Coupling effects at SOLEIL

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- Sensitivity of the SOLEIL lattice to betatron coupling
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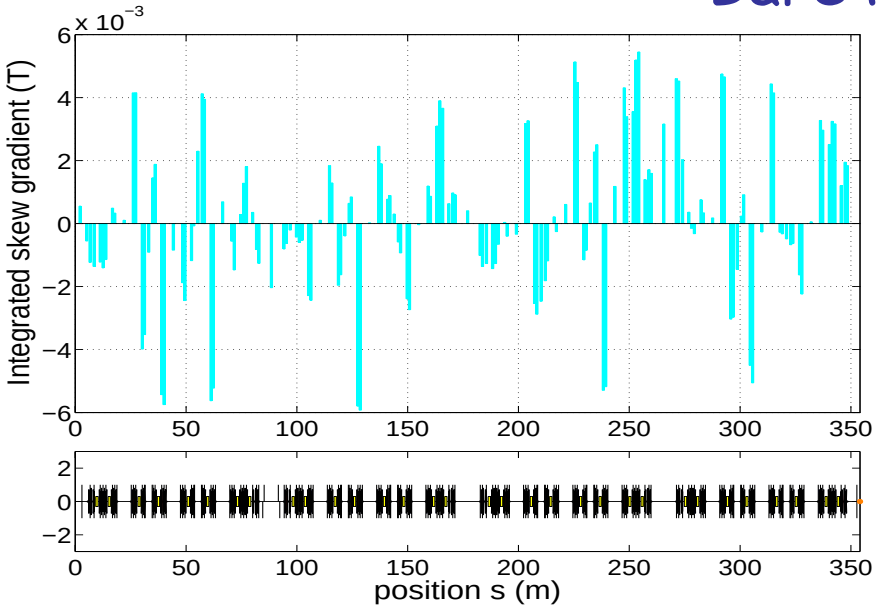
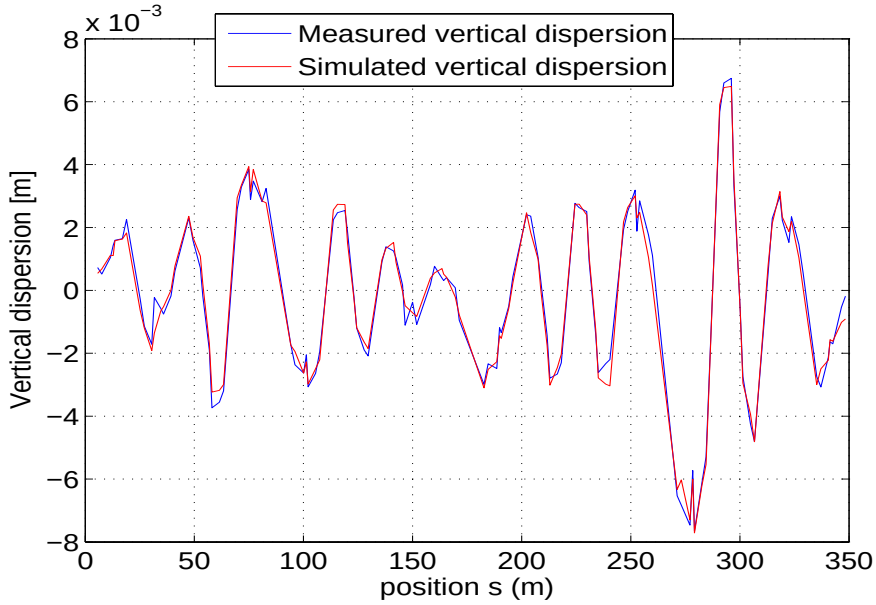
Model for Coupling (I)

- Coupling main contribution at SOLEIL
  - Mostly vertical displacement of sextupole magnets
    - Thanks to the excellent quadrupole magnet alignment and magnetic axis centering
    - Contribution of vertical closed orbit in sextupoles is small
- Model
  - 152 virtual skew quadrupoles located in all 120 sextupole magnets and in straight sections (to take into account possible ID coupling effect)
- Method (Cross Talk Closed Orbit - CTCO)
  - Weighted least square (SVD) fitting of the off diagonal response matrices and vertical dispersion function

Model for Coupling (II)

Bare machine





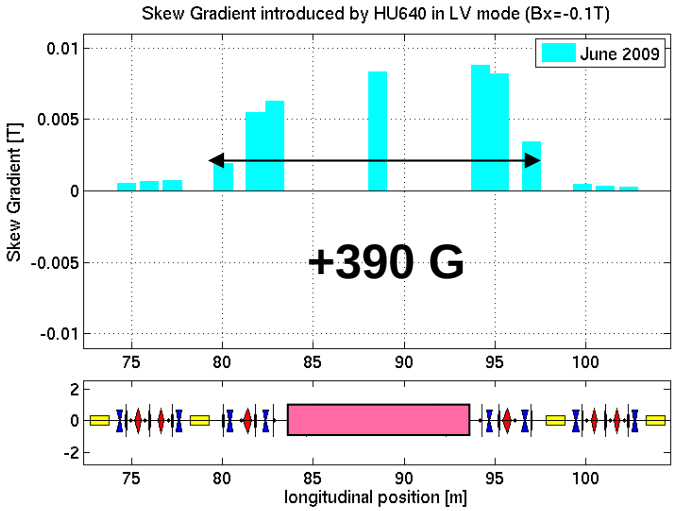
R.M.S. value of the virtual skew quadrupoles: σ_{Gx}=25 10^{-4} T

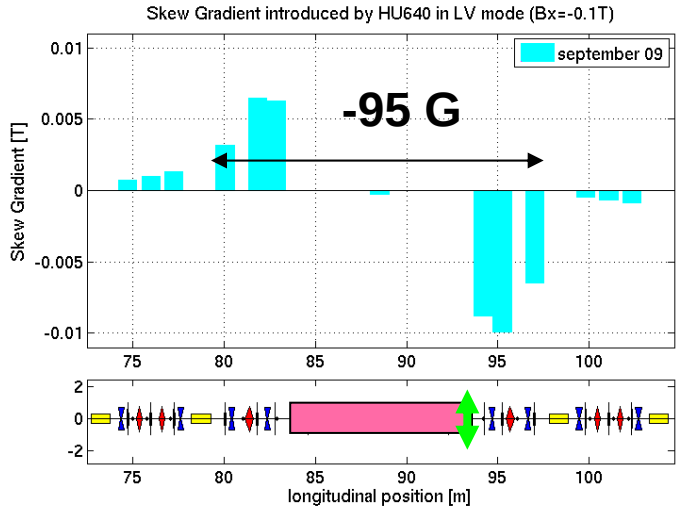
→ corresponding to a vertical alignment error in sextupole magnets of $\sigma_{z\ sextupole}$= 40µm (consistent with alignment measurements when taking into account correlation due to the girders).

Spurious vertical dispersion from the simulation fits well the measured data when crosstalk from BPM electronics is subtracted.

Model for Coupling (III)

The measurements of the off diagonal matrices allow to identify any local coupling error: example of the 10m long HU640 undulator skew gradient evolution

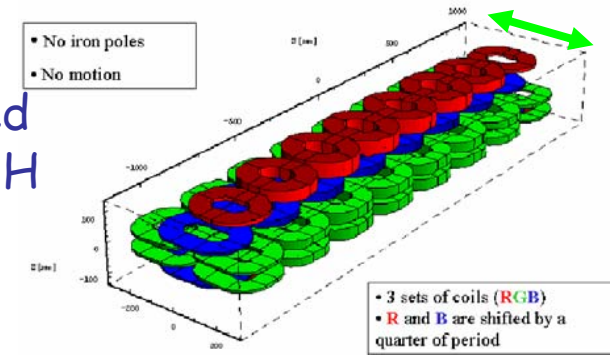




10m HU640 undulator
LV mode – Bx = -0.1 T

The agreement with beam based integral measurement using H bump is good

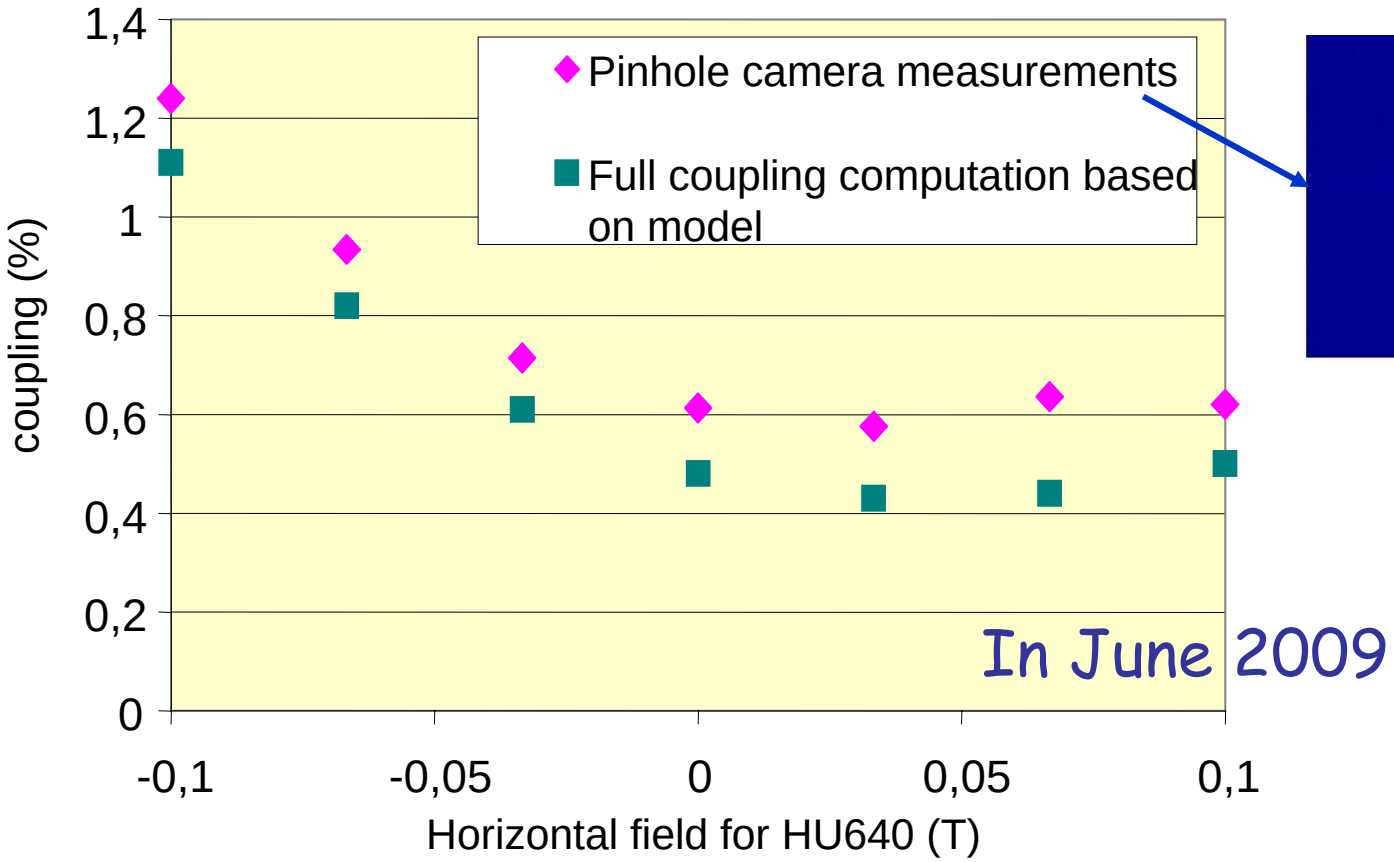
(see O. Marcouillé's talk)

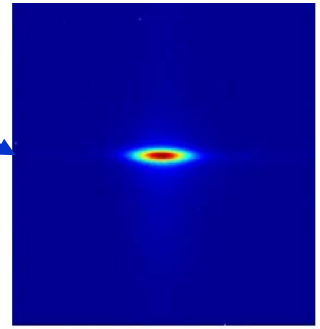


Induced coupling has been reduced thanks to end coil transverse displacement

Model for Coupling (IV)

The model is robust enough to predict the coupling introduced by the 10 m long HU640 electromagnetic undulator





(+370 G) (beam based integral measurement) (-390 G)

Sensitivity of SOLEIL lattice to betatron coupling – (I) Beam lifetime with IDs

- Beam lifetime measurements in presence of IDs – Nominal WP

HU640 (maximum horizontal field - LV mode) + 4 x in vacuum U20 undulators (closed at minimum gap: 5.5 mm)

$\nu_x = 18.202$ / $\nu_z = 10.317$
$\xi_x = 2$ / $\xi_z = 2.6$

Touschek dominant regime

	300 mA (300 bunches)		10 mA single bunch	
	Coupling value (%)	τ(h)	Coupling value (%)	τ(h)
Natural (Skew quad off)	1.4	7.0	1.7	1.3
Corrected to minimum value + Dz	1.3	6.7	2.2	1.4

- The reduction of the betatron coupling from 1.4% to (0.2% + vertical dispersion) does not improve the beam lifetime in the presence of IDs

Sensitivity of SOLEIL lattice to betatron coupling (II)
On momentum dynamic aperture with IDs

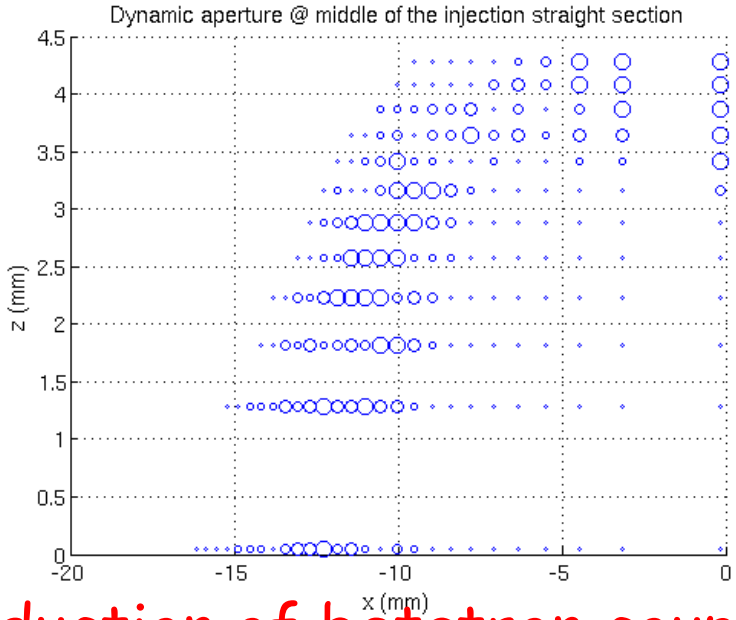
- HU640 (maximum horizontal field - LV mode) + 4 x in vacuum U20 undulators

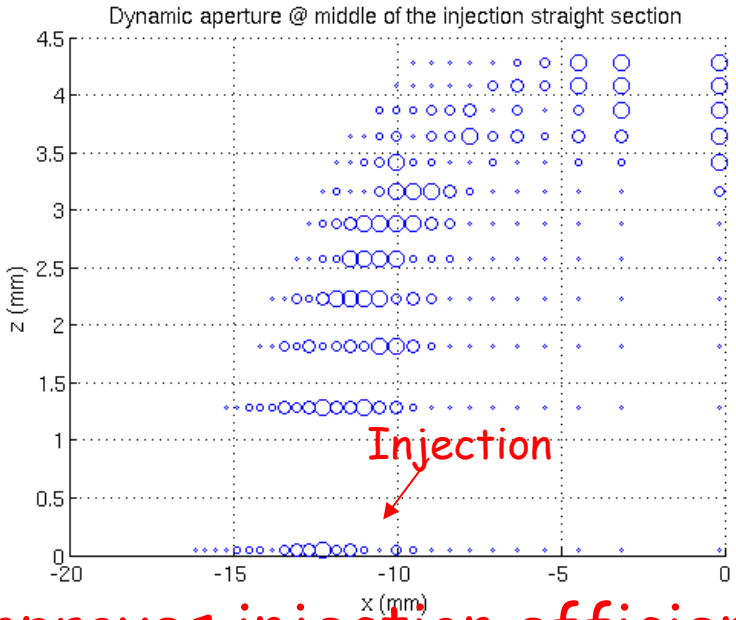
$\nu_x = 18.202$ / $\nu_z = 10.317$
$\xi_x = 2$ / $\xi_z = 2.6$

Injection efficiency: 71% 81%

Natural: skew quad. off

2% coupling with Vert. Disp

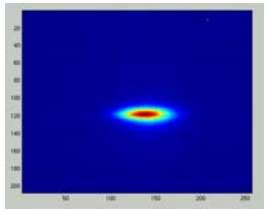


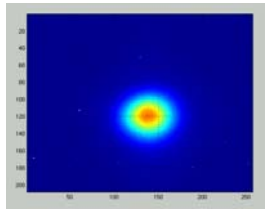


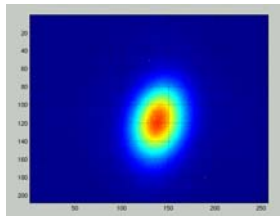
Reduction of betatron coupling improves injection efficiency

Coupling control by vertical dispersion bump – (I) Method

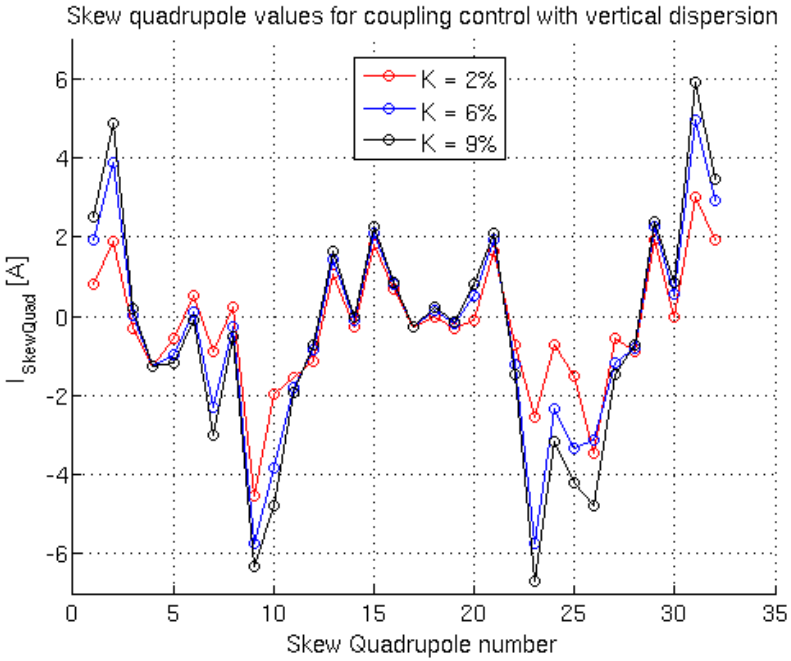
- Method tested on the SR


0.2%

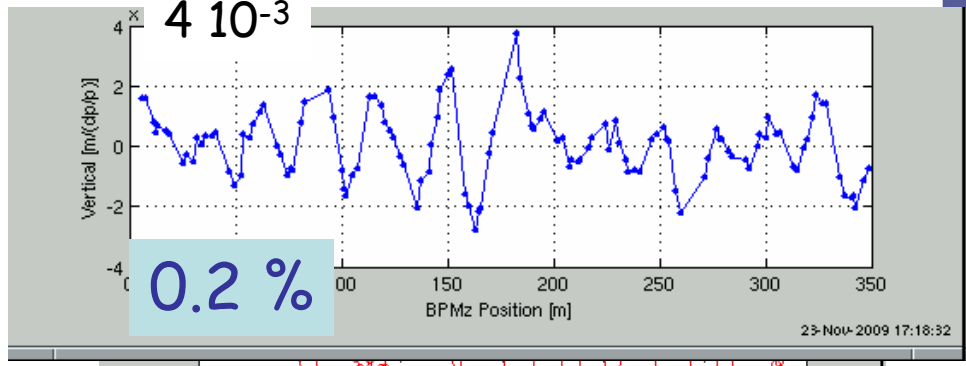

2%

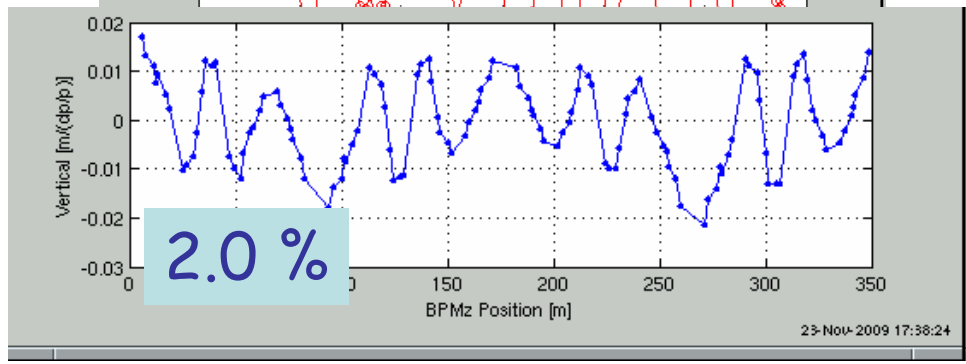

6%

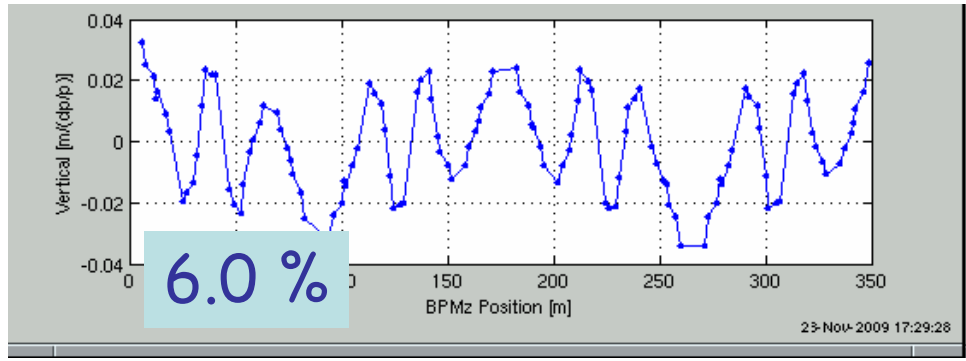
Max. current Value: +/-7 A



4 10^{-3}







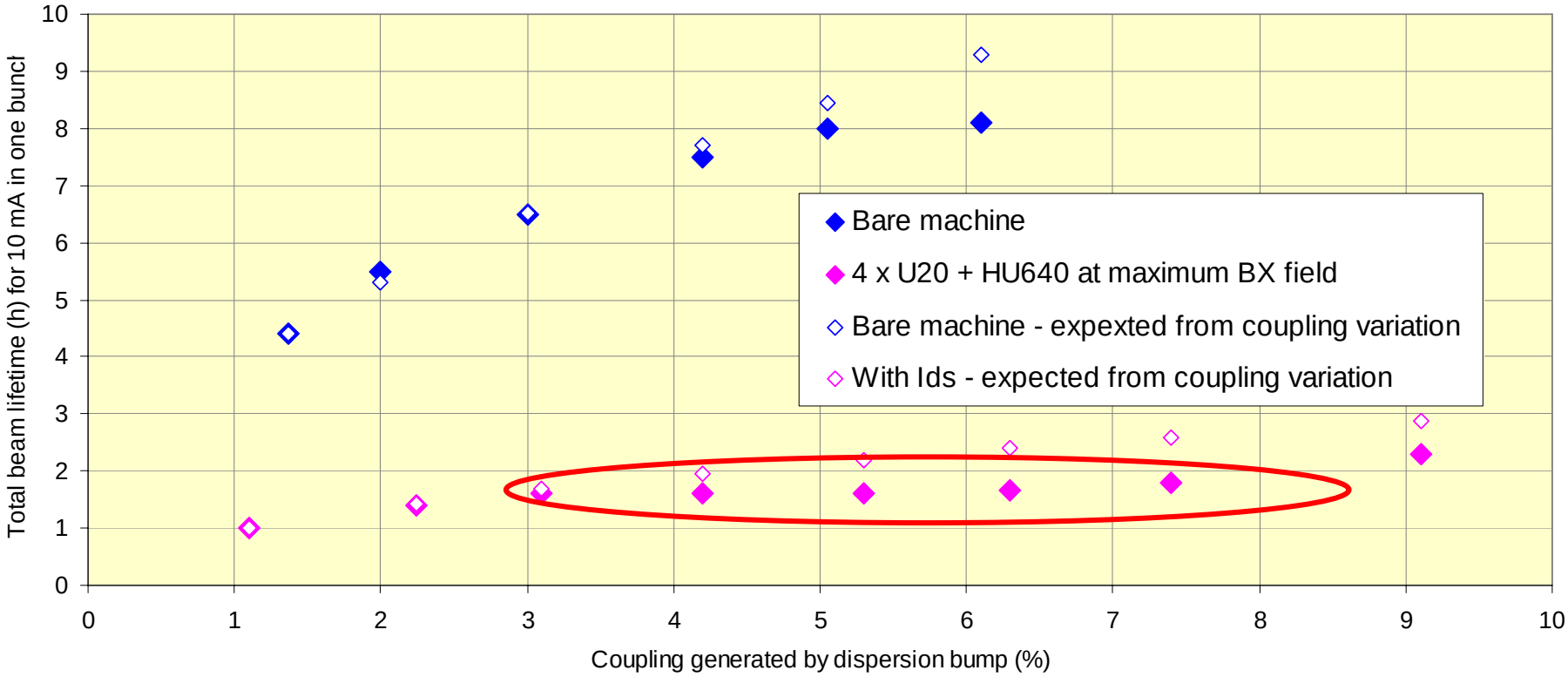
Coupling control by vertical dispersion bump - (II) Beam lifetime

ν_x = 18.202 / ν_z = 10.317
ξ_x = 2 / ξ_z = 2.6
10 mA single bunch

Beam lifetime (h) versus coupling	Natural Coupling	Minimum Betatron coupling	2% Dz coupling	6% Dz coupling
Bare machine	4.0 h (1.1%)	1.5 h (0.23%)	5.5 h	8.1 h
4 x U20 + HU640 LV mode - Bx = 0.1 T	1.3 h (1.7%)	0.6 h (0.38%)	1.4 h	1.6 h

- In the presence of IDs, beam lifetime is not increased when the coupling is increased.

Coupling control by vertical dispersion bump - (II) Beam lifetime

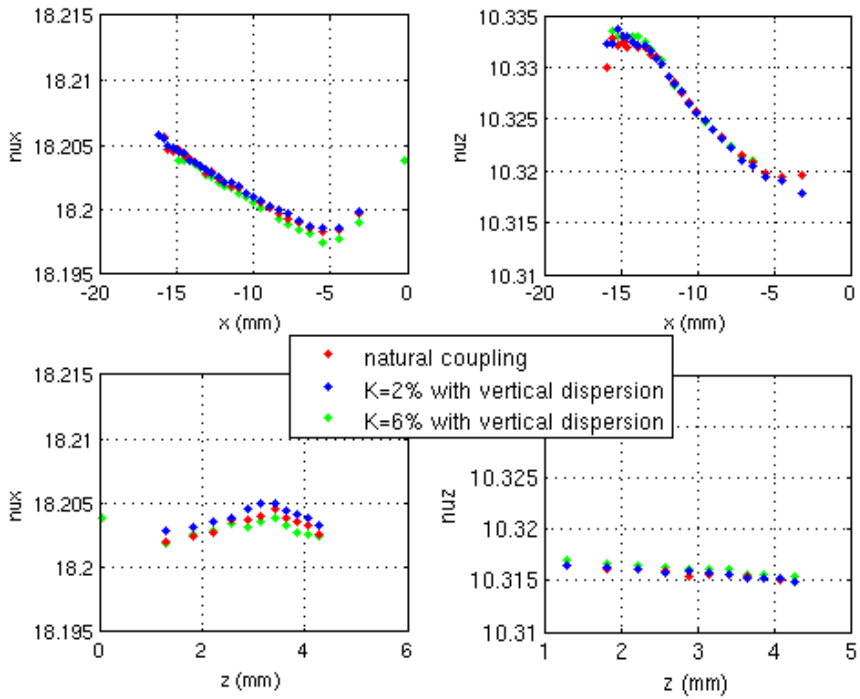


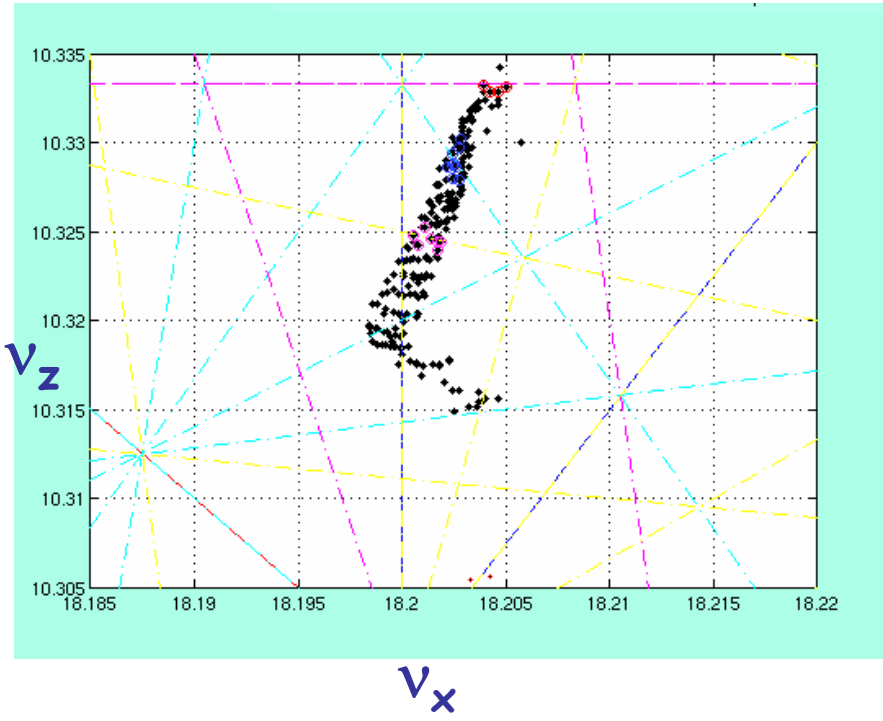
- In the presence of IDs, beam lifetime is not increased when the coupling is increased with the vertical dispersion.

Coupling control by vertical dispersion bump - (III)
On momentum dynamic aperture

HU640 (maximum horizontal field - LV mode) + 4 x in vacuum U20 undulators

- No significant variation of tune shift with amplitude for on momentum particles





- Best Guess: Beam dynamics with IDs are significantly modified by the strong skew octupolar components of the skew quadrupole fields → DB/B = -0.68 @ x = 35 mm

Summary

- At SOLEIL, natural coupling value is already low.
  - No strong request for reducing/increasing the coupling for operation
  - No significant improvement on beam lifetime when reducing the betatron coupling.
  - 10 % better injection efficiency when betatron coupling is reduced in presence of IDs.

- Without IDs, Touschek beam-lifetime can be controlled using vertical dispersion bump

- With IDs, increasing the coupling with vertical dispersion does not increase the beam-lifetime.
  - Skew quadrupole have a strong skew octupole component
    - → Strong candidate to reduce off-momentum dynamics for large coupling
    - → Experimental studies underway
    - → Having Skew quads in sextupole magnet is questionable
  - → Injection efficiency similar at 2% or 6% coupling value!