ATF現状報告

- 概要
- ATF2状況と今後の方針
- Fast kickerの進展
- その他（省略：スライド添付）

加速器研究施設　照沼信浩

第１３回リニアコライダー計画推進委員会 平成２３年１月２５日 KEK3号館１階会議室

2009年加速器学会報告より

ATF2の概要

ATF ダンピングリングで得られる低エミッタンスビームを利用し、ILC 最終収束系の技術開発研究・実証実験を行う。
(ILCのFinal Focusと同じ設計に基づくビームライン；energyは1.3GeV)
ATF2 Proposal, KEK Report 2005-2,9

1. 垂直方向37nmのビームサイズの達成

(1) Local chromaticity correctionに基づくCompact Final Focus Systemの試験
(2) ビームサイズの維持

2010年度を目標

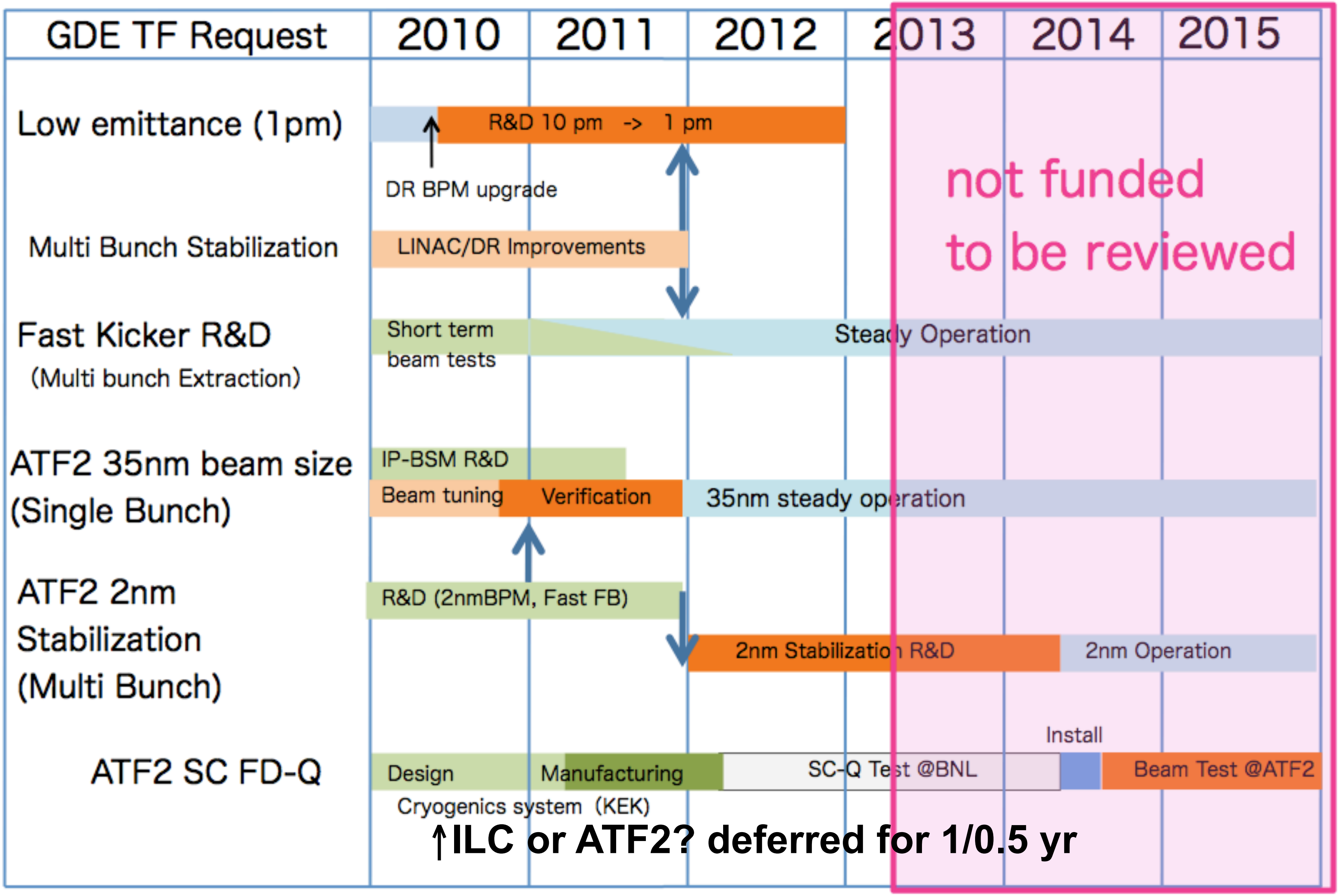
2. nmレベルでのビーム位置の制御

(1) IPにおいてナノメートル精度のビーム軌道安定化の試験
(2) ILC-like beamでのナノメートルレベルのビームジッター制御技術の確立

2012年度を目標

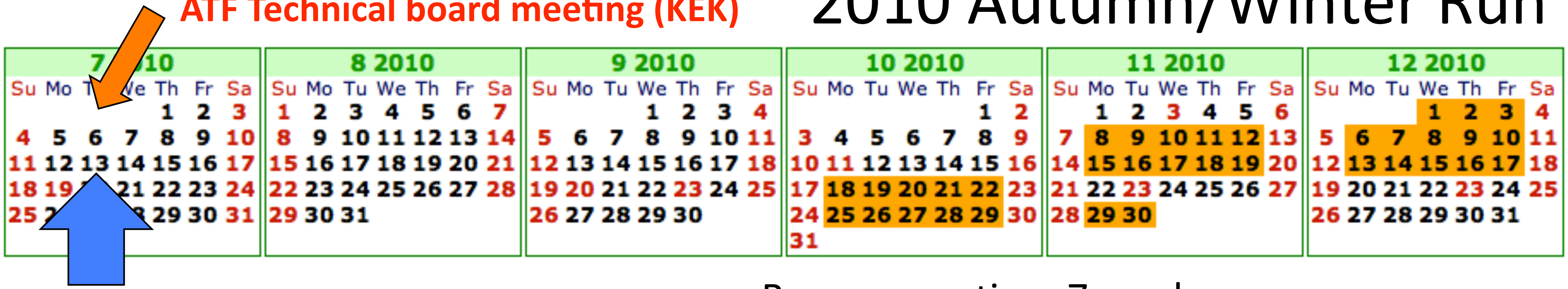
国際協力体制・分担の下で建設およびビーム開発試験を実施。

ATF long term plan



ATF2 project meeting
ATF Technical board meeting (KEK)

2010 Autumn/Winter Run



前回の推進委員会

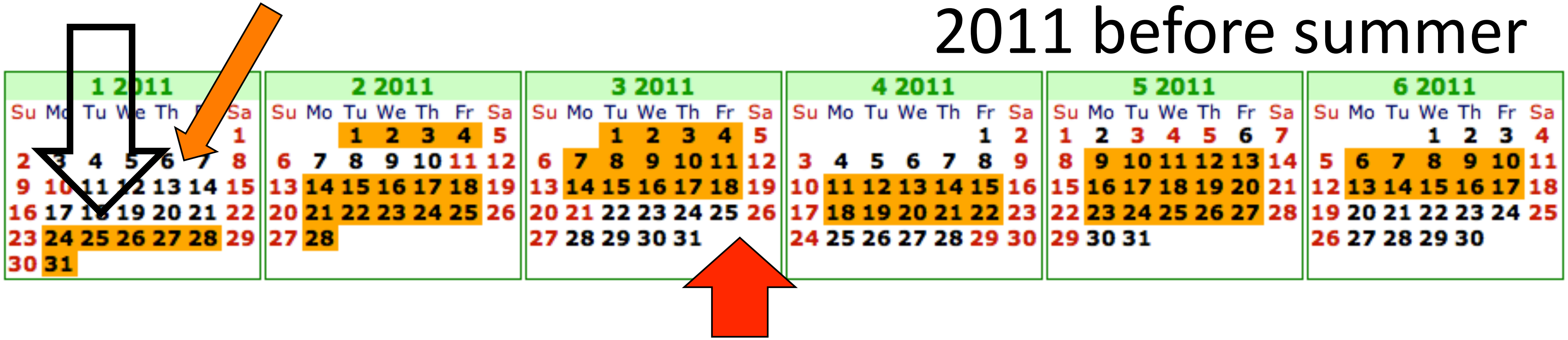
Beam operation: 7 weeks

- Fast kicker mode ... 2 weeks
- ATF2 continuous run ... 1 week

現在

ATF2 project meeting
ATF Technical board meeting (SLAC)

2011 before summer



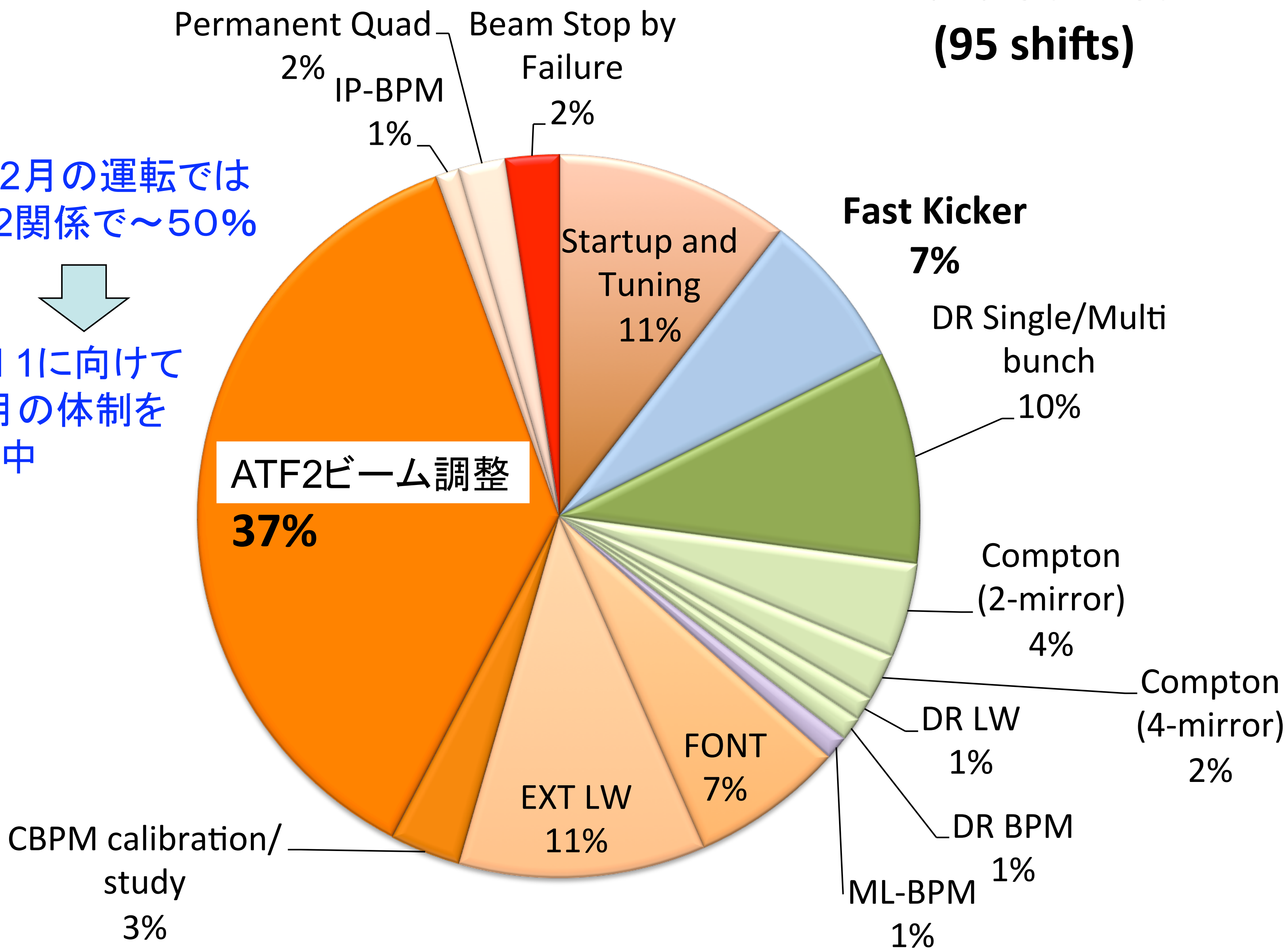
ATF2 Goal 1目標
（垂直ビームサイズ ~37 nm）

Beam Time Assignment 2010 Oct-Dec (95 shifts)

10-12月の運転では
ATF2関係で～50%

⇩

Goal 1に向けて
2-3月の体制を
調整中



ATF2の状況

ATF2 Project Meeting &
ATF Technical Board Meeting @SLAC

	13th January Thursday	14th January Friday
9:00 12:40	(Introduction) Instrumentation FONT5, QBPMs, IPBSM (Shintake monitor), IPBPM, LW, Multi-OTR,	Towards the 1st goal Effect of multipoles in ATF2 magnets, QEA field measurements, IPBSM operation and strategy Towards the 2nd goal IPBPM, FONT for IP feedback and milestones for 2011 to 2012
14:00 18:30	Beam Tuning DR, EXT, FFS,IPBSM, simulation, EXT/FFS matching & BBA, steering and dispersion (SVD), beam jitter at EXT/FFS	11th TB/SGC Meeting Summary of the ATF2 project meeting, proposals, future plan etc.

ATF2: 前回のLC委員会後の進展

- Final Doublet Quadの回転を修正
- Cavity BPM 読み出し系の改善
  LO信号分配系の改善→全てのBPMで高位置分解能
- IP-BPMのIPへの設置・立ち上げ
- Multi-OTRモニターの実用化
  エミッタンス測定の高速化→Coupling補正などの高速化

垂直ビームサイズ~37 nmへの調整試験

その他

- 四極電磁石(IHEP)のmulti-pole error対策・検討

Final doublet 四極磁石の再アライメント

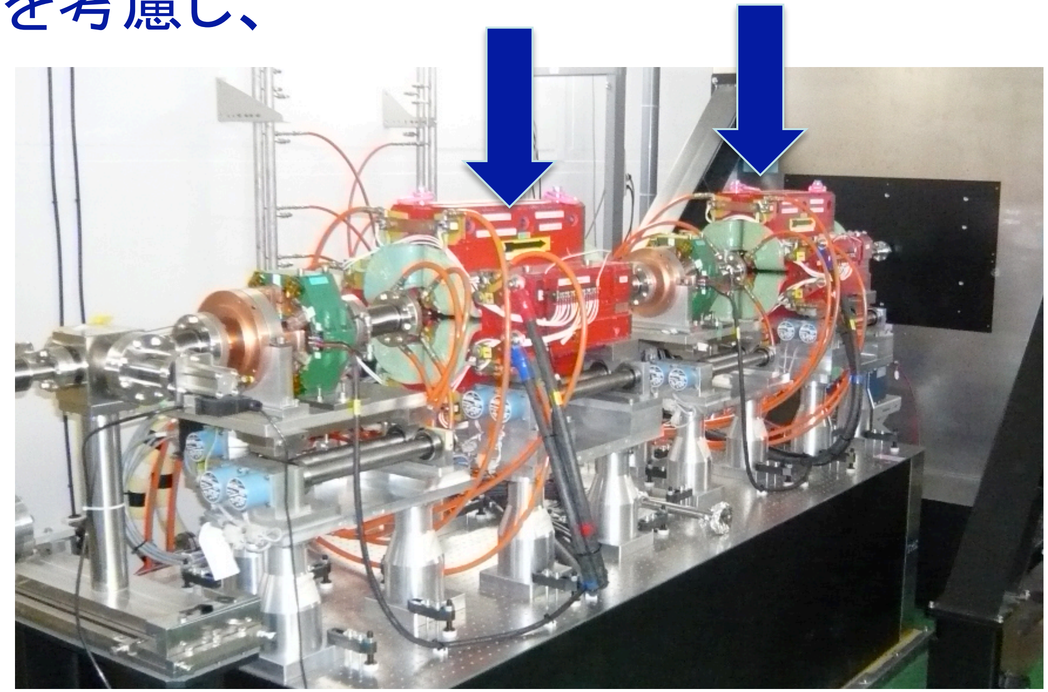
- 夏前までのビーム実験結果より**FD-Qの異常な設置エラー**を推測
- 夏期休止中にビームラインから磁石を降ろし、磁極形状を直接測定
- **アライメント基準座に対し、推測と同じレベルの回転を確認**

QF1: -6.25 mrad (upstream), -4.09 mrad (down-)
QD0: +2.69 mrad (upstream), +2.79 mrad (down-)

位置ムーバ-での調整具合を考慮し、
基準座に対して

QF1: +4.5 mrad
QD0: -2.5 mrad

回転させて再設置した。



Cavity BPM 読み出し系の改善

Resolutions: 2010/May

with 20dB att. 200 nm ~ 1.2 μm

w/o 20dB att. 27 nm

Improvements in 2010 summer

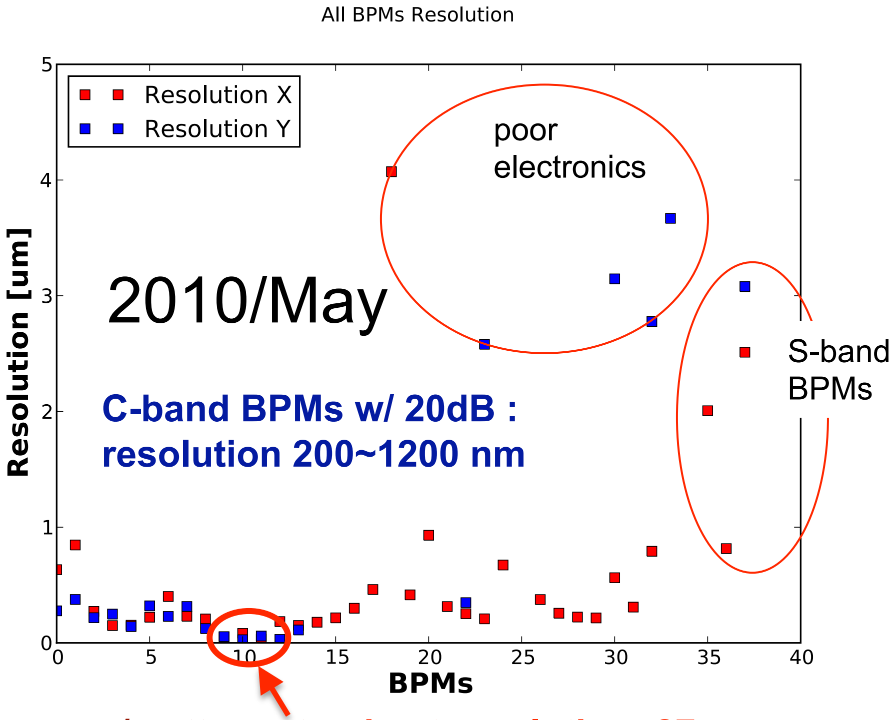
- thermal effect on the mixer electronics
- LO power distribution
- S-band BPM: de-tune the cavity

改善後のLO

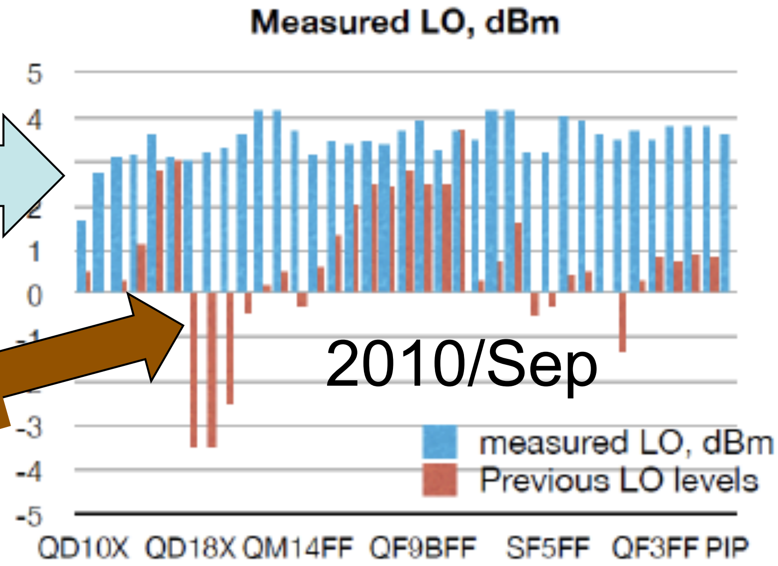
初期のLO

改善後

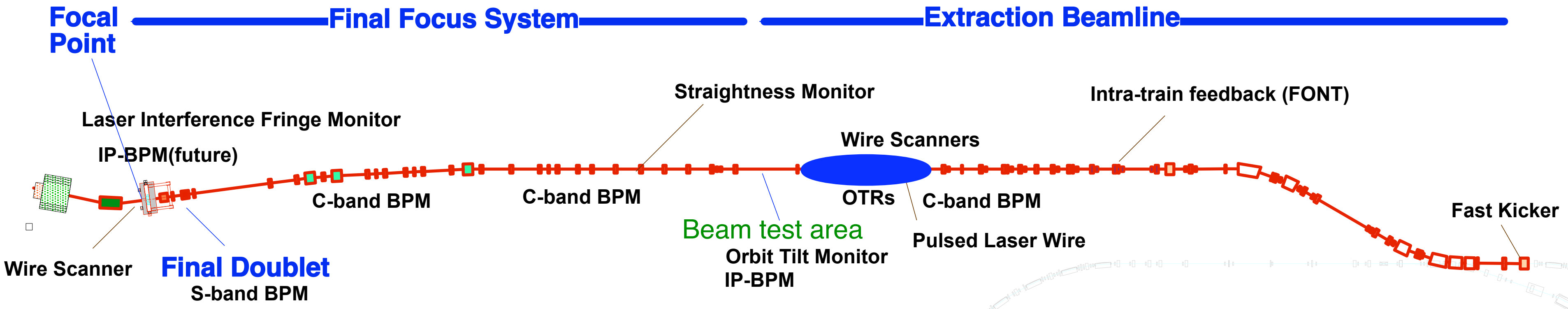
with 20dB att. 200 nm



w/o attenuator, best resolution: 27 nm



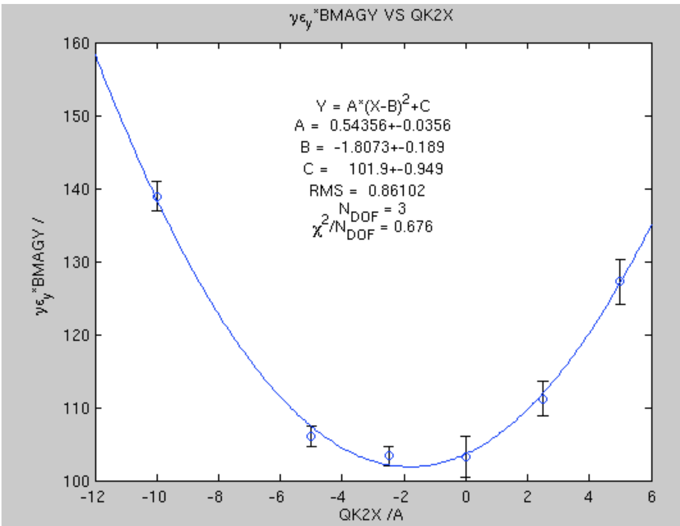
Multi-OTRs（4台）の立ち上げ



One shot beam size測定

FF入射ビームの高速なエミッタンス測定・
Coupling補正など

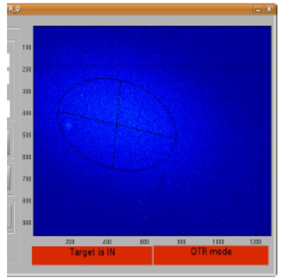
Y-emittance*BMAG



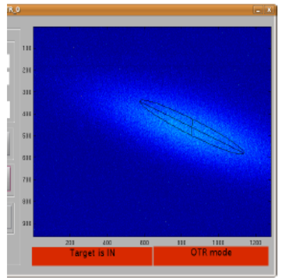
Skew Q (QK2X)

例えば
10 shot/point
左図で～2分
Wire scannerでは
30分~1時間

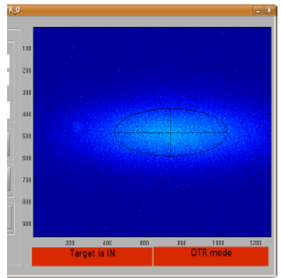
IFIC/SLAC/KEK



Before Correction

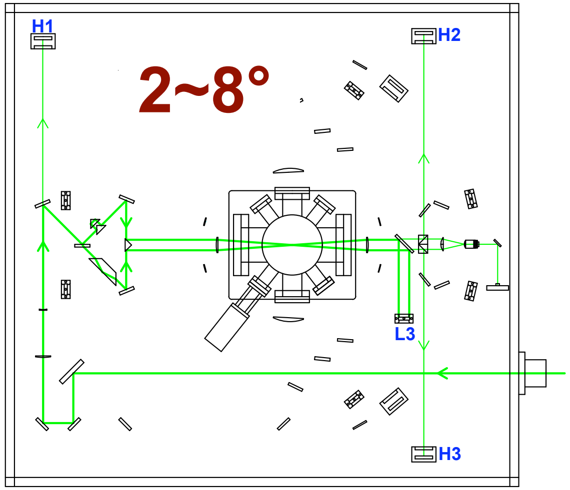


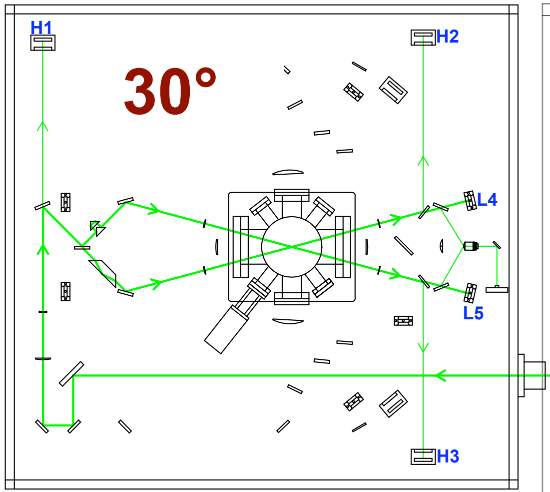
Dispersion Correction

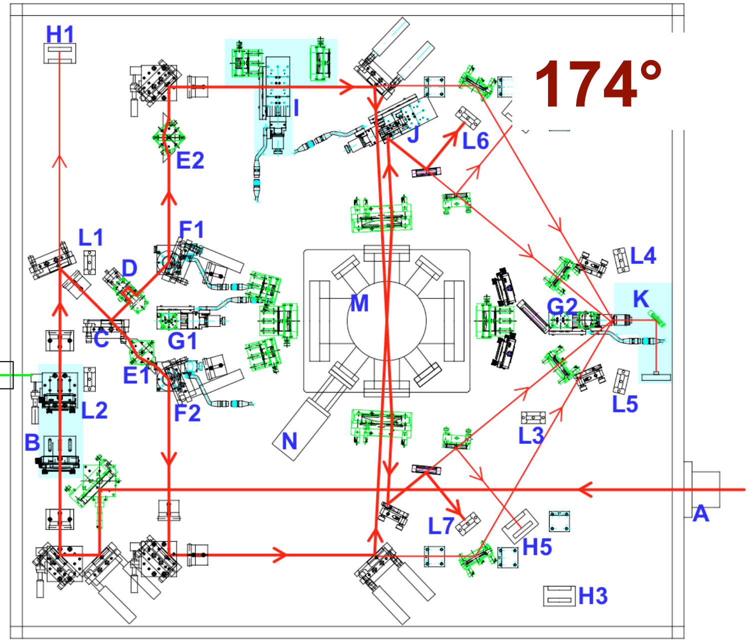


Coupling Correction

IP-BSM: Laser Interference Fringe Monitor



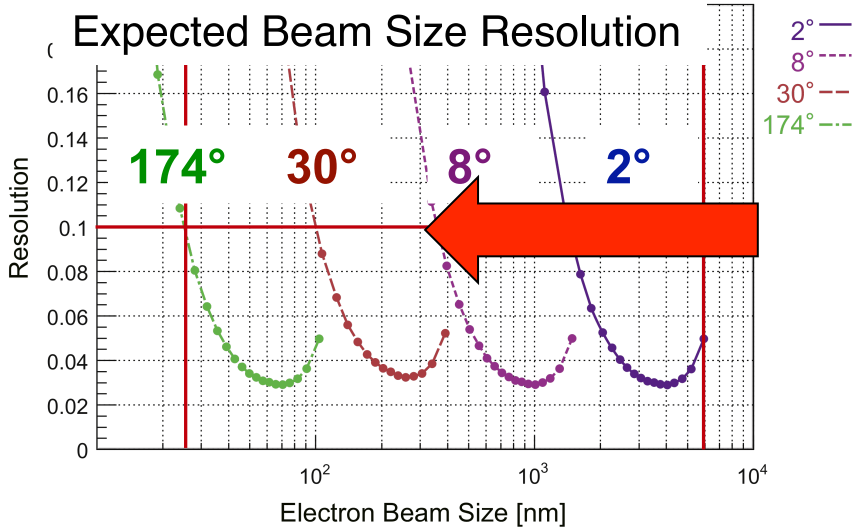




$$\text{fringe pitch}: \quad d = \frac{\lambda}{2\sin\theta/2}$$

λ = laser wavelength, θ = crossing angle

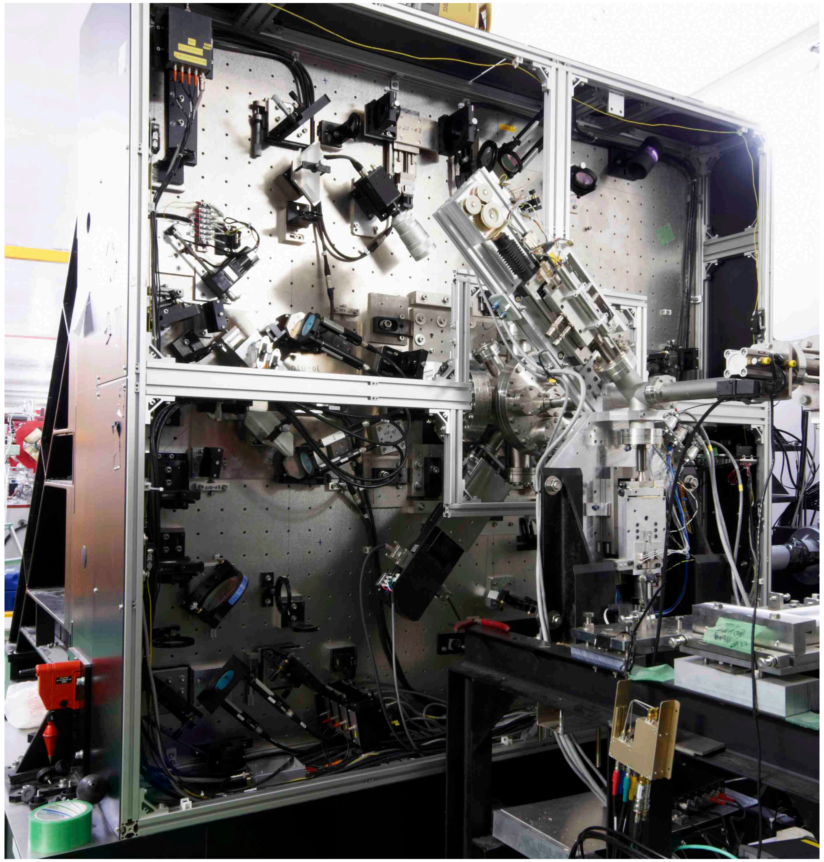
	174°	30°	8° ⟷	2°
Fringe pitch	266 nm	1.03µm	3.81µm	15.2µm
Minimum	**25 nm**	100 nm	360 nm	-
Maximum	**100 nm**	360 nm	-	6 µm



IPAC'10

東大/KEK

Measurement of the vertical beam size at ATF2

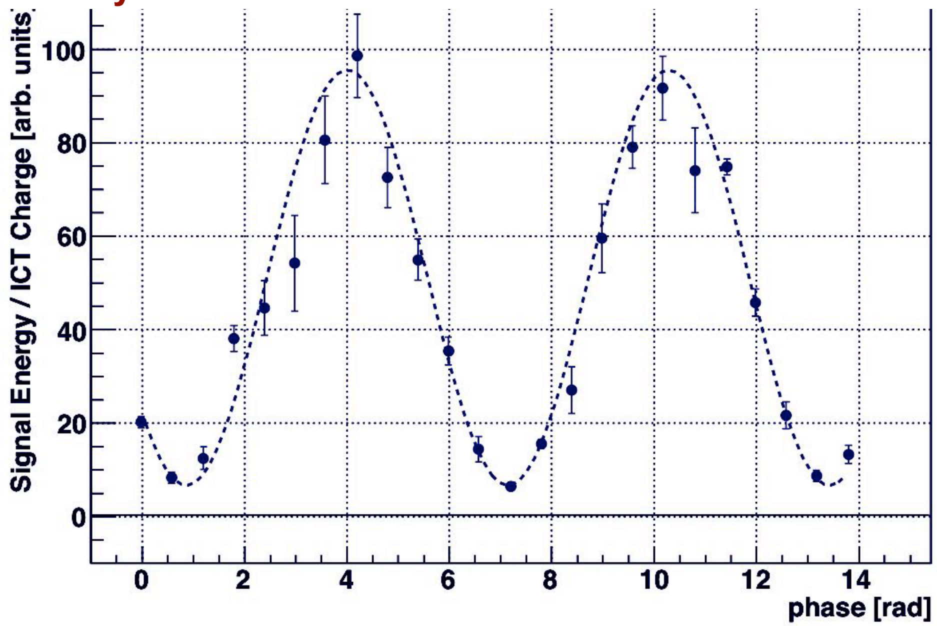


Example:

Smallest beam size measured under the ATF2 commissioning (2010/May/20)

Modulation Depth = 0.87 @ 8.0 deg. mode

σ_y = 310 +- 30 (stat.) +0-40 (syst.) nm



ATF2 Tuning Shifts Winter 2010

- 5 Weeks of shifts available for ATF2 tuning since spring/ summer run
- ~6 shifts per week weeks 1-4 + 1 week dedicated run week 5.

ATF2 Tuning Week Summary

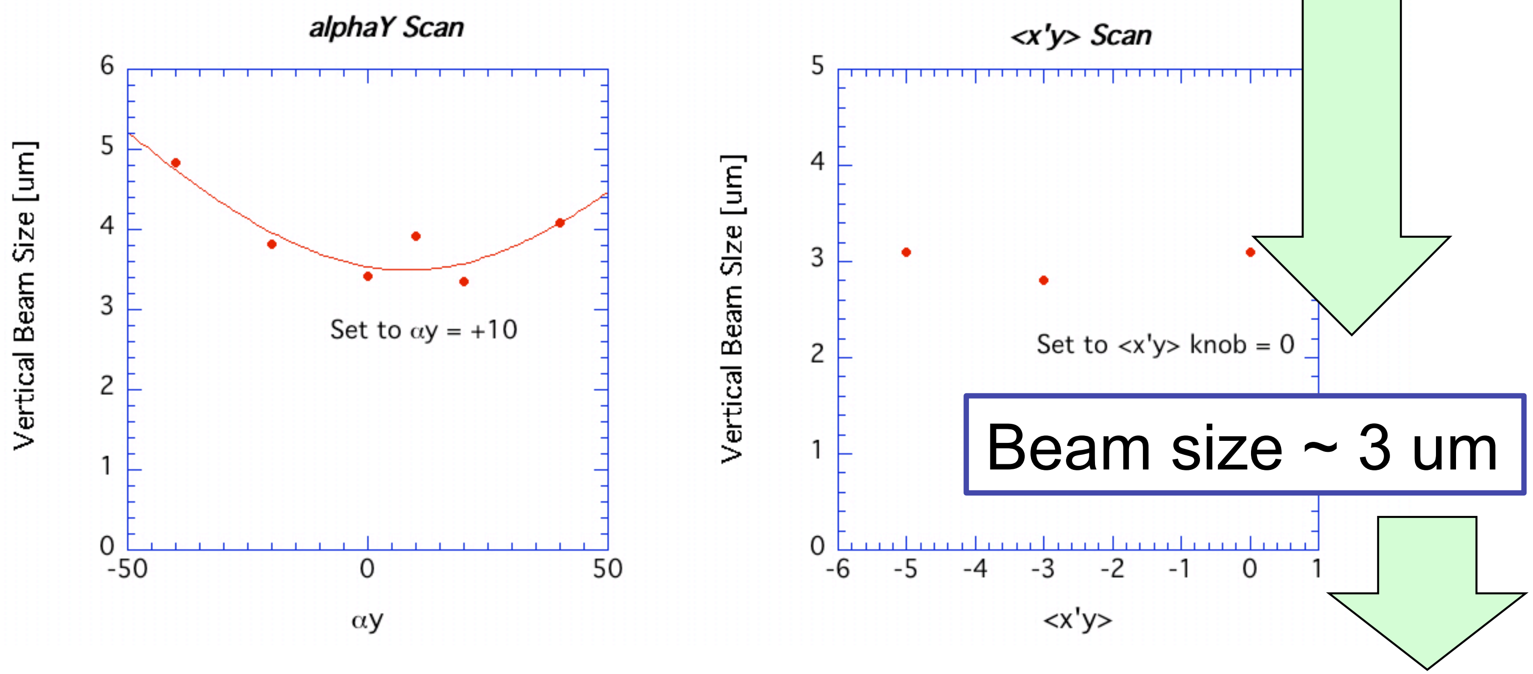
Monday	•DR setup + tune (ε_y = 14pm) •mOTR setup, tuning (ε_y<34 pm EXT, 27pm MW) •EXT Emit meas + cor •EXT Disp meas + cor
Tuesday	**•IP C wire measurements** •Sext BBA •BPM checks + diagnostics •IP $\sigma_y < 2$um
Wednesday	**•IPBSM 2 degree mode** •Start $\sigma_{y\,=}$ **1.8 um** •<x’y> scan, σ_y = **1.3um** **•IPBSM 6 degree mode** •σ_y = **1.0 um** •<x’y> scan, σ_y = **804 +/- 133 nm** •Waist_y scan, σ_y = **720 +/- 53 nm**
Thursday	•IPBSM tune, σ_y = **612 +/- 103 nm** •+ 4 hours, σ_y = 482,394,594,498 = **492 +/- 82 nm** •<xy> scan σ_y = 327,401,375 = **368 +/- 38 nm** **•IPBSM 30 degree mode**

Beam size minimization with Carbon Wire

Vertical beam size tuning with carbon wire scanner.

-> <x'y> and αy knobs were tested.

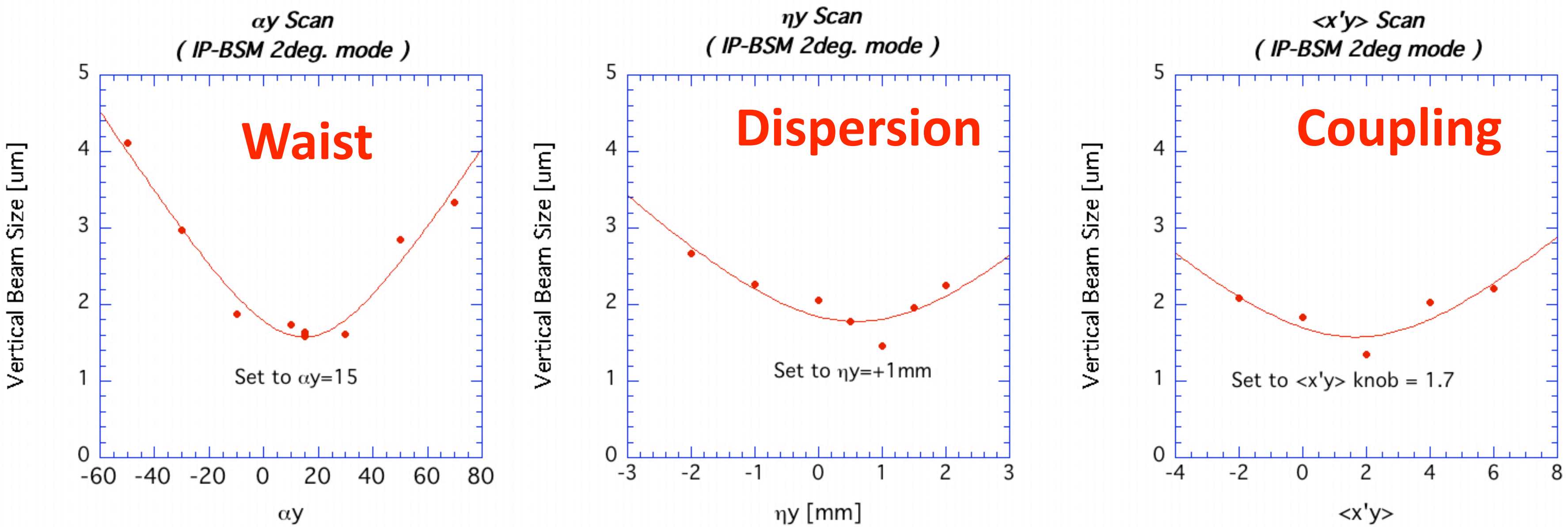
-> carbon wire was cut at the vertical beam size scanning.

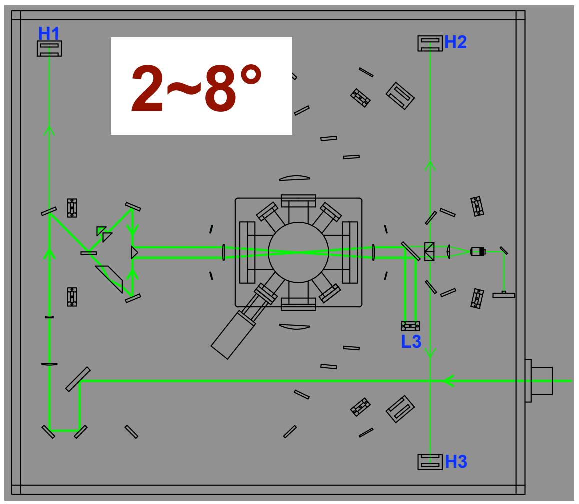


Therefore, we switched to the beam size measurement with IP-BSM.

T.Okugi (KEK)

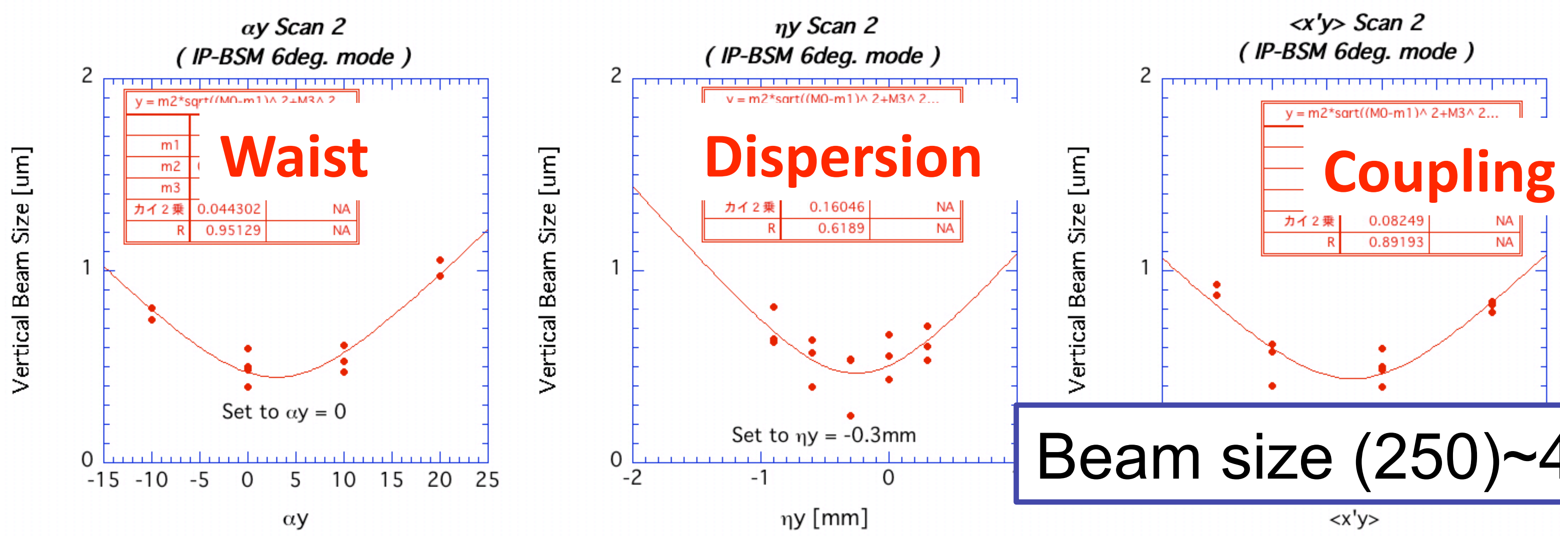
IP-BSM 2 degree mode





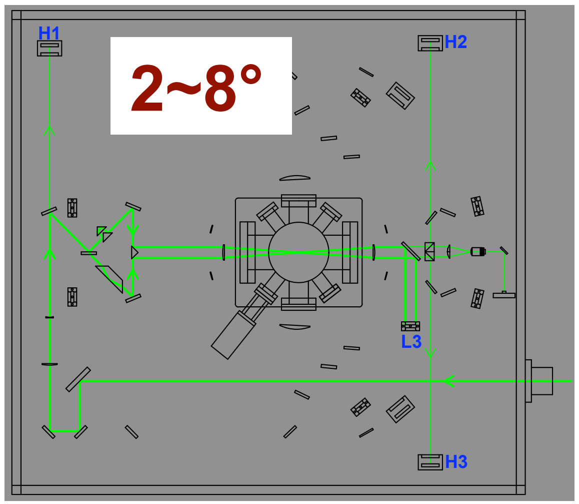
Since the beam size was roughly set to the optimum values,
we switched to the 6 degree mode.

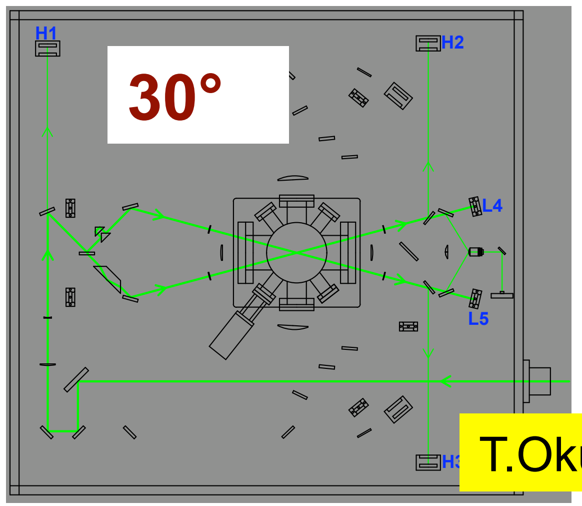
IP-BSM 6 degree mode



Beam size (250)~400 nm

2-8°連続モード → 30°モードへ切替





T.Okugi (KEK)

IP-BSM 30 degree mode

12月のRunでは30°モードに切替えた頃からレーザーが不安定に。

•一本のレーザーが十分に絞れておらず、Compton信号が弱い
•Laser Trigger系のドリフトにより、ビームと衝突しない状態が多発
•次第にレーザー用冷却水が不足（蒸発）し、インターロックで停止。
解除後も安定するまでに多くの時間を要した。

300 nm以下のビームサイズ調整をするための“目を失う”
12月のRunはここまで。
来週から再開する。

IP-BSM 改善と今後の対応

ハードウェア–の改善

•Laser Trigger系の安定化

原因となっていたアナログ系をデジタル（TD4）で再構成。**完了**

Drift ~100ns → 20 ps （ちなみにレーザー幅8ns）

•冷却水系の警報追加およびOnline monitor化。**準備中**

定期的に水量の確認をすれば当面はOKだが、対応を急ぐ。

•レンズ位置調整ステージの改修

一本のレーザーが絞れなかった原因は調整ステージの不調と判明。Readbackも無かった。→readback付きのものと交換へ

運用上の改善（もっと運用上の理解と経験を積むと言うこと）

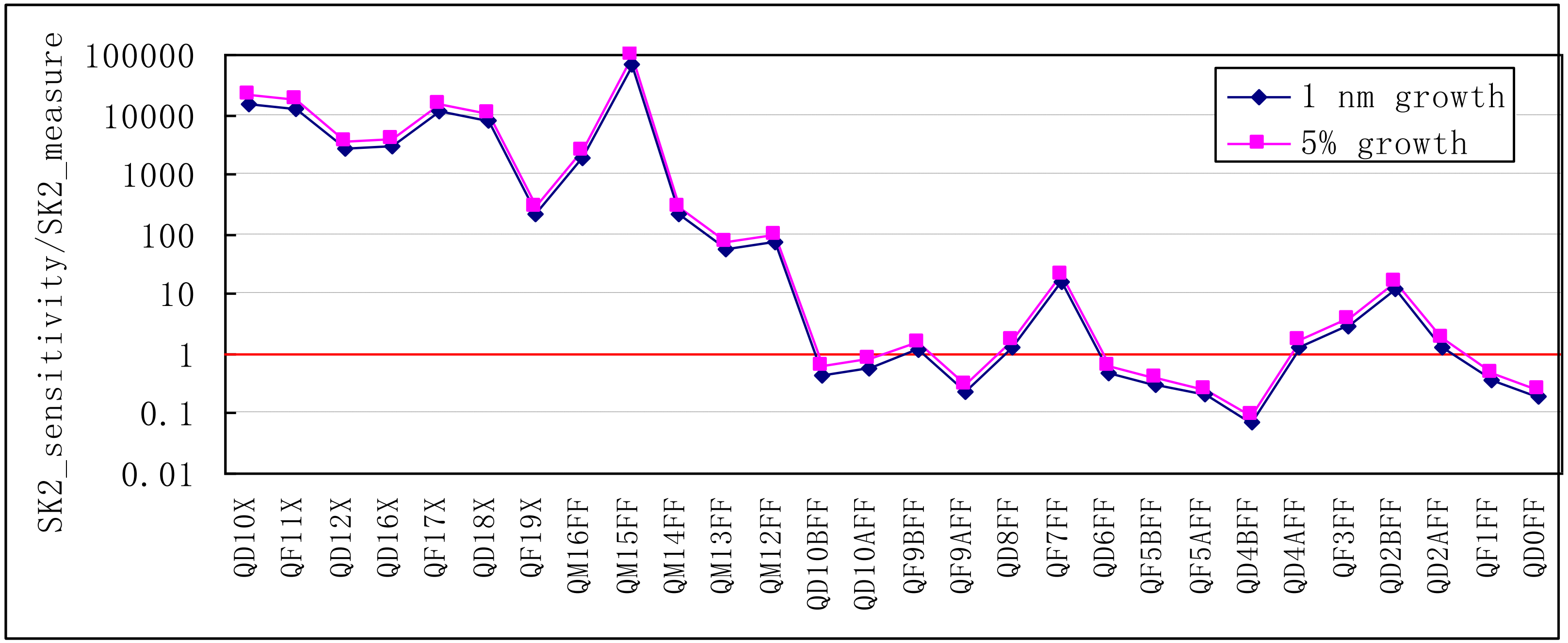
•例えば、ビーム調整中でビームサイズが大きい間（つまり干渉縞での測定ができるまでに至っていない）であっても、2本のレーザーそれぞれでビームを用いて十分に調整をする（レーザー・ワイヤーモード）。

四極電磁石(IHEP)のmulti-pole error対策・検討

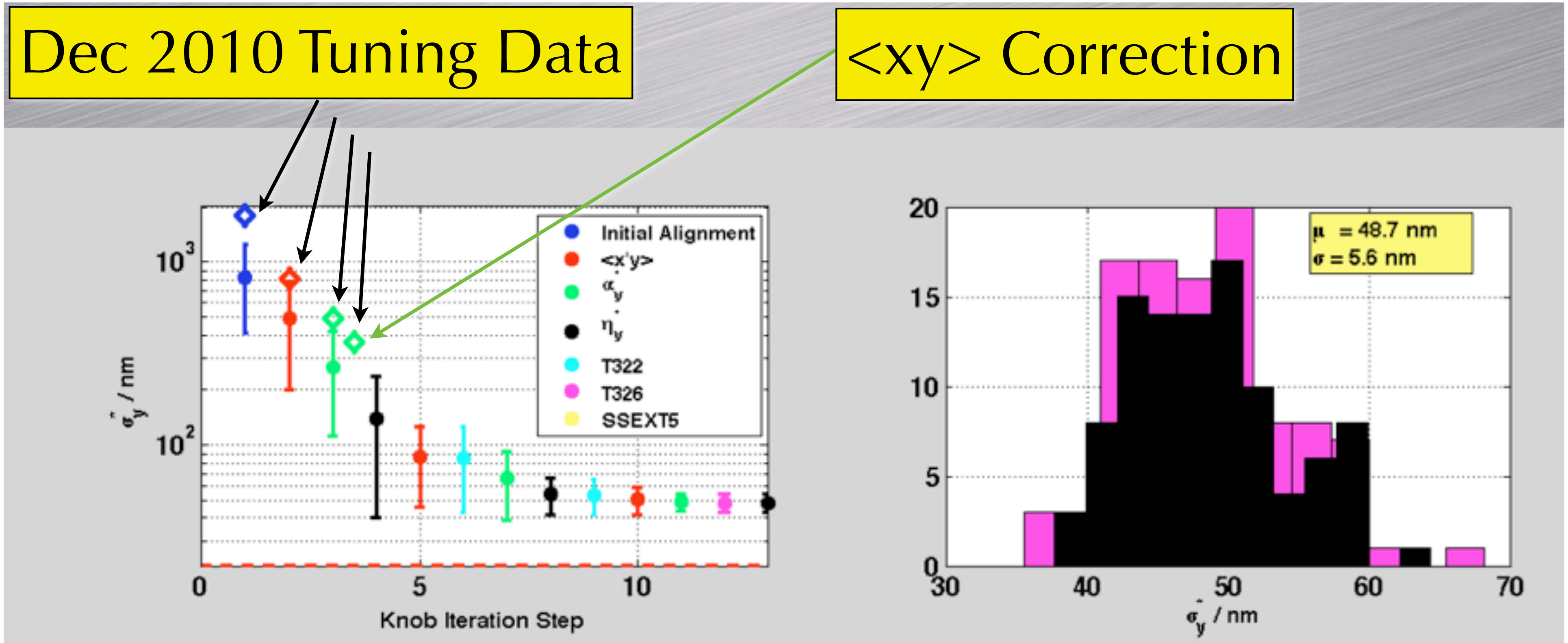
skew sextupole tolerance compared to the measurement for the quadrupoles

Best quadrupoles: QM15FF, QD10X, QF11X, QF17X, QD18X

Worst quadrupoles:QD4BFF, QD0FF, QF5AFF, QF9AFF, QF5BFF



Simulation with Multi-pole Errors



Glen White (SLAC)

1st strategy discussion: issue of magnet quality

(1) Magnet swaps (~ 4-6) → benefit threshold ?

時期を見て入れ替え
2011夏？

(2) Rotate sextupoles based on magnetic measurements → safe ?

(3) Tune installed skew sextupole → reliable ?

ビームラインに設置済
試験へ。

(4) Increase beta* for more tolerance to uncertainty

検討後に試験

→ re-evaluate above with more complete knowledge of multipoles now available (e.g. angle reference)

From ATF2 project meeting

ATF2 new Lattice:

現状のmulti-poleエラーを組み込んで評価

ATF2 Nominal Lattice

$\sigma_!$ "#$ %&#µ '

$\sigma_($ "#) &%$ #* ' #

$\beta_!$ "#+ ,# ' ' #

β_y=#+ , ,#µm

Squeeze sequence

ATF2 Inter 75 Lattice

$\sigma_!$ "#)%-#µ '

$\sigma_($ "#&)%J#* ' #

$\beta_!$ "#+ ,# ' ' #

β_y=#J$#µm

ATF2 Inter 42 Lattice

$\sigma_!$ "#)%-#µ '

$\sigma_($ "#. /%,#* ' #

$\beta_!$ "#+ ,# ' ' #

β_y=#) .#µm

ATF2 Ultra-low Lattice

$\sigma_!$ "#$ %&#µ '

$\sigma_($ "#. /%$ #* ' #

$\beta_!$ "#+ ,# ' ' #

β_y=#.$#µm

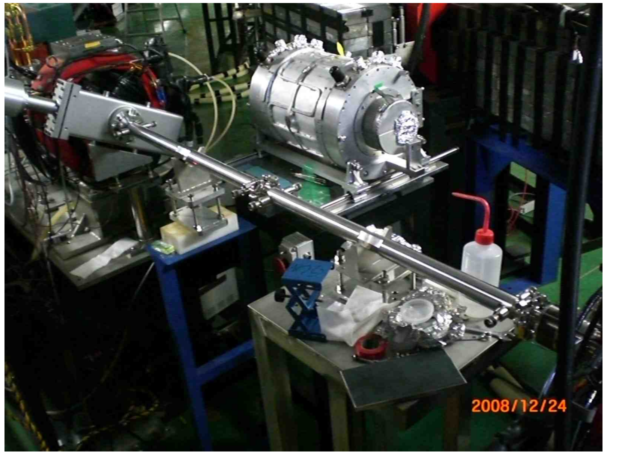
2 Intermediate lattices with β_y= 42 µm & β_y= 75 µm have been worked out.

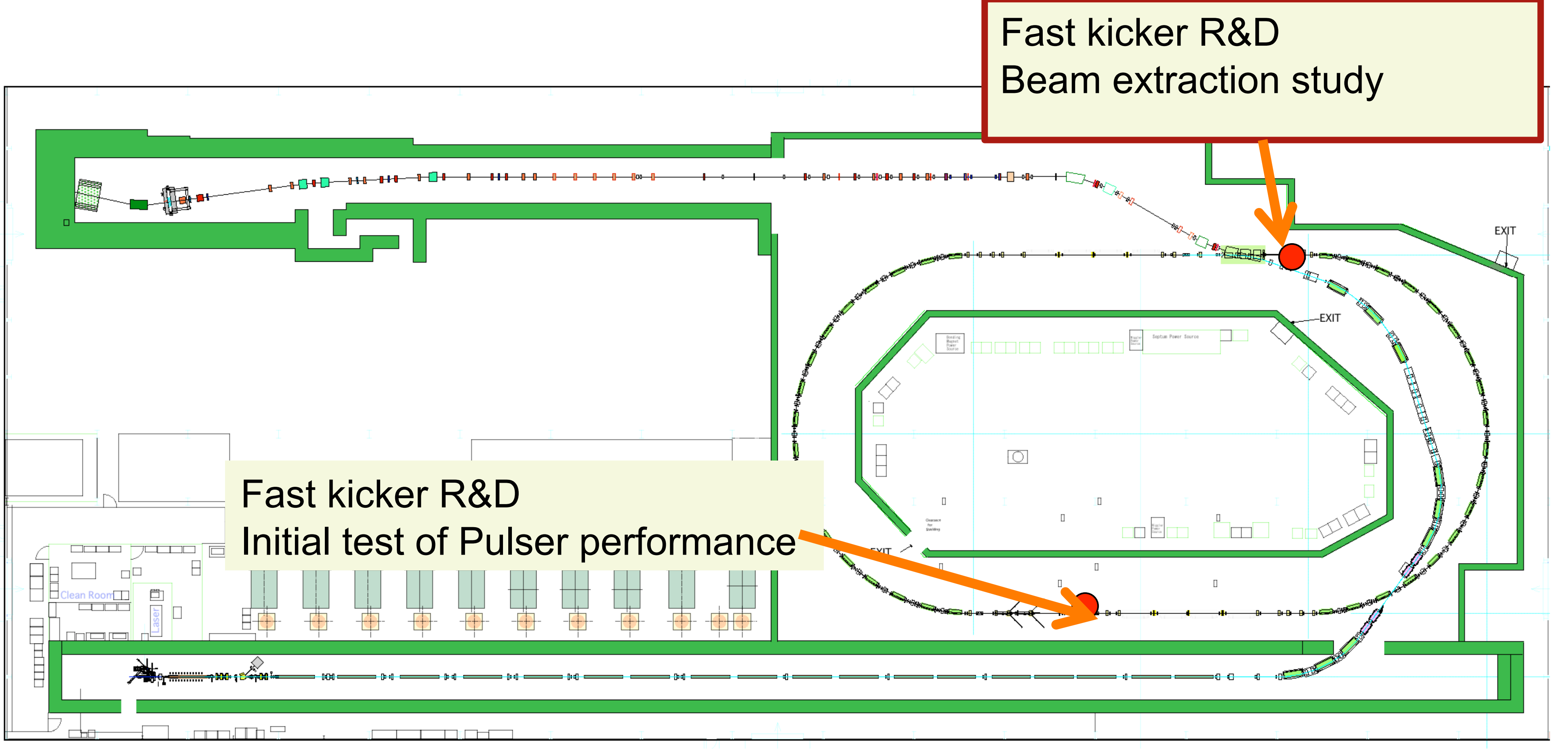
011#23454#16227845#694#6 : 6716 ; 14#62<#322=<>>81789%? 4 ; %849*%83>@AB@9>0CD.>E4?FGH127=I145>##

Edu Martin(CERN)

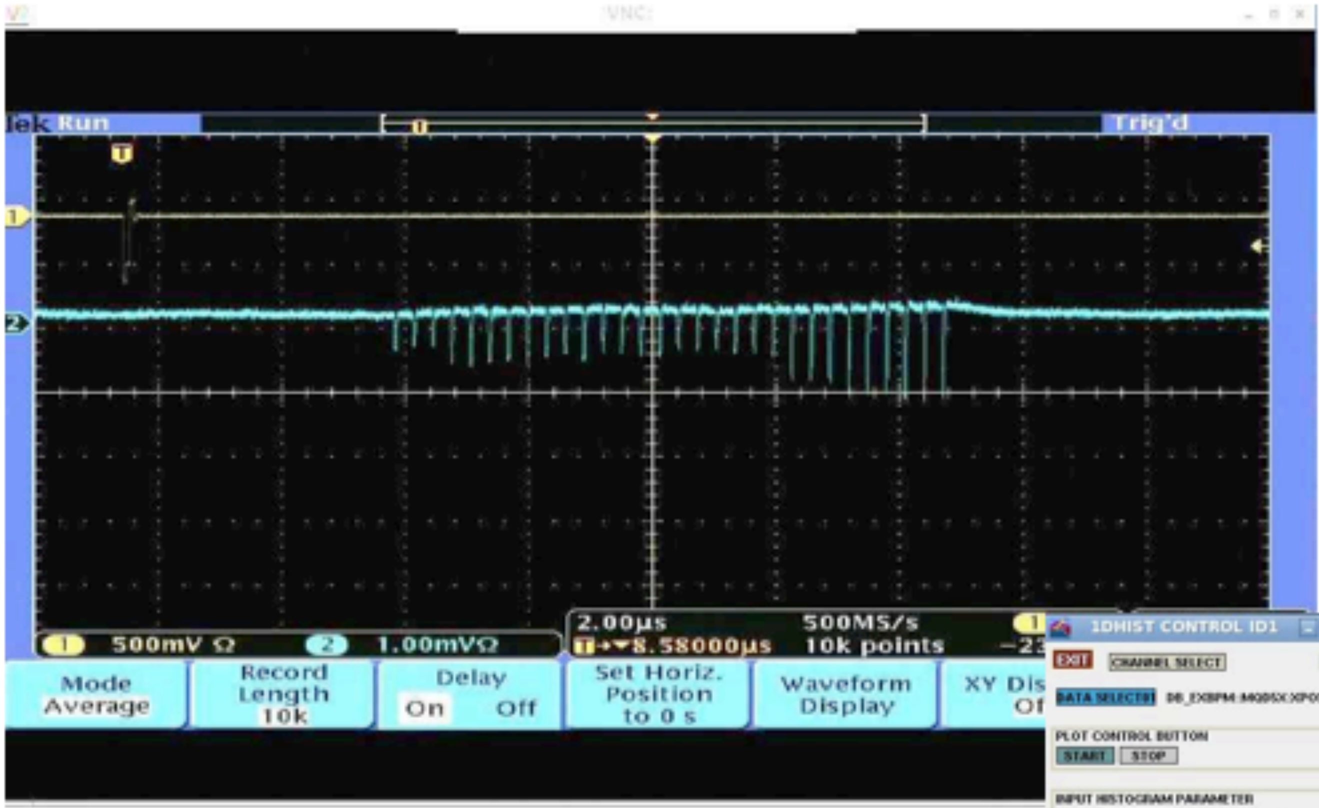
Fast Kicker開発

取り出しキッカーの入れ替えで試験
他のR&Dに大きな支障がないように長期運転期間の最初と最後に行う。



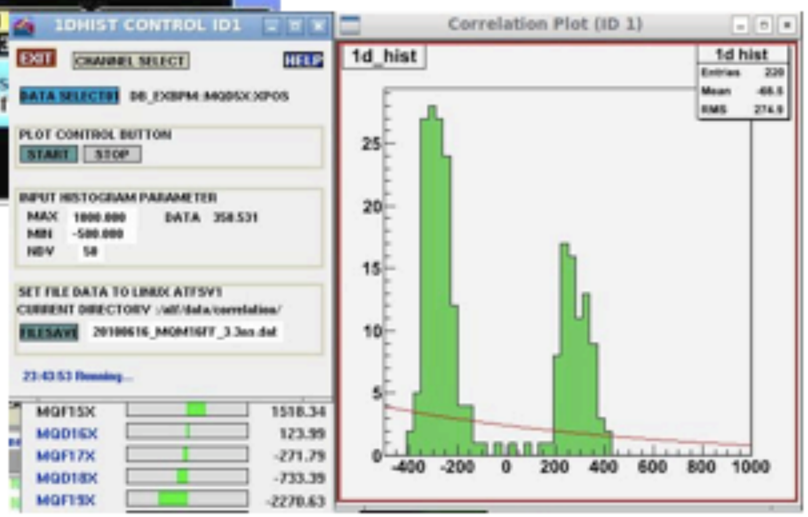


Multi-bunch extraction (30 bunches) with 308ns bunch spacing 2010/06/17



2010/June

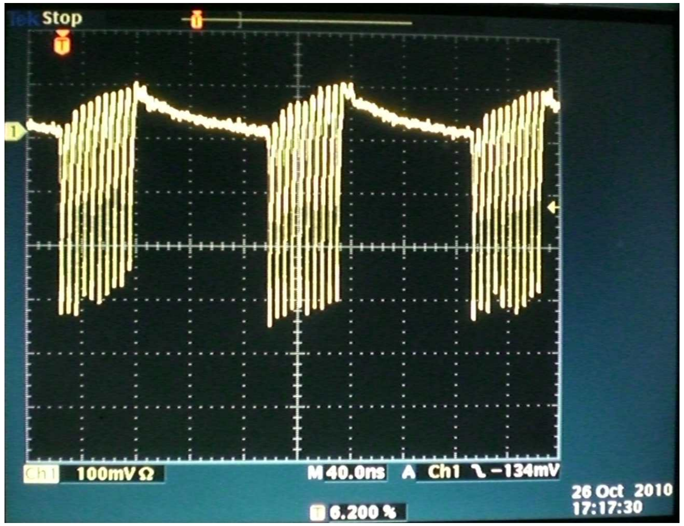
不均一なバンチ強度
Bi-stableな取り出し位置



The intensity of each bunch is not flat and unstable.
The horizontal beam position was distributed to two position.

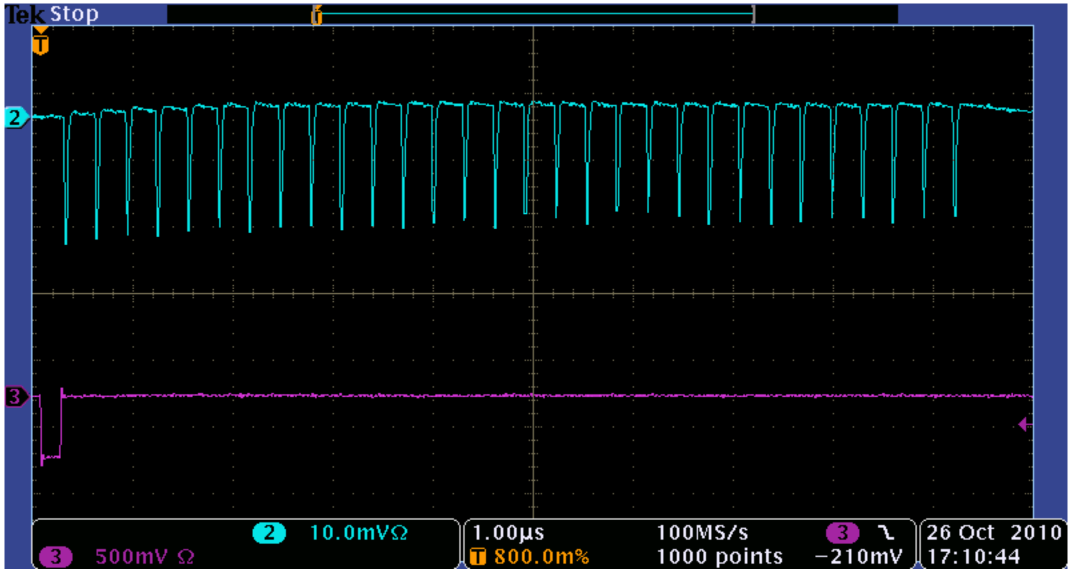
T.Naito

Multi-bunch Beam in the DR and the extraction line



30 bunches of the beam are stored to the DR, stably.

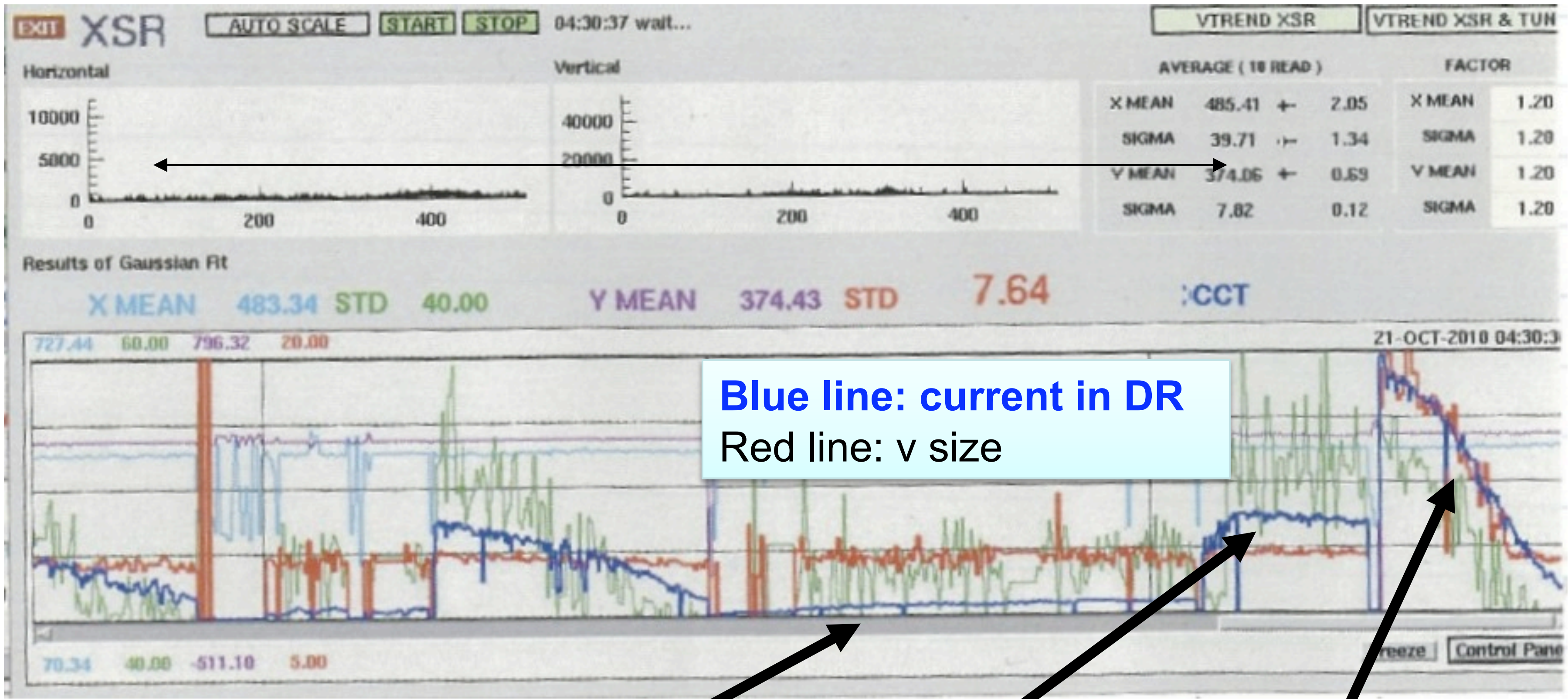
Stable beam extraction was confirmed at the extraction line. The beam reach to the beam dump without any beam



2010/October

均一で安定な取り出し

Problem on the fast kicker "for ATF"



2hour

single bunch
1 train

9 bunch
1 train
Itot=$2x10^{10}$

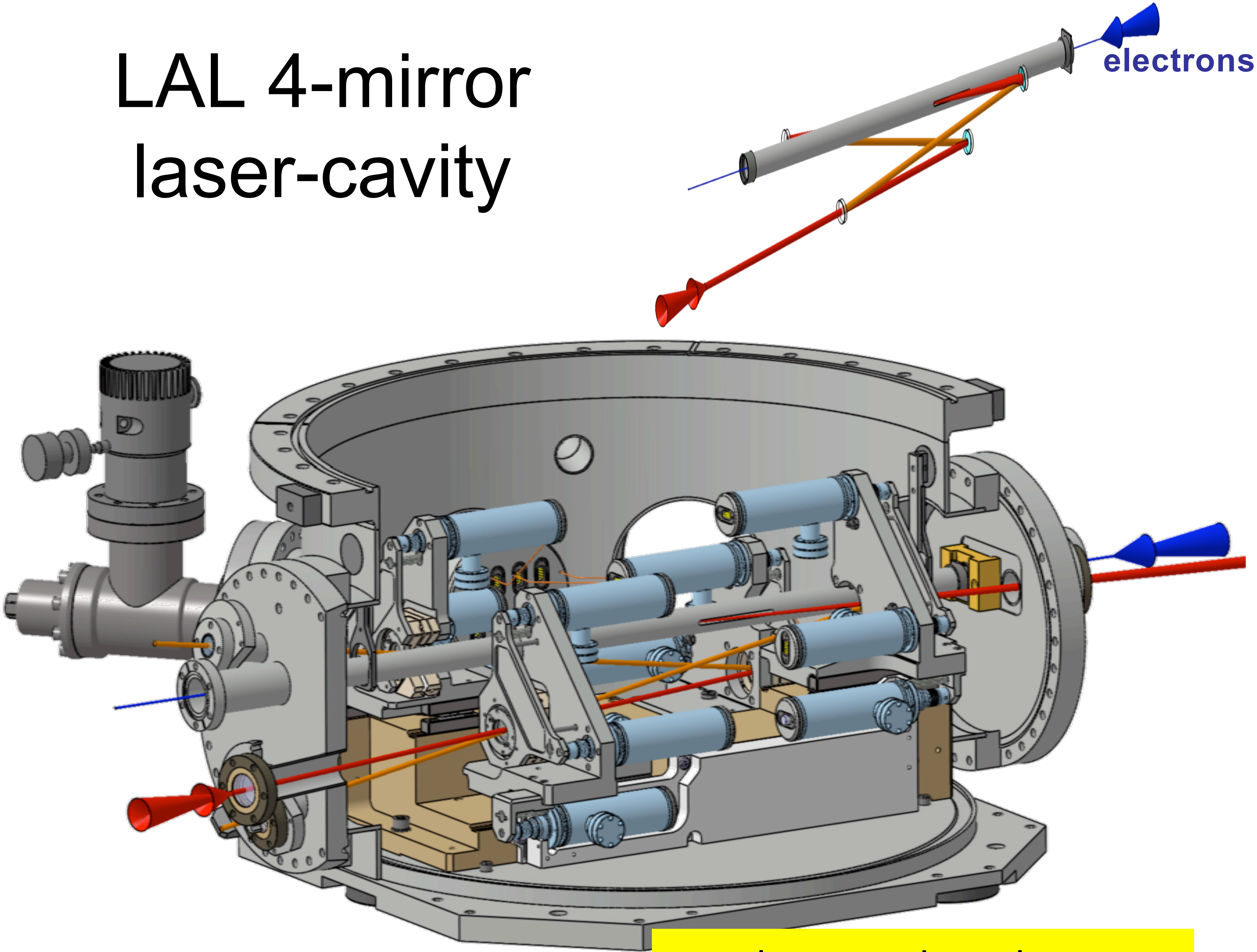
9 bunch
3 train
Itot=$6x10^{10}$

まとめ

- ATF2 Goal 1: ビームサイズ~37 nmの実現に向けて、装置・ツールの高度化や問題点の把握・克服を行いながらビーム調整を継続中
- Fast Kicker:リングから一様なマルチバンチビーム取り出しを達成し、このKickerの実用性を示した。
（ただし、現ATFでは配置的に無理をしており、高強度ビームでの利用にはリングの大幅な改良が必要。）

Backups

LAL 4-mirror laser-cavity



N.Delerue and D.Jehanno

4-mirror Compton Cavity

2010

08	09	10	11	12

Installation

07/27

08/21
Laser locked to 4M cavity

08/30
4M cavity alignment to beam

09/06
4M cavity connected to beam

4M cavity locked to ATF Clock
09/24

10/25

No laser

Laser shipped to Zurich

11/01
Laser Failure

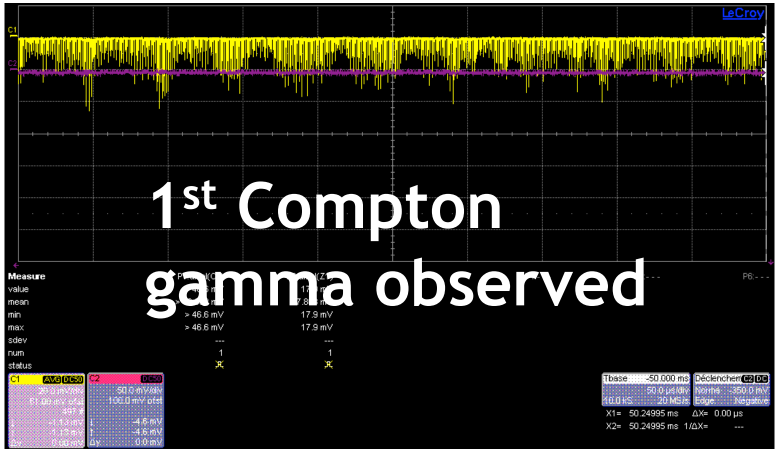
11/17
Laser repaired

12/08
Compton gamma observed

No laser

Laser shipped to Zurich
HW update

12/20



1st Compton gamma observed

N.Delerue and D.Jehanno(LAL)

Challenges toward the 1pm emittance

Simulation:
- **BPM offset error should be < 0.1 mm. (“BBA”) --> εy ~ 2 pm**
- **Magnet re-alignment, < 30 μm**

--> εy ~ 1 pm

DR BPM upgrade (FNAL, SLAC, KEK)

a high resolution BPM system

•a broadband turn-by-turn mode (< 10 μm resolution)

•a narrowband mode with high resolution (~ 100 nm range)

•Electronics for all DR BPM (96) is under preparation at FNAL.

•Installation will be done around the IPAC10 (May).

ATF Damping Ring in 2010 autumn Multibunch instability study

2011.1.13

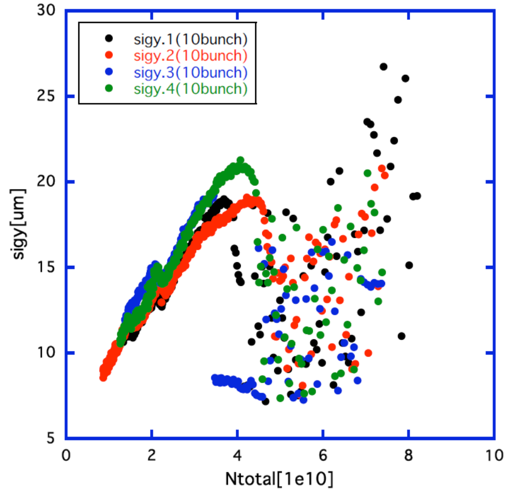
Measurement (S. Kuroda, T. Naito and K. Kubo) and

Calculation of ion trapping (Kubo)

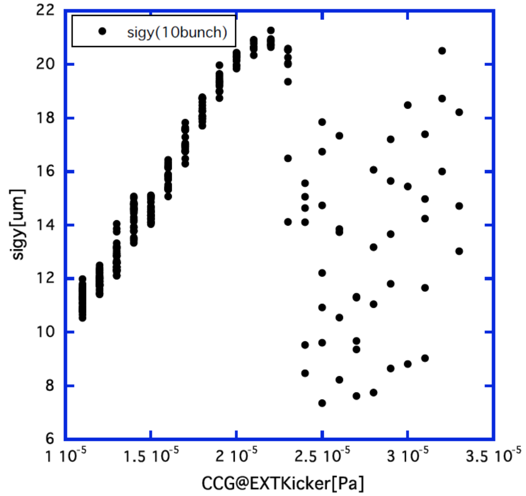
3-train mode

10 bunch

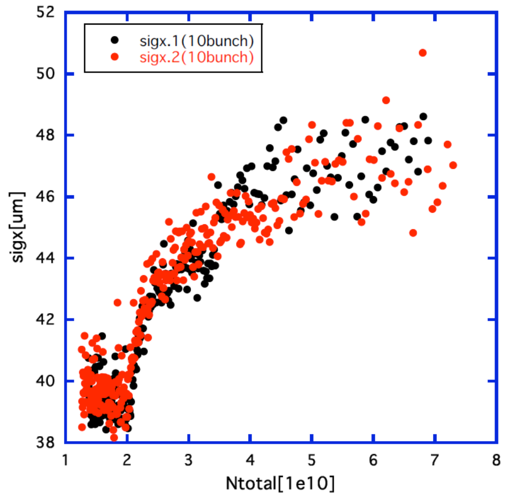
σ_y vs I_{total}



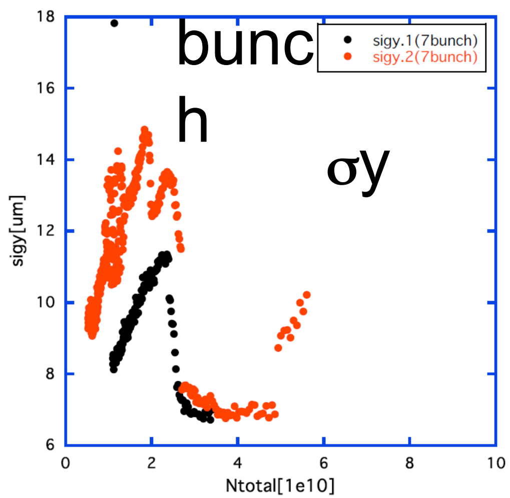
σ_y vs vac pressure$_{EXT\ Kicker}$



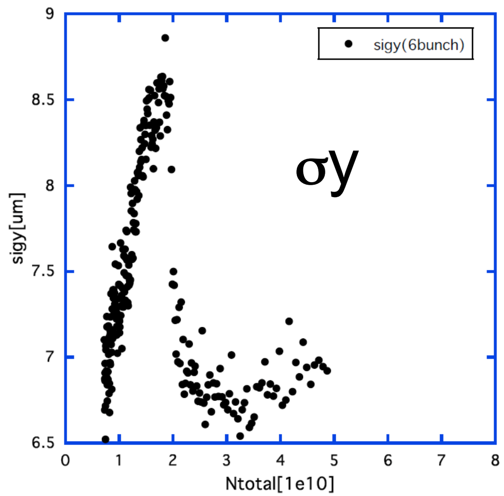
σ_x vs I_{total}



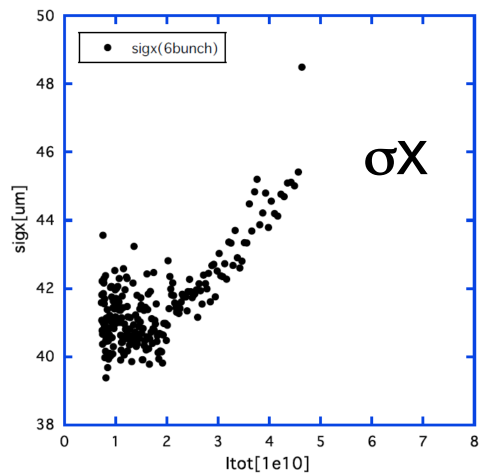
7 bunch



6 bunch

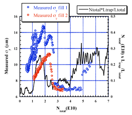


6 bunch



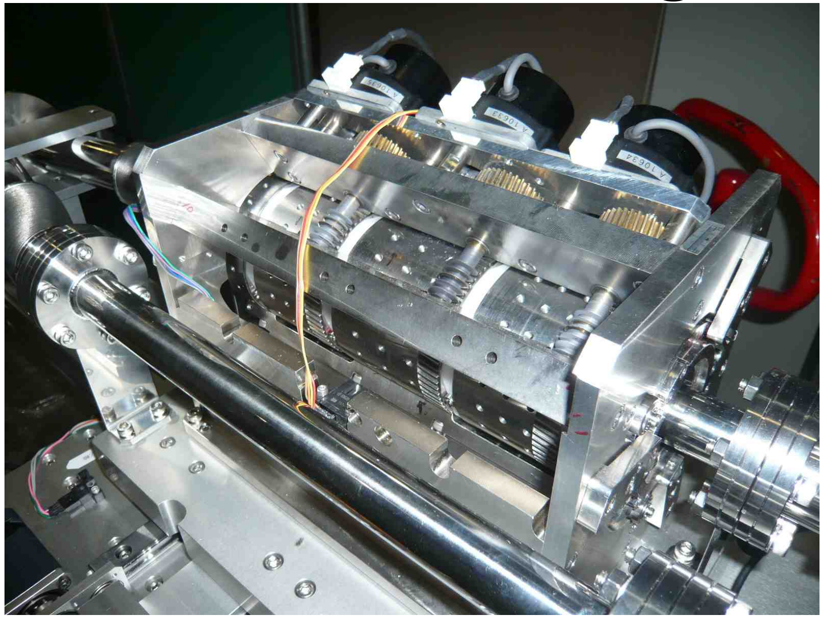
Compare measurement and ion trap calculation

3 train, 7 bunch/train



Preliminary

Extra beam operation on Dec 23rd Permanent Magnet Final-Quad (Kyoto Univ.)

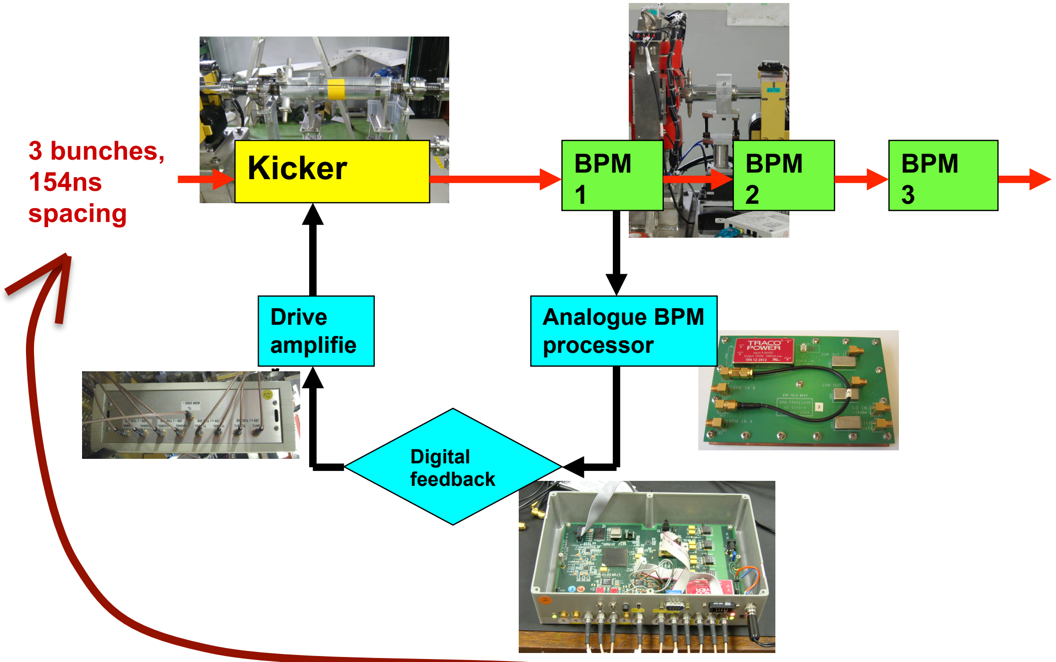


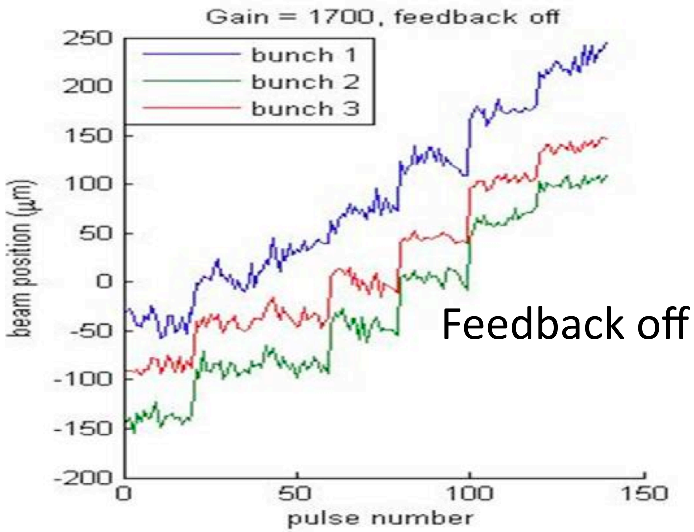
The magnet was assembled in Kyoto Univ in last fall.
It was delivered to KEK from Kyoto in the end of November.

- Field measurement by a rotating coil was done.
- It was temporally installed in ATF2 line from Dec. 21st to 25th.
- Demonstration with beam was done on Dec. 23rd for the master thesis.

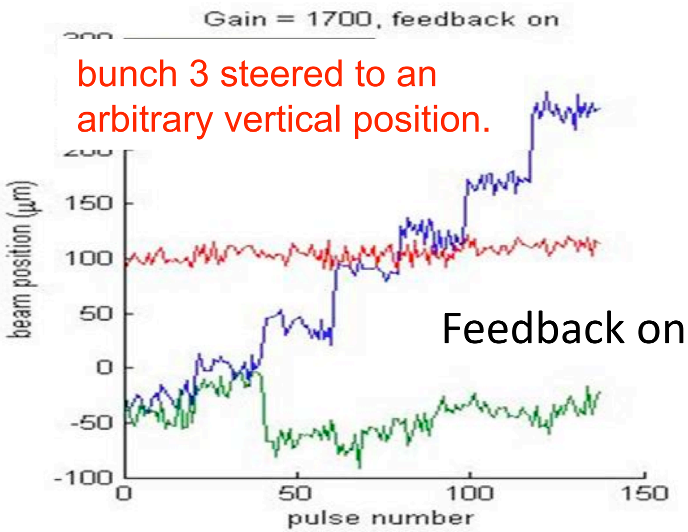
- Results should be reported in next meeting (ATF2 or TB).

FONT4: first digital intra-train feedback

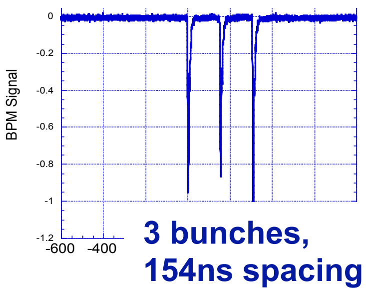




Beam position vs. pulse number

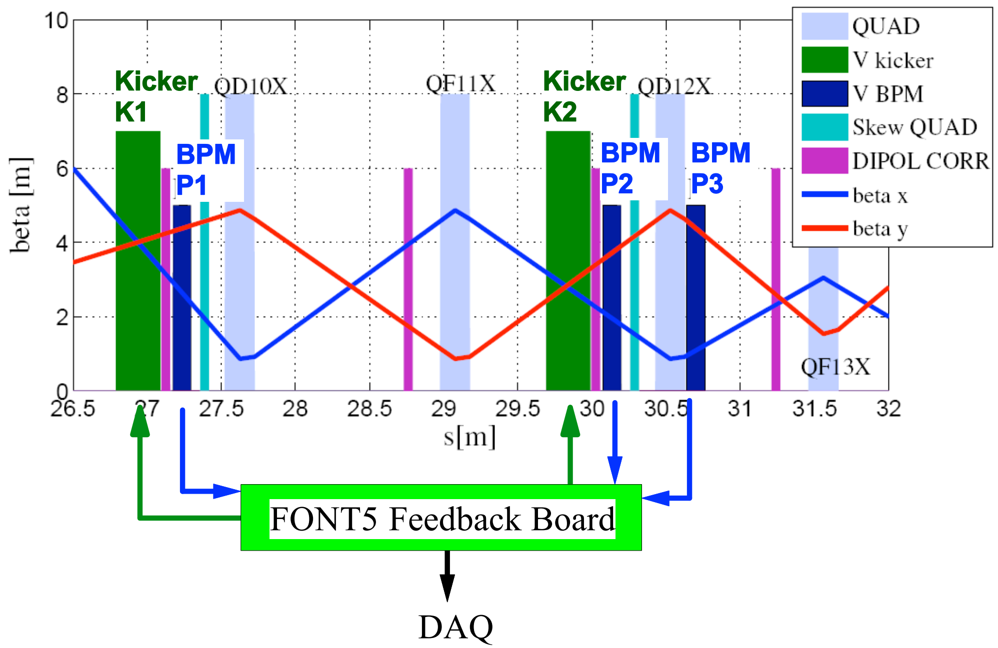


Extracted beam from DR

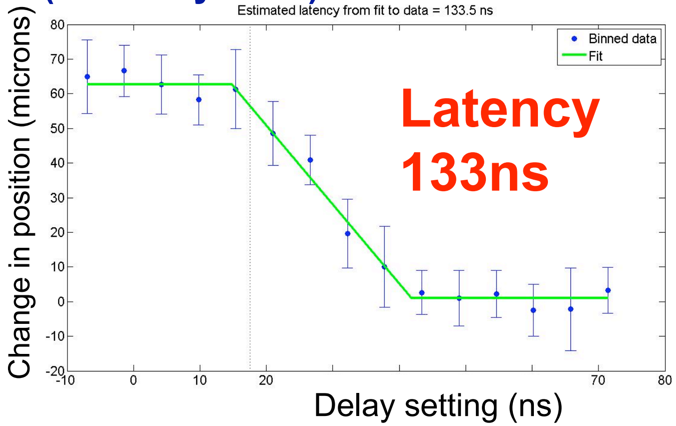


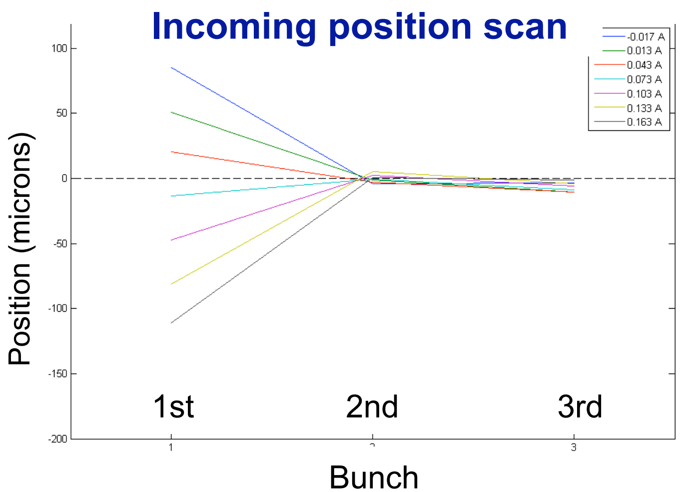
Shift the beam positions by a beam-steering dipole to simulate the possible beam jitter etc.

FONT5: intra-train feedback at ATF2



FONT5 P2 → K1 FB-loop
(February 2010)





FONT5 system

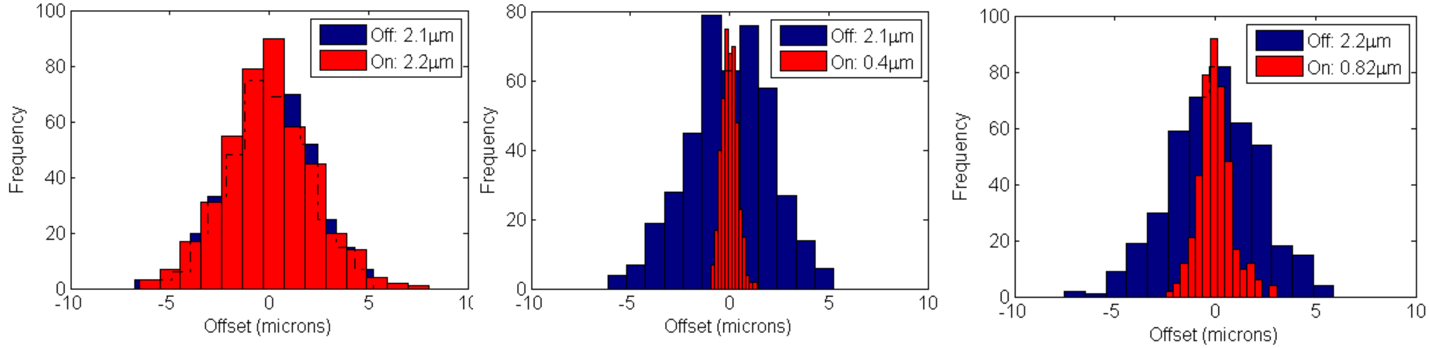
- flexible configurations
  two kickers and **three BPMs**
- **coupled feedback system of two loops correcting both position and angle jitter in the vertical plane**

Beam jitter reduction by FONT5

Results of P2 → K1 loop (measured)

(April 16 2010)

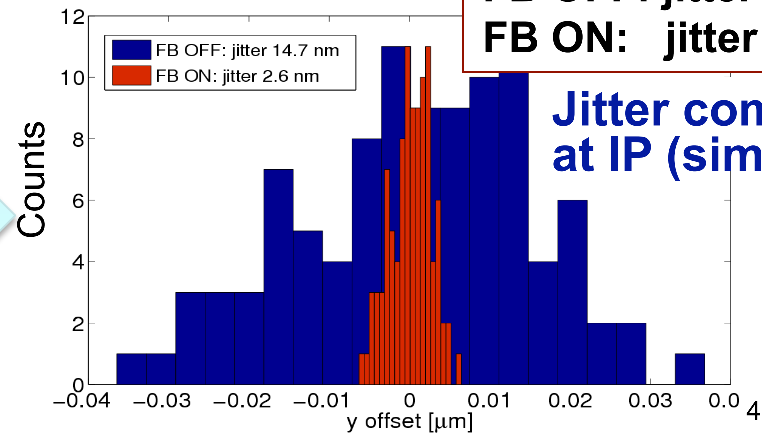
Bunch 1 Bunch 2 Bunch 3



2.1 um → 0.4 um → 0.8 um

Assuming perfect lattice, no further imperfections (!)

FB OFF: jitter 14.7 nm
FB ON: jitter 2.6 nm



Jitter comparison at IP (simulation)

Running R&Ds

ATF

low emittance beam

- Tuning, XSR, SR, Laser wire,…
- **1pm emittance** (DR BPM upgrade,…)

Multi-bunch

- Instability (Fast Ion,…)
- **extraction by Fast Kicker**

Others

- Cavity Compton
- SR monitor at EXT

- 多くのR&Dが密接に関連
- 有限のビーム時間
- サブグループ間での相互理解・交通整理

Improve the R&D efficiency
← LINAC/DR
Stabilization

ATF2

35 nm beam size

- **Beam tuning (Optics modeling, debugging soft&hard tools,…)**
- **Cavity BPM (C&S-band, IP-BPM)**
- **Beam-tilt monitor**
- **IP-BSM (Shintake monitor)**
- **Multi-OTR**

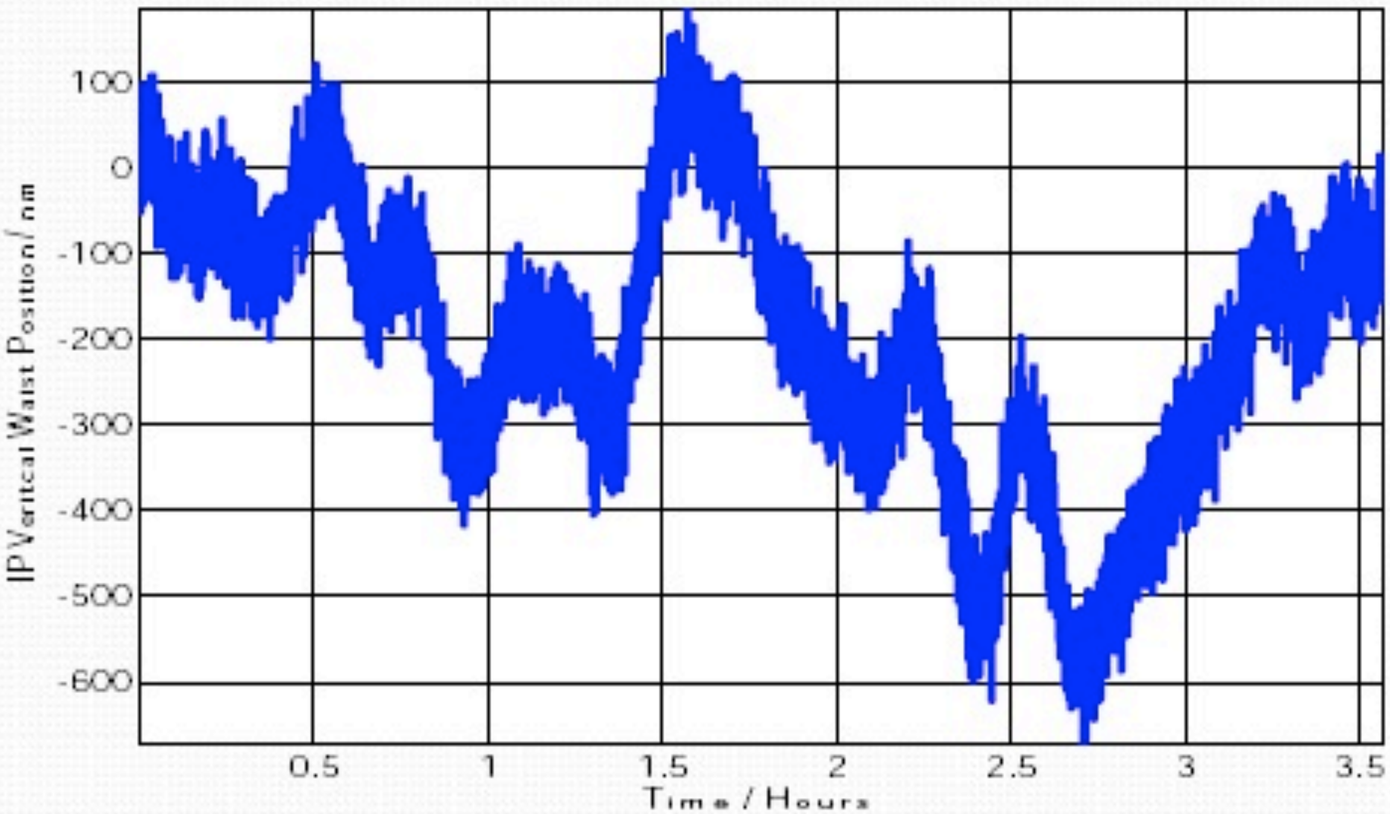
Beam position stabilization (2nm)

- **Intra-train feedback (FONT)**
- feed-forward DR->ATF2

Others

- Pulsed 1um Laser Wire
- Cold BPM
- **Permanent FD Q**
- **SC Final doublet Q/Sx**

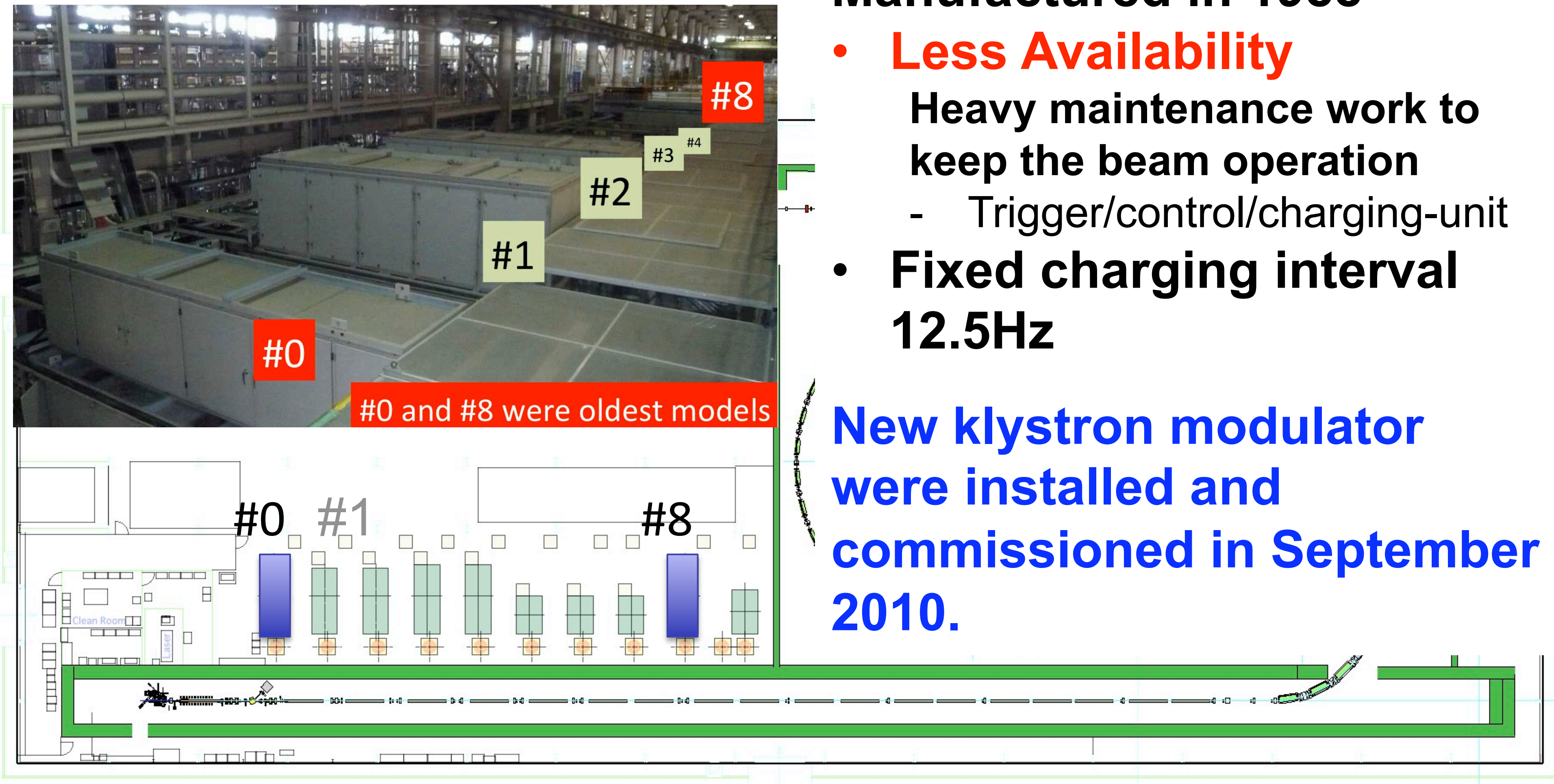
IP Motion



- 20,000 pulses @ 1.56 Hz (1 seed)
- IP vertical position drifts around on scales of a few 100 nm an hour.
- Slow enough that this can be 'de-trended' using Shintake Monitor as IP position monitor.

Glen White (SLAC)

Renewal of the LINAC klystron modulators(#0 and #8)



Manufactured in 1988

- **Less Availability**
  Heavy maintenance work to keep the beam operation
  - Trigger/control/charging-unit
- **Fixed charging interval 12.5Hz**

New klystron modulator were installed and commissioned in September 2010.