compensation of rf coupler kicks
1st attempt, continued

general investigations: sources of emittance growth

detailed results for various conditions

local & global compensation

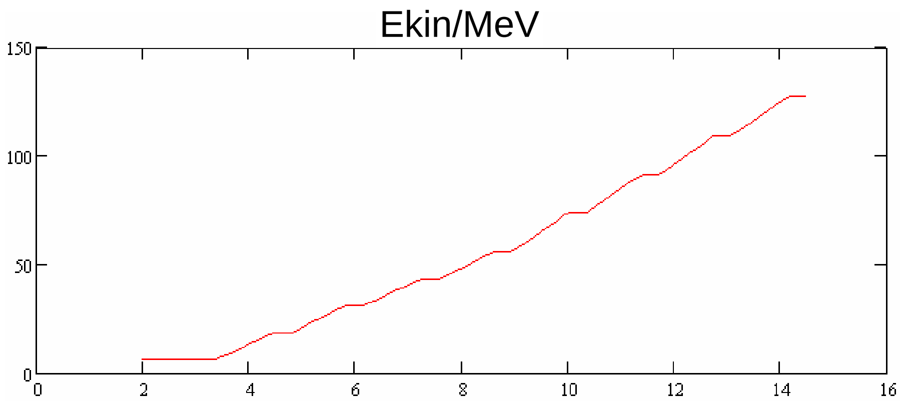
geometry

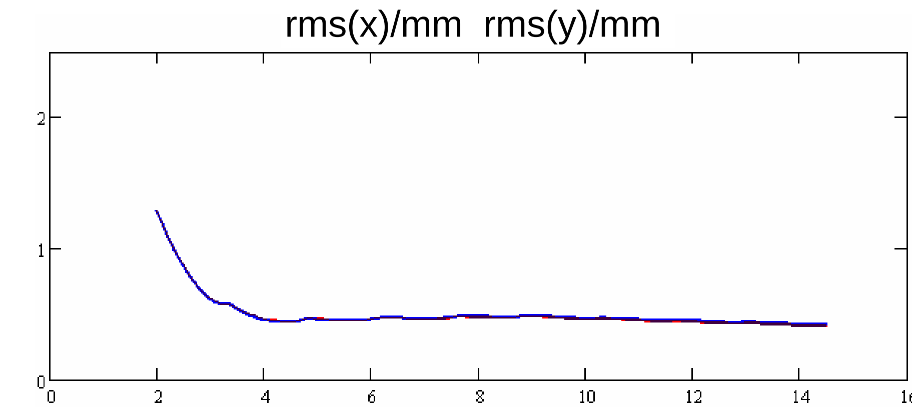
table of results

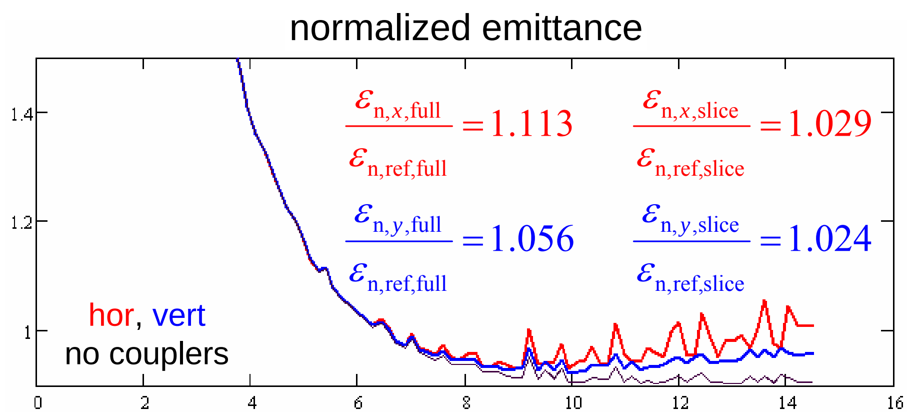
detailed results (local & global compensation)

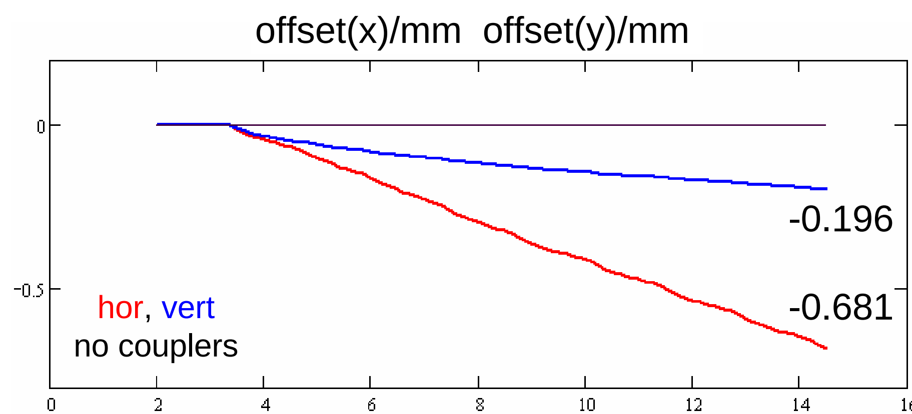
more

old configuration









reference solution (= no couplers)

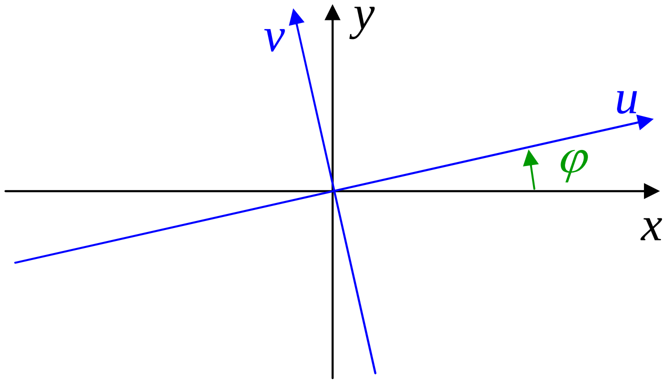
$$\varepsilon_{n,ref,full} = 0.906\,\mu m$$

$$\varepsilon_{n,ref,slice} = 0.659\,\mu m$$

full = all particles

slice = 10% of particles (central slice)

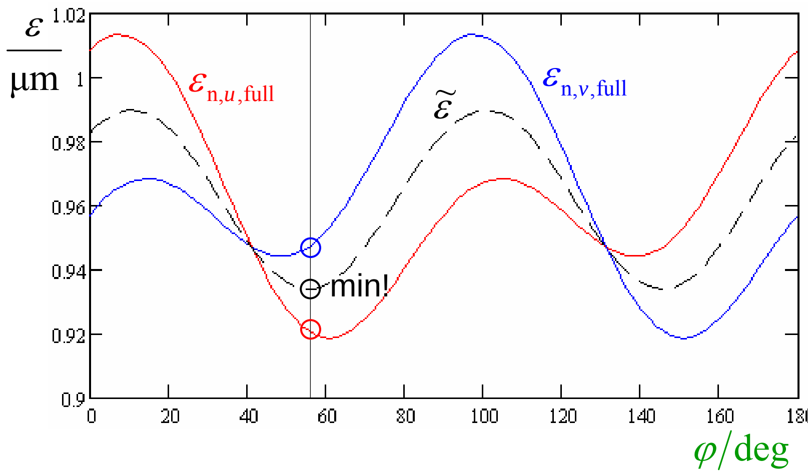
rotation of reference plane

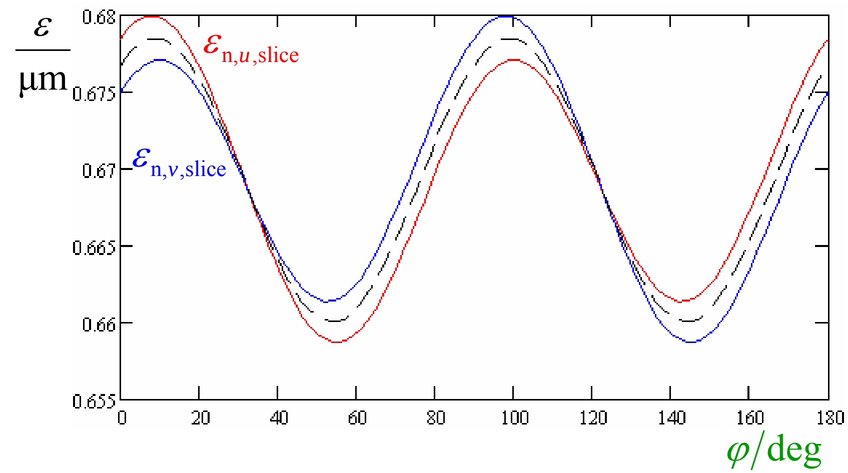


$$\varepsilon_u = \sqrt{\langle u^2\rangle\langle u'^2\rangle - \langle uu'\rangle^2}$$

$$\varepsilon_v = \sqrt{\langle v^2\rangle\langle v'^2\rangle - \langle vv'\rangle^2}$$

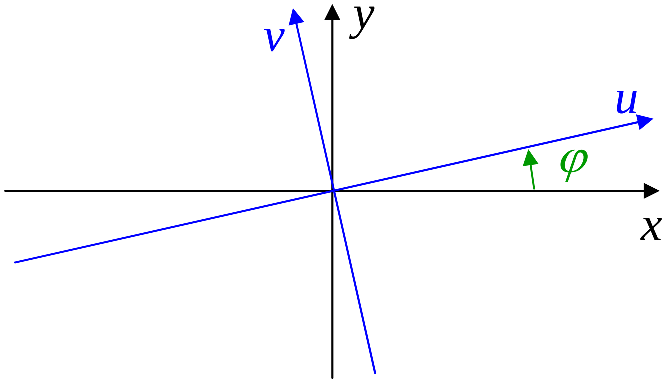
$$\tilde{\varepsilon} = \sqrt{\varepsilon_u \varepsilon_v}$$





$$\varphi = 55.8\ \text{deg} \qquad \frac{\varepsilon_{\text{n},u,\text{full}}}{\varepsilon_{\text{n,ref,full}}} = 1.017 \qquad \frac{\varepsilon_{\text{n},v,\text{full}}}{\varepsilon_{\text{n,ref,full}}} = 1.045$$

$$\varphi = 54.1\ \text{deg} \qquad \frac{\varepsilon_{\text{n},u,\text{slice}}}{\varepsilon_{\text{n,ref,full}}} = 0.999 \qquad \frac{\varepsilon_{\text{n},v,\text{slice}}}{\varepsilon_{\text{n,ref,full}}} = 1.003$$



$$\langle x\rangle = \langle y\rangle = 0 \qquad \langle x'\rangle = \langle y'\rangle = 0$$

$$x' = p_x / p_z \qquad y' = p_y / p_z \qquad p_z \approx \text{const.}$$

$$S_{xy} = \begin{bmatrix} \langle xx\rangle & \langle xx'\rangle & \langle xy\rangle & \langle xy'\rangle \\ \langle xx'\rangle & \langle x'x'\rangle & \langle x'y\rangle & \langle x'y'\rangle \\ \langle xy\rangle & \langle x'y\rangle & \langle yy\rangle & \langle yy'\rangle \\ \langle xy'\rangle & \langle x'y'\rangle & \langle yy'\rangle & \langle y'y'\rangle \end{bmatrix}$$

no coupling: $S_{xy} = \begin{bmatrix} \langle xx\rangle & \langle xx'\rangle & 0 & 0 \\ \langle xx'\rangle & \langle x'x'\rangle & 0 & 0 \\ 0 & 0 & \langle yy\rangle & \langle yy'\rangle \\ 0 & 0 & \langle yy'\rangle & \langle y'y'\rangle \end{bmatrix}$

$$\left|S_{xy}\right| = \varepsilon_x^2 \varepsilon_y^2 \qquad \tilde{\varepsilon} = \sqrt{\varepsilon_x \varepsilon_y} = \left|S_{xy}\right|^{1/4}$$

coupling: $S_{uv} = \cdots = R S_{xy} R^T$

$$\tilde{\varepsilon} = \sqrt{\varepsilon_u \varepsilon_v} \neq \left|S_{uv}\right|^{1/4}$$

$$R = \begin{bmatrix} \cos\varphi & 0 & \sin\varphi & 0 \\ 0 & \cos\varphi & 0 & \sin\varphi \\ -\sin\varphi & 0 & \cos\varphi & 0 \\ 0 & -\sin\varphi & 0 & \cos\varphi \end{bmatrix}$$

uv-emittance can be measured

$$\varphi_{\min} : \tilde{\varepsilon} \to \min \qquad \tilde{\varepsilon} = \sqrt{\varepsilon_u \varepsilon_v} \approx \left|S_{uv}\right|^{1/4}$$

but: $\begin{bmatrix} \langle uv\rangle & \langle uv'\rangle \\ \langle u'v\rangle & \langle u'v'\rangle \end{bmatrix} \neq \begin{bmatrix} 0 & 0 \\ 0 & 0 \end{bmatrix}$

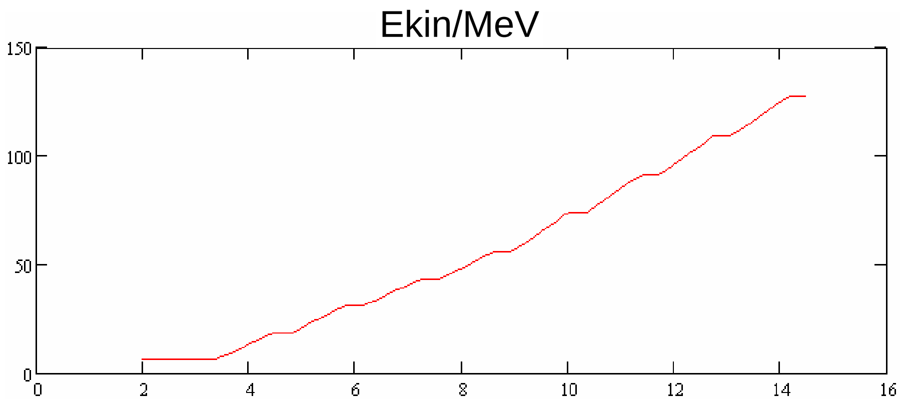
configuration	norm. xy-emittance full,relative		norm. xy-emittance slice,relative		norm. uv-emittance full,relative		norm. uv-emittance slice,relative		offset x/mm	offset y/mm
	$\frac{\varepsilon_{n,x,full}}{\varepsilon_{n,ref,full}}$	$\frac{\varepsilon_{n,y,full}}{\varepsilon_{n,ref,full}}$	$\frac{\varepsilon_{n,x,slice}}{\varepsilon_{n,ref,slice}}$	$\frac{\varepsilon_{n,y,slice}}{\varepsilon_{n,ref,slice}}$	$\frac{\varepsilon_{n,u,full}}{\varepsilon_{n,ref,full}}$	$\frac{\varepsilon_{n,v,full}}{\varepsilon_{n,ref,full}}$	$\frac{\varepsilon_{n,u,slice}}{\varepsilon_{n,ref,slice}}$	$\frac{\varepsilon_{n,v,slice}}{\varepsilon_{n,ref,slice}}$		
old configuration	1.113	1.056	1.029	1.024	1.017	1.045	0.999	1.003	-0.681	-0.196
$V = Re\{v_0\} + i\, Im\{\sim x,y\}$	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	-0.683	-0.183
$V = i\, Im\{v_0\} + Re\{\sim x,y\}$	1.108	1.057	1.029	1.024	1.015	1.042	0.999	1.003	0.002	0.000
without coupling	1.059	1.000	1.000	1.001	1.059	1.000	1.001	1.000	-0.677	-0.183

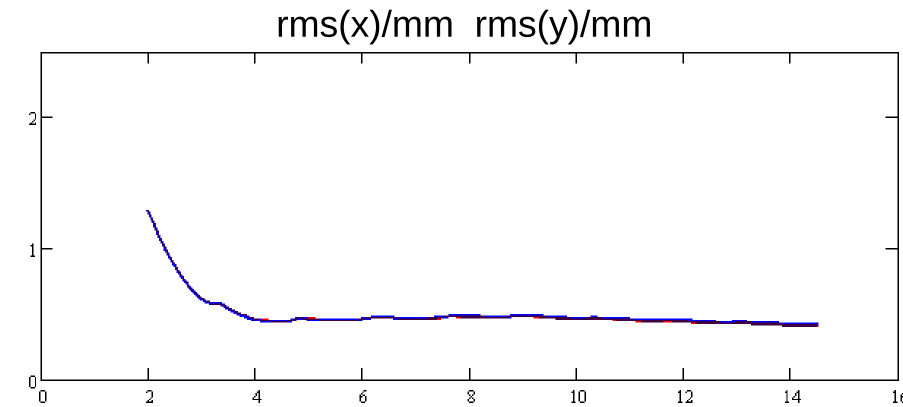
some conclusions:

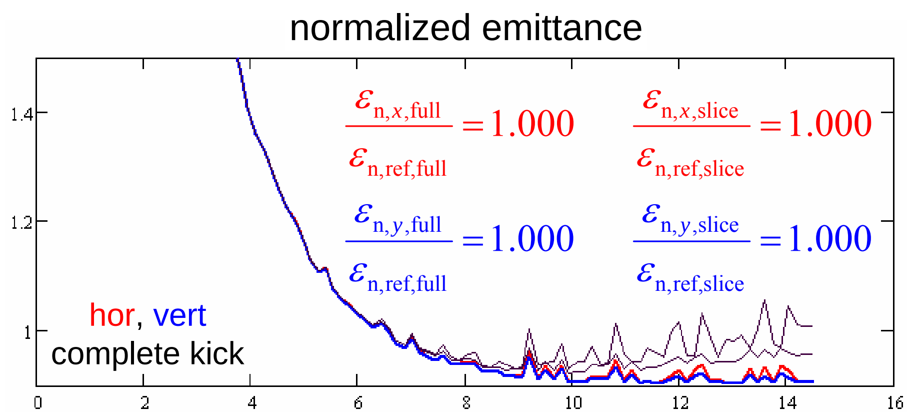
- uv-emittance growth ~ 5% caused by time dependency of fields $\mathrm{Im}\{V_{x,y}\}$
- offset dependency of fields causes xy- but not uv-emittance growth
  - more precise: it is the coupling term: $\partial_y V_x$, $\partial_x V_y$
- beam offset caused by $\mathrm{Re}\{V_{x,y}\}$

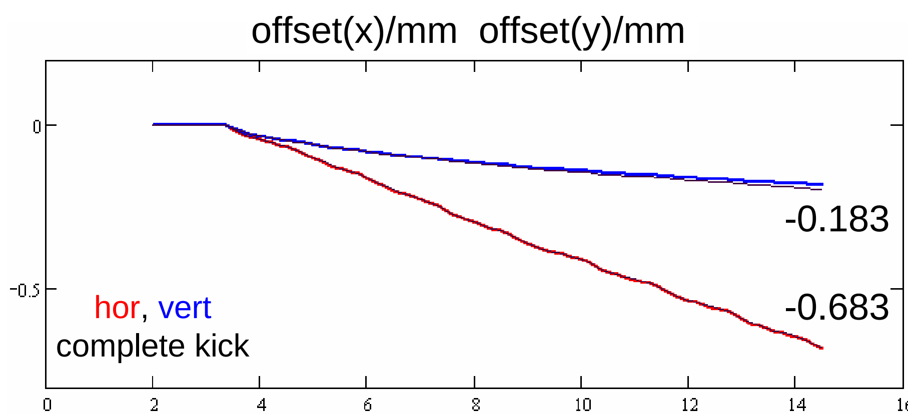
old configuration but:

$$\tilde{V}_{\perp}(x,y) = \mathrm{Re}\{V_{\perp}(0,0)\} + i\,\mathrm{Im}\{V_{\perp}(x,y) - V_{\perp}(0,0)\}$$









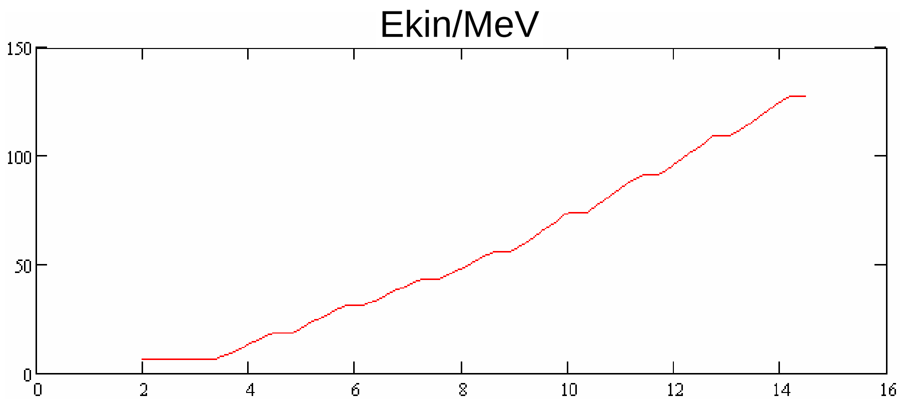
u-v plane:

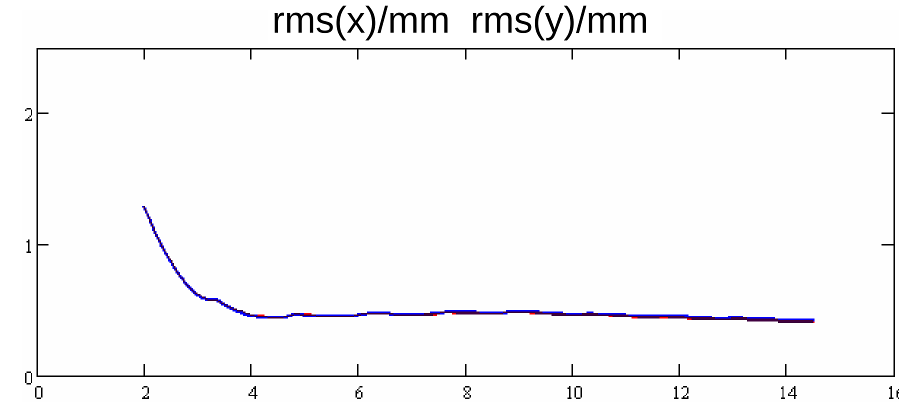
$$\frac{\varepsilon_{n,u,\mathrm{full}}}{\varepsilon_{n,\mathrm{ref,full}}} = 1.000 \qquad \frac{\varepsilon_{n,u,\mathrm{slice}}}{\varepsilon_{n,\mathrm{ref,slice}}} = 1.000$$

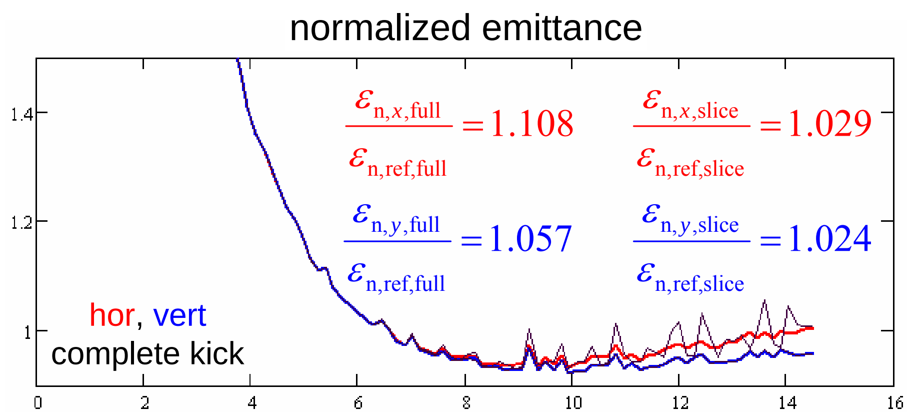
$$\frac{\varepsilon_{n,v,\mathrm{full}}}{\varepsilon_{n,\mathrm{ref,full}}} = 1.000 \qquad \frac{\varepsilon_{n,v,\mathrm{slice}}}{\varepsilon_{n,\mathrm{ref,slice}}} = 1.000$$

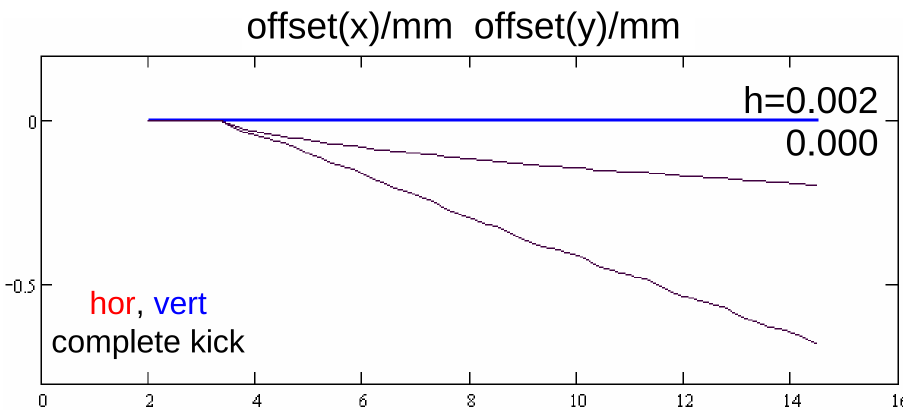
old configuration but:

$$\tilde{V}_\perp(x,y) = i\,\mathrm{Im}\{V_\perp(0,0)\} + \mathrm{Re}\{V_\perp(x,y) - V_\perp(0,0)\}$$









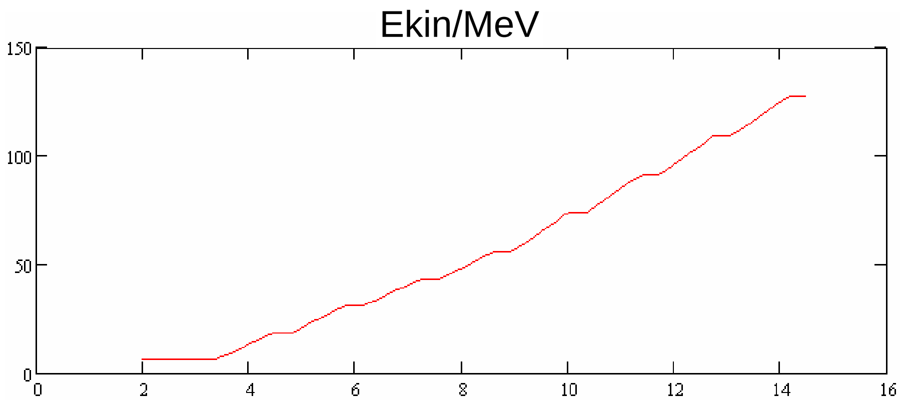
u-v plane:

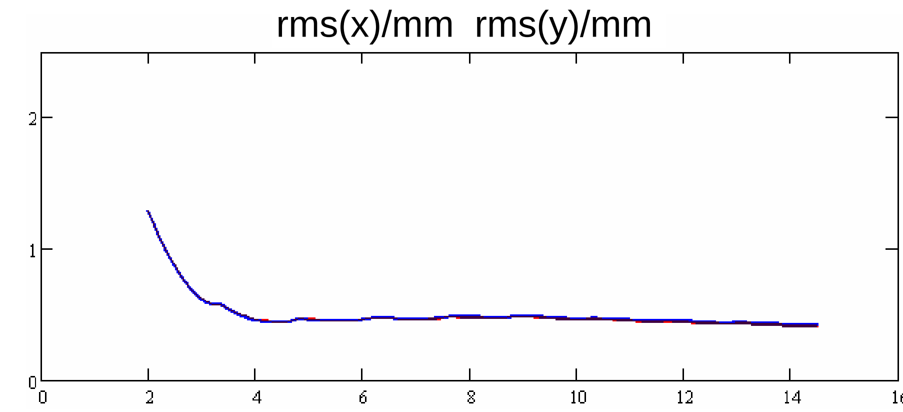
$$\frac{\varepsilon_{n,u,full}}{\varepsilon_{n,ref,full}} = 1.015 \qquad \frac{\varepsilon_{n,u,slice}}{\varepsilon_{n,ref,slice}} = 0.999$$

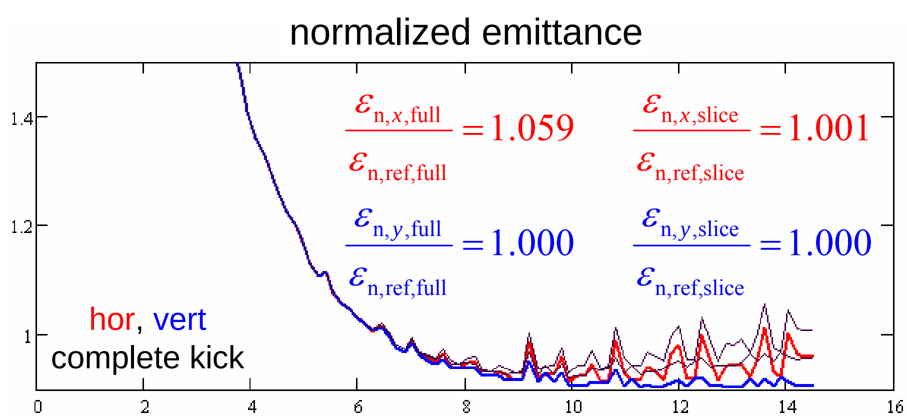
$$\frac{\varepsilon_{n,v,full}}{\varepsilon_{n,ref,full}} = 1.042 \qquad \frac{\varepsilon_{n,v,slice}}{\varepsilon_{n,ref,slice}} = 1.003$$

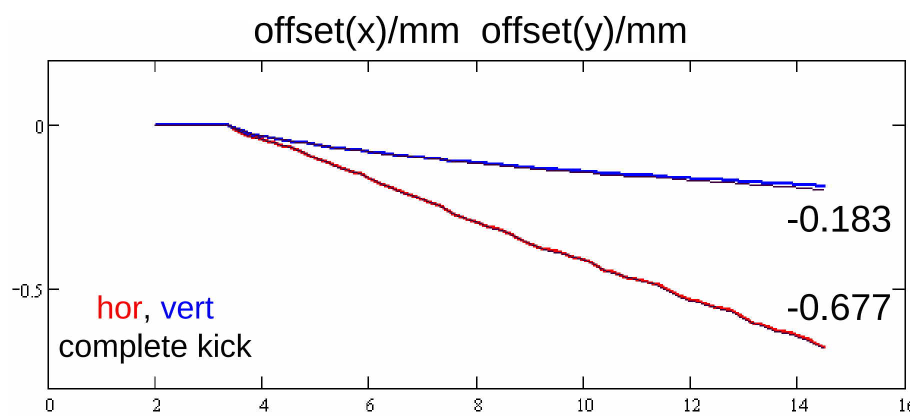
old configuration but without coupling:

$$\tilde{V}_x(x,y) = V_x(0,0) + x \cdot \partial_x V_x(0,0) \quad \tilde{V}_y(x,y) = \ldots$$









u-v plane:

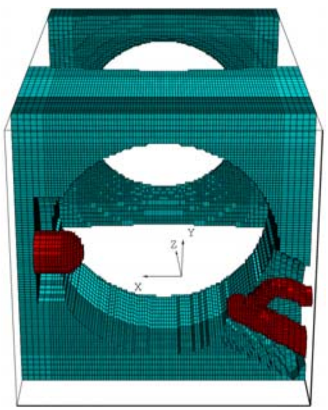
$$\frac{\varepsilon_{n,u,\mathrm{full}}}{\varepsilon_{n,\mathrm{ref,full}}} = 1.059 \qquad \frac{\varepsilon_{n,u,\mathrm{slice}}}{\varepsilon_{n,\mathrm{ref,slice}}} = 1.001$$

$$\frac{\varepsilon_{n,v,\mathrm{full}}}{\varepsilon_{n,\mathrm{ref,full}}} = 1.000 \qquad \frac{\varepsilon_{n,v,\mathrm{slice}}}{\varepsilon_{n,\mathrm{ref,slice}}} = 1.000$$

local compensation (upstream):

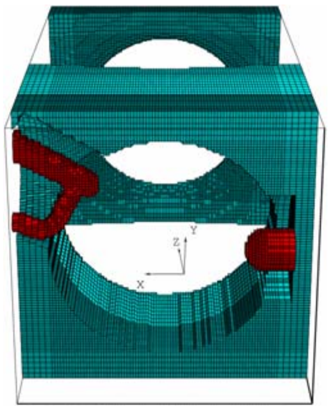
more see s2e-meeting, 28th Jan 2008

comp 8



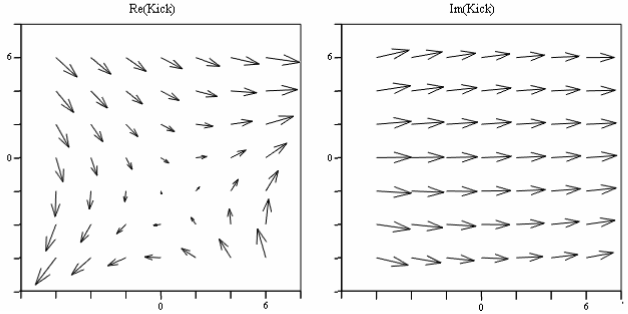
(1) modify cavity

comp 9

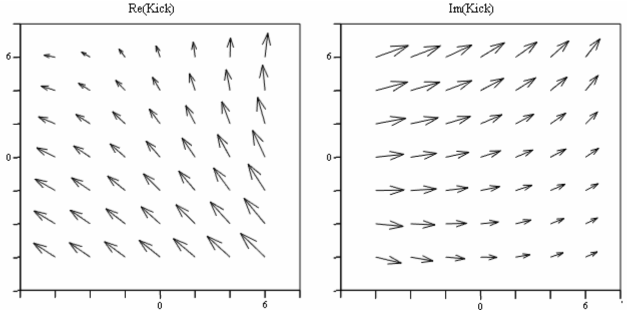


(1) modify cavity
(2) interference with cavity environment expected

comp 8 = reduce real part of ∑-kick



comp 9 = reduce imag. part of ∑-kick



global compensation:

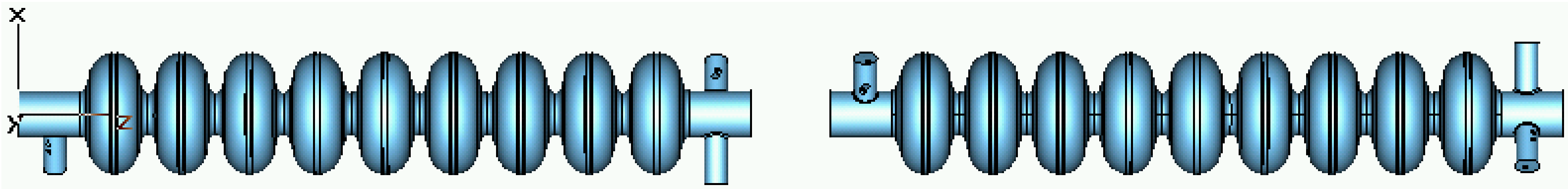
zrot=180deg of cavities 2,4,6,8

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

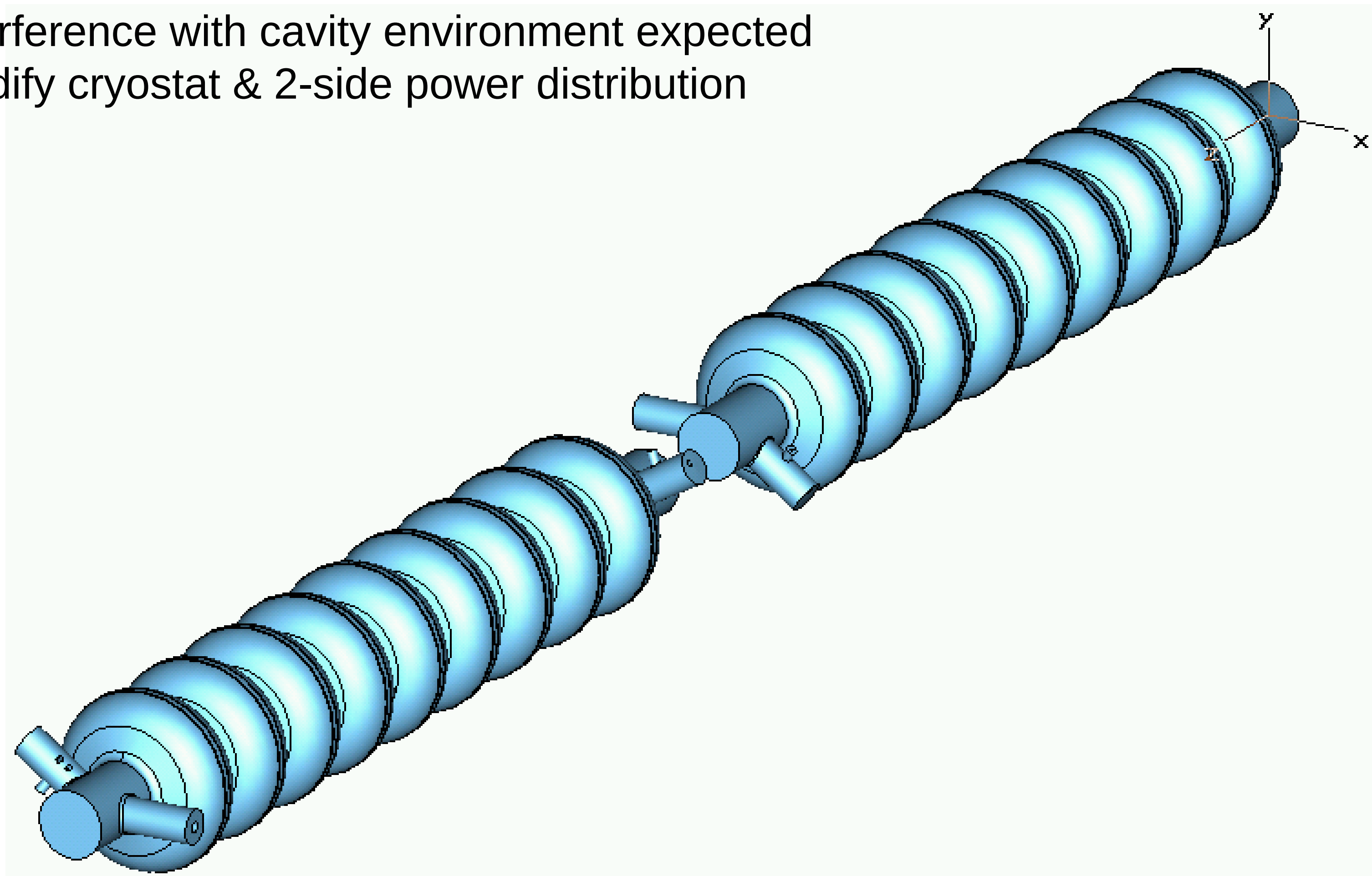
yrot=180deg of cavities 2,4,6,8

z-mirror of cavities 2,4,6,8

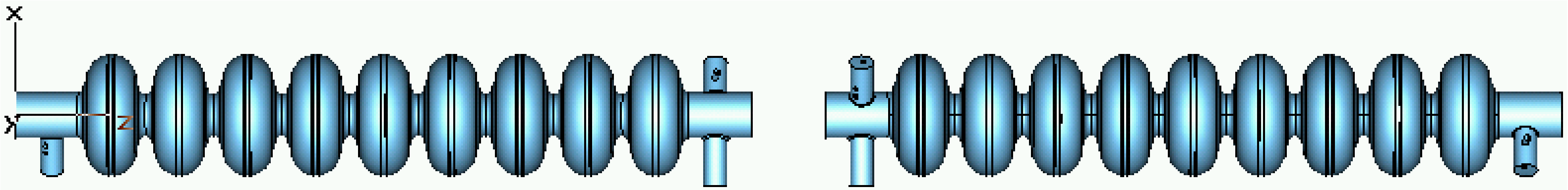
global: zrot=180deg of cavities 2,4,6,8



(2) interference with cavity environment expected
(4) modify cryostat & 2-side power distribution

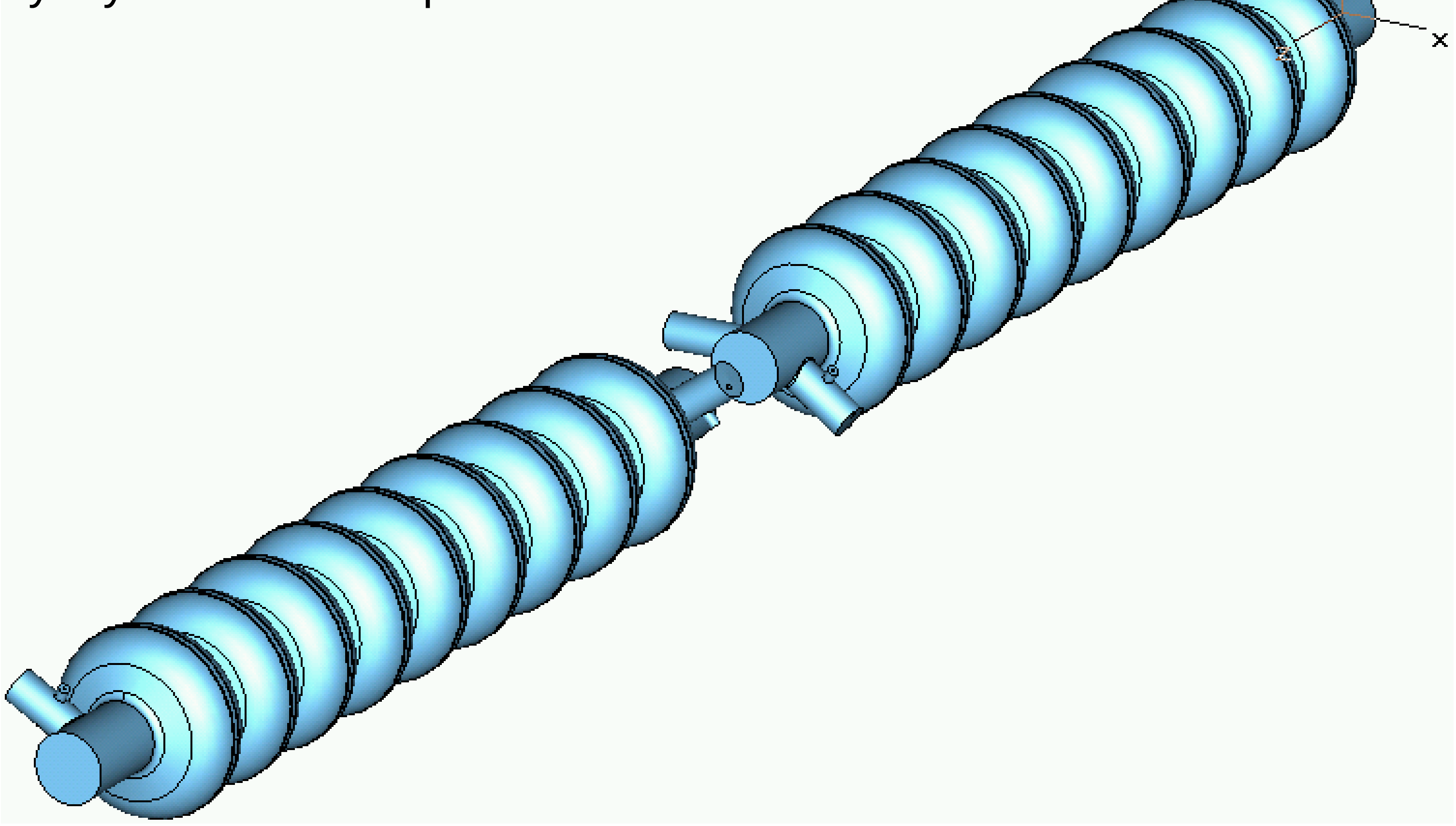


global: xrot=180deg of cavities 2,4,6,8

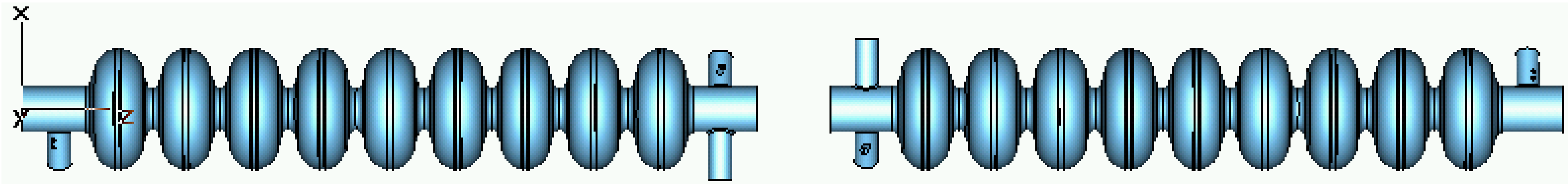


(2) interference with cavity environment expected

(3) modify cryostat & 1-side power distribution

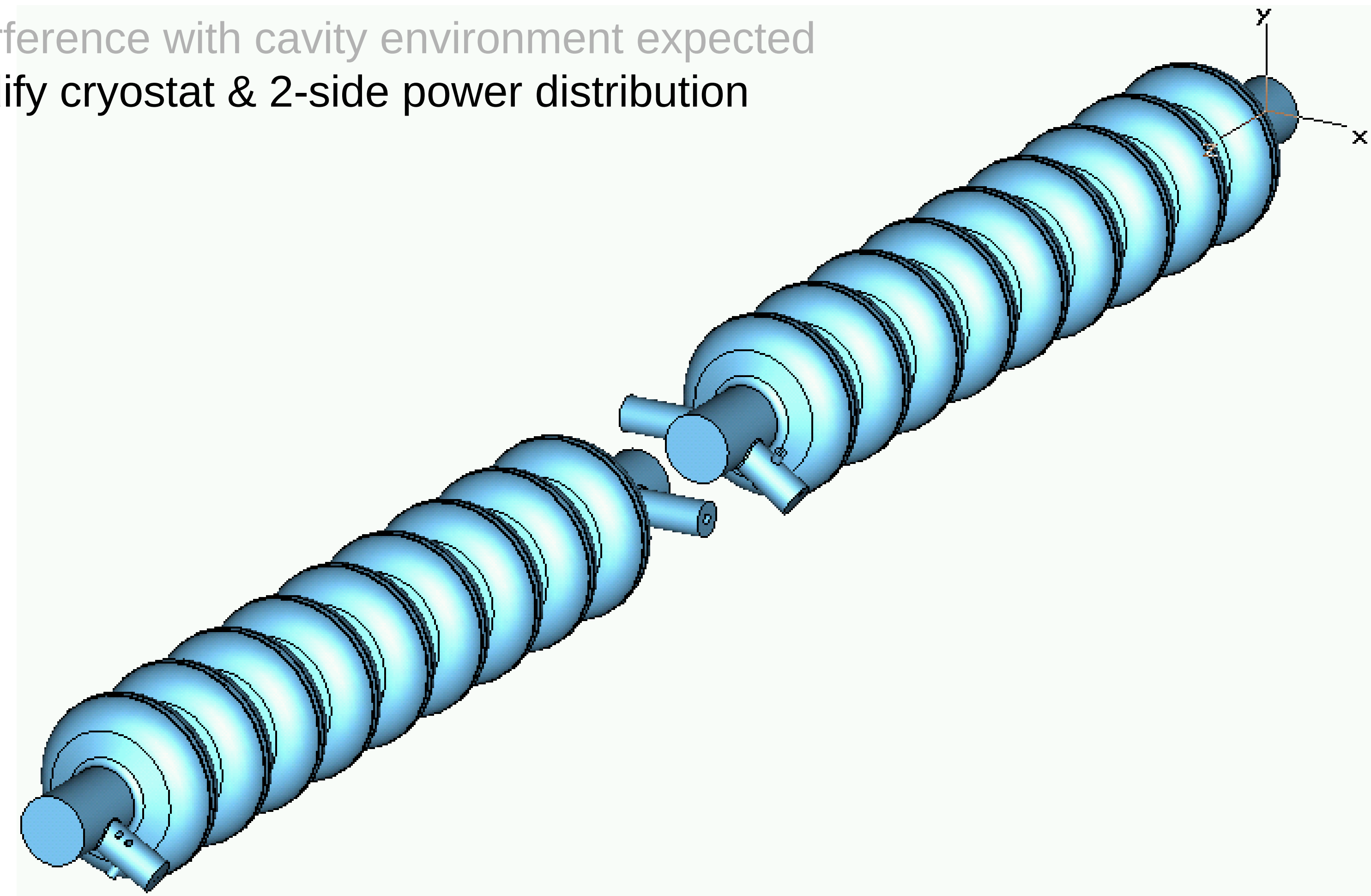


global: yrot=180deg of cavities 2,4,6,8

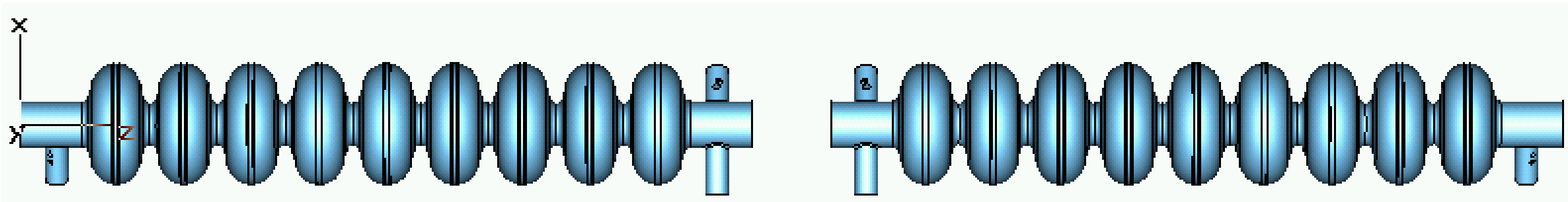


(2) interference with cavity environment expected

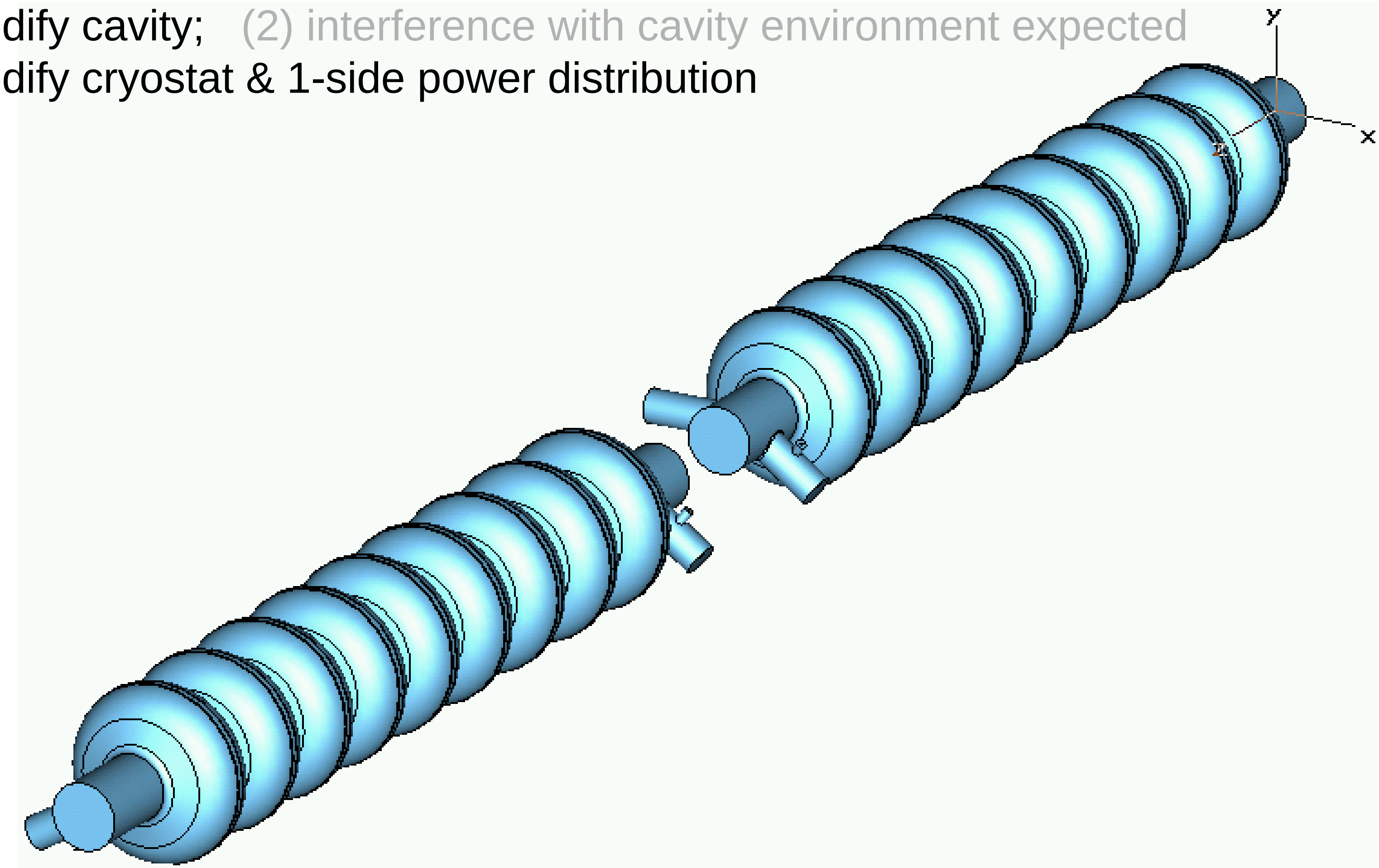
(4) modify cryostat & 2-side power distribution



global: z-mirror of cavities 2,4,6,8



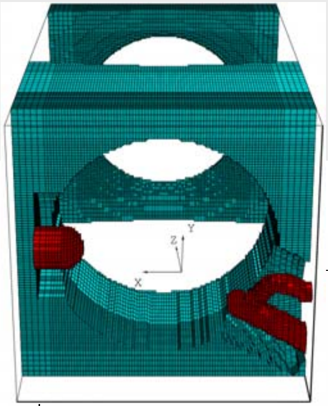
(1) modify cavity; (2) interference with cavity environment expected
(3) modify cryostat & 1-side power distribution



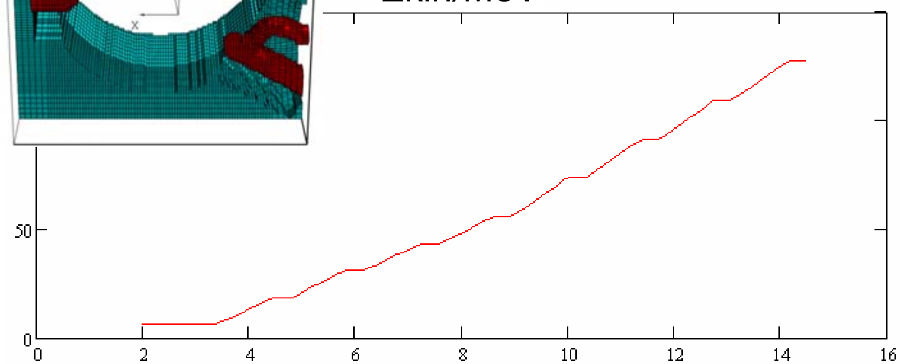
configuration	norm. xy-emittance full,relative		norm. xy-emittance slice,relative		norm. uv-emittance full,relative		norm. uv-emittance slice,relative		offset x/mm	offset y/mm
	$\frac{\varepsilon_{n,x,full}}{\varepsilon_{n,ref,full}}$	$\frac{\varepsilon_{n,y,full}}{\varepsilon_{n,ref,full}}$	$\frac{\varepsilon_{n,x,slice}}{\varepsilon_{n,ref,slice}}$	$\frac{\varepsilon_{n,y,slice}}{\varepsilon_{n,ref,slice}}$	$\frac{\varepsilon_{n,u,full}}{\varepsilon_{n,ref,full}}$	$\frac{\varepsilon_{n,v,full}}{\varepsilon_{n,ref,full}}$	$\frac{\varepsilon_{n,u,slice}}{\varepsilon_{n,ref,slice}}$	$\frac{\varepsilon_{n,v,slice}}{\varepsilon_{n,ref,slice}}$		
old configuration	1.113	1.056	1.029	1.024	1.017	1.045	0.999	1.003	-0.681	-0.196
local: comp8 (1)	1.172	1.066	1.027	1.025	1.090	1.044	0.999	1.004	0.203	-0.174
comp9 (1,2)	1.053	1.066	1.025	1.025	0.997	1.014	0.998	1.004	-0.495	0.578
global: z-rot (2,4)	1.058	1.056	1.028	1.024	0.994	1.008	0.999	1.003	-0.117	-0.034
x-rot (2,3)	1.052	1.033	1.018	1.014	1.003	1.017	0.999	1.002	-0.243	-0.226
y-rot (4)	1.046	1.033	1.018	1.014	0.999	1.015	0.999	1.002	-0.551	0.000
z-mirror (1,3)	1.057	1.002	1.002	1.001	1.007	1.051	1.000	1.001	-0.151	-0.107

(1) modify cavity; (2) interference with cavity environment expected
(3) modify cryostat & 1-side power distribution
(4) modify cryostat & 2-side power distribution

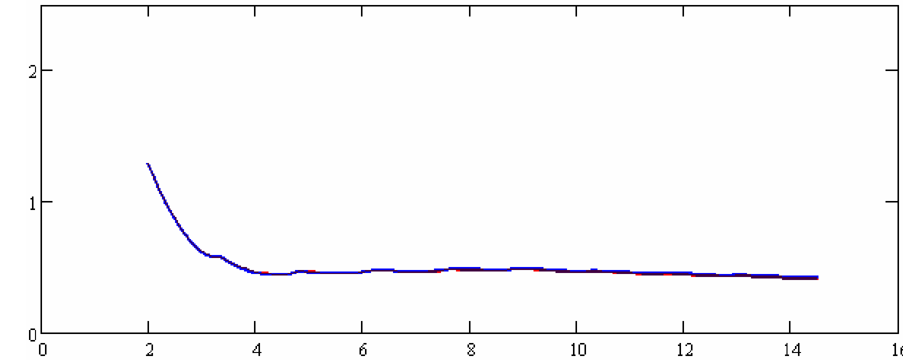
comp8



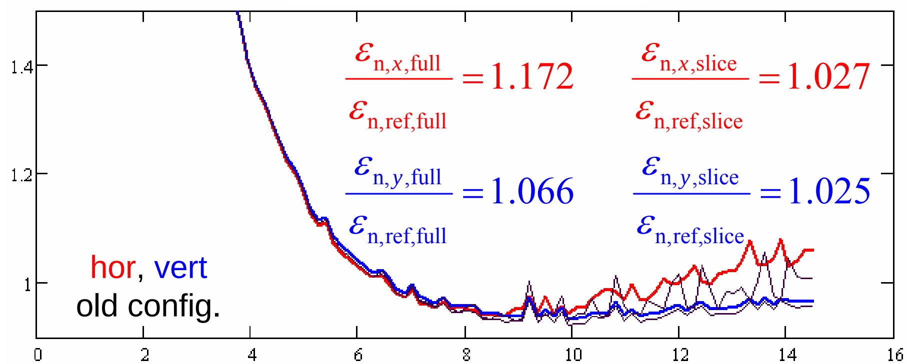
Ekin/MeV



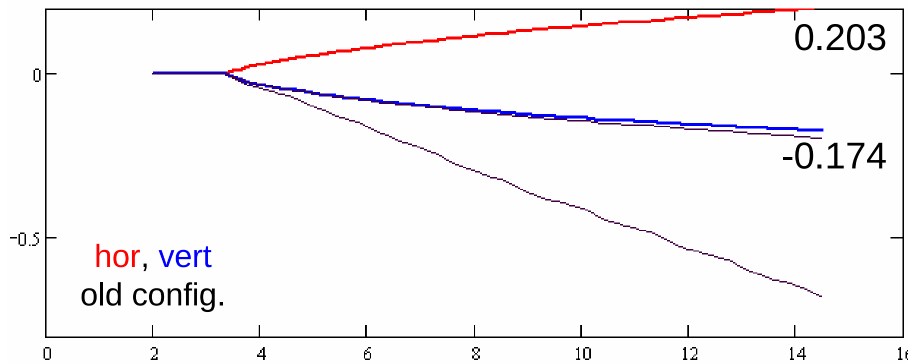
rms(x)/mm rms(y)/mm



normalized emittance



offset(x)/mm offset(y)/mm

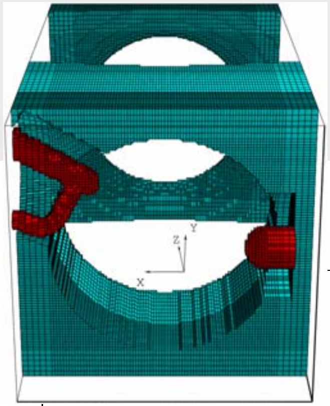


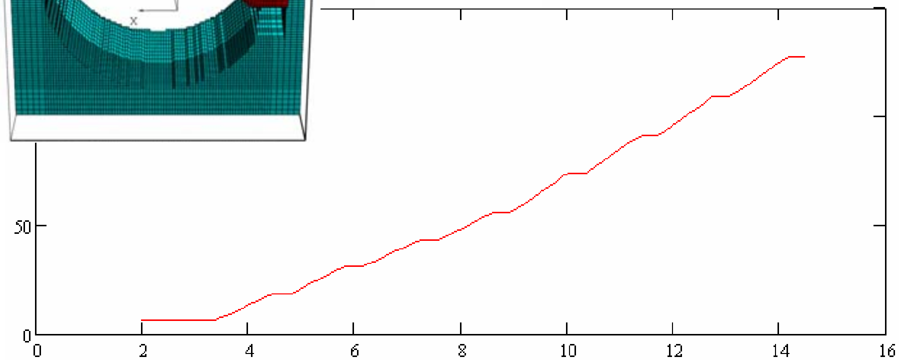
u-v plane:

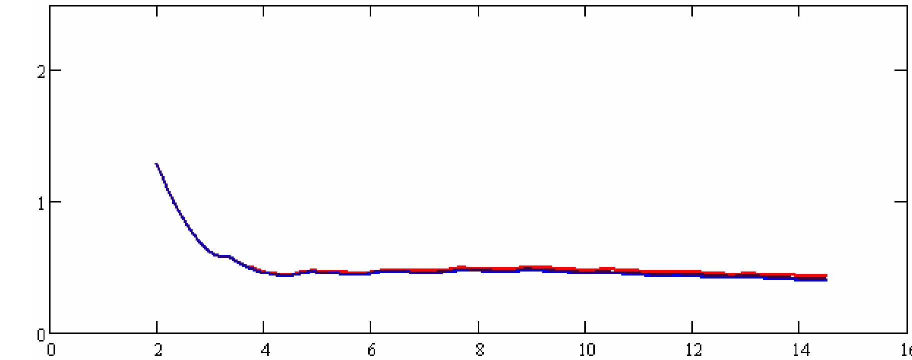
$$\frac{\varepsilon_{n,u,full}}{\varepsilon_{n,ref,full}} = 1.090 \qquad \frac{\varepsilon_{n,u,slice}}{\varepsilon_{n,ref,slice}} = 0.999$$

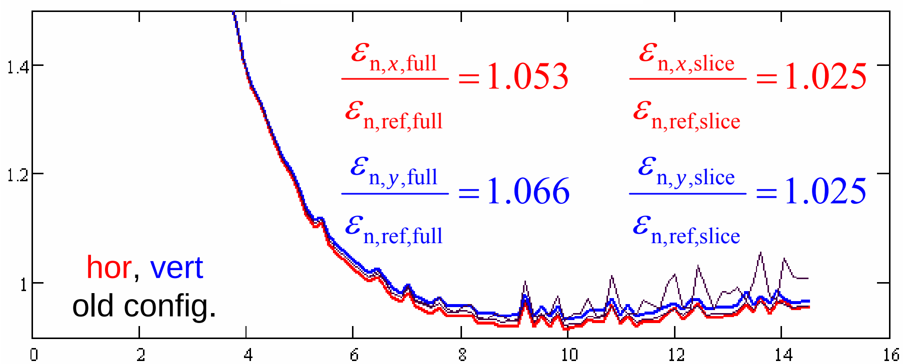
$$\frac{\varepsilon_{n,v,full}}{\varepsilon_{n,ref,full}} = 1.044 \qquad \frac{\varepsilon_{n,v,slice}}{\varepsilon_{n,ref,slice}} = 1.004$$

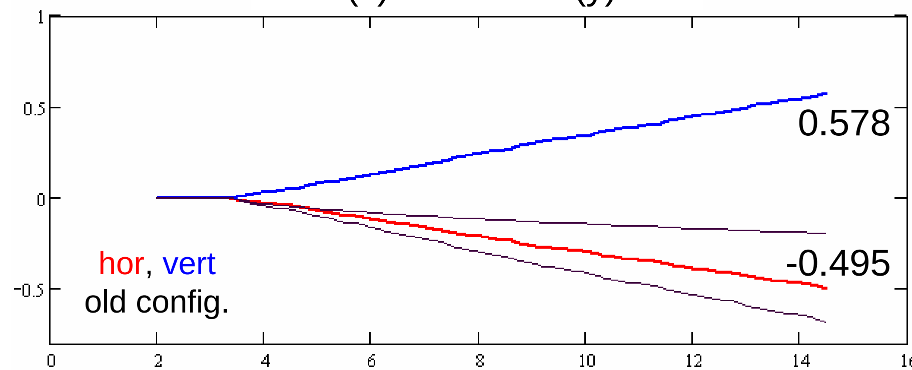
comp9









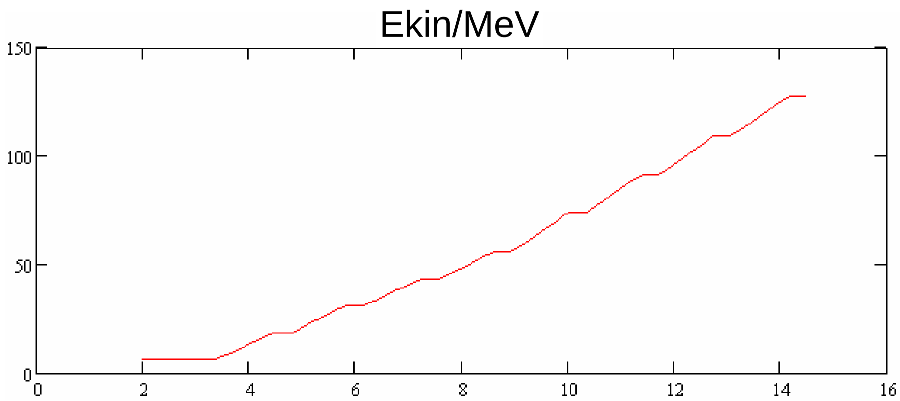


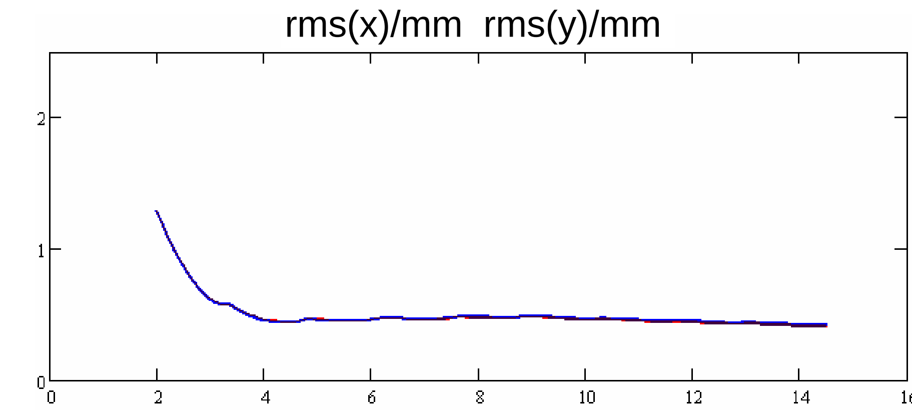
u-v plane:

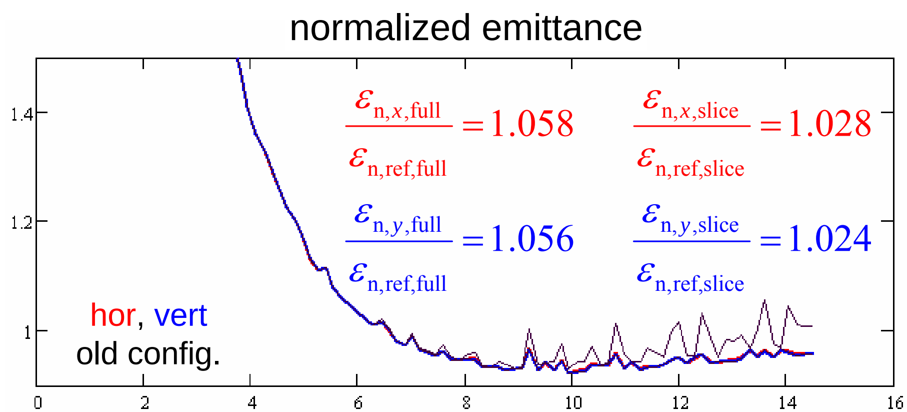
$$\frac{\varepsilon_{n,u,full}}{\varepsilon_{n,ref,full}} = 0.997 \qquad \frac{\varepsilon_{n,u,slice}}{\varepsilon_{n,ref,slice}} = 0.998$$

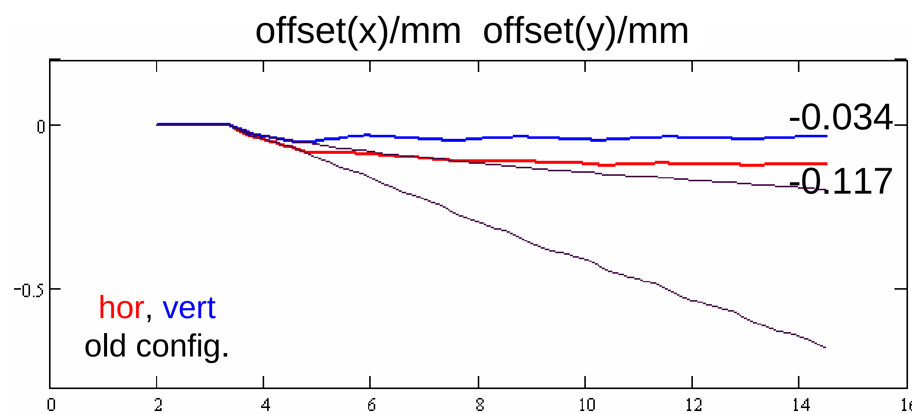
$$\frac{\varepsilon_{n,v,full}}{\varepsilon_{n,ref,full}} = 1.014 \qquad \frac{\varepsilon_{n,v,slice}}{\varepsilon_{n,ref,slice}} = 1.004$$

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







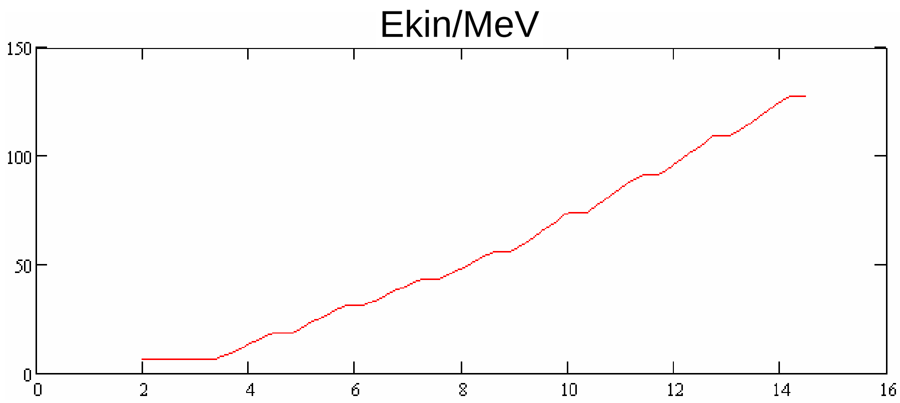


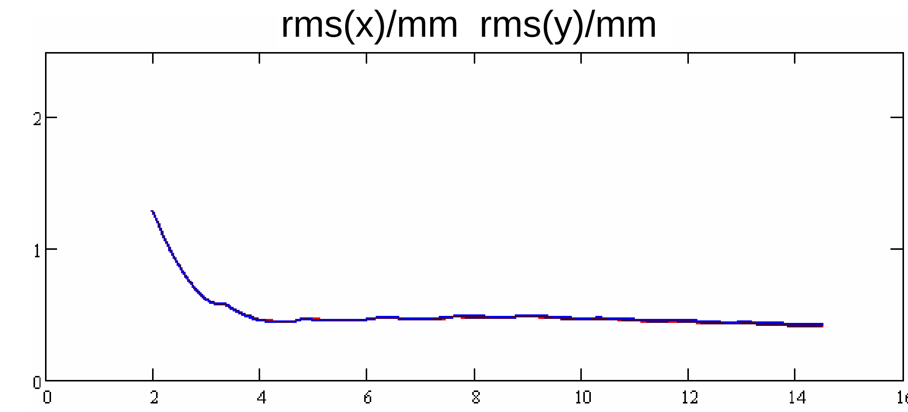
u-v plane:

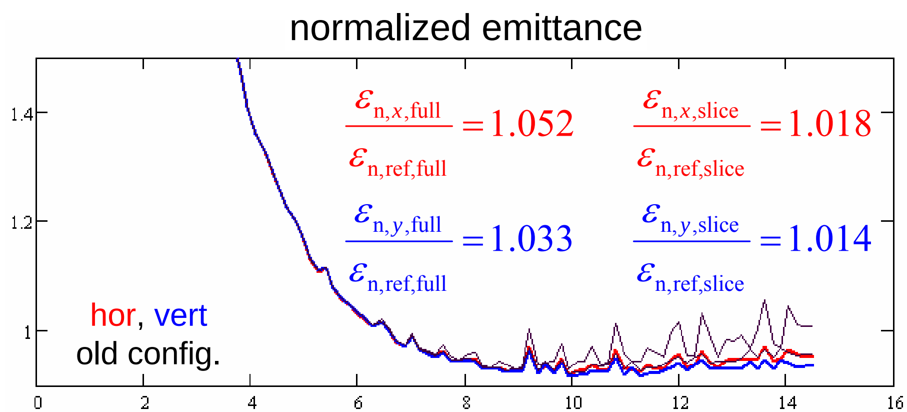
$$\frac{\varepsilon_{n,u,full}}{\varepsilon_{n,ref,full}} = 0.994 \qquad \frac{\varepsilon_{n,u,slice}}{\varepsilon_{n,ref,slice}} = 0.999$$

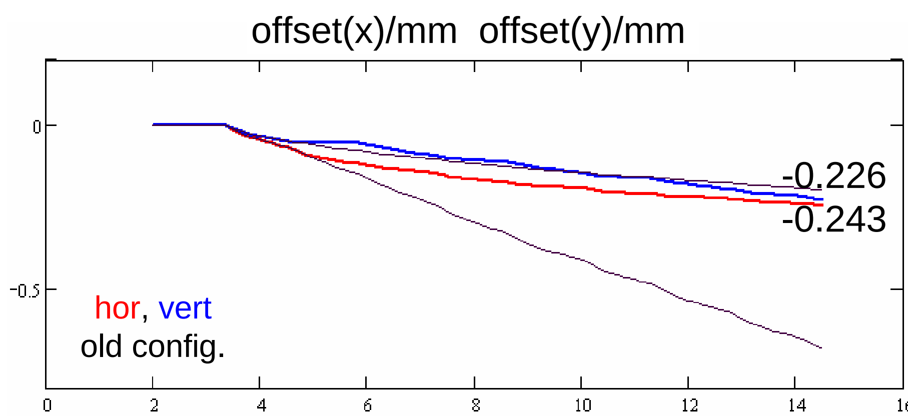
$$\frac{\varepsilon_{n,v,full}}{\varepsilon_{n,ref,full}} = 1.008 \qquad \frac{\varepsilon_{n,v,slice}}{\varepsilon_{n,ref,slice}} = 1.003$$

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









u-v plane:

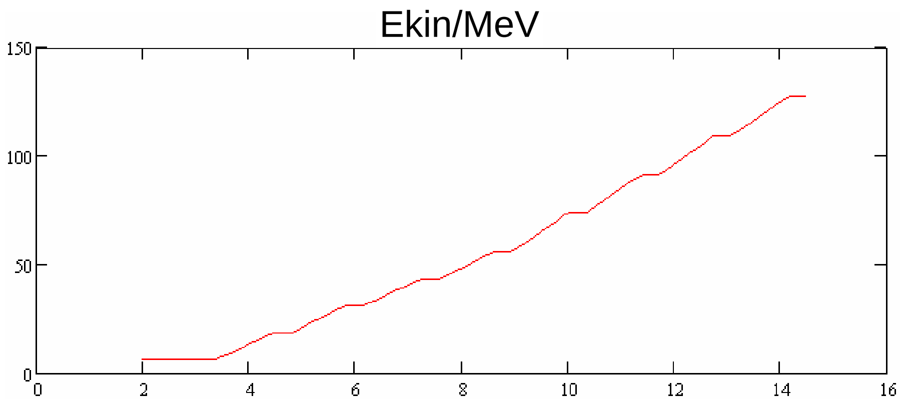
$$\frac{\varepsilon_{n,u,full}}{\varepsilon_{n,ref,full}} = 1.003 \qquad \frac{\varepsilon_{n,u,slice}}{\varepsilon_{n,ref,slice}} = 0.999$$

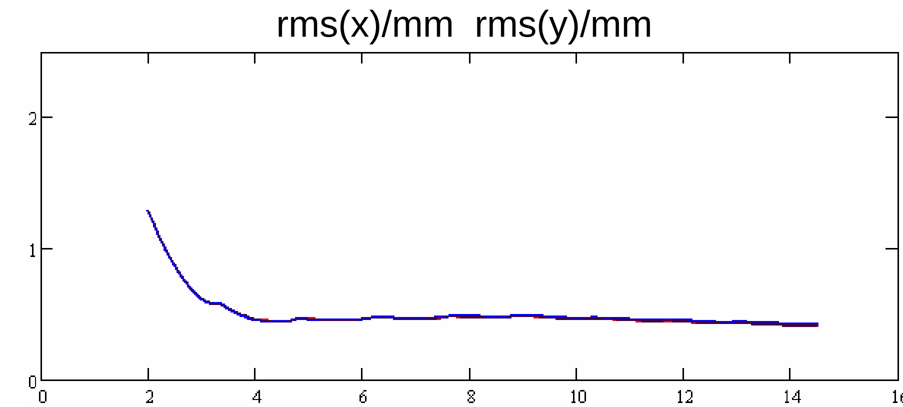
$$\frac{\varepsilon_{n,v,full}}{\varepsilon_{n,ref,full}} = 1.017 \qquad \frac{\varepsilon_{n,v,slice}}{\varepsilon_{n,ref,slice}} = 1.002$$

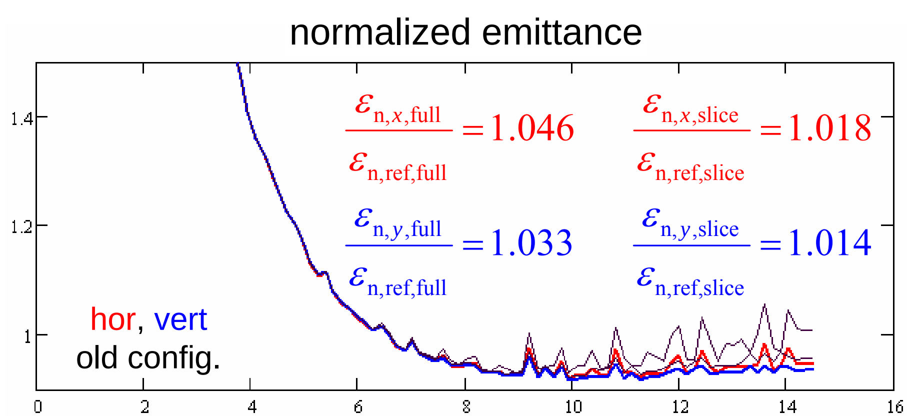
$$x(14.5\,\mathrm{m}) = -0.243\,\mathrm{mm}$$

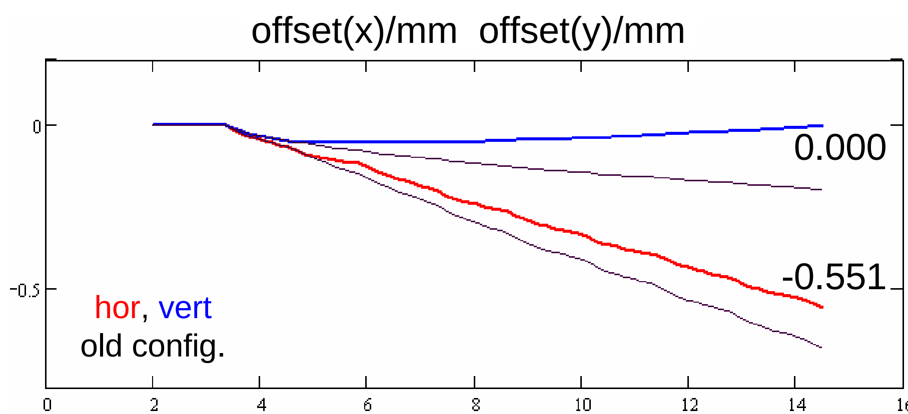
$$y(14.5\,\mathrm{m}) = -0.226\,\mathrm{mm}$$

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









u-v plane:

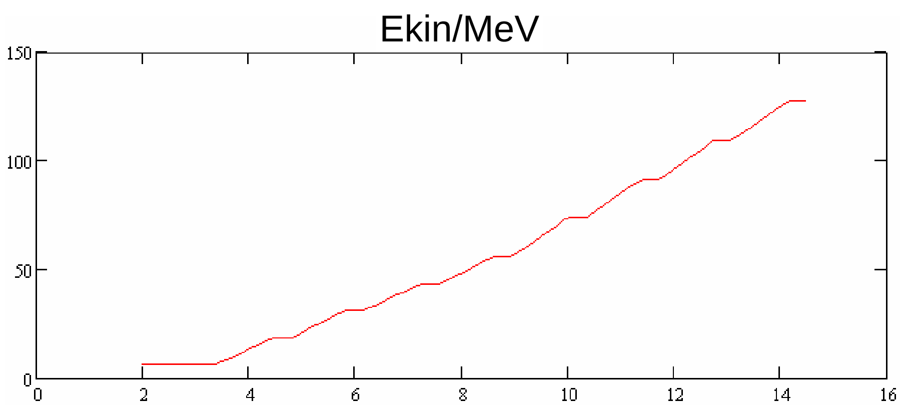
$$\frac{\varepsilon_{n,u,full}}{\varepsilon_{n,ref,full}} = 0.999 \qquad \frac{\varepsilon_{n,u,slice}}{\varepsilon_{n,ref,slice}} = 0.999$$

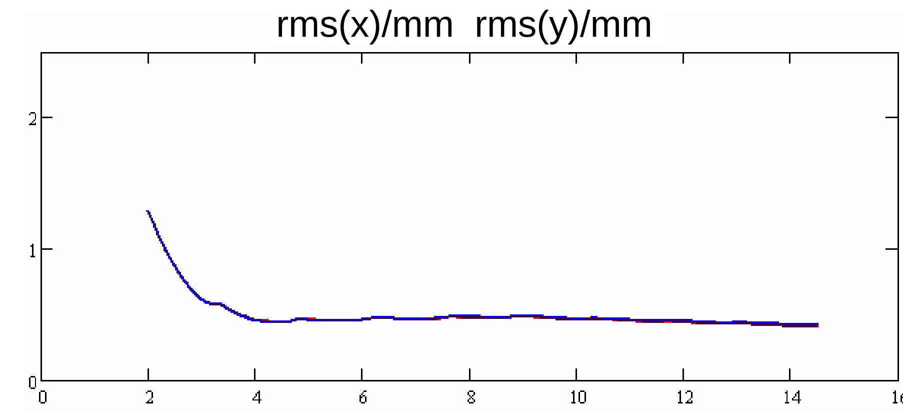
$$\frac{\varepsilon_{n,v,full}}{\varepsilon_{n,ref,full}} = 1.015 \qquad \frac{\varepsilon_{n,v,slice}}{\varepsilon_{n,ref,slice}} = 1.002$$

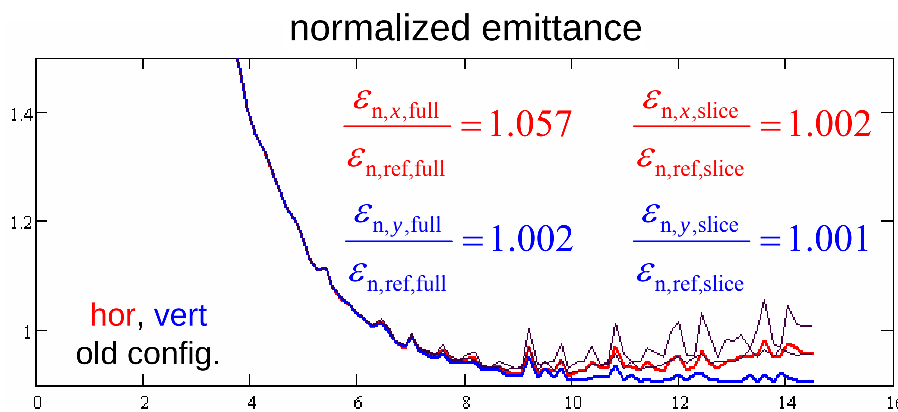
$$x(14.5\text{m}) = -0.551\,\text{mm}$$

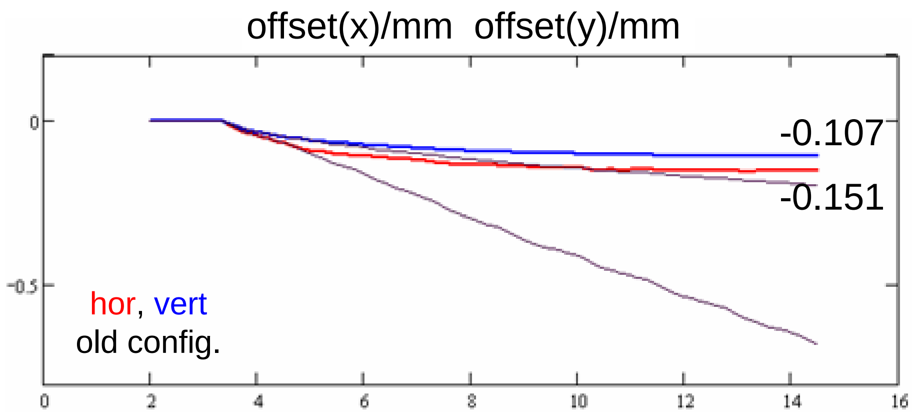
$$y(14.5\text{m}) = 0.000\,\text{mm}$$

global: z-mirror of cavities 2,4,6,8









u-v plane:

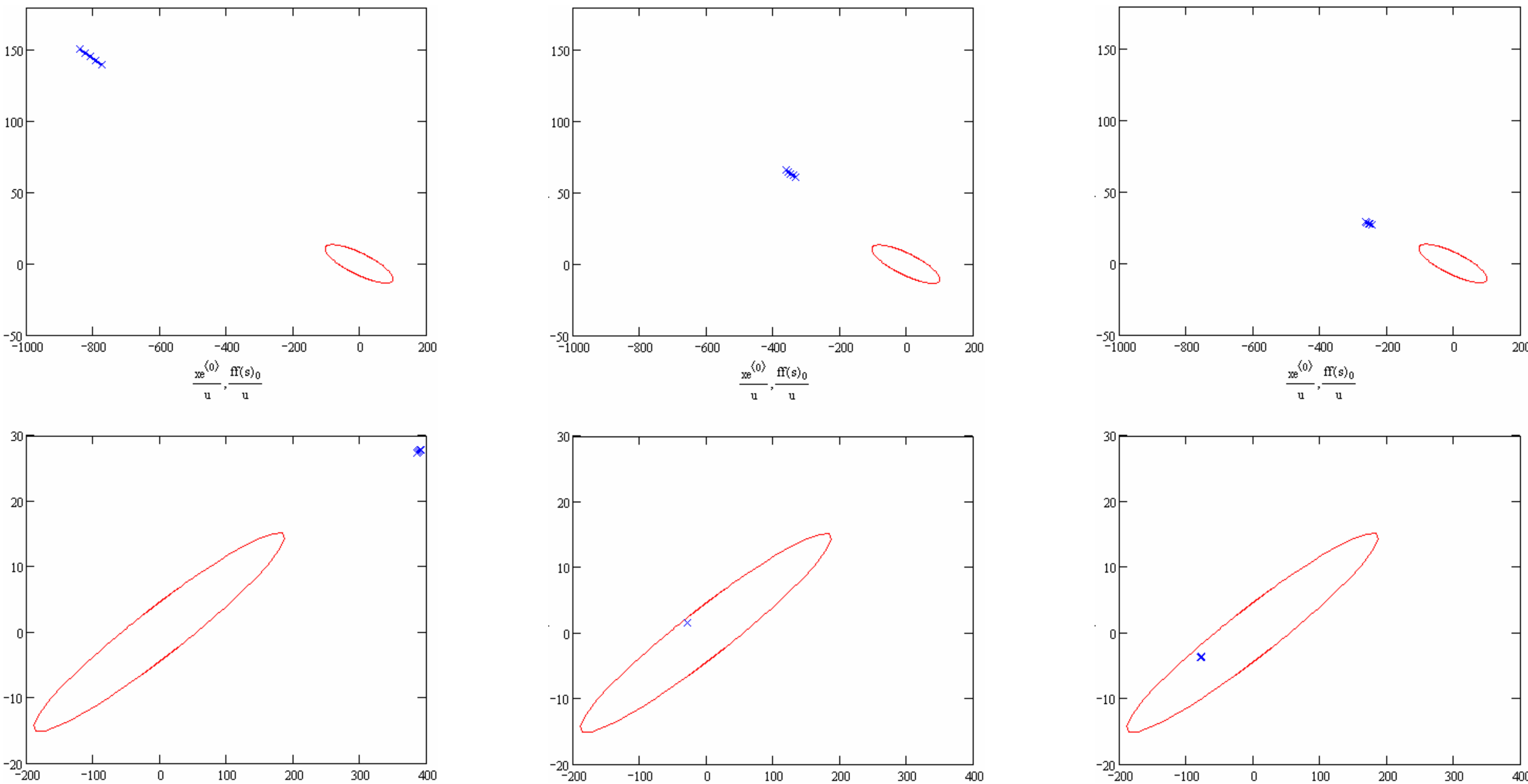
$$\frac{\varepsilon_{n,u,full}}{\varepsilon_{n,ref,full}} = 1.007 \qquad \frac{\varepsilon_{n,u,slice}}{\varepsilon_{n,ref,slice}} = 1.000$$

$$\frac{\varepsilon_{n,v,full}}{\varepsilon_{n,ref,full}} = 1.051 \qquad \frac{\varepsilon_{n,v,slice}}{\varepsilon_{n,ref,slice}} = 1.001$$

more

phase space after ACC5; all modules on crest

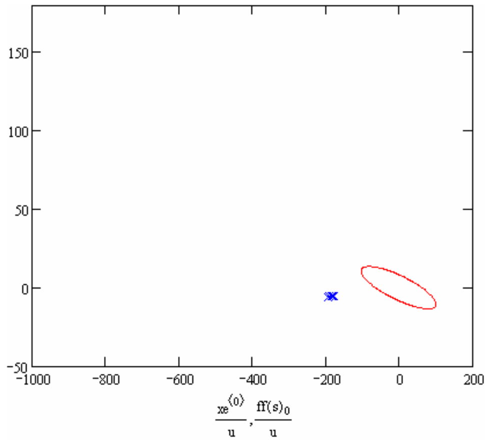
coupler kicks only from ACC1	coupler kicks only from ACC2	coupler kicks only from ACC3

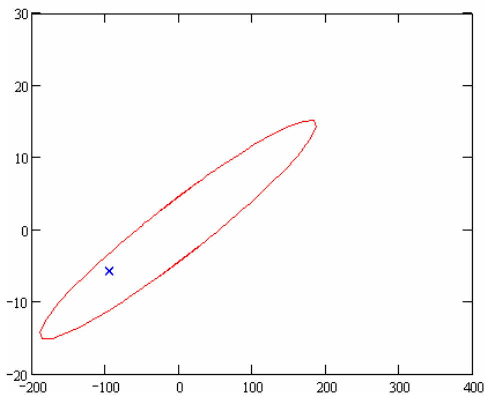


slice centroid, phase = +- 2mm · 2π/λ

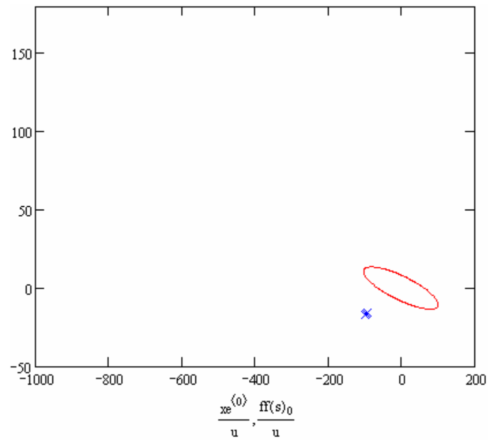
phase space after ACC5; all modules on crest

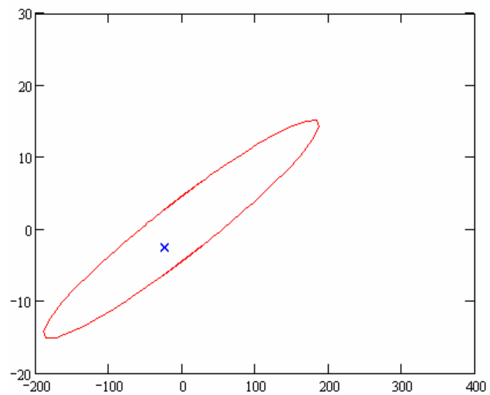
coupler kicks
only from ACC3





coupler kicks
only from ACC4





TYPE	ENERGY	MUX/2π	MUY/2π
CAV	0.0155	0.4665	0.467
CAV	0.0260	0.4853	0.485
CAV	0.0365	0.4952	0.495
CAV	0.0470	0.5019	0.502
CAV	0.0677	0.5071	0.507
CAV	0.0885	0.5117	0.512
CAV	0.1092	0.5161	0.516
CAV	0.1300	0.5206	0.521
CAV	0.1447	2.4721	2.798
CAV	0.1594	2.4808	2.806
CAV	0.1741	2.4898	2.815
CAV	0.1888	2.4990	2.825
CAV	0.2034	2.5086	2.834
CAV	0.2181	2.5185	2.844
CAV	0.2328	2.5286	2.854
CAV	0.2475	2.5391	2.864
CAV	0.2622	2.5583	2.880
CAV	0.2769	2.5726	2.888
CAV	0.2916	2.5894	2.896
CAV	0.3062	2.6091	2.902
CAV	0.3209	2.6317	2.908
CAV	0.3356	2.6570	2.914
CAV	0.3503	2.6840	2.918
CAV	0.3650	2.7114	2.923
CAV	0.3797	2.7489	2.930
CAV	0.3944	2.7635	2.936
CAV	0.4091	2.7744	2.944
CAV	0.4237	2.7828	2.954
CAV	0.4384	2.7894	2.968
CAV	0.4531	2.7948	2.988
CAV	0.4678	2.7992	3.019
CAV	0.4825	2.8030	3.064
CAV	0.4972	2.8088	3.157
CAV	0.5119	2.8131	3.195
CAV	0.5266	2.8181	3.222
CAV	0.5412	2.8242	3.240
CAV	0.5559	2.8317	3.253
CAV	0.5706	2.8411	3.263
CAV	0.5853	2.8531	3.271
CAV	0.6000	2.8688	3.277