First WFS simulations for ATF2

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Outline

- Principle WFS
- FACET experiment
- ATF2
- Motivation
- Simulation parameters
- Results
- Discussion

WFS principle

- Dispersion Free Steering:
  - use beams with different energy and minimise the orbit difference (due to dispersion)

- Wakefield Free Steering:
  - use beams with different charge and minimise the orbit difference (due to wakefields)

Wakefield-Free Steering (WFS)

- In DFS one measures the system response to a change in the energy
- In WFS one measures the system response to a **change in the charge**
  (for the test beam we used 80% of the nominal charge, i.e. ~2.6 nC)

Recall: the DFS system of equations

$$\begin{pmatrix} y \\ \omega(\eta - \eta_0) \\ 0 \end{pmatrix} = \begin{pmatrix} \mathbf{R} \\ \omega\mathbf{D} \\ \beta\mathbf{I} \end{pmatrix} \begin{pmatrix} \theta_1 \\ \vdots \\ \theta_m \end{pmatrix}$$

We propose: the WFS system of equations:

$$\begin{pmatrix} y \\ \omega_{DFS} \cdot (\eta - \eta_0) \\ \omega_{WFS} \cdot y_w \\ 0 \end{pmatrix} = \begin{pmatrix} \mathbf{R} \\ \omega_{DFS} \cdot \mathbf{D} \\ \omega_{WFS} \cdot \mathbf{W} \\ \beta \cdot \mathbf{I} \end{pmatrix} \begin{pmatrix} \theta_1 \\ \vdots \\ \theta_m \end{pmatrix}$$

The success is not obvious: DFS relies on an effect which affect the bunch as a whole;
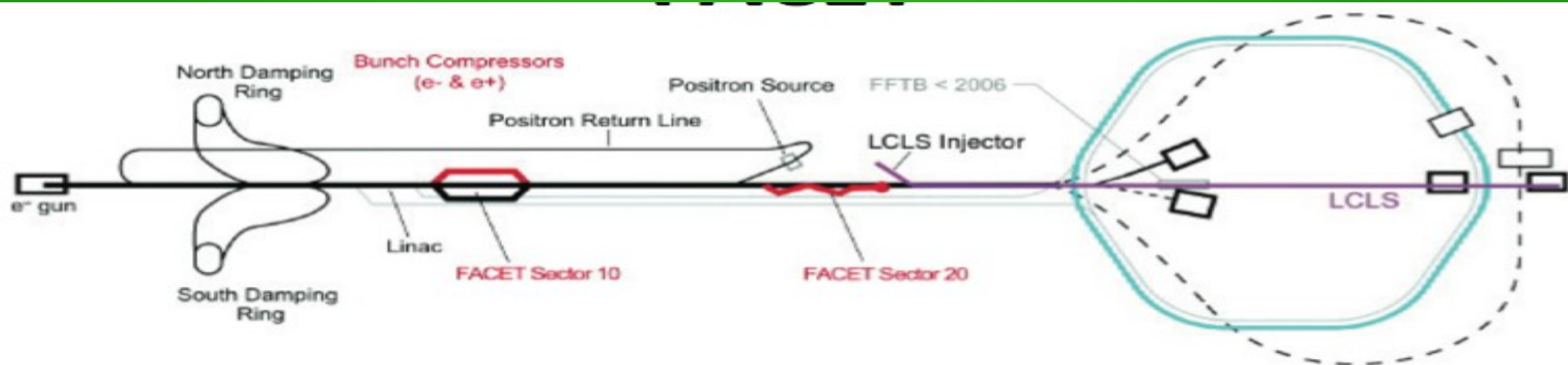WFS relies on an effect with act **within** the same bunch.

Andrea Latina at LCWS 2013

R = Response matrix nominal beam
D = Response matrix off-energy beam
W= Response matrix off-charge beam

ω_{DFS} = weight for DFS
ω_{WFS} = weight for WFS
β = regulation parameter
(equivalent to cutting on singular values)

$$\omega_{ideal} = \sqrt{\frac{\sigma_{res}^2 + \sigma_{align}^2}{2\,\sigma_{res}^2}}$$

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FACET (Facility for Advanced Accelerator Experimental Tests) is a User Facility at SLAC National Accelerator Laboratory.

- The first User Run started in spring 2012 with 20 GeV, 3 nC electron beams.
- The facility is designed to provide short 20 μm bunches and small (20 μm wide) spot sizes
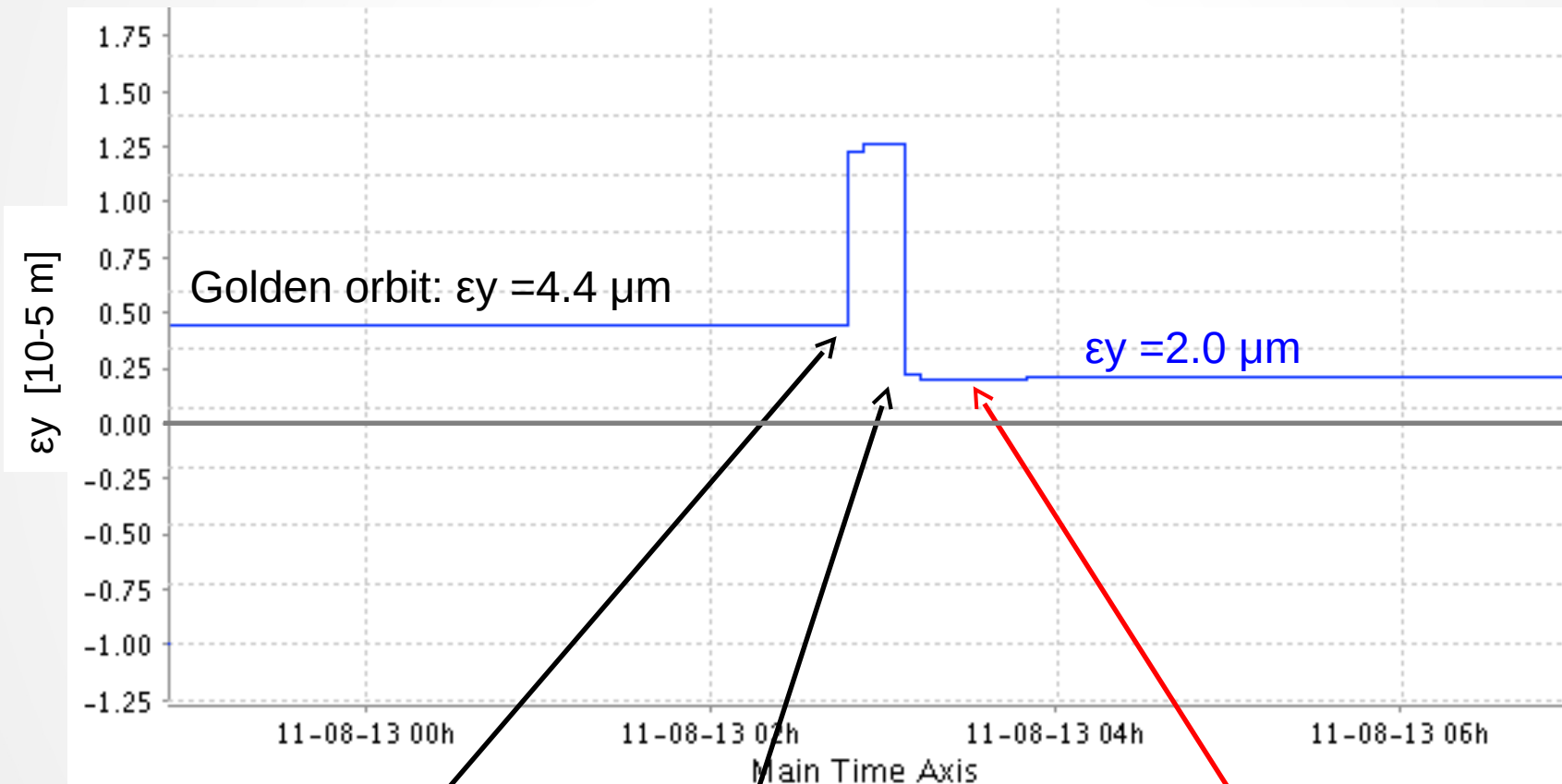
Experiments at FACET:

- Plasma wake field acceleration, dielectric structure acceleration, Smith-Purcell radiation, magnetic switching, terahertz generation ...
- *E-211: Beam-Based Alignment*

Andrea Latina at LCWS 2013

- Strong wakefields

- Good test bench

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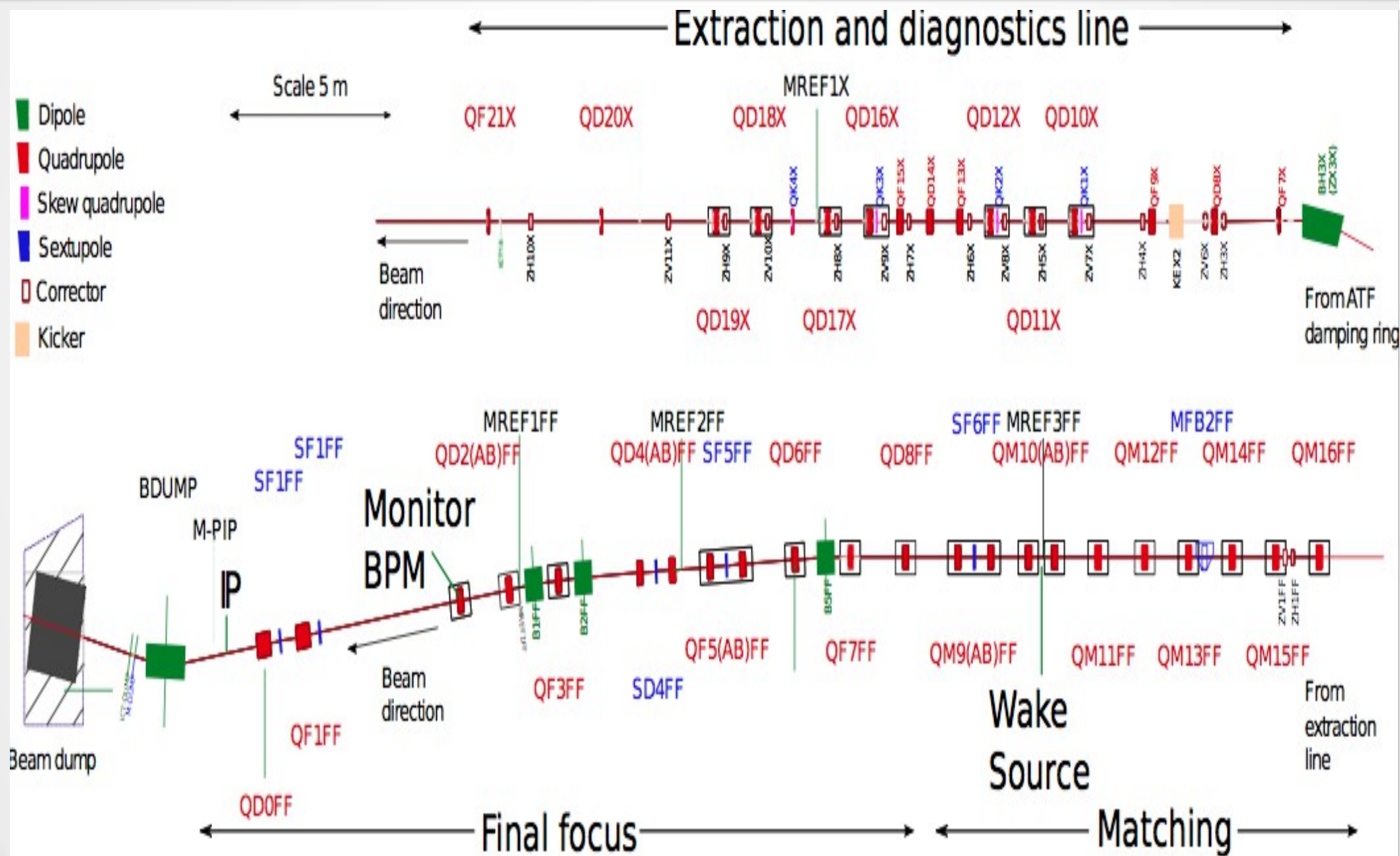
FACET

SLC's emittance log in Sector 04

Golden orbit: εy =4.4 μm

εy =2.0 μm

1. We spoiled the emittance

2. We applied WFS

Lower emittance achieved in S04!

Andrea Latina at CLIC project meeting December 2013

ATF2

# ATF2

- Goal 1: reach 37 nm vertical beam size at the IP
- 55 BPMs:
  - Stripline BPMs (resolution ~1-2 um) in extraction line
  - Cavity BPMs (res. ~200nm attenuated, 30nm non-attenuated) in Final Focus
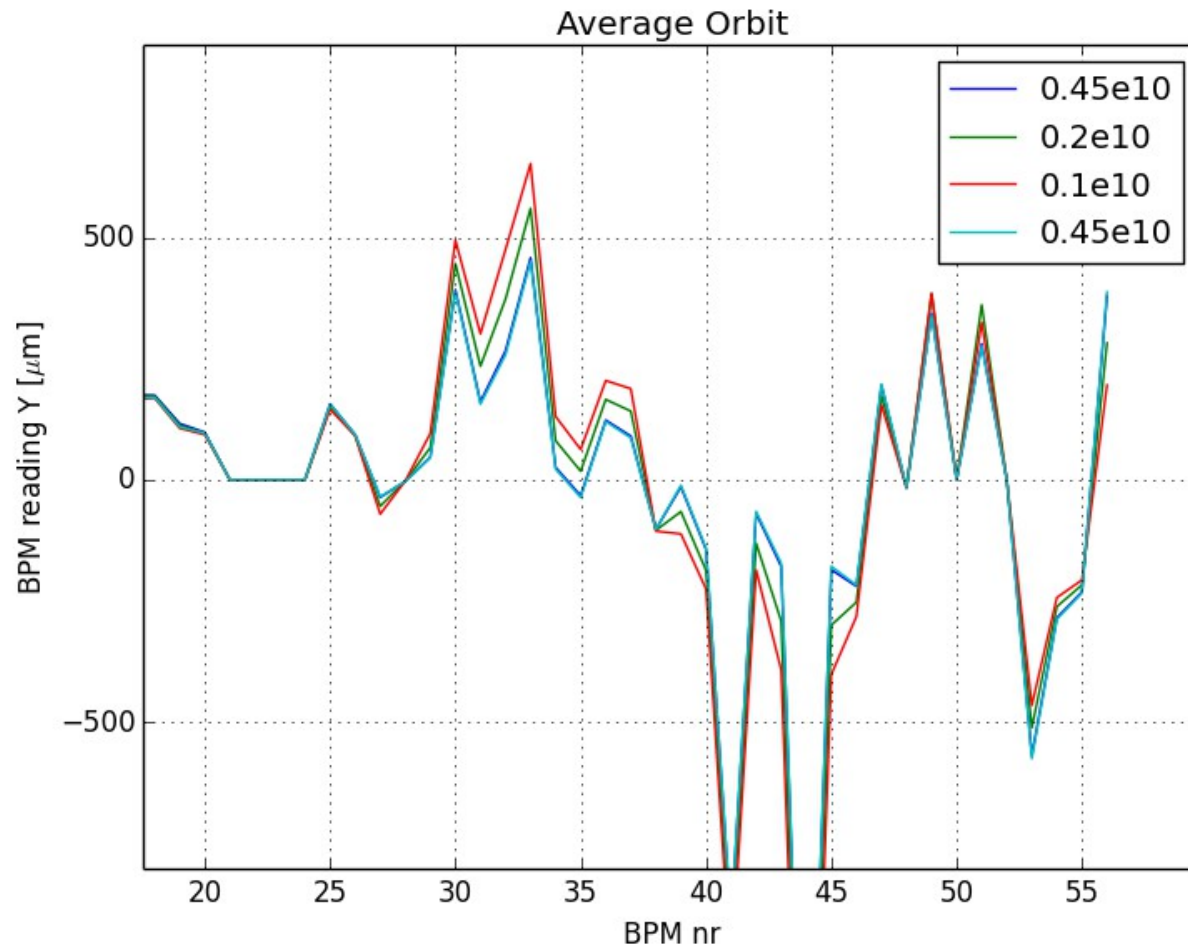- 11 horizontal and 11 vertical correctors mostly in extraction line
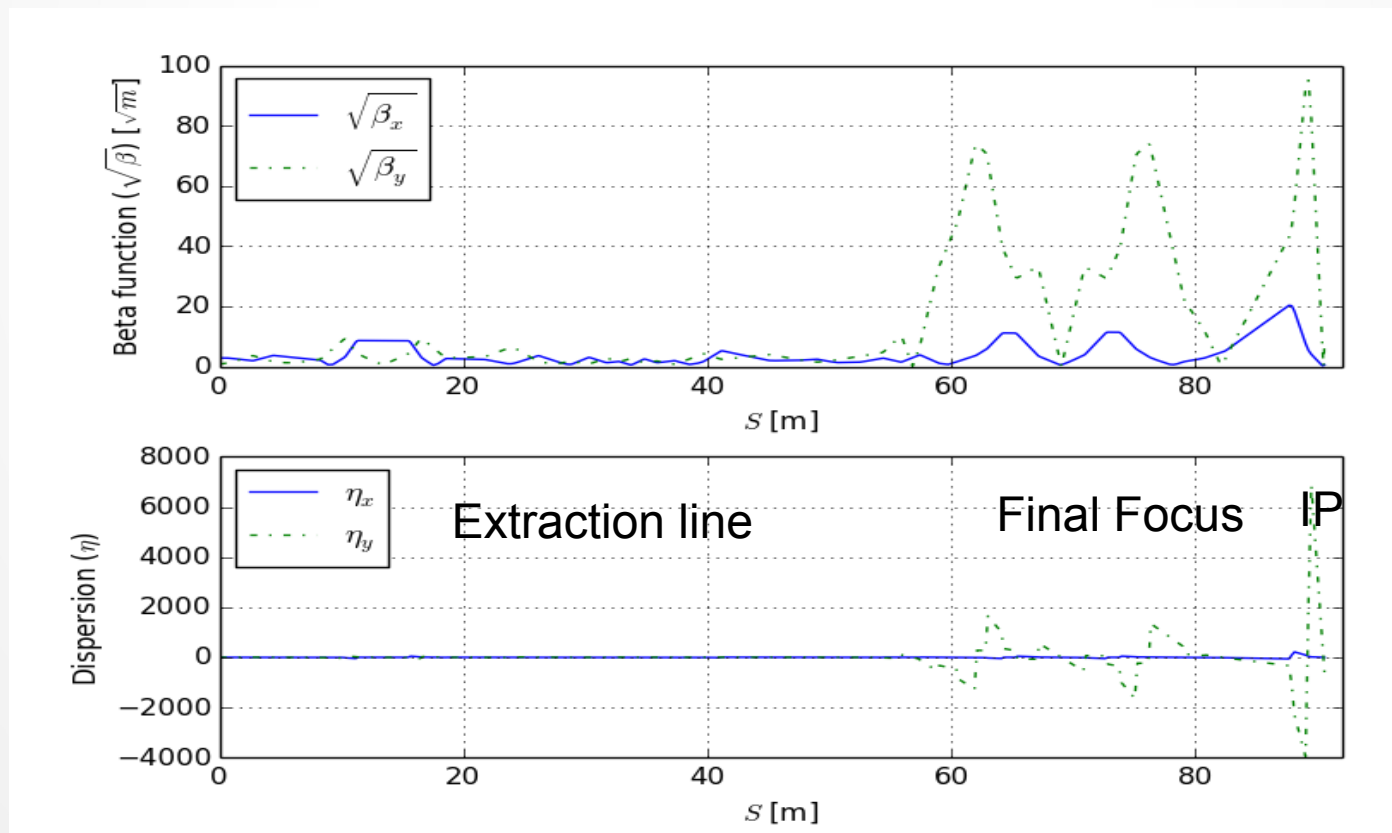
Motivation

- In 2013 ~60-70 nm beam size was achieved, but only at very low intensity

- Strong intensity dependence on beam size

  - Wakefield contribution is strongly suspected

- Larger modulation means smaller beam size

Okugi-san
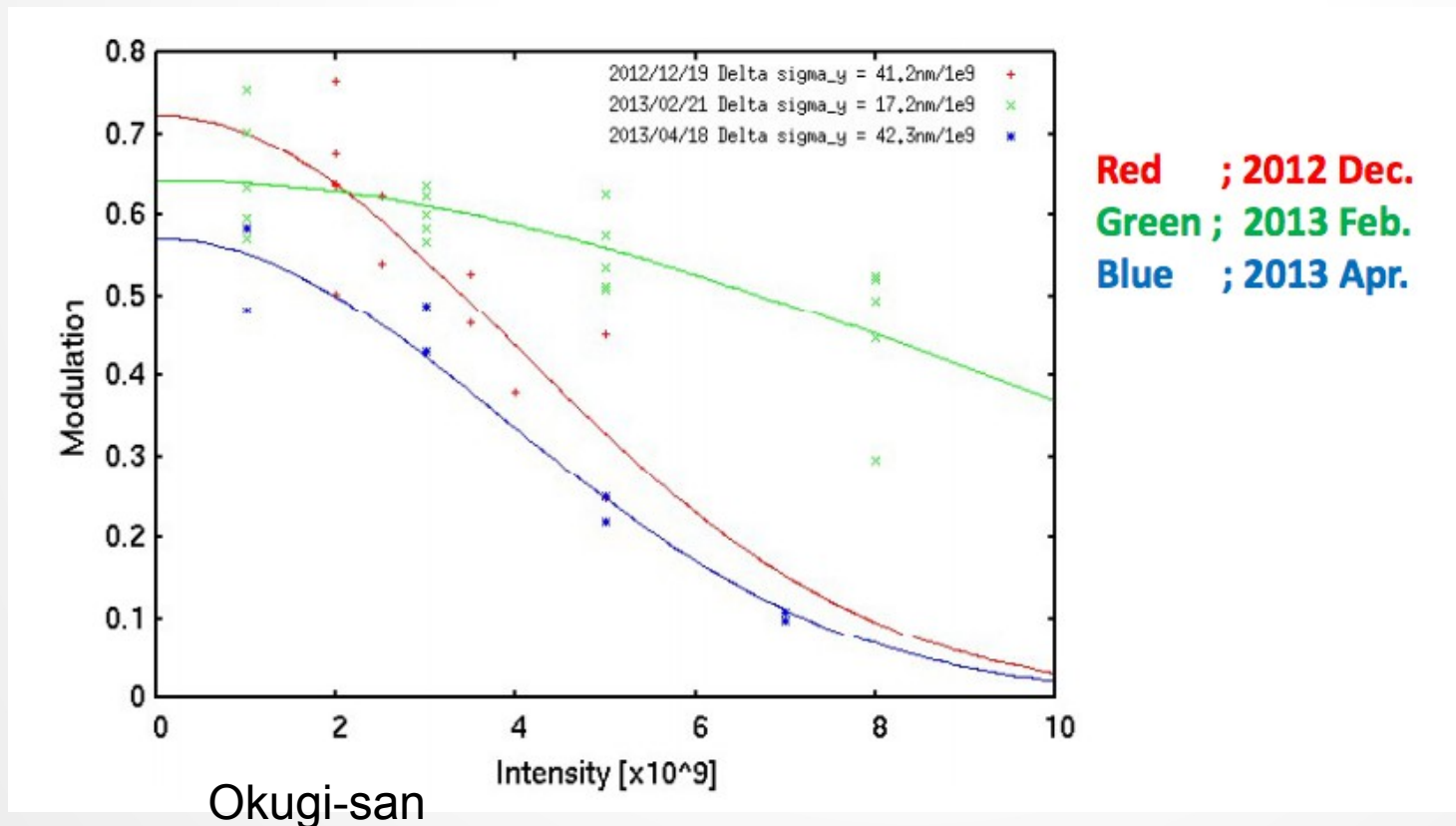
Motivation

Also strong intensity dependence on orbit

Data 22 April 2013

BPM selection

- As system is overdetermined (55 BPMs for 11 correctors), not all 55 BPMs needed

- For stability 10 BPMs selected at most sensitive high beta locations and end of Final Focus
  - QD10BFF, QD10AFF, QF9BFF, QD8FF, QF7FF, QD6BFF, QF5FF, QD4BFF, QF3FF, QD2BFF

- All attenuated cavity BPMs with similar resolution ~200nm
  - weight in WFS algorithm can now put higher
    (more aggressive correction)

BPM resolution vs charge

Cavity BPM with attenuator (20dB)

$$R = R_0 \sqrt{\frac{A^2}{q^2} + 1}$$
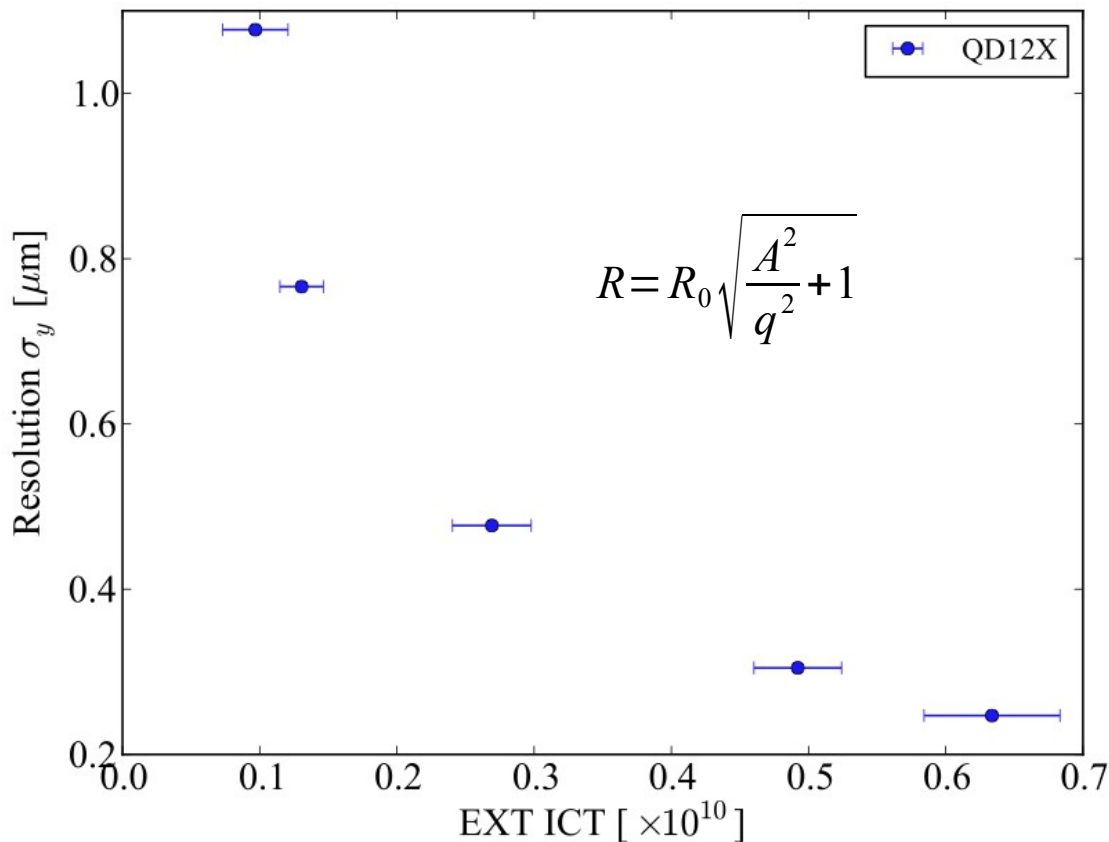
Charge (q)	Resolution(R)	WFS weight
1e10	220nm	32
0.8e10	230nm	31
0.5e10	270nm	26
0.1e10	940nm	7.5

Effect implemented in simulation

Simulation parameters

- Default WFS simulation settings:
  - Sextupoles off
  - Charge: 0.5e10 and 0.8e10
  - Misalignment 30 µm
    - BPMs and Quadrupoles, vertical and horizontal
  - Wake fields as obtained from simulation added at cavity BPMs only
  - "Fixed beam"
    - no beam jitter added, done for simplicity.
    - In practice averaging and jitter subtraction needs to be added
  - Response matrices obtained from simulation
  - WFS Weights:
    - $\beta = 5$
    - $\omega_{WFS} = 26$
  - 3 iterations
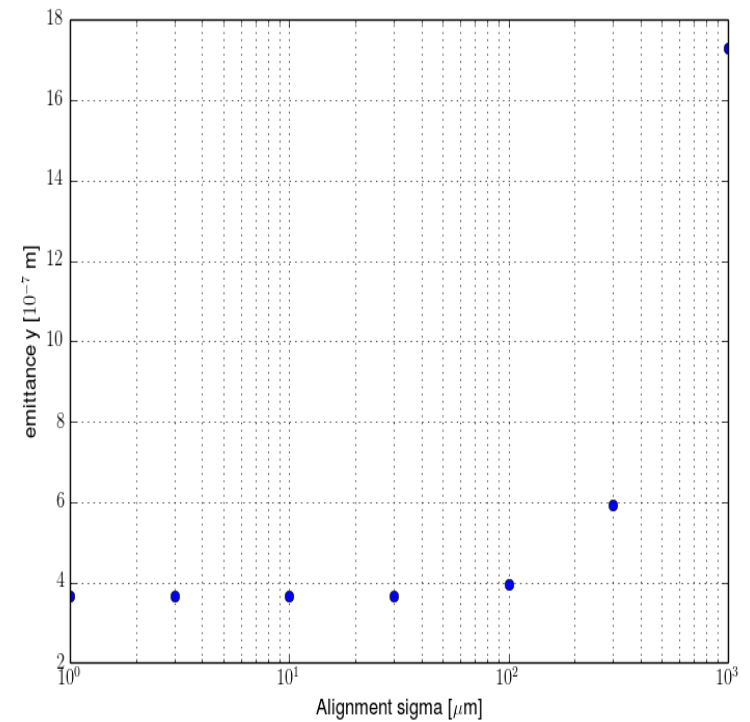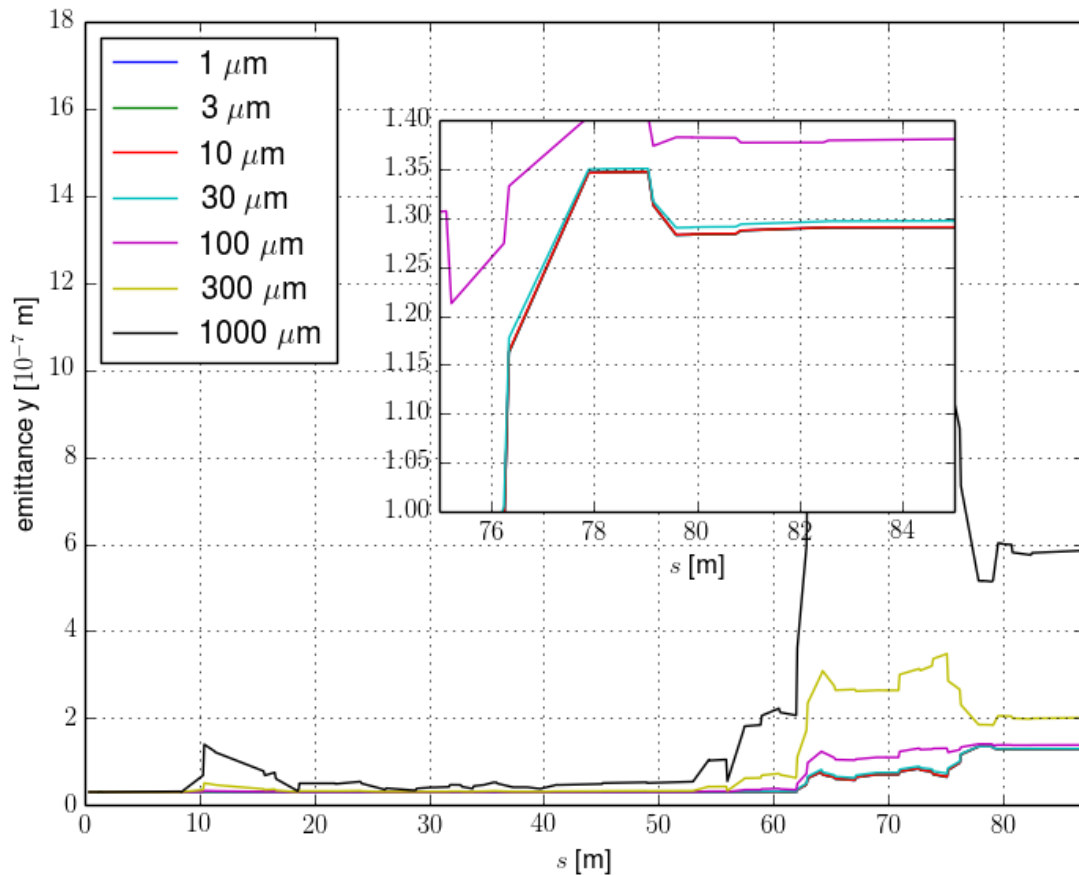 - 100 machines (misalignment seeds)

Emittance
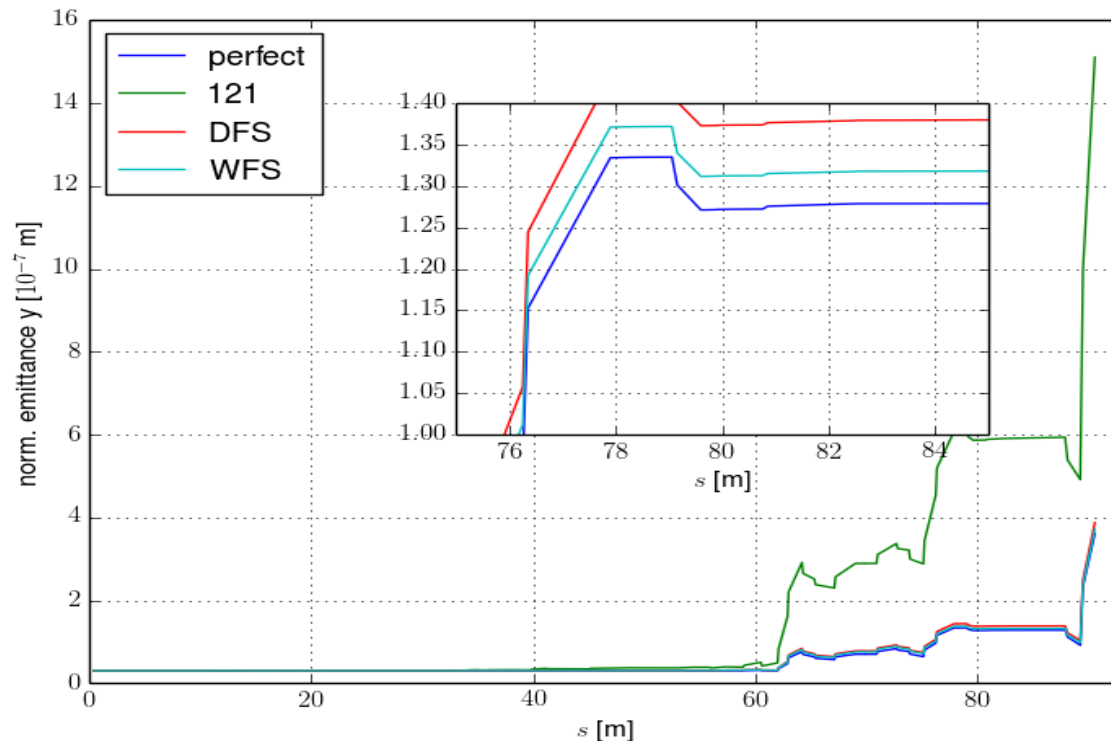
- WFS recovers almost all of the emittance growth

- Performs better than 1-to-1 steering or DFS

- Hard to measure experimentally at ATF2

- Therefore look at differential orbit for the different charges

Beta scan
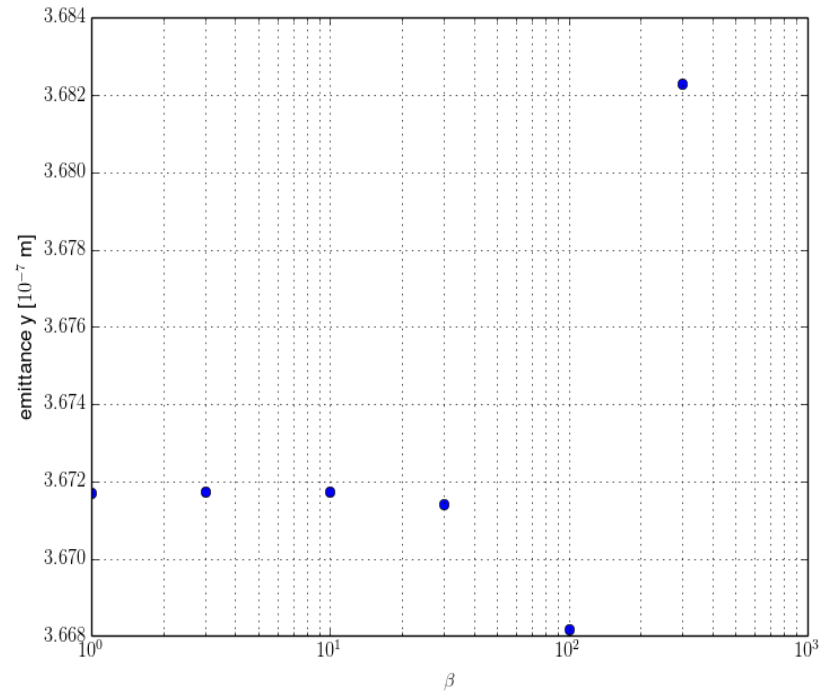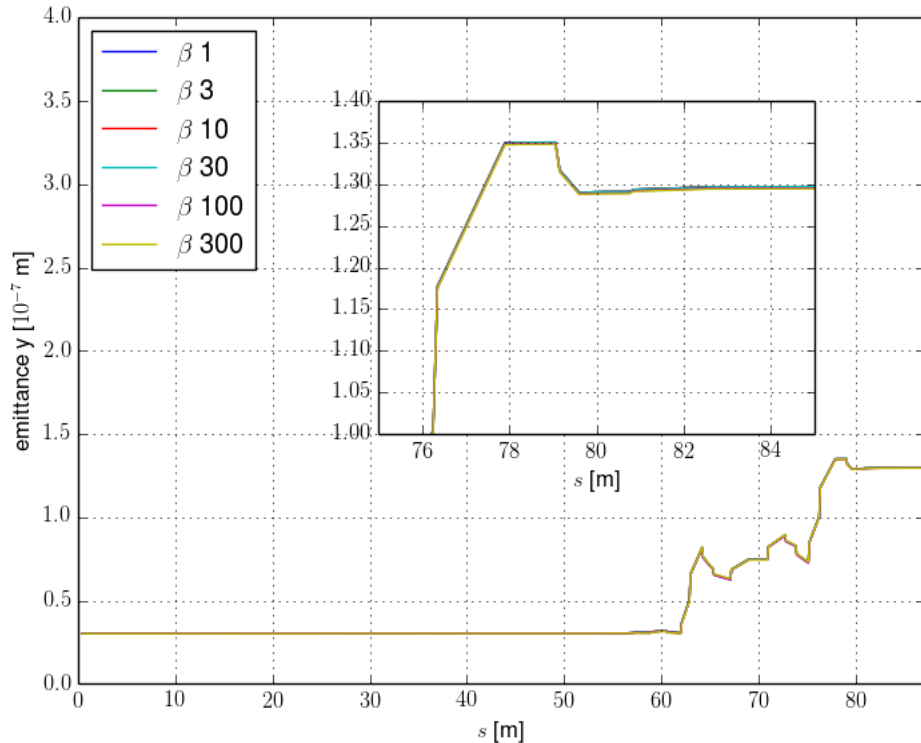
- β parameter (stability parameter) seems not so important, β = 5 was chosen
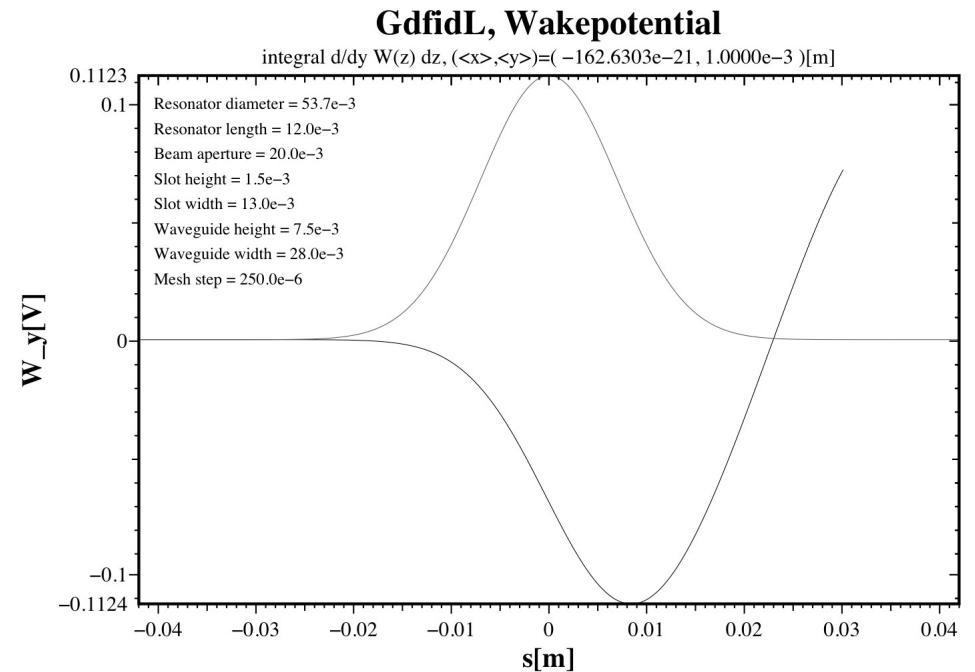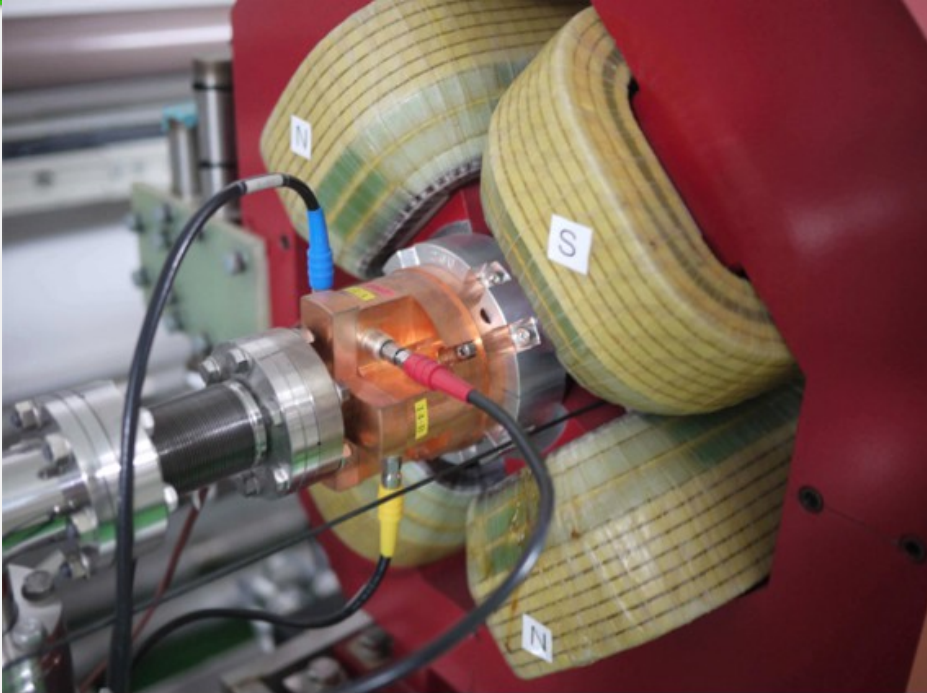
Alignment Scan

- Gaussian distributed misalignment with different standard deviation
- Possible to recover also with severe misalignment

Conclusion + Outlook

- WFS looks to be a promising method for finding a wakefield free orbit in ATF

- Include DFS and WFS together in simulation
  - Could add stability for correction, as observed in FACET
  - WFS needs to be done in parallel with dispersion correction
- Add full tuning to see effect on beam size
- Need to plan some experimental tests

  - Measure response matrices
  - Perform WFS test with verification
- To be presented at ATF2 project meeting next week

Back-up

C-band CBPM

GdfidL, Wakepotential

integral d/dy W(z) dz, (<x>,<y>)=(−162.6303e−21, 1.0000e−3)[m]

Resonator diameter = 53.7e−3
Resonator length = 12.0e−3
Beam aperture = 20.0e−3
Slot height = 1.5e−3
Slot width = 13.0e−3
Waveguide height = 7.5e−3
Waveguide width = 28.0e−3
Mesh step = 250.0e−6

- High-impedance device (to provide a high position sensitivity)
- Typical resolution with attenuators ~200nm
- 30 nm without attenuation
- ~40 cavities in the beamline, the effect may be multiplied (although this depends on the orbit, beta function and alignment)
- Y.I. Kim et al. http://prst-ab.aps.org/pdf/PRSTAB/v15/i4/e042801
- Recent ATF review presentation: https://ilcagenda.linearcollider.org/getFile.py/access?subContId=0&contribId=7&resId=0&materialId=slides&confId=5973