Machine Learning

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This project has received funding from the European Union's Horizon Europe Research and Innovation programme under Grant Agreement No 101057511.

Context

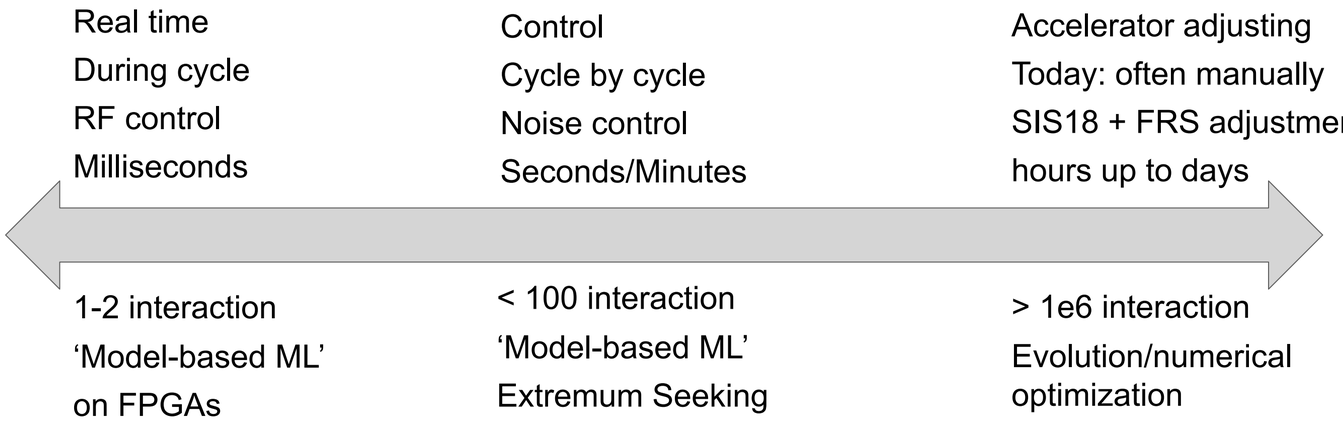
- Introduction
- python toolkit: GeOFF
- GeOFF implementation at GSI
- CEA report
- Outlook

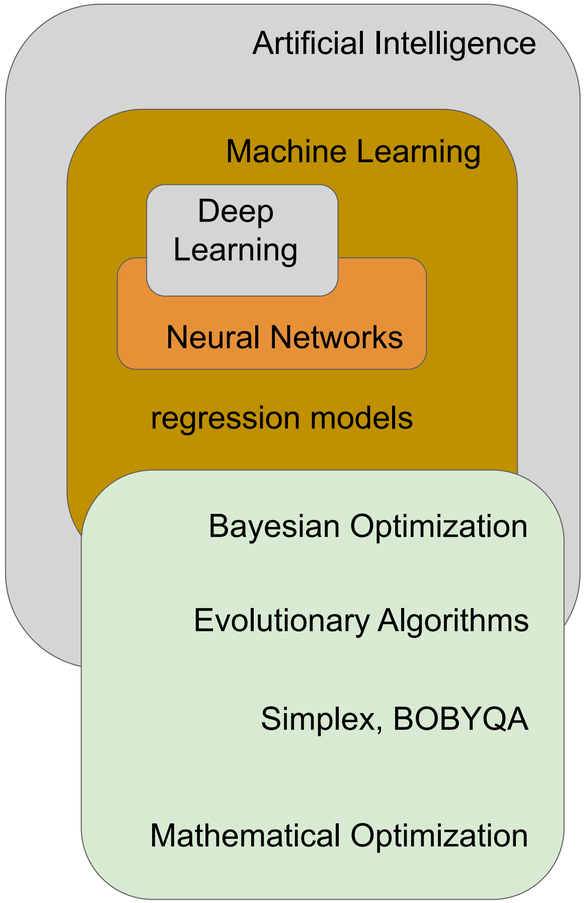
Machine Learning to improve facility performance

Automation: Facilitation of manual tuning → numerical optimization → machine learning

Accelerator (machine parameter) optimization:
Performed live on the machine with mathematical optimizers (+ ML).
Numerical optimizers often build simple surrogates during their progression.

Accelerator surrogates and ML:
From simple regression models to artificial neural networks
Training from real machine or/and simulation data
Goal: Fast, invertible models for analysis/optimization

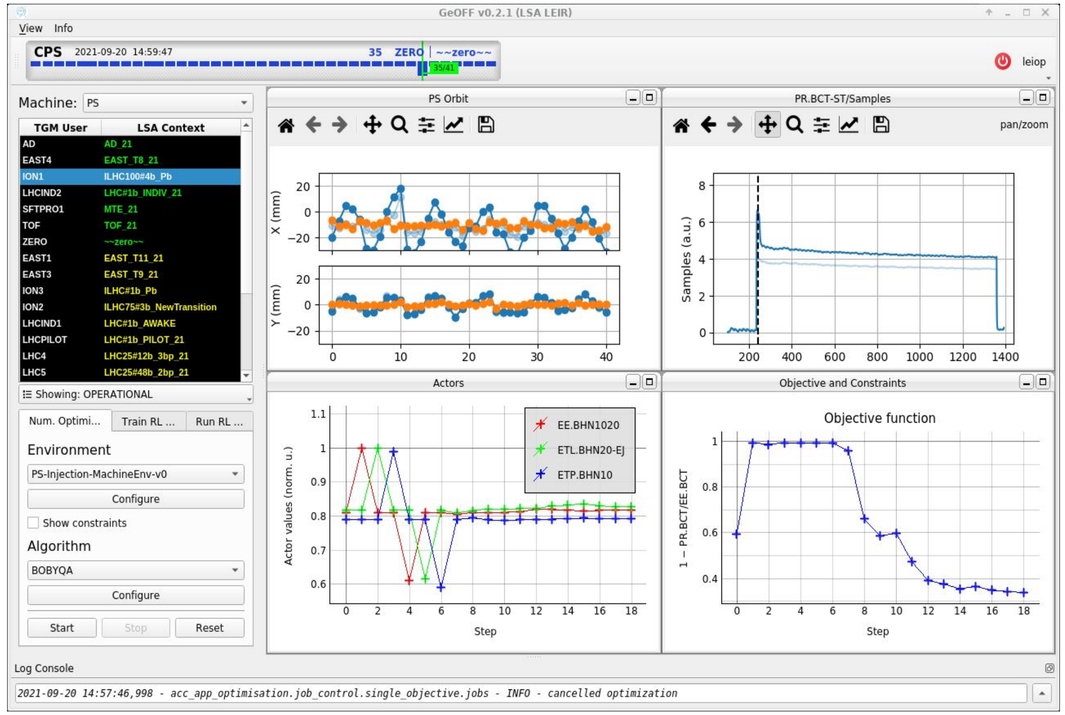




Python toolkit GeOFF

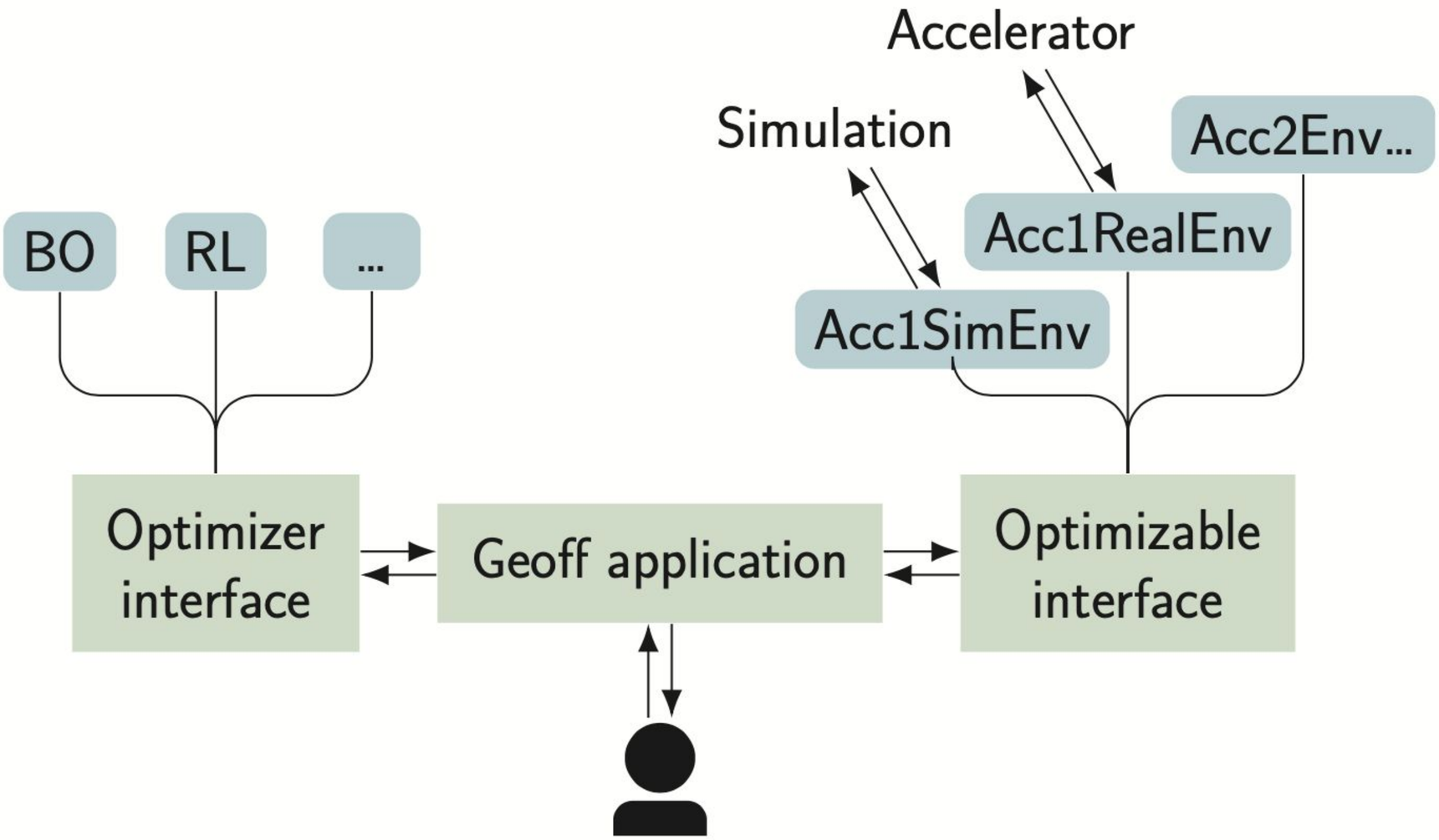
Generic Optimization Frontend and Framework (GeOFF) is the graphical application for generic numerical optimization and reinforcement learning on CERN accelerators.

- lists, configures and runs optimization problems
- built-in list of optimizers
- optimization problems are loaded as plugins pre-packaged or at runtime
- standardized interfaces and adapters for various packages via Common Optimization Interfaces
- Standard framework for testing automation + ML at CERN



[GEOFF (CERN gitlab)]

Python toolkit GeOFF



Model of *Geoff* and its components

Python toolkit GeOFF: PS example

Optimization of 3 PS accelerator magnets at CERN

Sidebar with settings

Custom plots supplied by the optimizable

Built-in graph of the optimization progress

S. Appel (GSI)

Python toolkit GeOFF

geoff › geoff-app

G **geoff-app**

Project ID: 103494

461 Commits | 2 Branches | 55 Tags | 18.8 MiB Project Storage

Reference frontend for the GeOFF project

pipeline passed | coverage unknown | Latest Release none

Table of Contents

License

A lot of documentation are available and GeOFF is licensed

Gitlab: https://gitlab.cern.ch/geoff/geoff-app

Milestone report:
https://data.192.135.24.99.myip.cloud.infn.it/s/ibeQoC0rWGX4Dw4

COI — Common Optimization Interfaces

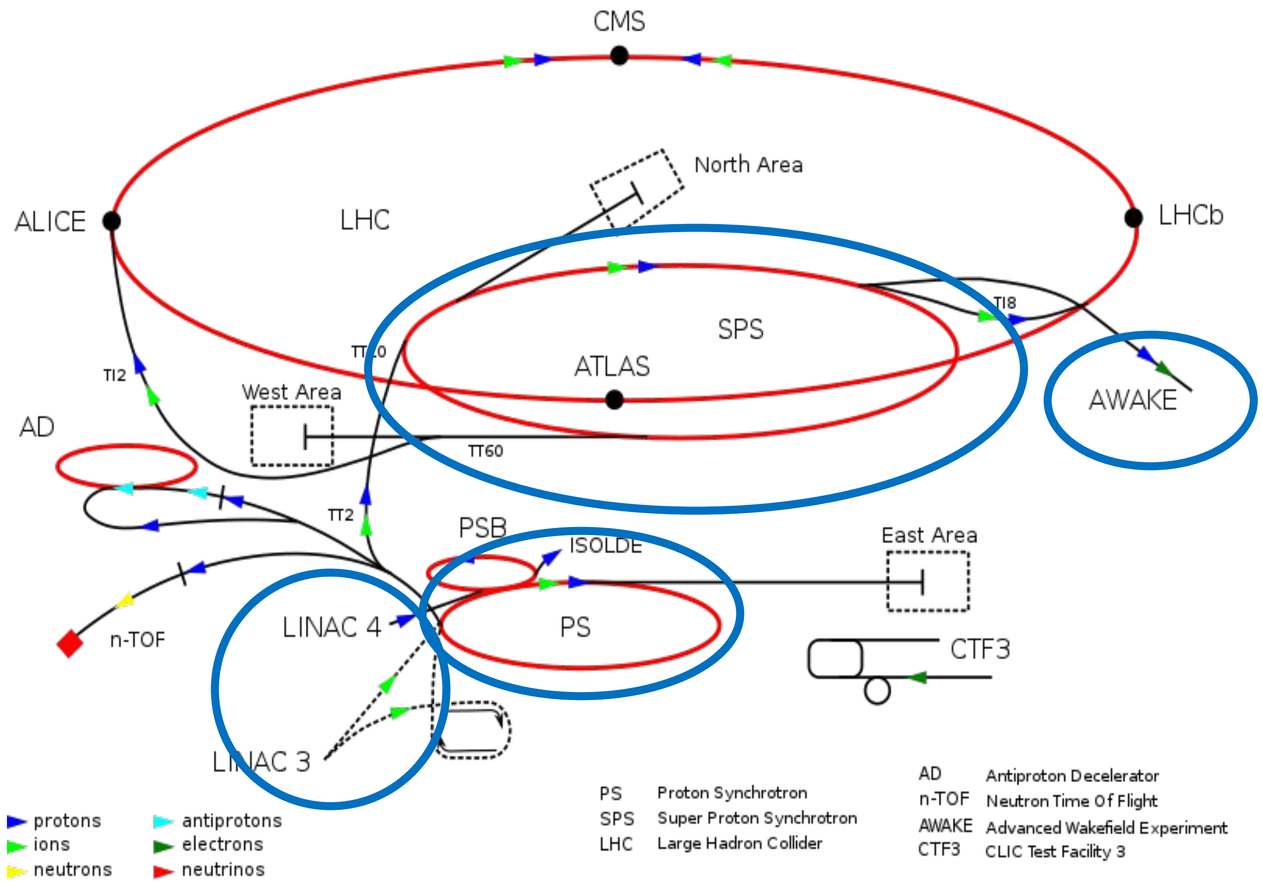
CERN ML is the project of bringing numerical optimization, machine learning and reinforcement learning to the operation of the CERN accelerator complex.

CERNML-COI defines common interfaces that facilitate using numerical optimization and reinforcement learning (RL) on the same optimization problems. This makes it possible to unify both approaches into a generic optimization application in the CERN Control Center.

The cernml-coi-utils package provides many additional features that complement the COIs.

This repository can be found online on CERN's Gitlab.

Python toolkit GeOFF at CERN



CERN: used at almost all accelerators

Accelerator	Expert use	Operational use
Linac3	0	1
Linac4	2	0
PS Booster	2	2
PS	2	1
SPS	5	4
ISOLDE	0	0
LHC	0	0

Python toolkit GeOFF at CERN

GEOFF is used at almost all accelerators at CERN

(Linac 3+4, PSB, PS, SPS, LEIR)

most often used as an expert-level tool

SPS:

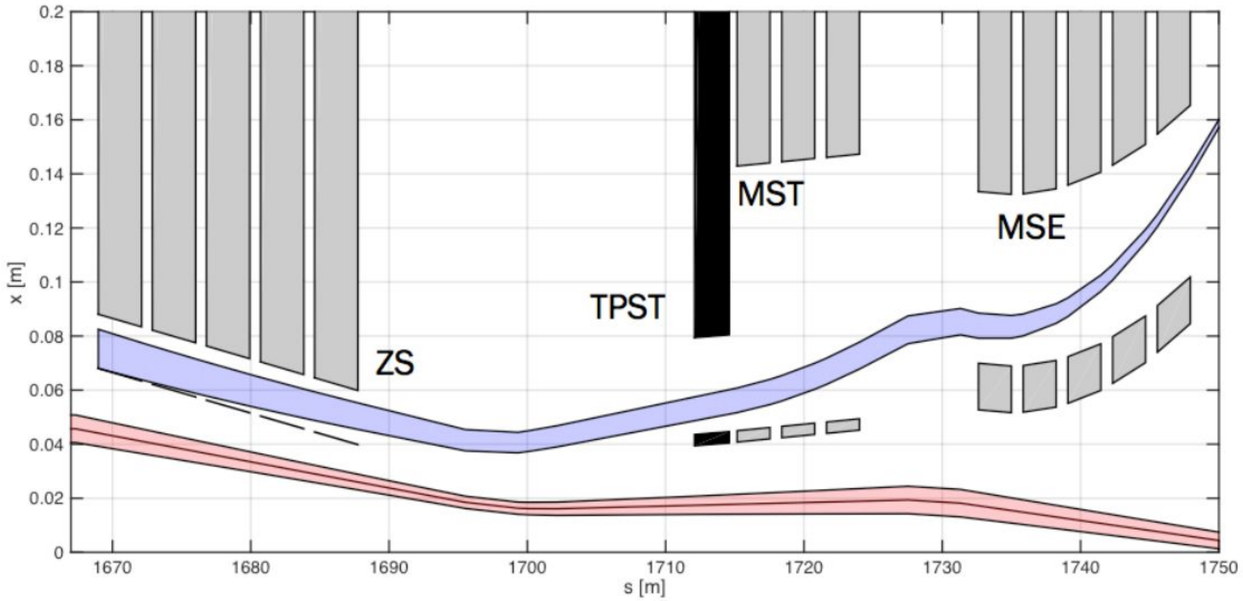
Septa alignment for slow extraction

Time spent aligning for 9 variables

before: ~ 8 h

2018: ~ 45 min (Powell algorithm)

2021: ~ 10 min (BOBYQA algorithm)



-> As the optimization time has be reduced, the septa alignment is now optimized more often

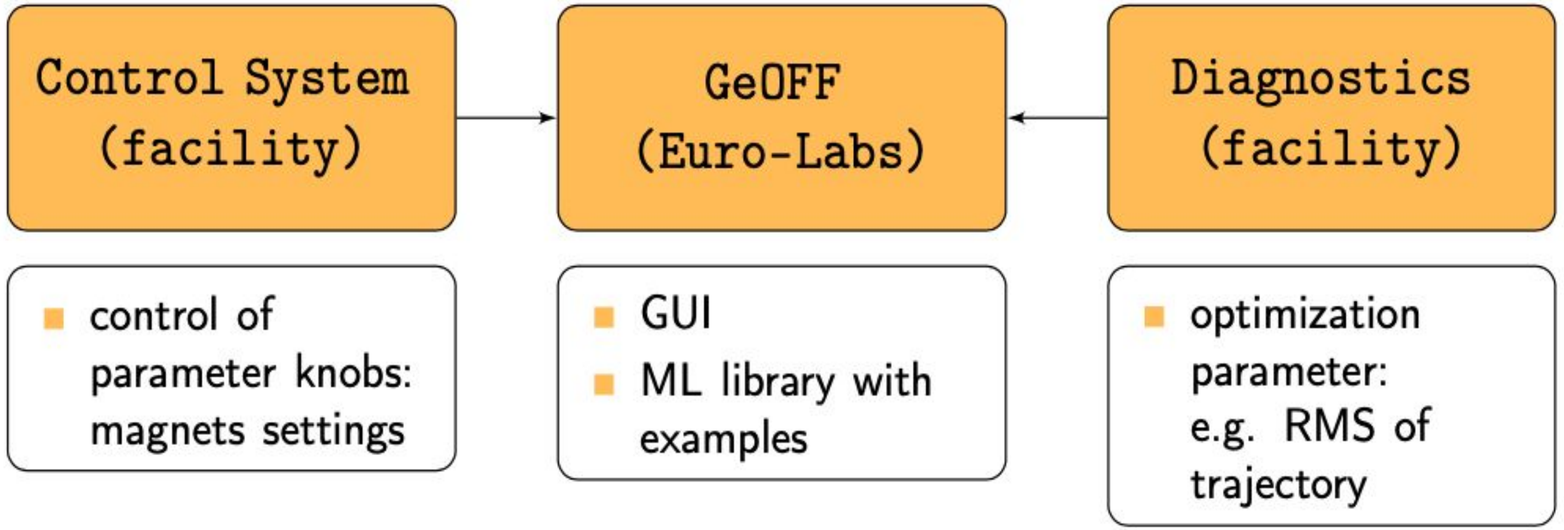
Possible implantation at other facility

At the example of GSI: Similar infrastructure as CERN

Homework done: All python interfaces have been checked:
Python access to control system (LSA) and diagnostics (FESA)

Team: A. Oeftiger, R. Müller, S. Appel

Settings management system: python access to LSA with *pjlsa-gsi*



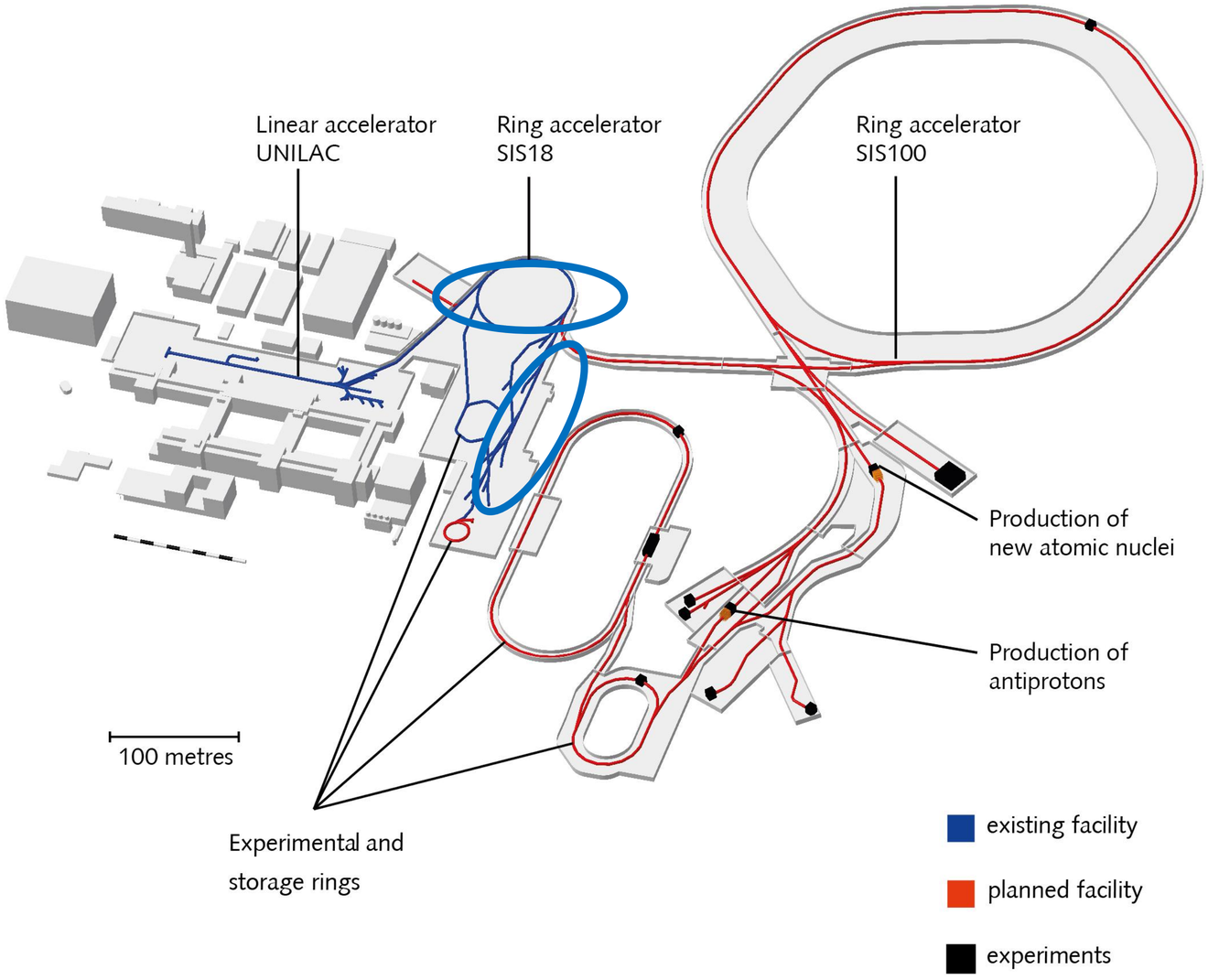
Team: U. Krause, D. Day, T. Habermann, M. Wiebel

Instrumentation: python access to FESA devices (e.g. measurement data) with *python-cmwrda*

https://www-acc.gsi.de/wiki/FESA/PythonCmwRda

https://git.gsi.de/scripting-tools/pjlsa_gsi

Python toolkit GeOFF at FAIR + GSI



Accelerator	planned to use next month
SIS18	2
FRS	1

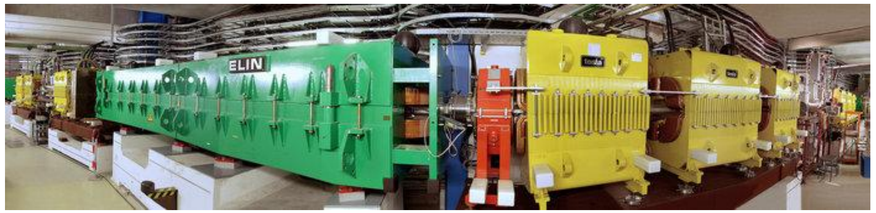
Planned to use GeOFF for ML optimization next month!

Only in November and December there will be beam at GSI, but only for machine development, no user operation

Python toolkit GeOFF at FAIR + GSI

Automate FRS/Super-FRS optical adjustments (User facility)

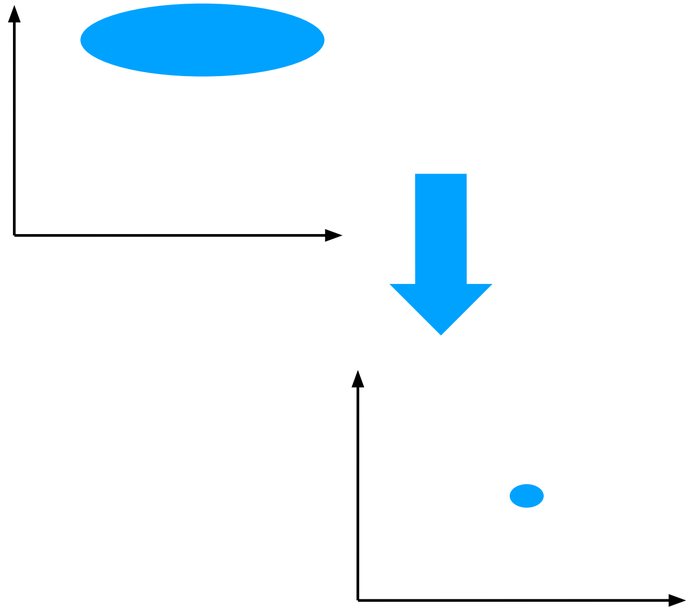
FRS



Thanks to the characteristics of the high-resolution magnetic spectrometer FRS, exotic nuclei can be produced, separated, identified and eventually stored in a storage ring.

Adjustment times are present at the FRS of 2-3 days

Due to the increased complexity (about 4 times more magnets), the setting up time for the Super-FRS is expected to largely increase



Aim of automation with GeOFF:

Centering beam on target including defined beam spot
by varying focus and steering magnets with numerical optimizers

Python toolkit GeOFF at FAIR + GSI

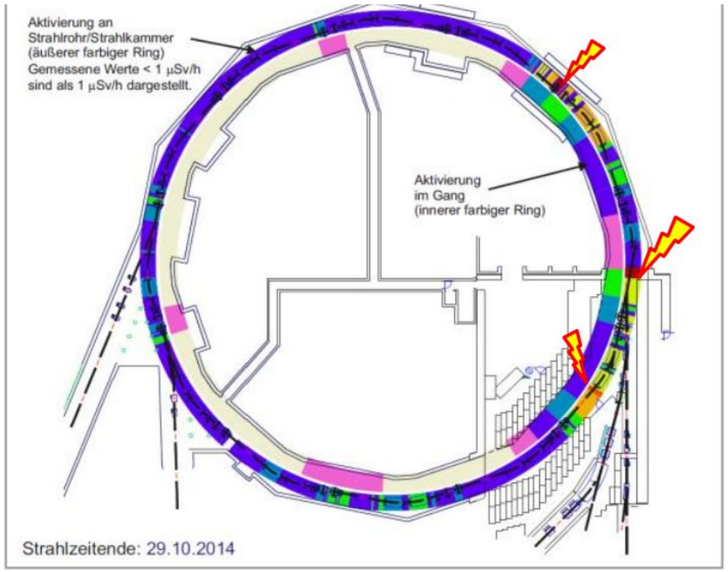
Automation of Multi-Turn Injection and slow extraction of SIS18

The heavy-ion synchrotron SIS18 deliver beams to experiments and will be the booster for FAIR synchrotron SIS100 (0.010 – 2 GeV/u)

SIS18 flexibility in providing a broad range of ions allow only Liouvilian injection schemes

Third-order resonance slow extraction from SIS18

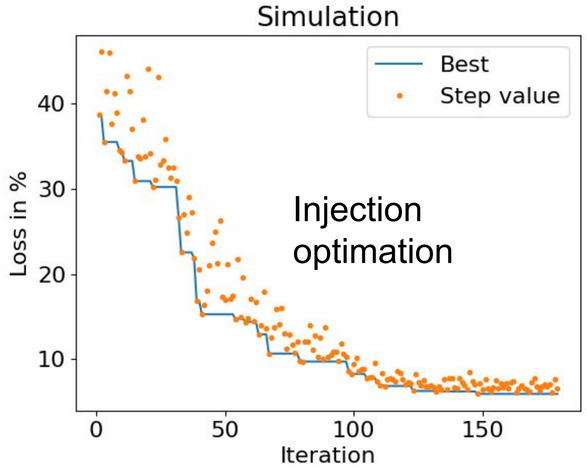
-> Both process have often major beam losses and large setting times



Aim of automation with GeOFF:

Reduce beam loss, shorten adjustment and increase beam quality

Minimize particle losses by varying variables will be performed with numerical optimizer and Reinforcement Learning



WP5 GSI summary and plans

Summary of the first period

Advertisement of PostDoc position (Nov ‘22)

Hiring Nico Madysa (March ‘23)

Milestone report and open-source availability of GeOFF via gitlab (April ‘23)

Preparing GSI facility (May ‘23)

Licensing of GeOFF (June ‘23)

Strategy meeting with CERN (July ‘23)

Plans for second period

Poster at AI STAR (September ‘23)

Optimization with GeOFF at GSI (Nov-Dec ‘23)

Implementation of the GeOFF at CEA (spring ‘24)

Preparing a publication and submitting it to Elsevier's SoftwareX (until middle ‘24)

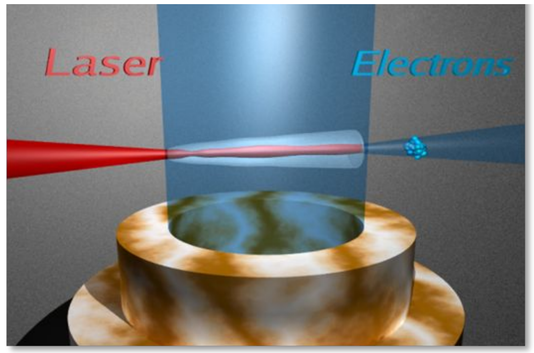
The new toolkit deployed at least two facilities and been used optimization, 31 Aug ‘24

Python toolkit GeOFF at CEA

LPA-UHI100 (Laser Plasma Accelerator on UHI100 laser facility)

= a platform providing electron beam line and experimental area dedicated to **laser-driven electron acceleration** studies in plasma media, and applications.
(FLASH Radiotherapy, secondary particles generation, diagnostic developments ….)

Laser-plasma Accelerator



- Up to **150MeV** over few mm length
- **10’s pC up to 100’s pC/ shot** depending on the acceleration mechanism
- **fs** range duration
- **few mrad** divergence

➡ **EURO-LABS funding for one year post doctoral position**

Objective: to adapt the toolkit GeOFF (Generic Optimization Framework and Frontend) developped by CERN and GSI to Laser Plasma Accelerator Specififfties

S. Dobosz Dufrénoy (CEA-Paris Saclay)

WP5 CEA summary and plans

Summary of the first period (sept 22 – august 23)

✔ As we are waiting for more than 2 years now for the **Nuclear Safety Authority** to allow us to run the accelerator after a move of all the facility from Saclay (main site) to Orme des merisiers (few kilometers away), we have delayed the hiring of a post doc for 8 months since

→ **we need a real beam to test the ML optimization toolkit.**

Advertisement of the 1 year post doctoral position in may 2023
on **CEA** website, and then via **EURO-LABS website**,
and all the different **network mailing lists**

✔ **<u>Development of automatic data saving system</u>**
(starting point for ML optimization)

- Database built → 90% completed
- Web interface structured
- Server implemented for data saving
- Tests to validate the full system planned for Oct-Dec (2023)

WP5 CEA summary and plans

Planning for the next period on the LPA-UHI100 facility

Update from august 2023 : Nuclear Safety Authority has given a temporary authorization to shoot with the laser on target with reduced electron beam characteristics (50MeV, 16pC, 1shot/min)
CEA waiting for authorization to operate the facility fully .

PLANNING: :

1/ test shots on the facility and validation of the automatized data saving/
Upgrade of the command control of the laser system **nov-dec 2023**

2/ implementation of the Machine Learning Toolkit Prototype GeOff developed by GSI
and adjustments to the Laser- plasma accelerator specificities (input: laser/target parameters)
spring 2024

3/ **1st campaign**: tests of a double compartments gas cell as new target to **generate low dispersion energy electron beams around 150 MeV** **summer 2024**