The PREX2/CREX Target

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February 28, 2020

This is a brief description of the prex2/crex target system and its operations. The target was installed in Hall A during spring 2019 and will be used during both the prex2 and crex data acquisition periods. More information about CREX and PREX2 Experiments could be found in their respective proposals [1] and [2]. This is a relatively simple target made of solid shapes and a water cell, especially when compared with a typical high power liquid hydrogen target system operated in Halls A or C.

It is your responsibility as a target operator to keep the target safe and working within operational restrictions.

Rules of thumb for keeping the CREX target happy:

1. Make sure the vacuum in the target chamber, **pcrexMKS_CC**, is lower than **1.e-6** torr all the time (Ca oxidizes easily).

2. Make sure the helium coolant has a minimum flow of **10** g/s during beam production (Ca targets have a heat loading of 350 W).

3. Make sure the temperature sensor on the cold ladder, **pcrex90_Top_T**, is less than 27 K at all times; and the coolant return temperature sensor, **pcrexUTube_Return_T** is less than 22 K at all times.

4. Make sure the MCC does not violate the operational restrictions on any target.

5. If any of the above rules is being violated, **STOP BEAM** consult with the target expert on-call and the RC.

6. Move the cold ladder to **HOME** position whenever production is not imminent (beam down for undetermined time, changeover to Moller measurement etc.).

7. Communicate clearly with the previous shift TO and the following shift TO about changes in target conditions and operations that affect the target.

Target procedures

The PREX2 and the CREX Experiments use two solid targets ladders that can move independently of each other. The production ladder is positioned horizontally and moves linearly with the direction of motion perpendicular to the beam line. This ladder is cooled with 15 K and 13 atm He from the End Station Refrigerator (ESR) and has 16 positions in beam. The Optics ladder is positioned at 45° to the horizontal line and is cooled by water. This ladder is moved by a linear motion system and it has 5 positions in beam. Ideally the two ladders move in the same x-y plane and aim at the same z-position on the beam line. On the target computer main gui the horizontal moving ladder is named **90 DEGREE TARGETS** and the Optics ladder is named **45 DEGREE TARGETS**. The target controls run on the Hall A Input-Output-Controller (IOC) IOCHA13. The target IOC is located in an electronics rack in the access labyrinth to Hall A. The target operator (TO) will monitor and control the target from the Hall A target computer *poltarac.jlab.org*, which is located in the Hall A Counting House. Before taking TO shifts you should have read the target OSP, which is posted at https://hallaweb.jlab.org/index/safety-docs/current

Starting the target controls. To login into the target computer the TO should use the username *poltar* with the standard password (it should be posted in the Counting House along with all other relevant passwords). After login, open a terminal window and navigate to /home/poltar/Desktop/PRex/ and type the command ./*tgtgui* which will start the prex2-crex target main gui.

Move the target. The prex2-crex target has two independent motion controls, which use identical controllers. To move a target ladder the TO has to make sure that the other ladder is in the HOME position (fully retracted from the beam line). Although there are hardware and software inhibits to prevent moving a target ladder while the other ladder is in beam, it is the responsibility of the TO to move one ladder only if the other one is in the HOME position. To move the target during normal operations please follow the steps:

1. Call MCC and tell them that you'd like to move the Hall A target, tell them to which position you'd like to move and ask them to mask the Hall A target motion FSD.

2. Once you get confirmation from MCC that the Hall A target motion mask is ON go to the target main gui and click on the position button corresponding to the target you'd like to move to. Remember, the other ladder has to be in the HOME position!

3. A pop-up will appear on the computer screen, click the MOVE button. Now the target motion sequencer will start moving the target. Kill the pop-up gui to prevent accidentally moving the target at later times.

4. At the end of the motion on the main gui the Brake should have a green dot next to it in the BDS Status. A green square should be next to the target position you moved to.

5. If the motion was successful call MCC back and let them know on which target you are, confirm the operational restriction with them, as listed on the link bellow, and

carry on with the program.

http://opweb.acc.jlab.org/internal/ops/ops_webpage/restrictions/ops_restrictions.html

At the end of a motion procedure compare the read-back encoder number with the one in the BDS-90 Position or BDS-45 Position table. For the cold ladder encoder 80,800 units correspond to 1 mm of motion and for the warm target ladder 80,400 units correspond to 1 mm of motion. Each target ladder is instrumented with a linear potentiometer, a metal string whose electrical resistance indicates that respective target ladder position. The read-back of each potentiometer is displayed on the target main GUI under *Pull string* and it is independent from each ladder's motor controller, see fig. 1. At the end of each motion compare the read-back value of the Pull string with the value in the table 1 or table 2. If either motion motor controller encoder starts having issues we can still determine the target ladders positions with the linear potentiometers.

Index	Target	CAD pos mm	Survey pos BDS Encoder	Pull String Ω
	LS- (motion stop)			
0	C-Pb-C	743.5	60,306,288	2921
1	DI-Pb-DJ	705.4	57,226,912	2867
2	C-208Pb1-C	667.3	54,147,540	2814
3	Carbon 1%	629.2	51,074,208	2755
4	DA-208Pb2-DB	591.1	47,993,624	2700
5	DC-208Pb3-DD	553.0	44,913,040	2630
6	DE-208Pb4-DF	514.9	41,832,456	2564
7	DG-208Pb5-D20	476.8	38,751,872	2491
8	D1-208Pb6-D2	438.7	35,671,288	2417
9	D3-208Pb7-D4	400.6	32,601,984	2342
10	D5-208Pb8-D6	362.5	29,532,678	2257
11	D7-208Pb9-D8	324.4	26,463,372	2165
12	D9-208Pb10-D10	286.3	23,394,068	2072
13	Carbon Hole	248.2	20,324,764	1972
14	40Ca 6%	197.4	16,224,300	1831
15	48Ca 6%	159.3	13,163,050	1712
16	HOME	0	0	1127
	LS+ (motion stop)			

Table 1: Cold ladder Survey and Alignment in air summary. The CAD position column is as taken from the 3D model of the target. The Survey position column corresponds to the alignment of the respective target position on the ideal beam line as determined in BDS encoder units, adjusted to account for the Carbon Hole alignment in beam on 6 Nov, 2019. The Pull String column has the linear potentiometer readings for the ideal position of the respective target on the beam line in air. Explanations for the target naming is given in the Appendix. About 80,800 encoder units correspond to 1 mm of motion for this motor

If the target motion failed and you do not know what happened call the target expert on call to address the issue. If you think that the target moves abnormally then click KILL

Index	Target	CAD pos mm	Survey pos BDS Encoder	Pull String Ω
	LS- (motion stop)			
0	Carbon Hole	262.8	21,078,440	2098
1	Carbon 0.2%	248.1	19,954,756	2064
2	Pb 0.9%	234.1	18,831,069	2025
3	Tungsten 0.3%	220.1	17,707,382	1995
4	Water Cell 2.77%	179.5	14,438,475	1876
5	HOME	0	0	1275
	LS+ (motion stop)			

Table 2: Optics ladder Survey and Alignment in air summary. The CAD position column is as taken from the 3D model of the target. The Survey position column corresponds to the alignment of the respective target position on the ideal beam line as determined in BDS encoder units. The Pull String column has the linear potentiometer readings for the ideal position of the respective target on the beam line in air. Explanations for the target naming is given in the Appendix. About 80,400 encoder units correspond to 1 mm of motion for this motor.

MOTION button, which will execute a hard stop of the target motion motor. To move the target after a KILL MOTION was executed try moving the respective ladder HOME. If the HOME switch light on the main gui turns green when the ladder gets there, then move to your previously intended position. If there are issues with executing any of the motion commands or if there is/are Fault/Error lights ON in either BDS 90 Status or BDS 45 Status call the expert on-call to address the issue(s).

Move the target manually. If the motion sequencer is faulty, either target ladder can be moved to any position by clicking the button *Set Absolute Position*. If you move the target by clicking this button you'll have to enter a number (corresponding to the BDS encoder steps, typically one of the target positions from either BDS-90 or BDS-45 Positions table) in the box and hit Enter on the *poltarac* keyboard.

Monitoring the target. The target main gui is similar in layout to main guis for jlab cryo-targets in Halls A and C, see fig. 1. Each target ladder has a table with target positions under BDS-45 Positions (warm ladder) and BDS-90 Positions (cold ladder) respectively. The BDS-90 ladder is cooled with 15 K/13 atm helium supply from the ESR. The cold helium gas flow is controlled with a Joule-Thomson (JT) valve. Once this valve is set to provide enough cooling power opening it more will not "cool" the target more and it will not prevent melting of a Pb foil. We estimate that for the nominal running in prex2 it will be enough to have 120 W of cooling power (no more than 5-10 g/s of 15 K He coolant) and no more than 350 W of cooling power for crex. The JT valve and the He coolant parameters will be monitored on the target main gui and the StripTool Cryo-Chart. The Optics ladder is cooled by a water chiller, which also provides one of the target materials for the Water Cell. The water flows in a closed circuit at a nominal volume of 1 GPM or 63.1 g/s. We do not control the water

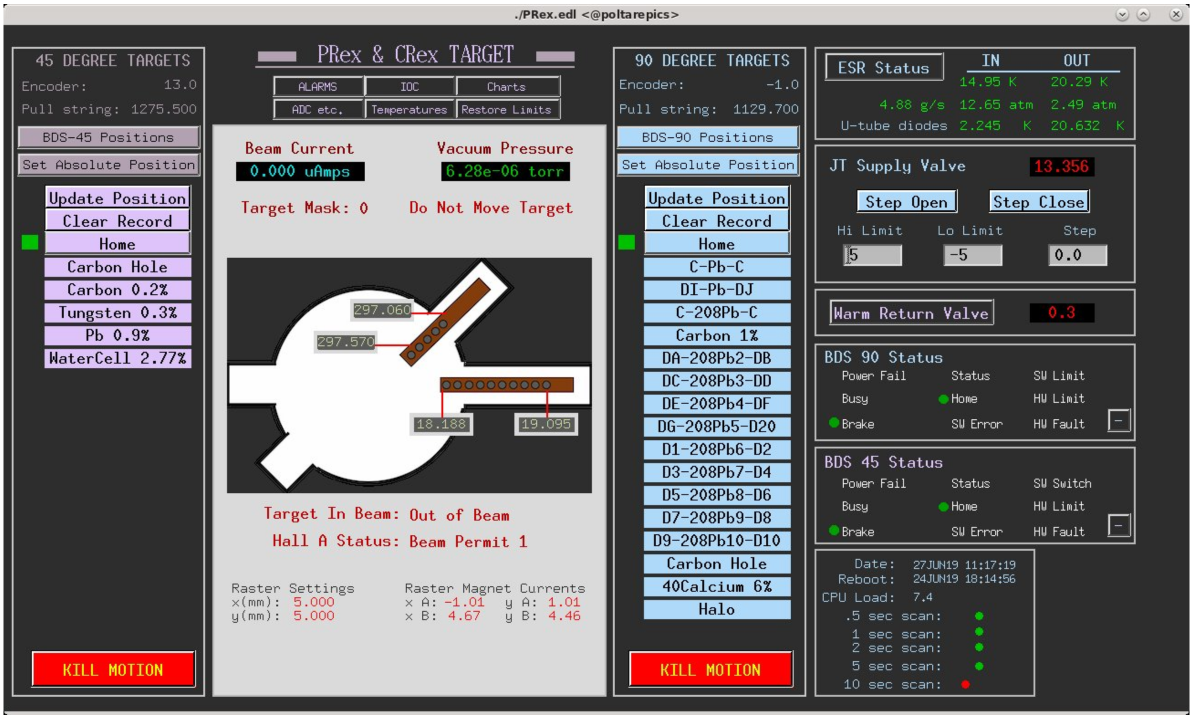


Figure 1: Target main GUI.

flow and we do not monitor its temperature, other than the two temperature sensors on the Optics ladder frame. The water chiller switch is connected to an FSD (Fast Shut-Down) signal and monitored by the MCC. If the Optics target ladder water chiller stops working, the MCC will get a persistent FSD and beam delivery to Hall A will not be possible until the water chiller is running again.

The two target ladders are each instrumented with two Pt temperature sensors. There are two diode temperature sensors, one in the supply and one in the return He lines. The sensors are read-back by LakeShore 218 temperature monitors and their values are displayed on the main target gui and in StripTool charts. More information about the expected thermal behavior of the target can be found in the **Thermal Analysis** section. The list of installed targets in both ladders can be found in the tables: 1 and 2. A detailed list of target measurements can be found in the Appendix. Pictures of the target ladders with the installed target foils for prex2 can be viewed in fig. 2 and fig. 3. You have to log target changes to the Hall A halog. At least once a shift you should post a "target status" log entry into the halog and attach a picture of the target main gui and the StripTool Charts.

Rebooting the target ioc or the target computer. If the target IOC heartbeat counter freezes or any of the target signals flat-lines it may be time to reboot the target IOC. To do this ask for beam OFF and then click on the IOC button on the target main gui. Pick a reason for rebooting and then click the Reboot button. Once the IOC is back up and running, check the target signals and the target position and if all look good ask for beam back ON. If the target computer, *poltarac.jlab.org*, freezes or starts acting abnormally it may be time to reboot it. To do this you do not have to ask for beam OFF. Reboot the computer either from a console or if non-responsive just power cycle it. Once the computer is back up and running follow the procedure **Starting the target controls.**

Figure 2: Cold ladder prex2 target configuration for summer 2019 run, upstream beam line view.

The Alarm Handler. The target controls are under the EPICS environment and we are using the EPICS Alarm Handler facility to monitor some essential signals. The alarm handler should be up and running at all times on *poltarac*. If, for some reason, it is not (killed accidentally) then restart it by clicking the button **ALARMS** on the target main gui, see fig. 1. Make sure that you are not running more than one instance of the Alarm Handler. When you have an alarm click on the alarm handler button and you'll get the alarm tree as in fig. 4 with the main branches on the left hand side and the actual signals on the right hand side. For the instance in fig. 4 the right hand side displays the signals for the **Target** branch. Clicking on the **P** button next to a signal displays the alarm levels for the respective signal as in fig. 5. The alarm handler can have up to two levels for warning. A signal is within normal operating conditions and its display color is green if its value stays between the **LOW** and **HIGH** levels. If its value is either between **LOLO** and **LOW** or between **HIGH** and **HIHI** then its alarm level is Warning and its display color is yellow. If the value of a signal is either smaller than the **LOLO** of higher than the **HIHI** then its alarm level is Critical and its display color is red. If a signal becomes disconnected from EPICS then its display color will be white.

You have to always respond to an alarm. Aside from the alarm level color code when a signal is in an alarm state there will be an audible alarm sound from the *poltarac*. The

Figure 3: Water cooled prex2 target ladder configuration for summer 2019 run, upstream beam line view.

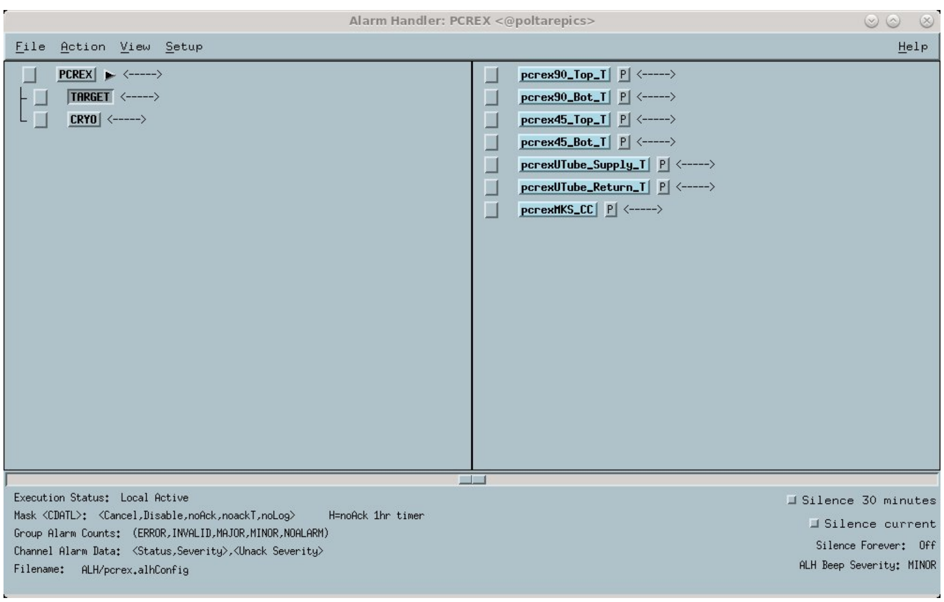


Figure 4: Alarm Handler tree structure.

sound and the color code will persist until the alarm condition is gone and the alarm has been acknowledged. An alarm should always be acknowledged at the lowest level in the Alarm tree. If the cause for an alarm was transitory and the read-back of the signal has

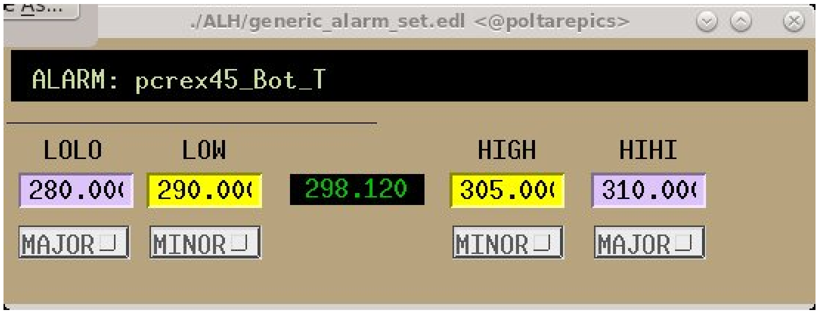


Figure 5: Alarm Handler level structure.

returned to the normal range (green colored), then go ahead and acknowledge the alarm and carry on with the program. If the condition for an alarm is persistent then the cause has to be addressed until the read-back of the signal returns to its normal range. If you do not know the cause for an alarm(s) or if you do not know how to address the cause of an alarm(s) then call the target expert on-call to have the issue addressed.

Do not change any alarm signal set points unless you get approval from the target expert on-call.

StripTool Charts. The recent history of certain target parameters values can be monitored with StripTool charts. The target main GUI has preset commands to start three default target StripTool charts. If the charts are not already up and running on the *poltarac* monitor they can be started by clicking the **Charts** button in the target main GUI, see fig. 1, and picking one of the three choices for default charts: **Target Charts, Cryo Charts,** or **Position Charts**. A screen capture of the target chart is shown in fig. 6. For this instance

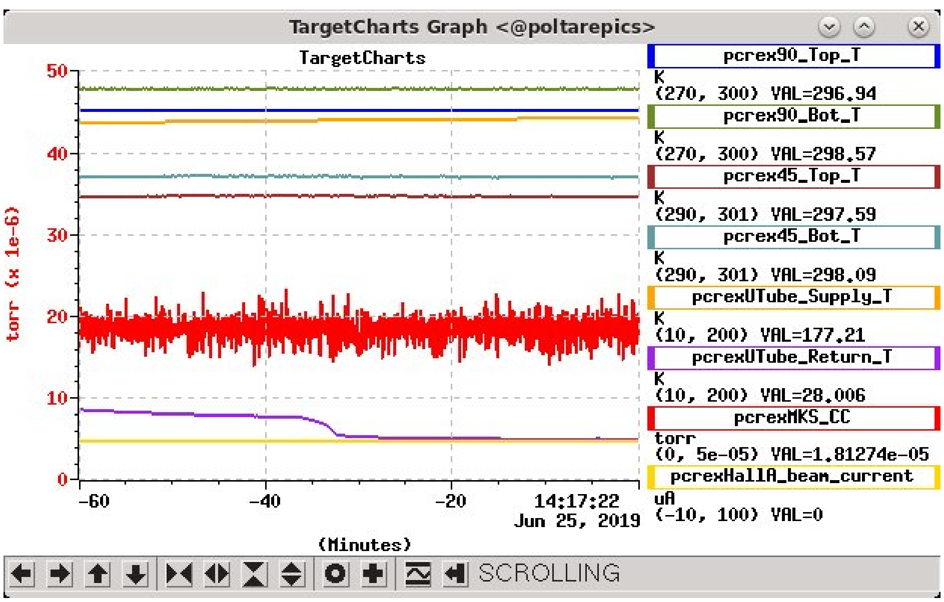


Figure 6: Target StripTool Chart.

of the chart the time span is one hour into the recent past. This StripTool chart displays

8 target parameters. To change the vertical scale among the signals just click on the signal EPICS Process Variable (PV) name on the right hand side of the chart. The signal ranges (vertical scale) and the time range (horizontal scale) can be changed by right clicking with the mouse while in the chart and picking the **Control Dialog...** from the choices. To change vertical ranges, click on **Curves** and **Modify**. To change the time span click on **Controls** and **Modify**.

Thermal Analysis.

A detailed thermal analysis with CFDFAC of the Ca targets can be found in the elog entry https://logbooks.jlab.org/entry/3782080 where both normal and off-normal running conditions are assessed. The off-normal conditions analyzed are the beam hitting the Ca target frame, back-mount and upstream collimator.

This section provides a summary of the thermal simulations studies done for the prex2/crex targets, for an in-depth description of the thermal simulations look in appendix B. The purposes of the thermal simulations were to aid in the engineering design of the target, to establish the operational conditions and limits for beam on target and to help in understanding the target foils behavior in beam.

The production targets for prex2 are ^{208}Pb foils. Though solid at room temperature, lead has the bad habits of melting at the relatively low temperature of 600 K and of having a low thermal conductivity coefficient over most of the temperature range encompassing its solid phase, see table 3. Prex1 has been plagued by lead's properties and the final result has been statistics starved, among other things, by the degradation of the target foils in beam. We leveraged the lessons learned with prex1 in the design of the prex2 target. The thermal

Target	T_{melt}	ρ	c_p	k	ℓ	dE/dx	I	P_{beam}
	K	g/cm^3	$J/kg.K$	$W/m.K$	mm	$MeV/g.cm^2$	μA	W
	He cooled ladder							
Pb	600	11.34	130	35	0.55	1.6	70	70
D	5000	3.51	435	>1000	0.25	2.2	70	13.5
C	3923	1.83	700	150	0.25	2.2	70	7
C-1%	3923	1.83	700	150	2.5	2.2	100	101
Ca	1115	1.54	600	<240	6.5	2.2	150	350
	Room temperature ladder							
C-0.2%	3923	1.83	700	150	0.5	2.2	100	20.1
W-0.3%	3695	19.3	130	170	0.01	1.6	50	1.6
Pb-0.9%	600	11.34	130	35	0.05	1.6	2	0.2
H_2O	273	1	4186	0.6	10	2.46	2	5
Cu-frame	1358	8.9	387	360	2.4	1.9	0	0

Table 3: The installed targets material properties for prex2, at room temperature. The expected beam heating power (last column) is at the nominal beam current.

assessment of the prex2/crex target foils has been done with Computational Fluid Dynamics (CFD). Two types of CFD simulations have been done: time-dependent and steady-state and each will be briefly described in what follows.

Time-dependent CFD Simulations. These simulations capture the evolution of temperature in the target Pb foils over time accounting for the real beam raster motion on the target. For a description of the beam raster motion please look in the appendix B. Figure 7 shows the CFD predicted time dependence of the maximum temperature in Pb and diamond at 70 μA beam current rastered on the target over an area of 4x4 mm^2 and for beam raster frequencies differences of 120 Hz, 240 Hz and 480 Hz. The intrinsic beam spot size was considered to be 120 μm, except for the last section for which it was twice that. The target foils were taken with their nominal thicknesses of 0.25 mm for diamond and 0.5 mm for lead. Diamond's thermal conductivity was assumed to be 1000 W/m/K. The copper frame that

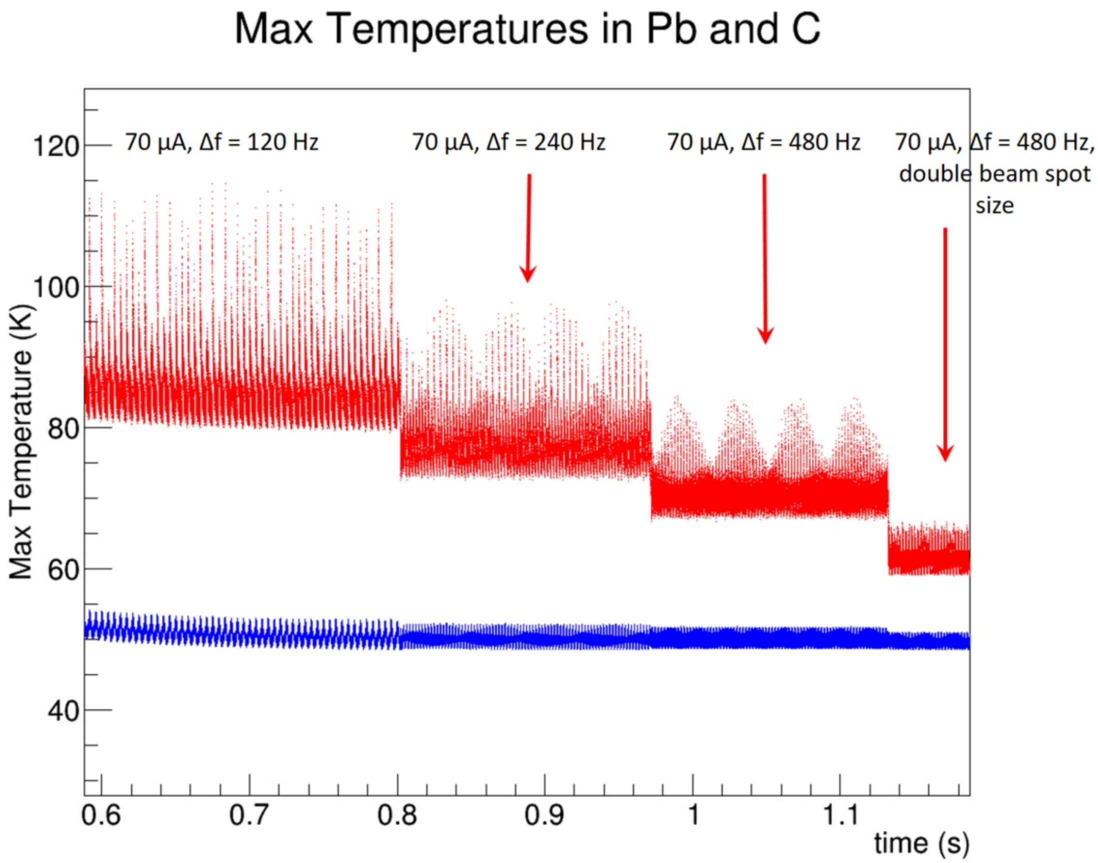


Figure 7: The time variation of the maximum temperature in a sandwich diamond-lead-diamond under nominal beam current conditions, 70 μA and 4x4 mm^2 for a nominal target thicknesses foils vs. raster frequencies difference.

supports the sandwich diamond-lead-diamond was assumed cooled by a 10 g/s flow of 15 K and 13 atm helium gas. Two triangular wave forms with frequencies around 25 kHz control the electron beam rastering system. The difference between the two frequencies is a multiple of 120 Hz. Fig. 7 shows that the average maximum temperature in Pb decreases by more than 50 % between beam raster frequencies difference of 120 Hz and 480 Hz for the same beam spot size, while at the same time the amplitude of the maximum temperature dramatically decreases. Doubling the beam spot size at the same raster frequencies difference substantially reduces the amplitude of the maximum temperature in lead and its average. The beam raster frequencies difference and the intrinsic beam spot size do not seem to have a significant influence on the maximum temperature in the diamond foils, for both its average and its amplitude over time. The Pb density in solid state varies by about 0.9 % over a 100 K temperature range. The hotter the Pb becomes and the larger the maximum temperature oscillations the larger the target noise contribution to the parity violating asymmetry width due to target density fluctuations.

As a consequence of these simulations we propose to run prex2 and crex with the beam raster frequency difference of 960 Hz. It would also be desirable to have the intrinsic beam spot size at least 150 μm in diameter.

Time-dependent simulations have also been run on the bare 50 μm lead foil installed on the warm target ladder. These simulations showed that a beam current up to 2 μA rastered over an area at least 16 mm^2 on the target would raise its temperature by some 40 K. The intrinsic beam spot size was assumed to be 160 μm.

Steady-state CFD Simulations. Steady-state CFD simulations are much more computationally inexpensive compared with the time-dependent ones. The steady-state simulations capture the maximum temperature in lead for certain boundary conditions, more or less the average value of the maximum temperature as captured in fig. 7. Figure 8 captures the summary of some of the steady-state CFD simulations done for lead foils. The horizontal axis is the thermal conductivity coefficient of the diamond foils. As the artificial diamond foils are exposed to the electron beam and its radiation the assumption is that their thermal conductivity coefficient decreases and the diamond foils become more and more thermal insulators. The CFD simulations confirm that if the diamond becomes more and more of an insulator the lead foils approach their melting point. As expected a larger raster area or a thicker diamond foil help reduce the maximum temperature in a lead foil, extending its lifetime. A colder helium coolant (going from 15 K to 4 K) does not seem to help much. A similar plot to the one in fig. 8 was done assuming that the coolant choices were cold liquid nitrogen and cold nitrogen gas as 77 K and 78 K respectively. Using nitrogen as coolant at 77 K, a lead foil starts melting when the diamond thermal conductivity decreases below 200 $W/m.K$ (same beam conditions), compared with below 50 $W/m.K$ if using 15 K helium gas.

If the diamond foils thermal conductivity coefficient remains above 1000 $W/m.K$, with good thermal contact between diamond and lead and between diamond and copper, then regardless of the coolant choice (15 K or 4 K helium) or the raster area (above 16 mm^2) the lead foil lifetime would be well in excess of the running time for prex2.

CFD studies with various insulator thicknesses between Pb and diamond or between diamond and the copper frame (bad contacts) show that these would have to be on the order of 100 μm or more and to have thermal conductivities lower than 1-2 W/m.K to have a significant effect on the maximum temperature in a Pb foil.

CFD predicted thermal maps. These are temperature profiles from steady-state CFD

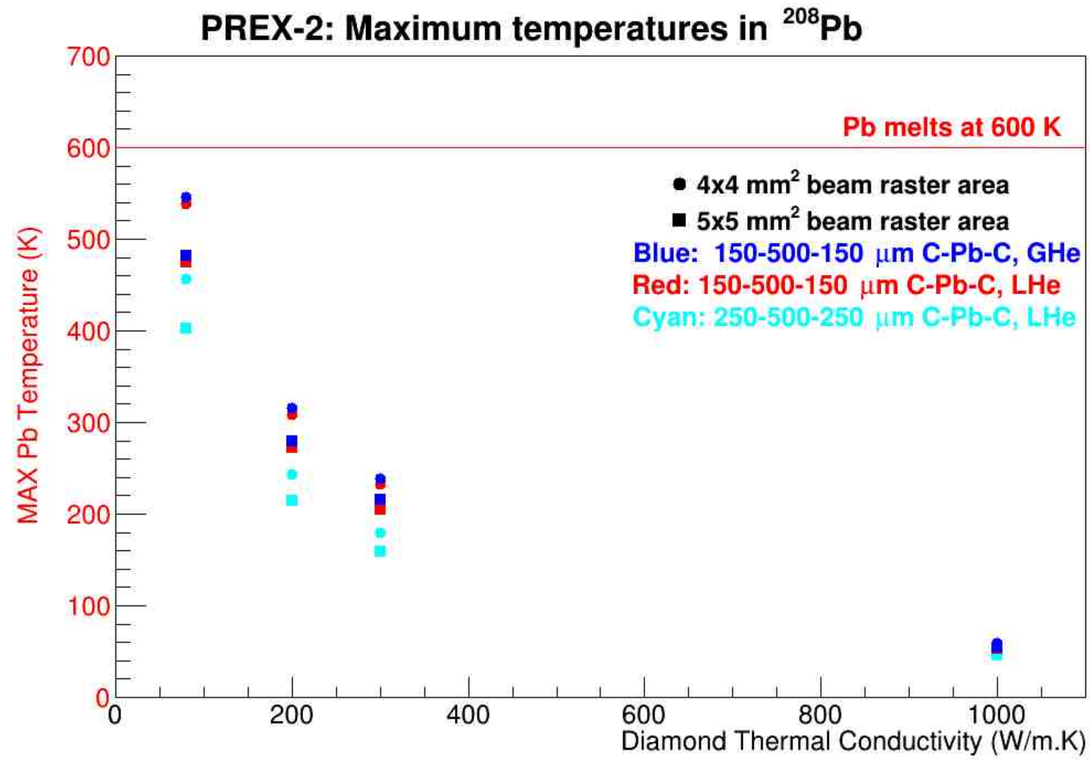
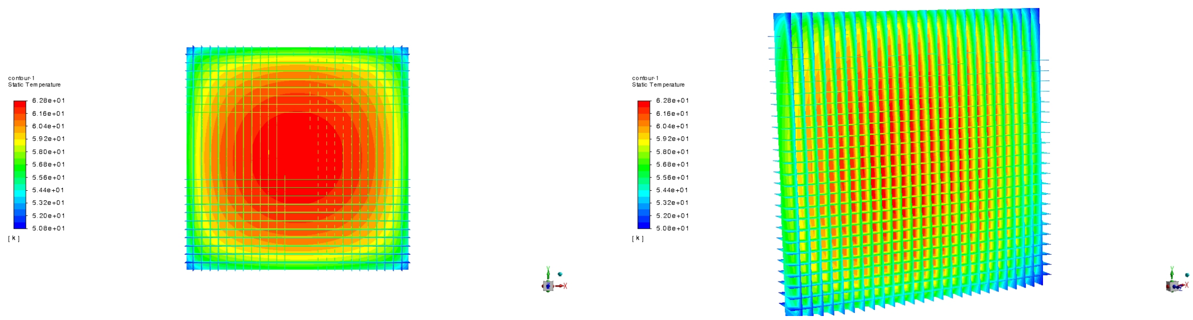


Figure 8: Summary plot showing the maximum temperature variation in Pb with the thermal conductivity coefficient of diamond for two beam raster sizes, two diamond foil thicknesses and two coolant types. The beam current is assumed to be 70 μA and the beam heating is assumed to be uniformly distributed in the raster illuminated volume inside a foil.

simulations.



Front face Side tilt

Figure 9: Temperature profile in Pb in the raster illuminated volume of DA-208Pb2-DB foil. The beam is 70 μA rastered on a square of side 4 mm. The diamond foils have 1000 W/m.K thermal conductivity coefficient and the copper frame is cooled by 10 g/s of 15 K helium gas. The side tilted profile shows that there is a temperature gradient between the core of the Pb foil and its beam-normal faces of about 10 K/0.25 mm in these conditions. The grid lines show the spatial resolution of the mesh.

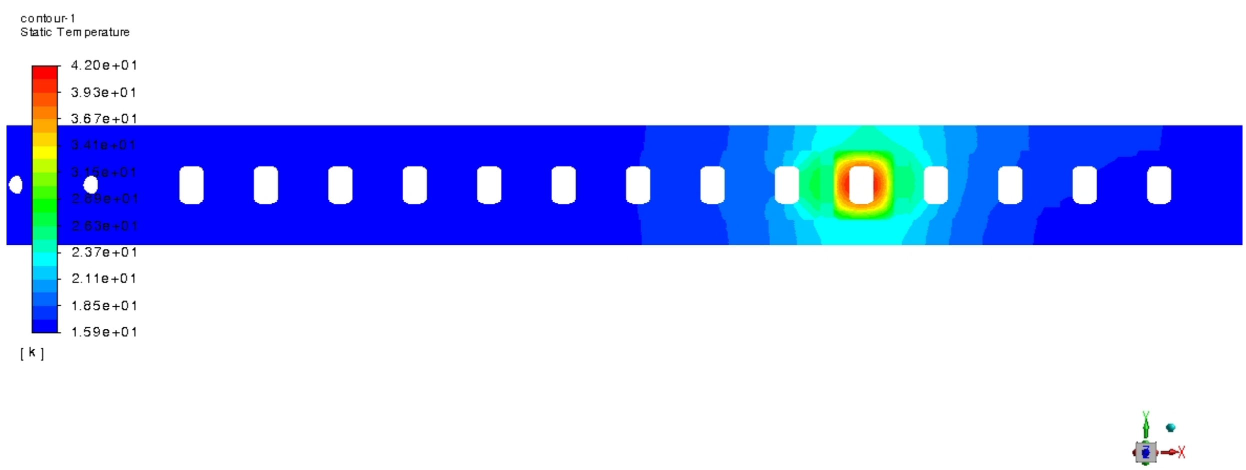


Figure 10: Temperature distribution in the copper frame in nominal conditions with beam on DA-208Pb2-DB target (lead with graphite foils). One temperature sensor on the cold ladder would measure about 18-20 K, while the other would measure about 16-17 K.

A Target Foils Measurements.

Coming soon!

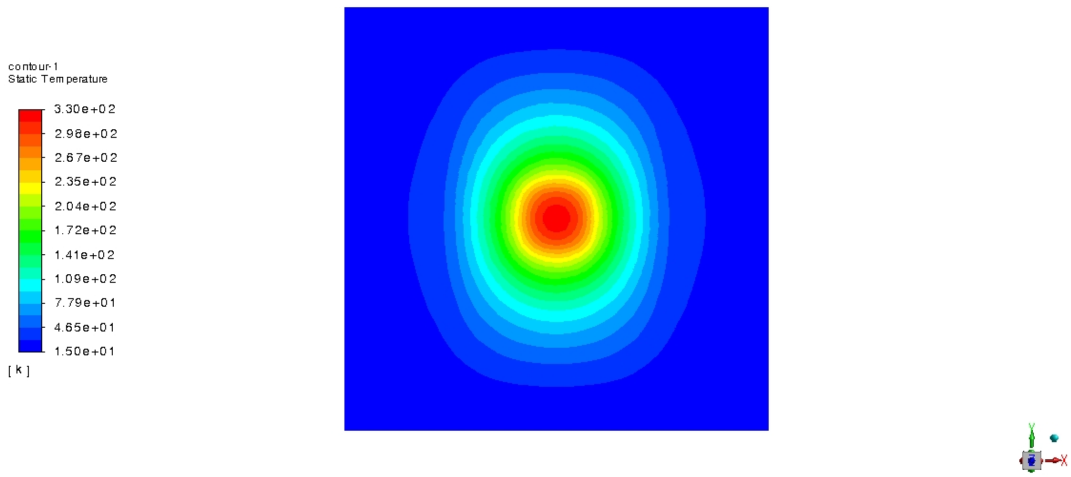


Figure 11: Temperature distribution in mid-section of Pb perpendicular to the beam line. The target is C-208Pb1-C, with graphite foils. The beam is nominal at 70 μA and square raster area of side 4 mm, the coolant is 15 K helium gas at 10 g/s. The maximum temperature in the Pb foil is predicted to reach 330 K with graphite foils compared with about 63 K with diamond foils in the same beam conditions.

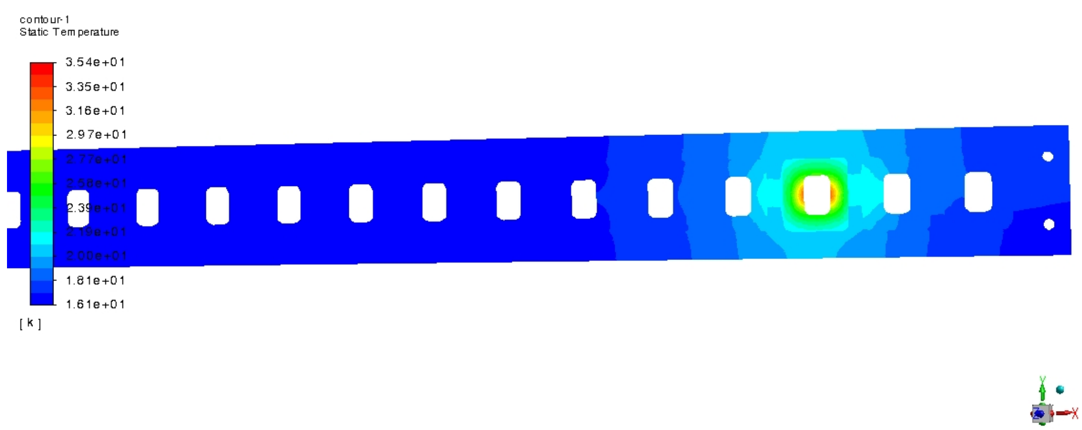
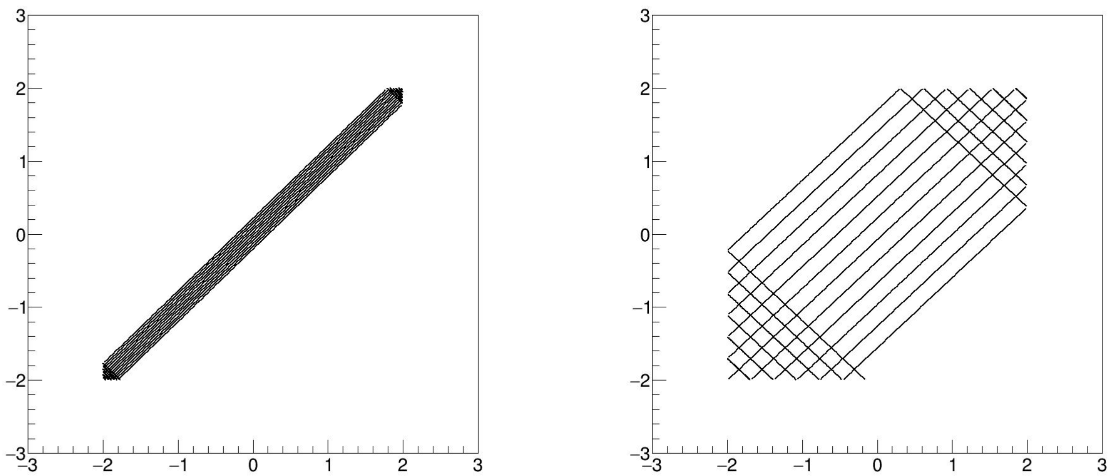


Figure 12: Temperature distribution in the copper frame in nominal conditions with beam on C-208Pb1-C target (lead with graphite foils). One temperature sensor on the cold ladder would measure about 20-22 K, while the other would measure about 16 K.

B CFD Simulations.

Prex2 has installed 10 ^{208}Pb foils, 9 foils are sandwiched between diamond foils and one is sandwiched between graphite foils. The most robust prex1 ^{208}Pb target foil was sandwiched between 0.25 mm thick diamond foils, which is the thickness of all the prex2 diamond foils. The thermal assessment of prex1 target foils with Computational Fluid Dynamics (CFD) simulations shows that under a 70 μA electron beam heating with a beam spot at least 4x4 mm^2 a diamond-lead-diamond sandwich approaches the melting point of lead as the thermal conductivity coefficient of diamond decreases significantly below 1000 W/m.K. The



$|f_y - f_x| = 120$ Hz. $|f_y - f_x| = 960$ Hz.

Figure 13: Target area painted by the fast raster in the same amount of time for two different raster frequencies differences. The raster shape is square with a side of 4 mm.

electron beam heating effects on the target foils have been assessed using ANSYS-CFD (the specific software engine used was *Fluent*. The thermal simulations were run on a dedicated 256 CPU High Performance Computing (HPC) farm operated by CFD-FACility (CFDFAC) at jlab. The CAD models of the installed target ladders were prepared for CFD simulations using ANSYS-WorkBench. A meshed model from the WorkBench was imported into *Fluent*, where boundary and operating conditions were set and then the model was iterated to observe convergence in either steady-state or time-dependent simulations. Steady-state simulations are quicker computationally. Time-dependent simulations can take a long time depending on the time range considered to account for the beam raster motion.

The Hall A fast raster has a triangular shape in both x and y, where x and y are the perpendicular directions to the electron beam traveling direction, horizontally and vertically, respectively. The frequencies of the fast raster are typically $f_x = 24,960$ Hz and $f_y = 25,080$ Hz, which makes the period of the fast raster about 40 μs. To sample the fast raster electron beam motion on the target, a time step about 10-20 times smaller would be needed in the CFD simulations. The total time it would take to simulate 1 s of beam time, accounting for the fast raster motion, would be about 1 month. Optimization of the CFD

Fluent case could reduce this to about 1 week of HPC farm time for simulating 1 s of real electron beam motion on the target, hence the computational expense of time-dependent simulations.

Jefferson Lab Alignment Group

Data Transmittal

TO: D. Meekins, K. Paschke, C. Gal, S. Corvig	**DATE:** 20 Jun 2019

FROM: Chris Gould	**Checked:**	**# :** A1928

DETAILS: M:\align\DATA\Step2B\HALLA\PREX2019\190618A

Below are the final results of the PREX experiment assembly. The target locations were measured to the upstream face of the copper target ladder. Values are reported in a beam following system relative to the Hall A Center. A positive X is beam left, a positive Y is up and a positive Z is downstream.

	IDEAL FROM HALL A CENTER (mm)				FOUND BFS (mm)				ROTATIONS (Degrees)	
	X	Y	Z		X	Y	Z		rX (Pitch)	rY (Yaw)
PREX Tgt.	0.00	0.00	-1151.20						0.0000	0.0000
90_TGT_16					0.04	-4.93	-16.43		-0.1771	0.1327
90_TGT_15					-0.07	-4.36	-16.23		0.1346	0.0074
90_TGT_14					0.12	-3.72	-16.08		-0.0361	-0.0509
90_14_Carbon Hole					0.29	-2.98				
90_TGT_13					-0.10	-3.15	-16.11		-0.0398	-0.0074
90_TGT_9					-0.20	-0.66	-15.68		-0.0023	-0.0374
90_TGT_4					-0.07	1.68	-15.20		0.0649	0.0720
90_TGT_1					-0.12	2.33	-14.84		0.0666	0.1585
45_TGT_5					0.00	-1.93	-0.96		-0.3255	-0.8839
45_TGT_4					0.15	-1.72	5.33		-0.2242	-2.2232
45_TGT_3					0.08	-1.64	5.28		-1.4220	1.0885
45_TGT_2					0.27	-1.65	5.11		0.6747	0.1170
45_TGT_1					-0.03	-1.50	5.17		0.7826	-0.5469
45_1_Carbon Hole					-0.33	-1.74				

	IDEAL FROM HALL A CENTER (mm)				FOUND BFS (mm)				ROTATIONS (Degrees)		
	X	Y	Z		X	Y	Z		rX (Pitch)	rY (Yaw)	rZ (Roll)
Collimator	0.00	0.00	-245.59		0.06	-0.03	1.38		0.0177	-0.0034	0.0072
Septum	0.00	0.00	700.00		0.18	2.40	0.75		0.0176	-0.0063	0.0179
R. Q1 Col. Fids measured 5/21/19											
1	-348.37	90.74	1329.34		-0.78	0.36	0.04				
2	-399.51	0.00	1318.00		-0.31	0.60	-0.62				
3	-348.37	-90.74	1329.34		-0.21	0.54	-0.93				
4	-246.07	-90.74	1352.01		-0.11	0.54	-1.06				
5	-194.93	0.00	1363.35		-0.18	0.90	-1.08				
6	-246.07	90.74	1352.01		-0.26	0.66	-0.57				
L. Q1 COL. Fids measured 5/21/19											
1	246.07	90.74	1352.01		1.06	-0.22	0.14				
2	194.93	0.00	1363.35		0.57	-0.04	0.13				
3	246.07	-90.74	1352.01		0.19	-0.30	0.02				
4	348.37	-90.74	1329.34		0.18	-0.69	-0.07				
5	399.51	0.00	1318.00		0.69	-0.87	0.06				
6	348.37	90.74	1329.34		1.09	-0.65	0.06				

Jefferson Lab Alignment Group

Data Transmittal

TO: D. Meekins, S. Covrig Dusa, J. Butler, R. Wines, W. Seay	**DATE:** 06 Nov 2019
FROM: Kelly Tremblay	**Checked:** / **# :** A1947

DETAILS:

data : step2b\halla\prex2019\target\191023a

The CREX target was surveyed October 23rd, 2019. The results below show the location of the targets based on the ideal center of the CREX target. The resulting can location is also shown for reference. The targets were exercised in and out and the results are marked below.

The first two tables show the coordinates for the horizontal and forty five degree ladders. These coordinates are based at the CREX target center and are looking downstream. A positive dx value is to the beam left looking downstream along beam from the ideal; a positive dy is higher vertically from ideal; A positive dz is downstream from ideal.

The third table shows the reference information for the hall center (normal target), CREX target and the as-found beam following location of the can.

Horizontal Target Ladder				
target	dx[mm]	dy[mm]	dz[mm]	Comment
CA40	0.43	-2.49	-15.58	
CA48	0.28	-1.92	-15.53	
CarbonHole	0.42	-0.48	0.69	
CarbonHole**	0.46	-0.50	0.69	After ladder exercised in/out

45 Degree Target Ladder				
H2O	-0.43	0.24	0.93	
H2O_REP	-0.45	0.02	0.90	After ladder exercised in/out
CARBONHOLE_45_1	-1.42	-0.51	10.80	
CARBONHOLE_45_2	-1.45	-0.56	10.40	After ladder exercised in/out

	Ideal [m]			As- Found BFS [mm]			As-Found BFS rotations [deg]		
	X	Y	Z	x[mm]	y[mm]	z[mm]	dYaw	dPitch	dRoll
Hall A Center	-32.95843	100.02200	-393.03108						
CREX Target	-33.65924	100.02200	-392.11777						
CREX Can	-33.65924	100.02200	-392.11777	-0.33	-0.76	2.04	0.01279	-0.03151	0.07964

References

[1] *CREX: Parity-Violating Measurement of the Weak Charge Distribution of* ^{48}Ca *to 0.02 fm Accuracy (E12-12-004), CREX Collaboration, 2013, Submitted to PAC40.*

[2] *PREX-II: Precision Parity-Violating Measurement of the Neutron Skin of Lead (E12-11-007), PREX2 Collaboration, 2012, Submitted to PAC38.*