Application of Machine Learning for Accelerators

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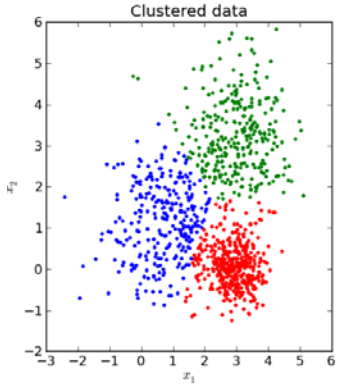
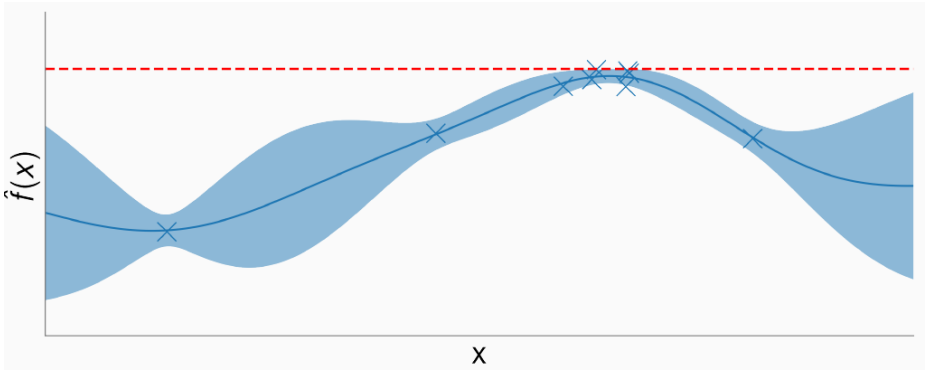
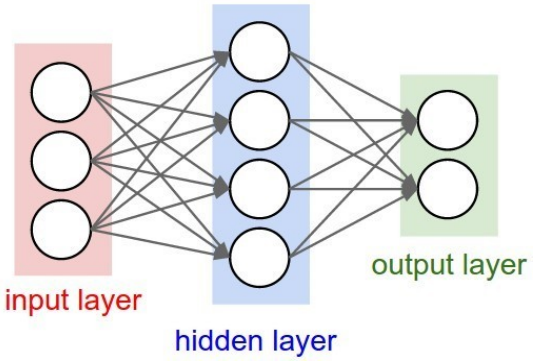


K-means



Gaussian Process



Neural Network

Challenges

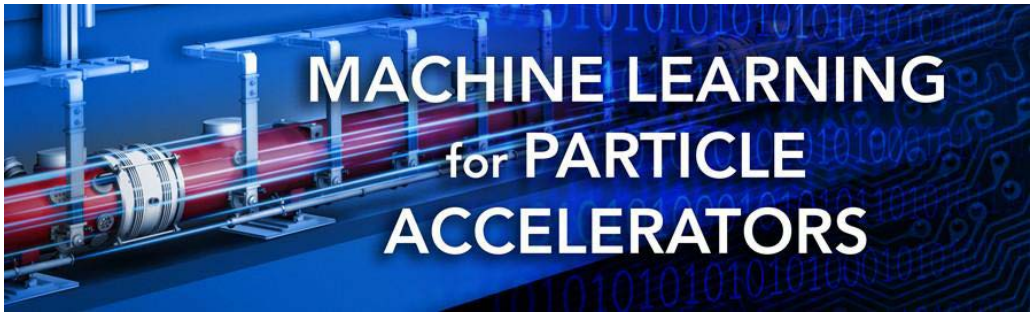
- Dynamic systems
  - many unknown/inaccessible parameters
  - status of the accelerators could change on daily basis
- Many components
- Non-linear beam physics
- Time consuming simulation runs
- High data output in the real accelerators
- Complex diagnostics data
  - important but invasive electron diagnostics
  - profiles and images not directly used

→ Application of Machine Learning techniques

Machine learning in accelerator community

- Though long history in high energy physics…
- … relatively fresh idea for accelerators!

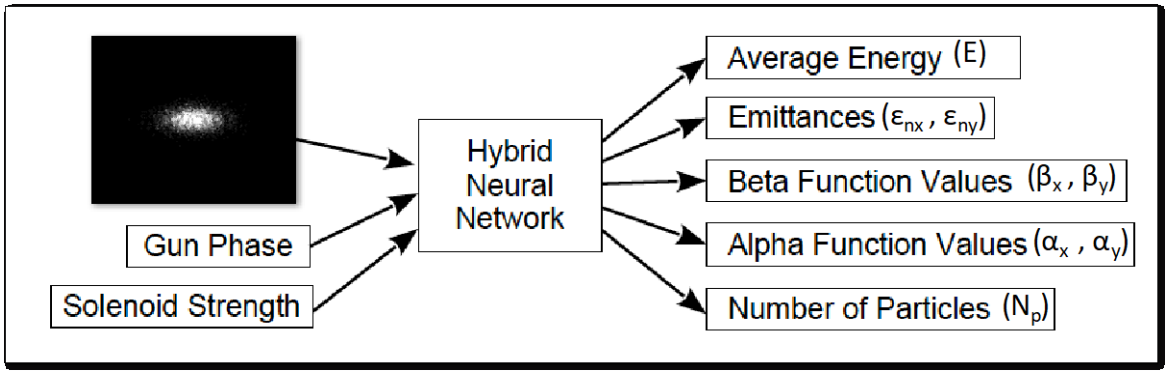
- ‘Machine Learning for Particle Accelerators’ workshop (27.2.2018 – 2.3.2018 at SLAC)



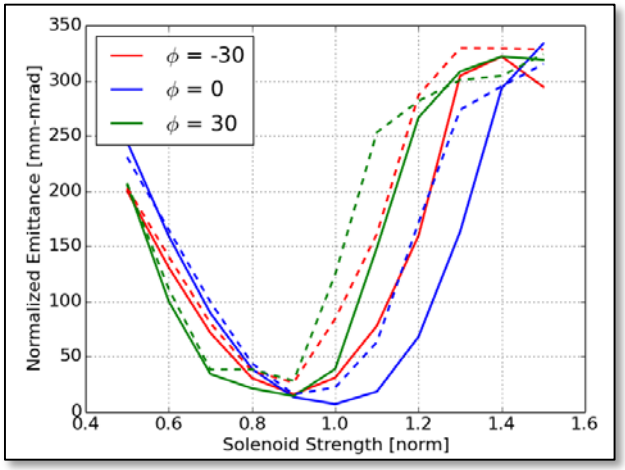
Potential application: prediction

- Example: Predict the normalized emittance
- Method: Neural network model trained on simulation data

training



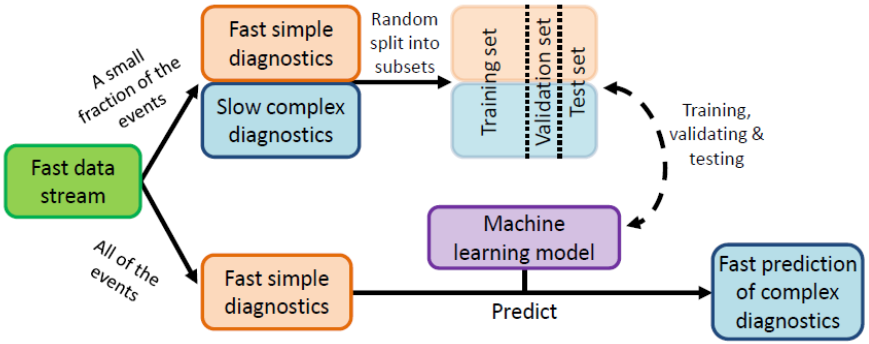
prediction

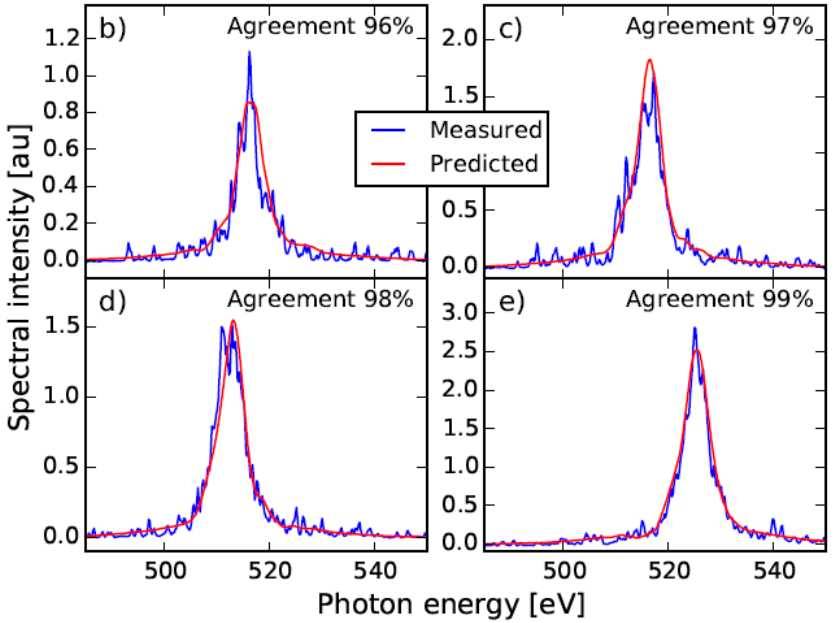


Courtesy: J. Edelen
(FAST, Fermilab)

Potential application: prediction

- Example: Predict the complex diagnostics and FEL pulse energy
- Method: Neural network trained on real machine data

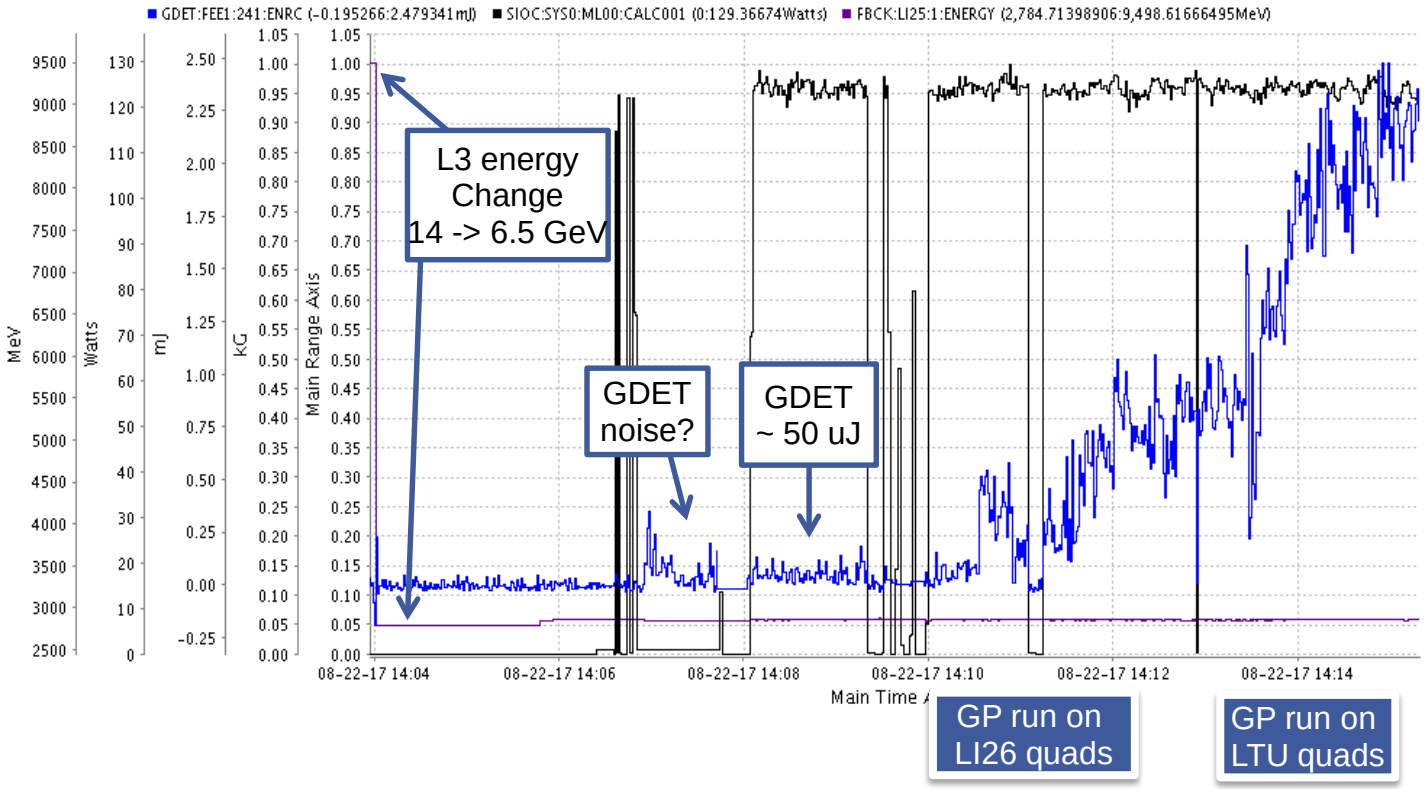




Courtesy: A. Sanchez-Gonzalez (LCLS & Imperial College)

Potential application: optimization

- Example: FEL tuning at LCLS
- Method: Bayesian optimization using Gaussian Process

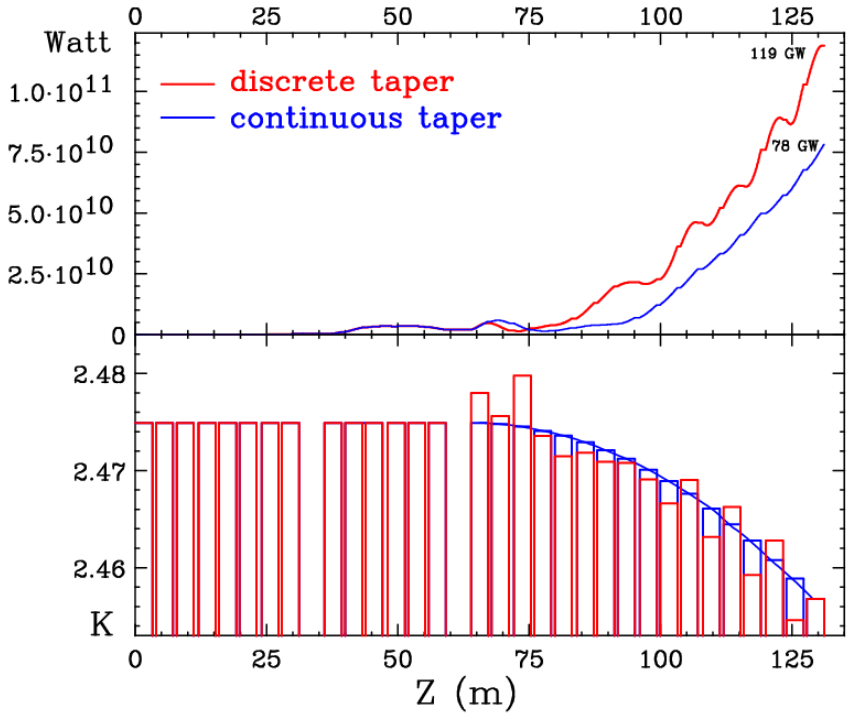


Courtesy: J. Duris (LCLS, SLAC)

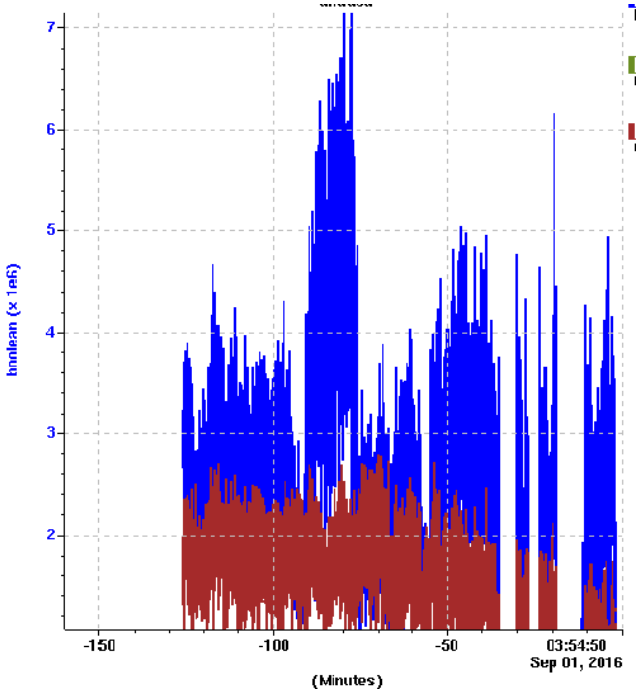
Potential application: optimization

- Example: FEL taper tuning at LCLS
- Method: Reinforcement learning and clustering

Zig-zag taper learned from S2E simulation



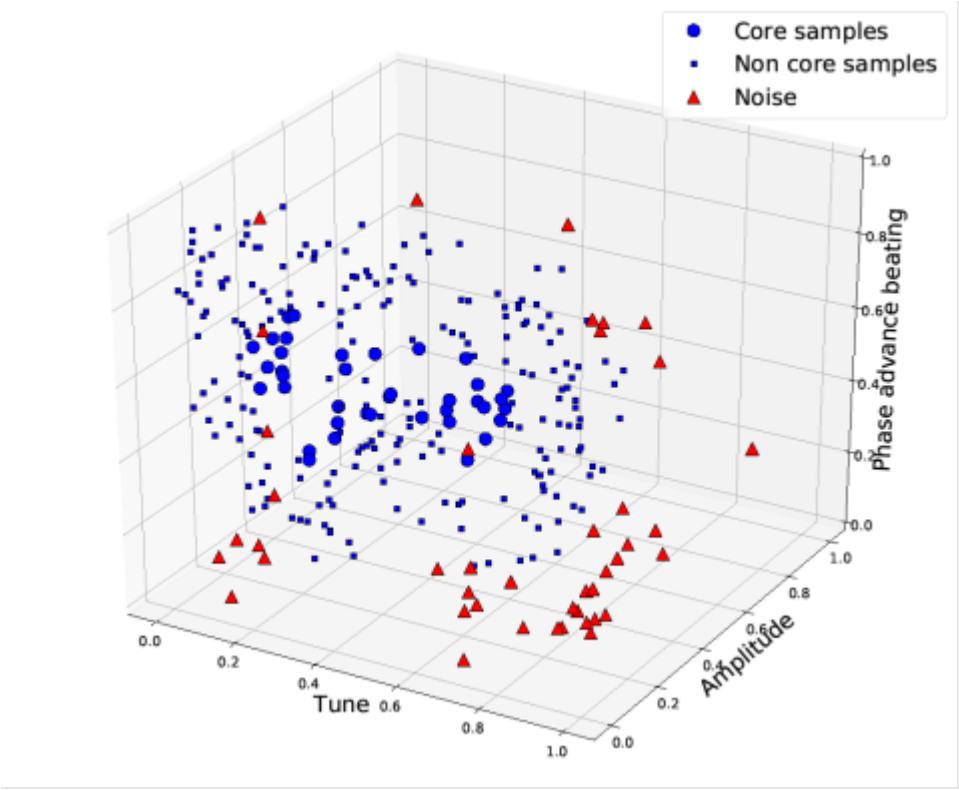
Applied onto real machine



Courtesy: J. Wu (LCLS, SLAC)

Potential application: prognosis

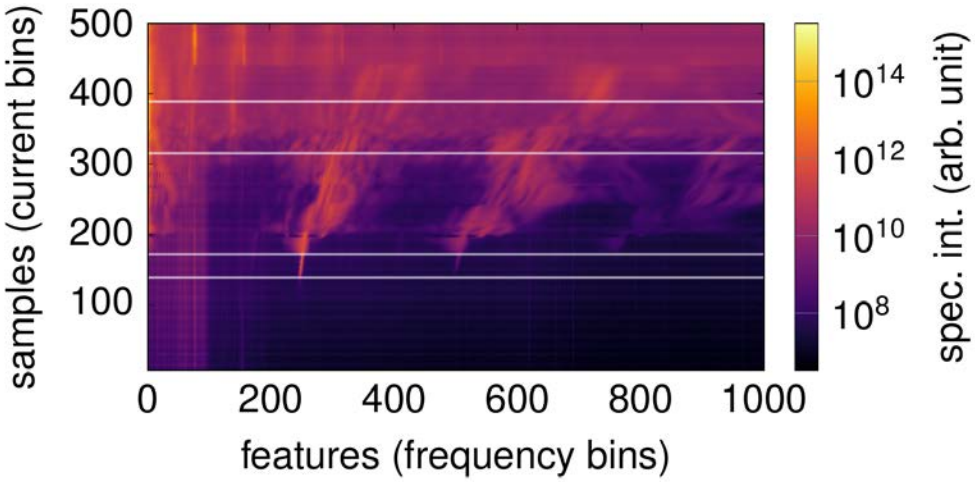
- Example: Detection of faulty BPM at LHC
- Method: Clustering on real machine data

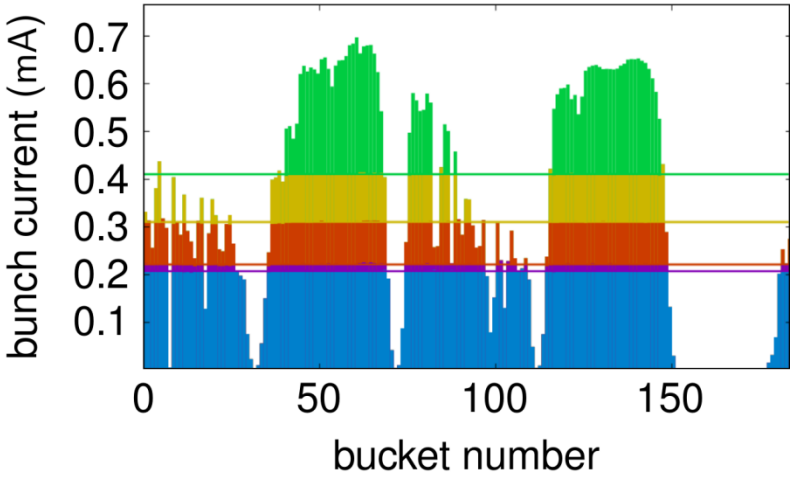


Courtesy: E. Fol (LHC, CERN)

Potential application: data analysis (Activities at KIT)

- Example: Automated identification of bursting regimes
- Method: Classification



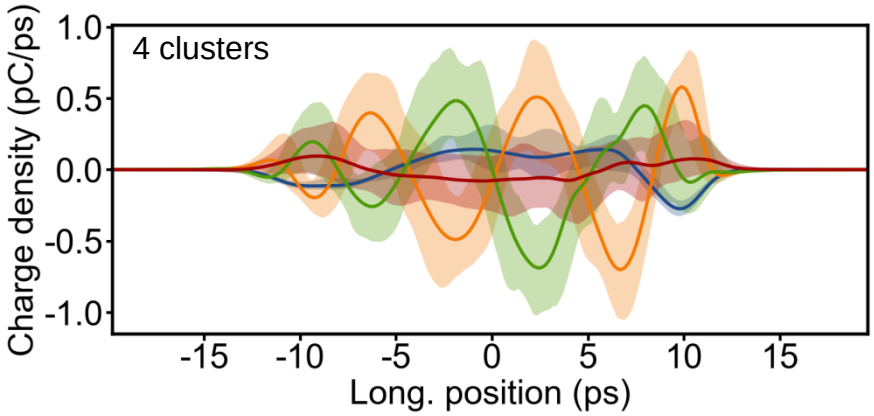


Courtesy: F. Raemisch (KARA, KIT)

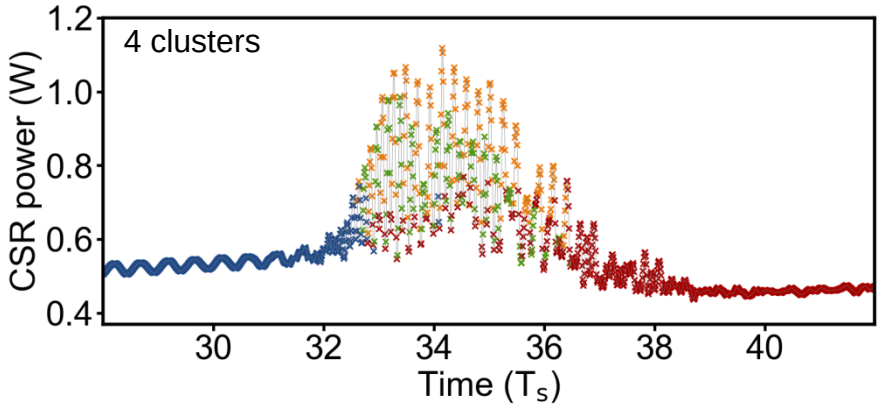
Potential application: data analysis (Activities at KIT)

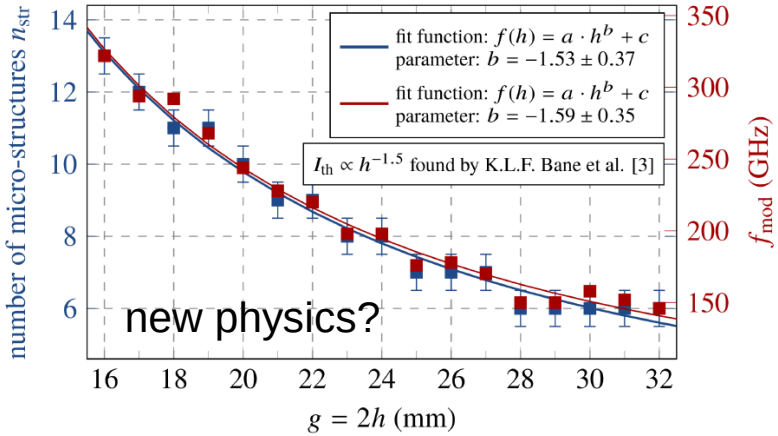
- Example: Extract micro-structures on the longitudinal profiles
- Method: Clustering

Simulation of 10000 longitudinal profiles



Correlation with the CSR power





Courtesy: T. Boltz (KARA, KIT)

Perspectives

- First applications showed clear benefits of Machine Learning for accelerators
- Many other applications of Machine Learning to be explored for accelerators
- Need expertise and advises from Machine Learning experts
- Collaborate with other communities?
  (e.g. computer science, robotics, autonomous driving communities)