A few Evolutions in SAD

V1.1k64

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Extended dispersion for 6D optics

The *extended dispersion matrix* E in SAD is defined by

$$E \equiv \begin{pmatrix} \left(1-\dfrac{|H_x|}{1+a_h}\right) I & \dfrac{H_x J H_y^T J}{1+a_h} & -H_x \\ \dfrac{H_y J H_x^T J}{1+a_h} & \left(1-\dfrac{|H_y|}{1+a_h}\right) I & -H_y \\ -J H_x^T J & -J H_y^T J & a_h I \end{pmatrix} , \tag{1}$$

where

$$H_{x,y} \equiv \begin{pmatrix} \zeta_{x,y} & \eta_{x,y} \\ \zeta_{p_{x,y}} & \eta_{p_{x,y}} \end{pmatrix} , \tag{2}$$

$$J \equiv \begin{pmatrix} 0 & 1 \\ -1 & 0 \end{pmatrix} , \tag{3}$$

$$I \equiv \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} , \tag{4}$$

and

$$a_h^2 = 1 - |H_x| - |H_y| \ . \tag{5}$$

Some characteristics of *E*

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- E is a symplectic matrix: $EJE^TJ = -I$.
- $E(H_{x,y})^{-1} = E(-H_{x,y})$.
- In the case of $\zeta_{x,y} = \zeta_{p_{x,y}} = 0$, E reduces to a usual 5D dispersion matrix:

$$E \Rightarrow \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & -\eta_x \\ 0 & 1 & 0 & 0 & 0 & -\eta_{p_x} \\ 0 & 0 & 1 & 0 & 0 & -\eta_y \\ 0 & 0 & 0 & 1 & 0 & -\eta_{p_y} \\ \eta_{p_x} & -\eta_x & \eta_{p_y} & -\eta_y & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix}. \tag{1}$$

Separation of Longitudinal Coordinate

- The matrix E separates a 6D transfer matrix M_{12} from location 1 to 2 into transverse and longitudinal parts:

$$M_{12} = E_2^{-1} \begin{pmatrix} P & T & 0 \\ S & Q & 0 \\ 0 & 0 & C \end{pmatrix} E_1 \ . \tag{1}$$

- The longitudinal Twiss parameters α_z, β_z, ψ_z are defined by the 2 by 2 matrix C in the usual manner.

- The x-y coupling and transverse Twiss parameters are calculated from the transverse components P, Q, S, T in the usual manner.

- The momentum/temporal dispersions η_x, η_{p_x}, η_y, η_{p_y} / ζ_x, ζ_{p_x}, ζ_y, ζ_{p_y} correspond to *physical dispersions*, *i.e.*, `PEX, PEPX, PEY, PEPY/PZX, PZPX, PZY, PZPY` in SAD. They are translated to *normalized dispersions* `EX, EPX, EY, EPY/ZX, ZPX, ZY, ZPY` with the x-y coupling parameters `R1, R2, R3, R4`.

Remark: the separation above does not work when *x*-*z* or *y*-*z* coupling is too strong, where exchange of coordinates is necessary (not implemented in SAD yet).

Usage

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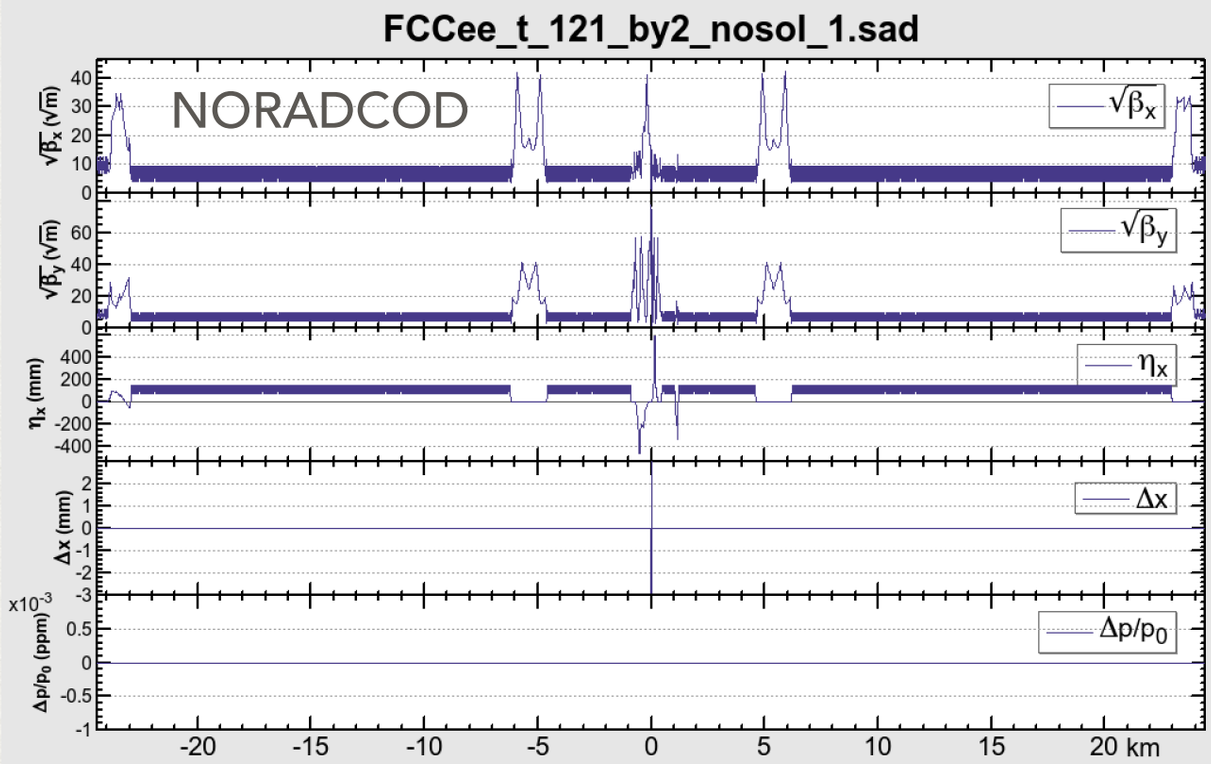
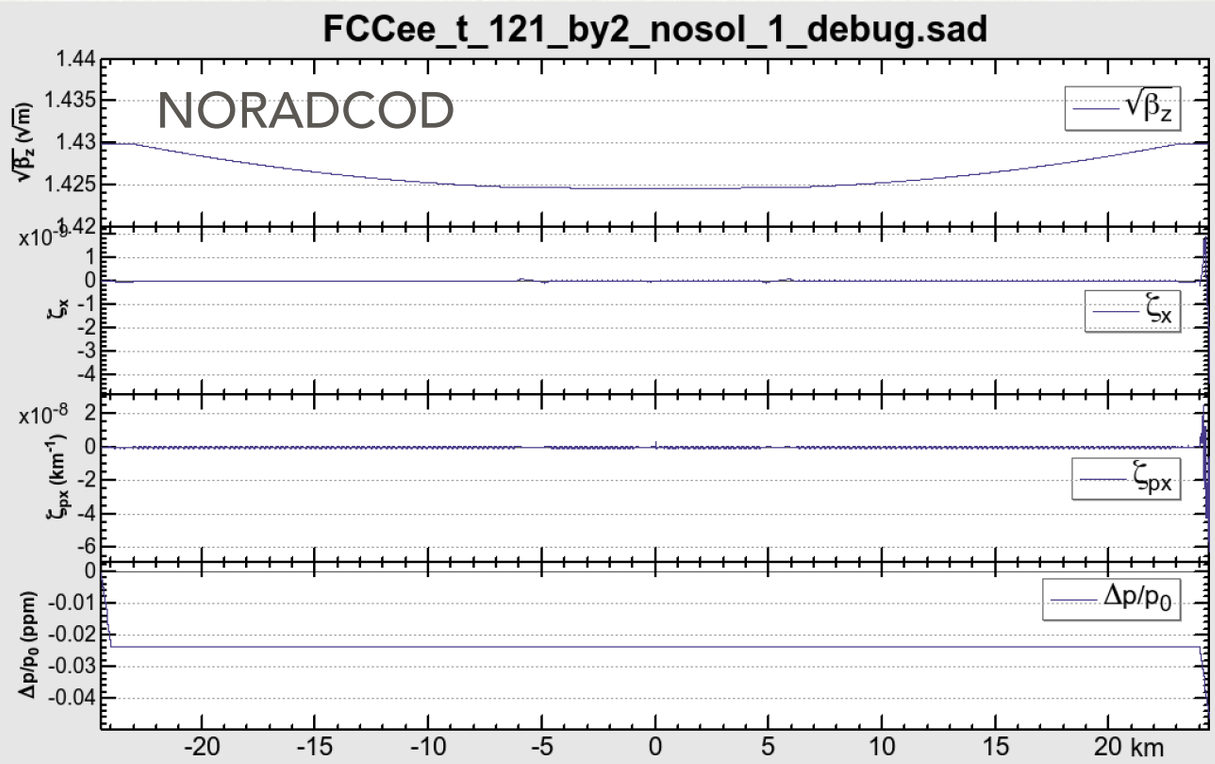
- The flag `CALC6D` enables 6D optics calculation in `CALC` and `GO`.
- `CALC4D` is the antonym of `CALC6D`.
- The default is `CALC4D`.
- Flags `RFSW`, `RADCOD`, `RADTAPER` are usable with `CALC6D`.
- `DISP Z` prints out the longitudinal parameters `AZ, BZ, NZ, ZX, ZPX, ZY, ZPY, DZ, DDP`.
- `OpticsPlot[]/DRAW` plots the 6d optics.
- `MAT` and `TransferMatrix[]` returns a 6 by 6 matrix with `CALC6D`.
- With `CALC6D` and `CODPLOT`, `EMIT/Emittance[]` dumps optics and the closed orbit.

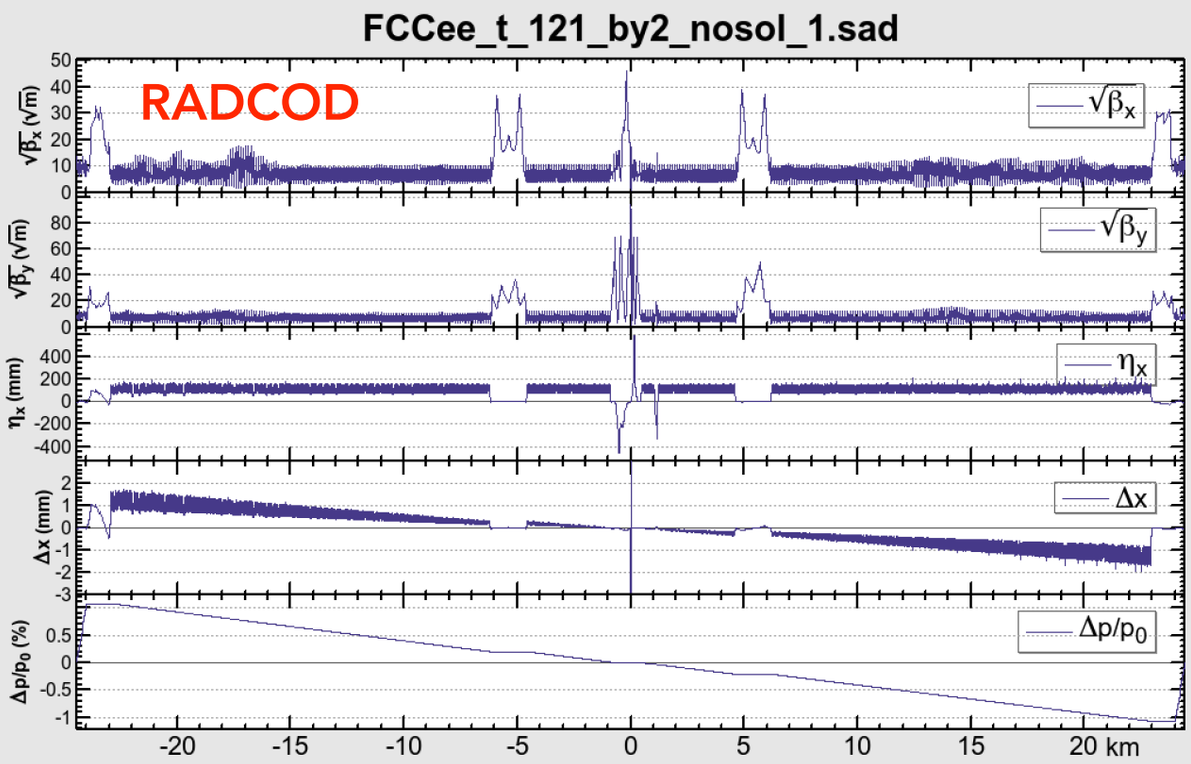
Remark: The off-momentum matching & finite amplitude matching
have not been implemented yet,

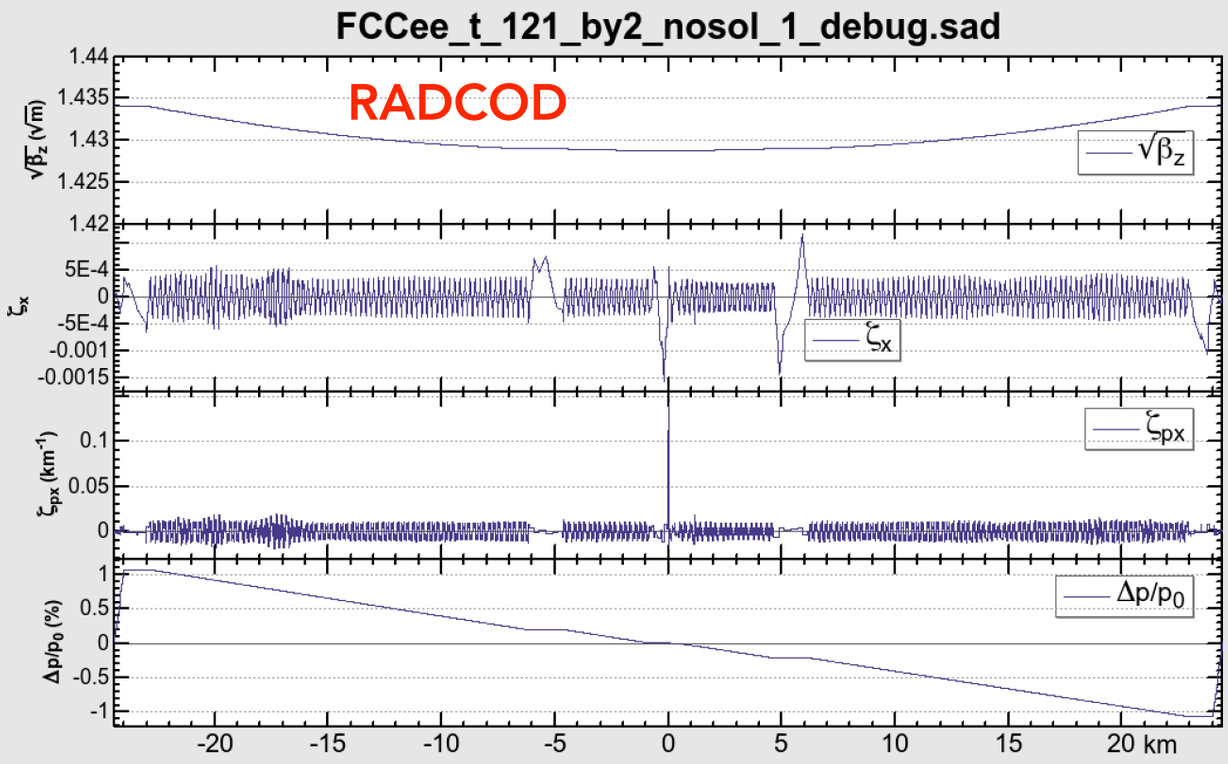
Example 1: Sawtooth effect

CALC6D;CALC;

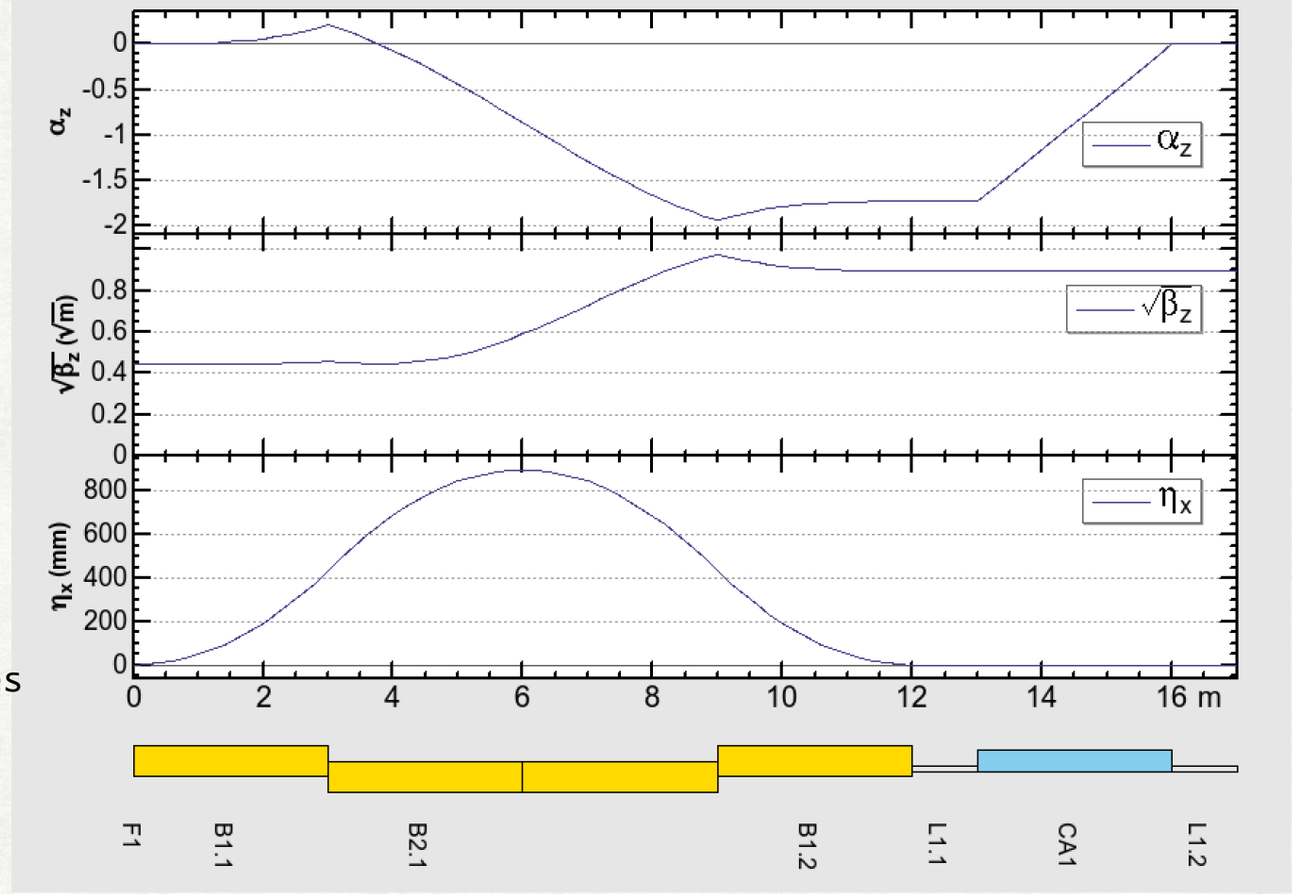








Example 2: Energy compressor



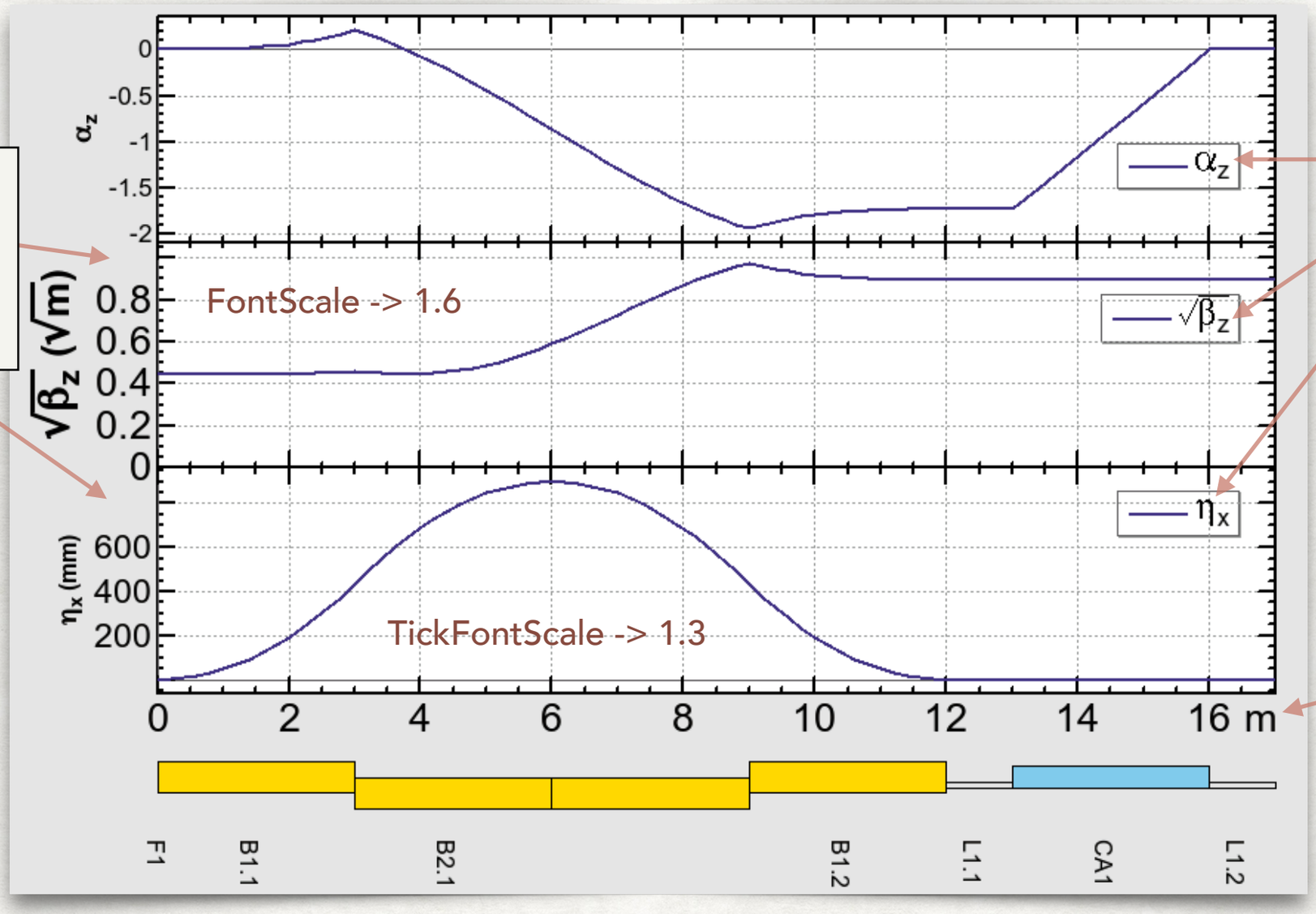

```
rfsw;trpt;ins;calc6d;
fit az 0;
fit ^^^ $$$ bz 4;
coup b2 b1 -1;
free ca1 b*;
???-FFS-Info-Component B2.1 is coupled to B1.1
???-FFS-Info-Component B2.2 is coupled to B1.1
go;
Iterations  Residual    Method      Reduction  Variables
      3     1.337       (NEWTON)   6.2500E-02      3
      4    0.4571       (NEWTON)   0.2500          3
      5    0.3421       (NEWTON)    1.000          3
      6    5.0679E-03   (NEWTON)    1.000          3
      7    6.1154E-07   (NEWTON)    1.000          3
 Matched. ( 2.6648E-15) DP = 0.01000  DP0 = 0.00000  ExponentOfResidual = 2.0  OffMomentumWeight =   1.000
F1/$$$    f BZ   4         1   4.000000 $$$        AX    #######  #  -1.734642 $$$        BX    #######  #  40.089797
$$$         NX    #######  #    .166770 $$$        AY    #######  #   -.504477 $$$        BY    #######  #  12.055708
$$$         NY    #######  #    .265221 $$$        AZ   0         1  3.6437E-8 $$$        LENG  #######  #  17.000000
 draw az & bz & ex lat;
```

Remarks:

- FitValue is not applicable to the longitudinal functions and temporal dispersions, so far.

More options for Graphics

```
OpticsPlot[{{"AZ"},{"BZ",FontScale->1.6},{"EX",TickFontScale->1.3}},Names->"*",Thickness->2]
```



Tick labels hide if collide to each other.

The legend box searches a location to avoid collision with the contents.

UnitLabel

The component labels in OpticsPlot automatically thin out to avoid collisions.

- Now the graphics of SAD comply with PRAB's standard!

PHYSICAL REVIEW ACCELERATORS AND BEAMS **19,** 111005 (2016)

Since 1986 SAD Strategic Accelerator Design

- Now the graphics of SAD comply with PRAB's standard!

Other changes since ~June 2016

1. Removed almost all 32-bit memory allocations, except for a few obsolete routines.

2. The expansion of a beam line in MAIN level is rewritten using a new module with new types sad_el and sad_comp, and module routines loc_comp, loc_el, idcomp, dircomp, idcompc,idelc, idtypec, idvalc, direlc, compelc, pnamce, lpnamec.

3. Common blocks are largely replaced with modules.

4. Physical constants are updated with PDG2014 data in all .f and .c routines.

5. MULT with nonzero ANGLE was reviewed to be more consistent with BEND or QUAD. The Maxwellian fringes of K1 and higher are not yet implemented though.

6. New keywords F1K1F, F2K1F, F1K1B, F2K1B are introduced to describe asymmetric fringes at the entrance and the exit of QUAD and MULT. The traditional F1 and F2 are still valid: F1 + F1K1F(B) F1 + F2K1F(B) work at the entrance(exit) if the orientation of the element is positive, and vice versa when negative.

7. A routine to find out keywords of an element is renewed for efficiency. A new key KEYWORDS_ALL is added in Element to return all keywords including voids ('-').

8. The position of a legend in graphics now searches to avoid an overlapping with the contents of the graph. Also the size and frame are modified.

9. FindRoot is modified to handle a function that becomes invalid with non-real argument.

More changes

10. A wrong usage of mkstemp creating unnecessary files has been corrected.

11. The flag RADTAPER no longer needs CODPLOT.

12. Closed orbit finding with RADTAPER has been revised.

13. Accessing keys of elements with an internal table kytbl has been changed to use parameters if possible.

14. Fitting value specification with two locations treats the value as the ratio for BX, BY, BZ, and as the difference for other functions:

FIT P1 P2; BX 1.5 : BX(P2) / BX(P1) == 1.5

FIT P1 P2; EX 0.2 : EX(P2) - EX(P1) == 0.2

15. A bug was created in around Sept. 2016, and fixed in temit.f. It might have affected the value of emittances.

16. More bugs have been generated and corrected…