RF field asymmetry simulations for the PITZ RF Photo Gun.

The PITZ RF Photo Gun

Motivation

Field simulations

Particle tracking simulations

Results

Conclusions

Igor Isaev
DPG-Frühjahrstagung
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DESY

The PITZ RF Photo Gun

The RF photo gun purpose is high brightness beam production for FEL application.

The RF photo gun operates with a standing wave regime in the π-mode with resonant frequency of 1.3 GHz

The gun consists of:
- normal-conducting cavity (1.6 copper cells)
- exchangeable molybdenum cathode with CuBe contact spring
- pair of solenoids

Design concept for the PITZ (XFEL) injector (RF gun) – *rotational symmetry* of the beamline.
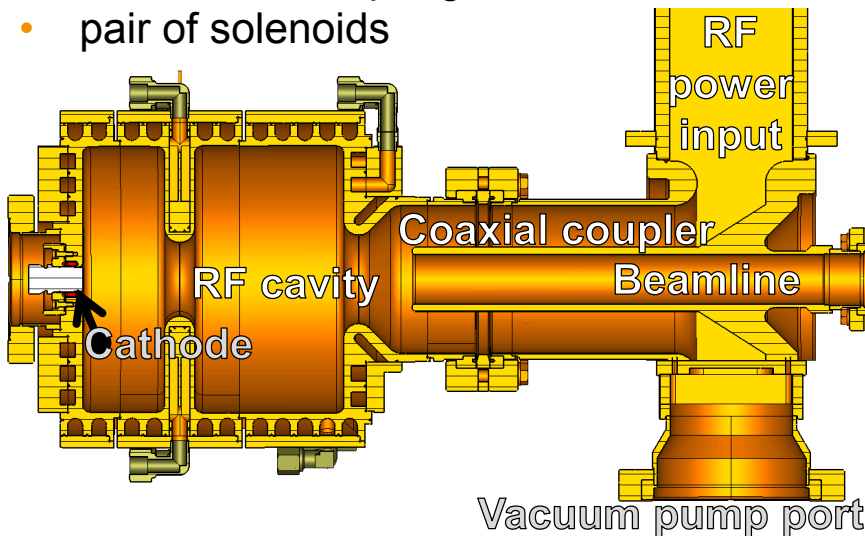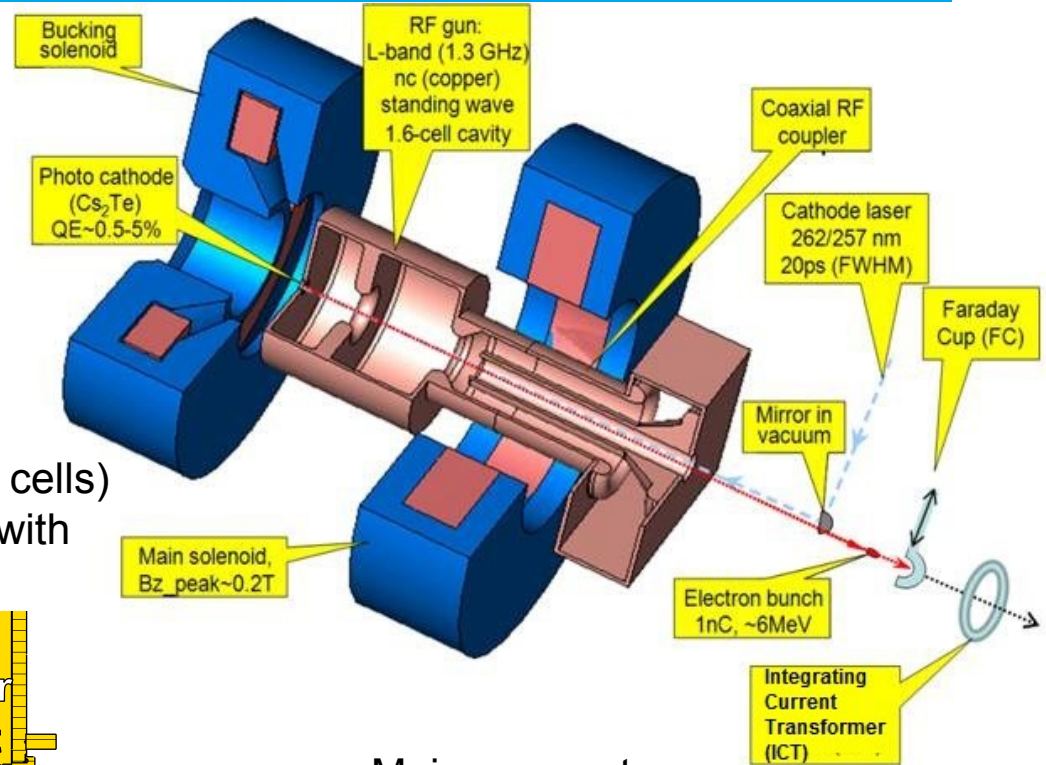
Main parameters

Accelerating gradient at the cathode, MV/m	60
Beam energy after gun, MeV	~6.5
Full RF power, MW	8
Number of bunches in the train	1..700
RF pulse, µs	≤800
Repetition rate, Hz	10

Motivation

> The electron beam asymmetry was observed during emittance measurements at PITZ.

> The asymmetry is found for the beam transverse profile.

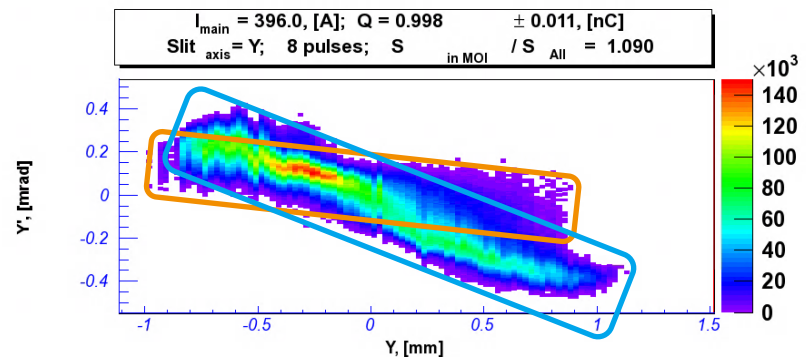> The electron beam emittance shows additional undesirable tails which say about beam asymmetry

Electron beam at the observation screen
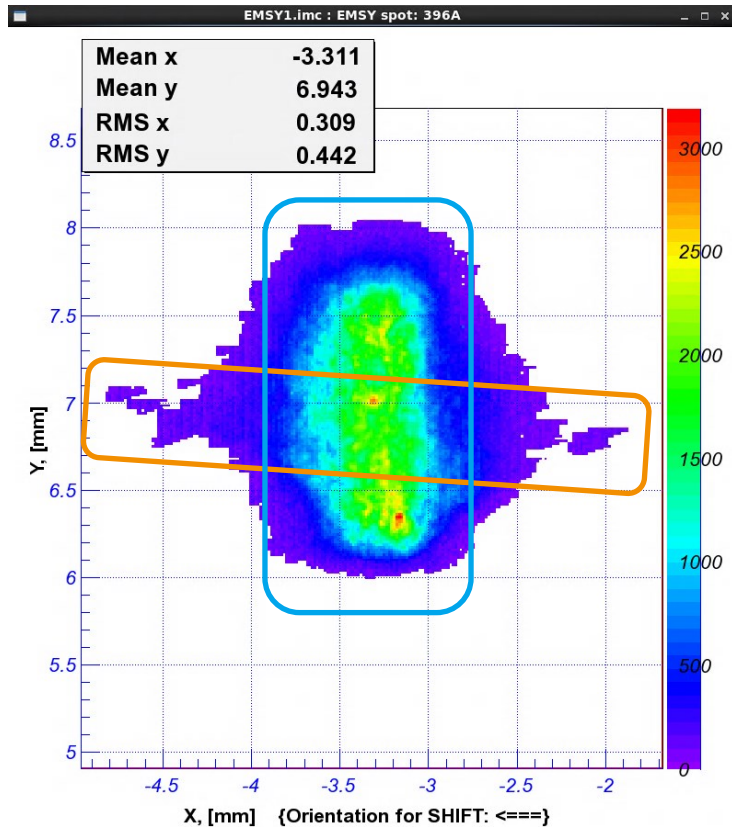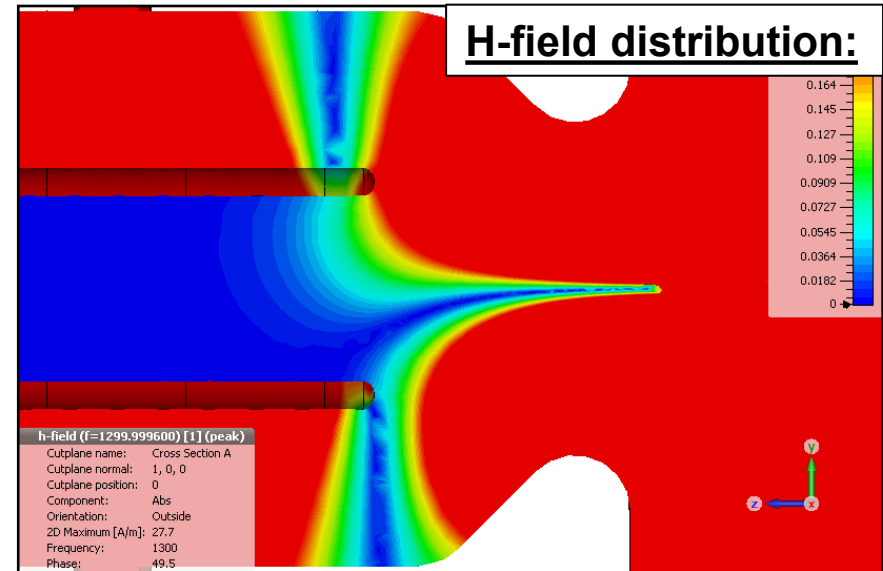

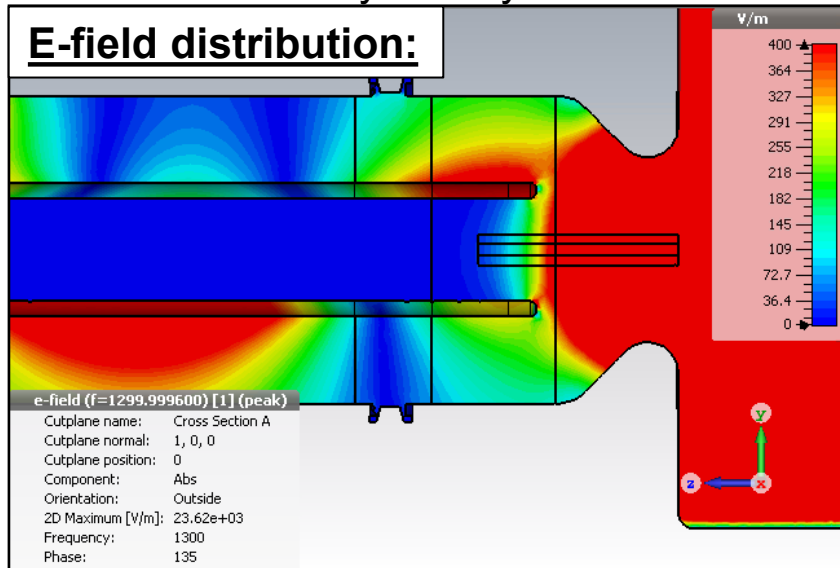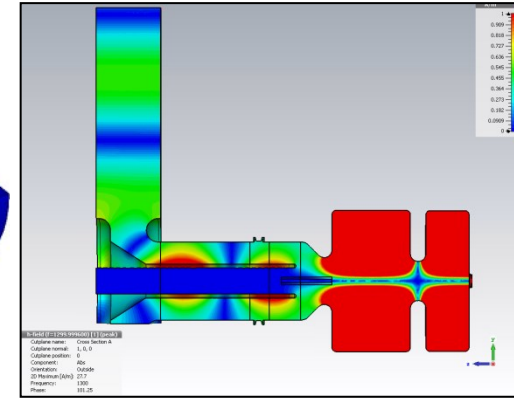## x phase space of the electron beam
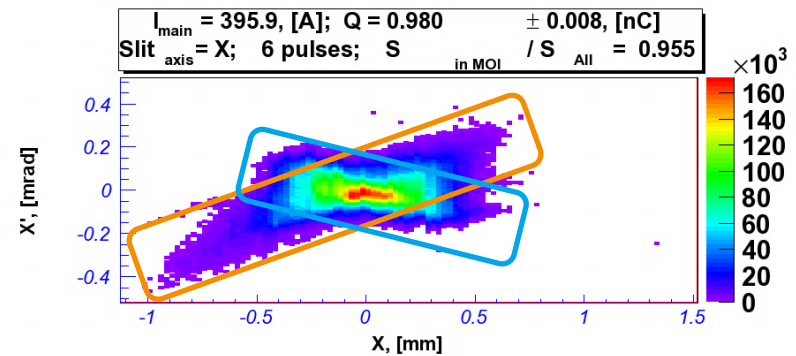
y phase space of the electron beam

> ## RF field simulations (CST MWS):

- The full model of the gun:
    - the gun cavity
    - the coupler
    - simplified cathode
- Frequency domain solver (F-solver)
- Tetrahedral mesh (~10^6 elements) with 2nd order curved elements
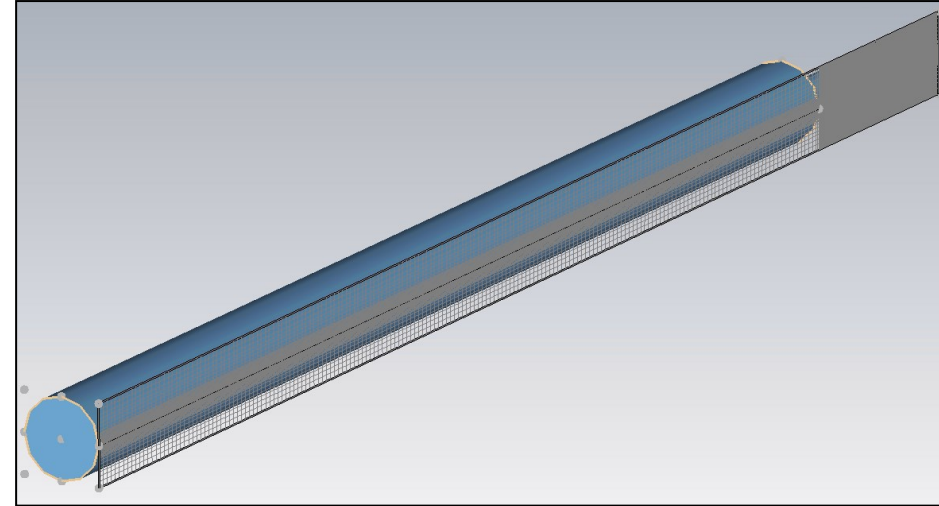- Half structure symmetry

E-field distribution:

H-field distribution:
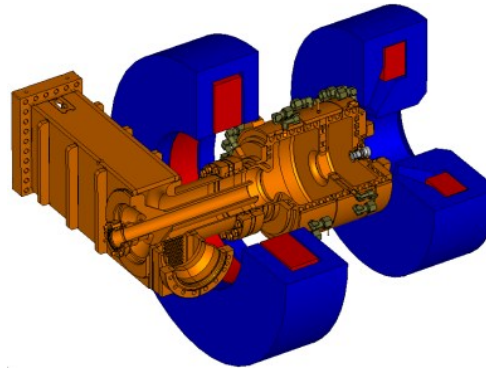
The kick origin is:
- *asymmetric transition* for WR650 to coaxial waveguide
- Too *short* coaxial *antenna*

Model for particle tracking

Particle tracking in CST particle studio

> - The simplified model of the gun:
>   - 2 cylinders for particle tracking
>   - 2 simplified cathode models
> - Solver:
>   - Tracking (Trk)
>   - Particle in cell (PIC)
> - Hexahedral mesh (~$1.2 \cdot 10^6$ elements)
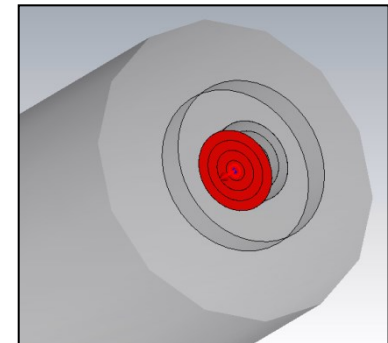> - Imported RF fields for the limited volume

Grid of the model for tracking

Imported electrical RF field distribution
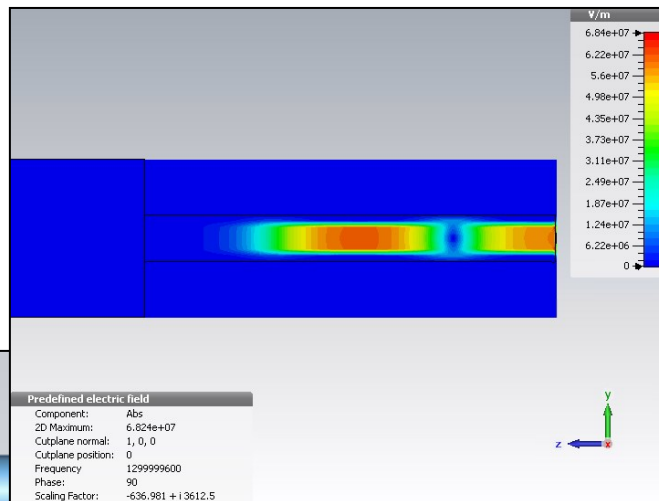
Cathode model / Particle source

Mean transverse beam position

Legend:
- x coordinate (w/o solenoid)
- y coordinate (w/o solenoid)
- x coordinate (w/ solenoid)
- y coordinate (w/ solenoid)

RMS transverse beam size

Legend:
- x coordinate (w/o solenoid)
- y coordinate (w/o solenoid)
- x coordinate (w/ solenoid)
- y coordinate (w/ solenoid)
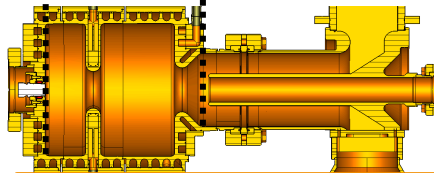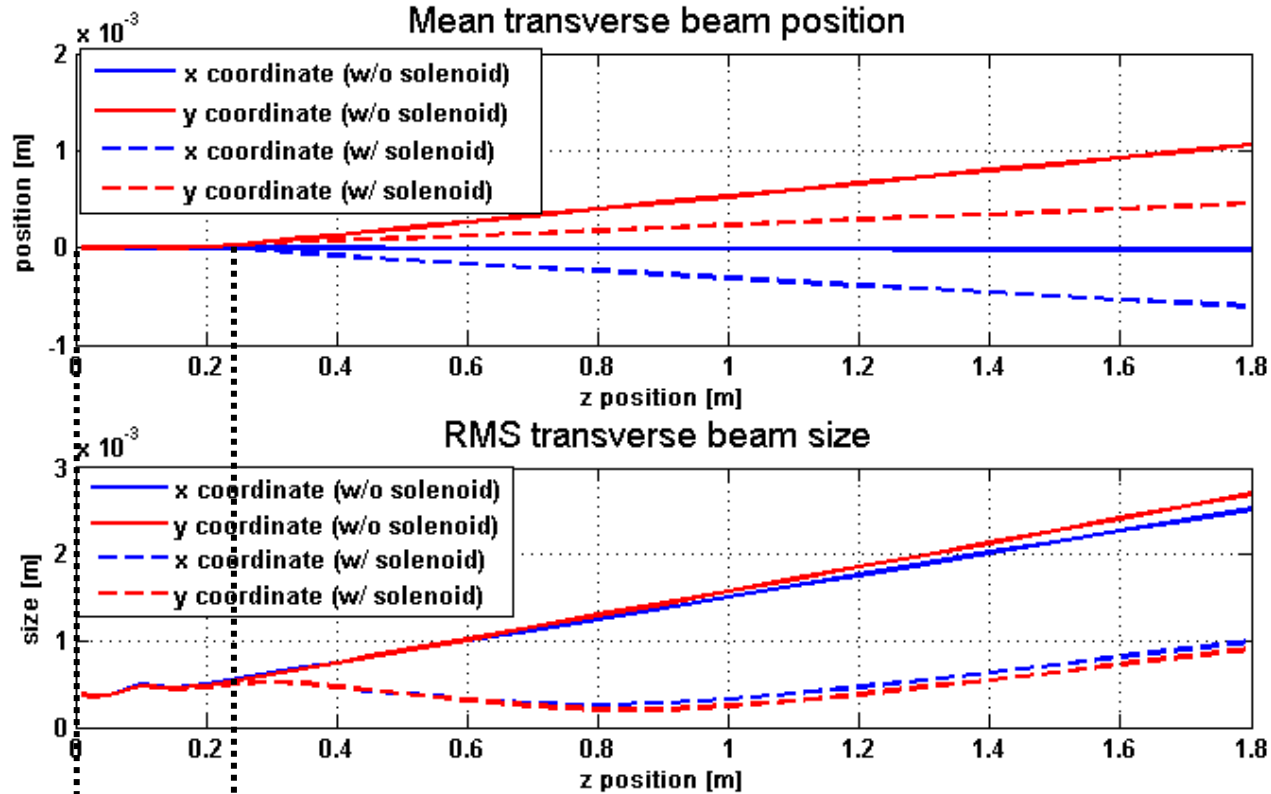
Numerical effect must be 0 →

x kick angle:
w/o solenoid: k_x = 0.01 mrad
w/ solenoid: k_y = 0.38 mrad

y kick angle:
w/o solenoid: k_x = 0.66 mrad
w/ solenoid: k_y = 0.27 mrad

Particle tracking in CST particle studio. PIC solver.

> Particle-in-cell solver

> Hexahedral mesh (~$4.7 \cdot 10^6$ elements)
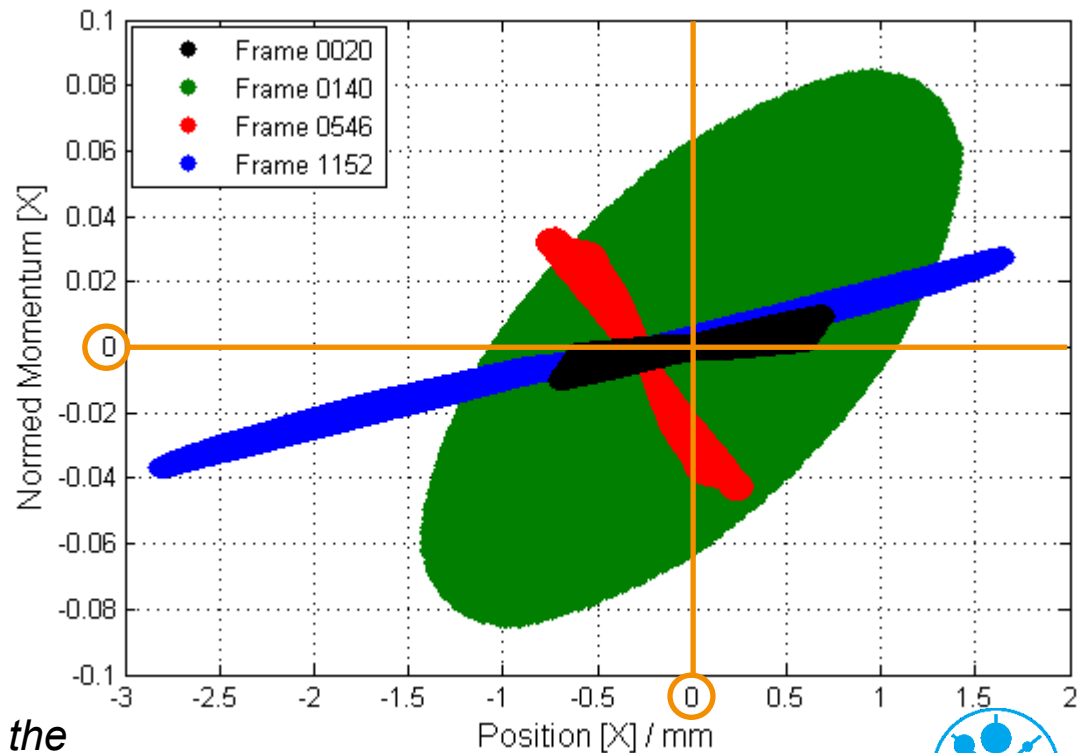
> Imported fields for the limited volume

> Particle source parameters:

- 0.6 mm radius
- 22 ps flattop pulse length
- 1 nC bunch charge

x kick angle: k_x = 0.31 mrad

y kick angle: k_y = 0.37 mrad

Detailed studies of the kick impact onto the phase space (emittance) are ongoing.

Frame	Time, ps	Z mean position, mm	X mean position, mm
0020	100.1	18 (1st cell)	0
0140	700.2	196 (RF coupler region)	-0.006
0546	2730.1	803 (LOW.Scr1)	-0.251
1152	5760.1	1708 (LOW.Scr3)	-0.589

Conclusions

> CST MWS simulations of the realistic PITZ (XFEL, FLASH) RF gun setup have revealed an **RF field asymmetry** within the coaxial coupler area. This transverse kick onto the accelerating particles is considered as possible reason of the electron beam asymmetry experimentally observed at PITZ

> Particle tracking studies using CST PS yield an estimation of the transverse kick on to the beam centroid for the nominal PITZ (XFEL) gun conditions (6.5MeV electron beam, solenoid on)

Coupler transverse kick	Particle tracking (no SC)		PIC (+SC)
	w/o solenoid	w/ solenoid	w/ solenoid
k_x (mrad)	0.01	0.38	0.31
k_y (mrad)	0.66	0.27	0.37

> The RF kick together with solenoid field can introduce a X-Y coupling into the phase space of electron beam. More detailed studies of this effect, its impact onto transverse phase space have to be performed. The transient effect (transverse to temporal coupling) has to be studies as well

> In order to avoid (reduce) the RF field asymmetry a re-design of the coupler area is required

symmetrical design
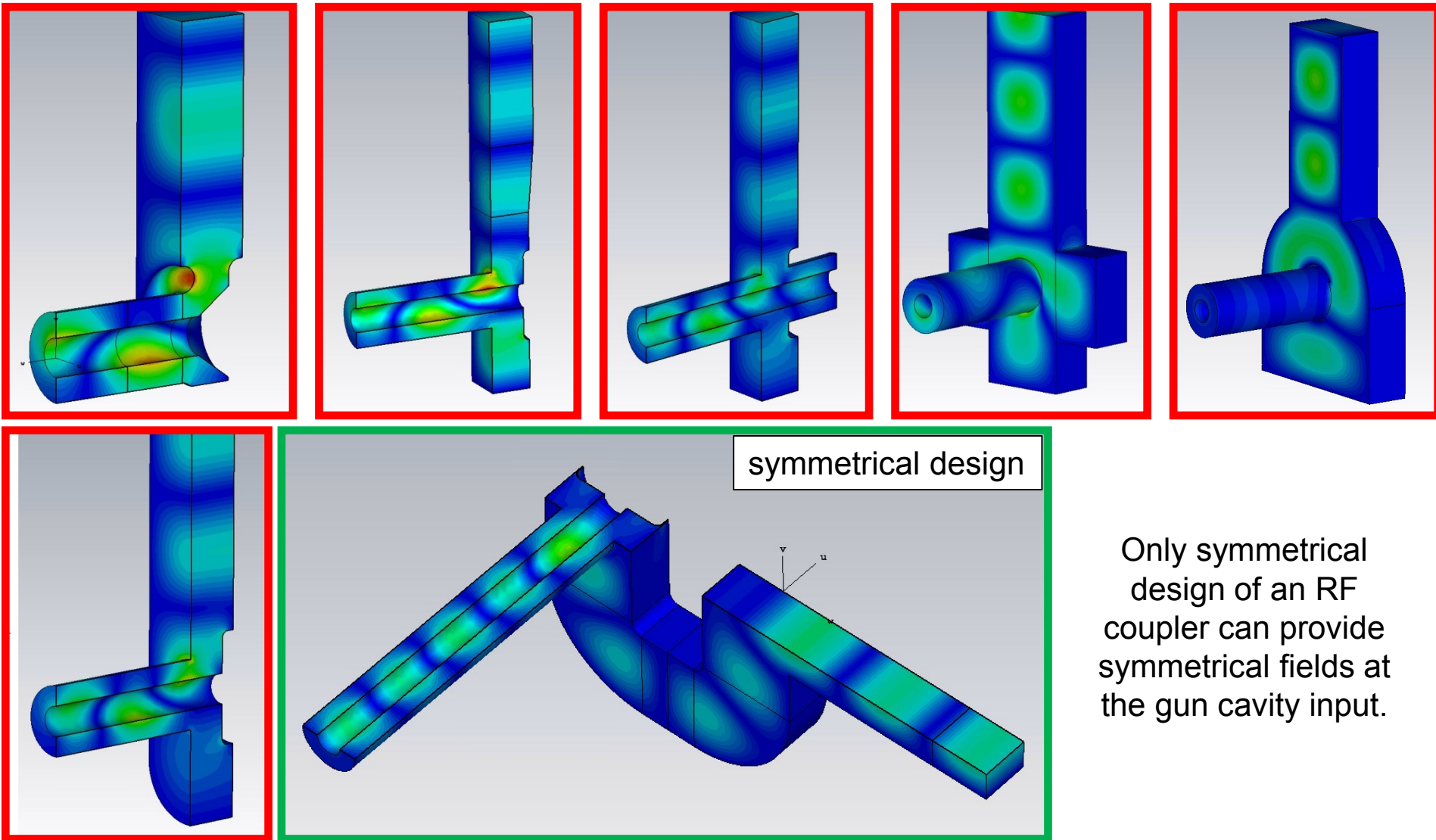
Only symmetrical design of an RF coupler can provide symmetrical fields at the gun cavity input.

Thank you for your attention.

Other Talks from PITZ:

AKBP7.5	Gaurav Pathak	➜	Gas density measurement
AKBP 9.3	Prach Boonpornprasert	➜	Start-to-End Simulations for a 100 μm SASE FEL at PITZ
AKBP9.5	Georgios Kourkafas	➜	Electron beam matching
AKBP14.1	James Good	➜	3D ellipsoidal laser system