CSpad detector calibration

November 3, 2010

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I. NEWS

- CSpad geometry data from optical measurement
- Fast algorithm for alignment
- Alignment of tilted ASIC pairs
- Alignment of the CSpad quad versus the beam center

II. CSPAD GEOMETRY FROM OPTICAL MEASUREMENT

TABLE I: CSpad geometry data from optical measurement (Christopher Kenney).

Point	X	Y	Z	SB	Pad X	Pad Y
1	0	0	0	15L		
2	43970	7	44	15L		
3	43978	21427	9	15L		
4	4	21427	20	15L	547	21846
5	17	23461	28	15s		
6	43996	23218	17	15s		
7	44117	44667	2	15s		
8	134	44906	24	15s	690	45312
9	632	47000	39	26L		
10	1137	90967	62	26L		
11	22579	90723	52	26L	22975	90179
12	22071	46766	30	26L		
13	24031	46694	25	26S		
14	24413	90681	62	26S		
15	45851	90478	39	26S	46253	89931
16	45471	46506	55	26S		
17	47761	90117	52	27L		
18	91725	89497	63	27L		
19	91425	68067	44	27L	90871	67667
20	47454	68689	34	27L		
21	47401	66724	32	27S		
22	91369	66127	41	27S		
23	91078	44700	5	27S	90523	44299
24	47107	45286	3	27S		
25	44135	-701	42	30L		
26	44389	43268	19	30L		
27	65838	43131	23	30L	66245	42592
28	65577	-829	30	30L		
29	67520	-911	38	30S		
30	67786	43050	24	30S		
31	89220	42921	2	30S	89628	42372
32	88952	-1040	51	30S		

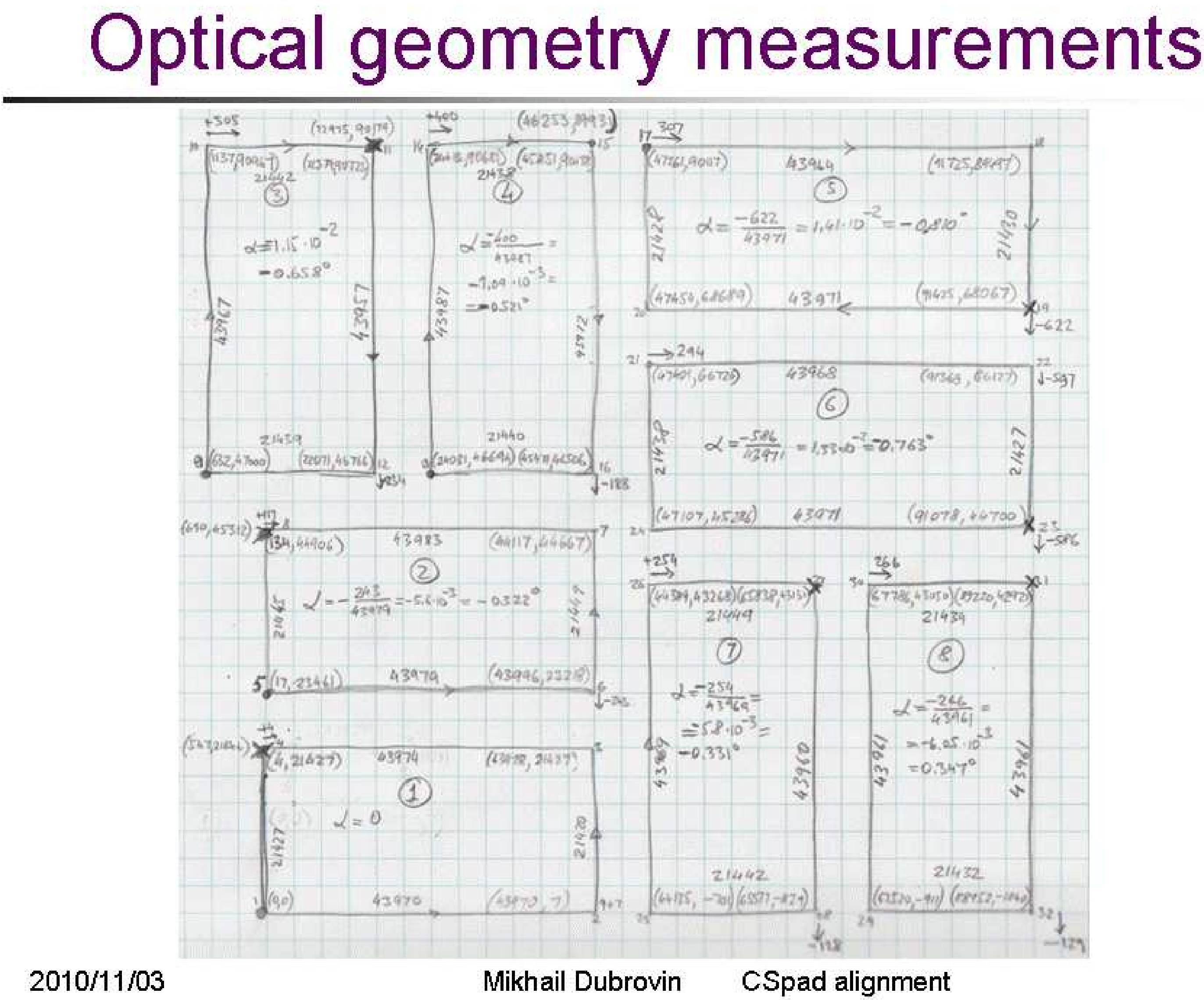

FIG. 1: Processing of data obtained in the optical measurement.

TABLE II: Derived pads' geometry from the optical measurement.

Sequence of measu.	ASIC pair	Pad length L (μm)	Pad width W (μm)	αL (μm)	Tilt angle α ($\circ$)	$\alpha - \overline{\alpha}$ ($\circ$)	My ($\circ$)
1	02-03	43970	21420	7	0±0.011	0.469	0.7
		43974	21427				
2	00-01	43979	21449	–243	–0.322±0.011	0.147	0.2
		43983	21445				
3	06-07	43967	21442	–505	–0.658±0.011	–0.189	0.1
		43957	21439				
4	04-05	43987	21438	–400	–0.521±0.011	–0.052	–0.1
		43972	21440				
5	10-11	43964	21430	–622	–0.810±0.011	–0.341	–0.4
		43971	21428				
6	08-09	43968	21427	–586	–0.763±0.011	–0.294	–0.4
		43971	21438				
7	14-15	43969	21449	–254	–0.331±0.011	0.138	0.1
		43960	21442				
8	12-13	43961	21434	–266	–0.347±0.011	0.122	0.1
		43961	21432				
Mean		43969.6	21436.3		–0.469±0.011	0	
Dispers.		8.3	8.4		0.272	0.272	

III. FAST ALGORITHM FOR ALIGNMENT

Previous algorithm, based on fit of the 2D PDF to the intensity image, works ≈5 min that looks too slow. The same problem can be solved faster by replacing the 2D fit by a series of 1D fits. First, we may find the profile of the image in one dimension, then fit a particular image shape (ring or part of the ring) in other dimension to the 1D profile histogram. We found that this algorithm consumes a few seconds in case ASIC pairs and any reasonable number of rings. A drawback is that this algorithm is not so stable w.r.t. variation of the initial geometry parameters. In particular, any variation of the image range selected for the fit leeds to the slightly different results.

IV. FIT FUNCTION IN CASE OF r-ϕ TRANSFORMATION

In case of the image consisting of a series of rings with common center it seems quite natural to use polar r-ϕ frame in stead of original for detector Cartesian x-y frame. From any x-y image histogram we may produce the r-ϕ histogram with a coarse approximation of the beam center position (x_0, y_0) in the individual histogram reference frame. Then, we assume that the beam center (x_c, y_c) is defined by the ring-image of radius R. The (x, y) point on the ring in Cartesian frame is constrained by the equation

$$(x - x_c)^2 + (y - y_c)^2 = R^2. \tag{1}$$

In polar frame the same point can be expressed in terms of (r, ϕ) coordinates

$$x = x_0 + r\cos\phi, \tag{2}$$

$$y = y_0 + r\sin\phi. \tag{3}$$

$$\tag{4}$$

Solution of these equations w.r.t. r gives a shape of this ring in polar frame as a function of the angle ϕ.

$$r(\phi|x_0, y_0, x_c, y_c, R) = -B \pm \sqrt{B^2 - C}, \tag{5}$$

where

$$B = \Delta x\cos\phi + \Delta y\sin\phi, \quad C = \Delta x^2 + \Delta y^2 - R^2, \tag{6}$$

and $\Delta x = x_0 - x_c$ and $\Delta y = y_0 - y_c$. Fit of this function to the ring image profile in polar r-ϕ frame allows to extract the values of beam center position (x_c, y_c) and radius R.

V. ASIC ALIGNMENT PROCEDURE

For each ASIC we subtract the background (dark image), apply the nominal rotation angle (0, 180°, or 270°) and combine them in pairs. Then, we apply a small tilt angle to each ASIC's pair. Both rotation angles are listed in the second column of Table IV.

In the coordinate frame of the ASIC pair histogram, shown in Fig. 2, we approximately define the beam center location (x_0, y_0) and select the most interesting parts of the rings in r-ϕ ranges, shown by lines. All parameters are stored in the configuration file. Then we transform the selected regions to the r-ϕ histograms shown in Fig. 3. Each vertical bin-slice of this histogram is fitted by the Gaussian function. Gaussian center and its uncertainty are shown by the points with error-bars for each ring. These profile histograms are combined in a single 2D histogram with bins in ϕ and ring #. By definition, each bin contains the ring radius with uncertainty w.r.t. the (x_0, y_0). Equation 5 in case of 2D histogram is extended to 2D function, which has common (x_0, y_0) and (x_c, y_c) and individual radial parameters for each ring #. From the fit we extract the (x_c, y_c) and radial parameter of each ring. Sequence of fits and their results are shown in Table III.

VI. FIT RESULTS

Based on these fits we found more precise values of the configuration parameters shown in Table IV, which gives a quadrant image like shown in Fig. 4.

VII. ALIGNMENT OF THE CSPAD QUAD VERSUS THE BEAM CENTER

Similar algorithm can be applied to entire quad in order to find the beam spot center. The only difference is that in stead of ASIC pair we have to use entire quad histogram, as shown in Fig. 5.

VIII. FIT TO TILTED ASIC PAIR

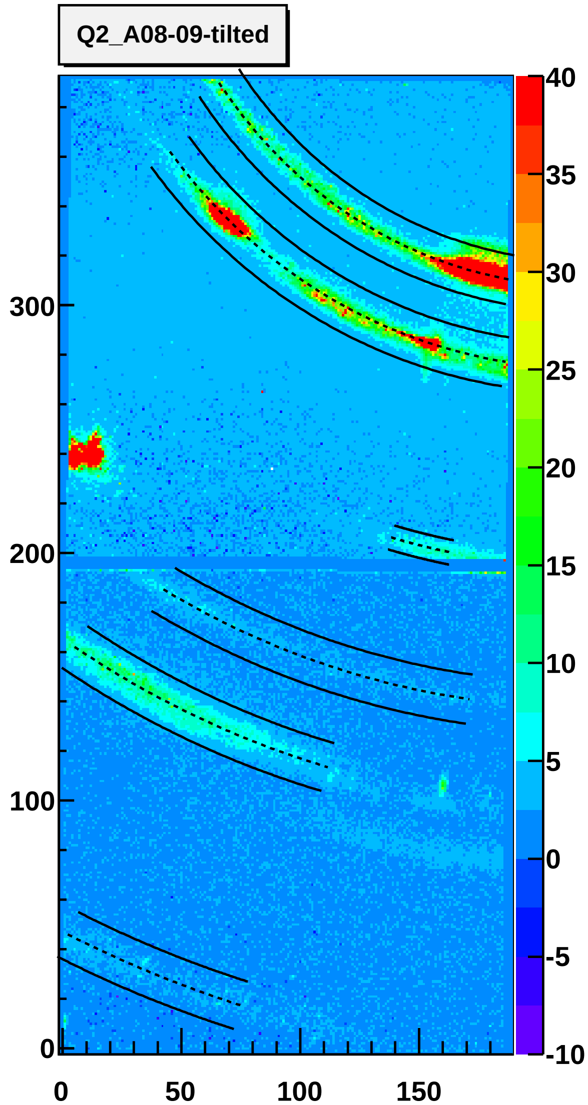

FIG. 2: r0547-s00, sum of 50 signal events, ASIC08-09, tilt angle is accounted; solid lines show the region for r-ϕ histogram.

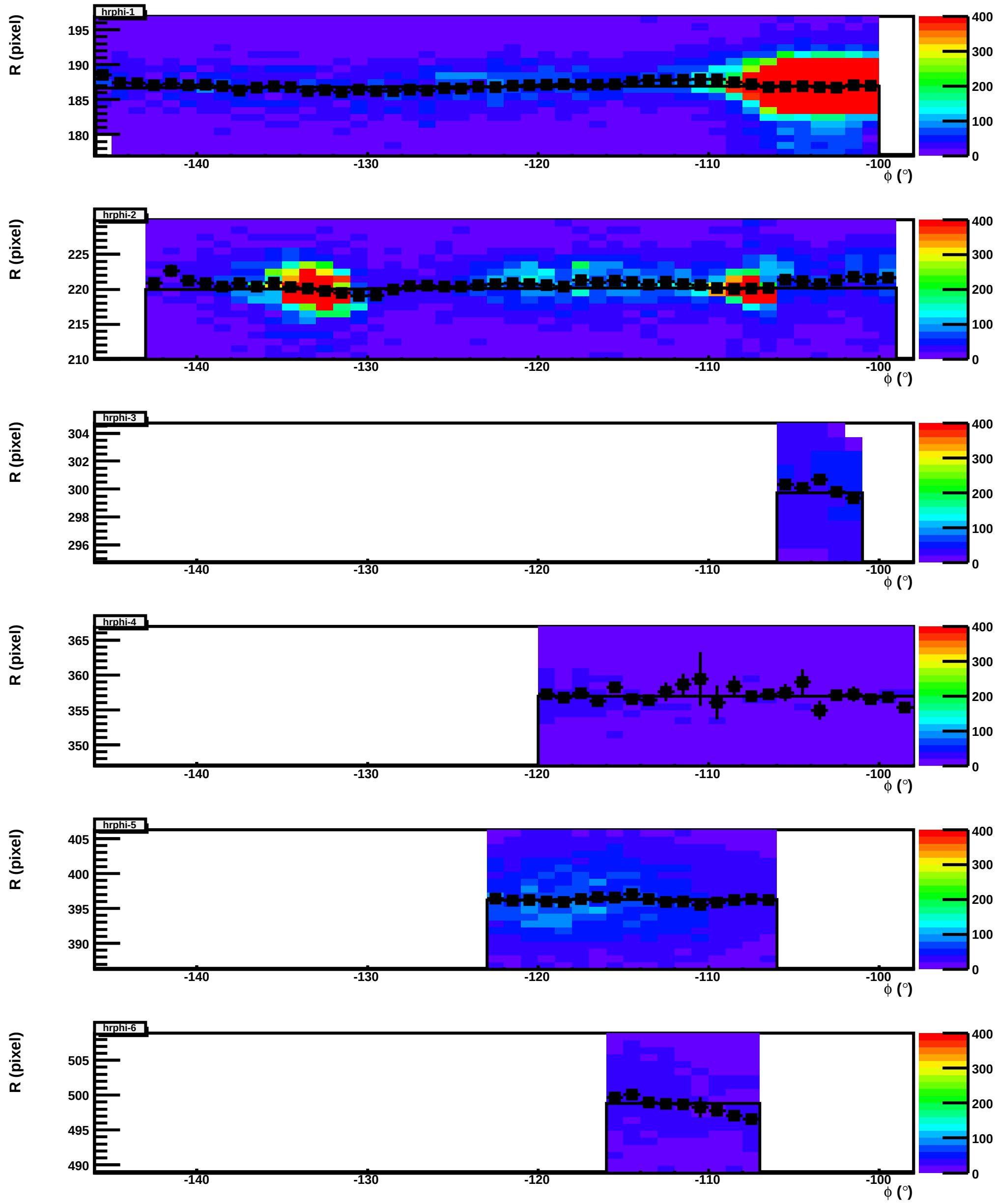

FIG. 3: r0547-s00, sum of 50 signal events, ASIC08-09; r-ϕ projection for the region around the 1st ring.

TABLE III: Fit results for tilted pairs.

Fit #	ASIC	x_c	y_c	Ring and radius
1	08-09	220.52±0.12	493.28±0.20	R1 = 185.77±0.23
				R2 = 219.03±0.23
				R3 = 298.60±0.23
				R5 = 355.84±0.26
				R6 = 395.12±0.23
				R7 = 497.71±0.27
2	12-13	269.018±0.007	303.502±0.001	R1 = 186.91-fixed
				R2 = 219.95-fixed
				R3 = 299.72-fixed
				R4 = 328.49±0.02
				R6 = 396.24-fixed
3	10-11	414.25±0.09	512.08±0.11	R4 = 328.49-fixed
				R6 = 396.24-fixed
				R7 = 500.92±0.06
				R8 = 562.01±0.06
4	14-15	11.04±0.04	517.38±0.02	R6 = 396.24-fixed
				R7 = 500.99-fixed
				R8 = 562.08-fixed
5	00-01	15.62±0.11	932.64±0.01	R6 = 562.08-fixed
				R11= 672.29±0.02
				R12= 713.11±0.02
				R13= 760.01±0.05
6	02-03	-200.06±0.13	930.97±0.07	R10= 652.29±0.03
				R12= 713.18-fixed
7	04-05	422.02±0.13	716.45±0.05	R8 = 562.68±0.05
				R9 = 584.50±0.06
				R12= 713.18-fixed
8	06-07	412.0-set	926.0-set	Nothing to fit...

TABLE IV: Configuration parameters. gap = 194+4 (pixel).

ASIC	orientation ($\circ$)	x_c (pixel)	y_c (pixel)
00	0 +0.1	15.76	932.65
01	0 +0.1	15.76	932.65-gap
02	0 +0.6	-200.19	930.88
03	0 +0.6	-200.19	930.88-gap
04	270 −0.2	422.26	716.34
05	270 −0.2	422.26-gap	716.34
06	270 +0.0	412	926
07	270 +0.0	412-gap	926
08	180 −0.5	220.84	494.37-gap
09	180 −0.5	220.84	494.37
10	180 −0.5	414.12	512.26-gap
11	180 −0.5	414.12	512.26
12	270 +0.0	26.95	303.53
13	270 +0.0	26.95-gap	303.53
14	270 +0.0	11.13	517.40
15	270 +0.0	11.13-gap	517.40

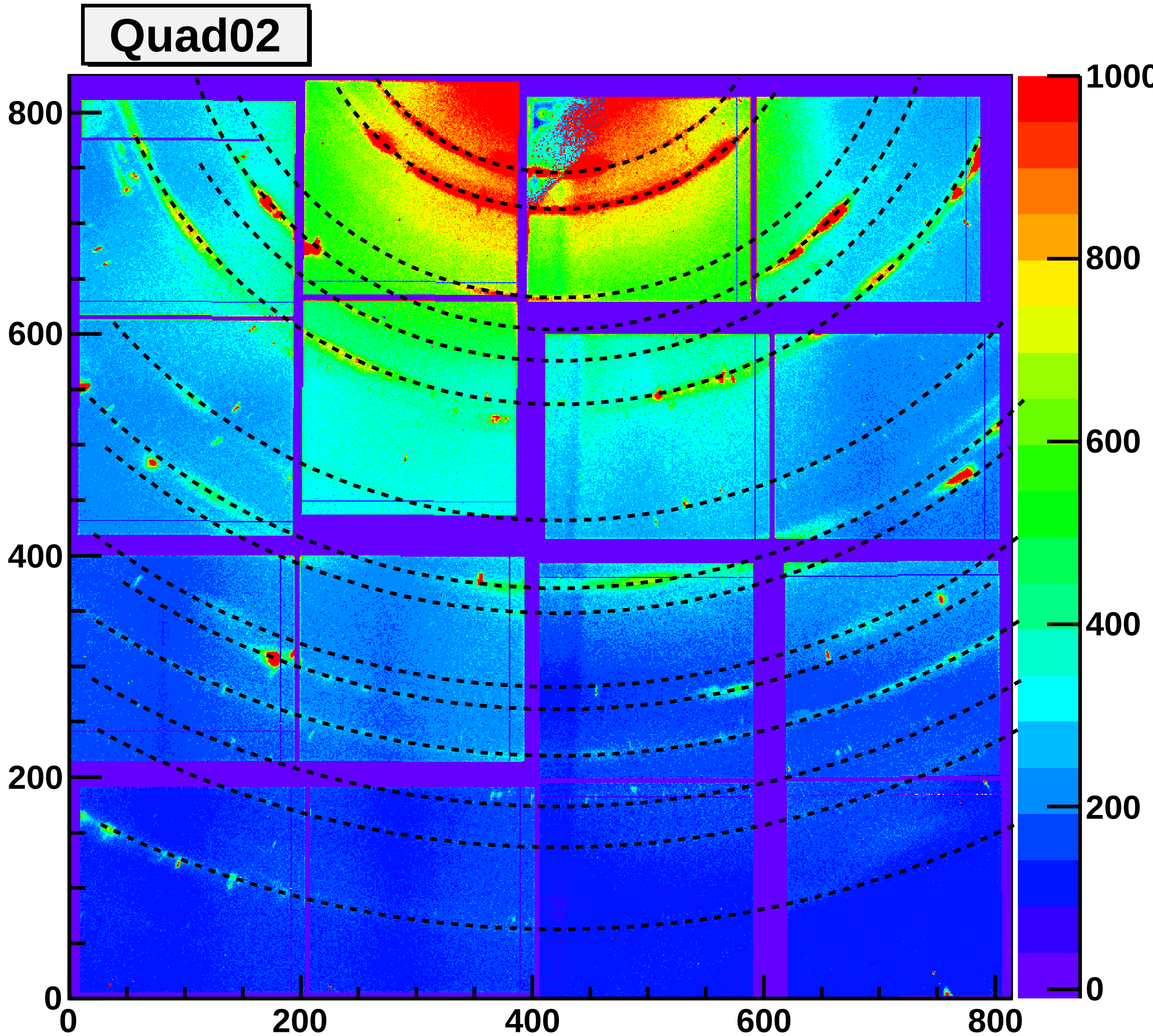

FIG. 4: r0549-s03, sum of 50 signal events, combined plot.

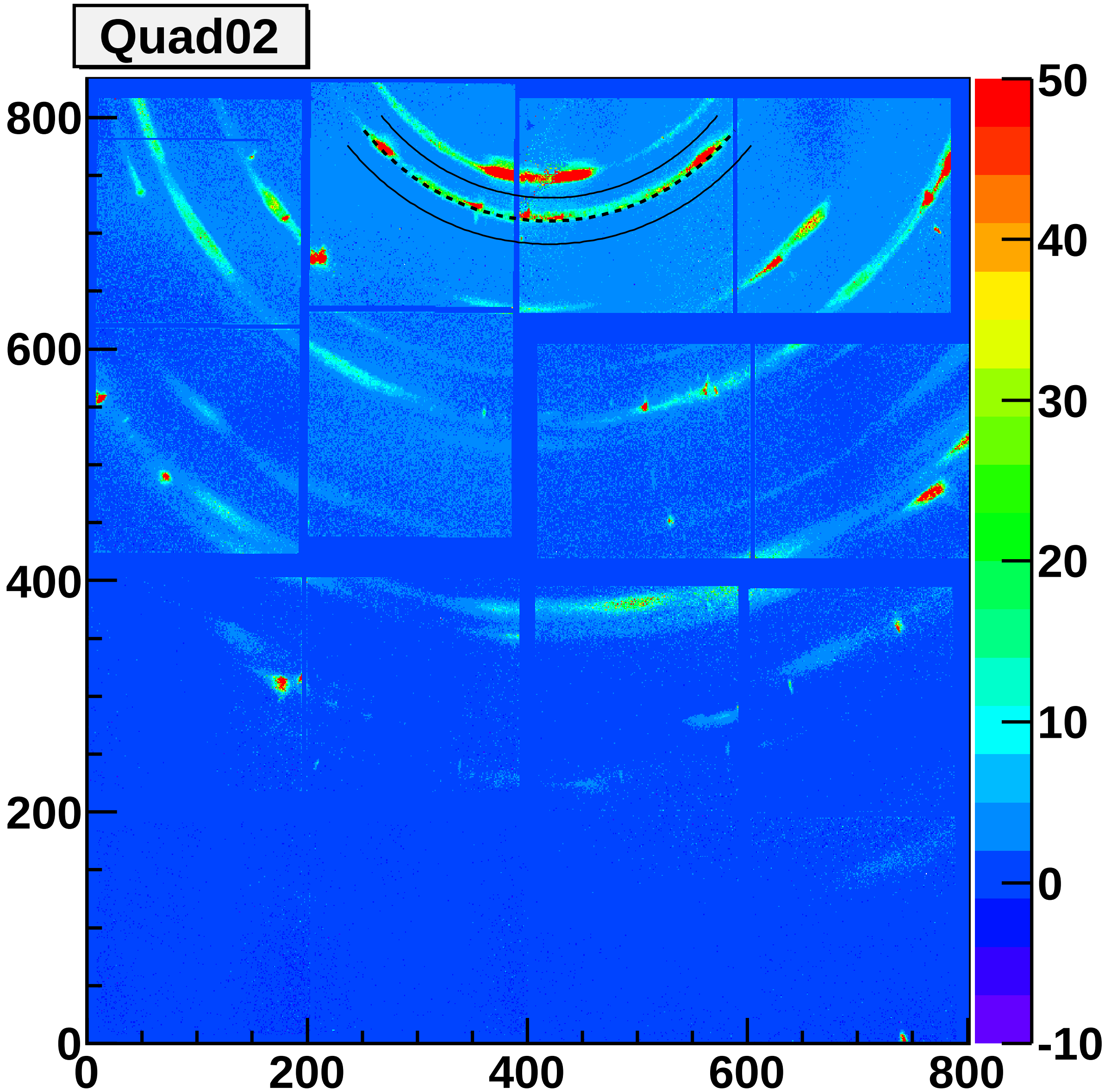

FIG. 5: r0547-s00, sum of 50 signal events, background is subtracted.