PBO Lab™ 2.0

(Particle Beam Optics Laboratory)

User Manual Supplement: TRANSPORT Application Module

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PBO Lab 2.0 User Manual Supplement: TRANSPORT Application Module

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Getting Started

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1. Getting Started

This Section is intended as a quick start introduction for running the TRANSPORT Application Module in the Particle Beam Optics Laboratory. The remainder of this Supplement describes the PBO Lab user interface features that are specific to the TRANSPORT Application Module. Refer to the PBO Lab User Manual for more general information on the PBO Lab user interface. The "TRANSPORT User Manual" describes the TRANSPORT program.

This Supplement describes the user interface features specific to the TRANSPORT Application Module. Refer to the main PBO Lab User Manual for more general information on the PBO Lab user interface. Refer to the "TRANSPORT User Manual" for a description of the TRANSPORT program.

Running TRANSPORT

Execution of TRANSPORT is accomplished from the Commands Submenu, shown in Figure 1, by selecting one of the Write Input and Run Transport commands.

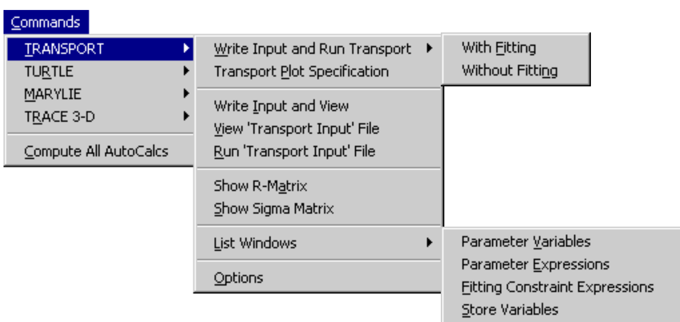

Figure 1. TRANSPORT Commands Menu.

The Commands Submenu for TRANSPORT is used to set various options and output parameters for the TRANSPORT Application Module as described in this Supplement.

The Write Input and Run Transport command provides options for running TRANSPORT with or without Fitting. Both options will generate the native input and execute TRANSPORT for the beamline in the Model Space of the Document Window. The second command in this group opens the Transport Plot Specifications Window.

The next group of commands provide options to separate the generation of input from the execution of TRANSPORT.

PBO Lab provides a group of commands that can be used to generate the native TRANSPORT input independently from the execution of the TRANSPORT program. Using these commands allows the input generated by PBO Lab to be modified directly before running TRANSPORT.

The next group of commands is for the display of diagnostic data, followed by a Submenu that provides access to user-specified Named Parameters, Variables, Expressions and Fitting Constraints for the entire beamline.

The last command in the TRANSPORT Commands menu is used to access various options and output parameters.

To Run the TRANSPORT Application Module simply select the command to Write Input and Run Transport without Fitting from the Commands Menu as illustrated in Figure 2. The native Transport Output file is automatically displayed in a scrollable Text Edit Window upon completion of the run. Use the Save As command in the File Menu of the Text Edit Window to rename the output file if desired. Both the Transport Input and Output files will be overwritten on any subsequent execution of the TRANSPORT Application Module.

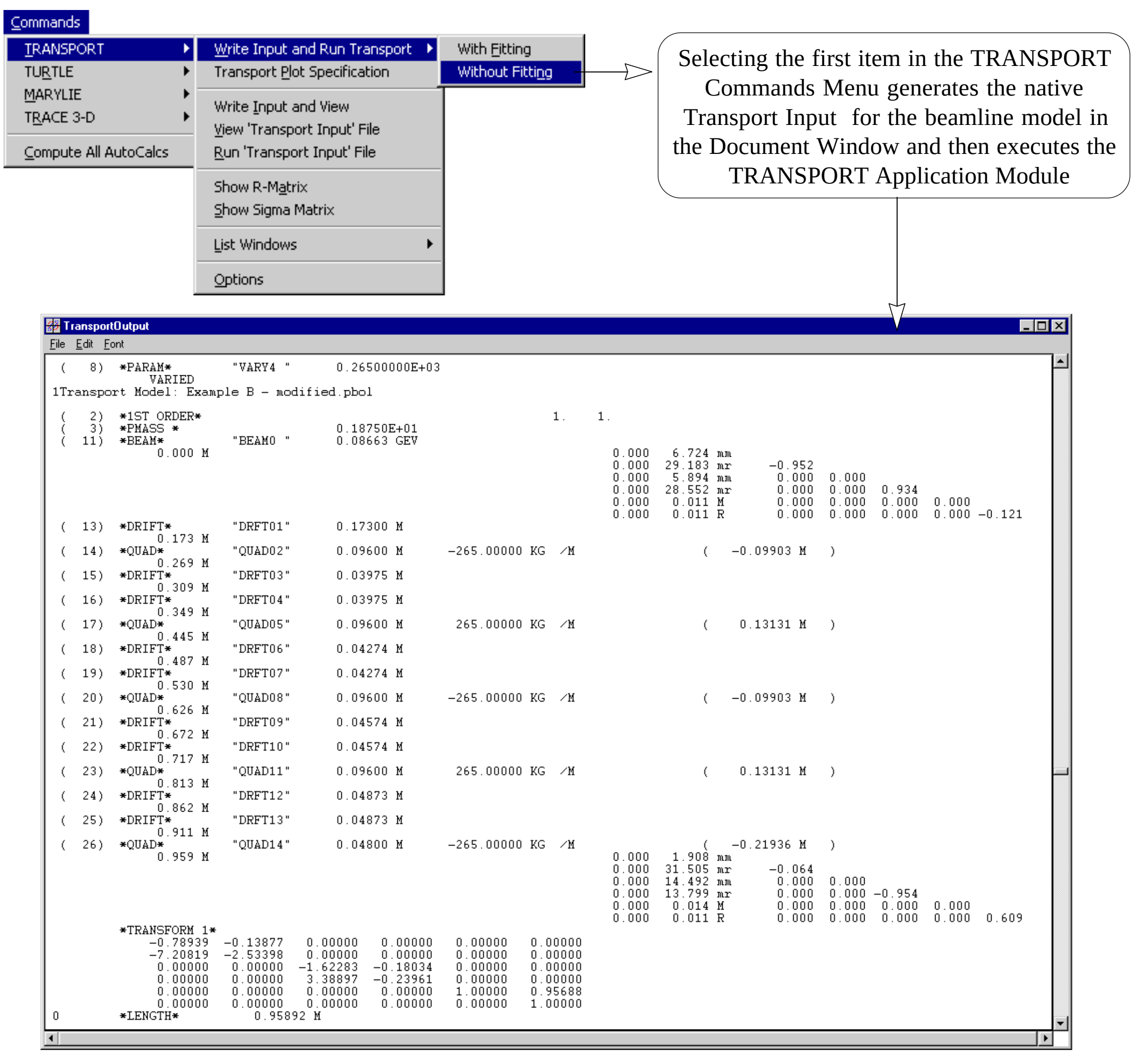

Figure 2. Executing the TRANSPORT Application Module.

Figure 2 illustrates the selection of the first command, which will write the native Transport Input file and run TRANSPORT for the current beamline model. The selected command is executed after the mouse button is released. Following execution, the Transport Output file will be displayed, as illustrated in Figure 2.

Figure 2 is an example of the output window that is displayed when the TRANSPORT run is completed. The content of the native Transport Output file will depend on various options and output parameters set by the user.

PBO Lab also provides graphic representations of data generated from TRANSPORT. The Transport Plot Specification command in the Commands Menu can be used to direct output to the Transport Plot file which is used by PBO Lab to generate interactive graph plots. Any plot specifications will result in PBO Lab Graph Plot Windows being opened automatically after execution of TRANSPORT. A description of Transport Plot Specifications can be found in Chapter 8 of this Supplement. The user interface for Graph Plot Windows is described in the main PBO Lab User Manual.

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TRANSPORT Application Module

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2. TRANSPORT Application Module

This Section describes the PBO Lab Application Context and Global Parameters that are specific to the TRANSPORT Application Module. Refer to the Getting Started and User Interface Chapters of the PBO Lab User Manual for more general information on the PBO Lab user interface. The "TRANSPORT User Manual," included with this Supplement, describes the TRANSPORT program in general and each of the native TRANSPORT input parameters.

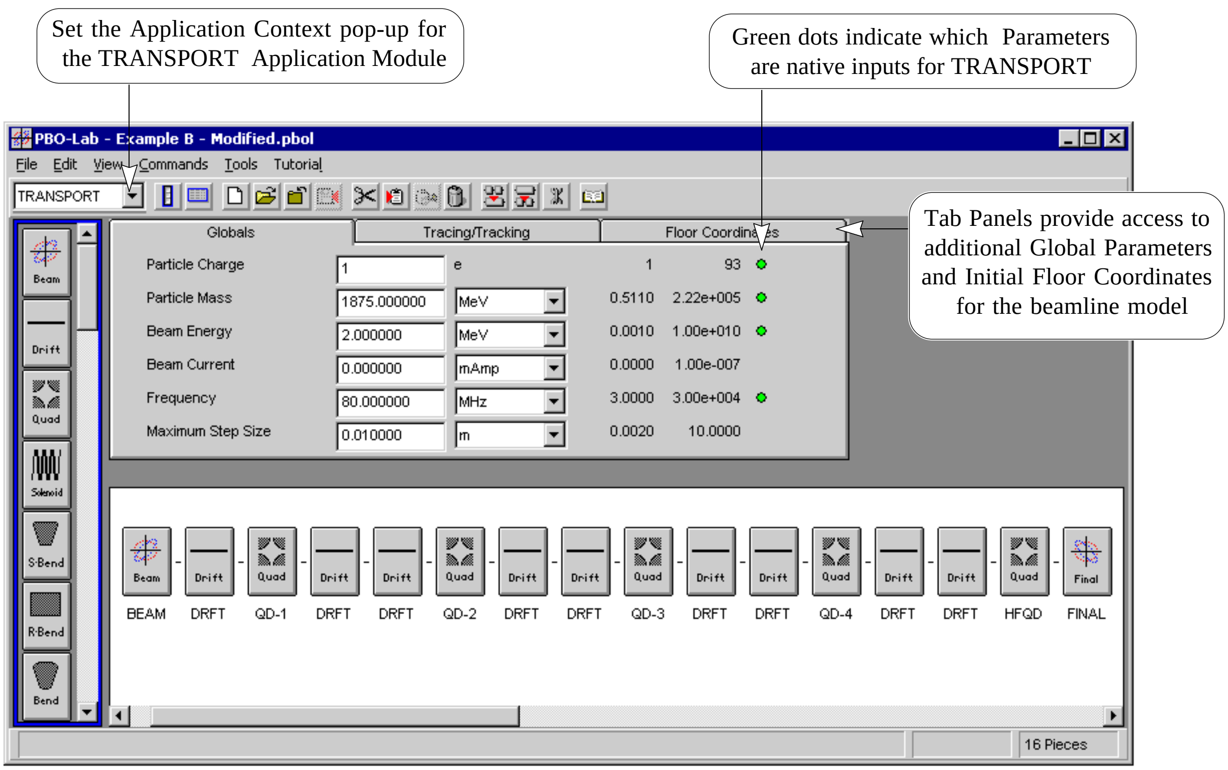

Figure 3. TRANSPORT Application Context and Global Parameters.

The Application Context pop-up in the Button Bar of the Document Window is shown in Figure 3. The Application Context does not need to be set for TRANSPORT in order to execute TRANSPORT commands. However, the Application Context is used to indicate which input parameters are native inputs for TRANSPORT. Native inputs are indicated in the Global Parameters and in each Piece Window using green dots that appear to the right of a parameter.

The Application Context is used to identify native parameters with green dot indicators.

The Application Context is also used to activate any application-specific buttons and in some cases, to determine which application-specific windows will be opened.

Beamline Global Parameters

The PBO Lab Beamline Global Parameters are described in the Getting Started and User Interface Chapters of the PBO Lab User Manual. This Section discusses the Global Parameters that are used by the TRANSPORT Application Module.

The PBO Lab Global Parameters include native TRANSPORT inputs such as the Particle Charge, Particle Mass, Energy and Frequency, which are global to the entire beamline model.

The native Global Parameters for TRANSPORT include the Particle Charge, Particle Mass, Beam Energy and Frequency. These parameters are indicated with green dots when the Application Context is set for TRANSPORT in the Document Window, as shown in Figures 3 and 4.

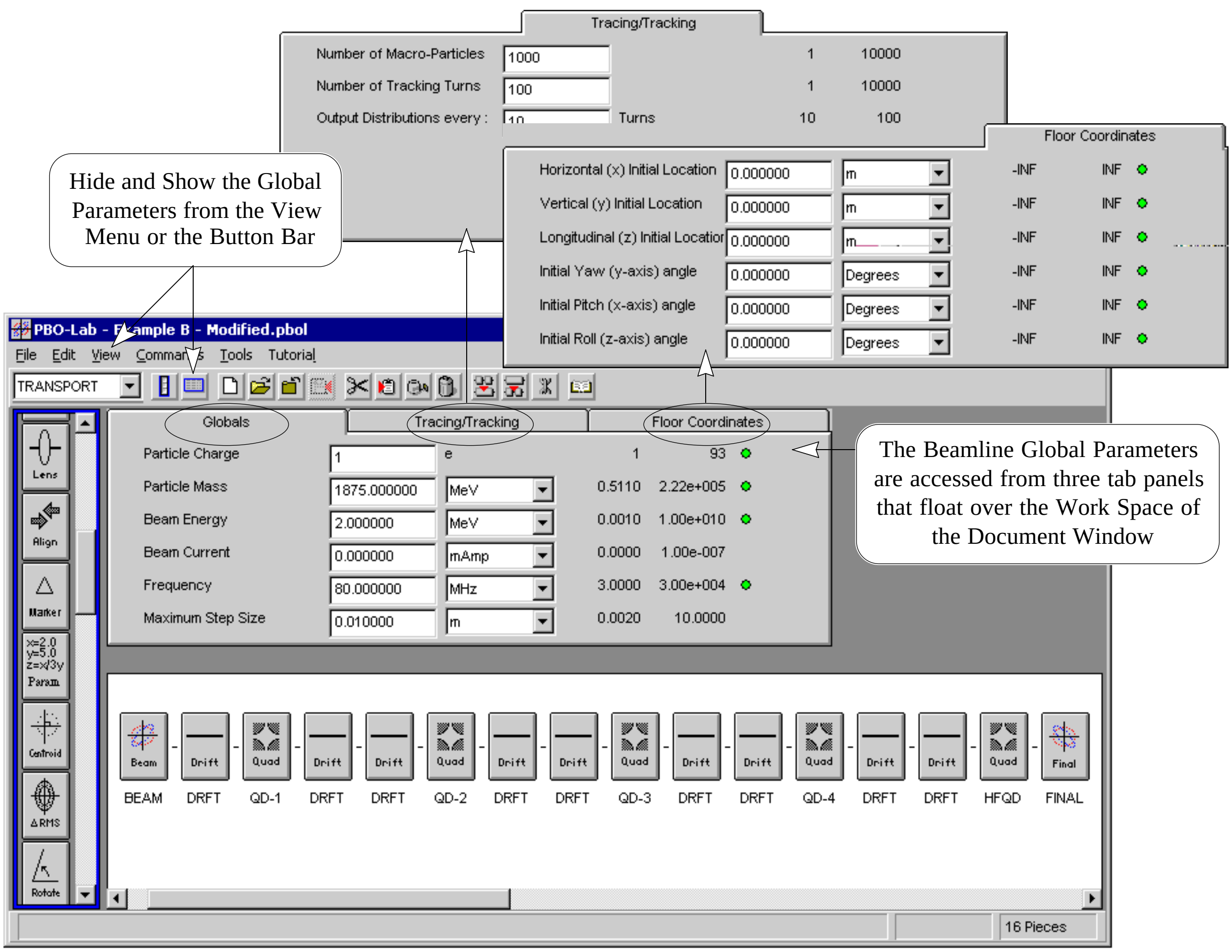

Figure 4. Beamline Global Parameters in the Document Window.

The Particle Charge Global Parameter is not a native TRANSPORT input. However, PBO Lab does use another native TRANSPORT input, PREF in order to scale all magnetic fields to a "reference momentum", which is different from the beam momentum "PO". Internally TRANSPORT converts all fields by the ratio of PO/PREF and in the native Transport Output file, the scaled fields are printed. The use of PREF in TRANSPORT is described in the "TRANSPORT User Manual" included with this Supplement. PBO Lab calculates an effective PREF and writes it to the Transport Input file, handling all other necessary conversions as well.

Although the Particle Charge is not a native TRANSPORT input, PBO Lab utilizes another TRANSPORT native input parameter, PREF, that is used to scale all magnetic fields to a "reference momentum" which is different from the beam momentum.

Several of the Global Parameters are also used for a variety of PBO Lab calculations and displays, although they may not be native inputs for TRANSPORT. Additional Global Parameters are accessed from the Tracing/Tracking tab panel and the Floor Coordinates tab panel as illustrated in Figure 4 on the previous page.

A green dot next to a parameter indicates that it is a native input for the current Application Context set in the Document Window.

The Tracing/Tracking Global Parameters tab panel (Figure 4) has inputs that are used by both the TURTLE and MARYLIE Application Modules. These parameters are described in each of the Supplements for those Application Modules. The Tracing/Tracking Global Parameters are not used by the TRANSPORT Application Module.

The Tracking and Tracing Global Parameters are not used by the TRANSPORT Application Module.

Initial Floor Coordinates and Orientation Parameters

Included with the beamline Global Parameters are a set of Initial Floor Coordinate Parameters of the beam reference trajectory, which are shown in Figure 4. These parameters are used to specify the initial coordinates and the orientation of the reference trajectory. If these parameters are zero (default values are zero) then TRANSPORT assumes that the beamline will start at the origin and proceed along the positive z-axis. Floor plots are specified in the Transport Plot Specification Window described in Chapter 8 of this Supplement.

Included with the PBO Lab Global Parameters are the Initial Floor Coordinates and Orientation inputs that are used by TRANSPORT.

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Beamline Elements

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3. Beamline Elements

The PBO Lab Pieces implemented for TRANSPORT are listed in Table 1 below. Native TRANSPORT inputs for these elements are indicated in the Piece Windows. As with the Global Parameters, green dots are found to the right of Piece Parameters that are native inputs. (The Application Context must be set for TRANSPORT in the Button Bar of the Document Window.)

Table 1. PBO Lab Pieces supported by TRANSPORT.

Beam	Bend	Accelerator	Eta
Drift	Edge	Align	Param
Quadrupole	Lens	Kicker	Special
Solenoid	Plasma Lens	ΔRMS	Marker
RF Gap	Sextupole	Rotate	Final
Sector Bend	Octupole	Septum	
Rectangular Bend	Centroid	Matrix	

Table 1 lists all of the Pieces that are recognized by TRANSPORT. Pieces in the beamline model that are not supported by TRANSPORT will be treated as zero-length drifts when PBO Lab generates the native input for TRANSPORT.

The Piece Window user interface is described in the Getting Started and User Interface Chapters of the PBO Lab User Manual. However, several pieces have features that are specific to TRANSPORT and those are described separately in this Chapter. The “TRANSPORT User Manual” (included with this Supplement) describes the implementation of the other elements supported by the TRANSPORT Application Module in PBO Lab. Many Pieces also provide run-time Tutorials that are accessed from the Tutorial buttons in the Piece Windows.

Beam Piece

The beamline model must include a Beam Piece in order to generate the native beam inputs for TRANSPORT.

The native beam inputs for TRANSPORT can be generated from either the Semi-Axes or Twiss Beam Piece Parameters.

TRANSPORT permits the use of the Twiss parameter representation only for the transverse phase planes (horizontal and vertical) of the initial beam.

Beam Piece

PBO Lab uses the Beam Piece to generate the initial Sigma-Matrix for TRANSPORT. The beamline model must include a Beam Piece, usually as the first piece in the beamline as illustrated in Figure 5. The Beam Piece is used to specify the initial Sigma-Matrix for TRANSPORT in two different ways, referred to as the Semi-Axes representation and the Twiss, or Courant-Snyder representation. The Semi-Axes representation is more general and allows for the complete specification of any Sigma-Matrix, including correlations between different phase planes. The Twiss parameter representation is useful for specifying initial beams in which the phase planes (horizontal, vertical and longitudinal) are decoupled. TRANSPORT permits the use of the Twiss parameter representation only for the transverse phase planes (horizontal and vertical) of the initial beam.

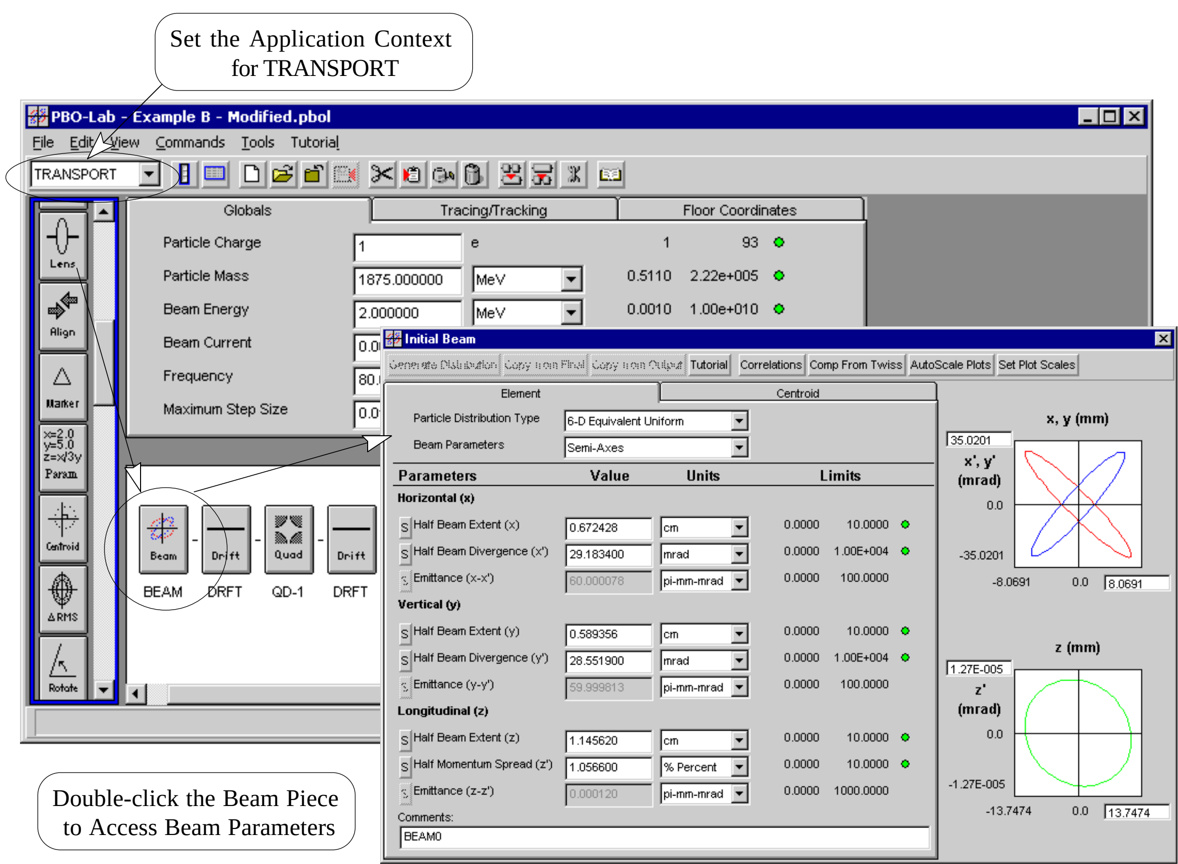


Figure 5. Initial Beam Parameters in the Beam Piece Window.

Both the Semi-Axes and Twiss parameters are shown in Figure 6 illustrating the Beam Piece Window. There is a Button Bar at the top of the window, two tab panels for parameter inputs (Beam and Centroid Parameters) and a set of dynamic phase space ellipse plots. The Centroid tab panel of the Beam Piece is not used by TRANSPORT. However, PBO Lab does provide a Centroid Piece that is supported by TRANSPORT. The Particle Distribution Type pop-up does not apply to TRANSPORT but the Beam Parameters pop-up is used to select between the Semi-Axes and Courant-Snyder (Twiss) beam parameter sets.

The Centroid Piece can be used to shift the centroid trajectory of the beam, relative to the reference trajectory, or axis, of the beamline.

The Beam Parameters pop-up is used to select between the two independent parameter sets for Semi-Axes or Courant-Snyder beam representations.

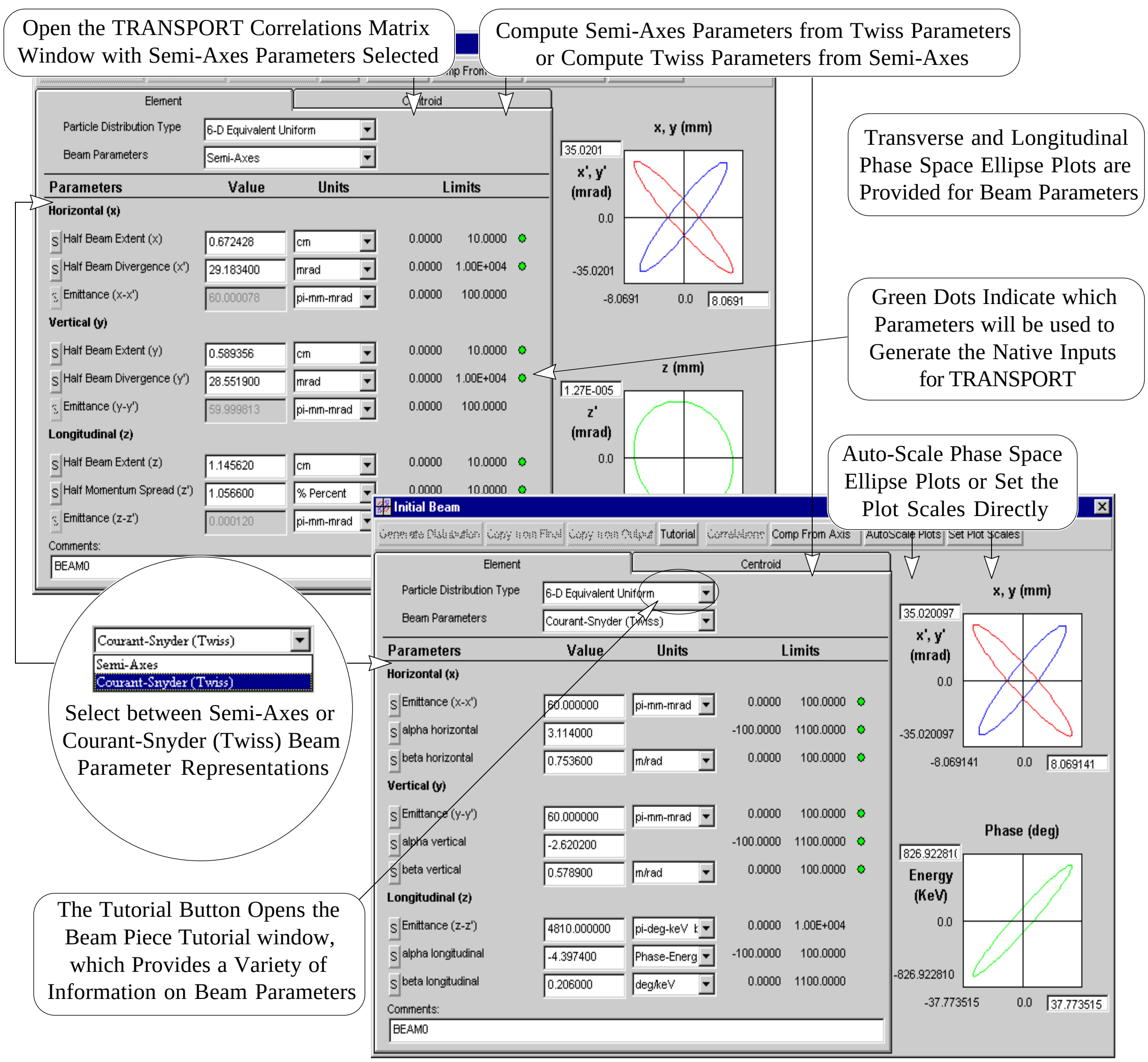


Figure 6 Semi-Axes and Twiss Beam Piece Parameters.

The two different beam parameter sets are independent, although one set may be calculated from the other.

The green dots to the right of individual parameters in the Piece Windows indicate which will be used to generate TRANSPORT input.

The two different beam parameter sets (Semi-Axis and Twiss) are independent, although one set may be calculated from the other. When the Twiss Beam Parameters are selected, the Compute From Semi-Axes button will calculate the equivalent Twiss parameters for the current Semi-Axes parameters. When the Semi-Axes parameter set is selected the Compute From Twiss button will calculate the equivalent Semi-Axes parameters for the current Twiss parameters. The Compute From... button is in the Button Bar at the top of the Beam Piece Window.

The Semi-Axes beam representation includes a correlation matrix in the beam description.

When Semi-Axes Beam Parameters are selected, correlations may be included in the beam description using the Correlations button in the Button Bar of the Beam Piece Window. The Correlations button opens the Correlation Matrix Window shown in Figure 7. Correlations may be entered directly as off-diagonal elements of the Sigma Matrix, or by entering values for the Reduced Sigma Matrix. The radio buttons at the top of the window toggle between these two modes. Corresponding values are calculated for the inactive selection using the inputs from the active selection.

The Beam Correlations Matrix Window is opened with the Correlations button in the Beam Piece Window.

Correlations may be entered directly as off-diagonal elements of the Sigma Matrix, or by entering values for the Reduced Sigma Matrix.

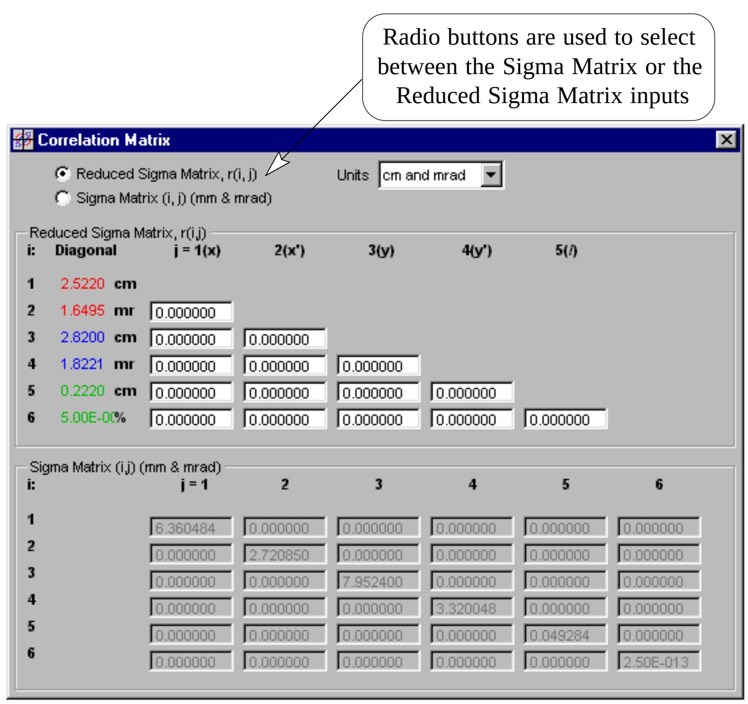


Figure 7. TRANSPORT Correlation Matrix Window.

The Beam Piece Window includes dynamic phase space ellipse plots for the current beam parameters. The top plot shows the horizontal (red) and vertical (blue) transverse phase space ellipses. The bottom plot is the longitudinal (green) phase space ellipse. The axis scales for the phase space ellipse plots can be calculated automatically with the Auto Scale Plots button in the Button Bar at the top of the window or the scales may be set directly by the user with the Set Plot Scale button.

The Beam Piece Window includes phase space ellipse plots for the current Beam Parameters.

The Tutorial button in the Button Bar at the top of the Beam Piece Window opens the PBO Lab Tutorial for the Beam Piece and leads to the Hypertext Tutorial shown in Figure 8. The Beam Piece Tutorial provides a variety of useful information including descriptions of the beam Sigma Matrix, Semi-Axes and Twiss parameter representations, phase space projections, the beam centroid and several other related topics.

The Beam Piece Tutorial provides a variety of useful information on modeling beams in TRANSPORT.

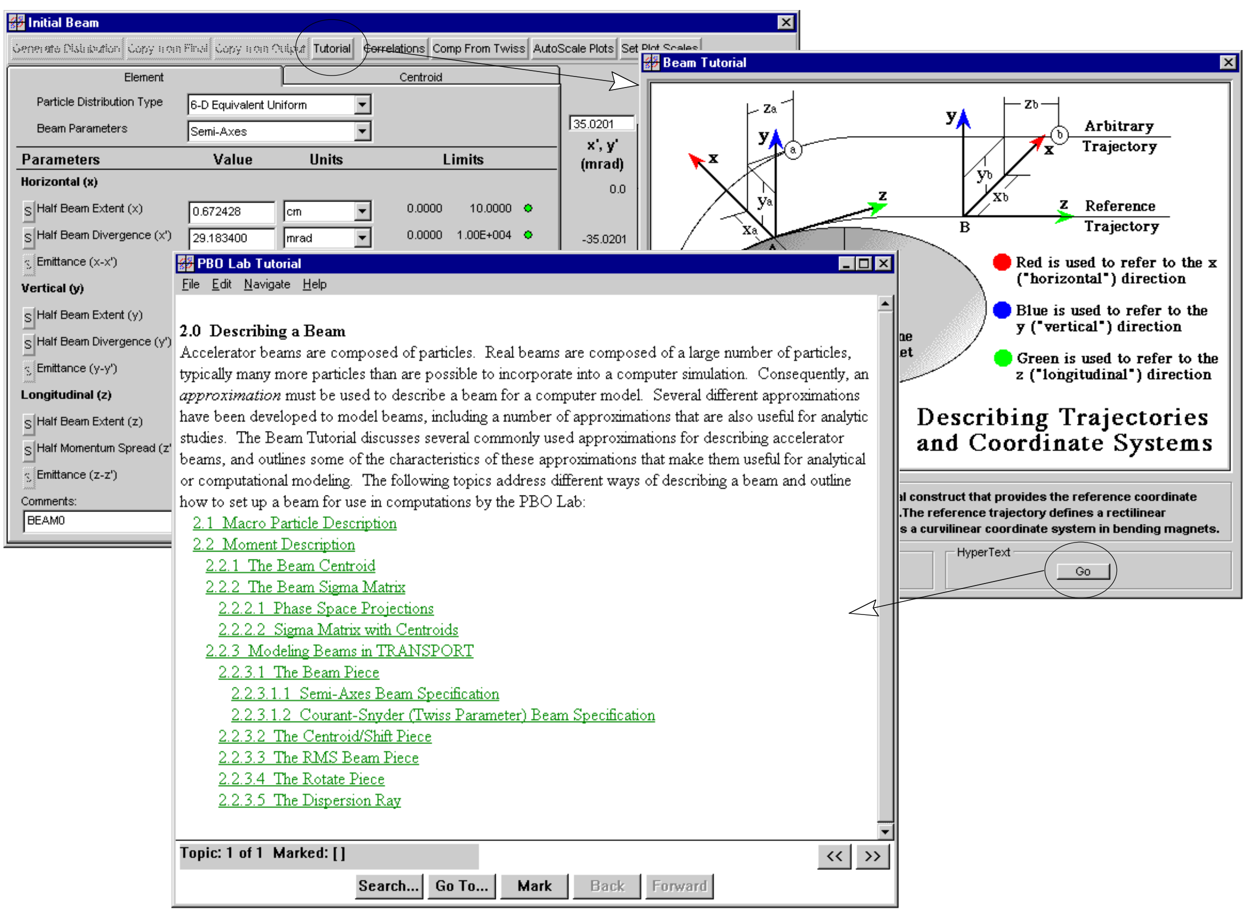


Figure 8. PBO Lab Beam Piece Tutorial Windows.

Marker Piece

Marker and Final Pieces

The Marker Piece is a special PBO Lab Piece that is used to specify application-specific Constraints, Diagnostics and Stored Parameters at specific locations in the beamline model. An example of the Marker Piece Window is shown in Figure 9.

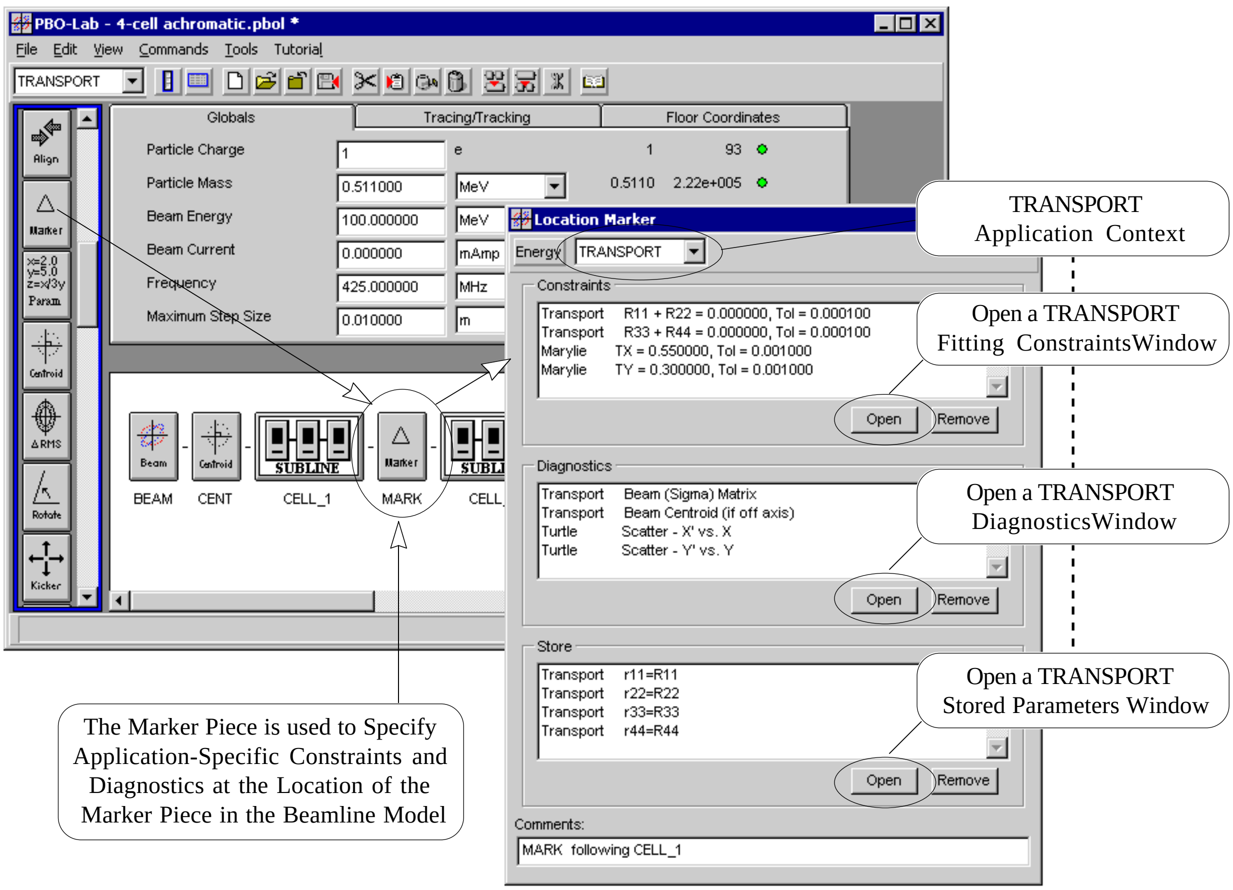
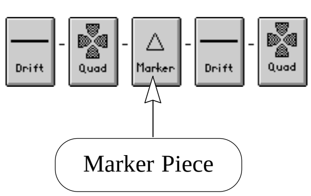


Figure 9. Marker Piece Constraints, Diagnostics and Stored Parameters.



The Marker and Final Pieces may be used to specify locations in the beamline where a Constraint is to be be imposed, Diagnostic data is to be output or Stored Parameter data is to be collected.

There are three scrollable lists in the Marker Piece Window that display selected Constraints, Diagnostics and Stored Parameters for installed Application Modules. The example in Figure 9 has Constraints specified for both the TRANSPORT and MARYLIE Application Modules. Diagnostics have been selected for TRANSPORT and TURTLE. Stored Parameters are specified for TRANSPORT only. Application-specific windows, tailored to the particular capabilities of each Application Module, are used to specify Constraints, Diagnostics and Stored Parameters.

The Open buttons in each panel of the Marker Piece Window are used to open the application-specific windows for the current Application Context. In order to open the TRANSPORT application-specific windows for Constraints, Diagnostics and Stored Parameters the Application Context pop-up must be set for TRANSPORT as illustrated in Figures 9 and 10 The Application Context can be set in either the Document Window or directly in the Marker Piece Window.

The Application Context pop-up must be set for TRANSPORT in order to open the TRANSPORT windows for Constraints, Diagnostics and Stored Parameters.

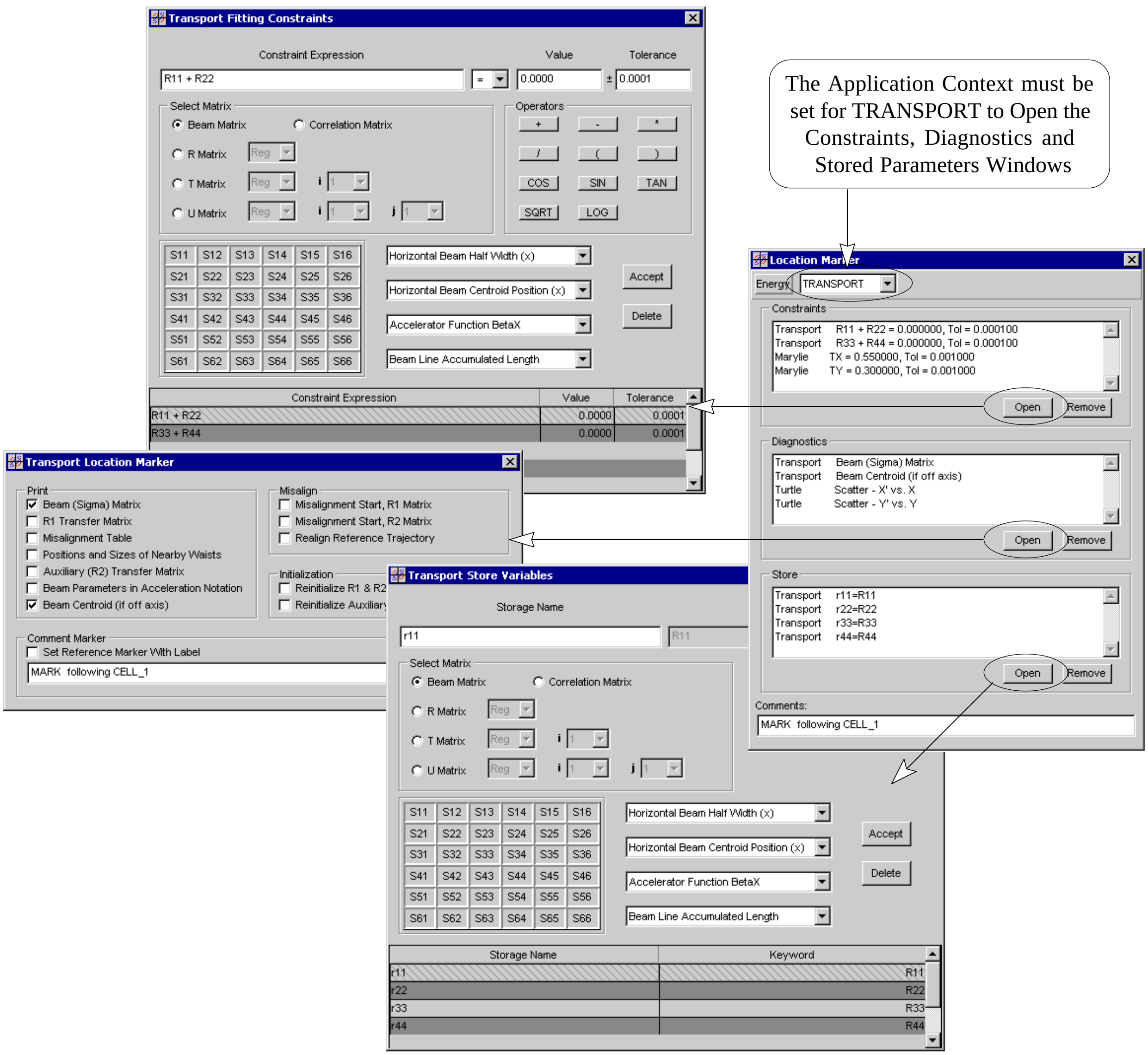


Figure 10. Location Specific Constraints, Diagnostics and Stored Parameters.

Location-Specific Constraints

Refer to the TRANSPORT Fitting Chapter for a description of using the PBO Lab Marker Piece for the specification of TRANSPORT Fitting Constraints.

The Open button in the Constraints panel opens the Transport Fitting Constraints Window as illustrated in Figure 10. Refer to the Transport Fitting Chapter for a description of using the Marker Piece for location specific fitting constraints.

Location-Specific Diagnostics

The Open button in the Diagnostics panel of the Marker Piece Window opens the Transport Location Marker Window. This window, shown in Figure 11, is tailored to the particular capabilities of TRANSPORT for generating output for specific locations in the beamline model. There are three panels in the window for selecting various options at the location of the Marker Piece in the beamline model. The Print panel provides a variety of diagnostic output options that will result in location-specific data written to the Transport Output file. The Misalignment and Initialization panels have options for location-specific commands that are used for misalignment and re-initialization of the R1 and/or R2 transfer matrices.

Many of the Print options in the Transport Location Marker Window can also be selected in the Transport Options Window for the end of the beamline model or after every element in the beamline.

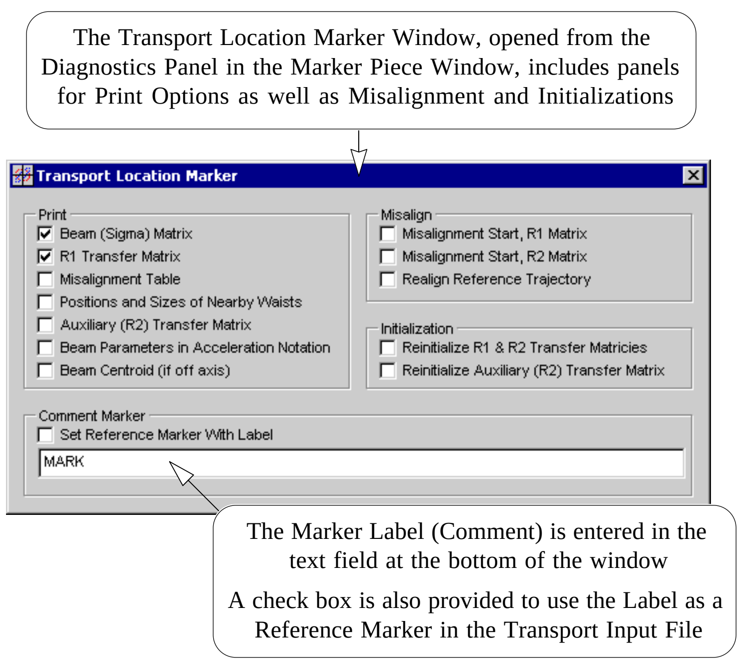


Figure 11. Transport Location Marker Window.

Location-Specific Stored Output Parameters

The Open button in the Store panel of the Marker Piece Window opens the Transport Stored Parameters Window shown in Figure 12. This window is used to specify the storage of TRANSPORT parameters at the location of the Marker Piece in the beamline model. Stored Parameters are shown in the TRANSPORT Output file and can also be used in Algebraic Parameter Expressions or in Fitting Constraint Expressions.

Refer to Table 5 in the TRANSPORT Fitting Chapter for a list of TRANSPORT keywords.

It is not necessary to know all of the TRANSPORT keywords, the Stored Parameters Window provides user friendly controls for selecting any applicable TRANSPORT output parameters.

Refer to the "TRANSPORT User Manual" for a description of individual output parameters that can be stored.

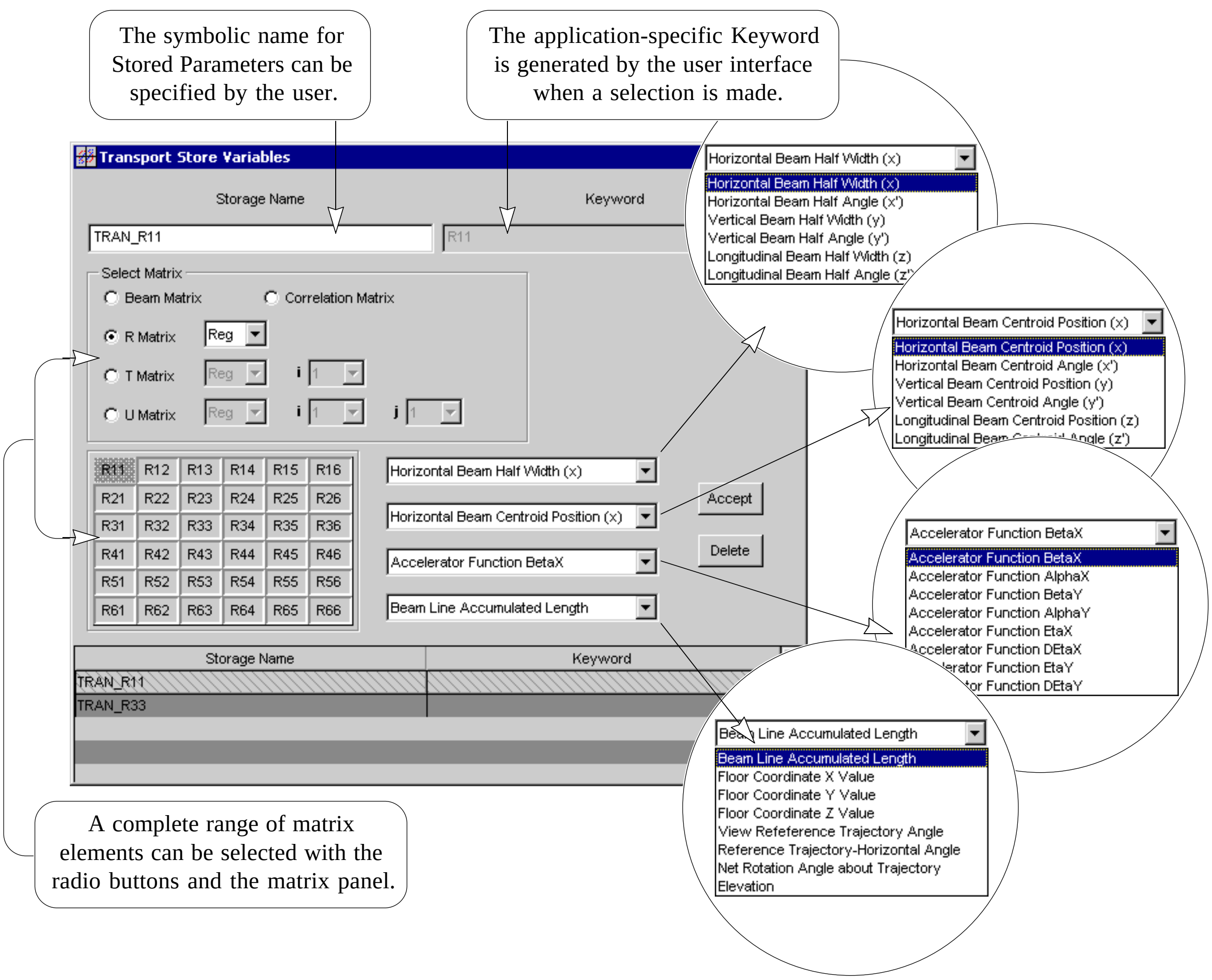


Figure 12. TRANSPORT Stored Parameters Window.

To Store a TRANSPORT Output Parameter, enter a unique parameter name in the Storage Name input field and select the Output Parameter with the controls provided in the Stored Parameters Window.

Copying Marker Pieces with Stored Parameters will duplicate Parameter Names and may result in unintended consequences.

To specify a Stored Output Parameter, enter a symbolic parameter name in the Storage Name input field at the top of the window. Stored Parameter Names should be unique. They should not be identical to any Parameter Names that have been defined for special parameter settings or other Stored Parameters. Note that creating a copy of a Marker Piece will also copy any Stored Parameters that have been defined for that Piece. This will result in duplicate Stored Parameter Names on the two Marker Pieces. The duplicate names will be sent to TRANSPORT but the value for the first parameter will be overwritten when the second parameter is encountered.

Stored Output Parameters can be selected from the five different matrices or the four pop-up controls in the Stored Parameters Window.

After a Storage Name has been entered, a TRANSPORT output parameter can be selected from the five different matrices or the four pop-up controls. To select a matrix element, first select the radio button for the desired matrix: Beam Matrix, Correlation Matrix, R-Matrix, T-Matrix or U-Matrix. Then a matrix element can be selected by clicking on the desired element in the matrix panel. The R-, T-, and U-Matrices also have pop-up controls to choose between Regular or Auxiliary matrices. The T- and U-Matrices have pop-ups for the additional dimensions of these matrices. The matrix panel is used to select elements for all of the matrices and it will reflect the corresponding elements when a matrix radio button is selected. After a selection has been made, use the Accept button to add it to the storage list at the bottom of the window.

In addition to matrix elements, there are four pop-ups that may be selected from: Beam Envelope and Beam Centroid parameters, Lattice Functions and Floor Coordinates. After a selection has been made from any of these pop-ups, the Accept button is used to add it to the storage list at the bottom of the window.

Stored Output Parameters are saved with the beamline model document.

All of the special parameter settings for a PBO Lab beamline model, including any Stored Parameter specifications, are saved using the Save or Save As commands in the File Menu of the Document Window.

Stored Parameters List Window

PBO Lab provides application-specific interactive List Windows that organize related data for the entire beamline model. The Stored Parameters List Window contains a list of location-specific Stored Output Parameters. Figure 13 illustrates opening the Stored Parameters List Window from the List Windows Submenu in the TRANSPORT Commands Menu.

All of the user-specified Stored Output Parameters can be accessed from a convenient List Window.

The Stored Parameters List Window can be used to quickly access Marker and Final Pieces with user-specified Stored Parameters. Double-clicking an entry in the window will open the associated Marker (or Final) Piece Window in the beamline model.

Double-click an entry in the List Window to open the associated Marker (or Final) Piece Window in the beamline model.

To resize a column in a List Window, place the mouse over the divider line in the column header. When the arrow turns into a cross-hair, resize by holding the mouse button down while dragging horizontally.

The header at the top of the List Window can be used to adjust the width of each column in the window.

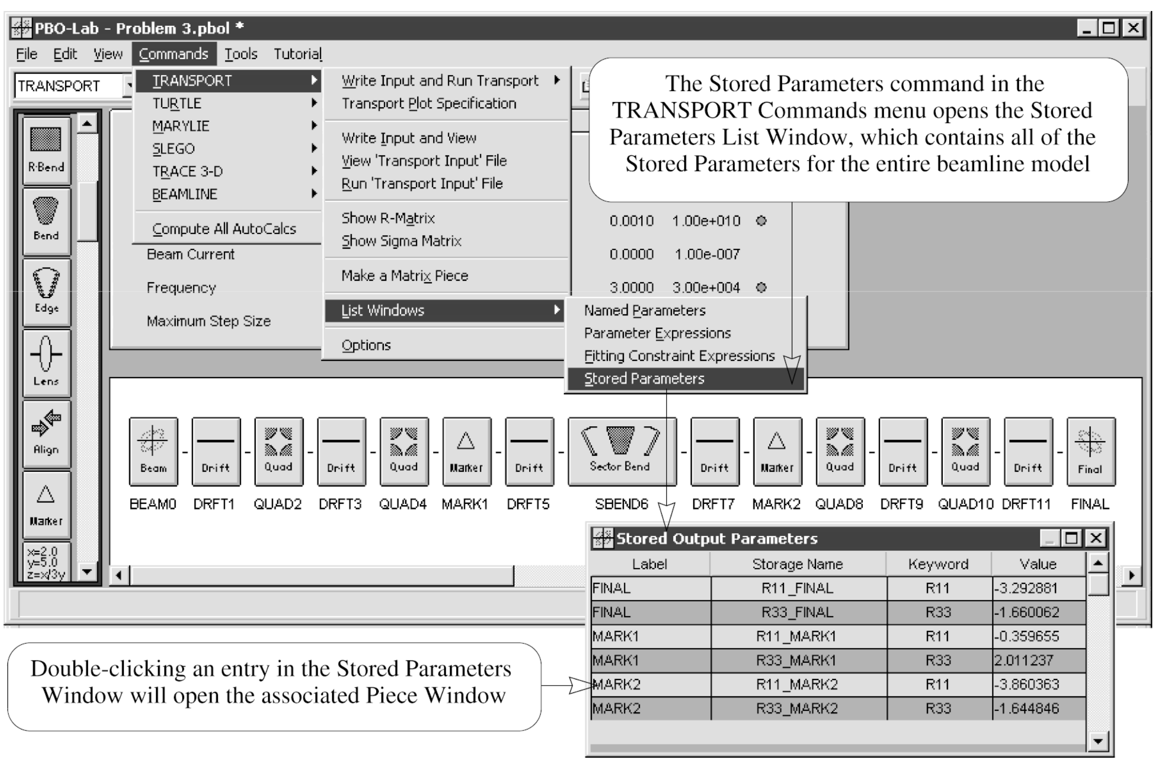
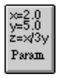


Figure 13. Opening the List Window for Stored Output Parameters.

Parameter Piece



Parameter (Param) Piece

Param Pieces may be placed in the Model Space or the Work Space. Param Piece Parameters can then be referenced from Pieces in the beamline model.

PBO Lab provides a Parameter (Param) Piece for user specified model parameters. A Param Piece may be inserted anywhere in the beamline model as illustrated in Figure 14. A Param Piece may also be placed on the Work Space and referenced from Pieces in the beamline model. Each Param Piece can be used to specify up to eight user defined parameters. The Param Piece supports Special Parameter Settings that are accessed with the "S" buttons to the left of each parameter in the Param Piece Window.

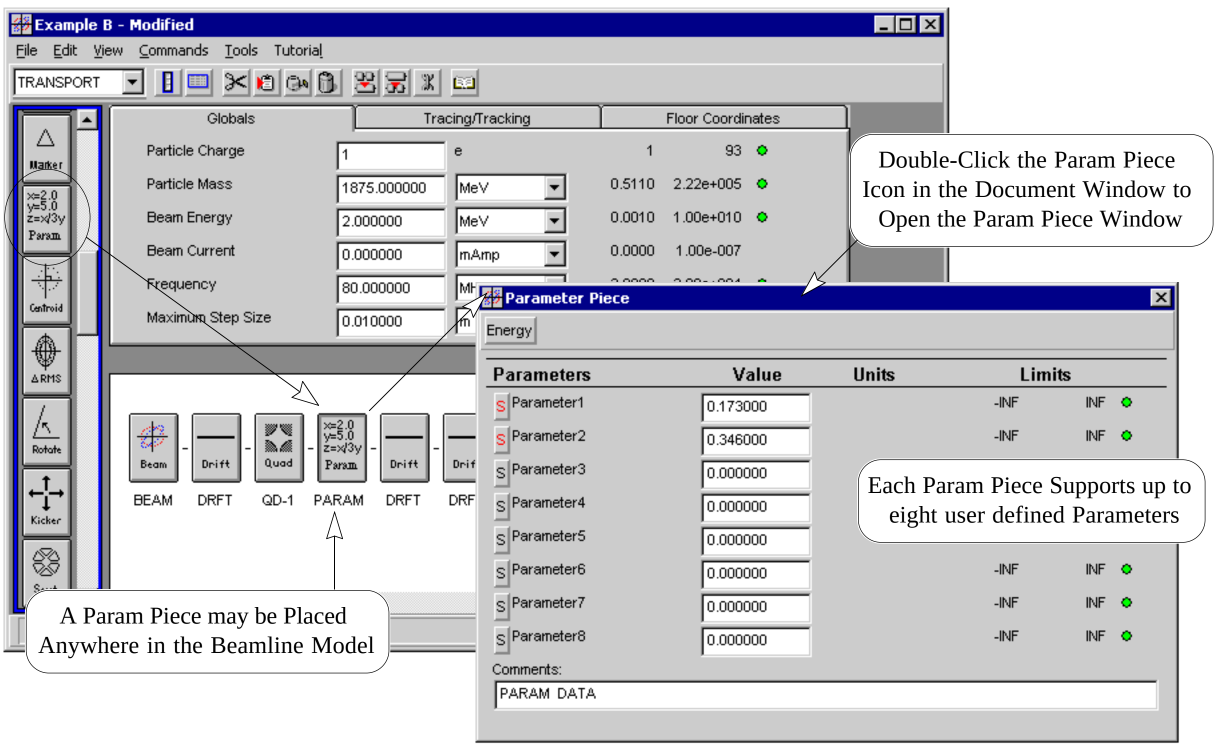


Figure 14. Parameter (Param) Piece Window.

Refer to the Section on Special Parameter Settings in this Chapter.

Param Piece Parameters require a Symbolic Parameter Name to be specified for each of the special parameter settings options.

The S-Buttons open Special Parameter Settings Windows (S-Windows) as illustrated in Figure 15. In the S-Window, a Param Piece Parameter may be defined as a numerical Value and used as a symbolic constant in Parameter Algebraic Expressions. They may also be selected as Fitting Variables or they may be specified by Algebraic Expressions. However, unlike other beamline elements, the Param Piece requires a Symbolic Parameter Name to be specified for each of the special parameter settings options. A Param Piece Parameter will only be written to the Transport Input file if a Symbolic Parameter Name has been specified in the S-Window.

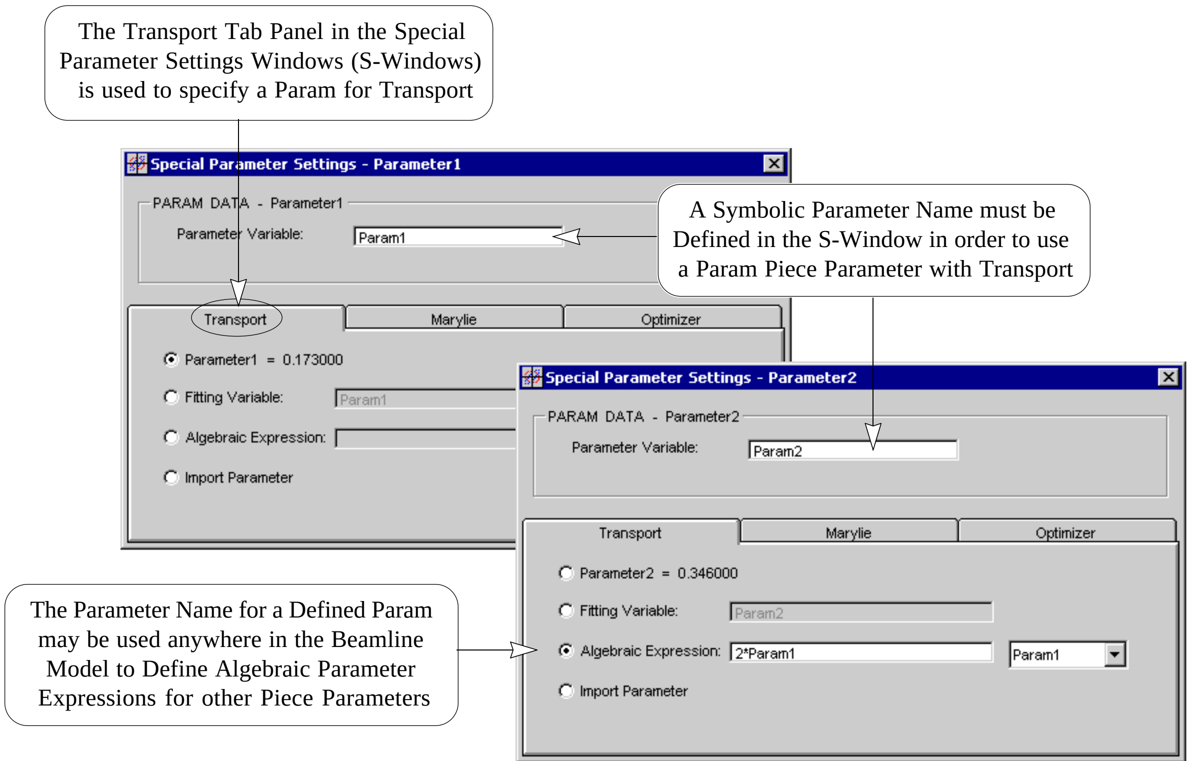


Figure 15. Param Piece Special Parameter Settings.

A Param Piece Parameter may also be selected as an Import Parameter in the Special Parameter Settings Window. Refer to the External Data Interface Section in the main PBO Lab User Manual for a description of Import Parameters.

Avoid using a Symbolic Parameter Name that is the same as a Piece Comment. This can cause unintended consequences when running TRANSPORT.

The Special Parameter Settings Chapter describes the S-Window in more detail.

Matrix Piece

Matrix Piece

The PBO Lab Matrix Piece is supported by the TRANSPORT Application Module and provides a means to represent any arbitrary transformation matrix. First-, Second- and Third-Order matrix elements may be specified directly in the Matrix Piece Window, which is illustrated in Figure 16 below. Alternatively, PBO Lab can use TRANSPORT to calculate the transfer matrix for a selection of one or more Pieces in the beamline model or for the entire beamline.

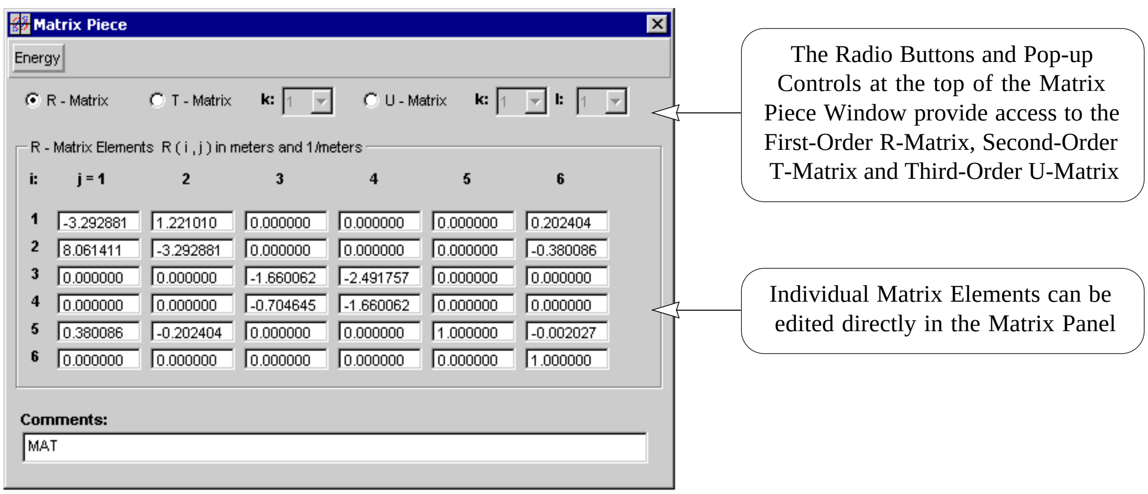


Figure 16. Matrix Piece Window.

The radio buttons and pop-up controls at the top of the Matrix Piece Window provide access to the First- Second- and Third-Order transfer matrices.

Radio buttons at the top of the Matrix Piece Window are used to toggle between the R-Matrix, T-Matrix and U-Matrix displays. The R-Matrix represents the First-Order transfer matrix R(i,j), displayed in meters and inverse meters. When the T-Matrix radio button is selected, the Second-Order matrix T(i,j,k), is displayed. The elements of the T-Matrix have an additional index that is selected with the pop-up to the right of the T-Matrix radio button. The Third-Order U-Matrix U(i,j,k,l), is selected with the U-Matrix radio button and has two additional dimensions that are also selected with pop-up controls located to the right of the U-Matrix radio button. The pop-up controls for the T and U matrices are only activated when the corresponding radio button has been selected.

A Matrix Piece can be placed in the beamline model or on the Work Space by dragging the Matrix Piece icon from the Palette Bar of the Document Window. The default Matrix Piece Parameters represent the identity matrix. Matrix elements can be entered directly into the Matrix Piece Window.

An arbitrary transfer matrix can be defined directly in the Matrix Piece Window.

A Matrix Piece can be also be generated for a selection of beamline elements using the Create Matrix command. After making a selection of Pieces in the beamline model, use the Create Matrix command in the TRANSPORT Commands Menu to generate a Matrix Piece on the Work Space that represents the selected beamline elements. Refer to the Create Matrix Command Section in Chapter 6: Displaying and Creating Matrices.

A Matrix Piece can be generated for a selection of one or more elements in the beamline model.

The Matrix Piece may be useful for speeding up TRANSPORT calculations for very large beamline models. For example, in a typical fitting calculation (Refer to Chapter 9: TRANSPORT Fitting) only a few Pieces will have Variable Parameters specified. The other static parts of the beamline may be replaced by Matrix Pieces generated as described in the preceding paragraph.

A Matrix Piece can be created for the entire beamline after executing TRANSPORT.

A Matrix Piece can also be generated for the entire beamline model from the Transport R-Matrix Window. After executing TRANSPORT the Show R-Matrix command will open the R-Matrix Window and the Create Matrix button will generate a Matrix Piece representing the entire beamline. Refer to the Creating a Matrix Piece Section in Chapter 6: Displaying and Creating Matrices.

The Matrix Piece Window displays the transfer matrices in units of meters, radians and inverse meters, radians regardless of the TRANSPORT Output File Option.

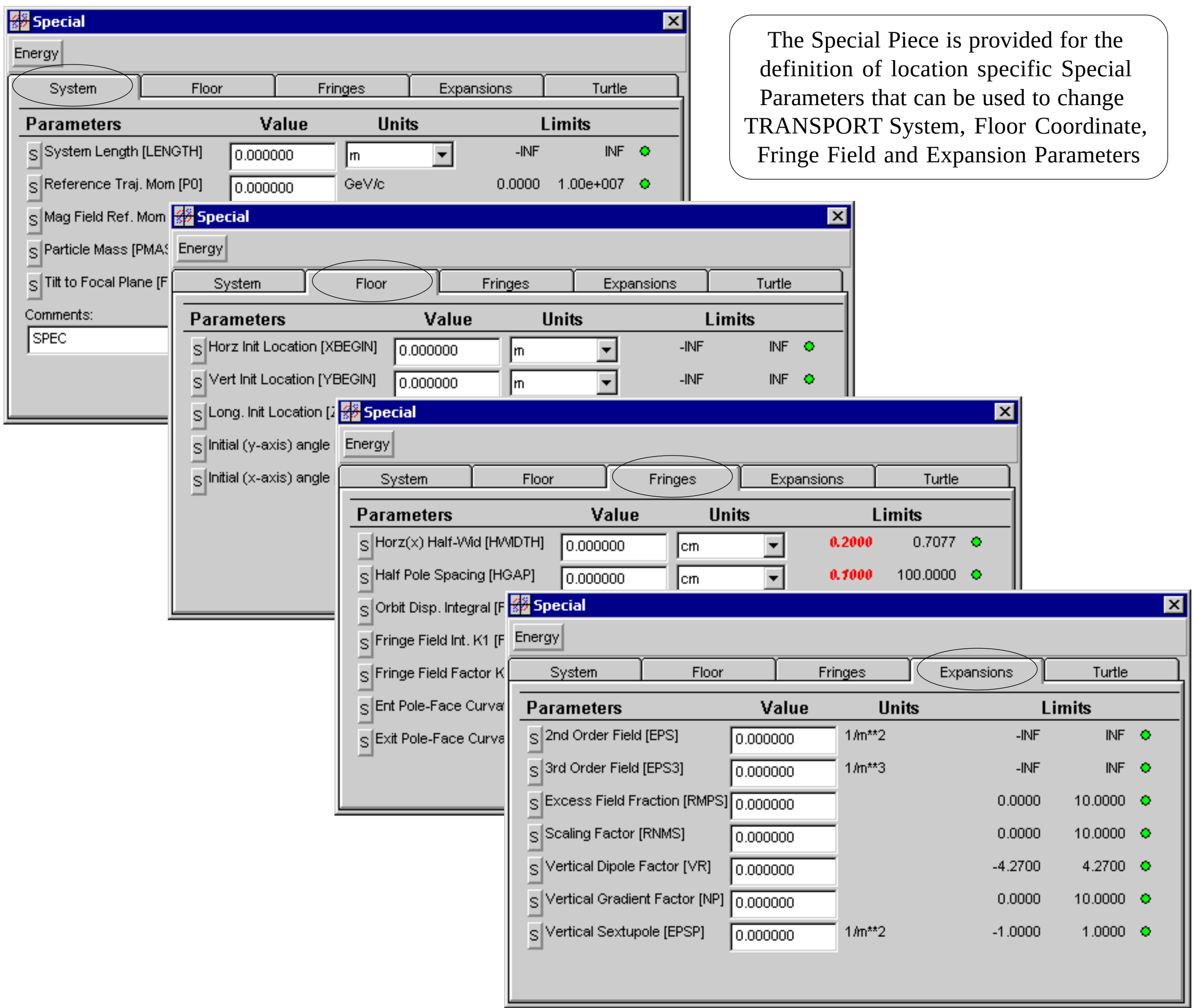
PBO Lab provides an Output File Option in the TRANSPORT Options Window that causes TRANSPORT to generate the transverse matrix components in millimeters and milliradians. This mixed units representation will only appear in the Transport Output File when this option is selected. The Matrix Piece Window will always display the matrix data in meters and inverse meters regardless of the TRANSPORT Output File Option.

Matrix Pieces may be used to replace static sections of a large beamline. If acceleration elements are in the beamline, Special Pieces may need to be added to change the beam (P0) or reference (PREF) momentum. Refer to the following Section for a discussion of the Special Piece.

Special Piece

Special Piece

The PBO Lab Special Piece is used by the TRANSPORT and TURTLE Application Modules. The Special Piece Window, shown in Figure 17, contains five tab panels. The first four tab panels are used exclusively for TRANSPORT. The fifth tab panel is used for the TURTLE Application Module.



The Special Piece is provided for the definition of location specific Special Parameters that can be used to change TRANSPORT System, Floor Coordinate, Fringe Field and Expansion Parameters

Figure 17. Tab Panels in the Special Piece Window.

The Special Piece is provided for the definition of location specific special parameters that can be used to change TRANSPORT System, Floor Coordinate, Fringe Field and Expansion Parameters. Table 2 list the Special Parameters and the corresponding TRANSPORT keywords.

Table 2. Special Piece Parameters and Keywords.

Special Piece Parameter	TRANSPORT Keyword
System Parameters	
System Length	LENGTH
Reference Trajectory Momentum	P0
Magnetic Field Reference Momentum	PREF
Particle Mass	PMASS
Tilt to Focal Plane	FOTILT
Floor Coordinate Parameters	
Horizontal Location	XBEGIN
Vertical Location	YBEGIN
Longitudinal Location	ZBEGIN
Y-Axis Angle	YAW
X-Axis Angle	PITCH
Fringe Field Parameters	
Horizontal Half-Width	HWIDTH
Half Pole Spacing	HGAP
Orbit Displacement Integral	FINT0
Fringe Field Factor K1	FINT
Fringe Field Factor K2	FINT2
Entrance Pole-Face Curvature	H1
Exit Pole-Face Curvature	H2
Expansion Parameters	
Second-Order Field	EPS
Third-Order Field	EPS3
Excess Field Fraction	RMPS
Field Scaling Factor	RNMS
Vertical Dipole Factor	VR
Vertical Gradient Factor	NP
Vertical Sextupole Factor	EPSP

Special Pieces must precede any element(s) to which they apply. Once a Special Parameter has been defined for a location in the beamline model, it will apply to all succeeding elements that are the appropriate type unless reset to a new value.

PBO Lab will only use Special Parameters that have been defined by a Symbolic Parameter Name in the parameters' Special Parameter Settings Window.

Note that the Fringe Field Factor K2 (FINT2) is no longer used by TRANSPORT, but is included for compatibility with older versions.

Refer to the "TRANSPORT User Manual" for a description of individual special parameters.

The Special Piece can be placed anywhere in the beamline by dragging the icon from the Palette Bar of the Document Window and inserting it at the desired location in the beamline model. Special Pieces on the Work Space are ignored when generating special instructions (SPEC cards) in the TRANSPORT input file. Special Pieces must precede any element(s) to which they apply. Once a Special Parameter has been defined at a specific location in the beamline, it will apply to all succeeding elements of the appropriate type unless reset to a new value.

Special Pieces on the Work Space are ignored when generating special instructions (SPEC cards) in the TRANSPORT input file.

Only Special Parameters that have been defined by a Symbolic Parameter Name in the parameters' Special Parameter Settings Window will be used by TRANSPORT.

Copying Special Pieces will duplicate any Symbolic Parameter Names and may result in unintended consequences.

A single Special Piece may be used to define multiple Special Parameters for a specific location in the beamline. Multiple Special Pieces can also be placed at different locations in the beamline to redefine a single Special Parameter. However, PBO Lab will only use Special Parameters that have been defined by a Symbolic Parameter Name in the parameter's Special Parameter Settings Window, as illustrated in Figure 18. Special Parameters should be defined with unique Parameter Names, particularly when the same Special Parameter is defined at different locations in the beamline model, otherwise the last non-unique Parameter Name and Value will be used for each Special Parameter defined by that Name. Copying a Special Parameter Piece will also copy any Special Parameter Settings including Symbolic Parameter Names. When a Special Piece is copied, care should be taken to assign unique Symbolic Parameter Names.

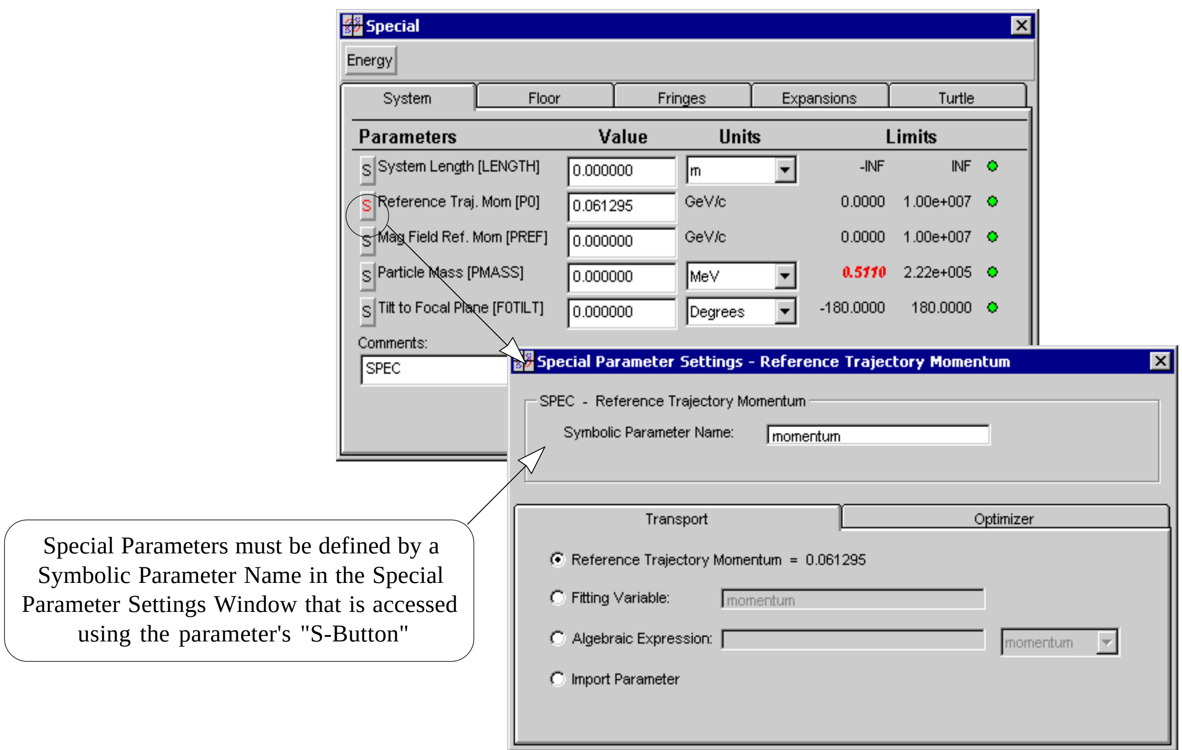


Figure 18. Defining a Symbolic Parameter Name for a Special Parameter.

Refer to the following Chapter for a description of the Special Parameter Settings Window.

PBO Lab™ 2.0

Special Parameter Settings

User Manual Supplement: TRANSPORT Application Module

4. Special Parameter Settings

Many Piece Parameters support application-specific special parameter settings that are accessed with the Special Parameter Settings Buttons ("S-Buttons") located next to each parameter in PBO Lab Piece Windows. The S-Buttons open a Special Parameter Settings Window ("S-Window") for the associated Piece Parameter.

Refer to the Piece Window Section in the PBO Lab User Manual for a complete description of the Piece Window user interface.

To access special parameter settings, select the TRANSPORT Application Context in the Document Window Button Bar and open a Piece Window by double-clicking the Piece icon on the Work Space or Model Space. Then click on the S-Button for the desired parameter as illustrated in Figure 19 below.

Access Special Parameter Settings Windows with the S-Button to the left of the desired parameter in the Piece Window.

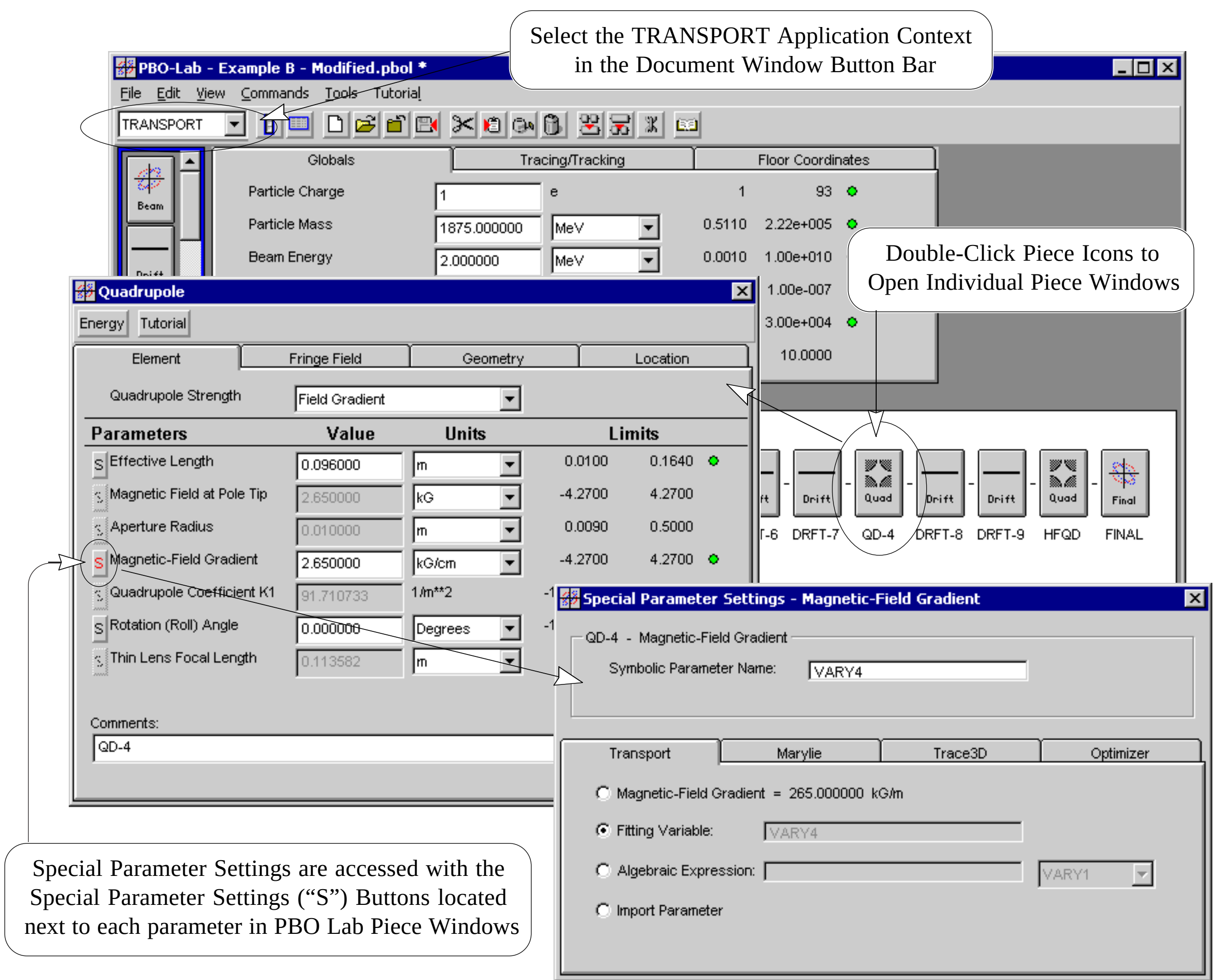


Figure 19. Opening a Special Parameter Settings Window.

Special parameter settings will be inactive for parameters that are not in the selected parameter set.

Many PBO Lab Pieces have multiple parameter sets that can be used to specify input parameters. The different parameter sets are accessed with a pop-up control at the top of the Piece Window. The S-Buttons will be inactive for parameters that are not included in the current parameter set. For example, in the Quadrupole Piece Window shown in Figure 19, the Quadrupole Strength pop-up specifies the Field Gradient parameter set. Only the three native TRANSPORT parameters for this set (Length, Field Gradient and Roll Angle) can be selected for special parameter settings. The native parameters are indicated with green dots on the right edge of the Piece Window. In order to select special settings for the Aperture Radius parameter, the Field and Aperture parameter set needs to be selected in the Quadrupole Strength pop-up. Refer to the Piece Window Section in the main PBO Lab User Manual for a description of multiple parameter sets.

Special Parameter Settings Windows contain tab panels for the installed PBO Lab Application Modules.

The bottom half of the S-Window contains tab panels that provide access to application-specific options for the different PBO Lab Application Modules. Your S-Windows will include tab panels for any installed Application Modules. However, some Application Modules may not support special settings for a parameter and therefore will not have a tab panel in the S-Window.

Special Parameter Settings are available for native TRANSPORT inputs that are supported as Fitting Variables or Algebraic Expressions.

When the TRANSPORT Application Module is installed, there will be a Transport tab panel in the Special Parameter Settings Window if that parameter is a native TRANSPORT input and it is supported as a Fitting Variable or Algebraic Expression by the TRANSPORT program. Otherwise there will not be a Transport tab panel in the S-Window.

All of the special parameter settings for a PBO Lab beamline model are saved from the Document Window with the Save or Save As commands in the File Menu.

Special Parameter Settings are saved with the beamline model document. The special parameter settings for TRANSPORT include selecting a parameter as a Fitting Variable or defining a parameter with an Algebraic Expression or selecting it as an Import Parameter. Refer to the Transport Parameter Settings Section in this Chapter for a description of the different parameter settings.

Creating a copy of a Piece with special parameter settings will also copy those settings. For example if a Piece Parameter is defined by a user-specified Parameter Name and that Piece is copied in the beamline, then there would be two parameters defined by the same Parameter Name. Both instances of the Parameter Name will be sent to TRANSPORT but the value for the first parameter will be used when the second parameter is encountered. This is also true for the initial values of Fitting Variables defined with identical Parameter Names. If there are duplicate Fitting Variable Names then the initial value of the first instance will be the initial value for all instances of the Variable with the same Symbolic Name. Copying Pieces that have Parameter Algebraic Expressions will duplicate those expressions on the copied Piece but otherwise present no difficulties. In some cases, it is desirable to use multiple Pieces with parameters that are defined by the same Parameter Name. However, if this is not the desired result, the Parameter Name will need to be changed to a unique name after making a copy of a Piece that includes special parameter settings. An alternative to copying Pieces that are to be represented with parameters that are defined with the same special parameter settings is to create an Alias Piece. An Alias Piece will maintain a persistent link to the original Piece so that any changes to the original are automatically reflected in the Alias. The Alias Piece also supports user specified deviations from the original Piece parameters without duplicating redundant data. Refer to the Alias Piece Section in the main PBO Lab User Manual for a discussion of Alias Pieces.

Copying Pieces with special parameter settings will duplicate Parameter Names and may result in unintended consequences.

An alternative to copying a Piece is to create an Alias Piece that will maintain a persistent link with the original Piece and will automatically reflect any changes in the original Piece Parameters.

Symbolic Parameter Names

The Parameter Name specified in the top panel of the S-Window is application-independent. The same Parameter Name is used for all installed Application Modules.

Using a Symbolic Parameter Name that is identical to a Piece comment may cause unintended results.

The top panel of the S-Window (Figure 20) is application-independent and displays the Piece Comment (Label) along with the name of the selected parameter. The Symbolic Parameter Name input field is application-independent and provides for a user-specified Symbolic Parameter Name to be defined for the parameter. When required, a default Parameter Name will be generated if a name has not been entered in the field at the top of the S-Window. The same Parameter Name is used for all installed Application Modules.

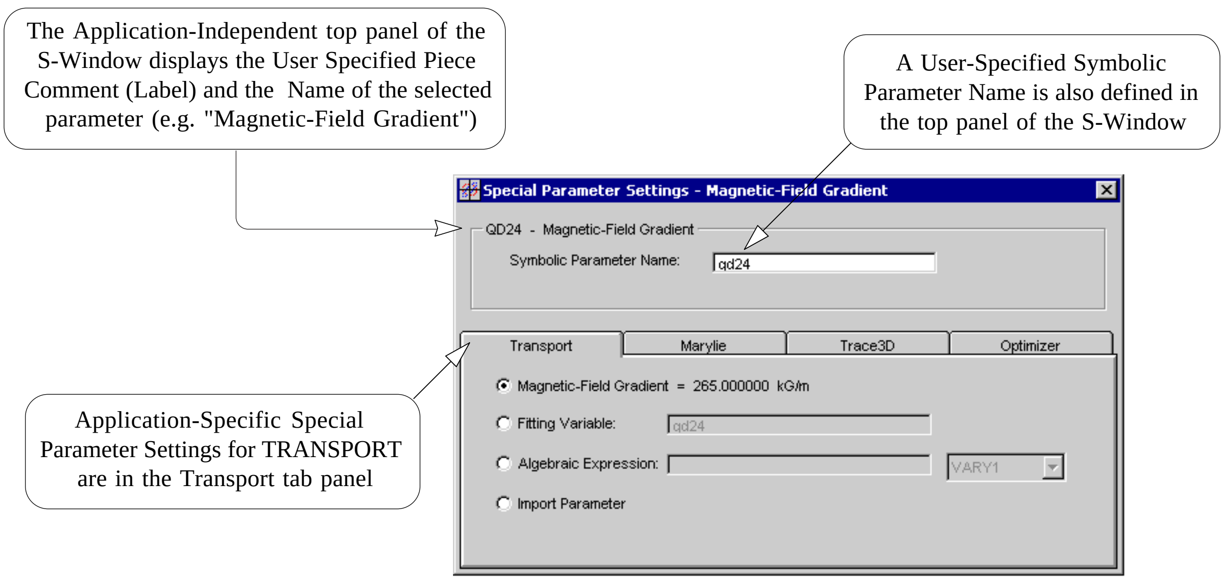


Figure 20. Special Parameter Settings Window.

Parameter Names can be used in Parameter Algebraic Expressions specified for other Piece Parameters as described in the Parameter Algebraic Expressions Section of this Chapter.

Symbolic Parameter Names used in the beamline model sould be unique. To define multiple parameters with the same value, define one parameter with a unique name and define the other parameters as Algebraic Expressions of that name.

A Symbolic Parameter Name is required when the parameter is selected as a Fitting Variable or Import Parameter in the Transport tab panel. However, Parameter Names can also be used for defining other parameters in terms of the named parameter even though the named parameter may not be selected as a Fitting Variable, i.e. the parameter is treated as a numerical constant defined by a symbolic name. When a Parameter Name has been specified, there will be a red “S” on the S-Button in the Piece Window and the Parameter Name may then be used in Parameter Algebraic Expressions for other Piece Parameters.

Transport Parameter Settings

The Transport tab panel in the Special Parameter Settings Window has four radio buttons for specifying the associated parameter as: a numerical Value, a Fitting Variable, an Algebraic Expression or an Import Parameter. These choices are exclusive. A parameter can only be defined by one of these special parameter settings, although the same Symbolic Parameter Name is used for all settings and for all Application Modules.

The first radio button in the Transport tab panel is the default selection. It indicates that the parameter is defined by the numerical Value entered in the Piece Window, i.e. there are no special settings currently selected for the parameter. The parameter may be defined with a Symbolic Parameter Name, although it is not required for this selection. If a Parameter Name is defined then that name will be used to create a symbolic constant in the Transport Input file. The parameter will be defined with that Parameter Name and the Name may then be used to define Algebraic Expressions for other Piece Parameters.

Parameters that have been given Symbolic Parameter Names are defined with those Names in the Transport Input file even when the Parameter has not been selected as a Fitting Variable or an Algebraic Expression.

The second radio button in the Transport tab panel selects the parameter as a Transport Fitting Variable using the Symbolic Parameter Name as described in the TRANSPORT Fitting Chapter of this Supplement.

Refer to the Fitting Chapter in this Supplement for a discussion of Fitting Variables.

The third radio button selects the parameter as an Algebraic Expression. With this selection, the input field and pop-up to the right of the radio button are activated. The following Section describes the use of Parameter Algebraic Expressions.

Refer to the following Section for a description of Parameter Algebraic Expressions.

The last radio button in the Transport tab panel selects the parameter as an Import Parameter. This selection works in conjunction with the PBO Lab External Data Interface Tools. The import option is not specific to TRANSPORT, but selecting an Import Parameter excludes that parameter as a Fitting Variable or Algebraic Expression. Refer to the External Data Interface Section in the PBO Lab User Manual for a description of Import Parameters.

Refer to the External Data Interface Section in the main PBO Lab User Manual for a description of the Import Parameter special parameter setting.

Parameter Algebraic Expressions

Symbolic Parameter Names may be defined for Piece Parameters, as described in the previous Sections, and used in Algebraic Expressions for other Piece Parameters.

Parameter Algebraic Expressions are not evaluated until TRANSPORT is executed.

Symbolic Parameter Names are not used for Piece Parameters defined with Algebraic Expressions.

The TRANSPORT Application Module supports the definition of Piece Parameters using Algebraic Expressions. Parameter Algebraic Expressions are specified in the Special Parameter Settings Window. To define an Algebraic Expression for a Piece Parameter, select the corresponding radio button in the parameters' Special Parameter Settings Window as illustrated in Figure 21. With this selection, the input field and pop-up to the right of the radio button are activated. An algebraic expression is entered in the input field, which will then be used to define the parameter in the Transport Input file. The pop-up to the right of the input field contains a list of all the Piece Parameters in the beamline model that have been given Symbolic Parameter Names in addition to Location Specific Stored Parameters. A Parameter Algebraic Expression can be defined in terms of these Symbolic Parameter Names as well as other TRANSPORT program variables and symbolic constants. Note that a Parameter Algebraic Expression is not evaluated when it is defined in the S-Window. Algebraic Expressions are evaluated when TRANSPORT executed.

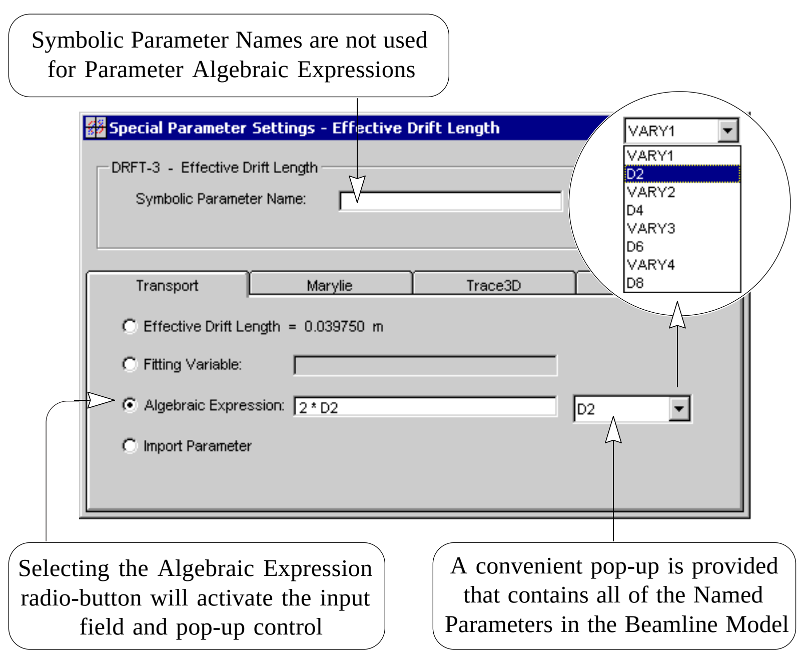


Figure 21. Parameter Algebraic Expressions.

Parameter Algebraic Expressions may be defined in terms of user-specified Parameter Names, Fitting Variables, Stored Parameters and may also contain TRANSPORT symbolic constants including those listed in Table 3 below.

Named Piece Parameters, Fitting Variables and Stored Parameters may be used to define Parameter Algebraic Expressions.

Table 3 TRANSPORT Symbolic Constants.

TRANSPORT Keyword	Numerical Value	Units
PI	3.12159265358979323	
TWOPI	2.0*PI	
DEGRAD	180.0/PI	
RADDEG	PI/180.0	
E	2.718281828459045	
EMASS	0.510099906E-03	GeV
PMASS	0.93827231	GeV
CLIGHT	2.99792458E+08	m/s
MTOIN	0.0254	
INTOM	1.0/MTOIN	

Parameter Algebraic Expressions may include TRANSPORT symbolic constants. Additional symbolic constants can be defined by the user with the Param Piece.

Additional symbolic constants can be defined by the user with the Param Piece (refer to the Parameter Piece Section in this Chapter). User-specified Parameter Names should not use the names that are reserved by TRANSPORT for symbolic constants.

There are a variety of mathematical operators and functions that can be used in Parameter Expressions. These are listed in Table 4 with the TRANSPORT keyword or symbol.

Table 4 Operations for Algebraic Expressions.

Keyword-Symbol	Operation	Keyword-Symbol	Operation
+	Addition	*	Multiplication
-	Subtraction	/	Division
SIN	Sine	COS	Cosine
SINH	Hyperbolic Sine	COSH	Hyperbolic Cosine
ASIN	Inverse Sine	ACOS	Inverse Cosine
SQRT	Square Root	ALOG	Natural Log
EXP	Exponential		

A variety of mathematical operators and functions may be used in Parameter Algebraic Expressions.

Algebraic Expressions specified by the user are saved even when the parameters are not set to use the expression.

All of the special parameter settings for a PBO Lab beamline model are saved from the Document Window using the Save or Save As commands in the File Menu. An Algebraic Expression for a parameter will be saved with the beamline model document even when it is not selected in the Special Parameter Settings Window. For example, you may define a parameter with an Algebraic Expression and run TRANSPORT to evaluate the expression. You could then update the beamline model and change the special parameter setting to use that value instead of having TRANSPORT reevaluate the Algebraic Expression on each execution. The expression will still be saved with the beamline model even though it is not active.

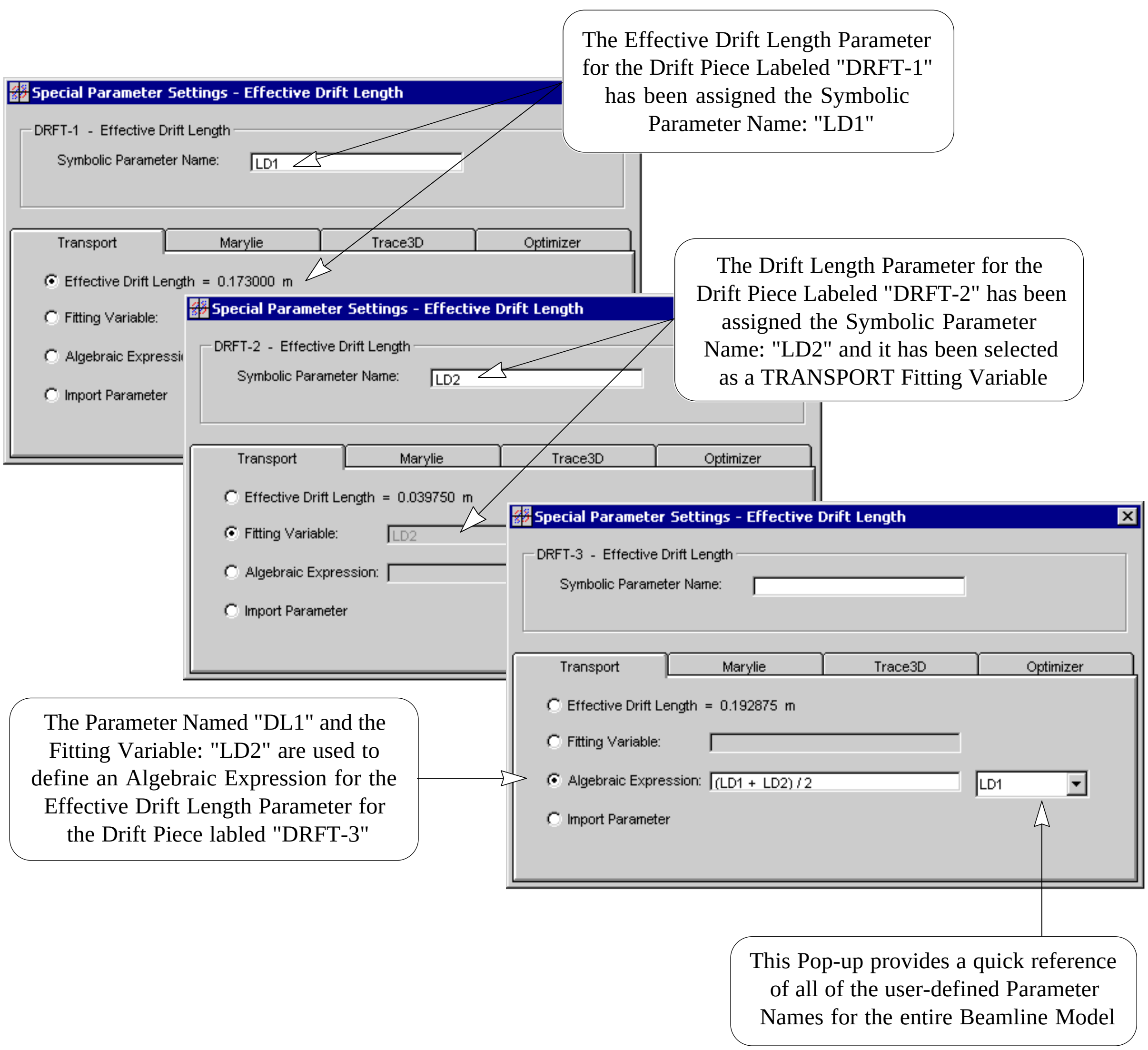


Figure 22. Parameter Algebraic Expressions.

Figure 22 on the previous page illustrates a simple example of a Parameter Algebraic Expression. The first S-Window defines a Parameter Name: “LD1” for the Effective Length of a Drift Piece. The second S-Window defines another Drift Length parameter with the Parameter Name: “LD2”, which is selected as a TRANSPORT Fitting Variable. The last S-Window in Figure 22 defines one more Drift Length Parameter as an Algebraic Expression of Named Parameters. The value of this parameter will be calculated by Q ANSPORT using the algebraic expression: (LD1 + LD2) / 2.

Updating Parameter Expressions

Parameter Algebraic Expressions are evaluated when TRANSPORT is executed. The resulting values are presented in the PBO Lab Update Window following the execution of TRANSPORT. The Update Window, shown in Figure 23, provides options to individually update selected parameters or to update all of the parameters at once. The Update Window also contains an update panel for any Parameters used as Fitting Variables. There are separate Update Buttons for Variable Parameters and Parameter Expressions in the Update Window. Both the Variable Parameters and Parameter Expressions panels have scroll bars to access additional entries that may not be visible. Fitting Variables are described in Chapter 9: TRANSPORT Fitting.

Parameter Algebraic Expressions are evaluated when TRANSPORT is executed. An Update Window is automatically opened for modifying Parameter Expression Values in the beamline model.

Refer to Chapter 9: TRANSPORT Fitting for an explanation of Fitting Variables in the Update Window.

The Expression Parameters panel in the Update Window has six columns. The user-specified Piece Label (Comment) is in the first column, the second column contains the name of the parameter as it appears in the Piece Window. The third column contains the Parameter Algebraic Expression. The Value column contains the current numerical value of the parameter and the Update column contains the new value computed by TRANSPORT, which will be assigned when the parameter is updated in the beamline model. If a parameter is not specifically updated, then the original value will be unchanged in the beamline model. The last column shows the units for each parameter.

If a Parameter Algebraic Expression is not specifically updated in the Update Window, then the original value will be unchanged in the beamline model.

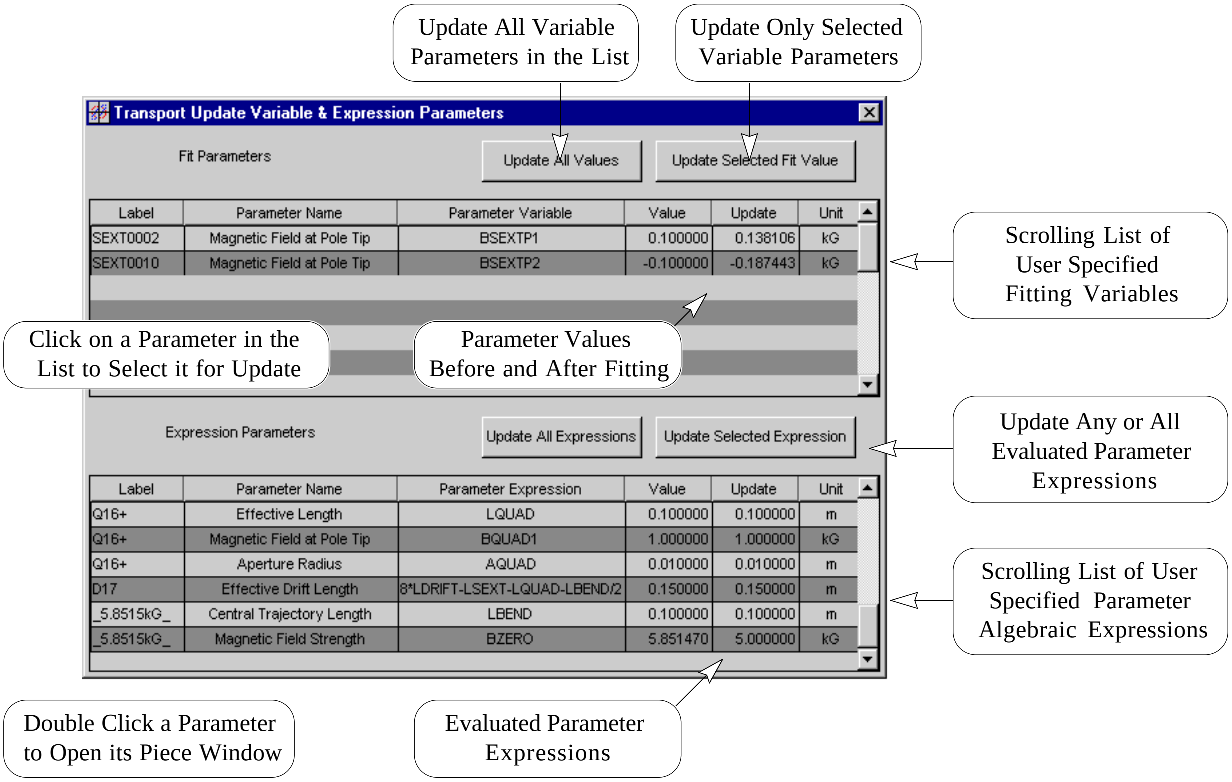


Figure 23. Parameter Update Window.

Double-clicking a parameter in the Update Window will open the associated Piece Window for that parameter.

The Update Window is automatically opened after execution of TRANSPORT. The Variables and Expressions do not have to be updated immediately. However, if the Update Window is closed prior to updating any parameters then TRANSPORT will have to be run again to access the Update Window. The Update Window can be left open without updating parameters, in order to examine other output results, and then parameters can be updated in the beamline model by bringing the Update Window to the foreground again. The Update Window may also be used to locate the Pieces in the beamline model with Variable Parameters or Parameter Expressions. Double-clicking an entry in the Update Window will open the associated Piece Window for the selected parameter.

Parameters & Expressions List Windows

PBO Lab provides application-specific interactive List Windows that organize related data for the entire beamline model. The Named Parameters List Window contains a list of Piece Parameters that have been given Symbolic Parameter Names. Figure 24 illustrates opening the Named Parameters Window from the TRANSPORT Commands Menu. The Named Parameters List Window can be used to quickly access Named Parameters. Double-clicking an entry in the window will open the associated Piece Window in the beamline model.

PBO Lab provides application-specific interactive List Windows that organize related data for the entire beamline model.

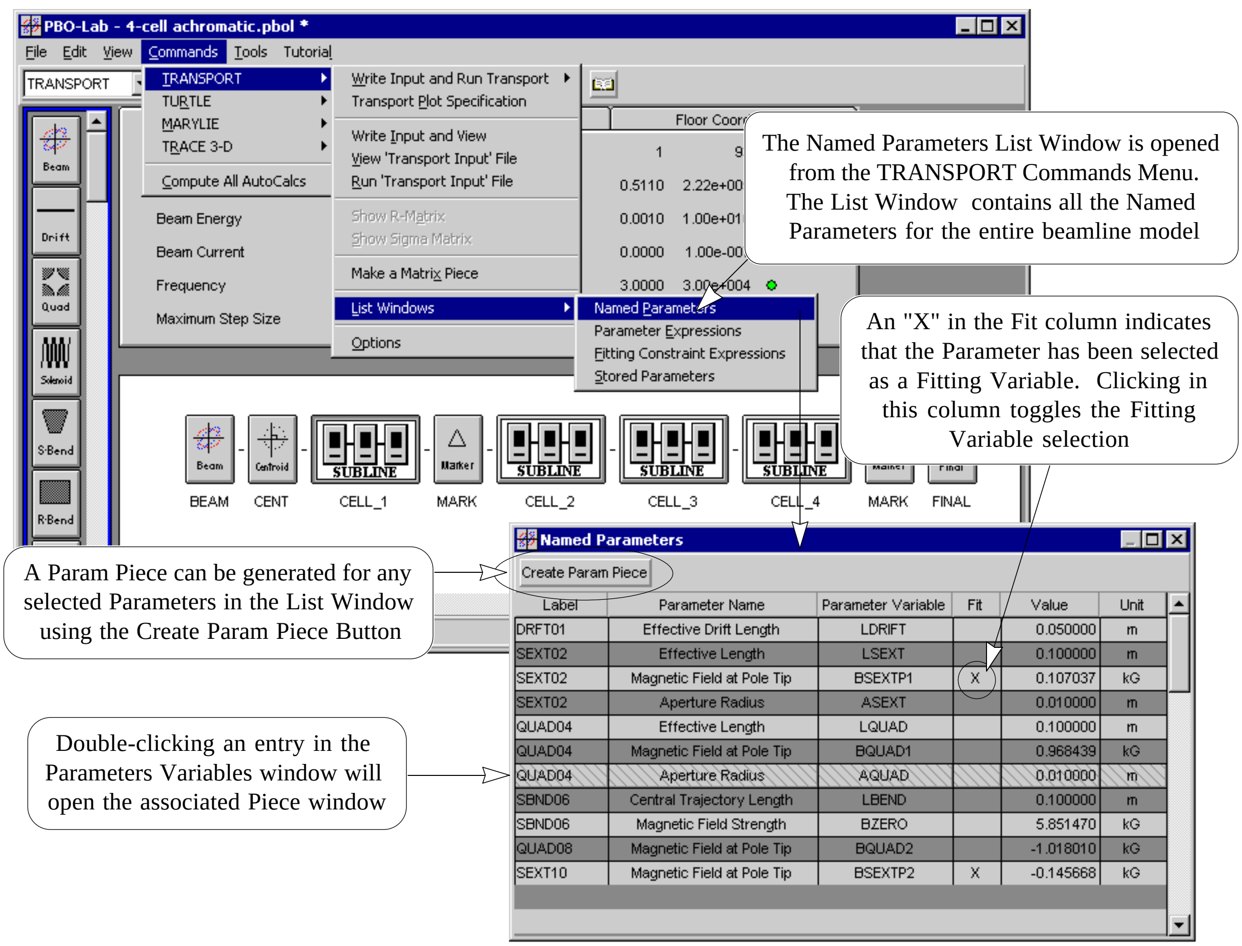


Figure 24. Named Parameters List Window.

The header at the top of all List Windows can be used to adjust the width of each column in the window.

The header at the top of all List Windows can be used to adjust the width of each column in the window. To resize a column, place the mouse over the divider line in the column header. When the arrow turns into a cross-hair, resize by holding the mouse button down while dragging horizontally. The List Windows themselves can also be resized to accommodate the number of entries and desired column widths.

Both Parameter Variables and Transport Fitting Variables are contained in the Named Parameters List Window.

Any Named Parameters that are selected as TRANSPORT Fitting Variables are indicated with an “X” in the Fit column of the List Window as illustrated in Figure 24. Named Parameters can be easily selected (and unselected) as Fitting Variables by clicking in the “Fit” column of the List Window.

A Parameter (Param) Piece can be created for selected parameters in the List Window by using the Create Param Piece Button.

A Param Piece can be created for selected parameters in the List Window by using the Create Param Piece Button. To create a Param Piece, select a parameter by clicking on the entry in the List Window. (Hold down the shift key to select multiple parameters.) Then use the Create Param Piece Button at the top of the window to generate a Param Piece on the Work Space of the Document Window. PBO Lab will automatically enter the Parameter Value in the Param Piece and the Symbolic Parameter Name in the S-Window for each parameter selected in the List Window. The Param Piece is described in the Parameter Piece Section of Chapter 3: Beamline Elements.

List windows include entries from Pieces in the Model Space and from the Work Space.

List windows include entries from Pieces in the Model Space and from the Work Space. This provides quick access to all Pieces that have special parameter settings. Pieces on the Work Space that have special parameter settings will also be included in the Transport Input file. This allows Pieces in the beamline model to reference Named Parameters from the Work Space in the definition of Parameter Algebraic Expressions.

A List Window is also provided for Stored Output Parameters that have been specified with Marker Pieces at specific locations in the beamline model. The Stored Parameters List Window supports features that are similar to the Named Parameters List Window and is opened from the List Windows Submenu in the TRANSPORT Commands Menu. Refer to the Stored Parameters List Window sub-section in the Marker Piece Section of Chapter 3: Beamline Elements.

PBO Lab also provides a List Window for location-specific Stored Parameters in the beamline model. The Stored Parameters List Window is described in a sub-section of the Marker Piece Section in Chapter 3: Beamline Elements.

PBO Lab also provides List Windows for Parameter Algebraic Expressions and for Fitting Constraint Expressions. These windows support the same features as the Named Parameters and Stored Parameters List Windows and are also accessed from the List Windows Submenu in the TRANSPORT Commands Menu.

PBO Lab also provides List Windows for Parameter Algebraic Expressions and Fitting Constraint Expressions.

Figure 25 illustrates the Parameter Algebraic Expressions and Fitting Constraint Expressions List Windows. As with the other List Windows, the window itself, as well as individual columns, can be resized. Double-clicking an entry will open the associated Piece Window for Algebraic Expressions and the associated Marker Piece Window for Constraint Expressions. Refer to Chapter 9: TRANSPORT Fitting for further description of these List Windows.

Double-clicking an entry in the Parameter Algebraic Expressions List Window will open the associated Piece Window for that parameter.

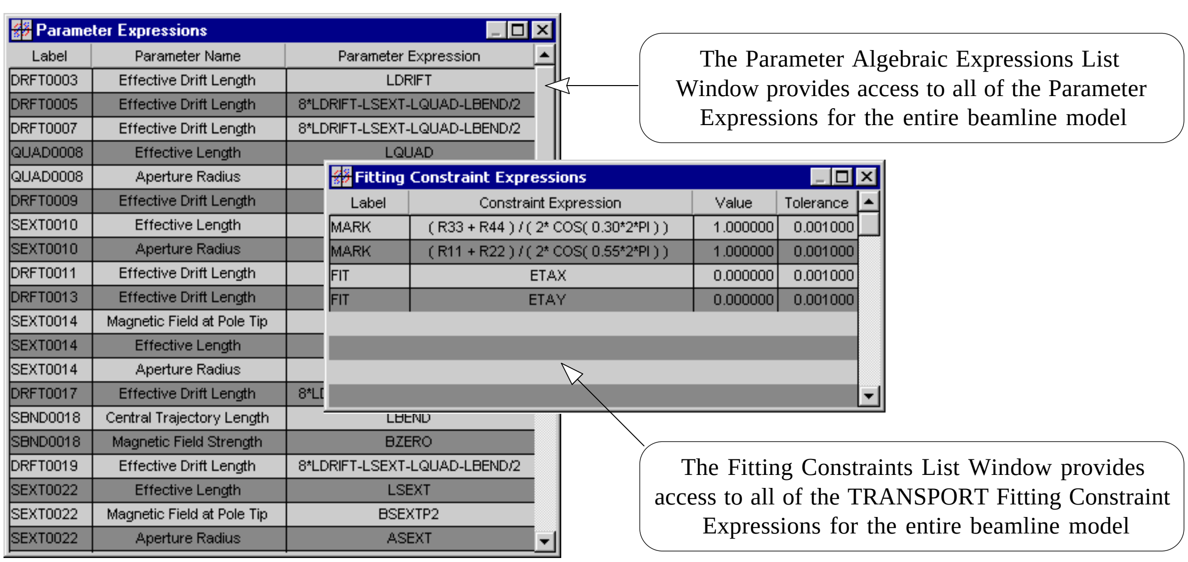


Figure 25. Parameter Expressions and Fitting Constraints List Windows.

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PBO Lab™ 2.0

TRANSPORT Menus

User Manual Supplement: TRANSPORT Application Module

5. TRANSPORT Menus

Application-specific commands are accessed from Submenus in the PBO Lab Commands Menu and View Menu at the top of the Document Window. When the TRANSPORT Application Module is installed, both the Commands Menu and the View Menu will contain Submenus for the TRANSPORT application, in addition to any other installed PBO Lab Application Modules. This Chapter includes an outline of the TRANSPORT Menus, as well as references to other Chapters in this Supplement that provide more detailed descriptions of specific menu commands.

Submenus for the TRANSPORT Application Module (as well as any other installed PBO Lab Application Modules) are found in both the Commands and View Menus of the Document Window.

TRANSPORT Commands Menu

The TRANSPORT Commands Menu is illustrated in Figure 26 and contains several options for specifying output and executing the TRANSPORT Application Module.

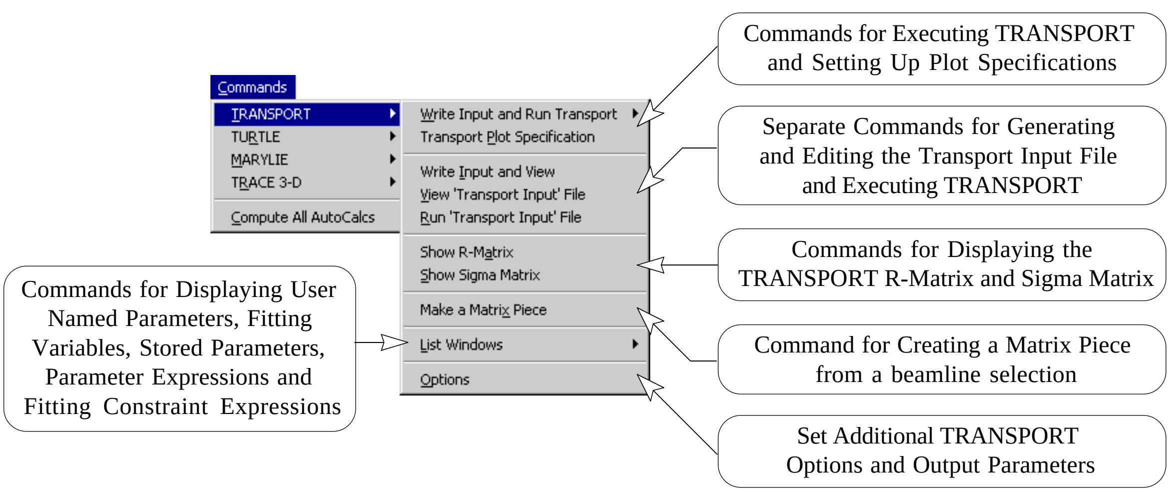

Figure 26. PBO Lab Commands Menu for TRANSPORT Module.

The TRANSPORT Commands Menu is divided into six groups of commands. The first group contains the two primary commands for specifying output and running TRANSPORT. The second group provides three additional commands for setting up and running Transport Input files. These are described in the following Execution Commands Section.

The Write Input & Run Transport command automatically creates and executes the Transport Input file which contains all the inputs required by TRANSPORT.

Execution Commands

TRANSPORT is executed from the Commands Menu using the Write Input & Run Transport Command. TRANSPORT reads and executes an input file that is generated by PBO Lab for the beamline in the Model Space of the Document Window.

The first command in the Commands Menu is used to run TRANSPORT and the second command is used to specify plot data output. The Write Input & Run Transport Submenu provides two options that can be used to write a Transport Input file for the beamline defined on the Model Space and execute the TRANSPORT program. TRANSPORT reads and executes the instructions contained in the MAD (Methodical Accelerator Design) formatted input file that is generated by PBO Lab. Figure 1 in the Getting Started Chapter illustrates an example using one of these commands.

The Write Input & Run Transport Command provides two options that can be used to run TRANSPORT with or without Fitting.

The Write Input & Run Transport Submenu includes two options for running TRANSPORT as illustrated in Figure 27. The first includes fitting and the second excludes fitting. The only difference between these two options is that PBO Lab will include the FIT instruction in the native Transport Input file for the first case and will exclude the FIT instruction for the second case. This allows any fitting variables and constraints that have been defined by the user to remain part of the model, without actually having to run the fitting procedure every time TRANSPORT is executed. Refer to the Chapter 9: TRANSPORT Fitting for a description of setting up and executing a TRANSPORT fitting problem.

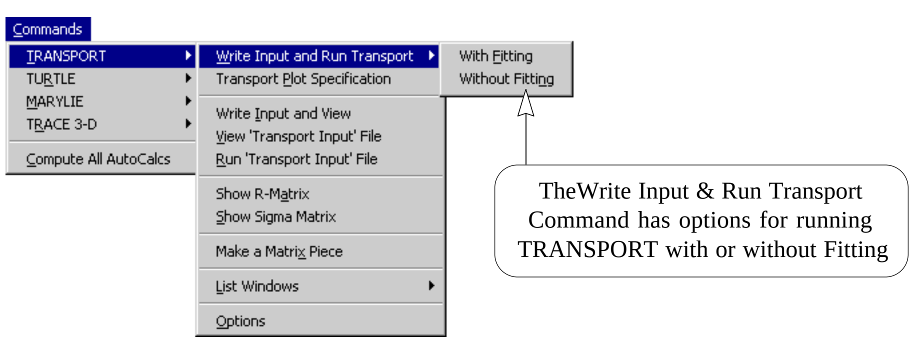

Figure 27. Write Input & Run Transport Submenu.

The Transport Plot Specification command opens the Transport Plot Specification Window, which is used to select a variety of TRANSPORT output parameters that will be written to the Transport Plot file. The Transport Plot Specifications are discussed separately in the Plot Specifications Chapter.

The Plot Specification command is used to set up options for different types of graphic output and must be set prior to running TRANSPORT.

The second group of commands in the TRANSPORT Commands Menu contains items to assist the user in directly editing the Transport Input file. With these commands, the native TRANSPORT input may be generated from the PBO Lab beamline model without automatically executing the TRANSPORT application. These commands are useful for implementing TRANSPORT instructions which may not be directly supported by the PBO Lab user interface. Changes made to the Transport Input file are not retained in the PBO Lab model data and the Transport Input file will be over written with subsequent Write Input & Run or Write Input & View commands.

The Transport Input file may be edited and saved by the user. TRANSPORT will read and execute the edited file (errors and all!) when the Run 'Transport Input' File command is selected.

These commands can also be used to evaluate any incompatibilities between TRANSPORT input files that were not generated with PBO Lab. For example, an older TRANSPORT input deck can be pasted into the Text Edit Window that is opened with the View 'Transport Input' File command. After saving the new Transport Input file with the Save command in the Text Edit Window, this file can then be executed with the Run 'Transport Input' File command. PBO Lab will not generate a new input file when using this command, instead the current Transport Input file will be used to execute the TRANSPORT program. Any incompatibilities will be noted in the Transport Output file. The input can then be corrected before Importing the file into PBO Lab in order to build a PBO Lab beamline model from the native TRANSPORT deck.

PBO Lab will not generate a new input file when using the Run 'Transport Input' File command. Instead the current Transport Input file will be used to execute the TRANSPORT program.

Text files can also be edited by using the Open Scratch File Command in the View Menu of the Document Window. This command opens an empty Text Edit Window. The Open Command in the File Menu of the Text Edit Window can be used to open any existing text file.

The different commands that generate the Transport Input file and execute TRANSPORT result in a rapid data flow which is transparent to the user. Each of these commands involves a few well defined steps which are summarized here.

When a Transport Input file is generated, the previous input file is overwritten.

When TRANSPORT is executed, the previous output files are overwritten.

(1.) Each time they are selected, the following PBO Lab commands write a new Transport Input file for the beamline in the Model Space of the Document Window, together with the Options settings, Plot Specifications and Fitting Constraints:

Write Input & Run Transport
Write Input & View

The first command will automatically write the input file and execute TRANSPORT. The second command will write the input file and display it in a Text Edit Window.

(2.) The following PBO Lab command will open the the most recent Transport Input file without generating new input from the beamline model:

View 'Transport Input' File

(3.) The following PBO Lab command executes the most recent Transport Input file, created by either (1.) or (2.) above:

Run 'Transport Input' File

If the Transport Input file does not exist, then the Run 'Transport Input' File command will not generate any output.

The Transport Input file is not updated with any changes made from the interface, this command simply executes an existing Transport Input file.

Some of the PBO Lab commands and beamline construction tasks may require a Transport Input file to be generated, thus overwriting any existing file.

Other PBO Lab commands or beamline construction tasks may also cause a Transport Input file to be generated, thus overwriting any existing file. For example, creating a Matrix Piece from a selection of Pieces in the beamline model will cause an input file to be generated, overwriting any existing file. This input file is executed by TRANSPORT and any existing output files are overwritten as well. All this is transparent to the user. When the Make Matrix Piece Command is selected, the Matrix Piece simply appears on the Work Space of the Document Window.

Matrix Commands

The third and forth groups of commands in the TRANSPORT Commands Menu contain commands for creating and displaying matrices. The first two commands in the third group are used for displaying the TRANSPORT R-Matrix and Beam Sigma Matrix. The forth group contains one command that is used to create a Matrix Piece for a selection of beamline elements. These commands are described separately in Chapter 6: Displaying and Creating Matrices.

Commands for Creating and Displaying Matrices are described separately in Chapter 6 of this Supplement.

List Window Commands

The fifth group of commands in the TRANSPORT Commands Menu contains commands for displaying user specified Named Parameters, Parameter Expressions, Storage Parameters, Fitting Variables and Fitting Constraints for the entire beamline.

The List Windows Submenu provides commands to open several PBO Lab List Windows as illustrated in Figure 28. Each of the List Windows organize related data for all of the Pieces in the beamline model and on the Work Space.

List Windows organize related data for all of the pieces in the beamline model and on the Work Space.

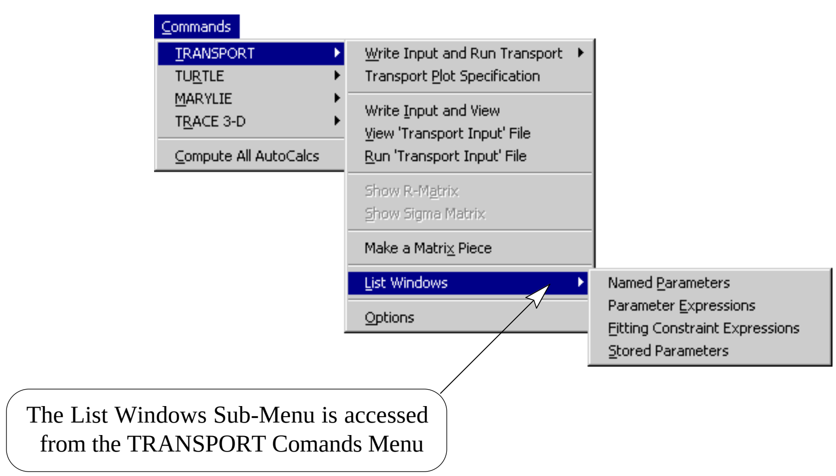

Figure 28. List Windows for TRANSPORT are Accessed from the List Windows Submenu in the TRANSPORT Commands Menu.

List Windows are provided for Stored Parameters, Named Parameters, Parameter Expressions and Fitting Constraint Expressions.

List Windows are provided for Stored Parameters, Named Parameters, Parameter Expressions and Fitting Constraint Expressions. The Stored Parameters List Window is described in the Marker Piece Section of the Beamline Elements Chapter. The Named Parameters List Window and the Parameter Expressions List Window are described in the Parameters and Expressions List Windows Section of the Special Parameter Settings Chapter. The Fitting Constraint Expressions List Window is described in Chapter 9: TRANSPORT Fitting.

Options Command

The TRANSPORT Options Window is described in Chapter 7: TRANSPORT Options.

The last group in the TRANSPORT Commands Menu contains one command. The Option Command is used to access TRANSPORT Options for the Order of Calculation and Output Result in addition to parameters for specifying data to be written to the Transport output files. These commands are discussed separately in Chapter 7: TRANSPORT Options.

TRANSPORT View Menu

The TRANSPORT Submenu in the View Menu of the Document Window contains several commands to open TRANSPORT I/O files.

The View Menu in the Document Window contains Submenus for any installed PBO Lab Modules. The TRANSPORT Submenu is illustrated in Figure 29 and contains several commands to open input, output, diagnostic and auxiliary files for the TRANSPORT Application Module.

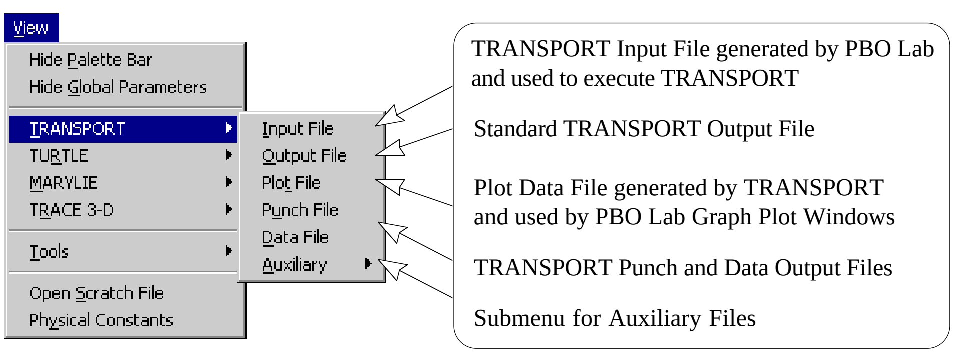

Figure 29. PBO Lab View Menu for TRANSPORT Module.

The View Menu commands do not execute TRANSPORT or cause new I/O files to be generated. These commands simply open the existing input, output and diagnostic files that have already been generated from a previous TRANSPORT run.

The View Menu commands do not execute TRANSPORT or cause new I/O files to be generated.

Each of the View Menu commands opens the associated file in a PBO Lab Text Edit Window. These windows provide standard editing capabilities and typical File, Edit and Font Menus. The Save As command in the File Menu of Text Edit Windows can be used to save any of the files using a different name. Since these files will be overwritten with the next execution of TRANSPORT, they should be saved with a different name if the data is to be retained. Renamed Text Edit Windows can remain open for comparison with other results. However, if the file is not renamed and the window is left open the new data from a subsequent TRANSPORT run will overwrite the existing data in the open window.

The Save As command in the File Menu of Text Edit Windows can be used to save any of the files using a different name.

There are five native TRANSPORT I/O files that can be accessed from the TRANSPORT View Submenu. These include the standard input and output files, in addition to the plot, punch and data files. The Transport Input file is the native input that is generated by PBO Lab for the beamline on the Model Space. The Transport Output file is the main output file generated with the execution of TRANSPORT. The Transport Plot file is the raw data generated by TRANSPORT and plotted by PBO Lab. The Transport Data file is an additional diagnostic output file that is provided for PBO Lab Professional users. This file may be used to add diagnostic write statements to the TRANSPORT FORTRAN source code. The Transport Punch file contains user-specified output data that is selected in the Punch File Options tab panel in the TRANSPORT Options Window. Refer to the Output and Punch File Options Section in Chapter 7: TRANSPORT Options.

The Auxiliary Files Submenu contains commands to view several Auxiliary input files that can be generated by TRANSPORT. These files are not generated unless they have been selected in the Output File Options tab panel in the TRANSPORT Options Window. Refer to the Output File Options Section in Chapter 7: TRANSPORT Options.

The last command in the TRANSPORT View Submenu is itself a Submenu for several Auxiliary input files that can be generated by TRANSPORT. The Auxiliary Submenu is illustrated in Figure 30. Table 5 lists the different Auxiliary files that can be generated for a beamline model. These files are not generated unless they have been selected in the Output File Options tab panel in the TRANSPORT Options Window. Refer to the Output File Options Section in Chapter 7: TRANSPORT Options. If an auxiliary file does not exist (has not been previously generated), then an alert will be given. If an auxiliary file has been previously generated, it will be opened with the associated View command in a PBO Lab Text Edit Window. Any of the Auxiliary files can be renamed with the Save As command in the File Menu of the Text Edit Window. Auxiliary files are named with the root name “Auxiliary.tout”. Each file type is then given its’ own extension which is appended to the root name. If a file of the same name exists when a new file is generated, then it will be overwritten with the new file.

Table 5. Auxiliary Files Generated by TRANSPORT

Keyword	**Description**
MAD	Methodical Accelerator Definition Input File
TRANSPORT	TRANSPORT Input File
LATDEF	Lattice Definition Input File
STRUCT	STRUCT Input File
ACAD	Autocad Input File

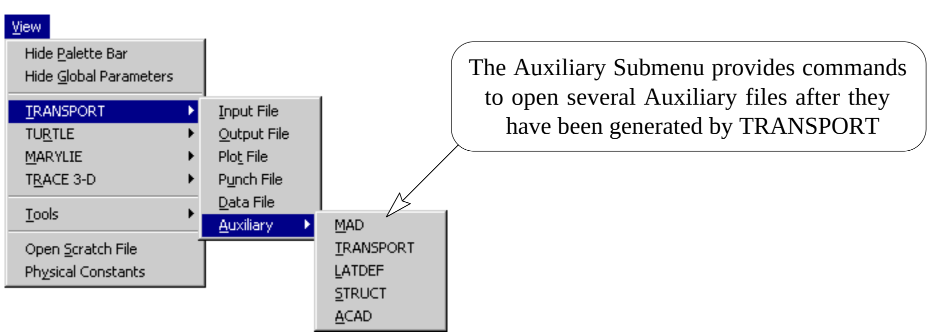

Figure 30. View Menu Commands to Open Auxiliary Files.

PBO Lab™ 2.0

Displaying & Creating Matrices

User Manual Supplement: TRANSPORT Application Module

6. Displaying and Creating Matrices

There are three commands in the TRANSPORT Commands Menu that are used for displaying and creating matrices. These commands are separated into two groups. The first group has two commands for displaying matrix data from the last execution of TRANSPORT. The second group contains one command that is used to execute TRANSPORT in order to create a Matrix Piece for a selection of beamline elements in the Model Space of the Document Window.

Show R-Matrix

The Show R-Matrix Command in the TRANSPORT Commands Menu opens the R-Matrix Window shown in Figure 31. This R-Matrix Window displays the transfer R-Matrix data at the end of the beamline for the last TRANSPORT run executed. No specific options settings are required to generate the data for the R-Matrix Window. However, the Show R-Matrix command will be inactive if TRANSPORT has not been executed.

The Show R-Matrix Command displays the R-Matrix for the last execution of TRANSPORT.

An unlimited number of R-Matrix Windows may be left open for comparing results from multiple TRANSPORT runs.

Creating a Matrix Piece

The Create Matrix Piece button in the Button Bar of the R-Matrix Window is used to generate a Matrix Piece from the R-Matrix data. The Matrix Piece is created on the Work Space of the Document Window as illustrated in Figure 31. The Matrix Piece represents the entire beamline model from the previous TRANSPORT execution that was displayed in the R-Matrix Window and may be used in place of the individual beamline elements. This may speed up calculations for very large models that have particular sections where the parameters are fixed so that Matrix Pieces can be generated and used to replace the individual beamline elements.

Matrix Pieces may be used in a beamline model to replace entire beamline segments with a single R-Matrix representation for that segment.

The Output File Option in the TRANSPORT Options Window that causes TRANSPORT to generate the transverse matrix components in millimeters and milliradians does not effect the R-Matrix Window, which will always display the matrix data in meters and inverse meters.

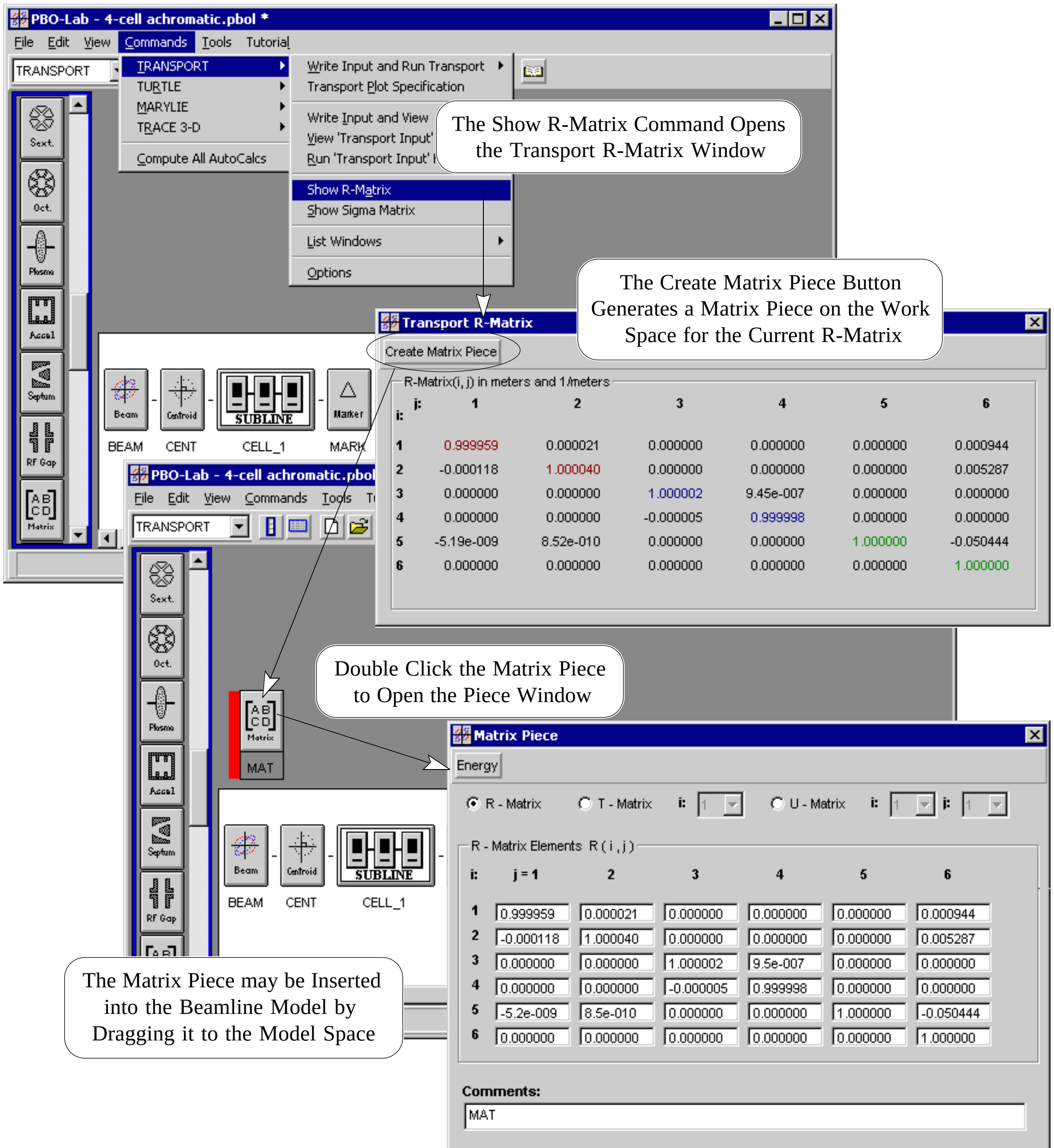

Figure 31. Creating a Matrix Piece from the Transport R-Matrix Window.

Show Sigma Matrix

The Show Sigma Matrix Command in the TRANSPORT Commands Menu opens the Output Sigma-Matrix Window as illustrated in Figure 32. This window displays the Output Sigma-Matrix (Beam Matrix) at the end of the beamline from the last TRANSPORT run executed.

The Show Sigma-Matrix Command displays the Sigma-Matrix for the last execution of TRANSPORT.

There are no specific option settings required to generate the data for the Sigma-Matrix Window. However, the Show Sigma-Matrix Command will be inactive if TRANSPORT has not been executed. An unlimited number of Matrix Windows may be left open for comparing results from multiple TRANSPORT runs.

There are two panels in the Output Sigma-Matrix Window. The top panel shows the TRANSPORT Reduced Sigma-Matrix and the bottom panel shows the full Output Sigma-Matrix in units of meters and radians. The first column of the Reduced Sigma-Matrix display, labeled: Diagonal, represents the half widths of the beam ellipsoid in each of the six beam coordinates. The remaining elements represent the correlation coefficients between coordinates.

Refer to the "TRANSPORT User Manual" for a description of the Sigma Matrix and Reduced Sigma Matrix formulation.

Creating a Beam Piece

The Button Bar at the top of the Sigma-Matrix Window provides an option for creating a PBO Lab Beam Piece from the TRANSPORT Output Sigma-Matrix data. The Create Beam Piece button will generate a new Beam Piece and place it on the Work Space of the Document Window as illustrated in Figure 32. The Beam Piece Parameters will be generated for the Sigma Matrix data and Phase Space Ellipse Plots will be displayed in the Beam Piece Window. The Beam Piece can be used in the beamline model or simply left on the Work Space for comparison with subsequent TRANSPORT runs.

The Sigma-Matrix Window provides a button for creating a PBO Lab Beam Piece from the TRANSPORT Output Sigma-Matrix data.

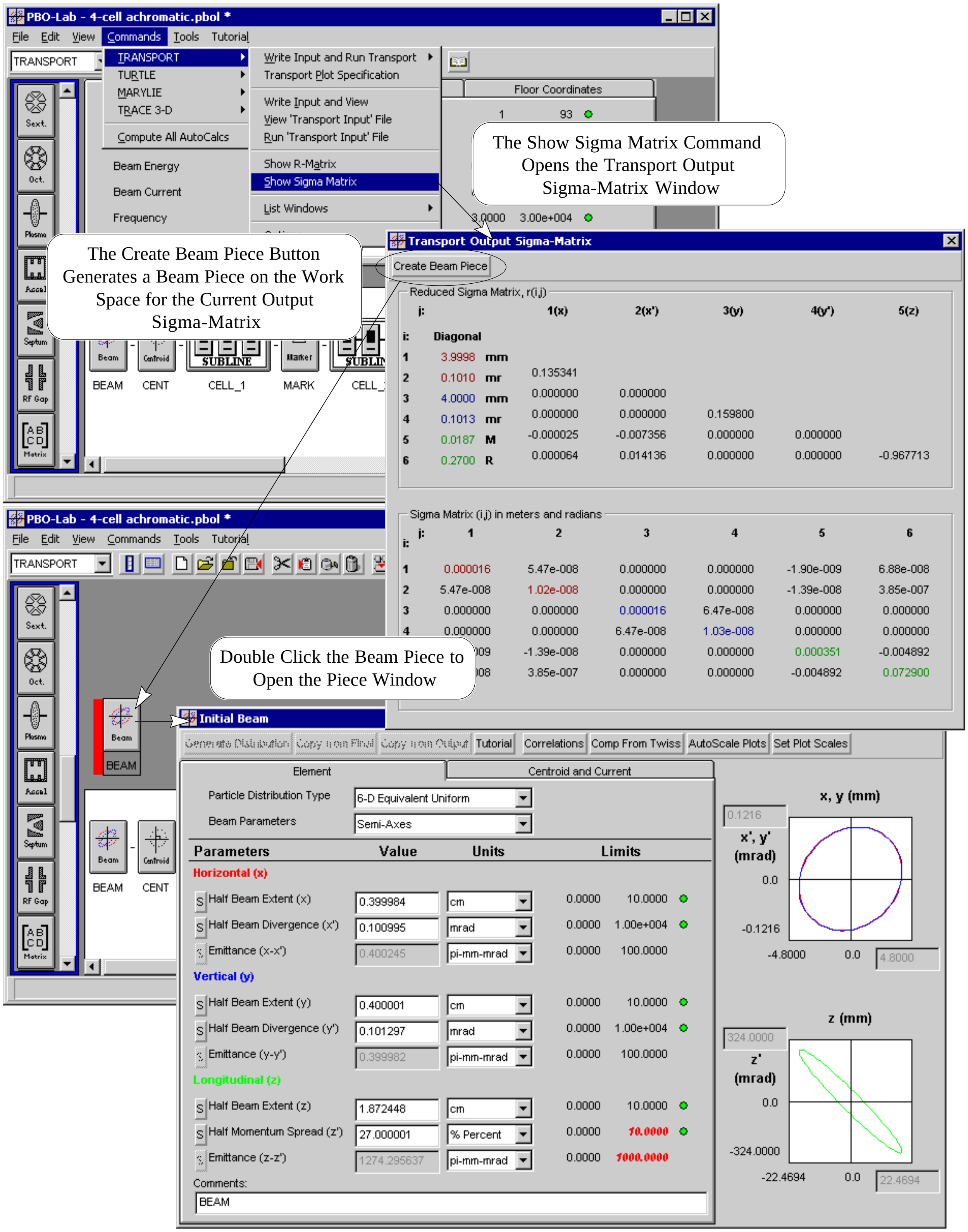

Figure 32. Creating a Beam Piece from the Output Sigma Matrix Window.

Make Matrix Piece Command

The Make Matrix Piece Command is used to create a Matrix Piece for a selection of pieces in the beamline model. Using a single Matrix Piece to replace a static beamline segment that contains many pieces can significantly speed up calculations for large models. This command is similar to using the Create Matrix Piece button in the Show R-Matrix Window. However, this command operates on a selection of pieces in the beamline model, unlike the R-Matrix Window button, which always creates a Matrix Piece for the entire beamline. The Make Matrix Piece Command in the Commands Menu is also different because TRANSPORT is automatically executed to compute the R-Matrix for the beamline model selection. When creating a Matrix Piece from the Show R-Matrix Window, the R-Matrix data from the last TRANSPORT execution is always used. Refer to the Show R-Matrix Section in this Chapter.

The Create Matrix Piece Command is used to create a Matrix Piece for a selection of pieces in the beamline model.

A Matrix Piece can also be created for the entire beamline model from the R-Matrix Window. Refer to the Show R-Matrix Section in this Chapter.

To create a Matrix Piece with the Make Matrix Piece Command, first make a selection of pieces in the beamline model and then select the Make Matrix Piece Command in the TRANSPORT Commands Menu. TRANSPORT will be executed to calculate the R-Matrix for the beamline selection. A Matrix Piece will automatically be generated and placed in the lower left corner of the Work Space as illustrated in Figure 33. The Matrix Piece can then be used to replace the original beamline selection in the Model Space.

To create a Matrix Piece first make a selection of pieces in the beamline model and then select the Make Matrix Piece Command in the TRANSPORT Commands Menu.

The original selection of pieces in the beamline model that are used to create the Matrix Piece are not changed or replaced automatically. Drag a copy of the original selection to the Work Space before deleting these pieces in the beamline because they can not be re-generated from the corresponding Matrix Piece. The Matrix Piece can then be placed in the beamline at the location of the original pieces. This command can also be used to generate an R-Matrix through a specific location in the beamline model for comparison with other results.

The original selection of pieces in the beamline model that are used to create a Matrix Piece are not modified. The Matrix Piece will appear on the Work Space and can then be used to replace the original selection in the beamline model.

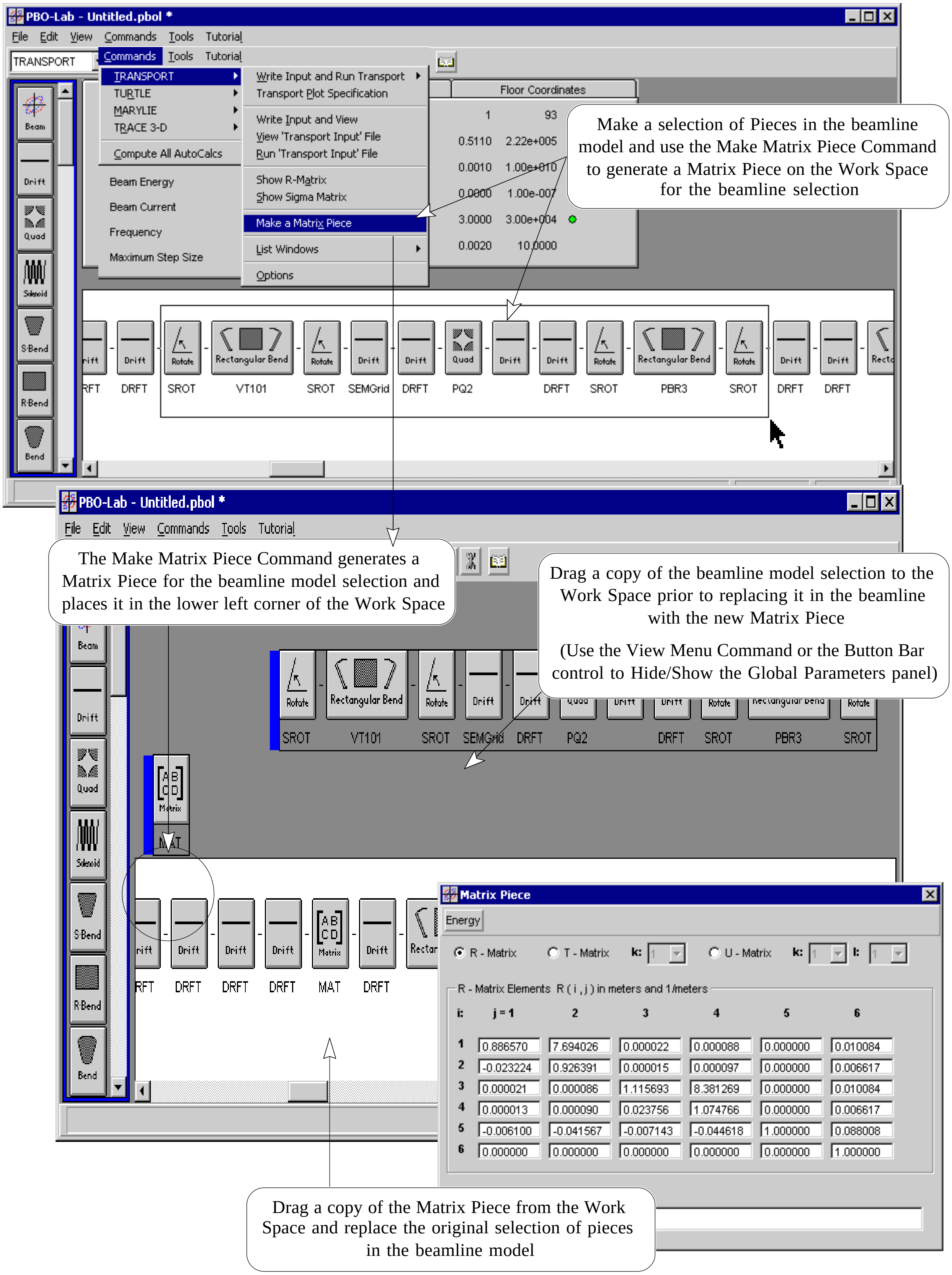

Figure 33. Creating a Matrix Piece for a Beamline Selection.

PBO Lab provides an Output File Option in the TRANSPORT Options Window that causes TRANSPORT to generate the transverse matrix components in millimeters and milliradians. This mixed units representation will only appear in the Transport Output File when this option is selected. The Matrix Piece Window will always display the matrix data in meters and inverse meters regardless of the TRANSPORT Output File Option.

The Matrix Piece Window displays the transfer matrices in units of meters, radians and inverse meters, radians regardless of units selection for the Output File in the TRANSPORT Options Window.

The Matrix Piece Window is described in more detail in the Matrix Piece Section of Chapter 3: Beamline Elements.

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PBO Lab™ 2.0

TRANSPORT Options

User Manual Supplement: TRANSPORT Application Module

7. TRANSPORT Options

PBO Lab provides several options for specifying parameters which direct TRANSPORT to write data to the Output and Punch files. TRANSPORT options also include parameters for setting the Calculation Order and Output Result for TRANSPORT runs. The Options Window is accessed with the last item in the TRANSPORT Commands menu as illustrated in Figure 34.

All of the TRANSPORT Options are saved with the beamline model in the Document Window when a Save, or a Save As command is executed.

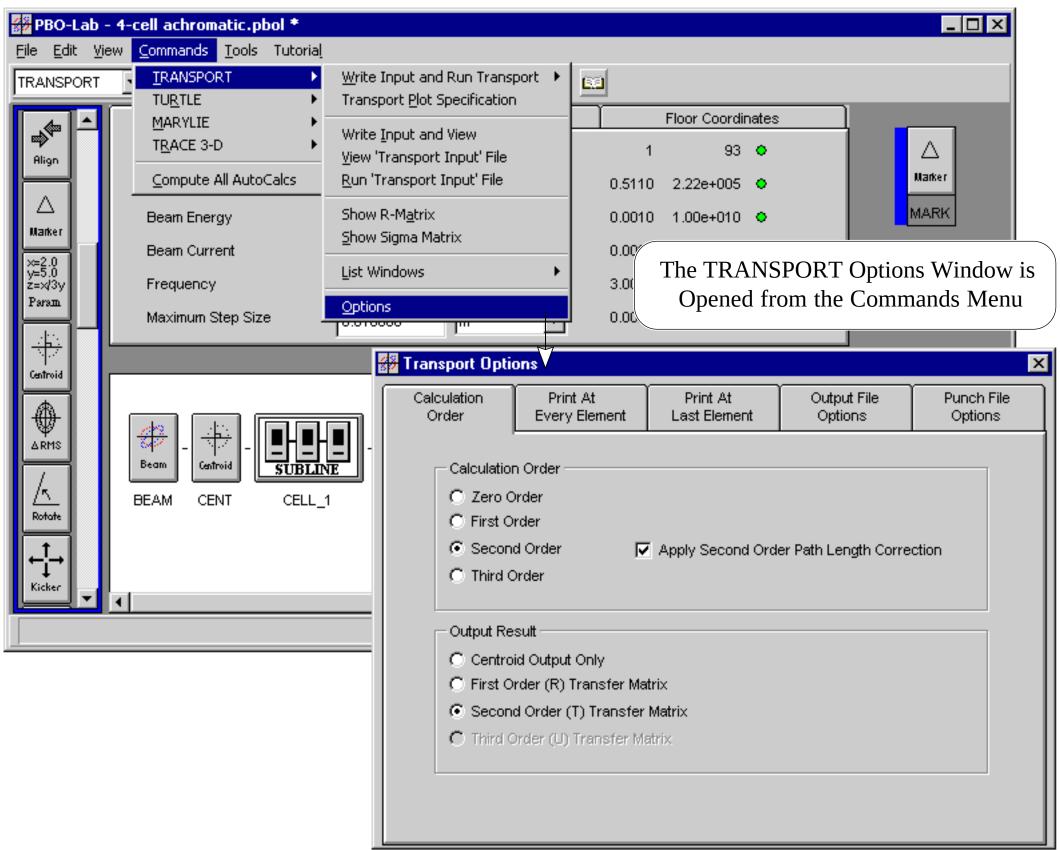

Figure 34. Opening the TRANSPORT Options Window.

TRANSPORT Options are presented in a single window with multiple tab panels for (1) calculation order and output result, (2) printing matrices after every beamline element, (3) printing matrices after the last element, (4) various format options for the Transport Output file, and (5) printing matrices to the Transport Punch file. All of the TRANSPORT Options are saved with the model file using the Save or Save As commands in the File Menu.

TRANSPORT output may also be specified at specific locations in the beamline using Marker Pieces as described in the previous Section.

Calculation Order & Output Result

The TRANSPORT Calculation Order and Output Result are set in the TRANSPORT Options Window.

The TRANSPORT Application Module integrated with PBO Lab can model optics problems up to the third order. The first tab panel in the TRANSPORT Options Window illustrated in Figure 35, is used to set up the Calculation Order and the Output Result matrices for TRANSPORT.

The Calculation Order represents the order to which the transfer matrices are calculated about the reference trajectory. Calculating to Zero Order simply traces the beam centroid through the beamline elements. Tracing the beam centroid has meaning only when the beam centroid is displaced from the reference trajectory with a Centroid Piece after the Beam Piece in the beamline model. The Output Result selection determines the Order of the transfer matrix to be written to the Transport Output and Transport Punch files.

The order of the Output Result can not be higher then the Calculation Order.

The options in the Order of Calculation Window are saved with the Document using the Save or Save As commands.

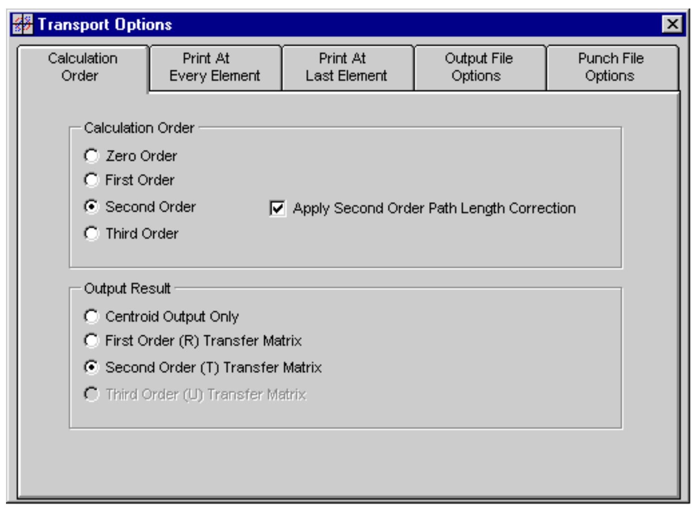

Figure 35. Calculation Order and the Output Result.

The Order of the Output Result can not be higher then the Order of Calculation. Output Result options higher than the specified Calculation Order will be inactive.

The Calculation Order tab panel also includes a check box to specify the use of a second-order path length difference correction. This second-order path length correction option corrects a long standing calculation error in TRANSPORT that has only recently been identified. The error involves the second-order path length difference for beamlines that use radiofrequency (RF) accelerator elements. The second-order path length option corrects this historical error in TRANSPORT. Transverse results for magnetic systems will be identical to the original TRANSPORT. However, for beamlines with RF accelerator elements the new path length correction will change (correctly) the second-order transverse results.

This correction only applies to the second-order path length with second or third-order calculations. The path length correction is on by default.

Print Options

The tab panels illustrated in Figure 36 may be used to specify Print Options at the end of the beamline model or after every piece in the model. However, it is also possible to specify output at specific locations in the beamline using the Marker or Final Pieces.

The Marker and Final Pieces may be used to specify output at specific locations in the beamline. Refer to the Marker Piece Section in the Beamline Elements Chapter.

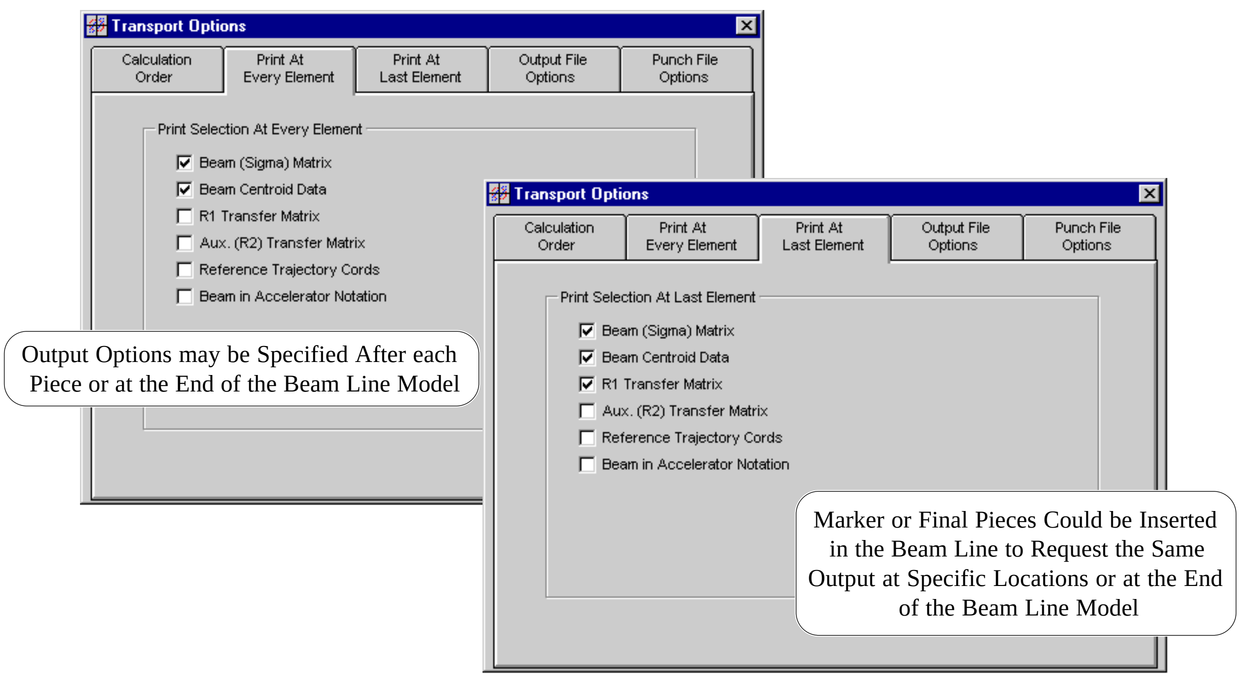

Figure 36. Specifying Output after every Piece or at the end of the Model.

Output and Punch File Options

The TRANSPORT Options Window is also used to set up several parameters for specifying and formatting data to be written to the Transport Output file and to the Transport Punch file. In addition, the Output File Options tab panel includes several options for generating Auxiliary files.

The Output File Options tab panel, shown in Figure 37, includes two options panels, one for Transport Output File Options and another for selecting among a variety of Auxiliary Files that can be generated from TRANSPORT. The File Options panel provides selections that effect the content and format of the Transport Output file. The Transport Output file is the native text file generated by TRANSPORT and displayed by PBO Lab automatically after TRANSPORT is executed. The options provided are those most frequently encountered by TRANSPORT users. Note that the Output File Options effect the Transport Output file only, not other PBO Lab display windows.

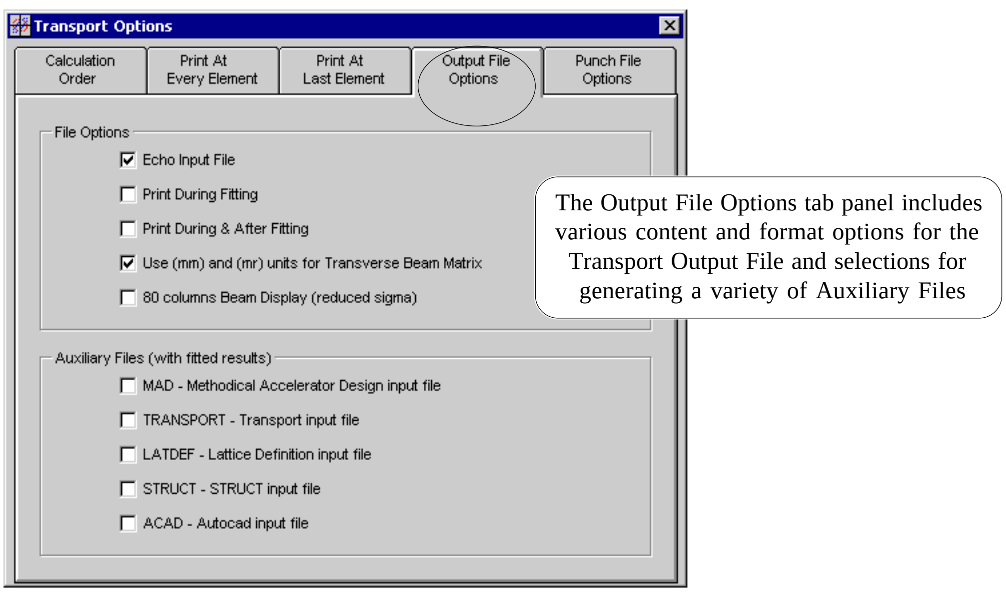

Figure 37. TRANSPORT Output File Options and Auxiliary Files.

The Auxiliry Files panel includes several different input files that can be generated by TRANSPORT for the beamline model in the Document Window.

The different Auxiliary files that can be generated include: (1) Methodical Accelerator Definition (MAD) input file, (2) TRANSPORT input file (created by TRANSPORT, not PBO Lab), (3) Latice Definition (LATDEF) input file, (4) STRUCT input file, and (5) Autocad input file. These files will be generated when TRANSPORT is executed for the corresponding selections in the Auxiliary Files panel. Once these files are generated, they can be viewed in Text Edit Windows using the PBO Lab View Menu commands in the Document Window. Refer to the TRANSPORT View Menu Section in Chapter 5: TRANSPORT Menus. All of the files use “Auxiliary.tout” as a root name with their own extensions appended to the end. For example if the MAD option is selected, a file named “Auxiliary.tout.mad” will be generated. If a file of the same name exists when a new file is generated then it will be overwritten with the new file.

Refer to the “TRANSPORT User Manual” for a description of the Auxiliary files that can be generated.

The Punch File Options tab panel, shown in Figure 38, provides options for writing transfer matrices to the Transport Punch file. The Punch file is a secondary data file generated by TRANSPORT that can be viewed in Text Edit Windows using the PBO Lab View Menu commands for TRANSPORT. As with the other TRANSPORT I/O files, the data will be overwritten each time TRANSPORT is executed. You can save previously generated output by using the Save As command in the File Menu of the Text Edit Windows used to view the files.

The Punch File Options tab panel provides options for writing transfer matrices to the Transport Punch file.

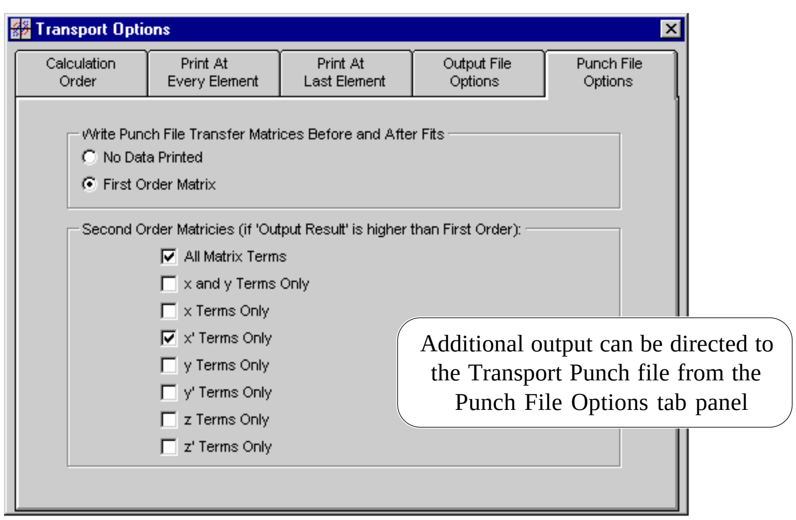

Figure 38. TRANSPORT Punch File Options.

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PBO Lab™ 2.0

TRANSPORT Plot Specifications

User Manual Supplement: TRANSPORT Application Module

8. TRANSPORT Plot Specifications

The Transport Plot Specification Window is used to define the type of plot data that will be generated by TRANSPORT and the Graph Plot Window that will be displayed by PBO Lab after TRANSPORT is executed. Figure 39 shows the window that is brought up when the Transport Plot Specification Command is selected in TRANSPORT Commands Menu.

Any Plot Specifications will be saved with the beamline model when the Save, or Save As, command is selected in the Document Window.

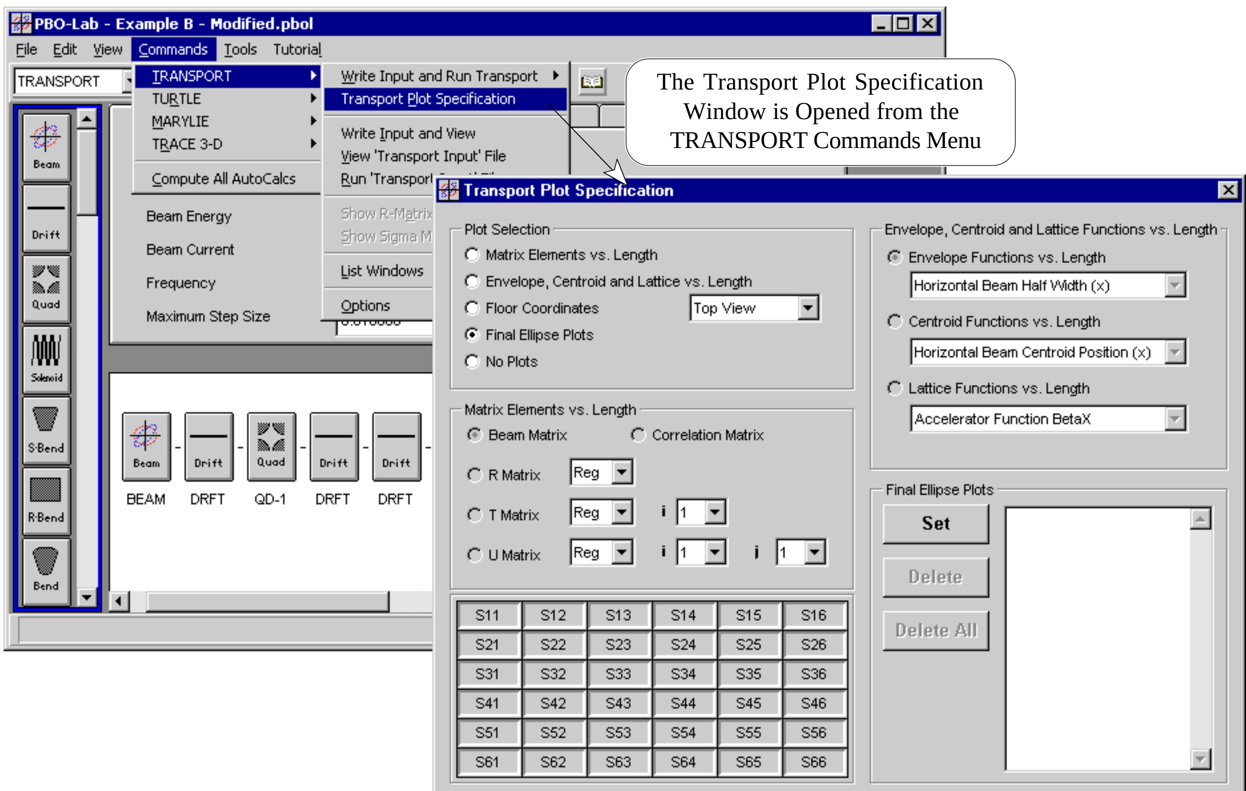

Figure 39. Opening the Transport Plot Specification Window.

The Plot Specification Window is used to set up a variety of different graphic output plots. TRANSPORT can only generate data for one plot type in a given run, so one of the available plot types must be selected using the radio buttons in the Plot Selection panel in the upper left corner of the window. Four plot types are available: (1) Matrix Elements vs. Length, (2) Envelope, Centroid and Lattice functions vs. Length, (3) Floor Plots, (4) Final Ellipse Plots, or No Plots.

In order to activate the Plot Selections panel so a different plot type can be selected, all plot variables for the current plot type must be cleared with the Delete All button.

The Matrix Elements vs. Length selection uses the matrix controls to select specific matrix elements (Figure 40). The Envelope, Centroid and Lattice functions vs. Length panel is used when the Plot Selection is set for this plot type. The Floor Plot type has an adjacent pop-up to specify Side View or Top View. The Final Ellipse Plot type and No Plot selections require no additional user input. The last panel in the lower right corner of the Plot Specifications Window is used to select up to four different plot variables for both the Matrix Elements vs. Length and Envelope, Centroid and Lattice functions vs. Length plot types.

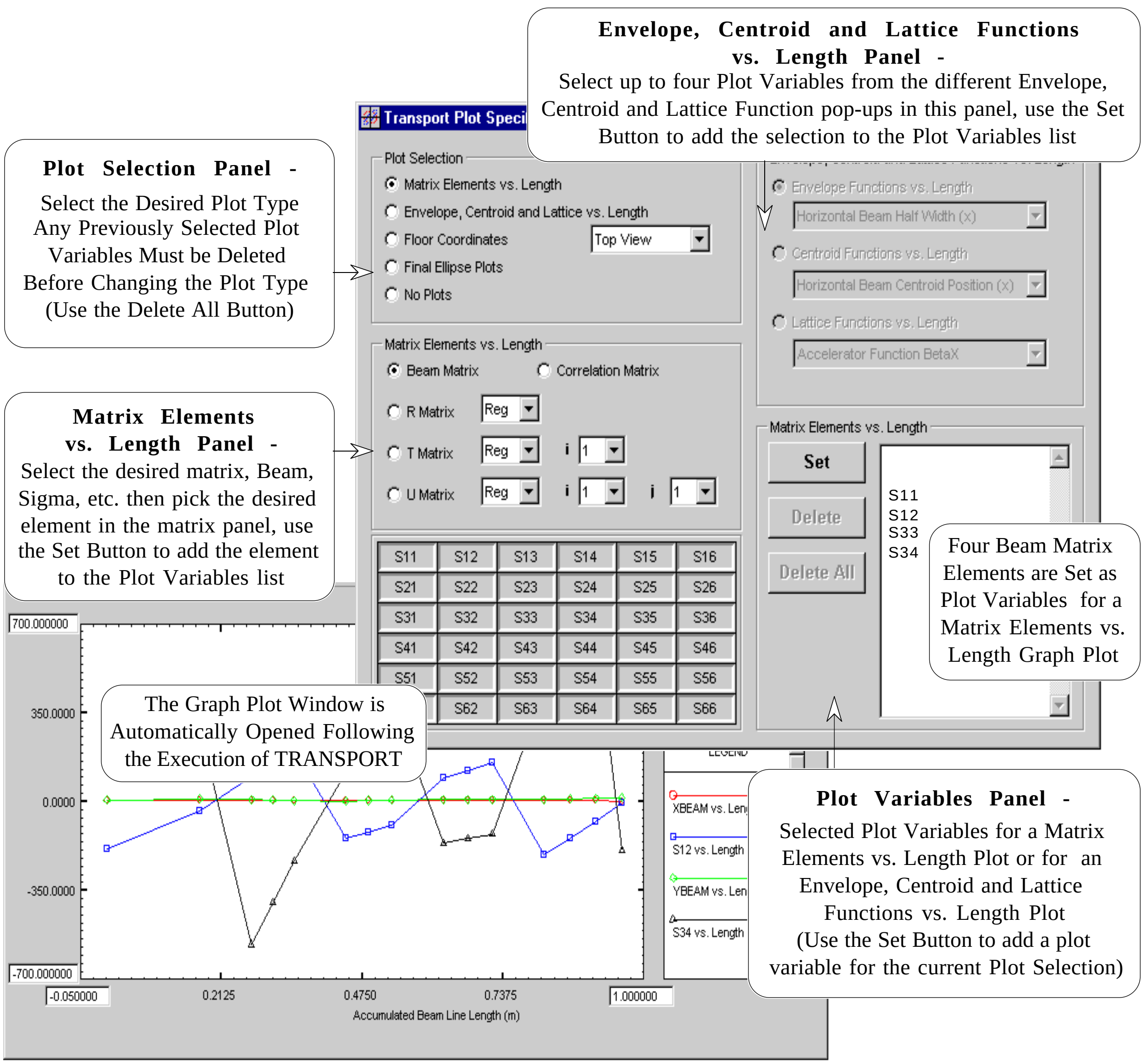

Figure 40. Transport Plot Specifications Window.

The last plot type in the Plot Selection panel is for no plots. This is the default plot type. When a new untitled Document is created the No Plots option is selected. Plot data will not be generated and a Graph Plot window will not be opened following the execution of TRANSPORT.

The following Sections describe each of the Plot Selections types separately. A description of the different features available in the PBO Lab Graph Plot Windows can be found in the main PBO Lab User Manual. The TRANSPORT keywords that are used to generate plot data are listed in Table 6.

Plotting Matrix Elements vs. Length

When choosing to plot Matrix Elements vs. Length, as many as four different matrix elements may be selected for an individual Graph Plot. The Matrix elements may be selected from: (a) R_{ij}, First-Order Transfer Matrix, (b) RA_{ij}, Auxiliary First-Order Transfer Matrix, (c) T_{ijk}, Second-Order Transfer Matrix, (d) TA_{ijk}, Auxiliary Second-Order Transfer Matrix, (e) U_{ijkl}, Third-Order Transfer Matrix, (f) UA_{ijkl}, Auxiliary Third-Order Transfer Matrix, (g) Beam Matrix, and (h) Correlation Matrix. The Matrix Elements panel in the lower left corner of the Plot Specification Window is active only when the Matrix Elements vs. Length radio button is selected in the Plot Selection panel (Figure 40).

To select a matrix element, first chose the radio button in the Matrix Elements vs. Length panel for the desired transfer matrix: R-Matrix, T-Matrix, U-Matrix, Beam Matrix or Correlation Matrix. The R and T Matrix selections also provide a pop-up to select between the Regular Matrix or the Auxiliary Matrix. The T-Matrix selection requires an additional selection to specify the i index, and the U-Matrix requires both i and j indices to be specified. This is done with the pop-ups to the right of the Matrix radio buttons. The 6x6 matrix table at the bottom of the Matrix Elements panel is then used to select individual matrix elements.

Clicking in a cell of the matrix table will highlight that cell and the selection can then be added using the Set button.

Clicking in a cell of the matrix table will highlight that cell and the selection can then be added using the Set button. After a selection is made, the corresponding TRANSPORT keyword (Table 6) will appear in the plot variable list in the lower right corner of the Plot Specification Window (Figure 40). Selections can also be removed from the list; first highlight the item to be removed by clicking on it, then press the Delete button. The Delete All button clears all plot variables from the list.

Table 6 shows the TRANSPORT Keywords that can be used for Plot Specifications.

When a plot selection is made, the TRANSPORT keyword will appear in the Plot Variable panel in the lower right corner of the Plot Specification Window.

Table 6. TRANSPORT Keywords.

Beam & Correlation:		Beam	Correlation
i, j, k & l = 1,6		S_{ij}	C_{ij}
Transfer Matrices:		Regular	Auxiliary
First-Order		R_{ij}	RA_{ij}
Second-Order		T_{ijk}	TA_{ijk}
Third-Order		U_{ijkl}	UA_{ijkl}
Beam Envelopes:		Half Width	Half Angle
Horizontal		XBEAM	XPBEAM
Vertical		YBEAM	YPBEAM
Longitudinal		LBEAM	DELBEAM
Beam Centroids:		Position	Angle
Horizontal		XC	XPC
Vertical		YC	YPC
Longitudinal		DLC	DELC
Lattice Functions:		Horizontal	Vertical
β_x	β_y	BETAX	BETAY
α_x	α_y	ALPHAX	ALPHAY
η_x	η_y	ETAX	ETAY
η'_x	η'_y	DETAX	DETAY

Plotting Envelope, Centroid and Lattice Functions vs. Accumulated Length

The Envelope, Centroid and Lattice Functions vs. Length panel in the upper right corner of the Plot Specification Window is active only when the corresponding radio button is selected in the Plot Selection panel.

Only one of the three options (Envelopes, Centroids or Lattice Functions) can be chosen at a time. First select one of the radio buttons and then make a selection from the corresponding pop-up (Figure 41). Up to four selections can be set for a given option by choosing the desired pop-up item and pressing the Set button. Use the Delete or Delete All buttons to removed a selected variable or clear all the plot variables from the list.

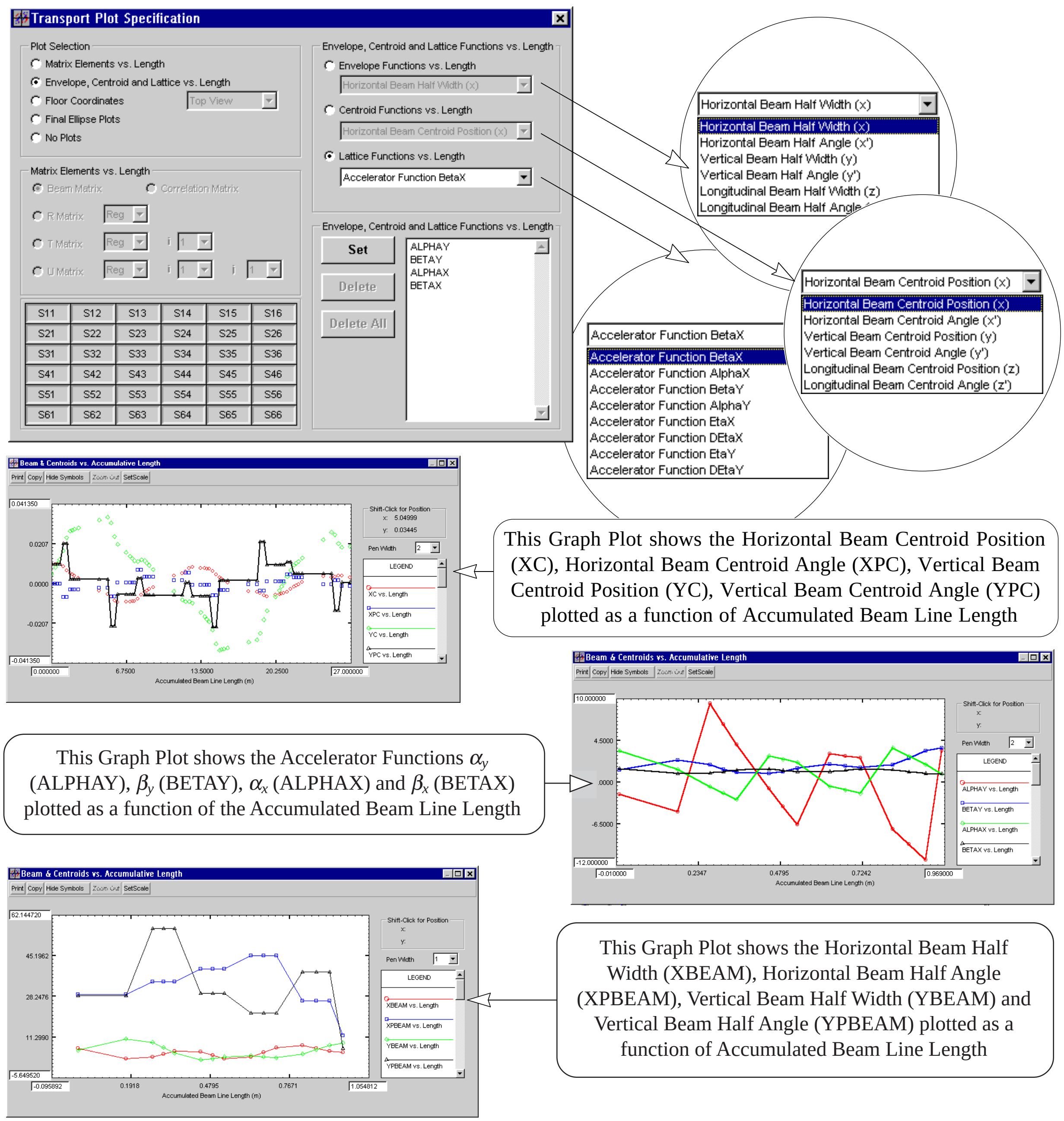

Figure 41. Beam Envelopes, Beam Centroids and Lattice Functions.

Plotting Floor Coordinates

Floor plots can also be generated using the PBO Lab Tools for Focusing and Bending Trajectories in the Tools Menu.

This plot type is used to generate top and side view Graph Plots for floor coordinates of the reference trajectory. The pop-up to the right of the Floor Coordinates radio button is used to select between top and side views. There is no additional input required in the Plot Specification Window. However, included with the Global Parameters in the Document Window are a set of Initial Floor Coordinate Parameters (Figure 4). These are used to specify the initial coordinates and the orientation of the reference trajectory for plotting floor coordinates.

Plotting Final Ellipses

You may need to clear previously selected plot variables with the Delete All button, in order to activate the Plot Selection radio buttons.

This plot type is used to generate horizontal and vertical Transverse Phase Space Ellipse Plots for the end of the beamline. There are no additional inputs required for this plot type, simply choose the Final Ellipse Plots radio button in the Plot Selection panel (Figure 39). A Final Ellipse Graph Plot Window (Figure 42) will be opened automatically after running TRANSPORT.

Example of a Phase Space Ellipse Plot (XP vs. X and YP vs. Y)

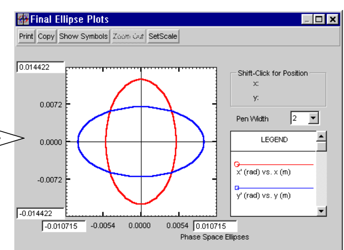

Figure 42. Phase Space Ellipse Plot.

Graph Plot Windows

A Graph Plot window is automatically opened, for the Transport Plot Specifications selected when the Write Input & Run Transport command is issued.

The selected Transport Plot Specification will be automatically generated in a PBO Lab Graph Plot Window after TRANSPORT is executed. The Graph Plot Windows provide a variety of interactive features which are described in the PBO Lab User Manual. Refer to the Graph Plot Windows Section in the Analysis Tools Chapter of the main PBO Lab User Manual.

PBO Lab™ 2.0

TRANSPORT Fitting

User Manual Supplement: TRANSPORT Application Module

9. TRANSPORT Fitting

The TRANSPORT program can be used to find solutions for a wide of variety of beamline fitting problems. Fitting problems are formulated in terms of constraints and variables. Selected beamline element parameters are varied in an effort to satisfy ("fit") the constraints. Fitting constraints are algebraic expressions defined in terms of user-specified Named Parameters and Fitting Variables in the beamline model as well as a number of different TRANSPORT output parameters.

Fitting problems are formulated in terms of fitting constraints and variables. Selected beamline model parameters are varied in an effort to satisfy ("fit") the constraints.

PBO Lab provides a drag & drop - point & click user interface for setting up and running a TRANSPORT fitting problem. Fitting Constraints are specified in user friendly windows accessed from Marker or Final Pieces that can be inserted anywhere in the beamline model. Parameter Variables are specified in Special Parameter Settings Windows accessed from any Piece Window. Interactive List Windows that organize all of the Fitting Variables and Constraints for the entire beamline model are accessed from the TRANSPORT Commands Menu. Fitting Variables can be examined after fitting and the beamline model can be updated with any or all of the fit values in the Update Window which is opened automatically following the fit procedure.

Fitting Constraints can be specified with Marker or Final Pieces that can be inserted anywhere in the beamline model.

Interactive List Windows provide quick access to all of the user-specified Variables, Expressions and Constraints for the entire beamline model.

A Symbolic Parameter Name may be defined for a Piece Parameter without using it as a Fitting Variable. These Named Parameters may then be used to define Parameter Algebraic Expressions for other Piece Parameters. Parameter Expressions can also be specified in terms of user-defined Fitting Variables and TRANSPORT program variables. Refer to chapter 4: Special Parameter Settings, for a description of Symbolic Parameter Names, Parameter Expressions and selecting a Parameter as a Fitting Variable.

A Symbolic Parameter Name may be defined for a Piece Parameter without using it as a Fitting Variable.

Parameter Algebraic Expressions may be defined in terms of user-specified Named Parameters and/or Fitting Variables.

Refer to the Special Parameter Settings Section in Chapter 4 of this Supplement.

This Chapter describes the user interface for setting up a TRANSPORT fitting problem. The "TRANSPORT User Manual" describes specific fitting capabilities of the program in more detail.

Fitting Variables

Fitting Variables are selected in Special Parameter Settings windows that are opened with the Special ("S") button to the left of most parameters in PBO Lab Piece Windows.

A Fitting Variable that has a Symbolic Parameter Name identical to a Piece Comment will also result in the first parameter (regardless of name) for that Piece to be varied.

Many of the input parameters for the various beamline elements can be selected by the user as TRANSPORT Fitting Variables. Fitting Variables are selected in Special Parameter Settings Windows that are opened with the Special ("S") button to the left of most parameters in PBO Lab Piece Windows. Figure 43 illustrates selecting the Magnetic-Field Gradient parameter in a Quadrupole Piece Window; pressing the "S" button opens the Special Parameter Settings Window for the associated parameter. The second radio button in the TRANSPORT tab panel of the S-Window, selects the parameter as a TRANSPORT Fitting Variable using the Parameter Name specified at the top of the window.

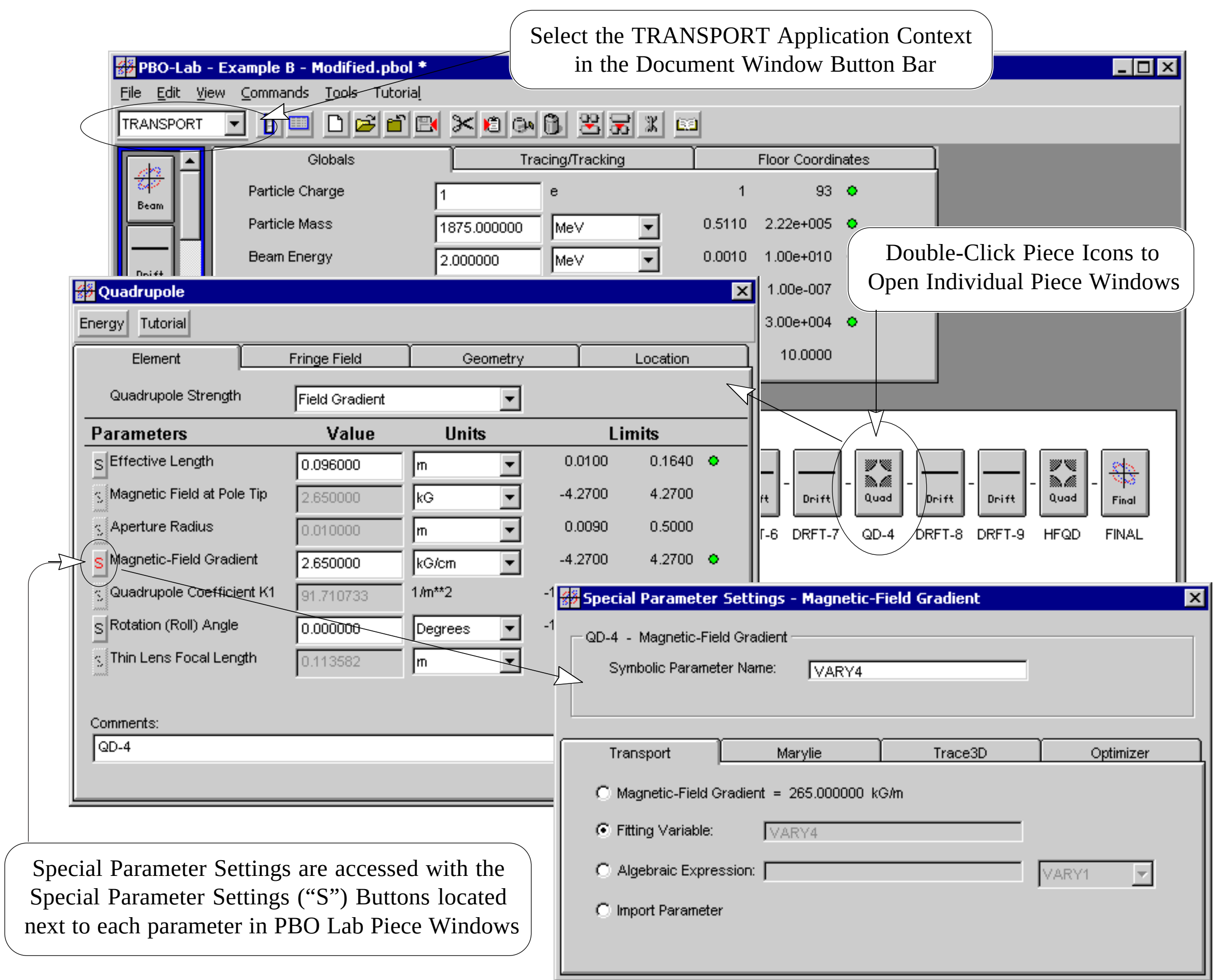

Figure 43. Opening a Special Parameter Settings Window.

Transport Fitting Variables must be native inputs to TRANSPORT in order to be varied during fitting. Green dots appear next to "native" TRANSPORT parameters in Piece Windows when the Application Context is set for TRANSPORT as illustrated in Figure 43. The S-Buttons will be inactive for those parameters without green dots. Native (green dot) parameters that do not support special parameter settings will not have a Transport tab panel in the Special Parameter Settings Window.

Some (but not all) Piece Parameters may be selected as Fitting Variables and used by TRANSPORT to fit user-specified Constraint Expressions.

Many PBO Lab Pieces provide alternative parameter sets for specifying inputs for TRANSPORT. For example the Quadrupole Piece illustrated in Figure 43 can be defined in terms of three different parameter sets (selected with the Quadrupole Strength pop-up at the top of the Quad Piece Window). Depending on the users preferred set, different Piece Parameters will be used as native inputs to TRANSPORT. The green dots next to native parameters will reflect the current parameter set and only those parameters will be used as TRANSPORT inputs for the Piece. A Fitting Variable previously defined for a different parameter set will have no effect. For example, both the Magnetic Field at Pole Tip and the Magnetic-Field Gradient parameters could be selected as Fitting Variables by switching the Quadrupole Strength selection. However, only one of these parameters will be used as input for TRANSPORT (according to the current Quadrupole Strength selection), so the other will not be an input for the Quad and will not be varied during fitting.

TRANSPORT supports up to twenty (20) independent user-specified Fitting Variables.

The green dots next to Piece Parameters reflect the current Application Context and the users parameter set selection. Only green dot parameters will be used as TRANSPORT input for the Piece.

The example illustrated in Figure 43 shows the Magnetic-Field Gradient defined by the Symbolic Parameter Name "VARY4". This parameter has been selected as a Fitting Variable in the Transport tab panel of the S-Window. Fitting Variables are always defined by the application-independent Symbolic Parameter Name specified in the S-Window. If a name has not been specified it will be generated when the Fitting Variable selection is made in the TRANSPORT tab panel.

All special parameter settings are saved with the beamline model when using a Save, or Save As, command.

A Parameter Name may be defined for use in an Parameter Algebraic Expression without selecting the Parameter as a Fitting Variable.

A Piece Parameter may be varied or it may be defined by an expression, but not both.

The Symbolic Parameter Names can also be used in Algebraic Expressions specified for other Piece parameters as described in the Parameter Algebraic Expressions Section of Chapter 4: Special Parameter Settings. During a fitting procedure, Algebraic Parameter Expressions are evaluated at each iteration. After fitting has completed, the new values for all of the Fitting Variables and Parameter Algebraic Expressions can be used to update the beamline model.

Alias Pieces can also be used to couple multiple beamline elements for a fitting problem.

Alias Pieces can also be used to couple multiple beamline elements during a fitting procedure. Refer to the Aliases Section in the User Interface Chapter of the main PBO Lab User Manual, for a description of Alias Pieces.

Creating a copy of a Piece with Special Parameter Settings, either with the cut/copy/paste commands or by simply dragging a copy to the work space, will also copy the Special Parameter Settings from the original Piece to the duplicate.

Creating a copy of a Piece with Special Parameter Settings will also copy those settings. For example if a Piece Parameter has been selected as a Fitting Variable and that Piece is copied in the beamline, then there would be two parameters defined by the same Parameter Name. Both instances of the Parameter Variable will be sent to TRANSPORT but the initial value for the first Fitting Variable encountered will be used for any other Variables in the beamline that have the same Parameter Name. Copying Pieces that have Parameter Algebraic Expressions will duplicate those expressions on the copied Piece but otherwise present no difficulties.

Using a Symbolic Parameter Name that is identical to a Piece comment may cause unintended results.

A Piece with a Comment that is the same as any Symbolic Parameter Name selected as a Fitting Variable can cause the first parameter of that Piece to be varied. This may be unintended. To avoid this, make sure that no Symbolic Parameter is used as a Piece Comment.

Named Parameters List Window

All of the Piece Parameters in the beamline model and on the Work Space that have been given Symbolic Parameter Names will be listed in the Named Parameter List Window. Named Parameters that are selected as Fitting Variables are indicated with an “X” in the Fit column of the Named Parameters List Window as illustrated in Figure 44.

Any Parameter with a Symbolic Parameter Name will be included in the Named Parameters List Window. Fitting Variables are indicated with an “X” in the Fit column of the Named Parameters List Window.

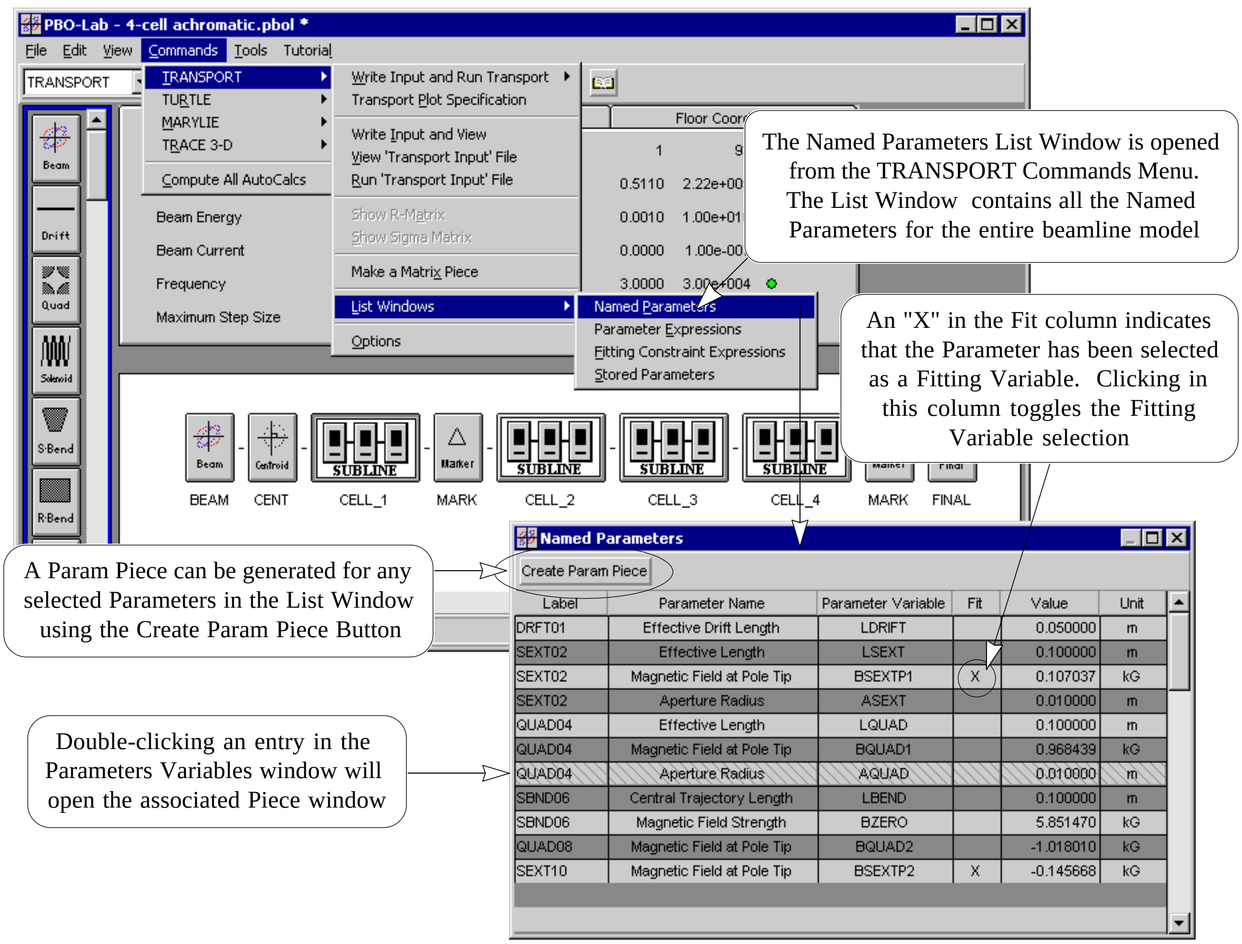

Figure 44. Named Parameters List Window.

Named Parameters can be easily selected (and unselected) as Fitting Variables by clicking in the “Fit” column of the List Window. A Param Piece can be created for selected parameters in the List Window by using the Create Param Piece Button. Refer to the Parameters and Expressions List Windows Section in Chapter 4: Special Parameter Settings.

Refer to the Parameters and Expressions List Windows Section in Chapter 4: Special Parameter Settings.

Fitting Constraints

Marker and Final Pieces

The Marker and Final Pieces are used to define application-specific Fitting Constraints and Diagnostics at specific beamline locations.

TRANSPORT Fitting Constraints are defined as location-specific algebraic expressions of user-specified Named Parameters and Fitting Variables, as well as a variety of TRANSPORT output parameters. Multiple Fitting Constraint Expressions may be defined for different locations in the beamline model.

Fitting Constraints are defined at user-specified locations in the beamline model using Marker or Final Pieces. Drag a Marker or Final Piece from the Palette Bar and insert it at the desired location in the beamline model. Open the Marker Piece Window by double-clicking the Piece icon as illustrated in Figure 45.

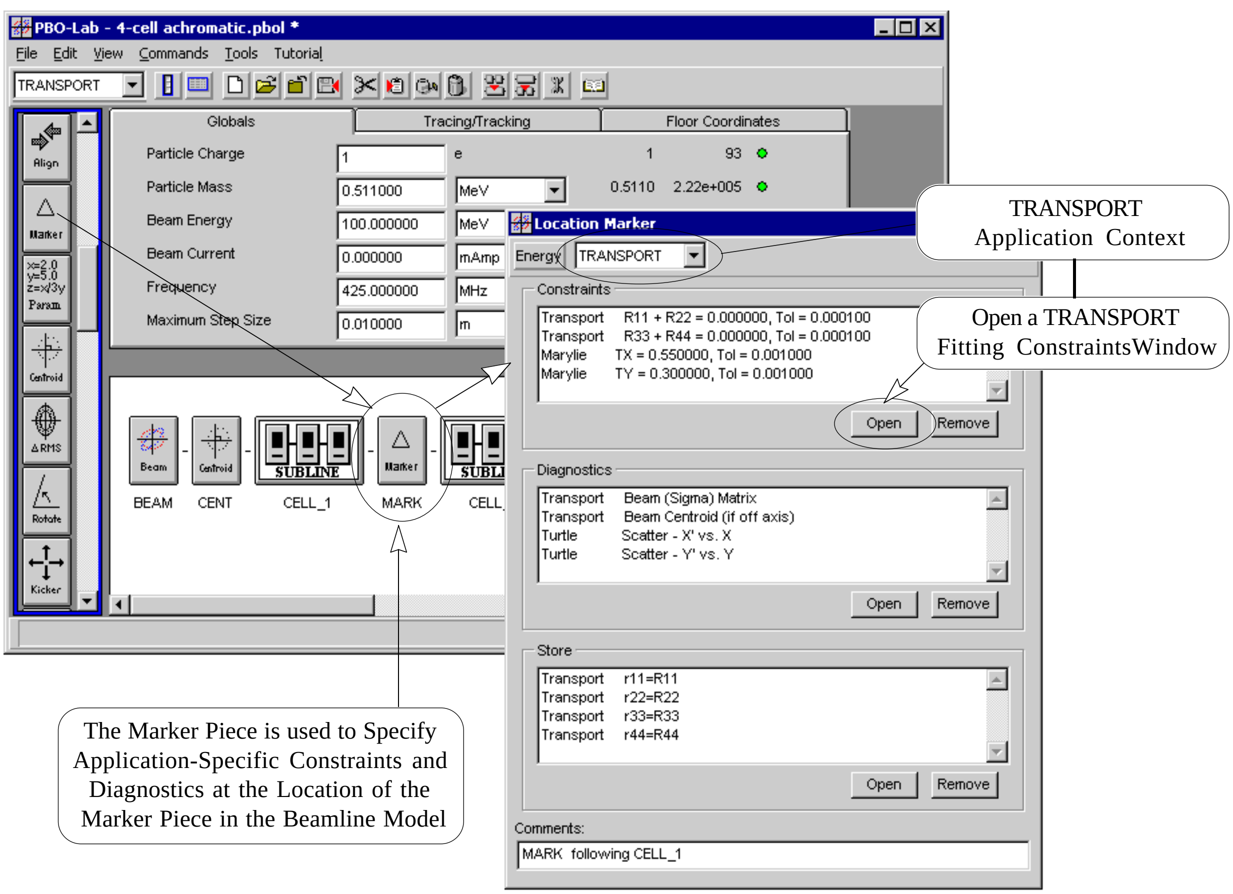

Figure 45. Marker and Final Pieces are used to mark locations in the beamline for specifying TRANSPORT Fitting Constraints.

A Marker Piece is used to define application-specific Constraints, Diagnostics and Stored Parameters that are dependent on a specific location in the beamline model. A Marker Piece can be used by all installed Application Modules and therefore depends on the current Application Context. The Application Context can be changed in the Document Window or directly in the Marker Piece Window as illustrated in Figure 46. Refer to the Marker Piece Section in Chapter 3:Beamline Elements for a description of using the Marker and Final Pieces.

The Open buttons in the Marker Piece window use the Application Context to open the appropriate application-specific user interface window.

The Constraints panel of the Marker Piece Window contains a list of all the specified Constraint Expressions for this location in the beamline. Each entry is preceded by the Application Module name. Making a selection in this list and pressing the Remove button will delete that entry from the list without having to open the Constraints Window.

The Constraints panel of the Marker Piece Window contains a list of all the specified Constraints for this location in the beamline model.

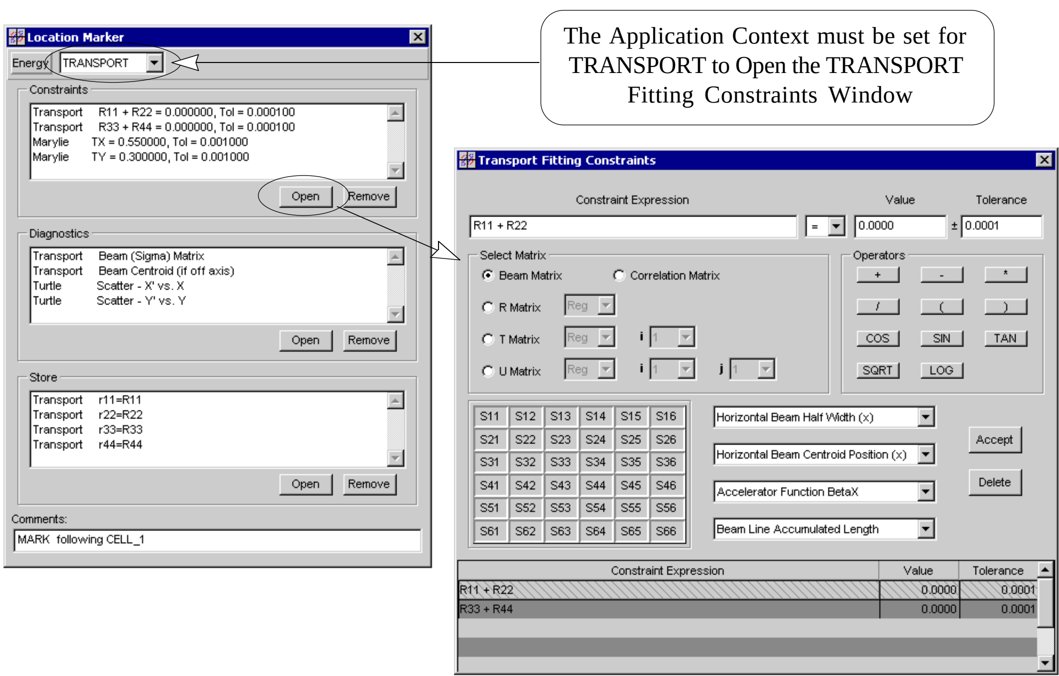

Figure 46. Marker Piece Window Constraints and Diagnostics.

With TRANSPORT as the selected Application Context in the Marker Piece Window, pressing the Open button in the Constraints panel will open the TRANSPORT Fitting Constraints Window (Figure 46).

To open the Transport Fitting Constraints Window the Application Context switch must be set for TRANSPORT.

Fitting Constraints Window

Transport Fitting Constraints Windows are accessed from Marker or Final Pieces placed in the beamline model.

A TRANSPORT Fitting Constraints Window is opened by double-clicking any Marker or Final Piece in the beamline model. The Open button in the Constraints panel of the Marker Piece Window opens the Fitting Constraints Window (Figure 46) for the current Application Context. The Application Context can be set in the Document window or directly in the Marker Piece window.

The Constraint Expression field at the top of the Fitting Constraints Window can be used to directly enter expressions defined in terms of Named Parameters, Fitting Variables as well as a variety of TRANSPORT output parameters.

The Constraint Expression field at the top of the Fitting Constraints Window (Figure 47) can be used to directly enter expressions in terms of Named Parameters, Fitting Variables and TRANSPORT output parameters. After assigning a Fit Value and Tolerance, the Accept button is used to add the Constraint to the list at the bottom of the window. Figure 47 illustrates the primary features of the Transport Fitting Constraints Window.

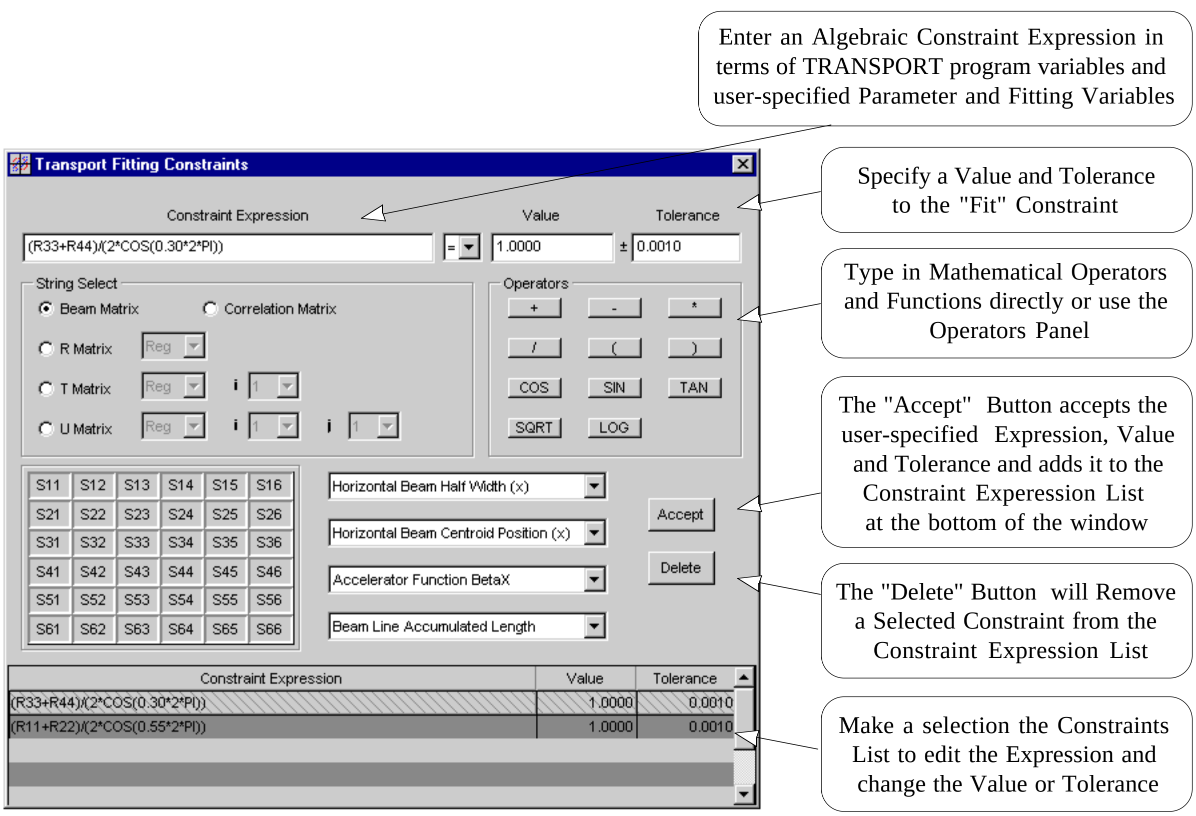

Figure 47. Transport Fitting Constraints Window.

Several TRANSPORT output parameters can be selected for use in Constraint Expressions. Table 7 lists the TRANSPORT keywords (output parameters) that are supported in Constraint Expressions. Each category in Table 7 is represented in the point & click interface of the TRANSPORT Fitting Constraints Window.

Several TRANSPORT output parameters can be selected for use in Constraint Expressions.

Table 7. TRANSPORT Keywords for use in Constraint Expressions.

Correlation Matrix (i,j =1,6)	**Keyword**
Beam Correlation Matrix Element	C ij

Beam Matrix (i,j =1,6)	**Keyword**
Reduced Sigma Matrix Element	S ij

Transfer Matrices (i,j,k,l =1,6)	**Keyword**
1st-Order Transfer Matrix Element	R ij
2nd-Order Transfer Matrix Element	T ijk
3rd-Order Transfer Matrix Element	U ijkl

Transfer Matrices (i,j,k,l =1,6)	**Keyword**
1st-Order Auxiliary Matrix	RA ij
2nd-Order Auxiliary Matrix	TA ijk
3rd-Order Auxiliary Matrix	UA ijkl

Beam Centroids	**Keyword**
Horizontal Beam Centroid Position	XBEAM
Horizontal Beam Centroid Angle	XPBEAM
Vertical Beam Centroid Position	YBEAM
Vertical Beam Centroid Angle	YPBEAM
Longitudinal Beam Centroid Position	LBEAM
Longitudinal Beam Centroid Angle	DELBEAM

Beam Envelopes	**Keyword**
Horizontal Beam Half Width	XBEAM
Horizontal Beam Half Angle	XPBEAM
Vertical Beam Half Width	YBEAM
Vertical Beam Half Angle	YPBEAM
Longitudinal Beam Half Width	LBEAM
Longitudinal Beam Half Angle	DELBEAM

Floor Coordinates	**Keyword**
Beamline Accumulated Length	L
Floor Coordinate X Value	XFLOOR
Floor Coordinate Y Value	YFLOOR
Floor Coordinate Z Value	ZFLOOR
View Reference Trajectory Angle	YAW
Reference Trajectory Horz. Angle	PITCH
Net Rotation Angle about Trajectory	ROLL
Elevation	ELEVATION

Lattice Functions	**Keyword**
Accelerator Function BetaX	BETAX
Accelerator Function AlphaX	ALPHAX
Accelerator Function BetaY	BETAY
Accelerator Function AlphaY	ALPHAY
Accelerator Function EtaX	ETAX
Accelerator Function DeltaX	DETAX
Accelerator Function EtaY	ETAY
Accelerator Function DeltaY	DETAY

The Beam Matrix, Correlation Matrix and Transfer Matrices are selected with the radio buttons shown in Figure 47. The Matrix panel in the lower left portion of the window will reflect the current matrix selection and is used to select specific matrix elements for all matrices. The pop-ups for the first-, second- and third-order Transfer Matrices are used to specify Regular and Auxiliary Matrices. The second- and third-order Transfer Matrices also have pop-ups for the additional dimensions required for these selections.

The Beam Matrix, Correlation Matrix and Transfer Matrices are selected with radio buttons; the Matrix panel in the lower left portion of the window is used to select specific matrix elements for all matrices.

Any keyword for a TRANSPORT output parameters including matrix elements, may be typed directly in the Constraint Expression field. For example "T346" would be entered as the keyword for the second-order Transfer matrix element T3,4,6.

There are also pop-up controls, which have several selections each, for four different categories: Beam Envelopes, Beam Centroids, Lattice (Accelerator) Functions as well as Floor Coordinates and Orientation variables. You don't need to know the TRANSPORT keywords in order to formulate a Constraint Expression with TRANSPORT output parameters. Simply chose a category, either from the matrix radio buttons or the various pop-up controls. Use the matrix panel to select a specific matrix element or make a selection from one of the pop-ups; the keyword for your selection will be generated automatically in the Constraint Expression Field at the top of the window. After assigning a Fit Value and Tolerance, use the Accept button to add the constraint to the list at the bottom of the window.

The Constraint Expression list at the bottom of the window contains all of the fitting constraints defined for this location in the beamline model.

The Constraint Expression list at the bottom of the window contains all of the Fitting Constraints defined for this location in the beamline model. To select an existing Constraint Expression click on the entry in the list. The selection will be highlighted and the edit fields at the top of the window will be updated with the selection. Press the Accept button to update the expression with any changes. The Delete button is used to remove an existing constraint. Select the constraint in the Constraint Expression list and press the Delete button. A constraint can also be deleted directly from the Marker Piece window without opening the Fitting Constraints Window. Select the constraint in the constraints list in the Marker (or Final) Piece Window and then press the Remove button in the Constraint panel.

The expression list in the Fitting Constraints Window includes only the constraints for that location in the beamline. Other constraints may be specified at different locations with additional Marker or Final Pieces. All of the user-specified Fitting Constraint Expressions for the entire beamline model are organized in the Constraint Expressions List Window, which is described in the next Section.

Constraint Expressions List Window

Multiple Marker and Final Pieces can be used to specify Fitting Constraints at different locations in the beamline model. PBO Lab provides a Constraint Expressions List Window that groups all of the application-specific constraints over the entire beamline model. The Constraint Expressions List Window (shown in Figure 48) is opened from the TRANSPORT Commands menu.

PBO Lab provides a Constraint Expressions List Window that groups all of the application-specific user-specified constraints over the entire beamline model.

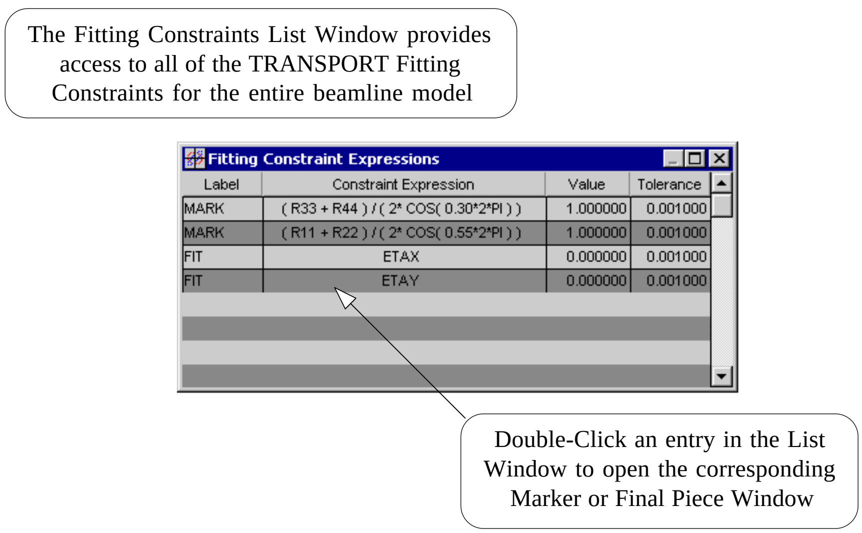

Figure 48. Constraint Expressions List Window.

This List Window provides quick access to TRANSPORT Fitting Constraints over the entire beamline. Simply double click an entry in the list to open the associated Marker or Final Piece Window. Only TRANSPORT Fitting Constraints are contained in this window. Other Applications have their own List Windows that are accessed from their respective Command Menus.

All of the user-specified Fitting Constraint Expressions for the entire beamline model are organized in the Fitting Constraint Expressions List Window.

PBO Lab List Windows may be resized to accommodate the number of entries. The columns in the List Windows may also be resized by placing the mouse over the column divider in the header of the List Window. The arrow cursor will turn into a cross-hair cursor and the column can be resized by holding down the mouse button and draging the column divider to the desired position.

List Windows may be resized to accommodate the number of entries. Column widths can also be adjusted within the List Windows.

Perform Fitting

The "Write Input and Run Transport" Command can be used to run TRANSPORT "with Fitting" or "without Fitting".

There are two options for running TRANSPORT with the "Write Input and Run Transport" Command. The Submenu for this command (Figure 49), can be used to run TRANSPORT "with Fitting" or "without Fitting". Once Fitting Variables and Constraints have been defined, the "with Fitting" option will generate the required native input to execute TRANSPORT with fitting. It is not necessary to remove Fitting Variables and Constraints from the beamline model in order to execute TRANSPORT without fitting. The only difference between the two options (with or without fitting) is that PBO Lab will not include the FIT instruction in the native TRANSPORT input if "without Fitting" is selected. Otherwise the Fitting Variables and Constraint Expressions are unchanged in the beamline model.

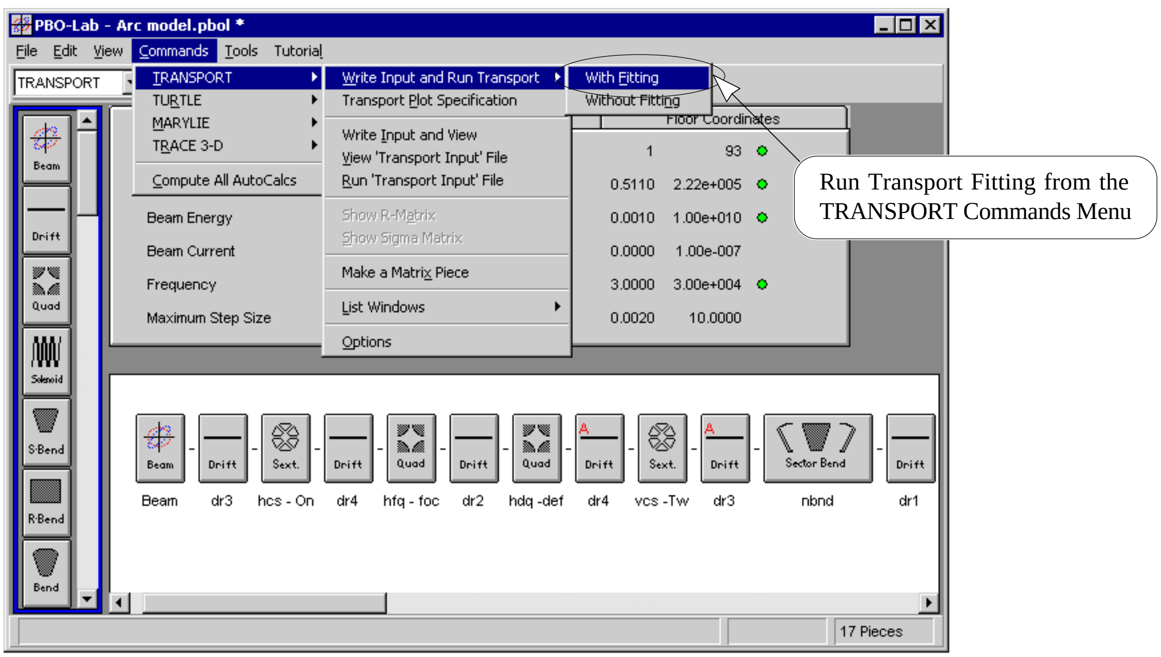

Figure 49. Execute TRANSPORT and Perform Fitting.

Output File Options in the TRANSPORT Options Window can be used to specify fitting output during and after fitting.

Output results and diagnostics for fitting are found in the Transport Output Window, which is automatically opened following the execution of TRANSPORT. Output File Options in the TRANSPORT Options Window can be used to specify fitting output during and after fitting.

In addition to the native Transport Output for fitting, PBO Lab provides an Update Window for examining the fitted parameter values and evaluated parameter expressions before deciding if the beamline model should be updated with any or all of these new values. The following Section describes the Update Variables & Expressions Window.

After a fitting operation, Fitting Variables are displayed in an Update Window along with Parameter Algebraic Expressions.

Update Variables & Expressions

After TRANSPORT has completed a fitting task, the new values for Fitting Variables and Parameter Expressions can be used to update Piece Parameters in the beamline model. The Update Parameter Variables & Expressions Window, shown in Figure 50, is automatically opened following the execution of TRANSPORT. The Update Window is used to examine the new values for Fitting Variables and Parameter Expressions and to update the beamline model with those values if desired.

The Update Window allows you to examine fitted parameter values and evaluated parameter expressions before deciding if the beamline model should be updated. The beamline model is not changed until the new values are explicitly accepted in the Update Window.

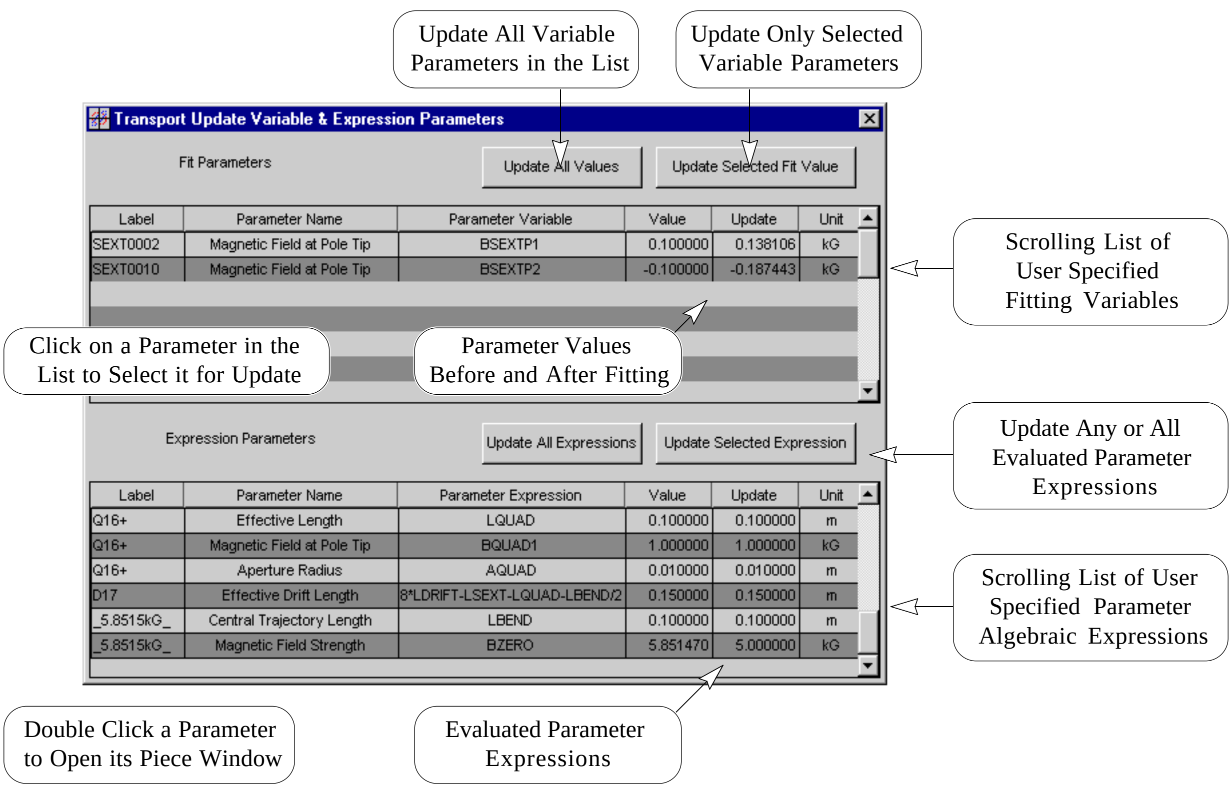

Figure 50. Update Variables and Expressions Window.

Double-click a Fitting Variable or Parameter Expression to open the Piece Window for that parameter.

The Update Window contains two scrolling lists, one for Fitting Variables and the other for Parameter Expressions. The list at the top of the window displays all of the user specified TRANSPORT Fitting Variables for the entire beamline model along with the initial and final values.

The list at the bottom of the Update Window contains all of the Piece Parameters that have been specified by Parameter Algebraic Expressions through out the beamline model, along with the final evaluation of those expressions.

Both the Variables and Expressions lists have buttons for updating the specific Piece Parameters in the beamline model with the new values displayed in the Update Window.

Using the mouse to double-click an entry in the Update Window, will open the Piece Window for that parameter.

Both the Variables and Expressions lists have buttons for updating the specific Piece Parameters in the beamline model with the new values displayed in the Update Window. The Update All Values button can be used to update all of the parameters in one step. Alternatively, the Update Selected Value button can be used to update parameters individually. (There are identical buttons for Parameter Algebraic Expressions in the lower half of the window.) To update Piece Parameters individually make a selection in the list of parameters and press the Update Selected Value button. When a selection is made in the list it will be highlighted. Using the mouse to double-click an entry in the list will open the Piece Window containing that parameter.

If the Update Window is closed prior to updating the beamline, then the fitting results will be disposed and the beamline model will remain unchanged.

The Update Window can be left open and the beamline will not be updated with the new parameter values until one of the Update buttons is used. However, if the window is closed prior to updating the beamline, then the fitting results are disposed and the beamline model will be unchanged.

Refer to the "TRANSPORT User Manual" for additional information on the TRANSPORT program.

This concludes the TRANSPORT Fitting Chapter and the TRANSPORT Application Module Supplement for the Particle Beam Optics Laboratory. Additional information about the TRANSPORT program can be found in the "TRANSPORT User Manual." Refer to the PBO Lab User Manual for general information about the PBO Lab user interface..

PBO Lab™ 2.0

Appendix: "TRANSPORT User Manual"

User Manual Supplement: TRANSPORT Application Module