Multi-OTR System for ATF2

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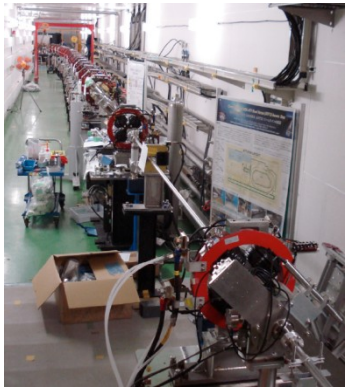
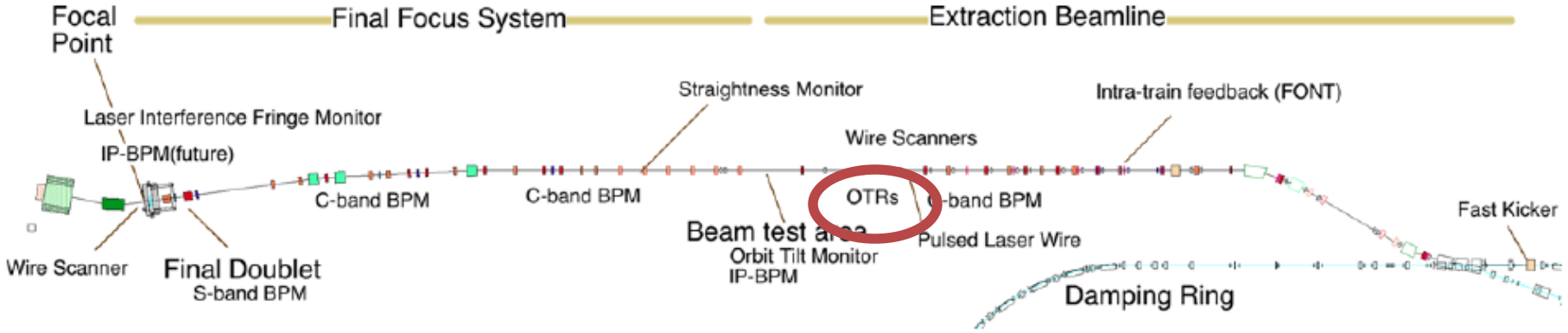
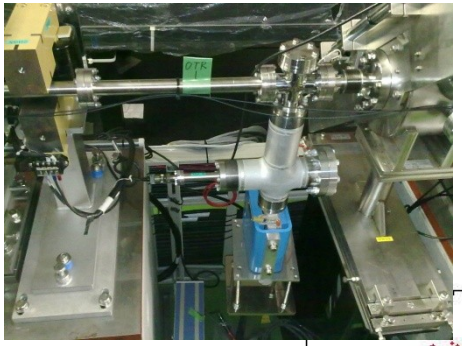
ATF/ATF2 Overview

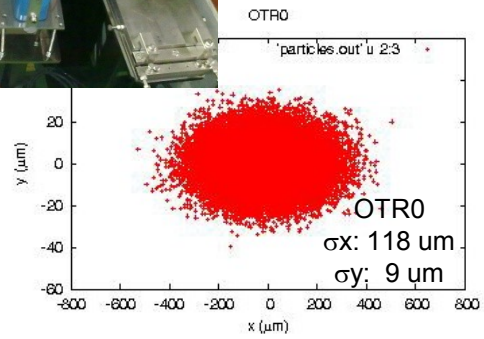
The Accelerator Test Facility (**ATF**) was built in KEK (Japan) to create small emittance beams.
The Damping Ring (DR) of ATF has a world record of the normalized emittance of 3×10^{-8} m rad.
ATF2 is built to study the feasibility of focusing the beam into a nanometer spot in a future linear collider (σy=37nm with nm level stability).



Multi-OTR System Overview







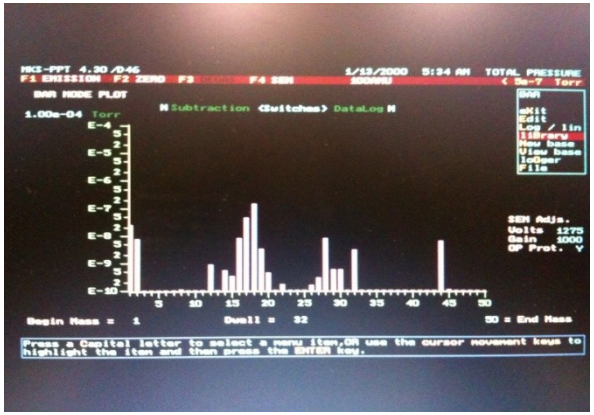
- The multi-OTR system is made of **4 OTRs** installed in the zero-dispersion part of EXT line
- **Fast emittance measurements** (single shot for beam size, 1min for emittance) with high statistics with **2um resolution** with **$2x10^{10}$ single bunch** and **$2x10^{11}$multibunch**
- Design based on existing OTR1X (**5um resolution with $2x10^{10}$)** with improved features (compactness, calibration setup and demagnifier system)
- **Installed near WS** for comparison and confirmation of OTR as a beam emittance diagnostic device

Multi-OTR System February 2010: Hardware Tests

Assembling and **first tests** at SLAC and IFIC labs after fabrication

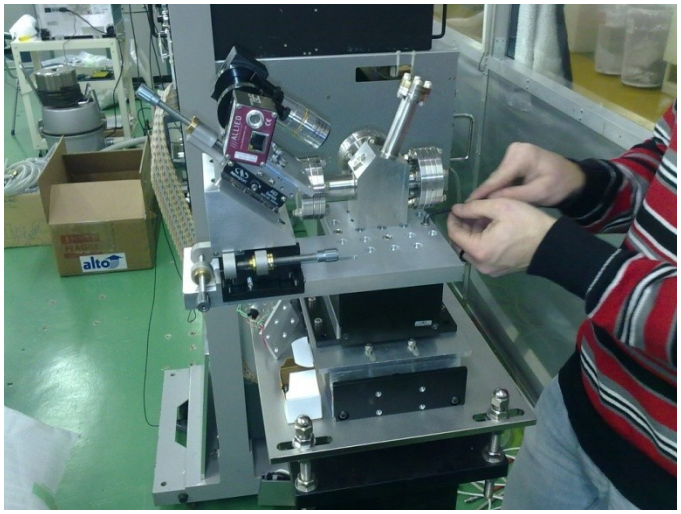
Vacuum test made at SLAC

without OTR

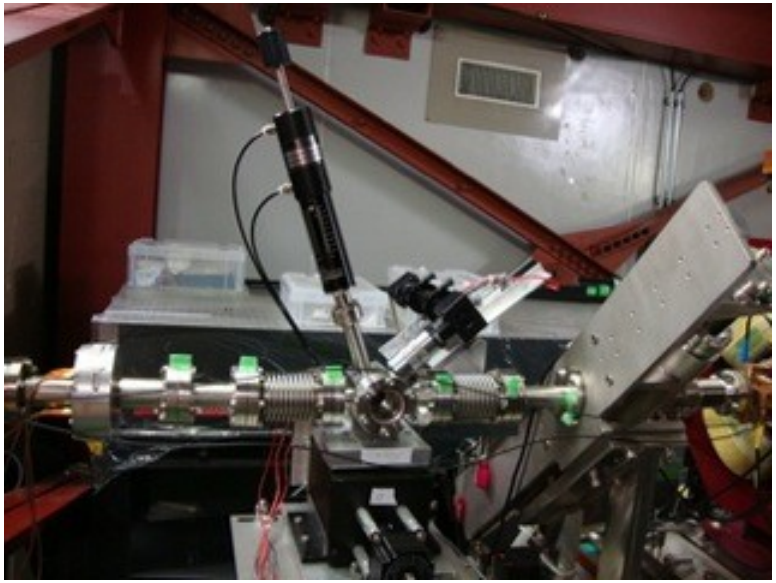


with OTR

Multi-OTR System April / May 2010: Hardware Installation

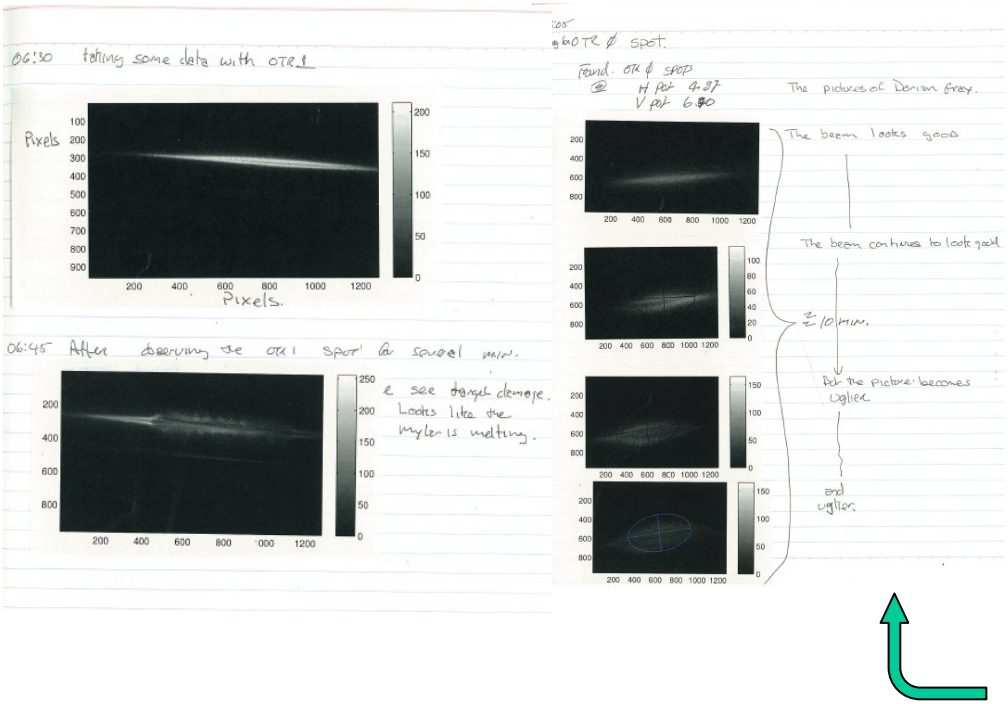


April: All **4 OTRs were assembled** at ATF clean room



May: All **4 OTRs installed** in the EXT line

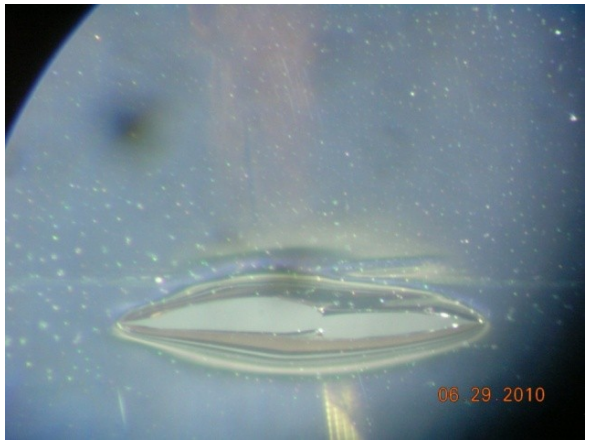
Multi-OTR System June 2010: First Measurements



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

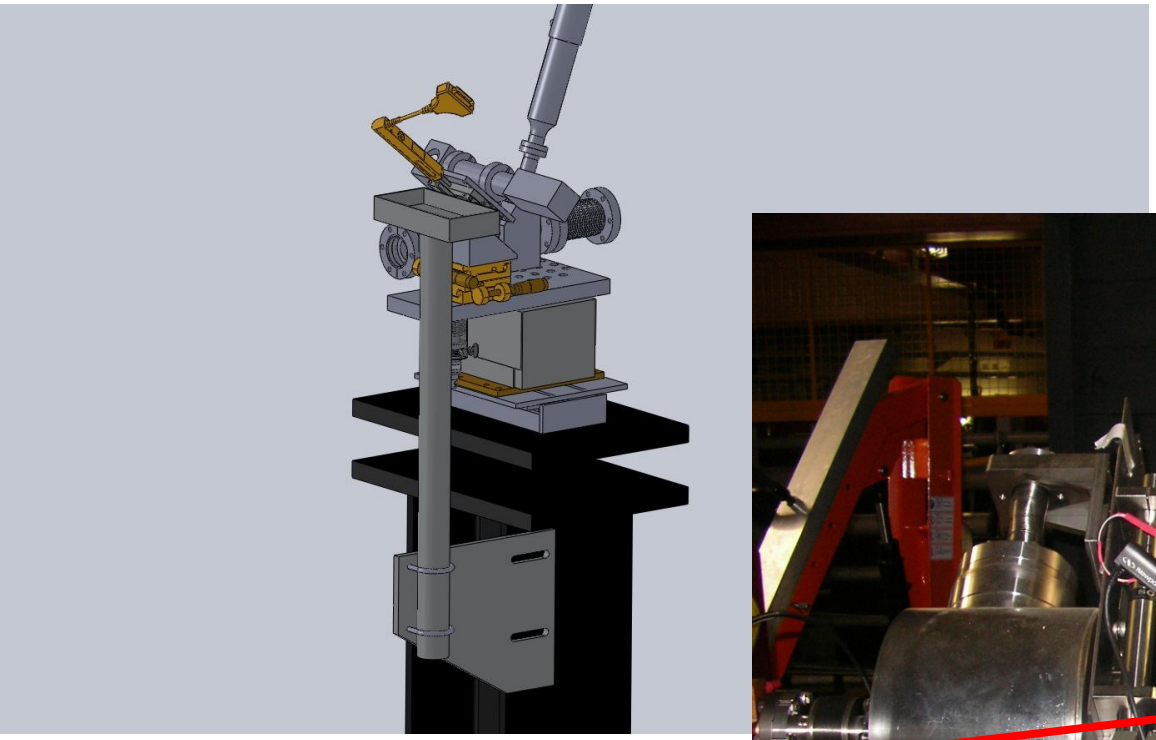
- Tests of 4 OTRs during beam time: beam seen but 3 **targets** (nitrocellulose coated aluminum)**were damaged** (4×10^9 e^- per pulse)

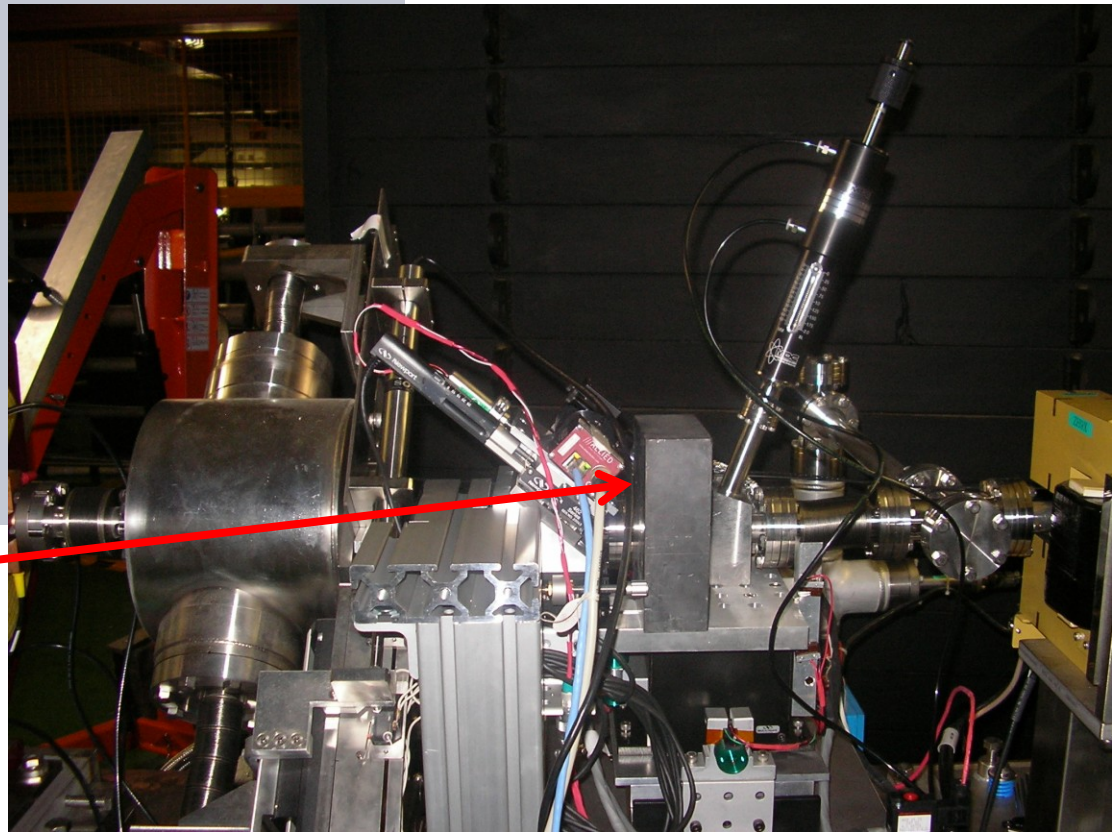
- CCD **Cameras** suffer from **radiation**, some pixel are dead.



Damaged target

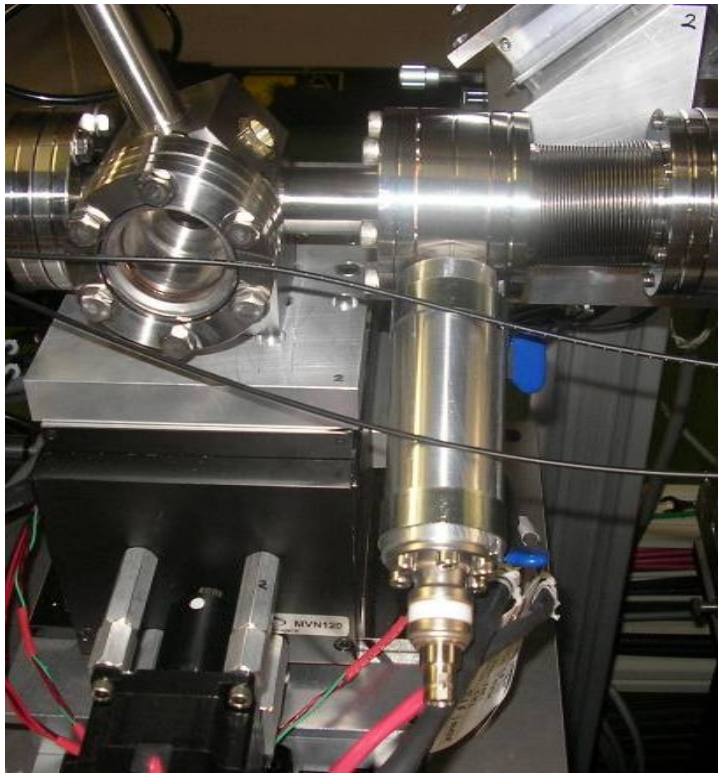
Multi-OTR System November 2010: Installation of cameras protection



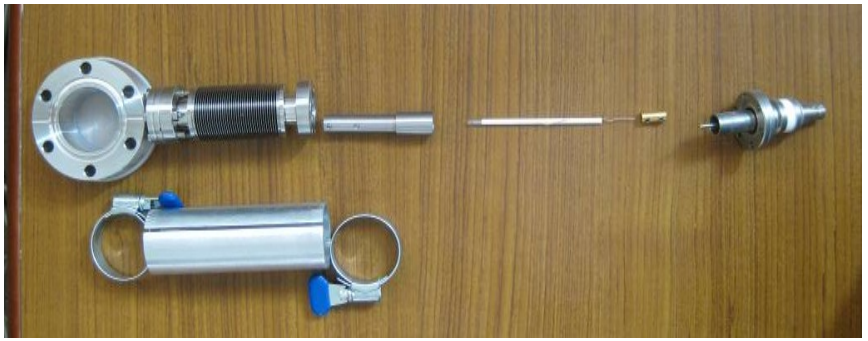


Lead blocks with a special holding support has been added to protect cameras from the radiation

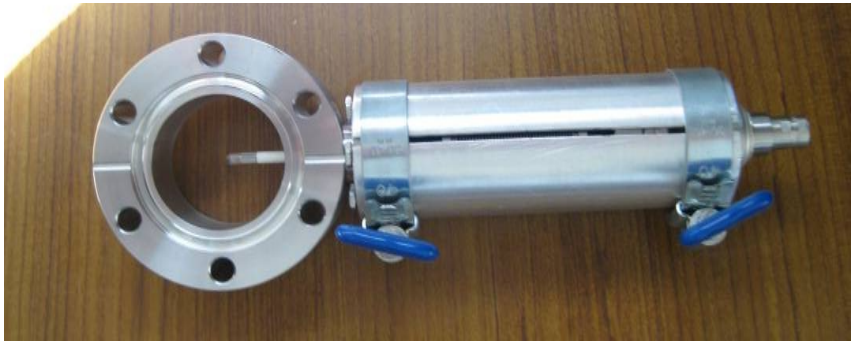
Multi-OTR System November 2010: Installation of calibration setup



Illuminators were **installed** to facilitate calibrating tasks by **lighting** the **target** from the **beam direction**

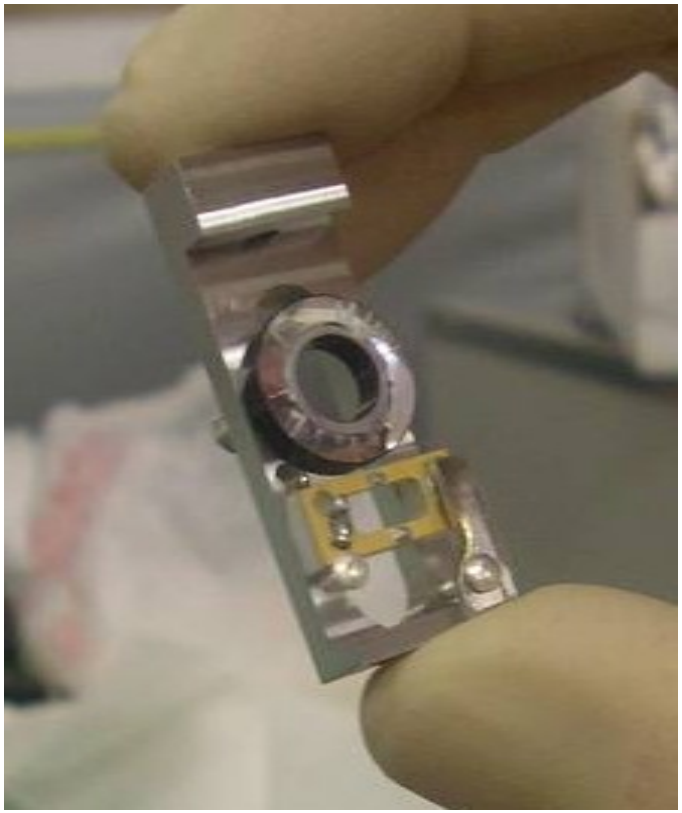


BNC feedthrough, copper connector, ceramic tube with bulb, stainless steel tube (ceramic tube holder), bellow and flange with port.



Aluminium tube and clamp to hold the bellow

Multi-OTR System November 2010: New targets installed and tested

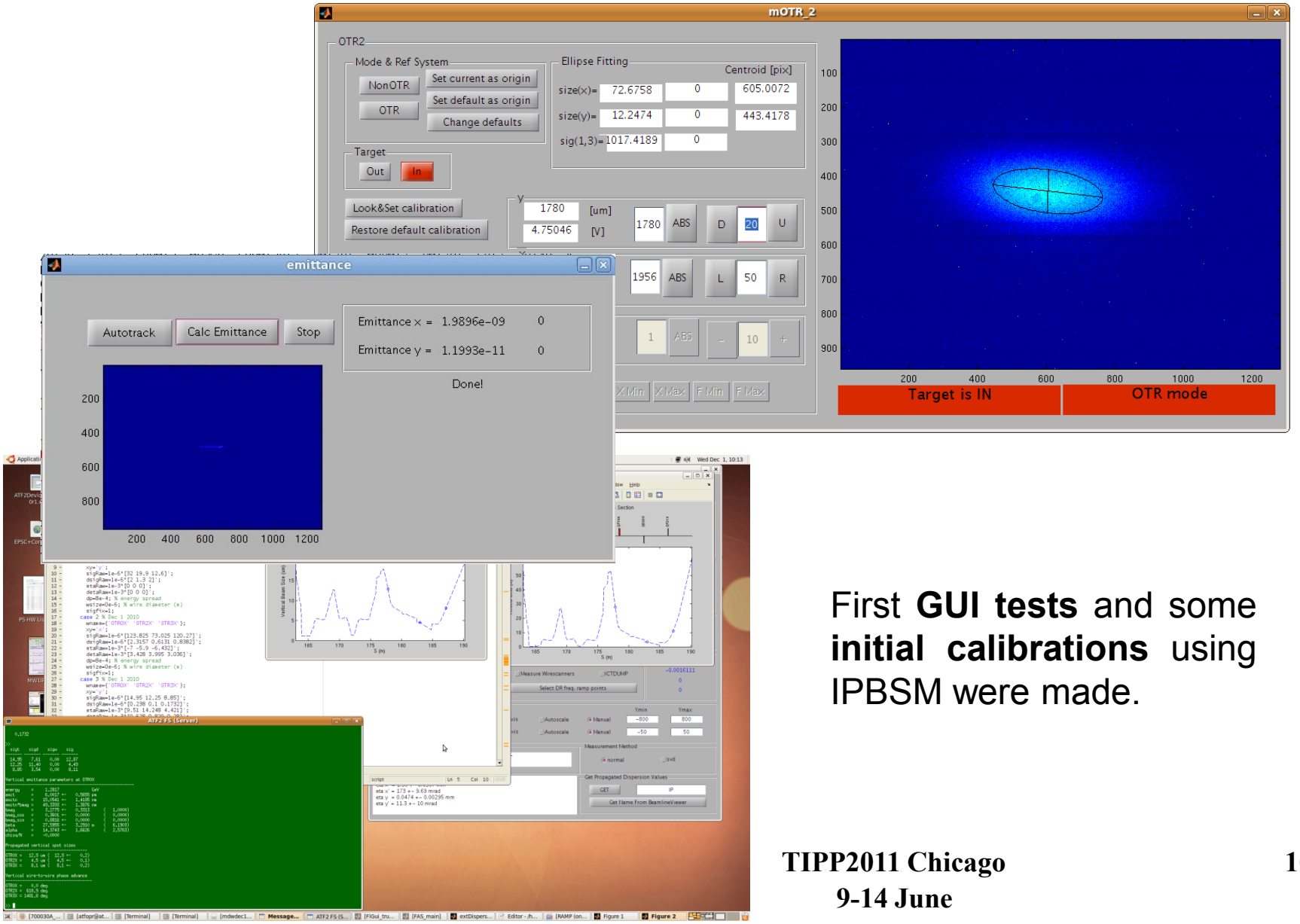


New targets could **stand the beam currents** for several minutes without being damaged

Two **new targets** were installed, two made with **aluminium and** two with **aluminized kapton**. Besides, together with all them were installed the **wire targets, made with 4 wire**, one horizontal, one vertical and two tilted.

Multi-OTR System

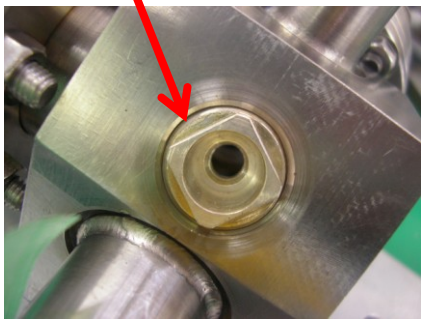
November 2010: First calibration of vertical scale and first software test

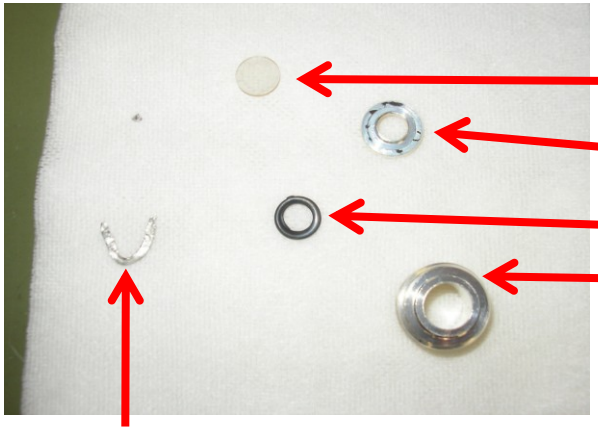


First **GUI tests** and some **initial calibrations** using IPBSM were made.

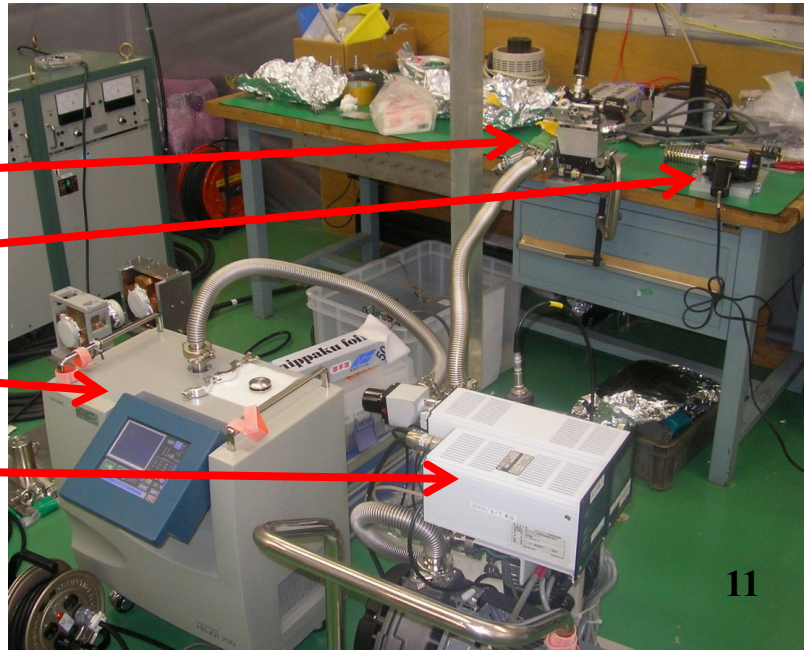
Multi-OTR System December 2010: Vacuum leak repaired

Leak in the camera window





Important **vacuum leak** in the camera window of OTR2 was **repaired** by changing the indium washer

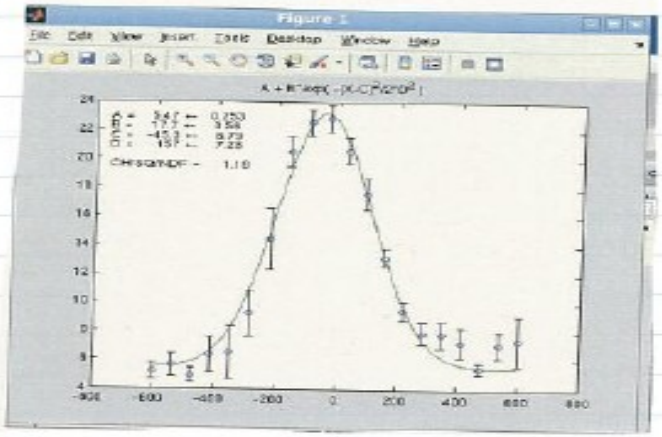


Multi-OTR System

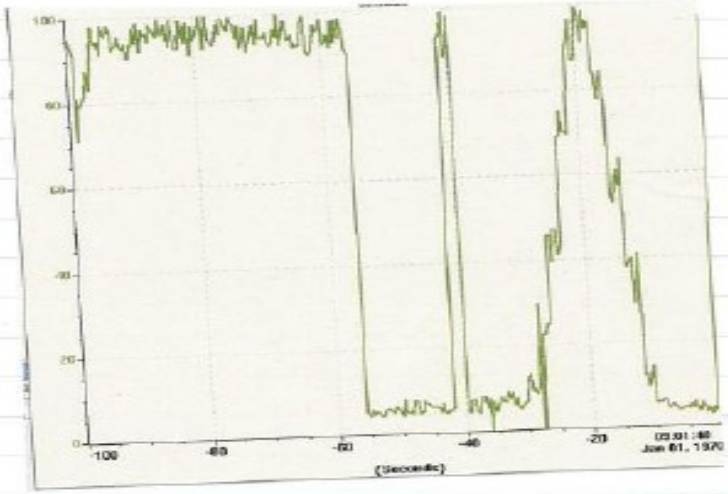
December 2010: OTR Wire Scans

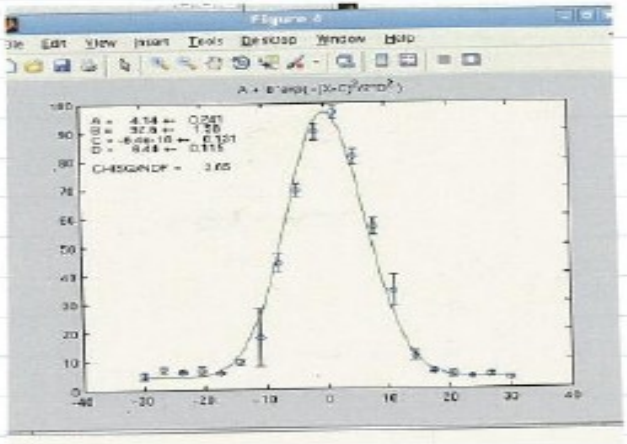
X wire scan from OTR3

σ = 157 ± 7 μm



Y wire scan from OTR3
BSM signal



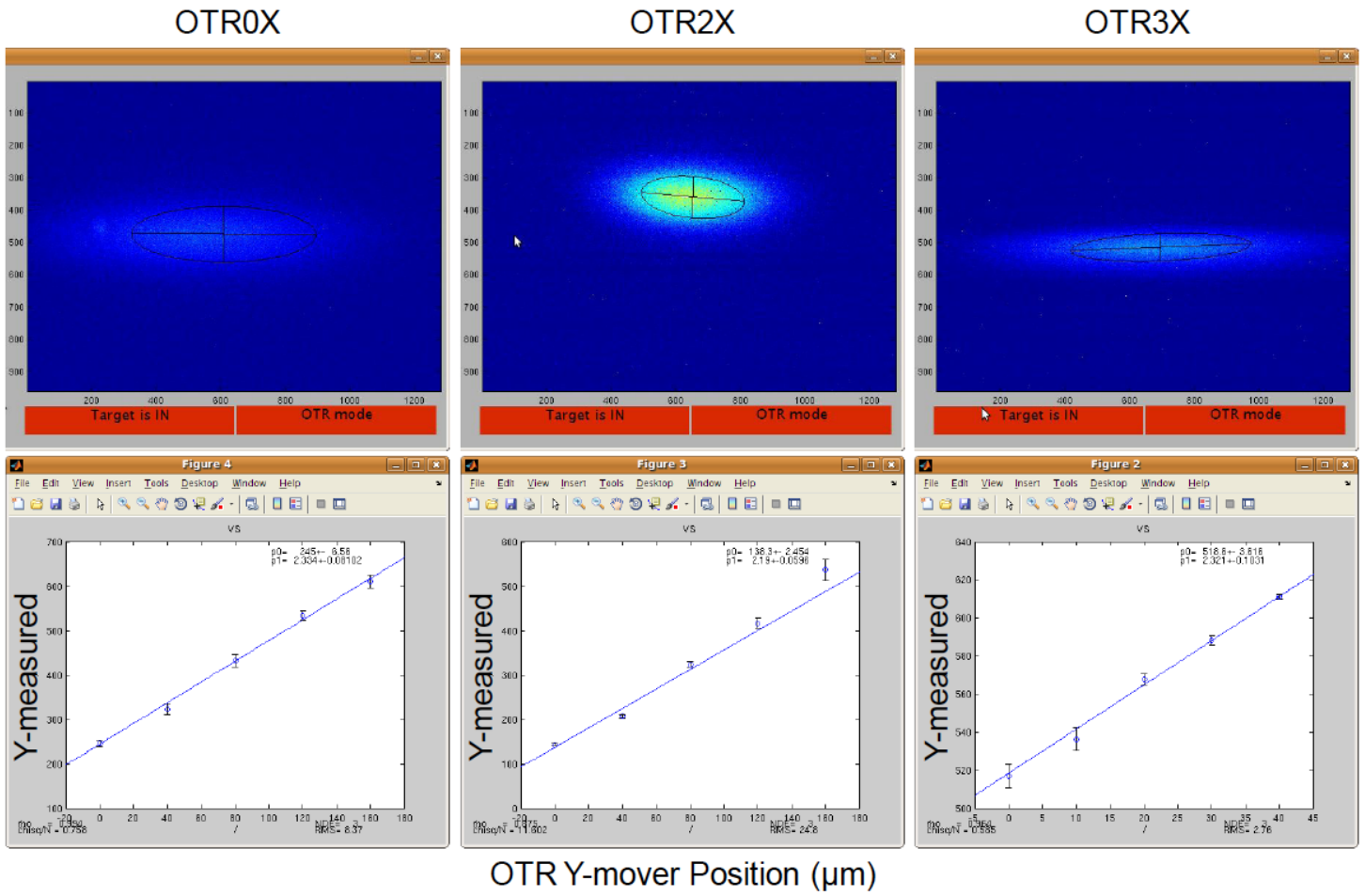


Scan wires versus signal from **IPBSM background** detector.

Made to cross check wire scans with observed beam sizes. Numbers agree within fit errors.

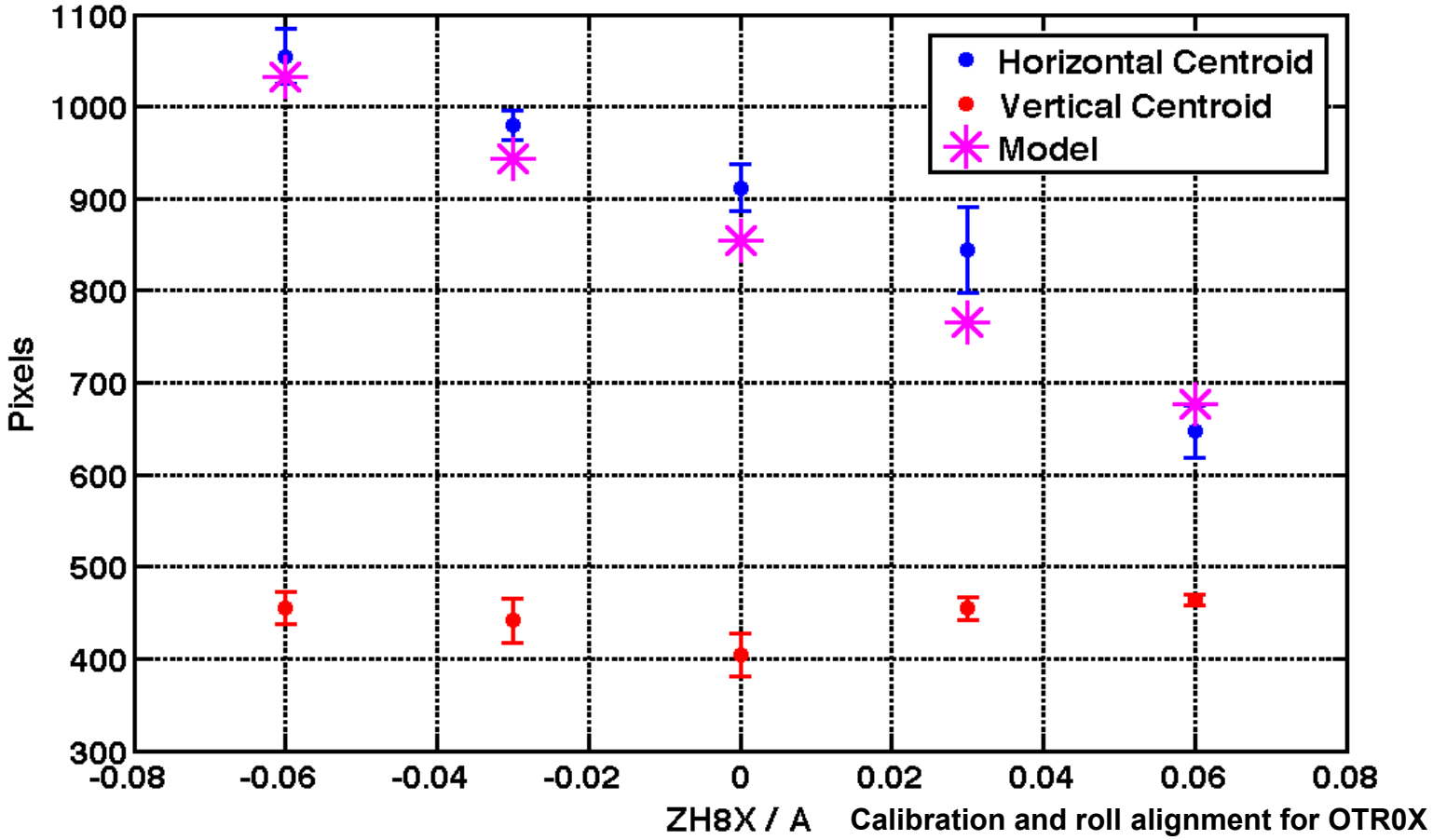
Multi-OTR System

December 2010: Vertical scale calibration



Vertical scale calibration done by scanning the vertical mover stage and recording the motion of the observed beam centroid. Thus the vertical calibration factor um/pixel is obtained.

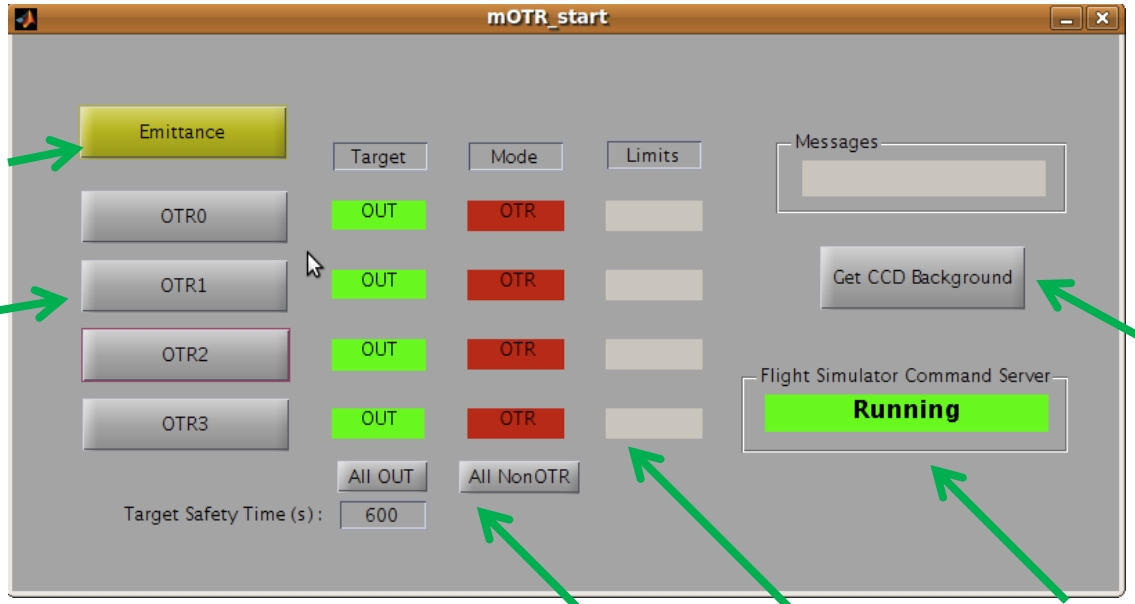
December 2010: OTR0x calibration test and roll alignment



To test the **calibration** an **upstream corrector is scanned** and the response in observed the OTR. To test **roll alignment (of the OTR CCDs)** we have to look for **no motion in the opposite plane**.

- **OTR sofware** is an standalone compiled executable from **Matlab**.
- Some functions like **emittance calculation** or beam finder need the Flight Simulator running.
- OTR status reported and displayed on global **ATF alarm panel** showing **OTR actuator status**.
- All useful **data is stored in EPICS** PVs and archived in the EPICS archival system.

Main start panel



Emittance calculation (next slides)

Single OTR panel (next slides)

Get CCD Background

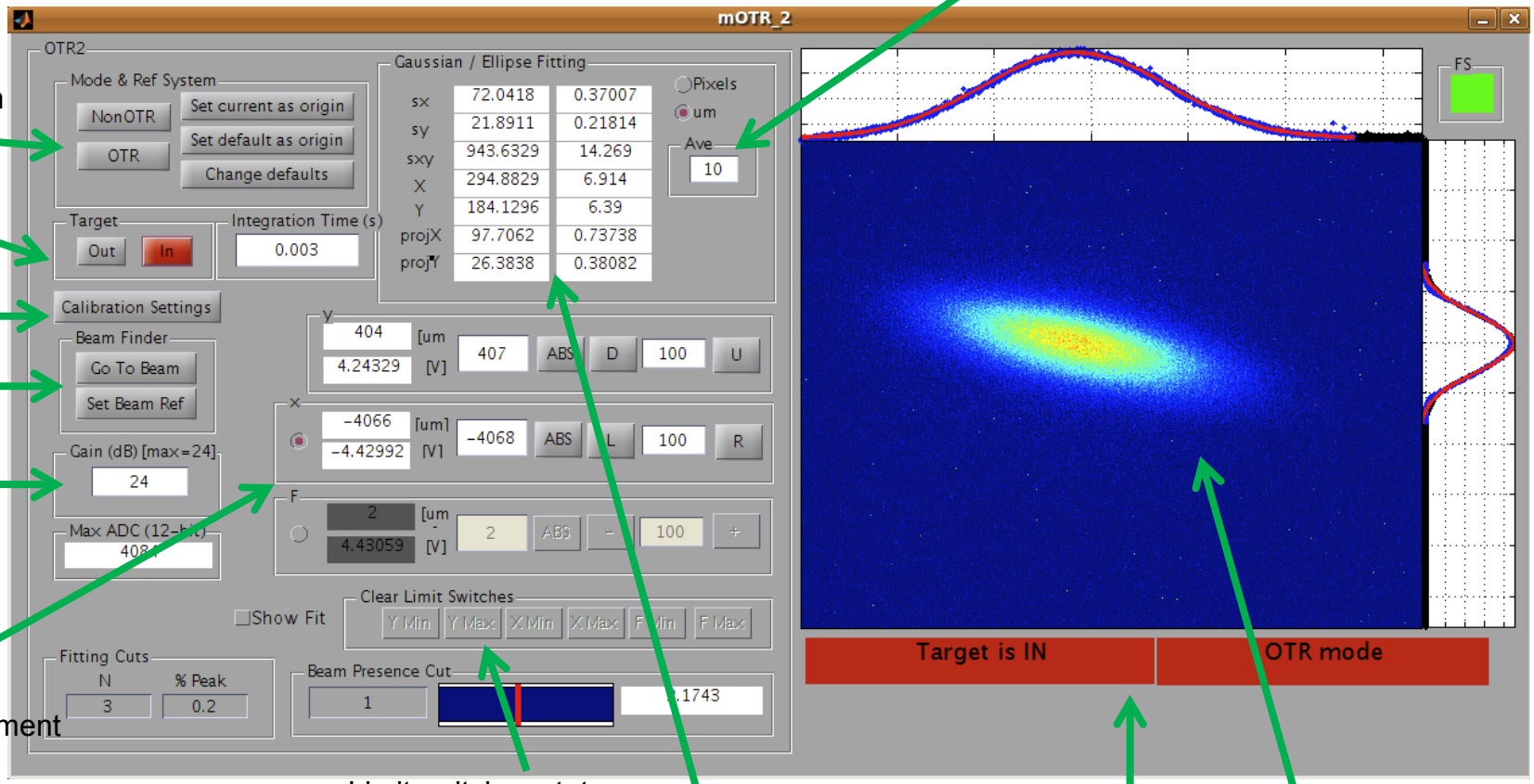
Flight simulator Status

Some machine status

Some protection controls

December 2010: Software development

Single OTR panel



Working mode & Reference system

Target control

Calibrations

Beam finder

CCD Gain

Position & movement of the movers

number of measurements

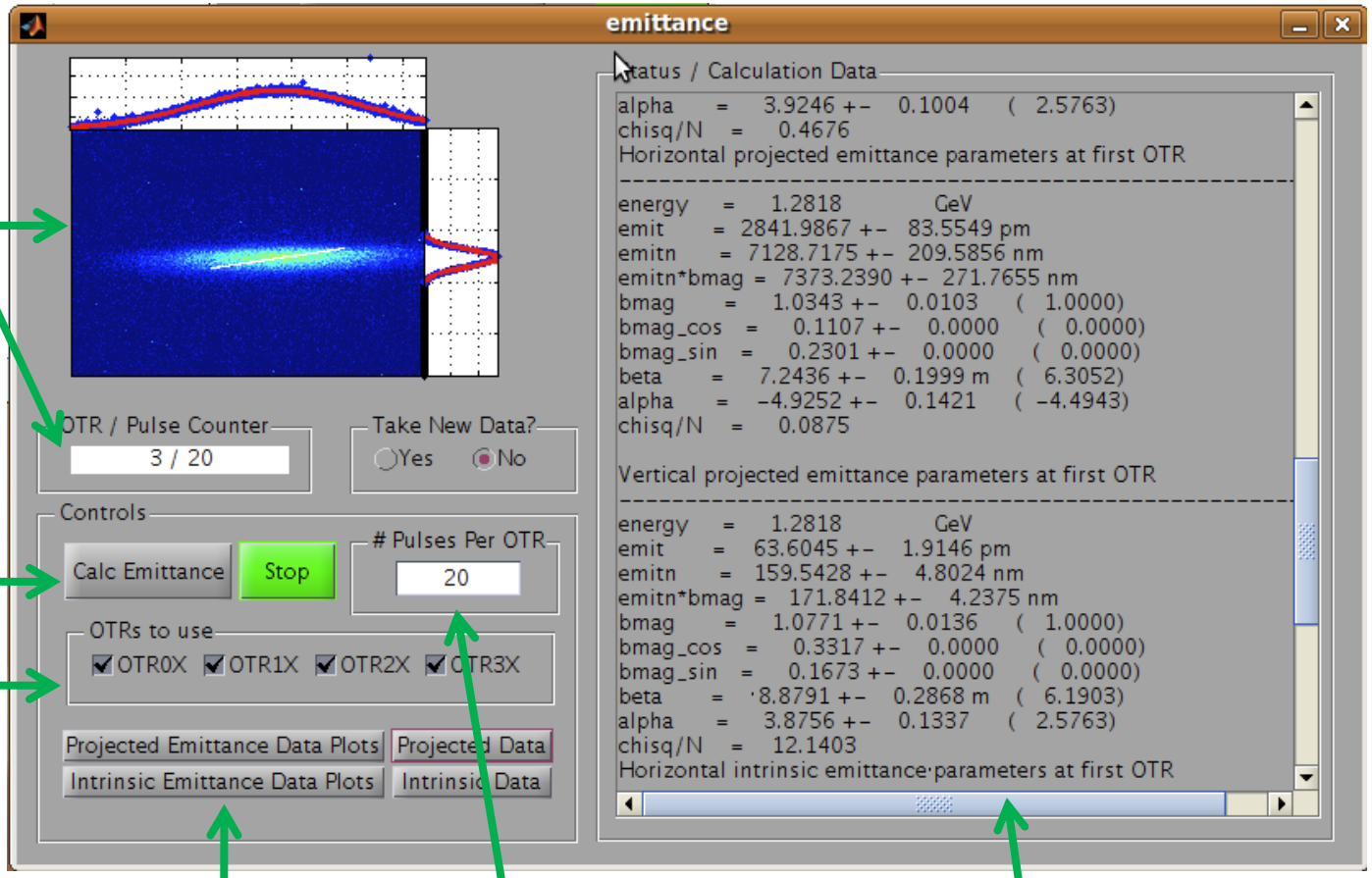
Limit switches status

Ellipse fitting and analysis

Machine status

CCD image and beam fitting

Emittance panel



Current OTR info

Start/stop emittance procedure

Number of OTR to be used

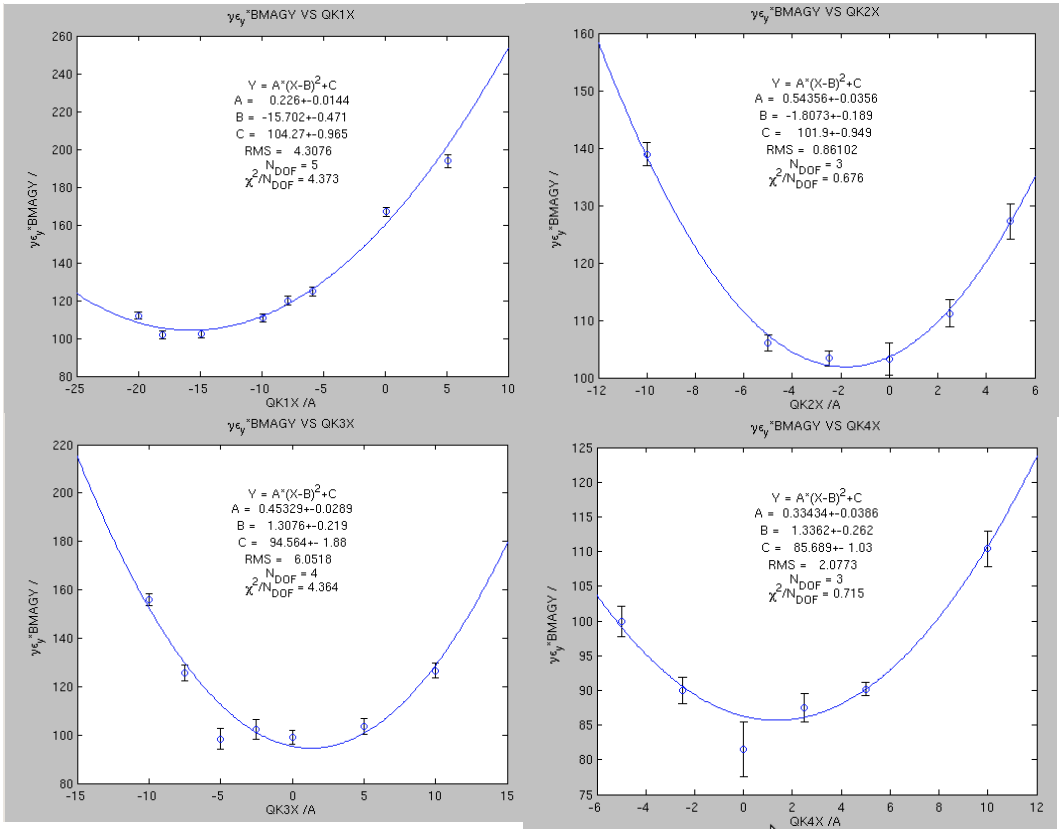
Data analysis and plots

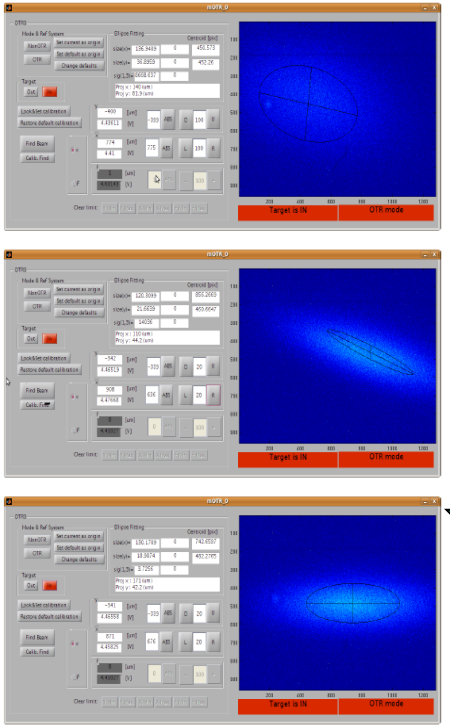
number of measurements per OTR

Calculation data

Multi-OTR System

December 2010: Coupling Correction

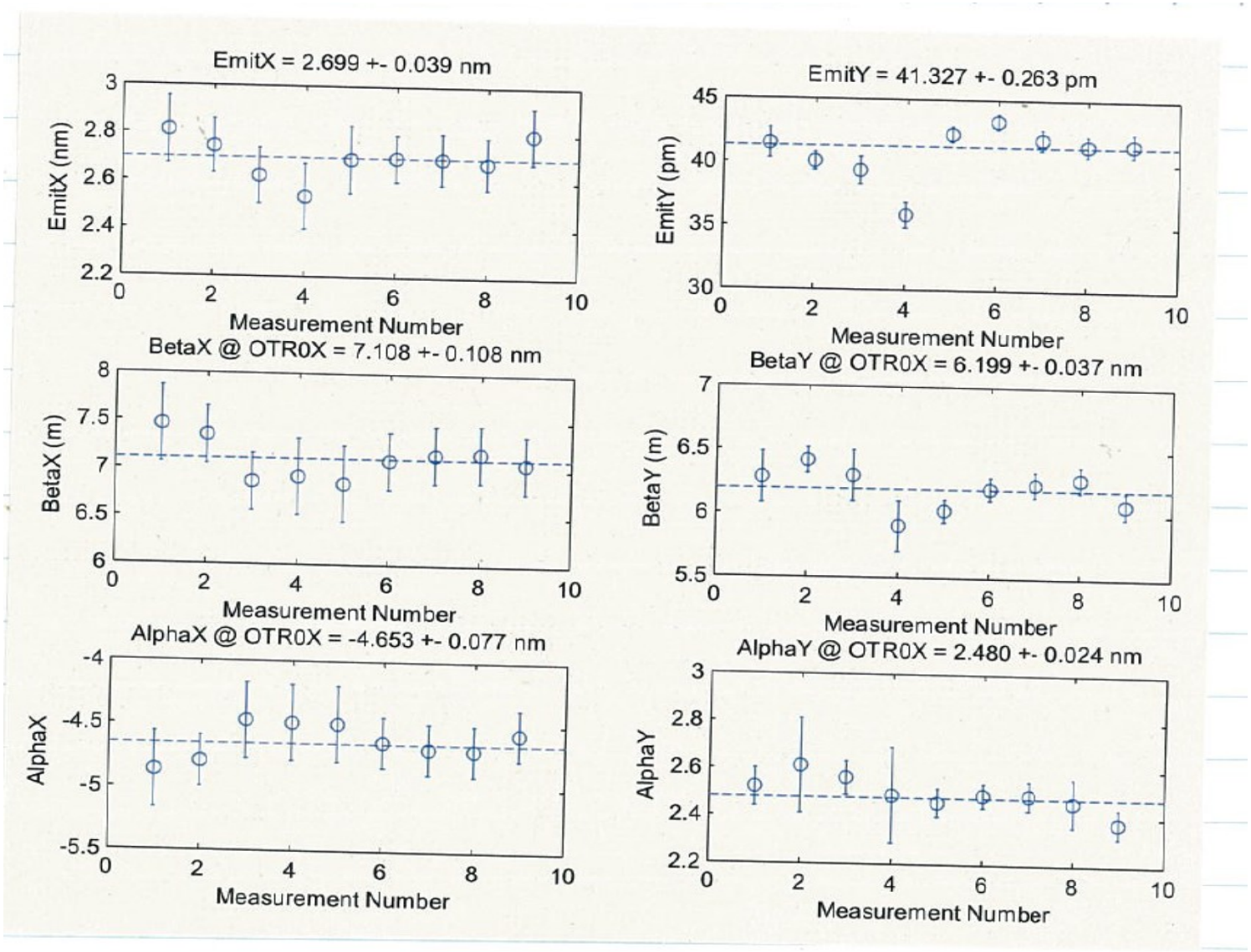




Coupling correction in the EXT achieved by **scanning each of the 4 EXT skew quads**. For each scan the quantity **(vertical normalised emittance)*BMAGY** is plotted and taken the optimal from a parabolic fit.

Multi-OTR System

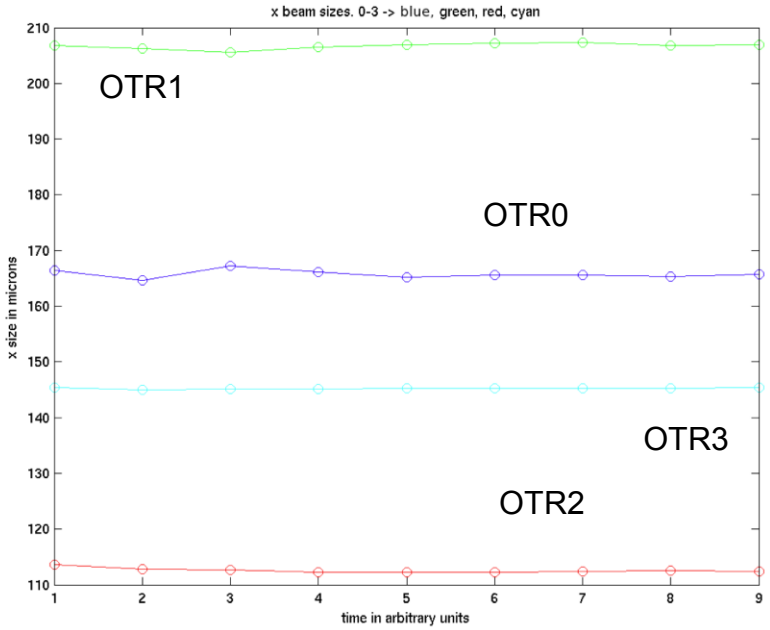
December 2010: Stability Measurement

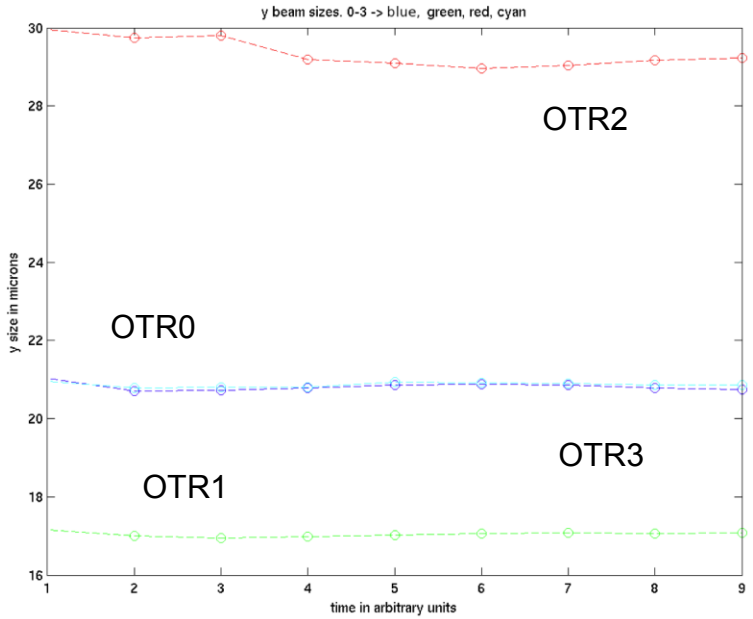


Multi-OTR System First period 2011: Systematic Measurements

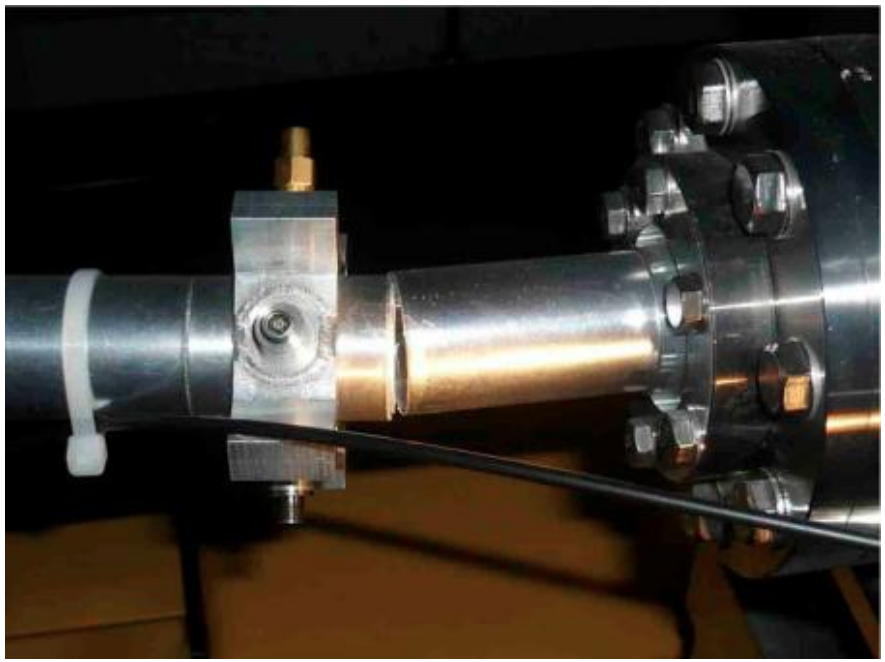
- Calibrations and alignments were made during the first part of the run period before to start a systematic measurement campaign

- A systematic measurement campaign was started in the first part of 2011





Multi-OTR System First period 2011: Systematic Measurements



- Impossible to finish because of the earthquake
- After the earthquake the hardware has been checked and works fine

Multi-OTR System

Simulation/experiments tracking comparison

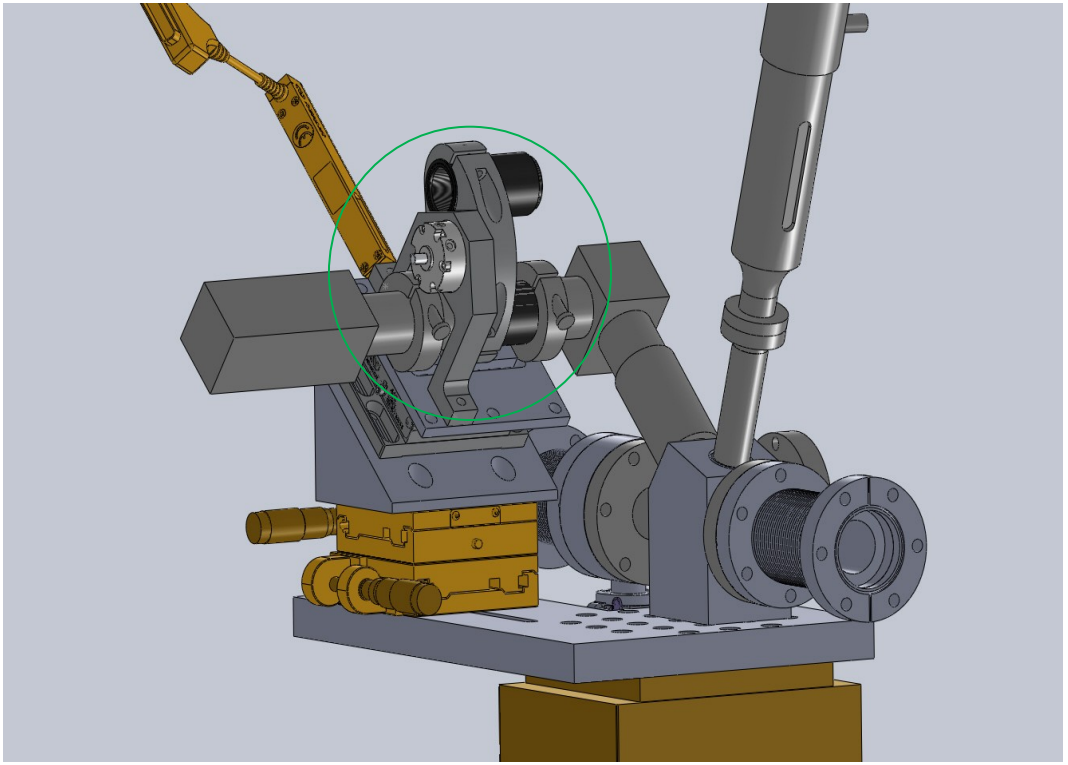
During first part of the year no systematic measurements were made. There are some records of tests but they are chaotic and not easy to analyze.

	x			y			
17-dic-10	Nominal	Tracked	Measured	Nominal	Tracked	Measured	
OTR0	115	183	143	11	20	24	um
OTR1	149	231	282	9	17	18	um
OTR2	91	93	96	15	22	26	um
OTR3	141	85	165	9	8	14	um <- ?

	x			y			
04-feb-11	Nominal	Tracked	Measured	Nominal	Tracked	Measured	
OTR0	115	180	164	11	22	21	um
OTR1	149	227	244	9	17	17	um
OTR2	91	92	114	15	19	31	um
OTR3	141	86	154	9	4	21	**um** <- ?

Measurements of 17 December 2010 and 04 February 2011 were compared with tracking using the recorded lattices for these days. The tracked beam sizes are similar to the measured ones but not exactly the same. The last OTR shows a rather big discrepancy which is not yet understood.

Multi-OTR System Demagnifier system

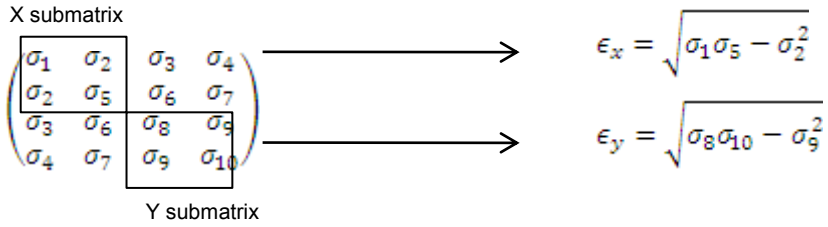


- A demagnifier system to speed up the beam finding and to measure horizontal size when beam is large in x is being constructed

By measuring the beam sizes in 4 places and knowing the optics in between the beam matrix could be reconstructed:

$$\begin{pmatrix} \sigma_1 & \sigma_2 & \sigma_3 & \sigma_4 \\ \sigma_2 & \sigma_5 & \sigma_6 & \sigma_7 \\ \sigma_3 & \sigma_6 & \sigma_8 & \sigma_9 \\ \sigma_4 & \sigma_7 & \sigma_9 & \sigma_{10} \end{pmatrix} \longrightarrow \begin{pmatrix} < x^2 > & < xx' > & < xy > & < xy' > \\ < xx' > & < xx'^2 > & < x'y > & < x'y' > \\ < xy > & < x'y > & < y^2 > & < yy' > \\ < xy' > & < x'y' > & < yy' > & < y'^2 > \end{pmatrix}$$

The emittances values are calculated by using the x and y sub-matrices: 2D emittance.



$$\epsilon_x = \sqrt{\sigma_1\sigma_5 - \sigma_2^2}$$

$$\epsilon_y = \sqrt{\sigma_8\sigma_{10} - \sigma_9^2}$$

To take in account the coupling terms the diagonalising of the beam matrix is needed: 4D emittances or intrinsic emittances

$$\begin{pmatrix} \sigma_1 & \sigma_2 & \sigma_3 & \sigma_4 \\ \sigma_2 & \sigma_5 & \sigma_6 & \sigma_7 \\ \sigma_3 & \sigma_6 & \sigma_8 & \sigma_9 \\ \sigma_4 & \sigma_7 & \sigma_9 & \sigma_{10} \end{pmatrix} \longrightarrow \begin{pmatrix} \varepsilon_1 & 0 & 0 & 0 \\ 0 & \varepsilon_1 & 0 & 0 \\ 0 & 0 & \varepsilon_2 & 0 \\ 0 & 0 & 0 & \varepsilon_2 \end{pmatrix}$$

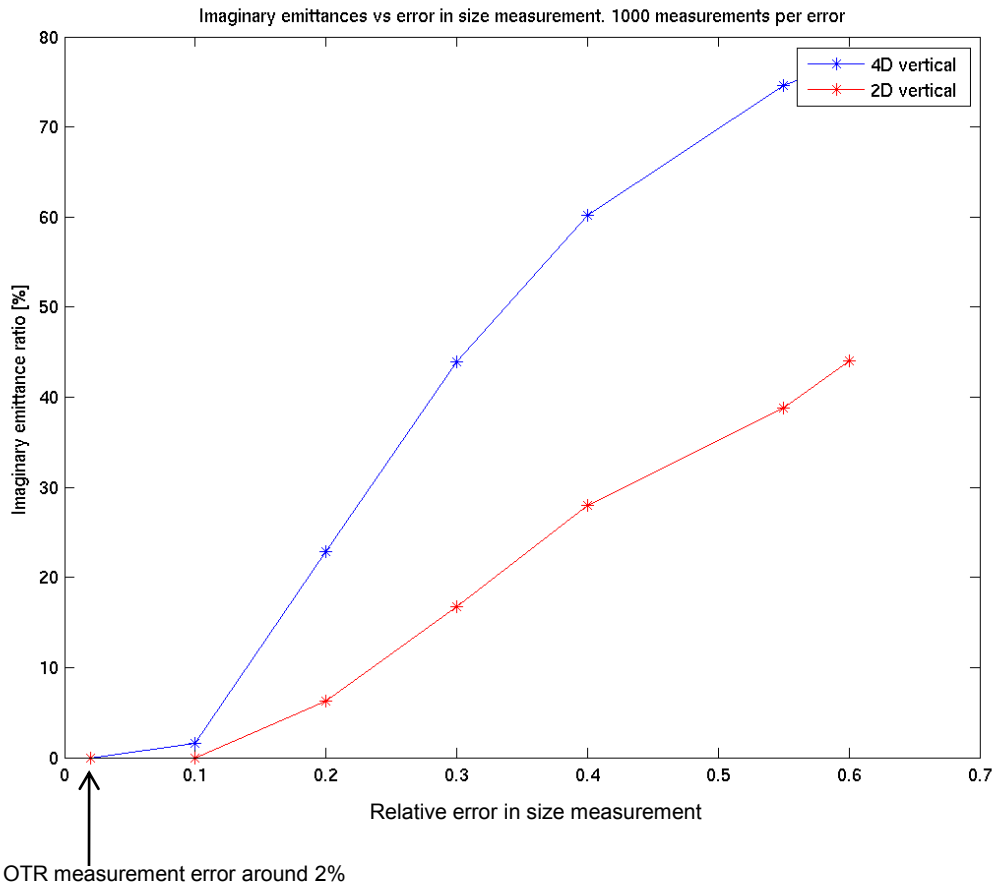
- 2D emittance reconstruction is fully implemented and it is working.
- Systematic measurements for comparison is needed.
- 4D algorithm is under study.

- The algorithm gives some times imaginary emittances!

Simulation parameters:

- 1000 emittance measurements per error.
- 50.001 particles.
- Standard nominal V3.1 optics
- Tracking with Lucretia

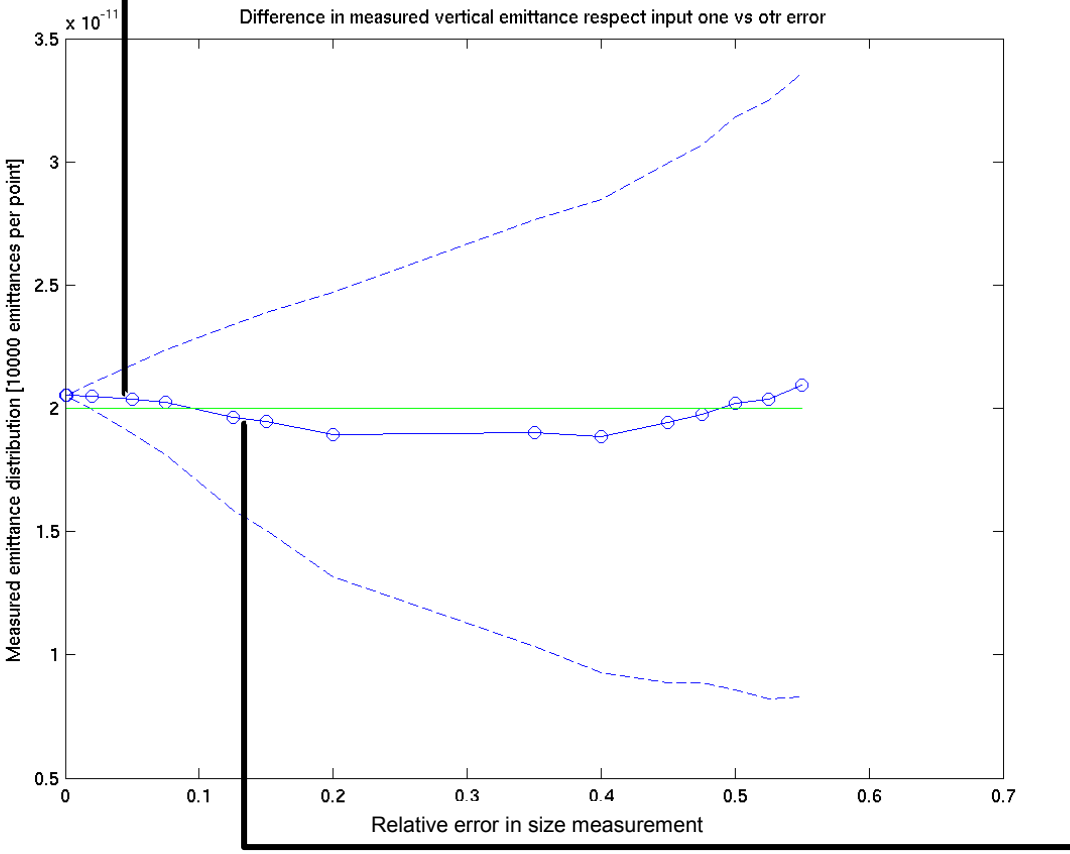
Emittances are vertical if not specified

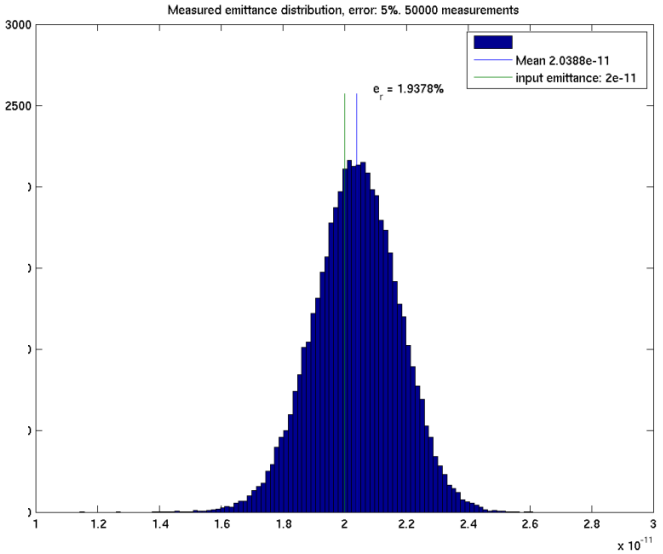


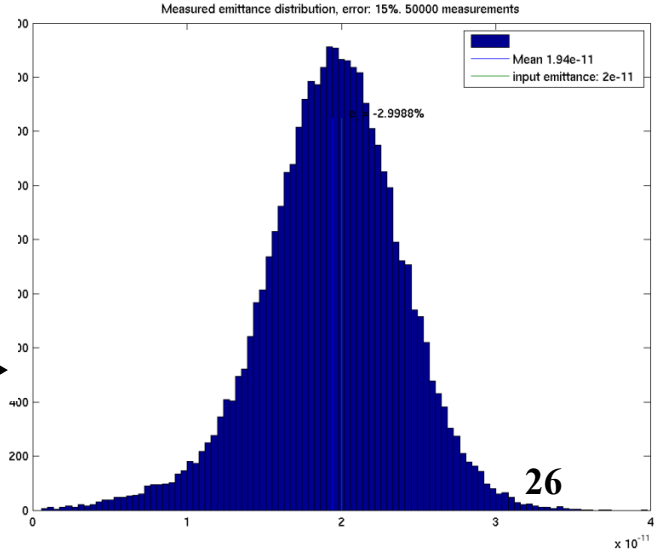
Multi-OTR System

Emittance reconstruction

- Mean of measured value compared with input one







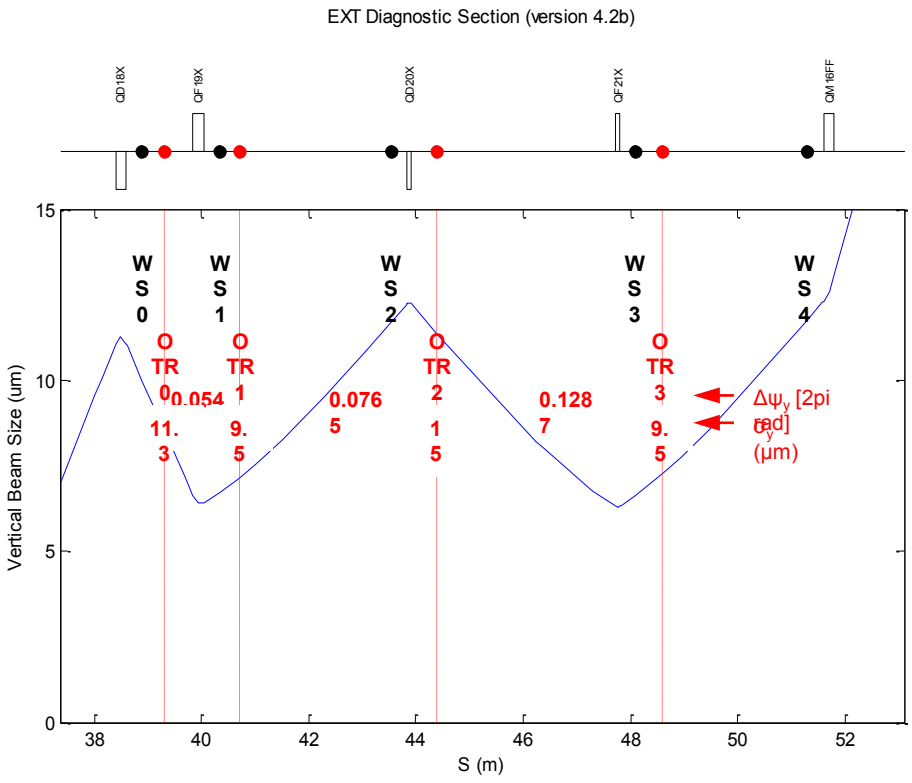
Input emittance

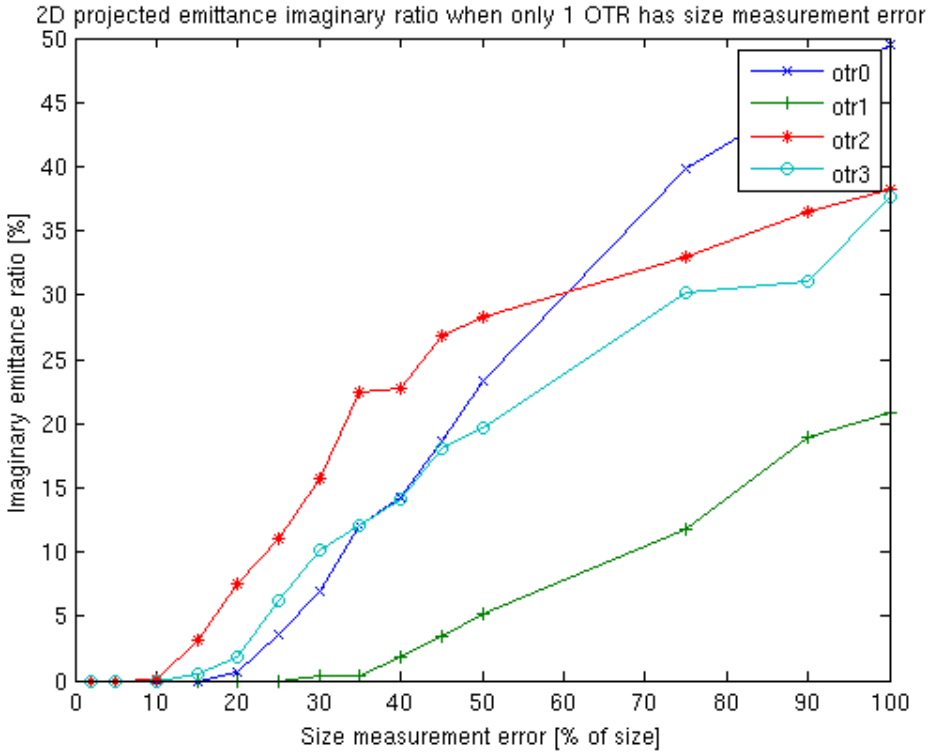
Mean of measured emittances

Standard deviation of measured emittances

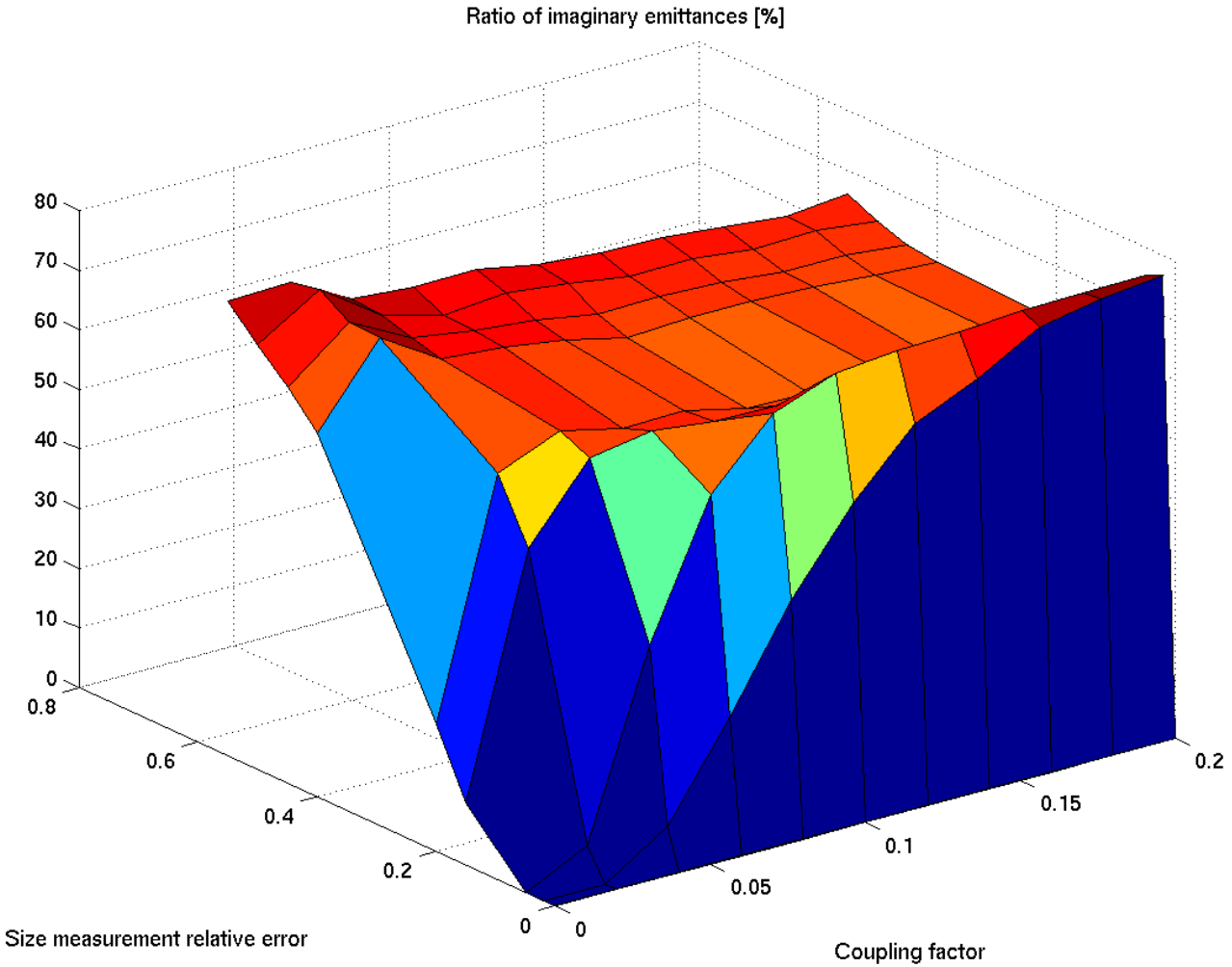
Multi-OTR System Emittance reconstruction

- Effect of each OTR in the emittance imaginary ratio

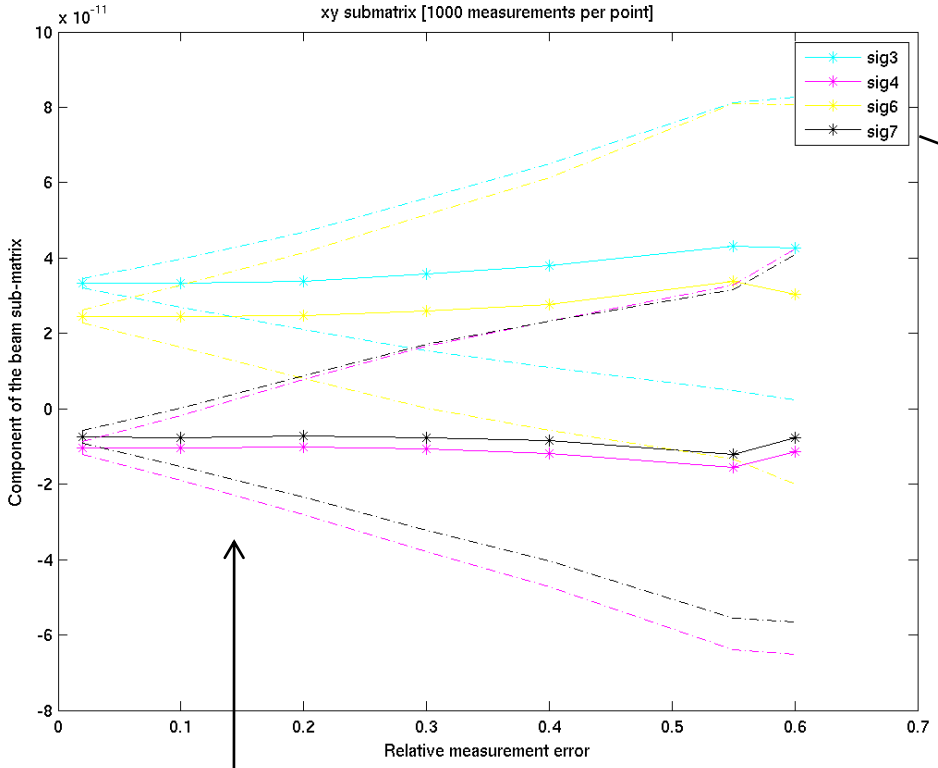




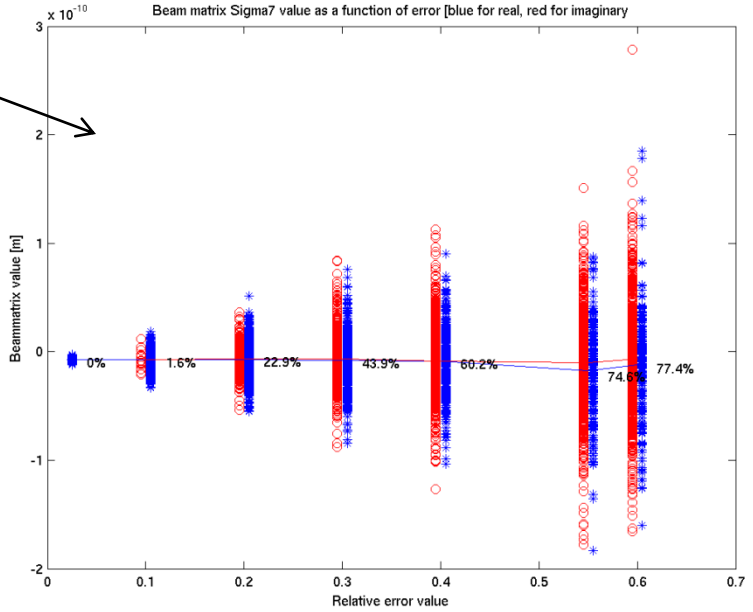
- Effect of coupling in the emittance imaginary ratio



- Study of the reconstructed beam matrix elements



σ_7



$$\begin{pmatrix} \sigma_1 & \sigma_2 & \sigma_3 & \sigma_4 \\ \sigma_2 & \sigma_5 & \sigma_6 & \sigma_7 \\ \sigma_3 & \sigma_6 & \sigma_8 & \sigma_9 \\ \sigma_4 & \sigma_7 & \sigma_9 & \sigma_{10} \end{pmatrix}$$

Blue dots are beam matrix elements hat lead to a real emittance value and red ones are for the imaginary value

Multi-OTR System To do list

- Get the **Beam finder** working.
  - -Work required on Flight Simulator online orbit fitting
  - -Work required on OTR software implementation

- Finish **test calibration and roll** for OTR1-3X (no roll means all OTRs in the same coordinate frame and can use ellipse fit tilt with other measurements for the 4D emittance measurement)

- **4D intrinsic emittance** calculation.
  - -Algorithm development, flight simulator calculation and OTR software implementation.

- Install a **LAN controllable power strip in-tunnel** and build in power cycle controls into the OTR software (CCD cameras can be put into a mode of operation unresponsive to the OTR software and needs to be reset by power cycling the cameras being the power supplies in-tunnel)

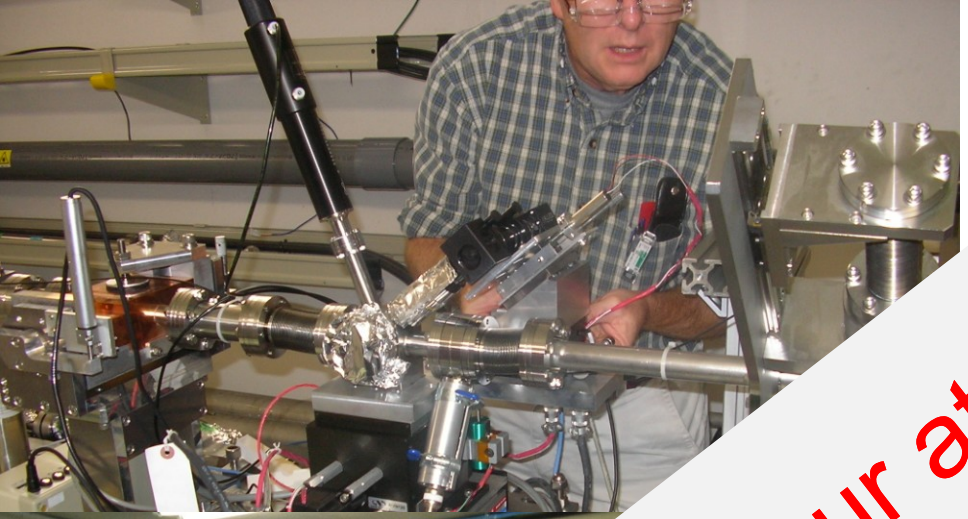
Multi-OTR System To do list

• Provide the capability of doing **automated scans from the emittance GUI** (e.g. Automate the scan QK*X and plot versus emit*BMAG to search the minimum).

• Install **switchable demagnifier lens**

• **Documentation** (user's guide started)

• Systematic **Measurement campaign during Fall 2011**



Thanks for your attention