Chapter 3

Implementation of design parameters and Calibration of SSM

SSM detectors are made with the optimized parameters discussed in the previous chapter. The principle of operation of the detector for measurement of energy and position of the incident photon is briefly discussed in this chapter. The characteristics of the detector like stability, detection efficiency, gas gain at different operating voltages, energy resolution, position resolution etc. are experimentally studied. A detailed description of the experiments and the results obtained are discussed in the following sections. Characterisation of the instrument with respect to its science objectives with few experiments is also discussed.

3.1 Brief overview of the SSM detector with coded-mask and electronics

SSM consists of three almost-identical one dimensional position-sensitive gas-filled proportional counters with a one-dimensional coded-mask on each detector. Each SSM is mounted to have a different Field of View (FOV) in the sky, with overlap of some part of the FOV with the others. The three SSMs are arranged such that there is one SSM at the centre and two on the sides canted with a 45° angle. The SSM detector at the centre is called the Central SSM, which has a FOV of $22.1^\circ \times 100^\circ$ (FWZM) and the two SSM detectors on the sides are called Edge SSMs with an FOV of $26.8^\circ \times 100^\circ$ (FWZM) each. All the three SSM detectors are mounted on a single platform which can rotate. The whole unit is rotated from $5^\circ$ to $355^\circ$, in steps of $10^\circ$ to scan the sky in step-and-stare mode.
SSM consists of three major elements: the detector, the electronics and the imaging system (coded-mask). The details of each of these elements is discussed in the following subsections.

### 3.1.1 Detector system

As discussed in the previous chapter, the detectors for SSM are position sensitive gas-filled proportional counters. The parameters which define the characteristics of position-sensitive gas-filled proportional counters are discussed in the previous chapter. SSM detector consists of multiple cells and are double layered. There are totally 20 independent cells (in two layers, 10 in each layer) which act as proportional counter units. Each cell consists of a central anode and wire-walled cathode surrounding it. The central eight cells in the top layer consist of position-sensitive anode wires which are carbon-coated quartz, that are resistive (with 8 kΩ/mm or 4 kΩ/mm) anodes. The cells in the bottom layer along with the end-cells in the top layer have conductive wires as anodes which are gold-coated tungsten and these form the veto layer for charge particle rejection. All anodes are powered with a high voltage (HV) of about 1500 volts with respect to that of the cathodes which are at zero potential. The geometric length of the anode in each cell is 62 mm, out of which 60 mm is available for charge collection due to photon incidence. The end-effects at the ends of the anodes are minimized largely. However, some of the anodes are still found to have some effect at the ends and hence, the effective length is about 50 mm leaving a maximum of 5 mm on either sides due to end-effects in the detector. These cells with the anode at the centre and wire-walled cathode around them form the wire-module of SSM. The wire-module is enclosed in a gas-filled chamber having an entrance window thin enough to allow the incident X-ray photons into the counter. Figure 3.1 shows the schematic view of the cells inside an SSM detector and figure 3.2 shows the photo of the wire module inside the detector.

**Principle of operation:**

Principle of photon detection, measurement of its energy and position of incidence in SSM detector is discussed in section 2.1.1 for position-sensitive proportional counters. In a position-sensitive detector the anode being resistive, the charge is proportionately divided between the two ends of the anode, depending on the position where the charge cloud is collected along the anode wire. This charge is converted into voltage using a charge sensitive preamplifier at both the ends of the anode. The corresponding voltage pulses at either ends of the anode are referred to as left and right outputs of the anode. Figure 3.1 shows a photon incident on one of the wires and the corresponding left and right outputs produced in that particular anode which detects the photon. The total amplitude of both
the outputs is proportional to the energy of the incident photon. The position (P) of the incident photon on the detector plane is derived using the amplitudes of the left and the right output pulses taken out at the ends of an anode. The details of deriving the position of an incident photon is discussed in section 3.4.

The information that we get about every photon that is incident on the detector are 1. Time of arrival 2. Energy and 3. Position of incidence. All the three parameters are measured using the electronics system of SSM, discussed in section 3.1.2.

### 3.1.2 Electronics System

The Electronics system for SSM consists of three units: (a) Charge Sensitive Pre-Amplifiers (CSPA) and post amplifiers (PA), (b) Front end electronics consisting of low voltage DC-DCs, HV programmer, logic unit for LLD/ULD/event-analysis, peak detectors, ADC, etc and (c) the Processing Electronics (PE) consisting of FPGA based system for event processing, buffer memory, telecommand and telemetry interfaces and the interface circuits for data transfer to Data Handling package. The detector is powered using High Voltage
distribution unit mounted behind the detector. Figure 3.3 shows the block diagram of the detector with the electronics.

**Processing of an event:**
The charge collected at the anode for every incident photon is converted to a voltage pulse using a CSP A on either sides of the anode. Thus, for every photon incidence on an anode wire, there are left and right outputs from either ends of the anode, fed to the respective CSPAs and converted to voltage pulses termed ‘L’ and ‘R’ respectively. The CSPA output is further shaped and amplified. There are seventeen such chains for each SSM detector unit, sixteen of them are connected to both ends of eight anodes and one of them is connected to the veto layer. The front end logic unit processes signals from each of these chains. Event outputs between Lower Level Discriminator (LLD) and Upper Level Discriminator (ULD) are accepted for processing. Charge particle rejection is done by the technique called anti-coincidence, where the event is rejected when (a) signals are present in both the top anode layer as well as the bottom veto layer simultaneously, or (b) more than one anode having an output pulse simultaneously. The amplitude of every accepted event is measured and digitised and then the Analog-to-Digital Converter (ADC) output of each event, both left
and right sides, are sent to the PE unit. In addition there are several channels for count rates from the anodes and veto, which are also sent to the PE. The PE which is an FPGA-based (Field Programmable Gate Array) unit accepts these events, stores them in buffer memory and interfaces with the Data Handling system of the spacecraft. The PE also acts as both telecommand and telemetry interface for the complete SSM electronics system. The time of incidence of every photon is tagged with the event by the PE using an on-board SSM clock. This clock is periodically matched and stored with the spacecraft Bus Management Unit (BMU) clock for conversion to Universal Time (UT) on ground. In addition, the electronics system also has circuitry for sensing and reducing High Voltage within high charge particle regions based on command-set thresholds and also for corona sensing with auto-shutoff. Data from the PE is sent from the buffer memory through Data Handling and stored in the main spacecraft Solid State Recorder (SSR) package for readout during visibilities. The detector and front end electronics packages are mounted on a rotating platform on the anti-sun-side of the spacecraft whereas the processing electronics is mounted inside the S/C. A flexible cable bunch is used between the packages.
3.1.3 Imaging System

SSM has a large FOV and coded-mask imaging technique is used in SSM. Coded-mask is an advanced version of a pin hole camera with multiple pin holes arranged randomly. In a pin-hole camera, the photons entering the pin hole form an image of the object. However, the sensitivity of the instrument will be limited by the small size of the pin hole. The sensitivity can be improved by having a number of pinholes, but the arrangement of the pin holes has to be random, so that the shadow of the pinholes on the detector plane cast by the each source in the sky is unique. This random pattern pin hole is referred to as a coded-mask (Zand, 1992).

**Basic principle of Coded-mask imaging** The three principal components of coded-mask imager are a coded-mask, a position-sensitive detector and a reconstruction technique. A coded-mask is a plate with closed (opaque) and open (transparent) elements for the photons to pass through and cast the shadow of the mask on the detector plane, as they get detected. The photons from a source in a particular direction in the sky cast the shadow of the mask on the detector plane. The shadow will have the same pattern as the mask, but shifted appropriately with respect to the direction of the source. Similarly, for a number of sources at different locations in the sky, the shifted mask patterns (corresponding to the different directions of the sources) get accumulated on the detector. The accumulated image of the coded-mask with respect to different sources at different locations in the sky has the information of the position and intensity of the sources. The image in the detector has to be deconvolved to reconstruct the sky image. It is important that every position in the sky is encoded on the detector in a unique way. This implies that the mask pattern should be selected appropriately that the autocorrelation function of the pattern should contain a single peak and flat side-lobes. In other words, this can be stated that for a single source casting the shadow of the mask on the detector, the decoded image should have a single peak corresponding to the single source in the field of view.

The quality of imaging depends on the type of mask pattern, the design of the detector, the spatial resolution of the detector and the decoding or the reconstruction technique used. The mask pattern should be chosen such that it satisfies two conditions: 1. The autocorrelation function of the pattern should give a single peak with flat side-lobes. 2. It is necessary that the mask pattern has $\geq 50\%$ transparency so that the signal to noise ratio is better than the $3\sigma$ limits. The imaging is better when a complete image of the mask is created for every observed position of the sky. The design of the instrument takes care of this. The distance between the detector and the mask has to be chosen appropriately such
that the image of a complete basic pattern of the mask is obtained for every observed source position in the sky, within the field of view of the instrument defined by its collimator. The spatial resolution of the detector should be half of the minimum size of the elements in the mask for good imaging quality. A detailed study of coded-mask imaging can be found in the Ph.D. thesis by Zand (1992).

The coded-mask for SSM is one dimensional. The minimum size of an element (open or close) in SSM coded-mask is 0.95 mm. Six different coded mask patterns are used in SSM detector, with 50% transparency. The six mask patterns are joined along the length and the resulting complete coded-mask plate is shown in figure 3.4.

3.2 Characterisation of SSM detectors

The position sensitive proportional counters have to be qualified for certain characteristics before it is considered for the SSM experiment. The important parameters to be studied are the stability of the detector, its detection efficiency, gas gain at the operating voltage, energy resolution and position resolution. Experiments are carried out to test for these parameters in detail. The SSM detectors are calibrated at different energies to understand the spectral response. The main objective of SSM is to detect and locate transient sources and hence deriving the position of the X-ray source in the field of view is of prime importance. Experiments are carried out to arrive at a methodology to derive the position of the X-ray source in the FOV of SSM. The positional calibration of SSM is carried out with various kinds of experiments. Details of different experiments on SSM for the study of various parameters are discussed in the following sections.

3.2.1 Stability

Stability of a detector means that its total output which is the sum of the left and the right output amplitudes for a photon of particular energy incident on the detector should remain
constant over a period of time. The first step to characterize the detector is to look for the stability of the detector, as this instrument SSM is to be flown on-board and has to survive the mission lifetime of about few years. The stability of the detector can be affected by various factors: degradation of the gas mixture due to contaminants, leak of gas from the detector, aging of the anode wires, high voltage fluctuations etc. The contamination of the gas mixture can lead to reduced output whereas the leak of gas from the detector leads to an increase in the total output. Aging of the anode wires can also lead to a reduced output and high voltage fluctuations can result in an increase or decrease in the total output of the anode.

One of the SSM detectors is tested for stability for over a period of few years. Figure 3.5 shows the stable output of one of the SSM detectors tested with $^{55}$Fe (which is a source of 5.9 keV X-rays). The total output is given in Channels which is a measure of voltage (1Ch=10mV). The variation in the total output is found to be within ± 2% (Seetha et al., 2006).

![Stability of the output of SSM detector](image)

**Figure 3.5:** Plot showing the stability of SSM detector over a period of 2.5 years.

In the laboratory on ground, in order to maintain the purity of the gas inside the detector, it is subjected to window-side evacuation everyday, where the window of the detector is connected to the vacuum pump (or the whole detector is put inside a vacuum chamber), so that any contaminant such as water molecule or O$_2$ which has entered the detector through the window can be removed. This kind of evacuation is not required while the detector is on-board a satellite in the orbit around the earth, as there is a pressure gradient due to
vacuum in space and there is no chance of the degradation of gas purity due to external contaminants. However, any micro-pore leak in the detector, which is not observed in the experiments in the lab, or which occurs due to meteorite hits, can yield to a detectable leak, when the detector is in near vacuum condition in space. In such cases when an on-board leak is detected from the data collected on-board and analysed here on ground, the HV is tuned by tele-commands, such that the gas gains are brought back to nominal values. Therefore, it is important that, when the SSM detectors are made here in the laboratory, great care is to be taken so that there is no leak present in the detectors. All the detectors are tested for stability by monitoring the total output for a monochromatic source ${}^{55}\text{Fe}$ for about two weeks initially and if found stable, they are qualified for further integration with other electronics units and studied for other parameters.

3.2.2 Detection Efficiency

Detection efficiency of a detector is defined in section 2.1.2 of chapter 2. Determining the detection efficiency of the detector experimentally, requires a source whose absolute count rate is known. The estimate of the count rate from the radioactive source ${}^{55}\text{Fe}$ (5.9 keV) from its strength can have errors in it. Therefore, the X-ray source has to be calibrated before it is used to determine the detection efficiency of the detector. Si-PIN detector which has a 99% efficiency at 6 keV is used to calibrate the X-ray source which is then used to determine the detection efficiency of the detector.

SSM detector is irradiated with the radioactive source ${}^{55}\text{Fe}$ placed at a height of 30 cm from the detector plane, such that it illuminates the entire detector area. The time of integration of the data is 15 minutes. In the same way, SiPIN detector is also irradiated with ${}^{55}\text{Fe}$ source for 15 minutes of integration time. The data from both the detectors are analysed to get the integrated counts in the energy spectra and the count rates recorded in both the detectors are calculated. The formula given in equation 3.1 is used to derive the detection efficiency of SSM at 5.9 keV.

$$DE_{SSM} = \frac{Cntrate_{SSM}}{\bar{Cntrate}_{SiPIN}} \times DE_{SiPIN} \times \frac{Area_{SiPIN}}{Area_{SSM}}$$  \hspace{1cm} (3.1)$$

where, $DE_{SSM}$ is the Detection Efficiency of SSM detector, $DE_{SiPIN}$ is the Detection Efficiency of SiPIN detector, $Cntrate_{SSM}$ is the count rate recorded in SSM detector for ${}^{55}\text{Fe}$ radioactive source at 5.9 keV, $Cntrate_{SiPIN}$ is the count rate recorded in SiPIN detector for ${}^{55}\text{Fe}$, $Area_{SSM}$ is the area of SSM detector and $Area_{SiPIN}$ is the area of SiPIN.
detector. The Detection Efficiency of the SiPIN detector used for this study is 99% at 6 keV. Area of the SiPIN detector is 4.44 mm$^2$. The geometric area of SSM is 60 × 96 mm$^2$. However, the detection area of SSM-Qualification model detector is 50 × 96 mm$^2$, which is 4800 mm$^2$, which is due to exclusion of an average of 5 mm on either sides of the anode where the counts registered are almost zero due to end-effects. The maximum detection area of SSM detector is 60 × 96 mm$^2$, which is 5760 mm$^2$. Considering the maximum area of the SSM detector gives the lower limit on the detection efficiency calculated.

Figure 3.6 gives the comparison between the theoretically estimated detection efficiencies of both the detectors, the SiPIN and SSM detectors. Detection efficiency of SSM at 5.9 keV derived experimentally is also plotted in the same figure. The lower limit on the data point is derived considering the total geometric area of the SSM detector and the upper limit is got by propagating the poissonian error on the counts detected in both the detectors.

![Comparison of Detection Efficiency of SSM and Si-PIN](image)

**Figure 3.6:** Comparison of theoretically estimated and experimentally derived values of detection efficiencies of SSM and Si-PIN detectors

### 3.2.3 Operating voltage

It is required that the detector be operated in its proportional region of operation so that the total output of the detector (which is proportional to the charge collected at the anode) is proportional to the energy of the incident photon. SSM detectors are tested for the proportional region of operation and a particular operating voltage is chosen such that the gas gain is about $10^4$. The tests are done with a monochromatic source $^{55}$Fe which produces
Chapter3 Implementation of design parameters and Calibration of SSM

X-rays of energy 5.9 keV. Figure 3.7 shows the total output of SSM detector as a function of operating voltage.

![Graph showing total output as a function of operating voltage for SSM with the gas mixture 25% Xe + 75% P-10.](image)

**Figure 3.7:** Total output as a function of operating voltage for one of the SSM detectors

A high voltage of 1500 volts gives a gas gain of about 13000 for the SSM cell geometry for the gas mixture of 25% Xe + 75% P-10. Thus, SSM detectors are operated at 1500 Volts where the gas gain is sufficient enough to produce a total output voltage of 3 Volts for a photon of 5.9 keV incident on the detector. The energy resolution and position resolution are found to be satisfactory at this operating voltage, details of which are discussed in the following sections.

### 3.2.4 Energy Resolution

One of the important characteristics of a radiation detector is its response to a monoenergetic source of radiation. The pulse height spectrum, which is the distribution of pulses of different amplitudes binned into channels, is generally a Gaussian for gas proportional counters. This is called the response function of the detector for the particular X-ray energy incident on it. Ideally, the pulse height spectrum should be a delta function for a monoenergetic X-ray source. The observed pulse height spectrum for a monoenergetic source is a Gaussian and has a definite width, which defines the energy resolution of the detector. The width indicates the fluctuations in the amplitude of every output pulse for every monoenergetic photon detected in the detector. The Full Width at Half Maximum (FWHM) of
the pulse height spectrum (which is a Gaussian) is defined as the width of the distribution at the ordinate with half of the maximum counts of the peak of the Gaussian. The energy resolution of a detector is defined as the FWHM divided by the centroid (peak) of the Gaussian. This dimensionless fraction is generally expressed in percentage.

The important factors that contribute to the width of the pulse height spectrum are the statistical fluctuations in the number of primary electron-ion pairs produced when the incident photon is absorbed in the detector medium, the statistical fluctuations in the charge produced during the avalanche process, the random noise due to the electronics of the system and the drift in the operating characteristics of the detector system. In the above mentioned factors, the statistical fluctuations in the number of primary electron-ion pairs plays the prime role in causing the width in the pulse height spectrum. Larger the width of the spectrum, poorer is the energy resolution. Energy resolution gives the measure of the capability of the detector to resolve between two different photon energies. Energy resolution for SSM is about 18% at 6 keV. Thus the energy resolution is about 1 keV at 6 keV, which is an order poorer compared to semiconductor detectors. Figure 3.8 shows the energy spectrum of a radioactive source $^{55}$Fe for SSM detector.

Since the objective of SSM is to scan a large part of the sky and detect and locate X-ray transient sources, energy resolution is not a critical parameter. However, calibration of the detector at different energies is required to derive the spectral response and the position resolution at different energies. So also, identification of the energy of each photon detected
is required to derive the count rate in different energy bands, which are used to calculate hardness ratio (ratio of the fluxes in two different energy bands [hard-Xray-band/soft-Xray-band] which will be used to understand the nature of X-ray source observed) of the source that will be observed by SSM. The details of calibrating the detector at different energies is discussed in section 4.4.

3.2.5 Position Resolution

Position resolution is one of the important parameters for SSM, as the objective of SSM is to detect and locate X-ray transients in the sky. Position resolution for any imaging proportional counters can be given in terms of FWHM which is a quadratic sum of at least four independent parameters as given in equation 3.2 (Fraser, 1989).

\[
\Delta x = 2.36[(\Delta x_r)^2 + (\Delta x_d)^2 + (\Delta x_t)^2 + (\Delta x_n)^2]^{1/2}
\]

where \(\Delta x_r\) is the contribution from the ranges of photoelectron and Auger electron, which depends on the energy of the incident photon and the pressure of the gas in the detector. The \(\Delta x_d\) is the contribution of lateral diffusion in the drift space of the counter and depends on the statistics of the initial number of primary electron-ion pairs (N). Diffusion effects are more prominent in position resolution at low energies, as the value of N is small. The
\[ \Delta x_t \] is the result of parallax effects due to oblique incidence of the X-rays into the detector and \[ \Delta x_n \] is the contribution of the noise in the readout unit. Position resolution is better at higher gas pressures (Fraser, 1989).

It is required that the position resolution be about half the size of the smallest element in the coded-mask (Zand, 1992). Figure 3.9 shows the position histogram for a collimated \(^{55}\text{Fe}\) radioactive source, placed on one of the anodes in SSM detector. The position resolution is \(~0.68\) mm at 6 keV. The position resolution is given after removing the beam-width of the X-ray source from quadrature. The details of deriving the position resolution is discussed in section 3.6.

### 3.2.6 Uniformity of the anode wire

Anode wires chosen for SSM are 25 microns diameter Carbon-coated Quartz wires. The anodes are of length 60 mm. Every anode can have some non-uniformities along its length. These non-uniformities show up in the total output of the anode for collimated source placed at every 1mm along the length of the wire. The variation in the total output could be due to the variations in the diameter of the anode wire.

It is required that the anode wire has a uniform diameter throughout its entire length for the gas gain to be a constant and hence the total output be constant for a particular energy of the X-rays incident on it. The collimated \(^{55}\text{Fe}\) source is placed at every 1 mm of the anode wire at its ends (in order to look for any variation due to end effects) and at every 5 mm at the central regions (as this region is less likely to have large variations in the total output) and the total outputs are measured. The collimated \(^{55}\text{Fe}\) source is placed close to the window of the detector and the data is acquired for about a minute for all the positions along the anode wire. Figure 3.10 shows the variations in the total output along the entire length of the anode. All the anode wires are tested at different positions over the entire length of 60 mm.

It can be seen that all the anodes do not have a uniform output throughout the entire length. These variations in the total output of each anode are due to variations in the gas gain which are attributed to the non-uniformities in the diameter of the anode wires and to end-effects at the ends of the anode. The variations in the total output at different positions along the anodes are typically \(\pm 2\%\) (Seetha et al., 2006), except for few positions. Maximum variations are found to be about \(\pm 5\%\) along the anode. These variations in the total output are within the limits of energy resolution of the output for a photon of particular energy and hence are within the tolerable limit. The anode wires are inspected
Figure 3.10: Plot showing the total output at different positions along the anode wire

Figure 3.11: Plot showing the total output of all the anodes in SSM-Qualification model detector at different positions along the anode wire
visually for any non-uniformity in the diameter, before being wired in the wire module, so that such non-uniformities along the anode wires be minimized as much as possible. In SSM, the energy resolution is 18% at 6 keV which corresponds to a total output of 300 channels (=3 Volts). Therefore, the FWHM is 54 channels which results in sigma of \( \sim 23 \) channels, which gives the variation threshold for the total output. The errors on the total output plotted in figures 3.11 and 3.12 are \( \pm 23 \) channels.

It is preferred that all the eight anodes give a total output of 300 channels at 6 keV. Therefore, the post amplifier of the respective anodes are fine-tuned to the appropriate gain settings so that the total output is very close to 3 Volts (or 300 channels). Figure 3.12 shows the total output of the anodes after fine tuning of the post amplifiers, so that the total output is within the resolution limits, which are shown as thick black lines in the plot.

![Figure 3.12: Plot showing the total output of the anodes after fine-tuning of the post amplifier gain](image)

### 3.3 Working Principle of SSM

SSM is a position sensitive detector. In a position sensitive proportional counter, the position of an incident photon is derived by the principle of charge division method. The anode wires have significant resistance per unit length, so the charge collected at the anode is divided between the amplifiers at either ends of the anode, as per the resistance seen by the
charge. The anodes in SSM are resistive wires, which have a resistance of 8 kΩ per mm. The proportion of division is related to the position of the incident photon, that is, the ratio of the charge read out on either sides is directly proportional to the position of the incident photon. Ideally, the position of the incident x-ray photon is given by the equation 3.3

$$P = \left[\frac{(Q_L - Q_R)}{(Q_L + Q_R)}\right] \times \left(\frac{L}{2}\right)$$

where $P$ is the position of the x-ray incidence, and $L$ is the length of the anode wire. The total charge is divided into $Q_L$ and $Q_R$ according to the resistance seen by it on either sides, where $Q_L$ is the charge read out at the left end and $Q_R$ is the charge read out at the right end. In practice, deriving the position of the incident photon is not that straightforward. The details of deriving the position of the incident photon is discussed in section 3.4.

3.4 Deriving the position of the incident photon

Equation 3.3 gives the position of an incident photon, where the length of the anode wire is required to derive the position. The actual length of the anode wire may not be the same as that of the mechanical dimensions of the wire module. This is because, the anode wires are glued, using conductive silver epoxy, to the conductive grooves placed inside the insulator (kel-F) which is in turn inserted into the wire-module of the detector. Since the anode wires are glued, the start and end points of the resistive wire which defines the length, varies from wire to wire. Thus, it is not possible to get the length of the anode wire from the mechanical dimensions of the detector. Therefore, it is necessary to know the electrical length of the anode wire (which is the length seen by the charge cloud) to derive the position of photons incident on the detector.

3.4.1 Deriving the length of the anodes from the measured outputs

It is necessary to know the electrical start and end points of the resistive anode wires inside the wire module, to derive the actual electrical length of the anodes. Studying the ratio of the left and right output pulses for a collimated X-ray source placed at different positions along the wire helps in estimating the electrical end points of the anodes. Tests were conducted with collimated $^{55}$Fe source placed at every 1 mm of the anodes, for the entire length(from 2 mm to 58 mm with respect to the detector plane). The positions at which the collimated $^{55}$Fe source is placed along the anodes at every 1 mm are defined as per the geometric or the mechanical co-ordinate of the detector.
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The data acquired for every position contains the left and right amplitudes of every photon incident on the anode wire at that position. The charge ratio which is the ratio of the left output to the total output for every photon is calculated and binned to get a spectrum of charge ratio. The peak of this charge-ratio spectrum is considered as the charge ratio value for that particular position. Similarly the charge ratio for all the positions along the anode is derived. The charge ratio values are plotted against the geometric positions (assumed position, i.e the position with respect to the detector co-ordinate) along the wire. This data is fitted with a straight line \( y = mx + c \), where \( y \) is the geometric/mechanical position and \( x \) is the charge ratio \( (L/(L+R)) \). The absolute value of the slope of the straight line fit gives the actual length of the anode (the electrical length) as seen by the charge cloud. The intercept gives the extended length of the anode beyond the geometric end point (beyond 60 mm) of the anode wire.

Similarly, the procedure explained above is followed using the charge ratio of the right output to the total output. The straight line fit to the charge ratio vs position gives the length of the anode wire which should be the same as that derived from the charge-ratio of left to total output. The intercept of the line gives the extended length of the anode beyond the geometric start point (beyond 0 mm) of the anode wire.

The intercepts obtained from the fits of both options of the charge ratios \( (L/(L+R)) \) or \( (R/(L+R)) \) give the extended length of the anode wires at both the ends of the anode.

If the charge ratio is \( (left/total) \), the slope is negative slope and the absolute value of the slope is the actual length of the anode and the intercept is equal to 60 mm plus the length of the wire beyond 60 mm at the right end. For example, for the anode 1, the intercept with respect to \( (left/total) \) vs position is 61.8 +/- 0.11 and the intercept with respect to \( (right/total) \) vs position is -11.66 +/- 0.14 as shown in figure 3.13 and 3.14. This means that the actual (electrical) start point of the wire is -11.66 mm and not 0 mm and the (electrical) end point of the anode is not 60 mm, but 61.8 mm. Similarly, straight line fitting to all the eight anode wire data sets give the actual electrical length of the wire, along with the offsets in the start and end points of the anodes. Figure 3.13 shows the plots of source position (which is the geometric position) as a function of charge ratio (right output/total output) and the straight line fits to the data, for all the eight anodes in the engineering model of SSM where the geometric length of the anodes are 60 mm. Similarly figure 3.14 shows the plots of source position as a function of charge ratio (left-output/total-output) and the straight line fits to the data for all the anodes. Figure 3.15 shows the overlayed plots of figures 3.13 and 3.14, so that the lengths of the anodes with the start and end points (the intercepts) within the wire module is shown clearly. Figure 3.16 shows the experimentally
Figure 3.13: Figure shows the plots of charge ratio (right/total) vs position on the anodes in SSM detector.
Figure 3.14: Figure shows the plots of charge ratio (left/total) vs position on the anodes in SSM detector.
Figure 3.15: Figure shows the actual length of all the anodes in the engineering model of SSM detector. The Y-axis between the two intercepts of the straight lines give the length of the anodes and the intercepts give the electrical start and end points of the anode wires.
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Figure 3.16: Figure shows the schematic of the wire module of SSM with the electrical start and end points of the anodes and geometric start (0mm) and end (60mm) of the anodes.

derived schematic of the wire module of one of the SSM detectors, with the actual start and end points of all the anodes. The shaded part of the anodes indicate the contact of the wire with the silver epoxy. The red lines are the 8 anodes and the two green lines are the veto wires. Table 3.1 gives the actual length of the anode wires and the start and end points at both the ends of the anodes.

The calculated length, which can be termed as the electrical length, of the anode wires are different from the geometrically defined length. This results in deviations in the actual positions from the theoretically expected position as calculated by equation 3.3, for every incident photon. The electrical position of the incident photon is different from the geometric position of incidence. The correction factors to convert the electrical position to geometric position are called the anode calibration constants. Every anode has its calibration constants and the position of every photon incident on an anode is calculated using
### Table 3.1: Table gives the actual length of the anodes and the actual start and end points on either ends for the engineering model of SSM.

<table>
<thead>
<tr>
<th>Anode num.</th>
<th>Actual length in mm</th>
<th>Start point (Left) in mm</th>
<th>End point (Right) in mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>73.46 +/- .23</td>
<td>-11.66 +/- .14</td>
<td>61.8 +/- .11</td>
</tr>
<tr>
<td>2</td>
<td>63.24 +/- .38</td>
<td>-0.63 +/- .21</td>
<td>62.62 +/- .22</td>
</tr>
<tr>
<td>3</td>
<td>72.37 +/- .22</td>
<td>-3.64 +/- .12</td>
<td>68.74 +/- .13</td>
</tr>
<tr>
<td>4</td>
<td>78.56 +/- .31</td>
<td>-9.77 +/- .16</td>
<td>68.7 +/- .2</td>
</tr>
<tr>
<td>5</td>
<td>70.72 +/- .2</td>
<td>-6.15 +/- .11</td>
<td>64.57 +/- .1</td>
</tr>
<tr>
<td>6</td>
<td>80.58 +/- .23</td>
<td>-10.92 +/- .13</td>
<td>69.66 +/- .12</td>
</tr>
<tr>
<td>7</td>
<td>70.72 +/- .2</td>
<td>-7.78 +/- .11</td>
<td>62.93 +/- .1</td>
</tr>
<tr>
<td>8</td>
<td>73.19 +/- .17</td>
<td>-10.51 +/- .1</td>
<td>62.67 +/- .08</td>
</tr>
</tbody>
</table>

The respective anode calibration constants using the equation 3.4.

\[
P = A \times (CR) + B
\] (3.4)

where P is the geometric position along the anode wire, CR is the charge ratio (either (left/total or right/total or (L-R)/(L+R), which is used in SSM), A and B are the anode calibration constants. This way of deriving the calibration constants for all the anodes in the detector is the position calibration of the detector. Section 3.6 discusses the step by step procedure and the details of position calibration of SSM.

### 3.5 Calibration of SSM detectors

SSM detectors are calibrated for position and energy response and also for detection efficiency at various energies. The details of on-ground calibration with the experiments conducted on the detectors are discussed in the following sections. The plans for on-board calibration are discussed in the next chapter. There is no radio-active source placed in SSM for on-board calibration. The Crab nebula, which is a standard celestial calibration source, can be used for on-board calibration. The Crab nebula is generally used for on-board calibration as its energy spectrum does not vary with time. Details of on-board calibration of SSM using Crab is discussed in section 4.7 of chapter 4. The following sections discuss about the position calibration of SSM.
3.6 Positional Calibration

The position of a photon incident on the detector is determined from the ratio of the charge collected on either sides of the anode. It has been observed that for photons incident at the geometric centre of the anode, the left and the right output amplitudes are not the same and hence the calculated position using the charge ratio from the output pulses using the equation 3.3, does not match with the geometric position, as discussed in section 3.4.1. Therefore, it is required to calibrate the detector for its positional response and to get the correction factor, which are called the anode calibration constants, with respect to every anode in the detector. The anode wires are tested at every 1 mm along the length with collimated $^{55}$Fe source and the non-uniformity is studied. In addition, the data from these tests are used to derive the anode calibration constants. Various experiments are carried out to verify the derived calibration constants. The details of the experiments and the results are discussed. The steps involved in positional calibration are discussed in the following sections.

3.6.1 Deriving the anode calibration constants

The collimated $^{55}$Fe source is placed at every 1mm position of the anodes and the data is acquired for two minutes each. The data contains the left and right amplitude values for all the photons detected on the anode. For every photon incidence, using the left and the right outputs measured, the charge ratio \((L-R)/(L+R)\), which is termed as observed-charge ratio, is calculated. The distribution of observed-charge ratio for a collimated beam of X-rays, at a particular position along the anode, is a Gaussian as shown in figure 3.17. This distribution is fit using Gaussian function and the peak of the distribution (called the observed-charge-ratio peak) is estimated for different source positions along the anode wire. Figure 3.17 shows the plot of counts-vs-charge ratio at different positions along the anode wire, which are fitted with Gaussian function, to derive the peak value of observed-charge ratio corresponding to that position. Thus, the observed-charge-ratio for different positions along the anode is derived.

Now, the geometric source position is plotted as a function of observed-charge-ratio peak. This data is fitted with a straight line as shown in figure 3.18. The constants derived from the straight line fit to the data gives the calibration constants for the anode. In this way, the calibration constants of all the eight anodes in SSM detector are derived. Figure 3.18 shows the fit to derive the anode constants for one of the anodes.
Figure 3.17: Distribution of counts as a function of observed-charge-ratio and the respective Gaussian fit functions.

Figure 3.18: Straight line fit done on position-vs-observed-charge ratio peak to derive the anode constants.
Figure 3.19: Position (derived position) vs counts at different positions along an anode wire.

Figure 3.20: Plot showing the comparison between derived and experimental source position at different positions along the anode wire.
Figure 3.21: Deviations of the derived positions from the experimental source positions along the anode wire.

Figure 3.22: Position resolution at 6 keV photon energy, at different positions along the anode wire; this is derived from the Gaussian fits made on the position-spectra shown in figure 3.19.
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Calibration constants are derived for all the anodes and these are used to calculate the position of every photon hitting the detector plane. Using these constants, the position spectra are derived for the collimated source placed at different positions along the anode wire. Figure 3.19 gives the distribution of counts against different positions for collimated $^{55}$Fe source placed at different positions along the anode wire. Fitting these position spectra with Gaussian function gives the position resolution, which is the FWHM of the Gaussian, at different positions along the anode wire. Figure 3.22 gives the variation in position resolution at different positions along the anode wire.

It is required to verify the derived calibration constants. Therefore, from the fits of the position spectra shown in figure 3.19 the position peaks are estimated and compared with the defined geometric positions of the collimated source. Figure 3.20 shows the comparison of the derived vs experimental source positions. This data is fit with a straight line to estimate the deviations in the derived positions from the experimental source positions. The deviations are shown in figure 3.21. These deviations in the position from the experimental source position is within the position resolution of the detector and hence it is within the tolerable limit.

3.6.2 Verification of the derived calibration constants

It is necessary to verify the calibration constants derived for the detector as per the positional response of the detector. The comparison of the derived source position to the geometric source position as shown in figure 3.20 in the previous section, indicates the correctness of the calibration constants. However, it is necessary to cross verify the calibration constants before continuing with the detailed tests, for which the ‘centre-blocked tests’ are carried out which is explained in the following sections.

3.6.3 Tests with the open source illuminating the whole detector plane

The open-bare $^{55}$Fe source is placed at a height of about 30 cm from the detector plane such that it illuminates the entire geometric area of the detector. The data is acquired for about 30 minutes. The position of every photon on the detector plane is calculated using respective anode constants, corresponding to the anode on which the photon is incident. The position histogram is generated. Figure 3.23 shows the position histogram of few of the anodes in the detector. It can be seen that the counts registered at the ends of the anode are less compared to that at the central region. This is due to end-effects in the engineering model of SSM, which is minimized in the qualification model as discussed in section 2.10.6.
of chapter 2. This test of illuminating the whole detector plane is done so that the position histogram from this data can be compared with that got from centre-blocked tests (which is discussed in section 3.6.4) for the central shadowed region.

### 3.6.4 Centre-blocked tests

The central 20 mm of the detector is blocked with iron bar such that X-ray photons will not be incident on this central 20 mm of the detector. Figure 3.24 shows the schematic picture of the detector plane blocked at the centre. The open-bare $^{55}\text{Fe}$ source is placed at a height of about 30 cm from the detector plane such that it illuminates the entire geometric area of the detector. The data is acquired for about half an hour and the position of every photon incident on the detector plane is calculated using the respective anode calibration constants and the position histogram is generated. The shadow pattern derived with this experimental set-up is shown in figure 3.25. Figure 3.26 shows the 3D view of the position histogram derived from the centre-blocked tests. The central 20 mm are shadowed as expected, indicating that the calibration constants are correct.
Figure 3.24: Schematic picture of the detector plane with the central 20 mm blocked with iron bar.

Figure 3.25: Position histogram from centre-blocked test.
Similar to the "centre-blocked test" experiment with the central 20 mm of the detector plane blocked, tests are conducted to get the shadow pattern of a single mask, which is one of the six mask patterns used in the coded-mask for SSM. The mask plate is placed on the detector plane and the X-ray source $^{55}$Fe is placed at a height of 50 cm above the detector plane, so as to illuminate the entire geometric area of the detector plane. Figure 3.27 shows the experimental set-up where a single mask plate is placed on the detector plane. Data is acquired for about half an hour in this set-up. The data is processed to derive the shadow pattern of the mask placed on the detector plane. Figure 3.28 shows the shadow pattern of the mask pattern, which is compared with the actual mask pattern with the divergence factor (which is calculated from the ratio of the distances between the detector plane and the source and the source and the mask plate) included in it, which corresponds to the height of the diverging open-bare $^{55}$Fe source that was placed at a height of 50 cm above the detector plane. The blue dotted histogram shows the close and open elements of the mask pattern and the red line shows the position histogram which is the shadow of the mask pattern cast on the detector plane. It can be seen in figure 3.28 that the shadow pattern matches with the mask pattern. The open elements of the mask pattern match with the high counts in the position histogram whereas the closed elements match with the relatively less counts in the position histogram. This provides an added proof of verification to the derived anode calibration constants.
**Figure 3.27:** Single mask plate placed on the detector plane

**Figure 3.28:** Experimentally derived Shadow pattern for a single mask pattern (mask6) placing the mask pattern on the detector plane.

**Figure 3.28:** Shadow of the mask pattern along with the actual mask pattern with the divergence factor included in it.
3.7 Tests to derive the position of the X-ray source

The detector is now calibrated and the verification of the calibration is done by the experiments discussed in section 3.6.2. The prime objective of this instrument is to derive the location of the X-ray source in the sky. In the laboratory, experiments are done with a single X-ray source (an X-ray gun) at a certain position (the centre of the FOV) within the field of view of the instrument. Data acquired is analysed to derive the position of this source.

3.7.1 Experiment to derive the position of source in FOV of SSM

This experiment includes the coded-mask with the collimator placed on SSM detector as shown in figure 3.29. The collimator with the coded-mask which has six unique mask patterns is placed on the detector. The X-ray source (here it is the X-ray gun with high intensity compared to $^{55}$Fe radioactive source) is placed at a height of about 2 m. This height is preferred for this experiment, as it is required to have the divergence factor of the source as minimum as possible. The requirement for having a low divergence factor is due to the fact that, as per the principle of coded-mask imaging discussed in section 3.1.3, the complete basic pattern of one of the six patterns of the coded-mask is required for reconstructing the image of the source plane with less coding noise. The X-ray gun which is used as the X-ray source here, gives a spectrum of X-rays and is not a monochromatic source. The current and voltage settings of the X-ray gun are 10 kV and 20 microAmp, so that it produces a continuum spectra of X-rays. The energy range of the continuum is found to be 6 to 10 keV at the SSM detector. Most of the low energy photons in the X-ray spectrum are absorbed due to the 2 m column of atmosphere. Figure 3.29 shows the test set-up with coded-mask and the source held at a height of about 2 m above the detector plane with the help of a pole.

Data is acquired for about half an hour. Position of every photon incident on the detector plane is calculated using the anode calibration constants as discussed in section 3.4. Position histogram is derived for the data.

The arrangement of the six mask patterns above the detector in SSM is such that the detector plane sees half of mask pattern-C and half of mask pattern-D, which are right above it. Therefore, the diverging source of X-rays, the X-ray gun, placed at about the centre of the field of view of the instrument, casts the shadows of the two central mask patterns on the detector plane. The first four anodes (named $A_0$, $A_1$, $A_2$ and $A_3$) have
the shadow cast by mask pattern-C, and the next four anodes (named A₄, A₅, A₆ and A₇) have the shadow cast by the mask pattern-D. The shadow of these mask patterns have a divergence factor of 1.18 included in them, as the X-ray source used is a diverging beam of X-rays. The divergence factor is calculated as distance of source from detector plane divided by distance of the source from the mask plate. The X-ray gun is placed at a height of 2029 mm and 1719 mm from the detector plane and the mask plate respectively. The ratio of these two values give the divergence factor, which is 1.18. Figure 3.30 shows the shadow pattern as recorded in the detector plane compared with the actual mask pattern shown in black histogram. Figure 3.31 shows the shadow pattern recorded in the detector with the mask pattern after including the divergence factor. Thus the actual mask pattern with the divergence factor included in it is found to match with the recorded shadow pattern.

Figure 3.32 and 3.33 gives a different view of the shadow pattern on anodes A₀, A₁, A₂ and A₃ along with the mask pattern 3 (aka C) and that on anodes A₄, A₅, A₆ and A₇ along with the mask pattern 4 (aka D) respectively, with the divergence factor included in the mask pattern, for the X-ray source at a height of about 2 m.
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Figure 3.30: Shadow of the mask patterns 3 on anodes $A_0$, $A_1$, $A_2$ and $A_3$ and shadow of the mask pattern 4 on anodes $A_4$, $A_5$, $A_6$ and $A_7$; the black histogram in the figure is the actual mask pattern.

Figure 3.31: Shadow of the mask patterns 3 on anodes $A_0$, $A_1$, $A_2$ and $A_3$ (top panel) and shadow of the mask pattern 4 on anodes $A_4$, $A_5$, $A_6$ and $A_7$ (bottom panel); the black line in the figure shows the mask pattern with the divergence factor included in it.
Shadow pattern on anodes 0, 1, 2 and 3 and the mask pattern C corrected for divergence of the source at a height of 2029 mm above the detector plane.

**Figure 3.32:** Shadow of the mask pattern C on anodes A₀, A₁, A₂ and A₃ with the divergence included in it, for the X-ray source placed at a height of about 2 m.

Shadow pattern on anodes 4, 5, 6 and 7 and the mask pattern D corrected for divergence of the source at a height of about 2029 mm above the detector plane.

**Figure 3.33:** Shadow of the mask pattern D on anodes A₄, A₅, A₆ and A₇ with the divergence factor included in it, for the X-ray source placed at a height of about 2 m.
The shadow pattern or the position histograms of all the anodes due to a single source at the centre of the FOV of the detector is got in the above mentioned procedure. The ideal requirement is a source which gives a parallel beam of X-rays so that it produces the shadow of the whole mask pattern on the detector plane. Since getting a parallel source of X-rays is difficult, the source is placed at a sufficiently larger distance (about 2 m) from the detector plane, so that the divergence be small enough that almost the whole shadow of the mask pattern is cast on the detector plane.

### 3.7.2 Deriving the source position

The position histograms derived experimentally are fitted with the simulated position histograms for a single source in the FOV, but for different locations. The data is run through iterative auto-correlation to correlate the experimentally observed position histogram and the simulated position histogram for the source at different locations in the FOV of the detector. The best fit gives the location of the source in the FOV of the detector and thus the position of the source is derived. The algorithm used is "Richardson Lucy Algorithm" to do an iterative fit to the position histogram to get the source position. The details of this algorithm is not discussed here, as it is outside the purview of this work.

![Surface plot of X-ray sources in the field of view of the detector for the X-ray source placed at a height of about 2 m](image-url)
Figure 3.34 shows the surface plot of the sources in the field of view of the detector, for the source placed at a height of about 2 m and figure 3.35 shows the contour plot of the field of view for the same source. These two figures give the sources in the field of view of SSM detector. The image plane at a height of 2 m from the detector plane is divided into a number of pixels. There are 125 pixels along X (i.e., along anode) and 55 pixels along Y (across anodes). The size of pixel along X is 6.2 mm and 78.54 mm across anode (Y). On the detector, the binning is done at 63 bins/anode (i.e., 0.95 mm is the pixel-width along X, this is equivalent to the smallest element of the coded-mask). The pixel-width along Y, on the detector is the spacing between the anode wires which is 12 mm. The images show the presence of a single dominant source at the centre of the FOV, as expected. The experiment was carried out with the X-ray gun at the centre of the FOV of SSM detector. It can be seen that the surface plot of the sources for the source placed at a height of about 2 m has a single dominant peak at the centre of the FOV (with a slight deviation in the source position from the centre of FOV, which is within the error limit) for the single source, along with small spurious peaks around it. These unwanted spurious peaks present in the surface plot could be due to the error in the divergence factor considered as well as due to small errors in the calibration constants etc. It is also true that due to the divergence factor of the X-ray source, the shadow of the whole mask pattern is not cast on the detector, which can be seen clearly in figures 3.32 and 3.33, where the experimentally derived position histograms do have the entire pattern of the mask. Hence, the auto-correlation of the shadow with the
mask pattern does not yield a single peak function corresponding to the single X-ray source in the field of view as per the principle of coded-mask imaging.

A parallel beam of X-rays will produce a single peak for a single source in the field of view of the detector, as it will cast the shadow of the whole mask pattern on the detector plane. While SSM is on-board, every source it observes, except extended sources like SNRs, Cluster of Galaxies etc., will produce a parallel beam incident on it, and hence the shadow of every mask pattern will be a complete pattern. Therefore, the auto-correlation of the observed position histograms or the shadow pattern and the simulated shadow pattern will give the positions of the X-ray sources in the field of view of SSM with a low coding noise. Thus the position of X-ray sources are derived.

### 3.8 SSM Background spectrum

It is equally important to study the background spectrum of the detector. The background spectrum is of two components, one is the external background seen by the detector and the other is the internal background generated by the detector in response to the incident spectrum. The background rejection is done by the principle of anti-coincidence logic in SSM. The veto layer which is beneath the anode layer and at the sides of the anode layer acts as the anti-coincidence unit in SSM. A charged particle incident on the detector will produce charges on the top anode layer as well as in the bottom veto layer, and hence will be rejected by the coincidence logic unit. Simultaneously output pulses from the veto layer and any one of the anodes in the anode layer is rejected. Also any highly energetic X-ray photon of energy greater than 10 keV is rejected as it will produce output pulses of amplitude greater than 5 V, which is above the ULD level for SSM or it can be detected by the veto layer and get rejected.

Experiments are done to estimate the efficiency of veto logic in SSM. The X-ray background in the laboratory is acquired for half an hour under two conditions: 1) with the veto-logic enabled to reject the background counts, 2) with the veto logic disabled so that the anodes in the SSM detector detect the background counts and the data is considered as valid counts and processed without rejecting the events. Figure 3.36 shows the lab background spectrum acquired by SSM detector with the veto-logic enabled and with the veto logic disabled, in which case the anti-coincidence logic is disabled and there is no rejection of any output pulse due to anti-coincidence. The ratio of the integrated counts from both the spectra gives the efficiency of the veto logic in SSM. The ratio of integrated counts of the background spectra acquired with veto-enabled condition to that of veto-disabled condition
is found to be 70%. Experiments have been conducted to increase the efficiency of veto further. When the end-to-end gain (ratio of the output of veto to the input to the CSPA of the veto unit) of veto unit is about half of the anode unit the vetoing efficiency is about 70%. It has been observed that with an increase in the post amplifier gain of the veto unit the efficiency improved. However, for higher end-to-end gain of the veto, the frequency of the saturated pulses in the output of the veto for charged particle hits is high enough to induce noise in the anode output channels. Hence, an increase in the gain of the veto to improve the veto efficiency along with added noise at the anode signals was not preferred. Therefore, the veto efficiency for SSM is 70%.

![Plot showing the vetoing efficiency of SSM](image)

**Figure 3.36:** Plot showing the vetoing efficiency of SSM

### 3.8.1 Lab-background spectrum

The X-ray background in the lab is mainly that of the cosmic ray spectrum at sea level. Primary cosmic rays are particles with very high energies whose origins in the cosmos are still largely unknown. They consist of energetic protons, electrons, positrons and heavy nuclei. It is believed that these energetic particles are produced during supernovae and solar flares.
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In the laboratory, charged particle background is very less. This is due to muons and highly energetic electrons, which form a part of the constituents of cosmic rays. The background count rate seen by detectors at sea level due to incidence of muons is given by equation 3.5 (MIT-report (2006) and references therein).

\[ S = 2\pi \times A \times D \times \rho \times I_{\nu} \] (3.5)

Here, \( A \) is the area of the detector, \( D \) is the thickness of the detection medium, \( \rho \) is the density of the detection medium and \( I_{\nu} \) is the intensity of the penetrating particles at sea level given as \( 0.83 \times 10^{-2} \text{ cm}^{-2} \text{ s}^{-1} \text{ str}^{-1} \) (MIT-report, 2006)(Rossi, 1948). The background count rate as seen by the SSM detectors in the lab calculated using equation 3.5 is \( \sim 0.02139 \) counts per sq-cm per sec in 180 ° FOV. Figure 3.36 shows the lab background spectrum acquired with SSM with the veto logic disabled so that there is no rejection of any background event happening. There is a cut off at 4.6 Volts due to the ULD settings which cuts off the high energy charge deposition.

The integrated count rate in the background spectrum acquired with the veto logic disabled is 1.128 cnts/sec. Therefore the background counts detected by SSM per unit area per sec is 0.023 cnts/s/cm², which agrees with the value calculated theoretically.

3.8.2 SSM background in-orbit

The background while SSM is in-orbit includes the local particle environment of the spacecraft (Charged particle background), induced radioactivity of the spacecraft due to the charged particle background, the cosmic diffuse x-ray background and the internal background of the detector due to the incident spectrum. Since SSM is a low energy X-ray detector, most of the charged particles produced by the spacecraft environment will be detected by the veto layer and will be rejected by anti-coincidence logic. Also, the induced radioactivity of the spacecraft due to charged particle background is likely to produce high energy gamma rays, which are beyond the energy range of operation of SSM and hence will be rejected by ULD threshold condition. The efficiency of background rejection for SSM is experimentally derived to be about 70%. This number will be valid for any calculations of the background count rate while SSM is on-board. This will help determine the errors on the flux detected from the sources while SSM is in-orbit.
In this chapter, the experiments carried out on SSM detector with the implementation of the design parameters discussed in chapter 2 are discussed. The results from all the experiments done to study different characteristics of SSM detector with reference to the objectives are successful. The working principle of SSM is briefly discussed. Different experiments to calibrate the SSM detector are done. The methodology to derive the position of the source, from which X-rays are incident on the SSM detector is discussed. The positional calibration on SSM detector gives the calibration constants which are required to derive the position of every incident photon on the detector. The steps involved in calibrating SSM detector are given in detail. Various experiments to verify the derived calibration constants are discussed. Experiment to derive the location of the source in the FOV of SSM is carried out and found successful. The background spectrum of SSM observed in the laboratory is studied and the background rejection efficiency of SSM is estimated. This will help understanding the background spectrum while SSM is on-board.