Ultra-low beta study

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CLIC Workshop
28/01/2015

* Also at Warsaw University of Technology

Outline

- Motivation
- Plan for the octupoles installation in ATF2
- Lower β_y* study ($10\beta_x 0.5\beta_y$) in ATF2 December run
  - Optics design
  - Estimation of β* values
  - Beam size tuning
  - IP vertical beam size measurements with IP-BSM
- Remarks on the measured beam size and tuning difficulty
- Conclusions

Motivation

for lower β_y^* in ATF2

- The main difficulty of the FFS is to correct the chromaticity ξ, which is necessary for beam focusing to the nm level at the IP;
- Larger ξ makes the FFS more difficult to operate;
- Level of ξ_y in ATF2 is comparable with ILC;
- ATF2 ultra-low (UL) β* optics is a project to test the tunability of the FFS at the chromaticity level comparable with CLIC;
- β_y^* value in ATF2 needs to be lowered by a factor of 4 (25 μm).

Project	Status	E [GeV]	β_y^* [mm]	L* [m]	**$\xi_y \sim L^*/\beta_y^*$**
ATF2	Measured	1.3	0.1	1.0	**10000**
ATF2 UL	Design	1.3	0.025	1.0	**40000**
ILC	Design	250	0.48	3.5 4.3	**7300** **9400**
CLIC	Design	1500	0.069	3.5	**50000**

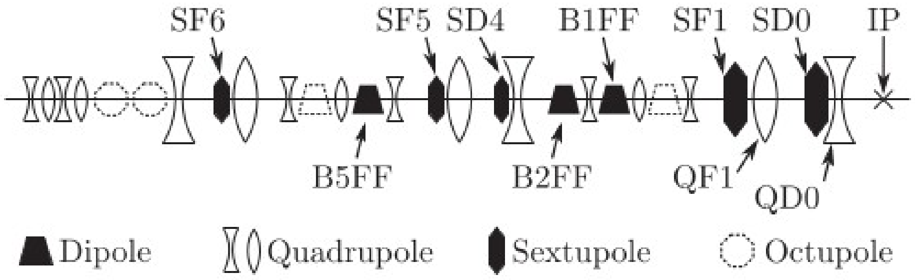


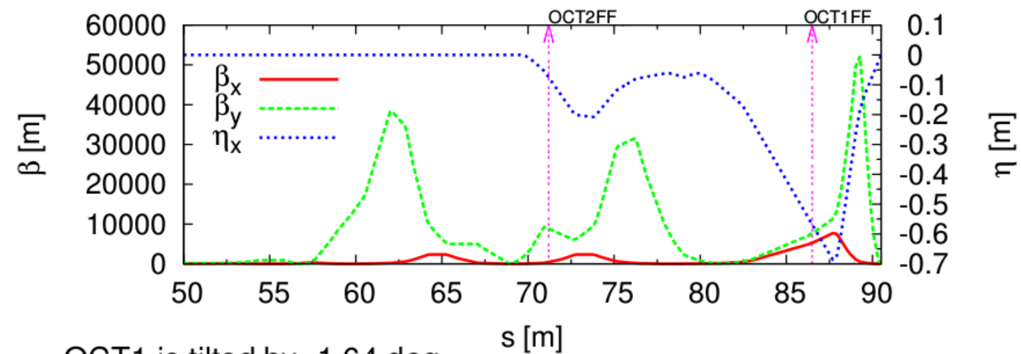
FIG. 1. Schematic of a final focus system with local chromaticity correction. Dashed components are not included in ATF2 test.

PRL **112,** 034802 (2014)

Octupole magnets for ATF2

Two octupole magnets are required for compensating the detrimental effect of the measured multipole components of the ATF2 magnets on the IP spot size for the ATF2 ultra-low β*.

- OCT1 at 86.41 m between QD2AFF and SK1FF (3.8 m)
- OCT2 at 71.85 m between QD6FF and SK3FF (1.0 m)

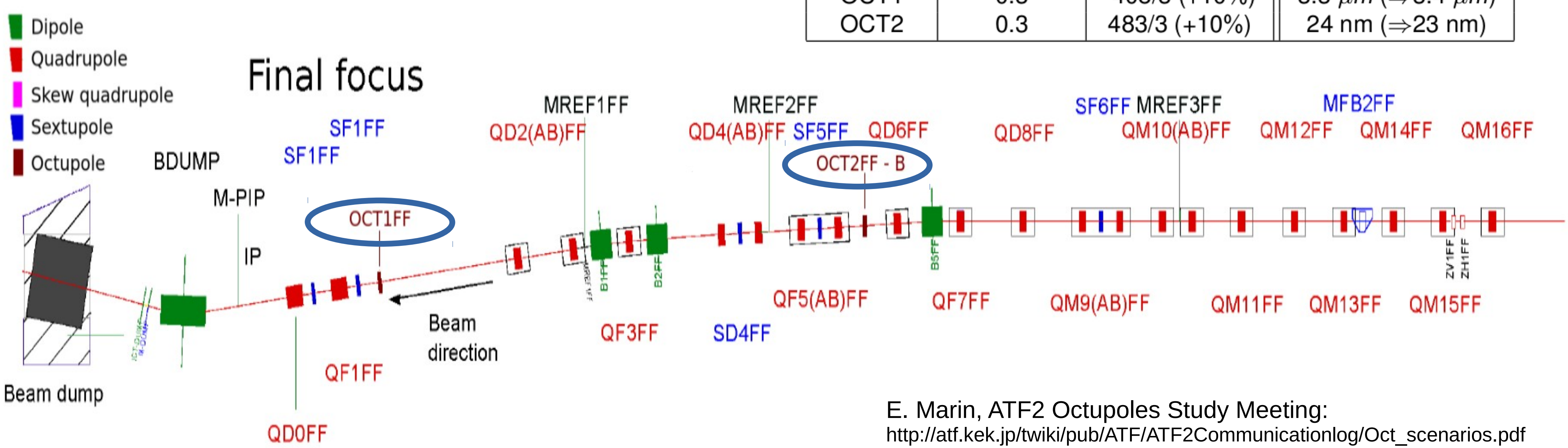


OCT1 is tilted by -1.64 deg

Octupole	Length [m]	k [m^{-4}]	σ^* (rms)
OCT1 OCT2	0.1 0.1	-408 483	3.5 μm 23 nm
OCT1 OCT2	0.2 0.2	-408/2 483/2	3.4 μm 23 nm
OCT1 OCT2	0.3 0.3	-408/3 (+10%) 483/3 (+10%)	3.3 μm (⇒3.4 μm) 24 nm (⇒23 nm)

<u>Expected vertical IP beam size:</u>

- Without octupoles: 27.4 nm
- With octupoles: 23.0 nm

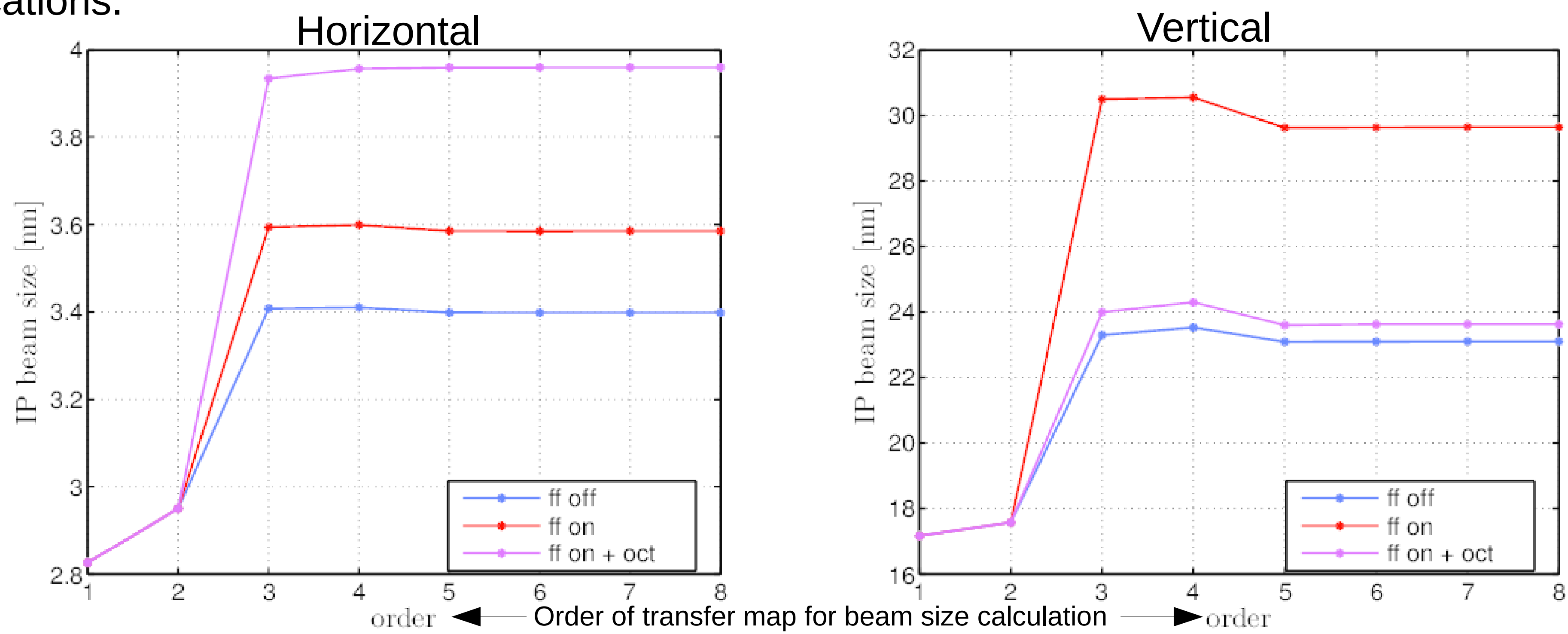


E. Marin, ATF2 Octupoles Study Meeting:
http://atf.kek.jp/twiki/pub/ATF/ATF2Communicationlog/Oct_scenarios.pdf

Octupole magnets for ATF2

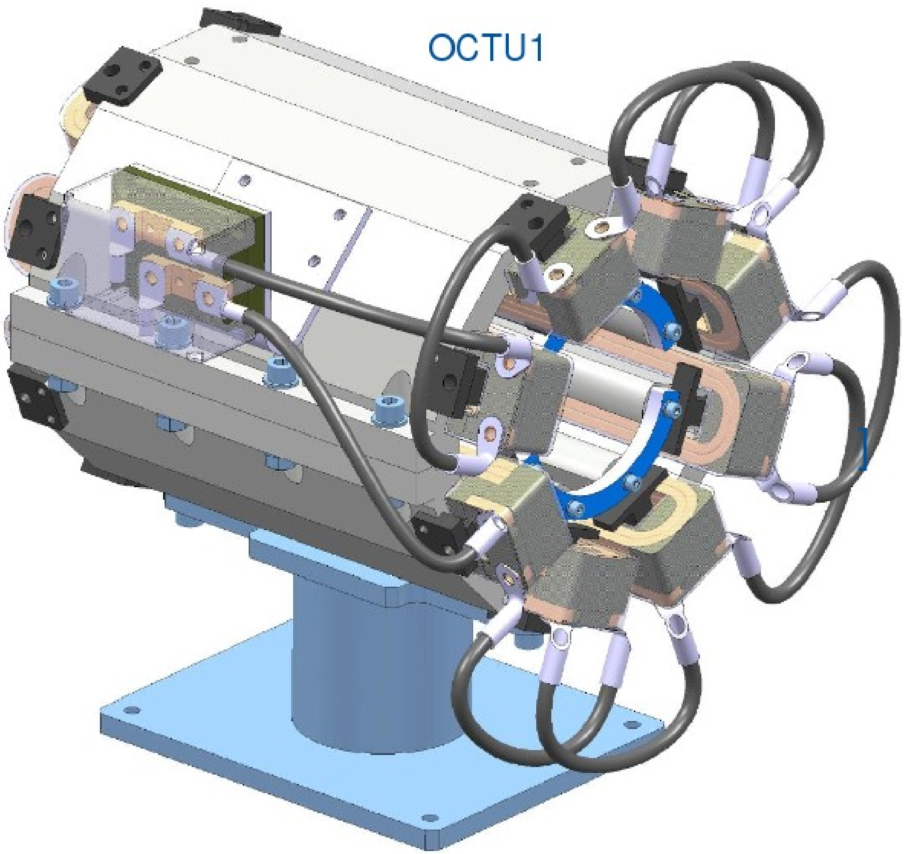
FD fringe fields effect cancellation

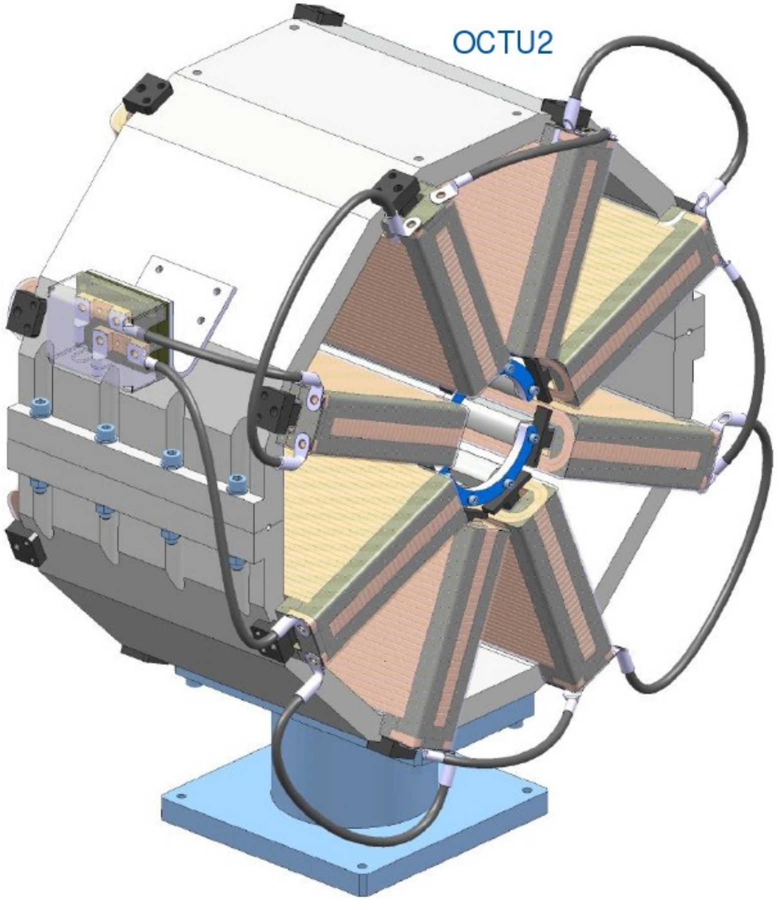
FD fringe fields are responsible for the IP beam size growth. Both multipolar components and fringe fields can be mitigated with the use of the octupole magnets installed in proposed locations.



OCT1 kL [m^{-3}]	OCT2 kL [m^{-3}]
50.4	162

Octupole magnets for ATF2



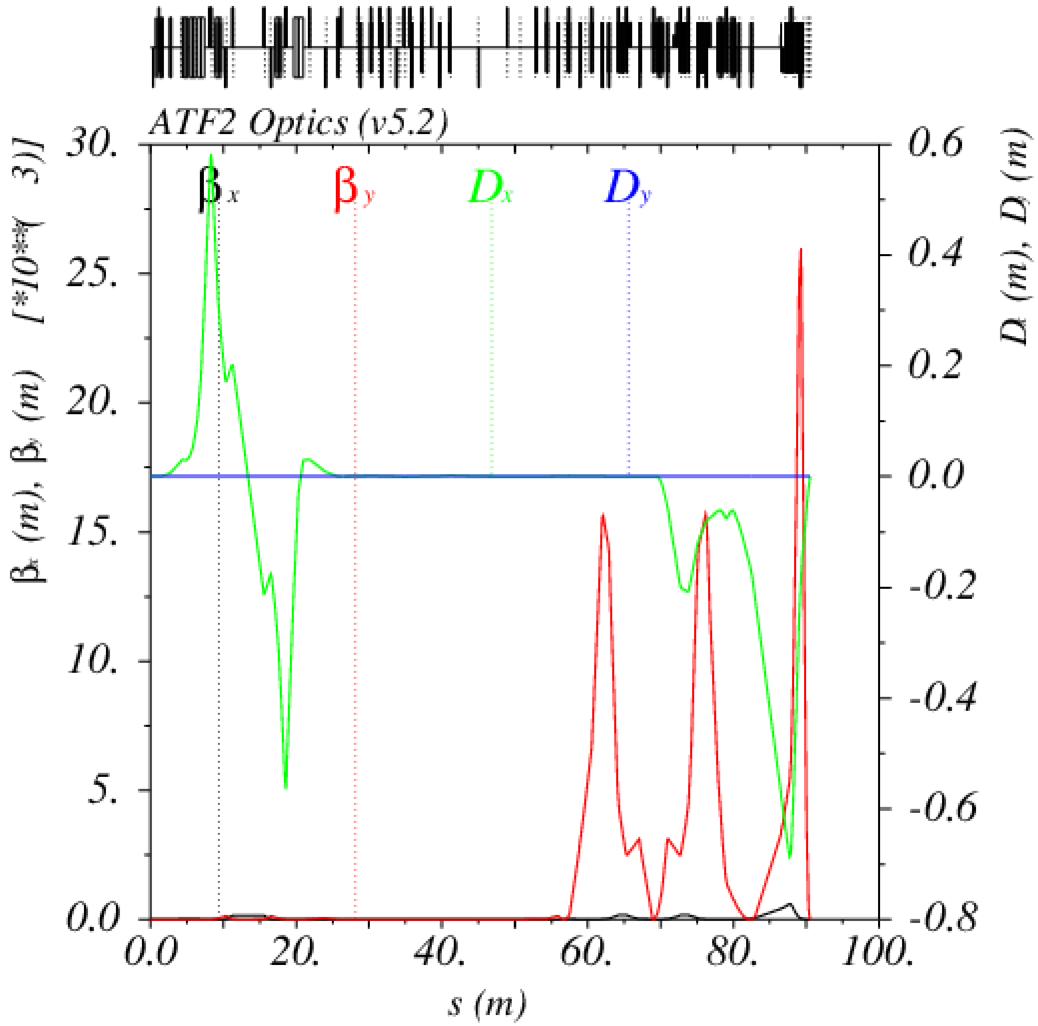


- Two designs in order to meet the requirements;
- Delivery and installation to ATF2 planned for **summer 2015**;
- More details in M. Modena talk in LCWS14:
  http://agenda.linearcollider.org/event/6389/session/14/contribution/50/material/slides/1.pdf
- See also M. Modena talk on Thursday
- This issue will be discussed during the 18th ATF2 Project Meeting in February

Lower β_y^* study in ATF2 December run

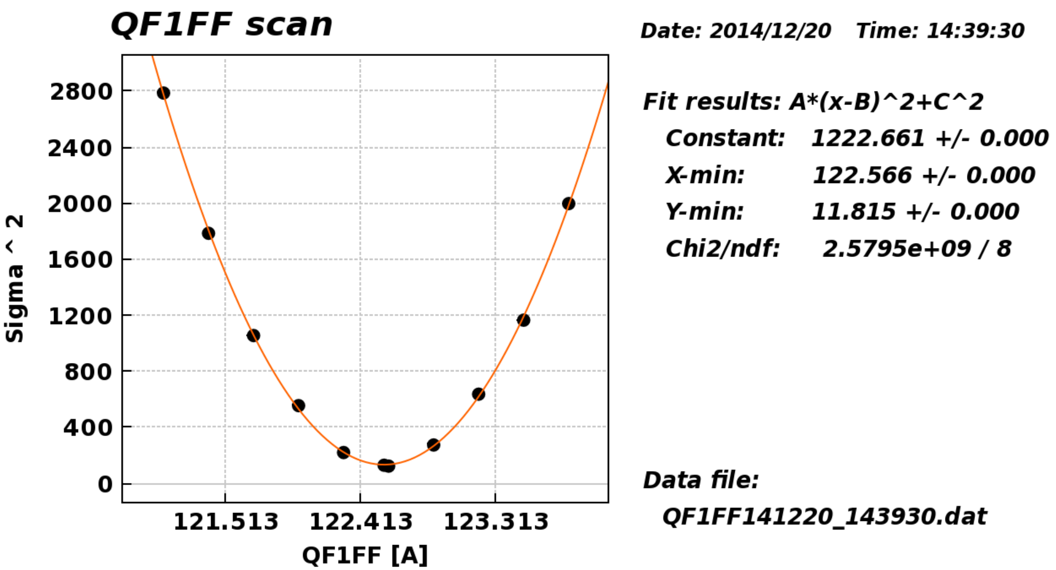
optics design

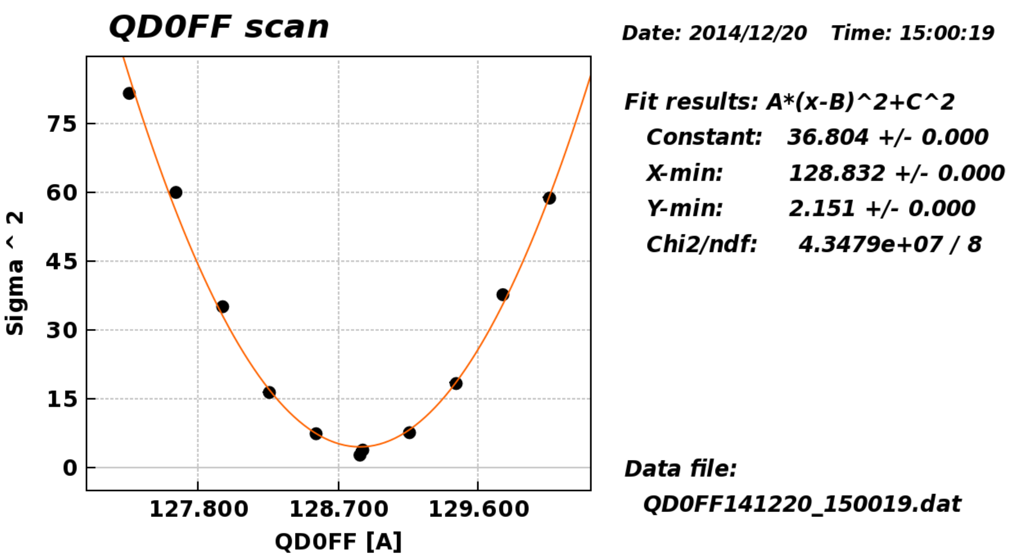
- For the December run the $10\beta_x 0.5\beta_y$ optics (40mm, 50µm) was applied;
- The optics was defined with the use of MADX and SAD simulations;
- The magnet strengths evaluated in simulations were translated to magnet currents and applied to the machine;
- **Expected IP vertical beam size: 26.5 nm**, after very fine tuning of sextupoles.



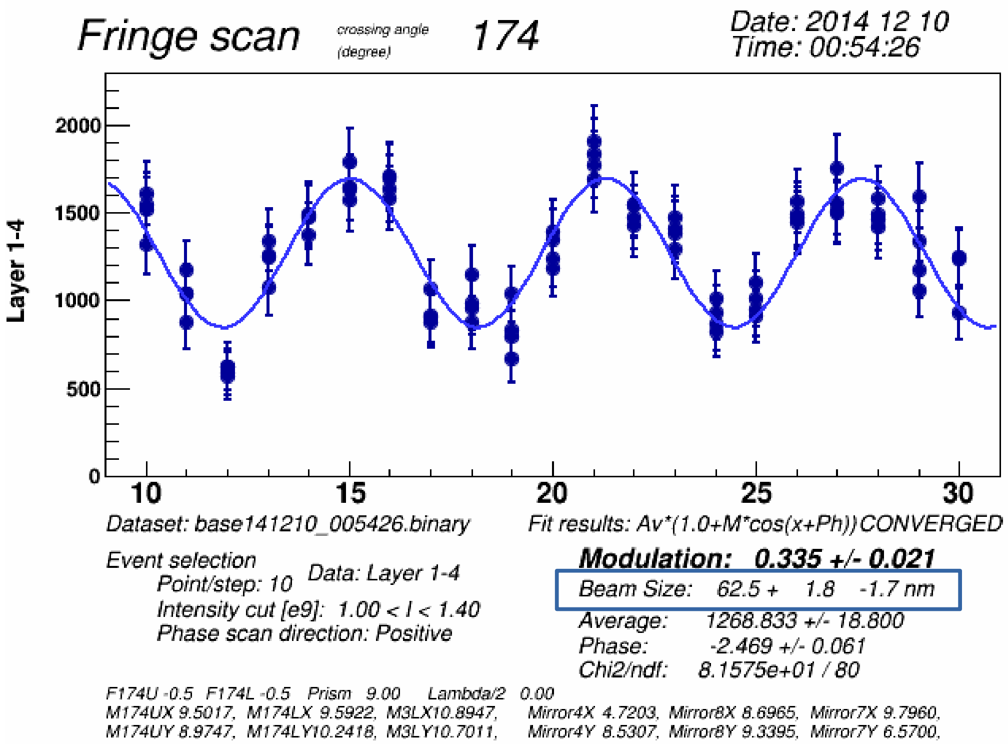
IP beta values estimation

- In principle to know the values of β* one does: $\frac{\sigma^2}{\varepsilon}$
- However, it may not be very precise;
- Instead, the beam divergence can be estimated from the QF1FF and QD0FF scans;
- For the presented scans and assumed emittance (2nm, 10pm) the estimated values of β* are (~40mm, ~47um).



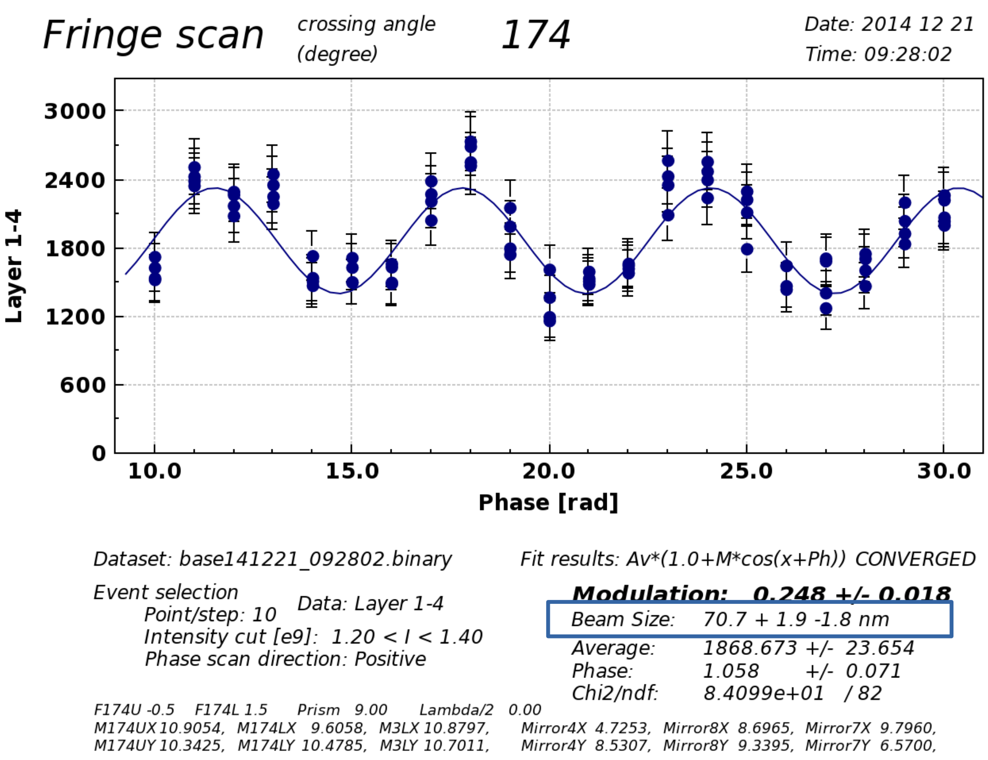


2nd week of Dec run: IP beam size tuning



- Tuning with the use of linear knobs: Ay, Ey, Coup2;
- After 8h of tuning the vertical beam size measured in 174 deg mode was **62.5 nm**;
- Modulation was lost during the pitch scan by problem with the lasers position;
- We tried to repeat the tuning but it was not succesful by the problem with lasers;
- The beam conditions were very promising...

3rd week of Dec run: IP beam size tuning



- Tuning with the use of linear knobs: Ay, Ey, Coup2 + scans of RefCav-YPos, OTR2-YPos, QD10A-Ypos + IP-BSM internal scans;
- Modulation was lower than 0.3 which makes tuning difficult;
- After 20h of tuning the vertical beam size measured in 174 deg mode was **70.7nm**;

Remarks on the measured beam size and tuning difficulty

- Lower β_y* optics:
  - Larger chromaticity requires very fine 2nd order beam size tuning with the use of normal and skew sextupoles.
  - Stronger focusing increases the beam divergence at IP + the angular jitter increases → larger signal jitters of IP-BSM;

Remarks on the measured beam size and tuning difficulty

- IP-BSM performance:
  - Signal fluctuation in Dec. was larger than in June even for the laserwire mode:
    - The multi-mode laser is used which longitudinal profile is not a perfect Gaussian;
    - The laser pulse length rms is 3 ns and electron bunch length is 20-30 ps → only 1% of the laser light is used for the laser-beam collision;
  - The measured modulation was M < 0.3, and difference of modulation for tuning knobs was small → finding maximum of modulation for each knob was more difficult;
  - From the simulations we know that reaching low beam size requires very fine 2nd order orbit correction → high accuracy of IP-BSM (high modulation, low fluctuation, ...)

Conclusions

- Lower β_y* study with $10\beta_x 0.5\beta_y$* optics was an important step towards ATF2 ultra-low (UL) β*;
- IP-BSM performance sets a limit in measuring low beam size also for nominal optics;
- High accuracy of IP-BSM is necessary for effective beam size tuning for lower β_y* optics;
- The octupole magnets are under preparations for installation during the summer 2015;

Thank you for your attention!

Many thanks to KEK collaborators for their help, expertise and support!