First WFS simulations for ATF2

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John Adams Institute for Accelerator Science

～宇宙と物質の起源と構造を探る～
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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:

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

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.

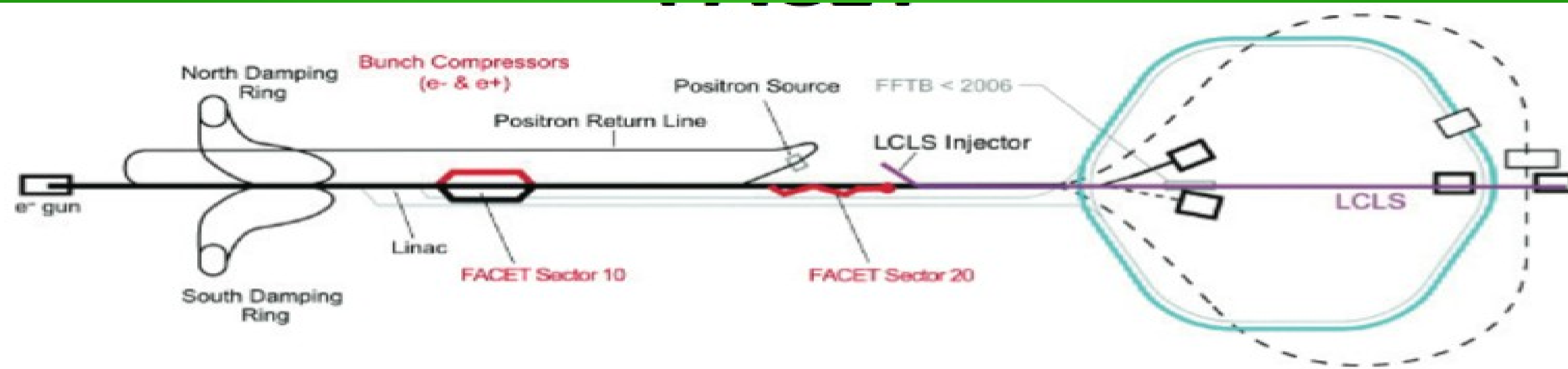
Andrea Latina at LCWS 2013

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)

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

FACET layout



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:

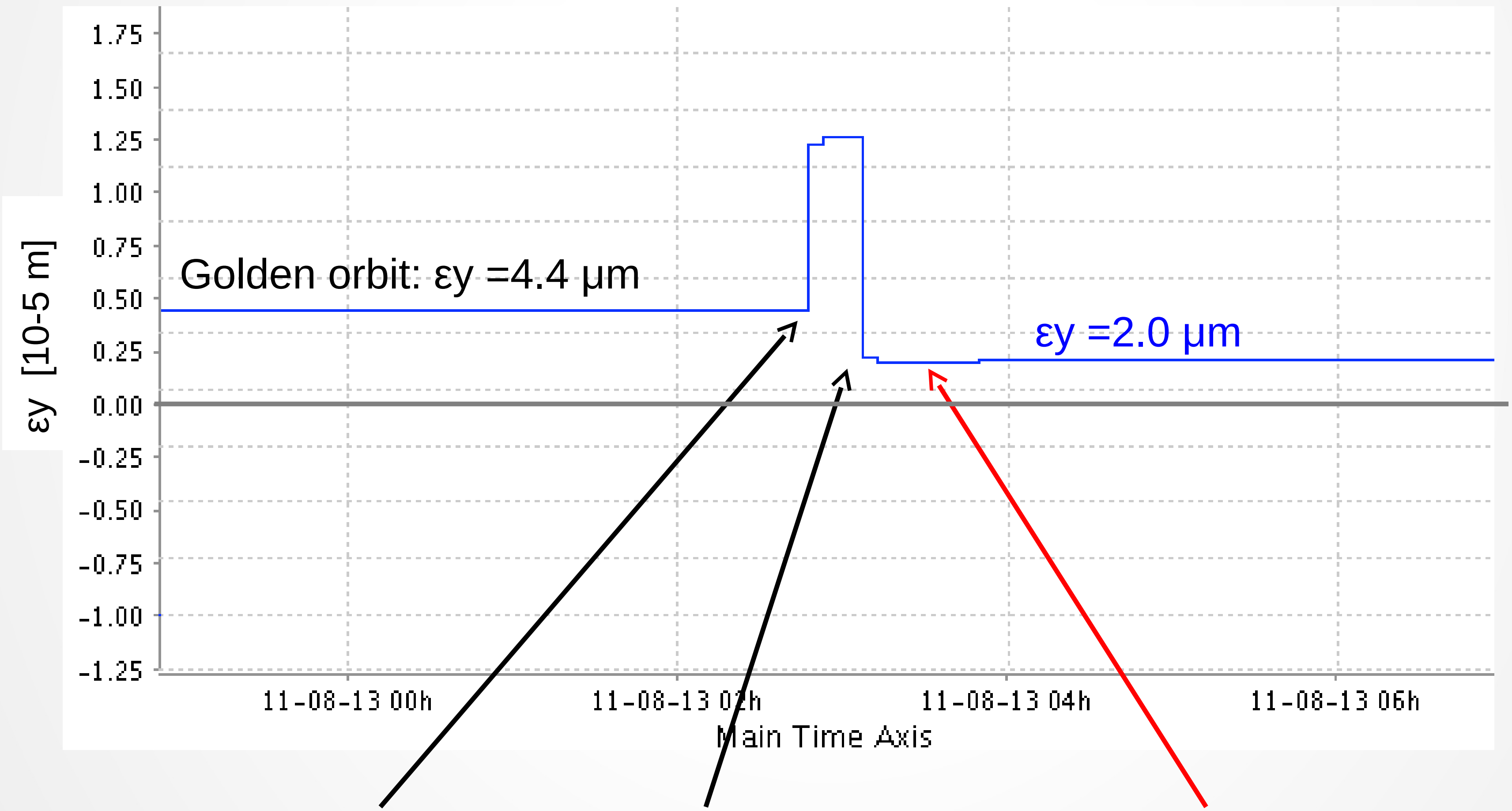
- Plasma wake field acceleration, dielectric structure acceleration, Smith-Purcell radiation, magnetic switching, terahertz generation ...
- ***E-211**: Beam-Based Alignment*

Andrea Latina at LCWS 2013

- Strong wakefields
- Good test bench

FACET

SLC's emittance log in Sector 04

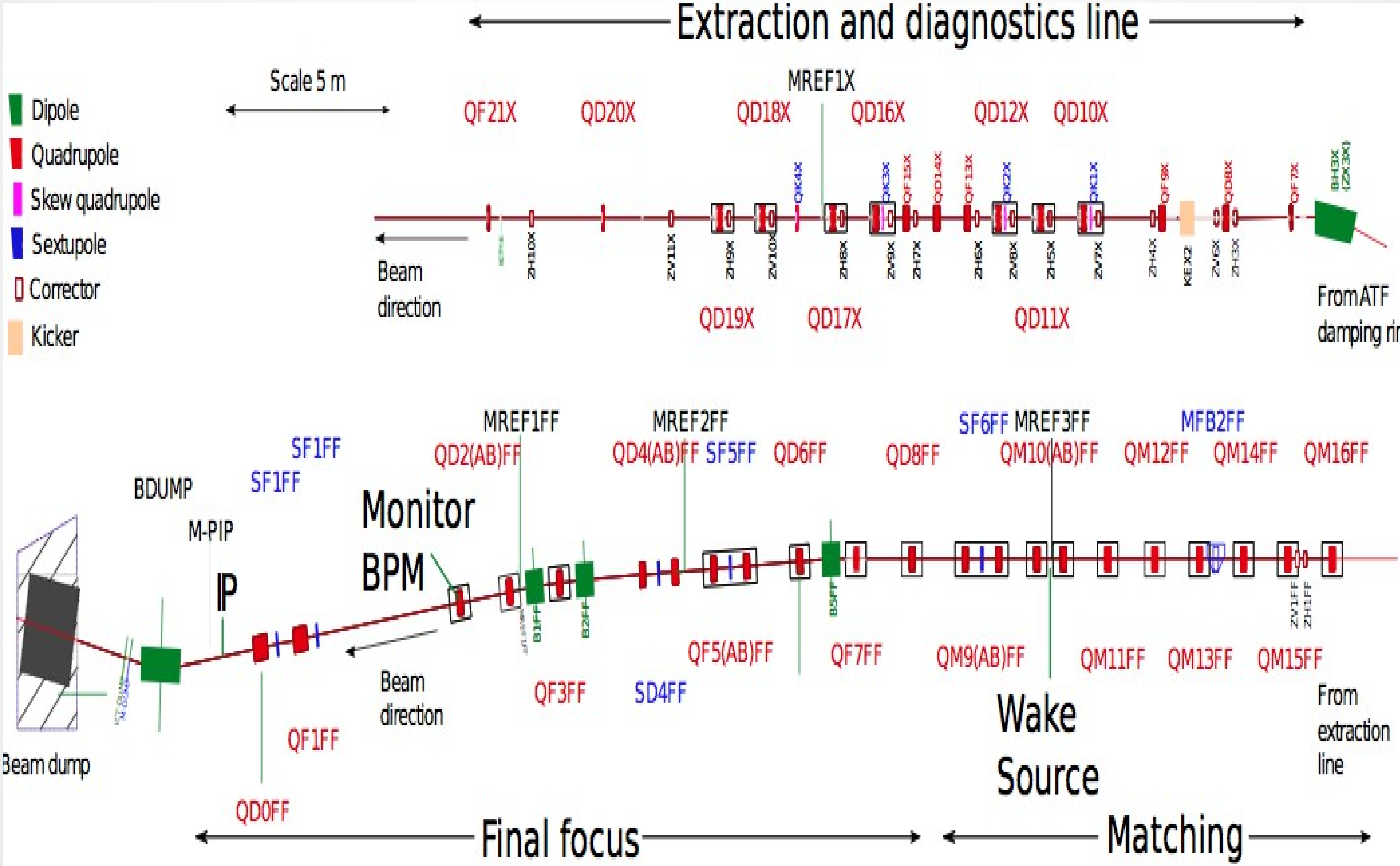


1. We spoiled the emittance

2. We applied WFS

Lower emittance achieved in S04!

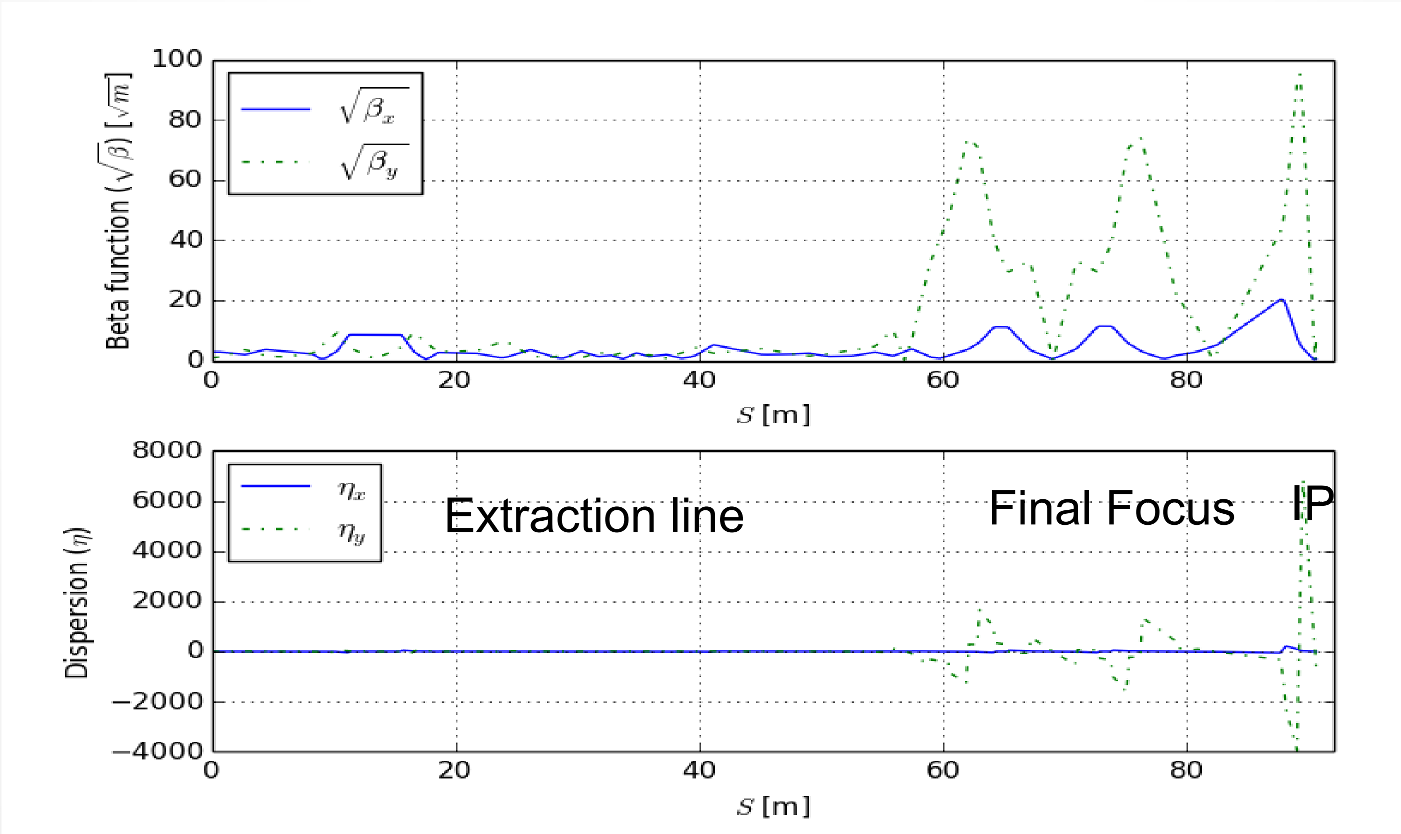
ATF2



Extraction and diagnostics line
Scale 5 m
Dipole
Quadrupole
Skew quadrupole
Sextupole
Corrector
Kicker
MREF1X
QF21X
QD20X
QD18X
QD16X
QD12X
QD10X
Beam direction
QD19X
QD17X
QD11X
From ATF damping ring
MREF1FF
MREF2FF
SF6FF
MREF3FF
MFB2FF
SF1FF
QD2(AB)FF
QD4(AB)FF
SF5FF
QD6FF
QD8FF
QM10(AB)FF
QM12FF
QM14FF
QM16FF
BDUMP
SF1FF
M-PIP
Monitor
BPM
IP
QF5(AB)FF
QF7FF
QM9(AB)FF
QM11FF
QM13FF
QM15FF
Beam direction
QF3FF
SD4FF
Wake
Source
From extraction line
Beam dump
QF1FF
QD0FF
Final focus
Matching

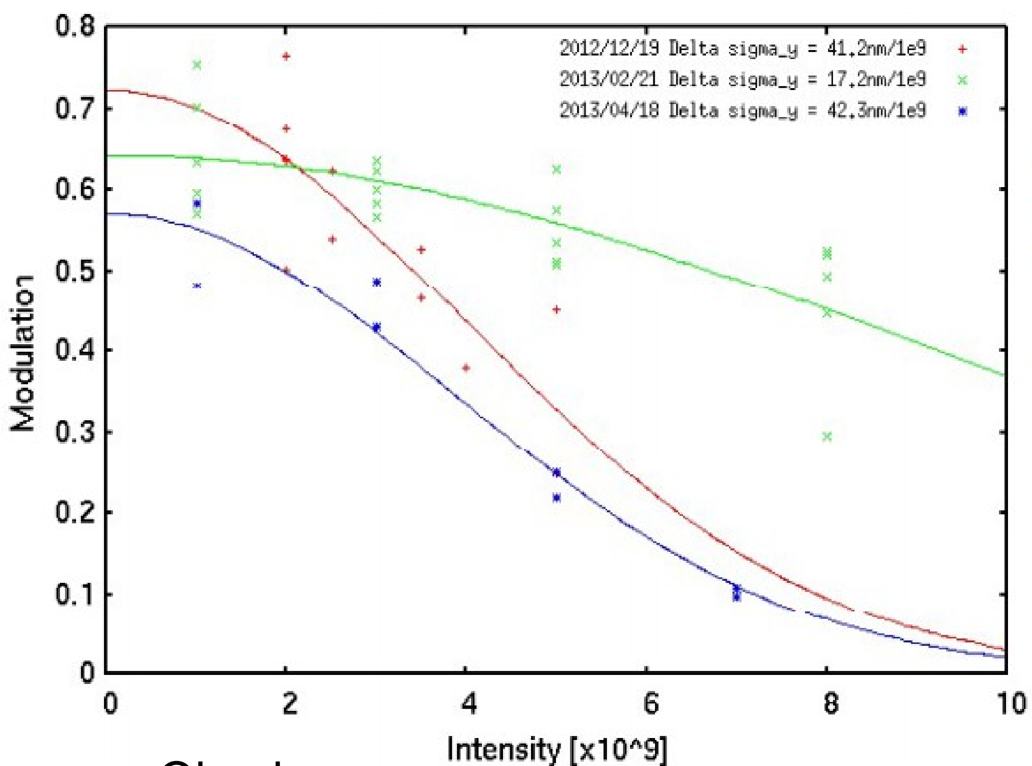
ATF2

- 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

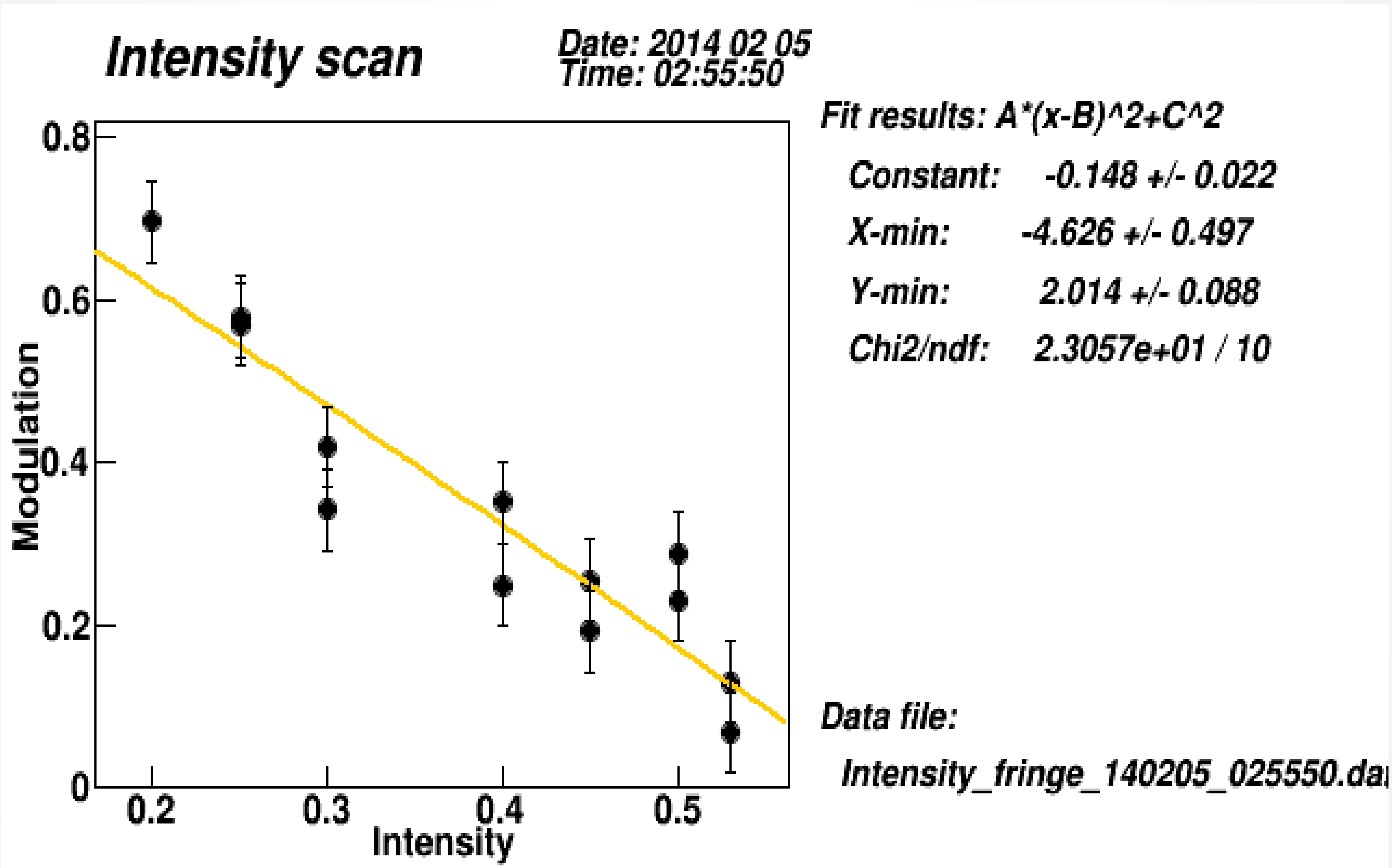
- In 2013 ~60-70 nm beam size was achieved, but only at very low intensity
- Strong intensity dependence on beam size
  - Wakefield contribution is strongly suspected
- Larger modulation means smaller beam size



Red ; 2012 Dec.
Green ; 2013 Feb.
Blue ; 2013 Apr.

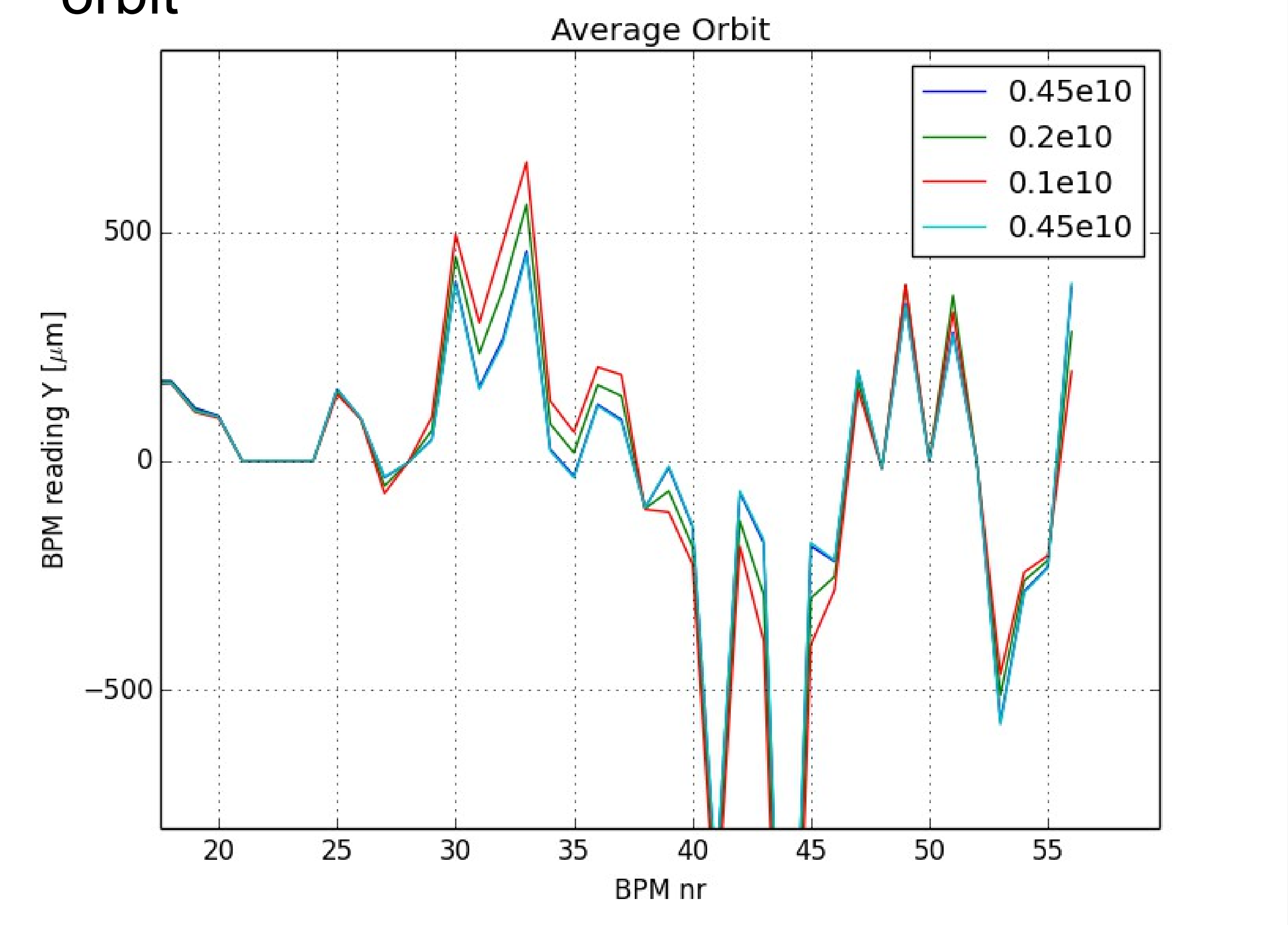
Okugi-san

Recent example



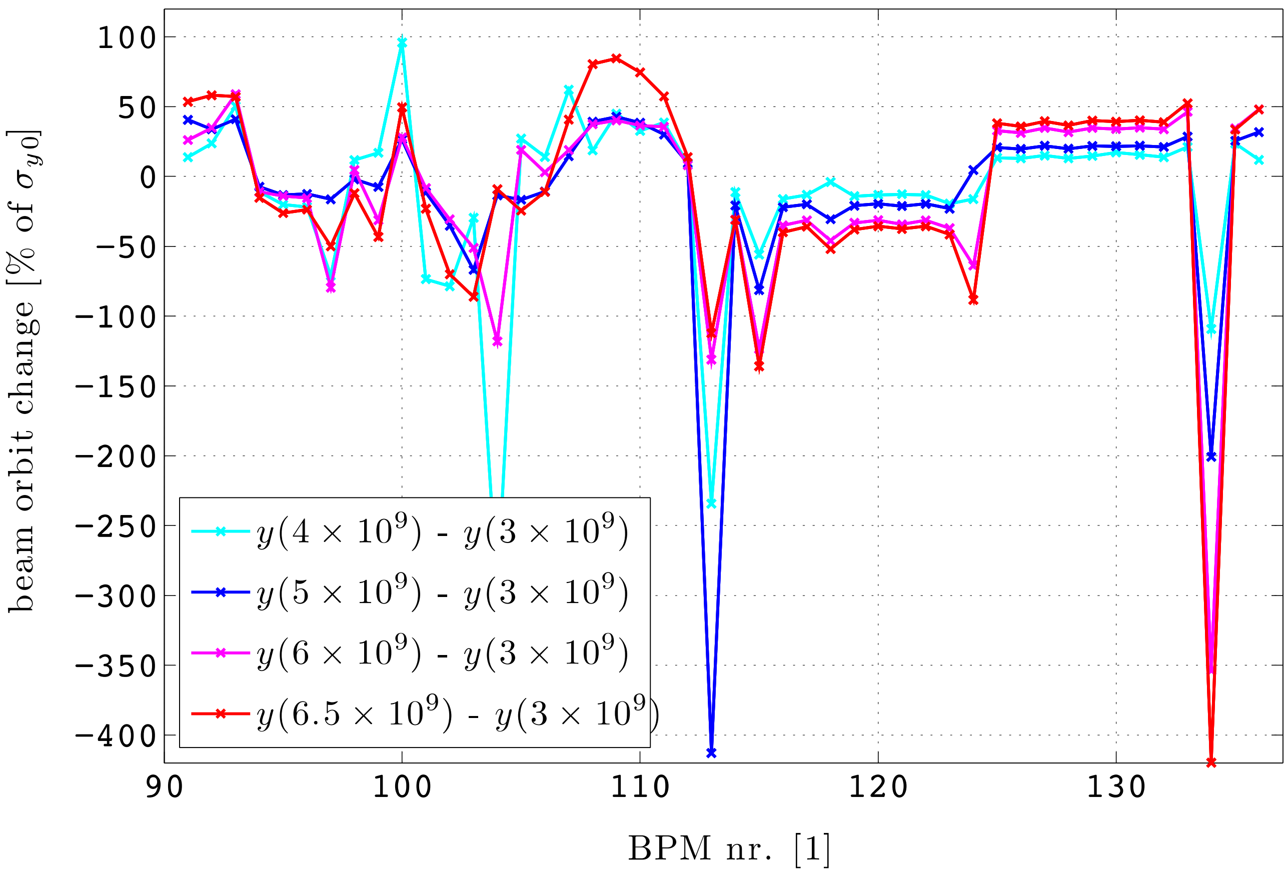
Motivation

Also strong intensity dependence on orbit



Data 22 April 2013

Change of absolute orbit due to intensity



- No dependence of diff. orbit on the intensity, but strong dependence on the absolute orbit
- Some problems with scaling of BPMs.
- There is a clear correlation between charge and beam offset (up to 100µm) after some point in the beam line.
- It seems this point is where the beta function starts to become bigger (before the FF).
- Candidates: cavity BPM or laser wire setup
- It is not clear, if there is no dependence before (low statistics) and dependence must not be linear with charge.

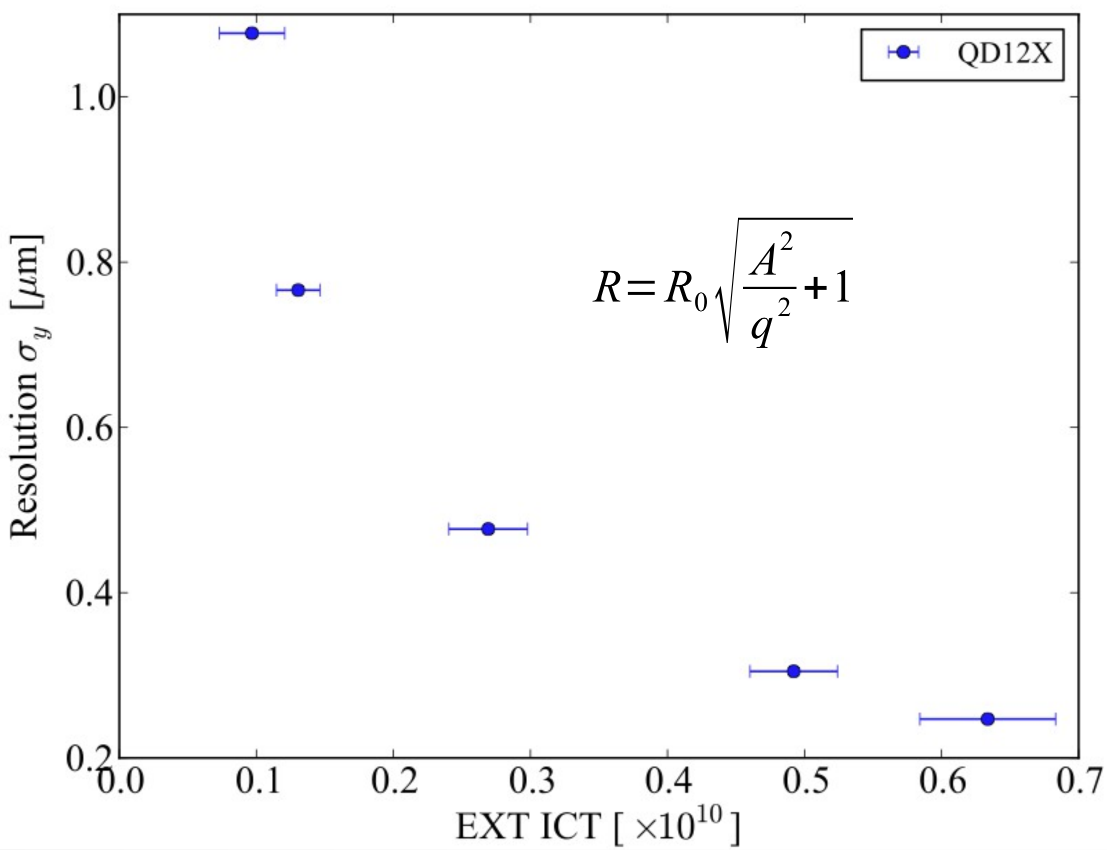
J. Pfingstner 24-5-2013

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)



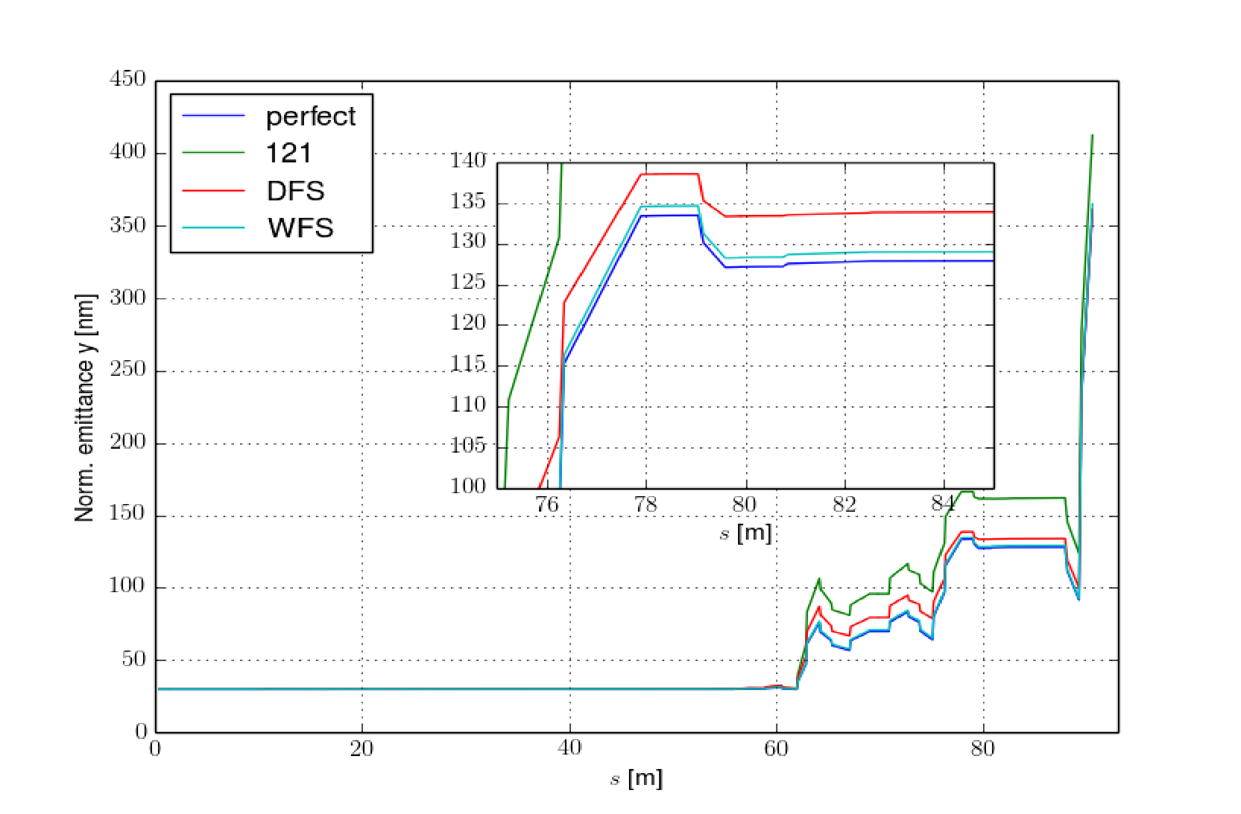
Charge (q)	Resolution(R)	WFS weight
1e10	220nm	32
0.8e10	230nm	31
0.5e10	270nm	26
0.1e10	940nm	7.5

Effect implemented in simulation

Simulation parameters

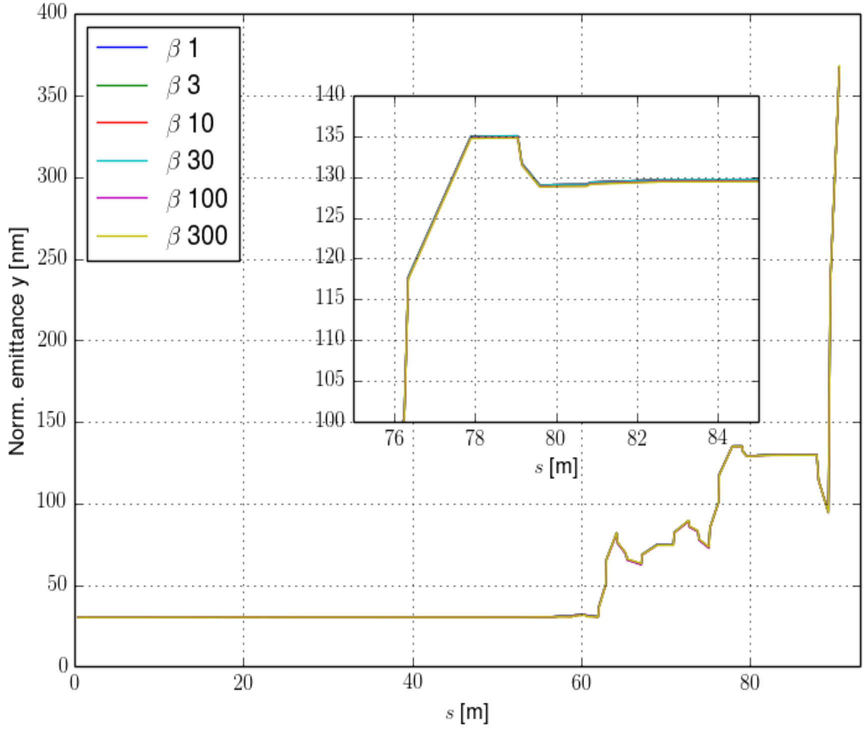
- Default WFS simulation settings:
  - Sextupoles off
  - Charge: 0.5e10 and 0.8e10
  - Misalignment 30 μm
    - BPMs and Quadrupoles, vertical and horizontal
  - Wake fields as obtained from simulation added at cavity BPMs only
  - “Fixed beam”
    - no beam jitter added, done for simplicity.
    - 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)

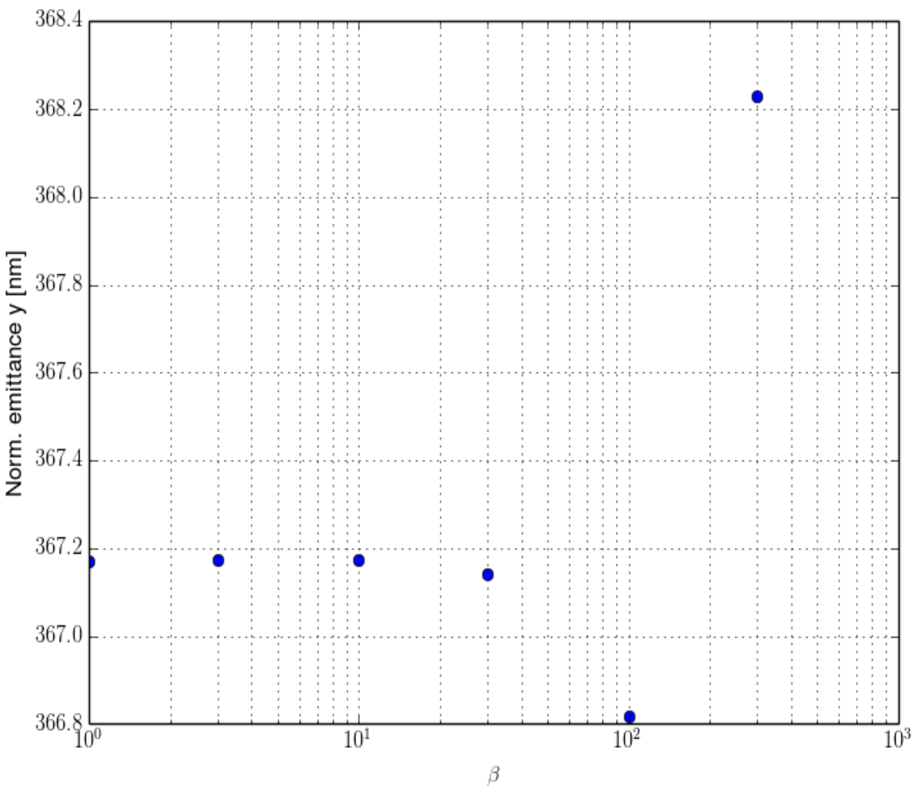
Emittance



- 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

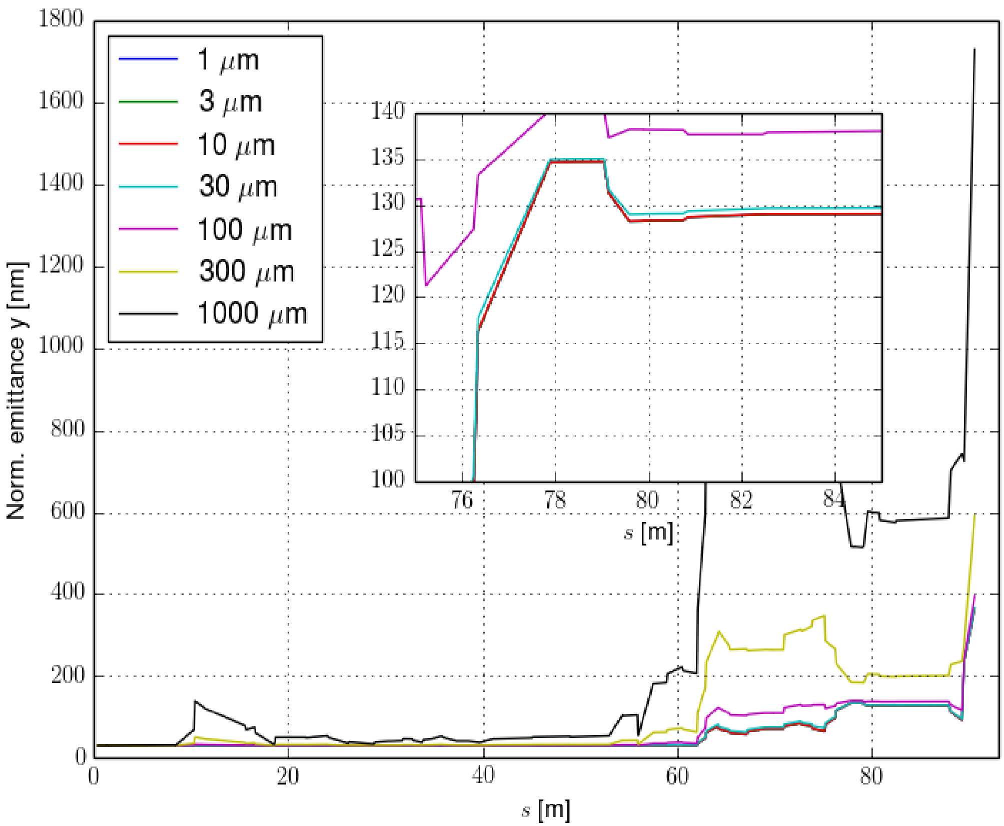
Beta scan

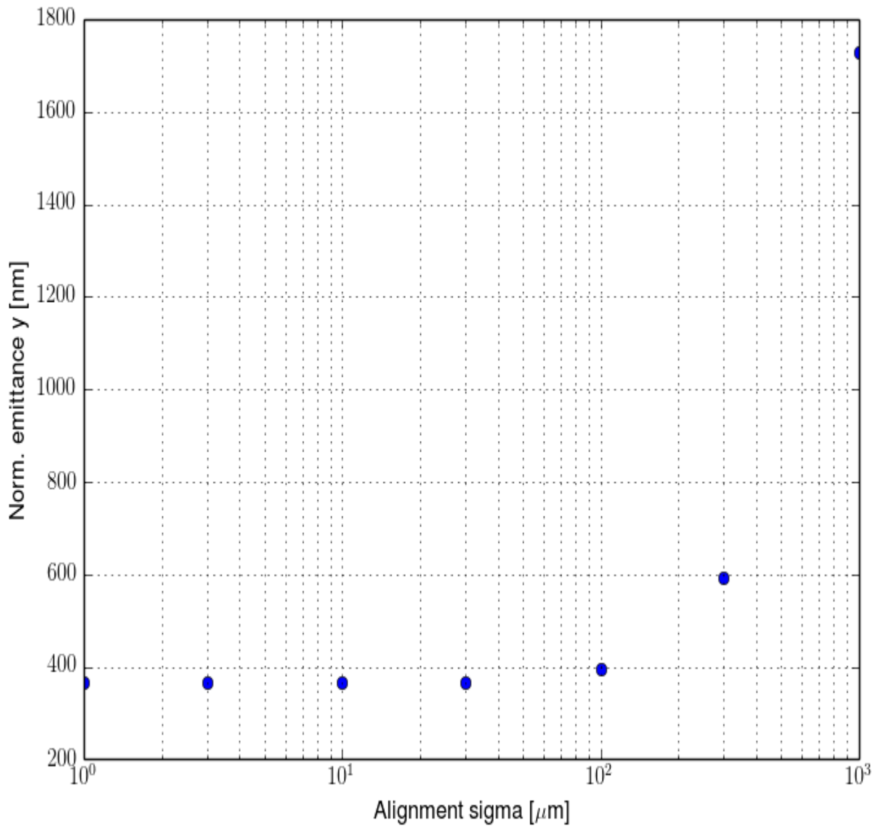




- β parameter (stability parameter) seems not so important, β = 5 was chosen

Alignment Scan





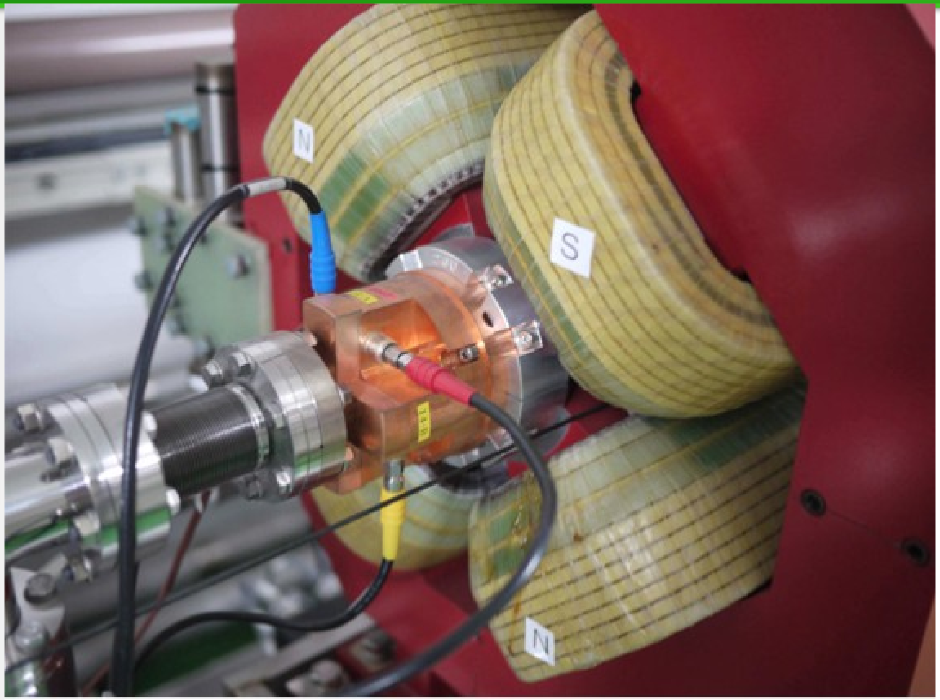
- Gaussian distributed misalignment with different standard deviation
- Possible to recover also with severe misalignment

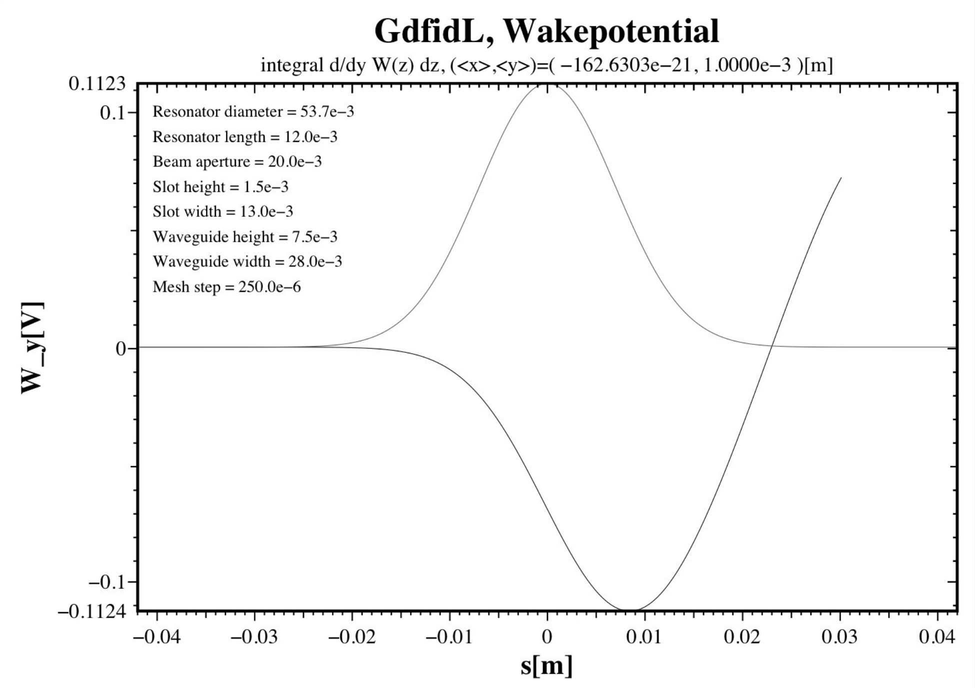
Conclusion + Outlook

- 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
    - Beam orbit
    - OTR emittance measurement
    - IPBSM beam size intensity dependence

Back-up

C-band CBPM





- 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