HELMHOLTZAI | ARTIFICIAL INTELLIGENCE COOPERATION UNIT

DESY.

KIT Karlsruhe Institute of Technology

Machine Learning Towards Autonomous Accelerators

Helmholtz AI Project

Annika Eichler (PI), DESY
Andrea Santamaria Garcia, KIT

July 16th 2020
PSI ML Luncheon
Online Meeting

PROJECT OVERVIEW

- The "Autonomous Accelerator" project is funded by Helmholtz AI, one of the five platforms initiated by the Helmholtz Information and Data Science Incubator
- It is a two year project in collaboration between DESY and KIT, **starting September 2020**

"Modern particle accelerators offer extraordinary beams for new discoveries in science. Increasing beam requirements make their operation more demanding, and a fully autonomous accelerator seems a long way off. However, this project is taking its first steps towards implementation. It brings reinforcement learning to the linear accelerator operation at DESY and KIT"

Press release

WHO WE ARE

Erik Bründermann
Head of Department:
Accelerator Research and Development + Operations II
Institute for Beam Physics and Technology (IBPT)
KIT

Andrea Santamaria Garcia
Research Associate
Laboratory for Applications of Synchrotron Radiation (LAS)
KIT

Annika Eichler (PI)
Senior Researcher
Machine Beam Control (MSK)
DESY

Florian Burkart
Junior staff
DESY-M ARD Team
DESY

To be filled!

Your Name
PostDoc
Machine Beam Control (MSK)
DESY

ARES @ SINBAD

ACCELERATOR RESEARCH EXPERIMENT AT SINBAD

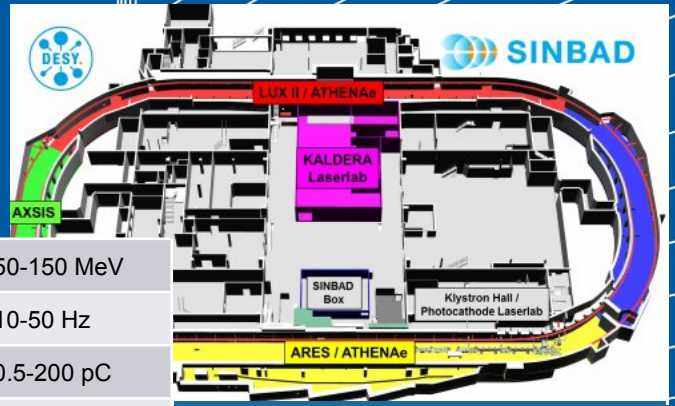
- Test facility for accelerator physics
- Normal conducting S-band electron linac for the production of ultra-short bunches

R&D topics

- Development of novel beam diagnostics
- Test accelerator for DESYs CAD migration to NX
- Accelerator R&D test facility via ARIES
- Low-charge ultra short bunches with fs synchronization

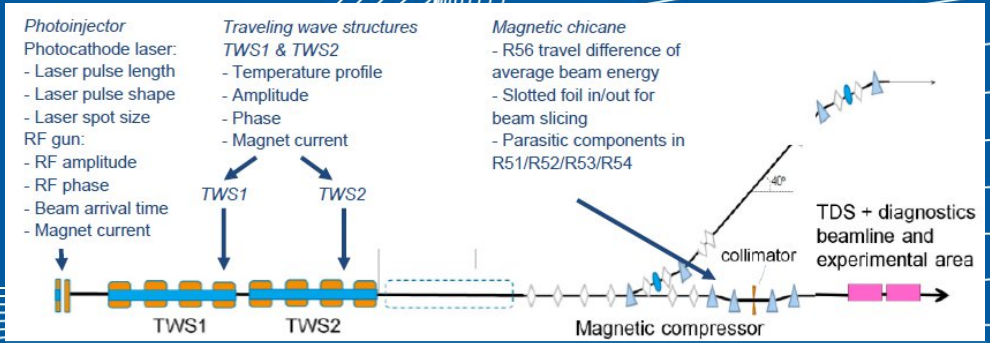
Autonomous Accelerator

- Use the controllable inputs marked in blue as input for the algorithm.
- Goal: control the longitudinal bunch profile.



Beam energy	50-150 MeV
Repition rate	10-50 Hz
Electron bunch charge	0.5-200 pC
Electron bunch length	0.2-10 fs

https://ard.desy.de/sinbad/



https://accelconf.web.cern.ch/ipac2019/papers/mopts026.pdf

FLUTE

FERNINFRAROT LINAC UND TEST-EXPERIMENT

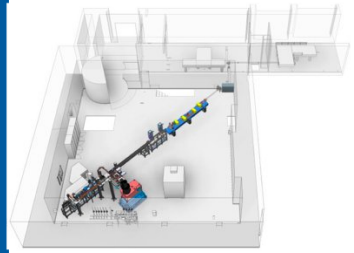
- Test facility for accelerator physics
- Experiments with THz radiation

R&D topics

- Serve as a test bench for new beam diagnostics and tools
- Systematic bunch compression and THz generation studies
- Develop single shot fs diagnostics
- Synchronization on a fs level

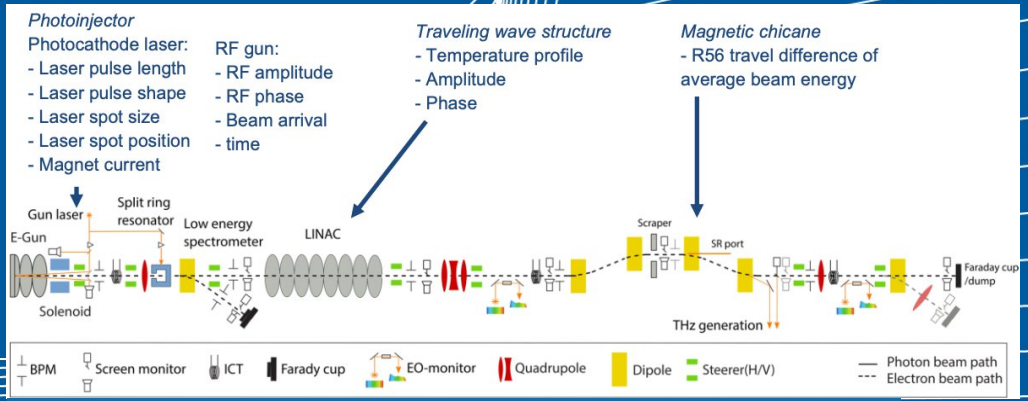
Autonomous Accelerator

- Use the controllable inputs marked in blue as input for the algorithm.
- Goal: control the longitudinal bunch profile.



Final electron energy	~ 41	MeV
Electron bunch charge	0.001 - 3	nC
Electron bunch length	1 - 300	fs
Pulse repetition rate	10	Hz
THz E-Field strength	up to 1.2	GV/m

www.ibpt.kit.edu/flute



"First electron beam at the linear accelerator FLUTE at KIT"

PROJECT DETAILS

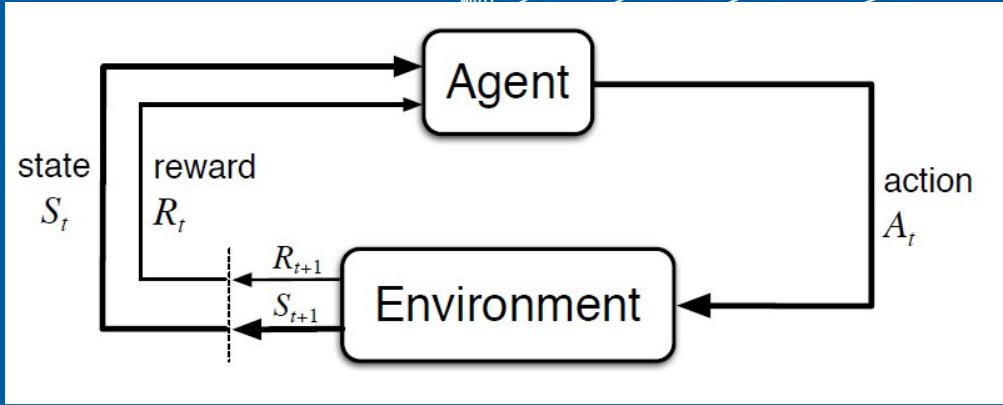
- Bring (deep) RL to accelerator control
- Control of the longitudinal bunch profile
- Apply results to two similar facilities, ARES and FLUTE

Challenges

- High-dimensional, continuous state and action spaces
- (Sub)-femtosecond requirements on bunch duration
- Nonlinear & collective effects
- Low repitition rate

Long-term goals

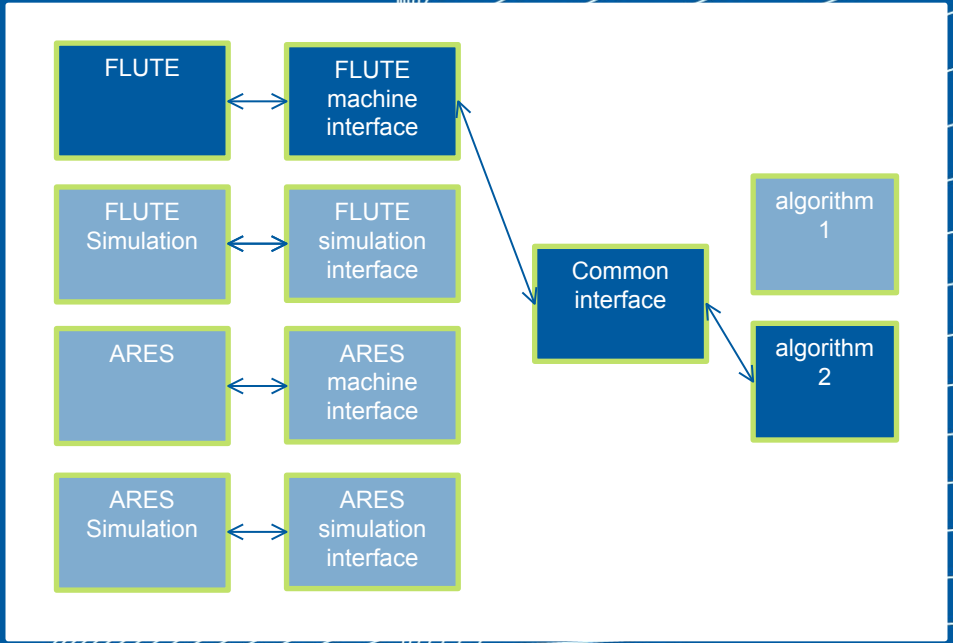
- Transfer learning and algorithm transfer:
  - How easy is the transfer between simulation and facility / the two facilities?
  - Transferability to other accelerators in the Helmholtz community (FLASH/European XFEL)
- From longitudinal to transversal bunch profile control to automatic startup



Sutton, Barto, 2014, "Reinforcement Learning: An Introduction", MIT Press

FIRST STEPS

- Start simple (with a subproblem)
- Start with simulations
  - ARES: OCELOT simulation exists
  - FLUTE: genetic algorithm already applied to the control of the longitudinal bunch profile [publication].
- Always compare to simple baseline controller
- Start with algorithms that have been applied in accelerator community [T. P. Lillicrap et al., "Continuous control with deep reinforcement learning," 4th Int. Conf. Learn. Represent. ICLR 2016 - Conf. Track Proc., 2016 --> at BESSY II]
- Keep it modular



THANK YOU!

More information on...

- the project
  https://confluence.desy.de/display/HAAA/Helmholtz+AI+-+Autonomous+Accelerator
- FLUTE
  www.ibpt.kit.edu/flute
- ARES
  https://ard.desy.de/sinbad/
- Helmholtz AI
  https://www.helmholtz.ai/