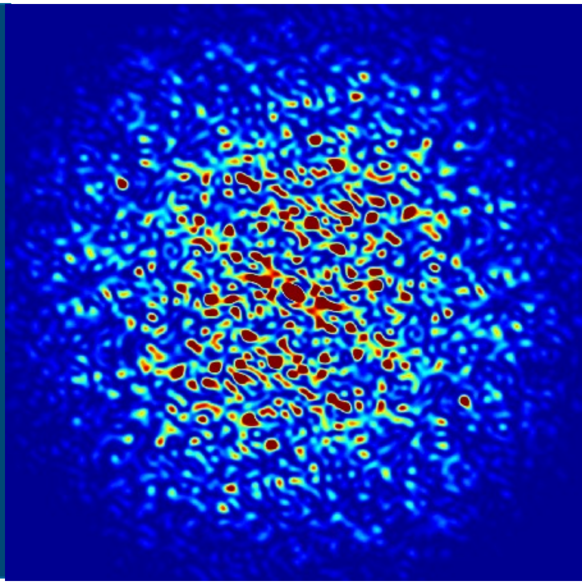
ACCURATE MEASUREMENTS OF UNDULATOR PARTICLE BEAM ENTRANCE/EXIT ANGLES USING IMPROVED HALL PROBES AND CALIBRATION PROCESS



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IPAC 21, Virtual Edition

Campinas, SP, Brazil

May 24-28, 2021

Improving Hall probe accuracy

Discussion

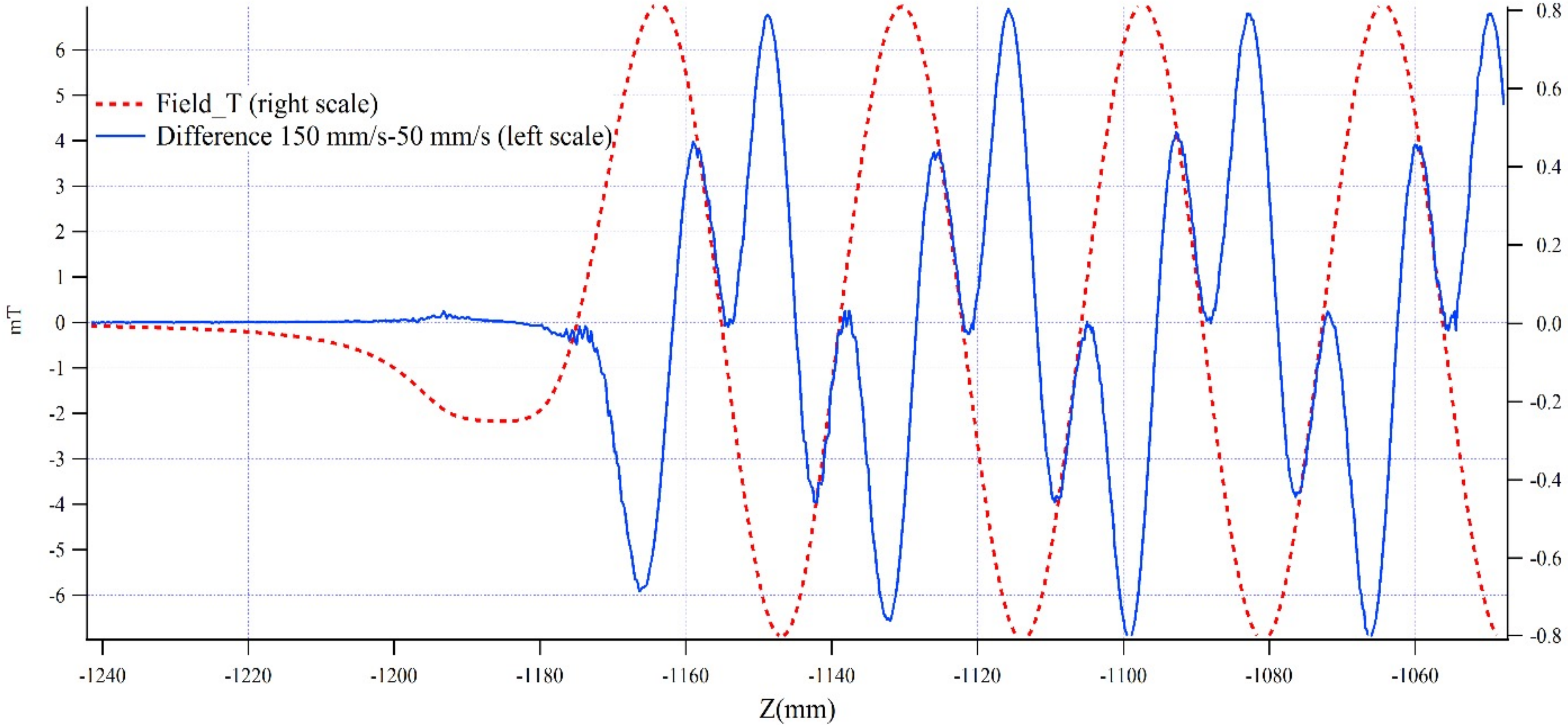
An issue regarding the general question of the accuracy of Hall probe measurements has been unclear until recently. Calibration of the probe with a calibration system and measurements of the undulators are done under quite different conditions. Calibration is done at rest with a stable field, and measurements are done on the fly in a high-gradient field. It is quite obvious that one cannot expect exact accuracy of the field obtained in this case. It is also obvious that it is easy to find the difference: just measure the field of the device on the fly and at rest at a few points or compare results done at different scan speed.

APS-U storage ring requirements

Table 1: Entrance and exit angles (in µrad) requirements for two independent (canted) IDs installed in a straight section.

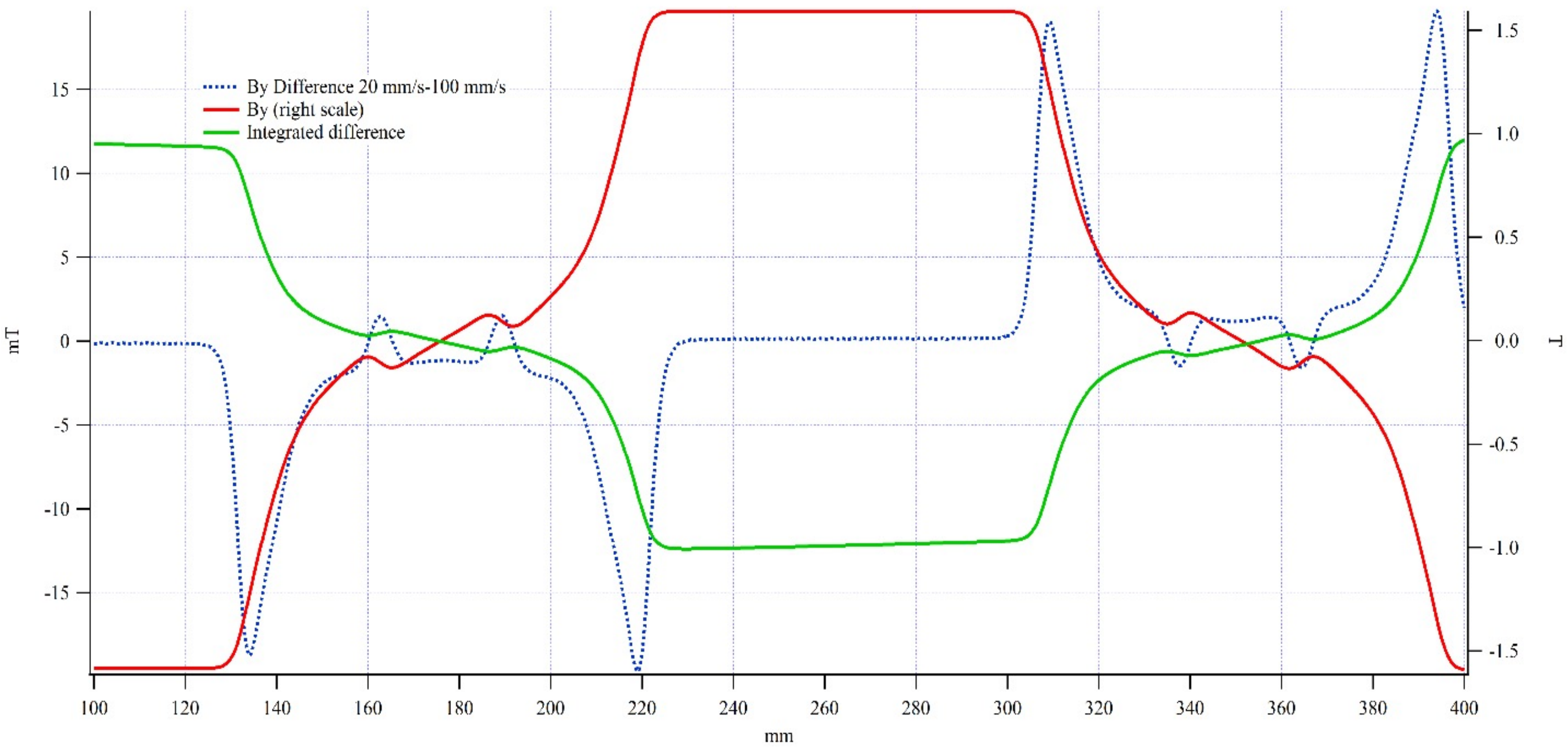
Entrance/ exit angles	Experiment gap range	Usable gap range	Full gap range
Horizontal	±3.9	±5	±10
Vertical	±1.25	±2.5	±10

33 mm period device



Hall probe scan difference at scanning speed of 150 mm/sec and 50 mm/sec

Long period device speed dependence

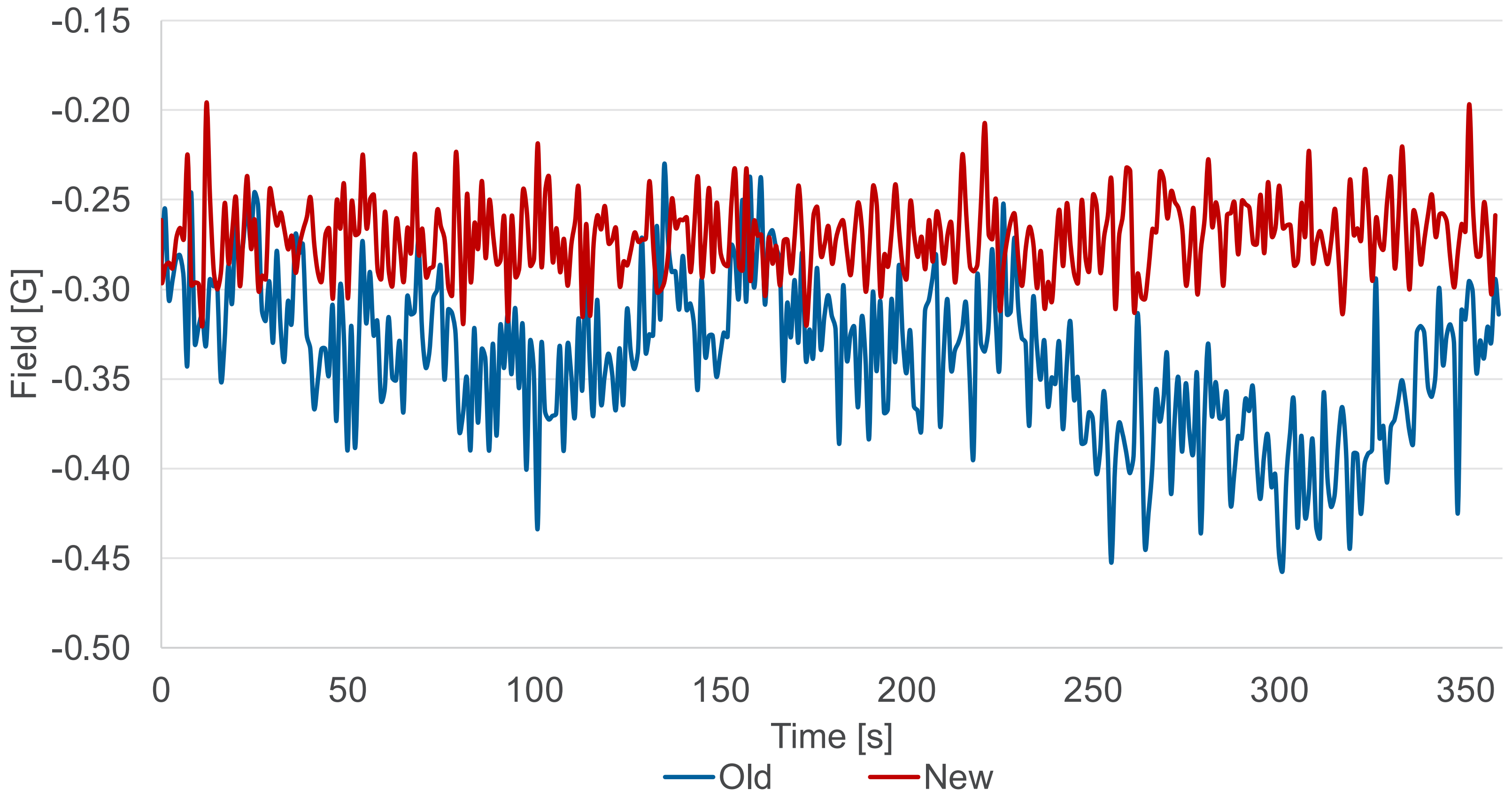


35 cm period device. Red curve: By field; blue: difference of the field measured at scans with speed of 100 mm/s and 20 mm/s; green: integral of the difference.

Discussion

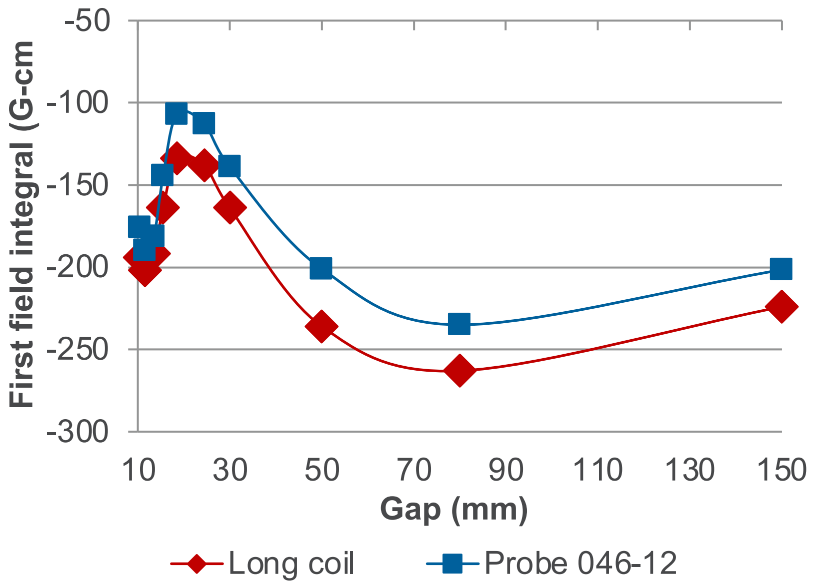
Results shown in previous slide indicate that the integral of the field difference for different speeds is very close to the locations of the strong field change. Integral of this difference is very close to the magnetic field. This proves that the effect is due to the existence of inductance and/or capacitance at a signal cable.

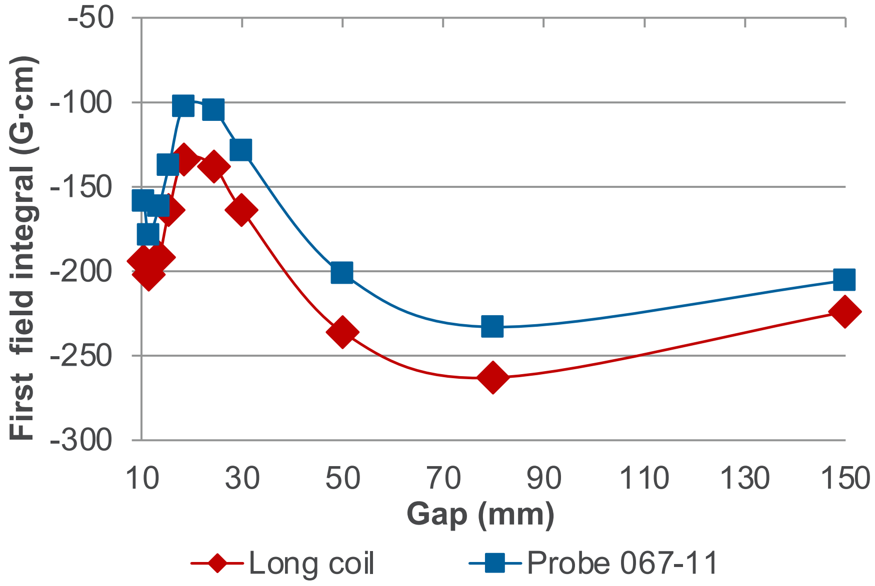
Comparison of zero drift



Old Hall probe RMS 0.066 G, zero field drift. New Hall probe RMS 0.02 G No zero Field Drift

Comparison of Hall probe and long stretched coil measurements





Discussion

The accuracy of angle determination to satisfy APS-U requirements must be at the level of ±0.5 μrad. To provide such accuracy, fine correction of the calibration table for the Hall probe was performed using long coil as a reference. A short description of the procedure is presented below in the next slide.

Fine tuning of the Hall probe calibration with long stretched coil measurements

The errors in the odd-numbered terms of Hall probe calibration coefficients have no effect on the end angles, only the even-numbered ones (symmetric components) have. While the even-numbered terms can be corrected by comparing the field integral measurements, of Hall probe and coil.

A short description of the procedure to correct the Hall probe calibration table is given below.

Step 1. Get the B-V curve of the Hall sensor $C_{ini}(V)$ from the regular calibration process with the help of a standard dipole magnet.

Step 2.Wipe out the symmetrical components in the B-V curve obtained in. Now only asymmetrical components remain in the new B-V curve, so we note the curve as $C_{asym}(V)$

$$C_{asym}(V) = \frac{C_{ini}(V) - C_{ini}(-V)}{2}.$$

Step 3. Measure an undulator over all gap ranges using the Hall sensor, keeping only the voltage data *V(g;z)*. With the help of the B-V curve obtained in step 2, translate the *V(g;z)* in step 3 into the magnetic field:

$$B(g;z) = C_{asym}(V(g;z)),$$

$$J_{asym}(g) = \int_z B(g;z)dz.$$

Generate a symmetrical B-V curve $C_{sym}(V)$ with the help of a linear model regression algorithm, which satisfies:

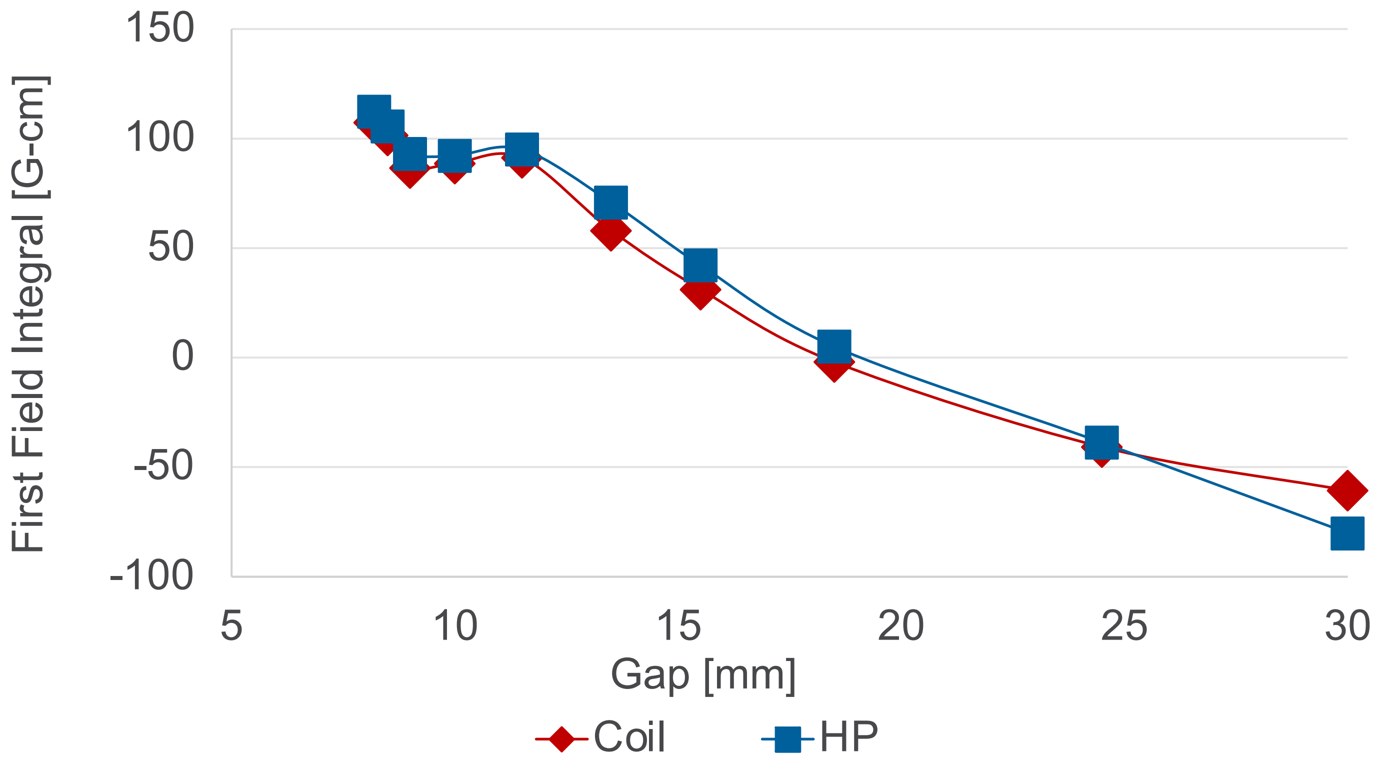
$$J_{asym}(g) + J_{sym}(g) = J_{coil}(g),$$

where $J_{coil}(g)$ denotes the field integral measured by the long coil, and

$$J_{sym}(g) = \int_z C_{sym}\big(V(g;z)\big)dz.$$

Where; B-magnetic field; V-Hall probe voltage; g- ID gap; z-ID longitudinal distance.

Comparison Senis probe vs Coil (after improvements)



Conclusion

As a result of improvements, it is possible now to achieve the requirement accuracy of Hall probe angles measurements of ±10 G-cm.