



## SLAC Traveler for LCLS-II HXU Measurement Results

This traveler is intended to document the checking of the final magnetic measurements of an Undulator Segment performed on the Kugler bench in the Magnetic Measurement Facility (MMF) at SLAC after the completion of the tuning process. It contains basic performance indicators compared against tolerances as well as documentary information both in graphical and textual representation.

Serial number from magnet label:	29H129-MOSO-013
Device name from magnet label:	HXU-013

### Measurement Procedure:

The measurements have been carried out after the undulator segment had been fully tuned according to the “LCLS-II Undulator Test Plan” (LCLS-TN-17-1).

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### Evaluation of Hall Probe Scans: Data Listings A

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MATLAB function "EvaluateUndulatorField" on	08/03/2020 15:02	
A. SCAN PARAMETERS		
z Scanning Date & Time Range	07/23/2020 10:28 - 07/24/2020 07:02	
Undulator Temperature	20.0736±0.0060	°C
x axis position	0.000258	mm
y axis position	-0.026608	mm
Calibration Position	B	
Close Loop Encoder	Full Gap	
Dead Band Gap	0.12	μm
Total number of poles per strongback	260	
Number of full field poles	254	
Number of core poles	246	
First core pole #	8	
Last core pole #	253	
Average $\lambda_u$	26.001	mm
RMS $\lambda_u$	15.0	μm
Scans averaged	3	
Tuning Gap	9.000	mm
Commissioning Gap	7.969	mm



**Evaluation of Hall Probe Scans at Tuning Gap: Data Listing B**

MATLAB function "EvaluateUndulatorField" on	08/03/2020 15:02	
B. CORE EVALUATIONS FOR TUNING GAP		
Tuning Gap Scanning Date & Time Range	07/23/2020 16:03	
Tuning Gap Temperature	20.07±0.06	°C
Planar Hall Effect Correction Range	1.544600 - 4.869800	m
Planar Hall Effect x Corr Function	-0.08 G + (z - 1.544600 m)×0.08 G/m	
Planar Hall Effect y Corr Function	+0.07 G + (z - 1.544600 m)×0.04 G/m	
Coil Range	1.407187 - 5.007187	m
$\langle \lambda_u \rangle$	26.001±0.001	mm
$\langle k_u \rangle$	241.65±0.01	1/m
$\langle K_u \rangle$	2.0116±0.0002	
$\langle K_{\text{eff}} \rangle$ @ Tuning Temperature	2.01207±0.00001	
$\langle L_{\text{eff}} \rangle$	3.32777±0.00004	m
$\langle L_{2\pi} \rangle$	0.078633±0.000003	m
I1X (Cell Range Total)	-4.30	μTm
I2X (Cell Range Total)	-85.70	μTm <sup>2</sup>
I1Y (Cell Range Total)	-21.78	μTm
I2Y (Cell Range Total)	-28.78	μTm <sup>2</sup>
PI (Cell Range Total)	19,570.8	T <sup>2</sup> mm <sup>3</sup>
Phase Shake	1.04	degXray
Cell Phase Advance ( over 4.012667 m)	49,210.5 (137×360-109.5)	degXray
Undulator Entrance Phase	2465.3±0.1	degXray
Undulator Exit Phase	2465.2±0.1	degXray
Undulator Phase Imbalance: Entrance - Exit	0.1±0.1	degXray
Cell Entrance min. Phase Shifter Correction	54.7	degXray
Cell Exit min. Phase Shifter Correction	54.8	degXray



**Evaluation of Hall Probe Scans at Commissioning Gap: Data Listing C**

MATLAB function "EvaluateUndulatorField" on	08/03/2020 15:02	
C. CORE EVALUATIONS FOR COMMISSIONING GAP		
Commissioning Gap Scanning Date & Time Range	07/23/2020 16:03	
Commissining Gap Temperature	20.07±0.06	°C
Planar Hall Effect Correction Range	1.544800 - 4.869600	m
Planar Hall Effect x Corr Function	-0.12 G + (z - 1.544800 m)×0.09 G/m	
Planar Hall Effect y Corr Function	-0.09 G + (z - 1.544800 m)×0.07 G/m	
Coil Range	1.407182 - 5.007182	m
$\langle \lambda_u \rangle$	26.001±0.001	mm
$\langle k_u \rangle$	241.65±0.01	1/m
$\langle K_u \rangle$	2.3392±0.0003	
$\langle K_{\text{eff}} \rangle$ @ Tuning Temperature	2.33961±0.00001	
$\langle L_{\text{eff}} \rangle$	3.32652±0.00004	m
$\langle L_{2\pi} \rangle$	0.097163±0.000004	m
I1X (Cell Range Total)	+0.93	μTm
I2X (Cell Range Total)	-70.91	μTm <sup>2</sup>
I1Y (Cell Range Total)	-20.56	μTm
I2Y (Cell Range Total)	-21.76	μTm <sup>2</sup>
PI (Cell Range Total)	26,451.3	T <sup>2</sup> mm <sup>3</sup>
Phase Shake	0.90	degXray
Cell Phase Advance (over 4.012667 m)	48,599.8 (135×360-0.2)	degXray
Undulator Entrance Phase	2158.8 (12×180-1.2)±0.1	degXray
Undulator Exit Phase	2161.0 (12×180+1.0)±0.1	degXray
Undulator Phase Imbalance: Entrance - Exit	-2.2±0.1	degXray
Cell Entrance min. Phase Shifter Correction	1.2	degXray
Cell Exit min. Phase Shifter Correction	359.0	degXray



**Undulator Encoder Settings: Data Listing D**

MATLAB function "EvaluateUndulatorField" on 08/03/2020 15:13

D. ENCODER SETTINGS

Upstream Gap Encoder Offset	-40.6103	mm
Downstream Gap Encoder Offset	-40.3521	mm
Upstream Wall Encoder Offset	92.25150	mm
Downstream Wall Encoder Offset	91.27700	mm
Upstream Aisle Encoder Offset	92.57680	mm
Downstream Aisle Encoder Offset	92.02190	mm

**Undulator Capacitive Sensor Values: Data Listing E**

E. CAPACITIVE SENSOR VALUES

Module	Pole	Capacitive Sensor Gap	Upstream Encoder	Downstream Encoder	
Ref	—	46.4797	50.0007	50.0002	mm
Ref	—	46.4797	50.0007	50.0002	mm
1	20	46.5050	46.4999	46.5000	mm
1	20	46.5050	46.4999	46.5000	mm
1	60	46.4850	46.4999	46.5000	mm
1	60	46.4850	46.4999	46.5000	mm
1	20	46.5050	46.4999	46.5000	mm
1	20	46.5050	46.4999	46.5000	mm
1	60	46.4850	46.4999	46.5000	mm
1	60	46.4850	46.4999	46.5000	mm
1	20	46.5050	46.4999	46.5000	mm
1	20	46.5050	46.4999	46.5000	mm
1	60	46.4850	46.4999	46.5000	mm
1	60	46.4850	46.4999	46.5000	mm
Ref	—	46.4797	50.0007	50.0002	mm
Ref	—	46.4797	50.0007	50.0002	mm

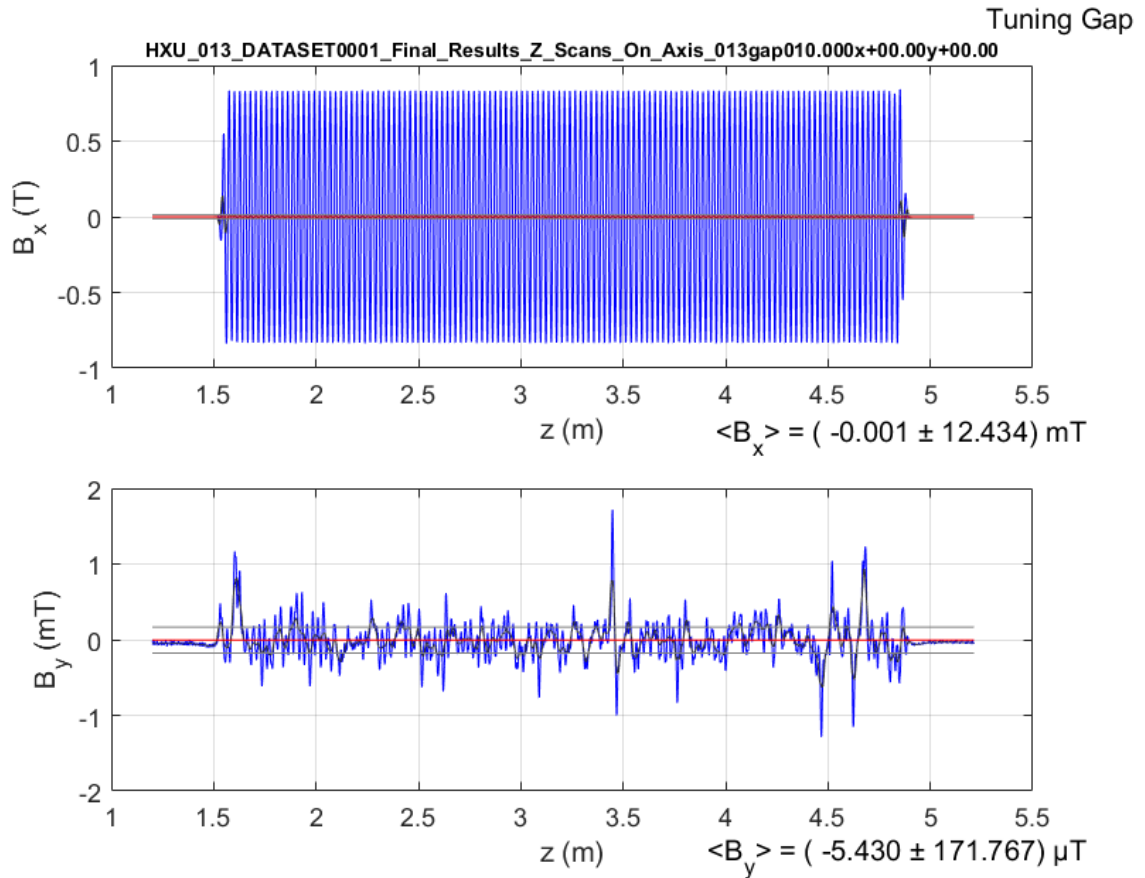
The following figures show result of the field analysis at the tuning gap.



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### Evaluation of Hall Probe at Tuning Gap: $B_x$ & $B_y$ Plot

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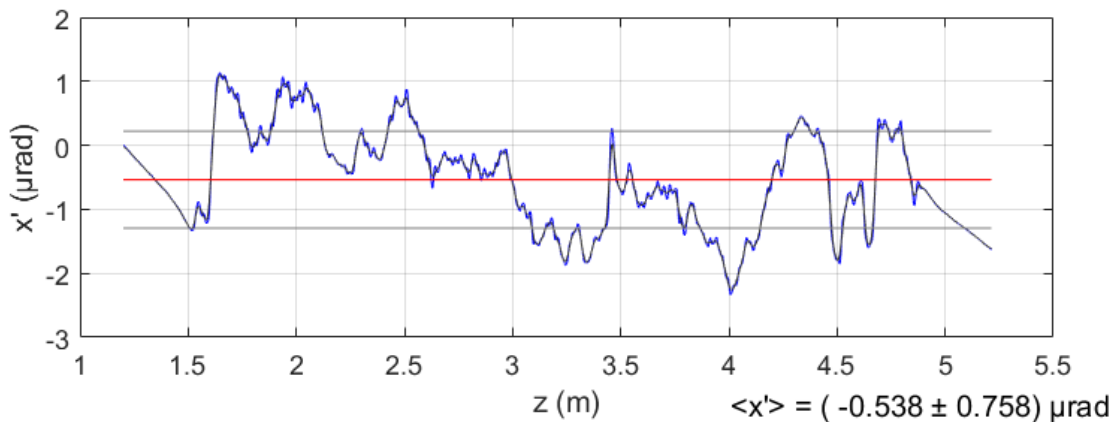
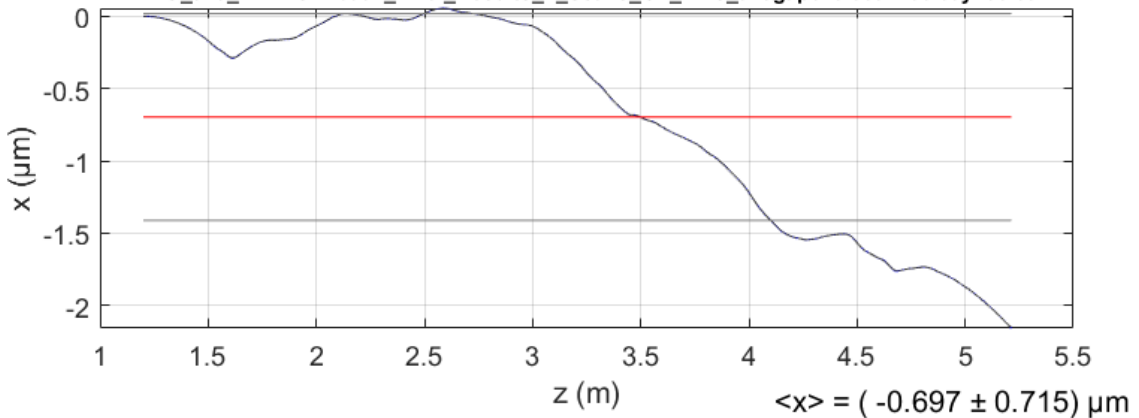
The figures show the x (upper) and y (lower) field components along the undulator tuning axis for the tuning gap. A running wiggler-period-average function is plotted in black (not very well visible in the lower figure). The horizontal lines indicate the mean (center red line) and the rms deviations from the mean (two black lines above and below the average) of that wiggler-period-average function. The corresponding mean and rms values are also printed on the right hand side underneath each figure. [Documentary Information]



Evaluation of Hall Probe at Tuning Gap:  $x$  &  $x'$  Plot

Evaluating at Energy = 4.0 GeV ( $\gamma=7827.8$ ;  $B\rho=13.3$  Tm) Tuning Gap

HXU\_013\_DATASET0001\_Final\_Results\_Z\_Scans\_On\_Axis\_013gap010.000x+00.00y+00.00



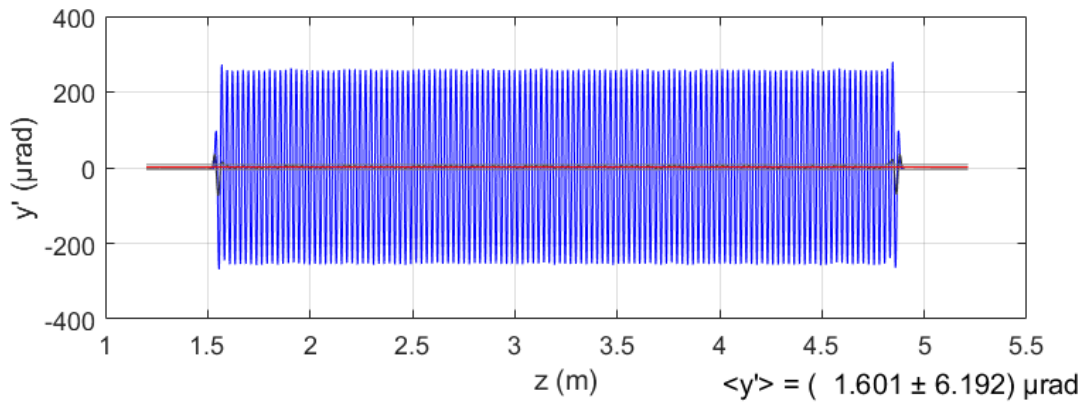
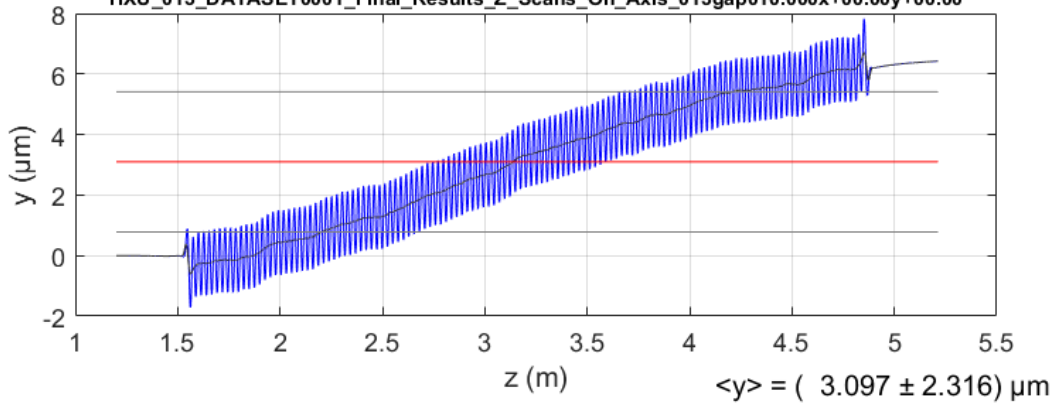
The figures show the  $x$  (upper) and  $x'$  (lower) electron beam trajectories along the undulator tuning axis for the tuning gap based on the measured magnetic field components and estimated for an electron beam energy of 4.0 GeV. A running wiggler-period-average function is plotted in black (difficult to see in the lower figure). The horizontal lines indicate the mean (center red line) and the rms deviations from the mean (two black lines above and below the average) of that wiggler-period-average function. The corresponding mean and rms values are also printed on the right hand side underneath each figure. [Documentary Information]



### Evaluation of Hall Probe Scans at Tuning Gap: $y$ & $y'$ Plot

Evaluating at Energy = 4.0 GeV ( $\gamma=7827.8$ ;  $B\rho=13.3$  Tm) Tuning Gap

HXU\_013\_DATASET0001\_Final\_Results\_Z\_Scans\_On\_Axis\_013gap010.000x+00.00y+00.00



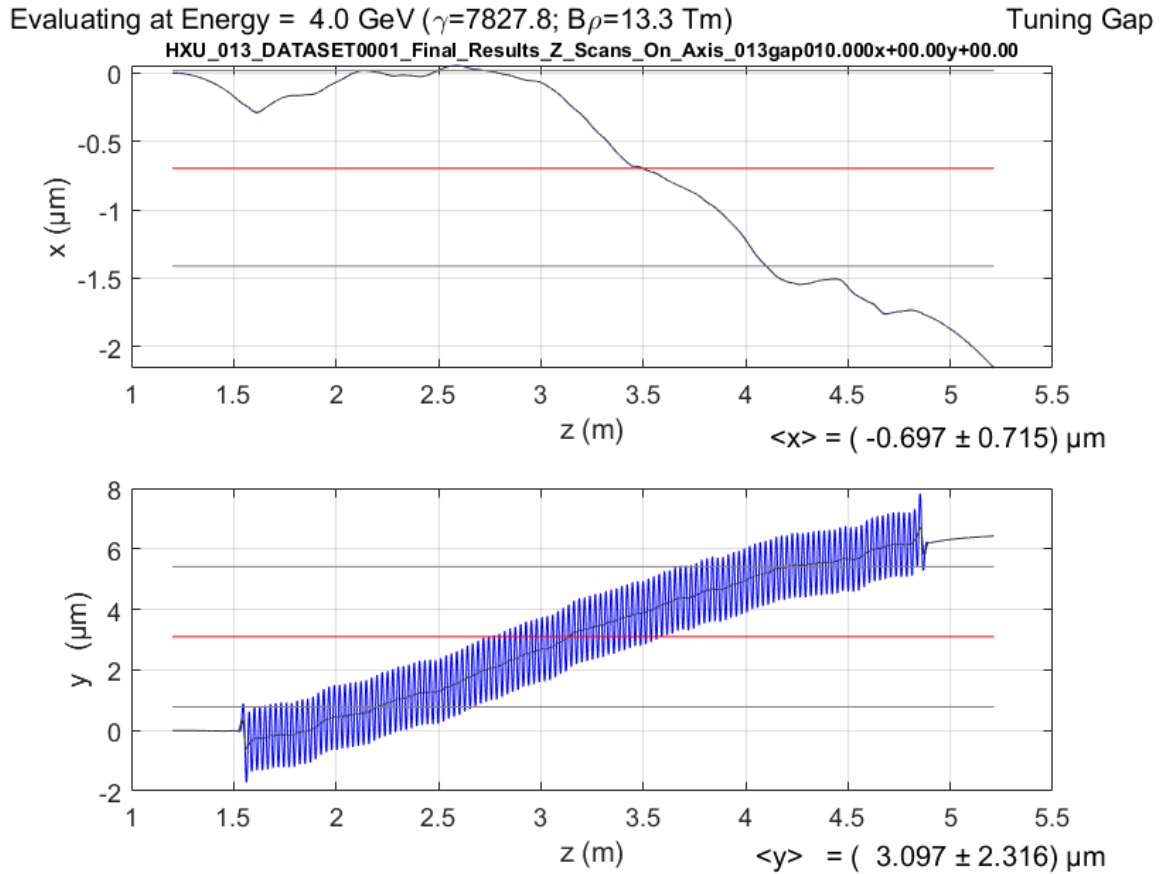
The figures show the  $y$  (upper) and  $y'$  (lower) electron beam trajectories along the undulator tuning axis for the tuning gap based on the measured magnetic field components and estimated for an electron beam energy of 4.0 GeV. A running wiggler-period-average function is plotted in black (difficult to see). The horizontal lines indicate the mean (center red line) and the rms deviations from the mean (two black lines above and below the average) of that wiggler-period-average function. The corresponding mean and rms values are also printed on the right hand side underneath each figure. [Documentary Information]



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### Evaluation of Hall Probe Scans at Tuning Gap: $x$ & $y$ Plot

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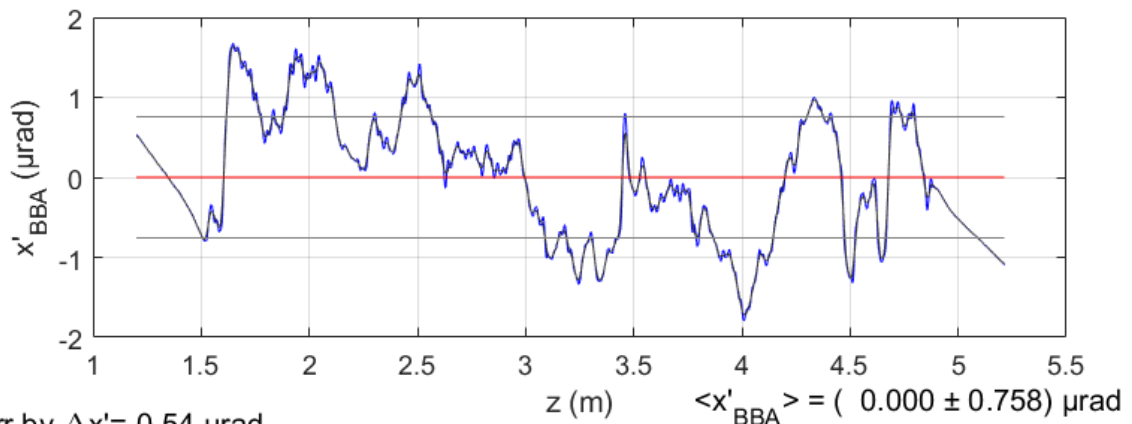
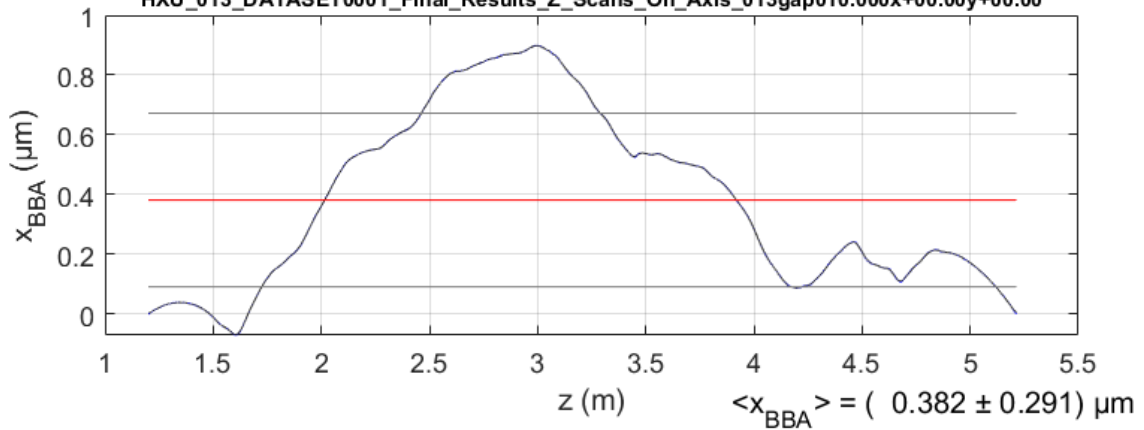
The figures show the  $x$  (upper) and  $y$  (lower) electron beam trajectories along the undulator tuning axis for the tuning gap based on the measured magnetic field components and estimated for an electron beam energy of 4.0 GeV. A running wiggler-period-average function is plotted in black (identical with the trajectory in the lower figure). The horizontal lines indicate the mean (center red line) and the rms deviations from the mean (two black lines above and below the average) of that wiggler-period-average function. The corresponding mean and rms values are also printed on the right hand side underneath each figure. [Documentary Information]



**Evaluation of Hall Probe plus BBA Correction at Tuning Gap:  $x$  &  $x'$  Plot**

Evaluating at Energy = 4.0 GeV ( $\gamma=7827.8$ ;  $B\rho=13.3$  Tm) Tuning Gap

HXU\_013\_DATASET0001\_Final\_Results\_Z\_Scans\_On\_Axis\_013gap010.000x+00.00y+00.00

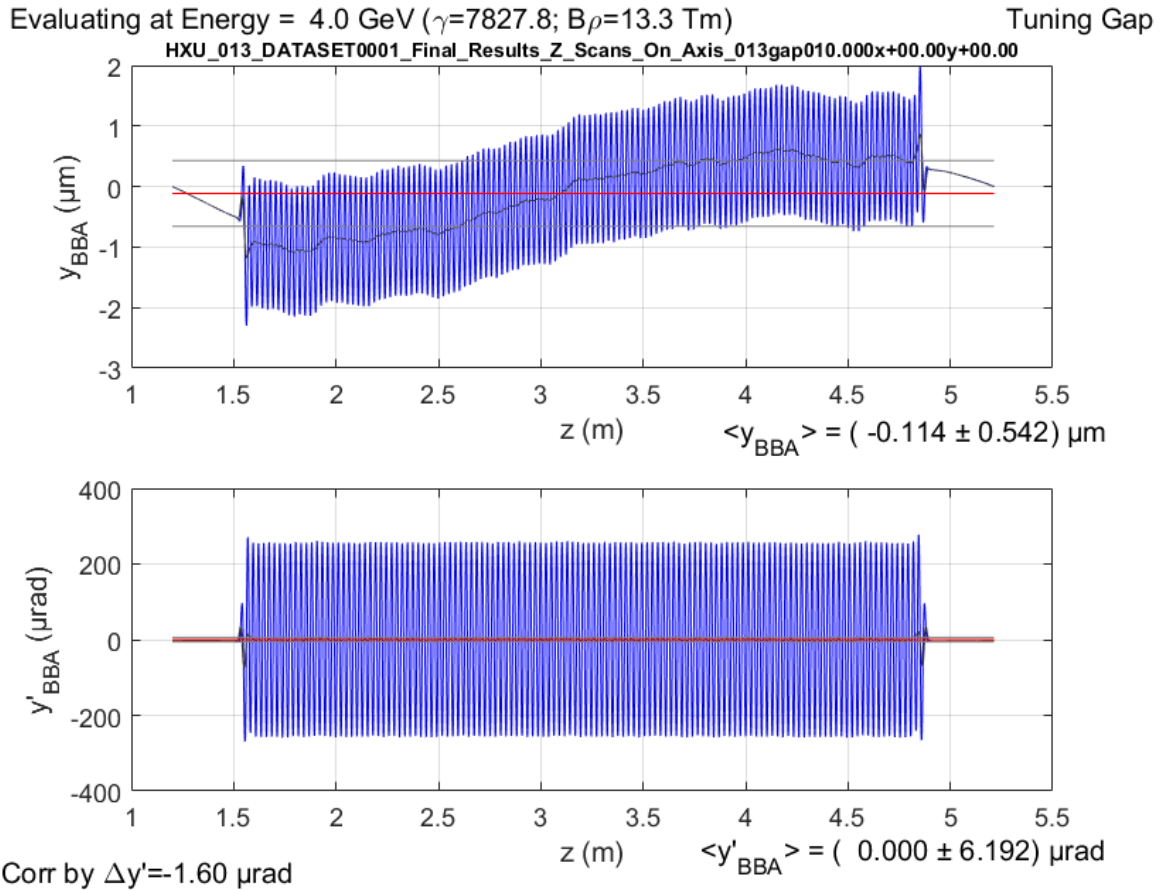


Corr by  $\Delta x' = -0.54 \mu\text{rad}$

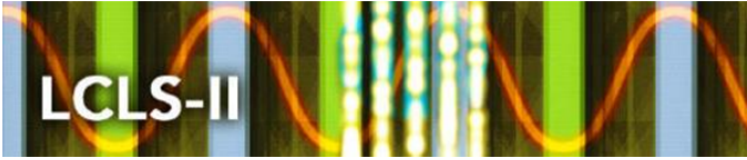
The figures show the  $x$  (upper) and  $x'$  (lower) electron beam trajectories along the undulator tuning axis for the tuning gap based on the measured magnetic field components after BBA correction (to zero the amplitudes at the cell boundaries) and estimated for an electron beam energy of 4.0 GeV. A running wiggler-period-average function is plotted in black (difficult to see in the lower figure). The horizontal lines indicate the mean (center red line) and the rms deviations from the mean (two black lines above and below the average) of that wiggler-period-average function. The corresponding mean and rms values are also printed on the right hand side underneath each figure. The amount of BBA correction applied is printed underneath the lower left corner of the lower figure. [Documentary Information]



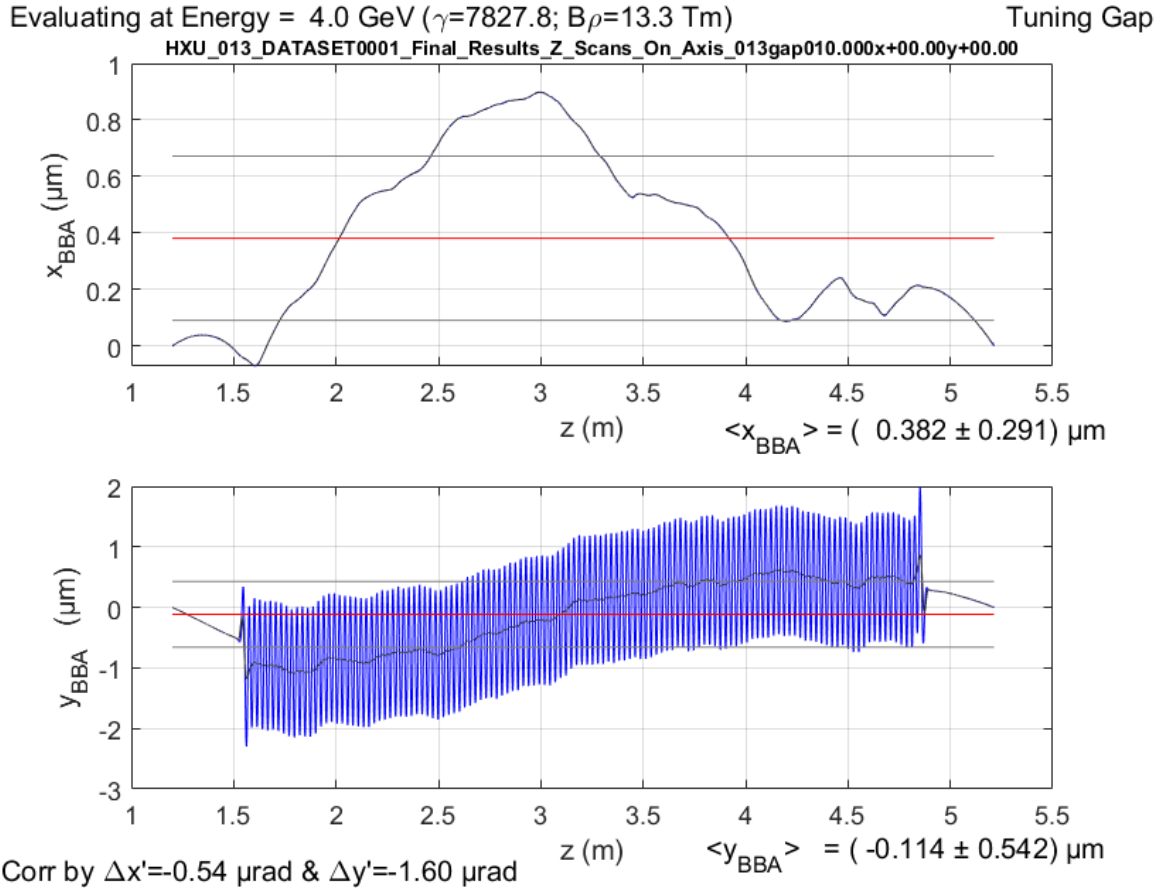
**Evaluation of Hall Probe plus BBA Correction at Tuning Gap:  $y$  &  $y'$  Plot**



The figures show the  $y$  (upper) and  $y'$  (lower) electron beam trajectories along the undulator tuning axis for the tuning gap based on the measured magnetic field components after BBA correction (to zero the amplitudes at the cell boundaries) and estimated for an electron beam energy of 4.0 GeV. A running wiggler-period-average function is plotted in black (identical with the trajectories). The horizontal lines indicate the mean (center red line) and the rms deviations from the mean (two black lines above and below the average) of that wiggler-period-average function. The corresponding mean and rms values are also printed on the right hand side underneath each figure. The amount of BBA correction applied is printed underneath the lower left corner of the lower figure. [Documentary Information]



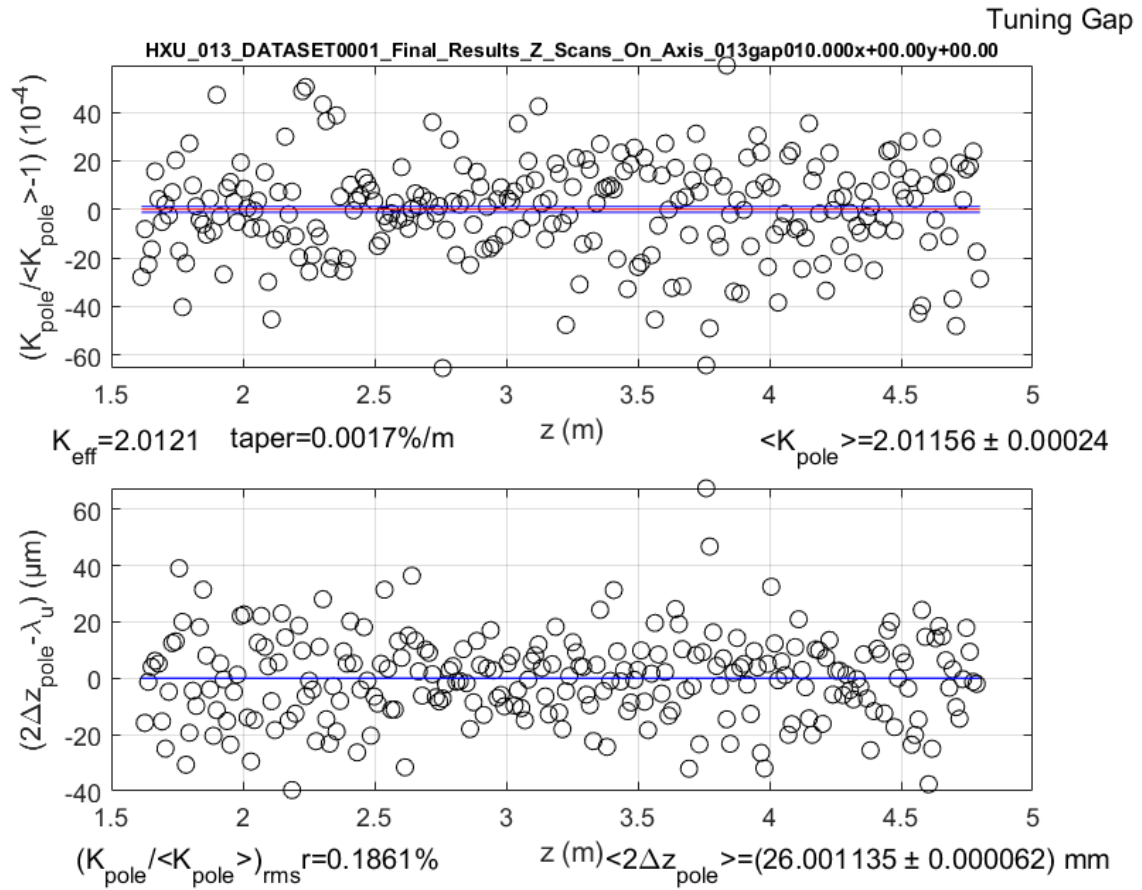
**Evaluation of Hall Probe plus BBA Correction at Tuning Gap:  $x$  &  $y$  Plot**



The figures show the  $x$  (upper) and  $y$  (lower) electron beam trajectories along the undulator tuning axis for the tuning gap based on the measured magnetic field components after BBA correction (to zero the amplitudes at the cell boundaries) and estimated for an electron beam energy of 4.0 GeV. A running wiggler-period-average function is plotted in black (identical with the trajectory in the lower figure). The horizontal lines indicate the mean (center red line) and the rms deviations from the mean (two black lines above and below the average) of that wiggler-period-average function. The corresponding mean and rms values are also printed on the right hand side underneath each figure. The amount of BBA correction applied is printed underneath the lower left corner of the lower figure. [Documentary Information]



Evaluation of Hall Probe at Tuning Gap:  $K$  and  $\lambda_u$  Plot



The figures show the per-pole undulator strength  $K_{pole}$  (upper) and the deviation of the pole width from the expected value of  $\lambda_u/2$  (lower) for the 246 core undulator poles for the tuning gap. The horizontal lines indicate the mean (center red line) and the rms deviations from the mean (two black lines above and below the average). The corresponding mean and rms values are also printed on the right hand side underneath each figure. [Documentary Information]

For description of  $K$  calculation see next page.



LCLS-II Undulator Segment Measurement Results

HXU-013

$K$  calculation description for previous page:

The undulator parameter,  $K_{pole}$ , in the upper figure, is calculated for each of the core poles based on the scanned vertical field values  $B_y(z)$  as well as an interpolation of the upstream,  $z_{(0-dn,pole)}$ , and downstream,  $z_{(0-up,pole)}$ , field zero crossing locations using the following formula:

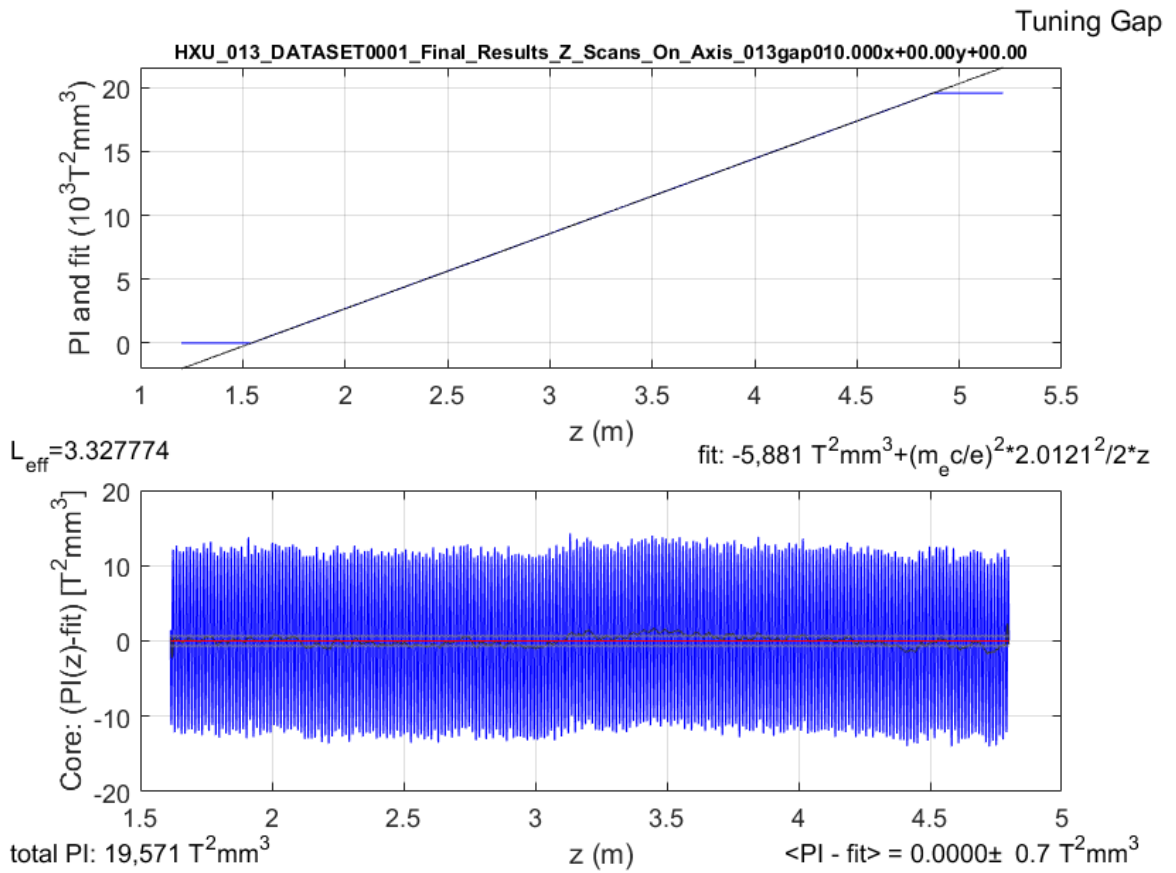
$$K_{pole}(z_{pole}) = \frac{\Delta z_{pole}}{2\pi} \frac{e}{m_e c} \sqrt{\frac{2}{\Delta z_{pole}} \int_{z_{0-up,pole}}^{z_{0-dn,pole}} B_y^2(\hat{z}) d\hat{z}}$$

The term  $\frac{e}{m_e c}$  uses the electron mass,  $m_e$ , the speed of light,  $c$ , and the electron's electric charge,  $e$ . The variable  $\Delta z_{pole}$  stands for

$$\begin{aligned} \Delta z_{pole} &= z_{0-dn,pole} - z_{0-up,pole} \\ z_{pole} &\approx \frac{1}{2} (z_{0-dn,pole} + z_{0-up,pole}) \end{aligned}$$



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



A description of the figure is given on the next page:



LCLS-II Undulator Segment Measurement Results

HXU-013

Figure description for previous page:

The upper figure shows the phase integral of an electron calculated from the measured on-axis magnetic field components for the tuning 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

$$BL_{x1,y1}(z) = \int_0^z B_{x,y}(\hat{z}) d\hat{z} - \frac{1}{L} \int_0^L \left\{ \int_0^{\hat{z}} B_{x,y}(\hat{z}) d\hat{z} \right\} d\hat{z}.$$

The function

$$\overline{PI}(z) = \overline{PI}(0) + z \left( \frac{mc}{e} \right)^2 \frac{1}{2} K_{\text{eff}}^2,$$

fitted to the measured phase integral  $PI(z)$  (along the undulator core) with fit coefficients  $\left(\frac{mc}{e}\right)^2 \frac{1}{2} K_{\text{eff}}^2$  and can be seen as a straight black line in the upper plot. The values of the fit coefficients are printed at the right hand side underneath the upper figure. On the lower left of the upper figure the effective undulator length is printed, which is obtained as the distance over the undulator core, where the blue and black lines in the plot are on top of each other:  $L_{\text{eff}} = PI(z_{\text{max}}) / \left(\frac{d\overline{PI}(z)}{dz}\right)$ .

The lower figure shows the residuals between the phase integral and the fit function over the core part of the undulator magnet. A running wiggler-period-averaged function is plotted in black. The horizontal lines indicate the mean (center red line) and the rms deviations from the mean (two blue lines above and below the mean) of that wiggler-period-averaged function. The corresponding mean and rms values are also printed on the right hand side underneath the figure. On the lower left of the plot, the total phase integral accumulated along the undulator magnet, is shown, i.e.,  $PI(z_{\text{max}})$ , the right-hand side value of the blue line in the upper plot.

The wiggler period averaged phase,  $\langle \Phi \rangle_{\lambda_u}(z)$  can be calculated from  $PI(z)$  via

$$\langle \Phi \rangle_{\lambda_u}(z) = \frac{2\pi}{L_{2\pi}} \left( \frac{e}{mc} \right)^2 \int_{z - \frac{\lambda_u}{2}}^{z + \frac{\lambda_u}{2}} (PI(\hat{z}) - \overline{PI}(\hat{z})) d\hat{z},$$

integrated over the undulator core.

Here  $L_{2\pi} = \lambda_u \left(1 + \frac{1}{2} K_{\text{eff}}^2\right)$  (see next figure) is the free space distance over which a phase slippage of  $2\pi$  occurs. The phase shake,  $\langle \Delta \phi \rangle_{\text{rms}}$ , which will be discussed later in this document, is calculated as

$$\langle \Delta \phi \rangle_{\text{rms}} = (\Delta \langle \Phi \rangle_{\lambda_u})_{\text{rms}} = (\langle \Phi \rangle_{\lambda_u}(z) - \langle \langle \Phi \rangle_{\lambda_u}(z) \rangle)_{\text{rms}}$$

The cell phase  $\phi(z)$  is calculated over the entire cell length (not just the undulator core)

$$\phi(z) = \frac{360 \text{ degXray}}{L_{2\pi}} \left( z - z_{\text{center}} + \left( \frac{e}{mc} \right)^2 PI(z) \right).$$

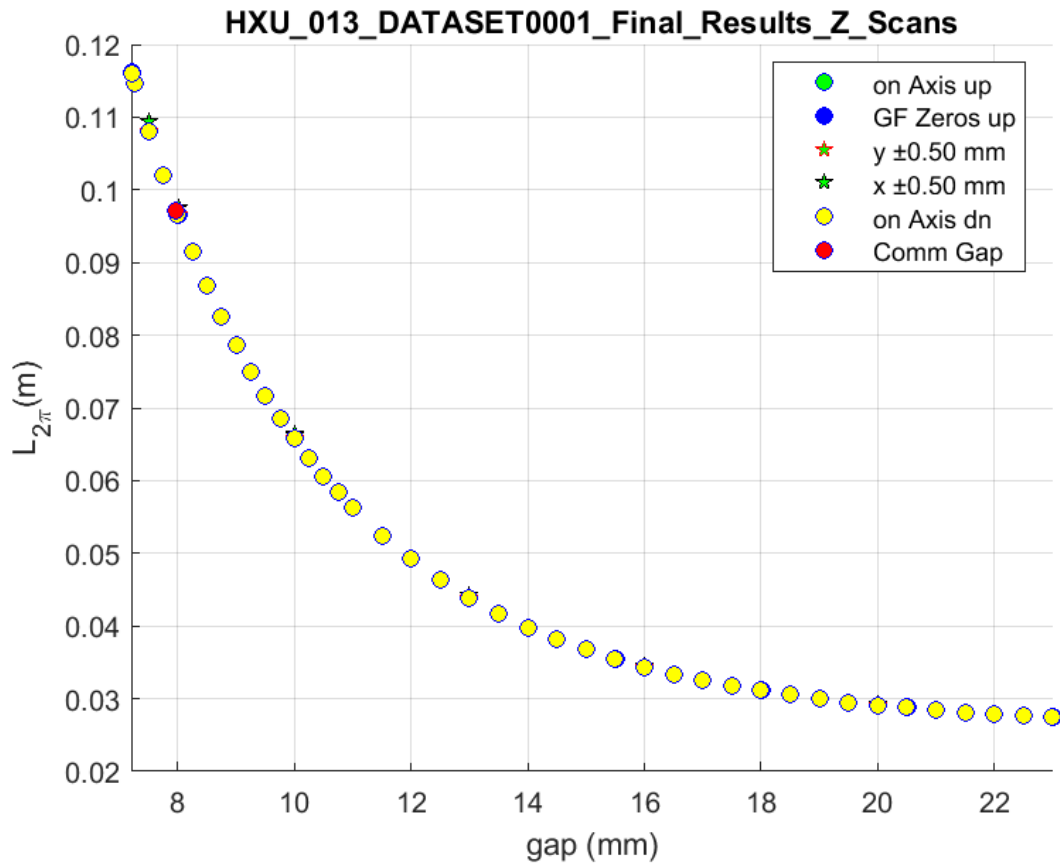
The following figures show the results of the gap dependent analysis.



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**Evaluation of Hall Scans:  $L_{2\pi}$  vs gap**

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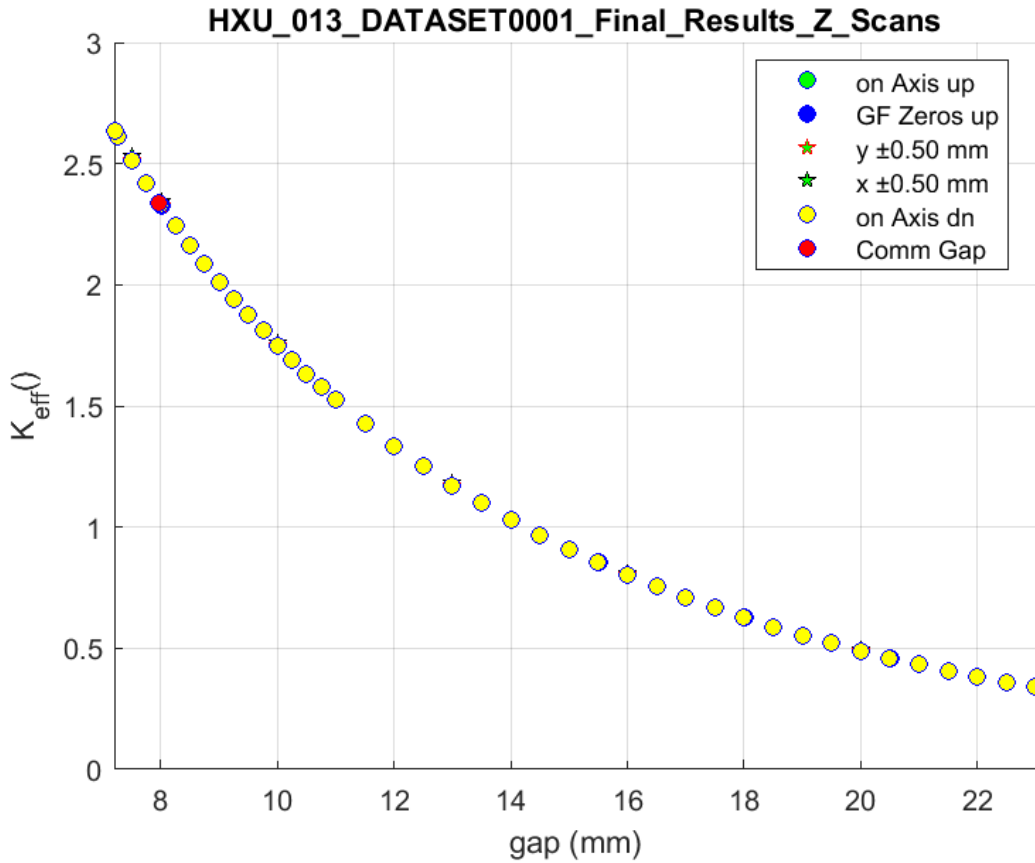
The figure shows the free space distance over which a  $2\pi$  slippage occurs between the radiation field and the electron bunch (see explanation above) as a function of undulator gap over the operational gap range. Note: the free space travel distance required to accumulate  $2\pi$  slippage gets shorter towards larger gap values, which correspond to shorter undulator wavelengths. [Documentary Information]



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### Evaluation of Hall Scans: $K_{\text{eff}}$ vs gap

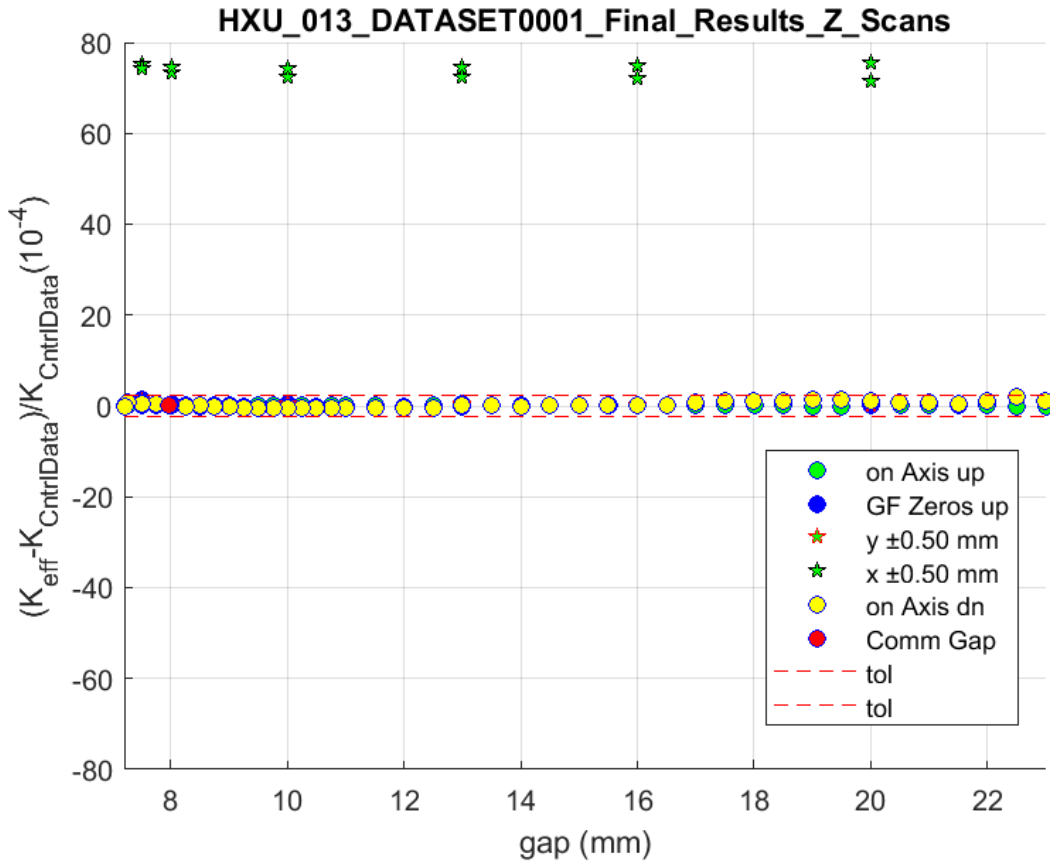
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The figure shows undulator strength  $K_{\text{eff}}$  as a function of gap over the 7.2 mm—20 mm operational range. The legend shows a number of different cases that will be explained later in this document because their effect cannot be observed in this full scale plot. Note: The gap values are derived from the readings of the two gap encoders installed on the HXU. In that sense these are nominal gap numbers that will be close but not identical to each of the individual pole separations measured across the undulator gap. The continuous conversion between the two axes (i.e.  $K_{\text{eff}}(\text{gap})$  and  $\text{gap}(K_{\text{eff}})$ ) will be done during operations based on the list of reference data points stored in file `hxu_013_k_vs_gap_spline.dat` in the Controls Data folder on the V: drive (see final section of this document for file information). From that list  $K_{\text{eff}}(\text{gap})$  and  $\text{gap}(K_{\text{eff}})$  can be calculated via cubic spline fits or equivalent. [Documentary Information]



Evaluation of Hall Scans:  $K_{\text{eff}} - K_{\text{control}}$  vs gap

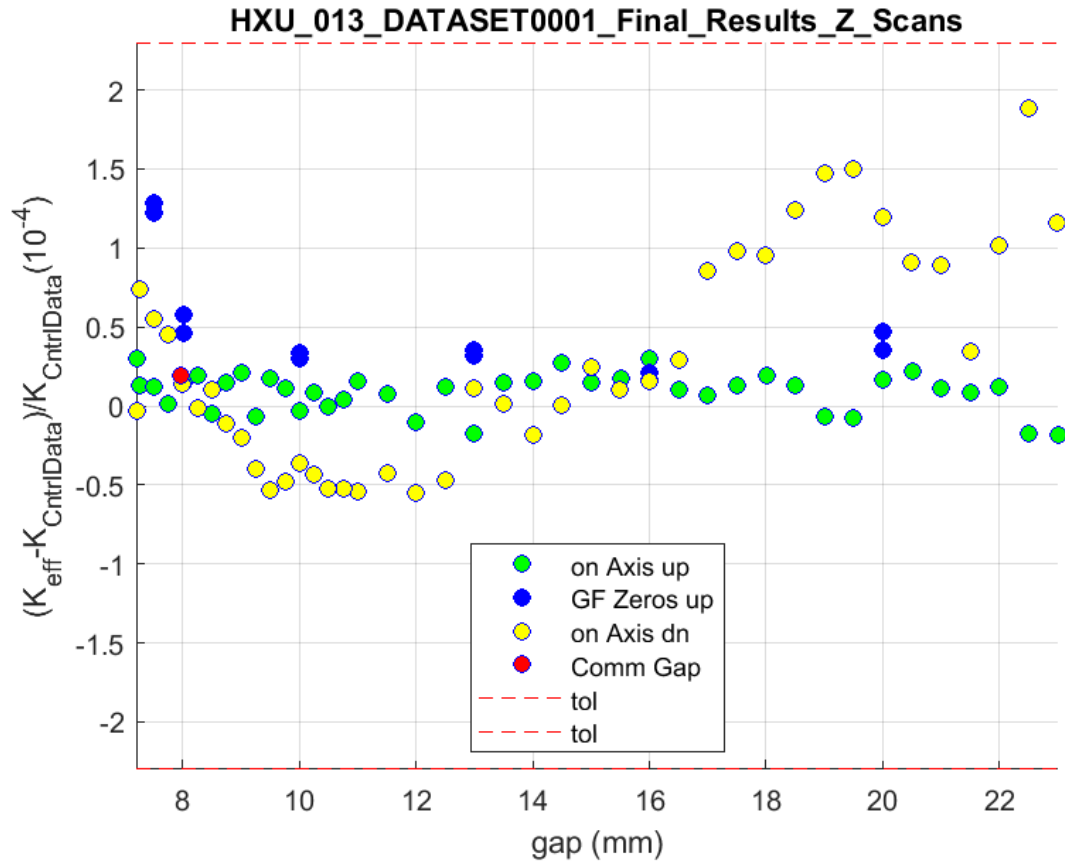


The figure shows the relative difference between the measured undulator strength  $K_{\text{eff}}$  and a cubic spline fit to the list of reference data points stored in file `hxu_013_k_vs_gap_spline.dat` in the Controls Data folder on the V: drive as a function of gap over the 7.2 mm—20 mm operational range.

The legend explains the different cases that are shown in the plot: The green filled circles are data acquired on axis as the gap was changed from close to open. The yellow filled circles are data acquired on axis as the gap was changed from open to close. The horizontal red dashed lines show the tolerance limits. Note: The undulator  $K_{\text{eff}}$  value shows a hysteresis, i.e., for a given gap, the value depends on the direction of gap motion to reach that gap. While this is not a desirable feature, its effect stays within the given tolerance and will be acceptable. The other symbols shown indicate off-axis measurements that are added for interest only. The tolerance limits apply for on-axis readings, only.



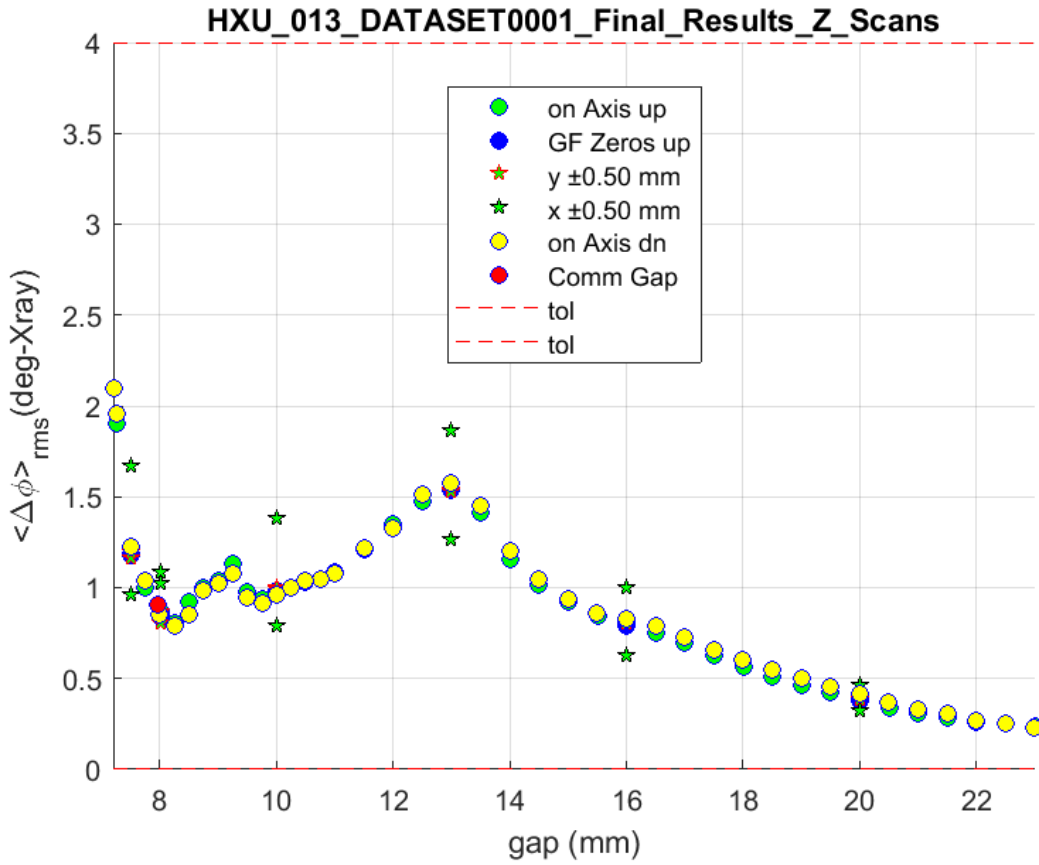
Evaluation of Hall Scans:  $(K_{\text{eff}} - K_{\text{CntrlData}}) / K_{\text{CntrlData}}$  vs gap



The figure shows some of the data shown in the previous figure but with a larger vertical scale that just captures the tolerance range. The off-axis measurements are not shown.



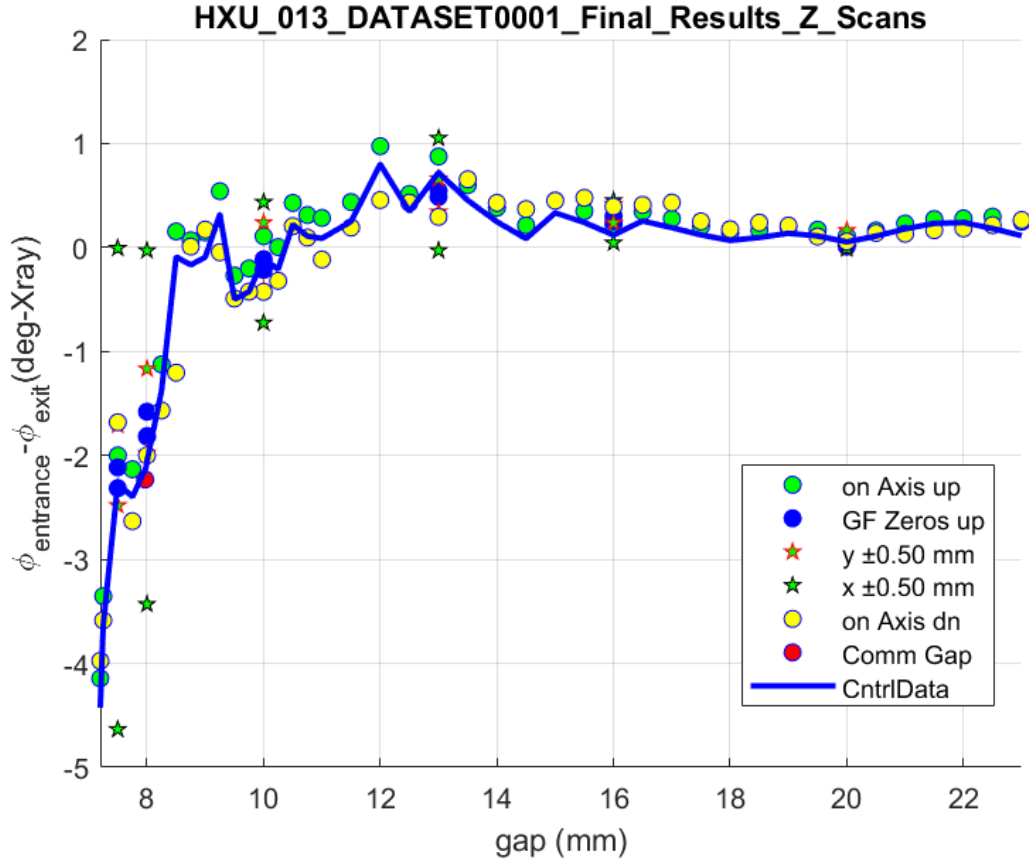
### Evaluation of Hall Scans: Phase Shake vs gap



The figure shows the phase shake,  $\langle \Delta\phi \rangle_{rms}$ , (see above) as a function of operational gap. The vertical axis extends over the entire tolerance range. The values show a slight hysteresis (show explanation above) but are well within tolerance.



**Evaluation of Hall Probe: Entrance to Exit Phase Error Balance vs. gap**



The figure shows a (negligible) imbalance of the entrance (cell boundary start to undulator core) to the exit (undulator core to cell boundary end) phase slippage for the undulator. In addition to the signals described above, the blue curve is a spline fit to the difference of the data in files

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"..._phase_match_enter_vs_gap_spline.dat"
"..._phase_match_exit_vs_gap_spline.dat".

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The small change in phase difference between opening and closing measurements shows the effect of gap hysteresis. The explanation for the legend items can be found on previous pages above. The entrance and exit phase slippage is calculated as

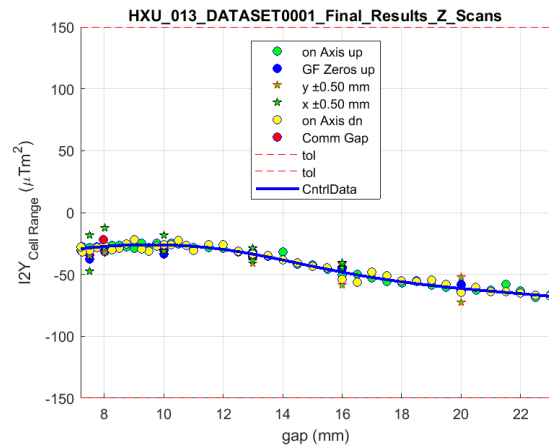
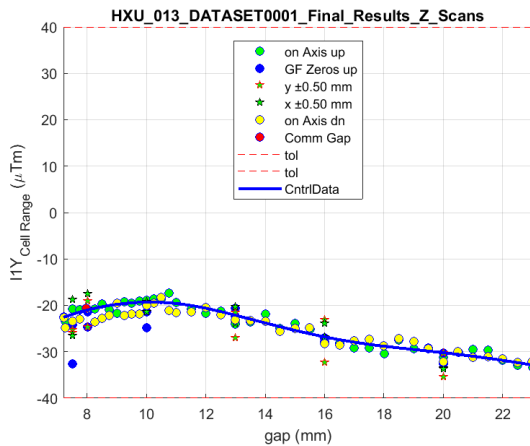
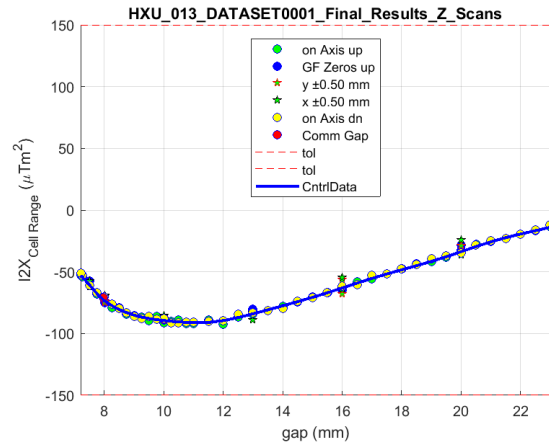
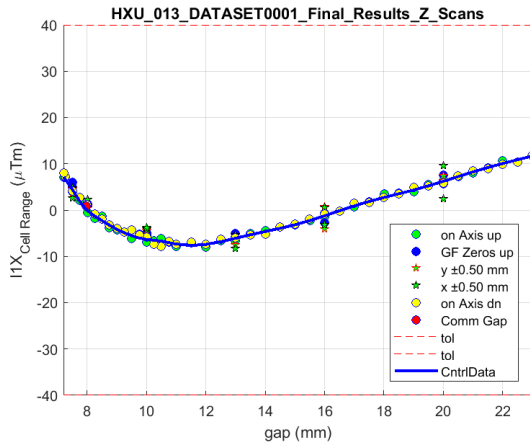
$$\phi_{\text{entrance}} = -\phi(z_{\text{Cell-Start}}) + \frac{1}{n+1} \sum_{j=1}^{n+1} (\phi(z_{B0,j}) - \pi(j-1)).$$

$$\phi_{\text{exit}} = -\phi(z_{\text{Cell-End}}) - \frac{1}{n+1} \sum_{j=1}^{n+1} (\phi(z_{B0,j}) + \pi(n+1-j)).$$

Here,  $z_{(B0,j)}$  is the  $z$  location of the zero crossing of  $B_y(z)$  in front of the  $j^{\text{th}}$  core  $B_y$  peak.  $z_{(B0,(n+1))}$  is the  $z$  location of the field zero of  $B_y(z)$  after the last core  $B_y$  peak.



Evaluation of Hall Probe: Field Integrals vs. gap



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

```

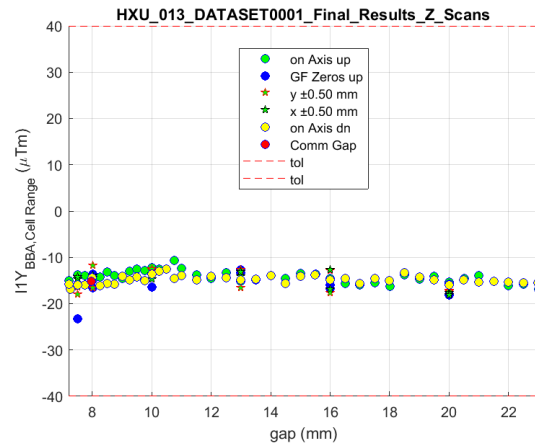
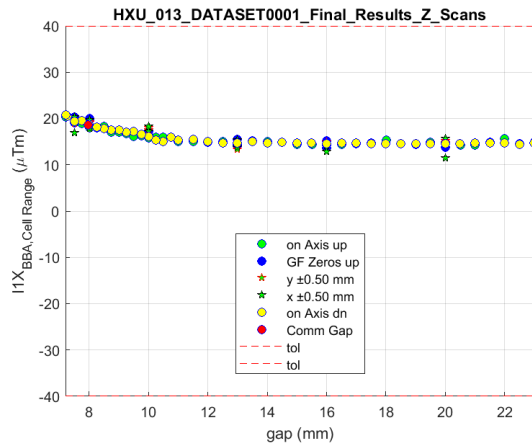
"...i1xvsgap_spline.dat",
"...i2xvsgap_spline.dat",
"...i1yvsgap_spline.dat",
"...i2yvsgap_spline.dat",

```

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 Probe: BBA Field Integrals

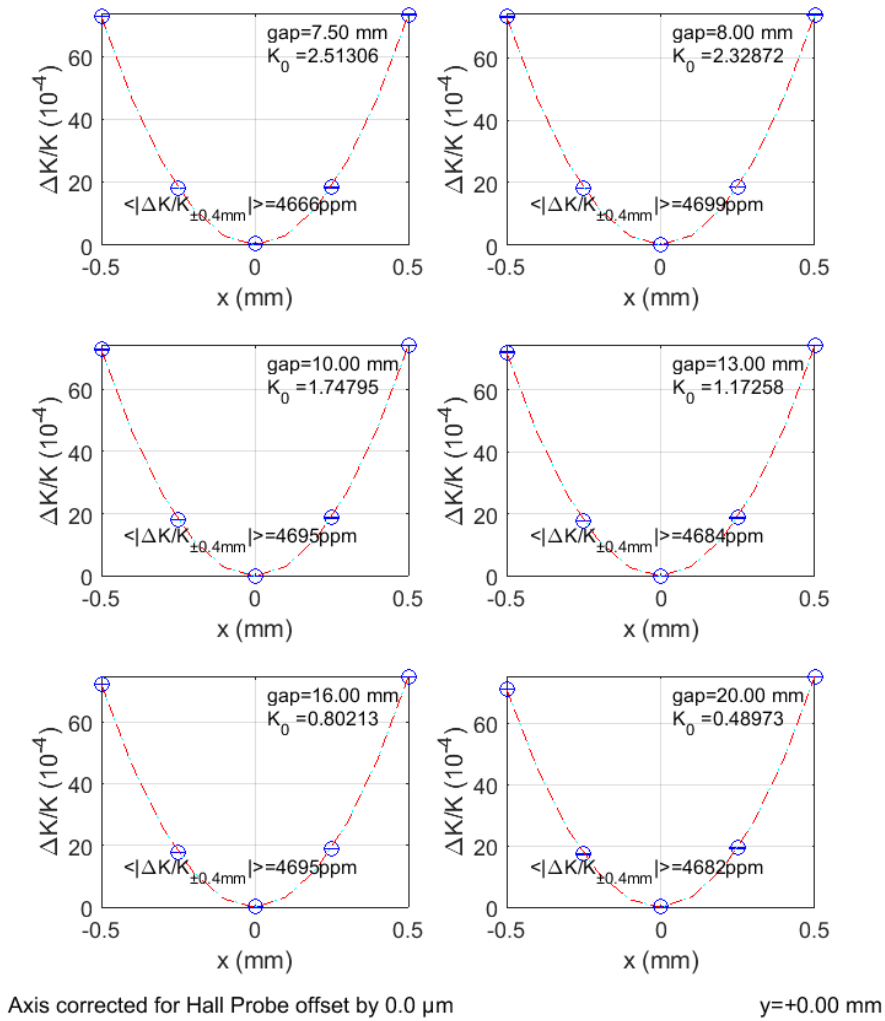


The figure shows the first integrals after a BBA equivalent correction was applied. The values stay within tolerance over the operational range.

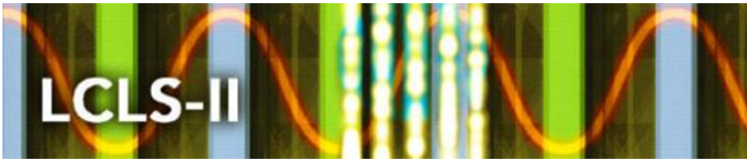


Evaluation of Hall Scans:  $K$  vs.  $x$  dependence

HXU\_013\_DATASET0001\_Final\_Results\_Z\_Scans

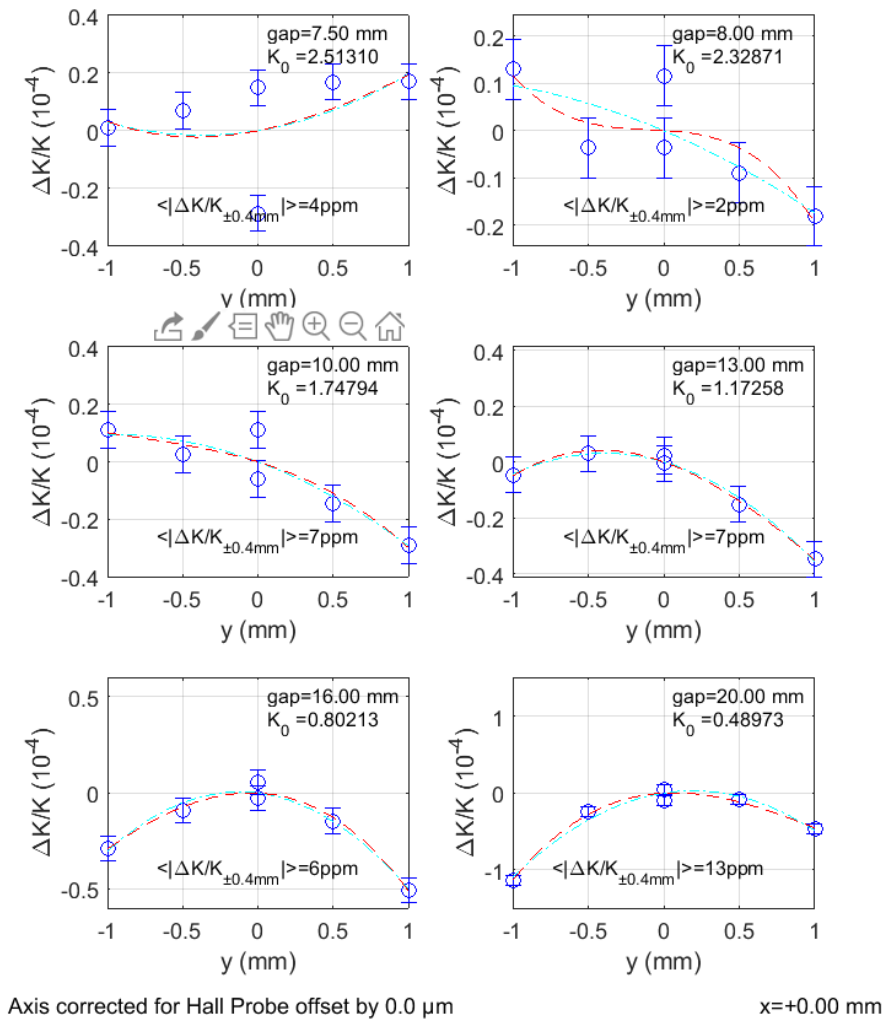


The figure shows the deviation of the relative undulator strength,  $K$ , from the off-axis value,  $K_0$ , as function of  $x$  at a number of operational gaps. The deviations follow closely the expected functional form  $(\cosh(k_u y) - 1)$ .



Evaluation of Hall Scans:  $K$  vs.  $y$  dependence

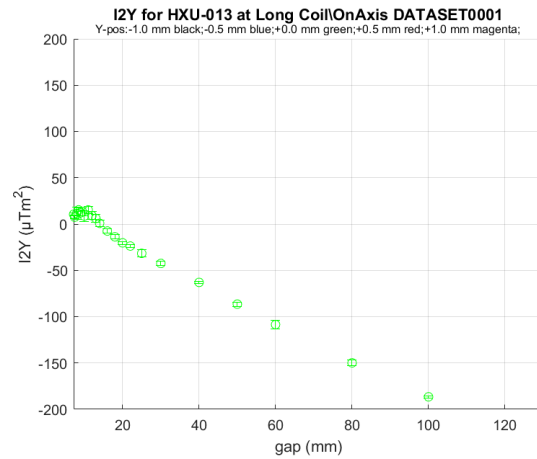
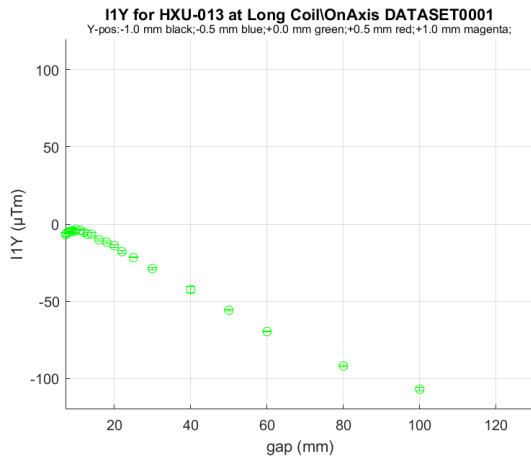
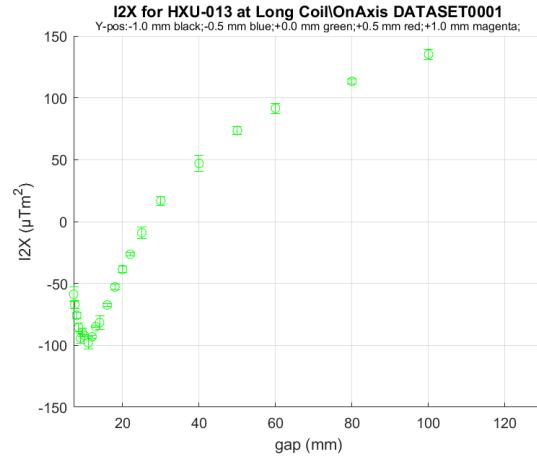
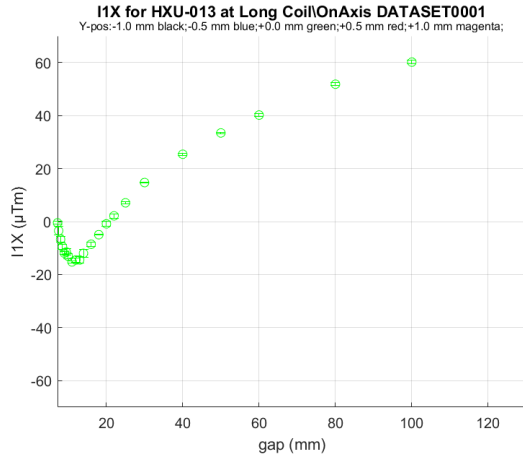
HXU\_013\_DATASET0001\_Final\_Results\_Z\_Scans



The figure shows the deviation of the relative undulator strength,  $K$ , value from the on-axis value,  $K_0$ , as function of  $y$  at a number of operational gaps. The average deviation at  $z = 0.4$  mm is well below the tolerance of 160 ppm in all cases.



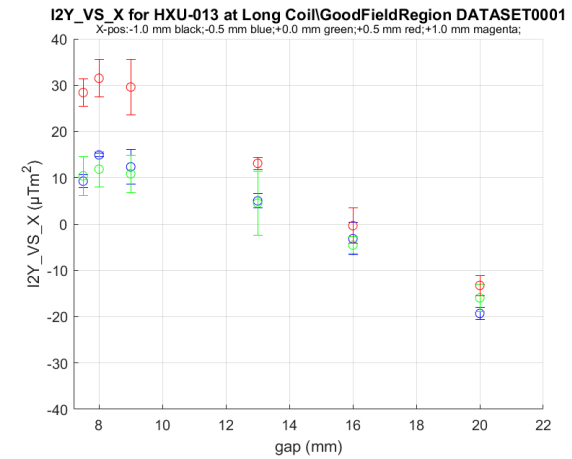
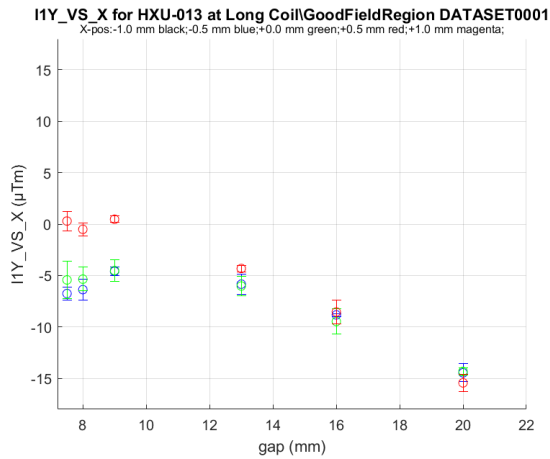
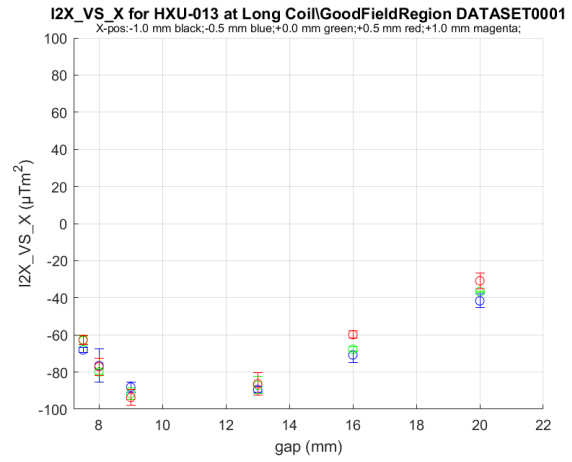
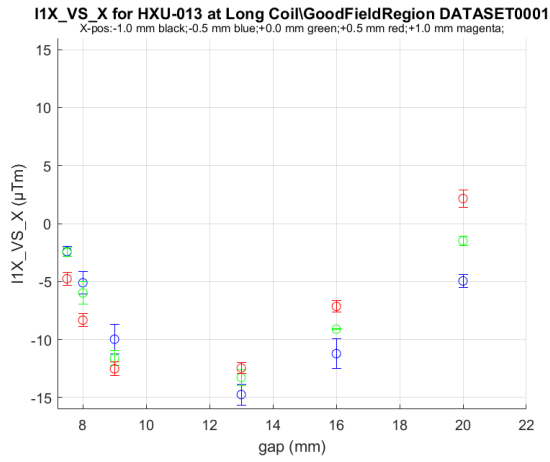
### Long Coil Measurement of the On-Axis Field Integrals



The figure shows the field integrals obtained from long coil measurements on-axis. The vertical axes extend over the tolerance range. All integrals are in tolerance.



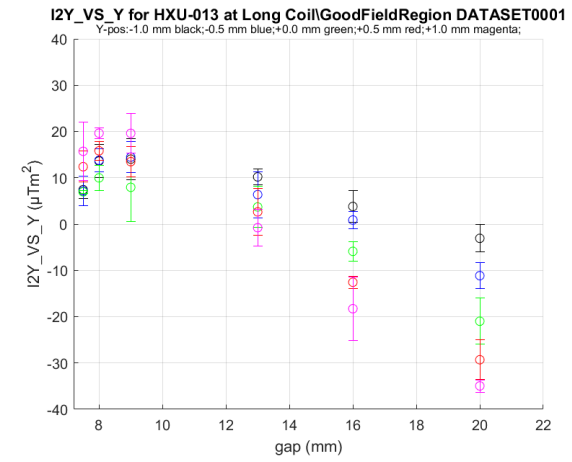
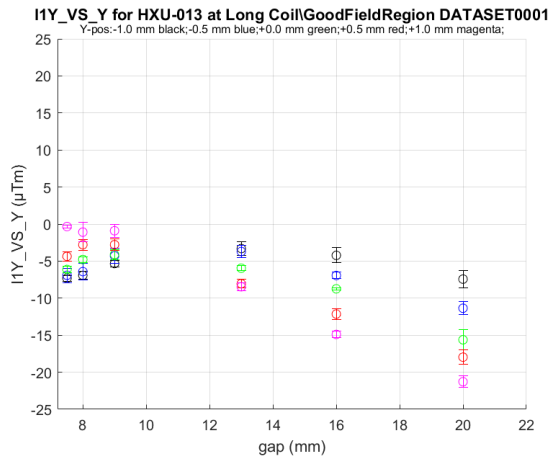
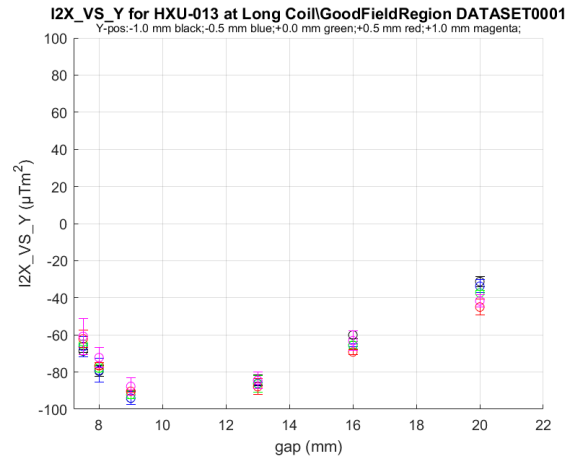
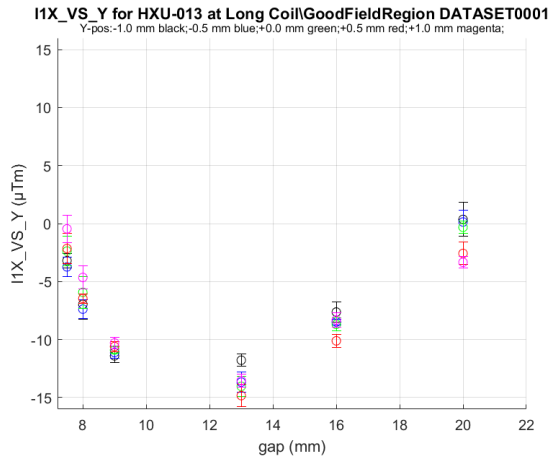
## Long Coil Measurement of the Horizontally Off-Axis Field Integrals



The figure shows the integrals obtained from long coil measurements off axis in the vertical plane using colors to indicate offset distance (black: -1.0 mm, blue: -0.5 mm, green: on-axis; red: +0.5 mm, magenta: +1.0 mm). The vertical axes extend of the tolerance range. All integrals are in tolerance.



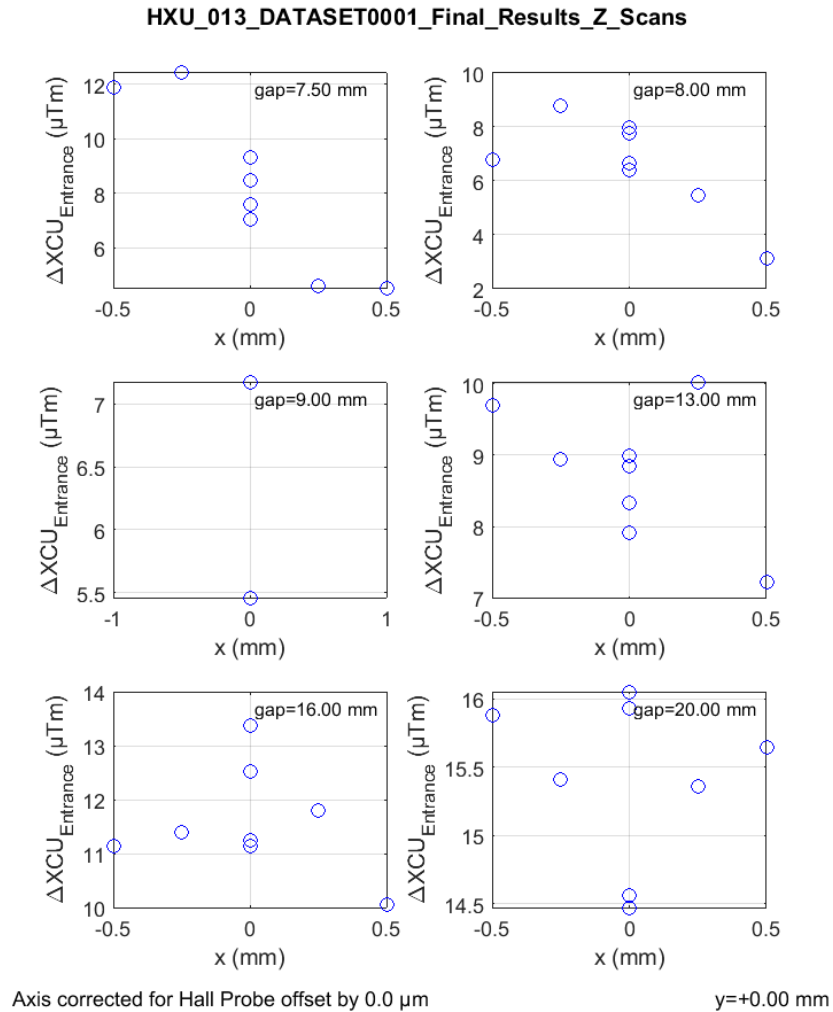
## Long Coil Measurement of the Vertically Off-Axis Field Integrals



The figure shows the field integrals obtained from long coil measurements off axis in the horizontal plane using colors to indicate offset distance (black: -1.0 mm, blue: -0.5 mm, green: on-axis; red: +0.5 mm, magenta: +1.0 mm). The vertical axes extend over the tolerance range. All integrals are in tolerance.



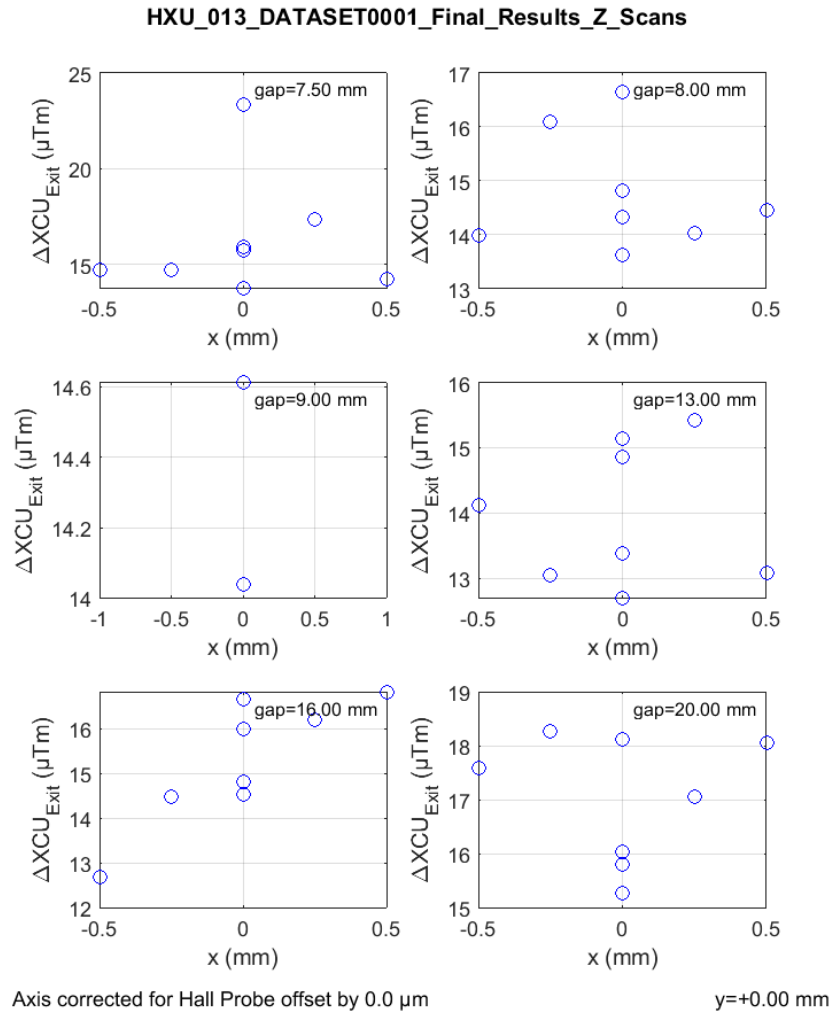
**Estimated Upstream Horizontal Corrector Strength Requirement vs.  $x$**



The figure shows the required strength of the upstream horizontal corrector to remove the second vertical undulator 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 small and well below the maximum correction capabilities of greater than 550  $\mu Tm$  of the actual correctors.



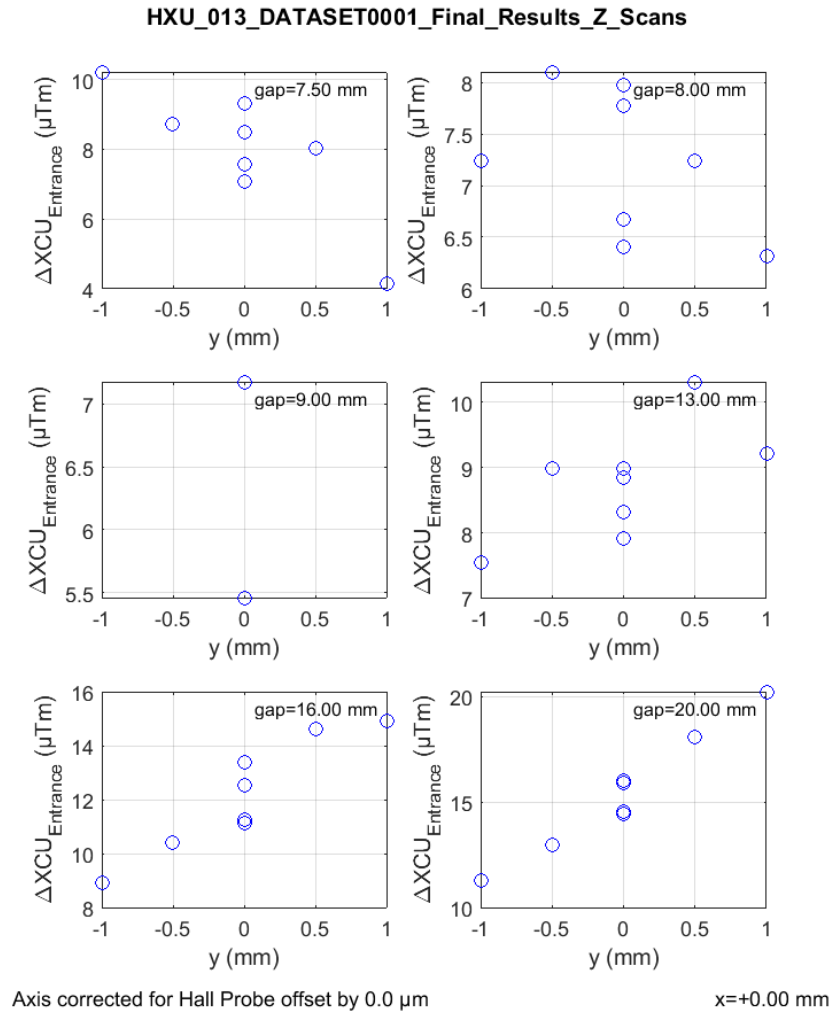
**Estimated Downstream Horizontal Corrector Strength Requirement vs.  $x$**



The figure shows the required strength of the downstream horizontal corrector to remove the first vertical undulator field integral 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 small and well below the maximum correction capabilities of greater than 550  $\mu Tm$  of the actual correctors.



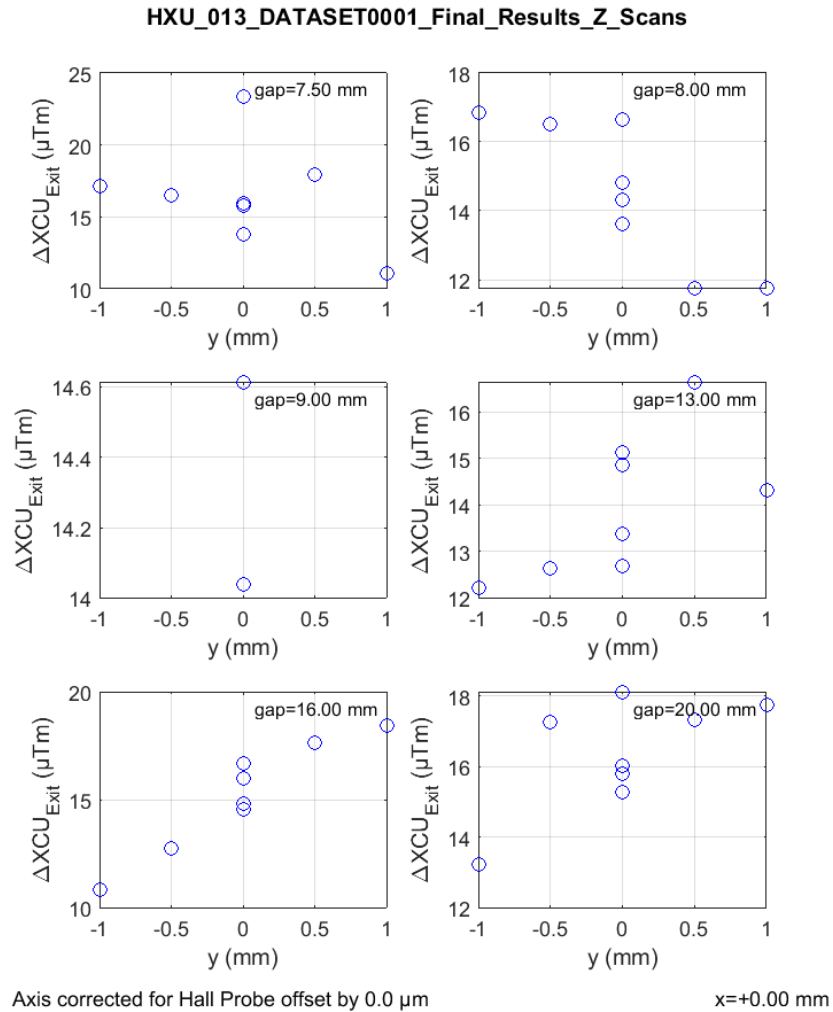
**Estimated Upstream Horizontal Corrector Strength Requirement vs.  $y$**



The figure shows the required strength of the upstream horizontal corrector to remove the second vertical undulator field integrals at the downstream BPM for a number of operational undulator gaps. The analysis was done at a number of off-axis locations in the  $y$ - $z$  plane. All values are small and well below the maximum correction capabilities of greater than 550  $\mu Tm$  of the actual correctors.



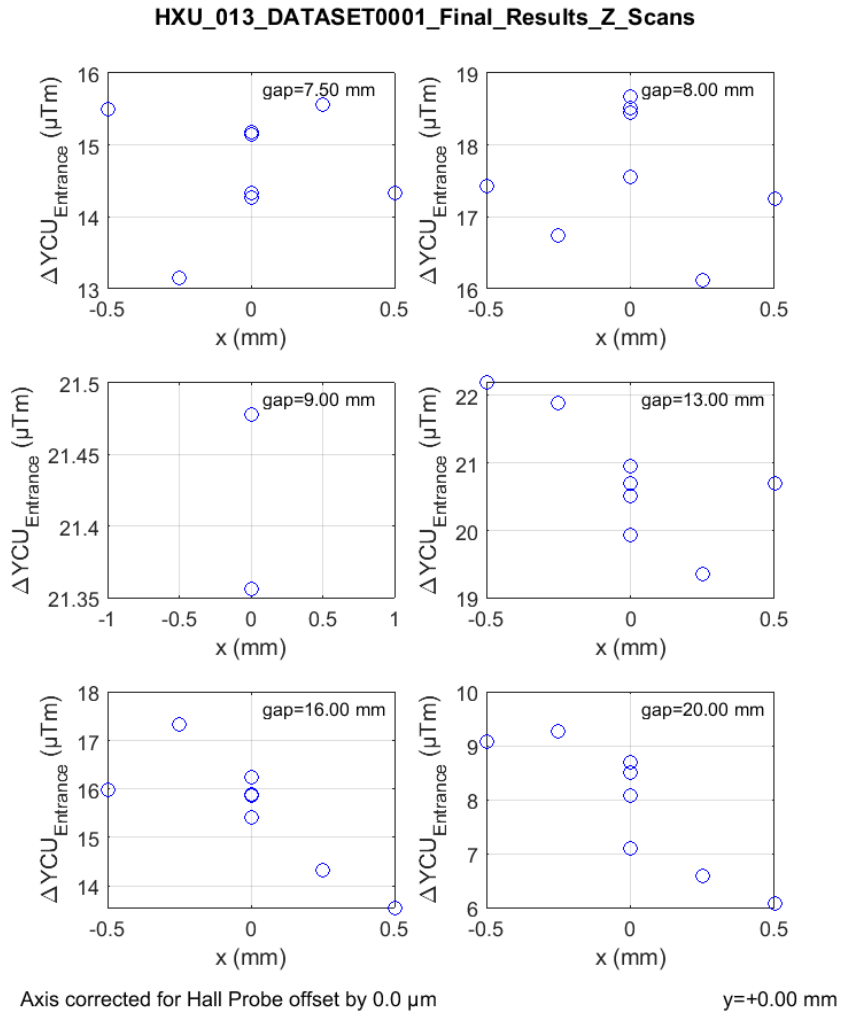
**Estimated Downstream Horizontal Corrector Strength Requirement vs.  $y$**



The figure shows the required strength of the upstream horizontal corrector to remove the first vertical undulator and upstream corrector field integrals at the downstream BPM for a number of operational undulator gaps. The analysis was done at a number of off-axis locations in the  $y$ - $z$  plane. All values are small and well below the maximum correction amplitude of greater than 550  $\mu Tm$  capabilities of the actual correctors.



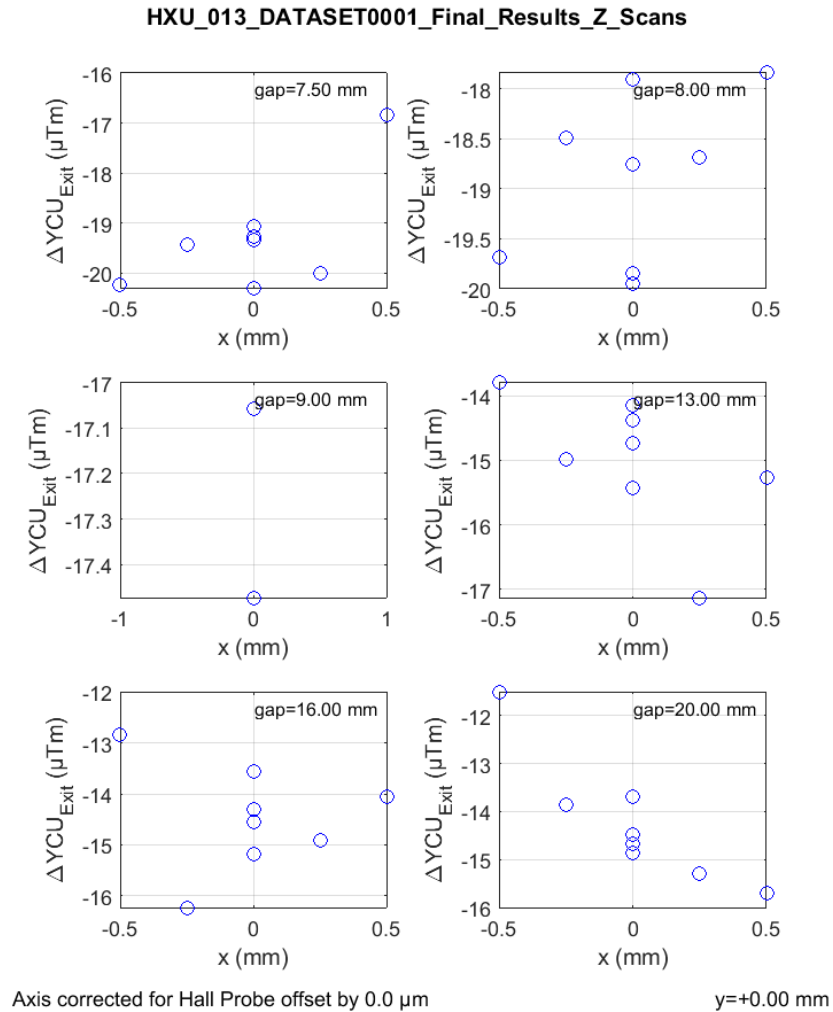
**Estimated Upstream Vertical Corrector Strength Requirement vs.  $x$**



The figure shows the required strength of the upstream horizontal corrector to remove the second horizontal undulator 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 small and well below the maximum correction capabilities of greater than 550  $\mu\text{Tm}$  of the actual correctors.



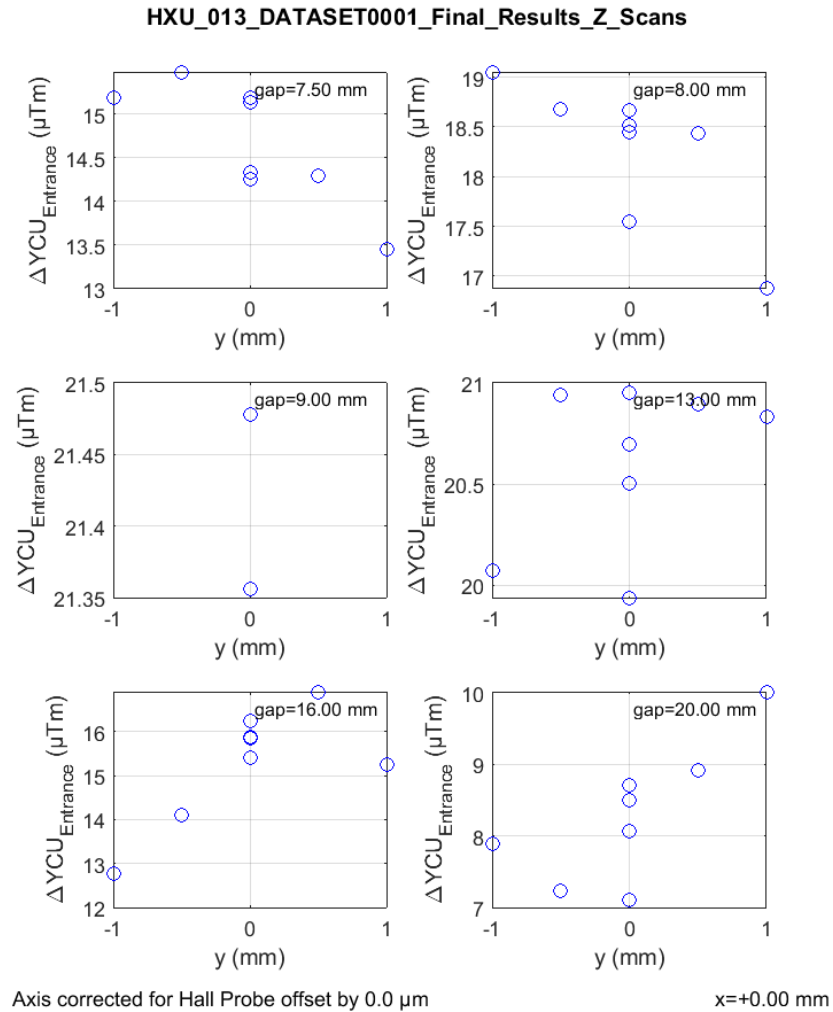
**Estimated Downstream Vertical Corrector Strength Requirement vs.  $x$**



The figure shows the required strength of the downstream vertical corrector to remove the first horizontal undulator field integral 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 small and well below the maximum correction capabilities of greater than 550  $\mu Tm$  of the actual correctors.



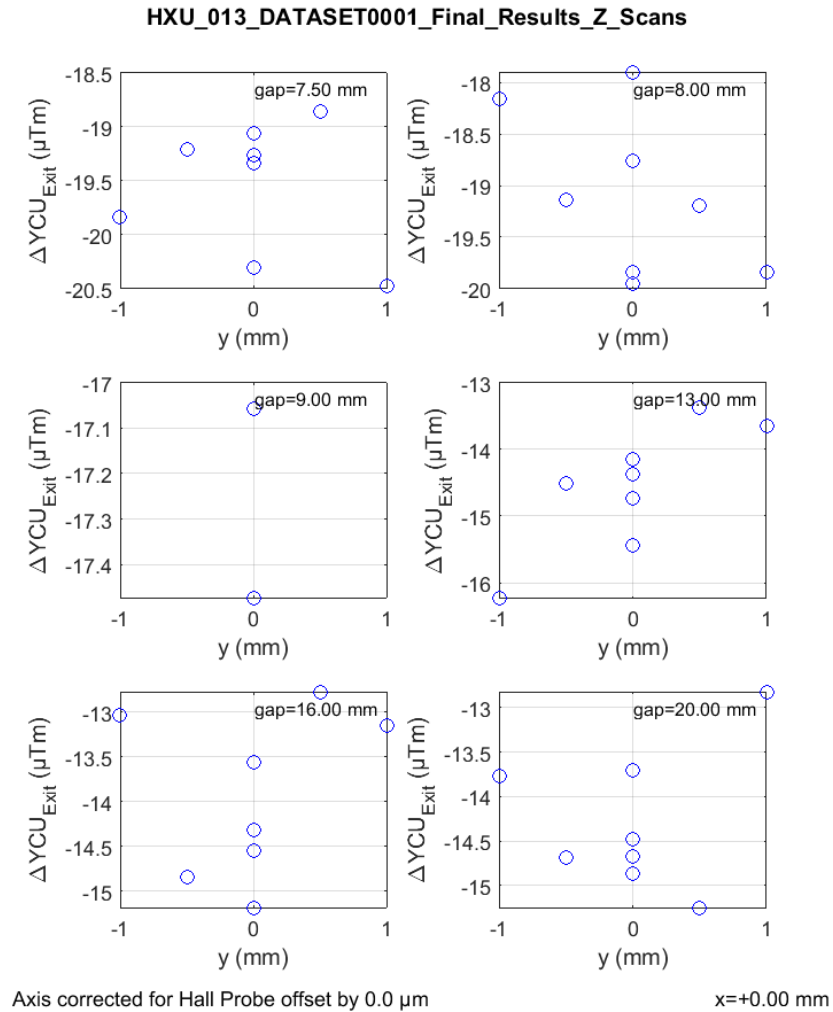
**Estimated Upstream Vertical Corrector Strength Requirement vs.  $y$**



The figure shows the required strength of the upstream vertical corrector to remove the second horizontal undulator 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  $y$ - $z$  plane. All values are small and well below the maximum correction capabilities of greater than 550  $\mu Tm$  of the actual correctors.



**Estimated Downstream Vertical Corrector Strength Requirement vs.  $y$**



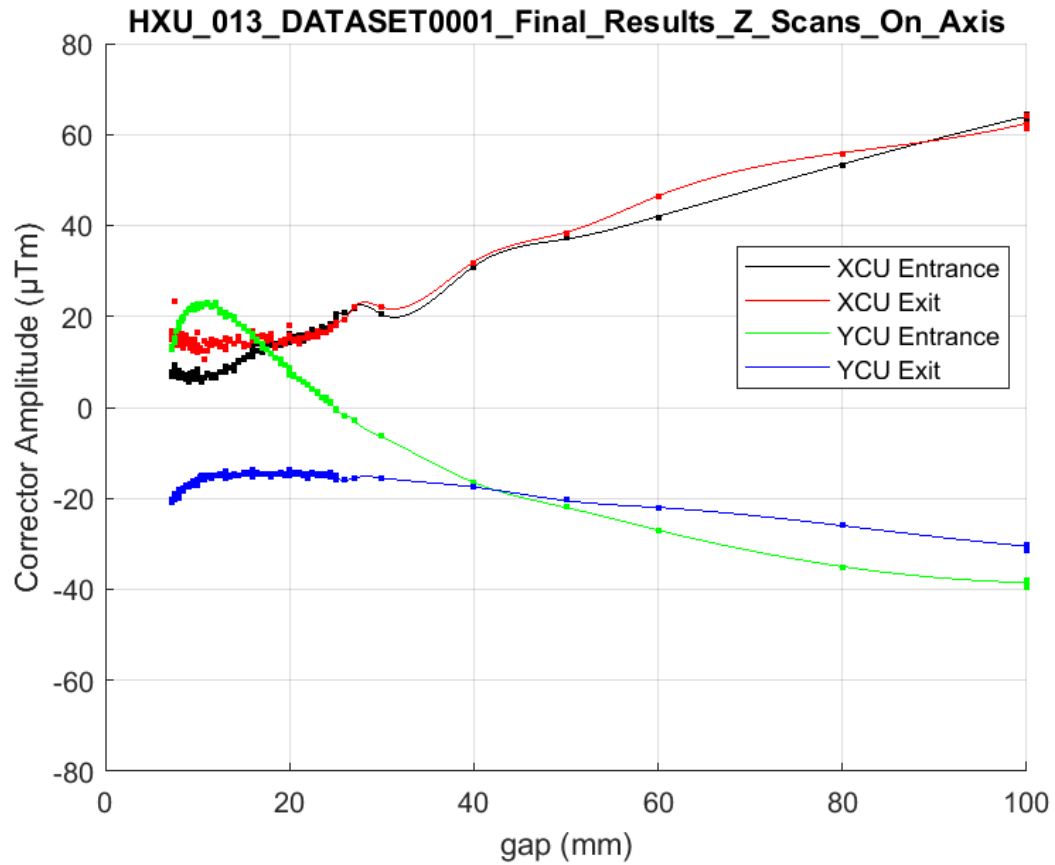
The figure shows the required strength of the downstream vertical corrector to remove the first horizontal undulator field integral and the upstream corrector field integral at the downstream BPM for a number of operational undulator gaps. The analysis was done at a number of off-axis locations in the y-z plane. All values are small and well below the maximum correction capabilities of greater than 550  $\mu Tm$  of the actual correctors.



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### Estimated Corrector Strengths Requirement vs. gap

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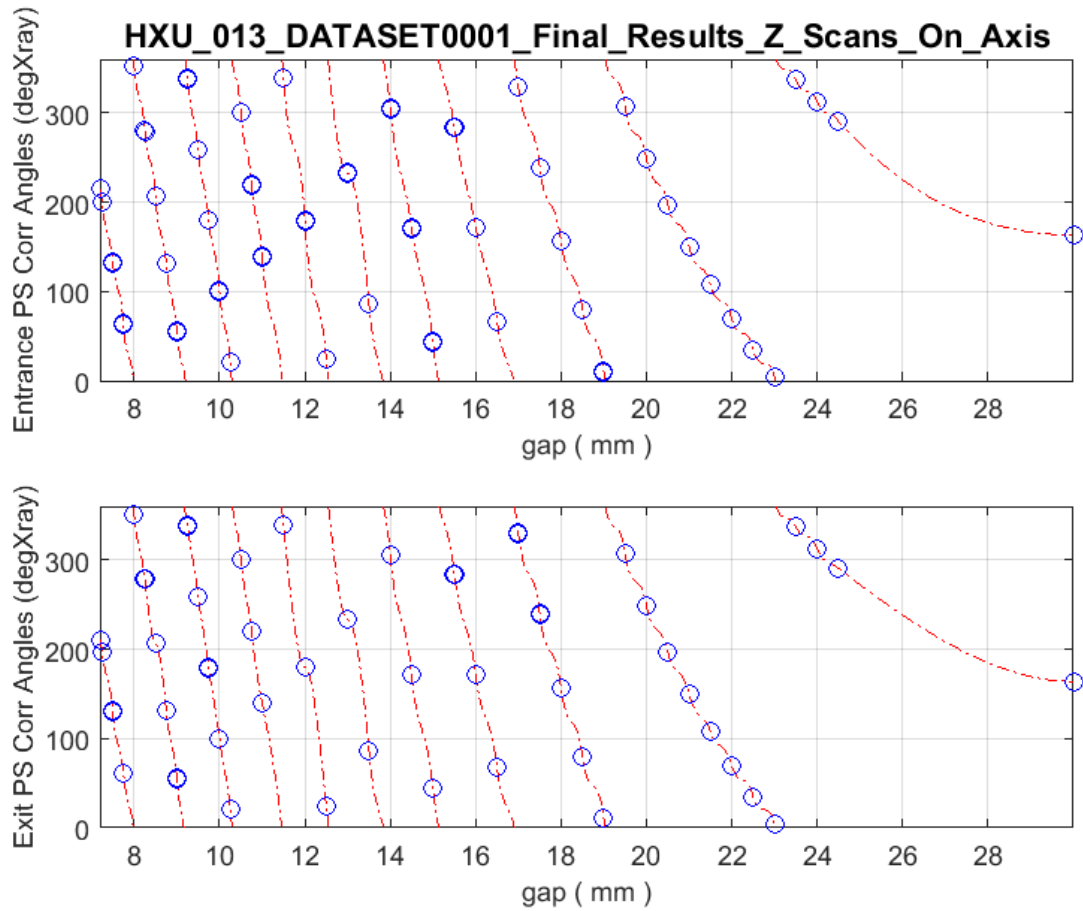
The figure shows as a function of undulator gap the required strengths of the upstream and downstream horizontal and vertical correctors to remove the effect of undulator field integrals at the downstream BPM over the entire available gap range. All values are small and well below the maximum correction capabilities of greater than 550  $\mu\text{Tm}$  of the actual correctors.



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### Estimated Phase Shifter Angle Change Requirement vs. gap

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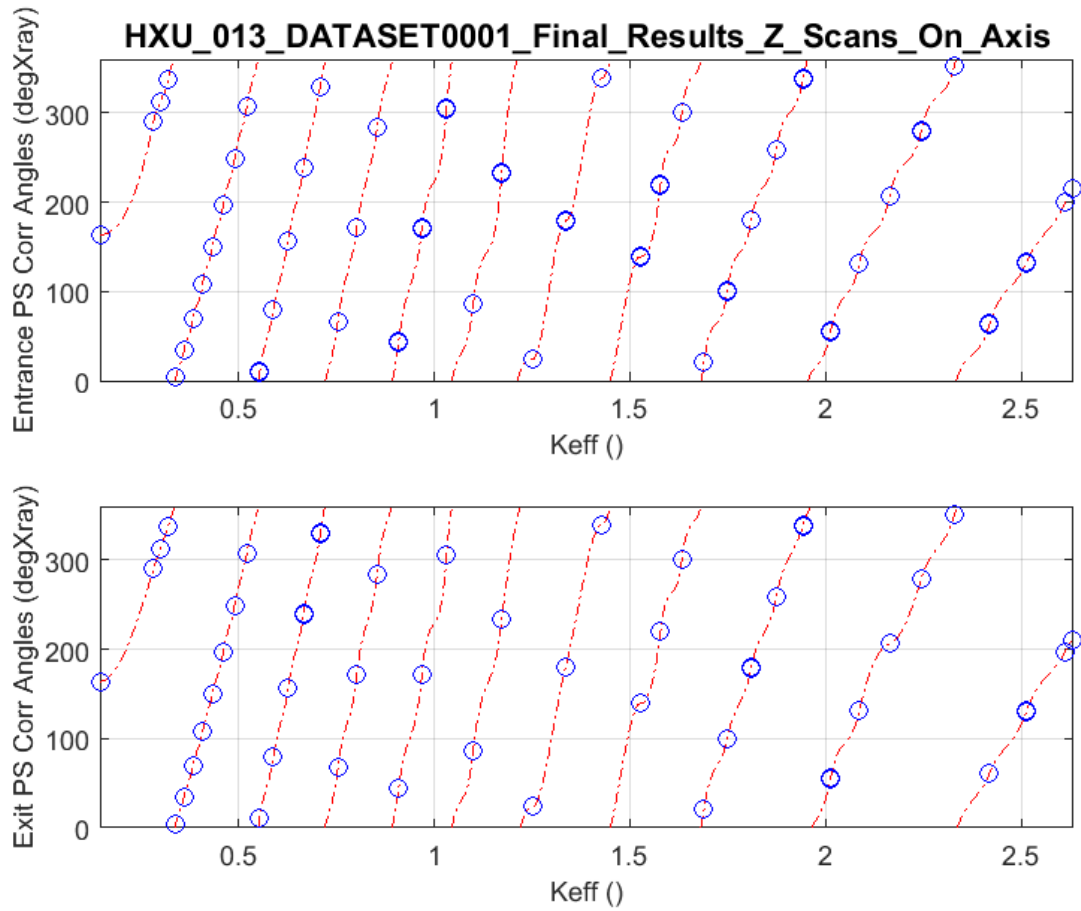
The top and bottom figures show as a function of undulator gap the required correction angles to be added to the upstream and downstream phase shifters, respectively. The red lines indicate the minimum required phase shifter phase angle increases, which are in the 0 to 360 degXray phase shift range. The blue circles indicate MMF measurements.



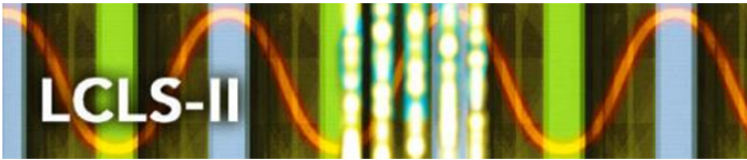
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**Estimated Phase Shifter Angle Change Requirement vs.  $K_{eff}$**

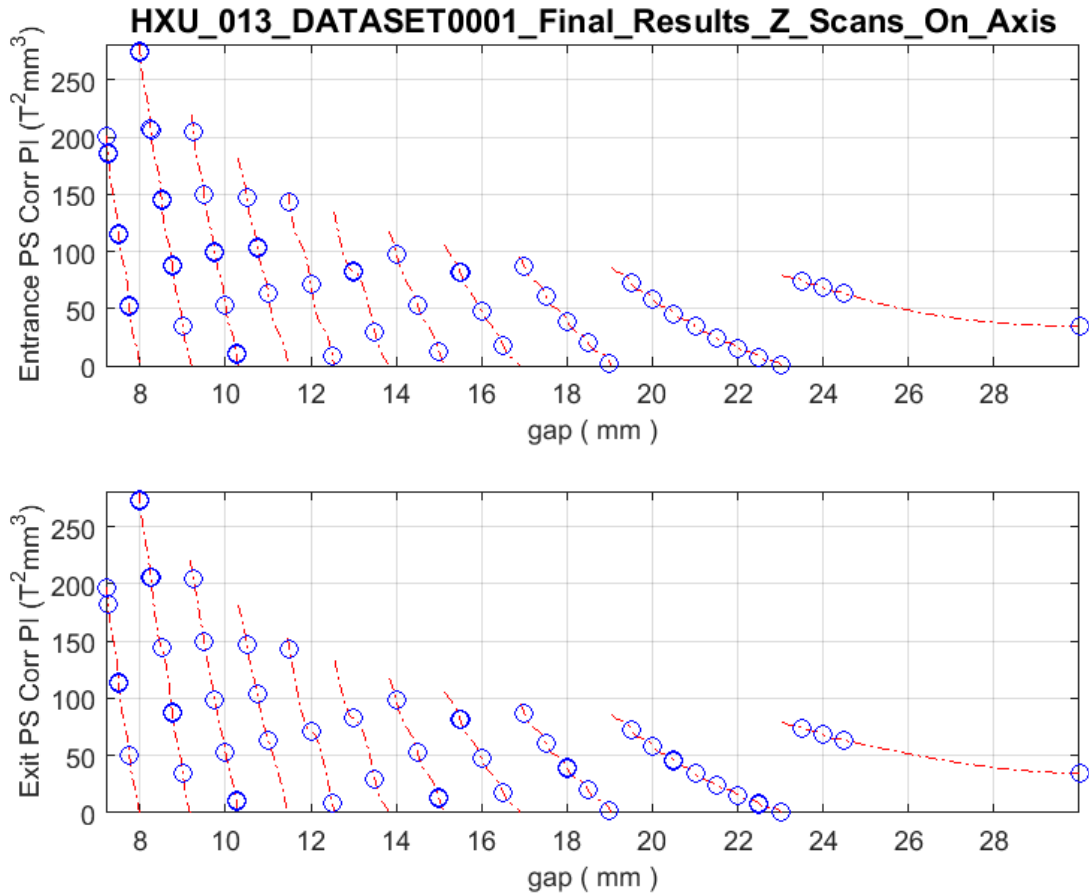
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The top and bottom figures as a function of undulator parameter  $K_{eff}$  the required correction angles to be added to the upstream and downstream phase shifters, respectively. The red lines indicate the minimum required phase shifter phase angle increases, which are in the 0 to 360 degXray phase shift range. The blue circles indicate MMF measurements.



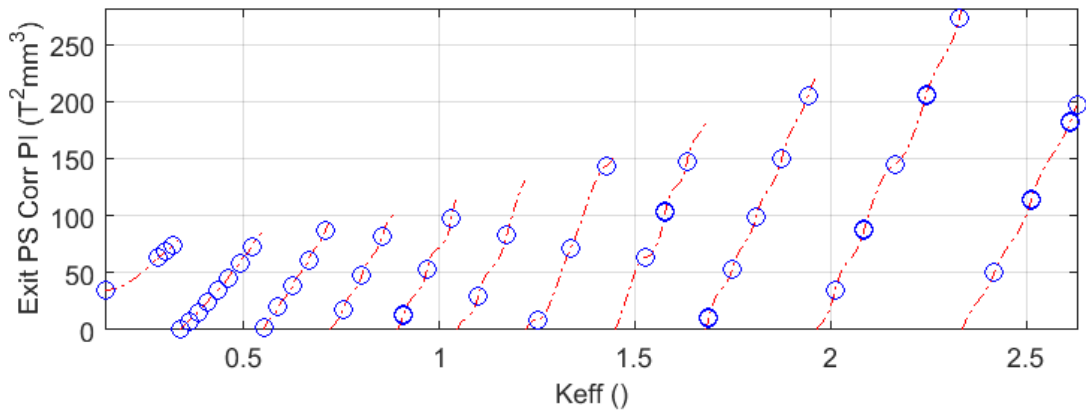
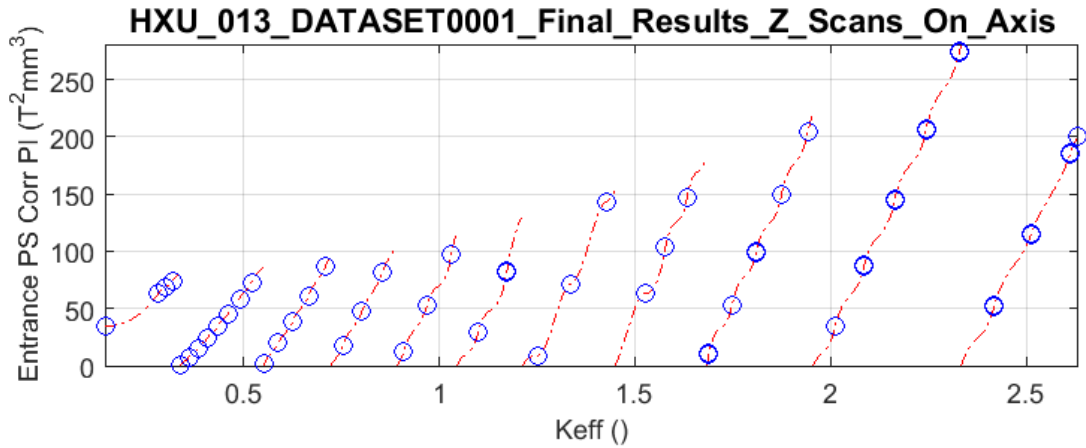
Estimated Phase Shifter Phase Integral Change Requirement vs. gap



The top and bottom figures show as a function of undulator gap the required correction phase integral (PI) values to be added to the upstream and downstream phase shifters, respectively. The red lines indicate the minimum required phase shifter phase angle increases, which are in the 0 to 360 degXray phase shift range. The blue circles indicate MMF measurements.



Estimated Phase Shifter Phase Integral Change Requirement vs.  $K_{eff}$



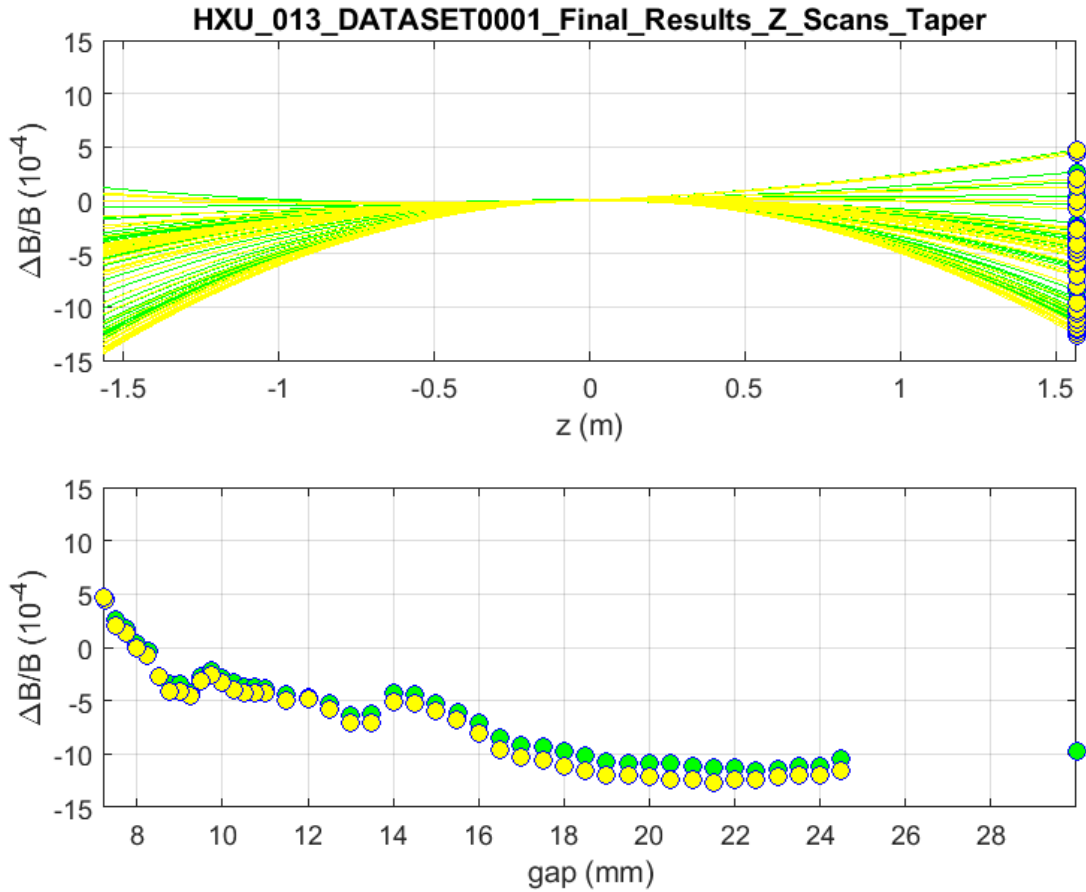
The top and bottom figures show as a function of undulator parameter  $K_{eff}$  the required correction phase integral (PI) values to be added to the upstream and downstream phase shifters, respectively. The red lines indicate the minimum required phase shifter phase angle increases, which are in the 0 to 360 degXray phase shift range. The blue circles indicate MMF measurements.



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### Zero Taper Fit vs. gap

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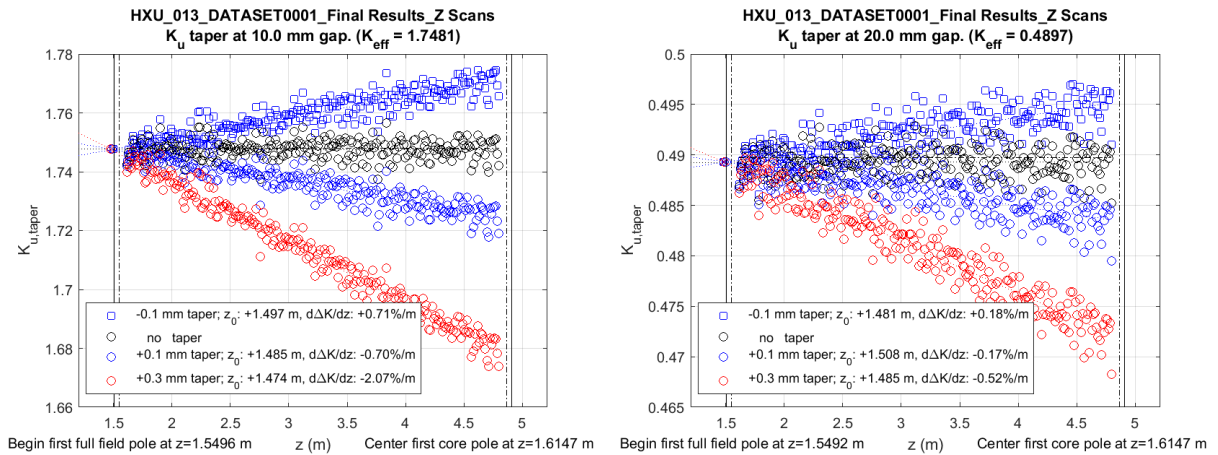


The top figure shows quadratic fits to the absolute values  $K_u$  for each core pole for different gaps when the device is set to zero taper. Green curves indicate that the gap was approached from smaller gaps, while yellow curves indicate approach from larger gaps. The fitted  $K_u$  value of the last pole is marked with a solid circle with the same color coding. The bottom shows the same solid circles as in the upper plot but this time plotted against the corresponding undulator gap encoder values. The figures show that the undulator has a small quadratic taper that varies with gap. This could explain the phase shake dependence on gap as shown in an earlier figure.

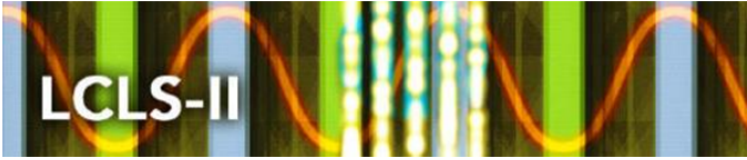


## Gap Tapering—Tapered $K_u$ Values

The SXU devices support a gap taper, which is controlled by the taper PV, which holds the difference between the upstream and downstream gap encoder readings measured in micro-meter. The taper can be varied over the  $\pm 300 \mu\text{m}$ -range.

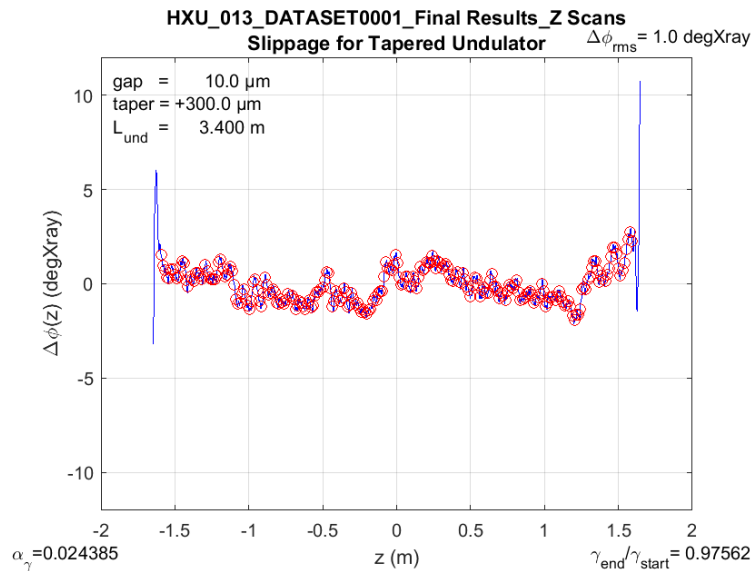
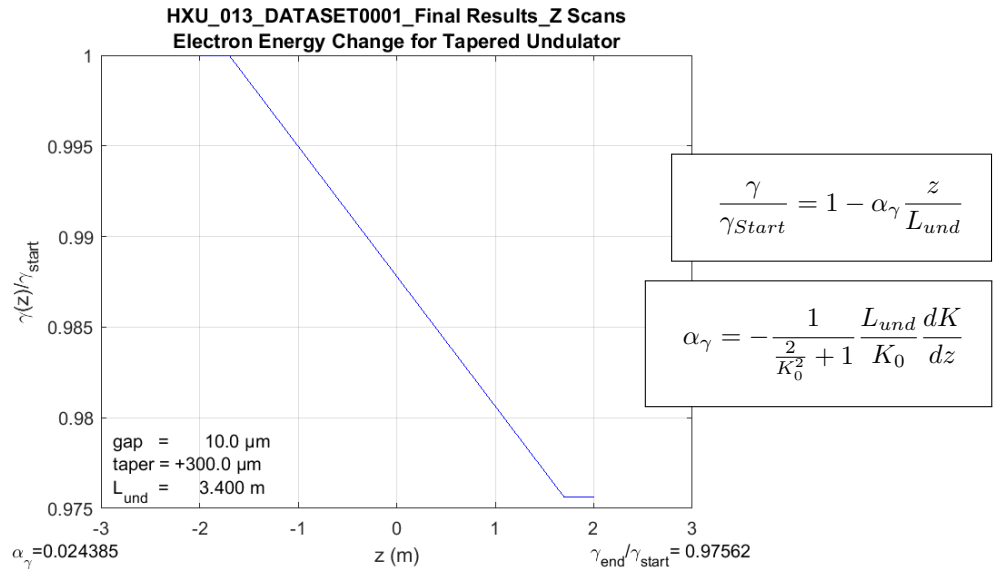


The figure shows  $K_u$ , taper for the 246 core poles based on Hall probe measurements versus  $z$  location for 4 different taper amplitudes ( $-100 \mu\text{m}$ ,  $0 \mu\text{m}$ ,  $+100 \mu\text{m}$ ,  $+300 \mu\text{m}$ ) and 2 different gaps (8 mm, 22 mm). The vertical dashed lines indicate the beginning of the first and the end of the last full field pole. The solid vertical lines indicate the longitudinal limits of strongback. The crosses on the left hand side of the undulator segment border surrounded by the  $K_u$ , taper symbol for the representative taper amplitude indicate the intersections between linear fits (indicated by dotted lines in the representative color) and the  $K_u$  values untapered case with each of the tapered cases. The horizontal dash-dotted line next to the figure center (hard to see) indicated the level of  $K_{\text{eff}}$  of the untapered undulator. The taper operation for this segment is functional.



## Gap Tapering—Tapered $K_u$ Values

Generally, gap tapering will cause significant increases in the phase shake within the undulator segment. If however during high gain FEL operation the electrons loose significant amounts of energy, a matching gap taper can reduce the total phase shake to stay within the original parallel gap phase shake tolerance for constant energy.



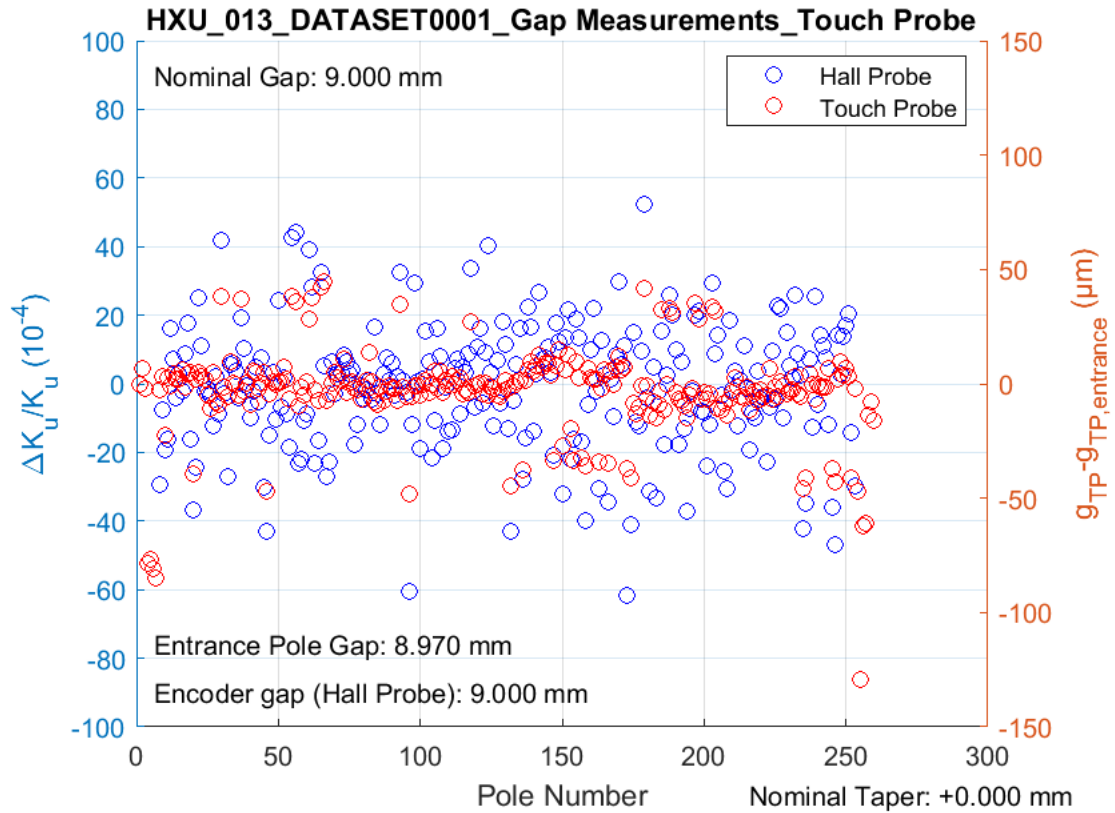
The upper figure shows a simplified linear energy loss function (Lorentz factor  $\gamma/\gamma_{Start}$ ) optimized for the 0.3 mm gap taper at an 10 mm nominal gap. The lower figure shows the phase error along the undulator segment for the same parameters.



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**Touch Probe (TP) Analysis — Per pole gap vs. per pole  $K$  (untapered)**

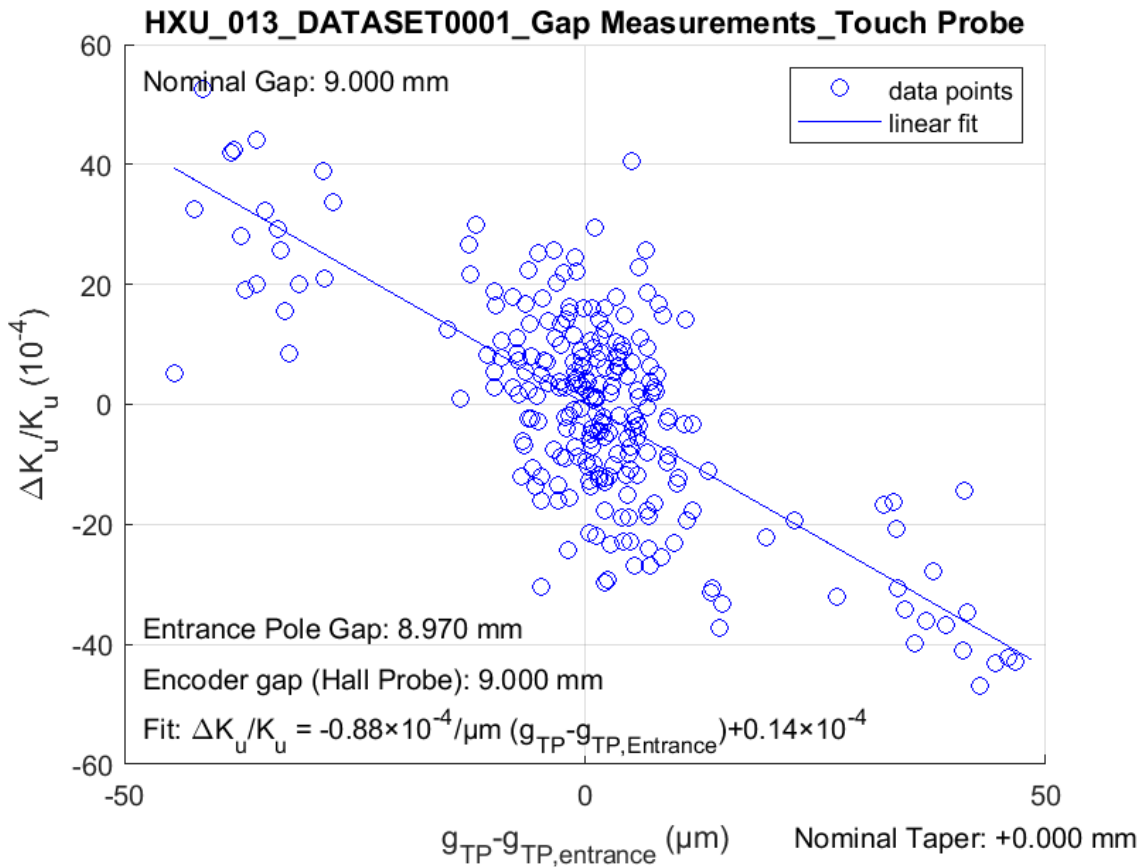
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The figure shows  $\Delta K/K$  (blue, left axis) (for the 246 core poles) as well as mechanical gap heights ( $\langle g_{TP} \rangle - g_{TP}$ ) (red, right axis) (for all 260 poles) based on touch probe measurements versus pole number. The large amplitude outliers are the result of tuning.



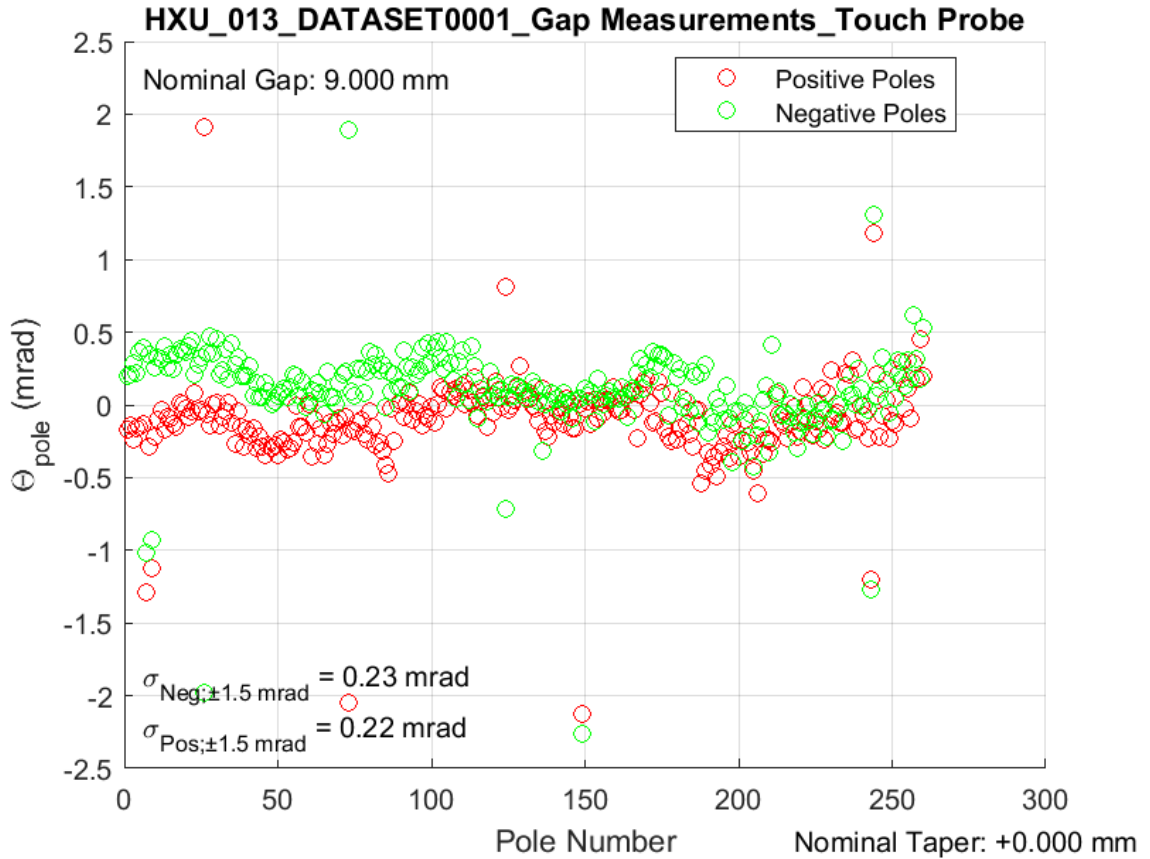
Touch Probe (TP) Analysis —  $K$  vs. per pole gap (untapered)



The figure shows the correlation between the  $\Delta K_u/K_u$  for each pole from Hall probe measurements for the tuning gap and the deviation of the pole gap measured by the touch probe relative to its average (for the 246 core poles). The average gap measured with the touch probe and the one measured with the gap encoder are shown in the lower left corner of the figure. Also shown is the fit function.



### Touch Probe (TP) Analysis — Pole Cant Angles (untapered)



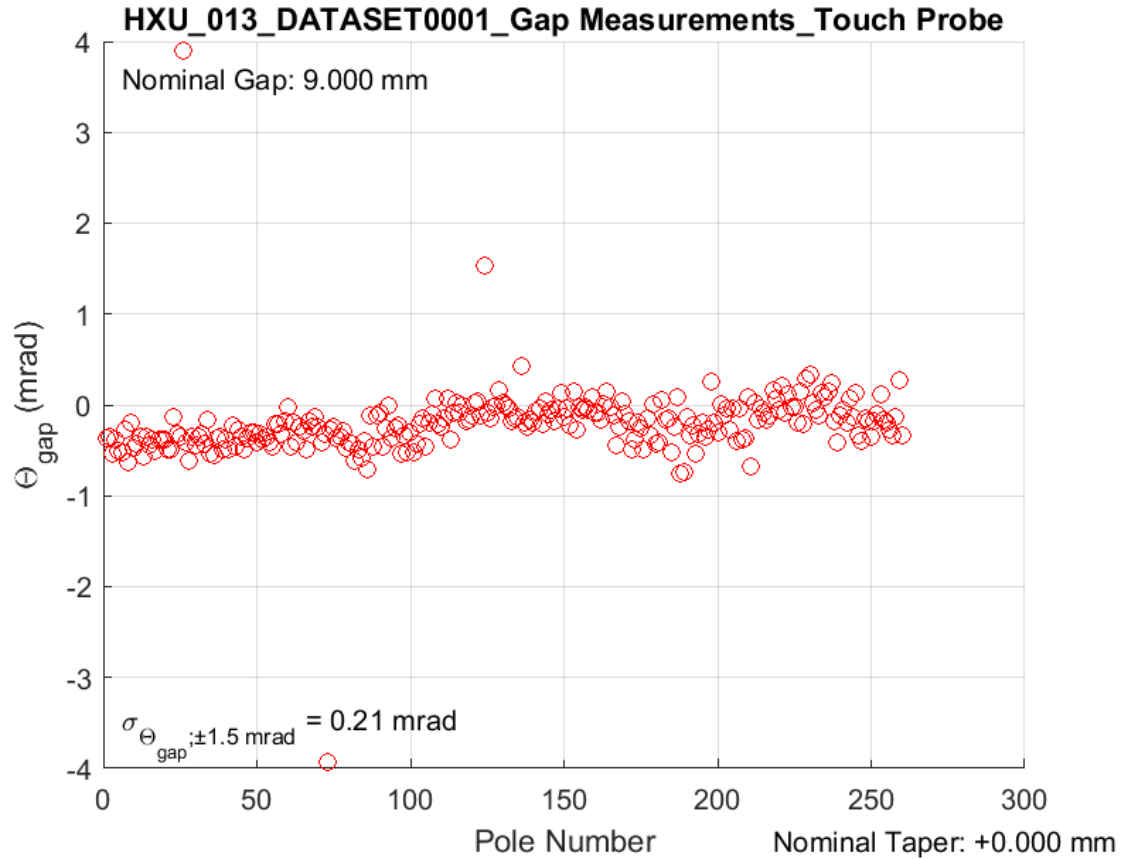
The figure shows the cant angles of each pole (top red, bottom green) relative to the horizontal plane defined by the Kugler bench at the Tuning Gap for all 260 poles, measured by the touch probe. The rms width of each distribution within a  $\pm 1.5$  mrad band is shown in the lower left corner of the figure.



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**Touch Probe (TP) Analysis — Gap Cant Angles (untapered)**

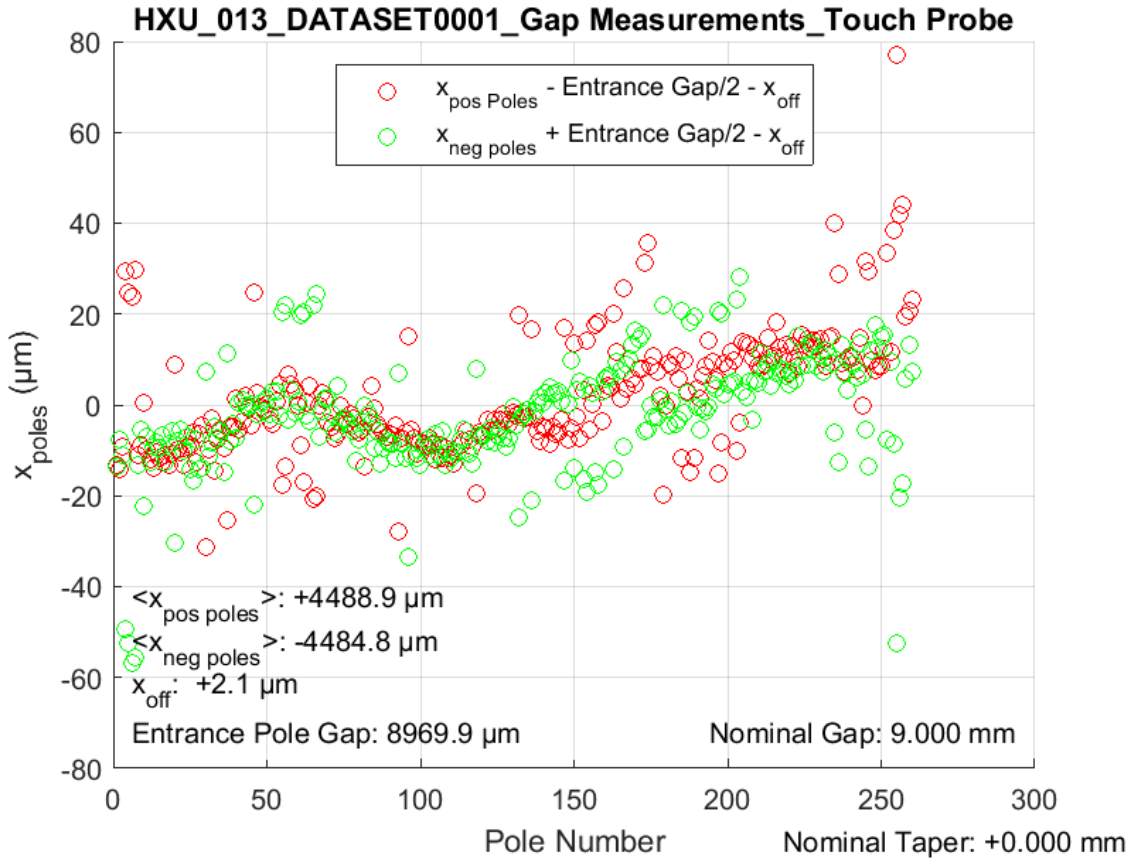
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The figure shows the cant angles between the top and bottom part of each pole at the Tuning Gap for all 260 poles, measured by the touch probe. The rms width of each distribution within a  $\pm 1.5$  mrad band is shown in the lower left corner of the figure.



Touch Probe (TP) Analysis — Pole Heights (untapered)



The figure shows the relative vertical positions of the center of each pole (top red, bottom green) relative to the horizontal plane define by the Kugler bench at the Tuning Gap for all 260 poles, measured by the touch probe.



## Measurement Results are stored:

### At V-Drive:

V:\MET\MagServe\MagData\LCLS-II\Undulator\  
 \_\_\_\_\_

### In Folder

HXU-013\DATASET0001\MagServe\Final Results\  
 \_\_\_\_\_

## Confirmation of File Locations:

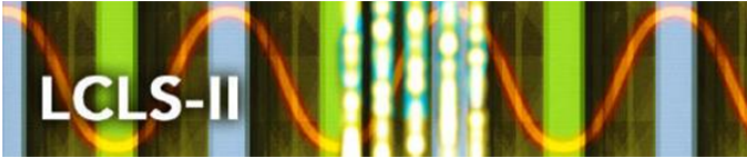
The following tables list all required data files documenting the tuning results. An existence check was done and the result is indicated next to each filename as “exists” or “missing”.

Sub folder: Z Scans\Good Field Region exists

001gap007.500x-00.50y+00.00\zscan.dat	exists
002gap007.500x-00.25y+00.00\zscan.dat	exists
003gap007.500x+00.00y+00.00\zscan.dat	exists
004gap007.500x+00.25y+00.00\zscan.dat	exists
005gap007.500x+00.50y+00.00\zscan.dat	exists
006gap007.500x+00.00y-01.00\zscan.dat	exists
007gap007.500x+00.00y-00.50\zscan.dat	exists
003gap007.500x+00.00y+00.00\zscan.dat	exists
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010gap007.500x+00.00y+01.00\zscan.dat	exists
011gap008.000x-00.50y+00.00\zscan.dat	exists
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014gap008.000x+00.25y+00.00\zscan.dat	exists
015gap008.000x+00.50y+00.00\zscan.dat	exists
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017gap008.000x+00.00y-00.50\zscan.dat	exists
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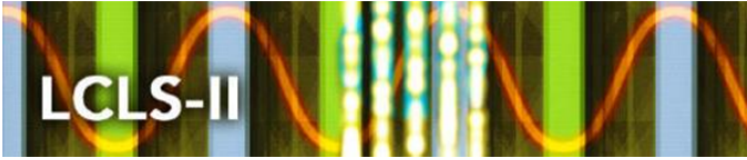
020gap008.000x+00.00y+01.00\zscan.dat	exists
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022gap010.000x-00.25y+00.00\zscan.dat	exists
023gap010.000x+00.00y+00.00\zscan.dat	exists
024gap010.000x+00.25y+00.00\zscan.dat	exists
025gap010.000x+00.50y+00.00\zscan.dat	exists
026gap010.000x+00.00y-01.00\zscan.dat	exists
027gap010.000x+00.00y-00.50\zscan.dat	exists
023gap010.000x+00.00y+00.00\zscan.dat	exists
029gap010.000x+00.00y+00.50\zscan.dat	exists
030gap010.000x+00.00y+01.00\zscan.dat	exists
031gap013.000x-00.50y+00.00\zscan.dat	exists
032gap013.000x-00.25y+00.00\zscan.dat	exists
033gap013.000x+00.00y+00.00\zscan.dat	exists
034gap013.000x+00.25y+00.00\zscan.dat	exists
035gap013.000x+00.50y+00.00\zscan.dat	exists
036gap013.000x+00.00y-01.00\zscan.dat	exists
037gap013.000x+00.00y-00.50\zscan.dat	exists
033gap013.000x+00.00y+00.00\zscan.dat	exists
039gap013.000x+00.00y+00.50\zscan.dat	exists
040gap013.000x+00.00y+01.00\zscan.dat	exists
041gap016.000x-00.50y+00.00\zscan.dat	exists
042gap016.000x-00.25y+00.00\zscan.dat	exists
043gap016.000x+00.00y+00.00\zscan.dat	exists
044gap016.000x+00.25y+00.00\zscan.dat	exists
045gap016.000x+00.50y+00.00\zscan.dat	exists
046gap016.000x+00.00y-01.00\zscan.dat	exists
047gap016.000x+00.00y-00.50\zscan.dat	exists
043gap016.000x+00.00y+00.00\zscan.dat	exists
049gap016.000x+00.00y+00.50\zscan.dat	exists
050gap016.000x+00.00y+01.00\zscan.dat	exists
051gap020.000x-00.50y+00.00\zscan.dat	exists
052gap020.000x-00.25y+00.00\zscan.dat	exists
053gap020.000x+00.00y+00.00\zscan.dat	exists
054gap020.000x+00.25y+00.00\zscan.dat	exists
055gap020.000x+00.50y+00.00\zscan.dat	exists



056gap020.000x+00.00y-01.00\zscan.dat	exists
057gap020.000x+00.00y-00.50\zscan.dat	exists
053gap020.000x+00.00y+00.00\zscan.dat	exists
059gap020.000x+00.00y+00.50\zscan.dat	exists
060gap020.000x+00.00y+01.00\zscan.dat	exists

Sub folder: Z Scans\On Axis exists

001gap007.200x+00.00y+00.00\zscan.dat	exists
003gap007.500x+00.00y+00.00\zscan.dat	exists
004gap007.750x+00.00y+00.00\zscan.dat	exists
005gap008.000x+00.00y+00.00\zscan.dat	exists
006gap008.250x+00.00y+00.00\zscan.dat	exists
007gap008.500x+00.00y+00.00\zscan.dat	exists
008gap008.750x+00.00y+00.00\zscan.dat	exists
009gap009.000x+00.00y+00.00\zscan.dat	exists
010gap009.250x+00.00y+00.00\zscan.dat	exists
011gap009.500x+00.00y+00.00\zscan.dat	exists
012gap009.750x+00.00y+00.00\zscan.dat	exists
013gap010.000x+00.00y+00.00\zscan.dat	exists
014gap010.250x+00.00y+00.00\zscan.dat	exists
015gap010.500x+00.00y+00.00\zscan.dat	exists
016gap010.750x+00.00y+00.00\zscan.dat	exists
017gap011.000x+00.00y+00.00\zscan.dat	exists
018gap011.500x+00.00y+00.00\zscan.dat	exists
019gap012.000x+00.00y+00.00\zscan.dat	exists
020gap012.500x+00.00y+00.00\zscan.dat	exists
021gap013.000x+00.00y+00.00\zscan.dat	exists
022gap013.500x+00.00y+00.00\zscan.dat	exists
023gap014.000x+00.00y+00.00\zscan.dat	exists
024gap014.500x+00.00y+00.00\zscan.dat	exists
025gap015.000x+00.00y+00.00\zscan.dat	exists
026gap015.500x+00.00y+00.00\zscan.dat	exists
027gap016.000x+00.00y+00.00\zscan.dat	exists
028gap016.500x+00.00y+00.00\zscan.dat	exists
029gap017.000x+00.00y+00.00\zscan.dat	exists



030gap017.500x+00.00y+00.00\zscan.dat	exists
031gap018.000x+00.00y+00.00\zscan.dat	exists
032gap018.500x+00.00y+00.00\zscan.dat	exists
033gap019.000x+00.00y+00.00\zscan.dat	exists
034gap019.500x+00.00y+00.00\zscan.dat	exists
035gap020.000x+00.00y+00.00\zscan.dat	exists
036gap020.500x+00.00y+00.00\zscan.dat	exists
037gap021.000x+00.00y+00.00\zscan.dat	exists
038gap021.500x+00.00y+00.00\zscan.dat	exists
039gap022.000x+00.00y+00.00\zscan.dat	exists
041gap023.000x+00.00y+00.00\zscan.dat	exists
043gap024.000x+00.00y+00.00\zscan.dat	exists
045gap025.000x+00.00y+00.00\zscan.dat	exists
046gap026.000x+00.00y+00.00\zscan.dat	exists
047gap027.000x+00.00y+00.00\zscan.dat	exists
048gap030.000x+00.00y+00.00\zscan.dat	exists
049gap040.000x+00.00y+00.00\zscan.dat	exists
050gap050.000x+00.00y+00.00\zscan.dat	exists
051gap060.000x+00.00y+00.00\zscan.dat	exists
052gap080.000x+00.00y+00.00\zscan.dat	exists
053gap100.000x+00.00y+00.00\zscan.dat	exists

Sub folder: Z Scans\Commissioning Gap exists

001gap007.968x+00.00y+00.00\zscan.dat	exists
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Sub folder: Z Scans\Gap with taper exists

005gap010.000taper-0.100x+00.00y+00.00\zscan.dat	exists
007gap010.000taper+0.000x+00.00y+00.00\zscan.dat	exists
001gap010.000taper+0.100x+00.00y+00.00\zscan.dat	exists
003gap010.000taper+0.300x+00.00y+00.00\zscan.dat	exists
006gap020.000taper-0.100x+00.00y+00.00\zscan.dat	exists
008gap020.000taper+0.000x+00.00y+00.00\zscan.dat	exists
002gap020.000taper+0.100x+00.00y+00.00\zscan.dat	exists
004gap020.000taper+0.300x+00.00y+00.00\zscan.dat	exists



Sub folder: Long Coil exists

Sub folder: Long Coil\Good Field Region exists

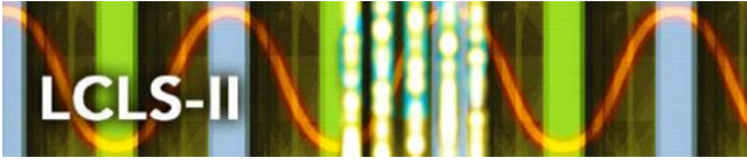
integrals_summary.txt	exists
011gap007.500x-00.50y+00.00.i1X.integrals.txt	exists
012gap007.500x-00.25y+00.00.i1X.integrals.txt	exists
013gap007.500x+00.00y+00.00.i1X.integrals.txt	exists
014gap007.500x+00.25y+00.00.i1X.integrals.txt	exists
015gap007.500x+00.50y+00.00.i1X.integrals.txt	exists
031gap007.500x+00.00y-01.00.i1X.integrals.txt	exists
032gap007.500x+00.00y-00.50.i1X.integrals.txt	exists
013gap007.500x+00.00y+00.00.i1X.integrals.txt	exists
034gap007.500x+00.00y+00.50.i1X.integrals.txt	exists
035gap007.500x+00.00y+01.00.i1X.integrals.txt	exists
051gap008.000x-00.50y+00.00.i1X.integrals.txt	exists
052gap008.000x-00.25y+00.00.i1X.integrals.txt	exists
053gap008.000x+00.00y+00.00.i1X.integrals.txt	exists
054gap008.000x+00.25y+00.00.i1X.integrals.txt	exists
055gap008.000x+00.50y+00.00.i1X.integrals.txt	exists
071gap008.000x+00.00y-01.00.i1X.integrals.txt	exists
072gap008.000x+00.00y-00.50.i1X.integrals.txt	exists
053gap008.000x+00.00y+00.00.i1X.integrals.txt	exists
074gap008.000x+00.00y+00.50.i1X.integrals.txt	exists
075gap008.000x+00.00y+01.00.i1X.integrals.txt	exists
091gap009.000x-00.50y+00.00.i1X.integrals.txt	exists
092gap009.000x-00.25y+00.00.i1X.integrals.txt	exists
093gap009.000x+00.00y+00.00.i1X.integrals.txt	exists
094gap009.000x+00.25y+00.00.i1X.integrals.txt	exists
095gap009.000x+00.50y+00.00.i1X.integrals.txt	exists
111gap009.000x+00.00y-01.00.i1X.integrals.txt	exists
112gap009.000x+00.00y-00.50.i1X.integrals.txt	exists
093gap009.000x+00.00y+00.00.i1X.integrals.txt	exists
114gap009.000x+00.00y+00.50.i1X.integrals.txt	exists
115gap009.000x+00.00y+01.00.i1X.integrals.txt	exists
131gap013.000x-00.50y+00.00.i1X.integrals.txt	exists
132gap013.000x-00.25y+00.00.i1X.integrals.txt	exists



133gap013.000x+00.00y+00.00.i1X.integrals.txt	exists
134gap013.000x+00.25y+00.00.i1X.integrals.txt	exists
135gap013.000x+00.50y+00.00.i1X.integrals.txt	exists
151gap013.000x+00.00y-01.00.i1X.integrals.txt	exists
152gap013.000x+00.00y-00.50.i1X.integrals.txt	exists
133gap013.000x+00.00y+00.00.i1X.integrals.txt	exists
154gap013.000x+00.00y+00.50.i1X.integrals.txt	exists
155gap013.000x+00.00y+01.00.i1X.integrals.txt	exists
171gap016.000x-00.50y+00.00.i1X.integrals.txt	exists
172gap016.000x-00.25y+00.00.i1X.integrals.txt	exists
173gap016.000x+00.00y+00.00.i1X.integrals.txt	exists
174gap016.000x+00.25y+00.00.i1X.integrals.txt	exists
175gap016.000x+00.50y+00.00.i1X.integrals.txt	exists
191gap016.000x+00.00y-01.00.i1X.integrals.txt	exists
192gap016.000x+00.00y-00.50.i1X.integrals.txt	exists
173gap016.000x+00.00y+00.00.i1X.integrals.txt	exists
194gap016.000x+00.00y+00.50.i1X.integrals.txt	exists
195gap016.000x+00.00y+01.00.i1X.integrals.txt	exists
251gap050.000x-00.50y+00.00.i1X.integrals.txt	exists
252gap050.000x-00.25y+00.00.i1X.integrals.txt	exists
253gap050.000x+00.00y+00.00.i1X.integrals.txt	exists
254gap050.000x+00.25y+00.00.i1X.integrals.txt	exists
255gap050.000x+00.50y+00.00.i1X.integrals.txt	exists
271gap050.000x+00.00y-01.00.i1X.integrals.txt	exists
272gap050.000x+00.00y-00.50.i1X.integrals.txt	exists
253gap050.000x+00.00y+00.00.i1X.integrals.txt	exists
274gap050.000x+00.00y+00.50.i1X.integrals.txt	exists
275gap050.000x+00.00y+01.00.i1X.integrals.txt	exists
291gap100.000x-00.50y+00.00.i1X.integrals.txt	exists
292gap100.000x-00.25y+00.00.i1X.integrals.txt	exists
293gap100.000x+00.00y+00.00.i1X.integrals.txt	exists
294gap100.000x+00.25y+00.00.i1X.integrals.txt	exists
295gap100.000x+00.50y+00.00.i1X.integrals.txt	exists
311gap100.000x+00.00y-01.00.i1X.integrals.txt	exists
312gap100.000x+00.00y-00.50.i1X.integrals.txt	exists
293gap100.000x+00.00y+00.00.i1X.integrals.txt	exists



314gap100.000x+00.00y+00.50.i1X_integrals.txt	exists
315gap100.000x+00.00y+01.00.i1X_integrals.txt	exists
016gap007.500x-00.50y+00.00.i2X_integrals.txt	exists
017gap007.500x-00.25y+00.00.i2X_integrals.txt	exists
018gap007.500x+00.00y+00.00.i2X_integrals.txt	exists
019gap007.500x+00.25y+00.00.i2X_integrals.txt	exists
020gap007.500x+00.50y+00.00.i2X_integrals.txt	exists
036gap007.500x+00.00y-01.00.i2X_integrals.txt	exists
037gap007.500x+00.00y-00.50.i2X_integrals.txt	exists
018gap007.500x+00.00y+00.00.i2X_integrals.txt	exists
039gap007.500x+00.00y+00.50.i2X_integrals.txt	exists
040gap007.500x+00.00y+01.00.i2X_integrals.txt	exists
056gap008.000x-00.50y+00.00.i2X_integrals.txt	exists
057gap008.000x-00.25y+00.00.i2X_integrals.txt	exists
058gap008.000x+00.00y+00.00.i2X_integrals.txt	exists
059gap008.000x+00.25y+00.00.i2X_integrals.txt	exists
060gap008.000x+00.50y+00.00.i2X_integrals.txt	exists
076gap008.000x+00.00y-01.00.i2X_integrals.txt	exists
077gap008.000x+00.00y-00.50.i2X_integrals.txt	exists
058gap008.000x+00.00y+00.00.i2X_integrals.txt	exists
079gap008.000x+00.00y+00.50.i2X_integrals.txt	exists
080gap008.000x+00.00y+01.00.i2X_integrals.txt	exists
096gap009.000x-00.50y+00.00.i2X_integrals.txt	exists
097gap009.000x-00.25y+00.00.i2X_integrals.txt	exists
098gap009.000x+00.00y+00.00.i2X_integrals.txt	exists
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116gap009.000x+00.00y-01.00.i2X_integrals.txt	exists
117gap009.000x+00.00y-00.50.i2X_integrals.txt	exists
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136gap013.000x-00.50y+00.00.i2X_integrals.txt	exists
137gap013.000x-00.25y+00.00.i2X_integrals.txt	exists
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140gap013.000x+00.50y+00.00.i2X.integrals.txt	exists
156gap013.000x+00.00y-01.00.i2X.integrals.txt	exists
157gap013.000x+00.00y-00.50.i2X.integrals.txt	exists
138gap013.000x+00.00y+00.00.i2X.integrals.txt	exists
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176gap016.000x-00.50y+00.00.i2X.integrals.txt	exists
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256gap050.000x-00.50y+00.00.i2X.integrals.txt	exists
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277gap050.000x+00.00y-00.50.i2X.integrals.txt	exists
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320gap100.000x+00.00y+01.00.i2X.integrals.txt	exists



001gap007.500x-00.50y+00.00.i1Y.integrals.txt	exists
002gap007.500x-00.25y+00.00.i1Y.integrals.txt	exists
003gap007.500x+00.00y+00.00.i1Y.integrals.txt	exists
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022gap007.500x+00.00y-00.50.i1Y.integrals.txt	exists
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081gap009.000x-00.50y+00.00.i1Y.integrals.txt	exists
082gap009.000x-00.25y+00.00.i1Y.integrals.txt	exists
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085gap009.000x+00.50y+00.00.i1Y.integrals.txt	exists
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102gap009.000x+00.00y-00.50.i1Y.integrals.txt	exists
083gap009.000x+00.00y+00.00.i1Y.integrals.txt	exists
104gap009.000x+00.00y+00.50.i1Y.integrals.txt	exists
105gap009.000x+00.00y+01.00.i1Y.integrals.txt	exists
121gap013.000x-00.50y+00.00.i1Y.integrals.txt	exists
122gap013.000x-00.25y+00.00.i1Y.integrals.txt	exists
123gap013.000x+00.00y+00.00.i1Y.integrals.txt	exists
124gap013.000x+00.25y+00.00.i1Y.integrals.txt	exists
125gap013.000x+00.50y+00.00.i1Y.integrals.txt	exists
141gap013.000x+00.00y-01.00.i1Y.integrals.txt	exists



142gap013.000x+00.00y-00.50.i1Y_integrals.txt	exists
123gap013.000x+00.00y+00.00.i1Y_integrals.txt	exists
144gap013.000x+00.00y+00.50.i1Y_integrals.txt	exists
145gap013.000x+00.00y+01.00.i1Y_integrals.txt	exists
161gap016.000x-00.50y+00.00.i1Y_integrals.txt	exists
162gap016.000x-00.25y+00.00.i1Y_integrals.txt	exists
163gap016.000x+00.00y+00.00.i1Y_integrals.txt	exists
164gap016.000x+00.25y+00.00.i1Y_integrals.txt	exists
165gap016.000x+00.50y+00.00.i1Y_integrals.txt	exists
181gap016.000x+00.00y-01.00.i1Y_integrals.txt	exists
182gap016.000x+00.00y-00.50.i1Y_integrals.txt	exists
163gap016.000x+00.00y+00.00.i1Y_integrals.txt	exists
184gap016.000x+00.00y+00.50.i1Y_integrals.txt	exists
185gap016.000x+00.00y+01.00.i1Y_integrals.txt	exists
241gap050.000x-00.50y+00.00.i1Y_integrals.txt	exists
242gap050.000x-00.25y+00.00.i1Y_integrals.txt	exists
243gap050.000x+00.00y+00.00.i1Y_integrals.txt	exists
244gap050.000x+00.25y+00.00.i1Y_integrals.txt	exists
245gap050.000x+00.50y+00.00.i1Y_integrals.txt	exists
261gap050.000x+00.00y-01.00.i1Y_integrals.txt	exists
262gap050.000x+00.00y-00.50.i1Y_integrals.txt	exists
243gap050.000x+00.00y+00.00.i1Y_integrals.txt	exists
264gap050.000x+00.00y+00.50.i1Y_integrals.txt	exists
265gap050.000x+00.00y+01.00.i1Y_integrals.txt	exists
281gap100.000x-00.50y+00.00.i1Y_integrals.txt	exists
282gap100.000x-00.25y+00.00.i1Y_integrals.txt	exists
283gap100.000x+00.00y+00.00.i1Y_integrals.txt	exists
284gap100.000x+00.25y+00.00.i1Y_integrals.txt	exists
285gap100.000x+00.50y+00.00.i1Y_integrals.txt	exists
301gap100.000x+00.00y-01.00.i1Y_integrals.txt	exists
302gap100.000x+00.00y-00.50.i1Y_integrals.txt	exists
283gap100.000x+00.00y+00.00.i1Y_integrals.txt	exists
304gap100.000x+00.00y+00.50.i1Y_integrals.txt	exists
305gap100.000x+00.00y+01.00.i1Y_integrals.txt	exists
006gap007.500x-00.50y+00.00.i2Y_integrals.txt	exists
007gap007.500x-00.25y+00.00.i2Y_integrals.txt	exists



008gap007.500x+00.00y+00.00.i2Y_integrals.txt	exists
009gap007.500x+00.25y+00.00.i2Y_integrals.txt	exists
010gap007.500x+00.50y+00.00.i2Y_integrals.txt	exists
026gap007.500x+00.00y-01.00.i2Y_integrals.txt	exists
027gap007.500x+00.00y-00.50.i2Y_integrals.txt	exists
008gap007.500x+00.00y+00.00.i2Y_integrals.txt	exists
029gap007.500x+00.00y+00.50.i2Y_integrals.txt	exists
030gap007.500x+00.00y+01.00.i2Y_integrals.txt	exists
046gap008.000x-00.50y+00.00.i2Y_integrals.txt	exists
047gap008.000x-00.25y+00.00.i2Y_integrals.txt	exists
048gap008.000x+00.00y+00.00.i2Y_integrals.txt	exists
049gap008.000x+00.25y+00.00.i2Y_integrals.txt	exists
050gap008.000x+00.50y+00.00.i2Y_integrals.txt	exists
066gap008.000x+00.00y-01.00.i2Y_integrals.txt	exists
067gap008.000x+00.00y-00.50.i2Y_integrals.txt	exists
048gap008.000x+00.00y+00.00.i2Y_integrals.txt	exists
069gap008.000x+00.00y+00.50.i2Y_integrals.txt	exists
070gap008.000x+00.00y+01.00.i2Y_integrals.txt	exists
086gap009.000x-00.50y+00.00.i2Y_integrals.txt	exists
087gap009.000x-00.25y+00.00.i2Y_integrals.txt	exists
088gap009.000x+00.00y+00.00.i2Y_integrals.txt	exists
089gap009.000x+00.25y+00.00.i2Y_integrals.txt	exists
090gap009.000x+00.50y+00.00.i2Y_integrals.txt	exists
106gap009.000x+00.00y-01.00.i2Y_integrals.txt	exists
107gap009.000x+00.00y-00.50.i2Y_integrals.txt	exists
088gap009.000x+00.00y+00.00.i2Y_integrals.txt	exists
109gap009.000x+00.00y+00.50.i2Y_integrals.txt	exists
110gap009.000x+00.00y+01.00.i2Y_integrals.txt	exists
126gap013.000x-00.50y+00.00.i2Y_integrals.txt	exists
127gap013.000x-00.25y+00.00.i2Y_integrals.txt	exists
128gap013.000x+00.00y+00.00.i2Y_integrals.txt	exists
129gap013.000x+00.25y+00.00.i2Y_integrals.txt	exists
130gap013.000x+00.50y+00.00.i2Y_integrals.txt	exists
146gap013.000x+00.00y-01.00.i2Y_integrals.txt	exists
147gap013.000x+00.00y-00.50.i2Y_integrals.txt	exists
128gap013.000x+00.00y+00.00.i2Y_integrals.txt	exists



LCLS-II Undulator Segment Measurement Results

HXU-013

149gap013.000x+00.00y+00.50.i2Y_integrals.txt	exists
150gap013.000x+00.00y+01.00.i2Y_integrals.txt	exists
166gap016.000x-00.50y+00.00.i2Y_integrals.txt	exists
167gap016.000x-00.25y+00.00.i2Y_integrals.txt	exists
168gap016.000x+00.00y+00.00.i2Y_integrals.txt	exists
169gap016.000x+00.25y+00.00.i2Y_integrals.txt	exists
170gap016.000x+00.50y+00.00.i2Y_integrals.txt	exists
186gap016.000x+00.00y-01.00.i2Y_integrals.txt	exists
187gap016.000x+00.00y-00.50.i2Y_integrals.txt	exists
168gap016.000x+00.00y+00.00.i2Y_integrals.txt	exists
189gap016.000x+00.00y+00.50.i2Y_integrals.txt	exists
190gap016.000x+00.00y+01.00.i2Y_integrals.txt	exists
246gap050.000x-00.50y+00.00.i2Y_integrals.txt	exists
247gap050.000x-00.25y+00.00.i2Y_integrals.txt	exists
248gap050.000x+00.00y+00.00.i2Y_integrals.txt	exists
249gap050.000x+00.25y+00.00.i2Y_integrals.txt	exists
250gap050.000x+00.50y+00.00.i2Y_integrals.txt	exists
266gap050.000x+00.00y-01.00.i2Y_integrals.txt	exists
267gap050.000x+00.00y-00.50.i2Y_integrals.txt	exists
248gap050.000x+00.00y+00.00.i2Y_integrals.txt	exists
269gap050.000x+00.00y+00.50.i2Y_integrals.txt	exists
270gap050.000x+00.00y+01.00.i2Y_integrals.txt	exists
286gap100.000x-00.50y+00.00.i2Y_integrals.txt	exists
287gap100.000x-00.25y+00.00.i2Y_integrals.txt	exists
288gap100.000x+00.00y+00.00.i2Y_integrals.txt	exists
289gap100.000x+00.25y+00.00.i2Y_integrals.txt	exists
290gap100.000x+00.50y+00.00.i2Y_integrals.txt	exists
306gap100.000x+00.00y-01.00.i2Y_integrals.txt	exists
307gap100.000x+00.00y-00.50.i2Y_integrals.txt	exists
288gap100.000x+00.00y+00.00.i2Y_integrals.txt	exists
309gap100.000x+00.00y+00.50.i2Y_integrals.txt	exists
310gap100.000x+00.00y+01.00.i2Y_integrals.txt	exists

Sub folder: Long Coil\On Axis exists

integrals_summary.txt	exists
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LCLS-II Undulator Segment Measurement Results

HXU-013

003gap007.200x+00.00y+00.00.i1X_integrals.txt	exists
004gap007.200x+00.00y+00.00.i2X_integrals.txt	exists
001gap007.200x+00.00y+00.00.i1Y_integrals.txt	exists
002gap007.200x+00.00y+00.00.i2Y_integrals.txt	exists
007gap007.500x+00.00y+00.00.i1X_integrals.txt	exists
008gap007.500x+00.00y+00.00.i2X_integrals.txt	exists
005gap007.500x+00.00y+00.00.i1Y_integrals.txt	exists
006gap007.500x+00.00y+00.00.i2Y_integrals.txt	exists
011gap008.000x+00.00y+00.00.i1X_integrals.txt	exists
012gap008.000x+00.00y+00.00.i2X_integrals.txt	exists
009gap008.000x+00.00y+00.00.i1Y_integrals.txt	exists
010gap008.000x+00.00y+00.00.i2Y_integrals.txt	exists
015gap008.500x+00.00y+00.00.i1X_integrals.txt	exists
016gap008.500x+00.00y+00.00.i2X_integrals.txt	exists
013gap008.500x+00.00y+00.00.i1Y_integrals.txt	exists
014gap008.500x+00.00y+00.00.i2Y_integrals.txt	exists
019gap009.000x+00.00y+00.00.i1X_integrals.txt	exists
020gap009.000x+00.00y+00.00.i2X_integrals.txt	exists
017gap009.000x+00.00y+00.00.i1Y_integrals.txt	exists
018gap009.000x+00.00y+00.00.i2Y_integrals.txt	exists
027gap010.000x+00.00y+00.00.i1X_integrals.txt	exists
028gap010.000x+00.00y+00.00.i2X_integrals.txt	exists
025gap010.000x+00.00y+00.00.i1Y_integrals.txt	exists
026gap010.000x+00.00y+00.00.i2Y_integrals.txt	exists
035gap012.000x+00.00y+00.00.i1X_integrals.txt	exists
036gap012.000x+00.00y+00.00.i2X_integrals.txt	exists
033gap012.000x+00.00y+00.00.i1Y_integrals.txt	exists
034gap012.000x+00.00y+00.00.i2Y_integrals.txt	exists
043gap014.000x+00.00y+00.00.i1X_integrals.txt	exists
044gap014.000x+00.00y+00.00.i2X_integrals.txt	exists
041gap014.000x+00.00y+00.00.i1Y_integrals.txt	exists
042gap014.000x+00.00y+00.00.i2Y_integrals.txt	exists
047gap016.000x+00.00y+00.00.i1X_integrals.txt	exists
048gap016.000x+00.00y+00.00.i2X_integrals.txt	exists
045gap016.000x+00.00y+00.00.i1Y_integrals.txt	exists
046gap016.000x+00.00y+00.00.i2Y_integrals.txt	exists



051gap018.000x+00.00y+00.00.i1X_integrals.txt	exists
052gap018.000x+00.00y+00.00.i2X_integrals.txt	exists
049gap018.000x+00.00y+00.00.i1Y_integrals.txt	exists
050gap018.000x+00.00y+00.00.i2Y_integrals.txt	exists
055gap020.000x+00.00y+00.00.i1X_integrals.txt	exists
056gap020.000x+00.00y+00.00.i2X_integrals.txt	exists
053gap020.000x+00.00y+00.00.i1Y_integrals.txt	exists
054gap020.000x+00.00y+00.00.i2Y_integrals.txt	exists
059gap022.000x+00.00y+00.00.i1X_integrals.txt	exists
060gap022.000x+00.00y+00.00.i2X_integrals.txt	exists
057gap022.000x+00.00y+00.00.i1Y_integrals.txt	exists
058gap022.000x+00.00y+00.00.i2Y_integrals.txt	exists
063gap025.000x+00.00y+00.00.i1X_integrals.txt	exists
064gap025.000x+00.00y+00.00.i2X_integrals.txt	exists
061gap025.000x+00.00y+00.00.i1Y_integrals.txt	exists
062gap025.000x+00.00y+00.00.i2Y_integrals.txt	exists
067gap030.000x+00.00y+00.00.i1X_integrals.txt	exists
068gap030.000x+00.00y+00.00.i2X_integrals.txt	exists
065gap030.000x+00.00y+00.00.i1Y_integrals.txt	exists
066gap030.000x+00.00y+00.00.i2Y_integrals.txt	exists
071gap040.000x+00.00y+00.00.i1X_integrals.txt	exists
072gap040.000x+00.00y+00.00.i2X_integrals.txt	exists
069gap040.000x+00.00y+00.00.i1Y_integrals.txt	exists
070gap040.000x+00.00y+00.00.i2Y_integrals.txt	exists
075gap050.000x+00.00y+00.00.i1X_integrals.txt	exists
076gap050.000x+00.00y+00.00.i2X_integrals.txt	exists
073gap050.000x+00.00y+00.00.i1Y_integrals.txt	exists
074gap050.000x+00.00y+00.00.i2Y_integrals.txt	exists
079gap060.000x+00.00y+00.00.i1X_integrals.txt	exists
080gap060.000x+00.00y+00.00.i2X_integrals.txt	exists
077gap060.000x+00.00y+00.00.i1Y_integrals.txt	exists
078gap060.000x+00.00y+00.00.i2Y_integrals.txt	exists
083gap080.000x+00.00y+00.00.i1X_integrals.txt	exists
084gap080.000x+00.00y+00.00.i2X_integrals.txt	exists
081gap080.000x+00.00y+00.00.i1Y_integrals.txt	exists
082gap080.000x+00.00y+00.00.i2Y_integrals.txt	exists



LCLS-II Undulator Segment Measurement Results

HXU-013

087gap100.000x+00.00y+00.00.i1X_integrals.txt	exists
088gap100.000x+00.00y+00.00.i2X_integrals.txt	exists
085gap100.000x+00.00y+00.00.i1Y_integrals.txt	exists
086gap100.000x+00.00y+00.00.i2Y_integrals.txt	exists

Sub folder: **Fiducialization** exists

HXU_013 Fiducial Report.pdf	exists
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Sub folder: **Gap Measurements** exists

Sub folder: **Gap Measurements\Touch Probe** exists

002gap008.000taper-0.100.pdf	exists
002gap008.000taper-0.100.txt	exists
001gap009.000taper+0.000.pdf	exists
001gap009.000taper+0.000.txt	exists
003gap008.000taper+0.100.pdf	exists
003gap008.000taper+0.100.txt	exists
004gap008.000taper+0.300.pdf	exists
004gap008.000taper+0.300.txt	exists

Sub folder: **Capacitive Sensors** exists

gap_dat_ru1.dat	exists
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Sub folder: **Controls Data** exists

hXu_013_parameters.txt	exists
hXu_013_k_vs_gap_spline.dat	exists
hXu_013_phase_match_enter_vs_gap_spline.dat	exists
hXu_013_phase_match_exit_vs_gap_spline.dat	exists
hXu_013_i1xvsgap_spline.dat	exists
hXu_013_i1yvsgap_spline.dat	exists
hXu_013_i2xvsgap_spline.dat	exists
hXu_013_i2yvsgap_spline.dat	exists



LCLS-II Undulator Segment Measurement Results

HXU-013



LCLS-II Undulator Segment Measurement Results


HXU-013

Summary of findings

Finding	Solution

Approval and Assignment by Heinz-Dieter Nuhn

Data Storage Checked:	Y	
Magnet Accepted:	Y	
Assigned Location:	HXU-013	

	Heinz-Dieter Nuhn	August 3, 2020
(Signature)	(Name)	(Date)