Future Plan for KEK-ATF

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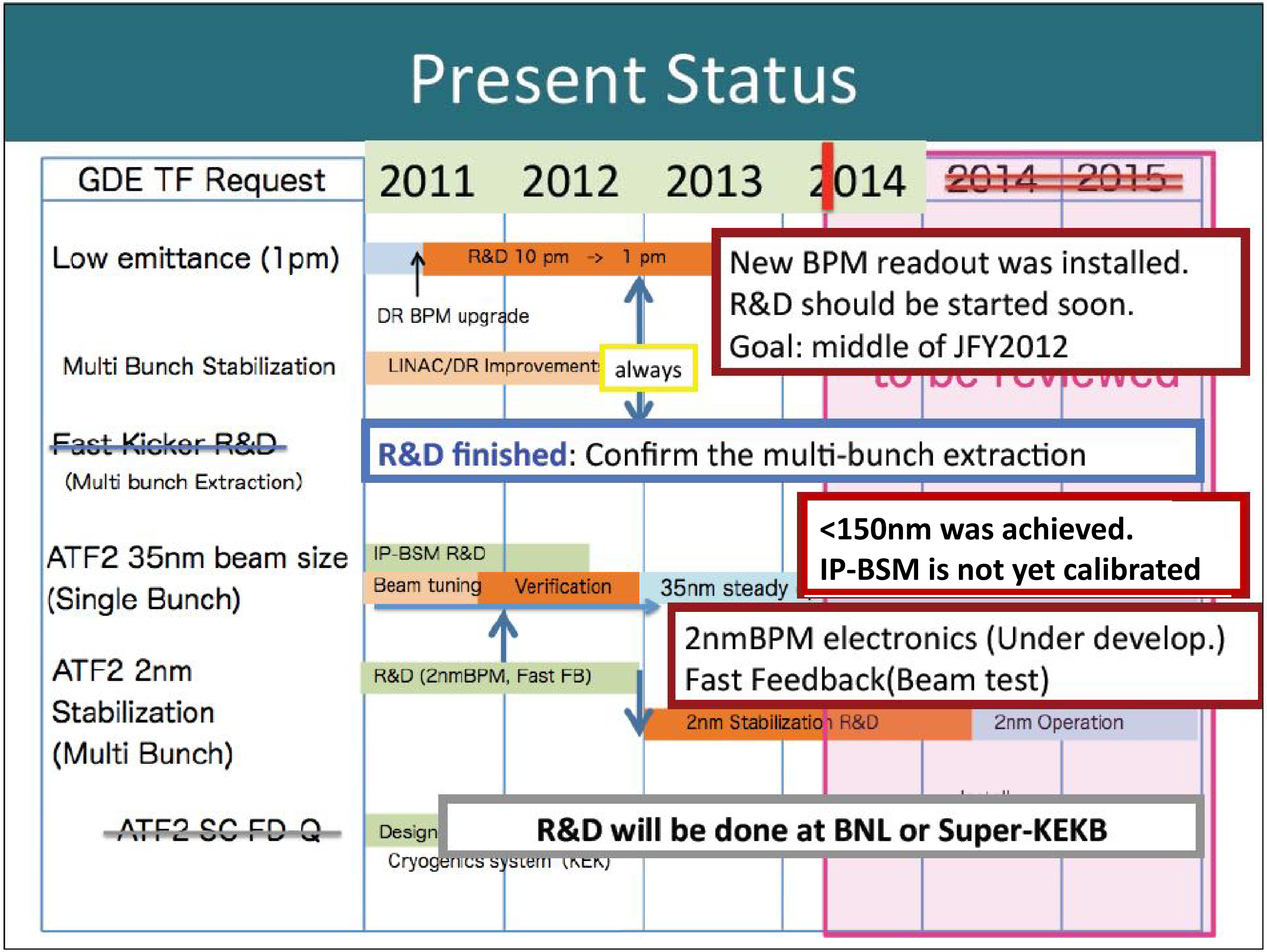
2012 / 3 /19

DESY/KEK meeting

DESY, Germany



Present Status
GDE TF Request
2011
2012
2013
2014
2014 2015
Low emittance (1pm)
R&D 10 pm -> 1 pm
DR BPM upgrade
New BPM readout was installed.
R&D should be started soon.
Goal: middle of JFY2012
Multi Bunch Stabilization
LINAC/DR Improvement
always
Fast Kicker R&D
(Multi bunch Extraction)
R&D finished: Confirm the multi-bunch extraction
ATF2 35nm beam size
(Single Bunch)
IP-BSM R&D
Beam tuning
Verification
35nm steady
<150nm was achieved.
IP-BSM is not yet calibrated
ATF2 2nm
Stabilization
(Multi Bunch)
R&D (2nmBPM, Fast FB)
2nmBPM electronics (Under develop.)
Fast Feedback(Beam test)
2nm Stabilization R&D
2nm Operation
ATF2 SC FD Q
Design
R&D will be done at BNL or Super-KEKB

Outline for the ATF future Plan

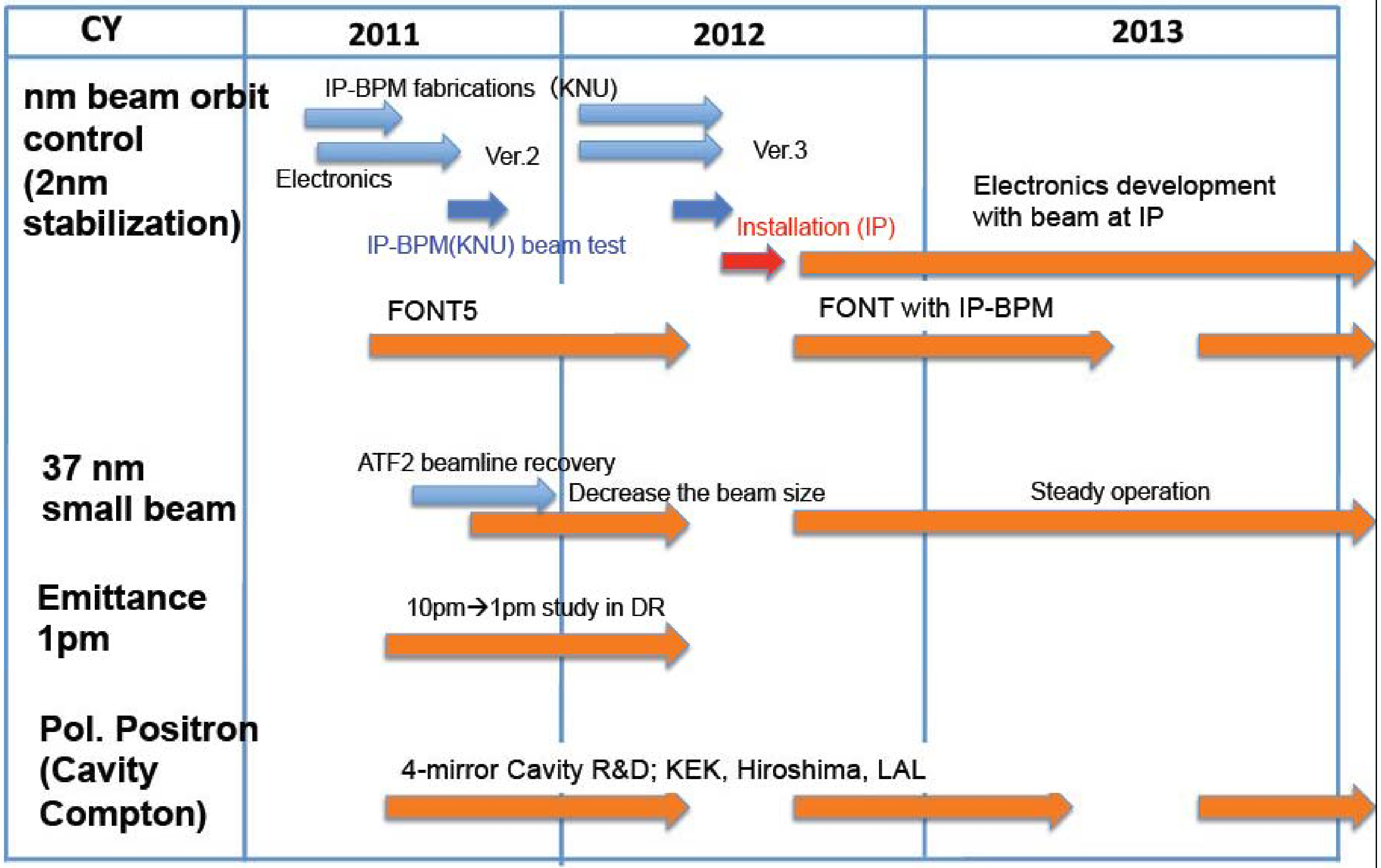
Present ILC dominated R&D will be continued at the end of JPY 2013.

- 1-2pm of vertical emittance generation in ATF-DR
- 35nm of vertical beam size evaluation at ATF2 beam line (1st goal of ATF2)
- 2nm of vertical beam stabilization at ATF2 beam line (2nd goal of ATF2)

Widening the ATF research not only ILC but also other science after JPY2014.

- Basic plan for the ATF operation is 50% for ILC and 50% for others.
- Obtain new (Non-KEK) funds to proceed new project.

Plan until the end of JFY2013



To Go to 1-2pm emittance in ATF-DR

From Simulations:

1, Improve magnet alignment

2, Improve BPM offset error wrt. nearest magnet

3, Improve optics error (magnet strength error)

Now, we are trying to achieve ~2 pm (or 1?).

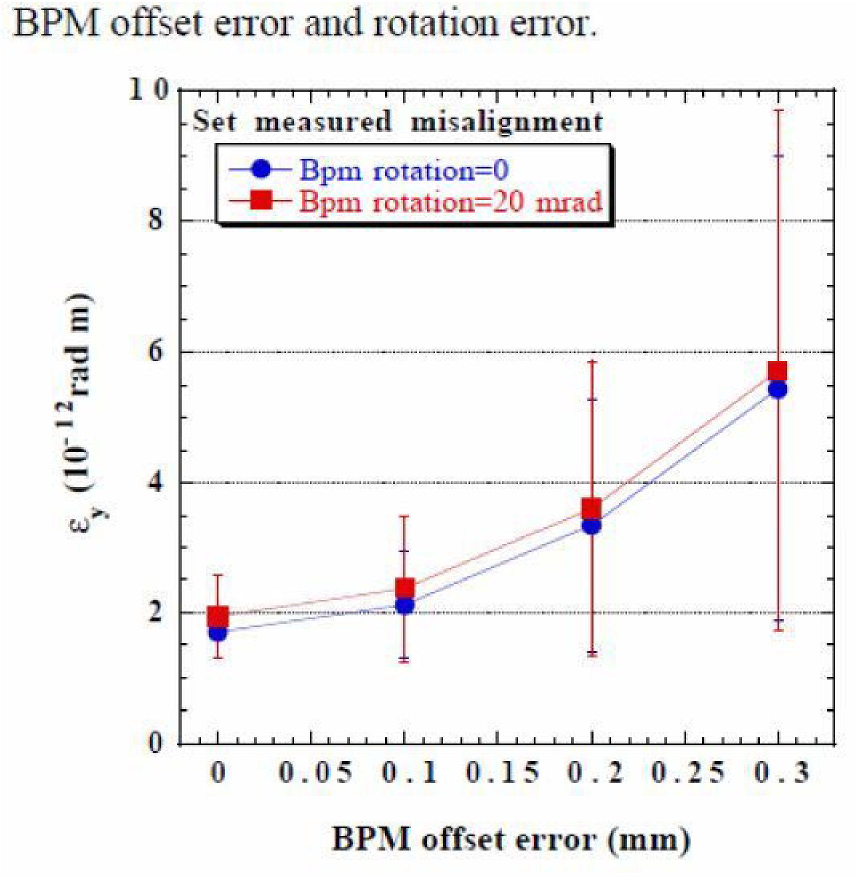
1, Re-alignment after the earth quake

2,3, Beam Based Alignment and Optics Correction

- Using improved BPM electronics system
- Orbit response to Quad strength change
- Orbit response to Steering

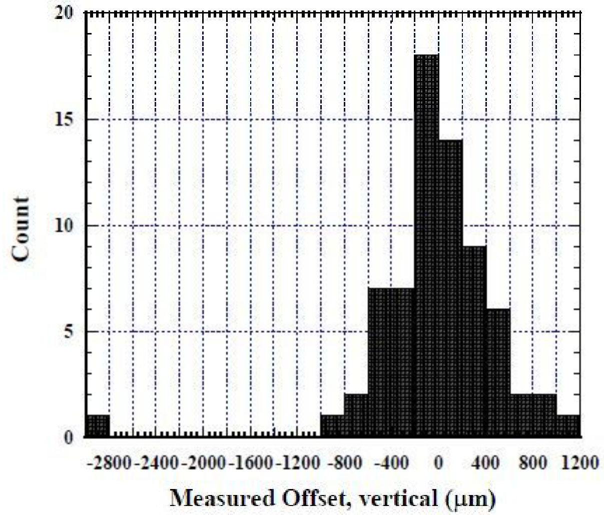
BPM offset Issue

Simulation (by K.Kubo)

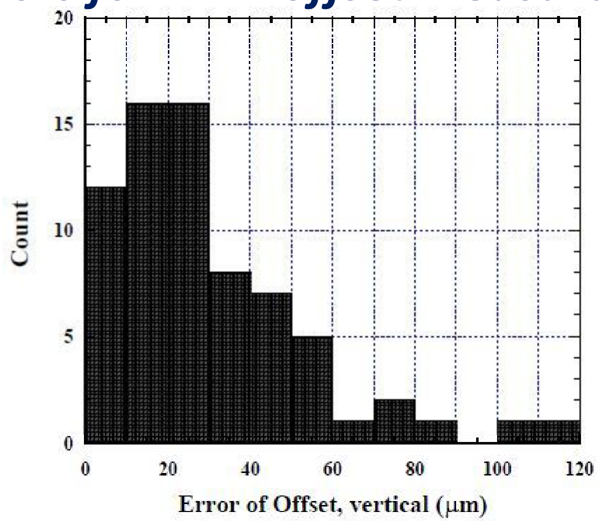


BPM offset should be less than 100um.

BPM offset by BBA

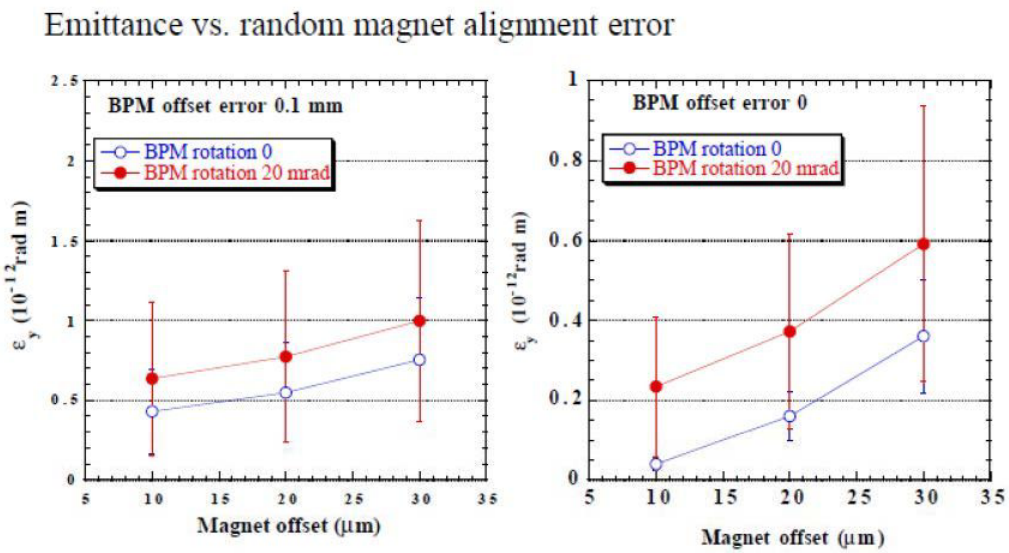


Errors for BPM offset measurement



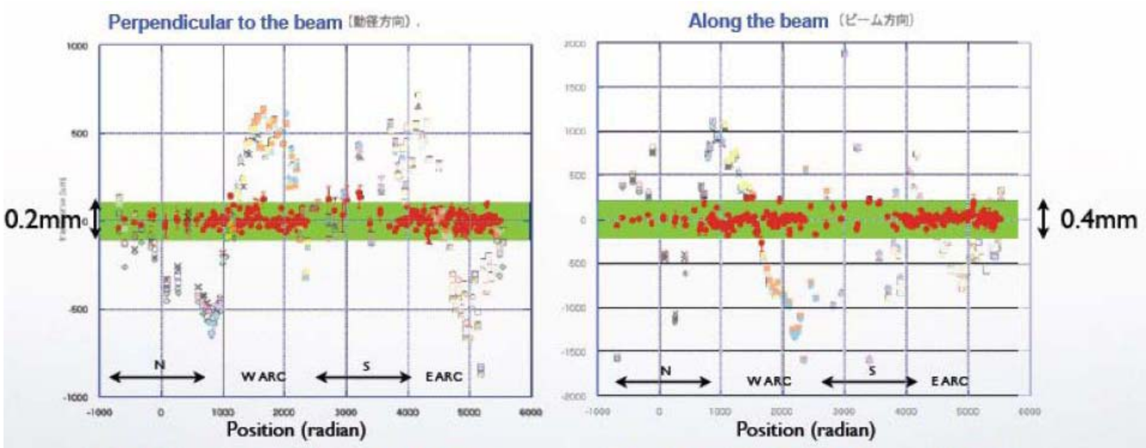
Magnet Alignment Issue

Simulation for magnet alignment (by K.Kubo)



In order to achieve 1pm emittance, the magnet misalignment should be less than 30um.

Alignment after earthquake (by S.Araki)



RMS transverse magnet offset 40um

What we must do …

- BPM system work well (at least with some maintenance by experts)
- BBA (offset) seems good enough.
- Magnet alignment seems fine but effects of actual misalignment not fully checked.
- Accuracy of X-SR beam size monitor?

What to do

- Keep BPM always reliable. (Communication between tuning team and BPM group)
- Need BBA for rotation (or x-y coupling) of BPM?
- Check effects of misalignment. More alignment if needed.
- DR Laser wire monitor for confirmation of emittance.
- ?

-> Laser wire with pulsed cavity resonater will be installed in 2012 summer.

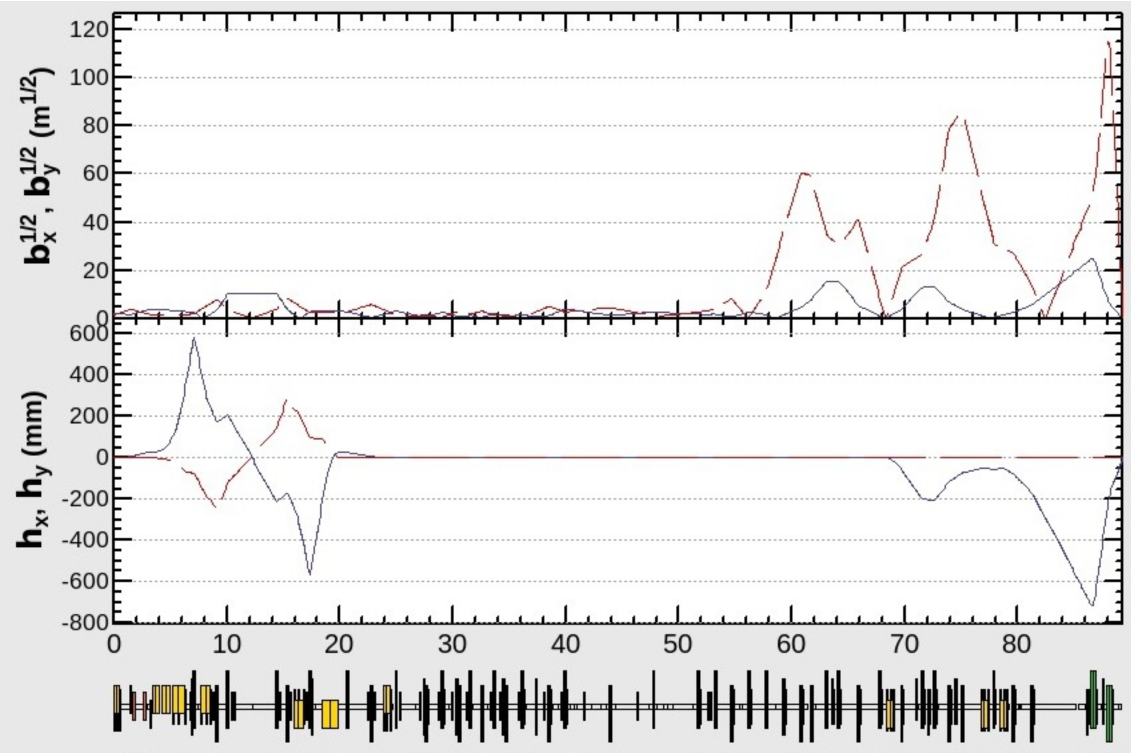
35nm of vertical beam size evaluation at ATF2 beam line

Present Status for ATF2 tuning

Beam Optics :   betax*=4cm, betay*=0.1mm optics

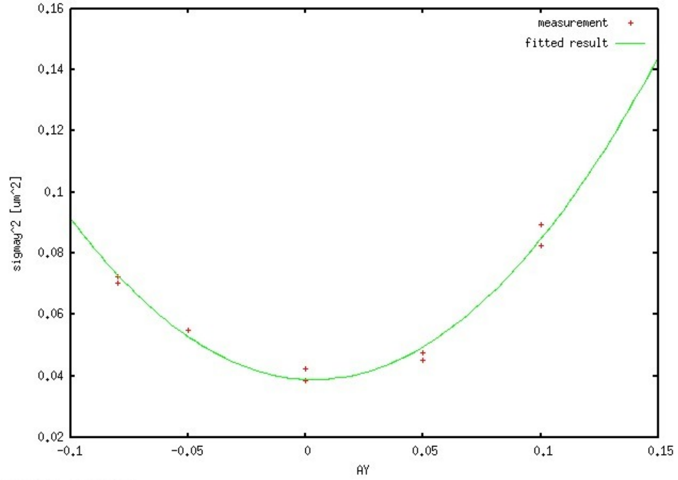
Maimum Modulation in 30degree mode : 0.45

Minimum Beam Size: < 150nm (temporary ; not yet calibrate)

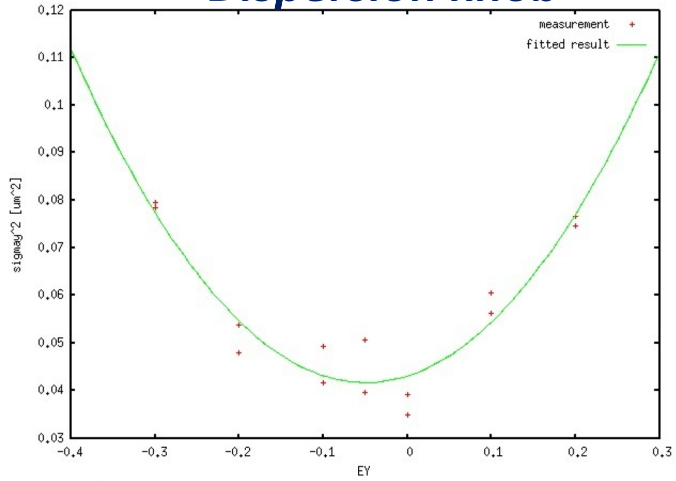


Optimization for Linear Knobs were done.

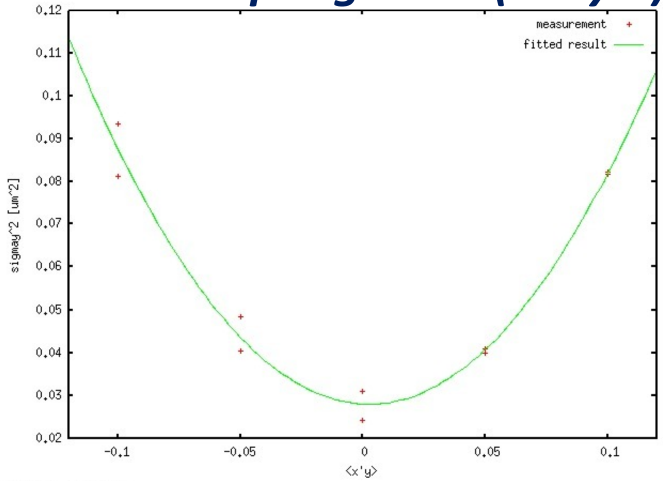
Waist knob



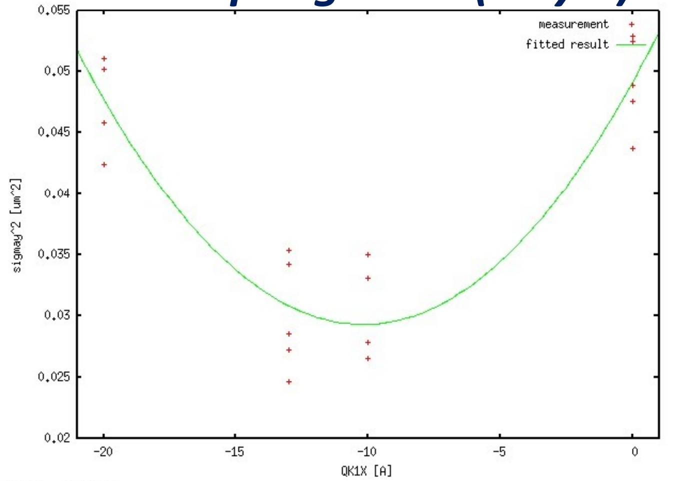
Dispersion knob



Coupling knob (<x'y>)

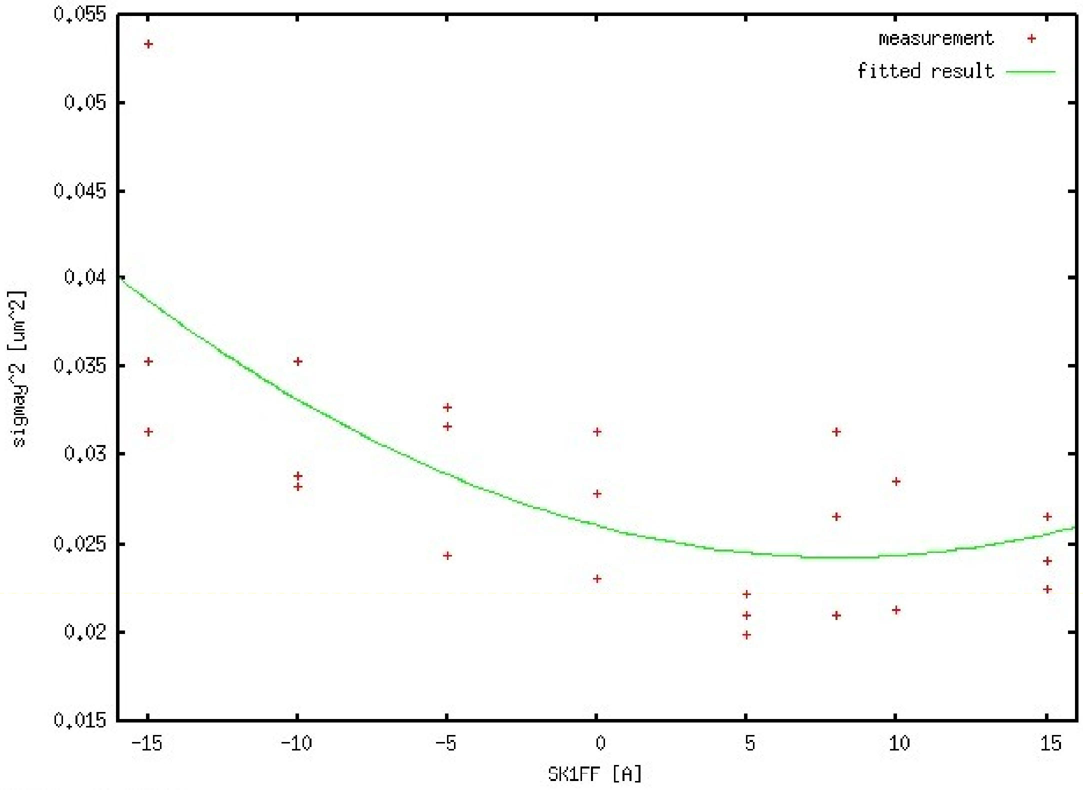


Coupling knob (<xy>)



Optimization of Non-linear knobs were on going …

Optimization of skew sextupole component was done.



Optimization of sextupole component was not yet done.

When the optimization of the strength for sextupole magnets, the laser condition was getting worth.

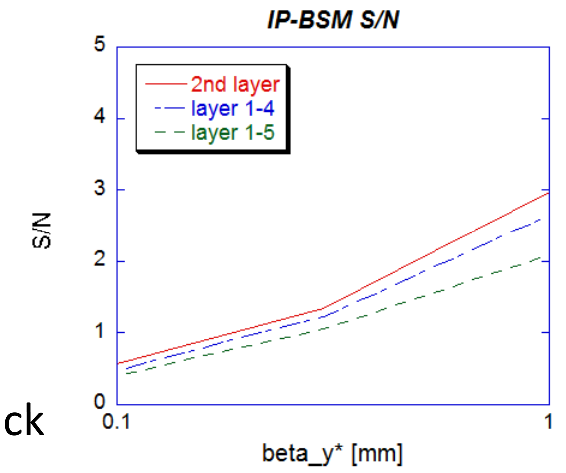
What we must do ...

Beam tuning

- Optimization of the nonlinear knobs (strength of sextupole magnets)
- Evaluation of the higer multipole errors for magnets (8pole and more)
- Establish of the beam tuning method

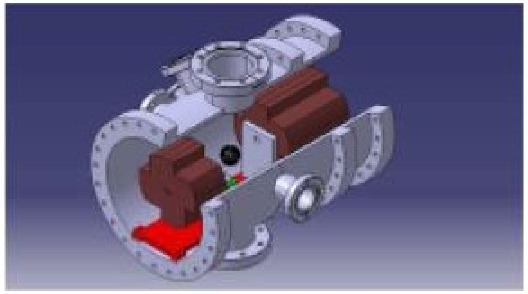
Beam Size Monitor

1. Laser Stabilization
2. Investigate the modulation reduction factor
3. Improve the S/N ratio
4. Development of phase monitor and phase feedback



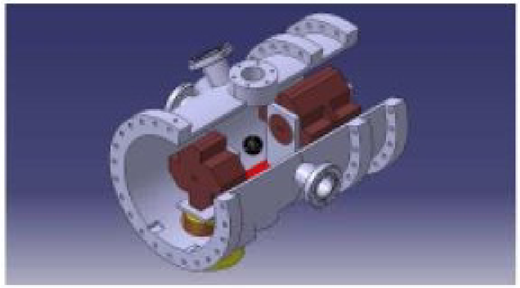
2nm of vertical beam stabilization at ATF2 beam line

IP Chamber Design (LAL)



Linear stages inside chamber

- Vacuum compatibility questionable (vacuum qualification will be done at LAL)
- BPM bending moment to take
- Simple design (and manufacture too)
- BPM mounted on removable plate at work shop
- 3D control at workshop (BPM alignment checking)
- Linear stages just below BPM's center weight

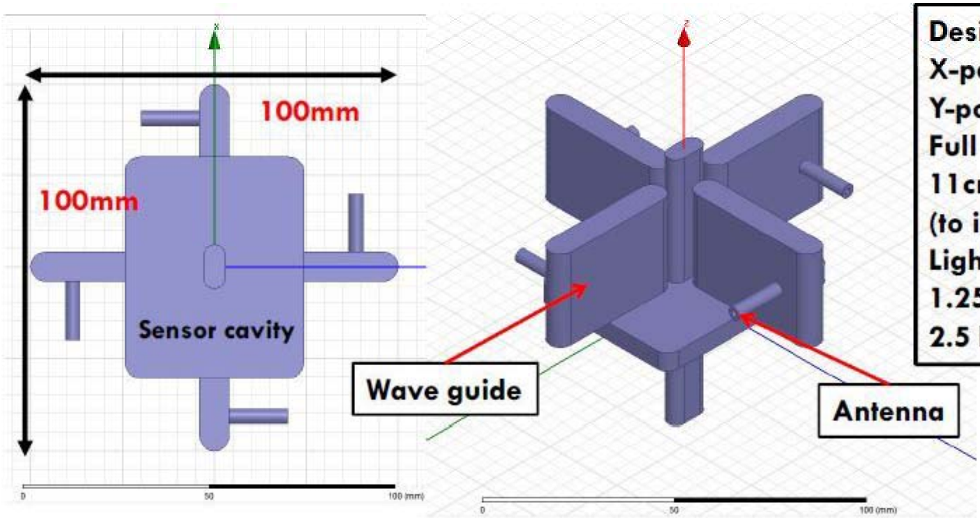


Linear stages outside chamber

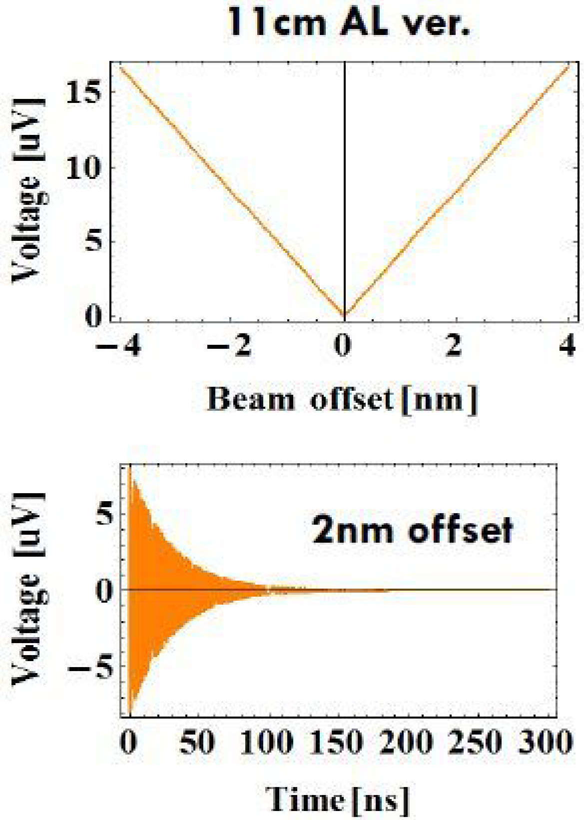
- Design more complicated (and manufacture too)
- Ip chamber slightly longer (downstream side)
- Vacuum compatibility unquestionable
- Linear stages just below BPM's center weight

Low Q IP-BPM Development (KNU)

HFSS Simulation



Designed frequency
X-port: 5.712 GHz
Y-port: 6.426 GHz
Full size :
11cmx11cm
(to install IP-Chamber)
Light weight:
1.25 kg (Single)
2.5 kg (Double)



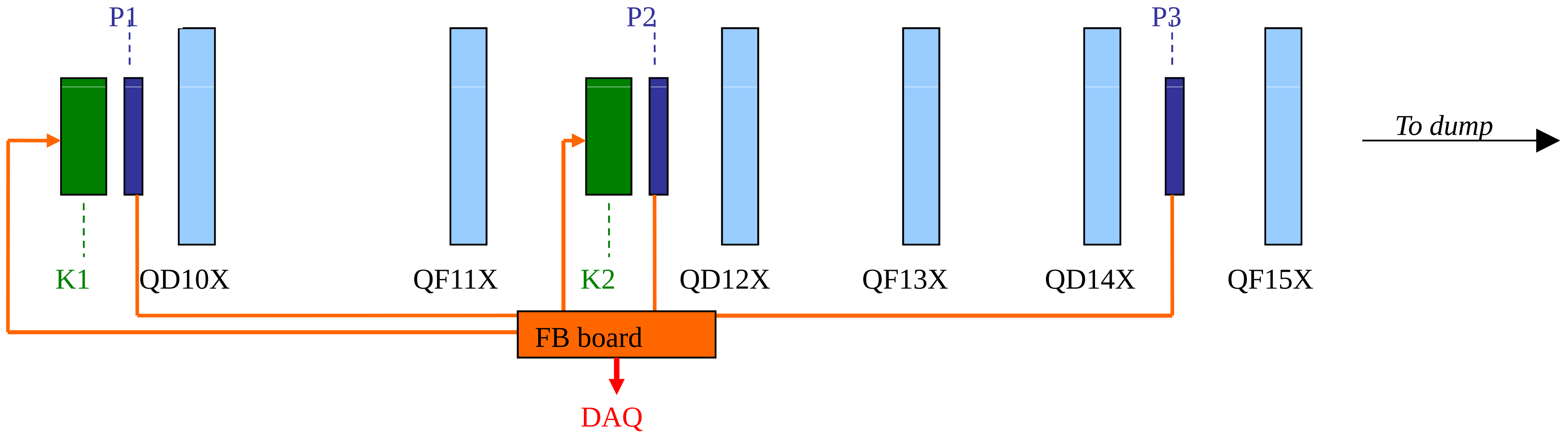
Port	f_0 (GHz)	β	Q_0	Q_{ext}	Q_L	τ (ns)
X-port	5.7123	4.992	4026.58	806.67	672.04	18.72
Y-port	6.4255	5.684	4014.13	706.16	600.51	14.87

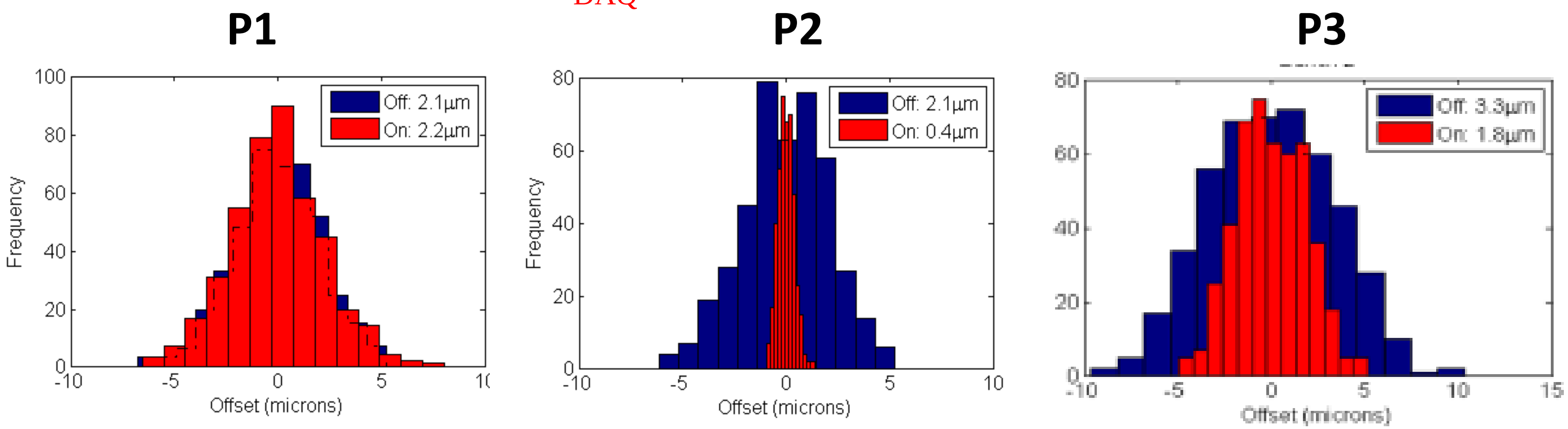
Multi-bunch Feedback (Oxford University)

FONT5

The feedback is testing at the ATF extraction line (not IP)

P2 → K1 ('position')
P3 → K2 ('angle')
P3 → K1
P2 → K2





Policy on the ATF future plan

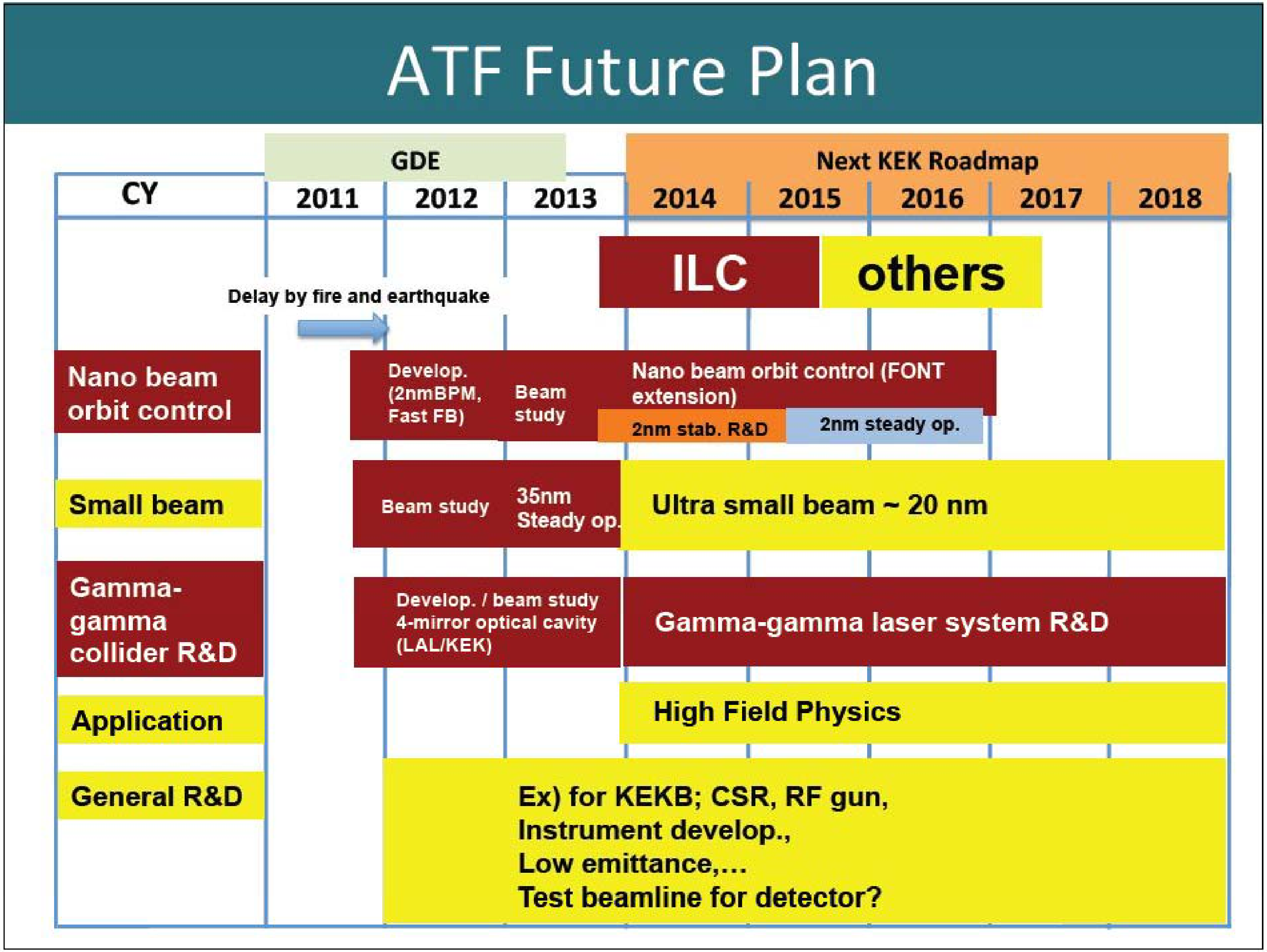
Researches with low emittance and small beam

- Advanced Accelerator technology
- **Multilateral cooperation**
- Education of young researchers

Other R&D（50%）

ILC related R&D（50%）

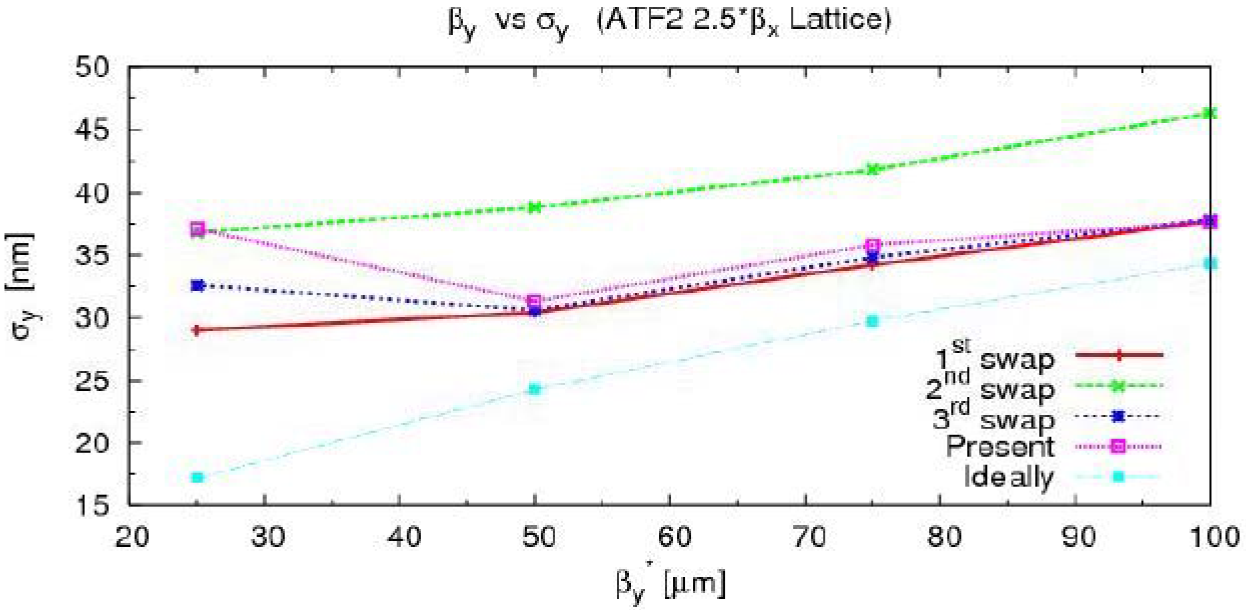
- Achievement of the remaining goal
- Establishment of technology


ATF Future Plan
GDE
Next KEK Roadmap
CY
2011
2012
2013
2014
2015
2016
2017
2018
ILC
others
Delay by fire and earthquake
Nano beam orbit control
Develop. (2nmBPM, Fast FB)
Beam study
Nano beam orbit control (FONT extension)
2nm stab. R&D
2nm steady op.
Small beam
Beam study
35nm Steady op.
Ultra small beam ~ 20 nm
Gamma-gamma collider R&D
Develop. / beam study 4-mirror optical cavity (LAL/KEK)
Gamma-gamma laser system R&D
Application
High Field Physics
General R&D
Ex) for KEKB; CSR, RF gun, Instrument develop., Low emittance,… Test beamline for detector?

Ultra-small beam Generation (beyond ATF2 design)

- Verify the very high chromaticity optics (for ILC?)
- Collaboration with CERN (for CLIC R&D)

Simulation for ultra-high low beta optics by Edu Marin (CERN)

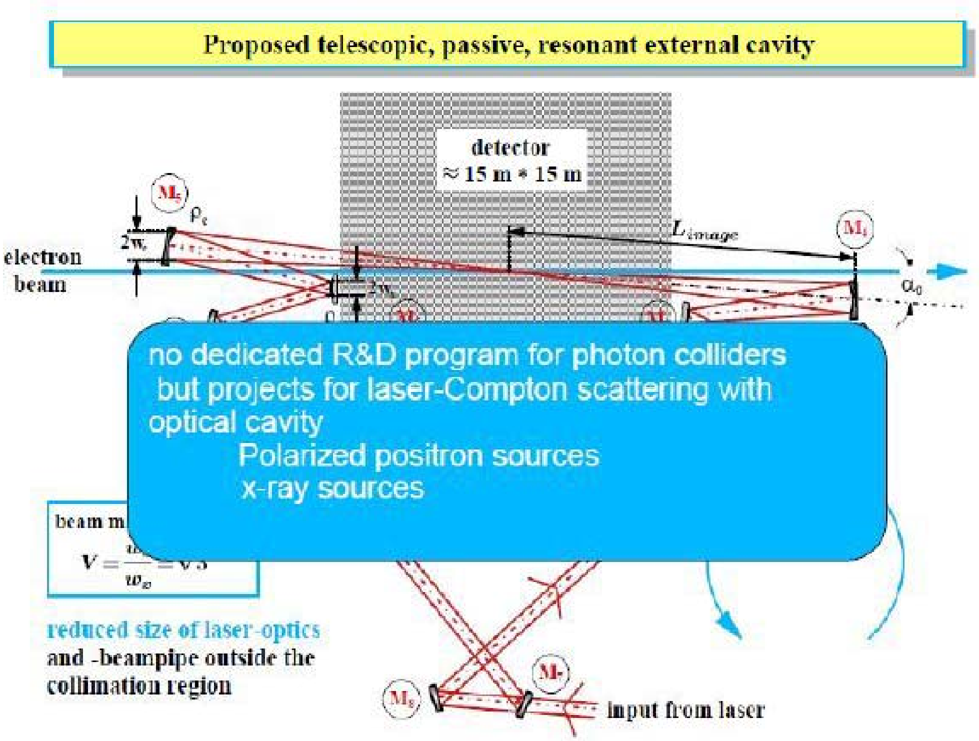


- 30nm is limited by multipole error of Final Doublet for the present ATF magnet.
  -> to be replaced with collaboration to CERN
- The IP-BSM must measure the 90% of modulation for 174degree mode
  -> further stabilization of IP-BSM measurement

R&D for Gamma-gamma collider

Establishment to the technology for PLC

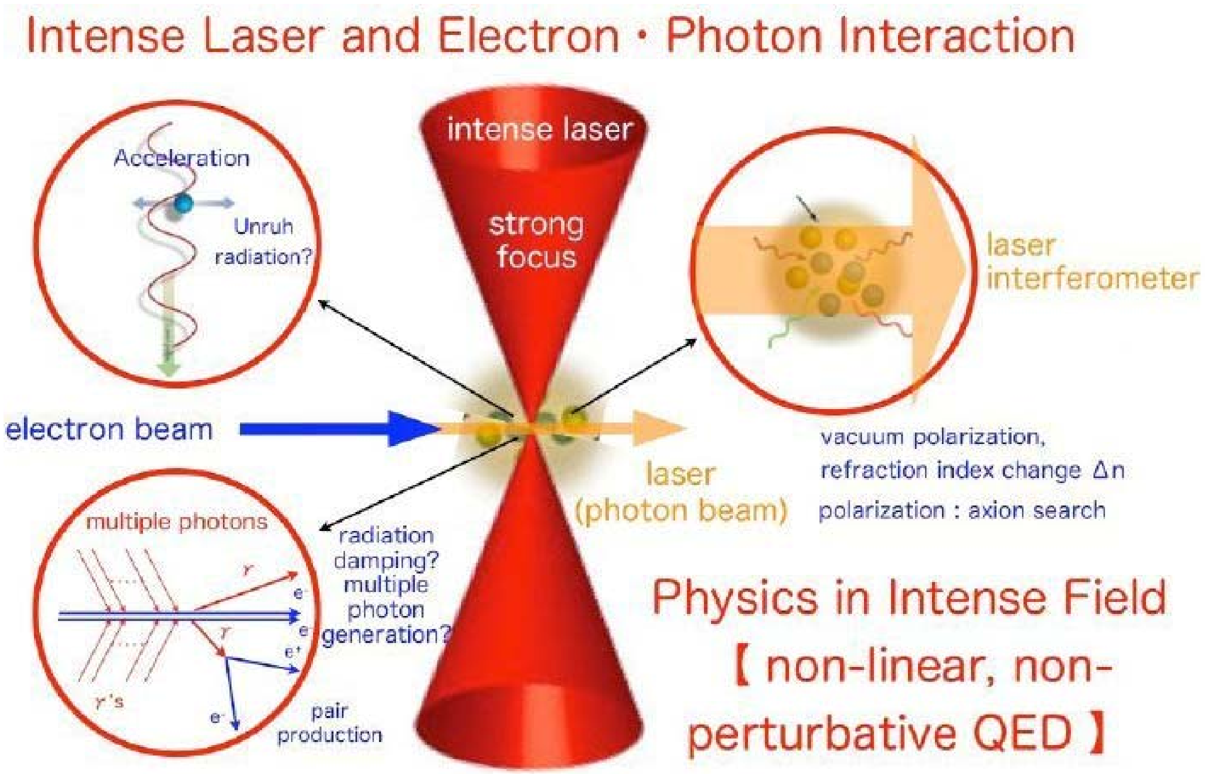
- a few 10m scale of optical cavity resonator
- storage of very high power laser light (5 joules)



Compact prototype cavity in ATF

In-kind collaboration (LAL)

High Field Physics (Non-ILC R&D)



200TW laser system is required for this R&D program

Summary of the Future Plan of KEK-ATF

Policy of the ATF project

•Investigation of advanced accelerator technology.
•Operation by global international collaboration.
•Education of young researchers.

Present ILC dominated R&D will be continued at the end of JPY 2013.

•1pm of vertical emittance generation in ATF-DR
•35nm of vertical beam size evaluation at ATF2 beam line (1^{st} goal of ATF2)
•2nm of vertical beam stabilization at ATF2 beam line (2^{nd} goal of ATF2)

Widening the ATF research not only ILC but also other science from JPY 2014.

The candidates for new KEK research programs are

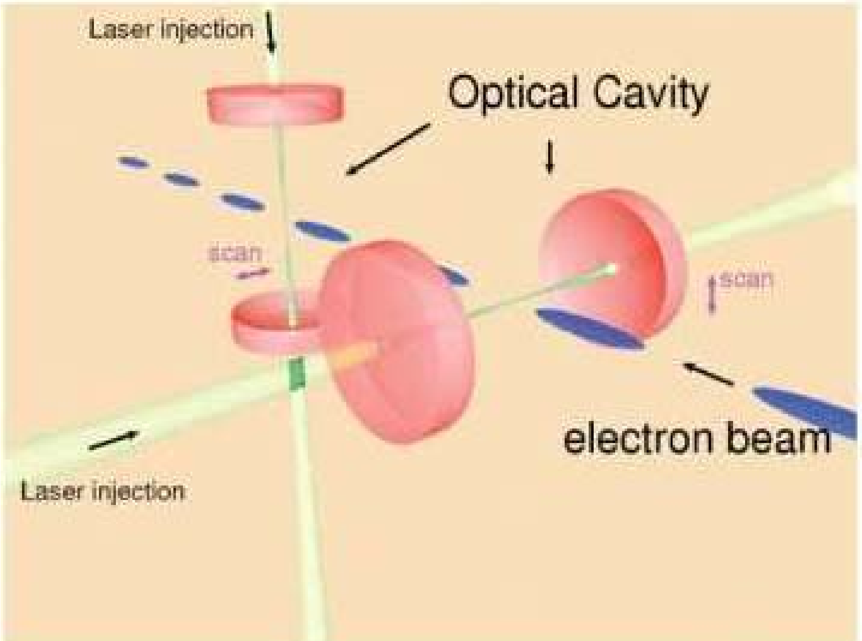
•Generation of 20nm small beam (for ILC and CLIC)
•Investigation of optical cavity for Gamma-gamma collider (for ILC)
•High field physics through intense laser and electron collision (non-ILC)

Backup

Cavity based Laser Wire Scanner

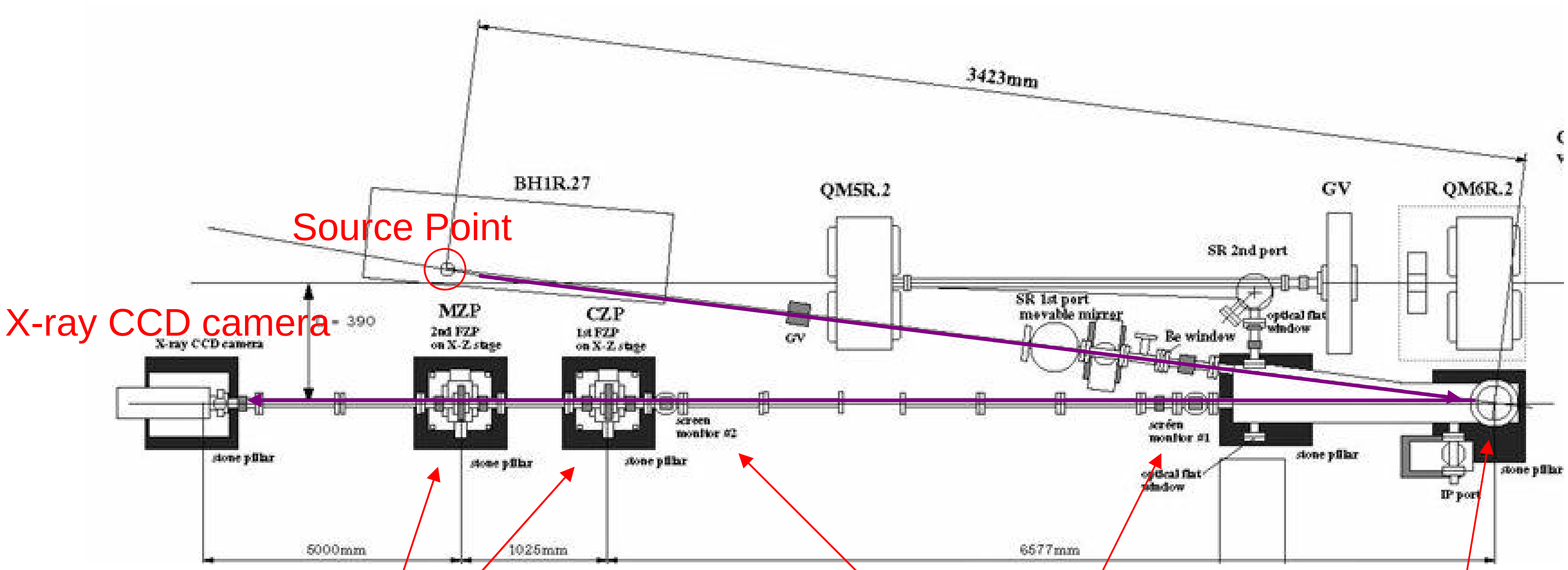
Concept of Cavity based Laser Wire

The peak power of CW laser is small,
but we can use the CW laser by amplification in optical cavity.

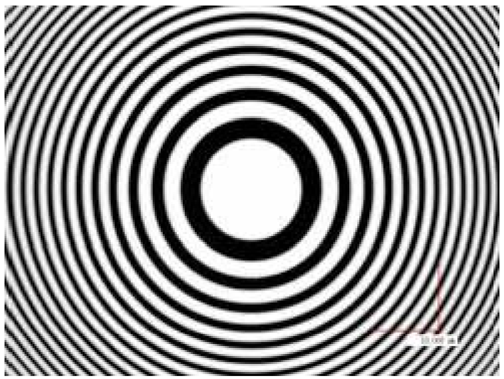


The advantage of the cavity based laser wire is laser wire stability (position and wai
by well stability of CW laser and mode cleaning effect in the optical cavity .

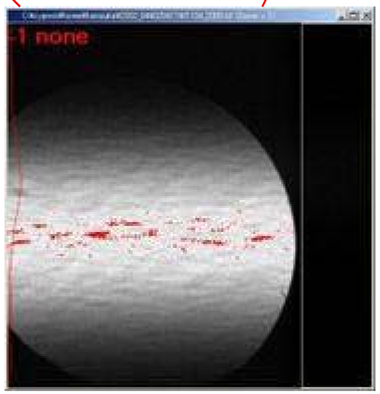
Experimental Setup



X-ray Mirror
(Bragg's Law)

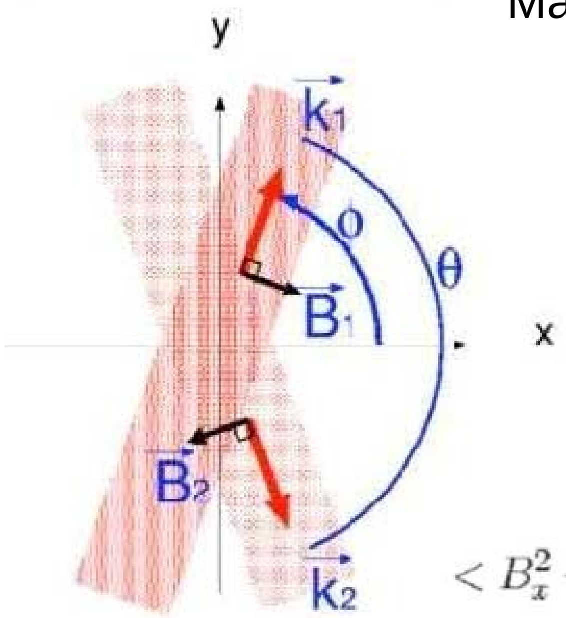


Fresnel Zone Plate



X-ray Screen

Interference Pattern



Magnetic field of laser light

$$\overrightarrow{B_1} = B\cos(\omega t - \overrightarrow{k_1}\cdot\overrightarrow{r})\hat{B}_1$$

$$\overrightarrow{B_2} = B\cos(\omega t - \overrightarrow{k_2}\cdot\overrightarrow{r})\hat{B}_2$$

$$\overrightarrow{B_1} + \overrightarrow{B_2} = \begin{pmatrix} 2B\sin\phi\sin(k_y y)\sin(\omega t - k_x x) \\ 2B\cos\phi\cos(k_y y)\cos(\omega t - k_x x) \end{pmatrix}$$

$k_x \equiv k\cos\phi$、$k_y \equiv k\sin\phi$

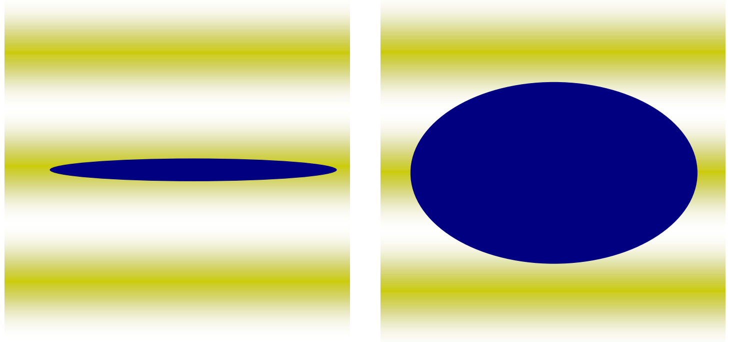
$$\begin{aligned} < B_x^2 + B_y^2 > &= 2B^2[\sin^2\phi\sin^2(k_y y) + \cos^2\phi\cos^2(k_y y)] \\ &= B^2[1 + \cos\theta\,\underline{\cos(2k_y y)}] \end{aligned}$$

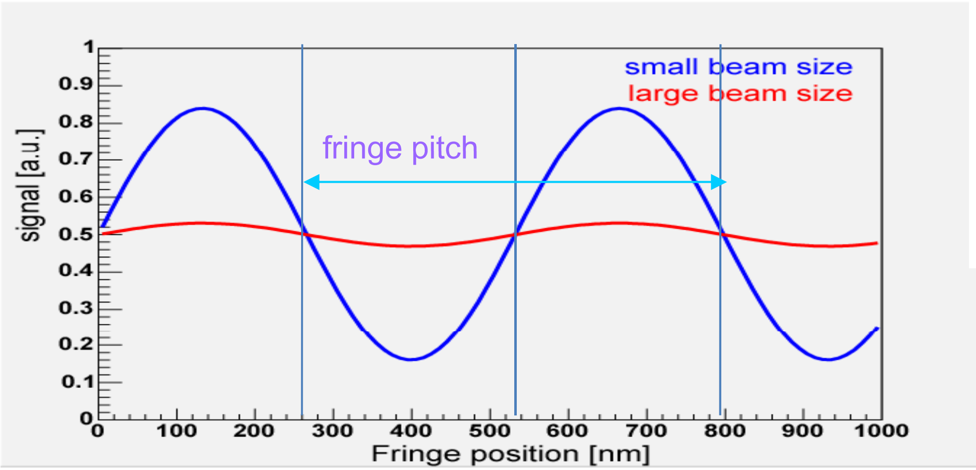
$$\boxed{d = \frac{\pi}{k_y} = \frac{\lambda}{2\sin(\theta/2)}}$$

The distance of the interference pattern is defined by laser collision angle

Beam Size Evaluation with Laser Interferometer

Small beam　　Large beam





Emitted Photon is evaluated
by the convolution of beam distribution.

$$N_\gamma \propto \int_{-\infty}^{\infty} \underline{\exp[-\frac{(y-y_0)^2}{2\sigma_y^2}]}(1+\cos\theta\cos 2k_y y)dy$$
$$= N_0[1+\cos(2k_y y_0)\cos\theta]\exp[-2(k_y\sigma_y)^2]$$

$$N_\pm = N_0[1 \pm \cos\theta \underline{\exp[-2(k_y\sigma_y)^2]}]$$

Amount of interference

$$M \equiv \frac{N_+ - N_-}{N_+ + N_-}$$
$$= |\cos\theta|\exp[-2(k_y\sigma_y)^2]$$
$$= |\cos\theta|\exp[-2(\frac{\pi\sigma_y}{d})^2]$$

$$\boxed{\sigma_y = \frac{d}{2\pi}\sqrt{2\ln\left(\frac{|\cos\theta|}{\underline{M}}\right)}}$$

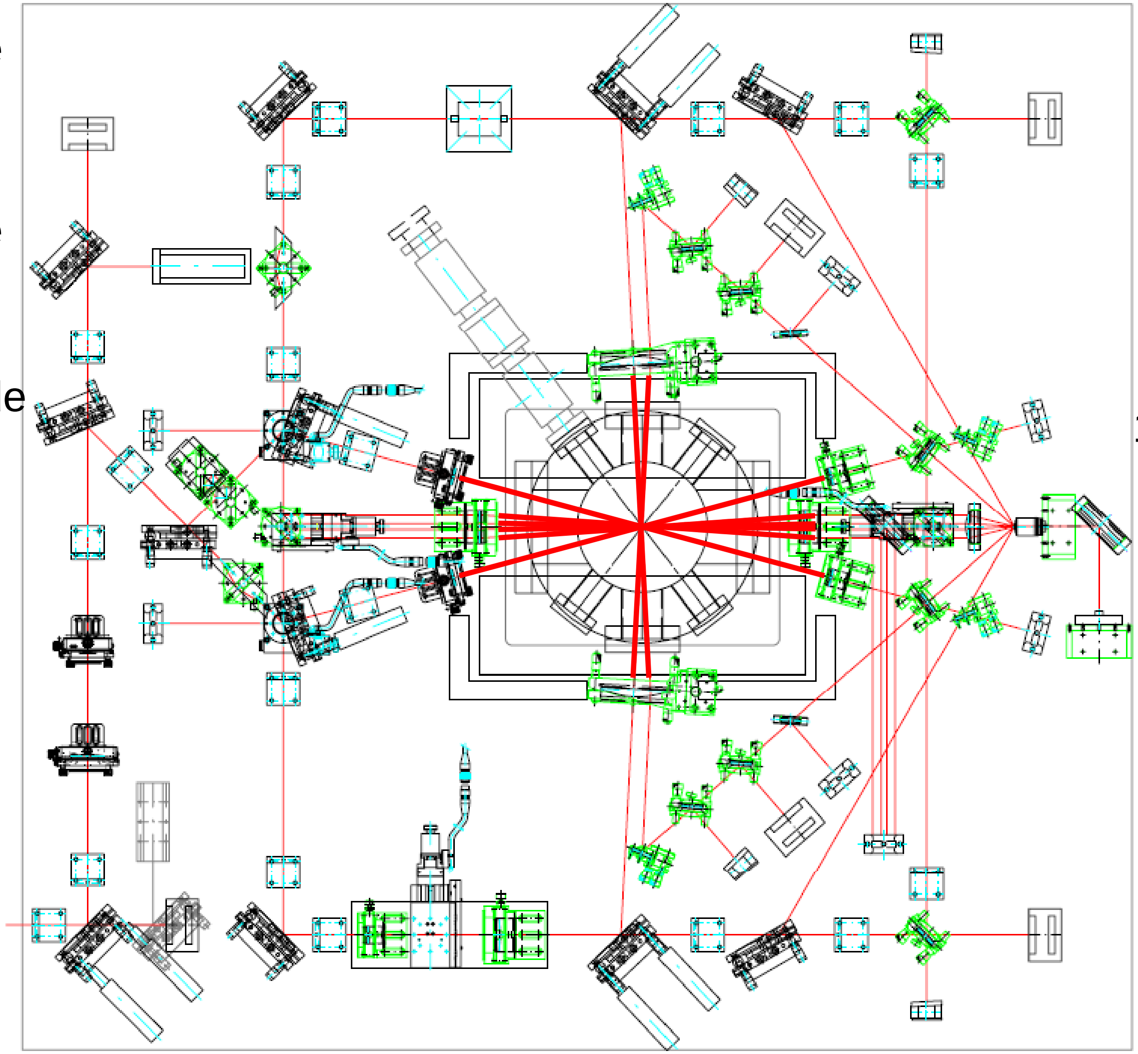
Layout of the Laser Table of ATF2 Laser Interferometer

2 degree mode

8 degree mode

30 degree mode

174 degree mode



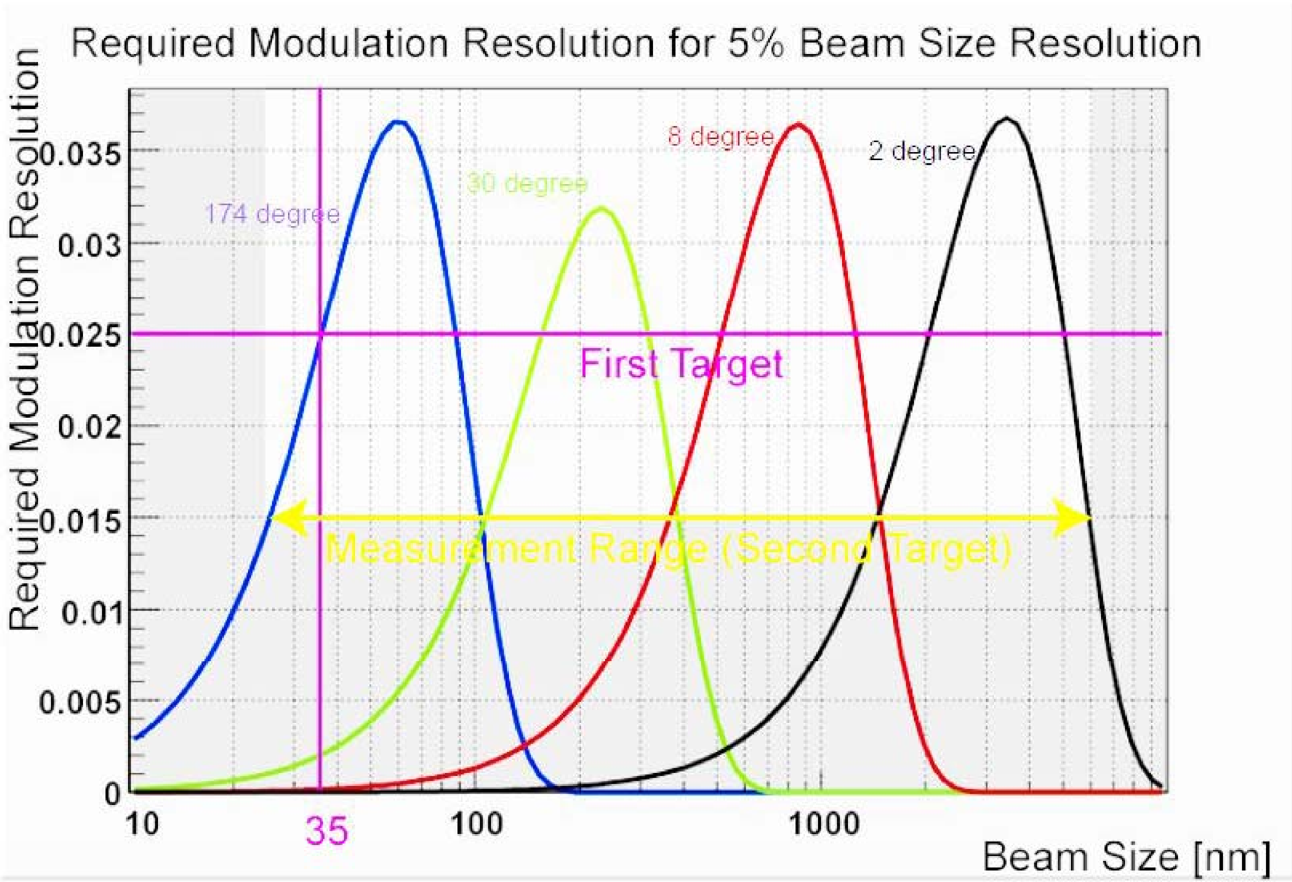
15μm pitch

3.8μm pitch

1.03μm pitch

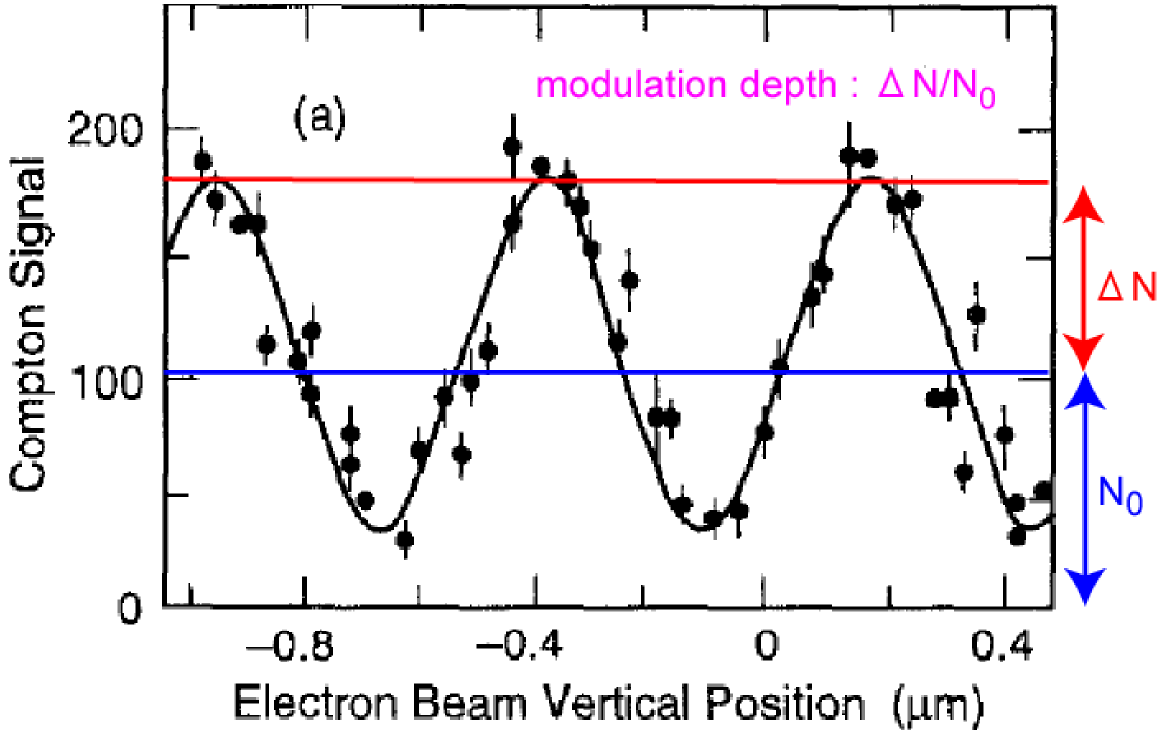
266nm pitch

Measurable Range of ATF2 Laser Interferometer



By changing 4 laser collision angle,
we can measure 25 – 6000 nm of beam size.

The beam size measurement at FFTB in SLAC

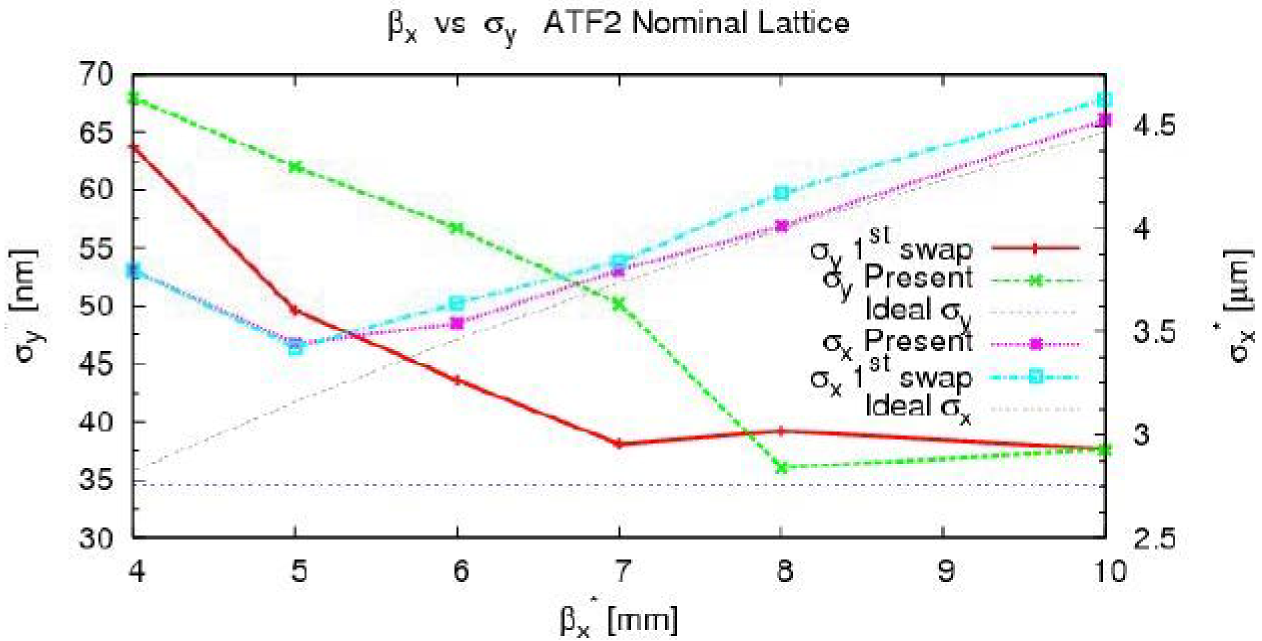


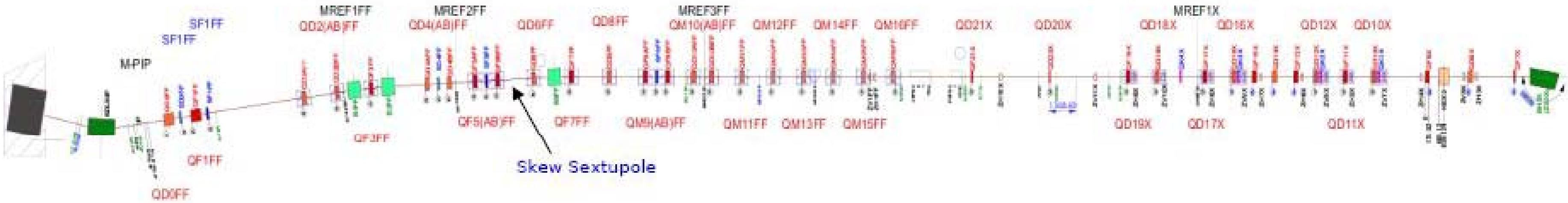
The 70nm beam size was measured in SLAC by laser interferometer.

Laser wavelength ; 1064nm

Beam energy ; 45GeV

Betax Optimization with multipole error for ATF2 beamline





1 SWAP

QM12FF	-->	QF9BFF
QD2BFF	-->	QF5AFF
QM13FF	-->	QF9AFF
QF19X	-->	QF5BFF
QM15FF	-->	QD4BFF
QD10BFF	-->	QD10AFF
QF17X	-->	QD6FF
QM11FF	-->	QD4AFF
QF7FF	-->	QD8FF

2 SWAP

QF1FF	-->	QD0FF

3 SWAP

QM12FF	-->	QF9BFF
QF17X	-->	QF5AFF
QM13FF	-->	QF9AFF
QM15FF	-->	QF5BFF
QF11X	-->	QD4BFF
QM16FF	-->	QD10AFF
QM14FF	-->	QD6FF
QD18X	-->	QD4AFF
QD16X	-->	QD8FF
QM11FF	-->	QD10BFF