High-fidelity Prediction of Megapixel Longitudinal Phase Space images at the European XFEL Photoinjector

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HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

DESY.

What is virtual diagnostic and why?

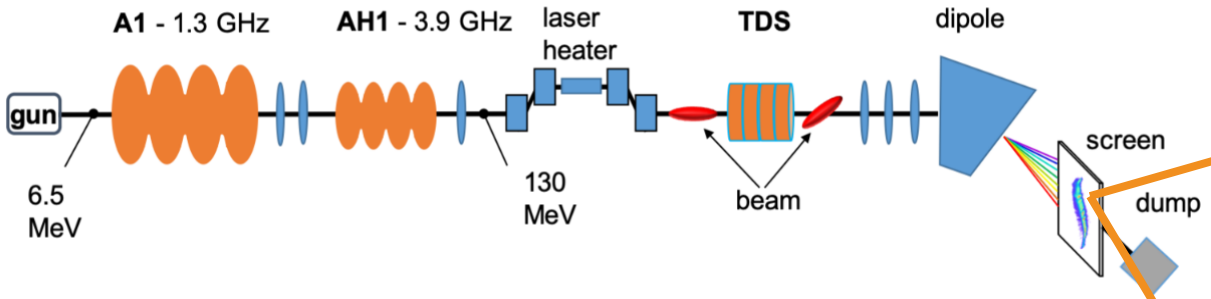
- Robotic systems

  Perception, Planning, Control

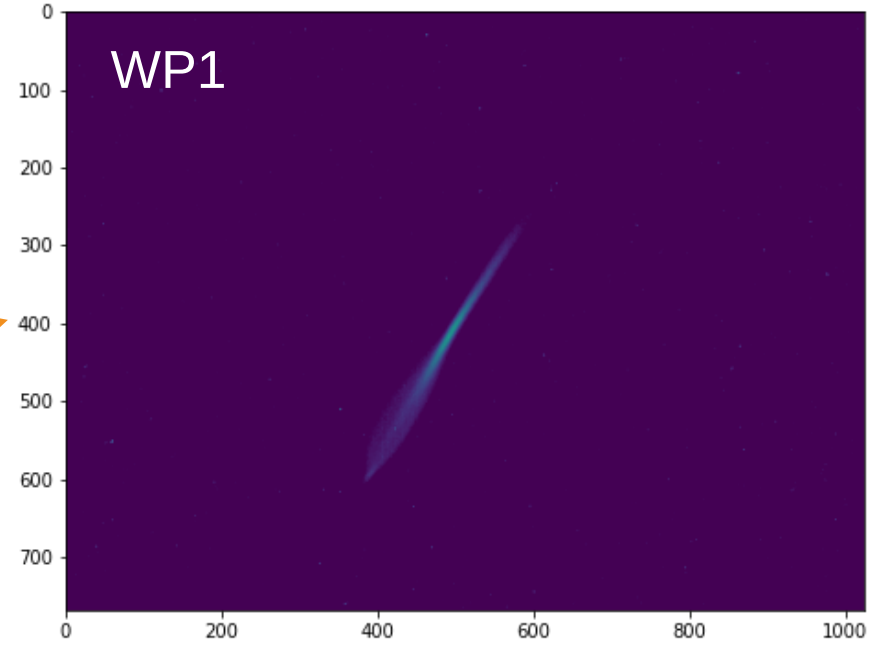
- Particle accelerators

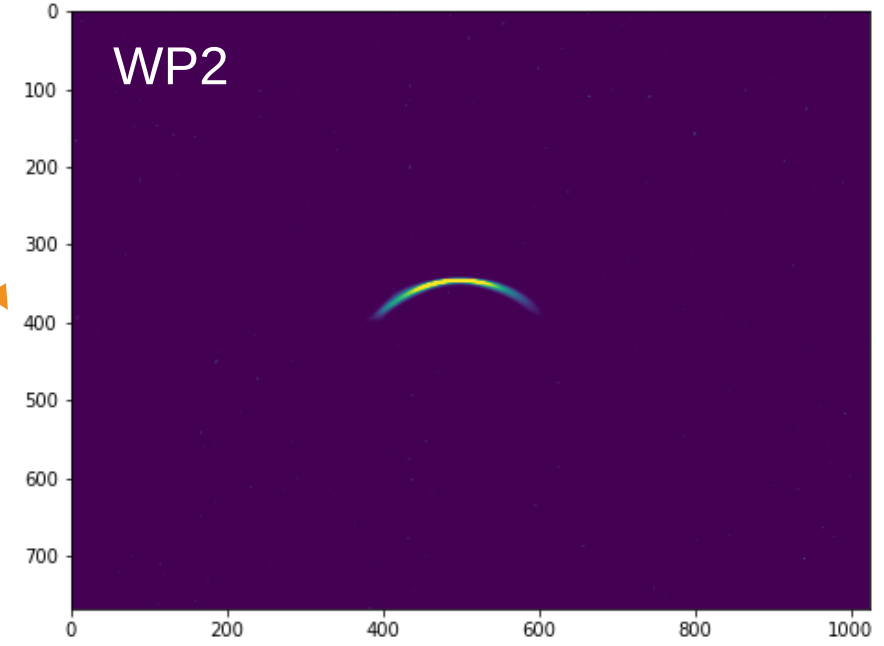
  - Operators (AI) decide the next step based on measurements
  - Many important beam diagnostics (e.g. image based) are destructive
  - **Bring destructive diagnostics online (virtually)**

A data-driven approach



	WP1	WP2
Gun phase (deg)	-3 ~ 3	-3 ~ 3
A1 phase (deg)	-6 ~ 6	-6 ~ 6
AH1 phase (deg)	-6 ~ 6	\
AH1 gradient	…	0



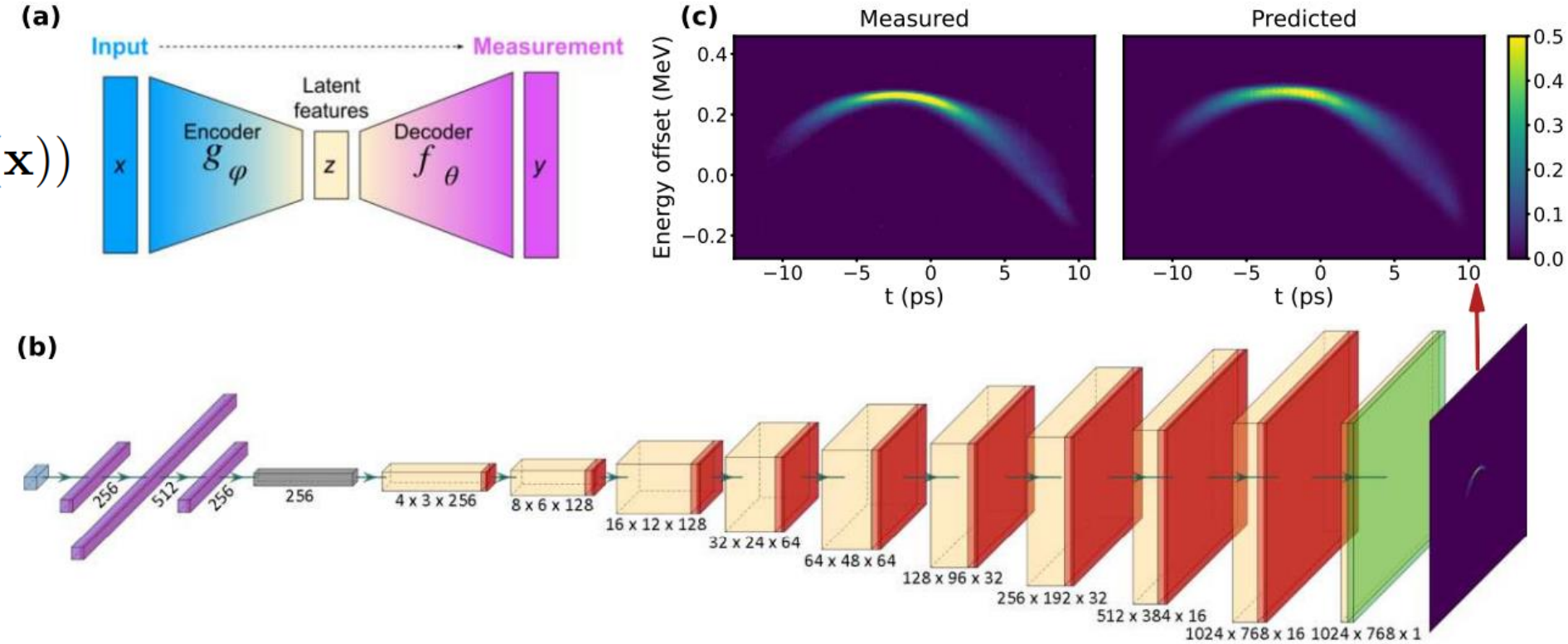


3000 shots for each working point

Encoder-decoder structure

- Demonstrate neural networks can generate an **explicit mapping** between the input and the output **megapixel** images in **a continuous space** with reasonable computational resources and data.

$$\min \ \mathcal{L}(\mathbf{y}, f_\theta(g_\varphi(\mathbf{x})))$$



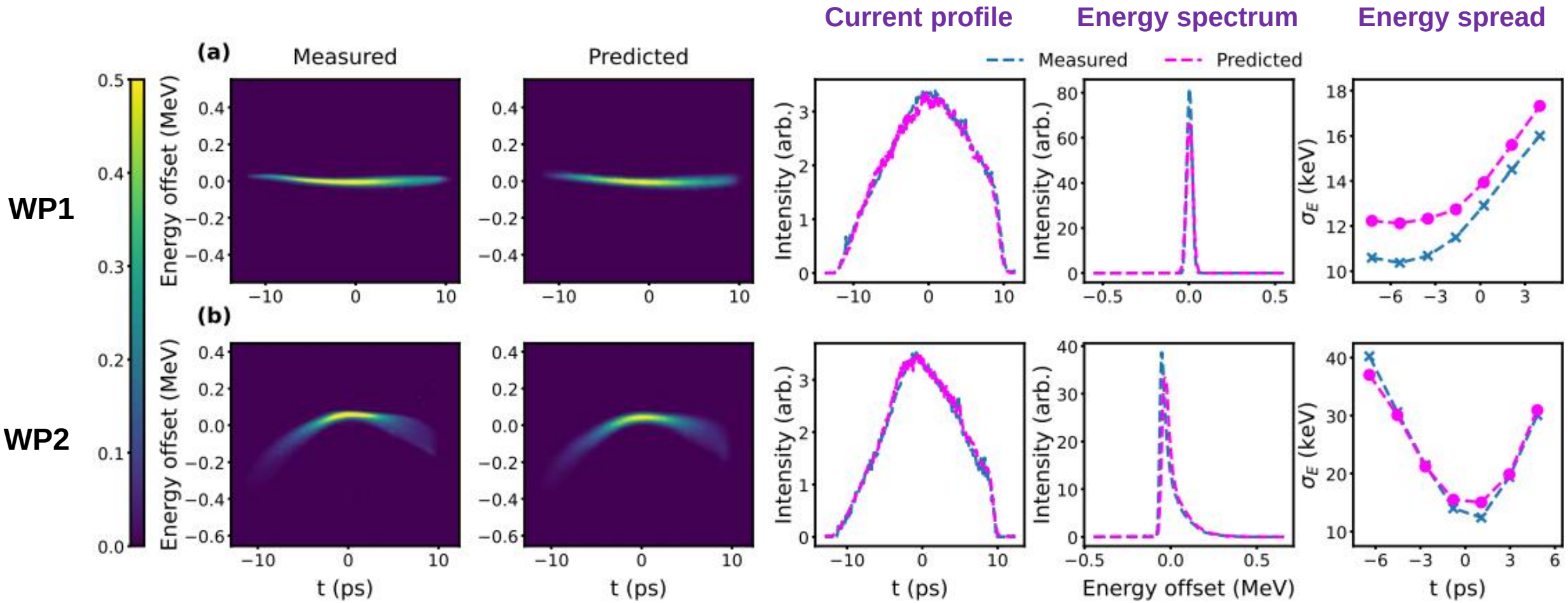
- Propose a way of building **scalable**, **interpretable** and **maintainable** applications.

J. Zhu, Y. Chen, F. Brinker, W. Decking, S. Tomin, H. Schlarb, Phys. Rev. Applied 16, 024005

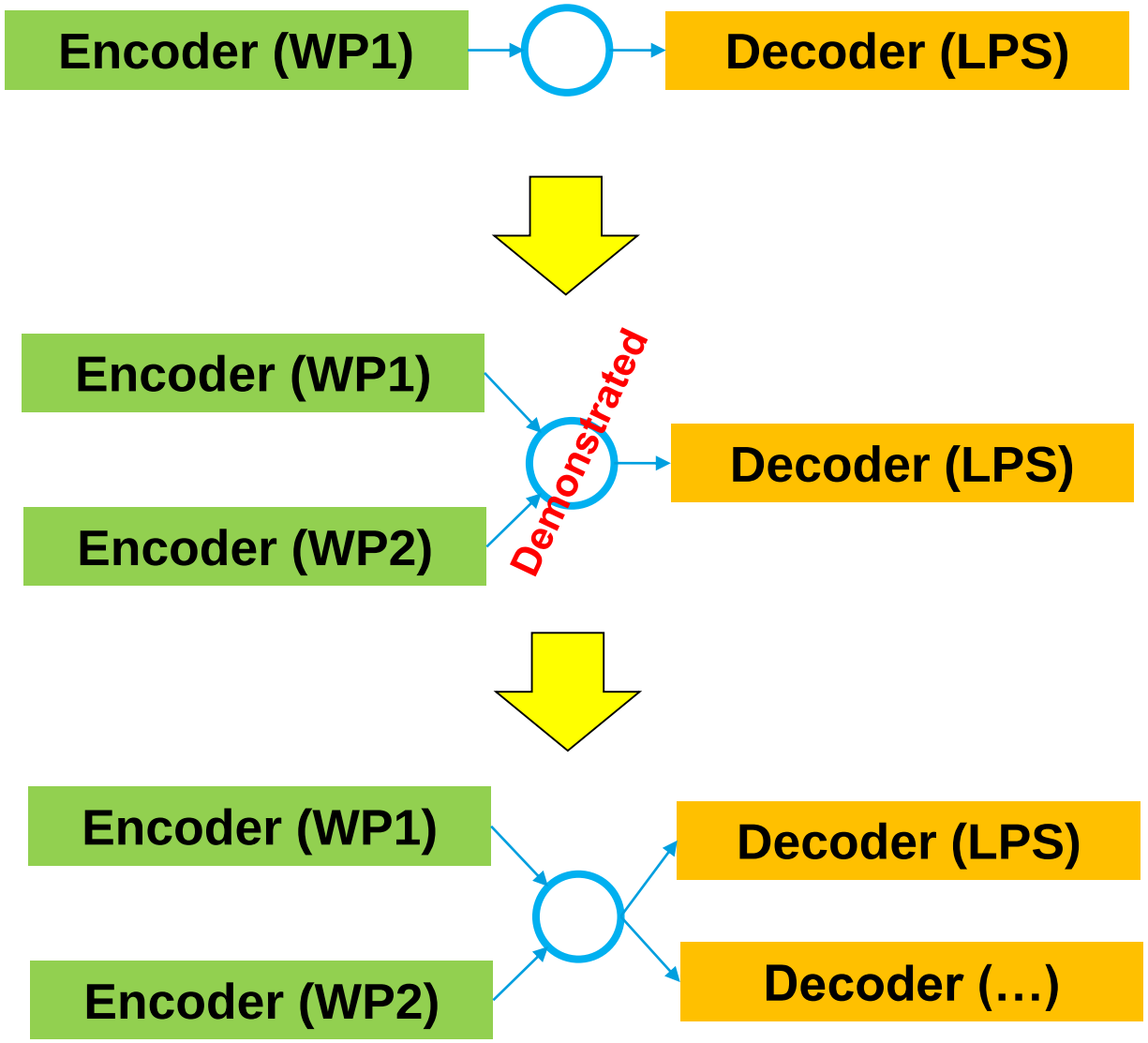
Prediction Quality

SSIM: ~0.995, MSE: ~3 x 10^{-5}

Major source of error: photocathode laser arrival time jitter



Scalability, Interpretability and Maintainability



- Reduce the input parameter space.
- **Time interval between data collections of different working points can be long.**
- Number and type of input data can change over time.
- Weights (information) sharing
- **Software engineering**

Code vs Code + data + weights

What's Next?

- More complicated longitudinal phase-space at the end of the linac
- Reproducibility
- More diagnostics
- Larger parameter space
- **This is a very generic model and approach which can in principle be applied to all the diagnostics.**