Optimization of synchrotron light sources using Genetic Algorithms

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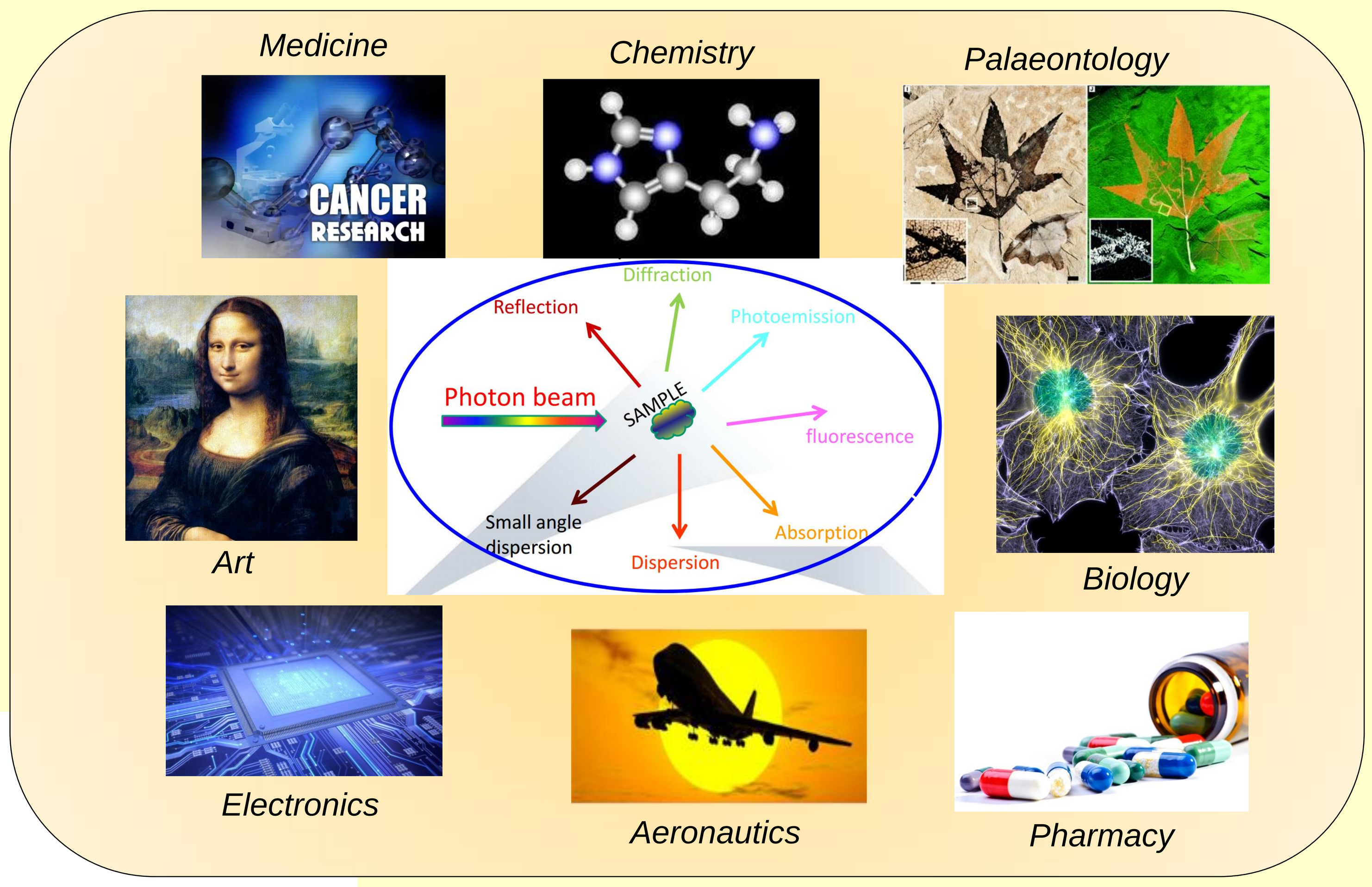
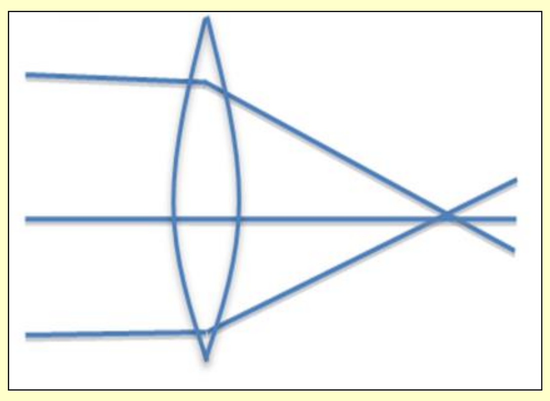
WHAT IS A SYNCHTRON LIGHT SOURCE?

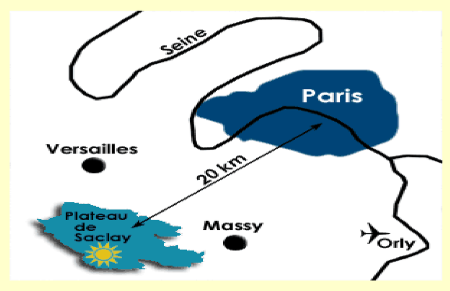
It is an accelerator complex designed to produce radiation called synchrotron radiation to study the matter.
The quality of the synchrotron radiation depends on the magnetic structure of the storage ring. The storage ring is composed by dipoles, quadrupoles, sextupoles and Radio Frequency cavities.



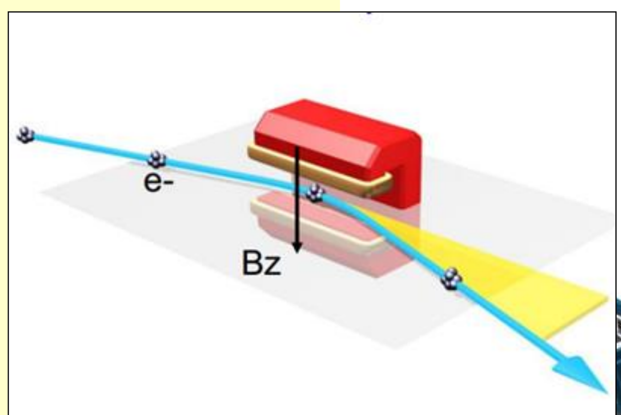
Examples of scientific applications of synchrotron radiation

Quadrupoles: to focus the electrons and give a much smaller beam size

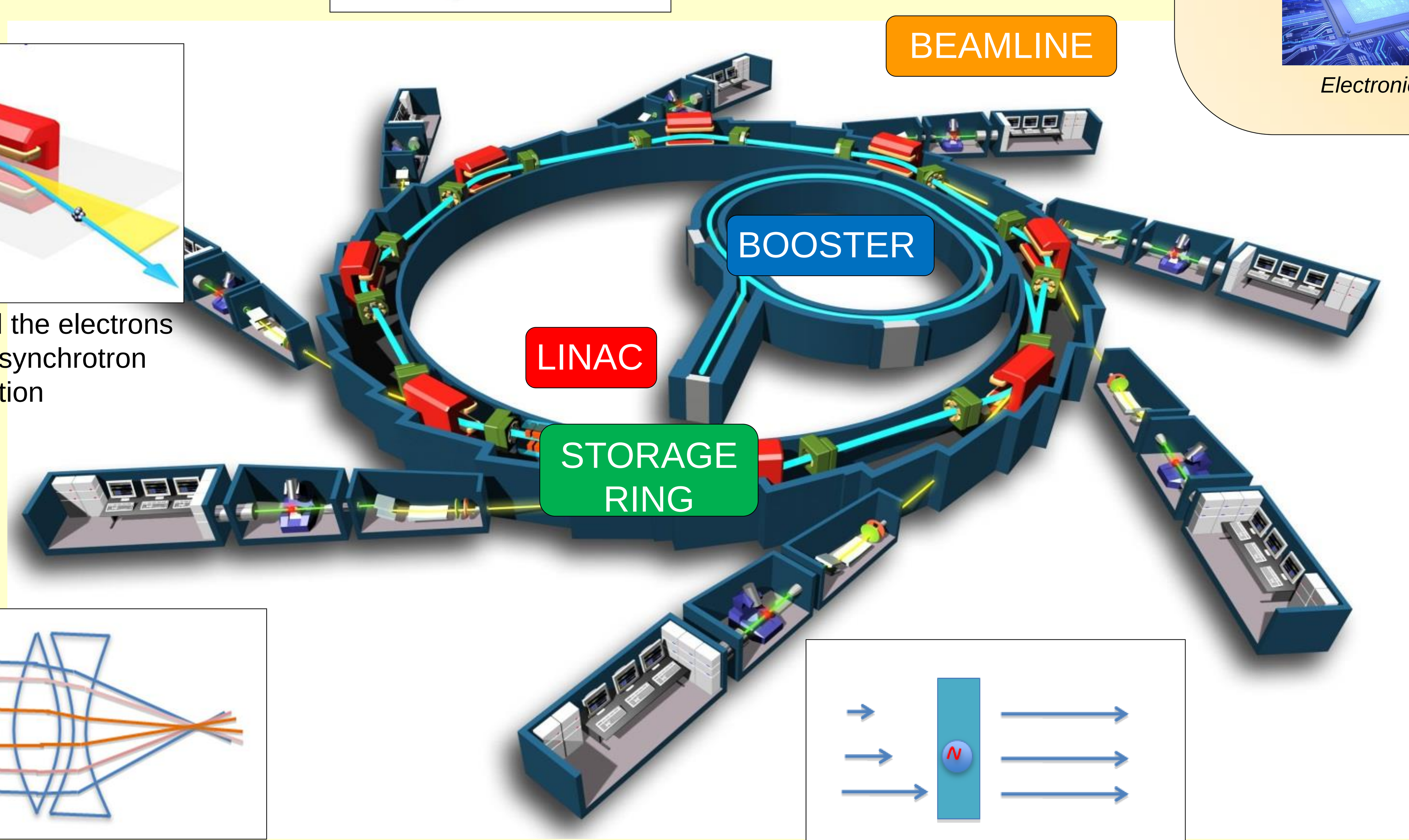




Location of synchrotron SOLEIL

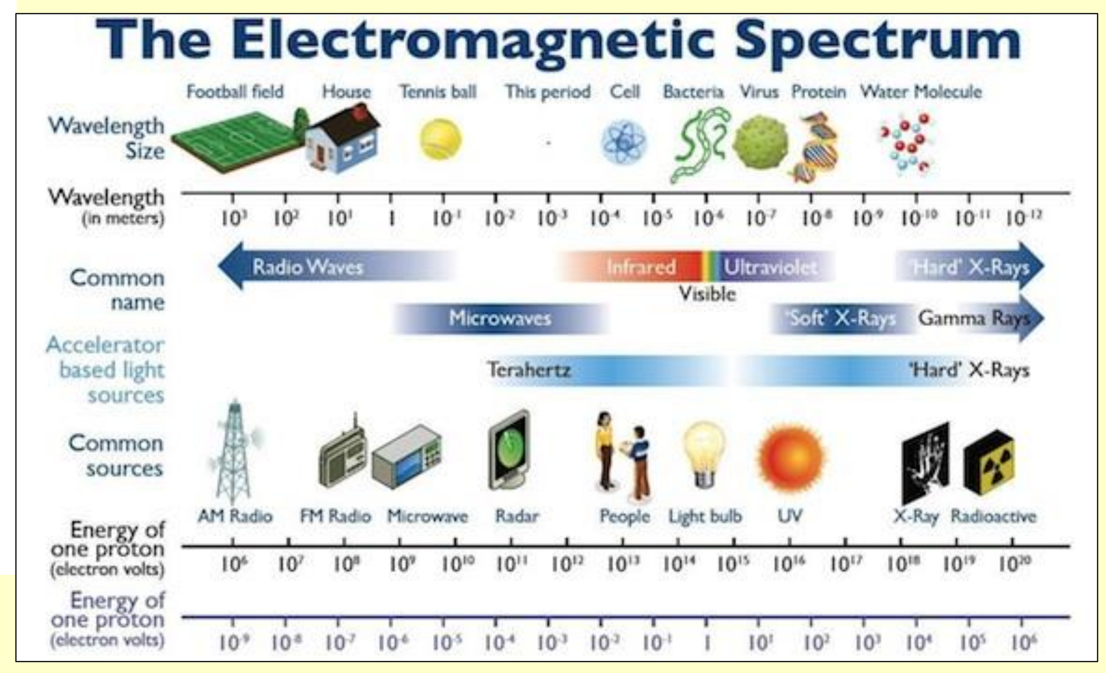


Dipole: to bend the electrons and produce synchrotron radiation



Particles accelerated	electrons
Energy [GeV]	2.75
Number of Beamlines	29
Number of dipoles	32
Number of quadrupoles	163
Number of sextupoles	122

Main parameters of synchrotron SOLEIL



The synchrotron radiation wavelength produced goes from 10^{-3} m to 10^{-10} m . Then we can study the matter at that level

Sextupole: to correct chromatic aberration introduced by quadrupoles

Radio Frequency cavities: to replace the energy lost by radiation

OBJECTIVE OF THE PROJECT

- Optimize the magnetic structure of the storage ring using Multi-objective Genetic Algorithms (MOGA) [1] to improve the performance of SOLEIL and, simultaneously, the quality of the synchrotron radiation.
- 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. Starting from a initial random population of solutions, the algorithm chose the best solutions to be the parents of the next generation. In our case, the objectives are related with the stability of the beam inside the machine.
- Appling GA, the best solutions are find among all the possible solutions under a number of constraints defined by the quadrupole and sextupole strengths.
- Test experimentally the simulated solutions in the control room of SOLEIL.

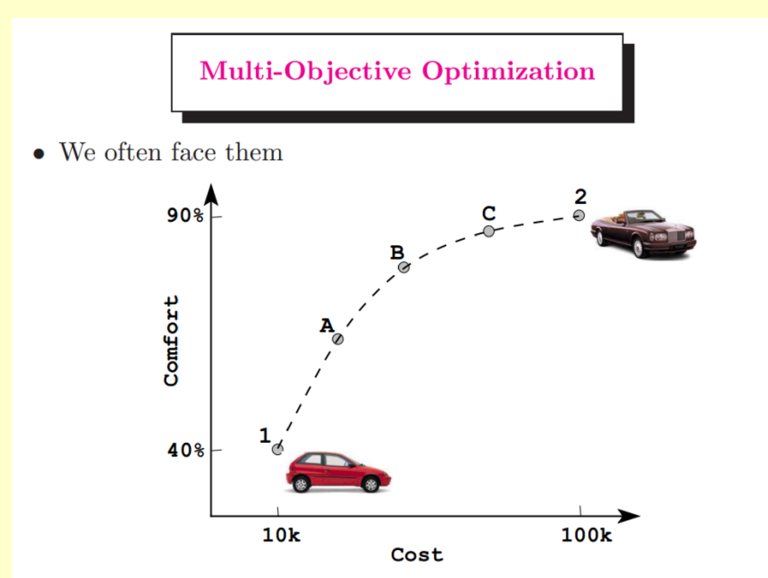
Control room of synchrotron SOLEIL

TOOLS

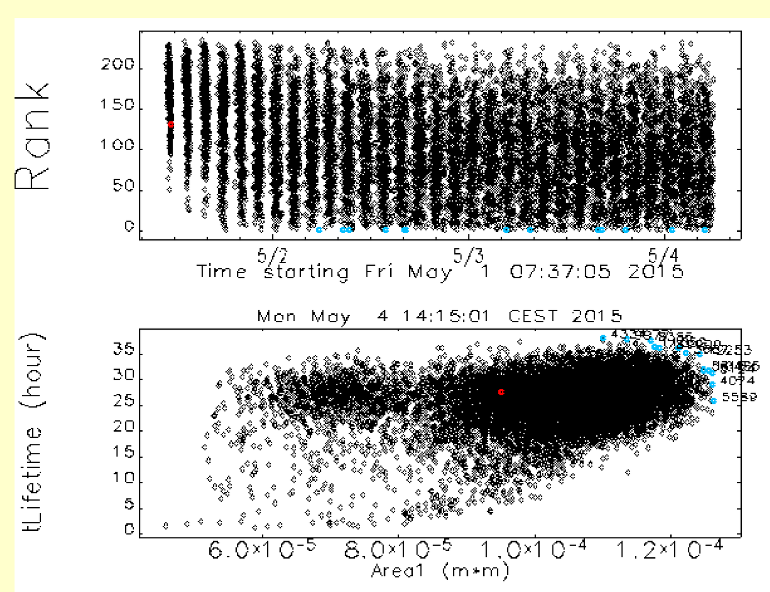
- We use codes to simulate the performance of the electrons inside the accelerator.
- A computational cluster with hundred of CPUs for genetic optimizations. A big computational effort is necessary to find new magnetic structures. The computational process is slow and sometimes we must wait 1 or 2 weeks to obtain good results!

SOLEIL cluster

RESULTS AND CONCLUSIONS



Example of multi-objective problems: buy a car



Example of our simulations: the red point is the current magnetic lattice of SOLEIL. The black points are all the solutions found by the algorithm. The blue points are the best optimized solutions

- The simulations show an improvement of the objectives even introducing the magnetic field errors produced by the magnets.
- Until now the experimental results do not show the improvement expected from simulations because there are real physical phenomena do not taken into account in the simulations.
- We must determine the best compromise between accuracy and computation time to use the GA in our machine. This is under investigation.

REFERENCES: [1] A. Konak, D. W. Coit, A. E. Smith, "Multi-objective optimization using genetic algorithms: A tutorial", 2006.