CLIC Workshop

8 March 2017

CERN

ATF2 Status

Presented by Douglas BETT on behalf of the ATF2 Collaboration

ATF/ATF2: Accelerator Test Facility

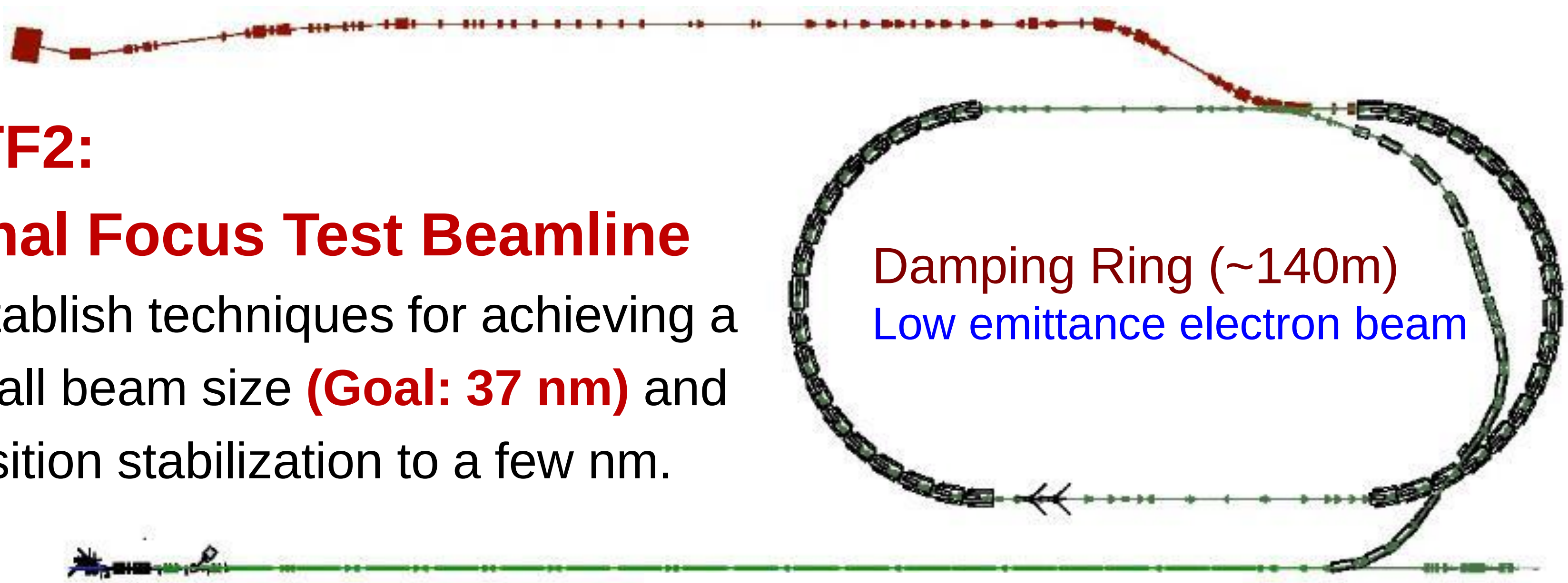
20th ATF2 Project Meeting

14-15 March 2017
CERN

https://indico.cern.ch/event/614198/registrations/34265/

Develop nanometer beam technologies for future LC

- **Key for luminosity maintenance**



ATF2:
Final Focus Test Beamline

Establish techniques for achieving a small beam size **(Goal: 37 nm)** and position stabilization to a few nm.

Based on a slide created by Nobuhiro TERUNUMA, KEK

Shuji Orito Prize

Congratulations to Nobuhiro Terunuma!

The **Shuji Orito Prize** is given by the Heisei Foundation for Basic Science, which was established by Professor Masatoshi Koshiba using the money awarded by his Nobel Prize. The award recognizes achievements in the fields of accelerator and/or particle physics based on high energy colliders.

For advanced results in the development of nanometer beam technology

Awarded for his work on the development of the nanometer beam required to achieve the ILC luminosity, and for his long contribution to the ATF/ATF2 program as a leader and a spokesperson of the collaboration.

ATF2 Status

- Beam tuning
- IPBPMs
- Intra-train beam position feedback
- Ground motion feed-forward
- Ultra-low β* optics (with octupoles)
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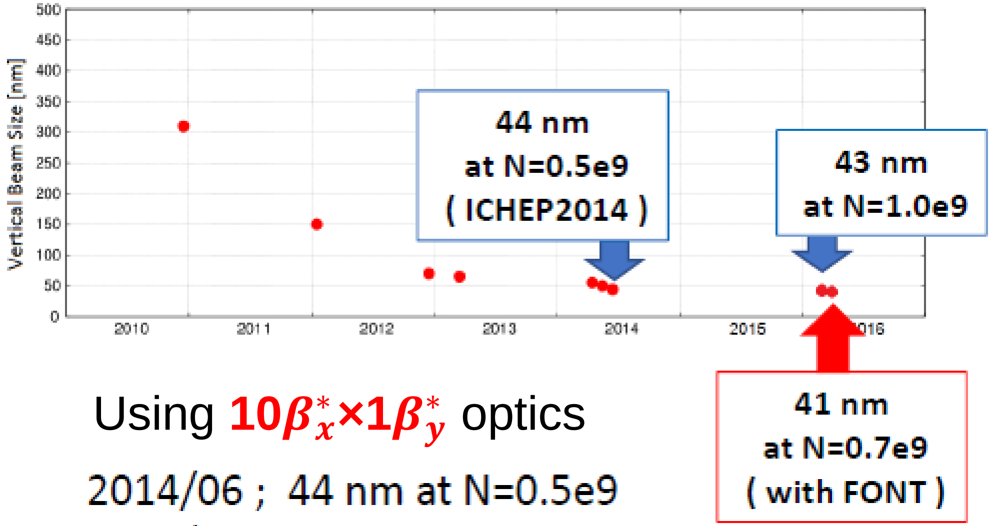
IP beam size trend of ATF2 beam size

Minimum beam size of 41 nm was measured on 2016/03/10
by using FONT orbit jitter correction at N=0.7e9.

ATF design beam size is 37 nm.

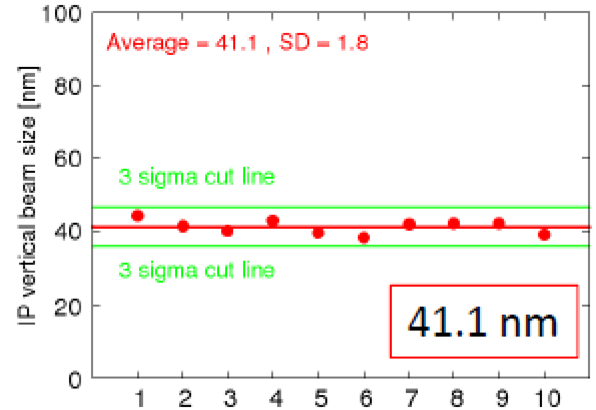


Using $10\beta_x^* \times 1\beta_y^*$ optics

2014/06 ; 44 nm at N=0.5e9
2016/02; 43 nm at N=1.0e9
2016/03; 41 nm at N=0.7e9 with FONT

Minimum beam size

presented by Y. Kano and T. Okugi
at ECFA LC workshop 2016.

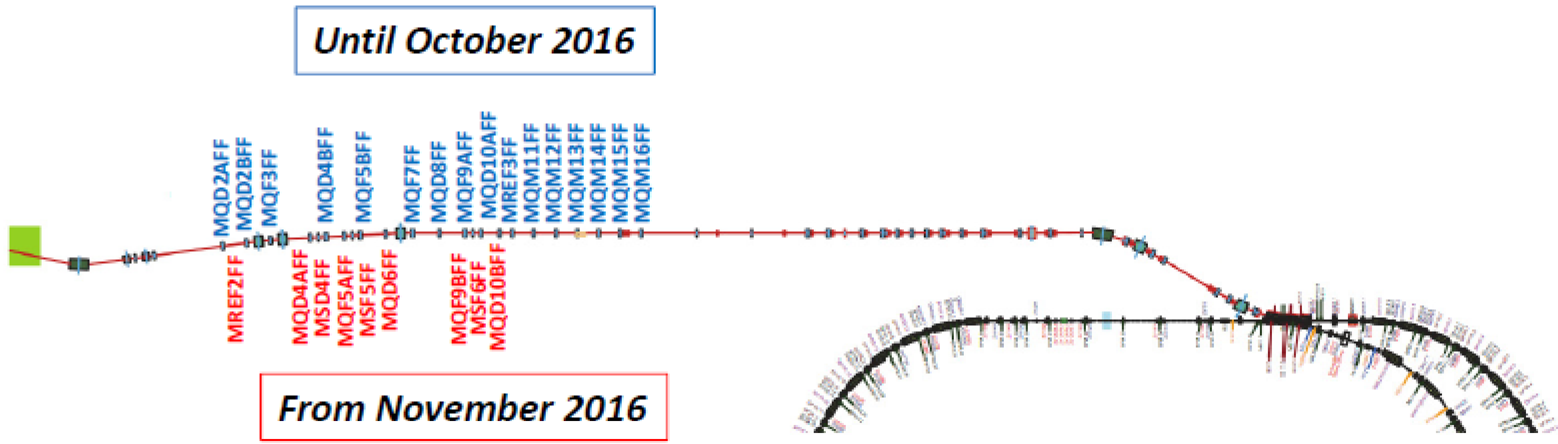


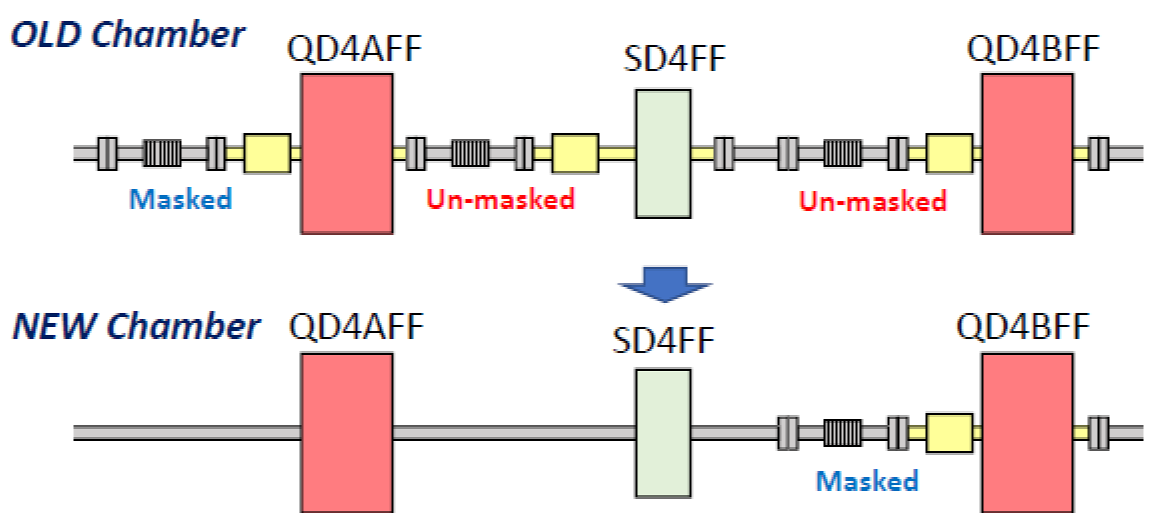
The beam jitter was subtracted with FONT(*) feedback

IP beam sizes were evaluated by assuming the perfect laser fringe contrast.

Slide courtesy of Toshiyuki OKUGI, KEK

Reduction of wake field source from ATF2 beam line for intensity dependence study





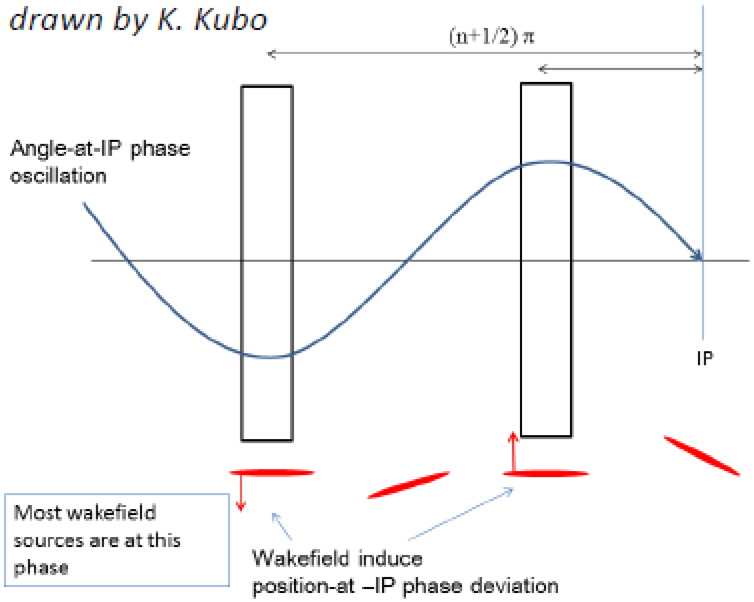
Slide courtesy of Toshiyuki OKUGI, KEK

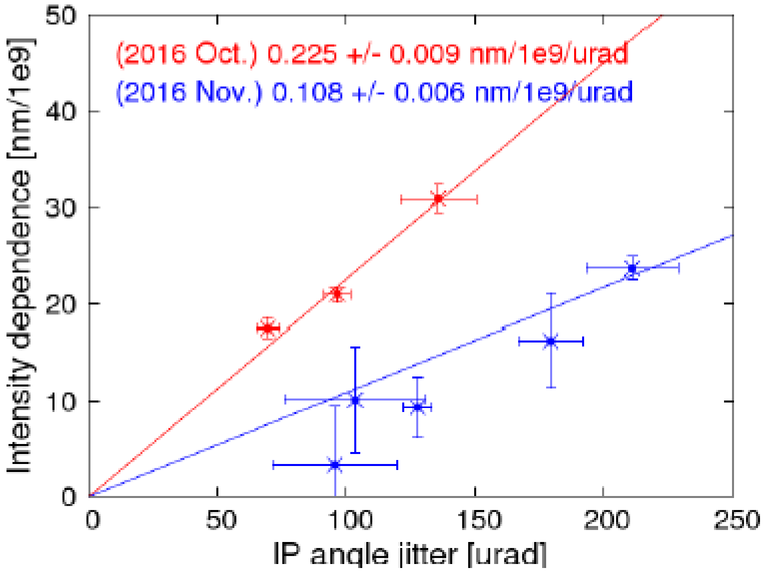
Dynamic effect of wakefield intensity dependence

- *Presented at ATF operation meeting by T. Okugi at 2016/12/02.*

by IP angle jitter via wakefield

drawn by K. Kubo





Summary Table

	Simulation	Measurement	Ratio
2016 Oct.	0.131	0.225	1.72
2016 Nov.	0.059	0.108	1.83

- *Intensity dependence was reduced after wake source reduction.*
- *The discrepancy of simulation and measurement was less than factor 2.*

Slide courtesy of Toshiyuki OKUGI, KEK

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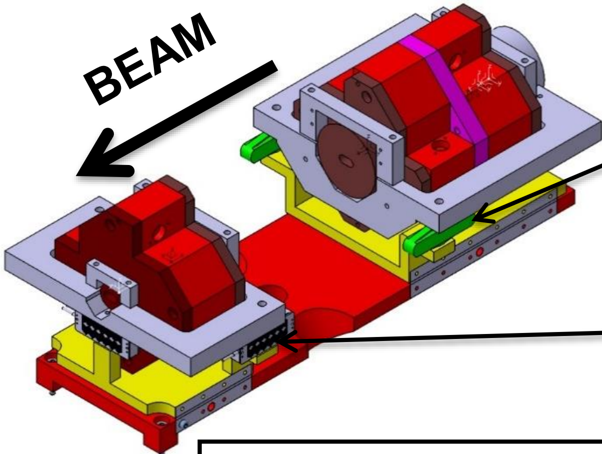
IPBPM mover system

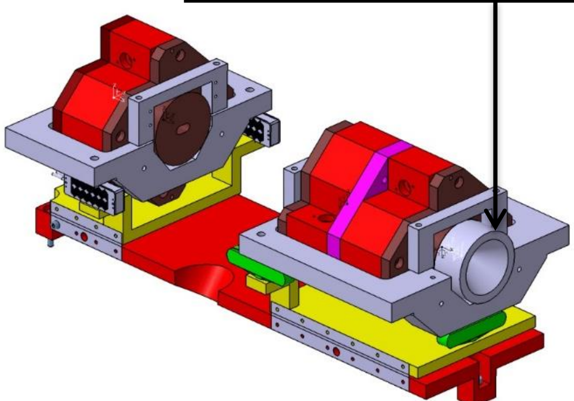
(to bring vertical and horizontal translation + a bit of roll and pitch)

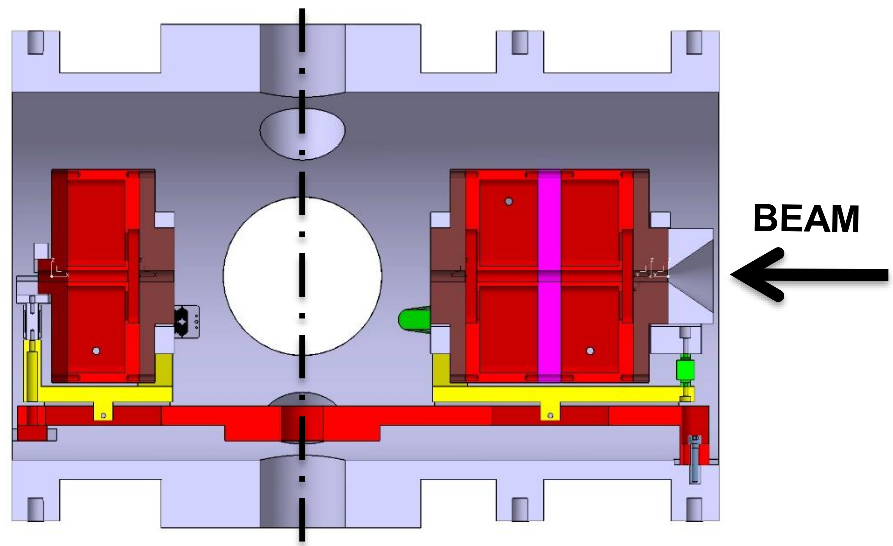


3 Cedrat APA200M piezo actuators
(nom. stroke / close loop res. : 230 / 2.3 μm)
acting as a tripod for BPM-AB vertical disp.
(plus 1 actuator for horizontal disp. [not shown])

3 PI P-602.3S0 piezo actuators
(nom. stroke / resolution : 300 / 3 μm)
acting as a tripod for BPM-C vertical disp.
(plus 1 actuator for horizontal disp. [not shown])

Upstream transition part (trumpet shape) next to BPM-AB to reduce wake field

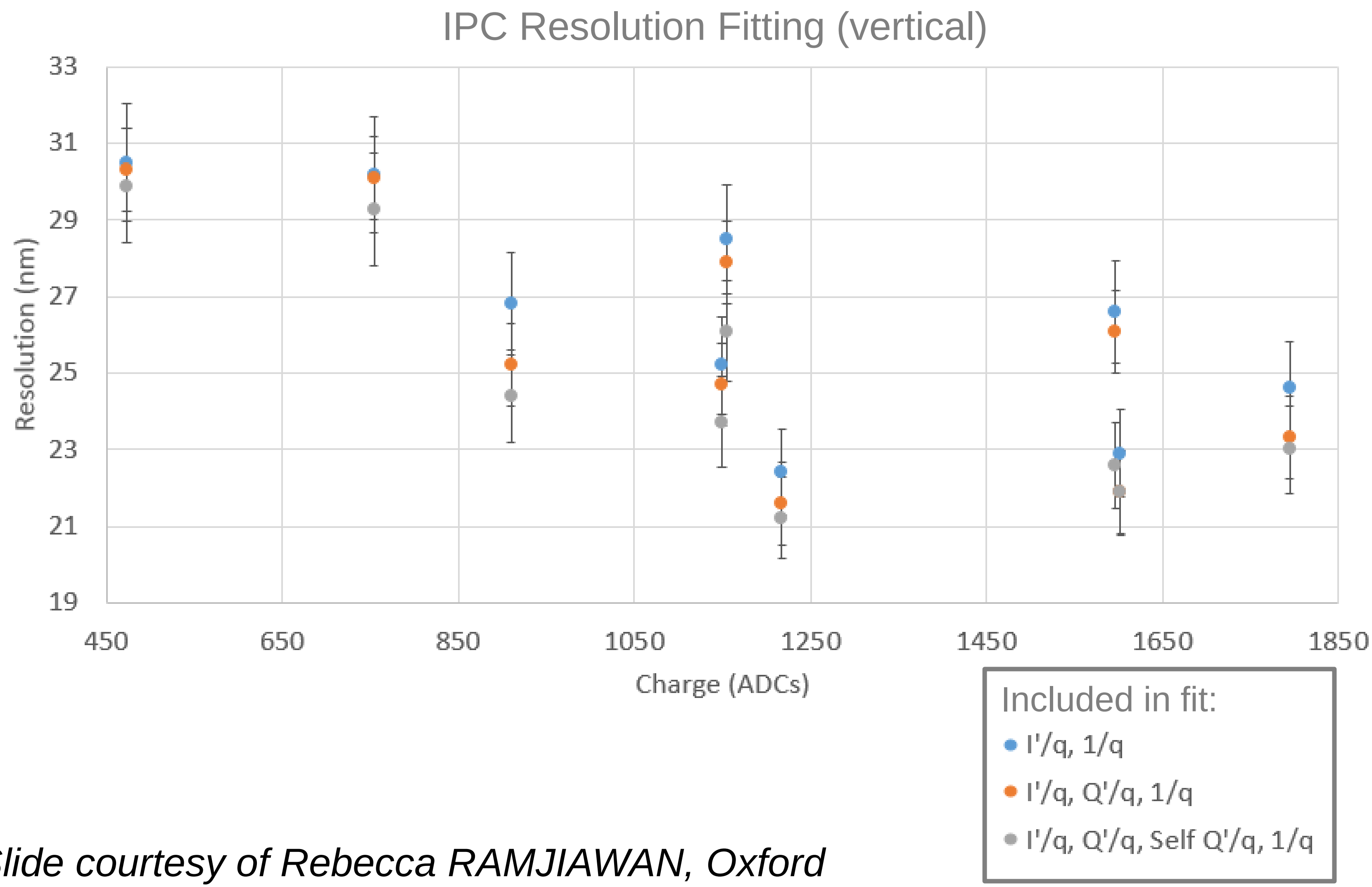




IP Plane

Slide courtesy of Sandry WALLON, LAL

IPBPM position resolution



Slide courtesy of Rebecca RAMJIAWAN, Oxford

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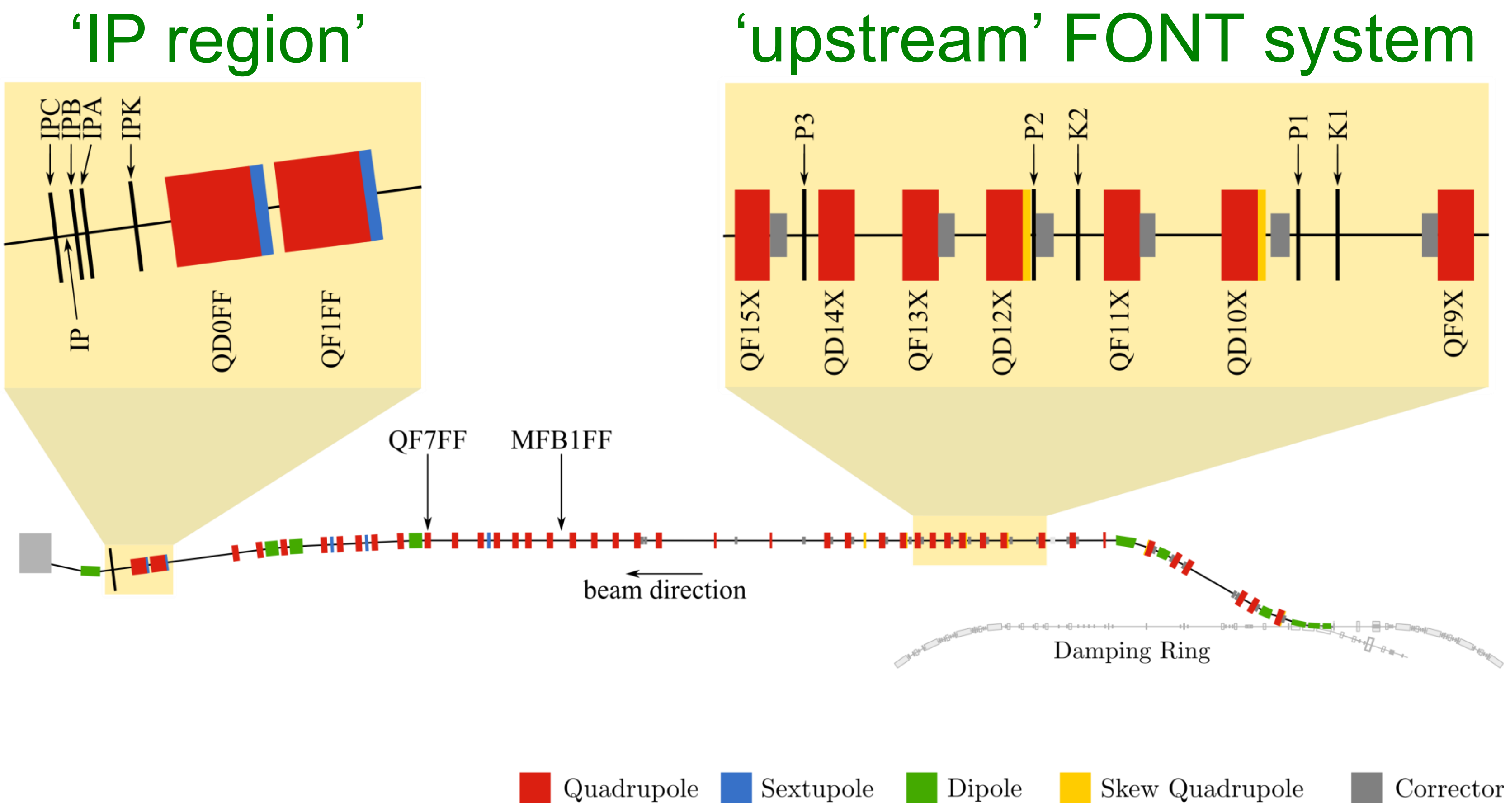
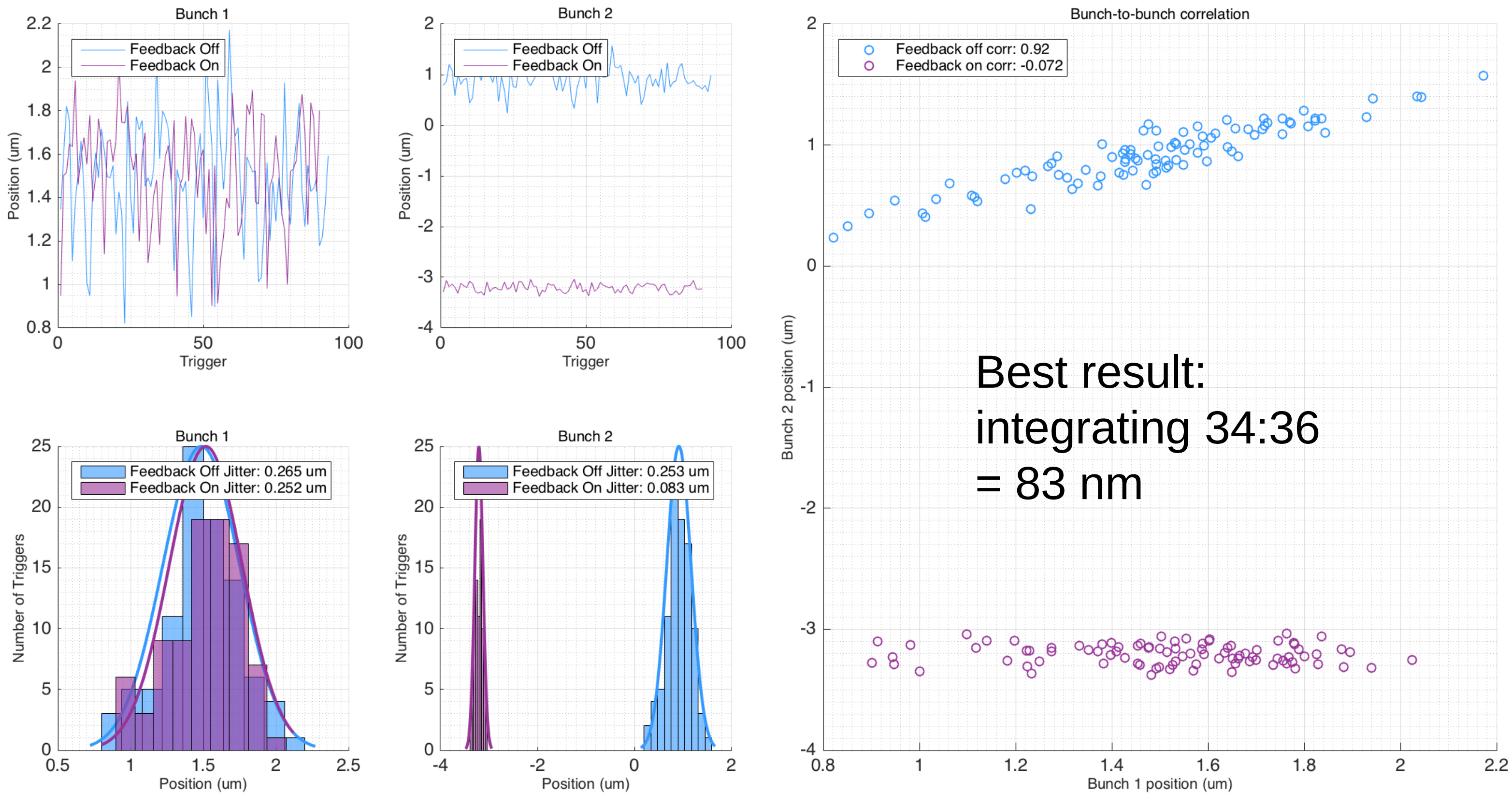
Extraction and final focus lines



based on figure from G. White et al. (PRL, 2014)

Slide courtesy of Neven BLASKOVIC KRALJEVIC, Oxford

IP intra-train beam position feedback

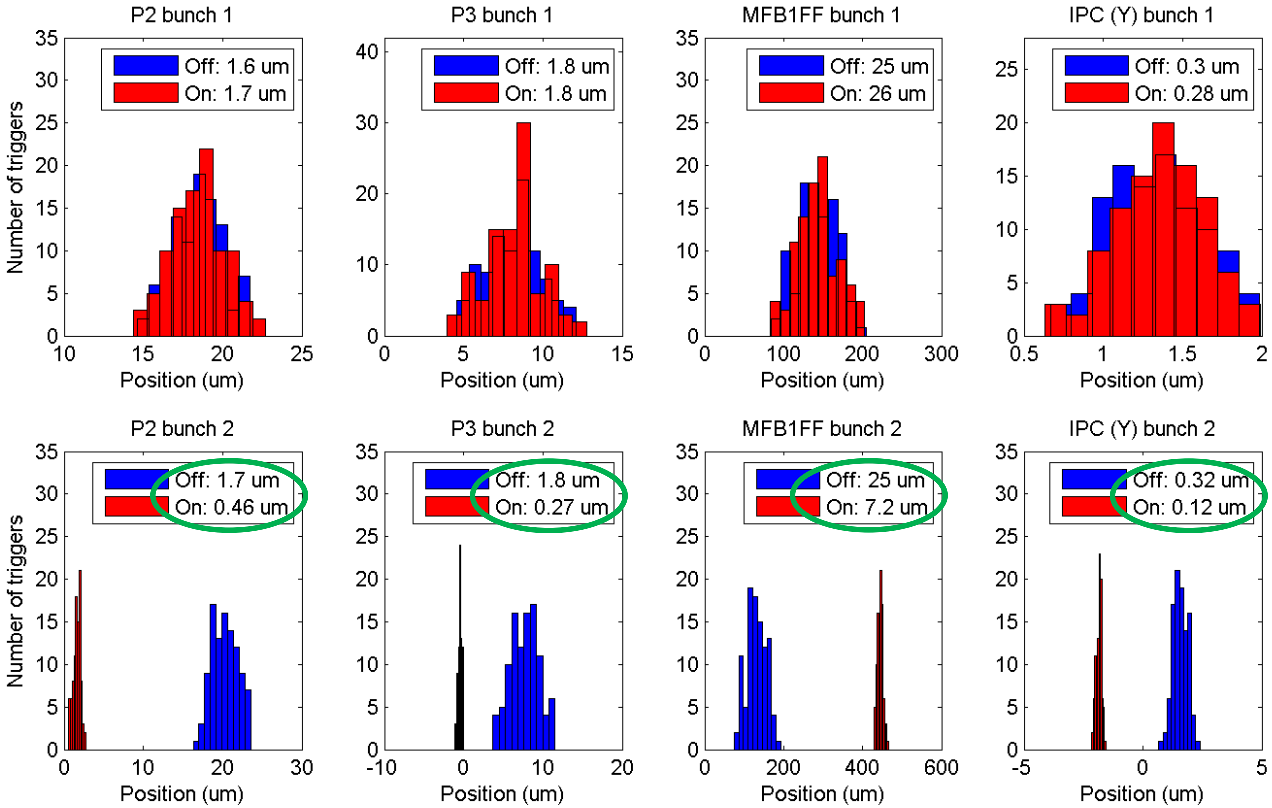


- Geometric resolution: 74 +/- 4 nm.

ipfbRun7_10dB_Board1_240217, Integrating samples 34:36, Reference sample 31

Slide courtesy of Talitha BROMWICH, Oxford

Upstream intra-train beam position feedback



stabilisation to <500 nm upstream

factor 3 stabilisation downstream

Slide courtesy of Neven BLASKOVIC KRALJEVIC, Oxford

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Ground motion feed-forward

Similar concept to orbit feedback but uses **seismometers** instead of BPMs to drive the correction.

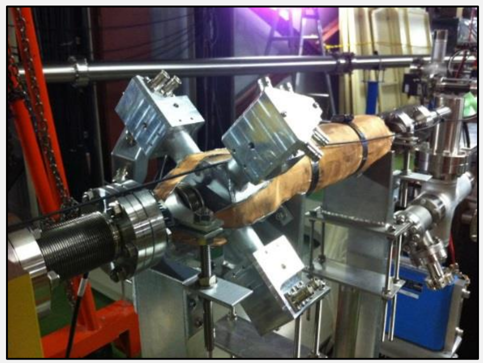
- Cheaper than active stabilization systems.
- Correct frequencies out of limits of orbit feedback.

Feed-forward setup

seismometers (mounted on quads)

velocity signals

stripline kicker "K2"



drive pulse

CompactRIO (processor)

kicker amplifier

trigger

drive signal

FONT5 board

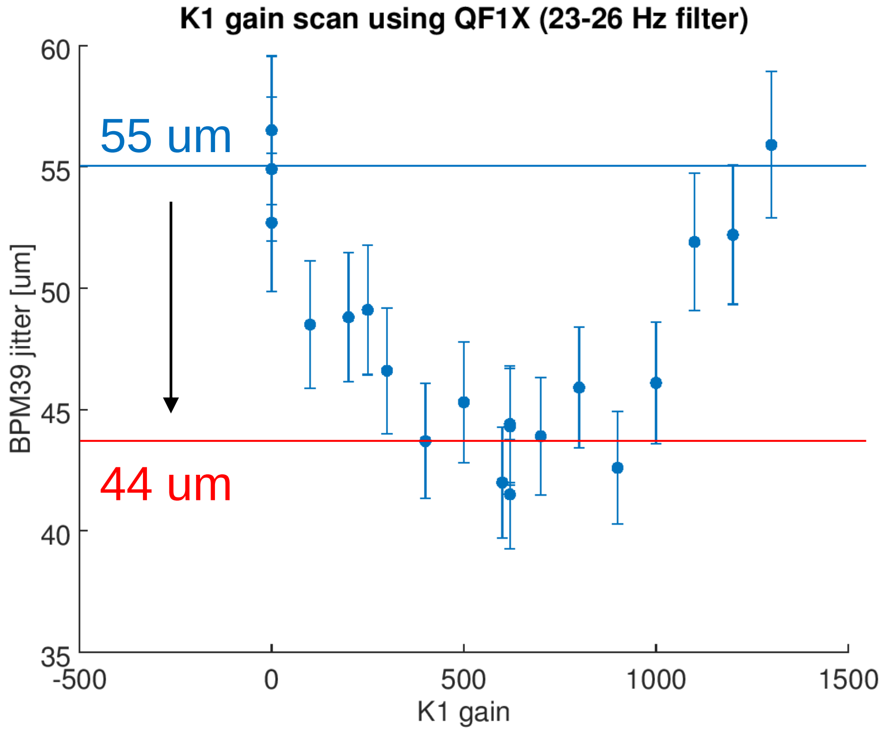
feed-forward correction value

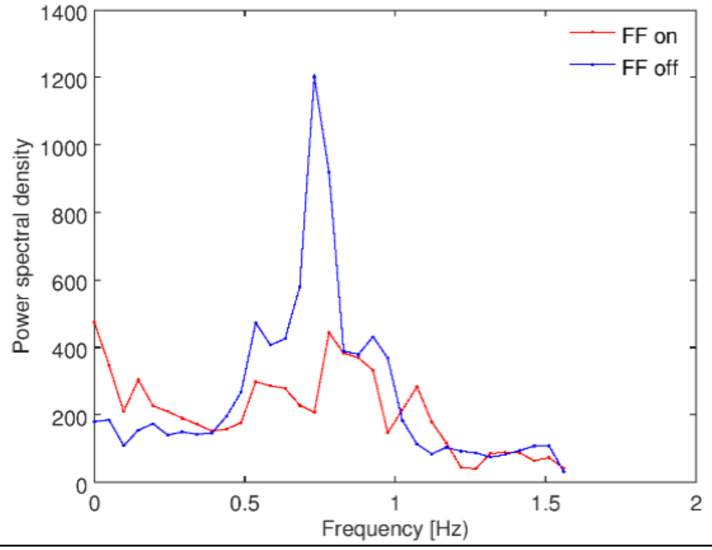
trigger

Feed-forward performance

Achieved first experimental demonstration of ground motion feed-forward technique.

Using a single seismometer and a single stripline kicker, consistently able to achieve a 20% reduction in beam jitter.





Dominant contribution to beam jitter comes from a ~24 Hz oscillation in the QD2X region believed to be due to cooling water pipes.

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Ultra-low β*

- ATF2 ultra-low β_y^* project aims to test a Final Focus System (FFS) with chromaticity (ξ_y) similar to that of CLIC
  - ATF2 with nominal optics has chromaticity comparable to ILC
  - Larger chromaticity makes the FFS more difficult to operate
- Ultra-low β_y^* optics reduces vertical beam size at IP down to 20 nm
- Octupole magnets are required to combat higher order aberrations

	β_y^* [μm]	σ_y^* [nm]	L^* [m]	ξ_y (L^*/β_y^*)
ILC	480	5.9	3.5 / 4.5	7300 / 9400
CLIC	70	1	3.5	50000
ATF2 nominal	100	37 (44[a])	1	10000
ATF2 half β_y^*	50	25[b]	1	20000
ATF2 ultra-low β_y^*	25	20[b]	1	40000

[a] measured June 2014 [b] using octupoles

Slide courtesy of Fabien PLASSARD, CERN

Half β*: latest results

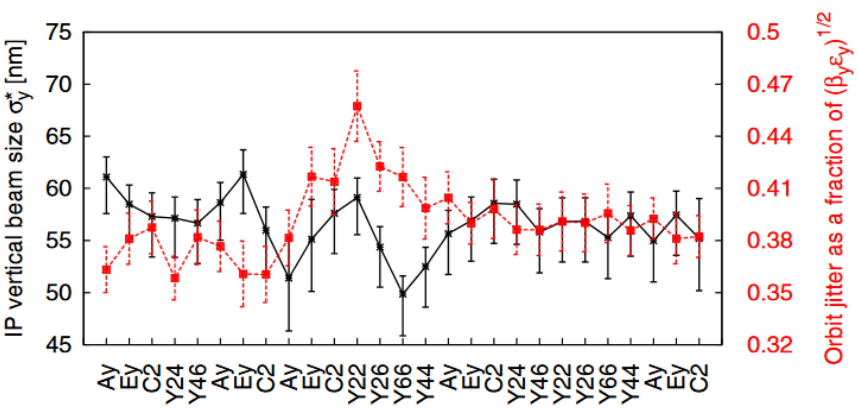
- In February 2016 tuning was performed for two sets of optics by applying several iterations of linear and non-linear knobs in order to reach a target beam size of 30 nm

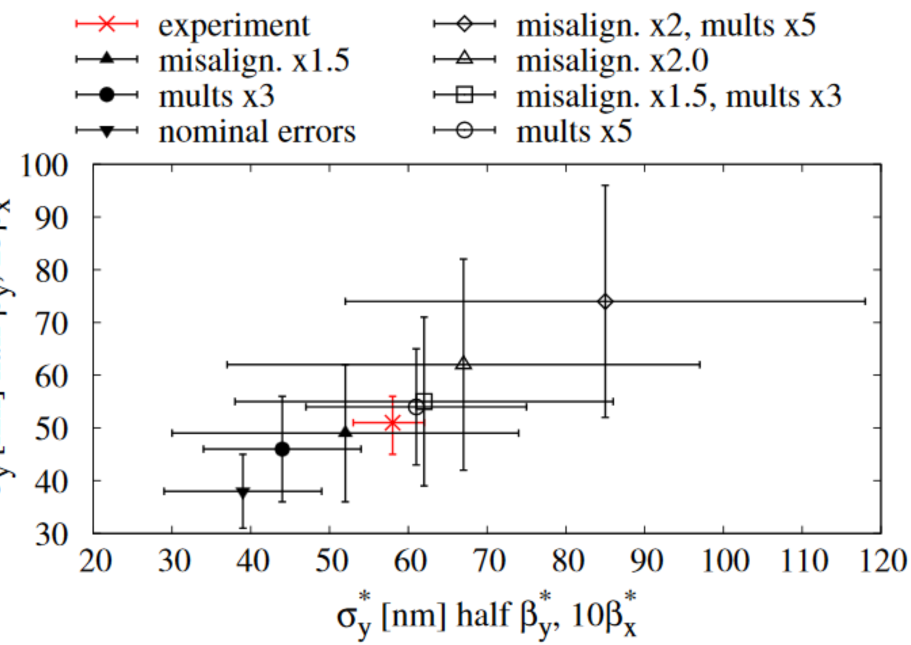
$10\beta_x^* \times 0.5\beta_y^*$

- Achieved beam size of 50 nm
- Tuning efficiency could be spoiled by orbit jitter, intensity fluctuation, IPBSM stability

$25\beta_x^* \times 0.5\beta_y^*$

Larger β_x^* reduces effect of multipole field errors

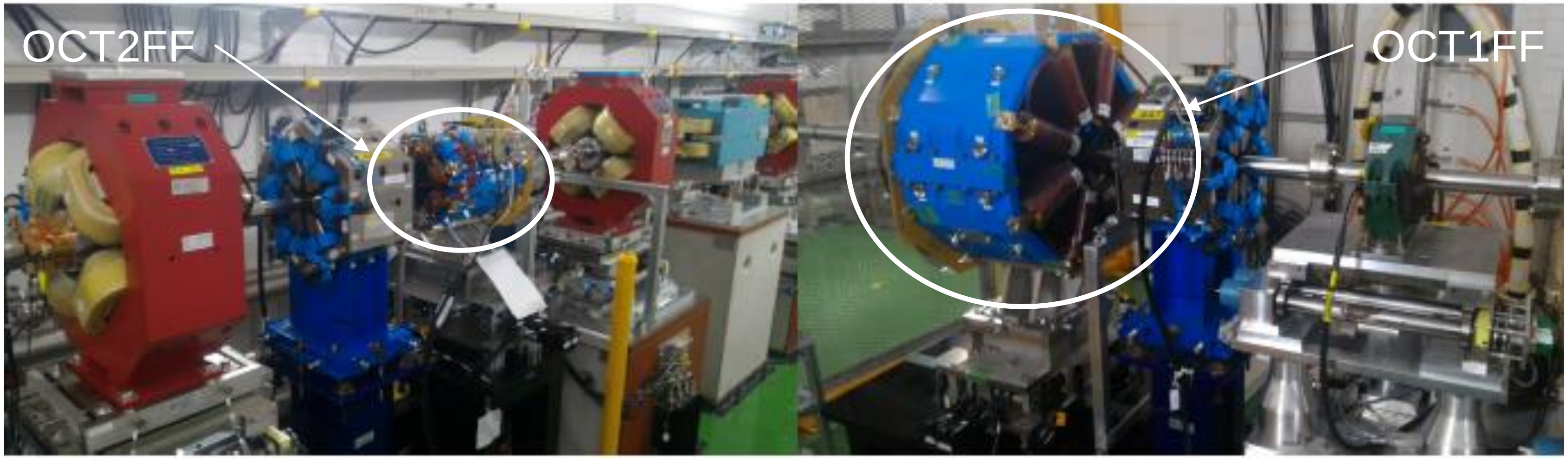




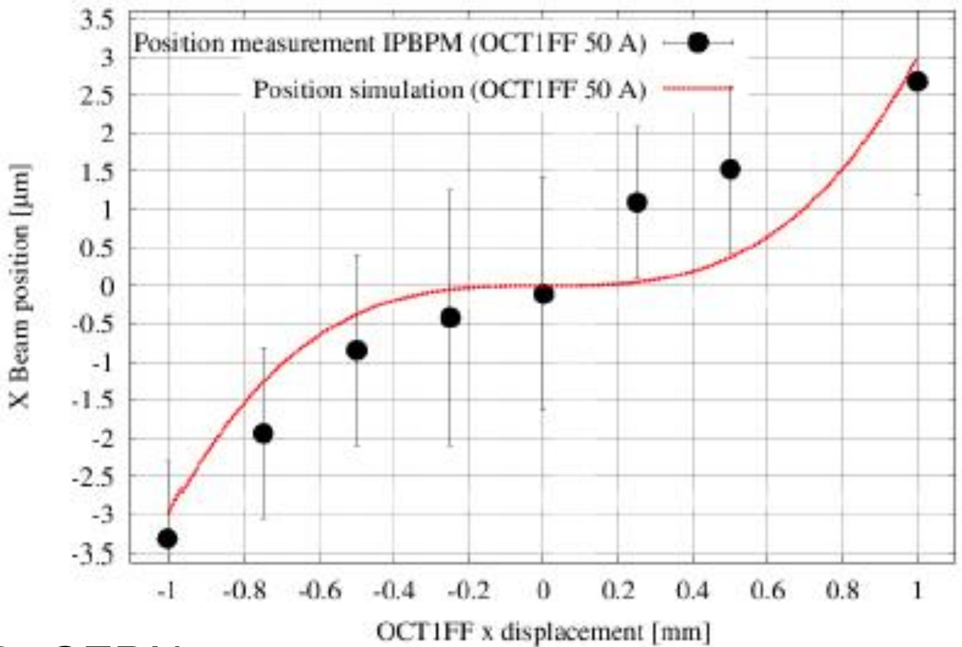
Plots courtesy of Marcin PATECKI, CERN

Phys. Rev. Accel. Beams **19**, 101001 (2016)

- Octupoles installed in ATF2 FF line and first test in Jan 2017



- BBA example of OCT1FF: octupole kick consistent with simulation
- Octupoles wil be dedicated for beam tuning at ultra-low β_y^* $(0.25\beta_y^*)$ for the next runs of 2017
- also be used as nonlinear knobs for tuning at nominal, half and ultra-low β_y^* optics
- Identify main limiting factors: fringe field, multipolar errors, high order aberrations, wakefield or alignment



Slide courtesy of Fabien PLASSARD, CERN

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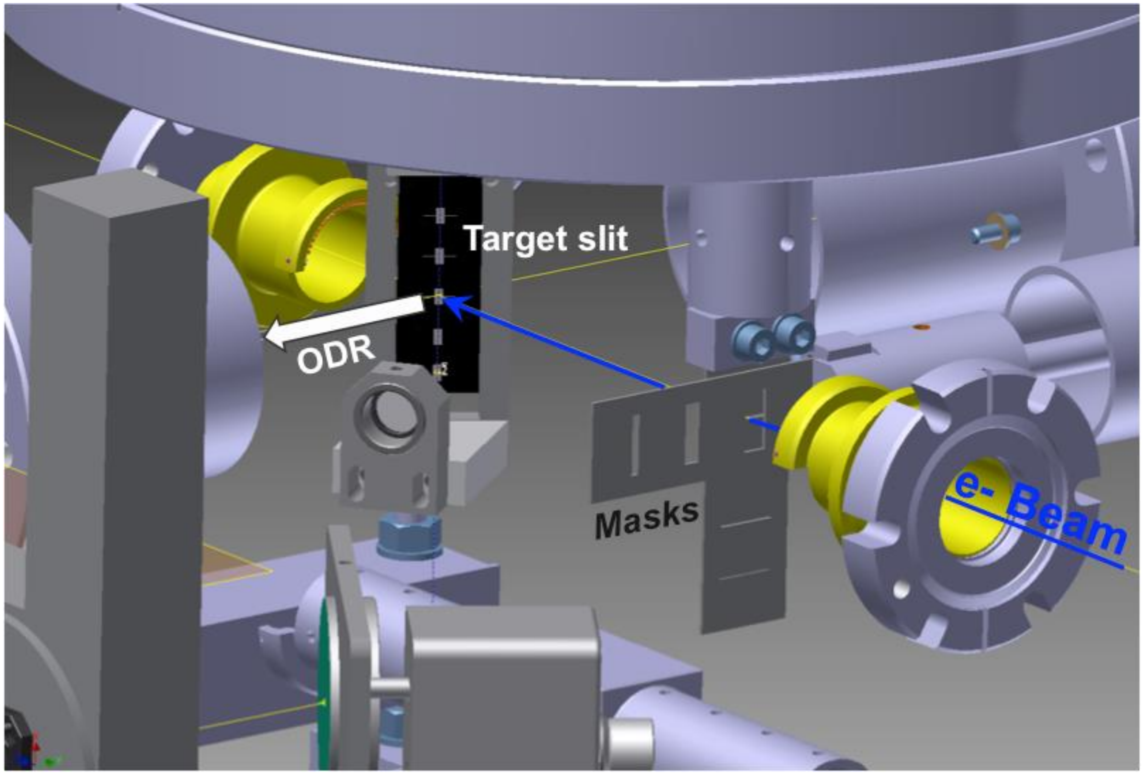
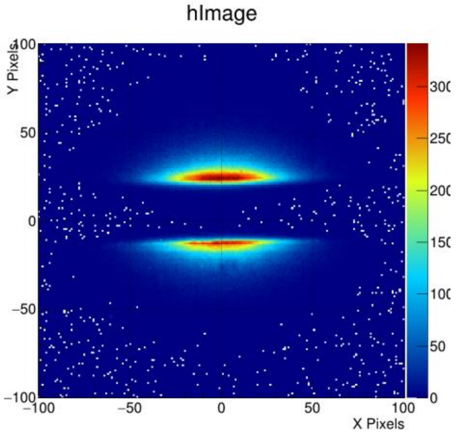
Optical Diffraction Radiation in KEK-ATF2

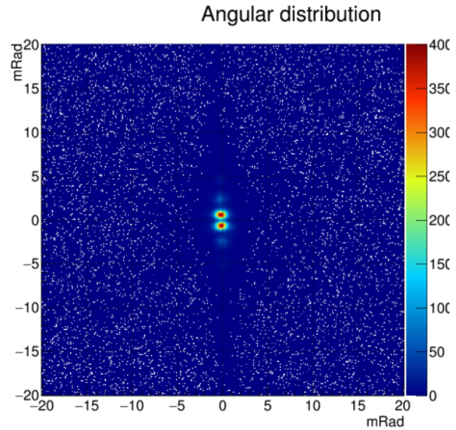
The tank was installed in February 2016 at the virtual interaction point of the ATF2 beam line, and has been successfully commissioned.

ODR light is emitted by the beam passing into the slits (50-200 um).

Two scientific cameras triggered to acquire synchronously the target surface image and angular distribution of ODR.





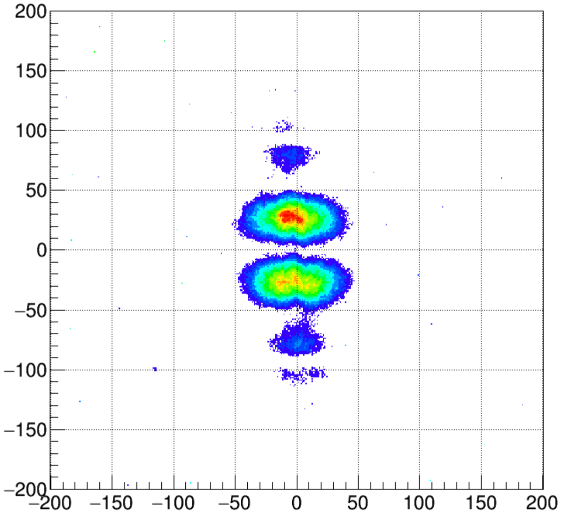
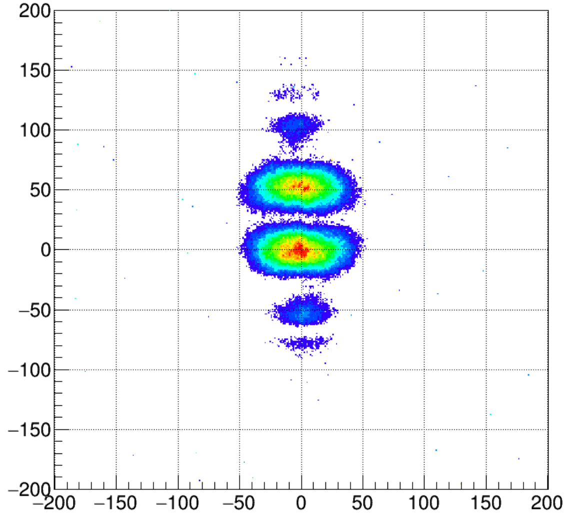
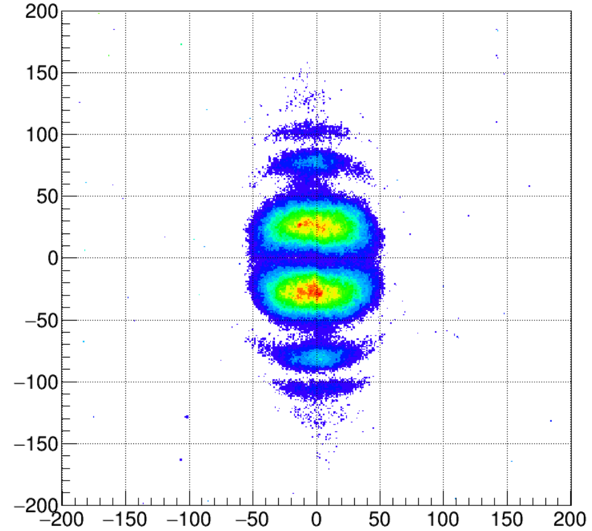
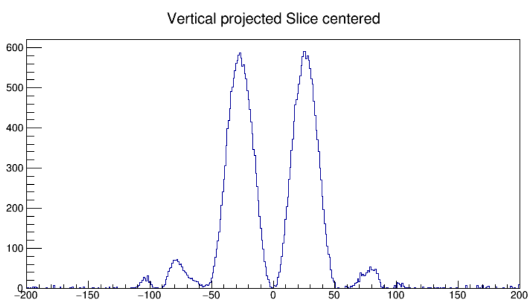


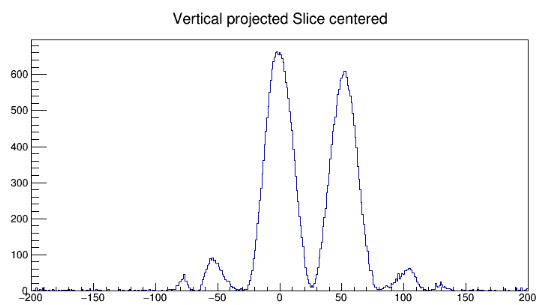
Slide courtesy of Robert KIEFFER, CERN

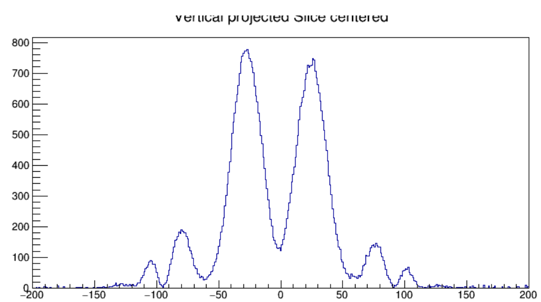
ODR measurement

June 2016

Beam 1um	Beam 18 um	Beam 30 um

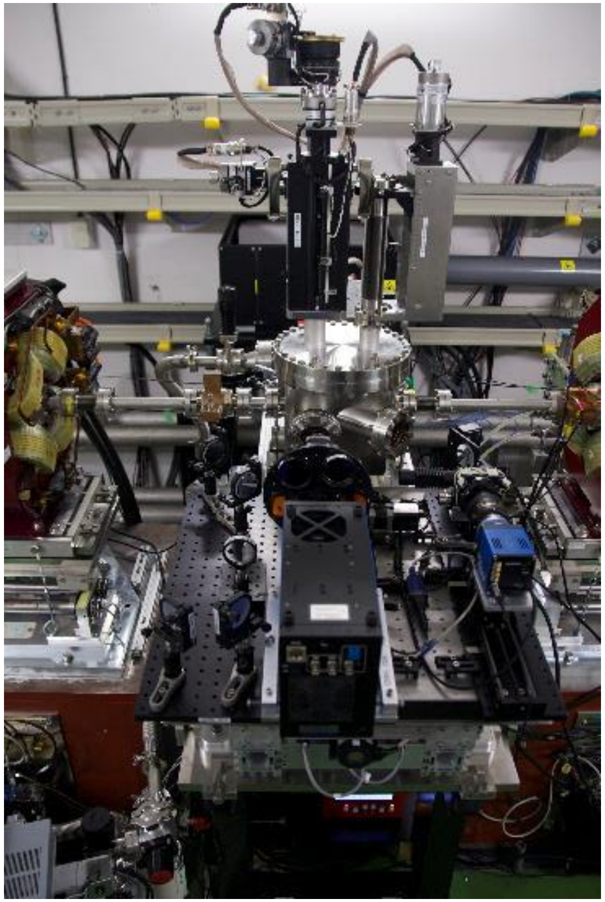




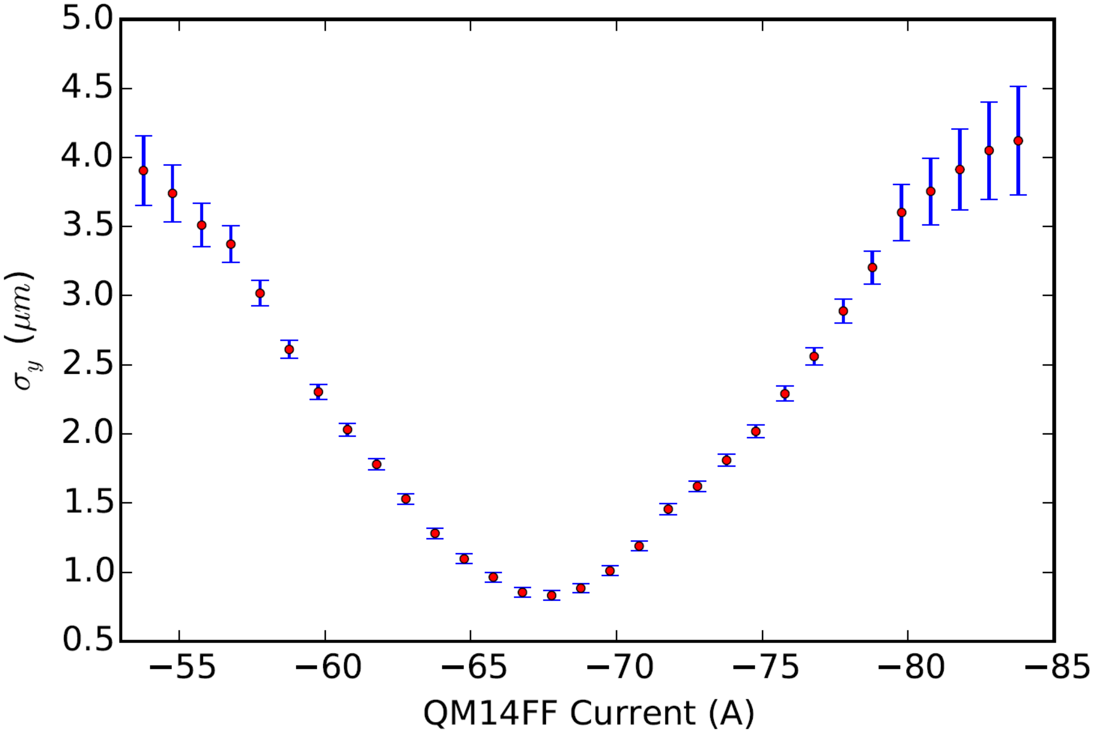
Slide courtesy of Michele BERGAMASCHI, CERN

OTR sub-micron measurement

February 2016



Sub-micron beam size data obtained through measurement of visibility of vertically polarized OTR signal: minimum vertical size **800nm**



Slide courtesy of Michele BERGAMASCHI, CERN

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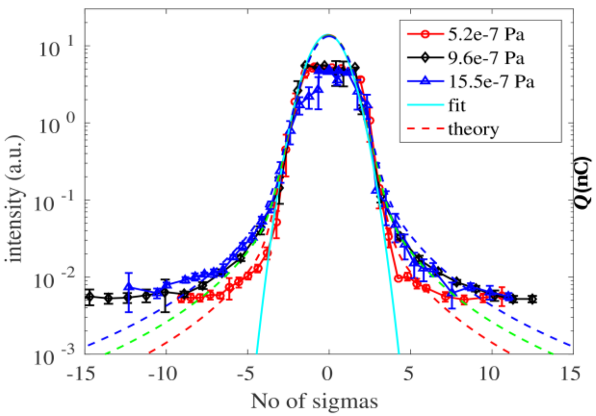
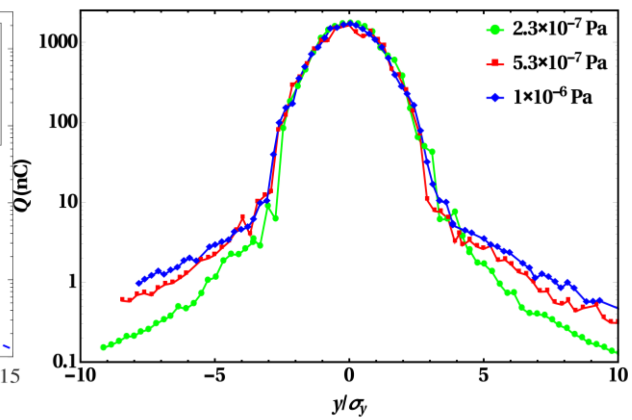
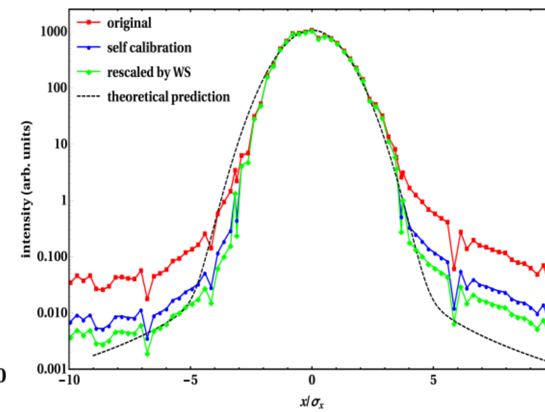
Investigation of beam tail/halo at KEK-ATF

Beam tail/halo is known as a major cause of beam loss and radioactivation in colliders and also induces background for high precision particle physics experiments.
However, the mechanism of halo formation in storage rings (DR) isn't well known.

<u>These plots show:</u>
1) Transverse beam tail/halo at different locations along ATF2 visualized by YAG, WS and DS.
2) Vertical beam halo is mainly caused by elastic beam gas scattering in DR as indicated by simulation (SAD) and measurement.
3) Horizontal beam profile measured in 2016 is higher than the prediction by elastic scattering theory by 2 order of magnitudes.





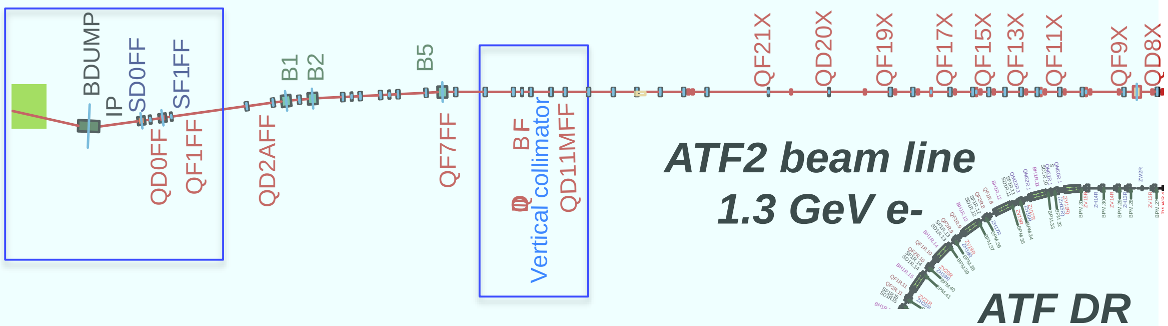


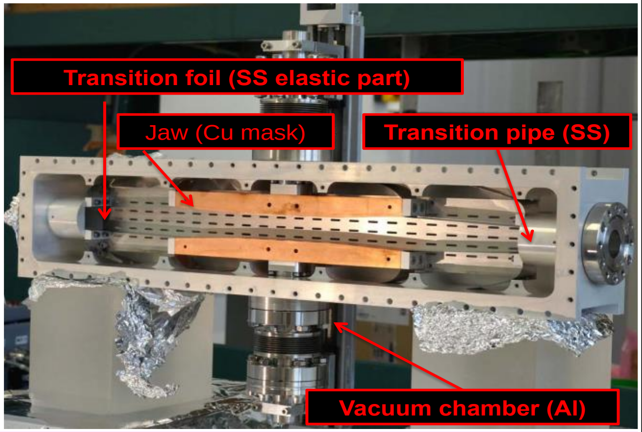
Conclusion:
- Vertical beam halo in DR is mainly caused by elastic beam gas scattering.
- Horizontal beam halo could be a result of elastic beam gas scattering and IBS.
- Monitoring of beam profile with different storage time and emittance in DR is proposed.

Slide courtesy of Renjun YANG, LAL

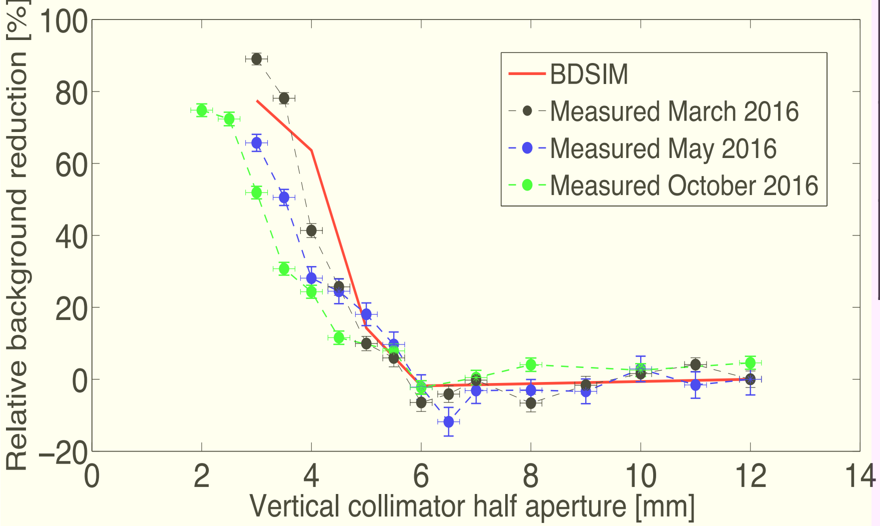
ATF2 Beam Halo Collimation and wakefield studies

A vertical collimation system was installed in March 2016





The **efficiency** of the vertical collimator in reducing the background photons at the Post-IP has been **demonstrated**



Collimator **wakefield** impact studies

[mm]	[mm]	κ_y [V/pC/mm]		
a	σ_z	Analytic calculation	CST PS[2] Numeric Calculation	Measured 2016 runs
4	9	0.033	0.037	0.038±0.003
3	9	0.059	0.066	0.063±0.004

Measurements agree with numeric simulation within the experimental uncertainties and **discrepancy with analytic calculation is within 15 %**

Slide courtesy of Nuria FUSTER MARTINEZ, IFIC

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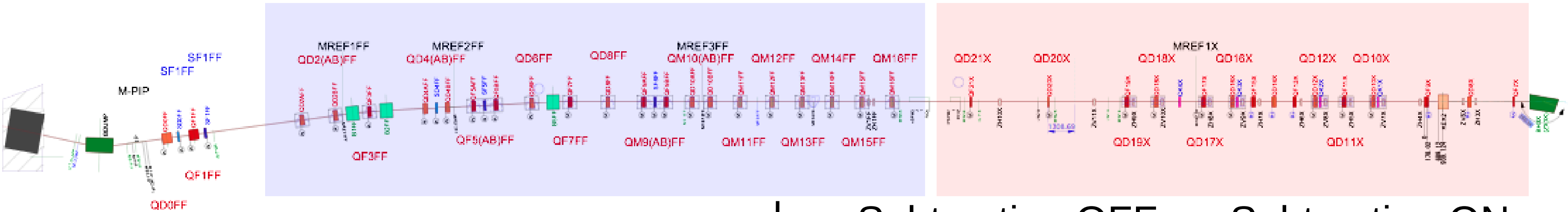
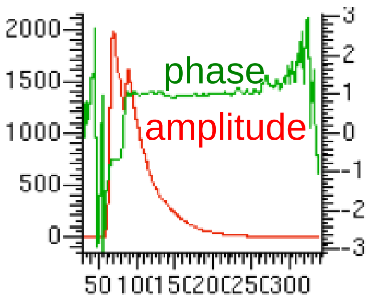
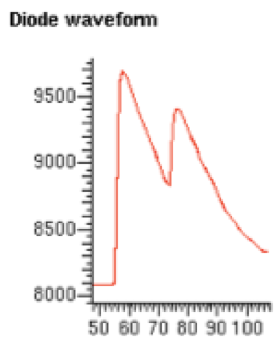
Multi-bunch cavity BPM processing

C-band BPMs (on movers) stripline/cavity BPMs (mounted rigidly)



Need to measure position of multiple bunches with bunch spacing smaller than or comparable to cavity signal decay time





Position measurement involves amplitude and phase, so subtraction done with phasors

Use charge-dependent reference signal for bunch detection

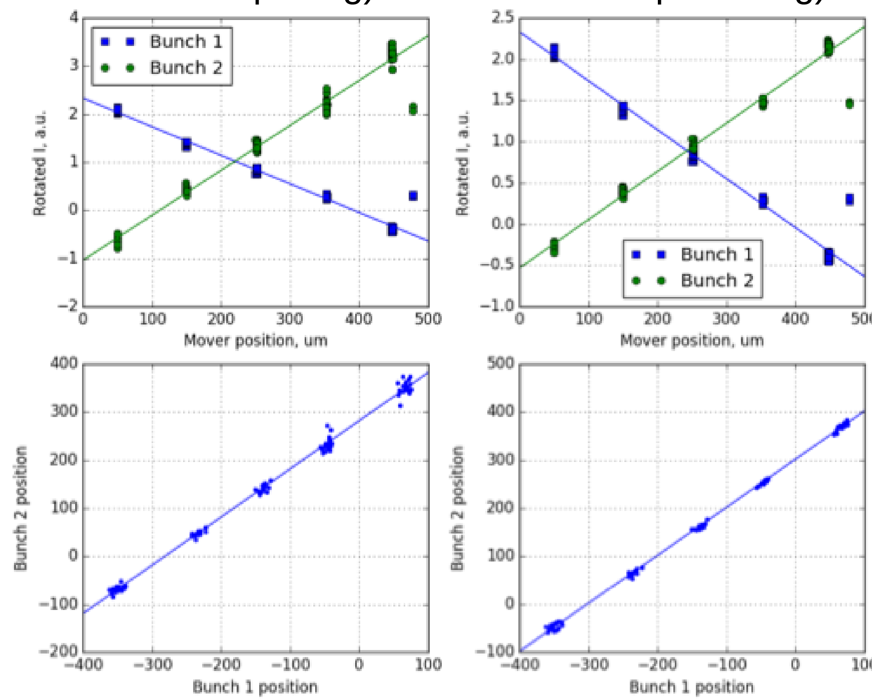
- Measure the decay time and frequency of the signal for propagation
- Subtract from consequent bunch with forward-propagation

Subtraction OFF

calibration scale differs by ~30% (depends on bunch spacing)

Subtraction ON

difference in scale < 3% (consistent with variation in sample timing)



Slide courtesy of Alexey LYAPIN, RHUL

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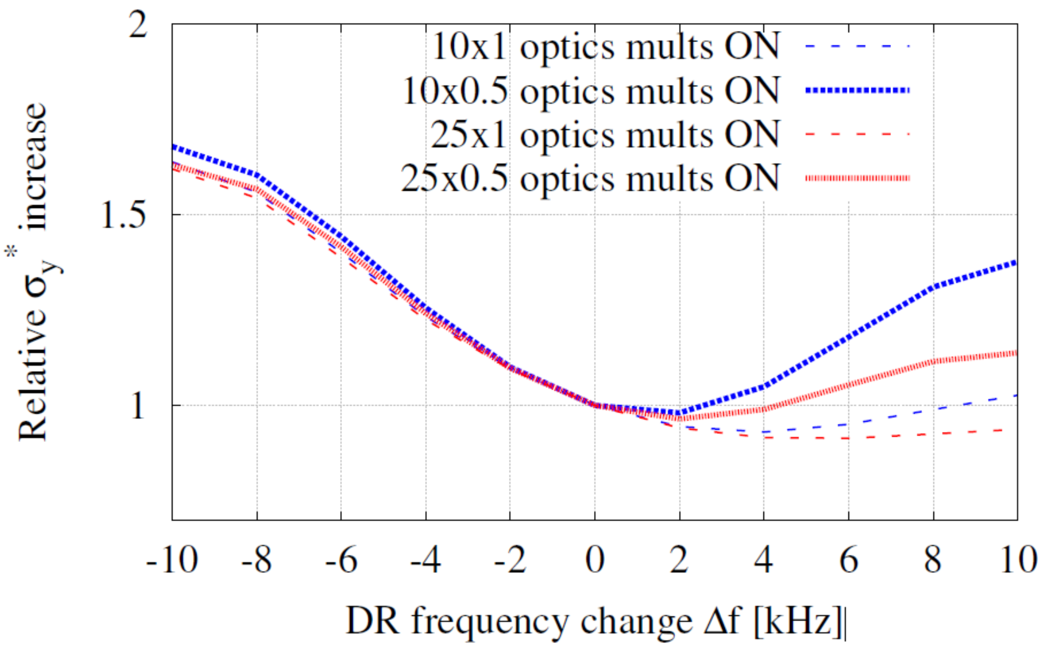
Proposed energy bandwidth measurement

- Perform an energy scan by changing the linac frequency and observing the effect on the beam size
- Compare measurement with simulation to determine the chromatic behaviour of the beam and the impact of non-linear fields



- Beam size monitor optimized for normal operation not for energy ramp
- New hardware needed to perform measurement

Slide courtesy of Fabien PLASSARD, CERN

Summary

- ATF2 continues to close in on primary goals:
  - Goal 1: 37 nm beam size (41 nm achieved)
  - Goal 2: ~nm stability (30 nm IPBPM res. achieved)
- Many significant achievements by ATF2 collaboration:
  - Intra-train beam position feedback performance increased
  - Ground motion feed-forward demonstrated
  - OTR/ODR commissioned
  - Multi-bunch cavity BPM processing implemented
  - Octupoles installed and tested with beam
  - Collimation system installed, cause of vertical halo understood
- **More details to come at 20th ATF2 Project Meeting**
  - **hosted here at CERN next week**

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