



SOLEIL performance improvement using optimization based on Genetic Algorithms

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1. Introduction
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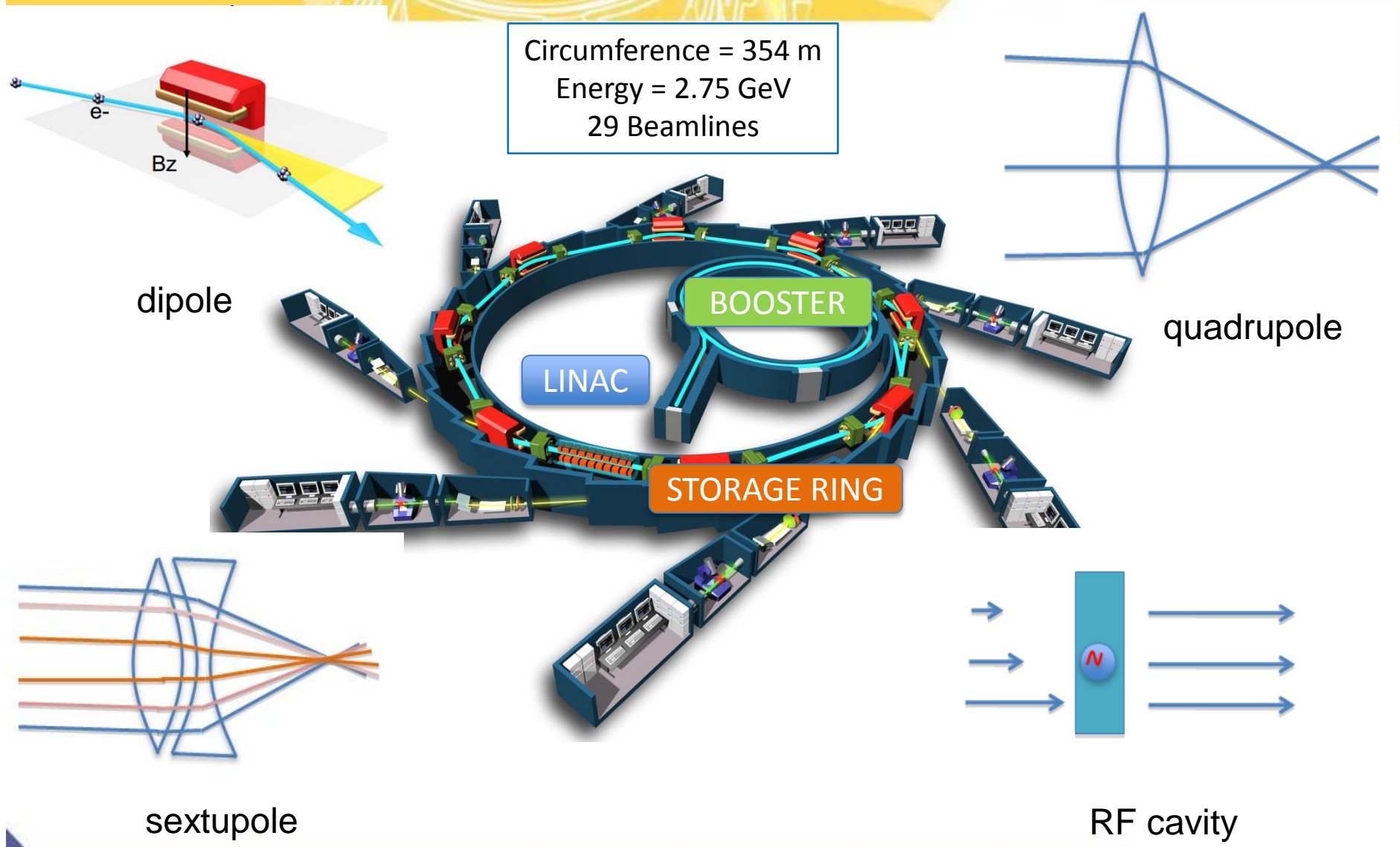
3. Simulated results

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 - i. Beam Lifetime studies

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1. Motivation

Circumference = 354 m
Energy = 2.75 GeV
29 Beamlines



➤ **Optimize the linear and non-linear beam dynamics:**

Strong focusing by quadrupoles: produce large **natural chromaticities**



Use of strong **sextupoles** to correct the natural chromaticities

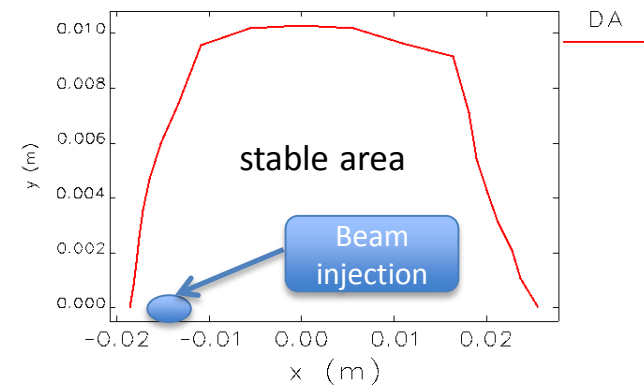
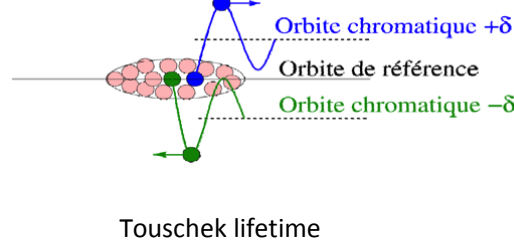
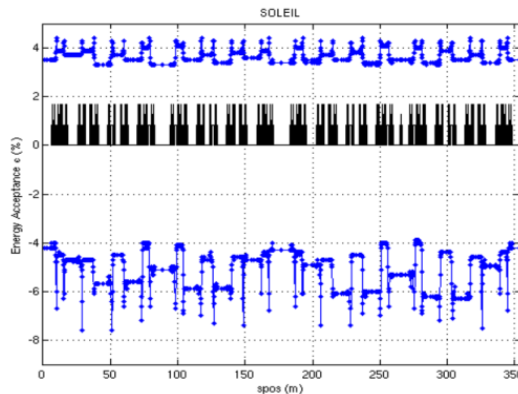


Introduction of **non-linear beam dynamics**: the beam is unstable close to **resonances lines**



Reduction of **Momentum Aperture (MA)**: reduction of the **Touschek lifetime**

Reduction of **Dynamic Aperture (DA)**: out of the this area the beam is unstable and the **injection efficiency** is reduced

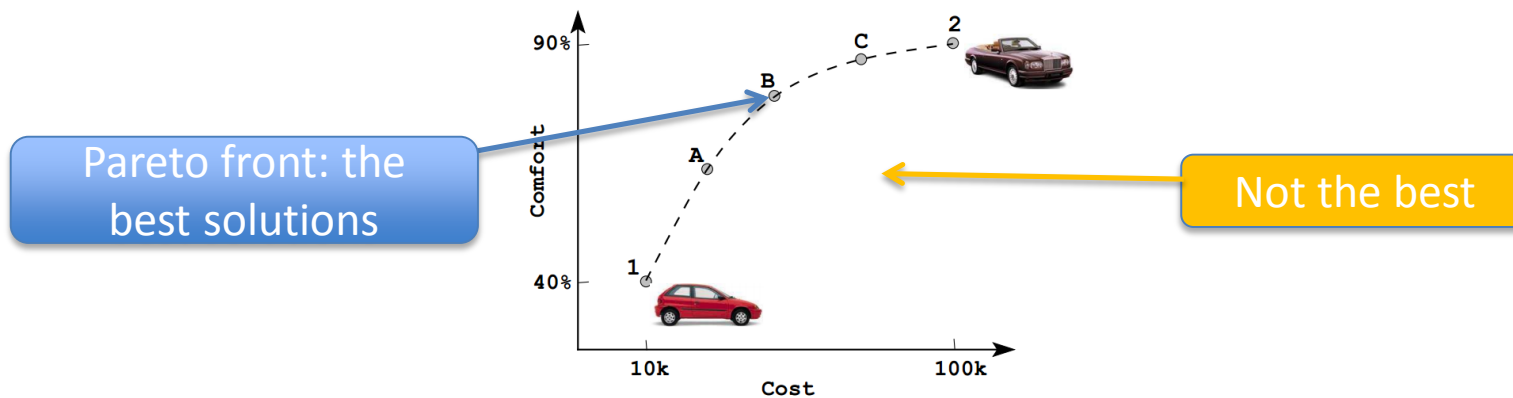


2. Multi-Objective Genetic Algorithm (MOGA)

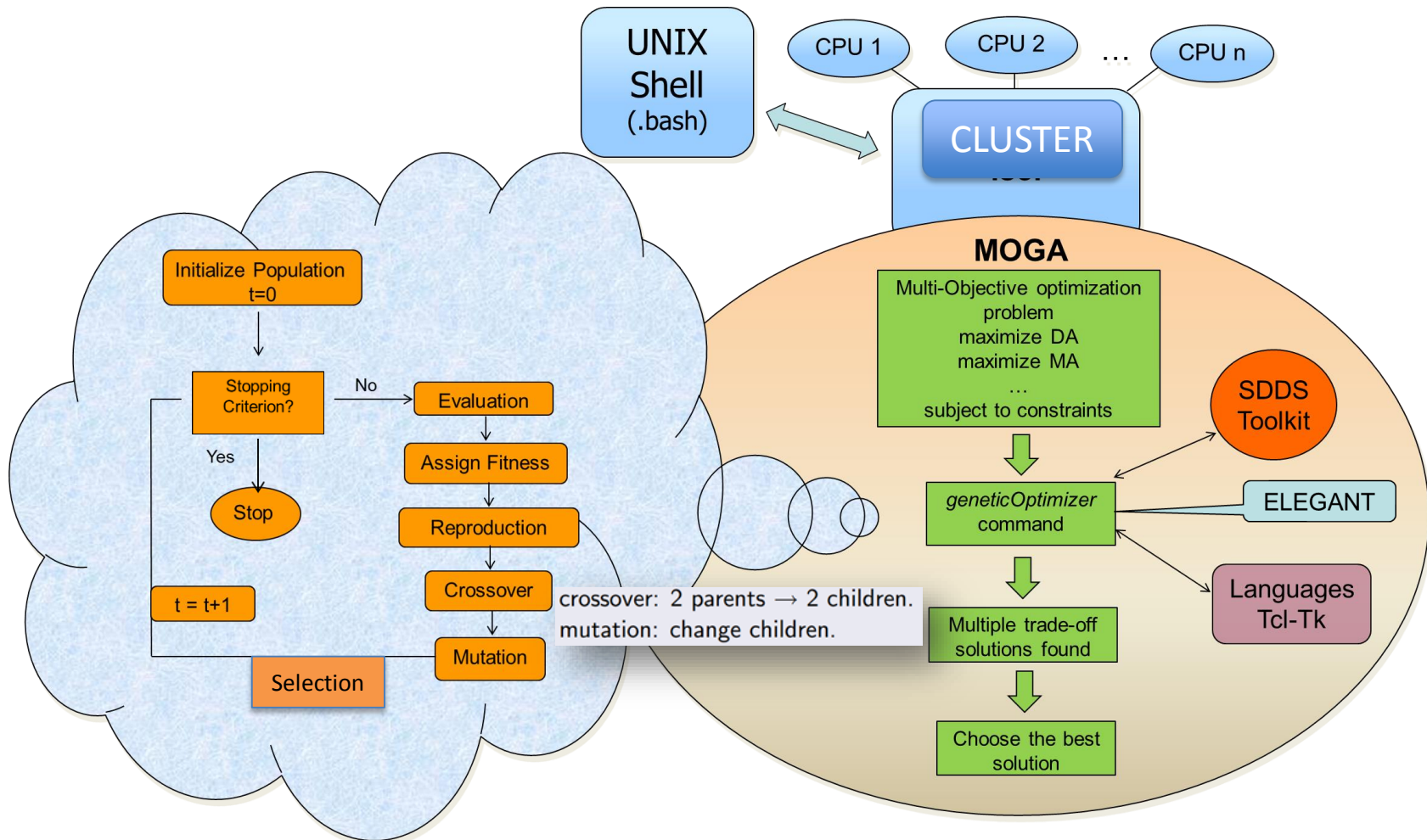
- **Genetic Algorithm** is a heuristic search that mimics the process of natural selection and generate solutions to optimization problems using techniques inspired by natural evolution, such as crossover, mutation and selection.
- We want to optimize different objectives at the same time for problems with large number of variables . Example: buy a car

Multi-Objective Optimization

- We often face them

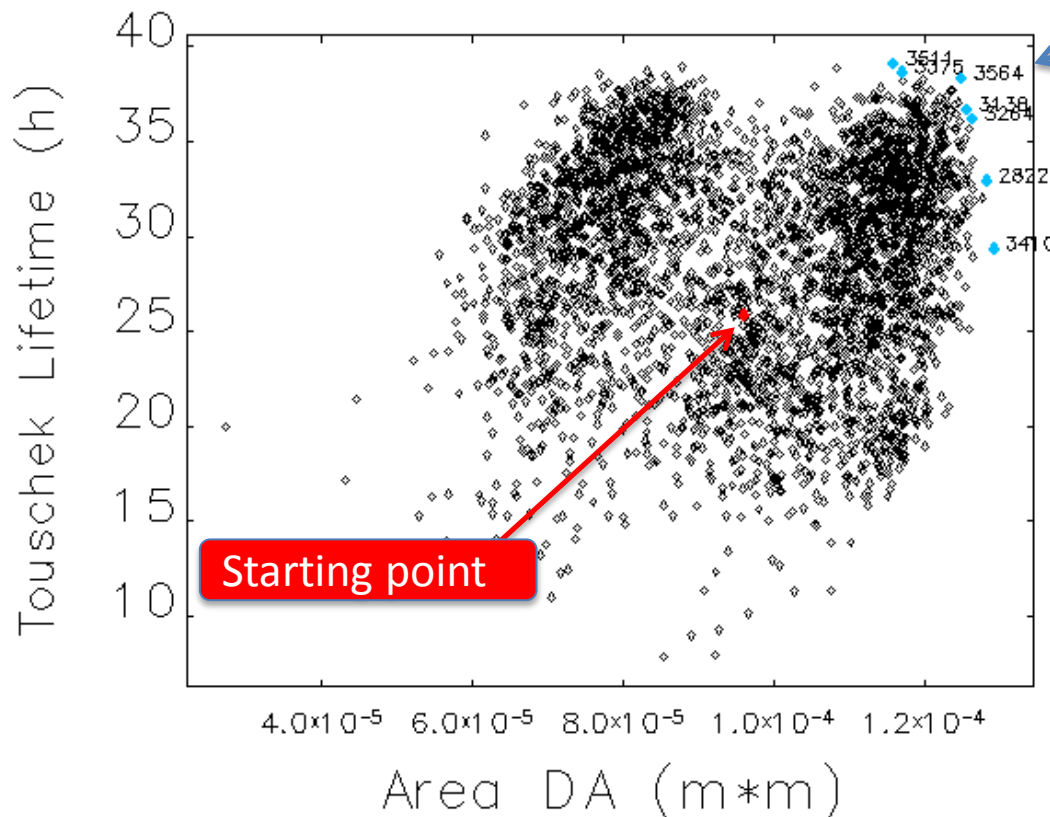


K. Deb. Multi-Objective Optimization using Evolutionary Algorithms.
John Wiley & Sons, Ltd, 2001



3. Results

- Model using 2 quadrupole families, 11 sextupole families, 6D tracking (RF voltage of 2,665 MV) , with vacuum chamber and without errors
- Using 200 CPUs during 3 days and 1000 turns for tracking



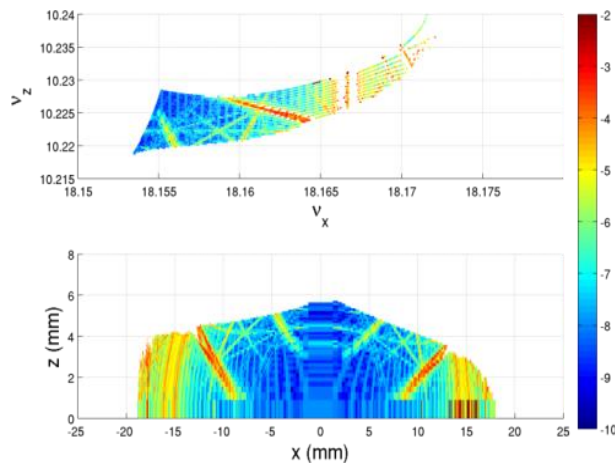
Using TRACY3 to put multipoles and study the beam dynamics of each solution

	TOUSCHEK LIFETIME (h)
Lattice ID	TRACY with multipolar field components
Nominal	24.5
#1735	28.7
#3264	27.2
#2822	28.4

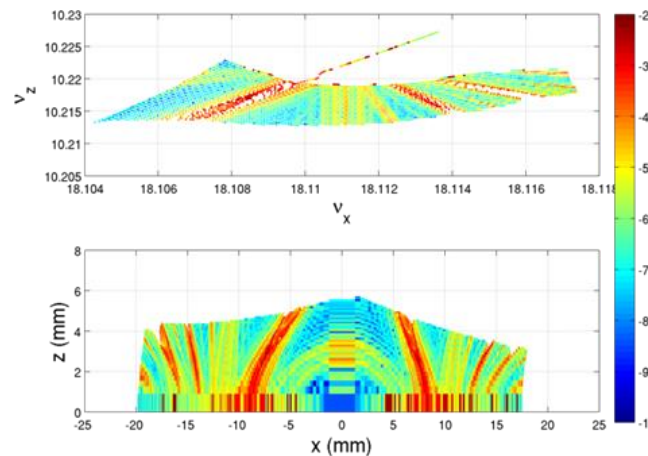
The improvement is confirmed by TRACY3

Comparison with TRACY3 with multipoles to study beam dynamics. Frequency Maps Analysis based in diffusion rate to study the stability of the beam and identify the resonance lines

Nominal lattice



#2822



- 1. Comparison of DA*
- 2. Comparison of MA*
- 3. Comparison of diffusion rate and injection efficiency*

Experimental results

- Beam based experiments in the control room to test experimentally the optimized solutions:
 - Measurements of beam lifetime of the SOLEIL nominal lattice for operation mode of 312 bunches and 430 mA of current and a RF voltage of 2.665 MV

$$\frac{1}{\tau} = \frac{1}{\tau_{gas}} + \frac{1}{\tau_{Tous}}$$

$$\tau_{Tous} \propto \frac{1}{I_b} \sqrt{\frac{k}{V_{RF}}} \cdot \sigma_l(I_b) \cdot \left(\frac{\varepsilon_{acc}^p + \varepsilon_{acc}^n}{2} \right) \cdot cte$$

$$\frac{1}{\tau_{gas}} = \frac{1}{\tau_{ES}(Z, P, a, b, \beta_{x,z}(s))} + \frac{1}{\tau_{INS}(Z, P, \varepsilon_{acc})} + \frac{1}{\tau_{ISES}(Z, P, \varepsilon_{acc})}$$

- Coupling (k)
- Internal scraper (a)
- External scraper (a)
- Vertical scraper (b)
- Bunch current (I_b)



The beam lifetime is strongly dominated by the Touschek contribution.

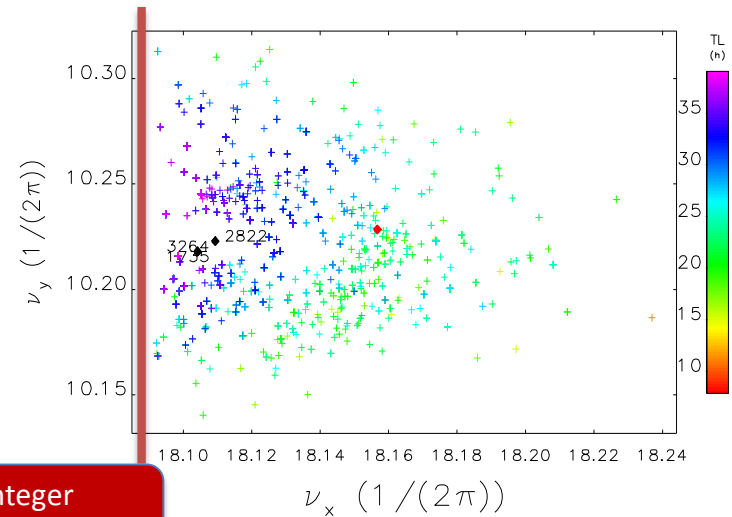
The simulated Touschek lifetimes (20 h) agree with the experimental ones.

Disagreement of a factor 2 between the simulated and experimental gas contribution due to 1) the difficulty to measure the gas lifetime in a regime dominated by the Touschek contribution and 2) the composition the residual gas

- Measurements of optimized solutions: improvement not confirmed. The algorithm does not take into account the beam dynamics as a figure of merit and converges to the integer resonance line

Lattice ID	τ^{MEAS} [h]*	τ^{SIM} [h]
Nominal	15.7 ± 0.2	16.0
#1735	4.9 ± 0.1	17.3
#3264	11.1 ± 0.1	16.7

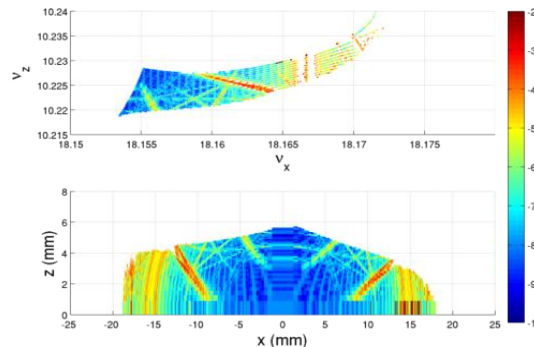
*DCCT monitor



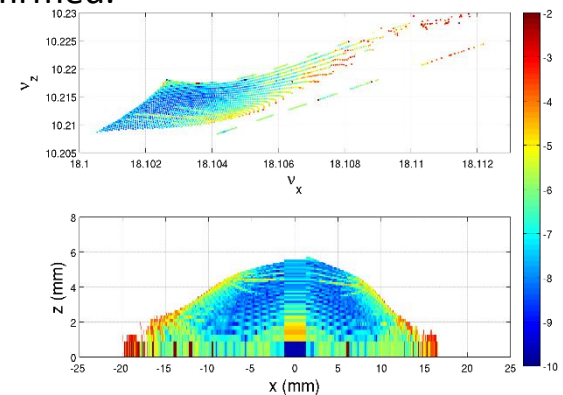
Integer
resonance line

- Measurements of injection efficiency : improvement not confirmed.

Lattice ID	Injection efficiency [%]
Nominal	90
#1735	36
#3264	35



Nominal lattice



#3264

- The SOLEIL nominal lattice with the dimensions of the vacuum chamber and the multipole field components has been optimized theoretically by MOGA. TRACY3 has been used to cross check the beam dynamics of these optimized solutions (FMA).
- The simulated improvement of the Touschek lifetime and injection efficiency is confirmed by TRACY3. However, the process does not take into account the diffusion rate as a figure of merit.
- A detailed study of beam lifetime has been done to redefine the knowledge of the beam lifetime.
- MOGA will be used to search new lattices reducing the horizontal emittance for the future upgrade of SOLEIL.

Thank you for your attention!!

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