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TECHNISCHE UNIVERSITÄT DARMSTADT

Coupler Kicks in the Third Harmonic Module for the XFEL

E. Gjonaj, W. Ackermann, T. Lau, T.Weiland (TEMF)
M. Dohlus (DESY)

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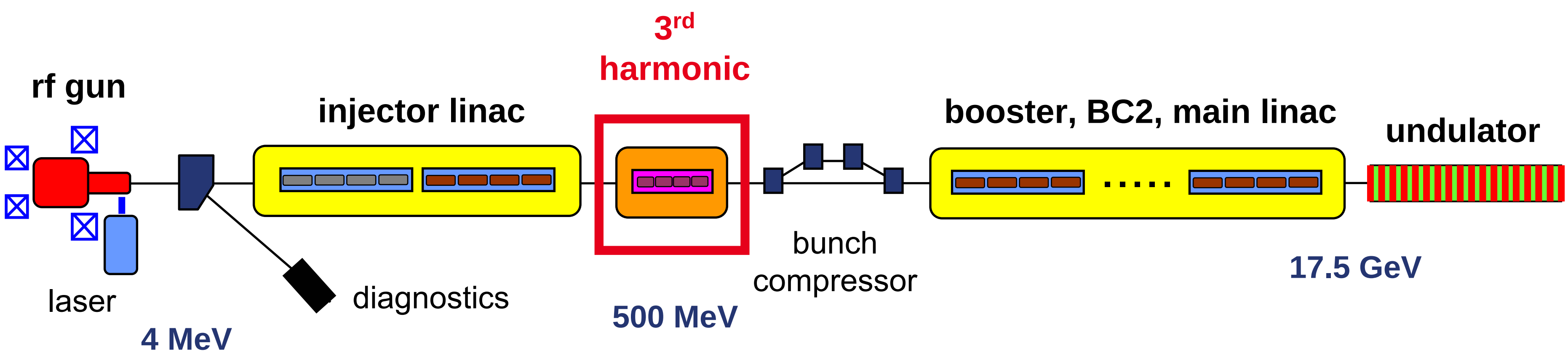
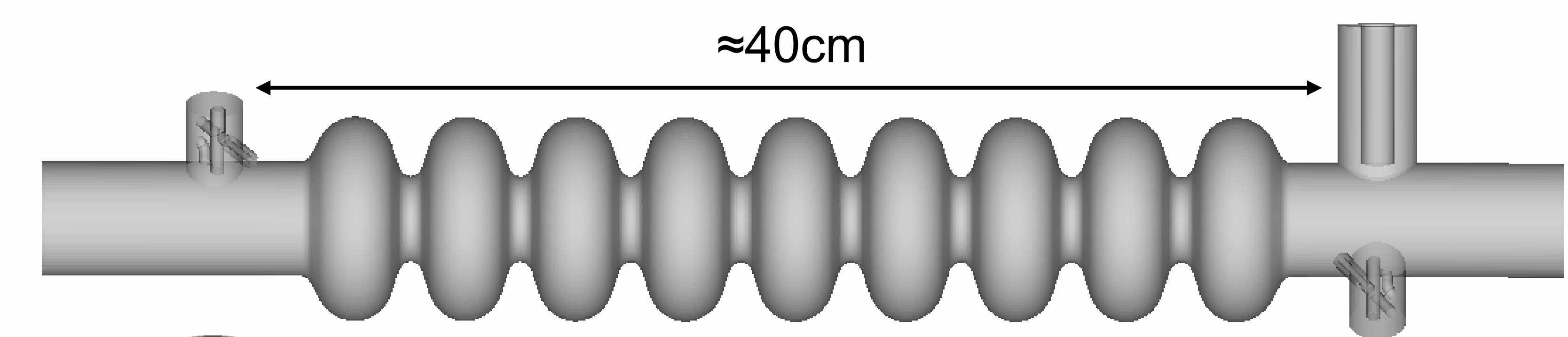
Introduction

- Third harmonic (3.9GHz) module for XFEL (and FLASH) at DESY. Designed at tested at FNAL
- Increase beam peak current by linearization of longitudinal phase space before the first BC
- Number of cavities/module and orientation of couplers still in discussion

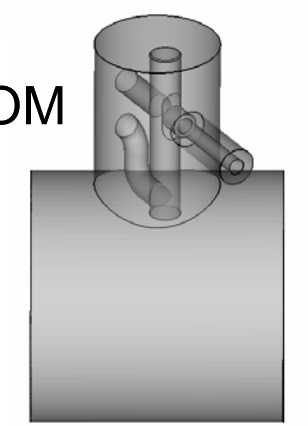


Introduction

Geometry of the 9-cell 3.9GHz cavity:



3.9GHz cavity



Coupler asymmetry causes transverse rf kicks and geometric wakefields on-axis

Introduction

Issues with the 3.9GHz system

- High field levels in the HOM coupler, thermal (?) quench with fracture: *solved by FNAL*
- Multipacting: *solved by FNAL*
- RF and wakefield kicks due to coupler asymmetry:
  - Low energy (E ~ 500MeV) and long beam (σ_z ~ 2mm). Strong impact of transverse rf and wake fields on beam quality
  - Higher frequency: fundamental mode field reach deeper into the tube and cavity cells. Larger transverse kick parameters than in 1.3GHz cavities are expected

Fundamental Mode Kicks

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Eigenvalue problem in the cavity:

$$\mathbf{C}^T\mathbf{C}\cdot\mathbf{e}-\omega^2\mathbf{M}\cdot\mathbf{e}=0$$

(for most discretization types)

- Requirement: full cavity analysis in 3D including couplers
- Problem: huge computational resources needed (several hundred millions of unknowns)
- Non-dissipative approach: standing wave at 3.9GHz
  - Must fulfill resonance condition by properly truncating input coax with electric (magnetic) boundaries
  - No approximation; less general but saves ½ of the dofs
  - Still very critical numerical issues (see paper WE2PBC04)

Fundamental Mode Kicks

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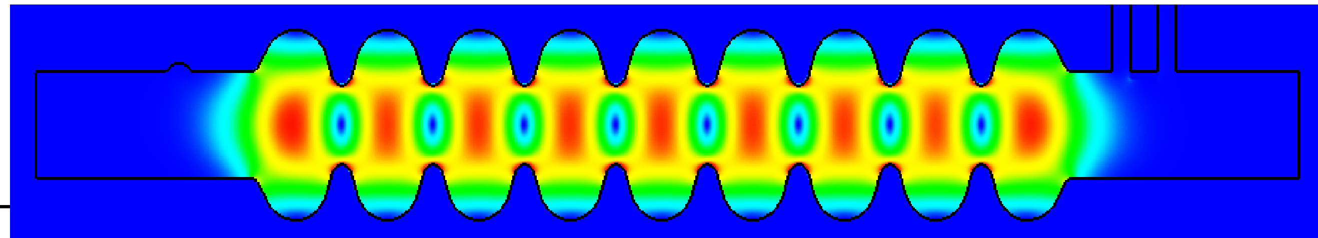
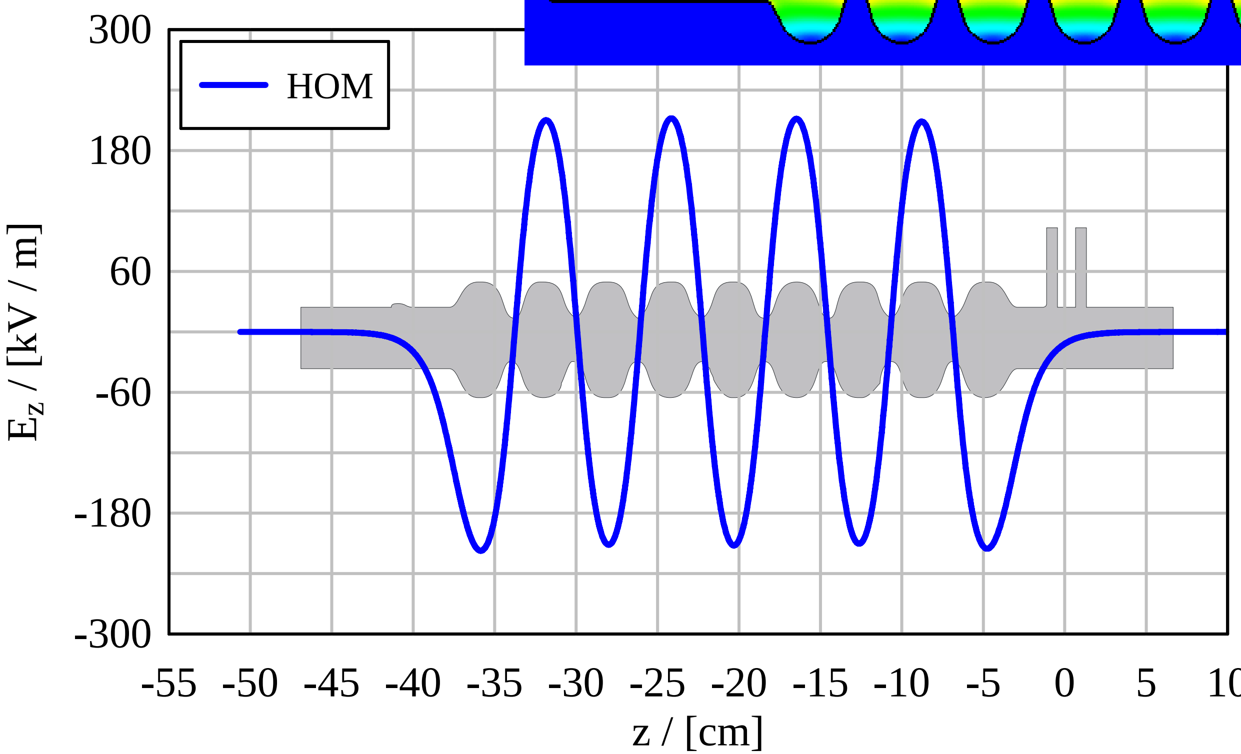
Peak input power:

P = 1W

electric field strength (horizontal plane)





resolution: 0.25mm

no. grid cells: ~240 mil.

no. processors: 338

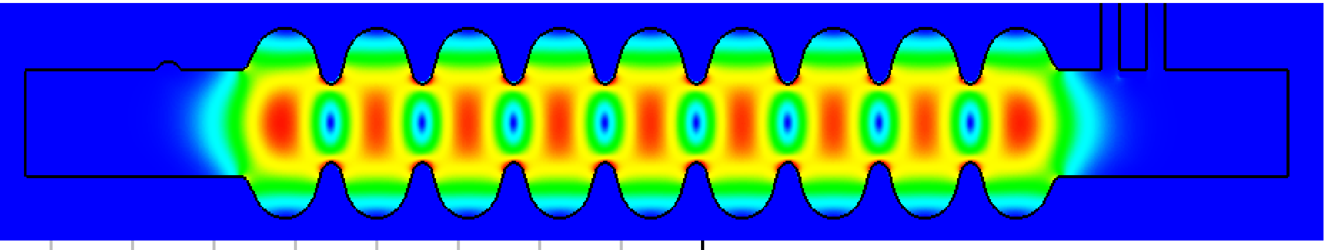
CPU time: ~20hrs

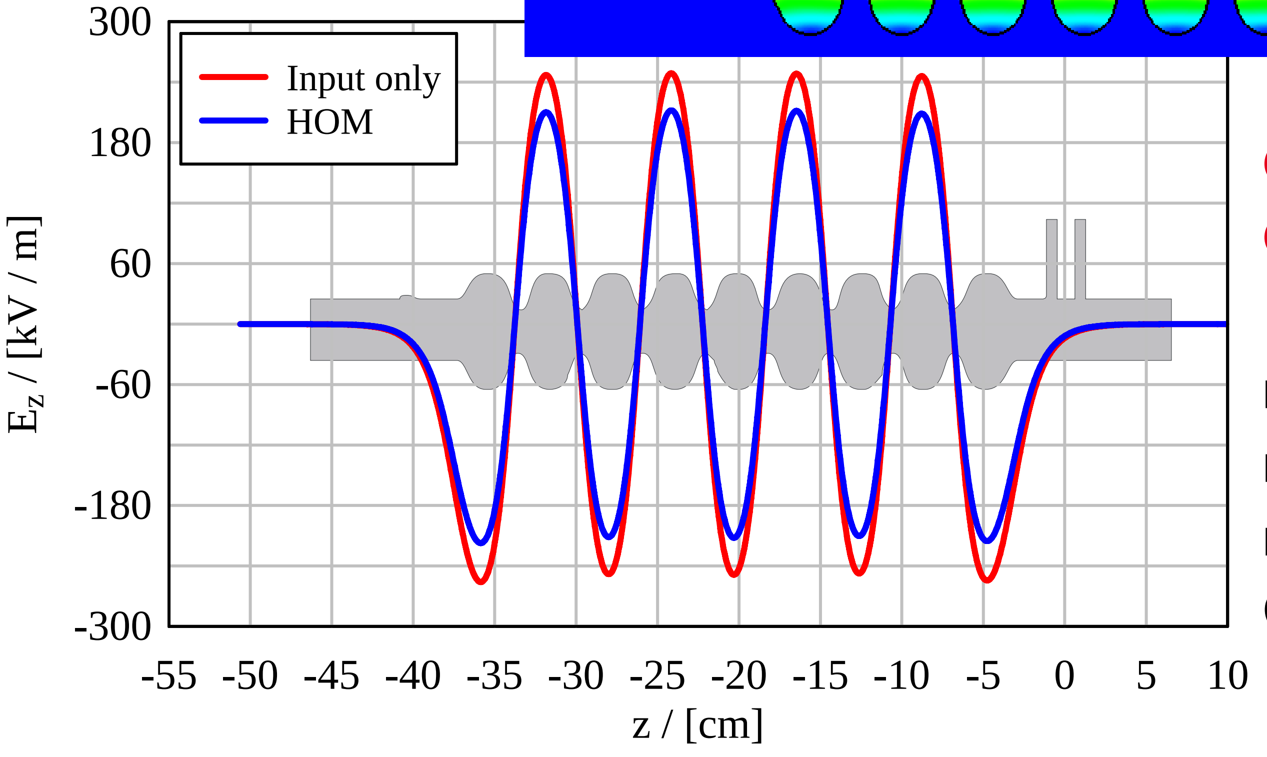
Fundamental Mode Kicks

Peak input power:

P = 1W

electric field strength (horizontal plane)





$Q_{ext}(\text{input}) = 1.2 \cdot 10^6$

$Q_{ext}(\text{HOM}) = 0.9 \cdot 10^6$

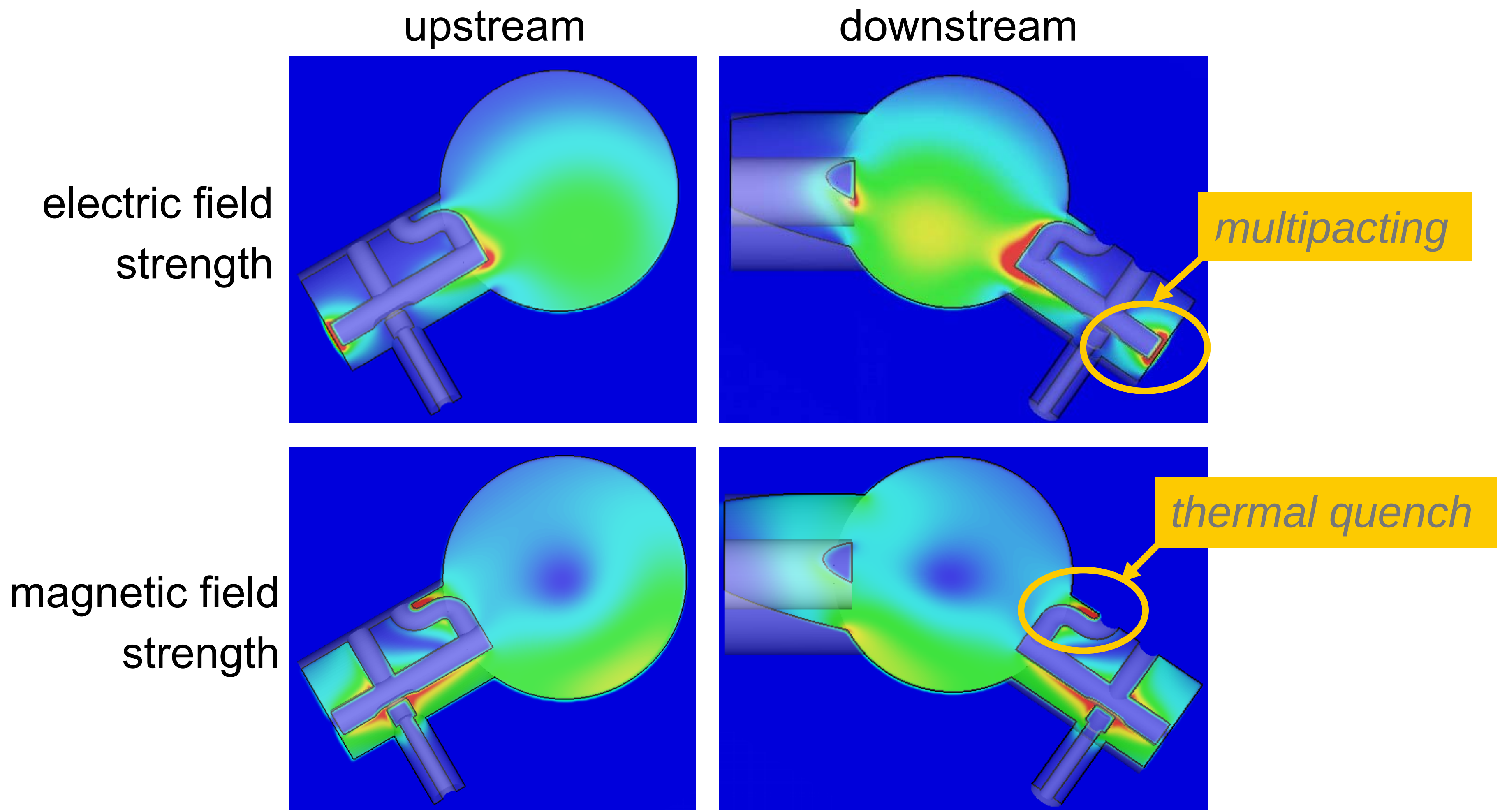
resolution: 0.25mm

no. grid cells: ~240 mil.

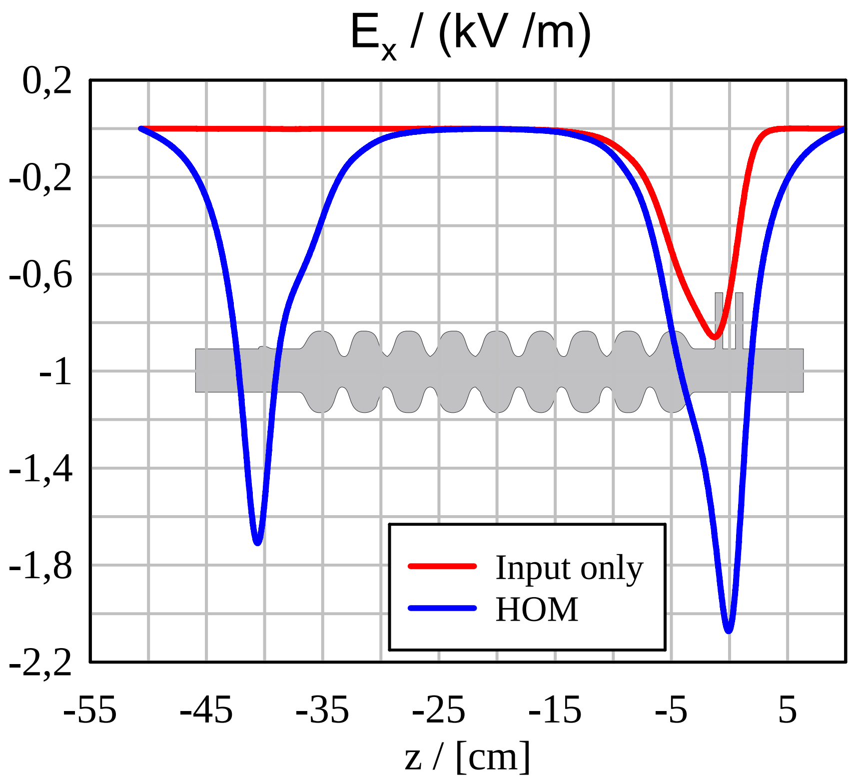
no. processors: 338

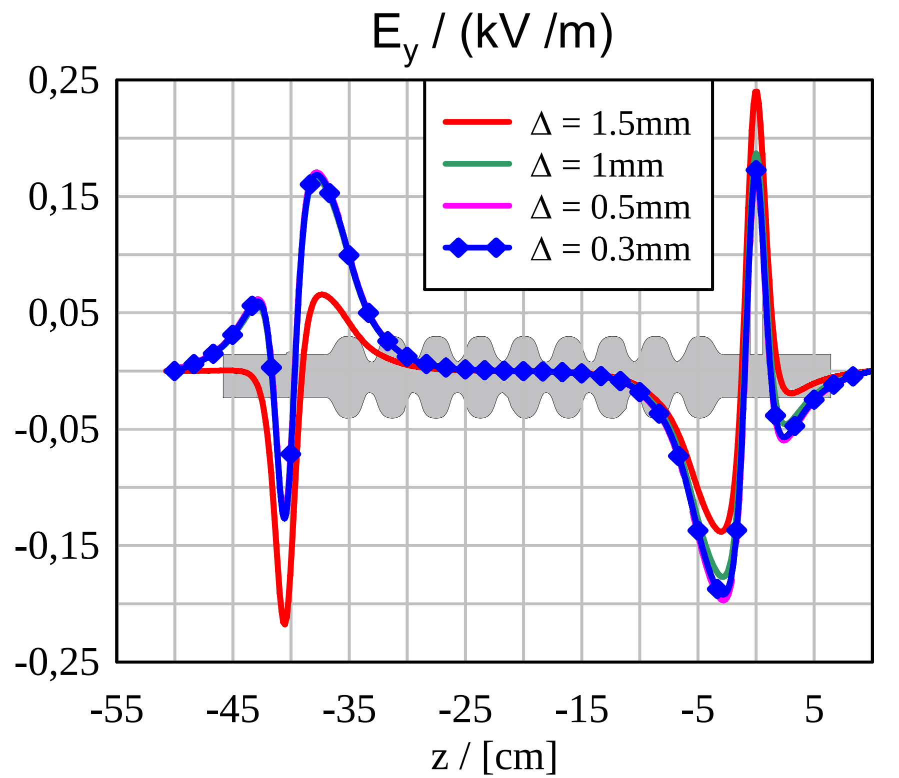
CPU time: ~20hrs

Fundamental Mode Kicks



Fundamental Mode Kicks





- Coupler fields penetrating up to 3 cells into the cavity
- Transverse components 10^3 smaller than accelerating field

Fundamental Mode Kicks

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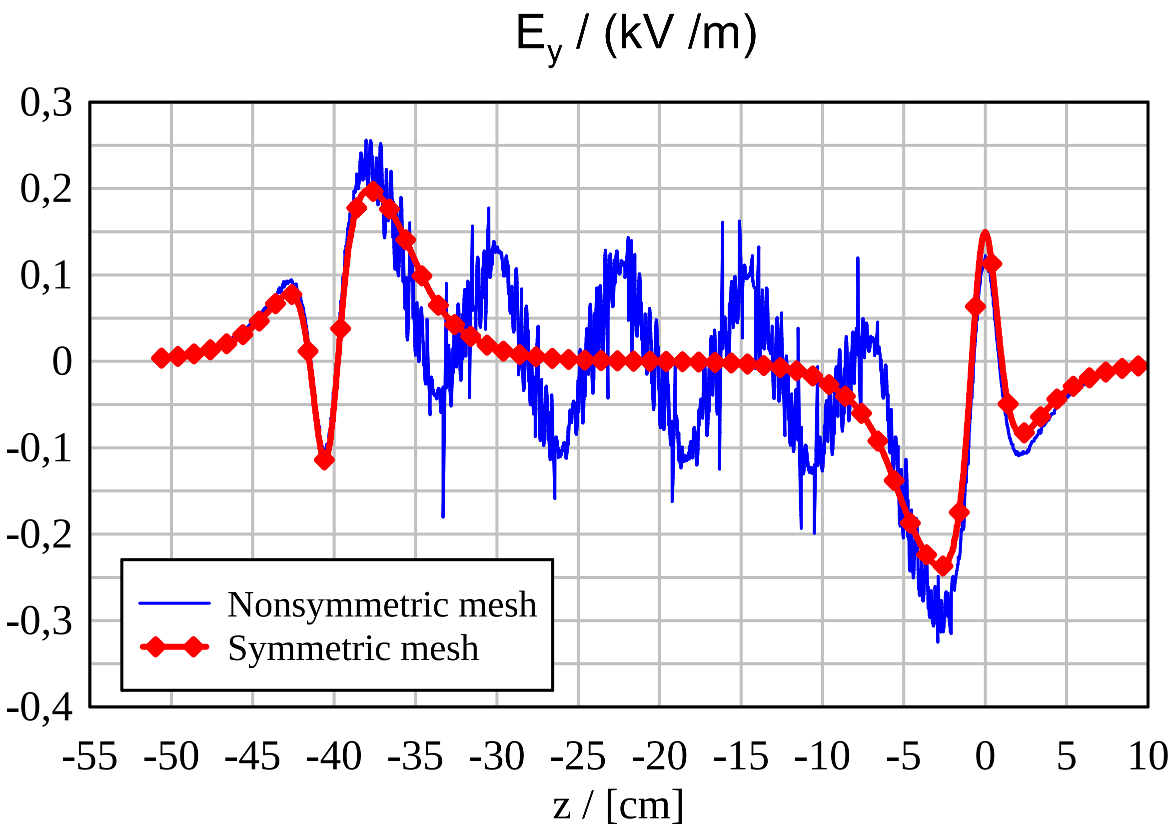
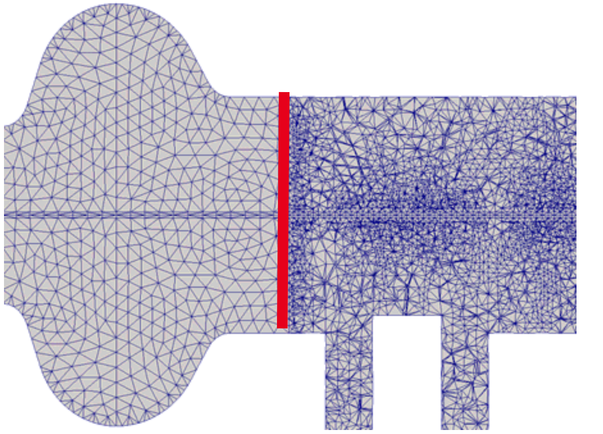
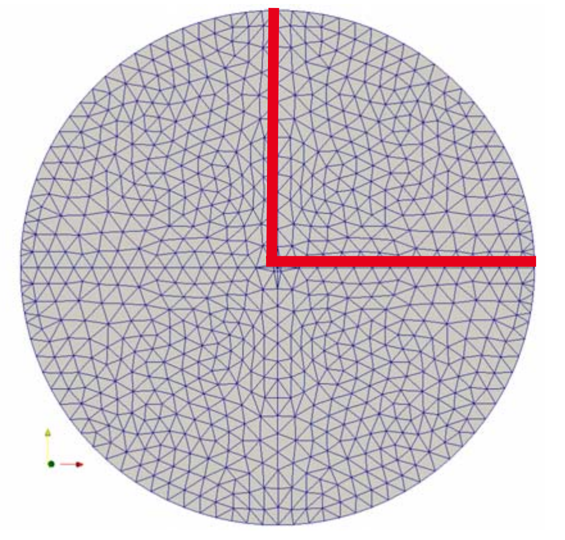
Construction of symmetric tet. meshes







Fundamental Mode Kicks

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rf kick parameters

	$10^6 \times V_x / V_z$	$10^6 \times V_y / V_z$
3.9GHz input only	-182.0 + 50.05 **i**	0.271 + 0.0 **i**
1.3GHz downstream*	-25.0 + 51.5 **i**	32.2 + 5.2 **i**
3.9GHz downstream	-378.0 - 96.19 **i**	65.7 + 199.9 **i**
1.3GHz upstream*	-57.1 + 6.6 **i**	-41.4 - 3.5 **i**
3.9GHz upstream	-140.8 + 262.5 **i**	-57.9 + 168.0 **i**
1.3GHz total*	-82.1 + 58.1 **i**	-9.2 + 1.8 **i**
3.9GHz total	-519.6 + 166.3 **i**	7.8 + 367.9 **i**

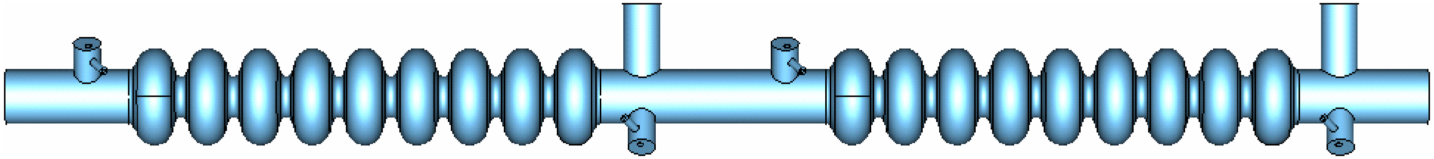
*I. Zagorodnov, M. Dohlus, ILC Workshop, DESY, 2007
*N. Solyak, EPAC 2008, MOPP042

Wakefield Kicks

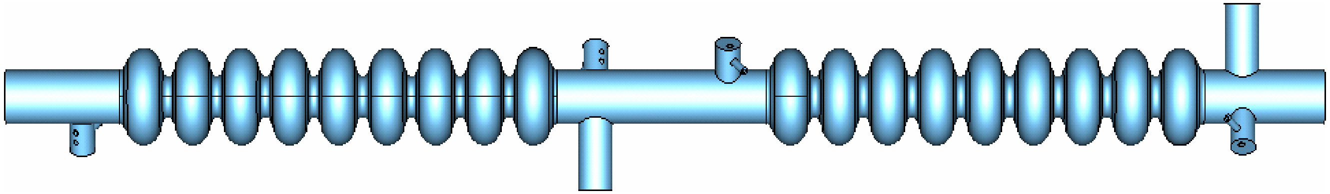
Computation of short range wakefields with PBCI

- Bunch parameters: $\sigma_z = 2mm, \sigma_x = \sigma_y = 0.35mm$
- Single and 4-cavity configurations: Global compensation of transversal wakes by rotating cavities

configuration (a): simple cavity string

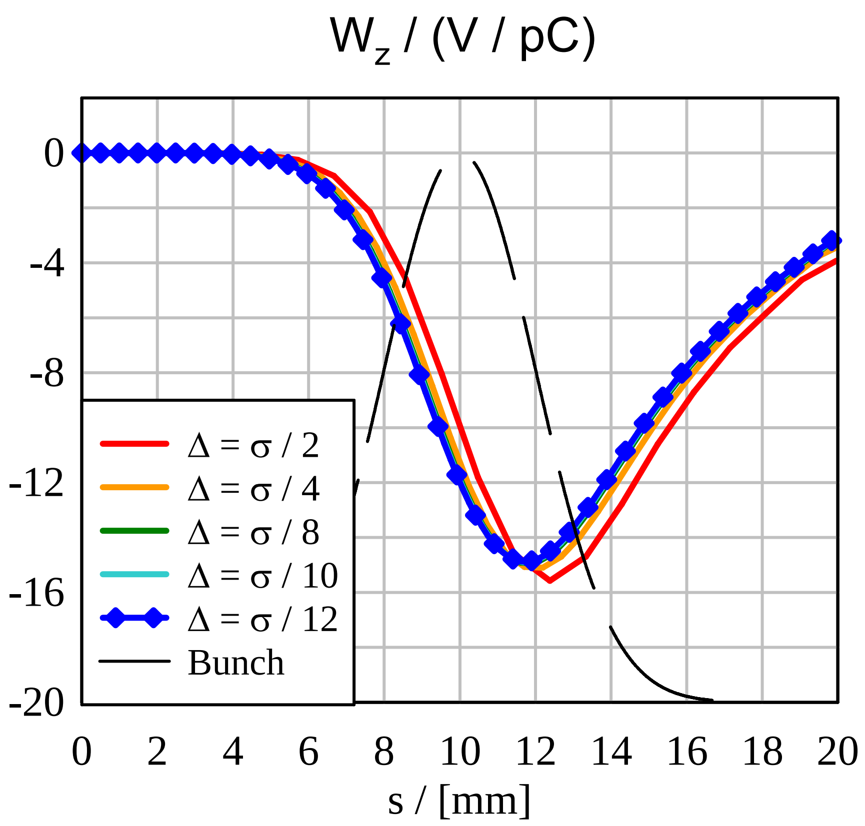


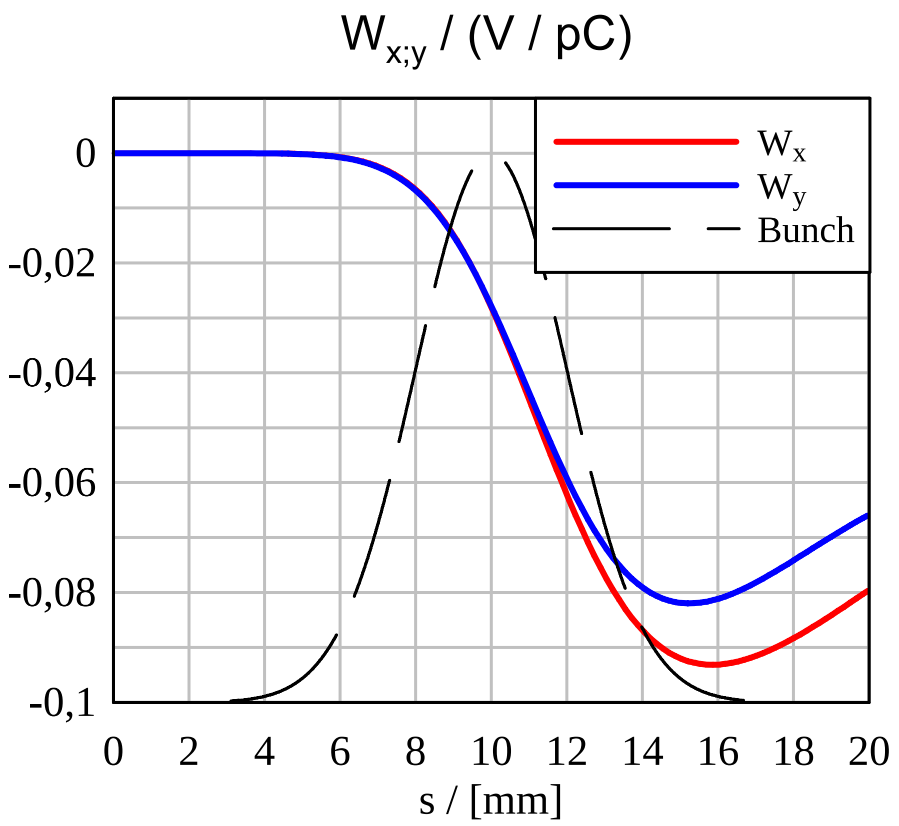
configuration (b): string with rotated cavities



Wakefield Kicks

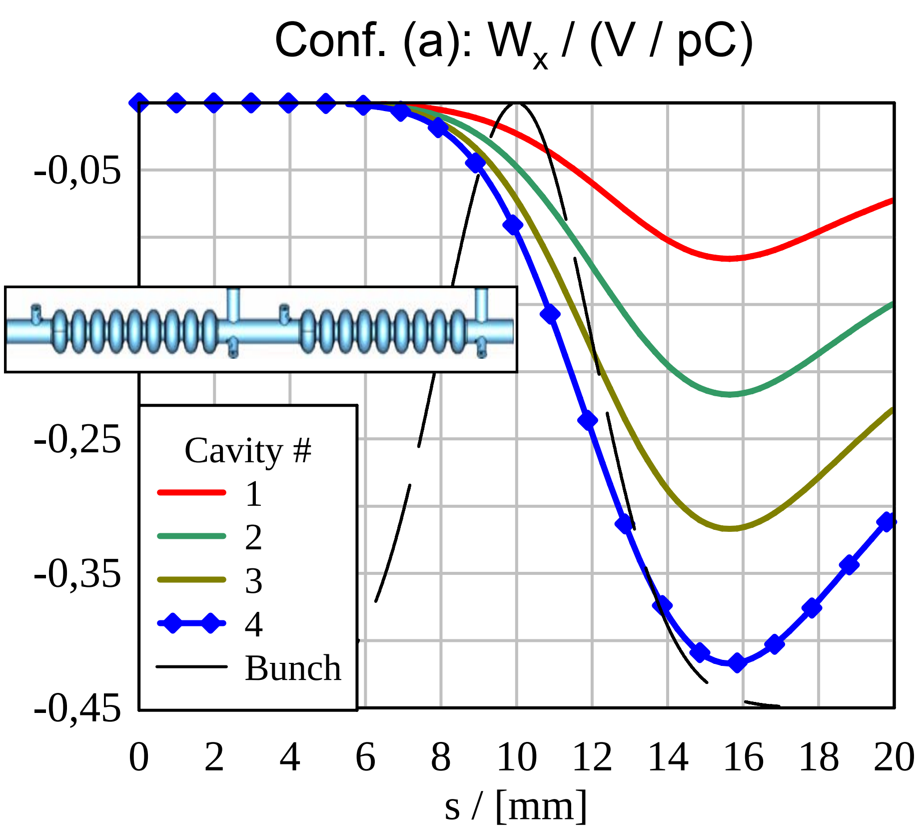
Wake potentials in the single cavity

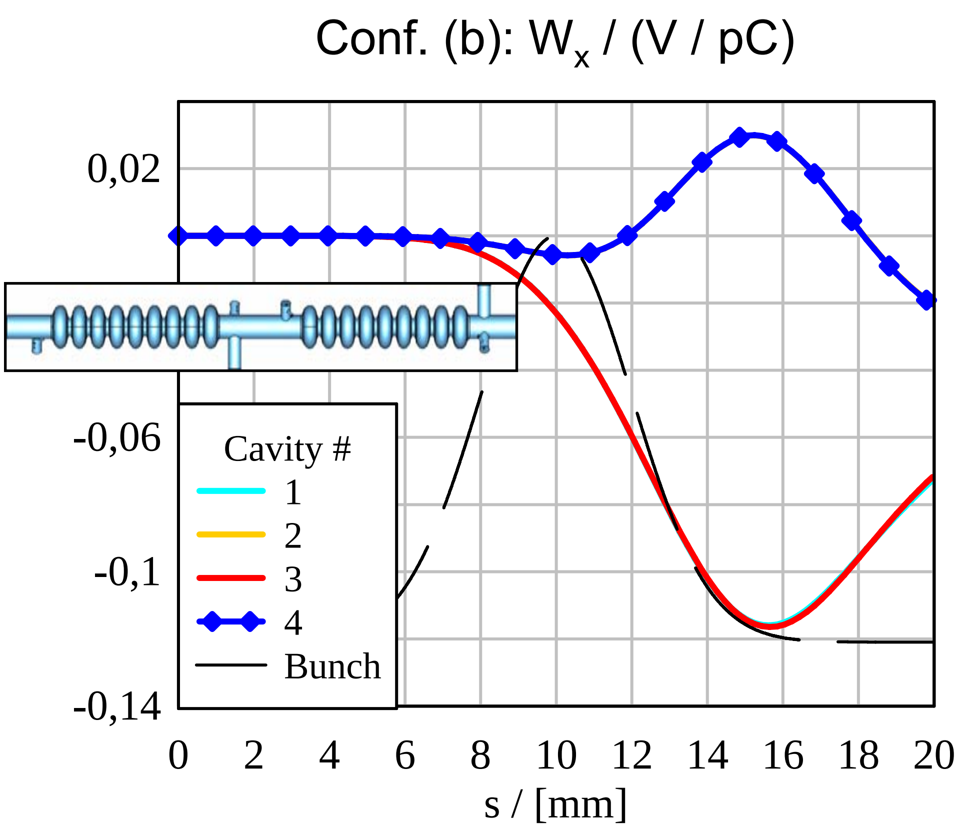




Wakefield Kicks

Wake potentials in 4-cavity module





Wakefield Kicks

wakefield kick parameters

	k_x (V / nC)	k_y / (V / nC)
1.3GHz: single cavity* (σ_z = 1mm)	-10.8	-10.0
3.9GHz: single cavity	-31.0	-29.9
1.3GHz: 4-cavities** (σ_z = 1mm)	-30.4	27.2
3.9GHz: 4-cavities	-125.5	-117.9
3.9GHz: 4-cavities (rotated)	0.75	0.9

*K. Bane et al, EPAC 2008, TUPP019

**M. Dohlus et al, EPAC 2008, TMOPP013

Discussion

- The computation of transverse fields in cavities with slightly perturbed rotational symmetry requires special attention
- Large impact of rf kicks on beam is expected. First estimation of emittance growth (using FLASH parameters):

$E_0 \approx 140\text{MeV}$, $G = 14\text{MV/m}$, $\sigma_z \approx 2\text{mm}$, $\varepsilon_0 \approx 1.7\text{mm-mrad}$

$\rightarrow \Delta\varepsilon \approx 0.1\text{mm-mrad}$ ($\Delta\varepsilon/\varepsilon_0 \approx 6\%$)

- More detailed emittance studies are necessary
- Wakefield contribution / cavity comparable with that in TESLA cavities
- In a 3.9GHz module with rotated cavities wakefield kicks can be (almost) perfectly compensated

Thank you for your attention