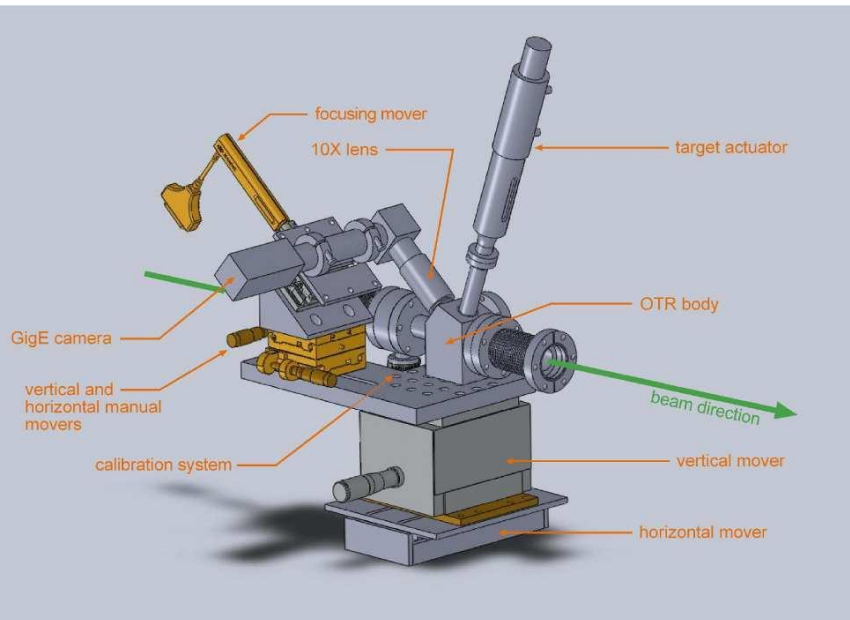


Multi-OTR status

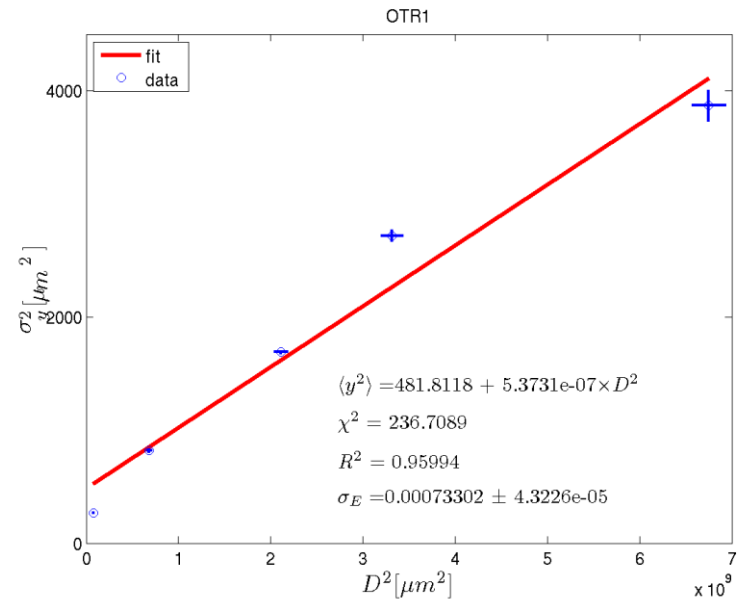
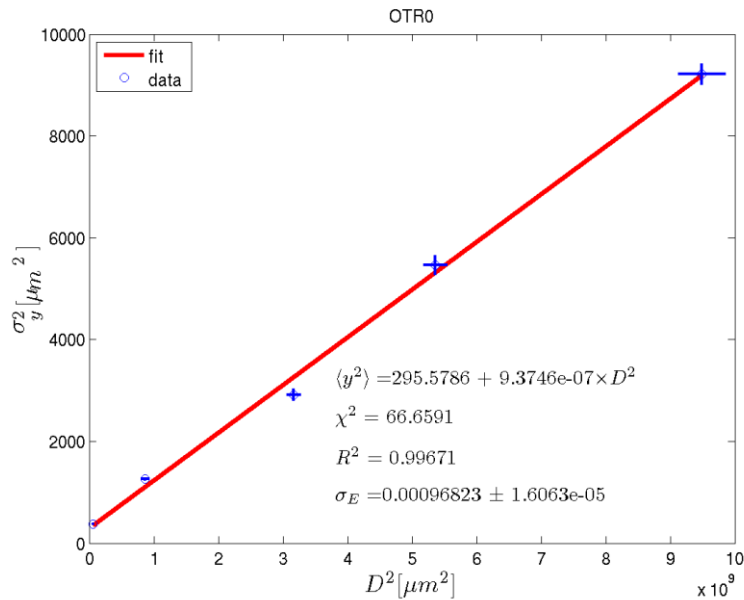


A. Faus-Golfe, J. Alabau, C. Blanch,
J.V. Civera, J.J. García Garrigós

IFIC Valencia

D. McCormick, G. White,
J. Cruz, M. Woodley

SLAC



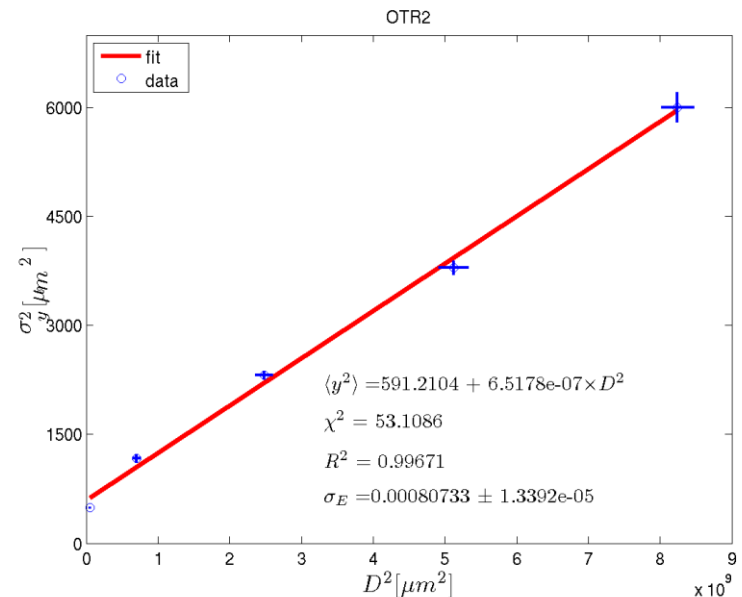
$$\sigma_y^2 = \beta_y \varepsilon_y + D_y^2 \sigma_E^2$$

Obtain the energy spread by changing the dispersion and measuring the change in size.

Dispersion changed with QS1X and QS2X.

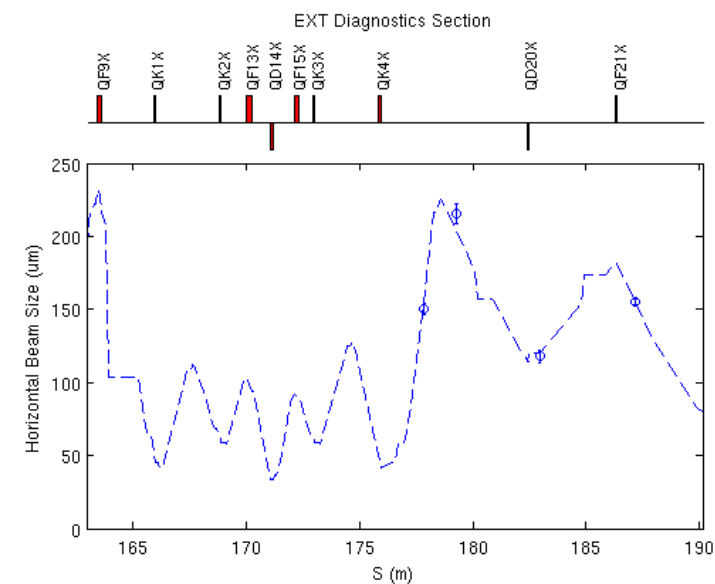
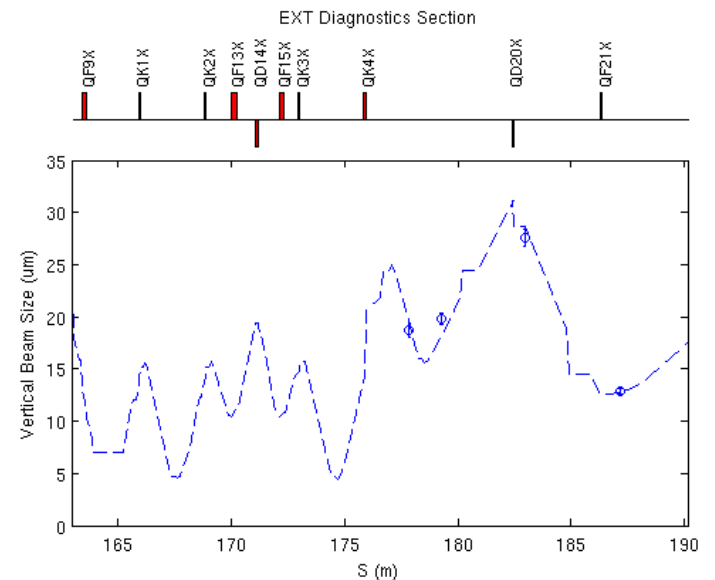
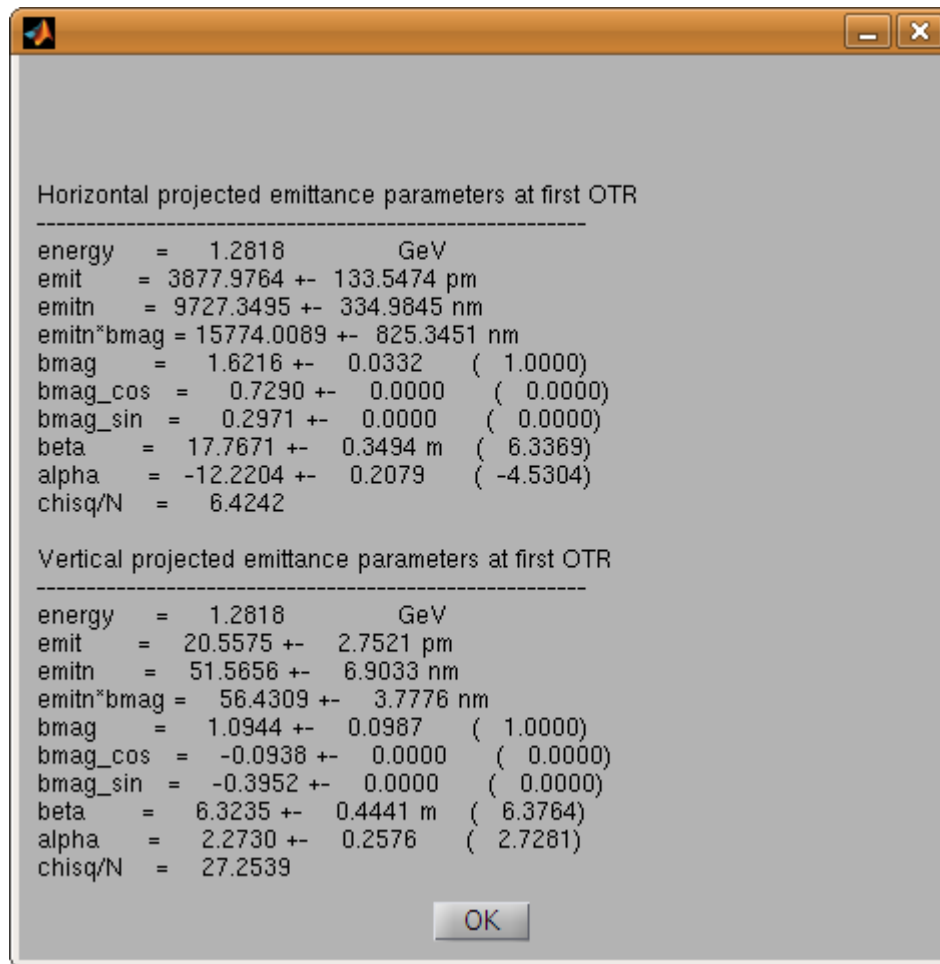
First measurement:

$$\sigma_E = (8.4 \pm 0.7) \cdot 10^{-4}$$



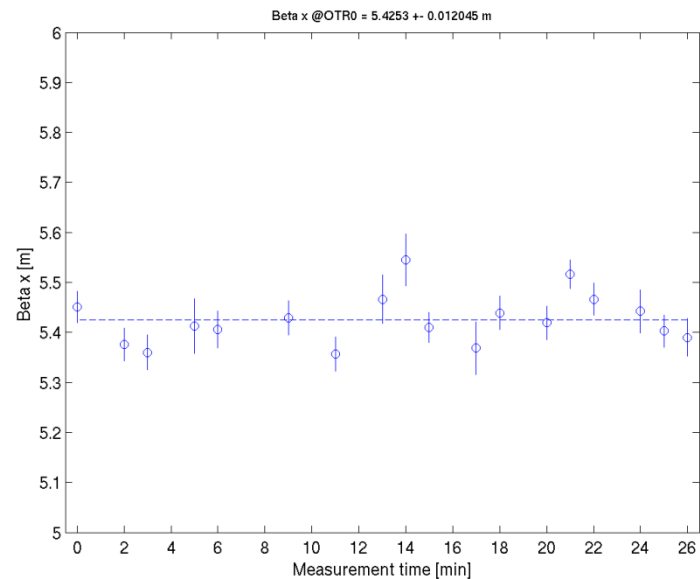
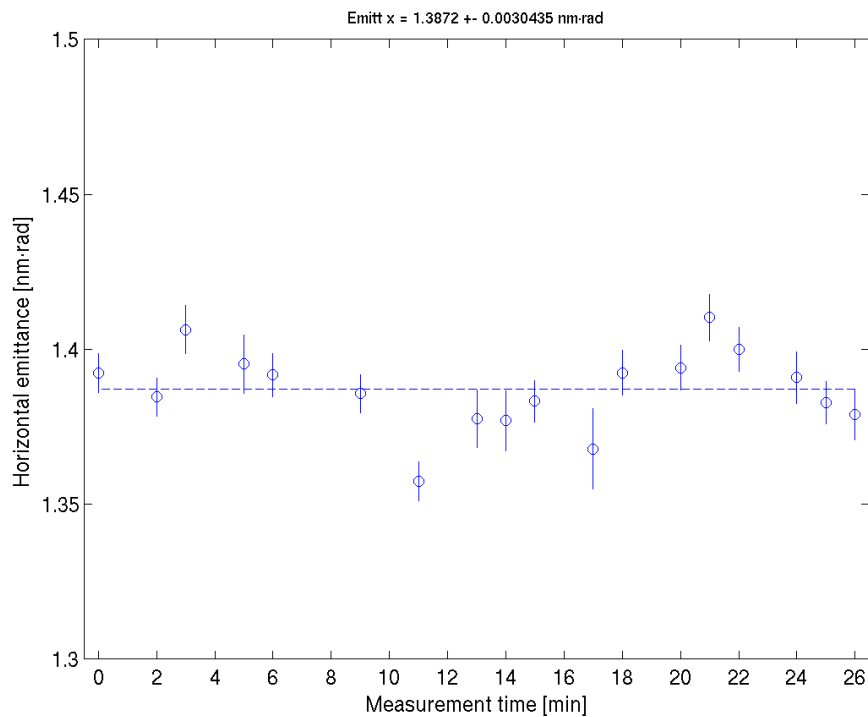
Multi-OTR System

Emittance measurements

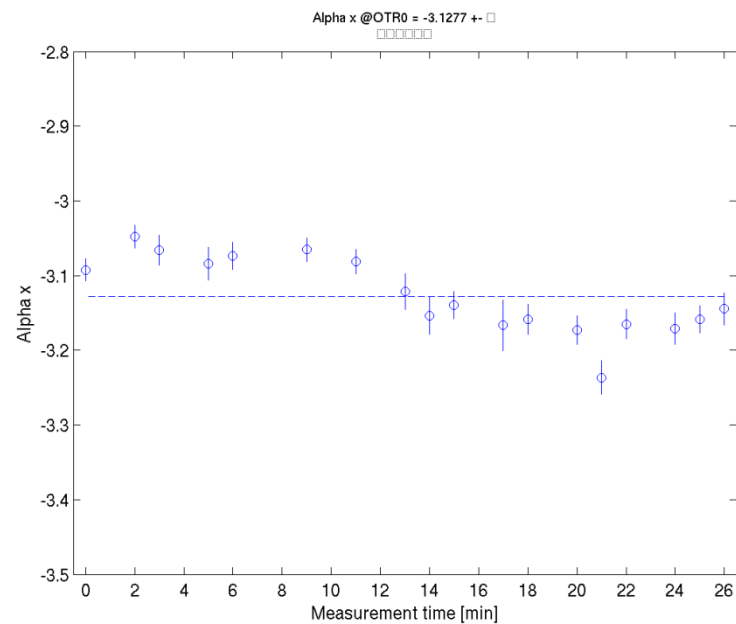


Multi-OTR System

Stability Measurements

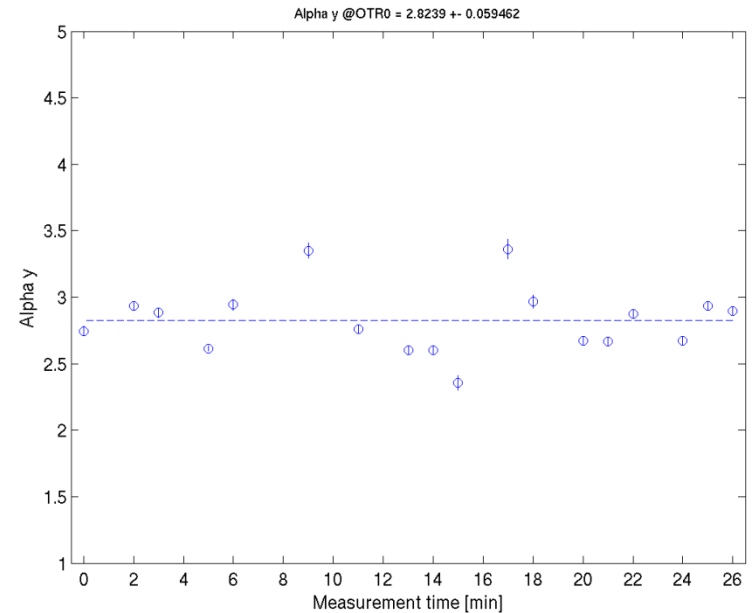
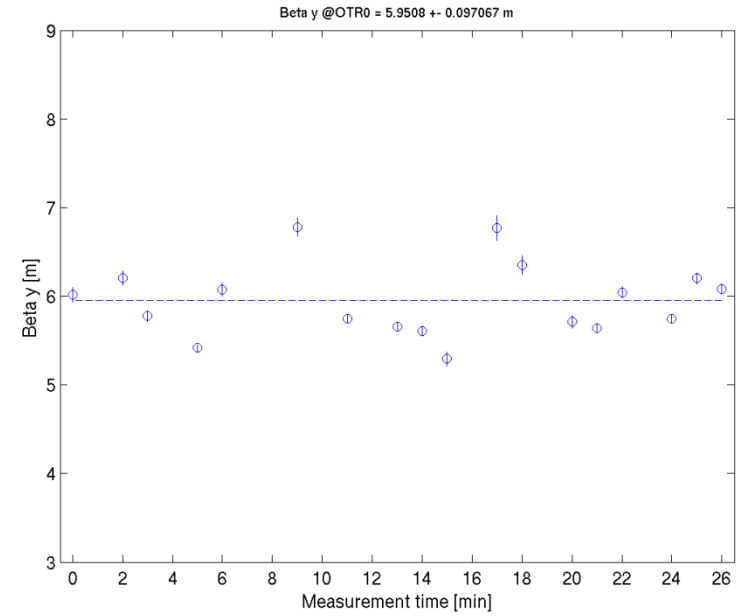
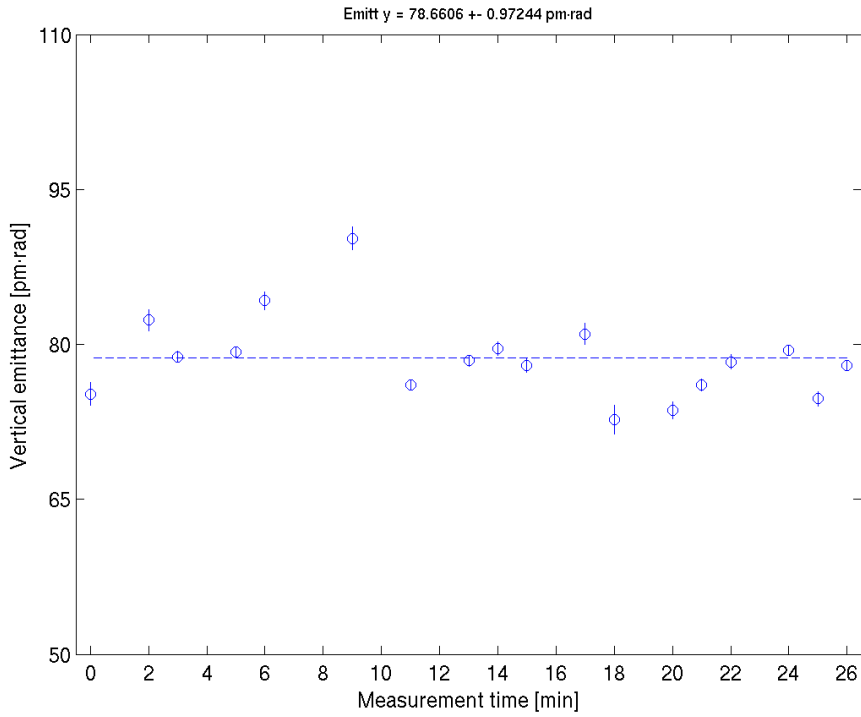


Emit_x = 1.387 +- 0.003 nm
Beta_x (OTR0) = 5.42 +- 0.01 m
Alpha_x (OTR0) = -3.12 +- 0.01



Multi-OTR System

Stability Measurements



Emitt_y = 78 +- 1 pm
Beta_y (OTR0) = 5.9 +- 0.1 m
Alpha_y (OTR0) = 2.82 +- 0.06

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

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

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

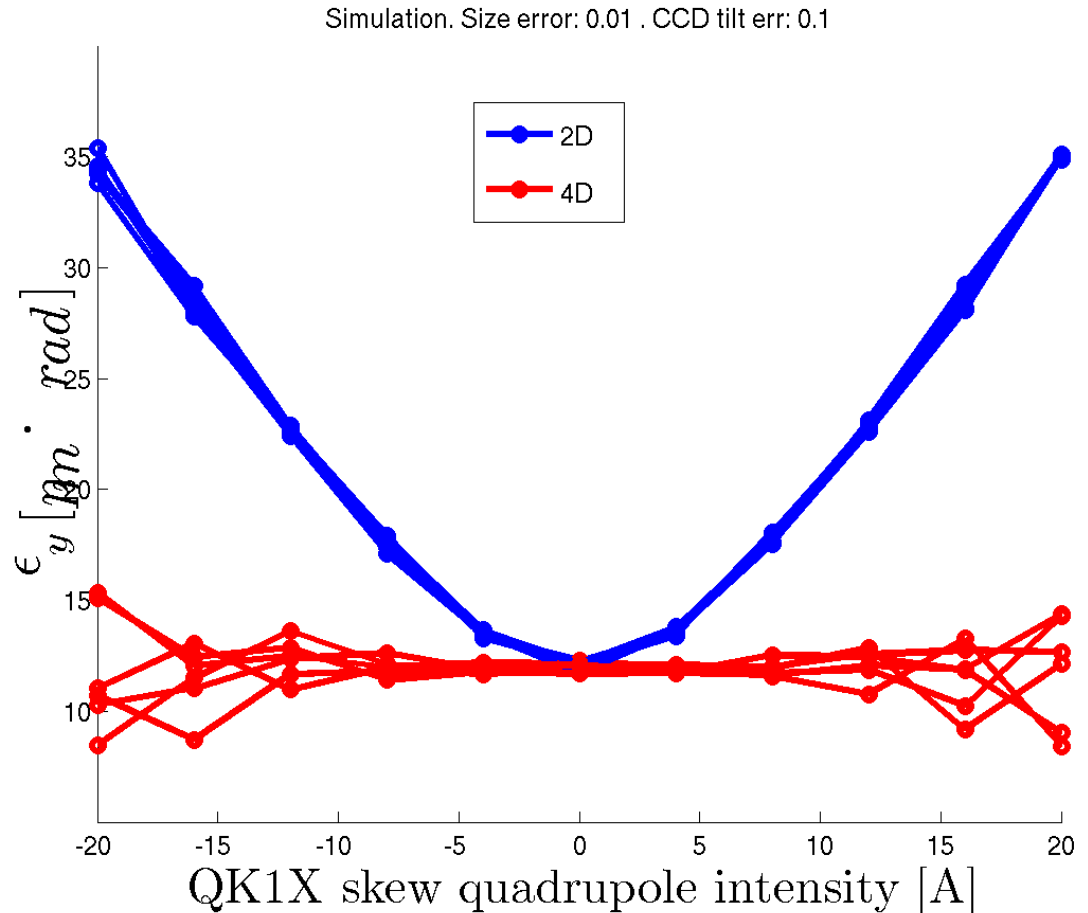
$$\begin{array}{c} \text{X submatrix} \\ \begin{pmatrix} \sigma_1 & \sigma_2 & \sigma_3 & \sigma_4 \\ \sigma_2 & \sigma_5 & \sigma_6 & \sigma_7 \\ \sigma_3 & \sigma_6 & \sigma_8 & \sigma_9 \\ \sigma_4 & \sigma_7 & \sigma_9 & \sigma_{10} \end{pmatrix} \\ \text{Y submatrix} \end{array} \begin{array}{l} \longrightarrow \\ \longrightarrow \end{array} \begin{array}{l} \epsilon_x = \sqrt{\sigma_1 \sigma_5 - \sigma_2^2} \\ \epsilon_y = \sqrt{\sigma_8 \sigma_{10} - \sigma_9^2} \end{array}$$

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

$$\begin{pmatrix} \sigma_1 & \sigma_2 & \sigma_3 & \sigma_4 \\ \sigma_2 & \sigma_5 & \sigma_6 & \sigma_7 \\ \sigma_3 & \sigma_6 & \sigma_8 & \sigma_9 \\ \sigma_4 & \sigma_7 & \sigma_9 & \sigma_{10} \end{pmatrix} \longrightarrow \begin{pmatrix} \epsilon_1 & 0 & 0 & 0 \\ 0 & \epsilon_1 & 0 & 0 \\ 0 & 0 & \epsilon_2 & 0 \\ 0 & 0 & 0 & \epsilon_2 \end{pmatrix}$$

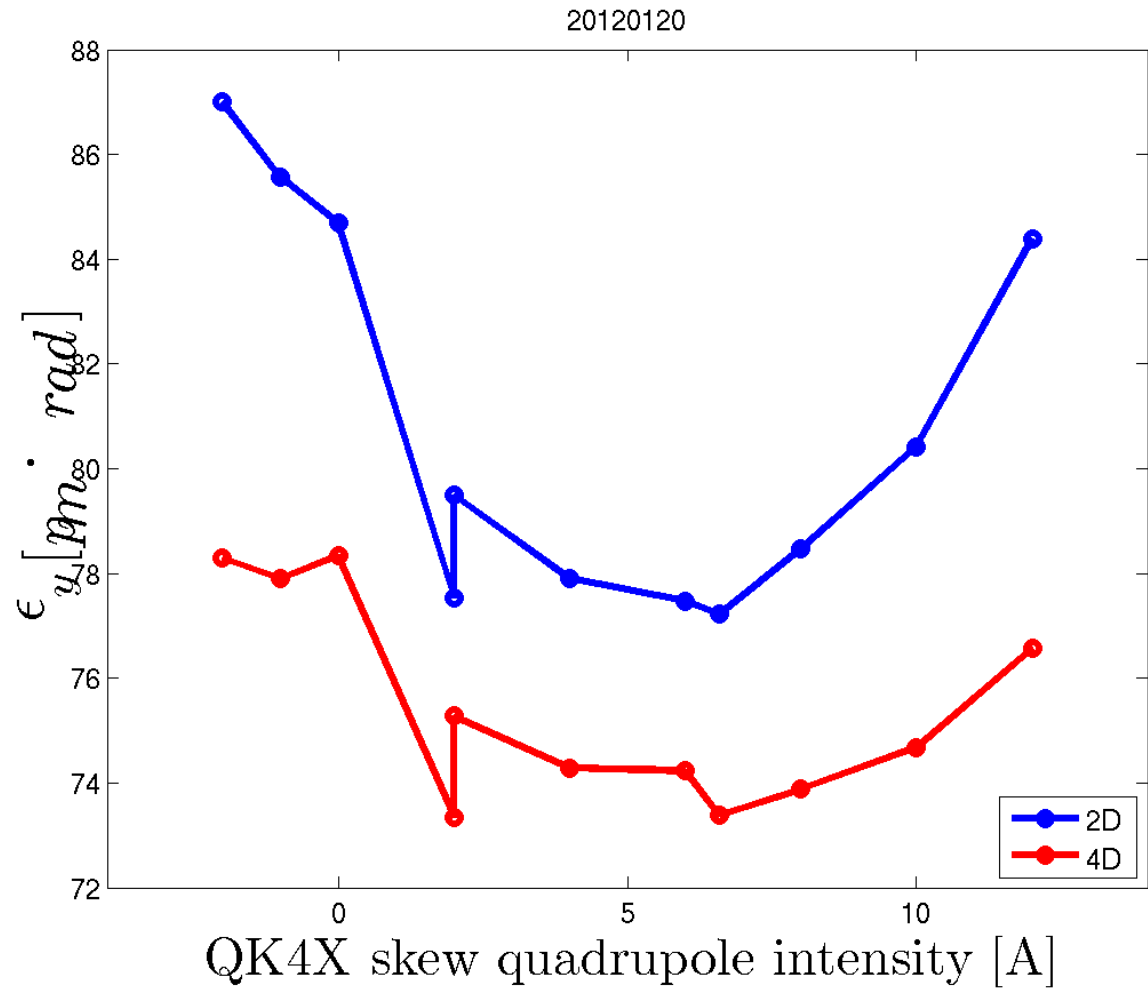
Simulation of 2D and 4D vertical emittance value when scanning a skew quadrupole.

Measurement errors (beam size and CCD tilt) are included.



Emittance
measurement during
a skew quadrupole
scan.

2D emittance
measurement online.
4D emittance
measurement offline.



Manual Skew Quad Scanning Method: Measurements with mOTR

Correction from 16th
November 2011

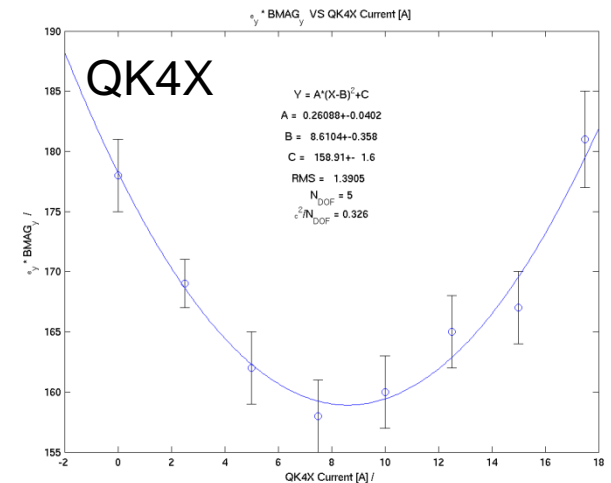
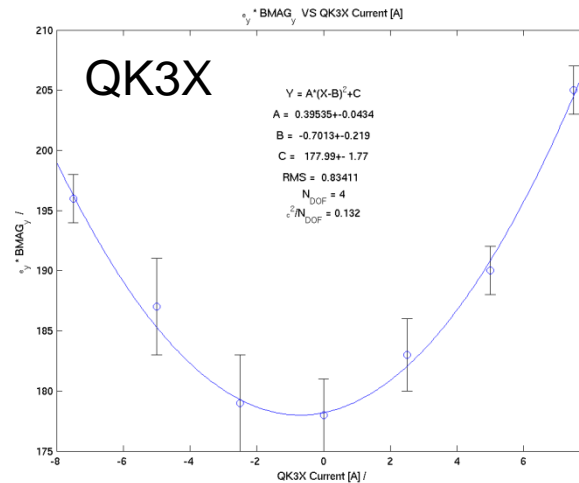
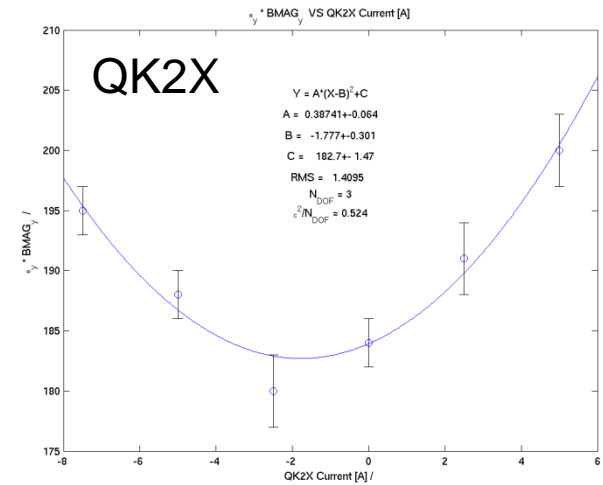
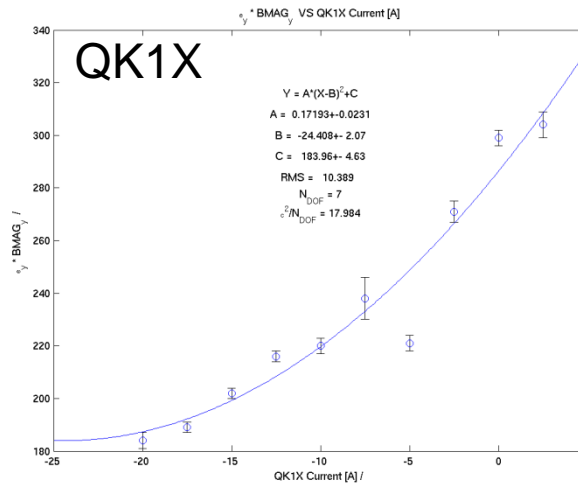
First all 4 skew set to 0

Emittance before:
 $E_y = 100 \text{ } 1\text{pm} \cdot \text{rad}$

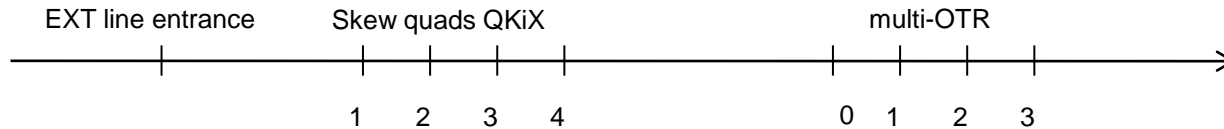
QK1X set to -20A
QK2X set to -1.8A
QK3X set to -0.7A
QK4X set to 8.6A

Emittance after:
 $62 \text{ } 2\text{pm} \cdot \text{rad}$

Emittance is
almost halved



Response Matrix Method: Procedure



$$\begin{pmatrix} \sigma_{13}^{OTR0} \\ \sigma_{13}^{OTR1} \\ \sigma_{13}^{OTR2} \\ \sigma_{13}^{OTR3} \end{pmatrix} = \begin{pmatrix} C_{11} & C_{12} & C_{13} & C_{14} \\ C_{21} & C_{22} & C_{23} & C_{24} \\ C_{31} & C_{32} & C_{33} & C_{34} \\ C_{41} & C_{42} & C_{43} & C_{44} \end{pmatrix} \cdot \begin{pmatrix} I_{skew1} \\ I_{skew2} \\ I_{skew3} \\ I_{skew4} \end{pmatrix}$$

Build the response matrix that relates each skew with each OTR through the coefficient C_{ij} .



Measure the coupling term σ_{13} ($\langle xy \rangle$ term) in each of the OTRs.

$$\begin{pmatrix} I_{skew1} \\ I_{skew2} \\ I_{skew3} \\ I_{skew4} \end{pmatrix} = pinv \begin{pmatrix} C_{11} & C_{12} & C_{13} & C_{14} \\ C_{21} & C_{22} & C_{23} & C_{24} \\ C_{31} & C_{32} & C_{33} & C_{34} \\ C_{41} & C_{42} & C_{43} & C_{44} \end{pmatrix} \cdot \begin{pmatrix} \sigma_{13}^{OTR0} \\ \sigma_{13}^{OTR1} \\ \sigma_{13}^{OTR2} \\ \sigma_{13}^{OTR3} \end{pmatrix}$$

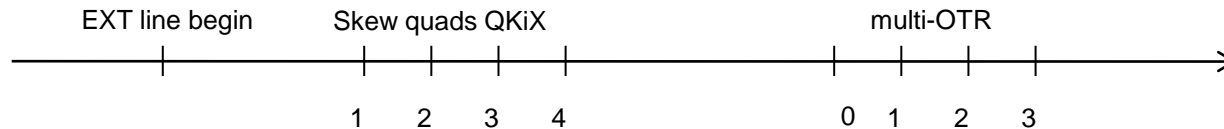
Goal

Calculate the needed strength to correct this coupling using the pseudo-inverse response matrix



Beam matrix as a function of skew intensities

Another approach: Solving the transport matrix



- 1) Use the beam matrix reconstruction algorithm **to obtain the beam matrix** σ^u upstream of the skews.
- 2) **Transport downstream** through the skews to OTR0 leaving the skew strength explicit in the calculation:

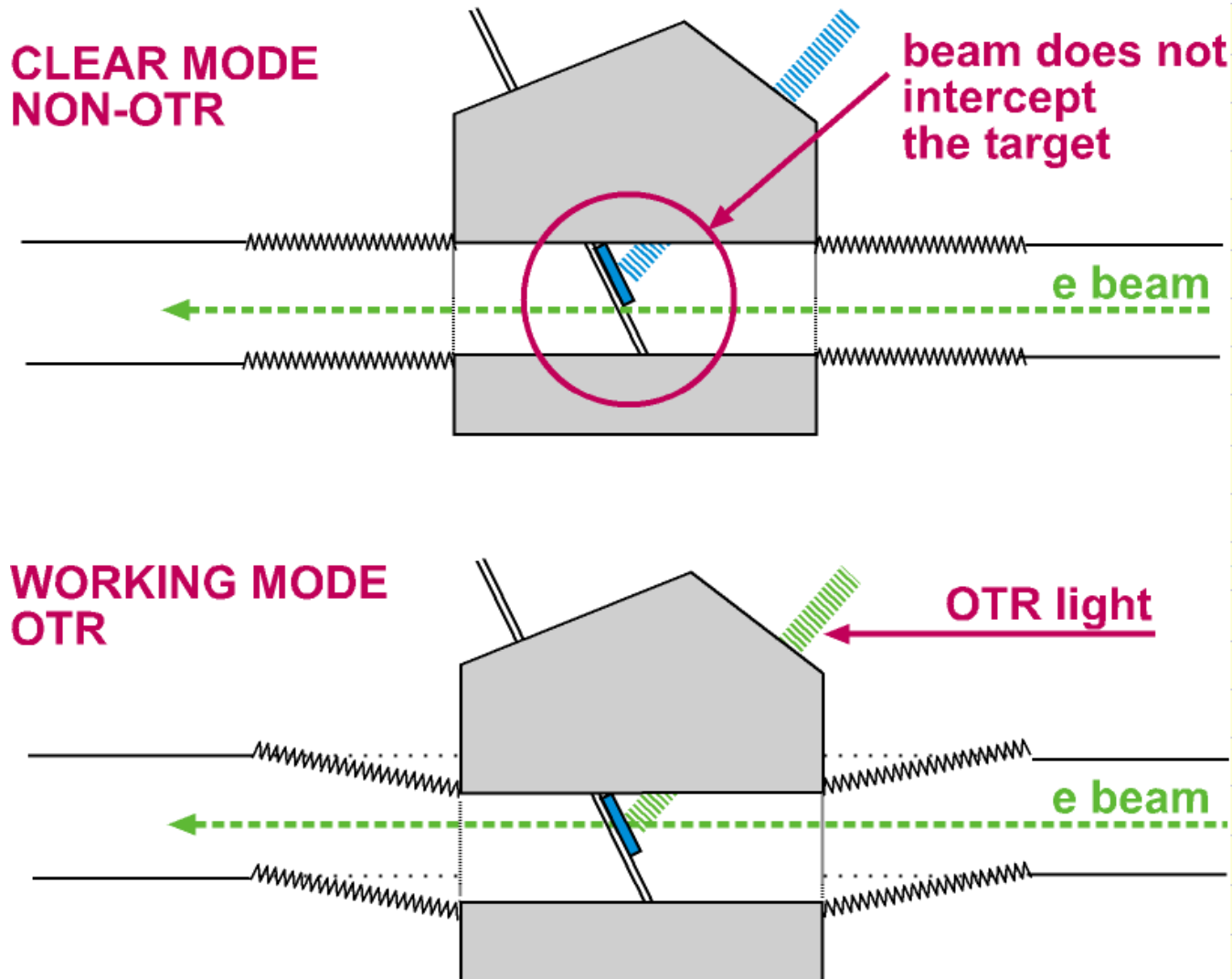
$$R_i = (R_{4 \rightarrow OTR0} \cdot R_{skew4} \cdot R_{3 \rightarrow 4} \cdot R_{skew3} \cdot R_{2 \rightarrow 3} \cdot R_{skew2} \cdot R_{1 \rightarrow 2} \cdot R_{skew1} \cdot R_{u \rightarrow 1})$$

- 3) **Solve the 4 equations and 4 unknowns system** to get the skew intensities that makes coupling terms equal 0.

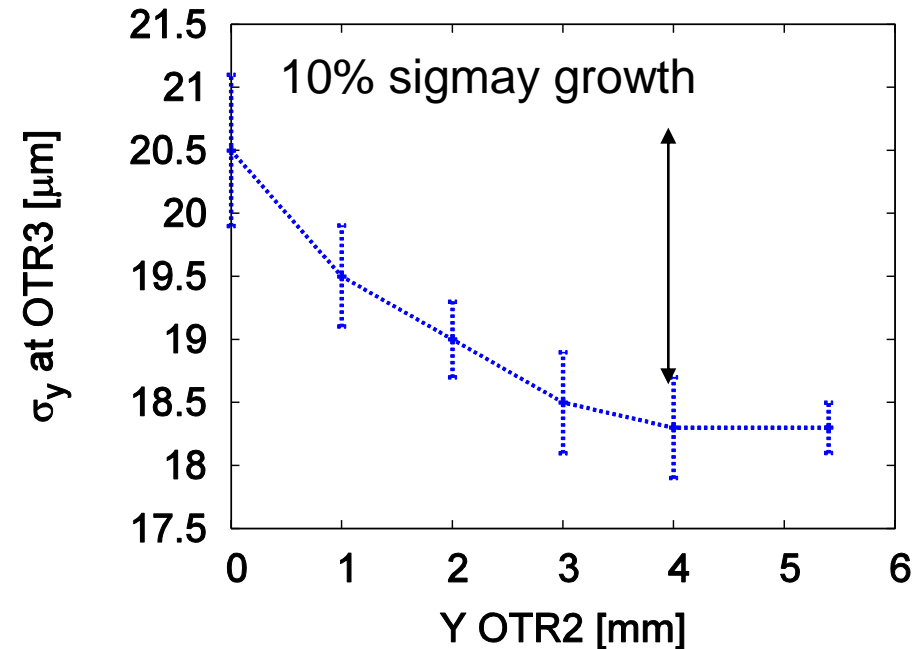
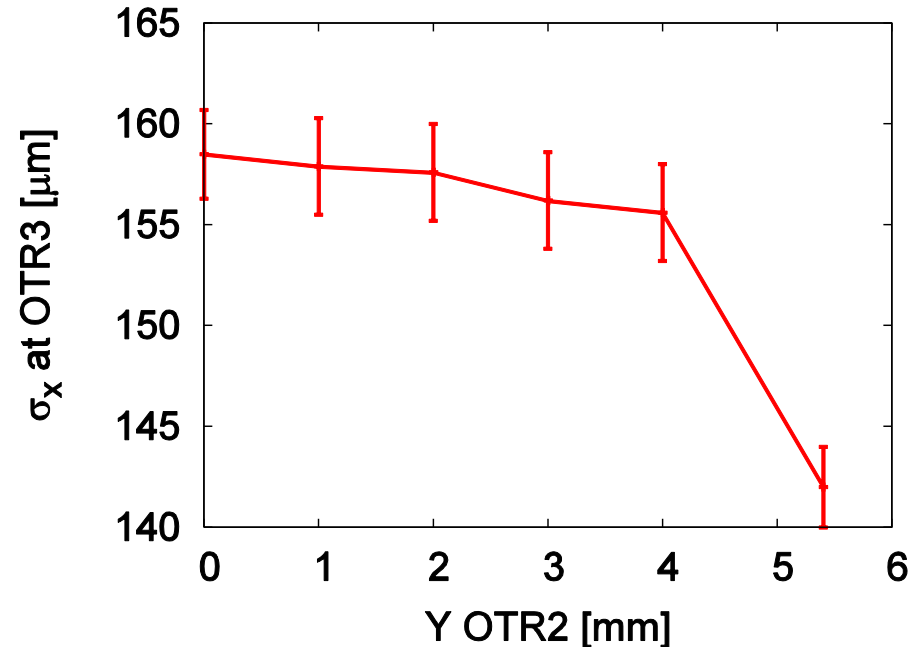
$$\begin{pmatrix} \sigma_{11} & \sigma_{12} & \sigma_{13} & \sigma_{14} \\ \sigma_{21} & \sigma_{22} & \sigma_{23} & \sigma_{24} \\ \sigma_{31} & \sigma_{32} & \sigma_{33} & \sigma_{34} \\ \sigma_{41} & \sigma_{42} & \sigma_{43} & \sigma_{44} \end{pmatrix}^d$$

$$\left. \begin{aligned} \sigma_{13}(I_1, I_2, I_3, I_4) &= 0 \\ \sigma_{14}(I_1, I_2, I_3, I_4) &= 0 \\ \sigma_{23}(I_1, I_2, I_3, I_4) &= 0 \\ \sigma_{24}(I_1, I_2, I_3, I_4) &= 0 \end{aligned} \right\}$$

Emittance growth due to wakefields in OTRs



Emittance growth due to wakefields in OTRs



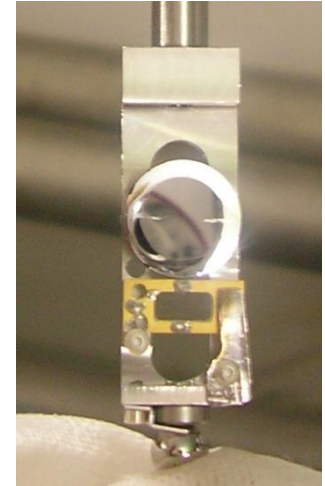
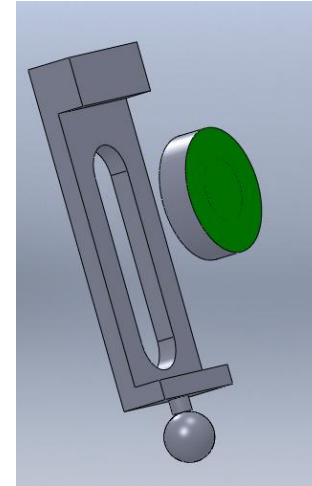
Changing vertical position of the OTR2 body from 6 mm [non OTR position] to measure mode position (0 mm) in steps of 1 mm. Then, recording beam size at OTR3.

From ~ 4 mm down the effect is clear

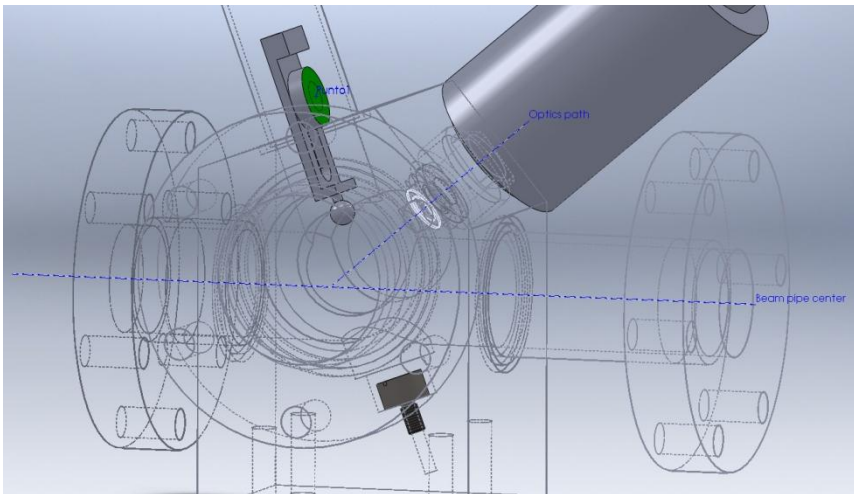
10% sigma growth (20% emitt growth)

Current target holder

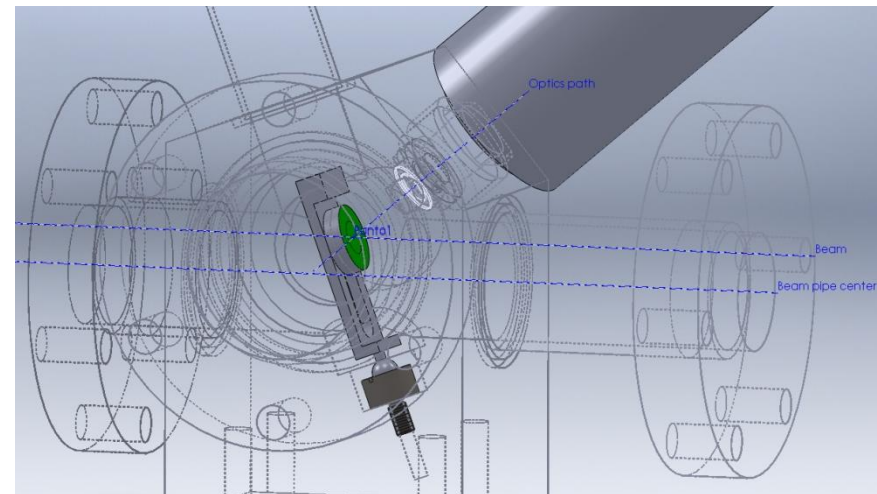
- The target is fixed to the holder by a screw in the back.
- It places the target about 7mm from the center of the beam pipe when it is inserted.
- The beam is in the center of the beam pipe when the OTR is in not measuring position (not lowered).



Target out

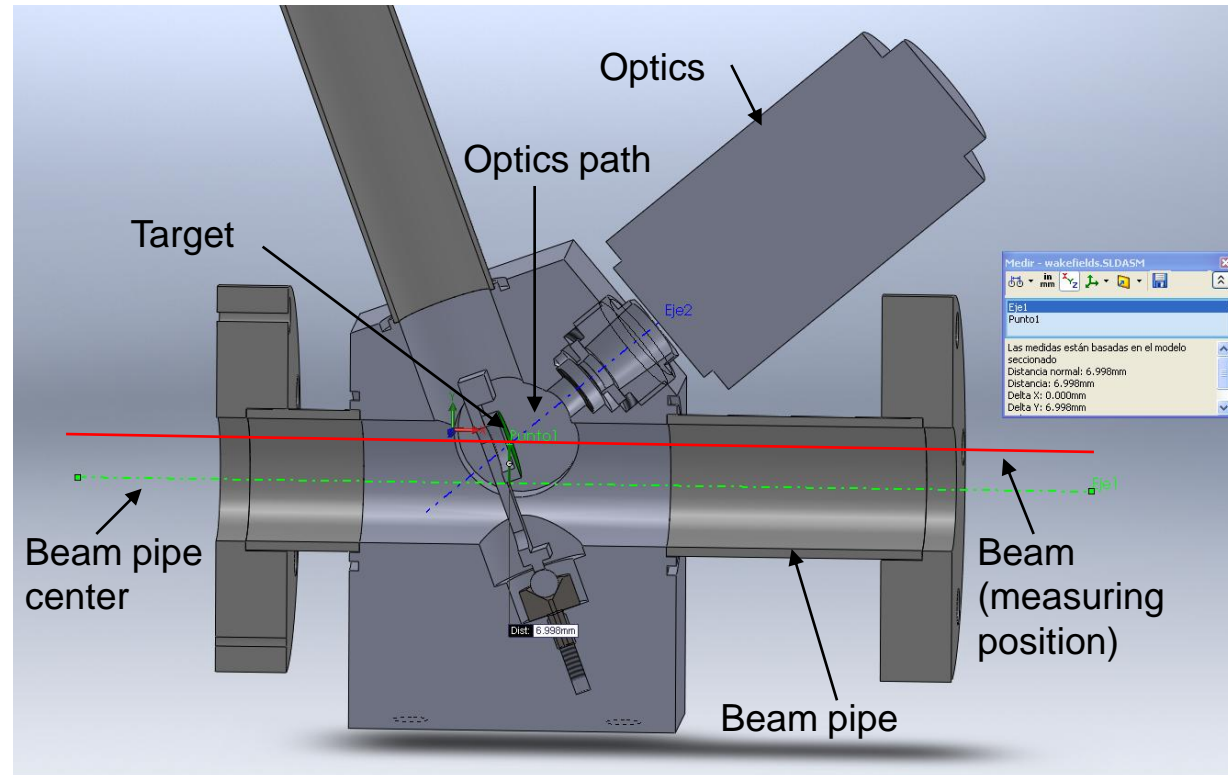


Target inserted



Current target position

- When OTR is not measuring the beam is in the beam pipe center.
- To make the beam intercept with the target, the OTR must be lowered by 7 mm. to measure (measure position).
- Beam pipe ID = 22 mm.
- Due to this, the beam goes close to the beam pipe edge (aprox. 4mm) when the OTR is in the measuring configuration causing wakefield effects.

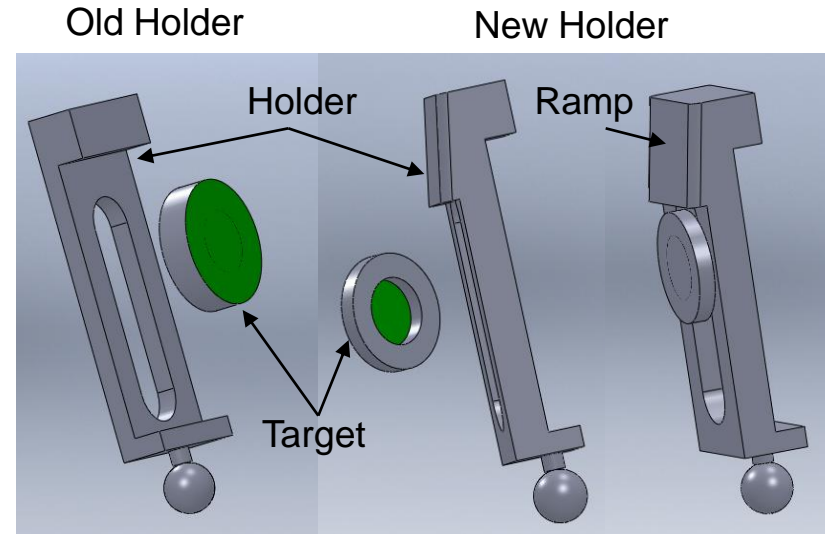


-To avoid this effect, the center of the target when it is inserted must be placed closer to the center of the beam pipe, but keeping in the way of the optics path to move the target towards downstream and down.

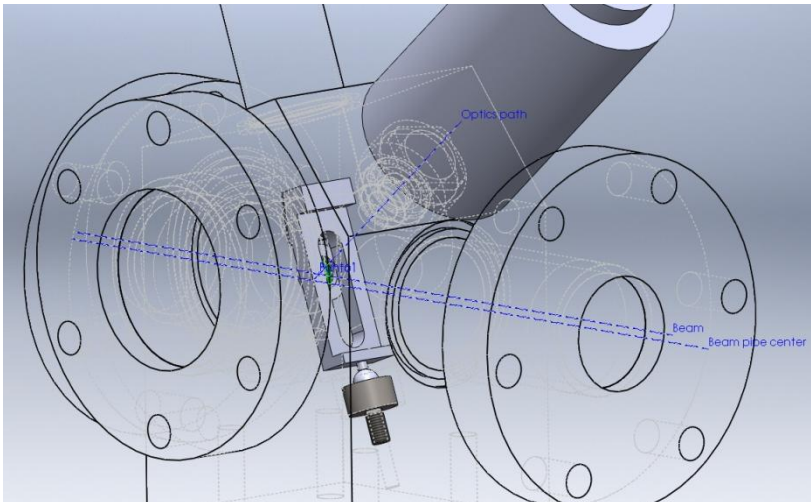
-A new design of the target and target holder is proposed in order to get the target in that position.

New target holder

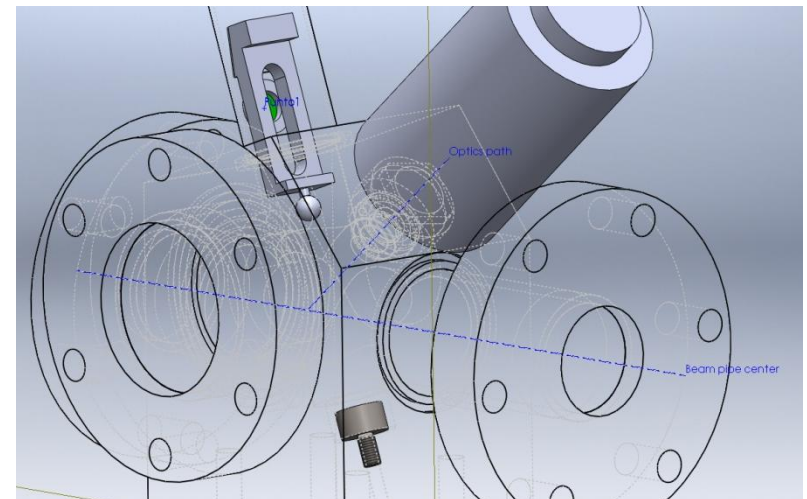
- To move the target down and downstream may cause the actuator pipe interfere with the target when it is withdrawn.
- To avoid this a special design of the target holder is needed.
- The new holder has a ramp to guide it inside the actuator pipe and avoid the interference between them.
- The target is flipped over so the aluminized face will be now in the opposite side, like this the center of the measuring surface gets lower.



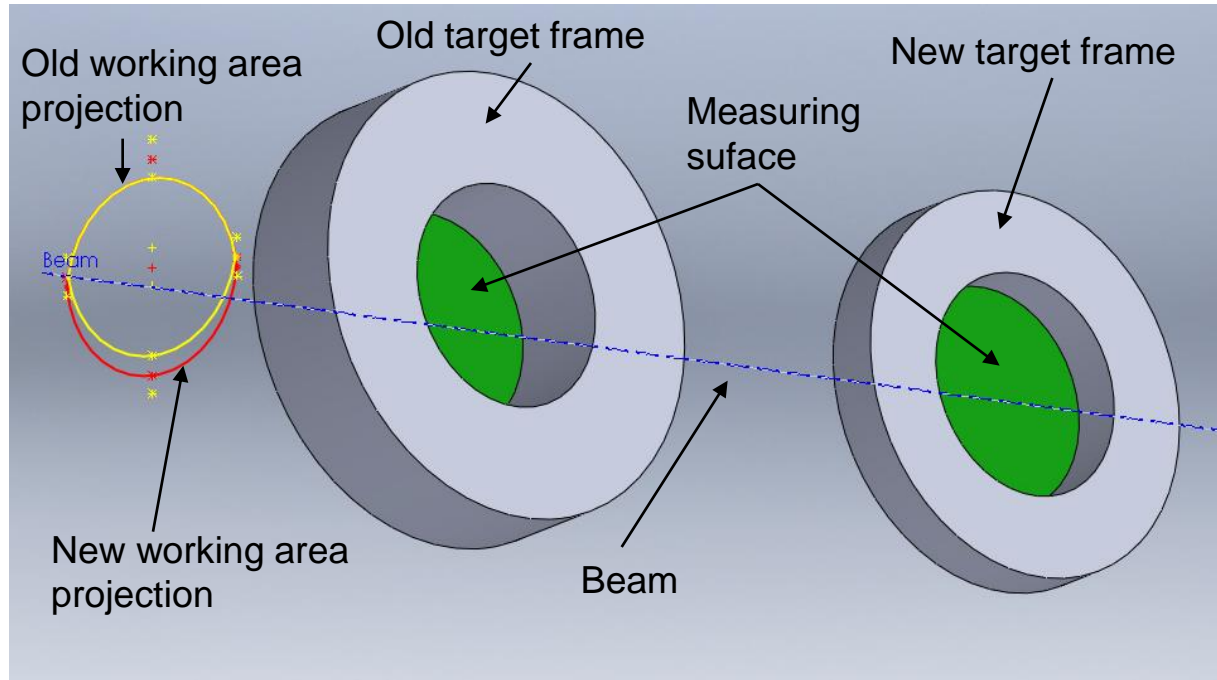
Target out



Target inserted



New target



-The target is flipped over so the aluminized surface (green face) is now on the rear face of the target frame.

-Due to this the frame of the target may cast “shadow” on the measuring surface reducing the working area.

- For this, **the thickness of new target will be reduced from 3.2mm to 1.5mm** by using a Stainless Steel washer as frame, increasing like this the working area.

New target position

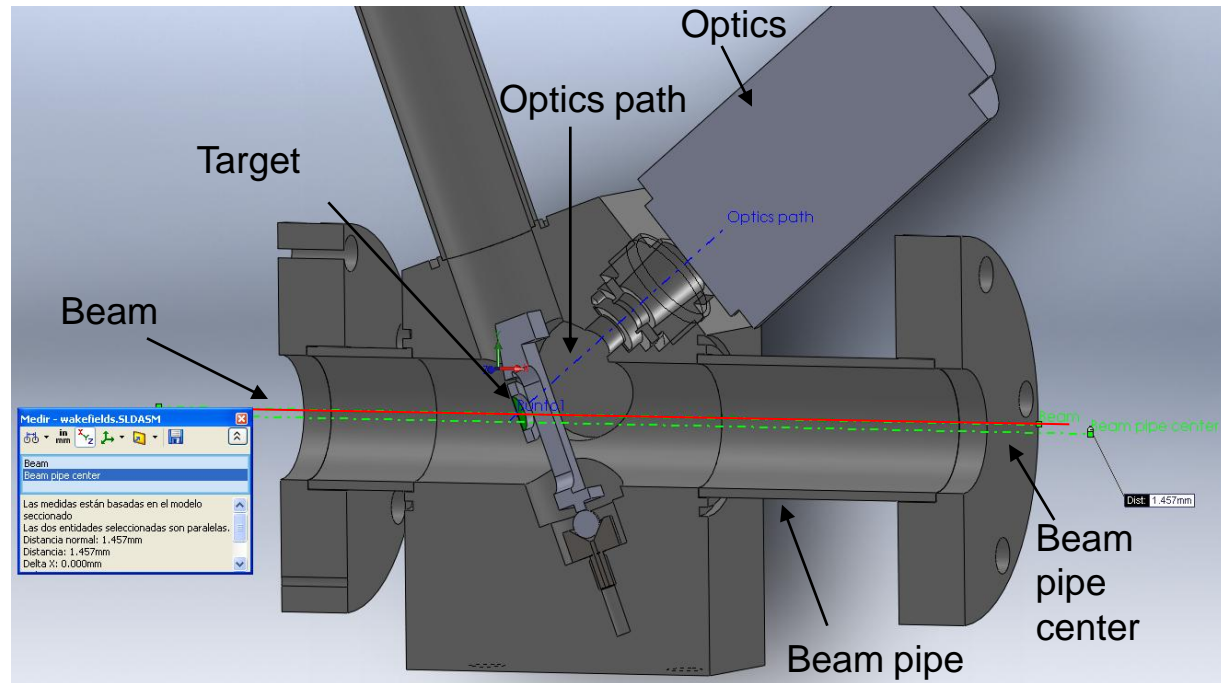
-The new holder places the target towards downstream and down.

-The center of the target is now 1.5mm from the center of the beam pipe.

-So with this set up the beam intercept the target just lowering the OTR by 1.5mm.

-In the measuring configuration the beam remains almost centered within the beam pipe and do not produce wakefield effects.

-Installation expected for Fall 2012



Thank you for the attention