Dr. Andrea Santamaria Garcia

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KIT — Karlsruhe Institute of Technology
IBPT — Institute for Beam Physics and Technology

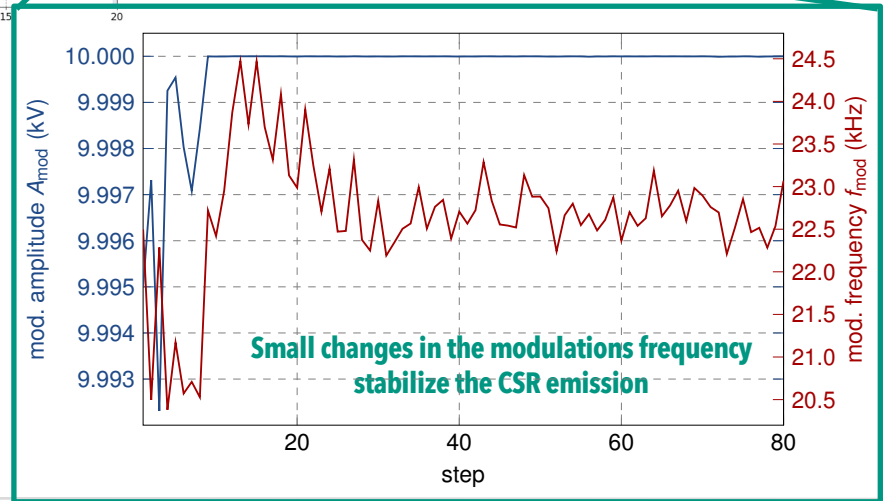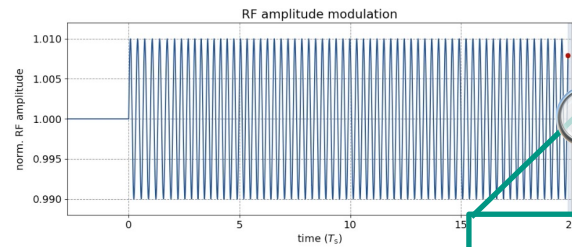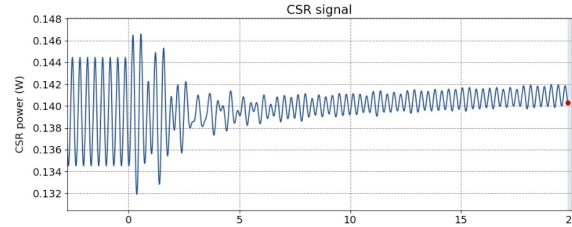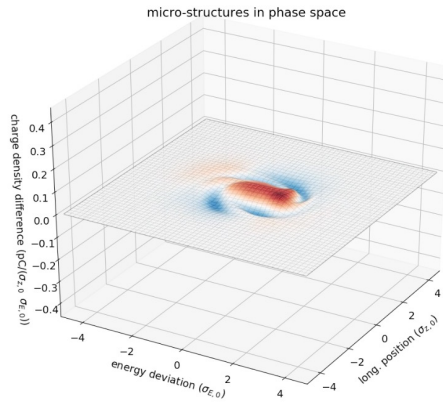|	
2014-2017	**Doctoral student (CERN, EPFL)**
	High luminosity LHC project
	Crab cavity failures
	Tracking simulations
2017-2019	**Fellow (CERN)**
	LHC Injectors Upgrade project
	PSB operation
2020-present	**Researcher (KIT)**
	Machine learning activities

Involvement in RL:

- Autonomous accelerator project with DESY (more info during tutorial)
  - ➤ Automatic steering and focusing of beam
- Control of the microbunching instability
  - ➤ Enhancement of coherent synchrotron radiation

I'm interested in:

- Advanced RL algorithms (safety, robustness, hierarchical, multi-agent, meta RL, mix with other algorithms)
- Simulation to real world
- Feature engineering / dimensionality reduction
- Non deep learning algorithms
- Continuous fast feedback with RL

Micro-Bunching Control with Reinforcement Learning (PPO)

micro-structures in phase space
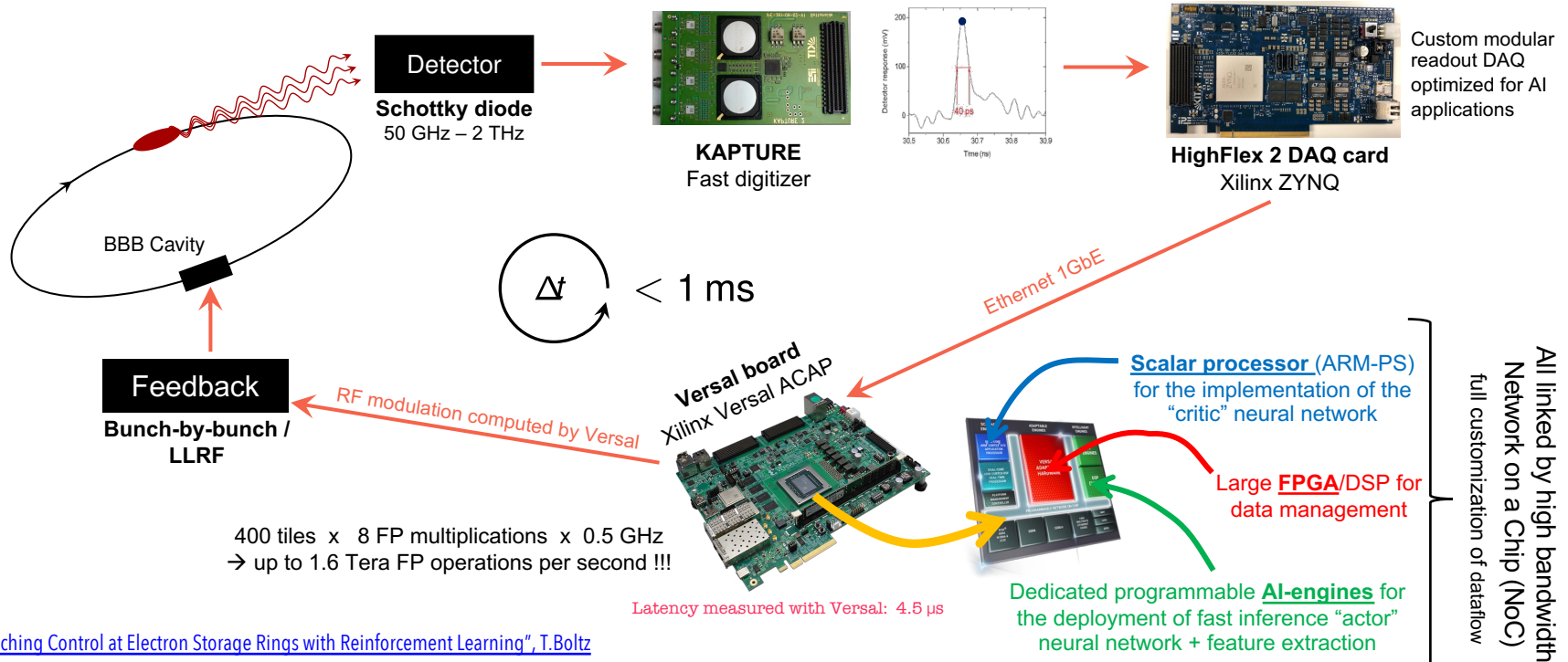
CSR signal

RF amplitude modulation

$$V_{RF} = \hat{V}(t) \sin(2\pi f_{RF} t)$$

$$\hat{V}(t) = \hat{V}_0 + A_{mod} \, \sin(2\pi f_{mod} + \varphi_{mod})$$

Small changes in the modulations frequency stabilize the CSR emission

IN PRACTICE: WE NEED HARDWARE!

Fast feedback for real-time optimization

BBB Cavity

Detector
Schottky diode
50 GHz – 2 THz

KAPTURE
Fast digitizer

Custom modular
readout DAQ
optimized for AI
applications

HighFlex 2 DAQ card
Xilinx ZYNQ

Δt < 1 ms

Feedback
**Bunch-by-bunch /
LLRF**

RF modulation computed by Versal

Ethernet 1GbE

Versal board
Xilinx Versal ACAP

Scalar processor (ARM-PS)
for the implementation of the
"critic" neural network

Large **FPGA**/DSP for
data management

Dedicated programmable **AI-engines** for
the deployment of fast inference "actor"
neural network + feature extraction

All linked by high bandwidth
Network on a Chip (NoC)
full customization of dataflow

400 tiles x 8 FP multiplications x 0.5 GHz
→ up to 1.6 Tera FP operations per second !!!

Latency measured with Versal: 4.5 µs

"Micro-Bunching Control at Electron Storage Rings with Reinforcement Learning", T.Boltz

"KINGFISHER: a framework for fast machine learning inference for autonomous accelerator systems", L. Scomparin

"Accelerated deep reinforcement learning for fast feedback of beam dynamics at KARA," W. Wang