Investigation of the Side Wall Influence on Synchrotron Radiation Generated at the First Bunch Compressor of FLASH by Numerical Simulation

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Introduction:

Synchrotron Radiation Bunch Diagnostics at DESY

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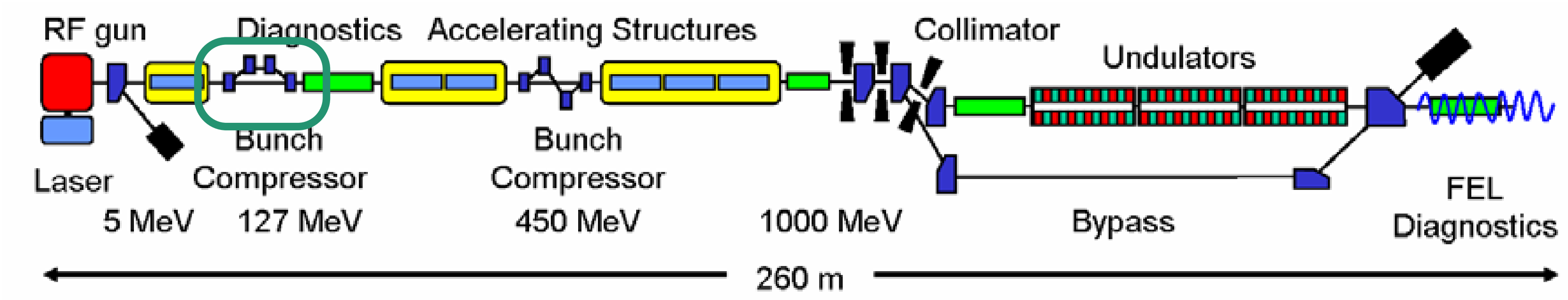
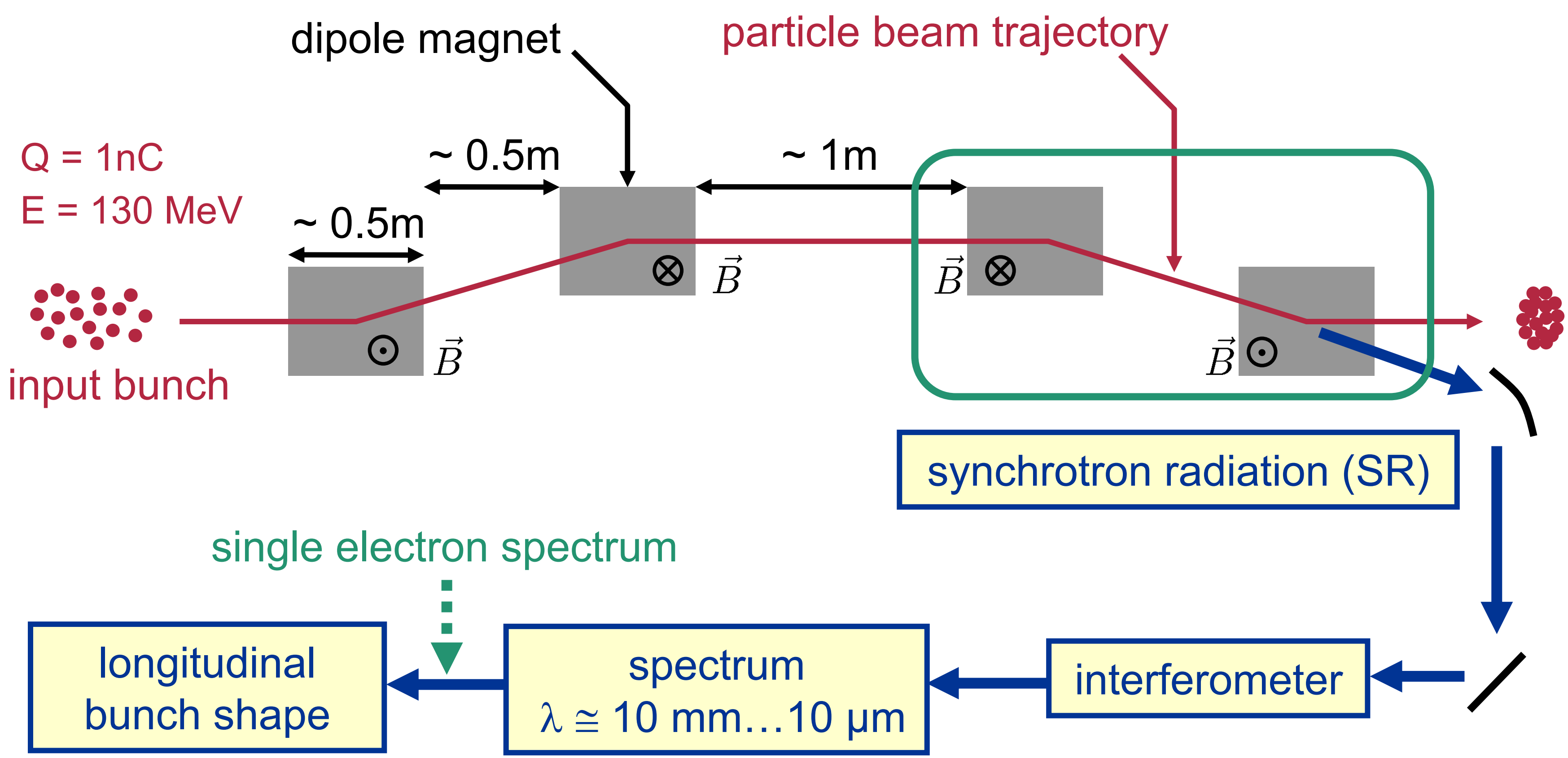
1st BC at FLASH





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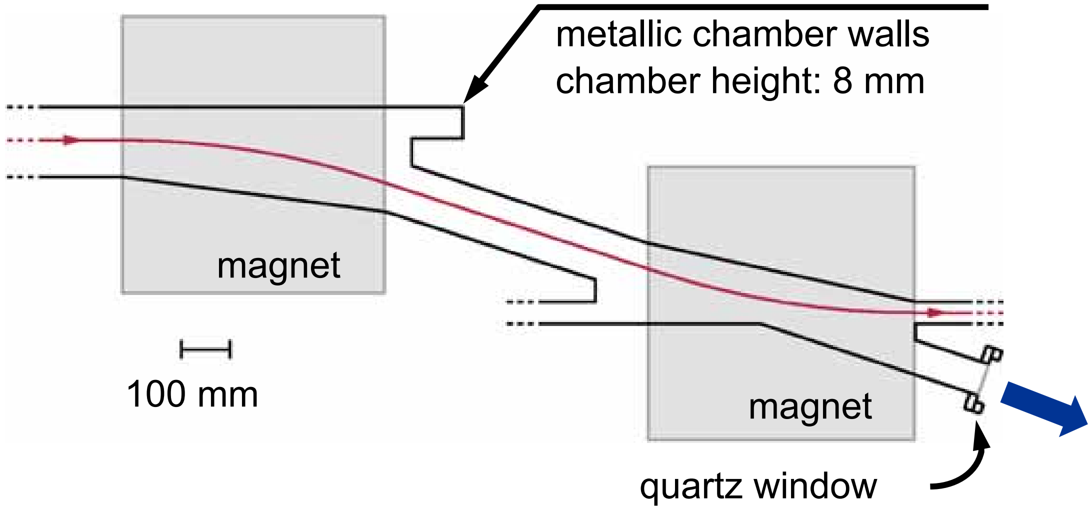
Vacuum Chamber

vacuum chamber



what is the influence of the chamber (side walls) on the spectrum?

numerical calculation?

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Outline

- Simulation Methods
- 2D Field Distribution Examples Inside the Chamber
- Influence of Side Walls (Intensity-Comparion)
- Comparison Simulation - Measurements
- Influence of Side Walls (Intensity Patterns)

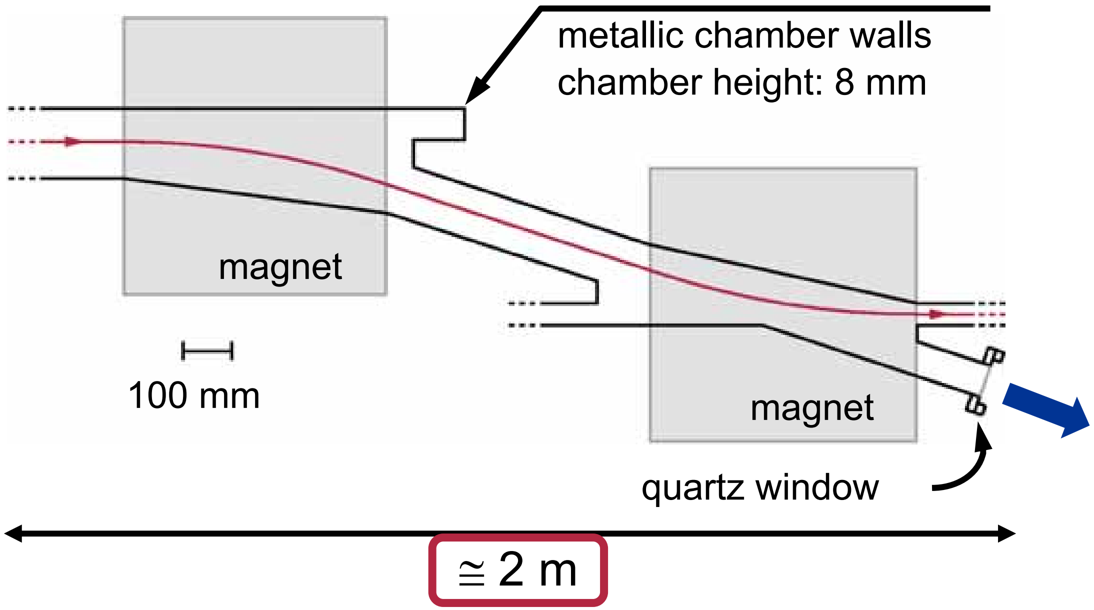
- Influence of Transversal Bunch Shape

Simulation Methods

Simulation Challenges

main simulation challenges for EM field calculation

- very high frequency problem
- broad frequency range



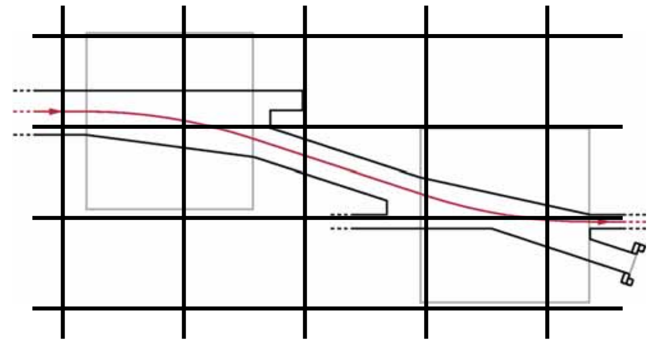
Q = 1nC

E = 130 MeV

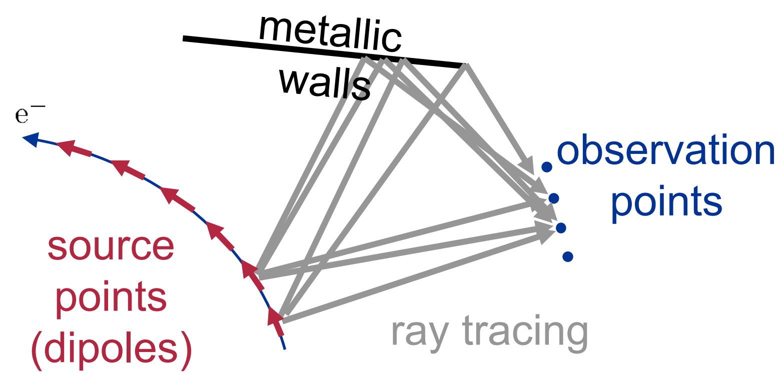
λ = 10 mm … 10 μm

Used Methods

- discretizing methods (FIT)
  - high memory consumption
  - dispersion error problems
  - 2D-Implementation



- asymptotic methods - UTD (geometrical optics based)
  - no discretization of structure but of source and monitor points
  - raytracing complex
  - accuracy limit
  - different formulations and models tested



- Fourier optics
  - radiation from waveguide exit
- point charge (single electron spectrum)

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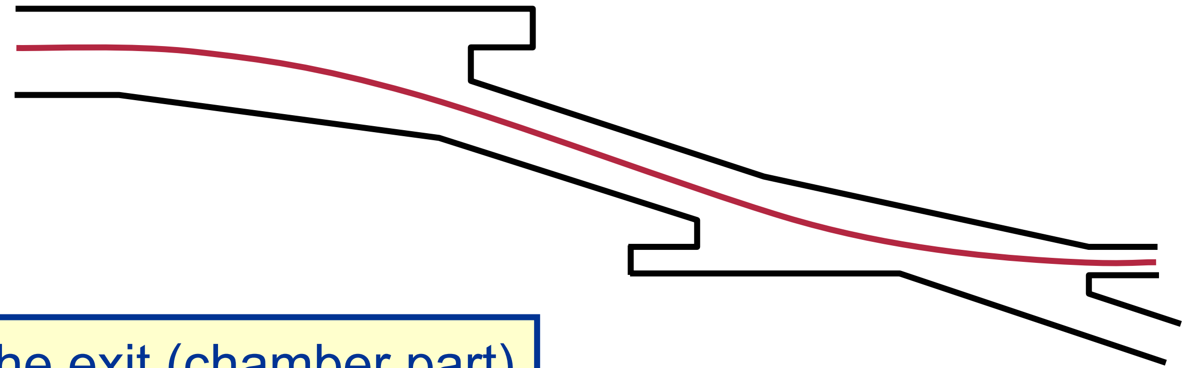
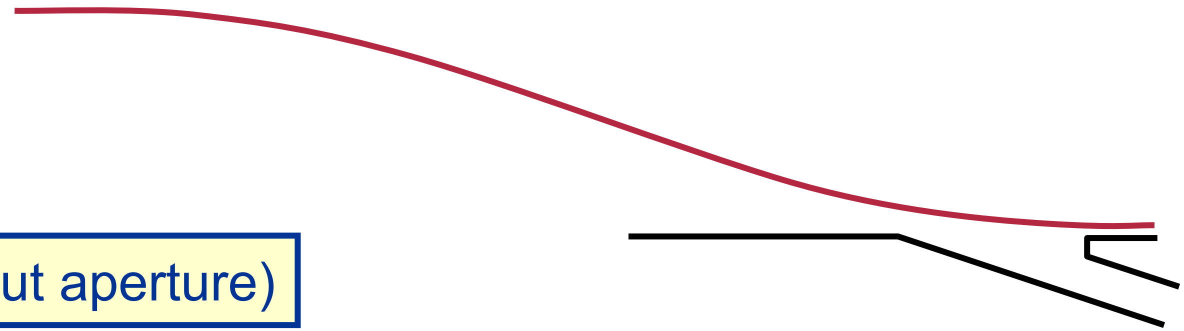
Chamber Models

all walls



only the walls near the exit (chamber part)



without side walls (but aperture)

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Basic Evaluation Results

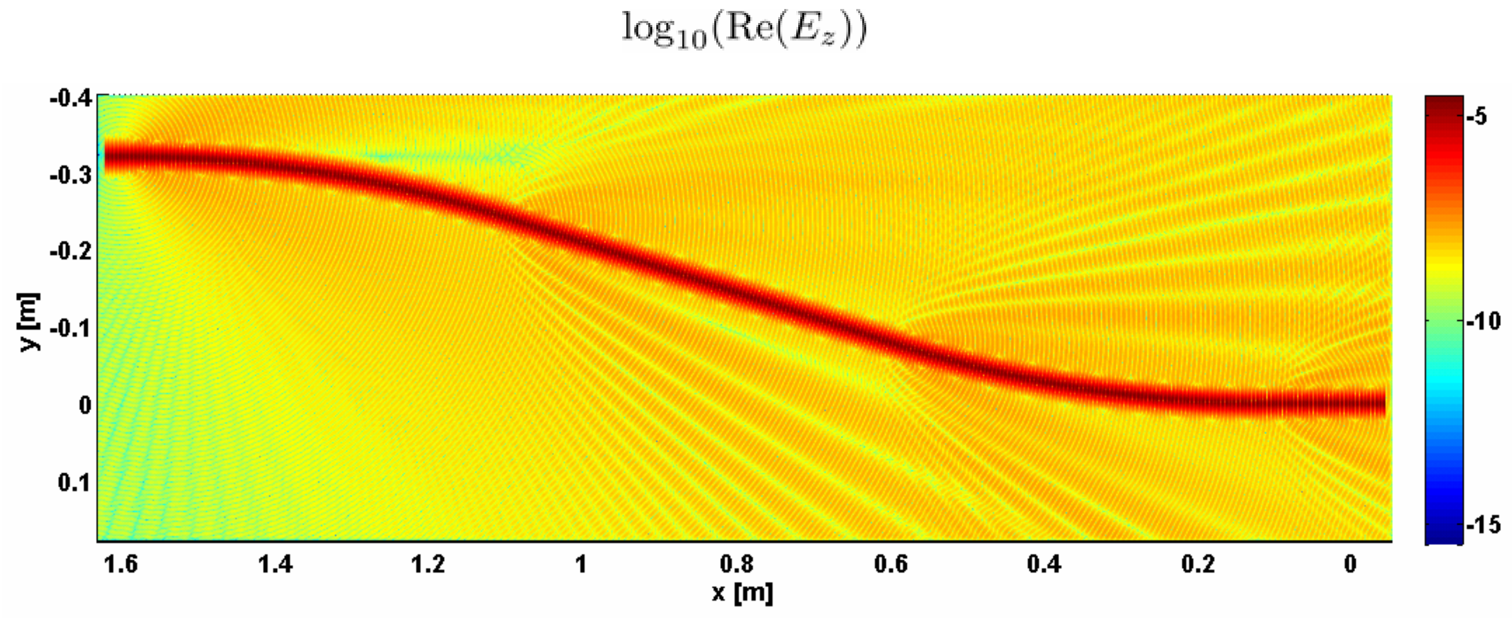
- FIT:
  - results better than expected
  - only for long wavelengths: λ > 2.5mm (5mm)
- optics:
  - good results for simple wall model
  - difficult to apply (many parameters, accuracy, runtime)
  - no universal method (wavelength and model dependent)
  - problematic for model with all walls
- Fourier optics after chamber exit
  - in general good results and efficient
  - resolution problems at 10um
- estimated accuracy (spectrum): ~1%..20% depending on wavelength, used method and model

2D Field Distribution Examples Inside the Chamber (FIT)

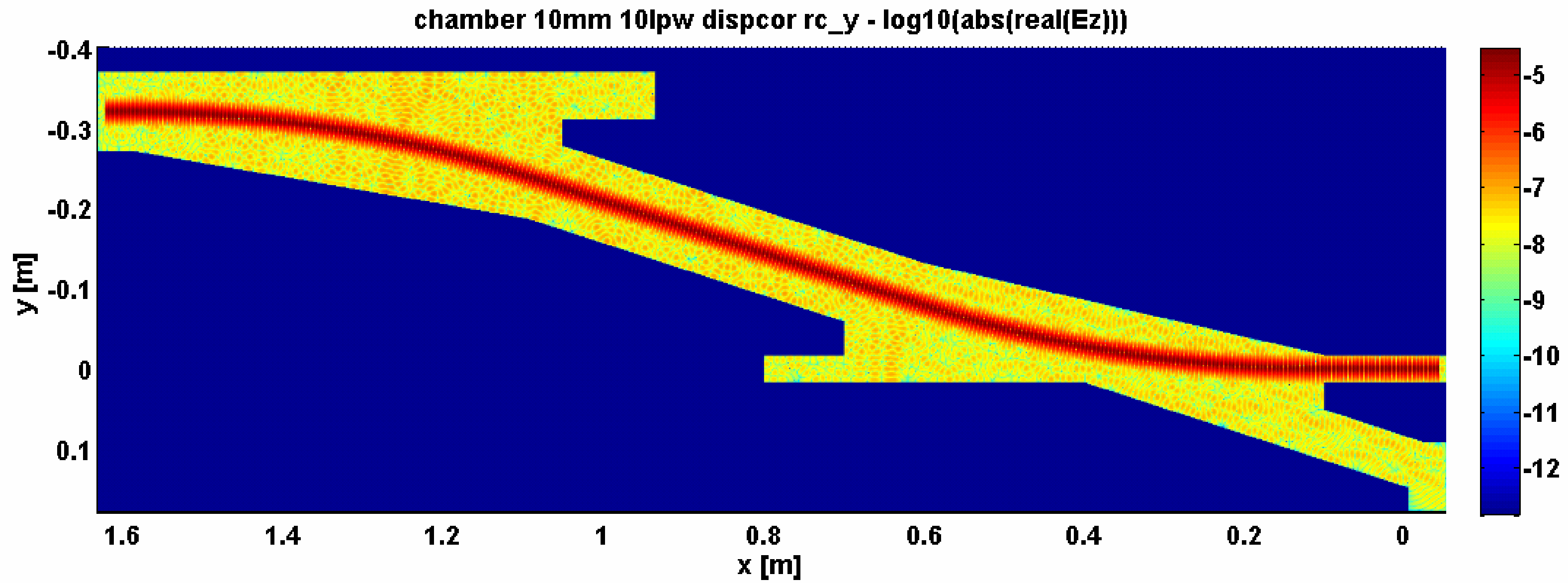
Example Result

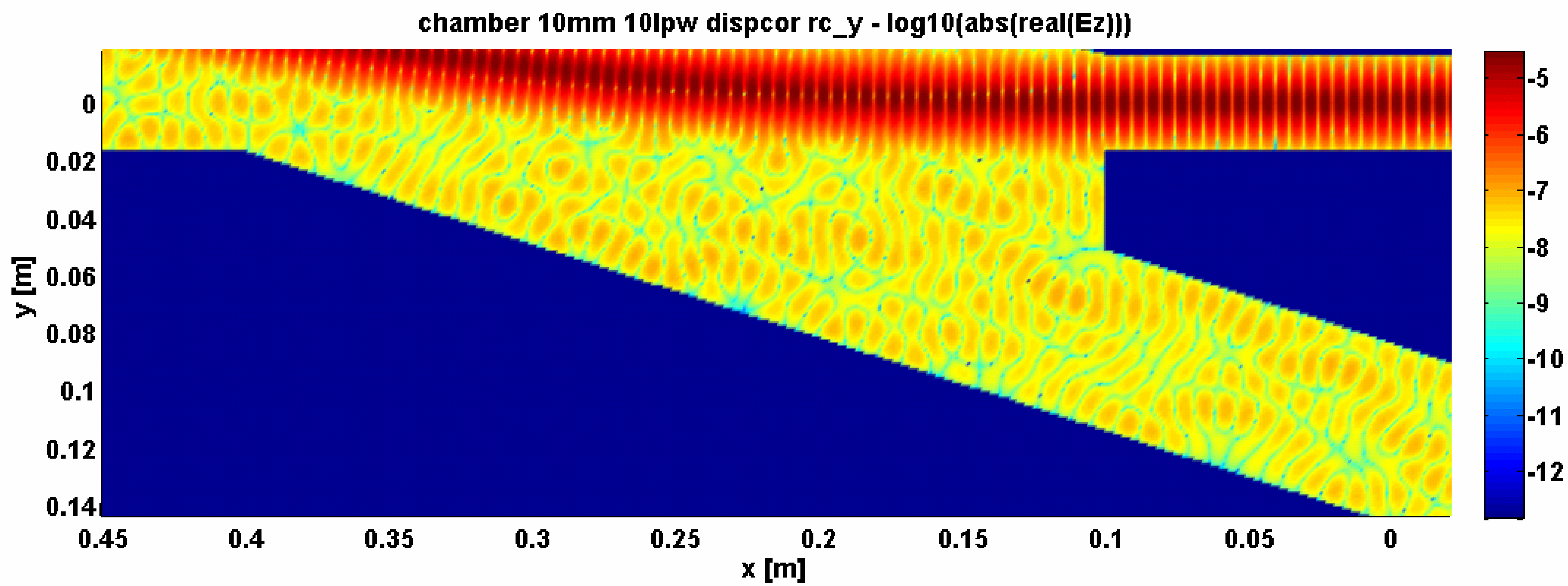
modell without side walls

λ = 10mm, mode 2

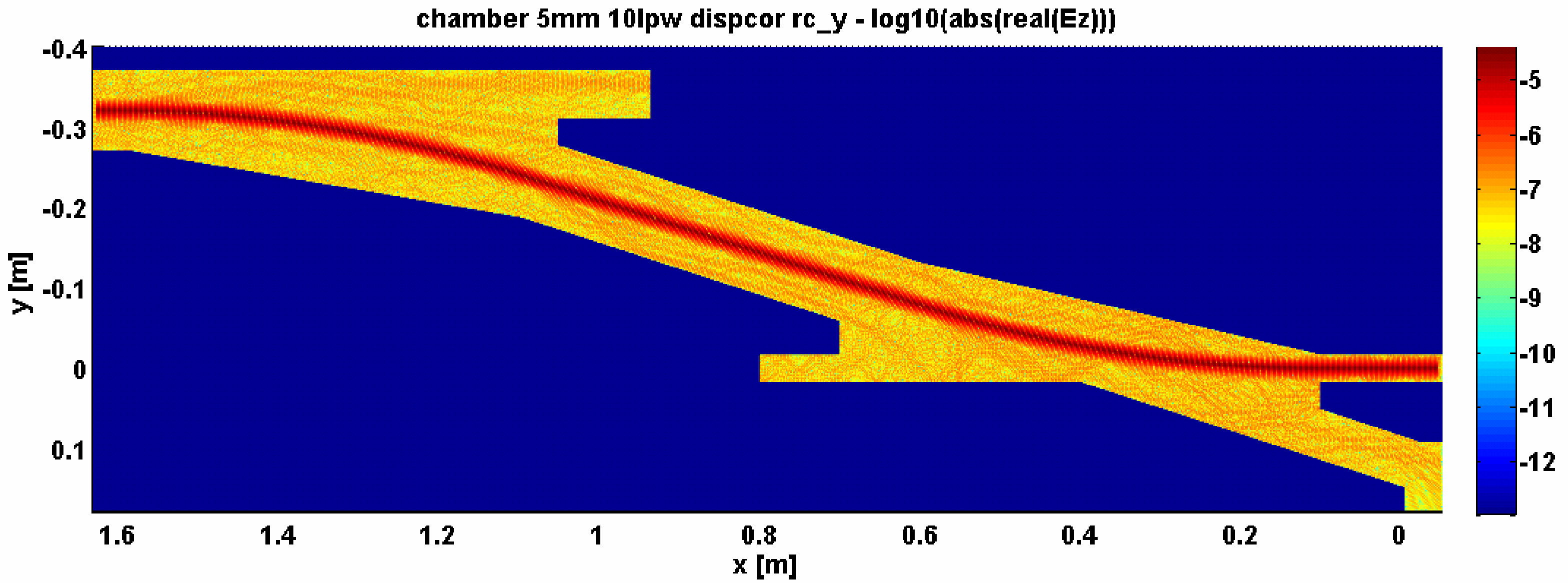


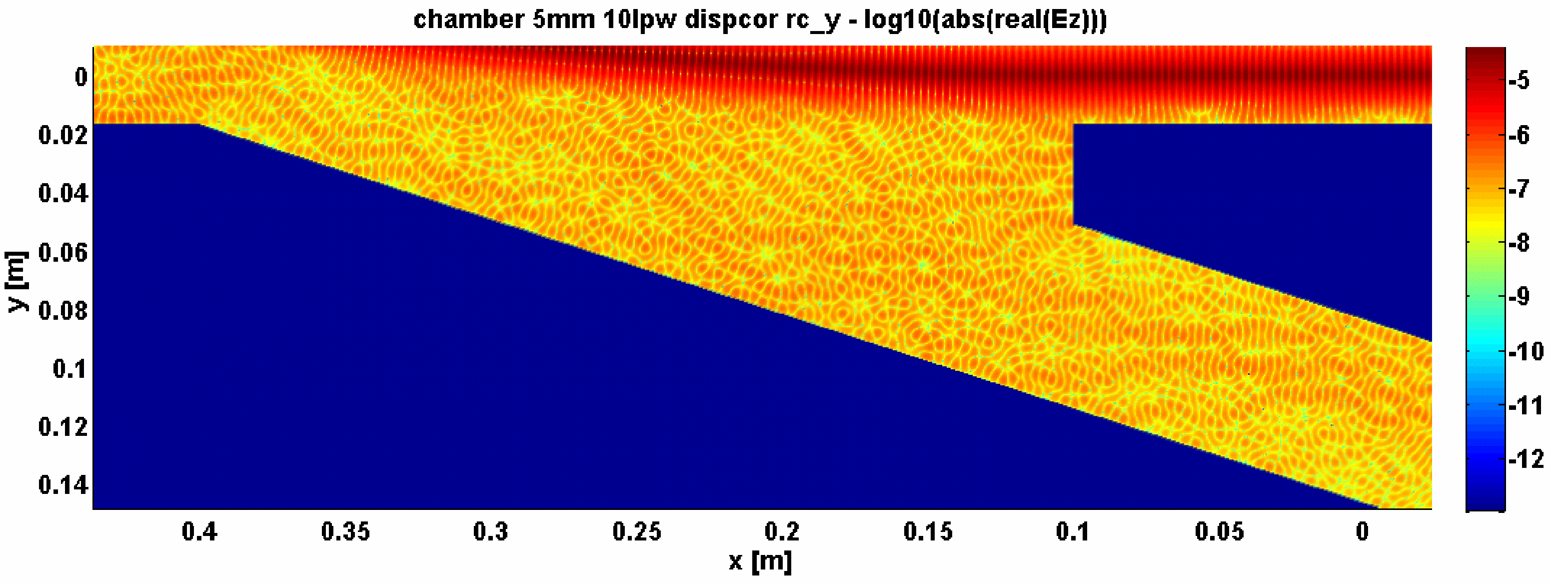
Chamber Fields at 10mm





Chamber Fields at 5mm





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Influence of Side Walls:
Intensity-Comparison

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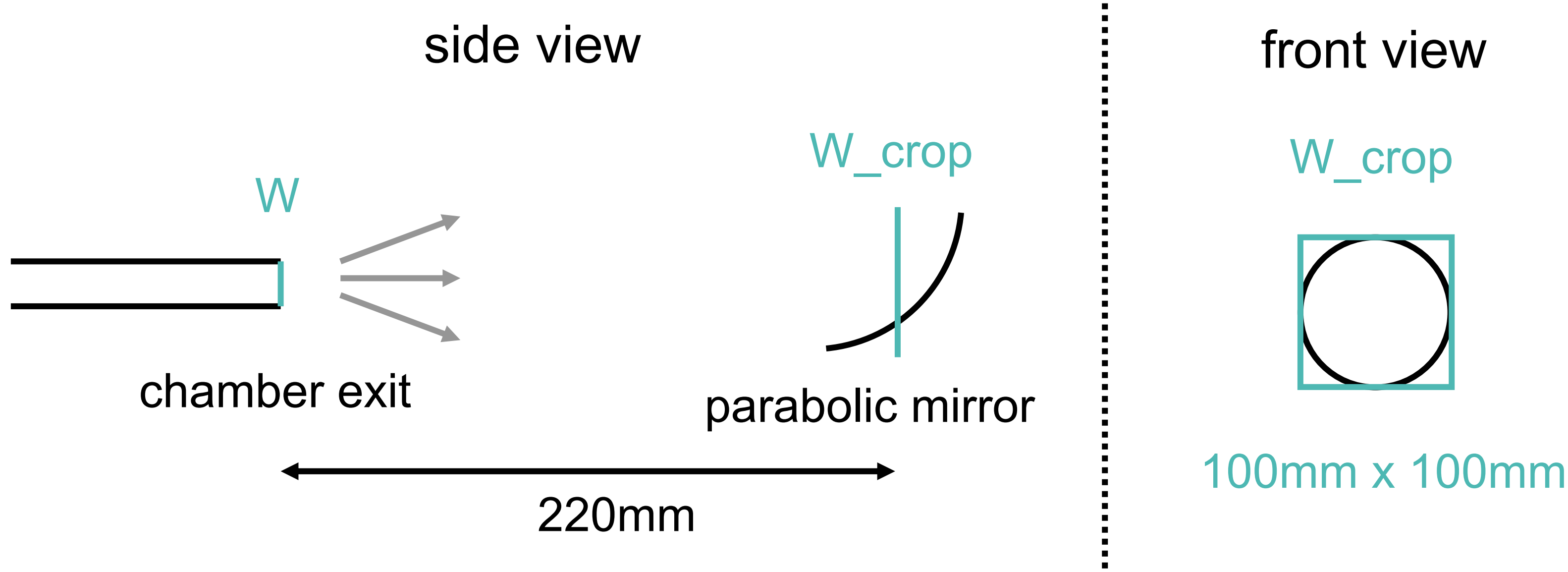
W and W_crop

radiated energy



W: though waveguide exit

W_crop: rectangular area at paraboloid

[W] = J/Hz

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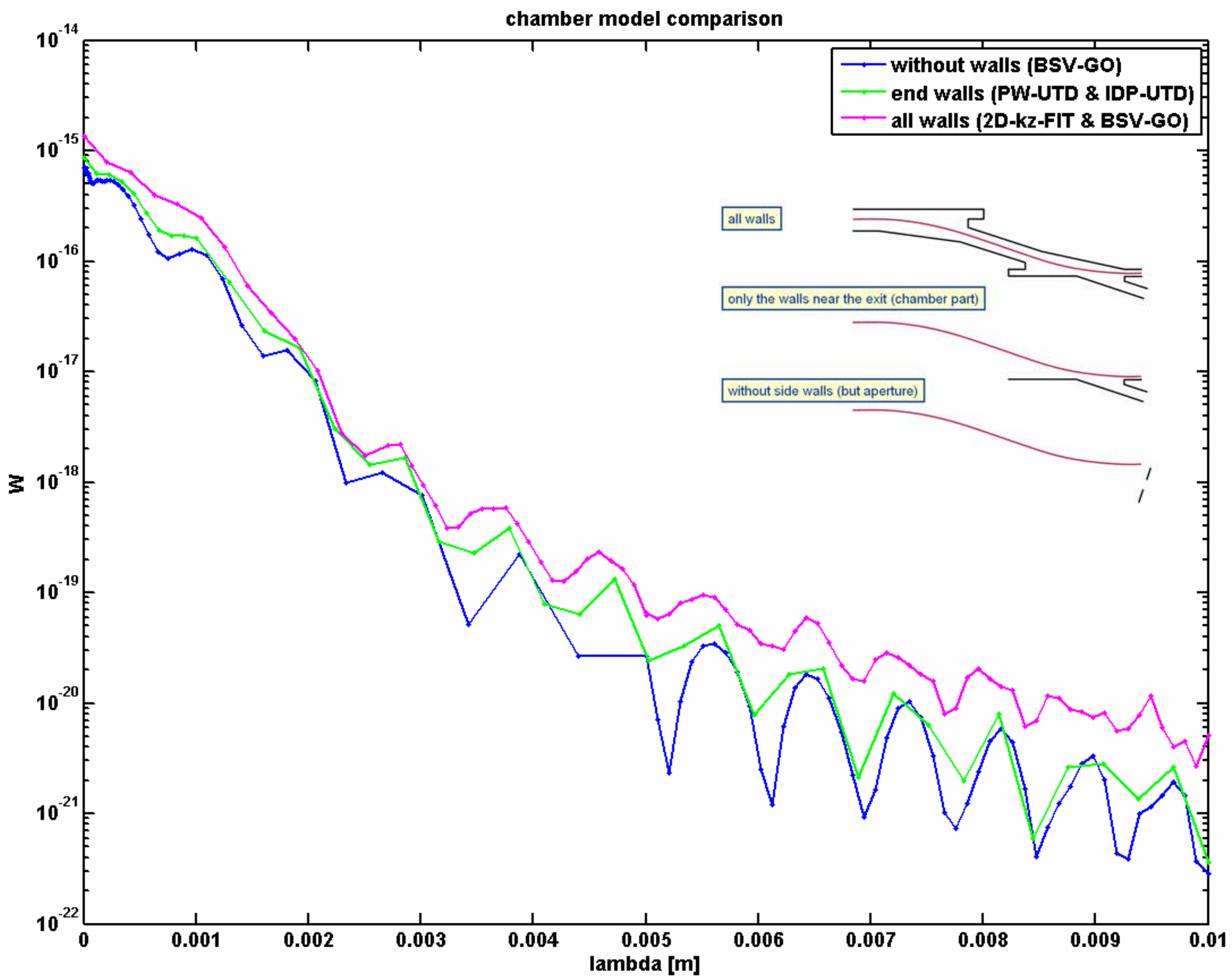
Wall Influence - W



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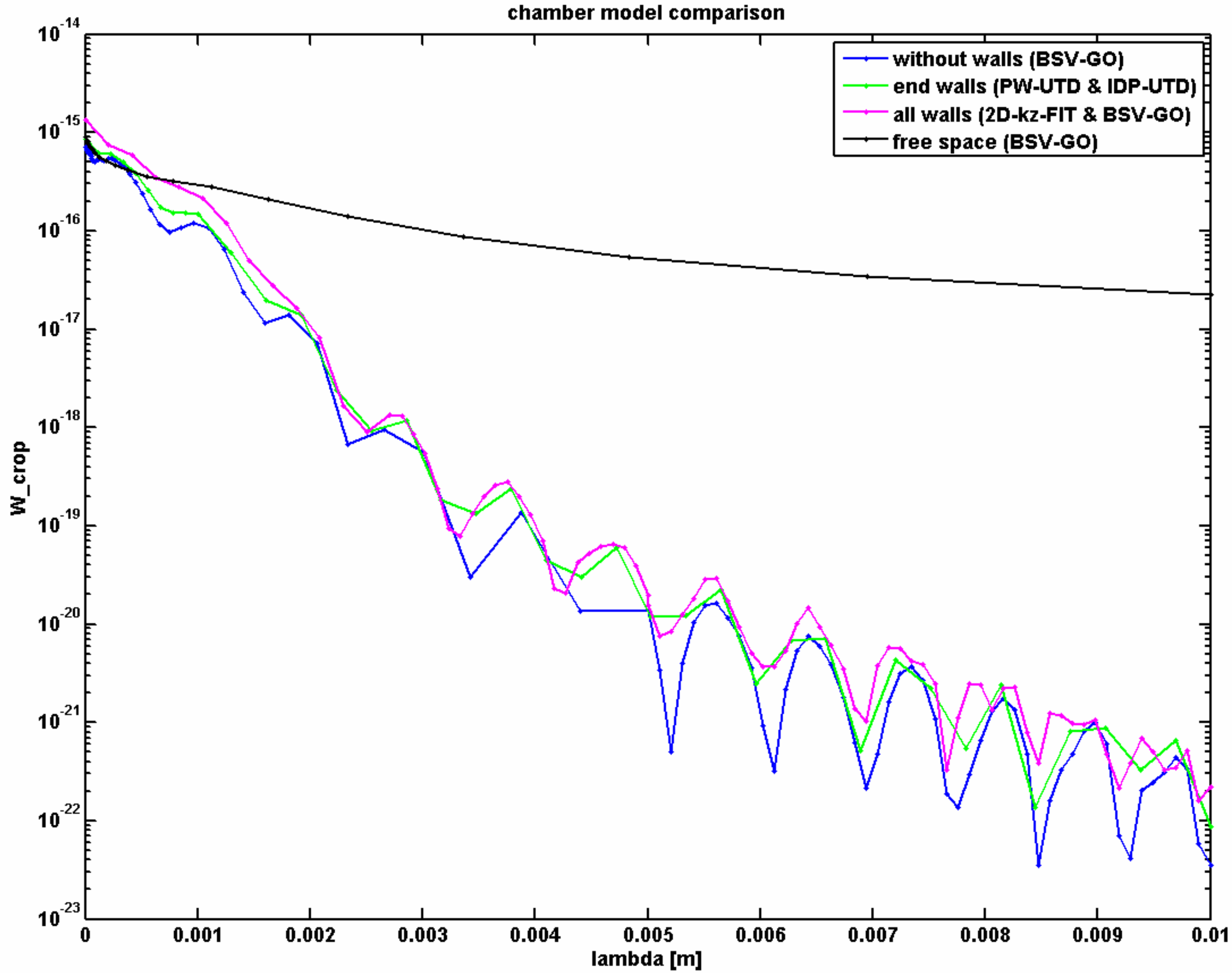
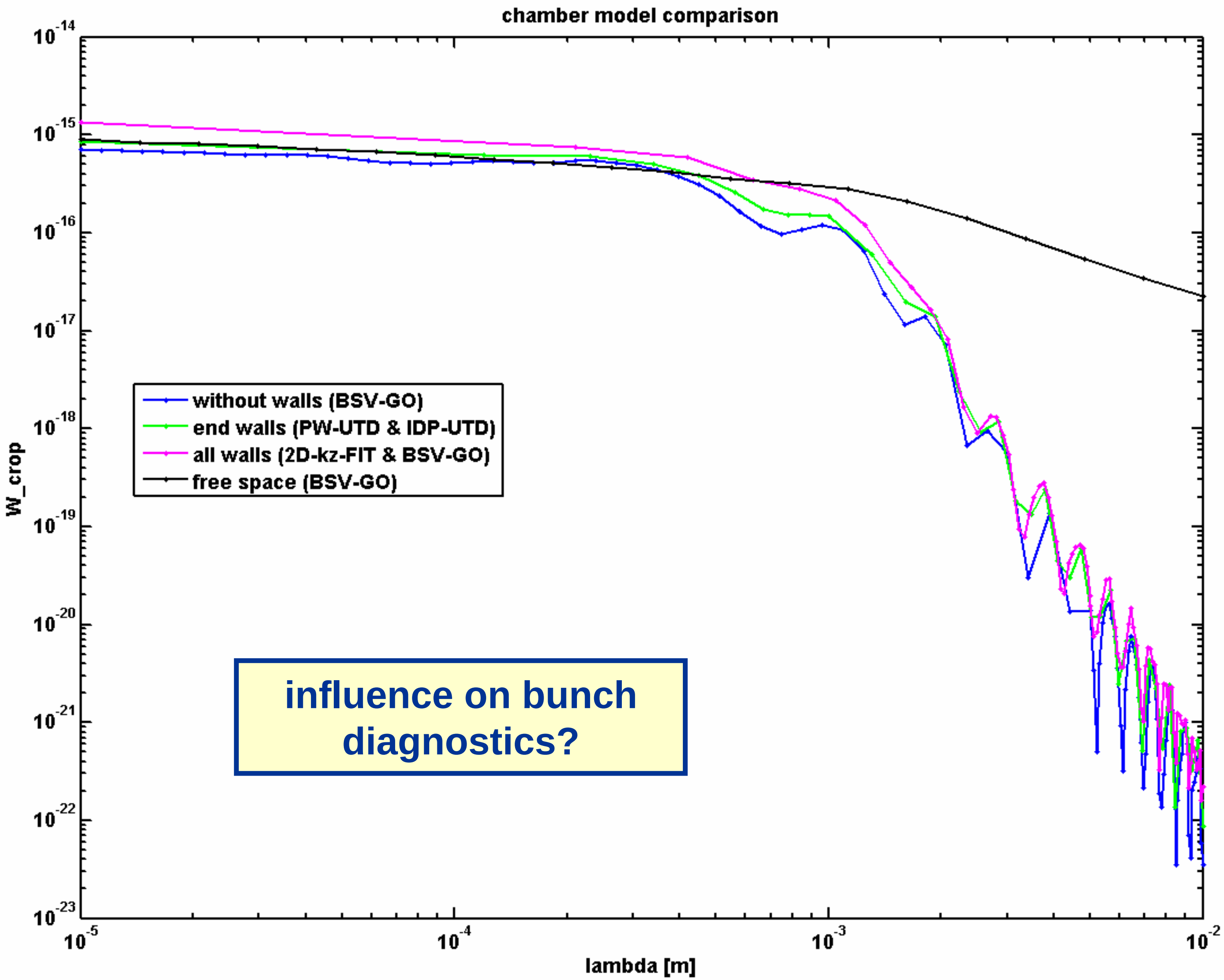
Wall Influence - W_crop



W_crop logarithmic



influence on bunch diagnostics?

Comparison
Simulation - Measurement

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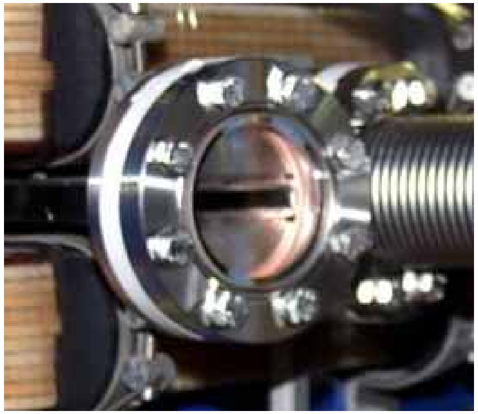
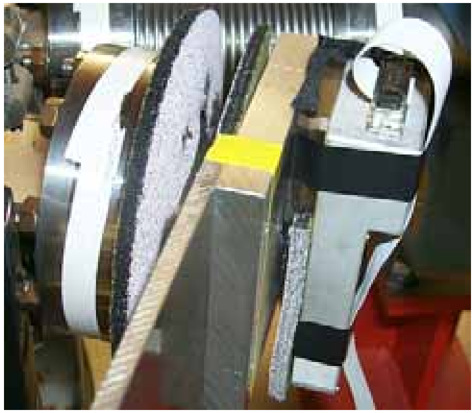
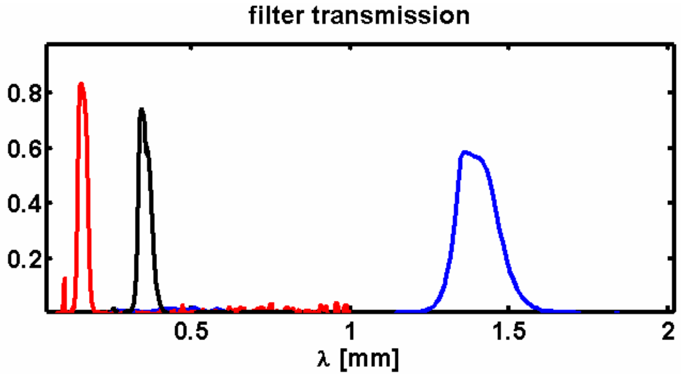
Measurement - Simulation

- fields in front of waveguide exit
  - 220 mm distance (parabolic mirror position)
  - 2D transversal scan





  - 3 frequencies
  - pyroelectric detector
- Simulation:
  - point charge
  - considering filter characteristic (10 frequency samples)
  - Poynting vector



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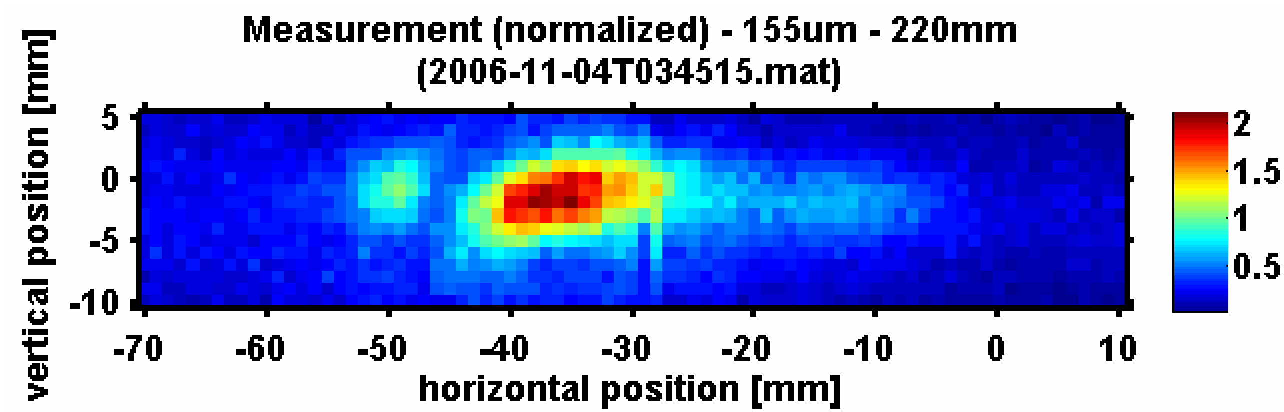
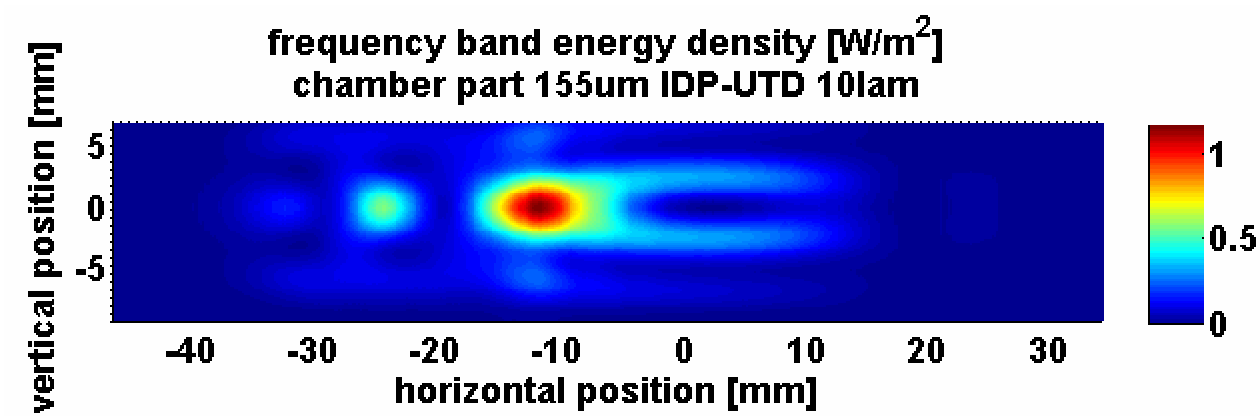
Meas. – Sim. 155um





measurement

good agreement

simulation

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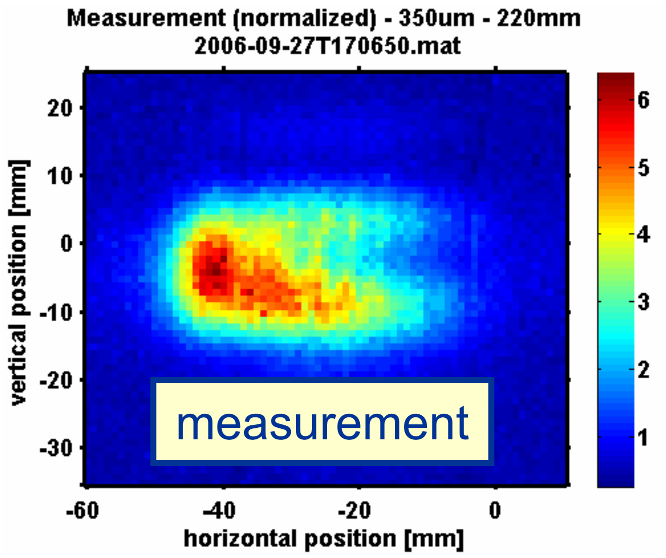
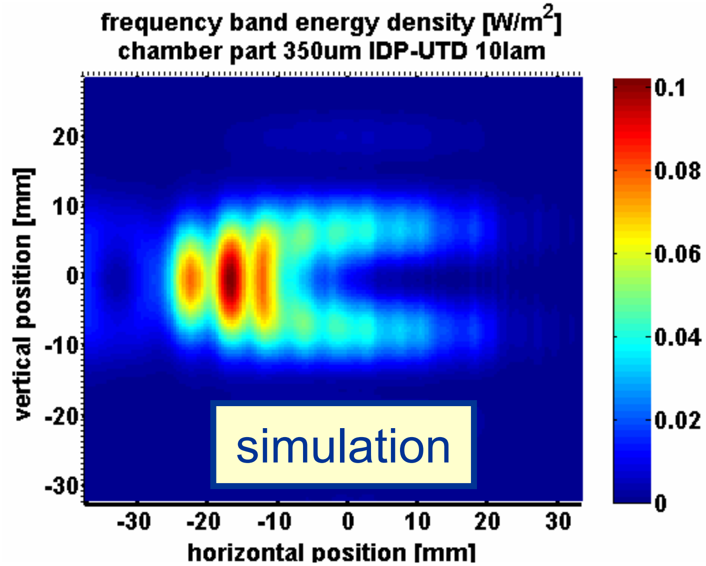
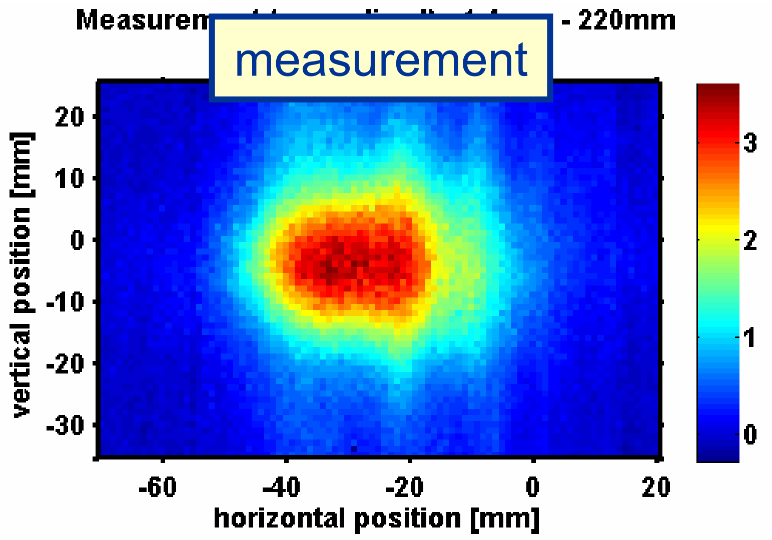
Meas. – Sim. 350um

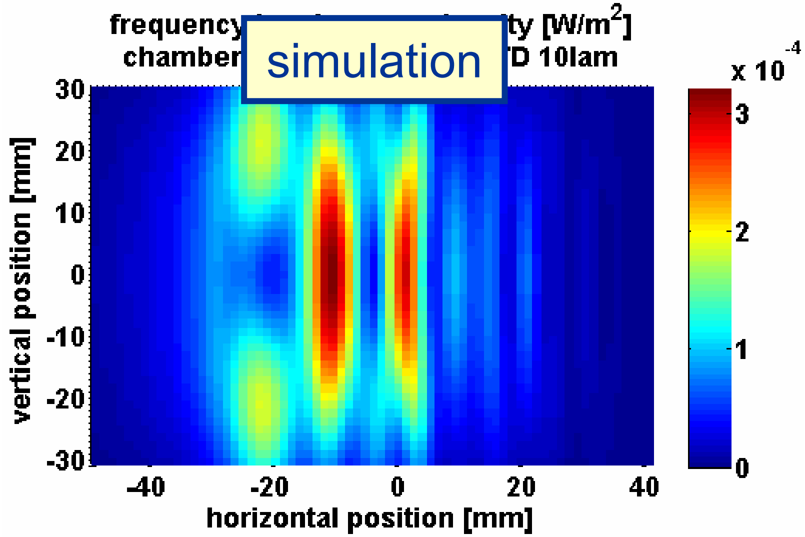




good agreement
except interference pattern not visible

Meas. – Sim. 1.4mm



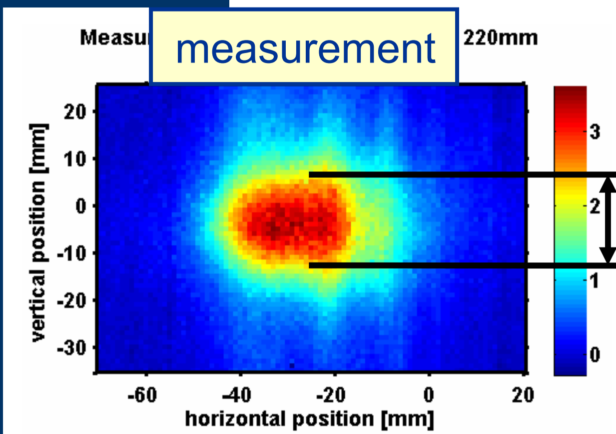


unexplained differences

no errors in simulation detected

problems with measurement?

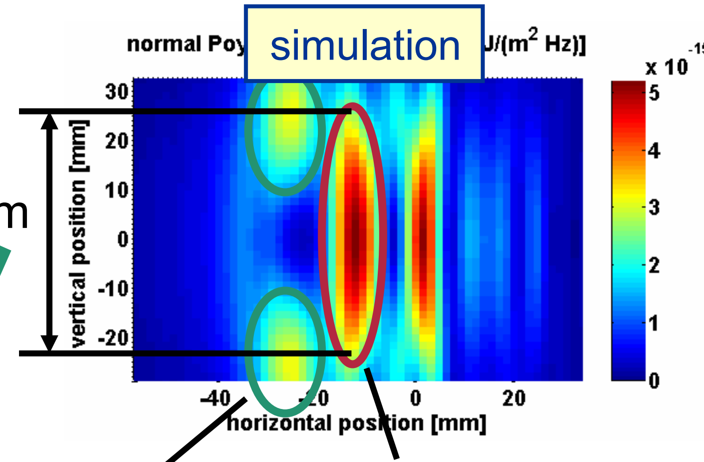
Plausibility of 1.4mm Meas.



spot size:

FWHM

~ 20mm ↔ ? ~ 50 mm



≅ TM_{01}-mode ≅ TE_{01}-mode

analytic intensity at 220mm for uniformly illuminated 8mm slit:

$$I \propto \left(\frac{\sin\left(\frac{\pi D x}{\lambda L}\right)}{\frac{\pi D x}{\lambda L}} \right)^2$$

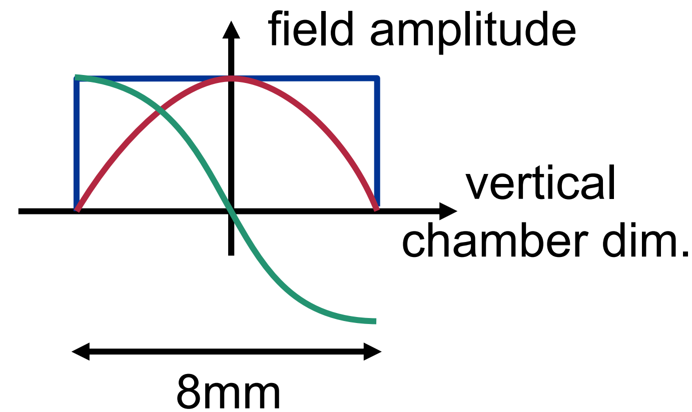
FWHM = 34mm

= minimum FWHM

(I ≅ Fourier trf. of slit field)

$FWHM_{measurement} < FWHM_{uniform}$!

$FWHM_{uniform} < FWHM_{TE01} < FWHM_{TM01}$



inconsistency in measurement

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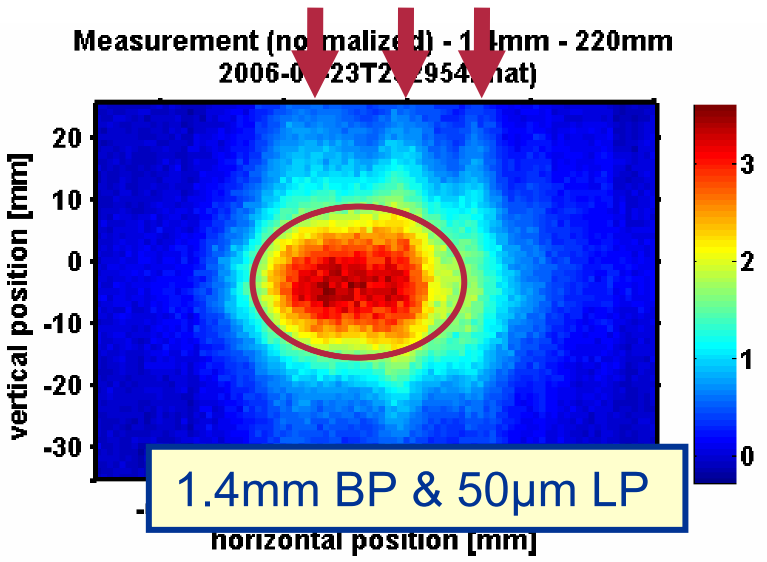
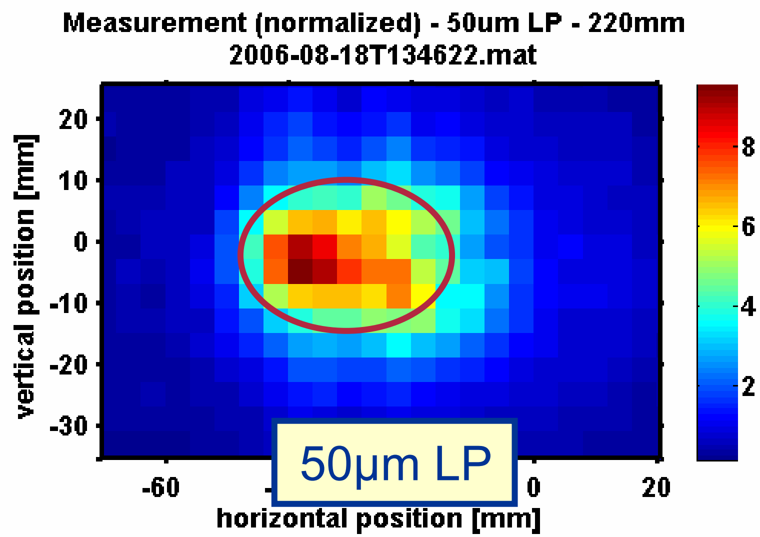
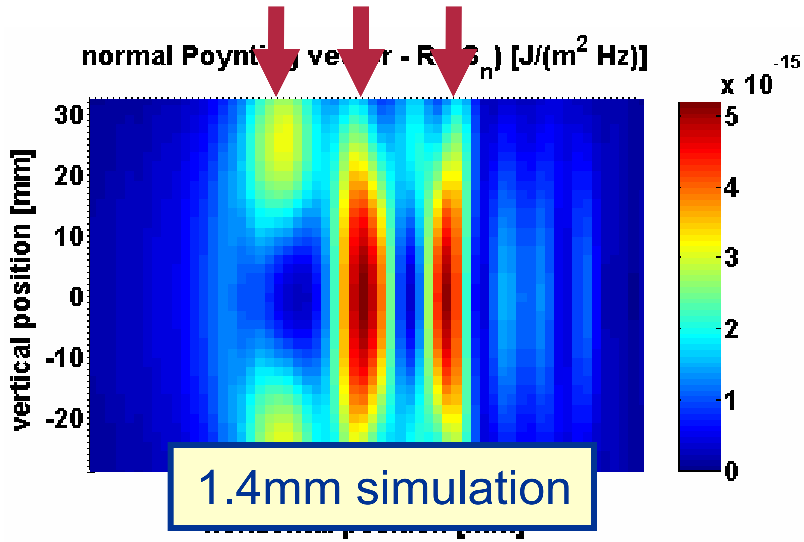
Explanation Attempt







no significant change in measurement pattern when 1.4mm BP added

pattern from simulation slightly seen in measurement

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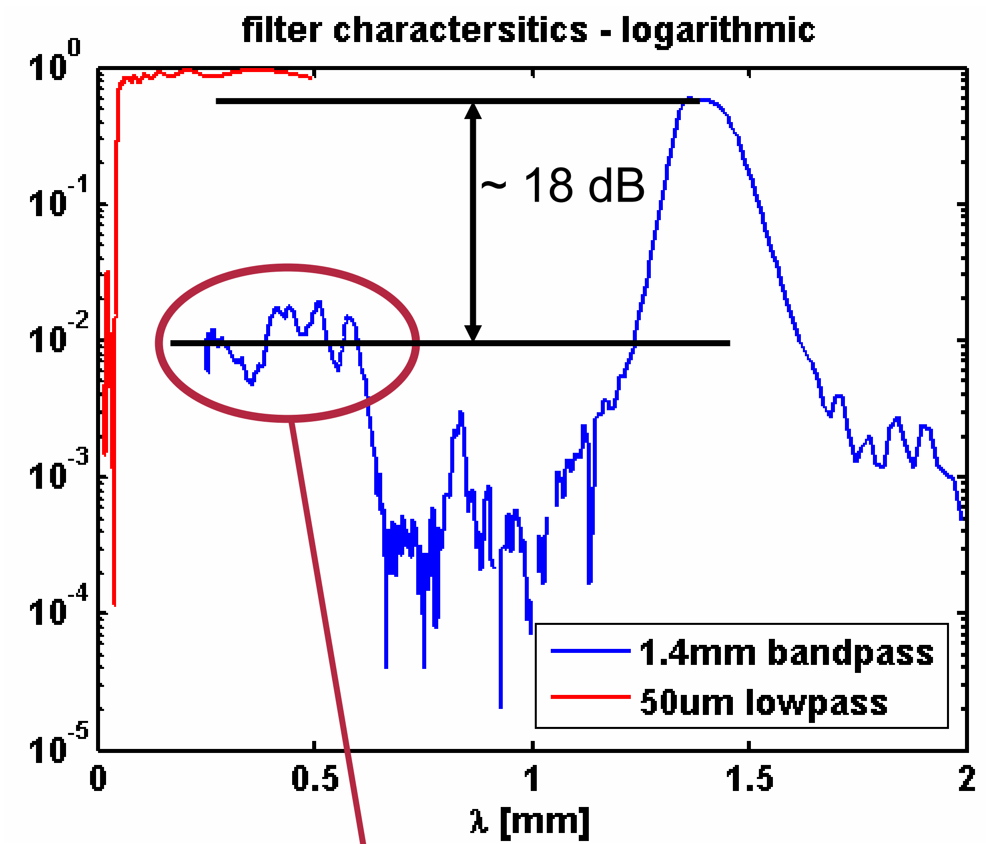
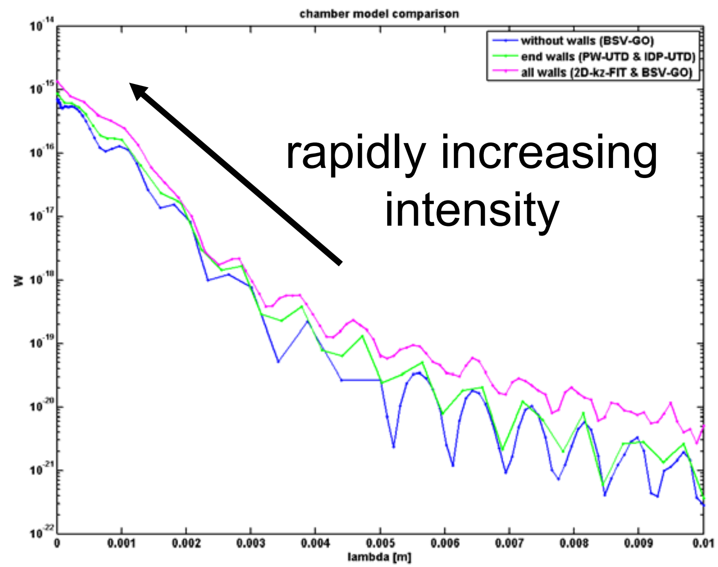
Explanation Attempt

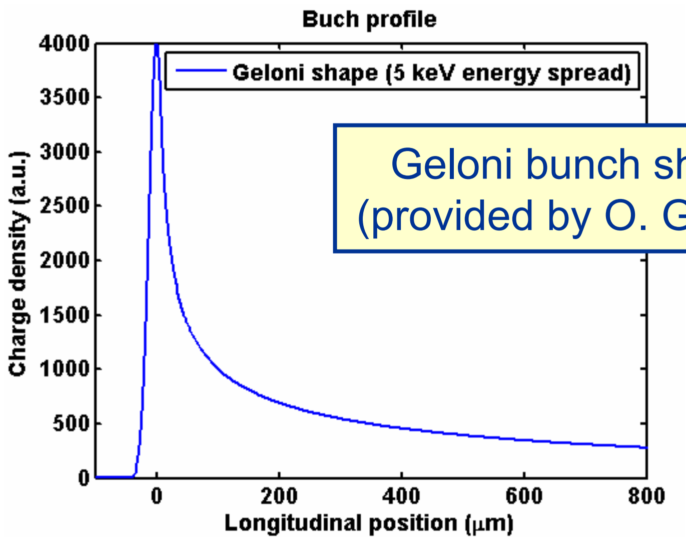




high intensity short wavelength radiation
+ imperfect filter characteristic
➔ 1.4mm signal “overshadowed” ?

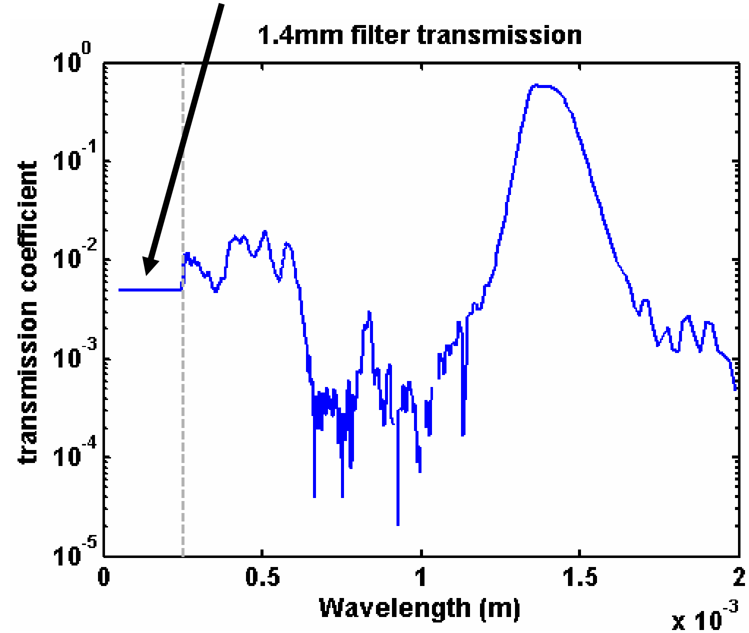
Explanation Attempt

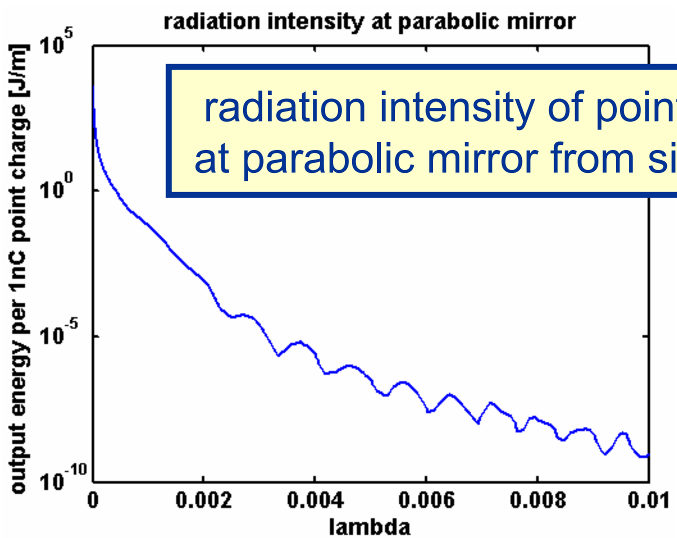
more detailed estimation with



Geloni bunch shape (provided by O. Grimm)

1.4mm BP filter transmission (250µm..2mm) with extrapolation (50µm..250µm)





radiation intensity of point charge at parabolic mirror from simulation

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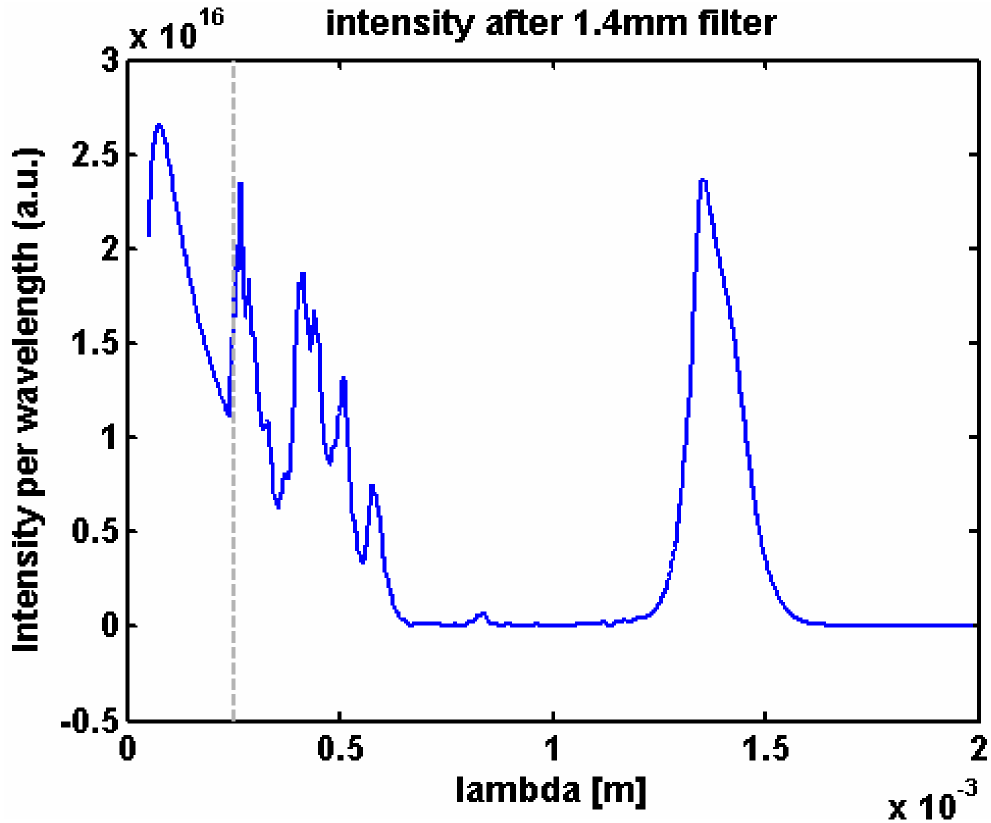
1.4mm Geloni Estimation



integrated intensity (a.u.):

4.1

7.8

3.2

→ 1.4mm signal overshadowed

Influence of Side Walls on Intensity Patterns at 220mm for Measurement Frequencies

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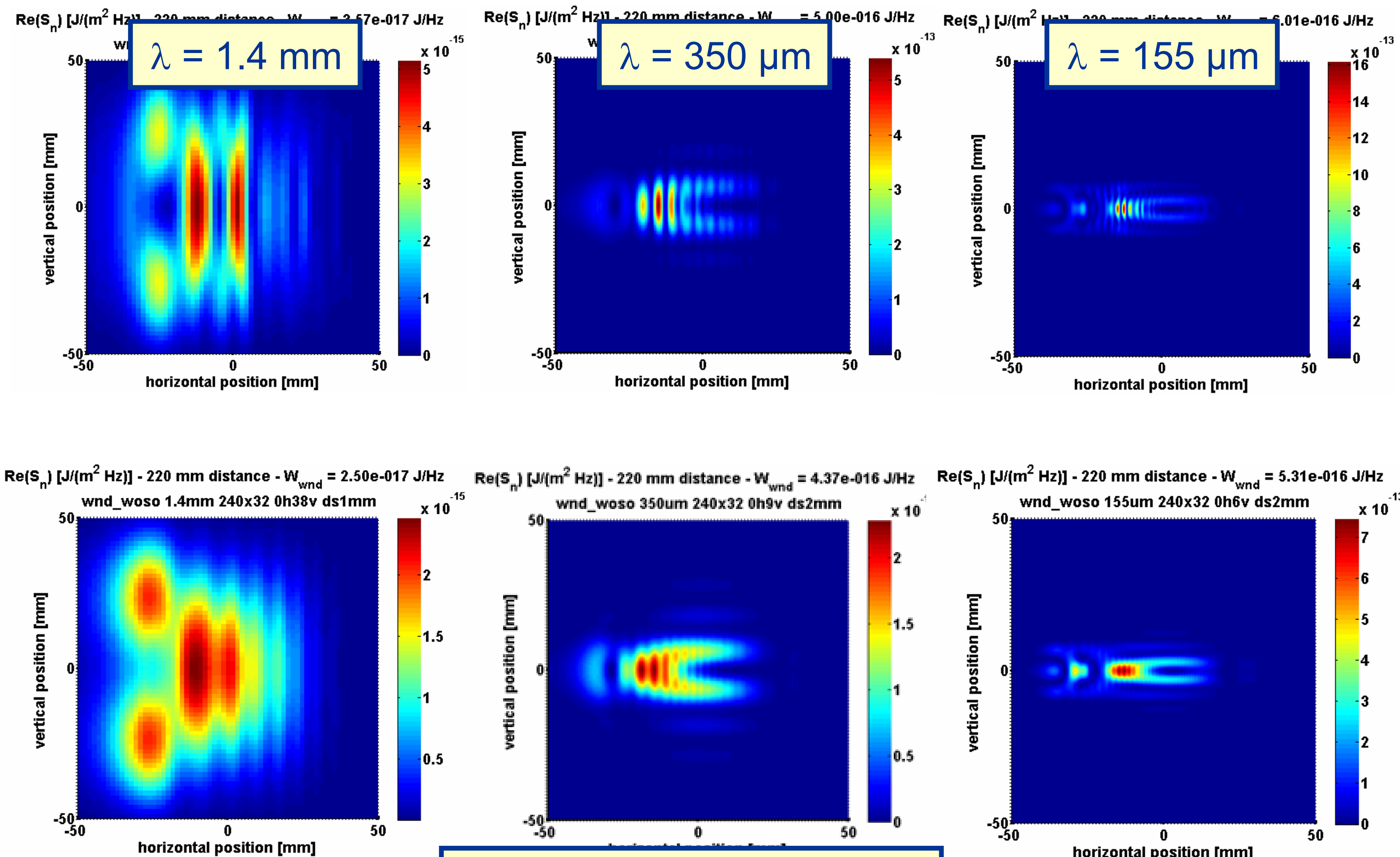
Influence of Sidewalls @ 220mm

top/bottom + side walls



top/bottom walls + aperture

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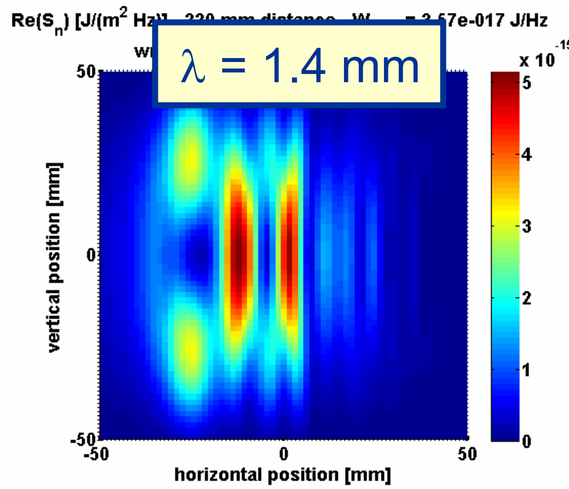
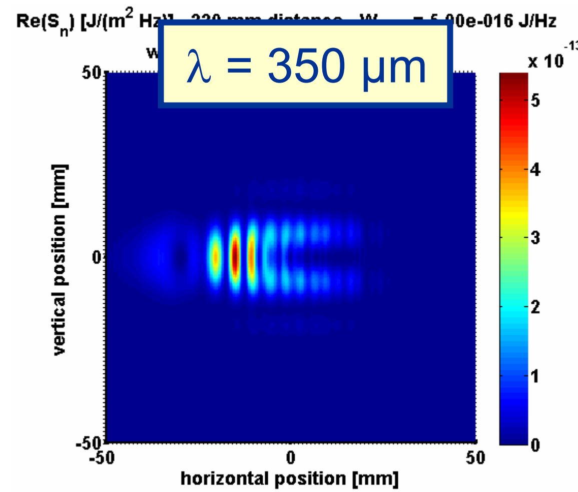
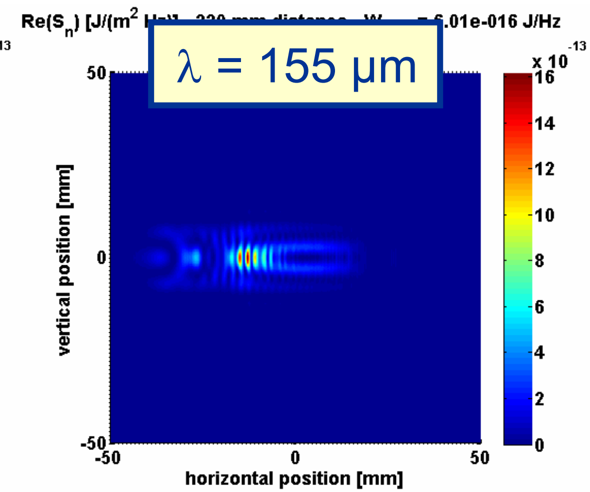
Influence of Sidewalls @ 220mm

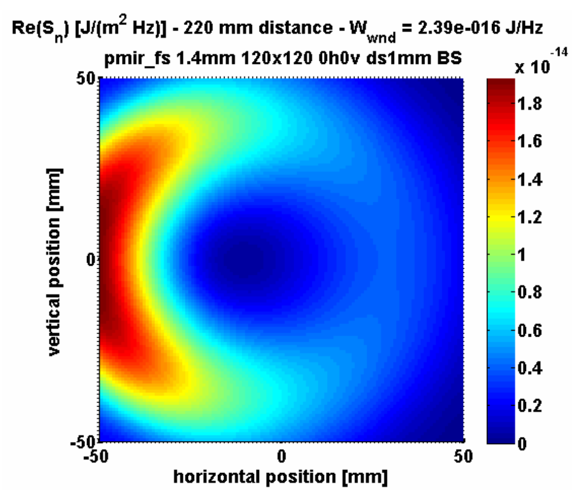
with top/bottom and side walls

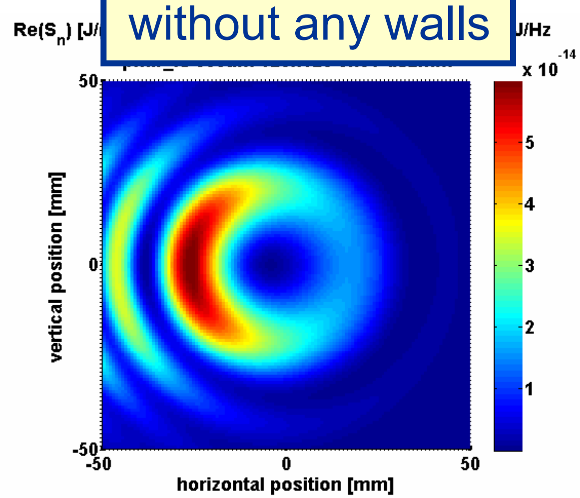


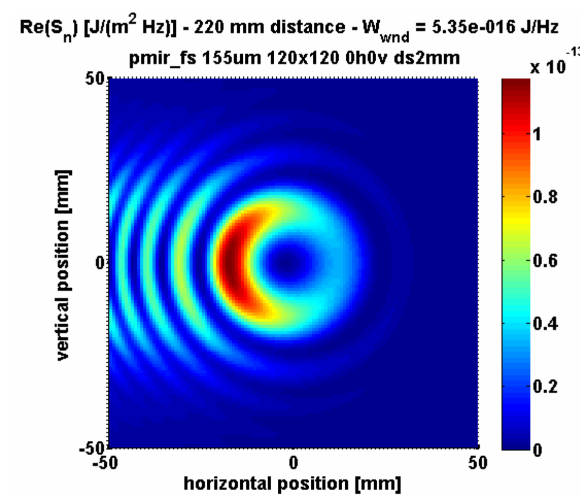




without any walls







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Transversal Bunch Effects

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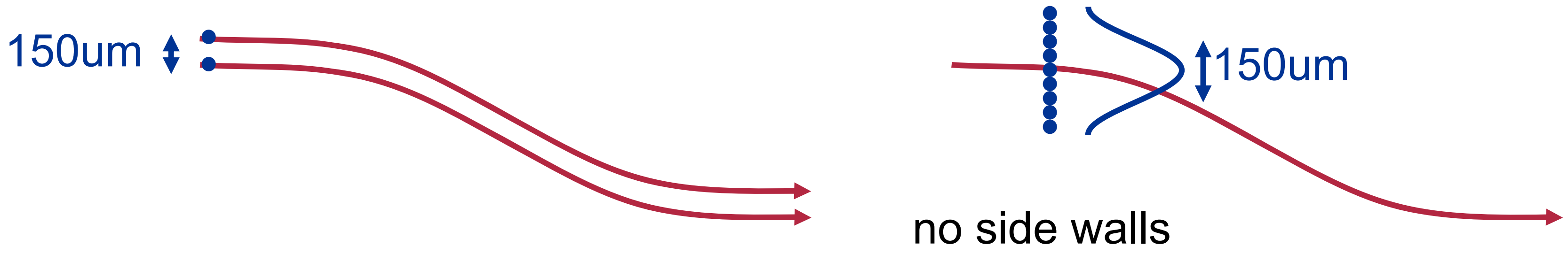
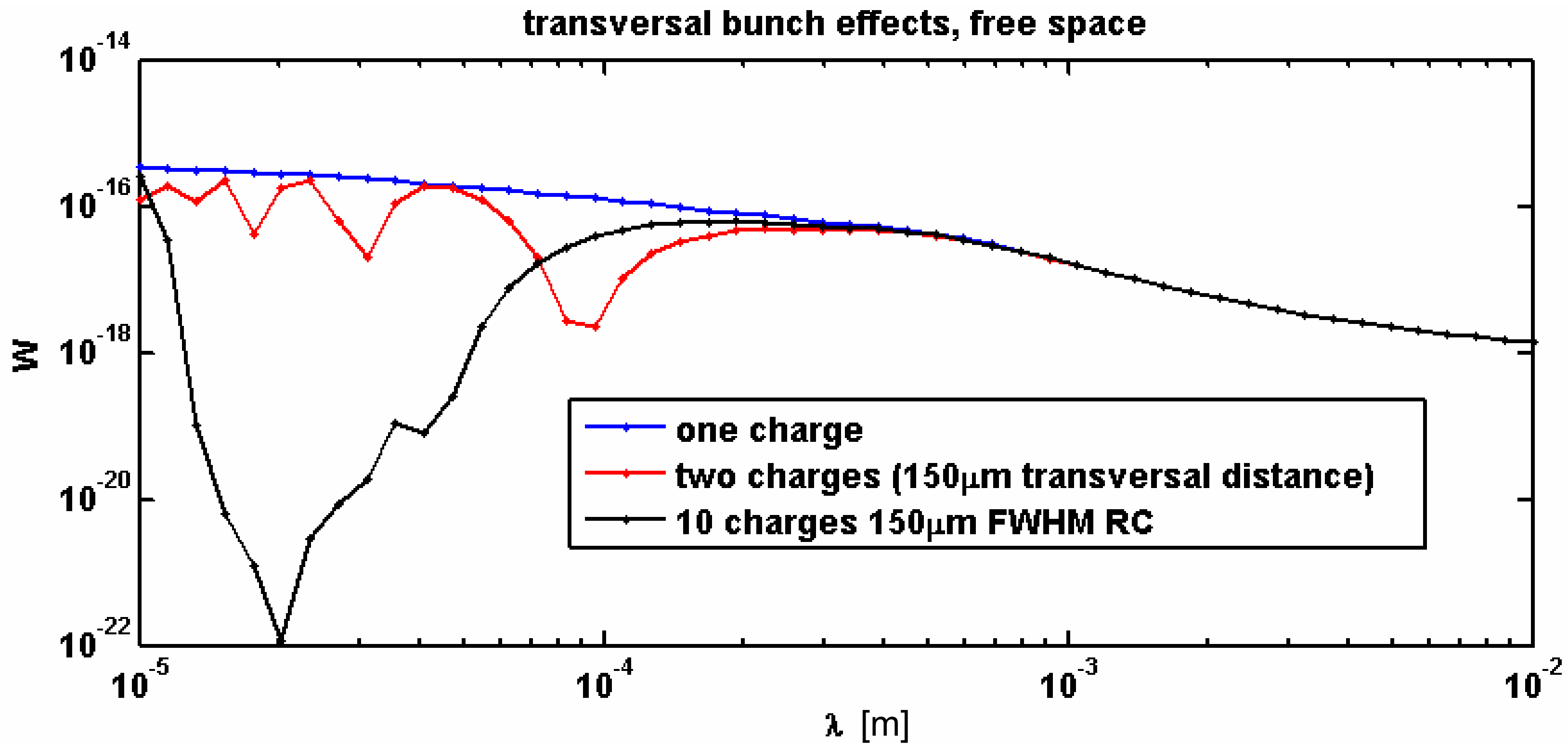
Test Transversal Influence

compare single point charge to





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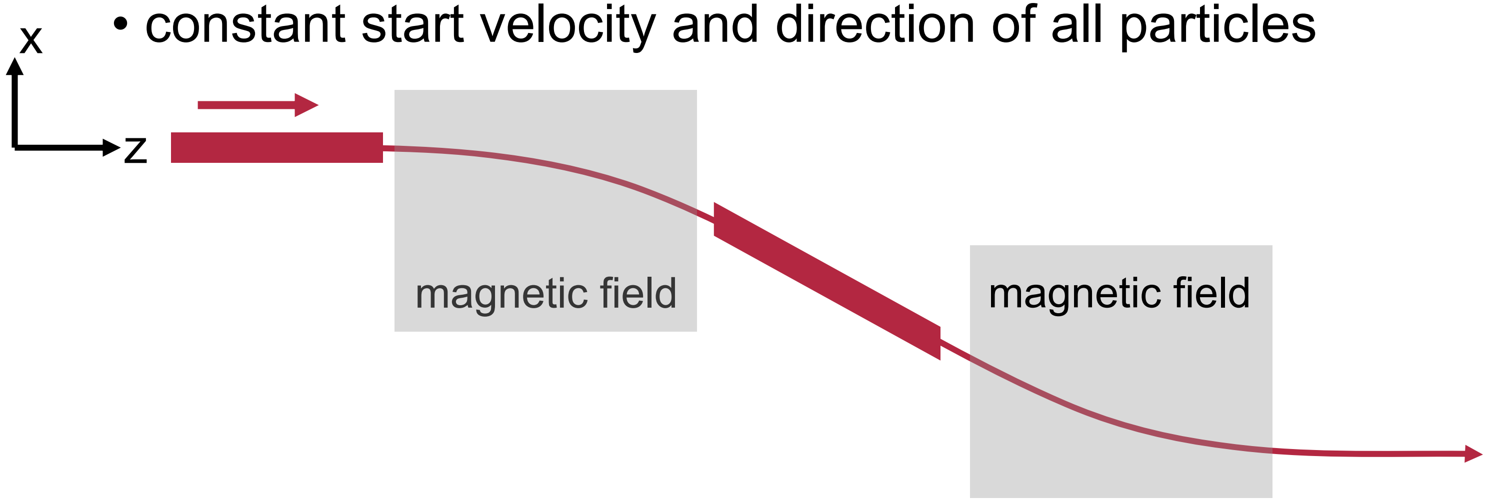
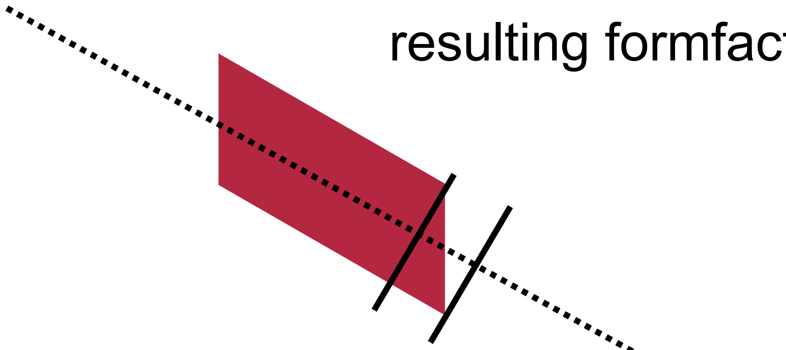
Explanation

assumptions:

- charge distribution: $f(x,z) = f_x(x)\, f_z(z)$
- constant start velocity and direction of all particles



resulting formfactor: $F = F_z(\omega)\, F_x(\omega \sin(18°))$



the shear causes mixing of transversal and longitudinal formfactor

consequences for practice?

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Conclusion

Conclusion

- influence of sidewalls on SR at first BC
- simulation by FIT and optics
- comparison with measurements
- influence of sidewalls seen
- transversal effects
- main open questions:
  - influence of sidewalls on bunch diagnostics?
  - influence of mirror focus and rest of beam line?
  - influence of transversal effects?