ELBD beamlet with Dimad

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1 Introduction

The ELBD optics in XML format is used here:

beamphys-kaltchev-OPTICS-ELBD .

A translator prepares Transoptr and Dimad lattices. The same solenoid model is used for both codes (hard-edge solenoid with an effective length, plus rotation). The buncher is OFF. The drifts are split using a predefined maximum drift length. The translator also makes three Dimad inputs: whole ELBD 300 KeV section (from anode), a section extending from anode to collimator, and a section from the collimator to the last beam screen.

After correcting the path-length element R_{56} in Dimad for the drift contribution, the 6x6 matrices found by Dimad and Transoptr (for 0 pC) for the whole ELBD agree.

The solenoid settings and momentum resolution have been found in Baartman's ``Tunes.pdf''.

Below, "suppl." means non-important, i.e. for reader's possible interest.

1.1 ELBD fitting with a slider GUI (suppl.)

A Mathematica slider helps the Dimad fitting (LMDIF). Sample image of the slider is shown on Figure 1. The user first chooses locations of two fit points: FIT1, FIT2 and a third such point FIT3 is automatically set at line exit. For the slider on Figure 1, there are four requested targets to be achieved by varying three solenoid currents. In this particular case, the requested targets are the values of $\sigma_x^{(1)}$, $\Delta\beta_x^{(2)}$, $\sigma_x^{(3)}$, $\sigma_x'^{(3)}$, where subscript denotes the FIT element and $w^{(i)}$, $i = 1, 2, 3, 4$ are the four weights. Upon moving a slider, or changing a weight, the GUI displays the x (red) and y (blue) envelopes and the dispersion (green) before and after fitting. It also shows the four `initial`, `requested` and `achieved` values for the targets and the `fitted` solenoid currents (Amperes) and the fitting error.

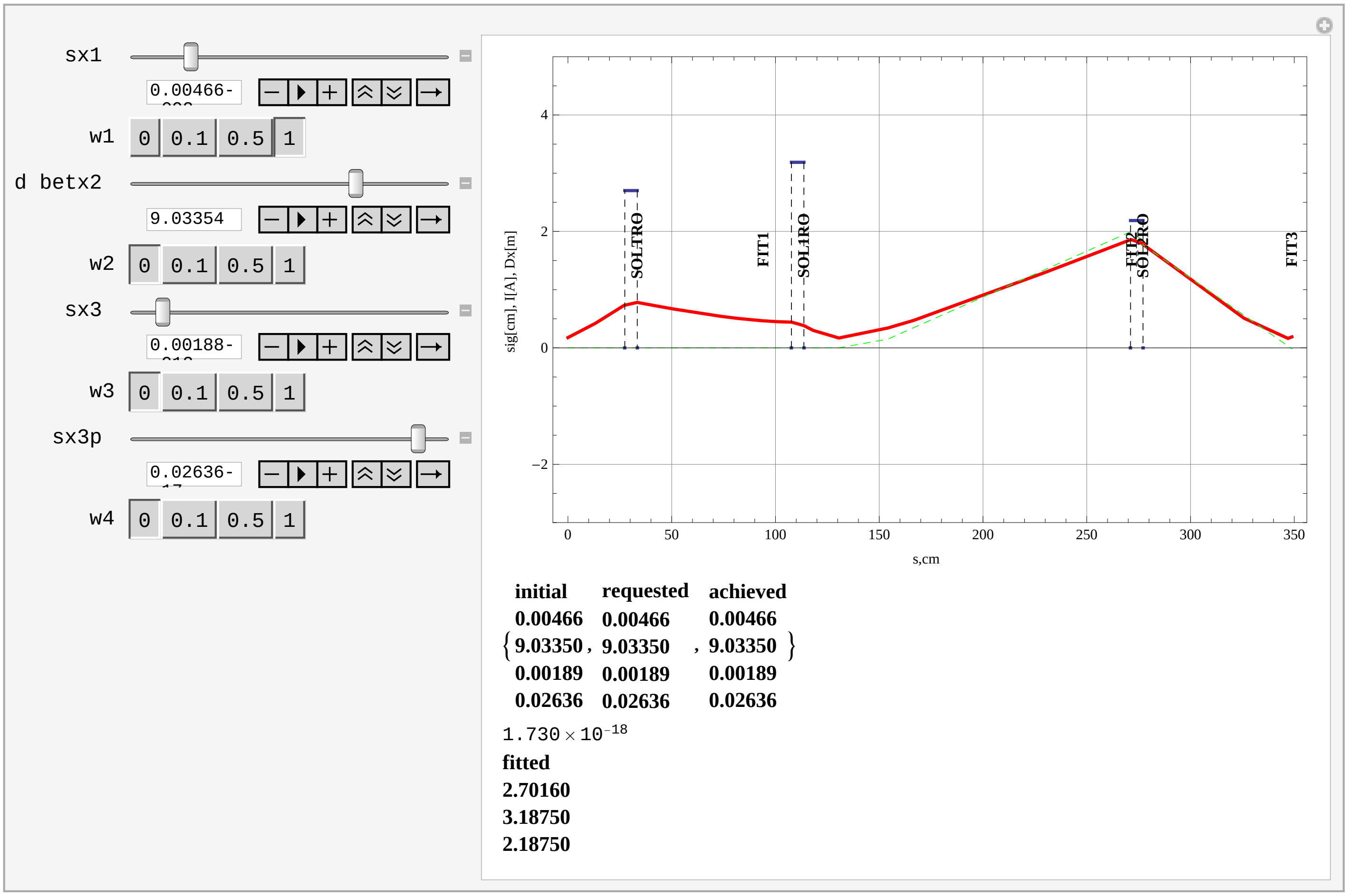


Figure 1: Math slider to manipulate Dimad fitting.

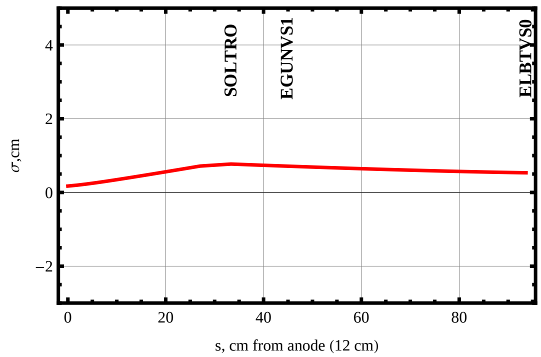
2 ELBD section before collimator

Here the settings are as in "Tunes.pdf". The initial beam has a non-normalized emittance $\epsilon = 34.5$ mm.mrad. This value is "2 σ" so divide all beam sizes by 4. The (round-beam) twiss parameters at entrance are $\beta = 0.08716$ m, $\alpha = -0.5549$. The exit is set at the collimator location `ELBTVS0`.

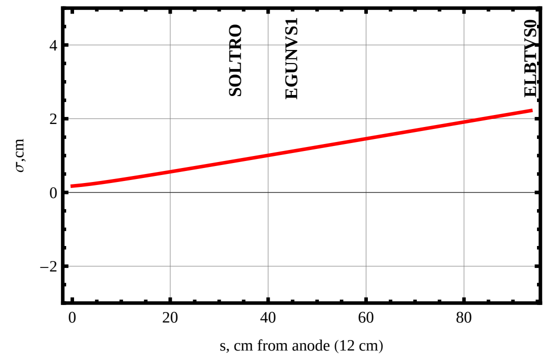
The Dimad result, envelopes and beam parameters at exit, for two values of c_0, the gun solenoid `SOLTro`, is shown on Figures 2(a), 2(b). These are almost exactly the same as in "Tunes.pdf":

a) for c_0=2.63 A, Figure 2(a), we have 5.4 mm by 6.8 mrad at the collimator plate – this is a waist.

b) if we set c_0=0 (to collimate angles better) Figure 2(b), the exit beam is 22.5 mm by 23 mrad, very far from a waist.



(a) If c_0= 2.63 A then at exit: 5.3 mm x 6.8 mrad



(b) If c_0=0A then at exit: 22.2 mm x 22.7 mrad

Figure 2: Line before collimator (Dimad) – envelopes and beam parameters at exit

3 ELBD section after collimator

The initial beam for the two cases above should be (Tunes.pdf):

a) If choosing a beamlet with the collimator then the divergence for the initial beam after collimator has the full 6.8 mrad.

b) If here we choose a tiny collimator hole, the divergence for the initial beam after collimator is 34.5um/22.5mm=1.5mrad.

We use the lattice section extending from the collimator at `ELBTVS0` to `ELBDVS1`. The Dimad run is again made with sliders, as shown on Figures 3, 4 and 5. Once slider settings are chosen, Dimad traces the envelopes and saves the first order 6x6 matrix. Again, the results agree with "Tunes.pdf" , see the captions. The momentum resolution defined as: $\texttt{resol} = \frac{|D_x[m]|}{2\sigma[m]}$.

For the Dimad lattice seen on Figures 3, 4 and 5, two correcting elements are added at line exit.

3.1 Adding a correction to Dimad's native R_{56} (linear transit time on energy)

Dimad uses the same coordinates as Transoptr $(x, x', y, x', l, \delta)$; l is the same as z in Transoptr. However, the Dimad matrix, in the non-relativistic case, does not include the drift-part contribution to `dR56` $L_{\mathrm{tot}}/\gamma^2 = 0.921462$, where L_{tot} is length of the section and γ is for 300 KeV. Therefore a matrix element `dR56` is installed immediately before exit, `ELBDVS1`:

```
dR56:matrix,l=0,R11=1,R22=1,R33=1,R44=1, R55=1,R66=1,R56=.921462;
```

This corrects for the path length as it multiplies the native Dimad matrix by:

$$\begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & L_{\mathrm{tot}}/\gamma^2 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix}$$

3.2 Adding global compensation of solenoid rotation

Optionally, if a flag `backrot=ON`, a `roll` element is installed immediately before line exit `elbdvs1`:

```
backro:roll,angle=-1*(c1*0.205066+ c2*0.205066) ;
```

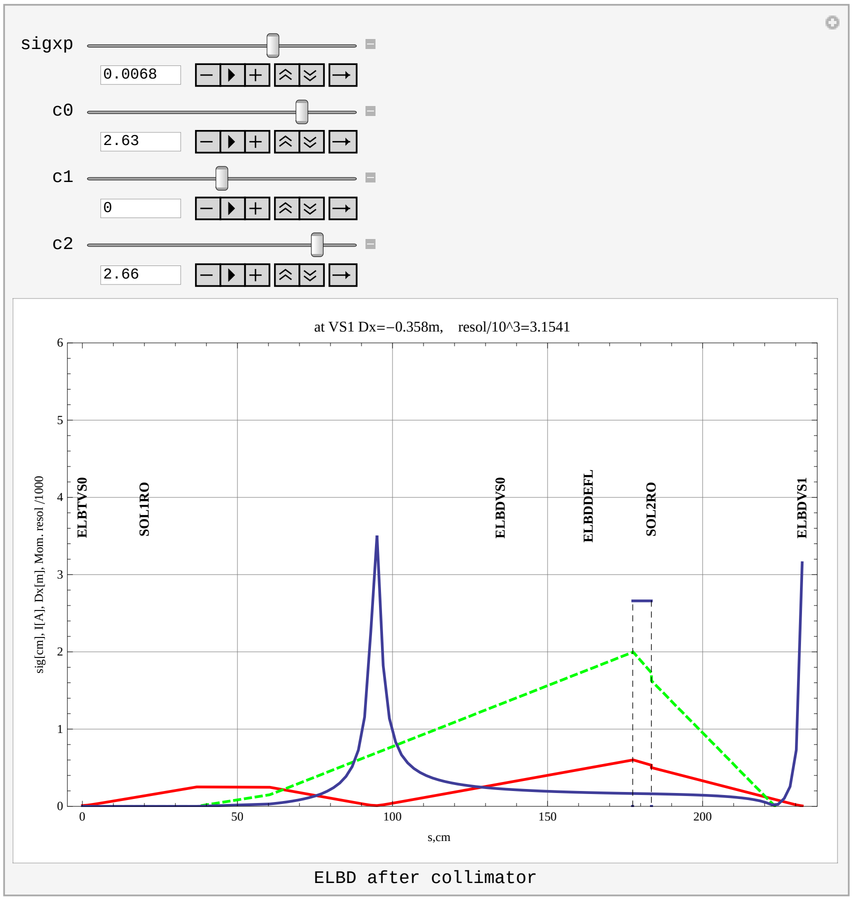


Figure 3: Settings of the slider for initial (at VS0) round-beam divergence **sigxp** $\sigma_{x'} = 6.8$ mrad. Ignore the c_0-slider (GUN SOL0 is not in the line). The SOL1 current is $c_1 = 0$ and the SOL2 is set at $c_2 = 2.67$A which gives maxim resolution at line exit (VS1): ~ 3150, in agreement with the values $c_2 = 2.67$ A and 2890 found in Baartman note "ELBD Tunes”

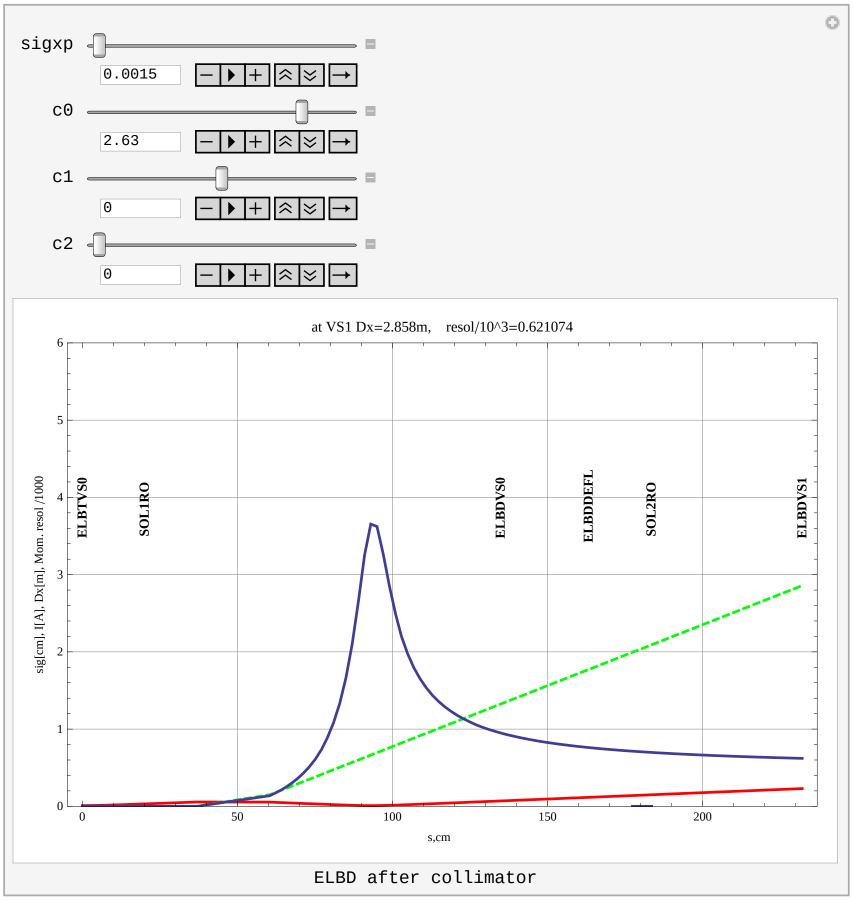


Figure 4: Settings of the slider for initial (at VS0) round-beam divergence `sigxp` $\sigma_{x'} = 1.5$ mrad. Ignore the c_0-slider (GUN SOL0 is not in the line). The SOL1 and SOL2 are off: $c_1 = c_2 = 0$ A. The resolution at line exit (VS1) is 621, same as in Baartman note "ELBD Tunes"

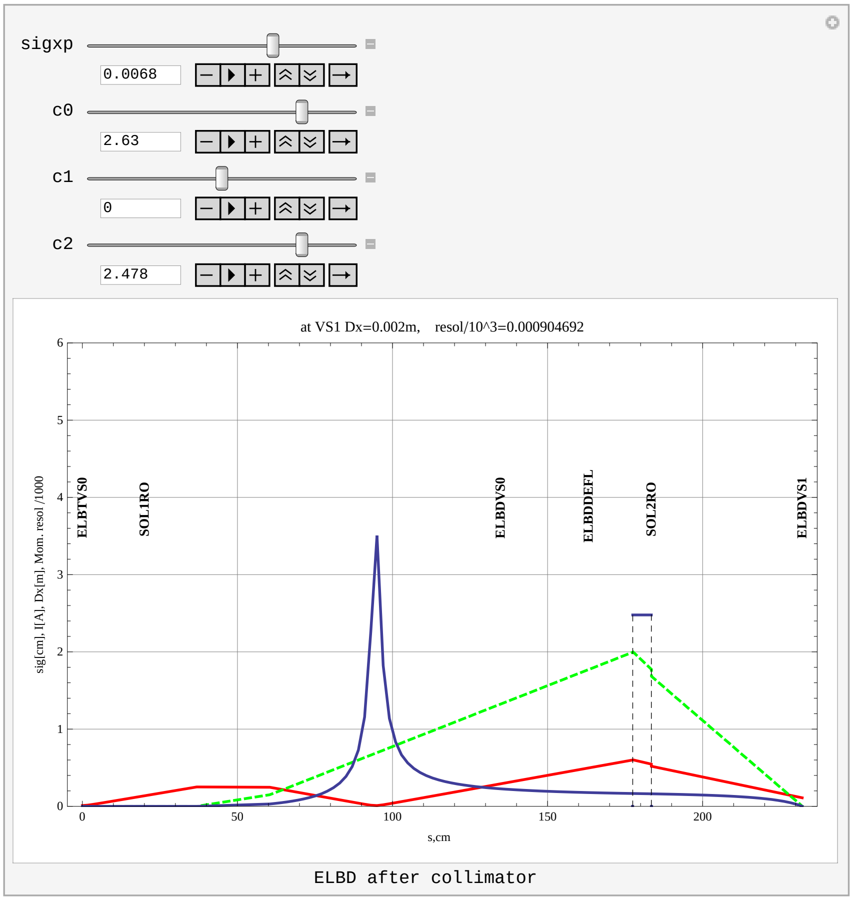


Figure 5: Same as Figure 4, but for zero dispersion at VS1

3.3 First order matrices for the cases maximum and zero resolution

We now look at the Dimad matrices with or without solenoid compensation: (`backrot` = ON/OFF). Let's take the two cases: maximum and zero resolution (all for $c_1 = 0$ A). The first order matrices are:

As on Fig. 3: $c_2 = 2.66$ A, `backrot` = ON

$$\begin{pmatrix} 0.5771 & 0.002239 & 0 & 0 & 0 & -0.4188 \\ 10.34 & 1.773 & 0 & 0 & 0 & -4.773 \\ 0 & 0 & 0.4789 & -0.05217 & 0 & 0 \\ 0 & 0 & 8.283 & 1.186 & 0 & 0 \\ 1.577 & 0.7318 & 0 & 0 & 1. & 1.007 \\ 0 & 0 & 0 & 0 & 0 & 1. \end{pmatrix}$$

As on Fig. 3: $c_2 = 2.66$ A, $\texttt{backrot} = \text{OFF}$

$$\begin{pmatrix} 0.4934 & 0.001914 & 0.2485 & -0.02707 & 0 & -0.358 \\ 8.843 & 1.516 & 4.298 & 0.6152 & 0 & -4.08 \\ -0.2994 & -0.001162 & 0.4094 & -0.0446 & 0 & 0.2173 \\ -5.367 & -0.9198 & 7.081 & 1.014 & 0 & 2.476 \\ 1.577 & 0.7318 & 0 & 0 & 1. & 1.007 \\ 0 & 0 & 0 & 0 & 0 & 1. \end{pmatrix}$$

As on Fig. 5: $c_2 = 2.48$ A, $\texttt{backrot} = \text{ON}$

$$\begin{pmatrix} -0.4046 & -0.1859 & 0 & 0 & 0 & 0.002794 \\ 8.442 & 1.408 & 0 & 0 & 0 & -3.957 \\ 0 & 0 & -0.3039 & -0.1891 & 0 & 0 \\ 0 & 0 & 6.767 & 0.9205 & 0 & 0 \\ 1.577 & 0.7318 & 0 & 0 & 1. & 1.007 \\ 0 & 0 & 0 & 0 & 0 & 1. \end{pmatrix}$$

As on Fig. 5: $c_2 = 2.48$ A, $\texttt{backrot} = \text{OFF}$

$$\begin{pmatrix} -0.3535 & -0.1625 & -0.1478 & -0.09201 & 0 & 0.002441 \\ 7.376 & 1.23 & 3.293 & 0.4479 & 0 & -3.457 \\ 0.1969 & 0.09048 & -0.2655 & -0.1652 & 0 & -0.001359 \\ -4.108 & -0.6853 & 5.912 & 0.8042 & 0 & 1.925 \\ 1.577 & 0.7318 & 0 & 0 & 1. & 1.007 \\ 0 & 0 & 0 & 0 & 0 & 1. \end{pmatrix}$$

We see that the longitudinal phase-space part does not depend on the optics setting or the solenoid compensation.

Further, coupling with transverse space through the terms R_{51}, R_{52} should be negligible.

The conclusion is that for the t longitudinal space it does not mater which setting we use for tracking. The only possible contribution would be from the buncher, which is currently OFF.

4 Tracking with dimad

Dimad tracks particles created by its generator using the second order matrix T_{ijk}.

The plan is to:

– check whether using T_{ijk} instead of R from section 3.3 would change anything;

– track the VECC particle distribution where according to our findings we should look at longitudinal space only and use any of the cases/matrices in section 3.3.

A small modification in dimad28.f allows to track with T_{ijk} the VECC particle distribution (reading initial particle coordinates from a file). However this turned up unnecessary – the longitudinal space transformation is linear.

4.1 Native Dimad tracking (suppl.)

We follow the notations in the Dimad manual. Dimad works in same coordinates as Transoptr $(x, x', y, x', l, \delta)$ and l is the same as z in Transoptr. Input beam is defined in the same way as in Transoptr.

For the generation of particles one defines at beamline entrance the beam centroid coordinates $(x_0,x'_0,y_0,y'_0,l_0,\delta_0)$ and the beam-sigmas: $(\sigma_x,\sigma_{p_x},\sigma_{p_y},\sigma_{p_y},\sigma_l,\sigma_\delta)$. The latter, when flag `nopt=1`, i.e. particles randomly generated on the surface of a six dimensional ellipsoid, coincide with the maximum extent of the beam. Alternatively, when `nopt=3`, these are the beam sigmas of a 6D Gaussian and then $n_{\sigma_1} \ldots n_{\sigma_5}$are the number of sigma above which the Gaussian is truncated.

To generate ellipse in some subspace, say l, δ one can use `nopt=1` and set the corresponding cut values to one, while the remaining are taken very small, $<< 1$.

By tracking ellipses, it was found that T_{ijk} instead of R affects only the transverse space. The longitudinal phases space remains linear.

4.2 Reading initial particle coordinates from a file

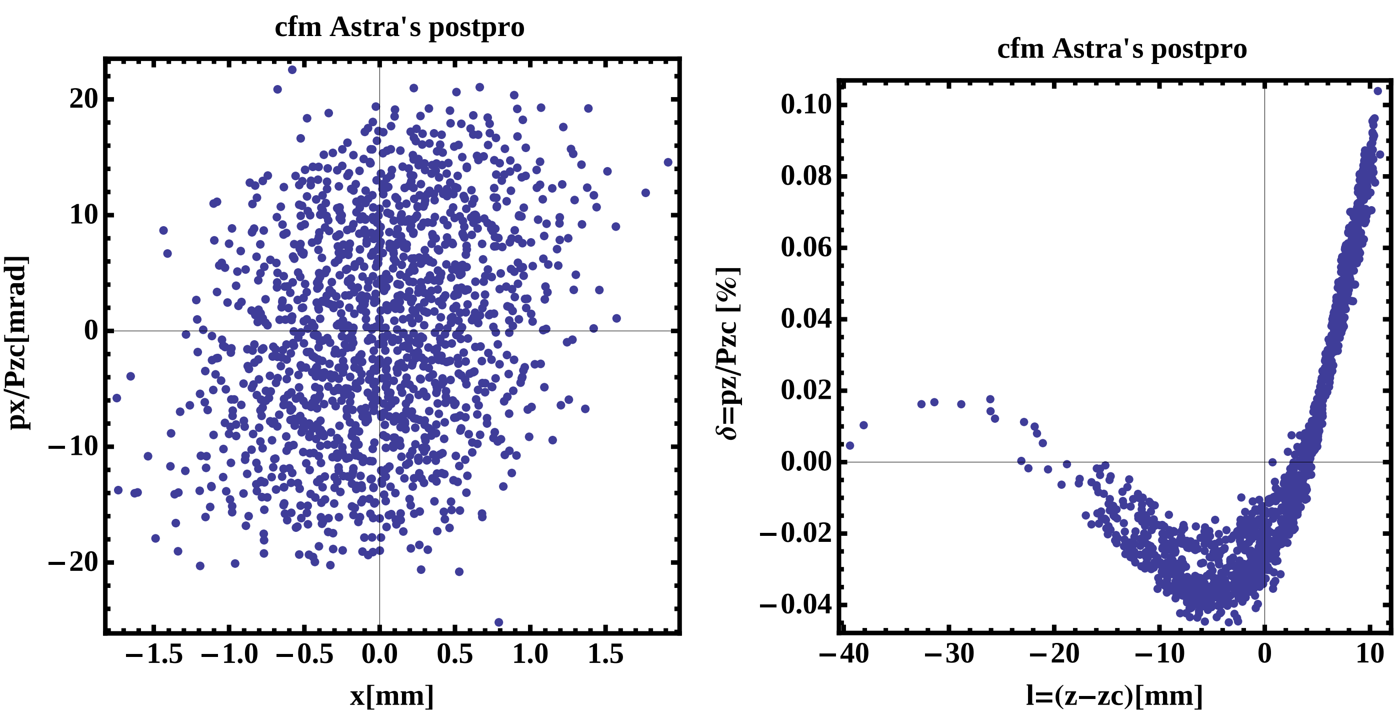
This text was added to dimad28.f (at label 3006). When `iflag` $=$ `1`, particles are read from file `track_in.dat`.

```
3006 open(unit=12,file="flag.dat",status="unknown")
     READ(12,*) iread
     close(12)
     If(iread.eq.1) then
```

```
        print *,"read ",npart," part coord from file track_in.dat"
        open(unit=12,file="track_in.dat",status="unknown")
        do ii=1,npart
           red(12,*,ERR=122)(part(ii,i) ,i=1,6)
        enddo
        close(12)
        goto 123
 122    print *,"error in reading particle file track_in.dat"
        stop
 123    continue
      endif
```

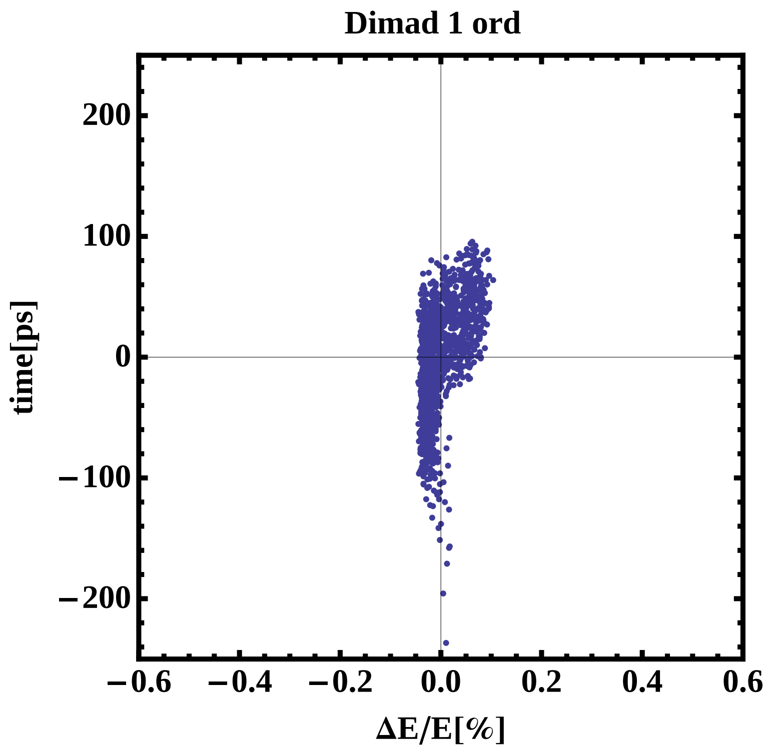
4.3 Tracking initial distribution VECC with a 1st order matrix

The buncher is off. We assume that after the collimator the initial particles distributed as in the VECC model: `VECC_10MeV/4mmR30PA16degmod149.ini`. The correction to R_{56} is now taken to be $L_{\mathrm{ELBD}}/\gamma^2 = 1.29$, where L_{ELBD}=3.258 m is the full length from anode to `ELBDVS1`. We track all 1490 particles (Figure 6) using either linear or second order matrix – the result is the same. Results are shown in Figure 7,top and and Figure 8, top.

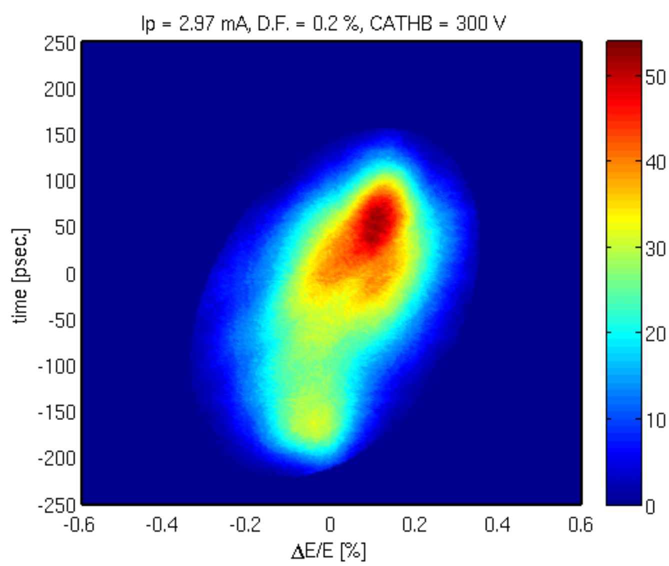


(a) $x - x'$ (b) $l - \delta$

Figure 6: VECC-distribution used as a starting one after the collimator, same as when plotted by Astra's post-processor

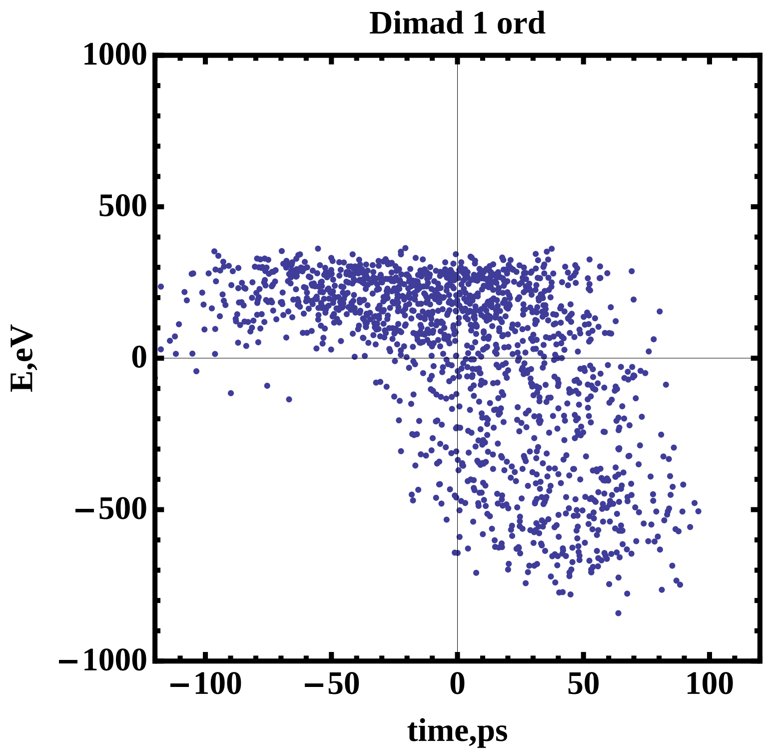


(a) Longitudinal space at line exit (`ELBDVS1`)

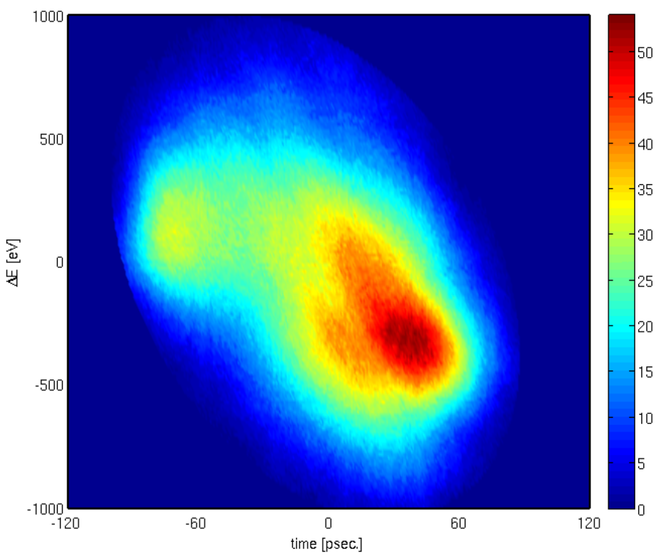


(b) The figure in "Tunes.pdf" – `ELBD_VS1-20140902-1932_2-97mA_CATHB300V`. Suresh: here time (vertical) is multiplied by 2.

Figure 7:



(a) Longitudinal space at line exit (ELBDVS1)



(b) image in http://beamphys/~suresh/elinac/longitudinal_emit/20140902/fig_ana/

Figure 8:

Images http://beamphys/~suresh/elinac/longitudinal_emit/20140902/fig_ana/: f1.png, f2.png, f3.png