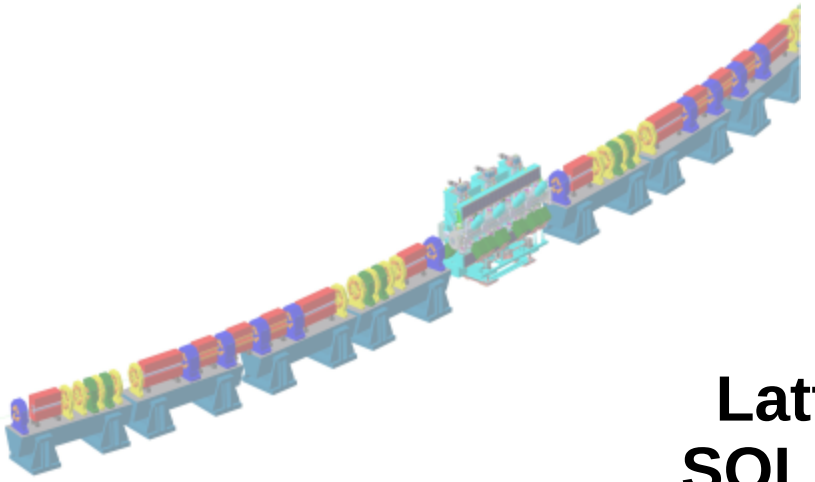


Lattice studies for SOLEIL ring upgrade

21-22 November 2017

Alexandre Loulergue

On behalf of the
accelerator physics group

Upgrade lattice outline

2016 proposition 200 – 250 pm.rad

2017 investigation < 150 pm.rad

Today baseline 72 pm.rad

Try vertical off axes injection

L. Farvacque et al. , A Low-Emittance Lattice for the ESRF, Proceedings of IPAC (2013)

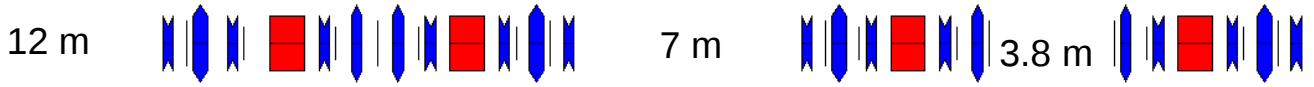
A. Streun, The anti-bend cell for ultralow emittance storage ring lattices NIMA, 737 (2014)

Upgrade lattice evolution

C=354 m 16 cells of 2 kinds

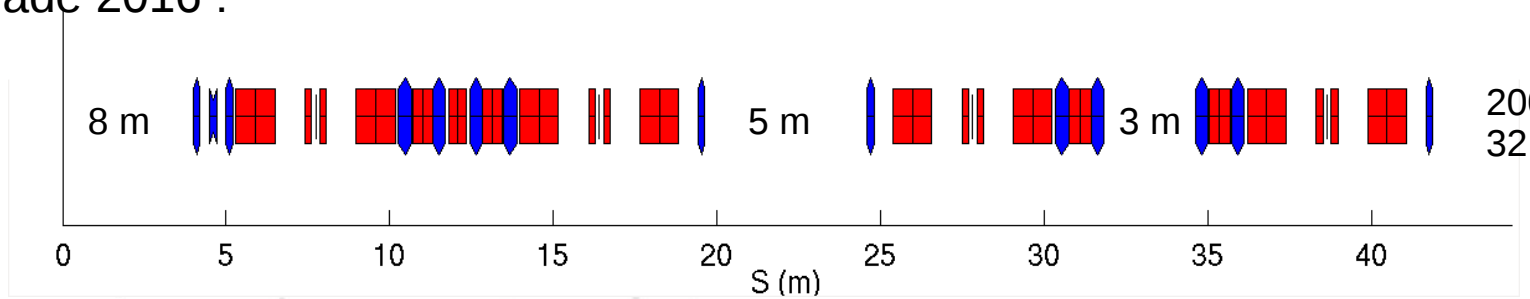
1/8 of the ring here
2.75 GeV

Actual :



4 nm
45 % of straights

Upgrade 2016 :



200 -250 pm
32 % of straights

7-BA 6-BA

Upgrade lattice evolution

The emittance of 250 pm was still considered rather high

We reduced again the straight length with pure 7BA cells and a symmetry of 16 with 16 straights of 5 m (22.5% of the circumference)

The natural emittance is reduced down to 140 pm.rad (125 with reverse bend)

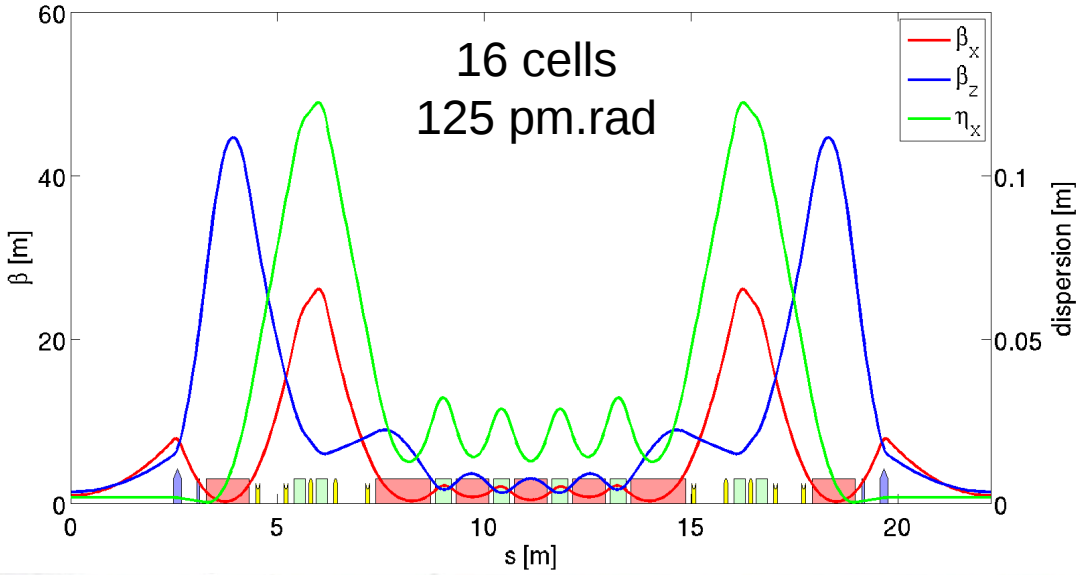
The optics includes low beta function (~ 1 m) at straight center for photon matching

Magnets not too strongs :

– Sext < 1000 T/m2
– Quad < 60 T/m
– Dip ~ 0.6 T & 25 T/m

Without long. grad. in bend

Nat. Chro. = -6.5 -5.3 per cell
= -103 -85 tot.



Upgrade lattice evolution

The number of straights (16) was not enough (24 today !) according to SOLEIL scientific case

We increased the number of cells from 16 to 20 with straights length of 4.4 m (25% of the circumference)

The natural emittance is reduced down to 72 pm.rad (60 with reverse bend)
At full coupling, the emittances are 50 pm.rad (42 with reverse bend)

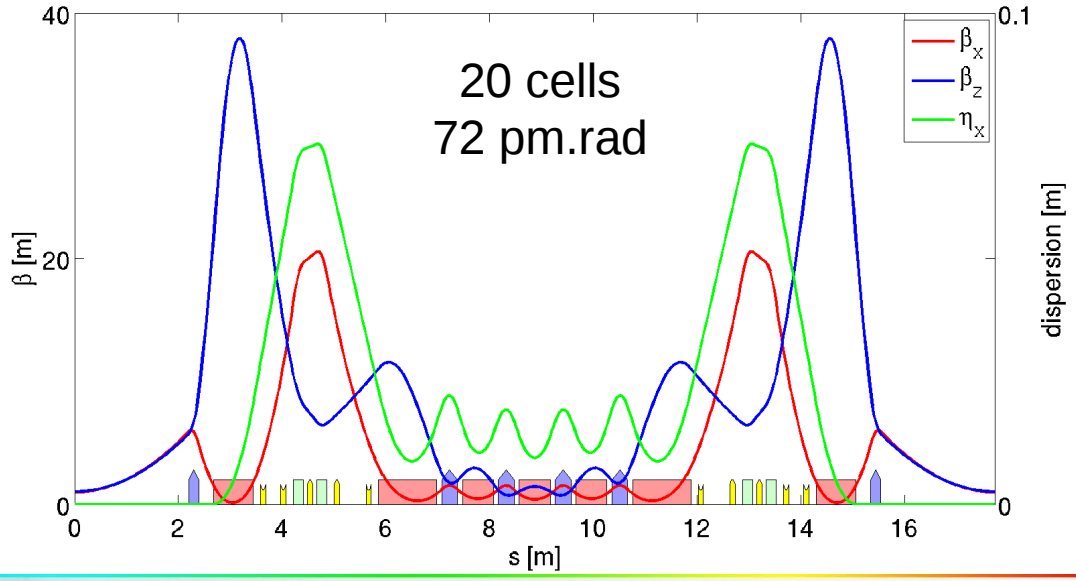
The optics also includes low beta function (~ 1 m) at straight center for photon matching

Magnets are stronger :

– Sext < 2000 T/m2
– Quad < 100 T/m
– Dip ~ 0.6 T & 40 T/m

Without long. grad. in bend

Nat. Chro. = -6.7 -6.3 per cell
= -135 -125 tot.



Ring beam dynamics

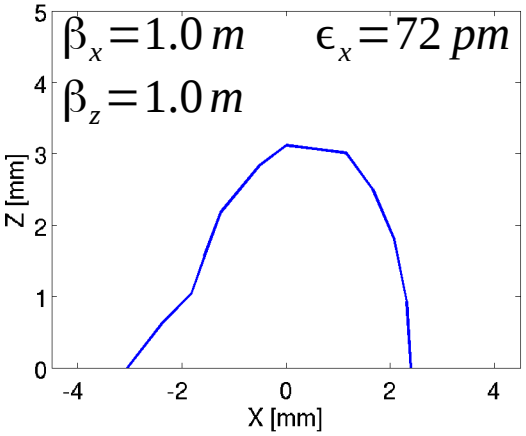
Perfect lattice
AT2.0

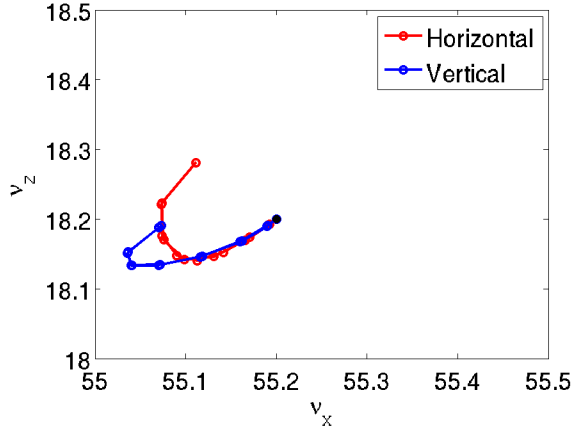
5 sextupoles families and 3 octupoles families are used here

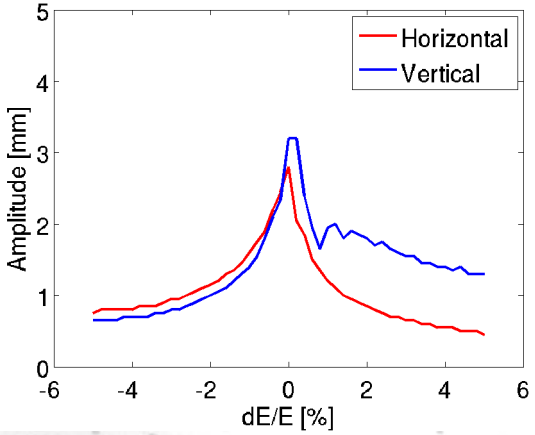
On momentum DA is about 3 mm in both planes

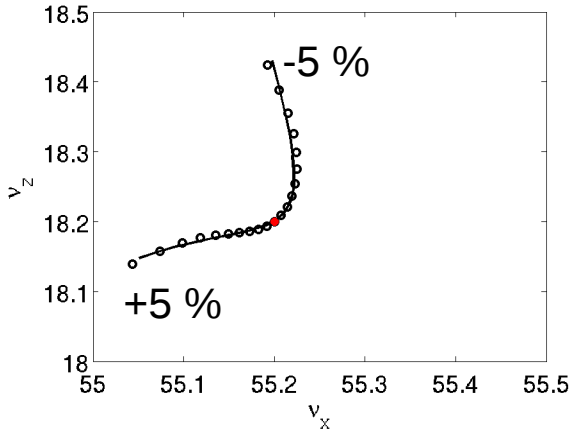
Tune footprints are kept ±0.1 over 1 turn

Fast drop of the amplitude with energy
Larger tune shift with amplitude when off momentum



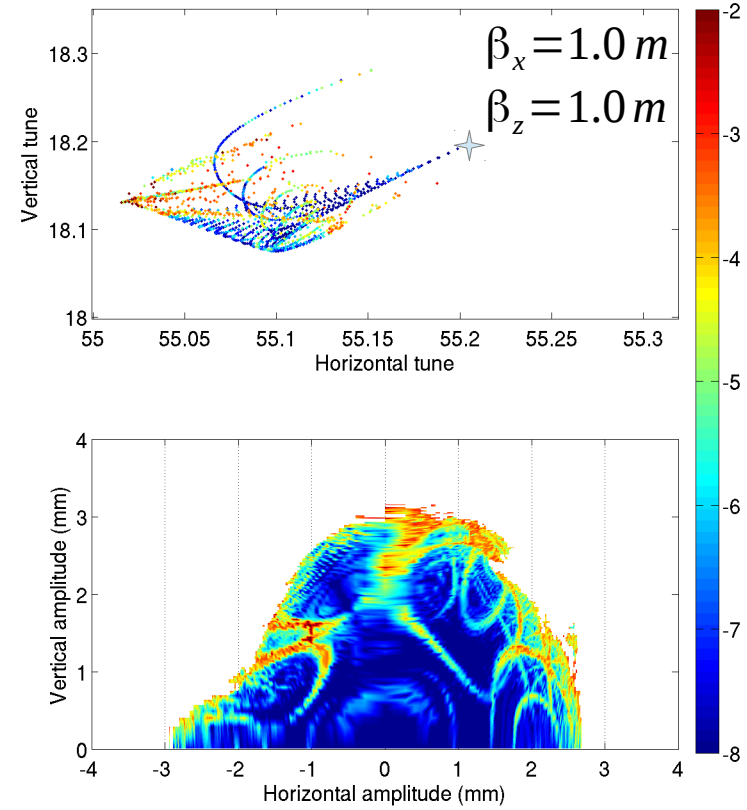


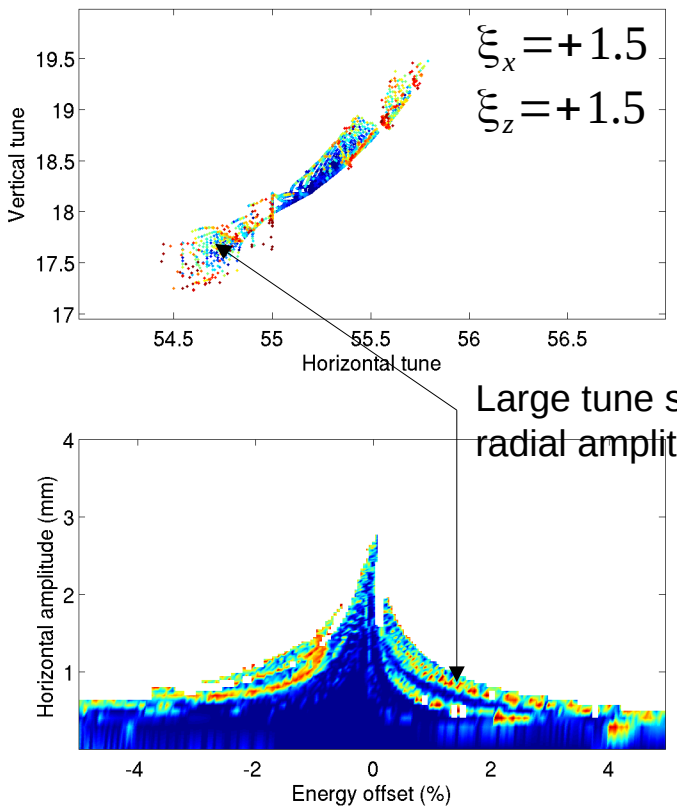




Ring FMA

Perfect lattice
TRACYIII

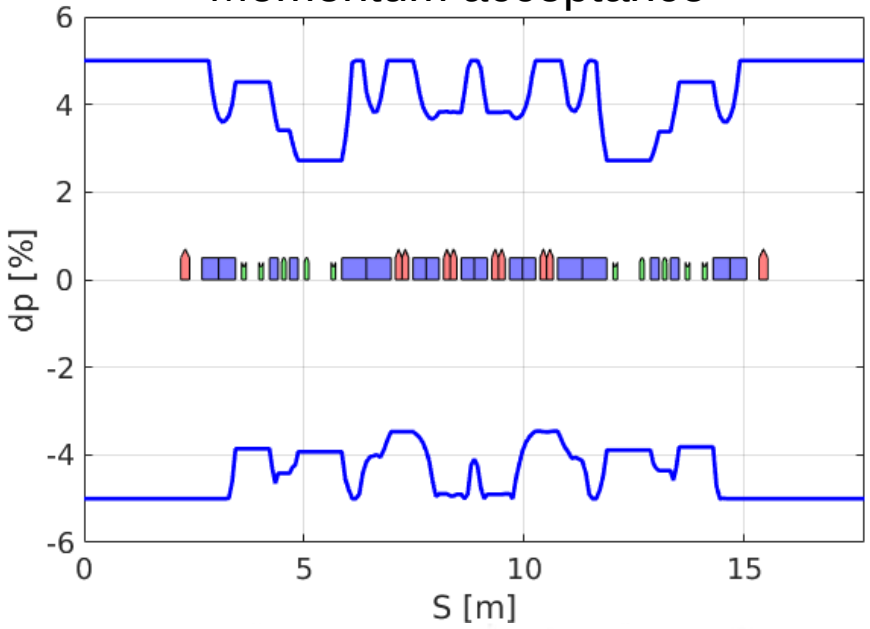




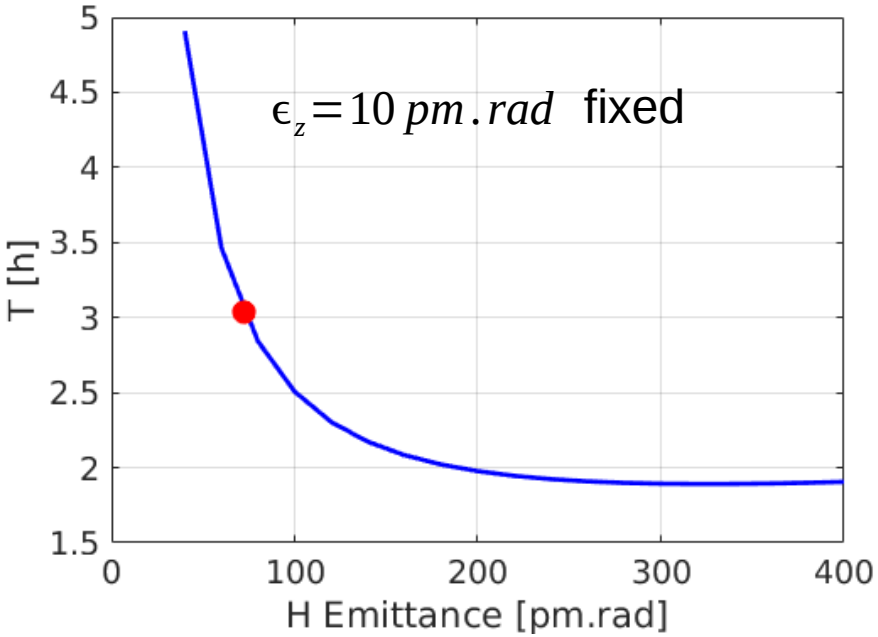
Large tune spread with radial amplitude

Lifetime

Momentum acceptance



Perfect lattice



Beam pipe diameter of 16 mm
RF Voltage of 1.1 MV
Natural bunch length of 3.7 mm rms

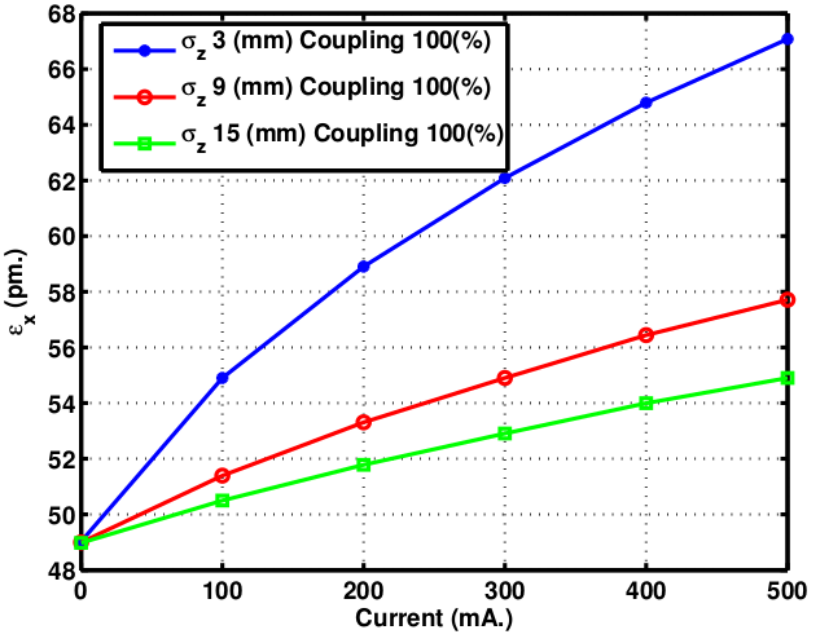
With 72 and 10 pm.rad the beam lifetime
Is about 3 h at 500 mA (1.4 nC per bunch)

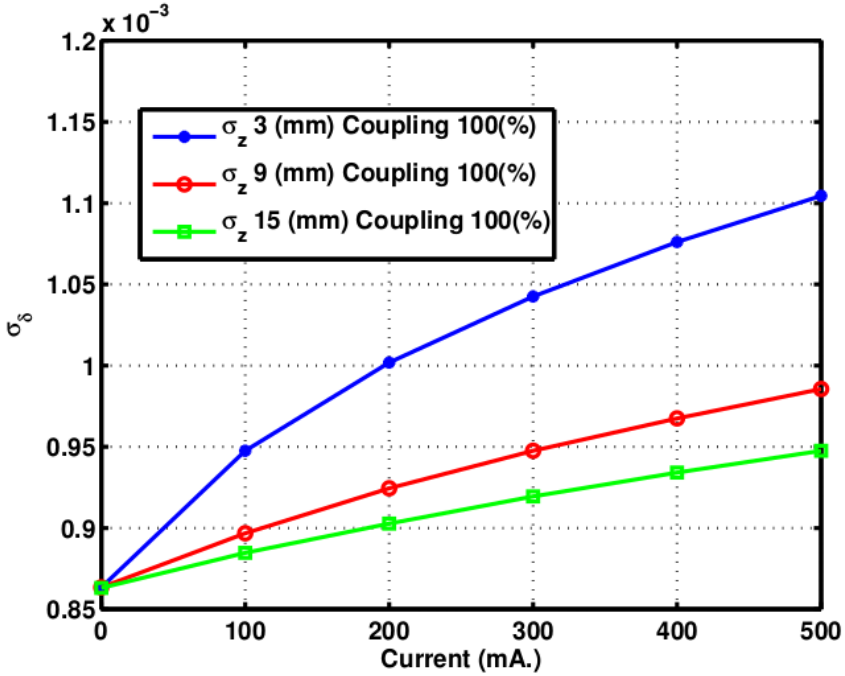
Up to 7 h at full coupling (50 x 50 pm.rad)

Simple horizontal emittance scan
Seems to be on the good side !

IBS emittance increase

Courtesy of K. Manukyan, SESAME



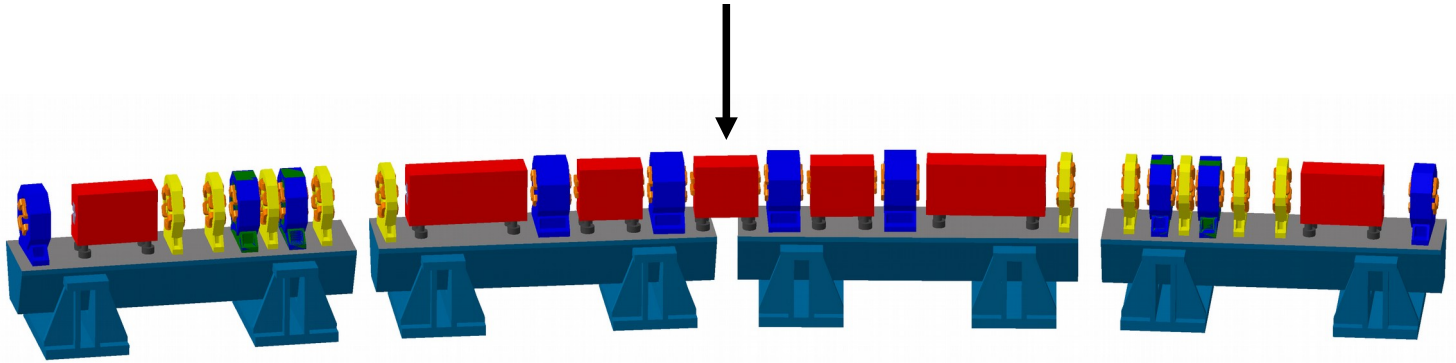


Preliminary IBS effect computed with Elegant code :
Simple Gaussian distribution model

ZAP code gives equivalent values

Emittance increase by 30 % with natural bunch length (0 mA)
Limited to 10 % with RF harmonic bunch lengthening (x 5)

3T super-bend

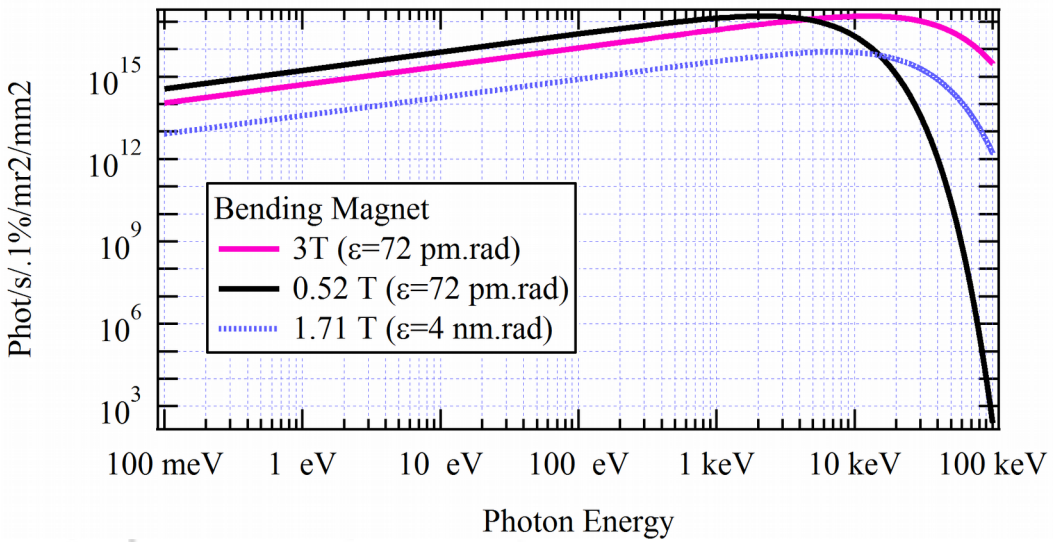


Insertion of 3T super-bend in the central magnet of the cell

4 are foreseen, one each 5 cells

Emittance impact is not negligible
The present H-function is not well suited

Courtesy of O. Marcouillé



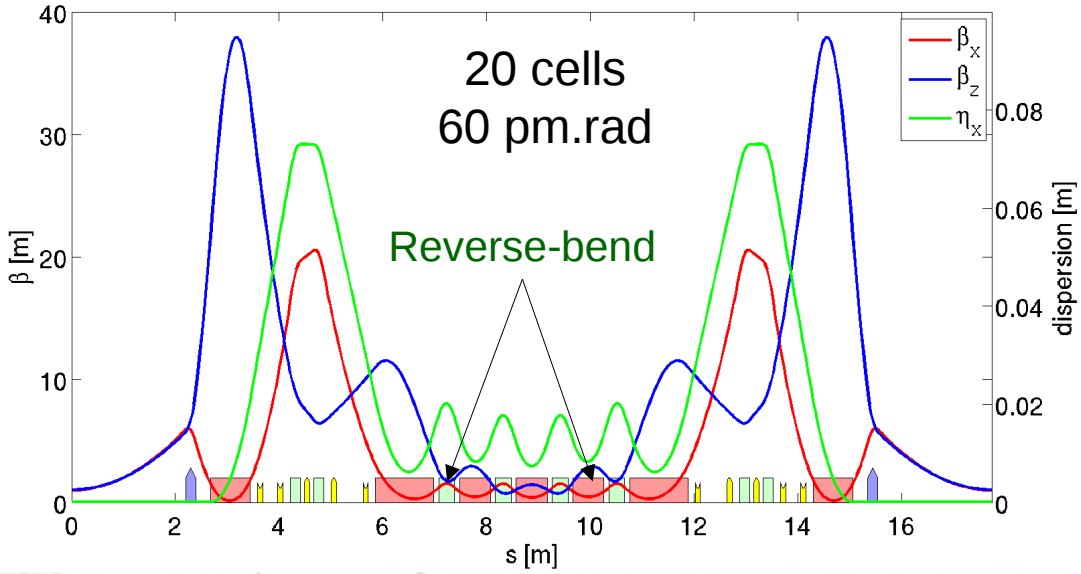
Ring lattice options with reverse bends

Including reverse bend in central part, the natural emittance is further decreased from 72 to 60 pm.rad, but at the cost of a higher horizontal damping partition Jx from 2.1 up to 2.45 leading to higher energy spread from 0.86 up to 1.1 ‰
It may alter the high harmonic photons from ID emission

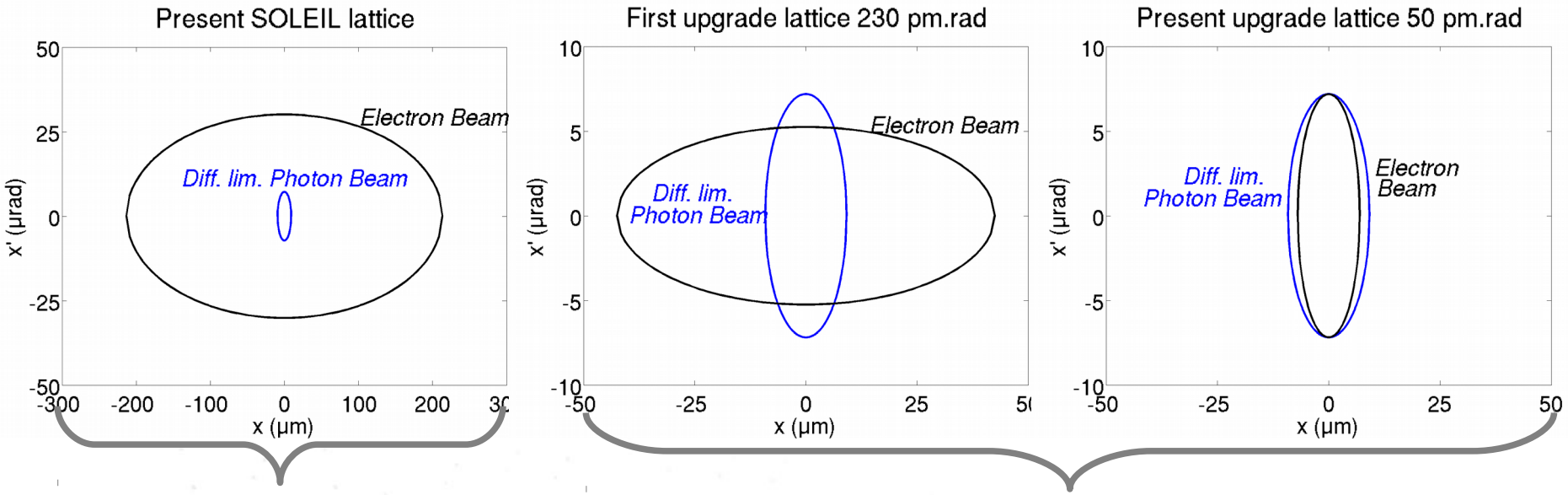
The beam dynamics is preserved and the beam lifetimes is even increased. At full coupling, the emittances are dropped down to 42 pm.rad.

The lower H-function in the central dipole make the inclusion of a 3T super-bend field almost transparent for the emittance.

Use few cells with reverse-bend to host the super-bend



Photon matching



Actual ID length

4m ID length

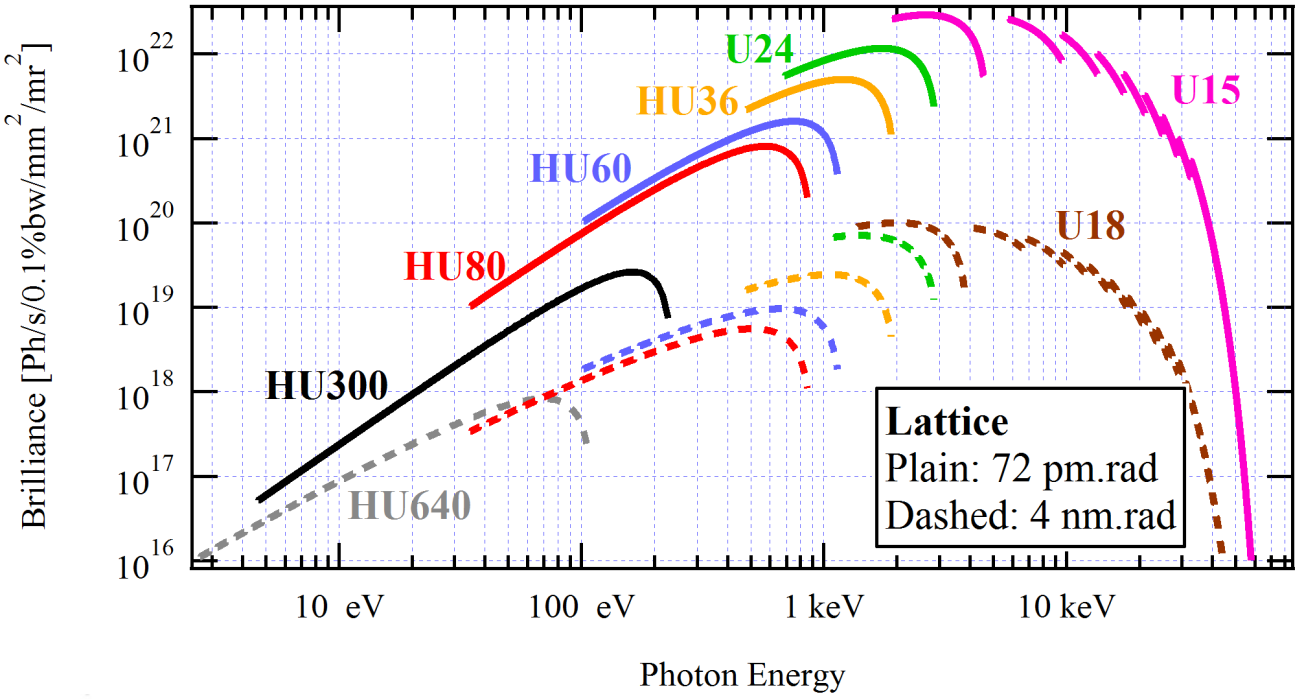
Diffraction limited photon beam emittance is 65 pm.rad at an energy of 3 keV

$\beta_{matched} = L/\pi \approx 1.27\,m$ for a undulator of 4 m

With 50 pm.rad and $\beta = 1\,m$ the beam size is 7 µm and 7 µrad rms in divergence in both planes at source.

Photon brilliance comparison

Courtesy of O. Marcouillé

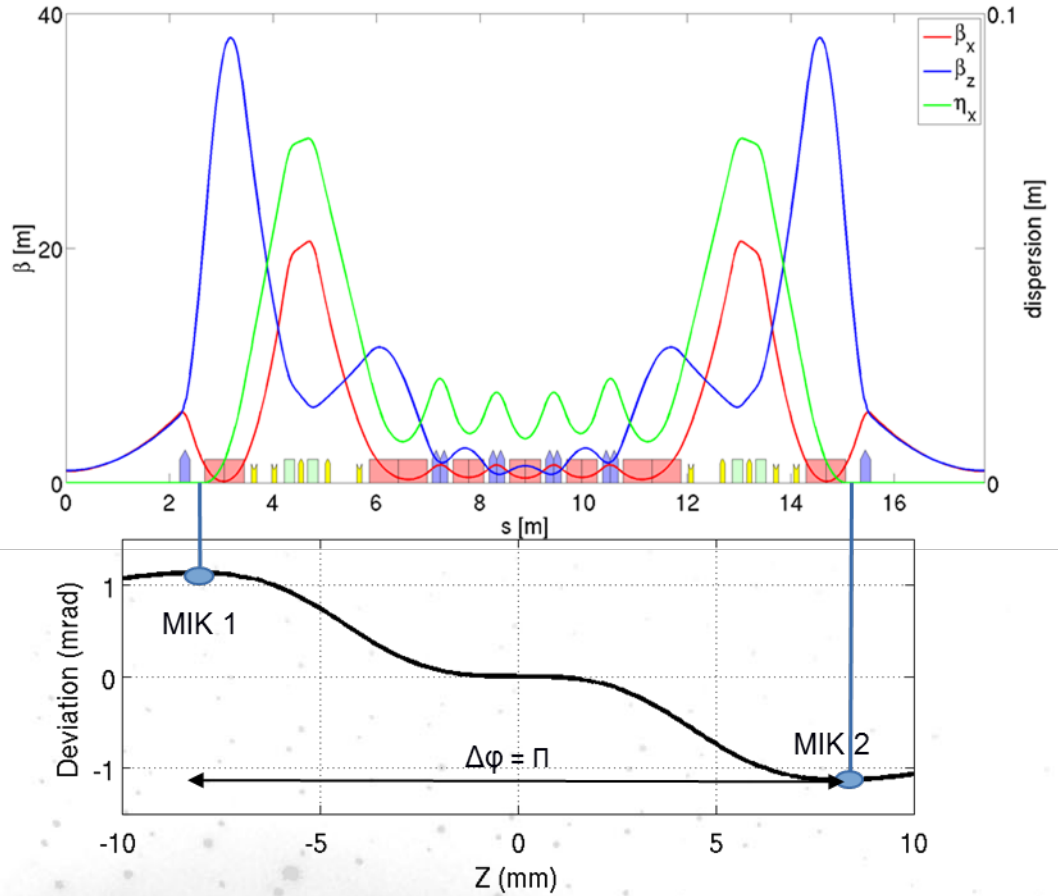


The brilliance increase reach two orders of magnitude in the region of interest:

Between 1 to 3 keV, exceeding a value of 10^{22} photons/s/mm2/mrad2/0.1%b.w

It can exceed 10^{20} photons/s/mm2/mrad2/0.1%b.w at 40 keV,

Try vertical injection with Non Linear Kicker



Take advantage of the phase to use two small NLK

Off axes to accumulate

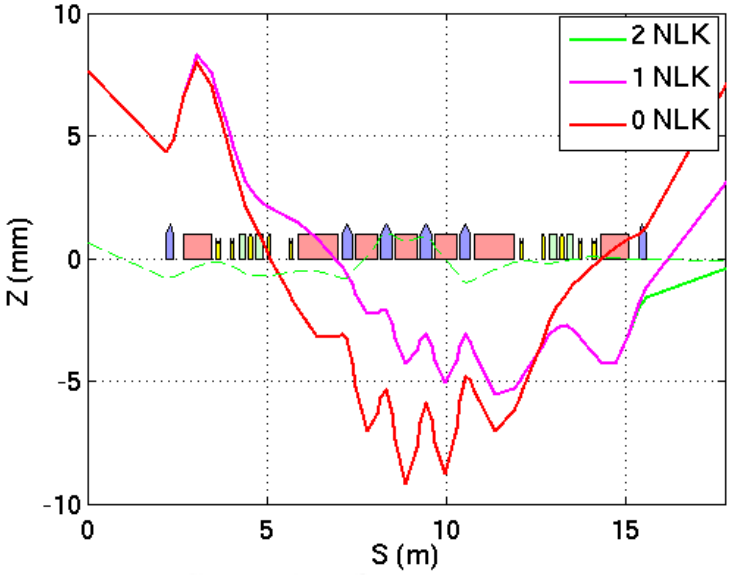
Keep the lattice symmetry

Take advantage of the large vertical beta function

Take advantage of the natural small vertical emittance of the booster

But : vertical betatron oscillation versus low gap ID …

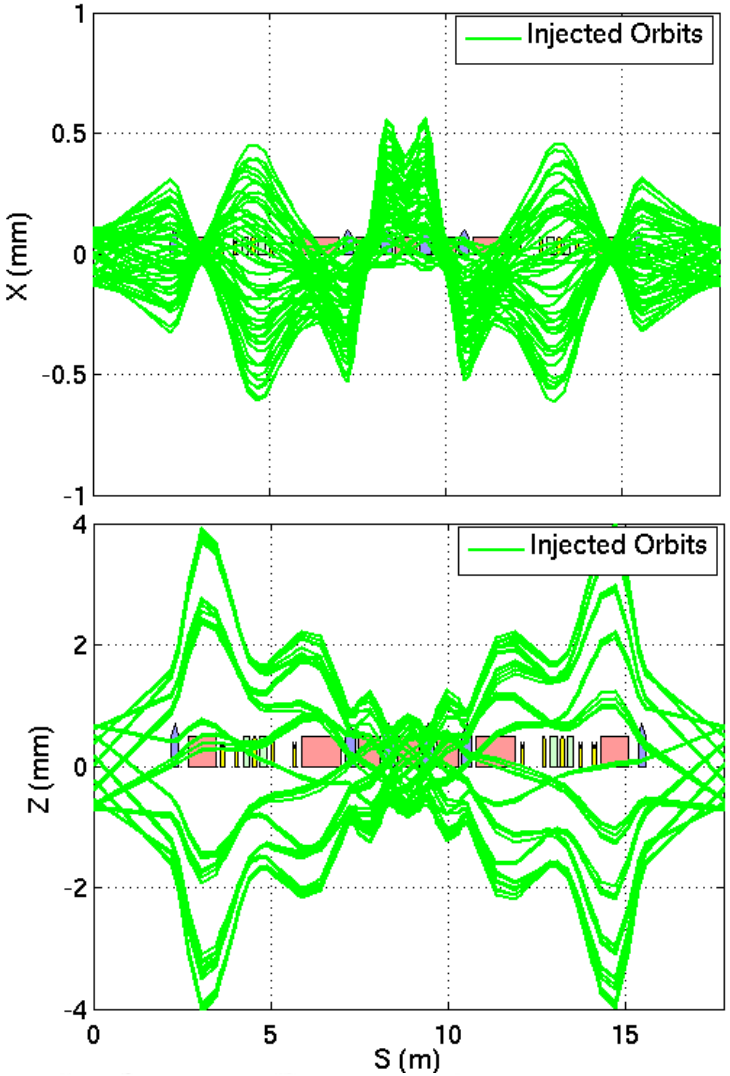
Try vertical injection with Non Linear Kicker



Orbits tracking in the first cell with the 2 MLKs

Deviation max : 2 mrad

Vertical off axes generate also small horizontal orbits



Try vertical injection with Non Linear Kicker

Perfect lattice

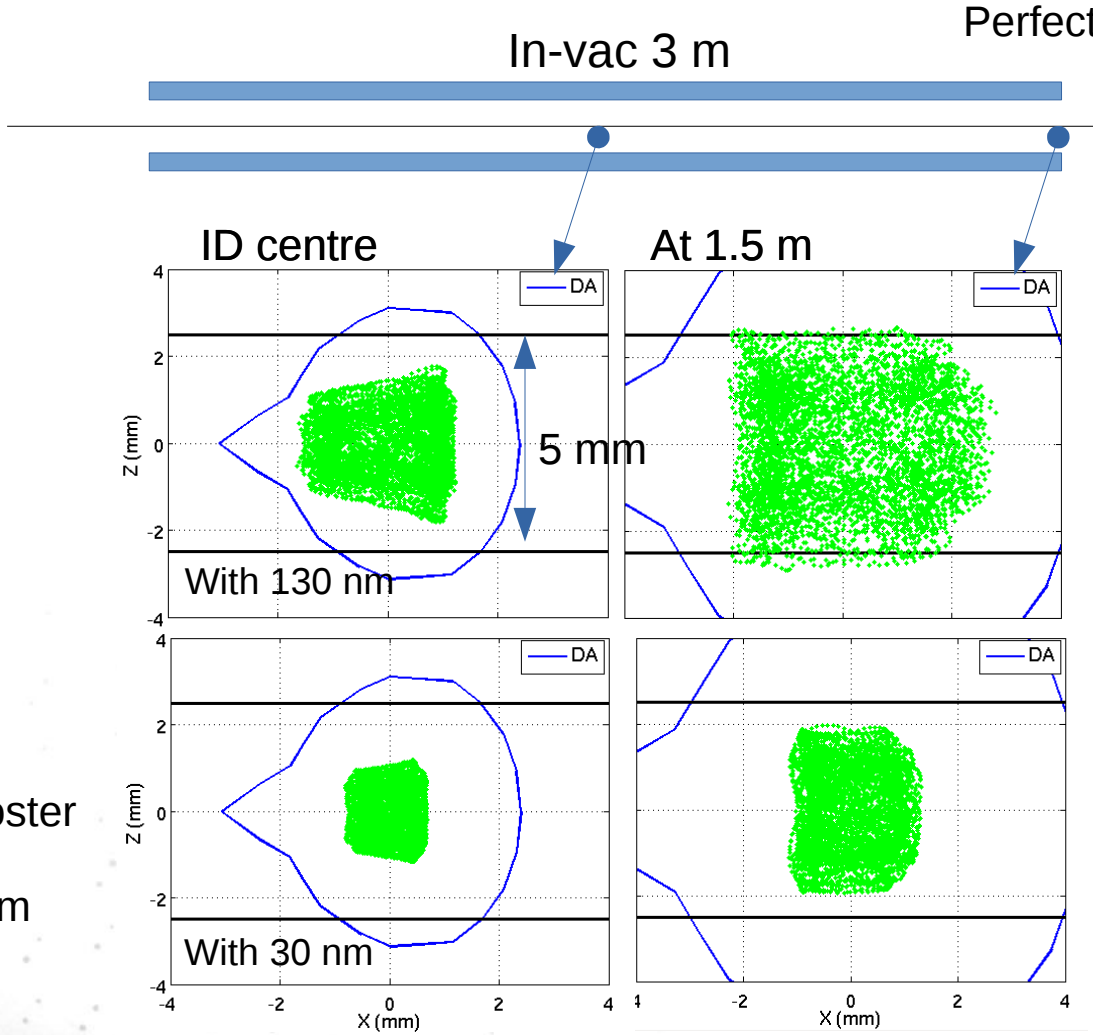
Tracking with emittance (9 rms):

With present 130 nm.rad from the booster

First cell large orbit and strong sextupoles enlarge the particles vertical excursions and reach the 5 mm gap

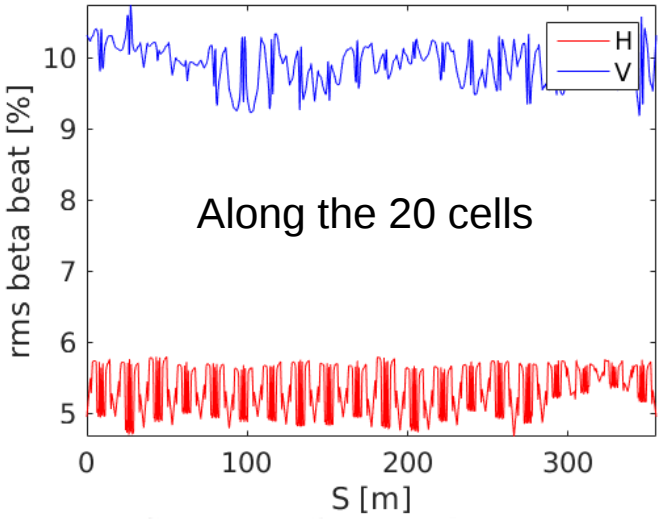
With only 30 nm.rad, vertical excursion are reduced

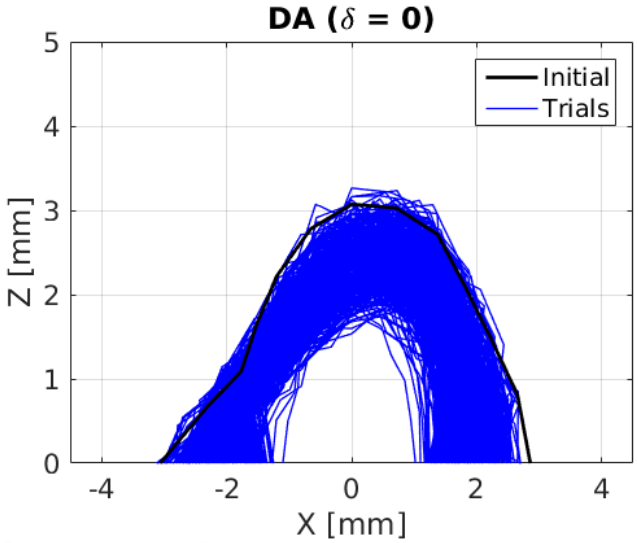
We envisage to upgrade the booster too :
=> Doubling the cells gives 30 nm
Reuse ring quad and sext ?

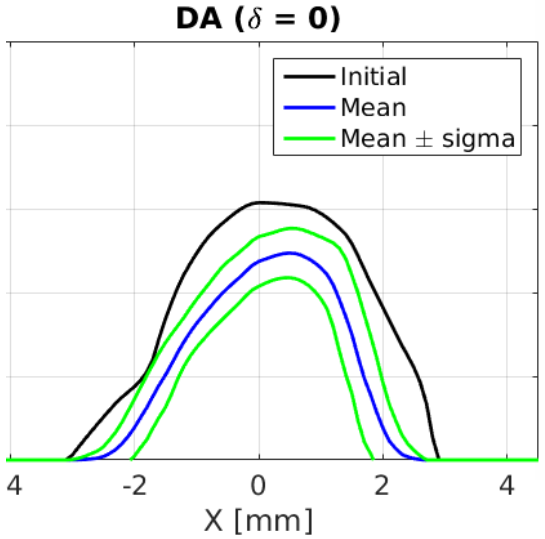


The booster 130 nm.rad became rather large as compared to low emittance acceptance lattices ...

Quadrupole strength errors





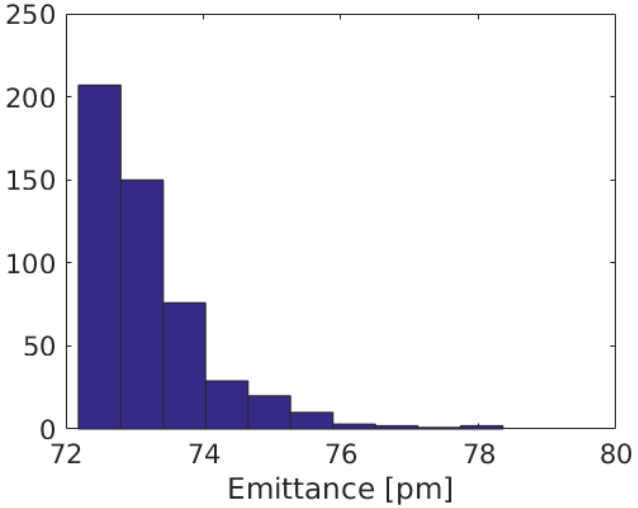


Simple error quad strength by 1‰ rms, 500 trials

Large beta beat of few percents

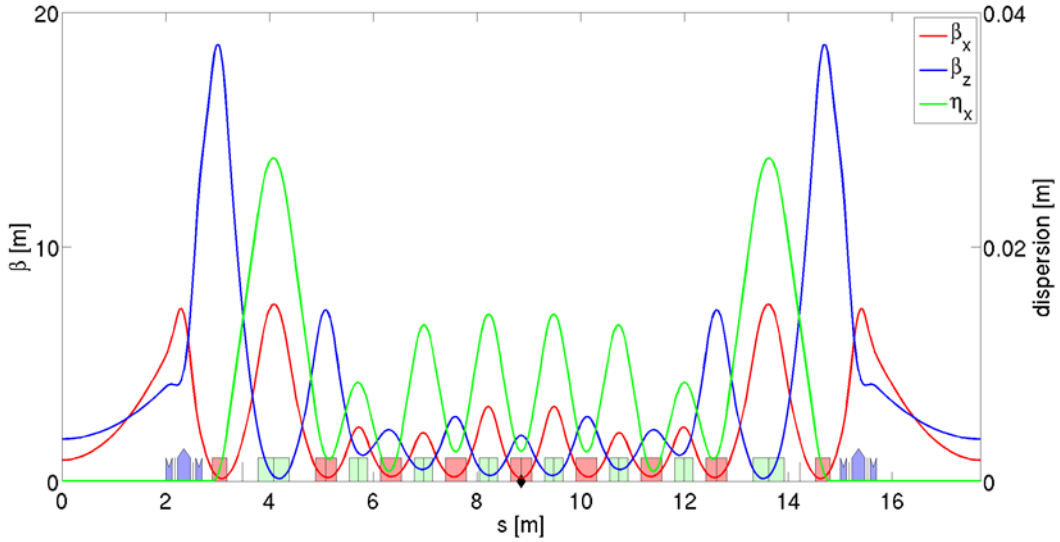
DA drops from 3 to ~2 mm

Natural emittance weakly affected



Lower emittance with on axes injection

As a possible candidate ...



9BA variation giving a natural emittance of 32 pm.rad
Also 20 cells for one turn

On momentum DA is limited but has a rather large off momentum DA
Intensive MOGA optimization
On axis injection / off momentum

Conclusion

The present SOLEIL upgrade lattice baseline achieve a low natural emittance of 72 pm.rad or 50 x 50 pm.rad at full coupling

Including a third harmonic cavity should guarantee a correct beam lifetimes as well as a limited emittance increase from IBS

Low beta function at straight level for a good photon matching up enabling a very high brilliance in the 1 to 3 keV region (SOLEIL scientific case target).

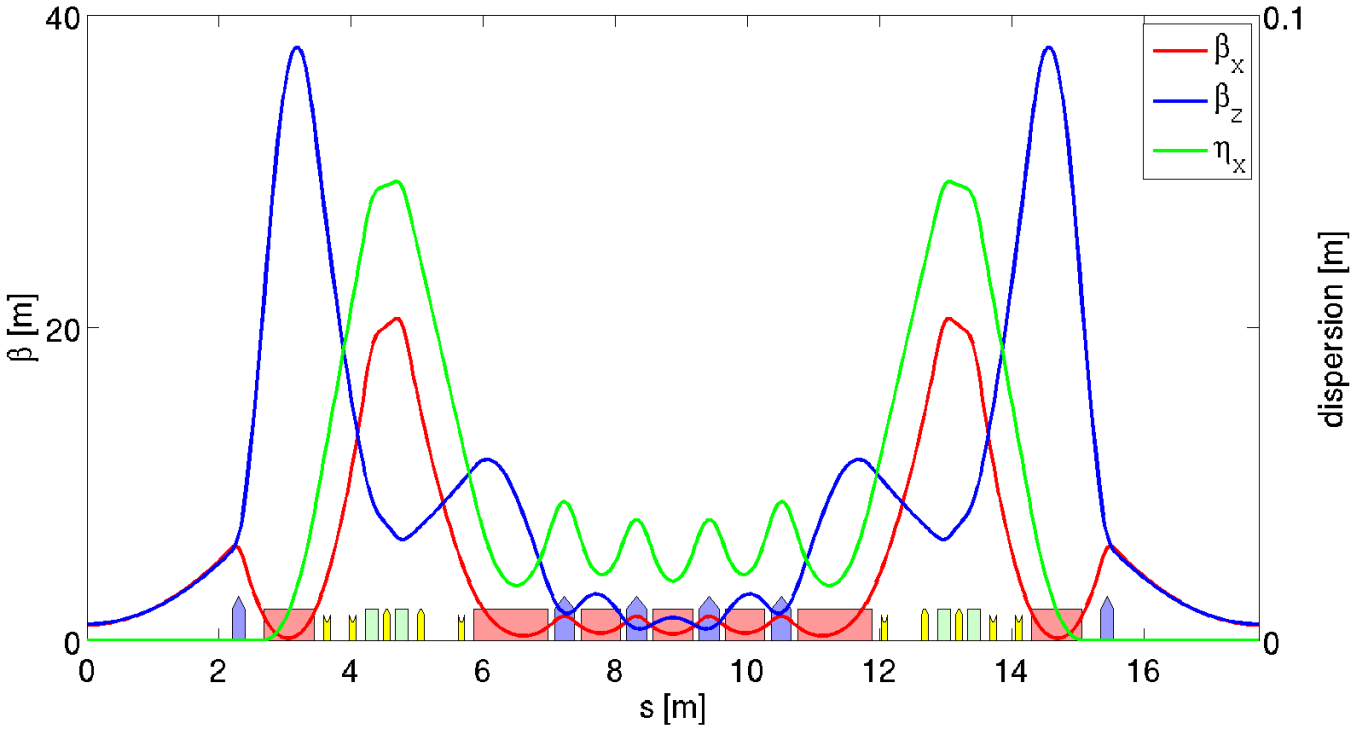
Off axes injection is still under investigation while keeping the high lattice symmetry enabling a more comfortable beam dynamics acceptance.

Injector upgrade with much lower emittance from the booster is envisaged too

Ongoing task :

- Extensive errors analysis
- Commissioning strategy
- Magnet R&D feasibility just started

Thank you for your attention


40
20
0
β [m]
0.1
0
dispersion [m]
0
2
4
6
8
10
12
14
16
s [m]
β_x
β_z
η_x