Using Linear Regression to Model the Parameters of the Flat Wires in TLS-EPU56

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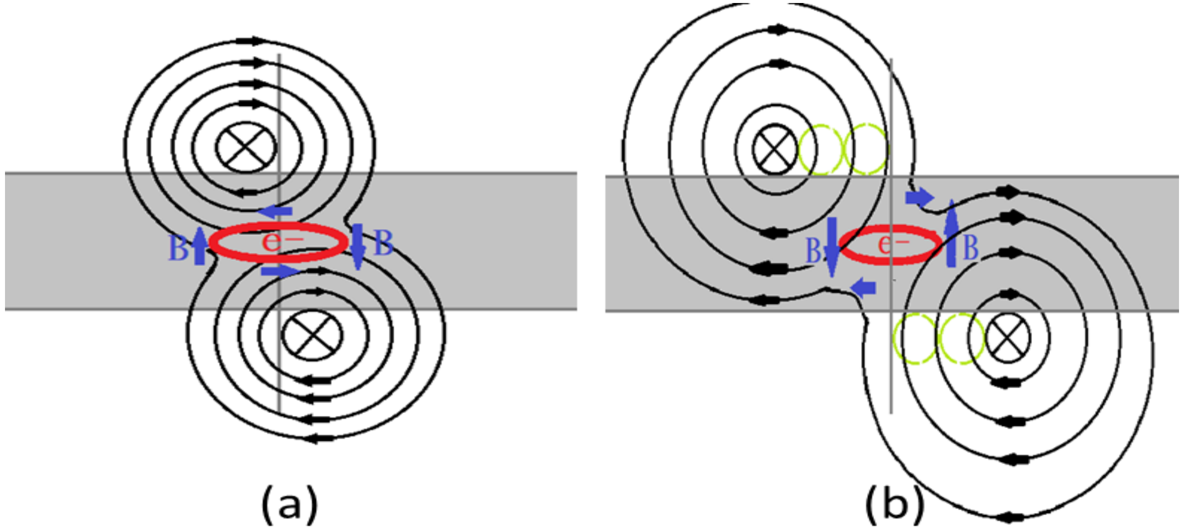
I. Introduction

Although the theoretical calculation could predict the setting currents of the flat wires, which were used to compensate the deviation in the Batatron tune caused by the elliptically polarized undulator (EPU), those setting currents still needed to be tuned in the reality. To approach the reality, a strategy of Machine Learning was adopted.

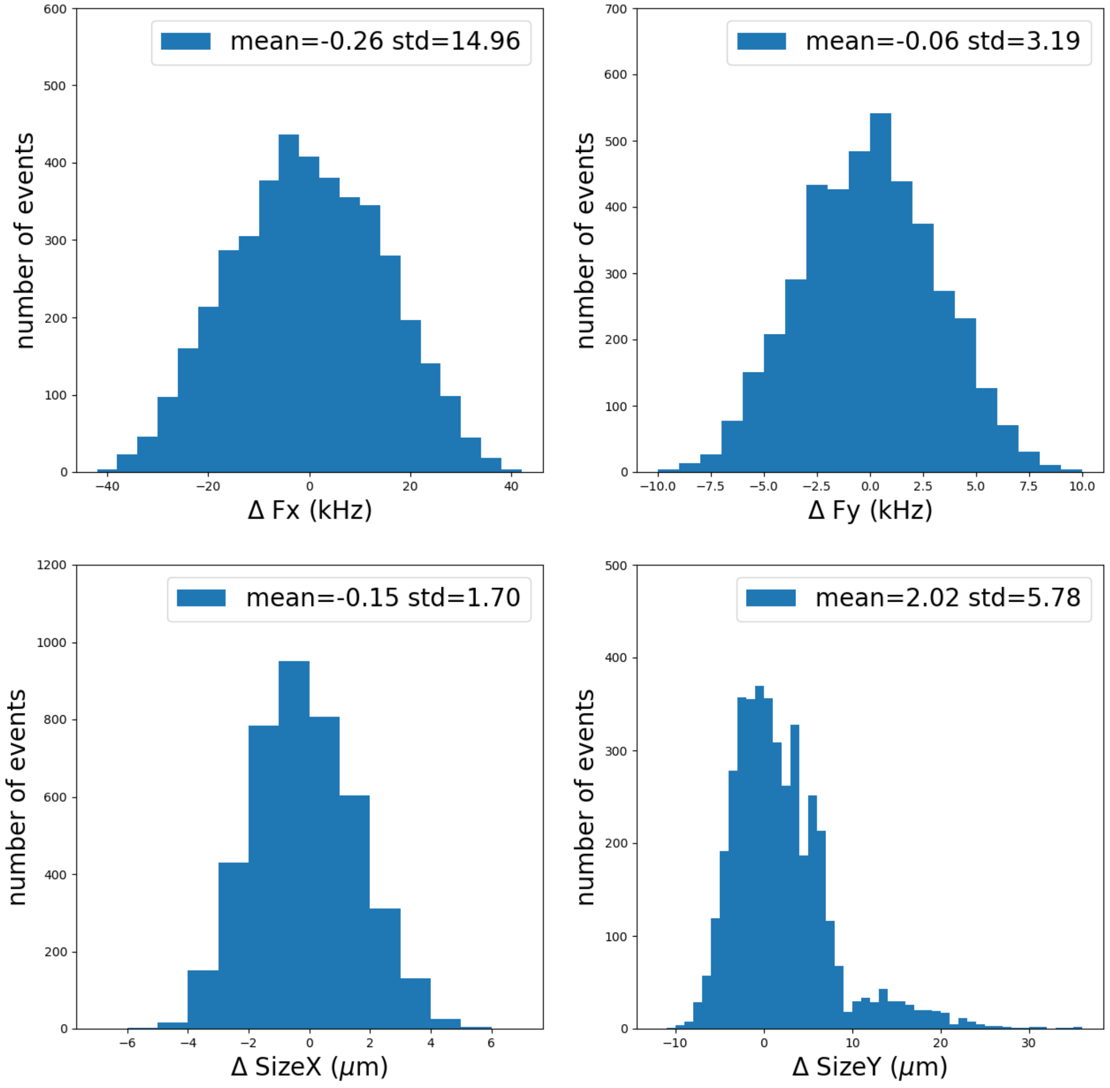
In this presentation, we show the modeling procedure, the prediction in different variables (the tune x, the tune y, and the beam size x), and a test under the real accelerator condition. By the test, the flat wire has also shown the possibility to benefit the beam injection issue.

Twenty-eight flat wires installed in the EPU 56 of the storage ring of the accelerator Taiwan Light Source (TLS)

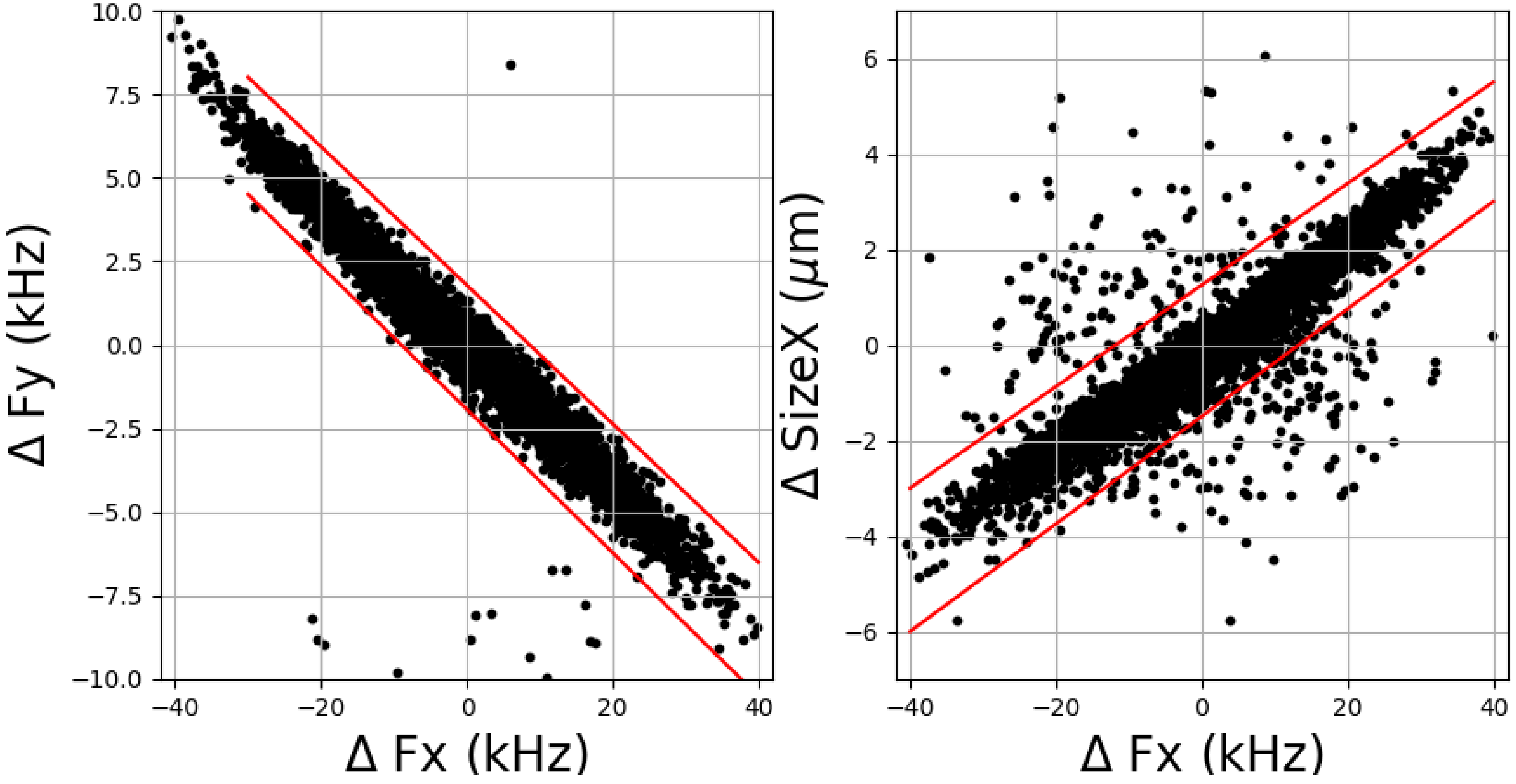


The present way of hardware setting is each two flat wires (called a pair) have the same current settings.

II. Data Collecting and Filtering



The distributions of 4 variables' variation in the learning data, which were collected by randomly scanning the current setting of 14 flat wire pairs in the range of ±2.0 A. The size y was not considered in this study.



The 2D scatter plot shows the correlations between three variables. The abnormal points were removed before the model training.

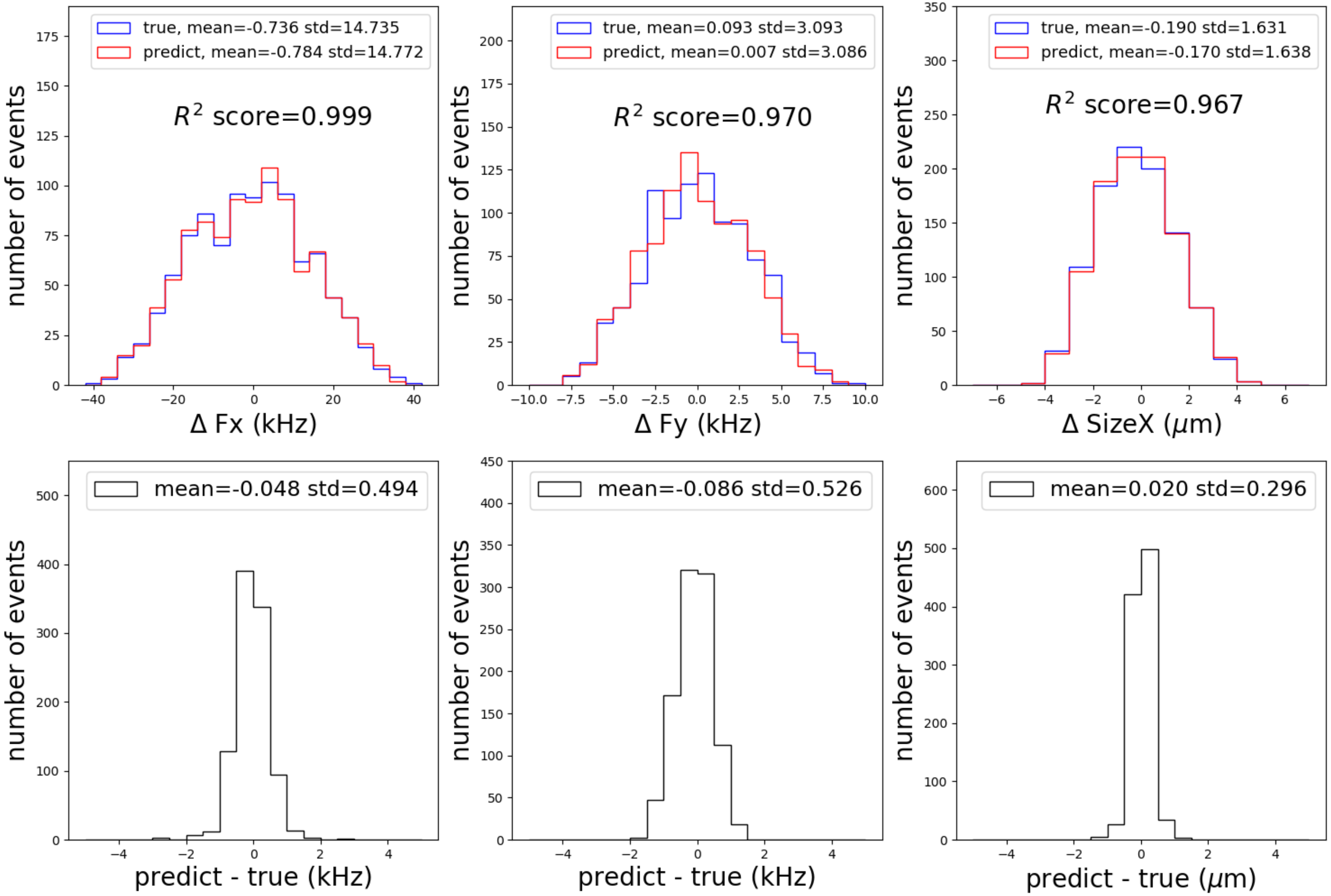
III. Model's Training and Prediction

Part of data was used for training model, and the other part was used to validate the model after the training. The model here was the linear regression

$$\hat{y}(\boldsymbol{w}, \boldsymbol{x}) = w_0 + w_1 x_1 + w_2 x_2 + \cdots + w_{14} x_{14}$$

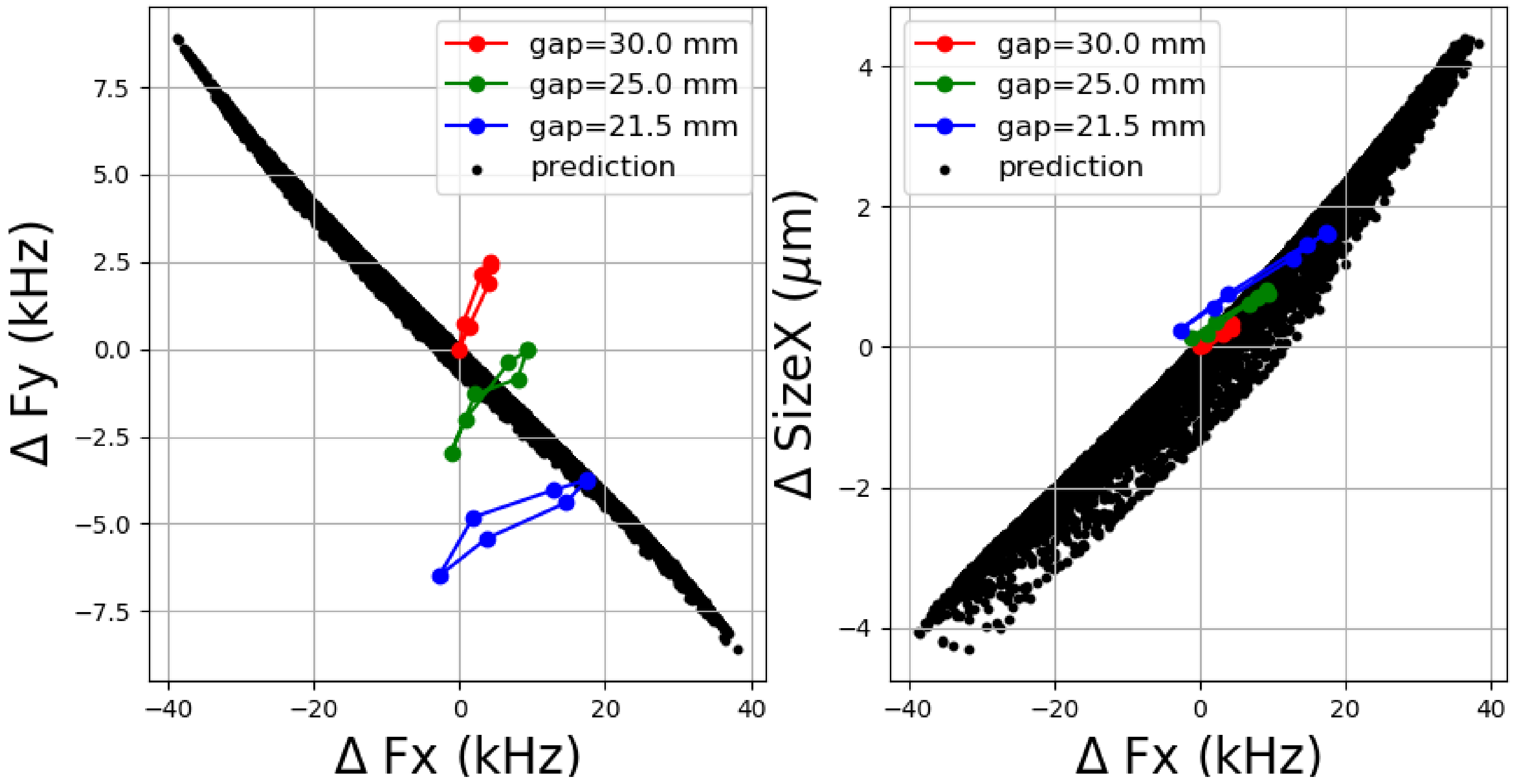
The parameters (w) were decided by minimizing the residual sum of squares (RSS)

$$RSS \equiv \sum_i (y_i - \hat{y}_i)^2$$



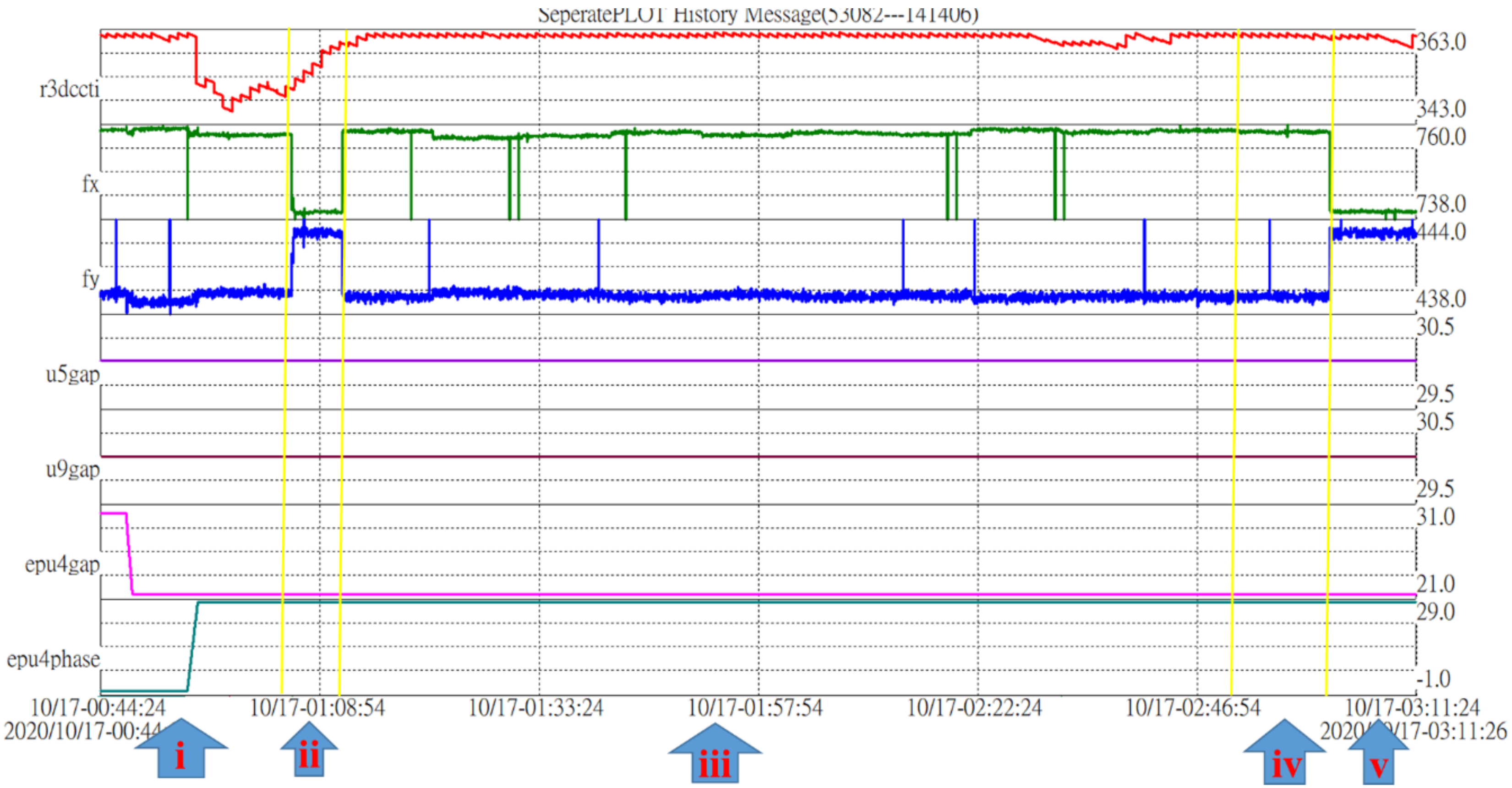
The performances of the linear regression model with the validation data in three variables. The R^2 score shows how well the model describe the data.

$$R^2\,score \equiv 1 - \frac{\sum_i (y_i - \hat{y}_i)^2}{\sum_i (y_i - \bar{y})^2}$$



The comparison of the model's prediction and the required amount of correction of EPU at different gaps and phases.

IV. Result of testing in the real accelerator



In the test, the EPU condition was changed from (gap,phase)=(30,0) to (gap,phase)=(21.5,28). The step (i) used the tune feedback system to compensate the deviation in the tune caused by the EPU, while the step (iii) used the flat wires.

V. Conclusion

- The linear regression model can model the behavior of flat wire well
- For some gap and phase, the flat wires have the ability to correct multiple variables in the same time. This is also confirmed in the test.
- Comparing with the tune feedback system, the flat wire seems to have less disturbing to the beam injection.