ADITYA-L1 MISSION

VELC

VELC PPS USER MANUAL

INDIAN INSTITUTE OF ASTROPHYSICS

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Technical Content Approvals

VELC PPS User Manual

Prepared by	**Payload Team**
Reviewed by	**Prof. R Ramesh** AL1/VELC, PI
Approved by	**Prof. R Ramesh** AL1/VELC, PI
Technical Contact	**Prof. R Ramesh** AL1/VELC, PI
E-mail	ramesh@iiap.res.in

CHANGE HISTORY

Version number	Date	Affected Section, Figure, Table	Nature of Change [A,M,D] *	Description
1.0	7th March, 2025	All	A	Document was generated.
1.2	24th June, 2025	2.0	M	Figure caption added and Section 2 updated
1.3	1st July, 2025	2.2	A	Added Section 2.2 for other VELC channels.
1.4	1st January 2026	2.1	M, A	Updated the proposal form.

* A – Addition, D – Deletion, M – Modification

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1. INTRODUCTION

The Visible Emission Line Coronagraph (VELC) is a major payload on board Aditya-L1. VELC is designed to carry out imaging and spectroscopic observations simultaneously. Images of the solar corona in the continuum at 5000Å, with a field of view (FoV) from 1.05 to 3 solar radii can be obtained. In addition, spectroscopic observations of the solar corona in three emission lines, namely 5303Å (Spectroscopy-1), 7892Å (Spectroscopy-2), and 10,747Å (Infrared, IR) can be carried out. Observations are limited to 5303Å (Spectroscopy-1) at present.

Spectroscopy-1 (5303Å):

Spectroscopic observations of the solar corona with VELC is carried out in the emission line centred at 5303Å [Fe XIV]. This is also called the 'green' line. The pass band (Full Width at Half Maximum, FWHM) of the filter in this spectroscopic channel is ~7Å. The FoV covers the solar corona in the heliocentric distance range 1.05 - 1.50 solar radii (i.e. a height range of ~0.05 – 0.50 solar radii above the solar limb whose heliocentric distance is 1 solar radii). The radius of the occulting disk in the VELC is 1.05 solar radii. The pixel resolution for observations in the 5303Å channel of VELC is 1.25 arcsec. The pixel size is 6.5um (i.e. 6.5 micrometre). Spectral dispersion is ~28.4mÅ.

VELC is designed for multi-slit spectrographic observations. The total FoV of 3 solar radii is covered by simultaneous observations using four slits. Each slit is of width 50um and height 15mm. The slits are spaced apart horizontally by 3.75mm. A Linear Scan Mechanism (LSM) consisting of two mirrors (FM-1 & FM-2), located in between the Imaging lens assembly (ILA-2) and slit plane (see Figure 1), is used to scan the FoV across the slits. The slits are stationary. Scan direction is perpendicular to the surface of FM1 & FM2. Mirror FM3 directs the scanned beam towards the slits (Multi-slit Assembly, MSA) of the spectrograph. To cover the entire FoV using the four slits, total scan length of ±(3.75/2)mm is required for the scanning mechanism (see Figure 2). The minimum step interval in the scanning mechanism is 20um. This corresponds to ~0.008 solar radii or ~7.7 arcsec in the image plane since a movement of 1um by the LSM translates to 2um lateral shift of the FoV across the slits. The slit width corresponds to ~9.6 arcsec in the image plane. The spacing between the adjacent slits correspond to ~ 12 arcmin, i.e. ~0.75 solar radii.

The center of the four slits are at -1.125, -0.375, +0.375, & +1.125 solar radii w.r.t the occulter center. -ve and +ve signs indicate solar east and west, respectively, in this case. Each slit can observe a distance range of 0.375 solar radii on either side of the above mentioned positions. This way the four slits together cover the total FoV from -1.50 to +1.50 solar radii in the horizontal direction (i.e. the wavelength or the spectral direction). The 15mm height of each slit covers similar heliocentric distance range from -1.50 to +1.50 solar radii in the vertical direction (i.e. the spatial or the slit length direction).

Spectroscopic observations can be carried out in either Sit and stare (SS) mode or Raster scan (RS) mode. Observations could be carried out in frame binning or snapshot mode, either with or without spatial binning. A wide range of exposure times are possible. The length of each slit is along the north-south direction of Sun, and width (dispersion) is along the east-west direction of Sun. One of the user inputs for the SS mode is related to the LSM so that the coronal location to be observed is positioned on the slit. The input can be either positive or negative depending on whether the coronal location to be observed is to the right or left of the slit positions mentioned in the previous paragraph. In RS mode, the LSM is moved in steps at chosen time interval to obtain image of the corona by combining data obtained with the four slits.

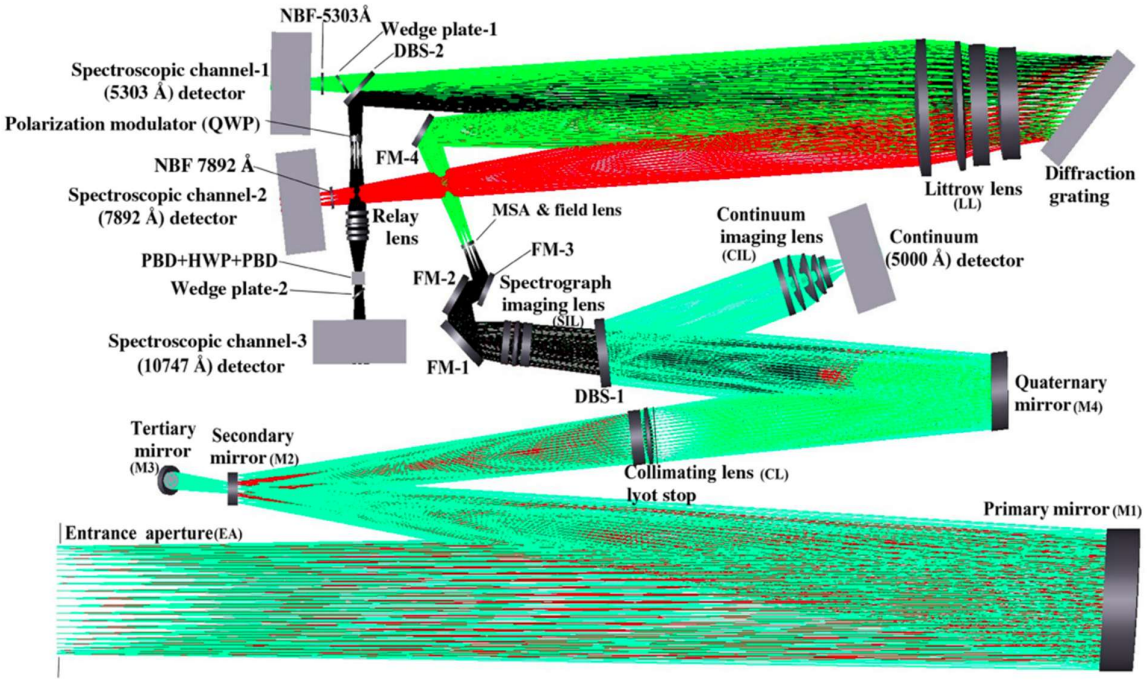


Figure 1: Optical layout of VELC.

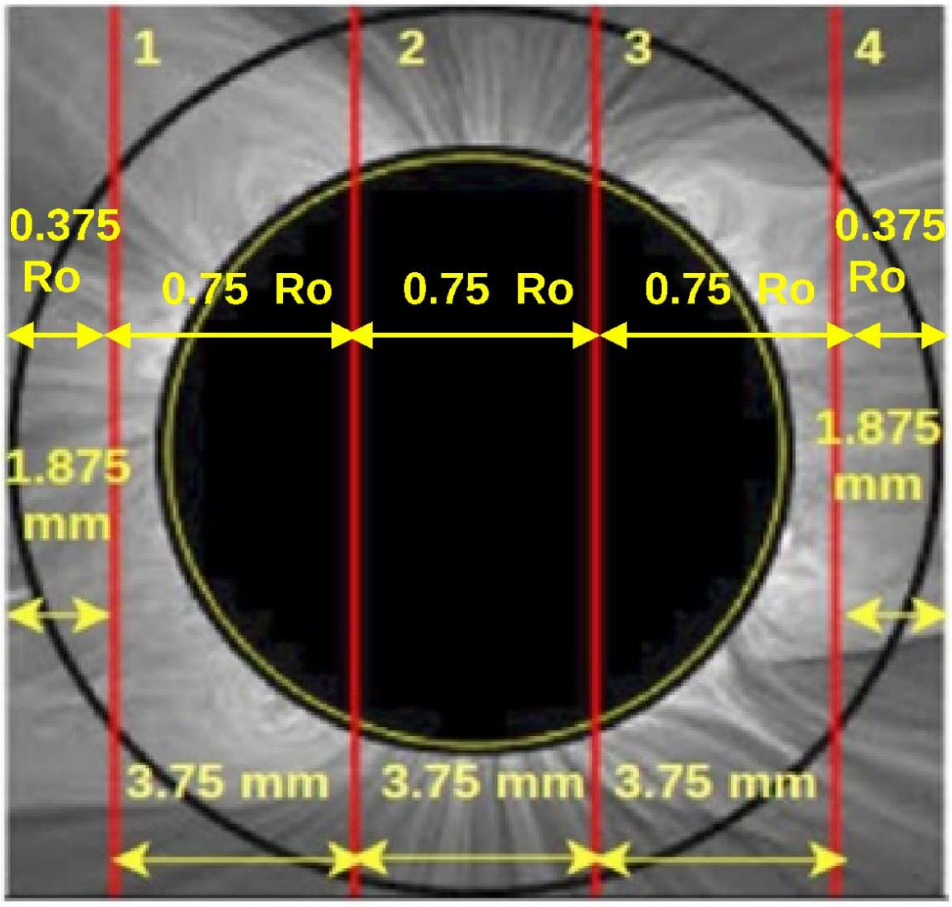


Figure 2: The positions of the slits in VELC multi-slit spectroscopy. The edges of the solar limb (at 1 solar radii), VELC occulter (at 1.05 solar radii), and FoV (at 1.50 solar radii) are indicated by the innermost yellow circle, the 'filled' black circle, and the outermost black circle, respectively. The vertical red lines specify the slits.

2. PROPOSAL SUBMISSION FORM

Refer ALPPS user guide for the overall process of submitting a science observation proposal. This section describes the instrument configuration section in the form for VELC.

2.1 Instrument Configuration:

The **"Instrument Configuration"** form template is shown in Figure 3. The following details need to be provided in this form:

1. **Select the Instrument(s):**
    - For VELC observations, the proposer must select the **"Remote Sensing"** tab, and then **"VELC."**

2. **Select the Channel:**
    - Spectroscopy: **5303Å (Fe XIV)**

    The proposer must select the **Spectroscopy** channel **5303Å (Fe XIV)** for observation.

3. **Select Mode:**
    - **Sit & Stare**
    - **Raster Scan**

    If the proposer wants to carry out spectroscopic observations, they must select the mode of observation, either **"Sit & Stare"** or **"Raster Scan."**

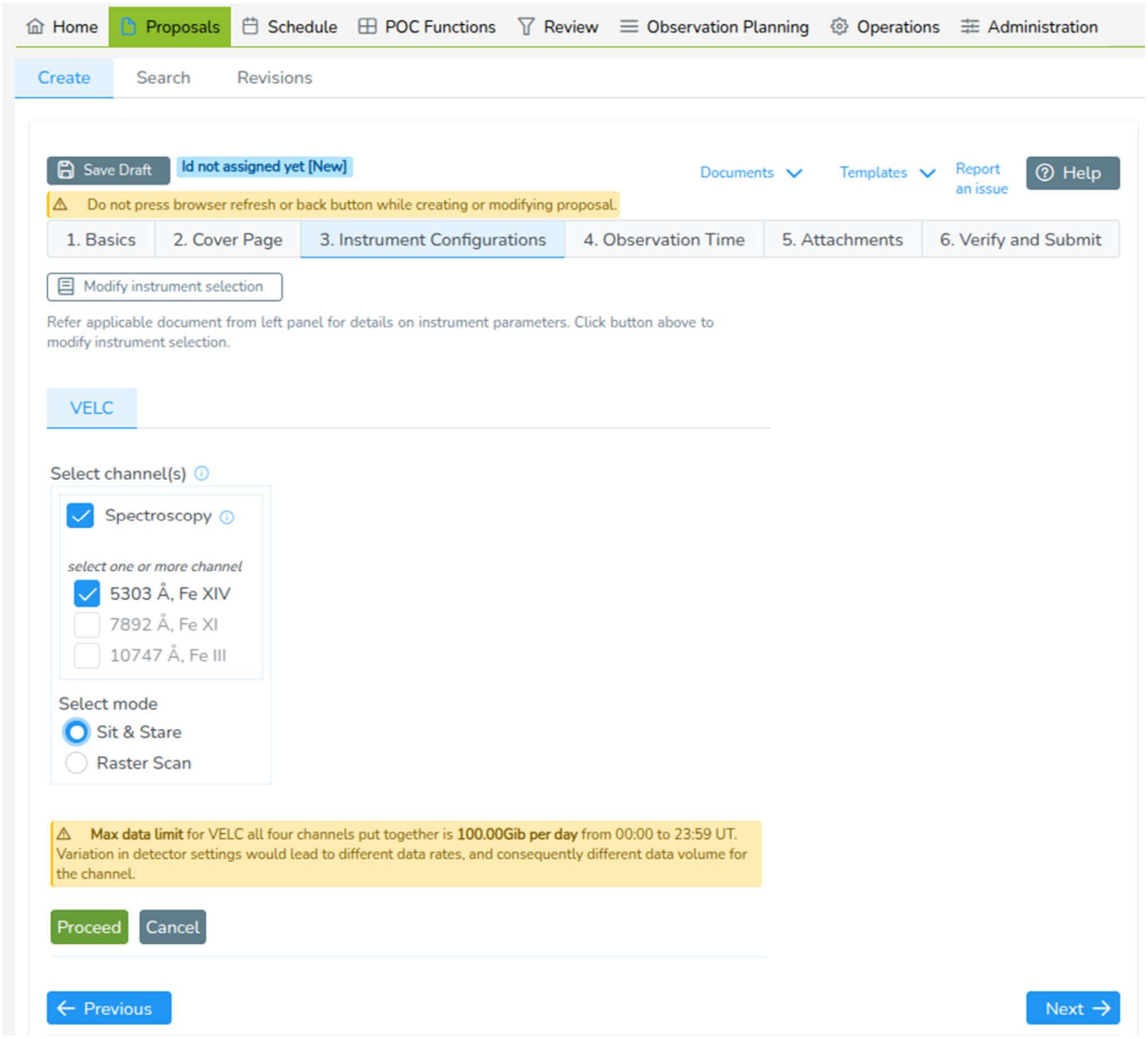


Figure 3: Instrument Configuration form

2.1.1 Sit & Stare:

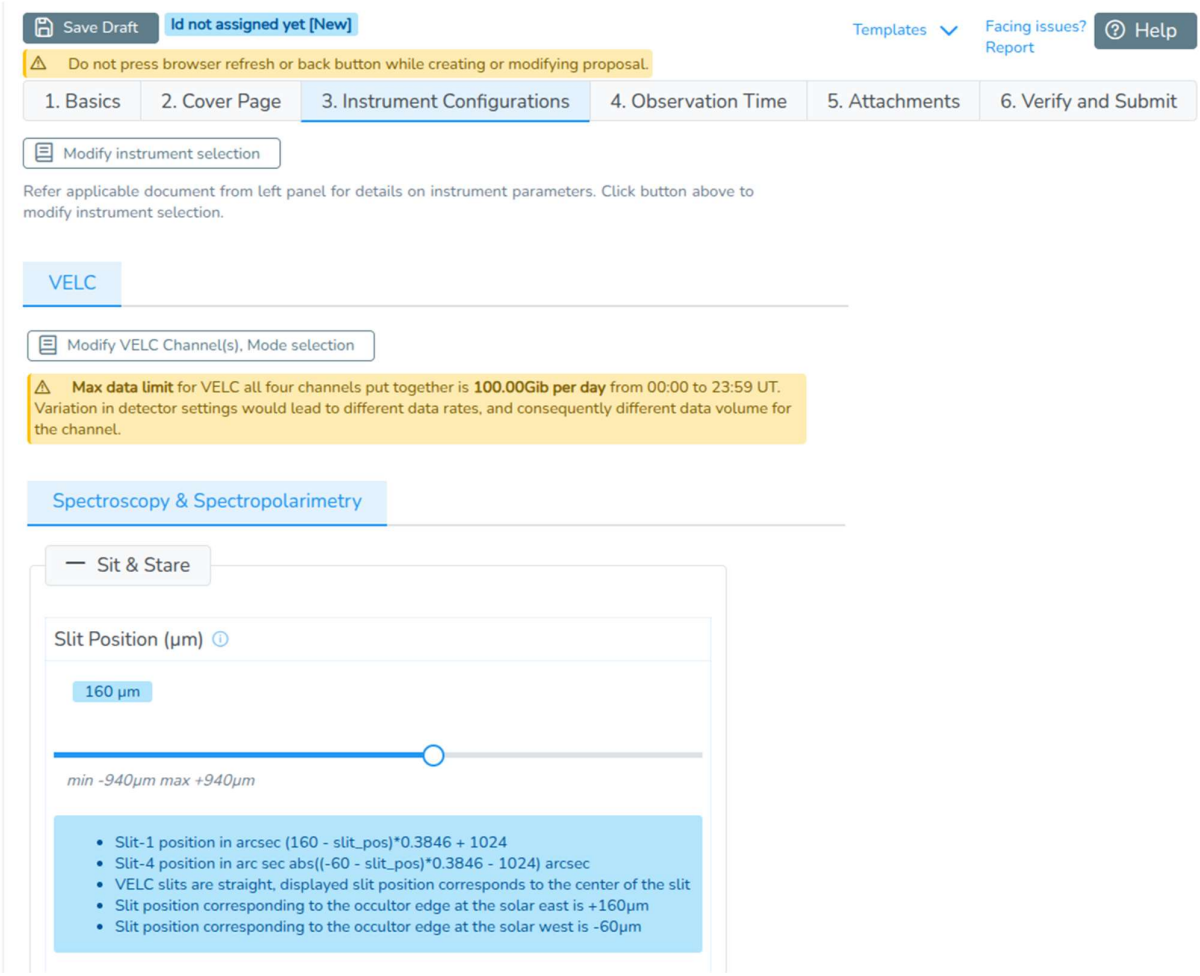


Figure 4: Sit & Stare configuration form

If the proposer selects **"Sit & Stare",** they must provide the desired slit position in micrometres (µm or um) as shown in Figure 4. The slit position range is from **-940µm to +940µm.**

Tips to the proposer: It is found that for Sit-Stare mode of observations at the occulter edge on the Sun east, the LSM is to be positioned at +160um (Slit 1). Similarly, for the occulter edge on the Sun west, the LSM is to be positioned at -60um (Slit 4). For observations of coronal locations away from the occulter edge on Sun east, the LSM position should be < +160um. Likewise, for Sun west, the LSM position should be > -60um.

2.1.2 Raster Scan:

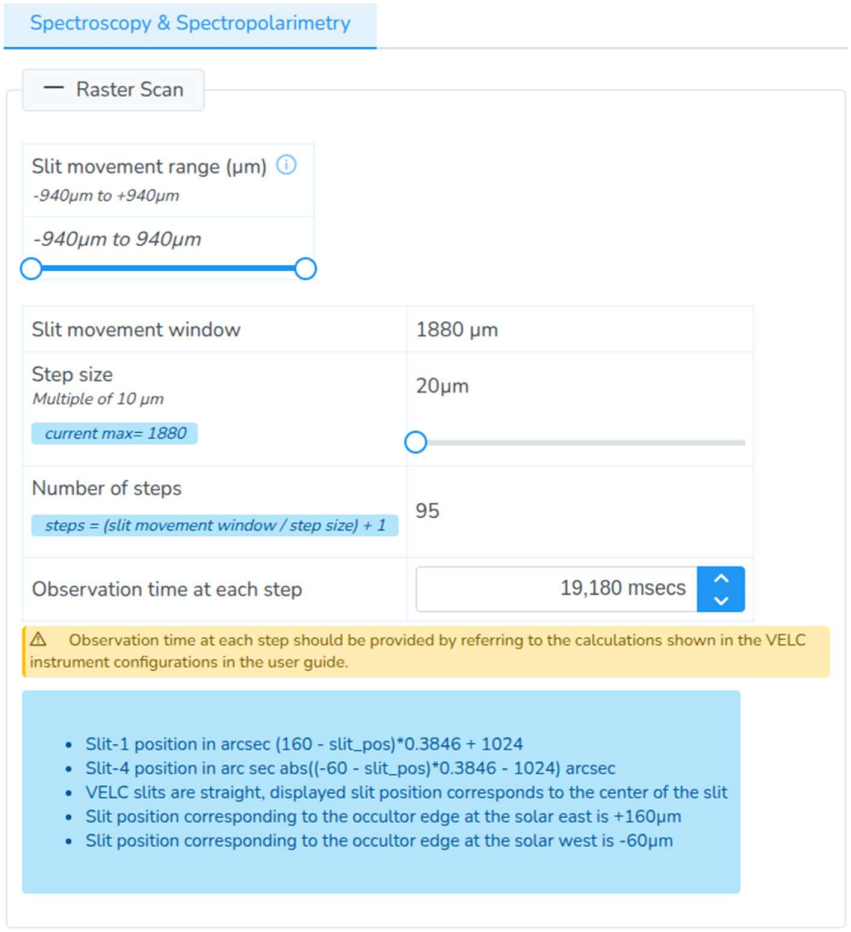


Figure 5: Raster Scan configuration form

If the proposer selects **"Raster Scan"** the following inputs must be provided in the form as shown in Figure 5:

"Slit movement range" - the maximum permitted range is from -940µm to +940µm.

"Step Size" - The minimum step size is 20µm. Other higher step sizes should be in multiples of 10µm, i.e. 30um, 40um, etc.

"Slit movement window" – This will be automatically calculated at the backend and displayed to the proposer. For example, if the slit movement range selected is -940µm to +940µm, then the Slit movement window is 1880µm.

"Number of Steps" – The maximum number of allowed steps is 126 steps. Accordingly, proposer have to select the **"Slit movement range"** and **"Step size"**. The formula for calculating the number of steps is **(Slit Movement Window / Step Size) + 1**. For example, if the slit movement range selected is -940µm to +940µm, step size as 20µm**,** then number of steps is 95 steps.

"Observation time at each step" – Proposer should provide the observation time at each step by following the calculations shown below.

The calculation at the backend is as below:

Time taken for one raster step = T1+T2+T3+T4+100

T1,T3 = Constant Overhead time of 160 msec.

T4 = Time taken to move the LSM to the desired position.

T2 = Time at which Slit is to be at that position.

Formula for calculating T4 = (step size/0.4167)*0.016*1000 msec

100 msec = Constant Overhead time

If step size is 20 µm, then T4 = 767.938 msec

T2 = Cadence – (T1+T3+T4+100)

= 20368 msec – (160+160+767.938+100)

T2 = 19.180 sec. T2 is the "Observation time at each step", if cadence and step size are 20.368sec and 20µm, respectively. The cadence should be preferably 5 times of the exposure time to minimize the effects of T1,T3, T4 and extra buffer time. Exposure time is 4 sec in the calculations shown above. Including the overhead time, the cadence is 20.368 sec. This is also the time taken for one raster step in this case.

"Single raster scan time" – This is the observation duration required for one raster scan. This will be calculated at the backend and displayed for the proposer to verify. The calculations are shown below:

For example, if the movement range is from -940µm to +940µm, and step size is 20µm, the number of raster step is 95. Then time taken to complete one raster scan (Tos) is

Tos = Ts + (Tobs × S) + buffer time

Ts = Time taken to move the LSM from Home position to the desired start position of the raster scan. Ts will be calculated as,

Ts = (abs(start_pos)/0.4167)*0.016*1000 msec

If the start position of the raster scan is -940µm,

then Ts = (940/0.4167)*0.016*1000 = 36093 msec.

Tobs = T1+T2+T3+T4+100 = 160+19180+160+767.938+100 = 20367.938 msec.

S = Number steps, which is 95 in this example.

Buffer time = 2.33 minutes = 140 seconds = 140000 msec.

Tos = 36093 + (20367.938*95) + 140000 = 2111047.11 msec = 35.184 minutes.

2.1.3 Detector Configuration:

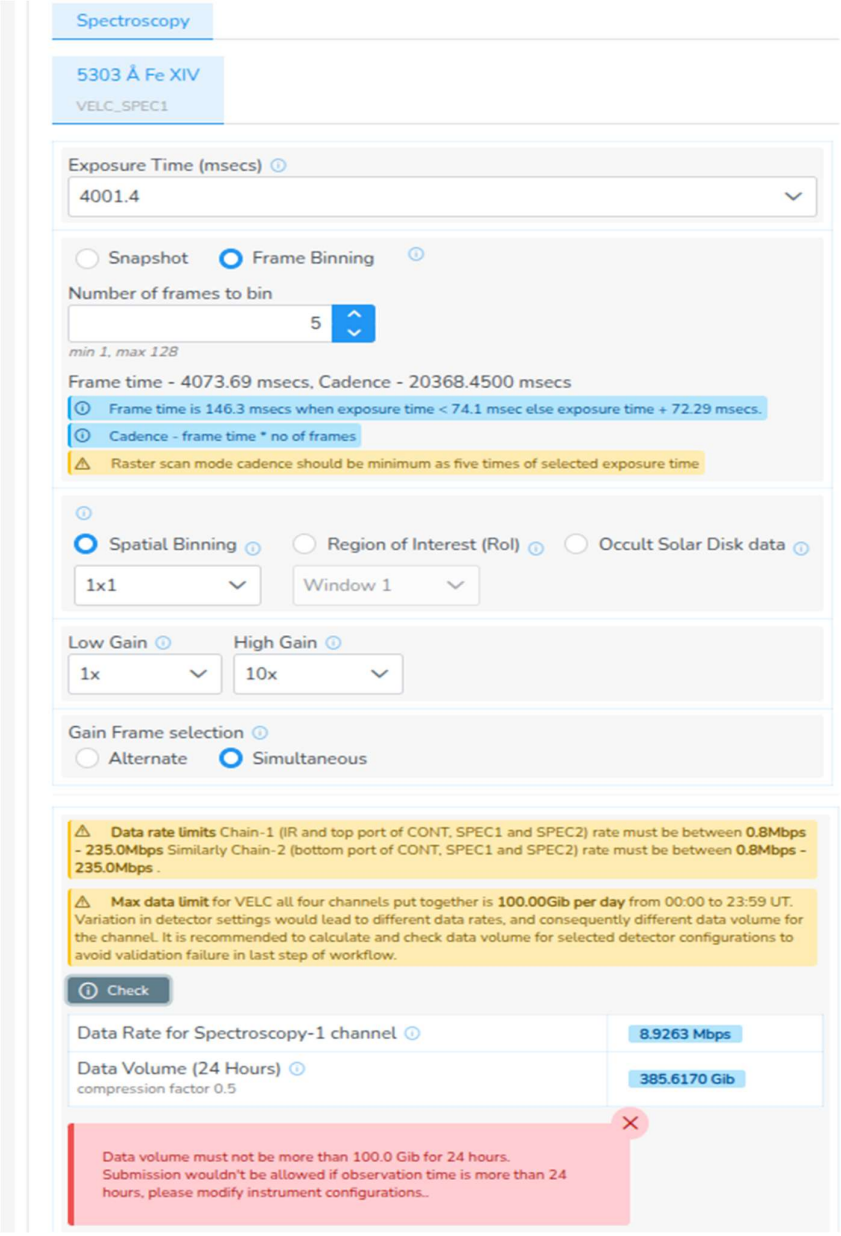


Figure 6: Detector Configuration form

The detector configuration form is shown in the Figure 6. The parameters which are shown in Figure 6 are the necessary detector configurations for the proposed observation. Detailed information on each of the detector configurations are mentioned below.

Exposure Time (ms):

The allowed options for the exposure time is from 148 msec to 100 sec.

Tips to the proposer: The optimal exposure times for the Spectroscopy-1 (5303Å) observations with VELC are found to be in the range **3 sec to 6 sec in Low gain (1X)**, depending on the variation in the size of the Sun over a year (see Figure 7).

Snapshot / Frame Binning:

Proposer have to select either of these two options which controls the mode of observation.

Number of Frames to Skip/bin:

The allowed options for the number of frames to skip is from 1 to 1023. The allowed options for the number of frames to bin is from 1 to 128. This controls the cadence for the observation.

Note that binning of more than 32 frames can lead to saturation. The read out from each frame is 11-bit data, which is 2048 counts (maximum). If 32 frames are binned, then the total count is 2048*32 = 64000. Maximum number of allowed bits for saving the data is 16, which is 65536 counts. So, binning of less than 32 frames is suggested.

Snapshot:

For example, if proposer selects the exposure time as 2 sec and number of frames to skip as 5, then detector will capture 5 spectra in 10 sec. The 1st spectra out of the 5 spectra will be saved in the on-board memory.

Frame binning:

For example, if proposer selects the exposure time as 2 sec and number of frames to bin as 5, then detector will capture 5 spectra in 10 sec. All the 5 spectra will be added in the on-board memory and one binned spectra will be saved.

For both the modes “Snapshot or Frame binning”, cadence (in the example mentioned above) will be taken as 10 sec.

Spatial Binning / Region of Interest (RoI) / Occulter:

The option **Spatial Binning** allows the proposer to spatially bin the data on-board itself to gain data volume. The allowed options are 1x1, 2x1, 4x1 and 8x1.

The option **Region of Interest** allows the proposer to select the region of interest. The allowed options are Window 1, Window 2, Window 3, and Window 4. The detector size is 2160x2560 (wavelength x spatial direction). There is ~~a~~ provision on-board to read only the data

corresponding to the pixel numbers [1081:2160,0:2560] as Window 1, [1:1080,0:2560] as Window 2, [1:2160,1:1280] as Window 3, and [1:2160,1281:2560] as Window 4. In the RoI mode, observations in Window 1 and Window 2 modes will have better signal to noise ratio since they cover the coronal region above the occulter west and east, respectively (see Figure 8).

The option **Occult Solar Disk data allows** the proposer not to read the pixels corresponding to the Occulter region.

The options Spatial Binning, Region of Interest and Occult Solar disk data are mutually exclusive options. Any one option can be selected at a time.

Low Gain Selection:

This option is to select the gain for the observation. The options are 1X and 2X. These are termed as "Low-gain". 1X gain corresponds to ~16 electrons per detector count and 2X gain corresponds to ~8 electrons per detector count.

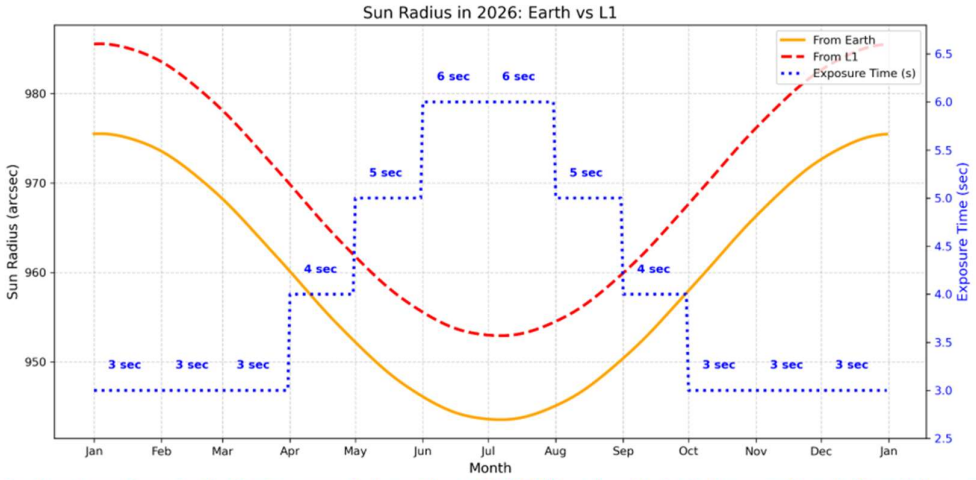
High Gain Selection:

The options are 10X and 30X. These are termed as "High-gain". 10X gain corresponds to ~1.7 electrons per detector count and 30X gain corresponds to ~0.5 electrons per detector count.

Gain Frame Selection:

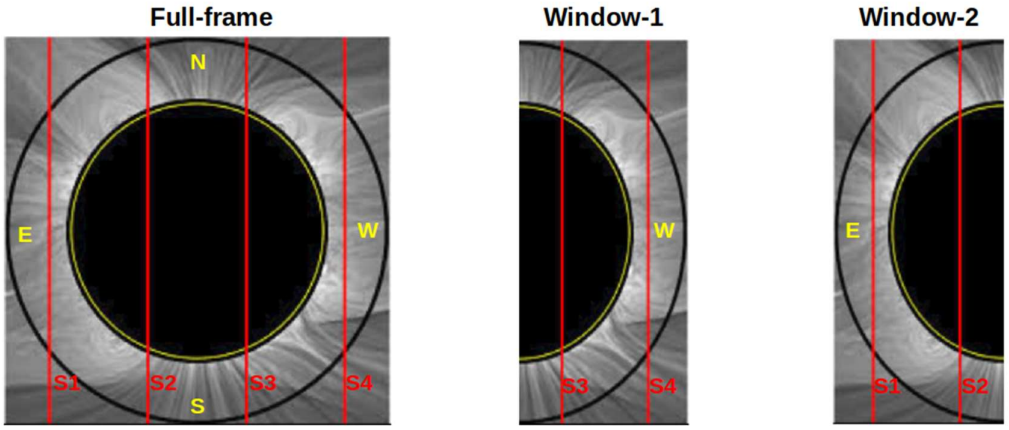
This option allows proposer to choose whether the data corresponding to both Low-gain and High-gain or only Low-gain or only High-gain is to be saved at a time. The options are **"Alternate"** or **"Simultaneous"**.

Alternate – The data corresponding to Low-gain and High-gain will be saved alternatively.
Simultaneous – The data corresponding to both Low-gain and High-gain will be saved together at the same time.



The optimal exposure times for the Spectroscopy-1 observations with VELC are found to be in the range **3 sec to 6 sec in Low gain (1X)**, depending on the variation in the size of the Sun over a year.

Figure 7: Changes in the Sun size with day of year, and the suggested exposure times for observations in the VELC 5303Å (Spectroscopy-1) channel.



S1, S2, S3, S4 – Slits 1,2,3,4 in VELC. Coronal locations covered by the slits as shown are for the **"home"** position of the LSM.
Window-1 covers the western hemisphere of Sun.
Window-2 covers the eastern hemisphere of Sun.

Figure 8: Coronal regions that can be observed in full-frame, Window 1, and Window 2 modes in the VELC 5303Å (Spectroscopy-1) channel.