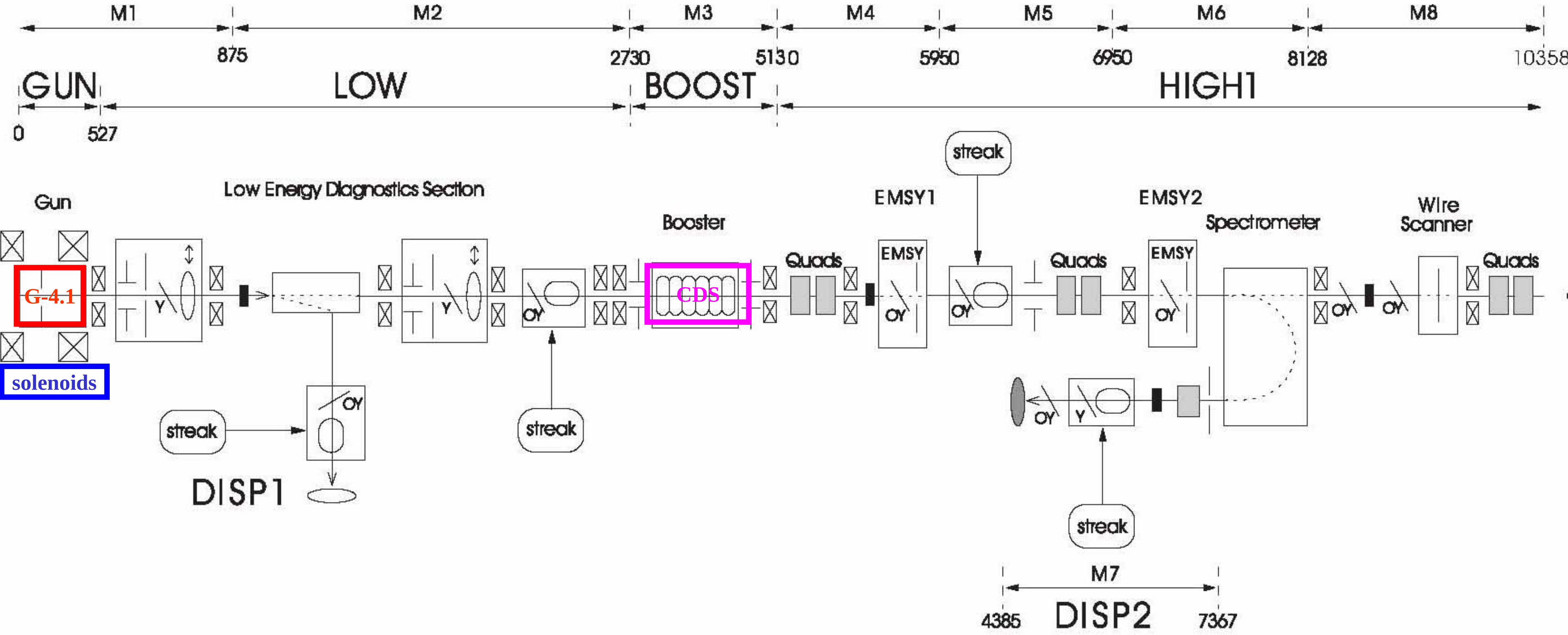
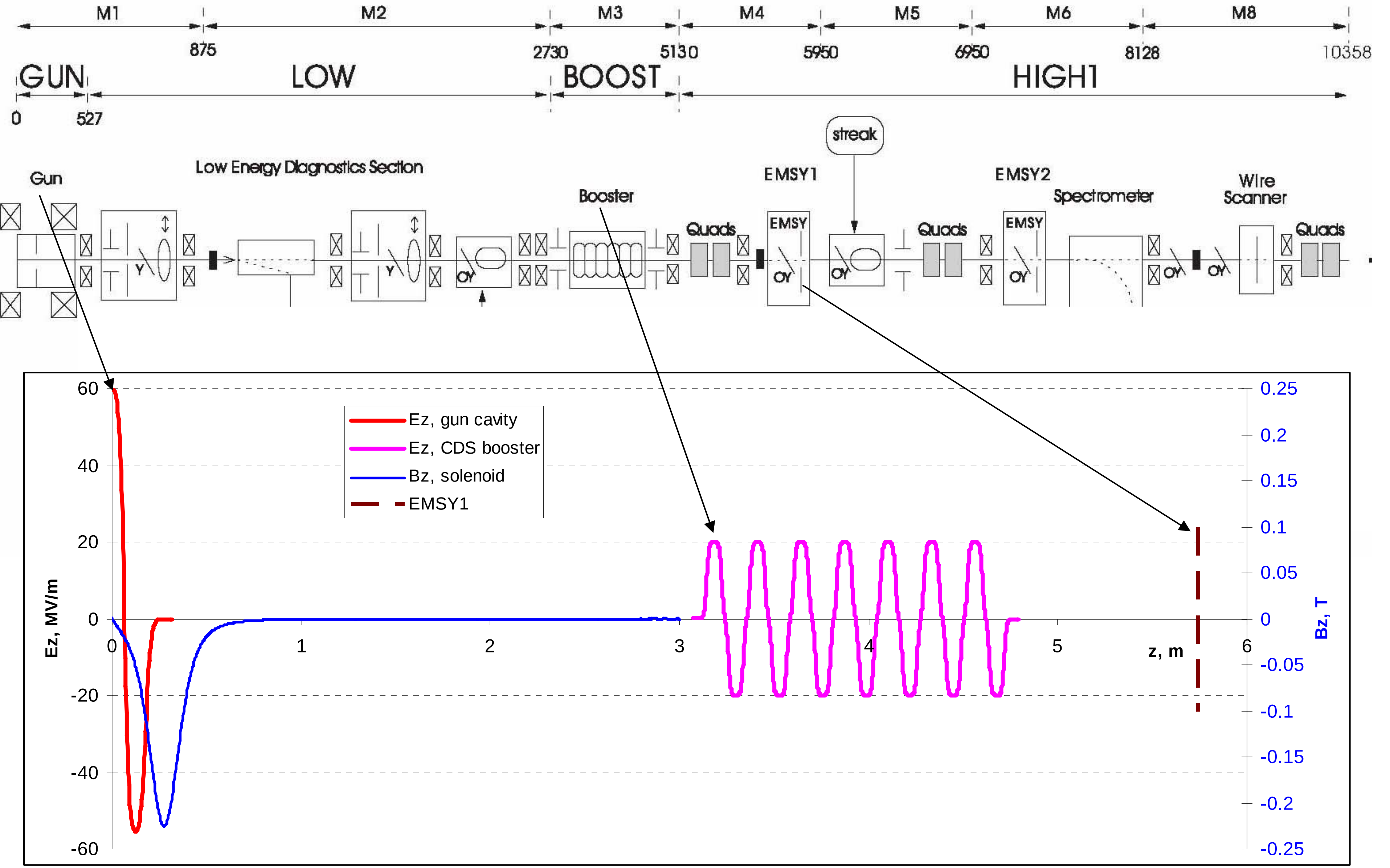



# Beam Dynamics Simulations for PITZ-1.8


*M.Krasilnikov,*

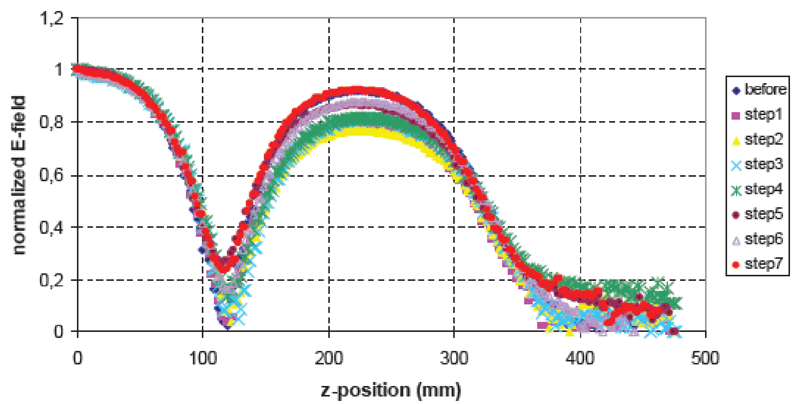
*PPS, 16.02.2009*

# PITZ-1.8 Setup



# Gun-4.2

Sakhorn Rimjaem, “**Tuning of Gun 4.1 and 4.2”**, PITZ Physics Seminar,April 3, 2007



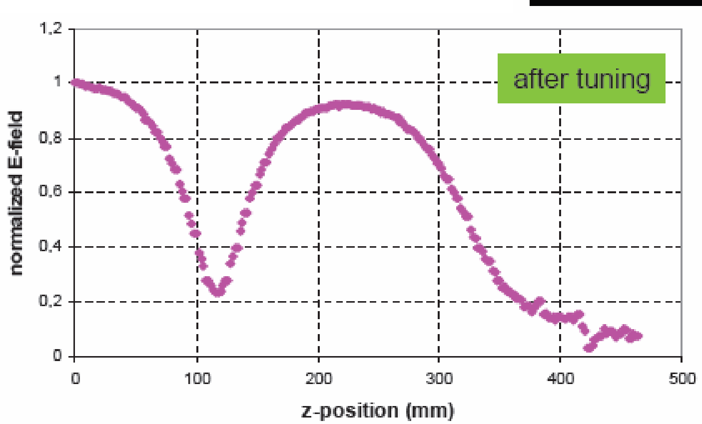
On-axis field distribution in the gun cavity for each the tuning steps

Measurement results of π-mode for each tuning steps

| iteration | $f_{air}$ (GHz) | flatness | $T_{op}$ (ºC) | tuning method |
|---|---|---|---|---|
| before | 1.300864 | 1.09 | 79 | - |
| step1 | 1.300383 | 1.25 | 57 | push full-cell |
| step2 | 1.300373 | 1.29 | 56 | push half-cell |
| step3 | 1.300326 | 1.23 | 54 | push half-cell |
| step4 | 1.300279 | 1.22 | 52 | push half-cell |
| step5 | 1.300186 | 1.17 | 48 | push half-cell |
| step6 | 1.300295 | 1.13 | 53 | pull full-cell |
| step7 | 1.300465 | 1.08 | 60 | pull full-cell |

After Tuning

| | |
|---|---|
| room temperature | 21.5 ºC |
| $f_0$ (π-mode) | 1.300465 GHz |
| Δf (no cathode – cathode) for π-mode | 280 kHz |
| Flatness for π-mode | 1.08 |
| Operating temperature for 1.3 GHz | 60ºC |

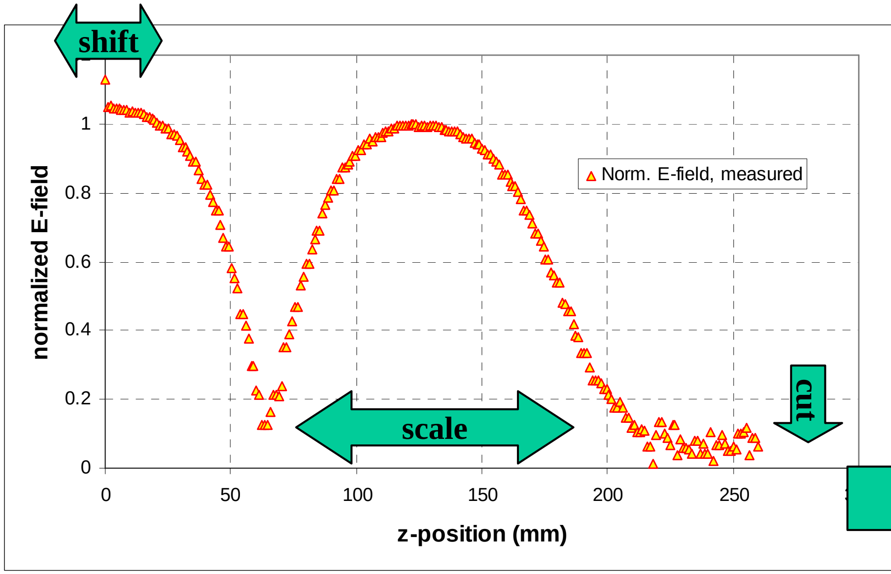


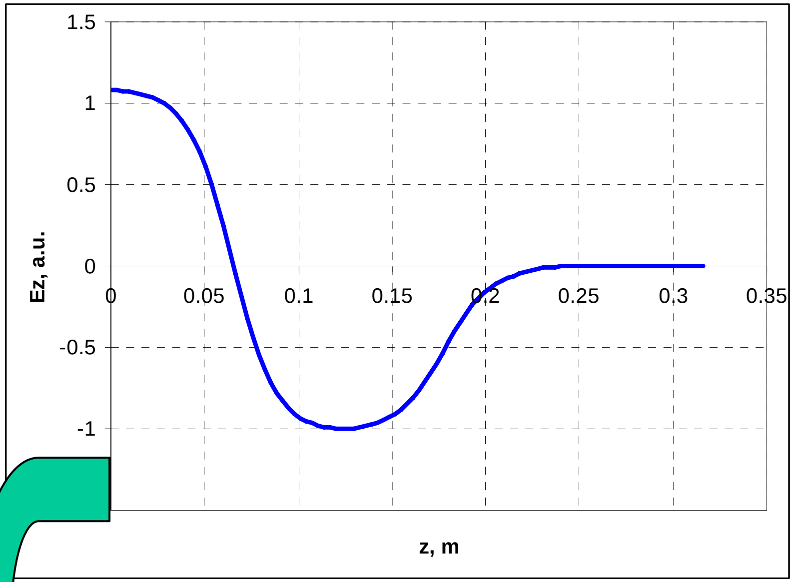
On-axis field distribution in the gun cavity after tuning completed.
After the tuning, the field in cathode cell is 8% higher than that is the full cell.

## Gun 4.1 (for π- mode):

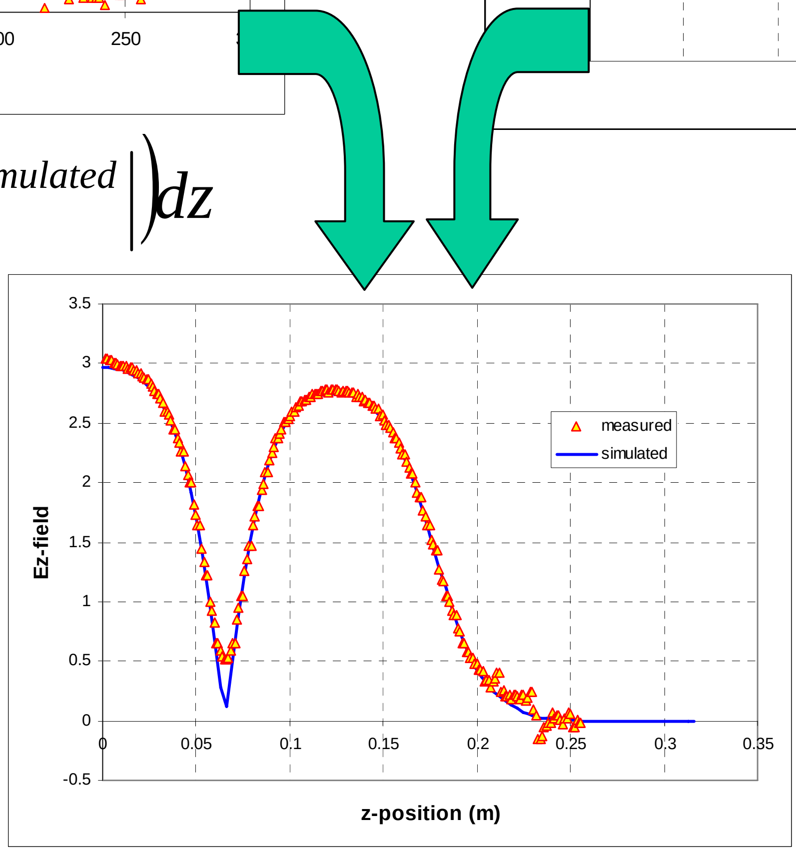
- $f_o$ after tuning = 1.300465 GHz
- Operating temperature = 60ºC (preferable temp.=55ºC)
  - → still in tolerance of the cooling system limit
  - → Gun4 has improved cooling channel design from Gun3
  - → higher $T_{op}$ may be suitable with Gun4 since it will be operated with higher power + longer pulses
- Field flatness = 1.08

# Gun-4.2: field profile simulations



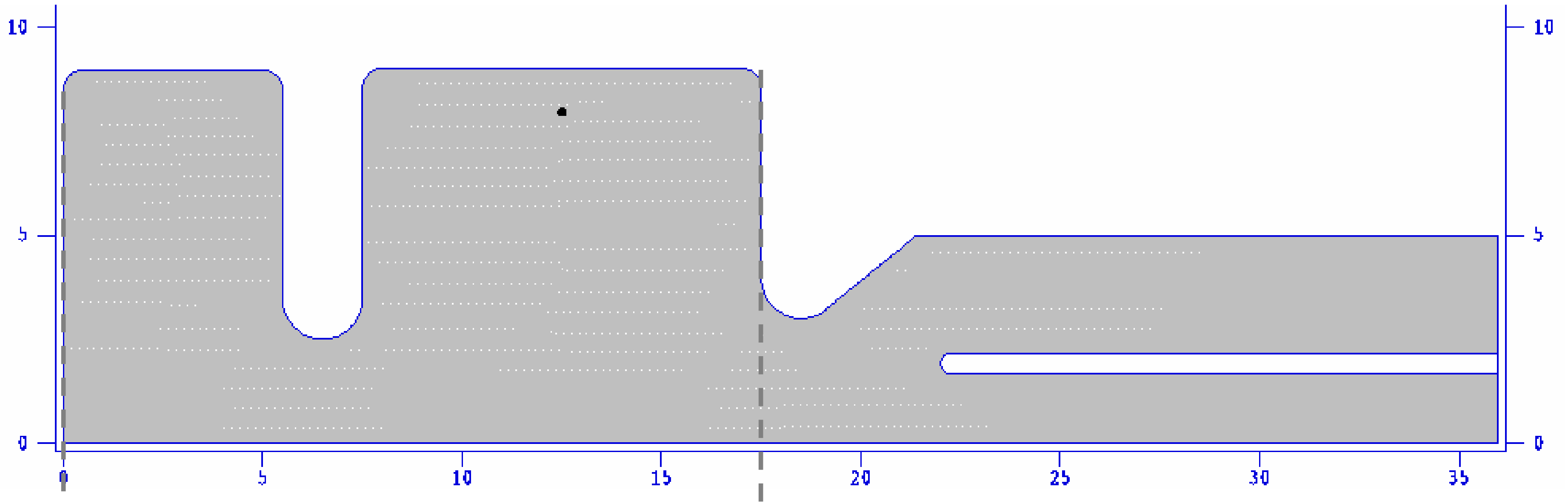




$$\delta \propto \int w \cdot \left( \left| \tilde{E}_z^{meas} \right| - \left| E_z^{simulated} \right| \right) dz$$

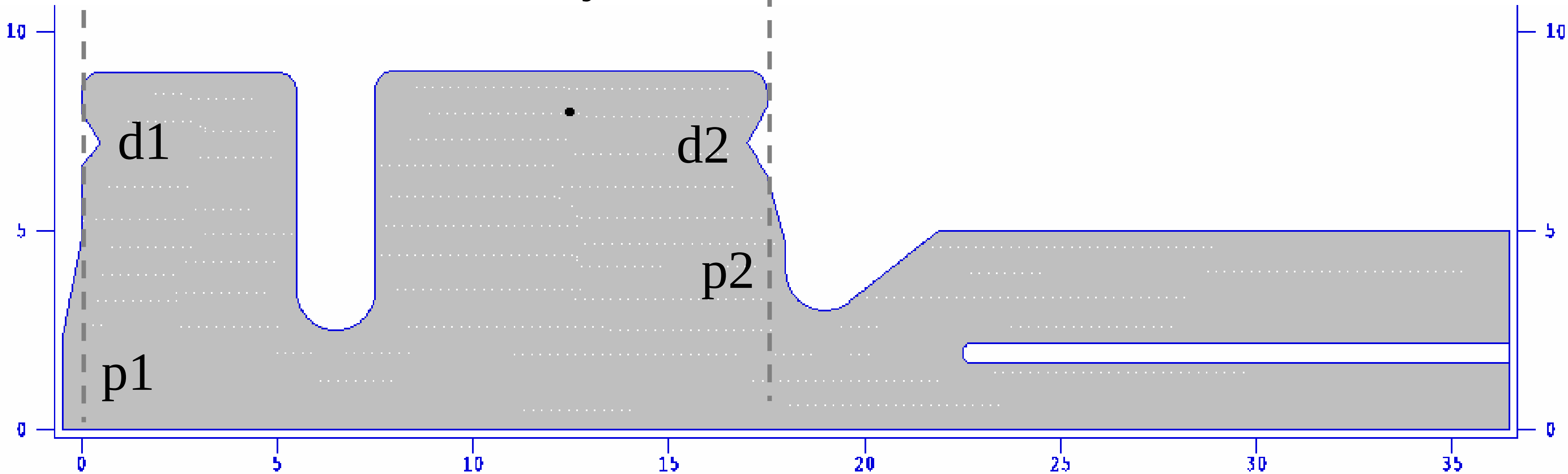



Scale=0.54779;
shift=-0.0015361;
cut=0.079998;
delta=0.075934

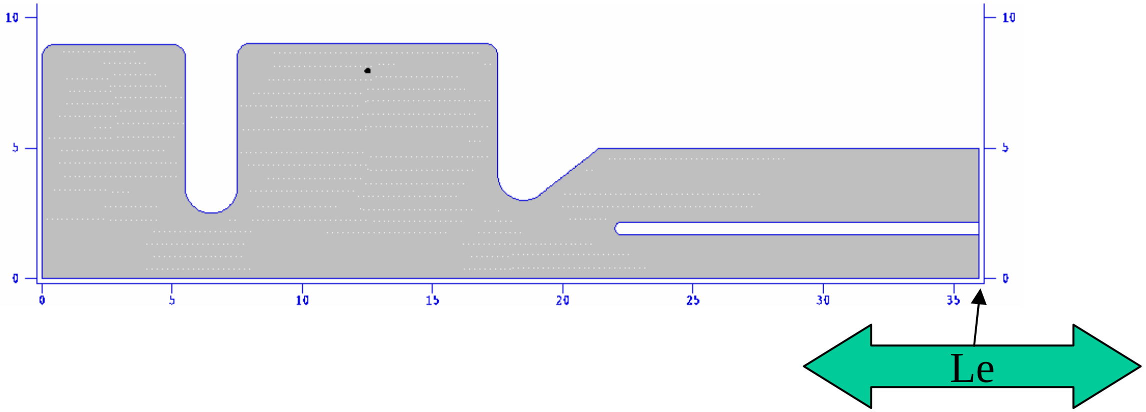
# Gun-4.1 simulation of measured field profile

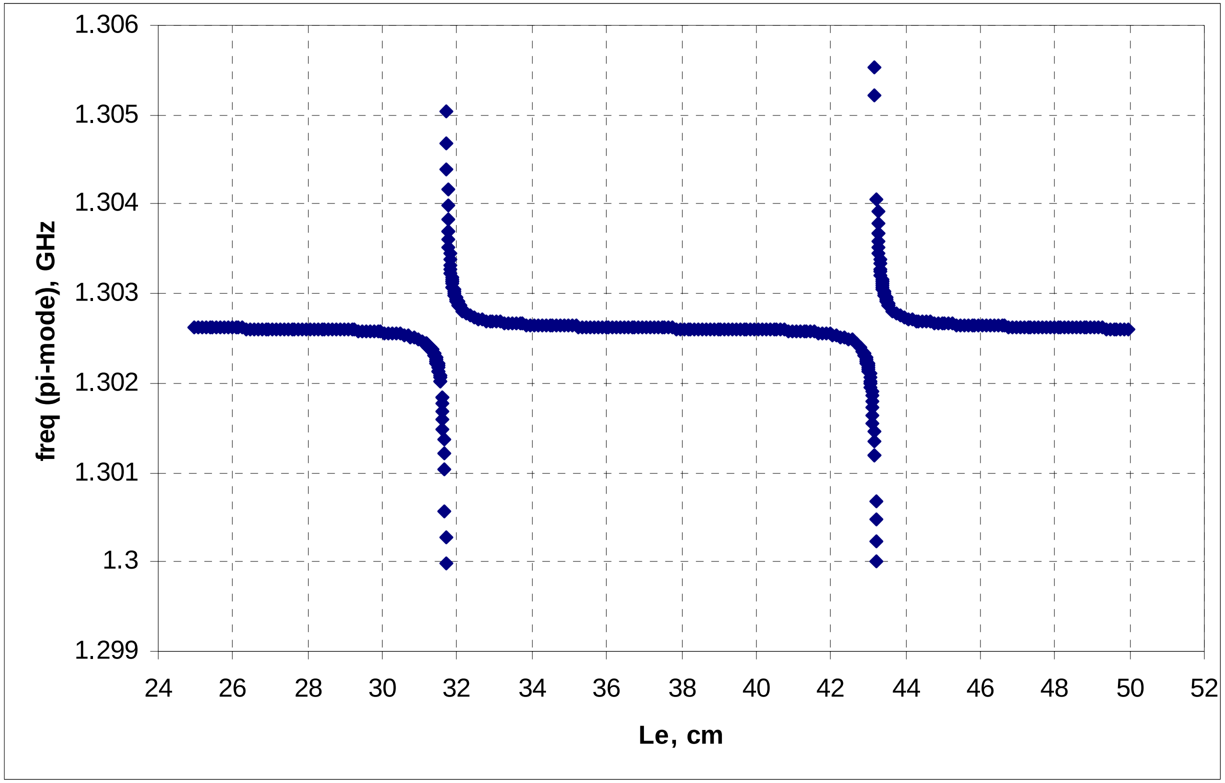



Cavity deformation model



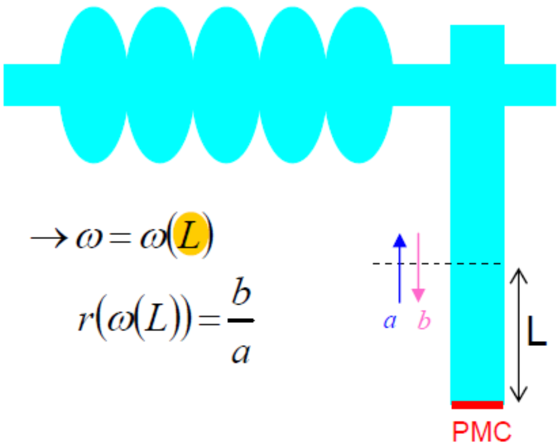
# Gun-4.1 : Le = length of the coupler



# Gun-4.1 : Le = length of the coupler

method 2
eigenmode solver (no losses)

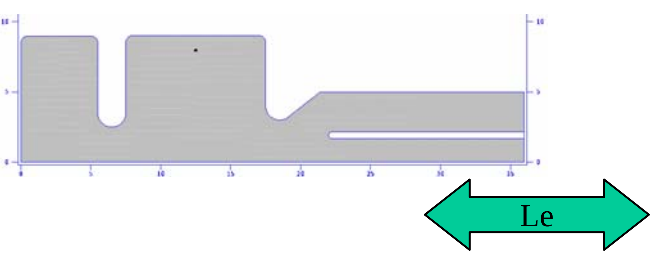


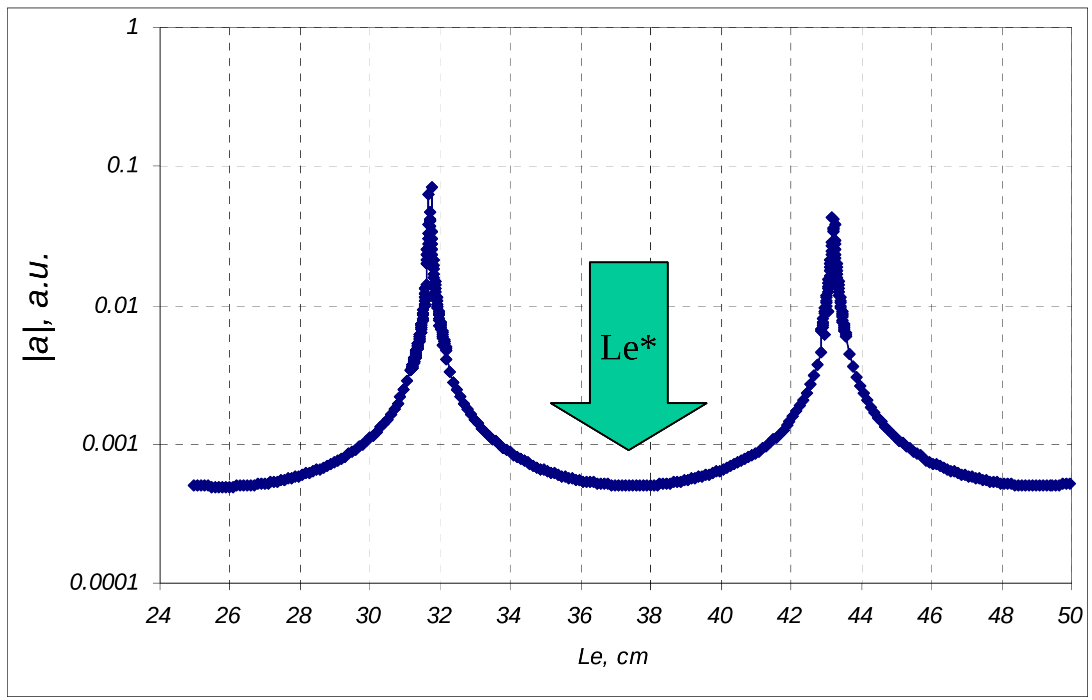

$$\rightarrow \omega = \omega(L)$$

$$r(\omega(L)) = \frac{b}{a}$$

Courtesy M.Dohlus “Some methods to calculate RF-coupler fields in accelerating cavities”, KWT2008

$$A(\omega) = \frac{W_{tot}(\omega)}{|a(\omega)|^2} \qquad A(\omega) = \max \rightarrow \omega_R$$



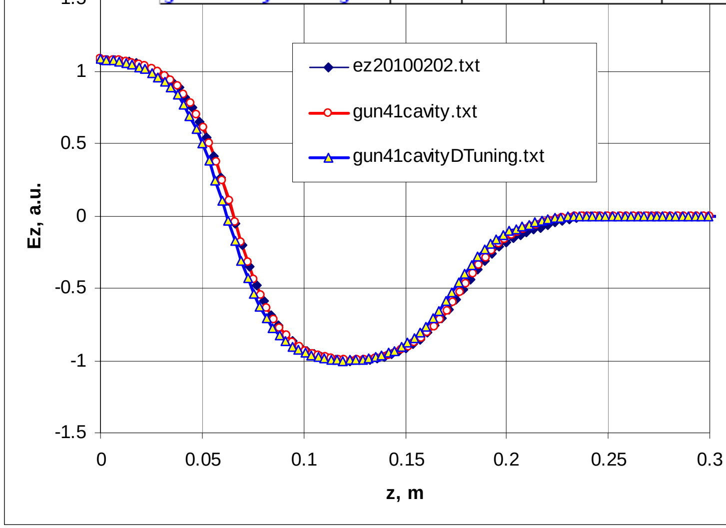



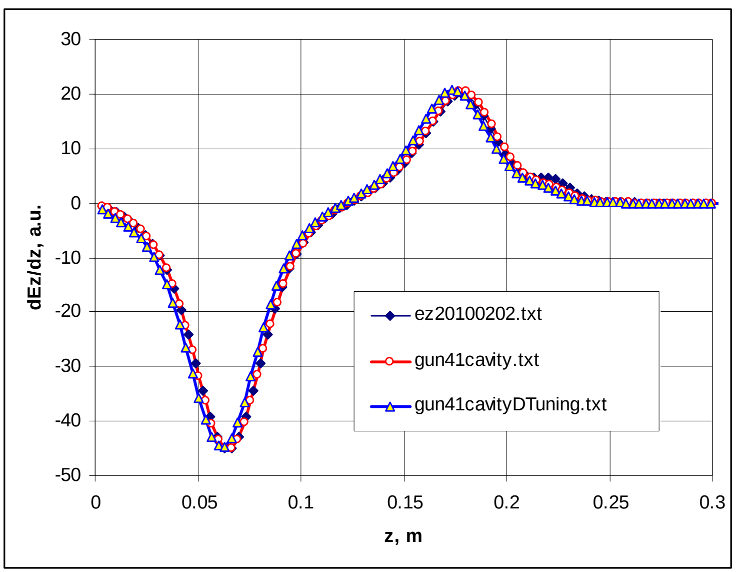
# Gun-4.1: summary

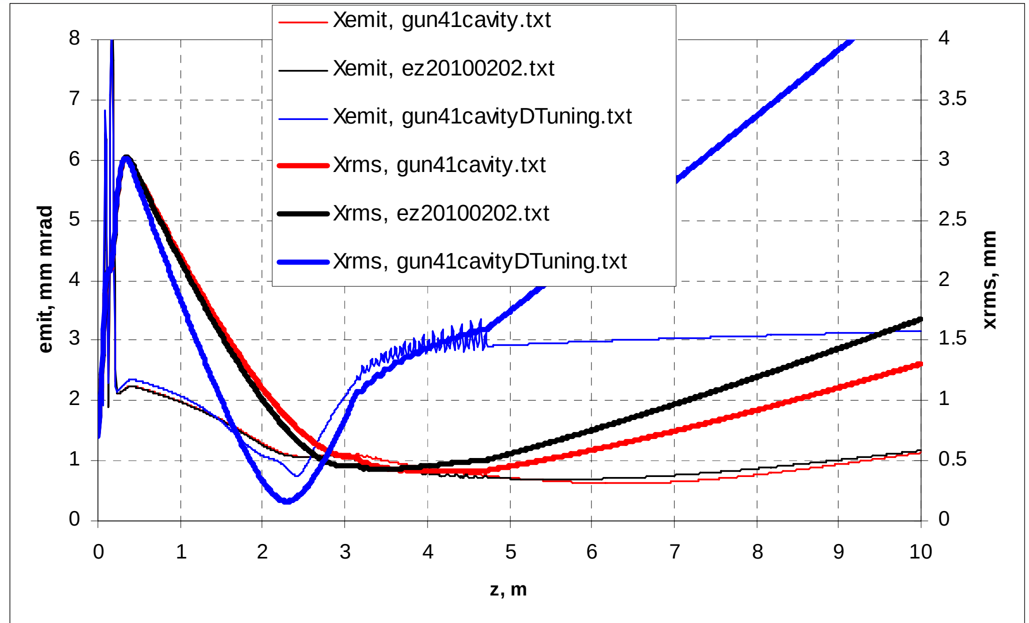
- Non-perturbed geometry → df=+2.6MHz (too much!)
- By simulation of the tuning procedure (p1,p2,d1,d2) it was not possible to simulate *simultaneously* frequency + field profile
- Only involving (R1,R2) helps to fit the measurements
- ? Once more check the geometry?
- ? Geometry deformation during welding?
- …

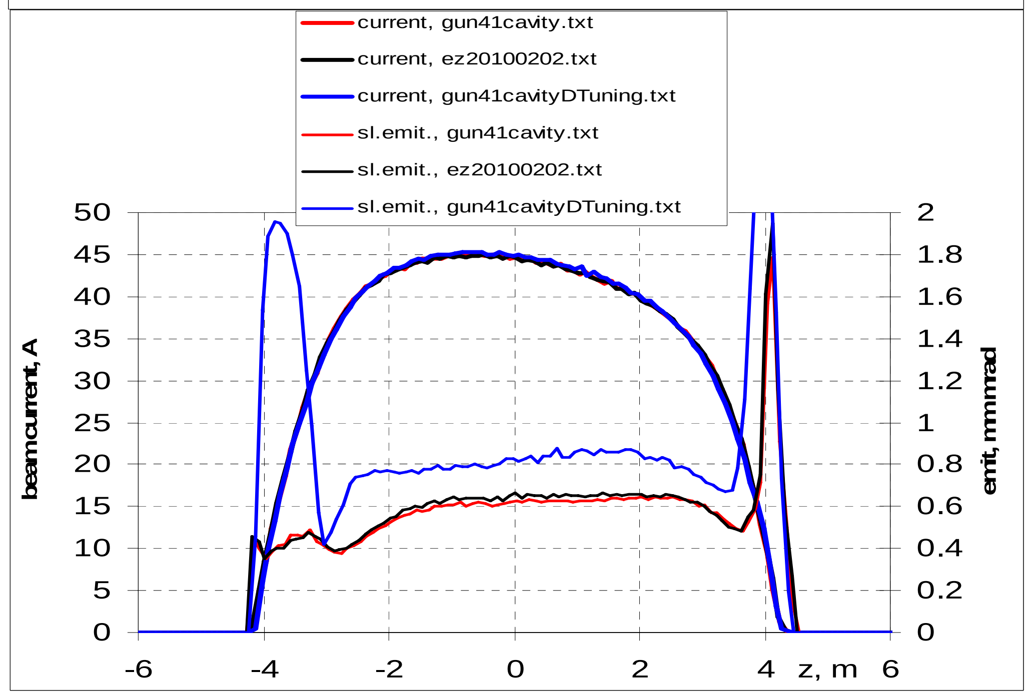
# PITZ-1.8 simulations using different gun field profiles

| filename | delta | scale | shift | cut | pencut | penshift | penscale |
|---|---|---|---|---|---|---|---|
| ez20100202.txt | 0.0671 | 0.55162 | -0.00097045 | 0.079901 | 1 | 1 | 1 |
| gun41cavity.txt | 0.0759 | 0.54779 | -0.0015361 | 0.079998 | 1 | 1 | 1 |
| gun41cavityDTuning.txt | 0.0819 | 0.54591 | 0.0016926 | 0.079998 | 1 | 1 | 1 |



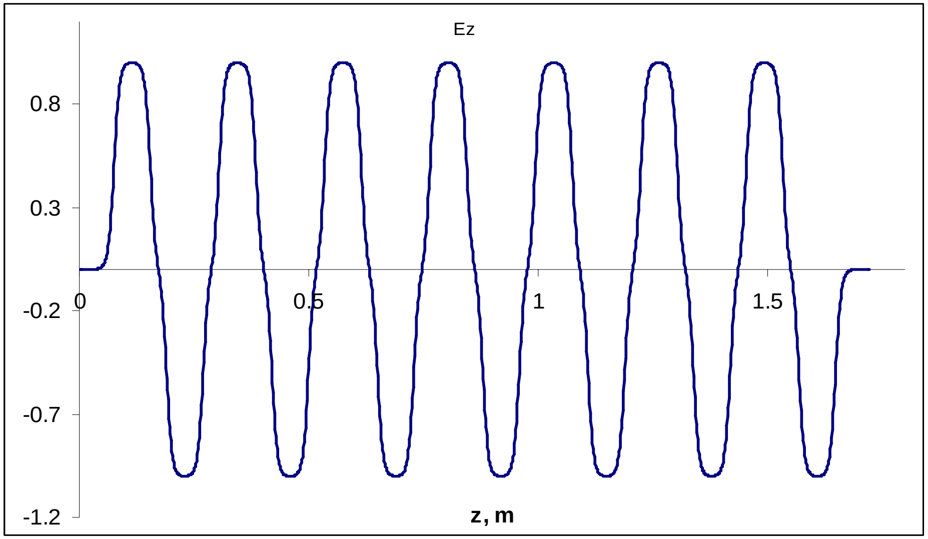



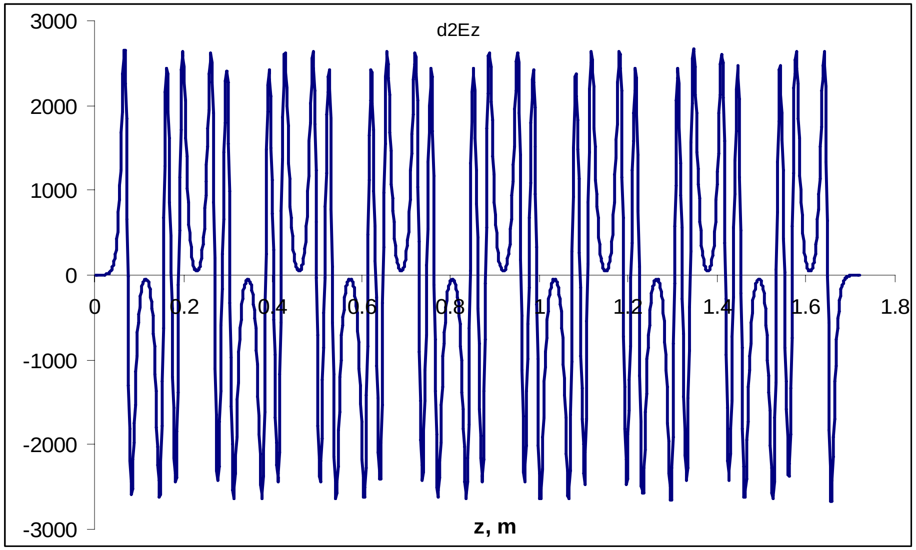



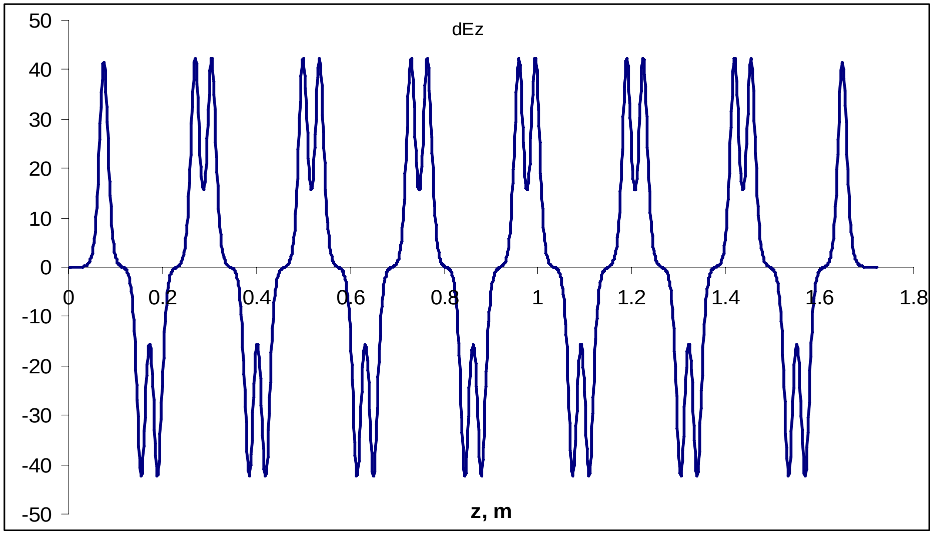
# CDS-booster: Ez field on the z-axis

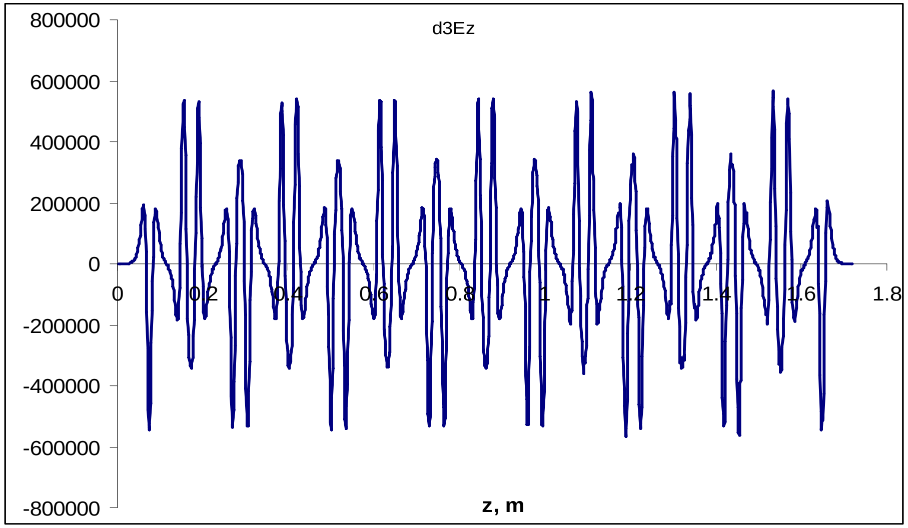
*Field distribution for ½-cell (+end cells) provided by V.Paramonov*

File: **CDS14_15mm.txt** = 14 cells for the structure with 15 mm aperture

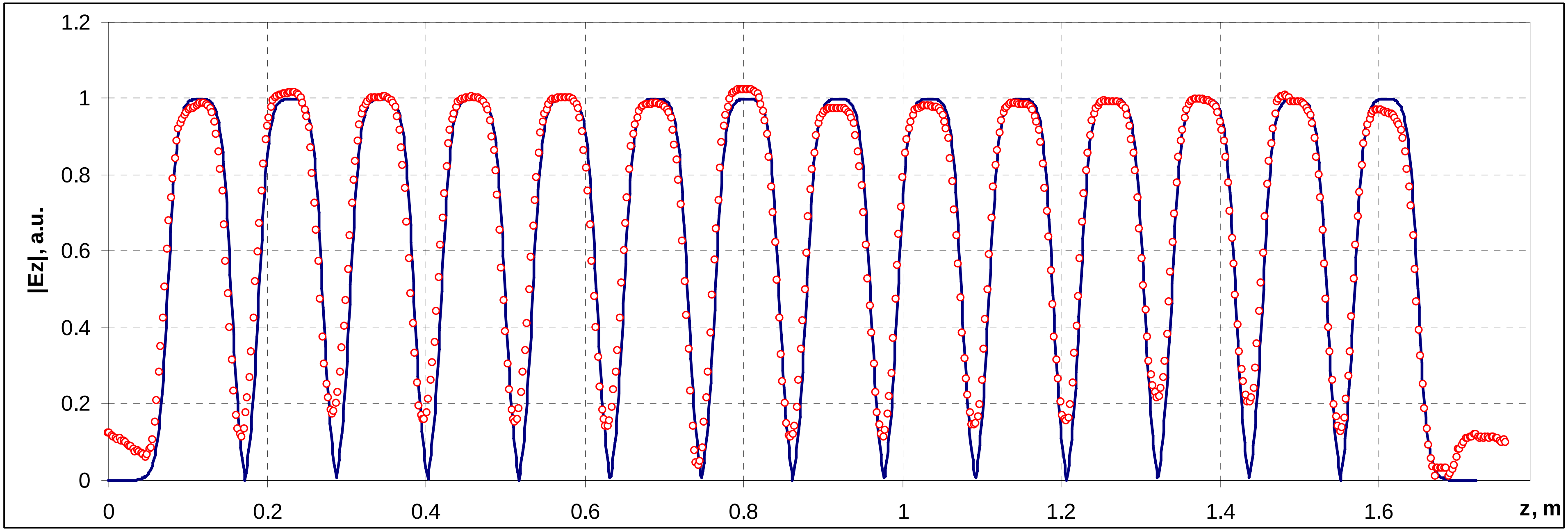


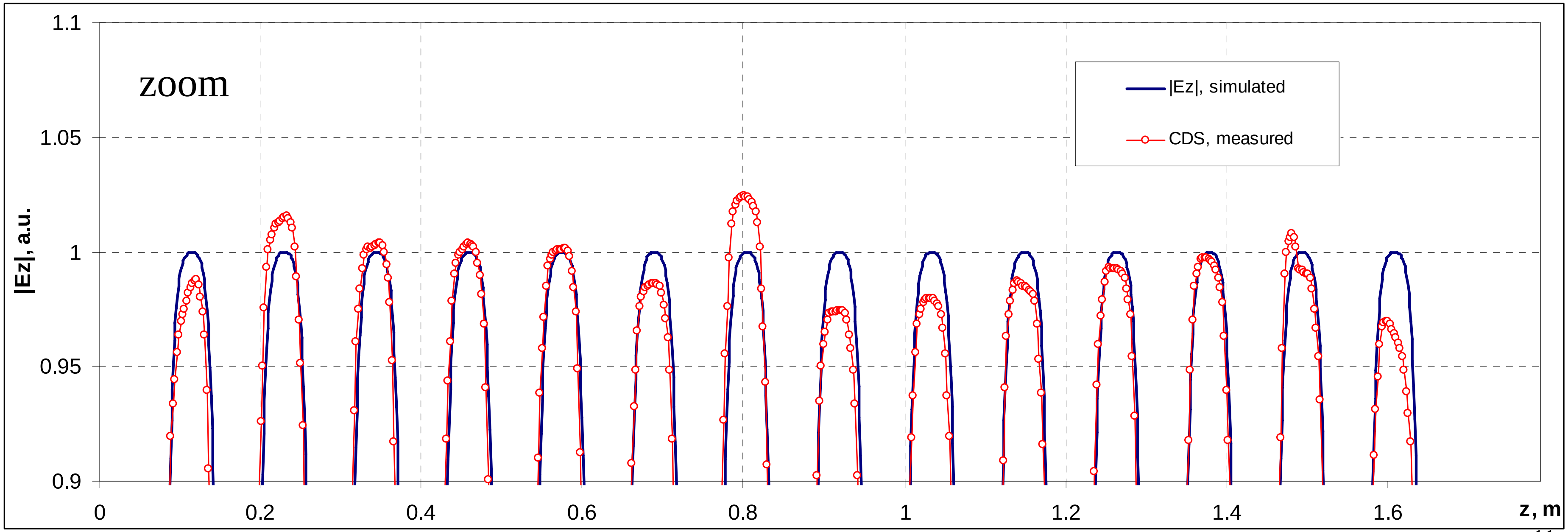



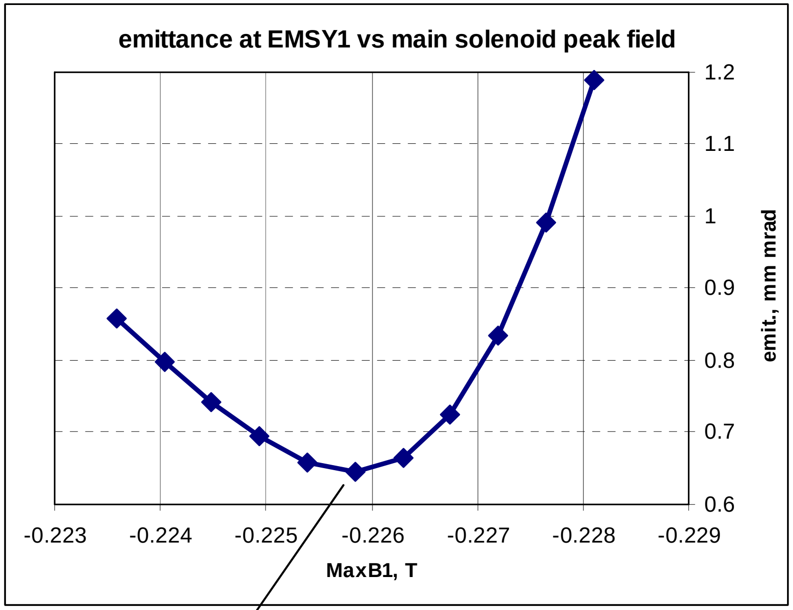



# CDS-booster: Ez field on the z-axis compared to measurements

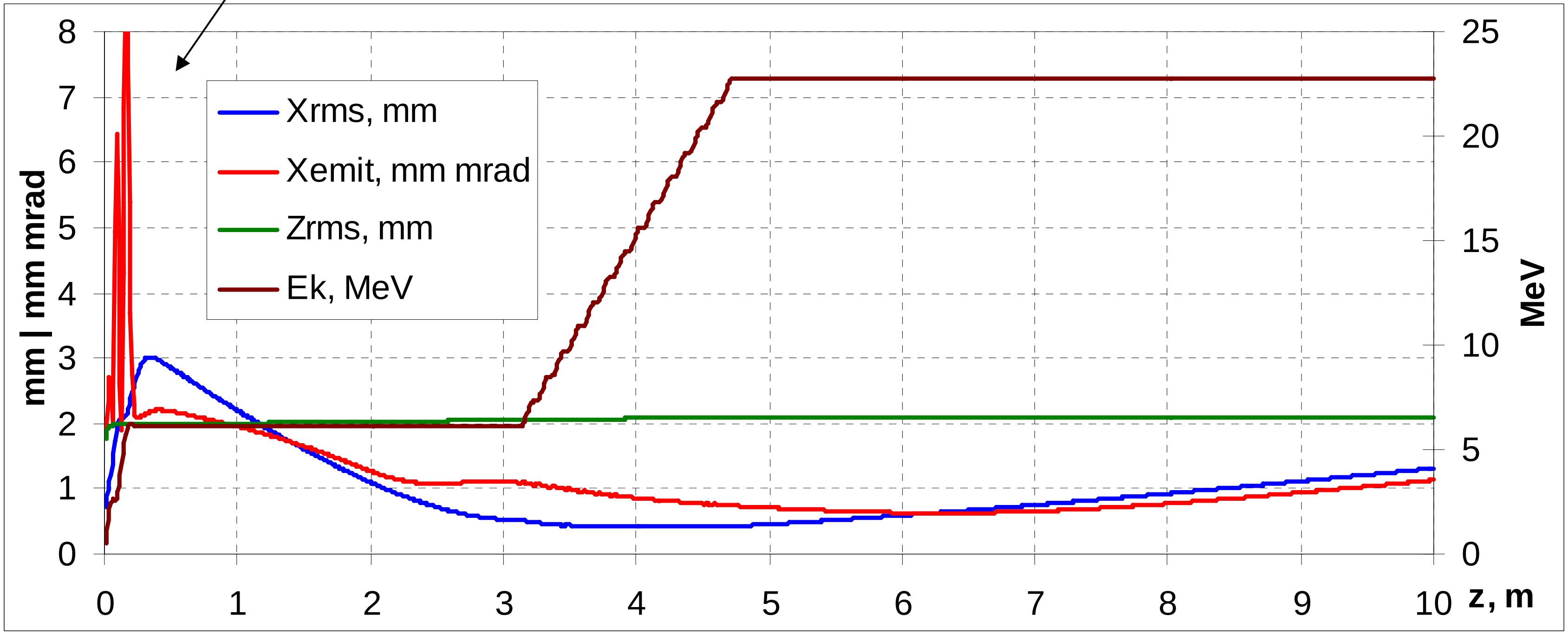


# PITZ-1.8 optimization, Q=1nC

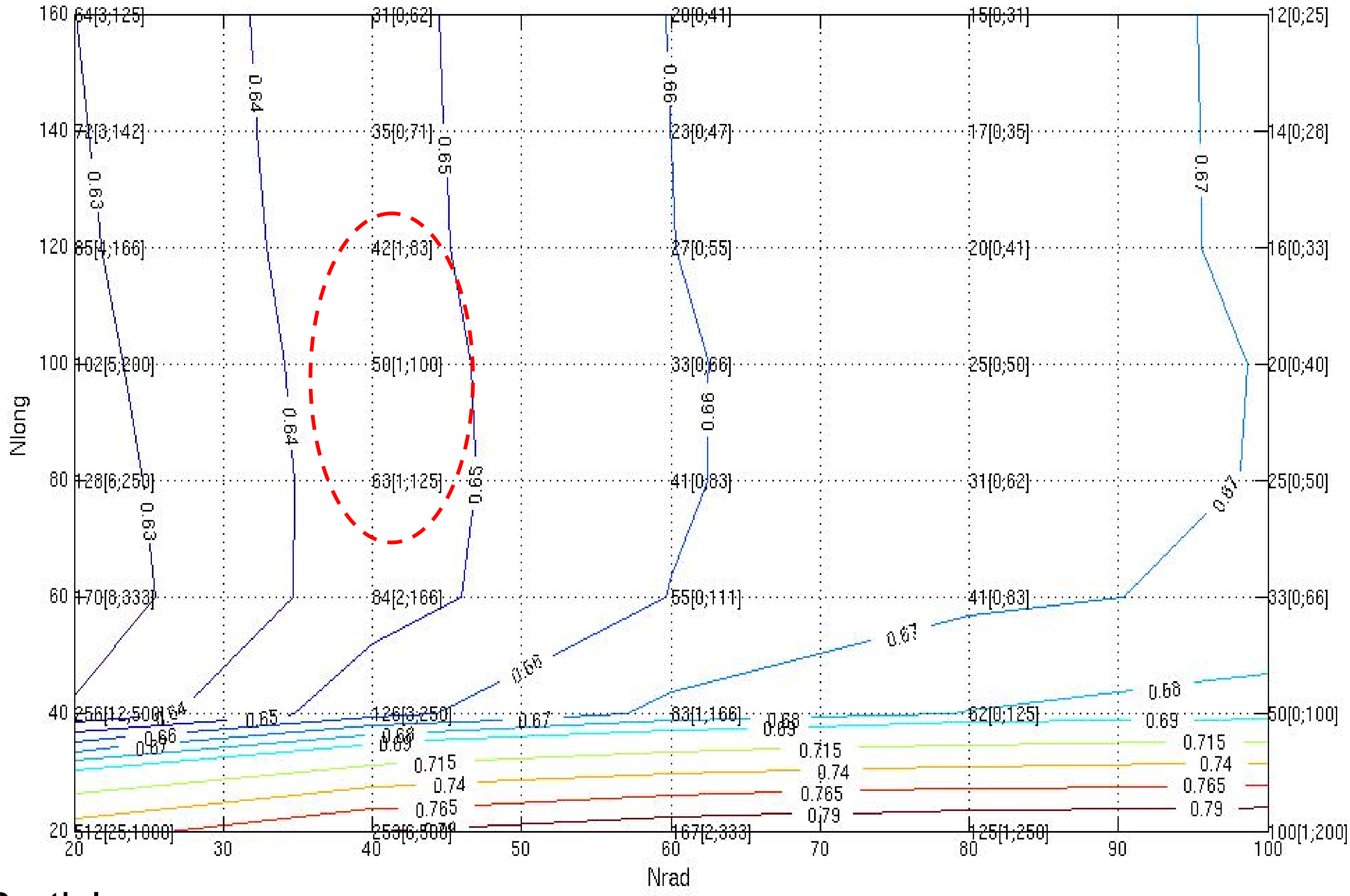



| | | parameter | value | unit | opti? |
|---|---|---|---|---|---|
| gun | cavity | Ecath | 60 | MV/m | no |
| | | phase | -1.93 | deg | yes |
| | solenoid | MaxB1 | -0.225843 | T | yes |
| | laser | Lt | 20 | ps | no |
| | | rt | 2 | ps | no |
| | | Ek | 0.55 | eV | no |
| | | XYrms | 0.4151 | mm | yes |
| booster | cavity | Emax | 19.1 | MV/m | yes |
| | | phase | 0 | deg | no |
| electron | emittance | EMSY1 | 0.646 | mm mrad | |
| | energy | Ek | 22.8 | MeV | |



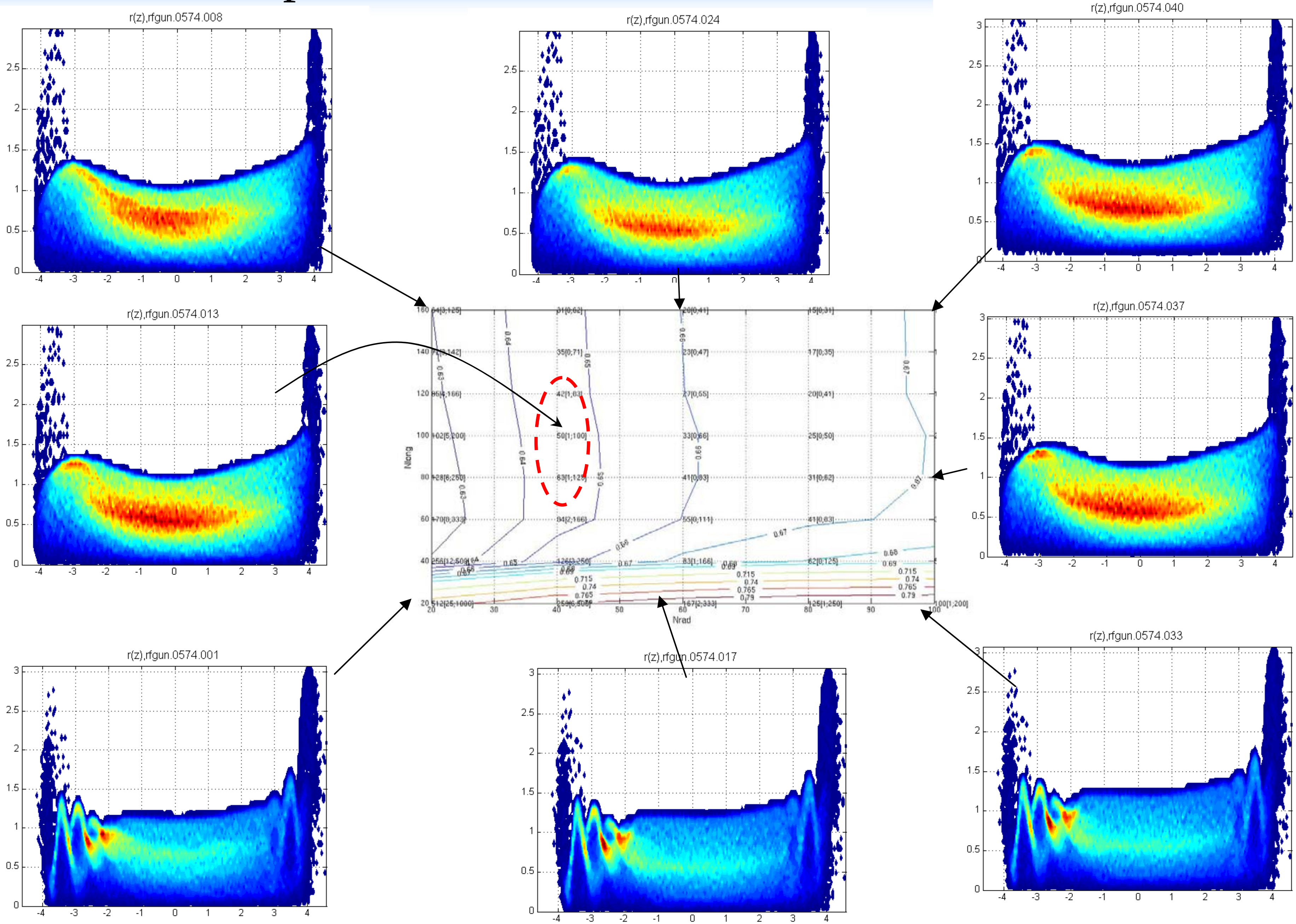
# PITZ-1.8 optimization, Q=1nC, SC mesh setup

Emittance(z=5.74m, Nrad,Nlong_in);   particles in cell [inner cell; outer cell]

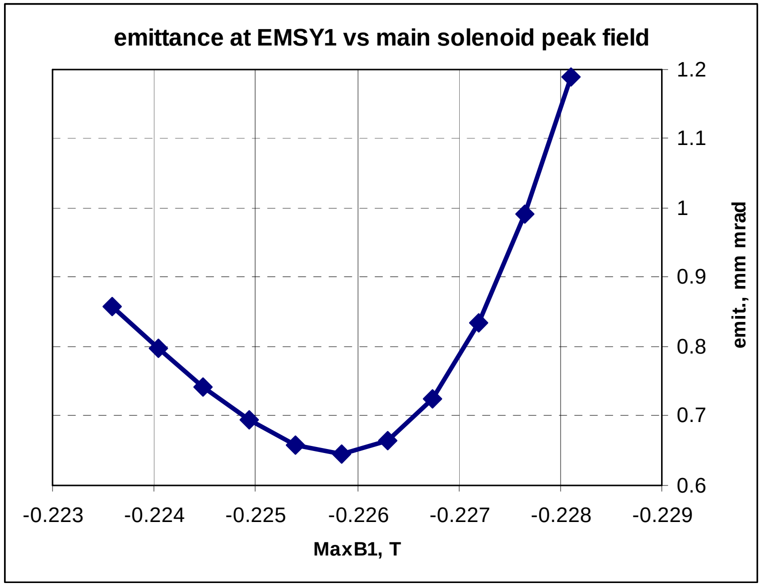


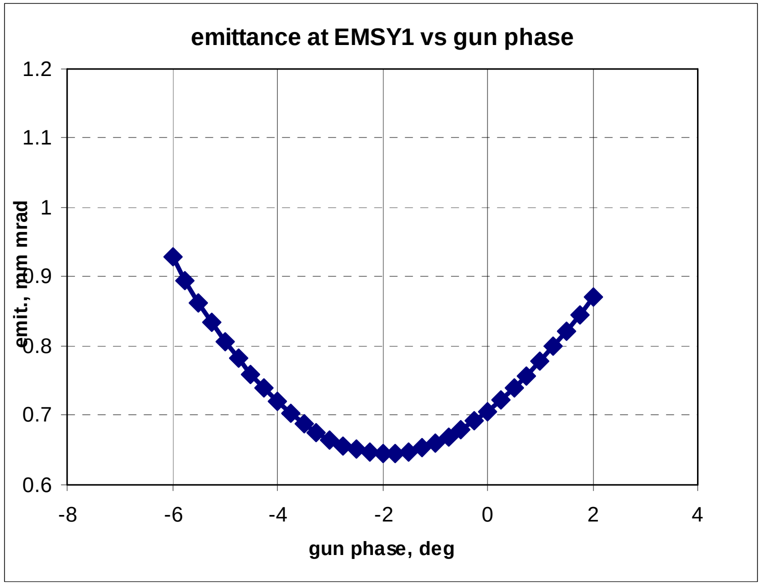

200kParticles

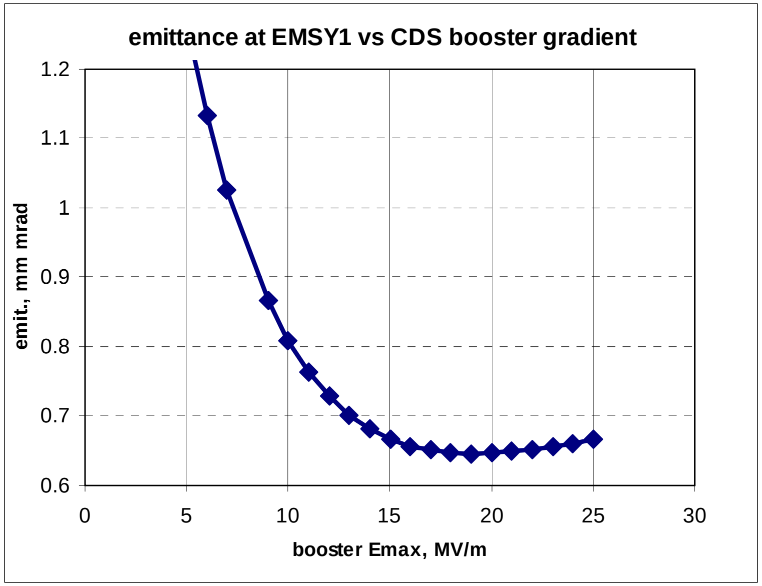
# PITZ-1.8 optimization, Q=1nC, SC mesh setup ←→ r(z)

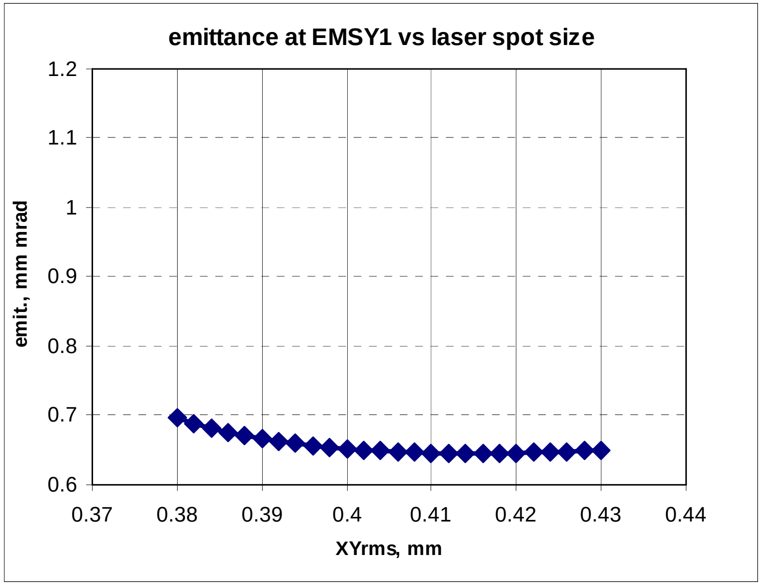


# PITZ-1.8 optimization, Q=1nC



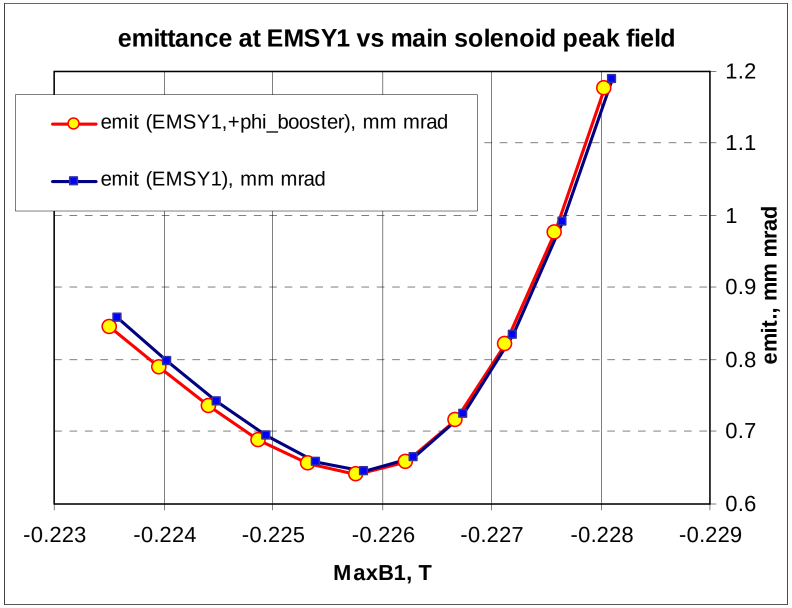



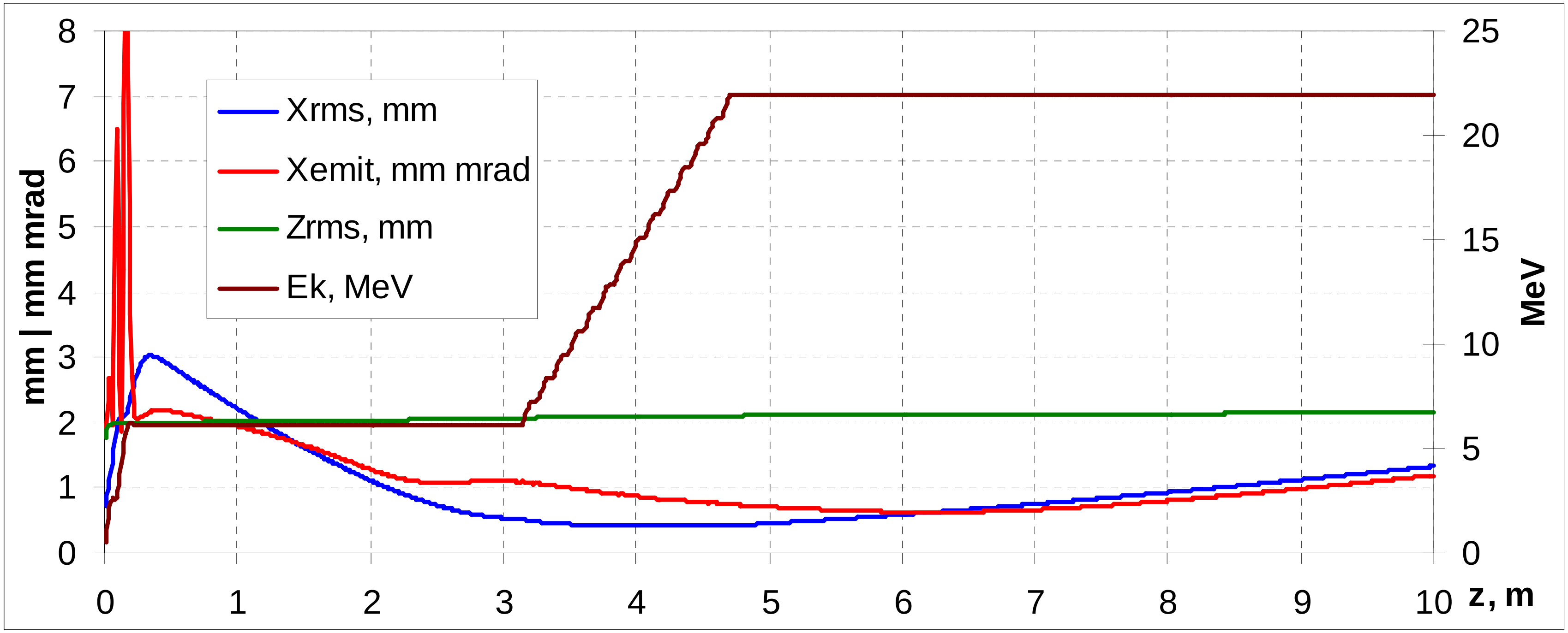

* booster phase is not optimized, on-crest operation

# PITZ-1.8 optimization, Q=1nC, +booster phase optimization

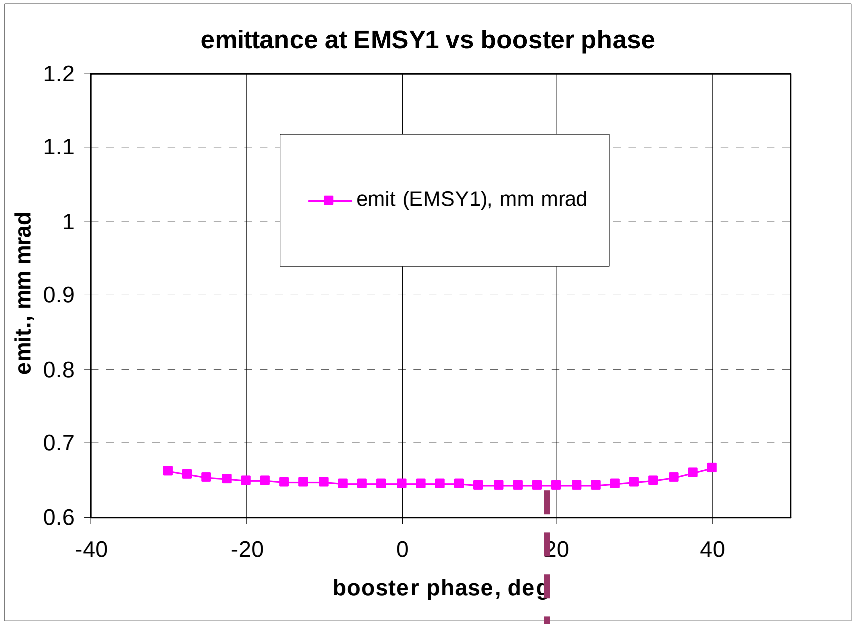


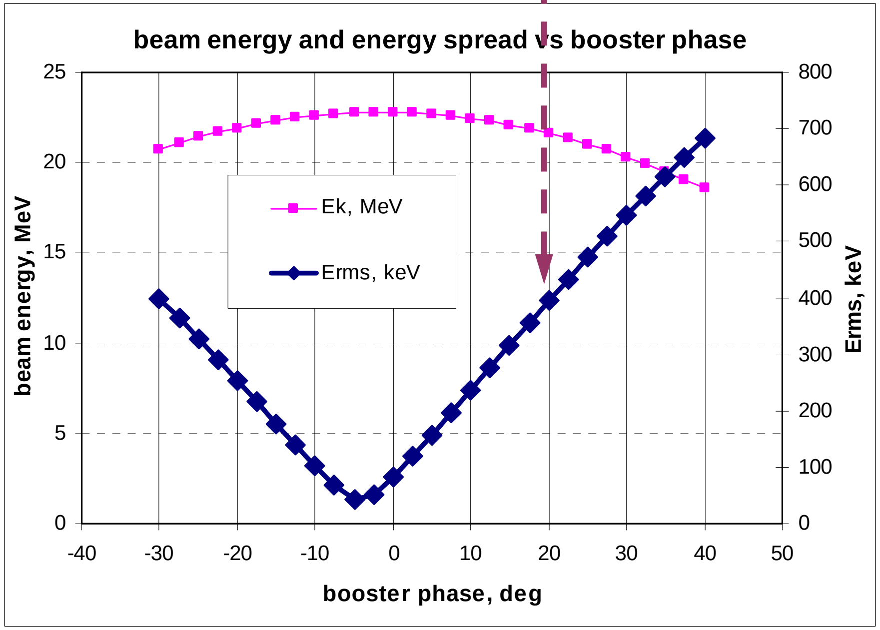

| | | parameter | value | | unit | opti? |
|---|---|---|---|---|---|---|
| gun | cavity | Ecath | 60 | 60 | MV/m | no |
| | | phase | -1.93 | -1.85 | deg | yes |
| | solenoid | MaxB1 | -0.225843 | -0.225771 | T | yes |
| | laser | Lt | 20 | 20 | ps | no |
| | | rt | 2 | 2 | ps | no |
| | | Ek | 0.55 | 0.55 | eV | no |
| | | XYrms | 0.4151 | 0.412 | mm | yes |
| booster | cavity | Emax | 19.1 | 19.4 | MV/m | yes |
| | | phase | 0 | 19.14 | deg | **yes** |
| electron | emittance | EMSY1 | 0.646 | 0.642 | mm mrad | |
| | energy | Ek | 22.8 | 21.9 | MeV | |

booster phase=0deg

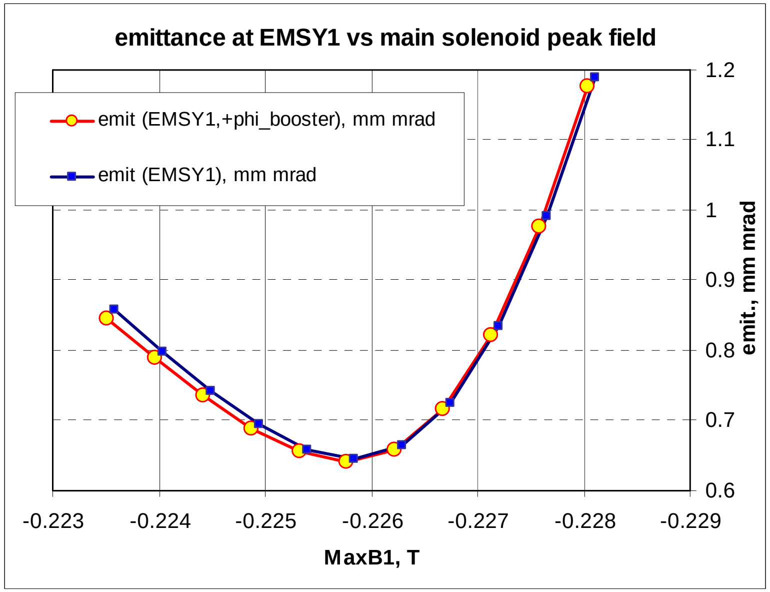


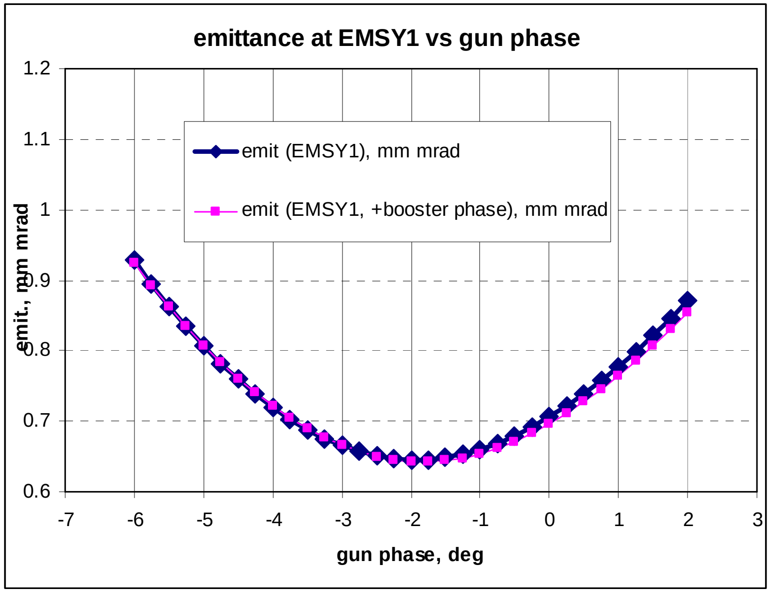
# PITZ-1.8 optimization, Q=1nC, +booster phase optimization

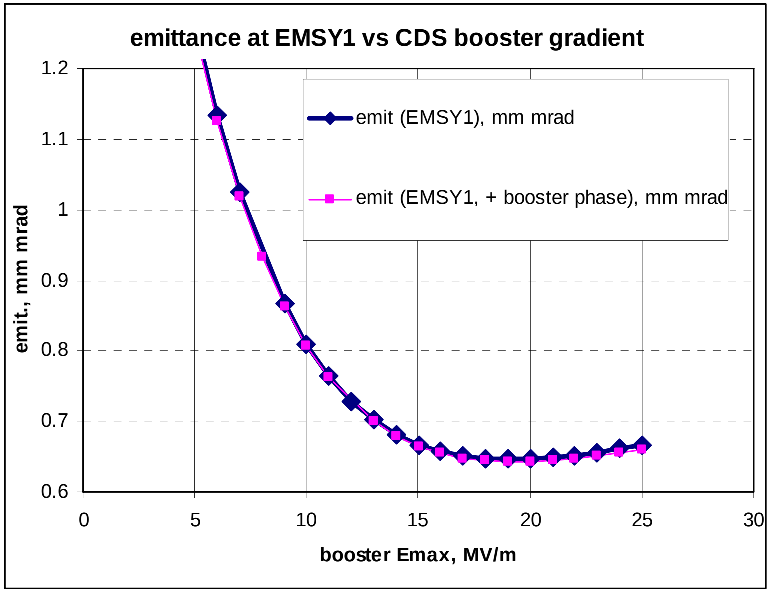


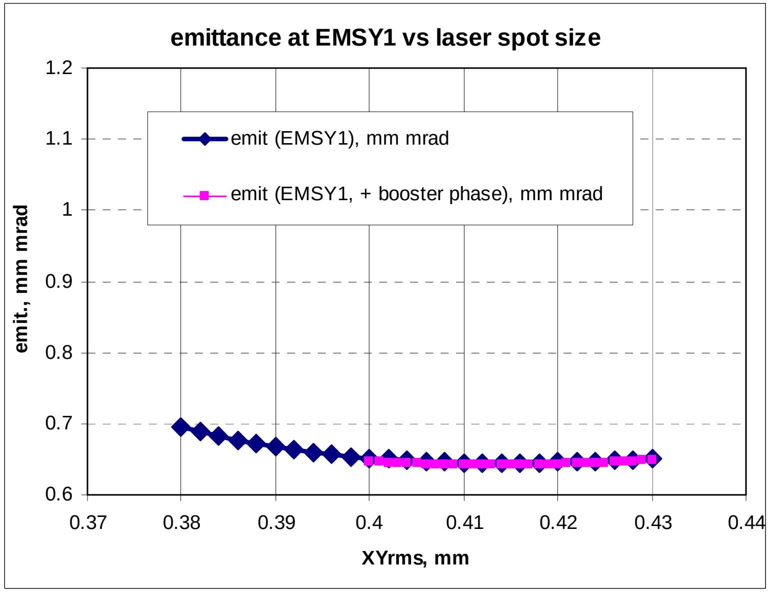



# PITZ-1.8 optimization, Q=1nC, +booster phase optimization

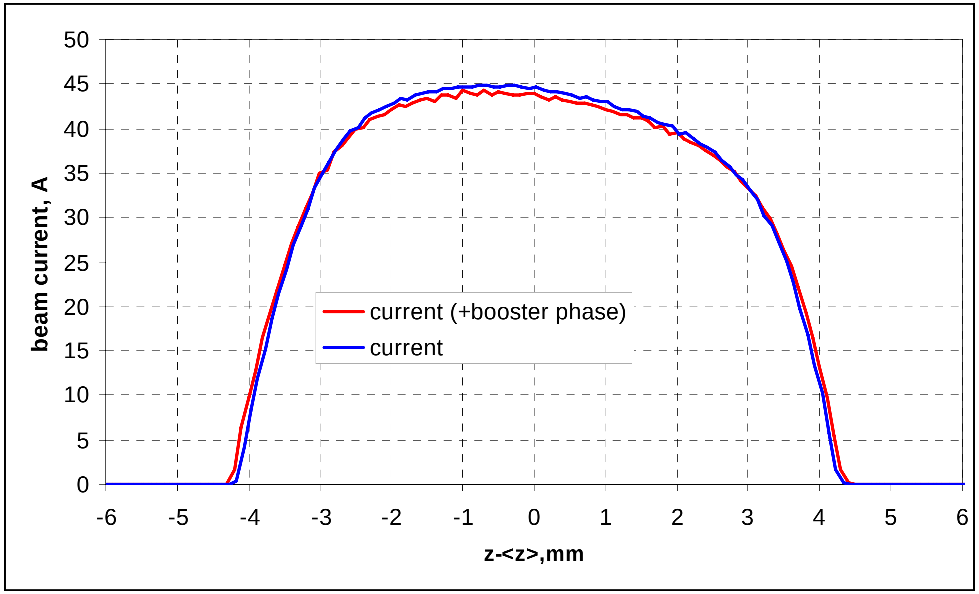


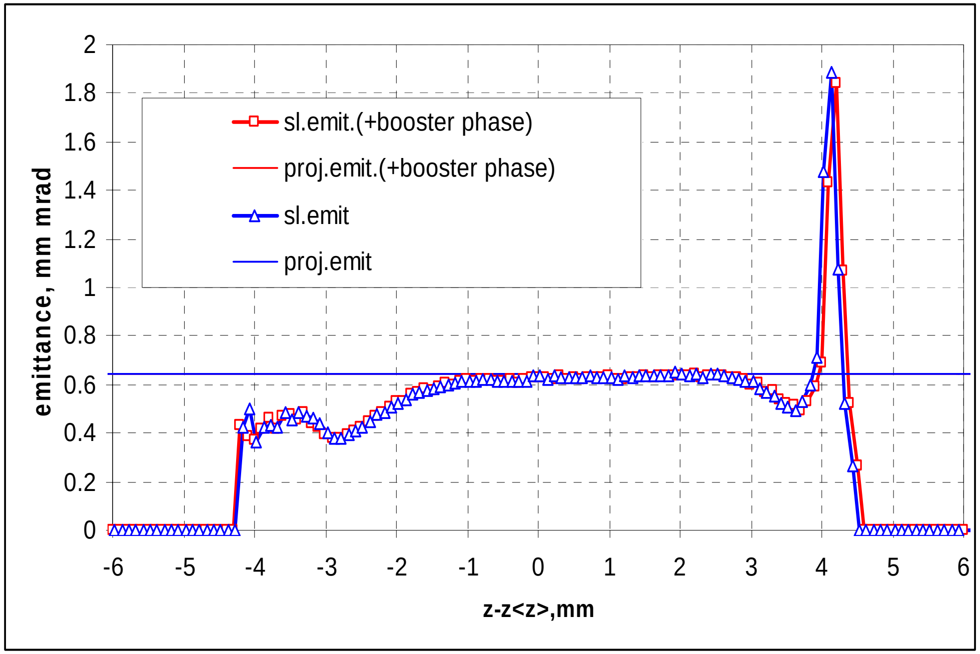



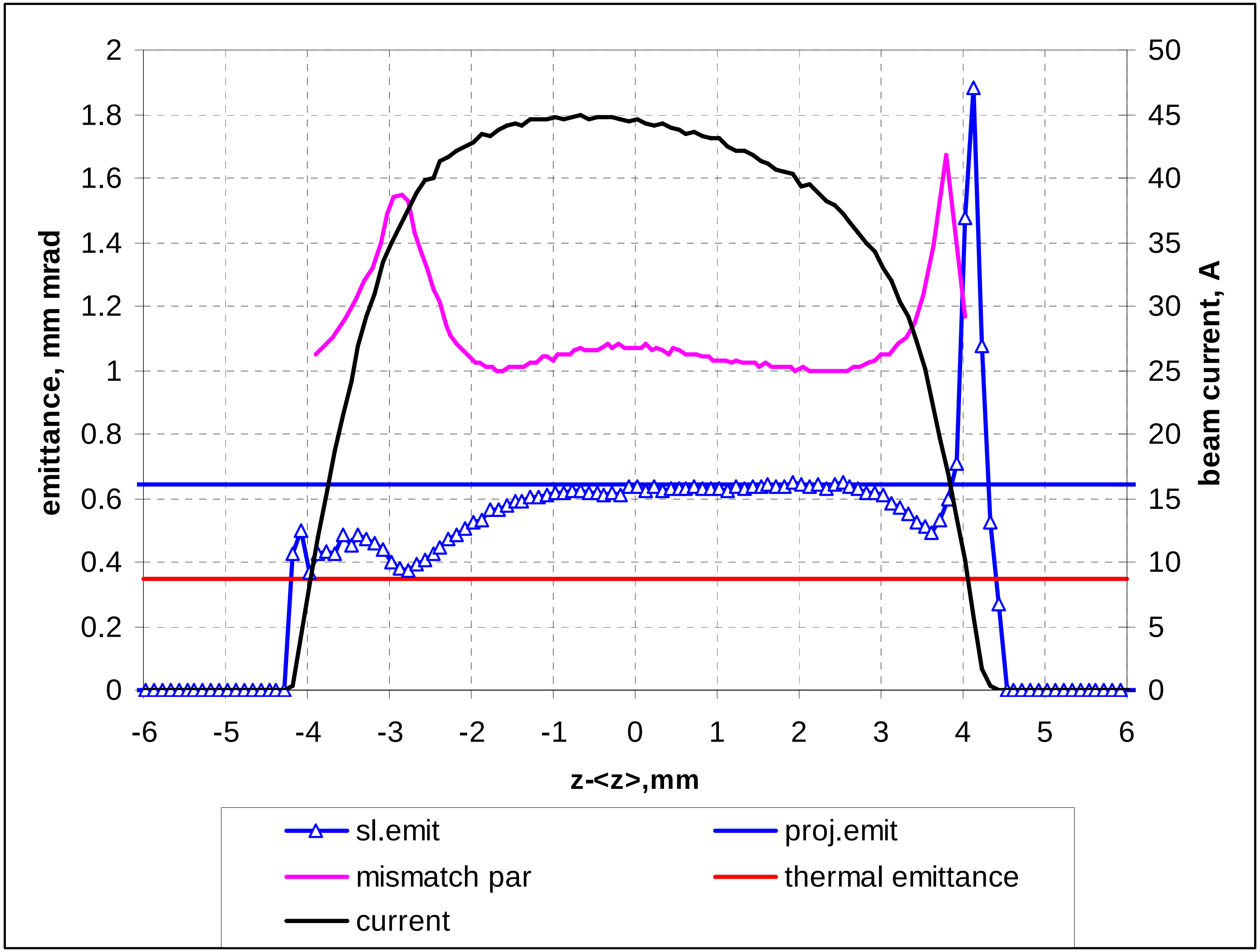



# PITZ-1.8 optimization, Q=1nC, slice parameters



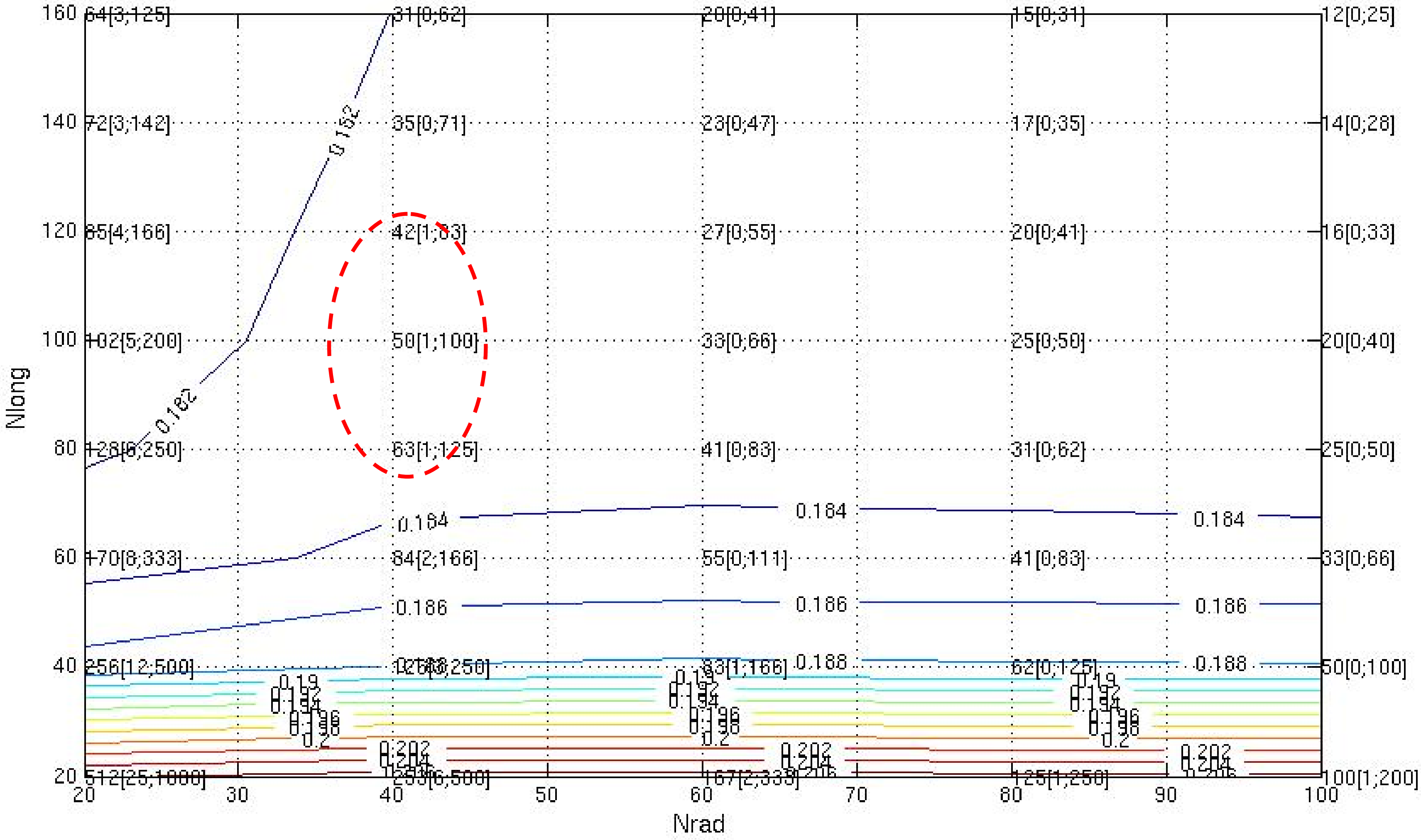
# PITZ-1.8 optimization, Q=1nC, slice parameters




- thermal emittance = 0.35 mm mrad → 54% of the projected emittance
- average mismatch parameter <ζ>=1.1

# PITZ-1.8 optimization for Q=0.1 nC

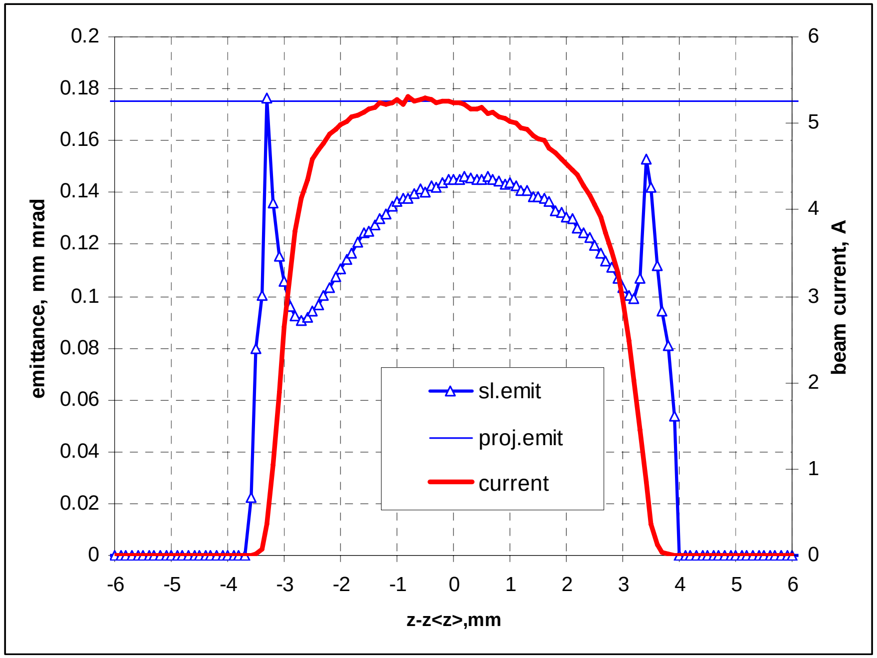
Emittance(z=5.74m, Nrad, Nlong_in); particles in cell [inner cell; outer cell]

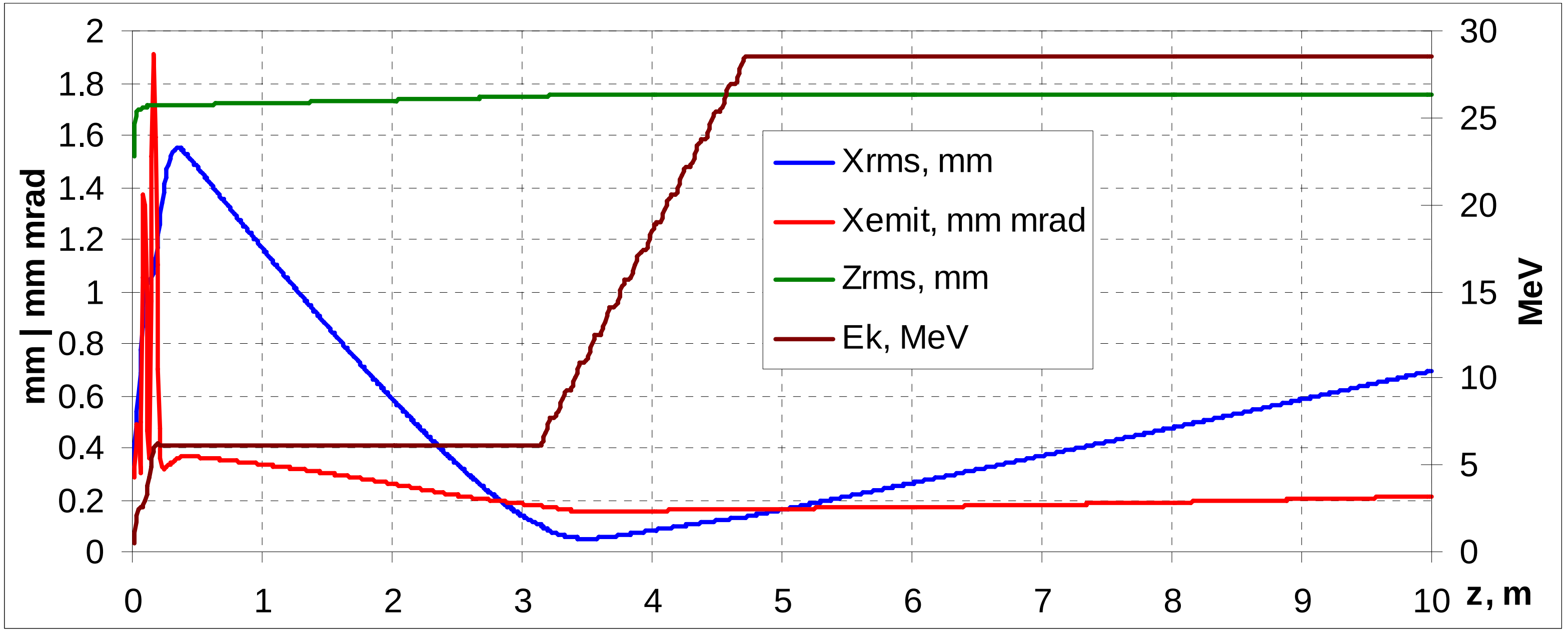


# PITZ-1.8 optimization for Q=0.1 nC

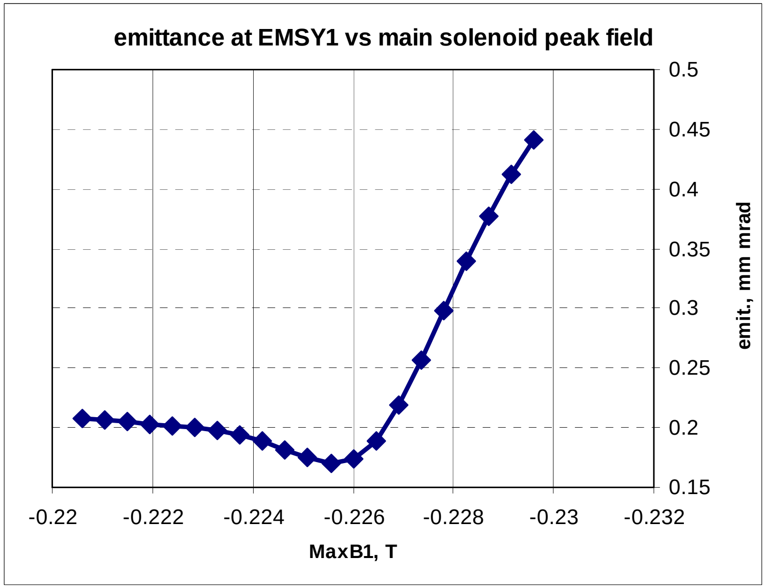
| | | parameter | value | unit | opti? |
|---|---|---|---|---|---|
| gun | cavity | Ecath | 60 | MV/m | no |
| | | phase | 1.04 | deg | yes |
| | solenoid | MaxB1 | -0.225551 | T | yes |
| | laser | Lt | 20 | ps | no |
| | | rt | 2 | ps | no |
| | | Ek | 0.55 | eV | no |
| | | XYrms | 0.105 | mm | yes |
| booster | cavity | Emax | 25.7 | MV/m | yes |
| | | phase | 0 | deg | no |
| electron | emittance | EMSY1 | 0.171 | mm mrad | |
| | energy | Ek | 28.5 | MeV | |

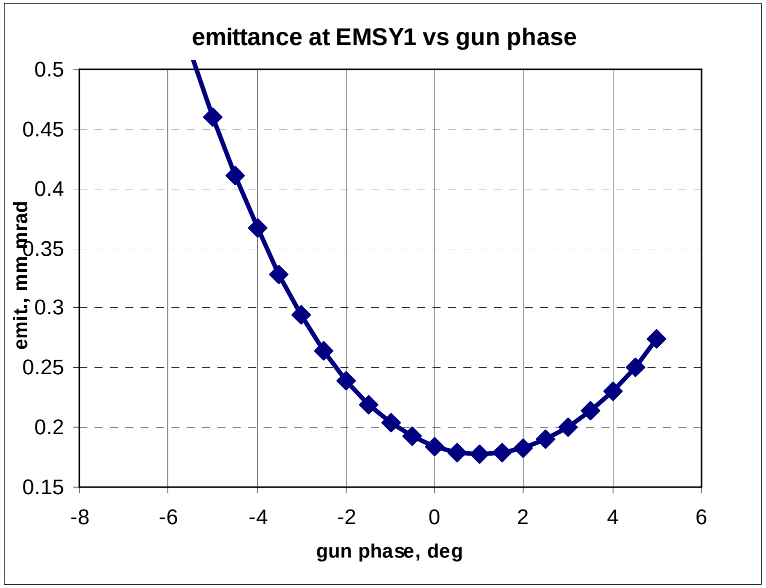
• thermal emittance = 0.089 mm mrad → 52% of the projected emittance

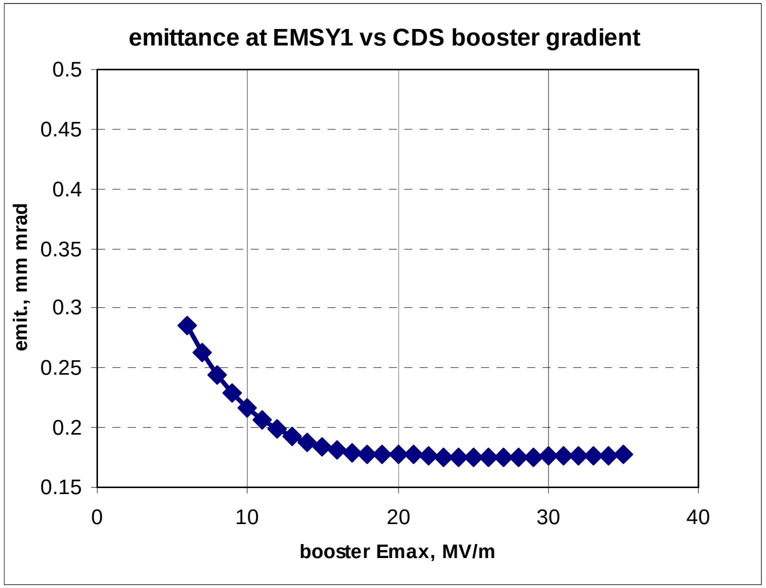


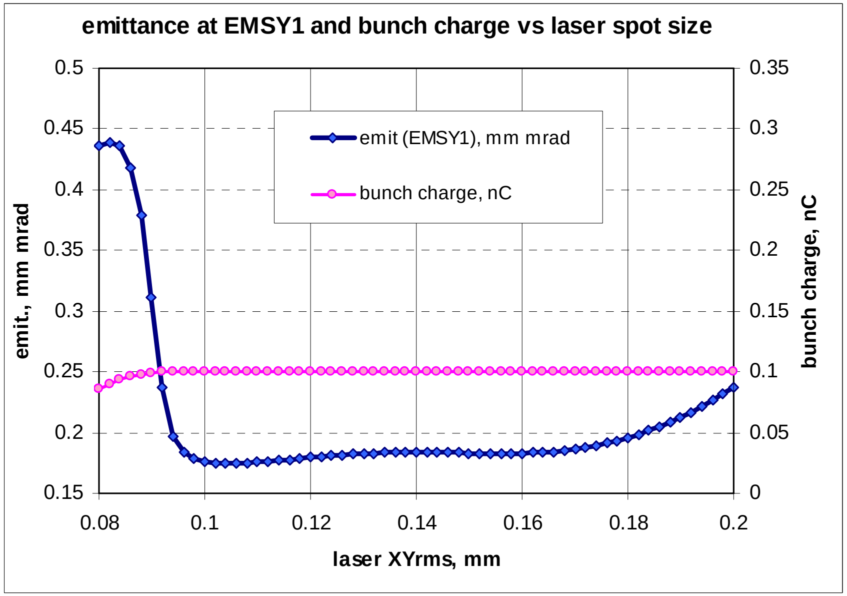



# PITZ-1.8 optimization for Q=0.1 nC

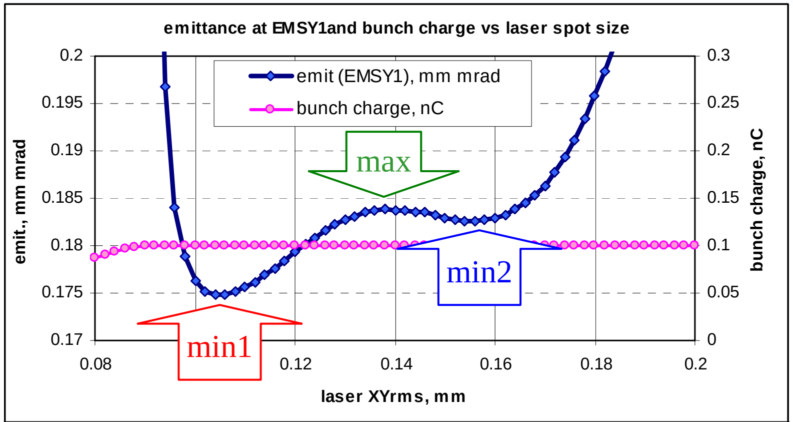


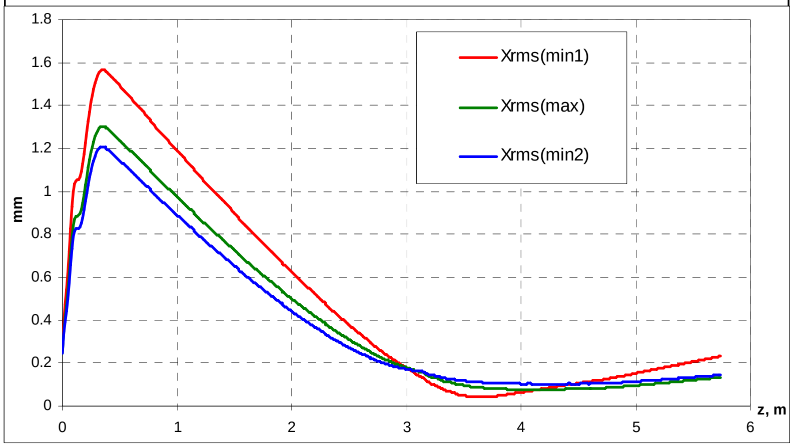



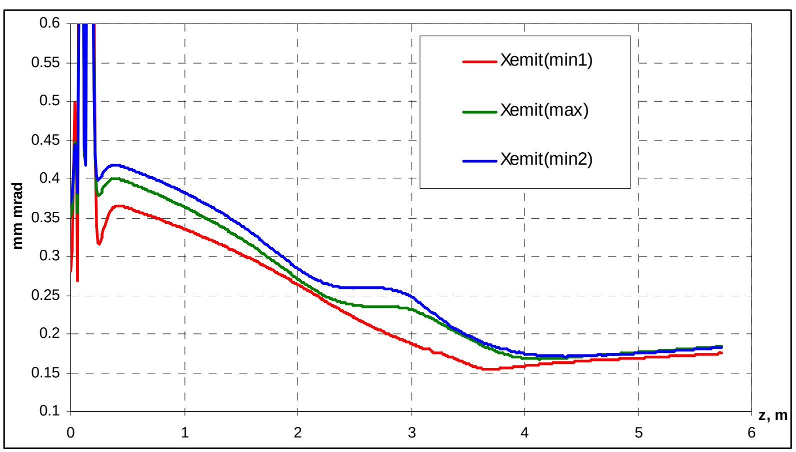



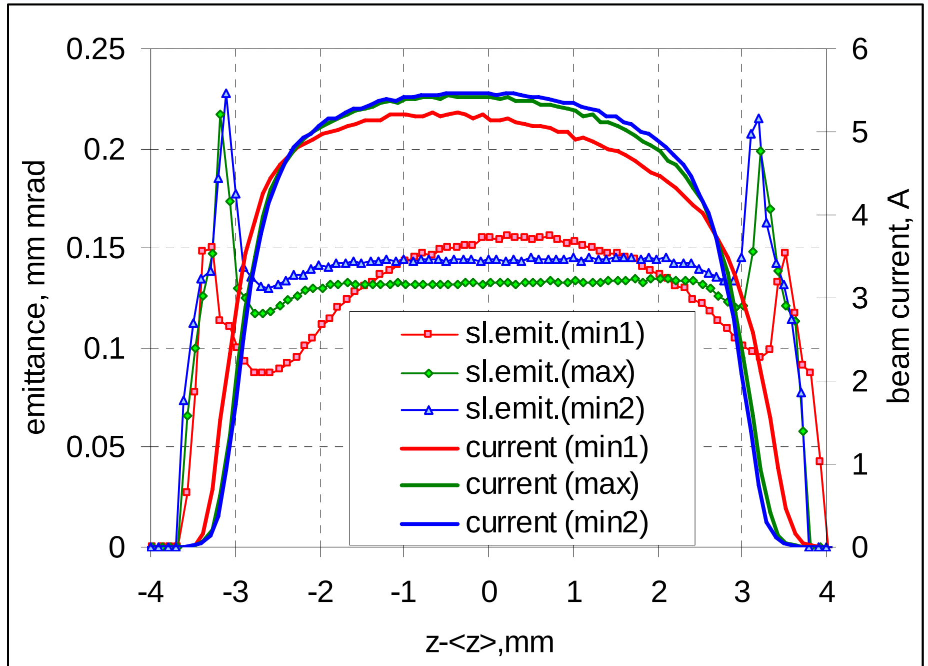



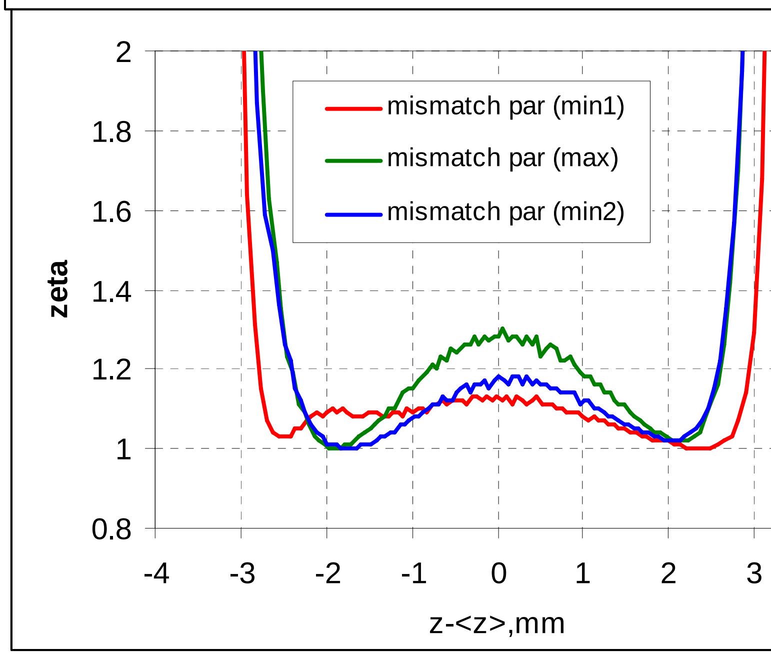
# PITZ-1.8 optimization for Q=0.1 nC




| | <ζ> |
|---|---|
| min1 | 1.23 |
| max | 1.28 |
| min2 | 1.18 |

# Conclusions

- RF-gun cavity fields:
  - BD simulations are very sensitive for the field profile used
  - ?geometry to checked once more (follow tuning procedure)
  - ?beam based cross check (long. momentum)
- CDS booster fields: measured profile could be somehow fitted to the simulated one, but the latter (smooth!) should be used for BD simulations
- PITZ-1.8 optimization for Q=1nC:
  - min.emit~0.65mm mrad (Ek=0.55eV→thermal emittance 54%), av. mism.par ~1.1
  - Tuning knobs: solenoid, gun phase, booster gradient, laser spot size
  - Optimum booster phase ~+20deg→only tiny emittance improvements, but probably not measurable due to the large energy spread
- PITZ-1.8 optimization for Q=0.1nC:
  - min.emit~0.17mm mrad (Ek=0.55eV→thermal emittance 52%), av. mism.par ~1.2-1.3
  - Tuning knobs: solenoid, gun phase, booster gradient, laser spot size
  - Double min in emittance dependence vs laser spot size → rather high mism. Parameter, further improvements might require setup optimization (booster and solenoid position, laser temporal length?)
- Space charge routine parameter control!