTrace Commands Menu.

Some TRACE 3-D commands that are not present in the PowerTrace Commands menu, (NEWFILE, INPUT, ADD, DELETE, QUERY, SAVE and END) are effectively

incorporated into the PowerTrace user interface. The NEWFILE command equivalents in PowerTrace are the New and Open commands in the File menu. The INPUT, ADD, DELETE and QUERY commands are not used since the PowerTrace interface handles these functions with graphical beamline set up and access to element parameters by double-clicking Pieces in the beamline model. The SAVE command equivalents in PowerTrace are the Save, Save As and Export commands in the File menu. The END command is equivalent to Quit in the File menu. These menu commands are discussed in Section 3 "PowerTrace Interface". Two other TRACE 3-D commands, CENTROID and APERTURE are integrated into the PowerTrace interface. The CENTROID equivalent in PowerTrace is the Centroid Parameters command in the Preferences menu, which provides access to beam centroid offsets. The APERTURE command is implemented in PowerTrace as a user option. This is described in the "Generate Aperture File" subsection in Section 6 of this manual. Two TRACE 3-D display commands which are not implemented in the PowerTrace interface are NOTE and COMMENT.

Refer to Table IV from Section 8 "User Instructions" of the TRACE 3-D Documentation.

The Show TRACE 3-D Data command can also be used to examine the input from the FORTRAN after the data exchange has occurred.

PowerTrace Commands are organized in four functional groups. The first group contains beam dynamics related commands. The second group of commands are for matching operations. The third group contains display commands and the last group includes some PowerTrace specific commands and miscellaneous TRACE 3-D commands. Most commands result in output to one of two different PowerTrace windows. Matching and display commands send output to a Text Output Window. Graph Beam Line and related commands send output to a Graphic Output window.

Commands will be dimmed if the front window is not a Document or one of the Output Windows.

Commands will be dimmed and not accessible if the front window is not a Document Window or one of the two Output Windows. Other commands such as Calculate Phase Advance and Show Modified Sigma, are dimmed prior to execution of a Graph command. Some commands that are interactive, use a PowerTrace dialog

after initial processing by TRACE 3-D. The dialog windows can be moved by dragging the title bar if they are covering previous output from TRACE 3-D. After responding to the dialog, processing of the command will continue.

Text Output Window

Text output from TRACE 3-D is sent to a Text Output window. The title of the window will be the same as the active Document Window. The Text Output window has a default size and location based on the size of your monitor. The Text Output window has a fixed width but can be resized vertically. Text output is appended to previous output when the window remains open. When output reaches the bottom of the window, it is cleared and resumes from the top. A continuous text file is also written (History file) which contains everything that is displayed in the Text Output window. After a command has completed, any data cleared from the Text Output window can be viewed using the Show History File command in the View menu. The History file will hold up to 32K characters, but this can be exceeded after continuous commands are executed. Rename, copy or clear the file to prevent history data from being lost.

The History file can be cleared automatically prior to executing TRACE 3-D commands. See Section 6 "User Preferences".

Graphic Output Window

When resized and left open the Graphic Output window will scale the output for the new size on the next execution of a TRACE 3-D command.

Graphic output from TRACE 3-D is sent to a Graphic Output window. The title of the window will be the same as the active Document Window. The Graphic Output window has a default size and location based on monitor size but can be resized in both vertical and horizontal directions. The current window contents are not re-scaled. When the window is left open after being resized, the graphic output will be scaled for the new window size with the next command. The Graphic Output window can not be resized smaller than the minimum size required for TRACE 3-D graphic output. The size is only limited by the size of the monitor.

Beam Dynamics Commands

Graph Beam Line

The <u>Graph</u> <u>Beam</u> <u>Line</u> (⌘-G) command generates the TRACE 3-D beam envelopes and phase-space ellipses in the Graphic Output window. Figure 5-2 shows the result of executing the Graph Beam Line command using the Example B model distributed with the application and described in the TRACE 3-D Documentation. The beamline elements are drawn first in the profile box at the bottom of the window. The initial phase space ellipses are then drawn. Horizontal (solid red) and vertical (dashed blue) ellipses in the top plot and longitudinal (dashed green) in the bottom plot. If the Initial Piece is to the right of the Final Piece in the beamline model, then the initial ellipses will be drawn on the left-hand side of the window; if the Initial Piece is to the right of the Final Piece in the beamline model then the beam traverses the model in the reverse direction and the initial ellipses will be drawn on the right-hand side of the window. Beam envelopes are then drawn in the beam profile box at the bottom of the window. The horizontal (solid red) and longitudinal (dotted green) beam profiles in the upper half of the profile box and the vertical (dashed blue) profile in the lower half. After the beam envelopes are complete, the final ellipses are drawn followed by various parameter values which are displayed in the center of the window as shown in Figure 5-2.

The Graph Beam Line command generates the beam envelopes and phase-space ellipses in the Graphic Output window.

Trace on Background

The <u>Trace</u> <u>on</u> <u>Background</u> (⌘-T) command generates beam envelopes and phase-space ellipses over the output from a previous Graph Beam Line command. The Trace command will be dimmed if a Graph command has not be executed. The Trace command is not useful if the beamline length has been changed or the Graphic Output Window has been resized since the last Graph command.

The Trace on Background command allows direct comparison of beams before and after parameter changes.

Figure 5-3 shows the results from the Trace on Background command, displayed over the Graph example illustrated in Figure 5-2, after the Perform Matching command was executed to convergence.
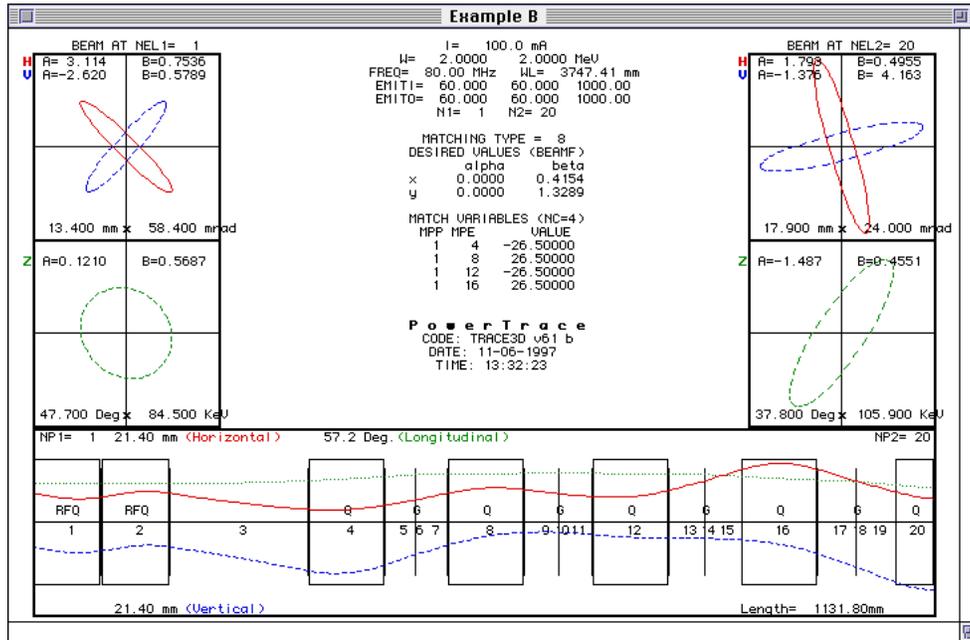
Figure 5-2.   Output from the Graph Beam Line Command.
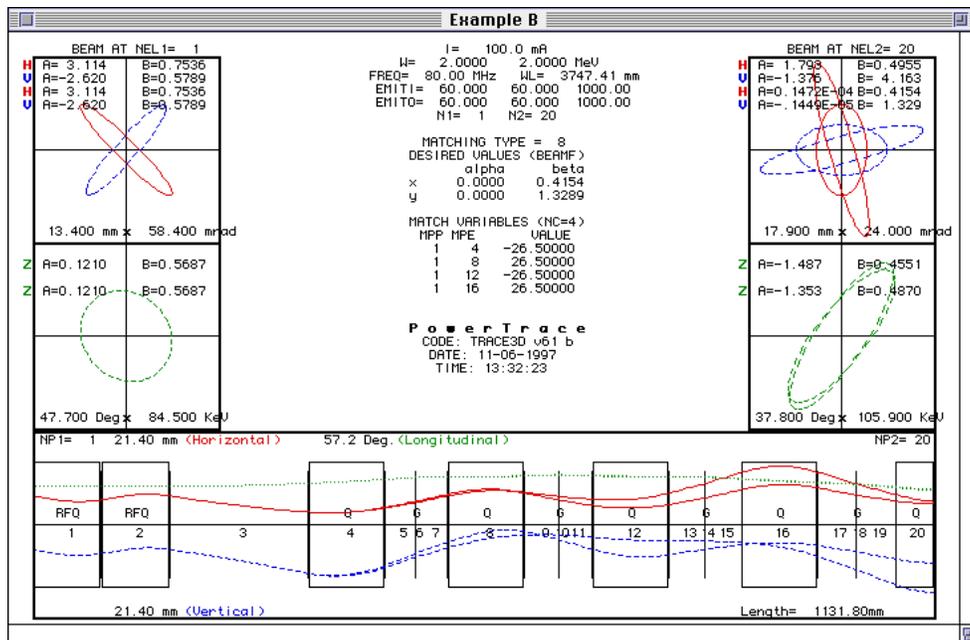
Figure 5-3.   Example of Trace on Background Command.

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Find Ellipses from Profile

The <u>Find</u> <u>Ellipses</u> <u>from</u> <u>Profile</u> (⌘-L) command is an interactive command which is used to determine the ellipse parameters and emittances in the two transverse planes based on measurements of beam half-widths at three locations in the beamline. After the command is selected, ellipses and profile plots are generated in the Graphic Output window followed by a PowerTrace dialog that is used to input the location for profile measurements and the corresponding horizontal and vertical beam half-widths. Figure 5-4 shows an example of the initial Graph and the input dialog, as well as the resulting graphic output with the specified measurement locations marked. If a realistic solution is found, the calculated emittances are displayed and the transverse beam profiles are plotted over the three specified locations.

The Find Ellipses from Profile command is used to find emittance ellipses from three different profile measurements.
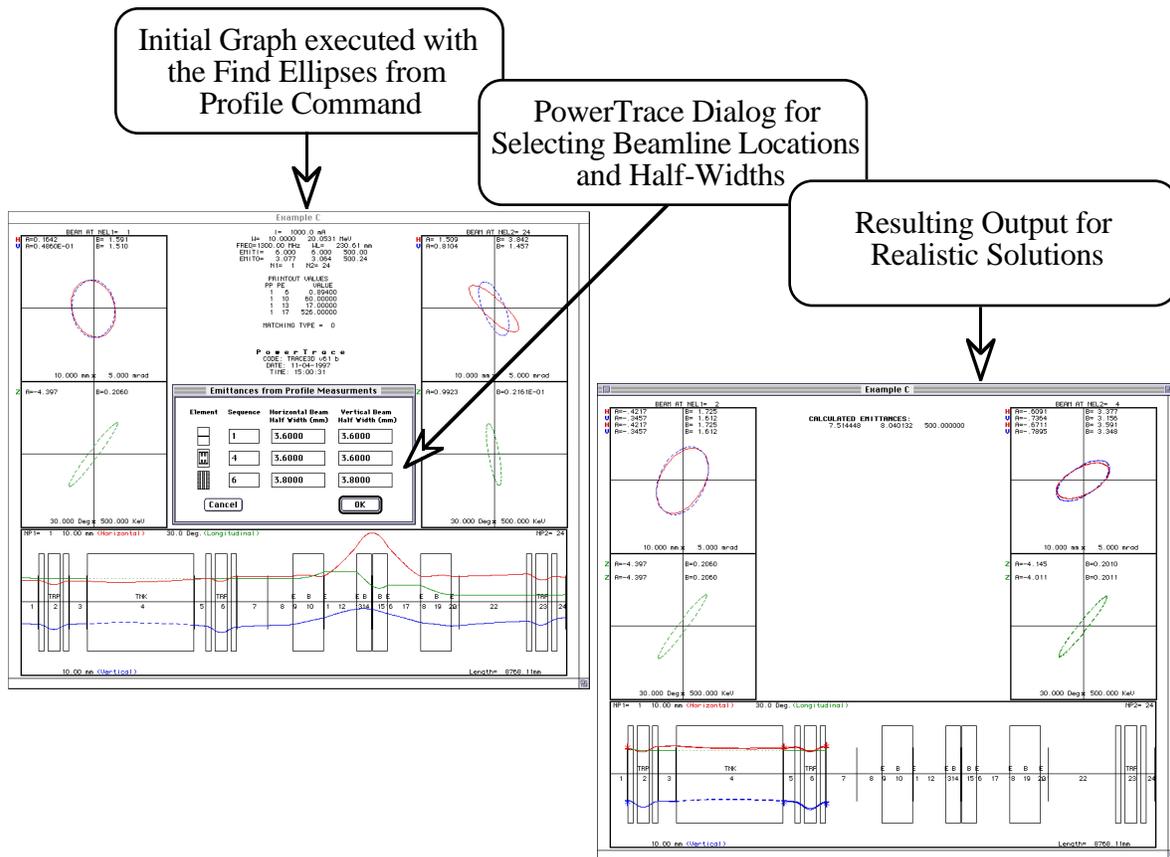
Figure 5-4. Ellipses from Profile Measurements Command.

Plot Projections

The <u>Plot</u> <u>Projections</u> (⌘-J) command requires the previous execution of a Graph command and will be dimmed if a Graph command has not be executed. Projections of the beam in *x-y,* *x-z* and *x-Δp/p* are displayed in the Graphic Output window. The upstream end of the system is shown on the left-hand side of the window and the downstream end on the right. Figure 5-5 shows the resulting display after executing the Plot Projections command.

The Plot Projections command is used to plot initial and final projections on x-y, x-z and x-Δp/p planes.
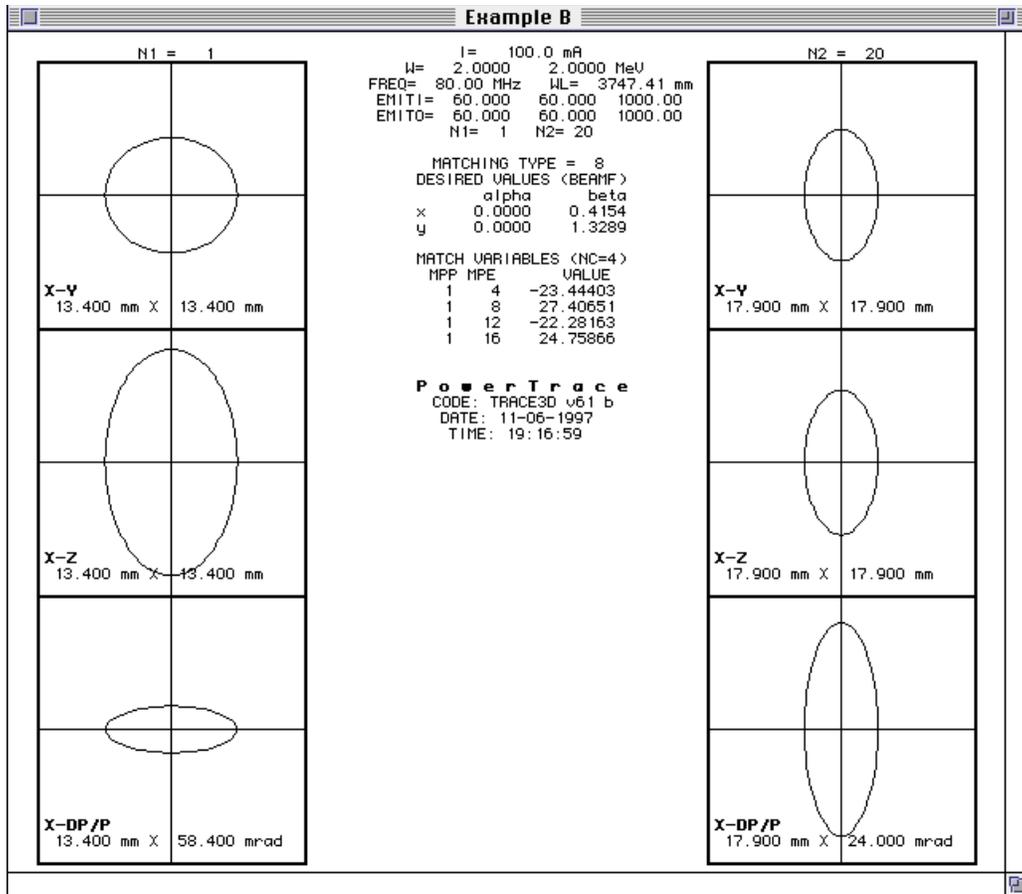
Figure 5-5. Output from the Plot Projections Command.

Calculate Phase Advance

The <u>Calculate</u> <u>Phase</u> <u>Advance</u> (⌘-F) command is used to calculate and display the phase advance (deg) and the Twiss (α & ß) beam ellipse parameters for each of the three phase-space planes. This command requires a previous execution of the Graph command. The phase advance is given in degrees, alpha and beta are in mm/mrad. The results are sent to the Text Output window. As with all text output from TRACE 3-D, this data is also written to the cumulative History file. An example of the resulting output from this command is shown in Figure 5-6.

The Calculate Phase Advance command calculates and displays the the phase advance and Twiss parameters for the three phase-space planes

```
                          Example B

TWISS PARAMETERS:
          SIG          ALPHA          BETA
 X   104.291548      0.911093       0.314364
 Y   261.672815      0.709659       0.474813
 Z    84.353239     -0.447008       0.389605
```

Figure 5-6 Output from Calculate Phase Advance Command.

Exchange Beams

The <u>Exchange</u> <u>Beams</u> (⌘-Option-B) command is used to store beam parameters in up to fourteen different holding positions, and then later exchange these back to either the initial or the final beams. Beams are stored in the 6 by 14 **HOLD** array of TRACE 3-D. The Exchange Beams command is an interactive command that uses a PowerTrace dialog to input parameters for the beam selection (initial, final or output), the holding position (1-14) and the exchange direction (*to* or *from* a hold position). The Text Output window is used to display the current beam vectors as well as any beams already in the hold array. The Exchange Beams dialog is then used to specify the exchange parameters.

The Exchange Beams command is used to store and retrieve beam-ellipse parameters.

After closing the Exchange Beams dialog, results of the exchange are displayed as shown in Figure 5-7.

Before Opening the Exchange Beams Dialog the Initial, Final and Output Beams are displayed in the TRACE 3-D Text Window, in Addition to Any Beams Currently Stored in the Holding Array and the Number of Available Hold Positions

After Closing the Exchange Beams Dialog, the Results are Written to the TRACE 3-D Text Window

Example B

```
BEAM VECTORS:
  beami: x=    3.1140    0.7536 y=   -2.6202    0.5789 z=    0.1210
  beamf: x=    0.0000    0.4154 y=    0.0000    1.3289 z=    0.0000
  beamo: x=    0.0000    0.0000 y=    0.0000    0.0000 z=    0.0000    0.0000

THERE ARE NO BEAMS STORED
 14 Hold Positions Available

INITIAL BEAM STORED IN POSITION  1
  hold1: x=    3.1140    0.7536 y=   -2.6202    0.5789 z=    0.1210
```

Enter Desired Hold Position Number or Use the Arrow Control to Select Between Fourteen Holding Positions

Select Between Initial, Final or Output Beams

Exchange Beams To or From Holding Positions

Exchange Beams

Select Beam
- ⦿ Initial Beam
- ○ Final Beam
- ○ Output Beam

Select Holding Position
Hold Position [1]

Select Exchange Direction
- ⦿ Beam -> Holding Position
- ○ Holding Position -> Beam

[Cancel]   [OK]

Figure 5-7.   Exchange Beams Command.

The function of the Exchange Beams command is essentially the same as the standard TRACE 3-D command. However, when using Exchange Beams *to take data from the holding positions* for use either as the initial or final beam in a subsequent command, the user should *execute the* Load Return Data (31→30) *after executing* Exchange Beams. The "Holding Position → Beam" returns beam data through the Tape 31 (return)

Use the "Auto Update After Match or Exchange" Option to always update after an Exchange Beams command.

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data structure; this must be reloaded into the Tape 30 (input) data structure to be used in a subsequent calculation, as described in Section 3 "PowerTrace Interface".

Calculate Mismatch

The Calculate Mismatch (⌘-Option-O) command calculates and displays the mismatch factor between the output beam (**BEAMO**) and the desired final beam (**BEAMF**). A match type must be set in the Set Match Type submenu of the the Match menu. Output is directed to the Text Output window. Figure 5-8 illustrates the resulting output from the Mismatch command, before and after the Perform Matching command. The Show Match Variables command was also used to generate the output shown in Figure 5-8. These commands are described in the following subsection.

The Calculate Mismatch command calculates and displays the mismatch factor between the output and final beams.

A definition of the mismatch factor is presented in Appendix C "Mismatch Factor" in the T R A C E 3 - D Documentation.

```
╔══════════════════════ Example B ══════════════════════╗

MATCH  VARIABLES:
      MP            VALUE
  param,sequence
    1      4          -26.5000
    1      8           26.5000
    1     12          -26.5000
    1     16           26.5000

MISMATCH  FACTORS:
  MMFx=    1.122568, y=    0.947500

MATCHING... (NIT=      30)
    1.122568   -26.500000   26.500000   -26.500000   26.500000
    2.437808   -30.591502   26.604968   -23.282943   26.841247
    0.544419   -23.915922   25.847169   -24.694673   25.417714
    1.017563   -27.036087   28.241554   -27.207524   26.444065
    1.400462   -25.976358   27.174954   -27.916941   27.899467
    0.411105   -23.559257   26.630471   -24.268055   25.609316
    0.133408   -23.648349   27.638375   -23.092963   24.xxx274
    0.091104   -23.462245   27.536202   -21.658321   24.xx633
    0.024767   -23.441206   27.387535   -22.086308   24.712357
    0.002486   -23.448828   27.393426   -22.253266   24.752873
    0.001023   -23.440648   27.409513   -22.288122   24.758669
    0.000222   -23.444663   27.407170   -22.282748   24.758886
    0.000017   -23.444121   27.406558   -22.281577   24.758669

MATCH VARIABLES:
      MP            VALUE
  param,sequence
    1      4          -23.4441
    1      8           27.4066
    1     12          -22.2816
    1     16           24.7587

MISMATCH  FACTORS:
  MMFx=    0.000004, y=    0.000017
```

Show Match Variables

Calculate Mismatch

Perform Matching

Show Match Variables

Calculate Mismatch

Figure 5-8. Example Using the Calculate Mismatch Command.

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Matching Commands

There are six different commands to perform matching or display match and coupling data. The use of these commands is described here. Section 4 "Matching Options" describes the steps for setting the match type and specifying match variables for a matching problem. The Perform Matching, Match without Print and Match in Range commands are used to find matched-ellipse parameters or values of specified match variables, to fit the final beam or specified matrix elements, depending on the particular match type selected. The match commands search for a solution to a set of nonlinear, simultaneous equations in an iterative procedure. The number of iterations (**NIT**) and the convergence factor (**DELTA**) are set from the Match Parameters window as described in Section 4 "Matching Options". If a solution has not been found within the specified number of iterations, then the match variables will be set to the values found which minimize the convergence factor.

The Matching procedure can be terminated using command-period (⌘-.). The matching variables will be set to the values from the last match iteration.

Perform Matching and Match without Print

After setting up a matching problem, the <u>Perform Matching</u> (⌘-M) and <u>Match without Print</u> (⌘-N) commands can be used to start the matching process. The match type must be set prior to execution of these commands. As their names imply, both commands perform matching, the first displays matching progress and the second does not. Output from the matching process includes the convergence criteria and the values for each of the match variables at every iteration. Figure 5-8 on the previous page illustrates output resulting from the Perform Matching command. Matching will proceed until the convergence factor (first column) falls below the user specified value or the number of iterations has been reached. Two beeps are sounded when the matching process converges. Values for the match variables appear left to right in the order they are held in the **MP** array.

The Perform Matching and Match without Print commands start the matching process.

The Load Return Data command must be executed following a matching command, to update model parameters from match variables.

Use the "Auto Update After Match or Exchange" Option to always update match variables after matching.

Match in Range

The <u>Match</u> <u>in</u> <u>Range</u> (⌘-U) command performs matching in a user specified range and step size for each of the match variables. The Match in Range command is used for match types 7-9. It is an interactive command which brings up a PowerTrace input dialog, illustrated in Figure 5-9. Each element with a parameter selected as a match variable is listed with it's Piece icon, sequence in the beamline model, type code, and name. The name and current value of each parameter to vary is also displayed. The user must input the range of variation and the step size. PowerTrace sets initial defaults for the Minimum and Maximum Range values of each parameter to be varied, as well as the Step Size to be used between these two limits.

The Match in Range command performs matching in a user specified range and step size.

Default values for the range are 90% and 110% of the current value of the match variable. The default step size is one-fifth of the extent of the range, i.e. (Max - Min)/5
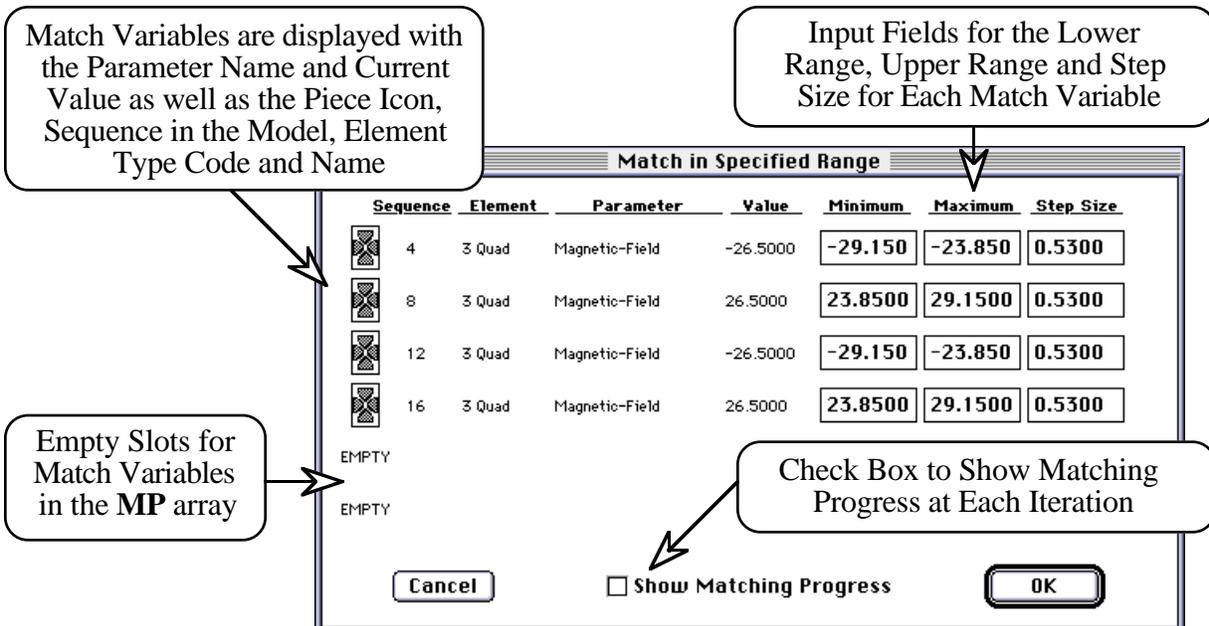
Figure 5-9. Match in User Specified Range Dialog Window.

The Match in Range procedure can take a long time to complete, especially if more than one match variable is being varied. An estimate of the maximum time needed can be made by multiplying the time for a Graph command to execute by the total number of iterations. The total number of iterations is given by the combined product of the number of steps for each variable.

The Match in Range procedure can take much longer to complete than the Perform Match command with similar results.

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Show Match/Couple

The <u>Show</u> <u>Match/Couple</u> command opens a PowerTrace window (illustrated in Figure 5-10) that graphically displays the status of the match and coupling selections and their order in the **MP** and **MVC** arrays. This window can also be accessed from the Match menu and is discussed in Section 4 "Matching Options".

The Show Match/Couple command displays the match and coupling selections.

Figure 5-10.   Show Match/Couple Command.

Show Match Variables

The <u>Show</u> <u>Match</u> <u>Variables</u> (⌘-Option-V) command is used to display the current values for parameters selected as match variables.   .For this command to generate any output, the match type must be set to a "Find Variables for Match" type (**MT**=5-9). Figure 5-11 illustrates the output from this command in combination with the Perform Matching and Restore Prematch Variables commands.

The Show Match Variables command displays the selected match variables.

Restore Prematch Variables

As the name implies, the <u>Restore</u> <u>Prematch</u> <u>Variables</u> command is used to restore match variables to their values prior to the last matching procedure. This command only applies to match types which "Find Variables for Match" (**MT**=5-9). Figure 5-11 shows the resulting output of this command using the Show Match Variables command to illustrate prematch variables, Perform Matching to modify the match variables, and then using the Restore Prematch Variables command to "unmatch" the variables.

The Restore Prematch Variables command can restore the values of match variables prior to the last matching command.


```
┌──────────────────────────── Example B ────────────────────────────┐
  MATCH  VARIABLES:
         MP            VALUE
    param,sequence
      1       4         -26.5000
      1       8          26.5000
      1      12         -26.5000
      1      16          26.5000


  MATCHING...  (NIT=      10)
      1.122568   -26.500000   26.500000  -26.500000   26.500000
      1.579695   -21.761137   27.306817  -25.207615   30.851469
      1.610566   -25.503277   23.481038  -25.972580   26.385324
      1.391865   -27.897962   29.372619  -26.544495   28.041062
      1.159095   -27.398653   28.017561  -25.619691   25.651434
      0.514964   -24.521208   28.253876  -25.667958   24.717008
      0.404214   -23.931734   27.281939  -24.474722   24.624680
      0.168278   -23.317907   26.181216  -21.941392   24.702989
      0.051912   -23.365165   27.176923  -21.867495   24.642102
      1.490016   -21.451646   18.221472   -9.033097   22.301867
      0.014922   -23.493914   27.474213  -22.313924   24.721919
      0.010148   -23.454632   27.385970  -22.182849   24.732963
      0.013446   -23.461484   27.378910  -22.147615   24.718370
      0.000160   -23.444183   27.407656  -22.283489   24.759708
      0.000010   -23.444049   27.406590  -22.281830   24.758736

  MATCH  VARIABLES:
         MP            VALUE
    param,sequence
      1       4         -23.4440
      1       8          27.4066
      1      12         -22.2818
      1      16          24.7587

  PREMATCH  VALUES  RESTORED

  MATCH  VARIABLES:
         MP            VALUE
    param,sequence
      1       4         -26.5000
      1       8          26.5000
      1      12         -26.5000
      1      16          26.5000
```

Perform Matching
(⌘-M)

Show Match Variables
(⌘-Option-V)

Restore Prematch Variables

Figure 5-11.   Restore Prematch Variables Command.

Note that the Restore Prematch Variables command can only restore values prior to the last match procedure. If the Preform Matching command is executed more than once to achieve convergence, this command will only restore the values prior to the last match attempt.

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Display Commands

A variety of commands are available for displaying data before and after a Graph command has been executed. Figure 5-12 illustrates the Text Output window after executing the Show Beam Vectors, Show R-Matrix, Show Modified Sigma, and Show Phase and Energy commands. This output is from Example B after matching to convergence.

Show Beam Vectors

The Show Beam Vectors (⌘-B) command is used to display all of the TRACE 3-D beam vectors. The initial beam (**BEAMI**), the final beam (**BEAMF**) and the output beam (**BEAMO**) are displayed, followed by the beam centroid offsets (**BEAMC**) and the initial beam centroid offsets (**BEAMCI**). All non-zero beams currently stored in the **HOLD** array are also displayed. The output for this command is illustrated in Figure 5-12.

Use the Show Beam Vectors command in place of the TRACE 3-D CENTROID command to display the beam centroid offsets.

Show R Matrix

When a Graph command is executed the 6x6 transfer matrix is stored in the **RM** array. The Show R Matrix (⌘-R) command displays this R matrix. A description of the R matrix for each element can be found in Section 6 "Transfer Matrices" in the TRACE 3-D Documentation. An example of the output generated by this command is illustrated in Figure 5-12.

Show Modified Sigma

The Show Modified Sigma (⌘-Z) command displays the modified Sigma matrix in the Text Output window. The Show Modified Sigma command will be dimmed prior to executing a Graph command. An example of the resulting output from the Show Modified Sigma command is shown in Figure 5-12.

```
═══════════════════════ Example B ═══════════════════════

BEAM  VECTORS:
  beami: x=     3.1140     0.7536 y=    -2.6202     0.5789 z=     0.1210     0.5687
  beamf: x=     0.0000     0.4154 y=     0.0000     1.3289 z=     0.0000     0.3570
  beamo: x=     0.0000     0.4154 y=     0.0000     1.3289 z=    -1.2261     0.4169
  beamc: x=     0.0000     0.0000 y=     0.0000     0.0000 z=     0.0000     0.0000
  beamci:x=     0.0000     0.0000 y=     0.0000     0.0000 z=     0.0000     0.0000   ◁   Show Beam Vectors

BEAMS  IN  HOLDING  POSITIONS:
  hold1: x=     1.7933     0.4955 y=    -1.3759     4.1635 z=    -1.4866     0.4551
  hold2: x=     0.0000     0.4154 y=     0.0000     1.3289 z=    -1.2261     0.4169
  12 Hold Positions Available

R-MATRIX:
    0.761061     0.329412     0.000000     0.000000     0.000000     0.000000
   -5.551055    -1.088724     0.000000     0.000000     0.000000     0.000000
    0.000000     0.000000    -4.047924     0.875751     0.000000     0.000000   ◁   Show R Matrix
    0.000000     0.000000    -0.972379    -0.036670     0.000000     0.000000
    0.000000     0.000000     0.000000     0.000000     0.478015     0.710460
    0.000000     0.000000     0.000000     0.000000    -1.628571    -0.328514

MODIFIED BEAM MATRIX    (mm, mrad, %dp/p)
    4.992399
   12.018270    -0.000008
    8.929452     0.000000     0.000000
    6.719337     0.000000     0.000000    -0.000034                                 ◁   Show Modified Sigma
    9.808736     0.000000     0.000000     0.000000     0.000000
    1.938342     0.000000     0.000000     0.000000     0.000000    -0.774942

LONGITUDINAL  DYNAMICS  AND  PHASE-SPACE:
  Phi=151.1602 deg,  W=    2.000000 MeV
  DP=   20.417475 deg,  DW=   77.492374 KeV                                         ◁   Show Phase & Energy
  DZ=    9.808736 mm,  DP/P=   19.383420 mrad, Ez=  120.166232   -mm-mrad
```

Figure 5-12. Example of Resulting Output from Various Display Commands.

Because the Sigma matrix is a symmetric matrix, only half of the elements are displayed. The format is shown in Figure 5-13 below.

$$
\begin{array}{llllll}
x_{max} & & & & & \\
x'_{max} & r_{12} & & & & \\
y_{max} & r_{13} & r_{23} & & & \\
y'_{max} & r_{14} & r_{24} & r_{34} & & \\
z_{max} & r_{15} & r_{25} & r_{35} & r_{45} & \\
\Delta p/p\,_{max} & r_{16} & r_{26} & r_{36} & r_{46} & r_{56}
\end{array}
$$

Figure 5-13.   Modified Sigma Matrix Format.

Show Phase & Energy

The <u>Show</u> <u>Phase</u> <u>&</u> <u>Energy</u> (⌘-Option-W) command is used to calculate and display the phase advance in degrees and the Twiss beam ellipse parameters for each of the three phase-space planes. An example of the resulting output from the Show Phase & Energy command is shown in Figure 5-12.

Show TRACE 3-D Data

The <u>Show</u> <u>TRACE 3-D</u> <u>Data</u> (⌘-Option-P) command displays the data that has been passed to TRACE 3-D FORTRAN from the PowerTrace Interface. An example of the output generated with this command is given in Figure 5-14. This data may require more lines than can be displayed in the Text Output Window. However, it is also written to the History file, as is all data generated from commands that output text.

The Show Tape 30 command in the View menu can be used to view and edit this data.

```
                         Example B

TRACE 3D DATA:
  FILENAME: Example B  UNITS: mm, mrad, T/m, mA, MV/m
  ER= 1875.00000   Q= 1.    W=    2.00000   XI=  100.000
  EMITI=     60.0000     60.0000   1000.0000
  BEAMI =     3.1140      0.7536     -2.6202      0.5789      0.1210      0.5687
  BEAMCI=     0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
  BEAMC =     0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
  BEAMF =     0.0000      0.4154      0.0000      1.3289      0.0000      0.3570
  FREQ=   80.000, PQEXT=  2.50, ICHROM= 0, IBS= 0 XC=  0.00
  XM= 17.9,  XPM= 58.4000,  YM= 21.4,  DPM=  0.,  DWM=   0.,  DPP= 57.
  N1=  1,  N2= 20,   SMAX=  5.0,  PQSMAX=  2.0
  NEL1 =   1,  NEL2 =  20,  NP1 =   1,  NP2 =  20
  MT= 8   NC=  4   LOC=  0   0   0
    MP(1,N)  MP(2,N)   VALUE         MVC        VALUE
        1        4     -23.44
        1        8      27.41
        1       12     -22.28
        1       16      24.76
    n  NT(n)   A(1,n)     A(2,n)     A(3,n)     A(4,n)     A(5,n)
    1   11    -0.7100   110.4000    86.4400    -28.7000     0.0000
    2   11     0.7100   110.4000    86.4400   -180.0000     0.0000
    3    1   173.0000
    4    3   -23.4441    96.0000     0.0000      0.0000     0.0000
    5    1    39.7500
    6   10     0.1815   -40.0000     0.0000      0.0000     1.0000
    7    1    39.7500
    8    3    27.4066    96.0000     0.0000      0.0000     0.0000
    9    1    42.7400
   10   10     0.1815   -40.0000     0.0000      0.0000     1.0000
   11    1    42.7400
   12    3   -22.2816    96.0000     0.0000      0.0000     0.0000
   13    1    45.7400
   14   10     0.1815   -40.0000     0.0000      0.0000     1.0000
   15    1    45.7400
   16    3    24.7586    96.0000     0.0000      0.0000     0.0000
   17    1    48.7300
```

Figure 5-14. Output from the Show TRACE 3-D Data Command.

Special PowerTrace Commands

The last group of commands in the Commands menu are unique to PowerTrace with the exception of the PARMILA Units command which is described last.

Load Return Data

The Load Return Data (31→30) command loads the data returned by TRACE 3-D (Tape 31) into the PowerTrace interface data (Tape 30). The "Data Structures and Data Flow" subsection in Section 3 of this manual describes the data flow between the PowerTrace interface data and the TRACE 3-D FORTRAN commons. This command can be used to force an update of the beamline model in the PowerTrace Document from the current contents of the TRACE 3-D FORTRAN commons. In some circumstances TRACE 3-D will modify the data shared with the PowerTrace interface, such as during a matching procedure or when the Exchange Beams command is used to move beams from a holding position into the initial or final beam vectors. This type of update is automatically done by PowerTrace if the "Auto Update After Match or Exchange" Option is selected in the PowerTrace Options Dialog. By default this option is selected so that the beamline model will be automatically updated after matching or a beam exchange. See Section 6 "User Preferences" for a complete discussion of the PowerTrace User Options.

The Load Return Data command can be used to force an update of the beamline model from the the TRACE 3-D FORTRAN commons.

The "Auto Update After Match or Exchange" Option provides automatic updates of the model after matching or beam exchange.

Reinitialize TRACE 3-D

The Reinitialize TRACE 3D (⌘-E) command allows the user to reinitialize all of the TRACE 3-D common variables and arrays, while keeping all the model data in the PowerTrace interface data structure. This command is also discussed at the end of the "Data Structures and Data Flow" subsection in Section 3 of this manual.

Help Submenu

The <u>Help</u> menu item has a submenu for five different pages of help information. Figure 5-15 shows the Help Dialog for the first item: "General Input" which gives a general description of TRACE 3-D parameters. The next three items present information on transport element parameters and the last item diagrams beam ellipse Twiss parameters.


Figure 5-15. Help Submenu and TRACE 3-D Help Dialog Window.

PARMILA Units

The <u>PARMILA Units</u> (⌘-Option-K) command will cause TRACE 3-D to write the PARMILA Data file. This file will then be opened in a PowerTrace text window. The PARMILA Data file contains PARMILA unnormalized input units and normalized output units converted from the TRACE 3-D **BEAMI**, **BEAMO**, **EMITI**, and **EMITO** parameters. Figure 5-16 shows an example of the PARMILA Data file generated with the PARMILA Units command.

```
═════════════════ PARMILA Data ══════════════════

PARMILA NORMALIZED RMS OUTPUT UNITS:  CM/MRAD CM*MRAD, DEG/MeV DEG*MeV
BEAMO=   -0.058234    0.033608   -1.527421    0.260755   -1.336384  539.994026
EMITO.RMS=    0.055440404    0.055440404    0.200000000
EMITO.RMS.NORMALIZED.LONGITUDINAL(CM MRAD)=    0.111034407


BEAM ENERGY=     2.000 MeV, TRACE3D TOTAL UNITS:
TRANSVERSE UNNORMALIZED, MM/MRAD MM*MRAD; LONGITUDINAL NORMALIZED, DEG/KEV DEG*K
BEAMI=    3.114000    0.753600   -2.620200    0.578900    0.121000    0.568700
EMITI.3D-UNIFORM=    60.0000000    60.0000000  1000.0000000

BEAM ENERGY=     2.000 MeV, TRACE3D TOTAL UNITS:
TRANSVERSE UNNORMALIZED, MM/MRAD MM*MRAD; LONGITUDINAL NORMALIZED, DEG/KEV DEG*K
BEAMO=   -0.058234    0.336079   -1.527421    2.607553   -1.336384    0.539994
EMITO.3D-UNIFORM=    60.0000000    60.0000000  1000.0000000
```

Figure 5-16. PARMILA Units Data File Display.

A previously generated file may be viewed using the Show PARMILA Data command in the View menu. However, the View menu command will not generate the file and will be dimmed if the file does not exist in the application folder. When the PARMILA Units command is executed any existing PARMILA Data file will be over written.

A previously generated file may be viewed using the Show PARMILA Data command in the View menu.

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6. User Preferences

This section discusses the remainder of the TRACE 3-D input parameters which are primarily concerned with screen display options. It also describes a number of options available in PowerTrace, which the user can enable or disable to suit particular requirements.

Preferences Menu

The <u>Preferences</u> menu illustrated in Figure 6-1 is used to access additional parameters which control plotting, scale graphic output, specify centroid offsets, display element parameters, and pass additional data to TRACE 3-D from the PowerTrace interface. The Preferences menu also provides access the PowerTrace User Options dialog.

Preferences

Plot Control NP & NEL
Graphics Parameters
Print Parameters
Extra Parameters
Centroid Parameters

Options
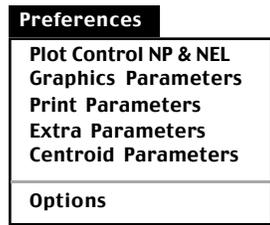
Figure 6-1. PowerTrace Preferences Menu.

Plot Control Parameters

The first item in the Preferences menu opens the <u>Plot Control</u> window shown in Figure 6-2. This window provides access to the TRACE 3-D plot control parameters **NP1**, **NP2**, **NEL1**, and **NEL2**. These parameters are primarily associated with graphic output from the Graph Beam Line, Trace on Background, and Plot Projections commands. **NP1** and **NP2** are the beginning and ending locations for the beam profile plot. **NEL1** and **NEL2** are the locations for the first and last ellipse plots.

Refer to subheading 9.3 from Section 9 "Input Variables" of the TRACE 3-D Documentation.

TRACE 3-D plot control parameters are automatically set by PowerTrace using the locations of the Initial and Final Pieces in the beamline model.

Plot Control

NEL1 First Ellipse Plot   `1`
NEL2 Last Ellipse Plot   `20`

NP1   Begin Profile Plot   `1`
NP2   End Profile Plot   `20`
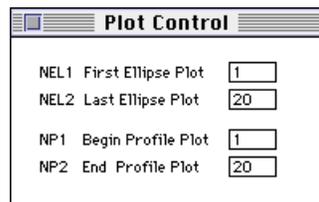
Figure 6-2. Plot Control Window.

The Plot Control window may be used to view and directly edit plot control parameters. However, these parameters are automatically assigned by PowerTrace.

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The default values for the Plot Control parameters are the same as the default values used in TRACE 3-D. The graphics scales may be edited using these windows. However, PowerTrace automatically generates scaled values for these parameters when the user opens and closes an "Initial" or "Final" element in a beamline model. A discussion of the scaling equations is given in using the locations of the Initial and Final Pieces in the beamline model. This automatic assignment may be turned off by disabling the "Auto update NP2 and NEL2" option in the PowerTrace User Options dialog. A complete discussion of all the user options is presented later in this Section.

"Auto update NP2 and NEL2" is on by default but this option may be disabled in the PowerTrace User Options dialog.

Refer to subheading 9.5 from Section 9 "Input Variables" of the TRACE 3-D Documentation.

Graphics Parameters

The Graphics Parameters item in the Preferences menu opens two windows for the Initial and Final graphic scaling parameters, as illustrated in Figure 6-3. These windows provide access to the TRACE 3-D graphics scales **XM**, **XPM**, **DPP**, **YM**, **XMI**, **XPMI**, **DPMI**, **DWMI**, **XMF**, **XPMF**, **DWMF**, **DPMF**. These parameters set values for the boundaries of the phase-space and profile plots in the TRACE 3-D Graphic Output Window and the plots in the Initial and Final Piece Windows. **XMI** (mm) and **XPMI** (mrad) are the axes for the initial transverse phase-space plots. **DPMI** (deg) and **DWMI** (keV) are the axes for the initial longitudinal phase-space plots. **YM** (mm) is the vertical axis for the transverse beam profiles, and **DPP** (deg) is the maximum phase profile. **XMF** (mm) and **XPMF** (mrad) are the axes for the final transverse phase-space plots. **DPMF** (deg) and **DWMF** (keV) are the axes for the final longitudinal phase-space plots. **XM** (mm) and **XPM** (mrad) are the axes for the projection phase-space plots.

Refer to subheading 9.5 from Section 9 "Input Variables" of the TRACE 3-D Documentation.

PowerTrace automatically generates scaled values for graphics parameters when the user opens and closes an "Initial" or "Final" element in a beamline model.

The graphics scales may be edited using these windows. However, PowerTrace automatically *generates scaled values* for these parameters when the user opens and closes an "Initial" or "Final" element in a beamline model. A discussion of the scaling equations is given in

the "Initial and Final Beam Pieces" subsection of Section 3 in this manual. This automatic graphics scaling may be turned off by disabling the "Use Graphics Scaling" option in the PowerTrace User Options dialog. A complete discussion of all the user options is presented later in this Section.

Figure 6-3 Graphics Scales Windows.
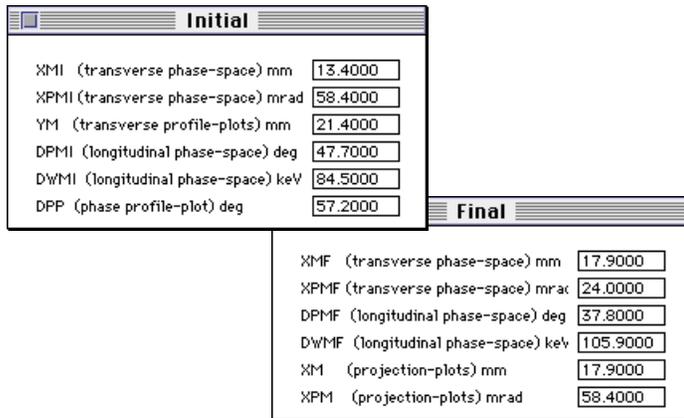
"Use Graphics Scaling" is on by default but this option may be disabled in the PowerTrace User Options dialog to prevent automatic graphics scaling.

Print Parameters

The <u>Print</u> <u>Parameters</u> item in the Preferences menu opens the Print Parameters window shown in Figure 6-3. This window provides access to the TRACE 3-D print parameters **NPRIN** and **IJPRIN**. These parameters are used to specify up to ten transport parameters to be displayed in the center of the Graphic Output window when a Graph Beam Line or Trace on Background command is executed. The value of **NPRIN** is the number of element parameters that will be displayed. **IJPRIN** is a two dimensional array which is used to hold the parameter number and the sequence of the element in the beamline model. An example of using print parameters is illustrated in Figures 6-4 and 6-5. In Figure 6-4, the first and forth parameters of the first and second elements in the beamline are to be displayed. In Figure 6-5, the results of a Graph command are shown for the print parameter settings shown in Figure 6-4.

Refer to subheading 9.6 from Section 9 "Input Variables" of the TRACE 3-D Documentation.

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Figure 6-4. Print Parameters Example.

All element parameters can of course be accessed directly in element Piece Windows.

Print Parameters Specify Printout Values in the Graphic Output Window to Display Beamline Element Parameters
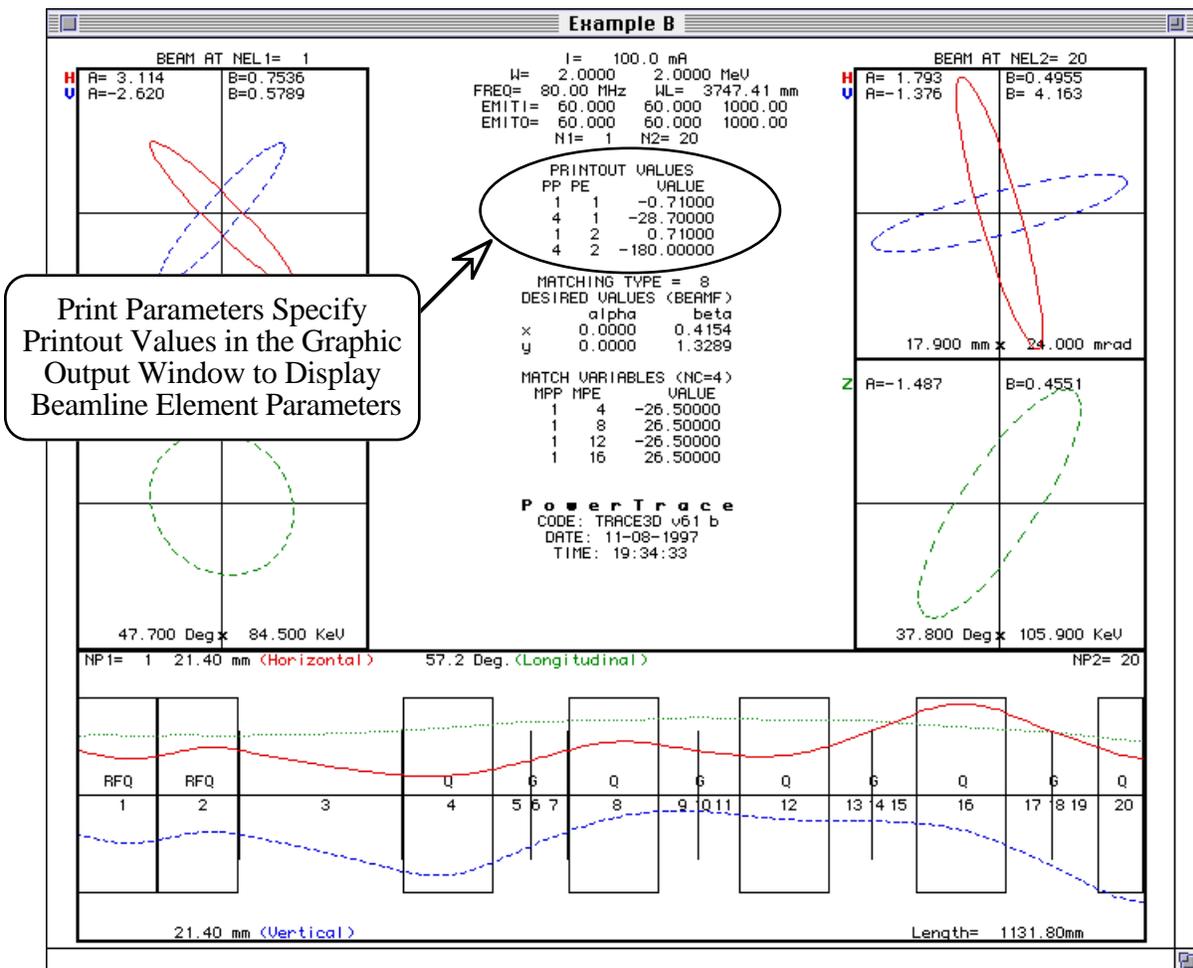
Figure 6-5. Graph Command Output Using Print Parameters.

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Extra Parameters

The <u>Extra</u> <u>Parameters</u> item in the Preferences menu is used to access the Extra Parameters window shown in Figure 6-6. This window is used to specify up to ten additional parameters which will be passed through the mixed language interface to TRACE 3-D and loaded into the **EXTRA** array. When customizing the TRACE 3-D FORTRAN, these parameters can provide access to additional arguments not related to a particular transport element. The value of **NEXTRA** is the number of **EXTRA** parameters that will be used.

*Refer to subheading 9.7 from Section 9 "Input Variables" of the TRACE 3-D Documentation.*
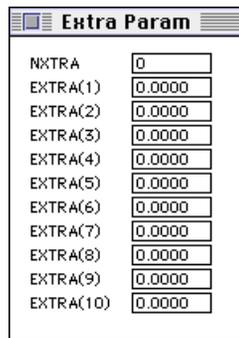
Figure 6-6 Extra Parameters Window.

Centroid Parameters

The <u>Centroid</u> <u>Parameters</u> item in the Preferences menu is used to access the Centroid Parameters window shown in Figure 6-7. This window is used to specify initial beam centroid displacement values and a centroid scale. These parameters provide access to the TRACE 3-D initial beam centroid offsets: x (mm), x' (mRad), y (mm), y' (mRad), z (Deg), and z' (keV), which are stored in the **BEAMCI** array. The Show Beam Vectors command, in the Commands menu, can be used to display the contents of the initial beam centroid offsets (**BEAMCI**) and beam centroid offsets (**BEAMC**) in the Text Output window. The centroid scale (**XC**) parameter is used in the profile plots for a displaced beam centroid as seen in Figure 6-8. If there is a centroid offset and the scale is zero, then a default scale

Refer to subheadings 9.2 and 9.5 from Section 9 "Input Variables" of the T R A C E 3 - D Documentation.

of one-tenth the transverse beam profile is used. The value of the centroid scale is displayed in the profile box at the bottom of the Graphics Output window.
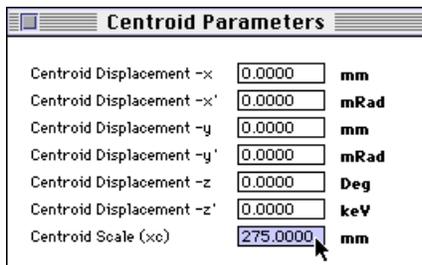

Figure 6-7 Centroid Parameters Window.
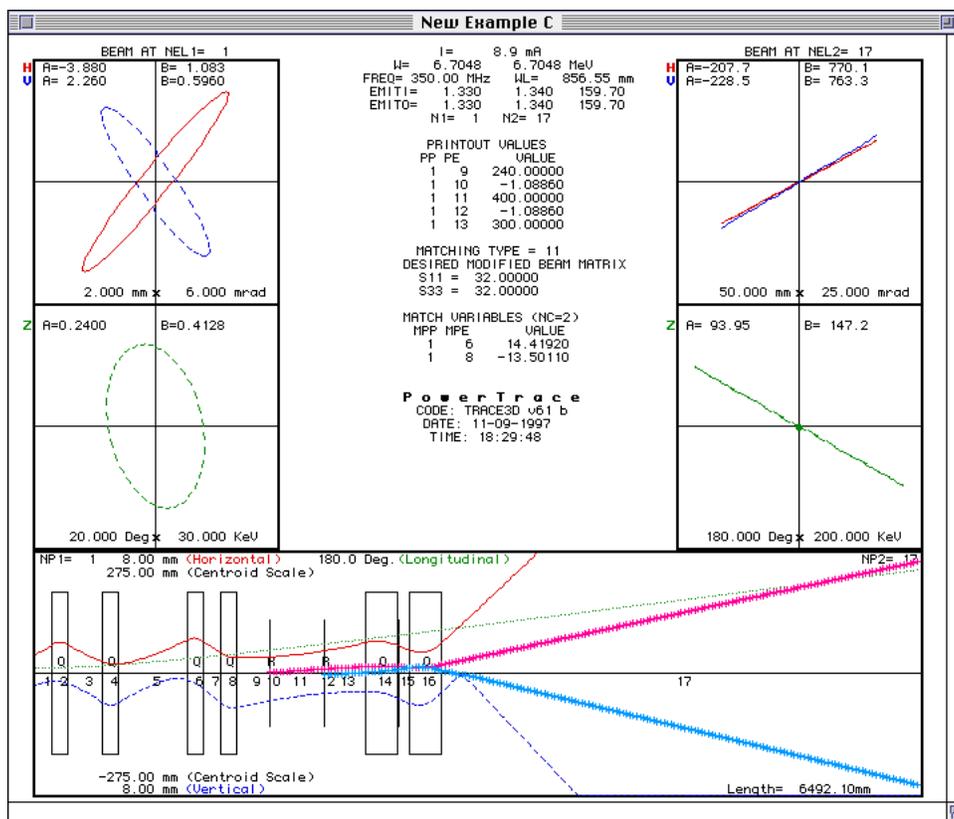
Figure 6-8 "New Example C" Graph Command.

Figure 6-8 is the resulting output from a Graph Beam Line command for the New Example C file distributed on the application disk. The beam centroid (**BEAMC**) is shown in Figure 6-8 by the darker profiles. The horizontal (red) and the vertical (blue) profiles are drawn with plus (+) symbols in the profile box.

Refer to subheading 11.3 from Section 11 "Examples" of the TRACE 3-D Documentation.

User Options

The <u>Options</u> menu item opens the PowerTrace User Options Dialog illustrated in Figure 6-9. User Options can be used to control various PowerTrace and TRACE 3-D interactions. The option selections shown in Figure 6-9 are the default selections. Changes to the defaults can be saved to a PowerTrace Preference file using the Save As Default button.   Original defaults can be recovered by discarding the PowerTrace Preference file in the System Preferences folder. If Save As Default is *not* used, changes to option selections will be retained until the application is terminated but will not be written to the Preference file.   Options apply to all PowerTrace Documents.

The Options item in the Preferences menu opens the PowerTrace User Options Dialog which is used to control various PowerTrace and TRACE 3-D interactions.
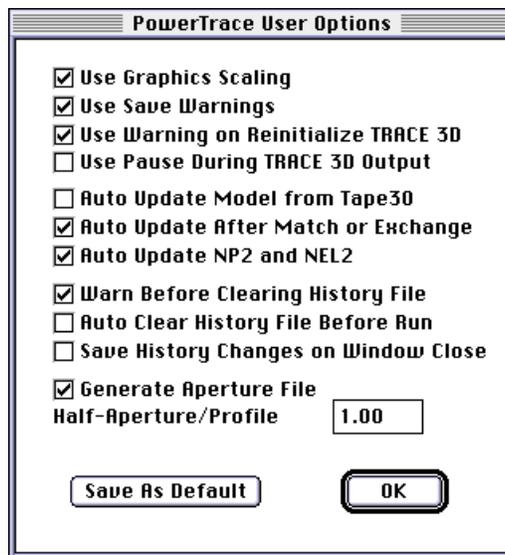
Figure 6-8 PowerTrace Default User Options.

Use Graphics Scaling

When the <u>Use</u> <u>Graphics</u> <u>Scaling</u> option is selected, the ellipse plots in the Initial and Final Piece Windows will be automatically scaled. Graphics in the PowerTrace Graphic Output Window will also be scaled automatically. If this option is *not* selected then no scaling will be applied. A discussion of graphics scaling

may be found in the "Initial and Final Beam Pieces" subsection in Section 3 of this user manual. The graphic scaling parameters may be accessed using the Graphics Parameters command in the Preferences menu as described earlier in this Section.

Use Save Warnings

When the Use Save Warnings option is selected, a warning alert will prompt the user to save the beamline model any time a Document window is closed. This is illustrated in Figure 6-10 below. If this option is *not* selected then there will be no warning.
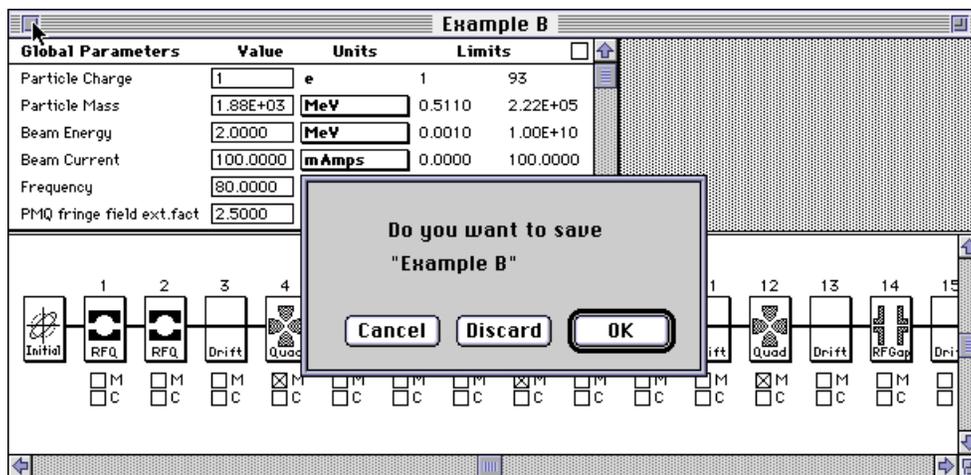
Figure 6-10.   Document Save Warning Alert.

The Save warning allows the close operation to be canceled with the Cancel button, or the user may select the Discard button which will cause the Document to be closed without saving any changes. If the OK button is selected the Document will be saved and any existing file of the same name will be overwritten. To save the Document under a different name, use the Save As… command in the File menu.

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Use Warning on Reinitialize TRACE 3D

The <u>Use</u> <u>Warning</u> <u>on</u> <u>Reinitialize</u> <u>TRACE</u> <u>3D</u> option prompts the user when the Reinitialize TRACE 3D command in the Commands menu is selected. Since this command will completely reinitialize the FORTRAN commons in TRACE 3-D, an opportunity to cancel the reinitialization is given if this option is selected, otherwise no warning will be given. As shown in Figure 6-11, if the OK button is selected then the TRACE 3-D commons are reinitialized. If the Cancel button is selected then the Reinitialize TRACE 3D command is not executed. See the discussion of this command in Section 3 in the "Data Structures and Data Flow" subsection.
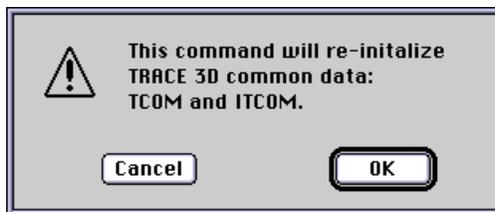
Figure 6-11. Warning Before Reinitialization.

Use Pause During TRACE 3- Output

The <u>Use</u> <u>Pause</u> <u>During</u> <u>TRACE</u> <u>3-D</u> <u>Output</u> option is used to pause between pages of text output written to the TRACE 3-D Text Output Window. If this option is selected then the alert shown in Figure 6-12 will prompt the user that text output has reached the bottom of the Text Output window. This provides an opportunity to view the current contents before it is cleared. The Continue button must be pressed to resume execution.

After a command has completed, any data cleared from the Text Output window can be viewed using the Show History File command in the View menu.

Figure 6-12. Pause Before Next Page.

Auto Update From Tape30

The Auto Update From Tape30 option allows the user to modify model parameters by editing the data in the Tape 30 window. If this option is not selected then editing data in Tape 30 window will have no effect on the model. There are restrictions on the use of the Tape 30 edit feature. Generally, any numerical parameter may be changed using the Tape 30 edit option. However, you *may not add or delete beamline transport elements* this way.

Auto Update After Match or Exchange

The Auto Update After Match or Exchange option, when selected, will automatically update the model with the data returned by the execution of any of the three TRACE 3-D matching commands: Perform Matching, Match Without Print and Match in Range, or data exchanged from the beam hold array into the Initial or Final beam vectors. This update is done internally in TRACE 3-D, but the data flow used in PowerTrace is such that the model data need not be immediately updated. This update can be effectively turned off. If this option is not selected then the model Data Tables are not modified after matching and the original data remains in Tape 30 while the new (matched) data is in Tape 31. The user may select to update the model at his leisure with the Load Return Data (31→30) option in the Commands pull down menu.

Auto Update NP2 and NEL2

When the Auto Update NP2 and NEL2 option is selected, PowerTrace automatically selects which transport element (**NP2**) will be the last to be shown in the profile plot, after executing the Graph Beam Line command, as well as the element (**NEL2**) after which the (output) phase space ellipses will be displayed. This automatic selection may be turned on or off with this option.

Warn Before Clearing History File

When the <u>Warn</u> <u>Before</u> <u>Clearing</u> <u>History</u> <u>File</u> option is selected, an alert will be issued any time a command is executed which will result in clearing the current History file. This is illustrated in Figure 6-13 below.

Figure 6-13. Clear History File Alert.

Pressing the OK button will clear the History file and execution will continue. If the Cancel button is selected then execution will continue without clearing the History file. This option can be used with the next two options: "Auto Clear History File Before Run" and the "Save History Changes on Window Close" to better manage the content of the History file. Note that the History file will hold up to 32K characters, but after reaching this limit data will be lost.

Auto Clear History File Before Run

The <u>Auto</u> <u>Clear</u> <u>History</u> <u>File</u> <u>Before</u> <u>Run</u> option will cause the History file to be deleted prior to executing any command which writes to the History File. The "Save History Changes on Window Close" option will save any editing done in the History file when the window is closed. This can be useful to manage content, add comments, or paste any other information copied from other text windows. The History file is discussed further in Section 5 "TRACE 3-D Commands".

Generate Aperture File

When the <u>Generate</u> <u>Aperture</u> <u>File</u> option is selected, the Half-Aperture/Profile value field is also provided in the options dialog to set the TRACE 3-D aperture multiplication factor. As illustrated in Figure 6-14, the PowerTrace default options include the Generate Aperture Data selection with a 1.0 Half-Aperture/Profile value.

When the Generate Aperture File Option is Selected, the Half-Aperture/Profile Field is Activated and it's value is used to set the TRACE 3-D Aperture Multiplication Factor
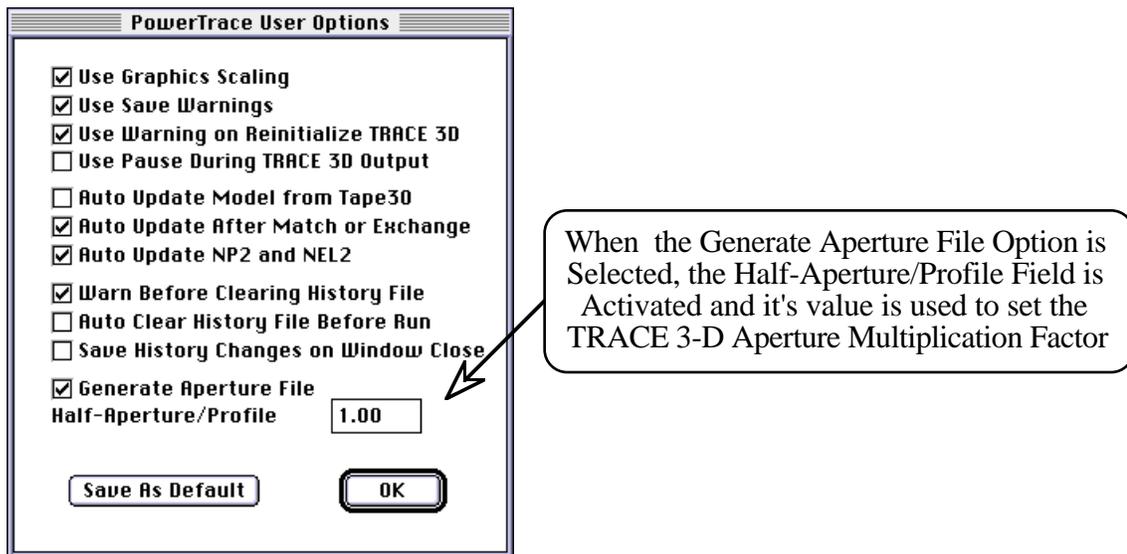
Figure 6-14.   PowerTrace User Options Dialog.

If the <u>Generate</u> <u>Aperture</u> <u>Data</u> option is selected in the PowerTrace User Options dialog then aperture data will be written during the execution of the Graph Beam Line or Trace on Background commands. When either of these commands is executed any existing Aperture Data file will be overwritten. The Aperture Data file can be opened using the Show Aperture Data command in the View menu. This command will be dimmed if the file does not exist in the application folder.

Aperture data will also be written when the Find Ellipses from Profile, Calculate Mismatch, Perform Matching, Match Without Print and Match in Range commands are executed.

The aperture data contains the transverse beam profile data (radial x- and y-profiles) that is used to generate the beam profiles in the Graphic Output Window with the Graph Beam Line or Trace on Background commands. Figure 6-15 shows the Aperture Data generated during a Graph Beam Line execution for Example B.

```
╔═════════════════════════════ Aperture Data ═════════════════════════════╗
PowerTrace     11-08-1997     21:22:31
 TRACE-3D PROFILES/APERTURE DATA (Aperture Multiplication Factor=    1.000000)
 (all units =  mm)
 Values at Point of Maximum Beam Extent:
                                                  Factor*  Factor*  Circular
   TRACE      Radial   Radial                     Profile  Profile  Beampipe
 Element      Profile  Profile   Center   Center  +Center  +Center   radius
   No.           X        Y        X        Y        X        Y        R

    1  RFQ       5.48     7.17     0.00     0.00     5.48     7.17     9.03
    2  RFQ       7.19     5.47     0.00     0.00     7.19     5.47     9.04
    3  Drft      3.06    11.33     0.00     0.00     3.06    11.33    11.74
    4  Quad      2.92    11.95     0.00     0.00     2.92    11.95    12.30
    5  Drft      4.15     9.69     0.00     0.00     4.15     9.69    10.54
    6  RF g      4.15     9.69     0.00     0.00     4.15     9.69    10.54
    7  Drft      5.48     7.31     0.00     0.00     5.48     7.31     9.14
    8  Quad      7.78     3.92     0.00     0.00     7.78     3.92     8.71
    9  Drft      7.50     2.49     0.00     0.00     7.50     2.49     7.90
   10  RF g      7.50     2.49     0.00     0.00     7.50     2.49     7.90
   11  Drft      6.58     2.51     0.00     0.00     6.58     2.51     7.04
   12  Quad      7.48     3.86     0.00     0.00     7.48     3.86     8.42
   13  Drft      9.70     3.90     0.00     0.00     9.70     3.90    10.45
   14  RF g      9.70     3.90     0.00     0.00     9.70     3.90    10.45
   15  Drft     12.24     4.23     0.00     0.00    12.24     4.23    12.95
   16  Quad     13.48     5.76     0.00     0.00    13.48     5.76    14.66
   17  Drft     11.94     7.78     0.00     0.00    11.94     7.78    14.25
   18  RF g     11.94     7.78     0.00     0.00    11.94     7.78    14.25
   19  Drft      7.07    13.95     0.00     0.00     7.07    13.95    15.64
   20  Quad      5.45    15.81     0.00     0.00     5.45    15.81    16.72

 MAX VALUES:   13.48    15.81     0.00     0.00    13.48    15.81    16.72

 VALUES ON ABOVE RUN:  I=    100.0mA   W(in)=   2.0000  W(out)=    2.0000MeV
      EMITi=  60.000    60.000  1000.00,   EMITo=  60.000   60.000  1000.00


 Minimum Beampipe Radius Required
 (Factor=  1.000)  R=   16.72 mm
╚══════════════════════════════════════════════════════════════════════════╝
```

Figure 6-15. Aperture Data File.