# Development of an Automatic Calibration System for BPM

L.L. Li, P.L. He, H.M. Xie, J. Yin, R.X. Tian, F.F. Ni, Z. Du, Y. Zhang, J.X. Wu , IMP, China

Beam Position Monitor (BPM) is used to measure the horizontal and vertical positions of the beam in the vacuum pip of the accelerator facility. Before online installation, it usually needs to be calibration. High Intensity Heavy-ion Accelerator Facility (HIAF) and China initiative Accelerator Driven System (CiADS) will need a large number of BPM, so it is a great challenge for BPM calibration work. In order to complete this work efficiently and accurately, this research designs and develops an automatic BPM calibration system. This paper mainly described the control and processing programs in this system. The control software was designed by C language to realize automatic calibration functions based on EP-ICS. A high-order fitting algorithm programmed by Python used to solve the problem of smaller linear range of the capacitive BPM. It significantly improves the accuracy of position measurement after calibration.

The hardware architecture of the whole system is shown in Fig. 1. It consists of four major sections, including simulate beam current equipment, calibration platform and motion device, BPM signal processing electronics and industrial computer. The automatic calibration system is usually performed using the metal wire stretch method. A straightened metal wire is passed through the BPM, and an RF signal is fed to the wire to simulate beam current. An RF signal generator feeds an RF signal by the SMA connector. The signal processing electronics connected the BPM detector via an RF coaxial line. It is used to process and analyse the output signal of the BPM, and acquire the position in-formation of the metal wire relative to the measured BPM detector electrical center. After that it send these data to the industrial computer after calibration ending.

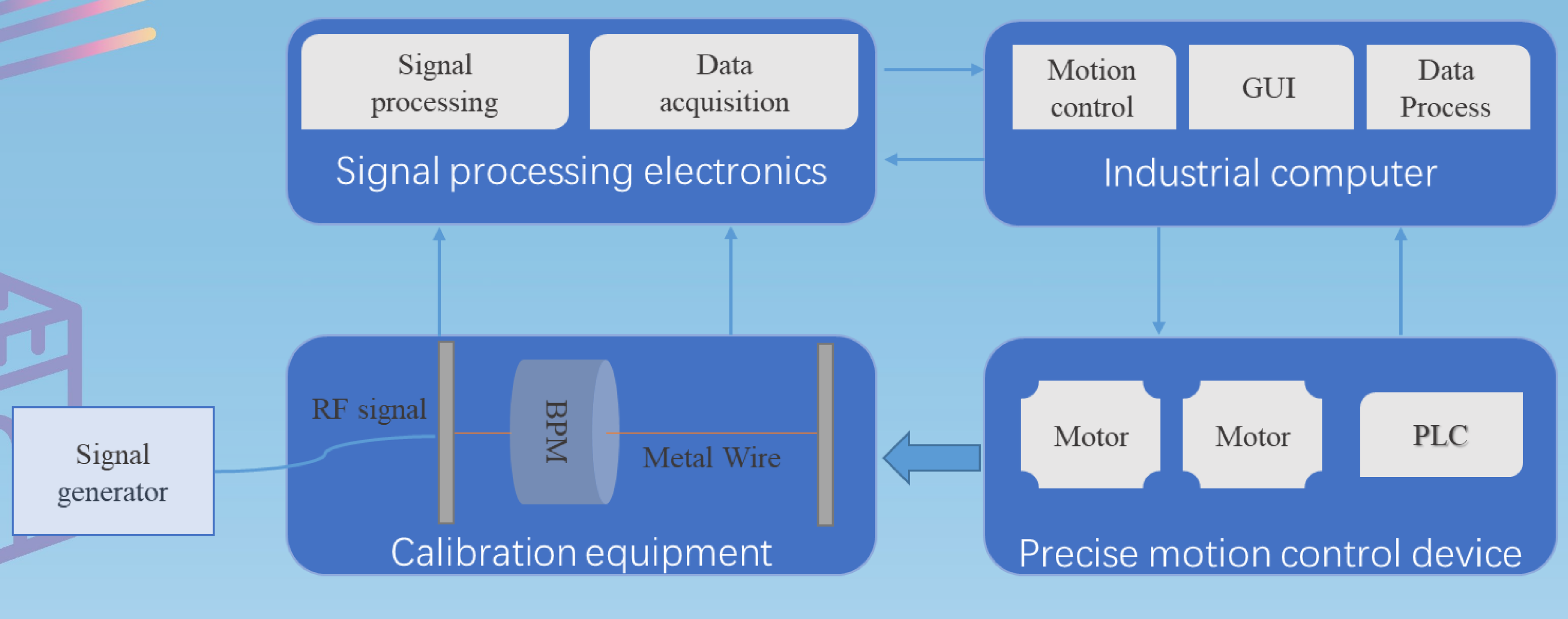


Figure 1: Hardware structure of calibration system.

Figure 2: Motion platform and test bench.

The capacitive BPM is mounted on a two-degree-of-freedom motion platform, which is fixed on a test bench. The motion platform and test bench are shown in Fig 2. The motion platform is produced by Zolix Company in Beijing. Its repeat positioning accuracy is 1 μm, and the measurement precision is 0.1 mm. The motion range in both degrees of freedom is ±150 mm, which guarantees the precision and accuracy of the calibration result and the comprehensive scanning range.

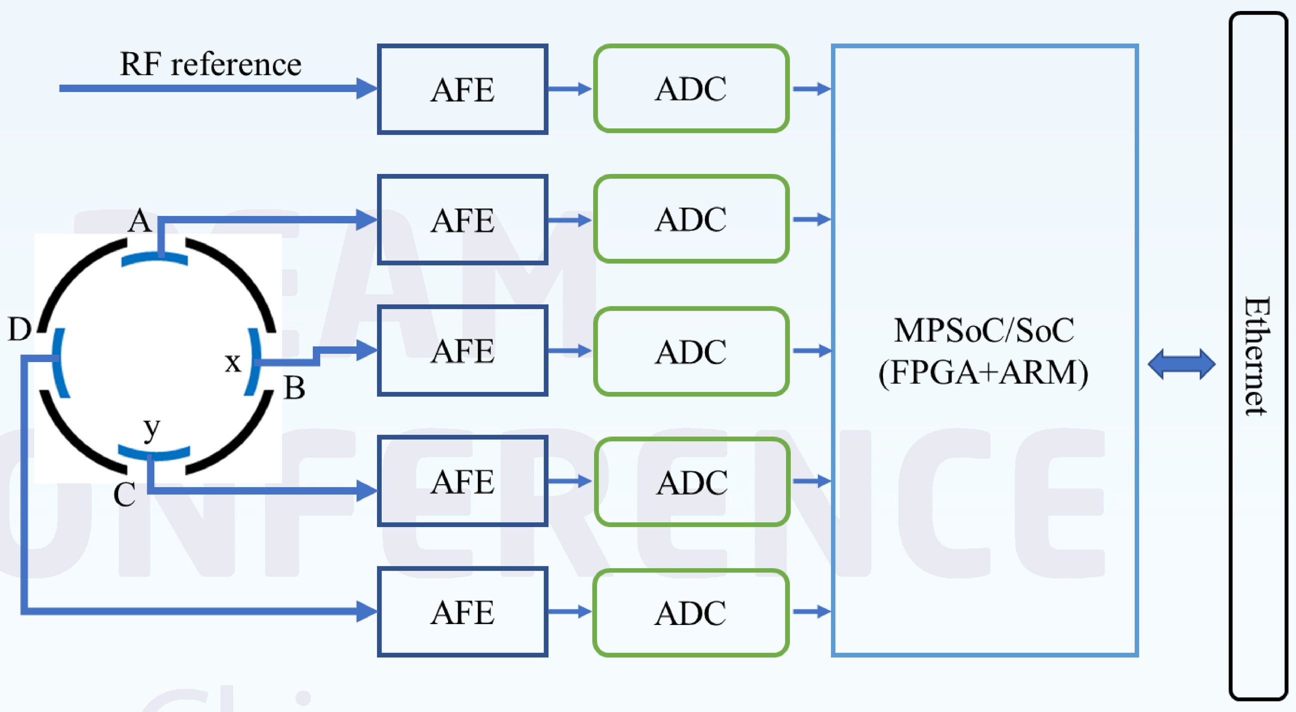


Figure 3: The diagram of the BPM signal processing electronics.

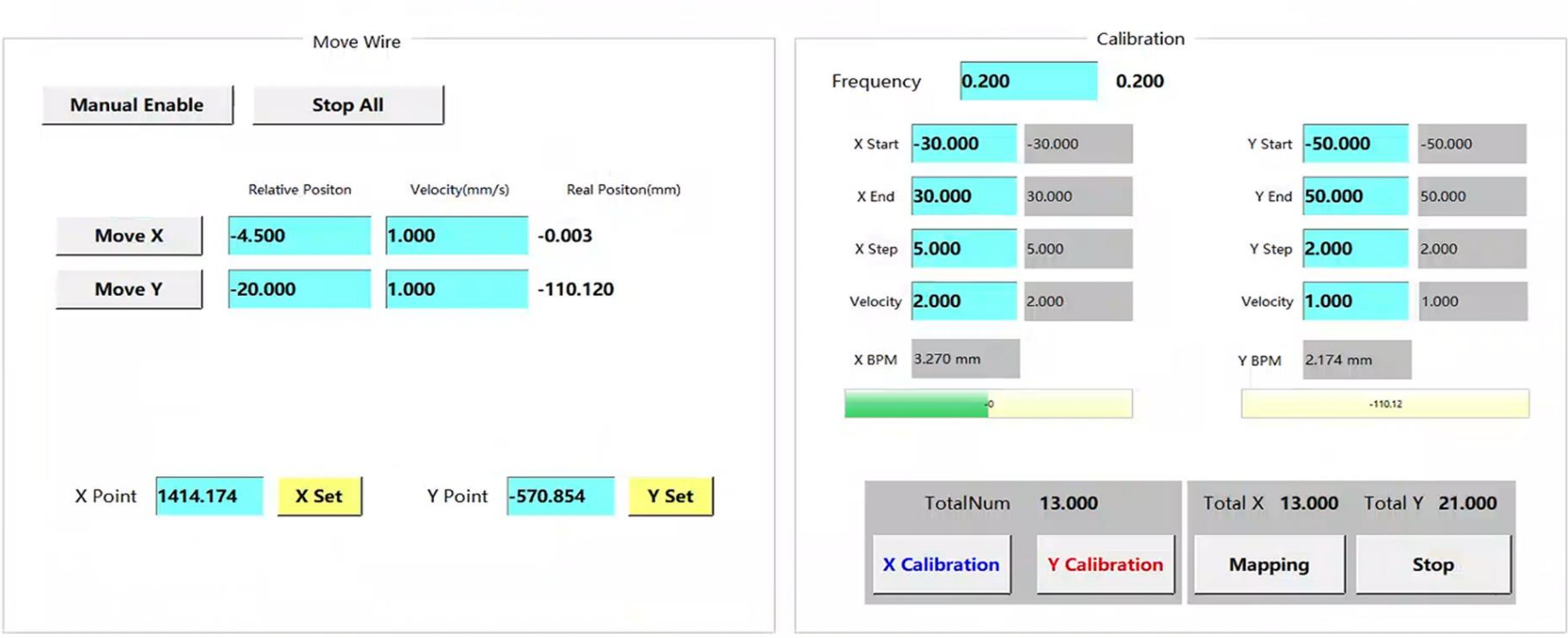


Figure 4: automatic calibration system GUI.

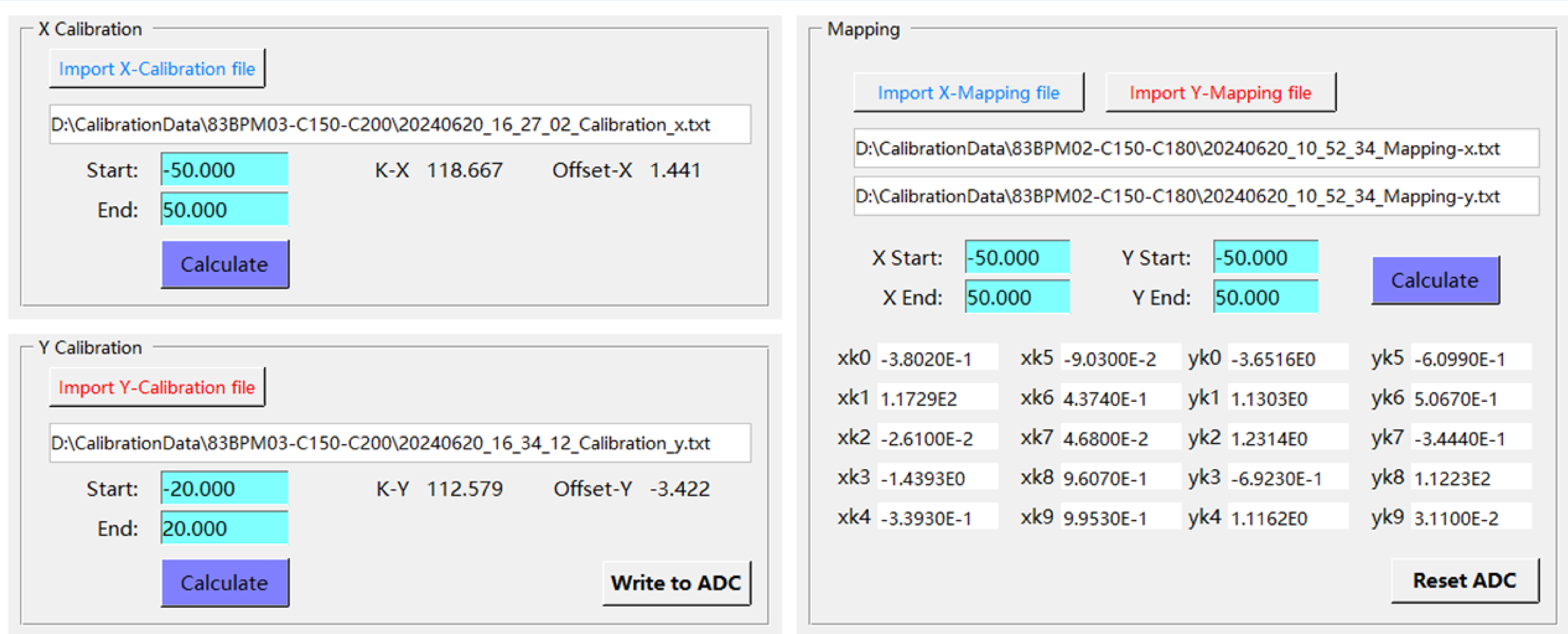


Figure 5: Off-line data analysis programed in Python.

When the beam position is expected to be in regions where the position cannot be computed linearly, a polynomial approach based on the Maclaurin expansion can be used. With $x=(\Delta/\Sigma)_x$ and $y=(\Delta/\Sigma)_y$ the two ratios, the position X using the Maclaurin expansion is shown as Eq.

$$X = k_{x0} + k_{x1}x + k_{x2}x^2 + k_{x3}x^3 + k_{x4}x^4 + k_{x5}y + k_{x6}y^2 + k_{x7}y^3 + k_{x8}y^4 + k_{x9}xy + k_{x10}x^2y + k_{x11}xy^2$$

$$Y = k_{y0} + k_{y1}y + k_{y2}y^2 + k_{y3}y^3 + k_{y4}y^4 + k_{y5}x + k_{y6}x^2 + k_{y7}x^3 + k_{y8}x^4 + k_{y9}yx + k_{y10}y^2x + k_{y11}yx^2$$

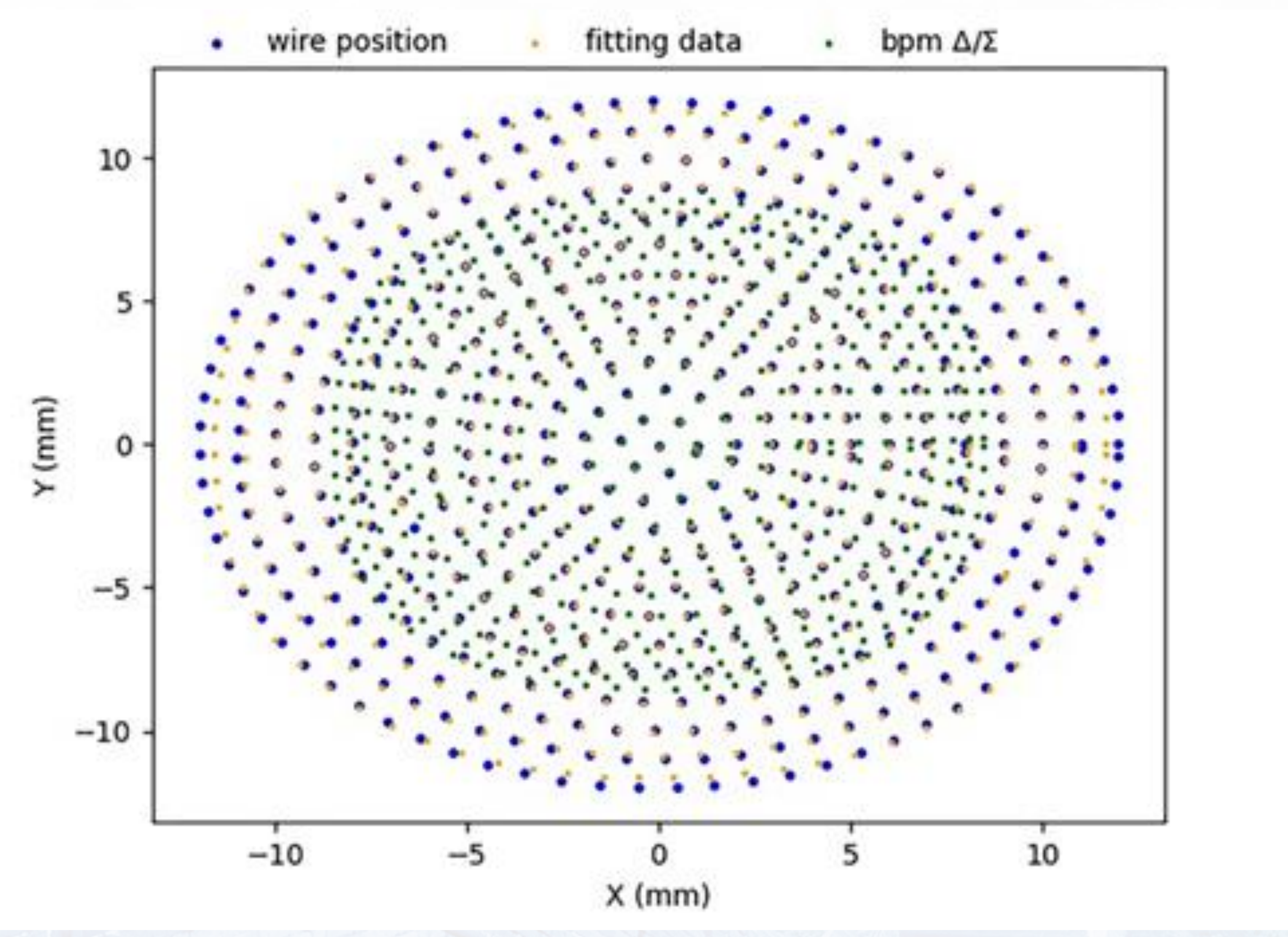


Figure 7: Theoretical and computational coordinates in a 12 mm-radius circle of pre-calibration

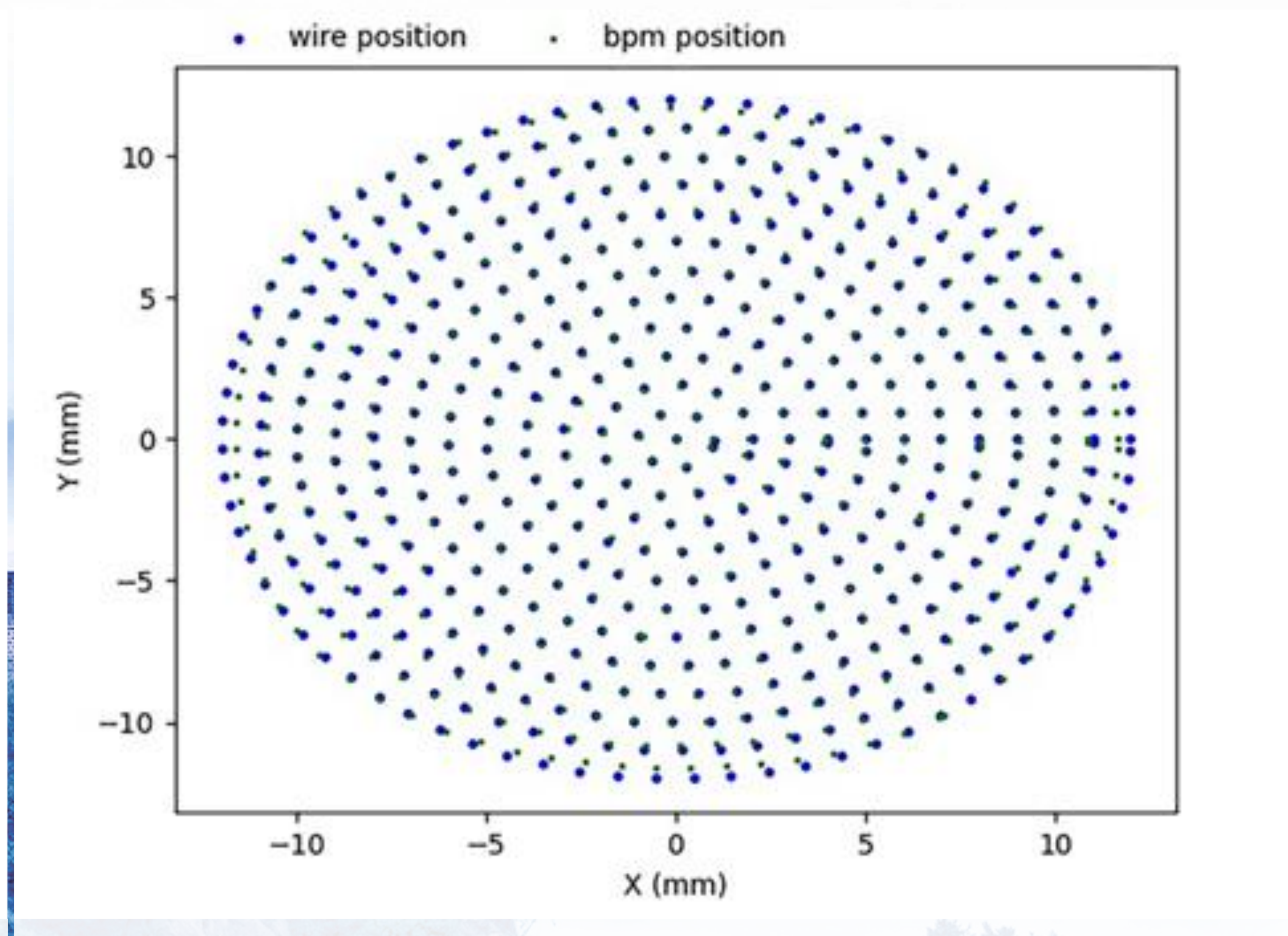


Figure 8:Theoretical and actual measurement coordinates in a 12 mm-radius circle of post-calibration

Conclusion: This paper designed an automatic calibration system for BPM probe and carried out a BPM probe calibration experiments. A high-order fitting algorithm programmed by python used to solve the problem of smaller linear range of the capacitive BPM. It significantly improves the accuracy of position measurement after calibration.

References:

[1] *Li Qin, Zhang Zhaoyi, Jiang Wei et al.*, "Calibration technology of intense pulse electron beam position monitor". *High Power Laser and Particle Beams*, 2024, 36: 064002.doi: 10.11884/HPLPB202436.240034

[2] *F.F. Ni, Z.X. Li, J.X. Wu, et al.*, "A new digital beam position and phase measurement implementation based on a field programmable gate array for the high intensity heavy-ion accelerator iLinac". *Review of Scientific Instruments*, 93(6):063301. doi: 10.1063/5.0089407.

[3] PyEpics:Epics Channel Access for Python.https://pyepics.github.io/pyepics/index.html

[4] *X.H. Tang, J. He, J.H. Yue, et al.*, "Development of an automatic calibration system for beam position monitor". *Nucl. Tech.*, vol. 45, p. 020102, 2022.