Joint surrogate modelling and reconstruction of Laser-Wakefield Acceleration by invertible neural networks

F. Bethke, R. Pausch, P. Stiller, A. Debus, M. Bussmann, N. Hoffmann

HZDR HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF

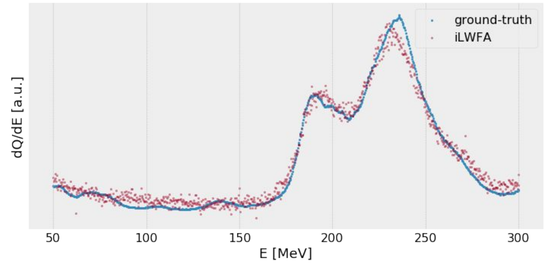
CASUS CENTER FOR ADVANCED SYSTEMS UNDERSTANDING

HELMHOLTZ AI | ARTIFICIAL INTELLIGENCE COOPERATION UNIT

Motivation

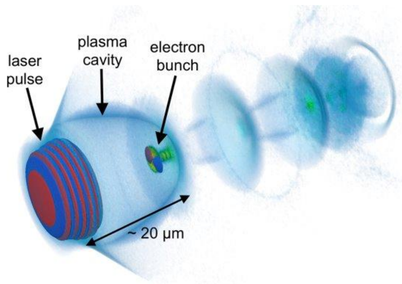
Surrogate model for computationally demanding Laser-Wakefield Acceleration

→ Reconstruction of experimental diagnostics requires fast approximation of non-linear mapping



Energy spectrum: generated

Simulation



Method

Invertible Neural Network

→ simulation and reconstruction done by same network

→ trained bi-directionally

→ resolves ambiguous inverse problems

→ uncertainty quantification for inverse pass

Results

Comprehensive study on 2.7 TB of training data generated by PIConGPU.

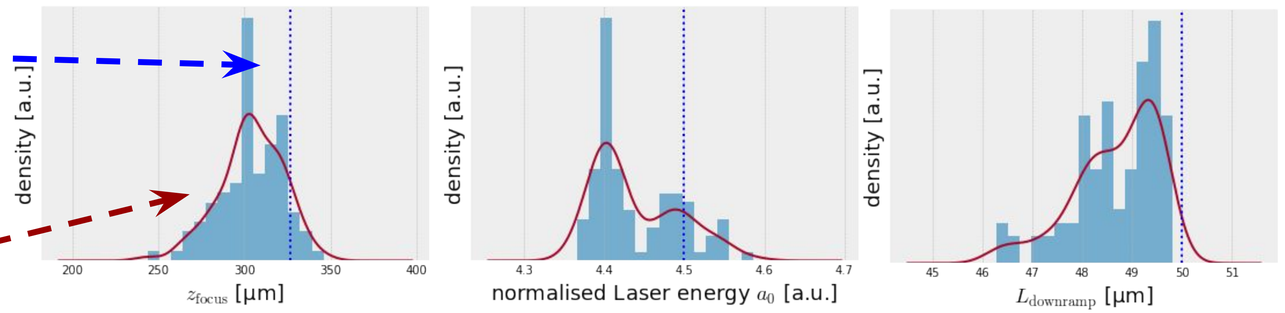
- inference time: 5 ms
- surrogate model: MSE < 0.007
- reconstruction: relative error < 8.2%

Network

Invertible Neural Network

Parameters: reconstructed

ground-truth

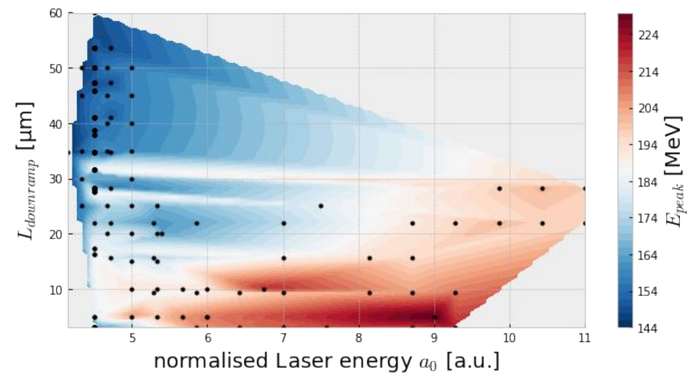


Posterior of INN
each mode = possible parameter configuration

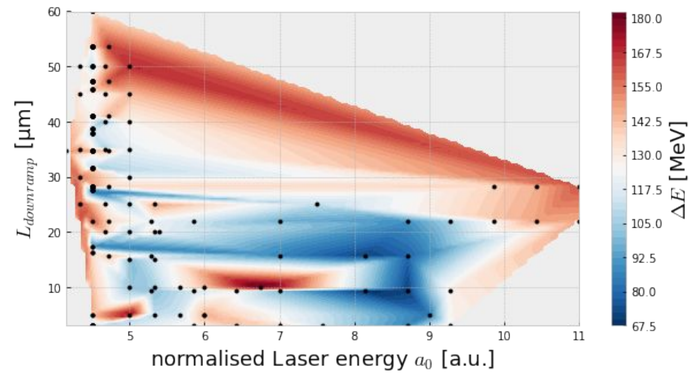
Application in Radiation Physics

Very fast **interpolation in derived moments** of energy spectrum.

1) Peak Energy



2) Full Width at Half Maximum



DRESDEN concept