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# USING ONE-DIMENSIONAL HALL PROBE TO MEASURE THE SOLENOID MAGNET FOR CSNS/RCS

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*Abstract*

CSNS(China Spallation Neutron Source) construction is expected to start in 2010 and will last 6.5 years. A long beam transport line is followed with the DTL linac to send the beam a rapid cycling synchrotron (RCS) accelerator. The beam will be focused by the solenoid magnet. This magnet will be located in LEBT system. It has been used with one-dimensional Hall probe to measurement by Institute of High Energy Physics, China. After the measurement, the measurement results meet the design requirements.

## INTRODUCTION

CSNS mainly consists of an H- linac and a proton rapid-cycling synchrotron. The accelerator is designed to deliver a beam power of 100 kW with the upgrade capability to 500 kW by raising the linac output energy and increasing the beam intensity. The solenoid magnet will be locating in linac portion of CSNS; the main function is used to focus the beam.

According to the physical design of the proposed requirements, the main content of the measurement is excitation curve and integral field of the main magnetic field (we called it Bz) and the radial magnetic field (we called it Bx and By). It is very difficult to measure the magnetic field of (Bx and By).

## THE DESCRIPTION OF HALL-PROBE MEASUREMENT FACILITY

The Hall-Probe measurement facility [1] is a 3-axis motion bench (Fig. 1). The movement of 3-axis (x, y and z) can be operated by computer. The positioning accuracy of x, y a nd z axis is ±0.001mm and the positioning repeatability accuracy is ±0.01mm. In addition, this machine can be also used to adjust the rotation and pitch adjustment probe ensure that the probe can measure the magnetic field perpendicular to enter the area of the magnet, so that the total is a five-dimentional adjustment system. The Teslameter and Hall probe are produced by Group3 Led. The sensitive of the MPT-141Hall Probe is 1× 0.5 mm [2].

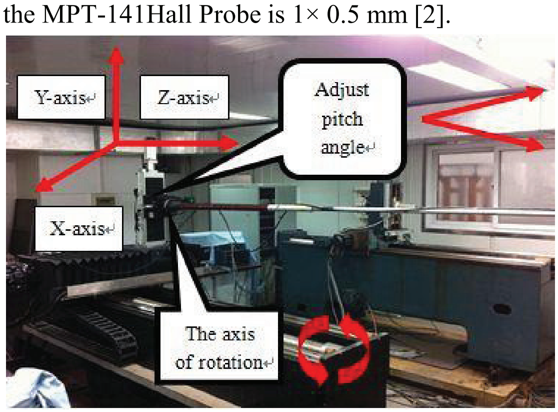


Figure 1: Hall-Probe Measurement Facility.

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The DTM-151 Digital Teslameters [2] offer accurate, high resolution measurement of magnetic flux densities, with direct readout in tesla or gauss, and serial communications by fiber optics or RS-232C for system applications.The instruments are light and compact, and the probes are easy to use. The DTM-151 has been engineered to withstand the severe electrical interference produced by high voltage discharge.

Table 1: The Performance Overview of DTM-151 and MPT-141

| Hall Probe | Sensitive area(mm) | The measurement of maximum magnetic field |
|---|---|---|
| MPT-141 | 1×0.5 | 3T |

| Accuracy/25℃ | Zero drift(μT/℃) |
|---|---|
| ±0.01% | ±1 |

| Basic accuracy | Temperature coefficient |
|---|---|
| 0.01% of reading + 0.006% of full scale | 10ppm/℃ overall achieved using temperature sensor in probe |

| Temperature Stability | Time stability |
|---|---|
| DTM-151 with MPT-141 probe: calibration: ±10ppm of reading/℃ max. Zero drift: ± (1 microtesla + 0.0003% of full-scale) /℃ max. Add -3ppm /℃for each meter of probe cable | ±0.1% max. over 1 year |

## THE PROCESS OF MEASUREMENT

### *The Content of Measurement*

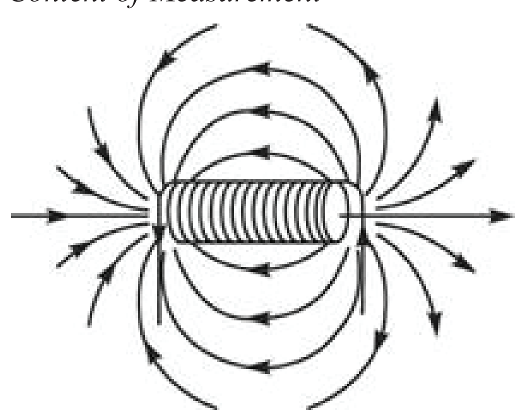

Figure 2: The Magnetic field distribution of Solenoid Magnet.

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According to the magnetic field distribution of the solenoid magnet (Fig. 2), the main content of the measurement is excitation curve and integral field of the main magnetic field (Bz) and the radial magnetic field (Bx and By).

### *The Process of Collimation*

The collimation of magnet is by Theodolite and Level. These devices are shown in Figure 3.

(1) The theodolite has been levelled, and then the probe has been moved back and forth along the Z axis for align ment of the theodolite.

(2) Adjusted the level of the magnet by the Level and the engraved lines of the magnet.

(3) Adjusted the rotation of the magnet by the theodolite and the engraved lines of the magnet.

The collimation of the magnet has been completed by the above steps.

Figure 3: The devices of collimation.

### *Discovery and Analysis of the Problem*

In the process of measurement, we found the data of radial magnetic field (Bx and By) is significantly larger (100-140 Gs). This obviously does not match the theoretical data.

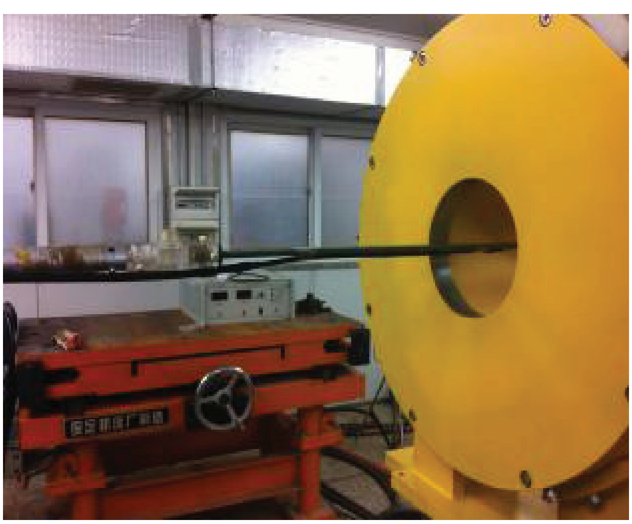

Figure 4: The Measurement of radial magnetic field. The data of the radial magnetic field is shown in Figure 5.

When the position of the Hall-probe has been located in the device center of the solenoid magnet, the data of field should be 0 or close to 0. In order to verify the results, we flipped the Hall-probe to measure [3].The measurements system is shown in Figure 4.

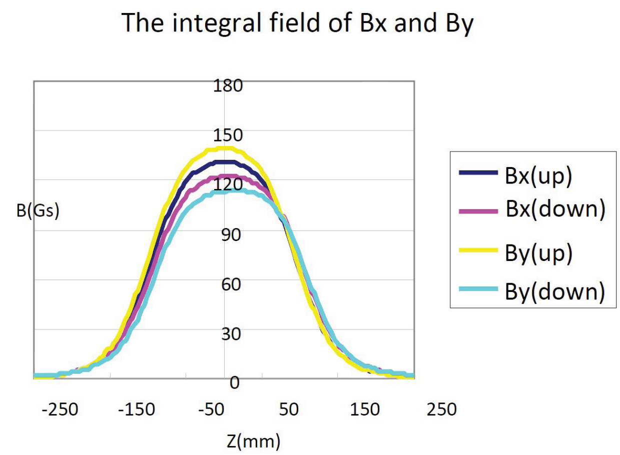


Figure 5: The data of the measurement.

According to the data of the measurement, we found that the measurement error mainly come from the collima tion system and the effect of gravity for Hall-probe. These errors led to the Hall-probe and the centre device of magnet is formed at an angle (we called it "Φ") in the measure ment (The angle is shown in Figure 5). Because it is very sensitive for the magnetic field of the solenoid magnet.

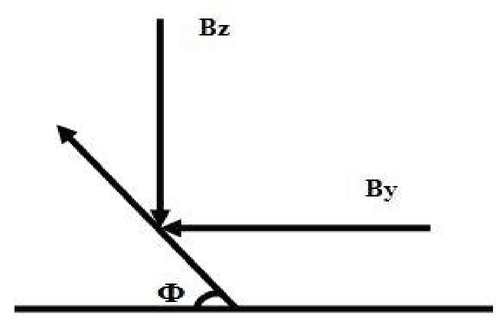


Figure 5: The angle (Φ).

We can know that the data measured by the probe is the vertical component of Bz and By or Bx. Therefore, we used two-way probe measurements obtained equations to solve for By or Bx.

$$\begin{cases} Bz \bullet \cos\phi + B_{y/x} \bullet \sin\phi = B_{up} \\ Bz \bullet \cos\phi - B_{y/x} \bullet \sin\phi = B_{down} \end{cases}$$

Because the angle equal to about 90°, so we can draw:

$$\begin{cases} Bz \bullet \cos\phi + B_{y/x} = B_{up} \\ Bz \bullet \cos\phi - B_{y/x} = B_{down} \end{cases}$$

$$B_{y/x} = (B_{up} - B_{down}) / 2$$

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## THE RESULTS OF MEASUREMENT

Table 2: The Transfer Function of Integral Excitation

| I(A) | Transfer function |
|---|---|
| 40 | 1 |
| 80 | 1.001 |
| 120 | 1.002 |
| 160 | 1.002 |
| 180 | 1.002 |
| 200 | 1.002 |
| 220 | 1.002 |
| 228.5 | 1.002 |
| 240 | 1.002 |

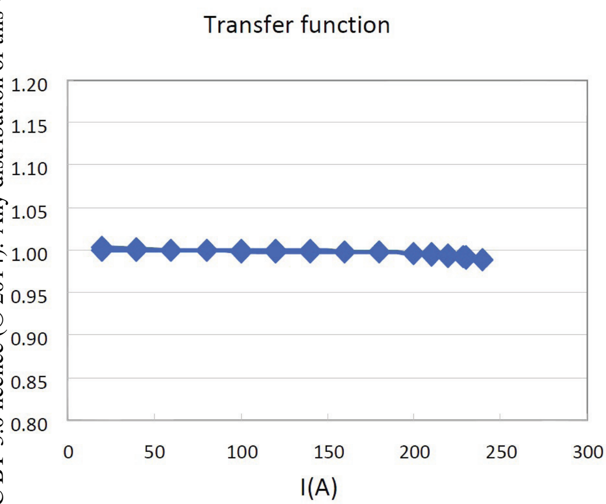

Figure 6: The Transfer Function.

Table 3: The Error Distribution of Bz

| X(mm) | BL(Gs*mm) | Error |
|---|---|---|
| -40 | 1037279.9 | 0.00026 |
| -20 | 1037131.8 | 0.00011 |
| 0 | 1037011.8 | 0 |
| 20 | 1036943.0 | -0.00006 |
| 40 | 1037368.9 | 0.00034 |
| 50 | 1037699.9 | 0.00066 |

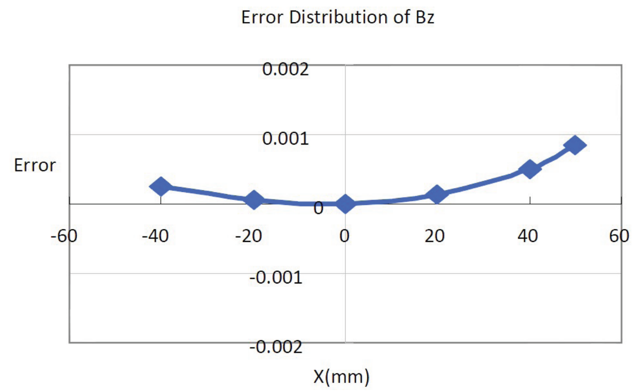

Figure 7: The Error Distribution of Bz.

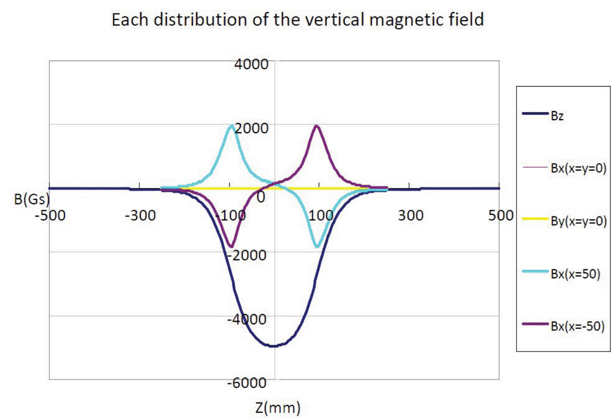

Figure 8: The Each Distribution of the Vertical Magnetic Field.

## CONCLUSION

According to the measurement results, when the current is 228.5A, the integral field of the main magnetic field for the solenoid magnet is 103.7T·mm. At the entrance of the solenoid magnet, the gradient of radial magnetic field is uniform. The radial integral field of the solenoid magnet is small. The measurement results fully meet the design requirements.

## ACKNOWLEDGEMENT

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