ATF2 studies and preparations for ILC
AR_D_10

2019 Joint workshop of TYL/FJPPL and FKPPL

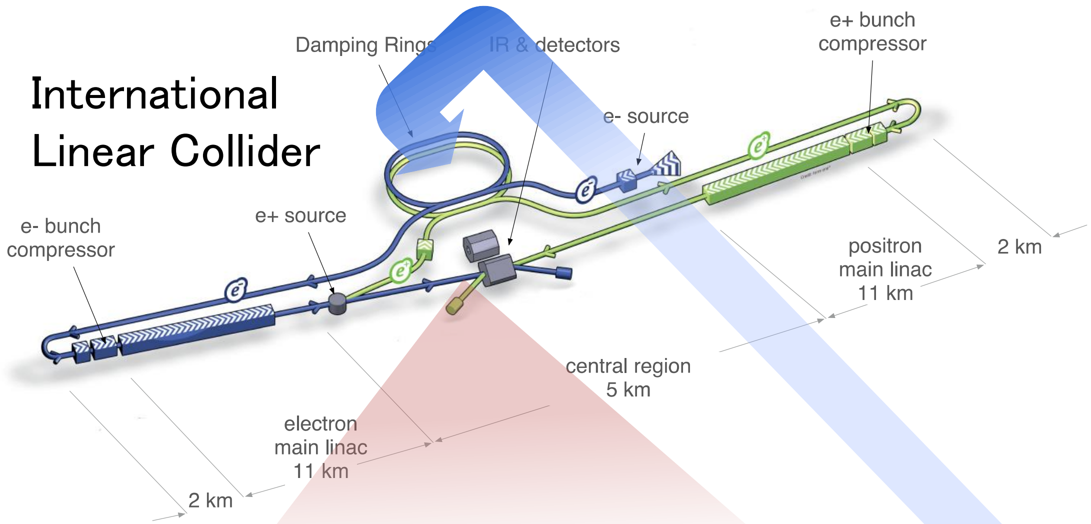
2019.5.10 Kiyoshi KUBO

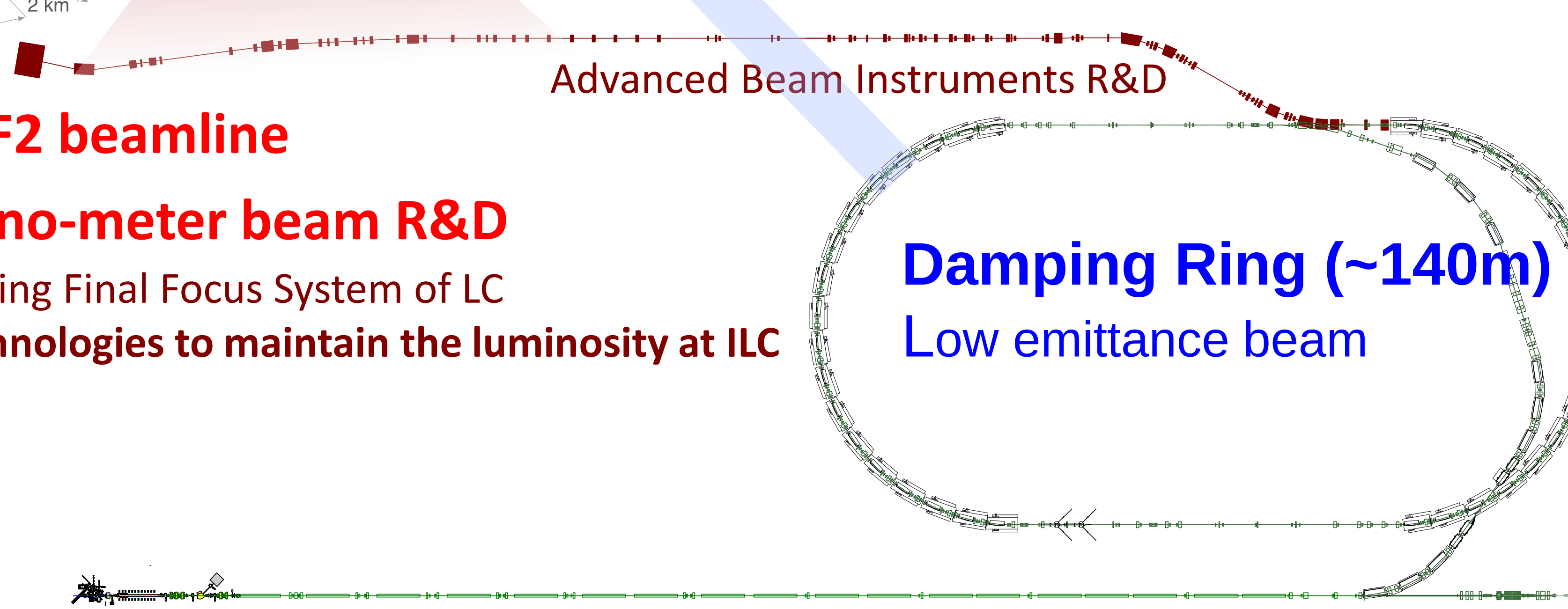
on behalf of the members of the project:

A. Faus-Golfe, P. Bambade, R. Yang, S. Wallon, A. Jeremie, L. Brunetti, G. Balik, T. Tauchi, T. Naito, N. Terunuma, S. Kuroda, T. Okugi, S. Araki, Y. Morikawa

Accelerator Test Facility

Energy: 1.3 GeV, Repetition: 3.12 Hz
Intensity: 1×10^{10} e-/bunch (max. 2×10^{10}),
1~20 bunches/pulse
Emittance: Design, 1 nm(H)/ 10 pm(V),
Achieved 4 pm(V)





ATF2 beamline

Nano-meter beam R&D

Testing Final Focus System of LC

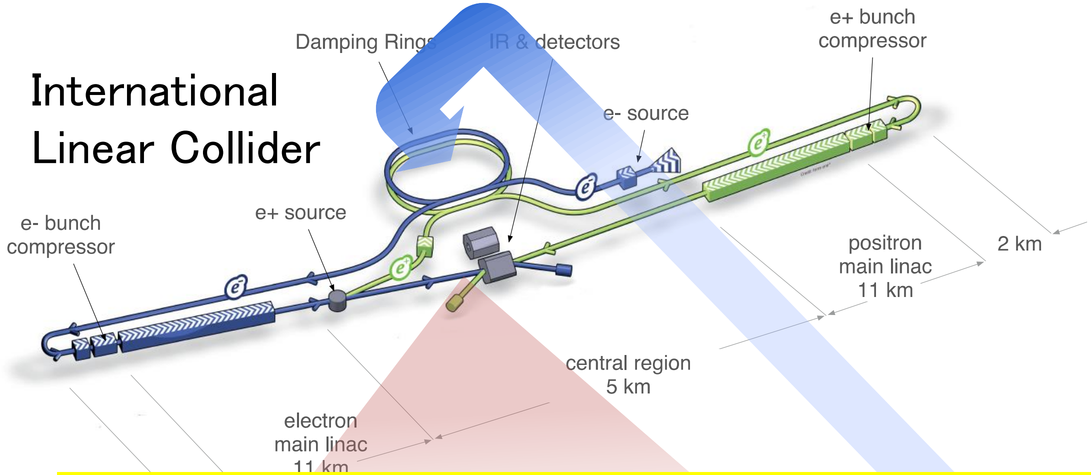
Technologies to maintain the luminosity at ILC

Damping Ring (~140m)

Low emittance beam

Cs_2Te Photocathode RF Gun

1.3 GeV S-band Electron LINAC (~70m)



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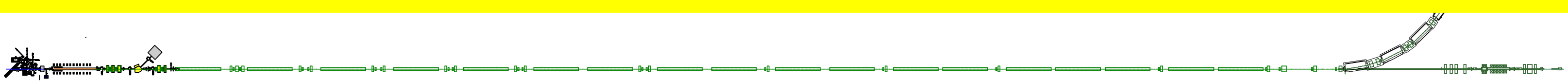
Achieved 4 pm(V)

ATF2 beamline

Prototype of Final Focus System of Linear Collider

Technologies to maintain high luminosity at ILC

ATF2 Goal: Small (37nm) and Stable (2nm) Beam



Cs_2Te Photocathode RF Gun

1.3 GeV S-band Electron LINAC (~70m)

AR_D_10

- KEK
  - Host and organize the project, ATF2.
  - Design study of ILC Final Focus System related to ATF2 experiments.
  - Study of wakefield effects in Final Focus Line
- LAL
  - Beam halo study. (Measurements and simulations)
  - Mover system of IP-BPM (nano-meter resolution beam position monitor)
- LAPP
  - Ground motion/Vibration study. (Measurements and Feedforward for stabilizing the beam)

In addition to French and Japanese institutes,
collaborative members from CERN, OXFORD and KNU

AR_D_10

- KEK
  - Host and organize the project, ATF2.
  - Design stu System related to ATF2 experimen
  - Study of wakefeild effects in Final Focus Line

Reporting here

- LAL
  - Beam halo study (Report prepared by R. Yang)
  - Mover system of IP-BPM (Report prepared by S. Wallon)
- LAPP
  - Ground motion/Vibration study.

    (Report prepared by L. Brunetti)

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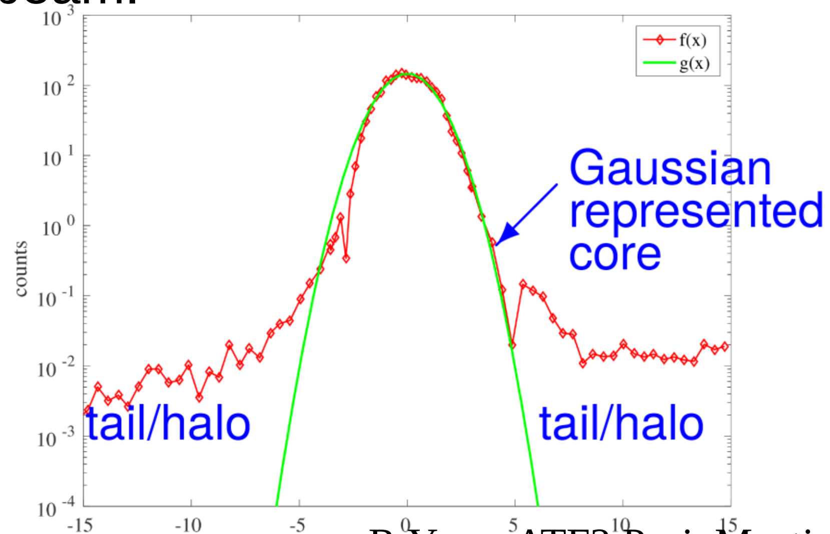
Beam Halo Study

What is beam halo?
- Particles far from center of the beam.
- Non-Gaussian distribution.

Why important?
- Cause background signals
- Cause damage to equipment

Difficult to measure accurately
- Very small part of beam

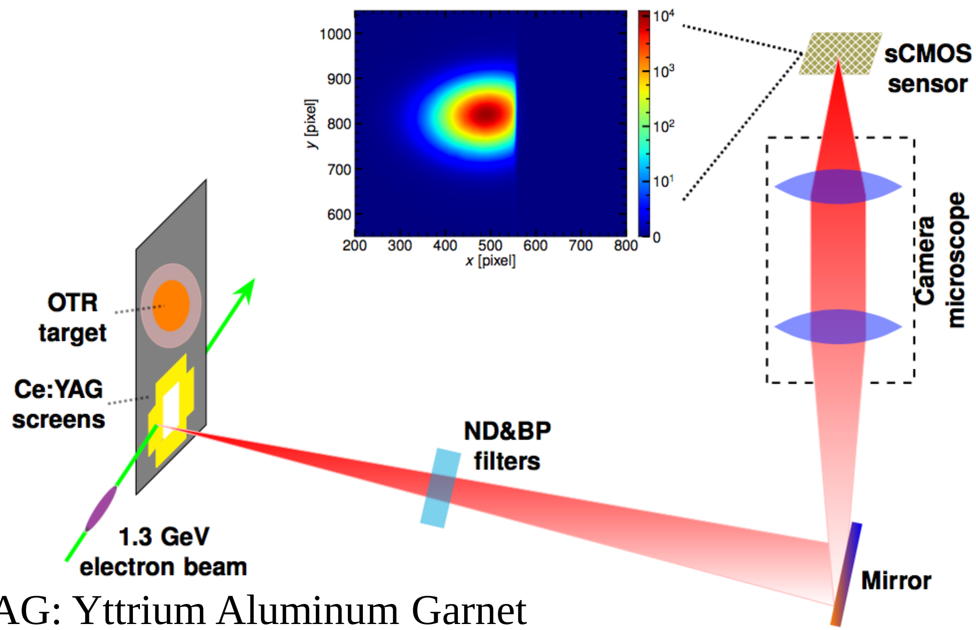


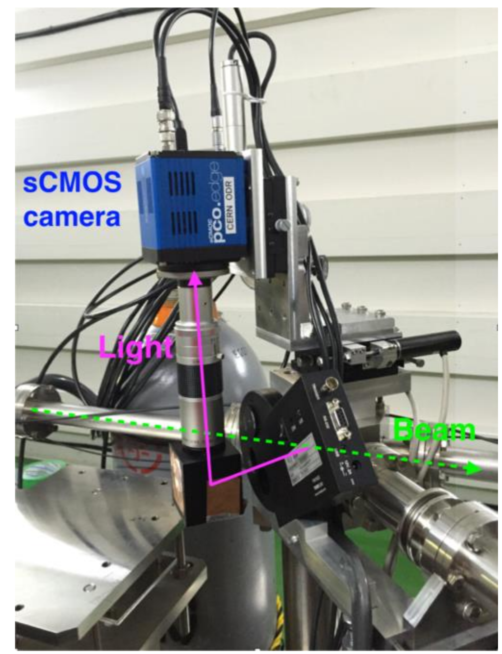
R. Yang, ATF2 Proj. Meeting, 2017

Mainly created in Damping Ring
- Beam Gas Coulomb Scattering, Bremsstrahlung
- Intra-Beam Scattering

Beam Halo Study
Development of a YAG/OTR Screen monitor

- Designed and constructed a new YAG/OTR monitor (in addition to Diamond Sensor (DS)) for fast (<10 min) and precise (Dynamic Range>10^5) beam halo and momentum tail measurement
- Under the collaboration of CERN, KEK and LAL



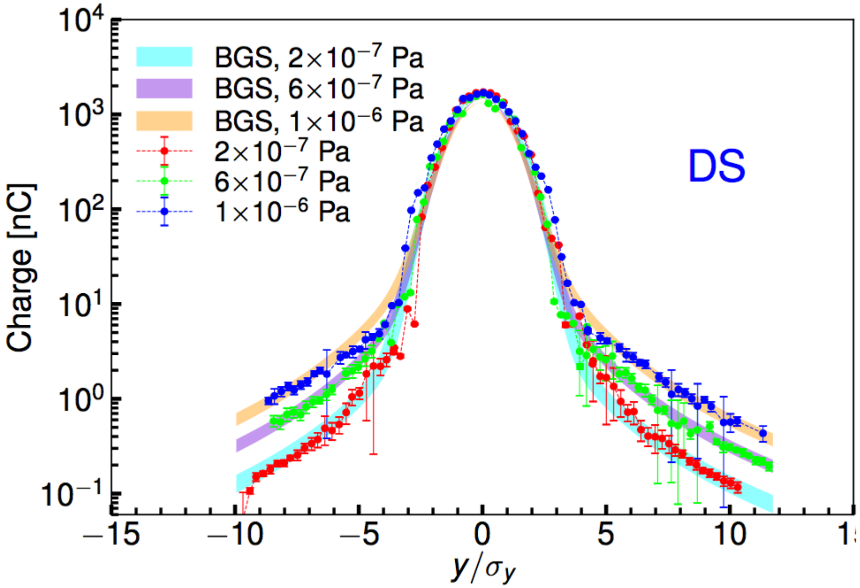


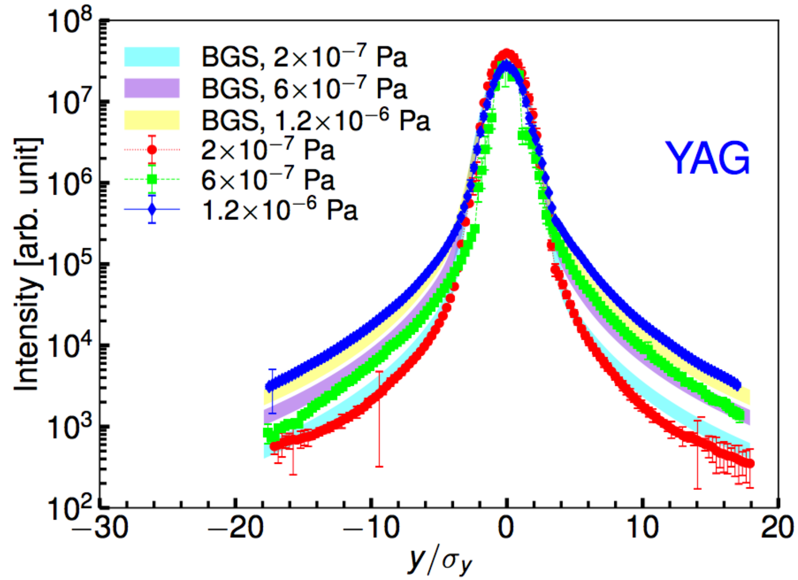
YAG: Yttrium Aluminum Garnet
OTR: Optical Transition Radiation

R. Yang *et al.*, Development of a YAG/OTR monitor for beam halo measurements at the KEK-ATF, submitted to PRAB

Beam halo formation mechanisms

- Simulations of beam halo from Beam-Gas Scattering (BGS) was developed and benchmarked (using SAD)
- Ver. betatron halo measured by DS and YAG monitors is consistent with BGS numerical predictions with significant vacuum dependence



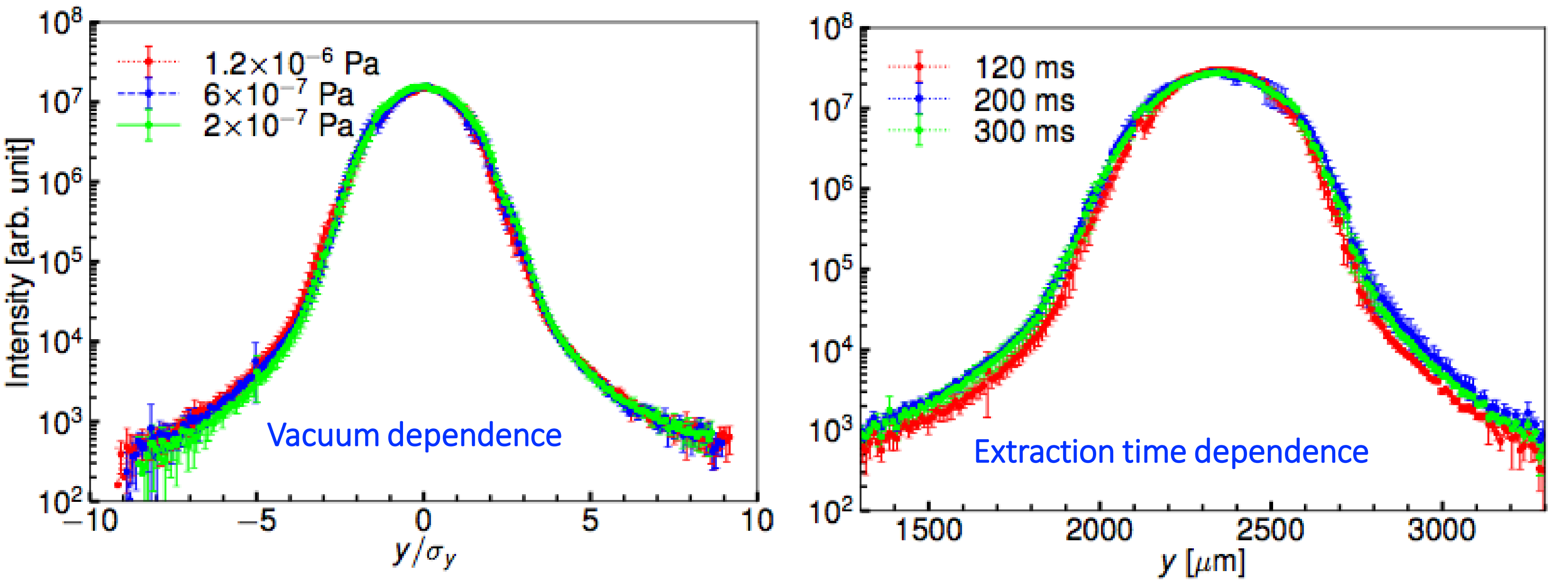


⇒ Vertical halo is dominated by elastic BGS process!

R. Yang *et al.*, PRAB, 21(5):051001, 2018

Momentum tail observation

- Momentum tail observed (1st time at ATF) using the YAG/OTR monitor (with vertical dispersion bump)
- Dependence of momentum tail on vacuum, beam intensity and extraction time agree with simulation of Intra-beam scattering
- **Intra-beam scattering is dominant source of momentum tail.** (BGS is not important)



R. Yang, PhD. thesis, Universite Paris-Saclay, 2018

Ground Motion – Feedforward Study

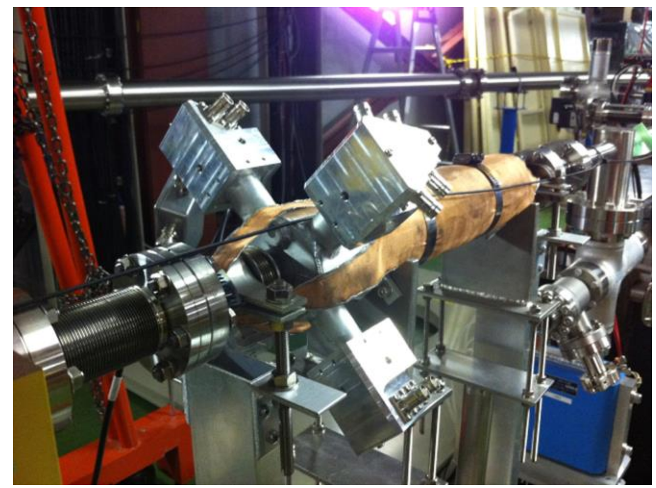
Feedforward (FF) Principle:

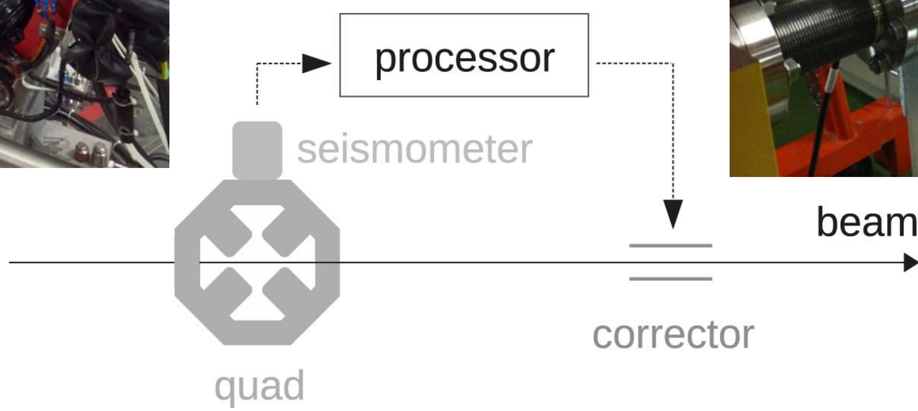
Measure motion of magnets and Correct beam orbit using the information

Important for Linear Colliders (esp. for CLIC)

Sensor on magnet

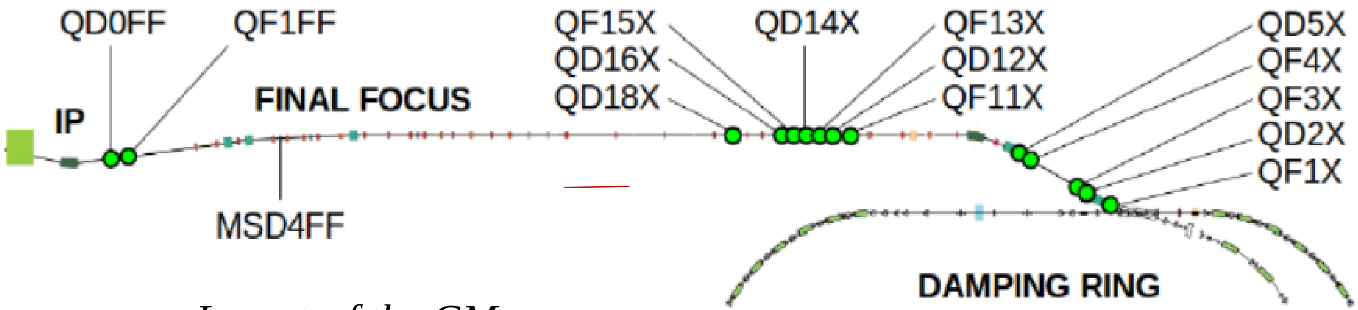
Corrector (strip line kicker)





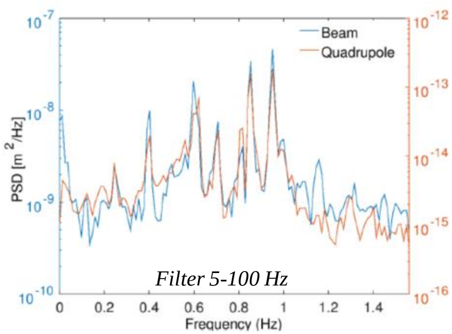
Figures from D.Bett et.al, Nucl. Instrum. Methods Phys. Res., A 895, 10, 2018

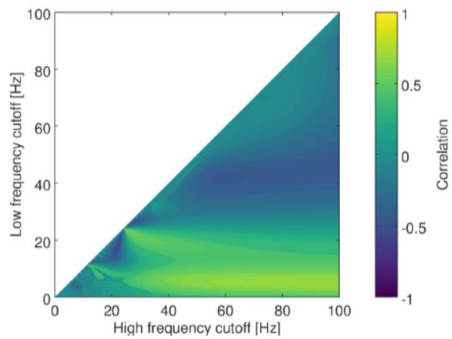
Feedforward

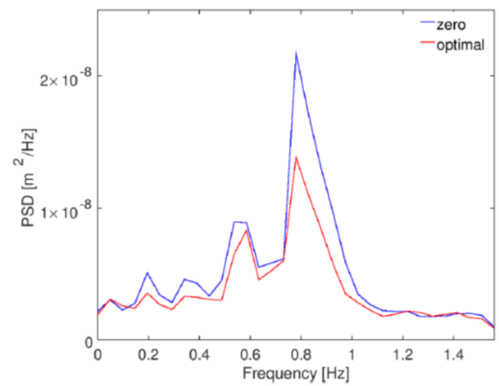


- Layout of the GM sensors-

- **Previous results - demonstration**
  - **<u>Gain</u>:** scanning method
  - **<u>Filter</u>:** determination of the bandwidth to reject the coherent part







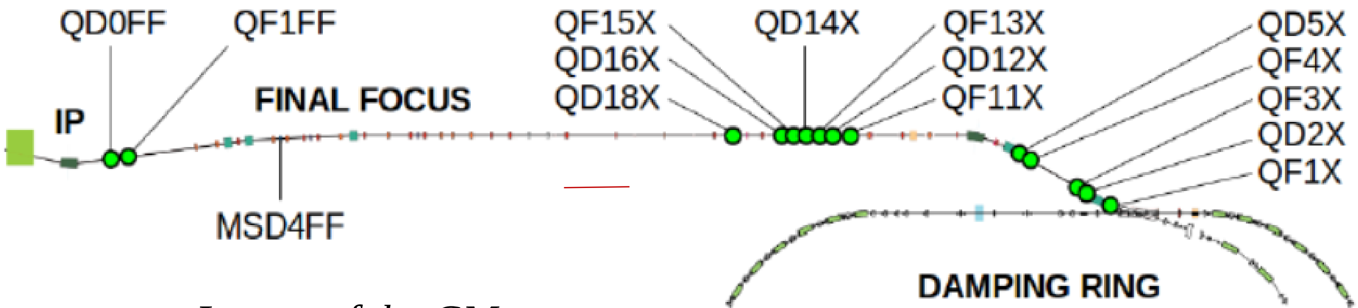
  - *Control these perturbations with the optimized **<u>gain</u>***

- The obtained experimental results by CERN team with 1 geophone and 1 kicker -

  - **"D. Bett et al, Compensation of orbit distortion due to quadrupole motion using feed-forward control at KEK ATF"**

- **Feedforward - issues**
  - To extract very accurately the disturbances (coherent vs incoherent motion) - Low frequencies are quite coherent
  - **To know very well the system** (the effects of the vibrations and of the magnets on the beam)

Feedforward



- Layout of the GM sensors-

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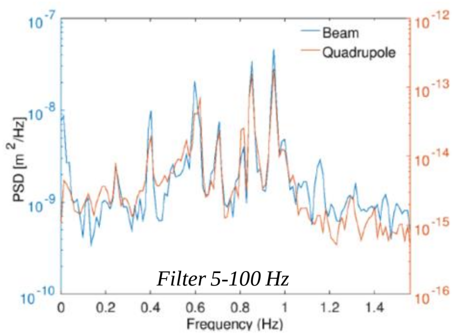
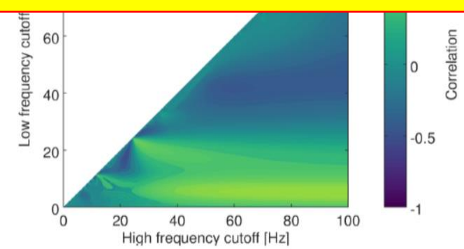
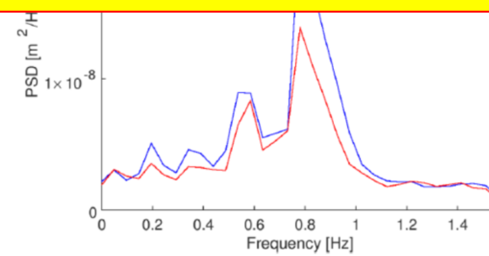
  - **Filter:** determination of t

Demonstrated
Beam jitter Reduction
by 1 sensor–1 corrector system







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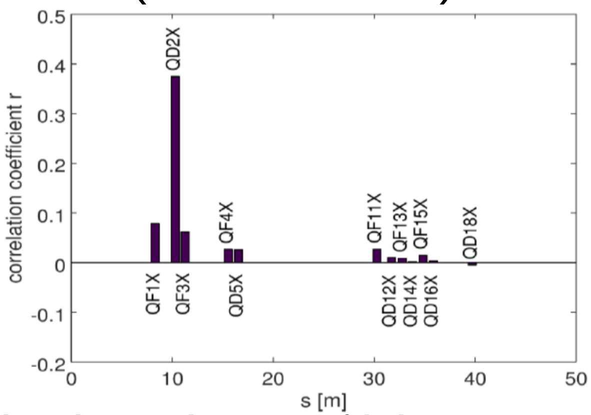
Ground Motion - Feedforward

▪ Multisensors control

First objective is to carry out feedforward control with the motion of the two main relevant magnets

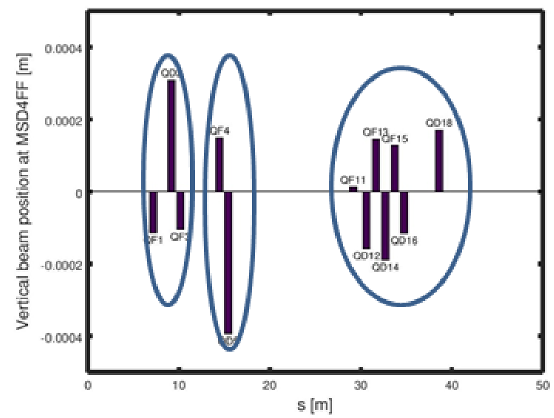
➢ Choice of the two main relevant magnets:

Correlation coefficient (Measurement)



Correlation between the position of the beam at MSD4FF and the positions of various seismometers measured by CERN team

Effect to Orbit at a (BPMMSD4FF) (Calculation)



Optics calculation with MADX (10BX1BY optics) displacing vertically by 1μm one quadrupole at a time and extracting the vertical beam position at MSD4FF

➢ The chosen magnets are the QD2X quadrupole, which reveals the most significant disturbances, and the QD5X quadrupole, which is the strongest magnet in this part of the line.

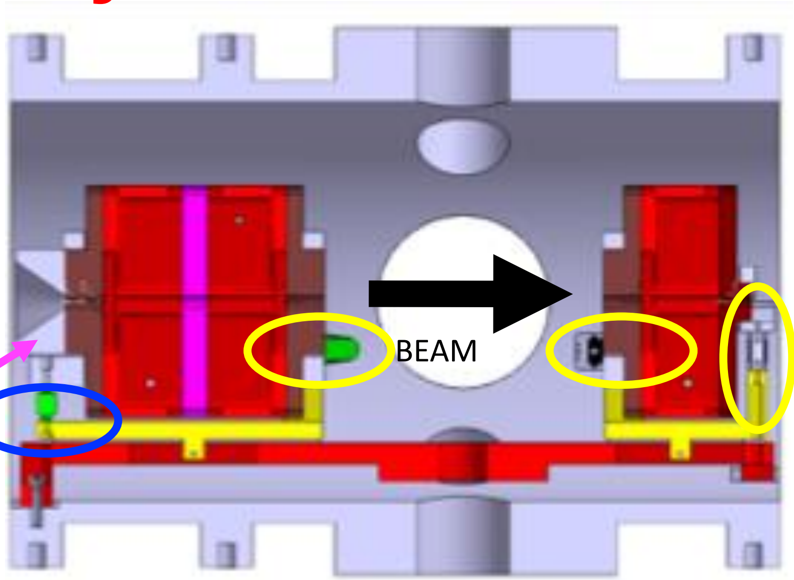
➢ **Study will be Continued**

IPBPM Mover System

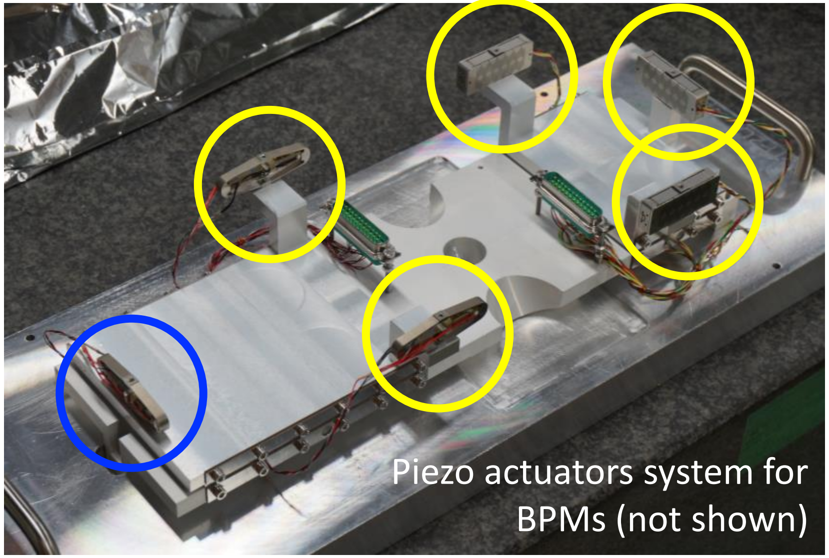
Accurate Control of positions (esp. vertical), role and pitch of IPBPM (nm-resolution BPM)

Done in 2018

- BPM-AB vert. mover ~~(near cavity A)~~ changed by new one
- Trumpet for wake field prevention removed to reduced upstream mover (i.e. near cavity A) load
- Vertical and lateral measurements done with interferometer for calibration and stability purpose
- Set new voltage range and mid stroke voltage for BPM-AB
- New set point var for BPM-AB vert. displacement :
- New calibration factors (gains, i.e. linear fitting) for Epics



IP chamber side view (cross section)



Piezo actuators system for BPMs (not shown)

IPBPM Mover System - Short term (vert.) stability

Configuration : BPMs still w/ movers on at 3.5V vert. & 3V hor. (BPM-AB) and at 5V (BPM-C);
Samples from a 100 s time span sliding window among at least 5 to 6 hours measurement;
Device : SIOS interferometer ; Initial drift and “accidents” removed

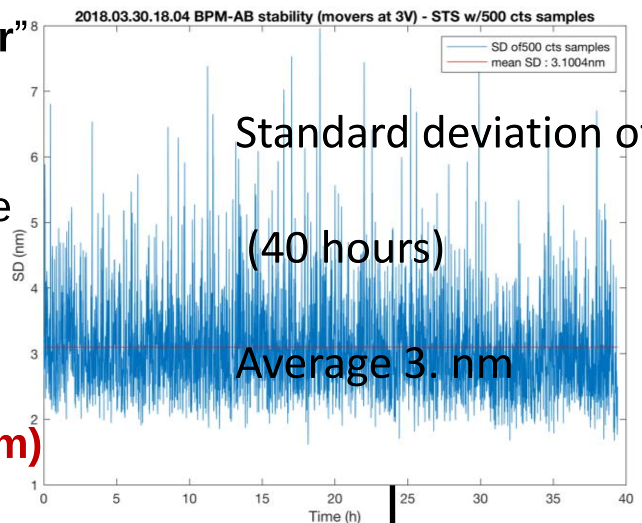
Higher “**mechanical jitter**” at upstream mover

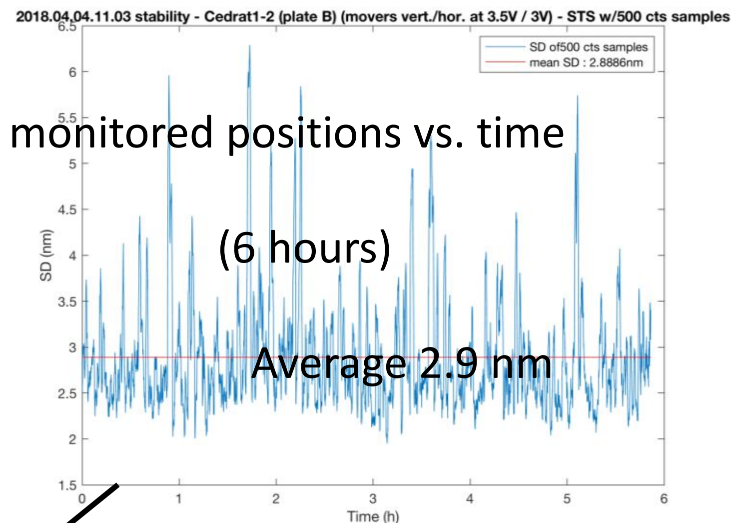
(8.3 nm vs 3.1 & 2.9)

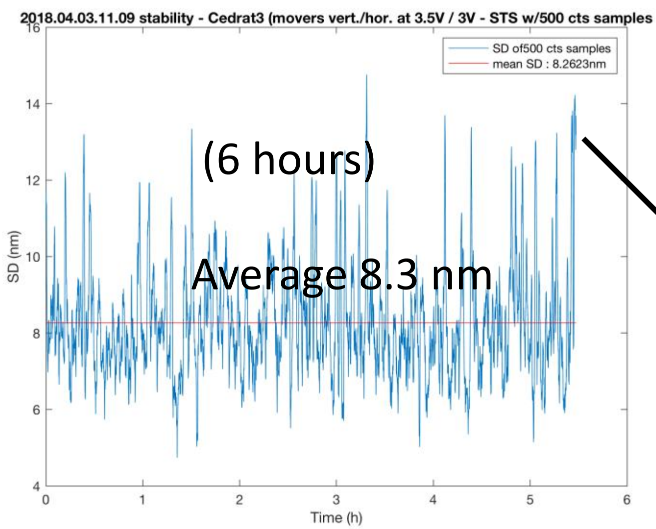
(Probably due to unstable mirror)

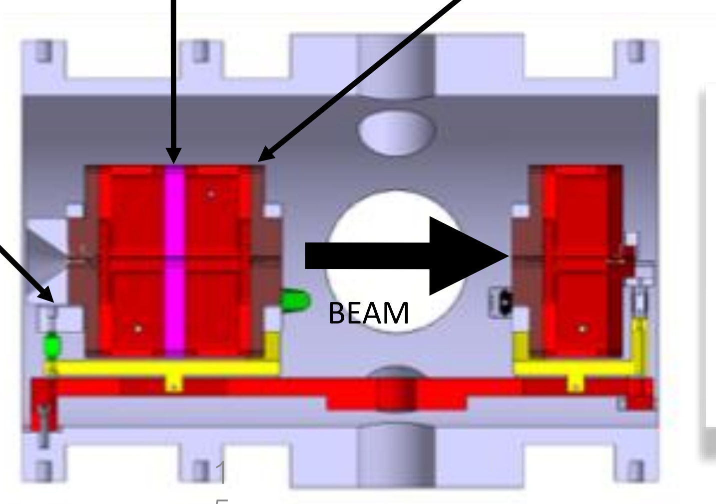
Much Smaller than design beam size (37 nm)

Standard deviation of monitored positions vs. time









All plots :

SD (nm) vs. Time (h)

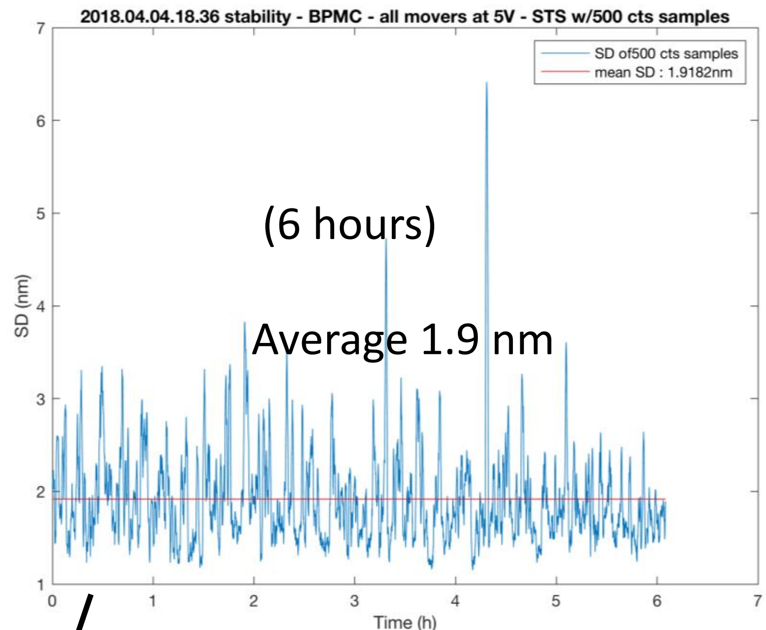
for 100 s raw data samples (sliding window)

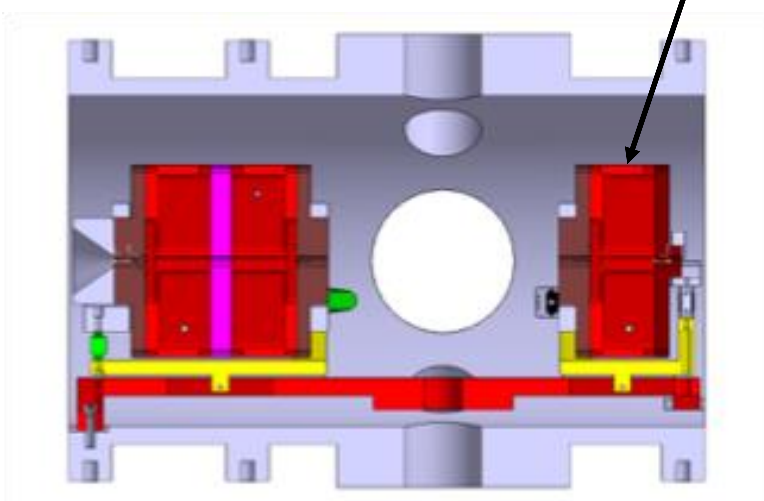
Black arrows show measurement locations

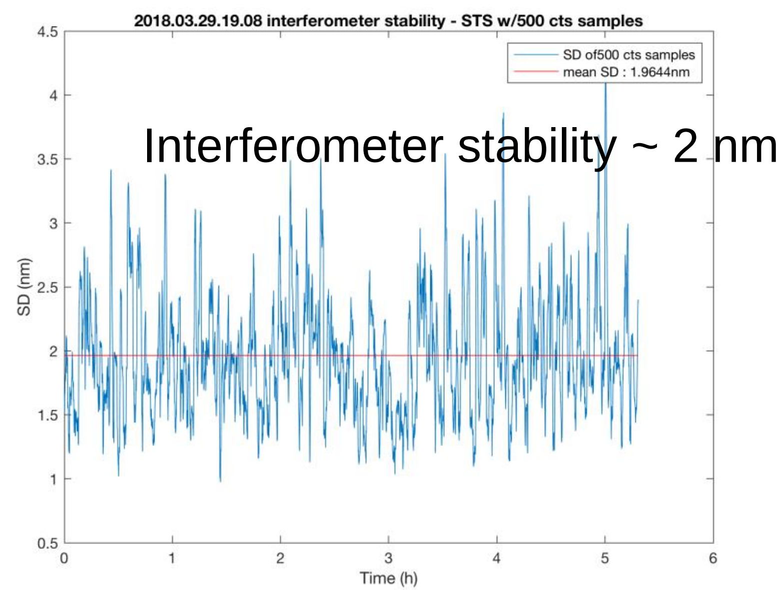
IPBPM Mover System - Short term (vert.) stability

BPM-C movers is much stable
1.9 nm mean SD of vert. displ.

(2 nm is the level of the interferometer's stability checked in situ [on a bench near the IP], at night to avoid local perturbations)







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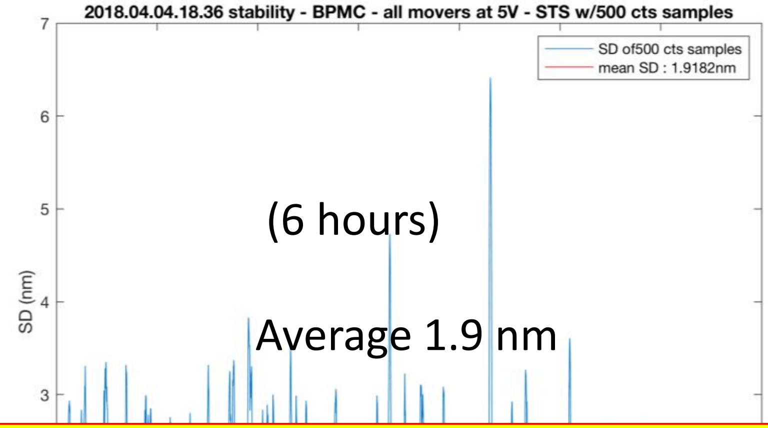
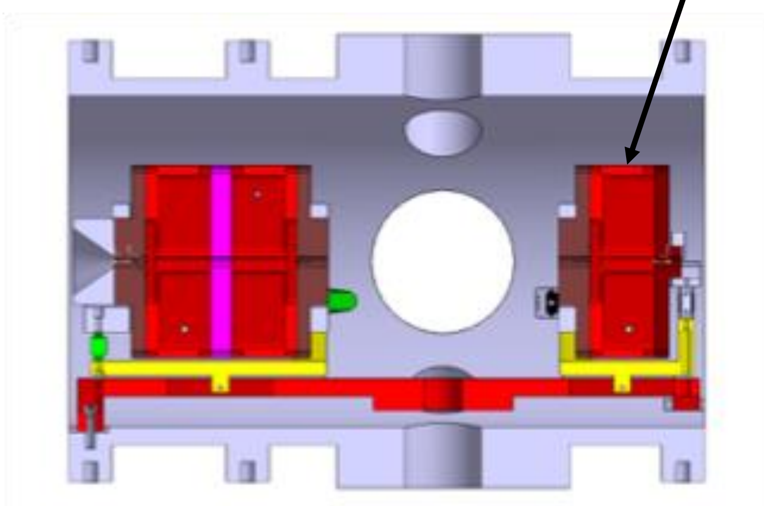
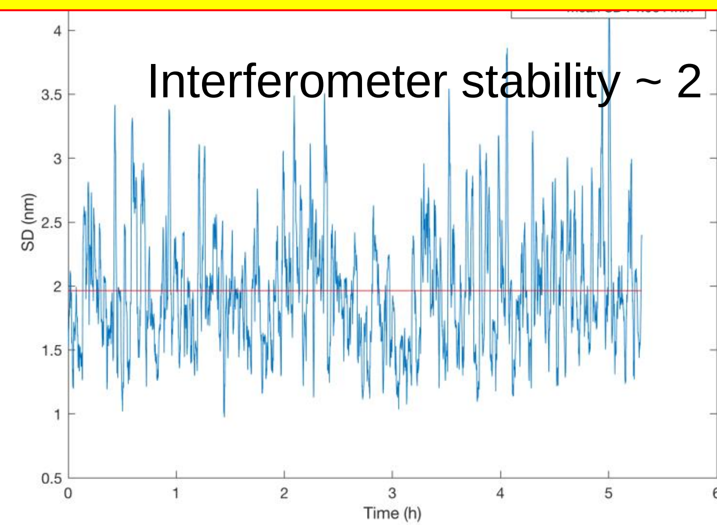
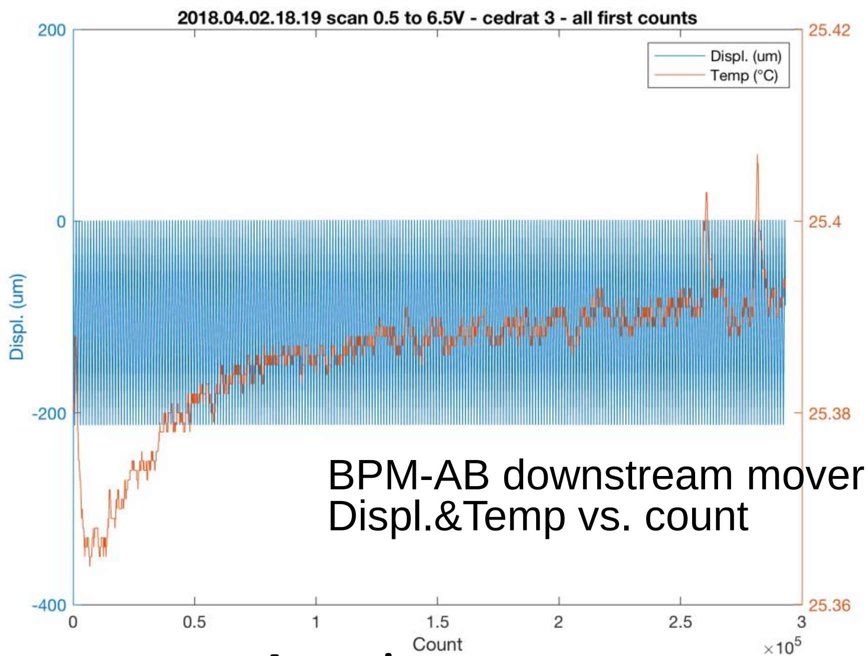


Positions are stable
Measurements limited by monitor's stability (~2 nm)
Much smaller than design beam size





IPBPM Mover System - Calibration



BPM-AB downstream mover
Displ.&Temp vs. count

BPMs vert. scanning from 0.5V to 6.5V (BPM-AB) and 0V to 10V & 4 to 6V (BPM-C);

For wide voltage ranges, 240 scanning cycles performed

Device : SIOS interferometer ; Initial drift and "accidents" removed

Gains quite stable over cycles

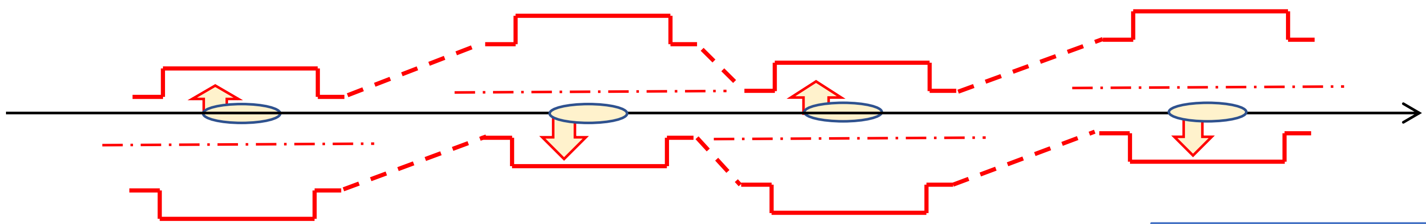
Avg gains

	BPM-AB upstream (cedrat3)		**BPM-AB cavity cover plate B**		**BPM-C (middle flat spot)**	
	avg gain (um/V)	SD (um/V)	avg gain (um/V)	SD (um/V)	avg gain (um/V)	SD (um/V)
	-35.4159	0.0035	-31.0987	0.0018	29.8536	0.0066
	-35.4655	0.0025	-31.3666	0.002	29.8643	0.0094
	From 240 cycles scans ; linear fits calculated for each up and down, then mean gains and SD calculated					

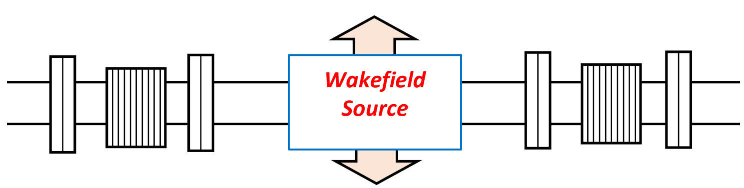
Intensity dependence of beam size at focal point

Static wakefield effect

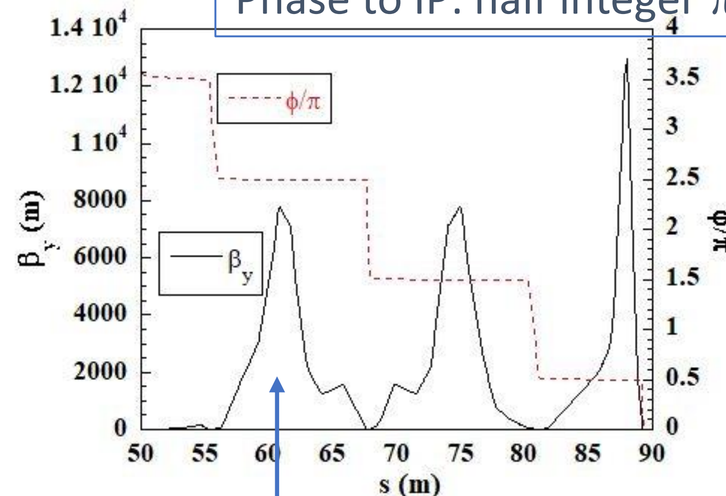
- *Generated by **vacuum component misalignment***
- *Large effect from components at high beta-function region*
- *The effect can be reduced by fine tuning of beam orbit w.r.t. the component center.*



Put wakefield source on mover.
Reduce total wakefield effect.



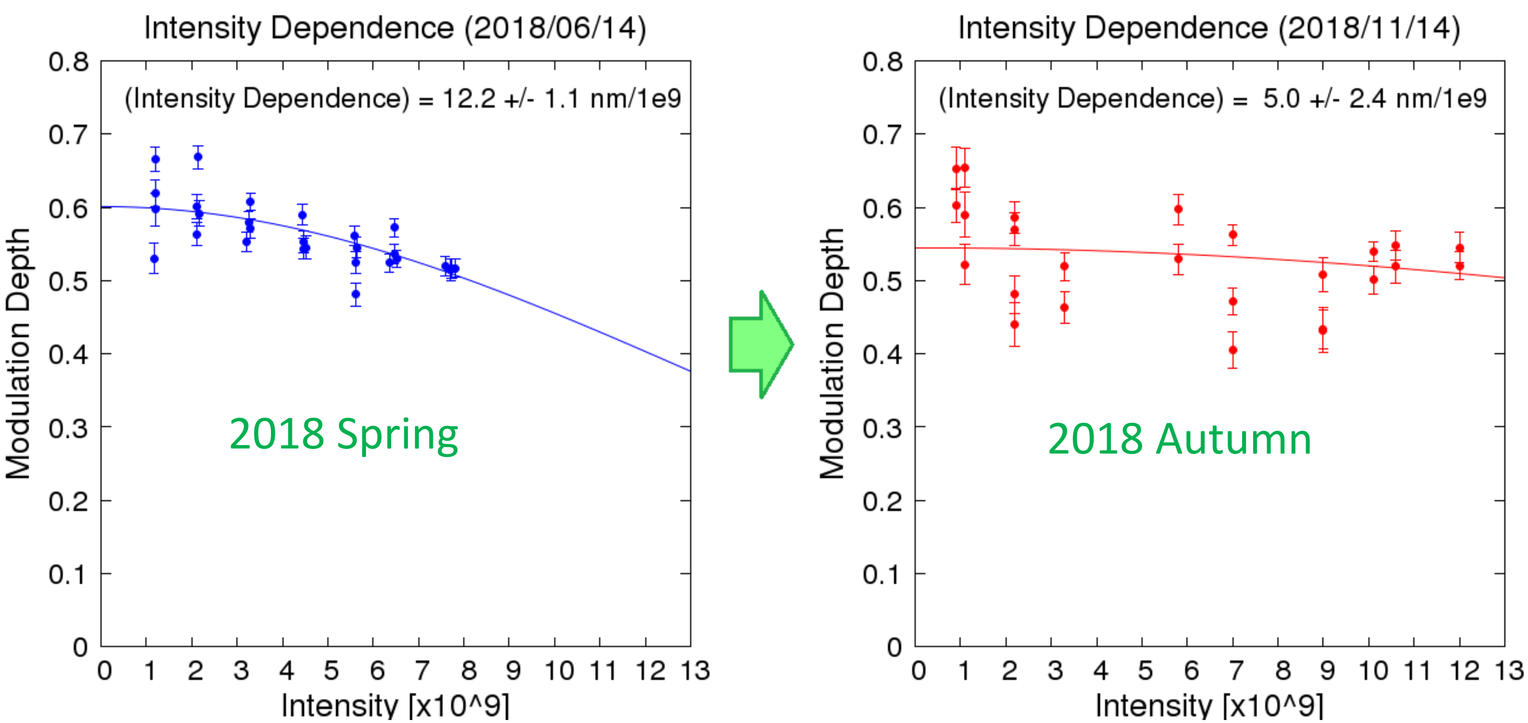
High beta region
Phase to IP: half integer π



Wake source on mover

Reduction of Static wakefield effect

Residual from different shapes of wakepotentials.
By changing wakefield sources, intensity dependence reduced.
Further reduction possible by optimizing wake source on mover.

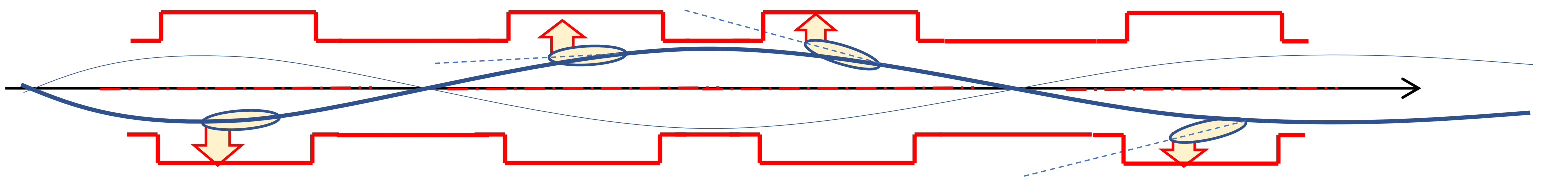


Large “Modulation” of beam size monitor

Small Beam

Dynamic wakefield effect

Generated by **orbit jitter in IP angle phase**
even if the vacuum components are well aligned.
The effect can be reduced only by reduction of orbit jitter.



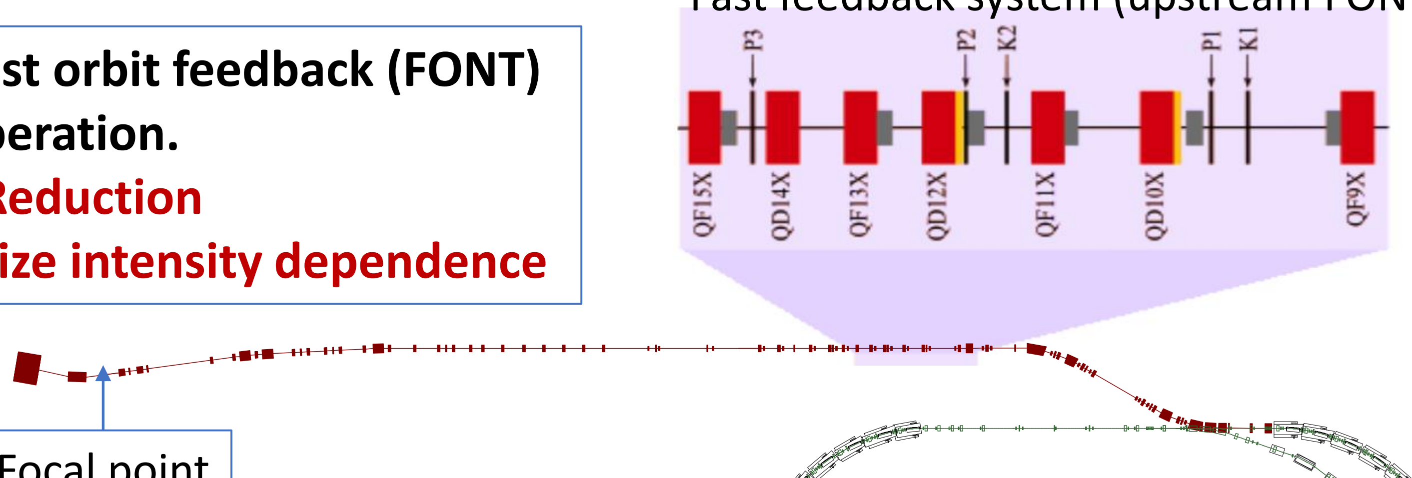
Orbit jitter will be small at ILC, with fast (bunch by bunch) feedback.

Effect of orbit feedback was Tested at ATF2
Introduce fast orbit feedback (FONT, Feedback On Nanosecond Timescales)

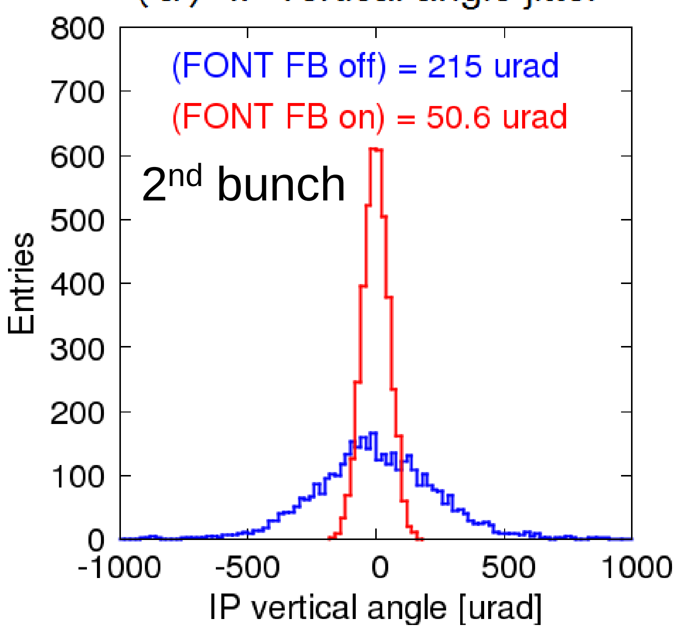
Reduction of Dynamic wakefield effect

Introduce fast orbit feedback (FONT)
2-bunch operation.
Confirmed Reduction
of beam size intensity dependence

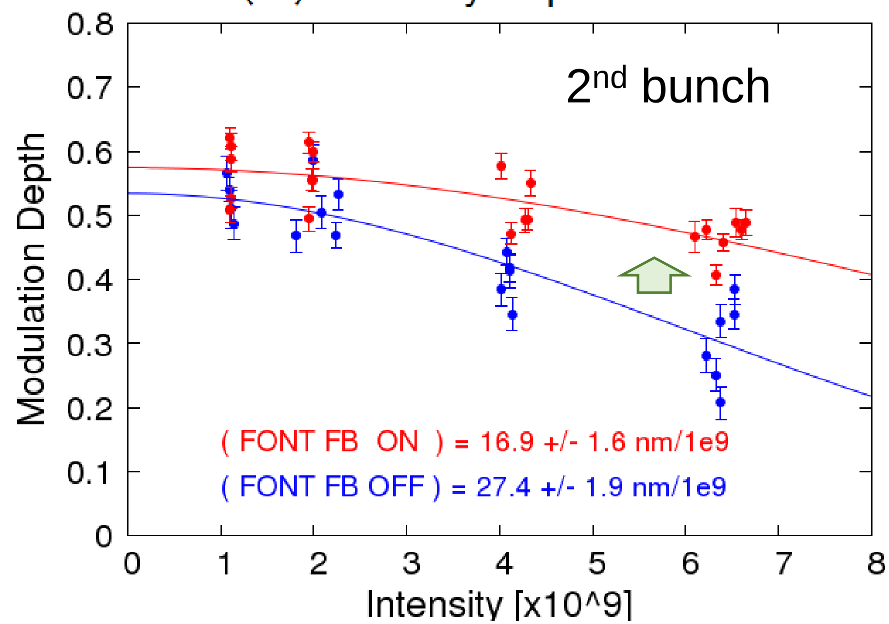
Fast feedback system (upstream FONT)



(a) IP vertical angle jitter



(b) Intensity Dependence



Publications (2018 ~)

- Compensation of orbit distortion due to quadrupole motion using feed-forward control at KEK ATF, D. R. Bett, et.al, Nucl. Instrum. Methods Phys. Res., A 895, 10, 2018
- Evaluation of Beam Halo from Beam-Gas Scattering at the KEK-ATF, R. Yang, et.al., Phys.Rev.Accel.Beams 21 (2018) no.5, 051001
- Beam halo collimation studies and measurements at the Accelerator Test Facility ATF2, N. Fuster-Martínez, et.al., Nucl.Instrum.Meth. A917 (2019) 31-42
- Development of a YAG/OTR monitor for beam halo measurements at the KEK-ATF, R. Yang *et al*., submitted to Phys.Rev.Accel.Beams

- Development of a YAG/OTR Monitor for Beam Halo Diagnostics, R. Yang et al., presented at the 7th International Beam Instrumentation Conference (IBIC 2018), Shanghai, China, 9-13 September 2018, IBIC2018-WEPB02, pp.429-433.
- Performance of Nanometre-Level Resolution Cavity Beam Position Monitors at ATF2, T. Bromwich et al., presented at the 9th International Particle Accelerator Conference (IPAC 2018), Vancouver, Canada, 29 April - 4 May 2018, TUZGBD5
- Development of a Low-Latency, High-Precision, Beam-Based Feedback System Based on Cavity BPMs at the KEK ATF2, R. Ramjiawan et. al., 2018. 4 pp. IPAC2018-WEPAL025

ATF2 project meeting
NOV. 20-22, 2018, @KEK

International ATF collaboration will be continued.
As a facility of nanobeam R&D, for ILC and CLIC