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Hawkeye

**Preliminary
Software Post-Processing Manual v.1.3
HawkeyeView**

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1 3VCPIview Data Processing Software

1.1 Introduction

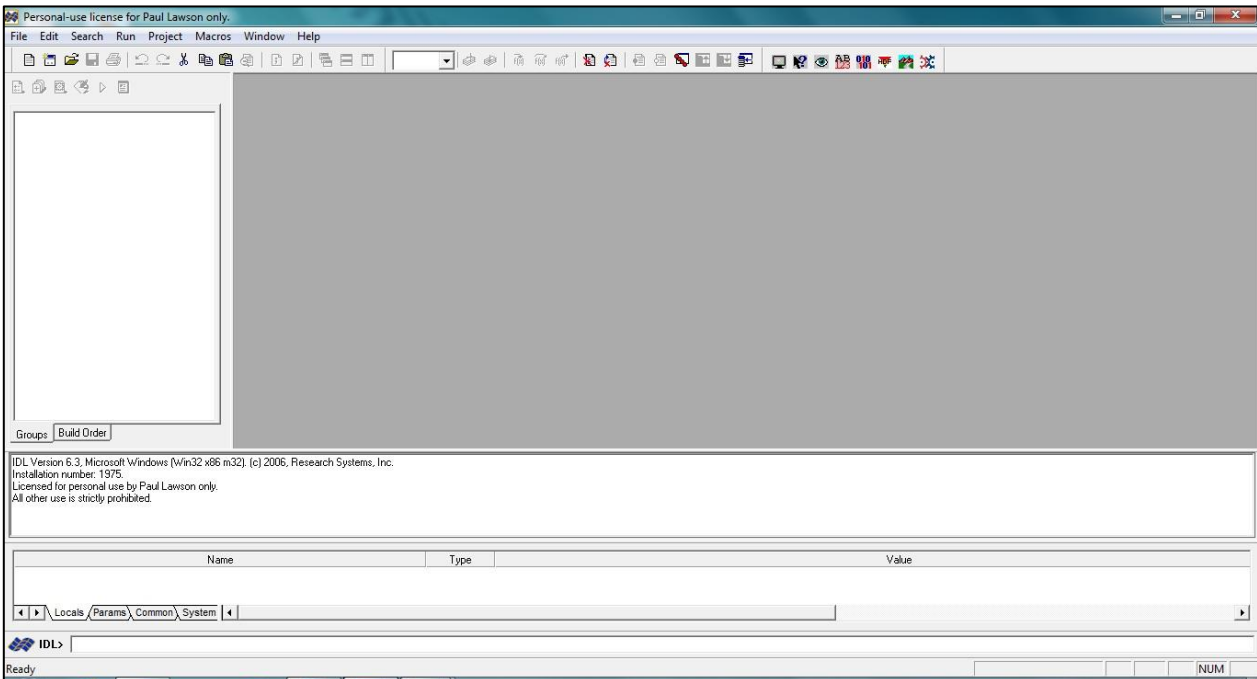
1.1.1 Installing 3VCPIview

To install 3VCPIview, the following PC requirements are recommended:

1. A PC running Windows XP, Vista, or Windows 7.
2. A licensed version of IDL 6.3.
3. Adobe Photoshop or comparable imaging software that reads Portable Network Graphic (PNG) images.
4. A screen resolution set to 1024 by 768 pixels or higher.

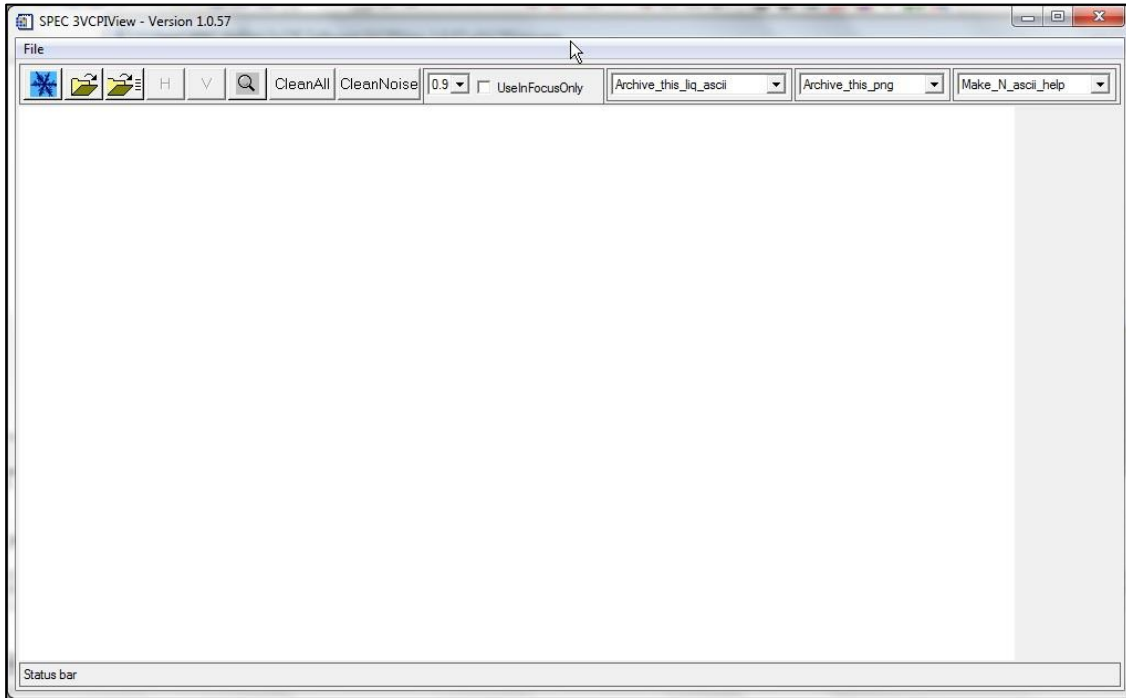
1.1.2 Running 3V-CPIview

1. After installing 3VCPIview, double click the **IDL** icon on your desktop. The IDL program is displayed.



2. Open an **IDL source file**.
3. Type **@compile3VCPI** in the IDL command line, which calls up the 3VCPIview program.

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4. Click on the **Snowflake** button to open the CPI Quicklook or Extractor.

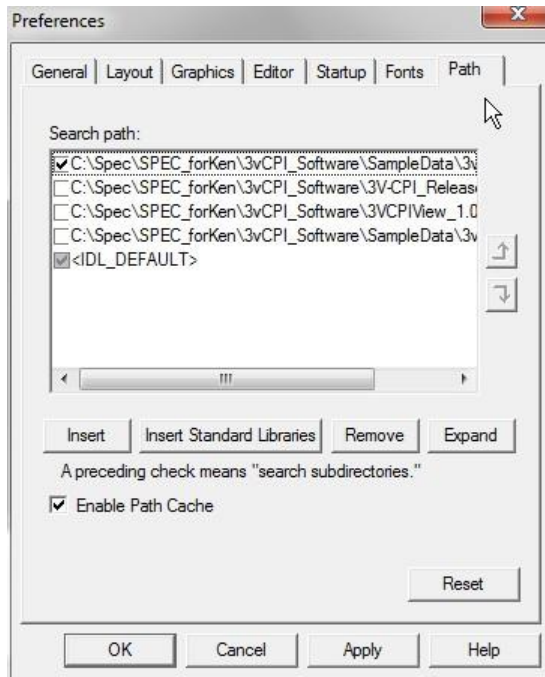
Note:

Use the following steps if 3VCPView is not displayed:

1. In IDL, select **File>Preferences**. The Preferences dropdown menu is displayed.

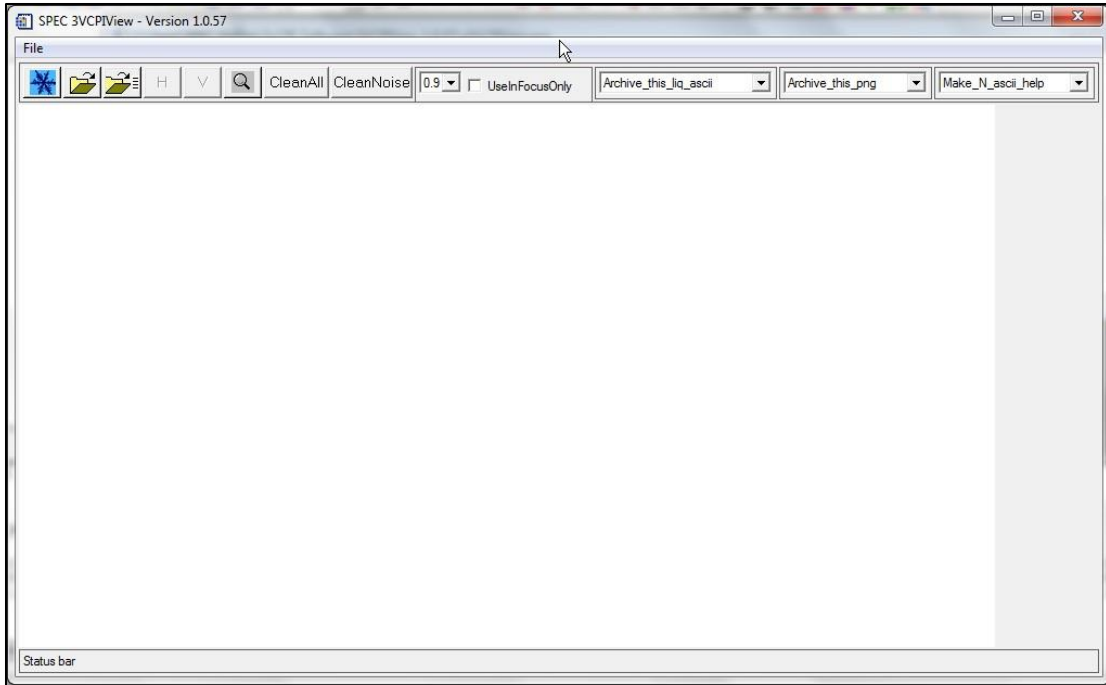


2. Click on the **Preferences** option. The Preferences window is displayed.



3. Select the **Path** tab.
4. Click the **Insert** button and navigate to the 3V-CPI directory for it to be added to the IDL path.
5. Select the **Checkbox** next to the directory path.
6. Click the **Up Arrow** to move the directory to the top of the list.
7. Click the **Apply** button and then click the **OK** button to close the Preferences window.
8. Open an **IDL source file**.

9. Type **@compile3VCPI** in the IDL command line, which calls up the 3VCPIview program.




10. Click on the **Snowflake** button to open the CPI Quicklook or Extractor

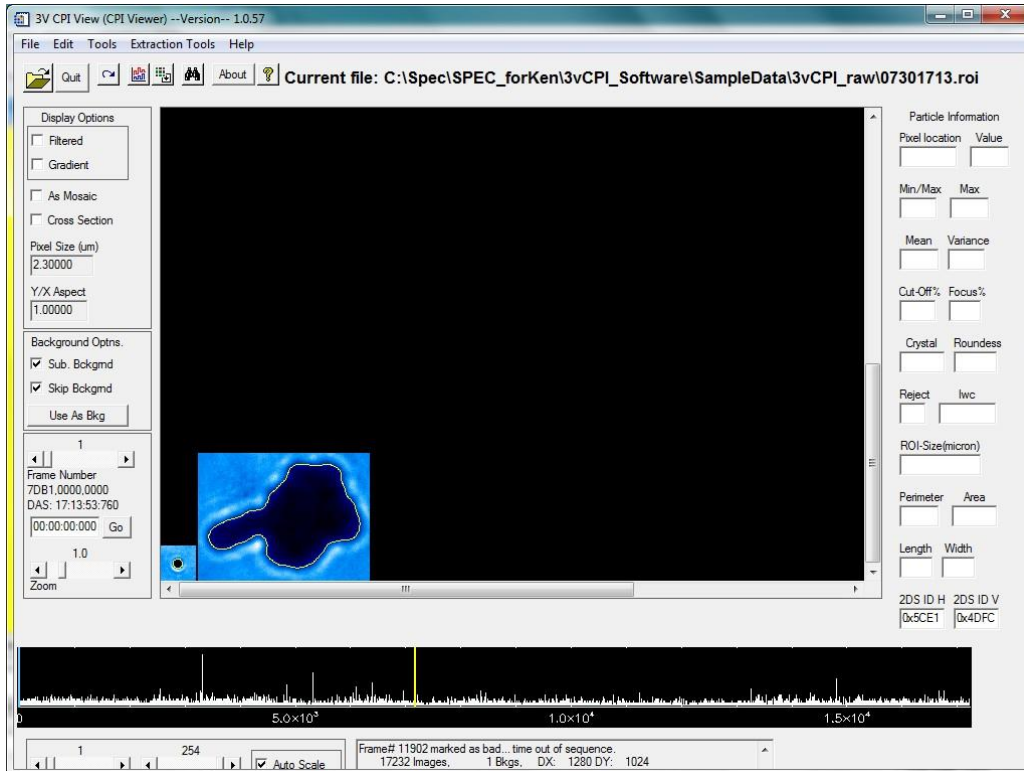


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1.1.3 Opening a Data File

Before you begin processing, you must open a data file. Data files end in .roi, which stands for “regions of interest.”

1. Select **File>Open** or click on the File Open button .
2. Navigate to the appropriate data directory and select an **.roi** file.
3. Click the **Open** button. Once the data file is loaded, the first particle is displayed.




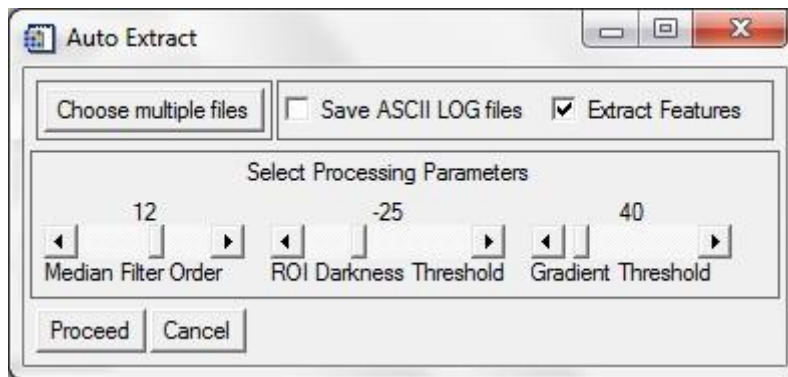
The scrolling text box in the lower right portion of the screen shows the following information:

- The number of images there are in the file.
- The number of background frames.
- The number of CCD camera pixels.
- The location of the current background frame.
- Error messages are also reported in the scrolling text box as the file is loaded.

4. To step through the file, click the Frame Number slider keys. The following data is displayed:
 - Information about each frame, including frame time and the number of particles detected by the PDS but not imaged (missed), is shown in the scrolling text box.
 - The concentration plot along the bottom displays the number of ROIs per frame for the file.
 - The BLUE line marks the current frame and the YELLOW line marks the current background.
 - When the cursor is placed over the particle, information about it, including extracted information if an OBJ file has been created (see Extraction Tools section), is displayed.

1.1.4 Data Extraction

The Extraction Tool  performs an analysis on each ROI and creates an object file (.obj). This file contains a rich set of parameters that can be used for crystal type identification and other classification techniques. If an .obj file was previously created, and is in the same folder as the .roi file, then it will automatically be opened when the .roi file is opened. The Auto-extract window is presented for fine-tuning of the algorithm.



Use the following steps to create a .obj file:

1. Select the **Extract Features** checkbox.
2. Set the **Median Filter Order**.

This is the number of consecutive applications of a 3x3 Median filter to the image. The median filter is used to remove "salt and pepper" noise.

3. Set the **ROI Darkness Threshold**.

Pixels with values above this threshold are not considered to be part of a particle. This is the primary criteria used in detecting and sizing particles.

4. Set the Gradient Threshold.

The magnitude of the 2-D gradient of the image is used to detect particle edges. Gradient values below this threshold are ignored, while values above it are used in conjunction with the ROI Darkness Threshold to determine the boundary of particles.

5. Press the Proceed button to continue. A progress bar is displayed.

If desired, click on the **Choose multiple files** button to process more than the currently open .roi file. A large .roi file usually takes more than an hour (depending on computer speed) to create the .obj file. A common process is to click on the **Choose multiple files** button and let it run overnight with a group of .roi files in their own separate folder.

Select the **Save ASCII LOG files** checkbox to create an ASCII version of the binary .obj file.

Note:

Processing can take a long time. A computer with a 1.0 Ghz processor or better is recommended. A dialog box is displayed when the processing is completed.

If a given .roi file does not have a background, the current directory will be searched for a nearby file that contains a background. This background will be used in the extraction process. The actual backgrounds used are listed in a log window at the completion of processing all the files.

1.1.4.1 Viewing Extracted Features

By moving the mouse pointer over an ROI, information from the extraction appears on the right side of the interface. By left-clicking on any ROI, the perimeter of the particle is displayed. If the extraction procedure fails, and no perimeter is displayed, the phrase "Particle Rejected" is displayed. When an .obj file is present upon opening an .roi file, the options available in the **Generate/View plots** particle acceptance criteria are increased to include the newly extracted data features, as described in Section 1.3.4.

1.1.4.2 Harmonics (eXtractor only)

In order to view the harmonics for the particle, it is necessary to restart 3VCPIview using the harmonics key word.







1. On the IDL command line type **3V-CPI/harmonics**.
2. Load a **.obj** file.
3. **Left click** on a particle to open the Harmonics window.

A new window, shown below, is displayed that shows the radial harmonics as well as the radial perimeter distances of the particle.

1.2 Basic Features

1.2.1 Menu Items

Each menu item has a corresponding Tool Bar icon, the icons are:

- **File** allows you to load a new *.roi file or to quit the program. You can also open a *.roi file by pressing the  button.
- The **Edit** menu allows you to redraw the frame (you can also use the  button). At times it is necessary to redraw the frame if the color table has changed. The color table changes when a time series is changed and may not change back automatically.
- The **Tools** menu allows you to generate/view plots (you can also use the  button.), which will be discussed in the Advanced Features section. From the menu (or using the  button), the color table may be adjusted for dark or light data or if the color table has changed.
- The **Extraction Tools** menu (also accessed via the  button), available on eXtractor, allows you to create .obj files for faster processing.
- The **Help** menu (you can also use the  button) gives revision notes on this version of 3VCPIview.

1.2.2 Particle Information

Particle Information	
Pixel location	Value
(88, 54)	14
Min./Max	Max
1/254	254
Mean	Variance
49.481	4987.3
Cut-Off%	Focus%
0	4
Crystal	Roundness
ice	0.47
Reject	lwc
NO	
ROI-Size(micron)	
324.3 x 223.1	
Perimeter	Area
983	45026
Length	Width
349	237
2DS ID H	2DS ID V
0x5CE1	0x4DFC

Particle information is displayed by moving the mouse cursor over an ROI image. Information about the particle is displayed in the **Particle Information** area. If no information is displayed, an .obj file has not yet been created, and the information will need to be extracted using the extraction tool. The information displayed is as follows:

- **Pixel Location:** The relative location of the cursor over the ROI in pixels.
- **Value:** The raw value of the cursor over the ROI in data units.
- **Min:** The minimum value of the ROI pixels.
- **Max:** The maximum value of the ROI pixels.
- **Mean:** The mean value of the ROI pixels.
- **Variance:** The variance of the pixels in the ROI.
- **Cut-off%:** The amount of the particle (0-100%) that is cut-off by the boundary of the ROI box. eXtractor calculates cut-off when an .obj file is made.
- **Focus%:** An estimate of the focus of the particle. This value is set during auto-extract. Values range from 0-100 with 100 being the in focus, which is default.

However, on occasion, the value can exceed 100, but should be interpreted as 100. (eXtractor only)

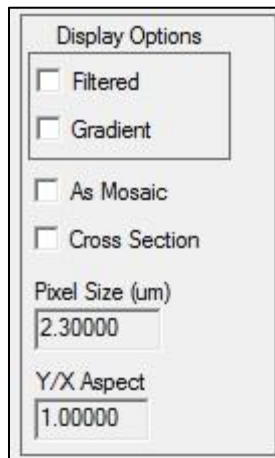
- **Crystal:** Either a user-set or auto-extract set crystal type classification. Right click on the ROI box to toggle through crystal selections of spheroid, ice, or particle rejection. Defaults are “spheroids” and “ice” based on roundness. (eXtractor only or can be set with manual features)
- **Roundness:** Auto-extract computed roundness value of particle, 0-1.0
- **Reject:** Either a user-set or auto-extract set parameter rejecting the particle. To manually reject a particle, right click multiple times to toggle the crystal type through spheroid, ice, and finally particle rejection.
- **ROI Size:** The Raw length and width from the .roi file, in microns.
- **Perimeter:** An Auto-extract computed perimeter in microns.
- **Area:** An Auto-extract computed area in microns.
- **Length:** An Auto-extract computed length in microns.
- **Width:** An Auto-extract computed width in microns.

Note:

Details on Manual Feature Processing (user-set options) are given below.

1.2.3 Display Options

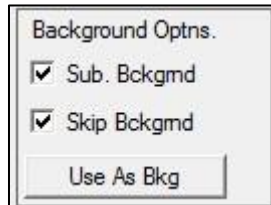
The following display options are shown to the left of the particle display window:



- **Filtered:** When checked, a 4th order median filter is applied to the ROIs.
- **Gradient:** When checked, a 4th order median filter followed by a Sobel filter is applied to the ROIs.

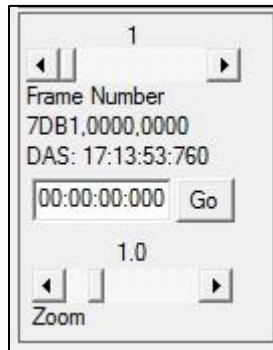
- **As Mosaic:** When checked, the frame is displayed with the ROIs arranged in the appropriate absolute locations relative to the CCD frame (represented by the box outline). When unchecked, the ROIs line up in the particle display window at a magnification of 1.0.
- **Cross Section:** When checked, you can select two points on a ROI using the left mouse button. The points under this line are plotted in the display window. Unchecking this box will clear the plot.
- **Pixel Size:** The currently active pixel size of the CCD imager in microns. This can be edited but should be reset before any processing begins.
- **Y/X Aspect:** The current aspect ratio applied to the display of ROIs. This can be edited for non-square pixels.

1.2.4 Background Options



- **Sub. Bckgrnd:** When selected, and if a background frame exists in the file, the background is subtracted from each displayed ROI.
- **Skip Bckgrnd:** When selected frames containing backgrounds are skipped. To see a background frame, unselect Skip Bckgrnd and Sub. Bckgrnd (select to display As Mosaic to see the background fully).
- **Use as Bkg:** Normally, the closest background in the file is the currently selected background. When viewing a background frame, this is over-ridden by pressing this button.

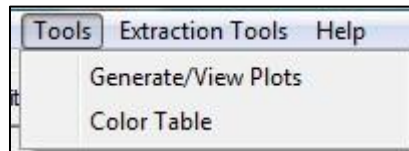
1.2.5 Frame Number Information



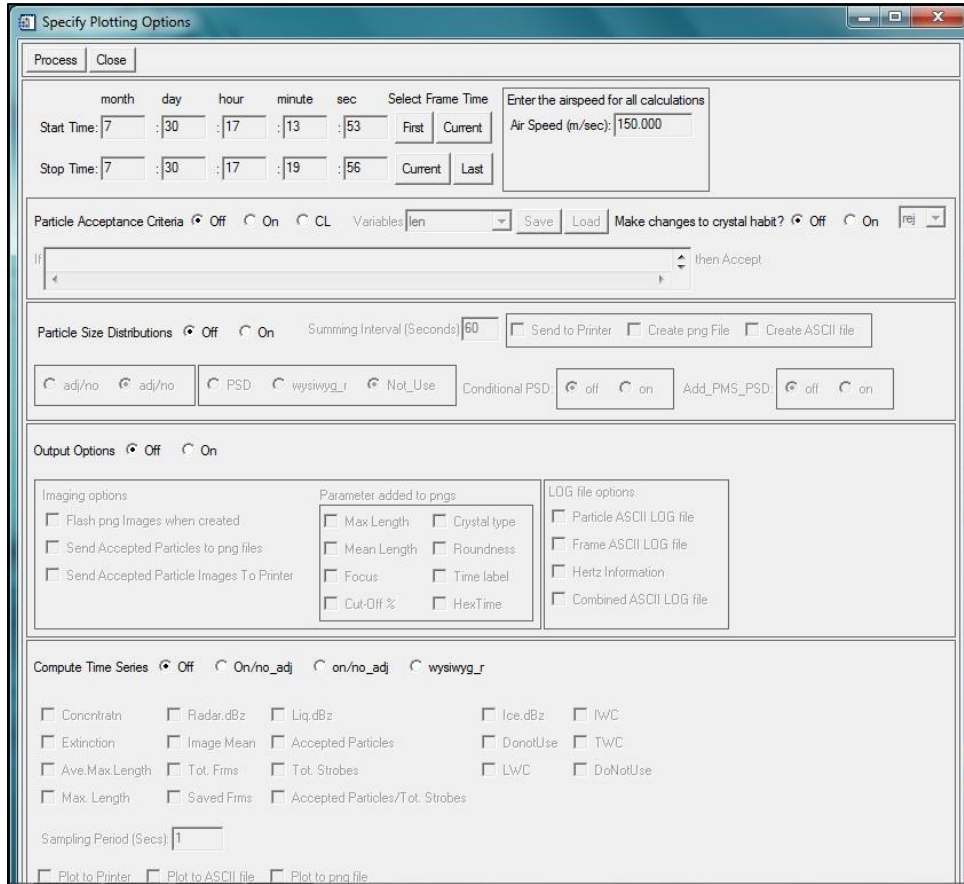
- **Frame Number:** Use this slider to select a particular frame that you want to display.
- **Times:**
 - CPI:** CPI Internal clock time in Hr:Min:Sec:msec
 - DAS:** Data Acquisition System time in Hr:Min:Sec:msec
- **Go:** Type in a DAS time (Hr:Min:Sec:msec) to display the image that corresponds to that time in the particle display window and click the Go button. If no image exists at the provided time, the image closest to the time will be displayed (note: if the particle information is not automatically displayed when hovering over the ROI with the mouse, advance forward one frame and back using the left and right arrows on the frame scrollbar to refresh the particle information).
- **Zoom:** Chooses the magnification factor applied to the display.

1.3 Advanced Features

1.3.1 Generate/View Plots



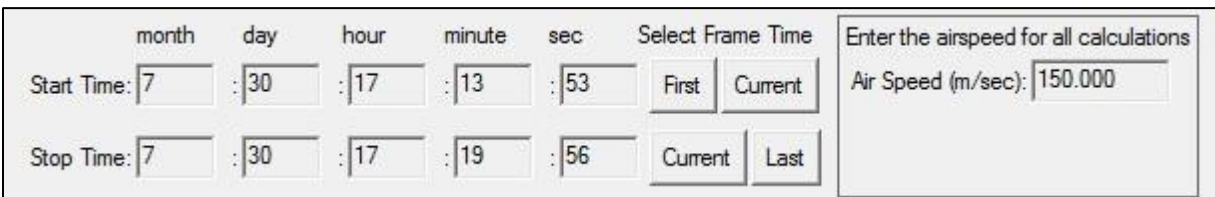
The **Generate/View Plots** option brings up the following **Specify Plotting Options** window. A description of each function is described below.



1.3.2 Process and Close

Press the **Process** button to generate and save the chosen data products. Press the **Close** button to exit the window without processing data.

1.3.3 Time Period and Air Speed Selection

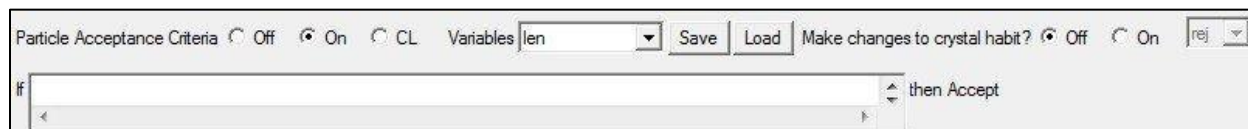


Enter time in the **Month, Day, Hour, Minute, Sec** entry boxes or select via buttons.

- **First** is the time for the first frame in the file.

- **Current** is the time for the currently displayed frame.
- **Last** is the time for the last frame in the file.
- **Airspeed(m/sec)**: Set the airspeed of the aircraft or the wind speed for surface data. This is utilized for calculating particle concentration in size distributions and in time series.

1.3.4 Particle Acceptance Criteria



The **Particle Acceptance Criteria** option allows for manually entering particle acceptance criteria that is used to filter particles.

- Selecting the **Particle Acceptance Criteria On** button enables this feature. Once enabled, criteria must be entered. The criteria are in the form of an **IF** (criteria) **THEN** accept.
- Selecting the **CL** button clears all criteria entered, which deletes the criteria from the program.
- The criteria are entered in the **If** text box.
- Once entered, the criteria can be saved to a text file with the **Save** button. Once a criterion is saved, it can be recalled at a later time using the **Load** button. In this way, multiple criteria can be easily called up and reused.
- The variables available for filtering are presented in the **Variables** dropdown menu. The available variables depend on whether or not an .obj file is loaded.
 - Without an .obj file (or in Quicklook), the variables are:
 - **Len**: represents the length of the raw roi
 - **Wid**: represents the width of the raw roi
 - **Focus**: represents the focus percentage (must be user set)
 - **Cut-off**: represents the Cut-off percentage (must be user set)
 - **Crystal**: represents the Crystal type number (must be user set)
 - With an .obj file, the variables are:
 - **Len**: length of particle along major axis (microns)
 - **Wid**: width of particle perpendicular to major axis (microns)

- **Area:** area of particle (square microns)
- **Perim:** perimeter of particle (microns)
- **Roundness1-3:** roundness measures (0-1)
- **Focus:** focus parameter in percent
- **FocusMin:** Minimum focus value for the particle
- **FocusMax:** Maximum focus value for the particle
- **FocusStdDev:** Standard Deviation of the focus values.
- **Cutoff:** amount that particle is cut-off in percent
- **Crystal:** classification number (1 for liquid, 15 for ice)
- **P1:** user set variable for custom identification purposes 0 or 1
- **Holearea:** the fraction of area above the shadow depth threshold
- **Reject:** rejection status of the particle (0 if rejected)

SPEC has created acceptance criteria for particle classification habits. An example of Cirrus cloud acceptance criteria strings and notes are shown in Appendix A. Examples of acceptance criteria are:

- Focus gt 75 and Cutoff lt 10
- Focus ge 50 and Crystal eq 2
- Crystal ge 5 and Crystal lt 8
- Focus gt 20 and len gt 100

Particle Classification acceptance criteria can be loaded and a classification number or a 3-letter identifier can be assigned as follows:

1. Load a crystal acceptance criteria by clicking the Load button, navigating to a previously saved acceptance criteria text file (see examples in Section 1.6), and select the **Make changes to crystal habit? On** button.
2. Select a crystal type from the dropdown menu.

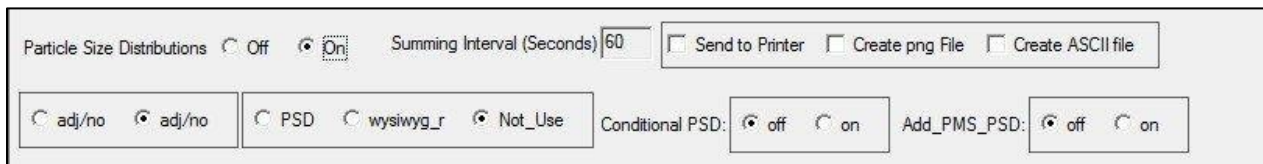
For example:

Loading a rosette criterion and then selecting the 3-letter identifier ros (followed by clicking **Process**) will assign “ros” to all particles that were accepted by the rosette criterion.

3. Acceptance criteria can be loaded, and new identifiers can be selected one at a time until all particles have been re-classified.

- Click on the appropriate box in Imaging options to see and/or save the particles that are being accepted by a criterion while processing, or output all images after all criteria have been loaded with an identifier labeled on each particle .
- After habit classification processing, moving the cursor over the ROI in the main screen will show the manually assigned particle type in the Crystal box. If a particle is not accepted by the criteria it will still be set to its default.
- Once a change to the crystal habits was been made, the OBJ will be modified and a new OBJ will need to be made if you want to start over.

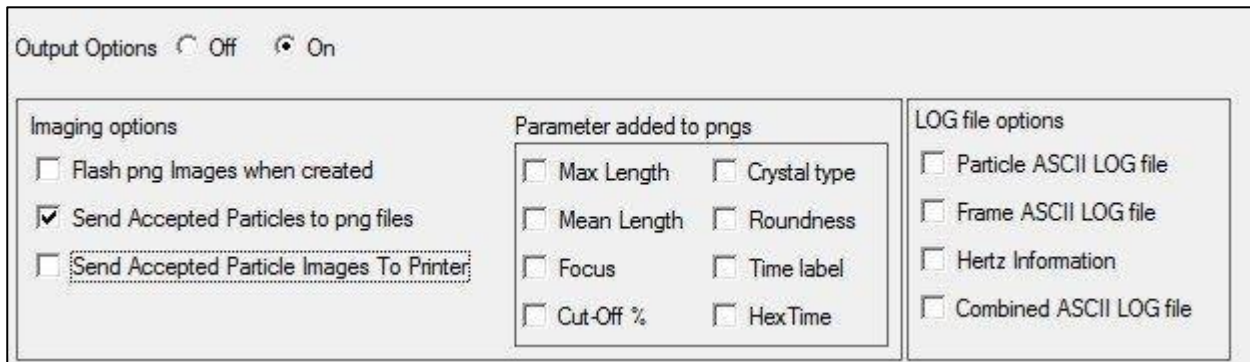
1.3.5 Particle Size Distributions



The screenshot shows a control panel for Particle Size Distributions. It includes a main toggle for 'Particle Size Distributions' set to 'On'. A 'Summing Interval (Seconds)' field is set to '60'. There are three checkboxes: 'Send to Printer', 'Create png File', and 'Create ASCII file', all of which are currently unchecked. Below this, there are two groups of radio buttons. The first group has 'adj/no' and 'adj/no' (the second is selected). The second group has 'PSD', 'wysiwyg_r', and 'Not_Use' (the last is selected). To the right, 'Conditional PSD:' has 'off' selected, and 'Add_PMS_PSD:' has 'off' selected.

These options are currently disabled.

1.4 Output Options



The screenshot shows the 'Output Options' control panel, which is currently set to 'On'. It is divided into three sections: 'Imaging options', 'Parameter added to pngs', and 'LOG file options'. In the 'Imaging options' section, 'Send Accepted Particles to png files' is checked, while 'Flash png Images when created' and 'Send Accepted Particle Images To Printer' are unchecked. The 'Parameter added to pngs' section contains six checkboxes: 'Max Length', 'Mean Length', 'Focus', 'Cut-Off %', 'Crystal type', 'Roundness', 'Time label', and 'HexTime', all of which are currently unchecked. The 'LOG file options' section contains four checkboxes: 'Particle ASCII LOG file', 'Frame ASCII LOG file', 'Hertz Information', and 'Combined ASCII LOG file', all of which are currently unchecked.

Select this feature by clicking the **Output Options On** button. This feature creates PNG files with ROI images on them and ASCII files with image information in them. Select the box beside an imaging or LOG file option to produce that particular output.

1.4.1 Imaging Options

- **Flash png Images when created:** as a PNG frame is generated, it is briefly displayed on the screen.
- **Send Accepted Particles to png files:** this sends the PNG frame to a file.
- **Send Accepted Particle Images To Printer:** prints a page(s) of image(s) to the default printer.

The PNG images contain a header that includes:

- the date
- the time period
- a size scale
- the particle acceptance criteria used

Note:

The scale is only accurate when the zoom factor is set to 1.0 on the 3VCPView window.

Next to the **Imaging options** there is the **Parameter added to pngs** options box that allows you to apply various options to each ROI in the PNG file. These are:

- **Max Length:** add the maximum dimension of the particle (μm).
- **Mean Length:** add the mean dimension of the particle (μm).
- **Focus:** add focus value (auto-extracted value).
- **Cut-Off%:** add cut-off value (auto-extracted value).
- **Crystal Type:** add crystal type number or 3-letter identifier (auto-extract created value or manually set value).
- **Roundness:** add roundness (auto-extract created) value)
- **Time Label:** add time label.

The **LOG file options** are used to create ASCII output. These are:

- **Particle ASCII LOG file:** outputs all available data in column format for each particle in two files: *_stats.csv and *_features.csv. Uses eXtracted values where appropriate.
- **Frame ASCII LOG file:** Outputs ASCII log file of data for every frame in the selected time period.
- **Hertz Information:** Creates a log file containing the probe's housekeeping data for the time period selected.

- **Combined ASCII LOG file:** Outputs all available data pertinent to particle size and dimensions for each particle, like **Particle ASCII LOG file** but only creates one file.

Log file contents are shown in the *ASCII Format Definitions* section, Section 1.6. SPEC programs that use these log files are shown in the *Format for Particle Size Distribution ASCII Output* section, Section 1.7.

1.4.2 Compute Time Series

Select one of the following three scaling options buttons to enable computation and display of time series. Once enabled, select the desired time series. Multiple data can be over-plotted onto the same graph. The available types are:

- **On/no_adj:** to calculate concentration (#/Liter in the sampling period) the number of imaged particles is counted and then divided by the estimated sample volume. This volume is given by the following equation:

$$\left(\text{sumsec s} - \sum \text{deadtimes} \right) \times \text{TAS} \times \cos(\pi / 4) \times dx \times dy \times \text{pixsize}^2$$

Where TAS is the true airspeed; $\cos(\pi / 4) \times dx \times dy \times \text{pixsize}^2$ is the cross sectional sample area.

- **wysiwyg_r scaled:** Every imaged particle in the sampling period is counted and the sum is calculated. Then the sum is divided by the estimated sample volume. This volume is given by the following equation:

$$\text{DOF} \times \text{totfrms} \times \text{area_viewed_by_camera}$$

The larger the particle is the greater the depth of field (DOF). DOF is capped at the window to window distance. Totfrms is the number of image frames taken during the time period.

The following is a list of the time series variables:

- **Concentration:** in units of #/Liter.
- **Extinction:** in units of 1/km. It is derived from the particle's projected area divided by the sample volume.
- **Ave.Max.Length:** average of the max lengths of all particles in sample period (μm).
- **Max.Length:** max length of largest particle in sample period (μm).
- **Radar.dBz:** radar reflectivity value from all particles.
- **Image Mean:** average value of the CCD frame in data units.
- **Tot. Frms:** number of frames in the sample period, includes empty frames.
- **Saved Frms:** number of frames with ROIs in the sample period.
- **Liq.dBz:** radar reflectivity of all liquid particles.
- **Accepted Particles:** count of accepted particles in the sample period.
- **Tot. Strokes:** number of PDS strokes in the sample period.
- **Accepted Particles/Tot.Strokes:** ratio of the two previous variables.
- **Ice.dBz:** calculated radar reflectivity from ice particles.
- **DoNotUse:** reserved for other time series.
- **LWC:** Liquid water content.
- **IWC:** ICE water content.
- **TWC:** Total water content (sum of liquid and ice water content).
- **DoNotUse:** reserved for future usage.

There is also an entry box for **Sampling Period (Secs)**, which sets the averaging interval for the time series plots.

Note:

For calculating IWC and LWC there are the following two choices:





- Auto select uses the extracted particle type for calculating either IWC or LWC.
- Manual select allows you to determine particle type by particle acceptance criteria.

When manual is selected, the particle type (as determined by the extraction process) is ignored. IWC and LWC will be calculated based on the particles that make it through the particle acceptance criteria. If your acceptance criteria selects only ice particles, and if you have selected a LWC choice, the result for LWC will be meaningless.

1.4.2.1 Time Series Plots

The time series viewer allows you to change the axis scales and elect between log and linear Y-axis.

The **Options** menu contains:

- **Print:**  send plots to printer.
- **Save Data to File:**  write an ASCII file of the data.
- **Save Plot to PNG:**  create a PNG file of the data.
- **Exit:**  will close the window.

1.5 Habit Classification Acceptance Criteria

During the extraction process 3VCPIview sets the variable called 'crystal' equal to:

- 15 for ice
- 1 for water
- 0 for rejected particles

You can further modify the values of 'crystal' either semi-automatically using the acceptance criteria option or manually by right clicking on any particle image. An example of acceptance criteria strings that we use for cirrus clouds follows:

Spheroid

Focus gt 20 and cutoff lt 6 and crystal eq 1

Focus gt 20 selects only particles of reasonably good image quality. Cutoff less than 6 selects particles that are completely or almost completely in the image frame. These two requirements are used for all habit types. Crystal equal 1 establishes spheroids as discussed above.

Column

Focus gt 20 and cutoff lt 6 and crystal ne 1 and (len gt 1.9*wid and perim/area lt 1.3*(2*(len+wid)/(len*wid)))

The column acceptance criterion eliminates the spheroids and insists that the length (len) be at least 1.9 times the width (wid). It also checks that the perimeter (perim) to area ratio is not too much higher than expected for simple columns.

Plate

Focus gt 20 and cutoff lt 6 and crystal ne 1 and not(len gt 1.9*wid and perim/area lt 1.3*(2*(len+wid)/(len*wid))) and (((h2 gt 0.01 and h3 lt 0.02 and h4 gt 0.01 and h5 lt 0.02 and h6 gt 0.01 and holearea gt 20)or(h2 gt 0.01 and h3 lt 0.02 and h5 lt 0.02 and h6 gt 0.01 and len lt 1.8*wid and len gt 75 and h4 lt 0.02) or (len gt 75 and h2 gt 0.01 and len lt 1.8*wid and ((h4 gt 0.01) or (h6 gt 0.01)) and h3 lt 0.02 and holearea gt 10)))

The plate acceptance criterion eliminates Columns and spheroids and then uses the low order harmonics (h2, h3...) and the amount of particle image area that is above a specified shadow depth in intensity (holearea).

Rosette

Focus gt 20 and cutoff lt 6 and crystal ne 1 and not(len gt 1.9*wid and perim/area lt 1.3*(2*(len+wid)/(len*wid))) and not(((h2 gt 0.01 and h3 lt 0.02 and h4 gt 0.01 and h5 lt 0.02 and h6 gt 0.01 and holearea gt 20)or(h2 gt 0.01 and h3 lt 0.02 and h5 lt 0.02 and h6 gt 0.01 and len lt 1.8*wid and len gt 75 and h4 lt 0.02) or (len gt 75 and h2 gt 0.01 and len lt 1.8*wid and ((h4 gt 0.01) or (h6 gt 0.01)) and h3 lt 0.02 and holearea gt 10))) and ((sqrt(area)/perim lt .175 and len gt 80))

The rosette criterion eliminates all of the above habits and then insists on the perimeter being at least as large as the square root of the area divided by 0.175. It also requires the length to be greater than 80 microns.

Budding Rosette

Focus gt 20 and cutoff lt 6 and crystal ne 1 and not(len gt 1.9*wid and perim/area lt 1.3*(2*(len+wid)/(len*wid))) and not(((h2 gt 0.01 and h3 lt 0.02 and h4 gt 0.01 and h5 lt 0.02 and h6 gt 0.01 and holearea gt 20)or(h2 gt 0.01 and h3 lt 0.02 and h5 lt 0.02 and h6 gt 0.01 and len lt 1.8*wid and len gt 75 and h4 lt 0.02) or (len gt 75 and h2 gt 0.01 and len lt 1.8*wid and ((h4 gt 0.01) or (h6 gt 0.01)) and h3 lt 0.02 and holearea gt 10))) and not((sqrt(area)/perim lt .175 and len gt 80)) and (sqrt(area)/perim lt .2 and len gt 40)

The budding rosette criterion is similar to the rosette criterion but first also eliminates rosettes and then only requires the perimeter to be at least as large as the square root of the area divided by 0.2 and also only requires the length to be greater than 40 microns.

Small Irregular

Focus gt 20 and cutoff lt 6 and crystal ne 1 and not(len gt 1.9*wid and perim/area lt $1.3 * (2 * (len + wid) / (len * wid))$) and not(((h2 gt 0.01 and h3 lt 0.02 and h4 gt 0.01 and h5 lt 0.02 and h6 gt 0.01 and holearea gt 20) or (h2 gt 0.01 and h3 lt 0.02 and h5 lt 0.02 and h6 gt 0.01 and len lt 1.8*wid and len gt 75 and h4 lt 0.02) or (len gt 75 and h2 gt 0.01 and len lt 1.8*wid and ((h4 gt 0.01) or (h6 gt 0.01)) and h3 lt 0.02 and holearea gt 10))) and not((sqrt(area)/perim lt .175 and len gt 80)) and not(sqrt(area)/perim lt .2 and len gt 40) and (len lt 200)

The particles not identified by one of the above criteria are classified as small irregulars if their length is less than 200 microns.

Big Irregular

Focus gt 20 and cutoff lt 6 and crystal ne 1 and not(len gt 1.9*wid and perim/area lt $1.3 * (2 * (len + wid) / (len * wid))$) and not(((h2 gt 0.01 and h3 lt 0.02 and h4 gt 0.01 and h5 lt 0.02 and h6 gt 0.01 and holearea gt 20) or (h2 gt 0.01 and h3 lt 0.02 and h5 lt 0.02 and h6 gt 0.01 and len lt 1.8*wid and len gt 75 and h4 lt 0.02) or (len gt 75 and h2 gt 0.01 and len lt 1.8*wid and ((h4 gt 0.01) or (h6 gt 0.01)) and h3 lt 0.02 and holearea gt 10))) and not((sqrt(area)/perim lt .175 and len gt 80)) and not(sqrt(area)/perim lt .2 and len gt 40) and not(len lt 200) and (len ge 200)

The particles not identified by any of the above criteria are classified as big irregulars if their length is greater than 200 microns.

1.6 ASCII Format Definitions

1.6.1 ASCII Particle Stats File

Col #	Heading	Format	Description
1	Year	Integer	Year of data acquisition
2	mm:dd:hh:mm:ss	Integer+float	Month-day-hour-minute-sec (sec is float to milliseconds)
3	ROI#	Integer	ROI Number in frame
4	ArrTime	Integer	Arrival time in μ sec
5	TS	Integer	Total strobe count
6	DeadTime	Float	Deadtime in milliseconds
7	Length	Float	Maximum length in μ m
8	Width	Float	Orthogonal width in μ m
9	Drk	Integer	Flag (see note 1 below)
10	Area	Float	Area in sq. μ m
11	Perim	Float	Perimeter in μ m
12	Centroid	Integer array	Co-ordinates of particle centroid in relative pixels
13	Rndness	Float	Roundness measure
14	X_mnt	Float	X moment - 1/2 area on each side of vertical line
15	Y_mnt	Float	Y moment - 1/2 area on each side of horizontal line
16	Rub_band	Float	Rubber band - Measure of boundary roughness
17	Fract_dim	Float	Fractal dimension
18	SampPer	Float	Sample period of harmonic array in pixels???
19	Focus	Integer	% focus 0-100 Mean of 20 points on perimeter (255 indicates failure)
20	Fmin	Integer	Min of 20 points on perimeter
21	Fmax	Integer	Max of 20 points on perimeter
22	FStDv	Float	Standard Deviation of 20 points on perimeter
23	Fgd	Integer	Focus Good - ???
24	Cutoff	Integer	Cut-off – percentage that particle is cut-off optically
25	Crystal	Integer	Crystal type – number specifying crystal type
26	P1	Float	Used for internal purposes
27	P2	Float	Used for internal purposes
28	P3	Float	Used for internal purposes
29	P4	Float	Used for internal purposes
30	CurvWin		Curvature_Window- # of points in the local radius of curvature measurement
31	Focus_Stats	Float array	Focus_Stats – (see note 2 below)
32	Intensity Stats	Float array	Intensity_Stats – same as above stats array
33	IntHLSts	Float array	Intensity_HoleLess_Stats – same as above stats array
34	GradSts	Float array	Gradient_Stats – same as above stats array
35	RadSts	Float array	Radii_Stats – same as above stats array
36	CrvSts	Float array	Curvature_Stats – same as above stats array
37	HCnt	Integer	Hole_Count – number of holes found
38	HASts	Float array	Hole_Area_Stats – same as above stats array
39	HintSts	Float array	Hole_Intensity_Stats – same as above stats array
40	HOSts	Float array	Hole_Other_Stats – same as above stats array
41	H1Ar	Float	Hole1 Area – area of hole
42	H1lsts	Float array	Hole1 Intensity_Stats – same as above stats array
43	H1Prm	Float	Hole1 Perimeter – perimeter of hole found

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Col #	Heading	Format	Description
44	H1Osts	Float array	Hole1 Other_Stats – same as above stats array
45	H2Ar	Float	Hole2 Area – area of hole
46	H2Ists	Float array	Hole2 Intensity_Stats – same as above stats array
47	H2Perim	Float	Hole2 Perimeter – perimeter of hole found
48	H2Osts	Float array	Hole2 Other_Stats – same as above stats array
49	H3Ar	Float	Hole3 Area – area of hole
50	H3Ists	Float array	Hole3 Intensity_Stats – same as above stats array
51	H3Perim	Float	Hole3 Perimeter – perimeter of hole found
52	H3Osts	Float array	Hole3 Other_Stats – same as above stats array

1.6.2 ASCII Particle-Features File

Col #	Heading	Format	Description
1	HrmCnt	Integer	Harmonics Count - size of Harmonics array (variable)
2	Harmonics	Float	Harmonics - array of circular perimeter harmonics
3	BndCnt	Integer	Boundary Count - size of Boundary array (variable)
4	Boundary	Integer	Boundary - array of relative perimeter in 1D pixels
5	RadCnt	Integer	Radii Count - size of Radii array (variable)
6	Radii	Float	Radii – array of radial lengths from centroid to perimeter (units?)
7	CurvCnt	Integer	Curvature Count - size of Curvature array (variable)
8	Curvature	Float	Curvature - local radius of curvature measurement

1.6.3 ASCII Frame File

Col #	Heading	Format	Description
1	SZE	Integer	
2	Version	Integer	Version number for data file. (determined by age of acquisition gui)
3	RoiCnt	Integer	Number of ROIs in frame
4	roisze	Integer	Number of pixels saved from the frame
5	HouseTime	Integer	Probe time since beginning of year
6	Date	Integer	Date format: dd:hh:mm:ss
7	IMGtype	Float	
8	SX	Integer	
9	Sy	Integer	
10	Ex	Integer	
11	Ey	Integer	
12	Bgrate	Integer	Background rate
13	Bkgpdst	Integer	
14	Frmsproc	Integer	
15	lthr	Integer	
16	Roierr	Integer	
17	Roiminsz	Integer	
18	Roiaspect	Integer	
19	Roifill	Integer	
20	Roifcnt	Integer	
21	Imgmn	Integer	
22	Bkgmn	Float	
23	Spr1	Float	

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Col #	Heading	Format	Description
24	ROIYPad	Integer	x-dim pad around particle in pixels
25	ROIYPad	Integer	x-dim pad around particle in pixels
26	Strbcnt		
27	Frmssvd	Integer	
28	Imgminval	Integer	
29	Imgmaxval	Integer	
30	Roissvd	Integer	
31	Chksum	Integer	
32	Pdshd1	Integer	
33	Pdshd2	Integer	
34	Pdshd3	Integer	
35	Time	Integer	
36	Arrvlt1		
37	Arrvlt2		
38	Transit_time		Transit time
39	Missed		Number of pds detections since camera was last available
40	Phght1		
41	Phght2		
43	Pdschks		
44	prbmode		

1.6.4 ASCII Combined Log File

Col #	Heading	Format	Description
1	Year	Integer	Year of data acquisition
2	mm:dd:hh:mm:ss	Integer+float	Month-day-hour-minute-sec (sec is float to milliseconds)
3	ROI#	Integer	ROI Number in frame
4	ArrTime	Integer	Arrival time in μ sec
5	TS	Integer	Total strobe count
6	DeadTime	Float	Deadtime in milliseconds
7	Length	Float	Maximum length in μ m
8	Width	Float	Orthogonal width in μ m
9	Area	Float	Area in sq. μ m
10	Perim	Float	Perimeter in μ m
11	Focus	Integer	% focus 0-100 Mean of 20 points on perimeter (255 indicates failure)
12	Cutoff	Integer	Cut-off – percentage that particle is cut-off optically
13	Crystal	Integer	Crystal type – number specifying crystal type
14	P1	Float	Used for internal purposes
15	IntHLSts	Float array	Intensity_HoleLess_Stats – same as above stats array
16	HrmCnt	Integer	Harmonics Count - size of Harmonics array (variable)
17	H1	Float	Hole1 Area – Area of Hole
18	H2	Float	Hole2 Area – Area of Hole
19	H3	Float	Hole3 Area – Area of Hole
20	H4	Float	Hole4 Area – Area of Hole
21	H5	Float	Hole5 Area – Area of Hole
22	H6	Float	Hole6 Area – Area of Hole
23	SX	Integer	

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Col #	Heading	Format	Description
24	Sy	Integer	
25	Ex	Integer	
26	Ey	Integer	

Notes:

1. Dark parameter codes (Dark: 2-byte word)	
Byte	Meaning
1st byte	darkness number
2nd byte	LS 5-bits = Particle cutoff index: 0-31 (no cut-off to almost fully cut-off)

2: Meaning of Statistic arrays		
Array Element	Name	Meaning
0	N	Size of sample set
1	Min	Minimum value
2	Max	Maximum value
3	Mean	Mean value
4	Median	Median Value
5	Mode	Mode
6	Std Dev	Standard Deviation
7	Skewness	Skewness
8	Kurtosis	Kurtosis

3.Codes for flag (Flags: 2-byte word)	
Bit Number	Meaning
0-7	out of focus number
8-11	crystal type 0=circular 1=column 2=stellar 3=other
12	Not used.
13	ROI was drawn manually.
14	Crystal type was manually corrected.
15	Particle was manually rejected.

4. Codes for ROI ERROR	
Value	Meaning
0	No error
1	ROI is smaller than Min Size limit
2	ROI Aspect Ratio is outside limits
3	ROI threshold density is too low - (not used in the newer Probes)
8	Image intensity was too low to process
9	Image intensity was too high to process
11	ROI record was generated while attempting to capture a background
15	ROI was generated as a test - Pre-Set ROIs option was selected

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1.7 Format for Particle Size Distribution ASCII Output

1.7.1 File Header

- Plotcount: the number of histograms saved in the file.
- Sumsecs: the number of seconds averaged for each histogram.
- Pixsize: Pixel size. 2.3 microns.
- Typescaling: 1 = Total strobes scaling, 0 = Deadtime scaled
- Samplevolume: number of liters of air sampled during time period.
- Sizetype: 'mean' for meansize or 'max' for maxsize.

1.7.2 Individual Data Header

- Missed: Total Strokes count.
- Deadtime: Deadtime during the period.
- Starttime: Start time for time interval (number of seconds since Jan 1)
- Totfrmcnt: Total frame count, the total number of frames taken during the time period.
- Roifrmcnt: Roi frame count, the number of frames that contained ROIs.
- Totimgpart: The total number of imaged particles
- Nonrejpact: Total number of particles that were not rejected
- Acceptepart: Total number of accepted particles.
- WYSIWYG: The WYSIWYG concentration for the time period.
- Datasize: Number of ROIs in the time interval.

Data: There is one data point for each roi in the interval. The dimension of the particle is listed in the data section. If the particle was rejected for any reason (obj rejected, or particle acceptance criteria rejected) the particle dimension is replaced with a 0.0 value.

2 Using the 3VCPI 2D-S Software

2.1 3V2D-S Data Pre-Processing: Basescan or Playback

Processing 3V2D-S data first requires running either basescan.pro (written in IDL) or Playback (the Spec2D executable, written in C and Visual Basic). After this initial processing step, the main processing and display of 3V2D-S data is accomplished via the 3V2D-S portion of 3VCPIview (referred to as 3V2D-Sview), an IDL-based program.

2.1.1 Basescan

basescan.pro is a replacement for Playback for 3V-CPI(2D-S) and Hawkeye 2D-S data. It converts baseYYMMDDHHMMSS.2DSCPI and baseYYMMDDHHMMSS.2DSCPIHK files into SORTED*.2DSCPI, HK_BIN*.2DSCPI, HK_TXT*.2DSCPI files required for further processing with 3V-CPI View.

The advantages of basescan are:

- Written in the same language as the rest of 3V-CPI View
- Runs significantly faster than Playback
- Written in a single language so it is easier to develop/maintain, instead of in a combination of obsolete Visual Basic 6 from 1998 and Visual C++
- Completely separated from the "Realtime" code
- Basescan generates plots of Housekeeping Data for the 2D-S and CPI

Note: Currently, the mask bit filling, assembling multi-packet images have not been implemented.

2.1.1.1 Running Basescan

If your IDL is set up with "Change Directory on Open", you can run basescan by opening basescan.pro, otherwise, add the basescan directory to the IDL path. Note that no additional compilation is required, as basescan follows the IDL compilation standards and auto-compile as needed.

1. Open basescan.pro in IDL
2. At the IDL command prompt, type basescan:
IDL> basescan
3. Use the pick file dialog to select the baseYYMMDDHHMMSS.2DSCPI file
(ensure that the baseYYMMDDHHMMSS.2DSCPIHK file is in the same directory)

2.1.1.2 Running Basescan with Images

To view images, run with:

```
IDL> basescan, 1
```

Note: viewing images substantially slows down processing -- it might take hours instead of minutes!

2.1.1.3 Additional Basescan Options

Several additional options are controlled by setting flags in the setup_globals procedure at the top of basescan.pro. Some of the more useful flags are outlined below.

Setting !just_HK to 1 reads only the Housekeeping file and quits before generating the SORTED files.

This is a quick way to view the Housekeeping data for a file.

!show_HK_plots toggles showing the Housekeeping plots.

!save_HK_plots toggles saving the Housekeeping plots to png images in the base file directory.

!output_TAS_file set to 1 to generate a True Air Speed file for use in FSSP/FCDP/Hawkeye FCDP processing

!output_CPI_frames_csv set to 1 to generate a csv of CPI frame rate

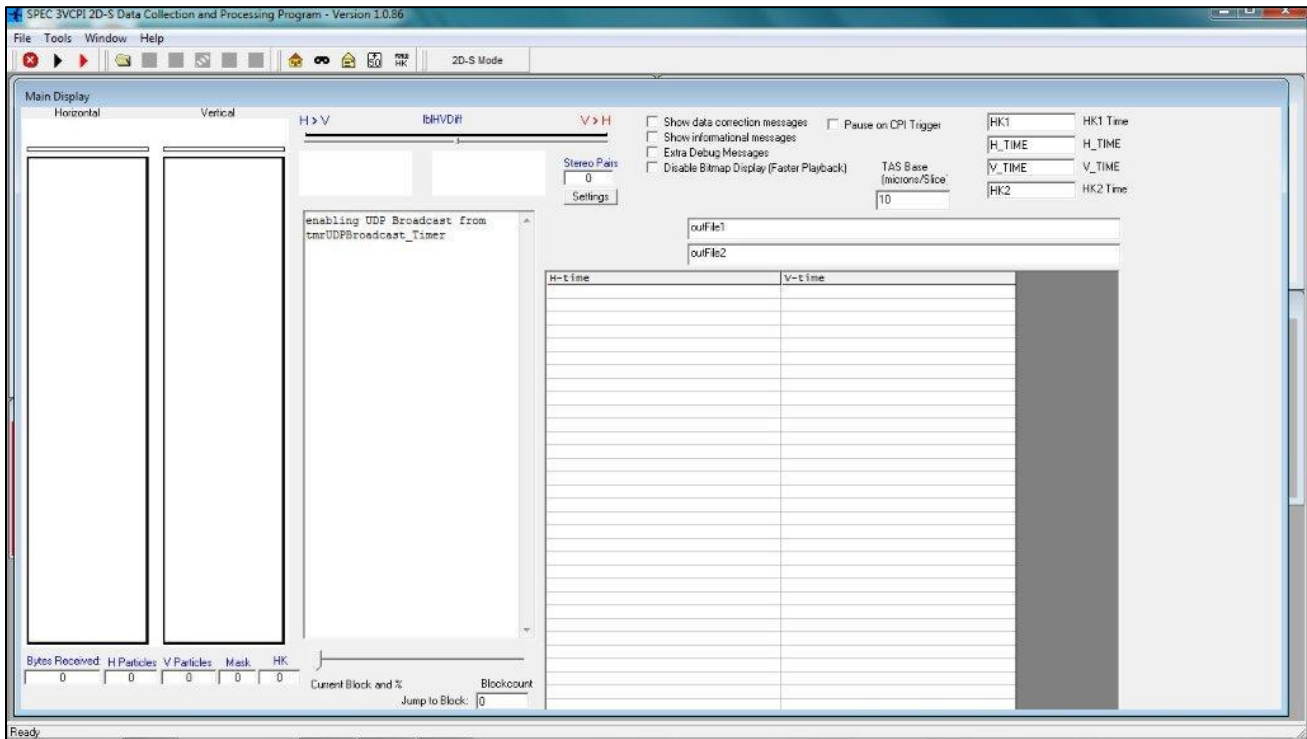
!manual_override_H50vs10micron and !H_resolution_microns can be used if there is a problem with auto-detection of the Horizontal channel resolution. Normal operation, leave


!manual_override_H50vs10micron set to 0, and !H_resolution_microns will be set automatically to 10 or 50 microns as specified in the base file.

2.1.2 Playback

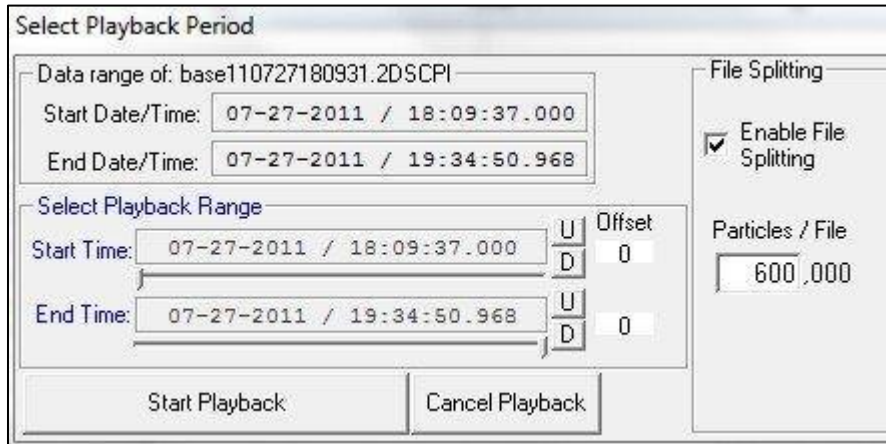
Note: Playback is being replaced with Basescan, these instructions are only included to facilitate the change-over in software, but Playback does not need to be run if Basescan was used, instead proceed to **Section 2.2**.

1. To pre-process the data for analysis, open the executable Playback program, which is the same program used to record the data file.



2. With the program open, click on the folder button .

It will prompt you to open a baseYYMMDDHHMMSS.2DS file, which is a raw data file. The file is binary and the images are compressed. Once a file is open, a time period selector box is displayed.



The screenshot shows a dialog box titled "Select Playback Period". It contains the following elements:

- Data range of:** base110727180931.2DSCPI
- Start Date/Time:** 07-27-2011 / 18:09:37.000
- End Date/Time:** 07-27-2011 / 19:34:50.968
- Select Playback Range:**
 - Start Time:** 07-27-2011 / 18:09:37.000 (with 'U' and 'D' buttons)
 - End Time:** 07-27-2011 / 19:34:50.968 (with 'U' and 'D' buttons)
 - Offset:** 0 (for both start and end times)
- File Splitting:**
 - Enable File Splitting
 - Particles / File:** 600,000
- Buttons:** Start Playback, Cancel Playback

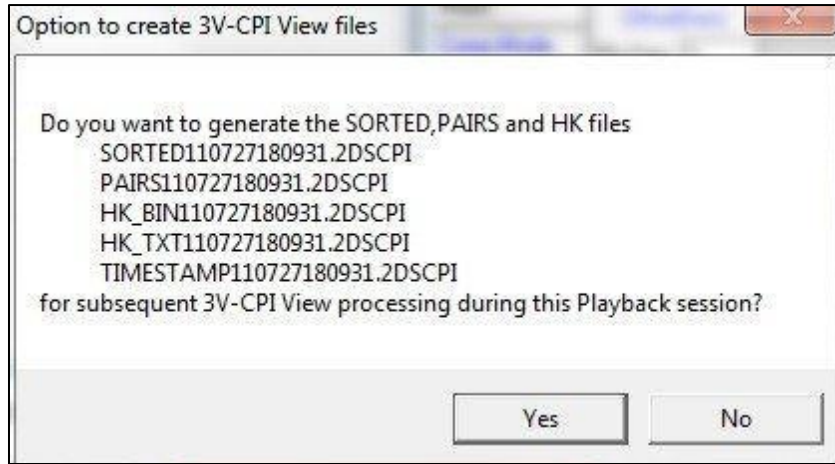
3. To select a time period, move the two **Start Time** and **End Time** sliders.

For an exact time period use the **U** and **D** buttons to increase and decrease time by one-second intervals.

Note:

2D-S view attempts to keep information on each particle in memory. When the memory is full, the program slows due to the use of virtual memory. This can result in unacceptably slow processing, which can be remedied by enabling file splitting. File splitting cuts the original large data file into processed data files of manageable sizes, according to a preset number of particles. A typical setting is 300,000 particles per file, but the optimum size will depend on the attributes of the computer used.

- Once the time period and file splitting options are chosen, click the **Start Playback** button. A window is displayed asking if you want to create 2D-S view pre-processed files, which are called sorted files.

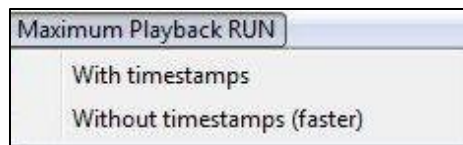


These files are also binary with compressed images, but various simplifications to the file structure have been made. For example, the data is sorted into time sequence. A sorted data file is necessary to run 2D-S view. Playback also produces the following files:

- HK_BINYYMMDDHHMMSS.2DS
- HK_TXTYYMMDDHHMMSS.2DS
- PAIRSYMMDDHHMMSS.2DS (obsolete)

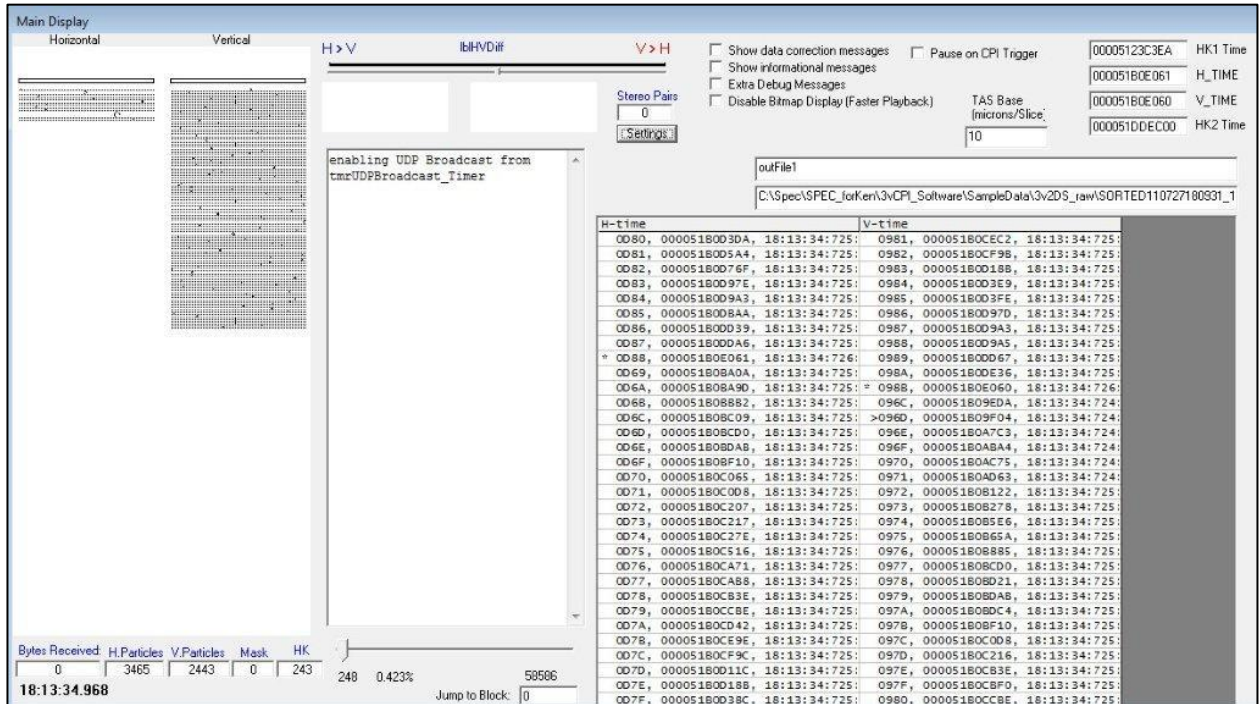
The first two files contain probe housekeeping data in binary and ASCII forms, respectively. These files allow you to obtain the housekeeping data independently of 2D-S view.

- Click the **Yes** button.
- Playback allows you to look at images while pre-processing the data. Select the **Maximum Playback RUN** dropdown menu and choose one of the two options:



- With timestamps – This option is very slow.
- Without timestamps – This option provides the fastest processing.



3V2D-S begins processing the data, as shown below.

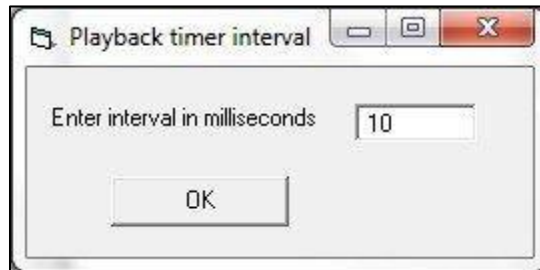




2.1.2.1 The Playback Buttons

The following information describes the playback buttons:




- The Play button  allows you to resume playback if the playback has been paused.
- The Speed button  allows you to set the speed of the playback. When you select the Speed button, the following window is displayed:



- The Pause button  allows you to pause the playback process.
- The Step button  allows you to step through the data, particle by particle.

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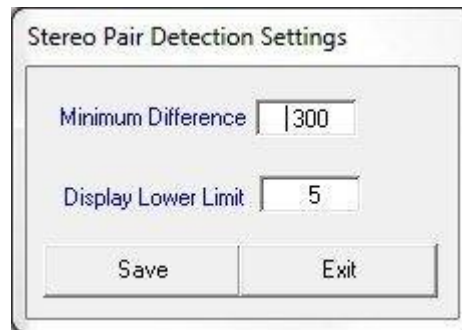
- The Preview Play button  allows you to preview the playback without saving the extracted data to disk.

2.1.2.2 The Stereo Pair Counter

The Stereo Pair counter displays horizontal and vertical particles that arrived at nearly the same time.



Clicking the Settings button displays the Stereo Pair Detection settings window, shown below.



- The Minimum Difference value defines the maximum acceptable difference allowed (in 10 μm slices) between the end points of any two events, one horizontal and one vertical. If they pass this criterion, the images could be stereo and they are displayed.
- If the size of one of those events is larger than the “display lower limit” setting, then Playback will stop upon displaying the images until you indicate to continue again.
- If you have made changes and want to reuse the settings in the future, click the Save button.

Note:

This option is an early attempt at determining stereo particles. It is currently considered obsolete in that more sophisticated determination has been implemented in 2DSview. However, for Quicklook purposes, this option can still be useful, especially if a large value is used for the size discriminator.

2.1.2.3 Masked Diode Filling

During data collection, a diode may become noisy. If the condition is serious enough, the real time software will detect this and mask the diode. This results in a white line running the length of any particle image that includes the masked diode. Examples are shown below.

H > V 947637 V > H

Stereo Pairs

Pixel Histogram Analysis

	Horiz.	Vert.	
103	11375	11650	
104	13147	11632	
105	14573	11898	
106	12852	12126	
107	13310	10437	
108	11692	10437	
109	11778	10566	
110	11863	11374	
111	12209	11718	
112	12457	12087	
113	12310	12153	
114	12005	14226	
115	14168	13294	
116	11680	10337	
117	10918	0	
118	11710	12142	
119	12591	11214	
120	12991	10422	
121	11999	14218	
122	11528	9449	
123	12424	11468	
124	11547	20381	
125	11132	10740	
126	11616	10355	
127	7007	9213	

	Hor.	Ver
Avg/bin:	11928.7	11760.0
Max:	17756	20381
Max Bin:	5	124

Horizontal
 Vertical diode 124
 diode 12
 diode 117

Double-click a cell in the table to cause that pixel to be masked during playback. Masked pixels will show a yellow color in the table. Double-click again to remove the masking. Pixel 0 is the left most column of the sensor, 127 the right most. Displayed setting are "sticky" and will be retained if the program is restarted.

Show Current Count
 Current Time: 11:03:39.531
 Write Data To Disk
 Reset Bin Counts

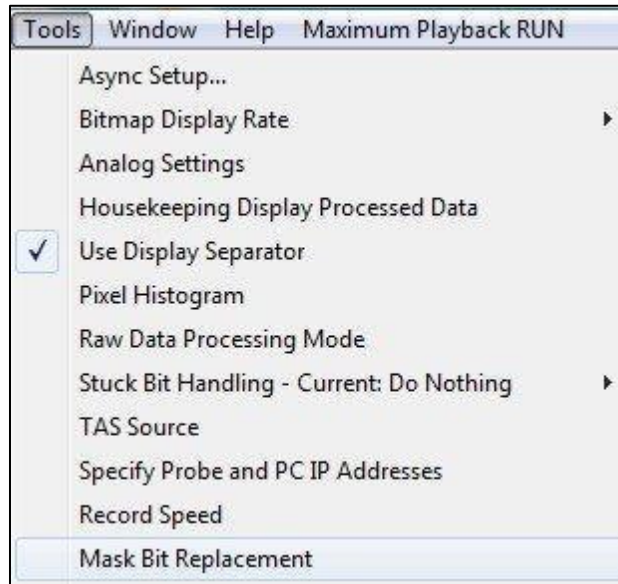
Bytes Received: 0 H.Particles: 27230 V.Particles: 32555 Mask: 0 HK: 88
 11:03:39.531

Filling these artificial white lines is important for the measurement of area, which also affects particle length when sizing corrections are used. It is even more important to fill

masked diodes when they are edge diodes, since that diode is used to determine if an image is complete or not.

Use the following steps to fill these lines within particle images:

1. In the **Menu** bar, select **Tools>Mask Bit Replacement**.



The Mask Bit Recovery Settings window is displayed.

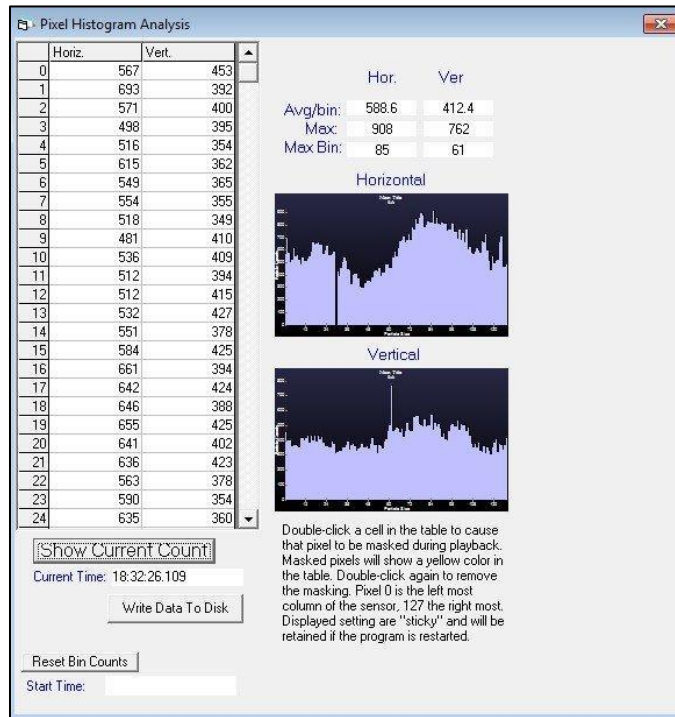


2. In the **Maximum width of mask bits that will be recovered** text box, enter the maximum number of consecutive masked diodes that can be filled. 5 is the recommended value.

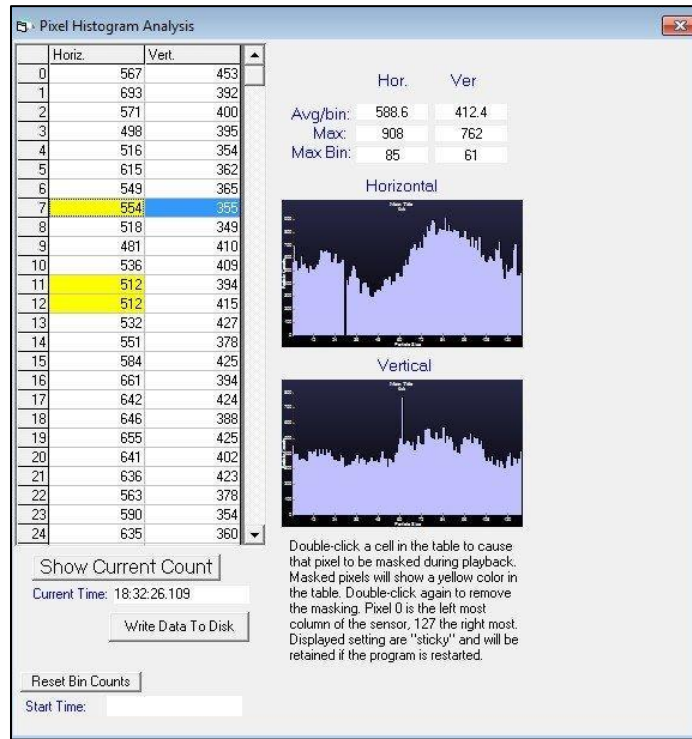
3. Select the **Enable Mask Bit Recovery** checkbox.
4. Click the **Save** button to save these settings.

2.1.2.4 Dead Diode Replacement

Similar to a noisy diode, a dead diode leaves a white line running through particle images. However, the real-time software cannot detect and mask the diode. Therefore, playback has an option to add a diode to the mask during pre-processing. The dead diode must be identified by using the **Pixel Histogram Analysis** window, shown below.



The number of counts each diode has had is displayed. Double clicking a numbered box turns it yellow and indicates that that diode will be considered masked for the next time playback is run.



Adding diodes to the mask is a two-step process:

- First, for the period being processed, you must run playback, monitor the histogram and double click on any diodes that you want added to the mask.
- Second, exit and restart playback.

The clicked boxes remain yellow and will be added to the mask for processing.

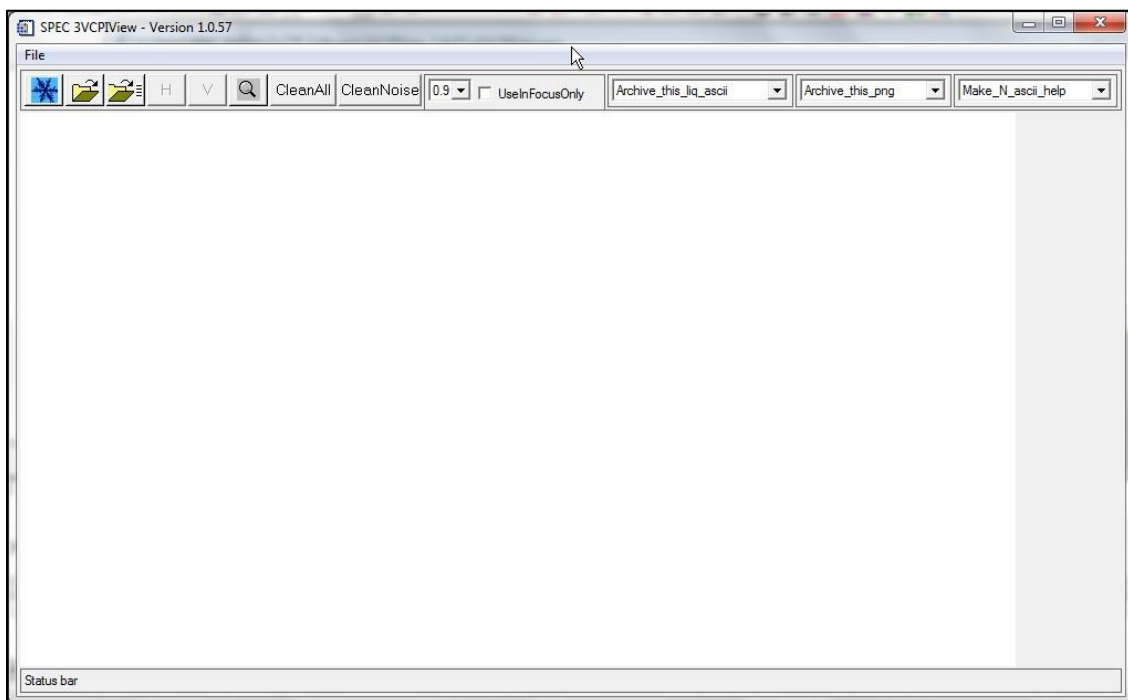
If a noisy diode is not detected and masked during data collection, it may be detected during these same steps and also added to the mask. This can shorten the time needed for 3V2D-Sview to process as it must also remove noisy diode effects.

2.2 3VCPI 2D-Sview: Data Processing

2.2.1 3V2D-Sview Initialization


3V2D-Sview is the 2DS portion of 3VCPIview. 3VCPIview runs on an IDL platform of 6.0 or higher. The projects programs should be stored in a folder called 3VCPIview-version#. To run the 3VCPIview software, follow these steps:

1. Open **IDL**.
2. In the command line at the bottom of the window type: **@compile3vcpi**.
3. Press **Enter**. The following window is displayed.



2.2.2 More Pre-Processing

Before performing quantitative analysis some additional pre-processing steps must be done. First, .BIN files are needed:


1. Click the **left folder** button  in 3V2D-Sview. This displays a list of all the sorted files created during run of either basescan or playback.
2. Select the SORTED file with the desired time interval and click the **Open** button.
3. A status bar in the lower left of the window shows the number of particles counted.
4. Once the file is loaded a window displaying warning messages is displayed. There may be messages regarding time inconsistencies found while processing the sorted file. Usually there are no messages. This window is an indication that this step of processing has completed.

The program will automatically generate the files required. All the .BIN files are placed into a subdirectory labeled Data. This process is only required one time for each sorted file. The program automatically looks in the data subdirectory and uses the appropriate .BIN file if it already exists from a previous run.

Note:

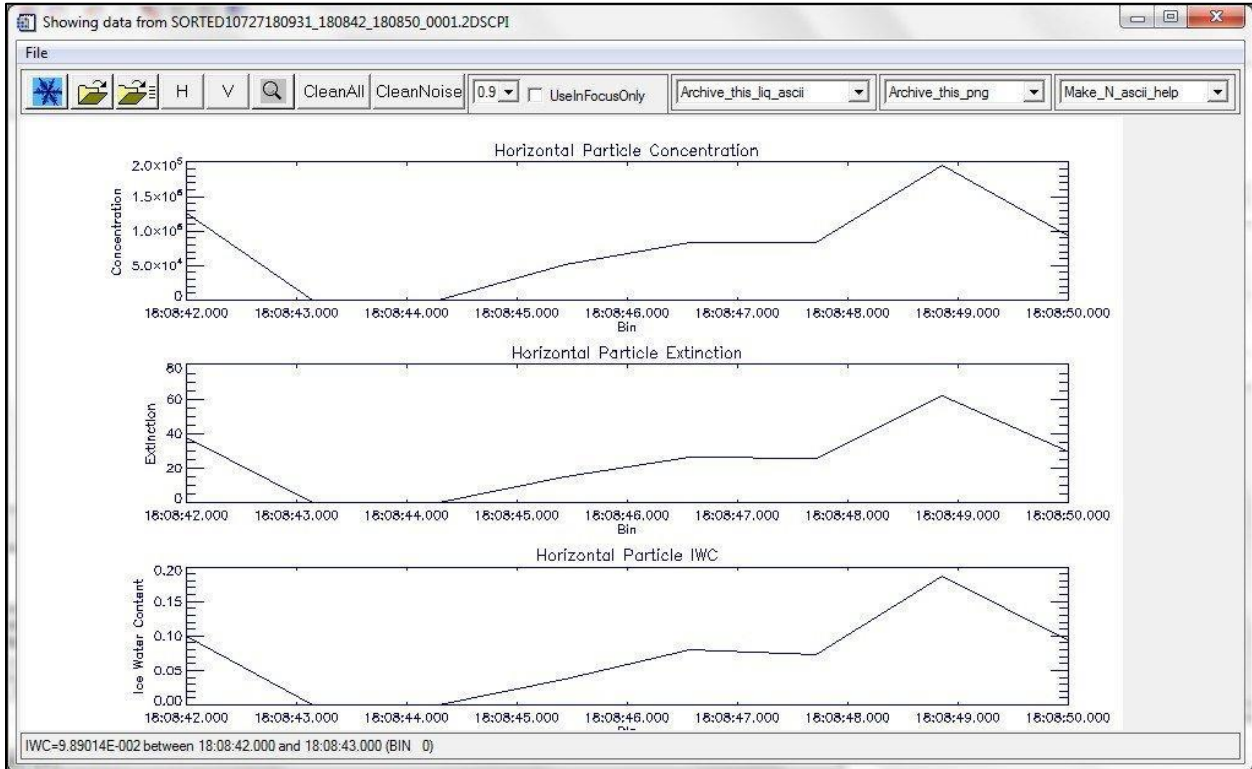
Due to file size, the time to create .BIN files can be quite extensive, but must be done for each SORTED file. This can also be done in batch mode for quicker processing of an entire flight, please see **Section 2.3**

To continue, open a .BIN file:

1. Click the  right folder button.
2. Open the **Data** folder.
3. Select a **.BIN file** for the desired time.
 - Additional 1 Hz data files are created in the data subfolder, if they do not already exist.
 - Several pop-up windows will flash depicting the raw data and the images are automatically saved in the data folder. These auto-saved files are labeled: horiz*.png.
 - The images can be viewed at any point from this point forward. These are created primarily for SPEC programmers
4. A warning message window is displayed showing warnings of idiosyncratic data events. This window is rarely empty but usually has several to a few dozen events.

Once this process is completed, the following three time series are displayed:

- Concentration
- Extinction
- Ice Water Content

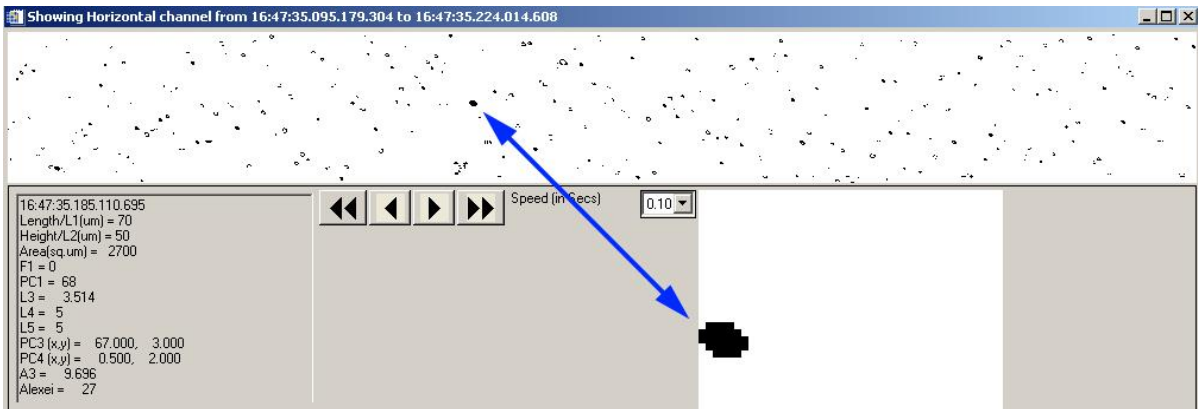


- If the file contains more than 300 seconds, the data is coarsely binned into 300 segments for Quicklook, using the 1 Hz data file that was generated upon opening the .BIN file.
- If the file is less than 300 seconds, then the 1 Hz data is used directly. These 1 Hz data are for Quicklook only. The processing uses a crude length parameter (L1, see Appendix B) and no artifact rejection.
- By default, the horizontal array time series are displayed. The arrays can be switched by clicking on the vertical or horizontal buttons.

2.2.3 Viewing Images

To view the particle images before artifact rejection has been applied:

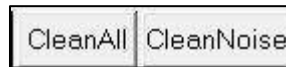
1. Choose the desired vertical or horizontal array via the buttons described above.
2. Move the cursor over any one of the three plots near the time you want to view.
3. Single click. The following window is displayed.



- The arrows buttons are used for changing the time interval. The single arrow button allows you to move the view one strip at a time, either backward or forward. The double arrow buttons allows you to fast forward or rewind the strip.
- The **Speed (in Secs)** dropdown menu controls the length of time each strip is in the window while fast forwarding and rewinding.
- Placing the cursor over a single particle displays the size and other parameters in the lower left hand corner. An enlarged image of the particle is also displayed.

2.2.4 Artifact Removal

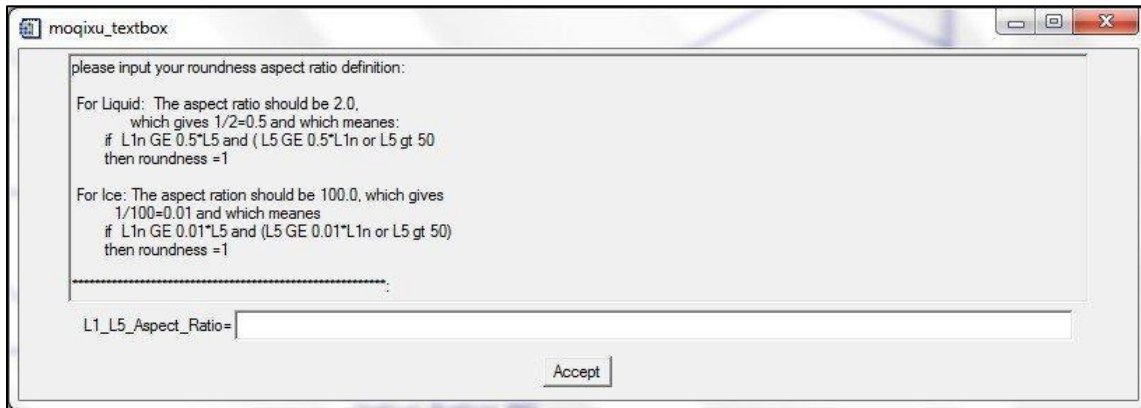
The .BIN files contain all the data captured by the 2D-S Probe. This includes: noise, splashed, and shattered events, as well as valid images. The program has the ability to remove unwanted data. Using the cleaning functions creates concentrated data for the time series and particle size distribution plots. If a cleaning method is not selected, all the images will be used. Before quantitative analysis, there are two options for data filtering:



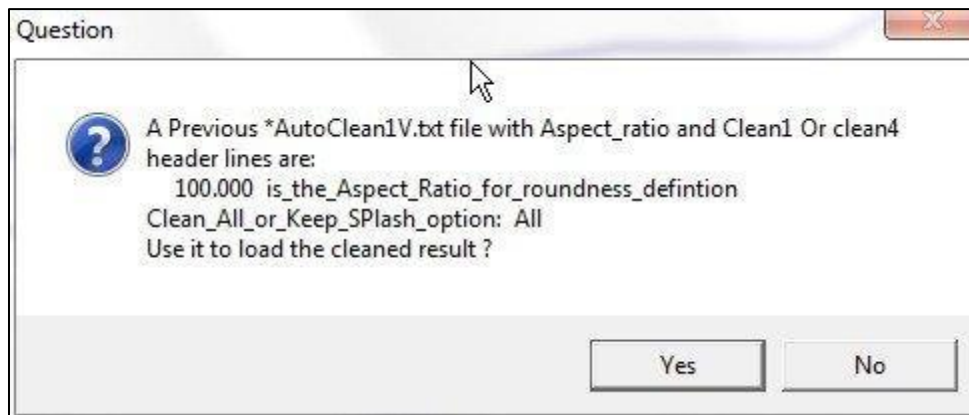
- **Clean all:** Removes noise, shattering, and splashing.
- **Clean noise:** Removes noise only.

To use the cleaning functions:

1. Specify the type of cleaning by clicking either the **CleanAll** button or the **CleanNoise** button on the toolbar. A text box window is displayed.



2. Enter the following information into the **L1_L5_Aspect_Ratio** text box.
 - If the cloud is known to be liquid, enter in 2.0.
 - If the cloud is known to be ice, enter a larger value.
3. Click the **Accept** button.
 - The data is automatically saved in the Data folder that stores the BIN files.
 - If a cleaning function is selected, the program searches for previous cleanings made for each .BIN file. If one is found, you will be prompted with the window shown below.

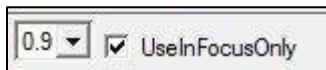


- If the aspect ratio is the same, click the **Yes** button. In doing so, the computer will not have to re-clean the data.

Note:

The program processes each particle individually based on statistics of many surrounding particles; processing large files can take days.

2.2.4.1 In Focus Only



The In Focus Only feature allows for further data filtering, which removes the out-of-focus particles with holes in them. If the area of the hole is greater than the specified size, the particle is eliminated from the data. For example, if 0.9 is the selected criteria, then only those images with holes having less than 10% of the total area will be used in the process.


To use the In Focus Only Feature:

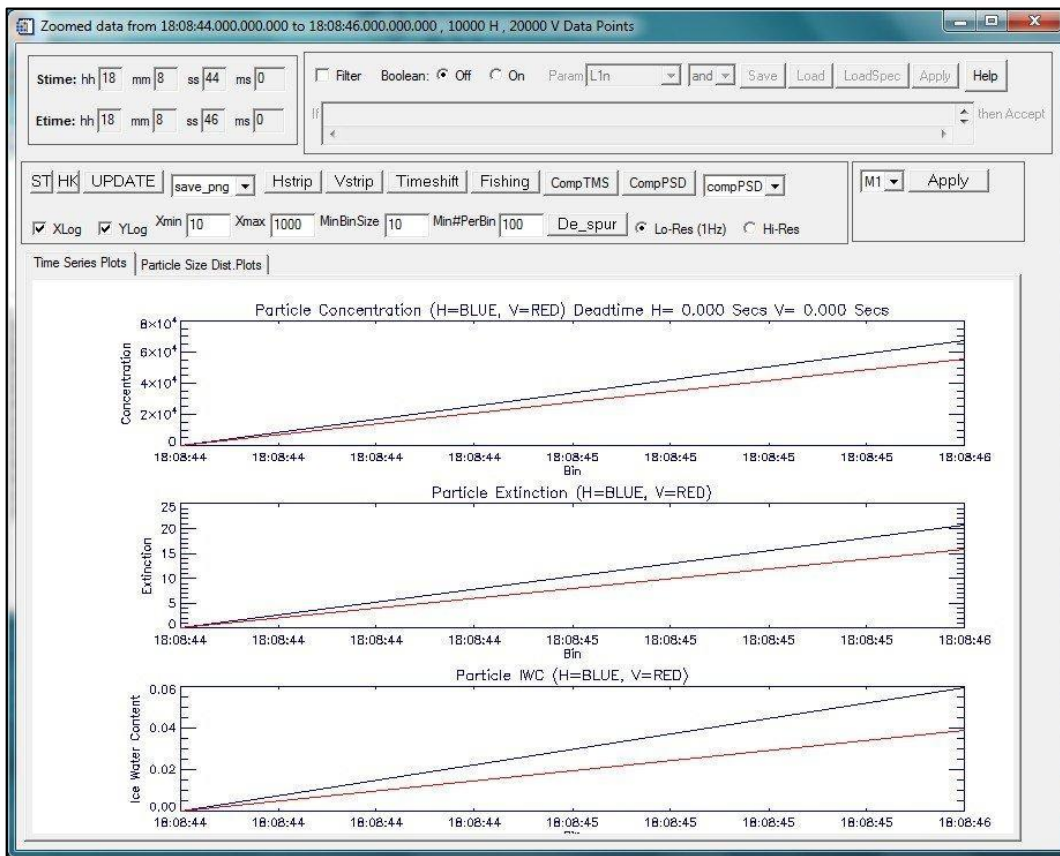
1. Select the **UseInFocusOnly** checkbox on the toolbar.
2. In the dropdown menu, select a value (**0.9, 0.8, 0.7**).
3. Continue to section 2.2.5.

2.2.5 Time Series and Particle Size Distribution (PSD) Plots

2.2.5.1 Zooming into a Time Interval

This process creates a smaller time interval, which significantly reduces subsequent processing time.

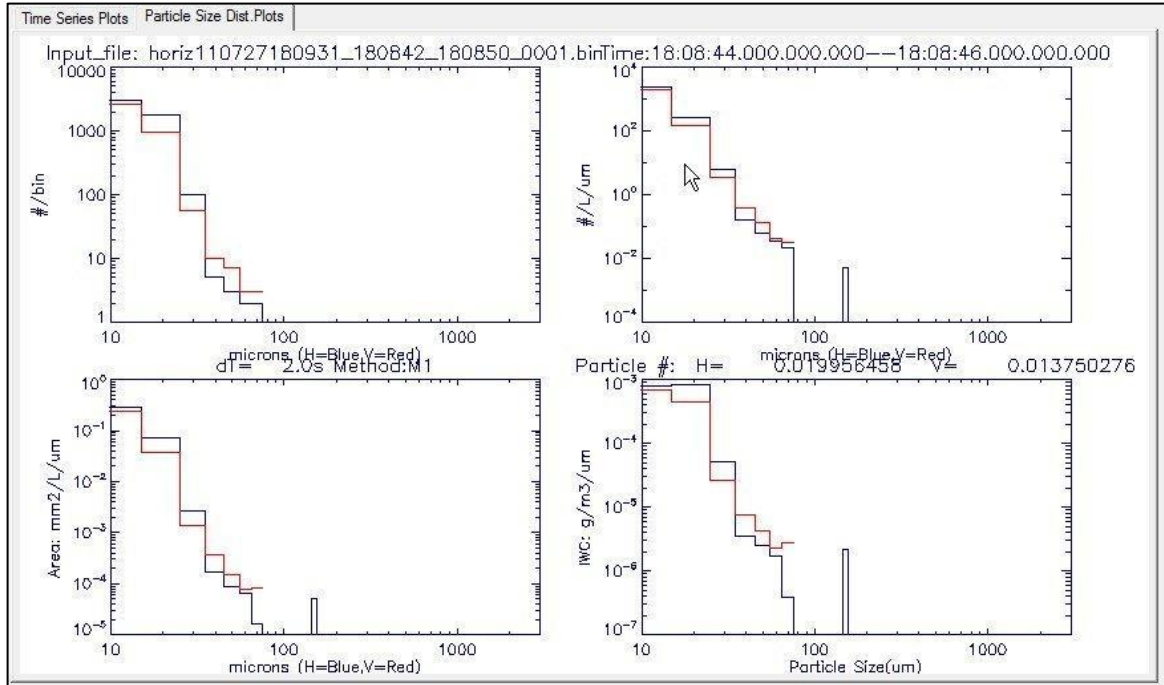
1. Click on the magnifying glass button .
2. Click once near the desired start time in any of the three time series.
3. Click a second time near the desired end time for analysis. The Zoomed Data window is displayed.



Similar to the previous window, this window displays concentration, extinction, and ice water content, read from the 1 Hz data file, on single time series plots (both H and V are shown simultaneously here).

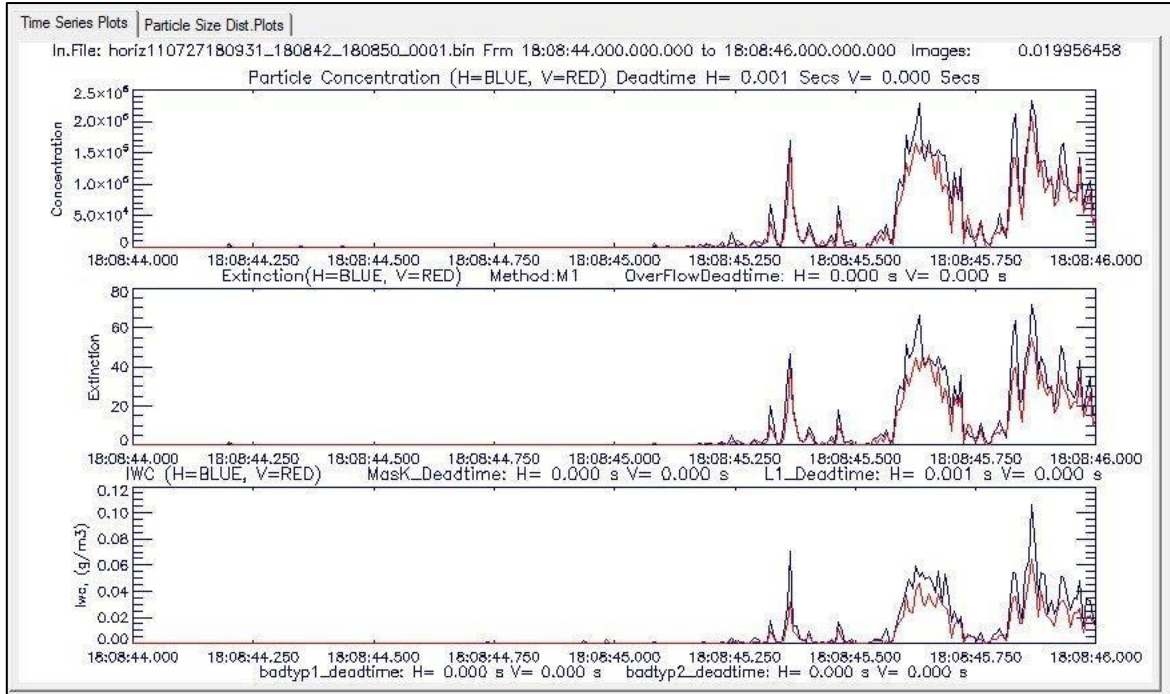
Additional Information

- PSDs are plotted as well. To view them, click on the **Particle Size Dist. Plots** tab. These are also crude Quicklook products using 1Hz data files. The zoomed-in data window allows for a much more in-depth data analysis.



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- In order to best utilize the analysis options in the window, select **Hi-Res**, and click the **UPDATE** button. Rather than the 1 Hz data, the higher resolution data will be used in further calculations.



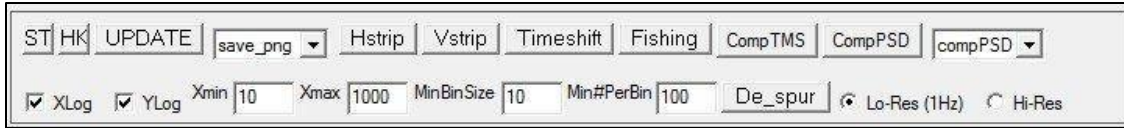
- The start and end times can be changed by typing new time values in the **Stime** and **Etime** boxes and clicking the **UPDATE** button.
- To save any time series or PSD plot as an image, select the **Save_png** option in the dropdown menu. To save the plot as an ASCII file, select the **Save_ascii** option. To print a plot, select the **Print** option.



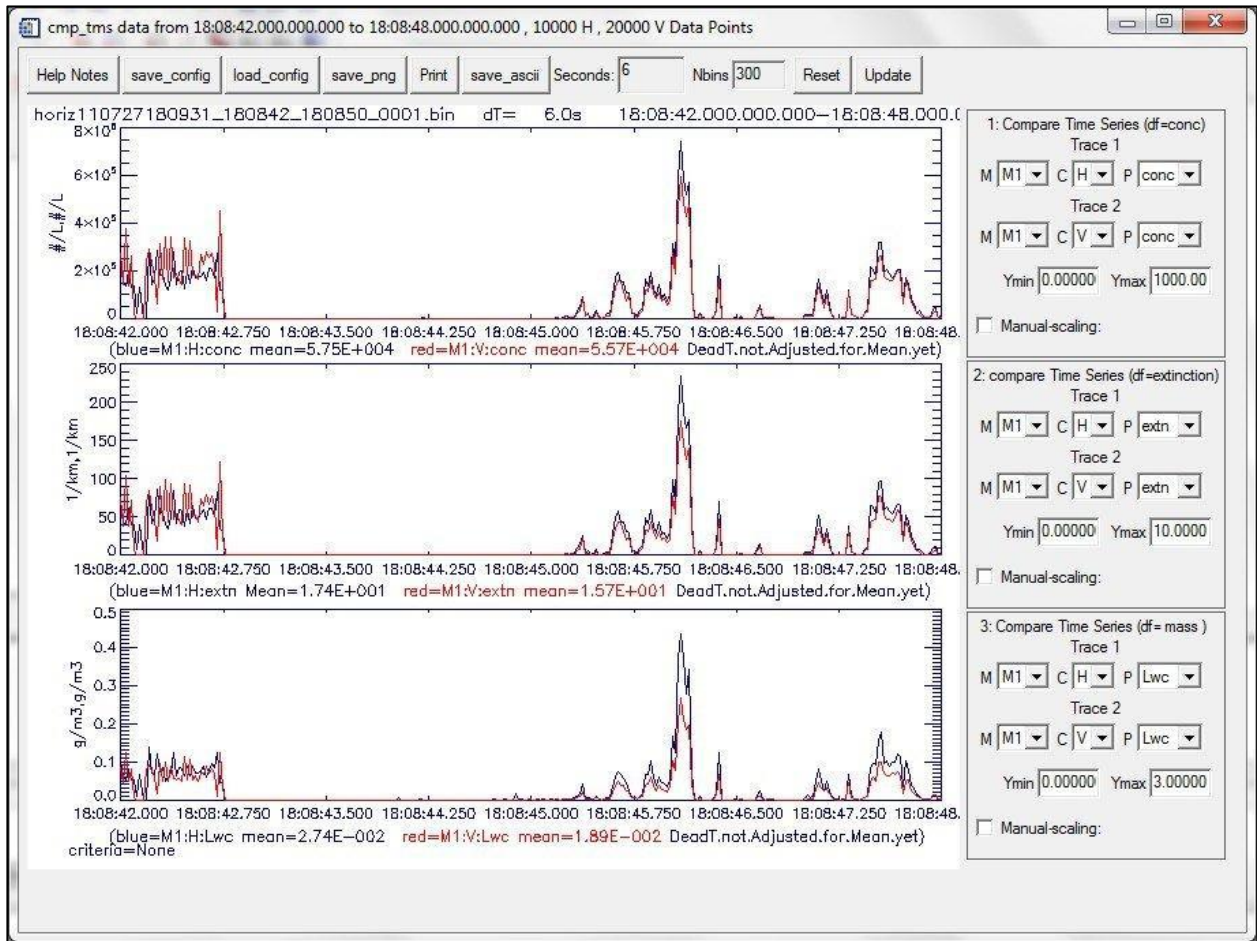
- The ST button **ST** is for displaying stereo images, which is currently not used.
- The HK button **HK** is for displaying the Housekeeping data. This data is used primarily by SPEC Inc.

2.2.5.2 Comparing Time Series

CompTMS Button



Use the CompTMS button to compare time series parameters. In this window, different sizing methods, arrays, and parameters can be plotted and compared. Sizing methods are described in Appendix A. ASCII and image files can be saved from this window.

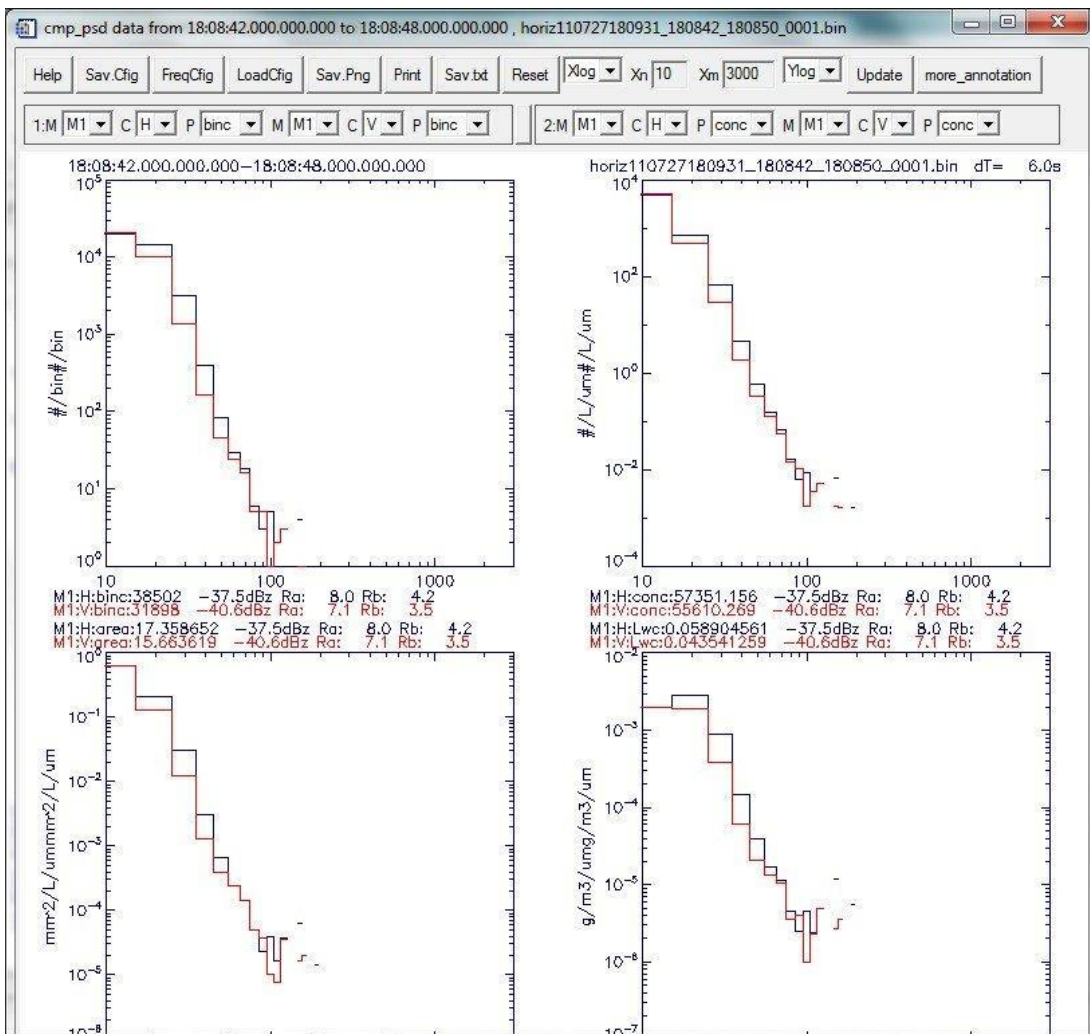


2.2.5.3 Comparing Size Distributions

CompPSD Button



Use the **CompPSD** button to compare particle size distributions. In this window, different sizing methods, arrays, and parameters can be chosen, plotted and compared. Sizing methods are described in Appendix B. There are four plotting windows, with two parameters plotted in each. To change a plot, choose the sizing method (M1-M6) from the **M** dropdown menu, the channel (H or V) from the **C** dropdown menu, and the parameter to be plotted (average values of counts, concentration, extinction, and ice water content) from the **P** dropdown menu. Do this for the two parameters of each plot, then click the **UPDATE** button to refresh the plots.



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2.2.5.4 Viewing the 2D-S Images from a Selected Time Interval



1. In the zoomed data window, select the **Filter** checkbox, if accepted images only are desired (for both display and processing).

Unselect the **Filter** checkbox to process and display all of the accepted and rejected images. Rejected images will be highlighted with a yellow background.

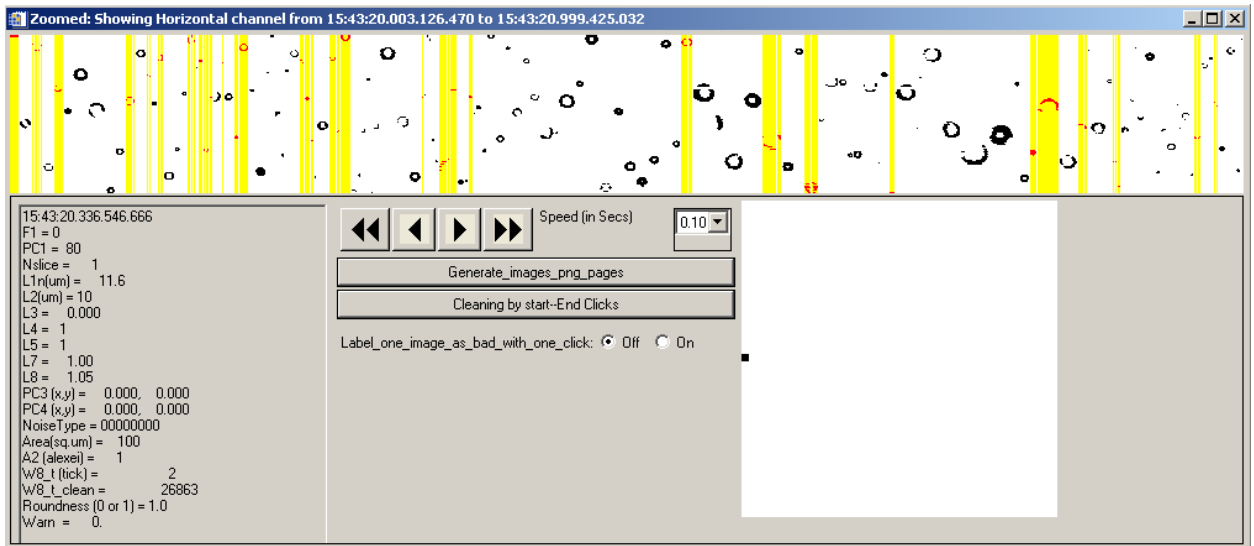
2. Click the desired **Hstrip** or **Vstrip** button.



If the filter box is not checked, images will be displayed including:

- Accepted particles
- Noise
- Splashes
- Shatters

The rejected images are red and are highlighted in yellow, as shown below.

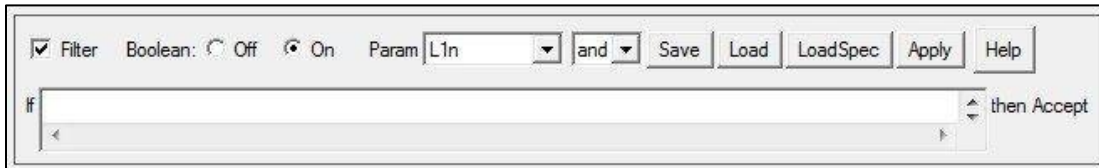


2.2.5.5 Additional Information

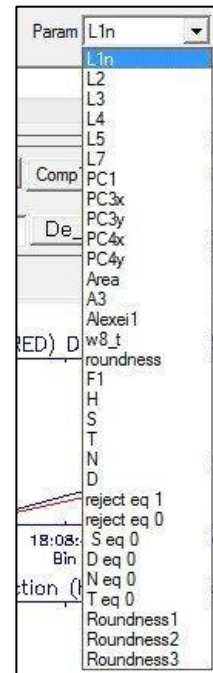
- The window shown above has the same functionality as described in the Viewing Images section.
- Clicking the **Generate_images_png_pages** button saves pages of images displayed on the computer screen to the data/png directory.
- The **Cleaning by start-End Clicks** button and **Label_one_image_as_bad_with_one_click Off/On** radio button are for manually removing bad images or noise, if the auto-cleaning method doesn't work completely.
- The **Timeshift**, **Fishing**, and **De_spur** buttons are used inside SPEC INC. for development and automatic removal of noise, splashes and shattering.

2.2.5.6 Boolean Filtering

The Boolean feature allows for further sub setting of data. It is possible to filter out particles based on size, location, and various other parameters. To use Boolean filtering:



1. From the Zoomed Data window select the **Boolean On** button.
2. Specify the **filtering parameter** from the dropdown menu.



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3. Use **Boolean** logic from the dropdown menu to add filter conditions.



- 4. If using numerical values, insert a space between the logic and numerical value.
- 5. Press the **UPDATE** button.

The IDL syntax for the Boolean symbols is defined below:

IDL Syntax	English Equivalent
and	And
or	Or
not	Not
eq	Equal to
ne	Not equal to
ge	Greater than or equal to
gt	Greater than
le	Less than or equal to
lt	Less than
*	Multiply
+	Addition
-	Subtraction
()	Used for order of operations

Example:

If you enter **L1n gt 10**, select the **Filter** checkbox and click the **Update** button. Only those accepted and rejected particles with size “L1n greater than 10 pixels” will be selected and displayed in the H-strip and V-strip fields. They will also be used to make the time series and PSD plots.

2.3 2D-S Data Batch Processing (Archiving)

2.3.1 Introduction

After many split sorted files are generated the data can be processed in batch mode, allowing the computer to run over night. When processing batches, all the SORTED files are converted to .BIN files and an All Clean filter is applied to them. This allows large quantities of data to be processed and filtered for use at a later date.

Batch processing is done in Ice mode.

2.3.2 Batch Processing

Archiving ASCII Files

1. Get IDL started. The initial window is displayed.
2. Open an **IDL source file**.
3. Type **@compile3VCPI** in the IDL command line, which calls up the 3VCPIview program.
4. Select **archive_multi_Ice_ascii** from the dropdown menu. A dialog window is displayed for you to select an input file of type Sorted*.2DS.
5. Navigate to the directory containing the raw data file and newly created SORTED*.2ds file that requires processing.
6. Select one of the sorted files and then click **Open**.
7. Press the **Accept** button.
8. Return to the IDL main window. All of the files for overnight processing are displayed.

The sorted files are processed one at a time in order. Some initial plots and warning messages are displayed, saved, and deleted. The progress is displayed in the status bar in the bottom of the 3V2DSview window (see example below). The IDL standard output screen will also print out some of the steps the archiving process has reached.

```
W8_t Autoclean1...V      115000 of  828565
-----
End of third loop----true ave_w8_t calculation H:\Wed Jun 10 12:52:04 2009
Wed Jun 10 12:52:04 2009nrm=    30
Done H channel Cleaning All****
Wed Jun 10 12:52:04 2009nrm=   891888
Begin w8_t_temp calculation*****\Wed Jun 10 12:52:14 2009
end w8_t_temp calculation*****\Wed Jun 10 12:52:14 2009
```

For example, the status bar shown above gives the following information:

- The V-channel automatic noise removal is being used.
- Of the 828565 images, it has examined 115000 particles.
- The end of the third loop noise removal process for the H channel was done at time: Wed Jun 10, 12:52:04 2009.

Additional Notes:

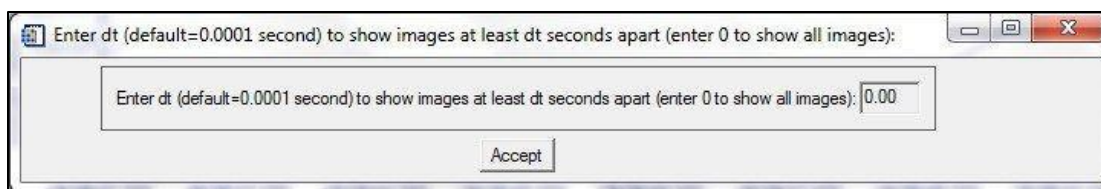
- As each SORTED**.2DS file is processed, many files are generated and saved in a sub-directory labeled data1, data2, data3, etc. in the directory where the original SORTED***.2DS files are stored.
- These files are initial plots of the file, warning messages encountered when loading the data file, the auto-clean results and the horiz***.BIN and vert**.BIN files.
- The most important two files are H_archive_2DS****_xxxx_Ns.txt and V_archive_2DS****_xxxx_Ns.txt. They are located under each data1, data2, data3 and etc. These two files contain the 1Hz concentration, extinction, ice water content, times series and particle size distributions. The header lines contain the detail data format of the archived file.

2.3.2.1 Archiving Images

After H_archive_2DS_***Ns.txt and V_archive_2DS_***Ns.txt 1Hz archive files are generated for each sorted***.2DS file, the 2dsview software can be used on the data. To archive the images:



1. Select **Archive_Multi_Ice_png** from the .png dropdown menu.
2. In the popup window, enter the desired number of images per second and press **Accept**.



The images are saved in the png subdirectory under the corresponding data1, data2, data3, etc. folders.

2.3.2.2 Combining the Archived Ice ASCII Files

To combine all the smaller archive files into a single data file for the whole flight, a separate IDL program is used. To combine all ASCII files follow these steps:

1. Copy all **H_archive_2DS**_Ns.txt** into one folder or directory.
2. Start **IDL**.
3. Select **File>Open>(Find2dsview_ver#)>combine_archive_TC4_Steve_gains_of_61BINs_HorV.pro**.
4. Click **Run>Compilecombine_archive_TC4_Steve_gains_of_61BINs_HorV.pro (Ctrl+F5)**.
5. Click **Run>Run combine_archive_TC4_Steve_gains_of_61BINs_HorV.pro (F5)**.
6. Select the **H** button or the **V** button, which determines whether horizontal or vertical files are being combined.

7. Go to the directory containing the files and select a file.
8. In the IDL command line type **y** and then press **Enter**.

All the H_archive_2DS_***.Ns.txt files are read and combined in a single archive file and saved in the same directory as the smaller archive files.

2.3.2.3 *Additional Notes*

- To batch archive with the noise only clean option, select **archive_multi_Ice_ascii_WS** from the dropdown menu and follow the same instructions as above.
- To do batch archiving without removing noise, select **archive_multi_Ice_ascii_NC** from the dropdown menu and follow the same instructions above.
- Selecting the **Archive_this_Ice_ascii** or **archive_this_Ice_png** in the initial zoomed window archives only the currently loaded data file in whatever cleaning state the data is in. If it has been cleaned, it will archive it using only the accepted images. If it has not been cleaned, it will use all images.
- The **make_multi_pbyp_asciis** option is a spare button for future use and it currently has no function.
- Clicking any of the “Make_N_ascii_Liq”, “Make_N_ascii_ice”, “Make_N_ascii_Liq_WS”, “Make_N_ascii_ice_WS”, “Make_N_ascii_NC” will batch generate many zoomed***.txt ascii files that contain information of each particle, in each line for users to do their own data processing and analysis.

3 Hawkeye FCDP Data Processing

3.1 Instructions

3.1.1 Raw Data Files

The Hawkeye FCDP produces five output files:

- ***scat.bin** contains the main particle by particle data.
- ***sig.bin** and ***qual.bin** contain the full signal and qualifier waveforms for selected events.
- ***hk.txt** contains 1 Hz housekeeping data.
- ***log.txt**.

Note:

* stands for yymmddhhmmss, the date and time of the first data record in the file.

In addition, the true air speed (TAS) is also required for processing. Typically the TAS can be acquired from an independent data file at 1 Hz. To integrate the TAS with the FCDP data, you must create an ASCII text file with the name ***TAS.txt** and place it into the folder with the FCDP data files. The software will automatically look for this file to read. The file has two columns, space separated:

- The first column contains the number of seconds since midnight of the day the file was started.
- The second column contains the TAS in m/s.

3.1.2 Standard Processing

The raw files needed for standard processing, which creates 1 Hz ASCII archive files, are the ***scat.bin** and ***hk.txt** files. Standard processing is performed in Matlab.

1. Edit the setup_options.m options file.

The following table shows the parameters that must be set.

Table 1 Parameters for the setup_options.m options file. Bold values are the recommended options. Add '_NB' to the probe_type string (e.g. FCDP_NB) to use smooth binning that ignores the Mie bumps.		
Set Parameter	Values	Description
probe_type	F_CDP	Sets type of probe data being processed.
SH_method	adaptive2 , none, ...	Sets shattering reduction method.
use_constant_TAS	Y, N	If 'y' a fix default TAS will be used.
default_TAS	15000	TAS used if 'use_constant_TAS' = 'y'
project	ICE-T, SPARTICUS	Sets the project the data is from.
noise_string	Boolean logic strings	Sets the logic used to reduce noise.
agg_cut_thresh	25000	Used in shattering removal algorithms.
tt_method	via size , old way, ...	Method of rejection based on transit times
TAS_method	set	Sets the method of obtaining the TAS.
remuv_noise	Y, N	Sets whether noise reduction is employed.
show_plots	Y, N	Sets whether plots are generated or not.
fishit	Y, N	Fishing statistic plots are generated or not.

2. Run Main_rewrite_dars_scabin_into_pbp_format_v#.m.

This produces two additional quasi raw data files (*scatPBP.bin and *scatPBPindex.bin) for subsequent processing. This step is slow, but allows subsequent quick access to the data.

After the above processing, there are several options:

Option 1 – The default option, and direct path to a 1 Hz archive file, is to run 'Main_make_Fast_Fssp_1Hz_archive_file_v#.m'.

- This program prompts you to choose the *scatPBPindex.bin created by the previous step.
- It also prompts you to open a TAS file.
Since the TAS is not recorded in the FCDP data files, you must provide the TAS as recorded in an independent aircraft data file.
- A fixed TAS may also be set when processing bench test data or bead calibrations.

WARNING!

THE STANDARD PROCESSING ALGORITHMS WILL NOT PERFORM WELL IF THE TAS IS NOT ACCURATE!

- As stated previously, to integrate the TAS with the FCDP data, you must create an ASCII TAS file with the name *TAS.txt and put it with the FCDP data files. The software will automatically look for this file.

The file format is two columns, space separated. The first column contains the number of seconds since midnight of the day the file was started. The second column contains the TAS in m/s.

- After running 'Main_make_Fast_Fssp_1Hz_archive_file_v#.m', the archive file is created in the 'results' subdirectory, which is in the folder containing the data.

To improve statistics, the archive contains the sample volume for each second so that the data may be averaged (sample volume weighted average) over longer periods. The number of counts in each size bin, and in total, is provided to guide you in such averaging. The format of the file is shown below in Table 2.

Column	Name	Unit	Description
1	Second	seconds of the day	time mark
2	conc(#/L)	#/L	Concentration
3	extn(1/km)	1/km	extinction
4	lwc(mg/L)	g/m ³	liquid water content
5	SV(Liter)	Liters	volume sampled
6	totCNTs	number	number of events accepted for sizing
7 - 27	Bin(#/L/um)##	#/L/micron	bin concentrations
28 - 48	NBin##	number	bin counts

- The 1 Hz archive file is the main access to the processed data. However, to quality control the data processing and for bench test and calibration processing another route is more practical (see Options 2 and 3).

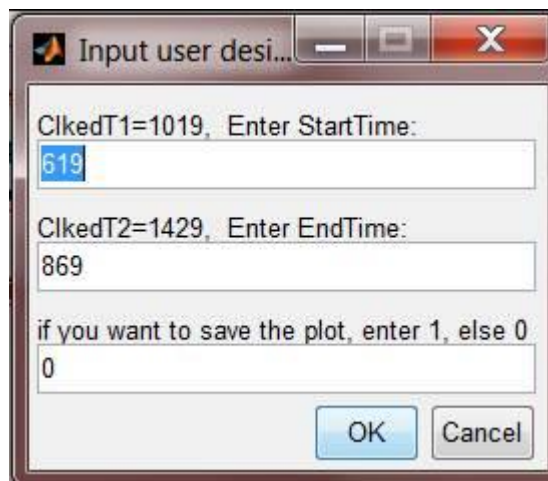
Note:

It is imperative that you verify that the processing is accurate using this option before batch processing. In particular, check that the transit time/size relationship is working well so that the desired subset of events are being selected by the transit time qualification steps.

Option 2 – To learn the time period contained in a data file and approximately the number of detection events each second, run 'Main_quicklook_Particle_per_second_TMS_v#.m'.

1. When prompted, first answer 'yes' then 'no'. A plot is created.
2. Choose a sub period to zoom into for a second figure.
3. You may run 'Main_quicklook_Particle_per_second_TMS_v#.m' again, answering 'no' then 'yes' to zoom in further on the current plot.
4. Take note of the seconds of flight (or since file start) values of the start and end of the period you want to process.

The following window shows the start and end time (in seconds since file start) of the period to be zoomed.



Option 3 – A selected time period may be processed, using the same core algorithm as used in the standard archive file processing described above, while making various diagnostic plots at each step of the processing.

1. Edit 'Main_GenFSSP_PBP_rawData_frm_T1_to_T2_v#.m', inserting the start and end times of the period into the variables 'Time1' and 'Time2' (currently lines 37 and 38).

2. Run 'Main_GenFSSP_PBP_rawData_frm_T1_to_T2_v#.m', which creates '*_frm_#_to_#_PBP.txt'.
3. Run 'input_file_from_parcel_periods_rv#.m', inputting the '*_frm_#_to_#_PBP.txt' file when prompted.
4. Run 'process_standard_period_rv#.m', which creates the plots and the final PSD in a variable called 'PSD_B'.

Note:

The setup option parameters shown in Table 1 may be set again in 'input_file_from_parcel_periods_rv#.m'. In particular, 'show_plots' must be set to 'y' to produce figures.

If set, the following 15 figures are created at the start and after each of the five processing steps:

- A distribution of transit times.
- A size distribution where each particle is assigned a size linearly interpolated across the standard bins.
- A distribution of the peak signal voltages.
- A distribution of the peak qualifier voltages.
- A distribution of the areas under the signal voltage curves (signal area, i.e. the sum of the discrete voltages).
- A distribution of the half peak transit times (time from event start to signal peak).
- Scatter plot of half peak transit times versus transit times.
- Scatter plot of signal area versus signal peak.
- Scatter plot of transit times versus signal peaks.
- Scatter plot of transit times versus sizes.
- Scatter plot of the square of the quantity half peak transit times TAS versus the logarithm of the squared sizes.
- Two plots of the distribution of times between particle detection events.
- A particle size distribution.
- If the variable 'fishit' is set to 'y', a plot of the fishing statistic.

3.1.3 Calibration Processing

Calibration using glass bead data of various sizes is accomplished by using `calibrate_glass2water_v#.m`.

- The bead data must be processed.
- For bead data, manually set the TAS setup options file so that the desired events are selected at the transit time qualification step.
- For each set of bead data of a given size, a peak voltage must be identified. This is accomplished by using the signal distribution plots at the various stages of processing. A recognizable peak in the distribution must be identified.
 - Matlab's curve fitting options can be helpful for identifying the peak value on these histogram style plots. Use the following options in `input_file_from_parcel_periods_rv#.m` for calibrating bead data processing:
 - `remuv_noise = 'n'`
 - `fishit = 'n'`
 - `SH_method = 'none'`
- In '`calibrate_glass2water_v#.m`', the bead sizes and signal peak values are written into the variables `x_gmeas` and `y_gmeas`, respectively.
- Also, the variable 'probe' must be set to the correct value, 'F_CDP'.

The `calibrate_glass2water_v#.m` program creates a calibration plot, as shown in Figure 1, and an output 'calibration_results.txt' file contains the results for bin edge maximums. The output is displayed in a six column format:

- 1st and 4th columns in microns
- 2nd and 5th columns in voltages
- 3rd and 6th columns in A-to-D counts

These data are used in the real time configuration file and in the post processing 'sizepbp_rv#.m' file. Two options are created:

- The first three columns are found by using the Mie bumps to choose the bin edges.
- The final three columns are found using the quadratic fit to the Mie curve with evenly spaced bins.

Appendix E discusses the motivation for using the latter, though Mie theory does apply.

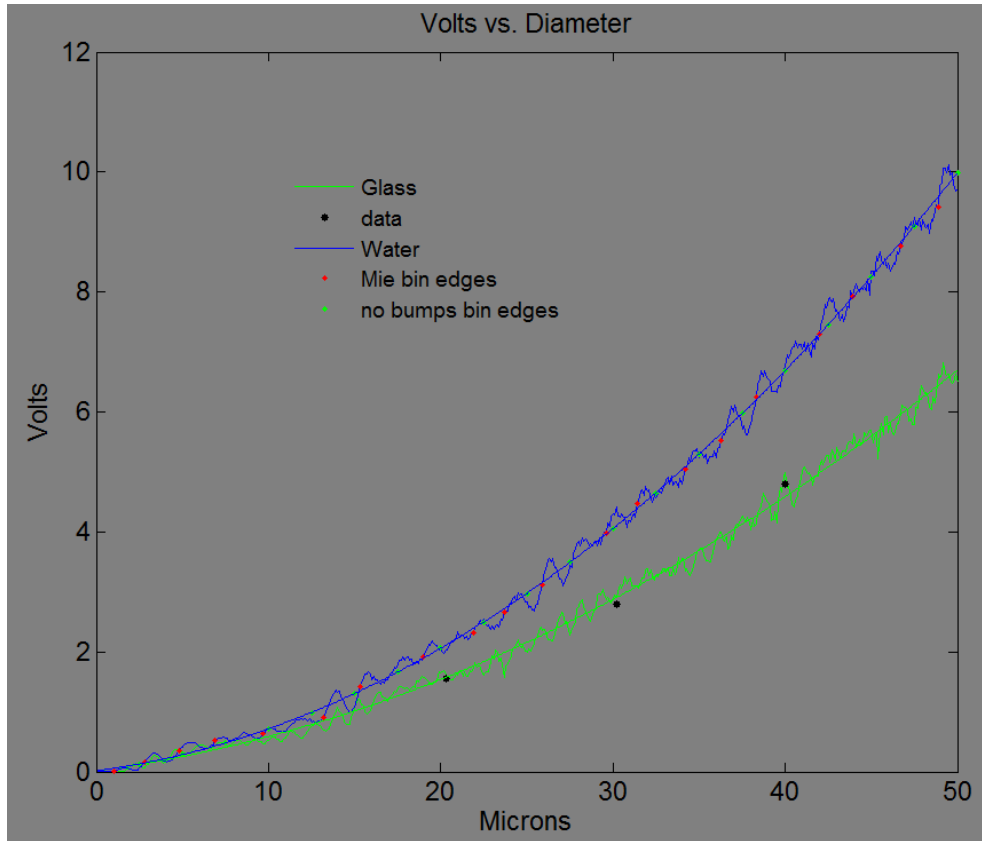


Figure 1

Voltage versus diameter (microns) for water (blue) and glass (green) sphere Mie curves where both have been adjusted by the same multiplicative value, determined to fit the glass curve to the data (black dots) using equal weighting for each data point (the straight average of the adjustment ratio for each point). Also shown are the quadratic fits to the Mie curves. The glass one is used for the fitting, rather than the actual bumpy Mie curve, while the water curve fit is used for the evenly spaced bin edges.

Other calibration factors are needed to calculate the sample volume, namely the Depth of Field (DOF) and Beam Width (BW).

- The BW is also needed for ideal transit time estimates.
 - These are set near the start of 'process_standard_period_rv#.m'.
 - For situations where they differ, a BW for calculating sample volume (BW_SV) is set independently of BW_tt, which is used for transit time estimations.
- Both the BW and DOF may be estimated in the lab.
- The effective product of the two, the sample area, can also be estimated via modeling the optical system.

- For the FFSSP, the BW_tt can also be estimated from droplet data via the relationship between transit times, TAS, BW_tt and droplet size (see Section 3.2.3 on transit time rejection).

3.2 Description of Algorithms and Examples

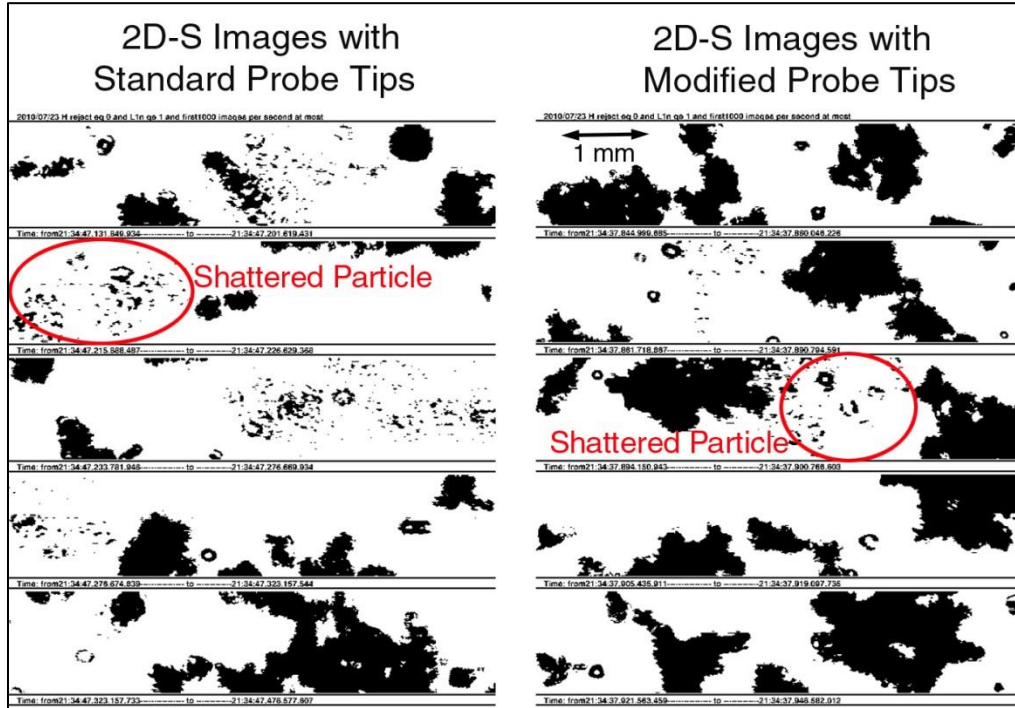
3.2.1 Overview

Processing takes four main steps:

- Noise reduction and DOF qualification
Noise reduction (thresholding the signal and/or transit times) and DOF qualification (signal > qual for the SFFSSP, signal < qual for the F_CDP) are straight forward.
- Shattering reduction
Shattering reduction is also straight forward, but not generally standard, so it will be described in Section 3.2.2, with some examples.
- Transit time qualification
Our transit time qualification is new, non-standard, and makes a significant difference to the results. It will be described in Section 3.2.3, with examples.

3.2.2 Shattering Reduction

When a drop or crystal impacts and shatters, it creates a clump of fragments that may move through the sample volume. The image below shows example images of shattered fragments from the 2D-S imaging probe.



- **Low Density Cloud**

In a low density cloud, these fragments are more closely spaced than the natural particles, and thus can be identified and removed based on their spacing, as long as two or more fragments are detected from a given shattering event. That is, if a particle's nearest neighbor is closer than a specified cutoff, the particle is rejected. The rare natural particles that are removed by this criterion are accounted for by using standard statistics.

- **High Density Cloud**

In a high density cloud, the natural particle spacing can be similar to the shattered fragment spacing, and thus the spurious fragments cannot be removed this way (if the fragments are moving slow enough relative to the air speed through the probe, they may be removed using the transit time qualification). However, in this case the effect of shattering is small compared to the natural concentration. To optimize shattering removal versus retaining real particles with varying concentrations, the cutoff distance for rejection is varied. The maximum cutoff is set at 25,000 clock ticks (625 us) or about 10 cm at the typical jet true air speed (TAS) of 160 m/s. This is based on 2D-S images of

shattering events and on the results of applying the fishing test to the droplet spacing data (Fig. 2).

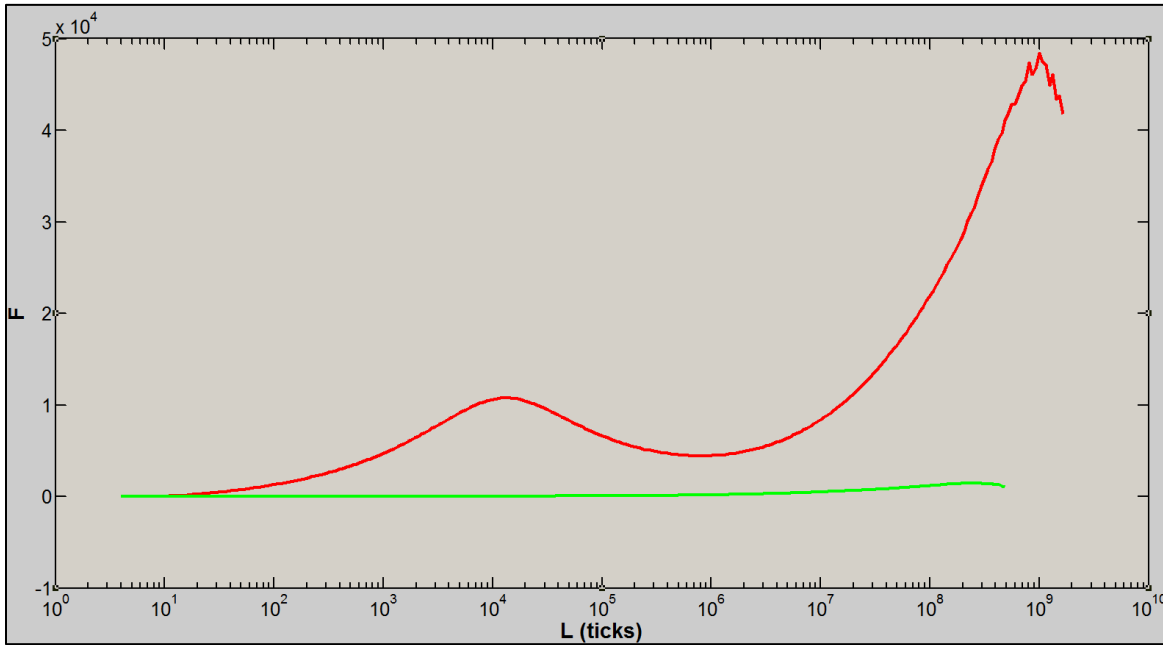


Figure 2. The results of the fishing test applied just before (red) and after (green) the shattering removal processing step. The data are from a period of large ice aggregates from 21:34:18–21:37:16UTC on 23 July 2010 (SPARTICUS).

Figure 2 shows the fishing before test and after the shattering reduction step. The peak at about 12,500 ticks before shattering reduction indicates that there are clumps of particles on a scale of about 25,000 ticks, or in this case, 10 cm. The reduction in that same peak after shattering reduction indicates a significant shattering reduction effect has been achieved. The distribution of inter-arrival times before and after shattering reduction (Fig. 3) also demonstrates the effect that has been achieved.

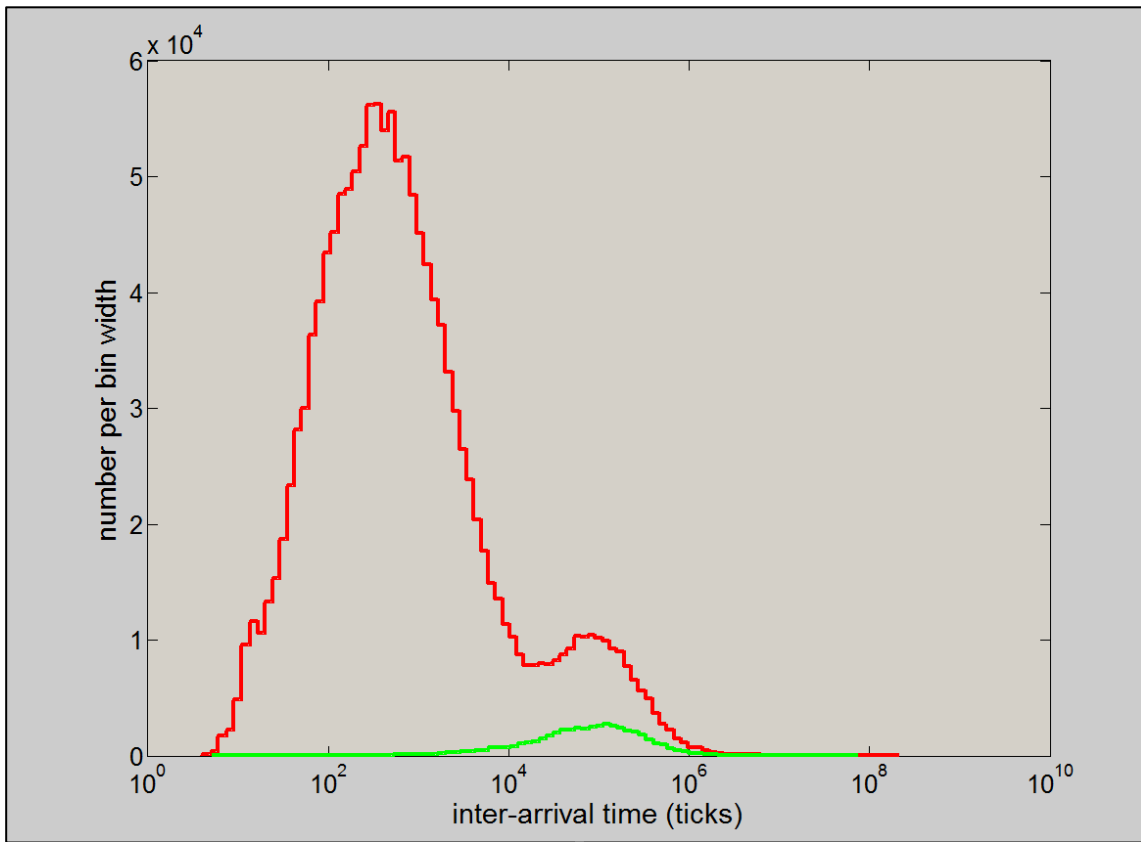


Figure 3. The inter-arrival time distributions before (red) and after (green) the shattering removal processing step. The data are from a period of large ice aggregates from 21:34:18–21:37:16UTC on 23 July 2010 (SPARTICUS).

While acknowledging that significant reduction in the effects of shattering is achieved here (Fig. 4), it is important to emphasize, especially in cases such as this where the majority of detection events are rejected as shatter fragments, that the remaining events may still be partially or entirely shatter fragments that were not removed. For example, if only one fragment passed through the sample.

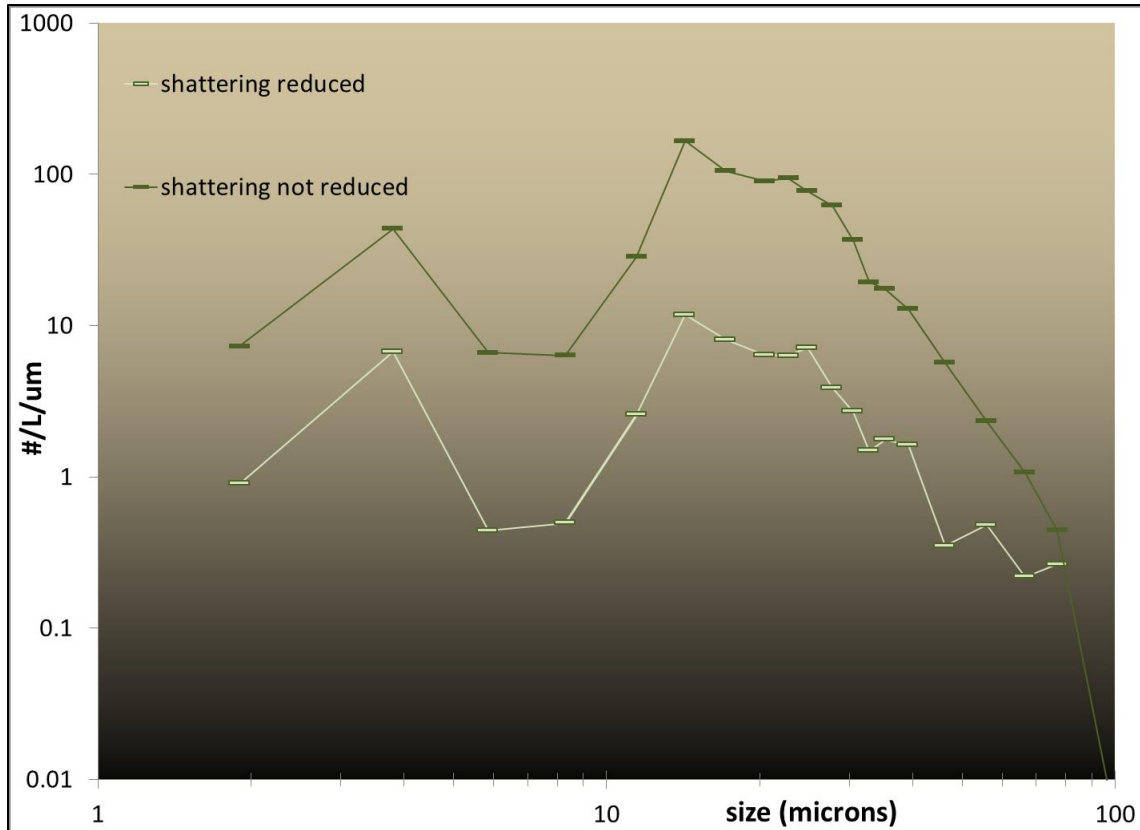


Figure 4. The final PSD produced with and without using the shattering reduction processing step. The data are from a period of large ice aggregates from 21:34:18–21:37:16UTC on 23 July 2010 (SPARTICUS).

As stated above, the maximum cutoff used is 25,000 ticks. The minimum cutoff used is the value such that, given the average inter-arrival time of the data, 20% of the events would be rejected, if the data were homogeneous (unless such value would be > 25,000, in which case the cutoff is 25,000).

- The value used may be anywhere between the minimum and maximum cutoffs, depending on the situation. The minimum is used initially.
- If the data are homogeneous, the resulting concentration will not change significantly from the value found without shattering reduction, because of the statistical correction. If however the data are clumped, e.g. due to shattering, more than 20% of the events will be rejected and the resulting concentration will be lower than the value found without shattering reduction.
- If it is lower by 20% or more, the cutoff is reassigned using the new average inter-arrival time (determined after the shattering reduction step using the

previous cutoff), and the process repeated. This iteration continues until the change in concentration is less than 20%.

- We call this algorithm 'adaptive' since it adapts to the situation. An option to use a fixed cutoff threshold of 25,000 ticks we call 'aggressive'. Figs. 7, 8 and 9 show additional comparative results using the various shattering removal options.

3.2.3 Transit Time Qualification

The first transit time qualification is the same for both the FFSSP and F_CDP. This qualification step compares the half peak transit times, which is the time from the event start to the peak signal value, with the full transit times. To qualify, the half peak transit time must be between 0.33 and 0.60 times the full transit time. For a smooth symmetric pulse, the time to the peak, i.e. the half peak transit time, should be just a bit under half the full transit time, due to the event ending threshold being below the event initiating threshold. Hence the step helps eliminate erratic non-symmetric events.

The next transit time rejection steps are quite different for the FFSSP and F_CDP, so will be discussed separately.

3.2.3.1 FFSSP

For FSSPs, transit time qualification was originally implemented to remove the detection events when a particle passes through the edge of the beam. This results in under sizing and shorter transit times than a particle passing through the beam center. It is implemented by only accepting events for which the transit time is greater than the mean transit time. For a cylindrical beam, theoretically, this is 0.626 of the events. It works very well when the concentration is low and there are only small particles, especially if the size distribution is narrow.

However, when coincidence or large particles cause longer than normal transit times, the mean is biased, causing the rejection of valid events, while accepting the long transit time events, which tend to be oversized. Similarly, even without coincidence, the technique biases towards large particles since they cause longer transit times. We apply a transit time rejection that is particle size dependent and thus reduces those biases.

An ideal, or expected, transit time is calculated for each particle based on:

- Its size
- The TAS
- The width of the FFSSP laser beam

A particle is accepted if its transit time is within 0.785 to 1/0.785 of the ideal transit time.

The following will show:

- That the transit time measurements, even for ice, are accurate enough to detect that longer transit times are associated with larger particles and that the values are in reasonable theoretical agreement with the top hat beam profile model for the given TAS, beam width, and particle size.
- That the size dependent transit time qualification algorithm reduces the biases discussed above.
- The size dependent transit time qualification algorithm may also prove valuable for reducing shattering and noise effects.

3.2.3.1.1 Transit time – Size Relationship

The time period analyzed here contains both small and large ice particles. Figure 5 shows CPI images. The transit time/size relationship should be stronger for water droplets, but demonstrating it for ice is good in that it shows that it is still operable for ice. 0.785 is the mean transit time for a cylindrical beam of diameter 1 and 0.626 is the fraction of transit times larger than the mean.

The transit time distribution for a given size drop should peak at the transit time of a drop going through the center of the beam. Table 3 and Fig. 6 show that except for the smallest signals, which are presumably way off because they are dominated by events that went through the edge, the estimated ideal transit times are reasonably realistic.

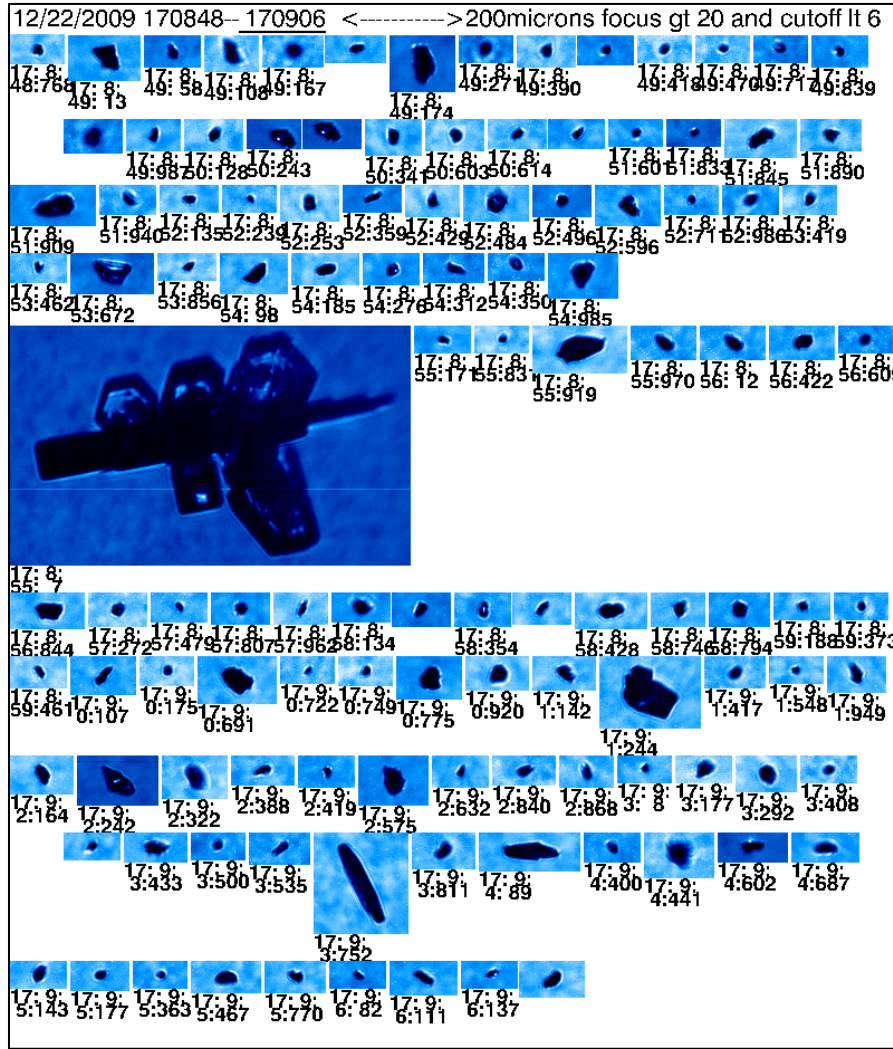


Figure 5

Table 3
Expected and observed mode transit times for a range of particle sizes.
Data from 22 December 2009, 17:08:20-17:10:20 (FSSP time), after the DOF rejection step.
5th row includes an additional reject step
(half_peak_trans_time <= 1.15*t/2 & half_peak_trans_time >= 0.7*t/2).
6th row includes aggressive shattering removal, which rejects the majority of events (see Fig. 5).

Size Range Microns	Nominal Size Microns	Transit Time Estimate In Ticks	Mode Transit Time (mtt) In Ticks	mtt After ½ Peak Rejection In Ticks	mtt After Shattering Rejection In Ticks
< 5	5	61	30 & 47	30 & 48	47
5 – 13	9	63	60	57	55
13 – 24	18	68	68	69	65
24 – 34	29	75	76	75	73
34 – 42	38	80	78	77	73
42 – 61	51	87	86	83	85
61 - 82	71	99	92	88	82

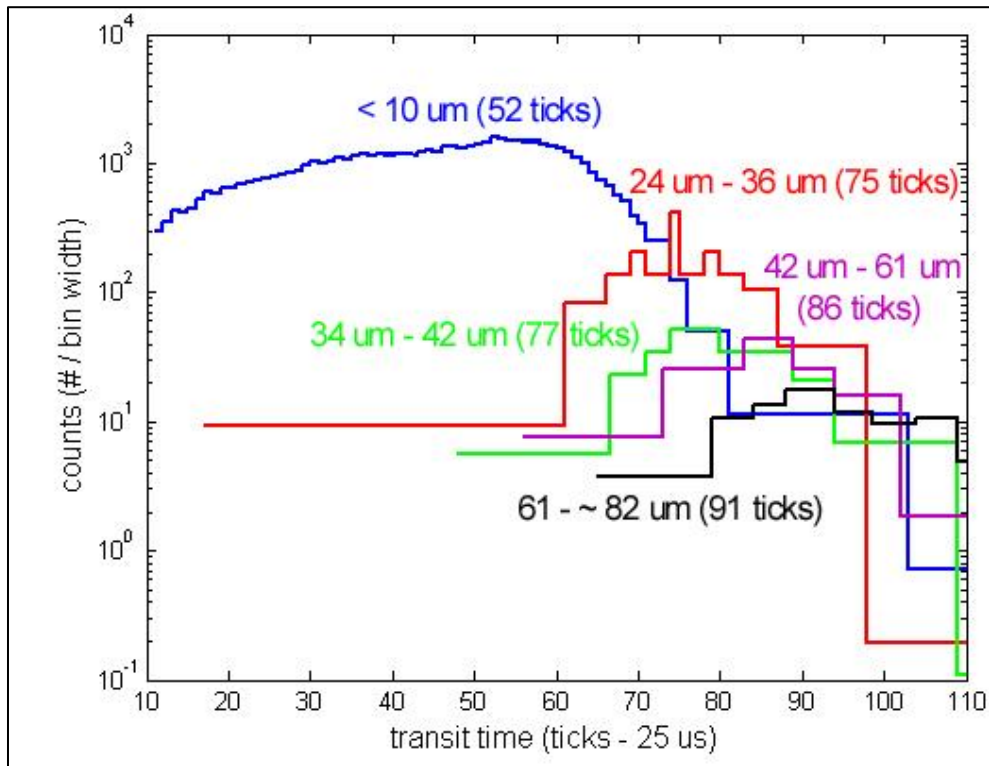


Figure 6. Data from 22 December 2009, 17:08:20-17:10:20 (FSSP time). Transit time distributions for various size ranges created after the DOF rejection step, without shattering removal. The size ranges and location of the peaks are indicated.

3.2.3.1.2 Size Dependent Transit Time Qualification Reduces Biases

Figures 7 and 8 show the expected small effect that the various transit-time rejection options have on the PSD when the mean is not significantly biased.

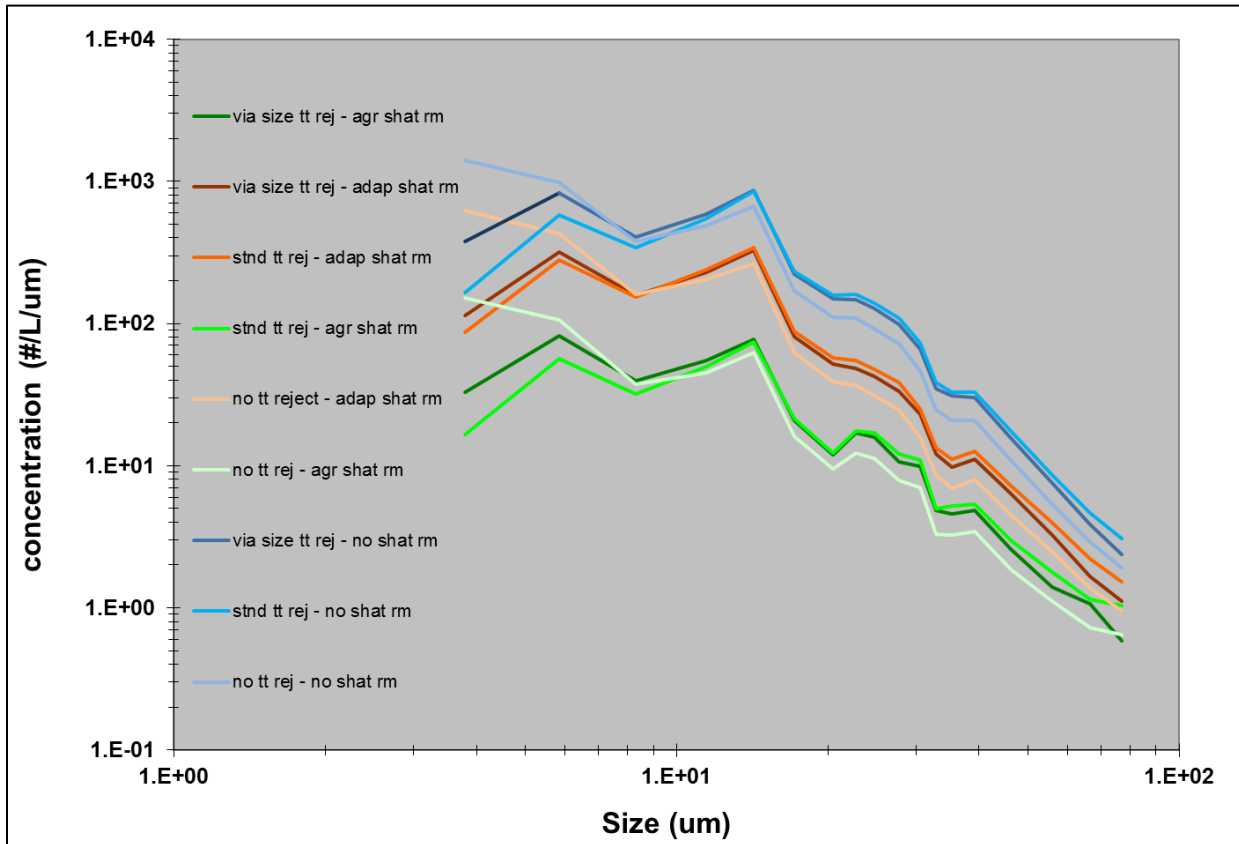


Figure 7. PSDs using various transit-time and shattering rejection options for the same data shown in Figs. 5 and 6.

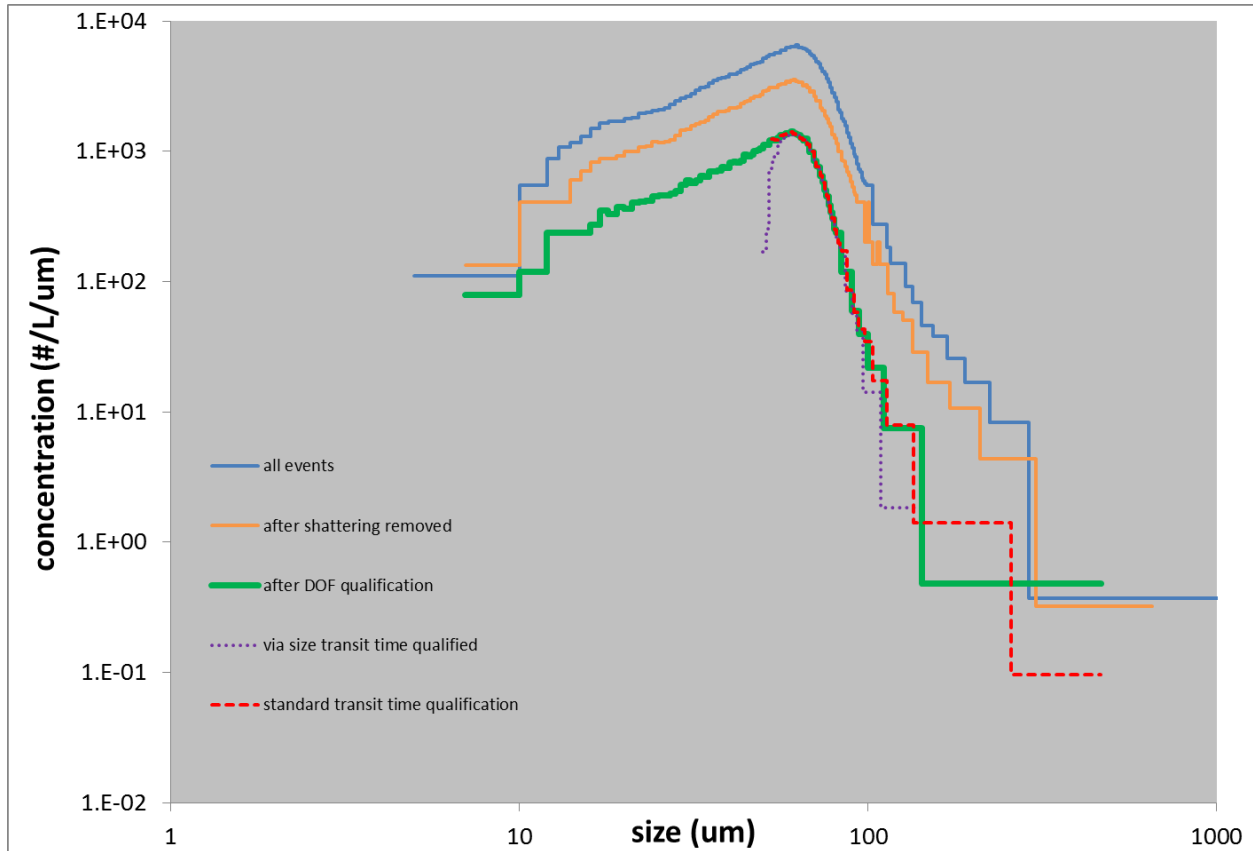


Figure 8. Transit-time distributions at various stages of the processing and for each of the final transit time qualification steps; via size and standard, for the same data as in Figs. 7, 8, and 9.

The next example shows data from a period of large ice aggregates from 21:34:18–21:37:16UTC on 23 July 2010. 2D-S images are shown in Fig. 3.

Adaptive shattering removal runs four iterations where it reaches the maximum cutoff threshold of 25,000. This seems to remove most of the shattering, as indicated by the fishing test and inter-arrival time distributions before and after the shattering removal step (Fig. 9). This does not, however, unequivocally imply that the remaining events are not also shattering remnants.

Figure 10 shows the results of processing four ways:

- With and without shattering removal, indicated as adapt or none, respectively.
- Transit time qualification via size.
- The standard way along with the 2D-S PSDs.

Figures 11 and 12 show that for this case with a heavily biased mean transit time, the new size dependent transit time qualification chooses better events (those at the peak

of the distribution) for sizing than the standard transit-time-greater-than-the-mean qualification does.

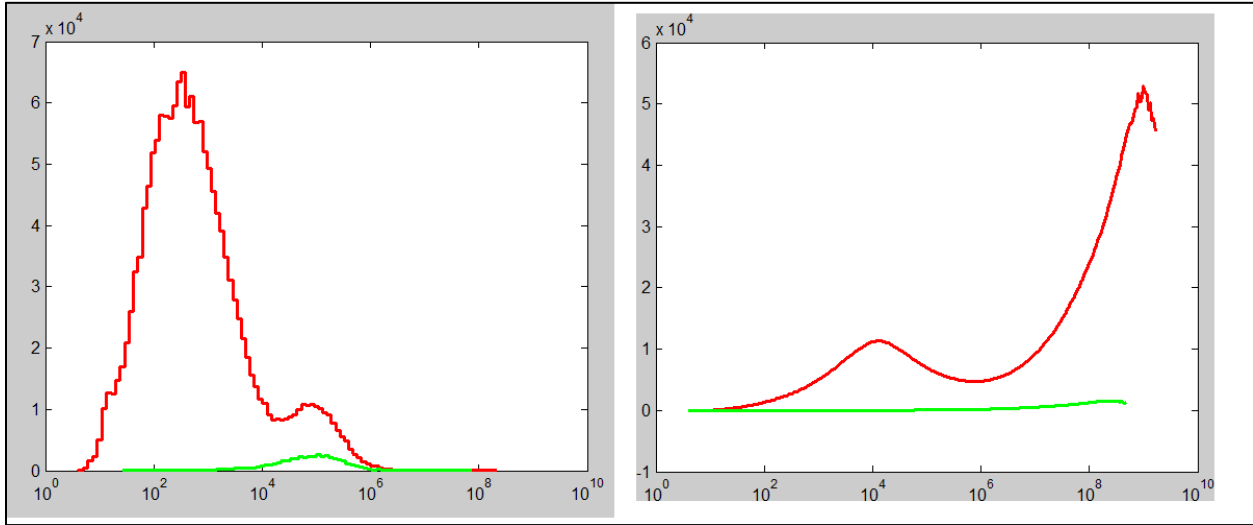


Figure 9. Inter-arrival times (left) and fishing results (right) from just before (red) and after (green) the shattering removal (adaptive = aggressive in this case) step.

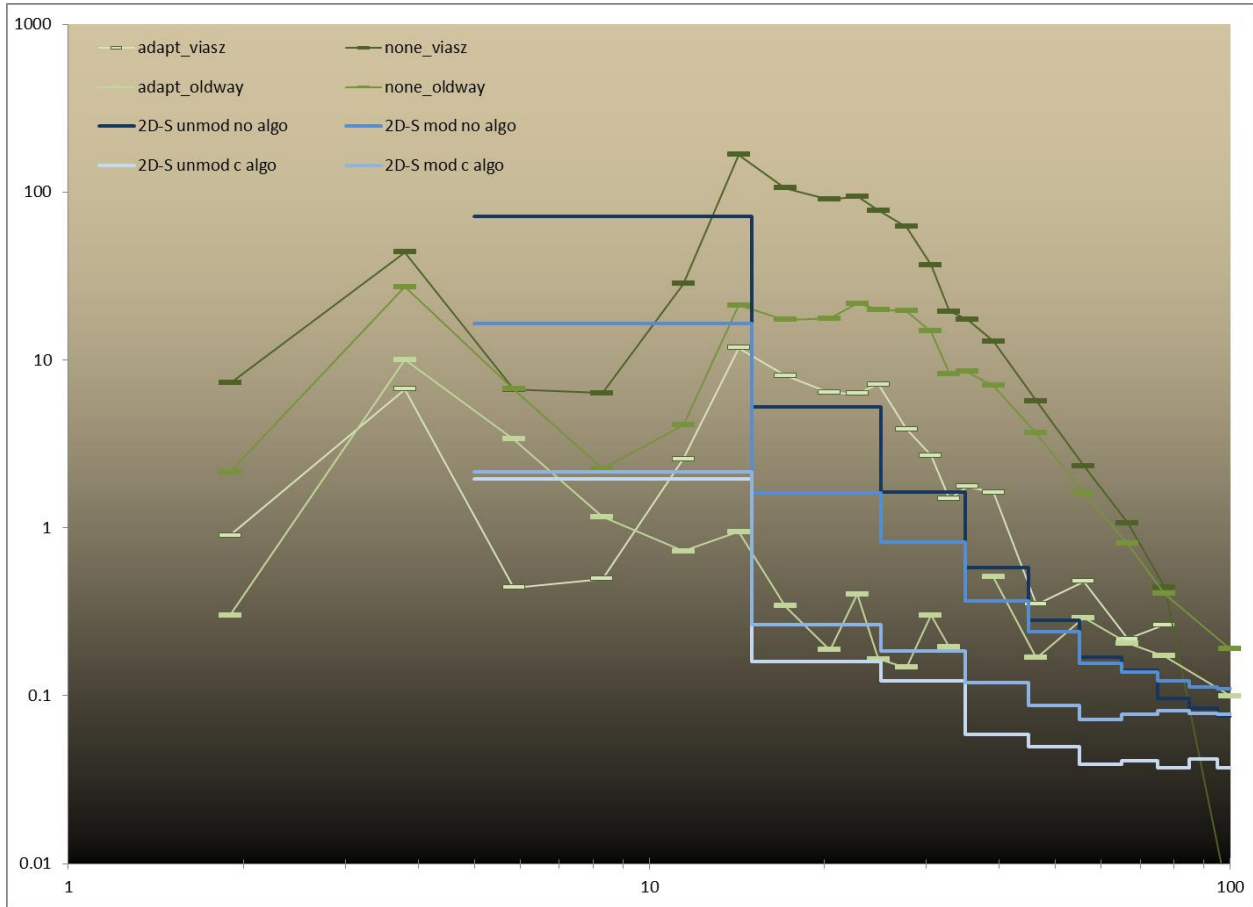


Figure 10. 2D-S and FFSSP PSDs via various processing options. ‘Adapt’ and ‘none’ refer to adaptive and no shattering removal respectively. ‘viasz’ and ‘oldway’ refer to the transit-time qualification size dependent or standard, respectively. For the two 2D-S probes, ‘mod’ and ‘unmod’ refer to whether they had tips modified to reduce shattering effects or not, respectively, while ‘c algo’ and ‘no algo’ refer to whether the particle proximity algorithm for shattering removal was used or not, respectively.

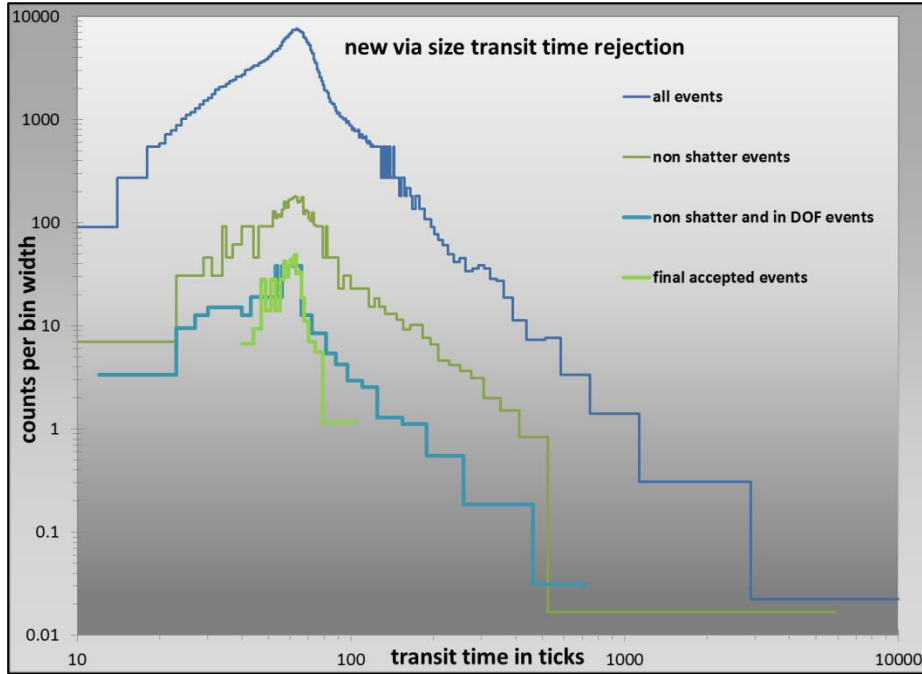


Figure 11. Transit-time distributions at various stages of the processing, indicating that the new via-size transit time rejection worked well here.

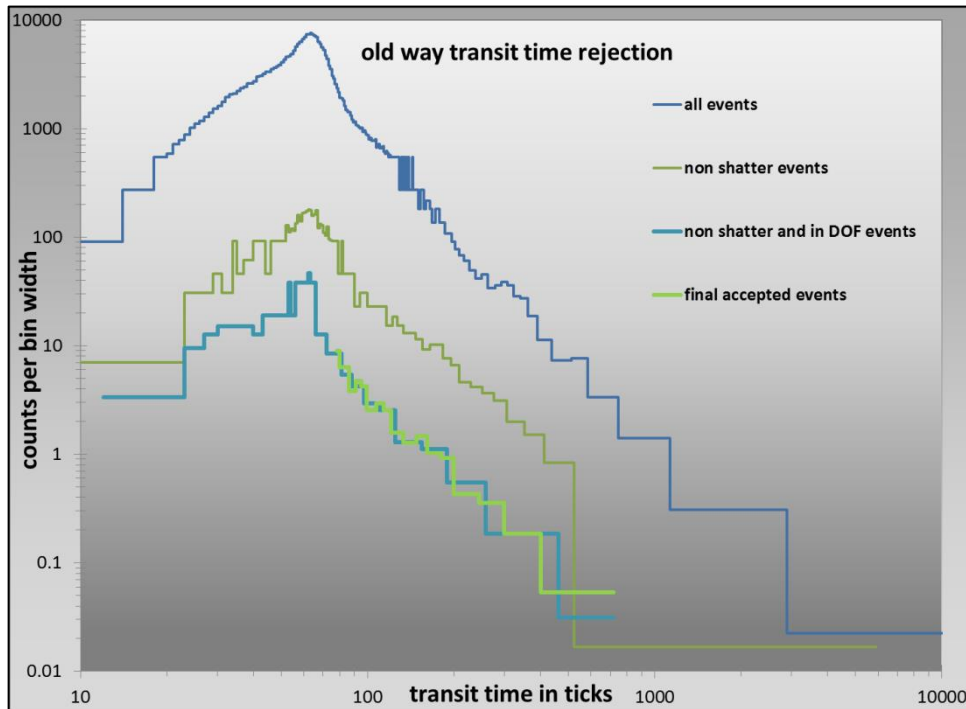


Figure 12. Transit-time distributions at various steps of the processing, indicating that the standard (mean transit time sets the cutoff) transit time rejection worked poorly here.

Other possible effects of the size dependent transit-time qualification

Example 1

A case used the standard transit-time qualification (17 April 2010 SPARTICUS) where apparent noise events exceeded the noise threshold and were counted as real events, which yielded an incorrect concentration of about 1000 L^{-1} . However, because the noise events had transit times inconsistent with their apparent sizes, they were all removed by the size dependent transit-time qualification, yielding 0 L^{-1} concentration.

Example 2

A case where it appeared that shatter events were more efficiently removed by the size dependent transit-time qualification, again due to transit times inconsistent with their sizes, than by the proximity algorithm specifically designed for shattering removal. This may or may not be an anomalous case. More study is required.

3.2.3.2 *F_CDP*

The *F_CDP*'s beam profile and optical system are quite different compared to the FFSSP. The slit optics are very effective at removing beam edge events (those that have short transit-time rejection for the FFSSP) at the same time as DOF qualification (i.e. $\text{qual} > \text{signal}$). However, transit-time qualification is still useful to eliminate coincident events, i.e. events with transit times that are too long. As with the FFSSP, an ideal transit time is calculated based on the TAS and particle size, which is compared with the actual transit time. The event is accepted if the transit time is less than 1.2739 times the ideal transit time.

The outstanding difference between the FFSSP and *F_CDP* is in how the ideal transit times are calculated.

- For the FFSSP it is a simple calculation summing the BW and the droplet size, all divided by the TAS, which is based on a top-hat beam profile assumption.
- The Gaussian shaped *F_CDP* bead profile deviates too much from a top-hat profile for this to have validity. However, assuming a Gaussian beam and scattering proportional to the square of the droplet size, a linear relationship is expected between the square of the quantity half-peak transit-times times TAS and the logarithm of the squared sizes.

Fitting this plot on clean data using Matlab's linear fit tool yields the coefficients C1 and C3 (Fig. 13) that are needed to calculate the ideal transit times for the *F_CDP*.

The relationship holds reasonably well during a given project if the thresholds are not changed or the probe otherwise altered.

However, it is expected that the relationship will change and the coefficients must be re-determined if the thresholds or other probe characteristics are changed. Fig. 14 shows the transit times versus size directly.

A number of interesting facets can be seen in Figs. 13 and 14.

- A large majority of events are eliminated by the DOF qualification (we knew this, it is simply very evident graphically here). The slit optics perform incredibly well, and as designed, regarding eliminating events where the particle passed through the edge of the beam.
- A large fraction of unqualified events have transit times much longer than expected. The best guesses as to why:
 - Out of DOF events are also out of focus and as such are also enlarged,
 - Or, the beam is narrower in the center.

Regardless, the qualified events plot linearly on Figure 13 and non-linear but very tight on Figure 14.

- Even with the small beam there are some coincident events in the data (particularly Fig. 14D).
- The ideal transit time comparison works well removing those events but is not perfect. There is room to tighten down that comparison for specific, manually-processed cases where one wants the maximum accuracy.
- The half peak transit times yield a more linear relationship than the full transit times (Fig. 13), which is why this plot was chosen for the linear fit to determine C1 and C3. However, since it is the full transit times that we need to predict (ideal transit times), it may be better to use that relationship.

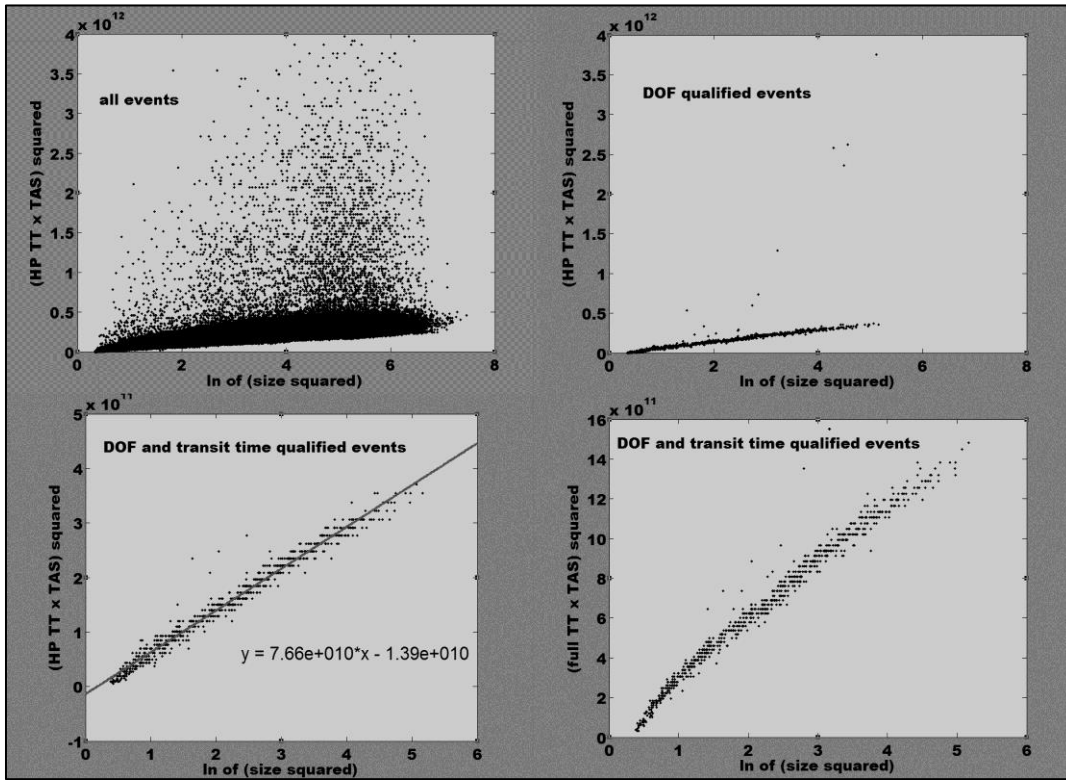


Figure 13. The square of the quantity half peak transit-times times TAS versus the logarithm of the squared sizes, for some clean (single particle events) F_CDP data (110704165500_frm_4594_to_4598_PBP.txt). Top left shows all the events, upper right shows DOF qualified events only, lower left shows DOF and transit-time qualified events (with the linear fit shown), and bottom right shows the square of the quantity full transit-times TAS versus the logarithm of the squared sizes for DOF and transit-time qualified events only.

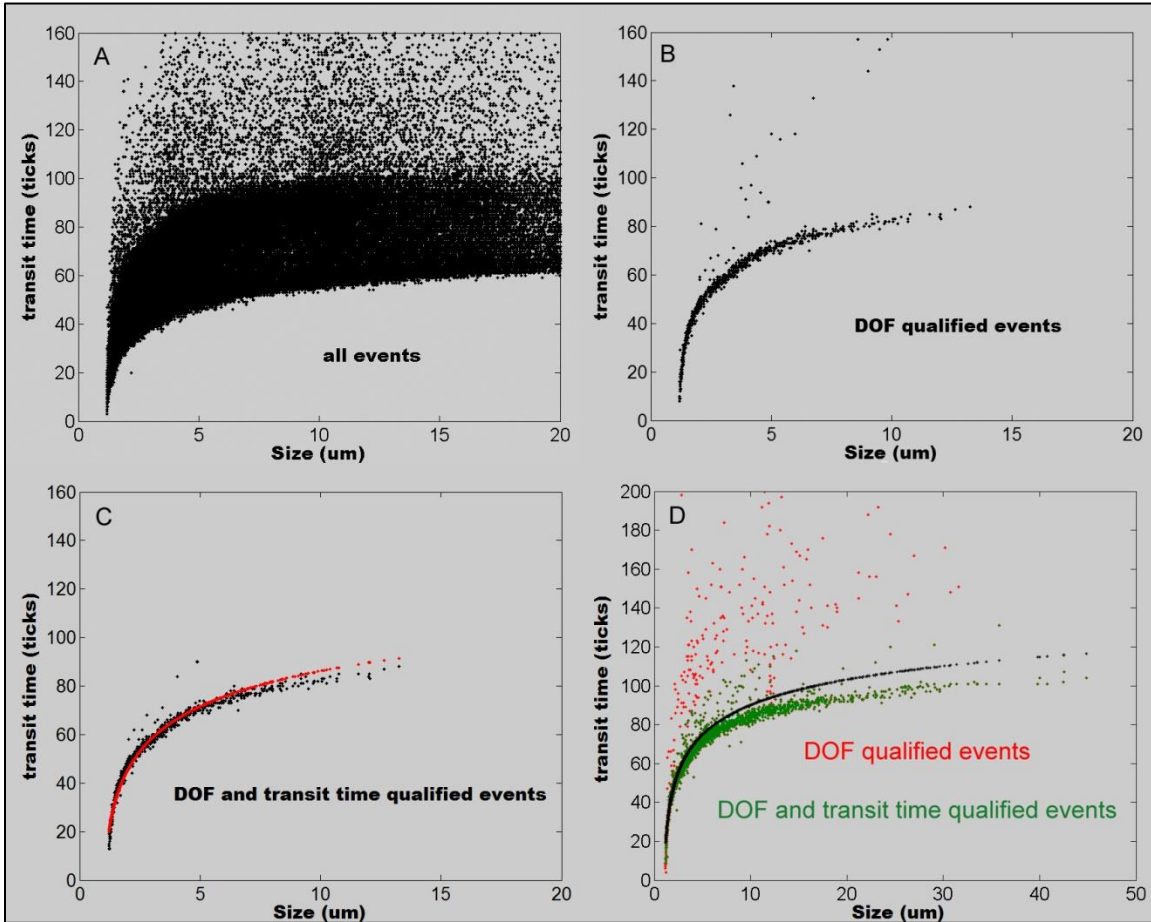


Figure 14. A - C transit times versus size for the same data as shown in Fig. 12. A shows all the events, B the DF qualified events only, and C after transit-time qualification as well as DOF. The red points in C are the ideal transit times and the black points are the actual. D shows similar data but from a later flight. Here black points are the ideal transit times, red the data after DOF qualification, and green after transit -time qualification as well.

4 Appendix A – 3VCPI Raw Data File Format Information

This file was supplied by Jeffrey Schuenke to Brad, Paul, and Tara Jenson on 6/23/1999. You can use this information to write codes and to read and process 3V-CPI raw data file.)

A 3V-CPI raw .roi file is structured as follows:

{File header} {House Keeping block } {House Keeping block } ... {Frame Block}... {House Keeping block}

Where the HK blocks occur on 1 second intervals until a frame block is output. The frame block has priority, so multiple frame blocks may occur before the next HK block. If the frame blocks take more time to output than 1 second, the required HK blocks are buffered, and output when possible. Each HK block and each Frame block has a time stamp in seconds of year. Each Frame block has a matching HK block with the same time stamp. This HK block will always come after the Frame block and has the deadtime value associated with the frame.

4.1 File Header Structure

Field Name	Type	Description
Ver	Int	File version
Year	Int	Year
Month	Int	Month
DX	Int	Max Width of frame
DY	Int	Max Height of frame
Text	BYTARR(70)	Misc. text descriptor

4.2 Frame Header Structure

Field Name	Type	Description
BlockNum	0	Header Block Marker
ItemSize	0L	Total bytes in this frameheader only
Ver	0	Version number of this frame
ROIsCount	0	number of ROIs in this frame
TotROIsSize	0L	total bytes of IMAGE data
day	0B	time of frame 1-31
hour	0B	time of frame 0-23
minute	0B	time of frame 0-59
sec	0B	time of frame 0-59
msec	0	time of frame 0-999
ImgType	0	bit array with data information
sx	0	upper left X corner of image
sy	0	upper left Y corner of image
ex	0	lower right X corner of image
ey	0	lower right Y corner of image
BGRate	0	time between backgrounds in tenths of a second, 0 means no

SPEC Inc. reserves the right to make improvements and changes to the Hawkeye and related software at any time and without notice

Field Name	Type	Description
		bckgnds
BkgPDSThresh	0	number of machine strobes before a background can be collected
FrmsProc	0L	total number of frames processed so far
IThresh	0B	Image threshold 0-255, 0 means no thresholding done.
ROIErr	0B	ROI Rejection/Failure code
ROIMinSize	0	min particle rejection size
ROIAspect	0.0	particle aspect criteria
ROIFill	0.0	min value for (#pixels within ROI threshold)/# pixels in ROI)
ROICount	0L	# pixels within ROI above threshold
ImgMean	0B	image mean value
BkgMean	0B	background mean value
Spare1	0	Unused
ROIYPad	0	width of border around sides of particle in pixels
ROIYPad	0	width of border around top/bottom of particle in pixels
StrobeCount	0L	Probe's strobe count per image
FrmsSaved	0L	number of frames saved to disk so far
ImgMinVal	0B	min image mean for an acceptable frame
ImgMaxVal	0B	max image mean for an acceptable frame
ROIsSaved	0L	total number of ROIs saved so far
ChkSum	0	Checksum
PDSHead	INTARR(3)	PDS data block
Time	0L	seconds of year
ArrivalT1	0	Arrival time
ArrivalT2	0	Arrival time
TransitT	0	Transit time
Missed	0	number of particles missed while processor is busy
PHeight1	0	
PHeight2	0	Note: header file only has one of these listed!!
PDSChkSum	0	check sum
ProbeMode	0	probe mode

4.3 Image Header

Data contained in the raw ROI file from the instrument.

Field Name	Type	Description
BlockMark	0	Block mark
ROIInfoSize	0L	Total bytes in this block (variable because of the last two fields)
ROIVer	0	Tracks this structures version
sx	0	Start X upper left corner of roi (relative to CCD frame)
sy	0	Start Y upper left corner of roi (relative to CCD frame)
ex	0	End X upper left corner of roi (relative to CCD frame)
ey	0	End Y upper left corner of roi (relative to CCD frame)
PixBytes	0	Bytes per pixel in image
Flags	0	Contains info about particle (see definition below)
Len	0.0	Computed Length of particles major axis
SLen	0L	1D index coordinate of start of length vector
ELen	0L	1D index coordinate of end of length vector
Wid	0.0	Computed width of particle (perpendicular to length vector)

SPEC Inc. reserves the right to make improvements and changes to the Hawkeye and related software at any time and without notice

Field Name	Type	Description
SWid	0L	1D index coordinate of start of width vector
EWid	0L	1D index coordinate of end of width vector
Dark	0	Info on particle depth and cut-off (See definition below)
Area	Float	Area of roi in pixels
Perimeter	Float	Perimeter of roi in pixels

Note:

ROI image data follows each image header. The .min file leaves this data out.

4.4 Object Structure Version 30

Field name	Organization	Type	Description
BlockMark	Scalar	Int	Block mark
ROIInfoSize	Scalar	Long	Total bytes in this block (variable because of the last two fields)
ROIVer	Scalar	Int	Tracks this structures version
Sx	Scalar	Int	Start X upper left corner of roi (relative to CCD frame)
Sy	Scalar	Int	Start Y upper left corner of roi (relative to CCD frame)
Ex	Scalar	Int	End X upper left corner of roi (relative to CCD frame)
Ey	Scalar	Int	End Y upper left corner of roi (relative to CCD frame)
PixBytes	Scalar	Int	Bytes per pixel in image (if zero then image data excluded!)
Flags	Scalar	Int	Contains info about particle (see below)
Len	Scalar	Float	Computed Length of particles major axis
Slen	Scalar	Long	1D index coordinate of start of length vector
ELen	Scalar	Long	1D index coordinate of end of length vector
Wid	Scalar	Float	Computed width of particle (perpendicular to length vector)
SWid	Scalar	Long	1D index coordinate of start of width vector
EWid	Scalar	Long	1D index coordinate of end of width vector
Dark	Scalar	Int	Info on particle depth and cut-off (See definition below)
Area	Scalar	Float	Area of object in square pixels
Perimeter	Scalar	Float	Perimeter of object in pixels
Centroid	1D Array	Int	Centroid of particle (2 elements)
Roundness	Scalar	Float	Measure of particle roundness
X_Moment	Scalar	Float	1/2 area on each side of vert line
Y_moment	Scalar	Float	1/2 area on each side of horiz line
Rubber_Band	Scalar	Float	Measure of boundary roughness
Fractal_dim	Scalar	Float	Fractal dimension
Harmonic_len	Scalar	Int	Number of elements in Harmonic array
Bound_len	Scalar	Int	Number of elements in Boundary array
Sample_period	Scalar	Float	Sample period of harmonic array in pixels
Focus	Scalar	Byte	% focus 0-100 Mean of 20 points on perimeter
FocusMin	Scalar	Byte	Min of 20 points on perimeter

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Field name	Organization	Type	Description
FocusMax	Scalar	Byte	Max of 20 points on perimeter
FocusStdDev	Scalar	Float	Std Dev of 20 points on perimeter
FocusGoodSamples	Scalar	Byte	
CutOff	Scalar	Byte	% particle is cut-off 0 – 100
Crystal	Scalar	Byte	Scalar type index meaning TBD
Confidence	Scalar	Byte	Factor assessing confidence in particle use 0-10
P1	Scalar	Float	1 if manual features set
P2	Scalar	Float	Place holder
P3	Scalar	Float	Place holder
P4	Scalar	Float	Place holder
Harmonics	1D Array	Float	Circular harmonics of boundary(var. len)
Boundary	1D Array	Int	Location of boundary pixels in ROI array (1D indices) (var. len)

Note:

The roi image data may follow at this point if PixBytes not equal to zero. Option not currently implement.

An object file consists of a file header (see below), and a sequence of object frames. Object frames contain a frame header and a sequence of object headers, one for each ROI in the original frame.

4.4.1 Dark: 2-byte word

Byte	Meaning
1st byte	darkness number
2nd byte	LS 5-bits = Particle cutoff index: 0-31 (no cut-off to almost fully cut-off)

4.4.2 Flags: 2-byte word

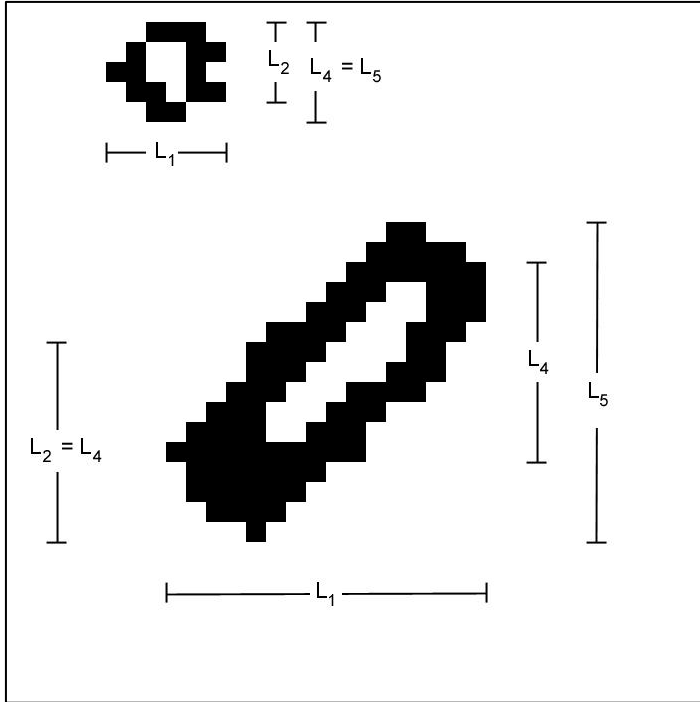
Bit Number	Meaning
0-7	out of focus number
8-11	crystal type 0=circular 1=column 2=stellar 3=other
12	Not used.
13	ROI was drawn manually.
14	Crystal type was manually corrected.
15	Particle was manually rejected.

4.4.3 Scan List Structure

The Scan List Structure is used to gather file info at load time.

Field Name	Type	Description
BlockMark	int	Marker
Fpos	long	File position
ImgType	int	Image type: 1 = normal frame with ROIs 2 = background 0 = error type -1 = house keeping block
HTime	long	House keeping time
day	byte	Day From header unless HK, then computed from Htime
hour	byte	Hour From header unless HK, then computed from Htime
minute	byte	Minute From header unless HK, then computed from Htime
sec	byte	Sec From header unless HK, then computed from Htime
msec	int	Msec From header unless HK, then 0
ROIsCount	int	Number of ROIs in block, 0 for HK blocks
HouseSize	int	Size of House Keeping block or 0 if Image block

5 Appendix B: Derived Parameters, Methods, Equations in 2DSView



5.1 Derived Parameters

'Timestamp', 'Index' of same event's image in the sorted file, 'A₁' = number of shaded pixels, 'L₁' = number of pixels in TAS direction that the event lasted for, 'L₂' = number of shaded pixels in array direction for the slice during the event for which the number of shaded pixels is maximized, 'L₃' = the diameter of the circle that just circumscribes the shaded event pixels. 'L₄' = similar to 'L₂' except it is the total number of pixels between the shaded end pixels instead of just the shaded pixels. 'L₅' = is similar to 'L₄' except it is the distance between the extreme shaded end pixels from all the slices whereas for 'L₄' it is the end pixels in a given slice. See Figure 1. $A_3 = (\pi/4)L_3^2$, 'F₁' = 0 if neither edge was shaded, 1 if left edge only was shaded, 2 if right edge only was shaded, 3 if both edges were shaded (for any slice during the event), 'Adj₁' = adjustment factor #1 (defined below), 'Adj_n' = adjustment factor #n (defined further below), 'PC₁' = position of particle center on array, determined as the center between the extreme edge points of the slice that determined L₂. 'PC₃' = the position of the center of the circumscribing circle. 'PC₄' = position of particle center on array, determined as the center between the extreme edge points that determined L₅. For logistic reasons, the derived files will also

have TAS included. L_6 = the number of white pixels in the strip(s) that defined L_4 . So L_4 is the strip for which the end shaded pixels are farthest apart which can be a surrogate for the outer diameter of an out of focus ring. L_6 then is a surrogate for the inner diameter of the ring as it is the number of white pixels for the strip that defined L_4 . If there are two or more strips for which L_4 is maximized then let L_6 be the maximum value for those strips. L_7 is the Alexei scheme corrected size as follows:

First of all use the maximum value of the two inside-perimeter area estimates. Next we simply use the table at the end of Alexei's report. For each image we have a total area (A_2 = max of 2 inside perimeter area estimates, from Alexei's Matlab algorithm) and an image area (shaded pixels, also in Alexei's code but we already have this = A_1). We take the square root of 1 minus the ratio of the later to the former. We look up the closest value in the appropriate column of the table (that is the Dspot/ Dmax column)(we are using table 40% shadow depth). We find the corresponding value in the 2nd column (that is the Dmax/Do column). We take the inverse of that and multiply by Dmax to obtain Do, which is our corrected size estimate for the bead. If the corrected size (Do) is larger than the original size (Dmax), do not use the correction! use Dmax instead. For round images Dmax might be better estimated from total area but for the bead data we will have to use the along the array size (L_4) as the bead's speeds through the probe varied (unless TAS is well adjusted and speeds don't vary too much).

L_8 is just as L_7 above except instead of $D_{max} = L_4$, use $D_{max} = \sqrt{\frac{4}{\pi} A_2 * \frac{L_4}{L_1}}$. (in both L_7 and

L_8 above we are using L_4 instead of the possibly more logical L_5 because of the tilted arrays giving skewed images... L_8 tries to account for elongated images with the ratio L_4 : L_1)

For both L_7 and L_8 above, L_4 should be used for in-focus images at the 90% level. I. E. after calculating L_7 and L_8 , replace their values with L_4 's value for the subset of data that is in-focus at the 90% or better level.

Adj₁ is calculated as follows:

$$Adj_1 = \frac{SV_{default}}{SV_{1_{actual}}} = \frac{SA_{default}}{SA_{1_{actual}}}$$

$$SV_{default} = TAS \times \Delta t \times SA_{default}$$

$$SV_{1_{actual}} = TAS \times \Delta t \times SA_{1_{actual}}$$

SV stands for sampled volume (Liters), SA for sample area (mm²), TAS (m/s) the speed of air through the probe sample area, and Δt (seconds) the time period of the measurement.

$$SA_{default} = 128 \times pxs \times d_{ww}$$

Where 'pxs' = 0.01 mm (10 μ m) is the optically realized size of the array elements and d_{ww} = 63 mm (6.3 cm) is the window to window distance. 'Strbsz' is the pixel size in the TAS direction (strobe size) and should also = 10 μ m but could differ if the aircraft flies too quickly or an incorrect TAS is sent to the probe during data acquisition.

$$SA_{1_{actual}} = (127 + L_1 \times strbsz/pxs) \times pxs \times \min[d_{ww}, d_{of}]$$

where d_{of} stands for depth of field and

$$d_{of}(mm) = (F_{dof} \times L_1^2 \times strbsz^2(\mu m^2))/1000.$$

where $F_{dof} = 5.13 (\mu m^{-1})$.

PC₁ can be found as the halfway point between the edge points of the image on the array for the slice that defined L₂.

PC₃ can be found as the center of the circle that defined L₃.

5.2 Methods - Equations

5.2.1 Method 1 (M1)

(TAS direction, all particles): For each time bin (of size Δt),

Concentration (#/L) = $K \times \sum Adj_1 / SV_{default}$. Where K = unit conversion factor.

Counts time series: the number of particle events per time bin.

Extinction (Km^{-1}) = $2 \times K \times \sum (Adj_1 \times Area \times pxs \times strbsz) / SV_{default}$ Where K = unit conversion factor.

IWC: (g/m^3) = $K_1 \times \sum (Adj_1 \times \min[\alpha \times A^\beta, \rho_i \frac{K_2 \pi}{K_1 6} \times (L_1 \times strbsz)^3]) / SV_{default}$ where A = (Area x pxs x strbsz)/1000000, $\alpha = 0.115$, $\beta = 1.218$, $\rho_i = 0.917$, and where K_1 and K_2 are unit conversion factors.

LWC: (g/m^3) = $K \times \sum (Adj_1 \times \frac{\pi}{6} \times (L_1 \times strbsz)^3) / SV_{default}$. Where K_2 is unit conversion factor.

Counts PSD: For each size bin, the formula for bin height is simply the number of particles in that size bin. Use size bins with width equal to strbsz for now. Bin ($L_1 \times strbsz$) into the size bins. The first size bin has events for which $L_1 = 1$ and the bin edges are $0.5 \times strbsz$ and $1.5 \times strbsz$, the n^{th} size bin has events for which $L_1 = n$ and $(n - 0.5) \times strbsz$ and $(n + 0.5) \times strbsz$ as bin edges....

Concentration PSD (#/L/ μm): For each size bin, the formula for bin height is $K \times \sum (Adj_1) / (bin_width(\mu m) \times SV_{default})$ where the sum is over all events in that size bin and Where K = unit conversion factor. Bin as above for counts PSD.

Area PSD ($mm^2/L/\mu m$): For each size bin, the formula for bin height is $K \times \sum (Adj_1) \times A / (bin_width(\mu m) \times SV_{default})$ where the sum is over all events in that size bin and A=(Area x pxs x strbsz)/1000000 and Where K = unit conversion factor so the units come out. Bin as above for counts PSD.

Ice Mass PSD (g/m³/μm):

$$K_1 \times \frac{\sum (Adj_1 \times \min[\alpha \times A^\beta, \rho_i \frac{K_2}{K_1} \frac{\pi}{6} \times (L_1 \times strbsz)^3])}{(bin_width(\mu m) \times SV_{default})}$$
 where A=(Area x pxs x strbsz)/1000000, $\alpha = 0.115$, $\beta = 1.218$, $\rho_i = 0.917$, and where K_1 and K_2 are unit conversion factors.

Liquid Mass PSD (g/m³/μm):
$$K \times \frac{\sum (Adj_1 \times \frac{\pi}{6} \times (L_1 \times strbsz)^3)}{(bin_width(\mu m) \times SV_{default})}$$
 Where K = unit conversion factor.

5.2.2 Method 2 (M2)

(All in, along array): For each time bin (of size Δt),

Concentration (#/L) =
$$K \times \frac{\sum Adj_2}{SV_{default}}$$
 where $Adj_2 = \frac{SV_{default}}{SV_{2_{actual}}} = \frac{SA_{default}}{SA_{2_{actual}}}$ where

$$SA_{2_{actual}} = (127 - L_4) \times pxs \times \min[d_{ww}, d_{of_2}]$$

and $Adj_2 = 0$ if either edge pixel is shaded ($F_1 \neq 0$). Where $d_{of_2}(mm) = (5.13(\mu m^{-1}) \times L_4^2 \times pxs^2(\mu m^2)) / 1000$. and where K = unit conversion factor.

Counts time series: the number of particle events per time bin.

Extinction (Km⁻¹) =
$$2 \times K \times \frac{\sum (Adj_2 \times Area \times pxs \times strbsz)}{SV_{default}}$$
 where K = unit conversion factor.

IWC: (g/m³) =
$$K_1 \times \frac{\sum (Adj_2 \times \min[\alpha \times A^\beta, \rho_i \frac{K_2}{K_1} \frac{\pi}{6} \times (L_4 \times pxs)^3])}{SV_{default}}$$
 where A=(Area x pxs x strbsz)/1000000, $\alpha = 0.115$, $\beta = 1.218$, $\rho_i = 0.917$, and K_2 and K_1 are unit conversion factors.

LWC: (g/m³) =
$$K \times \frac{\sum (Adj_2 \times \frac{\pi}{6} \times (L_4 \times pxs)^3)}{SV_{default}}$$
. Where K = whatever you have to make it so the units come out.

Counts PSD: For each size bin, the formula for bin height is simply the number of particles in that size bin. Use size bins with width equal to pxs for now. Bin ($L_2 \times pxs$) into the size bins. The first size bin has events for which $L_2 = 1$ and the bin edges are $0.5 * pxs$ and $1.5 * pxs$, the n^{th} size bin has events for which $L_2 = n$ and $(n - 0.5) * pxs$ and $(n + 0.5) * pxs$ as bin edges....

Concentration PSD (#/L/ μm): For each size bin, the formula for bin height is $K \times \sum (Adj_2) / (bin_width(\mu m) \times SV_{default})$ where the sum is over all events in that size bin and where K = unit conversion factor.

Area PSD ($mm^2/L/\mu m$): For each size bin, the formula for bin height is $K \times \sum (Adj_2) \times A / (bin_width(\mu m) \times SV_{default})$ where the sum is over all events in that size bin and $A = (Area \times pxs \times strbsz) / 1000000$ and where K = unit conversion factor.
Bin as above for counts PSD.

Ice Mass PSD ($g/m^3/\mu m$):
$$K_1 \times \frac{\sum (Adj_2 \times \min[\alpha \times A^\beta, \rho_i \frac{K_2 \pi}{K_1} \frac{\pi}{6} \times (L_4 \times pxs)^3])}{(bin_width(\mu m) \times SV_{default})}$$
 where $A = (Area \times pxs \times strbsz) / 1000000$, $\alpha = 0.115$, $\beta = 1.218$, $\rho_i = 0.917$, and K_2 and K_1 are unit conversion factors.

Liquid Mass PSD ($g/m^3/\mu m$):
$$K \times \frac{\sum (Adj_2 \times \frac{\pi}{6} \times (L_4 \times pxs)^3)}{(bin_width(\mu m) \times SV_{default})}$$
 where K = unit conversion factor.

5.2.3 Method 3 (M3)

(All in, simple non-adjusted spheres): For each time bin (of size Δt), **concentration** =
$$K \times \frac{\sum Adj_3}{SV_{default}}$$
 where
$$Adj_3 = \frac{SV_{default}}{SV_{3_{actual}}} = \frac{SA_{default}}{SA_{3_{actual}}}$$
 where
$$SA_{3_{actual}} = (127 - L_3) \times \min[pxs, strbsz] \times \min[d_{ww}, d_{of_3}]$$

and $Adj_3 = 0$ if either edge pixel is shaded ($F_1 \neq 0$). Where $d_{of_3}(mm) = (5.13(\mu m^{-1}) \times (L_3)^2 \times \min[pxs, strbsz]^2 (\mu m^2)) / 1000$. and where K = unit conversion factor.
Reject events for which $L_4 \gt 2.1 * L_1$ or $L_4 \lt 0.49 * L_1$ and area $\gt 2$.

Counts time series: Simply plot the number of accepted particle events per time bin.

Extinction (Km⁻¹) = $\frac{\pi}{2} \times K \times \sum (Adj_3 \times L_3^2 \times p_{xs} \times strbsz) / SV_{default}$ where K = unit conversion factor.

Rejects events for which L4 gt 2.1*L1 or L4 lt 0.49*L1 and area gt 2.

IWC: (g/m³) = $0.917 \times K \times \sum (Adj_3 \times \frac{\pi}{6} \times (L_3 \times \sqrt{p_{xs} \times strbsz})^3) / SV_{default}$ where K = unit conversion

factor. Reject events for which L4 gt 2.1*L1 or L4 lt 0.49*L1 and area gt 2.

LWC: (g/m³) = $K \times \sum (Adj_3 \times \frac{\pi}{6} \times (L_3 \times \sqrt{p_{xs} \times strbsz})^3) / SV_{default}$ Where K = unit conversion factor.

Reject events for which L4 gt 2.1*L1 or L4 lt 0.49*L1 and area gt 2.

Counts PSD: For each size bin, the formula for bin height is simply the number of particles in that size bin. Use size bins with width equal to $\sqrt{p_{xs} \times strbsz}$ for now. Bin ($L_3 \times \sqrt{p_{xs} \times strbsz}$) into the size bins. The first size bin has edges of $0.5 \times \sqrt{p_{xs} \times strbsz}$ and $1.5 \times \sqrt{p_{xs} \times strbsz}$, the nth size bin has $(n - 0.5) \times \sqrt{p_{xs} \times strbsz}$ and $(n + 0.5) \times \sqrt{p_{xs} \times strbsz}$ as bin edges. Reject events for which L4 gt 2.1*L1 or L4 lt 0.49*L1 and area gt 2.

Concentration PSD (#/L/μm): For each size bin, the formula for bin height is $K \times \sum (Adj_3) / (bin_width(\mu m) \times SV_{default})$ where the sum is over all events in that size bin and where K = unit conversion factor. Bin as above for counts PSD. Reject events for which L4 gt 2.1*L1 or L4 lt 0.49*L1 and area gt 2.

Area PSD (mm²/L/μm): For each size bin, the formula for bin height is $\frac{\pi}{2} \times K \times \sum (Adj_3 \times L_3^2 \times p_{xs} \times strbsz) / (bin_width(\mu m) \times SV_{default})$ where the sum is over all events in that size bin and where K = unit conversion factor. Bin as above for counts PSD. Reject events for which L4 gt 2.1*L1 or L4 lt 0.49*L1 and area gt 2.

Ice Mass PSD (g/m³/μm): For each size bin, the formula for bin height is $0.917 \times K \times \sum (Adj_3 \times \frac{\pi}{6} \times (L_3 \times \sqrt{p_{xs} \times strbsz})^3) / (bin_width(\mu m) \times SV_{default})$ where K = unit conversion factor. Reject events for which L4 gt 2.1*L1 or L4 lt 0.49*L1 and area gt 2.

Liquid Mass PSD (g/m³/μm): $K \times \sum (Adj_3 \times \frac{\pi}{6} \times (L_3 \times \sqrt{p_{xs} \times strbsz})^3) / (bin_width(\mu m) \times SV_{default})$

where K = unit conversion factor. Reject events for which L4 gt 2.1*L1 or L4 lt 0.49*L1 and area gt 2.

5.2.4 Method 4 (M4)

(All In, Ring-Spot Adjusted Spheres A): For each time bin (of size Δt),

$$\text{Concentration} = K \times \sum \text{Adj}_4 / \text{SV}_{\text{default}} \quad \text{where} \quad \text{Adj}_4 = \text{SV}_{\text{default}} / \text{SV}_{4_{\text{actual}}} = \text{SA}_{\text{default}} / \text{SA}_{4_{\text{actual}}} \quad \text{where}$$

$$\text{SA}_{4_{\text{actual}}} = (127 - L_7) \times \min[\text{pxs}, \text{strbsz}] \times \min[d_{\text{ww}}, d_{\text{of}_{-4}}]$$

and $\text{Adj}_4 = 0$ if either edge pixel is shaded ($F_1 \neq 0$). Where $d_{\text{of}_{-4}}(\text{mm}) = (5.13(\mu\text{m}^{-1}) \times (L_7)^2 \times \min[\text{pxs}, \text{strbsz}]^2 (\mu\text{m}^2)) / 1000$. and where K = unit conversion factor. Also reject events for which $L5 \text{ gt } 2.1 * L1$ or $L5 \text{ lt } 0.49 * L1$ and area gt 2.

Counts time series: Simply plot the number of accepted particle events per time bin.

$$\text{Extinction (Km}^{-1}\text{)} = \frac{\pi}{2} \times K \times \sum (\text{Adj}_4 \times L_7^2 \times \text{pxs} \times \text{strbsz}) / \text{SV}_{\text{default}} \quad \text{where K = unit conversion factor.}$$

Reject events for which $L4 \text{ gt } 2.1 * L1$ or $L4 \text{ lt } 0.49 * L1$ and area gt 2.

$$\text{IWC: (g/m}^3\text{)} = 0.917 \times K \times \sum (\text{Adj}_4 \times \frac{\pi}{6} \times (L_7 \times \sqrt{\text{pxs} \times \text{strbsz}})^3) / \text{SV}_{\text{default}} \quad \text{where K = unit conversion}$$

factor. Reject events for which $L4 \text{ gt } 2.1 * L1$ or $L4 \text{ lt } 0.49 * L1$ and area gt 2.

$$\text{LWC: (g/m}^3\text{)} = K \times \sum (\text{Adj}_4 \times \frac{\pi}{6} \times (L_7 \times \sqrt{\text{pxs} \times \text{strbsz}})^3) / \text{SV}_{\text{default}} \quad \text{where K = unit conversion factor.}$$

Reject events for which $L4 \text{ gt } 2.1 * L1$ or $L4 \text{ lt } 0.49 * L1$ and area gt 2.

Counts PSD: For each size bin, the formula for bin height is simply the number of particles in that size bin. Use size bins with width equal to $\sqrt{\text{pxs} \times \text{strbsz}}$ for now. Bin $(L_7 \times \sqrt{\text{pxs} \times \text{strbsz}})$ into the size bins. The first size bin has edges of $0.5 * \sqrt{\text{pxs} \times \text{strbsz}}$ and $1.5 * \sqrt{\text{pxs} \times \text{strbsz}}$, the n^{th} size bin has $(n - 0.5) * \sqrt{\text{pxs} \times \text{strbsz}}$ and $(n + 0.5) * \sqrt{\text{pxs} \times \text{strbsz}}$ as bin edges.... Reject events for which $L4 \text{ gt } 2.1 * L1$ or $L4 \text{ lt } 0.49 * L1$ and area gt 2. Do not adjust bin heights by multiplying by the ratio of total events to accepted events.

Concentration PSD (#/L/ μm): For each size bin, the formula for bin height is $K \times \sum (\text{Adj}_4) / (\text{bin_width}(\mu\text{m}) \times \text{SV}_{\text{default}})$ where the sum is over all events in that size bin and where K

= unit conversion factor. Bin as above for counts PSD. Reject events for which L4 gt 2.1*L1 or L4 lt 0.49*L1 and area gt 2.

Area PSD (mm²/L/μm): For each size bin, the formula for bin height is $\frac{\pi}{2} \times K \times \sum (Adj_4 \times L_7^2 \times p_{xs} \times strbsz) / (bin_width(\mu m) \times SV_{default})$ where the sum is over all events in that size bin and where K = unit conversion factor. Bin as above for counts PSD. Reject events for which L4 gt 2.1*L1 or L4 lt 0.49*L1 and area gt 2.

Ice Mass PSD (g/m³/μm): For each size bin, the formula for bin height is $0.917 \times K \times \sum (Adj_4 \times \frac{\pi}{6} \times (L_7 \times \sqrt{p_{xs} \times strbsz})^3) / (bin_width(\mu m) \times SV_{default})$ where K = unit conversion factor. Reject events for which L4 gt 2.1*L1 or L4 lt 0.49*L1 and area gt 2.

Liquid Mass PSD (g/m³/μm): $K \times \sum (Adj_4 \times \frac{\pi}{6} \times (L_7 \times \sqrt{p_{xs} \times strbsz})^3) / (bin_width(\mu m) \times SV_{default})$
where K = unit conversion factor. Reject events for which L4 gt 2.1*L1 or L4 lt 0.49*L1 and area gt 2.

5.2.5 Method 6 (M6)

(In focus only, combined): This method is for when there are sufficient particles to use in focus only and when there is need to extend to larger sizes than can be adequately sampled by 'all in' techniques. It uses M2 in-focus-only after CleanAll for sizes smaller than 265. It uses M1 in-focus-only without cleaning for sizes greater than 325. For sizes between 265 and 325, it uses the average of the preceding two methods. A future improvement should be to replace the M1 part with a reconstruction technique.

6 Appendix C: Removing Spurious 2D-S Events

2D-S raw data include spurious effects. These are primarily from instrument noise and from splashing of precipitation. Algorithms used to clean the data of the majority of these spurious effects while retaining the majority of the valid images are described here.

There are 5 quasi-independent steps to the algorithm implemented via two loops through the data:

First Loop:

- Test for roundness.
- Test for splashing events based on black and white area considerations.
- Test for noise via line and dot patterns.
- Test for noise via statistics of particle center locations.

Second Loop:

- Test for splashing events based on inter-event-distances if the probe is in precipitation.

Each step will be described in detail after defining terms.

6.1 Four measures of image length are shown in figure A.1.

“ L_1 ” is the number of slices (pixels in the direction of travel) for which the event lasted. “ L_2 ” is the number of shaded diodes (pixels in the direction along the array) for the slice for which the same quantity is maximized. “ L_4 ” is the number of diodes between, and including the shaded end diodes, for the slice that maximizes the same quantity. “ L_5 ” is the distance between (and including) the shaded end diodes considering all of the slices together.

Other size parameters are a corrected size for out of focus images based on Korolev’s work (L_7), the number of shaded pixels for the entire image (summed over all slices) (A_s) and an estimate of total number of pixels, shaded or not, for the entire image (A_t). The algorithm for A_t is part of the Korolev size correction method.

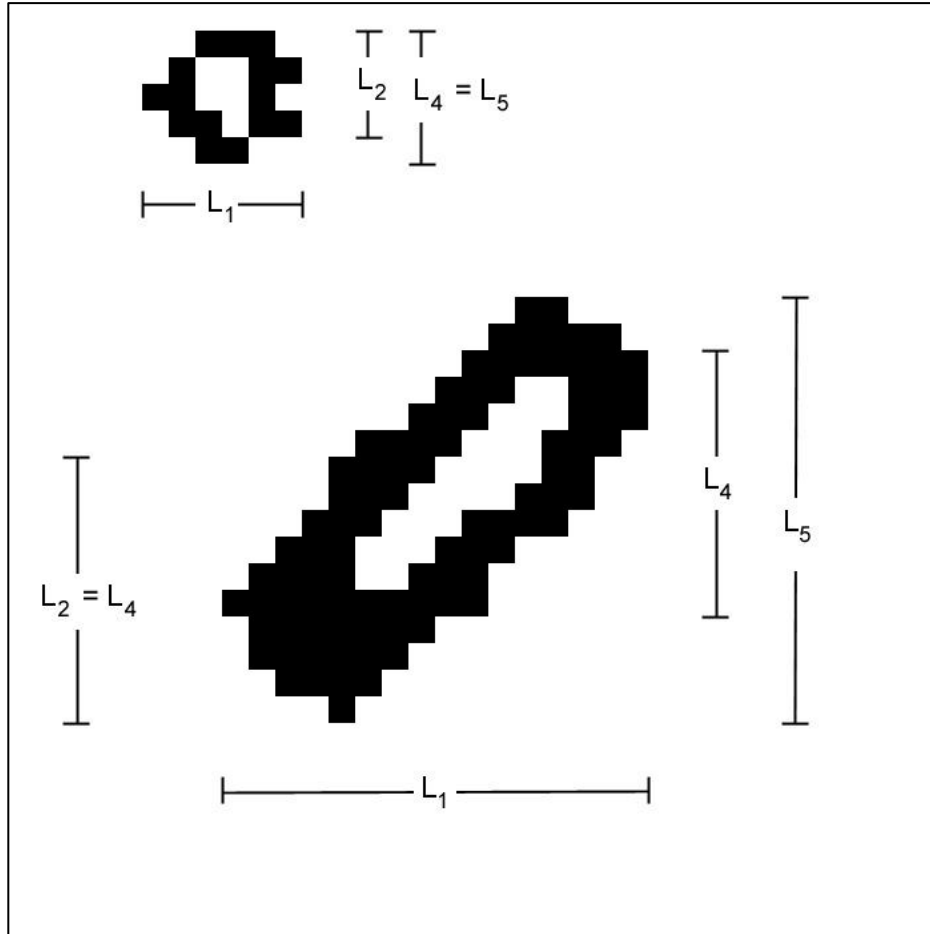


Figure B.1: Two example particle images designed to demonstrate the four measures of image size described in the text.

1. An image is determined to be round if $L1 \geq 0.5 \times L5$ and $L5 \geq 0.5 \times L1$. If an image is not round, it is rejected. An exception is made for the very large images that do not fit within the array. If $L5 > 50$ (500 μm) then an image is determined to be round if $L1 \geq 0.5 \times L5$. I.E. an image is determined to be round if $L1 \geq 0.5 \times L5$ and ($L5 \geq 0.5 \times L1$ or $L5 > 50$).
2. The larger a valid image is the greater the percentage of shaded pixels. Splash effects often create large images that have lower percentages of shaded pixels than valid images. The follow criteria are used to eliminate such spurious images. If any of these five criteria are met the image is rejected.
 - ($L5 > 10$ or $L1 > 10$) and ($At > 3.0 \times As$)
 - ($L5 > 15$ or $L1 > 15$) and ($At > 2.5 \times As$)

- $(L5 > 20 \text{ or } L1 > 20) \text{ and } (At > 2.0 \times As)$
- $(L5 > 35 \text{ or } L1 > 35) \text{ and } (At > 1.5 \times As)$
- $(L5 > 2.2 \times L7) \text{ and } (L1 > 10.0)$

3. Figure B.2 shows some examples of noise generated images appearing in line plus dot patterns.

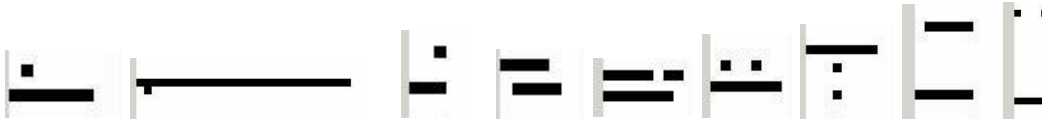


Figure B.2: Examples of line plus dot patterns caused by noisy diodes.

These are eliminated using the following criteria:

- i. $(L1 = As) \text{ and } (L2 = 1) \text{ and } (L1 > 4)$
- ii. $(As \leq 1.35 \times L1) \text{ and } (L4 = L5) \text{ and } (L1 > 4) \text{ and } (L2 = 2)$
- iii. $(L1 > 10) \text{ and } (L1 > 0.75 \times As) \text{ and } (L1 \leq 1.5 \times As)$
- iv. $(L4 = L5) \text{ and } (At > 0.9 \times L1 \times L5) \text{ and } (L2 = 2) \text{ and } (L2 \neq L4)$
- v. $(L4 = L5) \text{ and } (At > 3.0 \times As) \text{ and } (L2 = 2)$
- vi. $(L4 = L5) \text{ and } (At > 4.0 \times As)$

If any of these six criteria are met the image is rejected.

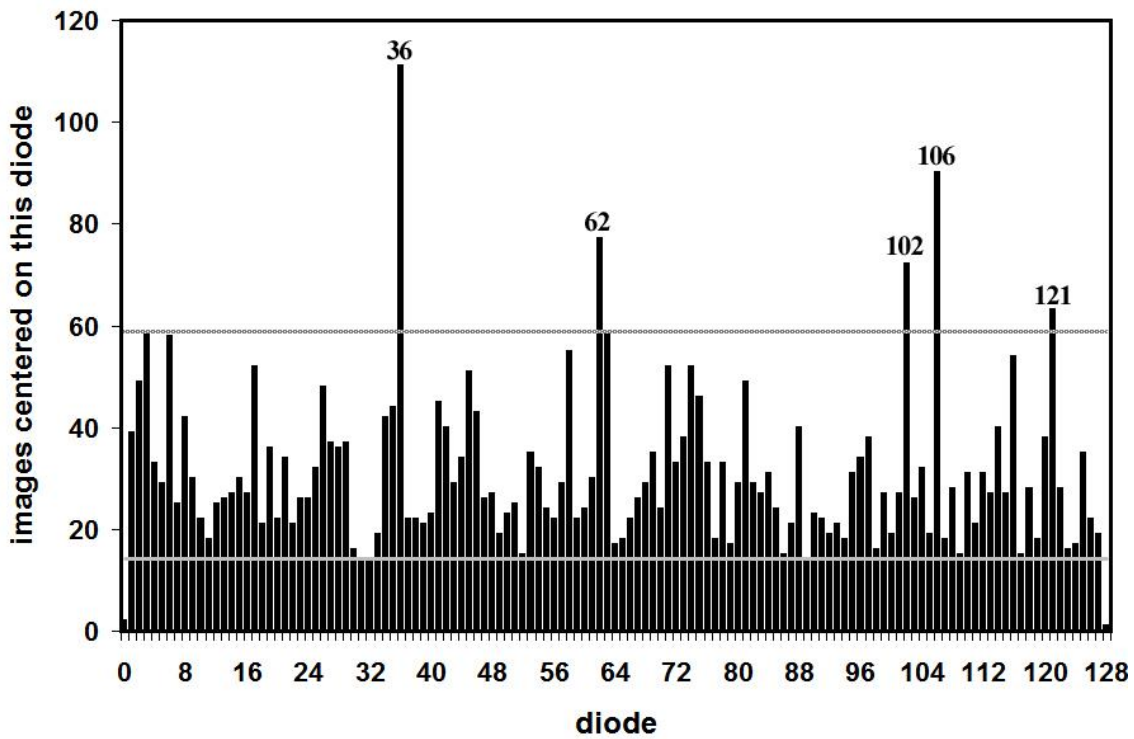
4. The final step, of this first cleaning loop, is another noisy diode removal method, based on the statistics of image center locations calculated over 4000 images approximately centered on the image being evaluated. When a diode is noisy there are more image centers located on that diode than are located on quiet diodes. A diode is labeled bad when it has more particle center locations than the threshold value ($TH = \max(M + 5 \times \sqrt{M}, 1.5)$). Where M is the mean number of image centers per diode across the array, for diodes having more than a minimum number of image center counts.

This minimum number is $Mt - 3 \times \sqrt{Mt}$, where Mt is the mean number of image centers per diode across the array, for all diodes. If less than 33 diodes satisfy the requirement of having more than Mt counts then M is calculated from all diodes. Mt and M are recalculated after bad diodes are identified, ignoring those

diodes, and the process repeated until no diodes exceed the threshold. An image whose center falls on a bad diode is rejected unless it meets one of the following criteria:

- i. $(L1 \geq 15)$ and $(L5 \geq 15)$ and $(As > 0.7 \times At)$
- ii. $(L1 \geq 4)$ and $(L5 \geq 4)$ and $(As \geq 0.5 \times At)$ and $(L2 > 0.25 \times L5)$ and $(L1 < 50)$
- iii. $(L2 = L4)$ and $(L2 = L5)$ and $(L2 \geq 2)$ and $(As \geq 0.5 \times At)$

Figure B.3 shows an example of noisy diode data and the distribution of image centers across the array.



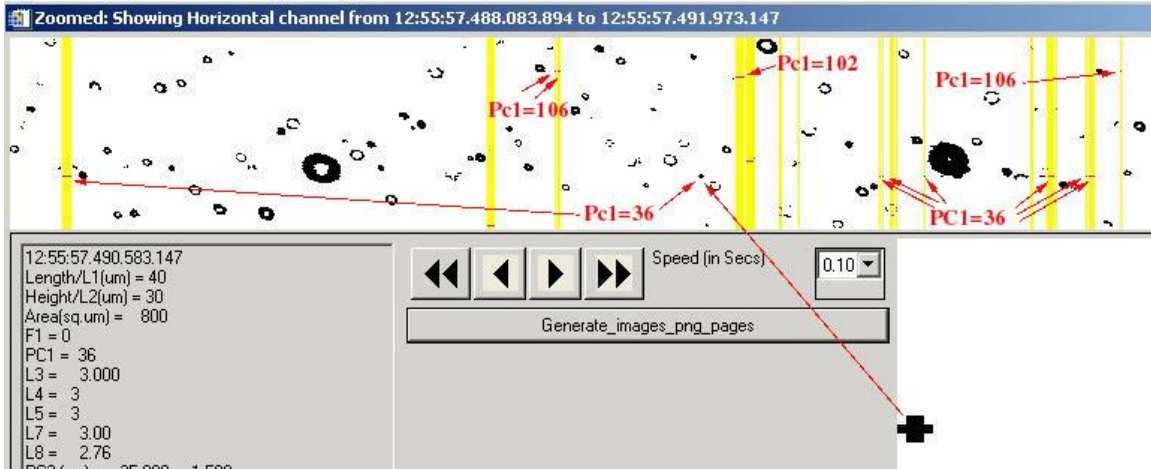


Figure B.3: Shows an example of noisy diode data intermixed with good particle data. The images highlighted in yellow are rejected. Labels in red point to images centered on diodes determined to be bad (too noisy) by the criteria described in the text and exemplified in the particle center location distribution shown above.

Note: The 4000 images includes all images, whether rejected by previous steps or not, and is updated every 100 images so that the 4000 images are approximately centered on the current image. If the file contains less than 4000 images then all images are used. 4000 was chosen because of the approximate match between the mean ($4000/128 = 31$) and threshold.

5. This final step is another loop through the data but is applied only if the current precipitation status is 'yes'. The current precipitation status is 'yes' if there is one or more particle(s) with $L7 > 100$ microns in the 10000 particles, accepted by the previous 4 cleaning steps, centered approximately on the current particle. It is approximately centered because the precipitation status is updated only every 100 particles², instead of for every particle, to improve speed. Another parameter, the current mean inter-particle time (aveW8), is similarly updated every 100 particles¹ and calculated as the average inter-particle time between the 10000 images, accepted by the previous 4 cleaning steps, centered approximately on the current particle. All the particles in the previous second are used instead of 5000 particles if there are less than 5000 particles in the previous second, similarly for the following 5000 particles or second. If $aveW8 > 40000$ then $C_1 = 2000$ and $C_2 = 8000$. If $aveW8 < 40000$ then $C_1 = 0.05 \times aveW8$ and $C_2 = 0.2 \times aveW8$. A particle is rejected if the precipitation status is

¹ The precipitation status and current mean waiting time are updated every particle, instead of every 100, if the valid particle rate is slower than 1000 per second, averaged over the surrounding 0.2 seconds.

'yes' and either: a) the particle's inter-particle time or the following particle's inter-particle time is less than C_1 or b) both the particle's inter-particle time and the following particle's inter-particle time are less than C_2 . Finally, a variable, adj_0 , is calculated for each image. It is 0 for rejected images, 1 for accepted images if precipitation status is 'no'. When precipitation status is 'yes', then for accepted images, we calculate a new true average inter-particle time (TaW) = the average inter-particle time of particles accepted by all the steps minus C_1 . Then calculate

$$k = 1 - e^{\left(\frac{-2C_1}{TaW}\right)} + e^{\left(\frac{-2C_1}{TaW}\right)} \left(1 - e^{\left(\frac{-C_2}{TaW}\right)}\right)^2$$

k is limited to a maximum of 0.9 and then $adj_0 = \frac{1}{1-k}$. adj_0 is used elsewhere, in the algorithms for calculating concentrations etc., to increase the weight of each accepted particle to account for those good particles rejected by the inter-particle time criteria.

k is the fraction of events eliminated by the criteria given a true waiting time distribution with mean of TaW . $1 - e^{\left(\frac{-C_1}{TaW}\right)}$ is the probability of, or fraction of events with, inter-arrival times less than C_1 . $1 - e^{\left(\frac{-2C_1}{TaW}\right)}$ is the fraction of events eliminated due to the first criteria, leaving $e^{\left(\frac{-2C_1}{TaW}\right)}$ not eliminated by the first criteria. Of those, a fraction $\left(1 - e^{\left(\frac{-C_2}{TaW}\right)}\right)^2$ are eliminated by the second criteria.

7 Appendix D: Updating the 2DS Real-Time/Post Processing Program

The 2DS Real-Time and Playback program is installed to a computer by an executable install program. The program then needs to be updated with the latest version. When SPEC releases a new version the executable needs to be replaced in the Program Files/SPEC, Inc/SPEC2DS folder. Occasionally another file, SPEC2DS.ocx, located in the WINNT/system32 folder needs to be replaced. In order to replace it you need to unregister the previous version and then copy over the file and re-register it. To do this click on Windows Start button and click Run. In command line type:

```
Regsvr32 /u c:\winnt\system32\spec2ds.ocx.
```

A box should pop up confirming the registry change was successful.

Copy in new .ocx file and type:

```
Regsvr32 c:\winnt\system32\spec2ds.ocx
```

After another confirmation, the program is updated.

7.1 Installing 2DSview:

2DSview comes in a folder; the only step to installing 2DSview is to set the IDL path to this folder. Open Project file and follow directions as detailed in Section 6.1

8 Appendix E - Setting the size bins - Mie bump considerations

Note that all the PSDs shown so far (Figs. 6, 9, and 12) are at least bi-modal. In the following we will show that this is likely a spurious effect, due to the way the bin edges have been chosen to accommodate the Mie bumps.

During processing, besides the PSD using the standard fixed bins, an additional PSD with fixed statistics but variable bins (unihist) is produced. To make the unihist PSD, every particle must be assigned a size. This is accomplished in the subroutine 'sizebbp_rv#.m' by interpolating the signal voltages across the fixed bins that they fall into. I.E. if a given signal voltage lies half way between its two voltage bin edges than it is assigned the size that lies half way between the corresponding two size bin edges. This PSD helps reveals that there is likely a problem with our technique, of determining bins, that takes into account the Mie bumps. The calibration routine thus creates two calibration tables, one using the Mie bumps and one with evenly spaced bins (see Fig. 2).

Assuming that the size distribution is smoothly varying, then because of the Mie bumps, the signal distribution will be bumpy. Consider e.g. the Mie curve and the bin edge points for the FFSSP shown in Fig. A1. The bin from ~ 7 to ~ 10 μm has a wide size width and small signal width relative to surrounding bins, whereas the bin from ~ 13 to ~ 15 has just the opposite, a narrow size bin width and wide signal bin width. Thus for a smoothly varying, or uniform, size distribution, we can expect that the signal distribution will have relatively more, and less respectively, in these two bins than neighboring bins.

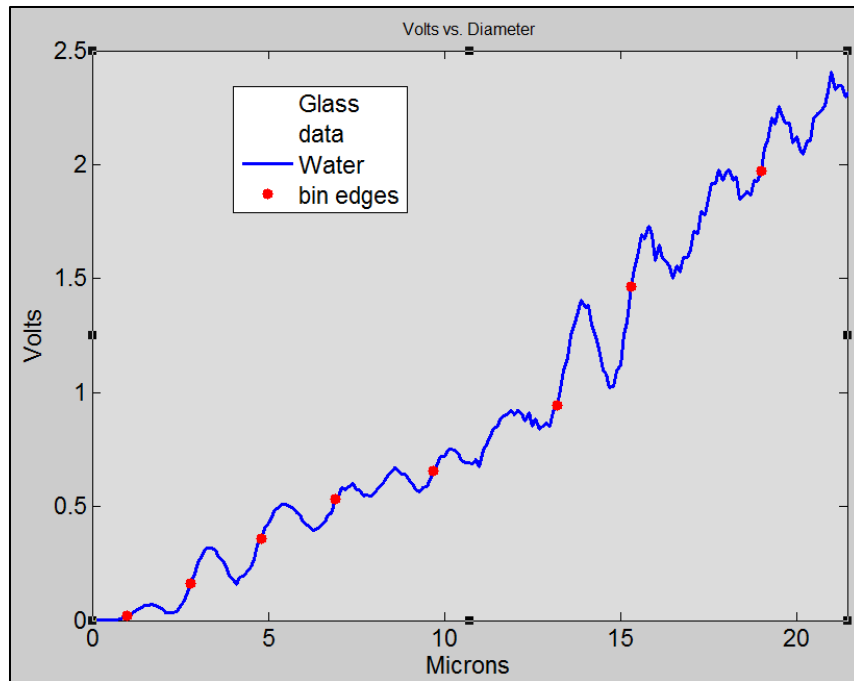


Figure A1: Mie curve, signal voltage versus size, and bin edges for the FFSSP.

What we observe in the data however, can be just the opposite. The signal distribution can be smooth (Fig. A2) and the size distribution, using the Mie bumps calibration, has bumps or jumps (Fig. A3) specifically at the above mentioned bin's edges. The same effect occurs to the usual PSD (Fig. A4) but is not as obvious. I.e. we might believe the bimodality seen in Figs. 6, 9, 12, and A4 as a cloud physics effect rather than seeing it for the spurious effect that it seems to be. Figs. 2 - 4 were made using all the data events instead of just the qualified events because it is easier to observe the phenomenon this way. Most ICE-T data periods have too few droplets, after qualification, in these small bins to show the effect clearly. Figs. 5 - 7 show another data period (ICE-T RF7, seconds 2983 to 2990) using qualified events only, chosen because it does exhibit the same effects, though more subtly. Note that the spikes at ~ 1.8 V in the signal distributions and ~ 24 μm in the PSDs are a separate spurious effect that still needs resolving.

These results suggest it may be better to ignore the Mie bumps. This is likely due to a number of effects that smear out the Mie bumps. In particular, the Mie curve varies with position relative to the focal plane. That is, the Mie curves shown in Figs. 2 and A1 were calculated for a droplet at the focal plane of the optical system. Away from the focal plane but still within the depth of field, the curves vary enough to effectively blur the bumps away.

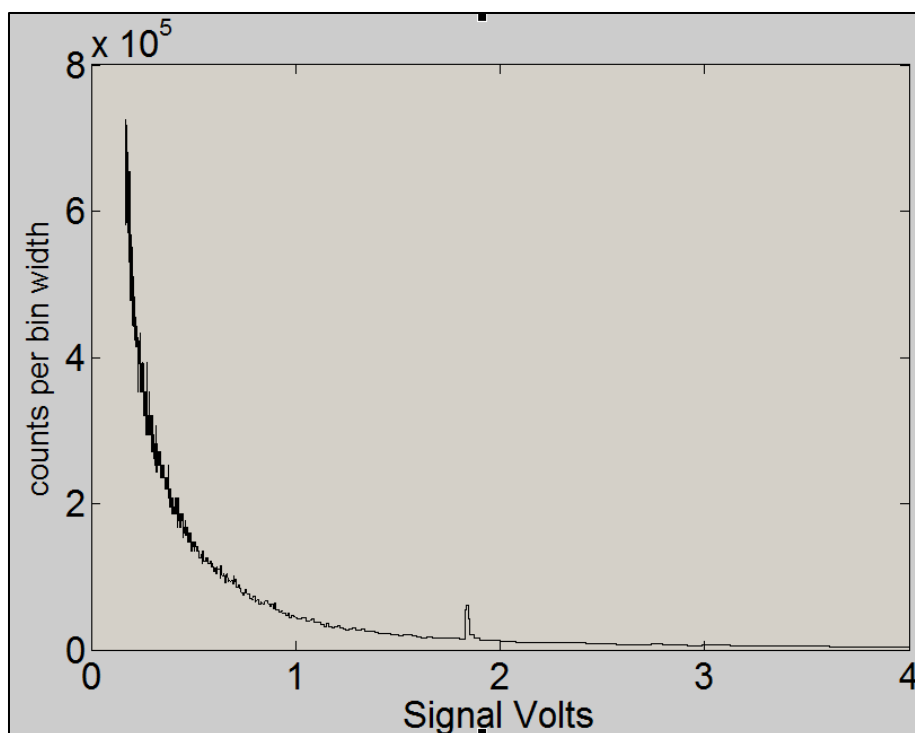


Figure A2: Example of a typical signal peak distribution. The spike near 1.8 V is a quirk that has already been documented but not solved.

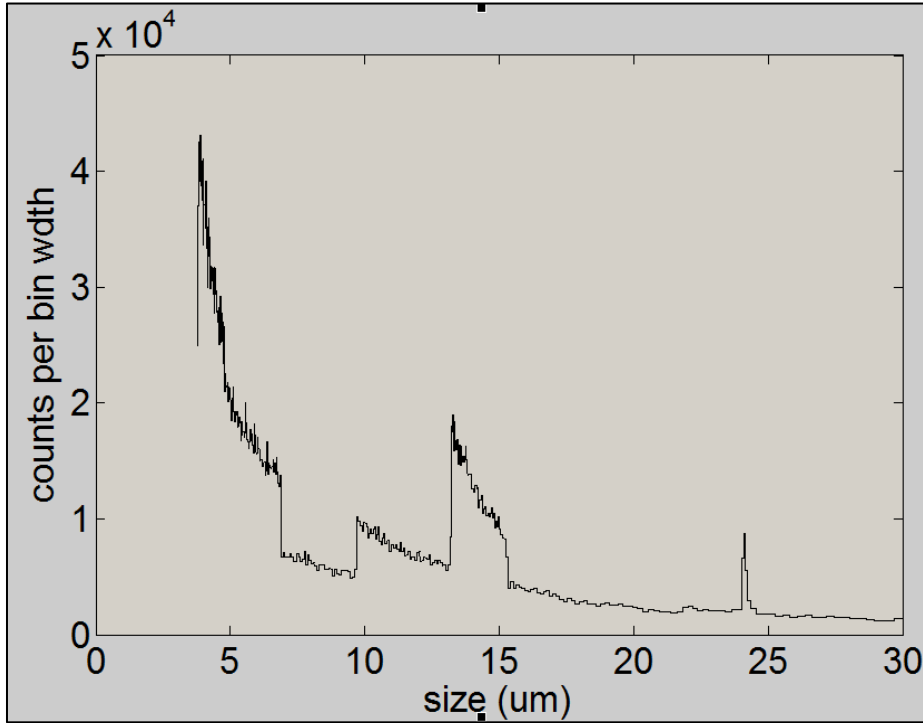


Figure A3: Unihist sizes distribution, using the binning determined to account for the Mie bumps, for the signals shown in Fig. A2.

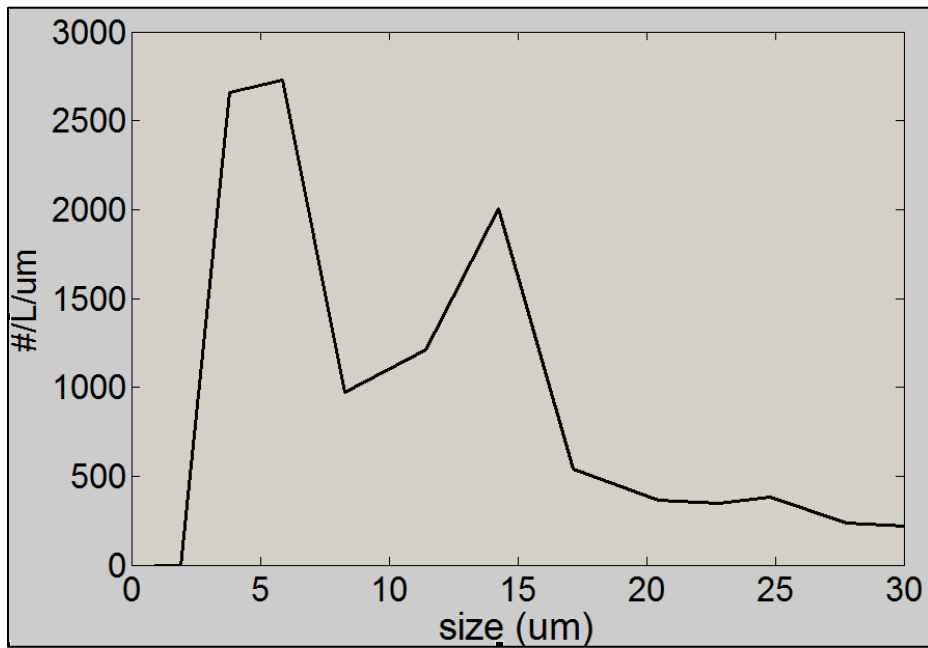


Figure A4: standard PSD, using the binning determined to account for the Mie bumps, for the data shown also in Figs. A2 and A3.

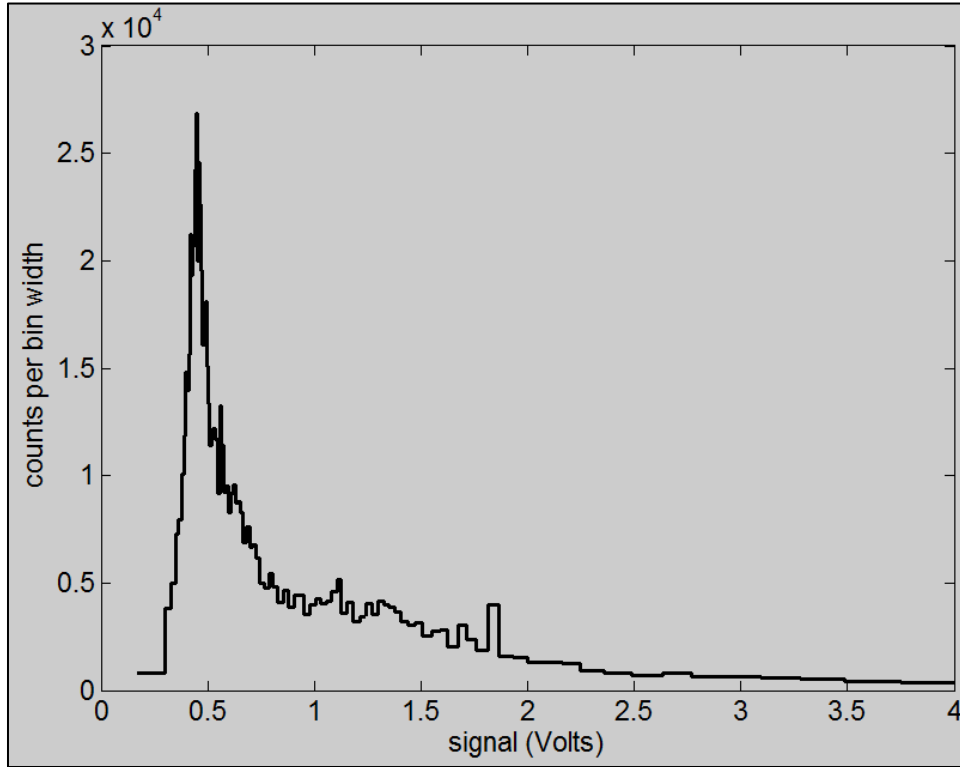


Figure A5: Distribution of peak signal voltages for fully qualified events only.

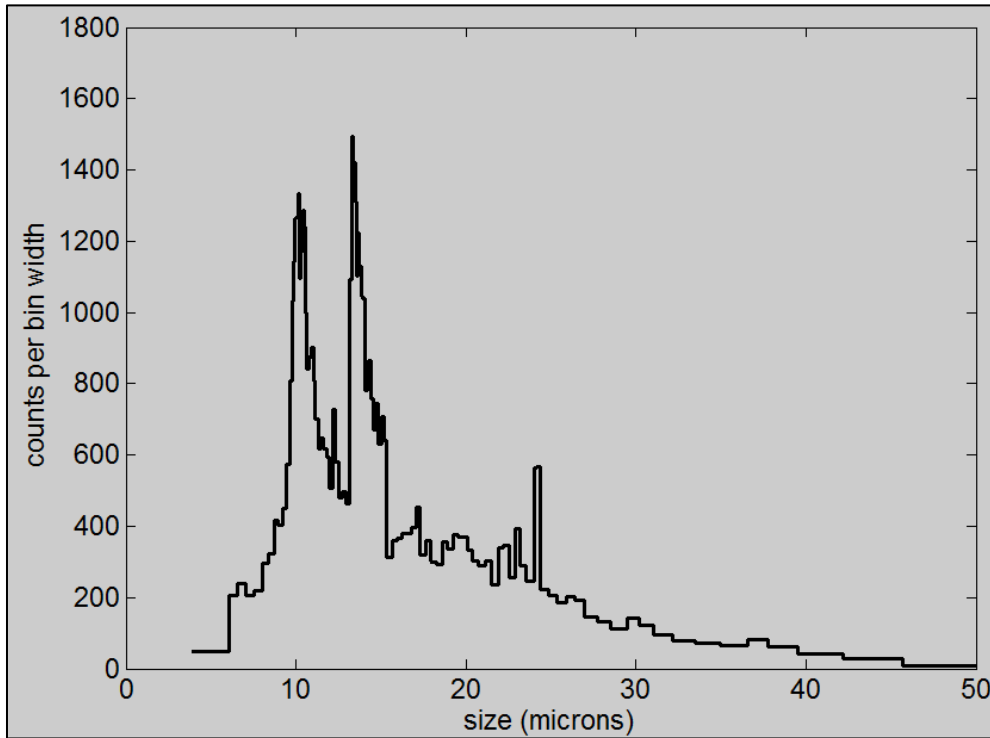


Figure A6: Size distribution using the binning determined to account for the Mie bumps.

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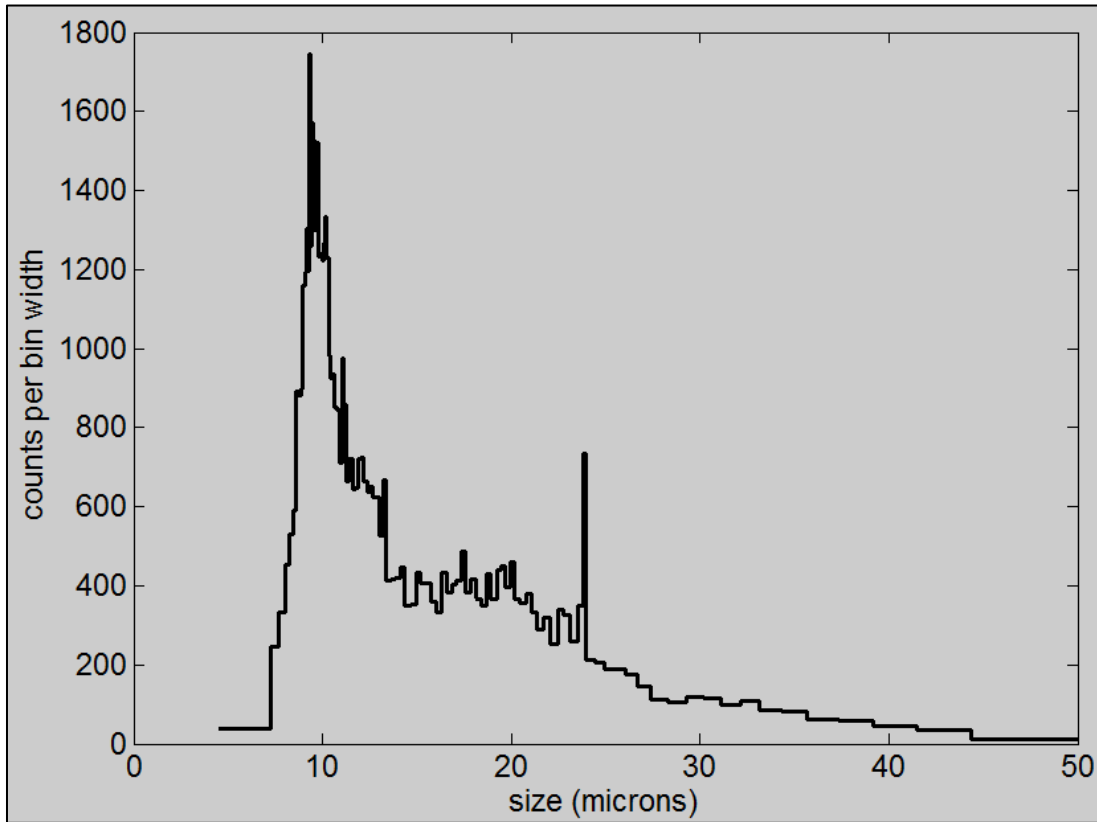


Figure A7: Size distribution using the binning determined ignoring the Mie bumps.