MULTI-OBJECTIVE OPTIMIZATION OF THE NON-LINEAR BEAM DYNAMICS OF SYNCHROTRON SOLEIL

X. N. Gavaldà*, L. S. Nadolski, A. Díaz Ortiz

Synchrotron SOLEIL, Gif-sur-Yvette, France

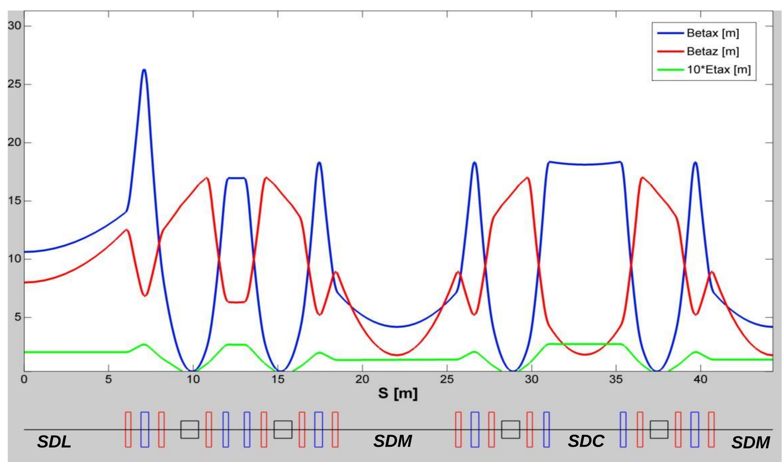
* xavier-nuel.gavalda@synchrotron-soleil.fr

INTRODUCTION

- SOLEIL is the French 3rd generation light source routinely operating since 2007 with a low emittance (3.9 nm·rad) and high intensity (430 mA) beam.

Energy [GeV]	2.75
Circumference [m]	354.1
Nominal current [mA]	430 (multibunch)
Horizontal emittance [nm .rad]	3.91
Emittance coupling (adjusted)	1%
Betatron tunes	(18.18,10.23)
RF frequency [MHz]	352.2

SOLEIL current standard machine parameters



SOLEIL original lattice functions over 1/8th of the ring showing long (SDL), medium (SDM) and short (SDC) straight sections

- The purpose of the application of Multi-Objective Genetic Algorithms (MOGA) is to optimize the linear and non-linear beams dynamics and to search for unexplored solutions.

GENETIC ALGORITHMS

- The need of sextupoles in synchrotron light sources to correct the chromaticity introduces non-linear effects. These non-linear effects reduce the Dynamic Aperture (DA) and the Momentum Aperture (MA) responsable for the injection efficiency and the Touschek lifetime (TL) respectively.
- Genetic Algorithms (GA) is a computational method to search the best solutions of multi-objectives problems using techniques inspired in natural evolution like crossover, mutation and evolution.
- MOGA optimizes multi-dimensional problems and need to be provided with a list of constraints. In this study case, this multi-parameter space is defined by the settings of quadrupole and sextupole magnet strengths. The list of constraints is related with the optical parameters of the storage ring such as the betatron functions, the chromaticities and the betatron tunes.
- Appling GA, the best solutions (Pareto front) are find among all the possible solutions (Pareto optimal set) under a number of constraints [1].

SOLEIL CLUSTER

- One interactive node with 16 processors Intel Xeon Dunnington hexacore at 2.66 GHz, 96 cores in total with 512 Gbyte of RAM.
- One interactive node with 8 processors Intel Xeon Wetsmere EX at 2 GHz, 80 cores in total with 4 Tbyte of RAM.
- An Intel MPI library is implemented with a total of 1072 processors and 11.4 Tflops of memory.
- The monotask character of MOGA requires a high number of processors exclusively assigned to run this computational tool. Until now, 160 processors have been assigned exclusively to run MOGA.

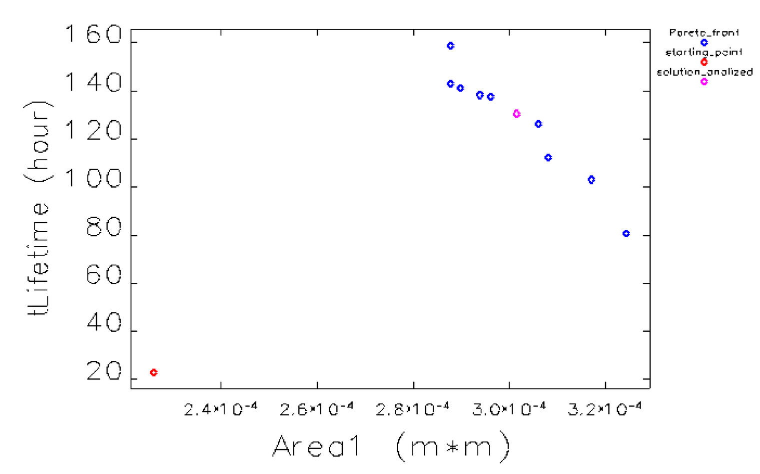
SOLEIL cluster

OPTIMIZATION PARAMETERS

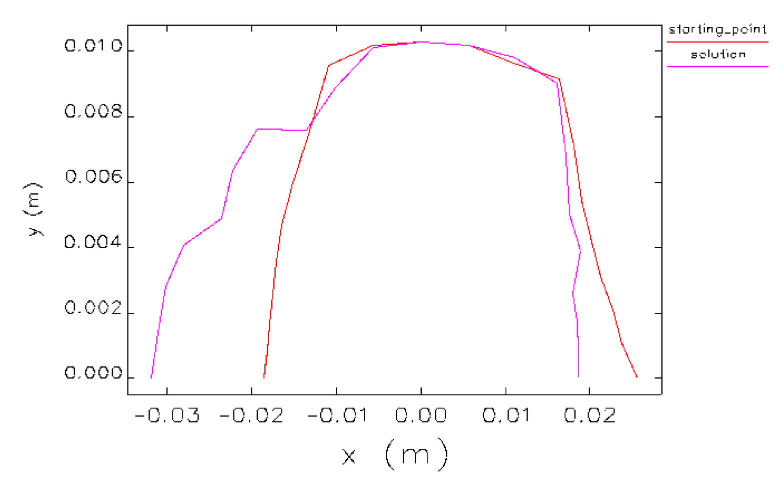
- Contraints:
  - Betatron tunes allowed close to the nominal value with variation confined between the integer and half-integer resonance lines.
  - Desired chromaticities values are fixed at 2 and 3.5 for the horizontal and vertical planes, respectively.
- The tracking calculation performed by ELEGANT (version 25.2.1) [2] to obtain the DA and Touschek lifetime (TL) uses 400 turns.
- The DA is calculated at the injection location where the values of the horizontal and vertical betatron functions are respectively 11.6 m and 7.9 m.
- To compute the beam lifetime, the tracking process does not consider the RF cavities for now (4D tracking) and the calculation is located at the sextupole position to save computation time.
- Optimizations results obtained during 6 days of computations using 80 processors.

RESULTS

- Ideal storage ring model without coupling or multipole errors, using 2 quadrupole families to correct the tunes and 11 sextupole families to optimize non-linearities.



Optimization results (blue points) of the DA area vs. the Touscheck lifetime of the ideal SOLEIL storage ring model (red point)



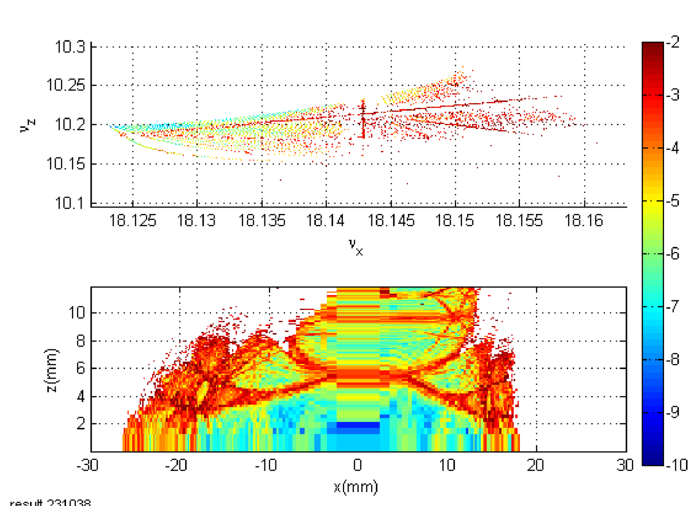
Comparison of DA between the SOLEIL nominal lattice and one optimized solution

- Increase of 12 mm in the negative side of the DA and a reduction of 5 mm in the positive side. The Touschek lifetime is increased by 100 hours from the 22.7 hours of the starting point.

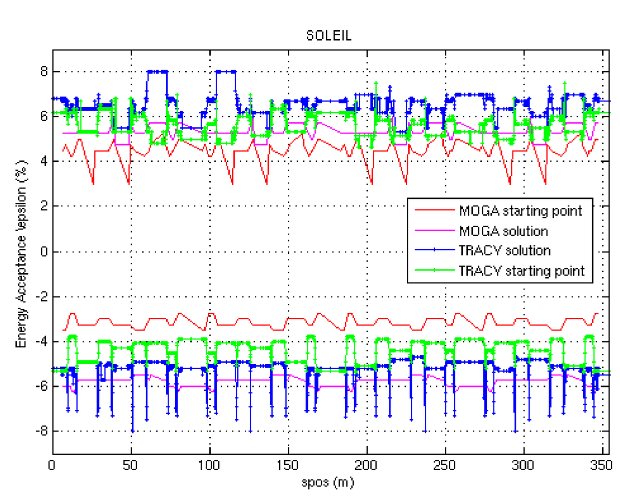
TRACY-III COMPARISON

- Use of TRACY-III [3] to examine the completeness of MOGA's solution of the ideal model adding the vacuum chamber, the multipole errors and both at the same time.

Ideal storage ring model

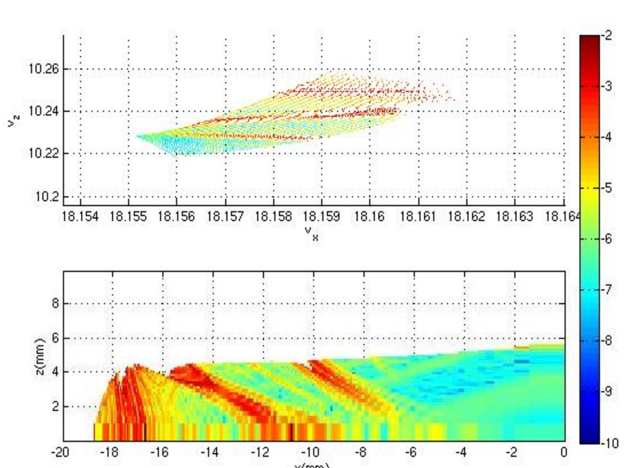


DA of a particular solution of MOGA of the ideal storage ring model using TRACY-III



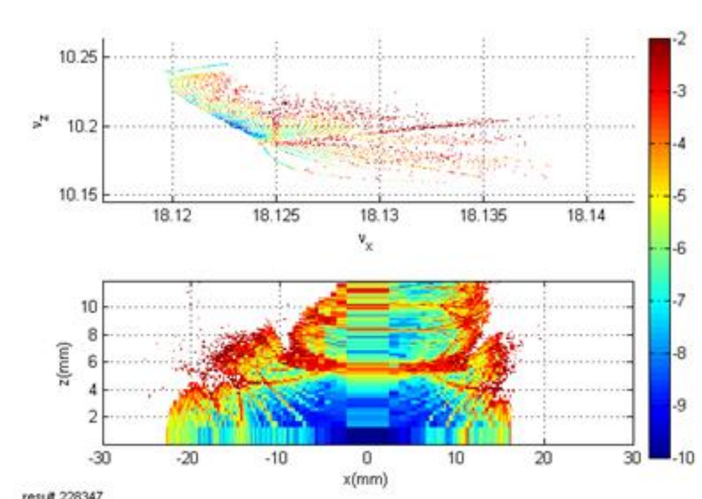
MA comparison between MOGA and TRACY solutions for the ideal storage ring model

Adding vacuum chamber



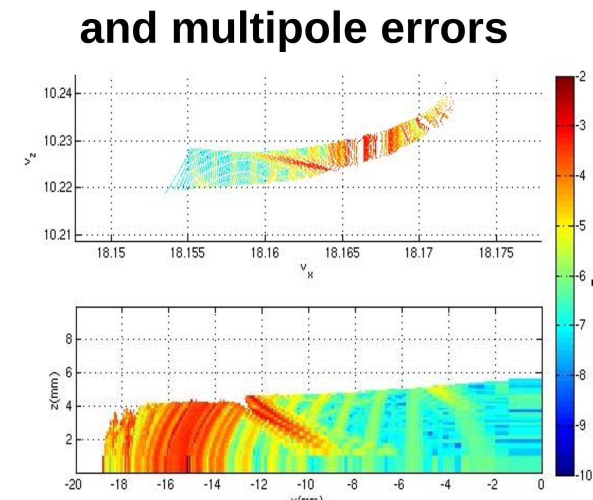
DA of a particular solution of MOGA adding the vacuum chamber dimensions using TRACY-III

Adding multipole errors



DA of a particular solution of MOGA adding the multipole magnetic errors using TRACY-III

Adding vacuum chamber and multipole errors



DA of a particular solution of MOGA adding the multipole magnetic errors and vacuum chamber using TRACY-III

- The improvement of the ideal model by MOGA is confirmed by TRACY-III.
- The Touschek lifetime values computed by ELEGANT and TRACY-III disagree due to a mistake in the parameters introduced in ELEGANT. This is under investigation.
- The optimization constraints must be more restrictive to explore more efficiently the non-linear beam dynamics effects of the ideal storage ring model.

Parameters	Ideal Model	Ideal Model adding vacuum chamber	Ideal Model adding mutlipole errors	Ideal Model with vacuum chamber and multipole errors
DA (mm)	-27 (-21)	-19 (-19)	-22 (-19)	-19 (-19)
TL(h)	160 (92)	60 (51)	92 (72)	45 (53)

Negative side of DA and Touschek lifetime value for each case. The values in brackets correspond to the values of the current SOLEIL storage ring.

CONCLUSIONS

- A preliminary study of the non-linear beam dynamics of SOLEIL was done.
- This study will be completed adding in the optimization of the ideal storage ring model the dimensions of the vacuum chamber, the magnetic multipolar errors, the radiofrequency cavities in the tracking computation and all the quadrupole families to optimize the linear beam dynamics.

REFERENCES: [1] A. Konak, D. W. Coit, A. E. Smith, "Multi-objective optimization using genetic algorithms: A tutorial", 2006. [2] M. Borland, "elegant: A Flexible SDDS-Compliant Code for Accelerator Simulation," Advanced Photon Source LS-287, September 2000. [3] TRACY-III, SOLEIL's version.

This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 289485