Status and plans for the ATF2 ultra-low β_y^* optics

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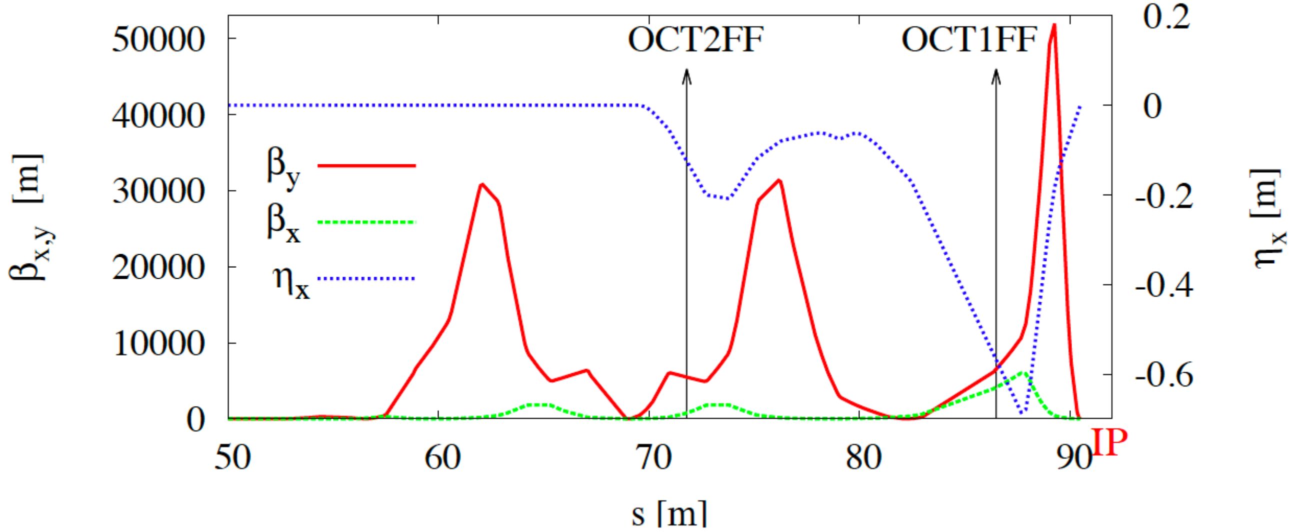
Outline

- Summary of December 2017 Machine Tuning with ultra-low β_y^* optics
- Summary of February 2018 Machine Tuning with ultra-low β_y^* optics
- Summary of May-June 2018 run
- Plans for November and December 2018 beam operations
- Conclusions

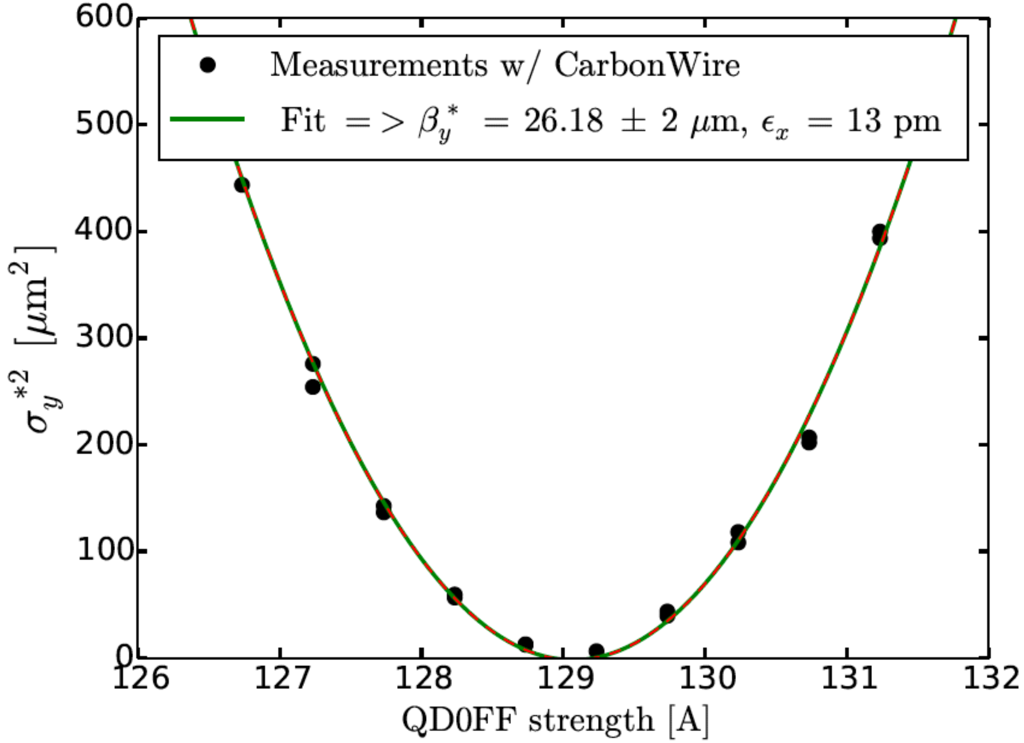
Summary of December 2017 Machine Tuning with ultra-low β_y^* optics

- The goal of the ultra-low β_y^* optics tuning at ATF2 is to demonstrate the feasibility of the Local scheme FFS at chromaticity ξ_y level comparable to CLIC
- In December 2017 operation was the first long tuning attempt using ultra-low β_y^* optics (β_y^* = 25 µm) at ATF2
- The FFS was running with a target of β_x^* = 100 mm ($25\beta_x^*$ x $0.25\beta_y^*$ optics) in order to reduce the impact of multipole error fields and to ease the tuning
- The ultra-low β_y^* optics requires the use of octupoles to reduce σ_y^* down to 20 nm in design. The other goal of the ultra-low β_y^* study is to quantify the benefit on the beam size of using the new pair of octupoles installed at ATF2



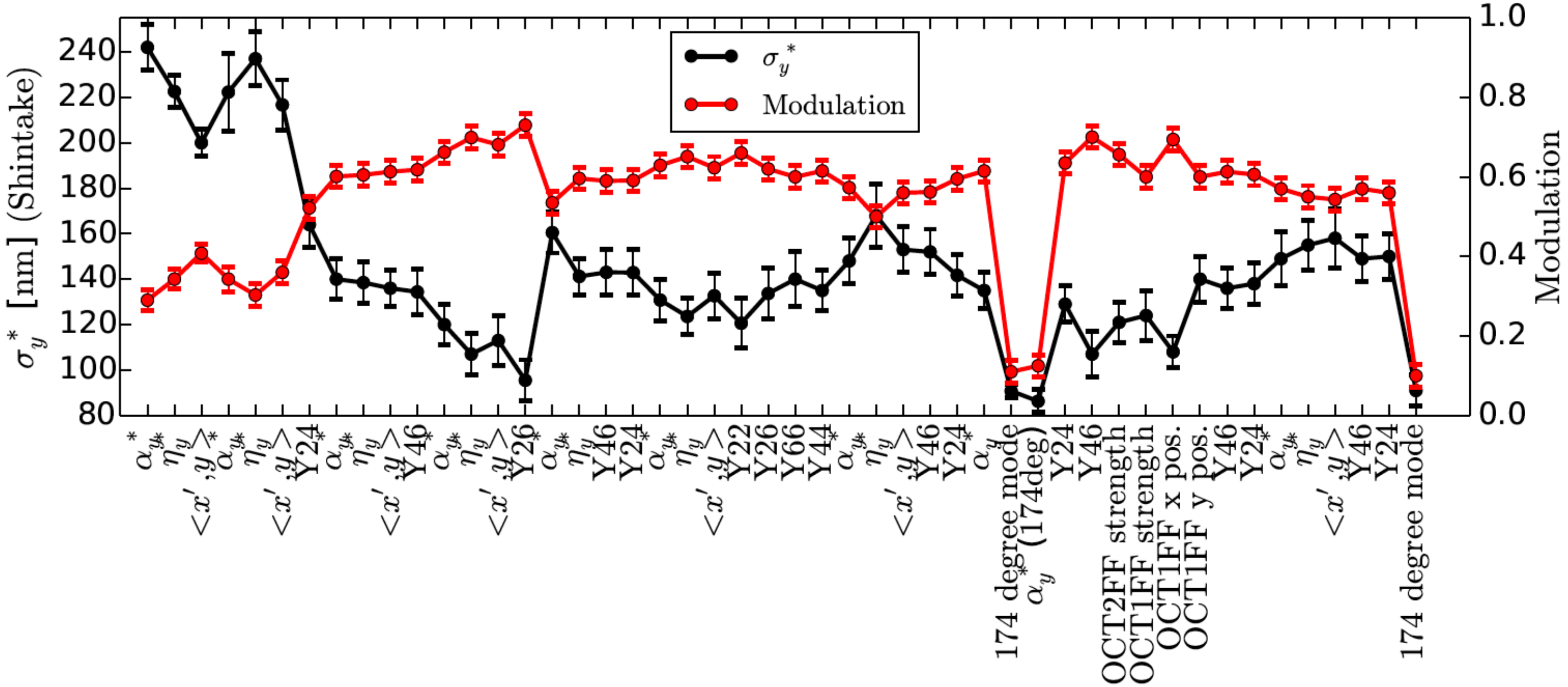
Summary of December 2017 Machine Tuning with ultra-low β_y^* optics

- The $25\beta_x^*$ x $0.25\beta_y^*$ optics was applied → rematch the optics by varying QF21x, QD20x (EXT line) and the matching quads (QM16FF → QM11FF)
- The assumed vertical emittance was ϵ_y = 13 pm as measured in the DR (no multi-OTR was available) → β_y^* was well matched to approximately 25 µm
- β_x^* was measured of 85 mm but a fitted ϵ_x^* twice the design value indicating that the scan was biased by large horizontal dispersion at the IP
- The measured η_x^* was around 34 mm → β_x^* was smaller than measured



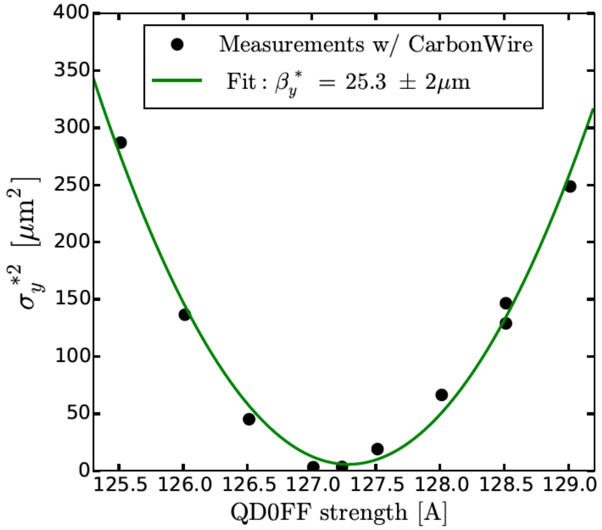
Summary of December 2017 Machine Tuning with ultra-low β_y^* optics

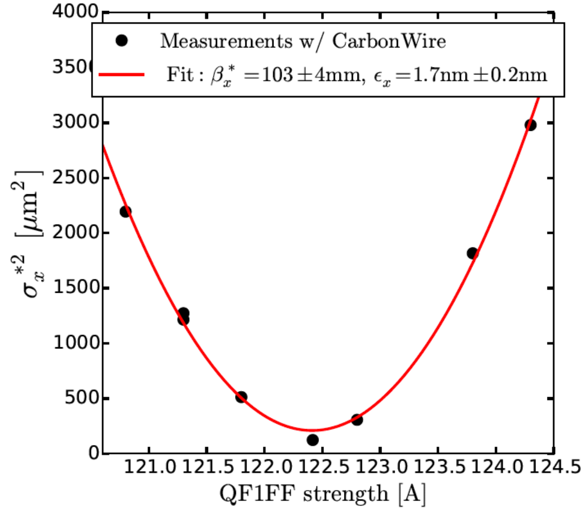
- Linear and Nonlinear knobs were applied iteratively and sextupoles strength changed according to the ultra-low β_y^* optics model
- After 5 shifts (5 x 8 hours) of tuning, no clear modulation was found at 174 degree mode
- The beam size could not be tuned below ≈**100 nm**
- It is difficult to observe the impact of the octupoles at 30 degree mode while it was not possible to tune the beam at 174 degree mode as the modulation was close to the noise level (M~0.1)



Summary of February 2018 Machine Tuning with ultra-low β_y^* optics

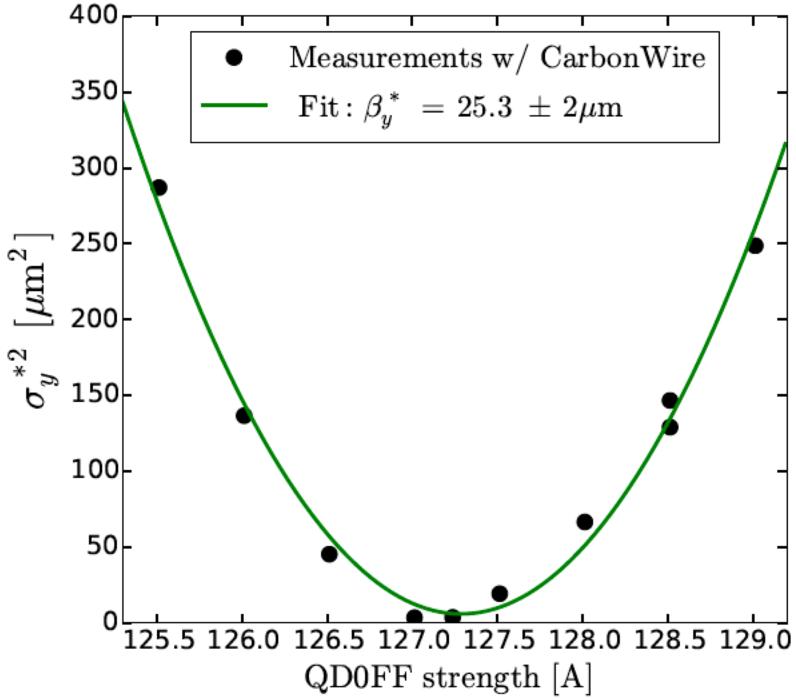
- For the second attempt the $25\beta_x^*$ x $0.25\beta_y^*$ optics was rematched in simulation before the run
- The sextupoles were re-optimized for the new optics
- Smaller β_y^* target (15µm) was needed to measure β_y^* of ~ 25µm but β_x^* was very consistent with the optics model and matched directly ~ 100 mm
- Residual dispersion was corrected from the fit of the quad scans → the measured η_x^* was around 3 mm

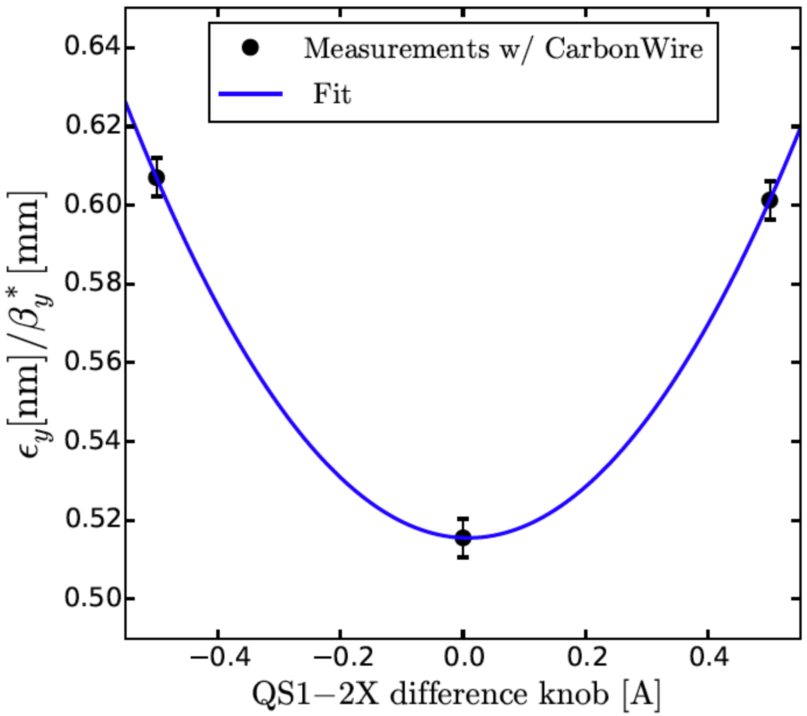




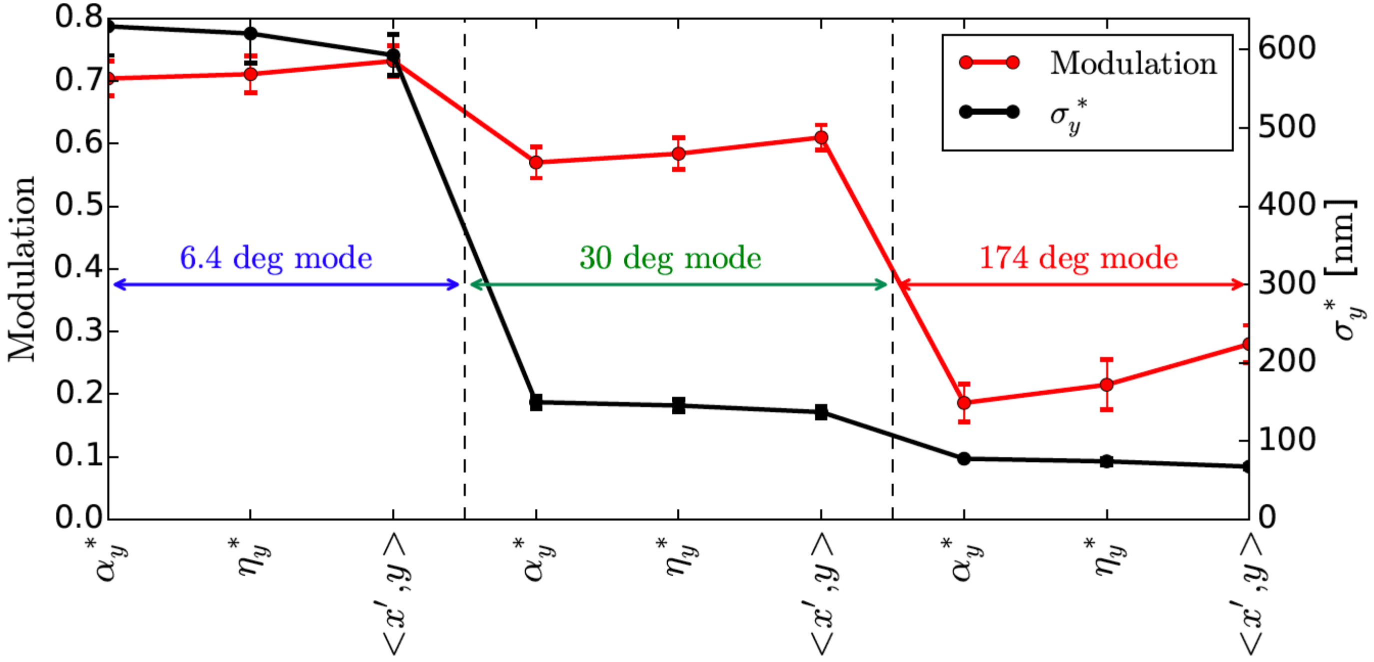
Summary of February 2018 Machine Tuning with ultra-low β_y^* optics

- In order to check that the QD0FF scan was not bias by <x,y> coupling which would lead to an overestimation of the measured divergence, a quick scan of the QS1X-QS2X difference knob was performed



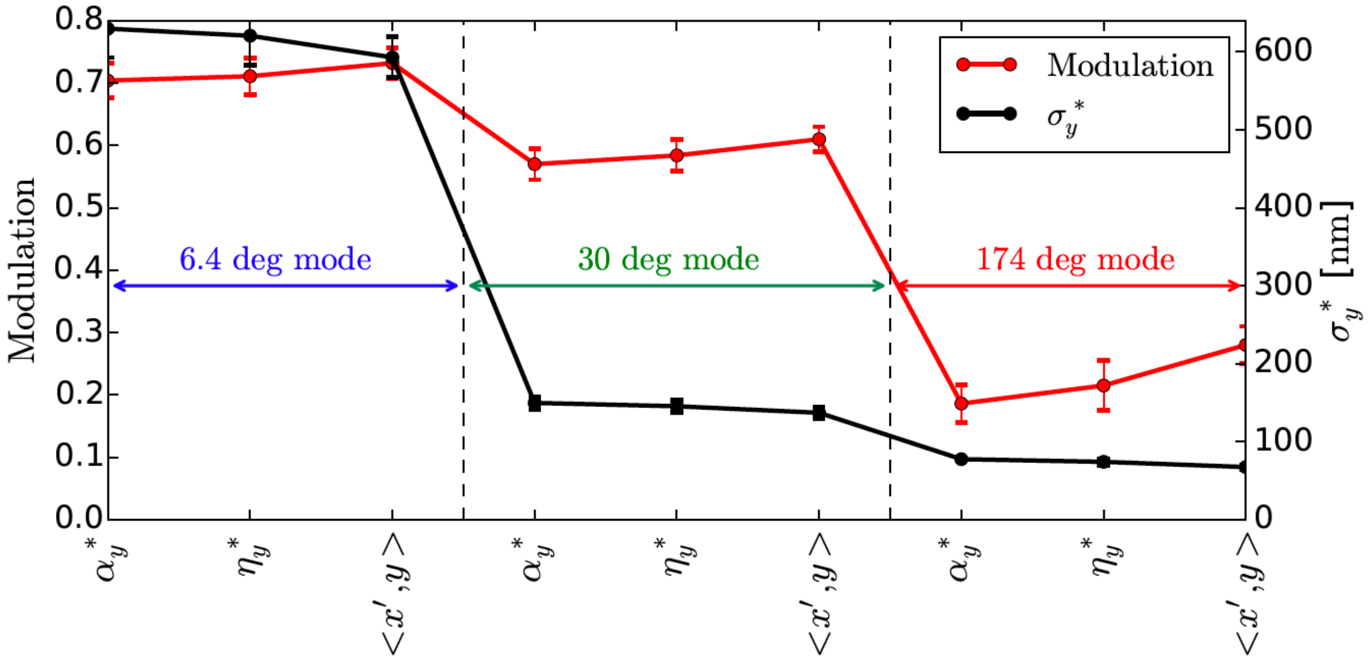


Summary of February 2018 Machine Tuning with ultra-low β_y^* optics



- Tuning time reduced compared to Dec17 run due to multiple reasons: long correction of the very large background generated from the larger beam size along the FF; rematch of the Shintake laser tuning and of the optics that was also retuned after 4 shifts → QF1FF strength was not reset to its original value leading to a large increase of β_x^*

Summary of February 2018 Machine Tuning with ultra-low β_y^* optics



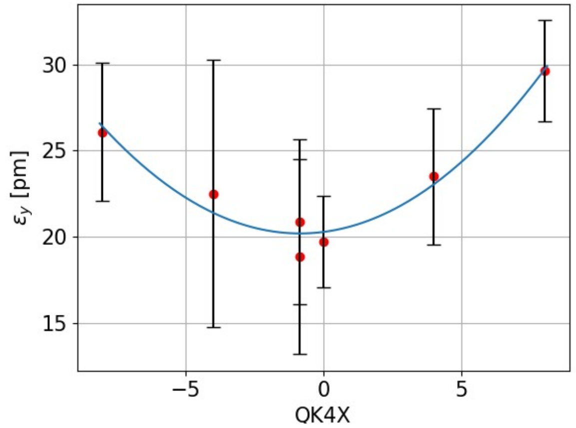
- Despite the shorter tuning time and without applying 2nd order sextupole knobs or octupoles, the beam size could be squeezed rapidly and modulation could be observed at 174 degree mode
- The minimum beam size measured at 174 degree mode was **σ_y^*= 64 ± 2 nm** by applying only linear knobs → **improved optics and performance compared to Dec17 operation**

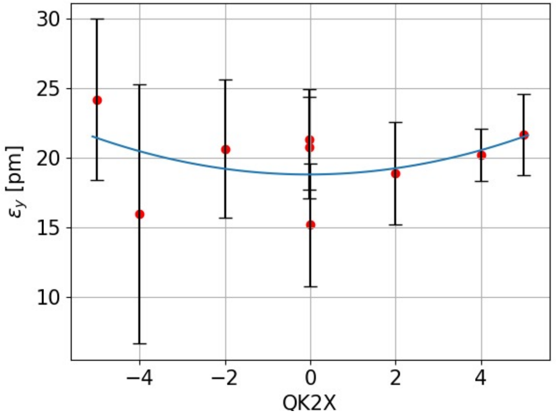
Summary of May-June 2018 run

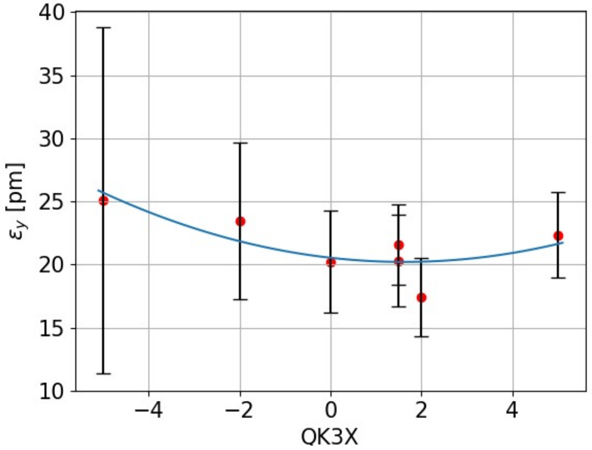
- During December 2017 and February 2018 runs the biggest problem was the not availability of the multi-OTR
- During May 2018 beam operations, the multi-OTR was ready to operate again
- Loading of the same optics used in February 2018 but with the advantage of measuring the emittance → the time allocated for the ultra-low β_y^* study was too little to perform a complete machine tuning
- The results only include the emittance measurements with multi-OTR → preparation for next winter beam operations
- Before moving to the multi-OTR emittance measurements, the orbit was corrected and the dispersion was reduced in the OTRs region to $\pm$ 10mm in the vertical plane
- The emittance measured was 23 $\pm$ 4 pm → to reduce this value we proceeded with the <x,y> coupling correction

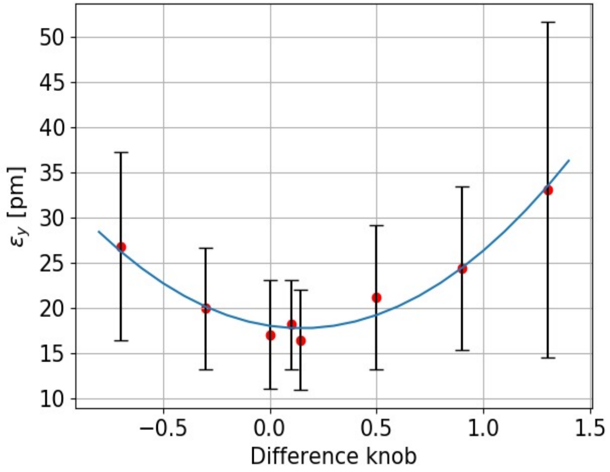
Summary of May-June 2018 run

- The <x,y> coupling correction is performed by scanning the strength of four skew quadrupoles (QK1X, QK2X, QK3X and QK4X) in the extraction line and by applying the Δ-knob with the vertical emittance measured by the multi-OTR system being a figure of merit



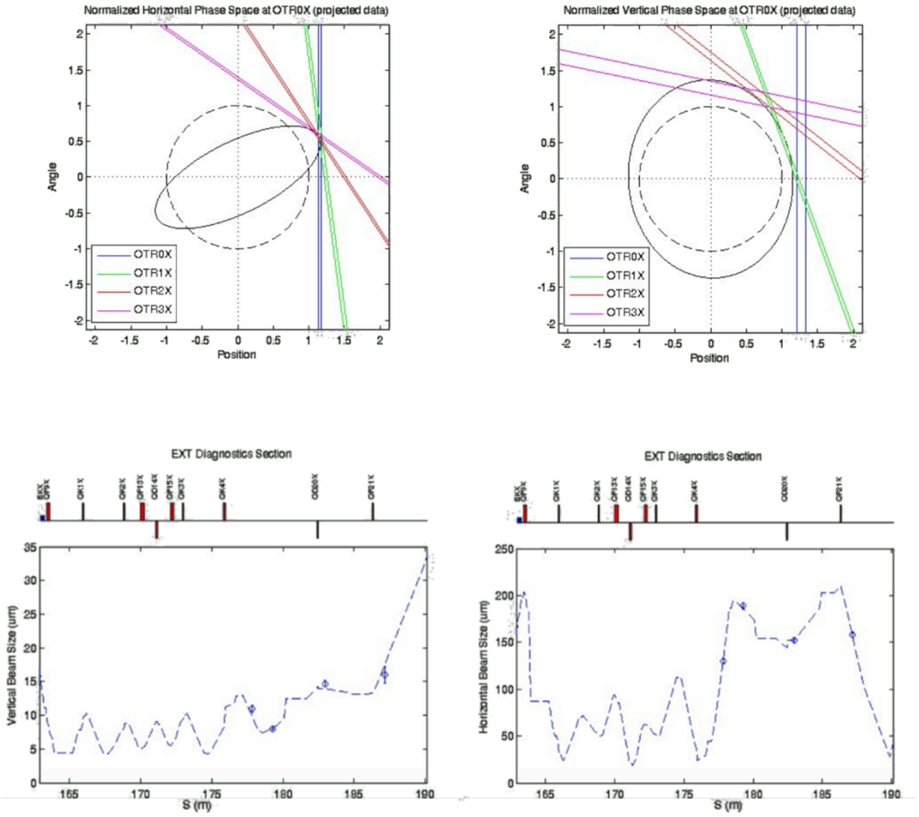


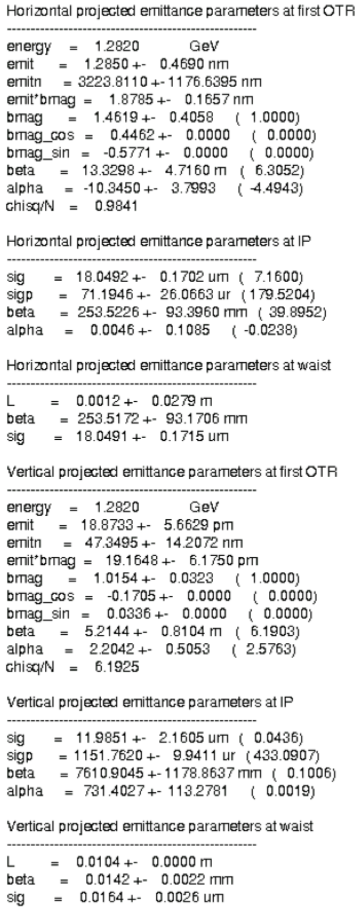




Summary of May-June 2018 run

- The value of the emittance at the entrance of the FFS after the coupling correction was **19 ± 6 pm**





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Horizontal projected emittance parameters at first OTR
----------------------------------------------------------
energy    =   1.2820          GeV
emit      =   1.2850 +-   0.4690 nm
emitn     = 3223.8110 +- 1176.6395 nm
emit*bmag =   1.8785 +-   0.1657 nm
bmag      =   1.4619 +-   0.4058    (  1.0000)
bmag_cos  =   0.4462 +-   0.0000    (  0.0000)
bmag_sin  =  -0.5771 +-   0.0000    (  0.0000)
beta      =  13.3298 +-   4.7160 m  (  6.3052)
alpha     = -10.3450 +-   3.7993    ( -4.4943)
chisq/N   =   0.9841

Horizontal projected emittance parameters at IP
----------------------------------------------------------
sig       =  18.0492 +-   0.1702 um (  7.1600)
sigp      =  71.1946 +-  26.0663 ur ( 179.5204)
beta      = 253.5226 +-  93.3960 mm (  39.8952)
alpha     =   0.0046 +-   0.1085    ( -0.0238)

Horizontal projected emittance parameters at waist
----------------------------------------------------------
L         =   0.0012 +-   0.0279 m
beta      = 253.5172 +-  93.1706 mm
sig       =  18.0491 +-   0.1715 um

Vertical projected emittance parameters at first OTR
----------------------------------------------------------
energy    =   1.2820          GeV
emit      =  18.8733 +-   5.6629 pm
emitn     =  47.3495 +-  14.2072 nm
emit*bmag =  19.1648 +-   6.1750 pm
bmag      =   1.0154 +-   0.0323    (  1.0000)
bmag_cos  =  -0.1705 +-   0.0000    (  0.0000)
bmag_sin  =   0.0336 +-   0.0000    (  0.0000)
beta      =   5.2144 +-   0.8104 m  (  6.1903)
alpha     =   2.2042 +-   0.5053    (  2.5763)
chisq/N   =   6.1925

Vertical projected emittance parameters at IP
----------------------------------------------------------
sig       =  11.9851 +-   2.1605 um (  0.0436)
sigp      = 1151.7620 +-   9.9411 ur ( 433.0907)
beta      = 7610.9045 +- 1178.8637 mm (  0.1006)
alpha     = 731.4027 +- 113.2781    (  0.0019)

Vertical projected emittance parameters at waist
----------------------------------------------------------
L         =   0.0104 +-   0.0000 m
beta      =   0.0142 +-   0.0022 mm
sig       =   0.0164 +-   0.0026 um
```

Plans for November and December 2018 beam operations

- Load $25\beta_x^*$ x $0.25\beta_y^*$ optics used in February run
  → try to use the DFS for the ultra low β_y^* optics

- Use of the multi-OTR (?)
  → measure emittance and correct dispersion and couplings at the entrance of the FF line
  → multi-OTR will be used also for rematching the twiss parameters in the matching section

- Reduce the background level of the Shintake monitor
  → verification of the vertical collimator alignment + re-installation of the old collimator

- Tuning procedures
  → linear knobs, sextupole knobs, octupole tuning and intensity dependence measurements

Conclusions

- During the second tuning attempt of the $25\beta_x^*$ x $0.25\beta_y^*$ FF lattice, the performance of the system in terms of beam size achieved was improved despite the shorter tuning time and the fact that nonlinear knobs were applied

- These results highlight the supicions raised during the Dec17 operation about the applied optics

- The tuning performance of the updated lattice optimized for the February 2018 run could be further improved with the use of all the 2nd order sextupole knobs and to use and the optimization of the octupoles for 3rd order correction on the IP beam size in order to achieve beam sizes below 30 nm (in simulation)

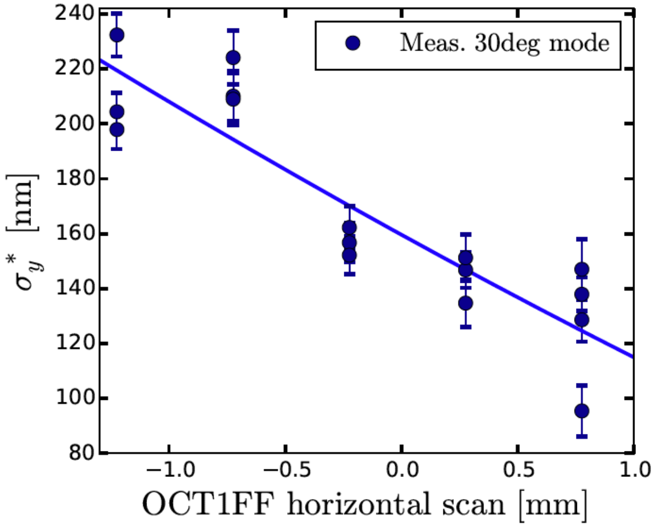
- The abscence of multi-OTR was an important limitation for tuning the optics in February 2018 run but since May 2018 run the software is working again

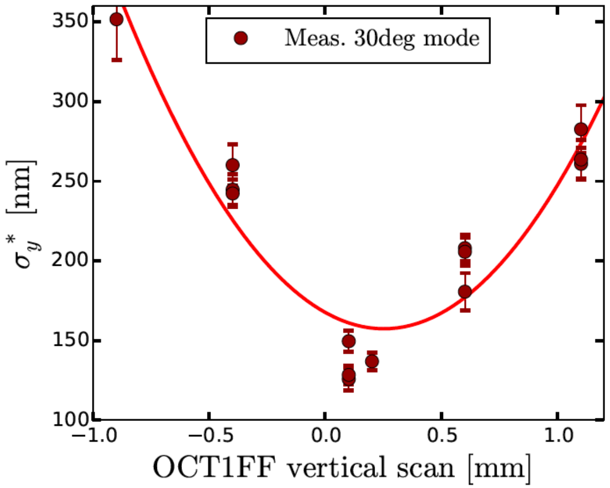
- The last tuning session ends on an incomplete tuning study for the exploration of the ultra-low β_y^* performance → **a whole week will be allocated to the study in December 2018 beam operation**

Thanks for the attention!

Back-up Slides

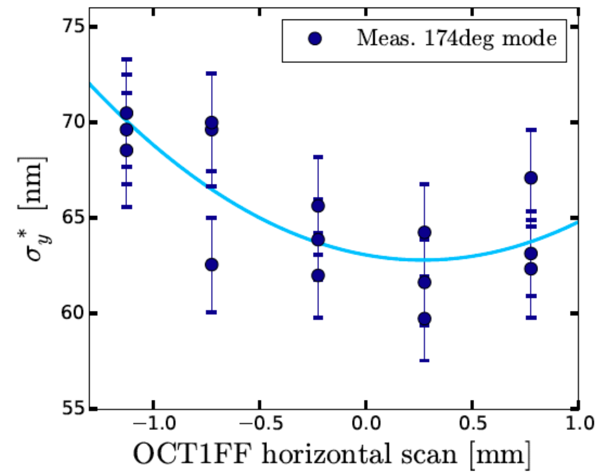
- The impact of the octupoles beam size at ultra-low β_y^* is in the order of ≈9-10 nm in simulation
- The resolution of the beam size measurement at 30 degree mode is to large to observe octupolar correction
- However the OCT1FF position scan gave us possible useful informations about the lattice:

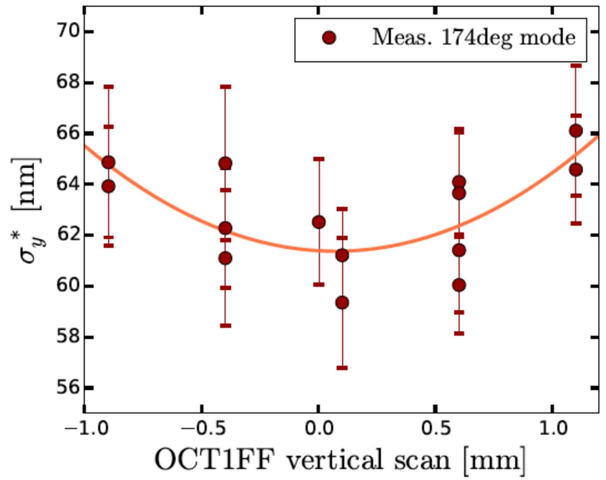


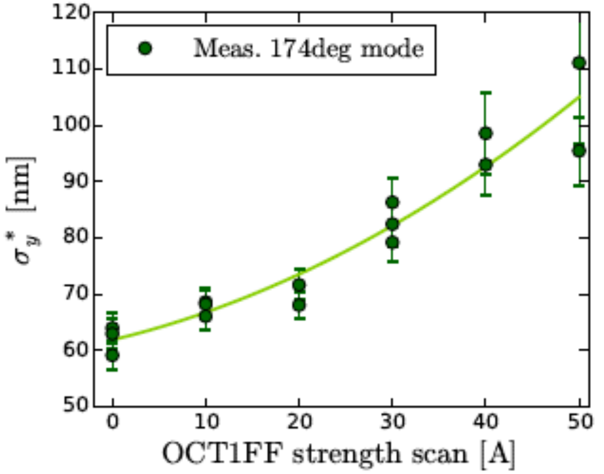


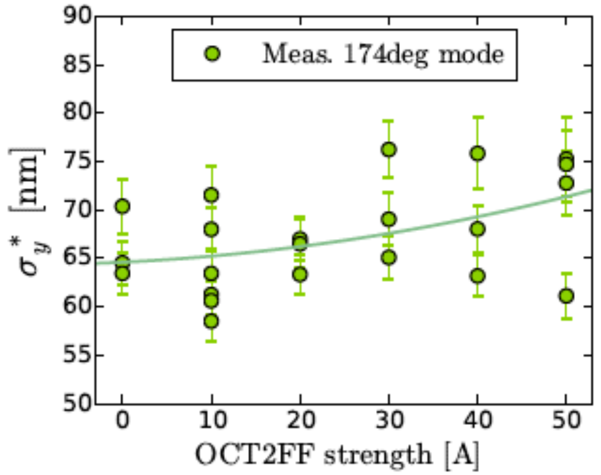
- Horizontal offset of a normal octupole generates normal sextupolar field (can generate Y24 and Y46 aberrations)
- Vertical offset generates skew sextupolar field (can generate Y22, Y26, Y44 and Y66 aberrations)
- **Possible mismatch of the linear optics with the normal sextupole strength applied for ultra-low β_y^***
- Same observations for the nominal optics (10β_x^* x 1β_y^*) for December 2017 operations

December 2017 (modification in the 10x1 optics):



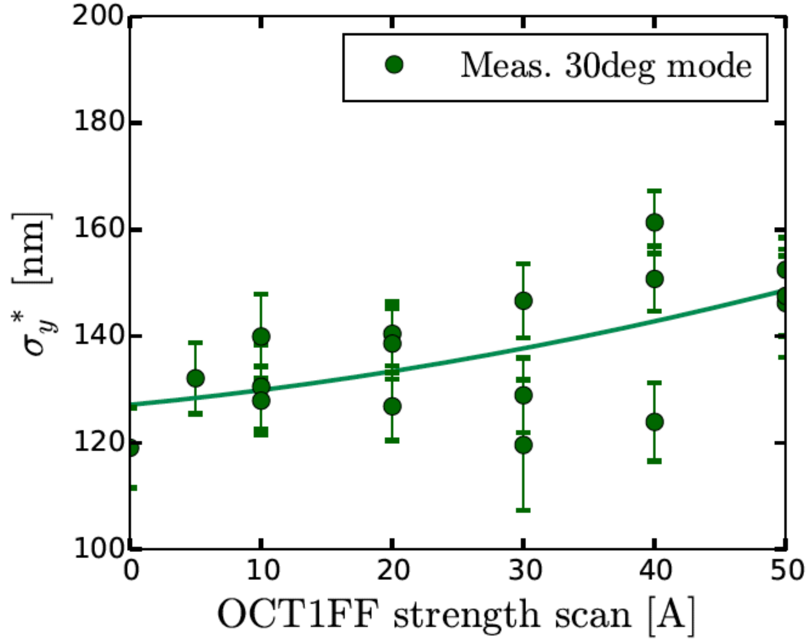




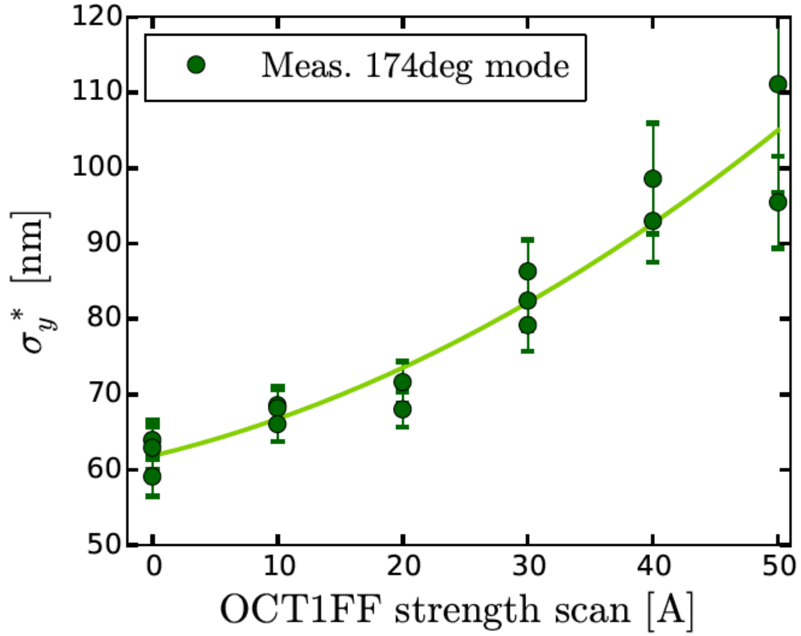


- At 30 degree mode the resolution of the beam size measurement is too large to observe the impact of the octupoles
- Octupolar correction on the vertical beam size will observed only at 174 degree mode

Measured at 30 degree mode (10x1 optics)



Measured at 174 degree mode (10x1 optics)



- Before moving to the carbon wire measurements we corrected the dispersion in the FFS region with the Σ-knob QS1X-QS2X
- The values of the β_x^* and β_y^* measured with the carbon wire scans were: 229 mm and 40 μm (for an emittance of 18 pm) or 27 μm (for an emittance of 12.5 pm → measured in the DR)