Tomographic Reconstruction of Visible Plasma Emission in the GOLEM Tokamak

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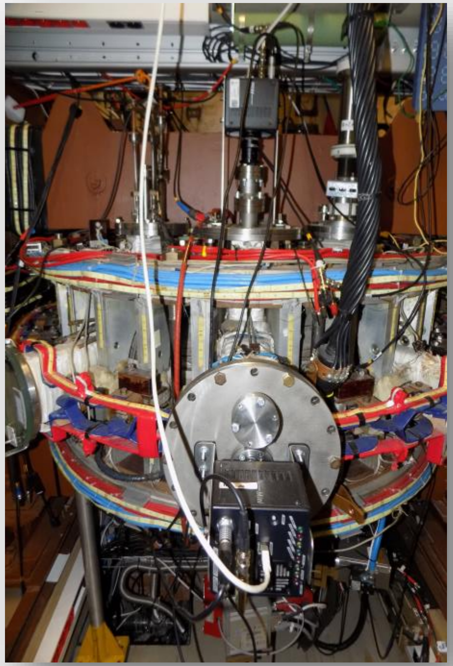
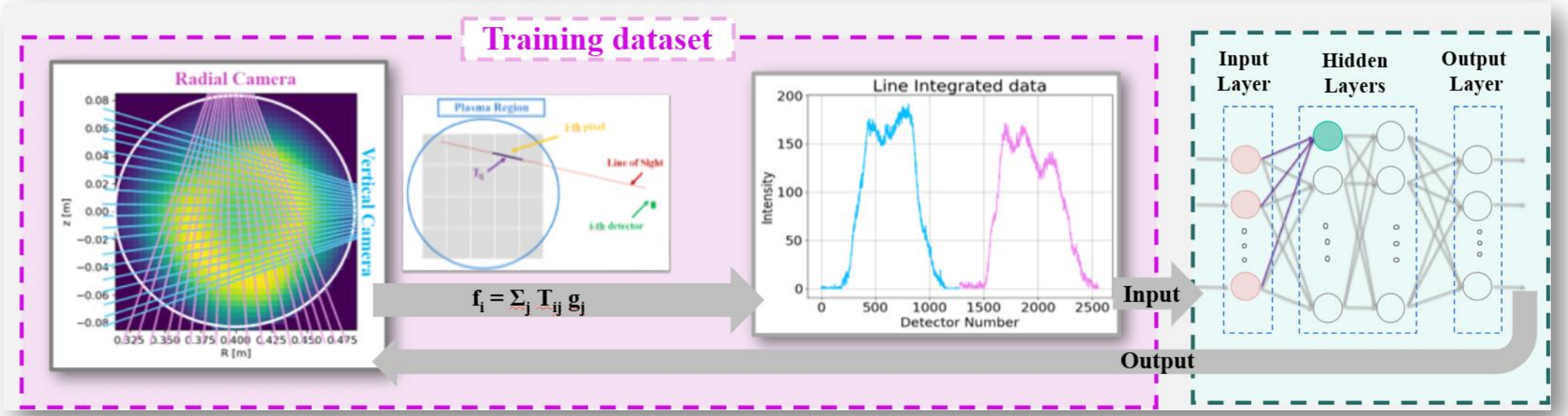
GOLEM Tokamak and Visible Cameras

Tokamak GOLEM located at:
Faculty of Nuclear Physics and Physical Engineering
(Czech Technical University in Prague).
Minor radius = 0.085 m
Major radius = 0.4 m
Discharge duration ~ 50 ms



Visible Camera Photron FASTCAM Mini UX 50
Maximum Frame Rate :160,000 fps (1280 × 8 pixels)
Pixel size = 10 μm × 10 μm
Frame Rate = 40,000 fps (1280 × 56 pixels)

ANN-based Tomography at GOLEM Tokamak



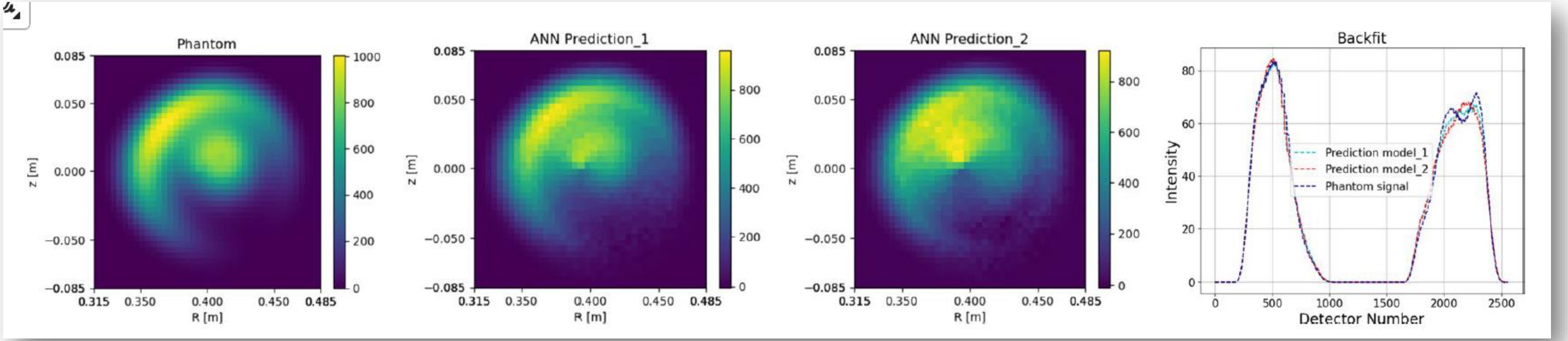
Training Dataset

The training dataset was constructed using 4000 emissivity phantoms of one poloidal cross-section of the GOLEM tokamak with associated line integrated data.

Training Process

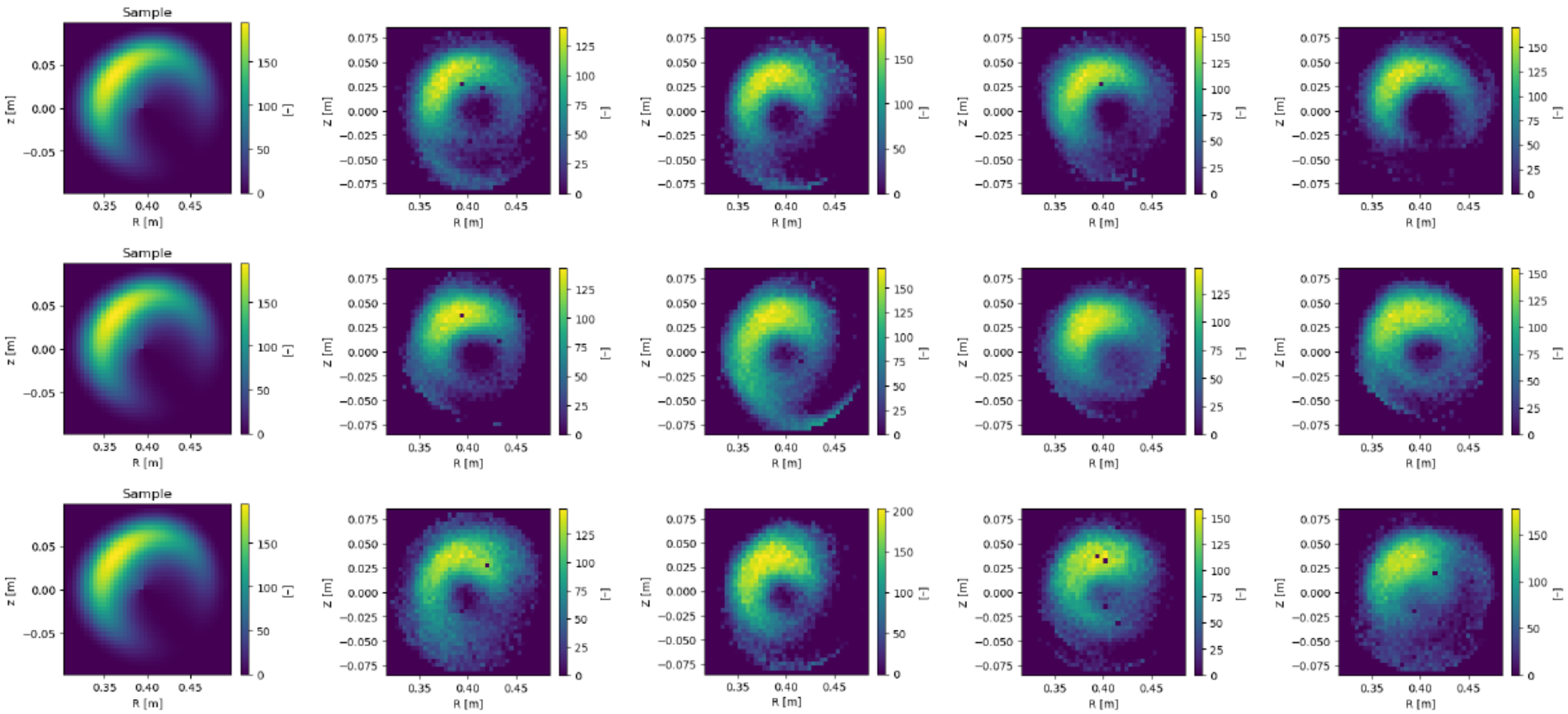
neural network: an input layer of 2560 neurons (input features number), two hidden layers, an output layer with 1600 neurons (output features number).

Prediction



From left to right: Phantom sample, the prediction of Model_1 , the prediction of Model_2 and the corresponding backfit of line integrated measurements, respectively.

Training dataset



Model performance is tested on varying **dataset sizes** and **quality changes** -adding noise, dropping pixel rows, and introducing random gaps- to simulate measurement uncertainties, reduced resolution, and missing data. As shown in Figure (left to right: original sample, prediction without distortion, then with noise, drop-pixel, and gaps; top to bottom: training datasets of 11,000, 5,000, and 2,000 samples), model accuracy depends on dataset completeness and quality.

Training Model

1. Fully Connected MLP

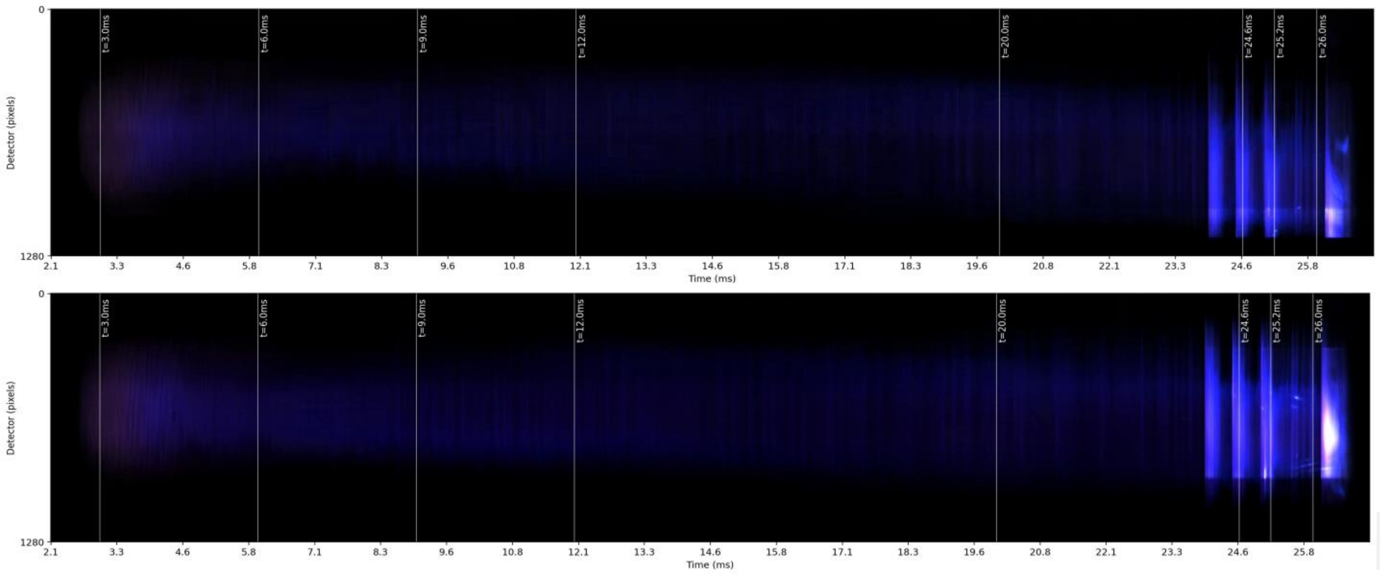
No spatial structure
Many parameters
Learns slowly
Sensitive to noise and unrealistic shapes

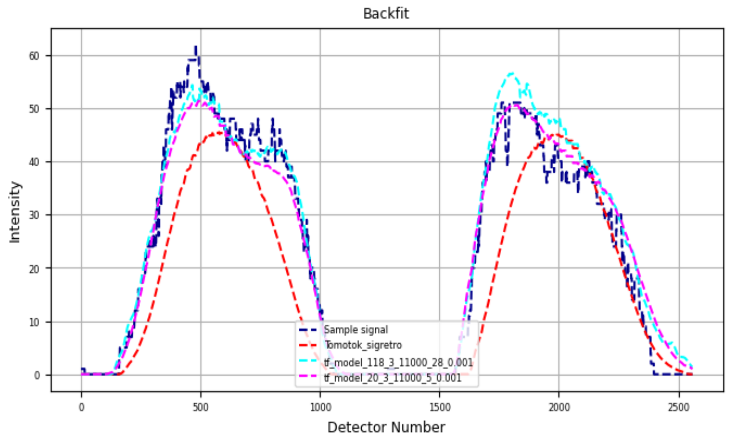
2. Convolutional Neural Network (CNN)

Preserves spatial locality
Fewer parameters
Learns edges, rings
Much faster convergence

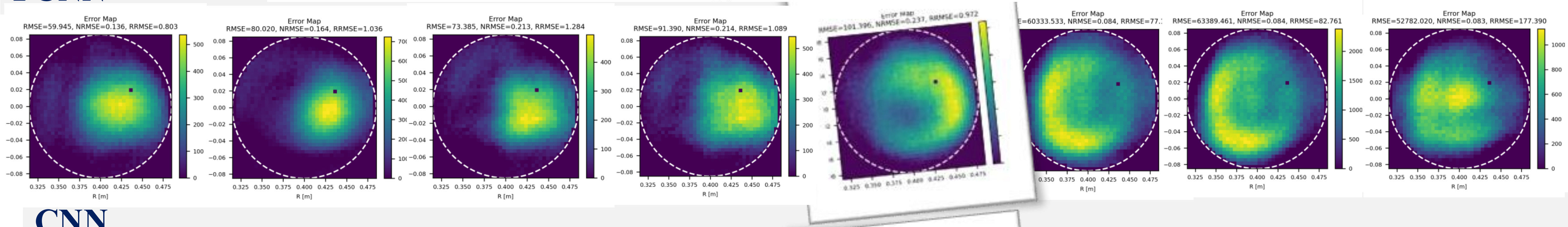
Reconstruction

shot # 49841

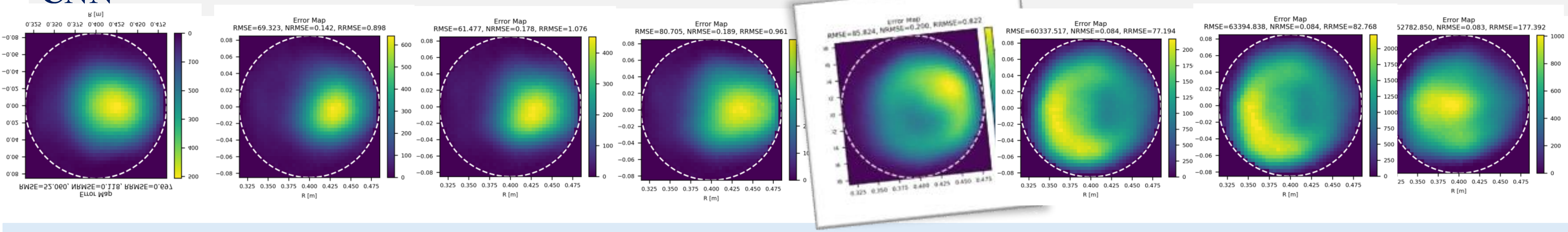




FCNN



CNN



Key Limitation of Both Models

Neither MLP nor CNN can reconstruct plasma position & radius perfectly, because:

- The inverse problem from LOS signals alone is **underdetermined**
- Multiple emissivity distributions can result in **similar LOS signals**
- LOS projections cannot fully resolve:
  - vertical displacement
  - horizontal displacement
  - plasma radius
  - shape elongation

- **These are ill-posed inverse problems using only LOS signals.**
- **Therefore: extra diagnostic information is needed.**

Conclusion

- Previous ANN (MLP) works for synthetic samples but lacks spatial awareness
- CNN provides more accurate and stable tomographic reconstructions
- Both models suffer from ambiguity if LOS signals are the only input
- Future work:
- Integrate physics information and other diagnostics
- Validate on real GOLEM discharge

1. Jan Mlynar et al., In: Fusion Science and Technology 58.3 (2010), pp. 733–741.
2. Sara Abbasi et al., Fusion Engineering and Design 193, 113647 (2023)
3. A. Jardin, J. Bielecki, D. Mazon, J. Dankowski, K. Król, Y. Peysson, M. Scholz, Neural networks: from image recognition to tokamak plasma tomography. Laser Part. Beams 37(2), 171–175(2019)

Thanks For Your Attention

VOLDA, Madrid, November 2025