A_RD_10:
The nanometer stabilization studies at ATF2 since 2013

also collaboration with IFIC Valencia, CERN, OXFORD University and Korean University,
for nanometer stabilization program

presented by

Toshiaki Tauchi (KEK)

2016 Joint workshop of TYL/FJPPL and FKPPL, 18-20 May 2016, KIAS, Seoul, South Korea

FJPPL (TYL) application 2016-2017

Fiscal year April 1st, 2016 – March 31st, 2017

ID: A_RD_10	Title: Nanometer stabilization studies at ATF2

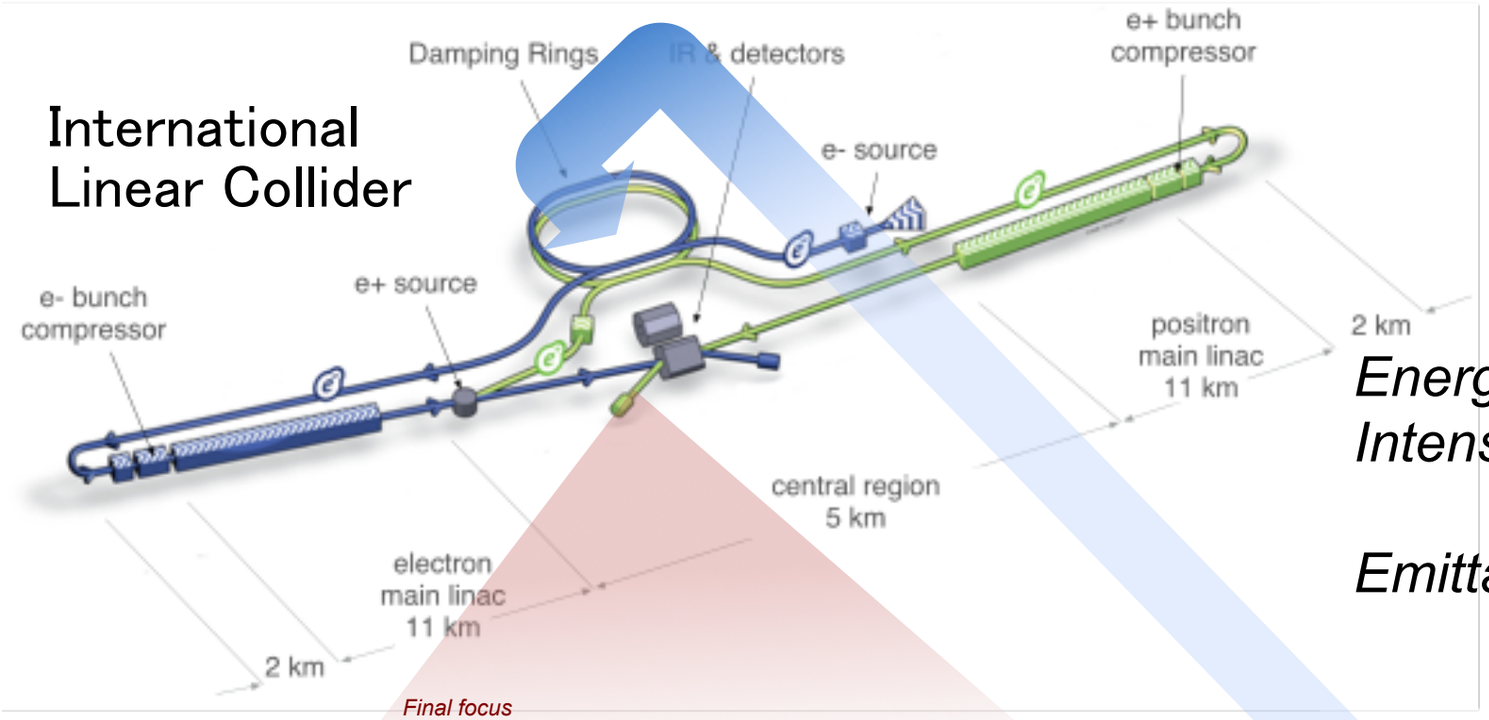
	French Group			Japanese Group		
	Name	**Title**	**Lab./Organis.**	**Name**	**Title**	**Lab/Organis.**
Leader	Andrea Jeremie	IRHC	LAPP/IN2P3	Nobuhiro Terunuma	Prof.	KEK
Members	Philip Bambade	DR1	LAL/IN2P3	Toshiaki Tauchi	A.Prof.	KEK
	Renjun Yang	PhD st.	LAL/IN2P3	Takashi Naito	A.Prof.	KEK
	Sandry Wallon	IR2	LA/IN2P3L	Kiyoshi Kubo	Prof.	KEK
	Frédéric Bogard	IE2	LAL/IN2P3	Shigeru Kuroda	A.Prof.	KEK
	Patrick Cornebise	IE2	LAL/IN2P3	Toshiyuki Okugi	A.Prof.	KEK
	Hayg Guler	CDD	LA/IN2P3L	Sakae Araki	Eng	KEK
	Viacheslav Kubytskyi	CDD	LAL/IN2P3	Hiroshi Yamaoka	Eng	KEK
	Laurent Brunetti	IR2	LAPP/IN2P3			

Funding Request from France

Description	€/unit	Nb of units	Total (€)	Requested to:
LAPP travel to KEK and FJPPL: meetings and measurements with sensors		2 travels	7000	IN2P3
LAL travel to KEK and FJPPL (meetings, installation work, beam tests)		4 travels	10000	IN2P3
LAL beam collimator transport to KEK		1 transport	1500	IN2P3
Total			18500	

Funding Request from KEK

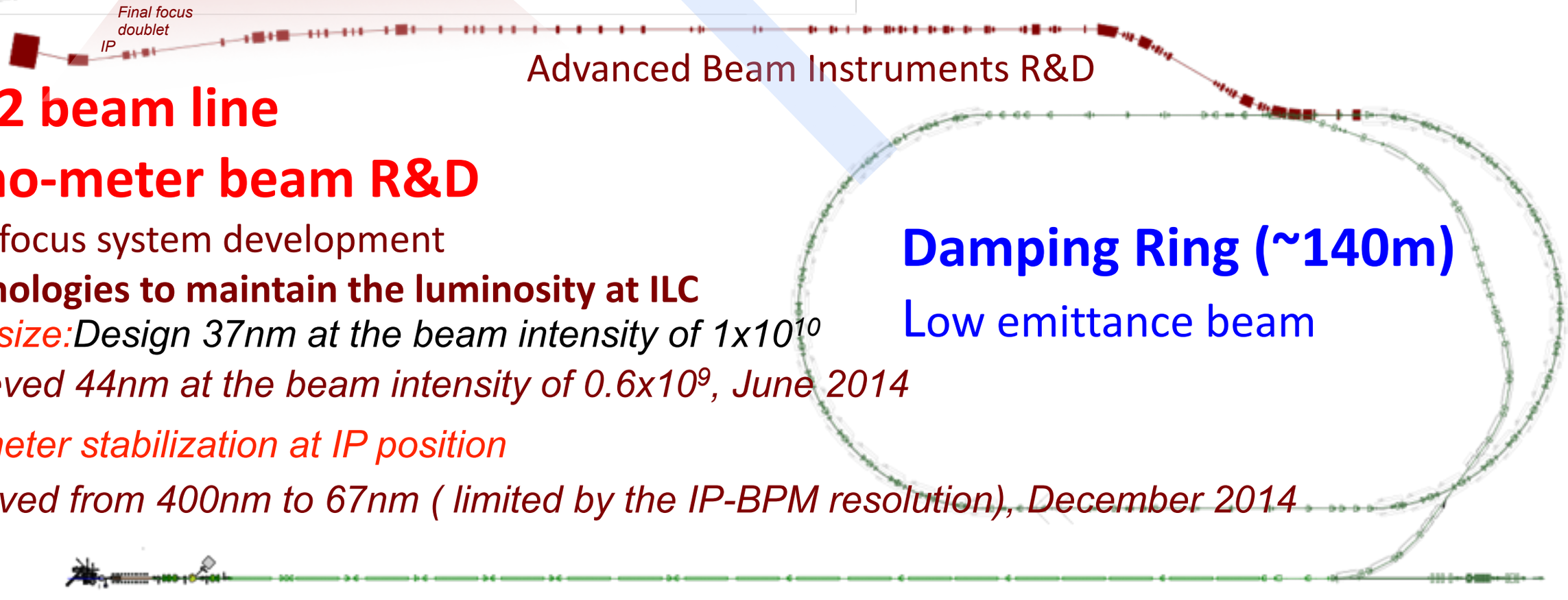
Description	k¥Unit	Nb of units	Total (k¥)	Requested to:
Travel	150	3 travel	450	KEK
Visit to France	20/day	27.5 days	550	



ATF at KEK, Japan

Accelerator Test Facility

Energy: 1.3 GeV, Repetition: 3.12 Hz since 2012
Intensity: 1x10^{10} e-/bunch (max. 2x10^{10}),
1~20 bunches/pulse
Emittance: Design, 1 nm(H)/ 10 pm(V),
Achieved 4 pm(V), May 2003



Advanced Beam Instruments R&D

ATF2 beam line

Nano-meter beam R&D

Final focus system development

Technologies to maintain the luminosity at ILC

Beam size:Design 37nm at the beam intensity of 1x10^{10}

Achieved 44nm at the beam intensity of 0.6x10^{9}, June 2014

Nanometer stabilization at IP position

Achieved from 400nm to 67nm (limited by the IP-BPM resolution), December 2014

Damping Ring (~140m)

Low emittance beam

Cs_2Te Photocathode RF Gun

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

Activities in the fiscal year of 2015

KEK

1. Host of the ATF and ATF2 at KEK, e.g. commissioning, tuning the beam
2. The front-end electronics of the nanometer resolution beam position monitors (IPBPMs) and the software to acquire the IPBPM waveforms.
3. Nanometer stabilization at IP in collaboration with Korea University and Oxford University groups as well as LAL (the piezo mover system for the IPBPMs) and LAPP (the stable support system for the final doublet) , first studies on the position resolution of the IPBPM at nanometer level.

LAL

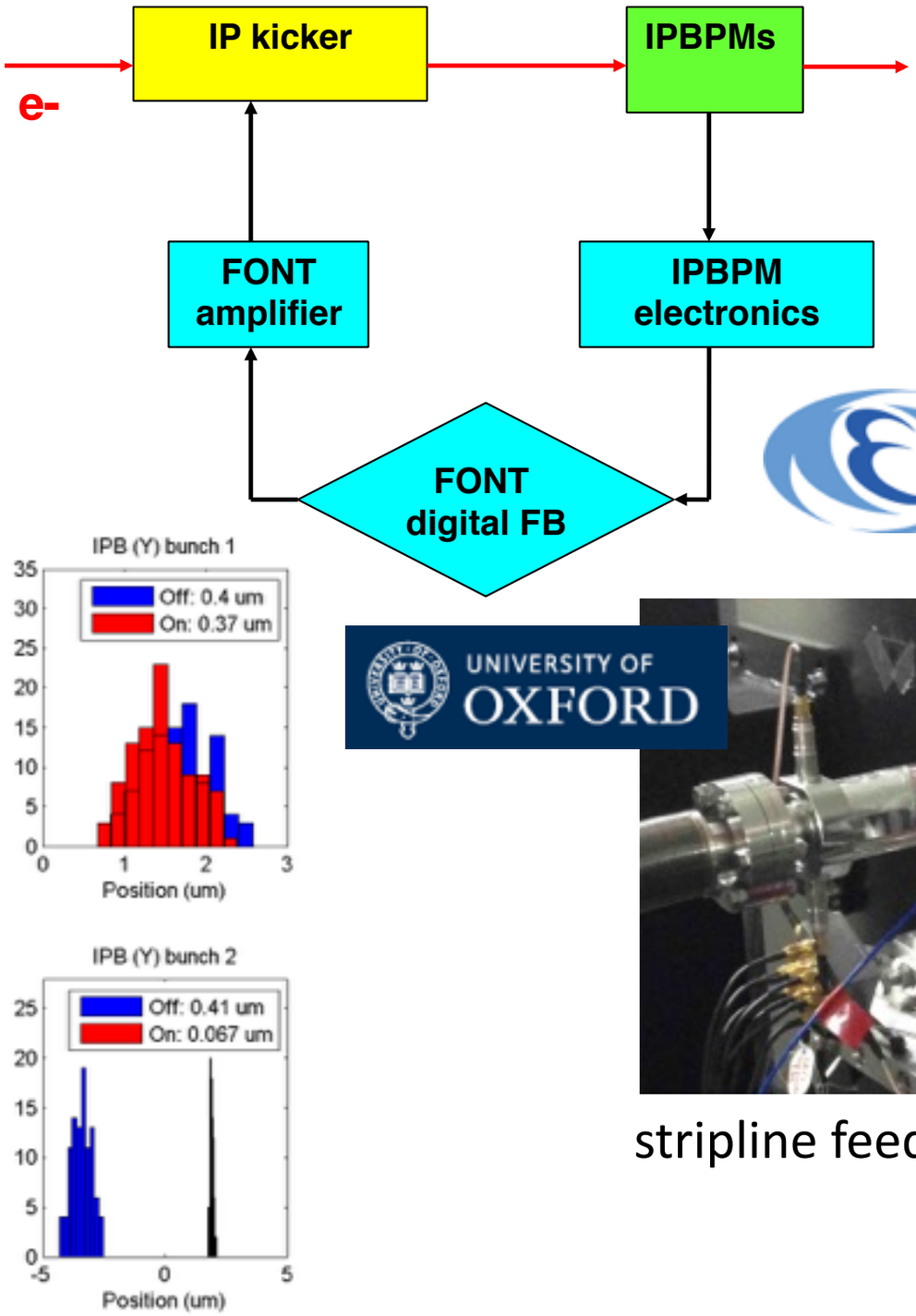
1. The measurement of the beam halo profile as a function of vacuum pressure levels in the ATF damping ring, where the halo control is essential for reduction of backgrounds in the IP beam size measurement.
2. The clear identification of cuts in the halo from upstream apertures such as beam pipe
3. Installation of the collimator system in collaboration with the IFIC-Valencia group in Spain
4. Two Ph.D's defended by Shan LIU who was awarded the 2015 FCPPL Best Thesis Prize for Outstanding Detector Development Work and Oscar BLANCO (50% on ATF2) .
A new Ph.D student Renjun YANG whose visit to ATF in February-March 2016 supported by the TYL-FJPPL Student & Early Stage Researcher Secondment program
5. Host of the ATF2 project meeting at LAL, 12-15 January 2016

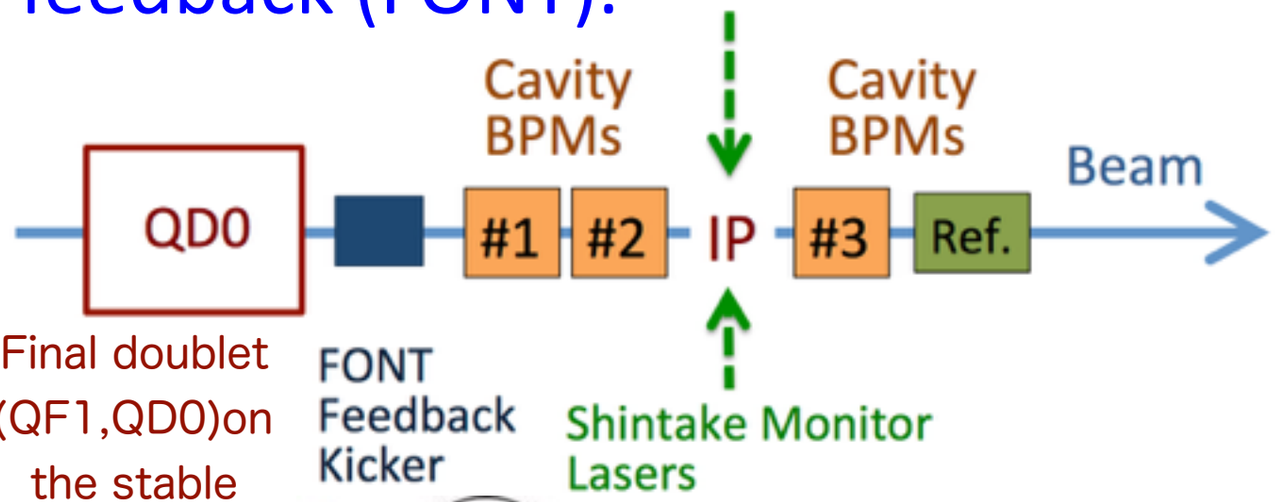
LAPP

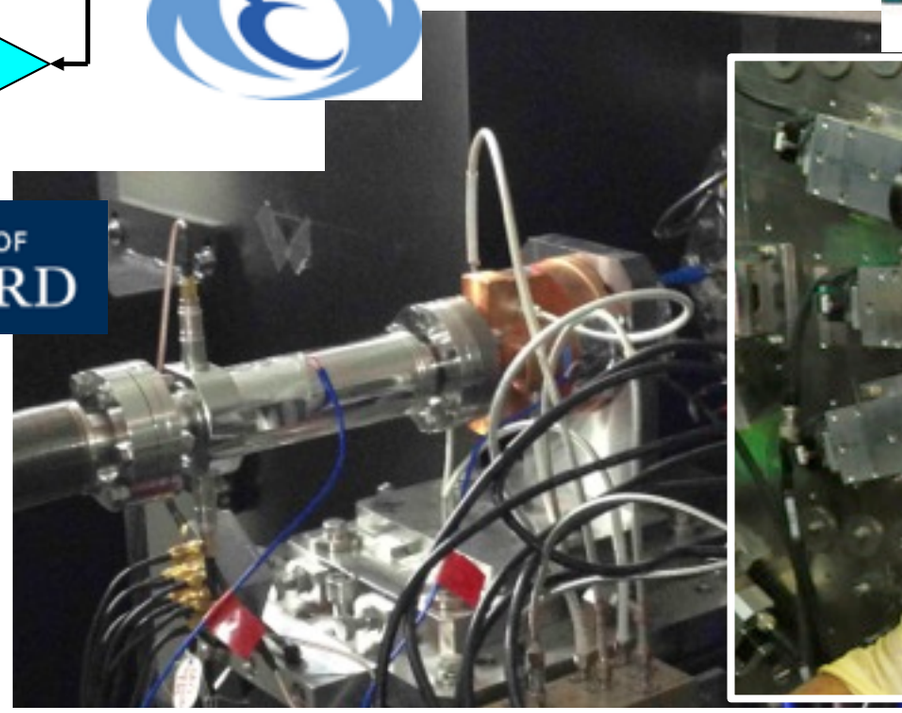
1. Identification of the vibration source
2. Commissioning of the GM feedforward system in collaboration with CERN group
3. The design, fabrication and transport of a new QF1FF Final Focus magnet support
   - an external vibration source deteriorates the vibration behavior in horizontal direction

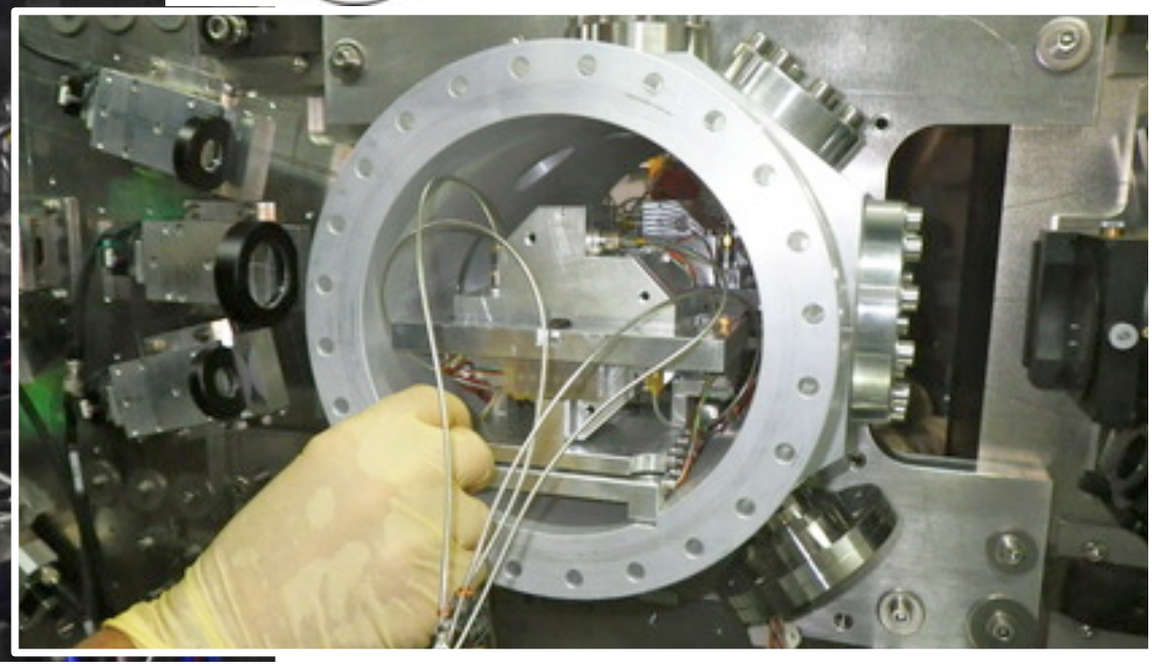
Nanometer Stabilization at ATF2

Stabilize the second and later bunches by using the first bunch as a pilot bunch for the intra-train fast feedback (FONT).





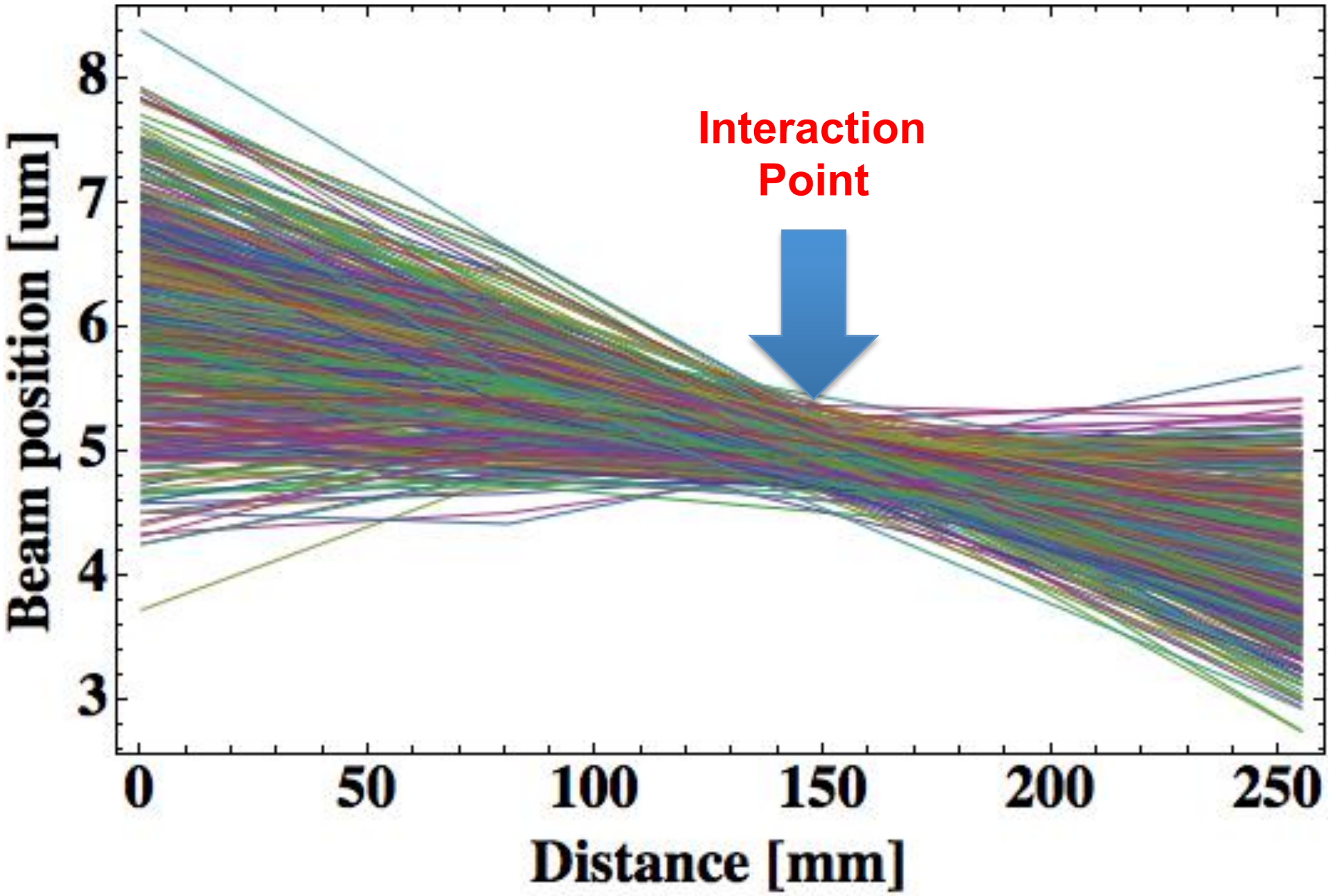




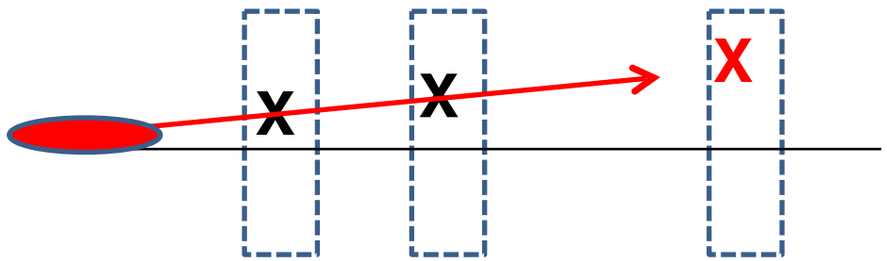
stripline feedback IP kicker

IP-BPMs on the movers in vacuum chamber

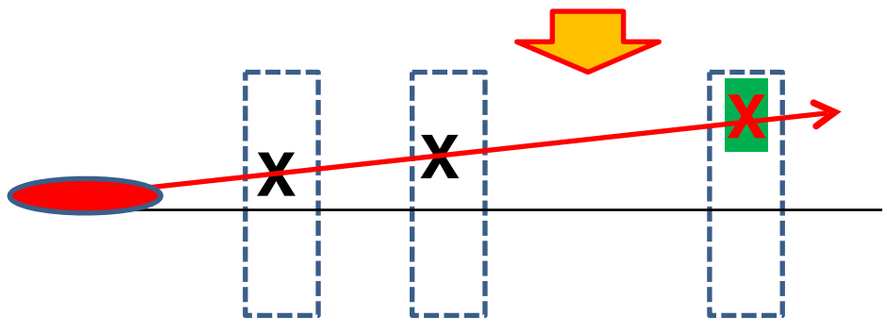
Orbit reconstruction



The results of IPBPM resolution test in Dec 2015 at ATF2

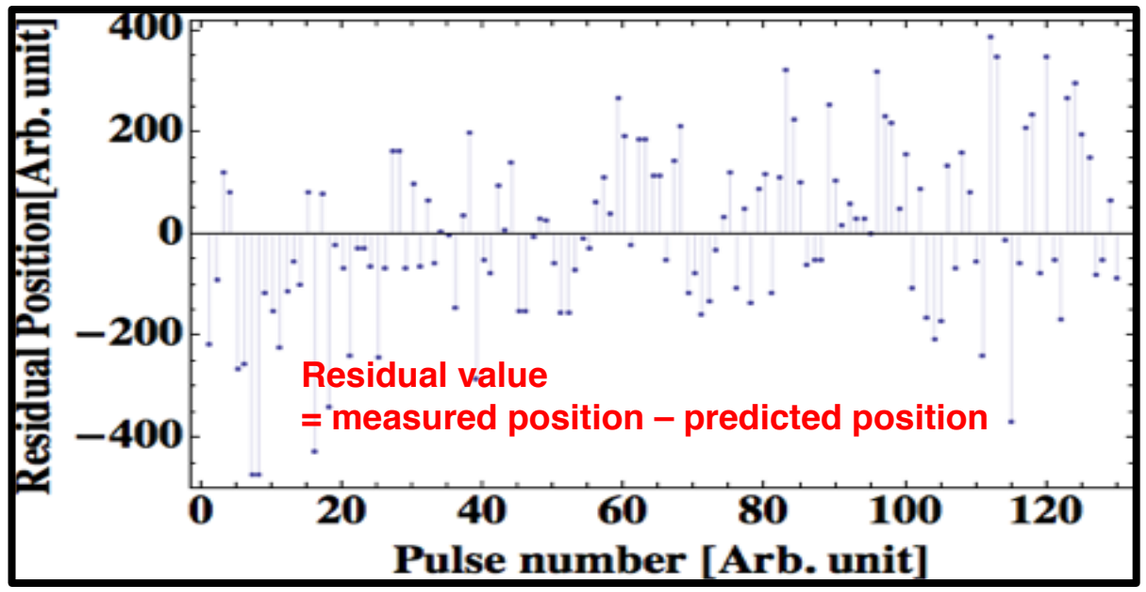


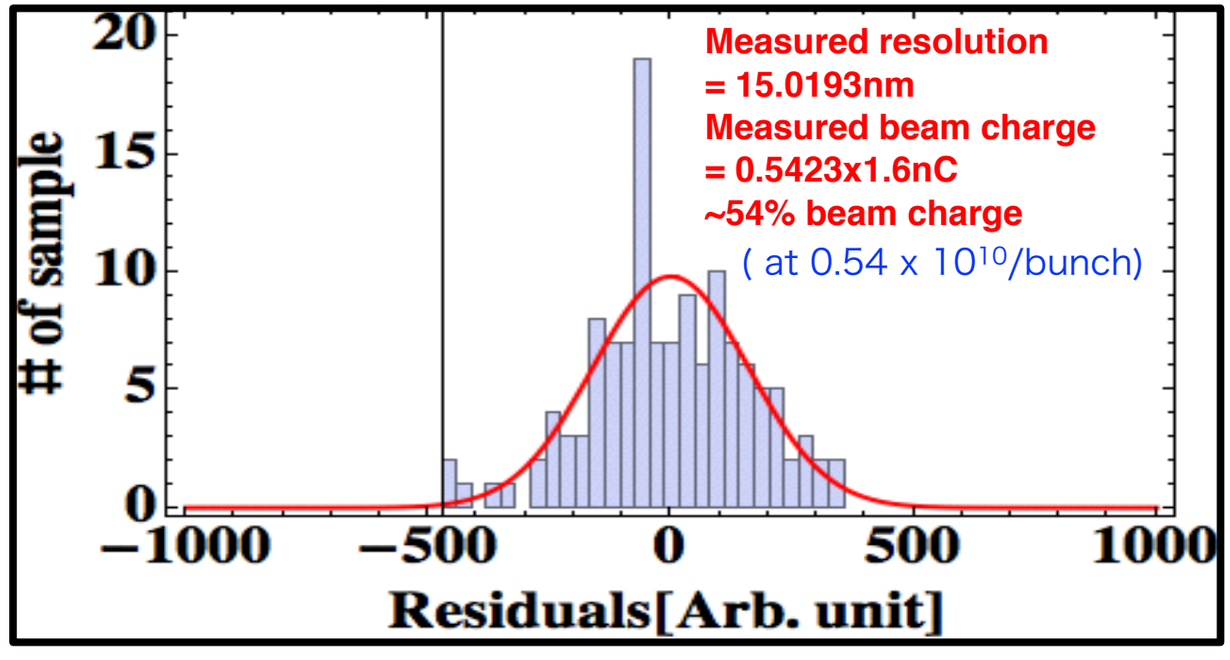
Beam position prediction

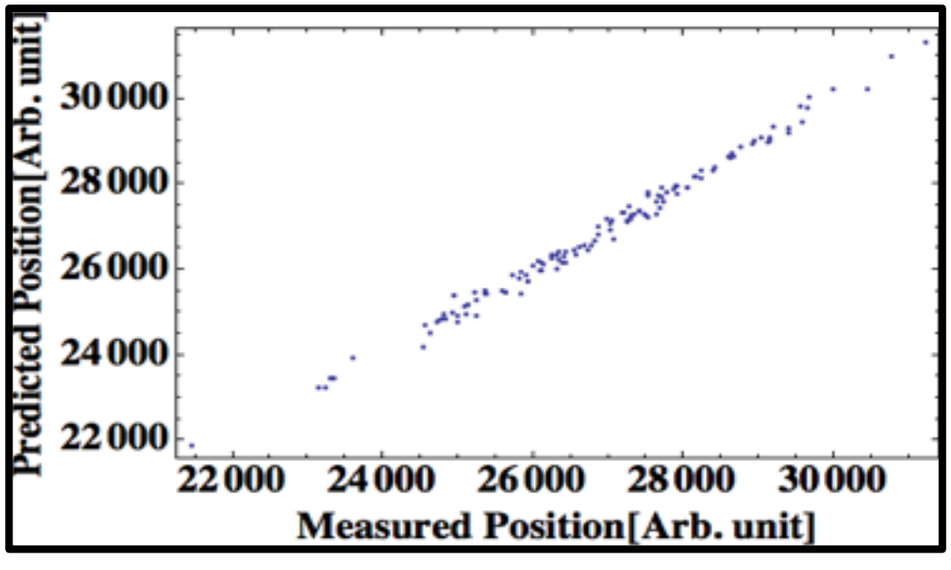


Beam position measurement

Convert to residual



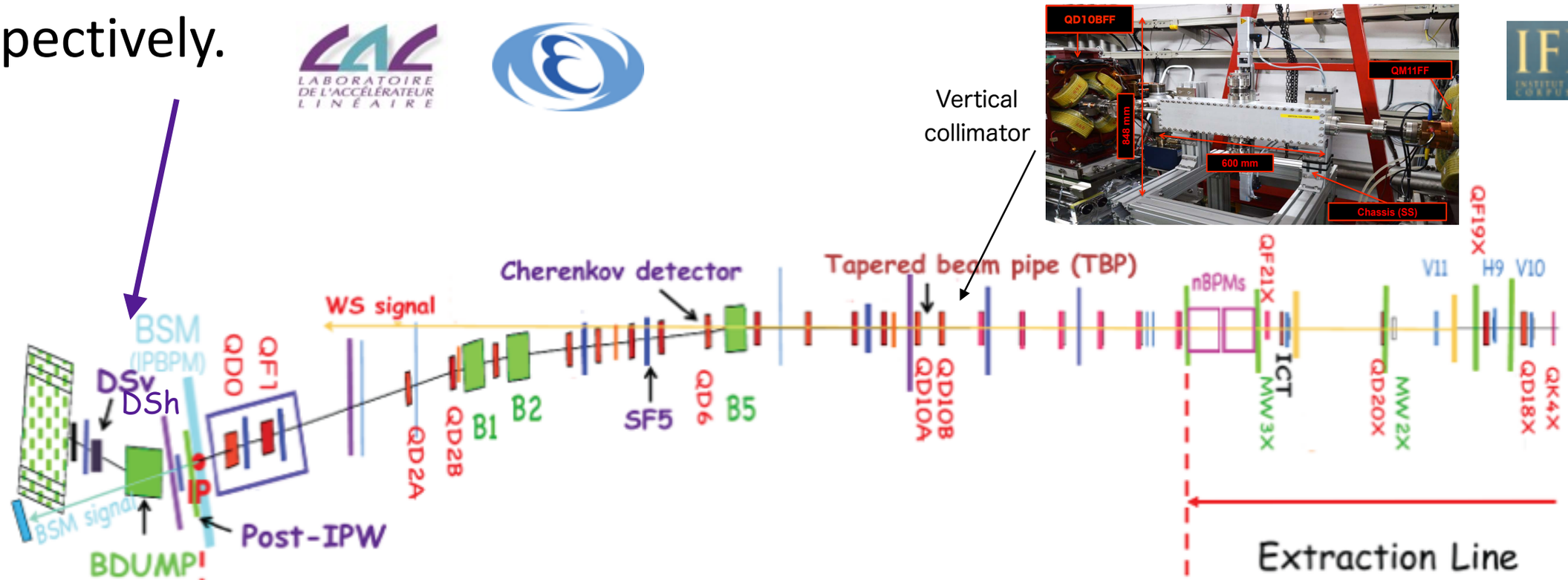




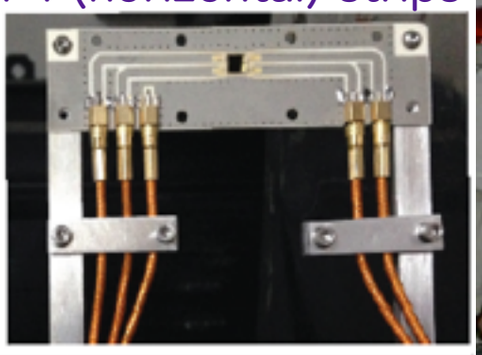
Norm. Resolution = Geo. factor x $\frac{\text{RMS of residual}}{\text{Calibration factor}} \times \frac{\text{Measured charge}}{\text{Nominal charge}}$ = **8.1nm**

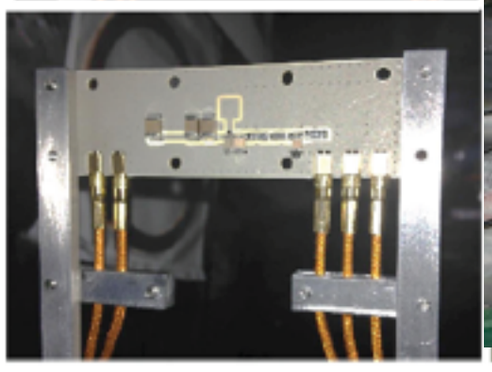
(1 x 10¹⁰/bunch)

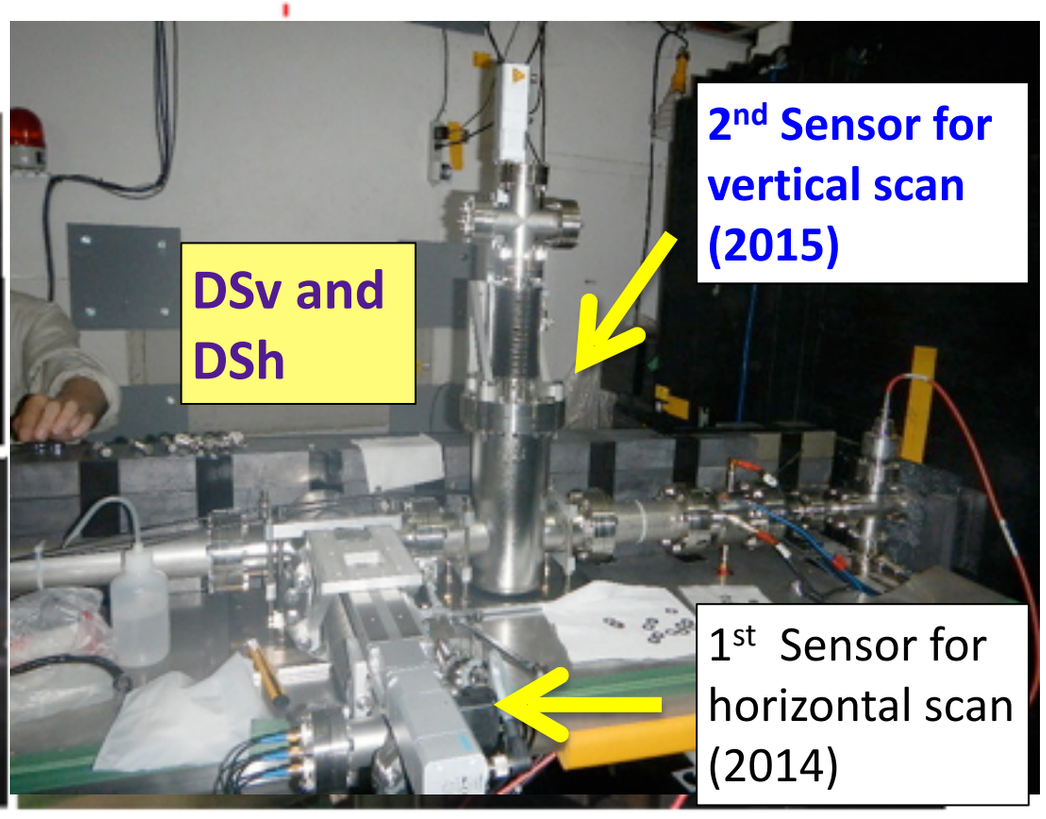
Horizontal and Vertical Diamond Scanners (DSh, DSv) 1.5 m after BDUMP magnet. Installed + commissioned in Nov-Dec 2014 and May-June 2015, respectively.



(Vertical) Diamond sensor with 4 (horizontal) strips

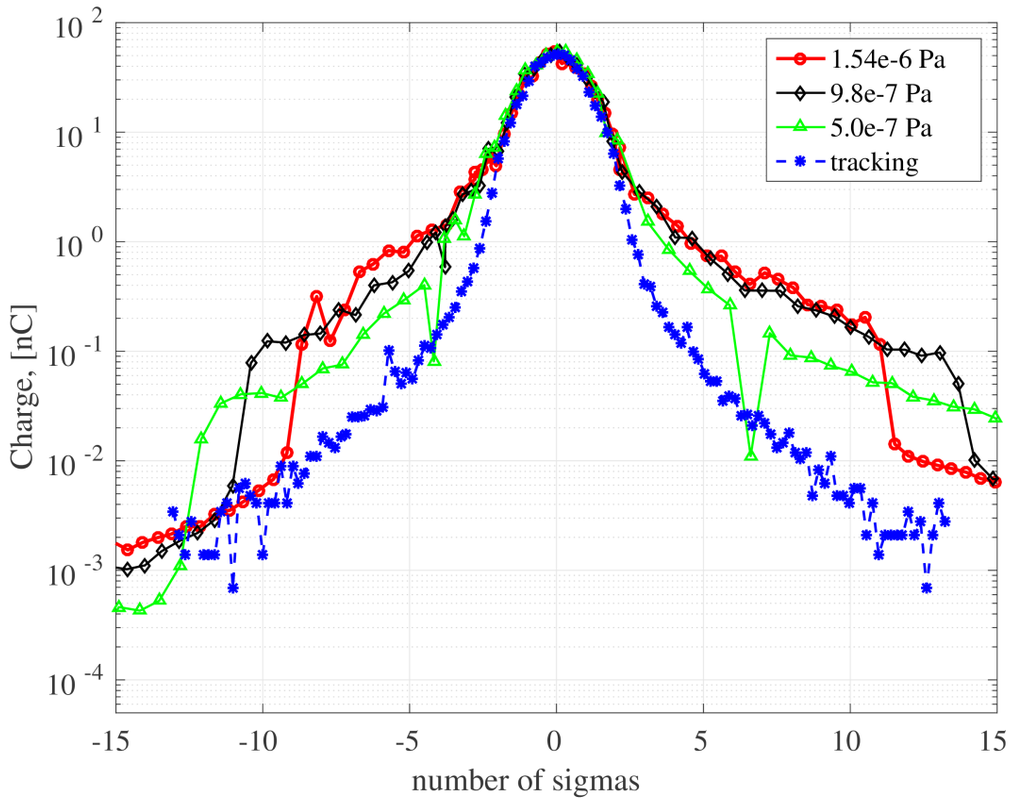


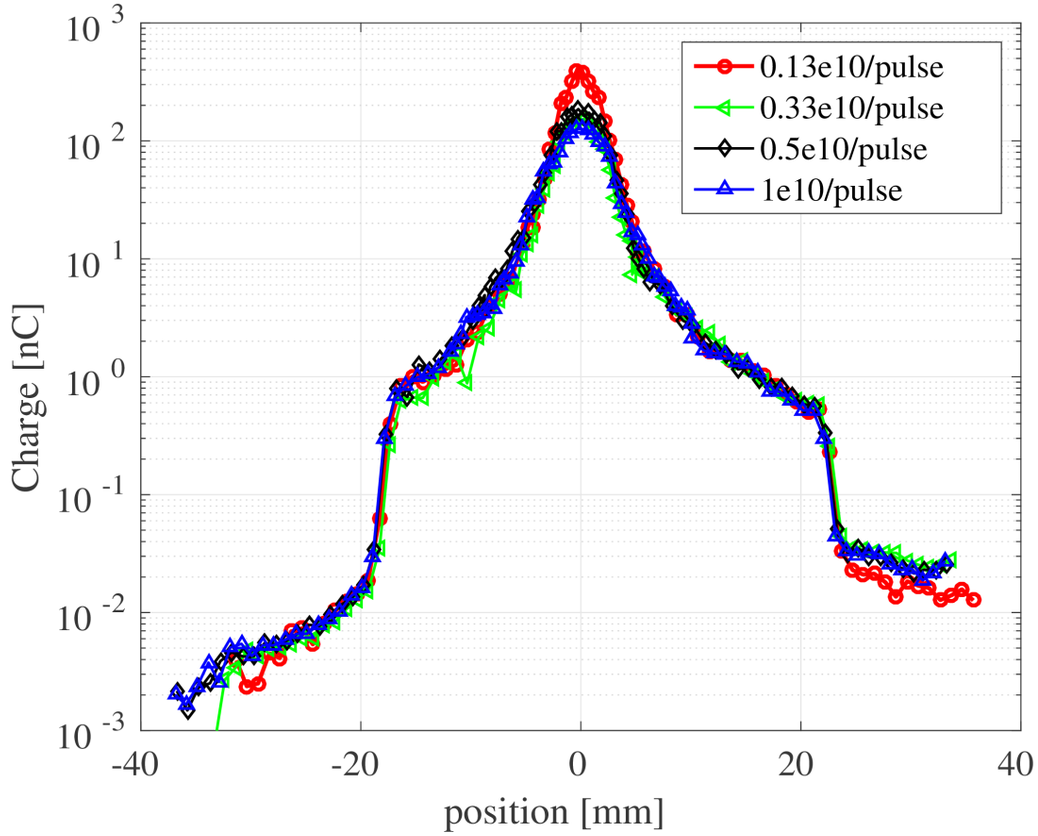




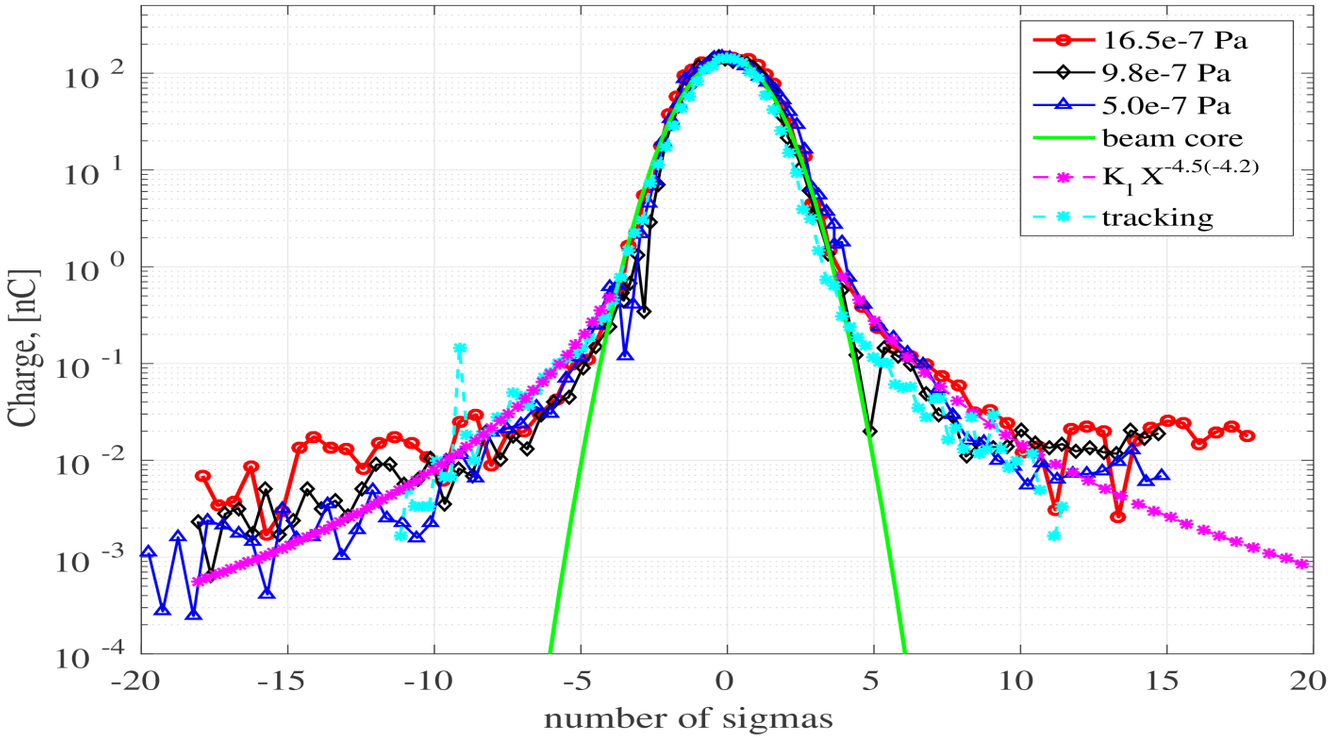
Measurements of Beam Halo

1. Vertical direction as a function of DR vacuum pressure and the beam intensity





2. Horizontal direction as a function of DR vacuum pressure

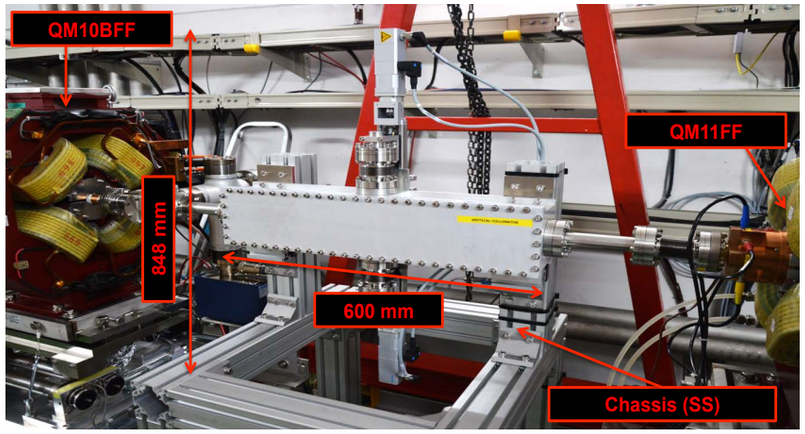


1. Vertical beam halo is mainly determined by elastic beam gas scattering in the damping ring(DR). The beam size increases with the beam intensity as expected from the intra-beam scattering.

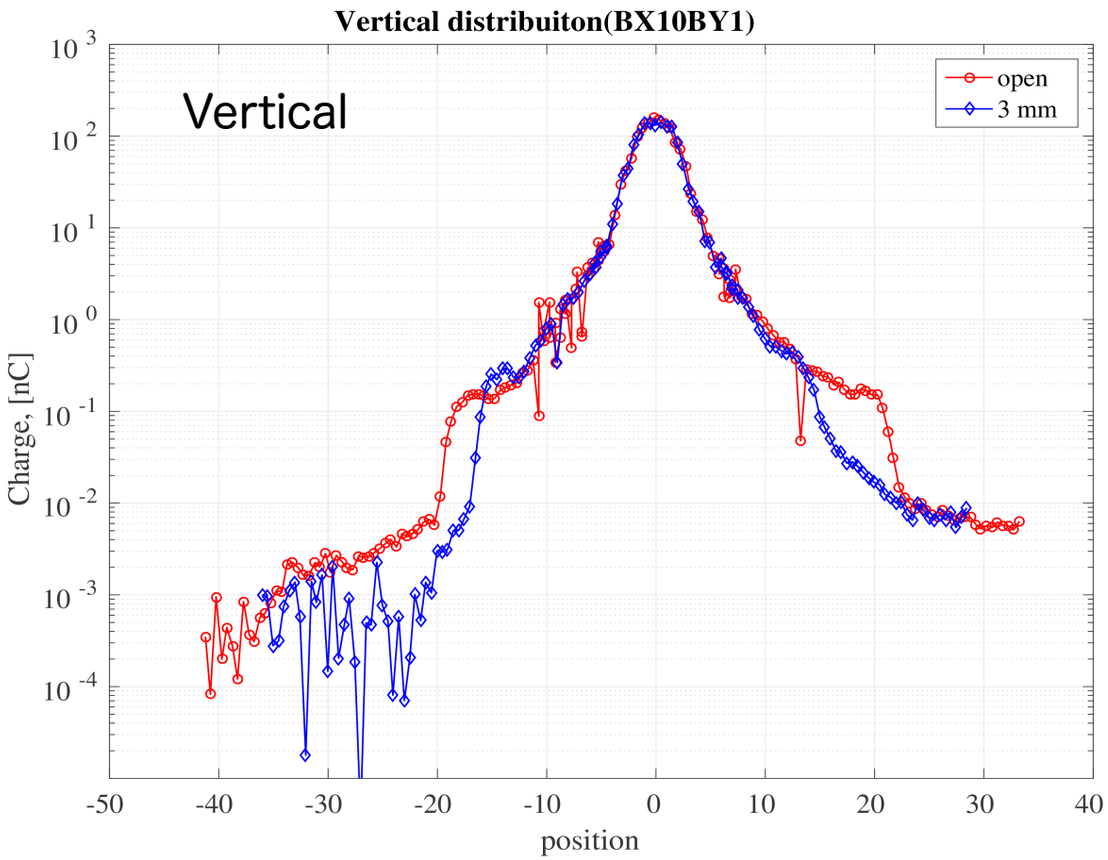
2. Horizontal beam halo is dominated by the other source for less dependence on the DR vacuum pressure.

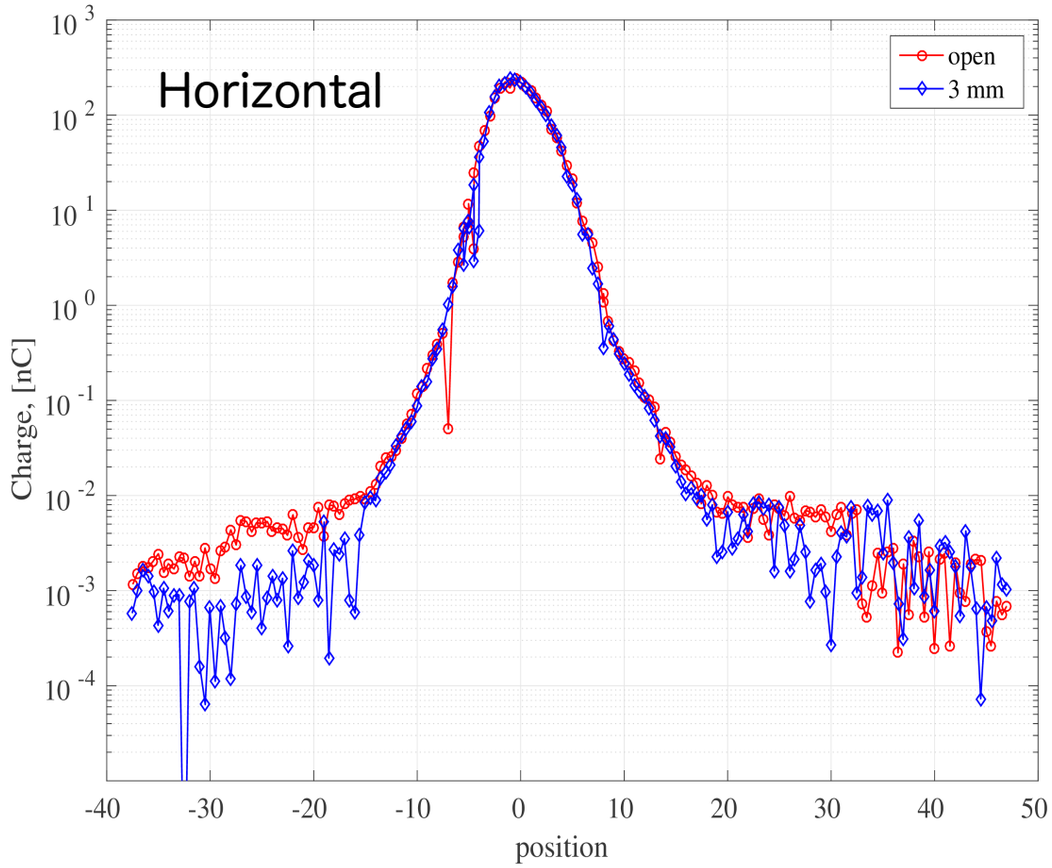
RJ. Yang, Poster for the IPAC 2016, 4 May 2016

Beam cut by collimator



- Beam optics: bx10by1
  beam intensity: 0.3e10 /pulse
  damping ring vacuum: 5.07e-7 Pa
- Collimator setting: open (red line)and closed to 3 mm (blue line)



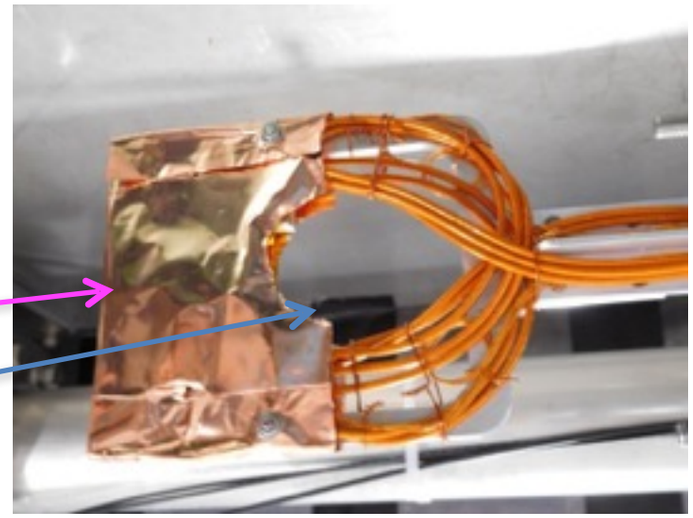


1) Vertically, symmetric cuts by vertical collimator are observed
2) In vertical plane, less residual halo beyond cut by collimator (fewer secondary particles when closing collimator)
3) Horizontally, less residual halo on low energy side when collimating vertically

RJ. Yang, presented at the ATF operation meeting, 1 April 2016

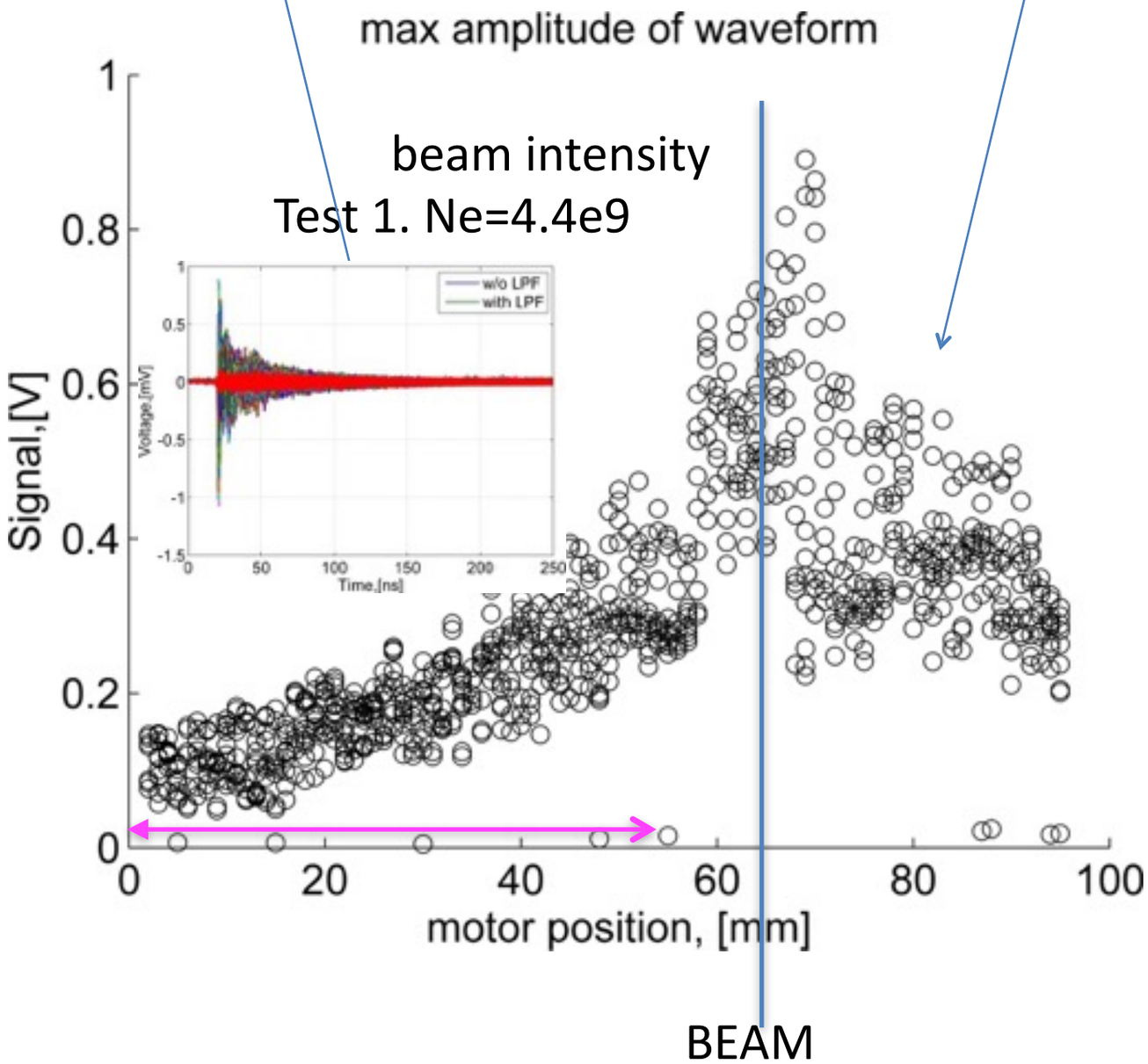
Issue to be mitigated : The electromagnetic Pickup questions.

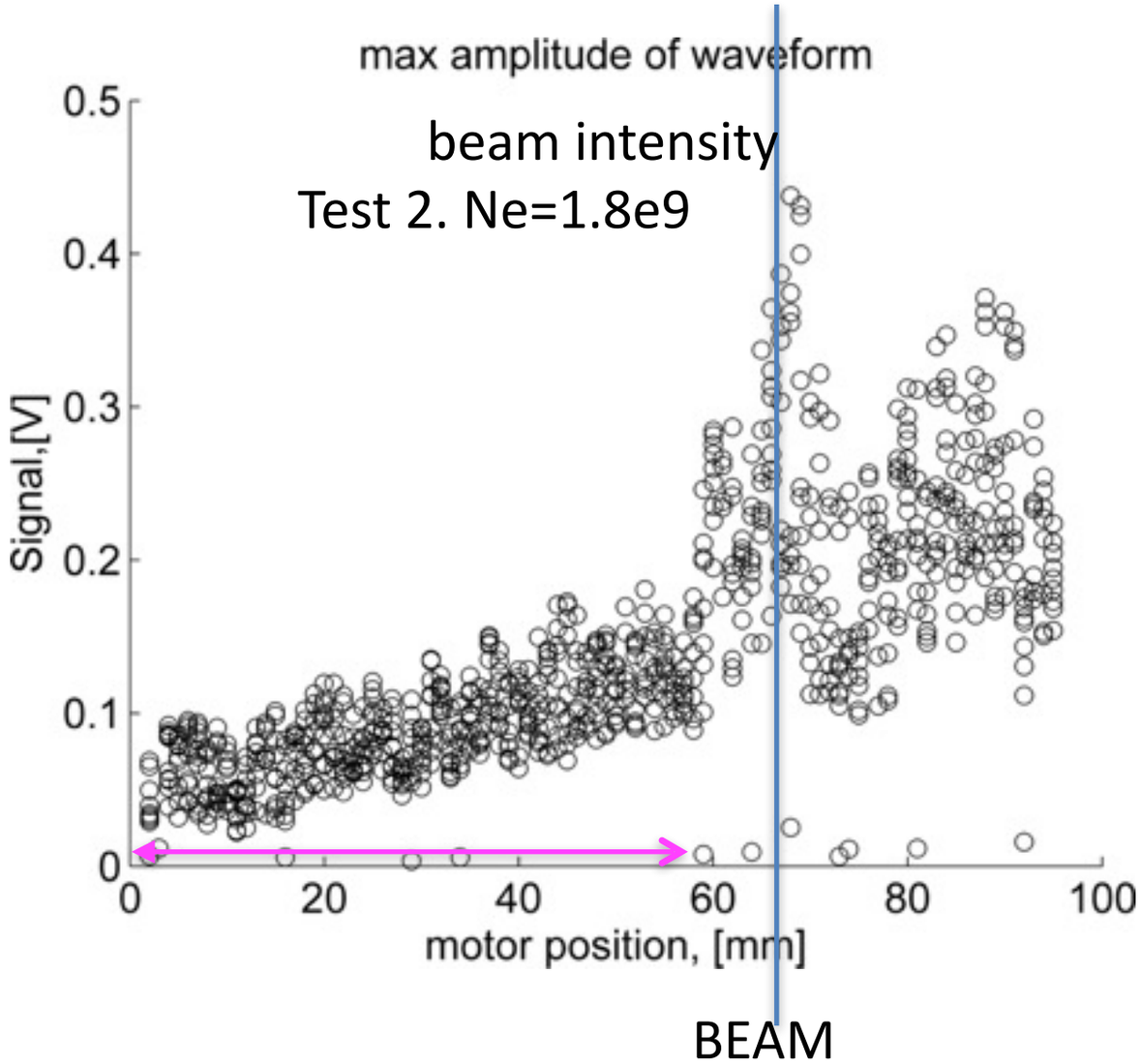
For example by the Vertical Diamond Sensor (DS).



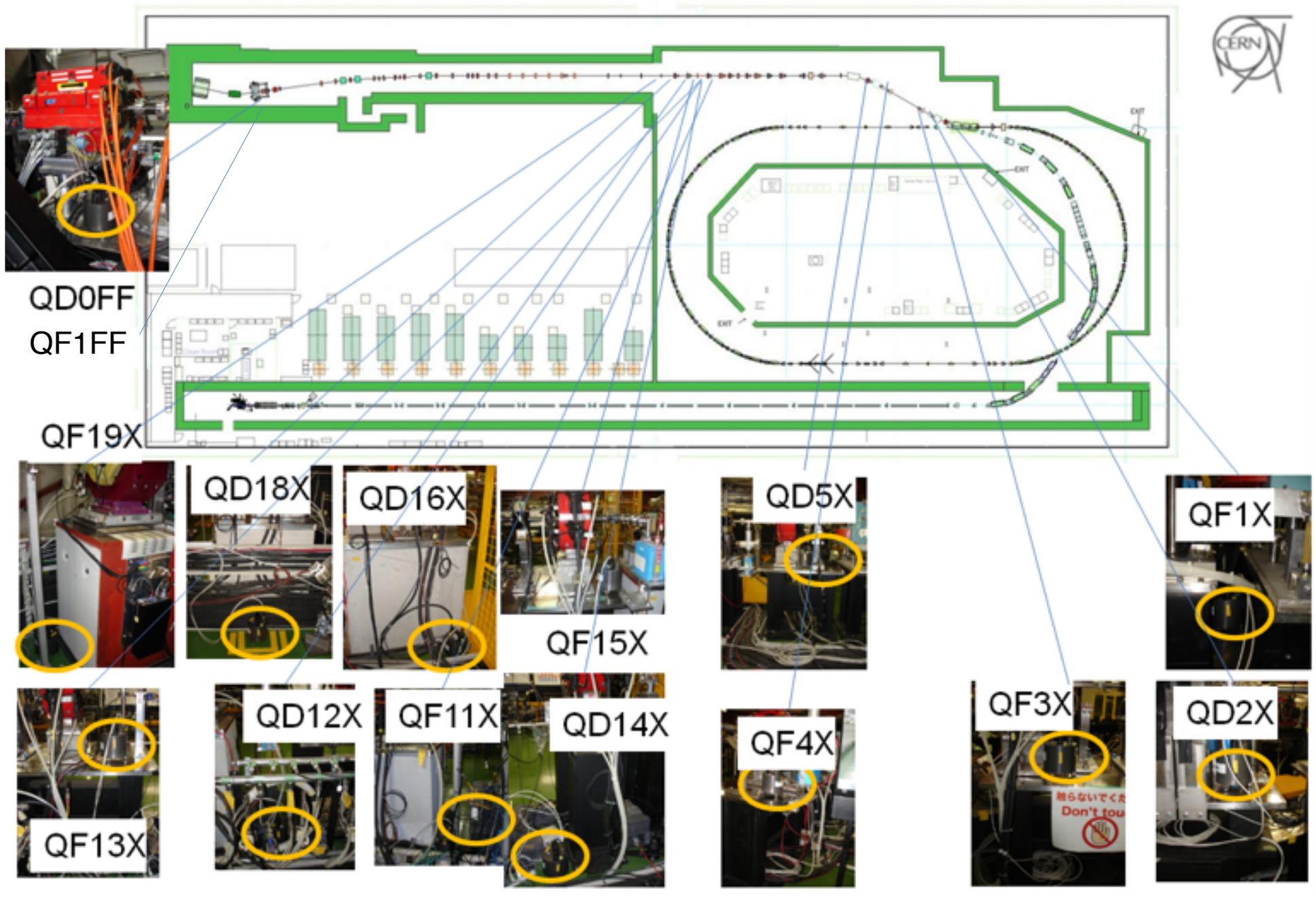
Shielding closed

Shielding open



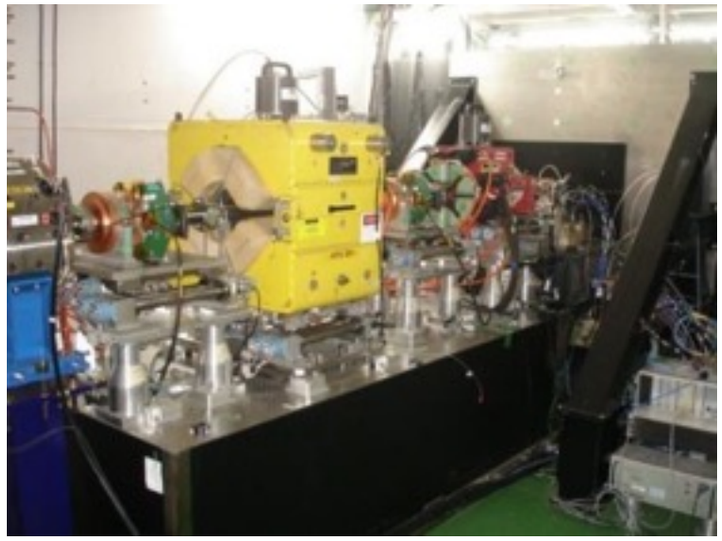


14 Guralp CMG-6T sensors all along ATF2 for GM studies and GM feedforward



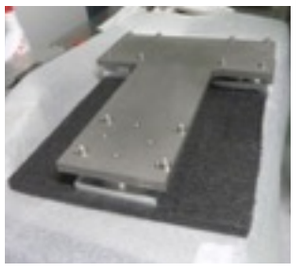
Guralp CMG-6T: 0.5Hz-100Hz, two directions connected (vertical and horizontal can be placed parallel or perpendicular to beam direction), mainly in Extraction line, 2 sensors easily relocated

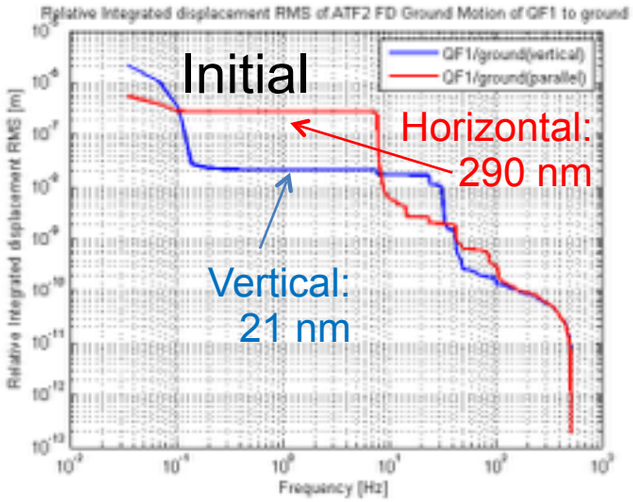
Vibration source identification and mitigation

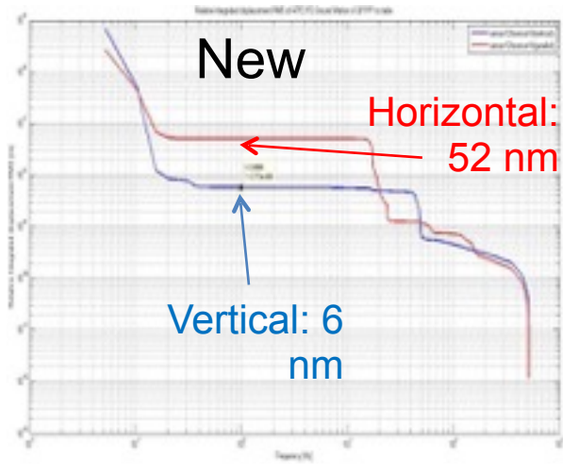


New QF1FF magnet (better multipole behavior) 3 times heavier => needed support study

- New support design, fabrication, installation in 2015
- Comparison between initial and new support



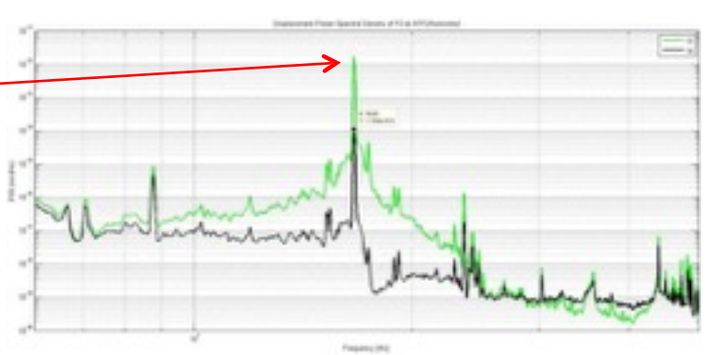




Rel. Displ. RMS @ 1Hz QF1FF vs tabletop	Initial support		New support
Horizontal	290 nm	÷~6	52 nm
Vertical	21 nm	÷~4	6 nm

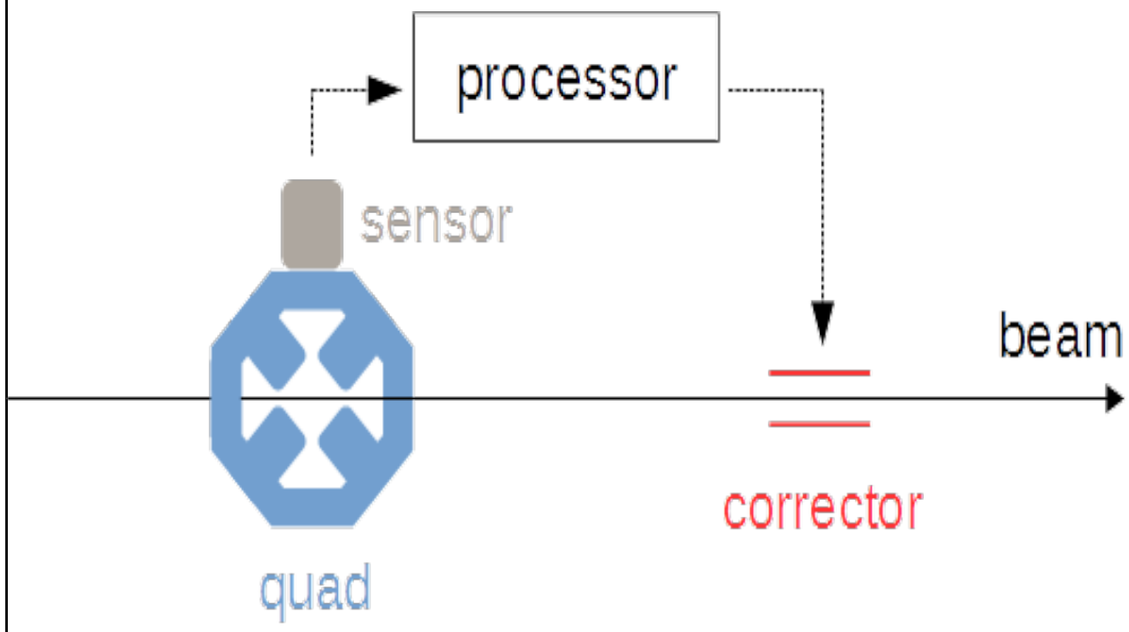
Success in vibration mitigation

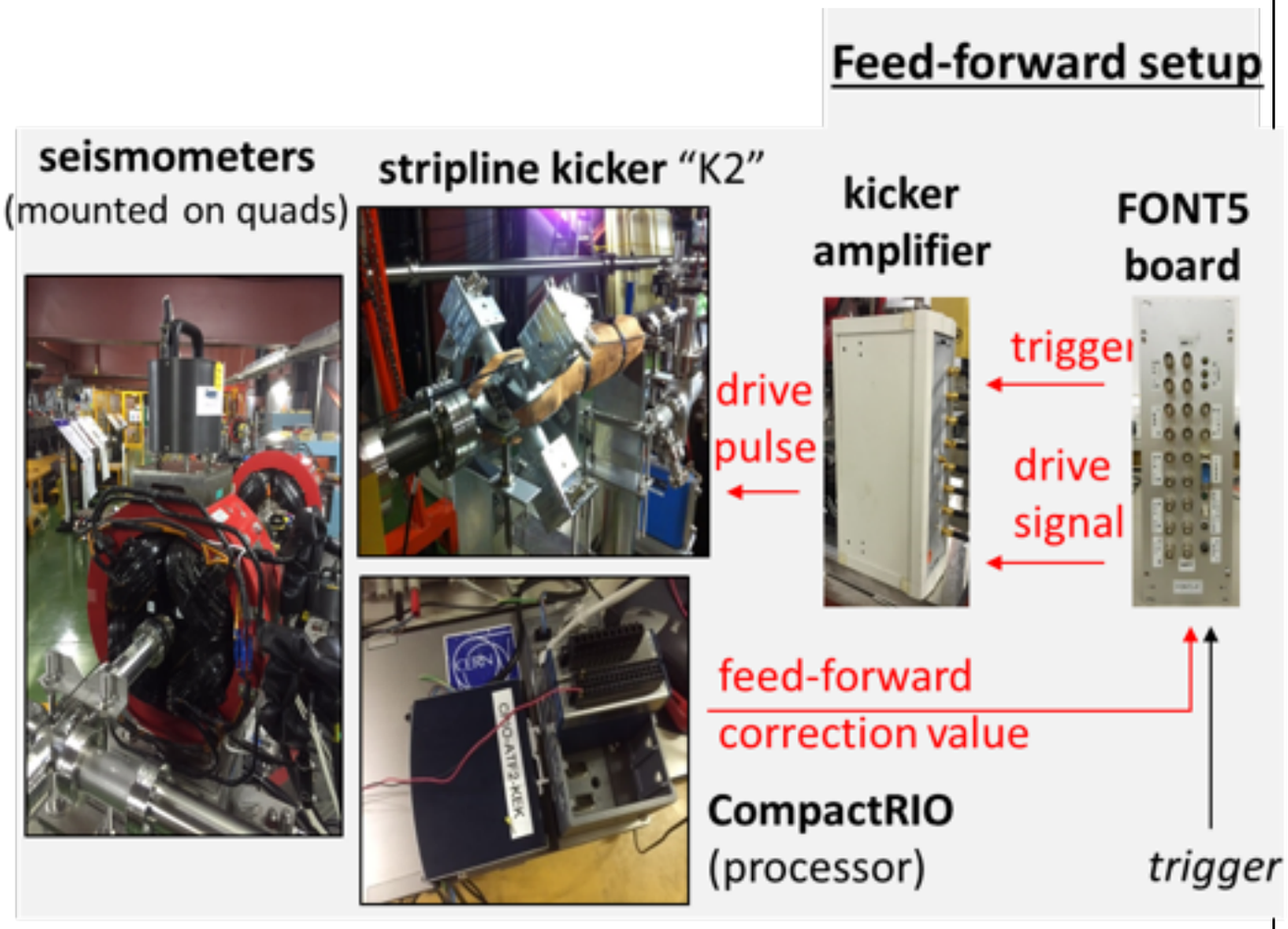
But ongoing work: identify origin of a 16.5Hz vibration that appears sometimes



Ground motion feed-forward

Similar concept to orbit feedback but uses **seismometers** instead of BPMs to drive the correction, also predicts the orbit





ADVANTAGES

Cheaper than active stabilization systems.

Correct frequencies out of limits for orbit feedback systems.

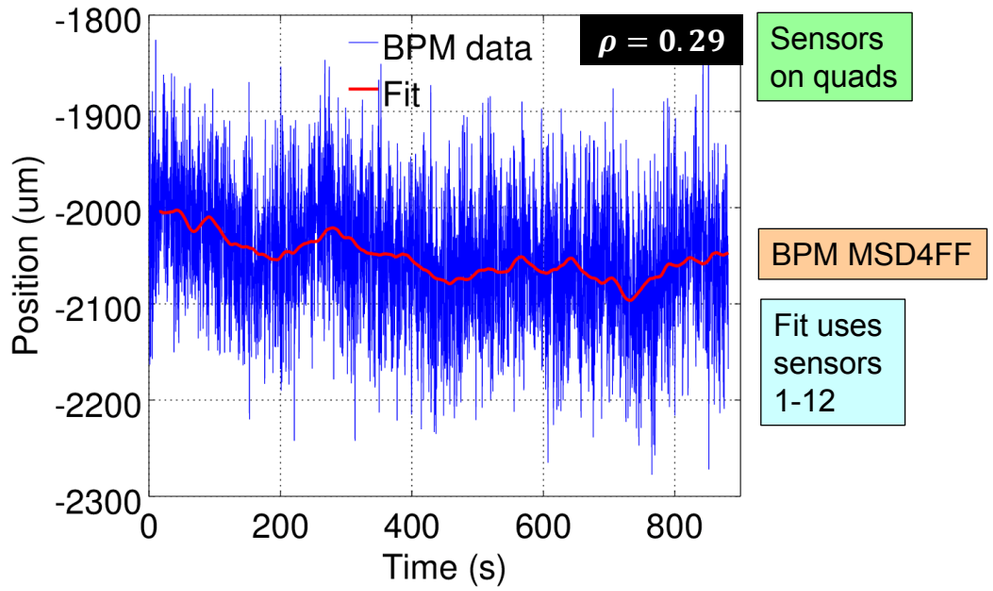
Fit position at selected BPM as a function of (filtered) sensor position(s)

ρ: correlation between fit and measurement => usable for feedforward tests, feasibility

jitter reduction ➡ $$\frac{\sigma_f}{\sigma_i} = \sqrt{1-\rho^2}$$

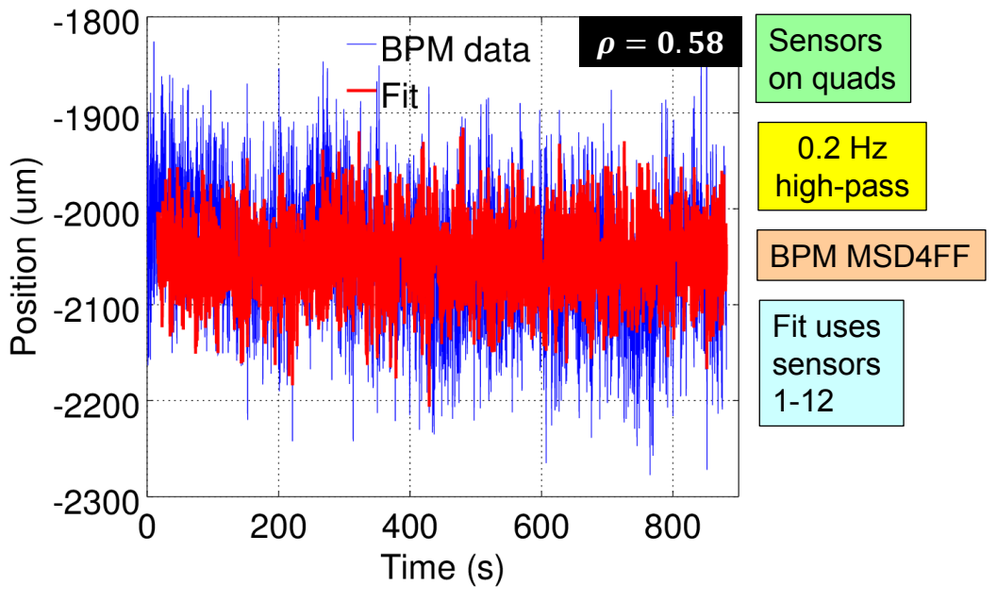
Fit to beam position

Data set: ATF2_2015-05-22_14h15m19s.502.mat



Fit to beam position

Data set: ATF2_2015-05-22_14h15m19s.502.mat



Expected performance

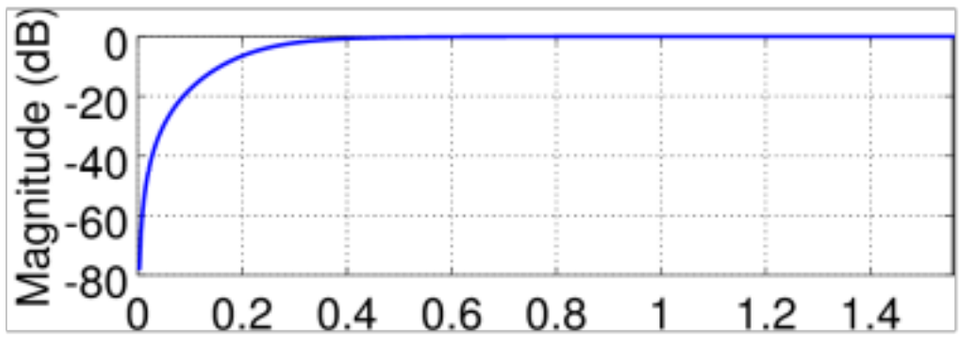
- Using a 0.2 Hz high-pass filter doubles the correlation from 0.29 to 0.58
- This increases the expected reduction in jitter from ~5% to ~20%
- 20% at the typical jitter levels of the FF BPMs corresponds to ~15 µm and thus should be easily measurable

MSD4FF

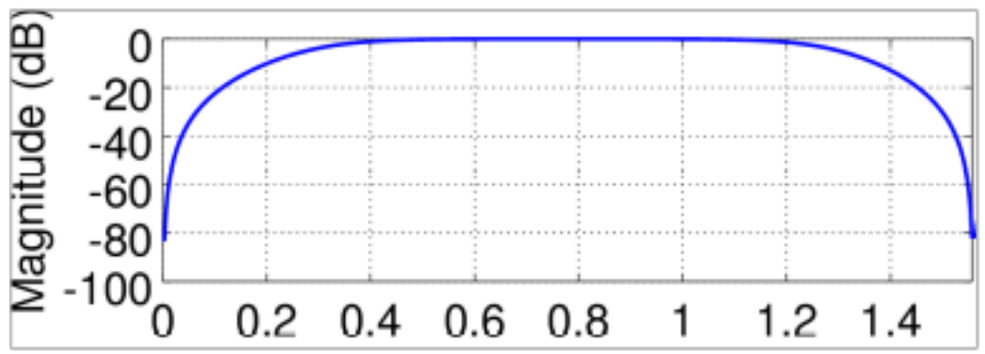
Fit using sensors 1-5

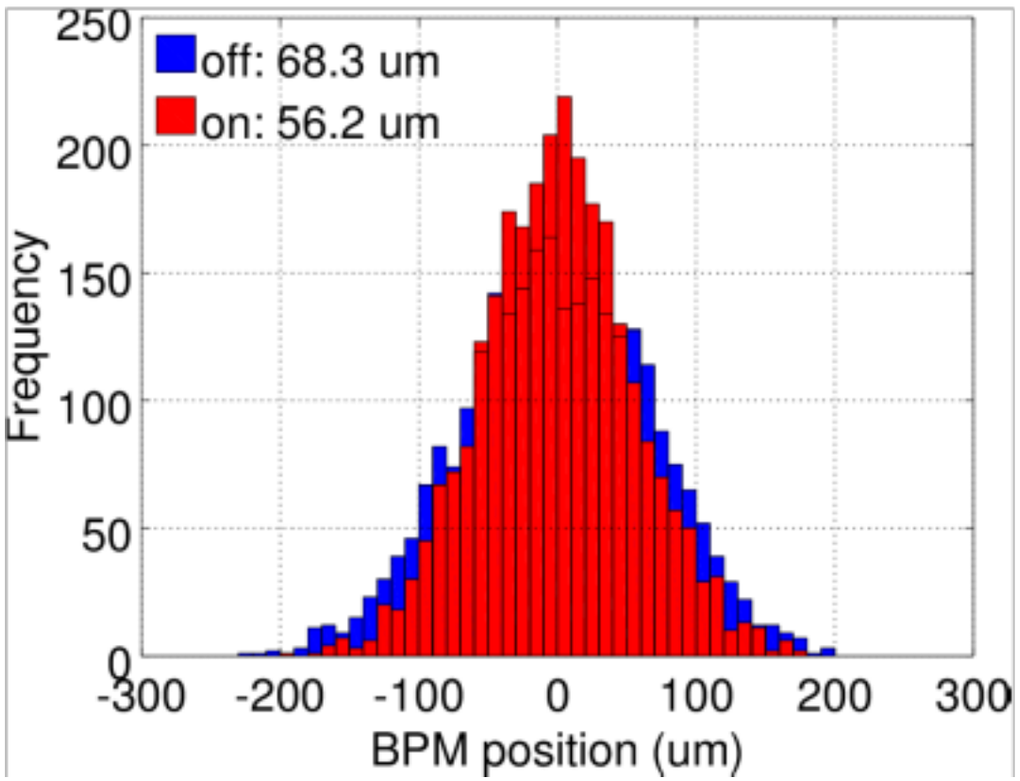
Performance comparison

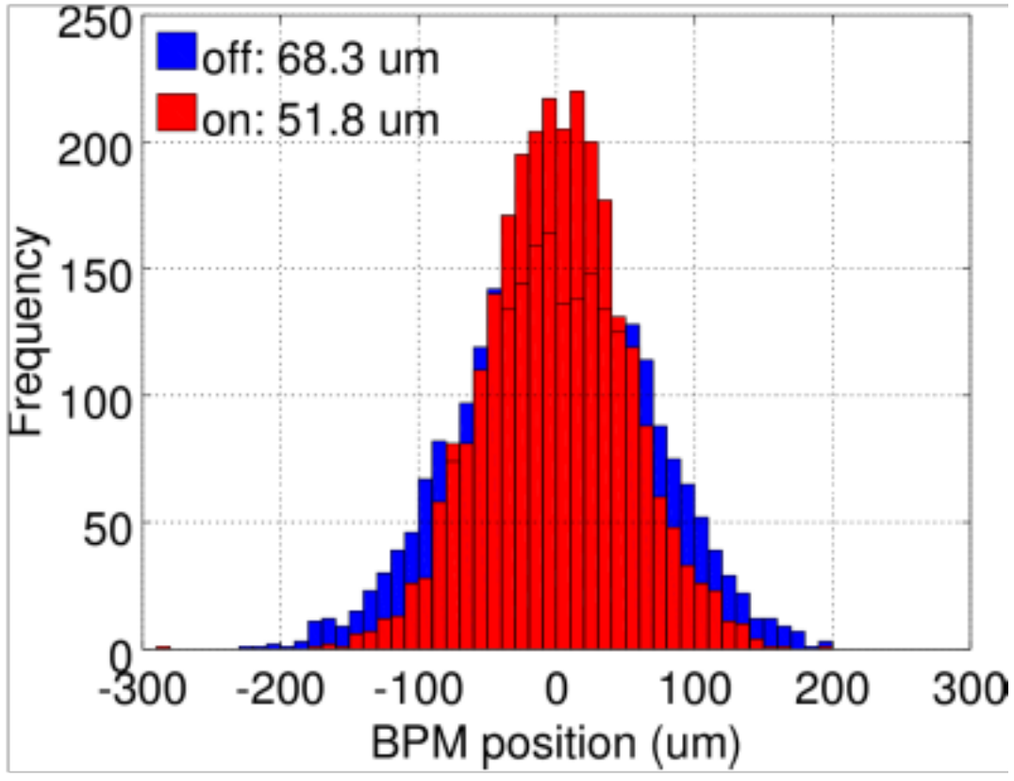
High-pass filter
> 0.27 Hz
18% reduction in jitter



Band-pass filter
0.32 Hz – 1.26 Hz
24% reduction in jitter







Publication in fiscal year of 2015

1) In vacuum diamond sensor scanner for beam halo measurements in the beam line at the KEK Accelerator Test Facility, by S. Liu et al.: arXiv:1512.08024, submitted to NIMA (December 2015)

2) Realistic Beam Halo Model study in the Extraction Line of ATF2 , by N. Fuster-Martinez et al.: TUPTY019.PDF, presented at the 6th International Particle Accelerator Conference (IPAC 2015), Richmond, Virginia, USA, 3-8 May 2015

3) Design Study and Construction of a Transverse Beam Halo Collimation System for ATF2 , by N. Fuster-Martinez et al.: WEPMN059.PDF, presented at the 6th International Particle Accelerator Conference (IPAC 2015), Richmond, Virginia, USA, 3-8 May 2015

4) Status of ATF2 IP-BPM Project, by O.R. Blanco-Garcia et al.: MOPHA003.PDF, presented at the 6th International Particle Accelerator Conference (IPAC 2015), Richmond, Virginia, USA, 3-8 May 2015

5) Investigation of Beam Halo Using In Vacuum Diamond Sensor at ATF2 , by S. Liu et al.: MOPHA008.PDF, presented at the 6th International Particle Accelerator Conference (IPAC 2015), Richmond, Virginia, USA, 3-8 May 2015

6) Measurements around QF1FF support, by A.Jeremie et al, ATF report, ATF–15–012015/ 10/ 09

Activity plans in the fiscal year of 2016

KEK

1. Host of the ATF2 studies, especially on the nanometer stabilization at IP based on the fast feedback (FONT) with the IPBPM system.

LAL

1. The investigation and control of beam halo in both horizontal and vertical directions
2. Mitigation of the electromagnetic pickup to detect backscattered Compton electrons, e.g. to see the (non-)linear Compton scattering
3. Halo measurements with a new horizontal collimator in collaboration with the IFIC Valencia group
4. Parallel development of the diamond sensors at PHIL at LAL for the LEETECH detector calibration facility.
5. Engineering and technical support for the piezo mover system of the IPBPMs

LAPP

1. The detection of the ground motion effect on the beam in collaboration with CERN, LAL, Oxford University and KEK
2. Installation of new acquisition and control hardware with specific software for the GM feedforward system
3. Identification of the vibration sources. Especially, we will study the best way to monitor vibrations more systematically to help identify the source of the 16.5Hz resonance.
4. Vibration studies around the new LAPP QF1FF support