ATF status & plans

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On behalf of the ATF international collaboration

Thanks to P. Burrows, G. Christian, Y.I. Kim, S.W. Jang, N. Terunuma, J. Yan

LCWS12, Arlington, Texas

22-26 October 2012

ATF talks @ LCWS12

Status of the optical cavity R&D at KEK-ATF
Tohru Takahashi - Wednesday 9.45

IP Feedback tests at ATF2
Philip Burrows - Wednesday 11.45

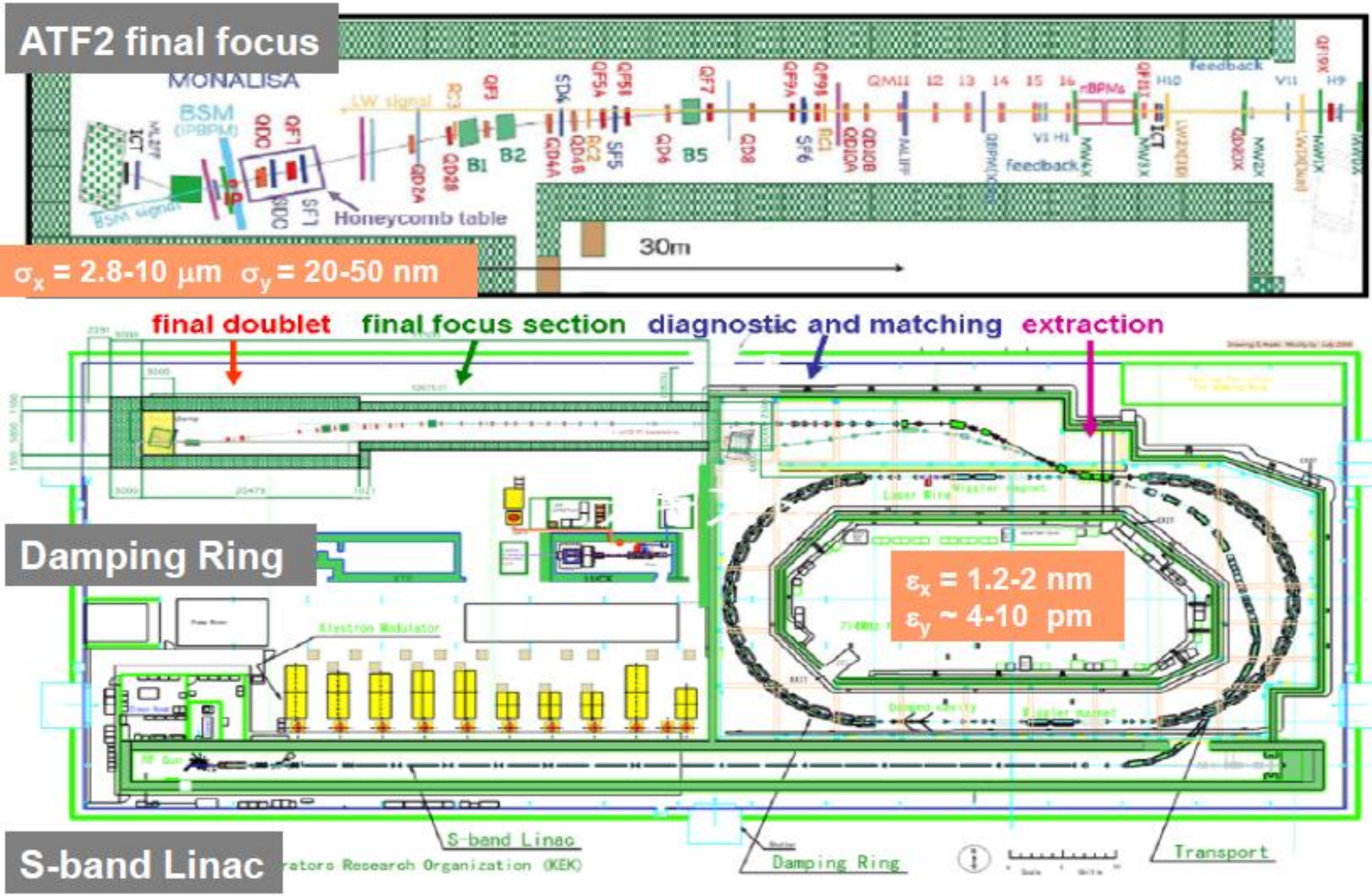
Ground motion feedback for ATF2
Yves Renier - Thursday 9.50 (webex)

Development of nanometer electron beam size monitor
Jacqueline Yan - Thursday 8.30 (webex)

Beam Dynamics Studies at ATF2
Toshiyuki Okugi - Thursday 15.00 (webex)

Progress and future of ATF experimental program
Junji Urakawa – Tuesday 8.30 Thursday 16.00

Accelerator Test Facility @ KEK



Parameters	ATF2	ILC	CLIC
Beam Energy [GeV]	1.3	250	1500
L* [m]	1	3.5 - 4.5	3.5
$\gamma\varepsilon_{x/y}$ [m.rad]	**5E-6 / 3E-8**	**1E-5 / 4E-8**	**6.6E-7 / 2E-8**
IP $\beta_{x/y}$ [mm]	**4 / 0.1**	**21 / 0.4**	**6.9 / 0.07**
IP η' [rad]	0.14	0.0094	0.00144
δ_E [%]	~ 0.1	~ 0.1	~ 0.3
Chromaticity ~ β / L*	**~ 1E4**	**~ 1E4**	**~ 5E4**
Number of bunches	1-3 (goal 1)	~ 3000	312
Number of bunches	3-30 (goal 2)	~ 3000	312
Bunch population	1-2E10	2E10	3.7E9
IP σ_y [nm]	**37**	**5.7**	**0.7**

$$L \sim \frac{n_b N_e^2 f}{4\pi\sigma_x\sigma_y} H_D$$

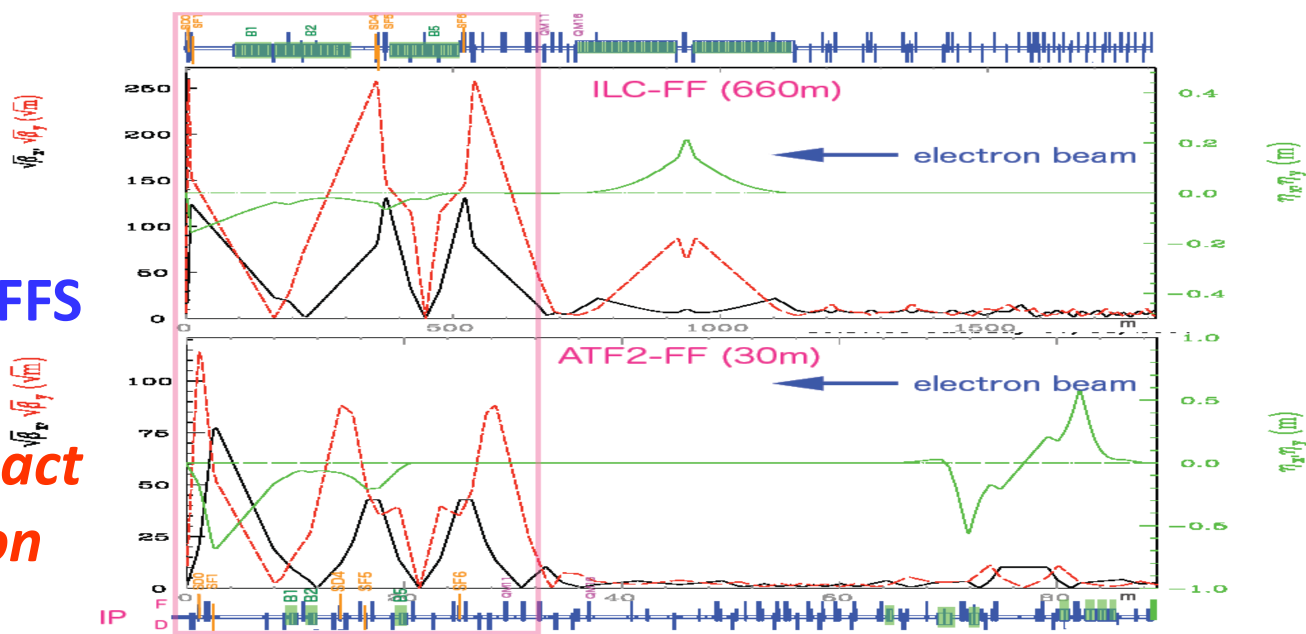
$$L \sim \eta \frac{P_{electrical}}{E_{CM}} \sqrt{\frac{\delta_{BS}}{\varepsilon_{n,y}}} H_D$$

$$\sigma^2 = \varepsilon_N \beta / \gamma$$

ATF2 =

- ✓ **scaled ILC FFS**
- ✓ **start point of CLIC FFS**

concept of local compact chromaticity correction



Main BDS issues addressed by ATF/ATF2

validate concept(s), develop, practice, train,…

- Beam instrumentation
  - nm-level position
  - profile (x, y, tilt)
- Stabilization
  - passive / active mechanical stabilization
  - beam / vibration measurement based feed-back/forward
- 4+1 dim. phase space tuning & control for IP spot minimization
  - emittance minimization via radiation damping
  - mitigation of 1st, 2nd and 3rd order optical aberrations
  - convergence time ↔ dynamical errors (sismic & thermal effect)
- Halo control
  - modeling, generation, propagation, monitoring…
  - collimation (physical, optics)

ATF / ATF2 Goals

- ❑ **Very small damping ring vertical emittance**
  - **from ~10 pm → 4 pm (achieved !) → 1-2 pm**

- ❑ **Small vertical beam size** *"goal 1"*
  - **achieve σ_y ~37 nm (cf. 5 / 1 nm in ILC / CLIC)**
  - **validate "compact local chromaticity correction"**

- ❑ **Stabilization of beam center** *"goal 2"*
  - **down to~2nm**
  - **bunch-to-bunch feedback (~300 ns, for ILC)**

- ❑ **R&D on nanometer resolution instrumentation**

- ❑ **Train young accelerator scientists on "real system"**
  - **maintain expertise by practicing operation**

→ *open & unique facility*


IP


Shintake Monitor
Monitor
IP


Final Doublet

ATFに参加している代表的研究機関
- ATF International Collaboration -

欧州原子核研究機構(CERN)
ドイツ(Germany)
- **電子シンクロトロン研究所(DESY)**

フランス(France)
- **IN2P3; LAL, LAPP, LLR**

イギリス(UK)
- **Univ. of Oxford**
- **Royal Holloway Univ. of London**
- **STFC, Daresbury**
- **Univ. of Manchester**
- **Univ. of Liverpool**
- **Univ. College London**

イタリア(Italy)
- **INFN, Frascati**

スペイン(Spain)
- **IFIC-CSIC/UV**

ロシア(Russia)
- **Tomsk Polytechnic Univ.**

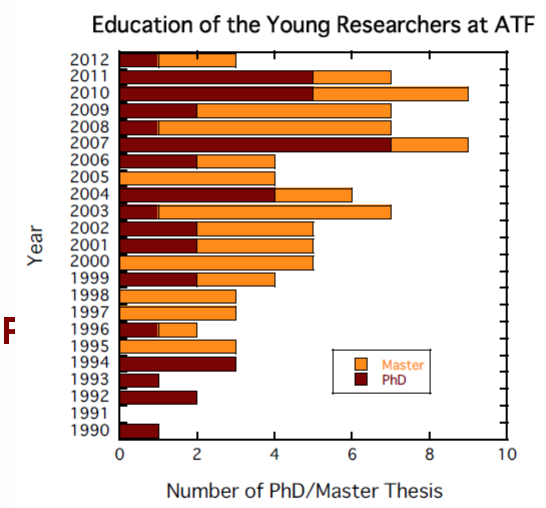
アメリカ(USA)
- **SLAC国立加速器研究所**
- **ローレンス・バークレー国立研究所(LBNL)**
- **フェルミ国立加速器研究所(FNAL)**
- **ローレンス・リバモア国立研究所(LLNL)**
- **ブルックヘブン国立研究所(BNL)**
- **コーネル大学(Cornell Univ.)**
- **ノートルダム大学(Notre Dome Univ.)**

日本(Japan)
- **高エネルギー加速器研究機構(KEK)**
- **東北大学　(Tohoku Univ.)**
- **東京大学　(Univ. of Tokyo)**
- **早稲田大学(Waseda Univ.)**
- **名古屋大学(Nagoya Univ.)**
- **京都大学　(Kyoto Univ.)**
- **広島大学　(Hiroshima Univ.)**

中国(China)
- **中国科学院高能物理研究所(IHEP**

韓国(Korea)
- **ポハン加速器研究所(PAL)**
- **キョンプク大学(KNU)**

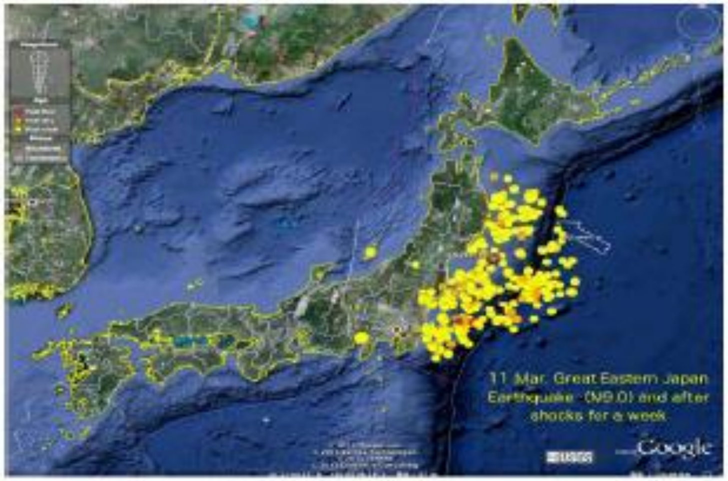
インド(India)
- **Raja Ramanna Centre for Advanced Technology**



relatively independent R&D teams

Great Eastern Earthquake – March 11, 2011

Nobuhiro Terunuma (KEK)

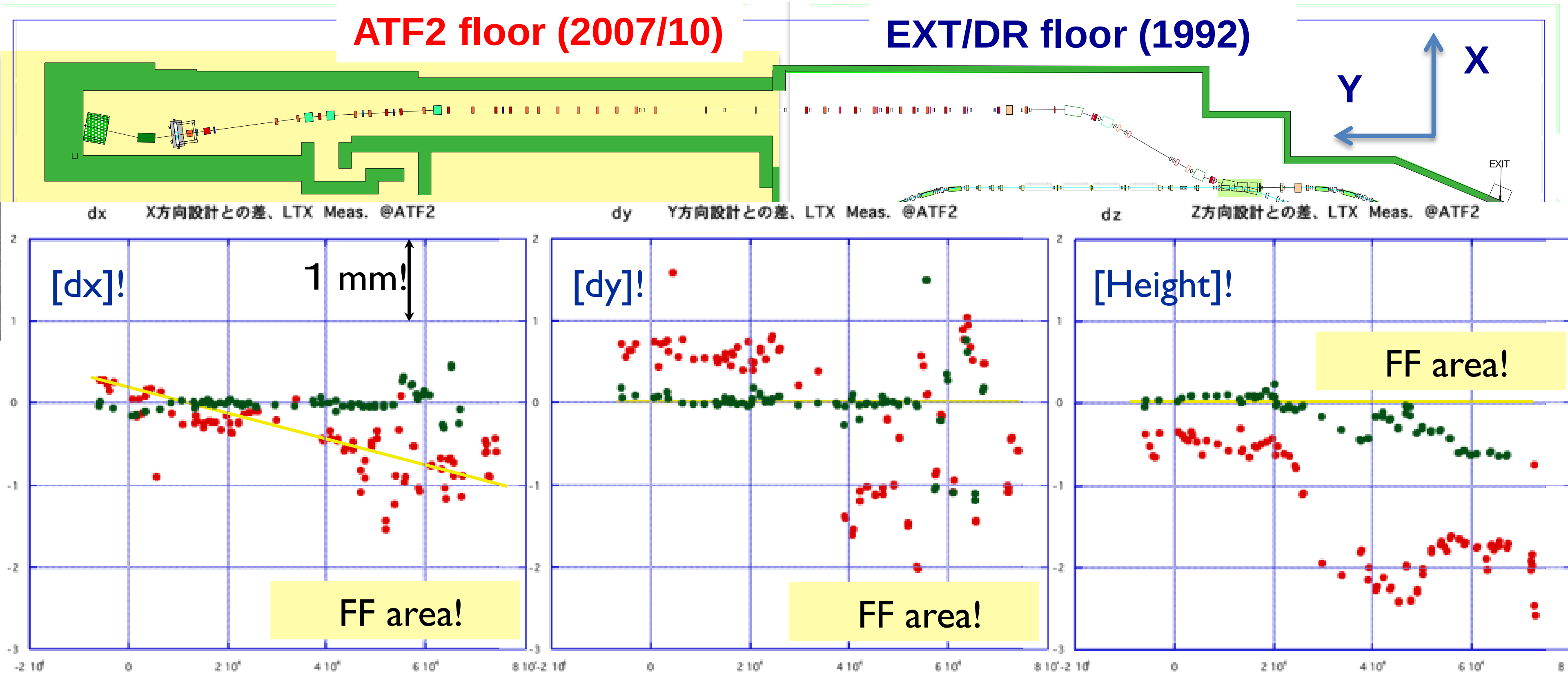


- Since there is a big earthquake in the northeast Japan, and it also has some influence on KEK and ATF. The ATF building still looks fine, but facility outside damages, and will be expected to recover in June.

Beams recovered in June !

→ but ~9 month delay in ATF2 program…

Alignment of the ATF2 beamline



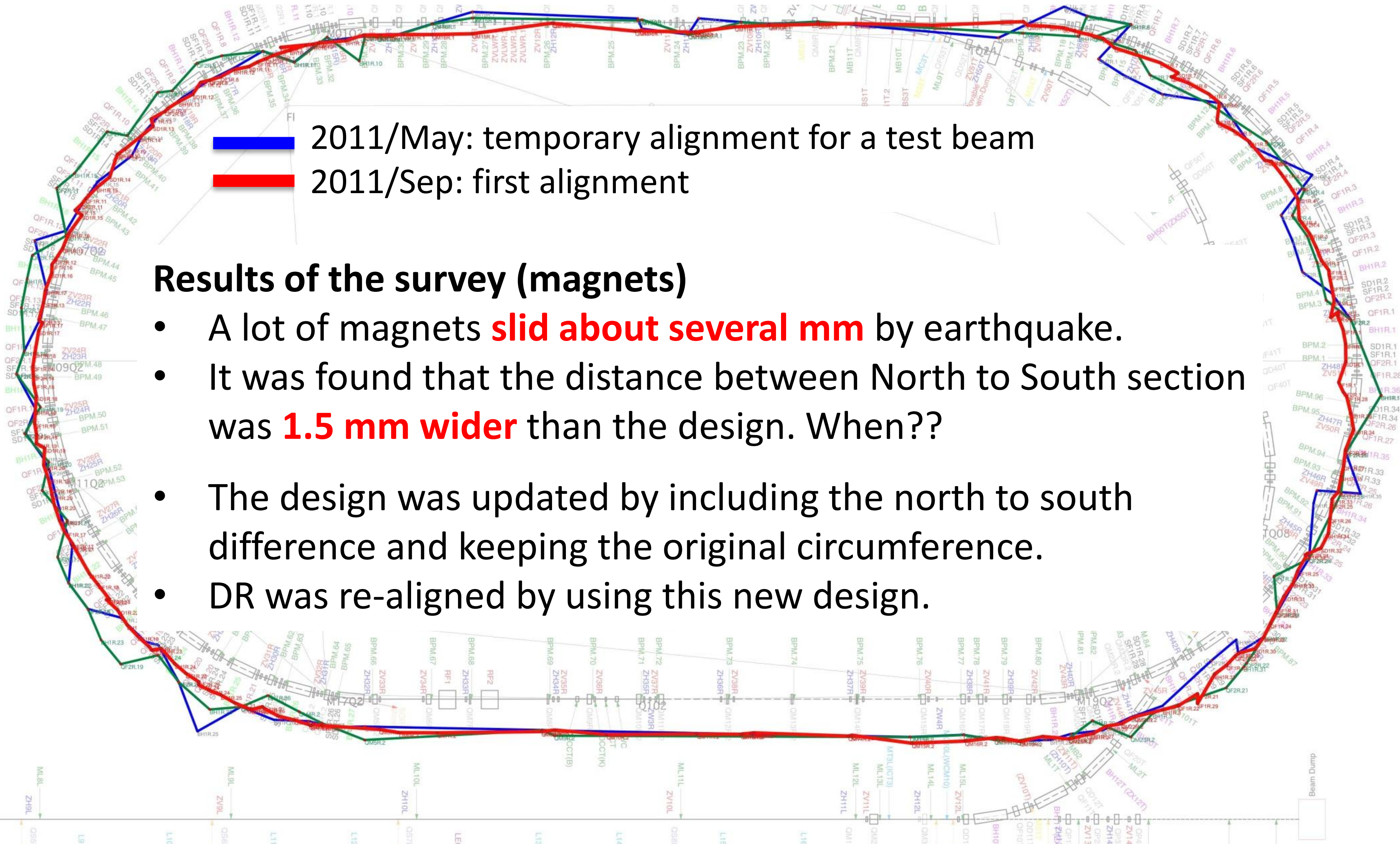
● After the earthquake (surveyed in Sep.)

● Aligned in October 2011

Floor of ATF2 sank about 1.5 mm.

2012/Jan S.Araki

DR displacement (Enlarged image)

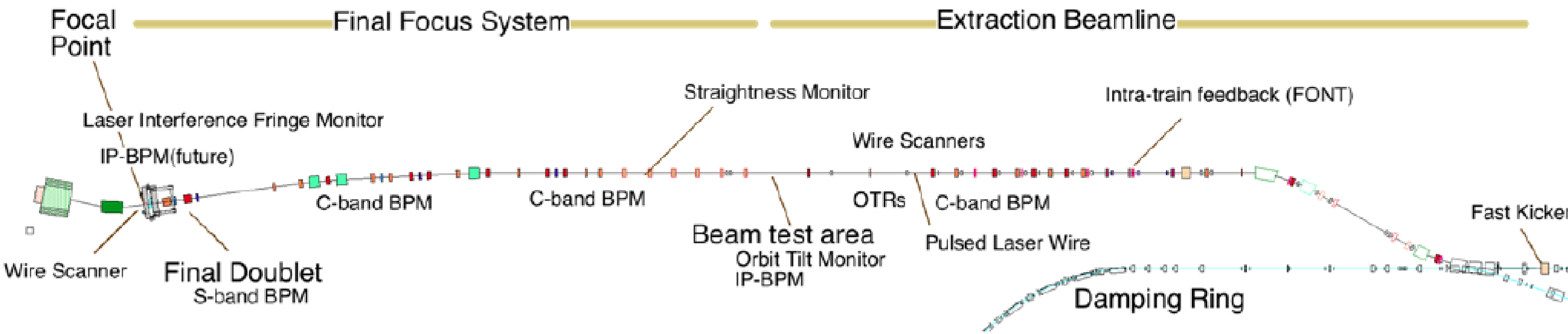


2011/May: temporary alignment for a test beam
2011/Sep: first alignment

Results of the survey (magnets)

- A lot of magnets **slid about several mm** by earthquake.
- It was found that the distance between North to South section was **1.5 mm wider** than the design. When??
- The design was updated by including the north to south difference and keeping the original circumference.
- DR was re-aligned by using this new design.

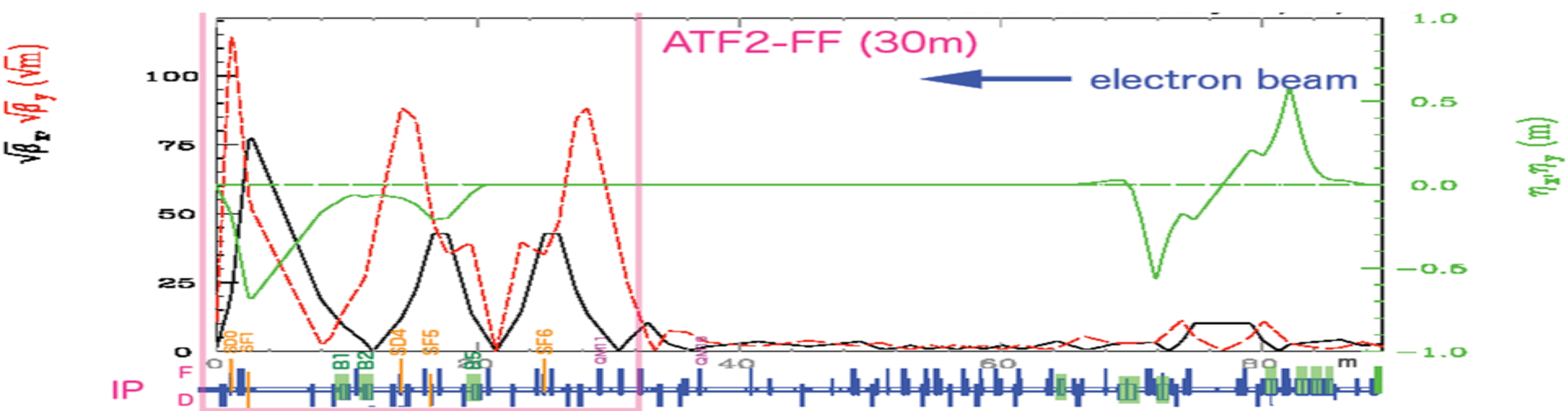
ATF2 operation & instrumentation R&D



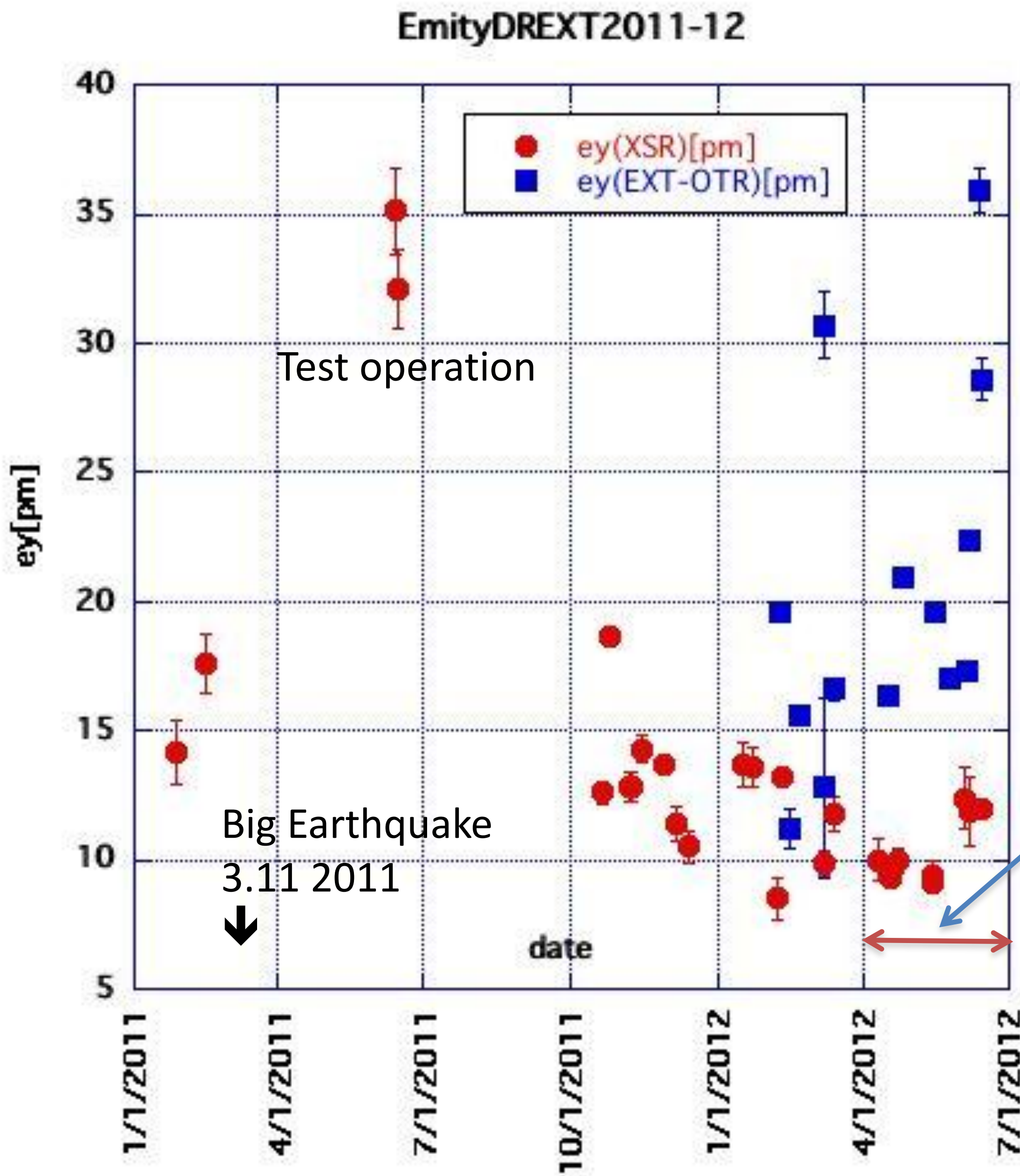
2nd order telescope
fine tuning of local errors

Match optics into FF
buffer section for input errors

DR extraction
setup, stability



Emittance Summary



Emittance in DR is around 10-12 pm

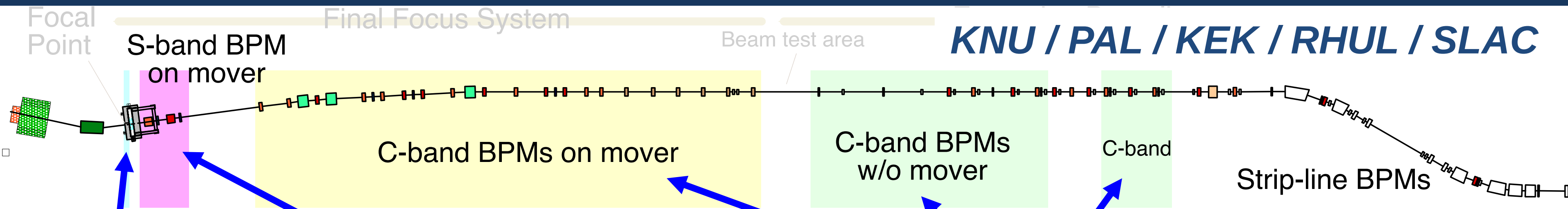
On-going R&D

→ Laser wire measurement

→ New BPM calibration concept (K. Kubo, A. Wolski)

Nano-meter Beam Position Monitors

KNU / PAL / KEK / RHUL / SLAC

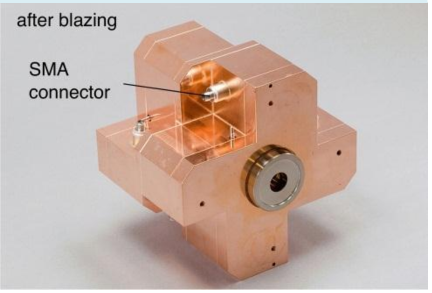


IP BPM system

(BPM + Ref) Cavity **1 unit**

Target : 2 nm

Aperture: 6 mm(V)



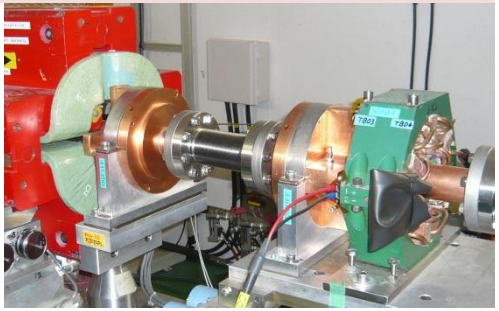
S-band BPM system

BPM cavity: **4 units**

Ref. cavity: **1 unit**

Target : 100 nm

Aperture: ϕ40 mm



C-band BPM system

BPM cavity: **34 units**

Reference cavity: **4 units**

Target resolution: 100 nm

Aperture: ϕ20 mm

Achieved resolution at ATF

8.72 +-0.28(stat) +-0.35(sys) nm

@ 0.7×10^{10} electrons/bunch,

@ 5 μm dynamic range

[Y. Inoue et al., Phys. Rev. ST-AB 11, 62801 (2008)]

Proto-type

Achieved resolution

15.6 nm

@dymamic range $\pm 20\mu$m

Operational status of the ATF2 Cavity BPMs

C-band BPM

It is in the steady operation for ATF2.

<u>**Achieved Resolutions:**</u>

- 200 nm for typical BPMs with 20 dB attenuator to realize the wider dynamic range (~10 mm) for ATF2 tuning.
- **50 nm for BPMs w/o attenuator**
- 27 nm was confirmed when BPMs are carefully tuned and a beam is well centered.

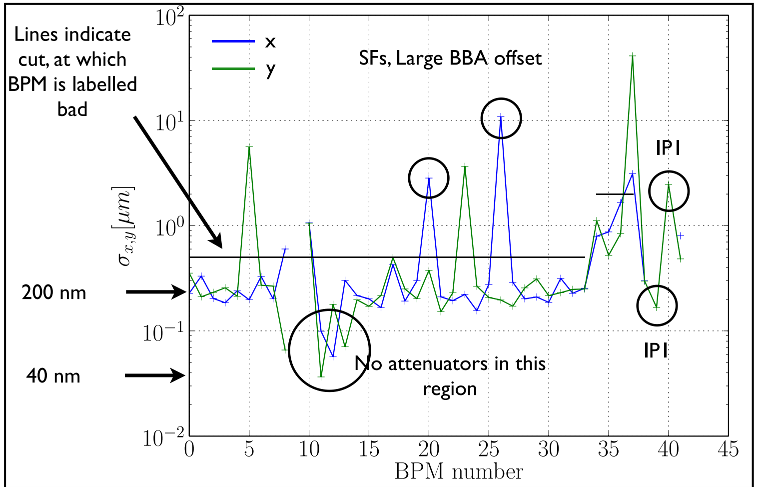
The Cavity BPM on ATF2 demonstrates well the target resolution of ILC, 100 nm.

S-band BPM

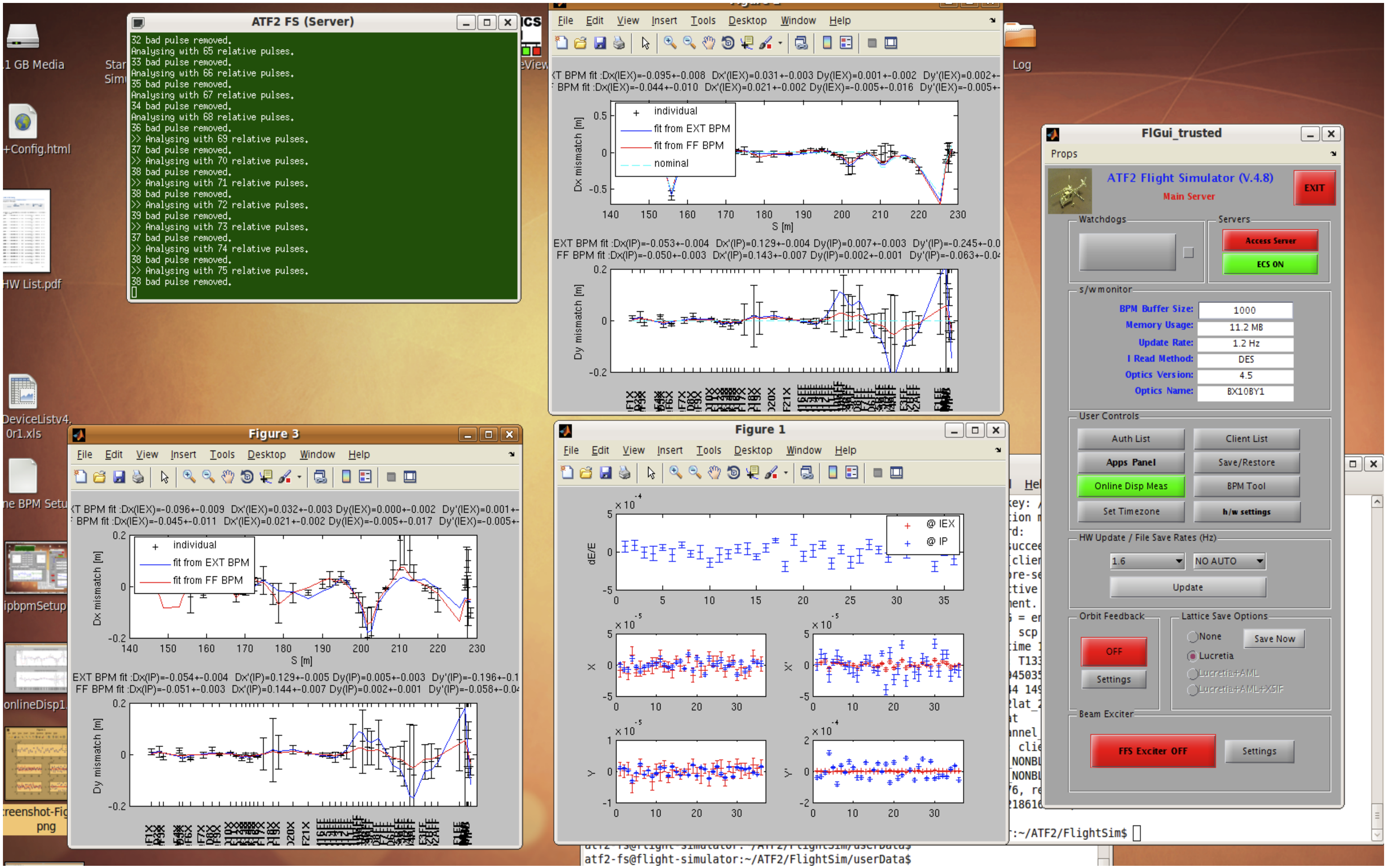
It needed only for the ATF2 large aperture final doublet. Not for ILC.
Present resolution ~ 1 μm

IP-BPMs

Trial installation: ~several 100 nm



Online Dispersion Monitoring



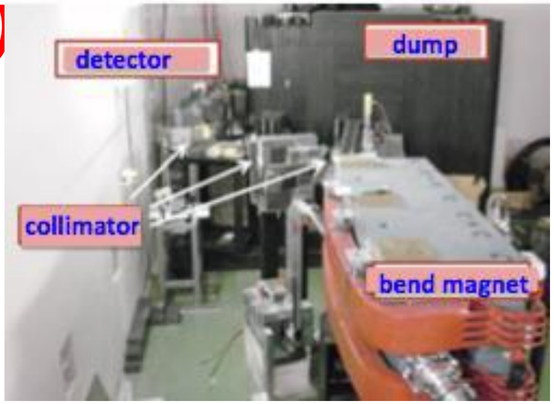
Nano-meter Beam Size Monitor

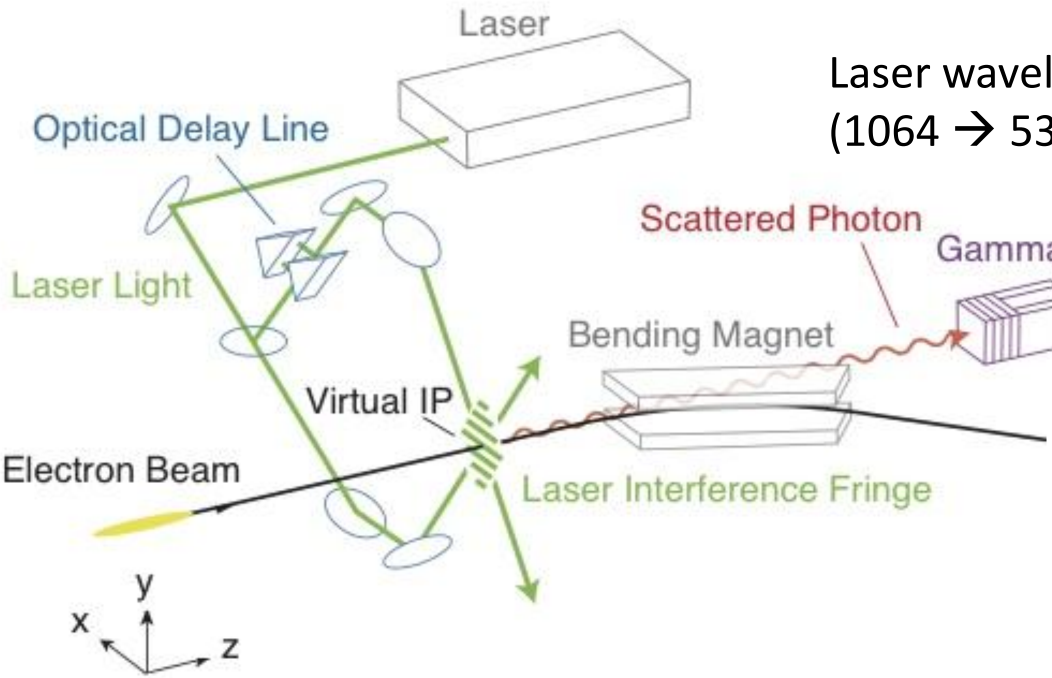
Univ. Tokyo / KEK

Beam Size Measurements at ATF2-IP

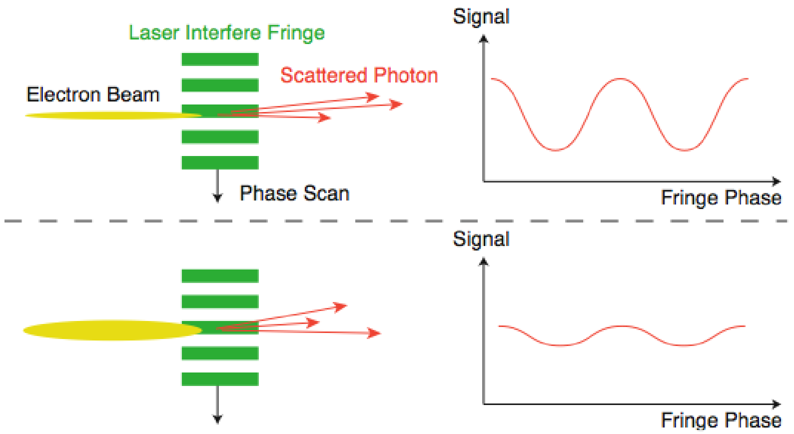
- Solid (W,C) wire Scanners (meas. for 2um or more)
- Laser interference fringe monitor (meas. for 20nm~6um)

FFTB ~70nm(measured) -> ATF2 37nm(goal)

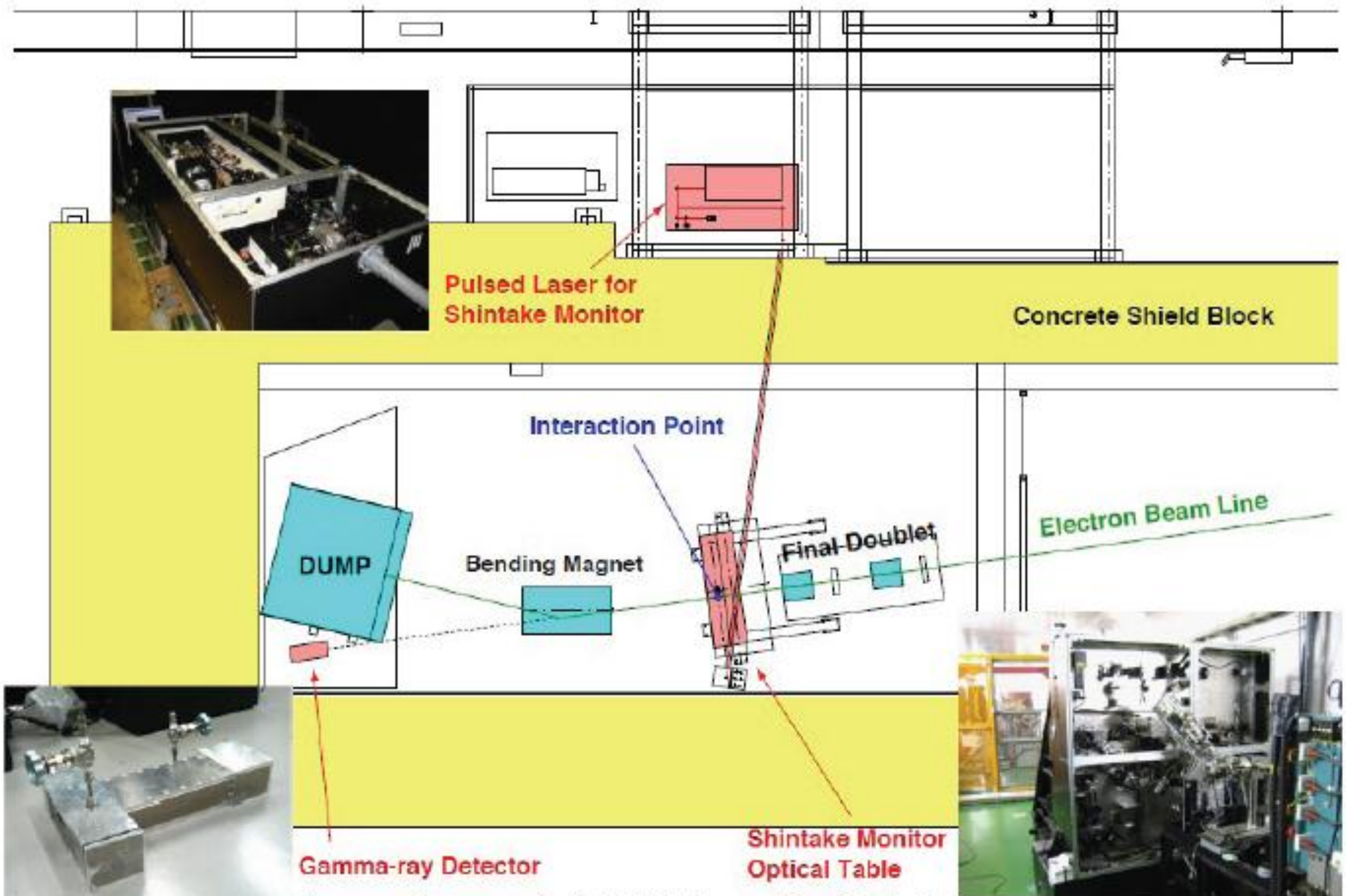




Laser wavelength
(1064 → 532 nm)

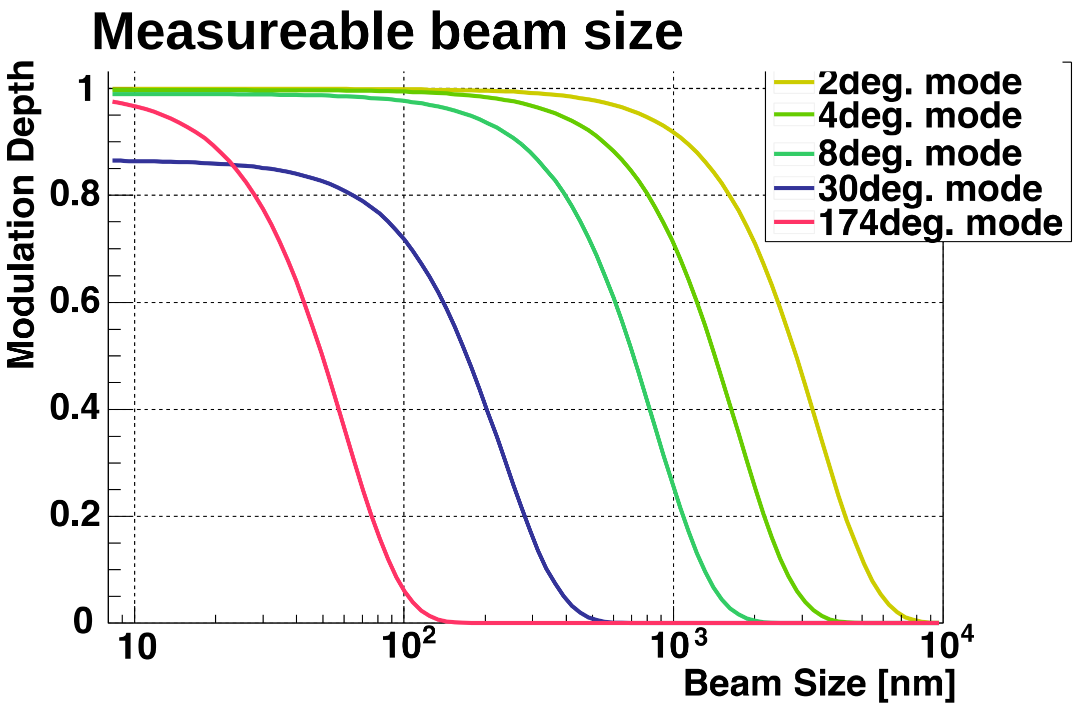


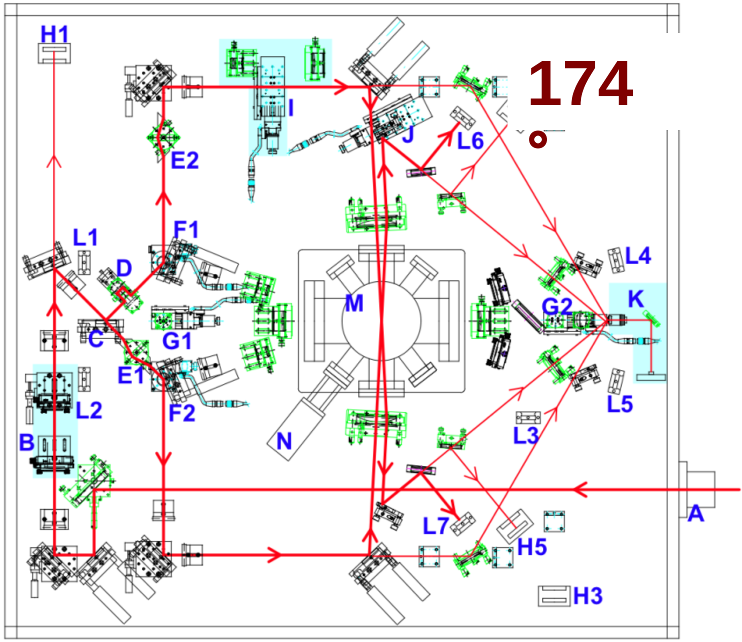
Shintake Monitor : Layout

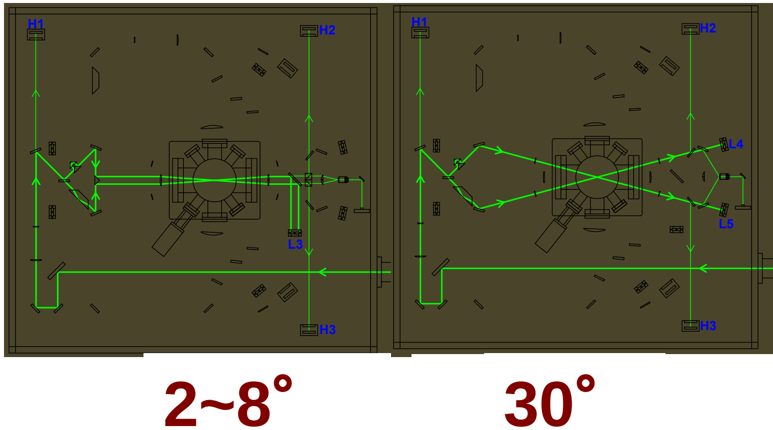


Layout around ATF2 Interaction Point

Laser Interference Fringe Monitor for ATF2

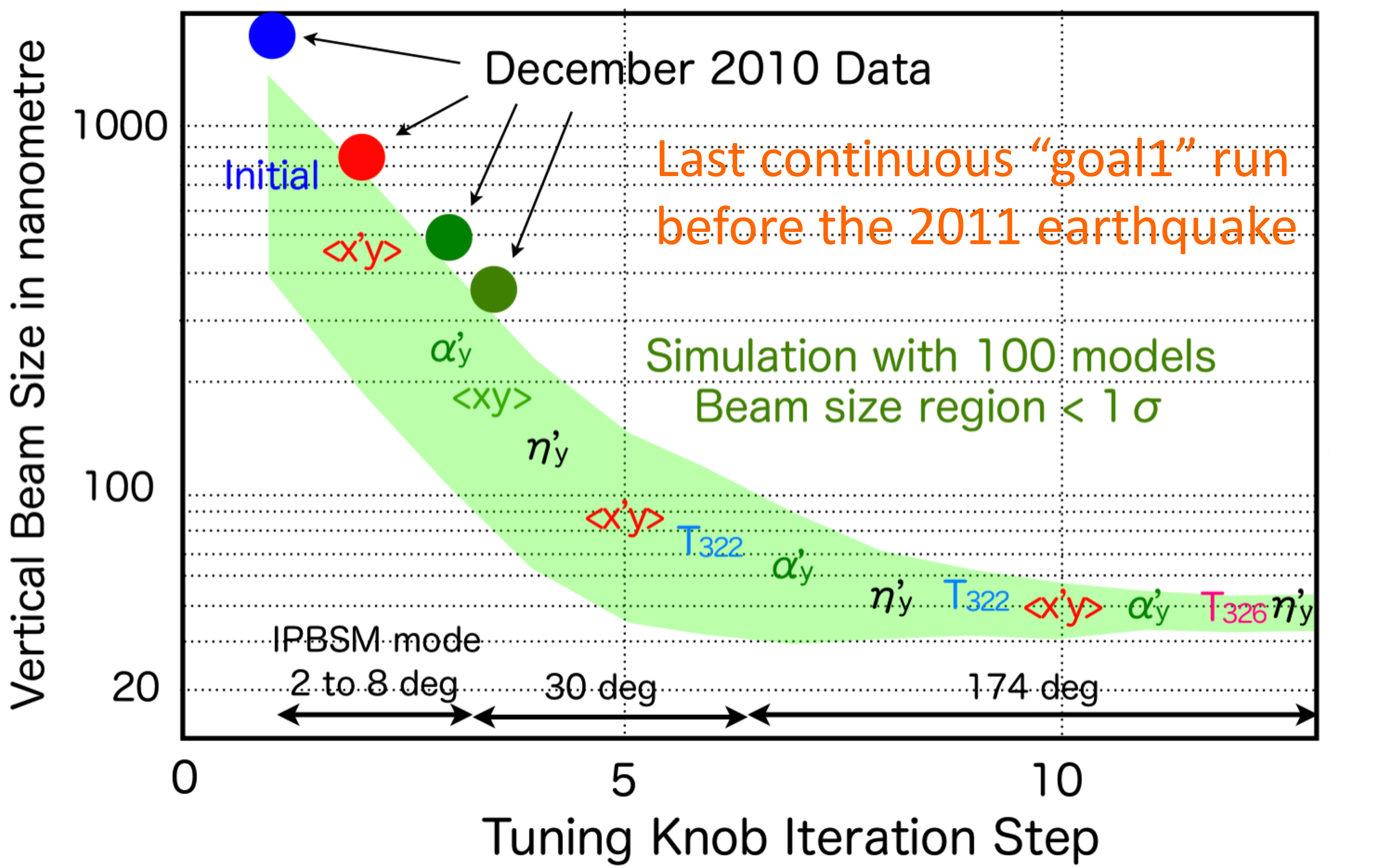






	174°	30°	8° ⟷	2°
Fringe pitch	266 nm	1.03μm	3.81μm	15.2μm
Minimum	**25 nm**	100 nm	360 nm	-
Maximum	**100 nm**	360 nm	-	6 μm

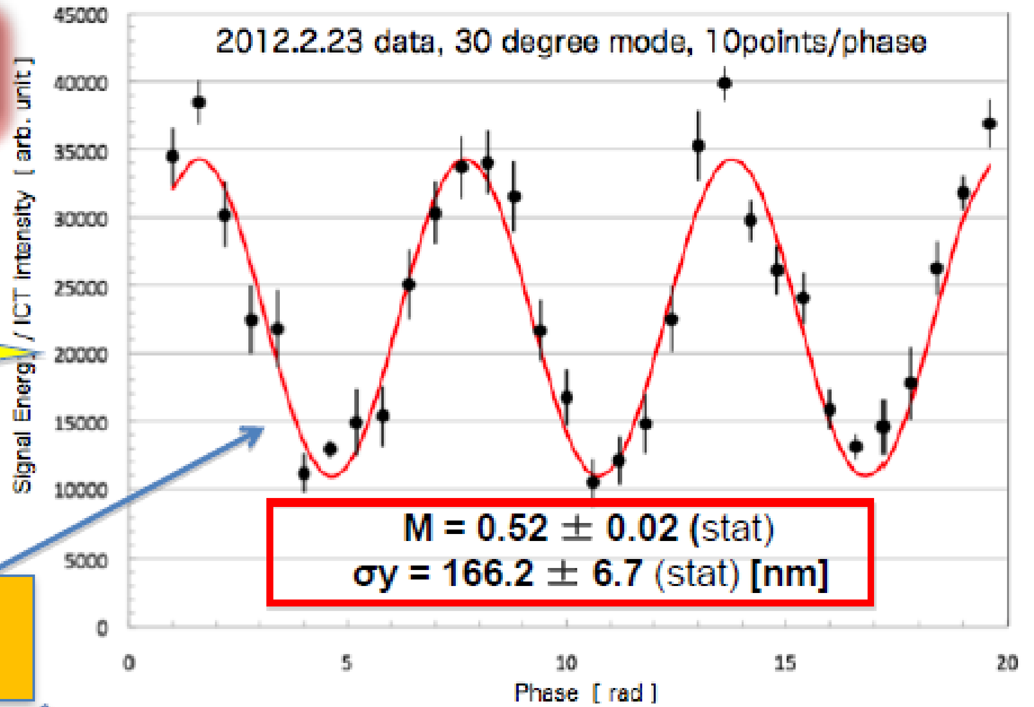
Tuning the ATF2 vertical beam size



Beam time status in 2012

full commissioning of 30° mode
First Modulation detection
(10 x β_x^*, 10 x β_y^* optics)

stably measure σy* ~ 160 nm
(10 x β_x^*, 3 x β_y^* optics)



2 - 8° mode

Measured larger σy（～few 100 nm）
with clear **contrast**
（**i.e. high M : 0.8 – 0.9**)

➔ Syst error study
- ✓ upper limit on M_meas
- ✓ consistency of σy_meas

Began commissioning of 174° mode

- ➢ **hardware check**
- ➢ **Optimization of scan strategies**

Obstacles (2012 Feb)
- •Beam condition drift (over many hours)
- •Not very focused σy* (still at 3 x β_y^* optics)

one more step before full commissioning of 174° mode i.e. consistent fringe scans

Laser Interference Fringe Monitor for ATF2

2-8° mode

Spend most beam time in 2010~2011.

- beam tuning down to 300 nm
- commissioning of the fringe monitor
- beam size ~ 300 nm

30° mode

First modulation was detected in February 2012.

- beam size ~165 nm

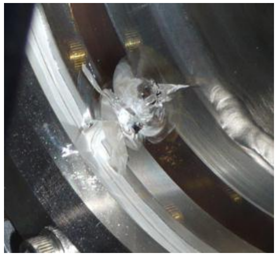
174° mode

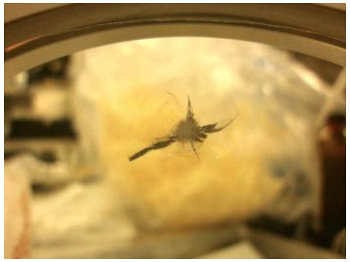
Modulation is not yet detected.

- Need improvement on the split laser handling (crossing angle control) in summer.

Improvements on the fringe monitor

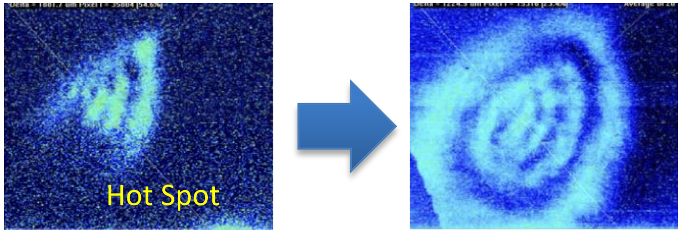
Damage → laser spot size optimization vs Compton Signal



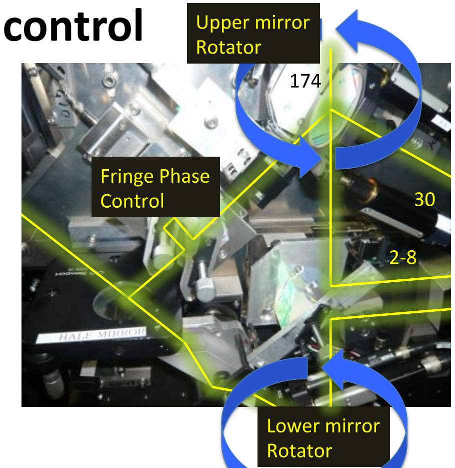


pointing stabilization → *BeamLok* device

profile improvement → laser cavity exchange

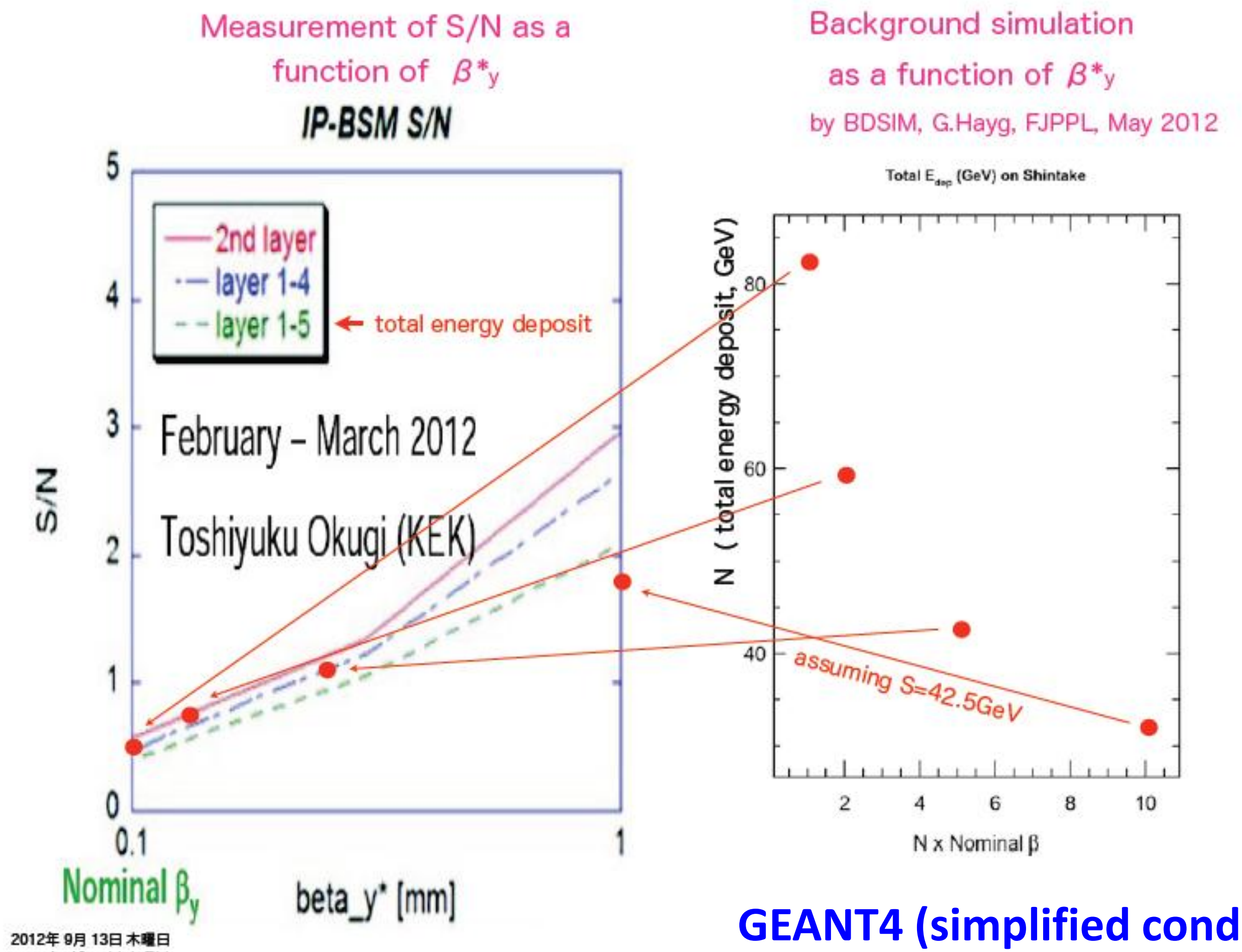


Laser crossing angle control



Summer 2012 upgrades & partial redesign

Beam halo and BSM background issues



GEANT4 (simplified conditions)

Halo intercepted on

post-IP bend magnet vertical gap
final doublet beam pipe
chromatic correction c-band BPM apertures

under study…

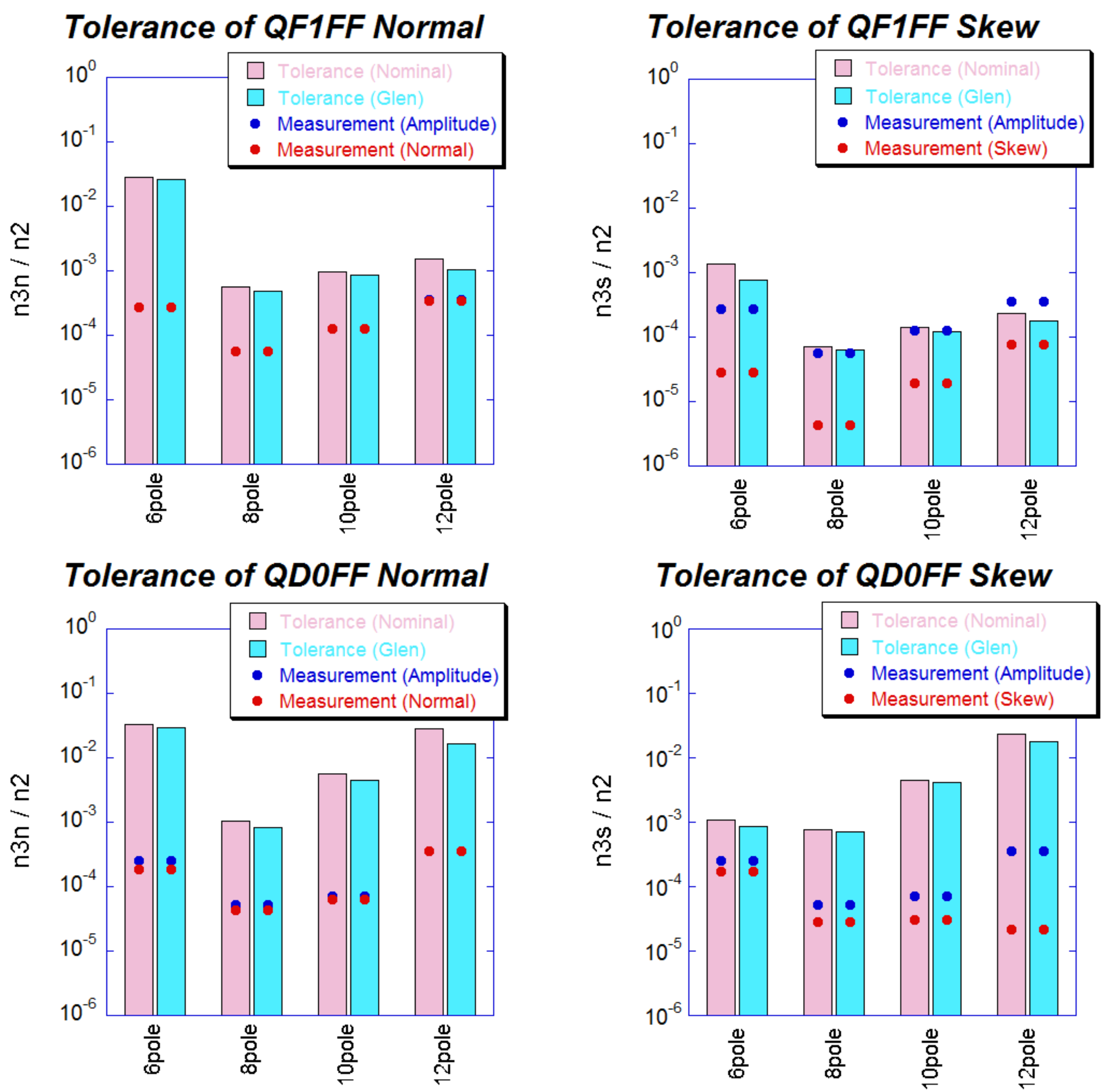
Issue of magnet field quality

- Unfavorable low energy scaling → tolerances at ATF2 tighter compared to ILC or CLIC
- QD0 and several FFS quads have large <u>anomalous skew sextupole</u>
- QF1 has significant <u>anomalous skew dodecapole</u>
- Affects vertical beam size, especially for the reduced β* regime relevant for CLIC FFS demonstration

Mitigation

- Operate ATF2 with increased horizontal β*
  - presently $10 \times \beta_x$ and $1 \times \beta_y$ are used
- Replace QF1 with very good quality PEP II quadrupole (imminent)
- Additional knobs to control higher order aberrations using FFS normal sextupoles and four newly installed skew sextupoles
- Swap "bad" ↔ "good" FFS quads ➔ too disruptive, not now…

Tolerances for Multipole Errors for Final Doublet

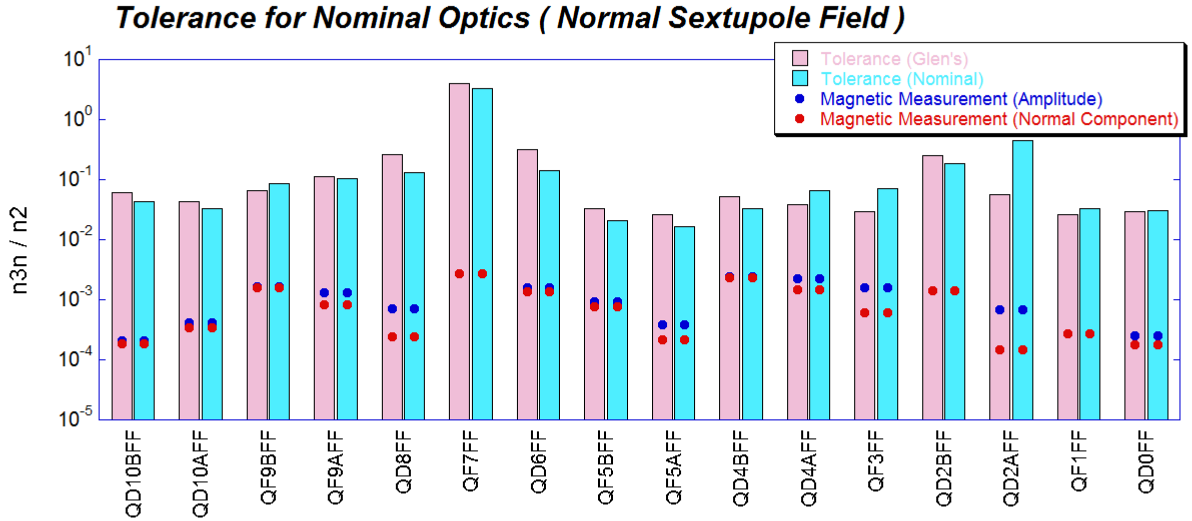


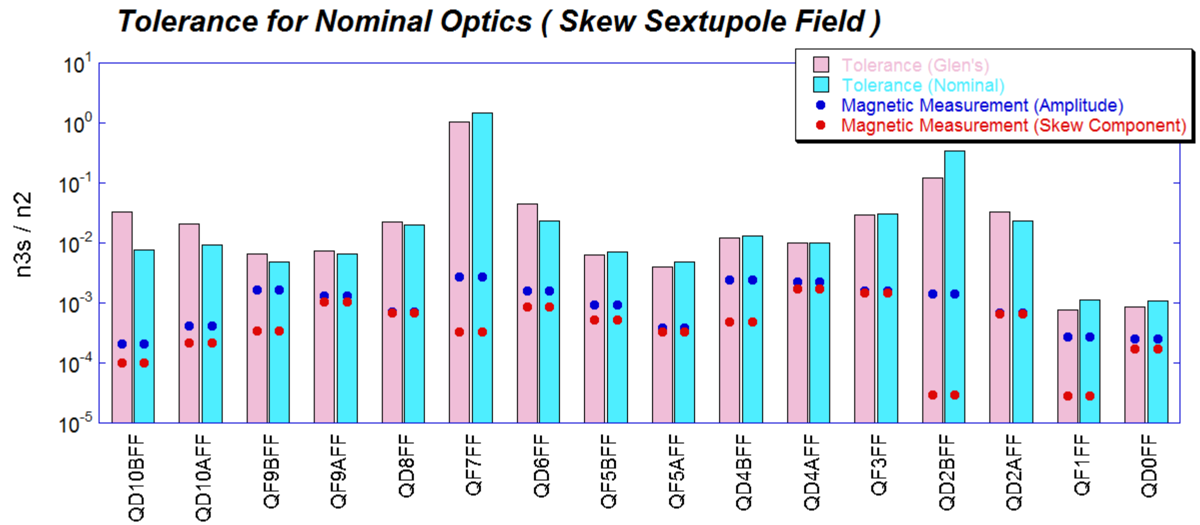
Red ; Nominal 2.5x1
Blue; Glen's 2.5x1

emitx = 2nm
emity = 12pm

with Y24 Y46 Y22 Y26 Y66 Y44 correction

Tolerances of Sextupole Field Errors for FF Quads





Red ; Glen's 2.5x1

Blue; Nominal 2.5x1

emitx = 2nm

emity = 12pm

with Y24 Y46 Y22 Y26 Y66 Y44 correction

Nano-meter Beam Position Stabilization

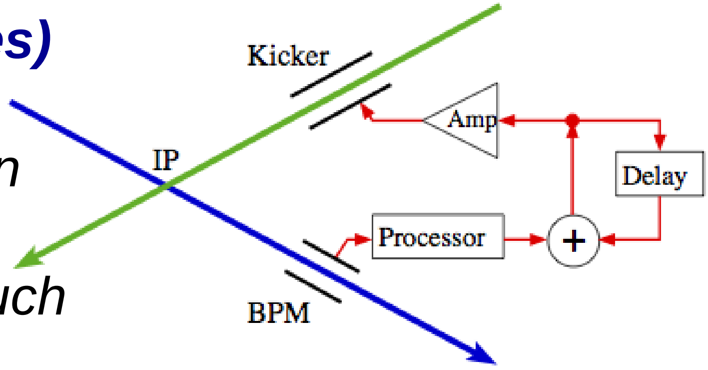
Oxford / KNU / RHUL / KEK

One of the challenging goals for ATF2

1. *achieving of the 37 nm vertical beam size*
2. ***Stabilize a beam in a few nanometer level at the IP.***

FONT (Feedback On Nano-Second Timescales) has been developed

- *as a prototype of a beam-based intra-train feedback system for IP of LCs.*
- *Correct the impact of fast jitter sources such as the vibration of magnets.*



FONT1~FONT3

Analogue feedback system for very short bunch-train LCs.

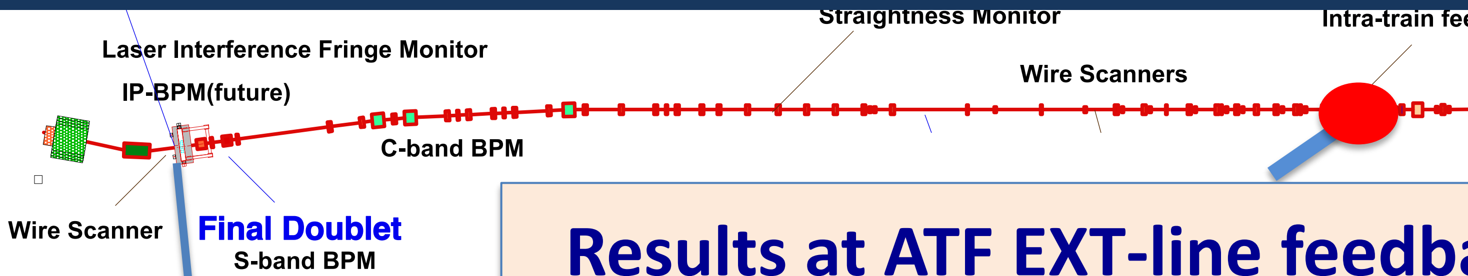
Latency FONT3(ATF) 23 ns.

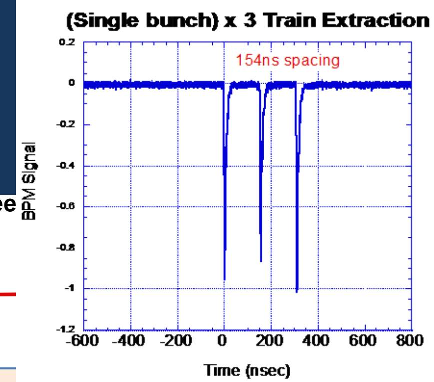
FONT4 & FONT5 (ATF2)

Digital feedback system for long bunch-train ILC.

allow the implementation of more sophisticated algorithms

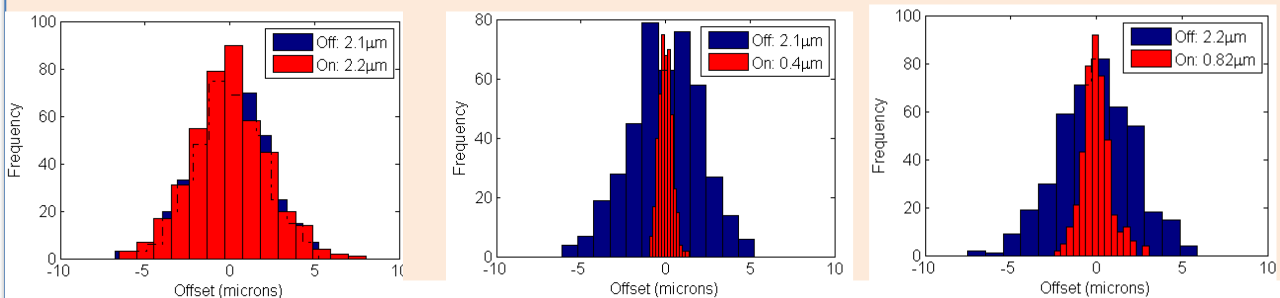
Results of the fast feedback





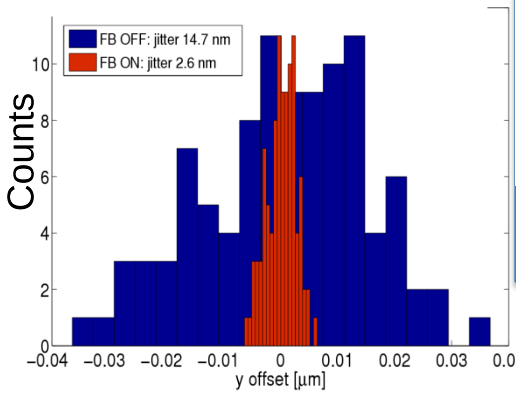
Results at ATF EXT-line feedback

Bunch 1 Bunch 2 Bunch 3



2.1 um → 0.4 um → 0.8 um

Jitter comparison at ATF2-IP (simulation)



Assuming perfect lattice, no further imperfections (!)

Simulation

FB OFF: jitter 14.7 nm

FB ON: jitter 2.6 nm

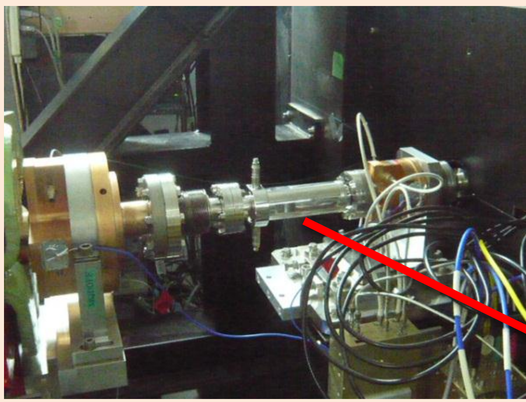
FONT + IP-BPM

"for ATF2 Goal 2"

Preparation for the nm-beam position stabilization IPBPM+FONT

FONT-kicker

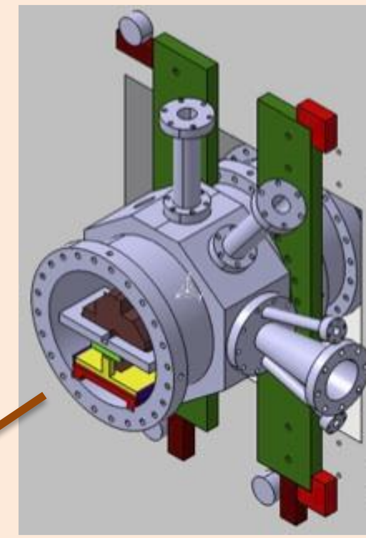
Installed near the ATF2-IP.
Tested in June 2012.

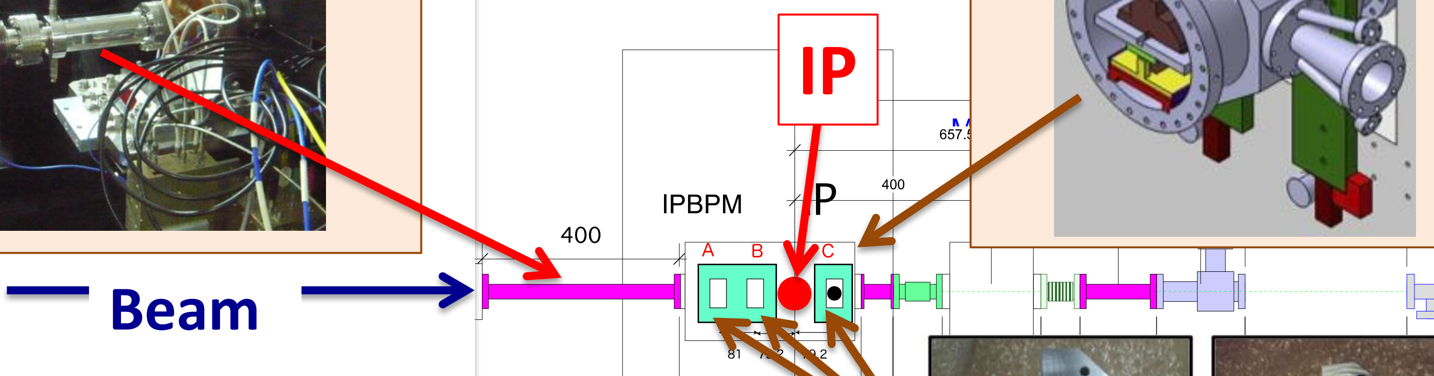


Full setup will be assembled at IP in early 2013.

New vacuum chamber

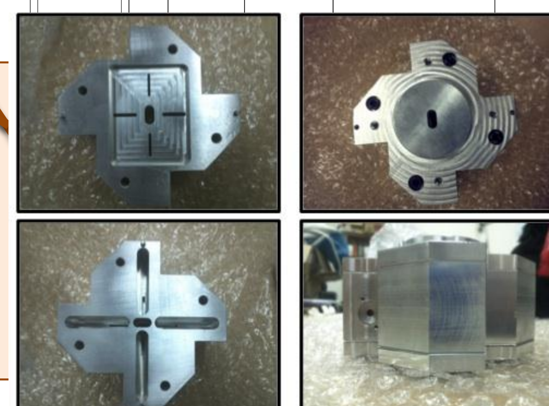
Precise positioning of IPBPM triplet. Fabrication at LAL.



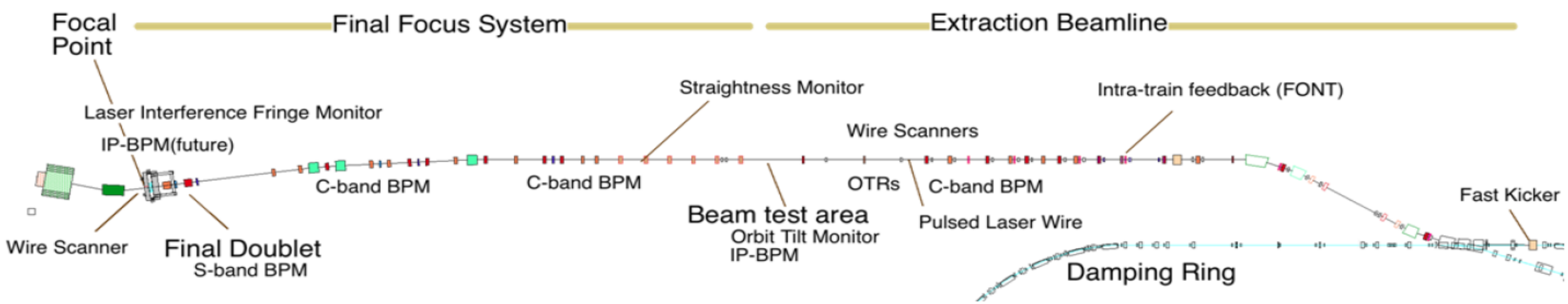


IPBPM

Triplet of the Low-Q cavity BPM. Fabricated by KNU.
Sensitivity tested at ATF LINAC.
Readout electronics tested at ATF2.



Recent progress towards “goal 2”



New IP chamber being built in Orsay to house ‘Shintake’ BSM and new set of lower Q high resolution cavity BPMS from KNU

- **Expected to be installed early 2013**

Meanwhile, new kicker installed near IP. Use existing higher Q IP-BPMs (with the vertical waist shifted) to investigate:

- **Effect of the upstream FB system on IP stability (ultimate performance of upstream system)**
- **Feed-forward from upstream BPMs (eg P2 & P3) to the IP kicker**
- **Local FB correction (problem: no independent monitor of the FB performance on beam)**

Check whether any significant jitter at IP originates from motion of final doublet

Concluding comments

- ATF/ATF2 unique as R&D facility, especially for instrumentations
- Invaluable training of early stage accelerator scientists on "real systems", in collaborative, flexible, yet competitive environment

- Extraordinary support provided by KEK and ATF staff as hosts
- Exemplary speed of recovery after major earthquake

- Excellent results on performance of new instruments and control methods, especially BPMs, profile monitors, feedback for "goal 2"
  - this is what our collaboration does best…

- Regular (but slower) progress toward "goal 1"
  - Focus reliably σy < 40 nm, maintain over long time
  - Validate Raimondi-Seryi local chromaticity correction scheme
  …. is experimental tuning of such a system more problematic ?

➔ premature to conclude at this stage…

Special “goal 1” challenge at ATF ?

1) **NEEDS** all components of the entire facility to operate reliably, and all at once ➔ not easy when key elements treated as projects for students who “learn by doing”

2) **NEEDS** stable & continuous centrally managed operation as for “luminosity” in facilities operated for users, not a succession of user defined independent R&D

3) **NEEDS** full community support and priority :
- more joint publications
- dedicated common funding sources
- more coherent integration and management of collaborators

Prospect for coming runs

- Attempt to apply model of HEP experimental collaborations to organize “goal 1” dedicated continuous operation for N days (N>5)
- 12 “students” volunteered from R&D groups, trained as “operators”
- A senior KEK accelerator physicist (<u>K. Kubo</u>) has accepted to act as overall leader, to develop more central planning and coordination

Stay tuned for our progress at ATF/ATF2 in 2013 !

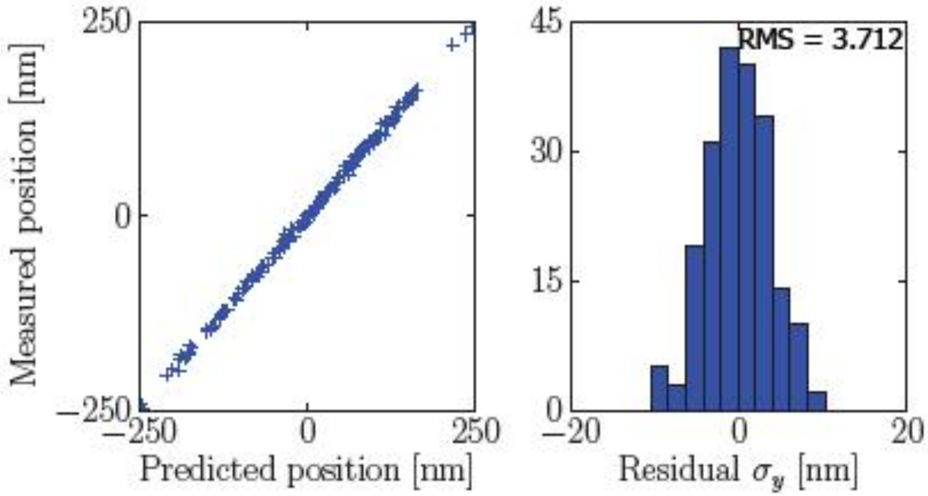
Thank you for your attention !

Additional slides

For Goal 2 :

Preliminary result of IPBPM

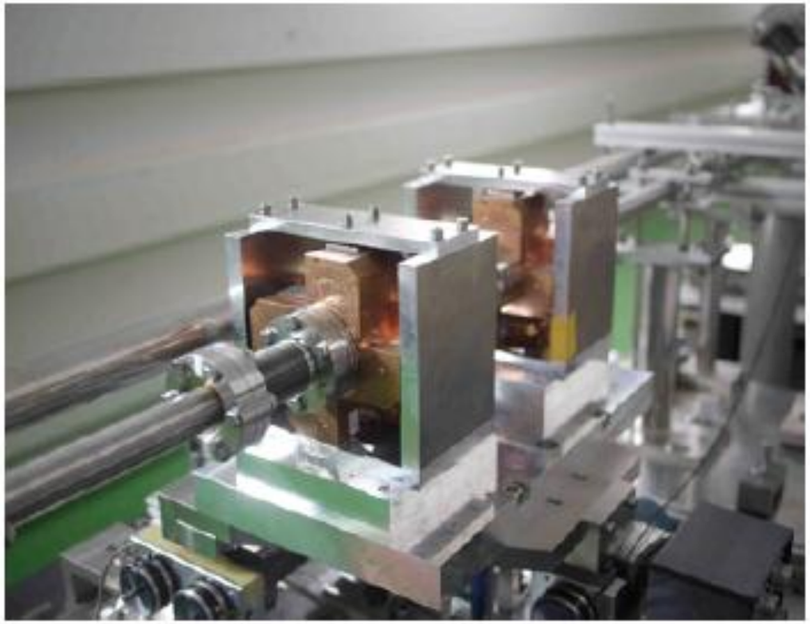
PhD thesis, YoungIm Kim (KNU)



RMS = 3.7 nm

Charge > 0.70 10^{10} electron/pulse

diagnostic section



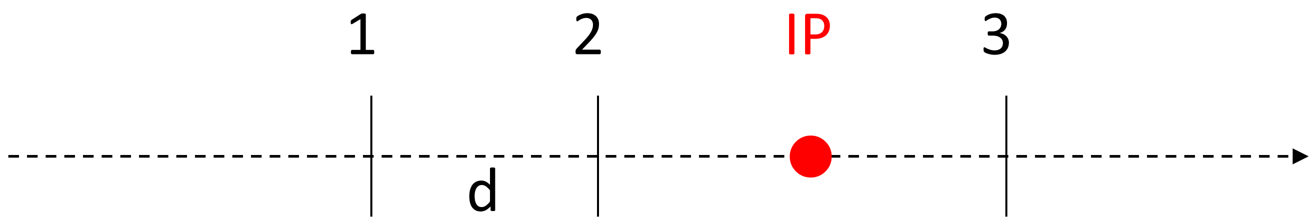
Data taken three shifts in three weeks in November to December, 2011, i.e. 1shift/week and 8h/shift

Published resolution :

8.72 +- 0.28 (stat.) +- 0.35 (sys.) nm

Y. Inoue et al, Phys. Rev. ST Accel. Beams 11, 062801 (2008)

Required precision on relative IP-BPM scale factors depends on beam parameters



$d \sim 0.1$ m
$\varepsilon_y \sim 12$ pm
$\sigma_{jitter} / \sigma \sim 10\%$

$\theta_{IP} = (y_2 - y_1) / d$ $\quad$ ξ = calibration error of 1 relative to 2

$y_{IP} = 2\, y_2 - y_1$ $\quad$ $\rightarrow\; 2\, y_2 - y_1 \sim y_{IP} + 2\, \xi\, \theta\, d$

$\beta \sim 1$ m (e.g. diagnostic section)

$\theta_{jitter} \sim (\varepsilon / \beta)^{0.5}\, d\, (\sigma_{jitter} / \sigma) \sim 10^{-7}$ rad $\Rightarrow \xi \sim 10^{-2}$ for 1 nm error

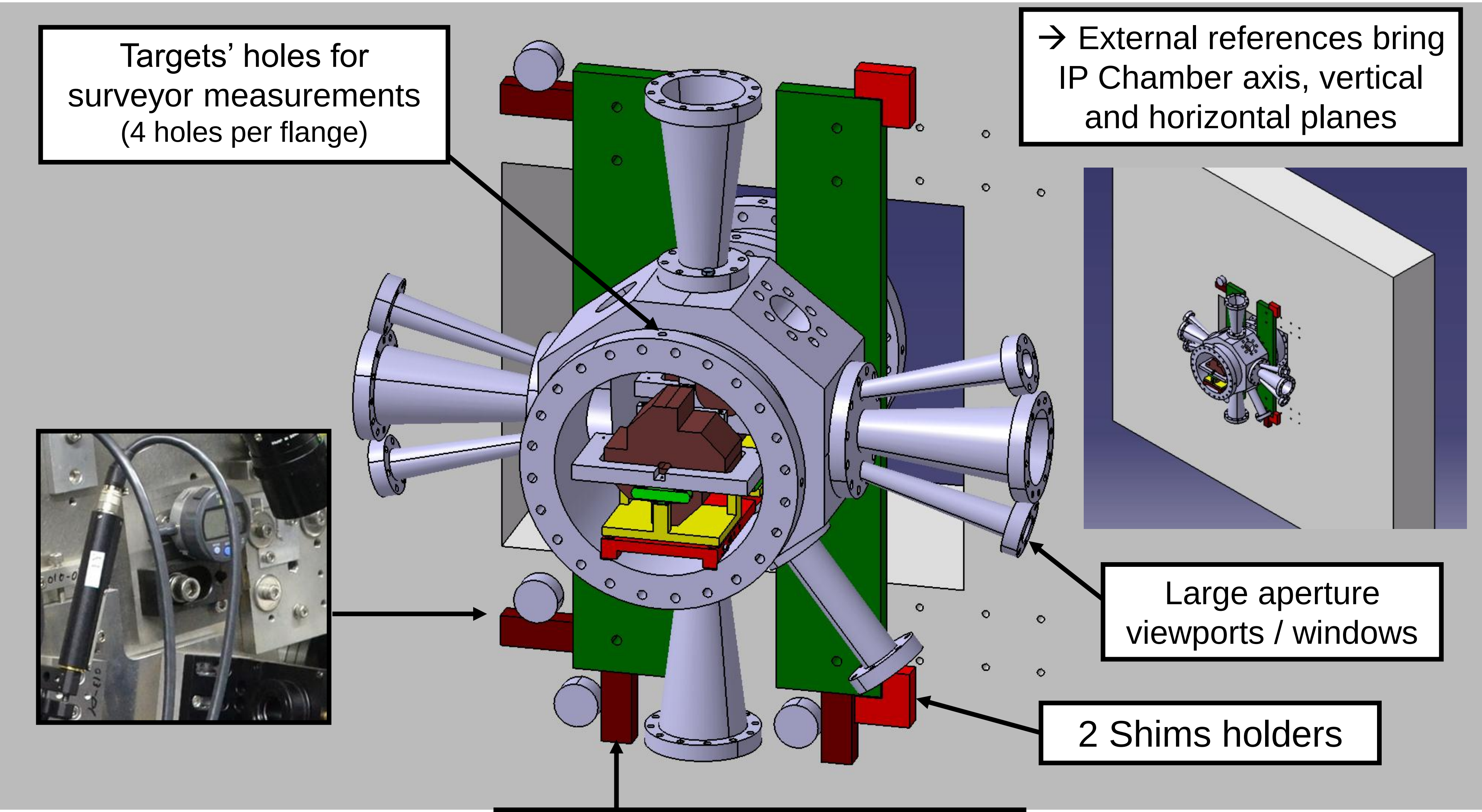
$\beta \sim 10^{-4}\; 10^{-3}$ m (interaction point : nominal 10 x optics)

$\theta_{jitter} \sim (\varepsilon / \beta)^{0.5}\, d\, (\sigma_{jitter} / \sigma) \sim 10^{-9}$ rad $\Rightarrow \xi \sim 10^{-4}$ for 1 nm error

$\xi \sim 10^{-3}$ for 10 nm error

$\xi \sim 3\; 10^{-3}$ for 1 nm error

New IP Chamber

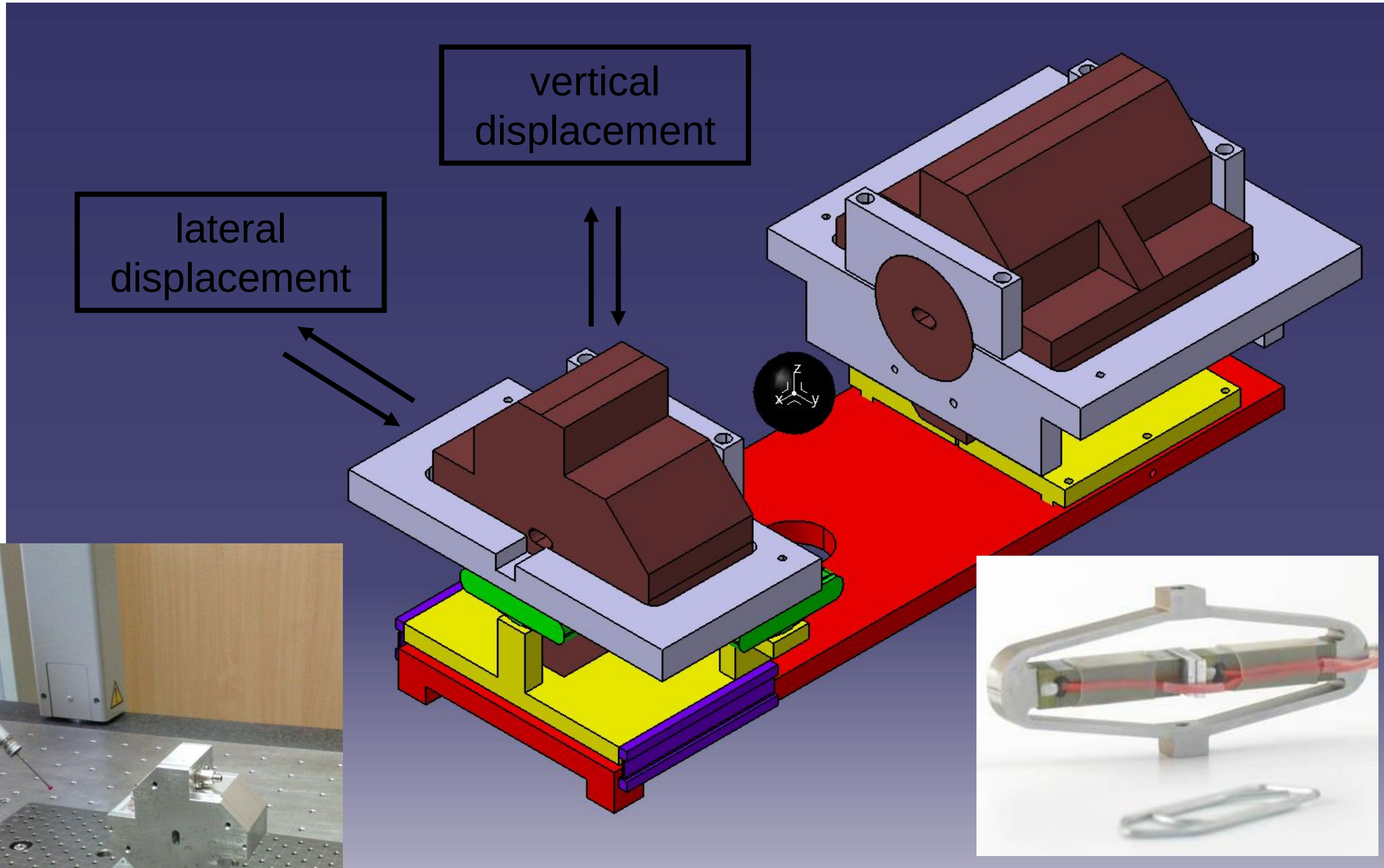


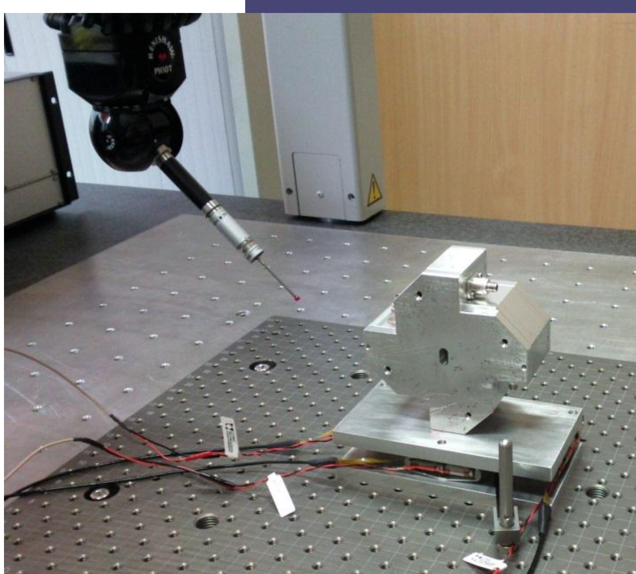
Downstream side

4 External (manual) movers to
adjust IP-Chamber position

**Sandry Wallon &
Frédéric Bogard (LAL)**

BPM displacement





BPM tripod 3d motion test
(Bruno Leluan)

piezo actuator
(Cedrat APA200M)