Shadow depths due to the calibration wire

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Abstract

In order to help in the calibration of the eight anode wires, it was decided to place a wire across the anode wires and above the detector window in each of three Scanning Sky Monitor (SSM) cameras. This report gives an account of the simulations done to estimate the shadow depths achievable due to different dimensions of the calibration wire.

It was estimated that for the calibration of the anode wires about a million events (including contributions due to both the background and the source) are necessary and such an event list can be obtained once a week. A Monte Carlo simulation was performed with an SSM camera rotating at a rate of 15° s^{-1} along the mask coding direction. A 40 crab source was used in order to record about 0.7 million photons in the detector during its rise to set in the field of view. The simulation results were obtained for different combinations of the following parameters:

- Positional Resolution of the anode wires along the mask coding direction: σ_x = 0.5 mm & 1 mm
- Diameter of the calibration wire: 1 mm & 2 mm

For all the cases, the calibration wire was placed at the center of the detector plane along the mask coding direction and at a height of 9 mm above the anode plane (just above the window support rods). Similar tests were performed with a calibration wire placed at a height of 6.5 mm above the anode plane (just below the detector window), but it was decided not to have the calibration wire within the detector gas chamber because of some other mechanical constraints and in this report the results for a calibration wire placed at a height of 9 mm above the anode plane only will be presented.

The recorded photon strike positions were binned with different bin-sizes: 0.25, 0.5 & 1 times per mask element width (which is $\approx$ 0.95 mm). The figure 1 shows the shadow of the calibration wire placed at a height of 9 mm above the anode plane on the anode wire 8, the bin size being chosen to be equal to that of a mask element. The top panels in the figure are for a calibration wire diameter of 2 mm and the bottom ones are for 1 mm. The left side panels are for a position resolution σ_x = 0.5 mm and those on the right are for σ_x = 1 mm. The error on the bin-counts are just their square-root values obtained assuming a Poissonian distribution.

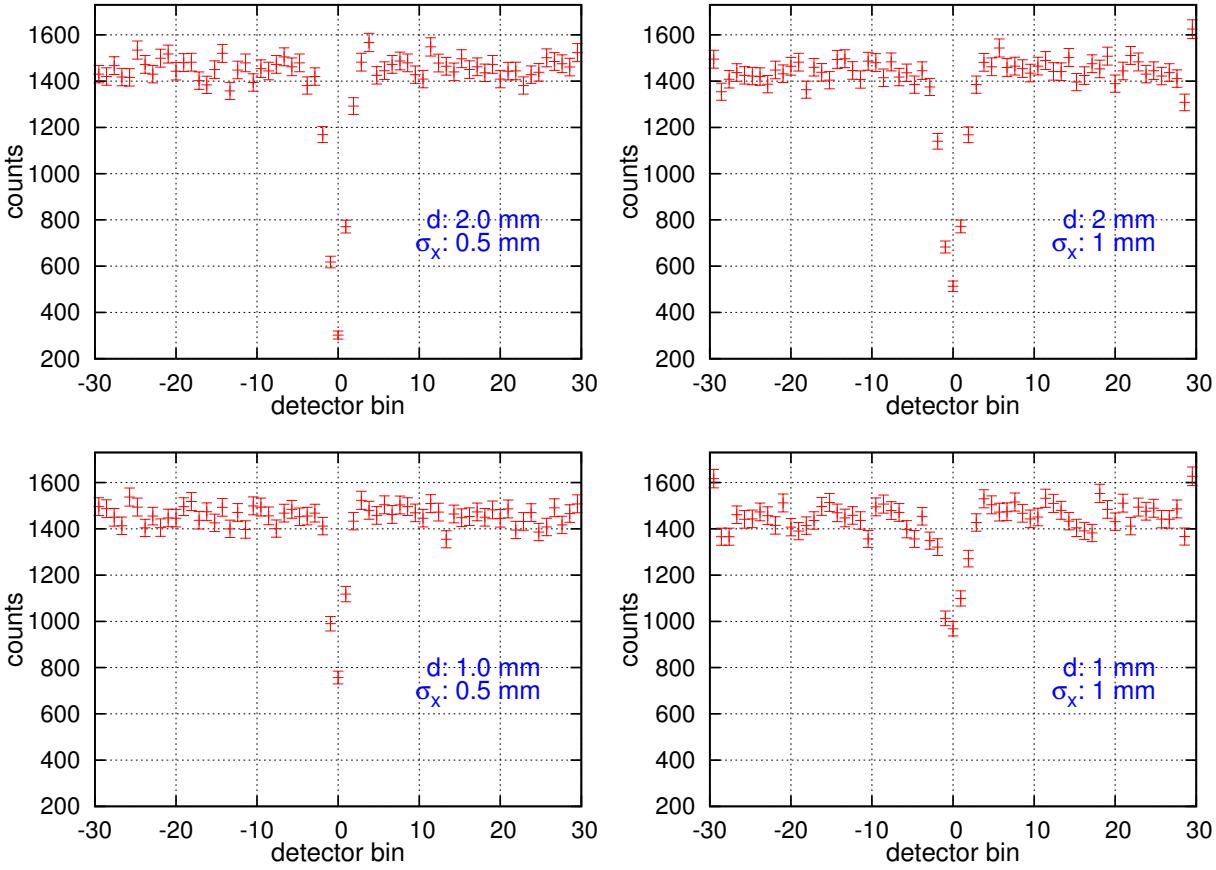

Figure 1: Shadow of the calibration wire, placed at a height of 9 mm above the anode plane, on anode wire 8. d indicates the diameter of the calibration wire and σ_x indicates the position resolution of that anode wire.

The $\sim$ 25% shadow depth achievable with a 1 mm diameter calibration wire for a position resolution of 1 mm (bottom-right panel in figure 1) has been found to be satisfactory and so the further analysis was done for this case (i.e. calibration wire of 1 mm diameter placed at a height of 9 mm from the anode plane). The set of data points, binned with a bin-size equal to 0.25 times the mask element width, within

the shadow depths due to the calibration wire of diameter 1 mm for all the anode wires (similar to the ones in the bottom panels of figure 1 which is for anode wire 8) have been fitted with parabolic equations using the tool gnuplot (which uses an implementation of the Marquardt-Levenberg algorithm). The fit equations used are of the form:

$$f(x) = a + x \times (b + x \times c)$$

The range of bins in the shadow depth used for fitting, the reduced chi-square (χ^2) value of the fit, the fit parameters (a, b, c) along with the error values on them ($\Delta a, \Delta b, \Delta c$ respectively) are tabulated in tables 1 and 2. Table 1 is for the case with the position resolution, σ_x of the anode wires assumed to be 1 mm while table 2 is for σ_x of 0.5 mm. The last column of the tables are the errors in the units of mm with which we will be able to identify the position of the calibration wire along the coding direction for each of the eight anode wires.

Id	Fit range mm:mm	χ^2	a mm, Δa mm	b mm, Δb mm	c mm, Δc mm	Δx, mm $\left\lvert \left(\frac{-b}{2c}\right)\left(\sqrt{\left(\frac{\Delta b}{b}\right)^2 + \left(\frac{\Delta c}{c}\right)^2}\right)\right\rvert$
1	$-1.89 : 2.13$	0.80	$246.87, \pm 5.17$	$2.93, \pm 3.46$	$20.22, \pm 3.06$	0.086
2	$-1.66 : 1.90$	0.30	$250.44, \pm 3.47$	$-3.67, \pm 2.69$	$47.93, \pm 9.31$	0.046
3	$-1.42 : 1.66$	1.11	$237.64, \pm 6.95$	$-3.54, \pm 5.53$	$31.71, \pm 6.97$	0.088
4	$-2.13 : 2.13$	0.66	$245.75, \pm 4.51$	$-2.12, \pm 2.53$	$21.56, \pm 2.14$	0.059
5	$-2.13 : 1.66$	0.75	$243.11, \pm 5.03$	$5.02, \pm 4.12$	$23.79, \pm 3.44$	0.088
6	$-1.66 : 1.89$	1.32	$231.26, \pm 7.20$	$-7.22, \pm 5.59$	$32.70, \pm 6.30$	0.088
7	$-1.90 : 2.37$	0.79	$240.04, \pm 5.09$	$1.15, \pm 3.44$	$22.12, \pm 3.04$	0.078
8	$-2.13 : 1.89$	1.49	$233.26, \pm 6.89$	$2.61, \pm 4.74$	$28.17, \pm 4.15$	0.084

Table 1: Fit parameters for the case $\sigma_x = 1$ mm, Calibration wire diameter = 1 mm, being placed at a height of 9 mm above the anode plane. Id in the table represents the anode ID and the bin-size of the data is 0.25 times the width of per mask element.

Id	Fit range mm:mm	χ^2	a mm, Δa mm	b mm, Δb mm	c mm, Δc mm	Δx, mm $\left\lvert \left(\frac{-b}{2c}\right)\left(\sqrt{\left(\frac{\Delta b}{b}\right)^2 + \left(\frac{\Delta c}{c}\right)^2}\right)\right\rvert$
1	$-1.42 : 1.89$	0.55	$203.54, \pm 4.48$	$-14.57, \pm 4.43$	$59.94, \pm 4.81$	0.038
2	$-1.66 : 1.90$	1.83	$201.17, \pm 7.92$	$-2.84, \pm 6.61$	$54.97, \pm 7.24$	0.060
3	$-1.42 : 1.66$	0.57	$195.79, \pm 4.77$	$-7.00, \pm 4.70$	$76.51, \pm 6.01$	0.031
4	$-1.42 : 1.66$	1.19	$199.00, \pm 6.86$	$3.83, \pm 6.56$	$63.44, \pm 8.44$	0.052
5	$-1.66 : 1.42$	1.09	$188.69, \pm 6.25$	$15.70, \pm 5.51$	$73.18, \pm 6.74$	0.039
6	$-1.19 : 1.19$	0.56	$194.72, \pm 5.43$	$16.14, \pm 6.44$	$87.18, \pm 11.76$	0.039
7	$-1.66 : 1.42$	2.94	$187.67, \pm 10.16$	$9.28, \pm 9.04$	$72.08, \pm 10.89$	0.063
8	$-1.66 : 1.19$	0.75	$184.05, \pm 5.39$	$15.64, \pm 6.68$	$75.87, \pm 8.22$	0.045

Table 2: Fit parameters for the case $\sigma_x = 0.5$ mm, Calibration wire diameter = 1 mm, being placed at a height of 9 mm above the anode plane. Id in the table represents the anode ID and the bin-size of the data is 0.25 times the width of per mask element.

As is evident from table 1, even for σ_x of 1 mm, the position of the calibration wire using the shadow on any anode wire can be estimated within an error bar of about 10% of a mask element width and is quite satisfactory. So, a calibration wire of diameter 1 mm is sufficient at the height of 9 mm from the anode plane.