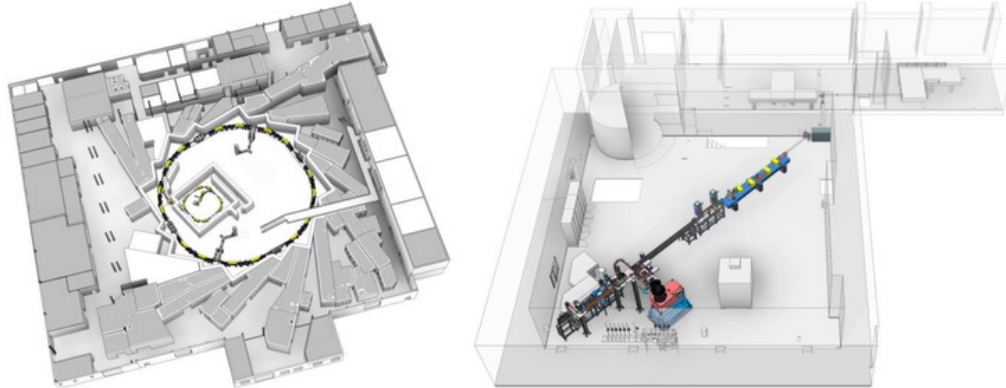


Machine Learning Activities for Particle Accelerators at KIT

Andrea Santamaría García, Tobias Boltz, Niky Bruchon, Erik Bründermann,
Chenran Xu, Anke-Susanne Müller

ACCLAIM Innovationspool end-of-year meeting (15-12-2021)



Tobias Boltz successfully defended his doctoral thesis!



“Micro-Bunching Control at Electron Storage Rings with Reinforcement Learning”

DOI: [10.5445/IR/1000140271](https://doi.org/10.5445/IR/1000140271)

Next year he will be working as a research Associate in the Machine Learning Initiative and Accelerator Directorate at SLAC

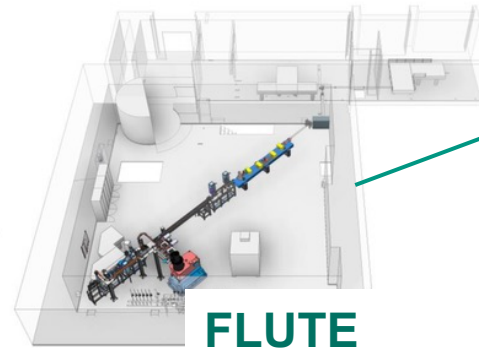
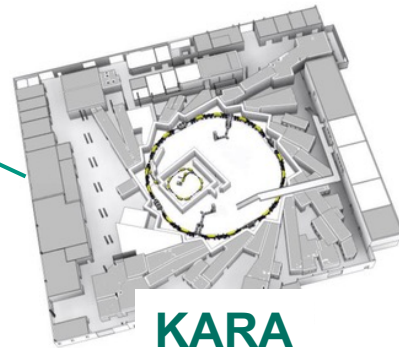
- Best of luck!

Overview of activities 2021

- Bayesian optimization of the injection efficiency
Chenran Xu
- BPM anomaly detection with autoencoders
Niky Bruchon
- Control of the micro-bunching instability with reinforcement learning
Tobias Boltz
DOI: [10.1109/TNS.2021.3084515](https://doi.org/10.1109/TNS.2021.3084515)
DOI: [10.5445/IR/1000140271](https://doi.org/10.5445/IR/1000140271)

“Autonomous Accelerator” Helmholtz AI project ZT-I-PF-5-6




- Laser pulse shaping with Spatial Light Modulators and convolutional neural networks
DOI: [10.18429/JACoW-IPAC2021-WEPA289](https://doi.org/10.18429/JACoW-IPAC2021-WEPA289)
- Beam control with reinforcement learning
DOI: [10.18429/JACoW-IPAC2021-TUPAB298](https://doi.org/10.18429/JACoW-IPAC2021-TUPAB298) Chenran Xu



Bayesian optimization of the injection efficiency

Chenran Xu

Code successfully optimizes the injection efficiency two times faster than manual tuning
Code used in commissioning phase of new injection magnets
Stored current used as contextual parameter correctly predicts Touschek scattering effects

-  Include safety constraints
-  Include hysteresis effects in injection magnets
-  Include microtron and booster injection elements

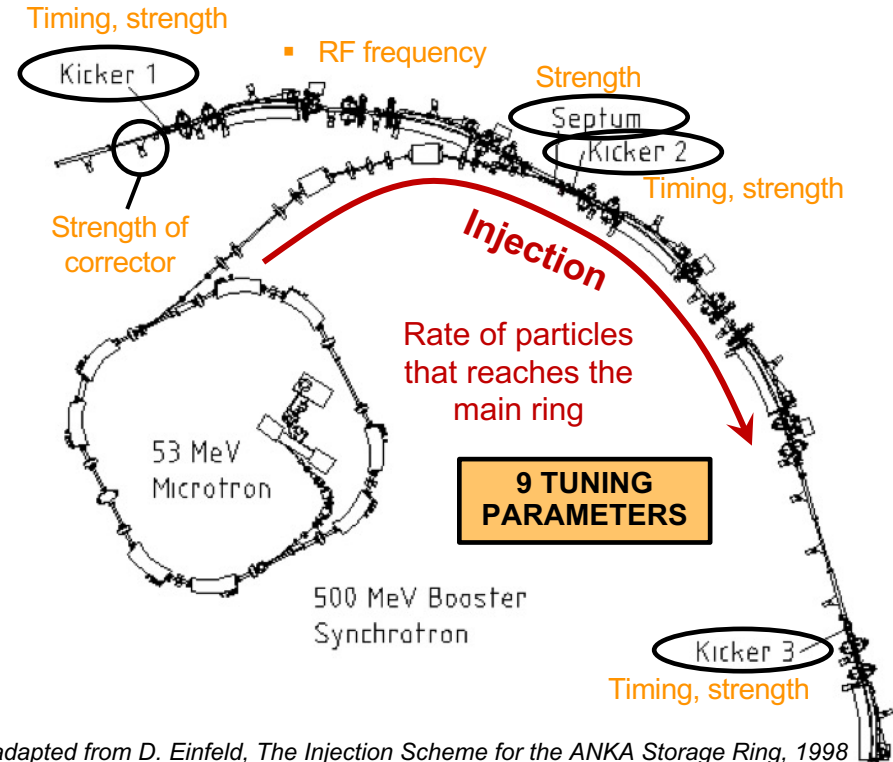







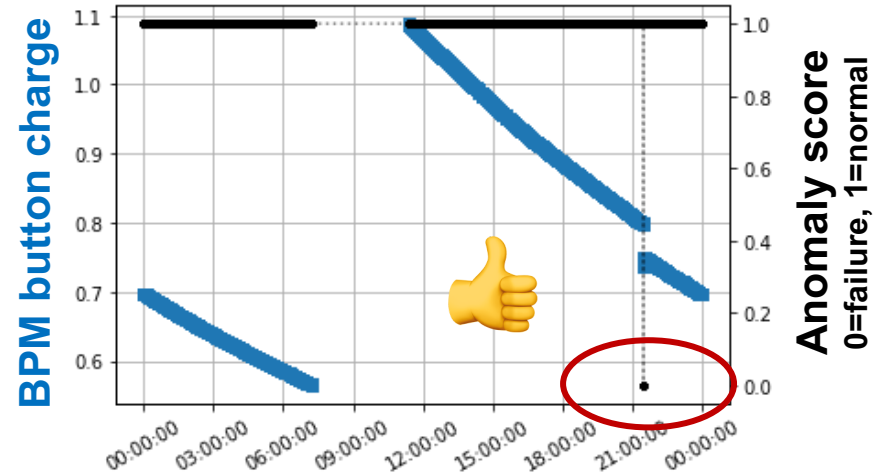
Figure adapted from D. Einfeld, *The Injection Scheme for the ANKA Storage Ring*, 1998

BPM anomaly detection with autoencoders

Niky Bruchon

BPM failures identified
Data collection and preparation
Preliminary feature selection
Proof-of-principle autoencoder for 1
BPM and 1 week of data

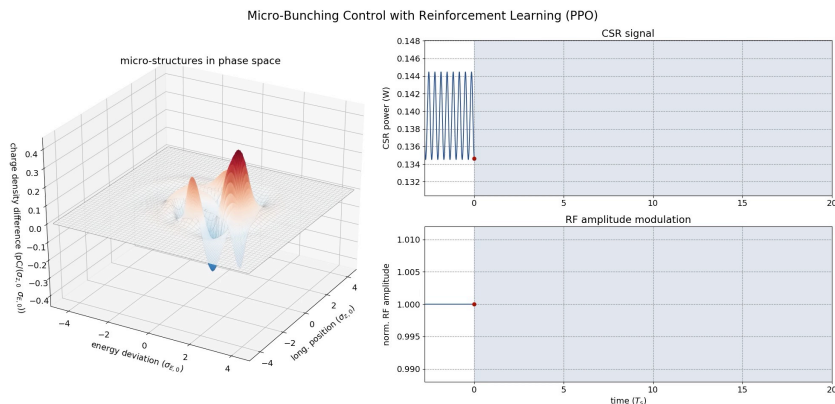
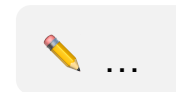
-  Train 1 autoencoder per BPM
-  Automatic feature selection
-  Adaptive autoencoder architecture
-  Build training database
-  Address explainability



Control of the micro-bunching instability with reinforcement learning

Tobias Boltz

Identification of effective method to influence microstructures
Excitation and mitigation of micro-bunching instability demonstrated in simulation
Excitation of the micro-bunching dynamics tested experimentally
Mitigation of instability with RL agents in 20 synchrotron periods in simulation
Charge distribution or CSR signal as observable, several agents
Implementation of DDPG agent in FPGA, time constraints for inference met






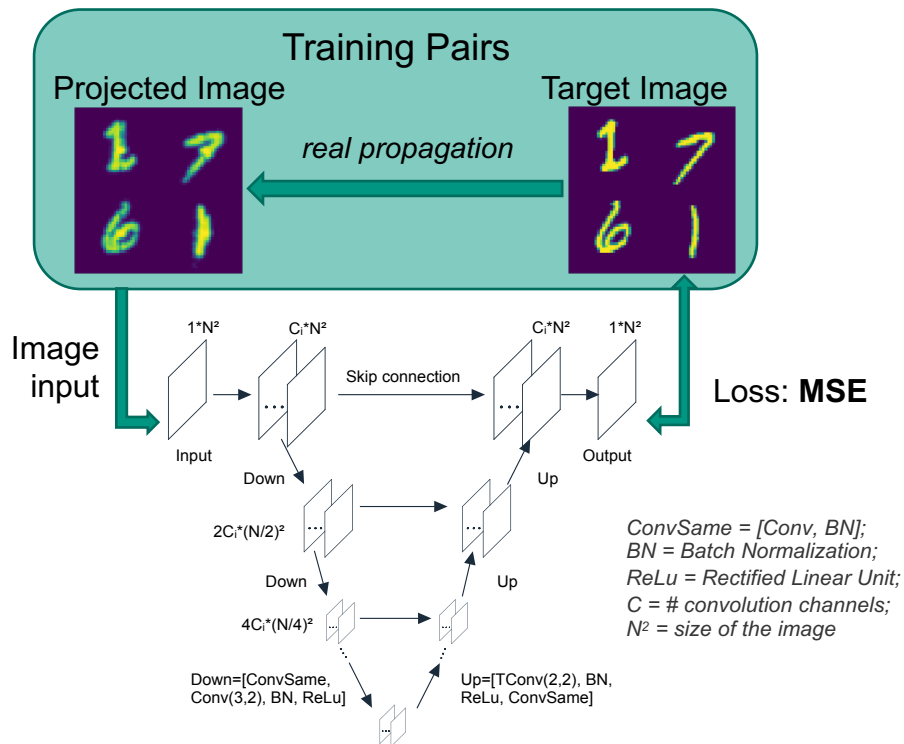
Stay tuned for the next talks on hardware!
Institute of Data Processing and Electronics (IPE)
Michele Caselle, Luca Scomparin

Laser pulse shaping with Spatial Light Modulators and convolutional neural networks

Chenran Xu

Transverse test set-up with 638 nm laser
CNN successfully applied to test setup

-  Finish setup with the 800 nm FLUTE laser
-  Generation of electrons with modulated laser
-  Test with CNN







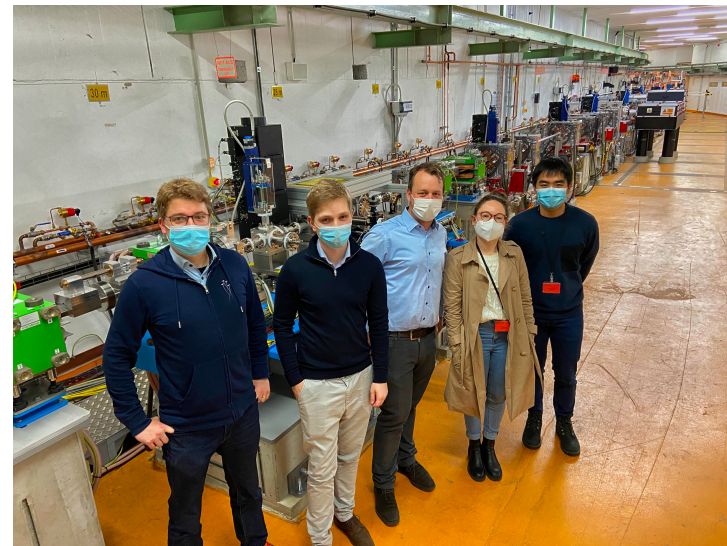
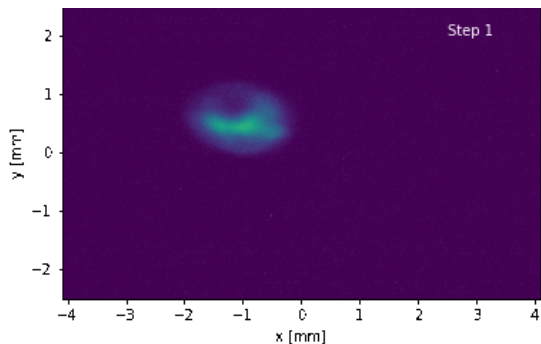
Beam control with reinforcement learning

Chenran Xu



Trained multiple RL agents on HPC-Cluster at KIT
Applied the agents at ARES

-  More training steps
-  More realistic environment conditions in training
-  Systematic evaluation of RL performance
-  Increase number of actuators and control tasks



ARES beamtime 12-10-2021 during the Autonomous Accelerator workshop

Happy holidays and until next year!

