# DISPERSION MEASUREMENT AND CORRECTION IN THE VUV-FEL (FLASH)

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37th ICFA Advanced Beam Dynamics Workshop on Future Light Sources
Hamburg, 16 May 2006

# Index

- Introduction
- Dispersion Measurement
  - Procedure
  - Measurements
- Dispersion Correction
  - Procedure
  - Response matrix measurements
  - Dispersion correction simulations
  - 1$^{st}$ dispersion correction measurements
- Summary and next steps

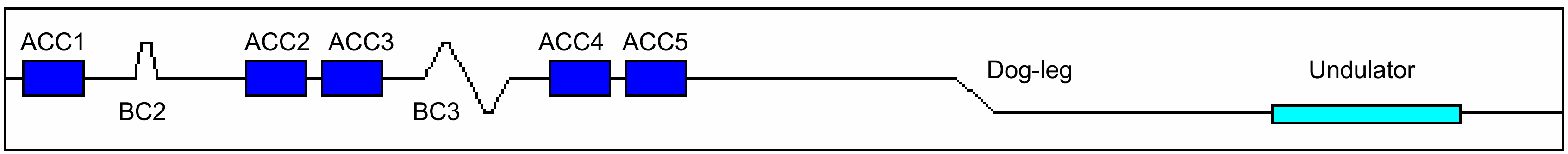
# Introduction

$$\eta_x = \frac{\Delta x}{\Delta p / p}$$

$$\sigma = \sqrt{\varepsilon \cdot \beta(s) + \eta(s)^2 \cdot \left(\frac{\Delta p}{p}\right)^2}$$

**Goal**: dispersion in the undulator of **1 cm**

## VUV-FEL (FLASH)




### Generation mechanisms

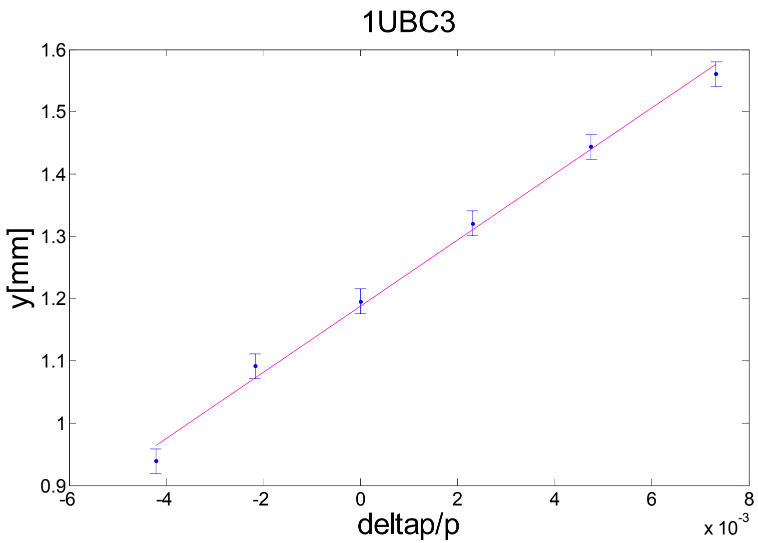
| Source | Error (in all the lattice) | Error (only in the dog-leg) | Dispersion (after the dog-leg) |
|---|---|---|---|
| *Quad malign* | 17 um | 50 um | ~ 1cm |
| *Dipole field error* | 0.25 % | 5 % | |
| *Quad field error* | 0.75 % | 0.75 % | |

- Quad misalignment seems to be the most important dispersion source
- Dog-leg is a critical zone for dispersion generation

# Dispersion Measurement Procedure

- Measure the orbit for different energies
  1. Change RF gradient of the module
  2. Apply orbit correction to restore launch conditions after the module
  3. Read BPM positions downstream last correction BPM

- Derive the dispersion

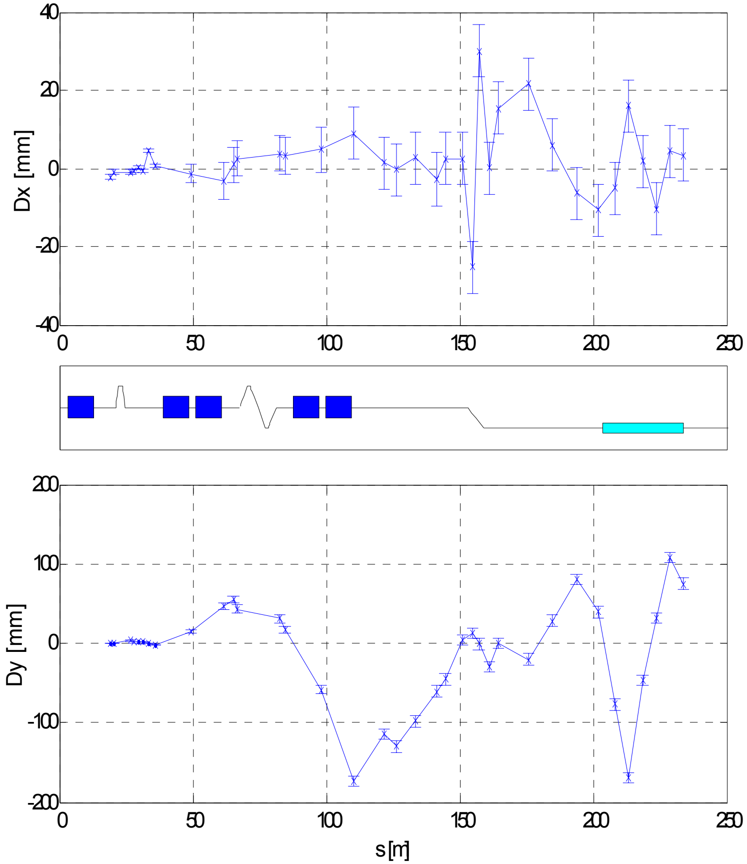



$$x = x_0 + D_0 \frac{\Delta p}{p} + D_1 \left( \frac{\Delta p}{p} \right)^2 + \ldots$$

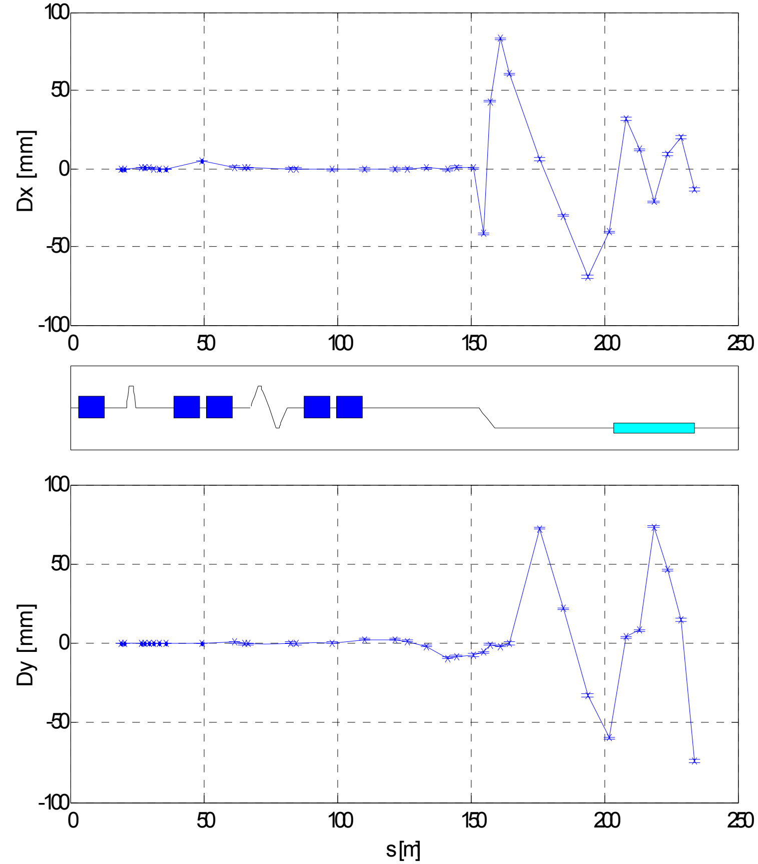
Dispersion ($D_0$)

# Dispersion Measurements (Nov. 05)

## From DBC2




## From ACC4-5



# Dispersion Correction Algorithm

It corrects both orbit and dispersion, using the orbit and dispersion response matrices

- Orbit response term $O_{i,j} = \frac{\Delta x_i}{\Delta \theta_j}$
- Dispersion response term $D_{i,j} = \frac{\Delta D_i}{\Delta \theta_j}$

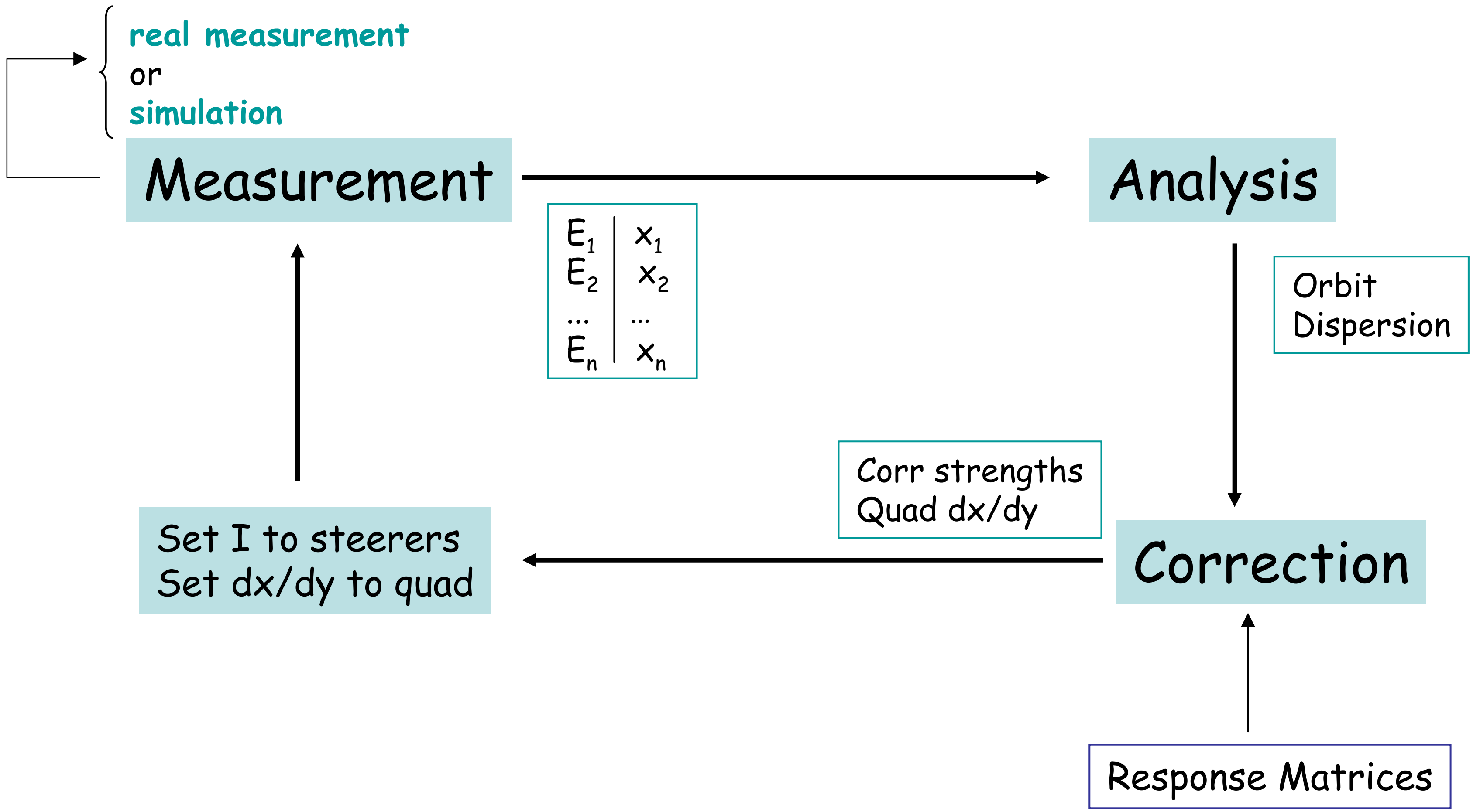
$\Delta x_i$ / $\Delta D_i$ ----------> change of the orbit / dispersion at the BPM *i*
$\Delta\theta_j$ -----------> change of the kick angle of the steerer *j*

$$\begin{pmatrix} \underline{\underline{O}} \cdot (1-w) \\ \underline{\underline{D}} \cdot w \end{pmatrix} \cdot \underline{\Delta\theta} = \begin{pmatrix} \underline{x} \cdot (1-w) \\ \underline{d} \cdot w \end{pmatrix}$$

- $\underline{\underline{O}}$, $\underline{\underline{D}}$: Response matrices
- $\underline{\Delta\theta}$: Corrector strengths
- $\underline{x}$: Orbit
- $\underline{d}$: Dispersion
- $w$: Weighting factor

$$\sum \left[ \begin{pmatrix} \underline{x}_{meas} \\ \underline{d}_{meas} \end{pmatrix} - \begin{pmatrix} \underline{x} \\ \underline{d} \end{pmatrix} \right]^2 = \min \Rightarrow \underline{\Delta\theta}$$

# Dispersion Correction Procedure

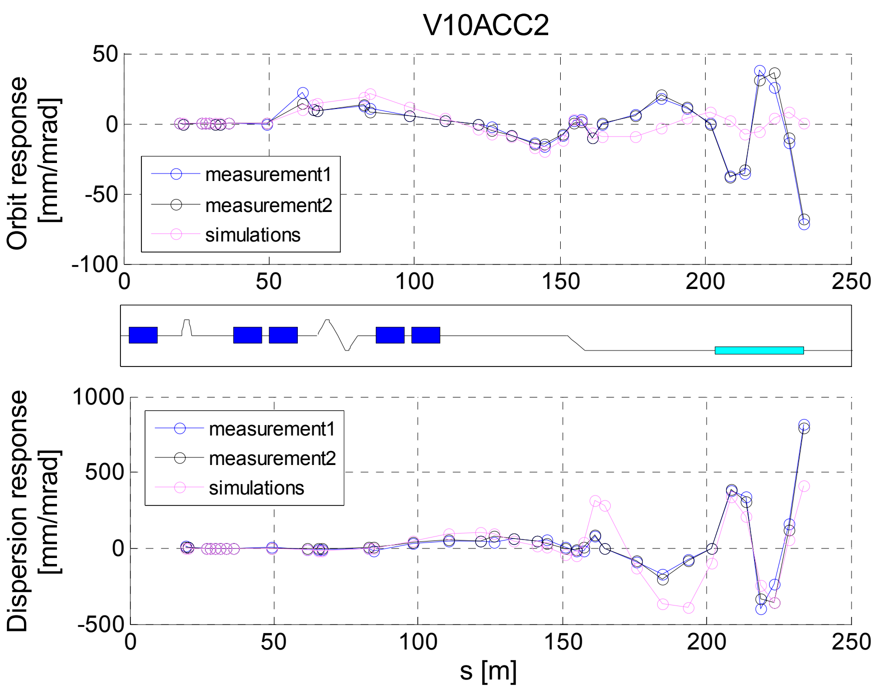


# Response matrix measurements (April 06)

- For dispersion correction, optics of the machine have to be close to the design optics or one has to use the measured response matrices

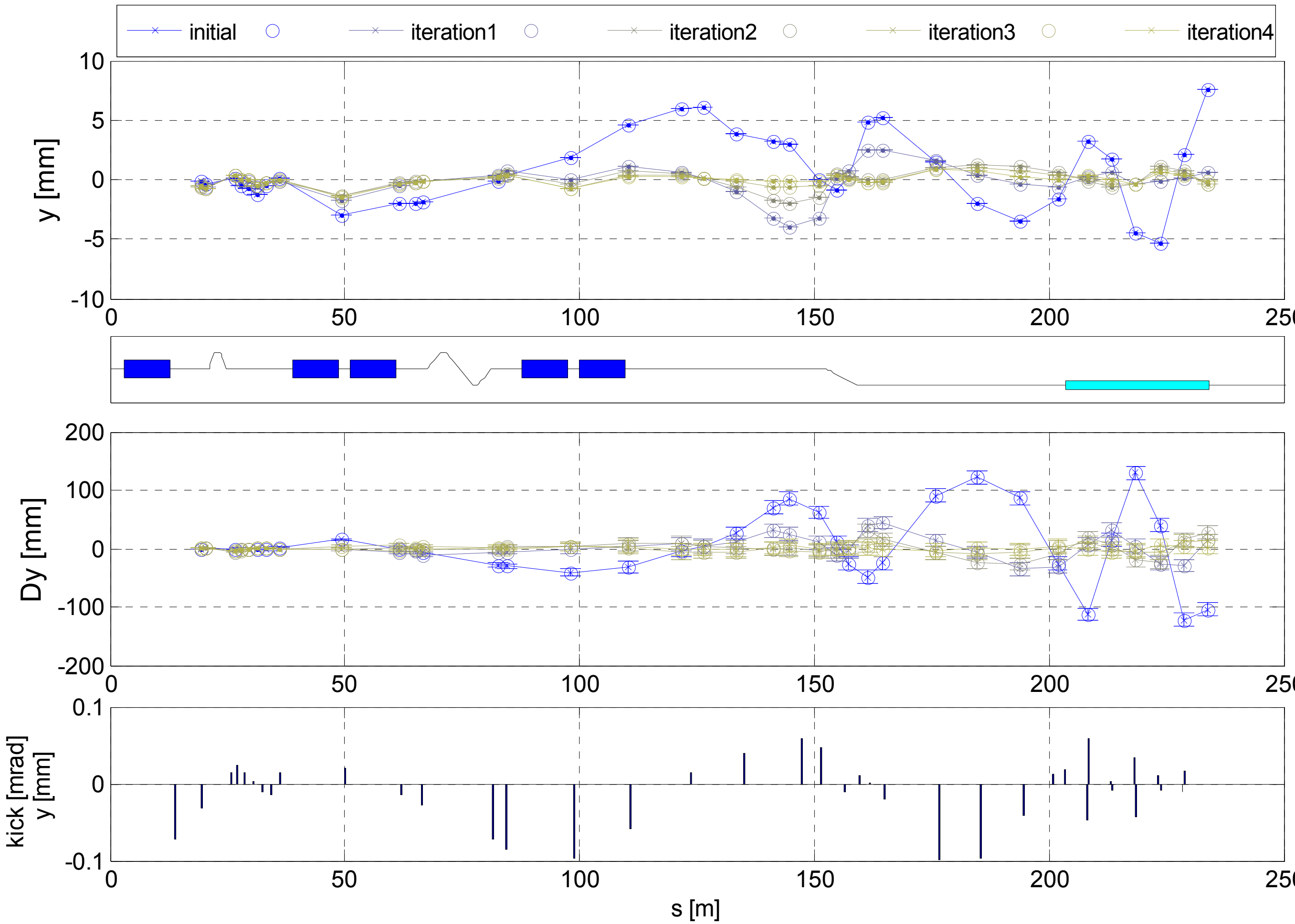
- Comparing the measured and simulated orbit and dispersion response will let to fix possible optic errors

- We have measured the complete response for the machine and the data is presently being analyzed

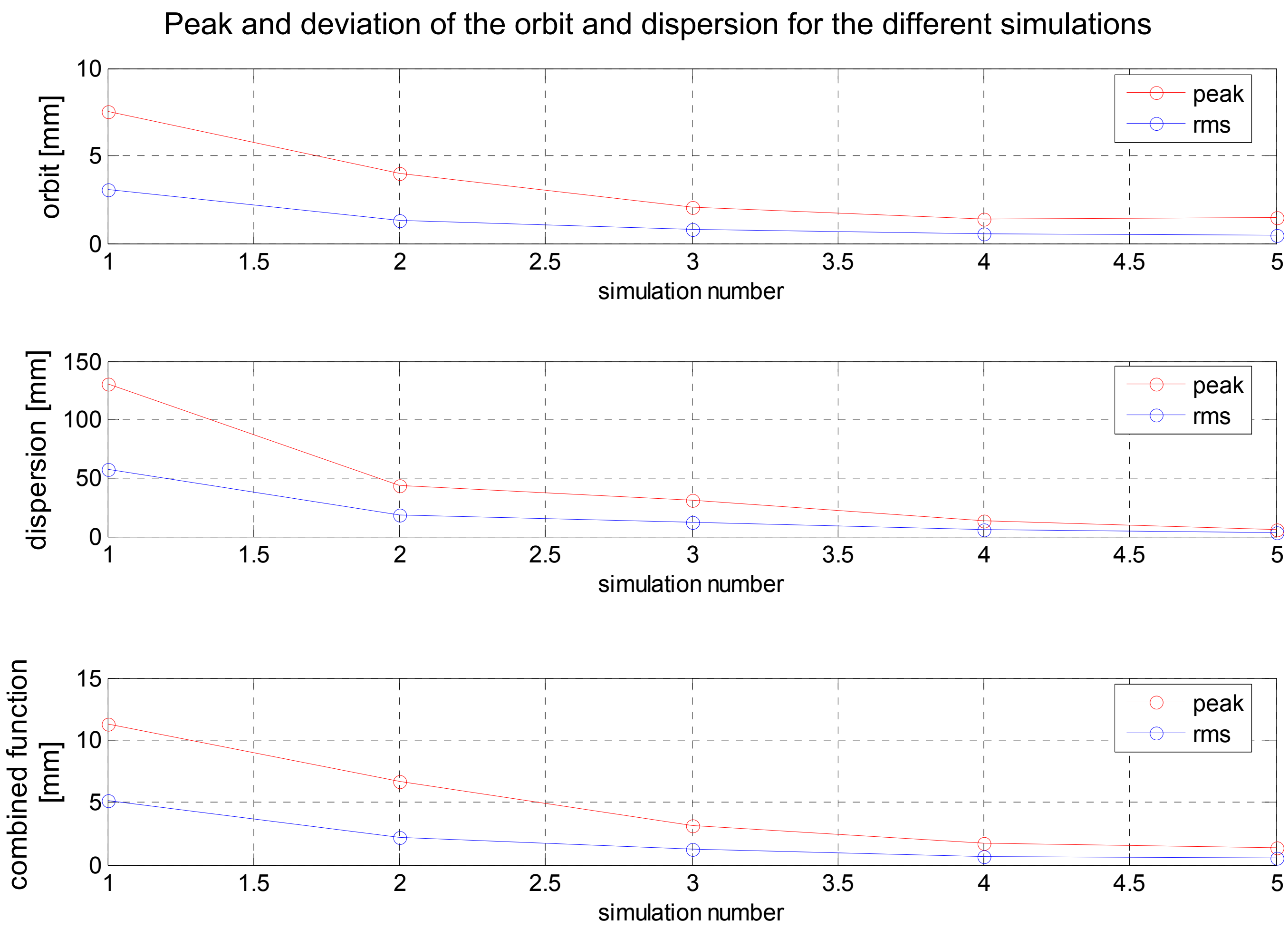


# Dispersion correction simulations

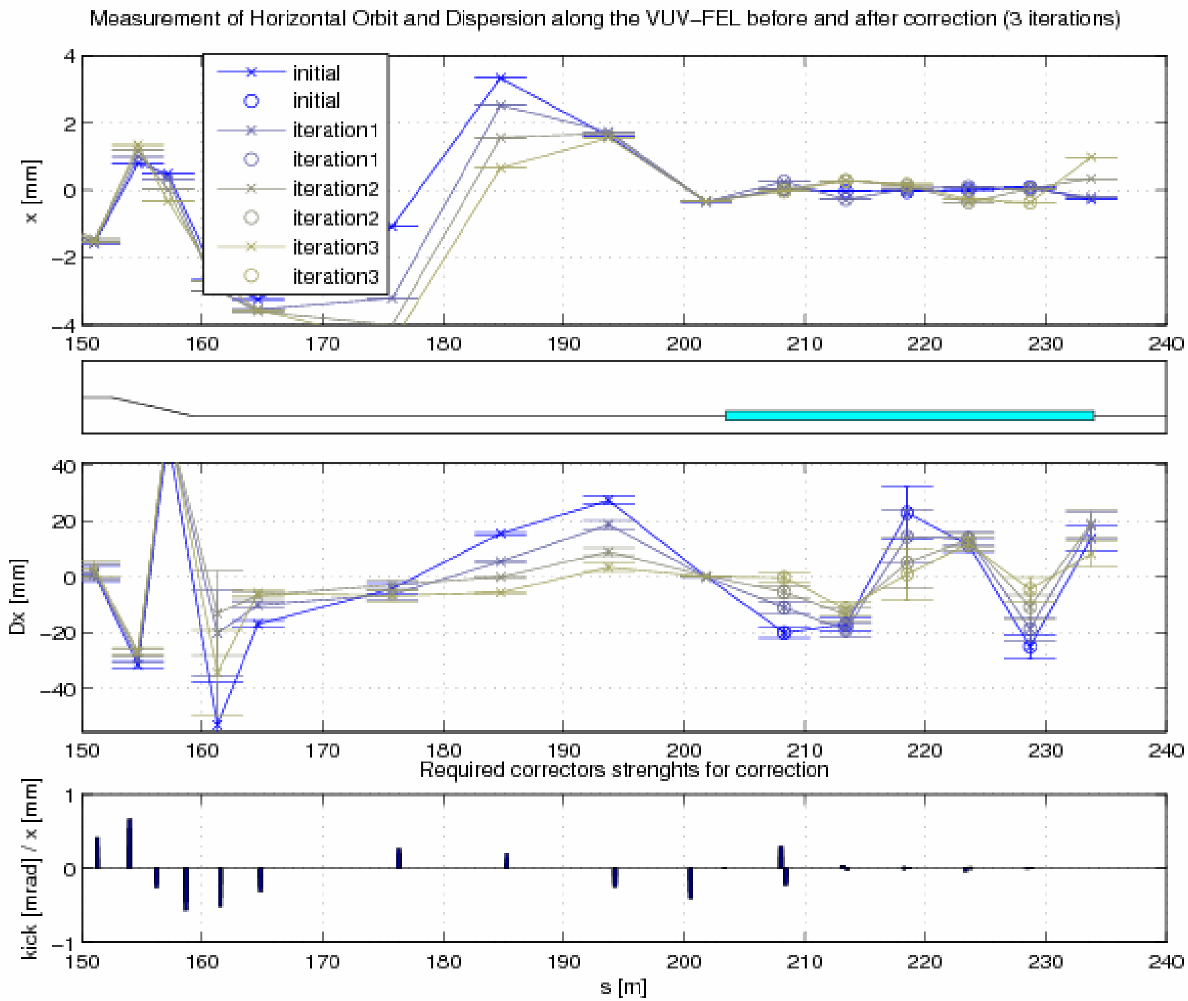
vertical plane, w = 0.1; quad malign = 200um, dipole field error = 1%;
quad field error = 1%; bpm noise = 20um; bpm off-set = 100um; all bpm's ; all steerers



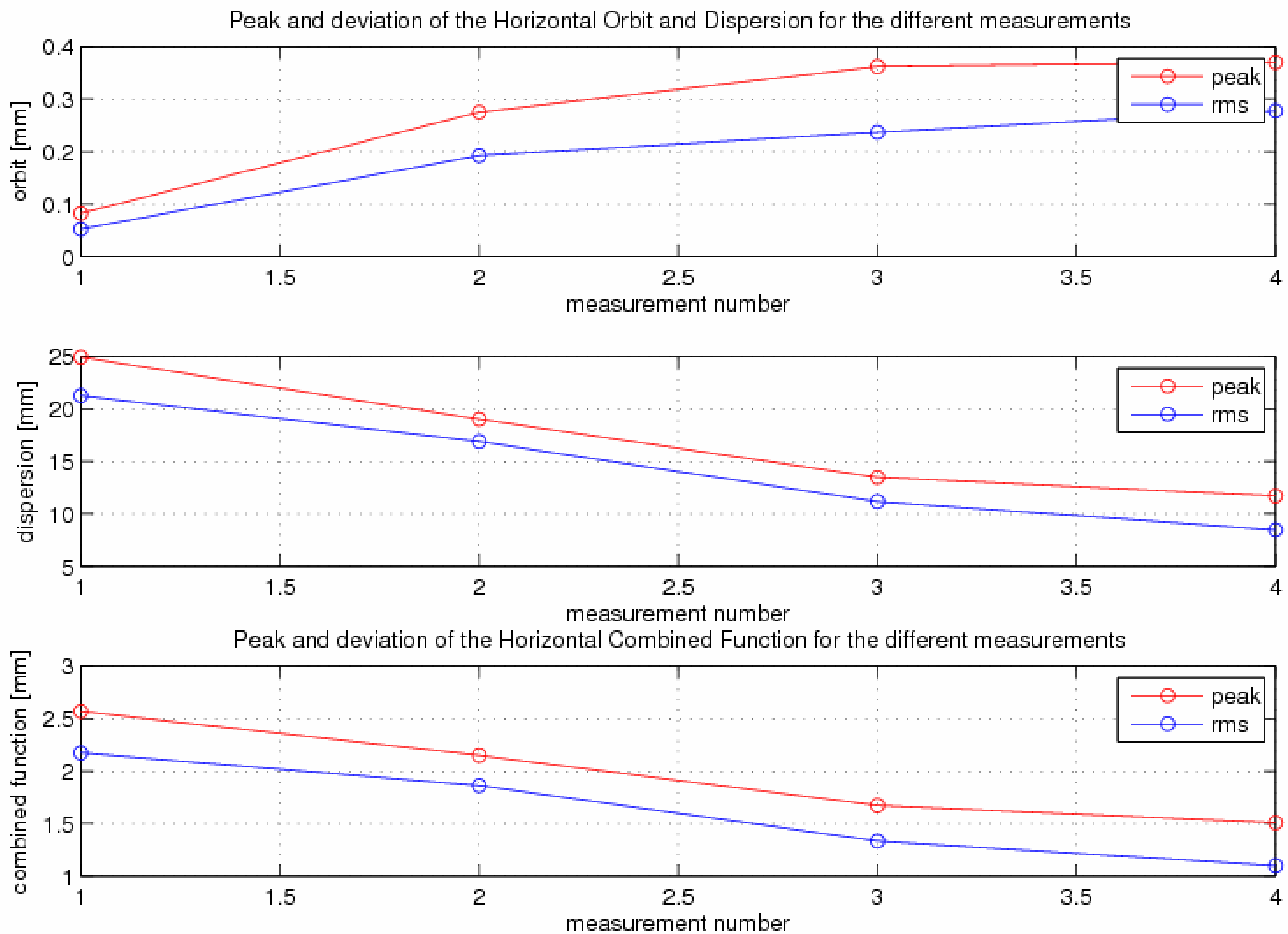
# Dispersion correction simulations



# $1^{st}$ Dispersion correction measurements (April 06)



# 1st Dispersion correction measurements (April 06)



# Summary and next steps

**Summary:**

- A tool for measuring and correcting orbit and dispersion has been developed
- Several dispersion measurements done on November 05
- Complete response matrix measurement has been done
- Simulations of dispersion correction have been performed
- Dispersion correction in the undulator in the horizontal plane done

**Next steps:**

- Analyze data from orbit and dispersion response measurements
- Make dispersion correction program more user friendly
- Correct dispersion in vertical plane