Magnetic modes in superconducting RF cavities

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1. Static magnetic field in normal conducting
   RF – photoelectron guns

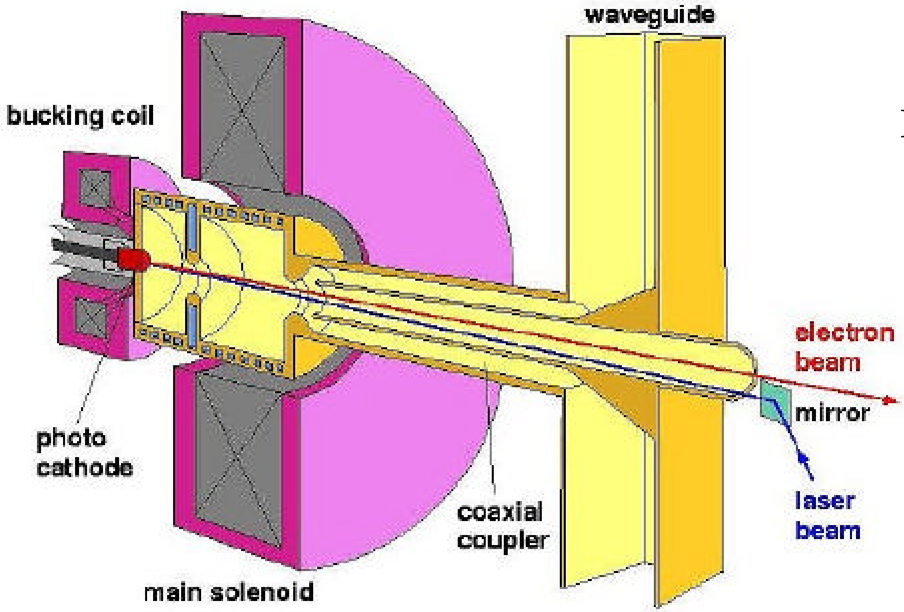
2. Electric and magnetic modes

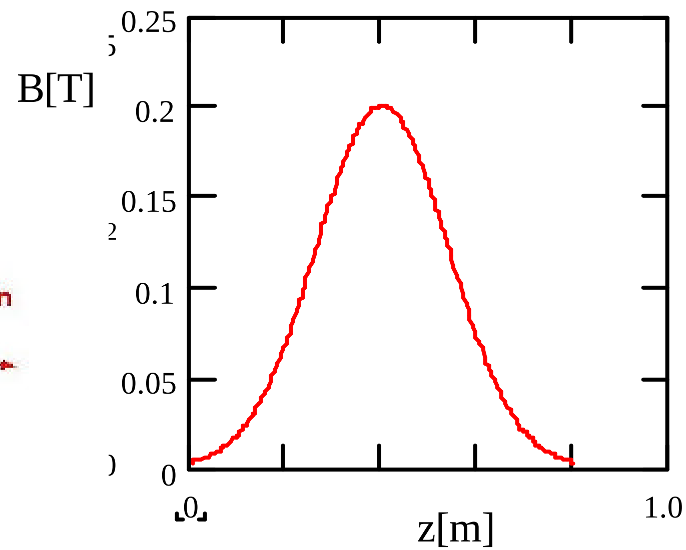
3. Power input of different modes

4. Calculation of beam properties

5. Possibilities for realization

Static magnetic field in normalconducting RF photoelectron guns





RF photoelectron gun DESY

Electric and magnetic modes

<u>Helmholz equation</u>

(? $+ k^2$) **E = 0** (? $+ k^2$) **H = 0** k=? /c

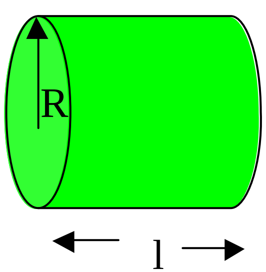
rot **H** = i*e* ? ***E**

<u>Boundary conditions</u>

surface: $\mathbf{E}_{paralel} = 0$, $\mathbf{H}_{senkrect} = 0$

<u>Pillbox cavity</u>

TM – Mode : E_z, E_r, B_f TE – Mode : B_z, B_r, E_f

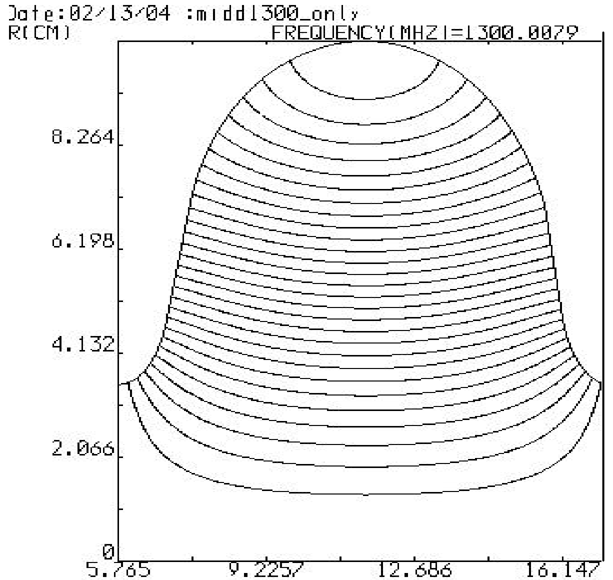


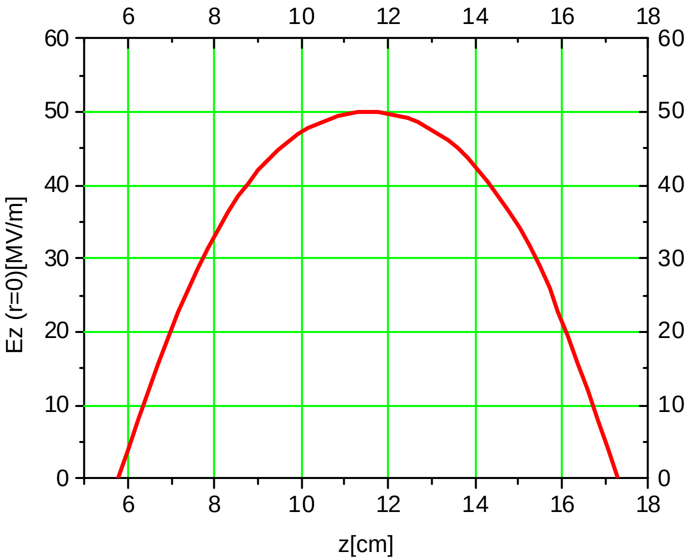
? $_{TM}$ = 2.4048*c/R

? $_{TE} = c^* \sqrt{\frac{\pi^2}{l^2} + \frac{(3.8317)^2}{R^2}}$

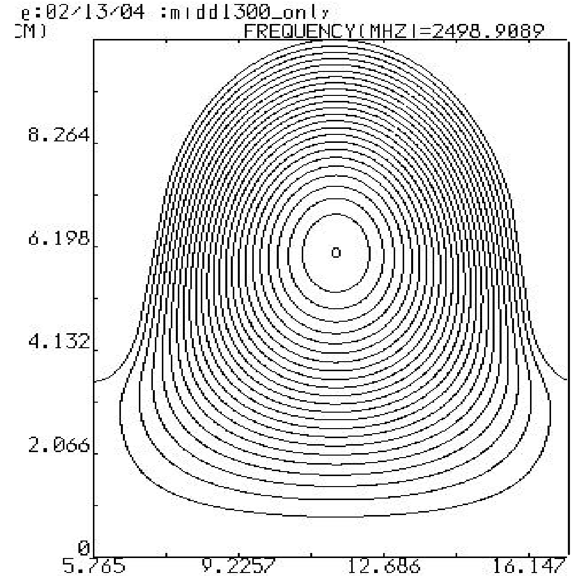
TESLA middle cell, W_{TM} = 10.04 J, W_{TE} = 16 J

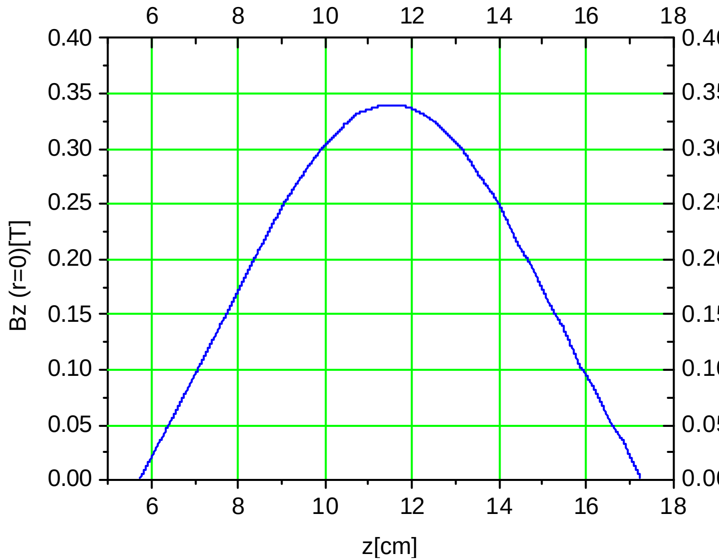
f = 1300 MHz, Ez_{max}(r=0) = 50MV/m





f = 2499 MHz, Bz_{max}(r=0) = 0.34T





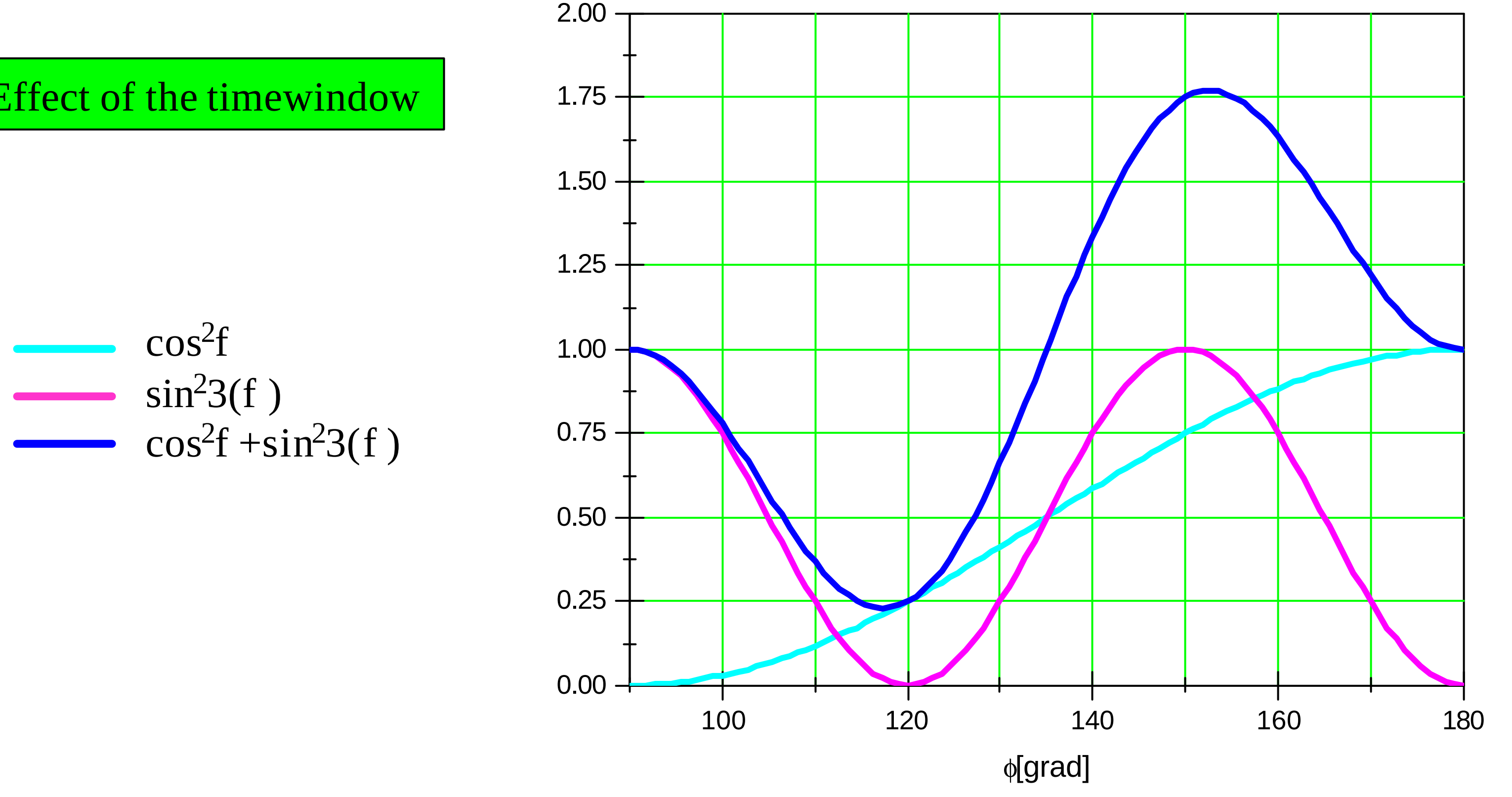
Power input of different modes

$P \sim B^2_{max}(s)$ TM – Mode: $P \sim B^2_{f,max}(s)$, TE – Mode: $P \sim (B^2_r(s) + B^2_z(s))_{max}$

Example : TESLA cavity, TM – Mode, Ez_{max} = 50 MV/m, $B_{f,max}(s)$ = 0.176 T

Common input of TE and TM modes ($f_{TE} = 3 * f_{TM}$)

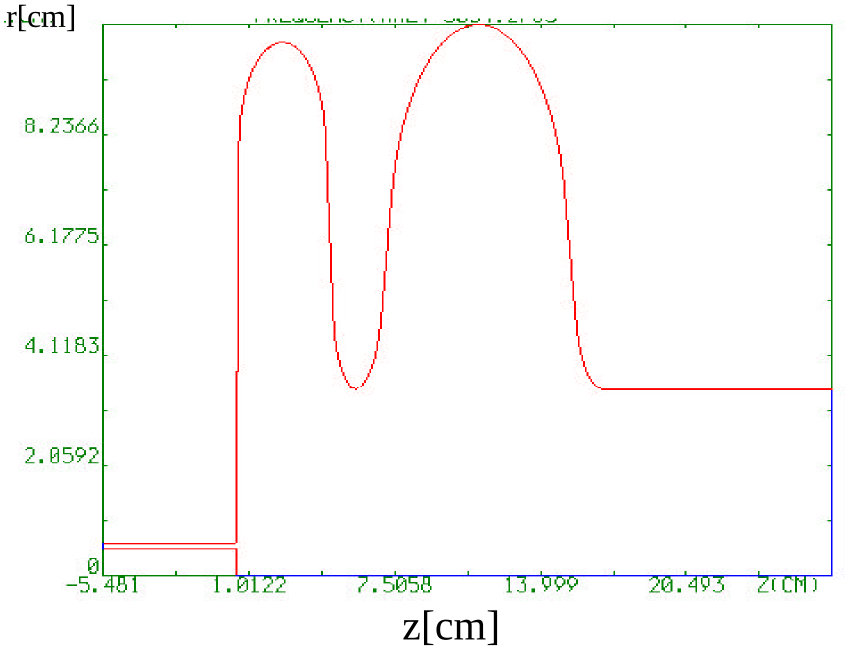
Effect of the timewindow



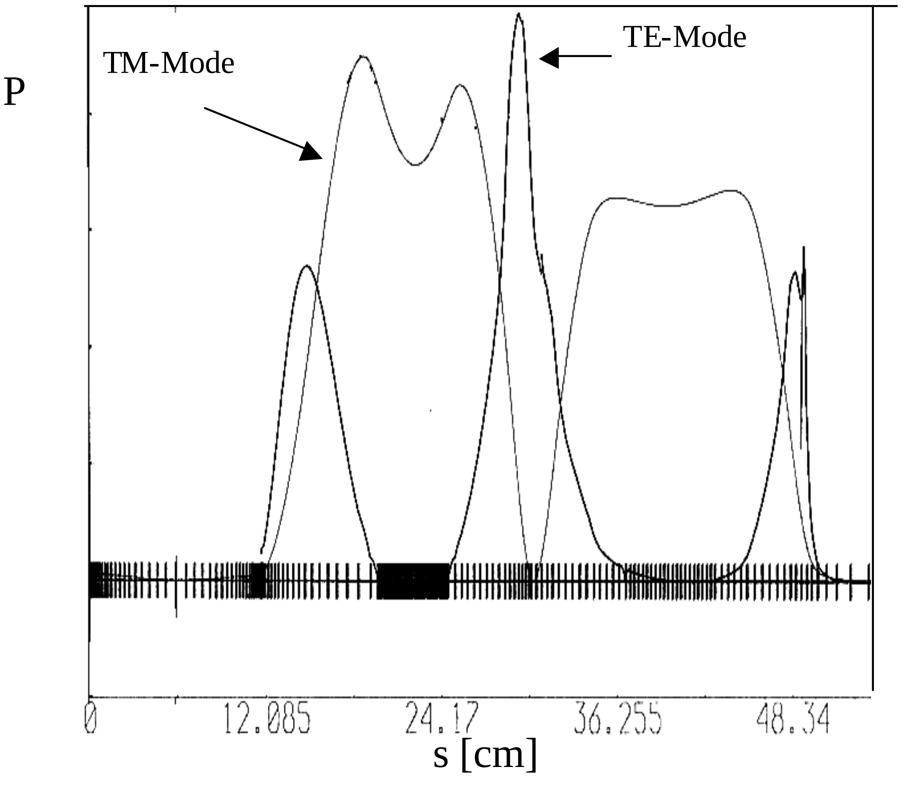
Spatial separation of the maximum power input

Cavity shape

f_{TM}=1300MHz, f_{TE}=3900MHz



Power input elong of the surface

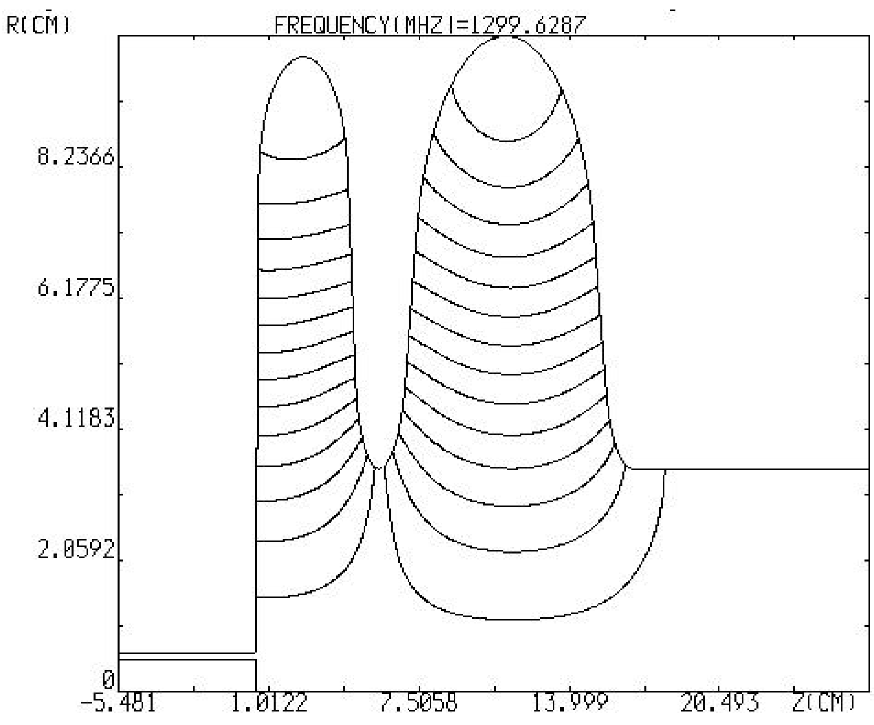


Magnetic modes create no fieldemission

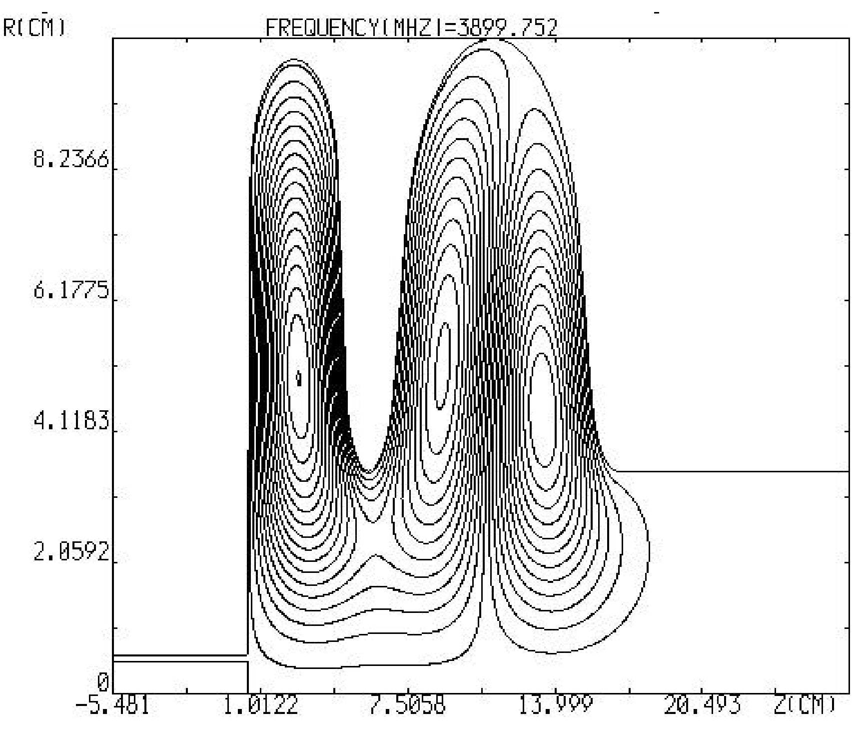
In cw – time regime the maximal possible accelerating fieldstrength of a superconducting cavity can not be used. (Large consumption of cryo power, large power losses in the Inputcoupler)

Beam dynamic of a superconducting RF photoelectron gun with electric and magnetic RF modes

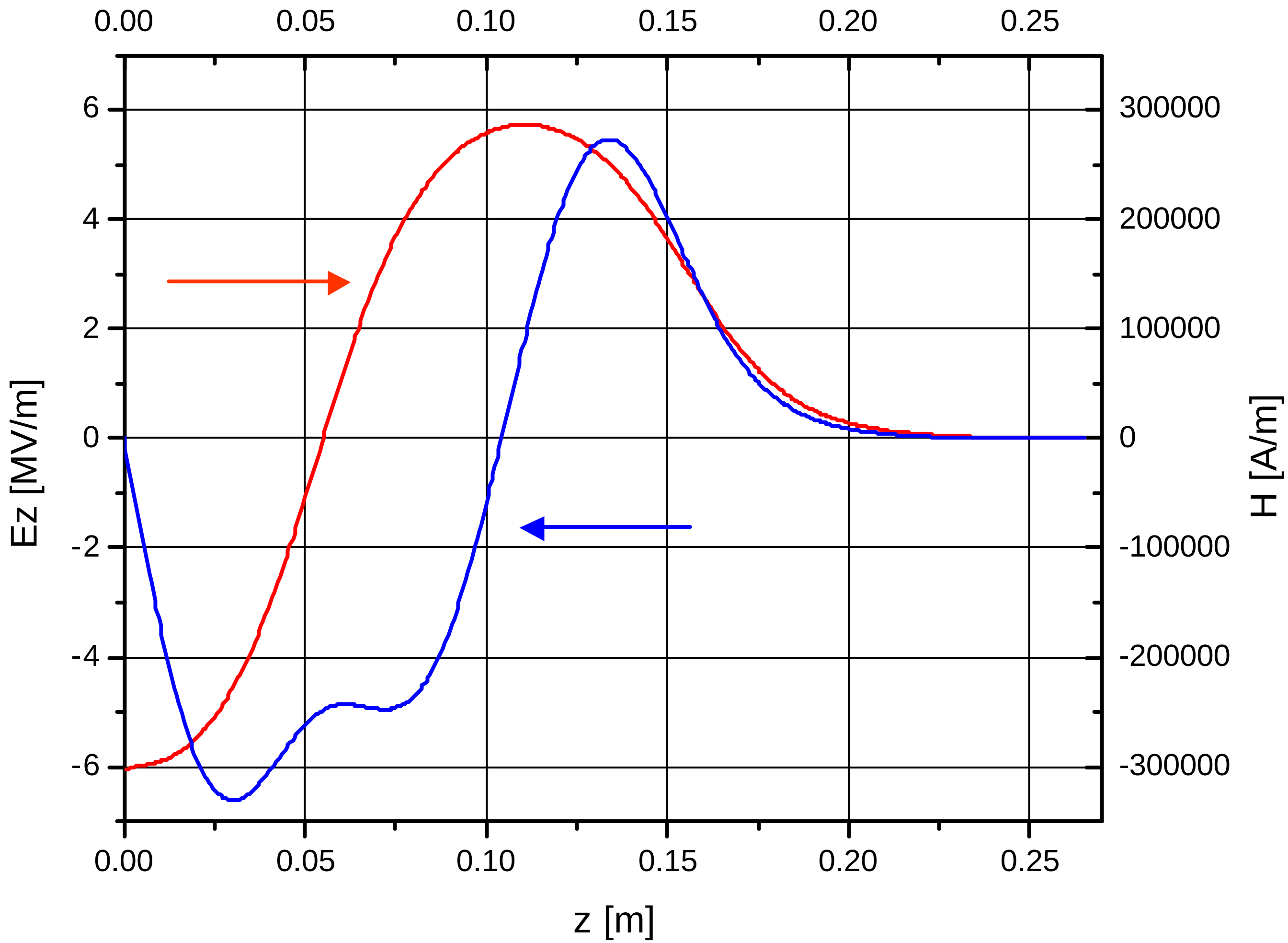
TM - Mode



TE - Mode



Magnetic and electric fieldstrength on the axis



Bunchparameter: Q = 1nC

Flat top profil $r = 1.2$ mm

$l = 20$ ps

Fieldparameter:

Electric mode

$f = 1300$ MHz

$f_{TM} = 58°$

$Ez_{max}(r=0) = 50$ MV/m

$Bs_{max} = 0.11$ T

Magnetic mode

$f = 3900$ MHz

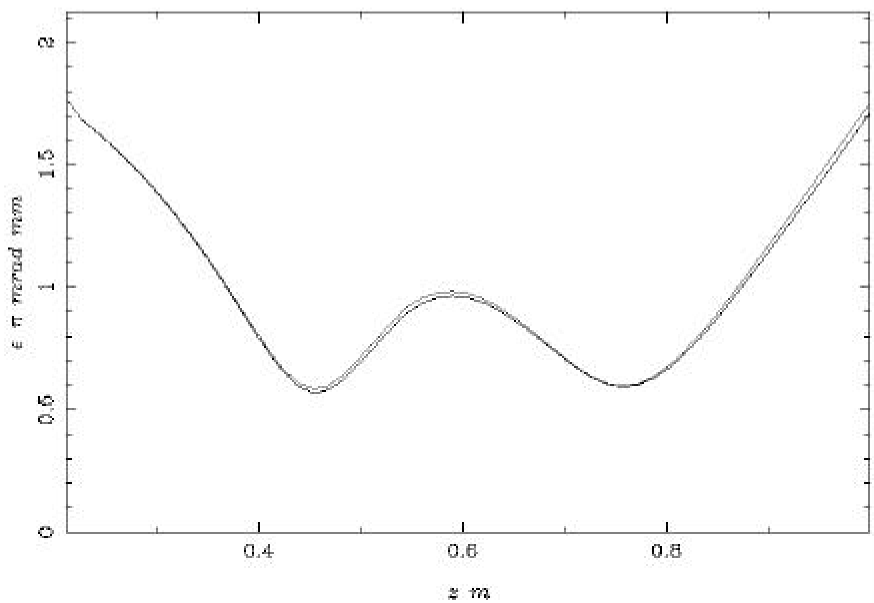
$f_{TM} = 57°$

$Bz_{max}(r=0) = 0.34$ T

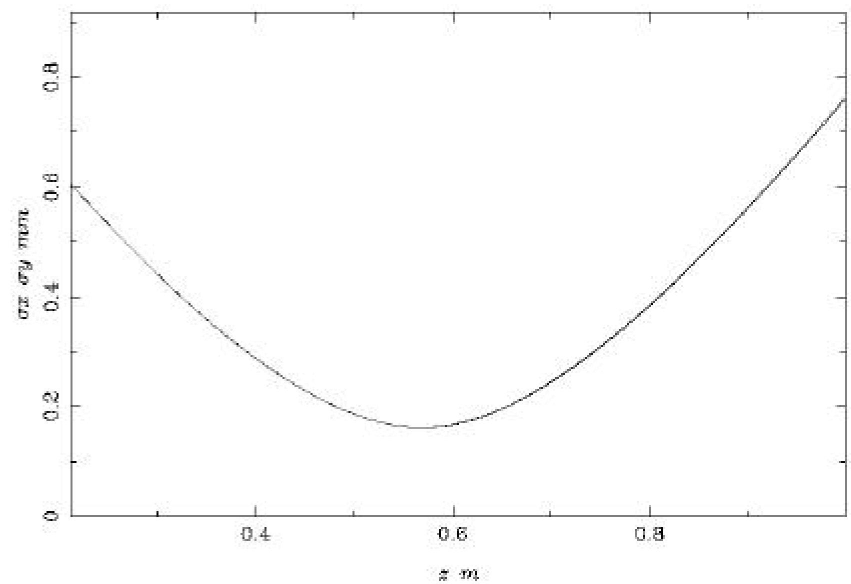
$Bs_{max} = 0.24$ T

Results

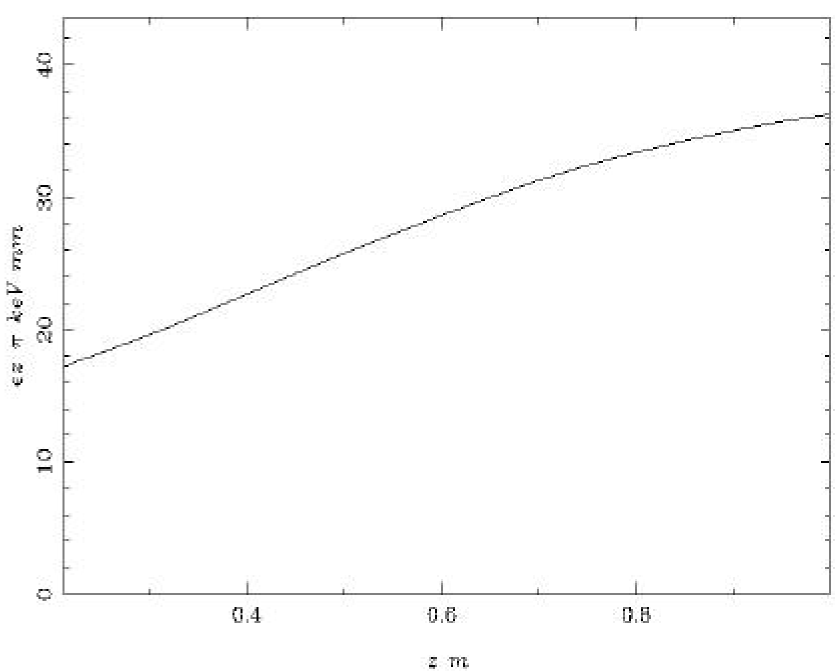
Transverse Emittance



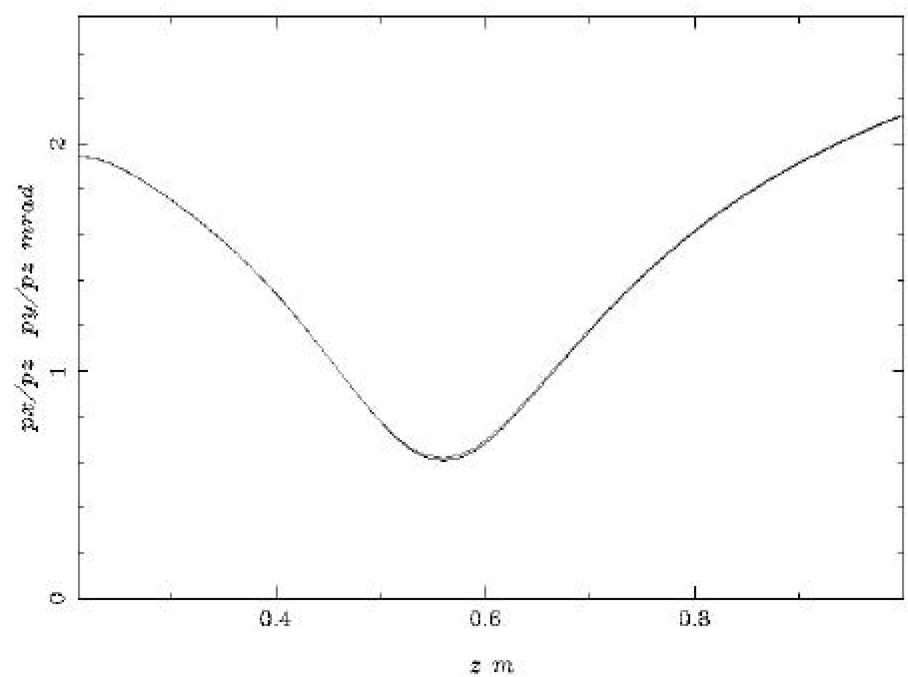
Beam Size



Longitudinal Emittance



Beam Divergence



Results:

$z = 0.47 m$

$s_{x,rms} = 0.2 mm$

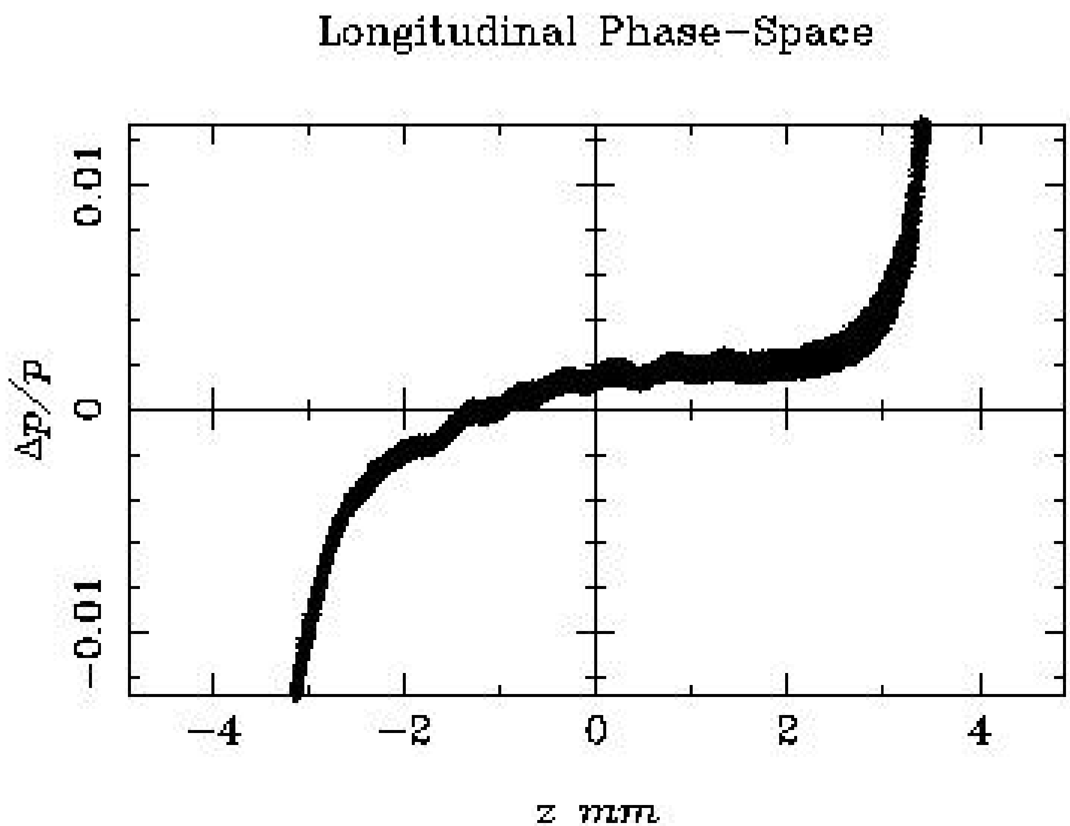
$s_{z,rms} = 1.9 mm$

$E = 4.44 MeV$

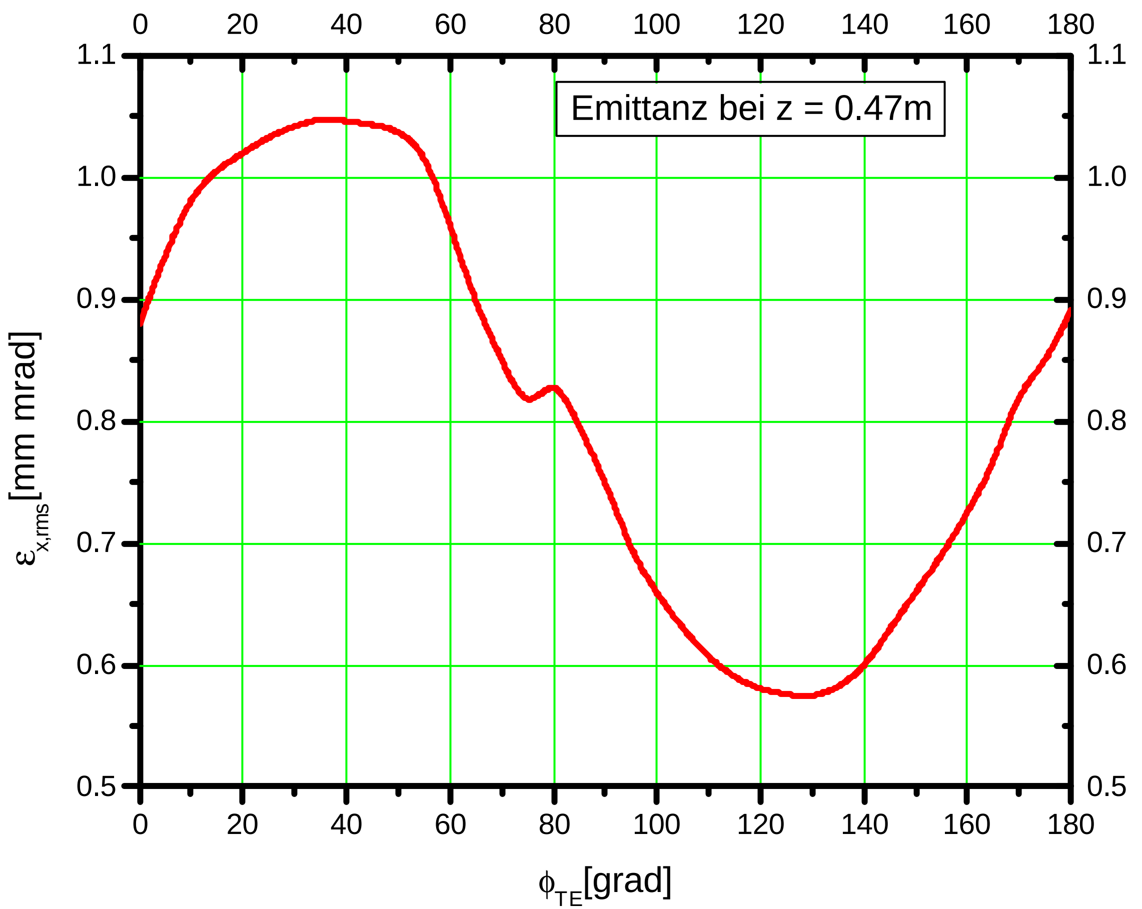
$e_{x,rms} = 0.6 mm mrad$

$e_z = 24 mm keV$

? E = 21 keV

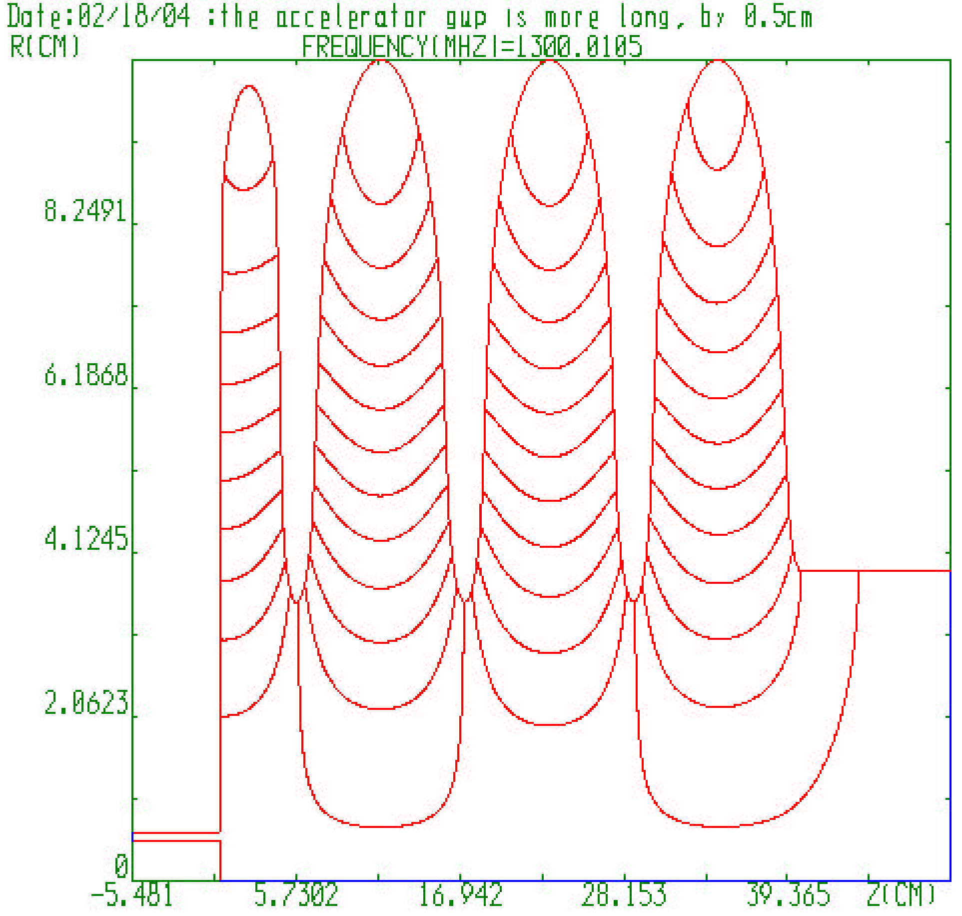


Phasedependence of the der emittance

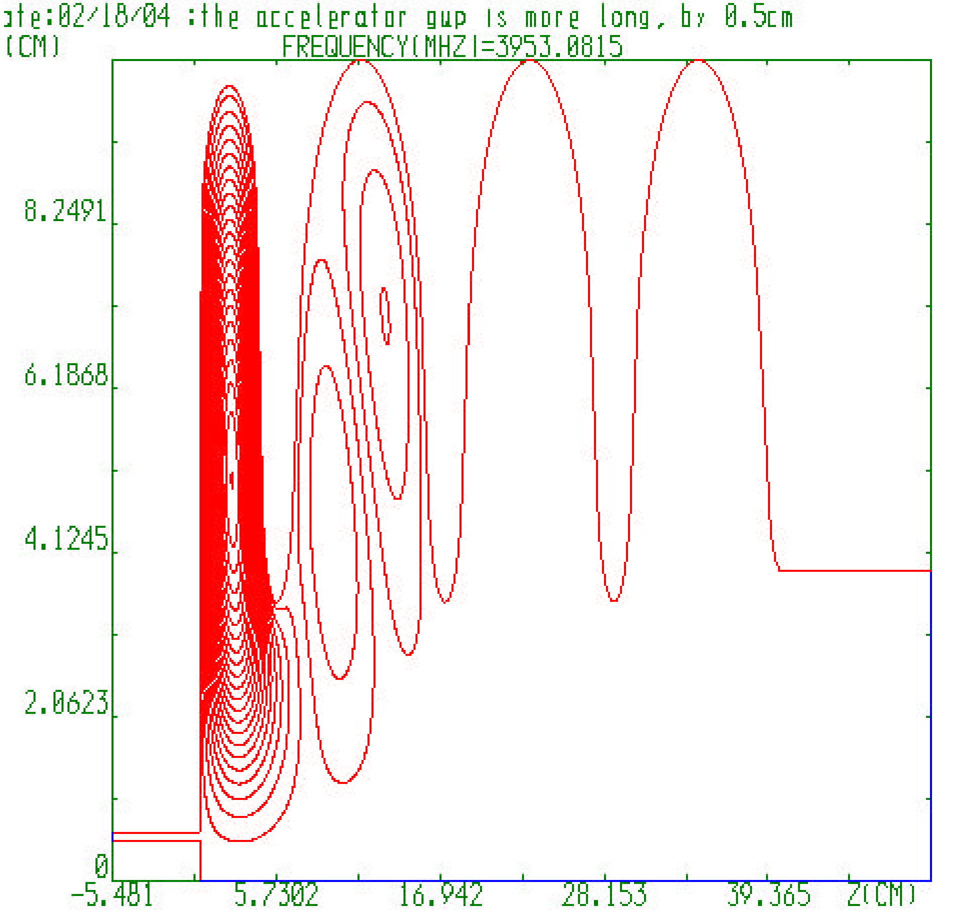


Fielddistribution in a 3 ½ cell cavity
Full cells have TESLA shape

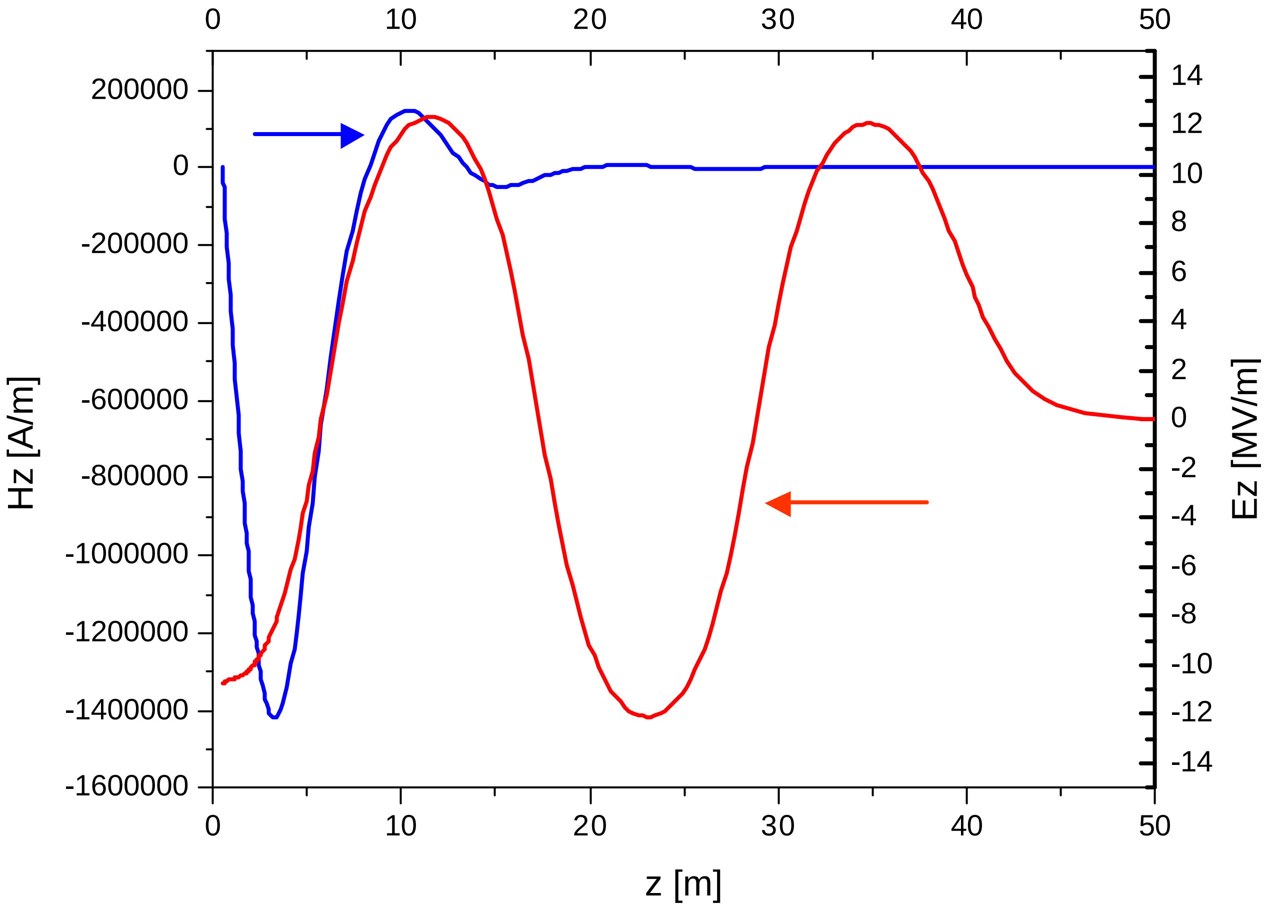
TM - Mode



TE - Mode



Fieldstrength at r = 0



Bunchparameter:	Q = 1nC		
	Flat top profil	r = 1.2 mm	
		l = 20 ps	

Fieldparameter:	Elektrical mode	f = 1300 MHz
		f_{TM} = 60°
		$Ez_{max}(r=0)$ = 50 MV/m
		Bs_{max} = 0.11 T
	Magnetic mode	f = 3953 MHz
		f_{TE} = 65°
		$Bz_{max}(r=0)$ = 0.338 T
		Bs_{max} = 0.223 T

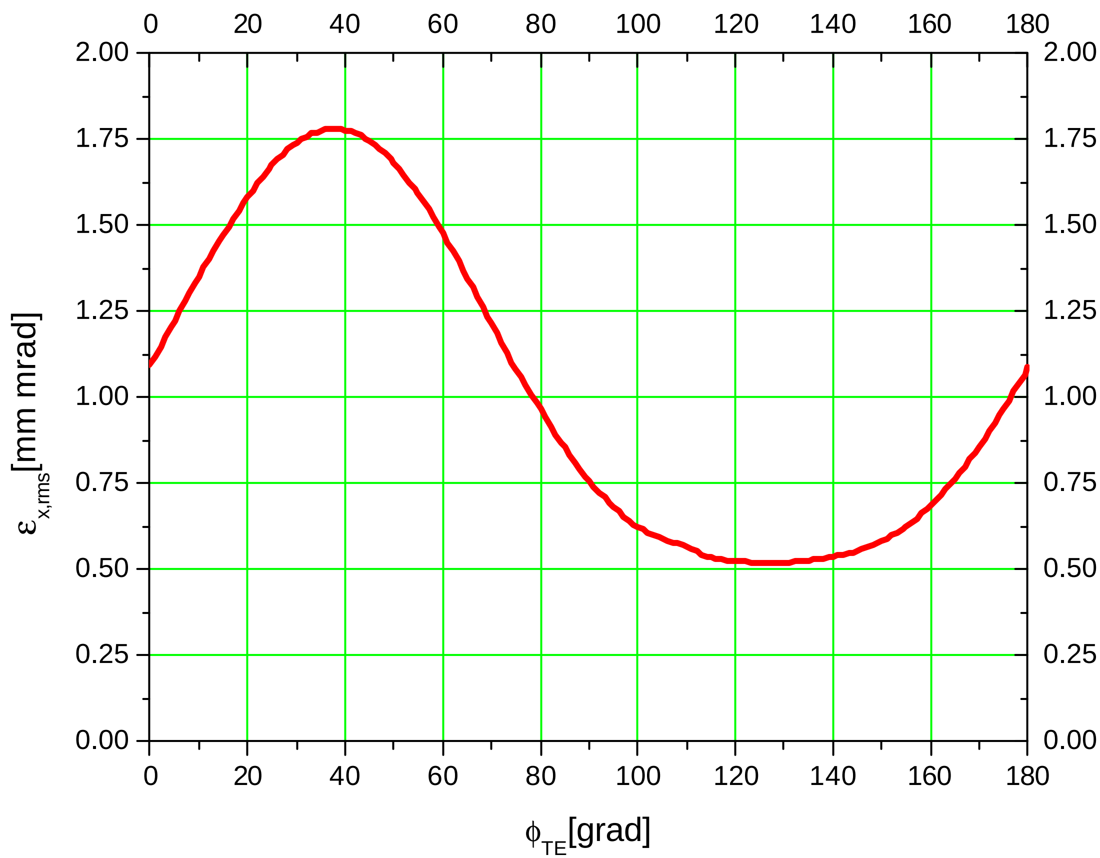
Results: z = 1.65m $e_{x,rms}$ = 0.5 mm mrad

$s_{x,rms}$ = 0.3 mm e_z = 41 mm keV

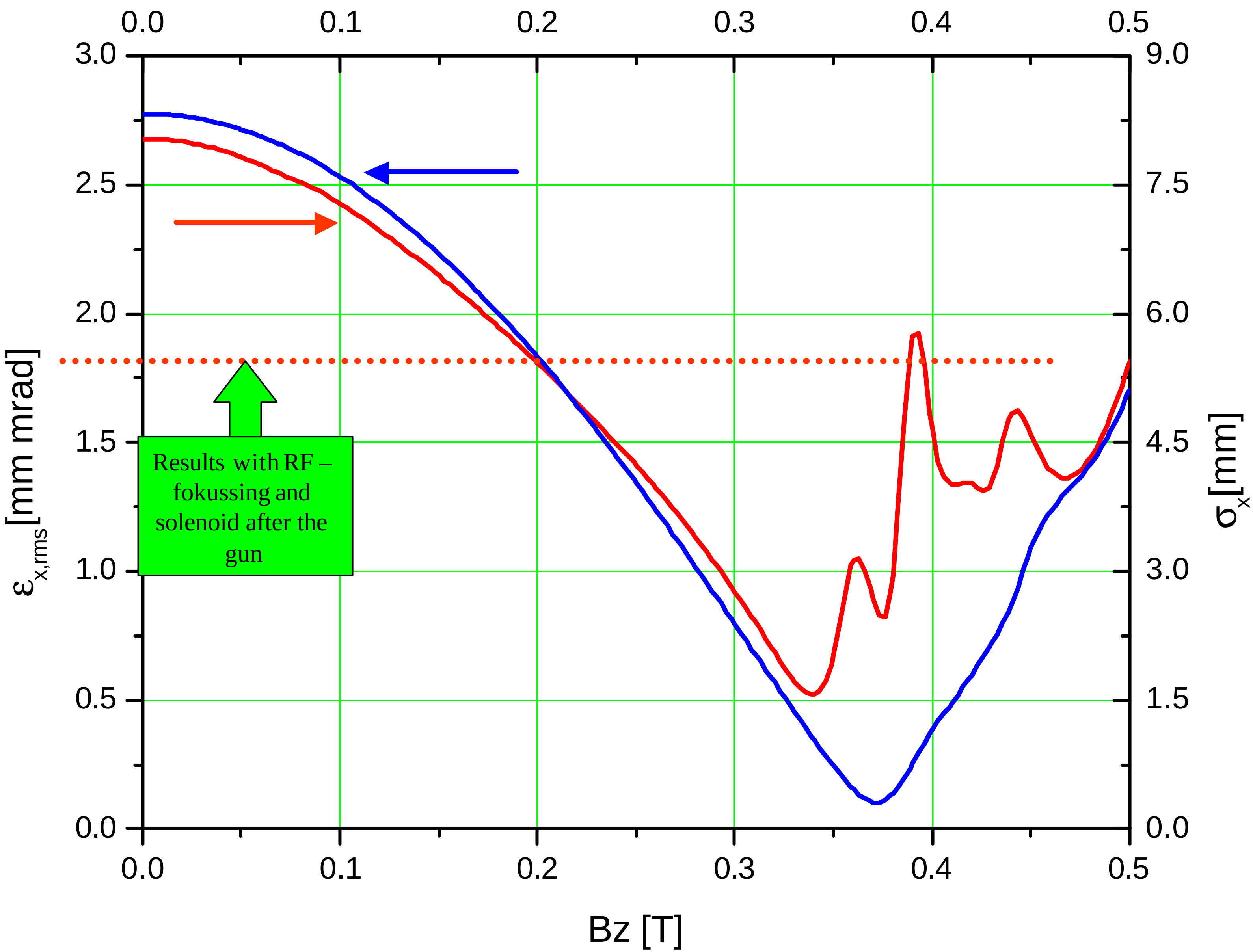
$s_{z,rms}$ = 2.1 mm ? E = 20 keV

E = 10.2 MeV

Transversale emittance as funktion of the phase of the TE - mode



Dependence of emittance and beam cross section of the magnetic field amplitude at z = 1.65m



Possibilities of realization

-Input of the TE – mode by the HOM coupler

-Measurement of the fieldstrength limits

-Tuning of TE und TM modes in the same cavity