Effects of RF Induced Coupler Kicks before BC1

1.3 GHz

1. coupler kicks induced by 1.3GHz rf
   definition
   TESLA cavity
   remarks

2. effects of these kicks (optics March 2007, Winnie's component list)

3. compensation of coupler kicks
   3.1. local compensation I (at coupler)
   3.2. local compensation II (cavity pairs)
   3.3. global compensation (along LINAC)

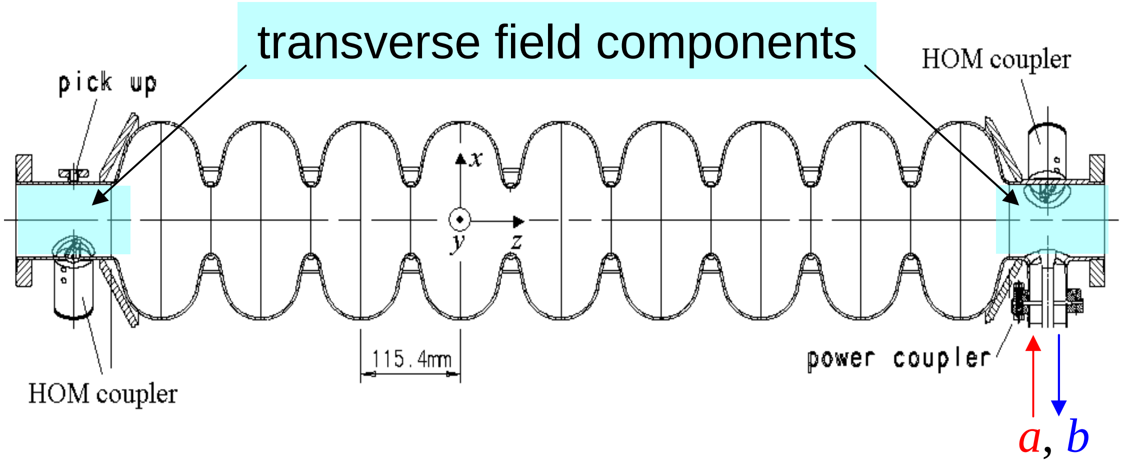
3.9 GHz

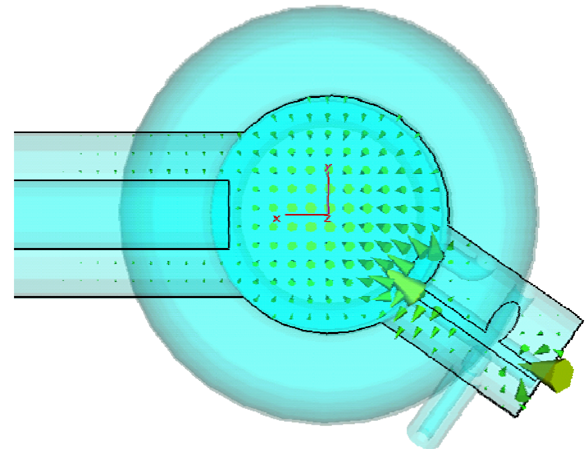
4. coupler kicks induced by 3.9GHz rf
   4.1 calculation of kick factors
   4.2 effects of these kicks

5. summary

1. Coupler Kicks Induced by 1.3GHz RF

coupler kick: definition





steady state solution:

$$\mathbf{Field}(\mathbf{r},t) = \mathrm{Re}\{\mathbf{Field}(\mathbf{r})\exp(i\omega t)\}$$

$$\mathbf{Field}(\mathbf{r}) = a\cdot\mathbf{Forward\_Field}(\mathbf{r}) + b\cdot\mathbf{Backward\_Field}(\mathbf{r})$$

complex coupler kick (f.i. forward mode):

$$\mathbf{V}(\mathbf{r}_\perp) = \int(\mathbf{E}+\mathbf{v}\times\mathbf{B})\exp(i\omega z/c)\,dz$$

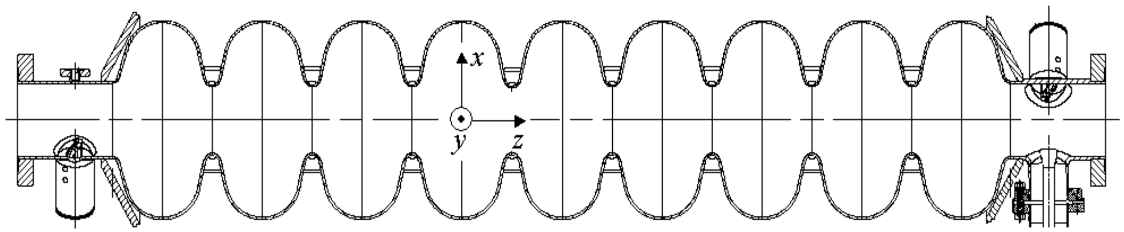
normalized coupler kick:

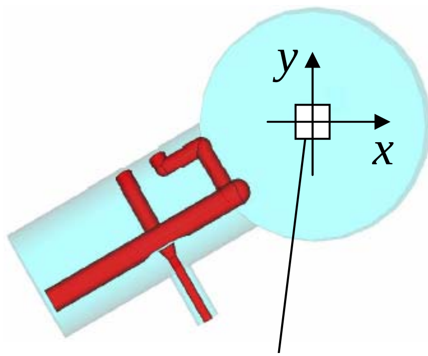
$$\mathbf{v}(\mathbf{r}_\perp) = \frac{\mathbf{V}(\mathbf{r}_\perp)}{V_z(\mathbf{0})}$$

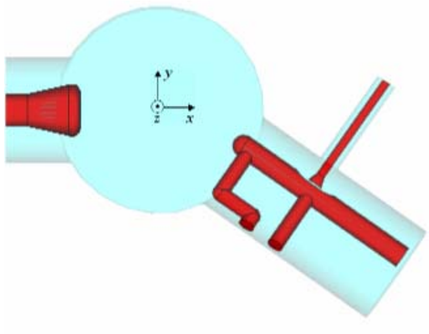
$\mathrm{Re}\{\mathbf{v}\}$ is the relative kick seen by a particle on crest

1. Coupler Kicks Induced by 1.3GHz RF

coupler kick: TESLA cavity





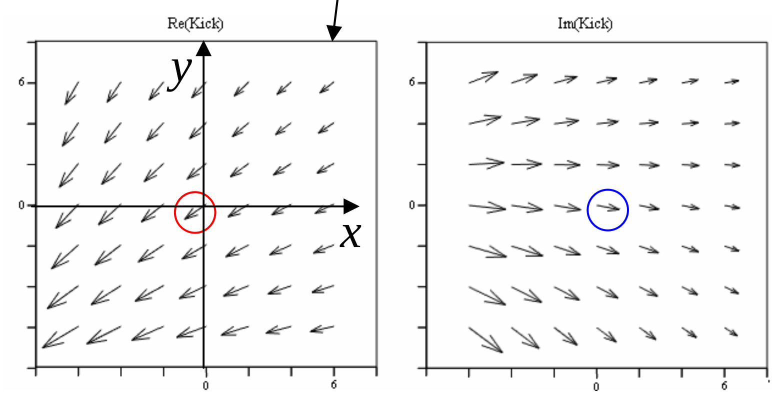


$v_x = -0.000059 + 0.000009i$

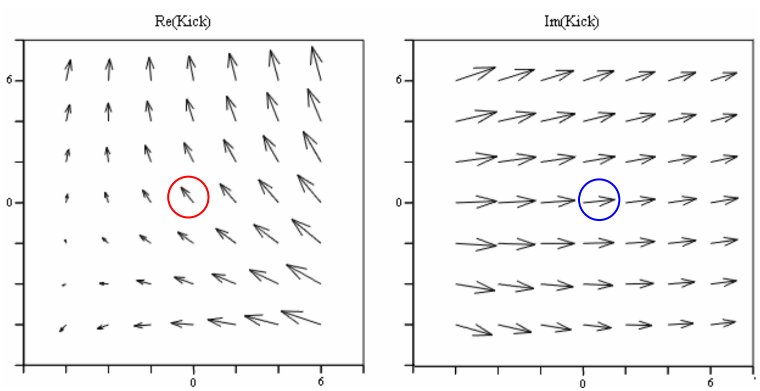
$v_y = -0.000043 - 0.000002i$

$v_x = -0.000024 + 0.000054i$

$v_y = 0.000031 - 0.000006i$



(range = ± 6mm)



(forward mode)

1. Coupler Kicks Induced by 1.3GHz RF
remarks

power coupler & HOM couplers cause kicks;

kick of power coupler is horizontal;
depends on penetration depth and Qext;
depends on SWVR;

HOM-coupler kicks are of same magnitude as of power coupler;
are horizontal & vertical;
depend only on the cavity field;

order of magnitude 1.3 GHz: ~ 50 µrad
3.9 GHz: ~ 300 µrad

2. Effects of these Kicks

kicks are time dependent and offset dependent

0th order: distortion of trajectory (depends on cavity phase)

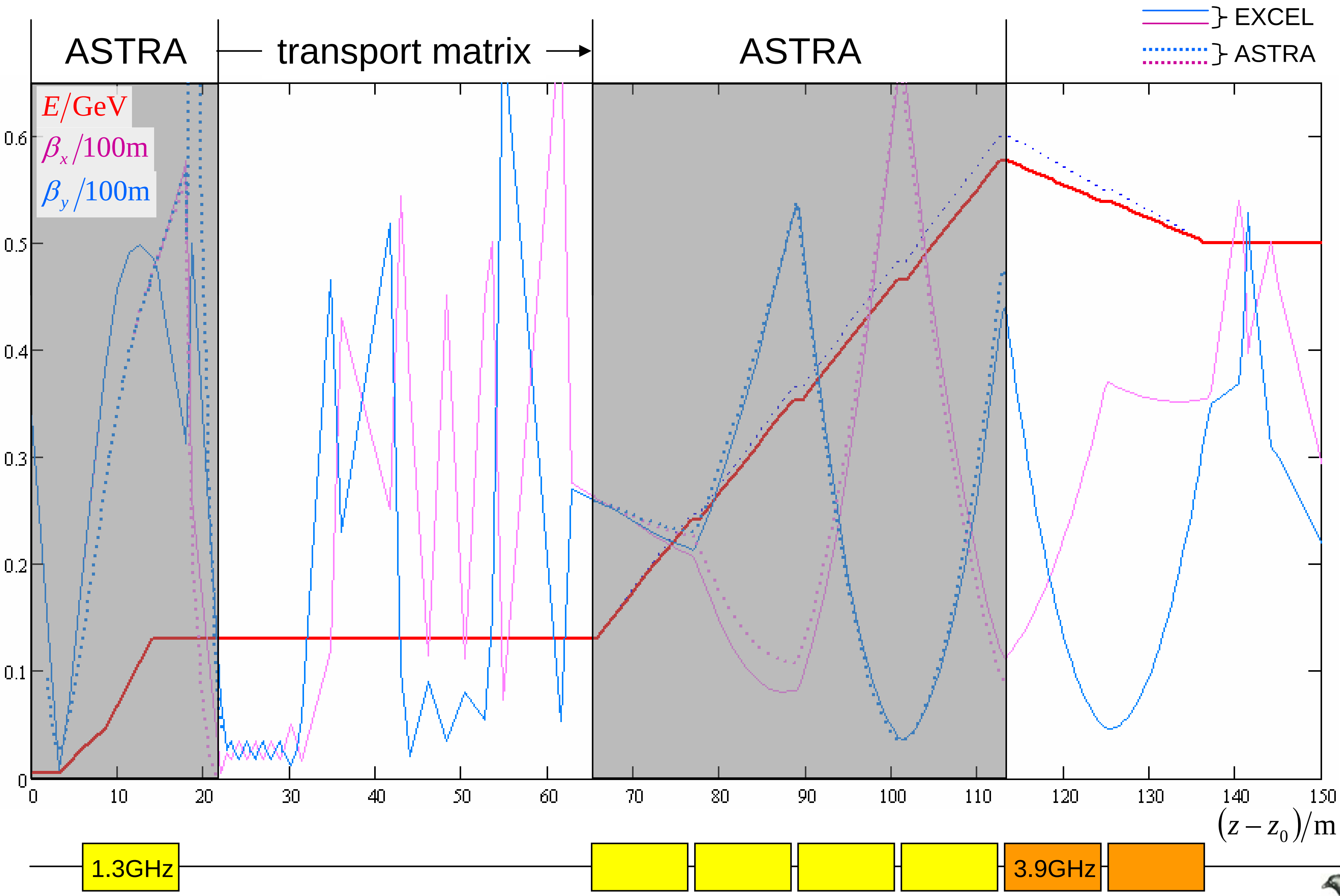
1st order, time: different centroid positions of different longitudinal slices
growth of projected emittance
could be compensated by time dependent fields

1st order, offset: x-y coupling
emittance growth (slice & projected)
could be compensated by static fields

along ACC1: time and offset dependent effects are of same order
up to BC1: time dependent effects dominate

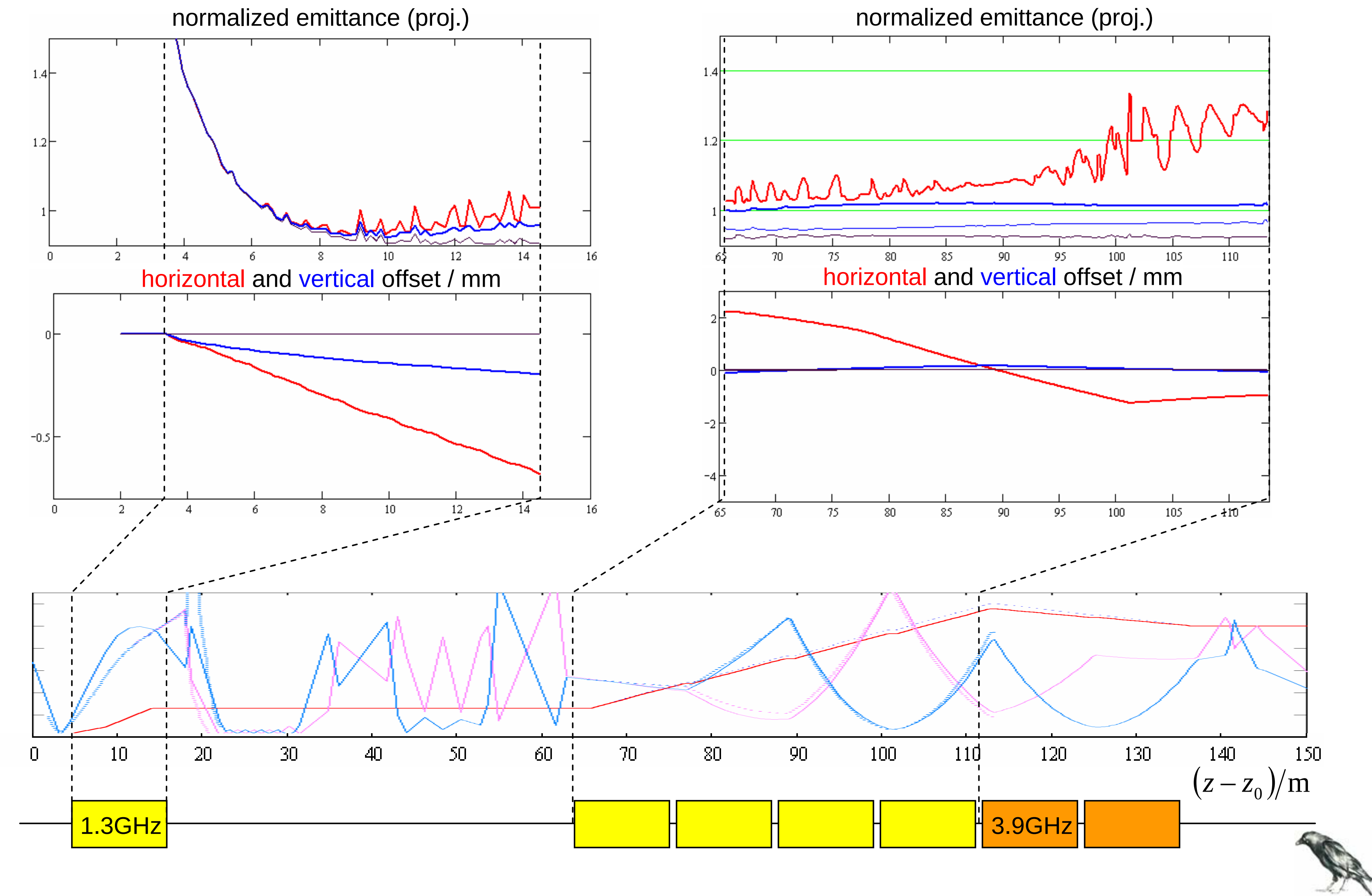
2. Effects of these Kicks

injector & L1 calculation (optics, march 2007)



2. Effects of these Kicks

projected emittance and offset (optics, march 2007)



3. Compensation of Coupler Kicks

previous and more discussions:

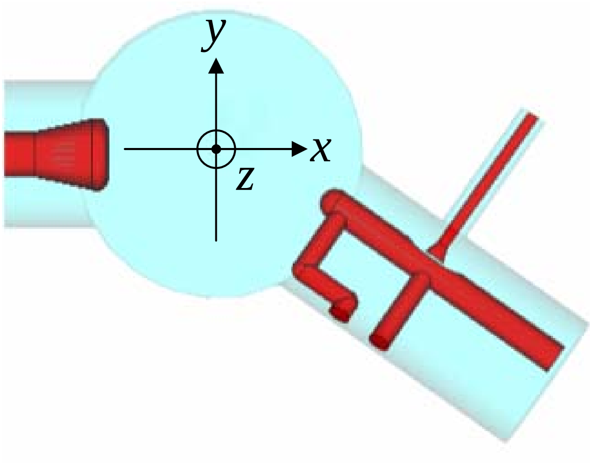
3.1. local compensation I (at coupler) $\rightarrow$ 1
3.2. local compensation II (cavity pairs) $\rightarrow$ 2
3.3. global compensation (along LINAC) $\rightarrow$ 3
4. 3.9 GHz rf $\rightarrow$ 4

http://www.desy.de/xfel-beam/talks_2008.html
(21.05.2007) Emittance Growth by RF Coupler Kicks
1=(14.01.2008) Compensation of RF Coupler Kicks First Attempt
2=(28.01.2008) Compensation of RF Coupler Kicks First Attempt (Continued)
3=(25.02.2008) Compensation of RF Coupler Kicks First Attempt (Further Cont.)
4=(17.03.2008) Coupler Kicks of 3rd Harmonic RF

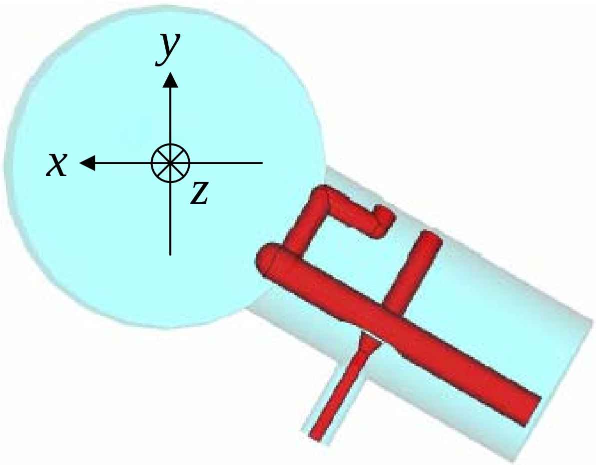
3.1. Local Compensation I (at coupler)

existing version

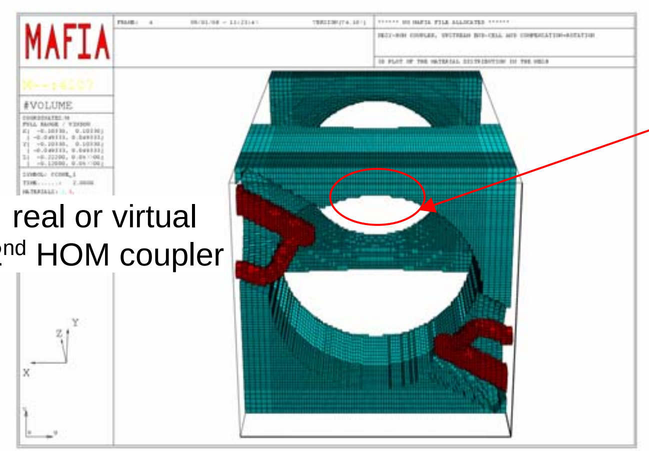
downstream



upstream

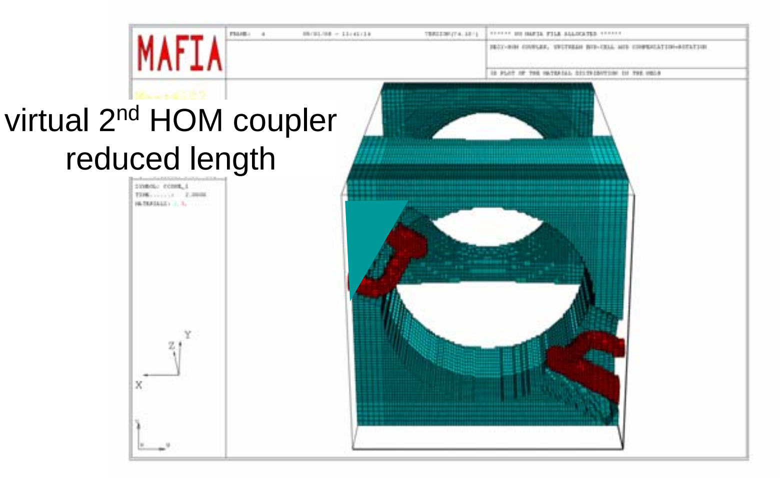


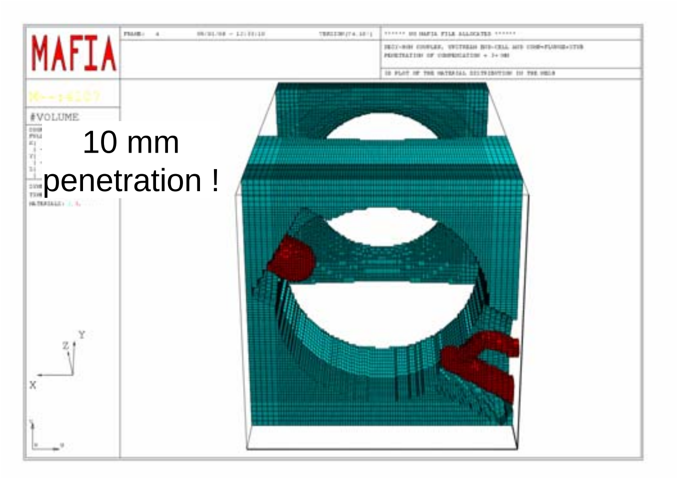
local compensation - upstream



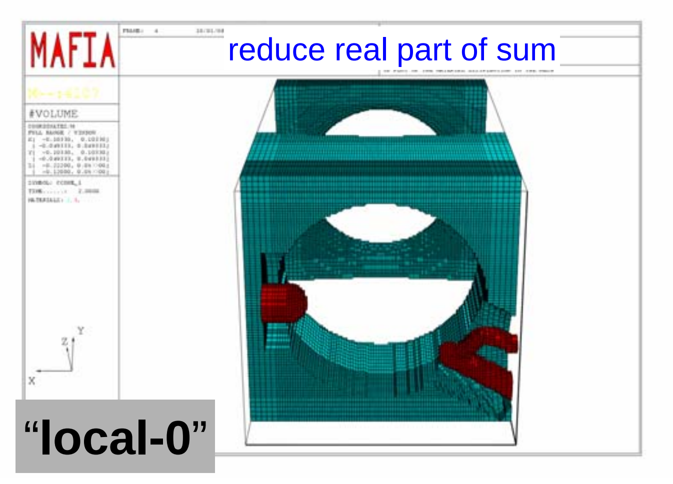
3.1. Local Compensation I (at coupler)

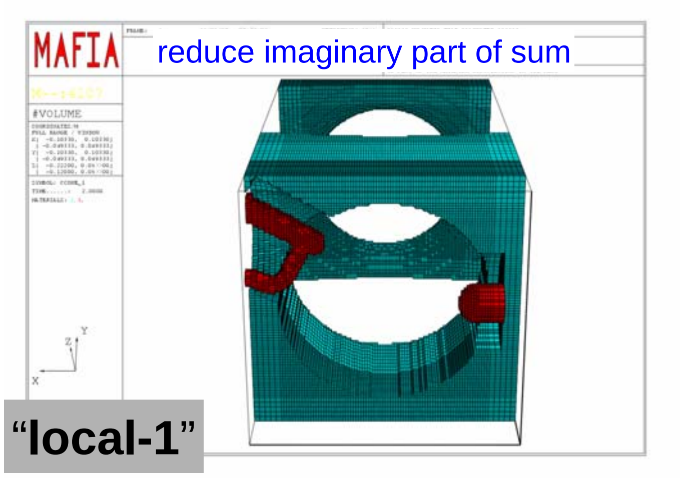
local partial compensation - upstream





reduction of up + downstream kicks at upstream coupler





3.1. Local Compensation I (at coupler)

remarks

local- or quasi-local compensation: fixed (not tunable) reactive element
partial compensation of some effects

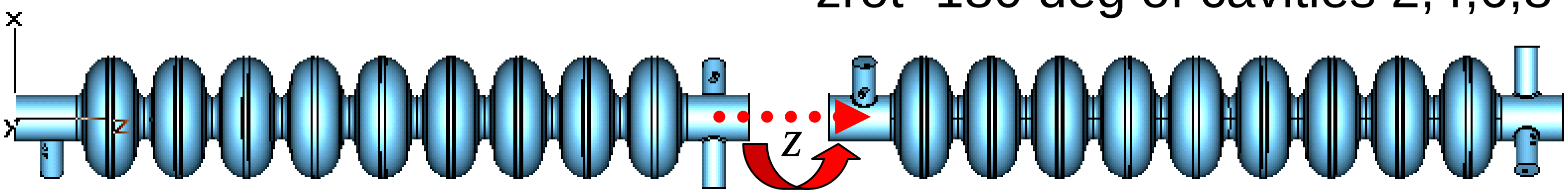
optimal geometry for rf induced kicks is not necessarily identical
with geometry for minimal wake field effects

strong geometrical constraints: tuner (local)
cryostat (in general)
E sensor

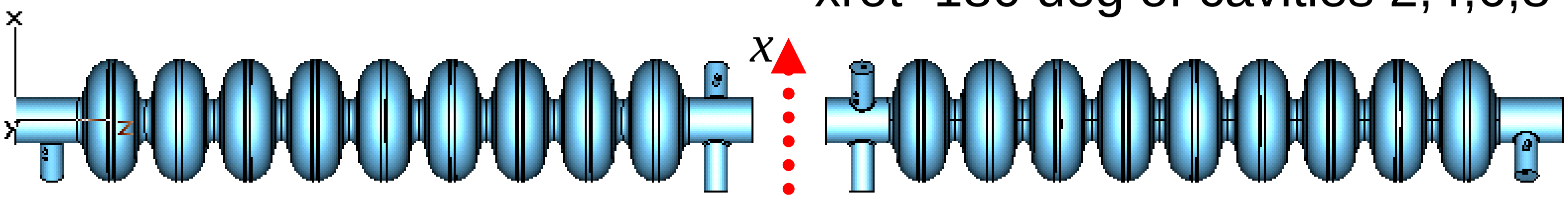
some results (for “local-0” and “local-1”) follow in table “local comp. II”

3.2. Local Compensation II (cavity pairs)

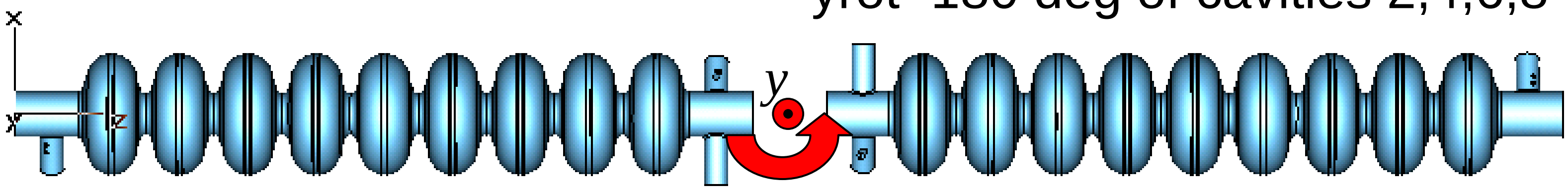
zrot=180 deg of cavities 2,4,6,8



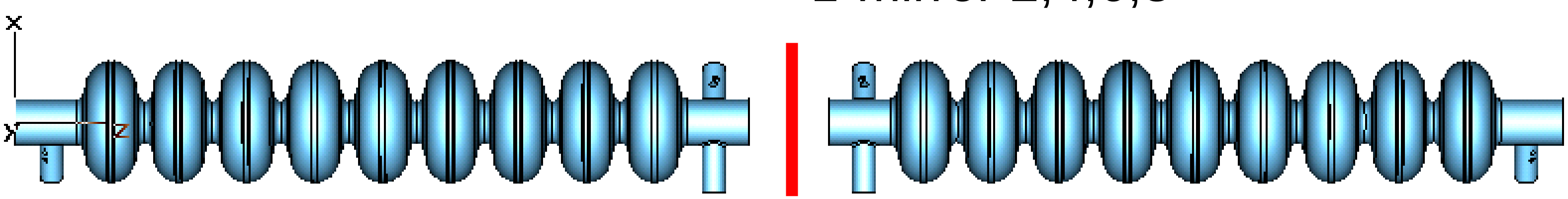
xrot=180 deg of cavities 2,4,6,8



yrot=180 deg of cavities 2,4,6,8



z-mirror 2,4,6,8



3.2. Local Compensation II
after ACC1

configuration	norm. xy-emittance projected $\frac{\max\{\varepsilon_x, \varepsilon_y\}}{\varepsilon_{\text{ref}}}$	norm. uv-emittance projected $\frac{\max\{\varepsilon_u, \varepsilon_v\}}{\varepsilon_{\text{ref}}}$
old configuration	1.113	1.045
local-0 (a)	1.172	1.090
local-1 (a,b)	1.066	1.014
cav.-pairs: z-rot (b,d)	1.058	1.008
x-rot (b,c)	1.052	1.017
y-rot (d)	1.046	1.015
z-mirror (a,c)	1.057	1.051

cavity and module design:

(a)
modify cavity

(b)
interference with cavity environment expected

(c)
modify cryostat
1-side power distribution

(d)
modify cryostat
2-side power distribution

3.3. Global Compensation (along LINAC)

some experiences from calculations of injector & L1

it is not sufficient to compensate the kick of the 1st coupler

… kicks before and after the 1st cavity

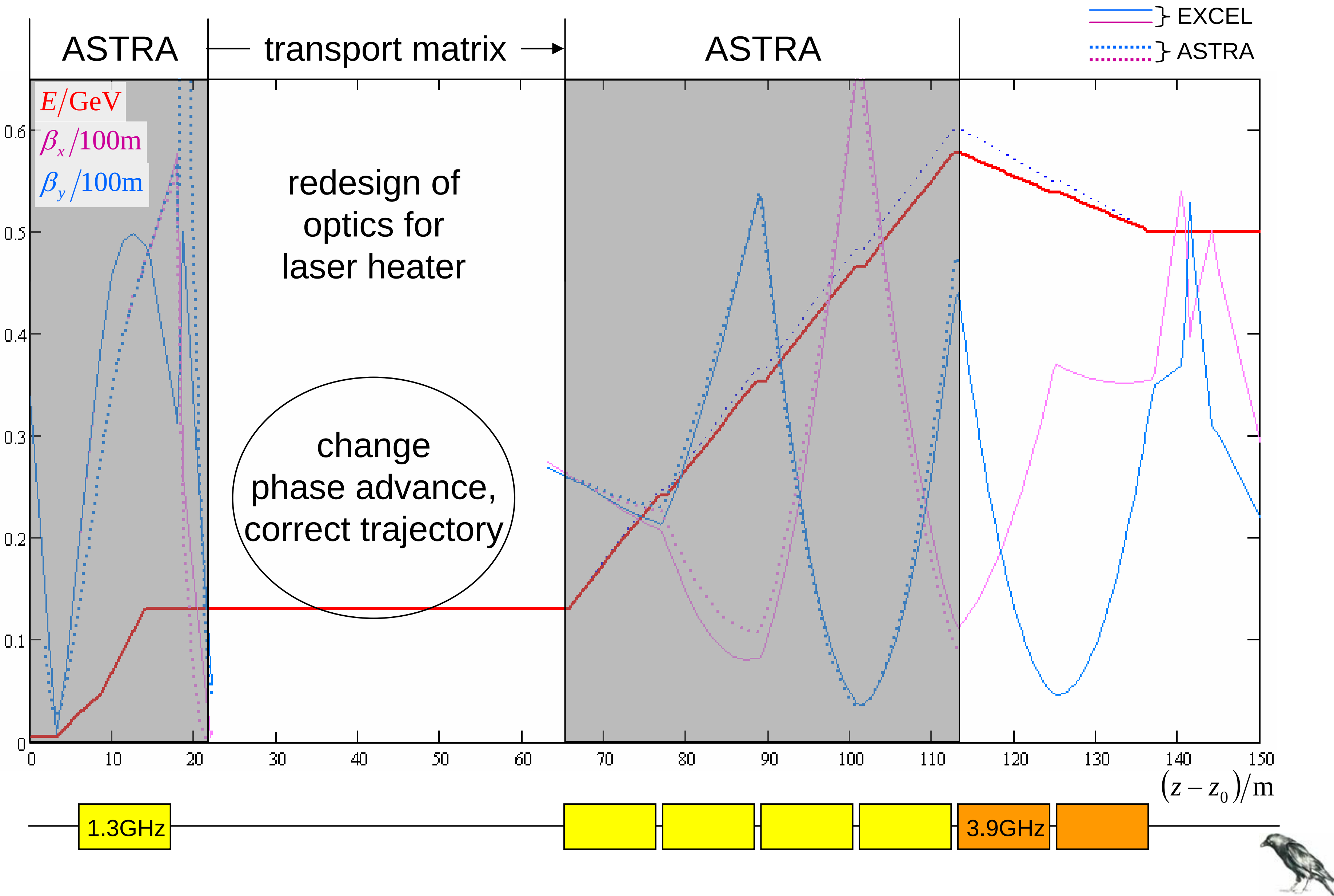
… kicks in the 1st module

either kicks in many modules have to be compensated or reduced (local compensation),
or effects along the LINAC have to work against each other (global compensation)

local = compensation of effects on a length short compared to the betatron wavelengh; → optic independent compensation

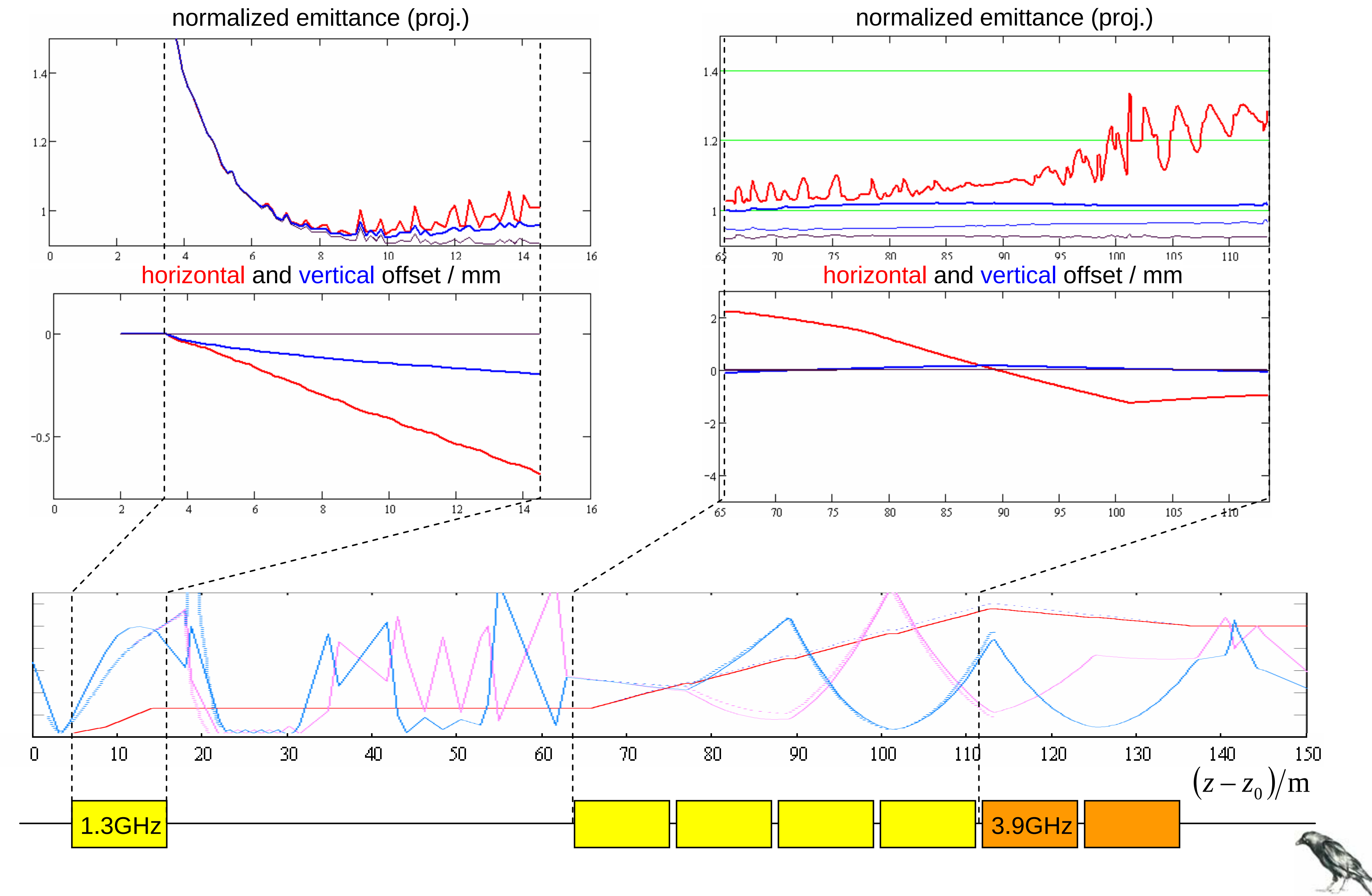
global = compensation of effects on a length that is not short compared to the betatron wavelengh; → optic & rf dependent compensation

3.3. Global Compensation (along LINAC)



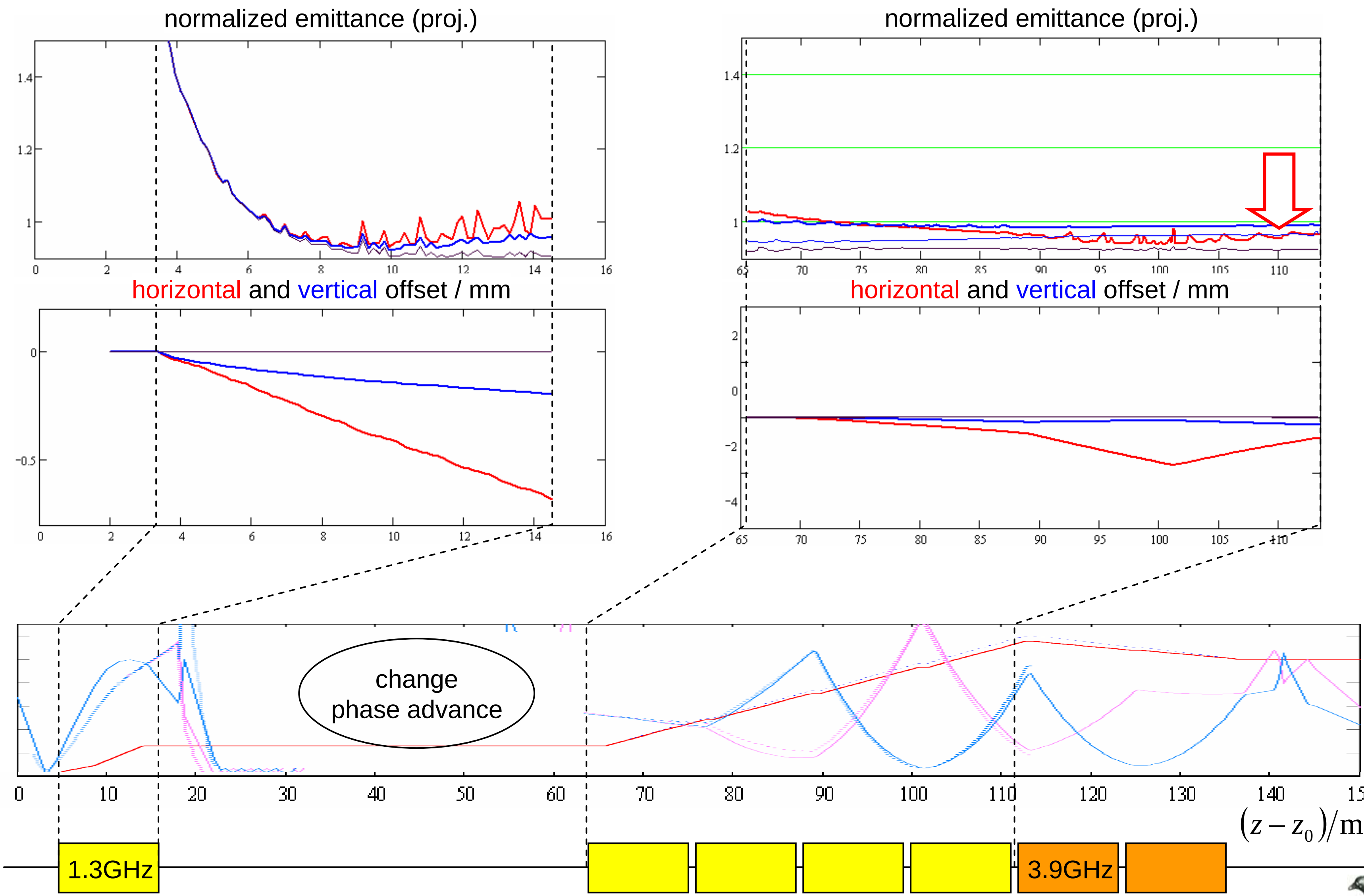
3.3. Global Compensation (along LINAC)

projected emittance and offset (optics, march 2007)



3.3. Global Compensation (along LINAC)

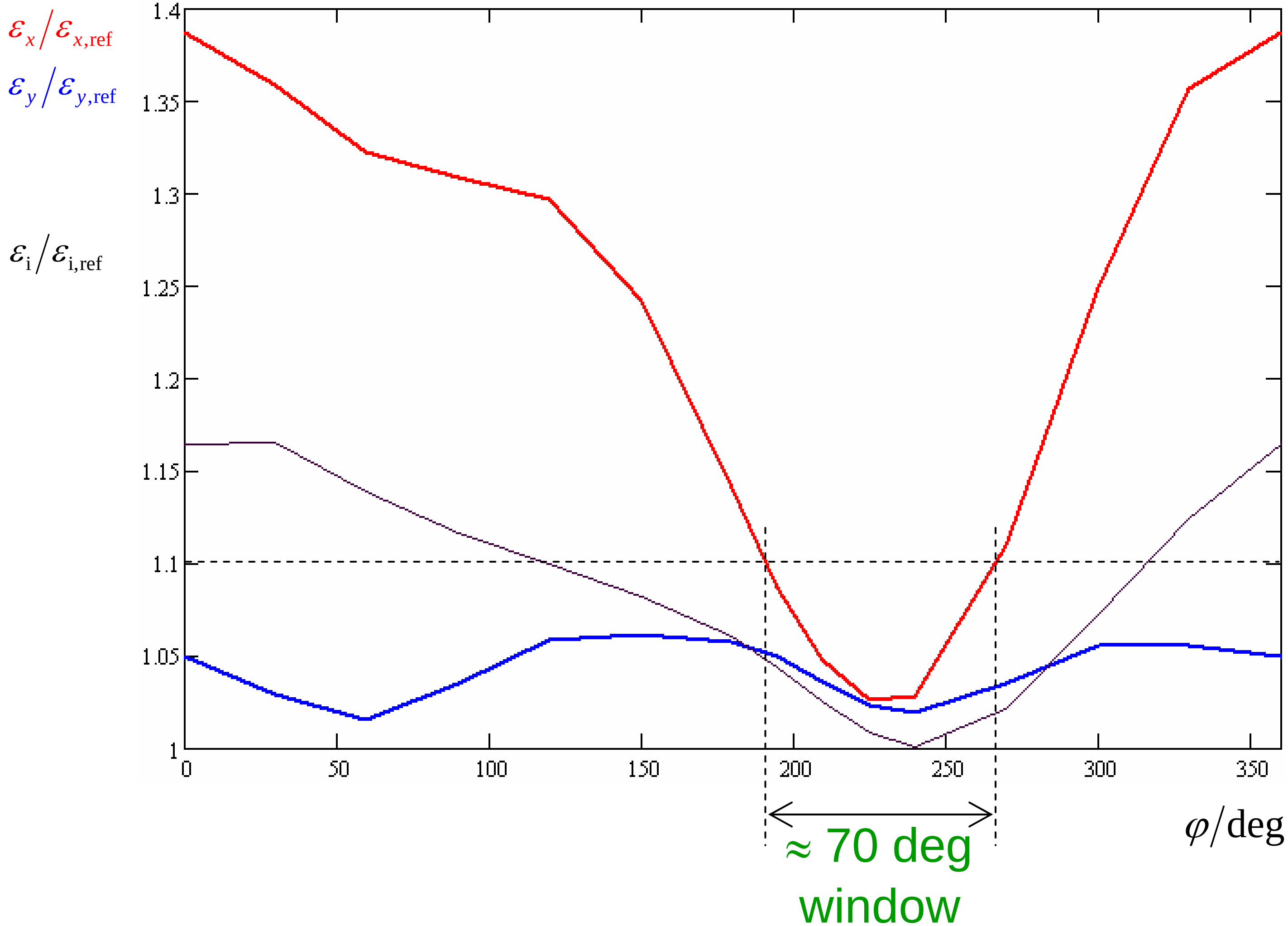
projected emittance and offset (modified phase advance)



3.3. Global Compensation (along LINAC)

scan of phase advance

$$\mu_{x/y}(65.5\,\mathrm{m}) \leftarrow \varphi + \mu_{x/y}(65.5\,\mathrm{m})$$



3. Compensation of Coupler Kicks
summary – 1.3GHz

local compensation

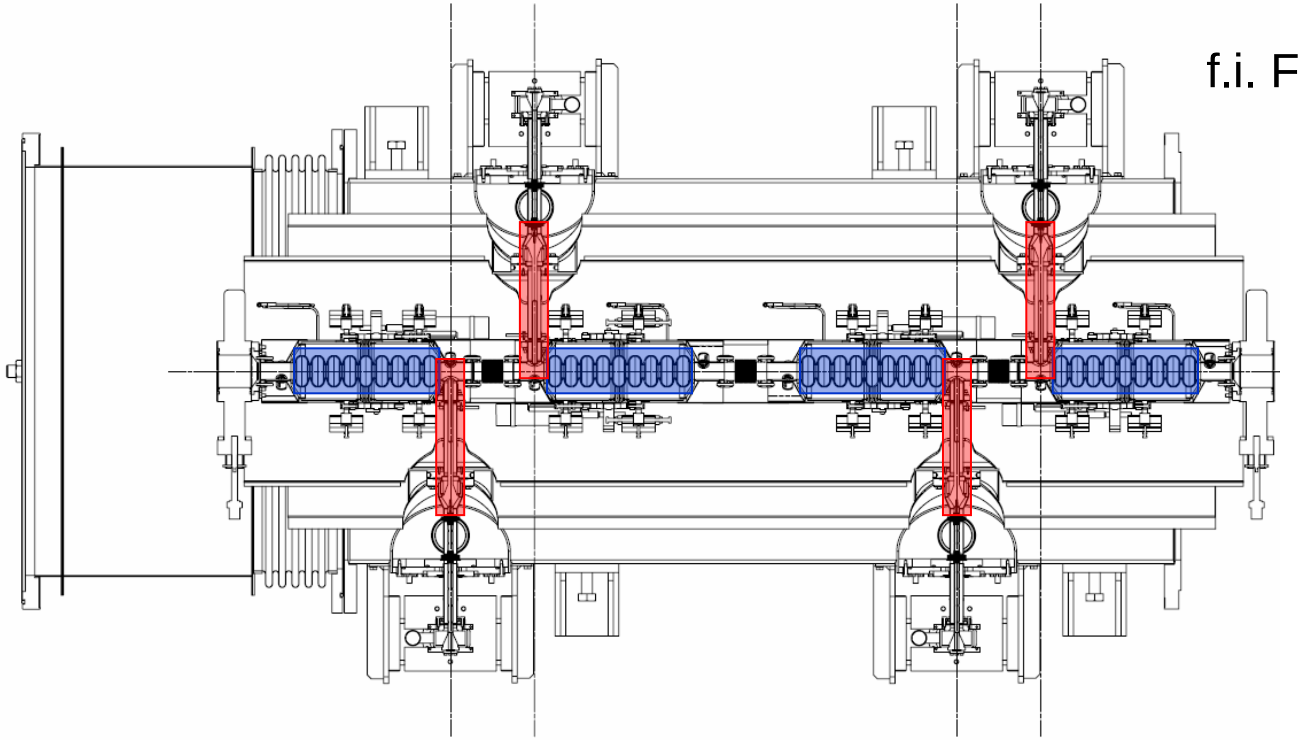
is optic independent
at couplers (in principle) possible
of cavity pairs (in principle) possible
but: geometric constraints,
design changes
required in more than one module

global compensation

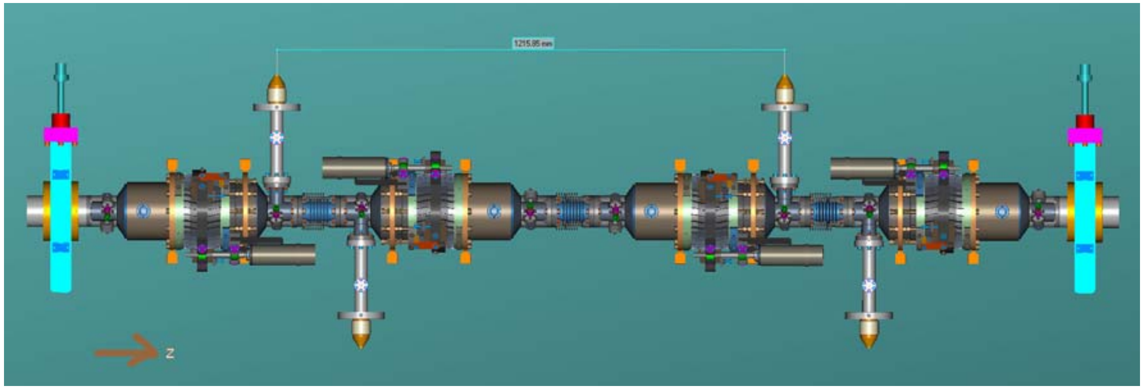
is optic & rf dependent (keep flexibility in optics)
phase advance window of 70 deg to keep projceted emittance growth < 10%
no changes in rf-, cavity- and module-design

4. Coupler Kicks Induced by 3.9GHz RF

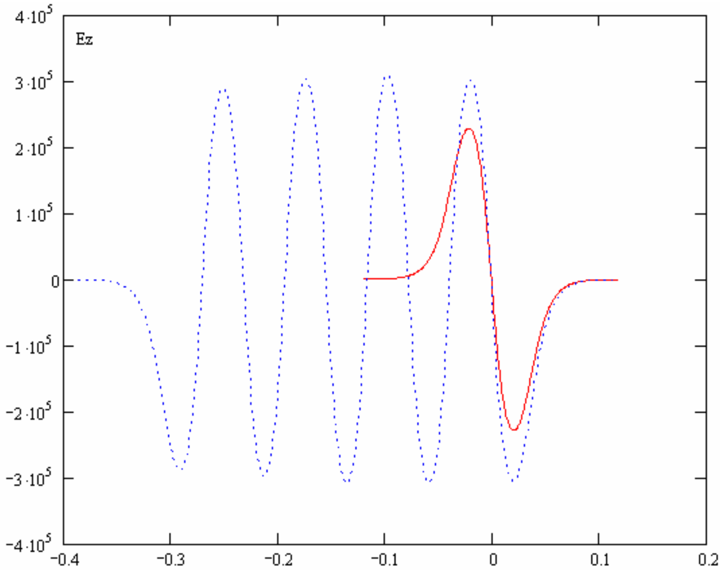
f.i. FLASH setup



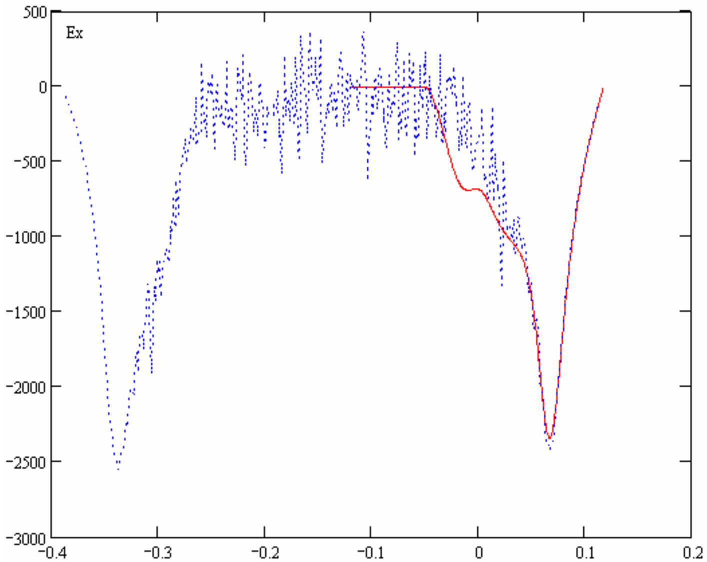
→ horizontal rotation
= “yrot”

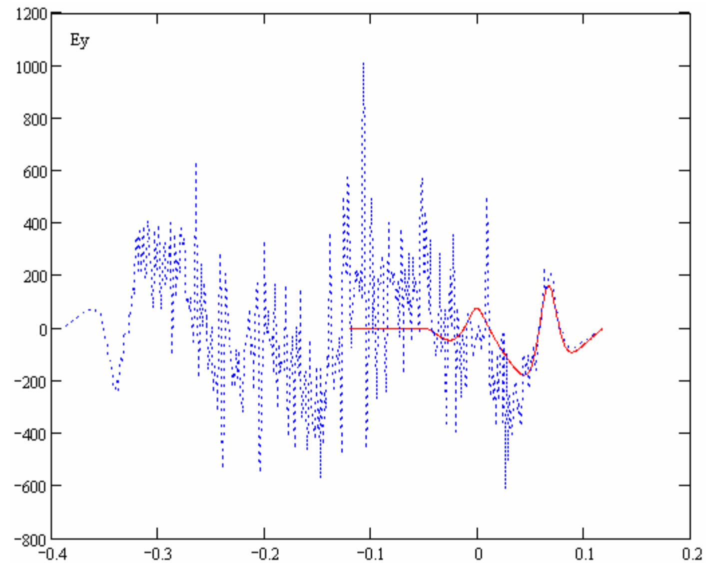


4.1. Calculation of RF Kick factors
comparison HFSS & MWS



MWS, 2 cells, Cartesian mesh
HFSS, 9 cells, tetraeder grid





4.2. Tracking
(based on XFEL EXCEL table)

calculation based on HFSS field calculation, offset independent

	ε_{xn} / µm	ε_{yn} / µm
no coupler kicks	0.926	0.969
identical orientation	1.812	1.002
yrot of each second	1.278	1.010
zrot of each second	0.940	0.984

(projected emittance)

calculation based on MWS field calculation

	ε_{xn} / µm	ε_{yn} / µm
no coupler kicks	0.926	0.969
identical orientation	3.304	1.377
yrot of each second	1.948	1.417
zrot of each second	0.953	0.988

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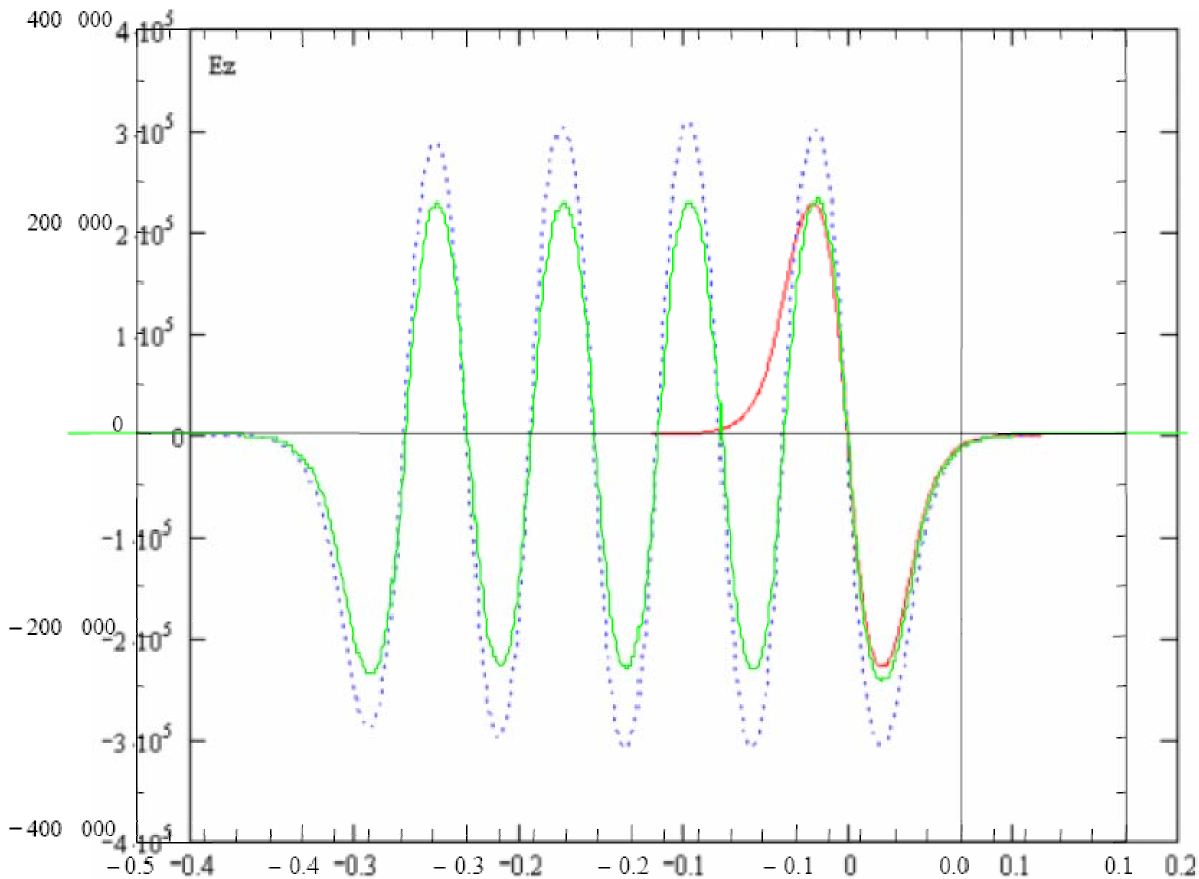
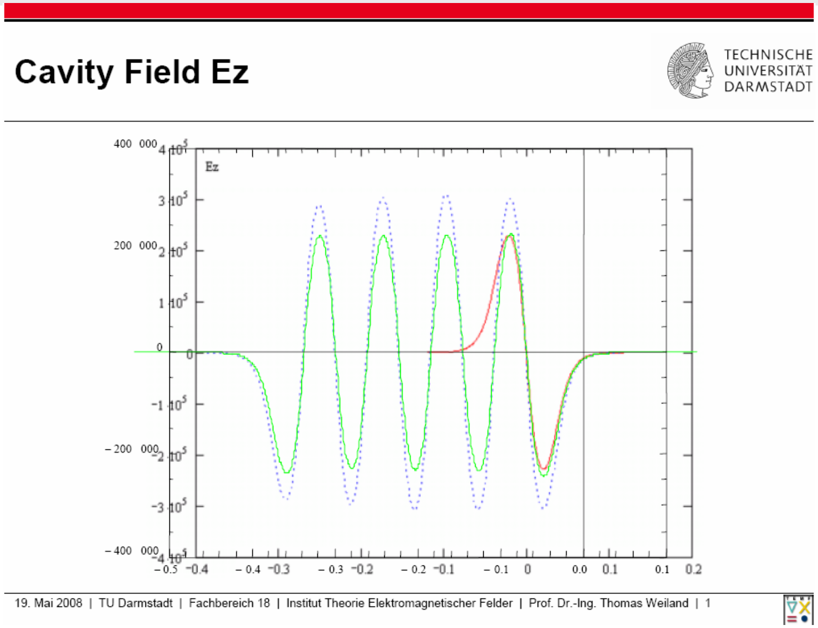
Cavity Field Ez



4.1. Calculation of RF Kick factors

work in progress



MWS, 2 cells, Cartesian mesh

HFSS, 9 cells, tetrahedron grid

1st result: FEM eigenmode solver

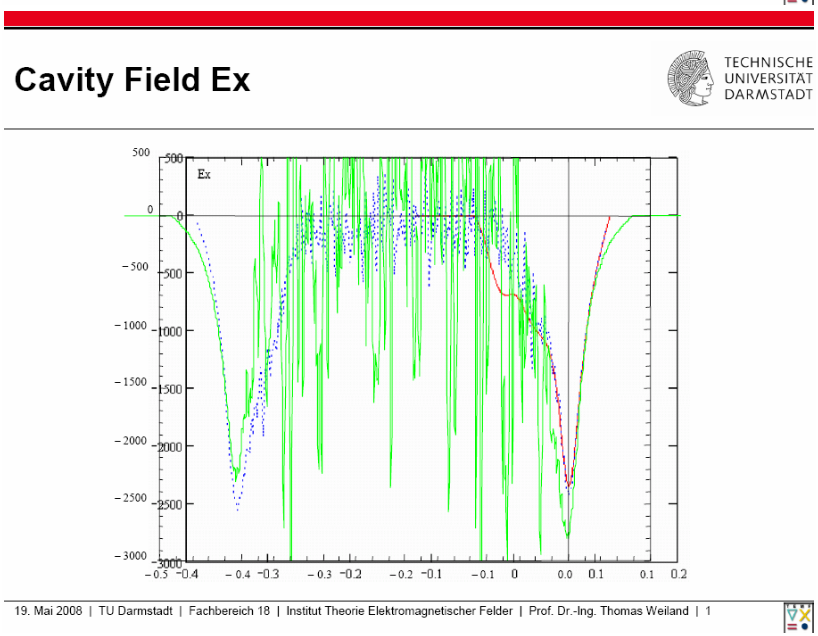
10^6 tetrahedron elements, 1st order

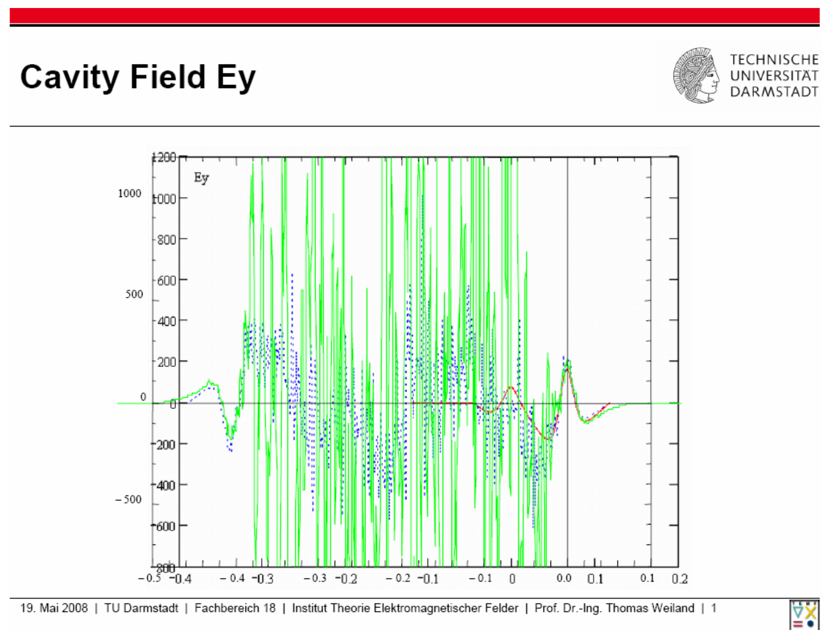
TUD Wolfgang Ackermann

further MWS investigations

with 2&9 cell models

TUD W.O.Müller and W.Ackermann





5. Summary

1.3 GHz

local compensation

is optic independent, is in principle possible,

needs design changes, is required in more than one module

global compensation

is optic & rf dependent (keep flexibility), 70 deg window for phase advance

no changes in rf-, cavity- and module-design

3.9 GHz

imprecise & uncertain **calculation of rf kick factors**

offset independent kicks ~ 5..10 x larger than in TESLA cavities

work in progress: TUD

global compensation not possible

local compensation:

reduction of Re or Im does not help in general (off crest operation)

significant emittance growth for “identical orientation” and yrot setup

below 3% emittance growth for **zrot setup** even for the worst kick numbers