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

**Motivation**
Surrogate model for computationally demanding Laser-Wakefield Acceleration
- Reconstruction of experimental diagnostics requires fast approximation of non-linear mapping

**Simulation**
- plasma cavity
- electron bunch
- 25 μm

**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%

**Application in Radiation Physics**
Very fast interpolation in derived moments of energy spectrum.

1) Peak Energy

![Peak Energy Diagram](image)

2) Full Width at Half Maximum

![Full Width at Half Maximum Diagram](image)

**Parameters: reconstructed**

**Posterior of INN**
each mode = possible parameter configuration

**Energy spectrum: generated**