ATF2

T. Tauchi,

ILC PAC, 14 -15 November 2011, Institute of Physics, Academy of Sciences, Prague

ATF2 Final Goal

Ensure collisions between nanometer beams; i.e. luminosity for ILC experiment

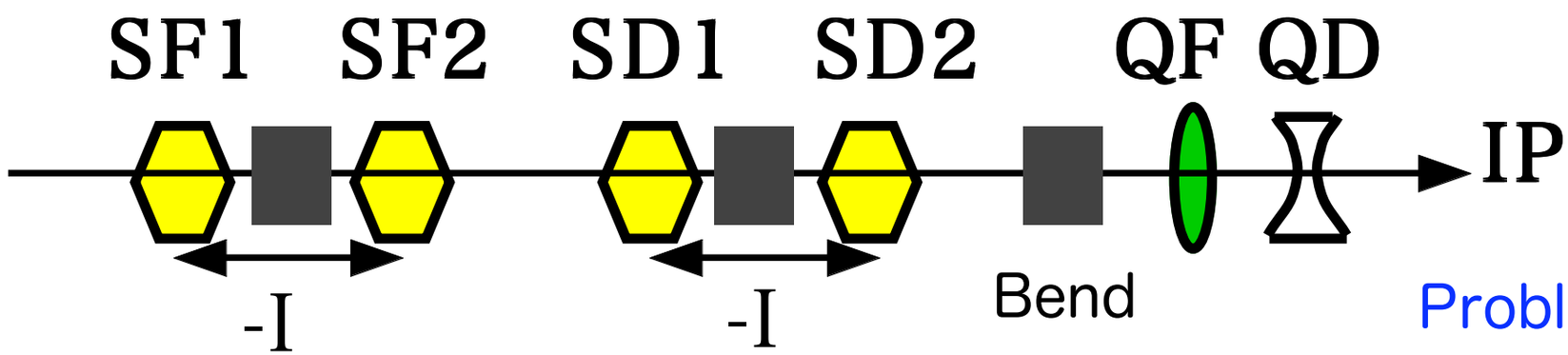
Reduction of Risk at ILC

Optics and bean tuning
Stabilization

FACILITY construction, first result	ATF2/KEK; 1.3GeV 2005-08-11?	FFTB/SLAC; 47GeV 1991-93-94
Optics	Local chromaticity correction scheme; very short and longer L* (β^*_y=100μm, L_{FF}=30m)	Non-local and dedicated CCS at upstream; high symmetry in x, y ; i.e. orthogonal tuning (β^*_y=100μm, L_{FF}=185m)
Design beam size	2.3μm / 34nm, aspect=82 ($\gamma\varepsilon_y$=3 x 10^{-8} m)	1.92μm /52nm, aspect=37 ($\gamma\varepsilon_y$=2 x 10^{-6} m)
Achieved	?	70nm (FD jitter remains !)

Optics design choice

(1) Non-local correction ; Conventional and tested at FFTB/SLAC

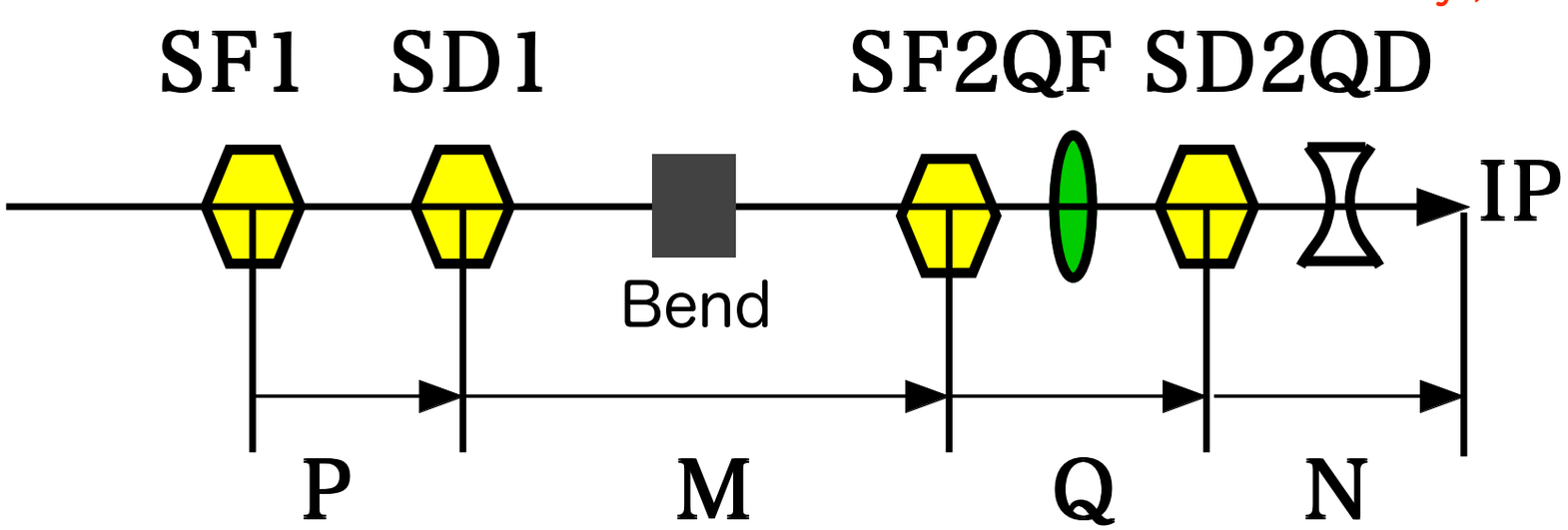


geometric aberration cancellation
and ξ correction at far upstream
in exclusive sections

Problem :
Large aberrations
for off-momentum
particles (beam halo)

(2) Local correction ; ILC choice and to be tested at ATF2/KEK

P.Raimondi and A.Seryi, Phys. Rev. Lett. 86 3779 (2001)



geometric
aberration
cancellation

higher order
aberration
cancellation

ξ correction at FD

Compact
Large IP bandwidth
Small aberration
for beam halo

Traditional FFS for CLIC?

H. Garcia

	Traditional 1	Traditional 2	Nominal
Length [km]	3	1.5	0.5
Luminosity [L_0]	0.80	0.73	1
Bandwidth [%]	0.40	0.37	0.59

Current local chromaticity FFS scheme is clearly superior to the traditional design, to be improved

ATF2 : Goal - I

A. Achievement of 37nm beam size

A1) Demonstration of a new compact final focus system; proposed by P.Raimondi and A.Seryi in 2000,

A2) Maintenance of the small beam size (several hours at the FFTB/SLAC)

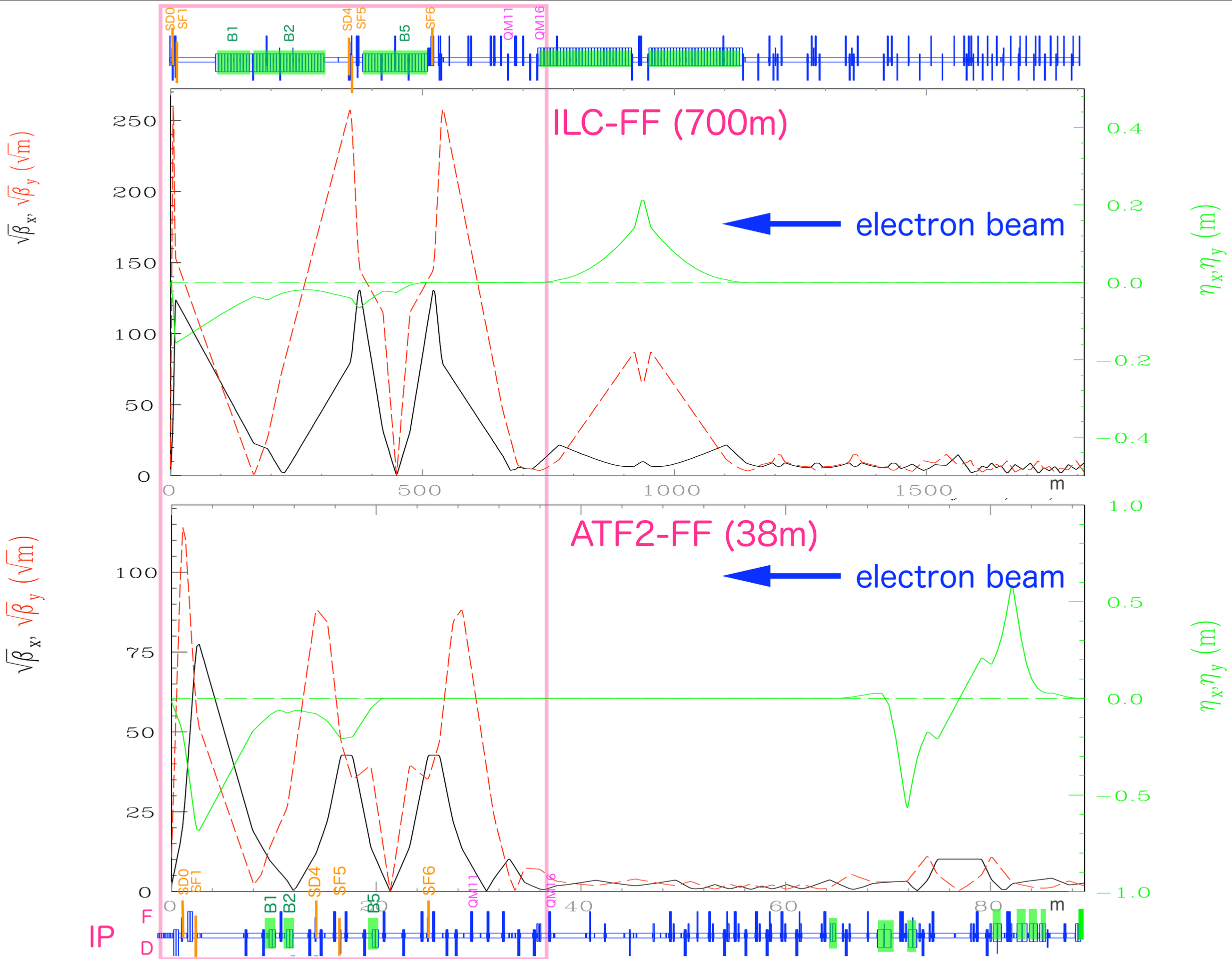
Goal - II

B. Control of the beam position

B1) Demonstration of beam orbit stabilization with nano-meter precision at IP. (The beam jitter at FFTB/SLAC was about 40nm.)

B2) Establishment of beam jitter controlling technique at nano-meter level with ILC-like beam

Parameters	unit	ATF2	ILC	CLIC	S-KEKB (LER/HER)
Beam Energy	GeV	1.3	250	1500	4/7
L*	m	1	3.5-4.5	3.5	0.47/1.3
$\gamma\varepsilon_x$	m-rad	5×10^{-6}	1×10^{-5}	6.6×10^{-7}	$2.5/3.3\times10^{-5}$
ε_x	nm	2	1.0 (DR)	0.1 (DR)	3.2/2.4
$\gamma\varepsilon_y$	m-rad	3×10^{-8}	4×10^{-8}	2×10^{-8}	$1.0/1.2\times10^{-7}$
ε_y	pm	12	2(DR)	1(DR)	13/8.4
β^*_x	mm	4	21	6.9	32/25
β^*_y	mm	0.1	0.4	0.07	0.27/0.41
η'	rad	0.14	0.0094	0.00144	
σ_E	%	~0.1	~0.1	~0.3	0.08/0.06
Chromaticity	L^*/β^*_y	$\sim10^4$	$\sim10^4$	$\sim5\times10^4$	$1.7/3.2\times10^3$
σ^*_x	μm	2.8	0.655	0.039	10.2/7.8
σ^*_y	nm	37	5.7	0.7	59/59

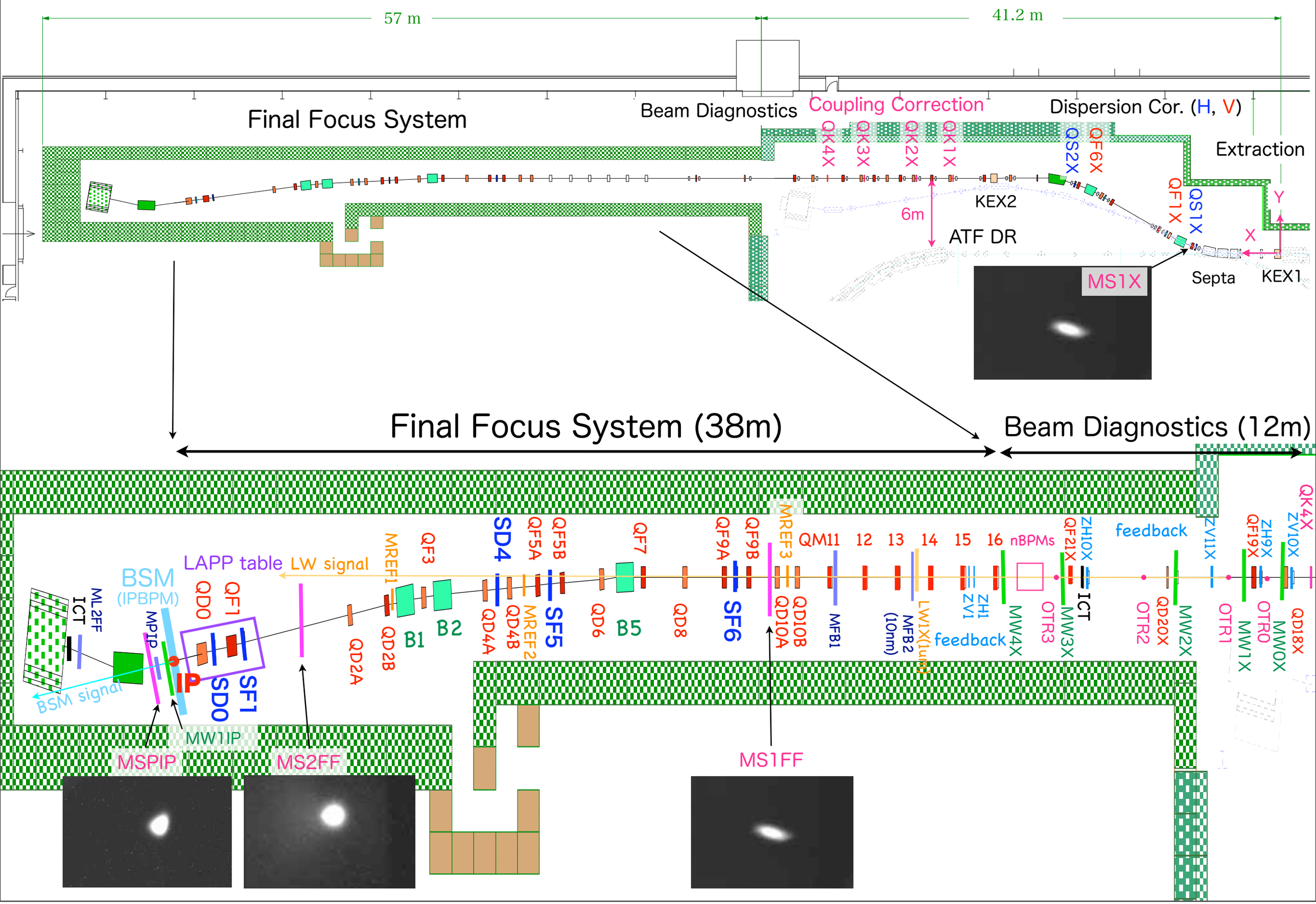

ILC-FF (700m)
electron beam
ATF2-FF (38m)
electron beam
SD0
SF1
B1
B2
SD4
SF5
B5
SF6
QM11
QM16
IP
F
D
m
$\sqrt{\beta_x}, \sqrt{\beta_y}\ (\sqrt{m})$
$\eta_x, \eta_y\ (m)$

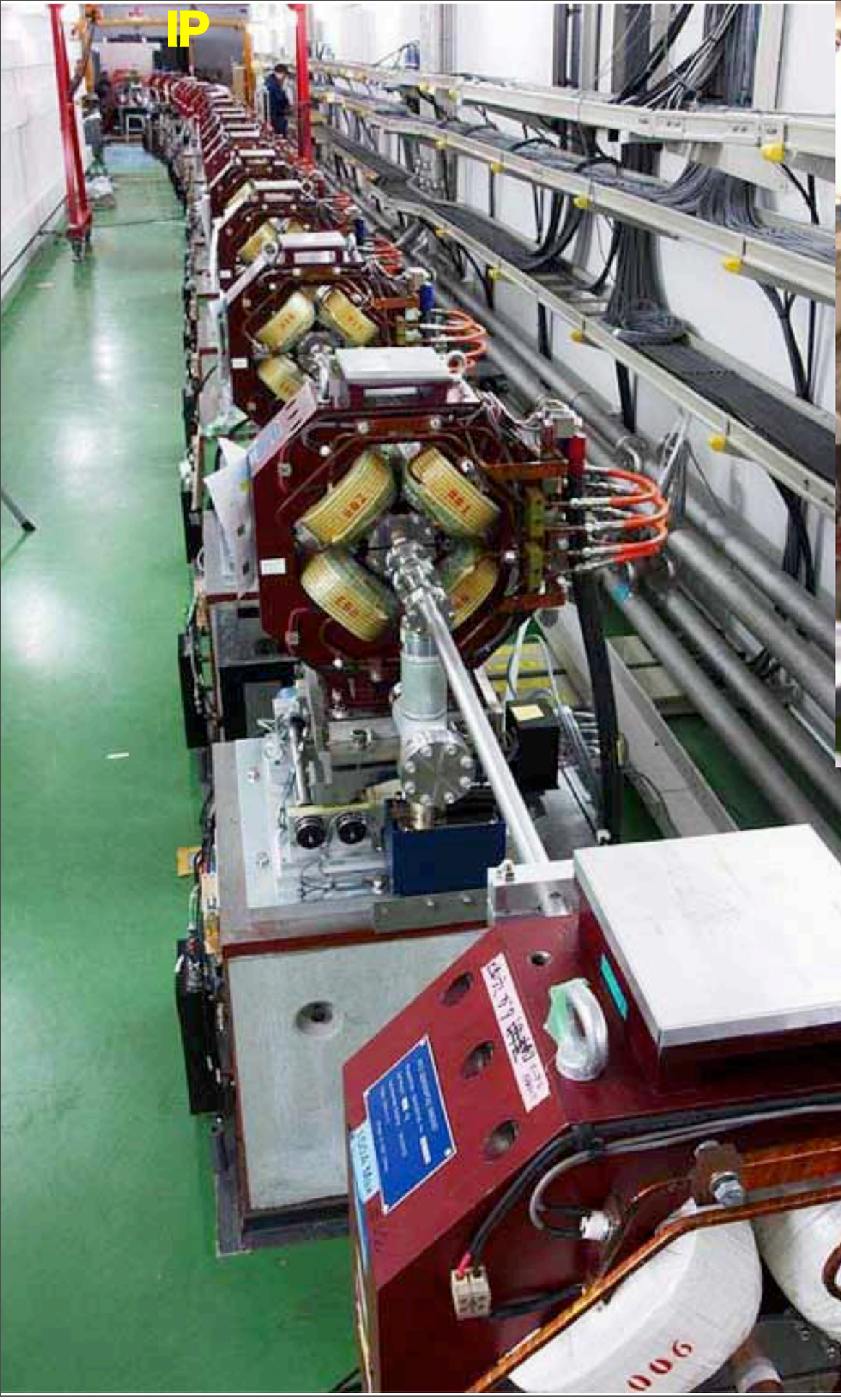
ATF2 Features

- The same number of magnets as the ILC-FF.
- The tuning knob, methods are the same,too.
- Beam instrumentation has been developed with the ILC specifications; BPMs, BSMs, movers, magnet support, laserwires, HA power supplies, FONT-feedback system etc. .
- International participation in the commissioning and operation

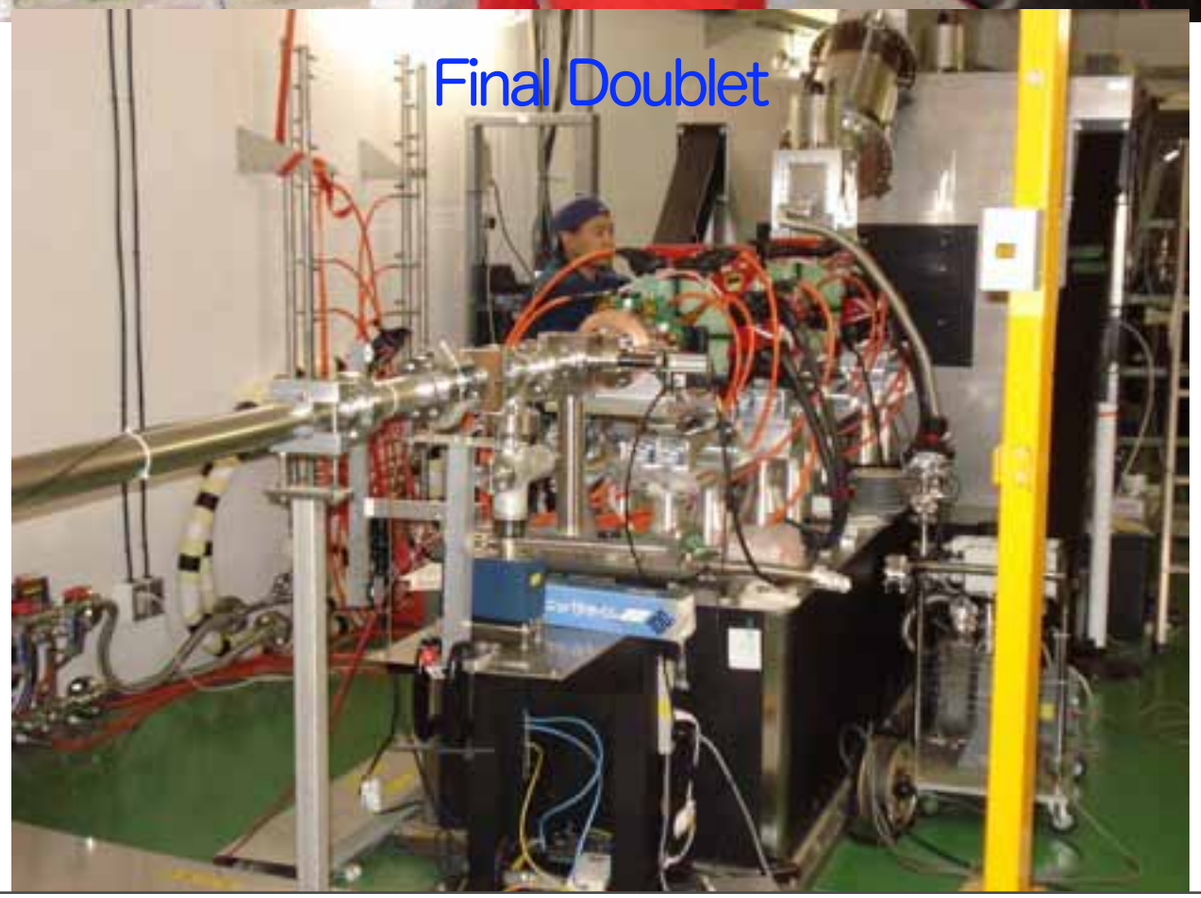
Parameters at ATF2

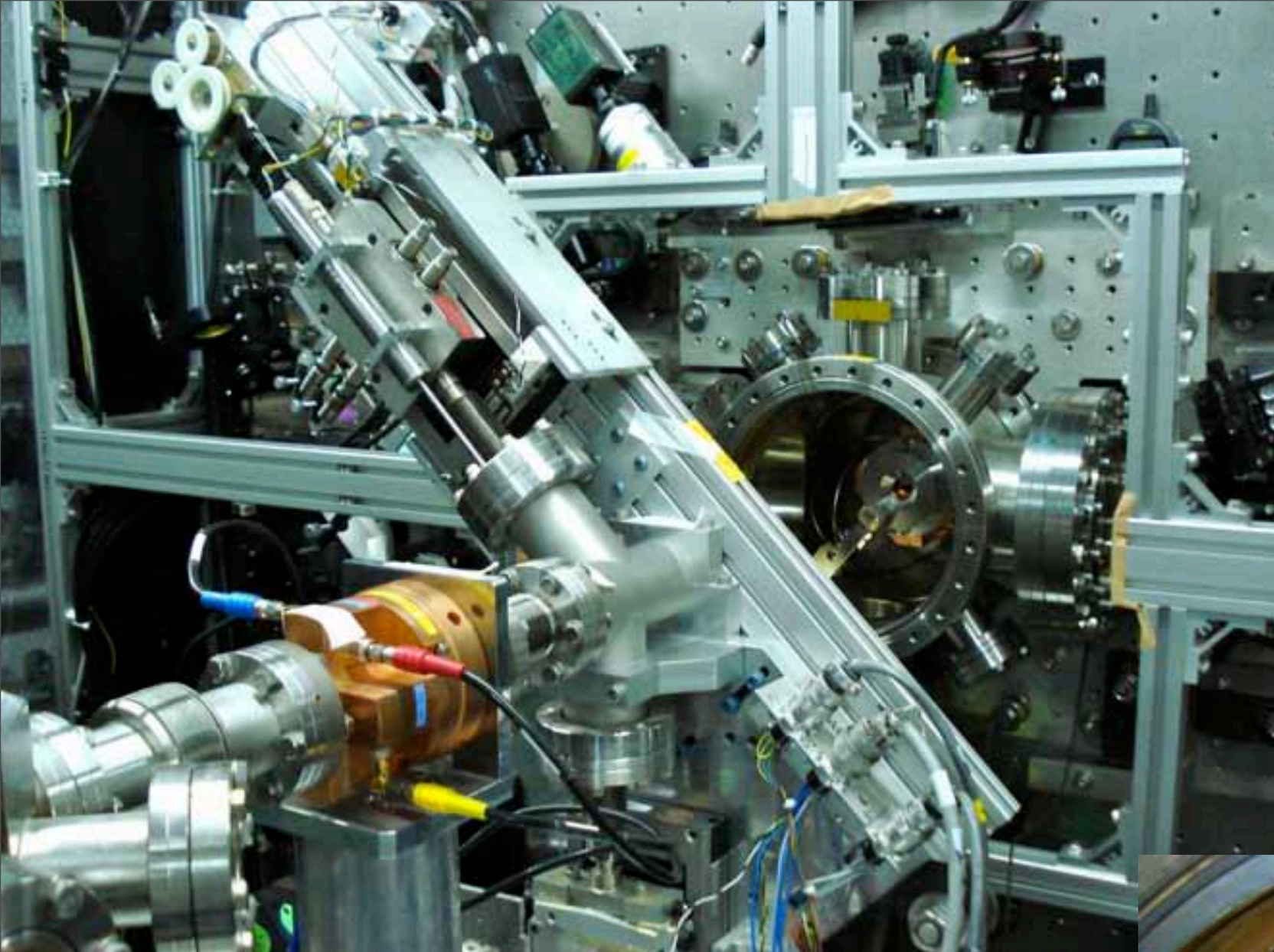
IP Parameter	nominal	April 2010	May 2010	Dec 2010
Beam energy	1.3GeV	1.3GeV	1.3GeV	1.3GeV
Emittance in x	2 nm	1.7nm	1.7nm	1.8-2.7nm
Emittance in y	12 pm	<10pm	<10pm	28-64pm
Beta function in x	4 mm	4cm	4cm	10mm
Beta function in y	0.1mm	1mm	1mm	0.1mm
beam size in x	2.8 μm	~10 μm	~10 μm	7.5μm
beam size in y	35 nm	900 nm	300 nm	439(247) nm


57 m
41.2 m
Final Focus System
Beam Diagnostics
Coupling Correction
Dispersion Cor. (H, V)
Extraction
QK4X
QK3X
QK2X
QK1X
QS2X
QF6X
QF1X
QS1X
KEX2
6m
ATF DR
Y
X
Septa
KEX1
MS1X
Final Focus System (38m)
Beam Diagnostics (12m)
BSM
(IPBPM)
LAPP table
LW signal
ML2FF
ICT
MPIP
QD0
QF1
IP
SD0
SF1
BSM signal
MW1IP
MSPIP
MS2FF
MREF1
QF3
QD2A
QD2B
B1
B2
SD4
QD4A
QD4B
MREF2
QF5A
QF5B
SF5
QD6
B5
QF7
QD8
QF9A
SF6
QF9B
MREF3
QD10B
QD10A
MS1FF
QM11
MFB1
12
13
MFB2
(10nm)
14
LW1X(1um)
15
ZH1
ZV1
16
feedback
MW4X
nBPMs
OTR3
QF21X
ZH10X
ICT
MW3X
OTR2
QD20X
MW2X
OTR1
ZV11X
QF19X
ZH9X
ZV10X
OTR0
MW1X
MWOX
QD18X
QK4X


IP

Shintake
Monitor
IP

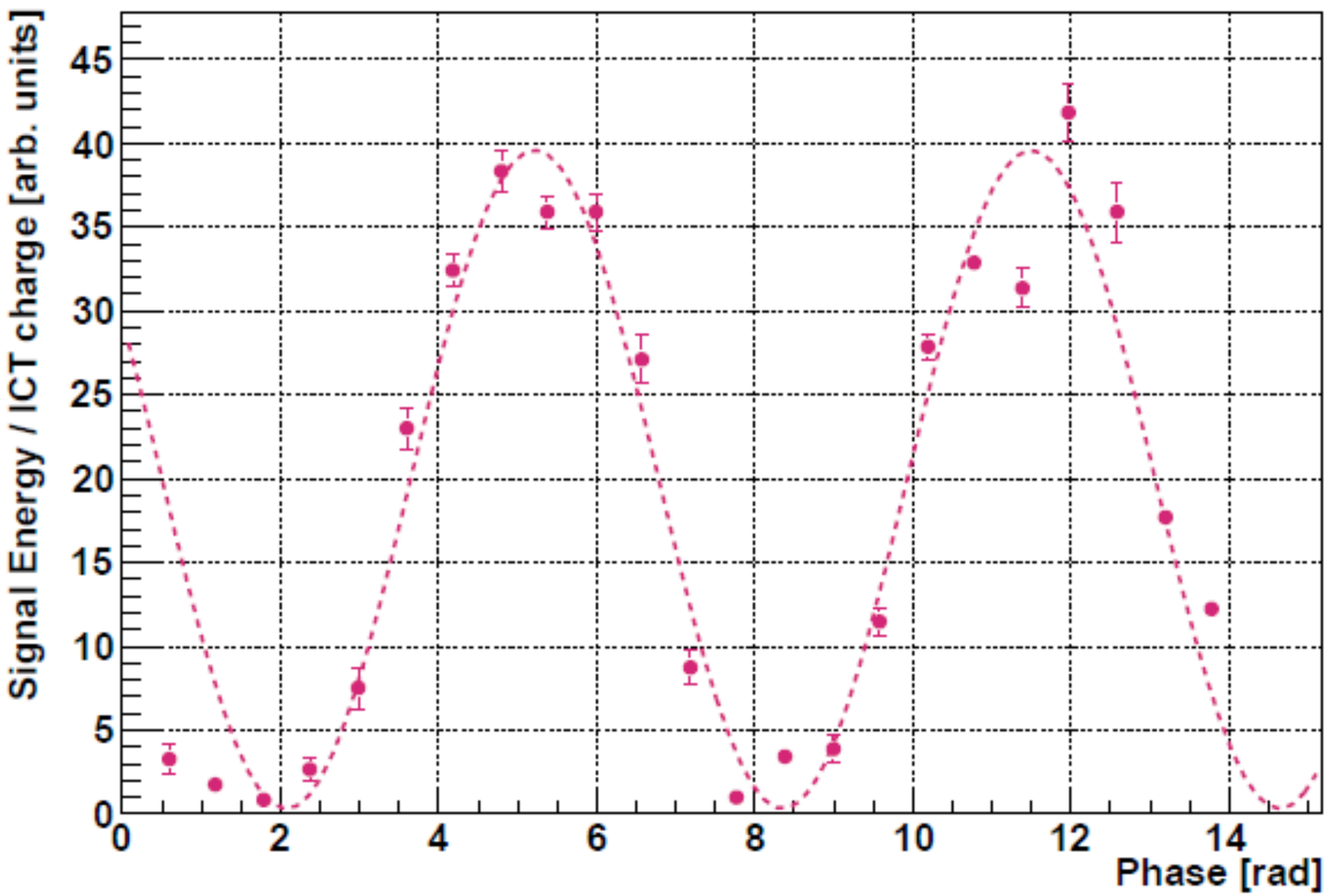

Final Doublet



IP region seeing from the downstream

IP carbon wires and IPBPMs in the IP chamber

Results of the continuous run in December, 2010



Interference scan plot for one of the smallest beam sizes measured at 5.96 degree on Dec 16, 2010.

$\sigma_y^* = 280 \pm 90$ nm

$M_{meas} = 0.918 \sim 0.984$

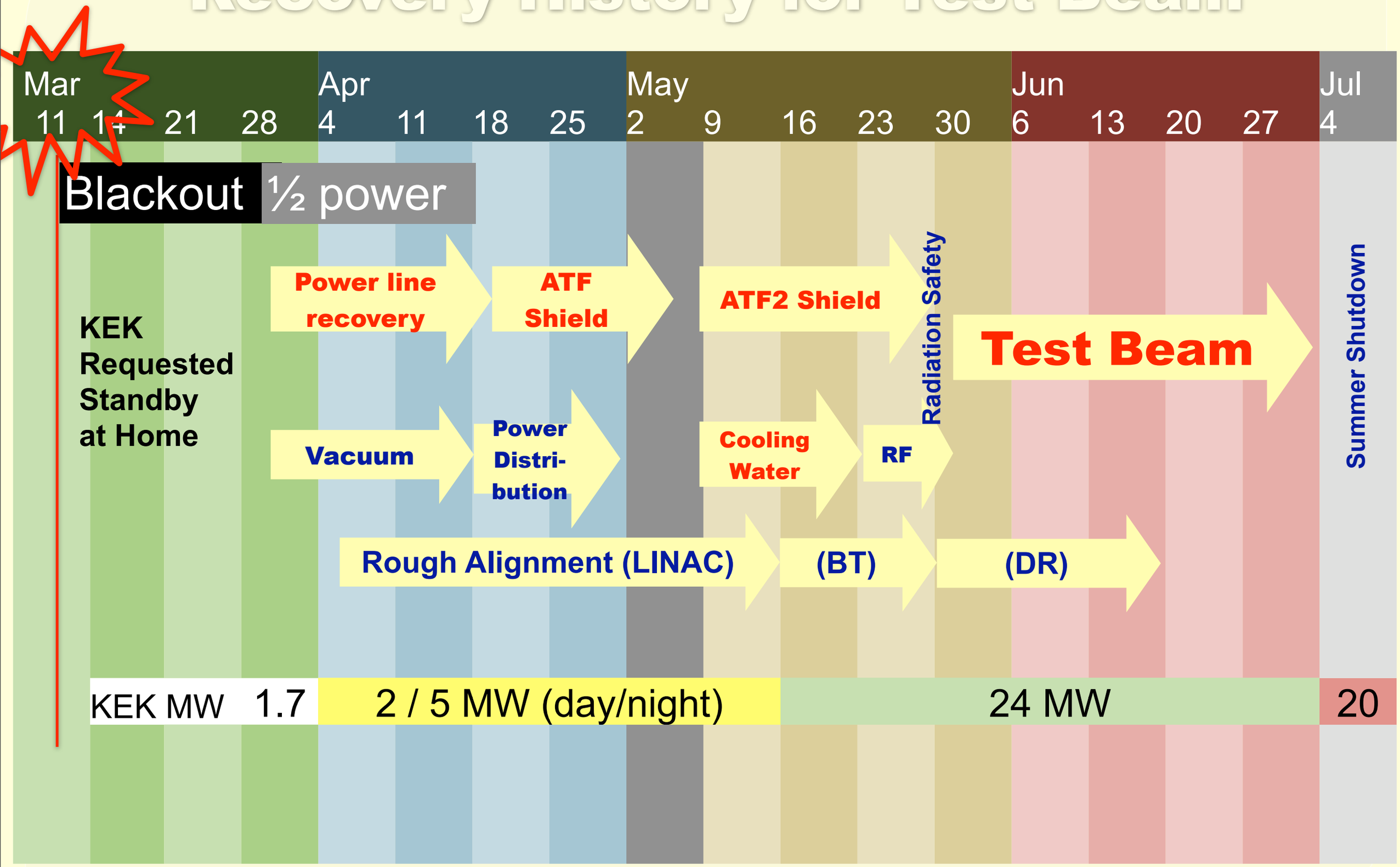
$\beta_x^* = 10$mm

$\beta_y^* = 0.1$mm

FD/IP shield works

N. Terunuma, ATF2 weekly Meeting,11 May 2011

Recovery History for Test Beam

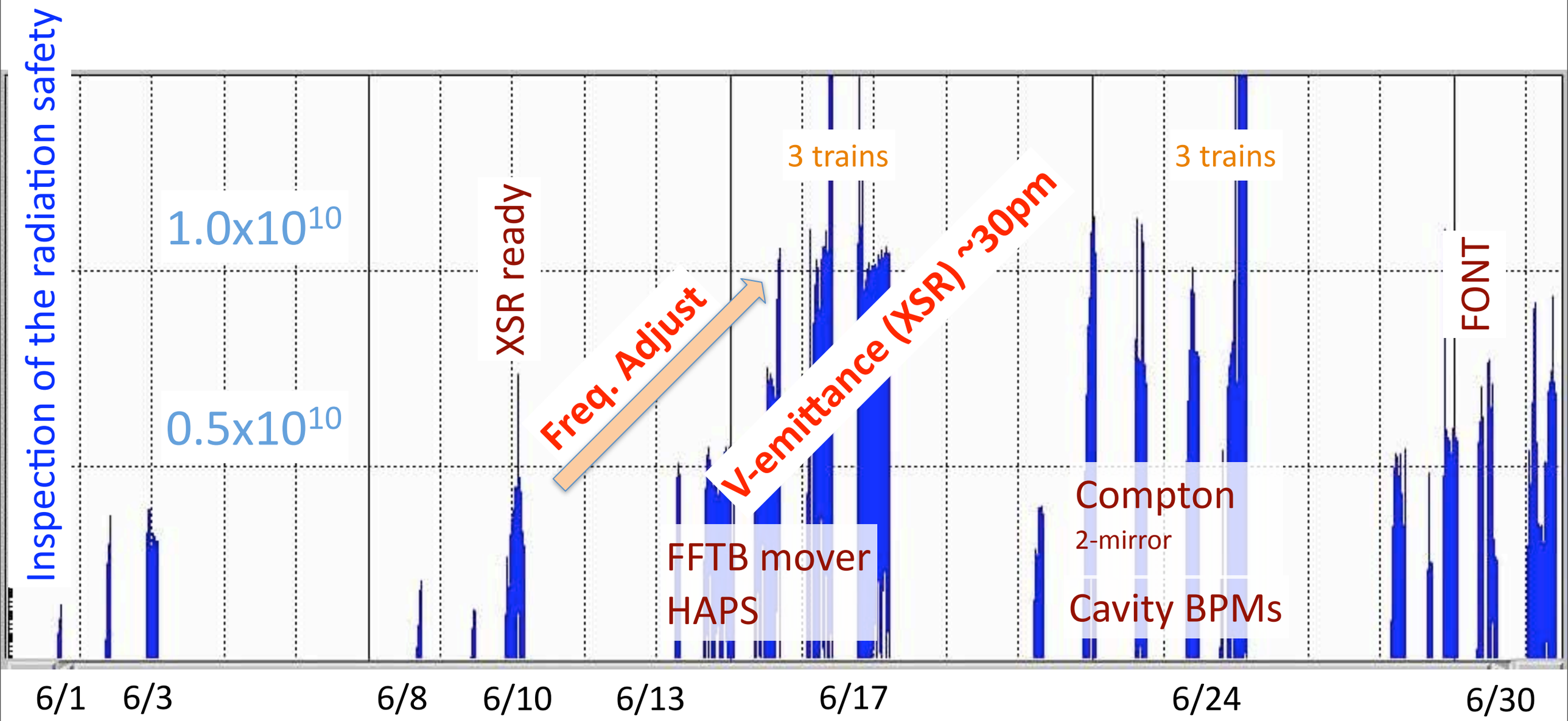


N.Terunuma, LCWS2011, 26-30 September,2011

Stored beam in DR (x10^{10} e/bunch)

A stored beam was delivered to the dump of ATF2.

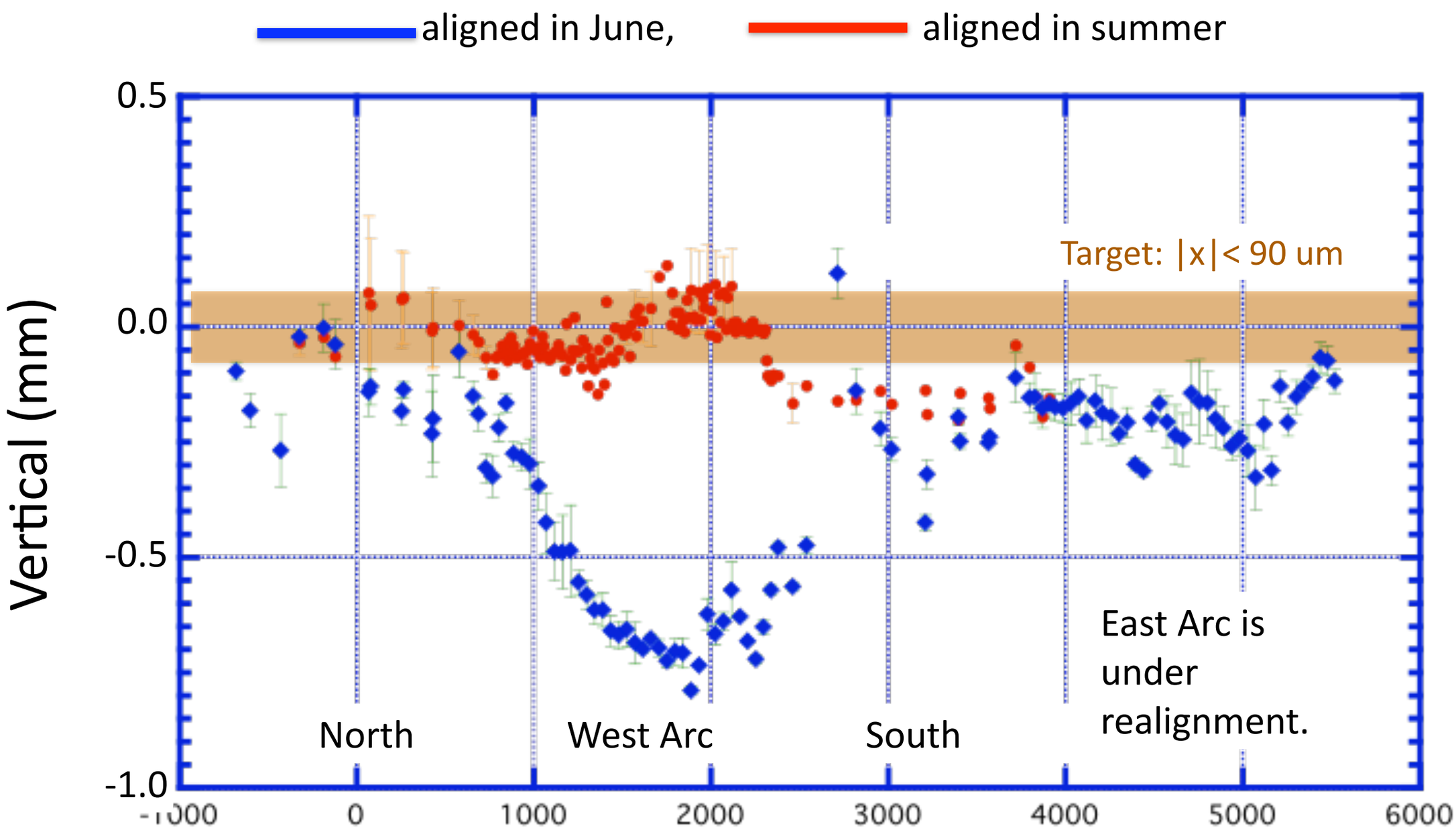
No critical damage on the accelerator was found.



DR rough alignment for checkout was continued in daytime.

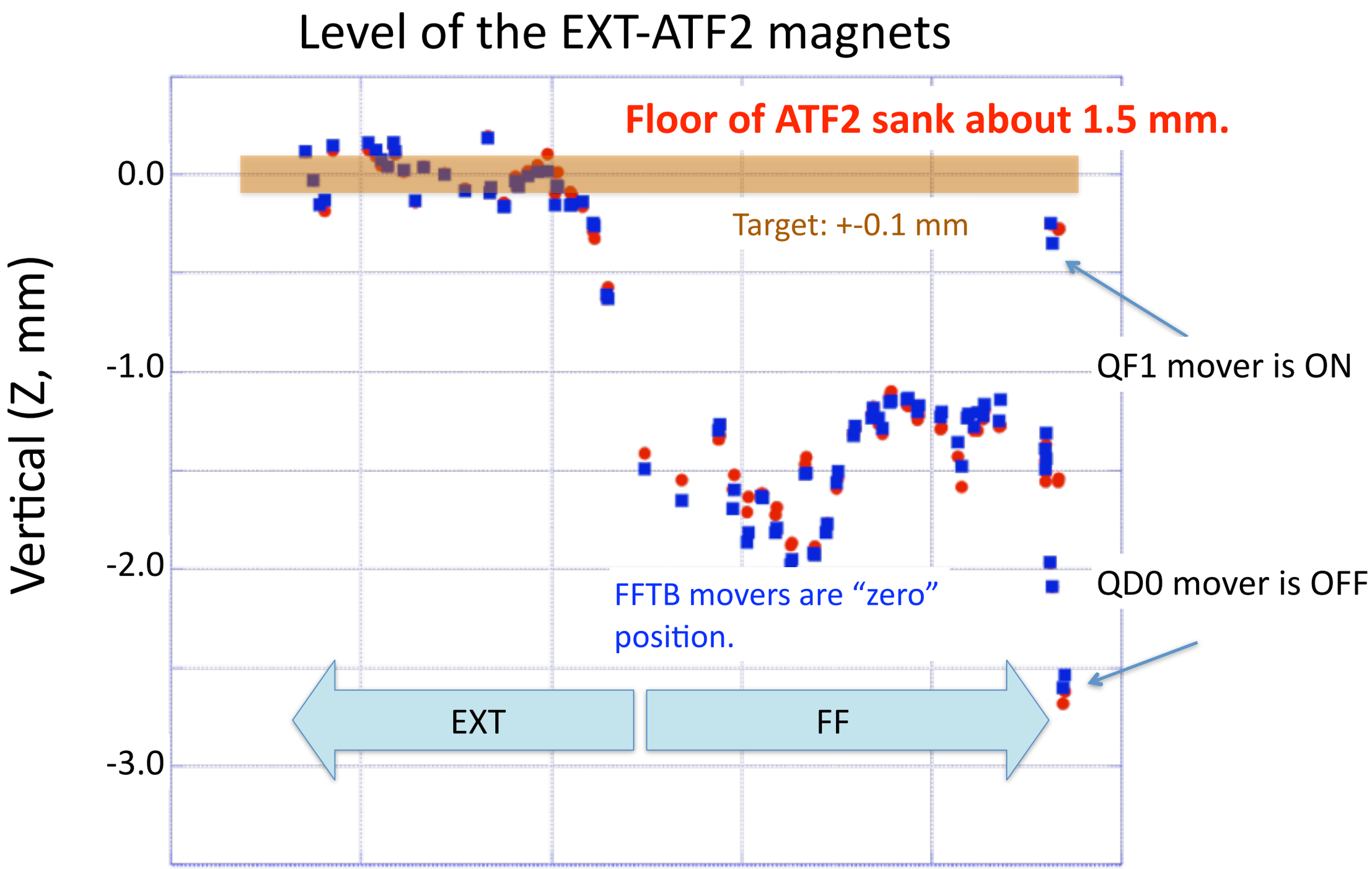
N.Terunuma, LCWS2011, 26-30 September,2011

Alignment: DR level



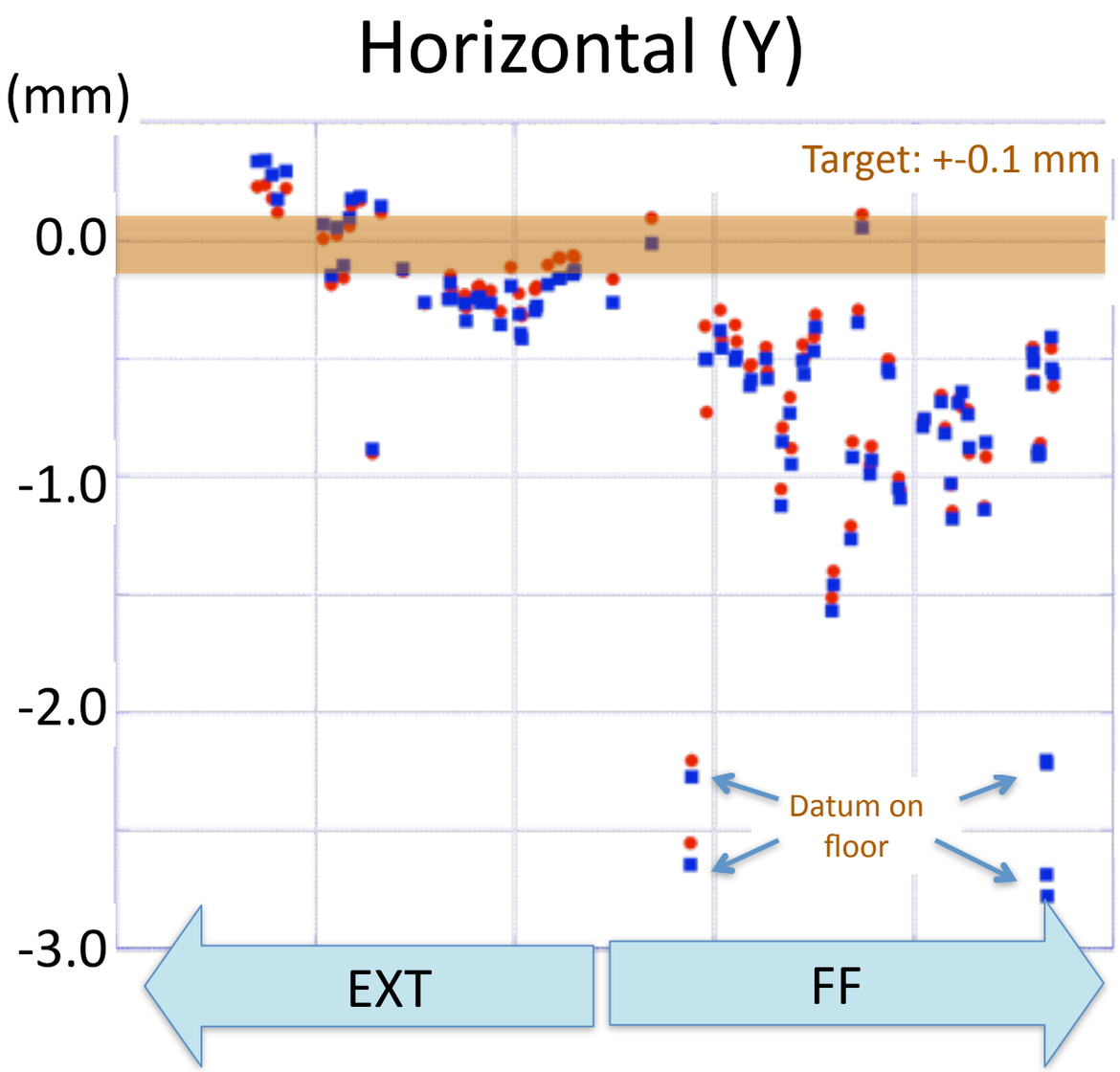
N.Terunuma, LCWS2011, 26-30 September,2011

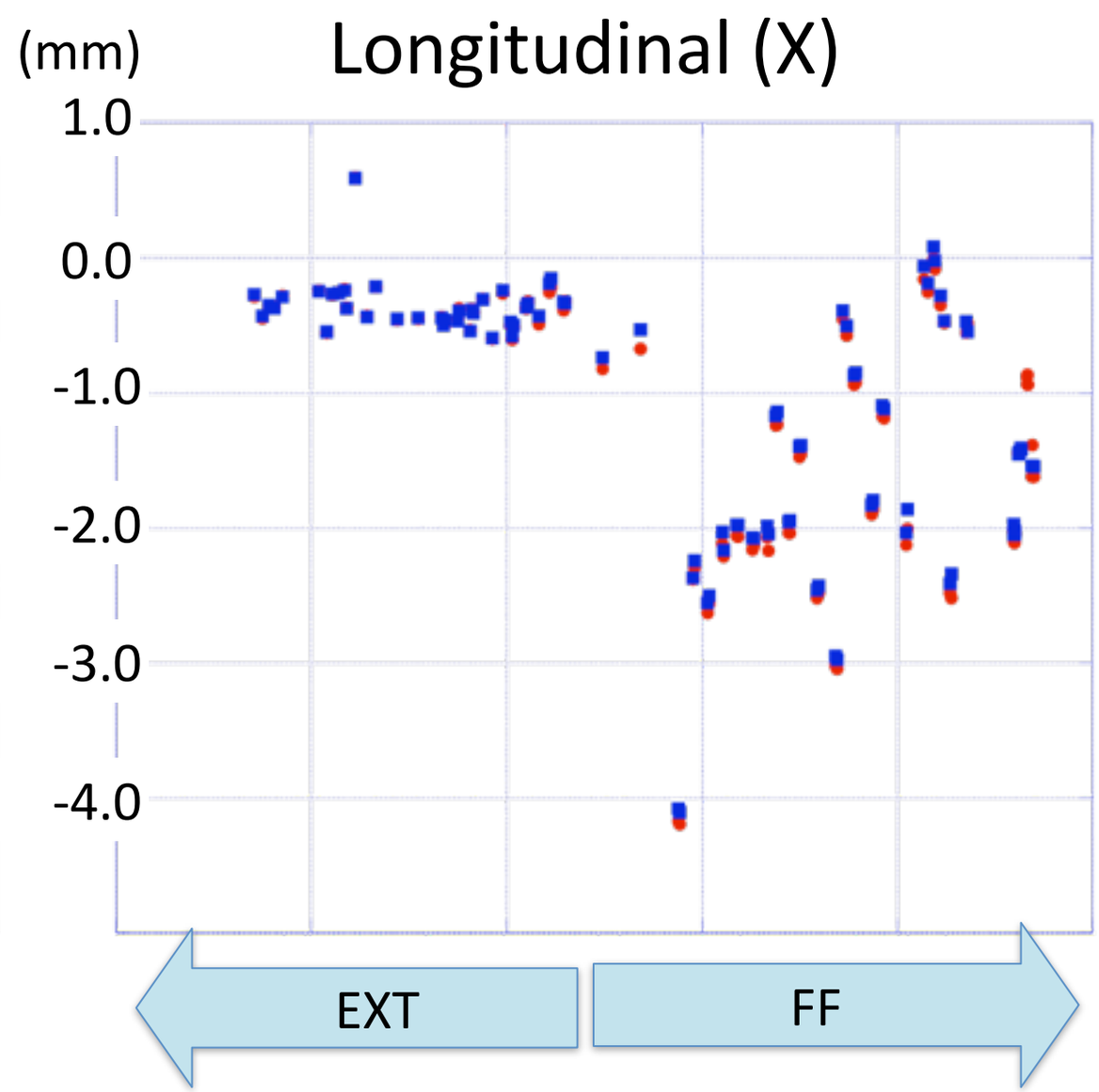
Waiting for alignment: ATF2



N.Terunuma, LCWS2011, 26-30 September,2011

(Waiting for) alignment: ATF2





We are checking the definition of the datum on the floor used at the ATF2 construction. Offset?

N.Terunuma, LCWS2011, 26-30 September,2011

Deep understanding of the beam tuning

Optical Matching Routines in Lucretia

- New software written in Lucretia, a "Match" class for first and higher-order beam matrix matching using tracking engine, fast 3rd-order polynomial fitting to IP beam particles and Matlab-based optimisation routines.
  - 'lsqnonlin' for first-order (Twiss) parameter matching
    - This produces a "first-pass" solution with the desired optical parameters but with existing 2nd and 3rd order geometric and chromo-geometric aberrations present at IP still.
  - 'fminsearch' (Nelder-Mead)
    - Remove higer-order aberrations by direct optimisation of sigma_11 and sigma_33 terms
- Generate range of matched FFS lattices with different IP beta functions.
- Match constraints
  - Waist at IP with given beta functions (IP vertical beta constrained : bcons)
  - Waists at MFB1FF and (MFB2FF OR LW1FF)
    - Ensures correct phase advances for FFS feedbacks
- Match variables
  - Matching quads + final doublet for initial Twiss match
  - All FFS quadrupole and sextupole strengths plus SK1FF strength, for final beam size optimisation.

Tuning Performance Summary

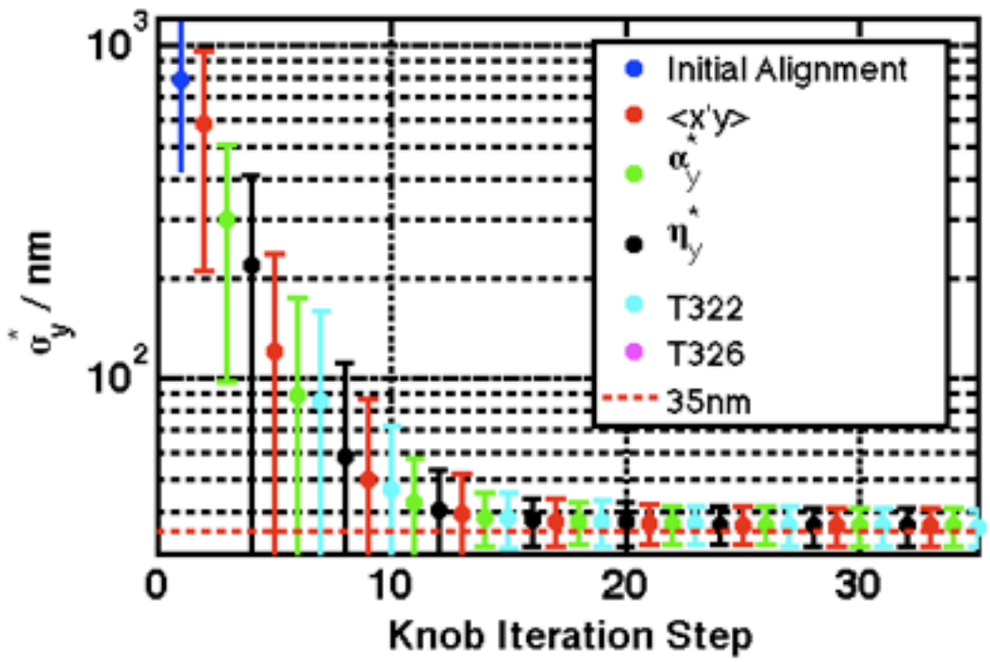
Will not tune

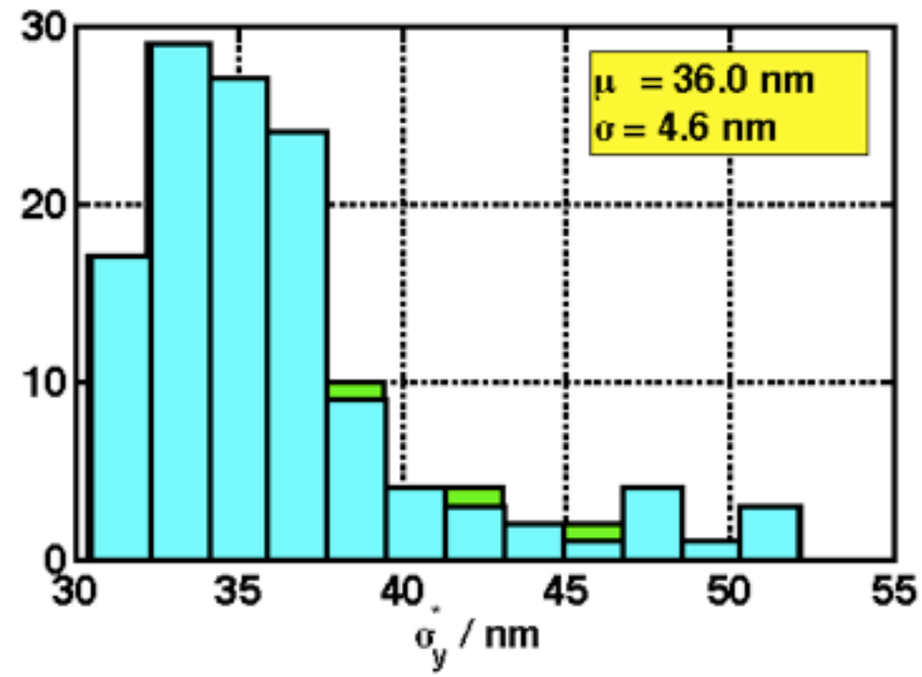
	BX1BY1	BX1BY1_bcons	BX2.5BY1	BX2.5BY1_bcons	BX10BY1	BX10BY1_bcons
σ_y (50% CL) / nm (core size)	39.6	45.7	35.5	41.9	34.8	X
σ_y (90% CL) / nm (core size)	48.3	64.6	43.1	50.8	41.8	X
$P(\sigma_y<37nm)$ / %	32	10	66	12	77	X
AGauss Spread (50%CL) / nm	6.8	4.8	4.0	5.9	2.7	X
AGauss Spread (90%CL) / nm	19.9	39.1	11.9	20	7.2	X
Convergence (lower better)	695	707	1183	684	992	X
Residual aberrations	T324 T326 T314	T324 <x'y> T322	T324 <x'y> α_y	T324 T314 T326	T322 T324 T312	X

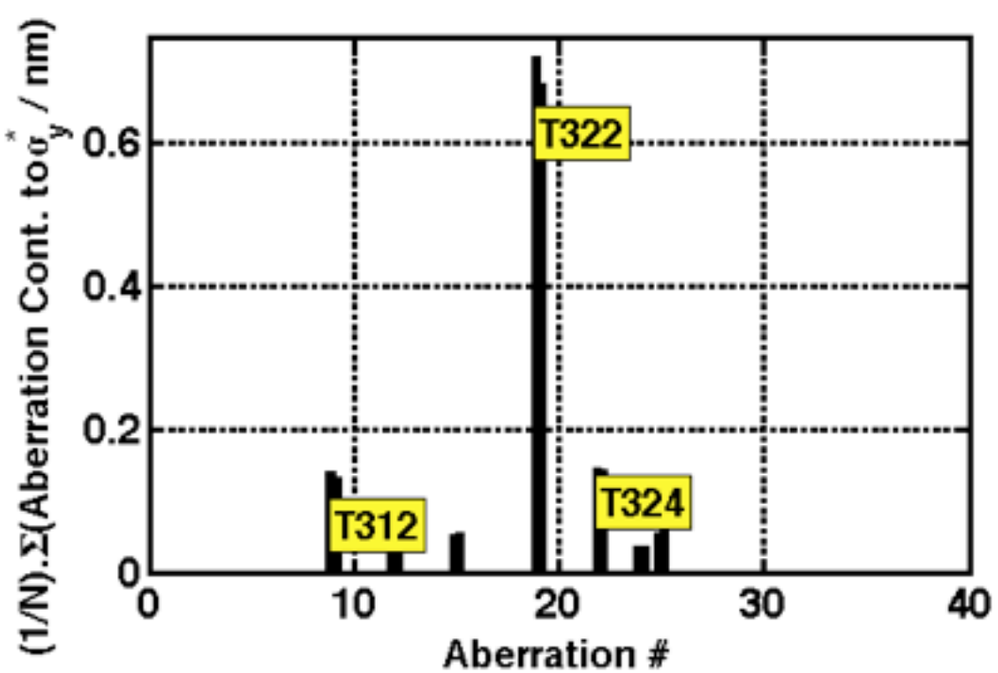
G.White, LCWS2011, 26-30 September,2011

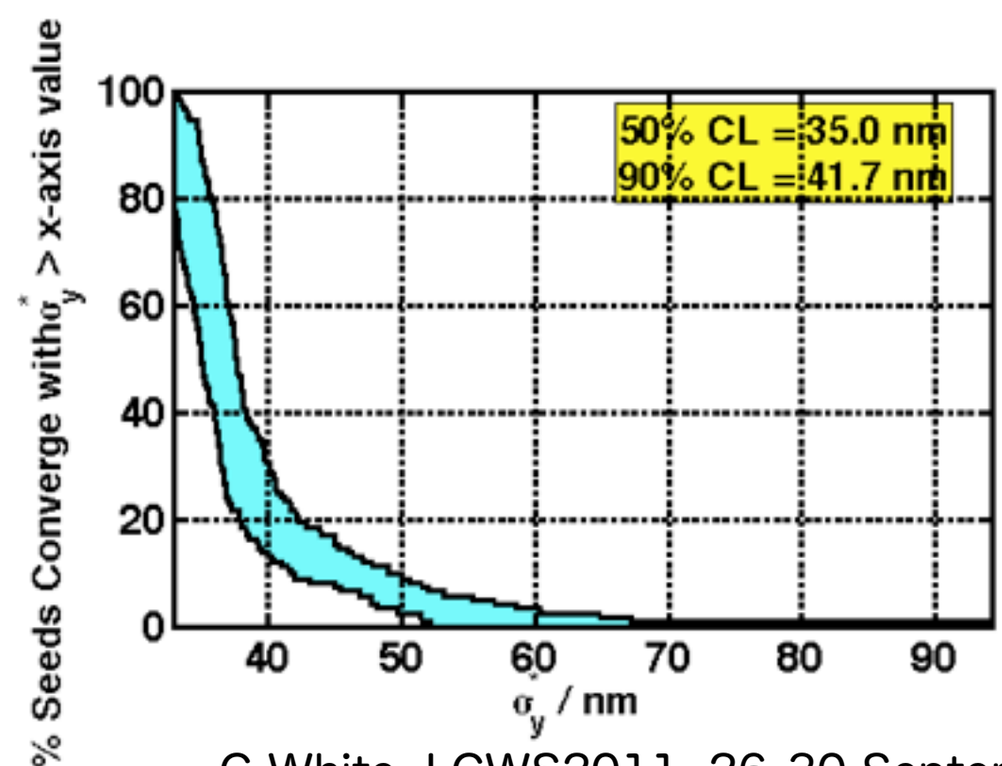
BX10BY1 Tuning Results

by simulation



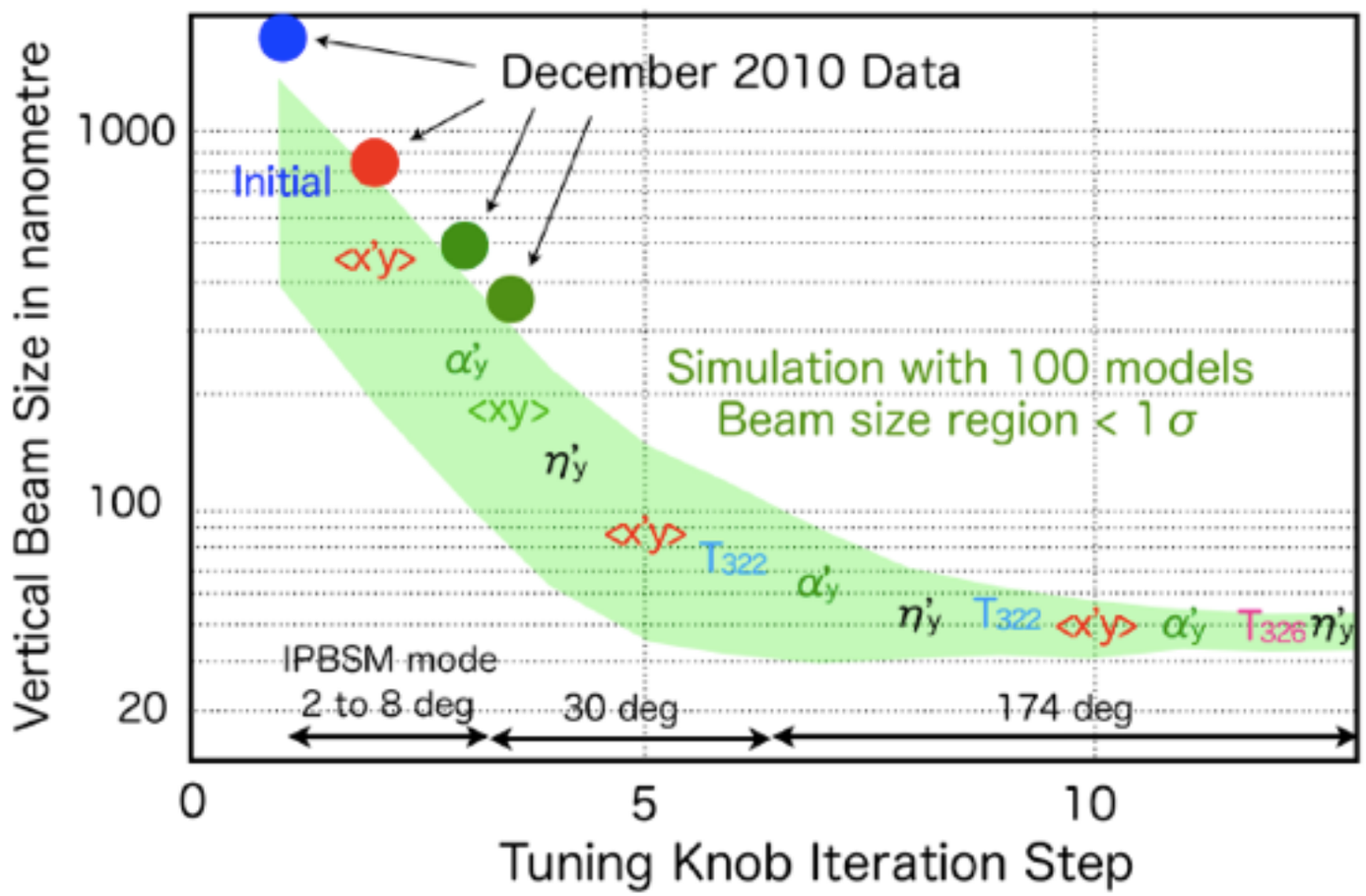






G.White, LCWS2011, 26-30 September,2011

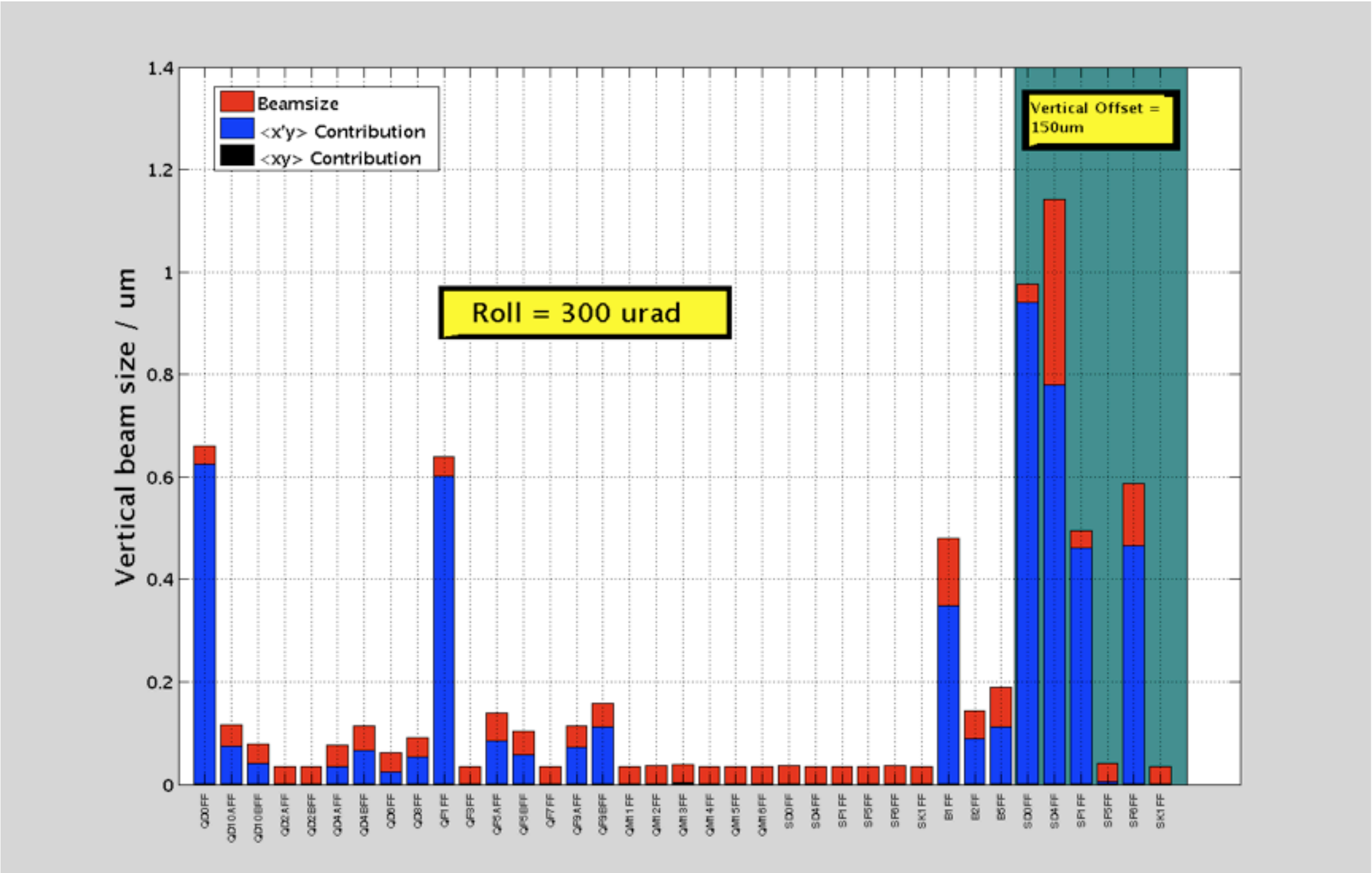
December Data



- Following ~expected curve.
- EXCEPT:
  - <xy>
  - Do not expect this aberration term to appear from simulations.
  - If corrected coupling at FFS entrance, nothing in FFS to introduce this (magnetically)

G.White, LCWS2011, 26-30 September,2011

Coupling Aberration Induced at IP due to FFS Magnet Rolls and Offsets

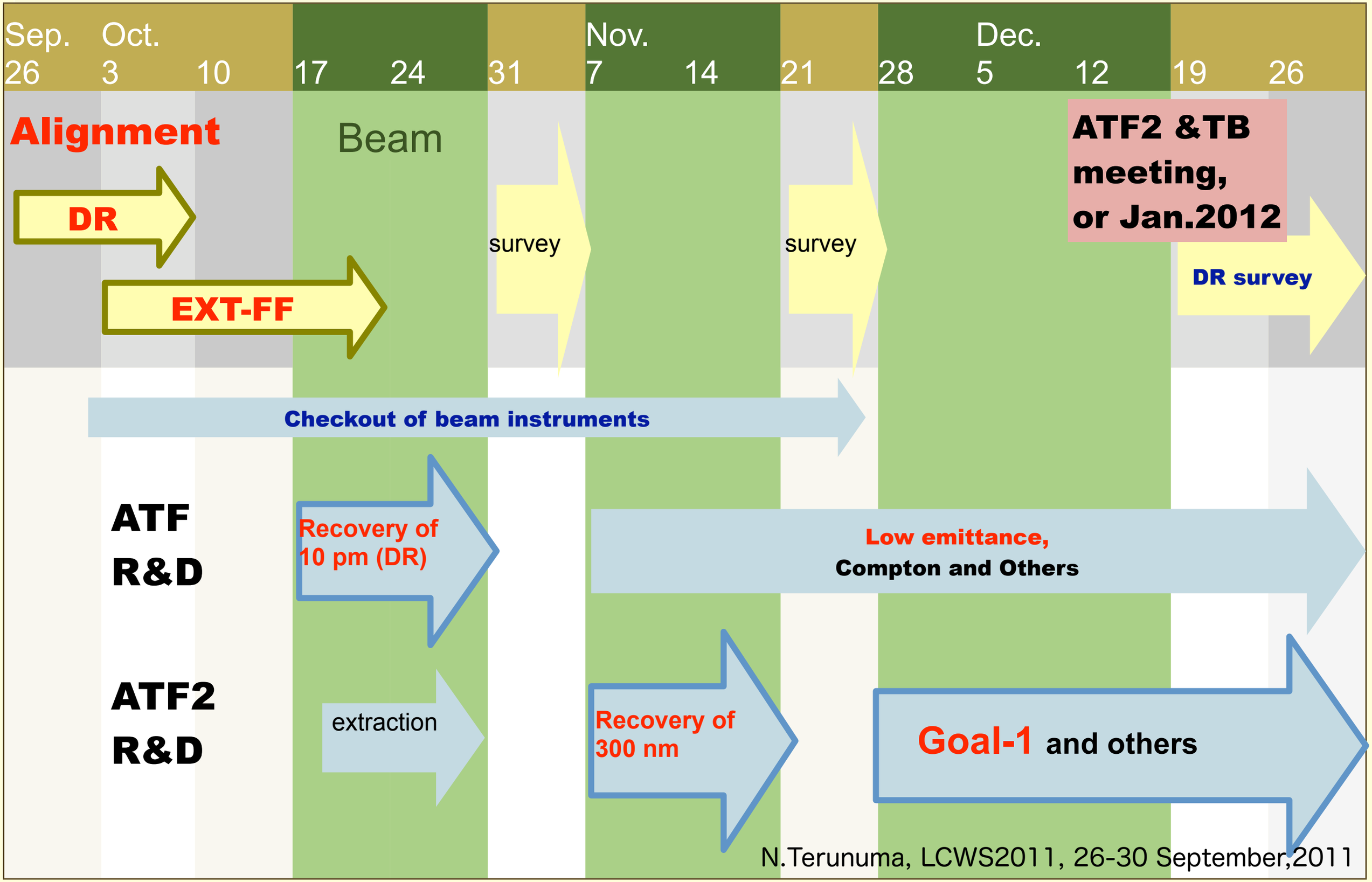


G.White, LCWS2011, 26-30 September,2011

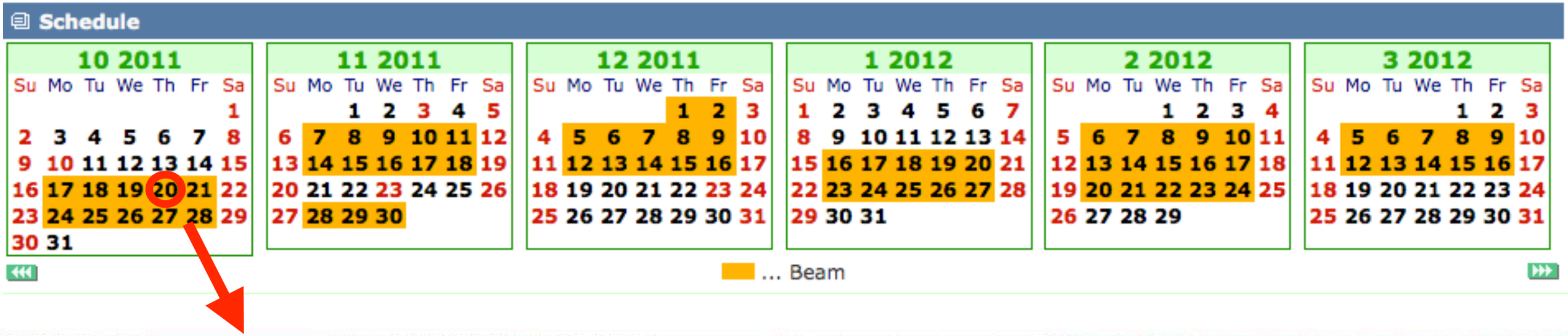
Why do we see beam size improvement with application of <xy> knob?

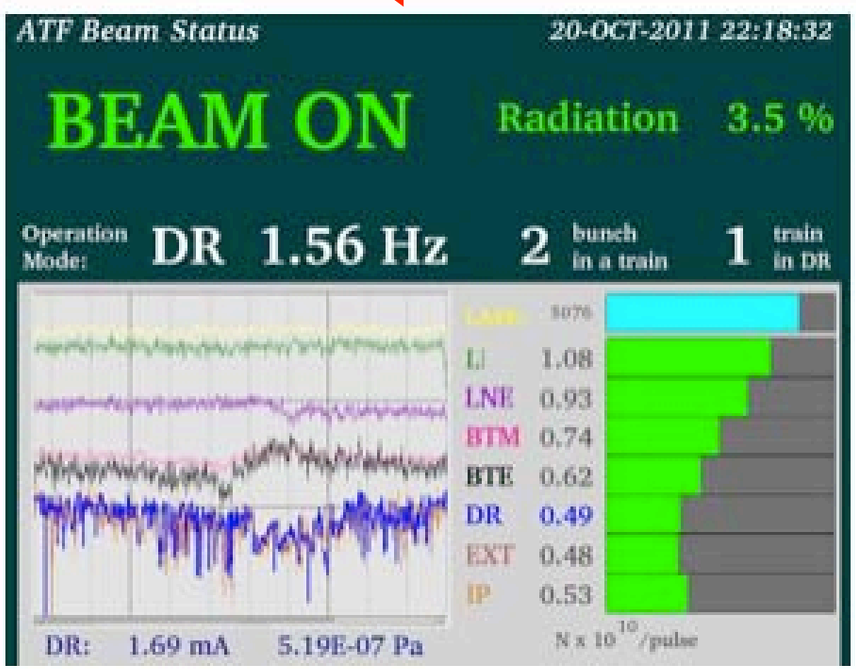
- Alignment of IPBSM fringes with respect to FFS alignment frame?
  - If plane of fringes rotated by ~**20 mrad** (~**3.5 degrees**), provides a similar contribution to beamsize in tuning simulations as that seen in experiment.
- IMPORTANT:
  - If waist not centred on IPBSM exactly, <x'y> generates <xy>, therefore **MUST FIRST REDUCE <x'y> AND α_y TERMS BEFORE USING <xy> KNOB**.
  - It could be that in Dec we hadn't fully removed <x'y> term and the waist was not exactly in place, and corrected <x'y> with <xy> knob.
- **Having <xy> source and <x'y> source at IP greatly complicates tuning process, we should try to find and eliminate any <xy> sources manually first.**
- **Using a larger β_x^* optics also makes this problem worse.**
- **!--- Probably essential to have roll control of IPBSM fringes ---!**
  - **@ ~100urad level (for 10um σ_x)**

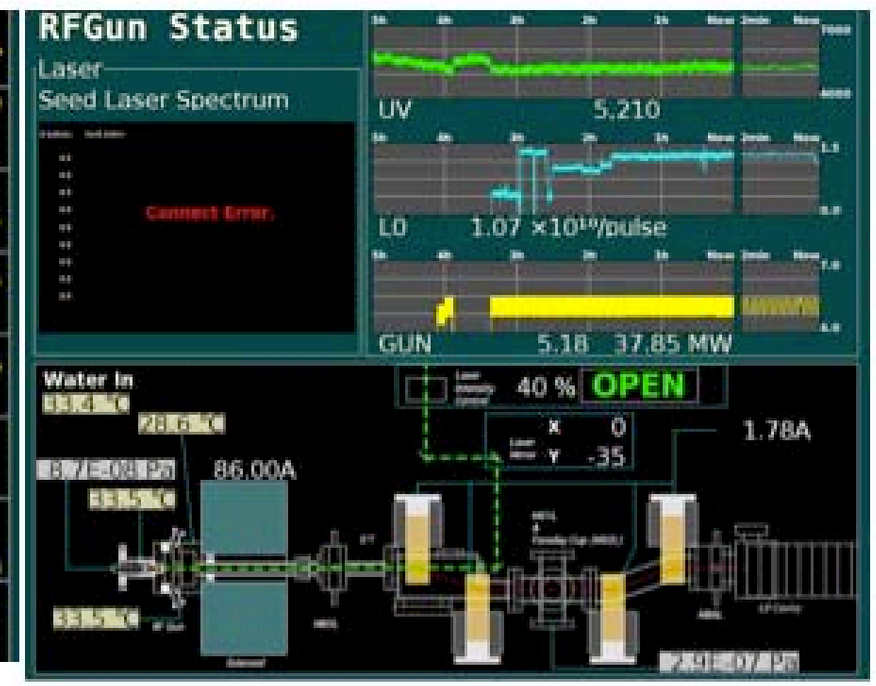
Schedule (draft for discussion)



Beam time in JFY 2011 and Present Status







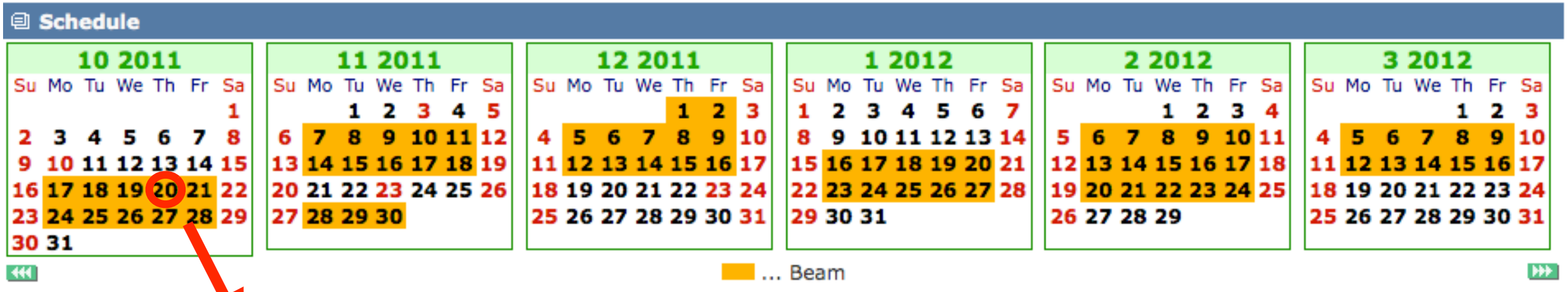
DR status, 21 October, 2011

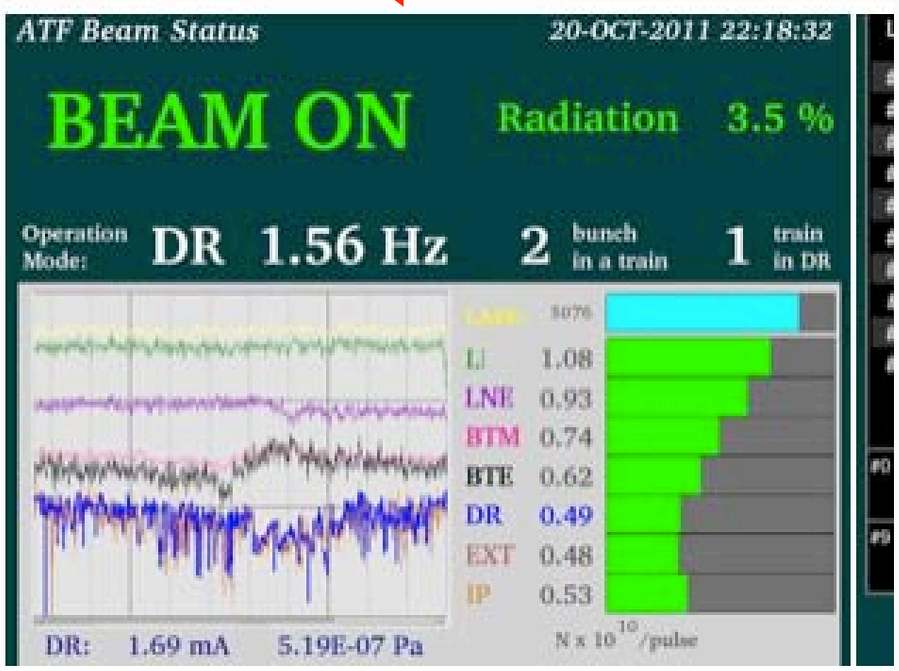
vertical emittance = 12.7 pm (XSR)

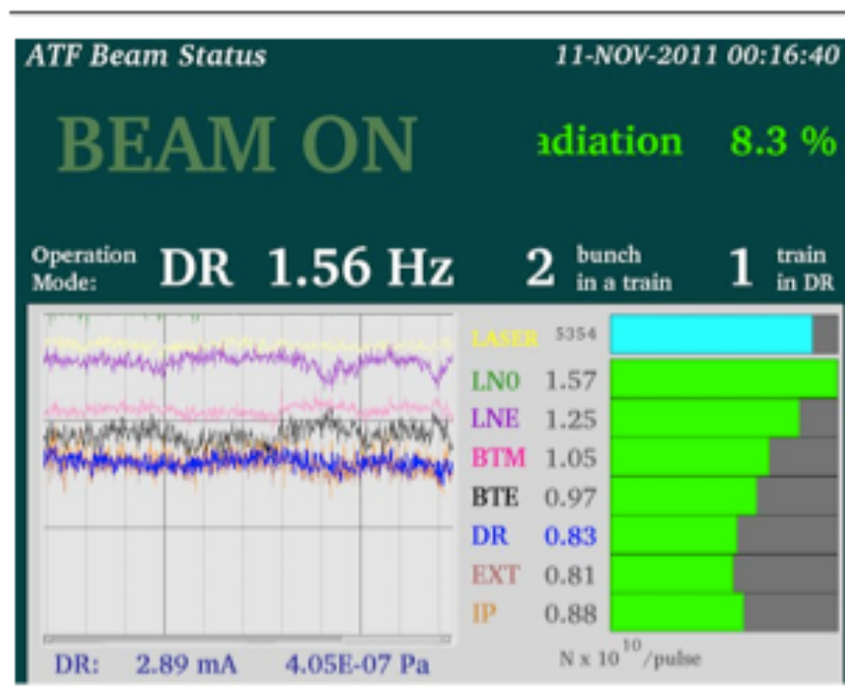
beam intensity = 0.5 x 10^{10}/bunch

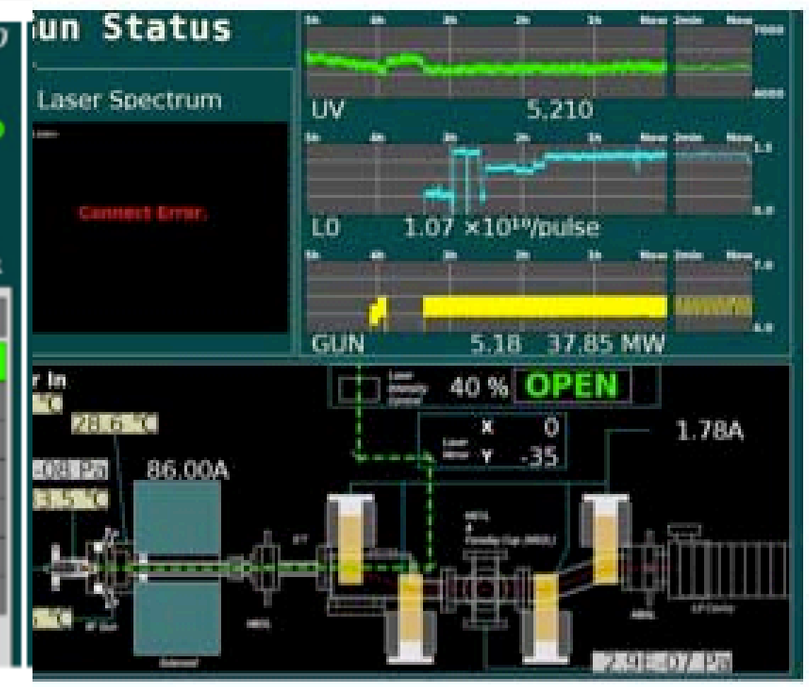
repetition rate =1.56Hz

Beam time in JFY 2011 and Present Status









DR status, 21 October, 2011

vertical emittance = 12.7 pm (XSR) → 12.8 pm (XSR)

beam intensity = 0.5 x 10^{10}/bunch → > 1 x 10^{10}/bunch

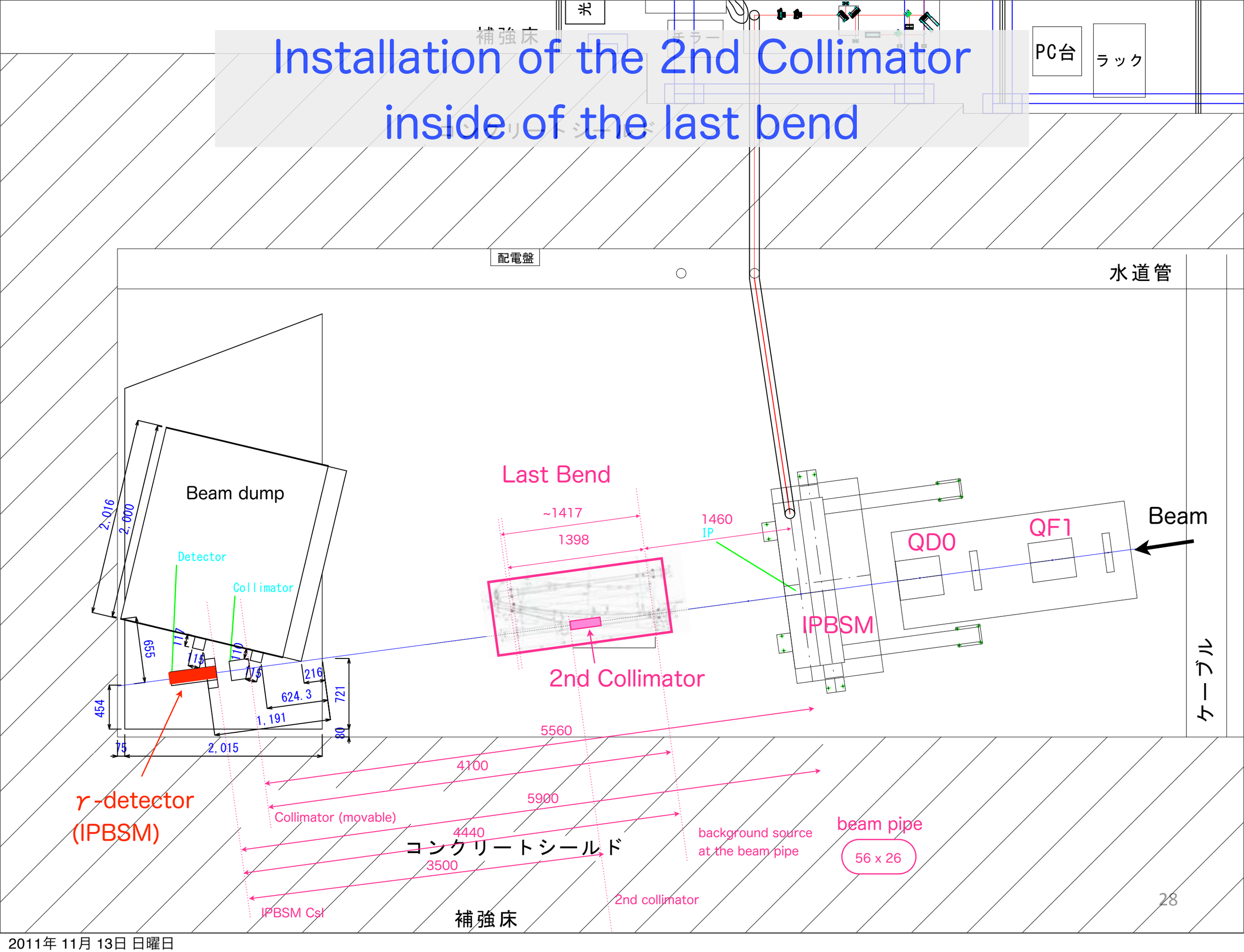
repetition rate =1.56Hz

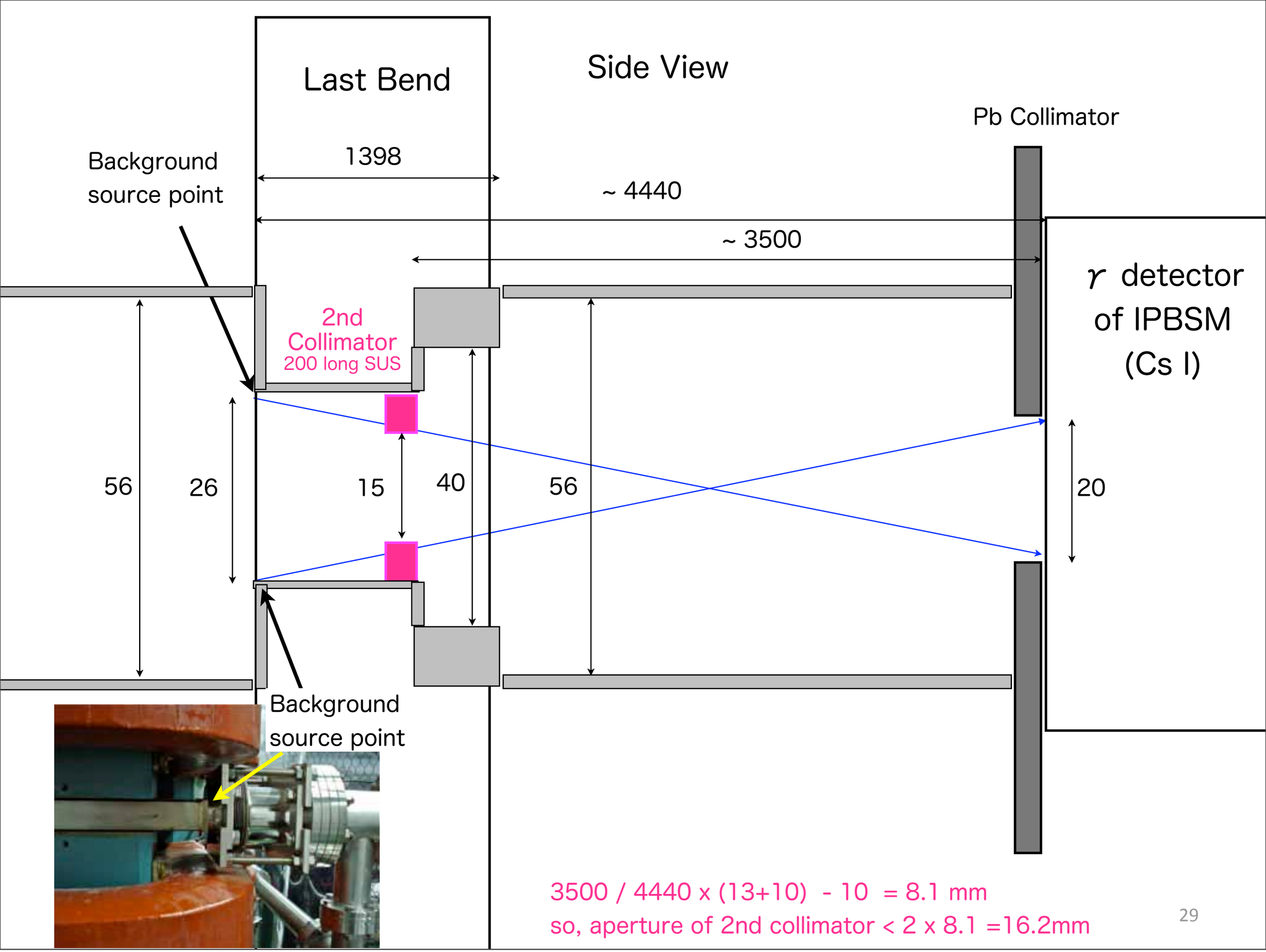
EXT-FF beam tuning, 8 Nov. 2011

vertical emittance at FF~ 20pm (OTR)

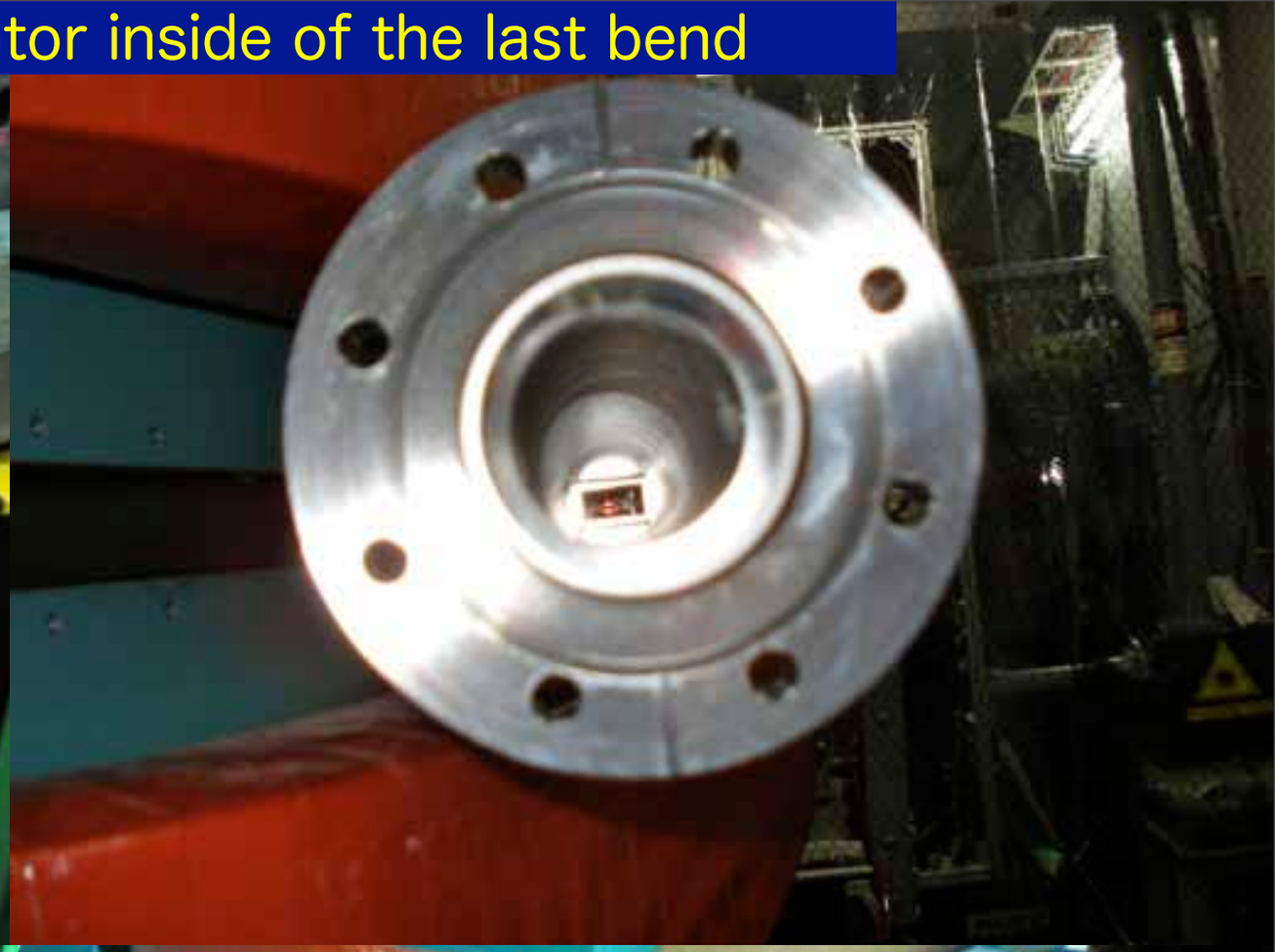
w/o corrections

Installation of the 2nd Collimator inside of the last bend



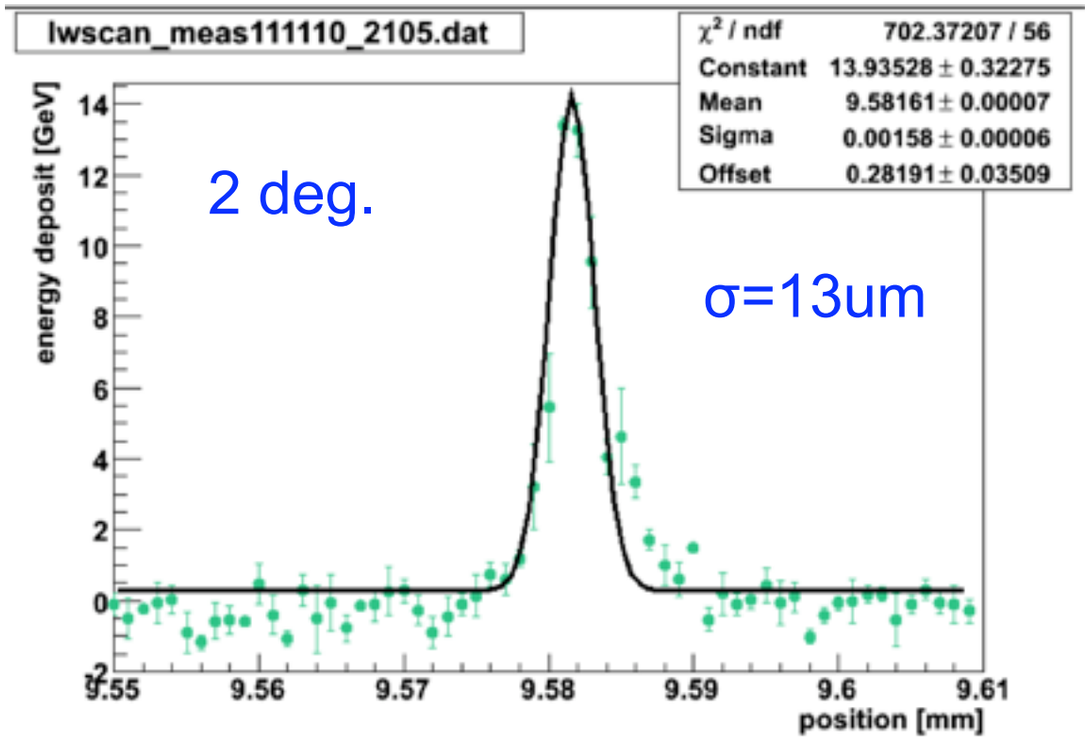

Last Bend
Side View
Pb Collimator
Background
source point
1398
~ 4440
~ 3500
γ detector
of IPBSM
(Cs I)
2nd
Collimator
200 long SUS
56
26
15
40
56
20
Background
source point
3500 / 4440 x (13+10) - 10 = 8.1 mm
so, aperture of 2nd collimator < 2 x 8.1 =16.2mm

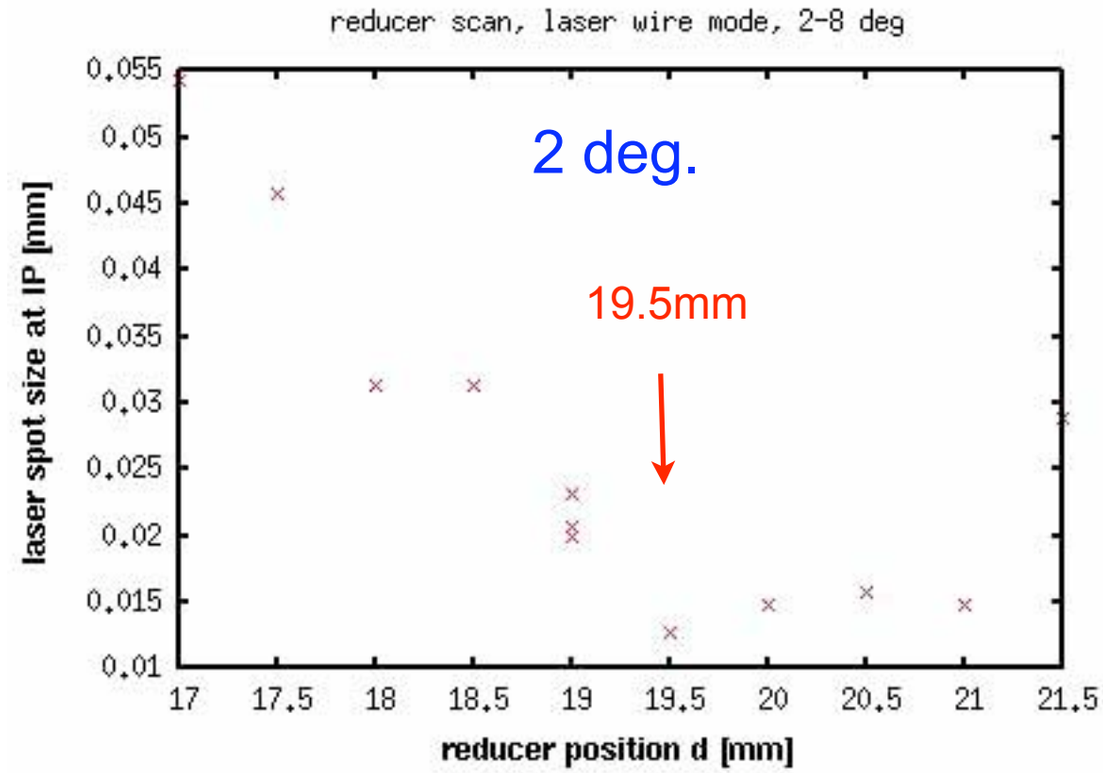
Installation of the 2nd Collimator inside of the last bend

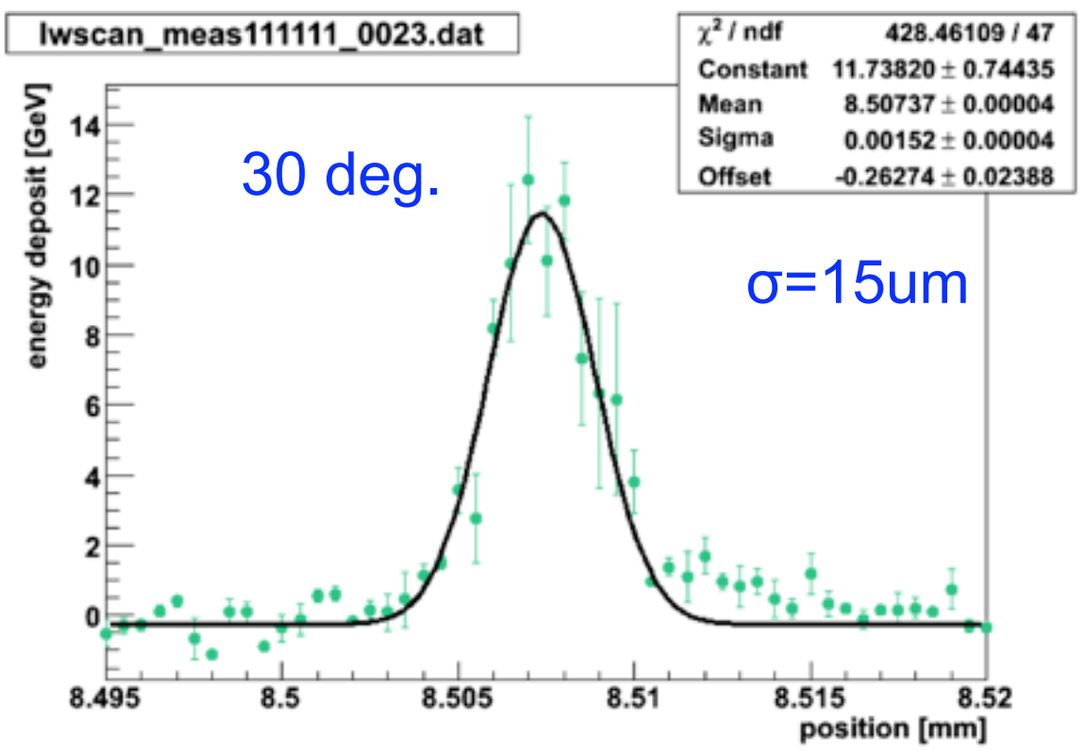


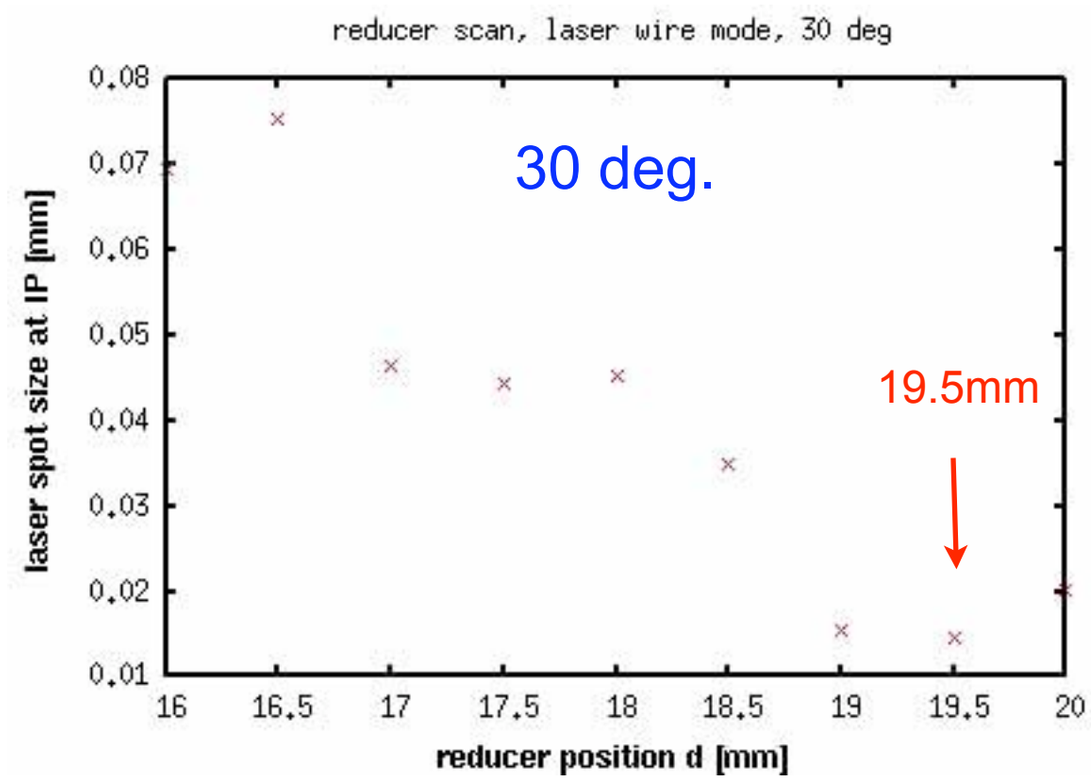
LW scan in 10-11 November 2011

with “nominal” optics and S/N = 5~6









Major issues

1. Commissioning of the 30 degree mode at IPBSM

   good collaborate between beam tuning and Tokyo groups

   signal, i.e. laser focus is a key issue done

   background control is a key issue done

2. Choice of optics, i.e. β^*_x =1 cm and β^*_y =0.1 mm

   background in IPBSM - 2nd collimator in the chamber, installed

   jitters of incoming beam monitored by BPM system with IPBPMs

3. Vertical emittance growth in EXT

   DR to EXT ?, e.g. monitoring the orbit and re-producibility

4. Large coupling correction needed at IP

   rotation of IPBSM fringes ? Alignment of optics system will be checked.

5. Effect of the Multipole components in the FF

   especially important for beam with σ^*_y < 100 nm

   mitigation by 2.5 times nominal horizontal beta function at IP

Conclusions

1. Brisk recovery works by end of June,2011
2. Prepared improved operation
   re-aligned all beam lines ; FF in 24-28 Oct. last of all
   stable timing and operation (already in Feb. 2011)
   understanding of multipole components
   full-commissioning of IPBSM etc.
3. Resumed the operation in 17 October, 2011
   checked out the instrumentations and
   tuning the DR at the first setout.
4. ATF2 will verify the ILC FF optics and demonstrate the nanometer stability at IP, which are important inputs to the TDR.