Online tuning of storage ring non-linear dynamics at SIRIUS and fast ORM measurement

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Optics Tuning and Corrections for Future Colliders Workshop
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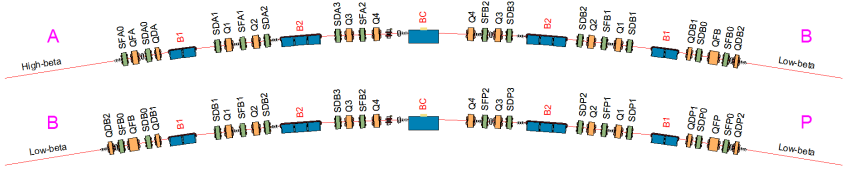
SIRIUS storage ring

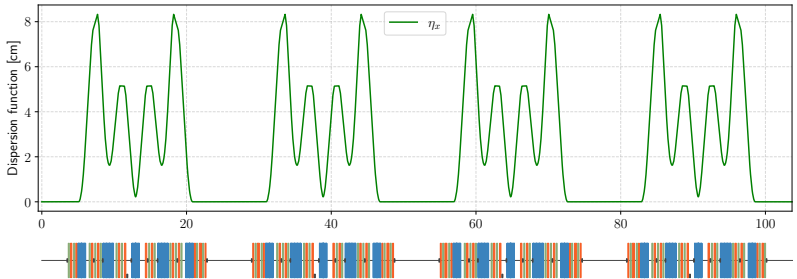
Designed, built and operated by the Brazilian Synchrotron Laboratory (LNLS), at the Brazilian Center for Research in Energy and Materials (CNPEM) campus, at Campinas, Brazil.

Parameter		Currently	Phase I
Energy	E_0	3 GeV	
Current	I_0	100 mA	350 mA
Operation mode		Top-up	
RF Cavities		1 NC	2 SC + HC
RF Voltage	$\hat{V}_{\mathrm{rf}}$	1.5 MV	3.0 MV
RF Frequency	f_{rf}	499.667 MHz	
Harmonic Number	h	864	
Momentum compaction factor	α	1.6×10^{-4}	
Energy Spread	σ_δ	8.5×10^{-4}	
Bunch length	σ_z	2.5 mm	12 mm
Energy loss p/ turn	U_0	470 keV	870 keV
Lifetime	τ	15 h	> 10 h

SIRIUS Lattice and Optics

20-cell 5BA lattice with 5-fold symmetric high (A) and low (B, P) betatron functions sections





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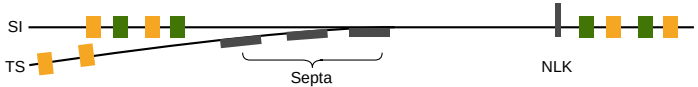
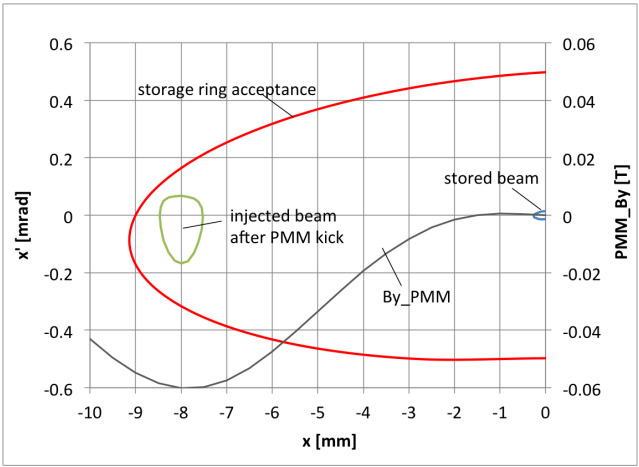
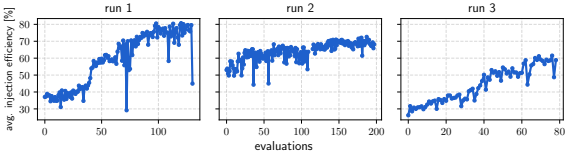
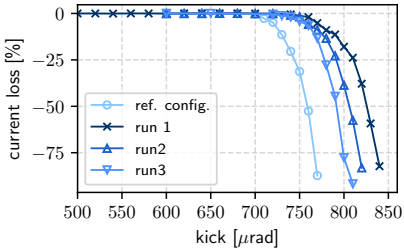
Off-axis injection scheme



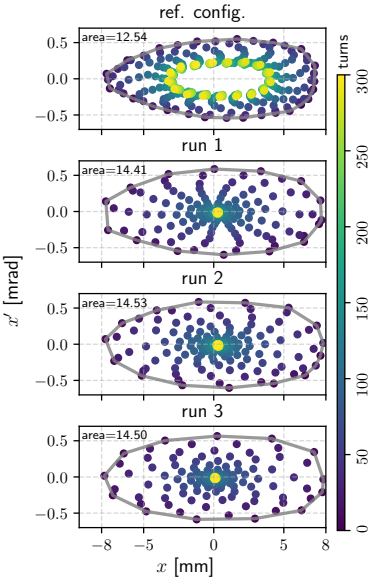


Tuning at $\nu_x = 49.08, \nu_y = 14.14$ (Working Point 1)

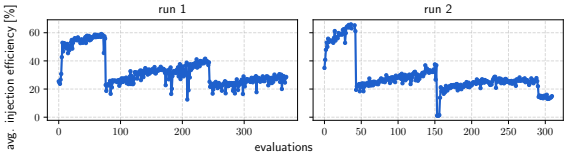


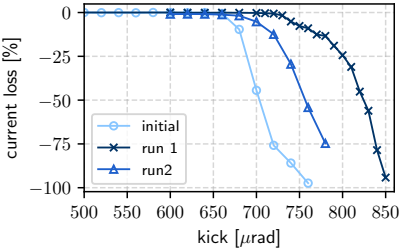


configuration	injection efficiency [%]
ref-config	88 ± 8
run 1	91 ± 1
run 2	98 ± 1
run 3	87 ± 3

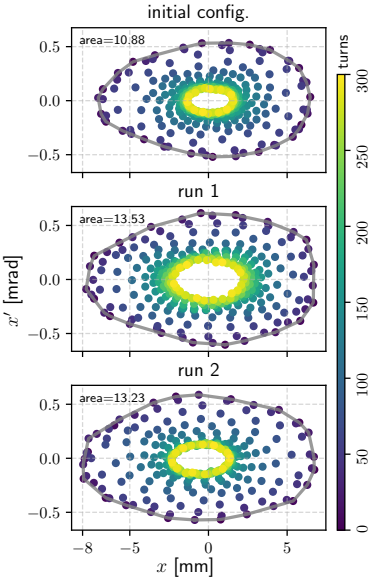


Tuning at $\nu_x = 49.20, \nu_y = 14.25$ (Working Point 2)

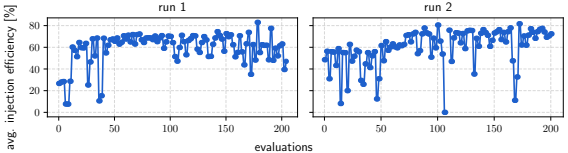


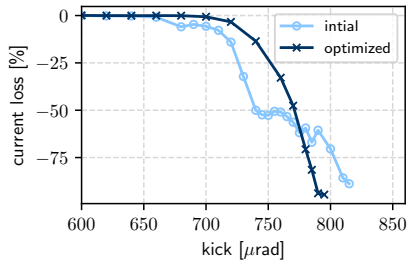


configuration	injection efficiency [%]
non-optimized	51 ± 1
run 1	79 ± 3
run 2	65 ± 1

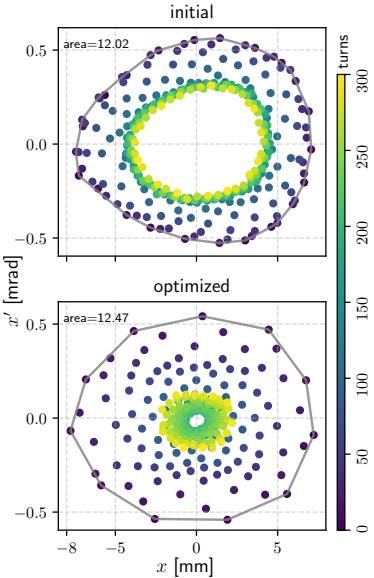


Tuning at $\nu_x = 49.16, \nu_y = 14.22$ (Working Point 3)





configuration	injection efficiency [%]
non-optimized	$-\pm 1$
optimied	93 ± 3



Summary

- Tuning was effective at optimizing injection efficiency
- Some mysteries
  - Larger kick resiliency $\not\Rightarrow$ larger phase portrait areas $\not\Rightarrow$ injection efficiency
- A good sextupole setting was found in WP 3, which contributed for SIRIUS recent milestone of reaching $< 1\%\sigma_x$ and $< 4\%\sigma_y$ orbit stability in the horizontal and vertical, respectively

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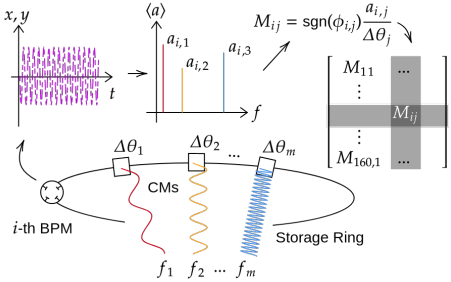
Fast ORM Measruement

Fast ORM Measurement



- Fitting to i-th BPM data $u_i(t_j)$:

$$\begin{bmatrix} \cos(2\pi f_1 t_1) & \sin(2\pi f_1 t_1) & \dots \\ \cos(2\pi f_1 t_2) & \sin(2\pi f_1 t_2) & \dots \\ \vdots & \vdots & \\ \cos(2\pi f_1 t_n) & \sin(2\pi f_1 t_n) & \dots \end{bmatrix} \begin{bmatrix} b_{i1} \\ c_{i1} \\ \vdots \\ b_{im} \\ c_{im} \end{bmatrix} = \begin{bmatrix} u_i(t_1) \\ u_i(t_2) \\ \vdots \\ u_i(t_n) \end{bmatrix}$$

- Expected beam motion

$$\Delta u_i(t)_n = \sum_j a_{i,j} \sin(2\pi f_j t_n + \phi_{i,j})$$

$$a_{i,j} = \sqrt{b_{i,j}^2 + c_{i,j}^2}, \quad \phi_{i,j} = \mathrm{atan2}(b_{i,j}, c_{i,j}) \in (-\pi, \pi]$$

- ORM elements:

$$M_{ij} = \mathrm{sgn}(\phi_{i,j}) \frac{a_{i,j}}{\Delta\theta_j},$$

Measurements at SIRIUS storage ring

SIRIUS BPMs-CMs circuit

- 160 BPM buttons
- $n_x = 120$ CHs, $n_y = 160$ CVs, $n = n_x + n_y = 280$ CMs

Measurment

- We excited the beam by driving the CMs of each of the **20 sectors** present in the Sirius storage ring.
- At each sector, the **6 CHs** drove frequencies $f_x = 3, 7, 13, 19, 29, 37$ Hz and the **8 CVs** drove frequencies $f_y = 5, 11, 17, 23, 31, 41, 47, 59$ Hz.
- The complete measurement took around $2.5 - 3$ min to be completed