Wakefield issues

15th ATF2 project meeting

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Outline

- Wakefield overview
- Simulations
  - Wakefield calculations
  - Tracking simulations
- Measurements
- Mitigation and future research possibilities

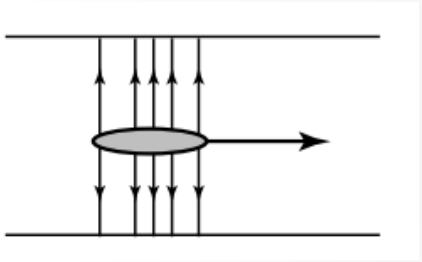
Wakefield

- Wakefield is mostly suspected to be the main cause of the remaining beam spot size growth in ATF2
- Main indications:
  - Beam size growth with increased intensity
  - Beam size has large dependence on reference cavity mover
- Introduces a yz beam coupling (tilt)
- Cannot be mitigated with e.g. sextupole knobs
- Reminder: also very important imperfection for SLC and ILC Main Linac

Wakefield

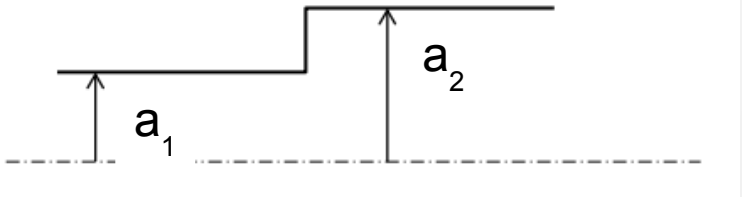
- Two main wakefield sources in ATF2 / BDS ILC
- Dipole resistive wall wake:

$$W(s) = \frac{Z_0 c}{2\pi^2 a^3}\sqrt{\frac{c}{\sigma s}}H(s)$$



- Beampipe step transition:

$$W(s) = \frac{Z_0 c}{\pi}\left(\frac{1}{a_1^2} - \frac{1}{a_2^2}\right)H(s)$$

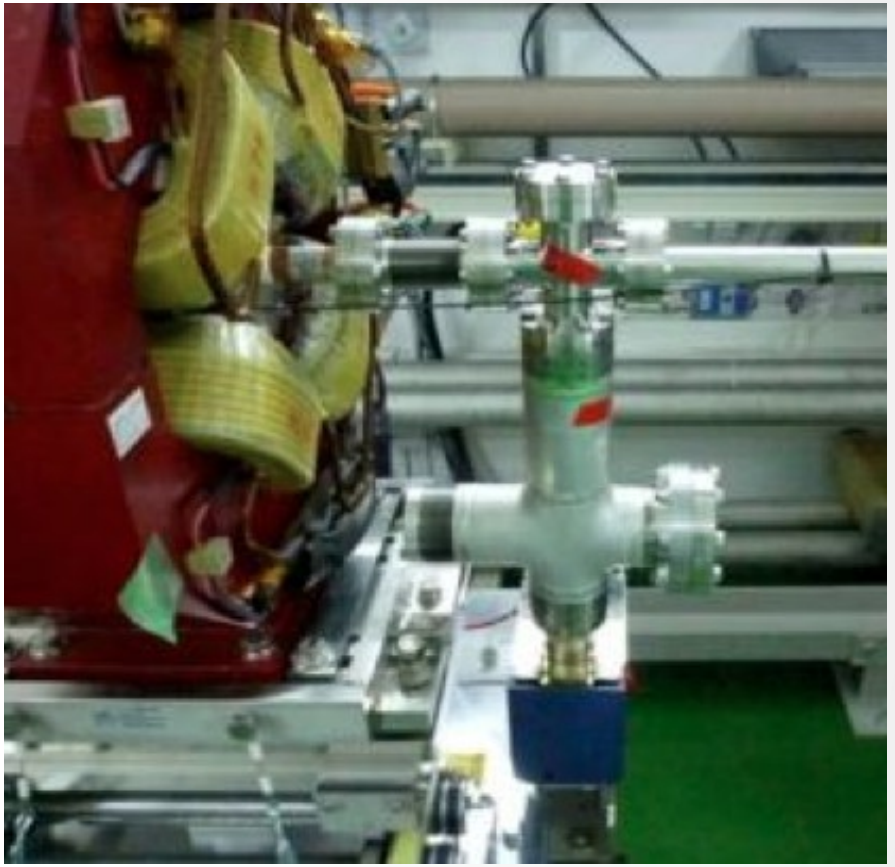


- (*a* aperture, *H(s)* beam distribution, σ beam conductivity)

  Bane, Seryi paper
  http://accelconf.web.cern.ch/AccelConf/p07/PAPERS/THPMS039.PDF

Wakefield sources in ATF2

- BPMs
- Bellows
- Vacuum ports
- Narrow beam pipe
- Beam pipe misalignment
- Sbends?
- ??

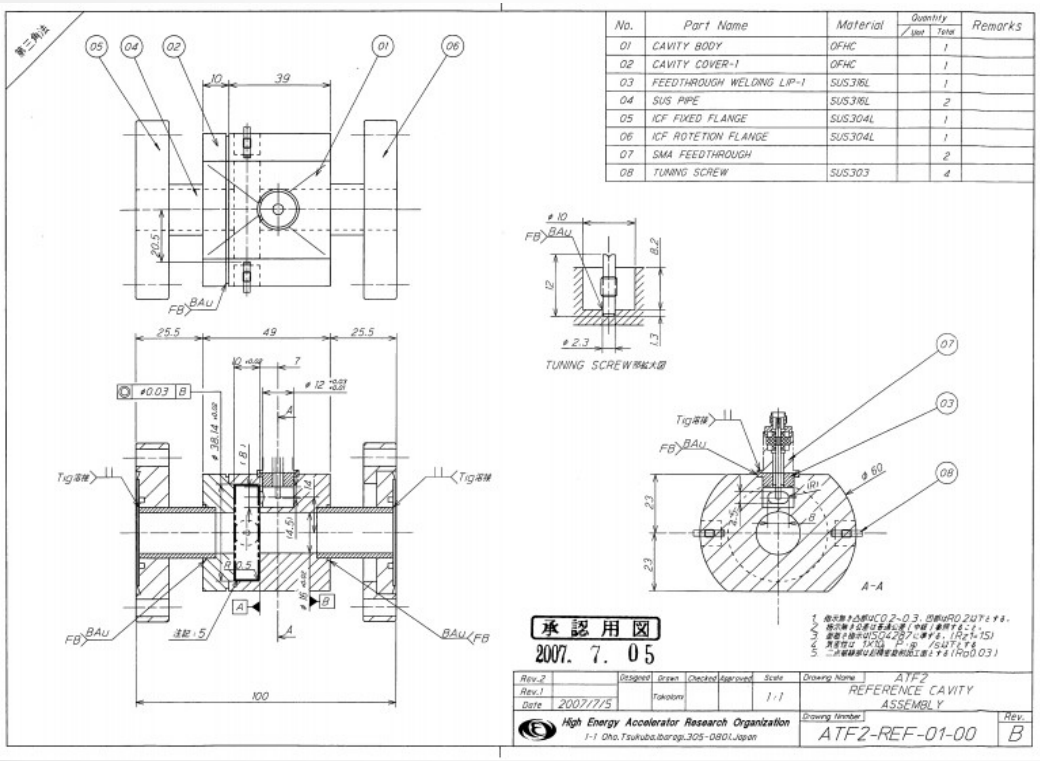


Simulation

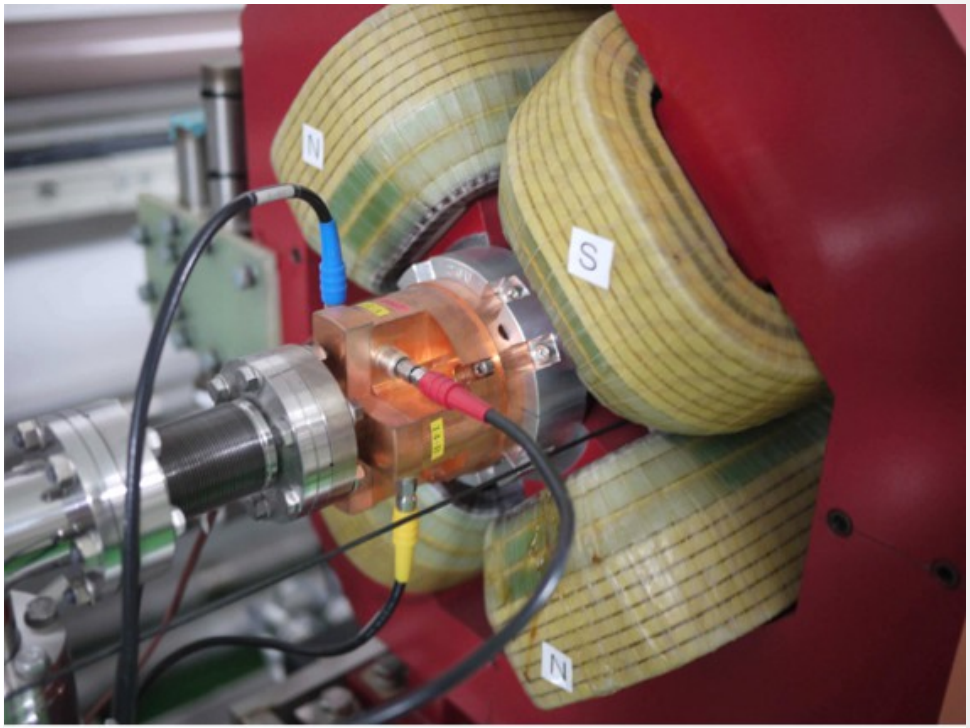
- Wake fields have been calculated with GdfidL program
  - Electromagnetic fields calculator in any 3D-structure
  - Finite element method
  - All higher modes included (up to cut-off frequency)
- CPU and labor-intensive simulations (A. Lyapin)
- Wake field shape dependent on beam shape itself!
  - Bunch length
  - Beam offset
  - Beam angle?
- Simulations correct up to about 10-15% ?

Cavity BPM

- High resolution cavity BPMs, sub 100nm resolution (with attenuation about 250nm)
- 35 currently installed at ATF2
- radius 10 mm (ref. cavity 8 mm)

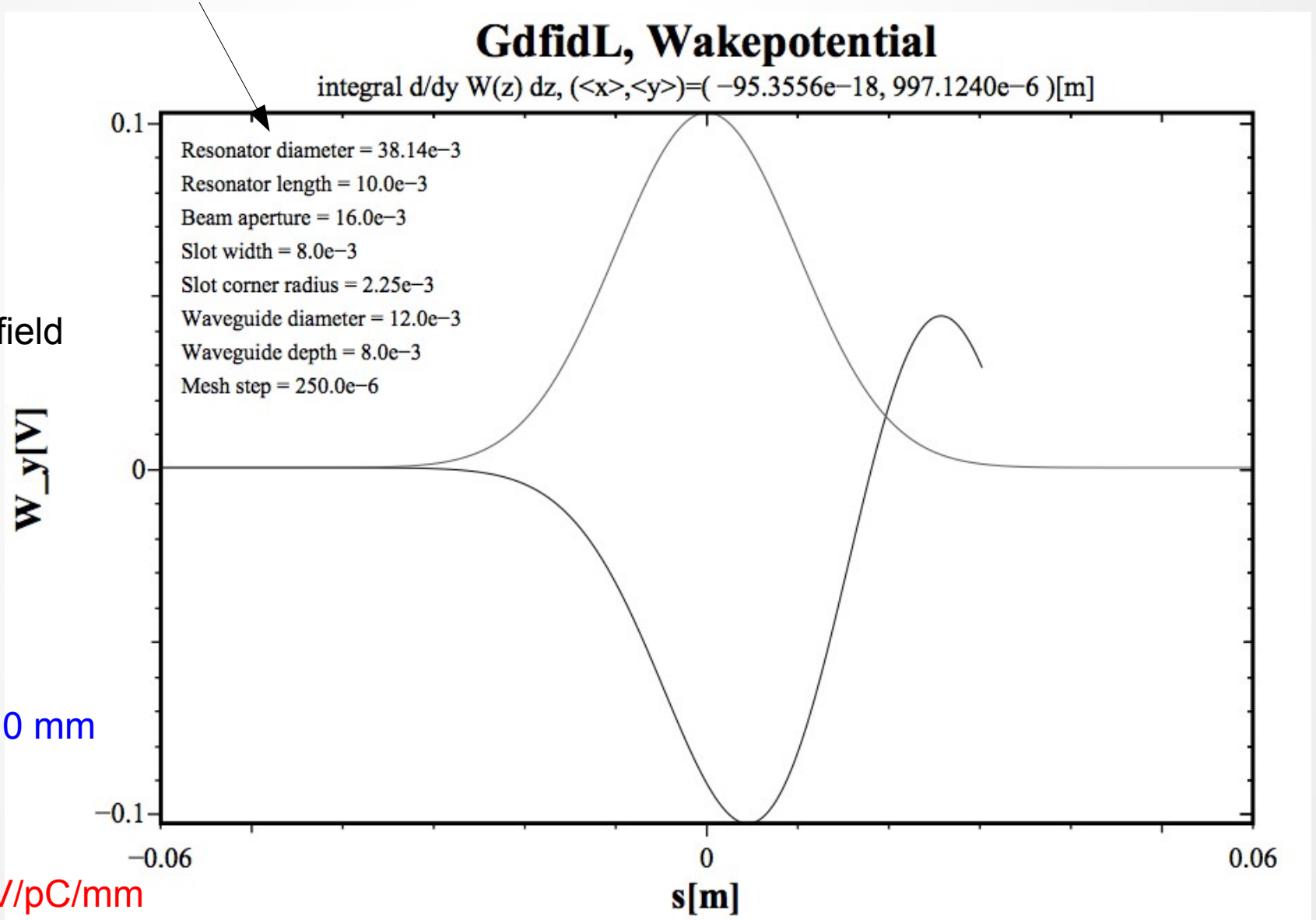


No.	Part Name	Material	Quantity / set	Quantity Total	Remarks
01	CAVITY BODY	OFHC		1	
02	CAVITY COVER-1	OFHC		1	
03	FEEDTHROUGH WELDING LIP-1	SUS316L		1	
04	SUS PIPE	SUS316L		2	
05	ICF FIXED FLANGE	SUS304L		1	
06	ICF ROTETION FLANGE	SUS304L		1	
07	SMA FEEDTHROUGH			2	
08	TUNING SCREW	SUS303		4	



Ref. Cavity BPM

Geometry parameters



Wake field (V)

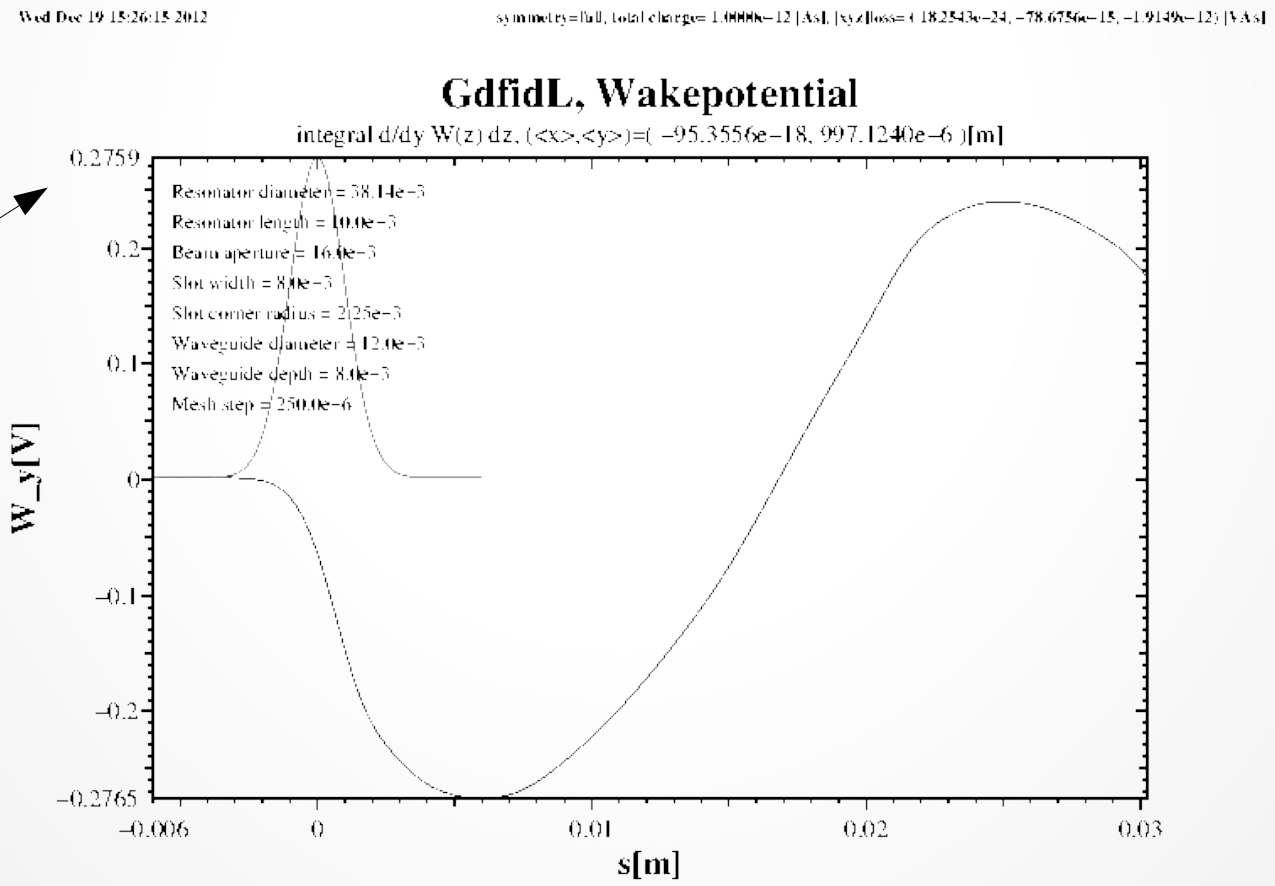
Bunch length 10 mm
Charge 1pC
1mm offset

Wakefield: 0.1V/pC/mm

Cavity BPM

- Different bunch lengths:

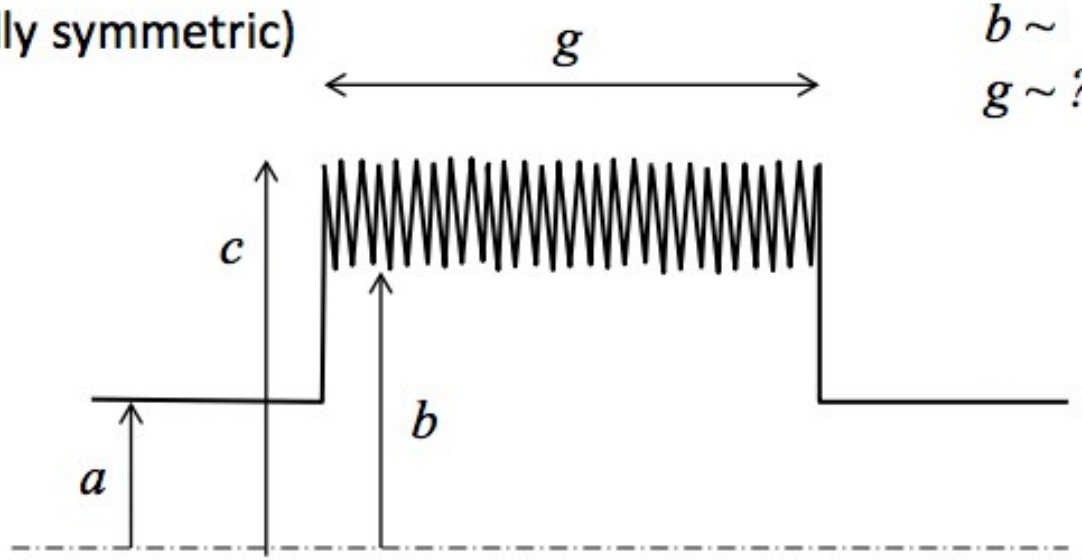
wakefield decreases with increasing bunch length



Bellows

Most common bellow but other types exist

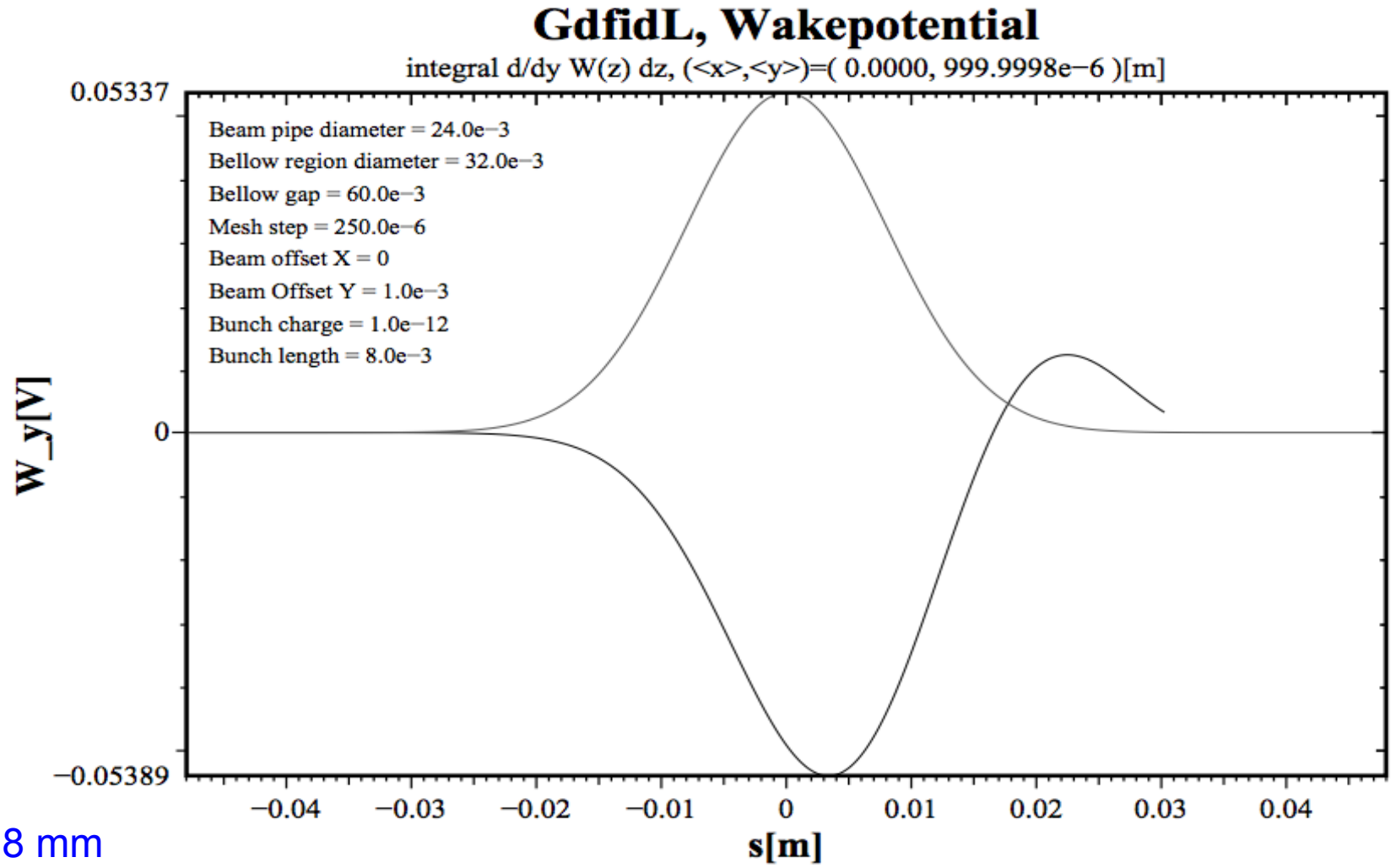
Bellows
(Cylindrically symmetric)



$a \sim 12\ mm$
$b \sim$ 12.5 mm
$g \sim ???\ \ 30 \sim 60\ mm$

Simulated as smooth surface as spikes much smaller than bunch length

Bellows (radius 12mm)

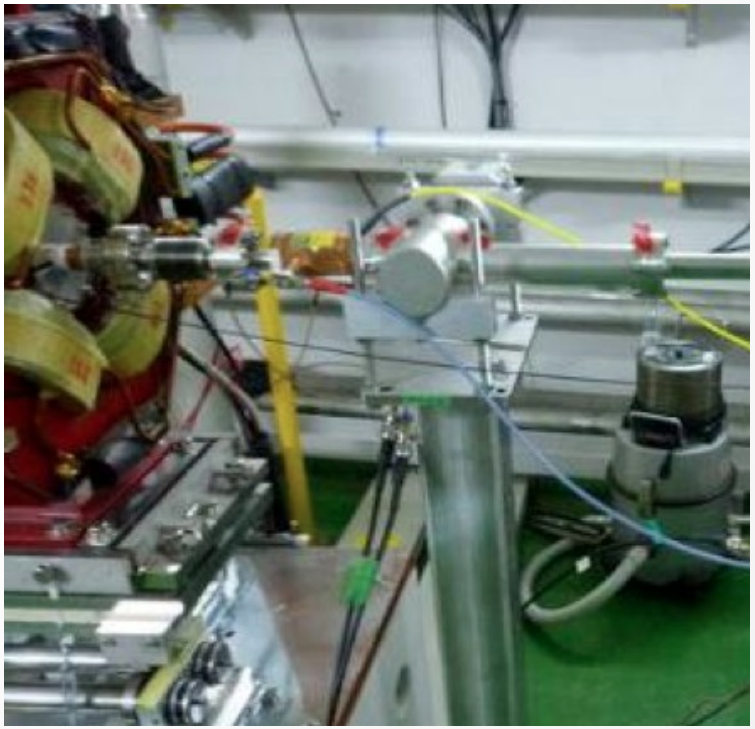


Bunch length 8 mm
Charge 1pC
1mm offset
Simulated here with different aperture (needs to be rechecked)
Wakefield ATF2 bellows: ~0.007 V/pC/mm

About 5% contribution wrt CBPM

Other beampipe transitions

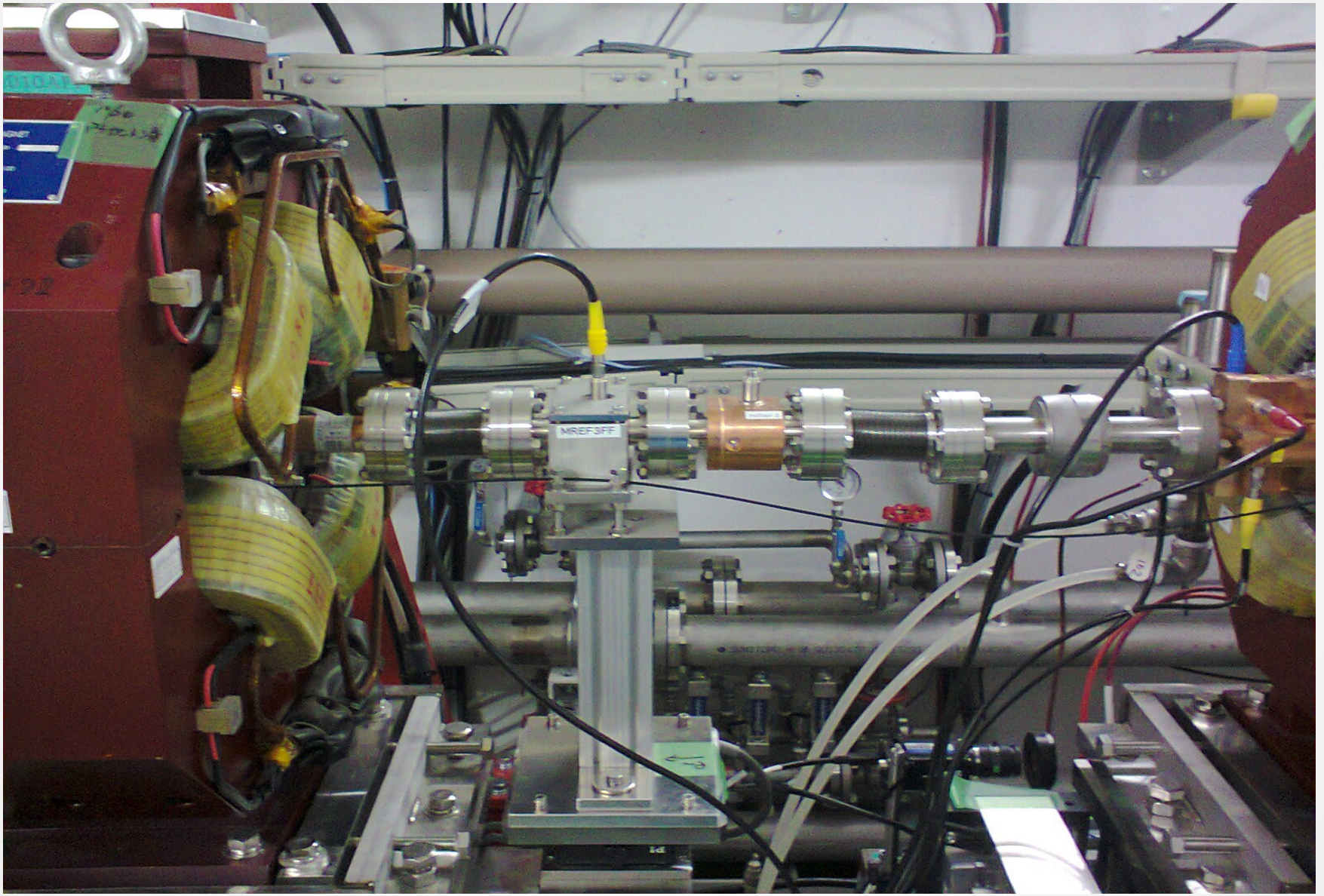
- Vacuum ports and gate valves
- Still to be done, work intensive (in progress)
- Would also be good to cross-check with other code (in progress)



Wakefield compensation

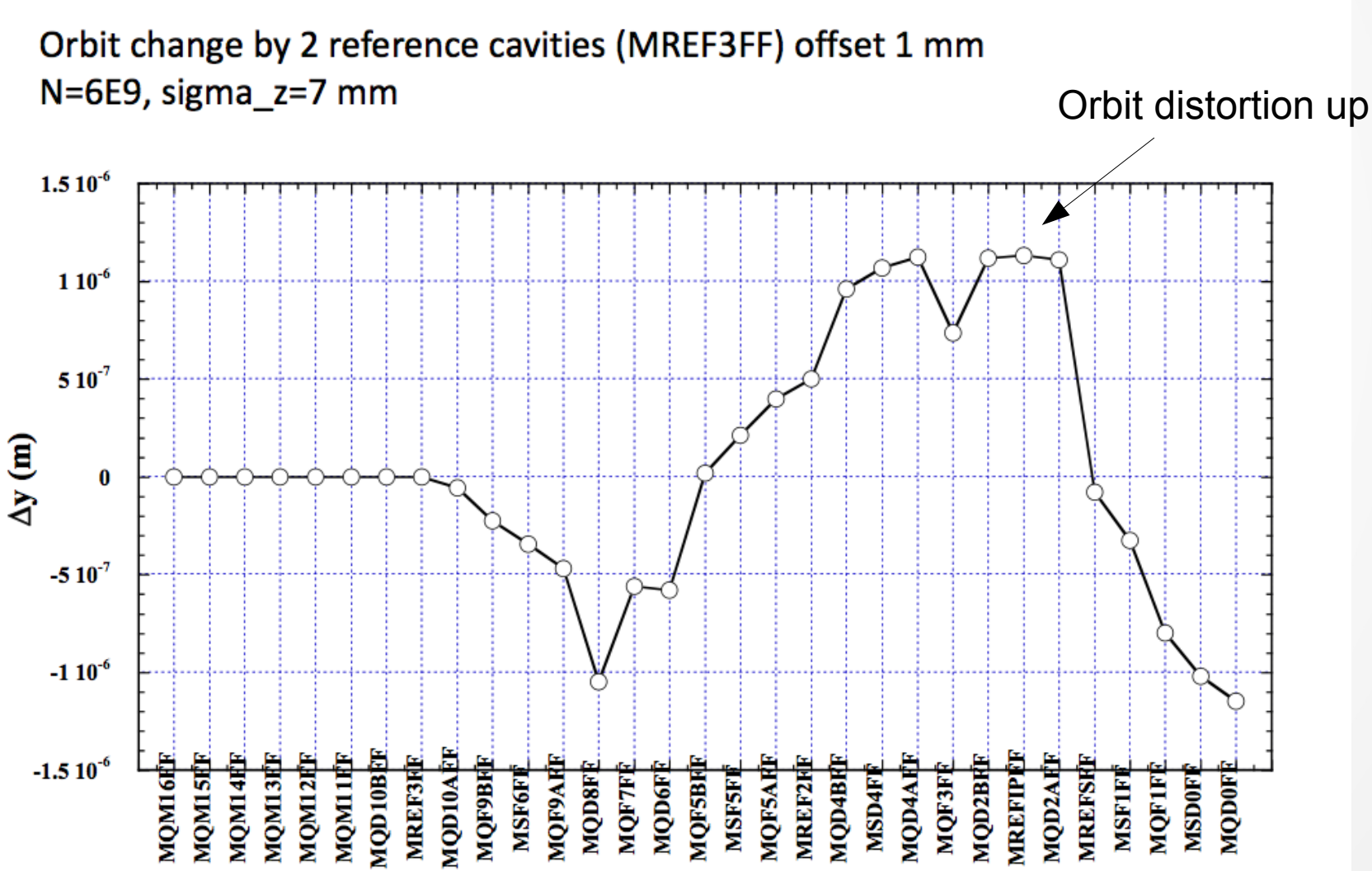
- Reference cavity on mover at high beta location (“MREF3FF”)
- Originally one, but then a second reference cavity added to double effect
- Total wakefield contribution (for typical bunch length 10mm):
  - 2 * ref. Cavity + 3*bellows (~count half, moved half way)
  - 2*0.1 + 3*0.003 = 0.21 V/pC/mm
- Goals:
  - Study CBPM wakefield
  - Compensate wakefields from other locations
    - Only those locations at about same phase advance
    - However simulation by Kubo-San (see previous presentation) showed that most wakefields can in principle be compensated

MREF3FF setup



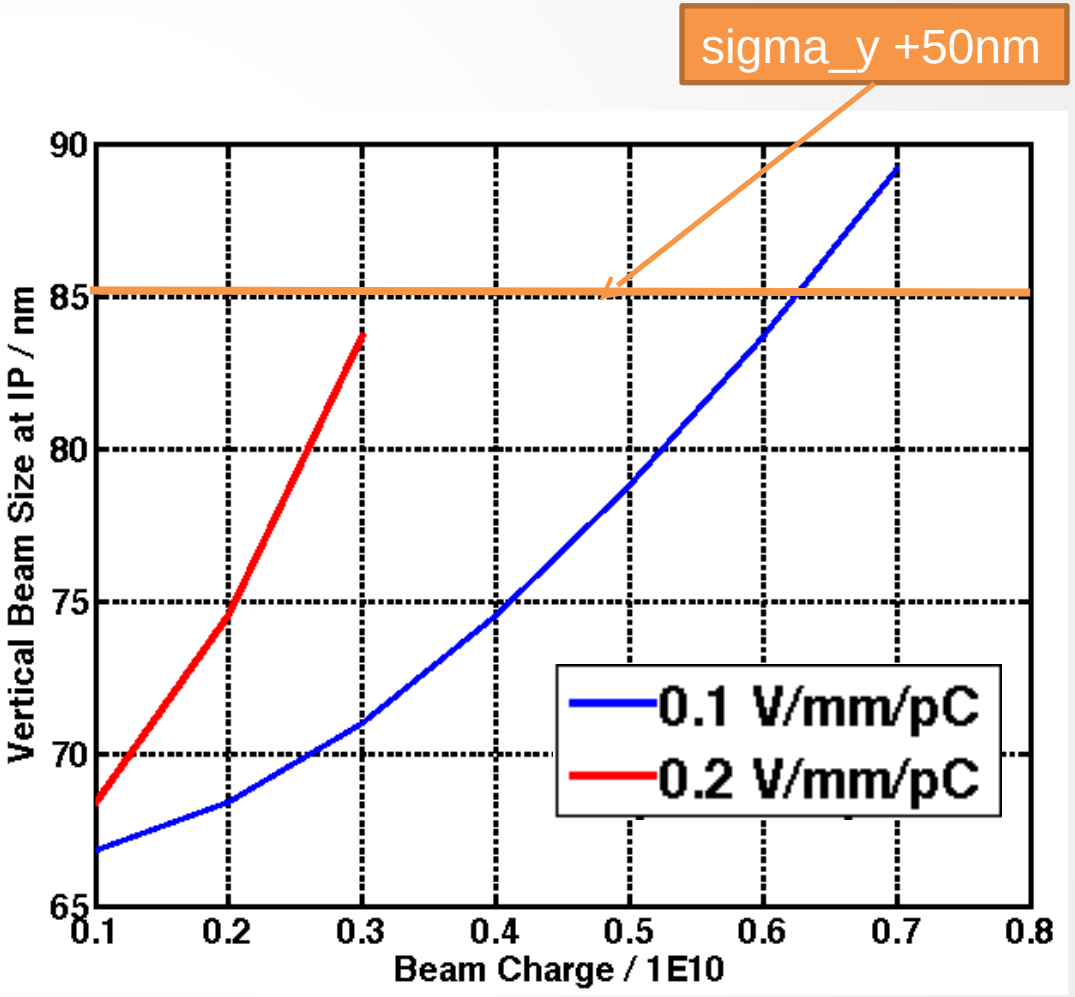
Orbit study

- Expected orbit change (Kubo-san):



Beam size at IP

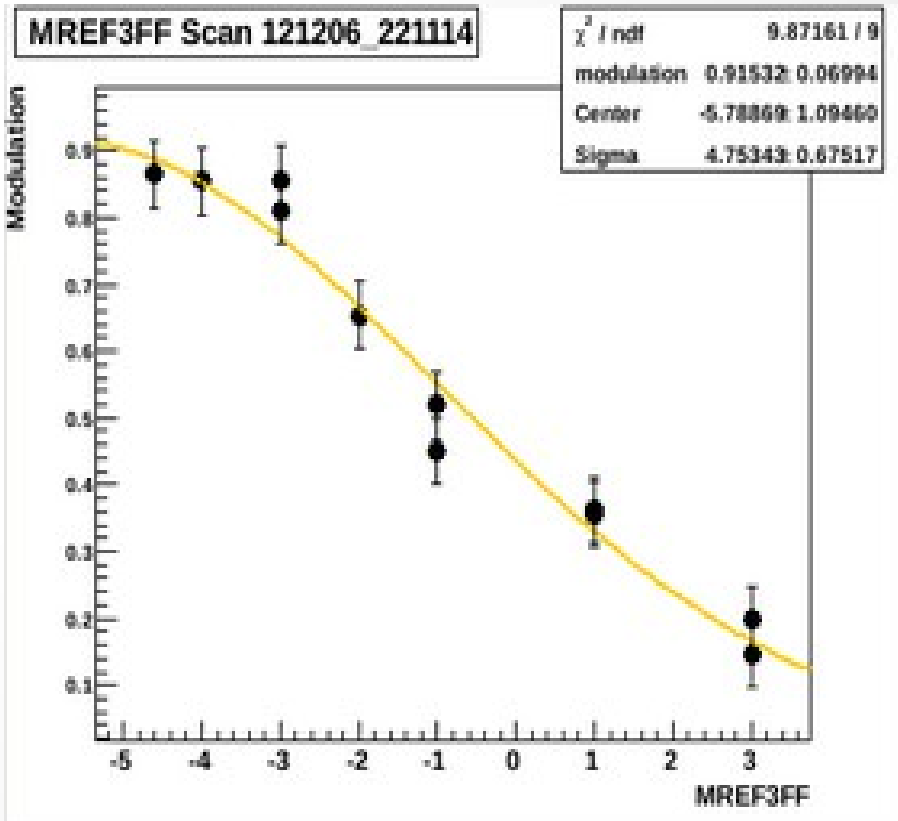
- Expected beam size growth with intensity (G. White)
- Using orbit data
- Observation from December run:
  - Are we closer to have 0.2 V/pC/mm per BPM?



Data

- Reference cavity mover part of regular tuning procedure in December run
- Large improvements seen from time to time
- Several times BPM orbit data recorded during these scans

Swing shift Thu 6-12 (7deg)



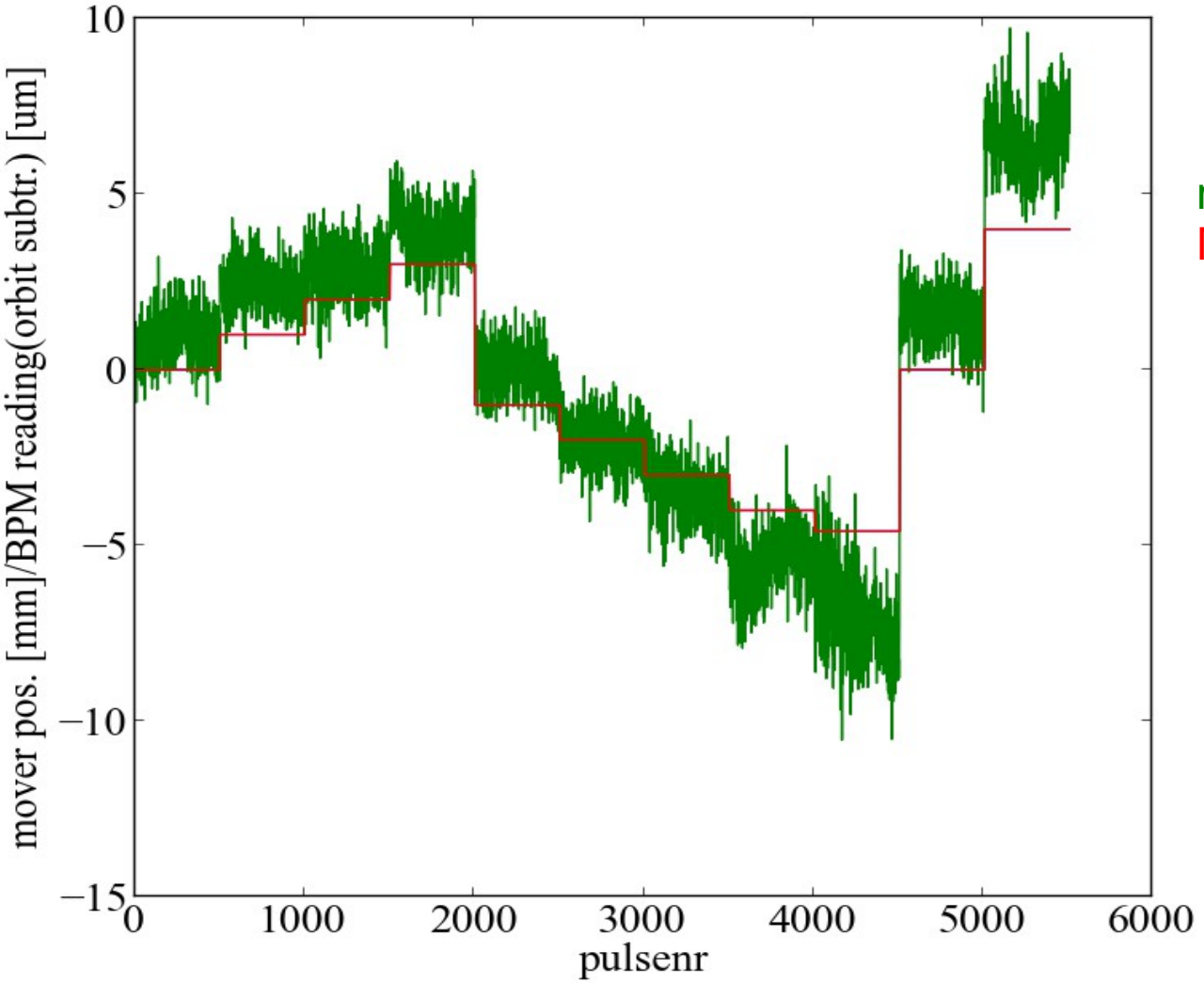
Orbit analysis

- Take all upstream BPM readings
- All BPM readings averaged subtracted
- Find contribution between those BPM readings and downstream BPM readings
- Subtract orbit per pulse (by matrix inversion)
- Remaining correlation with MREF3FF movement will give possible wakefield kick

Orbit analysis 2

- Divide BPM data wrt to reference cavity mover:
- Downstream orbit matrix A (n_1 BPMs x m pulses)
- Upstream orbit matrix B (n_2 BPMs x m pulses)
- Calculate correlation X (n_1 x n_2):
  - $AX=B \rightarrow X = A^{-1}B$ (inversion with SVD method)
- Residuals R (n_2 x m) (since over-constrained system):
  - $R = AX - B$

Example
QD2AFF vs MREF3FF position



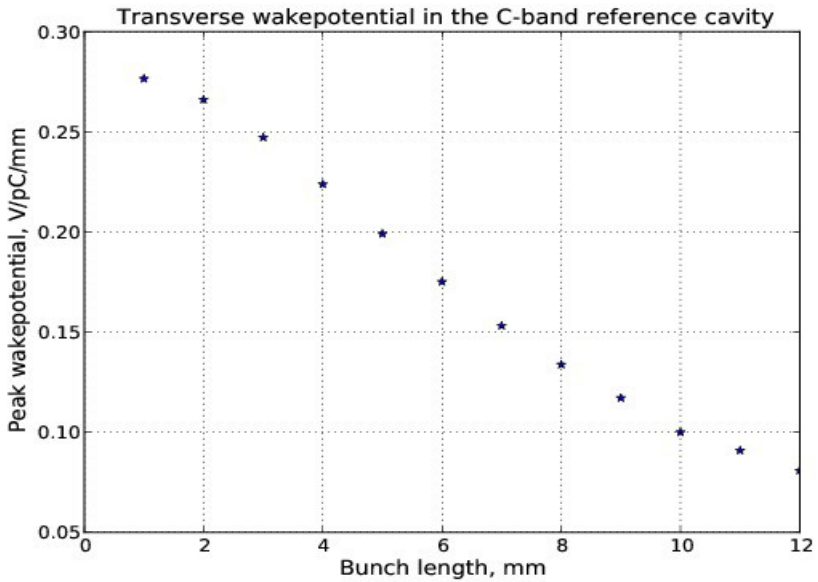
residual BPM reading QD2AFF [um]
MREF3FF position [mm]

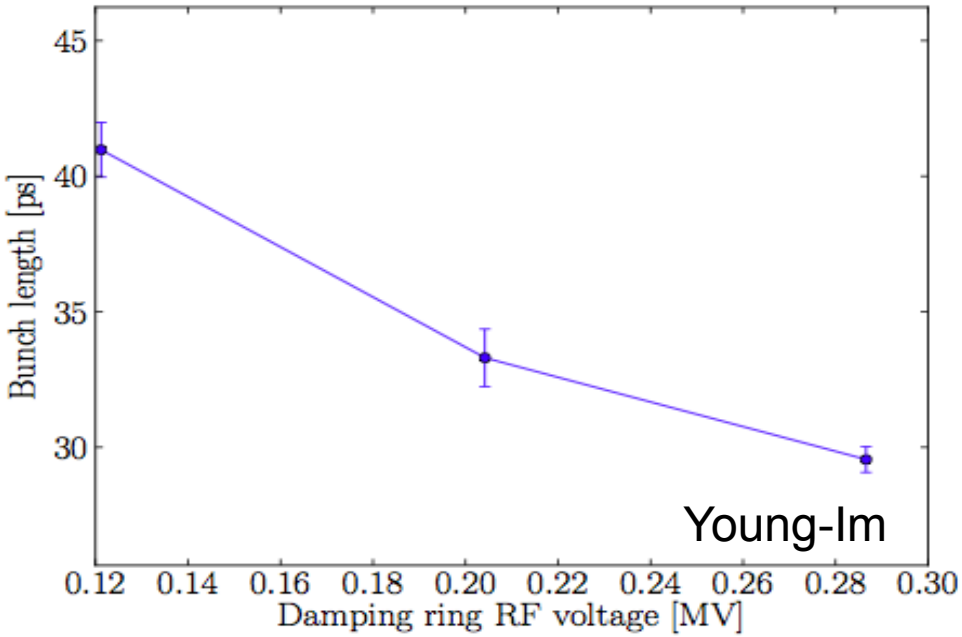
Clear correlation seen for all downstream BPMs with expected orbit pattern

But effect somewhat larger than expected.

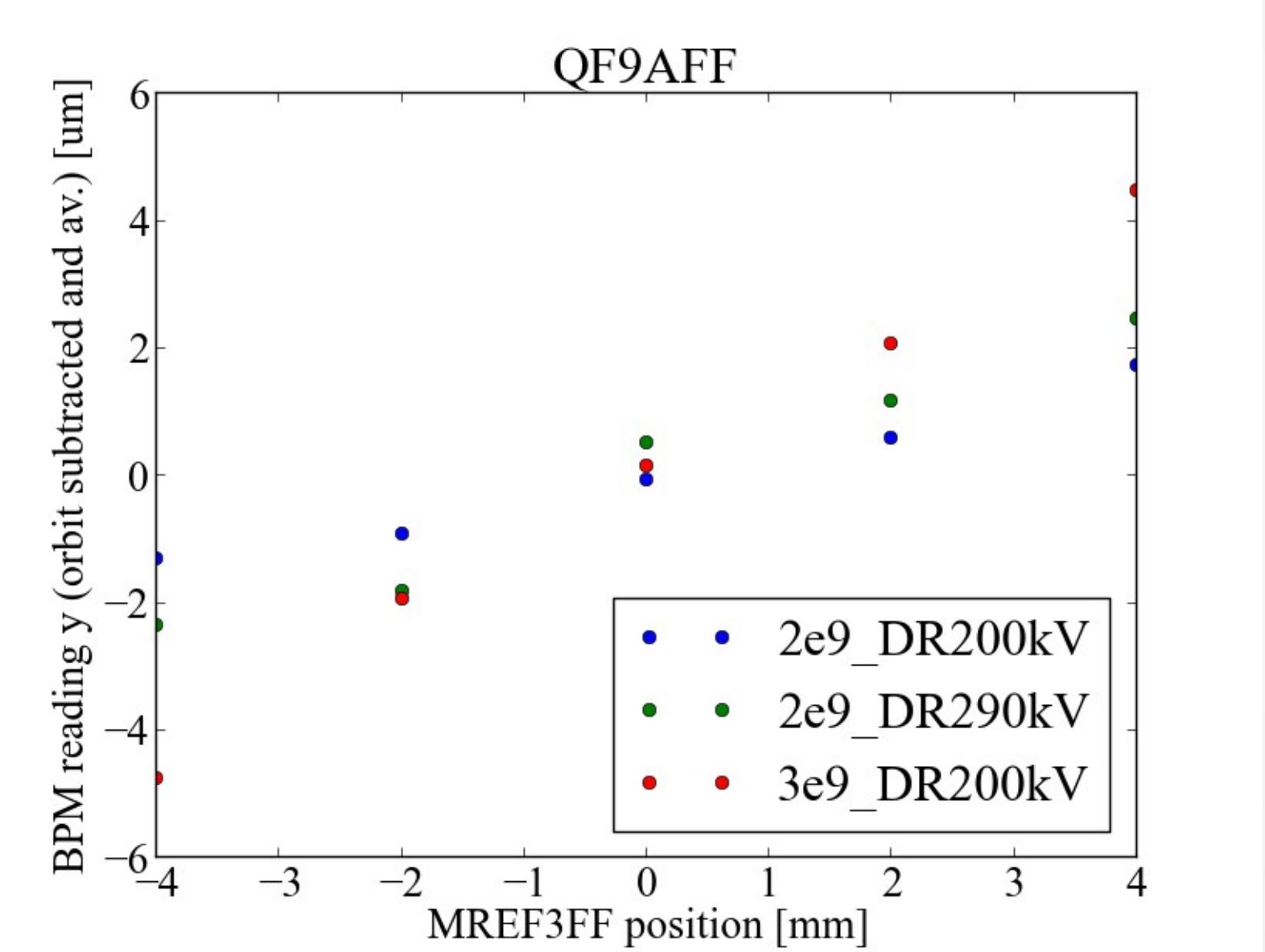
Intensity Scan

- Friday 21-12 day shift
- MREF3FF scan in y for different intensity and bunch length
  - Intensity: 2e9, DR voltage: 0.20 MV (bunch length: 33ps=11mm)
  - Intensity: 2e9, DR voltage: 0.29 MV (bunch length: 29ps=10mm)
  - Intensity: 3e9, DR voltage: 0.20 MV (bunch length: 33ps=11mm)
- Wake field kick decreases with bunch length, increased with intensity

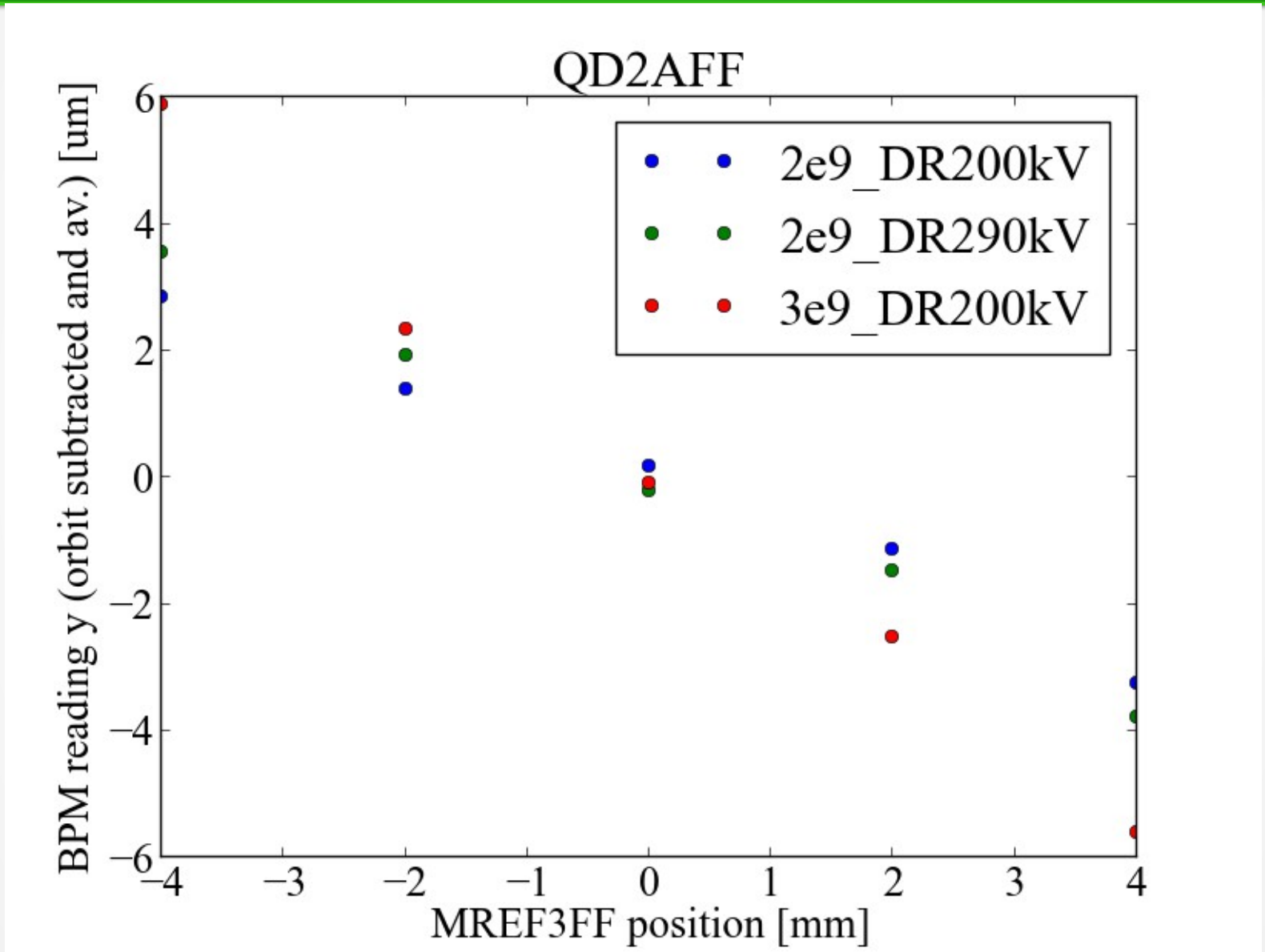




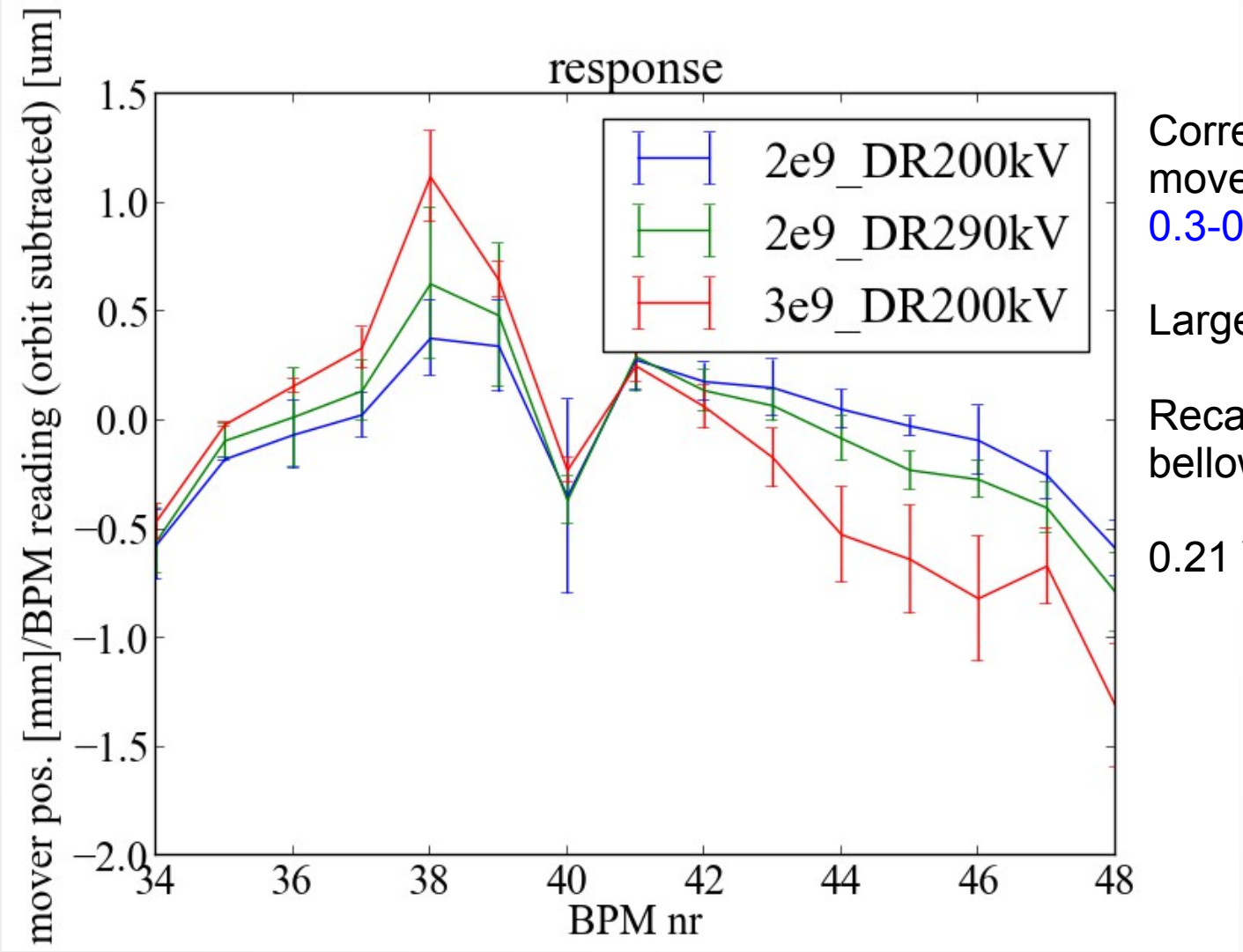
QF9AFF vs mover position



QD2AFF vs mover position



Orbit response



Corresponding wakefield of cavity mover system:
0.3-0.4 V/pC/mm

Larger value for higher charge?!

Recall simulation (including bellows):

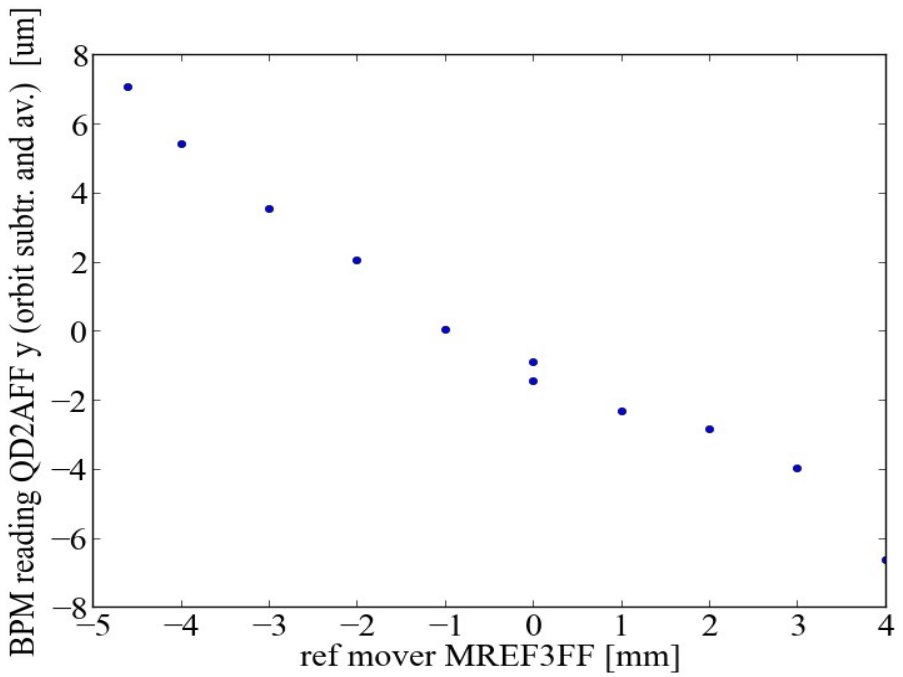
0.21 V/pC/mm

Possible explanations for difference

- Wakefield simulation of setup
- Error on bunch length measurement?
  - Non uniform distribution of charge in bunch?
- Non linear wakefield strength (next slide)
- ??
- Combination of all?

Possible explanation: 3rd order effect?

- Possibly the wakefield has a non-linear response
  - Suggested by Oide-San
- Analysis hints (but not conclusive) that it is consistently present in the data
- Could explain discrepancy between simulation and data
- Needs confirmation from simulation (unfortunately not yet finished)
  - If confirmed, where are the current simulation results with respect to the non-linear curve?
  - We could be both under- or overestimating right now
- Non linear response has been predicted and observed in collimator wakefield experiments e.g. http://accelconf.web.cern.ch/AccelConf/e02/PAPERS/WEAGB002.pdf



5 Dec 2012
Higher intensity
(about 7e9)

Conclusions

- Wakefield seems to be an important issue for ATF2 at this stage
- MREF3FF wakefield compensation worked reasonably well for ATF2 December run
- Improved understanding of wakefield problem
  - But many questions remaining
- Wakefield observed in beam orbit
  - Correct dependence of intensity and bunch length seen
- No complete agreement between simulation and data
  - Correct wakefield calculation is difficult, lots of effect
  - Several different methods suggest wakefield is higher by factor 1.5-2
- Future work and updates will be in:
  - http://atf.kek.jp/twiki/bin/view/ATF/Atf2Wakes

Future studies

- Orbit data with higher intensities
- If possible more bunch length variation
- Use CBPM as beam tilt monitor?
  - http://accelconf.web.cern.ch/accelconf/p03/PAPERS/WPPB062.PDF
- Normal CBPM on mover for comparison
  - Same position as MREF3FF now?

Mitigation possibilities (including ILC)

- Avoid beampipe steps as much as possible
- Larger aperture BPMs or remove BPMs at high beta region
- Centre BPM wrt (quadrupole) magnetic centre
- Second cavity mover at different phase advance
- Steer more through BPM-centres
- Wakefield free steering?
  - http://www.slac.stanford.edu/cgi-wrap/getdoc/slac-pub-5355.pdf

ILC only:

- Wakefield reduced cavity BPM design
- All BPM on movers
  - Might be necessary in any case to calibrate large number of BPMs
- Orbit bumps to correct wakefield upstream (needs long beamline)

Backup

3rd order fit

- For each BPM 3rd order polynomial fitted
- Coefficients plotted
- If 3rd order effect is present, a linear correlation is expected
  - Present for red
  - Indicative for blue