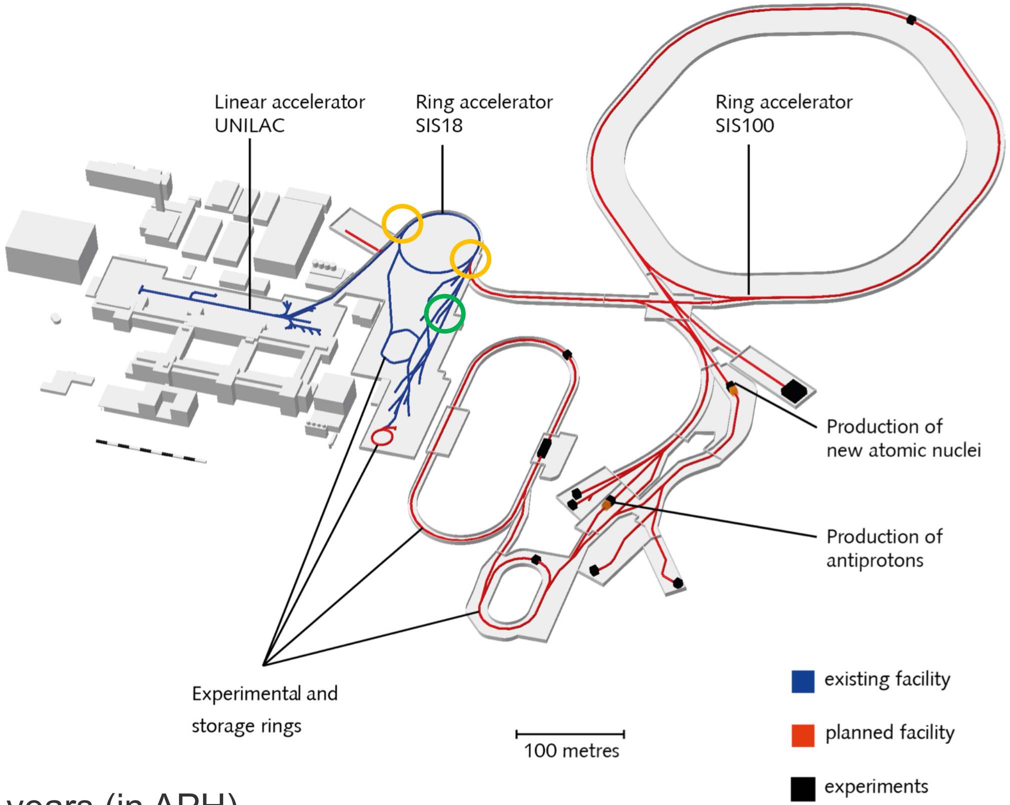
FAIR/GSI

Automation and optimization with Python:

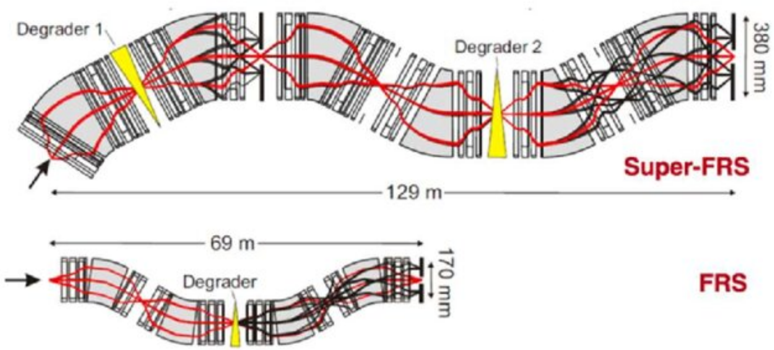
- Multi-turn injection loss minimization (SIS18)
- Tune scans (SIS18)
- Beam steering (TK)
- Closed orbit correction for non-standard optics (SIS18)
- Slow extraction loss minimization (SIS18)
- Beam steering and focusing (FRS)



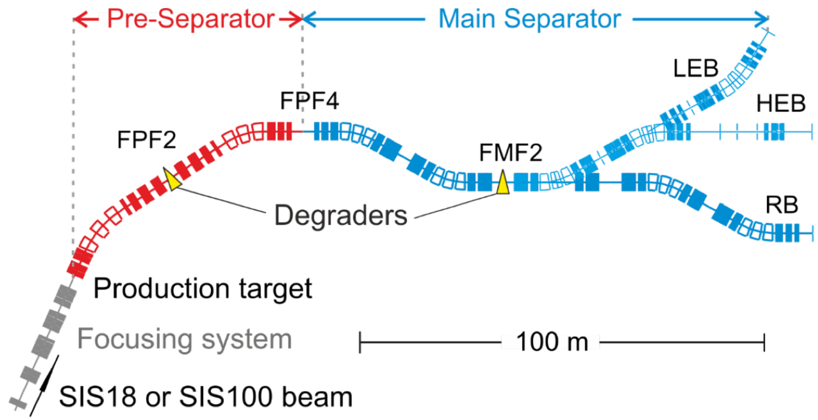
- EURO-LABS finances a scientific staff member for three years (in APH)
- Several TUDA Master and PhD students (with TUDA funding)

FRS (FRagment Separator) and Super-FRS

- Production and investigation of nuclear structure of exotic nuclei.
- characteristics of the high-resolution magnetic spectrometer FRS, exotic nuclei can be produced, separated, identified and eventually stored in a storage ring
- Super-FRS increas of acceptance and complexity (about 4 times more magnets), Gain factors of 1000 (^{12}C) and 7500 (^{132}Sn) can be reached[1].



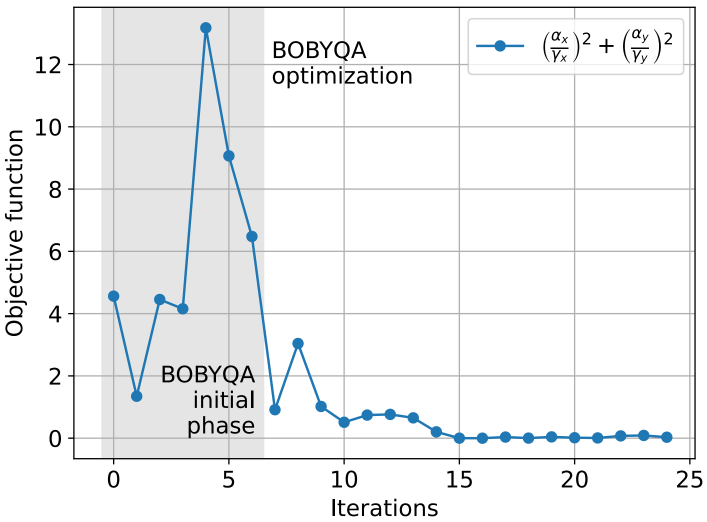
Super-FRS layout:

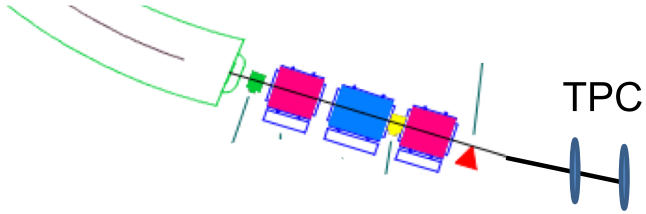


Automation and **Optimization**: Example FRS

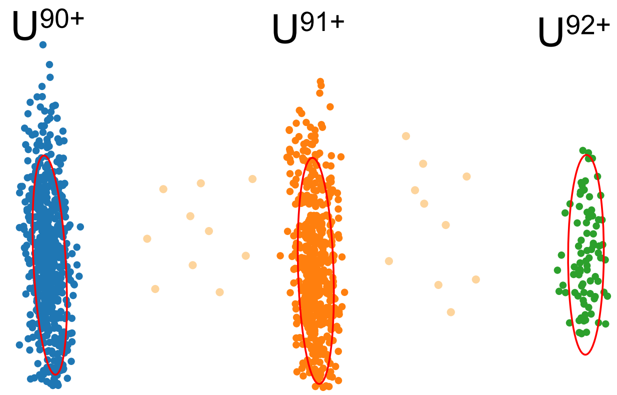
- FRS Testing Campaign is currently in progress to demonstrate automation of the FAIR SFRS. (manual setting generation will takes more than two days for FRS)
- Proof of principle: All the required systems for automation have been verified

Optimization





TPC Data analysis

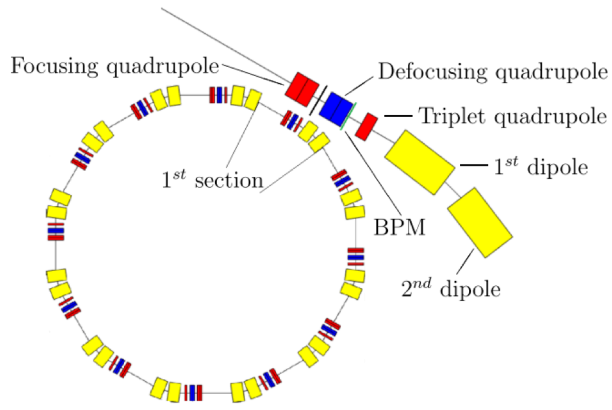


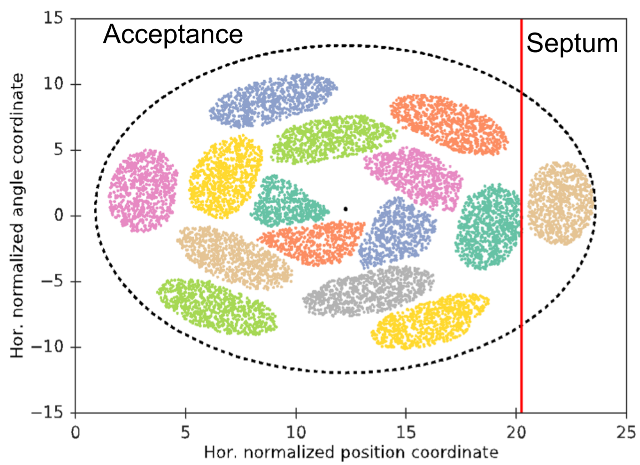
Optimization at FRS involves:

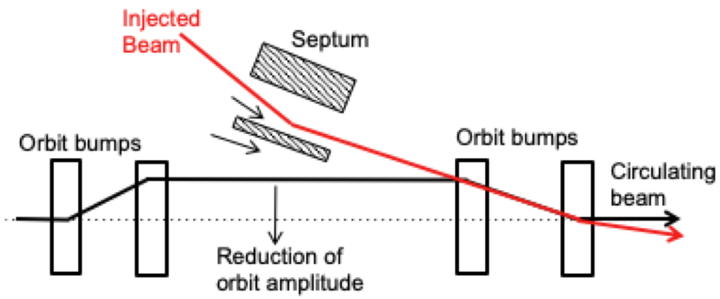
- LSA (trim steerers + magnets),
- FESA (SIS18 monitoring),
- Experiment instrumentation (TPC)
  - Including connection to GO4 server and classification with sklearn
- Device Access (FRS grids) for steering (Appendix)

SIS18 (SchwerIonenSynchrotron)

- Booster for FAIR SIS100 Synchrotron.
- Multi-turn injection into SIS18 is one bottleneck to reach intense beams.
- MTI has to respect Liouville's theorem: Injected beams only in free space
-
- The (incoherent) transverse space charge force is the main intensity limiting effect in the FAIR synchrotrons.
- For intermediate charge state ions, the loss-induced vacuum degradatior is another important key intensity-limiting factor.

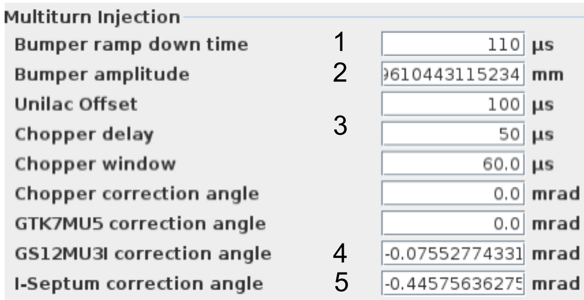




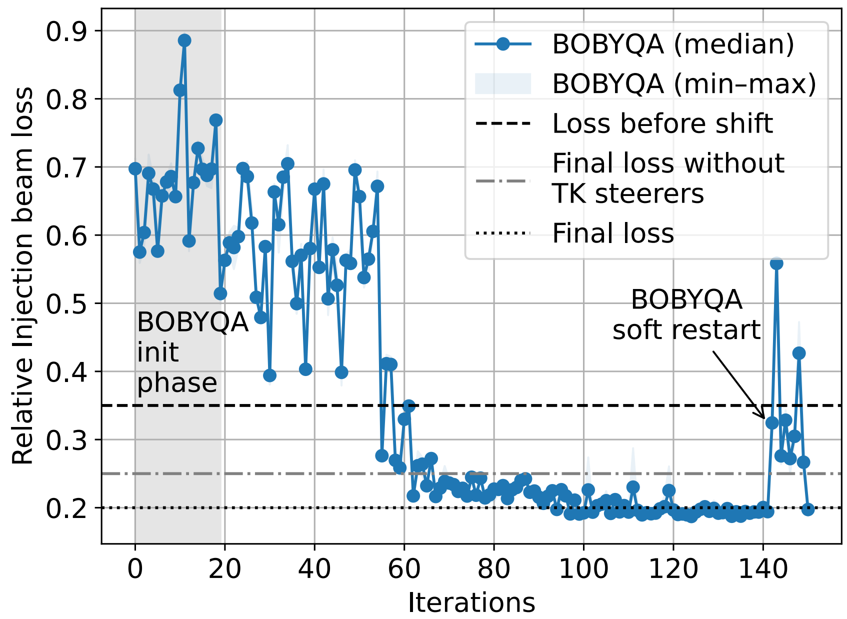


Automation of Multi-Turn Injection

- Using nine optimization parameters.



+ 4 TK Steers

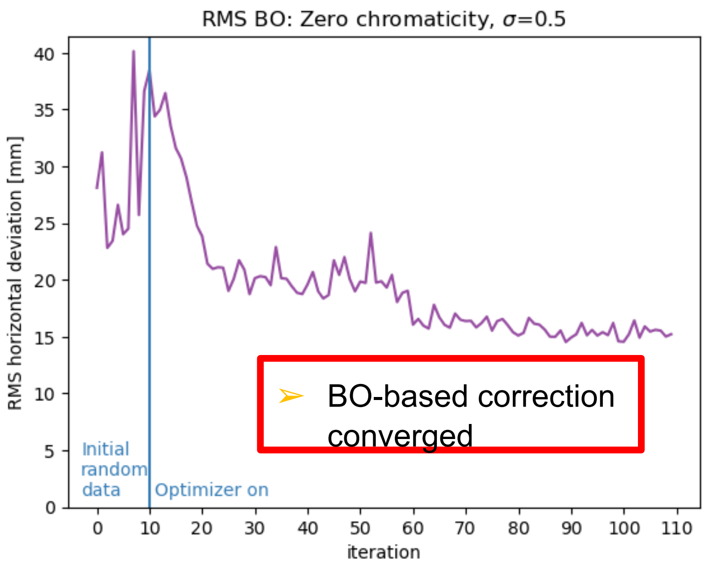


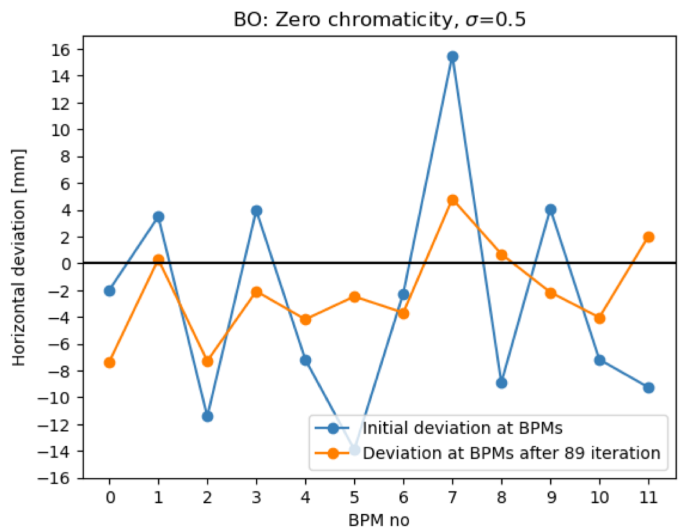
- **150** iterations required, which took about **30 minutes**.
- To reduce the variance of the objective function, each evaluation took the median of three measurement.
- The gray area marks the initialization phase.
- **Loss could be reduced from 35 % to 20 %.**

- Multi Objective Bayesian Optimization with BoTorch has been also performed

BO-based correction for non-standard SIS optics

- For non-standard SIS optics existing correction schemes often fail (for example, sigma optics: Optical setting with shifted transition energy)
  - Explore **Bayesian Optimization (BO)**
- Challenges due to:
  - Sextupole nonlinearity, BPM noise and asymmetric (sigma) optics





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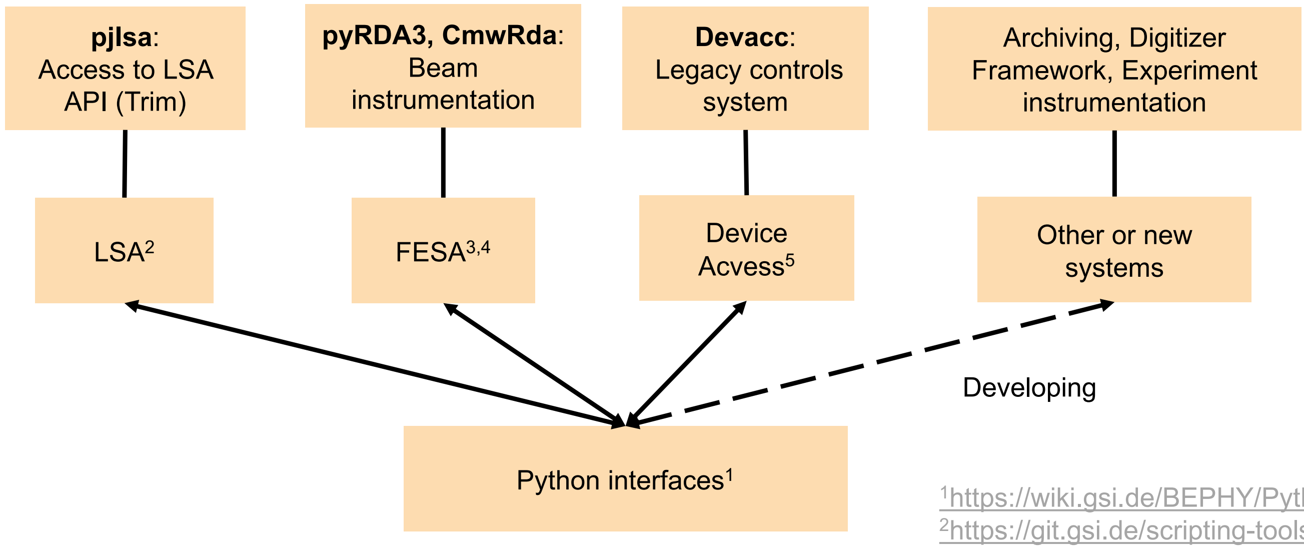
Appendix

Python interfaces to the control system

Automatic optimization:
All instruments and devices must **be as simple to access as possible via python** (accelerator + experiment (SFRS/FRS)).

Accessibility via Python has been verified and improved: Tutorials and developer guides written[1]

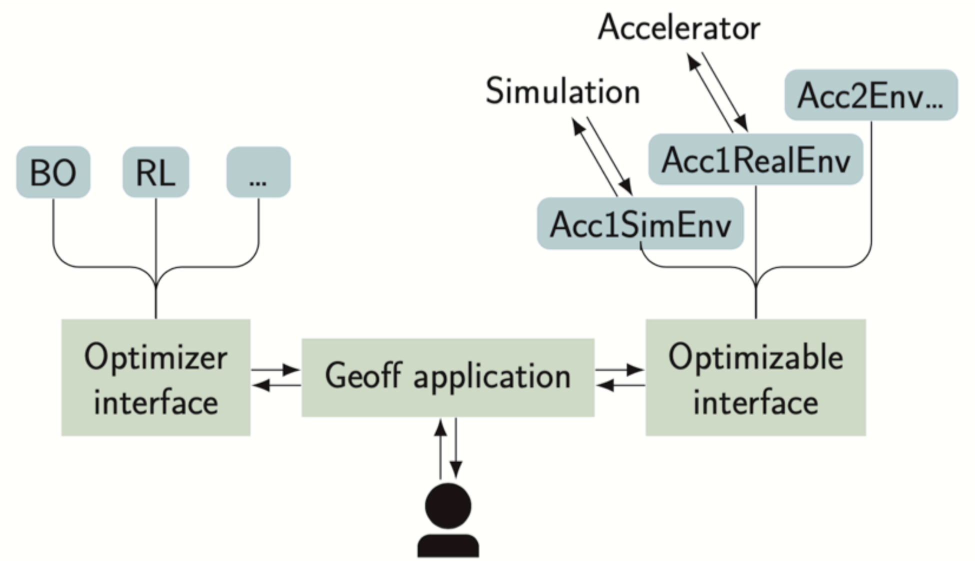


[1] https://wiki.gsi.de/BEPHY/PythonBridge,
[2] https://git.gsi.de/scripting-tools/pjlsa_gsipro,
[3] https://www-acc.gsi.de/wiki/FESA/PythonCmwRda,
[4] https://gitlab.cern.ch/acc-co/devops/python/prototypes/pyda
[5] https://www-acc.gsi.de/wiki/Frontend/DeviceAccessIntroduction

GeOFF at GSI

Generic Optimization Frontend & Framework (GeOFF) is a widely used framework for for deploying automation at CERN

- Python-based framework
- lists, configures and runs optimization problems
- standardized interfaces and adapters for various packages via Common Optimization Interfaces
- Optimization problem formulated as classes
- Class contains logic for live plotting, data logging, and communication with LSA, FESA and the Device Access system
- Quick adaptation of code and on-the-fly during shifts: This is made easy due to Flexibility of the framework.



GeOFF Development/Distribution/Maintenance (N. Madysa, APH, EU funded)