XFEL
X-Ray Free-Electron Laser

# Linear beam dynamics simulations for XFEL beam distribution system

- *Present Design*
- *Models for linear beam dynamics simulation of XFEL beam distribution system.*
- *Linear beam dynamics distortions*
- *Results*
- *Summary*

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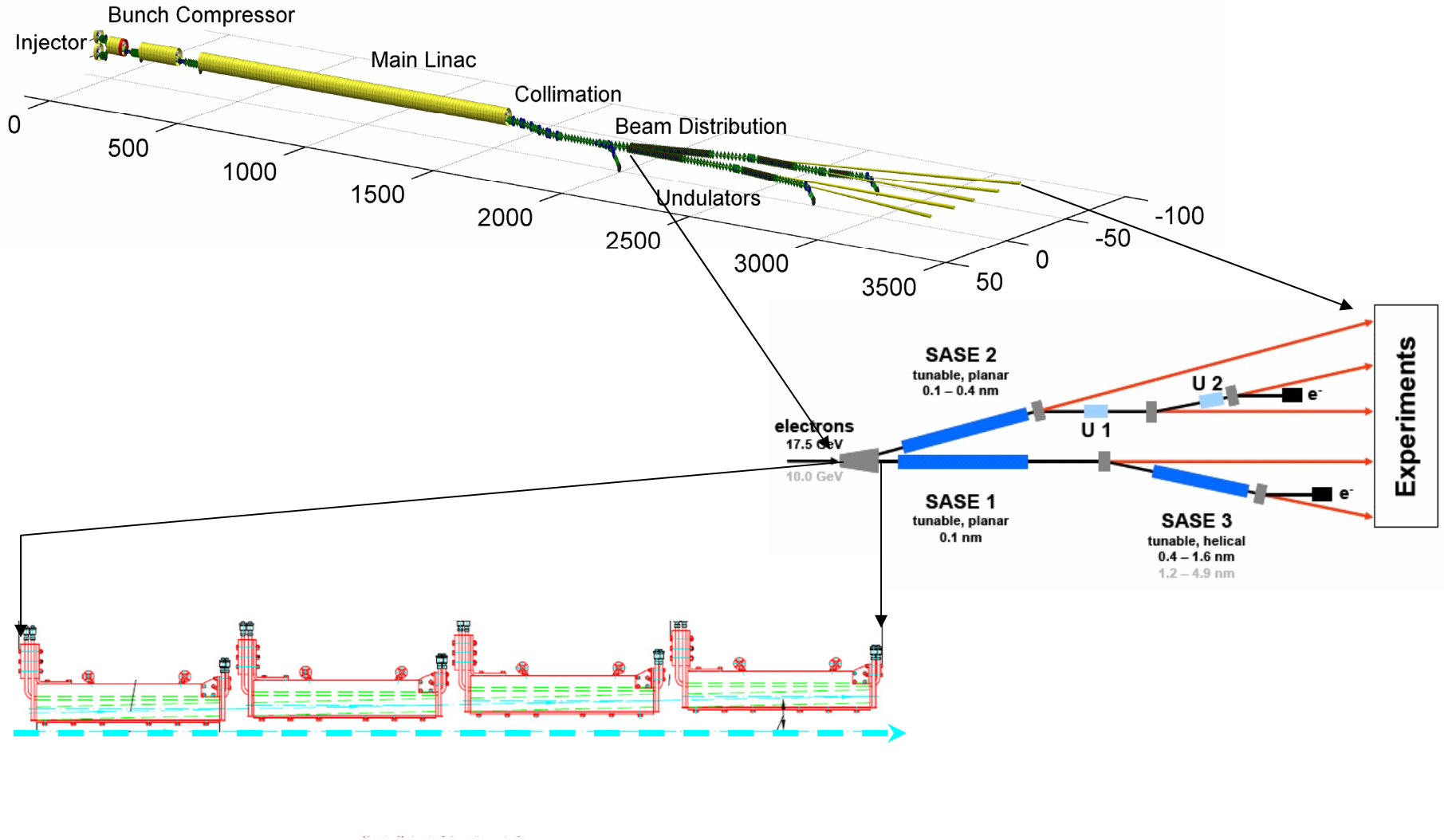
# Present Design

| | Value | Unit |
|---|---|---|
| Electron energy | 17.5 | GeV |
| Bunch charge | 1 | nC |
| Peak current | 5 | kA |
| Bunch length (rms) | 25 | μm |
| Norm. emittance (rms) | 1.4 | mm mrad |
| Energy spread (rms) | 1.5 | MeV |
| Bunches per RF pulse | 3000 | |
| Repetition rate | 10 | Hz |

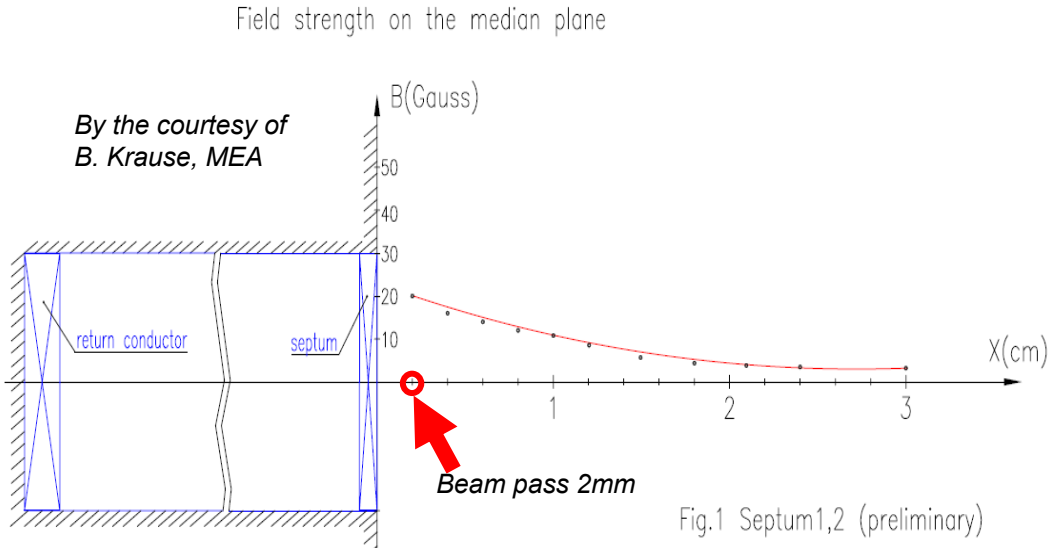
| | $\lambda$ [nm] | $\lambda_u$ [mm] | g [mm] | $B_{max}$ [T] | K | $\beta$ [m] | $L_{sat}$ [m] |
|---|---|---|---|---|---|---|---|
| SASE 1 | 0.1 | 35.6 | 10 | 1.0 | 3.3 | 32 | 133 |
| SASE 2 | 0.1 | 47.9 | 19 | 0.63 | 2.8 | 45 | 174 |
| | 0.4 | | 10 | 1.37 | 6.1 | 15 | 72 |
| SASE 3 | 0.4 | 80.0 | 23 | 0.44 | 3.3 | 15 | 81 |
| | 1.6 | | 10 | 0.91 | 6.8 | 15 | 50 |
| | 4.9 | | 10 | 0.91 | 6.8 | 15 | 45 |

# Present Design

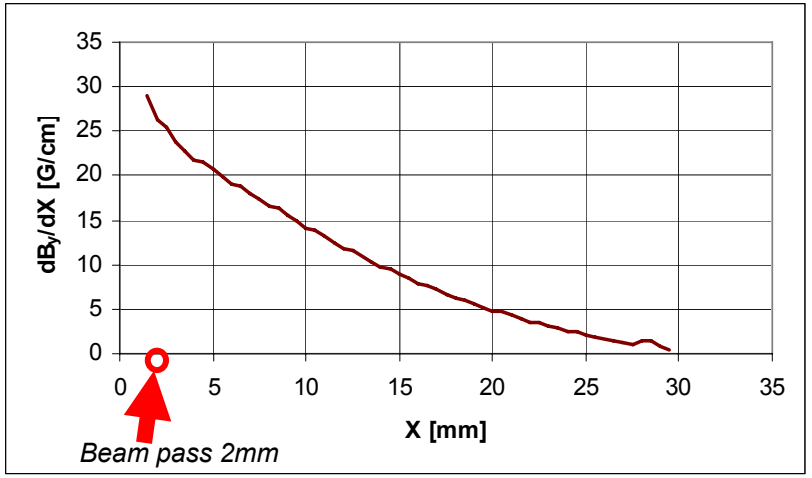


# Models for simulations.

## *Septum magnet stray field. Linear beam dynamics*




*Septum stray field gradient. By the courtesy of V. Khachatryan*




*Stray field dipole and quadrupole components have been considered.*

*Dipole*

$B_0 = 20$ G

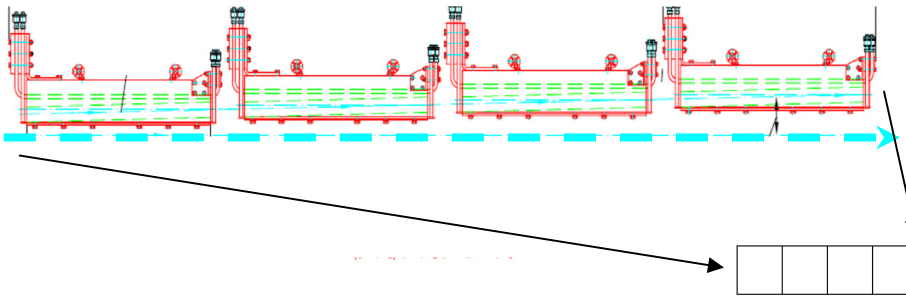
$\rho = 3.42\times10^{-5}$ [$m^{-1}$]

*Quadrupole*

$dB_y/dx = 25.5$ G/cm

$K = 4.36851\times10^{-5}$ [$m^{-2}$]

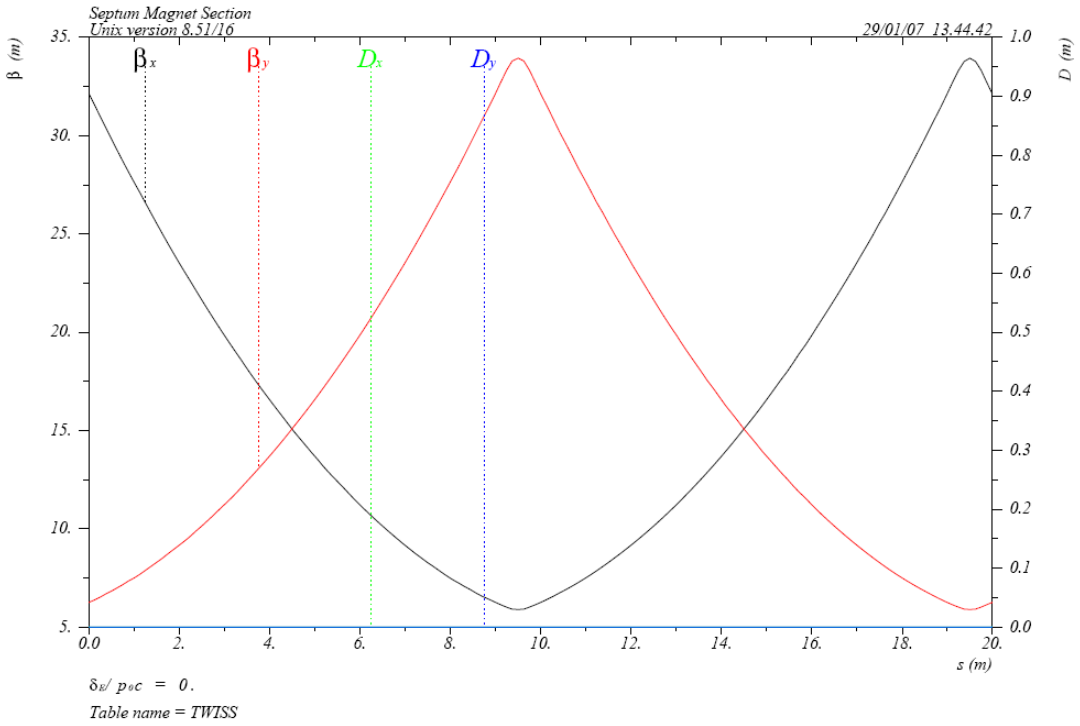
# Models for simulations.



## *Septum magnets section*

***Representing septum section as 4 magnets (Dipole / Dipole + Quadrupole) of 1 m length with corresponding strength.***

***Horizontal offsets of septum magnets are neglected.***
***Actually for straight beam the septum deviation leads to the stray field strength decrease, in the same time the dipole component curves beam close to the septum area.***



# Models for simulations.

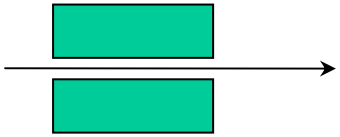
The septum section considered as composed of :

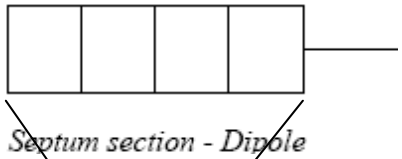
1) 4 kickers 1m long each

2) 4 kickers + Quads*.

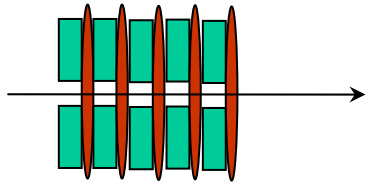
* ***Each 1 m kicker composed of 5 kickers ( 0.19m) + 5 D Quads (0.01m)***

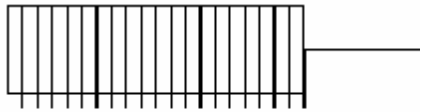
(1)

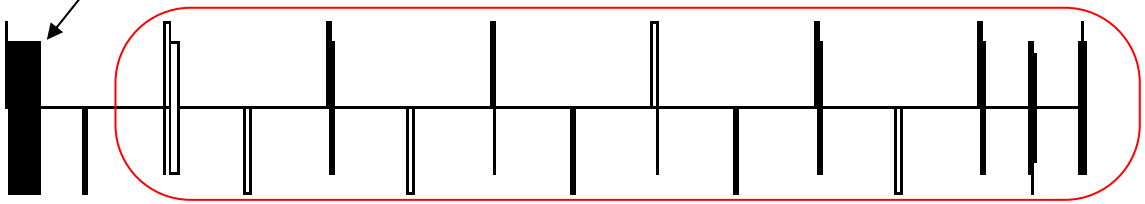





(2)



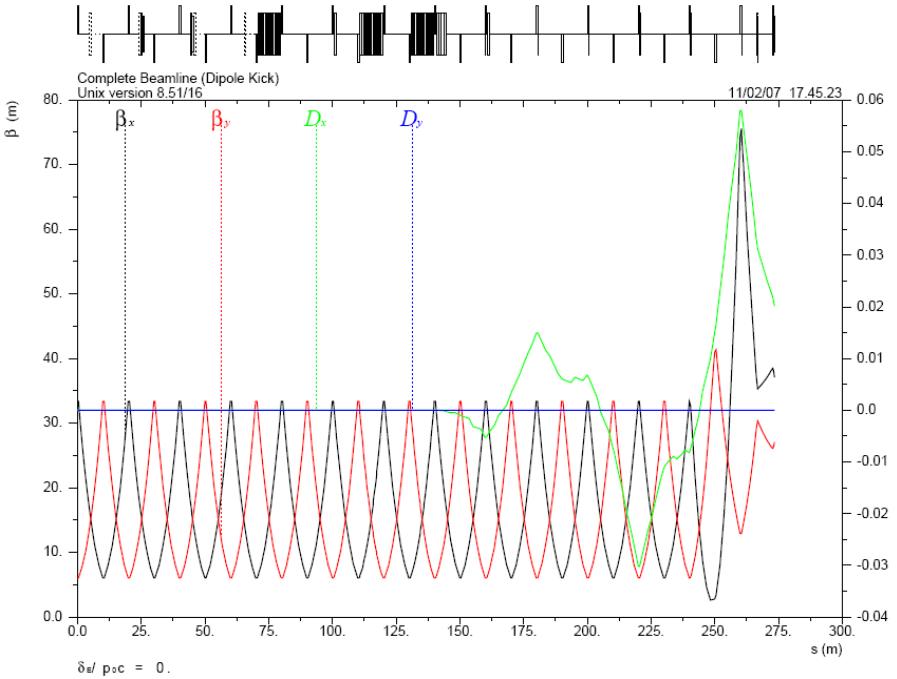


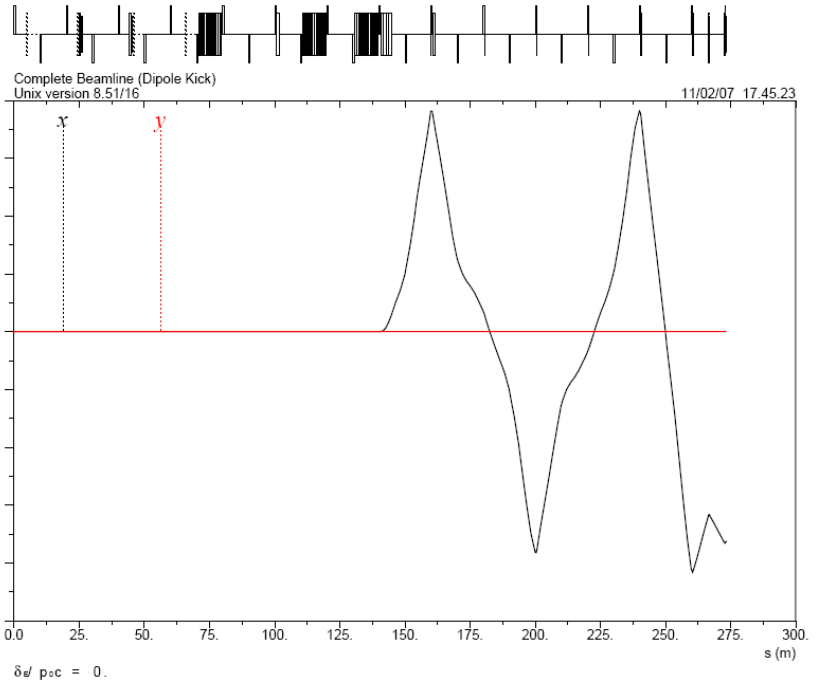



Next to septum magnets is matching section, which is used to suppress the distortions caused by the septum magnet stray field. The group of horizontal correctors implemented assuming them mounted on the Quads.

# Linear beam dynamics distortions.

## *Stray field caused distortions. Dipole component*

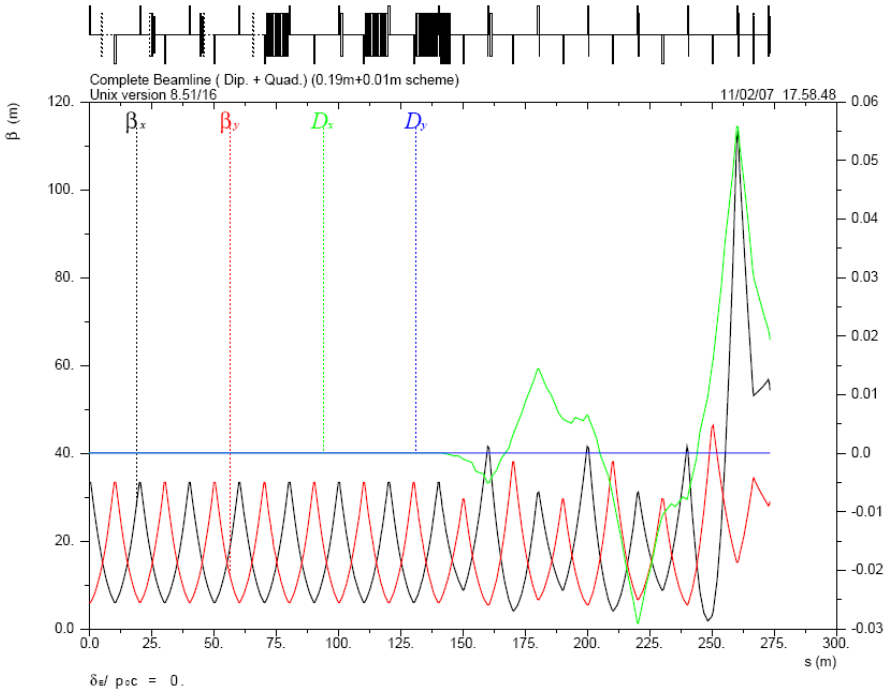


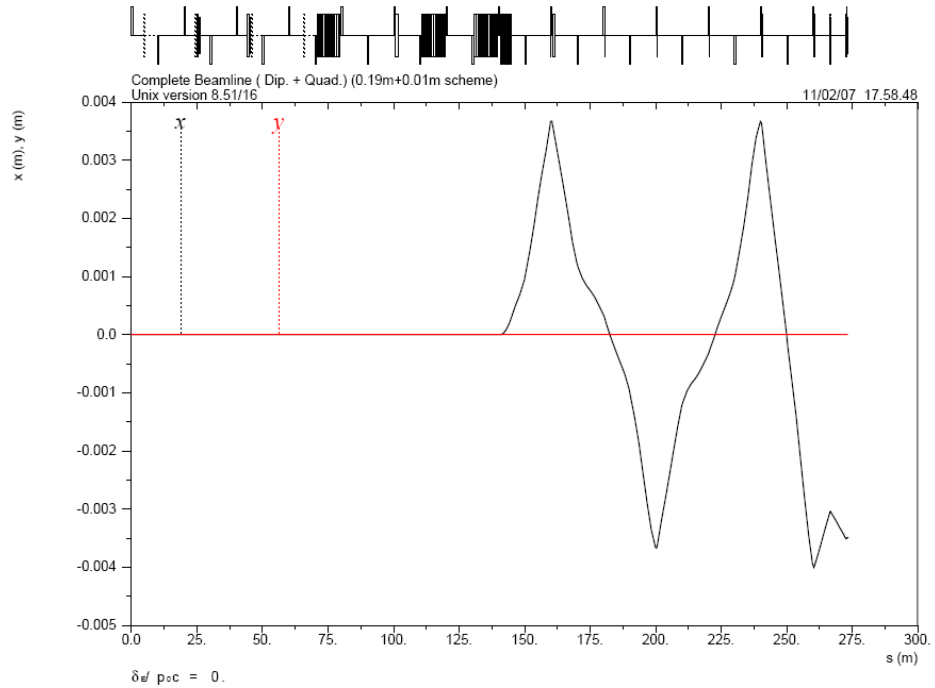



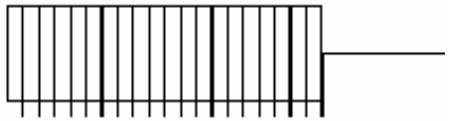

*Septum section - Dipole*

# Linear beam dynamics distortions.

## *Stray field caused distortions. Dipole + Quadrupole component*



*Septum section - Dipole + Quad*

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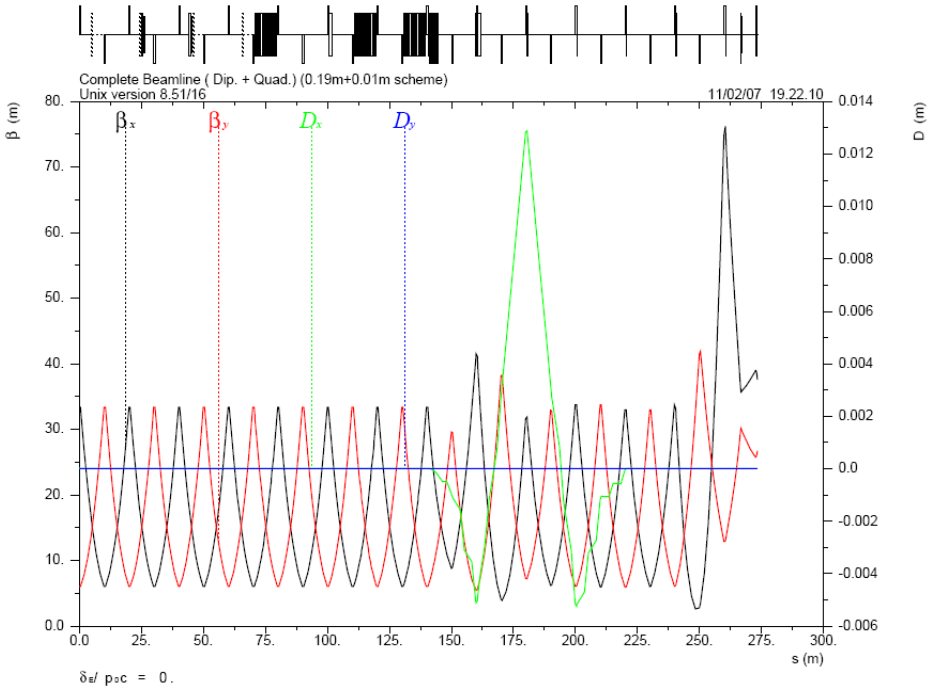
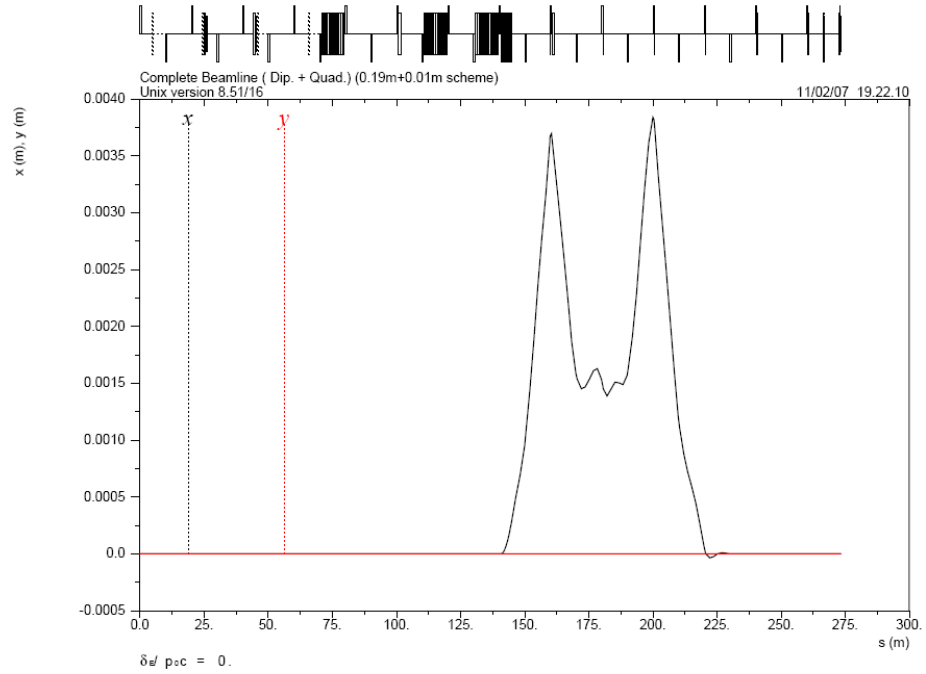
# Results

## *Dispersion and orbit correction. Dipole + Quadrupole component*

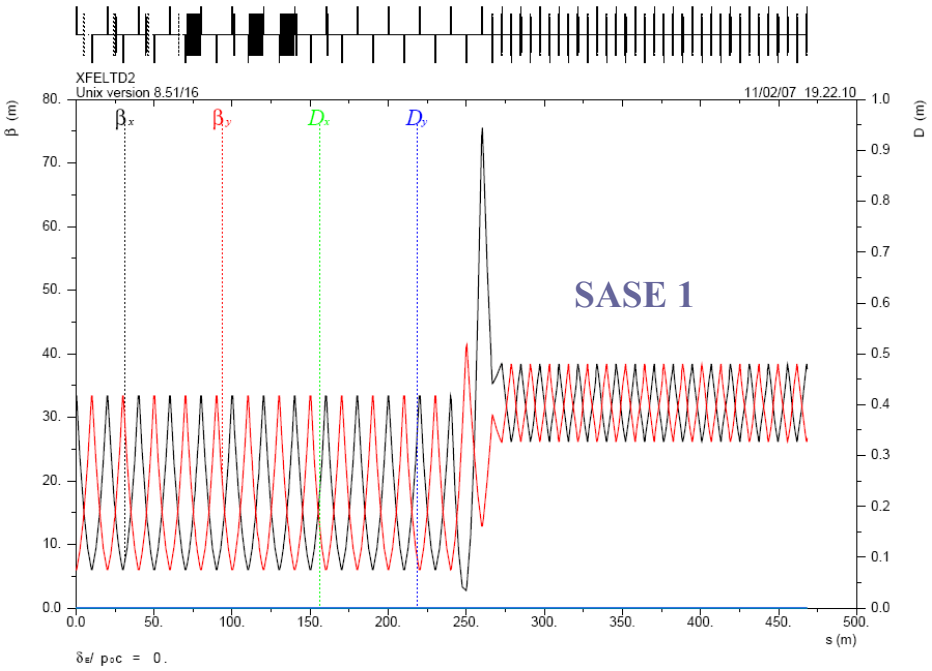


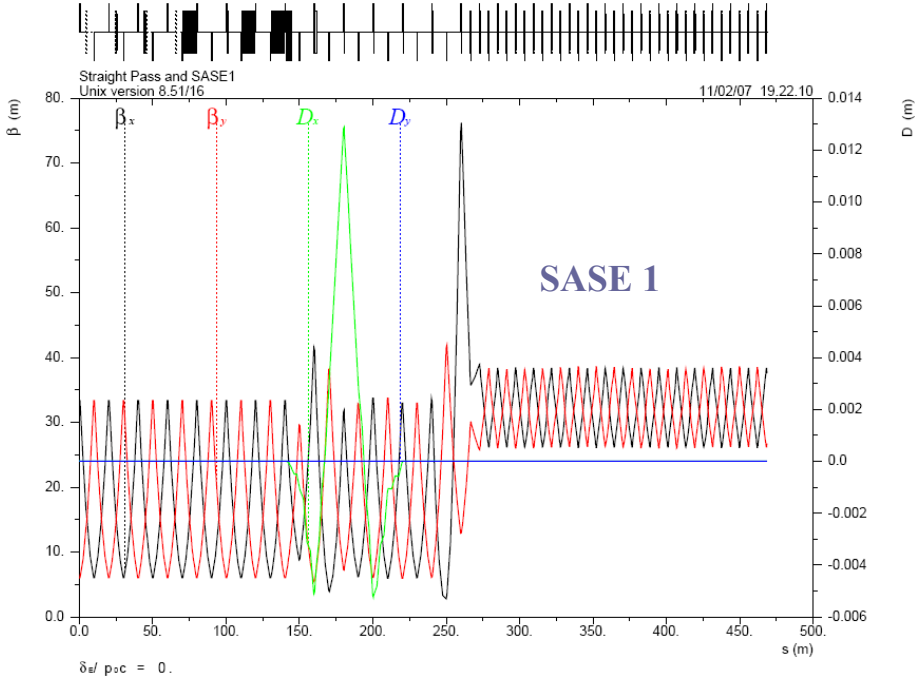




**For corrections 4 horizontal correctors ( out of 7 ) and 6 quads (out of 14) were used with the values:**
**2 correctors set to ~90% of maximum strength ( 0.083 T ) and 2 at less than 10%**
**Quadrupoles values are changed within ~10% from the nominal value.**

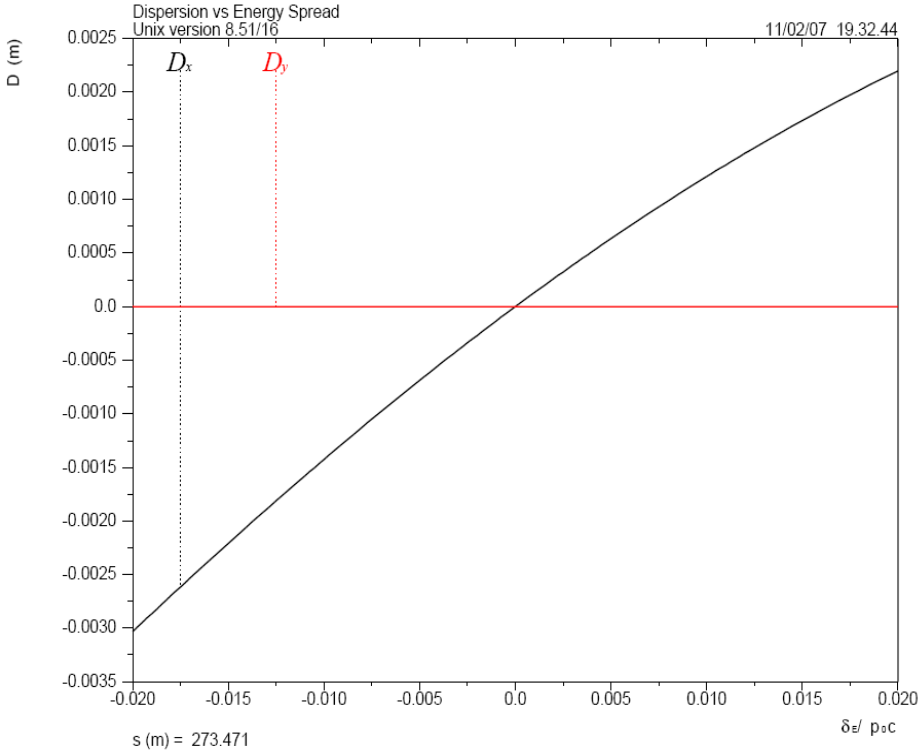
# Results

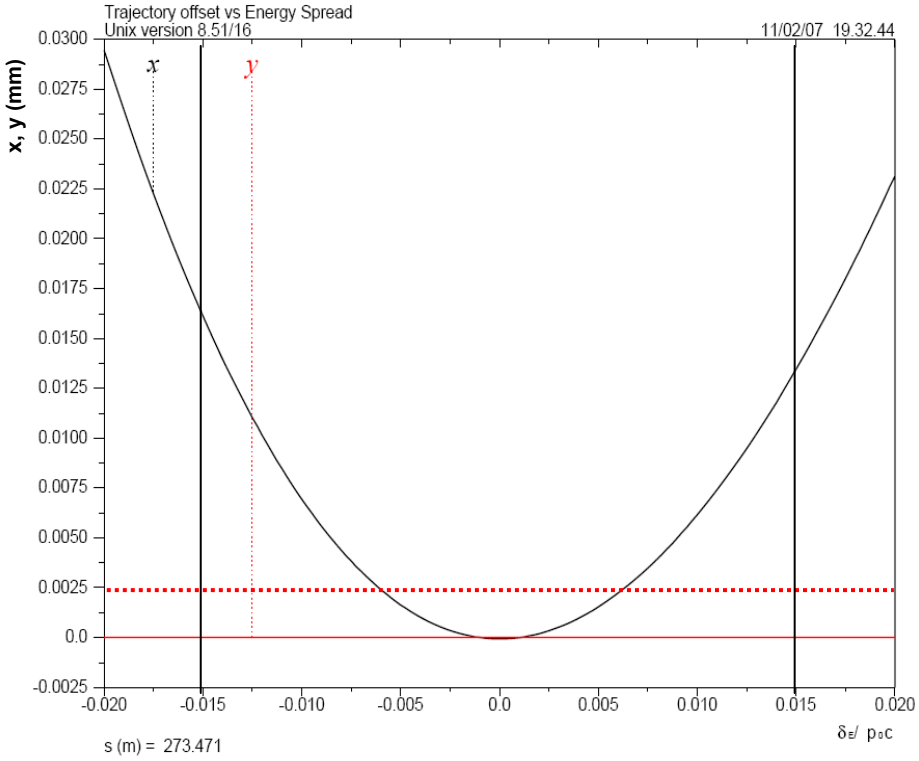
| *Twiss Param. (End SASE1)* | *No kick* | *Dip.+Quad. correct.* |
|---|---|---|
| $\beta_x$ [m] | 37.562 | 37.557 |
| $\beta_y$ [m] | 26.702 | 26.727 |
| $\beta_x(max)$ /$\beta_y(max)$ | 75.561 / 41.387 | 73.224 / 41.917 |
| $\alpha_x$ | 1.202 | 1.201 |
| $\alpha_y$ | -0.859 | -0.854 |
| $\mu_x$ | 4.428 | 4.434 |
| $\mu_y$ | 4.267 | 4.253 |



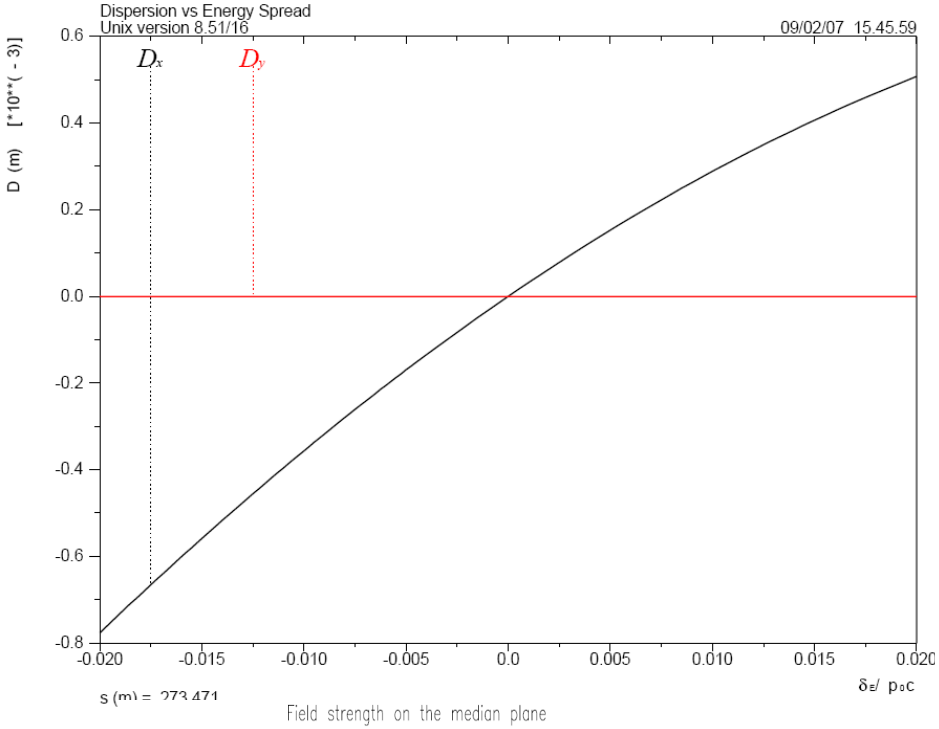
# Results



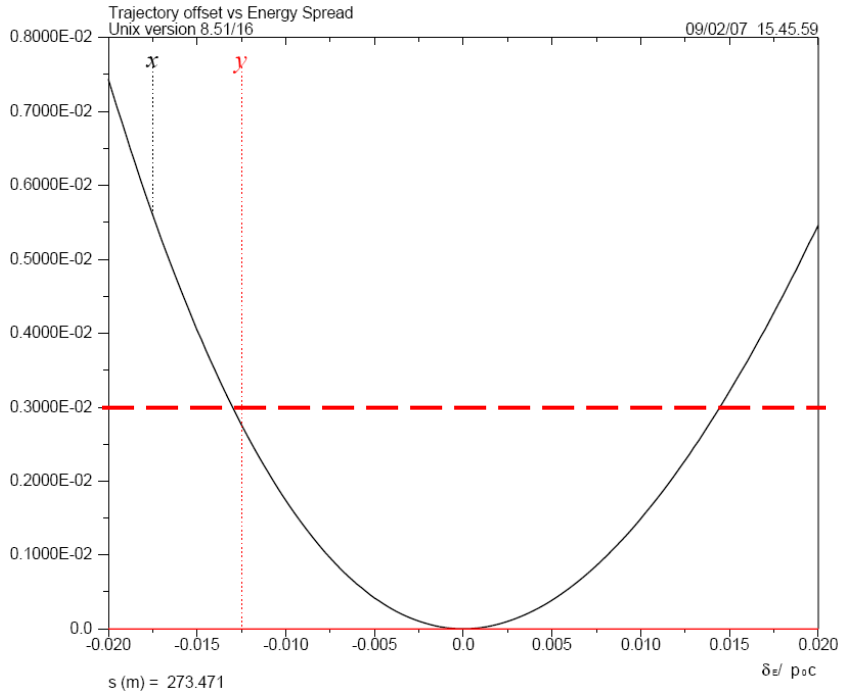




**The dispersion and trajectory offset vs energy spread ± 1.5 % at the beginning of SASE 1 undulator line.**

# Results




Field strength on the median plane



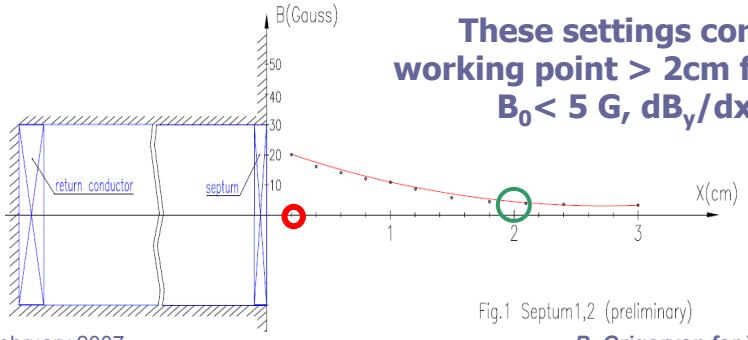
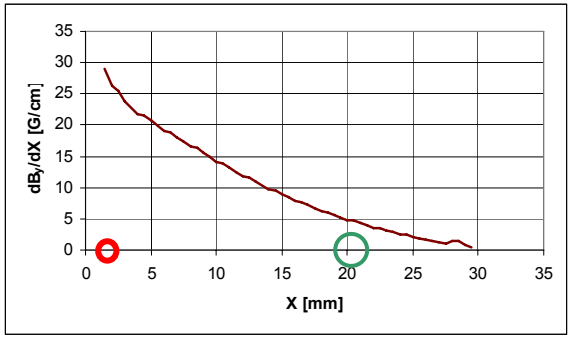




Fig.1 Septum1,2 (preliminary)

**These settings correspond to the working point > 2cm from septum, or to $B_0$< 5 G, $dB_y/dx$ < 5 [G/cm]**



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# Summary

- ✓ *Septum magnets stray field influence on linear beam dynamics was studied for present design of the beam distribution system (SASE1) straight pass.*
- ✓ *Correction scheme applied. Orbit and dispersion deviations are corrected for 0 energy spread and still out of tolerances for energy spread of ±1.5 %. To keep an orbit deviations for this energy spread the septum design improvement or design of additional correction system is needed.*

## Next Steps

- ➢ *The influence of septum stray field on the non-linear beam dynamics should be studied.*
- ➢ *The discussions with the magnet design group on the possible septum design improvements.*
- ➢ *Stray field caused distortions for the SASE2 line should be studied.*