Three-dimensional magnetic field mapping system for large spectrometer magnets utilizing on-fly technology

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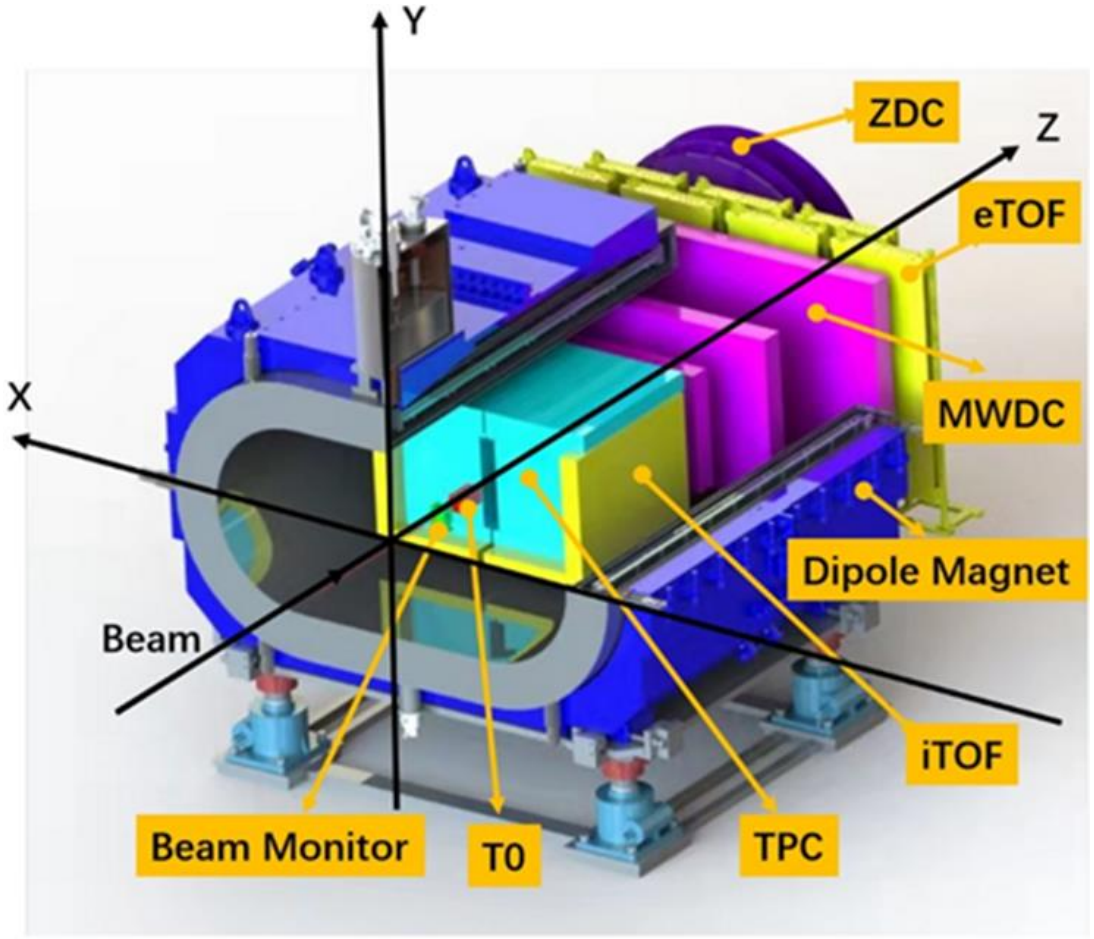
Tuesday, October 8, 2024

Introduction



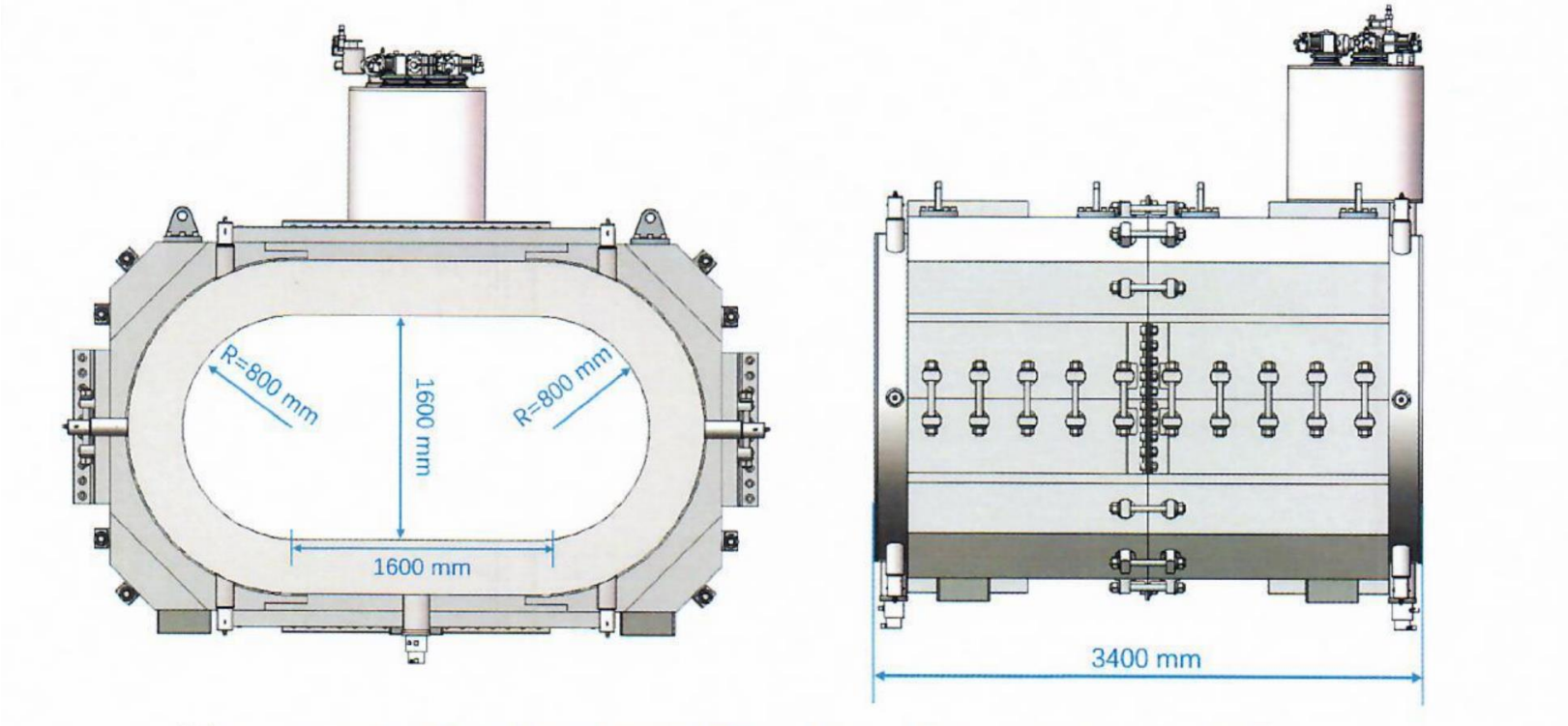
CEE superconducting magnets are used to provide background magnetic fields for relevant physics experiments

Specifications

- Superconducting
- Central magnetic field 0.5T
- Optimal magnetic field area
  1.0m(L)×1.2m(W))×0.9m(H)
- Magnetic field homogeneity <5%
- Height of the temperature hole 1.6m

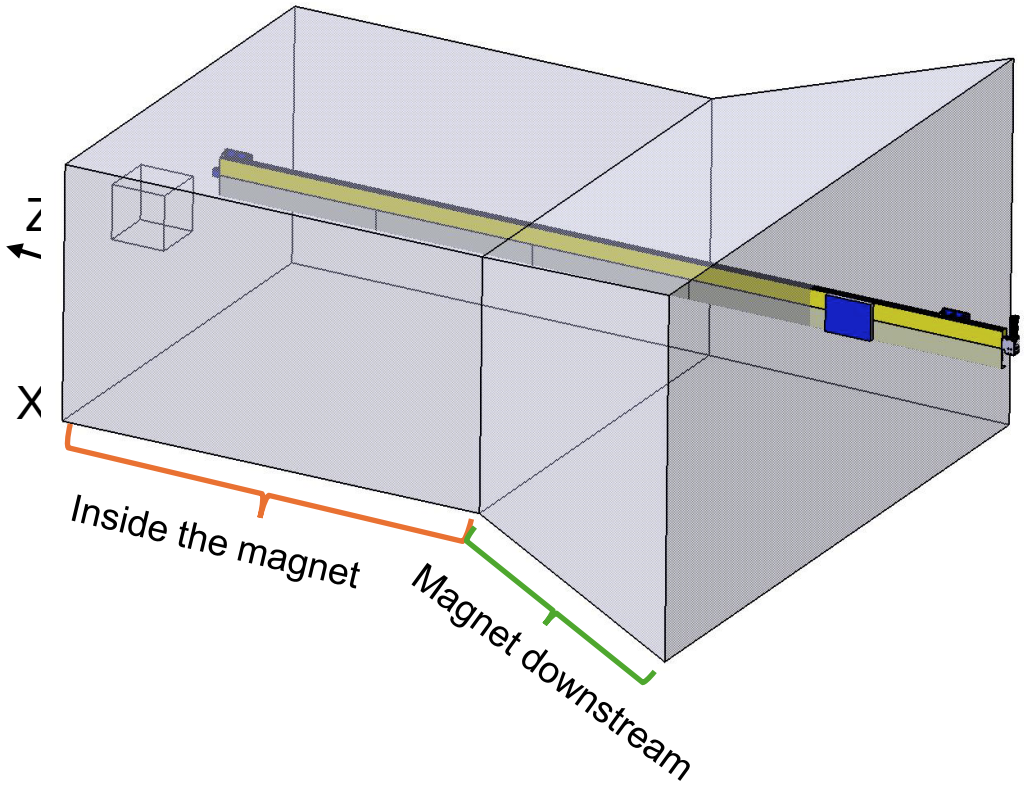
Large scale, 3D magnetic fields mapping 5000 gauss stabilized magnetic field,
Large number of measuring points, Limited measurement time

The magnetic field measurement area



CEE magnet internal net space for the runway type, its cross-section of the arc section radius of 800m, the length of the straight edge section of 1600mm, the height of 1600mm, the overall length of 3400mm

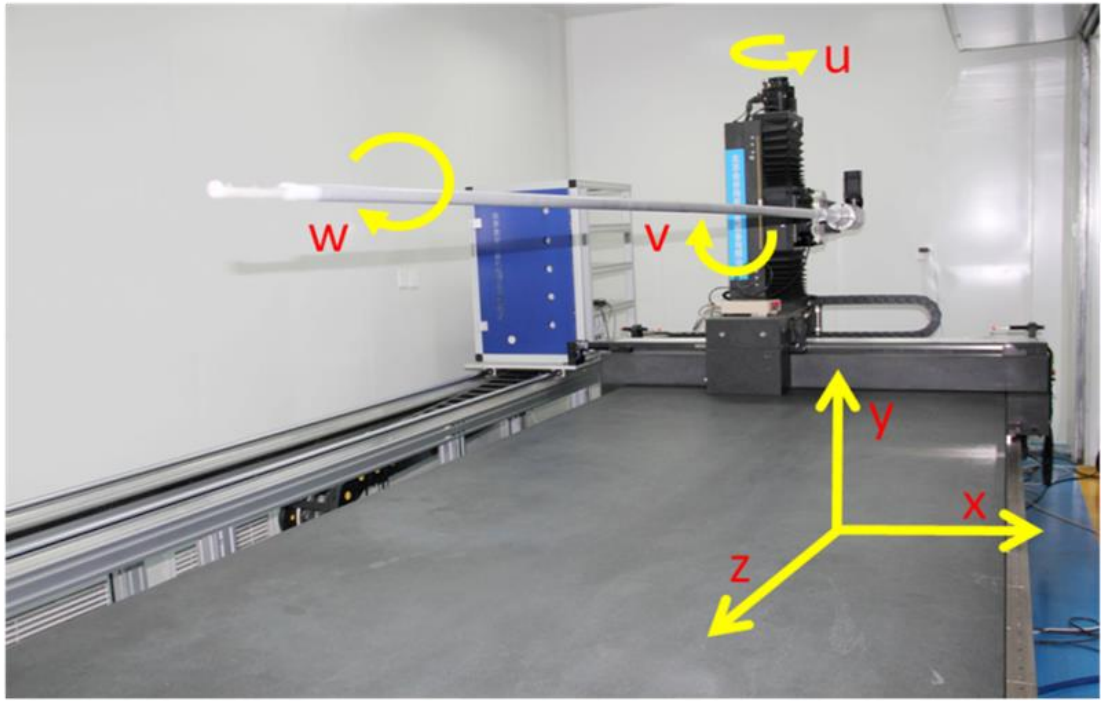
The magnetic field measurement area



Detectors	Z（cm）	X (cm)	Y (cm)
BM-TPC	-100.<z<-60.	±15.	±15.
iTOF & TPC	-70.<z<90.	±85.	±70.
MWDC 1&2	60.<z<135.	±95. (±115)	±45. (±64)
magnet edge	z=170.	±120	±60
MWDC3	195.<z<215.	±（140.+15）	±65.
eTOF	225.<z<275.	±（160+20）	±80.
ZDC	297.<z<301.	±（100+25）	±100.

The magnetic field measurement area is closely related to the physical detector and must cover all detection areas of the physical detector. The entire area is trapezoidal, spanning from the interior of the magnet to the edge of the magnet, which presents a significant challenge for the design of the measurement system, 3.5 meters required for z-direction.

The conventional point measuring systems

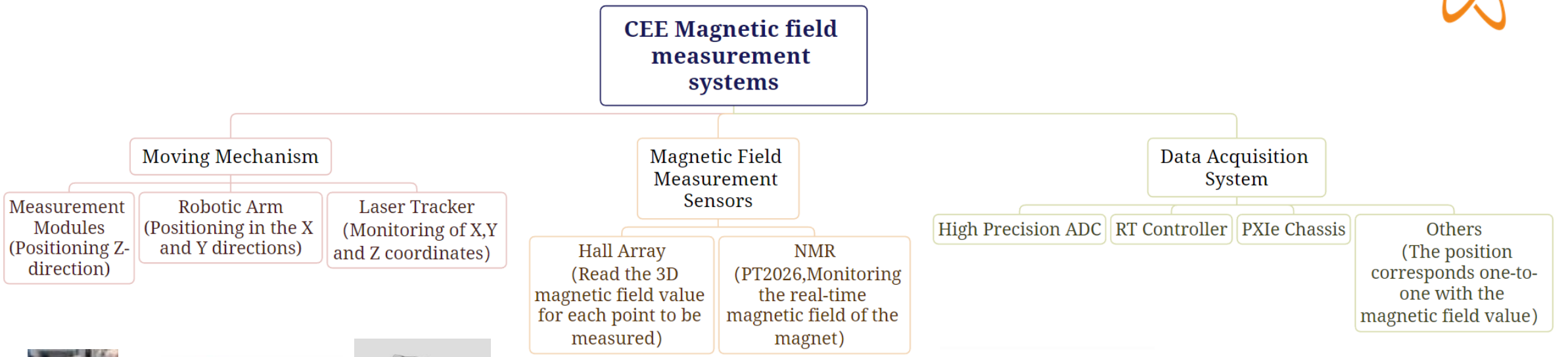


The point measurement system based on marble platforms

- Marble platform；
- Motion control systems are linear or servo motors；
- 6-axis motor system meets 6 degrees of freedom of Hall, Positioning accuracy of 10 microns is achieved with grating scale feedback in the x, y, and z axes；
- Acquisition mode is start-stop-acquisition-start, It takes about 15-25s to collect a point；
- Large in volume, not easily movable, Limited travel distance。

Need for a new point measurement system

magnetic measurement system design

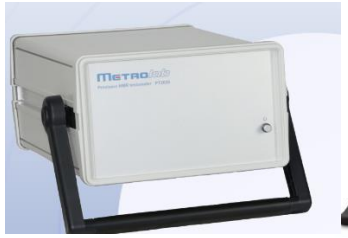


Measuring Modules

Kuka（KR210）

Lecia AT960

Senis F3A



Metrolab PT2026

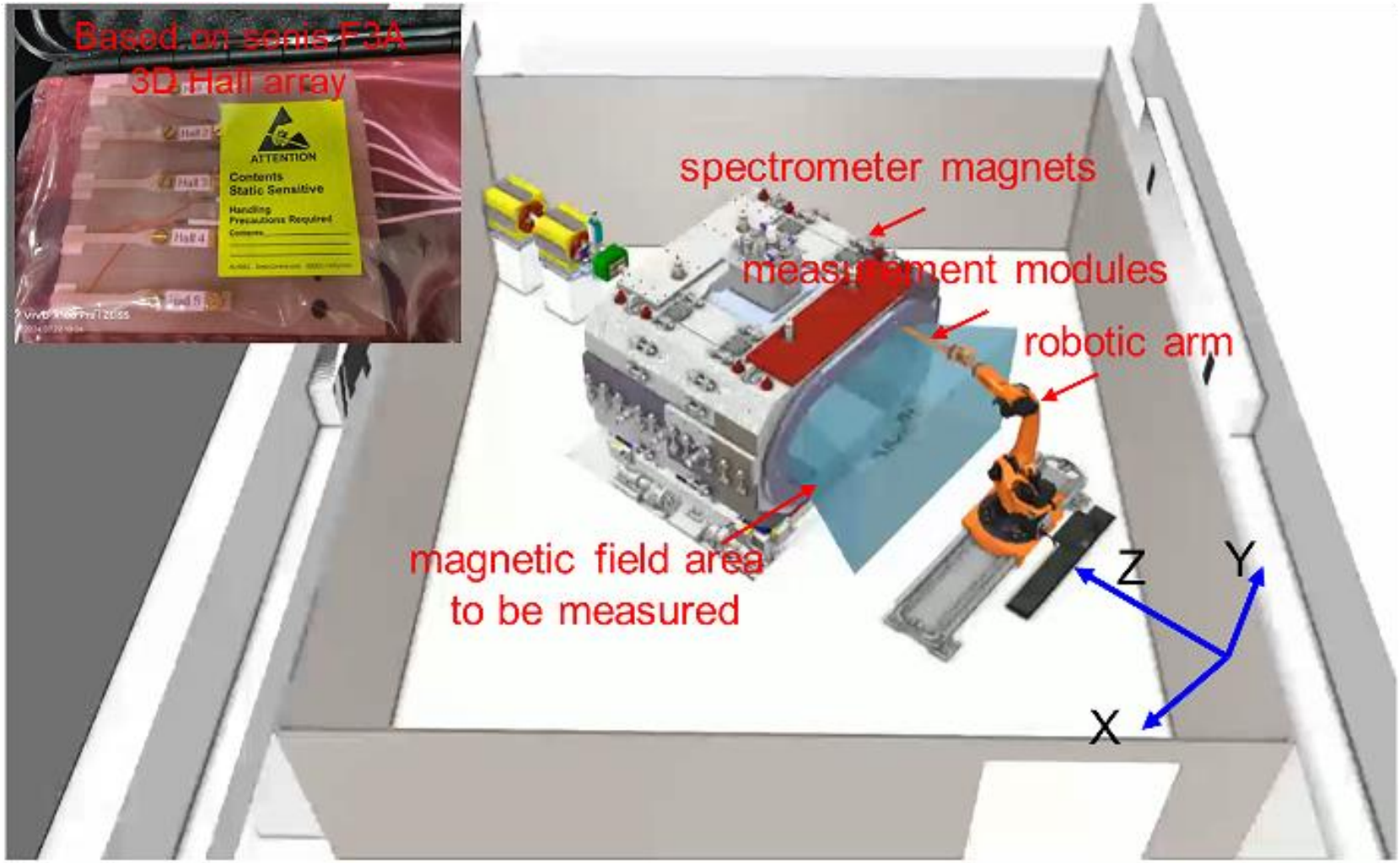
NI PXI-6358

NI PXIE-8842RT

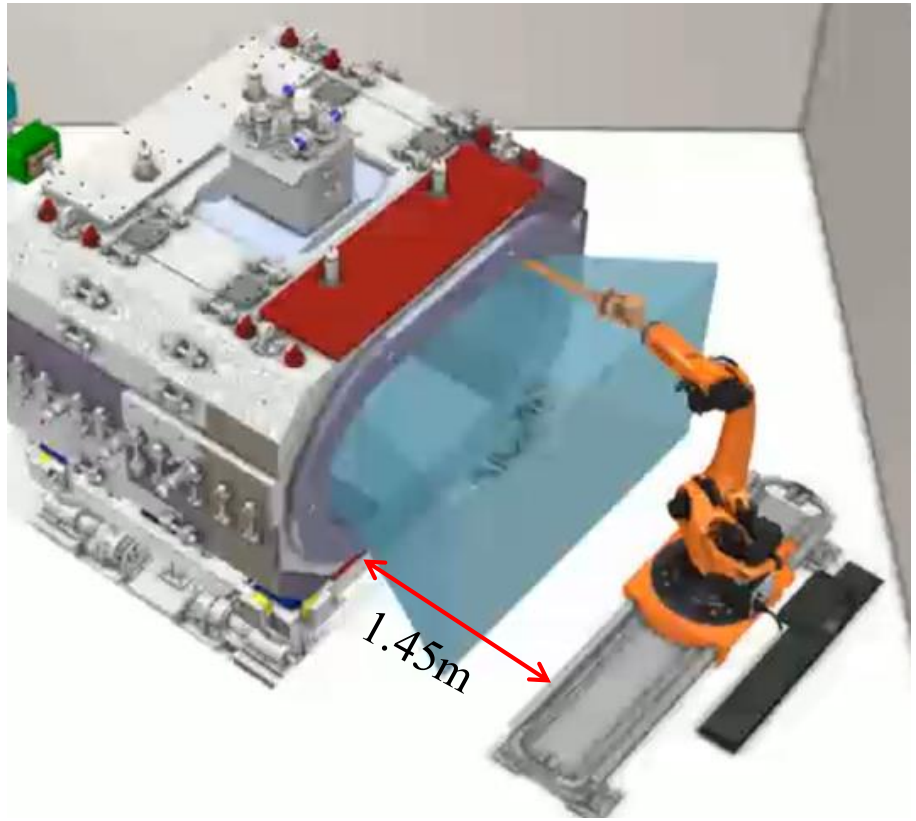
NI PXIE-1088

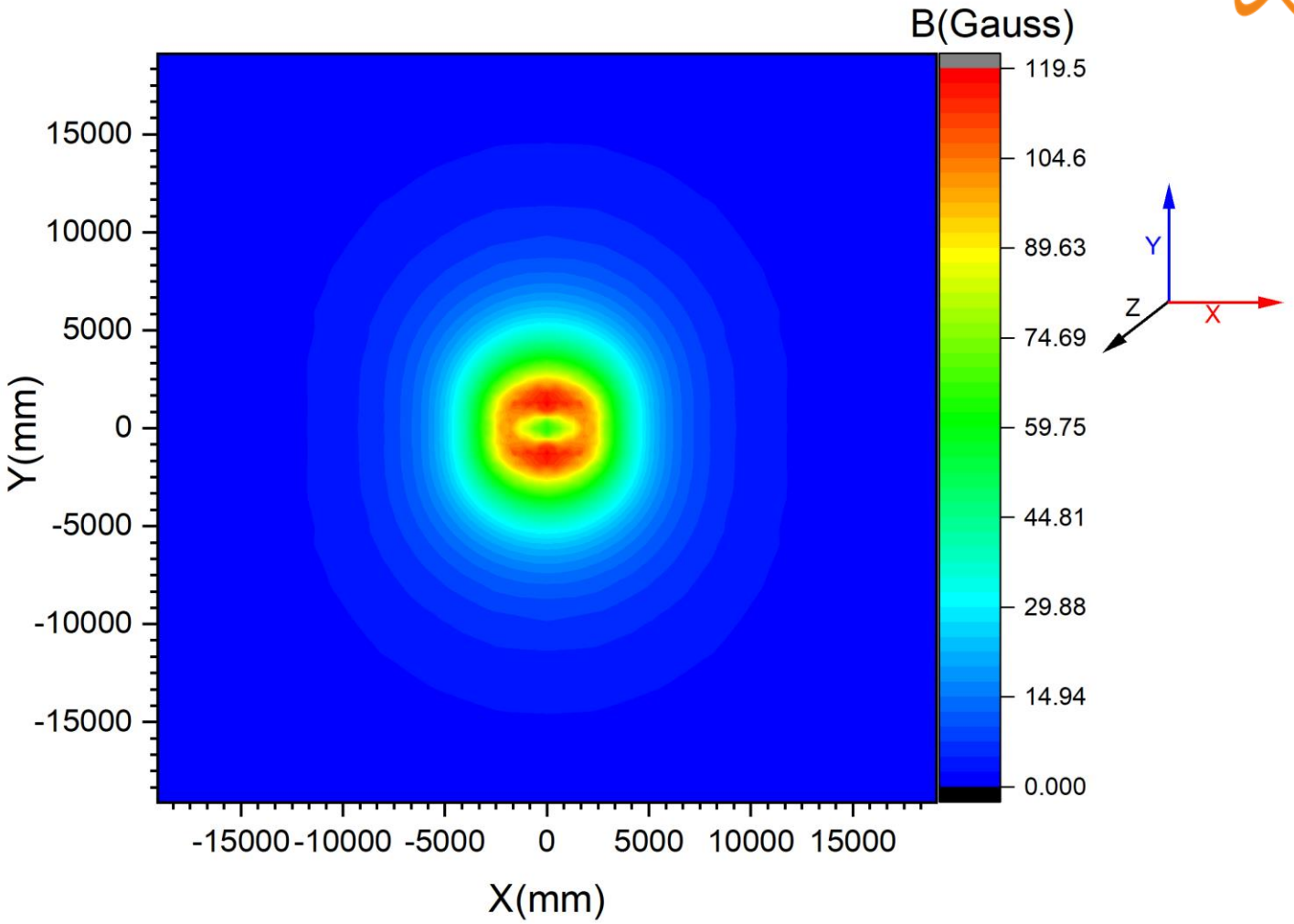
The robotic arm acquires x and y direction coordinates, while the measurement module obtains the Z direction coordinate, The measurement module emits TTL pulses during motion to synchronize the magnetic field and coordinates

CEE Magnetic Field Measurement System



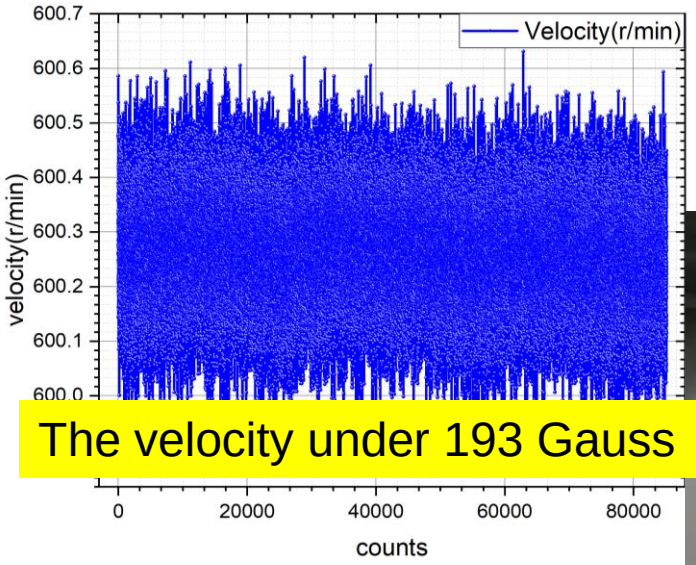
Motor testing in weak magnetic fields



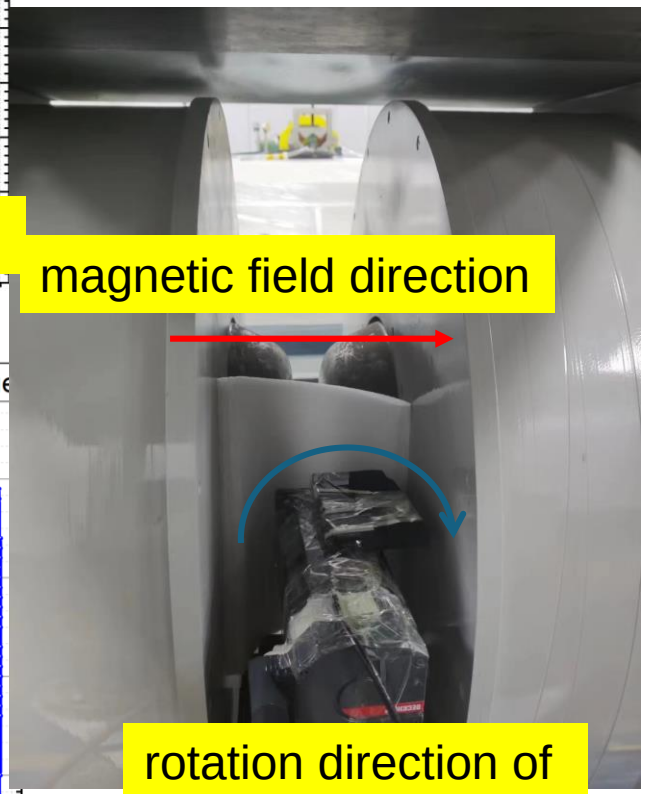


The final placement of the robotic arm is determined by considering the position of the magnet and the impact of the magnetic field on the motor of the robotic arm。

Motor speed and torque under a weak magnetic field

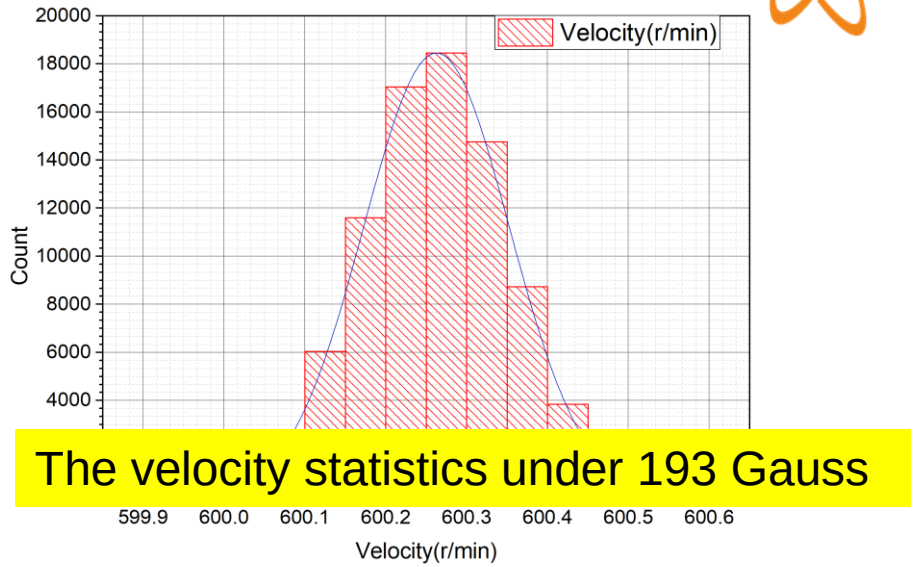


The velocity under 193 Gauss

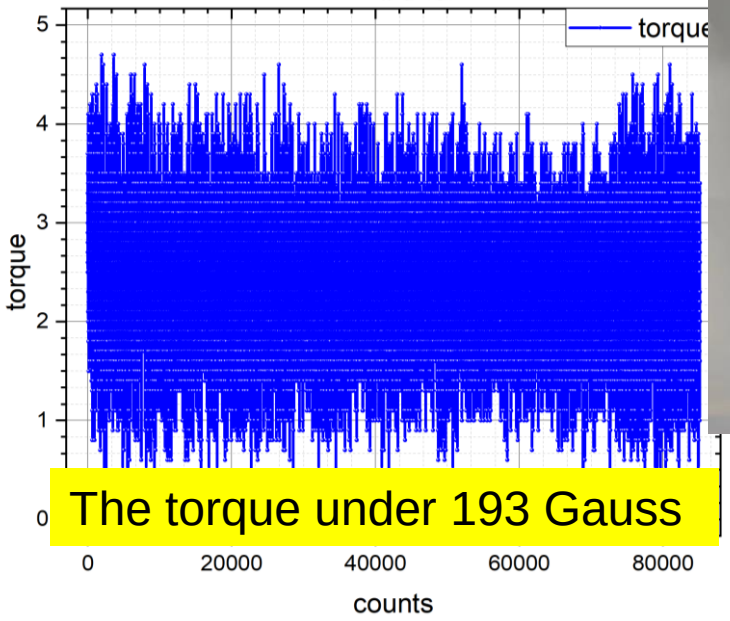


magnetic field direction

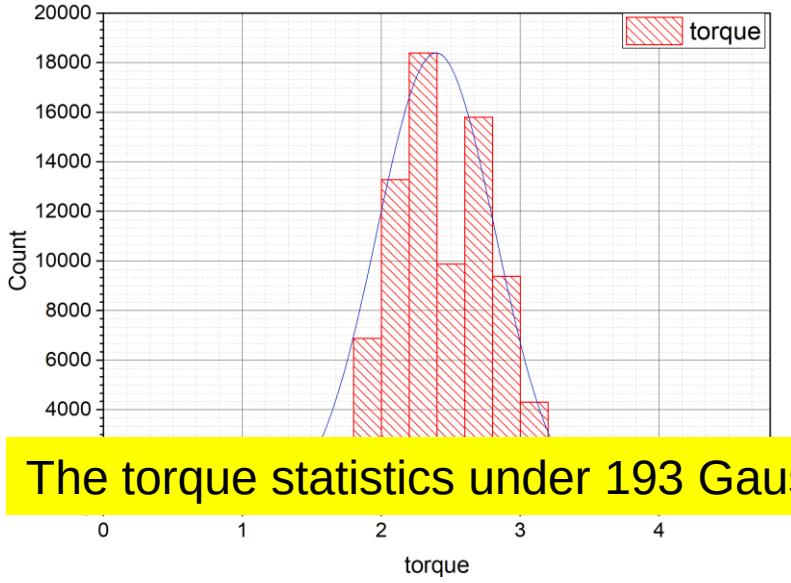
rotation direction of the servo motor



The velocity statistics under 193 Gauss

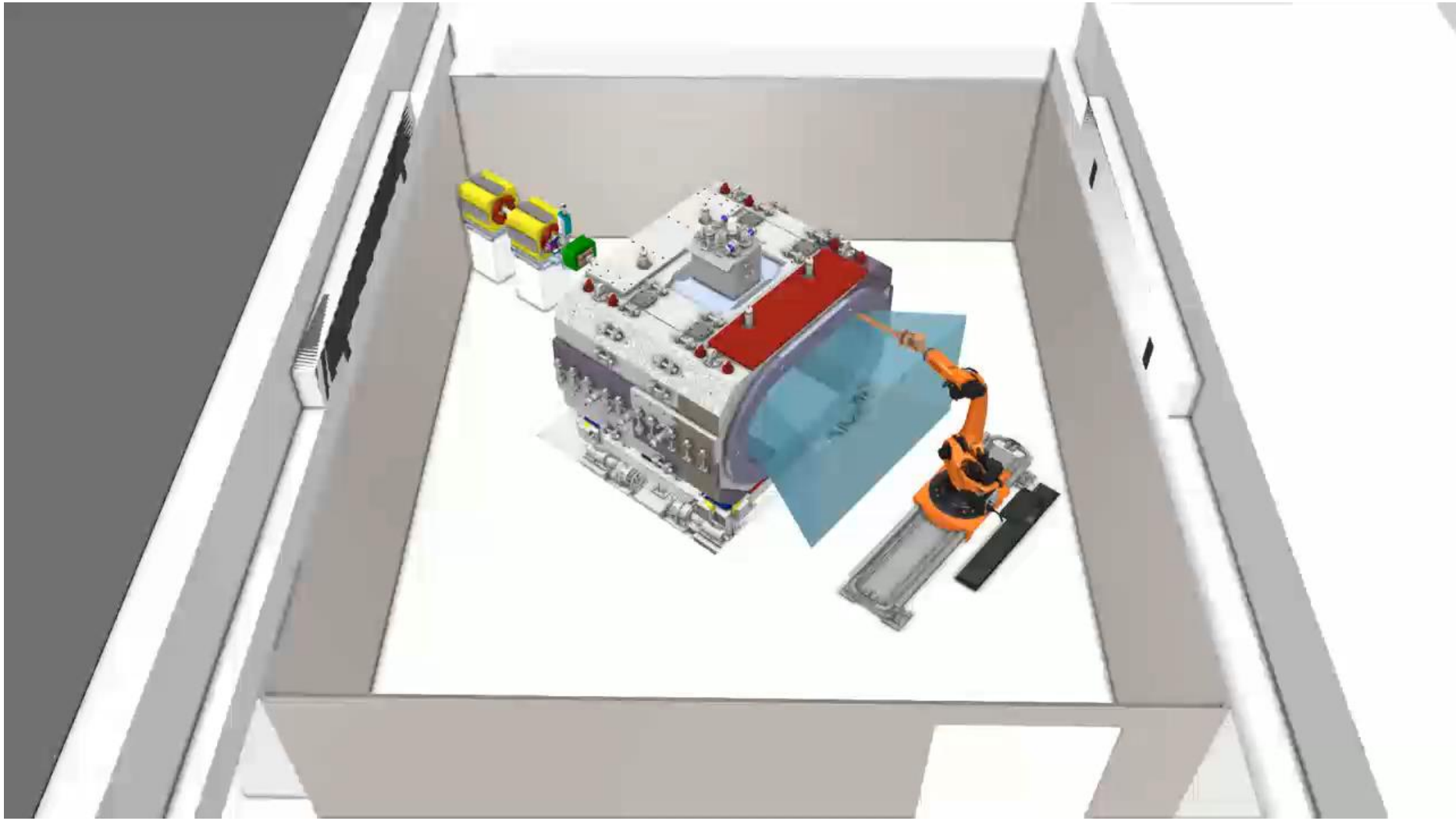


The torque under 193 Gauss



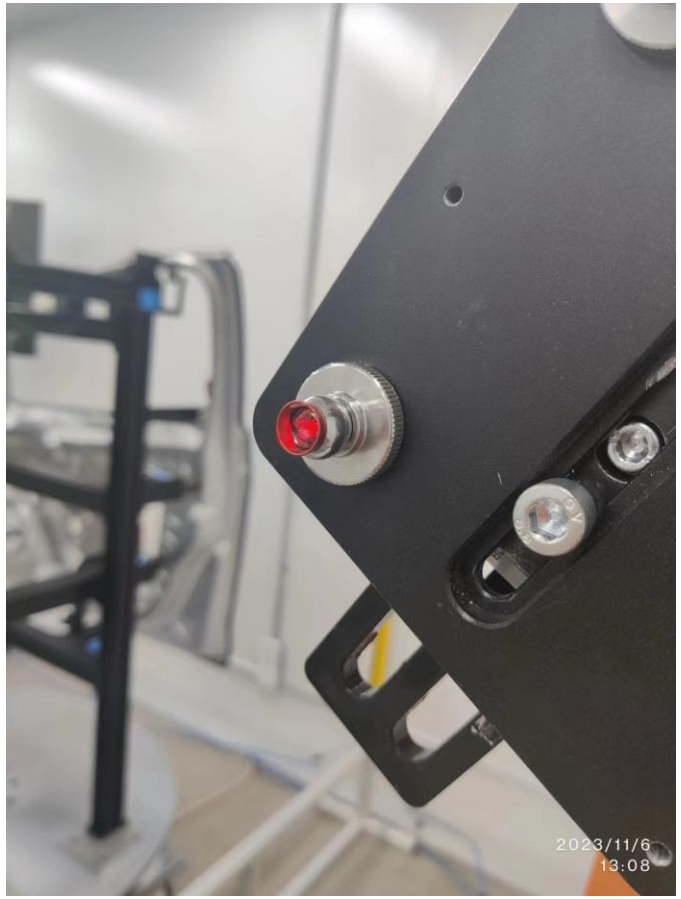
The torque statistics under 193 Gauss

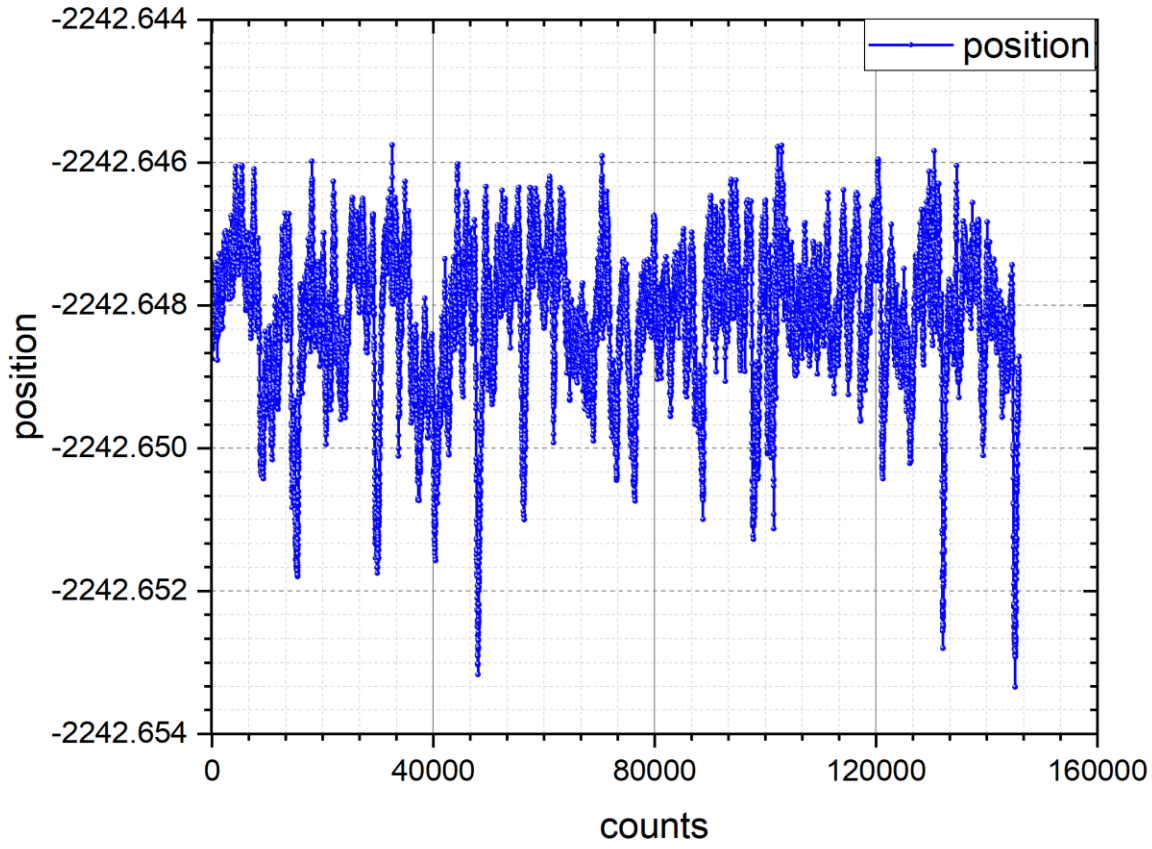
simulation results of the robotic arm



The robotic arm, combined with the ground rail, can meet the accessibility requirements of the magnetic measurement area

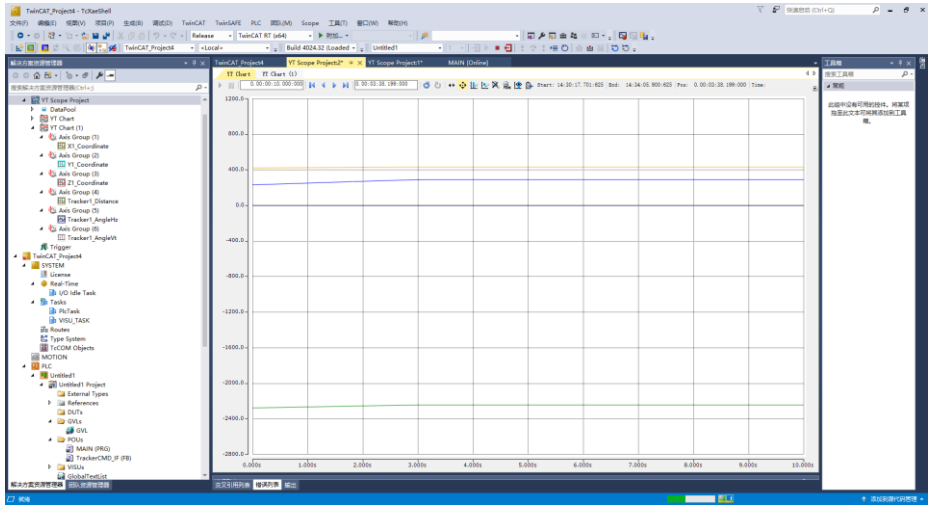
robot arm vibration testing

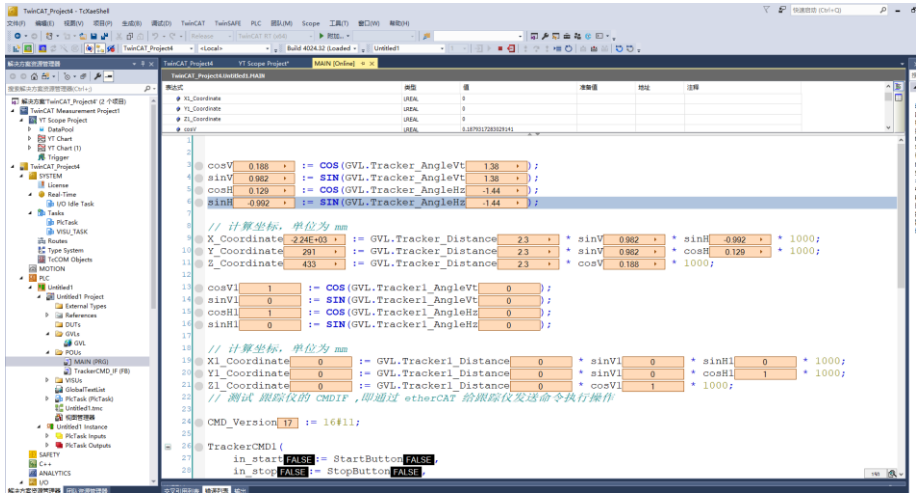




- The laser tracker target ball is placed at the end of the robotic arm, the robotic arm is stationary, and the target ball data is read；
- It is found that the robotic arm vibration is within 0.001mm.

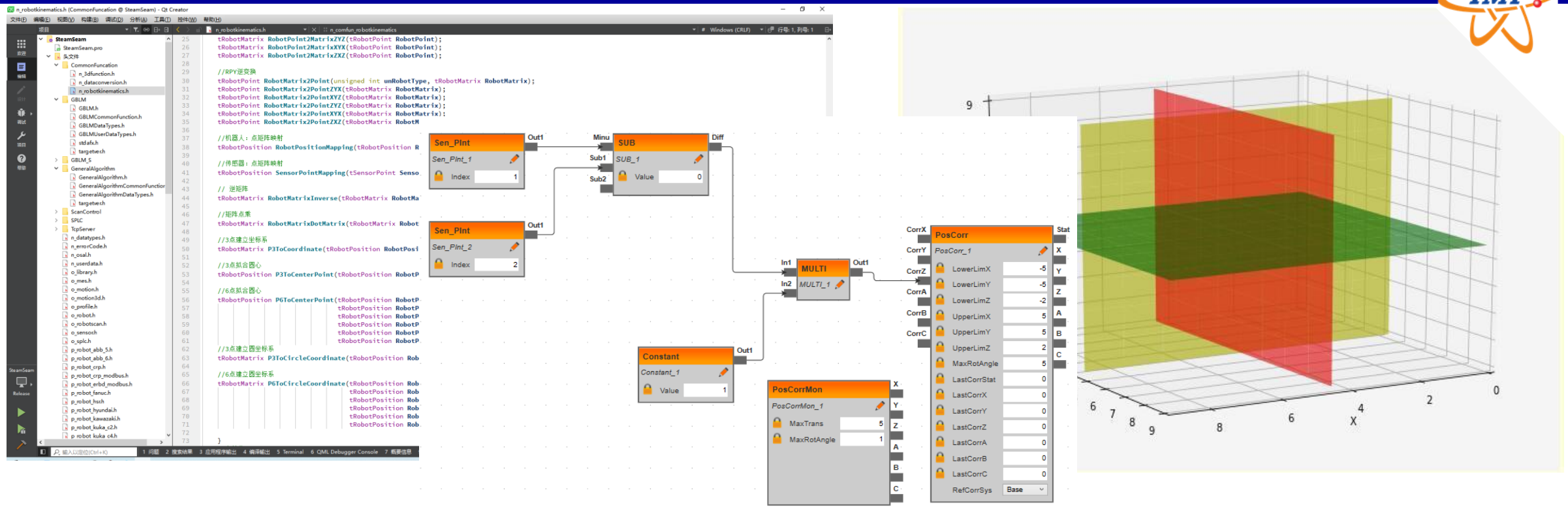
laser tracker coordinate transformation





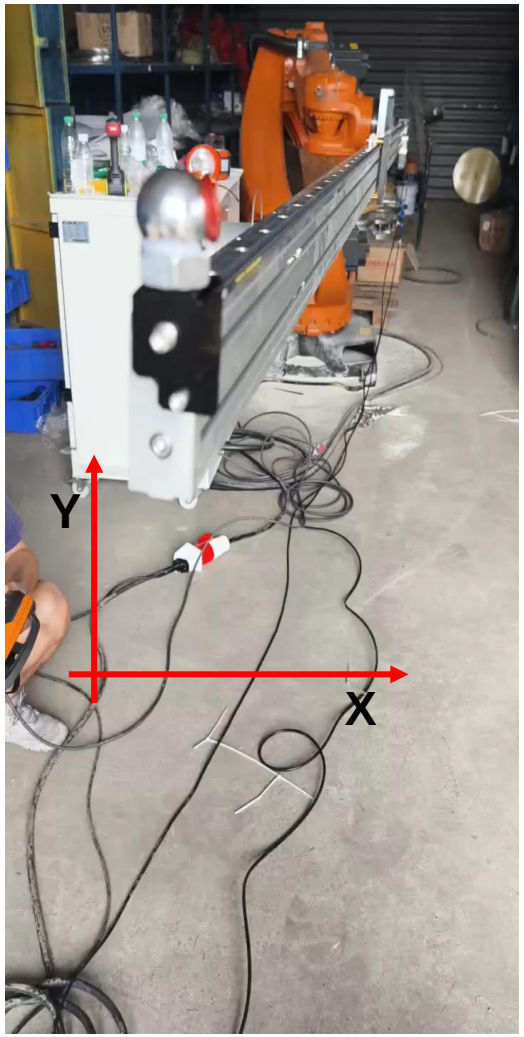
The transformation is required from the laser tracker's own coordinate system to the Cartesian coordinate system with the center of the magnet as the origin, the conversion work has been completed currently.

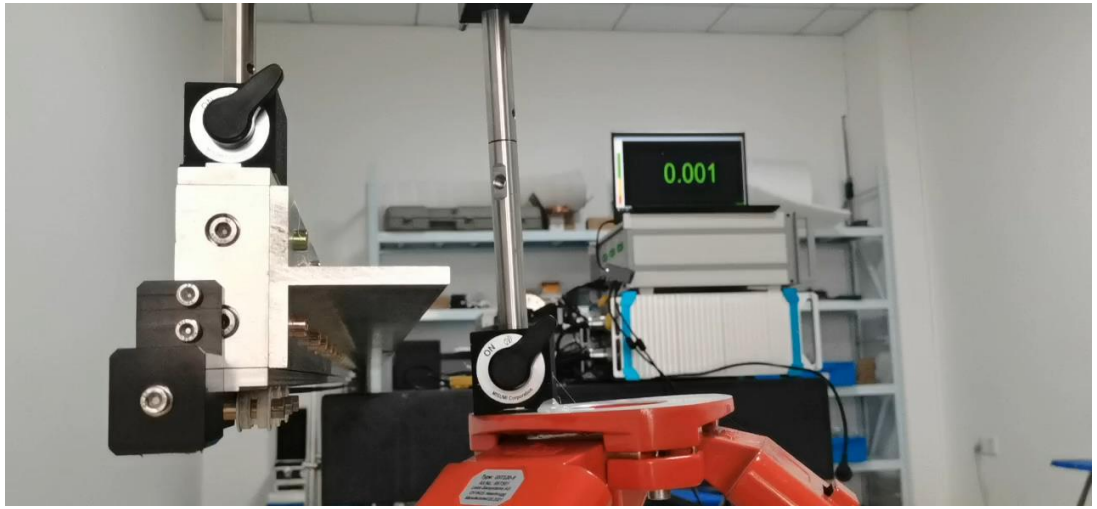
The status of the robotic arm commissioning



- build a testing platform for the establishment of a three-dimensional reference algorithm and display it in the Matplotlib environment；
- Implementation of algorithms related to the robot coordinate system unification.

measurement module experiments





The vibration testing of the measurement module

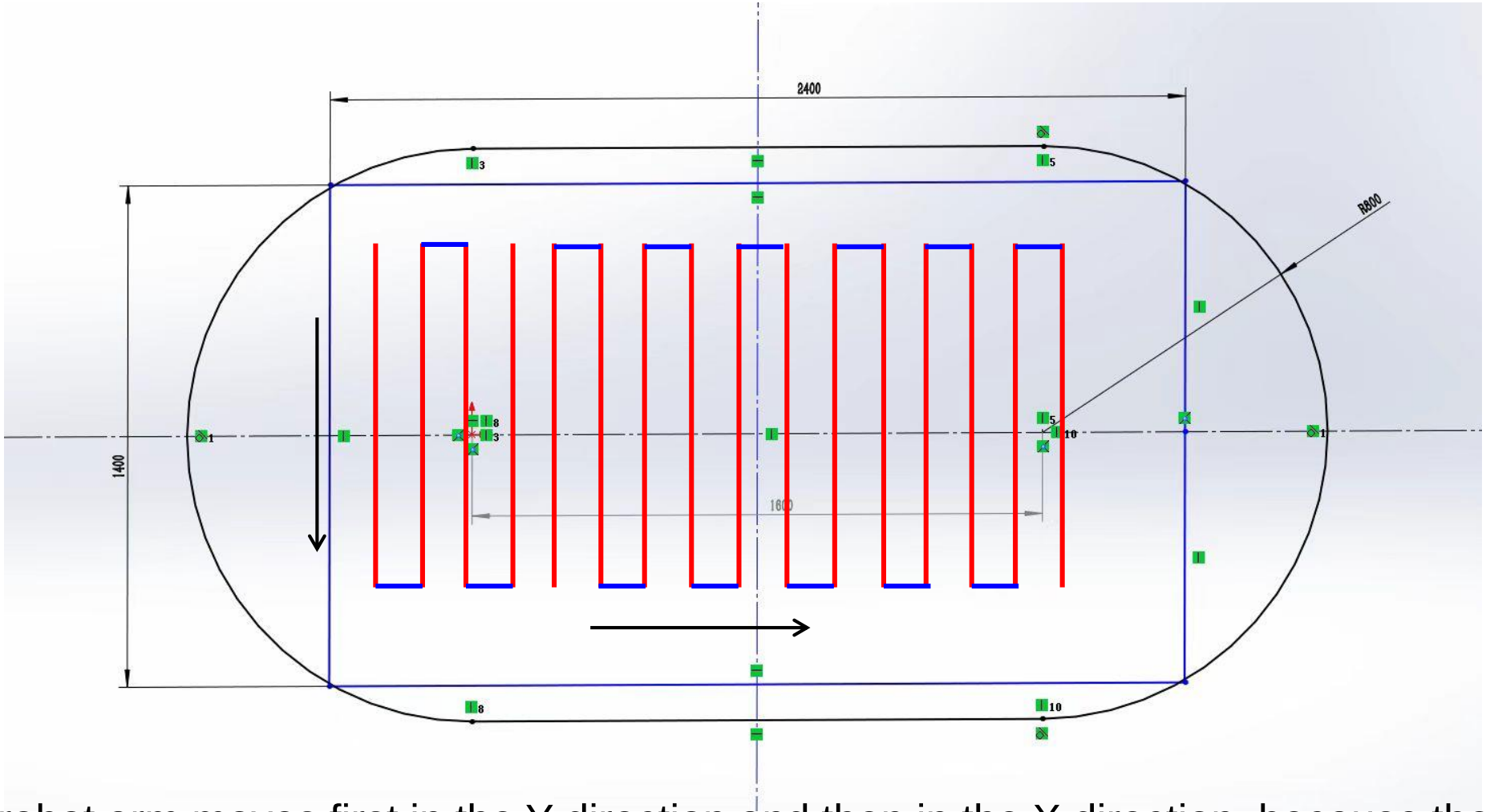
the measurement module

measurement module operating mode

different measurement modules

cross-sectional area of the measurement module

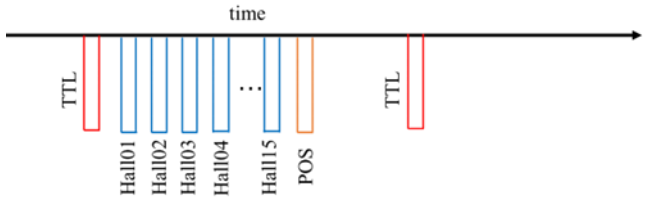
magnetic field measurement mode



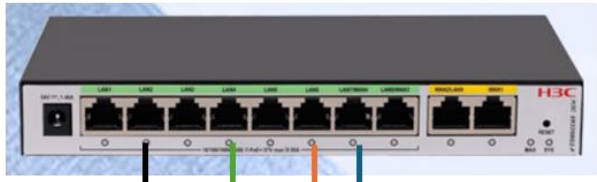
The robot arm moves first in the Y direction and then in the X direction, because the measuring module vibrates less in the Y direction and more in the X direction.

data acquisition system layout

logic of acquisition



router



PC

LAN

LAN

LAN

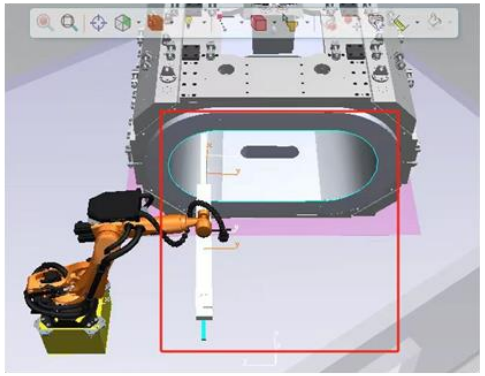
LAN

DAQ
（NI PXIe）

BECKHOFF controller

etherCAT

laser tracker

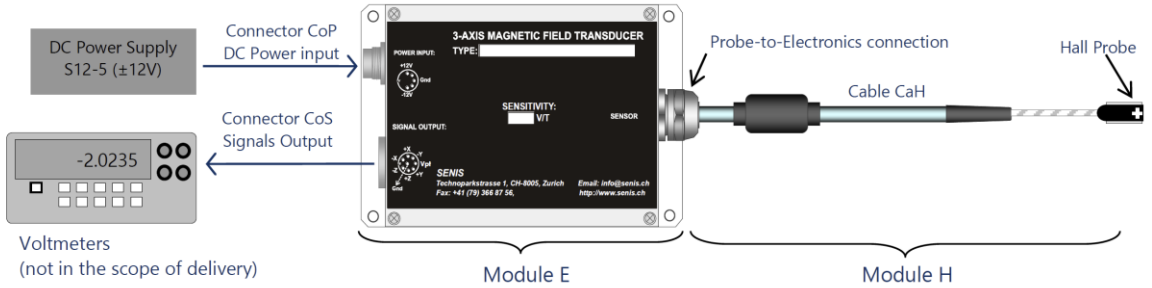


motion control system
for robotic arm and measurement module

0~10V

Hall Array
（Senis F3A）

The Hall array



- Composed of five SENIS company F3A units；
- Maximum range of 6000 Gauss, corresponding to an output voltage of 10V；
- Acquire signals from 15 channels of 5 F3A sensors every second, with magnetic field values ranging from tens of Gauss to 5000 Gauss.

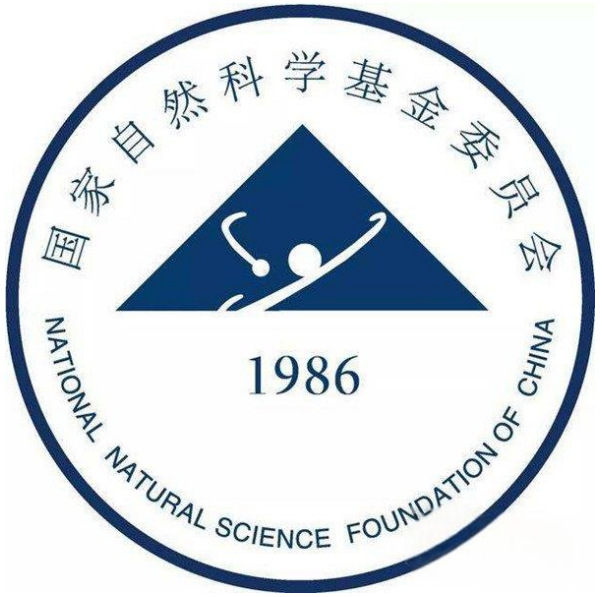
Hall array testing

- The Hall array testing and orientation marking have been completed；
- The Hall array is currently being integrated and debugged with the data acquisition system.

Conclusion and Outlook

- A magnetic field measurement system for large-sized spectrometer magnets has been constructed, using a robotic arm as the transmission device, with Senis company's F3A as the Hall probe, and the measurement technique employs on-the-fly technology to improve efficiency;
- Vibration tests were conducted separately for the robotic arm and the measurement module, with the vibration of the measurement module controlled below 10 seconds, and the performance of the robotic arm motor is unaffected under a magnetic field of 193 Gauss;
- The motion range of the robotic arm combined with the ground rail meets the requirements of the magnetic field measurement area;
- The data acquisition system is under debugging, and the vibration of the measurement module is being further optimized;
- The entire magnetic measurement system is expected to be completed by the end of the year.

Acknowledgements



No. 11927901

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Hefei, China

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