Octupoles study for ultra-low β_y^* at ATF2

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OUTLINES

1 Low-β_y^* study motivations

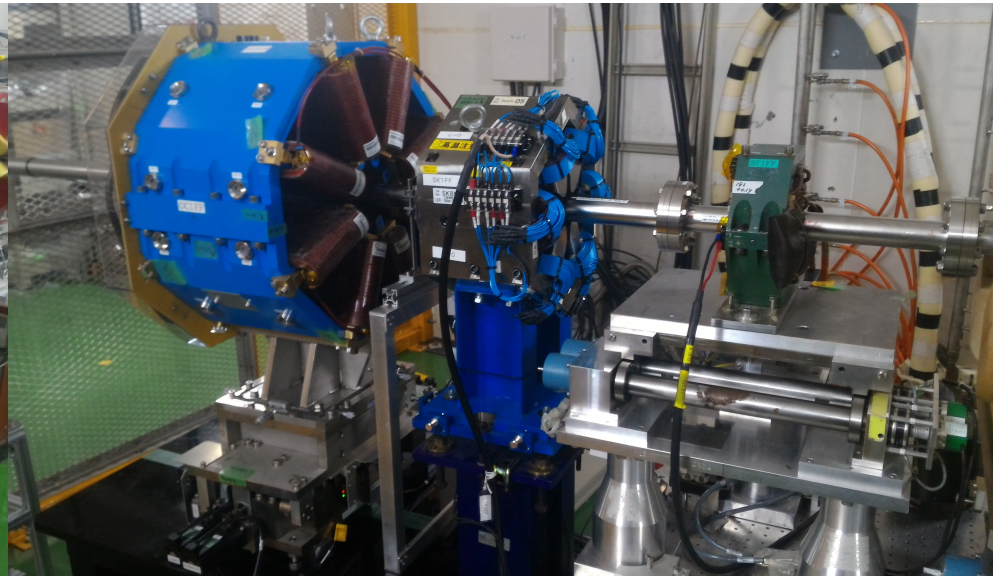
2 Octupole Beam Based Alignment

3 Octupole misalignment impact on tuning

4 Summary

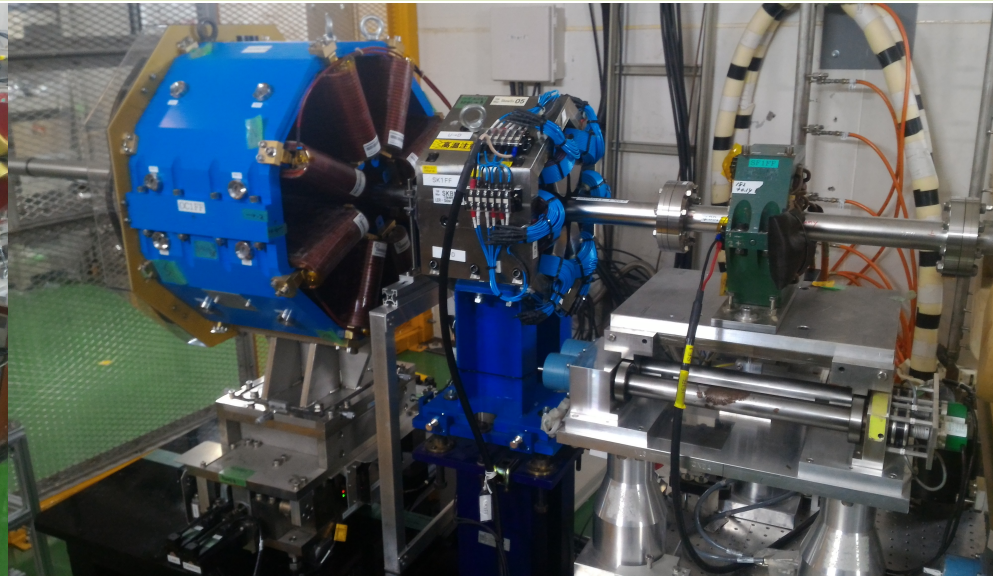
Low-β_y^* and octupoles study goals

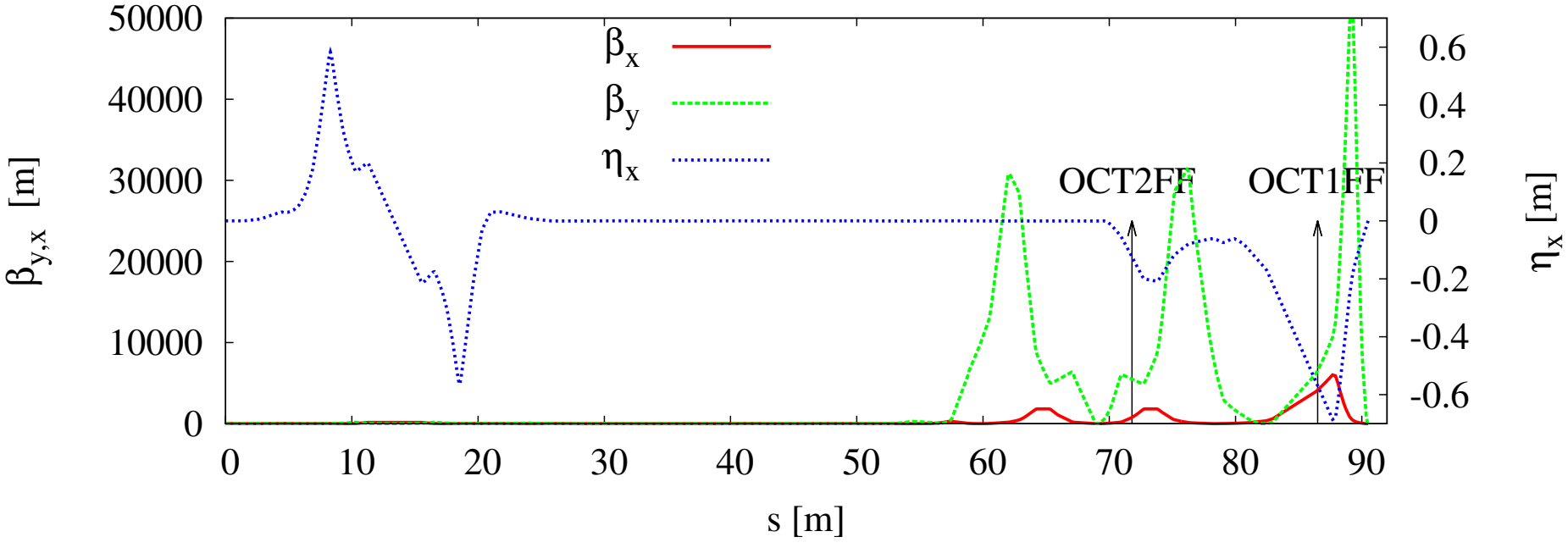
- ATF2 ultra-low β_y^* project aims to test a Final Focus System at the CLIC chromaticity level (≈5x higher than ILC)

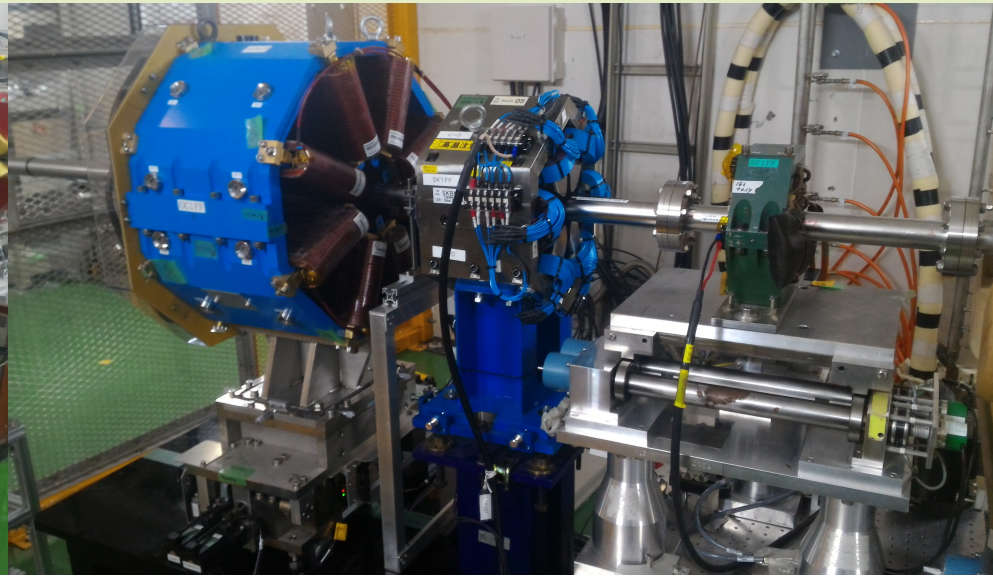
- **Octupoles installed in ATF2 FF line and first test in Jan 2017**
- Octupoles will be used to combat higher order aberrations of the ultra-low β_y^* optic and bring down σ_y^* from 29 to 20 nm
- also be used as nonlinear knobs for tuning at nominal, half and ultra-low β_y^*

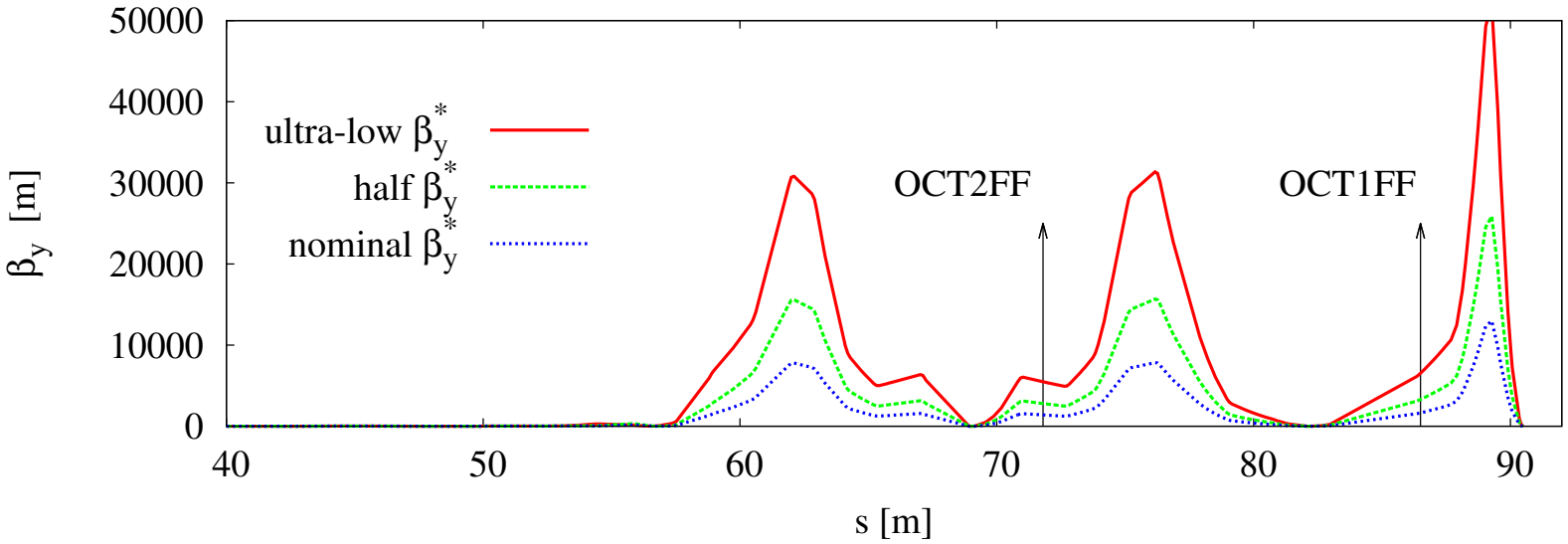
Low-β_y^* and octupoles study goals





Low-β_y^* and octupoles study goals





- Decreasing β_y^* makes the FFS more sensitive to beam line imperfections.
- Identify main limiting factors : **fringe field, multipolar errors, high order aberrations. wakefield or alianment**

Octupoles misalignment tolerances

All the multipolar components measured at CERN (detailed in Michele Modena's report on the octupoles) have been added to the model

R_{ref} = 20 mm	Average (units)
b_5	-0.93
a_5	-0.53
b_6	0.37
a_6	-0.41
b_7	-0.17
a_7	0.04
b_8	-0.02
a_8	-0.12
b_9	-0.01
a_9	0.01
b_{10}	0.01
a_{10}	0.01
b_{11}	0.02
a_{11}	-0.06
b_{12}	-0.27

R_{ref} = 20 mm	Units
b_5	2.20
a_5	-1.11
b_6	1.06
a_6	-0.35
b_7	-0.15
a_7	0.01
b_8	-0.04
a_8	-0.02
b_9	0.02
a_9	-0.03
b_{10}	0.02
a_{10}	0.00
b_{11}	0.00
a_{11}	0.01
b_{12}	-0.27

- Tolerances were recalculated :

Magnet	X (μm)	Y (μm)	ϕ (deg)
OCT1FF	130	23	$\approx$ 0.1
OCT2FF	250	90	0.9

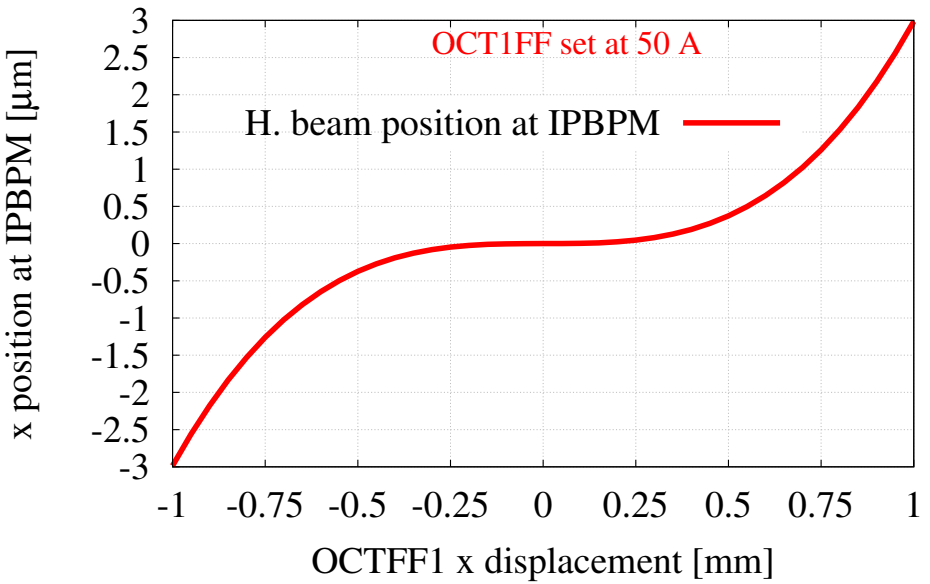
Tolerances reprensent a beam size increase of $\Delta\sigma_y^*$ = 2%

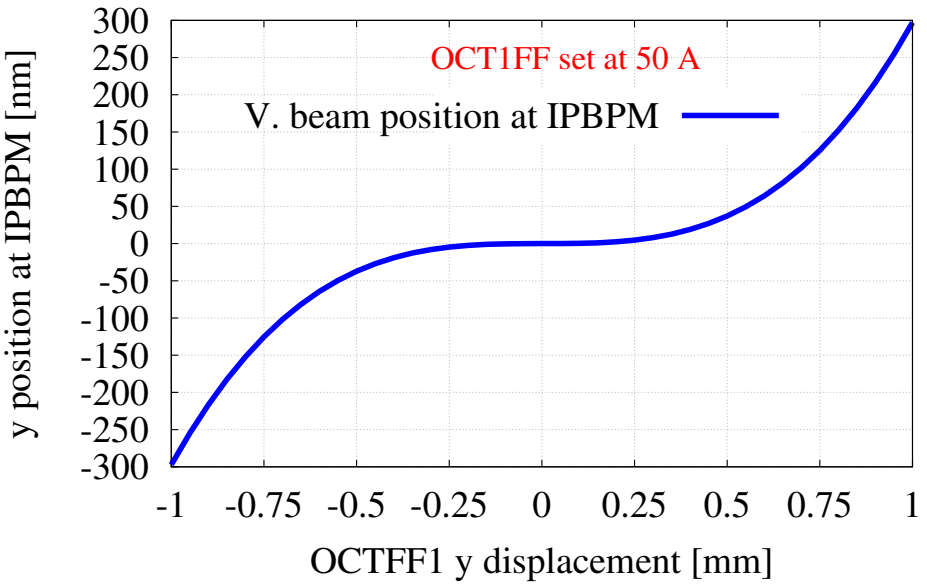
Before using octupoles for tuning one has to BBA them using IPBPM (for OCT1FF) and BPMs downstream of OCT2FF

OCT1FF BBA using IPBPM

OCT2FF ⇒max strength, furthest from IP ⇒ current = 50 (A) / G = 1302.2 (T/m^3)

OCT1FF ⇒max strength, closest from IP ⇒ current = 50 (A) / G = 10556.7 (T/m^3)



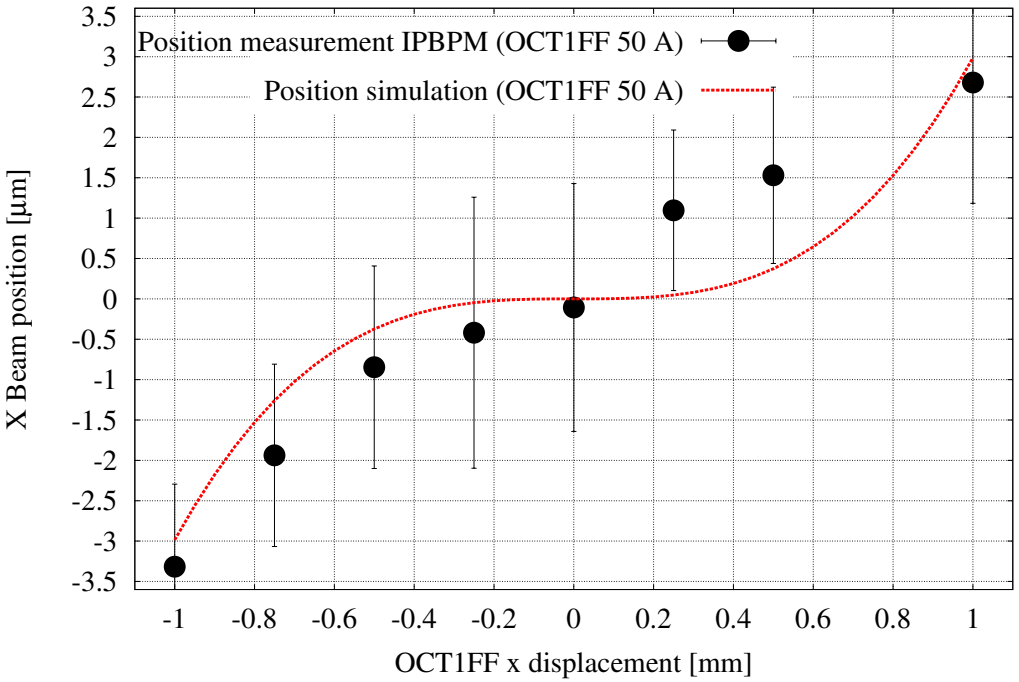


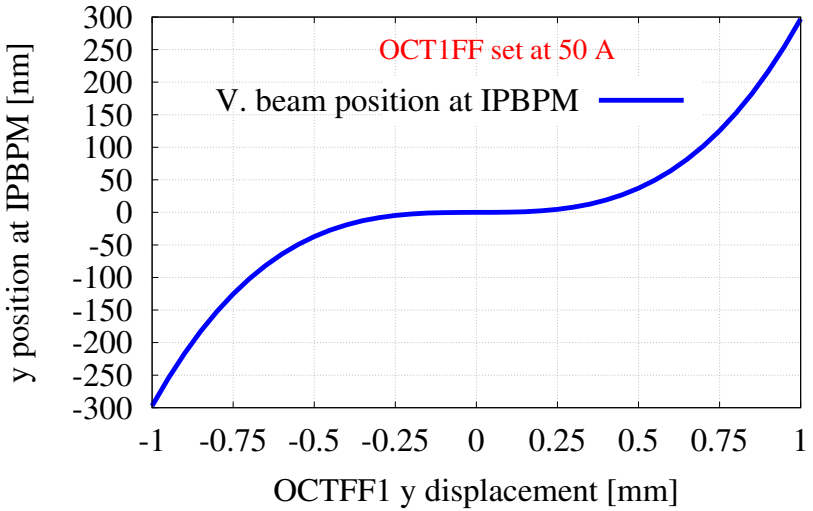
- Movers range is ± 1 mm
- In January operation the IPBPM resolution was around 1μm which was enough to observe the horizontal position shift due to horizontal displacement of OCT1FF but not for the vertical plane

OCT1FF BBA using IPBPM

OCT2FF $\Rightarrow$max strength, furthest from IP $\Rightarrow$ current = 50 (A) / G = 1302.2 (T/m^3)

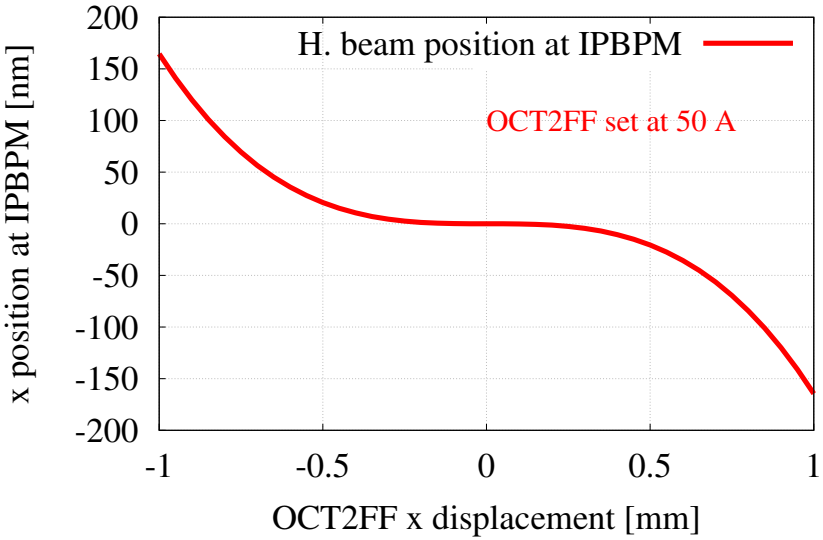
OCT1FF $\Rightarrow$max strength, closest from IP $\Rightarrow$ current = 50 (A) / G = 10556.7 (T/m^3)

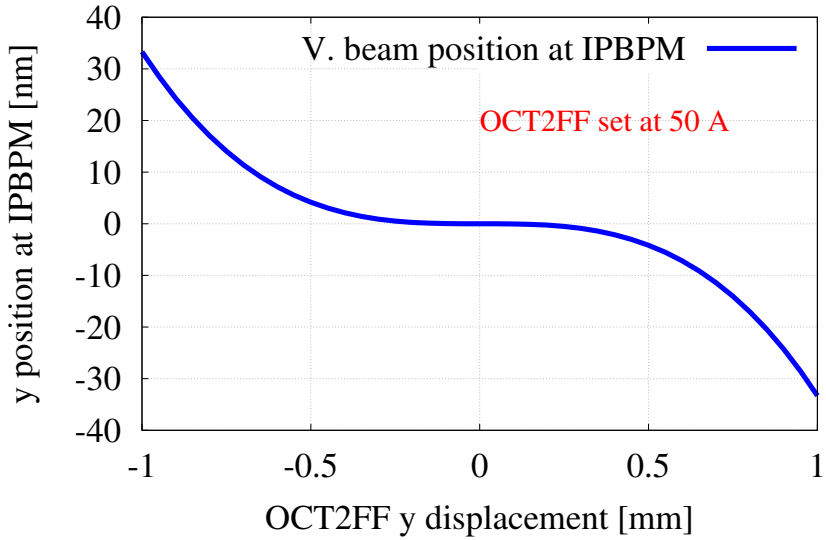


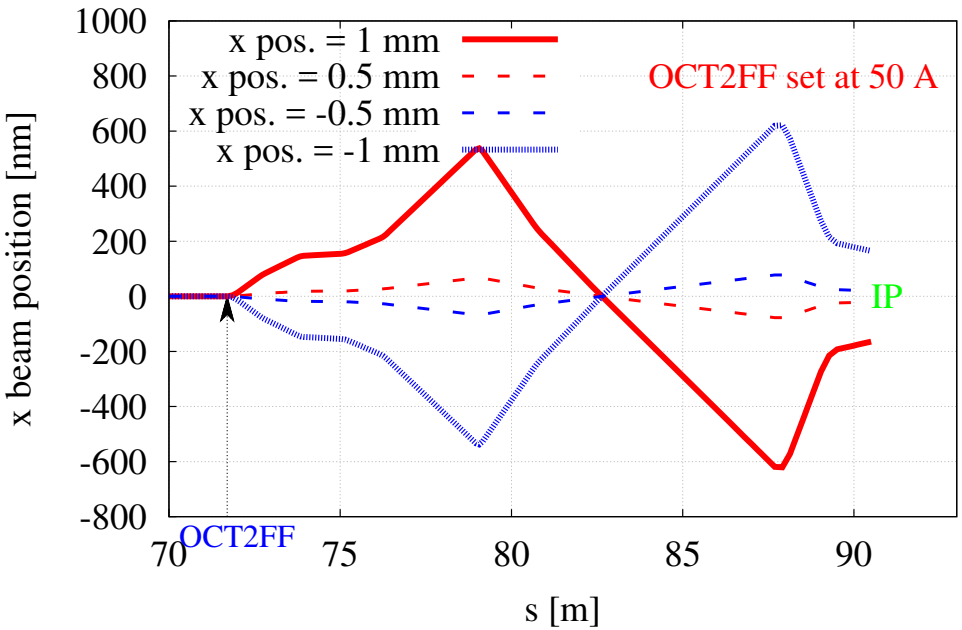


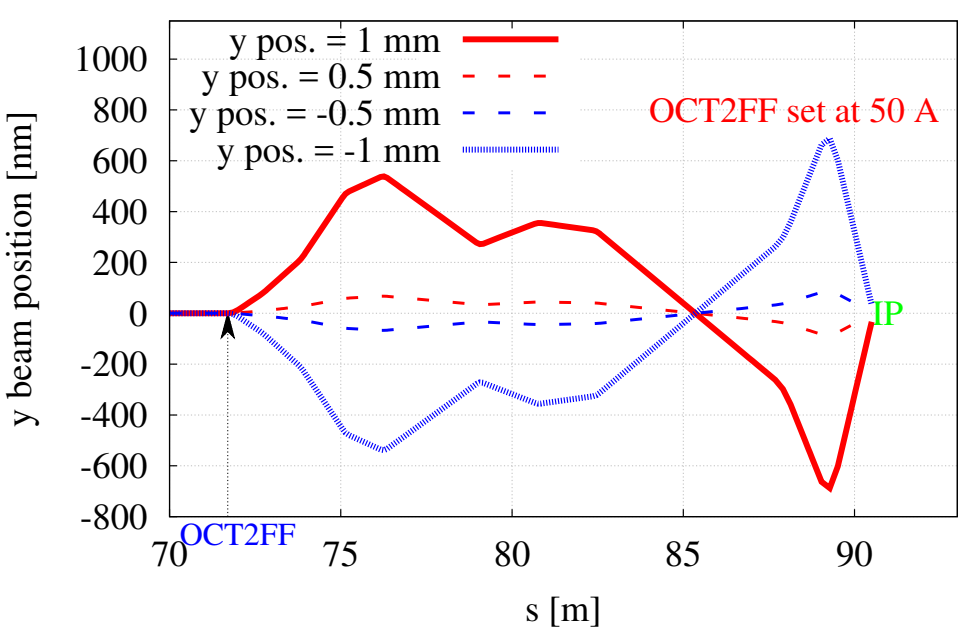
- In January operation the IPBPM resolution was around 1μm which was enough to observe the horizontal position shift due to horizontal displacement of OCT1FF but not for the vertical plane
- **Significant progress from the FONT group have been done on IPBPM resolution in February operation making the BBA of OCT1FF vertical plane feasible for next runs**

OCT2FF BBA using IPBPM or downstream BPMs

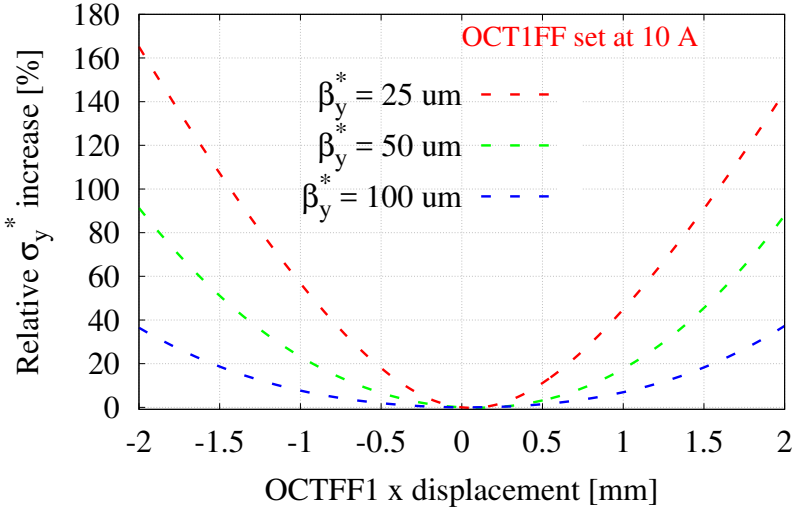


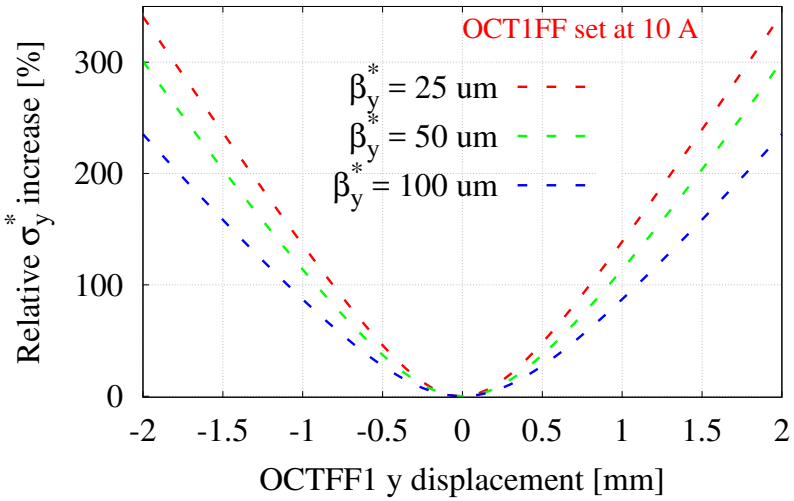


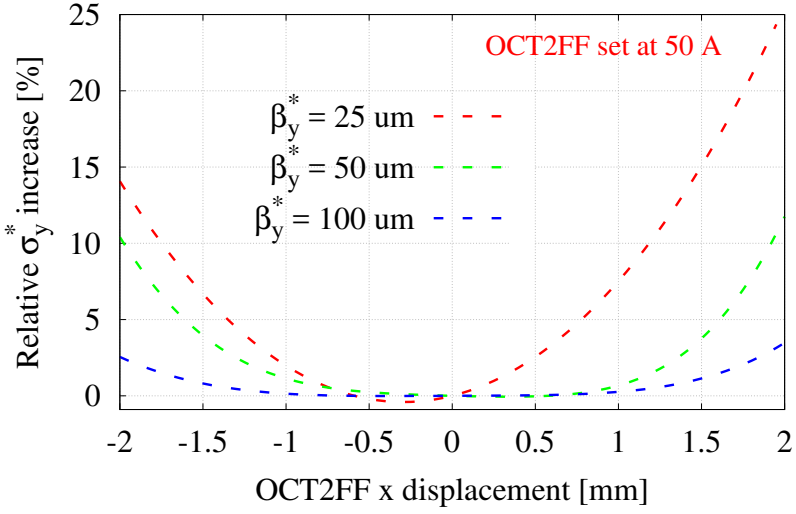


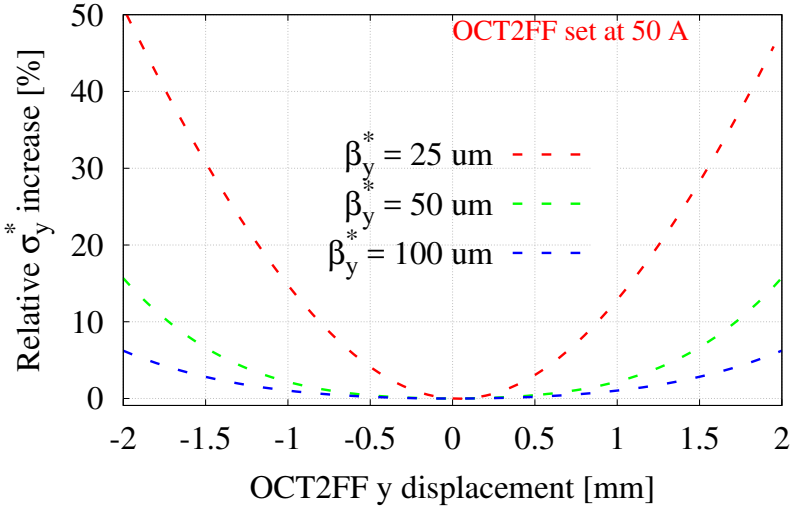


OCT1FF and OCT2FF BBA using IPBSM









Problem : In real machine one has to differentiate σ_y^* reduction from centering of the magnet and σ_y^* reduction from 2^{nd} order aberrations correction produced by octupoles transverse displacement.

$\Rightarrow$ Perform BBA on well tuned optics (Takes many shifts)

$\Rightarrow$ BBA with rotated octupoles (need to control rotation)

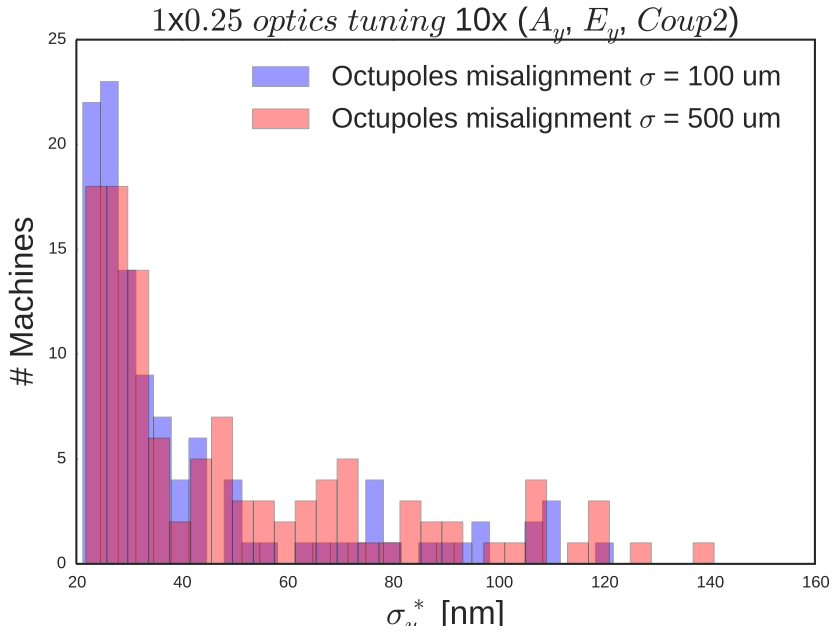
Tuning 1x0.25 optics : Octupole misalignment impact on performa

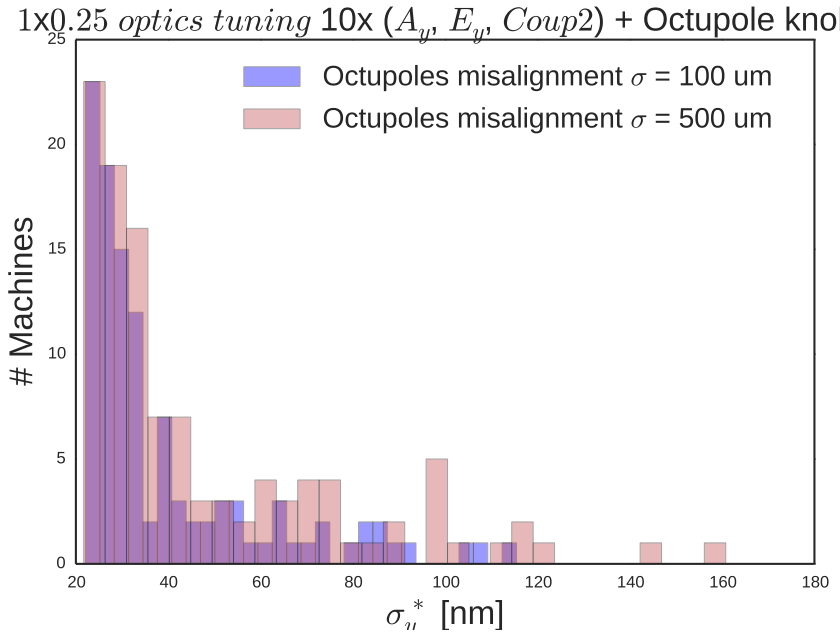
What is the impact on tuning of larger misalignment of the octupoles ?

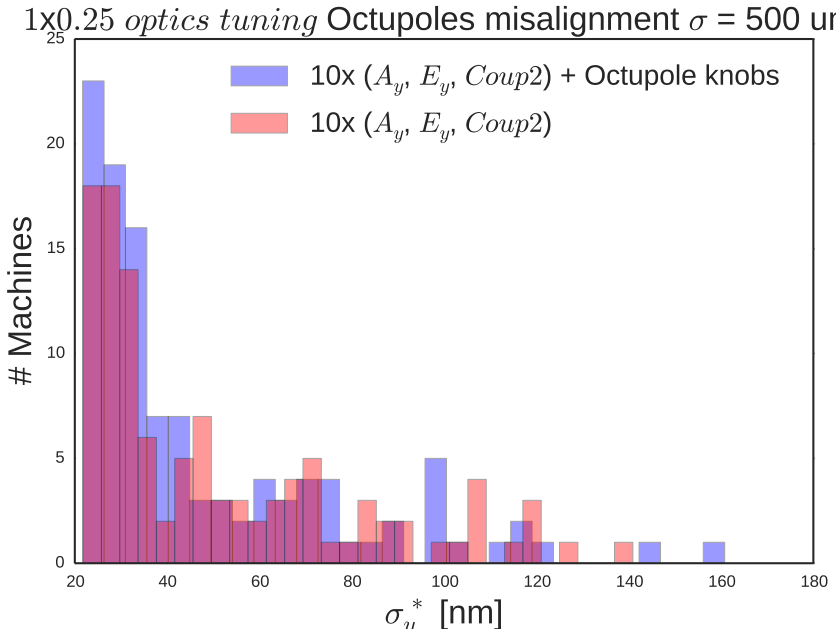
Can nonlinear knobs using transverse displacement of the octupoles can recover the beam size ?

Tuning comparison was performed between Octupoles misalignment of σ = 100μ and σ = 500μ with and without transverse displacement of the octupoles

Tuning 1x0.25 optics : Octupole mis. impact on performances







Oct. $\sigma_{mis.}$	Linear	Linear + Oct. knobs
100 μm	42 $\pm$ 14.5 nm	39 $\pm$ 10.5 nm
500 μm	50.5 $\pm$ 15 nm	47.4 $\pm$ 14.3 nm

- 5 iterations of octupole transverse displacements were applied (2nd order knobs) after 10 set of linear knobs
- The number of knob scans feasible within 3 shifts

Tuning measurement plan for future runs

- Octupoles impact on tuning simulation is in the order of **several nanometers**
- Such beam size reduction will be **visible only by using the Shintake monitor at 174 degree mode** $\Rightarrow$ beam should be well tuned down to at least 70 nm to start using Octupole knobs and see their impact on σ_y^*
- During January and February operations beam time dedicated to ultra-low β_y^* study was too short to be able to squeeze the beam below the required beam size to use the IPBSM at 174 degree mode
- **In order to prove the efficiency of the new octupoles, more beam time dedicated to ultra-low β_y^* optics tuning is required**

Summary

- New pair of octupoles were installed and are ready to be use for beam tuning
- The small position kick at the IP when octupoles are moved in horizontal and vertical plane make the Beam Based Alignment difficult to perform
- Thanks to the new progress made by the FONT group on the IPBPM resolution in February operation, BBA of OCT1FF in both plane and OCT2FF in horizontal plane should be possible in the next operations
- Over misalignment of the octupoles impact quite strongly the tuning performance but the impact can be reduce by applying octupole knobs
- Beam size reduction thanks to the octupoles will be visible with the IPBSM if the beam is already well tuned
- The demonstration of octupole efficiency can only be done if enough beam tuning time is allocated to low-β_y^* study