Wakefield Calculations for the ATF2 Beamline

A. Lyapin, John Adams Institute,
Royal Holloway, University of London

S. Boogert, J. Snuverink (JAI/RHUL, UK)
Y.-I. Kim (JAI/Oxford, UK)
K. Kubo, N. Terunuma (KEK, Japan)
G. White (SLAC, USA)

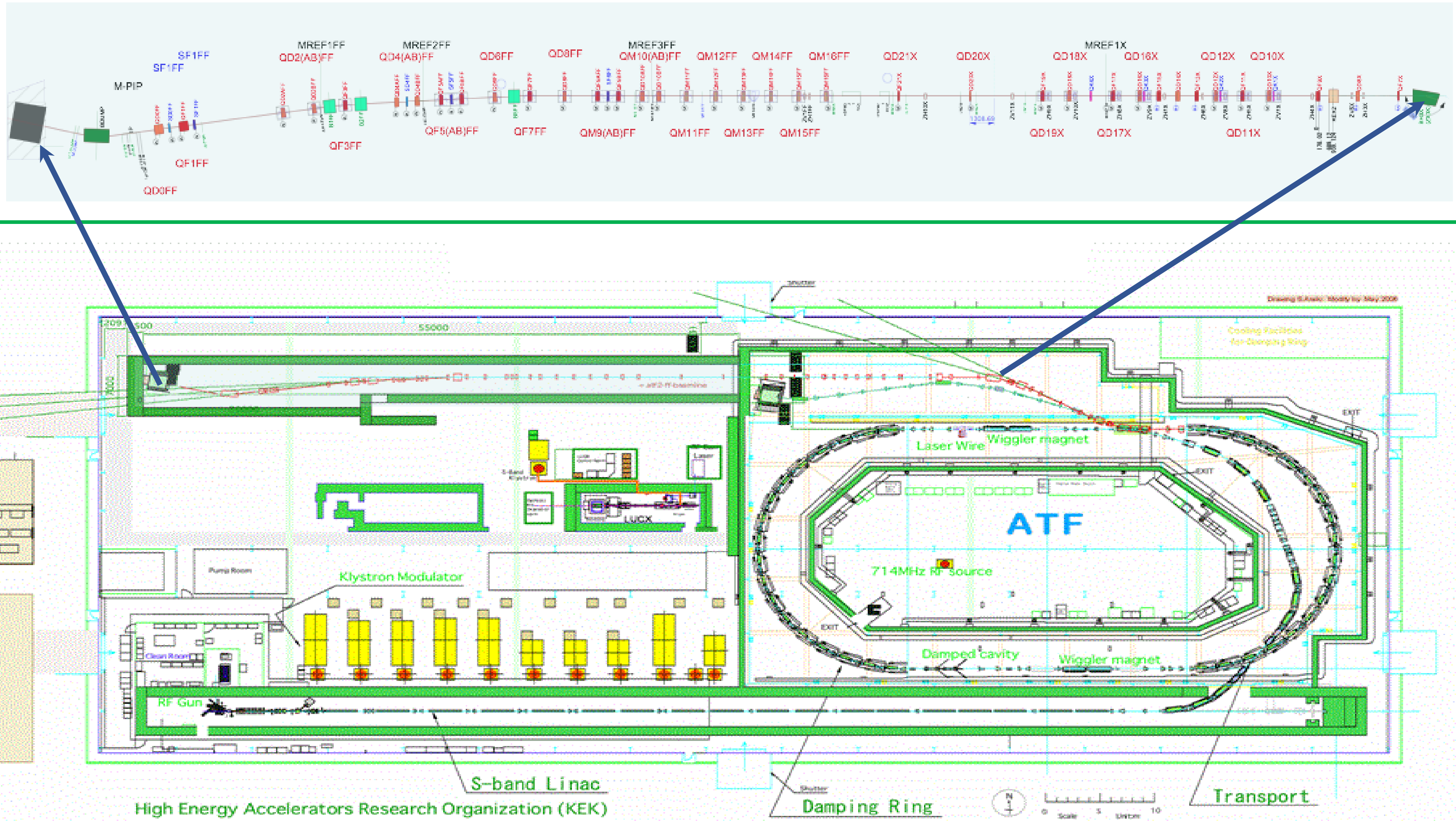
John Adams Institute for Accelerator Science

～宇宙と物質の起源と構造を探る～ KEK 高エネルギー加速器研究機構

SLAC NATIONAL ACCELERATOR LABORATORY

Accelerator test facility/ATF2

- Low-emittance facility, test system for 35 nm beam size next LC beam delivery system
- Very dense with instrumentation: wire scanners, OTRs, laserwires, laser interference BSM
- Relies mainly on cavity BPMs, currently ~ 40 in total



Problem

- Difficulties achieving < 100 nm vertical beam size at the IP
- Low charge operation gives better results
- Suspected wakefield effects
- Extraction beamline includes ~ 40 cavity BPMs + several reference cavities
- Started investigations into the wakes produced by these cavities as transverse wake kicks may affect the transverse beam size, which spread onto other beam elements as well as additional beam measurements…

ATF2 CBPM system

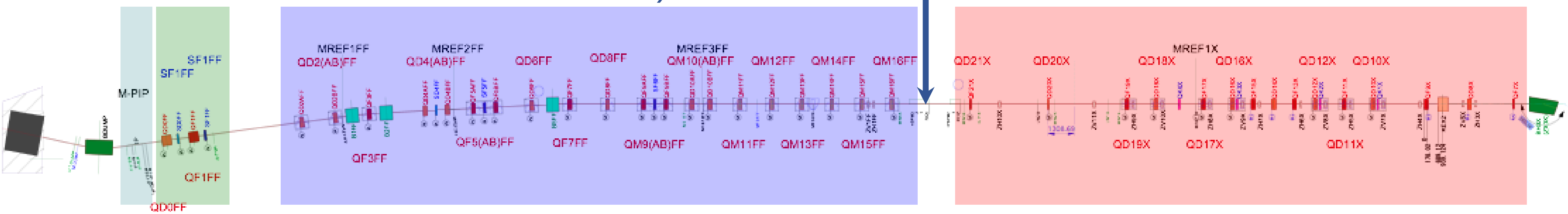
IP region

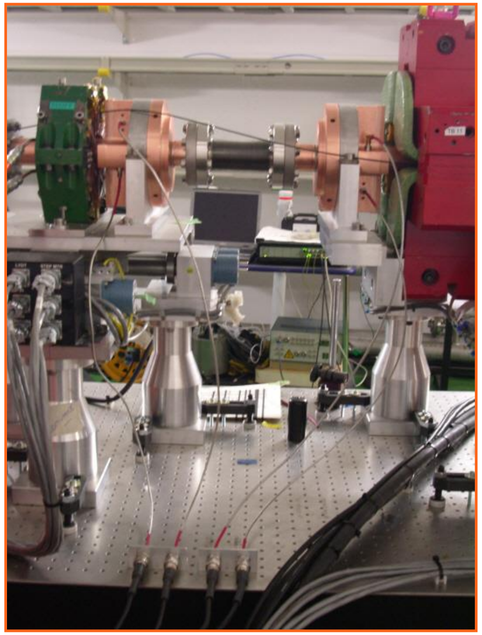
S-band BPMs (movers)

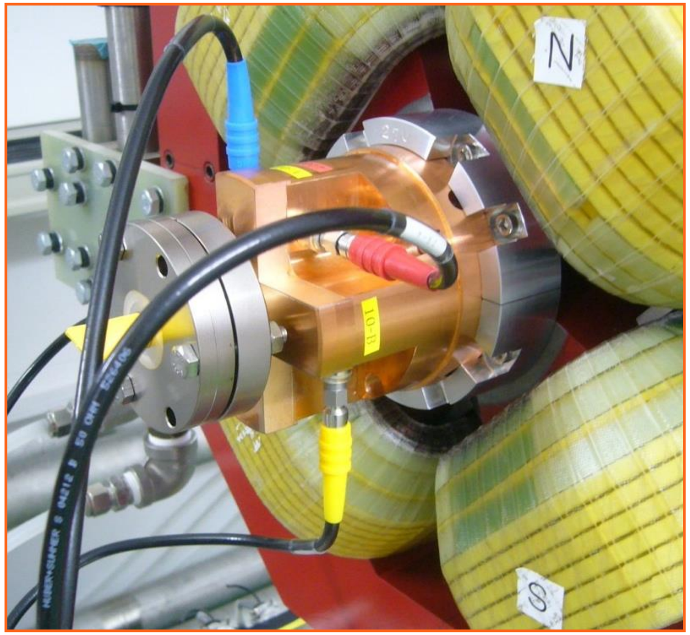
C-band BPMs (mounted on movers)

BPM test area

Strip line/Cavity BPMs (mounted rigidly)



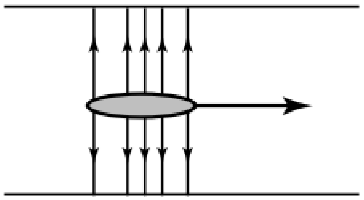




Wakefields

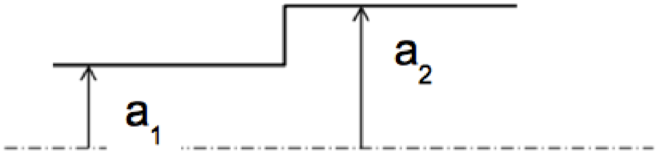
- Created due to interaction of the electromagnetic fields travelling with the beam with the walls of the beam chamber
- 2 components are considered
- Resistive wake due to the finite conductance of the walls (more important when short bunches are considered in narrow chambers)

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



- Geometric wake due to changes in the chamber size/geometry

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



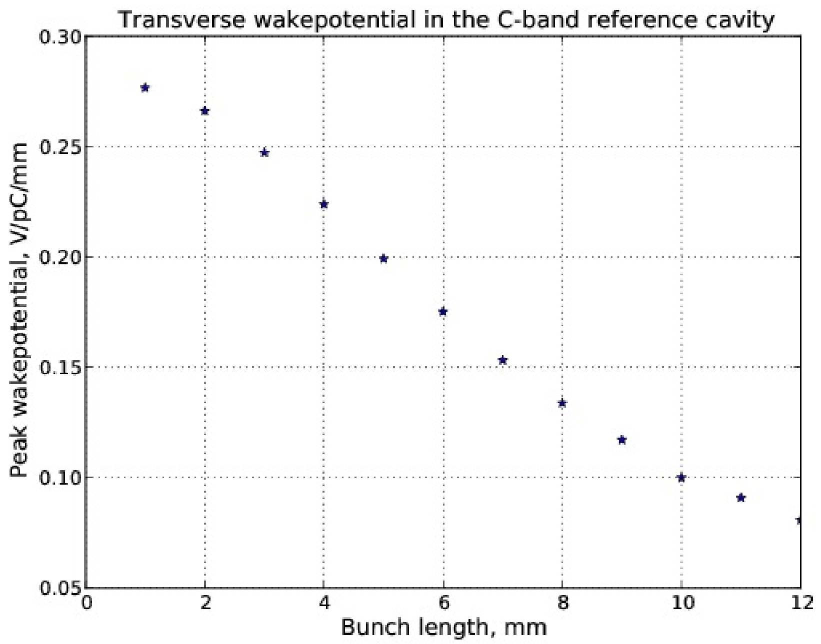
- Here considering geometric wakes only
- More detail at http://atf.kek.jp/twiki/bin/view/ATF/Atf2Wakes

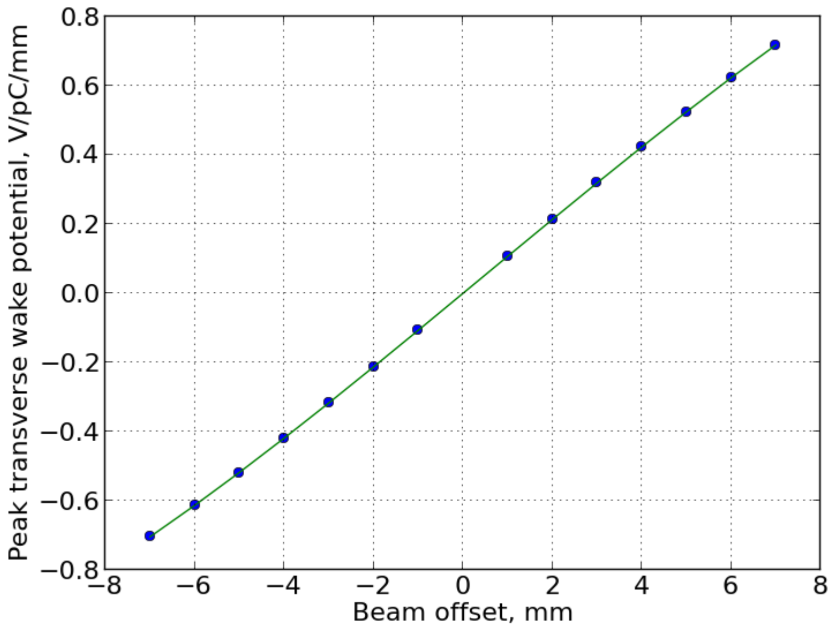
K. Bane, A. Seryi
http://accelconf.web.cern.ch/AccelConf/p07/PAPERS/THPMS039.PDF

Wakefields (2)

- Geometrical wakes computed numerically
- Using a finite difference code GdfidL (running on a cluster at RHUL), rectangular mesh
- The beam is represented as a line charge traveling along the *z*-axis with a possibility to specify offsets in *x* and *y*, Gaussian distribution in *z*
- www.gdfidl.de

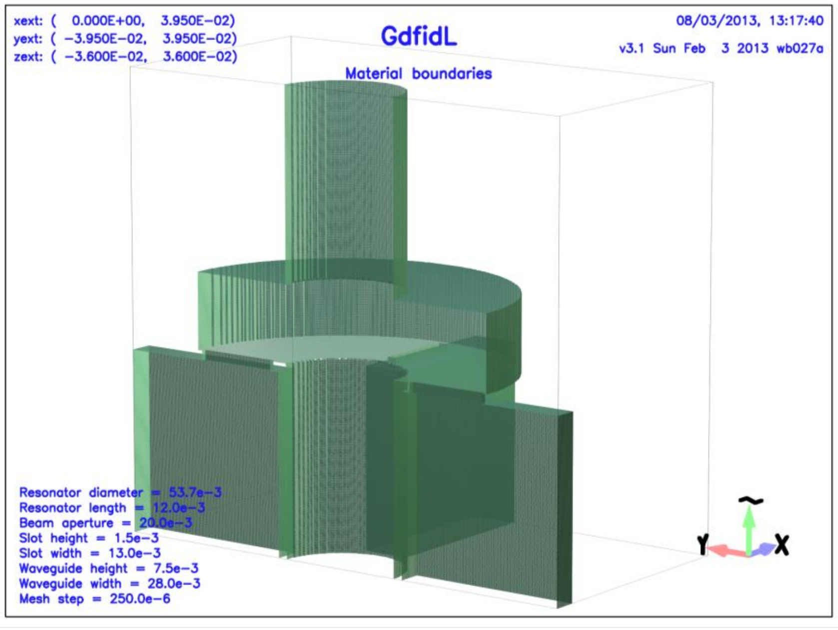
Wakefields (3)

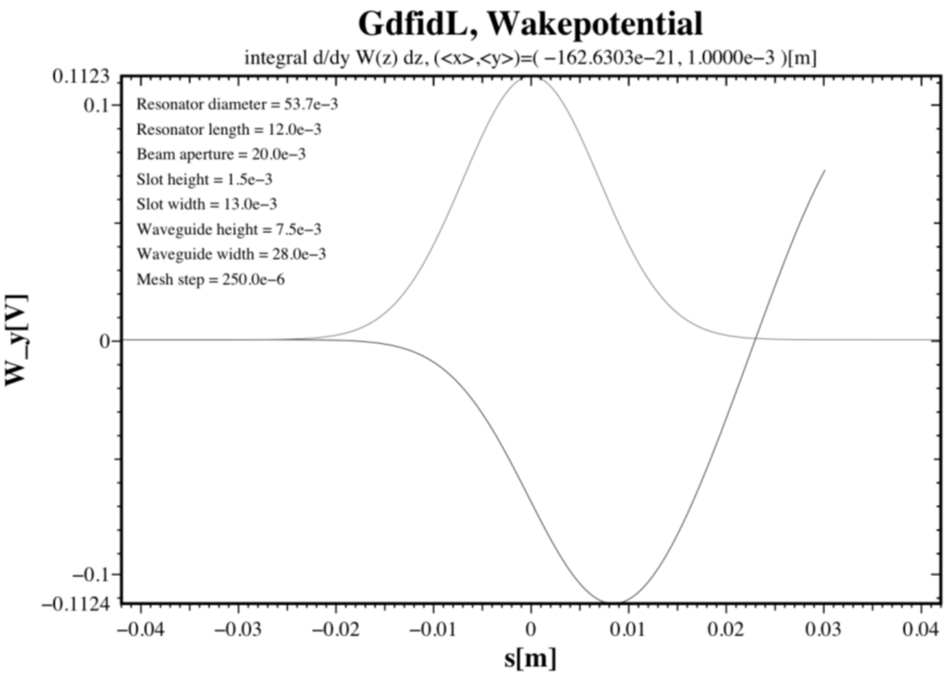




- Interested in transverse wakes □ transverse kicks □ beam size effects
- Typically strong dependence on the bunch length for ATF2 parameters (7-10 mm) and geometries
- Transverse wake is quite linear vs. offset

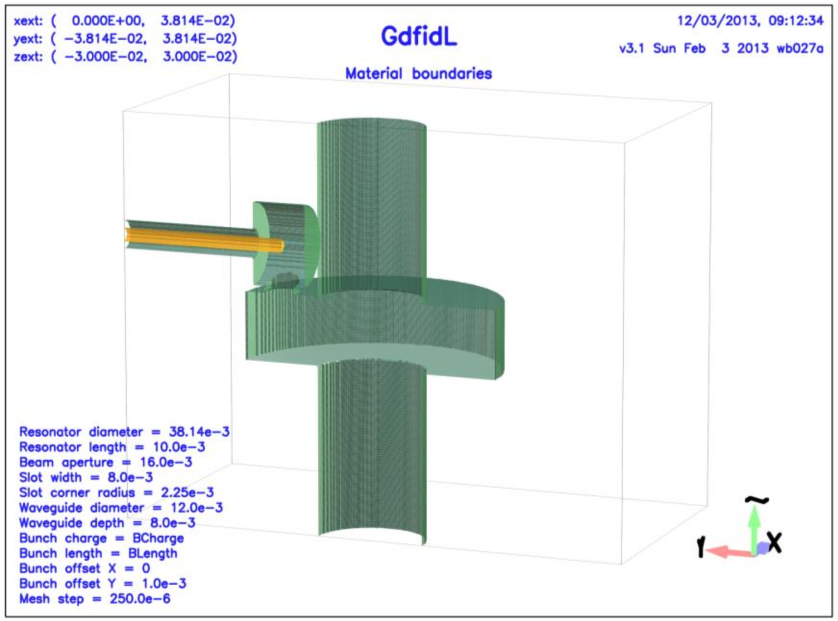
C-band CBPM

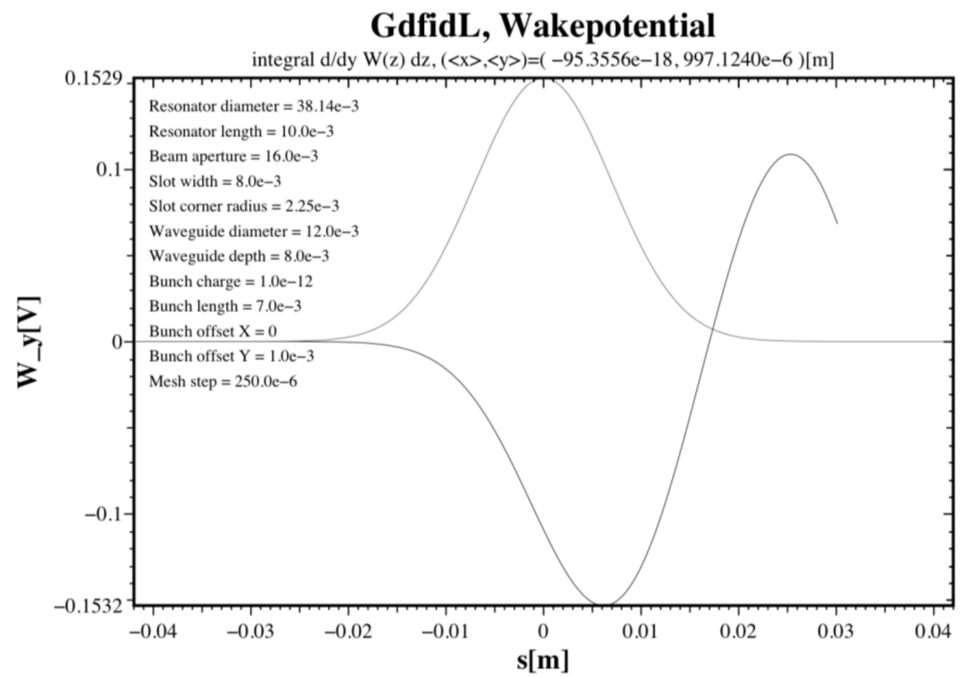




- Main suspect
  - High-impedance device (to provide a high position sensitivity)
  - ~40 cavities in the beamline, the effect may be multiplied (although this depends on the orbit and alignment)

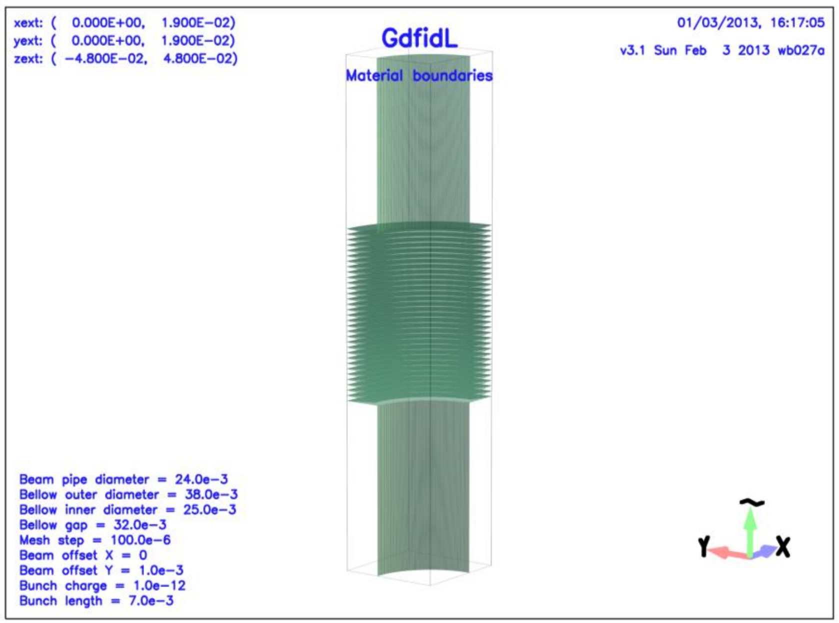
C-band reference

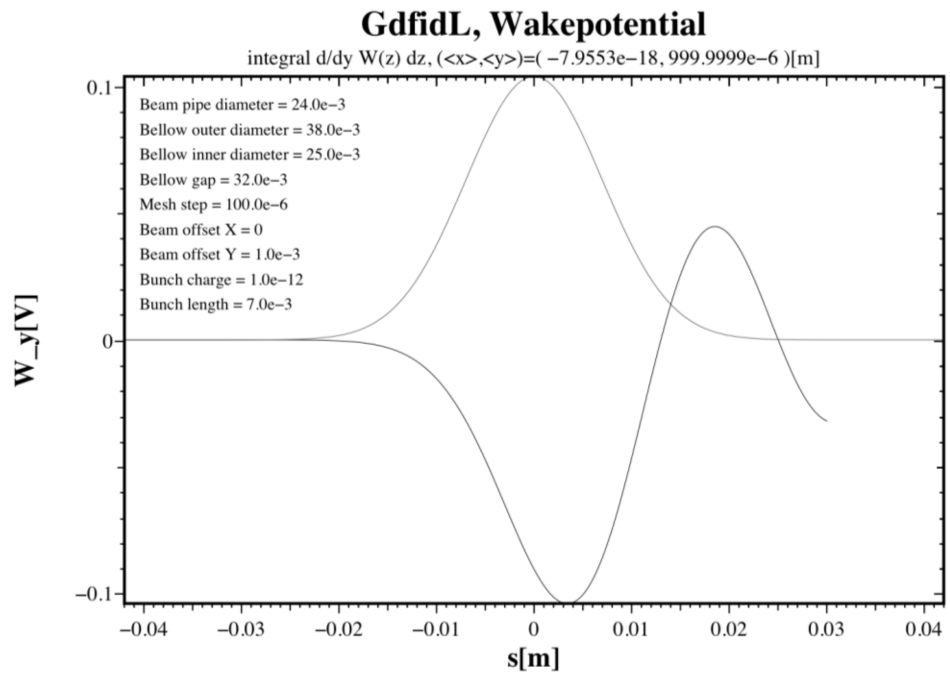




- Higher impedance than position cavity (smaller aperture and diameter)
- Used to be 4 in the beamline, now 1 providing the reference signal and 2 in the test location (on which more later)

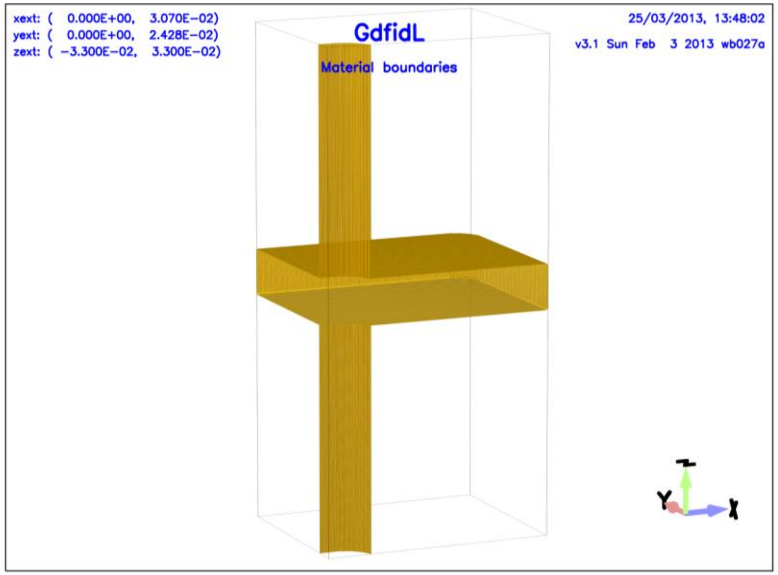
Bellows

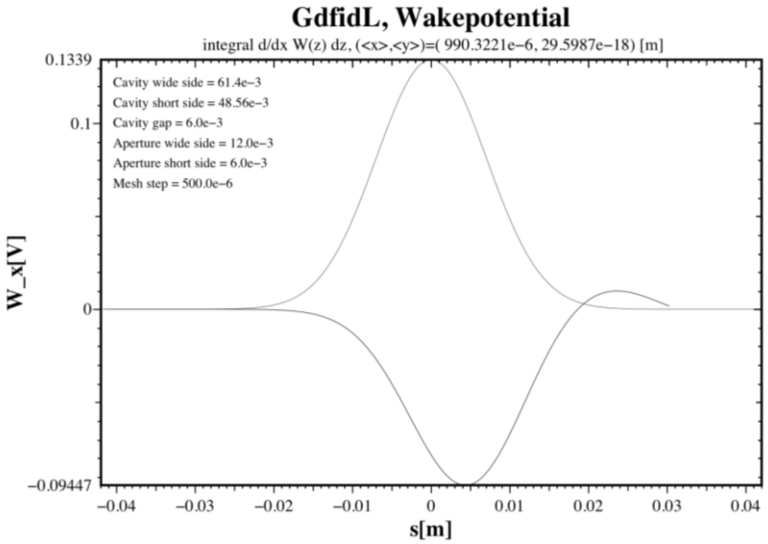


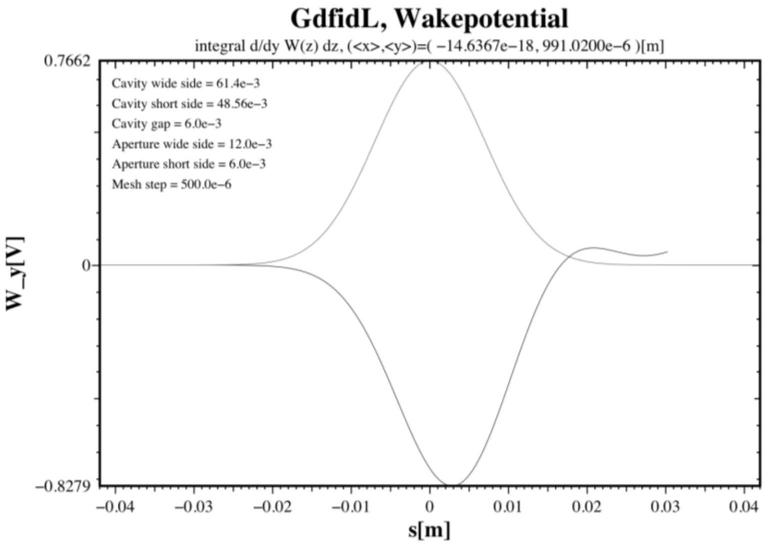


- A very difficult geometry to simulate – flexible, can be in many states throughout the machine, can be extended/contracted most can also be offset in one end with respect to the other
- ATF2 beamline probably includes ~100 bellows
- A best guess simulation shows a wake similar to cavity BPMs both in shape and magnitude

IPBPM



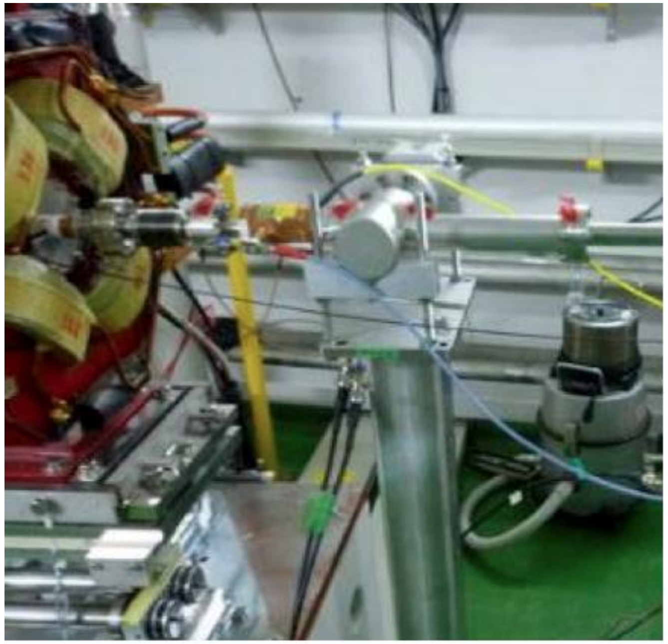




- Unique geometry – very small aperture in *y*
- Strong kick in vertical
- Location close to the IP
- Currently 2 devices before the IP
- Requirements on the alignment need to be understood (may affect the BPM's operation as well as the wakefields, which may contribute to the IPBSM background)

Other elements

- Beam aperture steps – many DIA 24-20 steps (around BPMs)
- S-band BPMs
- Gate valves
- Vacuum pump ports
- Experiment locations (chambers)
- Mostly smaller quantities/kicks
- Work is still in progress
- http://atf.kek.jp/twiki/bin/view/ATF/Atf2Wakes

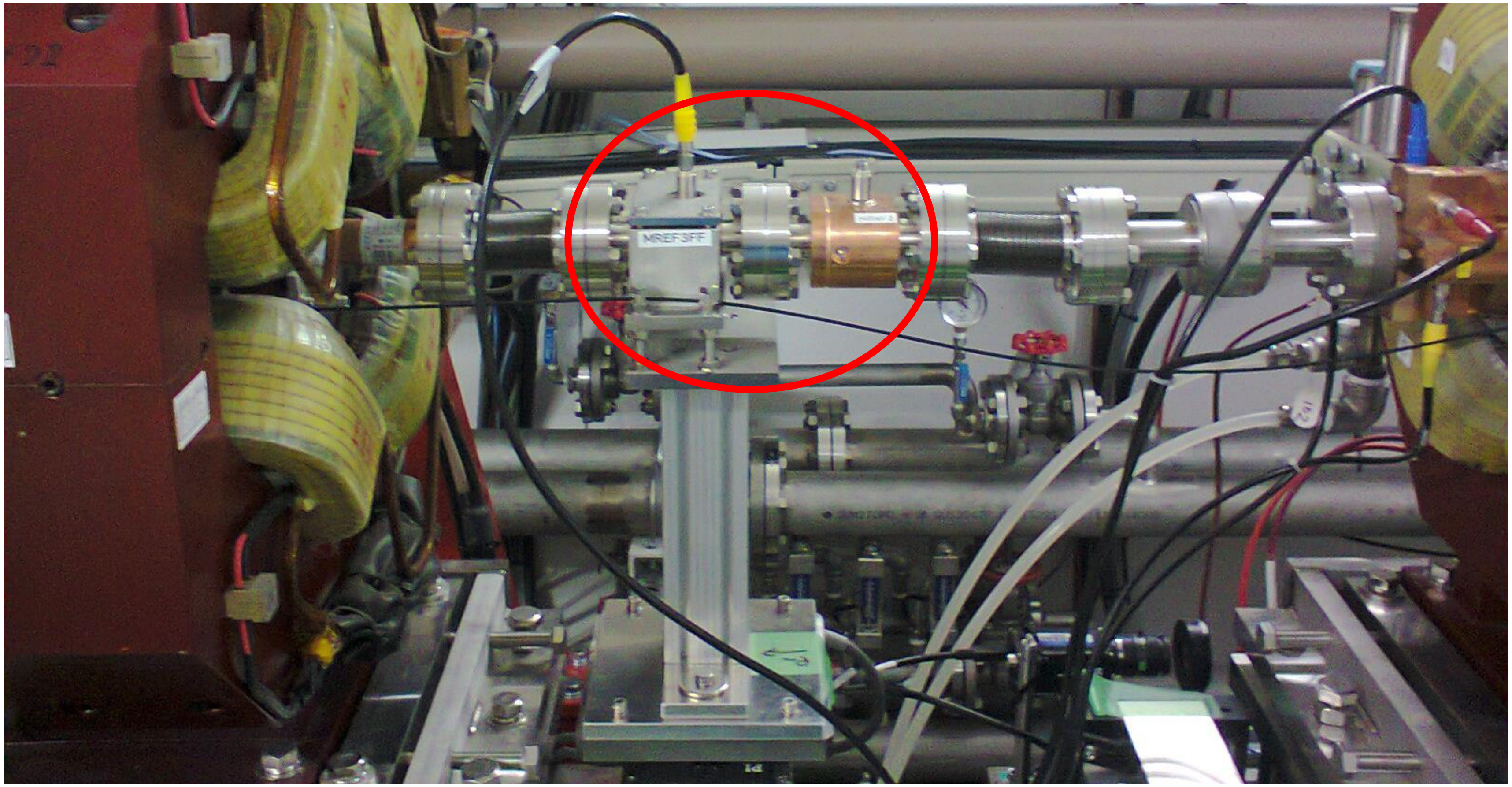


Naïve totals

Element	Peak wake, V/pC/mm	Quantity	Contribution, V/pC/mm
Bellows	0.1	100	10
C-band position	0.11	40	4.4
IPBPM (vert.)	0.7	2	1.4
24-20 mm transitions	0.008	100	0.8
C-band reference	0.15	4	0.6
Vacuum port (X)	0.07	6	0.42

- Offsets and proximity to the IP are important (not taken into account here)
- The major contribution may come from the bellows!
- Unfortunately, they are the most difficult element to simulate, and their state throughout the line is unknown, can only guess the average
- Position cavities are likely to be much better aligned compared to other elements
- Some components are omitted, also there may be hidden contributions
- Measurements are required to confirm

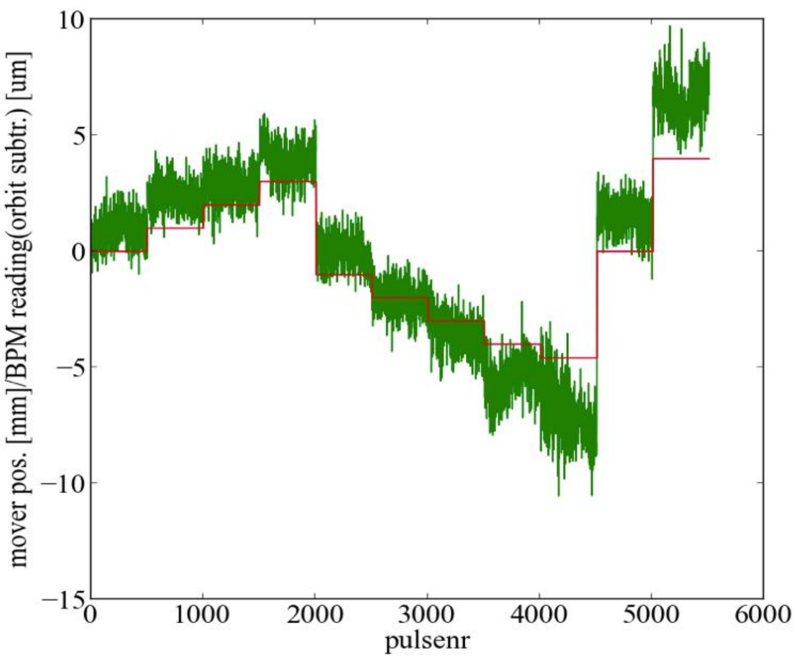
Wakefield kick measurements



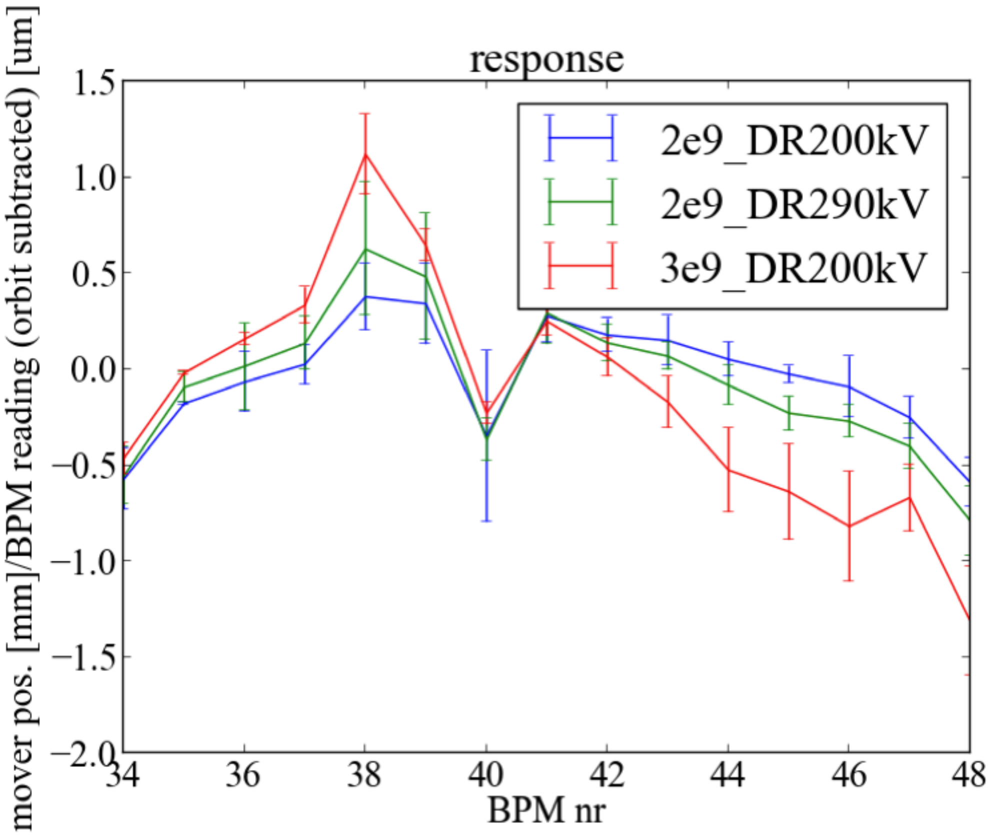
- Reference cavity on a mover in a high beta location MREF3FF
- A second cavity added later to multiply the effect
- Used for studying the wakefields, can also be used for corrections

Wakefield kick measurements (2)

- Wakefield kicks can be seen in downstream BPMs (showing QD2AFF)
- Used upstream BPMs for jitter subtraction (subtract prediction made using upstream BPMs from actual data)
- There is a clear effect, however, the kick is larger than expected from just the BPMs, need to take into account all the contributions in the test setup: bellows, steps, etc; then the balance is roughly right



Wakefield measurements (3)



- Simplified tracking simulations (2-bunch model, may result in an overestimate)
- Corresponding kick 0.3-0.4 V/mm/pC
- Bellows are not at the same offset, so the estimate is between 0.32 and 0.52 V/mm/pC
- Figures shown are for different charge (via laser power) and bunch length (via damping ring RF voltage) settings

Summary

- Wakefields may be affecting the transverse beam position and size
- There are several main beamline components which are likely to provide the major contributions, so far these seem to be: bellows, C-band BPMs, aperture transitions and potentially IPBPMs
- Many elements haven't been fully studied yet, and probably some haven't yet been identified (aperture steps around IPBPMs, for example)
- Wakefield kicks have been measured and a reasonable agreement with the models is in place, the same setup can be used for compensating the wakefield effects and minimising the beam size
- Further studies (planned for April) will include:
  - Bunch length measurements (with a streak camera for cross-calibration)
  - Bunch length and charge scans, more set points to see the dependencies (note that the bunch length and charge seem to be coupled)
  - Possibly removal of the cavities and their replacement with blank pieces (to establish the baseline) and/or additional bellows (to measure their wakes)