

CSPAD Geometry and Alignment

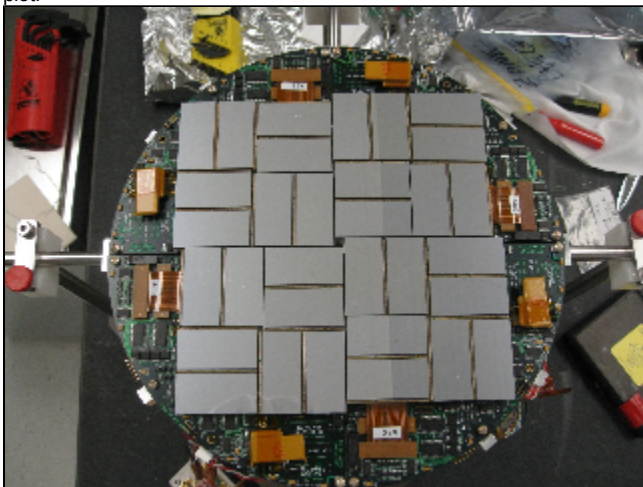
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Introduction

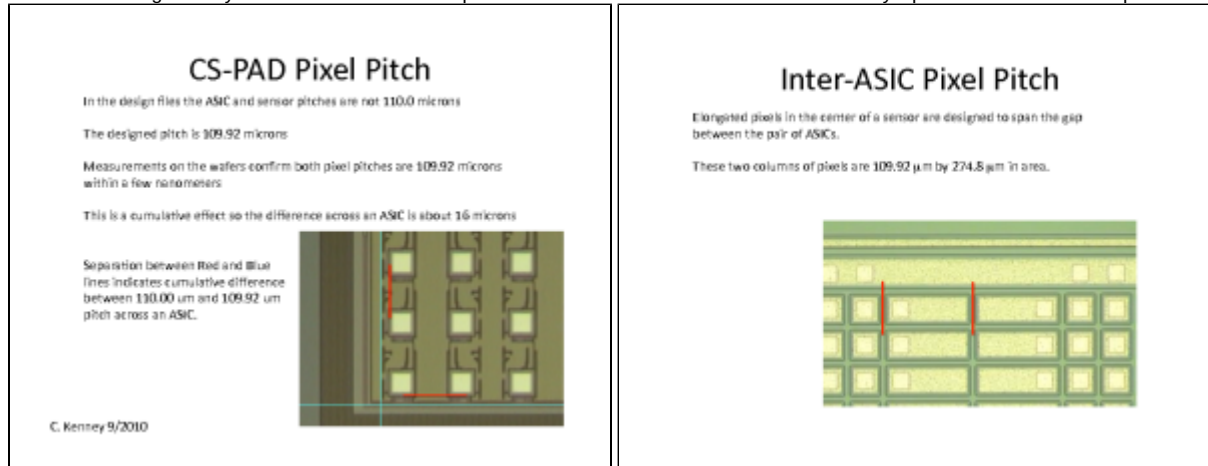
Cornell SLAC Pixel Array Detector (CSPAD) is an imaging X-ray detector made of silicon sensors (2x1) covering about 20x20cm² surface, as shown in the plot:



Pixel coordinates in 2x1 sensor chip are known with sub-micrometer precision. Construction of the detector allows significant freedom in relative positions of 2x1 sensors. To get precise pixel positions in the detector the 2x1 sensor coordinates needs to be calibrated. In this note we describe geometry of the CSPAD detector, optical and quad alignment procedure, parameters, and software providing access to precise geometry information.

2x1 Sensor Geometry

The 2x1 sensor geometry was tested with microscopic measurement. Two slides from Chris Kenney's presentation shows the pixel sizes:



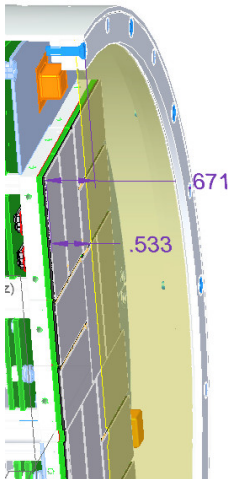
[The same slides in PDF format.](#)

Important 2x1 features:

- Number of rows x columns = 185 x 388. (In DAQ notation of rows and columns is interchanged...)
- Most of pixels have size 109.92 x 109.92 μm^2 .
- Gap between two ASICS is covered by the two rows of elongated pixels with size 109.92 x 274.8 μm^2 .
- Two versions of sensors have different dimensions between corners, so it is reasonable to define pixel coordinates w.r.t. the sensor center.

Shield to sensor distance

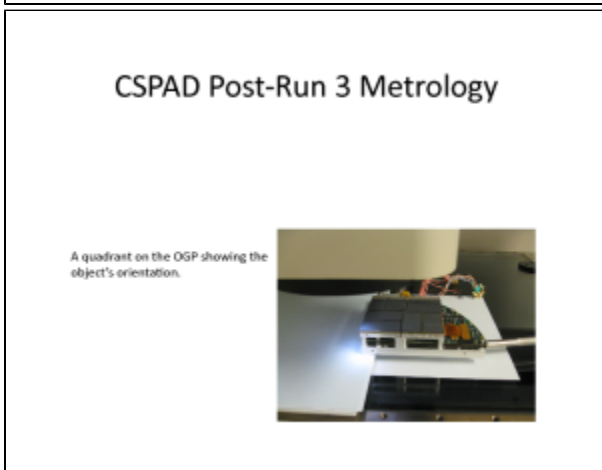
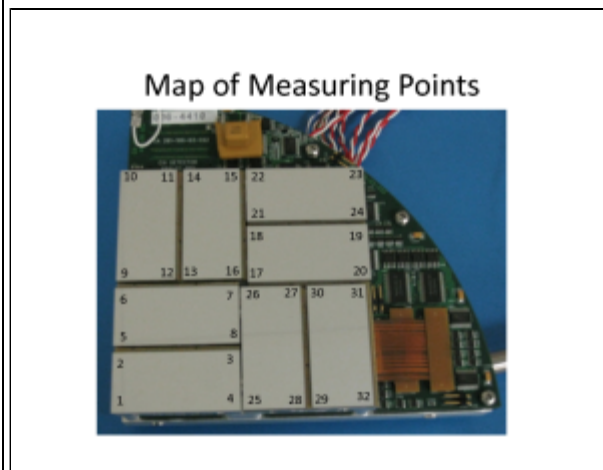
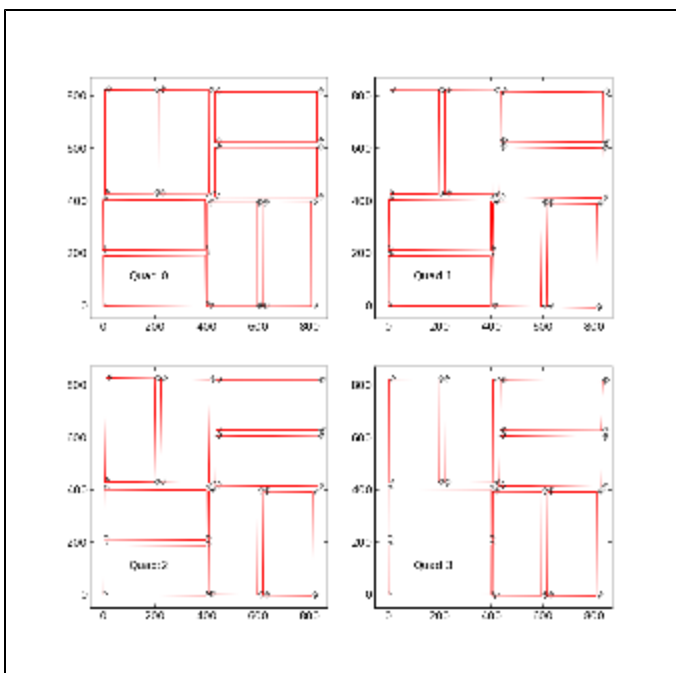
Chart of CXI Camera1 provided by Serge Guillet on 2017-06-12.



Optical measurement

Optical measurement is conducted by Gabriel Blaj. Detector or its quad is installed on microscope table and 3-d coordinates of all 2x1 sensor corners are measured with precision about 8 μm (RMS) in x-y plane. All corners in the measurement are numerated in arbitrary order. It is expected that numeration order should be the same for different measurements. This procedure depends on CSPAD construction;

- For CSPAD with movable quads (i.e. for CXI) optical measurement is done separately for each quad. The numeration of corners is shown in the plot:

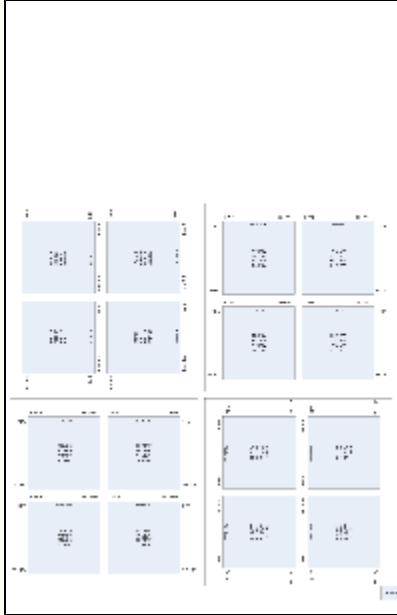


The same plots in PDF format: [CSPAD quad metrology](#) and [CSPAD pixel layout in quads](#).

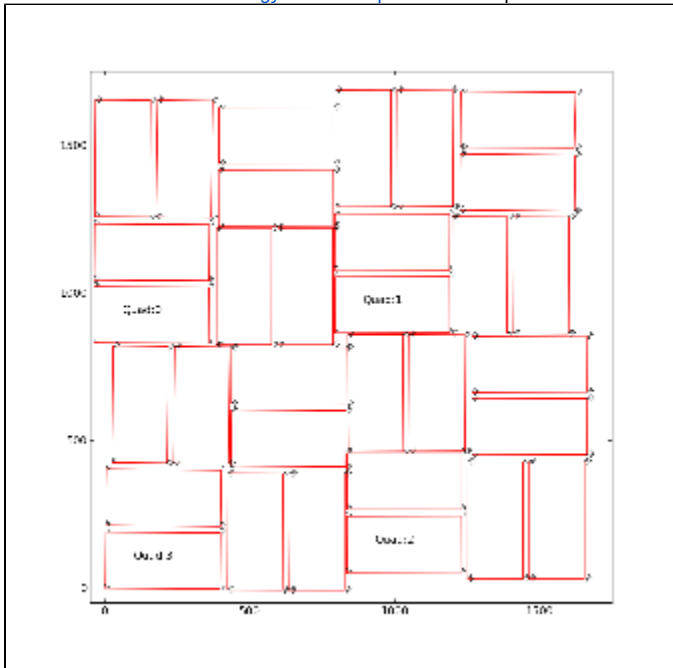
For each quad measurement is started from the point #1 which in assembled detector is closest to the beam. The 1-st point (x,y,z) coordinates are re-set to (0,0,0) in the beginning of measurements. At the end, it is checked that the 1-st point coordinates are reproduced within precision of measurement.



The order of points in optical measurement does not coincide with [numeration of 2x1 in DAQ](#), as shown in the plot (and in [PDF file](#)):



- For CSPAD with fixed quad geometry (i.e. for XPP) optical measurement is done for entire detector. The numeration of corners in this case is shown in the file [XPPMetrologyAnnotated.pdf](#) and in the plot:



The 1-st corner of the 3-rd quad (x,y,z) coordinates are re-set to (0,0,0) in the beginning of measurements. At the end, it is checked that the 1-st point coordinates are reproduced within precision of measurement.

Corner coordinates are measured in micrometers (um) and are saved in the xlsx format table, also containing numeration of quads and points. Then, xlsx format table is converted to the text file format in order to use it in python script.

Example of tables for CXI:

- [Metrology in XLSX](#)
- [Metrology in TXT](#)

Example of tables for XPP:

- [Metrology in XLSX](#)
- [Metrology in TXT](#) Python script converts this table to the table with standard numeration of points in quads:
- [Metrology in standard TXT](#)

Then, text table with "standard" numeration of points in quads is feed to the python script which provides quality check of optical measurement and evaluates the alignment parameters for quads. In the beginning, this script changes the numeration of points adopted in optical measurement to numeration of 2x1 used in DAQ. Further, all calibration parameters are associated with numeration of 2x1 sensors and quads in DAQ.

Quality Check Procedure

For quality check of optical measurement we calculate

S1 - 1st short side length of 2x1

S2 - 2nd short side length of 2x1

L1 - 1st long side length of 2x1

L2 - 2nd long side length of 2x1

D1 - 1st diagonal of 2x1 between corners 1 and 3

D2 - 2nd diagonal of 2x1 between corners 2 and 4

dS and dL are the deviations of the 1st and 2nd corner along the short and long sides, respectively. The sign of all dS are chosen in order to provide correct sign for the tilt angle (the same direction for all 2x1 sensors).

<dS/L> - the tilt angle of 2x1 averaged over two sides in radians.

angle(deg) - the same angle in degrees.

dD = D1 - D2

d(dS) = dS1 - dS2

d(dL) = dL1 - dL2

dz3(um) - signed distance from 2x1 sensor plane and corner 3, where the 2x1 sensor plane contains the corner points p1, p2, and p4. This plane is defined by the vectors v21=p2-p1, v41=p4-p1, and their orthogonal vector

$$\text{vort} = [\text{v21} \times \text{v41}].$$

Scalar product with normalization defines the distance from point 3 to the 2x1 plane containing 3 other points:

$$\text{dz3} = (\text{v31} \cdot \text{vort}) / |\text{vort}|.$$

Quality check parameters expected for perfect geometry:

S1=S2, L1=L2 - the 2x1 sides should have equal length and width,

D1=D2 - the 2x1 diagonals should be equal,

dS1 = dS2 ? (388/185)*dL1 = (388/185)*dL2 - tilt angle should provide consistent deviation for all corners,

dD=0, d(dS)=0, and d(dL)=0 - within precision of measurement.

dz3(um) = 0

Everything, excluding <dS/L> and angle(deg), are in micrometers.

Example of the table with quality check results:

pair: D2	S1 dD	S2 d(dS)	dS1 d(dL)	dS2 dz3(um)	L1	L2	dL1	dL2	<dS/L>	angle(deg)	D1
Quad 0											
pair: 0	20891	20913	200	222	43539	43541	-102	-100	0.00485	0.27766	48298
48297	1	-22	-2	2.981							
pair: 1	20910	20894	293	277	43540	43535	-127	-132	0.00655	0.37506	48302
48289	13	16	5	-23.986							
pair: 2	20890	20906	99	83	43536	43536	42	42	0.00209	0.11976	48290
48293	-3	16	0	-3.034							
pair: 3	20897	20895	131	133	43545	43543	65	63	0.00303	0.17369	48299
48297	2	-2	2	6.003							
pair: 4	20911	20896	-30	-45	43549	43547	17	15	-0.00086	-0.04934	48303
48306	-3	15	2	-5.994							
pair: 5	20901	20898	10	7	43540	43544	-8	-4	0.00020	0.01119	48296
48299	-3	3	-4	9.993							
pair: 6	20904	20903	104	105	43536	43540	55	59	0.00240	0.13752	48302
48290	12	-1	-4	52.002							
pair: 7	20901	20901	-7	-7	43545	43543	-3	-5	-0.00016	-0.00921	48299
48301	-2	0	2	14.001							
Quad 1											
pair: 0	20913	20914	-343	-342	43540	43550	165	175	-0.00787	-0.45066	48313
48303	10	-1	-10	-24.002							
pair: 1	20898	20901	-145	-142	43548	43551	62	65	-0.00330	-0.18880	48300
48309	-9	-3	-3	-23.005							
pair: 2	20895	20903	-151	-159	43535	43532	-74	-77	-0.00356	-0.20400	48289
48291	-2	8	3	-17.995							

pair: 3	20872	20909	-235	-272	43341	43354	-37	-24	-0.00585	-0.33507	48201
48036	165	37	-13	-13.010							
pair: 4	20940	20904	-455	-491	43527	43554	214	241	-0.01086	-0.62242	48309
48309	0	36	-27	1.101							
pair: 5	20910	20903	-302	-309	43546	43546	145	145	-0.00702	-0.40196	48304
48307	-3	7	0	6.016							
pair: 6	20901	20919	-421	-439	43529	43539	-213	-203	-0.00988	-0.56593	48296
48298	-2	18	-10	-8.026							
pair: 7	20907	20907	-452	-452	43548	43539	-201	-210	-0.01038	-0.59475	48315
48294	21	0	9	-8.982							
Quad 2											
pair: 0	20914	20914	-25	-25	43536	43540	10	14	-0.00057	-0.03290	48300
48300	0	0	-4	-11.013							
pair: 1	20901	20897	7	3	43546	43536	-1	-11	0.00011	0.00658	48293
48300	-7	4	10	4.036							
pair: 2	20899	20903	-256	-260	43533	43539	-127	-121	-0.00593	-0.33954	48293
48294	-1	4	-6	-1.023							
pair: 3	20912	20904	-210	-202	43540	43547	-106	-99	-0.00473	-0.27106	48300
48306	-6	-8	-7	24.004							
pair: 4	20910	20903	-543	-550	43535	43536	261	262	-0.01255	-0.71923	48298
48299	-1	7	-1	0.004							
pair: 5	20904	20905	-241	-240	43538	43544	111	117	-0.00552	-0.31647	48298
48301	-3	-1	-6	-6.024							
pair: 6	20903	20902	21	22	43539	43543	8	12	0.00049	0.02829	48298
48298	0	-1	-4	8.999							
pair: 7	20902	20903	82	81	43546	43547	35	36	0.00187	0.10723	48300
48306	-6	1	-1	9.995							
Quad 3											
pair: 0	20902	20898	-82	-86	43536	43543	30	37	-0.00193	-0.11054	48289
48302	-13	4	-7	1.994							
pair: 1	20900	20904	79	83	43548	43541	-35	-42	0.00186	0.10658	48301
48301	0	-4	7	-17.993							
pair: 2	20912	20894	181	199	43536	43535	97	96	0.00436	0.25005	48298
48289	9	-18	1	10.011							
pair: 3	20912	20905	119	126	43539	43538	57	56	0.00281	0.16121	48296
48301	-5	-7	1	-16.000							
pair: 4	20894	20912	-454	-436	43534	43545	212	223	-0.01022	-0.58560	48303
48296	7	-18	-11	2.023							
pair: 5	20906	20919	-336	-323	43527	43535	155	163	-0.00757	-0.43369	48295
48294	1	-13	-8	5.993							
pair: 6	20902	20905	-203	-206	43537	43525	-89	-101	-0.00470	-0.26916	48293
48287	6	3	12	2.981							
pair: 7	20900	20897	-140	-137	43539	43544	-68	-63	-0.00318	-0.18225	48298
48296	2	-3	-5	29.997							

This quality check works well to catch significant typos in input table. In case of obvious typos input table can be corrected. When the quality check is passed successfully the alignment parameters are saved and deployed under the calib.

Detector geometry model

Since 2014 we support universal detector geometry software which is documented in the [Detector Geometry](#) page and in [CSPAD-geometry-parameters.pdf](#)

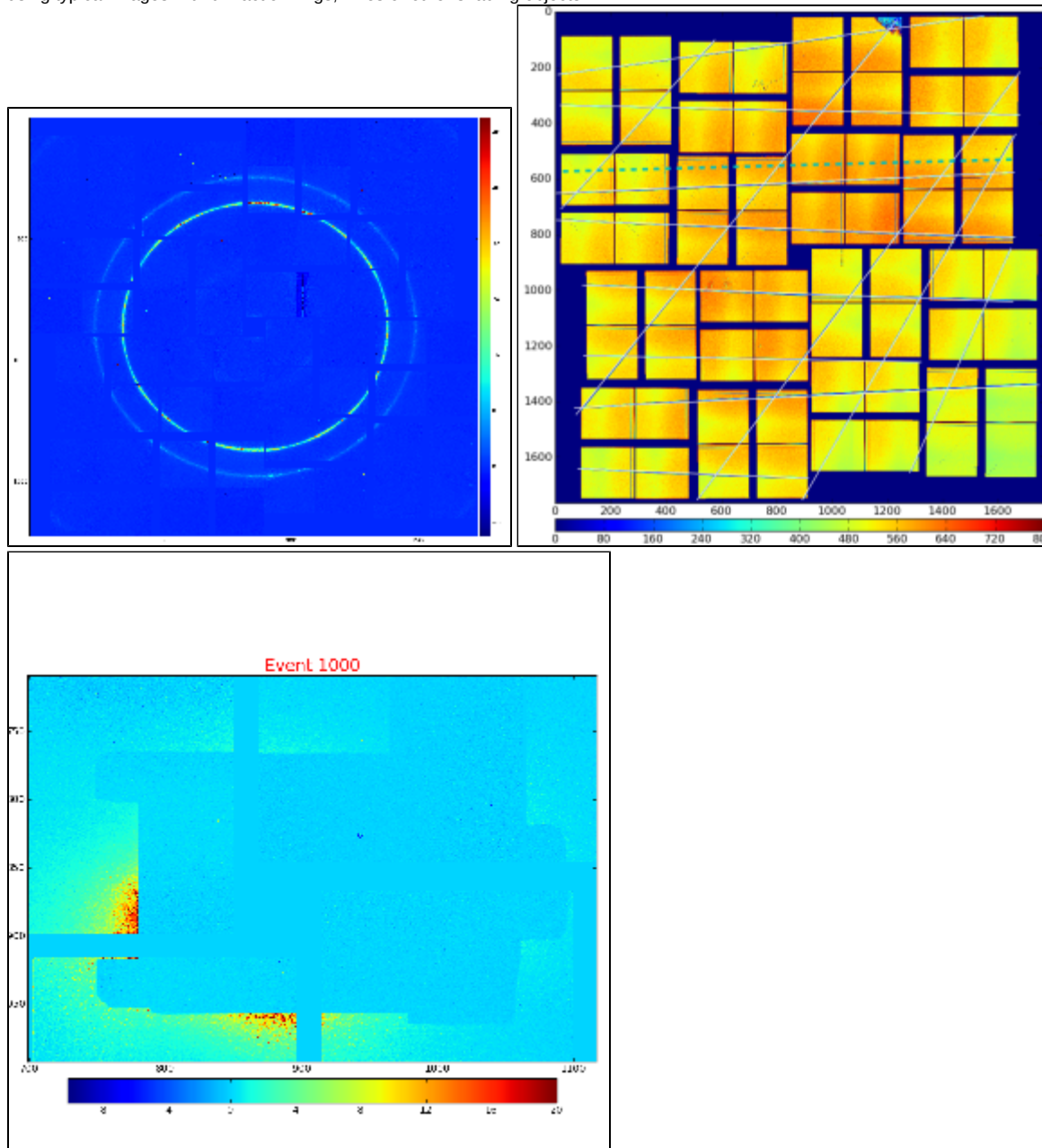
Alignment parameters from optical measurement

From optical measurement we extract coordinates of the center of each 2x1 sensor and its tilt angle. The center coordinates are evaluated as an averaged over 4 corners measurements for each axis.

The tilt parameters are used along with rotation to completely define orientation of 2x1 in quad (for CXI) or in detector (for XPP).

Alignment of quads in the detector

For CSPad with fixed quad geometry (like in XPP) optical measurement of entire detector (should) produces complete information for geometry alignment. For CSPad with moveable quads (like in CXI) quads relative position needs to be adjusted through the alignment parameters for quads. It is usually done using typical images with diffraction rings, wires or other shading objects:



Although few algorithms of automatic quad alignment were tried, we did not find good generic way for automated quad tuning. Currently, the quad tuning parameters in `marg_gap_shift` and `offset_corr` are adjusted manually for runs with specific images.

Calibration store

The official space for CSPAD alignment parameters is
`/reg/d/psdm/<INSTRUMENT>/<experiment>/calib/CsPad::Calib<VERSION>/<CSPad-name>/<type>/<run-range>.data`
 For example:

```
/reg/d/psdm/CXI/cxi80410/calib/CsPad::CalibV1/CxiDs1.0:Cspad.0/geometry/1142-end.data
```

The file name consists of the run range followed by the `.data` extension, for example, `0-end.data`, `11-end.data`, `47-52.data`, etc.

Calibration type

Detector geometry calibration information is located in a single file of type

- `geometry` - contains hierarchical description of all detector components; for example for CSPAD, sensors' location and rotation in the quads, quads - in the detector, detector - in the setup, etc.

Archive and History

Optical measurement and other alignment files can be found in

- `/reg/g/psdm/detector/alignment/cspad/`
- [Geometry History](#)

Detector data access software

- [Detector data access software](#)

References

- [CSPAD Geometry and Alignment - Deprecated](#) - old version of this page
- [Detector Geometry](#) - confluence page
- [CSPAD in DAQ](#) - schematic description of CSPAD geometry available in DAQ.
- [CSPAD quad metrology](#) - slides for CXI type CSPAD quads
- [CSPad pixel layout in quads](#) - pdf file with numeration of ASICs in the CSPAD quads
- [XPPMetrologyAnnotated.pdf](#) - order of measurements of XPP camera.
- [Geometry History](#) - page with references to calibration files.
- [Detector data access software](#) - auto-generated documentation of the Detector package.