Designing & Simulating a Drift Tube Linac (PARMILA DLT Modeling)

Part 1 - Design Mode

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Presentation Outline

Designing & Simulating a Drift Tube Linac

Part 1 - Design Mode

1. **The LINAC "Design Mode" of PARMILA (aka PARMILA-2) - Input**
   - **a. Text File Input - for LANL PARMILA-2 Code**
   - **b. Set Up using PBO Lab PARMILA-2 Module**
     ⇒ **PARMILA-2 Module Uses the LANL PARMILA-2 Executable**
2. **Example Output of DTL PARMILA Design Run**
   - **Text File Outputs**
3. **Modeling the DTL with TRACE 3-D from PARMILA Generated Model**

Part 2 - Simulation Mode

4. **Performance Study of a DTL - PARMILA "Simulation Mode"**
5. **Example Output of DTL PARMILA Simulation Run**
   - **Text File Outputs**
   - **Graphics Outputs Using Lingraf (PBO Lab PARMILA-2 Lingraf Module)**
   - **Other Beam Graphics Using PBO Lab (PARMILA-2 Plots Module)**
6. **Using PARMILA to Design & Simulate a DTL**
     ⇒ **You will use the Simulation Lab computers in the classroom**

1. The LINAC "Design Mode" of PARMILA - Input

- **Many Parameters Needed to Specify DTL *Beam Dynamics* Design**
  - **John Summarized Many of These**
  - **Other Parameters Needed to Specify the *Engineering* Design**
  - **PARMILA: *Beam Dynamics* Design with *Engineering* Considerations**
- **PARMILA Can Be Used to Design a DTL from User Specified "Goals"**
  - **A Primary Goal: Output Energy**
    Alternatively Can Specify Number of Cells as a Goal
  - **Another Important Goal: Maximum Power Requirement**
  - **Some Other "Goals" (lattice options, field ramping, …)**
  - **PARMILA Prioritizes User Goals ⇒ May Have to Iterate Design**
- **A Given Combination of Goals Will Not Necessarily Lead to a Design**
  - **May Get "Output" But It May Not Be Realistic**
  - **May Get Error or Warning Reports**
  - **User Needs to Interpret / Understand the Design Results**
- **Suppose You Don't Like Some of the "Goal" Details and/or Certain Output**
  - **"Change" Lines ⇒ Provides Considerable Flexibility (17 Types)!**

1. The LINAC "Design Mode" of PARMILA - Input (con't)
a. Text File Input - for LANL PARMILA-2 Code

- **John Showed a Minimal PARMILA 2 Input File - Lets Look at Some Details**
- **"DTL.LIN" for SNS DTL Text File Input - for LANL PARMILA-2 Code**
  - **Not a minimal input file, but it illustrates many of the capabilities**
  - **Section IV "Running Parmila" of LA-UR-98-4478 (Simulation Lab comp.)**

```
; In this example each DTL structure is 1 tank structure.
;-------------------Global Parameters---------------------
;PrintDesignLong
;PrintDynamicsLong
DesignOnly    ; this disables the dynamics calculation
;NoSFTableout
Power
FullWallPower
Run 1 1
Title
*** SNS example DTL Design***
;linac W0,     Fbunch, Ibeam, Mc^2,     Nq
linac  2.5    402.5  56.00  939.3014,   -1

;-------------------Beam Particle Distribution Spec---------
;
;ReadDist 0.
Startphase -45.
Input -8 1000   2.371911     96.567733   0.001582015
                -1.022037     29.001170   0.001490245
                -0.028191     57.609246   0.001764593
```

; = Comment Lines (Commands "Off")

Will Run in "Design Mode"

Will Create the "WallPwr.out" File

Adds Beam Power to "WallPwr.out"

(Note: Documentation Apparently Out of Date Regarding Required Order in File)

Generally Starts File

Title = Next Line Ignored if a Command!

linac = Initial Beam Energy (MeV), Radio-Frequency (MHz), Current (mA), Particle Mass (MeV), Particle Charge (|e|)

Permits Reading Input Beam Data from "part_rfq.dst" File (IF Uncommented)

Startphase = Design (Synchronous) Trajectory Initial Phase

Initial Beam Twiss Parameters for X, Y, Z
-8 = Uniform in 3-D Spatial Coords. (-) Fit to Twiss: Alpha, Beta, Emittance (Attention to UNITS, "0.0"!)
(Documentation Has Some Discrepancies)

1. The LINAC "Design Mode" of PARMILA - Input (con't)
a. Text File Input - for LANL PARMILA-2 Code (con't)

```
;-------------------------------------------------------------
;Structure id,Nlast,F0,Fsf,deltaphi
Structure   1 60  402.5 402.5  -2.8814
title
*** SNS *** .DTL. SNS DTL Tank 1
DTL 1  -60 -45.0  1.13 0.00407  3.80 0  0. 3. -3.
      3.5 5 5 11 0.    1.25 0. 0  0. 0
      1 1 2 0 0       -25
```

Structure: Identifies Different (RF) Structures (n/a if DTL only)
1 = Identifier - Must Be Unique and Monotonically Increasing
60 = Last Cell of Structure to be Used
402.5 402.5 (optional) = Linac Frequency, SFDATA Frequency
-2.8814 (optional) = Phase Shift (Degrees) Added to Particles

DTL ("tank" in PARMILA-1): Design Goals & Parameters
(more on next page)

```
change 14 2.49 3700.0 101.1 3700.
change 16 3700 1
```

14 = Ramp Quadrupoles with Particle Energy from 3700 G/cm at 2.49 MeV to 3700 G/cm at 101.1 MeV (No Ramp in this Example!)

16 = Sets Field Gradient (3700 G/cm) of First Quad in Tank 1

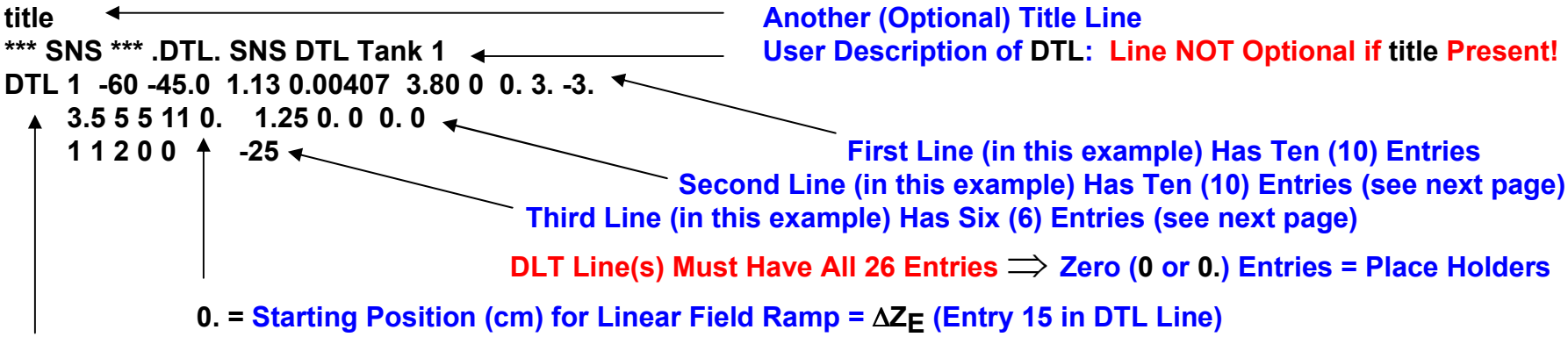
```
SFDATA
; Bore = 1.25, DTL
;   Beta      T        TP       S        SP       g/bl     Z         E/E0     Tave     dZctr
  0.070000  0.563010  0.099403  0.572469  0.022447  0.170421  49.8612     1.000000  0.563010  0.000000
  0.072500  0.581612  0.096563  0.566283  0.025463  0.167853  50.4299     1.000000  0.581612  0.000000
  0.075000  0.599051  0.093822  0.560088  0.028186  0.165729  50.9760     1.000000  0.599051  0.000000
  0.077500  0.615369  0.091189  0.553920  0.030637  0.163998  51.4976     1.000000  0.615369  0.000000
  0.080000  0.630698  0.088647  0.547776  0.032845  0.162626  51.9942     1.000000  0.630698  0.000000
  0.082500  0.644995  0.086223  0.541736  0.034826  0.161560  52.4719     1.000000  0.644995  0.000000
     •
     •
     •
  0.125000  0.793343  0.057036  0.454743  0.049088  0.158742  58.3995     1.000000  0.793343  0.000000
  0.130000  0.802303  0.055025  0.447951  0.049549  0.161141  58.8976     1.000000  0.802303  0.000000 -1
```

End

⇒ ***Will Now Take a Look at the DTL Line in More Detail***

1. The LINAC "Design Mode" of PARMILA - Input (con't)
a. Text File Input - for LANL PARMILA-2 Code (con't)

A Look at the "DTL" Line in More Detail



First Ten (10) Entries of DTL Line:

DTL ("tank" in PARMILA-1): Design Goals & Parameters:

1 = Tank Identifier - Must Be Unique and Monotonically Increasing Within Each Structure Section

-60 = The Minus (-) Overrides Default Meaning of "Final Energy Goal" (in MeV) Now Means "Final Cell # Goal"

-45.0 = Initial Synchronous Phase (Degrees)

1.13 = Initial Value of (spatially averaged) Axial Electric Field (MV/m) = E_0

0.00407 = Field Tilt Coefficient (1/cm) for Linear Ramp in the Axial Electric Field = C_{tilt}

3.80 = Maximum (Final) Value of (spatially averaged) Axial Electric Field (MV/m) = $E_{0,max}$

$$E_z = E_0 [1 + C_{tilt} (Z - \Delta Z_E)] \quad \text{for } Z > \Delta Z_E \text{ and } E_z \leq E_{0,max}, \text{ after which } E_z = E_{0,max}$$

0 = Distance (cm) to Next DTL Tank

0. = Phase Change (Degrees) to Next DTL Tank

3. = Coefficient of Constant Term in Quadrupole Strength Equation (overridden by change 14)

-3. = Coefficient of Linear Term in Quadrupole Strength Equation (overridden by change 14)

1. The LINAC "Design Mode" of PARMILA-- Input (con't)
a. Text File Input - for LANL PARMILA-2 Code (con't)

A Look at the "DTL" Line in More Detail (con't)

title

***** SNS *** .DTL. SNS DTL Tank 1** Reminder: DLT Line Must Have All 26 Entries ⇒Cannot Ignore "Place Holders"

DTL 1 -60 -45.0 1.13 0.00407 3.80 0 0. 3. -3. (PARMILA-1 Has 29 Entries, But 20-26 Are "Place Holders")

3.5 5 5 11 0. 1.25 0. 0 0. 0

1 1 2 0 0 -25

Second Line (in this example) Has Ten (10) Entries

Third Line (in this example) Has Six (6) Entries

Second Ten (10) Entries of DTL Line:

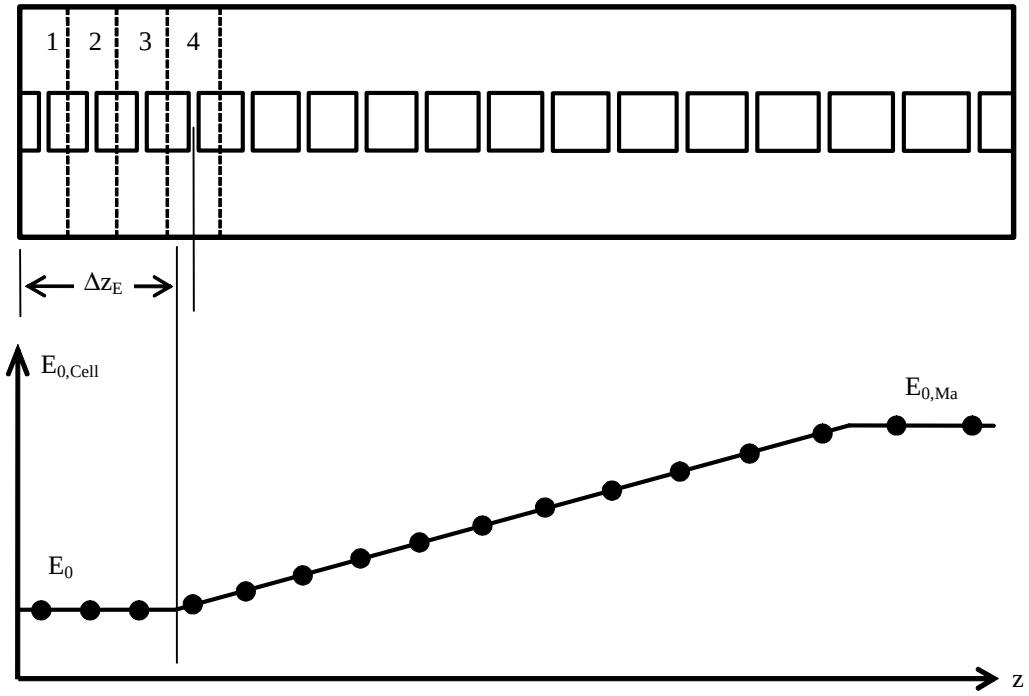
- **3.5 = Quadrupole Length (cm) But If Negative (-) this Parameter is the Quad Length as a Fraction of βλ**
- **5 = Tank Quadrupole Lattice is FFODDO (5 accepted values for this entry: 1, 2, 3, 4, 5 - Table IV-6)**
- **5 = Initial Quad at Start of the Tank is the 2nd "D" in the FFODDO Lattice (Points to the 5th Column in Table IV-6)**
- **11 = "Half Quads" at Entrance and Exit Walls of Tank (4 accepted values for this 2-digit entry: 11, 12, 21, 22)**
- **0. = Starting Position (cm) for Phase Ramp = ΔZ_E (see prior page for linear ramp, (overridden by entry 22 below!))**
- **1.25 = Bore Radius (cm) at Low Energy End of Tank**
- **0. = Bore Radius Remains Unchanged, But If Non-Zero this Parameter is the Bore Radius at High Energy End**
- **0 = Ignored But If Non-Zero this is the Cell Number Where the Bore Radius at High Energy End Starts**
- **0. = Ignored, But If Non-Zero this Parameter Provides a Goal for the Maximum Power (MW) for the Tank**
- **0 = Ignored (this a place holder for an unused parameter) But Must Be Present**

Last Six (6) Entries of DTL Line:

- **1 = Cell Length as an Integer Multiple of βλ** (PARMILA-1 Has A Cubic Ramp - No Longer Used)
- **1 = Linear Ramp (*RampType* 1) for the Axial Electric Field But Recalculates ΔZ_E To Fix The Separatrix**
- **2 = Delay Phase Ramp (*RampType* 1) To Start at Cell Number 2**
- **0 = Ignored, But If Non-Zero this Integer Parameter Specifies the Starting Cell Number for the Ramp**
- **0 = Ignored, But If Non-Zero this Integer Parameter Specifies the Ending Cell Number for the Ramp**
- **-25. = Maximum Value of Synchronous Phase (*RampType* 1) After Which Phase Ramp Ends**

1. The LINAC "Design Mode" of PARMILA-- Input (con't)

Linear E_0 ramp in a DTL tank for *RampType* 0 (Figure IV-1.)



PARMILA-2 Has Three (3) Field & Phase Ramp Options (*RampType*)

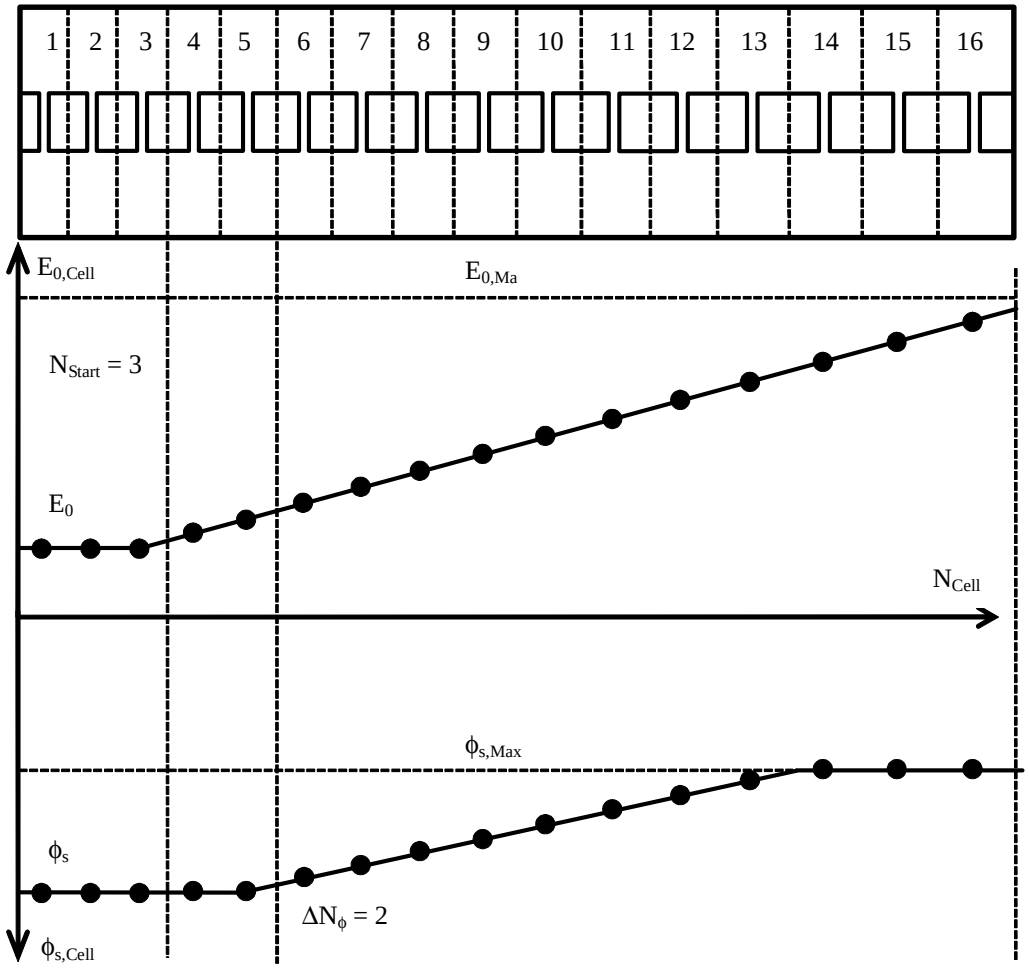
- ***RampType* 0 = Ramps Field Linearly, but Phase is Constant**
- ***RampType* 1 = Ramps Field Linearly, and Phase Adjusted to Fix Separatrix**
- ***RampType* 2 = Field and Phase Ramps Adjusted for Constant Long. Focus**

[PARMILA-1 Has Two (2) Field Ramp Options, But Does NOT Use *RampType* Input

- **Linear or Cubic Ramp, determined by size of Field Tilt Coefficient (1/cm) = C_{tilt} >1]**

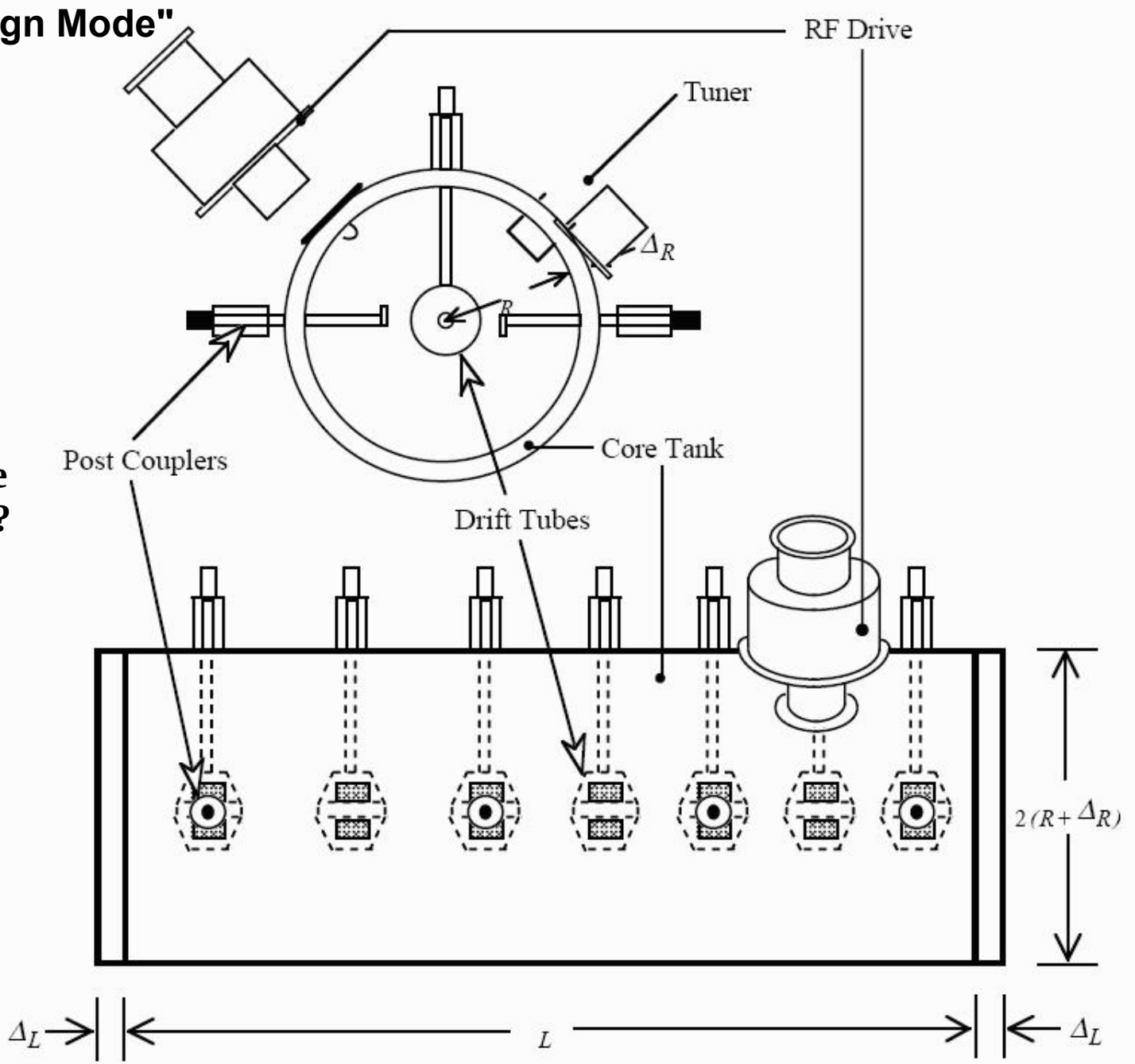
1. The LINAC "Design Mode" of PARMILA-- Input (con't)

Field & phase profiles for *RampType* 1 (mislabeled in Figure IV-2.)



1. The LINAC "Design Mode" of PARMILA (con't)

Is a 2D SUPERFISH Calculation Adequate for a 3D DTL Cavity?



1. The LINAC "Design Mode" of PARMILA-- Input (con't)
a. Text File Input - for LANL PARMILA-2 Code (con't)

Input Lines That Follow the SuperFish "SFDATA" Lines

```
change 14 2.49 3700.0 101.1 3700.
change 16 3700 1
```
These 2 Lines are Repeated from Earlier in DLT.LIN file
(Are These Lines Here Necessary?) HOMEWORK:
Yes ____ No____

```
linout 1
```
Outputs RF Structure and Beam Dynamics Parameters for DTL Tank (File "Design.out")

```
linout 4
```
; this outputs the linac geometry GHG uncommented 06/09/07
Outputs Geometry Parameters for DTL Tank (Documentation Says Only Useful for DTL, Not CCL,…)
Geometry Parameters Written to File "Design.out"

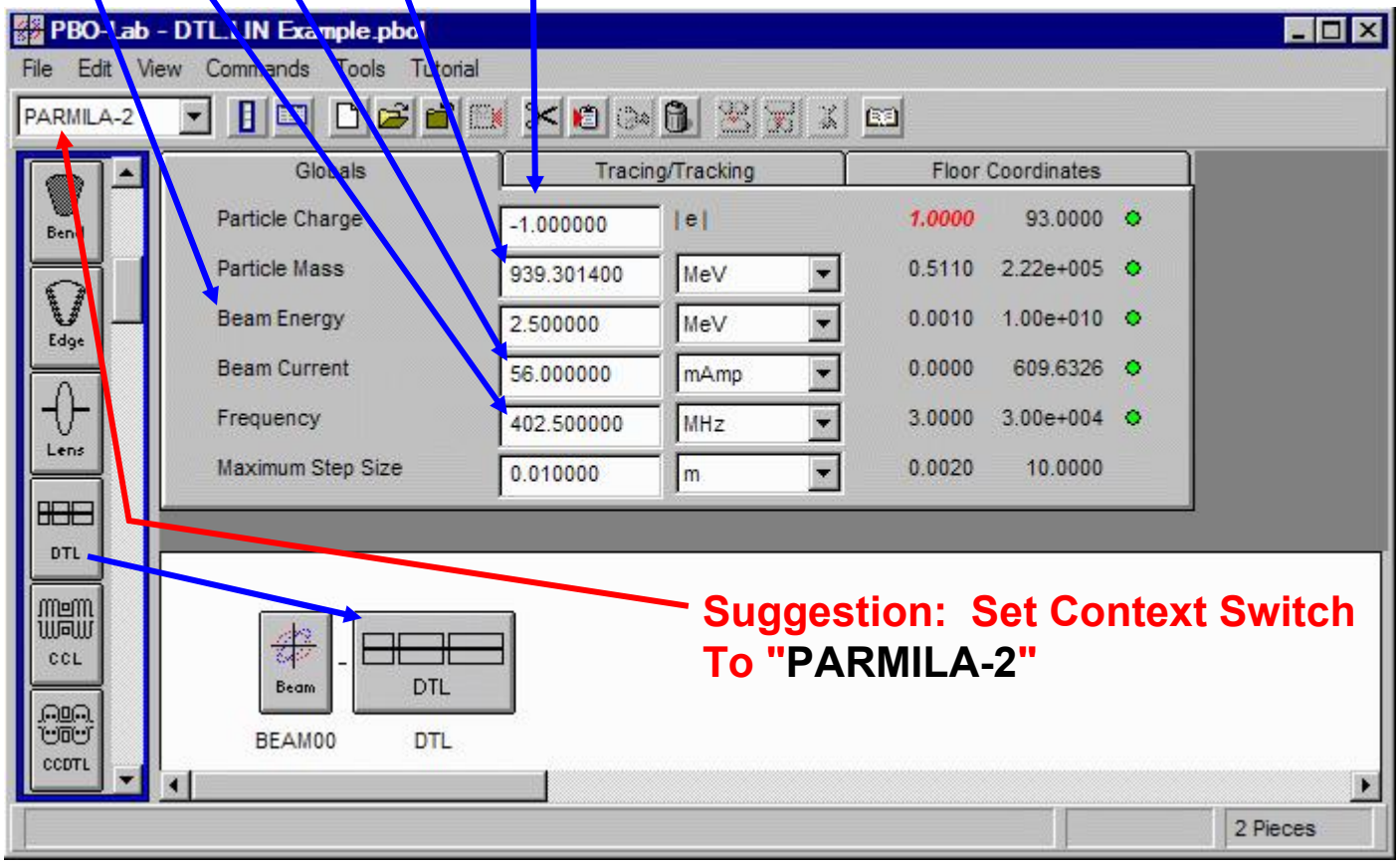
```
elimit 50.
;scheff deltaR. deltaZ, Nr, Nz, Nbunch, Nbetalambda, Remesh
scheff   0.05  0.05    20   40  0      0          1
start 1
stop 48
output 2 1  1 300 1
;output 3 1  1
;output 4 1  1
prtbeam
begin
    •
    •
    •
end
```
Ignored In "Design Mode"
("Simulation Mode" Discussed Later)

Stops the PARMILA Run

1. The LINAC "Design Mode" of PARMILA - Input (con't)
b. Set Up using PBO Lab PARMILA-2 Module

- **linac line set using Global Parameters**

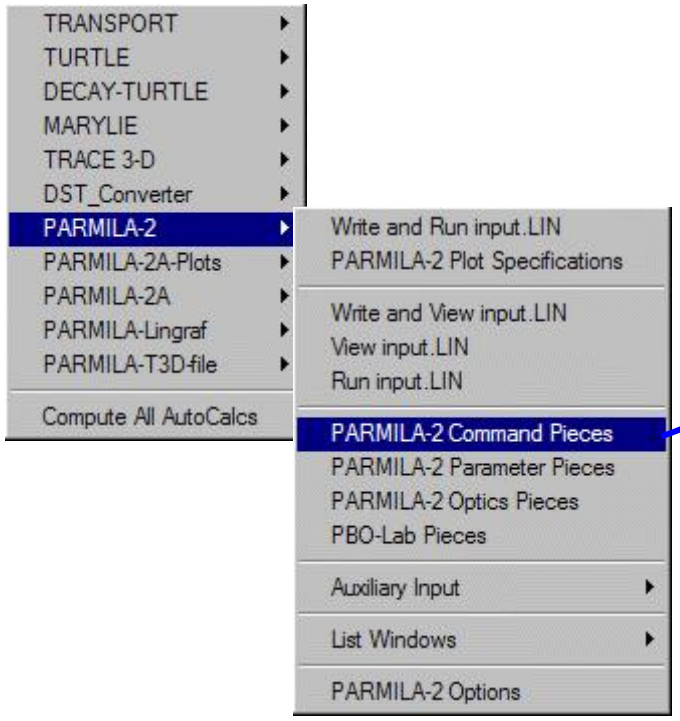
```
;linac W0,     Fbunch, Ibeam, Mc^2,     Nq
linac  2.5    402.5  56.00  939.3014,   -1
```

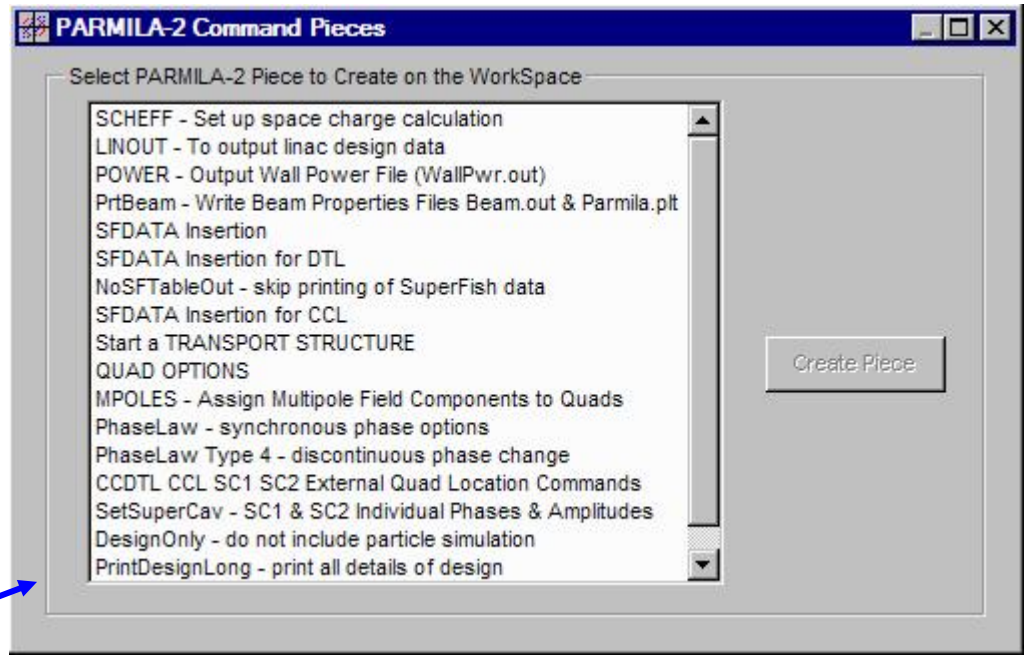


- **DTL is represented by a single (albeit complex) DTL Piece (more later)**

1. The LINAC "Design Mode" of PARMILA - Input (con't)
b. Set Up using PBO Lab PARMILA-2 Module (con't)

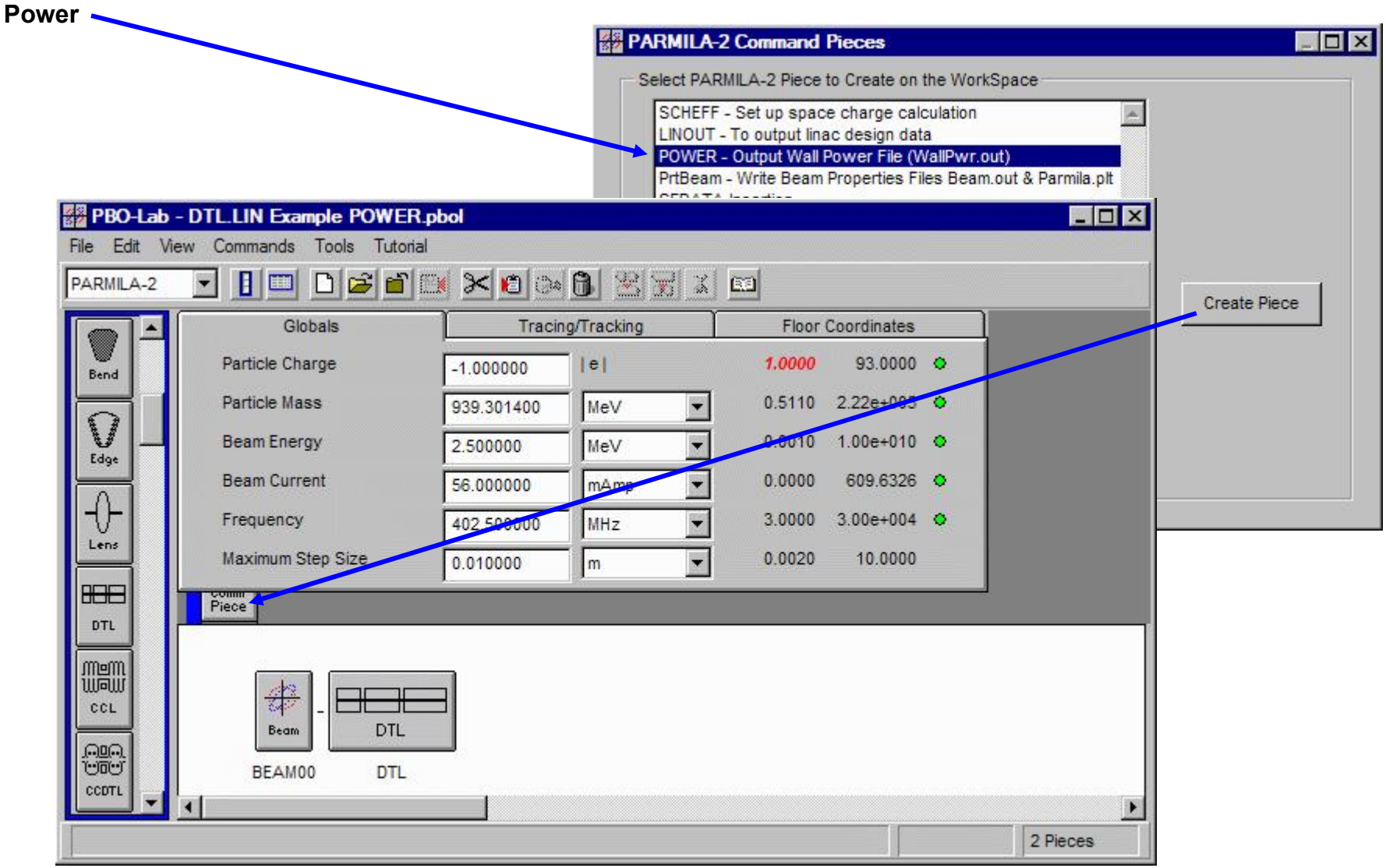
;PrintDesignLong
;PrintDynamicsLong
DesignOnly
;NoSFTableout
Power
FullWallPower





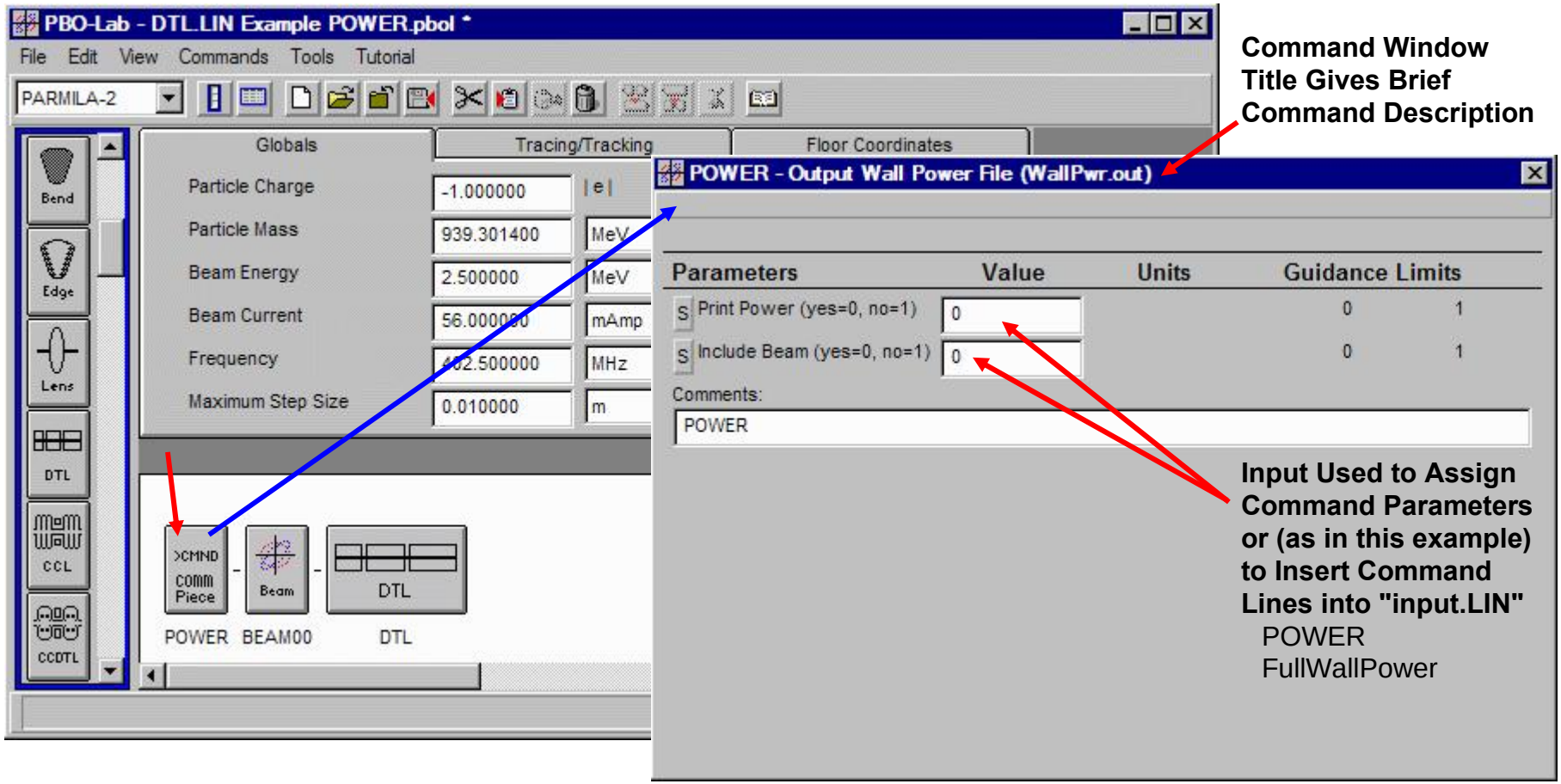
PARMILA-2 "commands" are implemented with PBO Lab PARMILA-2 Command Pieces

1. The LINAC "Design Mode" of PARMILA - Input (con't)
b. Set Up using PBO Lab PARMILA-2 Module (con't)



1. The LINAC "Design Mode" of PARMILA - Input (con't)
b. Set Up using PBO Lab PARMILA-2 Module (con't)

Power



Suggestion: Use a Mouse Move (Shift-Drag) to place Piece on Model Space, instead of a Mouse Copy (Drag) ⇒ eliminates Piece "pileup" on Work Space

1. The LINAC "Design Mode" of PARMILA - Input (con't)
b. Set Up using PBO Lab PARMILA-2 Module (con't)

- **Basically a one-to-one correspondence between**
  PARMILA-2 computational commands, and
  PBO Lab PARMILA-2 Command Pieces
- **Linked Commands grouped together on a single Command Piece**
- **Piece location in Model Space sets location in PARMILA-2 input file**
- **Other PARMILA-2 input file "instructions" set up using:**
  PBO Lab PARMILA-2 Parameter Pieces
  PBO Lab PARMILA-2 Optics Pieces (Funnel, Chopper)
  PBO Lab PARMILA-2 Options
  and, of course, the standard
  PBO Lab Optics Pieces (Beam, Drift, Quad, …)
  (for transfer lines, intertank matching sections, …)
  PBO Lab PARMILA-2 Complex Pieces (DTL, CCL, …)
- **Words define parameters of each type of PARMILA-2 PBO Lab Object**
  - parameter names follow standard conventions
  - choice of units for many parameters
  - default units for parameters correspond to PARMILA-2 units

1. The LINAC "Design Mode" of PARMILA - Input (con't)
b. Set Up using PBO Lab PARMILA-2 Module (con't)

Input -8 1000 2.371911 96.567733 0.001582015
-1.022037 29.001170 0.001490245
-0.028191 57.609246 0.001764593

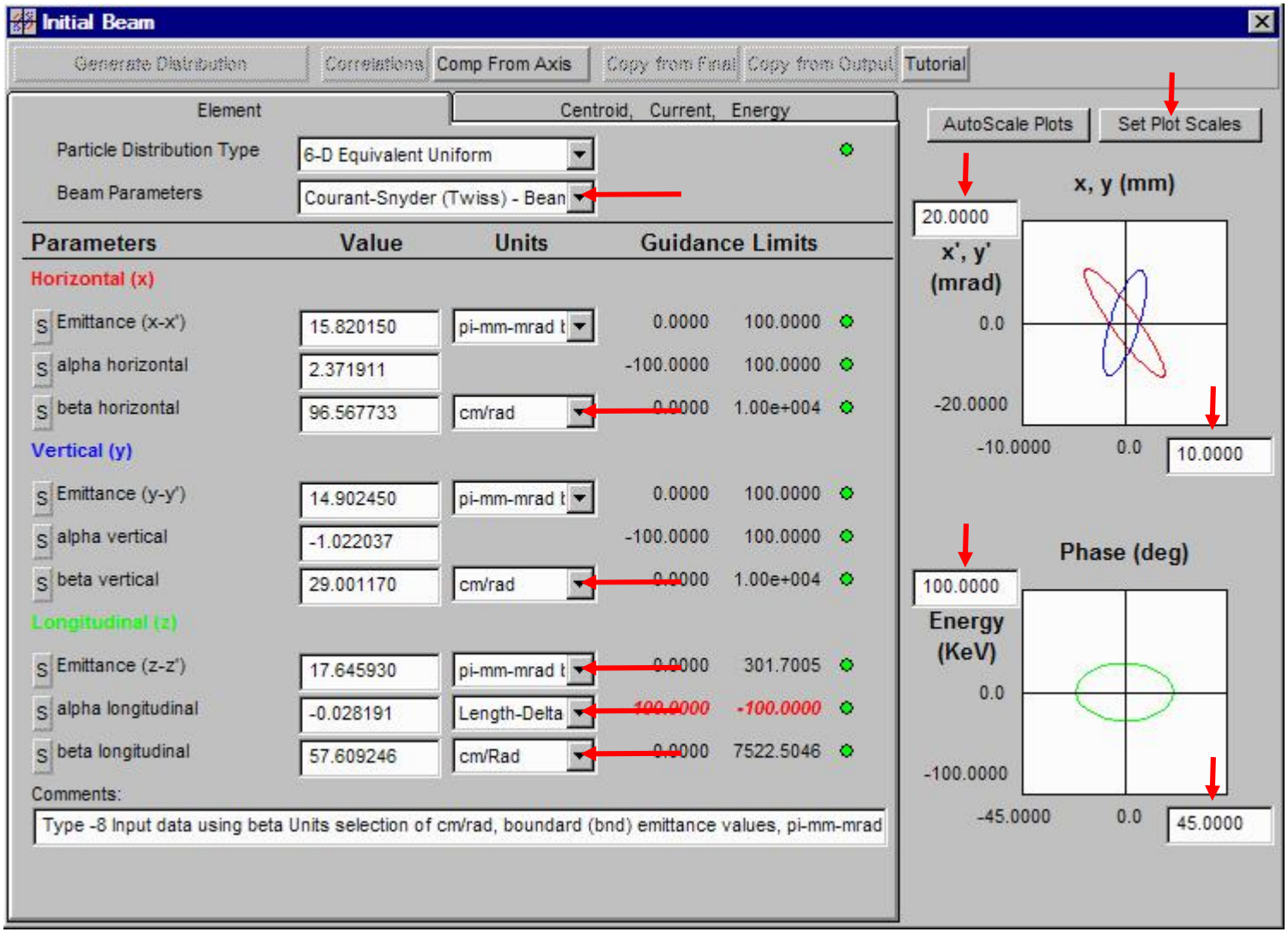
Suggestions:

⇒ Use Beam 2 (Twiss)

⇒ Units

⇒ Plot Scales

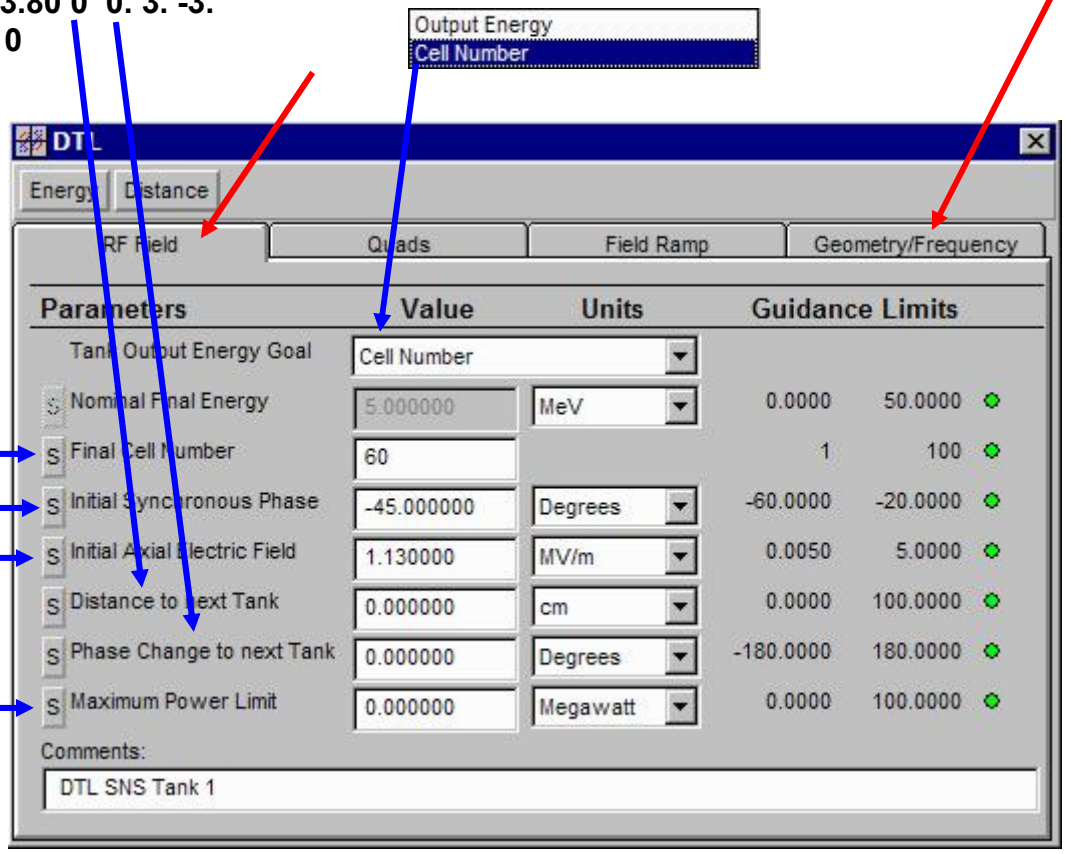
⇒ Set Beam 1 (Semi-Axes) from Beam 2



1. The LINAC "Design Mode" of PARMILA - Input (con't)
b. Set Up using PBO Lab PARMILA-2 Module (con't)

```
Structure   1 60  402.5 402.5  -2.8814
DTL 1  -60 -45.0  1.13 0.00407  3.80 0  0. 3. -3.
       3.5 5 5 11 0.    1.25 0. 0  0. 0
       1 1 2 0 0        -25
```

Structure data on Geometry/Frequency **tab panel**

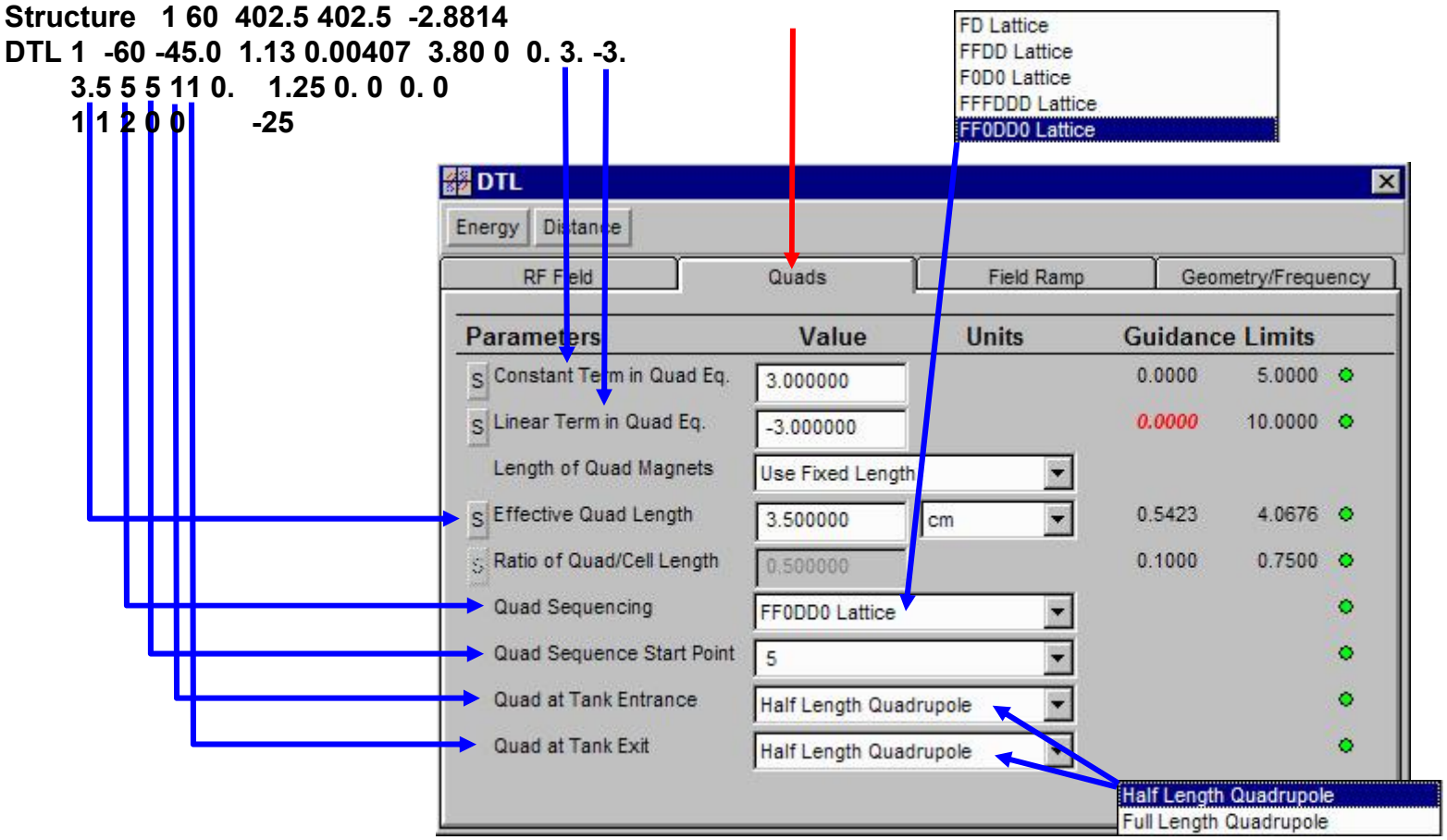


Suggestion:

⇒ **Use Comment Field**

- **Parameters grouped on Tab Panels according to "primary" technology**
- **Both "Structure" and "DTL" input file data lines set in DTL Piece**
- **User does not need to worry about parameter order, units, syntax**

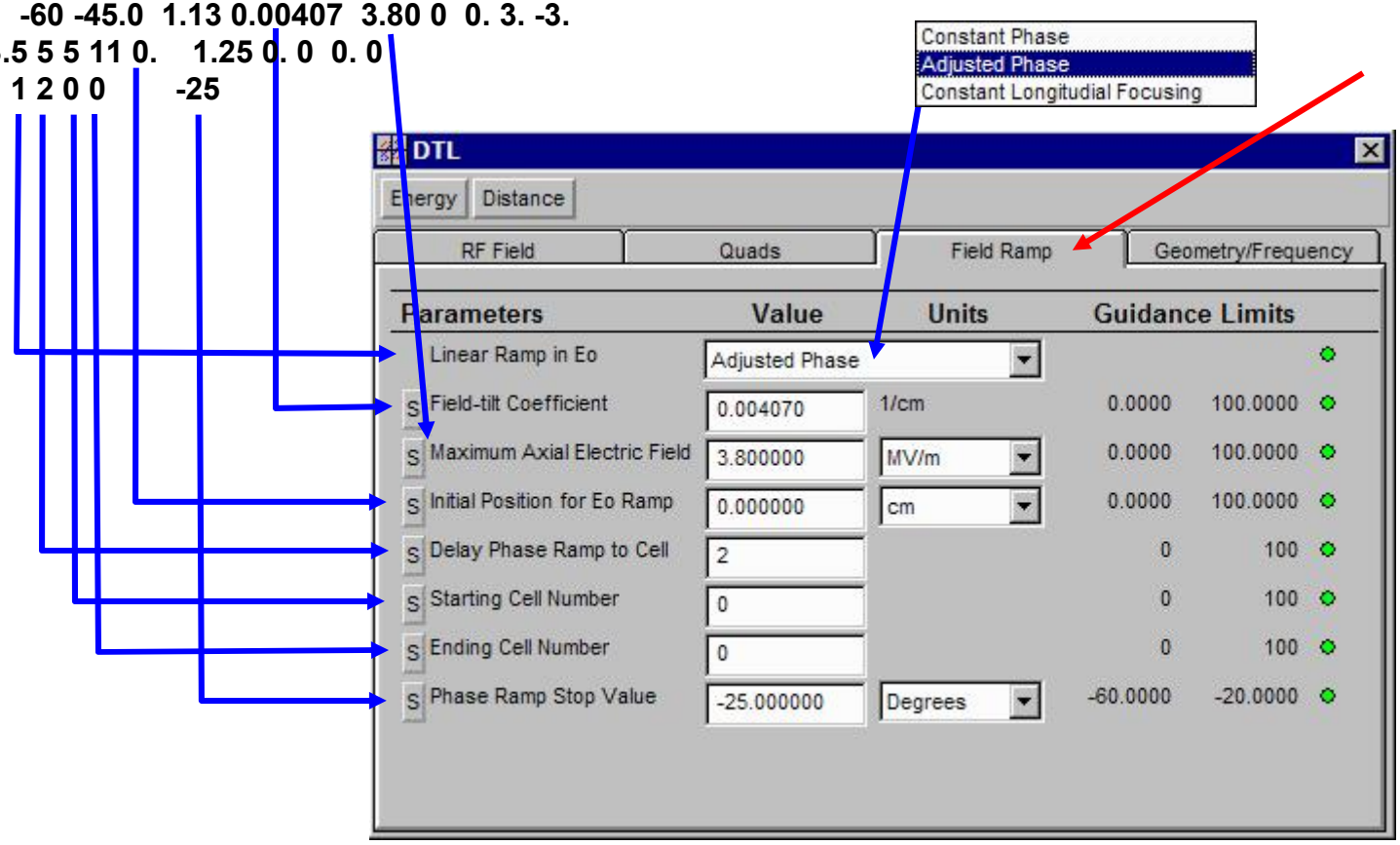
1. The LINAC "Design Mode" of PARMILA - Input (con't)
b. Set Up using PBO Lab PARMILA-2 Module (con't)



- The **Quad Eq.** formula - see Section 13.d, page 75, LA-UR-98-4478 (2005)
- Note: **Quad Eq.** parameters overridden by Change Lines (shown later)
- User does not need to worry about any "placeholder" zeroes

1. The LINAC "Design Mode" of PARMILA - Input (con't)
b. Set Up using PBO Lab PARMILA-2 Module (con't)

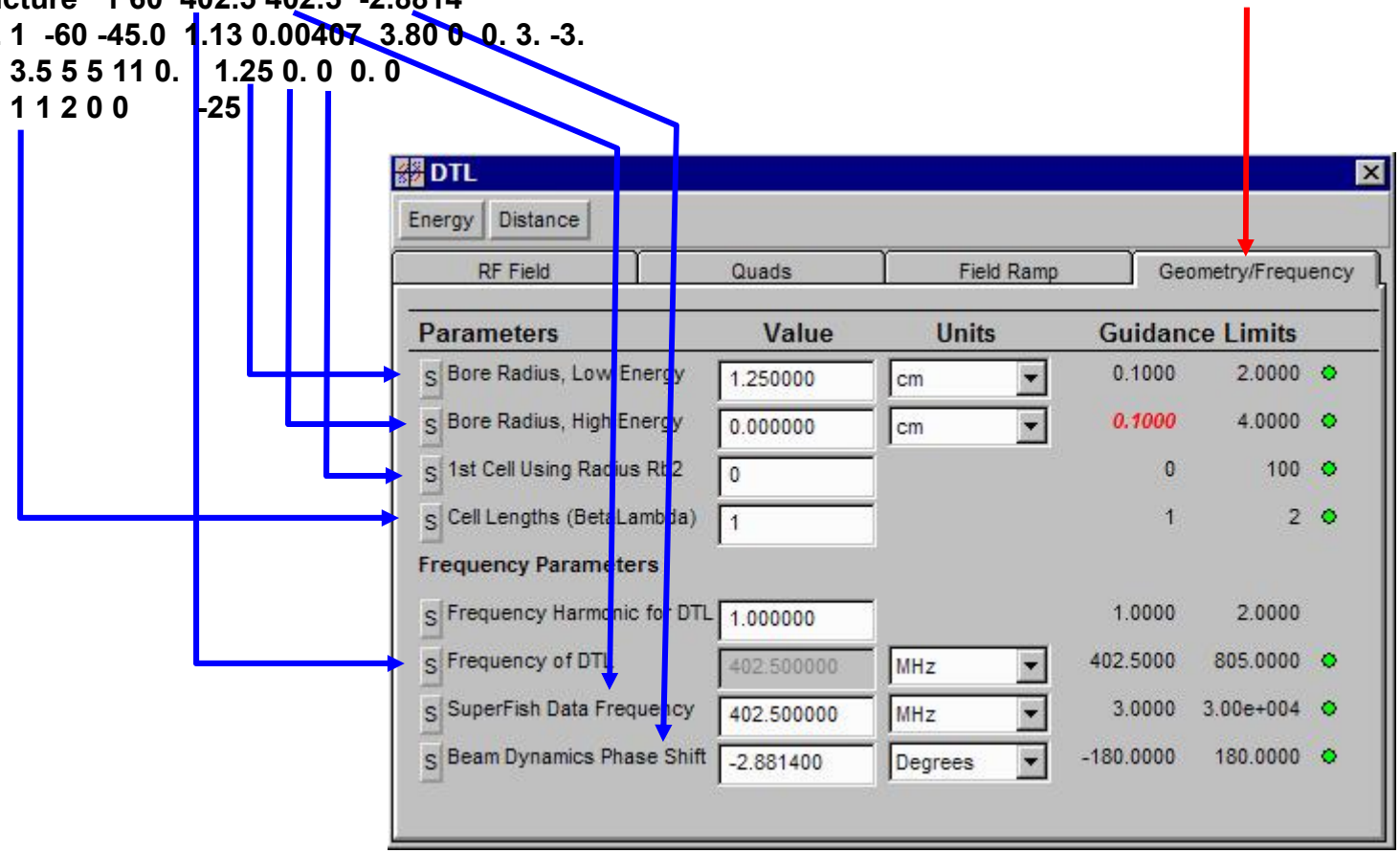
```
Structure   1 60  402.5 402.5  -2.8814
DTL 1  -60 -45.0  1.13 0.00407  3.80 0  0. 3. -3.
       3.5 5 5 11 0.    1.25 0. 0  0. 0
       1 1 2 0 0        -25
```



- **Adjusted Phase** - **Attempts to keep longitudinal Separatrix fixed**
- **See Section 13.b, page 73, LA-UR-98-4478 (2005)**

1. The LINAC "Design Mode" of PARMILA - Input (con't)
b. Set Up using PBO Lab PARMILA-2 Module (con't)

```
Structure   1 60  402.5 402.5  -2.8814
DTL 1  -60 -45.0  1.13 0.00407  3.80 0  0. 3. -3.
       3.5 5 5 11 0.    1.25 0. 0  0. 0
       1 1 2 0 0        -25
```



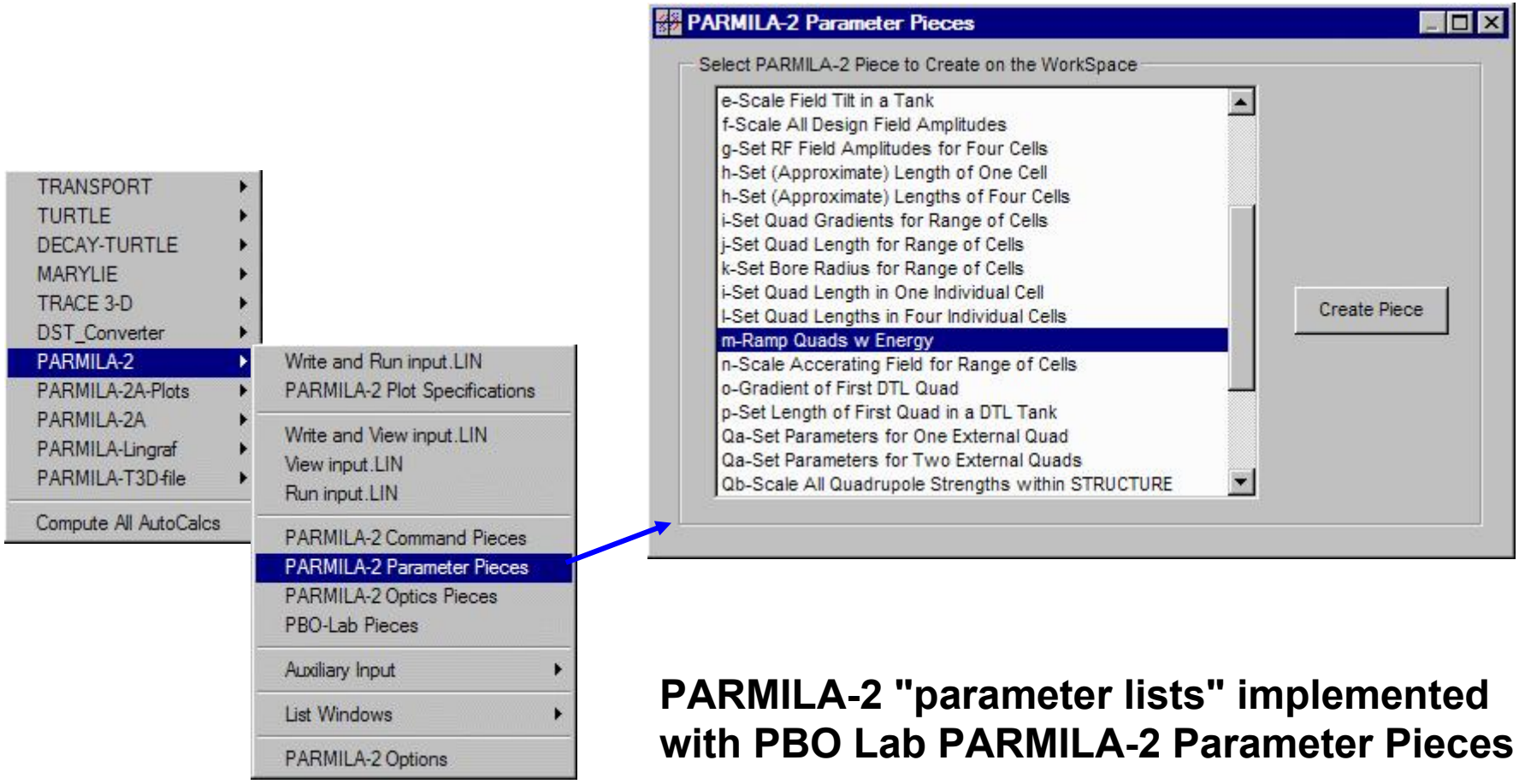
- **Assigns Frequency Harmonic for DLT (harmonic of Global Frequency)**
- **Beam Dynamics Phase Shift ignored in "Design Only" mode**

1. The LINAC "Design Mode" of PARMILA - Input (con't)
b. Set Up using PBO Lab PARMILA-2 Module (con't)

- Each PBO Lab DTL Object represents one DTL "Tank"
  One PARMILA-2 Structure Line for each DTL Tank
- Piece location in Model Space sets location in PARMILA-2 input file
- Parameters grouped on Tab Panels according to "primary" technology
- Structure and Tank IDs automatically set
  - assures uniqueness and monotonic increase in IDs
  - user does not assign ID values in PBO Lab interface
- Will need other PBO Lab PARMILA-2 Command Pieces for execution
  - SFDATA (SuperFish Data) file assignment
  - LINOUT to have data written to output file(s)
- May need other PBO Lab PARMILA-2 Pieces
  - Change Pieces (discussed next)
- May want other PBO Lab PARMILA-2 Pieces
  - Scheff for beam dynamics - not needed for Design Only
  (However, absence may create an annoying error message)
- BEGIN & END lines automatically included by PBO Lab PARMILA-2
  - These are used for beam dynamics calculations

1. The LINAC "Design Mode" of PARMILA - Input (con't)
b. Set Up using PBO Lab PARMILA-2 Module (con't)

change 14 2.49 3700.0 101.1 3700.
change 16 3700 1



PARMILA-2 "parameter lists" implemented with PBO Lab PARMILA-2 Parameter Pieces

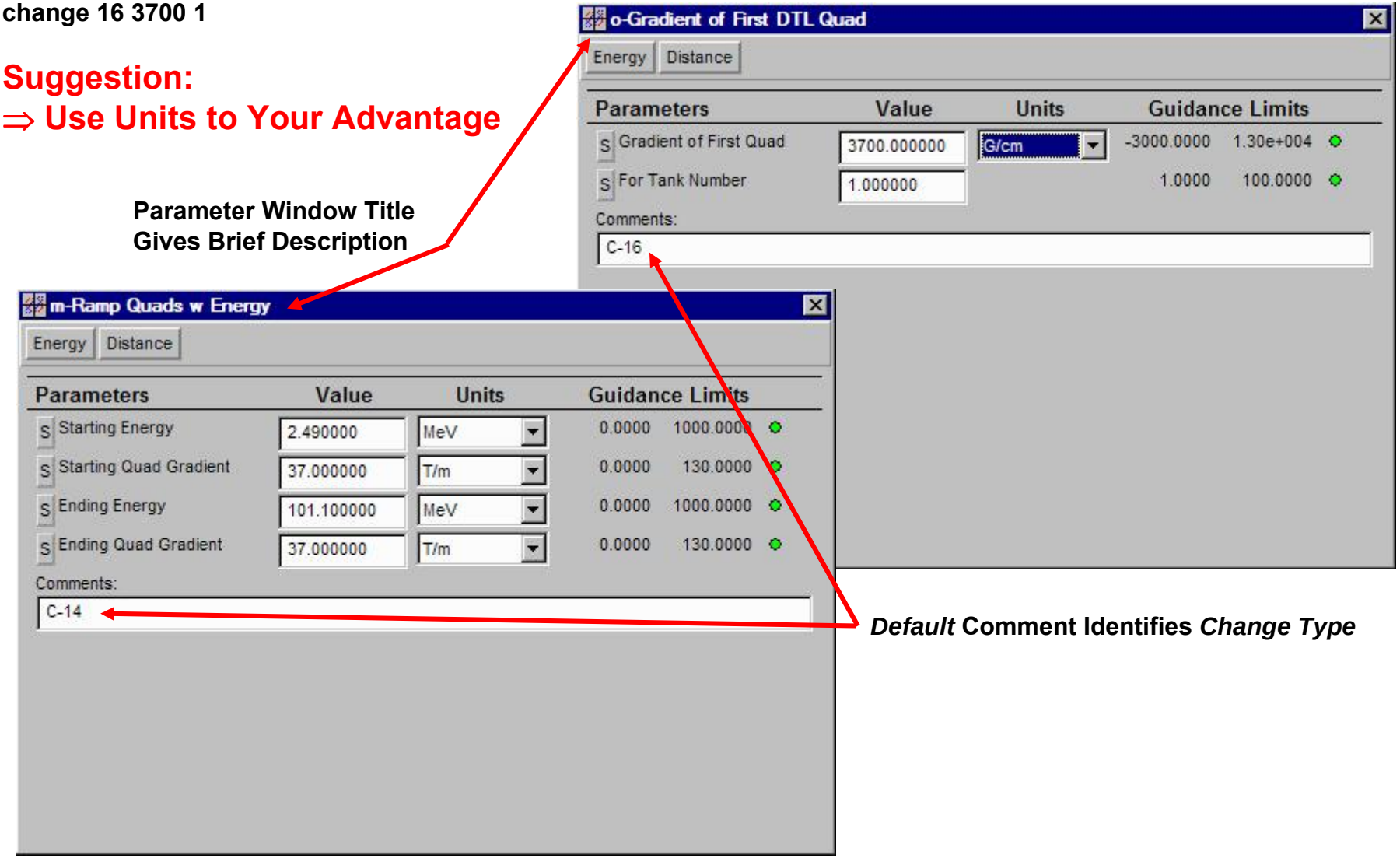
- **Parameter Piece names start with letter (e.g. "m") corresponding to subsections given in Section 23, page 87, LA-UR-98-4478 (2005)**

1. The LINAC "Design Mode" of PARMILA - Input (con't)
b. Set Up using PBO Lab PARMILA-2 Module (con't)

change 14 2.49 3700.0 101.1 3700.
change 16 3700 1

Suggestion:
⇒ Use Units to Your Advantage

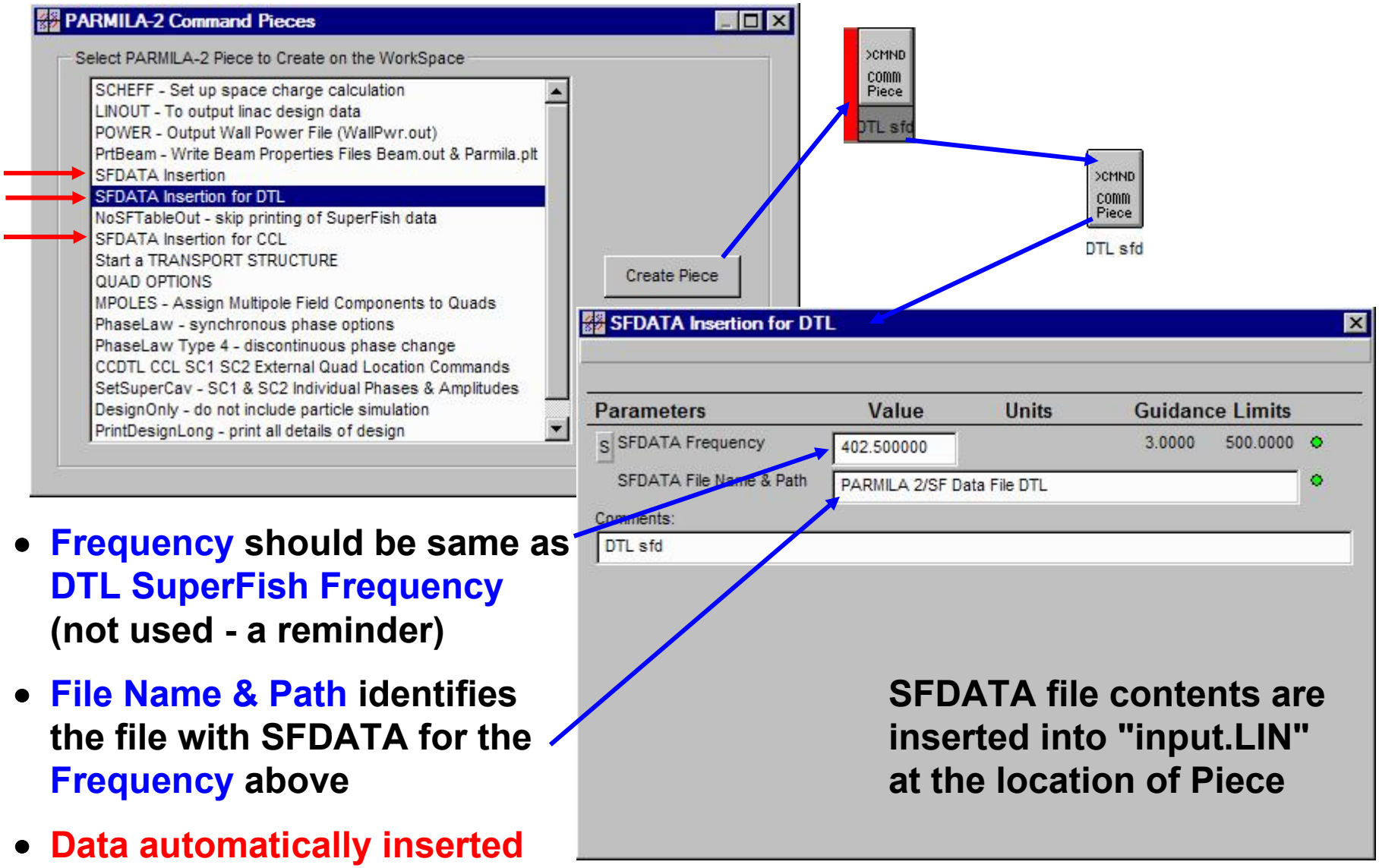
Parameter Window Title Gives Brief Description



Default* Comment Identifies *Change Type

1. The LINAC "Design Mode" of PARMILA - Input (con't)
b. Set Up using PBO Lab PARMILA-2 Module (con't)

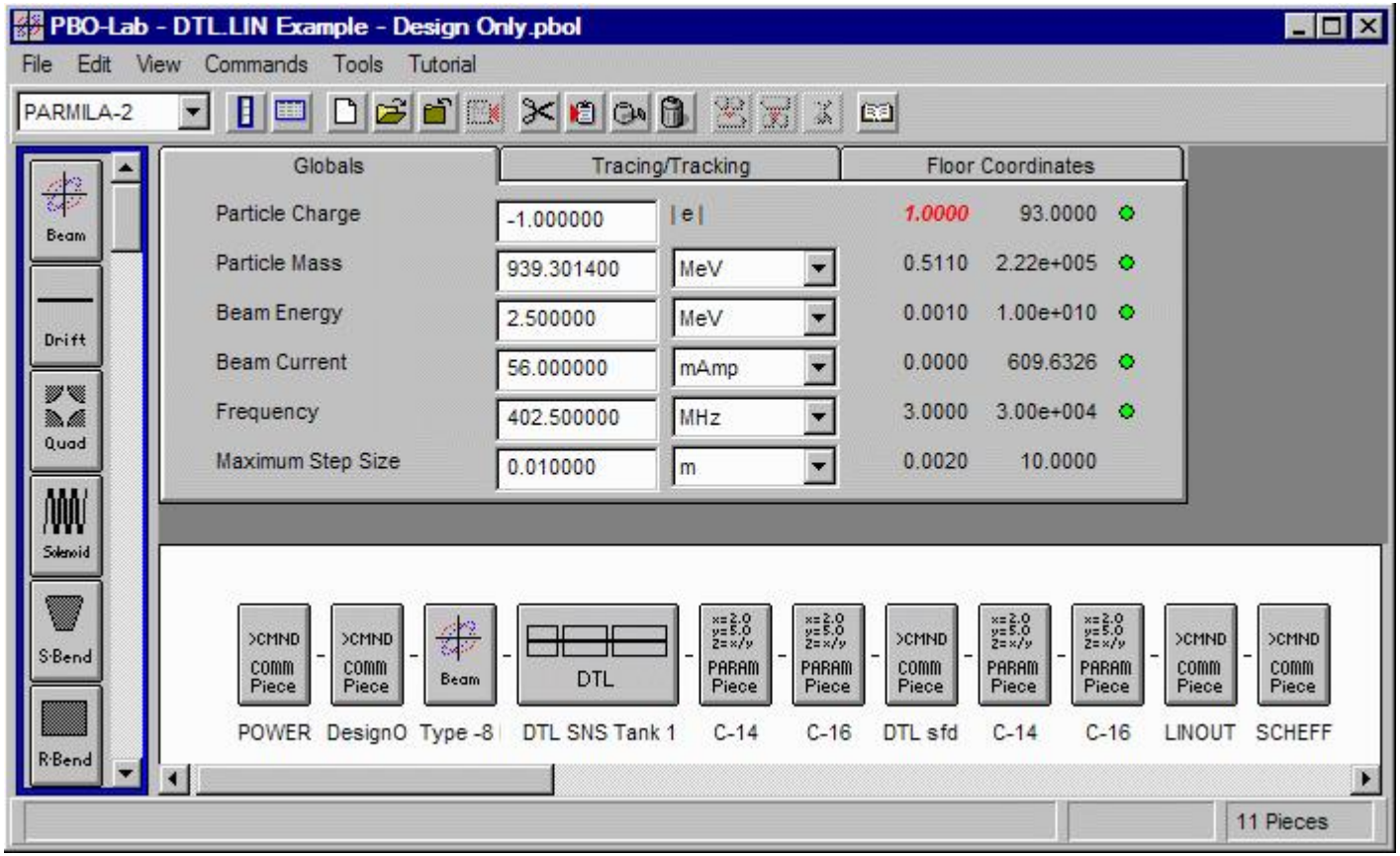
SFDATA



- **Frequency should be same as DTL SuperFish Frequency (not used - a reminder)**
- **File Name & Path identifies the file with SFDATA for the Frequency above**
- **Data automatically inserted**

SFDATA file contents are inserted into "input.LIN" at the location of Piece

1. The LINAC "Design Mode" of PARMILA - Input (con't)
b. Set Up using PBO Lab PARMILA-2 Module (con't)

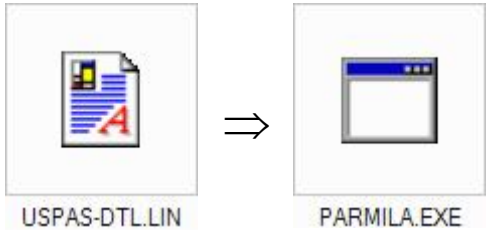


- **Add a couple of more Pieces (LINOUT, SCHEFF) leaving default values for parameters**

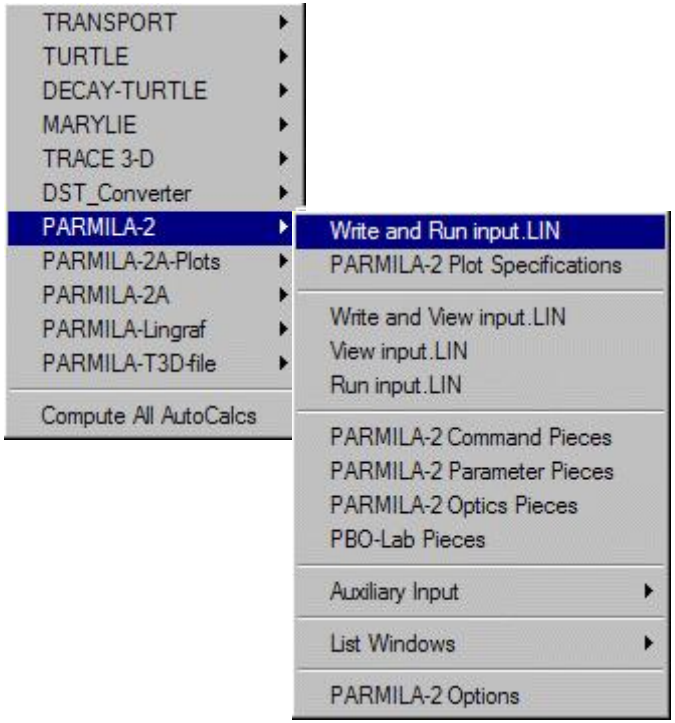
  ⇒ **Design Only mode example is ready to run**

2. Example Output of DTL PARMILA Design Run

a. Text File for LANL PARMILA-2 Code



b. PBO Lab PARMILA-2 Module



Run (PARMILA Execution) Generates Several Output Files Depending Upon PARMILA 2 Commands Used in Input

Run ⇒ File: PARMILA.OUT
⇒ File: Design.out
⇒ File: WALLPWR.OUT
⇒ File: QUAD.OUT
⇒ File: Tr3Din.t3d

•
•
•

⇒ We'll Go Through Several of These for USPAS-DTL.LIN Example

2. Example Output of DTL PARMILA Design Run

Run (with "linout 1") ⇒ File: PARMILA.OUT

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

-
- **(Copyright, disclaimers, etc., … reiteration of parts of input file)**
-

DTL cavity design details
E0 ramped linearly with beta starting at cell 1
Phase ramp starting at cell 3 with phase 0.0 deg and constant bucket phase width 138.0 deg
(Excluding beam power) tank 1, Cu power= 0.34391 MW

LIN: change 14 2.49 3700.0 101.1 3700.
LIN: change 16 3700 1
LIN: linout 1 **(PARMILA-1 this is Only in a Separate File)**
RF structure and beam-dynamics parameters for DTL tank 1
Tank of length 415.19332 cm contains 60 cells
Total RF power including beam and structure = 0.6252 MW
Cavity frequency = 402.5 MHz, wavelength = 74.482598 cm
Start of first cell occurs at Z = 0.0 cm.
The column headings are: **(Actually, the first column is Cell Number)**
W: Energy of the synchronous or design particle at the end of the cell in MeV
Beta: Velocity of the synchronous or design particle at the end of the cell
Lc: Cell length in cm
T: Transit-time factor cosine integral with reference position at electrical center
T': Derivative of T with respect to wave number
S: Transit-time factor sine integral (average magnitude of upstream and downstream halves)
S': Derivative of S with respect to wave number

2. Example Output of DTL PARMILA Design Run

Run (with "linout 1") ⇒ File: PARMILA.OUT (con't)

Lq: Quadurupole magnet length in cm
G: Quadurupole gradient in kG/cm
E0d: Design value of E0 for a DTL cell or an entire cavity or segment in MV/m
E0: Average axial electric field for the cell in MV/m (used in energy-gain calculation)
Phi Phase of the reference particle at the center of the gap in degrees
Phid Synchronous phase or design phase for symmetric segments in degrees
Z: Distance to end of cell (or center of magnet) from the beam-entrance end wall in cm

Cell	W	Beta	Lc	T	T'	S	S'	Lq	G	E0d	E0	
initial	2.5000	0.07281						1.750	-3.7000			
1	2.5253	0.07318	5.4326	0.5835	0.0961	0.5652	0.0259	3.500	0.0000	1.1300	1.1300	....
2	2.5515	0.07356	5.4601	0.5861	0.0957	0.5643	0.0263	3.500	3.7000	1.1550	1.1550	....
3	2.5784	0.07394	5.4894	0.5886	0.0952	0.5633	0.0267	3.500	3.7000	1.1802	1.1802	....
4												

	Phi	Phid	Z
....			0.0000
....	-45.000	-45.000	5.4326
....	-45.000	-45.000	10.8927
....	-44.939	-44.939	16.3821

58	7.1354	0.12256	9.0745	0.7852	0.0585	0.4599	0.0481	3.500	0.0000	2.9209	2.9209	....
59	7.3258	0.12417	9.1930	0.7885	0.0578	0.4575	0.0483	3.500	-3.7000	2.9629	2.9629	....
60	7.5230	0.12581	9.3140	0.7920	0.0570	0.4550	0.0485	3.500	-3.7000	3.0055	3.0055	....

....	-27.738	-27.738	396.6864
....	-27.388	-27.388	405.8793
....	-27.040	-27.040	415.1933

(RF Structure & Beam Dynamics Table Also Written to "Design.Out")

2. Example Output of DTL PARMILA Design Run

Run (with "linout 4") ⇒ File: PARMILA.OUT (con't)

LIN: linout 4 ; this outputs the linac geometry GHG uncommented 06/09/07
Geometric parameters for DTL tank 1
Tank of length 415.19332 cm contains 60 cells
Refer to Figure III-3 in the Parmila manual for a sketch of the geometry.
Cell boundaries are near the middle of drift tubes. Drift tube N follows gap N.
The column headings are:
N Cell number and drift tube number
W: Energy of the synchronous or design particle at the end of the cell in MeV
Beta: Velocity of the synchronous or design particle at the end of the cell
Lc: Cell length in cm
SL1(N) Length in cm of the upstream end of the drift tube downstream of this gap
g(N) Length in cm of the accelerating gap for cell N
SL2(N+1) Length in cm of the downstream end of the same drift tube referred to by the SL1(N) column
dg Displacement in cm of the gap center from the center of the cell
Lq: Quadurupole magnet length in cm (inside a drift tube if the line contains a cell number)
G: Quadurupole gradient in kG/cm
E0: Average axial electric field for the cell in MV/m
Phi Phase of the reference particle at the center of the gap in degrees
Z: Distance to end of cell (or center of magnet) from the beam-entrance end wall in cm

2. Example Output of DTL PARMILA Design Run

Run (with "linout 4") ⇒ File: PARMILA.OUT (con't)

Cell	W	Beta	Lc	SL1(N)	g	SL2(N+1)	dg	Lq	G	
initial	2.5000	0.07281				2.2551		3.5000	-3.7000	....
1	2.5253	0.07318	5.4326	2.2676	0.9099	2.2673	0.0062	3.5000	0.0000	....
2	2.5515	0.07356	5.4601	2.2801	0.9128	2.2802	0.0064	3.5000	3.7000	....
3	2.5784	0.07394	5.4894	2.2933	0.9158	2.2942	0.0066	3.5000	3.7000	....
4	2.6063	0.07434	5.5210	2.3077	0.9191	2.3075	0.0067	3.5000	0.0000	....
5										

		E0	Phi	Z
....				0.0000
....	1.1300	-45.0000		5.4326
....	1.1550	-45.0000		10.8927
....	1.1802	-44.9388		16.3821
....	1.2055	-44.7158		21.9031

.
.
.

57	6.9515	0.12099	8.9585	3.8002	1.4084	3.7959	0.0252	3.5000	3.7000	....
58	7.1354	0.12256	9.0745	3.8474	1.4312	3.8429	0.0257	3.5000	0.0000	....
59	7.3258	0.12417	9.1930	3.8954	1.4546	3.8908	0.0263	3.5000	-3.7000	....
60	7.5230	0.12581	9.3140	3.9444	1.4787	0.0000	0.0268	3.5000	-3.7000	....

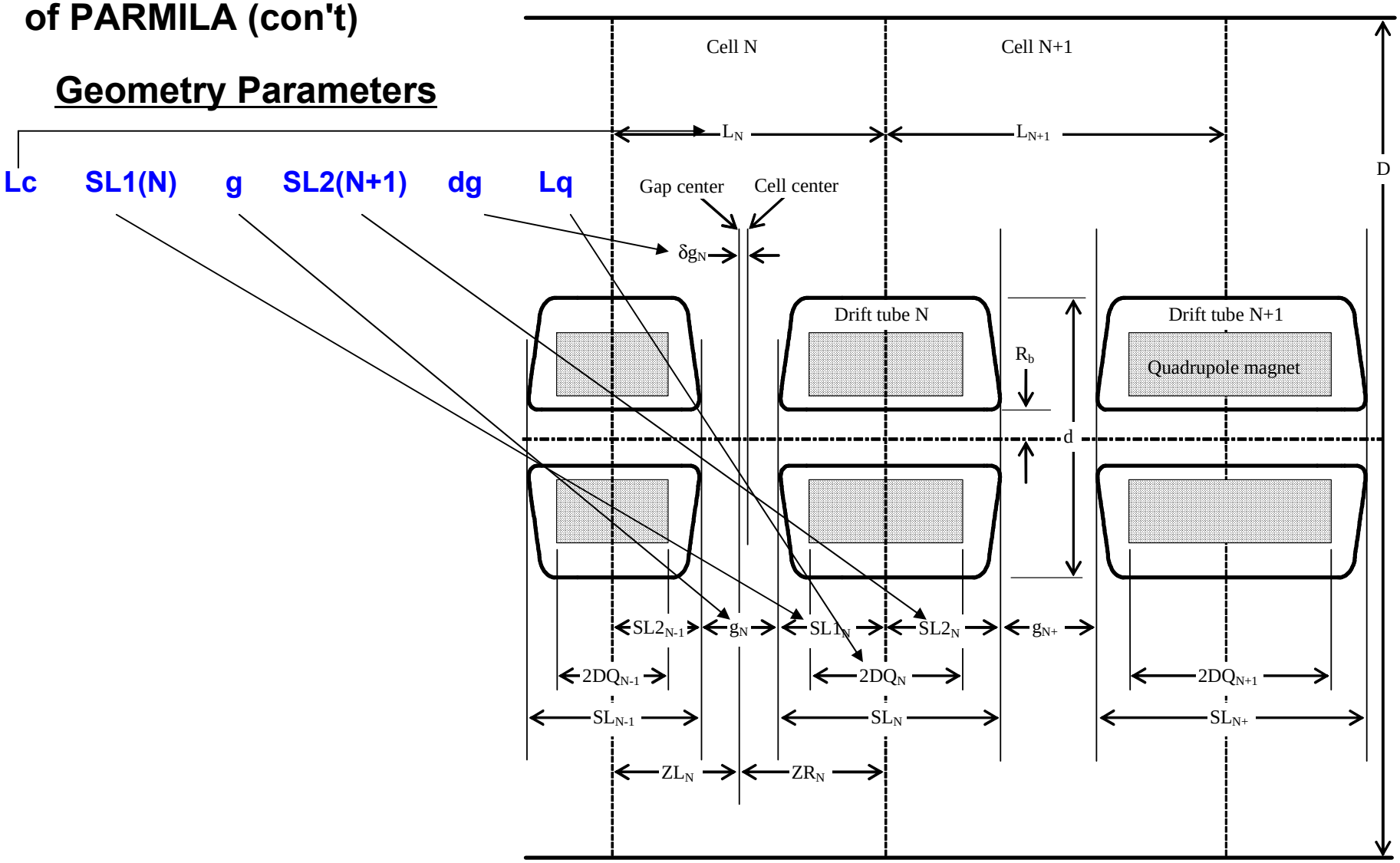
....	2.8795	-28.0894	387.6119
....	2.9209	-27.7381	396.6864
....	2.9629	-27.3882	405.8793
....	3.0055	-27.0397	415.1933

1. The LINAC "Design Mode" of PARMILA (con't)

Geometry Parameters

Lc SL1(N) g SL2(N+1) dg Lq

Three DTL Cells (Figure III-3)



2. Example Output of DTL PARMILA Design Run (con't)

Run (with "POWER" & "FullWallPower") ⇒ File: WALLPWR.OUT

Power loss estimate based on shunt impedance in SFDATA tables, and the cavity field and length.
Column headings are:
Cell Cell number for DTL, or cell number at the end of multicell segment
Cav Cavity number (structures other than DTL) at the end of the segment
Z Longitudinal position in cm at the end of the cell or segment
Beta Velocity relative to the speed of light of the design particle
W Kinetic energy in MeV at the end of the cell or segment
P Running power in MW dissipated in the walls of the linac to this point
Type "EndSeg" markes the ends of segments, otherwise blank
Pbeam Running power lost to the beam in MW
Iavg Average beam current at this point in mA
Ptotal Running total power in all structures in MW
Pst Running total power in the current structure in MW

Cell	Cav	Z	Beta	W	P	Type	Pbeam	Iavg	Ptotal	Pst
1	0	5.433	0.072820	2.525	0.00137		0.00142	56.000	0.00279	0.00279
2	0	10.893	0.073188	2.551	0.00281		0.00288	56.000	0.00569	0.00569
3	0	16.382	0.073565	2.578	0.00432		0.00439	56.000	0.00871	0.00871
4 ….										

2. Example Output of DTL PARMILA Design Run (con't)

Run ⇒ File: QUAD.OUT

Quadrupole magnets in all structures except DTLs ← **Quads Between DTL Tanks**

The column headings are:
W: Energy of the synchronous or design particle in MeV
Lq: Quadurupole magnet length in cm
G: Quadurupole gradient in kG/cm
Zc: Longitudinal coordinate at the center of the magnet in cm

W	Lq	G	Zc
7.5230	1.750	-3.7000	416.94332
7.5230	1.750	0.0000	424.52673
22.8381	1.750	0.0000	1032.49998
22.8381	1.750	3.7000	1046.87918
39.7889	1.750	-3.7000	1680.95376
39.7889	1.750	0.0000	1700.22051
56.5792	1.750	-3.7000	2343.27494
56.5792	1.750	-3.7000	2366.27178
72.4950	1.750	-3.7000	2997.60157
72.4950	1.750	0.0000	3023.53675

May Contain "Zero-Gradient" Quads (Maintains Transverse Lattice)

2. Example Output of DTL PARMILA Design Run (con't)

Run ⇒ File: Tr3Din.t3d

```
nt(    5)=3, a(1,    5)=  -3.7000e+1,   1.75000e+1,
nt(    6)=1, a(1,    6)=   0.96006e+1
nt(    7)=10, a(1,    7)=   3.5819e-2,    -45.00, 0., 1., 1.,
nt(    8)=1, a(1,    8)=   0.97251e+1
nt(    9)=3, a(1,    9)=   3.7000e+1,   1.75000e+1,
nt(   10)=3, a(1,   10)=   3.7000e+1,   1.75000e+1,
nt(   11)=1, a(1,   11)=   0.97369e+1
nt(   12)=10, a(1,   12)=   3.6961e-2,    -45.00, 0., 1., 1.,
nt(   13)=1, a(1,   13)=   0.98646e+1
    .
    .
    .
nt(  299)=3, a(1,  299)=  -3.7000e+1,   1.75000e+1,
nt(  300)=3, a(1,  300)=  -3.7000e+1,   1.75000e+1,
nt(  301)=1, a(1,  301)=   2.88016e+1
nt(  302)=10, a(1,  302)=  22.1693e-2,    -27.21, 0., 1., 1.,
nt(  303)=1, a(1,  303)=   2.93382e+1
nt(  304)=3, a(1,  304)=  -3.7000e+1,   1.75000e+1,
```

⇒ **TRACE 3-D Formatted Model (Drifts, Quads, RF Gaps)**

3. Modeling the DTL with TRACE 3-D from PARMILA Generated Model

- **TRACE 3-D Can Be Used to Provide a "Reality Check" on Design**
  - **PARMILA Outputs a File "Tr3din.t3d" with TRACE 3-D Lattice**
  - **"Tr3din.t3d" Written by PARMILA Only Has Beamline *Lattice***
  - **User Must Add Other Lines to "Tr3din.t3d" to Run TRACE 3-D**

  ⇒ **Use PARMILA to get a design; use TRACE 3-D for a first look**
- **PBO Lab 3.0 Can Import the PARMILA "Tr3din.t3d" Directly**

  ⇒ **Next Few Page Show How to Do This**

  ⇒ **Will Do This on Simulation Lab computers**

PBO Lab PARMILA-T3D-file Module Import of PARMILA "Tr3din.t3d"

Steps 1-3: Only IF You Ran Example Using the PARMILA.exe Executable

⇒ **Otherwise Go Directly to Step 3**

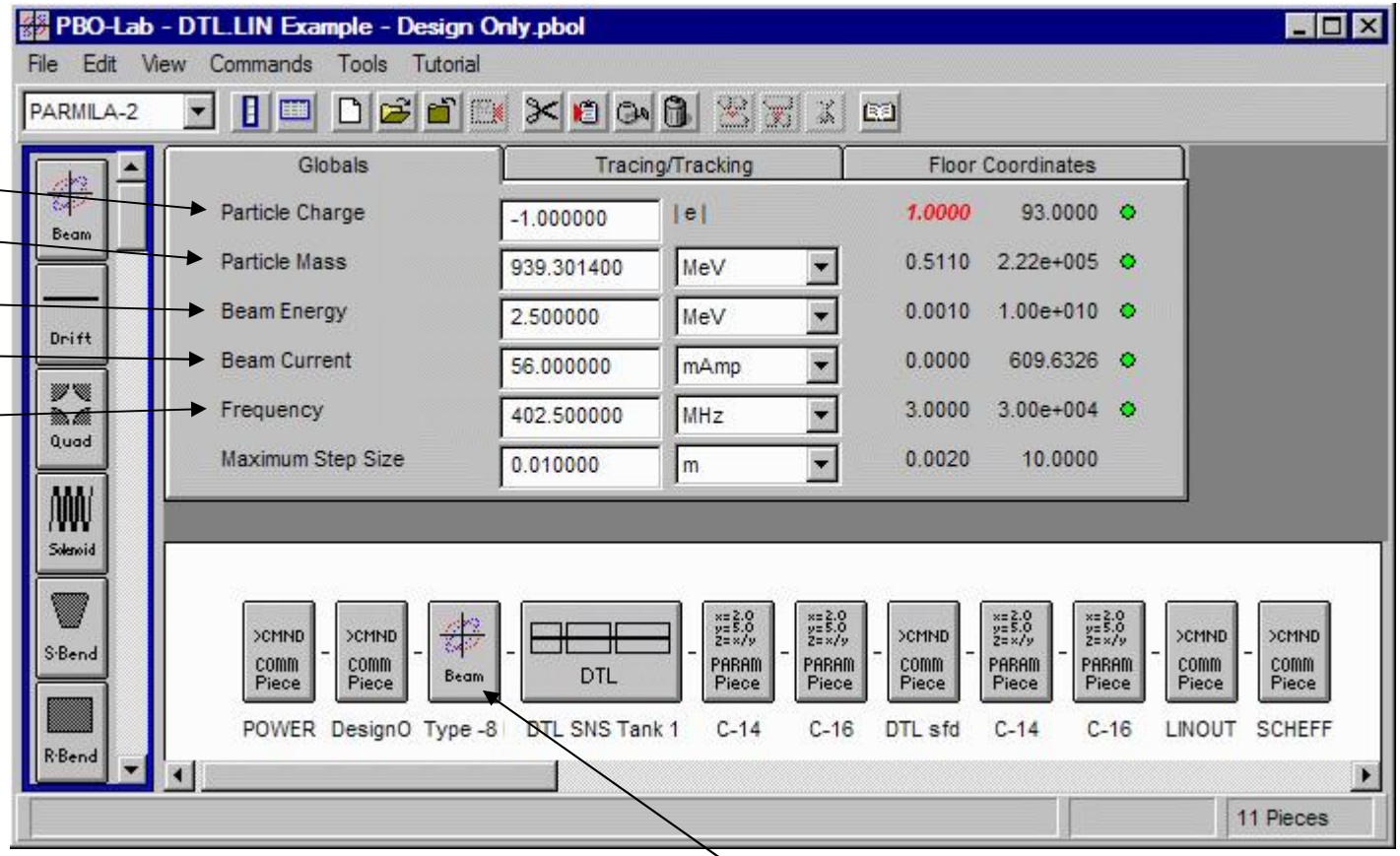
Step 1: Move a Copy of the File "Tr3din.t3d" to the PBO-Lab folder
(Do NOT Change the Name of the File from Tr3din.t3d)

3. Modeling the DTL with TRACE 3-D from PARMILA Generated Model (con't)

PBO Lab PARMILA-T3D-file Module Import of PARMILA "Tr3din.t3d" (con't)

Step 2: Set Globals for the Initial Beam / Reference Trajectory of "Tr3din.t3d"

Particle Charge
Particle Mass
Beam Energy
Beam Current
Frequency

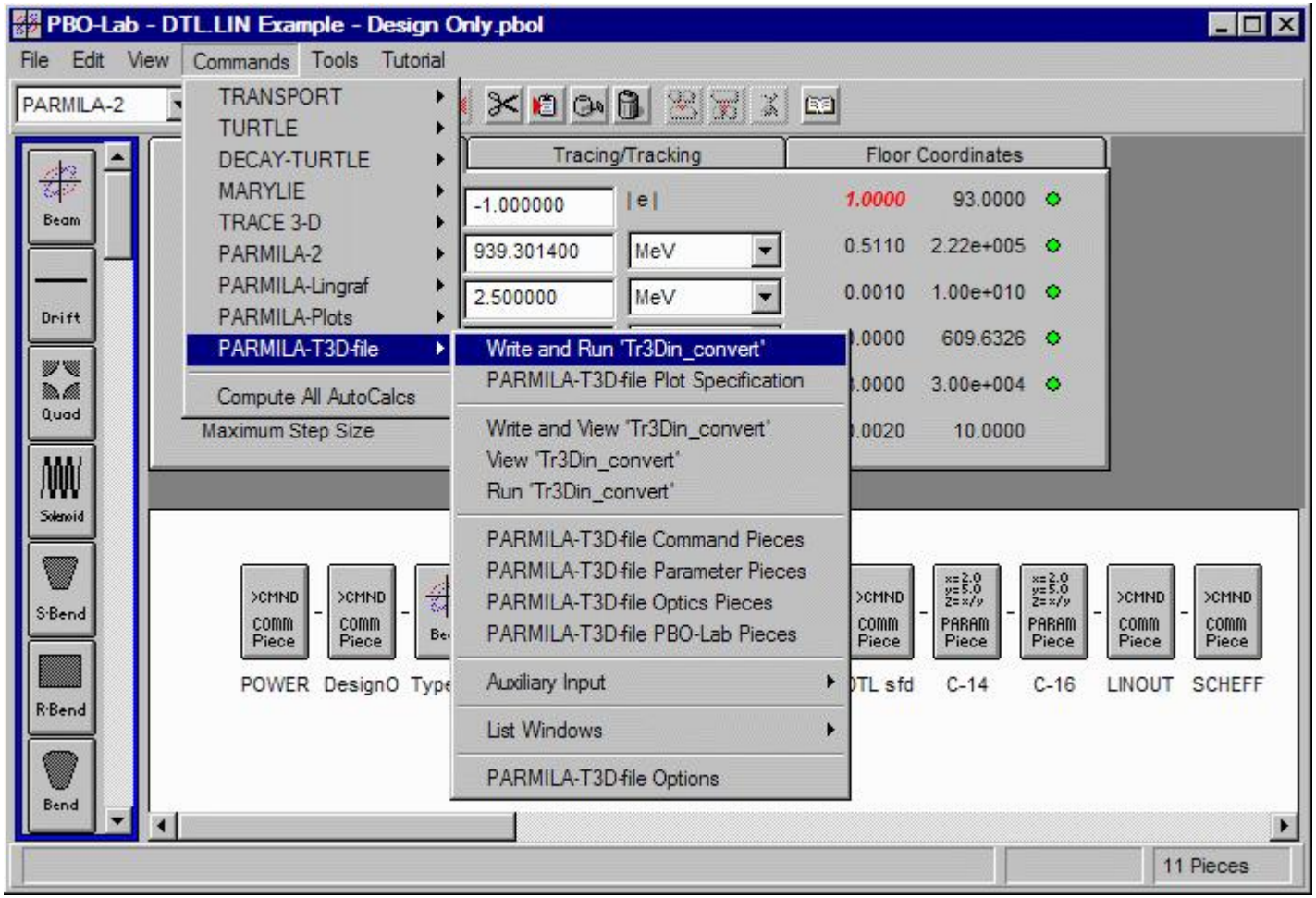


Step 3: Add a Beam Piece and Set Up Parameters

3. Modeling the DTL with TRACE 3-D from PARMILA Generated Model (con't)

PBO Lab PARMILA-T3D-file Module Import of PARMILA "Tr3din.t3d" (con't)

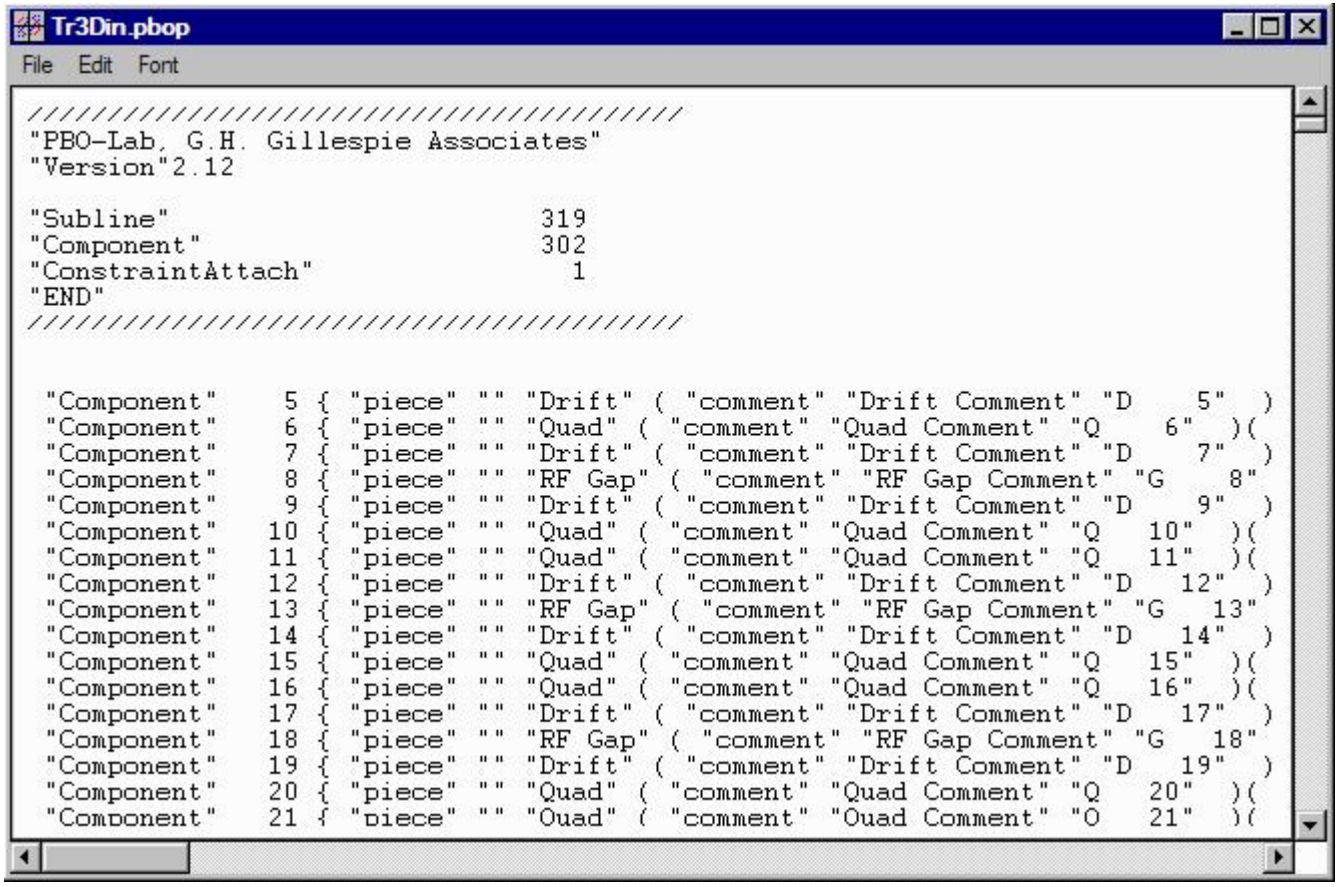
Step 4: Use PARMILA-T3D-file Command to Write and Run 'Tr3Din_convert'



3. Modeling the DTL with TRACE 3-D from PARMILA Generated Model (con't)

PBO Lab PARMILA-T3D-file Module Import of PARMILA "Tr3din.t3d" (con't)

When the PARMILA_T3D_file Command to Write and Run 'Tr3Din_convert' is Finished You Should See a Text File Named "Tr3din.pbop" Open on Your Computer Screen. It Will Look Something Like This:



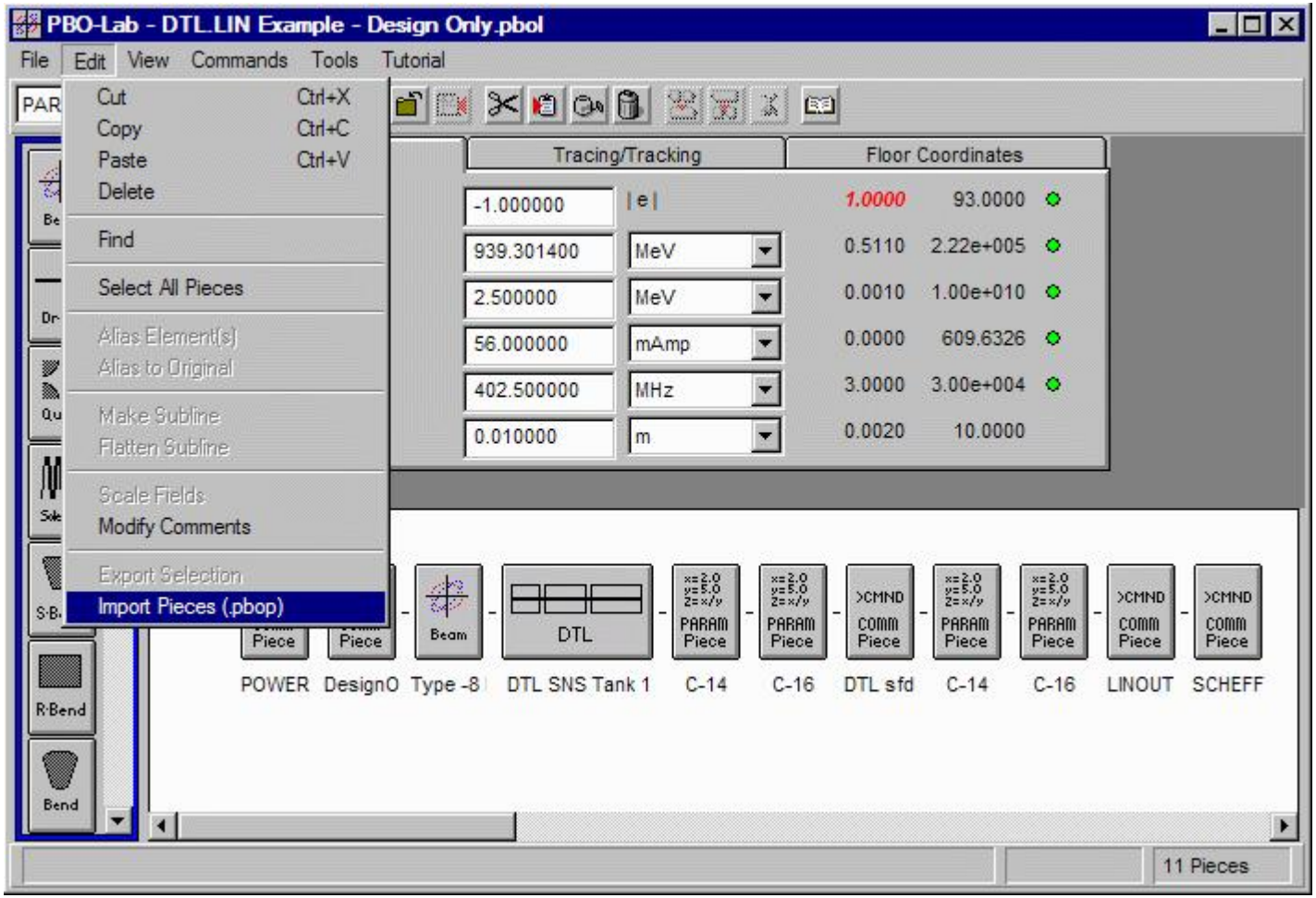
You Can Close This Window After It Has Been Displayed

⇒ **File "Tr3din.pbop" Contains a PBO Lab Object Model of the Lattice**

3. Modeling the DTL with TRACE 3-D from PARMILA Generated Model (con't)

PBO Lab PARMILA-T3D-file Module Import of PARMILA "Tr3din.t3d" (con't)

Step 5: Use the Edit Menu to Select Import Pieces (.pbop)

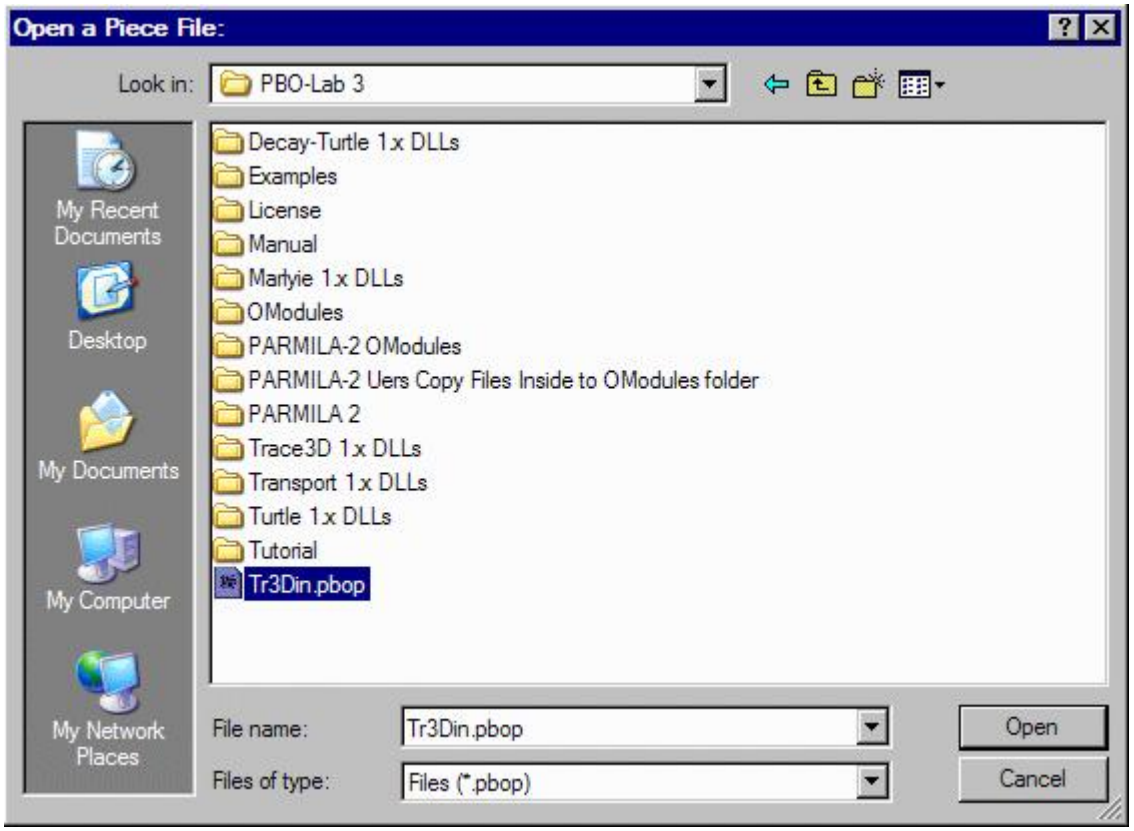


⇒ **This will open a standard Windows dialog for opening a file**

3. Modeling the DTL with TRACE 3-D from PARMILA Generated Model (con't)

PBO Lab PARMILA-T3D-file Module Import of PARMILA "Tr3din.t3d" (con't)

Step 6: In the Windows Dialog, Select the File Tr3din.pbop, Then Open



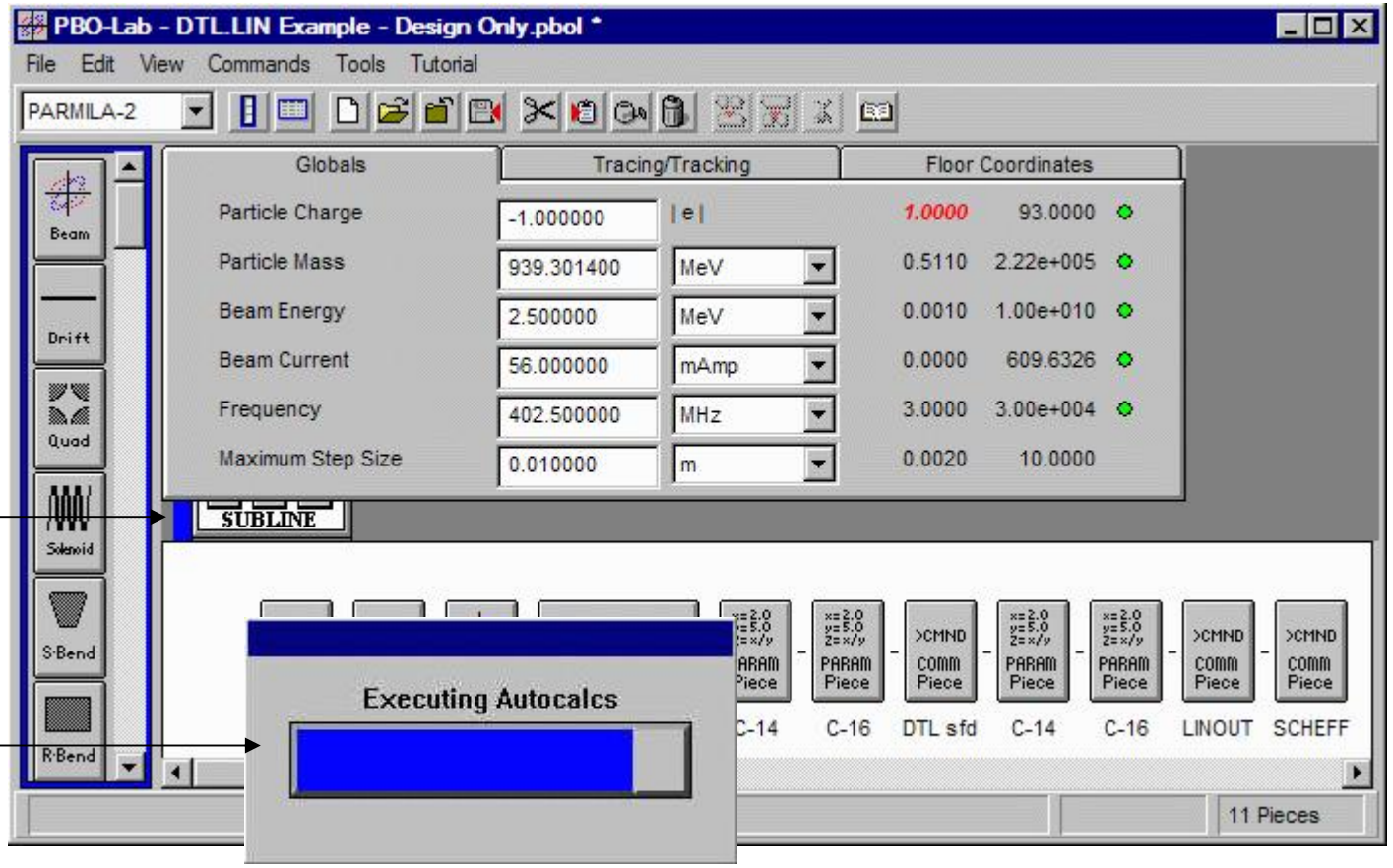
Open ⇒ **A "Subline" Will Appear on the Model Space**

⇒ **An "Executing Autocalcs" Progess Bar Will Appear (perhaps briefly)**

3. Modeling the DTL with TRACE 3-D from PARMILA Generated Model (con't)

PBO Lab PARMILA-T3D-file Module Import of PARMILA "Tr3din.t3d" (con't)

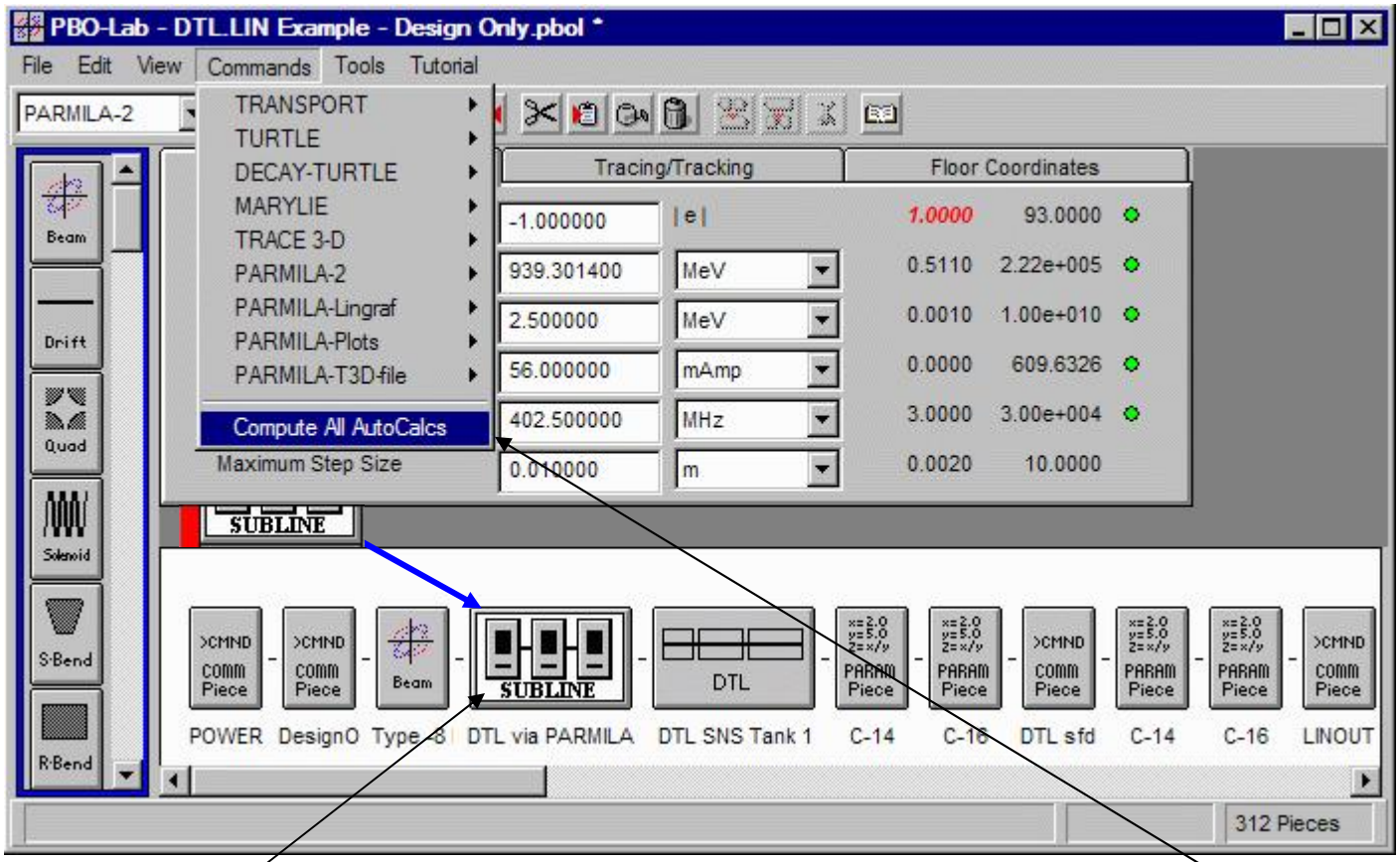
As the Import Pieces (.bpop) Edit Command Begins to Execute You Should See a Subline Appear on the Work Space (Bottom Left of Work Space - Partly Under the Global Parameter Pane) & Progress Bar that Will Look Something Like This:



3. Modeling the DTL with TRACE 3-D from PARMILA Generated Model (con't)

PBO Lab PARMILA-T3D-file Module Import of PARMILA "Tr3din.t3d" (con't)

Step 7: Move (Shift + Mouse Drag) the Subline from the Work Space to the Model Space, Add a Beam Piece, Use Command to Compute All AutoCalcs:



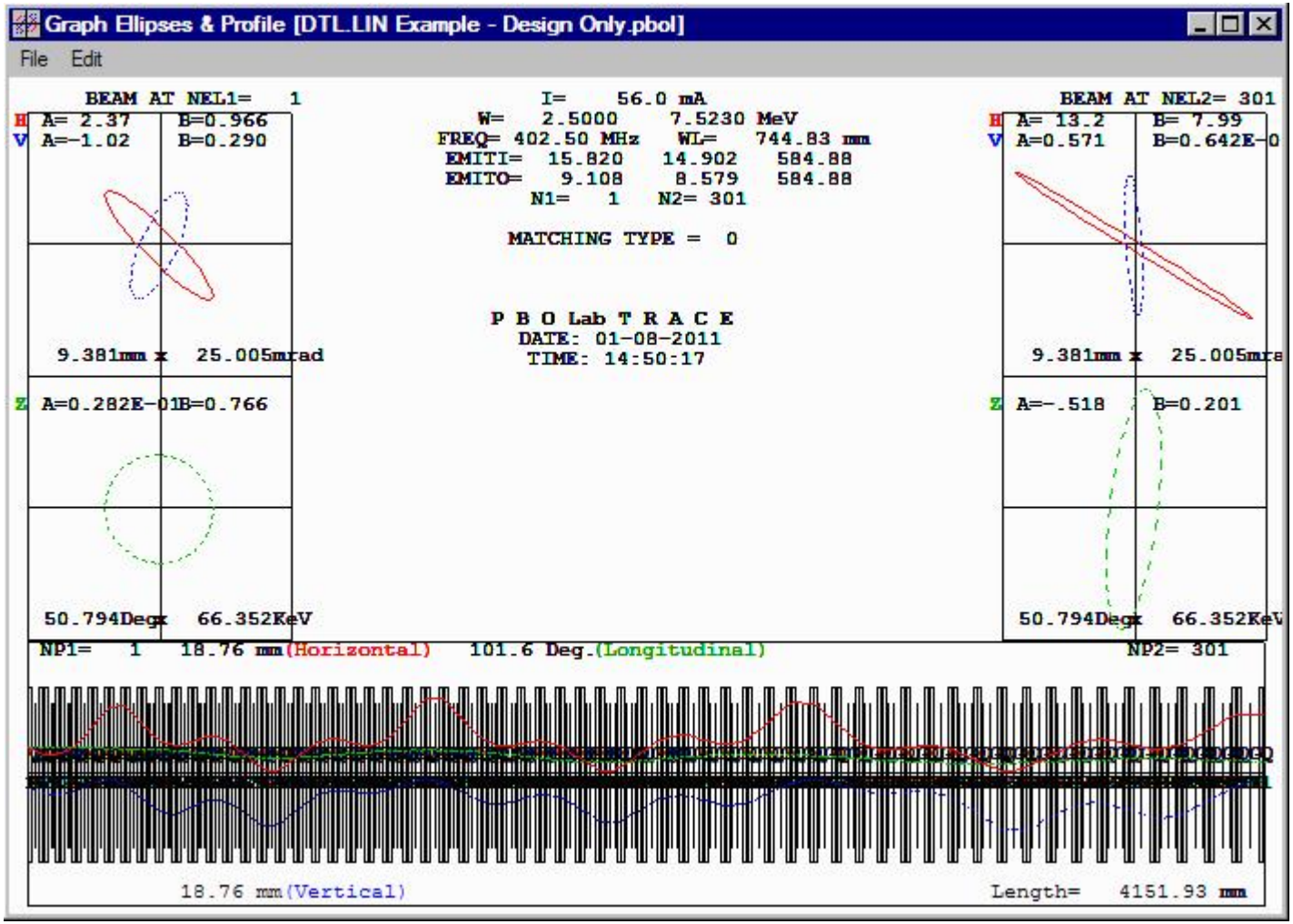
First Move Subline **Then Compute AutoCalcs**

These AutoCalcs May Take Longer and the Progress Bar May Move Slower

3. Modeling the DTL with TRACE 3-D from PARMILA Generated Model (con't)

PBO Lab PARMILA-T3D-file Module Import of PARMILA "Tr3din.t3d" (con't)

Step 8: Use TRACE 3-D Command to Graph Beam Line:



Suggestion: Use Automatic Graph Scales in TRACE 3-D Options ☑ Use Automatic Graphic Scales

3. Modeling the DTL with TRACE 3-D from PARMILA Generated Model (con't)

PBO Lab PARMILA-T3D-file Module Import of PARMILA "Tr3din.t3d" (con't)

- **Once "Tr3din.t3d" Has Been Imported Can Use Any PBO-Lab Modules**
  - **Run TRACE 3-D, TRANSPORT or TURTLE**
  - **Run PARMILA-2 (As a "Transfer Line" with RF Gaps & Acceleration)**

  ⇒ **May Be Useful for Design Verification / Validation**

- **Can Use Any PBO-Lab Tools/Features As Well**
  - **Export a "Complete" Tr3din.t3d File Use with LANL TRACE 3-D**
  - **Confirm Key Results (e.g. Beamline Length, Cumulative Energy)**

  ⇒ **Example for Length Shown on Next Slide**
  - **…**

  ⇒ **Useful for Verification / Validation of Imported Model**

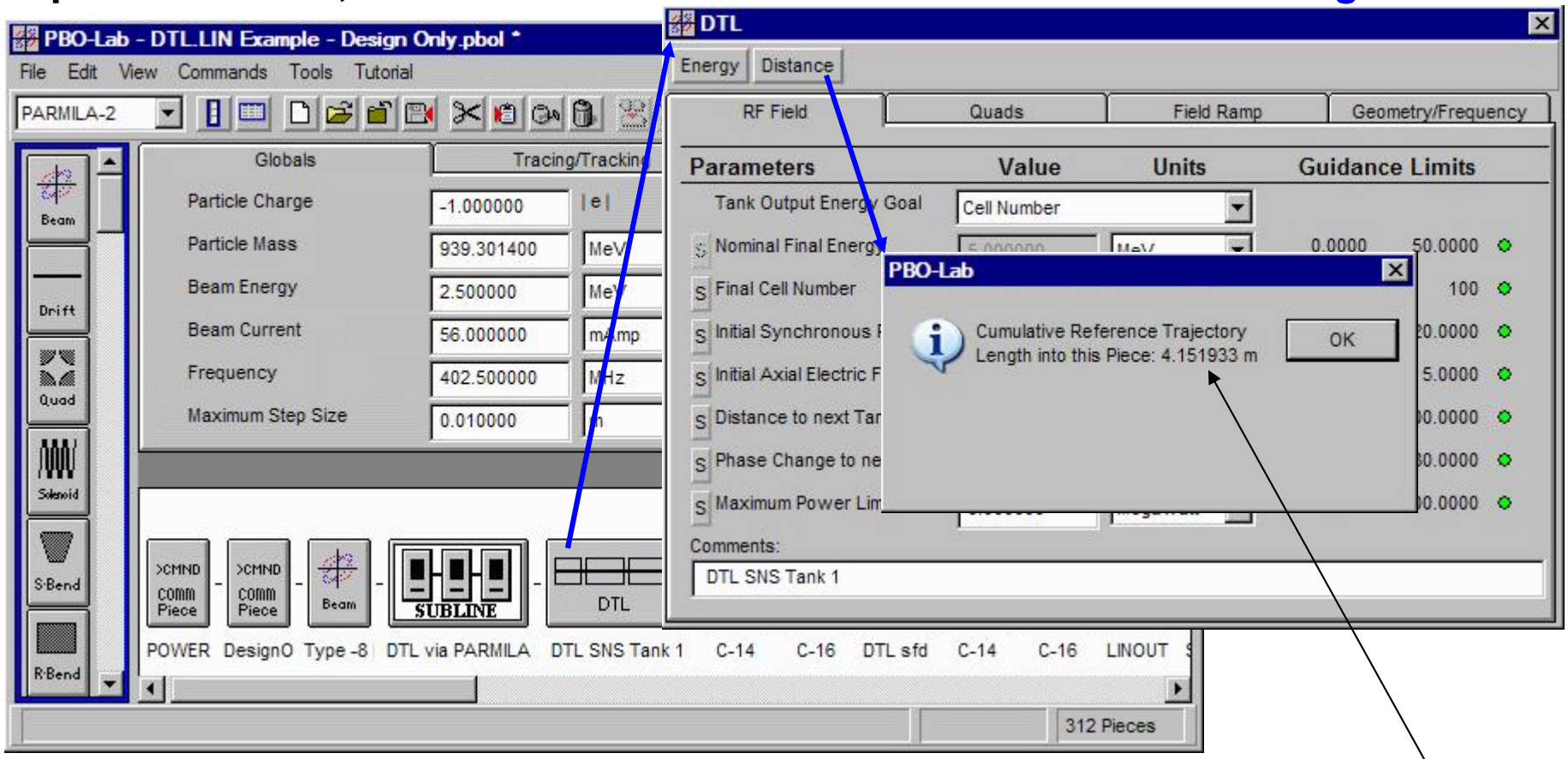
- **PARMILA-T3D-file Module Import of PARMILA "Tr3din.t3d" Relatively Easy**

  ⇒ **Can Do This on Simulation Lab Computers**

3. Modeling the DTL with TRACE 3-D from PARMILA Generated Model (con't)

PBO Lab PARMILA-T3D-file Module Import of PARMILA "Tr3din.t3d" (con't)

Another Good Check on the Imported Model is to Open the Piece Following the Imported Subline, and Then Use the Distance Button to Confirm Length



Distance Button ⇒ Reference Trajectory Length

Note: Energy Button is Approximate and May Not Be Accurate for All Models

3. Modeling the DTL with TRACE 3-D from PARMILA Generated Model (con't)

PBO Lab PARMILA-T3D-file Module Import of PARMILA "Tr3din.t3d" (con't)

How Good Is the "Tr3din.t3d" Imported Model of the Beamline?

Comparison of Beamline Length and Output Energy Suggests Pretty Good:

Source	Reference Trajectory Length	Reference Trajectory Energy
PARMILA-2	415.1933 cm	7.5230 MeV
TRACE 3-D	4151.93 mm	7.5230 MeV
PBO Lab	4.151933 m	7.5222980 MeV
TRANSPORT +PBO Lab	4.15194 m	(0.119120 GeV/c) 7.523132 MeV
TURTLE	4.152 m	-

Most Differences are Just in the Accuracy of the Printed/Displayed Output

⇒ **Will Compare Other Design Details in Simulation Lab**

Important Caveat: PBO Lab "Complex" Pieces *Unique* to PARMILA-2 (DTL, CCL, BCDTL, SC1, SC2) Do *NOT* Compute Their Own Length or Energy