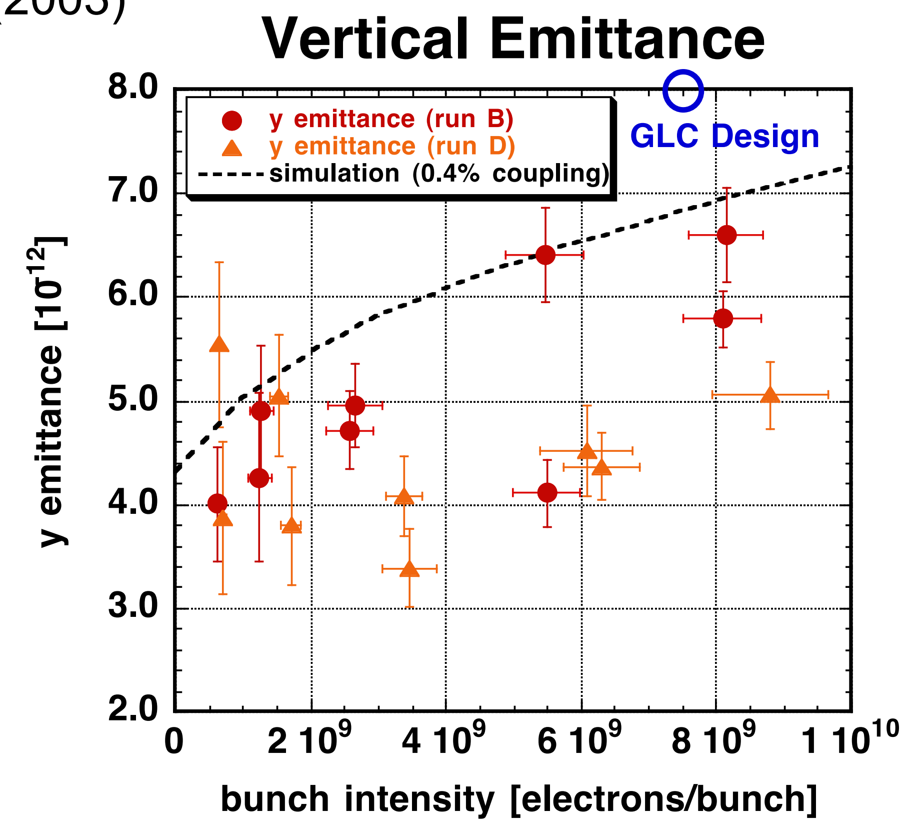
Emittance Growth in ATF EXT

A. Faus-Golfe (IFIC CSIC-UV), S.Kuroda(KEK)

1. Emittance history in ATF
2. mOTR monitor
3. Measured emittance in 2013
4. Summary

Emittance History in DR

- There were great efforts to achieve low vertical emittance since DR commissioning.
- From the end of 2000 to 2002, we observed very low vertical emittance in DR about 10 pm.
- After further improvement of hardware, with software and simulation works, we constantly achieved lower than 5 pm at low intensity (N →0), and lower than 8 pm at high intensity (N~1E10)., which was lower than “designed” emittance. (2003)



Emittance History in DR (2)

After this low emittance achievement

We have not really pursued lower emittance.

R&D of instrumentations were main tasks at ATF.

Emittance was as large as 20~30 pm (from 2006 ?) !!

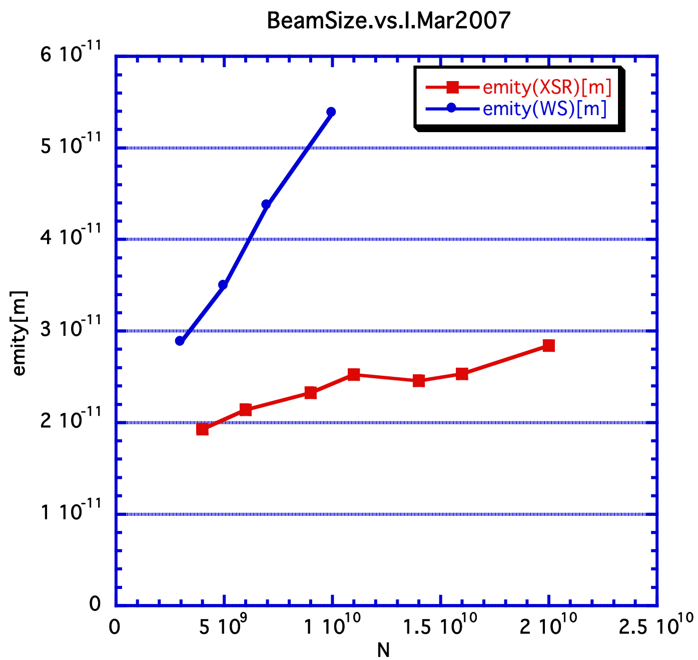
Why?

- No clear answer.

We have to make it small again

(smaller than before if possible)

- For ATF2



XSR meas. βx=1.69m 13Mar2007
WS meas. $\Delta p/p$=9e-4 15Mar2007

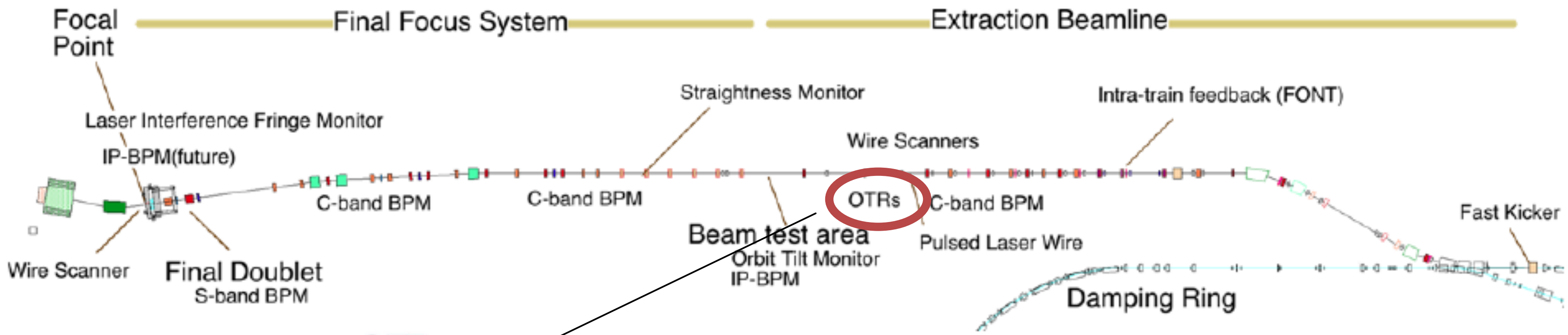
Here, EXT line was old, which was renewed with ATF2.
Emittance meas. was done by WSs.
Reason of the emittance growth was not clear. Non-linear field, wake, jitter,…?

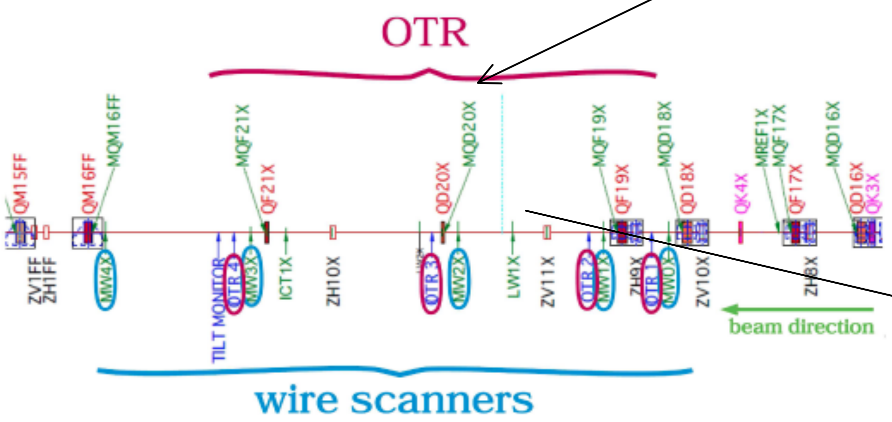
Recovery to Low Emittance in 2009

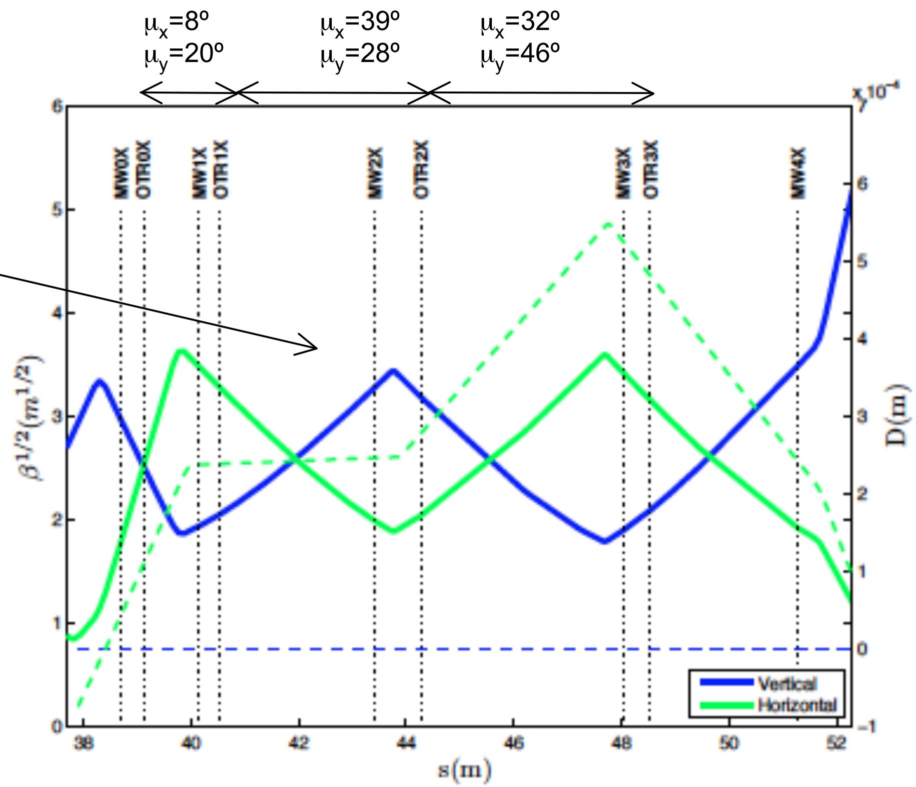
- Hardware issue
  - Re-alignment of magnets in DR
  - Introduction of electric load to correct DR main bend.
  - Beam size monitor improvement →following slides
- Start with 'design optics'
- Beam tuning method
  - β beat correction
    - Correction with QM18R.1&QM15R.2 trim.
  - Dispersion correction
    - η_x in straight section is corrected by QM trim
    - η_y is corrected by correctors
  - Coupling correction
    - Correction of vertical leakage of the horizontal kicks by a couple of horizontal correctors.
    - Correction is done by Skew Q winding trim coil of SX.

ATF2 Beam Line

Location and Optics







QM6R, which is common for DR and EXT, was replaced with big bore one in order to reduce non-linear field.

Introduction and Objectives

- The multi-OTR system is made of **4 OTRs** installed in the zero-dispersion part of ATF2 EXT line

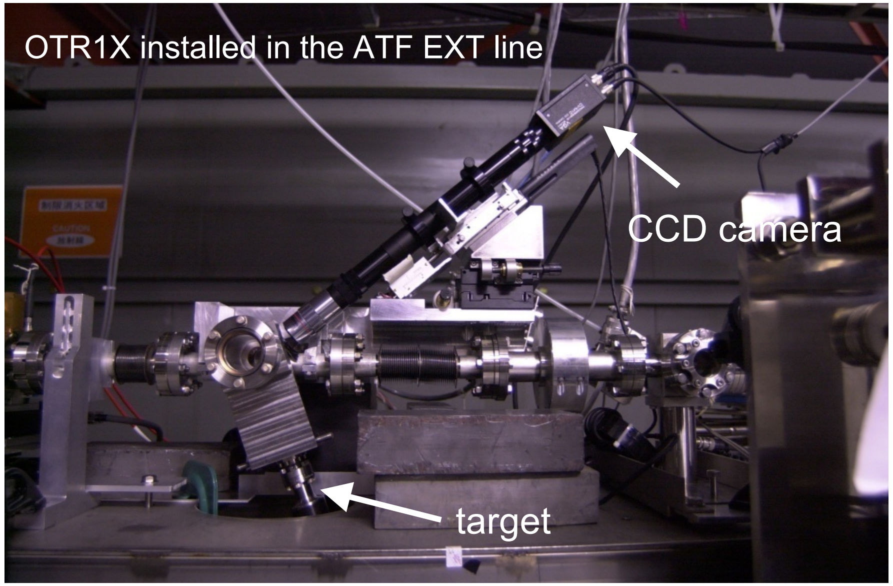
- The objective of this project is the **fast measurement of the emittance** (single shot for beam size, 1min for emittance) with:
  - high statistics
  - **2um** resolution
  - **$2x10^{10}$ single bunch** and **$2x10^{11}$** for **20 multi-bunched** beam (2.8 ns spacing)

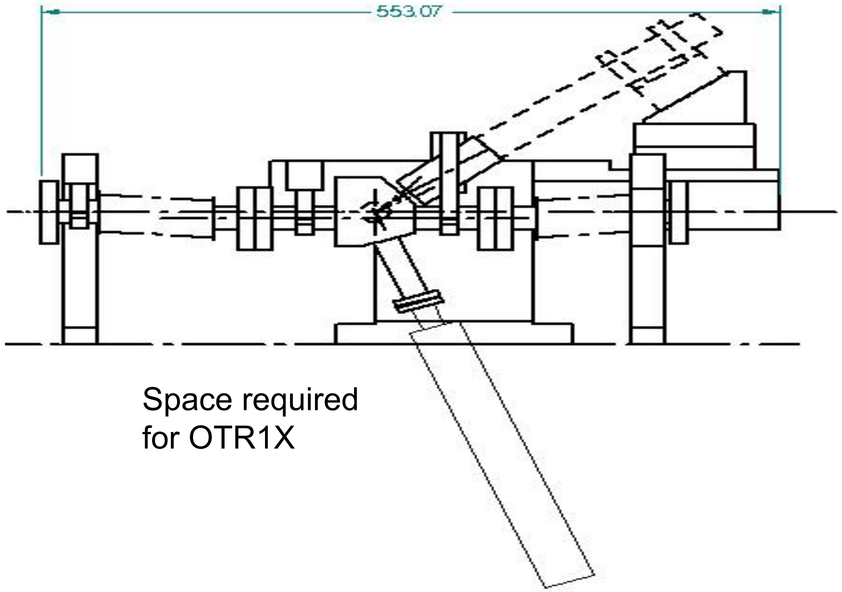
- The design is based on OTR1X at ATF EXT line (**5um resolution with $2x10^{10}$)** including improved features (compactness, calibration setup, demagnifier system..)

- The system **is installed near WS** for comparison and confirmation of OTR as a beam emittance diagnostic device

Technical Description HW I

The OTR1X

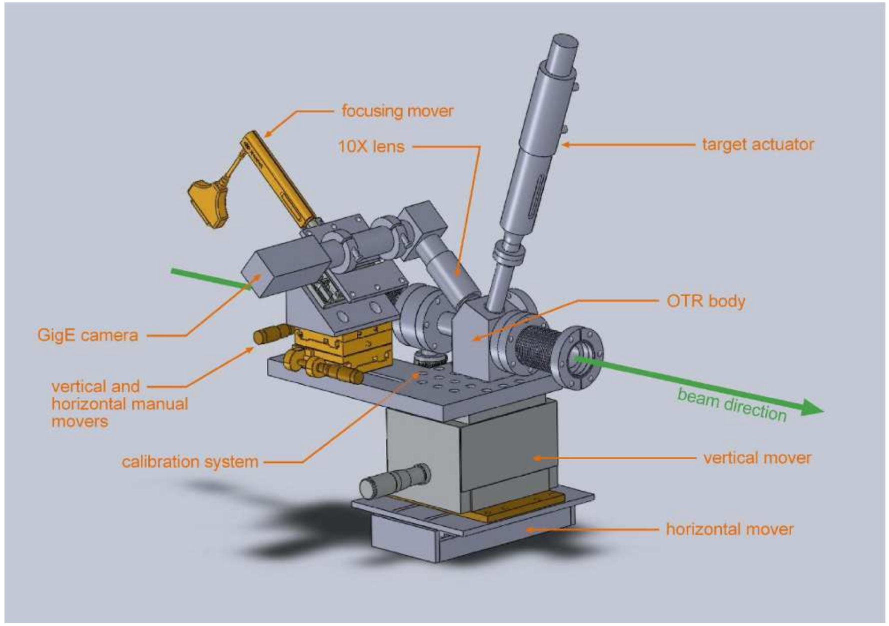




- The OTR1X was an **evolved design** rather than a **optimized one**. New parts were added to the existing OTR to add functionality, instead of making a new design. As a result the OTR1X was a patchwork of parts, taking up **a lot of beam line space**.
- The OTR **targets** were rather **thick**, about 0.5 mm of copper, beryllium or glassy carbon. This caused radiation darkening of the glass lens and camera damage.
- The camera **CCD** was **not parallel** to the **target**. This meant that the beam spot was in focus on only a small portion of the target. If the **beam moved**, the **image** had to be **refocused**.

Technical Description HW I

Fall 2009: First OTRs design



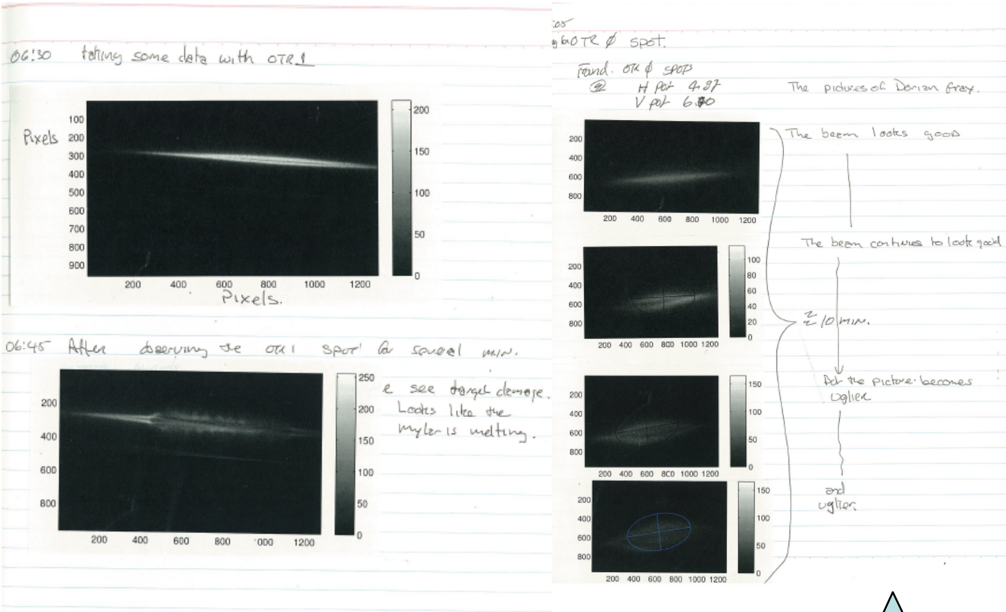
New OTRs have **same controls** and **motion capabilities** as OTR1X with the following improvements:

▪**Target actuator** relocated to the **top** (no interference with the girder) and smaller design, giving greater flexibility in the OTR placement
▪**Thinner target** that **reduces** lens **radiation** darkening

- The extreme **thinness** of the **aluminium target reduces** the **power deposition** in the aluminium and coupled to larger beam spot sizes should **eliminate target damage** problems.
- **CCD** camera "**parallel**" to **the target**. This puts the entire target into focus and **reduces** the need to **adjust focus** during normal operation giving greater depth of field.
- 12 bit **camera** for **more dynamic range** with **smaller pixel size** (3.75x3.75um) for more resolution (1280x960 pixels) with CCD sensor 1/3"
- **Calibration system** when there is no beam includes small lamp

Technical Description HW I

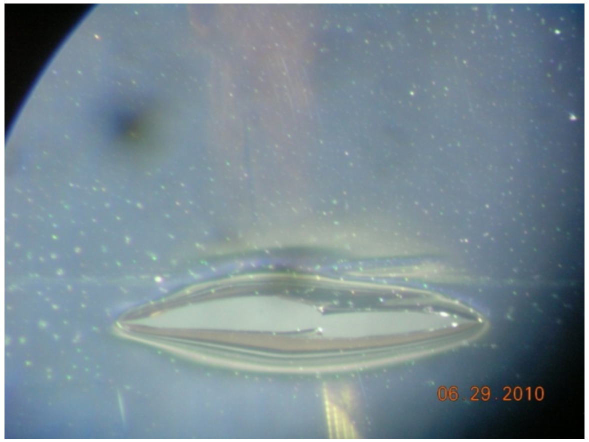
June 2010: Target test



- Exercise and **calibration** of vertical and horizontal **movers** and read-back **potentiometers**

- Tests of 4 OTRs during beam time: beam seen but 3 **targets** (nitrocellulose coated aluminum) were **damaged** ($4x10^9$ e^- per pulse)

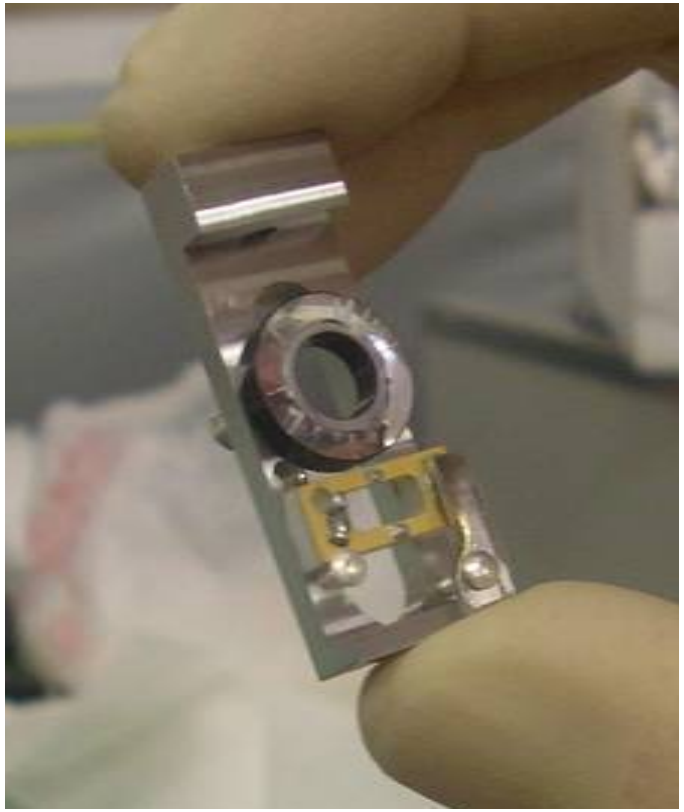
- CCD **Cameras** suffer from **radiation**, some pixel are dead



Damaged target

Technical Description HW I

November 2010: New targets installed and tested



New targets could **stand the beam currents** for several minutes without being damaged

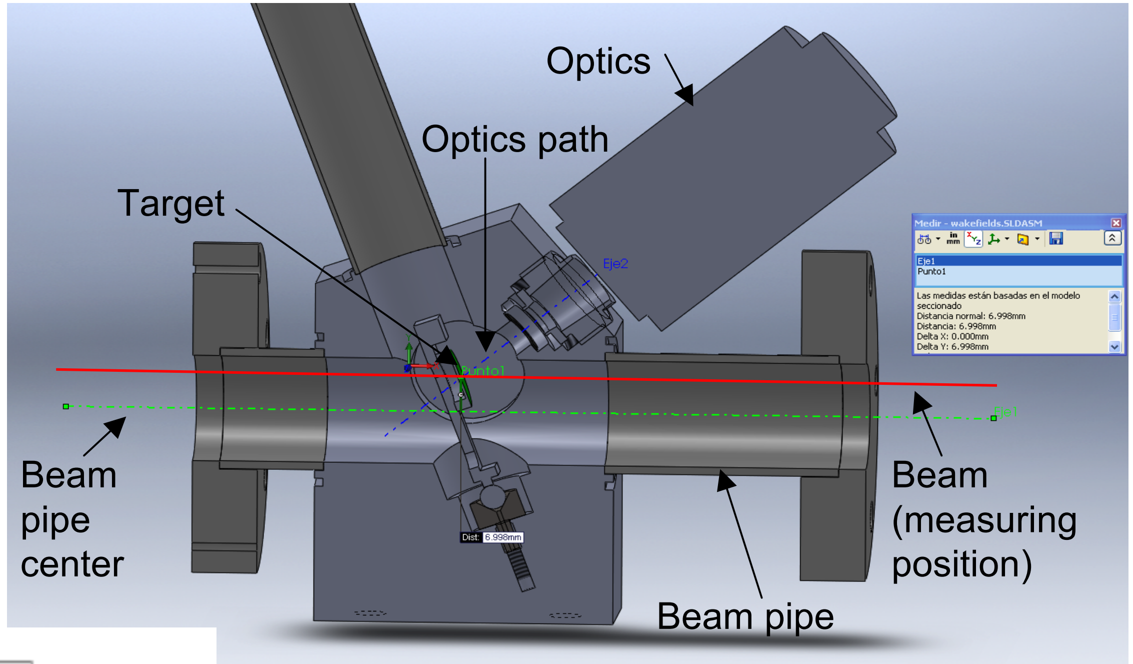
Two **new targets** were installed, two made with **aluminium** (2um) **and** two with **aluminized kapton** (3-5um with 1200 Amstrongs Al coating). Besides, together with all them, the **wire targets, made with 4** wire (10um tungsten), one horizontal, one vertical and two tilted were installed.

Technical Description HW III

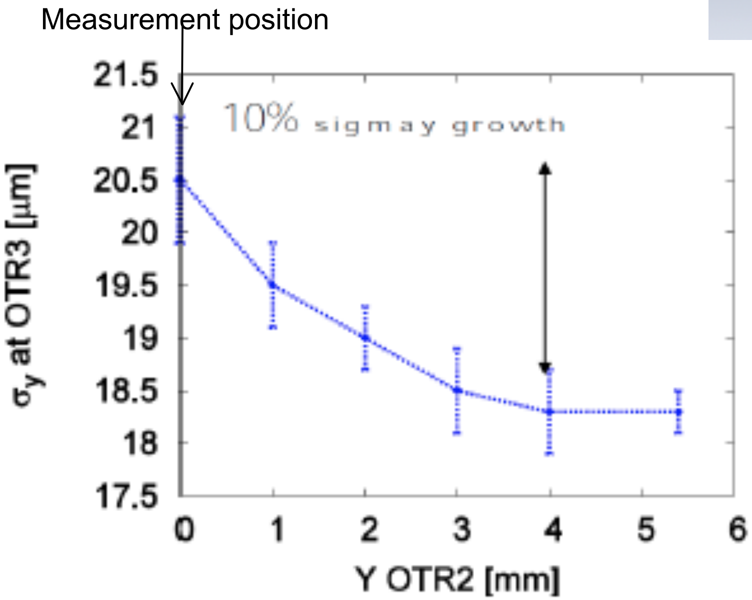
September 2012: Proposal of new Target holder and Optical system

When OTR is not measuring the beam is in the beam pipe centre.

For **measuring** the beam size the mOTR body is **lowered** about **7 mm** for intercepting the beam.



Current target position

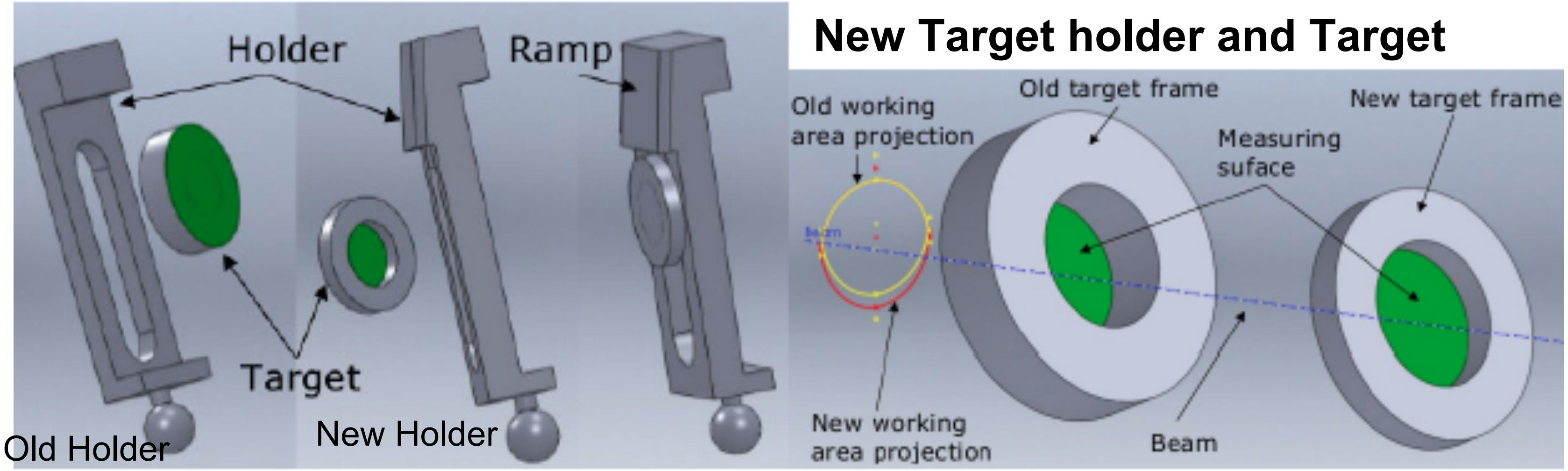


Wakefields are generated when lowering the **OTRs** for a **simultaneous measurement**

Technical Description HW III

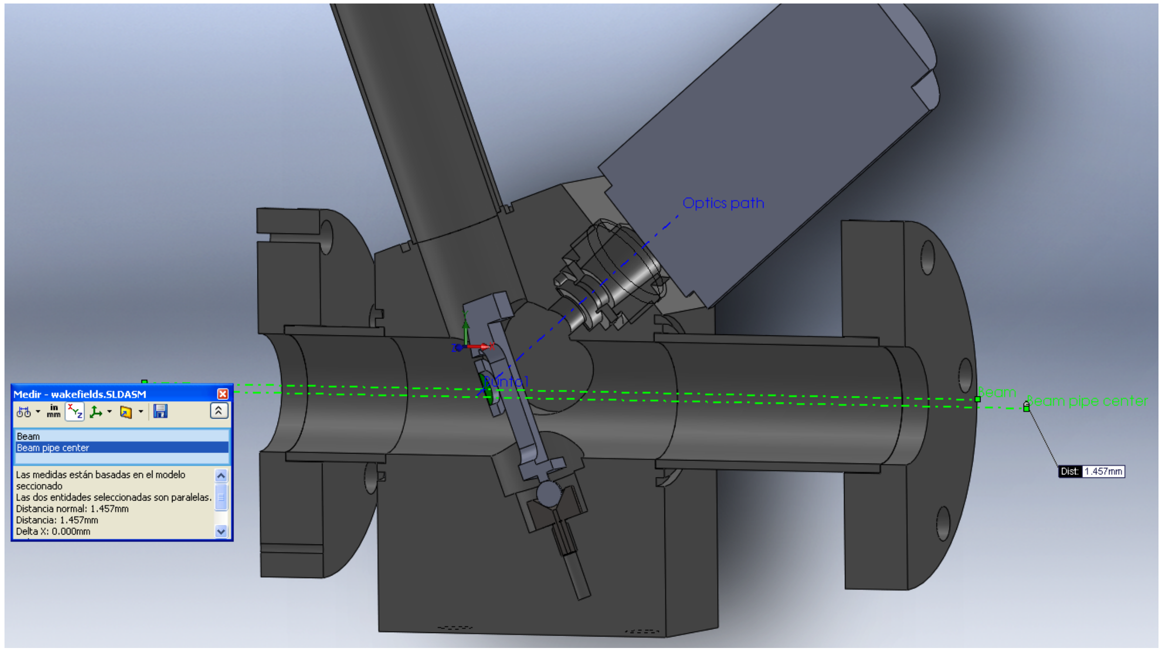
February-December 2012: Design and Construction of new Target holder and Optical system

New Target holder and Target



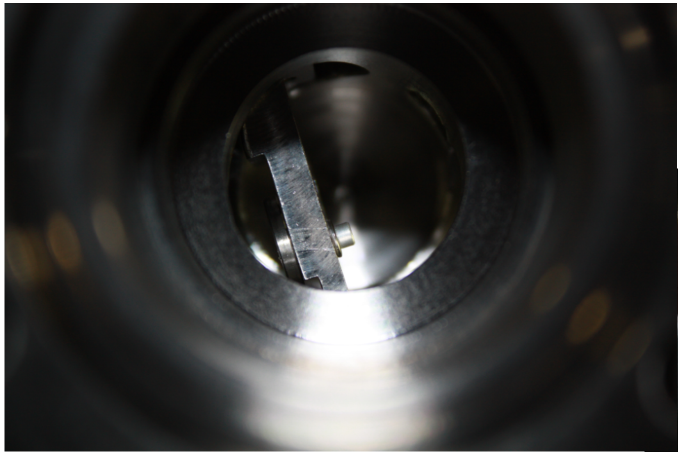
New target position

The required distance to be **lowered** for intercepting the beam is reduced from **7 mm** down to **1.5 mm**



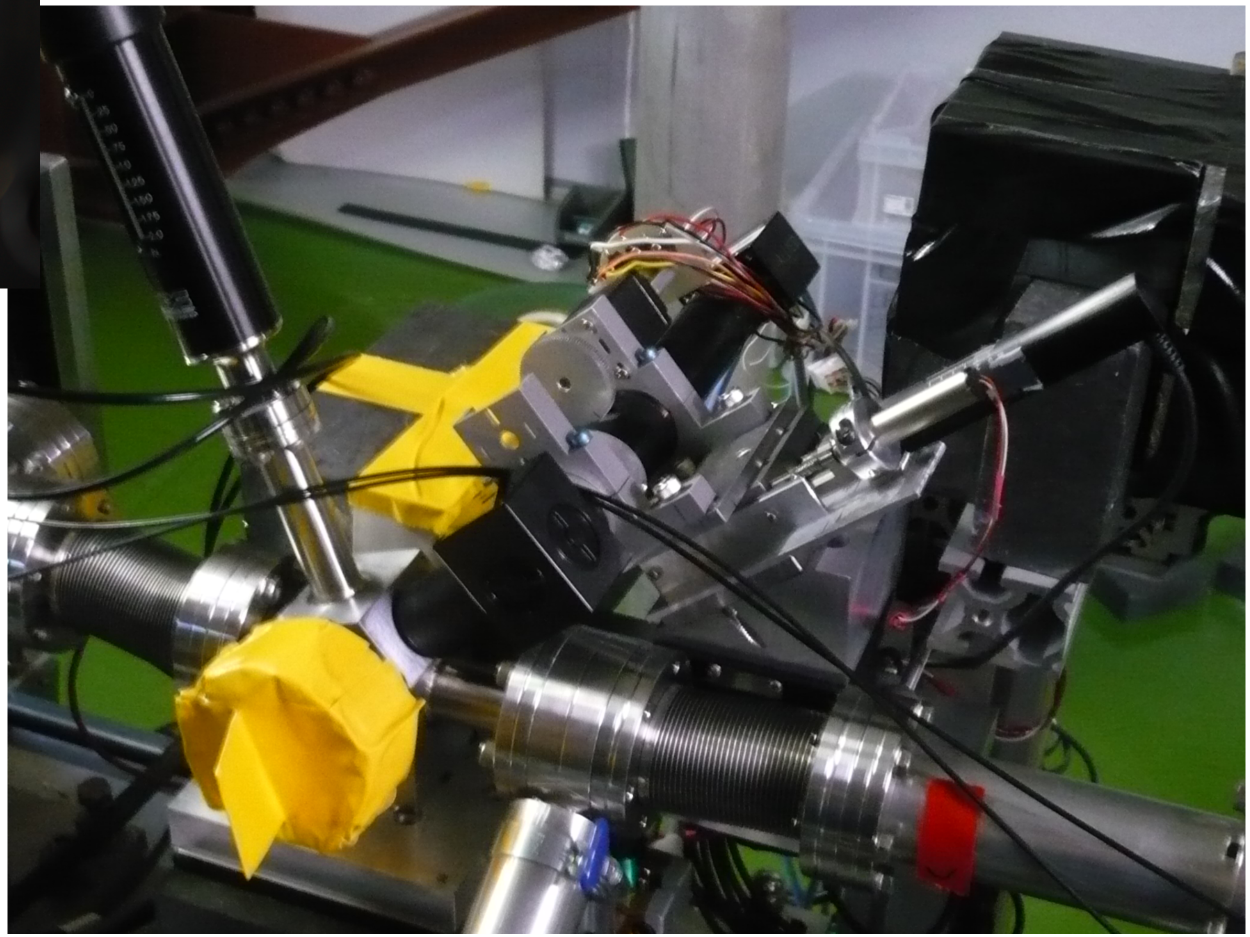
Technical Description HW III

February 2013: Installation of new Target holder and Optical system



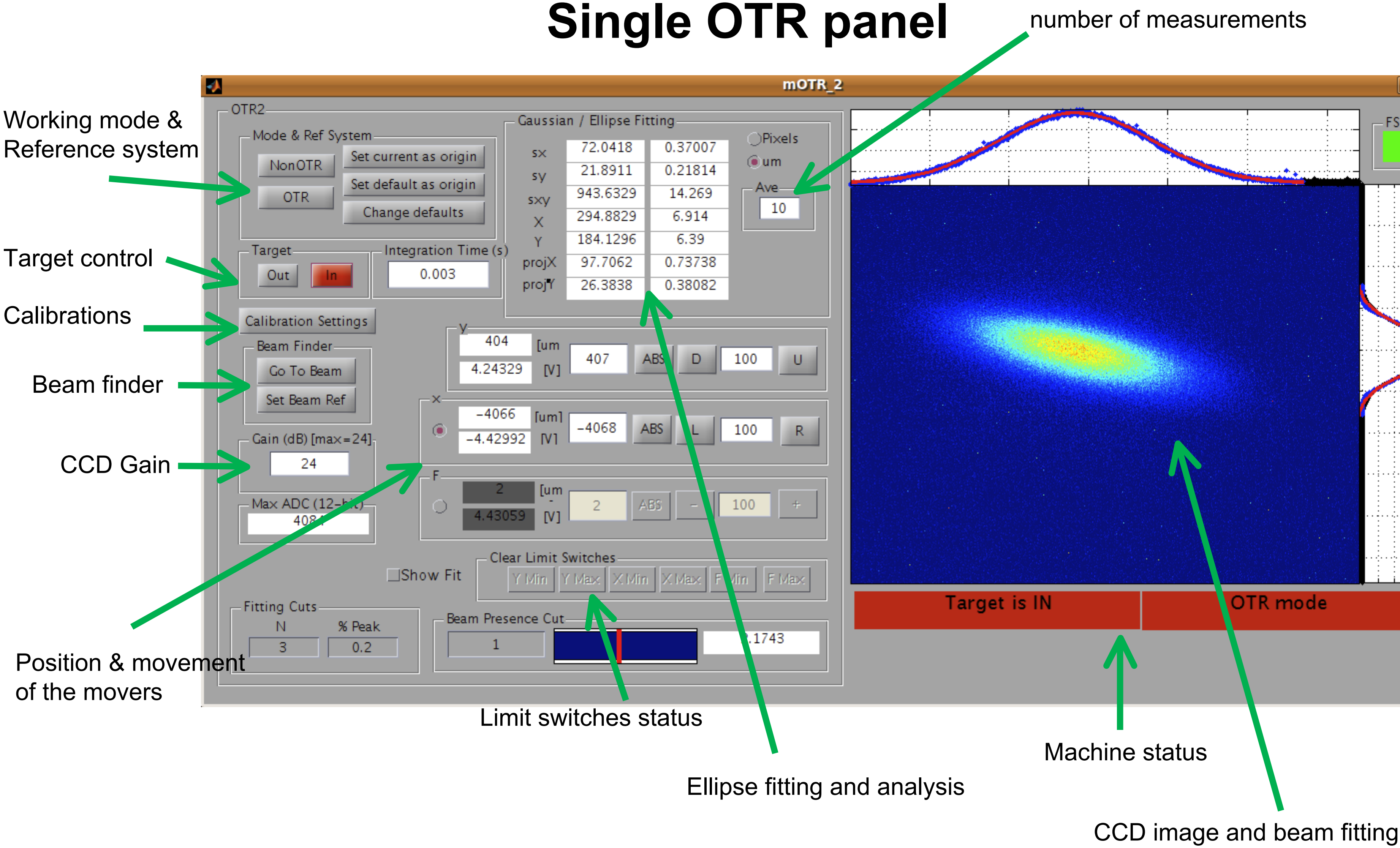
Long working distance target side view

OTR0 long working distance target external view

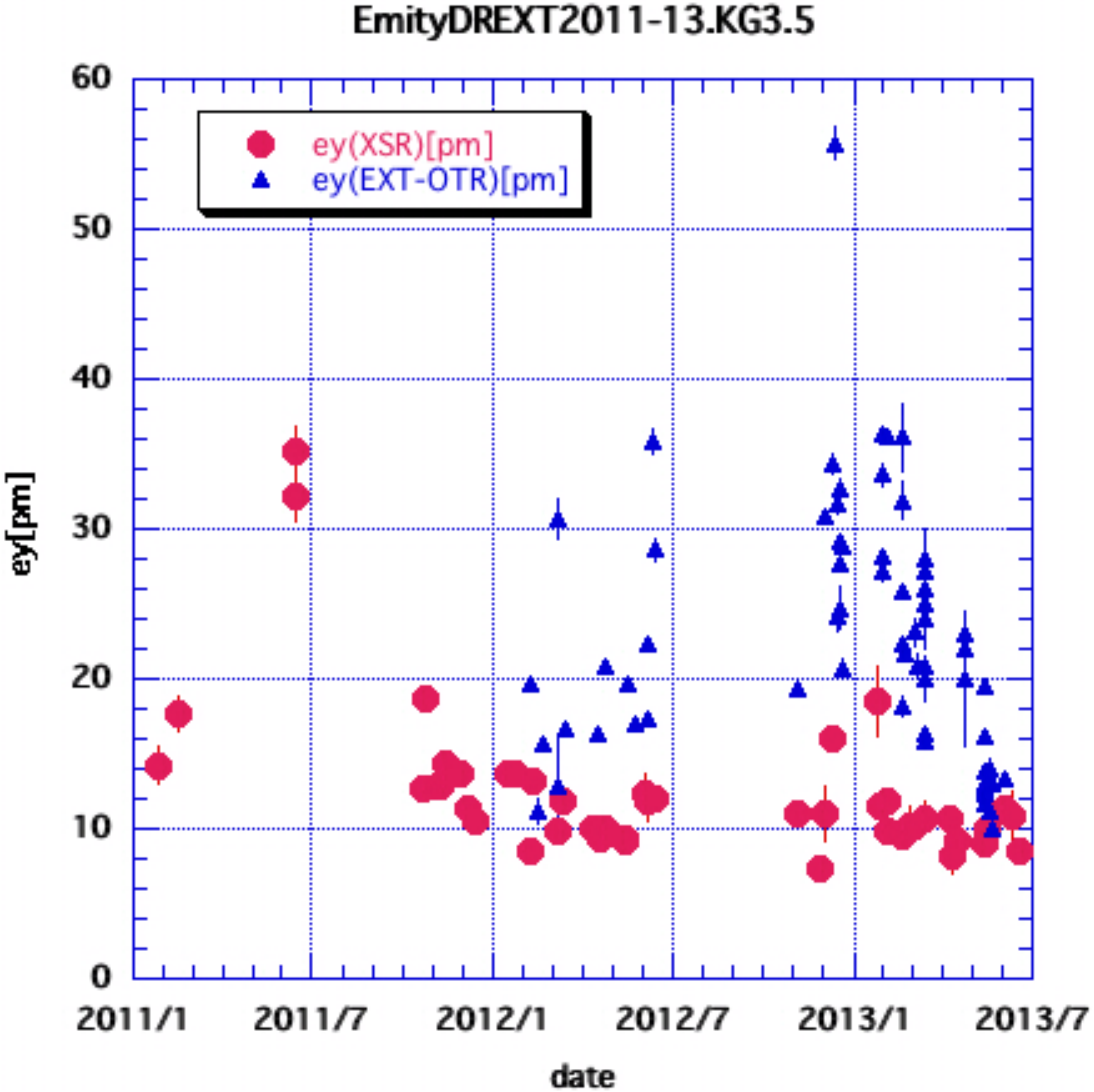


Installation of new target holders and optical system was made in **February 2013.**
Some test has been made after the installation and the system is working properly.

Single OTR panel



Summary of ε_y of ATF-DR 2011-2013



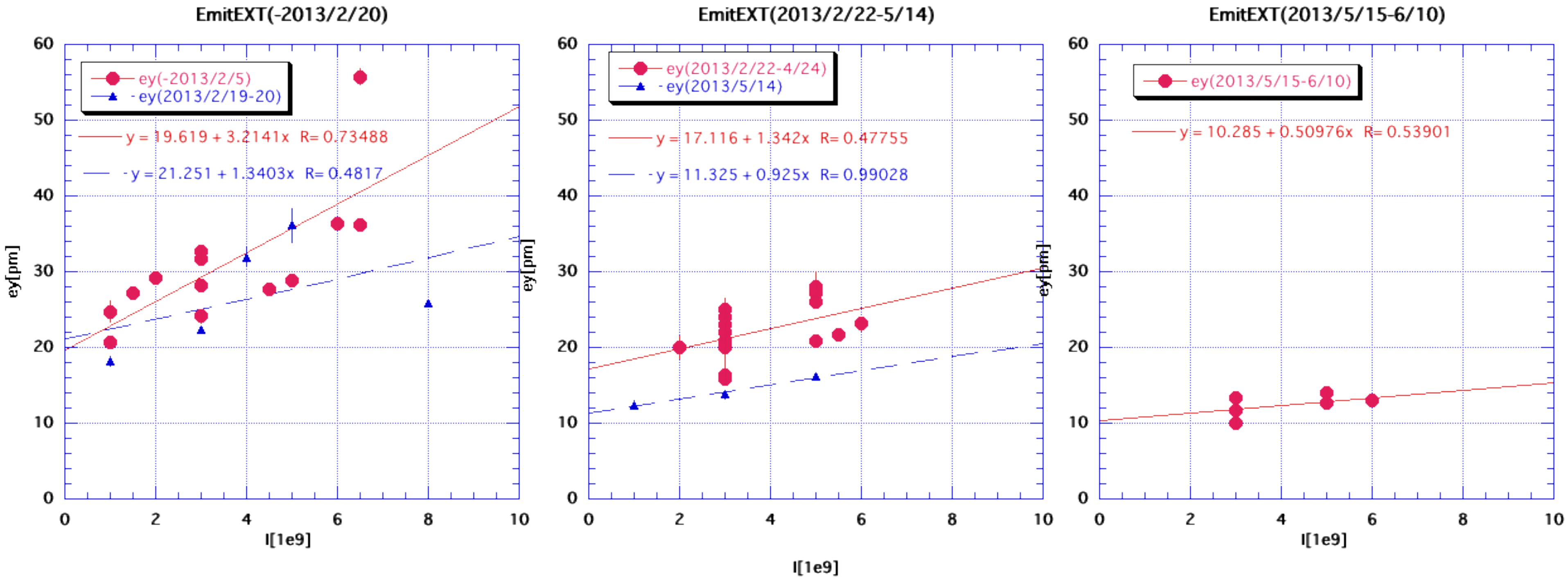
←$\varepsilon_y \approx$10pm

Works in ATF-EXT 2012-2013

Date	mOTR Monitor	Coupling Correction	General
		QK	
2012/Dec.			1.Remove possible wake sources[1)] 2.Ref.cav on mover for wake effect correction
-2013/Jan.	OTR3 not well-tuned		
2013/2/18		QS[2)]	
2013/2/20	New target system		
2013/5/9			Almost all bellows with shield
2013/5/15	OTR tuned[3)]	QS+QK	

1) http://atf.kek.jp/twiki/bin/view/ATFlogbook/Log20121212m
2) QS magnets are used independently, and QKs are set to 0.
3) Report by G.White in ATF operation meeting 2013/5/17

Summary of ε_y of ATF-EXT 2012-2013



- -2012/2/20 large ε_y and strong I dep.
- Monitor tuning and coupling correction made ε_y closer to DR one.

Summary

- Vertical emittance in ATFEXT is measured by mOTR monitor, which has been operated successfully with improvements.
- Many efforts has been done for small EXT emittance. There are still things to be studied. But the measured EXT emittance in June 2013 became very close to the DR emittance.

Back-up

Emittance Tuning in DR

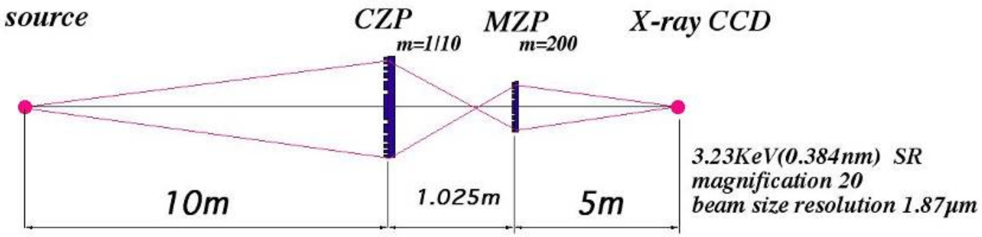
- Usually done just after the start-up

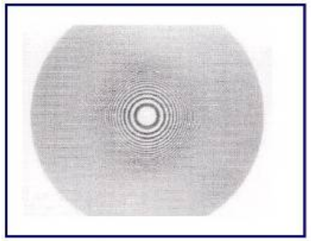
- Routine emittance tuning
  - Dispersion correction
    - η_x in straight section is corrected by QM trim
    - η_y is corrected by correctors
  - Coupling correction
    - Correction of vertical leakage of the horizontal kicks by a couple of horizontal correctors.
    - Correction is done by Skew Q winding trim coil of SX.

- DR study in June:Beta beat correction
  - -->Repot by Y.Renier

XSR Beam Size Monitor

X-ray SR monitor using zone plate (Tokyo Univ.)

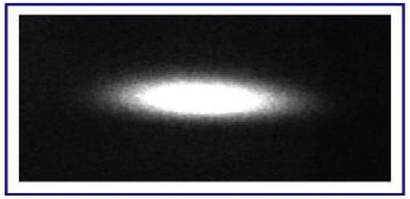




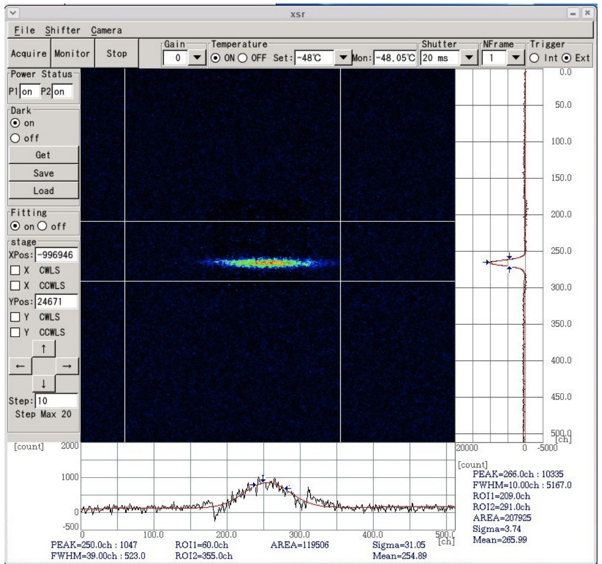
microscope image of zone plate

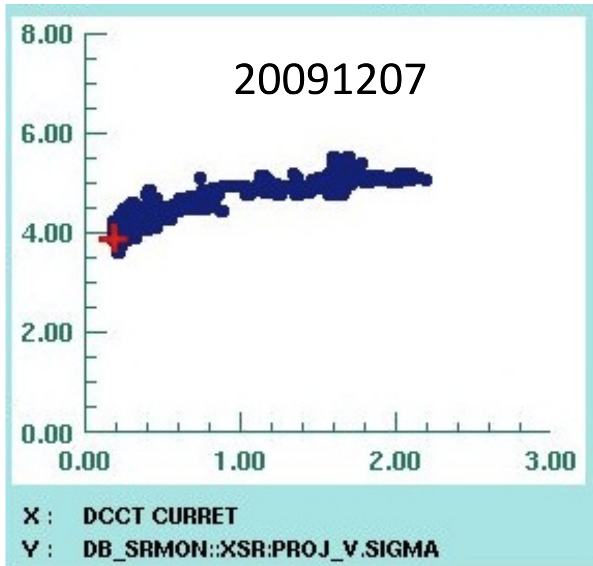
CZP : 3mm dia.
6497 zone rings
minimum zone width 108nm

MZP : 75μm dia.
584 zone rings
minimum zone width 127nm



Beam image (x:46.2, y:10.2μm)





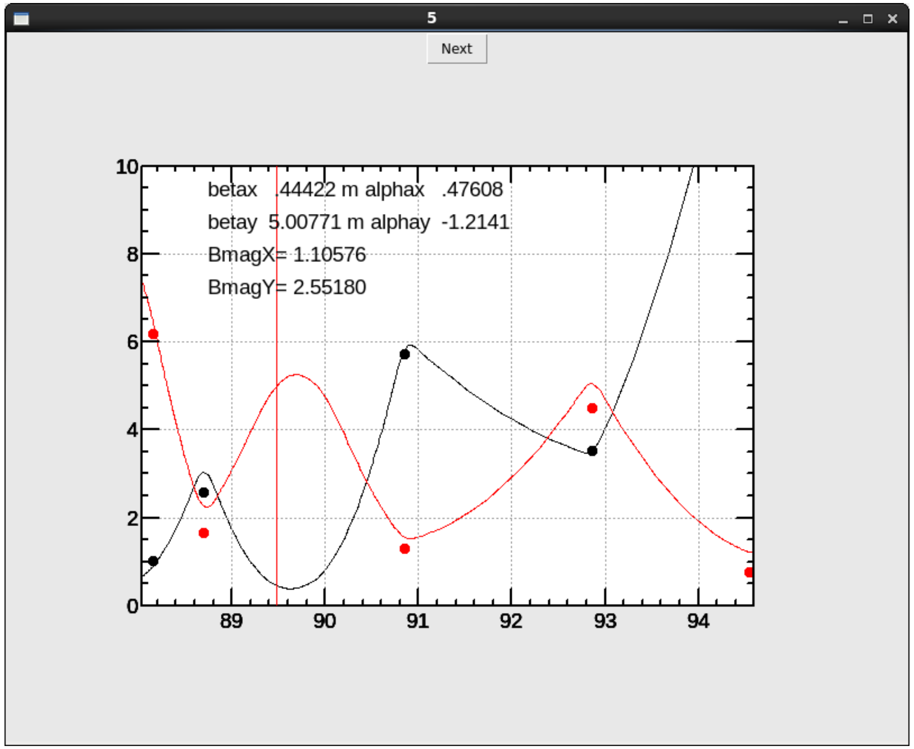
Beta Measurement

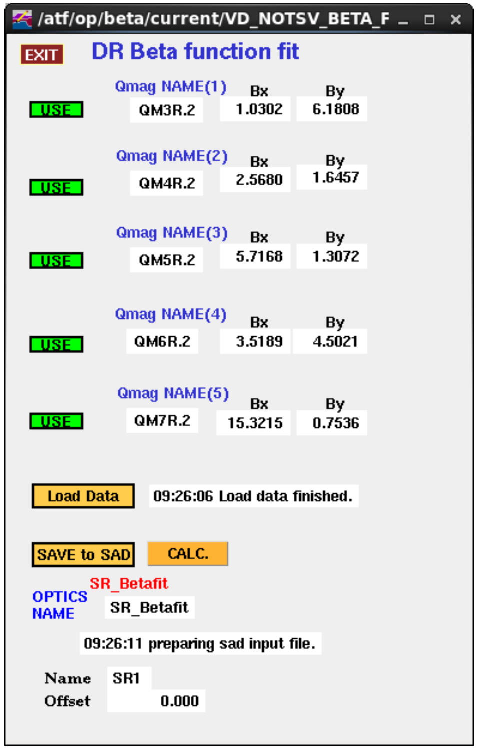
- Emittance is calculated by the formula;

$$\sigma_y^2=\beta_y\ \varepsilon_y$$

β is calculated by fitting the β s at near Qs, which are measured by tune slope.

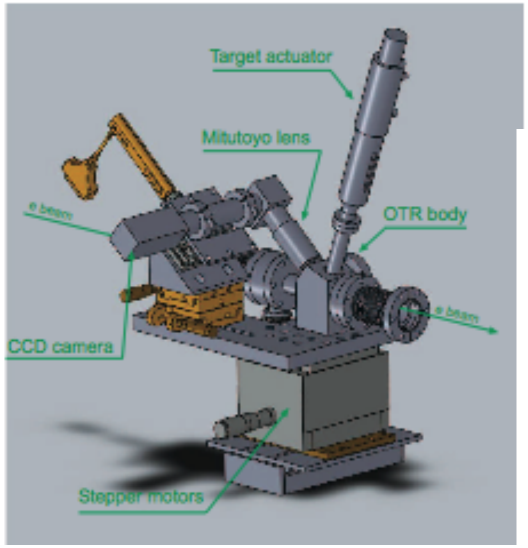
ex.)->

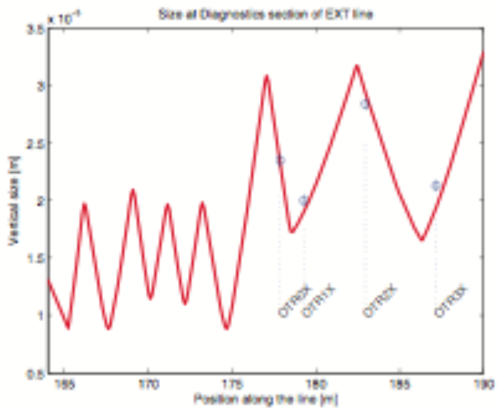


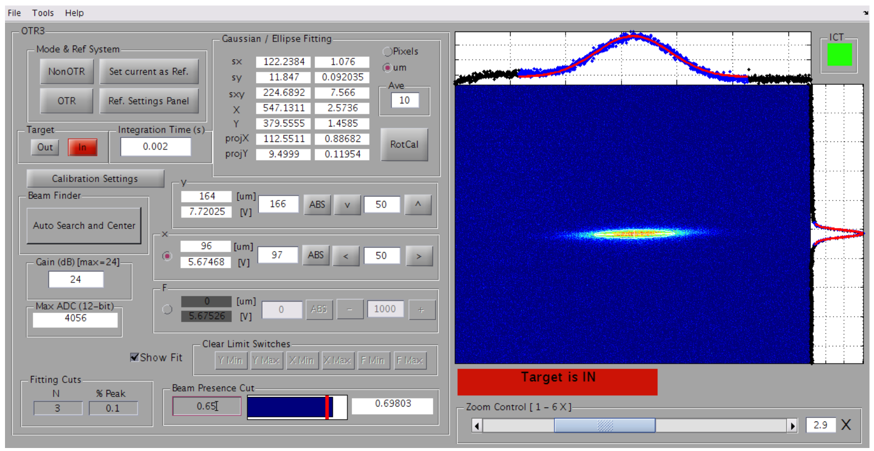


Emittance Tuning in EXT

- Dispersion correction
  - η_x is corrected by QF1X & QF6X
  - η_y is corrected by QS sum knob
- Coupling correction
  - QK or QS+orbit bump or both
- Emittance measurement by mOTR







November 2011/December 2012: Systematic Measurements II

Comparison between **OTR** and **WS** measurements made on Dec. 14th 2011