SLAC Traveler for LCLS-II SXPS Measurement Results

This traveler is intended to document checking of the final magnetic measurements of Soft X-Ray beamline (SXR) Phase Shifters (SXPS) performed on the Dover bench in the Magnetic Measurement Facility (MMF) at SLAC after the completion of all tuning activities. It contains basic performance indicators compared against tolerances as well as documentary information both in graphical and textual representation.

Serial number from magnet label:	SXPS-16349

Measurement Procedure:

The measurements have been carried out after the undulator segment had been fully tuned according to the "LCLS-II Phase Shifter Test Plan" (LCLS-TN-17-2).

Evaluation of Hall Probe Scans: Data Listings A

MATLAB function "EvaluatePhaseShifterField" on	10/01/2019 11:35	
A. SCAN PARAMETERS		
Serial Number	SXPS-16349	
z Scanning Date & Time Range	06/24/2019 22:52—06/25/2019 04:58	
Phase Shifter Temperature	20.0483±0.0296	°C
x axis position	0.0337	mm
y axis position	0.0000330	mm
Scans averaged	3	
Nominal Device Length	0.0825	mm
Total Sampling Distance	0.700	mm
Integration Cell Length	0.400	mm
Earth Field Correction B_x	-0.100	mm
Earth Field Corection B_y	-0.300	mm
Nominal Closed Gap Height	10.000	mm

Evaluation of Hall Probe Scans: Data Listing B

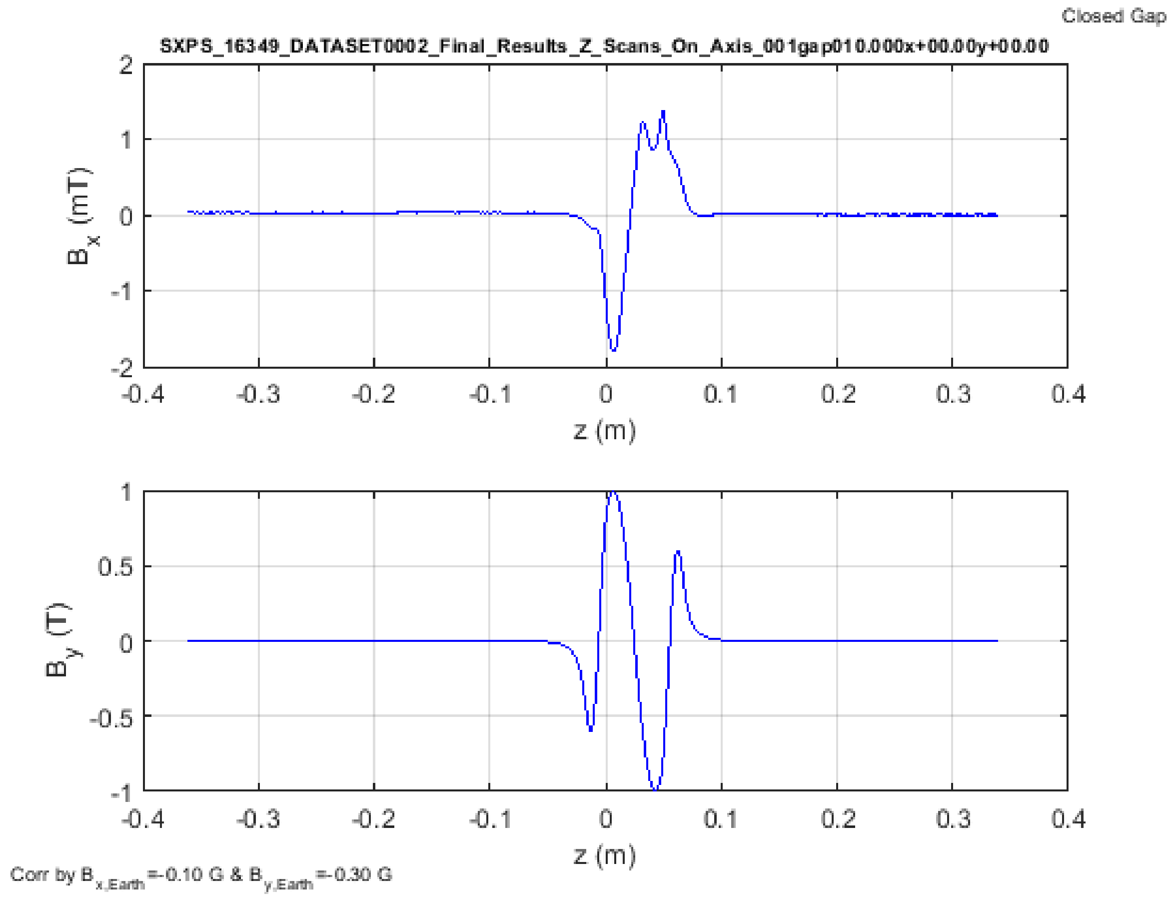
MATLAB function "EvaluatePhaseShifterField" on	10/01/2019 11:35	
B. CORE EVALUATIONS FOR CLOSED GAP		
Closed Gap Scanning Date & Time	06/25/2019 02:17	
Closed Gap Temperature	19.99± 0.20	°C
Encoder Gap	10.0000	mm
Encoder Gap Raw	394,956	
Measured $I1X$ (Cell Range Total)	+9.11 (46 % of Tolerance)	μTm
Measured $I2X$ (Cell Range Total)	+0.89 (2.0 % of Tolerance)	μTm^2
Measured $I1Y$ (Cell Range Total)	-10.58 (53 % of Tolerance)	μTm
Measured $I2Y$ (Cell Range Total)	-8.04 (16 % of Tolerance)	μTm^2
Measured PI (Cell Range Total)	4,464.9	T^{2}mm^3
Required min PI (Cell Range Rotal) at Closed Gap	3,814.0	T^{2}mm^3

MATLAB function "EvaluatePhaseShifterField" on	10/01/2019 11:35	
C. CORE EVALUATIONS FOR OPEN GAP		
Open Gap Scanning Date & Time	06/25/2019 03:52	
Open Gap Temperature	20.08± 0.19	°C
Encoder Gap	100.0000	mm
Encoder Gap Raw	2,194,956	
Measured $I1X$ (Cell Range Total)	+2.17 (11 % of Tolerance)	μTm
Measured $I2X$ (Cell Range Total)	+0.71 (1.6 % of Tolerance)	μTm^2
Measured $I1Y$ (Cell Range Total)	-2.05 (10 % of Tolerance)	μTm
Measured $I2Y$ (Cell Range Total)	-1.90 (3.8 % of Tolerance)	μTm^2
Measured PI (Cell Range Total)	8.5	T^{2}mm^3
Required max PI (Cell Range Rotal) at Open Gap	750.0	T^{2}mm^3

MATLAB function "EvaluatePhaseShifterField" on	10/01/2019 11:35	
D. ENCODER SETTINGS		
Gap Encoder Offset	9.7478	mm

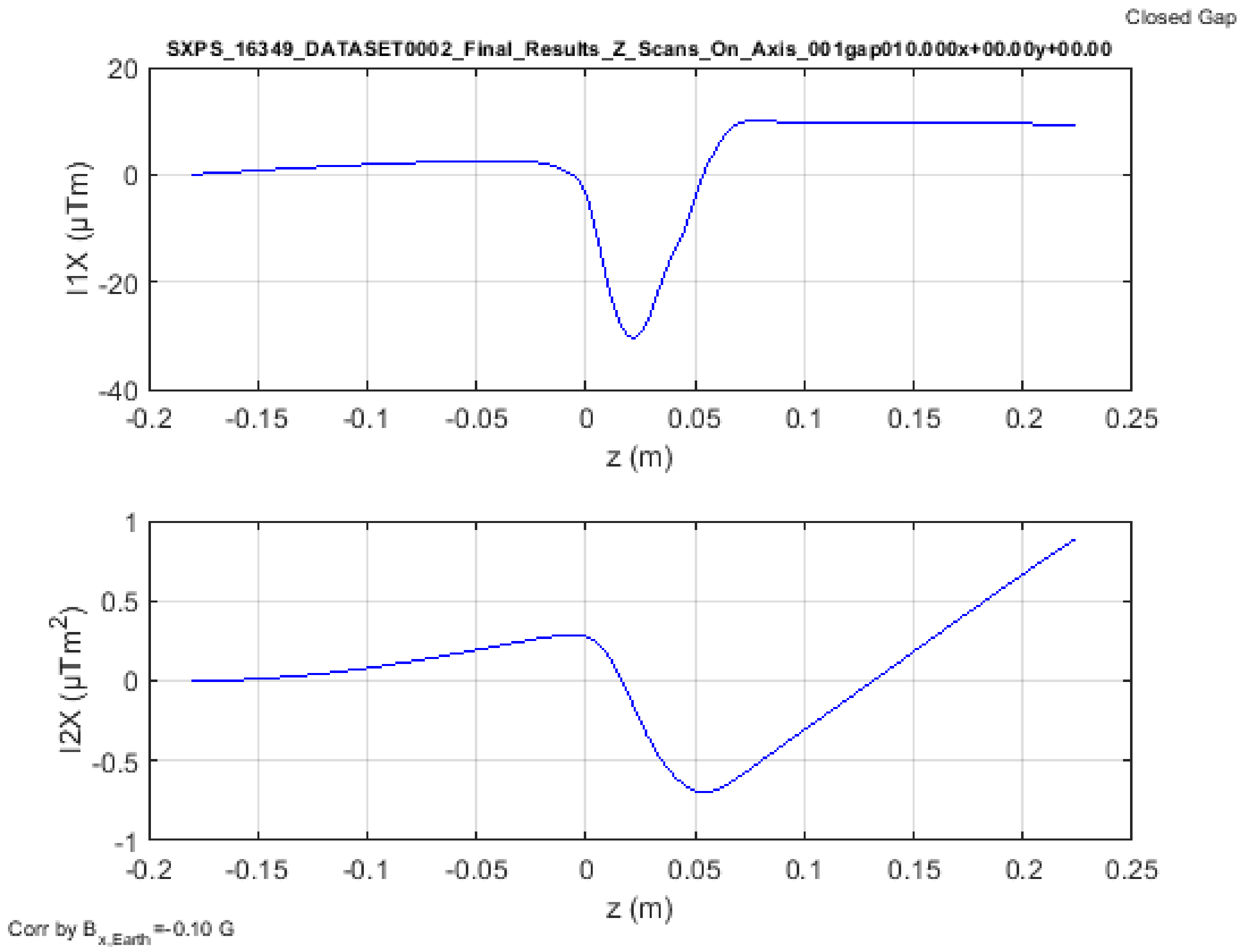
The following figures show result of the field analysis at the closed gap.

Hall Probe Scans at Closed Gap: Horizontal and Vertical Field



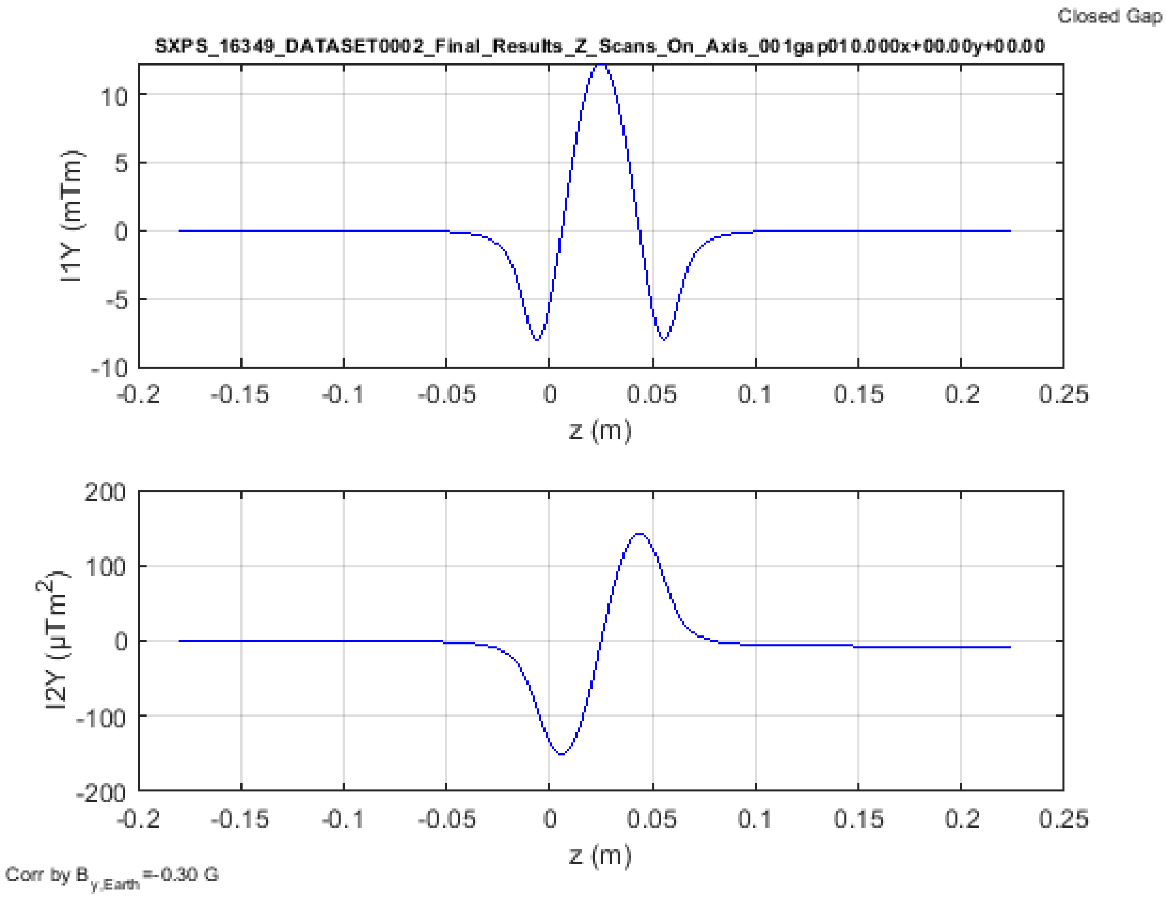
The figures show the x (upper) and y (lower) field components along the phase shifter beam axis for the closed gap. The amount of earth field correction applied is shown in the lower left hand side. [Documentary Information]

Hall Probe Scans at Closed Gap: Horizontal 1st and 2nd Field Integrals



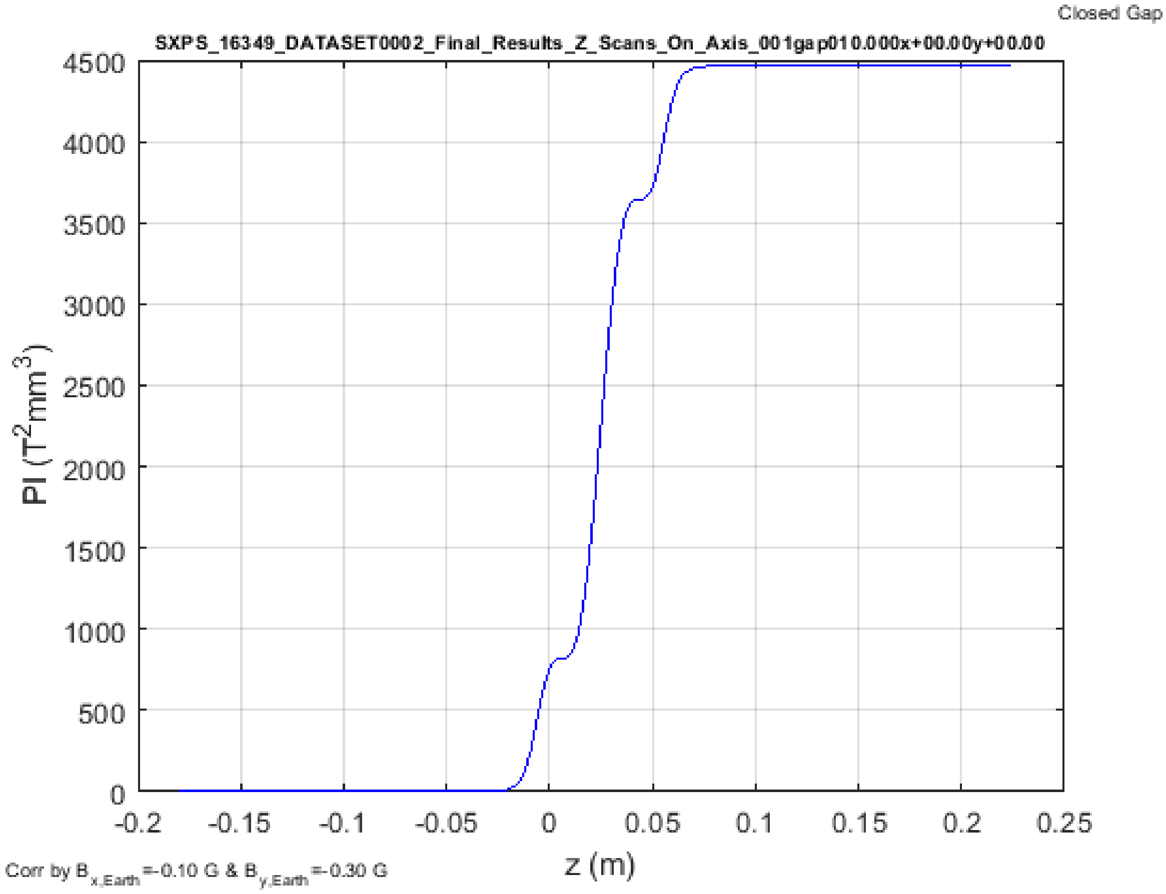
The figures show the horizontal first (I1X, upper) and second (I2X, lower) field integrals along the phase shifter beam axis for the closed gap. The amount of earth field correction applied is shown in the lower left hand side. [Documentary Information]

Hall Probe Scans at Closed Gap: Vertical 1st and 2nd Field Integrals



The figures show the vertical first (I1Y, upper) and second (I2Y, lower) field integrals along the phase shifter beam axis for the closed gap. The amount of earth field correction applied is shown in the lower left hand side. [Documentary Information]

Evaluation of Hall Probe Scans for Closed Gap: Phase Integral Plot



The figure shows the phase integral, PI, of an electron calculated from the measured on-axis magnetic field components for the closed gap:

$$PI(z) = \int_0^z BL_{x1}^2(\hat{z})\,d\hat{z} + \int_0^z BL_{y1}^2(\hat{z})\,d\hat{z}$$

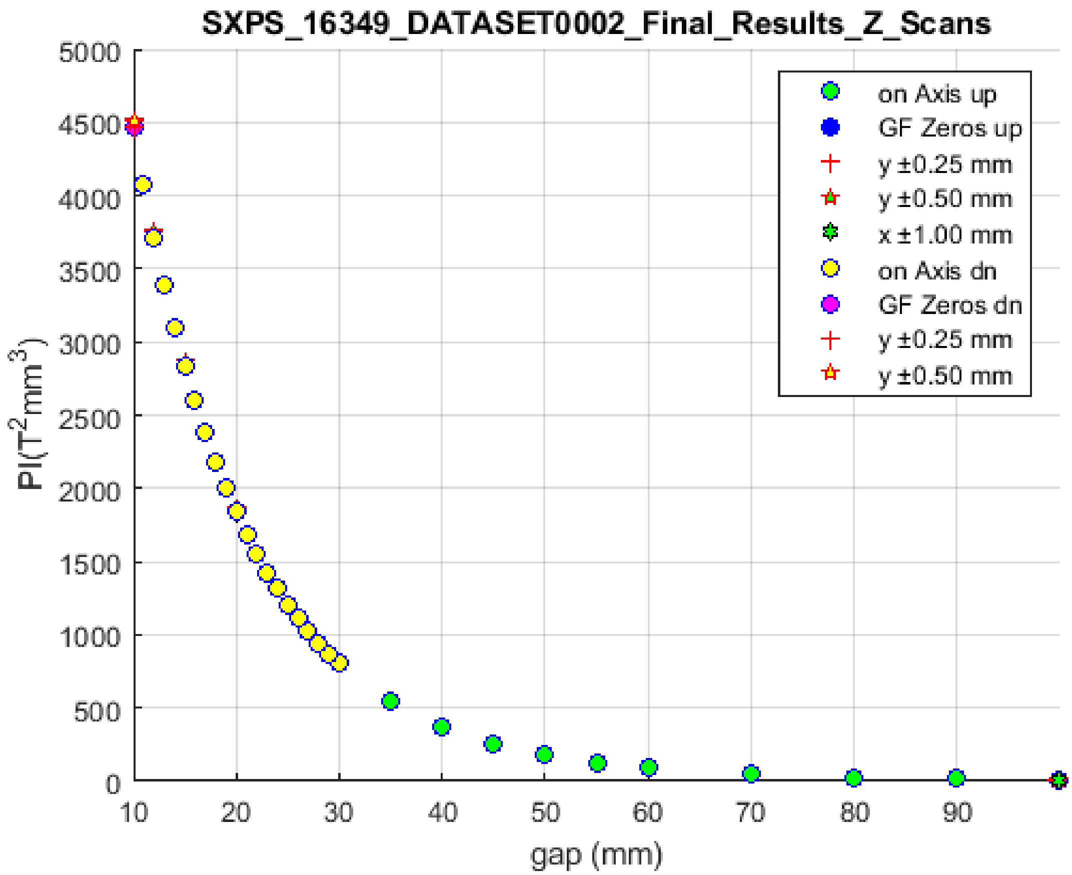
with

$$BL_{x1,y1}(z) = \int_0^z B_{x,y}(\hat{z})\,d\hat{z}.$$

The phase integral is proportional to the phase slippage due to the presence of the magnetic field. There is an additional contribution to phase slippage due to the fact that the speed of the electrons is less than the speed of light. This additional contribution is corrected by the undulator segment and does not need to be corrected again for the phase shifters.

The following figures show the results of the gap dependent analysis.

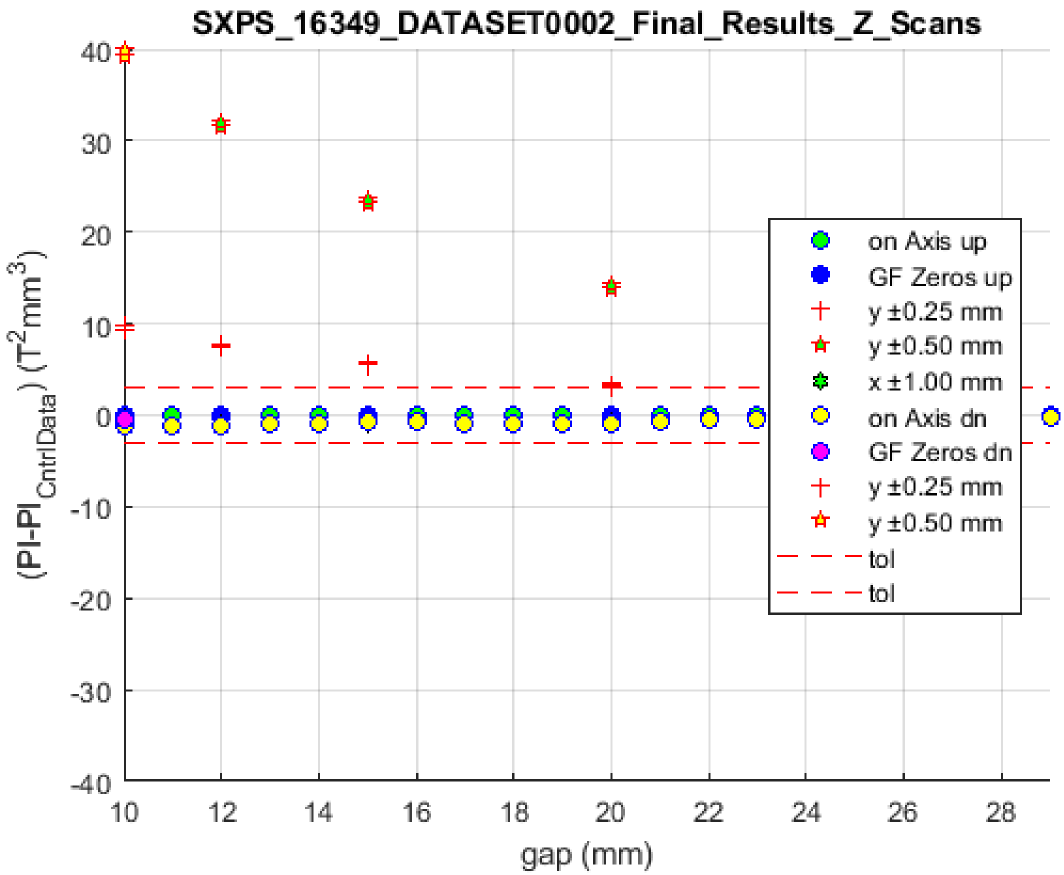
Evaluation of Hall Probe Scans: PI vs. gap



The figure shows phase shifter Phase Integral, PI, as a function of gap over the 10 mm—90 mm gap range. The legend shows a number of different cases that will be explained later in this document because their effect cannot be observed in this full scale plot. Note: The gap values are derived from the readings of the gap encoder installed on the SXPS. In that sense these are nominal gap numbers that will be close but not identical to each of the individual magnet block separations measured across the phase shifter gap.

The continuous conversion between the two axes (i.e., $PI(gap)$ and $gap(PI)$ will be done during operations based on the list of reference data points stored in file `sxps_16349_pivsgap_spline.dat` in the Controls Data folder on the V: drive (see final section of this document for file information). From that $PI(gap)$ and $gap(PI)$ can be calculated via cubic spline fits or equivalent. [Documentary Information]

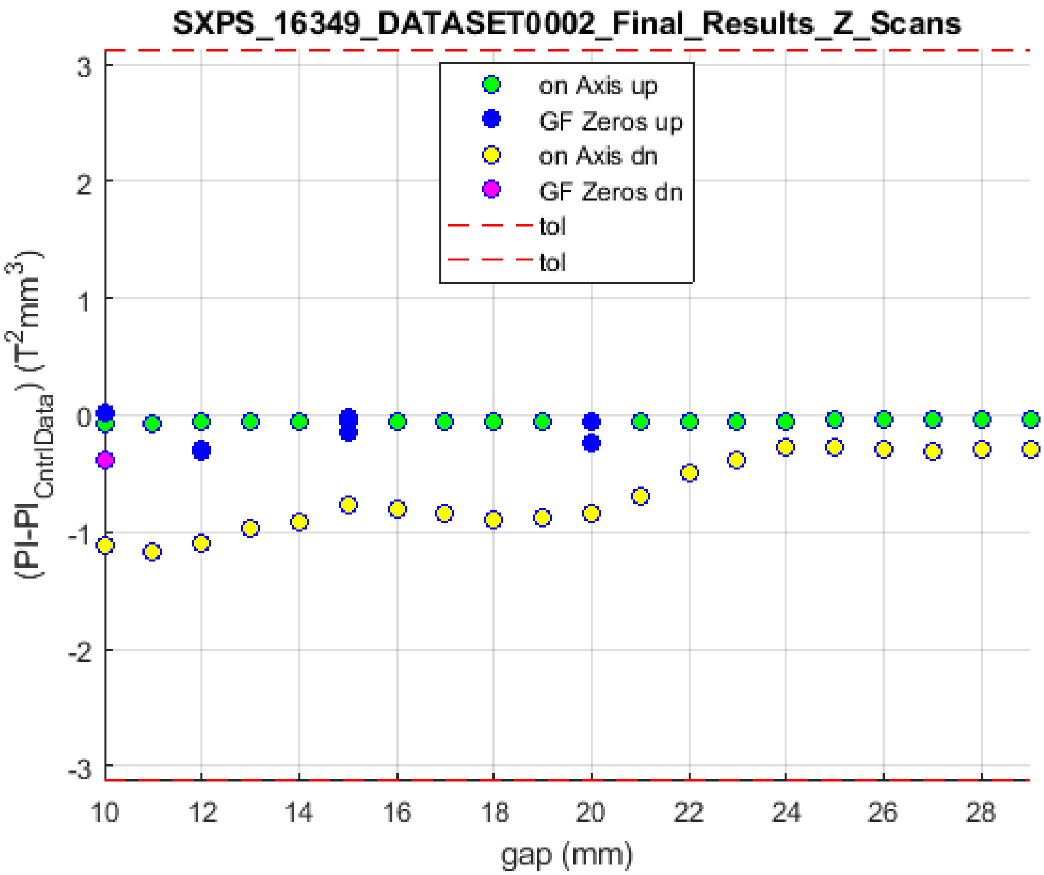
Evaluation of Hall Scans: $PI - PI_{\text{control}}$ vs. gap



The figure shows the relative difference between the measured phase shifter Phase Integral, PI, and a cubic spline fit to the list of reference data points as a function of gap over the 10 mm—30 mm operational range. The cubic spline fit data is stored on the V: drive in the Controls Data folder in file `sxps_16349_pivsgap_spline`.

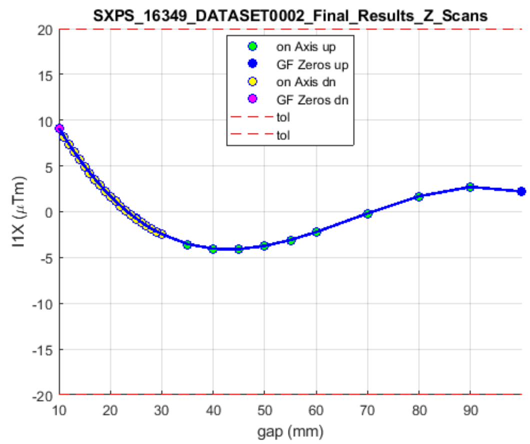
The legend explains the different cases that are shown in the plot: The data show as green filled circles have been acquired on axis as the gap was changed from closed to open. The yellow filled circles show data acquired on axis as the gap was changed from open to closed. The horizontal red dashed lines show the tolerance limits. The other symbols shown indicate off-axis measurements that are added for interest only. The tolerance limits apply for on-axis readings, only.

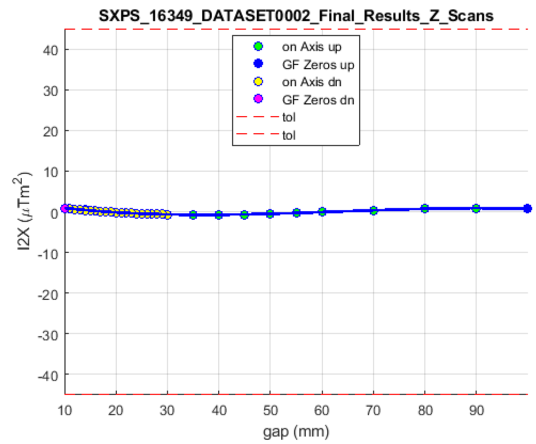
Evaluation of Hall Scans: $PI - PI_{\text{control}}$ vs. gap

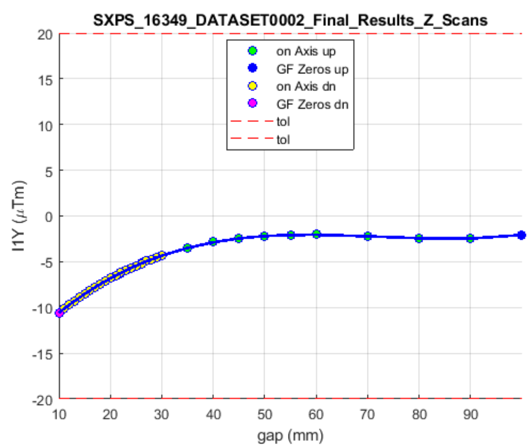


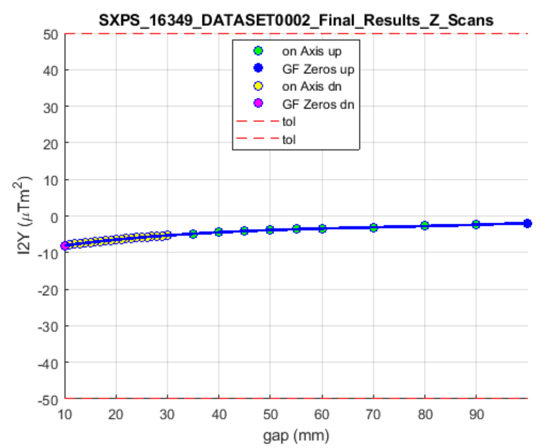
The figure shows some of the data shown in the previous figure but with a larger vertical scale that just captures the tolerance range. There is a hysteresis effect visible which is small enough to be acceptable. The off-axis measurements are not shown.

Evaluation of Hall Probe: Field Integrals vs. gap







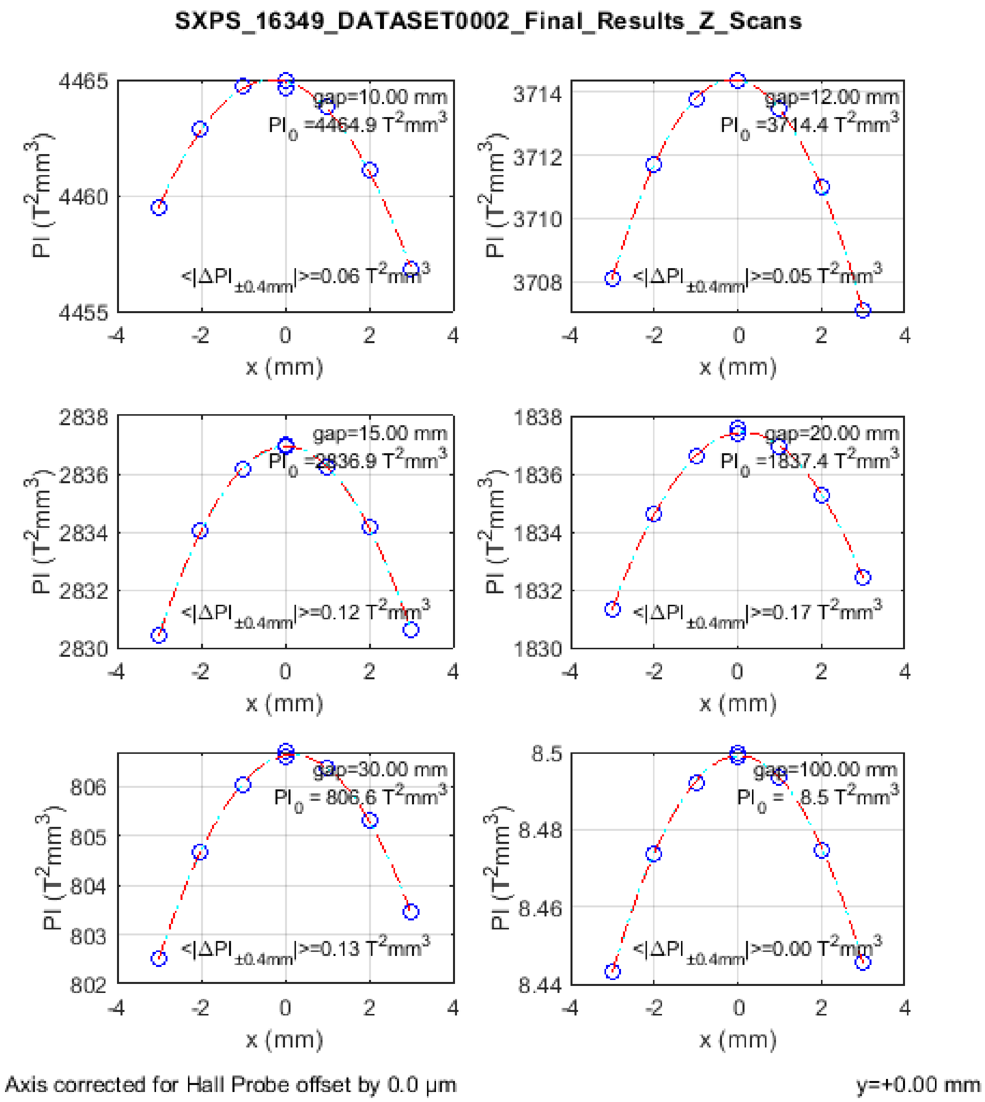


The figures show the field integrals (I1X, I2X, I1Y, I2Y) as function of the closed gap. The proximity of the green and yellow circles shows that the field integrals are not sensitive to the hysteresis in phase integral as seen on a previous page. The blue curves are spline fits to the data in files

“`...i1x_vs_gap_spline.dat`”,
“`...i2x_vs_gap_spline.dat`”,
“`...i1y_vs_gap_spline.dat`”,
“`...i2y_vs_gap_spline.dat`”,

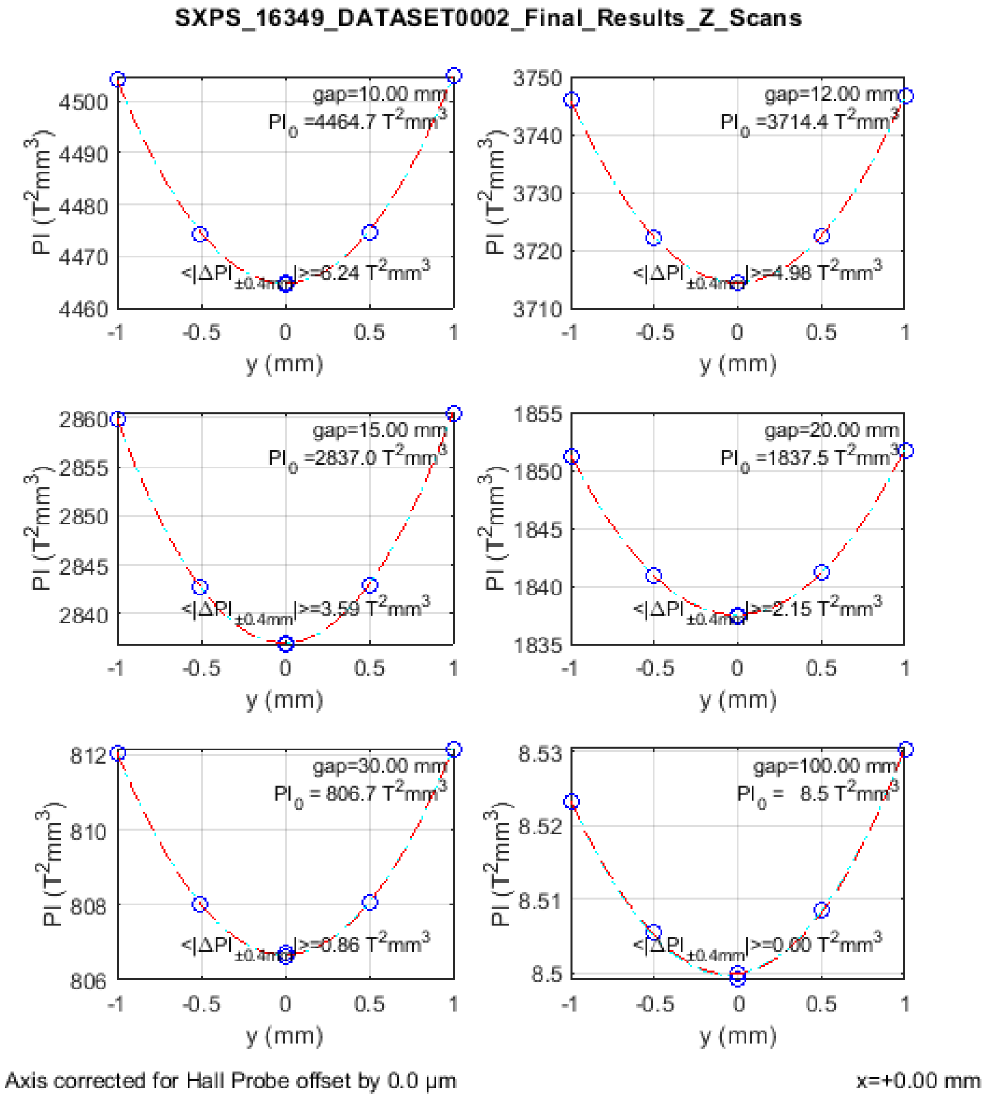
and demonstrate how the controls representations of the field integrals relates to the actual measurements (see final section of this document for file information).

Evaluation of Hall Scans: PI vs. x dependence



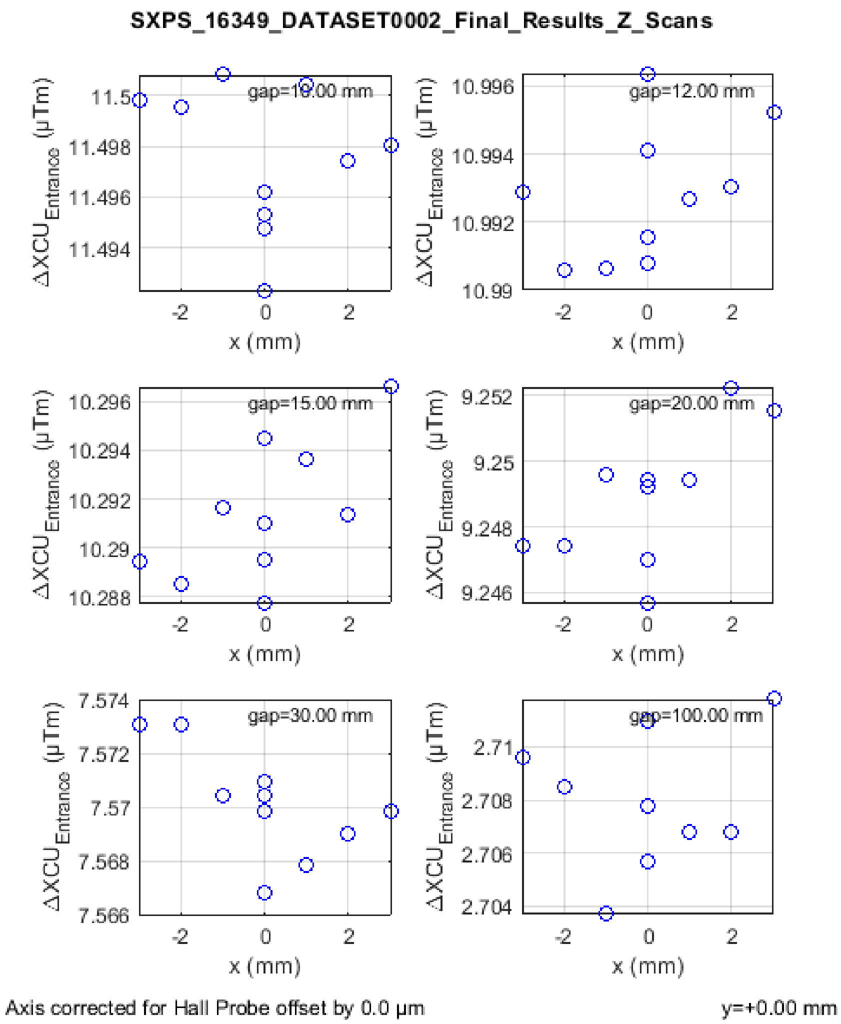
The figure shows the deviation of the phase integral, PI, from the off-axis value, PI_0, as function of x at a number of operational gaps. The average deviation at $z = \pm 0.4$ mm is printed at the lower part of each plot. [Documentary Information]

Evaluation of Hall Scans: PI vs. y dependence



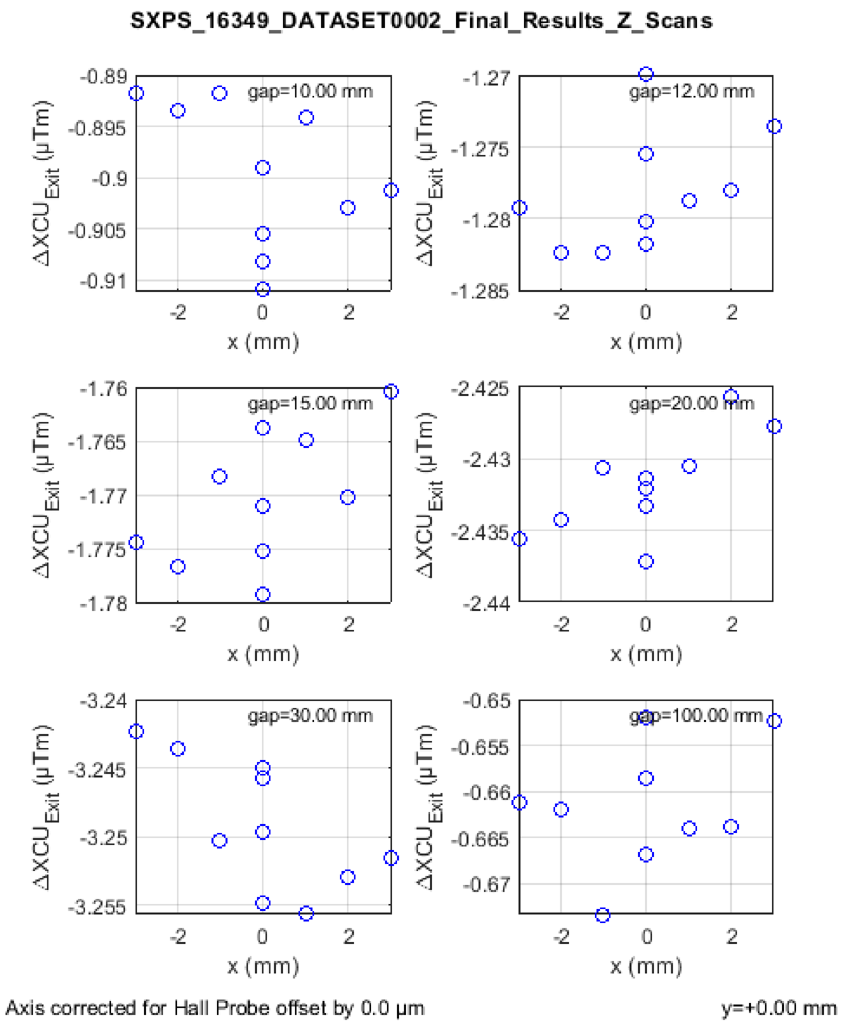
The figure shows the deviation of the phase integral, PI, value from the on-axis value, PI_0, as function of y at a number of operational gaps. The average deviation at $z = \pm 0.4$ mm is printed at the lower part of each plot. [Documentary Information]

Estimated Upstream Horizontal Corrector Strength Requirement vs. x



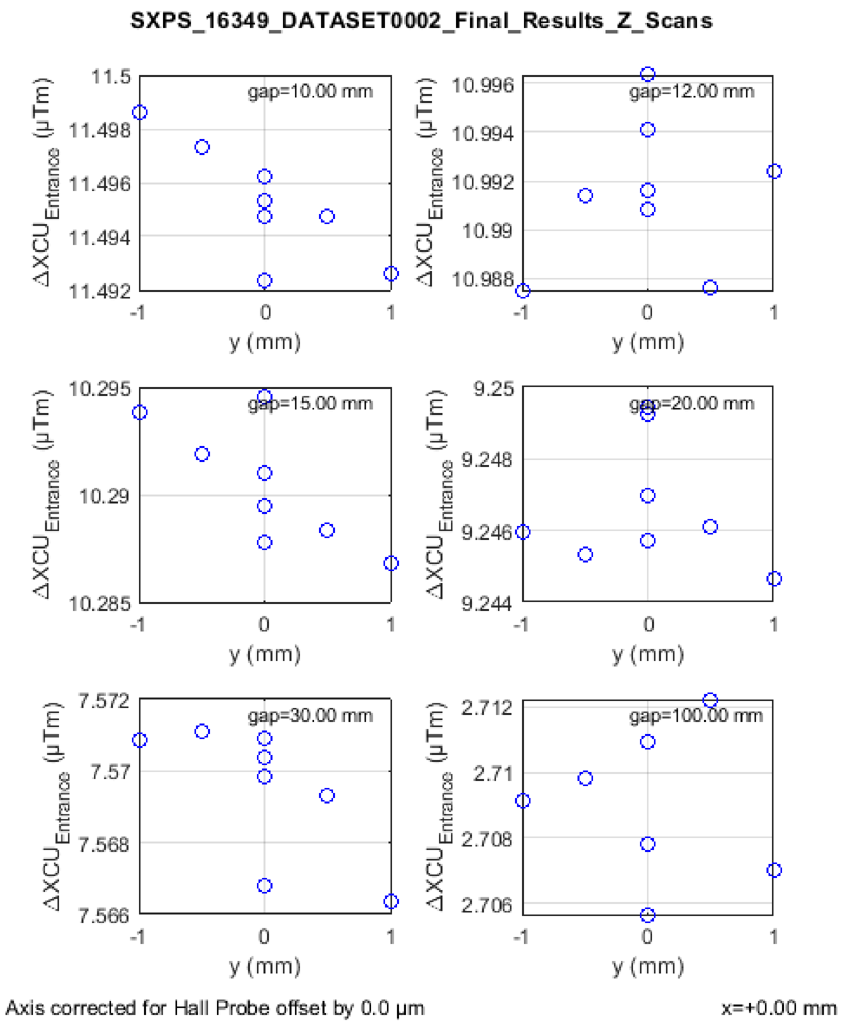
The figure shows the required strength of the upstream horizontal corrector to remove the second vertical phase shifter field integral at the downstream BPM for a number of phase shifter gaps. The analysis was done at a number of off-axis locations in the x—z plane. All values are very small.

Estimated Downstream Horizontal Corrector Strength Requirement vs. x



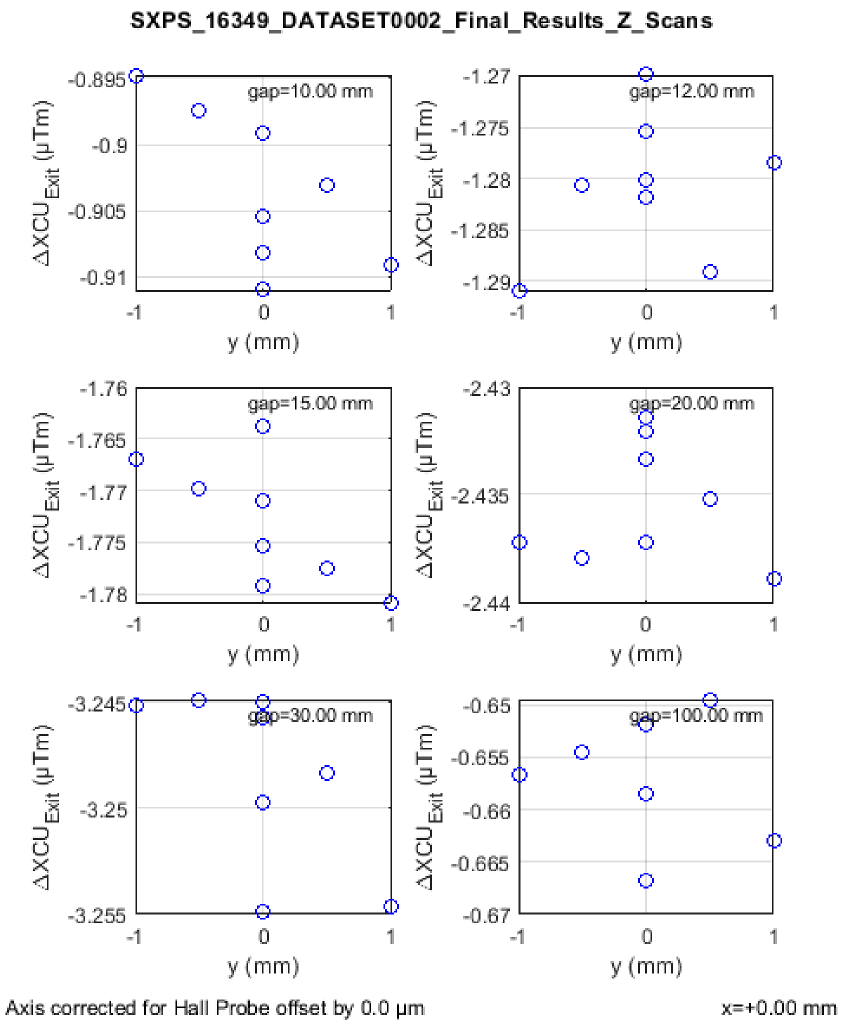
The figure shows the required strength of the downstream horizontal corrector to remove the first vertical phase shifter field integral and upstream corrector field integral at the downstream BPM for a number of operational phase shifter gaps. The analysis was done at a number of off-axis locations in the x—z plane. All values are very.

Estimated Upstream Horizontal Corrector Strength Requirement vs. y



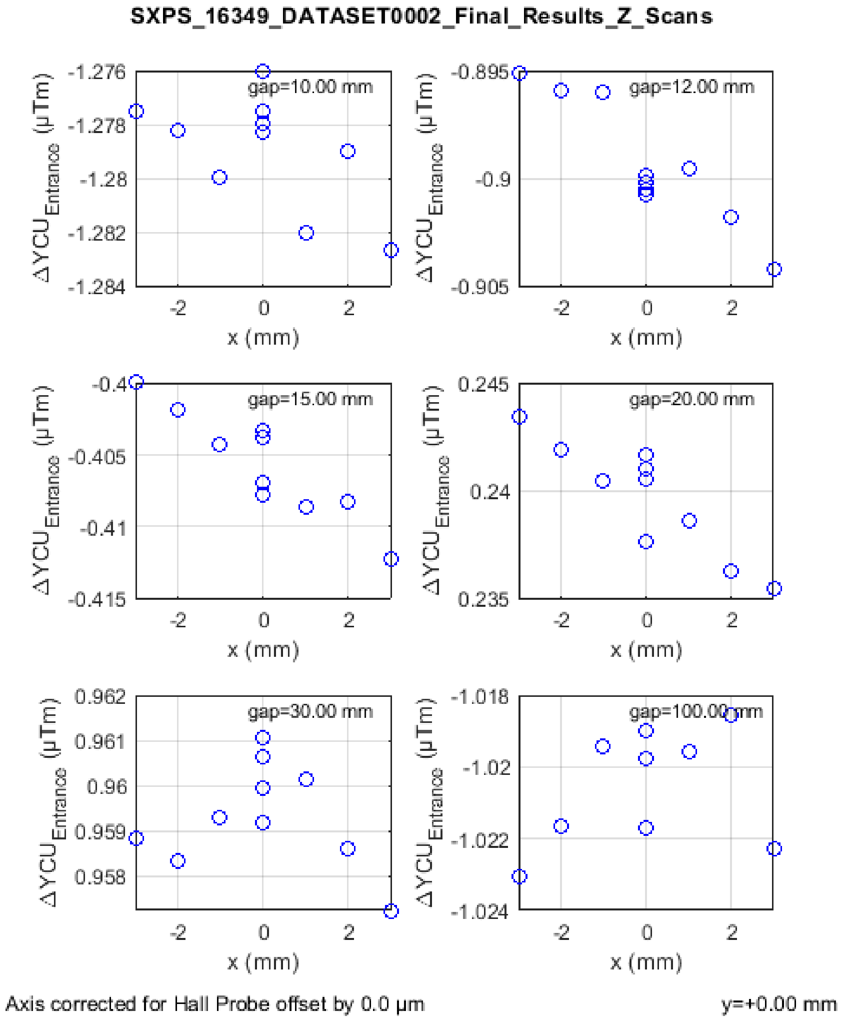
The figure shows the required strength of the upstream horizontal corrector to remove the second vertical phase shifter field integral at the downstream BPM for a number of operational phase shifter gaps. The analysis was done at a number of off-axis locations in the x—z plane. All values are very small.

Estimated Downstream Horizontal Corrector Strength Requirement vs. y



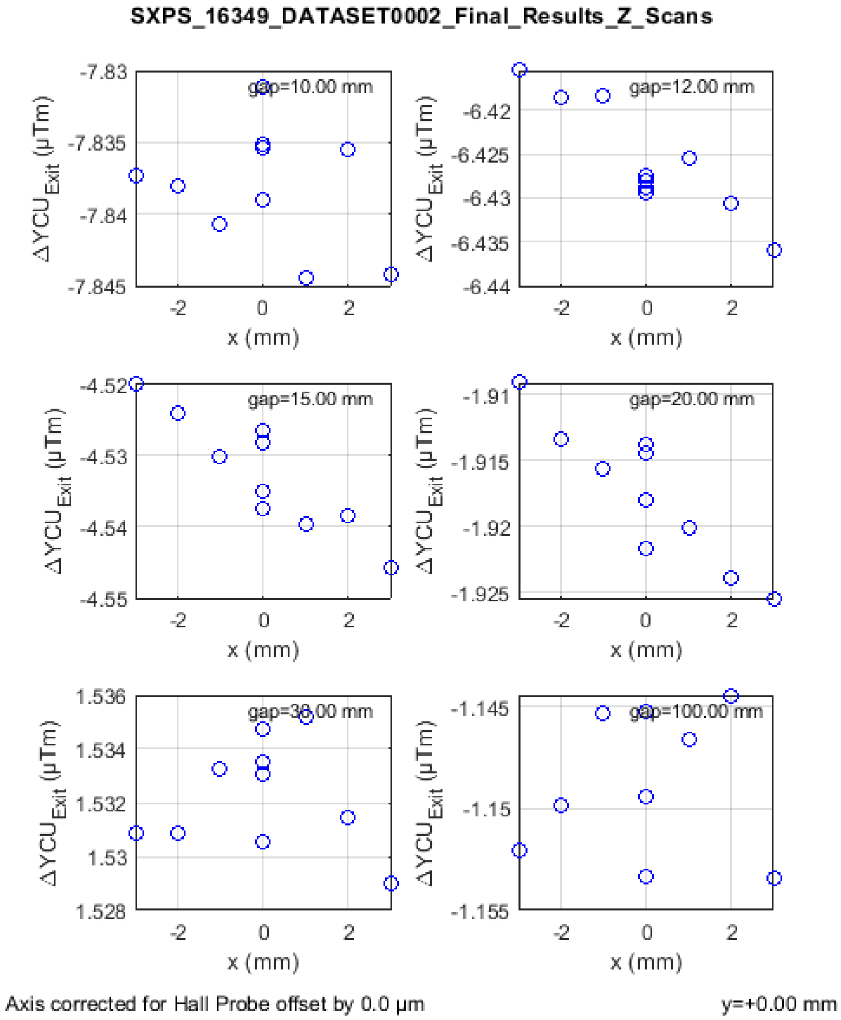
The figure shows the required strength of the upstream horizontal corrector to remove the first vertical phase shifter and upstream corrector field integral at the downstream BPM for a number of operational undulator gaps. The analysis was done at a number of off-axis locations in the x—z plane. All values are very small.

Estimated Upstream Vertical Corrector Strength Requirement vs. x



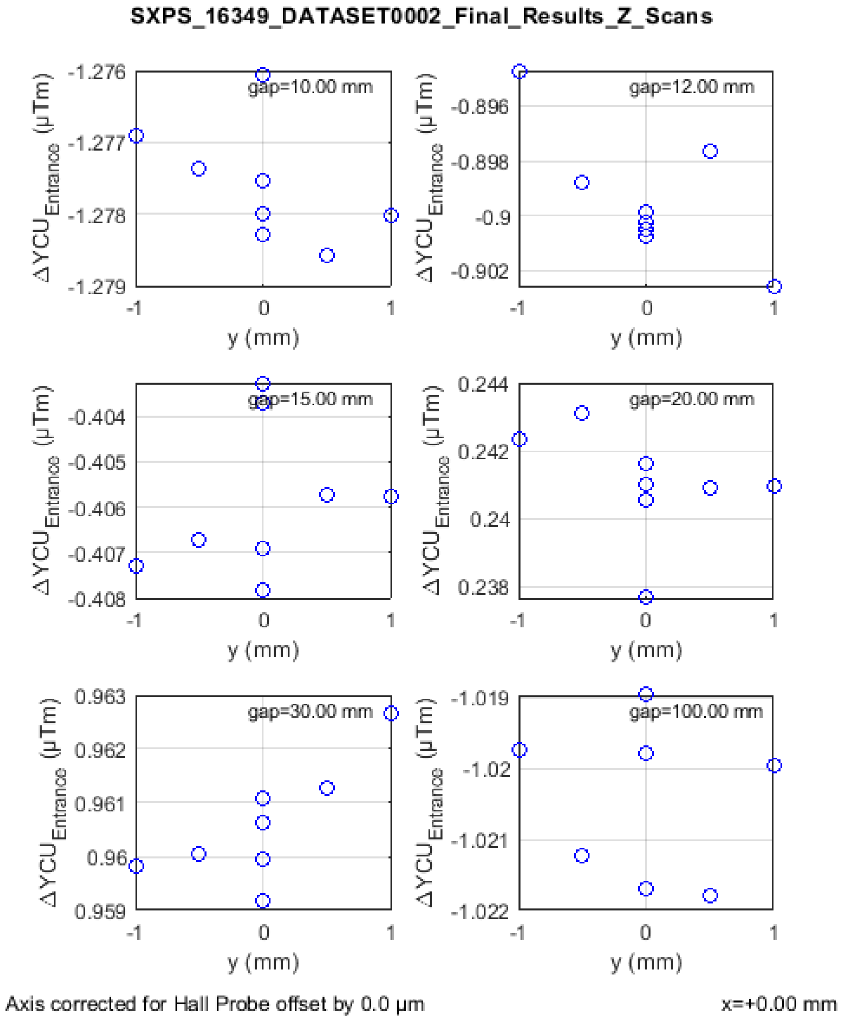
The figure shows the required strength of the upstream horizontal corrector to remove the second horizontal phase shifter field integral at the downstream BPM for a number of operational phase shifter gaps. The analysis was done at a number of off-axis locations in the x—z plane. All values are very small.

Estimated Downstream Vertical Corrector Strength Requirement vs. x



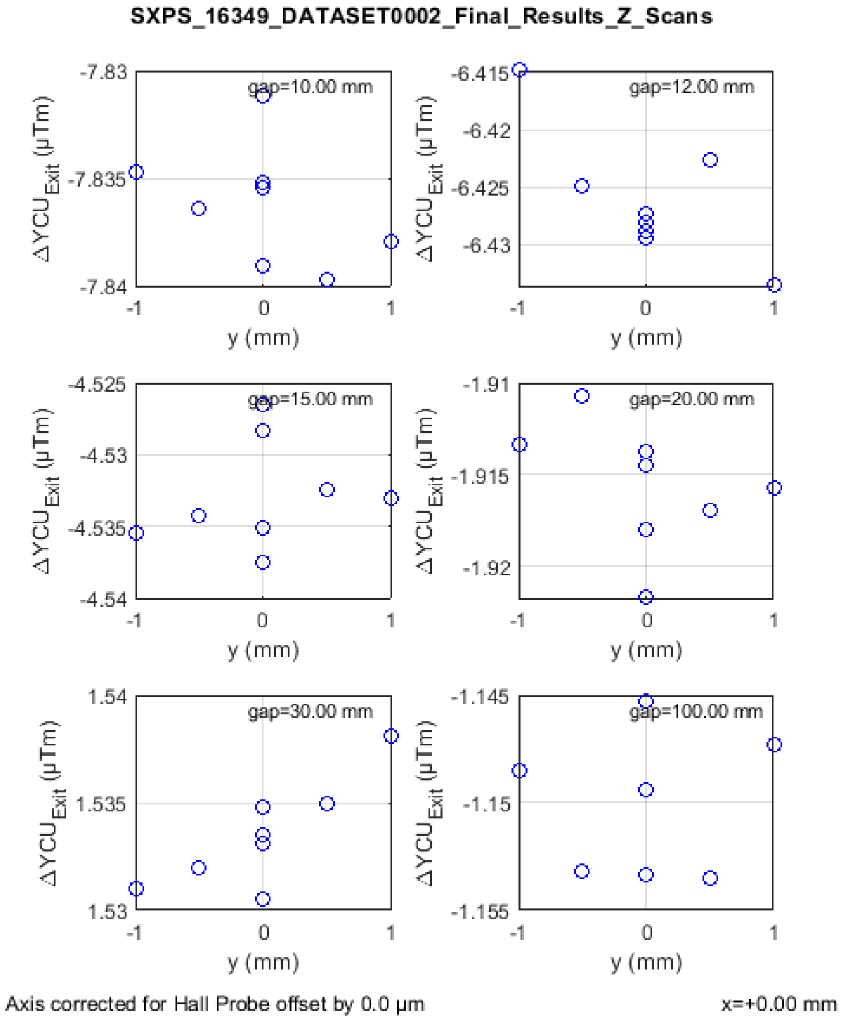
The figure shows the required strength of the downstream vertical corrector to remove the first horizontal phase shifter field integral and upstream corrector fields integral at the downstream BPM for a number of operational phase shifter gaps. The analysis was done at a number of off-axis locations in the x—z plane. All values are very small.

Estimated Upstream Vertical Corrector Strength Requirement vs. y



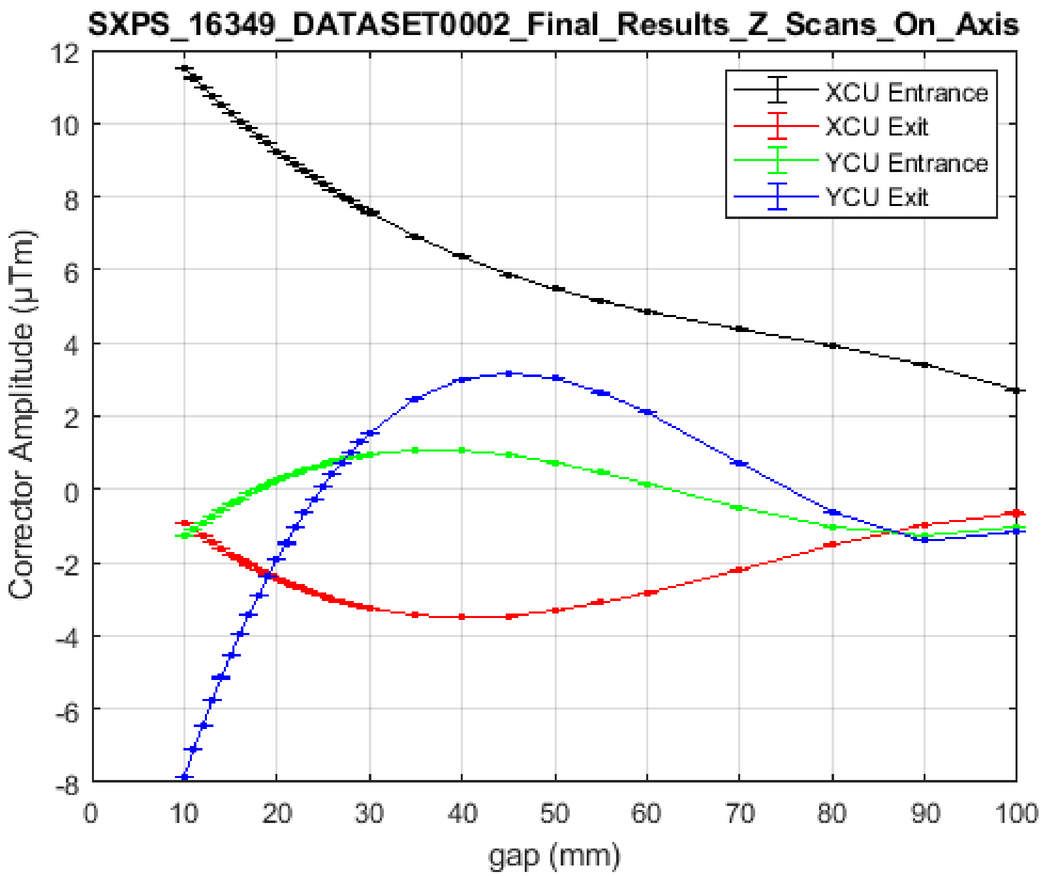
The figure shows the required strength of the upstream vertical corrector to remove the second horizontal phase shifter field integral at the downstream BPM for a number of operational phase shifter gaps. The analysis was done at a number of off-axis locations in the x—z plane. All values are very small.

Estimated Upstream Vertical Corrector Strength Requirement vs. y



The figure shows the required strength of the downstream vertical corrector to remove the first horizontal phase shifter field integral and the upstream corrector fields integral at the downstream BPM for a number of operational phase shifter gaps. The analysis was done at a number of off-axis locations in the x—z plane. All values are very small.

Estimated Corrector Strengths Requirement vs. gap



The figure shows as a function of phase shifter gap the required strengths of the upstream and downstream horizontal and vertical correctors to remove the effect of undulator field integrals at the downstream BPM over the entire available gap range. All values are very small.

Measurement Results are stored:

At V-Drive:

☒ V:\MET\MagServe\MagData\LCLS-II\Phase Shifter\

☐ ____________________

In Folder

☒ SXPS_16349\DATASET0002\MagServe\Final Results\

☐ ____________________

Confirmation of File Locations:

The following tables list all required data files documenting the tuning results. An existence check was done and the result is indicated next to each filename as "exists" or "missing".

Sub folder: Z Scans\Good Field Region exists

001gap010.000x-03.00y+00.00\zscan.dat	exists
002gap010.000x-02.00y+00.00\zscan.dat	exists
003gap010.000x-01.00y+00.00\zscan.dat	exists
004gap010.000x+00.00y+00.00\zscan.dat	exists
005gap010.000x+01.00y+00.00\zscan.dat	exists
006gap010.000x+02.00y+00.00\zscan.dat	exists
007gap010.000x+03.00y+00.00\zscan.dat	exists
044gap010.000x+00.00y-00.50\zscan.dat	exists
004gap010.000x+00.00y+00.00\zscan.dat	exists
046gap010.000x+00.00y+00.50\zscan.dat	exists
008gap012.000x-03.00y+00.00\zscan.dat	exists
009gap012.000x-02.00y+00.00\zscan.dat	exists
010gap012.000x-01.00y+00.00\zscan.dat	exists
011gap012.000x+00.00y+00.00\zscan.dat	exists
012gap012.000x+01.00y+00.00\zscan.dat	exists
013gap012.000x+02.00y+00.00\zscan.dat	exists
014gap012.000x+03.00y+00.00\zscan.dat	exists
049gap012.000x+00.00y-00.50\zscan.dat	exists
011gap012.000x+00.00y+00.00\zscan.dat	exists

051gap012.000x+00.00y+00.50\zscan.dat	exists
015gap015.000x-03.00y+00.00\zscan.dat	exists
016gap015.000x-02.00y+00.00\zscan.dat	exists
017gap015.000x-01.00y+00.00\zscan.dat	exists
018gap015.000x+00.00y+00.00\zscan.dat	exists
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020gap015.000x+02.00y+00.00\zscan.dat	exists
021gap015.000x+03.00y+00.00\zscan.dat	exists
054gap015.000x+00.00y-00.50\zscan.dat	exists
018gap015.000x+00.00y+00.00\zscan.dat	exists
056gap015.000x+00.00y+00.50\zscan.dat	exists
022gap020.000x-03.00y+00.00\zscan.dat	exists
023gap020.000x-02.00y+00.00\zscan.dat	exists
024gap020.000x-01.00y+00.00\zscan.dat	exists
025gap020.000x+00.00y+00.00\zscan.dat	exists
026gap020.000x+01.00y+00.00\zscan.dat	exists
027gap020.000x+02.00y+00.00\zscan.dat	exists
028gap020.000x+03.00y+00.00\zscan.dat	exists
059gap020.000x+00.00y-00.50\zscan.dat	exists
025gap020.000x+00.00y+00.00\zscan.dat	exists
061gap020.000x+00.00y+00.50\zscan.dat	exists
029gap030.000x-03.00y+00.00\zscan.dat	exists
030gap030.000x-02.00y+00.00\zscan.dat	exists
031gap030.000x-01.00y+00.00\zscan.dat	exists
032gap030.000x+00.00y+00.00\zscan.dat	exists
033gap030.000x+01.00y+00.00\zscan.dat	exists
034gap030.000x+02.00y+00.00\zscan.dat	exists
035gap030.000x+03.00y+00.00\zscan.dat	exists
064gap030.000x+00.00y-00.50\zscan.dat	exists
032gap030.000x+00.00y+00.00\zscan.dat	exists
066gap030.000x+00.00y+00.50\zscan.dat	exists
036gap100.000x-03.00y+00.00\zscan.dat	exists
037gap100.000x-02.00y+00.00\zscan.dat	exists
038gap100.000x-01.00y+00.00\zscan.dat	exists
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040gap100.000x+01.00y+00.00\zscan.dat	exists

041gap100.000x+02.00y+00.00\zscan.dat	exists
042gap100.000x+03.00y+00.00\zscan.dat	exists
069gap100.000x+00.00y-00.50\zscan.dat	exists
039gap100.000x+00.00y+00.00\zscan.dat	exists
071gap100.000x+00.00y+00.50\zscan.dat	exists

Sub folder: Z Scans\On Axis `exists`

001gap010.000x+00.00y+00.00\zscan.dat	exists
002gap011.000x+00.00y+00.00\zscan.dat	exists
003gap012.000x+00.00y+00.00\zscan.dat	exists
004gap013.000x+00.00y+00.00\zscan.dat	exists
005gap014.000x+00.00y+00.00\zscan.dat	exists
006gap015.000x+00.00y+00.00\zscan.dat	exists
007gap016.000x+00.00y+00.00\zscan.dat	exists
008gap017.000x+00.00y+00.00\zscan.dat	exists
009gap018.000x+00.00y+00.00\zscan.dat	exists
010gap019.000x+00.00y+00.00\zscan.dat	exists
011gap020.000x+00.00y+00.00\zscan.dat	exists
012gap021.000x+00.00y+00.00\zscan.dat	exists
013gap022.000x+00.00y+00.00\zscan.dat	exists
014gap023.000x+00.00y+00.00\zscan.dat	exists
015gap024.000x+00.00y+00.00\zscan.dat	exists
016gap025.000x+00.00y+00.00\zscan.dat	exists
017gap026.000x+00.00y+00.00\zscan.dat	exists
018gap027.000x+00.00y+00.00\zscan.dat	exists
019gap028.000x+00.00y+00.00\zscan.dat	exists
020gap029.000x+00.00y+00.00\zscan.dat	exists
021gap030.000x+00.00y+00.00\zscan.dat	exists
022gap035.000x+00.00y+00.00\zscan.dat	exists
023gap040.000x+00.00y+00.00\zscan.dat	exists
024gap045.000x+00.00y+00.00\zscan.dat	exists
025gap050.000x+00.00y+00.00\zscan.dat	exists
026gap055.000x+00.00y+00.00\zscan.dat	exists
027gap060.000x+00.00y+00.00\zscan.dat	exists
028gap070.000x+00.00y+00.00\zscan.dat	exists

029gap080.000x+00.00y+00.00\zscan.dat	exists
030gap090.000x+00.00y+00.00\zscan.dat	exists
031gap100.000x+00.00y+00.00\zscan.dat	exists

Sub folder: Stretched Wire exists

Sub folder: Stretched Wire\Good Field Region exists

011gap010.000x-02.00y+00.00_i1X_integrals.txt	exists
012gap010.000x-01.00y+00.00_i1X_integrals.txt	exists
013gap010.000x+00.00y+00.00_i1X_integrals.txt	exists
014gap010.000x+01.00y+00.00_i1X_integrals.txt	exists
015gap010.000x+02.00y+00.00_i1X_integrals.txt	exists
031gap010.000x+00.00y-02.00_i1X_integrals.txt	exists
032gap010.000x+00.00y-01.00_i1X_integrals.txt	exists
013gap010.000x+00.00y+00.00_i1X_integrals.txt	exists
034gap010.000x+00.00y+01.00_i1X_integrals.txt	exists
035gap010.000x+00.00y+02.00_i1X_integrals.txt	exists
051gap012.000x-02.00y+00.00_i1X_integrals.txt	exists
052gap012.000x-01.00y+00.00_i1X_integrals.txt	exists
053gap012.000x+00.00y+00.00_i1X_integrals.txt	exists
054gap012.000x+01.00y+00.00_i1X_integrals.txt	exists
055gap012.000x+02.00y+00.00_i1X_integrals.txt	exists
071gap012.000x+00.00y-02.00_i1X_integrals.txt	exists
072gap012.000x+00.00y-01.00_i1X_integrals.txt	exists
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Sub folder: Stretched Wire\On Axis `exists`

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042gap030.000x+00.00y+00.00_i2Y_integrals.txt	exists
050gap040.000x+00.00y+00.00_i2Y_integrals.txt	exists
054gap050.000x+00.00y+00.00_i2Y_integrals.txt	exists
058gap060.000x+00.00y+00.00_i2Y_integrals.txt	exists
062gap070.000x+00.00y+00.00_i2Y_integrals.txt	exists
066gap080.000x+00.00y+00.00_i2Y_integrals.txt	exists
070gap090.000x+00.00y+00.00_i2Y_integrals.txt	exists
074gap100.000x+00.00y+00.00_i2Y_integrals.txt	exists

Sub folder: Controls Data `exists`

sxps_16349_i1x_vs_gap_spline.dat	exists
sxps_16349_i1y_vs_gap_spline.dat	exists
sxps_16349_i2x_vs_gap_spline.dat	exists
sxps_16349_i2y_vs_gap_spline.dat	exists

Summary of findings

Finding	Solution

Approval and Assignment by Heinz-Dieter Nuhn

Data Storage Checked:	Y	
Magnet Accepted:	Y	
Assigned Location:	SXPS-16349	

[signature]	Heinz-Dieter Nuhn	October 4, 2019
(Signature)	(Name)	(Date)