TWIICE 2014
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Synchrotron SOLEIL, 16-17 January 2014

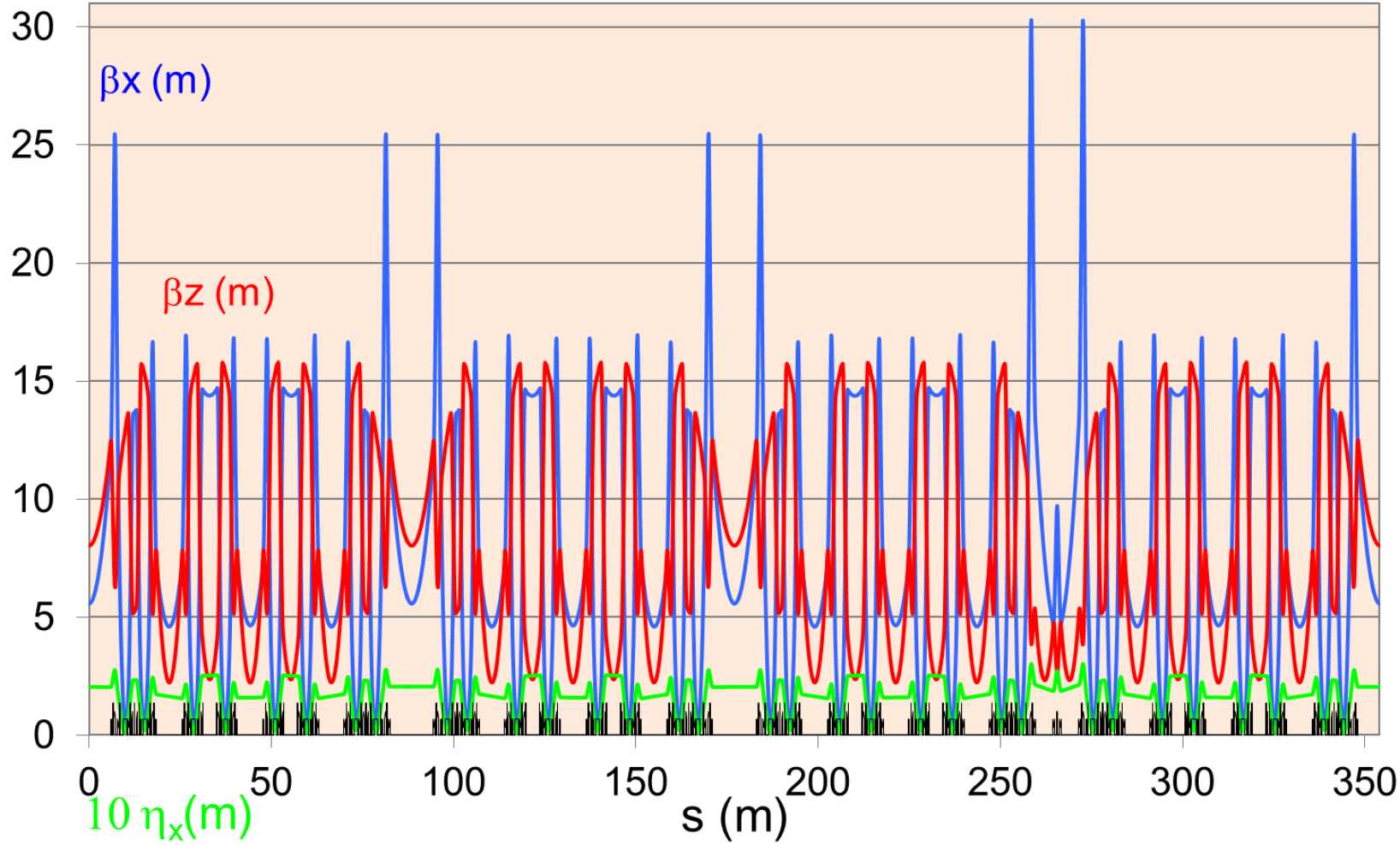
Impact of Incoherent Transverse Wakefield on Storage Ring Optics

P. Brunelle, L.S. Nadolski, R. Nagaoka

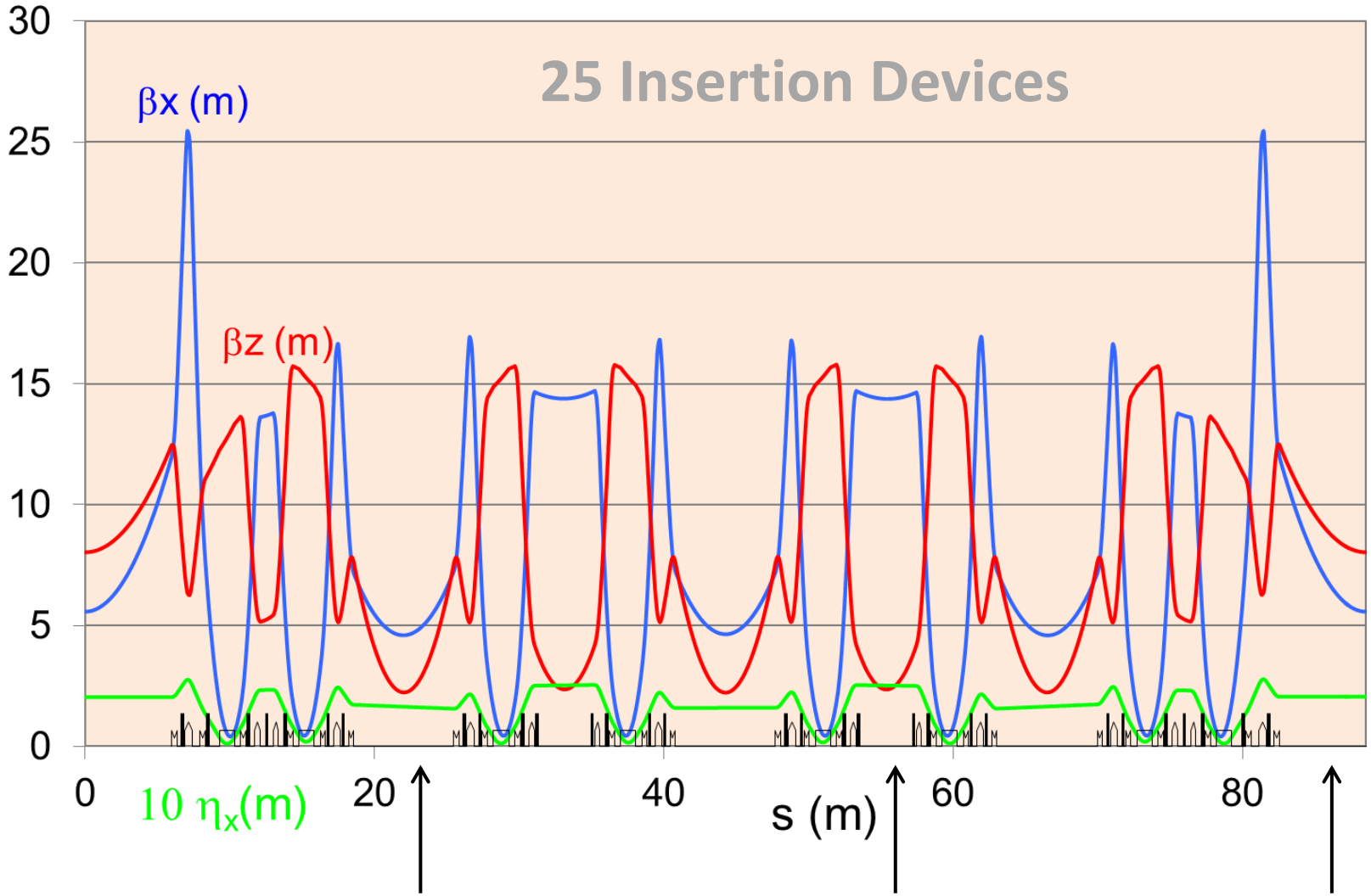
SOLEIL SYNCHROTRON

Optical functions

E = 2.75 GeV Tunes = 18.176 / 10.234 ex = 4 nm.rad



Magnetic Structure

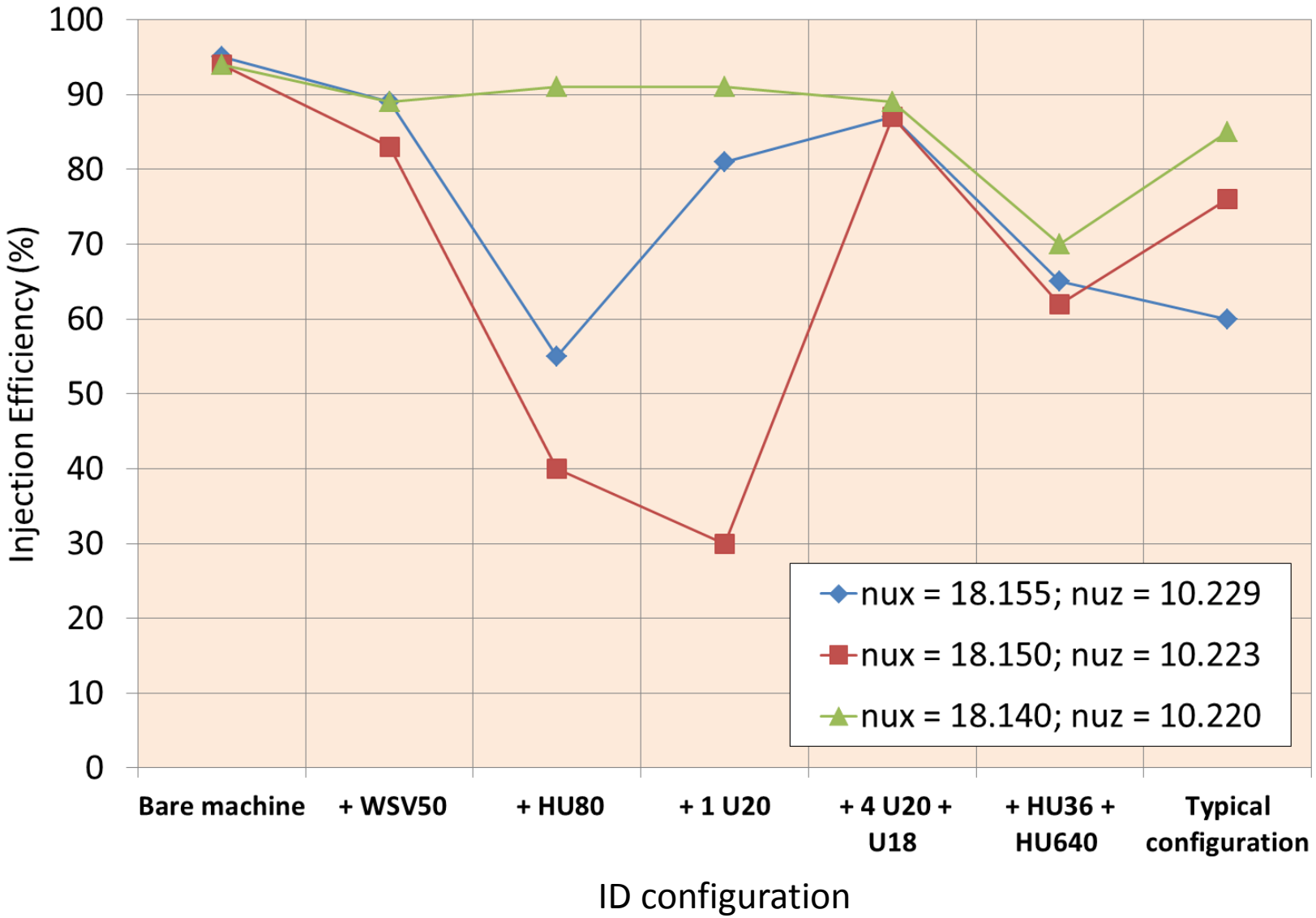


Medium straight section X 12

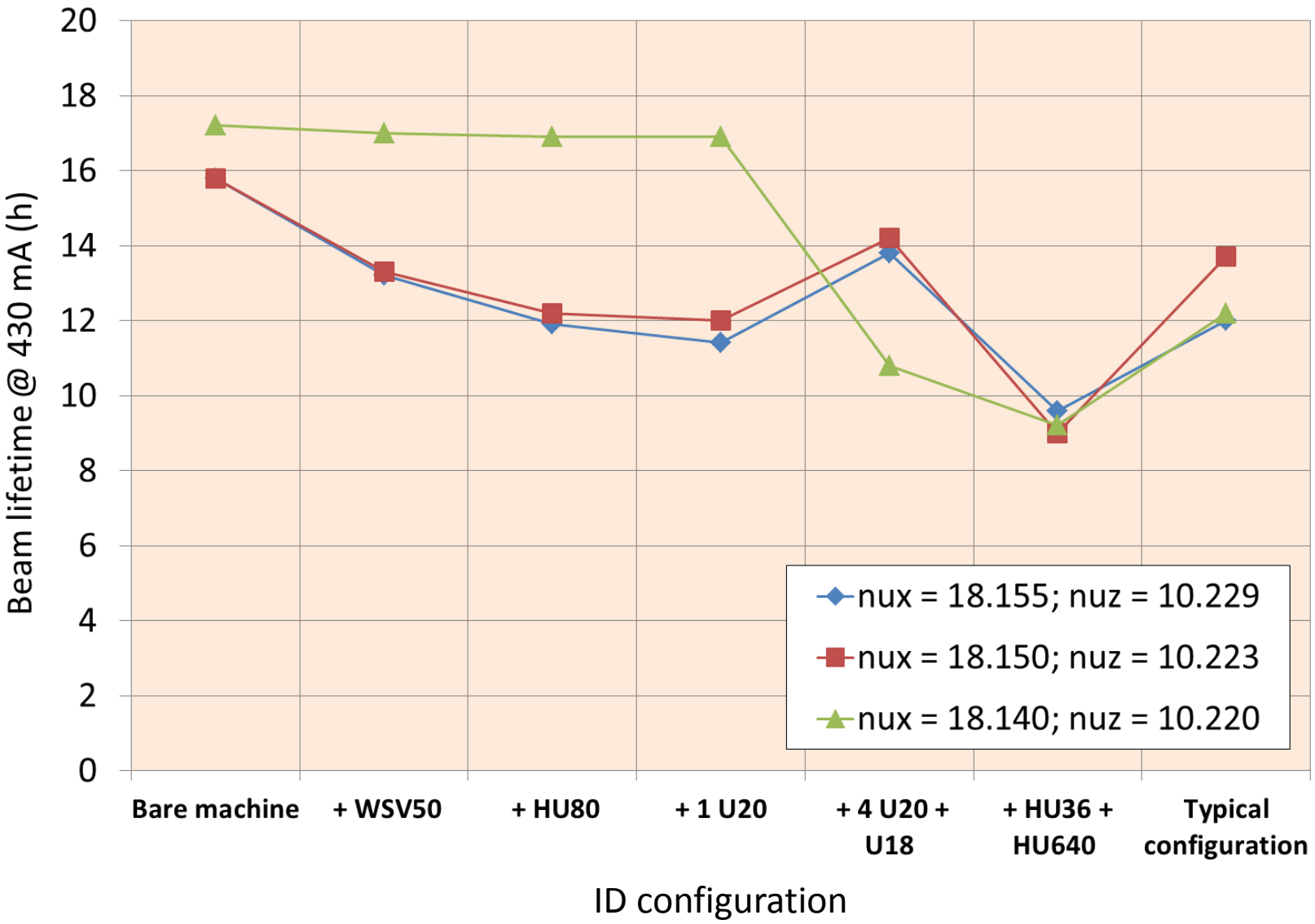
Short straight section X 8

Long straight section X 4

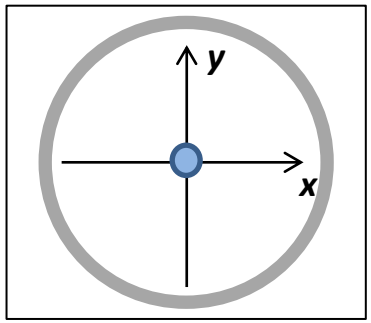
Variation of Injection Efficiency versus Tunes



Variation of Beam Lifetime versus Tunes



Incoherent Transverse Wakefields



Circular resistive-wall chamber

- no transverse wake is created
- due to the symmetry, as long as the driving beam stays on axis

Pioneering studies :
*- K. Yokoya, Part. Acc., **41**(1993) 221*
- A. Burov, V. Lebedev "Transverse Resistive Wall Impedance for Multi-Layer Flat Chambers", EPAC 2002
*- A. Chao, S. Heifets, B. Zotter, Phys. Rev. ST-AB **5**, 111001 (2002)*

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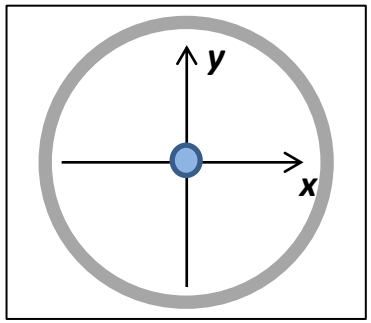

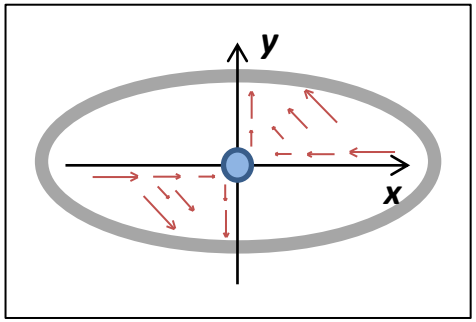

Circular resistive-wall chamber

- no transverse wake is created
- due to the symmetry, as long as the driving beam stays on axis

Non-circular resistive-wall chamber

- a transverse wake is created even if the driving beam stays on axis.
- Non-oscillating wakefields add up to build an extremely long range field.
- Its leading field component is "***quadrupolar***" type. Trailing particles are focused (defocused) "***incoherently***".
- Focusing strength depends linearly on the beam current and on the cross section geometry.

For SOLEIL with vertically low gap chambers in most of the ring, the incoherent wake was evaluated to be non-negligible for both single and multibunch modes (R. Nagaoka, EPAC 2004)

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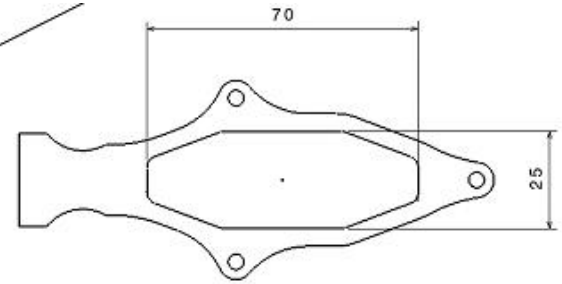
Vacuum Chamber Vertical Size Limitations

Standard chambers

X = 2 x 35 mm

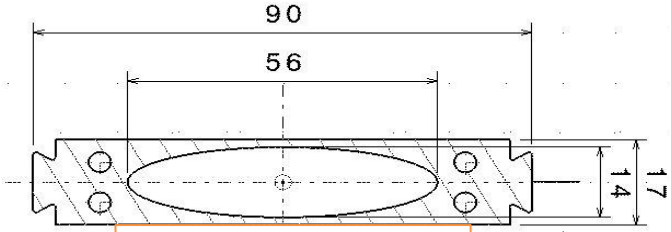
Z = 2 x 12.5 mm



Long SS chambers

X = 2 x 28 mm

Z = 2 x 7 mm

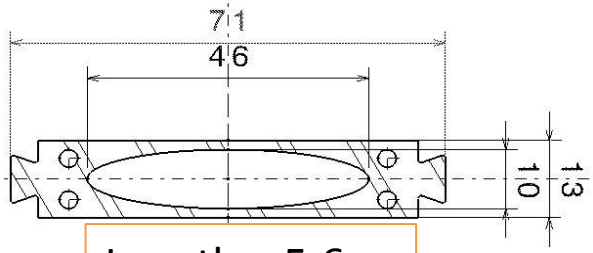


Length = 10.6 m

Medium SS chambers

X = 2 x 23 mm

Z = 2 x 5 mm



Length = 5.6 m

Vacuum Chamber Vertical Size Limitations

Standard chambers

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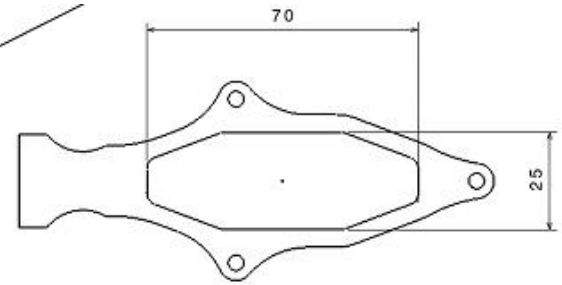

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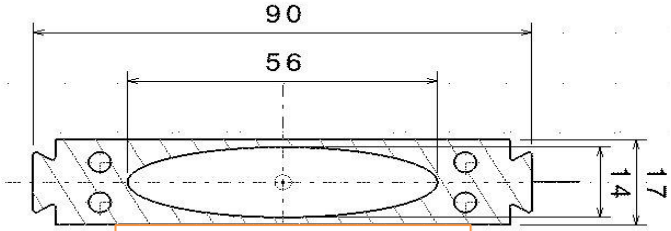

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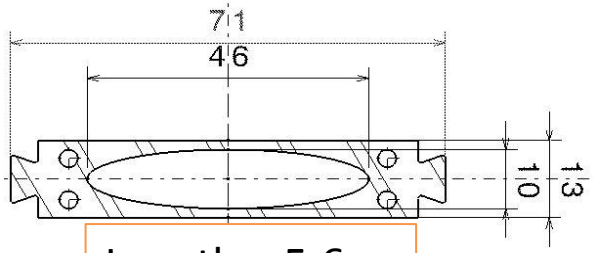
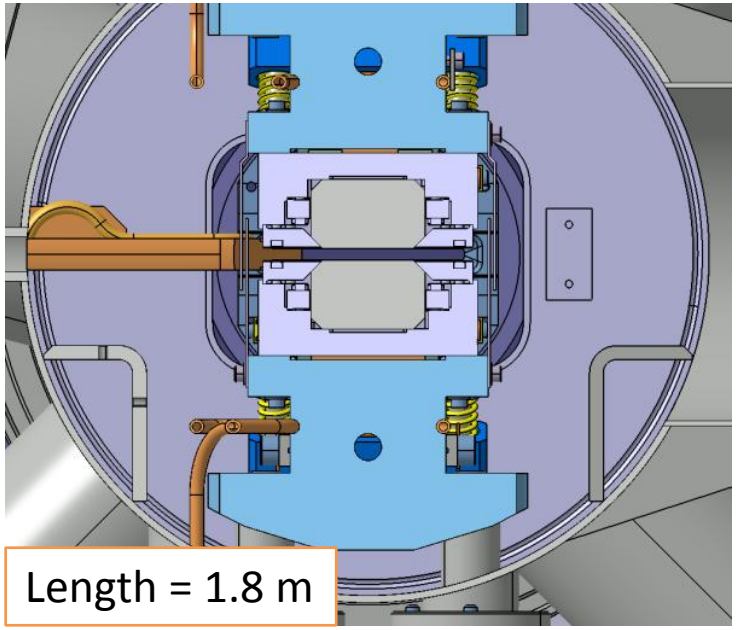


Length = 5.6 m

Short SS In vacuum U20 undulators

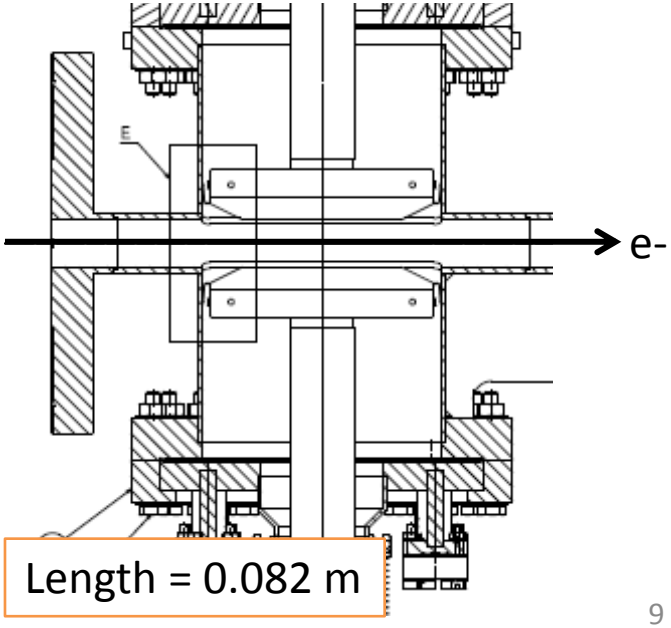
X = 2 x 52.5 mm **Z = 2 x 2.75 mm**



Length = 1.8 m

Long SS Vertical Scraper

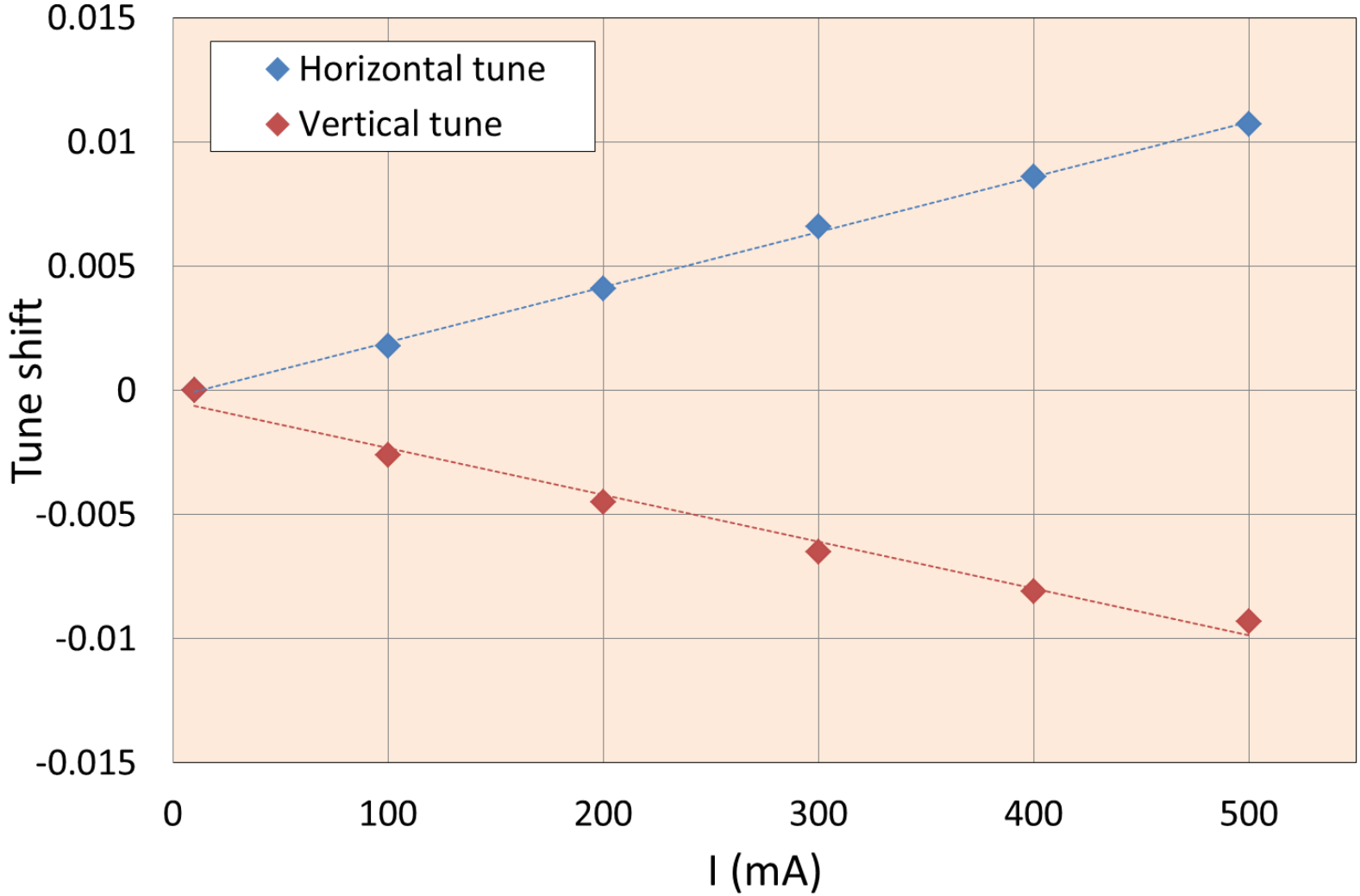
X = 2 x 35 mm **Z = 2 x 4.1 mm**



Length = 0.082 m

Incoherent Tune Shift versus Current for the Bare Machine

416 Bunch Filling Pattern (4/4)



Bunch current (mA) =	0.24	0.48	0.72	0.96	1.20

Restore the Model Optics using LOCO

- **Measure Response Matrix**

(122 BPM, 57 H-correctors, 57 V-correctors)

- **Adjust the Model to fit the Measured Response Matrix**

taking into account measured Dispersion, BPM noise, …

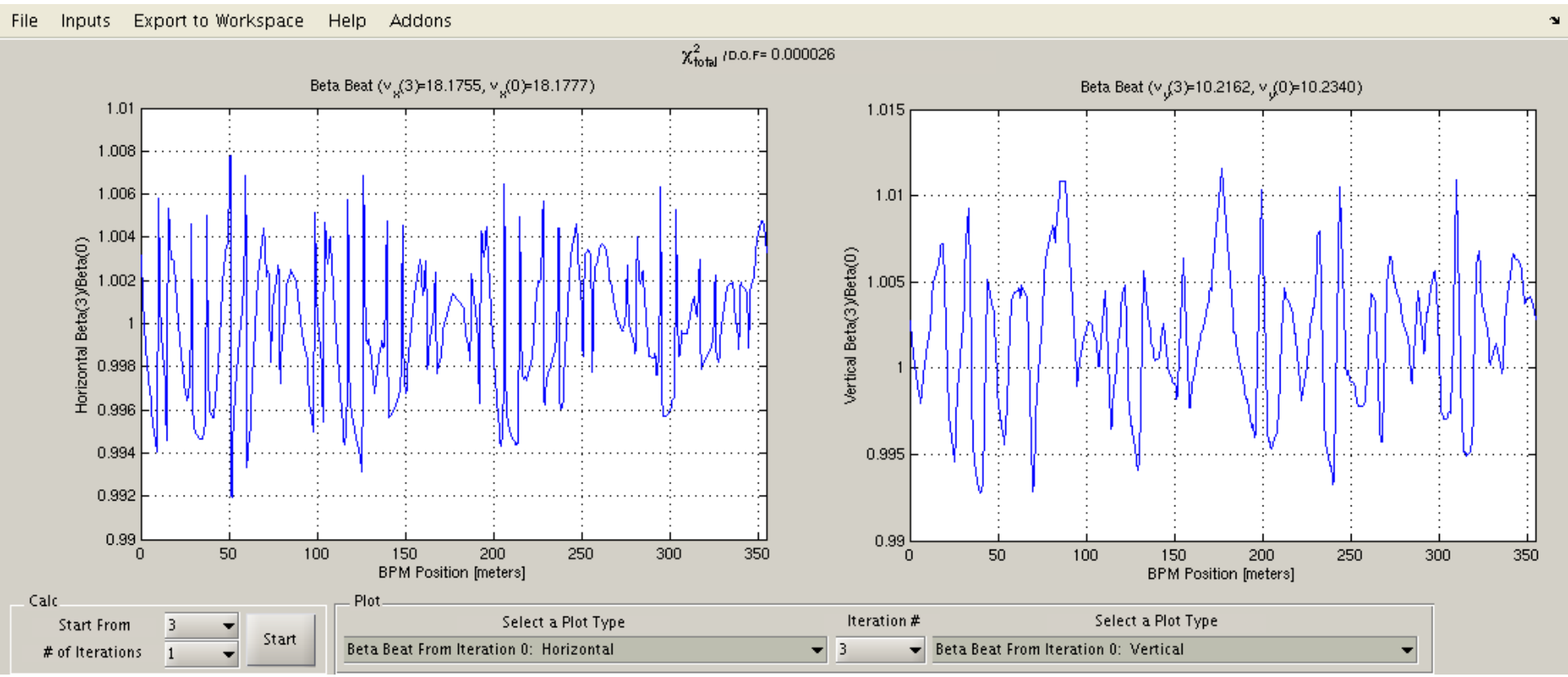
- **Use of the 163 quadrupoles of the machine**

and **24 virtual quadrupoles** located at the middle of the straight sections

MATLAB-based LOCO, J. Safranek, G. Portmann, A. Terebilo, SLAC SSRL, Stanford; C. Steier, LBNL, Berkeley; EPAC02 Proceedings, pp. 1184-1186.

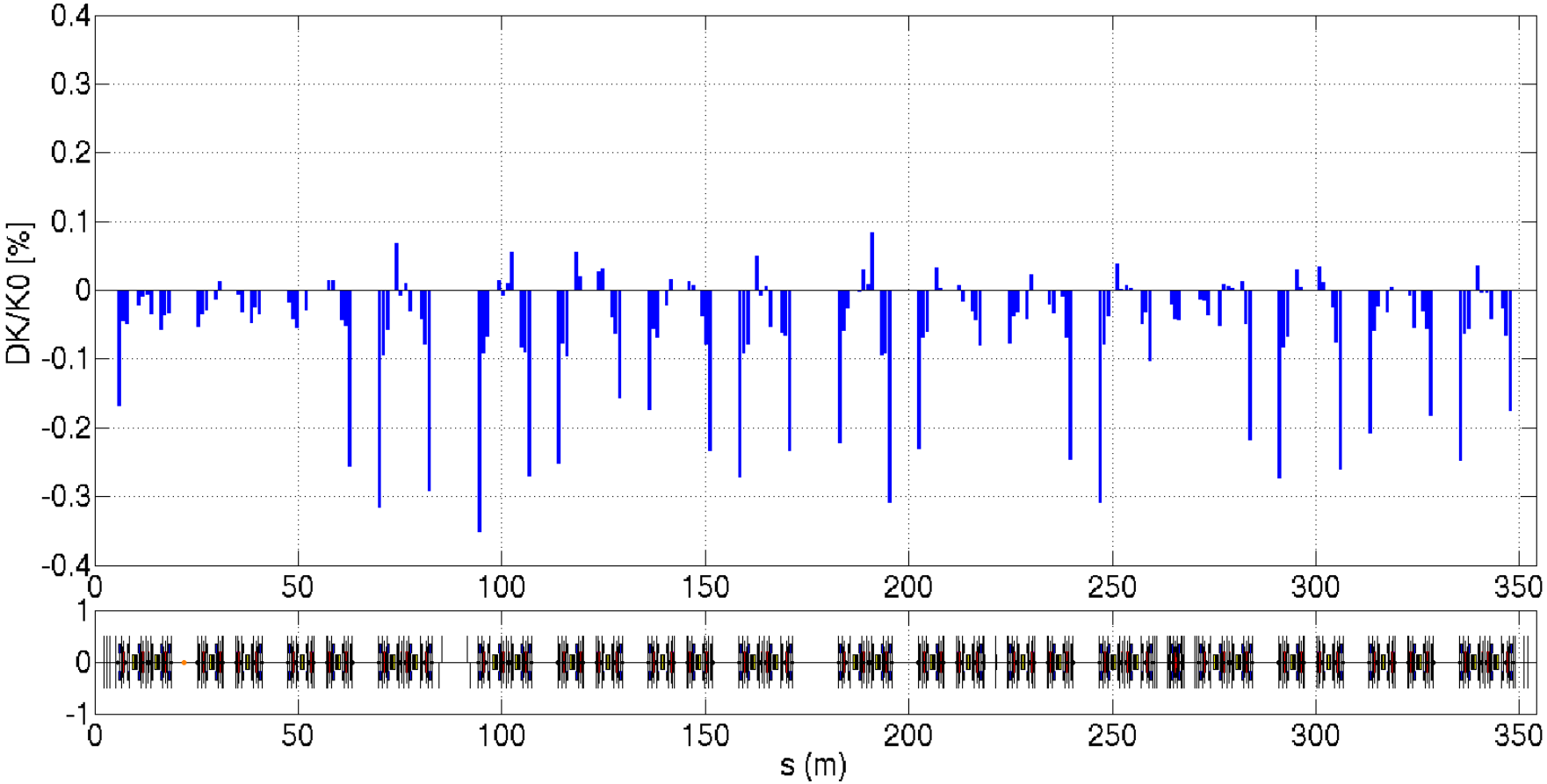
300 mA (4/4) - Bare Machine – β-beating

$\Delta\nu_x = +\ 0.0066$ $\Delta\nu_z = -\ 0.0068$



300 mA - Bare Machine – Quadrupole gradient variation

Main focusing effect comes from long and medium SS



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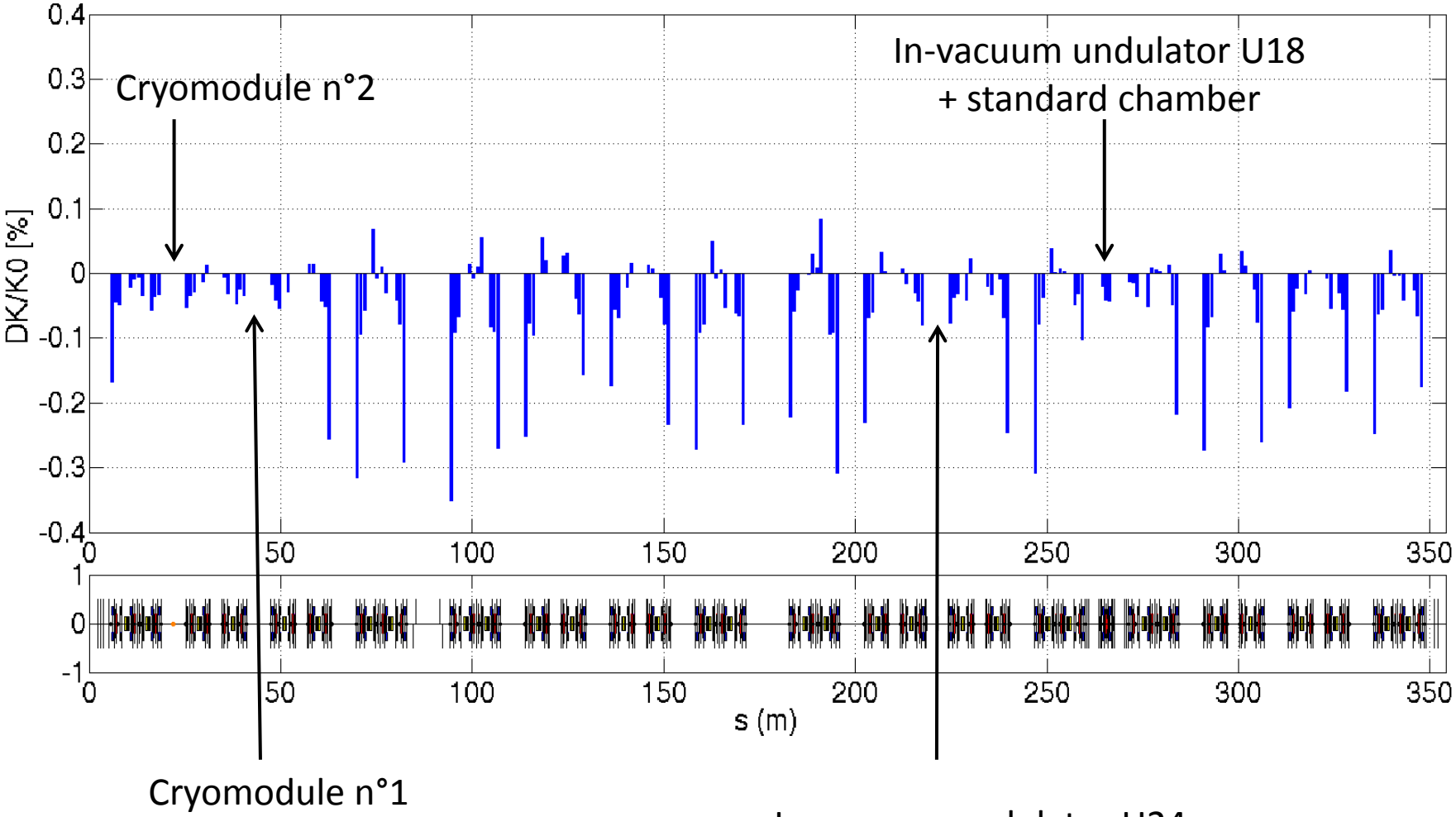
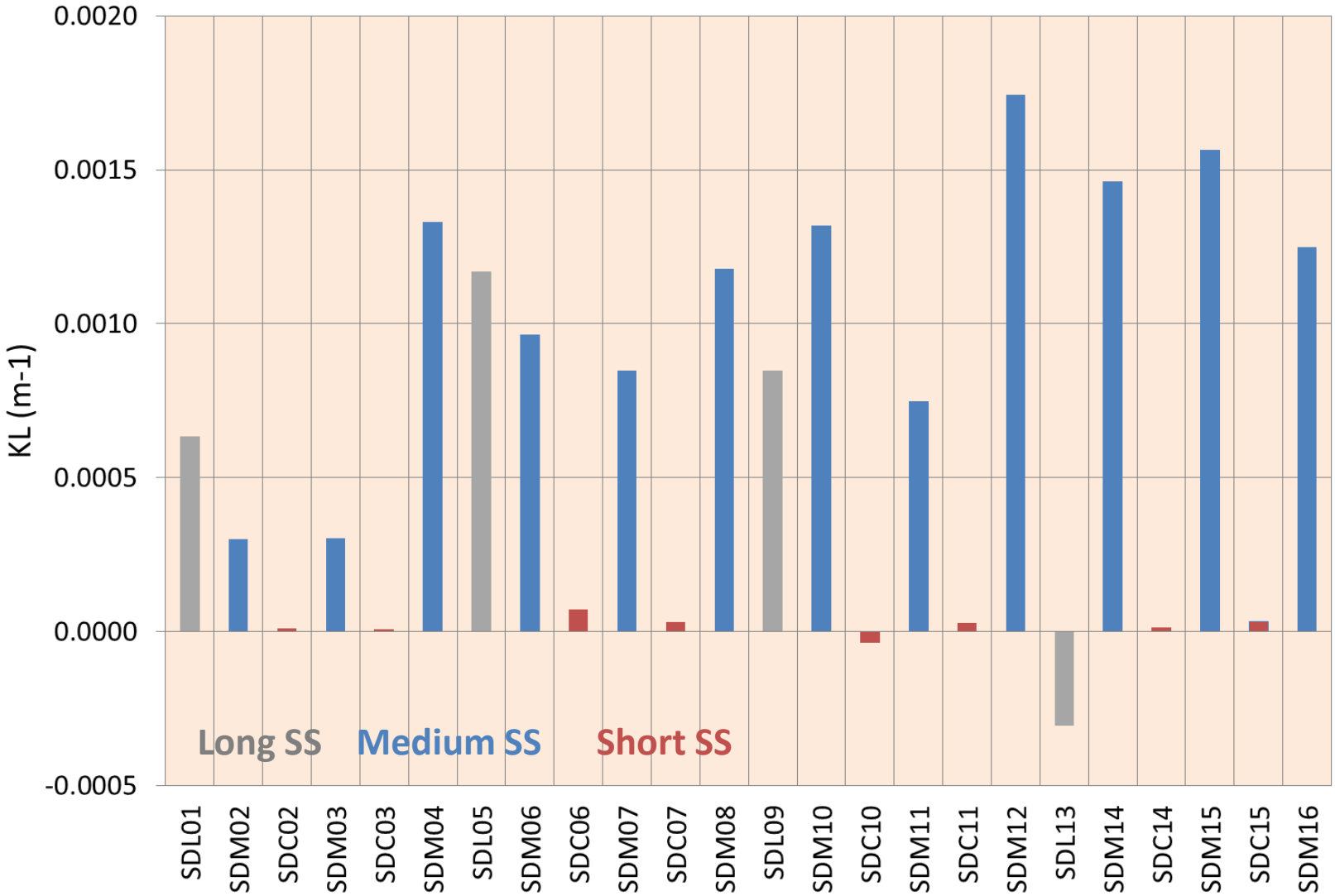
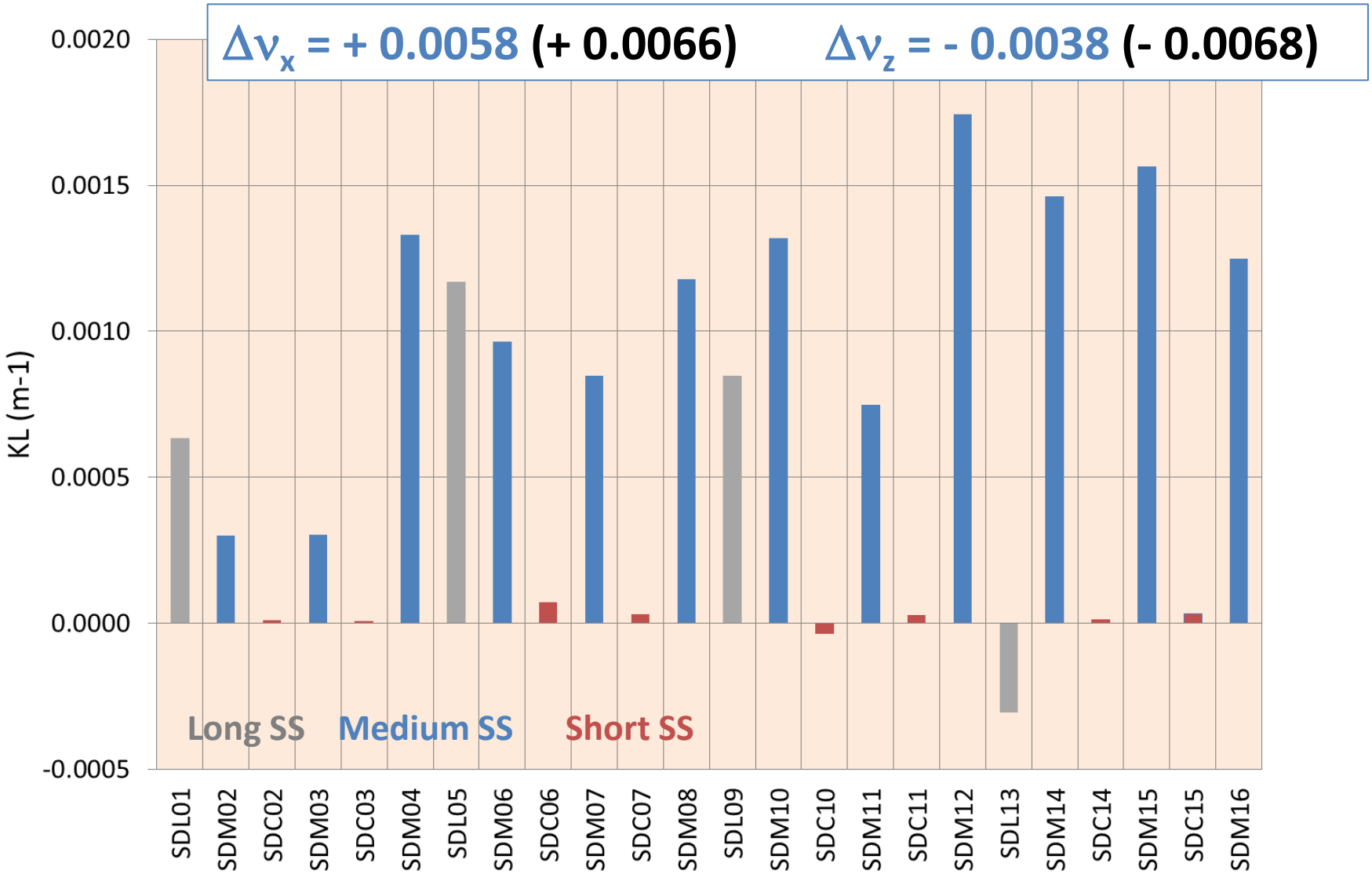


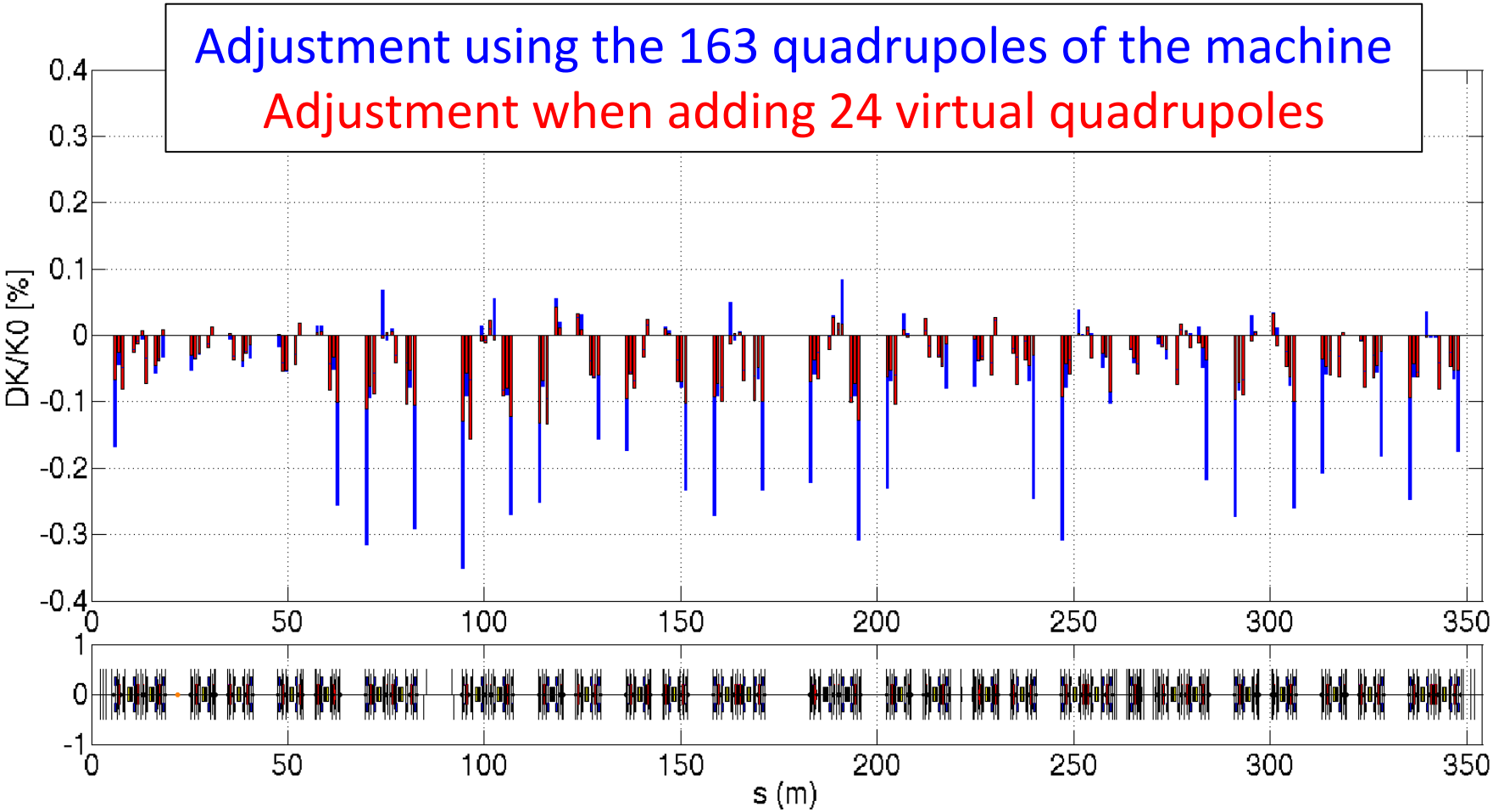
300 mA - Bare Machine – Virtual Quadrupole gradient



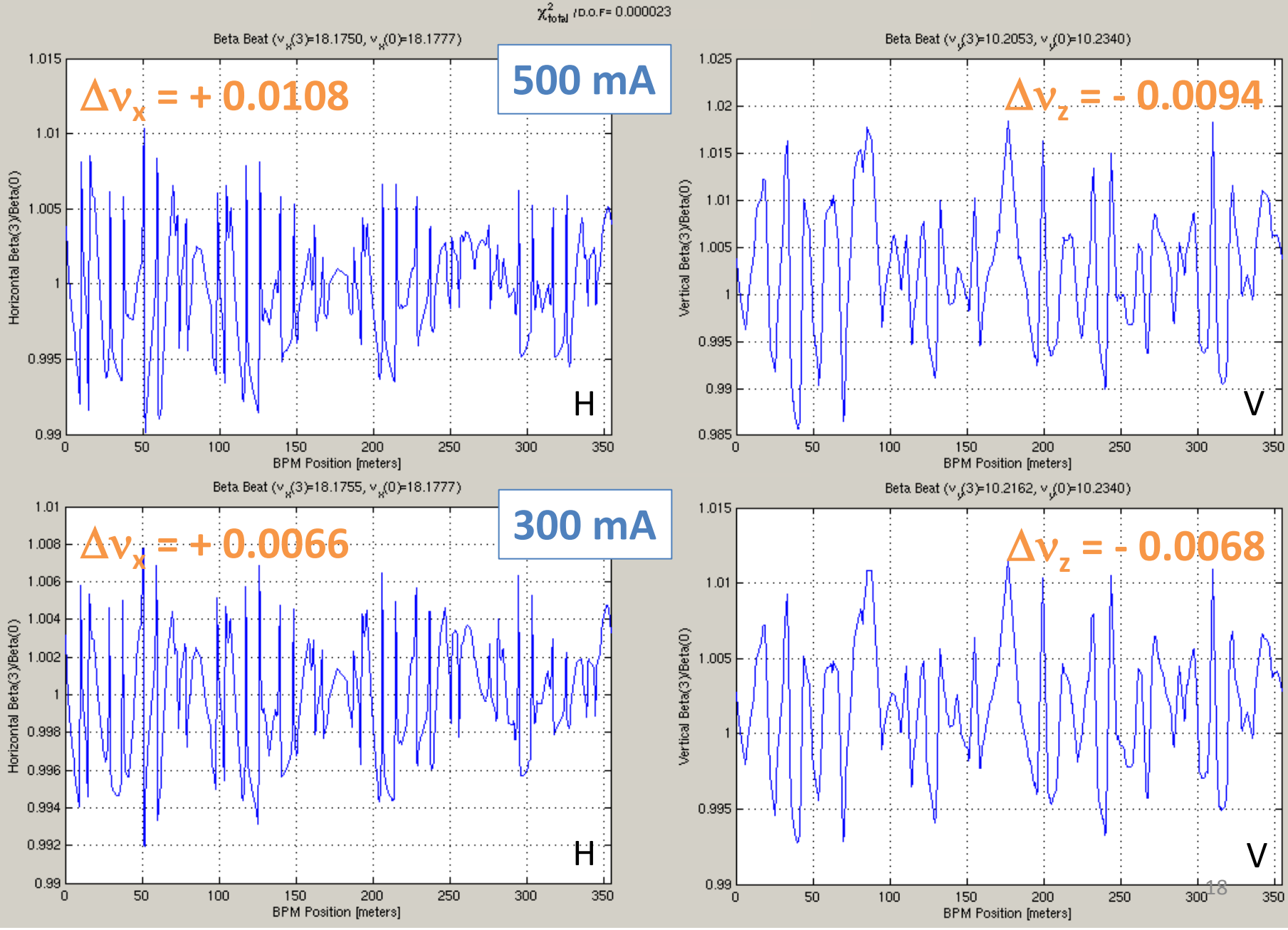
300 mA - Bare Machine – Virtual Quadrupole gradient



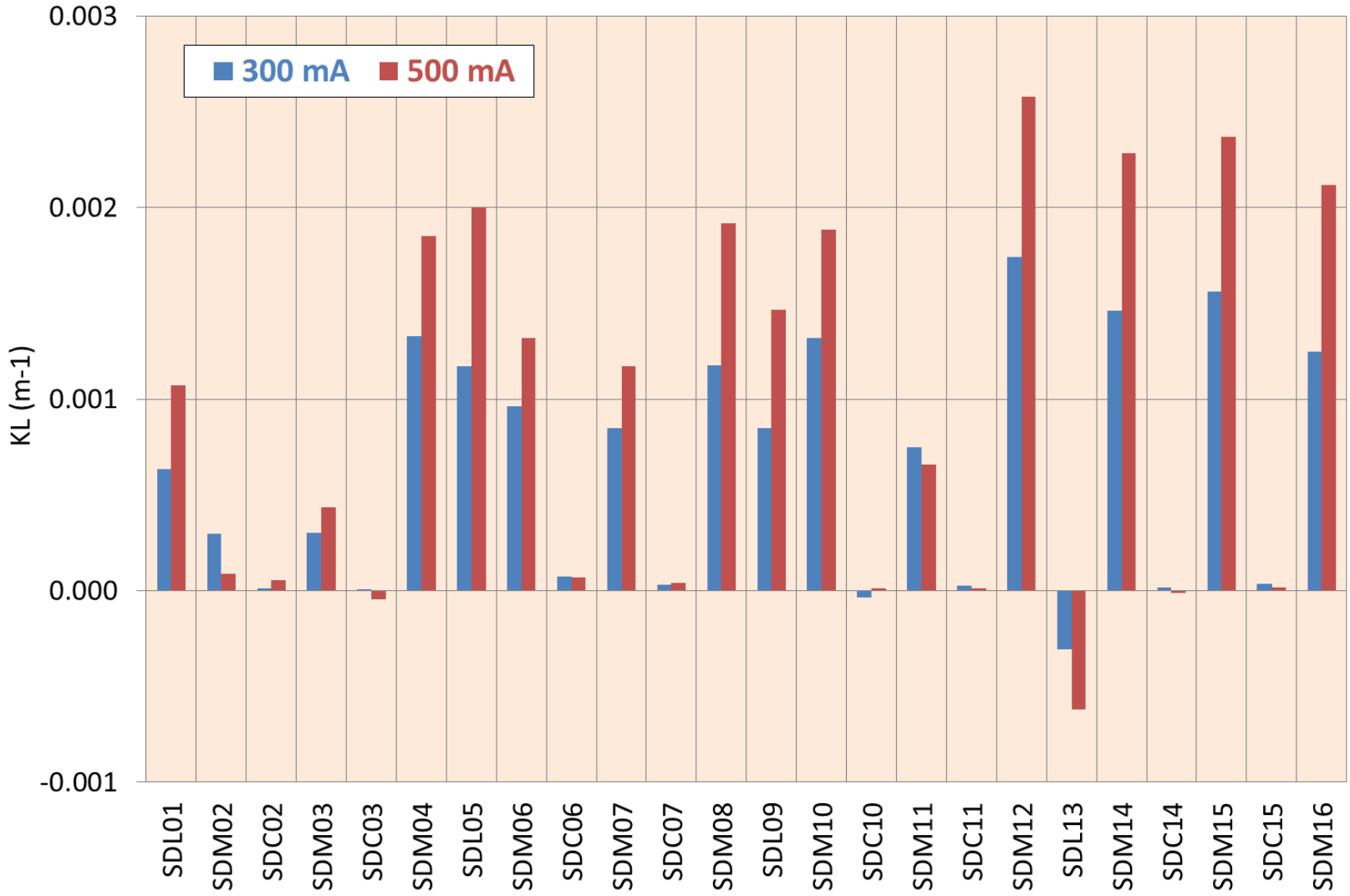
300 mA - Bare Machine – Virtual Quadrupole gradient



Comparison 300 mA / 500 mA - Bare Machine – β-beating



Comparison 300 mA / 500 mA
Bare Machine – Virtual Quadrupole gradient



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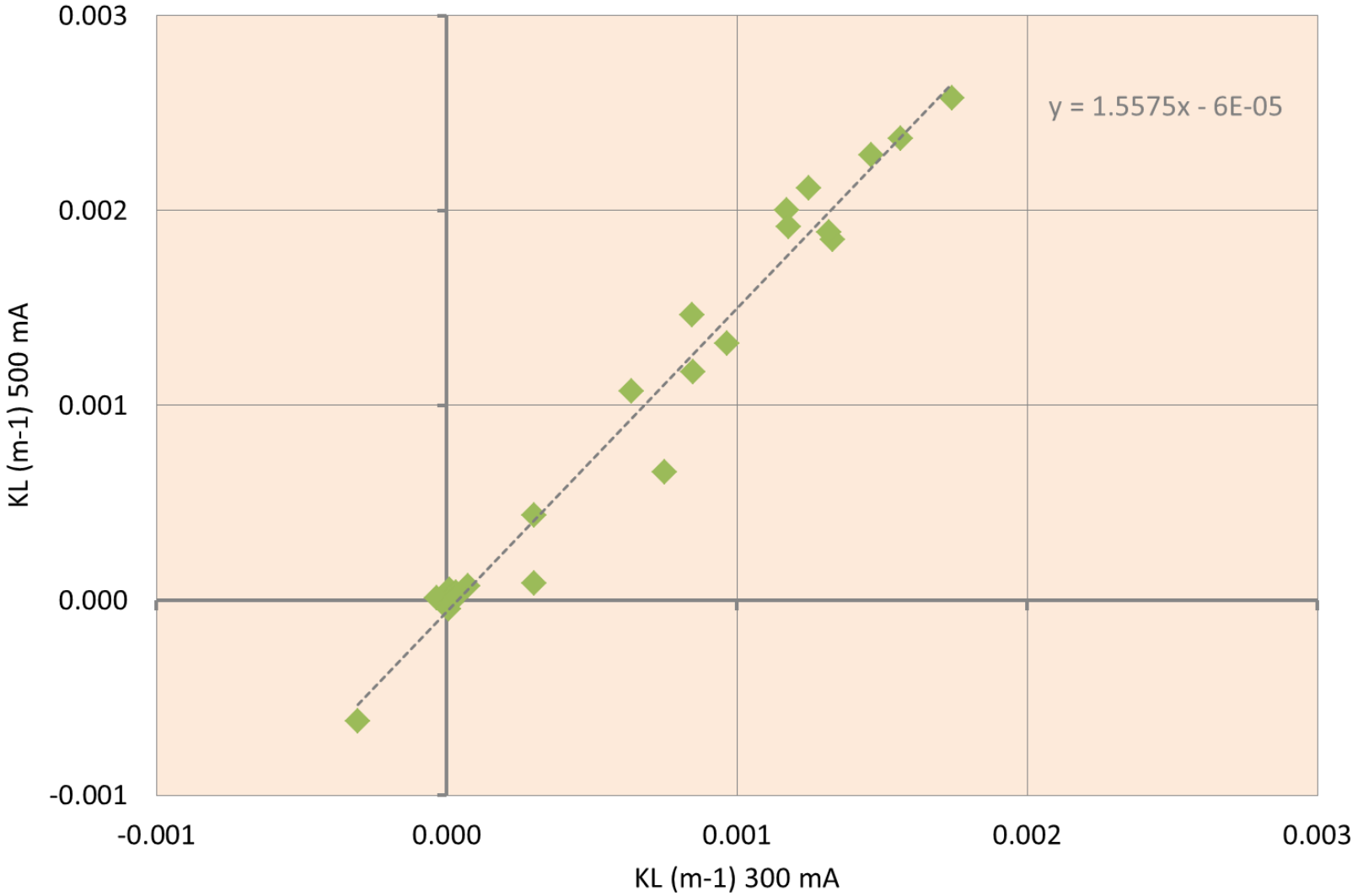
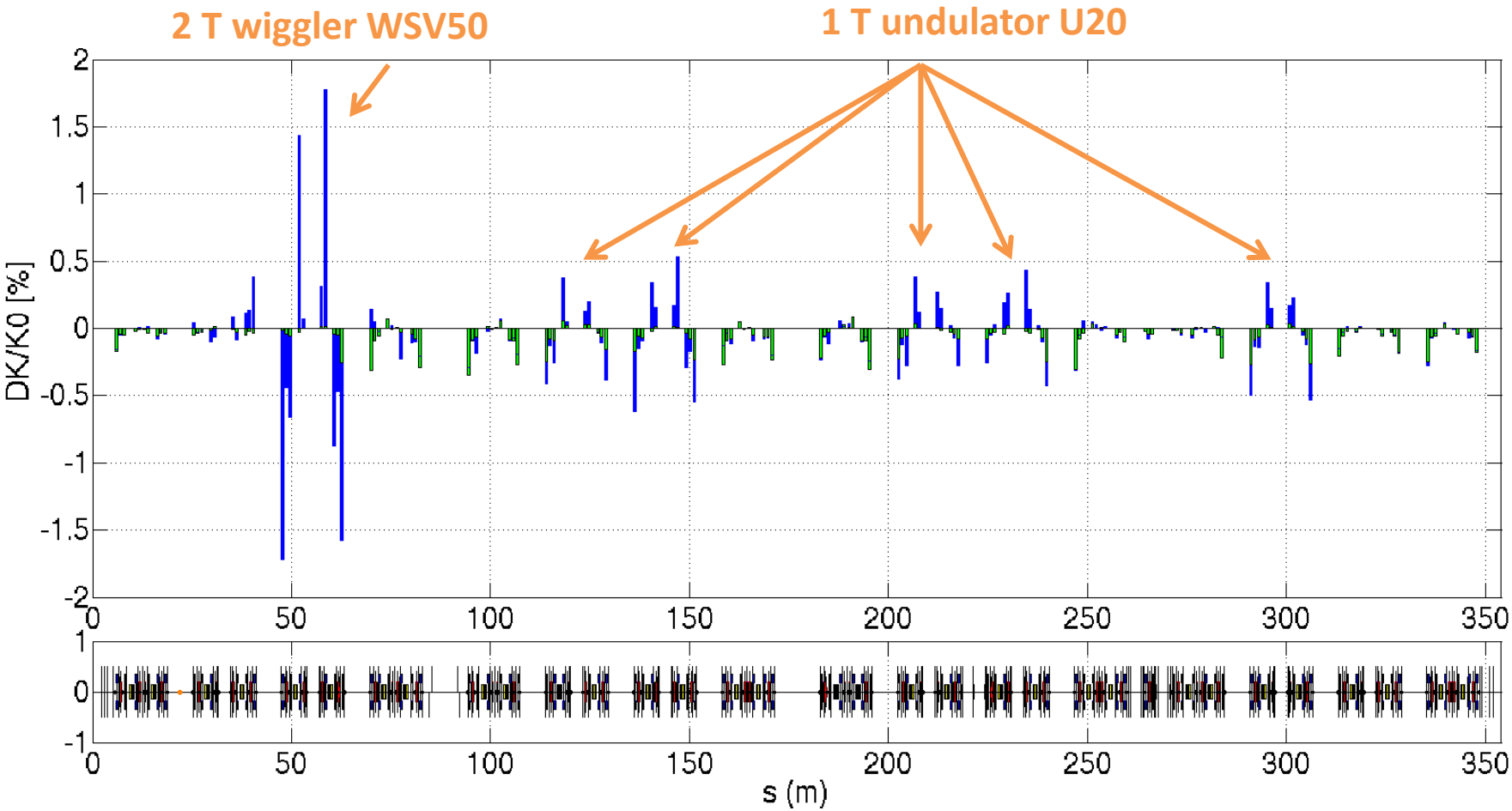


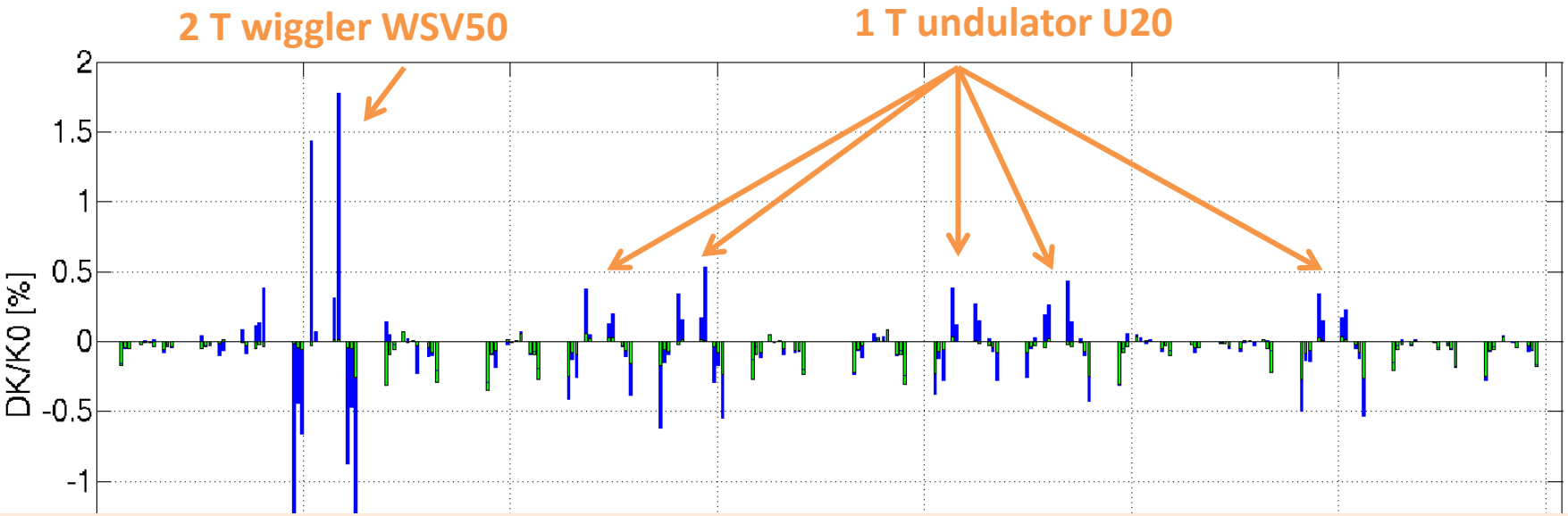
300 mA – 6 x In-vacuum Undulators are closed at 5.5 mm gap
Quadrupole gradient variation



"In-vacuum Undulators are closed"

"Bare Machine"

300 mA – 6 x In-vacuum Undulators are closed at 5.5 mm gap
Tune variation



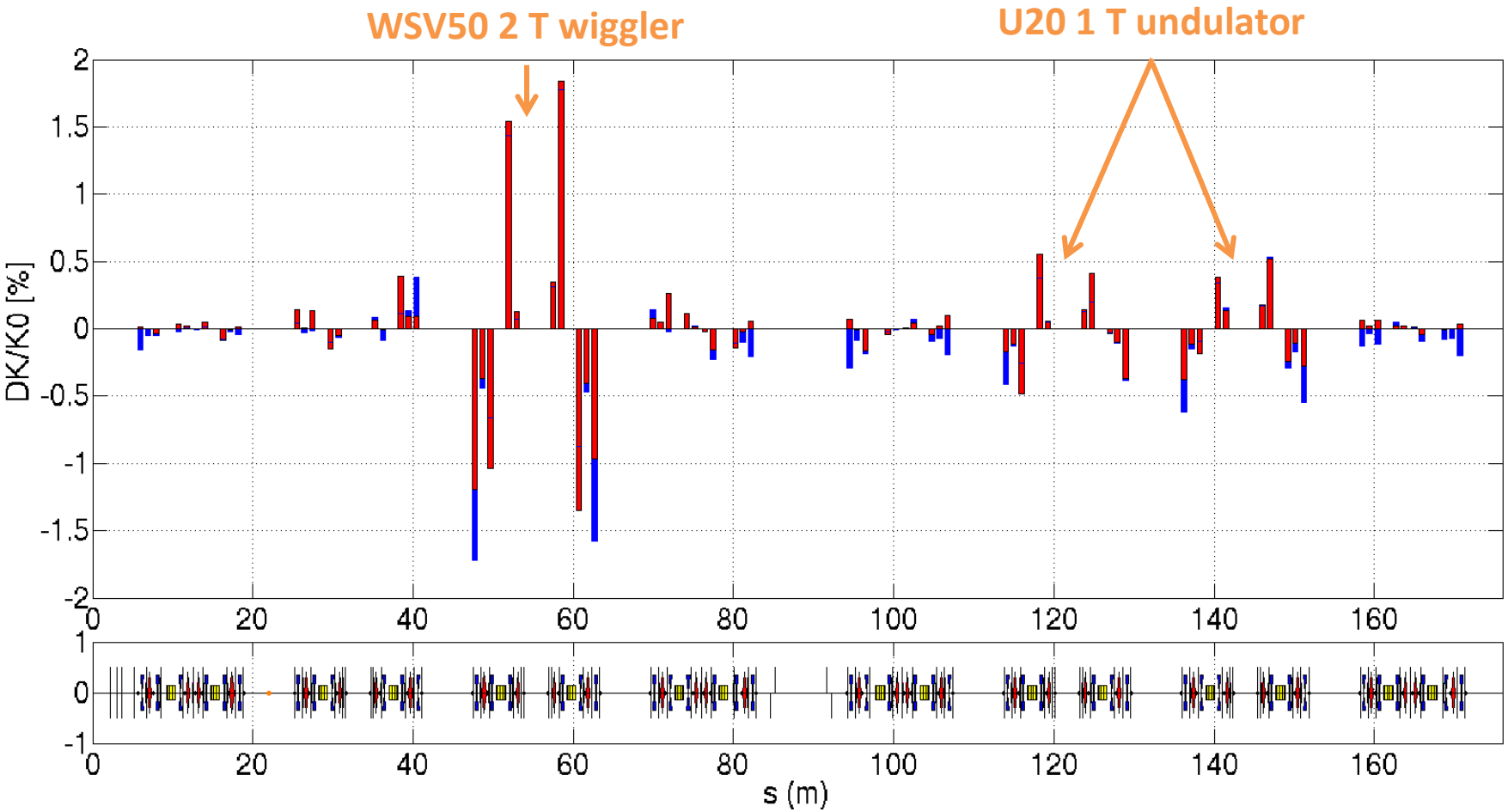
Total tune variation when In-vacuum Undulators are closed

$$\Delta\nu_x = +\,0.0203,\ \Delta\nu_z = +\,0.0094$$

Total tune variation for the Bare Machine

$$\Delta\nu_x = +\,0.0066,\ \Delta\nu_z = -\,0.0068$$

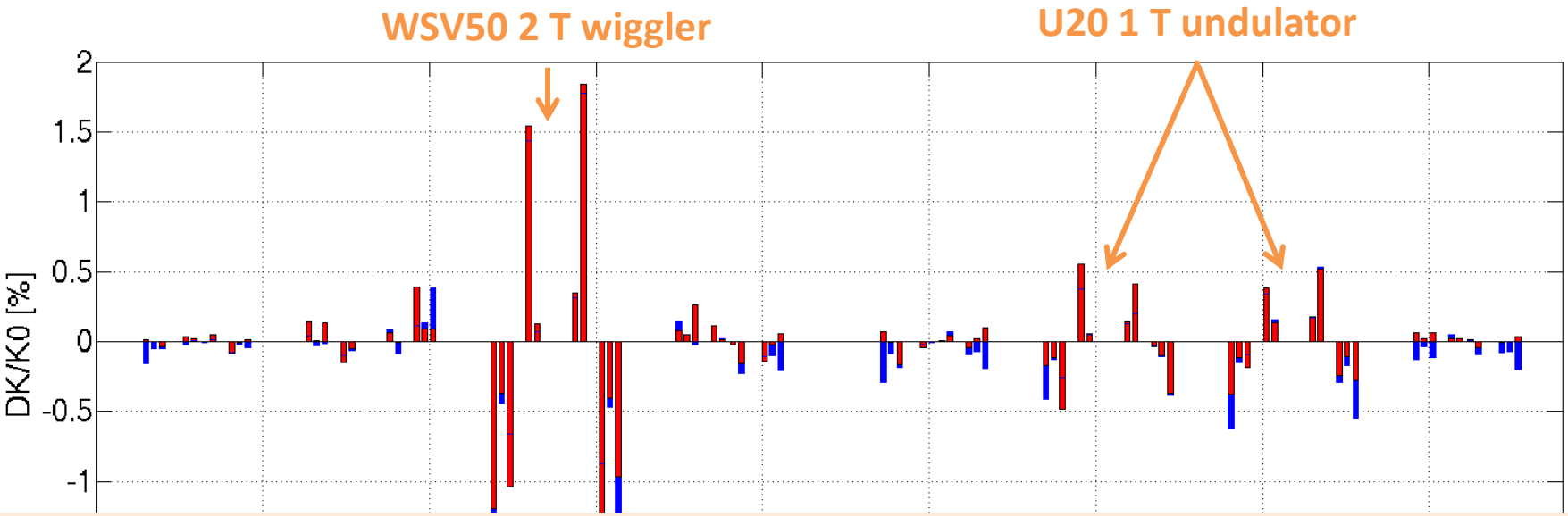
18 mA – 6 x In-vacuum Undulators are closed at 5.5 mm gap
Magnetic contribution measured at low current



"In-vacuum Undulators are closed @ 300 mA"

"Magnetic contribution @ 18 mA"

18 mA – 6 x In-vacuum Undulators are closed at 5.5 mm gap
Magnetic contribution measured at low current



Total tune variation when In-vacuum Undulators are closed @ 300 mA

$$\Delta\nu_x = +\,0.0203,\ \Delta\nu_z = +\,0.0094$$

Tune variation due to Magnetic contribution @ 18 mA

$$\Delta\nu_x = +\,0.0079,\ \Delta\nu_z = +\,0.0172$$

300 mA – 6 x In-vacuum Undulators are closed at 5.5 mm gap
Incoherent Transverse Wakefield Effect

Total tune variation when In-vacuum Undulators are closed

$$\Delta\nu_x = +\,0.0203,\ \Delta\nu_z = +\,0.0094$$

Tune variation due to Magnetic contribution

$$\Delta\nu_x = +\,0.0079,\ \Delta\nu_z = +\,0.0172$$

Tune variation due to Wakefield Effect

$$\Delta\nu_x = +\,0.0058,\ \Delta\nu_z = -\,0.0010$$

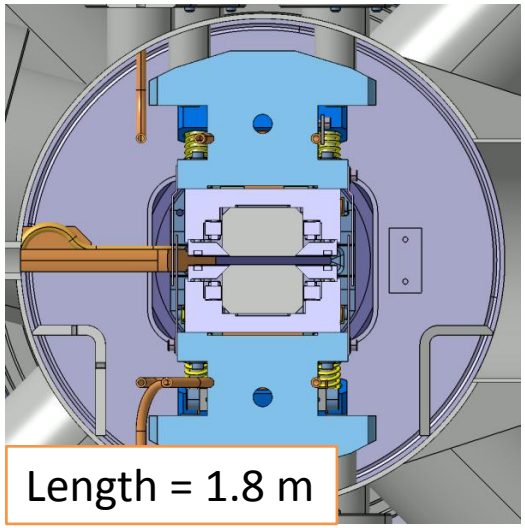
Total tune variation for the Bare Machine

$$\Delta\nu_x = +\,0.0066,\ \Delta\nu_z = -\,0.0068$$

Optical functions in short SS : $\langle\beta x\rangle = 14.3$ m, $\langle\beta z\rangle = 2.4$ m

300 mA – 6 x In-vacuum Undulators are closed at 5.5 mm gap
Incoherent Transverse Wakefield Effect

In vacuum U20 undulators
X = 2 x 52.5 mm
Z = 2 x 2.75 mm



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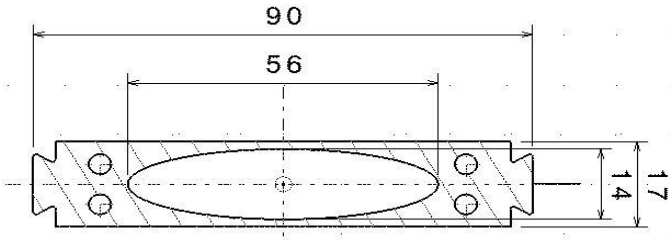

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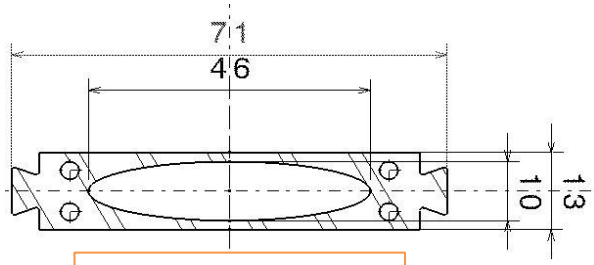

Length = 5.6 m

Incoherent $\Delta\nu_x$ = + 0.0058
Total length = 10.8 m
<βx> = 14.3 m
G x L = 0.046 T

G = 0.0043 T/m

Incoherent $\Delta\nu_x$ = + 0.0066
Total length = 71.6 m
<βx> = 5.8 m
G x L = 0.130 T

G = 0.0018 T/m

Conclusion

- **At SOLEIL, the non circular low gap chambers generate large incoherent tune shifts as predicted by calculations.**

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- **The incoherent transverse wakefield contribution of low gap in-vacuum undulators is not negligible in terms of focusing strength. At SOLEIL, the effect is amplified by the β_x high value.**

- **For machines of the future, the effect will be amplified by smaller vertical apertures.**

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- **At SOLEIL, the β-beat does not affect so much the beam lifetime and the injection efficiency**

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- **However, tune variations affect beam lifetime and injection efficiency when undulators gaps are varying**

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- **At SOLEIL, the β-beat does not affect so much the beam lifetime and the injection efficiency**

  → **The optics is restored on the model only at low current, for the bare lattice.**

- **However, tune variations affect beam lifetime and injection efficiency when undulators gaps are varying**

  → **Tunes are kept fixed thanks to a global feedback**

Thank you for your attention

SOLEIL SYNCHROTRON