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Optimisation of the CTF3 injector with 2 SHB's and 3 SHB's

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1. Introduction

A CTF3 injector layout has been proposed by Roger Miller [1], consisting of a thermionic gun followed by two sub-harmonic 1.5 GHz buncher cavities (SHB), a 3 GHz prebuncher cavity, a 4-cell travelling wave buncher and two travelling wave accelerating structures. All components downstream of the gun are embedded in a solenoid field. Starting from this proposal an extensive optimisation with PARMELA [2] has been performed with the following goals:

1. decreasing the transverse emittance,
2. decreasing the voltages of the SHB’s,
3. decreasing the charge of the satellite pulses.

2. Optimisations of CTF3 injector with two SHB's

Based on R. Miller's scheme, we optimised the solenoid field, locations and all phases of the SHB’s, prebuncher, buncher and accelerating structures[1]. As the result of this optimisation the voltages of both SHB’s and the emittance is reduced, however, the satellite signal is still about 10% of the main pulse. The results are listed in Table 1. The normalised transverse emittance and solenoid field along the beam line is shown in Figures 1 and 2. The locations of the injector components are drawn in figure 3. Phase and energy spectra are shown in figures 4a and 4b. Figure 1 shows that the emittance increase in the injector mainly happens in the 3 GHz buncher.

3. Proposal of CTF3 injector with three SHB's

It is shown that the velocity modulation bunching can not do very well for the suppression of the satellite signals. Following a suggestion of R. Miller [3], we inserted a third SHB, which follows the second SHB at a distance of 19cm. Redoing the optimisations, the satellite signal is reduced about a factor of 2, below 5% of the main pulse, as given in Table 1, while the voltages of first and second SHB’s are kept to be the same as the ones in the scheme with two SHB’s. The transverse emittance and solenoid field along the beam line are shown in Figures 5 and 6. The location of the injector components is shown in Figure 7. Its phase and energy spectra are also given in Figures 8a and 8b. As for the case with two SHB’s the emittance increase happens mainly in the 3 GHz buncher.

[1] A listing of the PARMELA input files used is appended to this note

4. Dependence of final emittance on gun emittance

In all simulations discussed above we assumed an initial normalised emittance from the thermionic gun of 5 π·mm·mrad. To investigate the sensitivity of the output emittance on this yet not well known number we performed a series of PARMELA runs to compute the output emittance as a function of the initial emittance for the three configurations discussed above. The results are shown in Figure 9. It can be seen that the output emittance is almost independent of the input emittance for input emittance values of less than 7 π·mm·mrad, while it increases linearly for higher values.

5. Power requirements of SHB's

Assuming a two gap waveguide type design of the SHB's as proposed by I. Syratchev [4] we compute the power requirements on the wideband 1.5 GHz power amplifier needed to drive the SHB's. The results are shown in table 2. It can be seen that in all cases the power requirements are dominated by the 2nd SHB and that the additional power needed for the 3rd SHB is almost negligible. In case a single gap configuration is used the power requirements have to be multiplied by $\sqrt{2}$.

6. Conclusions and Outlook

The CTF3 injector with two SHB's proposed by R. Miller has been optimised. This results in more relaxed power requirements for the SHB's as well as in a lower output emittance. However, it seems not to be possible to reduce the satellite pulse current to much less than 10% of the main pulse in a configuration with 2 SHB's only. Therefore a configuration with three SHB's has been investigated. This configuration allows two reduce the current in the satellite to 5% with only marginal increase in the power requirements and the final emittance. Therefore this configuration seems to be most favourable. Furthermore the influence of the thermionic gun emittance on the output emittance has been investigated. It turns out that this parameter is uncritical as long as it is less than ≈ 7 π·mm·mrad.

The PARMELA simulations show that the emittance growth in the injector happens mainly in the 3 GHz buncher. The parameters of the buncher have not been varied for the study in hand but should be the subject of further studies.

References

1. R. Miller, CERN-SLAC collaboration meeting, October 4-8, 1999.
2. L. Young, PARMELA code, LANL, 1998.
3. R. Miller, private communication (by E-mail), Jan. 6, 2000.
4. I. Syratchev, CTF3 Technical note in preparation

Table 1: Optimisation results for CTF3 injector

	R. Miller (2 SHB's)	2 SHB's	3 SHB’s
Energy (MeV)	5.77	5.77	5.88
Charge(nC)	3	3	3
Bunch length (mm, rms)	<1.3	<1	<1
Energy spread (rms)	<2%	~2-3%	~3%
Transmission	99%	98%	98%
Voltage of 1st SHB (kV)	13.0	9.2	9.2
Voltage of 2nd SHB (kV)	25.9	18.5	18.5
Voltage of 3rd SHB (kV)	----	----	5.6
Normalised transverse emittance (π·mm·mrad)	60	26	34
Satellite to main pulse	~10%	~9%	~4-5%

Table 2: SHB power requirements assuming double gap waveguide buncher

	R. Miller (2 SHB's)	2 SHB's	3 SHB's
power of 1st SHB (kW)	148	76	76
power of 2nd SHB (kW)	593	303	303
power of 3rd SHB (kW)	----	----	27
total	741	379	406

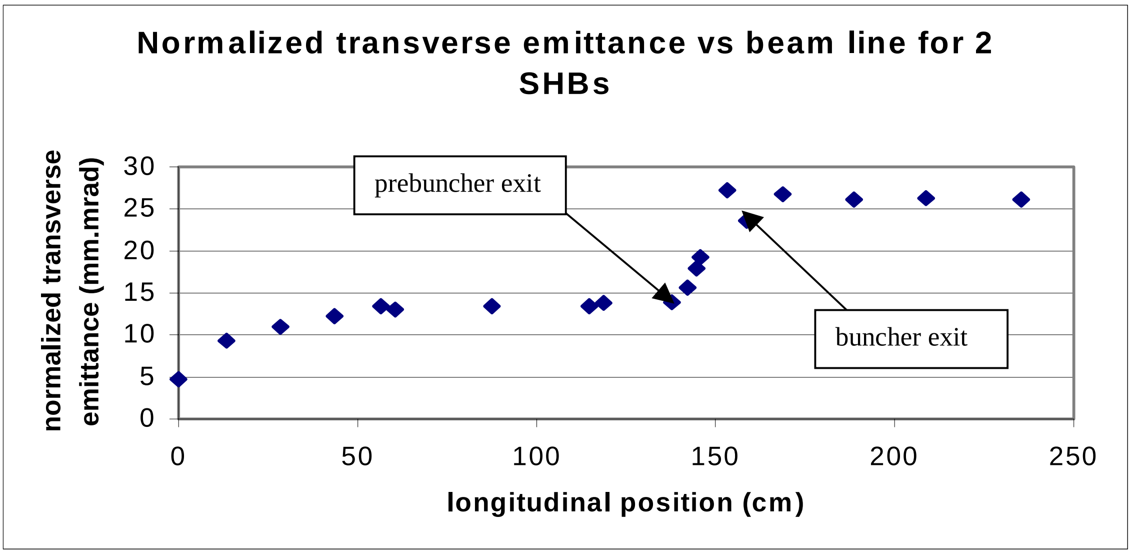

Figure 1: Normalized emittance for 2 SHBs

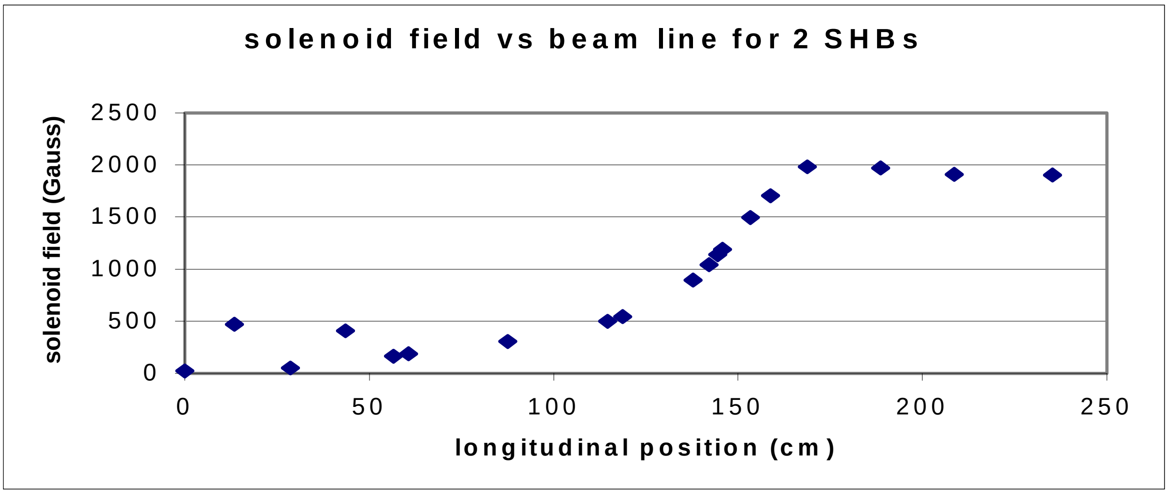

Figure 2: Solenoid field for 2 SHB’s

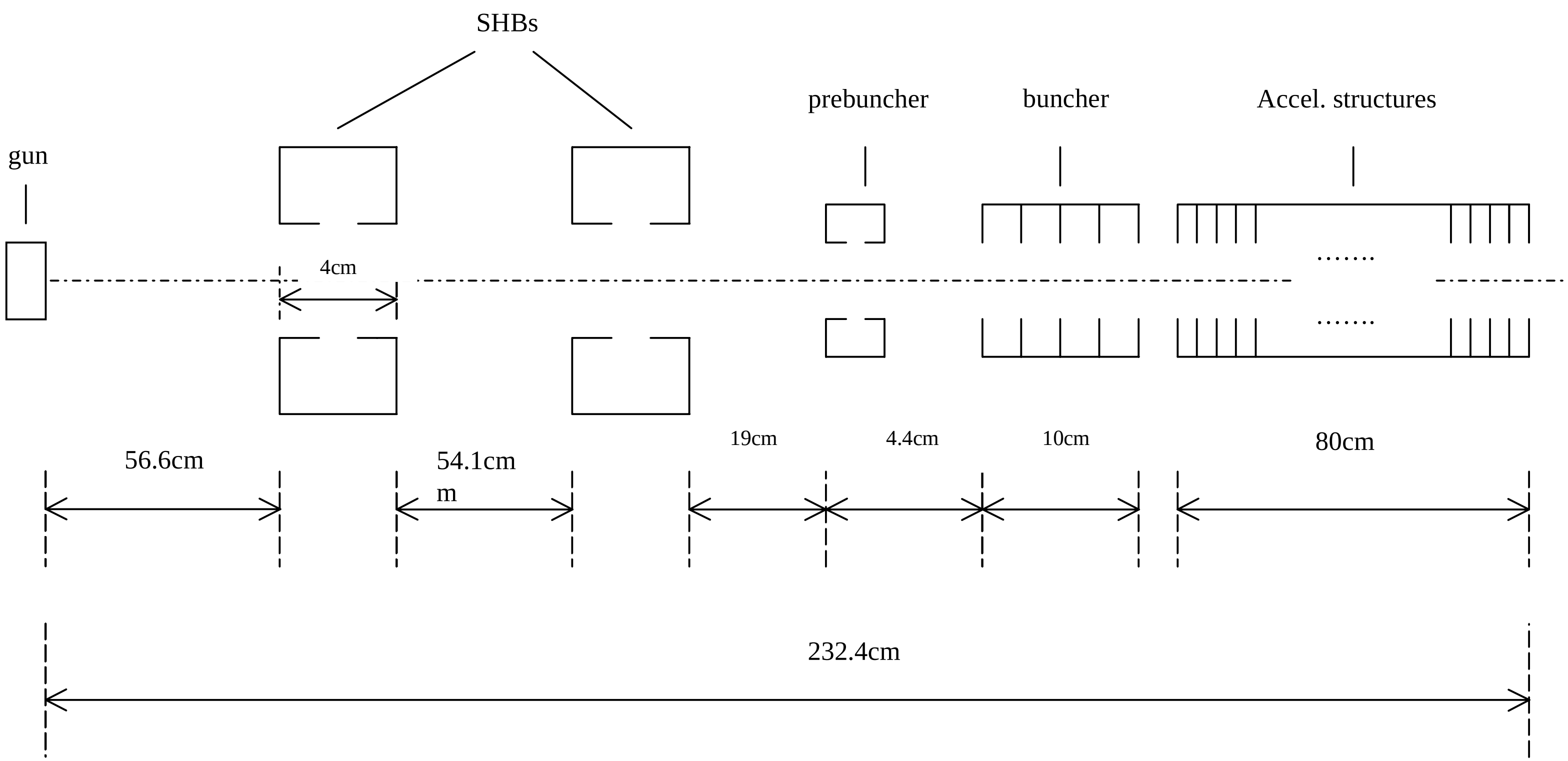

Figure 3: Location of components for CTF3 injector with 2 SHBs

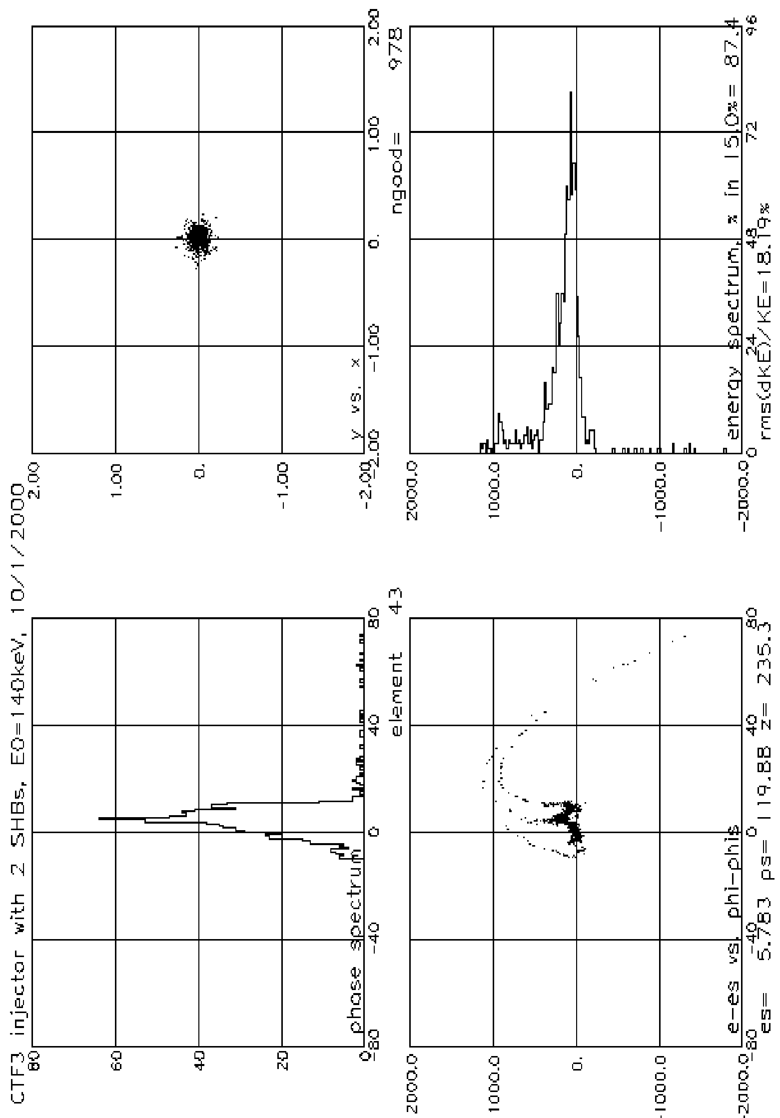

Figure 4a: Phase and energy spectrums for 2 SHBs

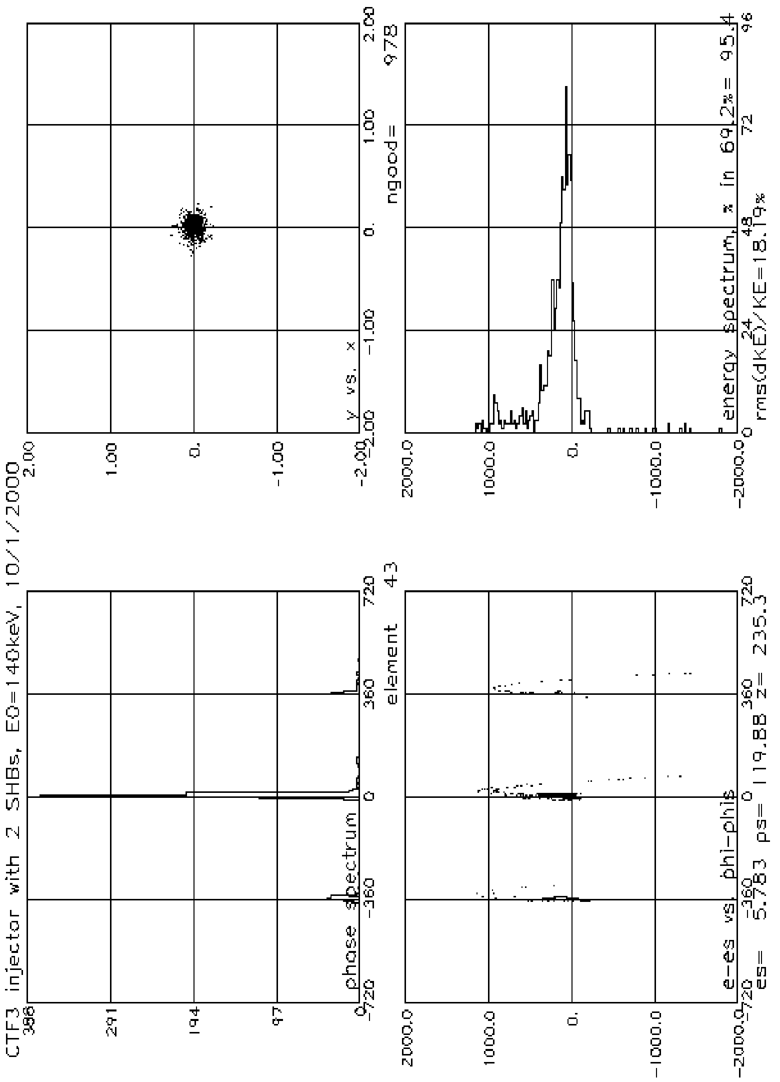

Figure 4b: Phase and energy spectrums for 2 SHBs

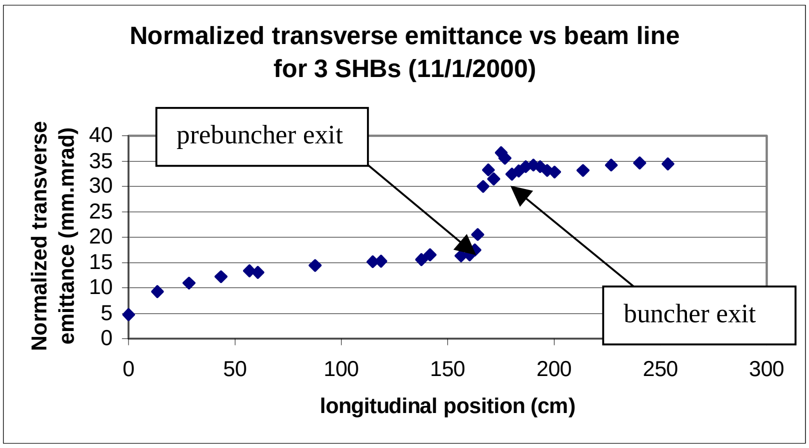

Figure 5: Normalised transverse emittance for 3 SHB's

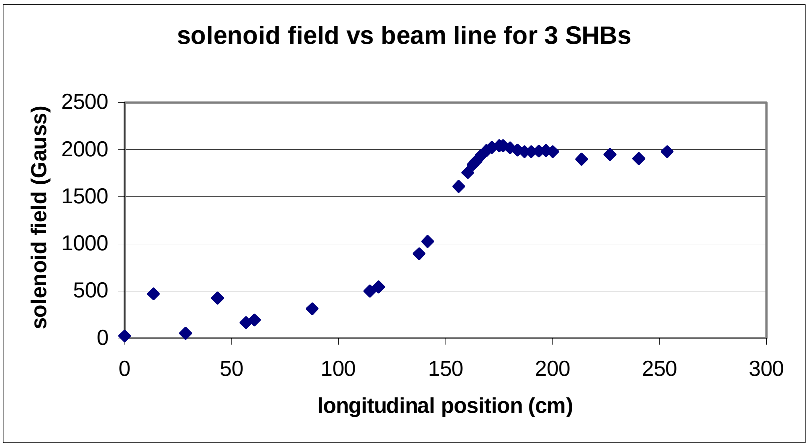

Figure 6: Solenoid field along the beam line for 3SHBs

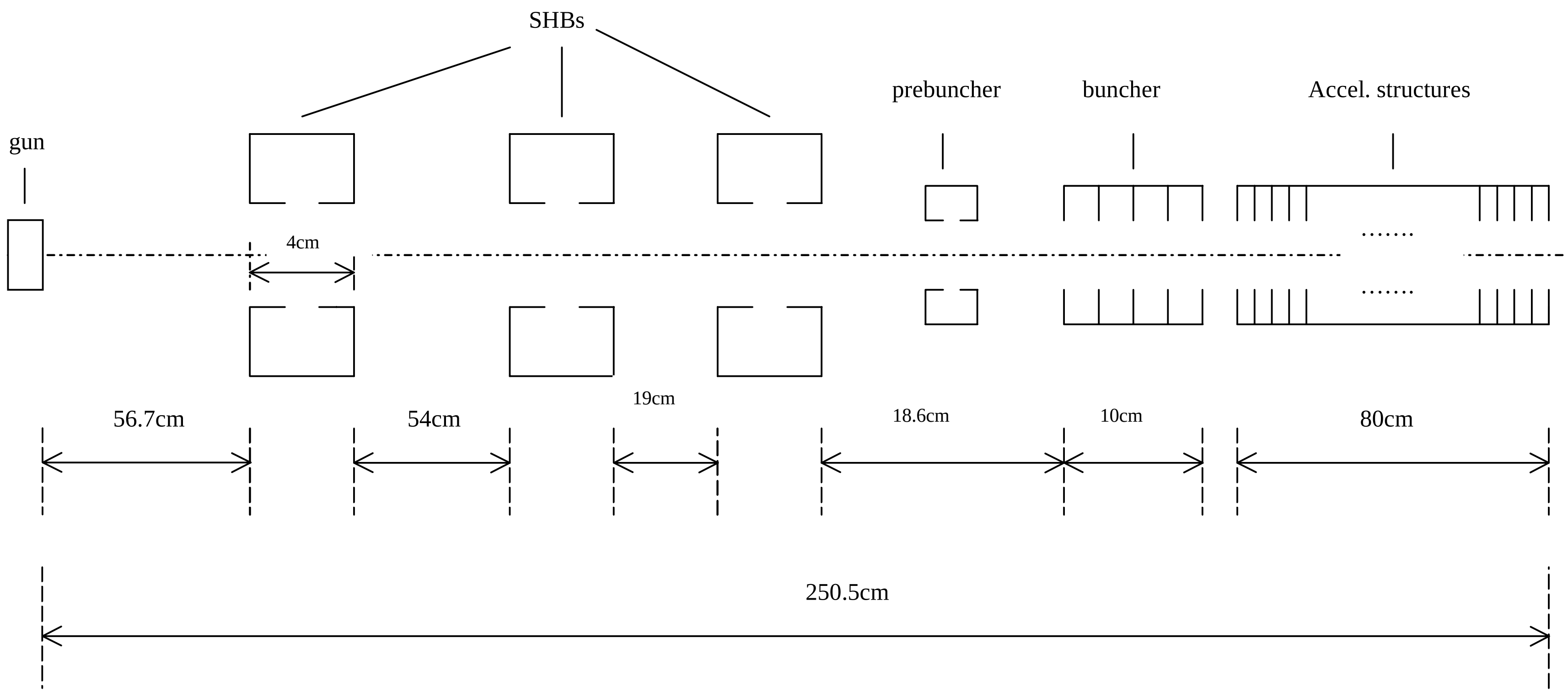

Figure 7: Location of components for CTF3 injector with 3 SHBs

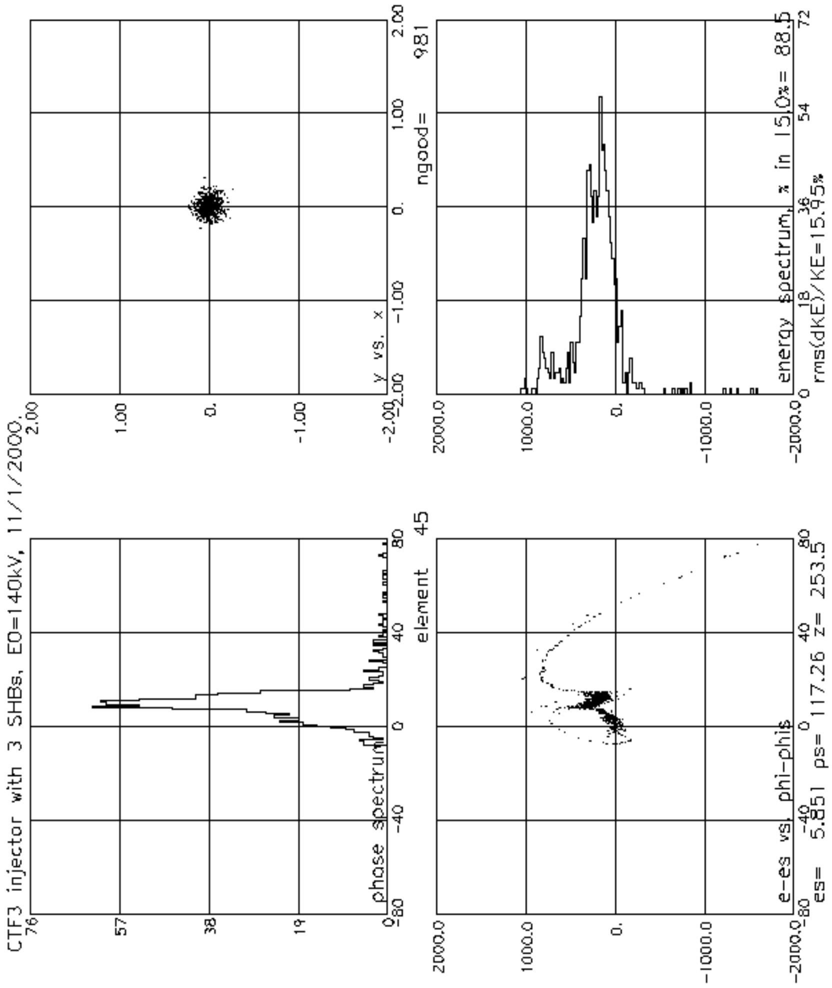

Figure 8a: Phase and energy spectrums for 3 SHBs

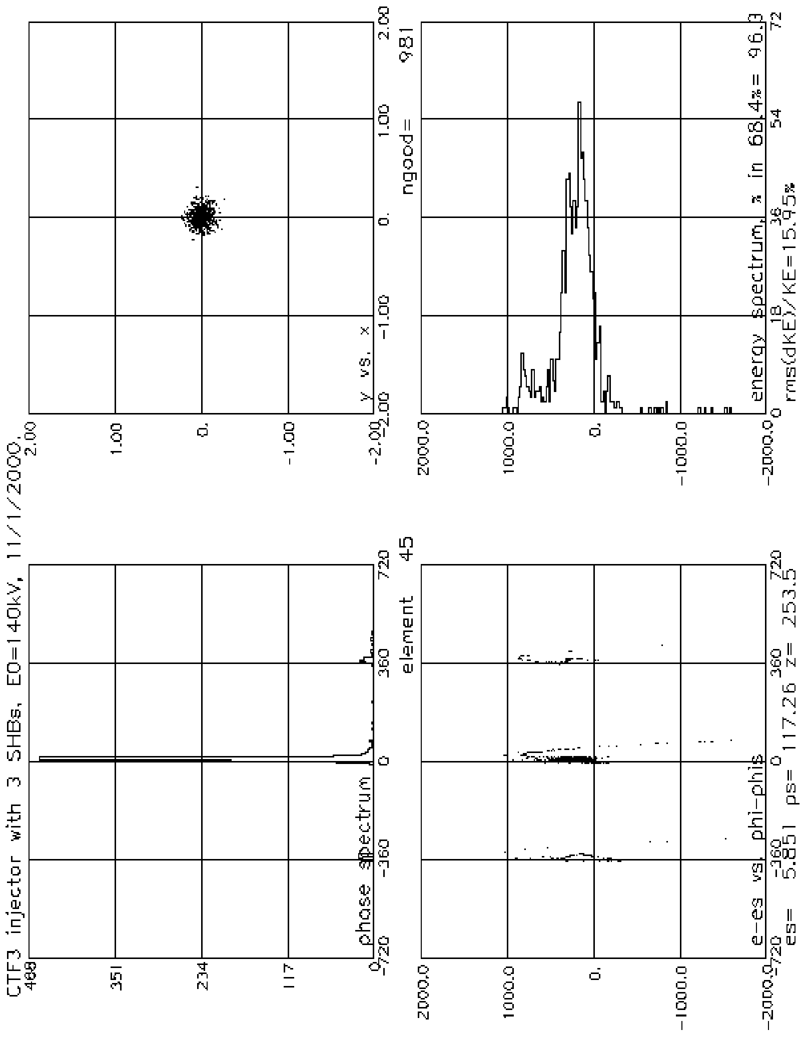

Figure 8b: Phase and energy spectrums for 3 SHBs

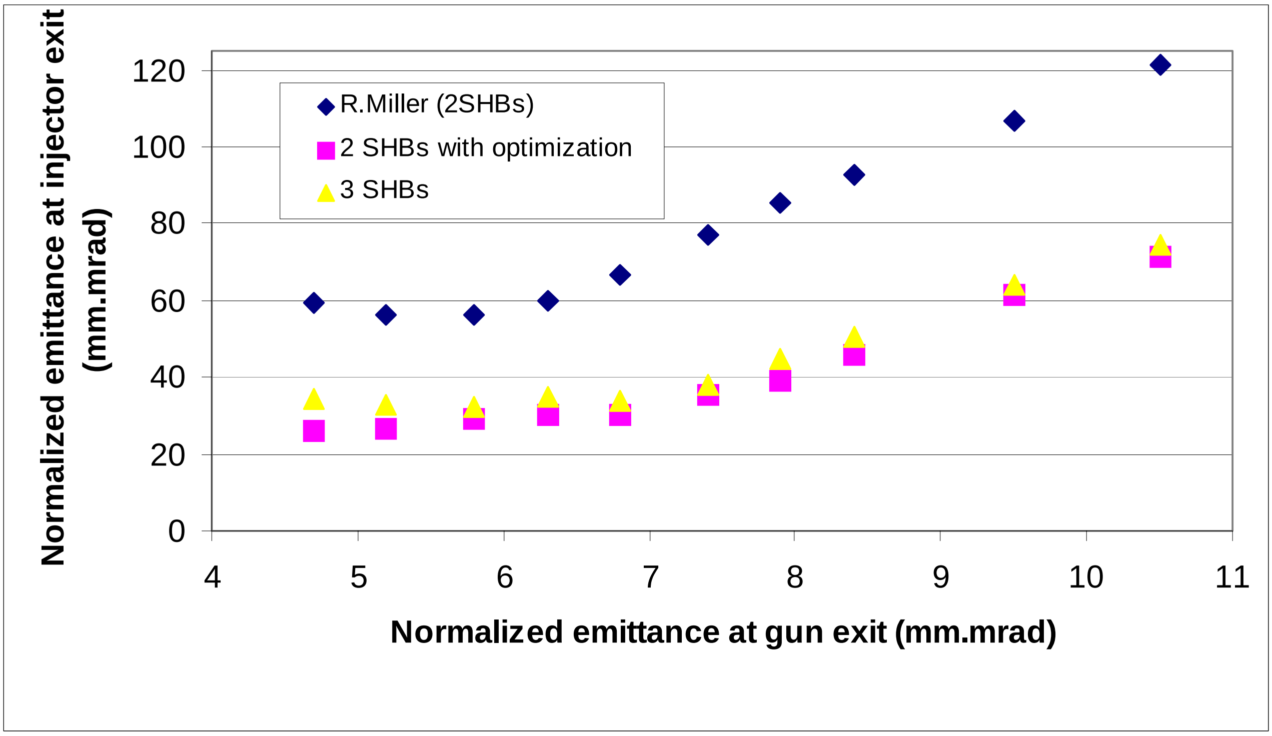

Figure 9: injector emittance vs. gun emittance

Appendix:

R.Miller's PARMELA input file (two SHBs)

```
title
__CTF3a.ctf,V0=140kV,9/30/99,3nC Bun,2SHBs,S-bndbuncav,14MeV/m
run 01 1 3000 -6.2   0.140  0
drift 0.0 1.7  1                              1
drift 13.5 1.7  1           'lens 401'            2
drift 15.0 1.7  1                              3
drift 15.0 1.7  1           'lens 403'            4
drift 13.2 1.7  1                              8
cell 4.0   1.7 1 -118 0.351 3 10 1 1500  0 0000 1.60   0    0      0
  0     0     0     0    0 0 0 0 0 0
drift  27 1.7 1                               17
drift  27 1.7 1                               17
cell 4.0   1.7 1 -017 0.701  3 10 1 1500  0 0000 1.60   0    0      0
  0     0     0     0    0 0 0 0 0 0
drift  19.5 1.7 1                               19
buncher 0.0 1.7 1 .052 3000 -184
drift   4.5 1.7 1                              20
cell 2.500 1.0 1 -190 4.6 1  2 1 3000 0 0000 1.10 .288409 -.019272
-.019129 -.000363 .001298 .000132 -.000099 -.000011 0. .000011 0 0 0
trwave 1.250 1 1 -280 4.6 1  2 3000 1 -5 +5 .666667 4  0 309 318 0 .5 30
.00033 -.00043 .00096 -.01432 .32144 .861 -.01812 .00008 .00033
-.00042 .00033
trwave 2.500 1 0 -280 4.6  1  2 3000 1
trwave 2.500 1 0 -280 4.6  1  2 3000 1
trwave 2.500 1 1 -280 4.6  1  2 3000 1
drift  0.25 1.0 0
cell 3.333 1.0 0 -100 14.0 2 10 1 3000 0 0000 1.10 .3476 -.038753 -.045551
.002849 .003938 .002101 -.002222 .001199 -.001133 .001155 0 0 0
trwave 1.752 1 1 -190 14.0 2 10 3000 2 -5 +5 .664700 86 0 323 335 0 .5 30
.00017 -.00045 .00142 -.01701 .25013 .645  -.02343 .00101 -.00003
-.00036 .00013
trwave 3.333 1 0 -190 13.5 2  2 3000 2
trwave 3.333 1 0 -190 13.0 2  2 3000 2
trwave 3.333 1 1 -190 12.5 2 10 3000 2
trwave 3.333 1 0 -190 12.0 2 10 3000 2
trwave 3.333 1 0 -190 11.5 2 10 3000 2
trwave 3.333 1 0 -190 11.0 2 10 3000 2
trwave 3.333 1 0 -190 10.5 2 10 3000 2
trwave 3.333 1 0 -190 10.0 2 10 3000 2
trwave 3.333 1 1 -190  9.5 2 10 3000 2
trwave 3.333 1 0 -190  9.0 2 10 3000 2
trwave 3.333 1 0 -190  8.5 2 10 3000 2
trwave 3.333 1 0 -190  8.0 2 10 3000 2
trwave 3.333 1 0 -190  7.5 2 10 3000 2
trwave 3.333 1 0 -190  7.0 2 10 3000 2
trwave 3.333 1 1 -190  6.5 2 10 3000 2
trwave 3.333 1 0 -190  6.0 2 10 3000 2
trwave 3.333 1 0 -190  5.5 2 10 3000 2
trwave 3.333 1 0 -190  5.0 2 10 3000 2
trwave 3.333 1 0 -190  4.5 2 10 3000 2
trwave 3.333 1 0 -190  4.0 2 10 3000 2
trwave 3.333 1 0 -190  3.5 2 10 3000 2
trwave 3.333 1 0 -190  3.0 2 10 3000 2
trwave 3.333 1 1 -190  2.5 2 10 3000 2
```

```
coil   9.9  2.54  -400  0  350
coil  11.1  2.54   600
coil  12.4  2.54   600
coil  13.7  2.54   600
coil  15.0  2.54   600
coil  16.3  2.54   600
coil  17.5  2.54  -400
coil  39.9  2.54  -400
coil  41.1  2.54   600
coil  42.4  2.54   600
coil  43.7  2.54   600
coil  45.0  2.54   600
coil  46.3  2.54   600
coil  47.5  2.54  -400
coil  70  25 5500
coil 100  25 6500
coil 125  25 7500
coil 150  25 9000
coil 175  25 11000
coil 155  25 13000
coil 165  25 16000
coil 175  25 26000
coil 200  25 40000
coil 225  25 40000
coil 250  25 40000
coil 275  25 40000
coil 300  25 40000
coil 325  25 40000
coil 350  25 40000
coil 375  25 40000
coil 400  25 40000
zlimit 50
zout
input 6  999  -2.0  100  .0027  -2.0  100  .0027 360   .0002
output 5
scheff  13.5 1.7 12.391 10 180 1 0  3 100 1.7
start   053 90. 2000. 1  0
end
------------------------------------------------------------
```

Optimized input file (two SHBs)

```
title
CTF3 injector with 2 SHBs, E0=140keV, 10/1/2000
run 01 1 3000 -6.2   0.140  0
drift 0.0 1.7  1                                 1
drift 13.5 1.7  1           'lens 401'            2
drift 15.0 1.7  1                                 3
drift 15. 1.7  1           'lens 403'             4
drift 13.1 1.7  1                                 8
cell 4.0   1.7 1 -112 0.25 3 10 0 1500  0 0000 1.60   0    0      0
  0     0     0     0    0 0 0 0 0 0
drift  27 1.7 1                                 17
drift  27.1 1.7 1                                17
cell 4.0   1.7 1 -17 0.50  3 10 0 1500  0 0000 1.60   0    0      0
  0     0     0     0    0 0 0 0 0 0
drift  19.0 1.7 1                                 19
buncher 0.0 1.7 1 .052 3000 -184
drift   4.4 1.7 1                                 20
cell 2.500 1.0 1 -190 4.6 1  2 1 3000 0 0000 1.10 .288409 -.019272
-.019129 -.000363 .001298 .000132 -.000099 -.000011 0. .000011 0 0 0
trwave 1.250 1 1 -280 4.6 1  2 3000 1 -5 +5 .666667 4  0 309 318 0 .5 30
.00033 -.00043 .00096 -.01432 .32144 .861 -.01812 .00008 .00033
-.00042 .00033
trwave 2.500 1 0 -280 4.6  1  2 3000 1
trwave 2.500 1 0 -280 4.6  1  2 3000 1
trwave 2.500 1 1 -280 4.6  1  2 3000 1
drift  0.25 1.0 0
cell 3.333 1.0 0 -100 14.0 2 10 1 3000 0 0000 1.10 .3476 -.038753 -.045551
.002849 .003938 .002101 -.002222 .001199 -.001133 .001155 0 0 0
trwave 1.752 1 1 -190 14.0 2 10 3000 2 -5 +5 .664700 86 0 323 335 0 .5 30
.00017 -.00045 .00142 -.01701 .25013 .645  -.02343 .00101 -.00003
-.00036 .00013
trwave 3.333 1 0 -190 13.5 2  2 3000 2
trwave 3.333 1 0 -190 13.0 2  2 3000 2
trwave 3.333 1 1 -190 12.5 2 10 3000 2
trwave 3.333 1 0 -190 12.0 2 10 3000 2
trwave 3.333 1 0 -190 11.5 2 10 3000 2
trwave 3.333 1 0 -190 11.0 2 10 3000 2
trwave 3.333 1 0 -190 10.5 2 10 3000 2
trwave 3.333 1 0 -190 10.0 2 10 3000 2
trwave 3.333 1 1 -190  9.5 2 10 3000 2
trwave 3.333 1 0 -190  9.0 2 10 3000 2
trwave 3.333 1 0 -190  8.5 2 10 3000 2
trwave 3.333 1 0 -190  8.0 2 10 3000 2
trwave 3.333 1 0 -190  7.5 2 10 3000 2
trwave 3.333 1 0 -190  7.0 2 10 3000 2
trwave 3.333 1 1 -190  6.5 2 10 3000 2
trwave 3.333 1 0 -190  6.0 2 10 3000 2
trwave 3.333 1 0 -190  5.5 2 10 3000 2
trwave 3.333 1 0 -190  5.0 2 10 3000 2
trwave 3.333 1 0 -190  4.5 2 10 3000 2
```

```
trwave 3.333 1 0 -190  4.0 2 10 3000 2
trwave 3.333 1 0 -190  3.5 2 10 3000 2
trwave 3.333 1 0 -190  3.0 2 10 3000 2
trwave 3.333 1 1 -190  2.5 2 10 3000 2
coil   9.9  2.54  -550  0  350
coil  10.9  2.54   600
coil  12.5  2.54   600
coil  13.7  2.54   700
coil  15.0  2.54   600
coil  16.3  2.54   600
coil  17.5  2.54  -400
coil  39.9  2.54  -400
coil  41.1  2.54   550
coil  42.4  2.54   450
coil  43.7  2.54   310
coil  45.0  2.54   600
coil  46.3  2.54   600
coil  47.5  2.54  -400
coil  70  25 5500
coil 100  25 6500
coil 125  25 7500
coil 150  25 9000
coil 175  25 11000
coil 155  25 13000
coil 165  25 16000
coil 175  25 26000
coil 199  25 40000
coil 225  25 40000
coil 251  25 40000
coil 276  25 40000
coil 300  25 40000
coil 325  25 40000
coil 350  25 40000
coil 375  25 40000
coil 400  25 40000
zlimit 50
zout
input 6  999  -2.0  100  .0027  -2.0  100  .0027 360   .0002
output 5
scheff  13.5 1.7 12.391 10 180 1 0  3 100 1.7
start   057 20. 16000. 1  0
end
-----------------------------------------------
```

Input file for three SHBs

```
title
 CTF3 injector with 3 SHBs, E0=140kV, 11/1/2000.
run 01 1 3000 -6.2   0.140  0
drift 0.0 1.7  1
drift 13.5 1.7  1
drift 15.0 1.7  1
drift 15. 1.7  1
drift 13.2 1.7  1
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;       the first SHB
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
cell 4.0   1.7 1 -110 0.25 3 10 0 1500  0 0000 1.60   0    0      0
  0     0     0     0    0 0 0 0 0 0
drift  27 1.7 1
drift  27 1.7 1
cell 4.0   1.7 1 0 0.50  3 10 0 1500  0 0000 1.60   0    0      0
  0     0     0     0    0 0 0 0 0 0
drift 19.0 1.7 1
cell 4.0   1.7 1 -2 0.15  3 10 0 1500  0 0000 1.60   0    0      0
  0     0     0     0    0 0 0 0 0 0
drift  14.5 1.7 1
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;       prebuncher
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
buncher 0.0 1.7 1 .052 3000 -170
drift   4.1 1.7 1
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;         buncher
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
cell 2.500 1.0 1 -190 4.6 1  2 1 3000 0 0000 1.10 .288409 -.019272
-.019129 -.000363 .001298 .000132 -.000099 -.000011 0. .000011 0 0 0
trwave 1.250 1 1 -280 4.6 1  2 3000 1 -5 +5 .666667 4  0 309 318 0 .5 30
.00033 -.00043 .00096 -.01432 .32144 .861 -.01812 .00008 .00033
-.00042 .00033
trwave 2.500 1 1 -280 4.6  1  2 3000 1
trwave 2.500 1 1 -280 4.6  1  2 3000 1
trwave 2.500 1 1 -280 4.6  1  2 3000 1
drift  0.2 1.0 0
cell 3.333 1.0 1 -98 14.0 2 10 1 3000 0 0000 1.10 .3476 -.038753 -.045551
.002849 .003938 .002101 -.002222 .001199 -.001133 .001155 0 0 0
trwave 1.752 1 1 -188 14.0 2 10 3000 2 -5 +5 .664700 86 0 323 335 0 .5 30
.00017 -.00045 .00142 -.01701 .25013 .645  -.02343 .00101 -.00003
-.00036 .00013
trwave 3.333 1 1 -188 13.5 2  2 3000 2
trwave 3.333 1 1 -188 13.0 2  2 3000 2
trwave 3.333 1 1 -188 12.5 2 10 3000 2
trwave 3.333 1 1 -188 12.0 2 10 3000 2
trwave 3.333 1 1 -188 11.5 2 10 3000 2
trwave 3.333 1 1 -188 11.0 2 10 3000 2
trwave 3.333 1 1 -188 10.5 2 10 3000 2
trwave 3.333 1 1 -188 10.0 2 10 3000 2
```

```
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trwave 3.333 1 1 -188  9.0 2 10 3000 2
trwave 3.333 1 1 -188  8.5 2 10 3000 2
trwave 3.333 1 1 -188  8.0 2 10 3000 2
trwave 3.333 1 1 -188  7.5 2 10 3000 2
trwave 3.333 1 1 -188  7.0 2 10 3000 2
trwave 3.333 1 1 -188  6.5 2 10 3000 2
trwave 3.333 1 1 -188  6.0 2 10 3000 2
trwave 3.333 1 1 -188  5.5 2 10 3000 2
trwave 3.333 1 1 -188  5.0 2 10 3000 2
trwave 3.333 1 1 -188  4.5 2 10 3000 2
trwave 3.333 1 1 -188  4.0 2 10 3000 2
trwave 3.333 1 1 -188  3.5 2 10 3000 2
trwave 3.333 1 1 -188  3.0 2 10 3000 2
trwave 3.333 1 1 -188  2.5 2 10 3000 2
coil   9.9  2.54  -550  0  350
coil  10.9  2.54   600
coil  12.5  2.54   600
coil  13.7  2.54   700
coil  15.0  2.54   600
coil  16.3  2.54   600
coil  17.5  2.54  -450
coil  39.9  2.54  -450
coil  41.1  2.54   550
coil  42.4  2.54   450
coil  43.7  2.54   400
coil  45.0  2.54   600
coil  46.3  2.54   600
coil  47.5  2.54  -400
coil  70  25 5500
coil 100  25 6500
coil 125  25 7500
coil 150  25 9000
coil 175  25 11000
coil 155  25 13000
coil 165  25 16000
coil 175  25 26000
coil 199  25 40000
coil 225  25 40000
coil 251  25 40000
coil 276  25 40000
coil 300  25 40000
coil 325  25 40000
coil 350  25 40000
coil 375  25 40000
coil 400  25 40000
zlimit 50
zout
input 6  999  -2.0  100  .0027  -2.0  100  .0027 360   .0002
output 5
scheff  13.5 1.7 12.391 10 180 1 0  3 100 1.7
start   053 20. 16000. 1  0
end
--------------------------------
```