XFEL BC System
BC lattice & chamber geometry

1. Official Setup

2. Increased Magnet Length (0.3m $\rightarrow$ 0.5m)
   (full length = const)

3. Increased M2-M3 Drift
   (0.5m magnets)

   Movable BC Chamber
   (Winni's arguments)

4. Flat & Round Chamber for BC2
   (0.5m magnets, increased M2-M3 drift)

5. Reduced M1-M2 & M3-M4 Drift
   (0.5m magnets, flat chamber)

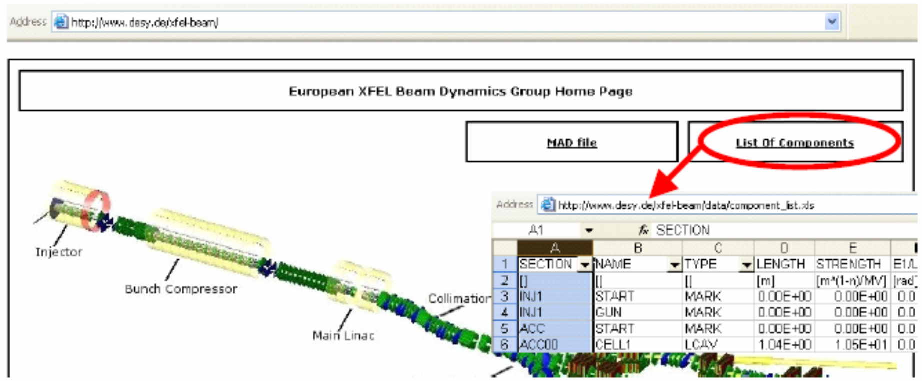
6. Conclusion

1. Official Setup

see FEL Beam Dynamics Group Talks: 18.12.2006 Bunch Compression System Review
http://www.desy.de/xfel-beam/data/talks/talks/bc_review/dohlus_-_bc_review_s2e_sim_20061218.pdf

official setup

Winni's EXCEL table (Dec 2005)



Klaus's gun & ACC0 settings: 1nC, 50A → $\varepsilon_{slice} \approx 0.58$ µm
(used for s2e simulations)

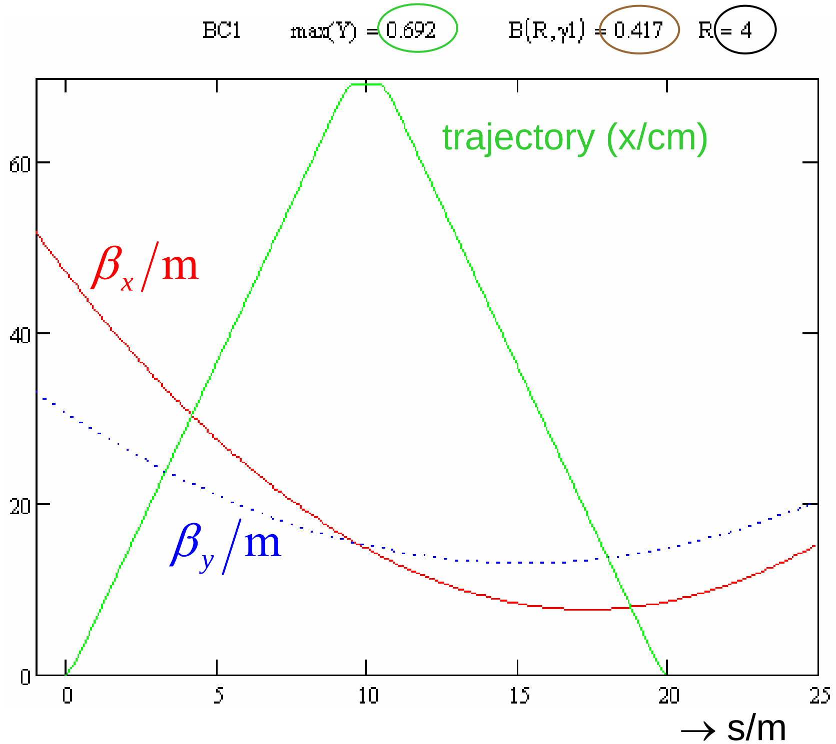
→ 6.9 MeV
→130 MeV, dog leg, laser heater
→500 MeV, 3r harm. rf, 50A → 1kA, r56 ≈ 103 mm
→2 GeV, on crest, 1kA → 5kA, r56 ≈ 14 (17) mm
→ 17.5 MeV

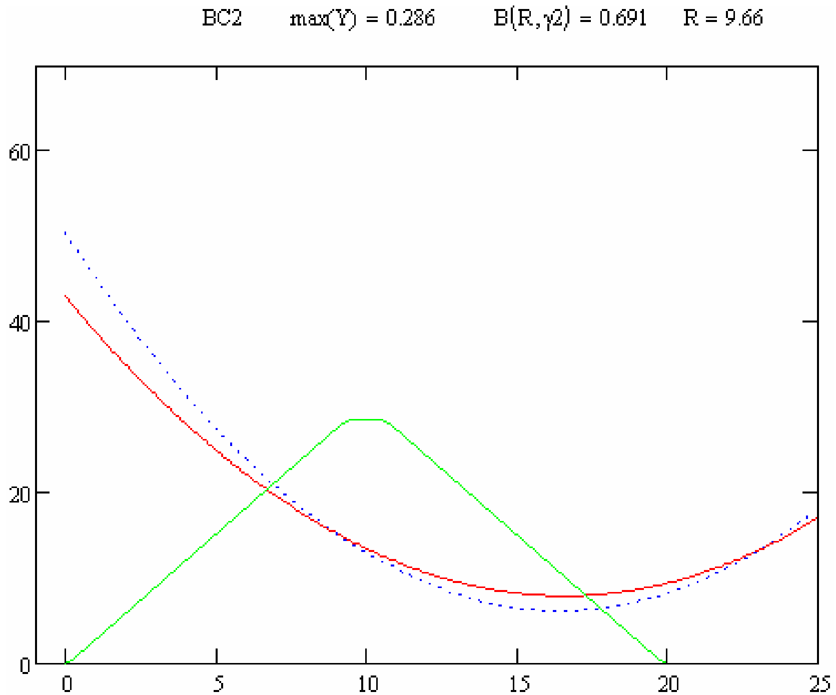
notation: magnet length
drift M1→M2 & M3→M4
drift M2→M3

BC1=0.3_8.9_1.0
r56/mm=-0.103258

BC2=0.3_8.9_1.0
r56/mm=-0.0175798

maximal offset (x/m) B/T bending radius/m





optics for all following calculations unchanged
phase advance BC1 → BC2 increased by π compared to EXCEL table

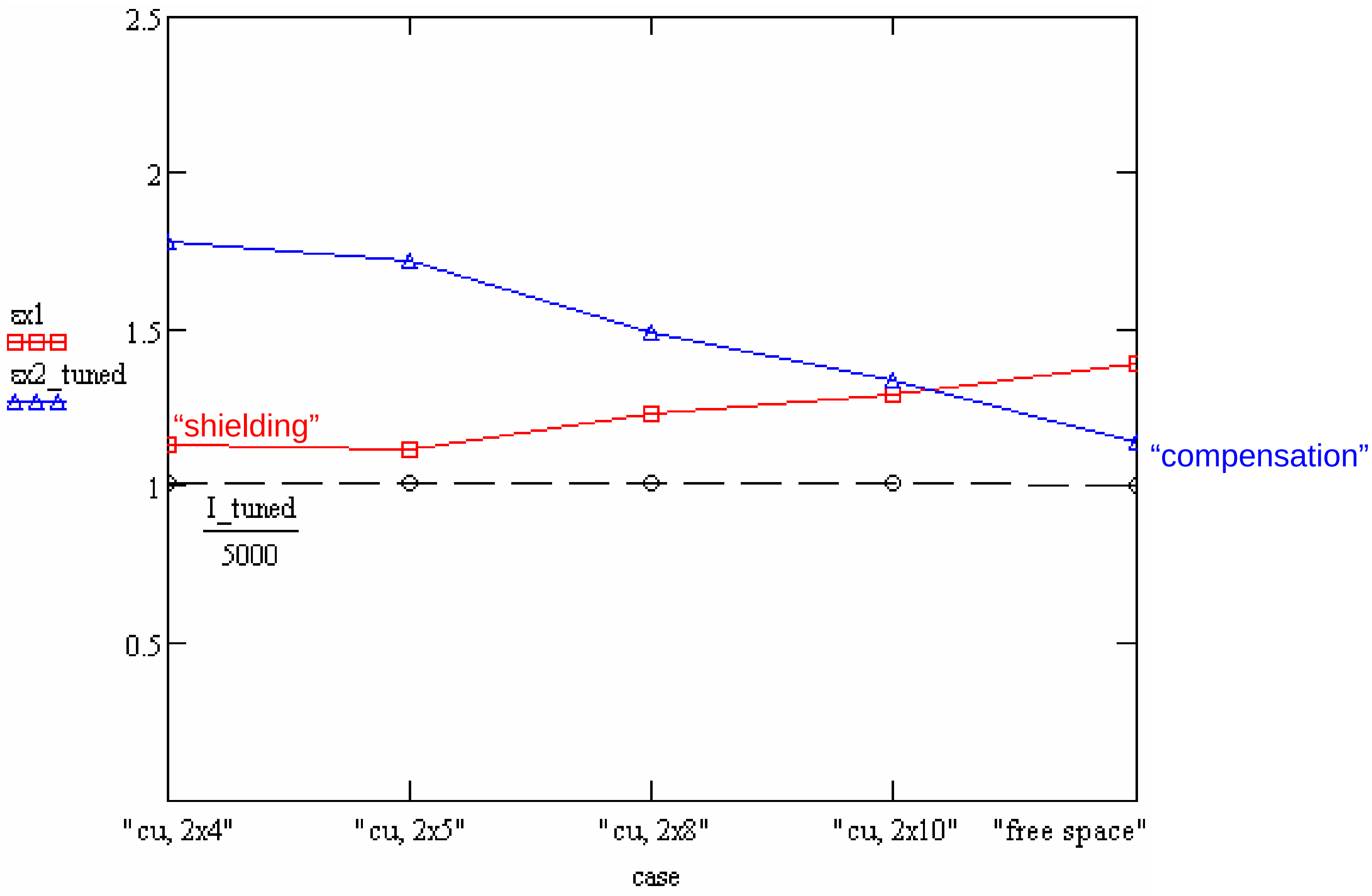
peak current and projected x-emittance

flat chamber

cu, h/mm	BC1	BC2	BC2, r56 tuned
“2x4”	Ipeak/A=1005 emit_hor/um=1.13	Ipeak/A=5831 emit_hor/um=2.24	Ipeak/A=5054 emit_hor/um=1.78 r56/mm=-0.016975
“2x5”	Ipeak/A=1004 emit_hor/um=1.12	Ipeak/A=5735 emit_hor/um=2.07	Ipeak/A=5.047 emit_hor/um=1.72 r56/mm=-0.017034
“2x8”	Ipeak/A=1003 emit_hor/um=1.23	Ipeak/A=5603 emit_hor/um=1.69	Ipeak/A=5041 emit_hor/um=1.49 r56/mm=-0.017119
“2x10”	Ipeak/A=1003 emit_hor/um=1.29	Ipeak/A=5571 emit_hor/um=1.50	Ipeak/A=5035 emit_hor/um=1.34 r56/mm=-0.017141
“inf”	Ipeak/A=1001 emit_hor/um=1.39	Ipeak/A=5124 emit_hor/um=1.16	Ipeak/A=5009 emit_hor/um=1.14 r56/mm=-0.017474

peak current and projected x-emittance

BC1=0.3_8.9_1.0
BC2=0.3_8.9_1.0

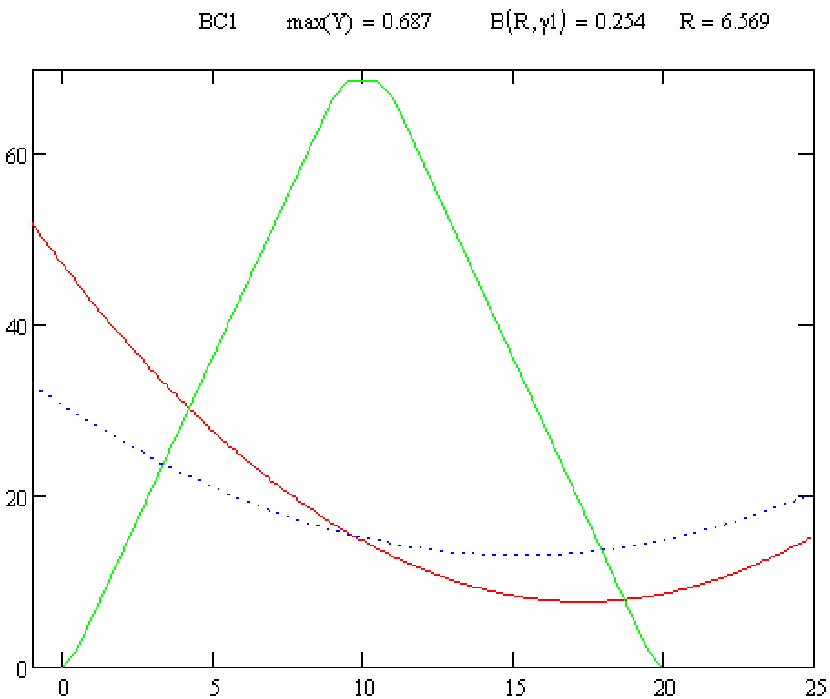


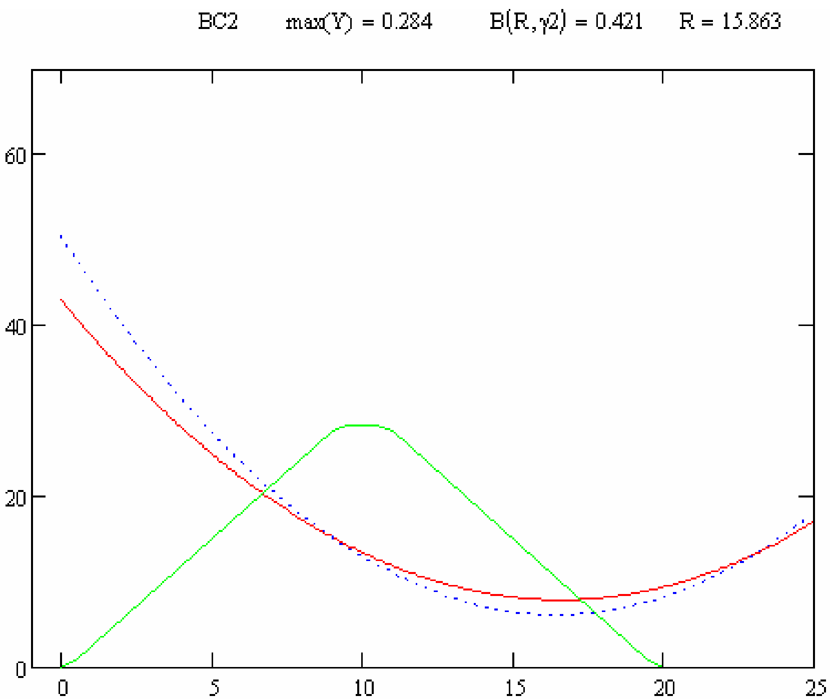
2. Increased Magnet Length (0.3m → 0.5m)

(full length = const)

BC1=0.5_8.5_1.0
r56/mm=-0.103258

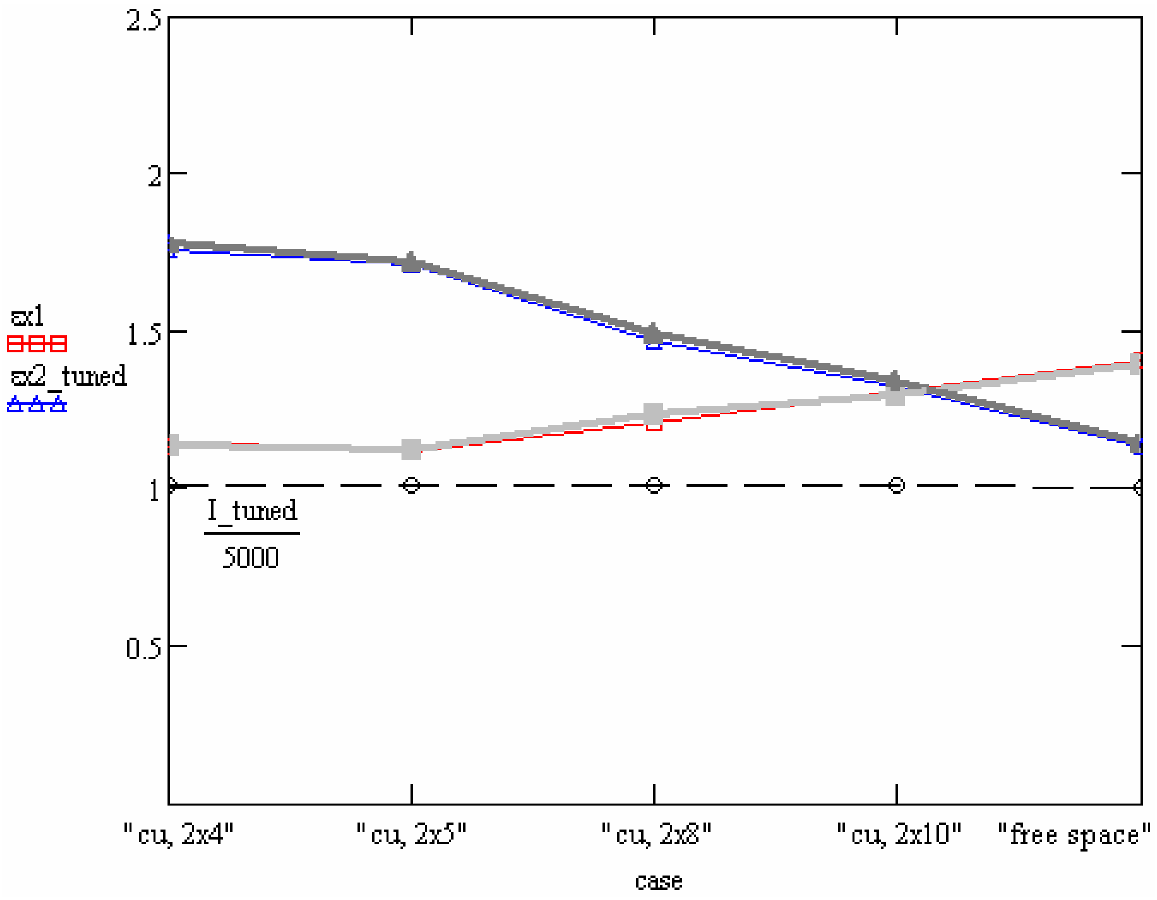
BC2=0.5_8.5_1.0
r56/mm=-0.0175798





peak current and projected x-emittance

BC1=0.5_8.5_1.0
BC2=0.5_8.5_1.0

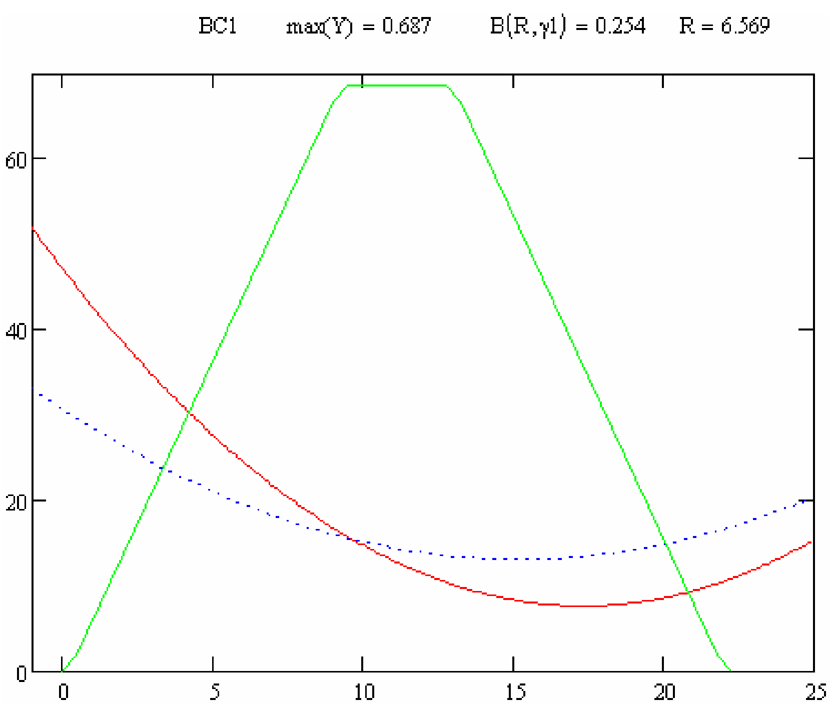


gray = official setup

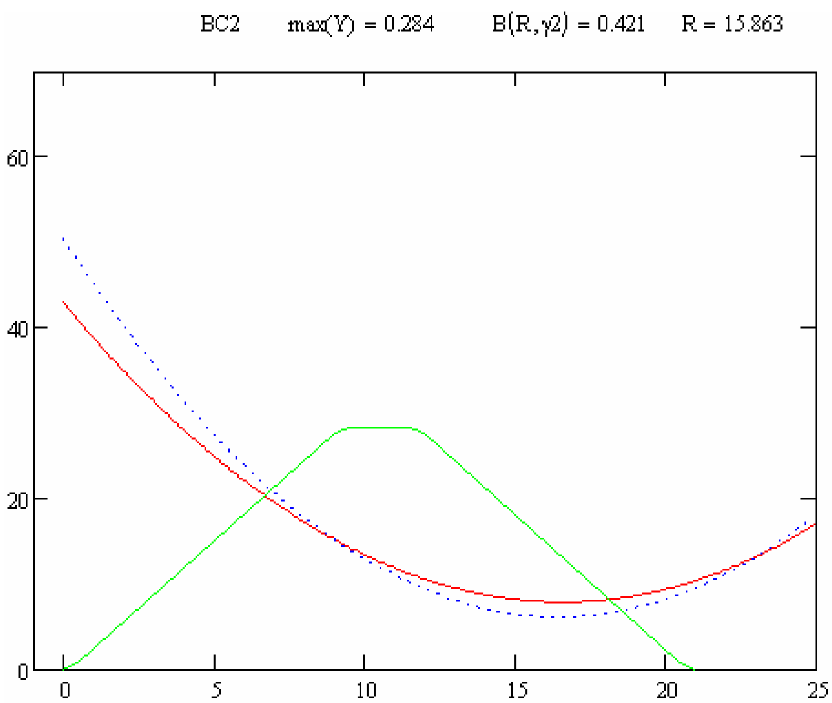
3. Increased M2-M3 Drift

(0.5m magnets)

C1=0.5_8.5_3.3
r56/mm=-0.103258

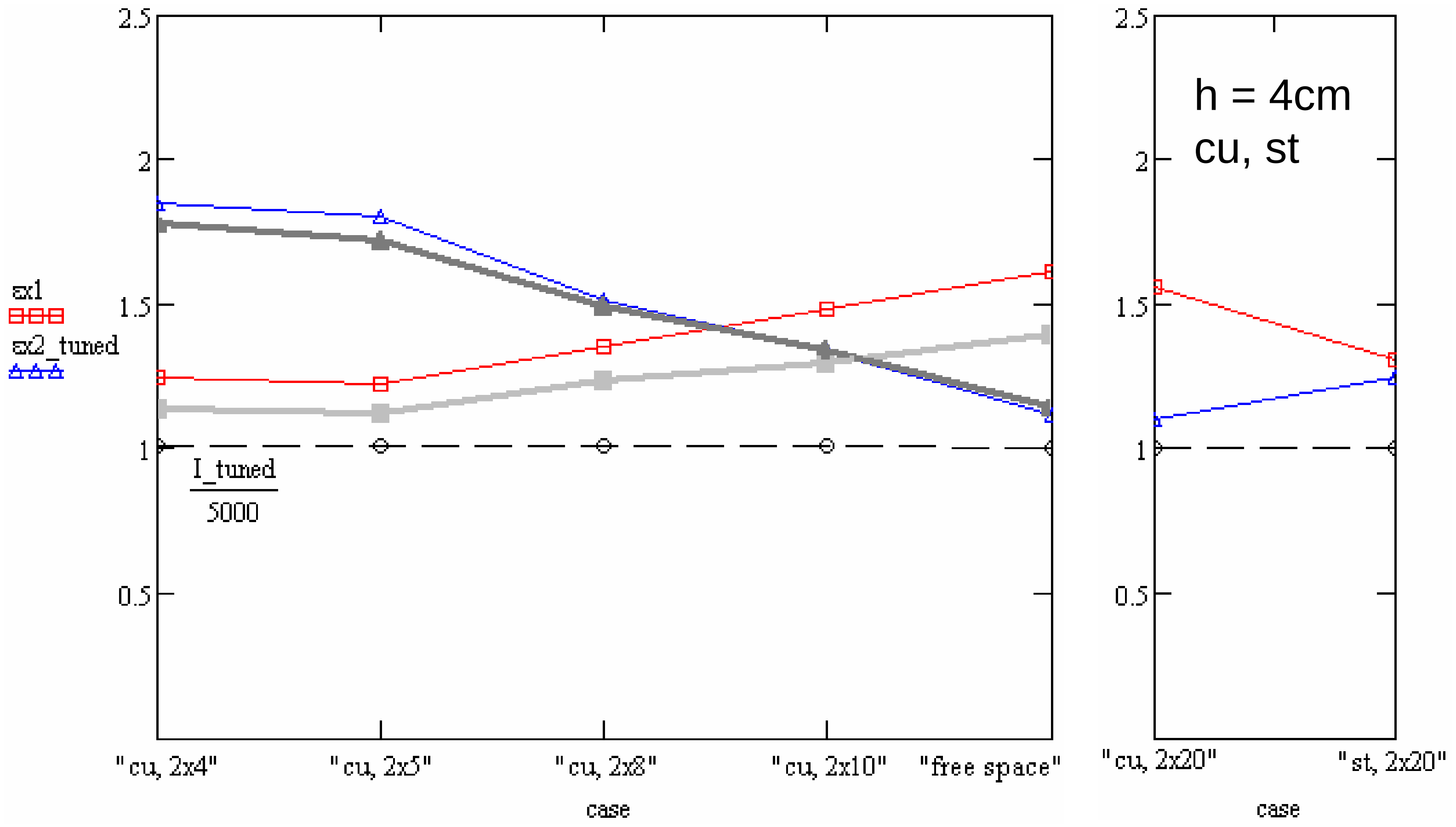


C2=0.5_8.5_2.0
r56/mm=-0.0175798



peak current and projected x-emittance

BC1=0.5_8.5_3.3
BC2=0.5_8.5_2.0



gray = official setup

Movable BC Chamber

Winni's Arguments

Winni Decking
26.07.2007

Arguments for movable bunch compressors

Variable R56

The compression scenario of the XFEL incorporates 2 bunch compressor chicanes. The nominal setting requires a compression by a factor of 100. The compression can be varied by varying the R56 (the ratio of path length variation with varying energy), which in turn is done by varying the angle (or offset) of the chicane.
The compression scenarios for the XFEL have been laid out such, that a broad range of parameters (different bunch length or peak currents) can be obtained. The exact balance of the compression factors depends on many parameters which are not well defined yet. That requires a large variation of the R56 in the two chicanes.

The first bunch compression chicane requires the smallest variation in R56, because even a small compression factor of 4 requires an R56 of at least 75 mm (assuming a correlated energy spread of 2% and 2mm initial bunch length). The maximum R56 is about 105 mm for a compression of 20. Consequently, the 2^{nd} chicane requires a larger tuning range. Assuming a constant total compression of 100, the extreme cases are an R56 of 20 mm for the compression factor 5 and an R56 of 80 mm for the factor 20 compression (assuming an energy of 2 GeV at BC3).
The following table summarizes the values – note that this is only one possible scenario and for instance the chicane offset depends strongly on the exact geometry of the chicane.

	Compression Factor	R56 [mm]	Chicane Angle [deg]	Chicane Offset [mm]	Full Beam Width [mm]	Beam Pipe Width for -/+10% R56 variation [mm]	
B1	4	75	3.7	580	4	-30	+30
	20	105	4.4	690	4	-35	+32
B2	20	80	3.8	600	1	-35	+32
	5	20	1.9	300	0.25	-15	+15

Winni’s Arguments …

Vacuum Chamber

A movable vacuum chamber can be positioned according to the required R56. A certain R56 range should be reachable without moving the chamber, thus a full width of 70 to 80 mm is necessary.
A large aperture chamber has to span the complete movable range, yielding a total width of 450 mm.

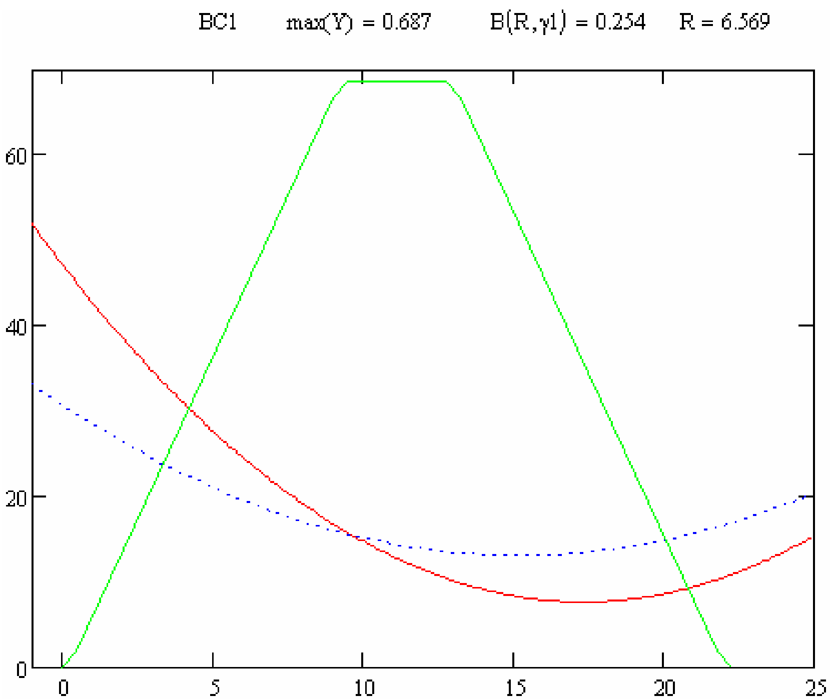
	Movable Chamber	**Fixed Chamber**
Inner Dimensions	80 x ~40 mm	450 x ~40mm
Advantages	• dipole gap can be small • energy resolving bpm is easier	• damage risk smaller
Disadvantages	• moving bellows are always a potential risk for operation • flexible bellow cannot be shielded due to the dust-free requirements	• complicated vacuum design • large dipole gap required • energy resolving bpm difficult

change of cross-section!

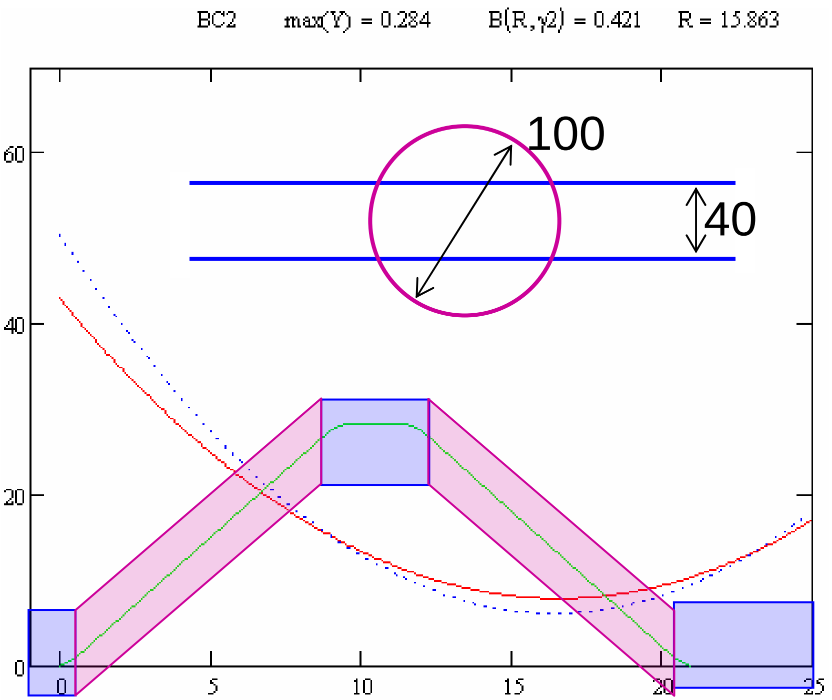
4. Flat & Round Chamber for BC2

(0.5m magnets, increased M2-M3 drift)

BC1=0.5_8.5_3.3
r56/mm=-0.103258
flat (2x20mm)

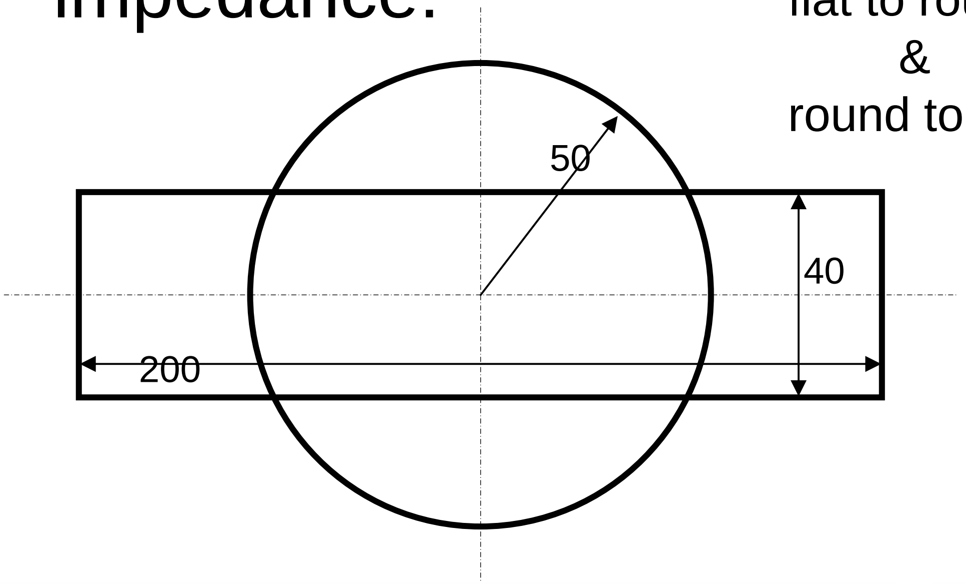


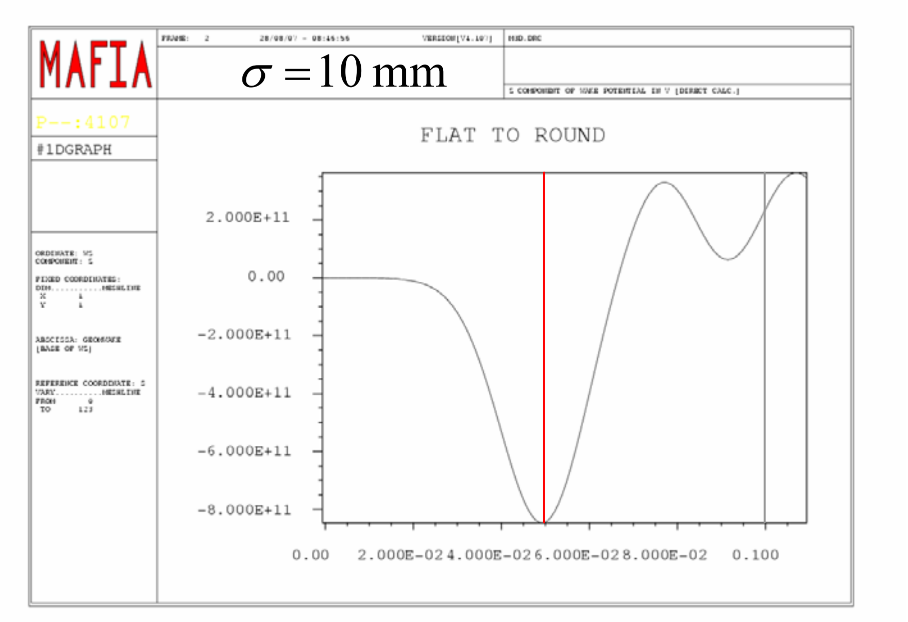
BC2=0.5_8.5_2.0
r56/mm=-0.0175798
flat (2x20mm), round (d=100mm)

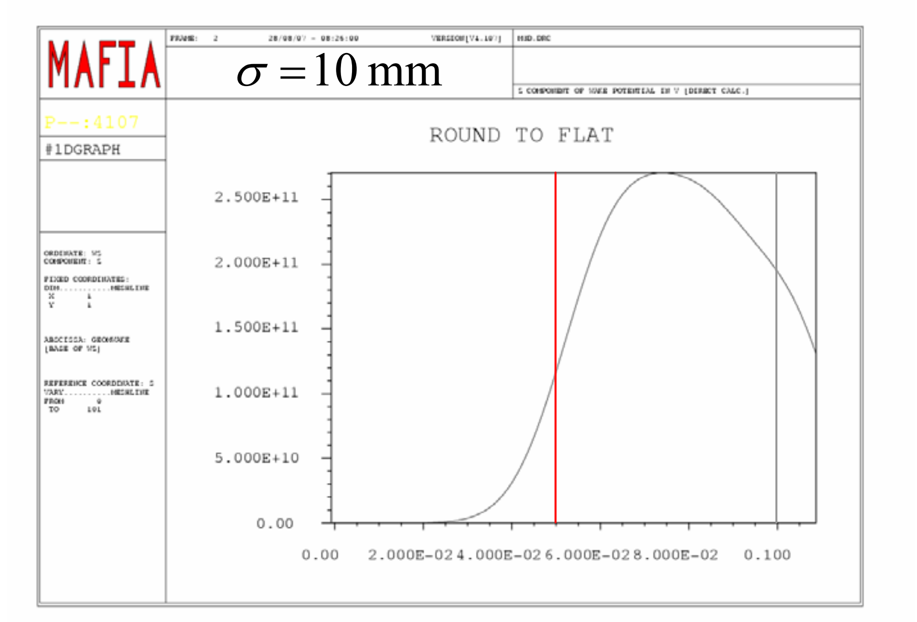


impedance:

flat to round
&
round to flat



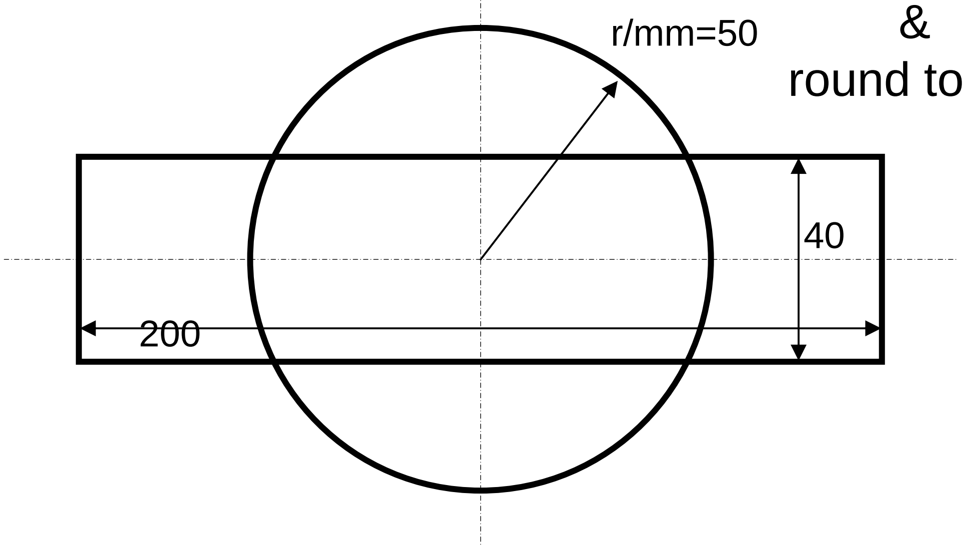




$\rightarrow Z \approx 71\,\Omega$

$\rightarrow |Z|$ small

impedance …



flat to round
&
round to flat

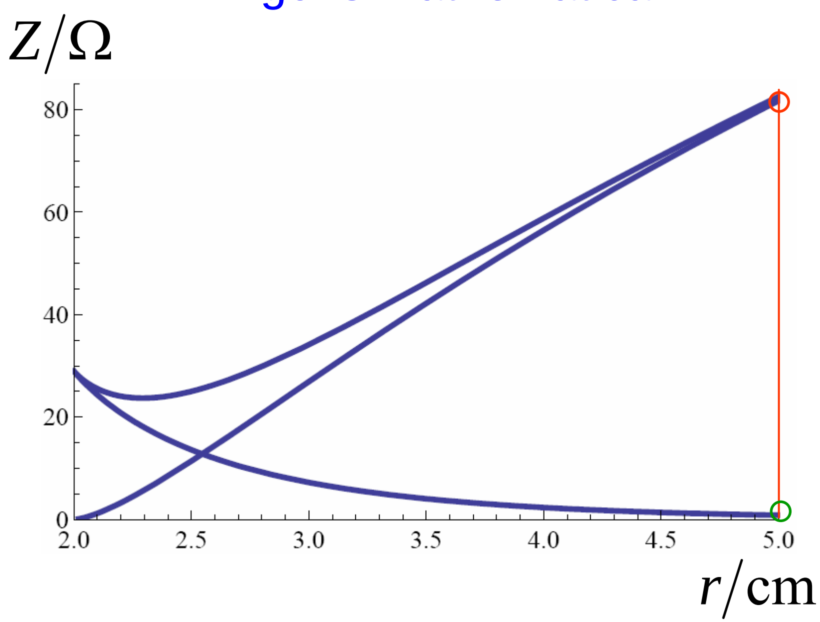
Impedance Calculations of Non-Axisymmetric Transitions Using the Optical Approximation*

SLAC-PUB-12370
DESY-07-023
February 2007

K.L.F. Bane, G. Stupakov
Stanford Linear Accelerator Center, Stanford University, Stanford, CA 94309

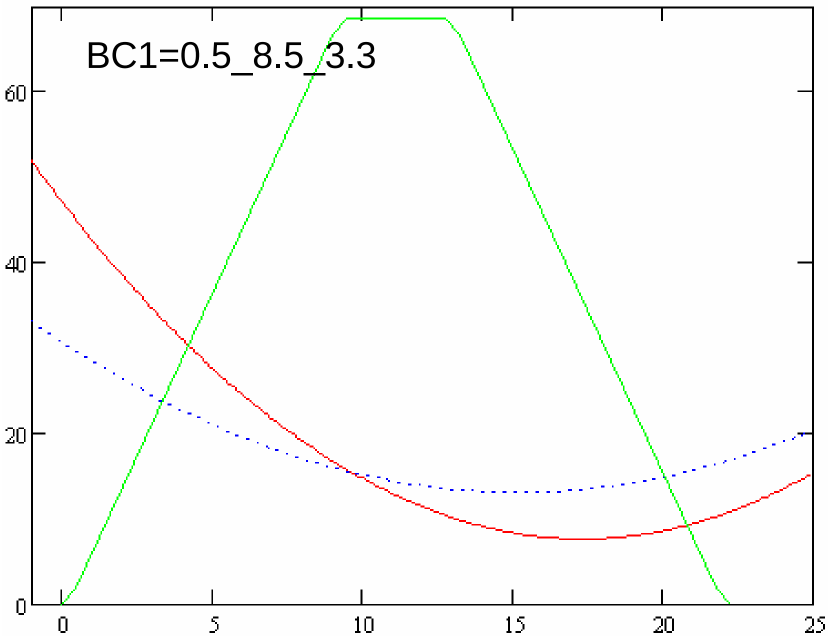
I. Zagorodnov
Deutsches Elektronen-Synchrotron, Notkestrasse 85, 22603 Hamburg, Germany

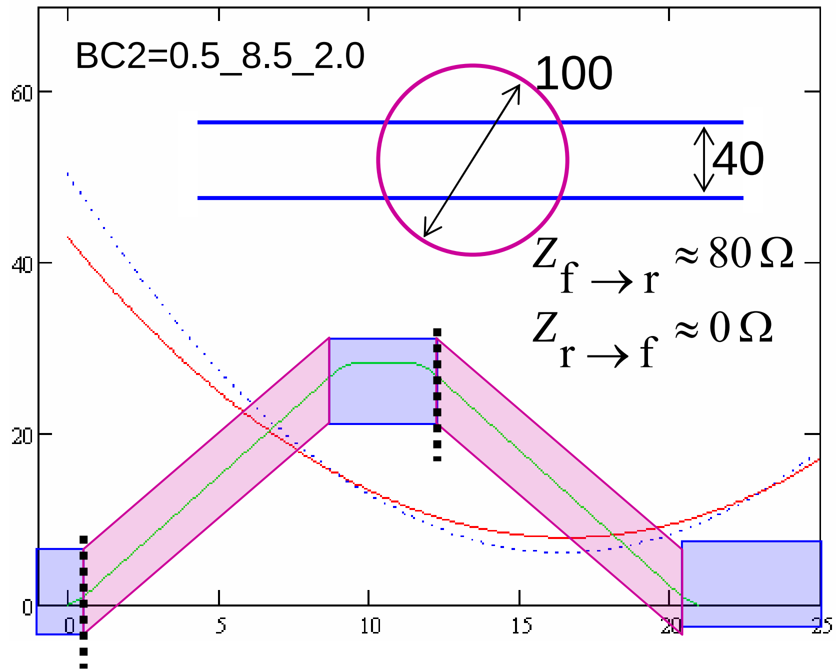
Igor's mathematica:



"flat to round"
$Z = 81.7406\,\Omega$

"round to flat"
$Z \approx 0.829439\,\Omega$





flat chamber in BC1

"2x20" cu	Ipeak/A=1002 emit_hor/um=1.56
"inf"	Ipeak/A=996 emit_hor/um=1.61
"2x20" st	Ipeak/A=1001 emit_hor/um=1.31

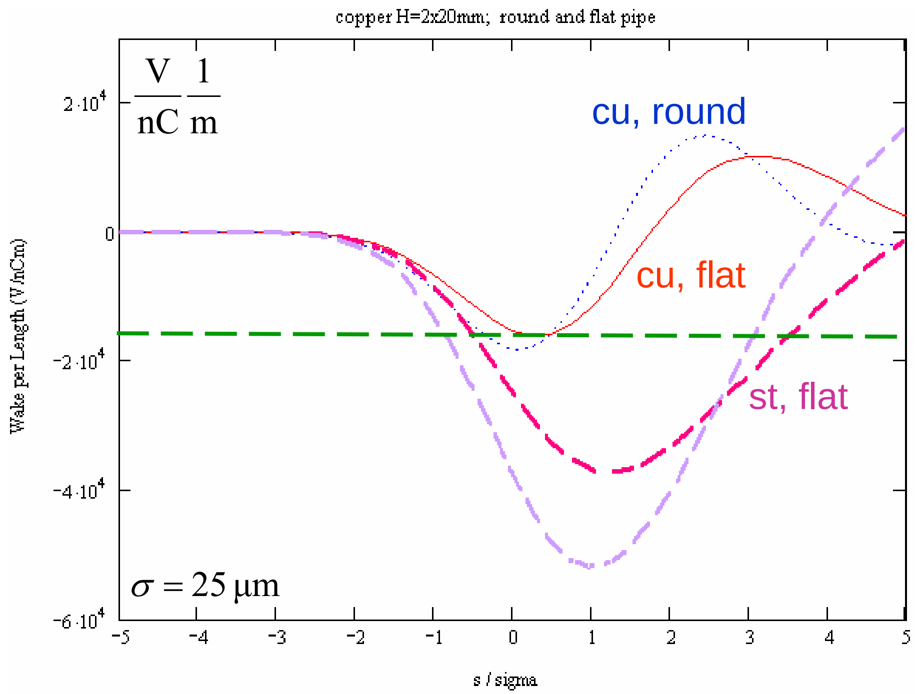
BC2: flat & round

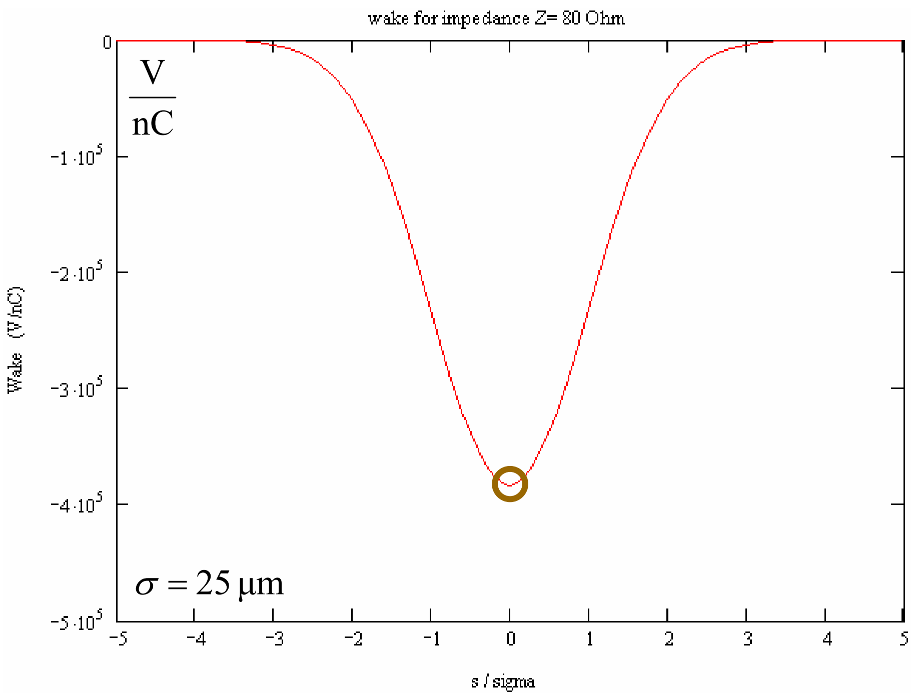
Ipeak/A=5076
emit_hor/um=1.36

Ipeak/A=5005
emit_hor/um=1.12

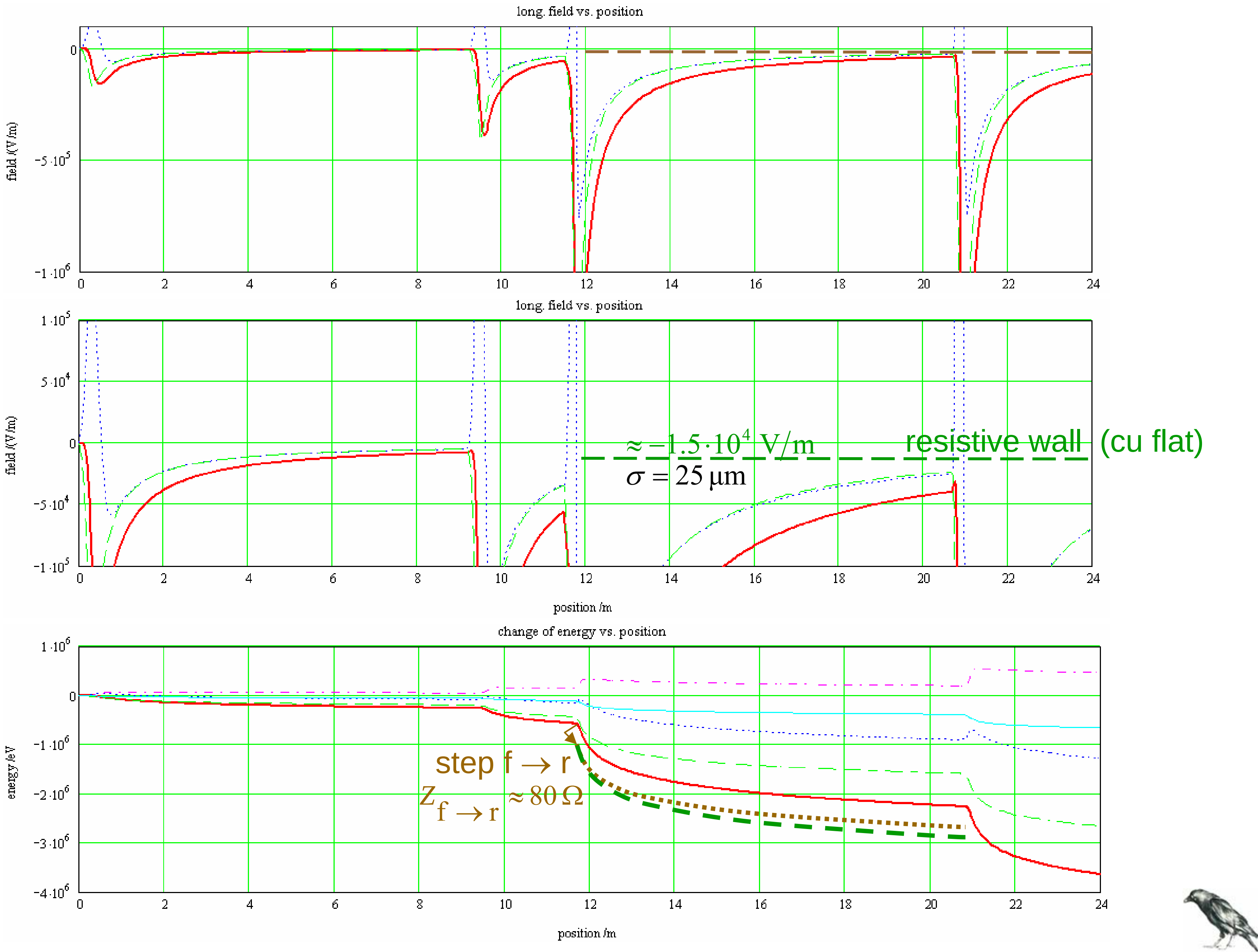
Ipeak/A=5065
emit_hor/um=1.59

magnitudes of effects:





long. field along BC2:



5. Reduced M1-M2 & M3-M4 Drift

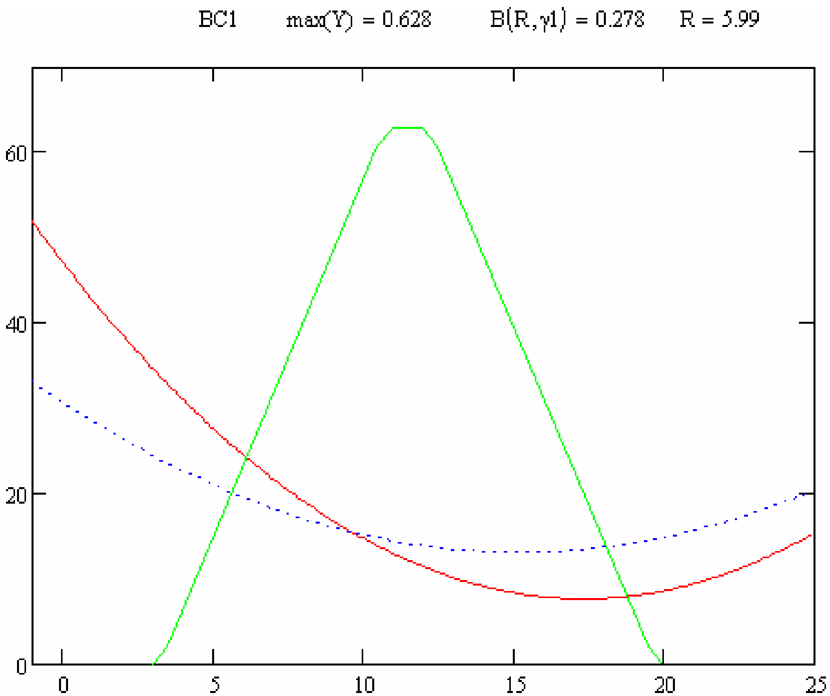
(0.5m magnets, flat chamber)

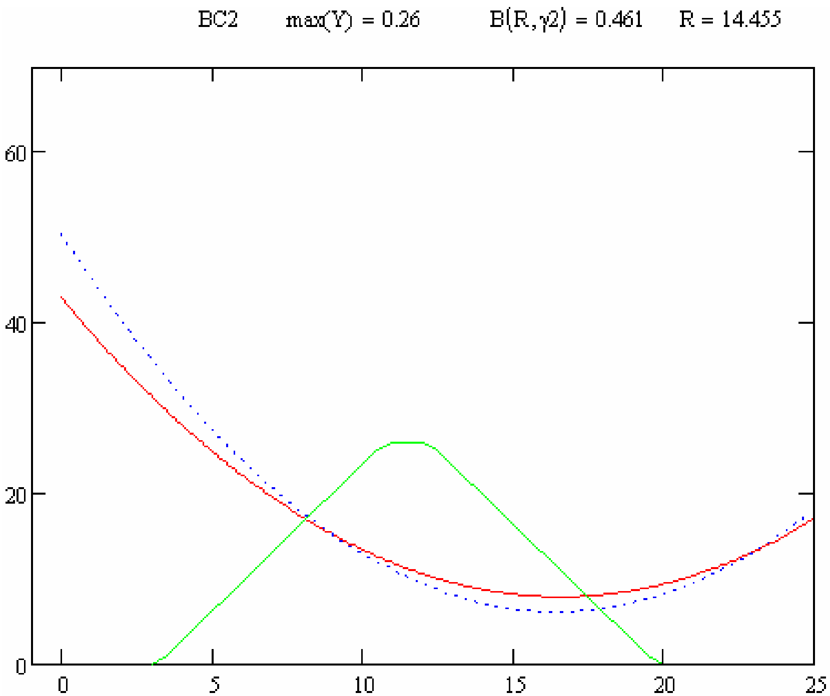
BC1=0.5_L_1.0
BC2=0.5_L_1.0

L / m	L_tot / m	max(x1) / cm	B1 / T	max(x2) / cm	B2 / T
8.5	20	69	0.278	28	0.421
7.0	17	63	0.000	26	0.461
5.5	14	56	0.312	23	0.517
4.0	11	49	0.361	20	0.600
2.5	8	40	0.445	17	0.741

BC1=0.5_7.0_1.0
r56/mm=-0.103258

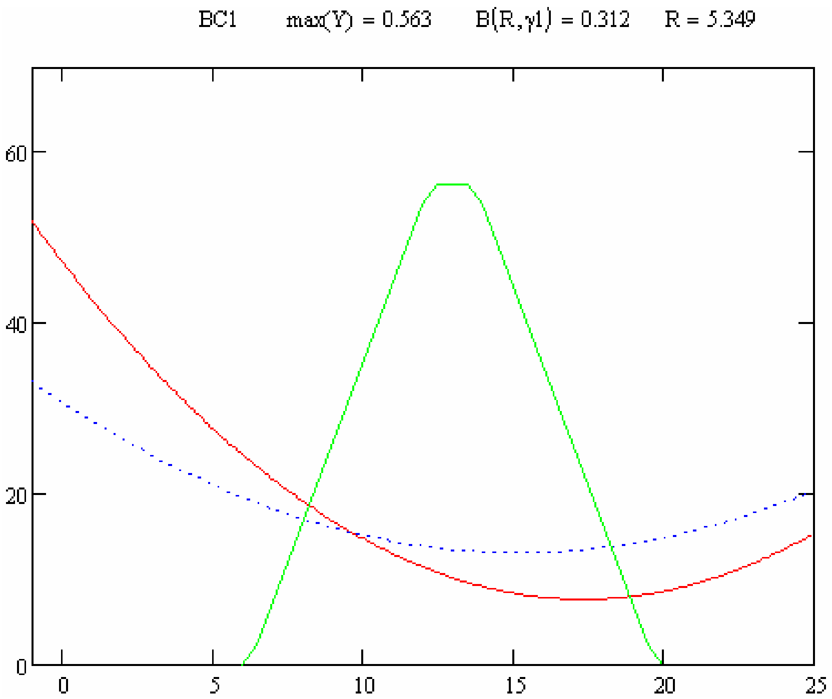
BC2=0.5_7.0_1.0
r56/mm=-0.0175798

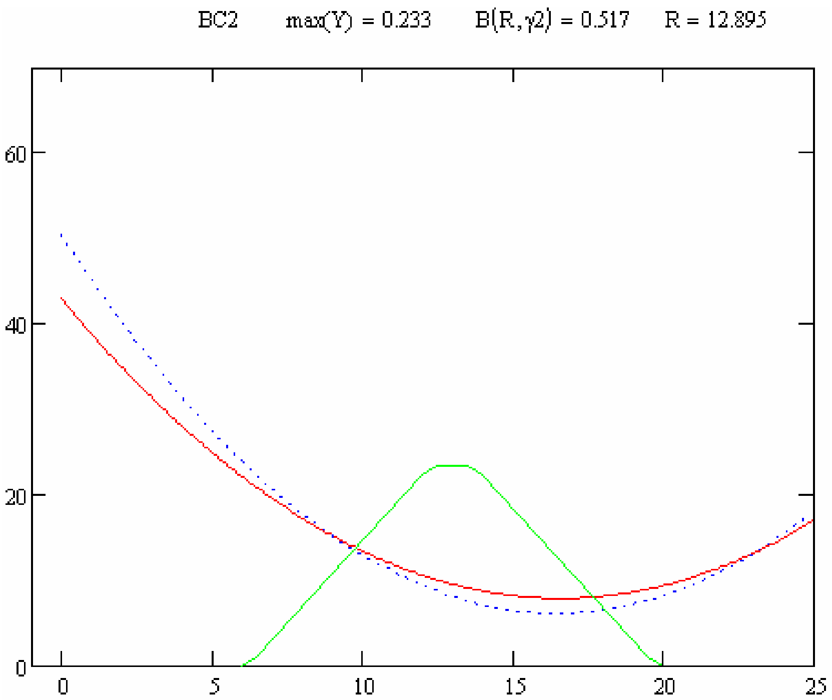




BC1=0.5_5.5_1.0
r56/mm=-0.103258

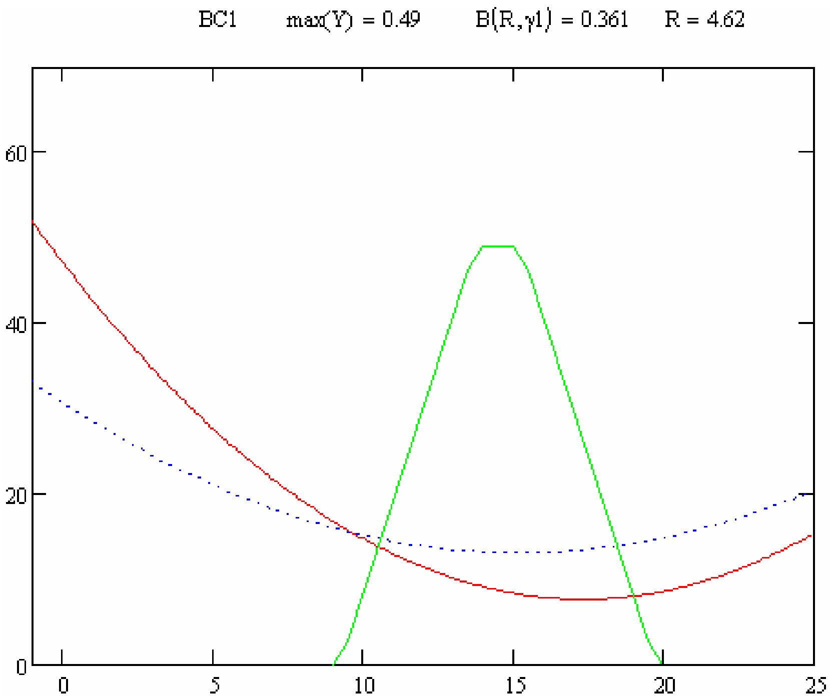
BC2=0.5_5.5_1.0
r56/mm=-0.0175798

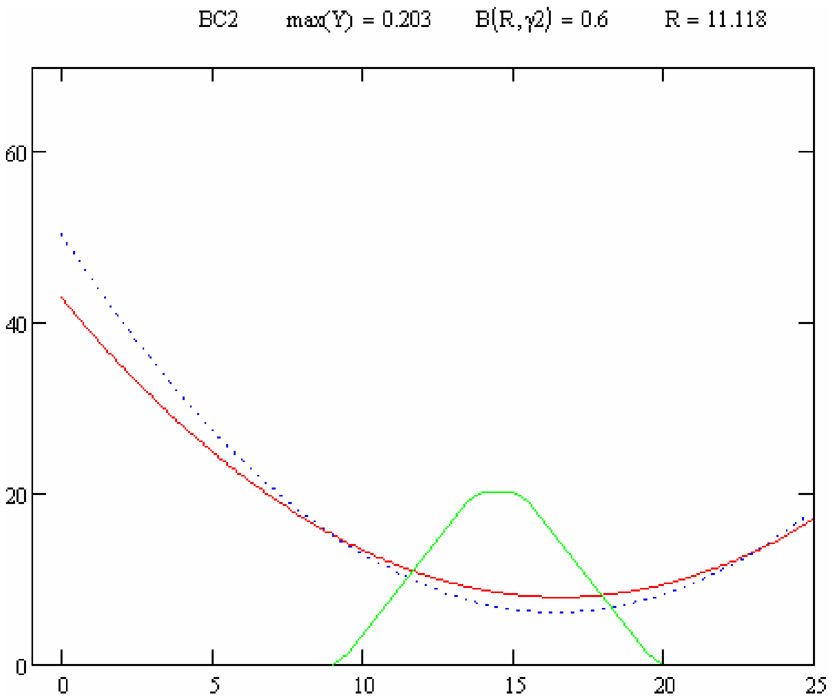




BC1=0.5_4.0_1.0
r56/mm=-0.103258

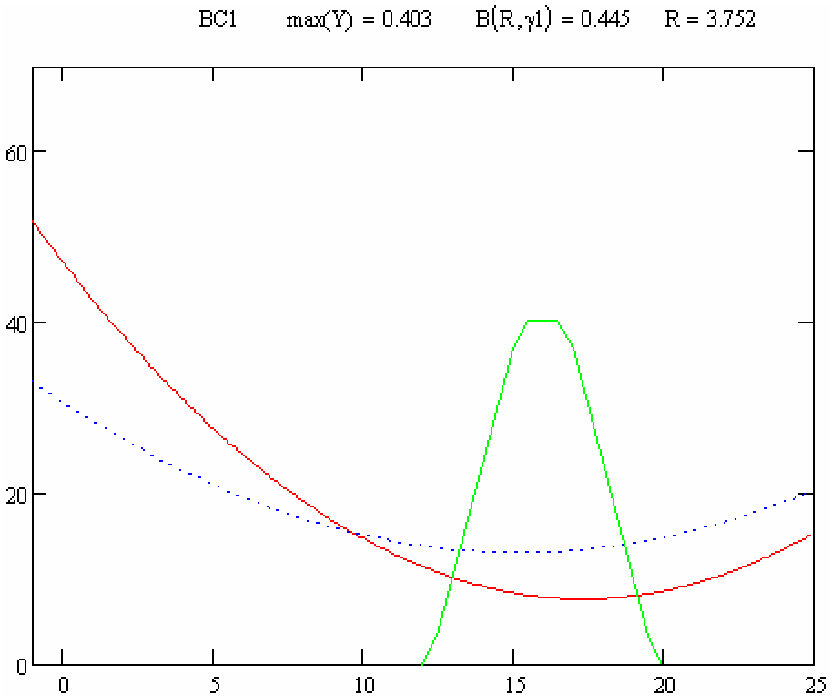
BC2=0.5_4.0_1.0
r56/mm=-0.0175798

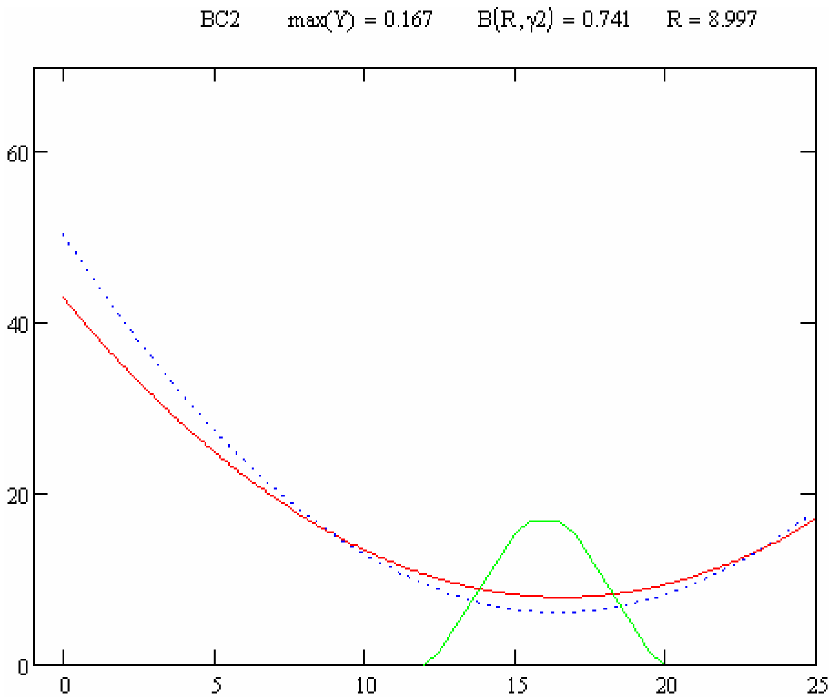




BC1=0.5_2.5_1.0
r56/mm=-0.103258

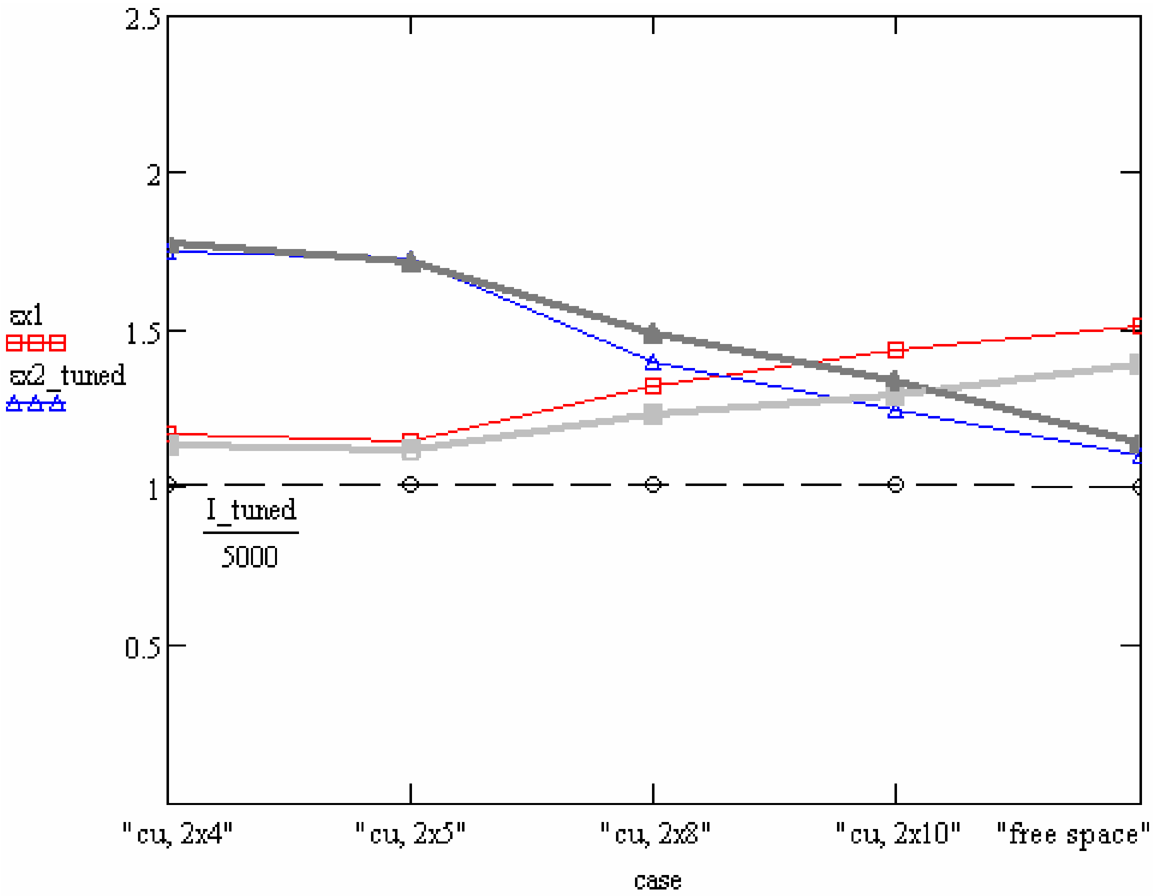
BC2=0.5_2.5_1.0
r56/mm=-0.0175798





peak current and projected x-emittance

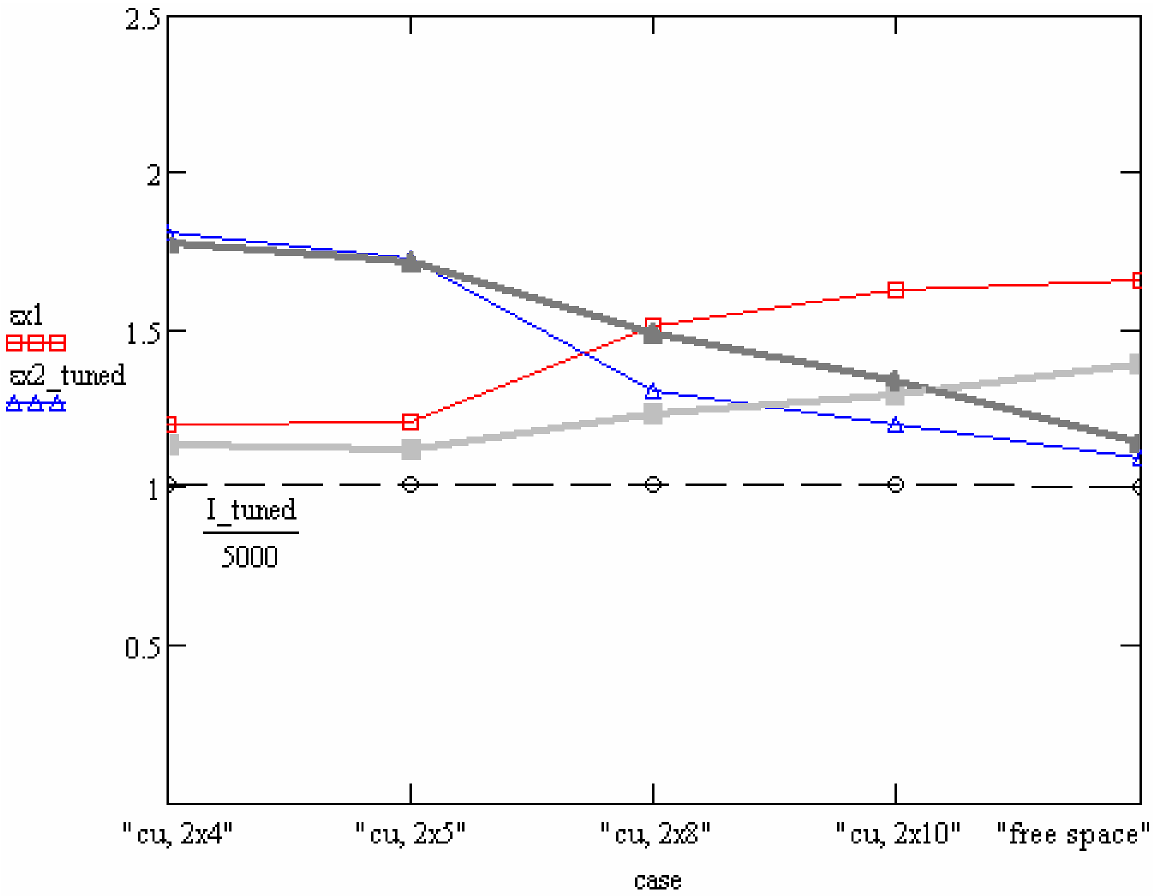
L / m	L_tot / m	max(x1) / cm	B1 / T	max(x2) / cm	B2 / T
7.0	17	63	0.000	26	0.461



gray = official setup

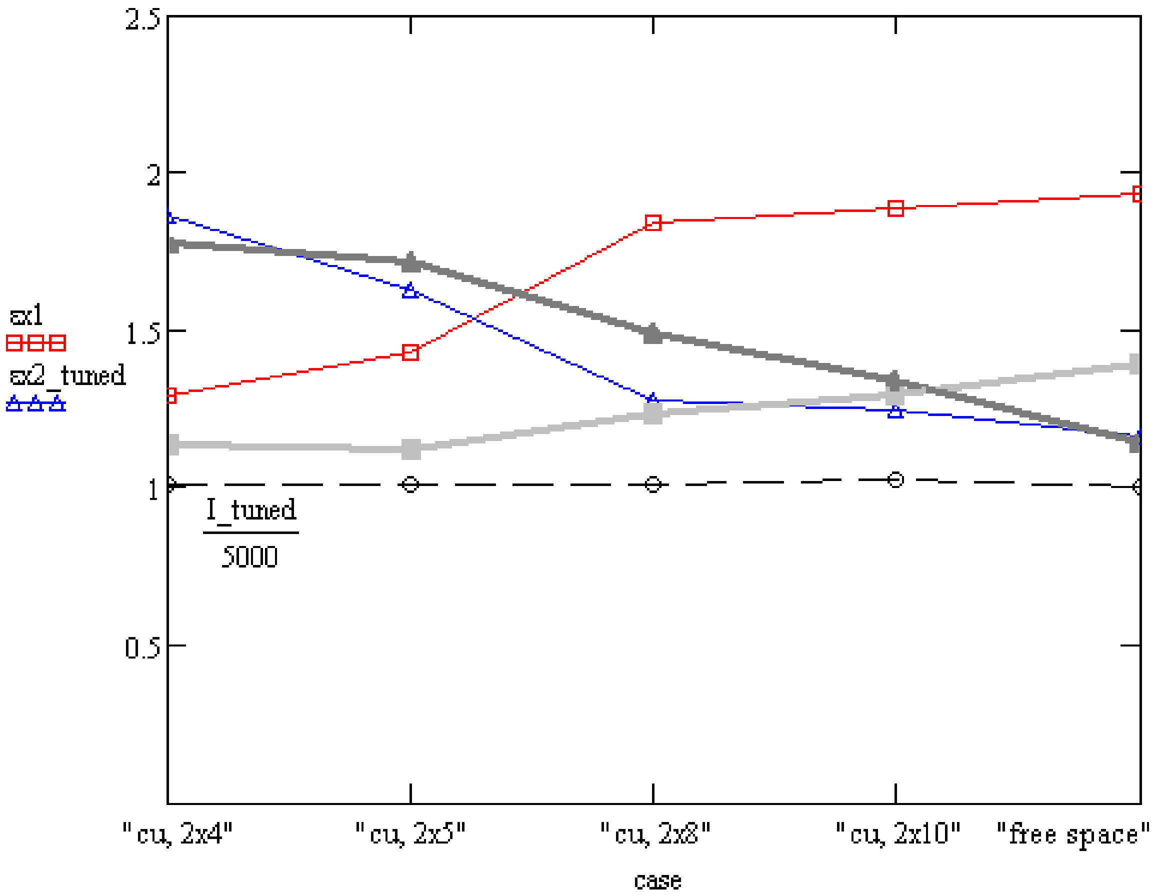
peak current and projected x-emittance

L / m	L_tot / m	max(x1) / cm	B1 / T	max(x2) / cm	B2 / T
5.5	14	56	0.312	23	0.517



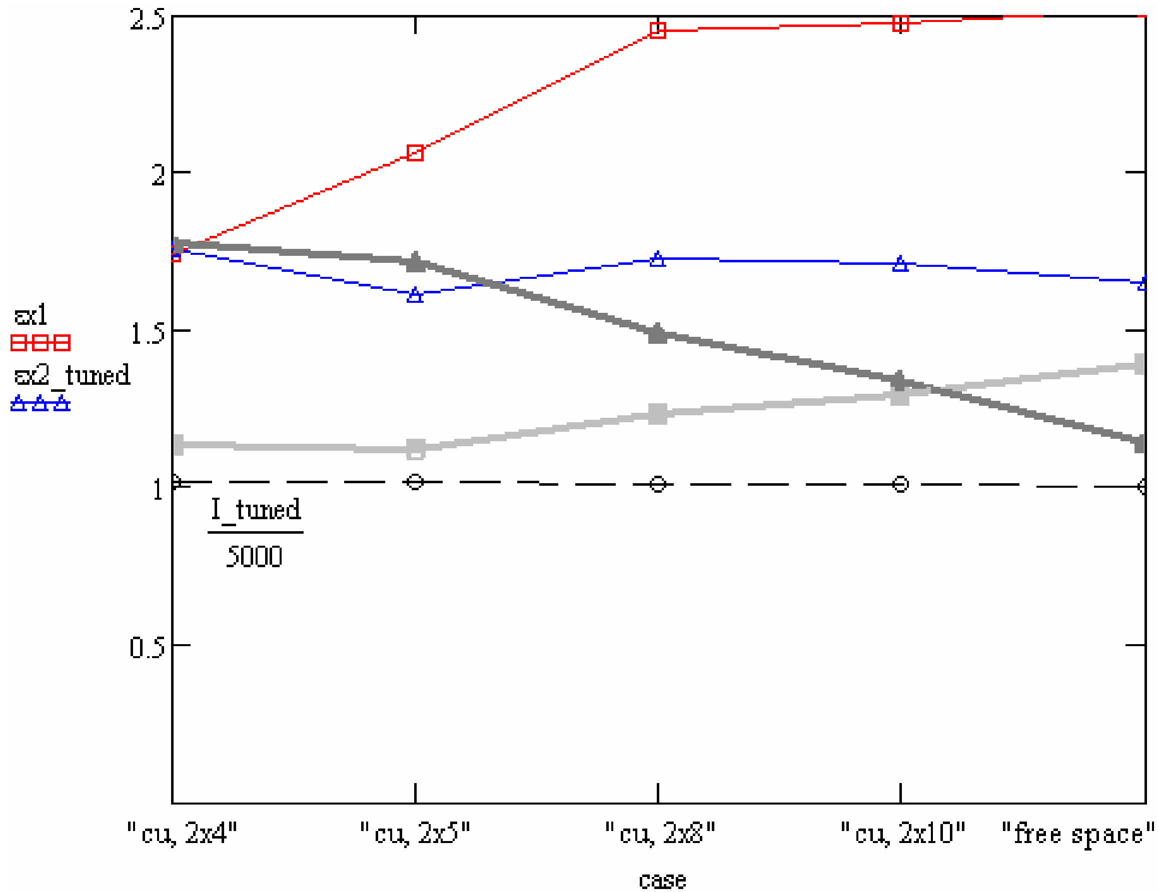
peak current and projected x-emittance

L / m	L_tot / m	max(x1) / cm	B1 / T	max(x2) / cm	B2 / T
4.0	11	49	0.361	20	0.600



peak current and projected x-emittance

L / m	L_tot / m	max(x1) / cm	B1 / T	max(x2) / cm	B2 / T
2.5	8	40	0.445	17	0.741



6. Conclusions

shielding vs resistive wall wake:

avoid rww $\rightarrow$ no or weak shielding

high and wide chamber

copper

increased magnet length (0.3 $\rightarrow$ 0.5m) ok

increased drift length (M2$\rightarrow$M3):

projected emittance growth slightly increased

after BC1 but compensated in BC2

BC2 with movable chamber **(operation different from 20x5 design!)**

BC2: bellows & round pipes for drift (M1$\rightarrow$M2, M3$\rightarrow$M4)

projected emittance increased from ~1.15 to ~1.35

$\rightarrow$ more work, better ideas

reduced drift length (M1$\rightarrow$M2, M3$\rightarrow$M4)

projected emittance after BC1 increased

essentially compensated in BC2 for Ltot > 11m

do not believe too much in compensation of effects in BC1 and BC2

(depends on optics, idealized particle dynamics,

20x5 compression with design parameters …)

only with design parameters!