



Optics experience with Q'' knob

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Motivation for negative Q''

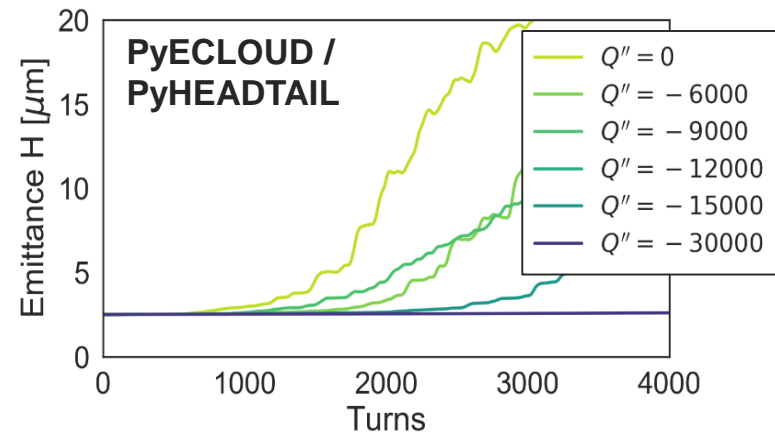
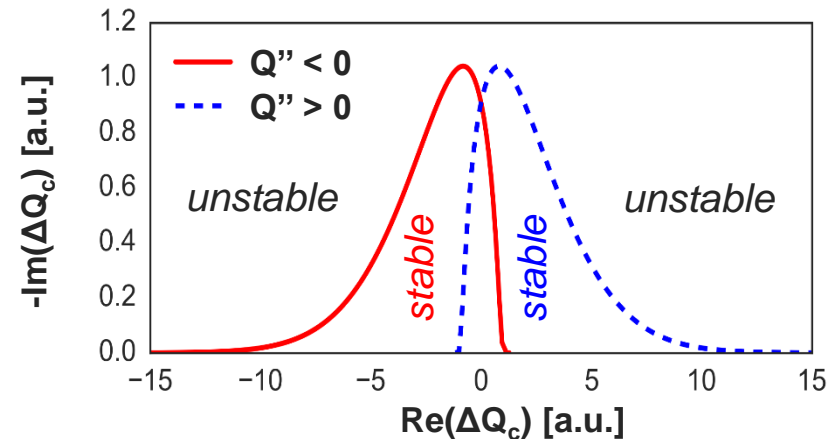
Landau damping from detuning with longitudinal amplitude $\Delta Q(J_z)$

- Can be introduced by means of Q''
- Experimental study of rf quadrupole
- Alternative to Landau octupoles?

MD1831: *Single Bunch Instabilities with Q'' and Non-Linear Corrections*

- Showed stabilisation of single bunches at 6.5 TeV using Q''
- Good agreement with simulations
=> Q'' helps against impedance-driven instabilities

Can Q'' help against e-cloud instabilities?



Q'' knob

- Wish list
 - Negative Q'' in both planes (only B1)
 - Transverse amplitude detuning 'free' knob
 - Minimum effect on Q', (Q''')
- 'Strong', localised powering of 4 sextupole families
$$\begin{array}{ll} Q''_x: & SF2.a12b1 + dKSF \quad \text{and} \quad SF2.a45b1 - dKSF \\ Q''_y: & SD2.a81b1 + dKSD \quad \text{and} \quad SD1.a56b1 - dKSD \end{array}$$
- dKSF and dKSD produce negative Q''_x and Q''_y respectively
- E.g. for Q''_{x,y} = - 30'000, would need dKSF = 0.620 and dKSD = -0.685 (MAD-X)

Q'' knob

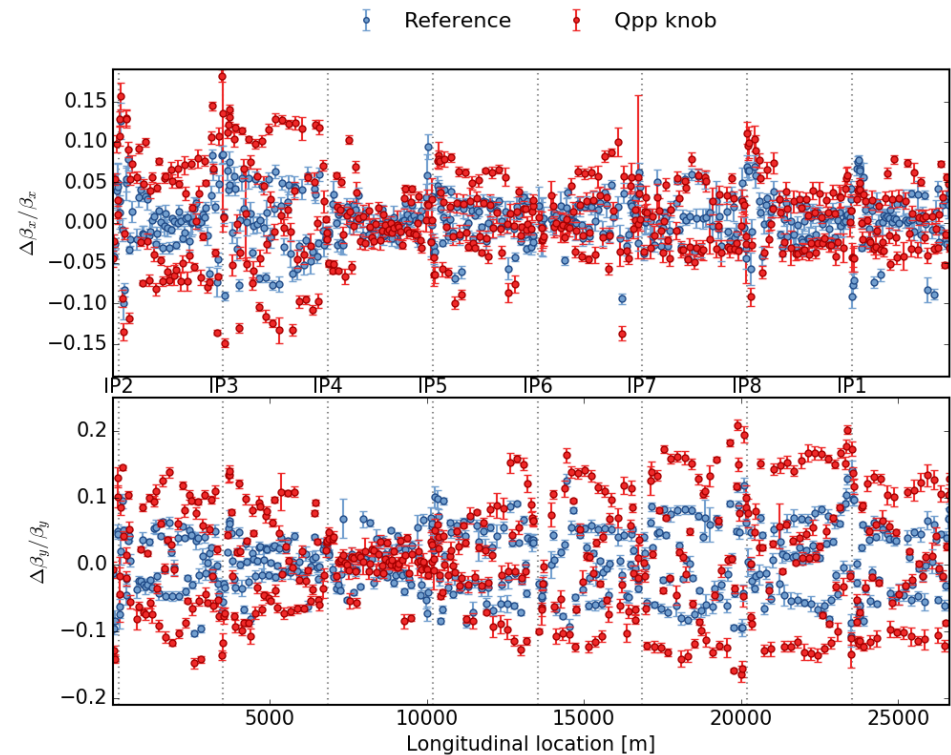
- Aim for two settings $Q'' = -30'000$ and $Q'' = -45'000$
- Trims 4 families of sextupoles
 - ~10 times stronger than nominal
- Similar knob was tested in June '17 and distortion of linear optics was observed
 - ~20% beta-beating and coupling ~0.002
 - Probably caused by feed-downs in misaligned sextupoles (~hundreds of μm)
=> Need for optics correction

Horizontal orbit bumps

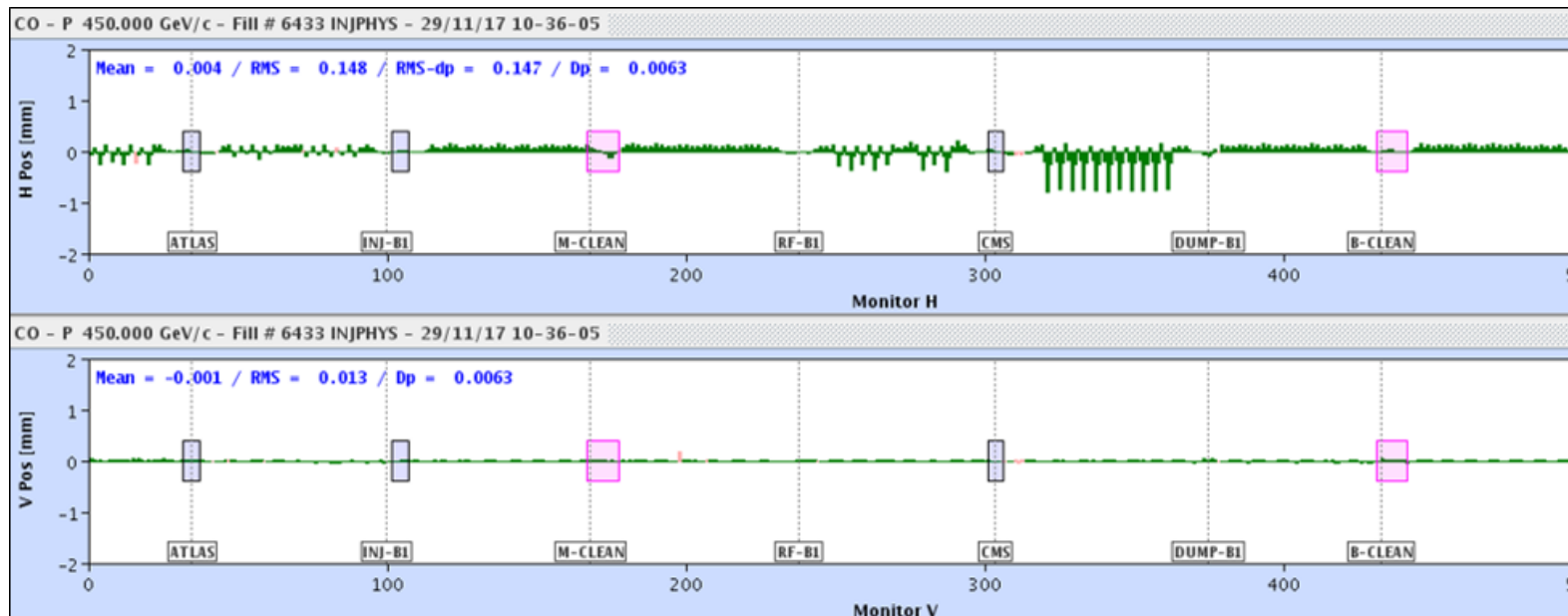
- Sextupoles belonging to a given family have π phase advances between them
- Neglecting other (weaker families)
- Not changing the orbit in IRs
- Combination of several π -bumps of same amplitude for each of Q” knob’s sextupole families
 - “holes” in bumps – some sextupoles are replaced by octupoles

Optics in MD

- Coupling change was small, well below 10^{-3}
- Want to correct only β -beating from Q'' knob, not generally
- Correction targets the reference measurement



Horizontal orbit bumps in



Orbit bumps at sextupole families:

ksf2.a12: 0.2 mm

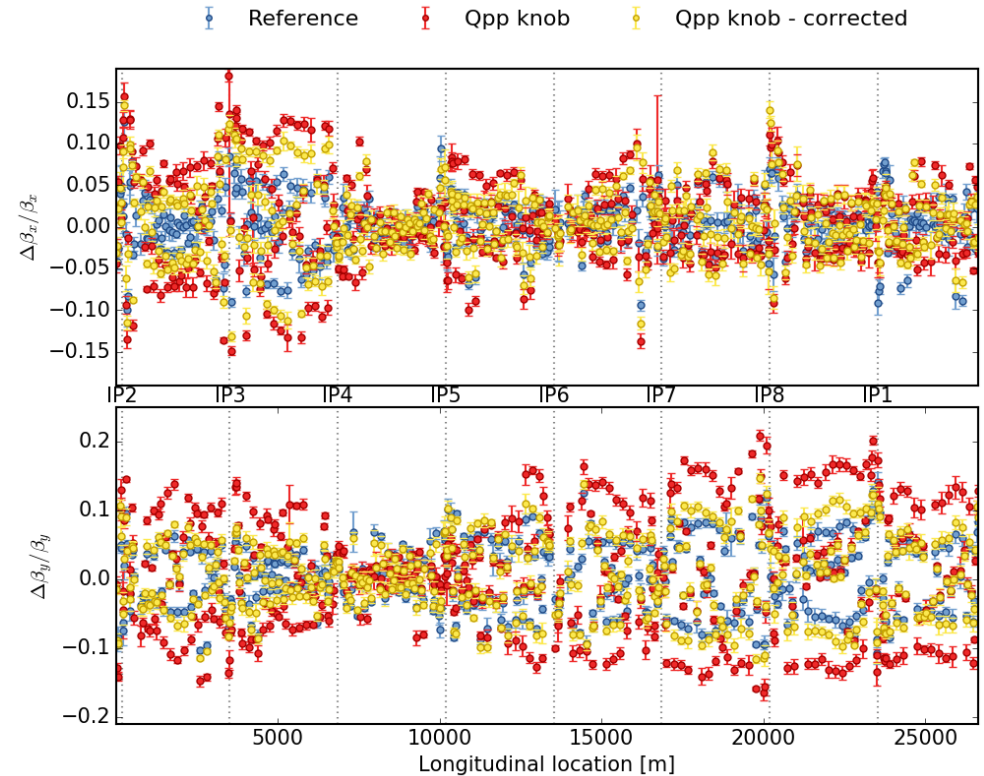
ksf2.a45: 0.4 mm

ksd1.a56: 0.25 mm

ksd2.a81: 0.1 mm

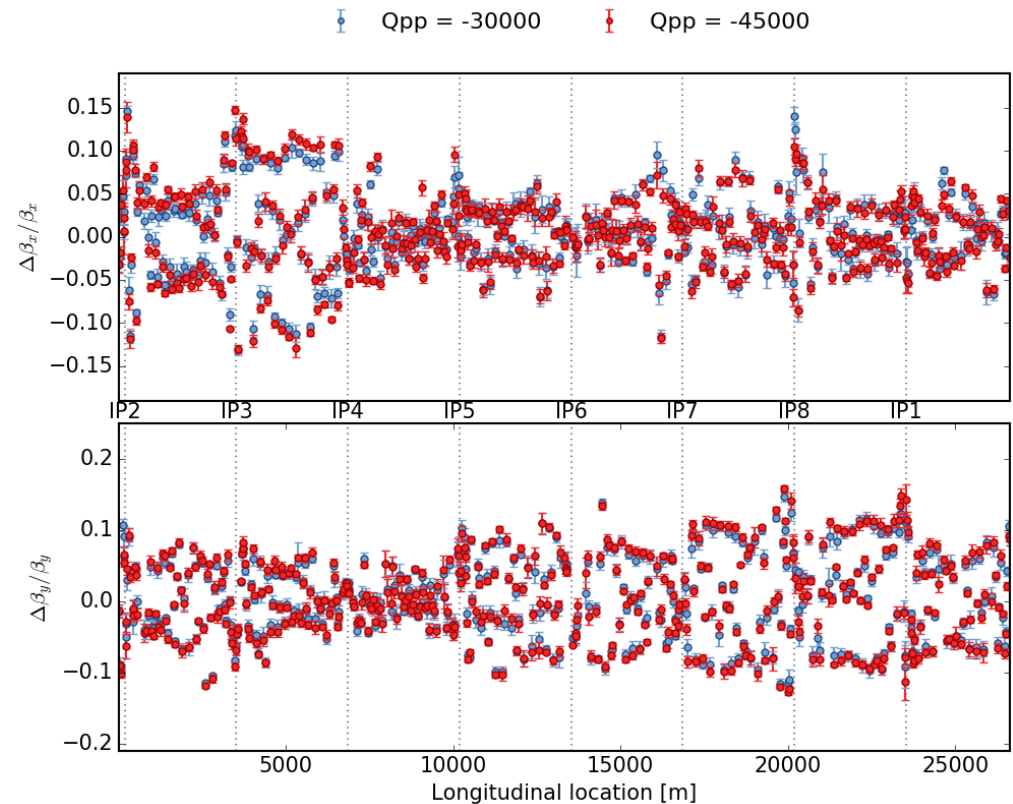
After correction

- β -beating improved
- Correction was a bit weaker
- Other sextupole families are in the orbit bumps
- Sextupoles do not have the same misalignments



Correction validation

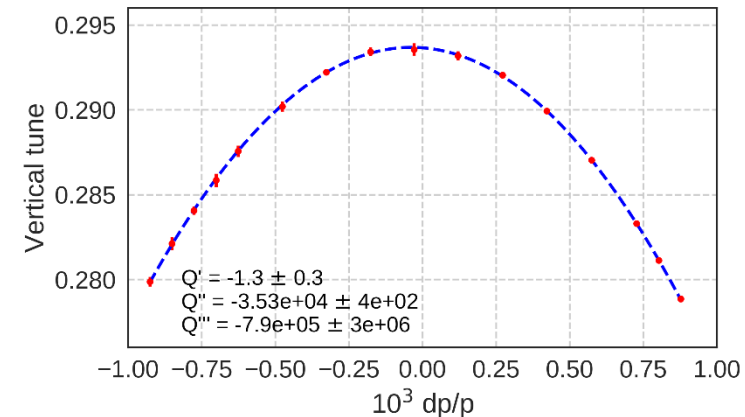
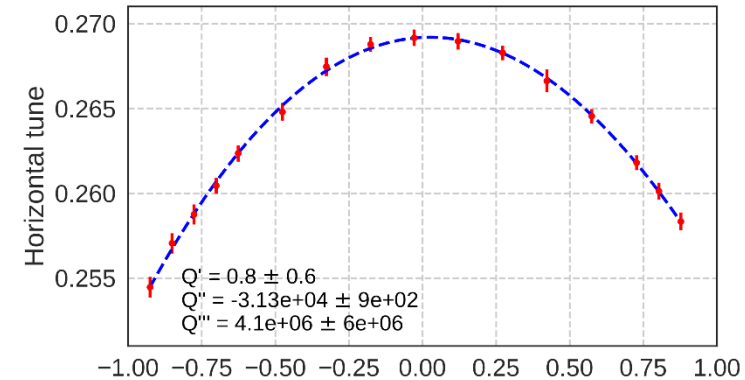
- Two Q'' knob settings
- Very similar β -beating
 - validates orbit bumps
- Few sextupoles were not in the bumps (IRs)



Measurement of Q''

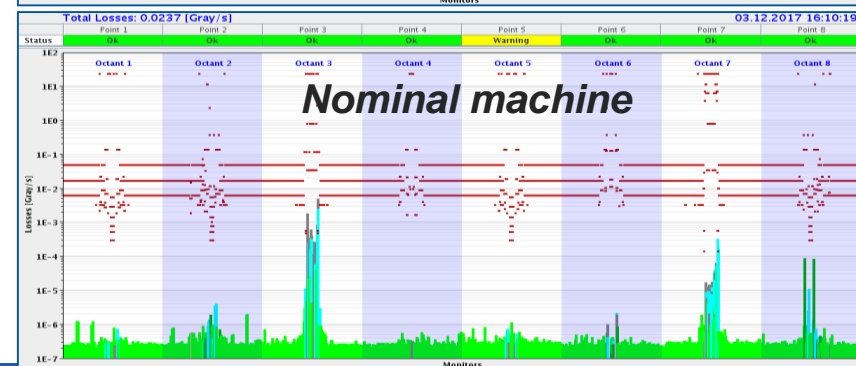
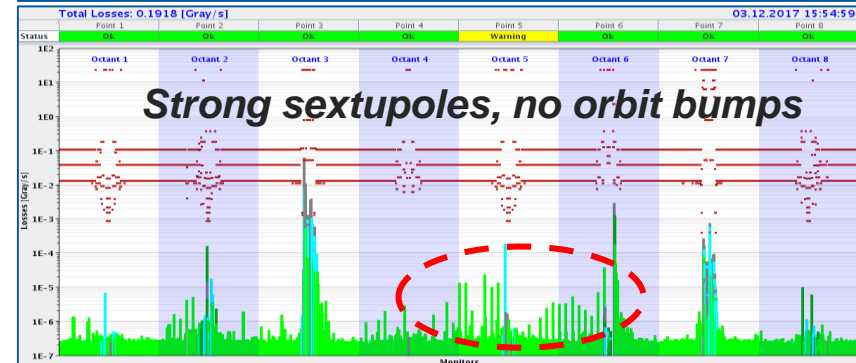
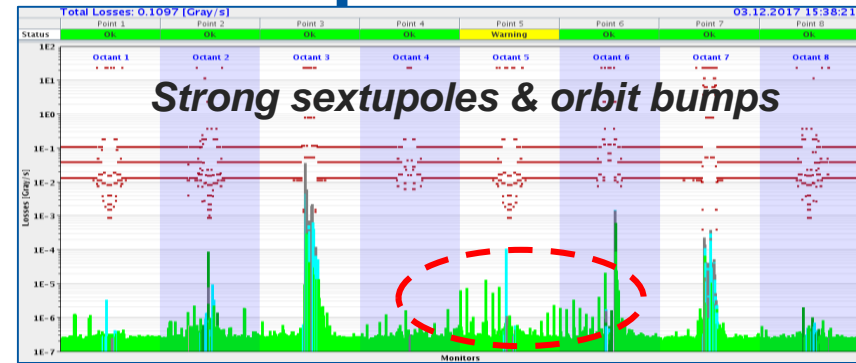
- **Measured Q vs. dp/p for expected $Q''_{x,y} = -4.5 \times 10^4$**
 - With $|dp/p|$ up to 9×10^{-4}
 - $Q''_x = (-3.13 \pm 0.09) \times 10^4$
 - $Q''_y = (-3.53 \pm 0.04) \times 10^4$
- **Agreement with MAD-X ok**
- **Possible explanations for difference**
 - Discrepancy of beta-function at sextupoles wrt. assumptions in the model (Q'' produced in that scheme is proportional to β^2)
 - Tunes are slightly off (0.27 / 0.295)
 - Other? (D^2)

dKSF = 0.7724 / dKSD = -0.8378
MAD-X: $Q''_x = -45000$ / $Q''_y = -45000$
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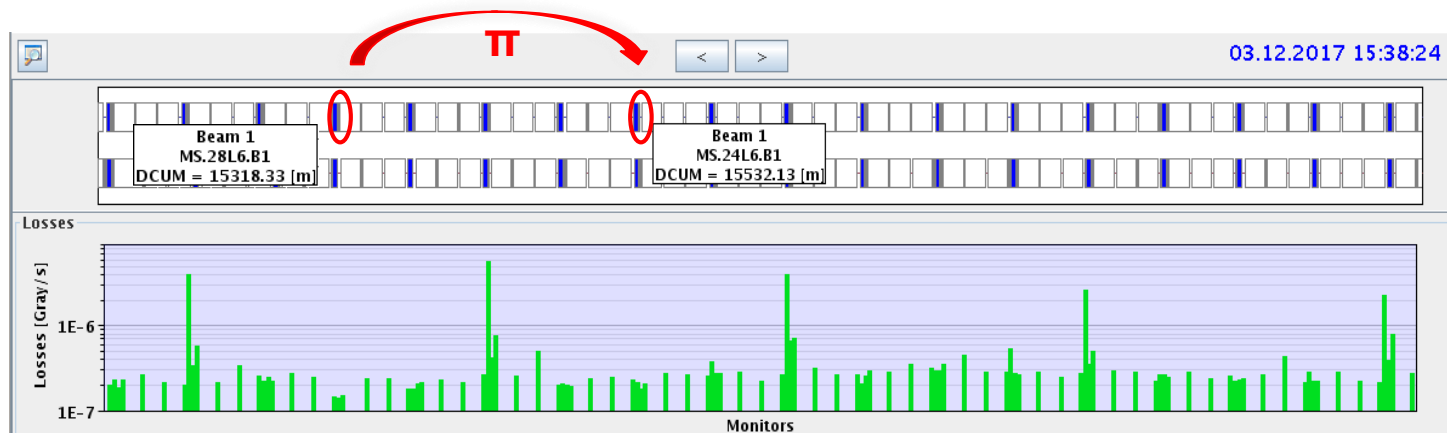
Off-momentum loss maps

- Betatron loss maps are OK
- Significant spikes on off-momentum loss maps ($@dp/p = -0.004$)
- Not caused by orbit bumps, but by the strong sextupole families themselves
- Unfortunately forbade injection of many bunches (600 b.) needed for e-cloud studies
- Losses stem from off-momentum beta-beating enhanced to produce Q''



Off-momentum loss maps

- Strong sextupoles from SD1.a56 family (e.g. 28L6, 24L6), separated by phase advance π give kick of off-momentum beta-beating which becomes largest at phase advance $\pi/2$
- The loss maps show exactly this behaviour: Losses occur in between the strongly powered sextupoles at the place of the largest off-momentum beta-beating



Conclusions

- Q'' knob distorts linear optics via feed-downs
- Beta-beating successfully corrected using π -bumps at Q'' knob's sextupole families
 - validated with stronger Q'' knob
- Only small change of coupling observed
 - not corrected
- Measured Q'' is negative as expected, but there is a discrepancy of about 20 - 30% wrt. MAD-X
- Off-momentum beta-beating causes significant losses
 - Either lower $|Q''|$ or lower dp/p cut in IR3 collimators?

Previous MD – optics distortion

