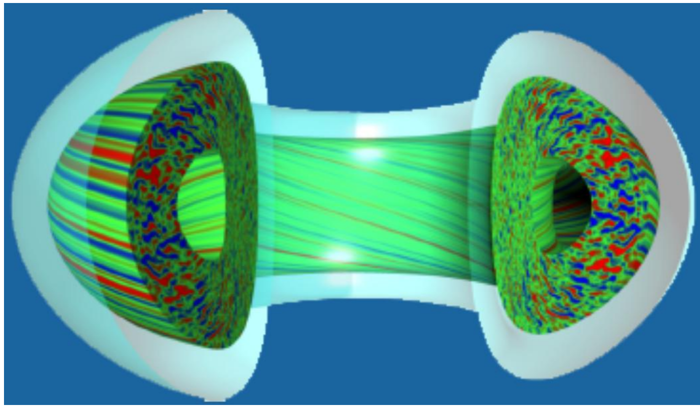

4th IAEA Technical Meeting on Fusion Data Processing, Validation and Analysis

Researches on the reconstruction algorithm of electron density profiles based on machine learning techniques

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Motivation

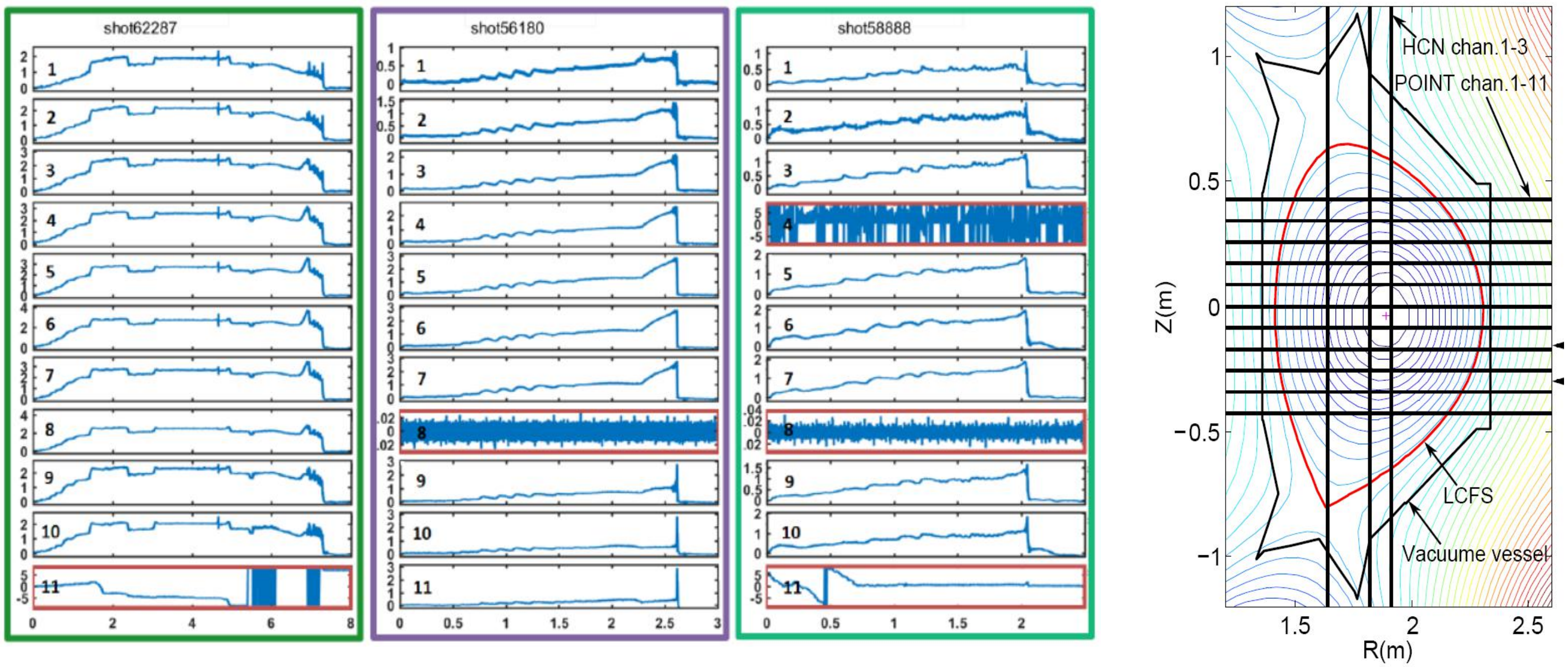
- **Obtaining accurate density profiles, which are reconstructed from the line integral data measured by the interferometer, is important to the reliable feedback control of density and the stable long-pulse operation of fusion devices.**

- **Unreliable data, which are caused by electromagnetic interference, mechanical vibration, or hardware failures, would greatly influence the density profile reconstruction.**

- **In this report, I will introduce a new profile reconstruction algorithm based on machine learning techniques, in which accurate density profiles are calculated without the influence of incorrect data. This algorithm has application value in on-line data analysis of fusion devices.**

Problems to be solved

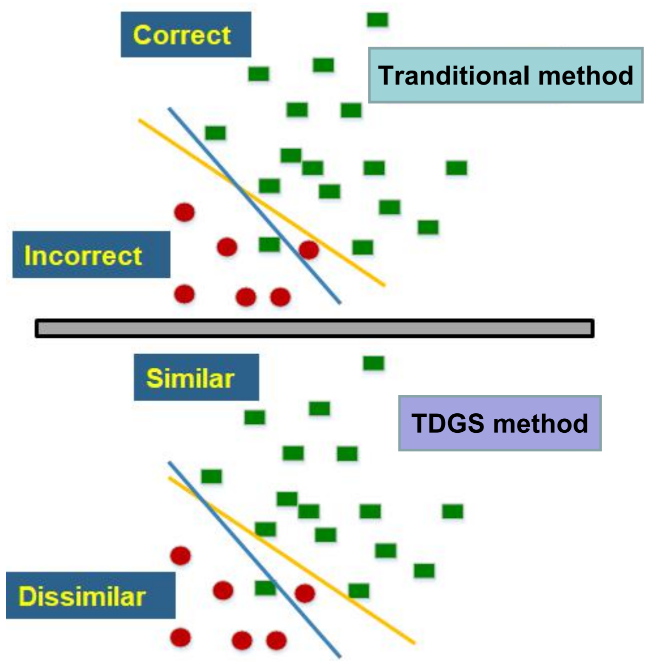
- How to recognize the incorrect data in on-line data analysis?
- After identifying and removing incorrect data, how to get the globally optimal solution using the rest correct data?



Advantages of using machine learning

- **To meet the requirements in fusion data processing, we have done many works based on machine learning techniques, including data cleaning, pattern recognition, noise reduction, and data classification.**

- **On the basis of previous works, we would solve these problems using machine learning techniques.**



Challenges for fusion data processing:

- General and clear criteria;
- Massive data and high-speed data flow;
- Real-time processing requirements;

The advantages of using machine learning:

- High-efficiency;
- Real-time speed;
- Reliability.

Method

- **Part 1: Identify and sort correct and incorrect interferometric data in millisecond. (Accuracy over 89% in 10 milliseconds.)**
- **Part 2: After sorting out the incorrect data, electron density profiles are reconstructed using the rest correct interferometric data.**
- **This report focuses on part 2.**
- **Algorithms to use:**
  - **Convolutional Neural Network**
- **Data to use:**
  - **Simulated interferometric data of POINT and HCN systems in EAST tokamak**

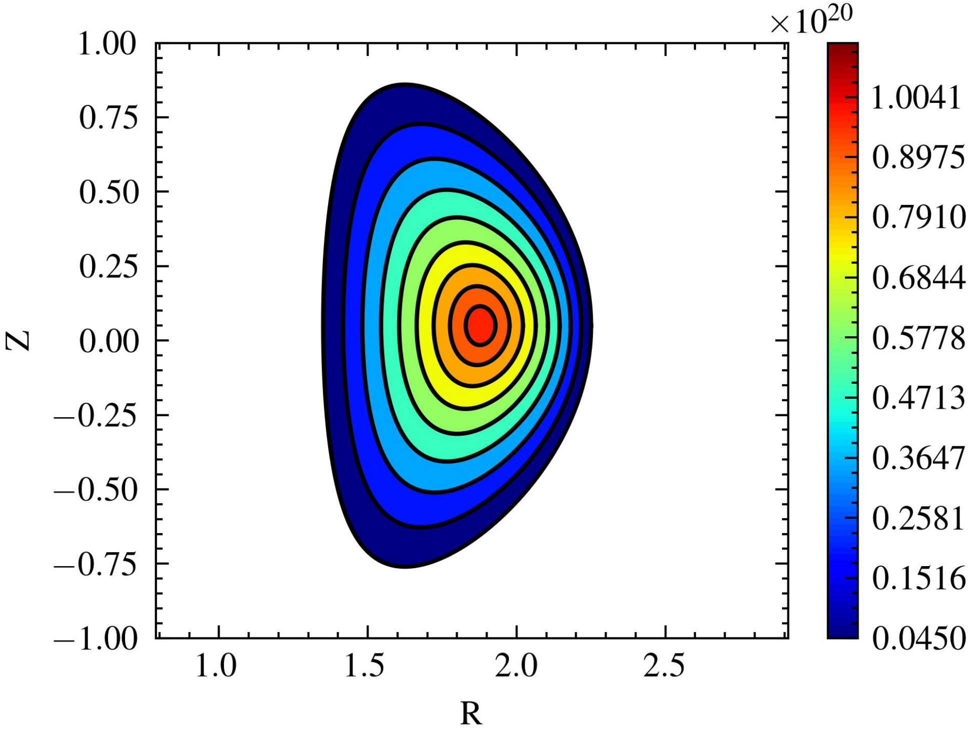
Distribution of plasma parameters

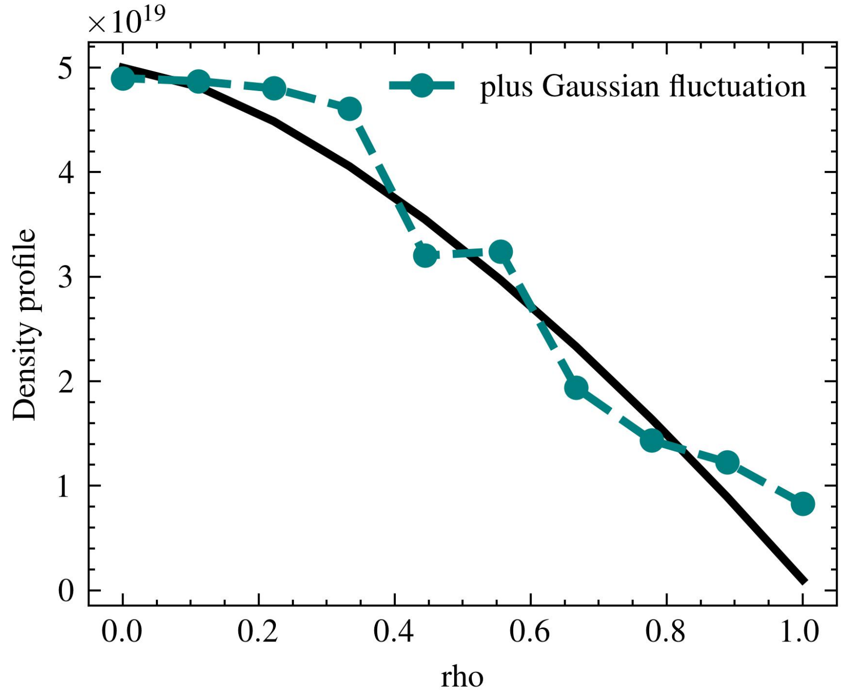
$R(r,\theta) = R_0(r) + r\cos(\theta + \arcsin\delta(r)\sin\theta),$

$Z(r,\theta) = Z_0(r) + ki(r) r\sin(\theta),$

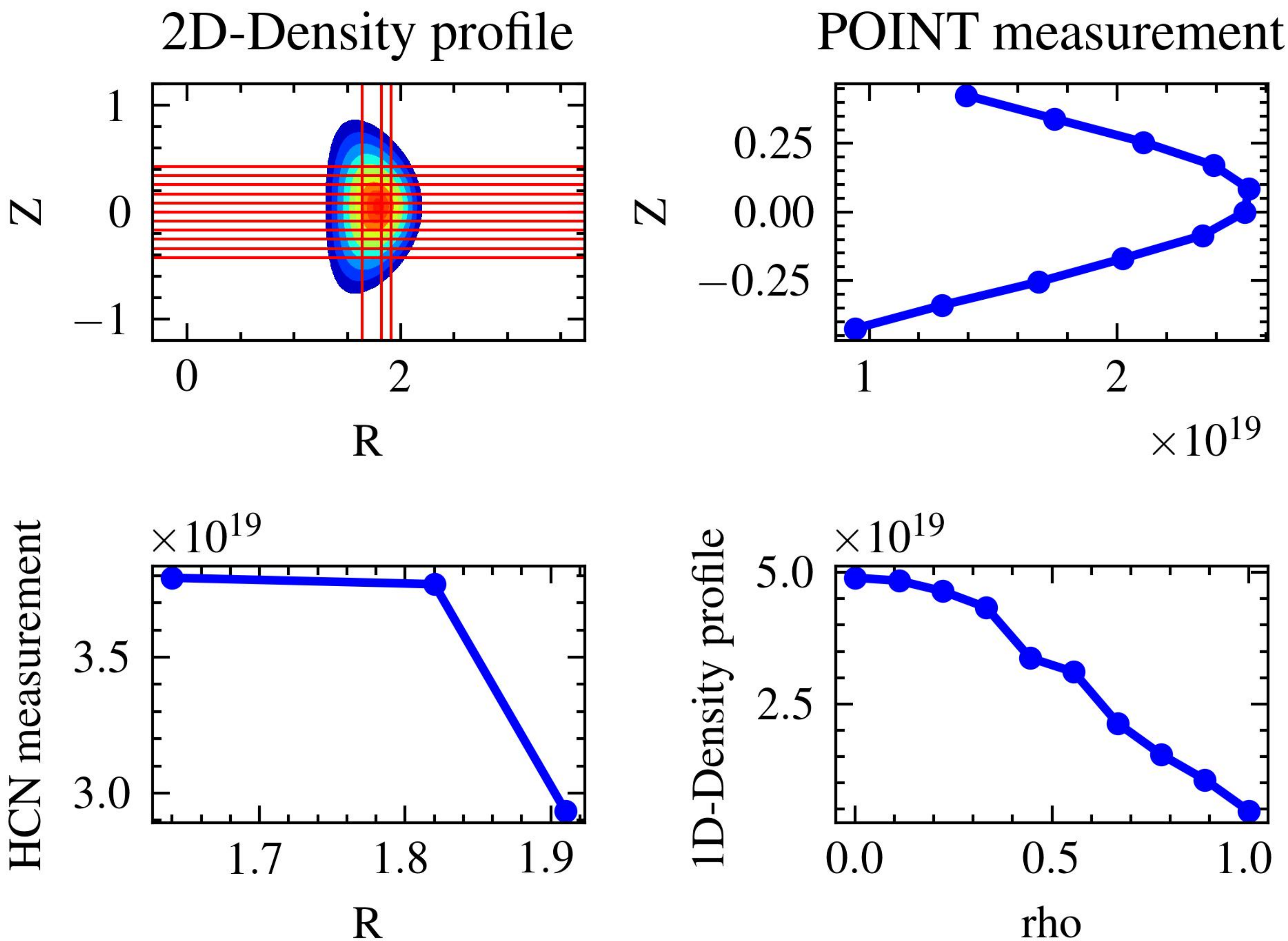
$n(r), \delta(r), ki(r), R_0(r) \sim C1(r/a)^P + C2,$

$R_0(r),\ Z_0(r),$ **fluctuation~ random variable**



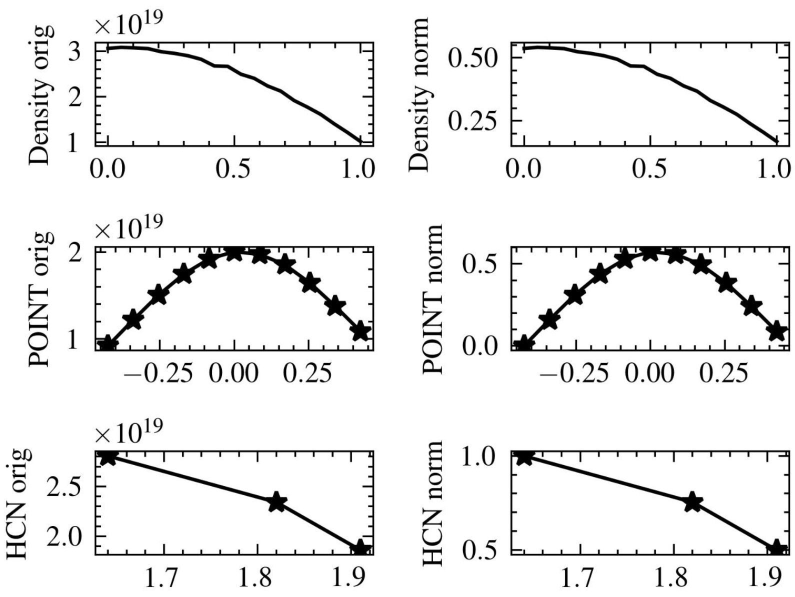


Simulated interferometric data of POINT and HCN systems in EAST tokamak

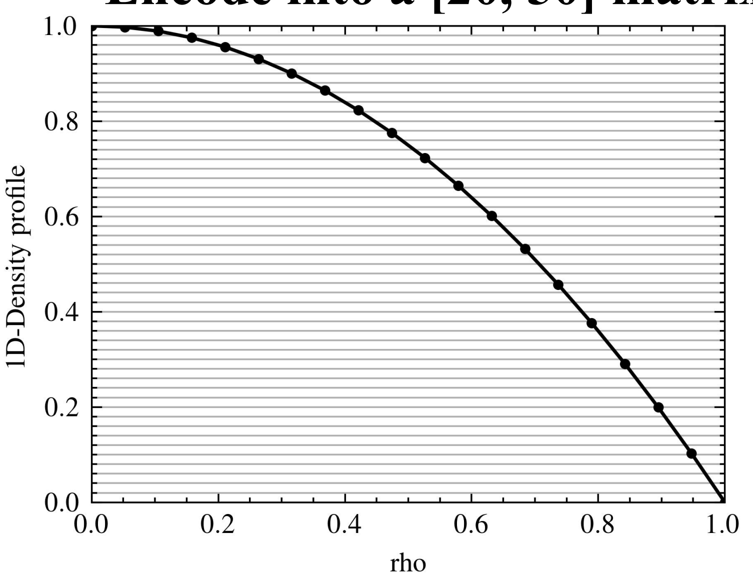


Data set construction

- Input: X_n, n=0,1,..,13. 11 from POINT, 3 from HCN. Output: 1D-density profile.
- Min-Max Scaling: $X_{norm} = \frac{X - X_{min}}{X_{max} - X_{min}}$
- Scaling range for input: [min[X_n], max[X_n]].
- Scaling range for output: [0.1*min[X_n], 2*max[X_n]].
- Label method: 20 magnetic surface; [0, 1] is divided into 50 classes.



Encode into a [20, 50] matrix



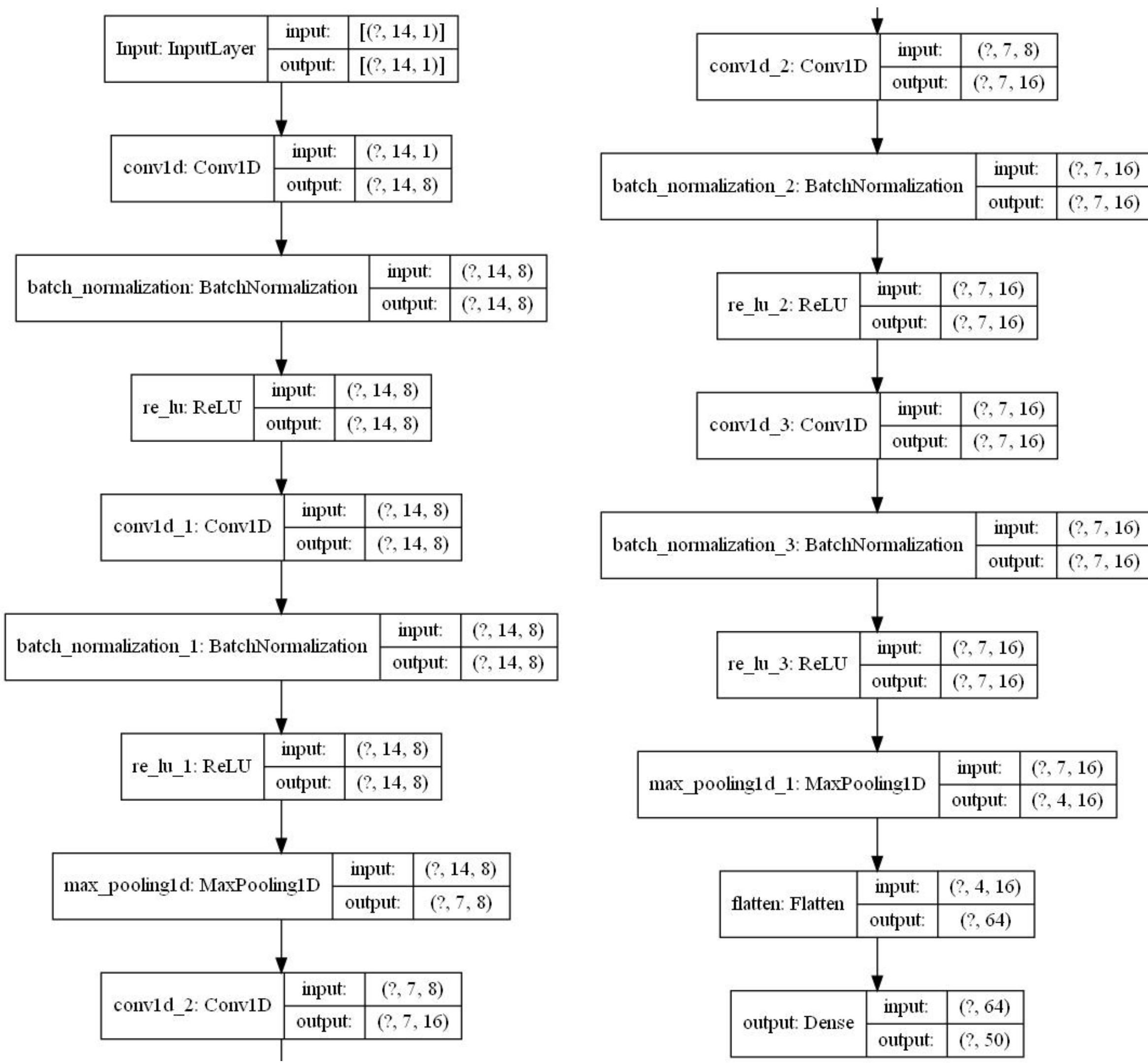
Data set with vacancy value construction

- Case A: Calculate profiles with 14 chords of interferometric data.
- Case B: Calculate profiles with more than 12 chords of interferometric data.
- Case C: Calculate profiles with more than 10 chords of interferometric data.
- The sample number of each case: 1e5.
- Processing of vacancy value:

- Replace by the symmetric position.
- Average of the nearest two values.
- Average of the next nearest, the third nearest two values, and so on.
- Average of the measurement by the same system.
- Average of the measurement by the other system.

Network structure

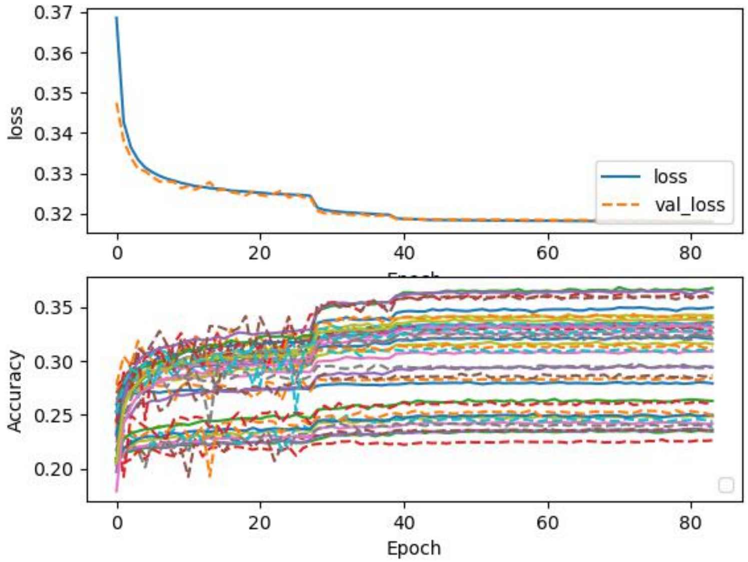
- Multi-task learning for the density of each magnetic surface.

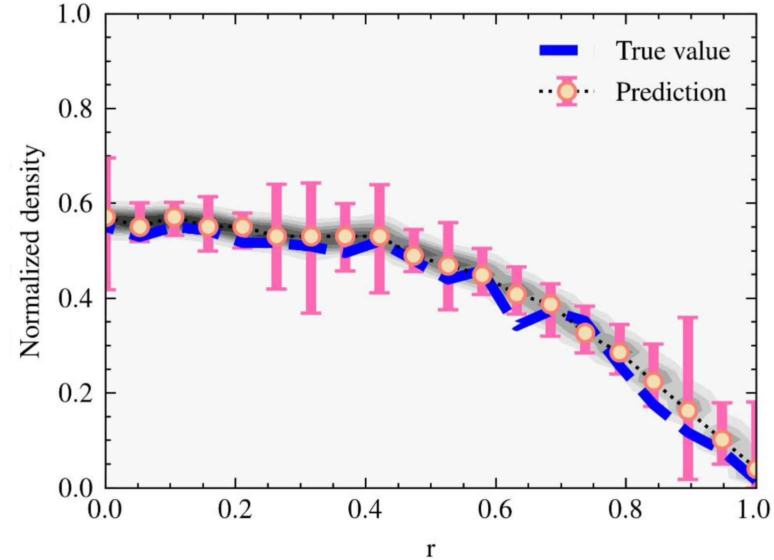


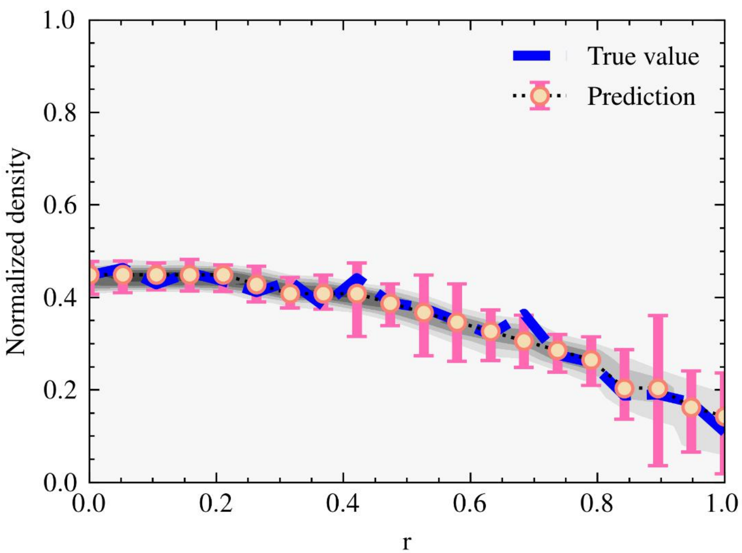
Basic unit refers to VGG.

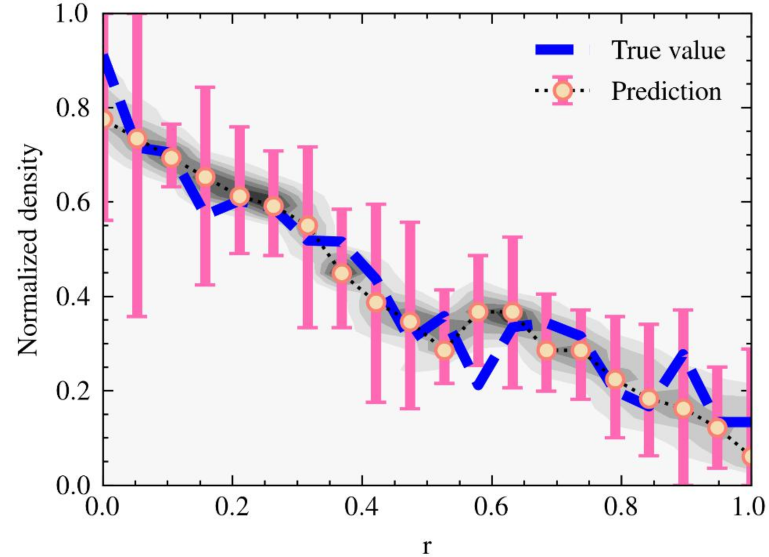
Optimizers: adam
Loss: MSE
Batch size: 32
Proportion of train-set: 0.8
Machine: Tesla V100 32G

Case A Results

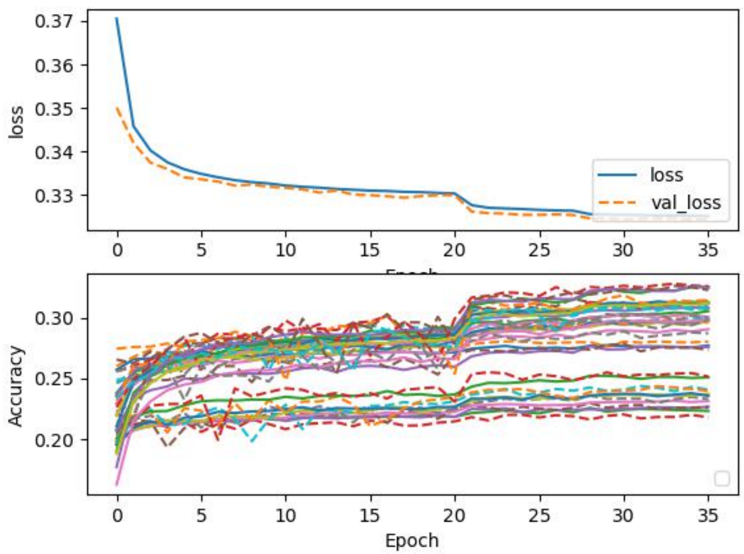


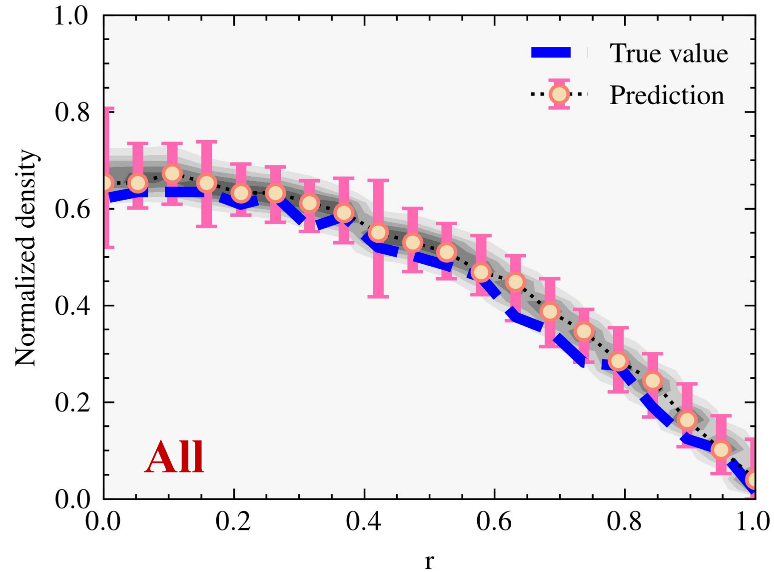


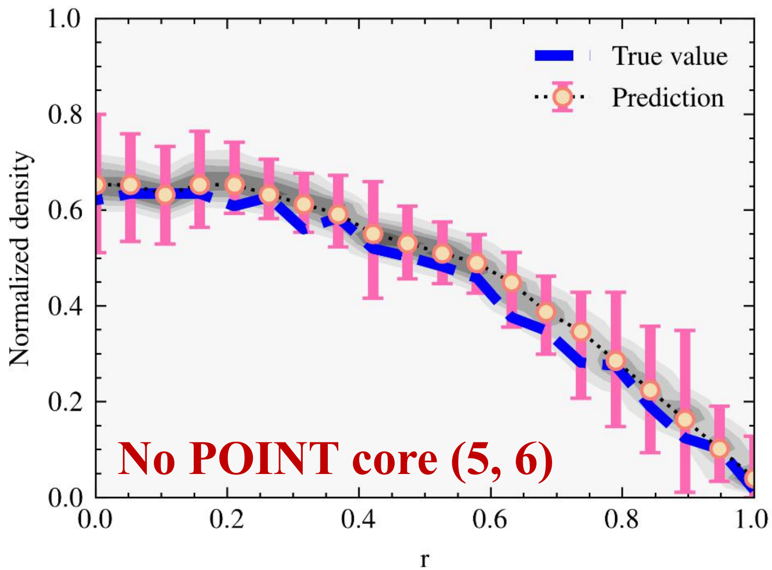


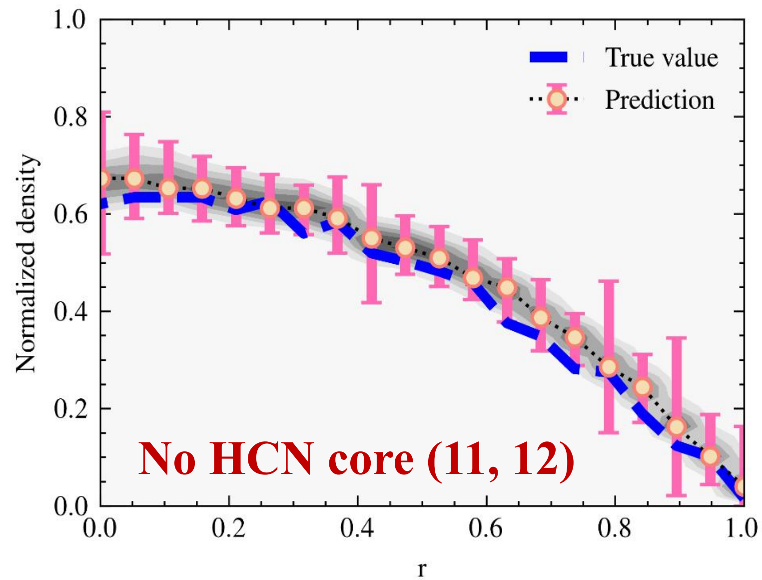


Case B Results

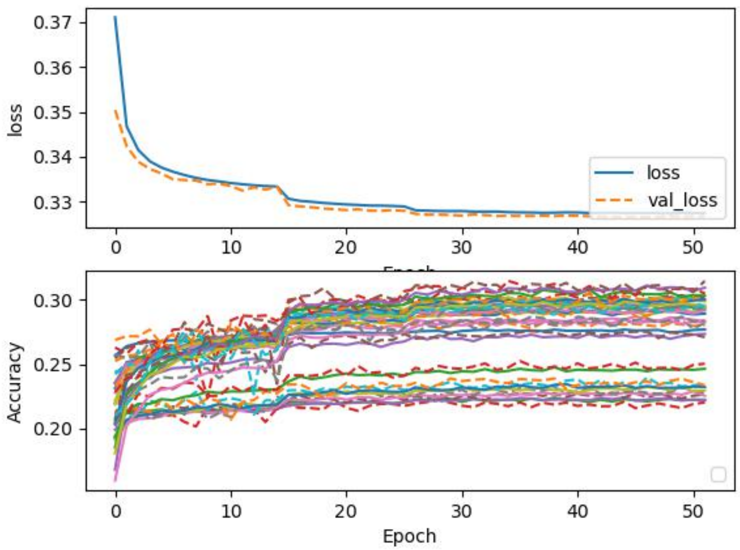


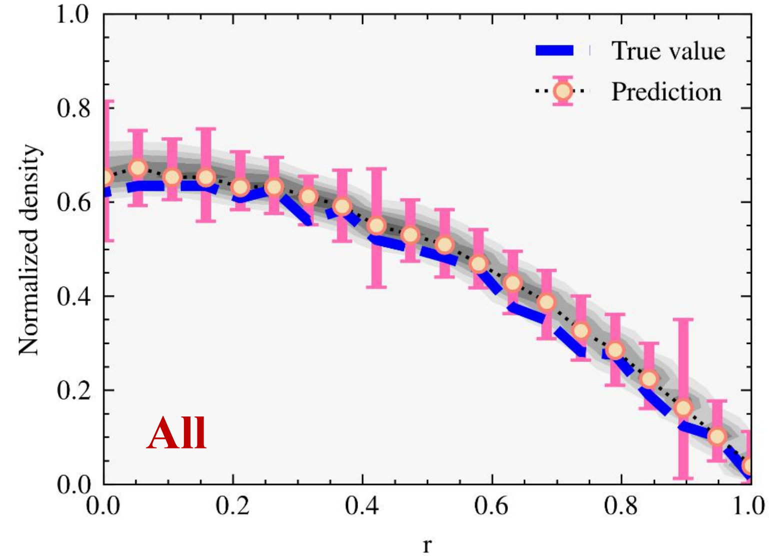


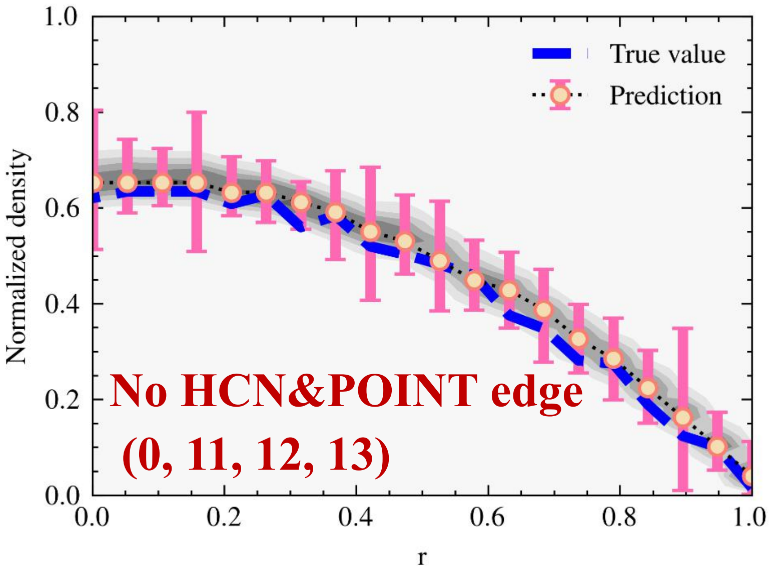


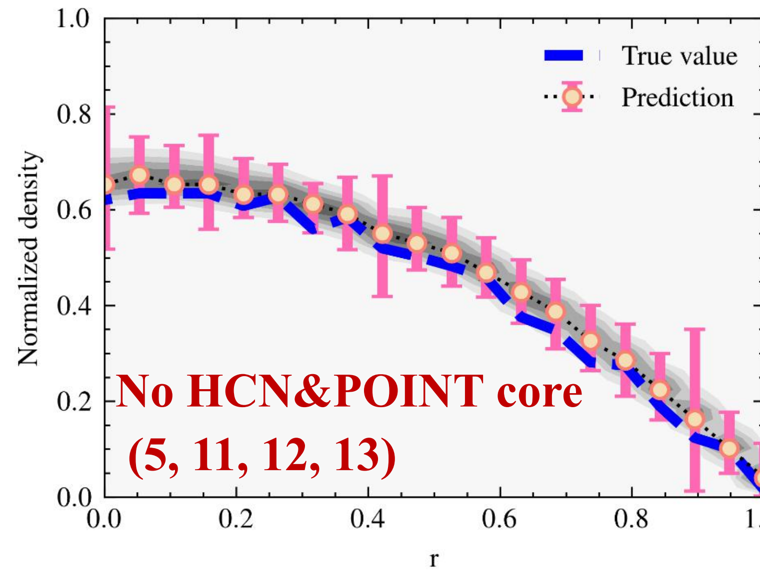


Case C Results

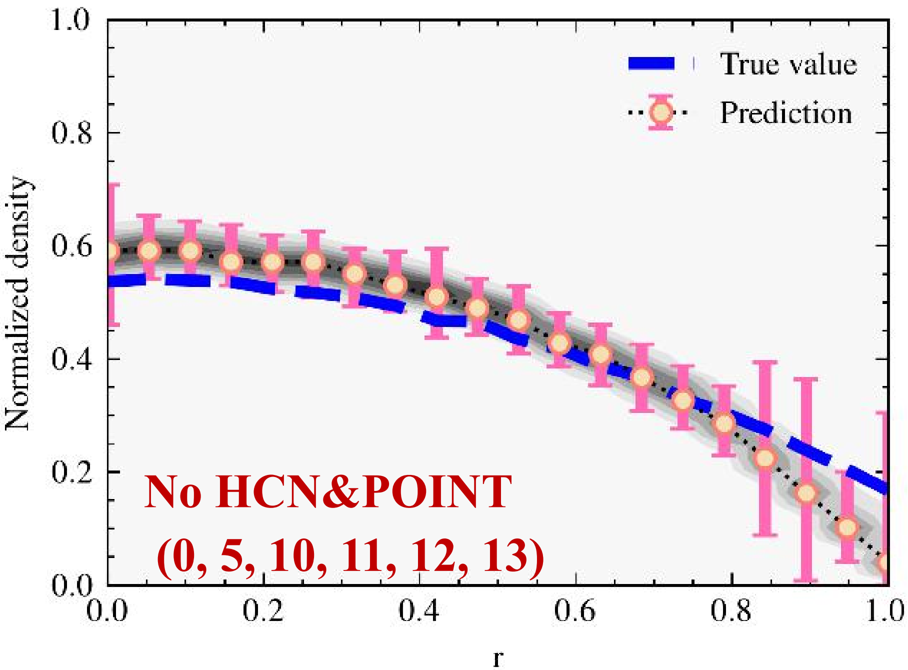


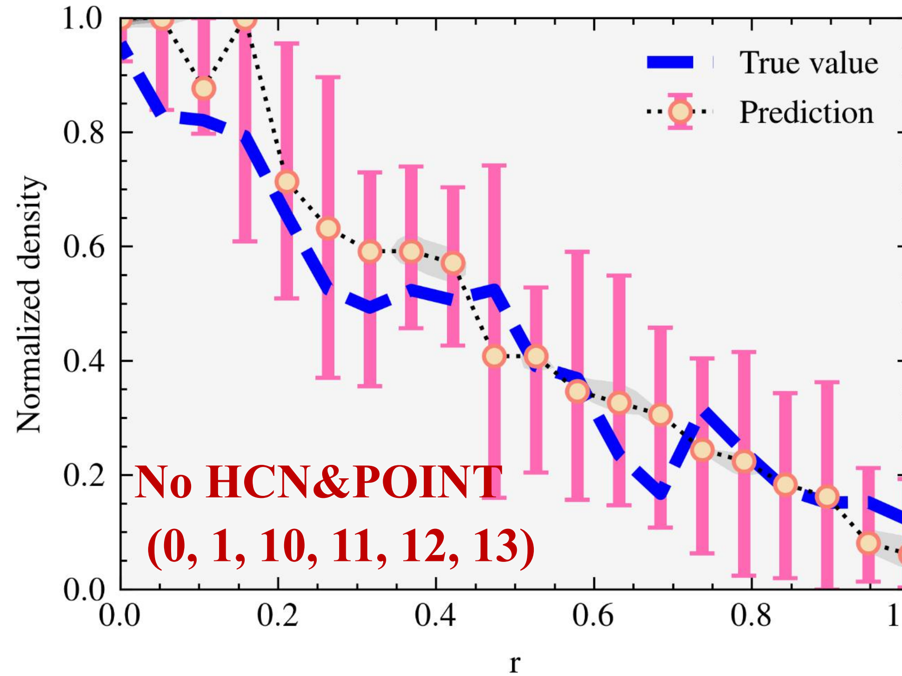






Results of other cases: more vacancy values





Summary

- **We introduce machine learning techniques into the reconstruction of electron density profiles using the diagnostic data from the interferometer systems in EAST tokamak. This algorithm has robustness to the vacancy values (less than 4) in the input dataset.**

- **This algorithm has a good application prospect in fusion data processing, and can be employed in the profile reconstruction of other diagnostic systems, which measure the line integrated parameters of plasma in fusion devices.**

- **Next step, we would include more density measurement data of other diagnostic systems and test this method using actual measurement data.**

Thank you!