1^{st} estimation of rf coupler kicks of 3^{rd} harm. cavity

source of information, fields and geometry

working point: FLASH $\leftrightarrow$ 1^{st} estimation

field integrals

field calculation by MWS

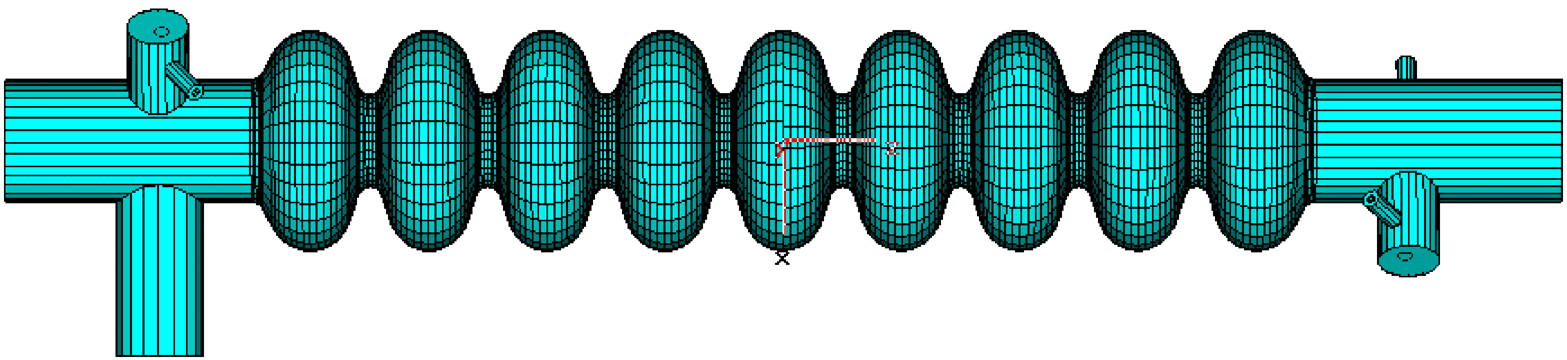
tracking with ASTRA (1^{st} estimation)

conclusions, to do

source of information, fields and geometry

= Timergali Khabiboulline
Fermilab

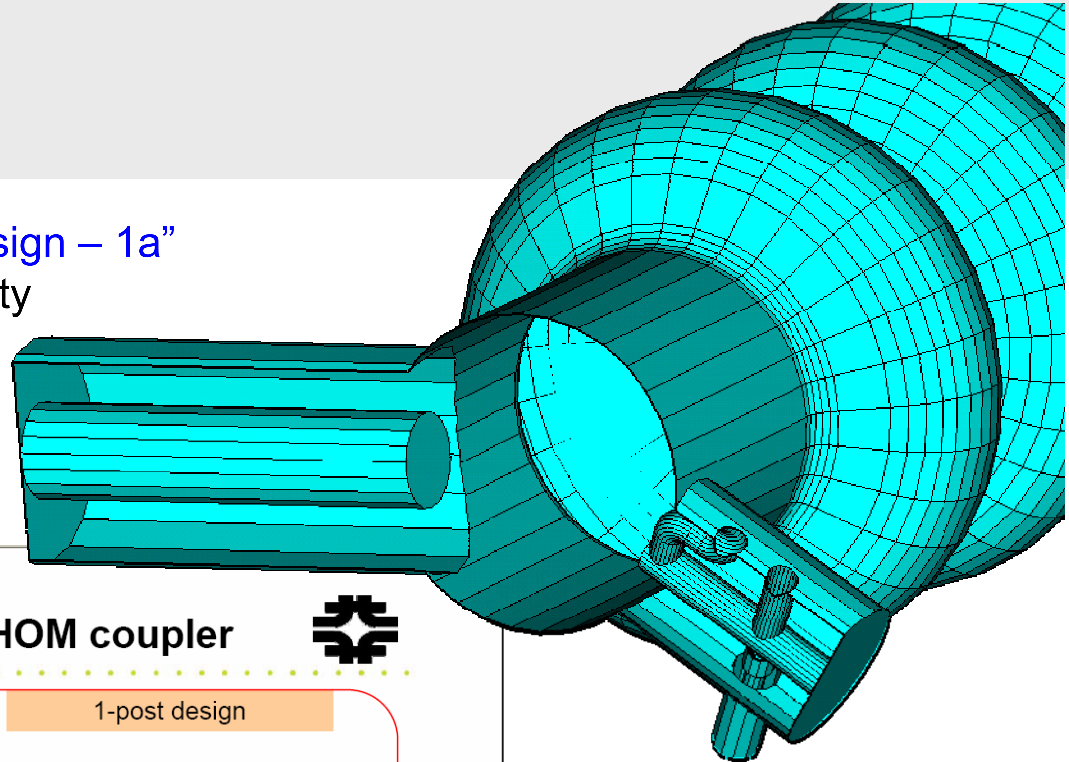
- 3D solid model sat file, similar was used for a HFSS calculations. It can be not optimal for Mafia/MWS and I will prepare smooth shaped solid model for you.



- 4 files ReE, ImE, ReH and ImH. Format of the files …
  Let me know, if you need other format.

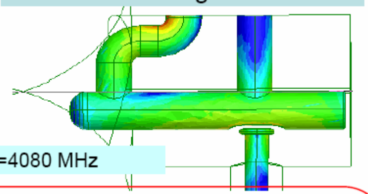
range: … . Power 1W from main coupler, no losses in the cavity, HOM ports are loaded (but Qext for them are pretty high). Qext of the power coupler is 1e6.

HOM coupler is "Trimmed Initial design – 1a"
same orientation as for TESLA cavity
but main coupler is upstr3eam

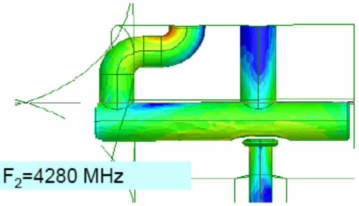


New Designs of the HOM coupler

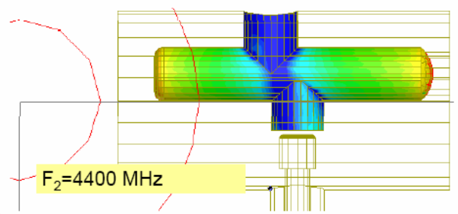
Initial design No.1



Trimmed Initial design -1a



1-post design



HOM field - Comparison

	Hpk/H	Epk/E
cavity	**7.4**	**3.5**
HOM1-original	1	1
HOM1-modif	**0.4**	**0.4**
HOM-1post	**0.67**	**0.31**

No MP up-to 23 MV/m
in modified design

working point
FLASH ↔ 1st estimation

3rd harmonic cavity in FLASH

possible working point

1.3 GHz system: 136.39 MV @ 10.82 deg --> 133.66 MeV
3.9 GHz system: 16 MV @ -176.2 deg --> 118 MeV
BC2 r56 = -165.1 mm --> compression factor = 7
1.3 GHz system: 338.15 MV @ 10.98 deg --> 450 MeV
BC3 r56 = -63.8 mm --> compression factor = 7

(r56 values from TESLA-FEL-06, page9)

sensitivity (10% change of compression)

1.3 GHz system before BC2: $|\Delta V| < 0.76$ MV, $|\Delta\varphi| < 0.025$ deg
3.9 GHz system: $|\Delta V| < 0.83$ MV, $|\Delta\varphi| < 0.075$ deg

from: s2e-seminar, Wakes in the 3rd Harmonic RF Modules (19.03.2007)

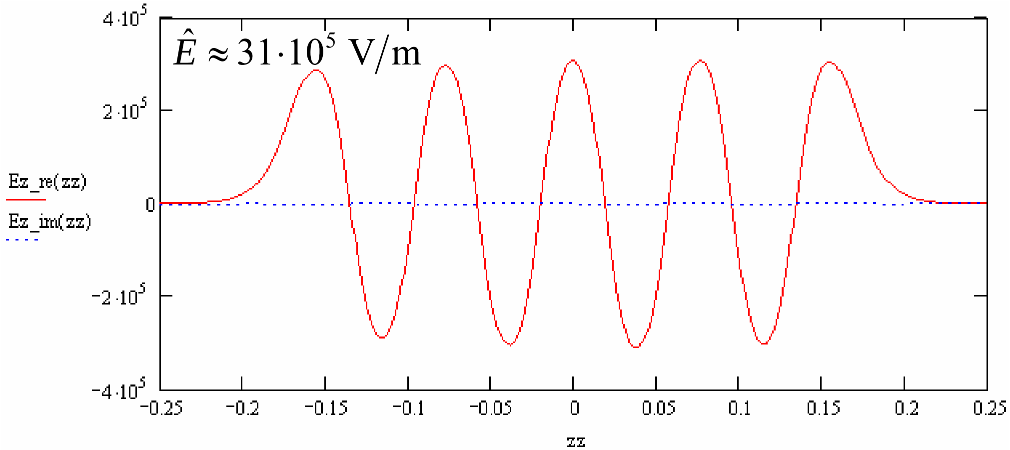
FLASH: 4 cavities; each with approximately at 4 MV, -180 deg = backward wave operation

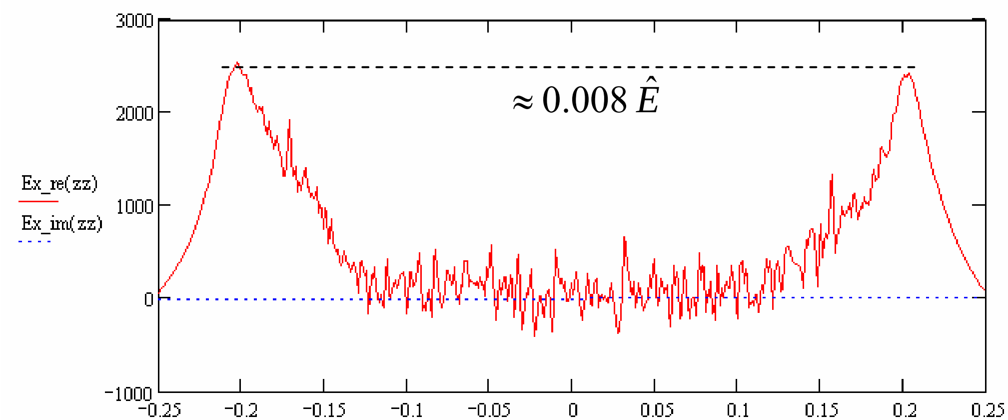
1st estimation: the field calculations from T. Khabiboulline and the following calculations assume standing wave operation!

field integrals

(fields from T. Khabiboulline)

electrical field, on axis





$$\mathbf{V} = \int \left(\mathbf{E} + \mathbf{v} \times \mathbf{B}\right) \exp\left(iz\omega/c\right) dz$$

$$|V_z| = 52\,\mathrm{kV}$$

$$P_f = 1\,\mathrm{W}$$

$$Q_e = 10^6$$

$$(R/Q) = \frac{|V_z|^2}{2\omega W_{\mathrm{tot}}} = 340\,\Omega \qquad W_{tot,SW} = 4 \times \frac{Q_e P_f}{\omega}$$

for comparison TESLA-FEL 2003-01: 375Ω

$$\frac{1}{V_z}\begin{pmatrix} V_x \\ V_y \end{pmatrix} = \begin{pmatrix} -416 - j219 \\ -36 + j144 \end{pmatrix} \cdot 10^{-6}$$

all couplers!

for comparison TESLA cavity:

$$\frac{1}{V_z}\begin{pmatrix} V_x \\ V_y \end{pmatrix} = \begin{pmatrix} -82 + j58 \\ -9.2 + j1.7 \end{pmatrix} \cdot 10^{-6}$$

(zpen=6mm, new geometry)

$$\frac{10^6}{V_z}\begin{pmatrix}V_x\\ V_y\end{pmatrix} = \begin{pmatrix}1 & 0 & 0\\ 0 & 1 & 0\end{pmatrix}\cdot\frac{V(0,0)}{V0_2\cdot \mathrm{urad}} = \begin{pmatrix}-416.511 - 218.376i\\ -35.729 + 144.141i\end{pmatrix}$$

$x = 0 \qquad y = 0.001$

$$\begin{pmatrix}1 & 0 & 0\\ 0 & 1 & 0\end{pmatrix}\cdot\frac{V(x,y) - V(0,0)}{V0_2\cdot \mathrm{urad}} = \begin{pmatrix}56.027 + 188.555i\\ 36.686 - 177.341i\end{pmatrix}$$

$x = -0.001 \qquad y = 0$

$$\begin{pmatrix}1 & 0 & 0\\ 0 & 1 & 0\end{pmatrix}\cdot\frac{V(x,y) - V(0,0)}{V0_2\cdot \mathrm{urad}} = \begin{pmatrix}-131.185 + 501.117i\\ -35.357 + 6.881i\end{pmatrix}$$

$x = 0 \qquad y = 0$

$$\begin{pmatrix}1 & 0 & 0\\ 0 & 1 & 0\end{pmatrix}\cdot\frac{V(x,y) - V(0,0)}{V0_2\cdot \mathrm{urad}} = \begin{pmatrix}0\\ 0\end{pmatrix}$$

$x = 0.001 \qquad y = 0$

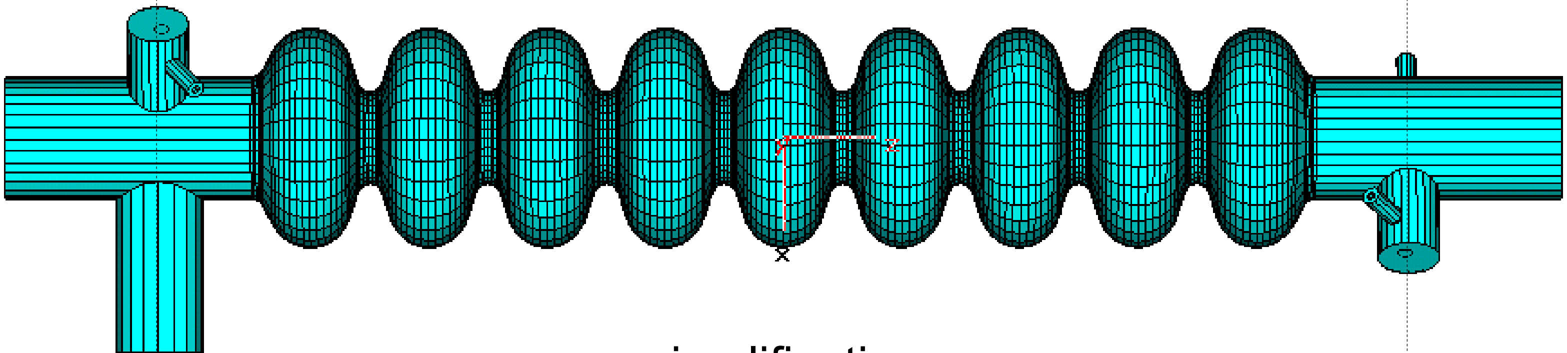
$$\begin{pmatrix}1 & 0 & 0\\ 0 & 1 & 0\end{pmatrix}\cdot\frac{V(x,y) - V(0,0)}{V0_2\cdot \mathrm{urad}} = \begin{pmatrix}-70.66 - 72.685i\\ -43.477 + 42.206i\end{pmatrix}$$

$x = 0 \qquad y = -0.001$

$$\begin{pmatrix}1 & 0 & 0\\ 0 & 1 & 0\end{pmatrix}\cdot\frac{V(x,y) - V(0,0)}{V0_2\cdot \mathrm{urad}} = \begin{pmatrix}-52.9 + 175.166i\\ 46.827 + 178.512i\end{pmatrix}$$

at least 10 x stronger than TESLA cavity
not very linear!
if the field quality is sufficient !?
beam pipes long enough …
→ MWS calculations

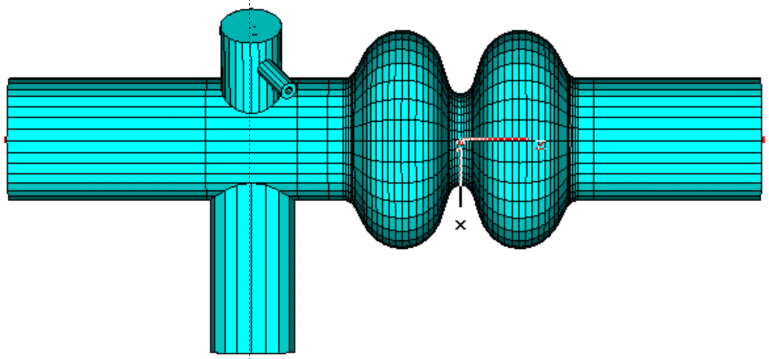
field calculation by MWS

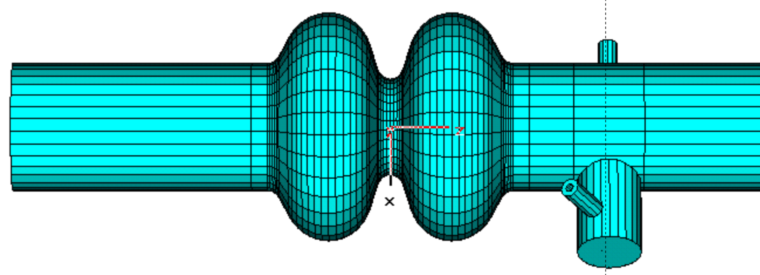


simplification
→ 2 end cells

upstream

downstream





beam pipe
still too short

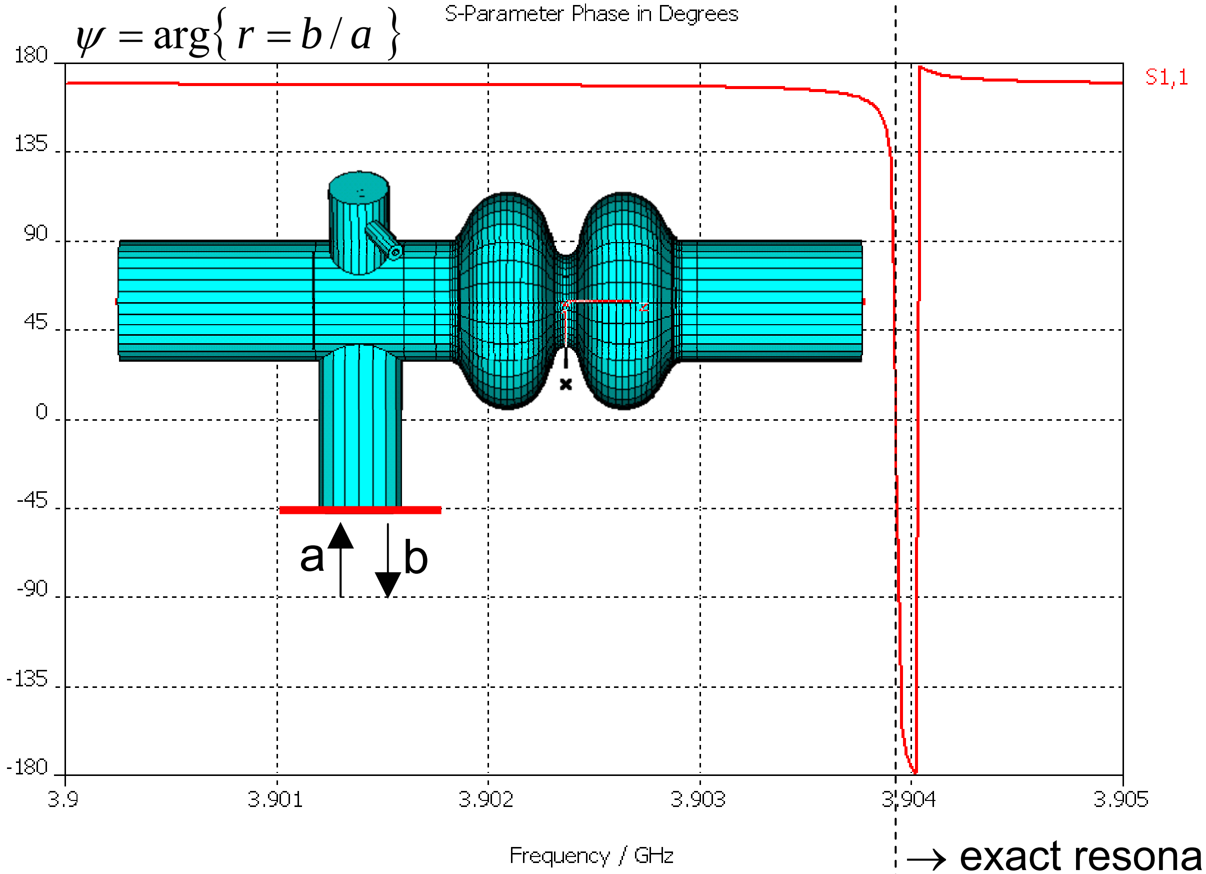
eigenmode

frequency domain
→ determine exact (!) resonance frequency
calculate SW field at resonance

all calculations for different meshes and meshtypes (if possible)

upstream

$$\psi = \arg\{\, r = b / a \,\}$$

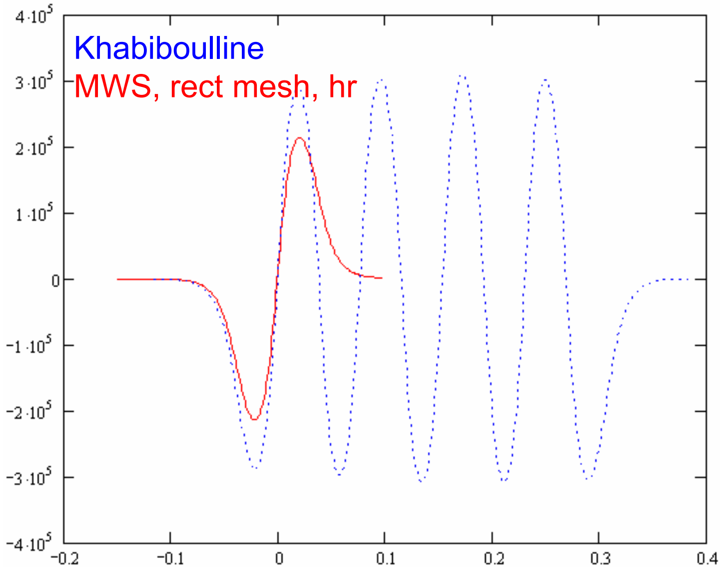


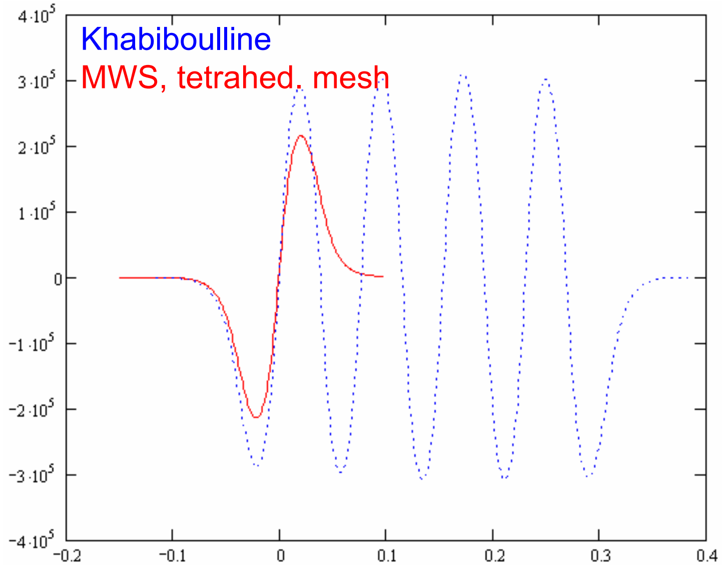
→ exact resonance frequency (depends on discretization)

$$Q_e \approx \frac{\omega}{4}\left|\frac{\partial \psi}{\partial \omega}\right| \approx 10^5$$

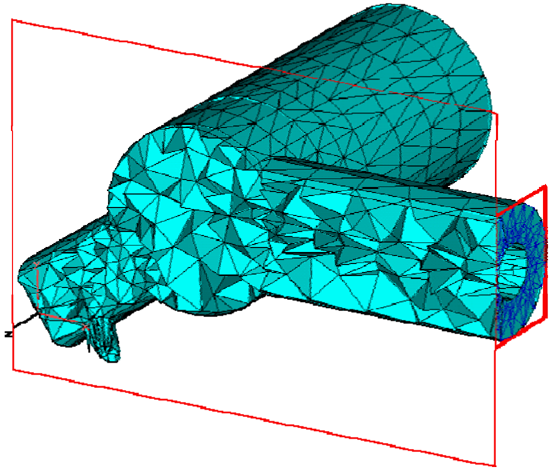
extrapolation to 9 cells: Qe ≈ $5 \cdot 10^5$; should be 10^6 (for all discretizations)

longitudinal field V/m
(same input power = 1W)

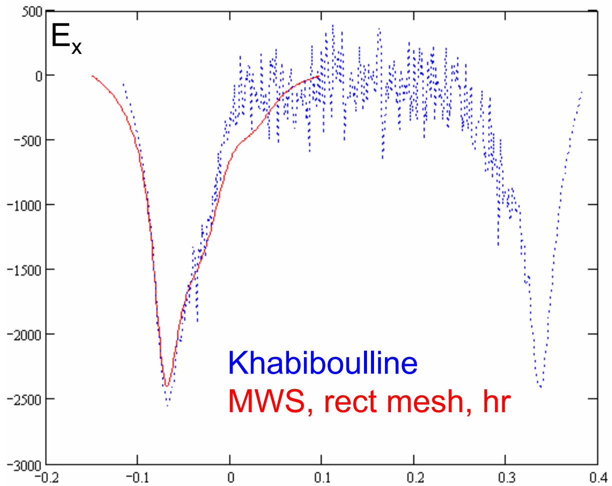


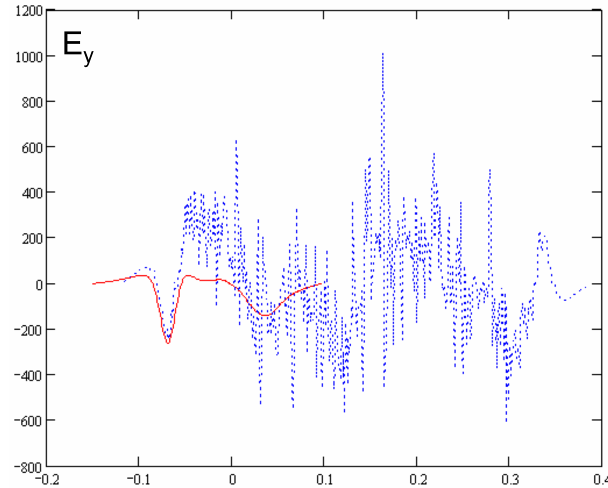


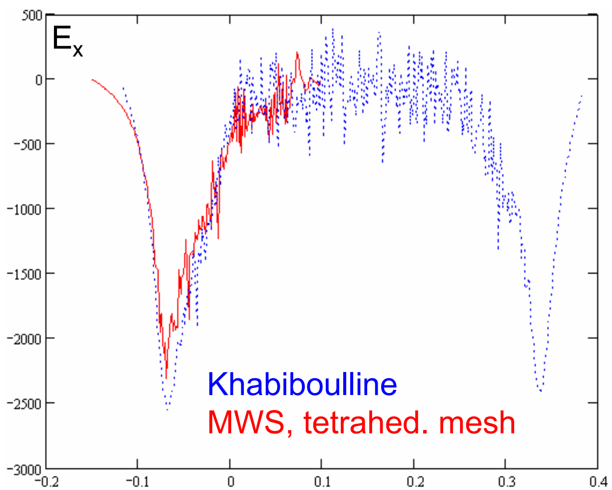
E peak of MWS is 75% of HFSS
→ 55% of field energy
→ Q_{ext} smaller by fact 0.55

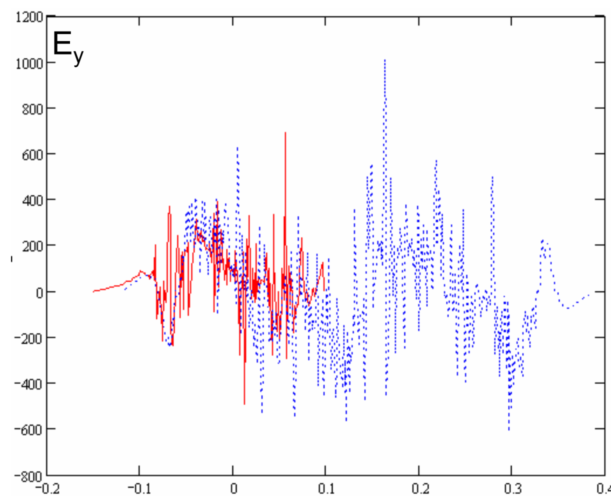


better agreement for transverse fields V/m

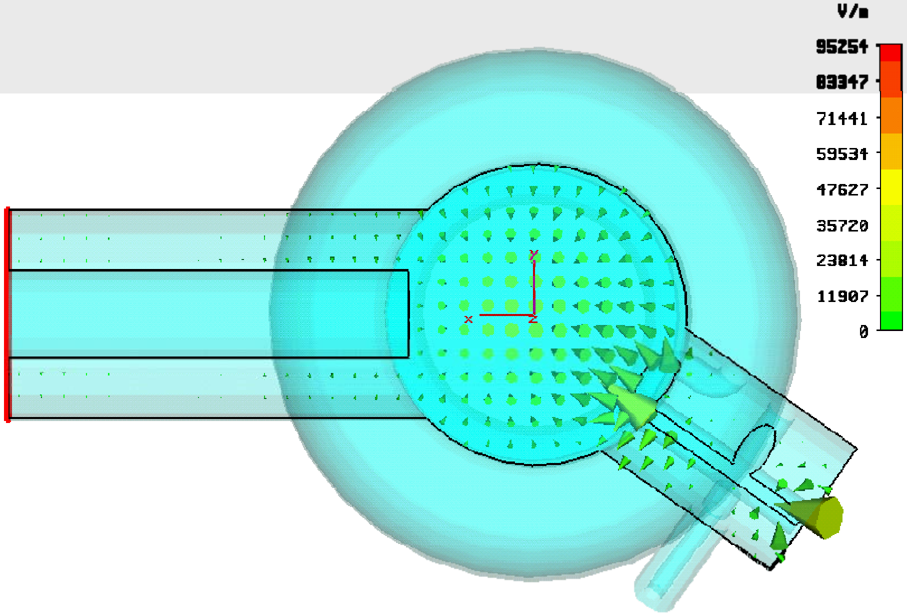






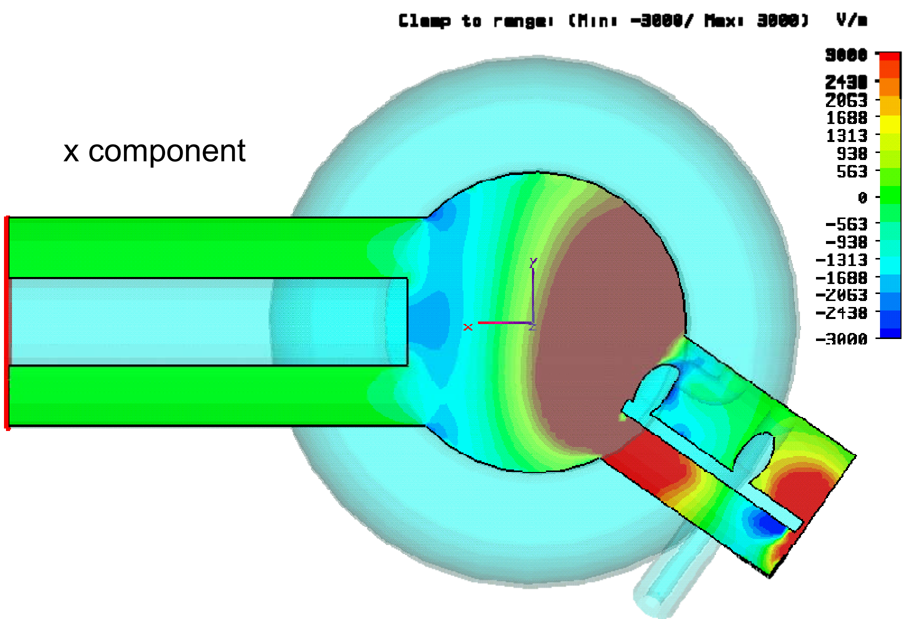


tetrahedral meshes are “noisy” for weak resolution



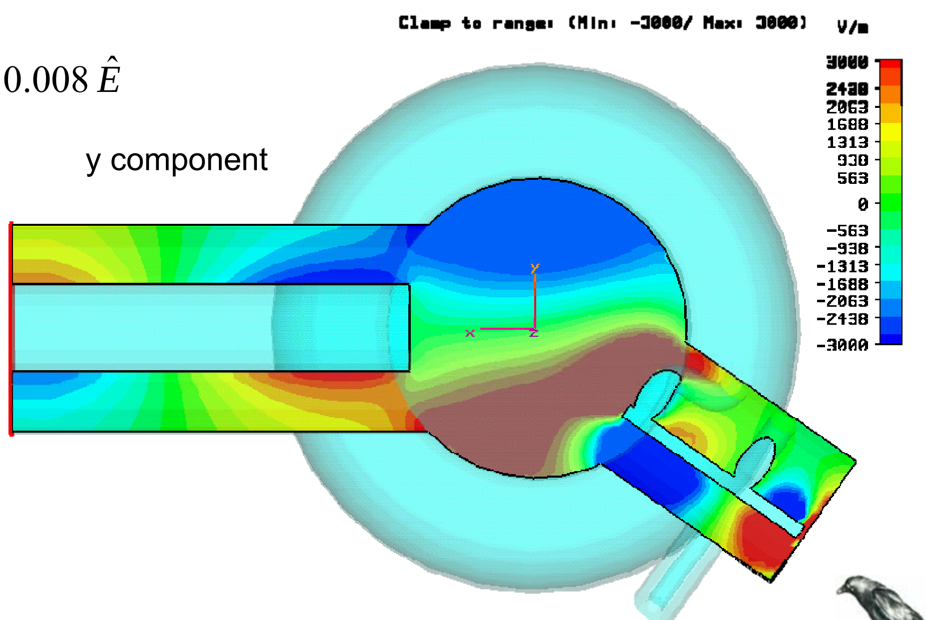
$\hat{E} \approx 31 \cdot 10^5$ V/m

x component

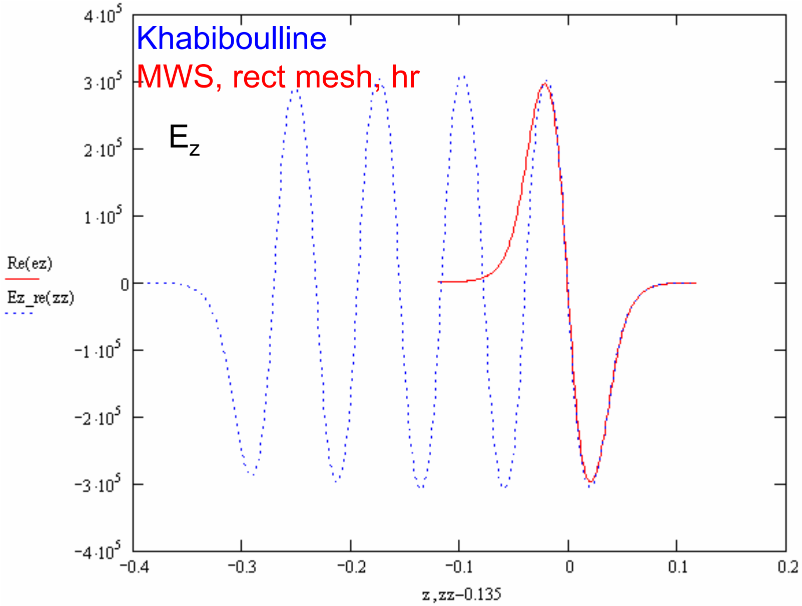


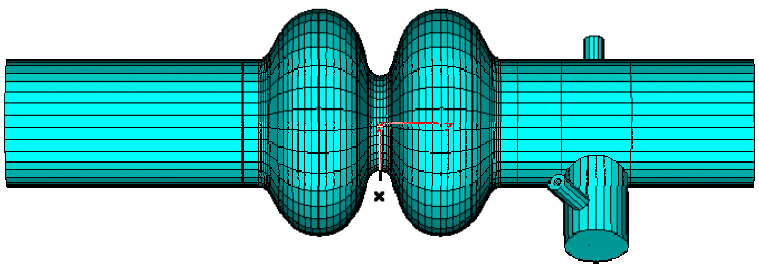
$\approx 0.008\,\hat{E}$

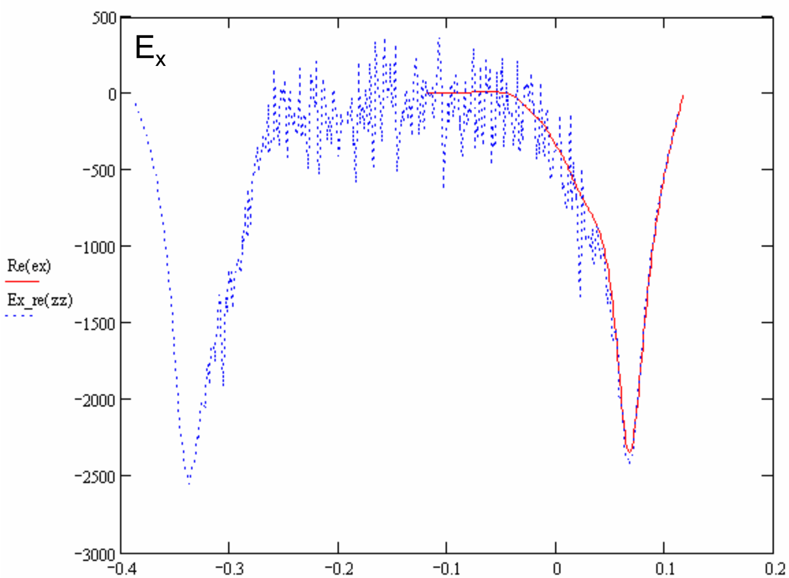
y component

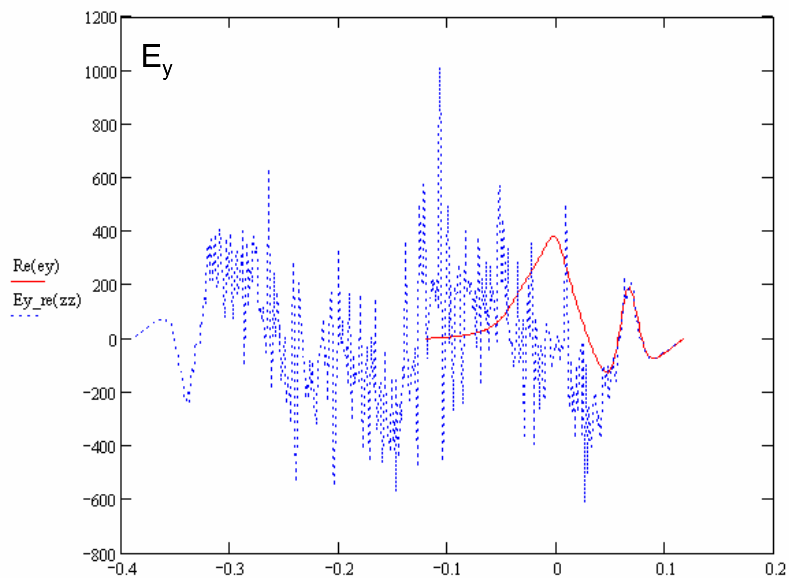


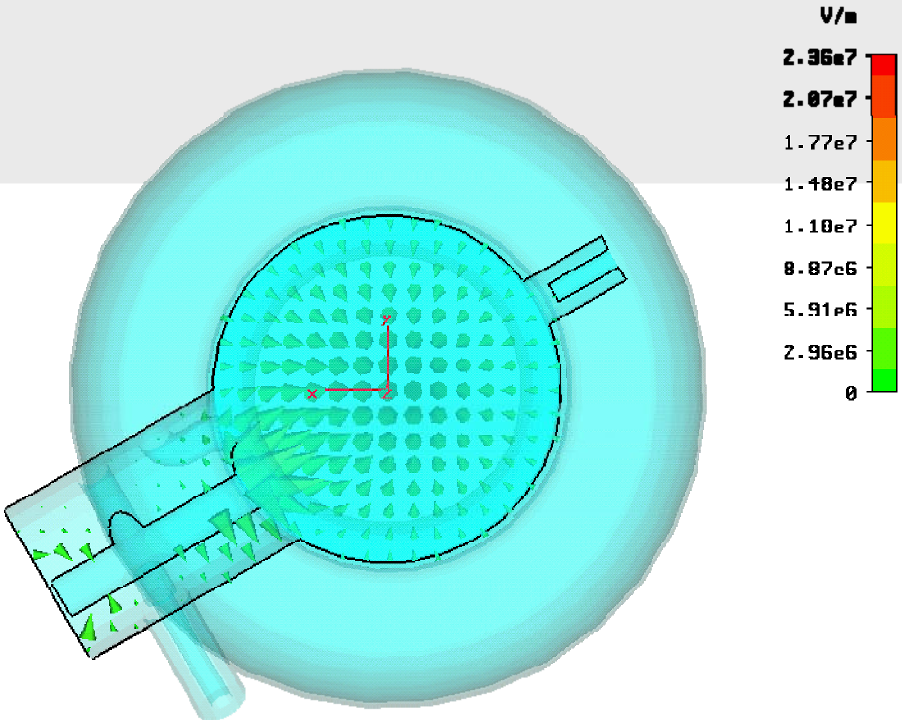
downstream


Khabiboulline
MWS, rect mesh, hr
Ez
Re(ez)
Ez_re(zz)
z, zz−0.135
4·10^5
3·10^5
2·10^5
1·10^5
0
−1·10^5
−2·10^5
−3·10^5
−4·10^5
−0.4
−0.3
−0.2
−0.1
0
0.1
0.2

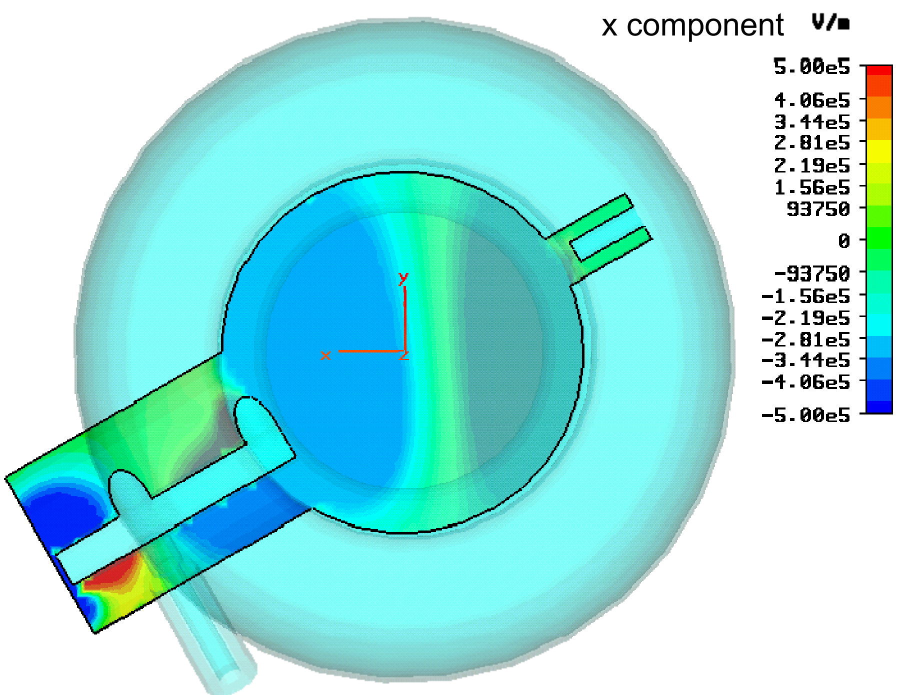


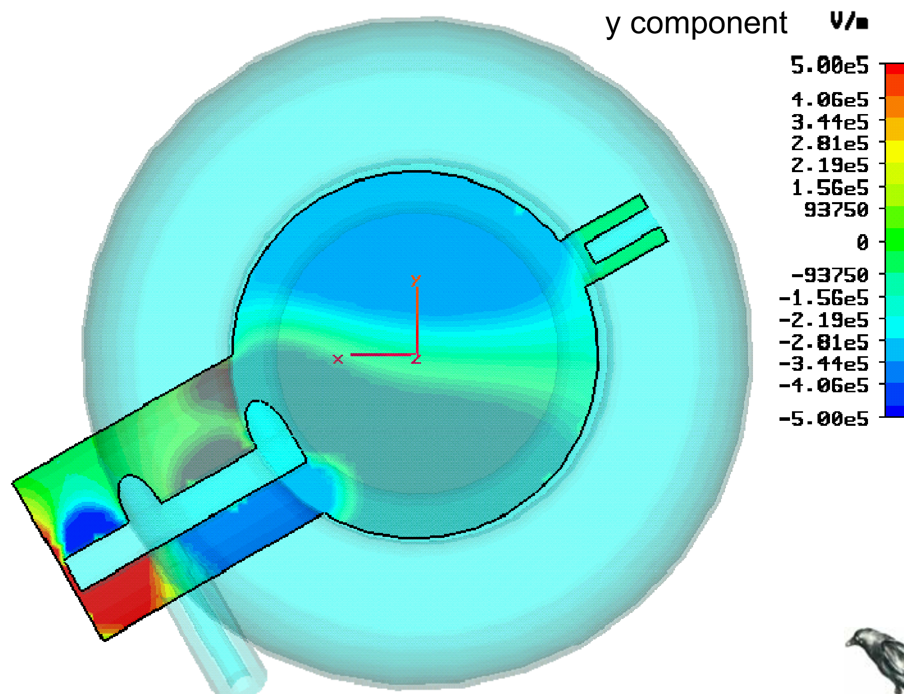

Ex
Re(ex)
Ex_re(zz)
500
0
−500
−1000
−1500
−2000
−2500
−3000
−0.4
−0.3
−0.2
−0.1
0
0.1
0.2


Ey
Re(ey)
Ey_re(zz)
1200
1000
800
600
400
200
0
−200
−400
−600
−800
−0.4
−0.3
−0.2
−0.1
0
0.1
0.2



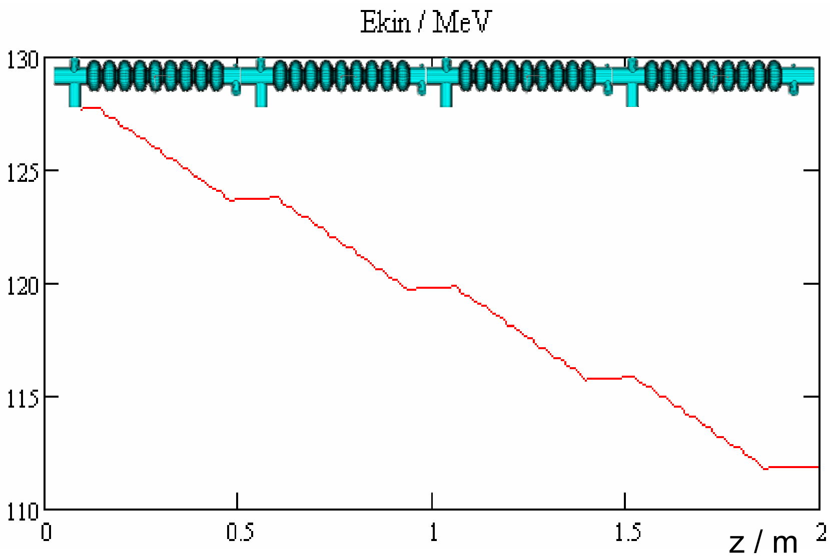
$$\hat{E} \approx 71.5 \cdot 10^{6} \text{ V/m}$$

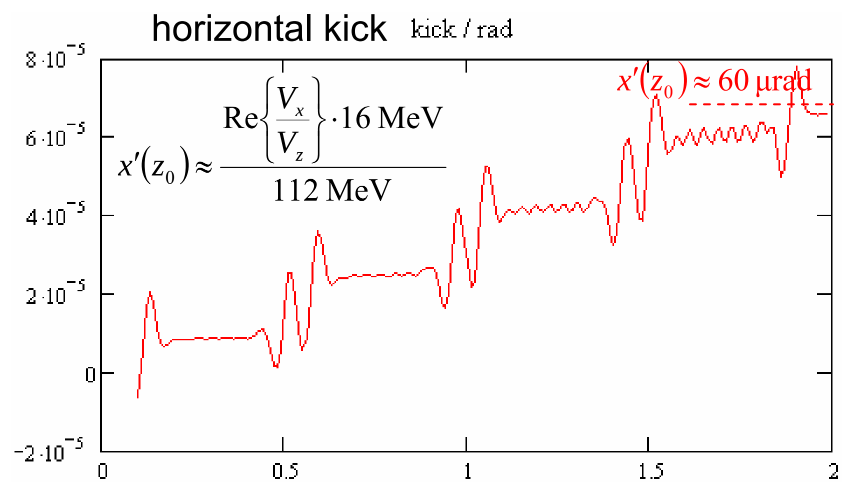


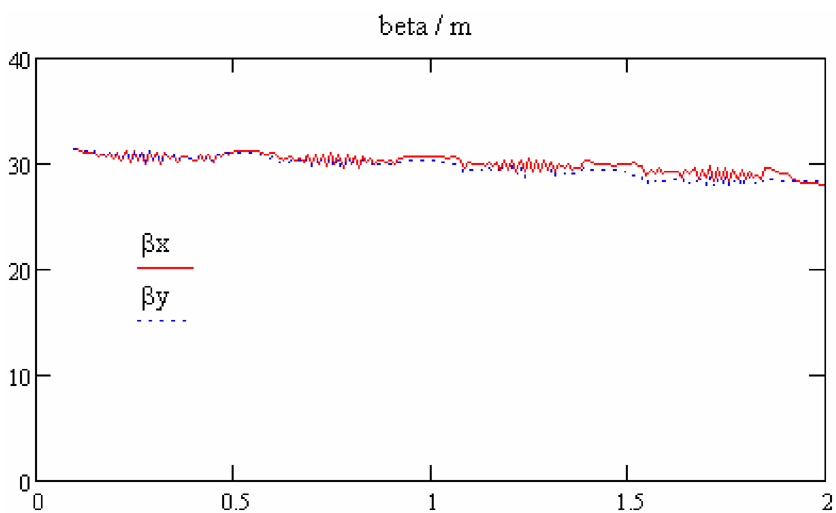


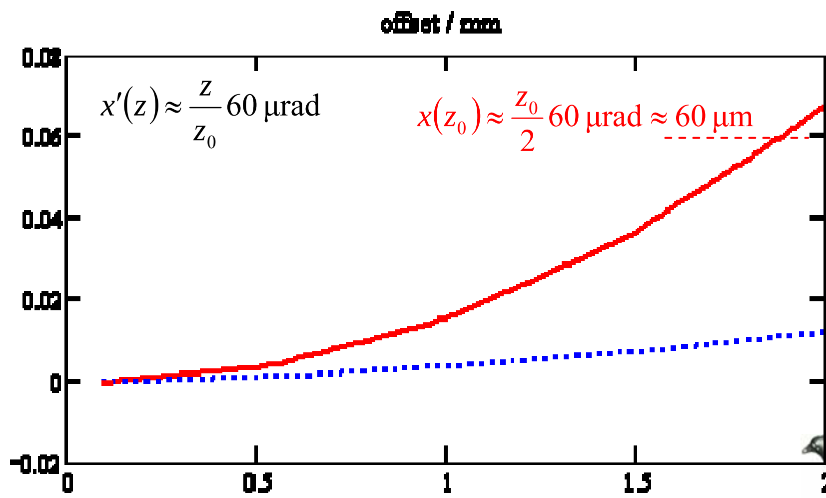
tracking with ASTRA (1st estimation)

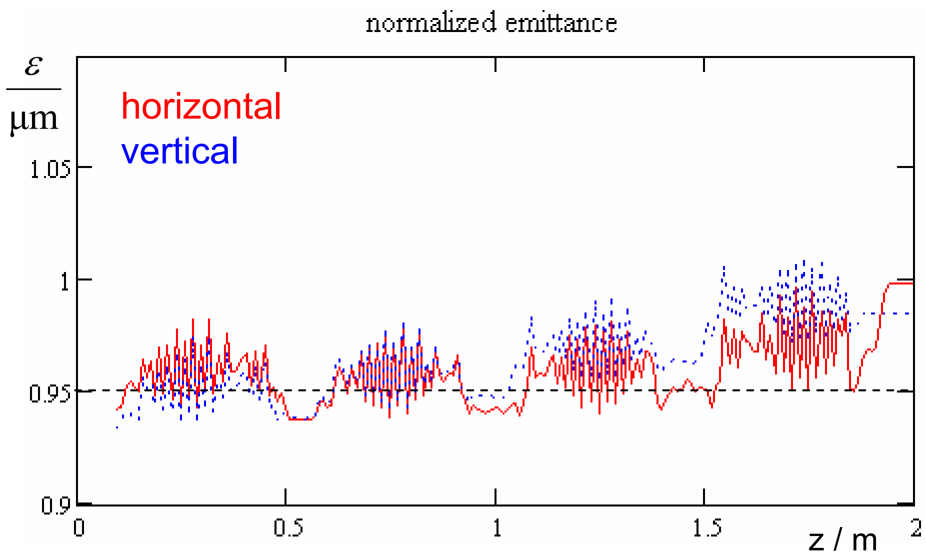
4x (3.9 GHz, 4MV,180deg, standing wave mode)
coupler fields offset independent











on anit-crest →

$$\frac{1}{V_z}\begin{pmatrix}V_x\\V_y\end{pmatrix}=\begin{pmatrix}-416-j219\\-36+j144\end{pmatrix}\cdot10^{-6}$$

$$\Delta V_{x,rms}\approx \mathrm{Im}\{V_x\}2\pi\frac{\sigma_{\mathrm{bunch}}}{\lambda_{\mathrm{3rd\_harm}}}$$

$$=219\frac{\mathrm{V}}{\mathrm{MV}}\cdot16\,\mathrm{MV}\cdot2\pi\frac{\sigma_{\mathrm{bunch}}}{\lambda_{\mathrm{3rd\_harm}}}$$

$$=690\ \mathrm{V}$$

$$\varepsilon\approx1\,\mu\mathrm{m}/\gamma_L$$

$$\beta\approx30\ \mathrm{m}$$

$$E_0\approx112\ \mathrm{MeV}$$

$$\sqrt{\overline{x_c'x_c'}}\approx\frac{\Delta V_{x,rms}}{V_{\parallel}}=\frac{690\ \mathrm{V}}{112\ \mathrm{MV}}\approx6\ \mu\mathrm{rad}$$

$$\tilde{\varepsilon}\approx\varepsilon\sqrt{1+\frac{\beta}{\varepsilon}\left(\overline{x_c'x_c'}\right)}\approx1.12\varepsilon$$

$$\sqrt{\frac{\varepsilon}{\beta}}\approx12\mu\mathrm{rad}$$

over estimation!:
assumes kicks of all couplers at once

conclusions, to do

conclusion

1st estimation: SW effects
neglects offset dependency
field in beam pipes truncated
→ no strong effect

but: is the estimation sufficient?

to do

FLASH set up (alternating couplers)
field calculation with longer beam pipes, better precision, …
precise working point (backward wave, phase etc.) → 3rd est.
wakes
XFEL (other working point, more cavities)