ADVAPIX TPX3 & MINIPIX TPX3
User Manual

Model No.: APXT3M-Xxxyymmdd
MNXT3S-Xxxyymmdd

Contents

1. Content of package

- *ADVAPIX* / MINI*PIX* Timepix3 device
- USB 3.0 cable - *ADVAPIX TPX3*
- +5 V DC adapter - *ADVAPIX TPX3*
- USB memory stick with control software ***PIXET* Pro**

2. Start guide

1. Connect the device to the water cooling system. Thermal stabilization to 20-25°C is strongly recommended.
2. Connect the device to the computer via USB 3.0 or USB 2.0 cable(s).
3. Plug in the power adapter (if it is needed)
4. Connect the attached USB memory stick to the computer.
5. Install the device drivers:
   - Microsoft Windows: run *drivers/setup.exe* and follow the instructions.
   - macOS: run *drivers/D2xxHelper_v2.0.0.pkg*.
   - Linux: installation of any special drivers is not required.
6. Install the ***PIXET* Pro** application:

***PIXET* Pro** for Windows is distributed as a single executable file for automatic installation. Run *setup.exe* and follow the instructions it the setup wizard.

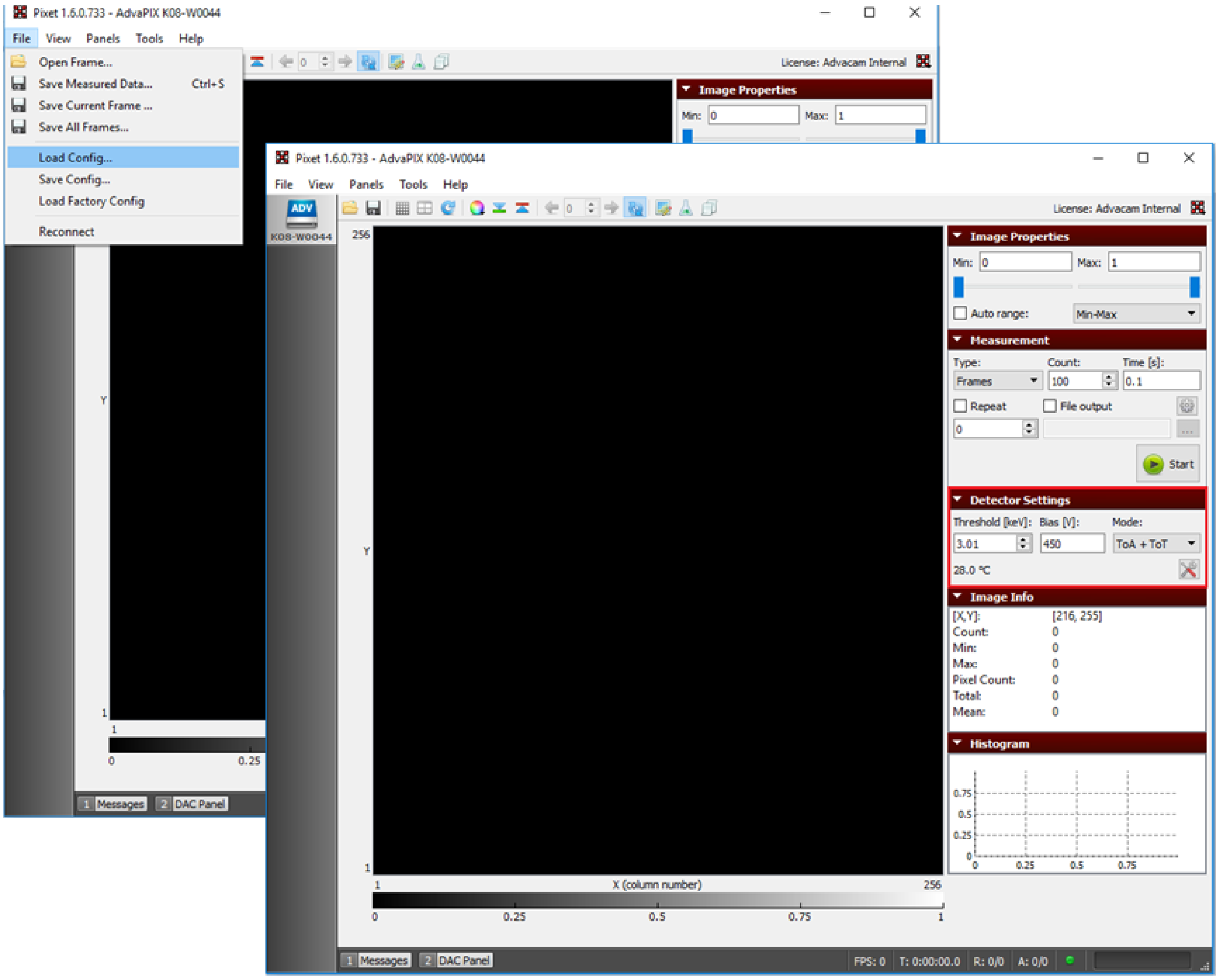
***PIXET* Pro** for macOS system is distributed as a standard *dmg* file (disk image file). After mounting the *pixet.dmg* file a window with disk content will open. To install, move the ***PIXET* Pro** folder to the Application folder.

***PIXET* Pro** for Linux system is distributed as a single *tar* file. To install, untar the file at a required location. The application is launched by executing the *pixet.sh* script.

7. Run ***PIXET* Pro** application. An icon with ID of your device must appear in the left panel.

Default configuration of the connected device is loaded automatically. Configuration file contains default settings of the detector including calibration of energy thresholds to keV. Settings of thresholds in keV and bias voltage are shown in the **Detector Settings** panel when the configuration is properly loaded. The device is now ready for use. However, **it is advisable not to start any measurements until the thermal equilibrium is established (~ 20 minutes).**

Last detector settings with all your modifications are stored locally on your computer when ***PIXET* Pro** is closed. The settings will be loaded again when starting ***PIXET* Pro** with the same device next time. The defaults can be restored at any time by loading the default configuration: Click **File → Load Config** in menu bar and choose the configuration file using system dialog window. It is located in the *Pixet/configs* folder and has *.xml* extension.



3. Timepix3

3.1 Timepix and Timepix3 – What is the difference?

- All previous chips of **Medipix/Timepix** family utilized the frame-based readout, i.e. the whole pixel matrix was read-out at once. The **Timepix3** has an event-based read-out where values recorded by pixel are read-out immediately after the hit. This way a full information about each event is recorded comprising coordinates, energy and detection time for each hit pixel. The chip therefore generates a continuous stream of data rather than a sequence of frames. Timepix3 is therefore much faster then Timepix.

- **Timepix** based detectors allow the photon counting, spectroscopic “time-over-threshold” and Time of arrival measurements. Each of these measurement modes must be run separately. The Timepix3 chip operates in all of them simultaneously.

- The Timepix3 time resolution of 1.56 ns is much higher compared with Timepix whose time resolution is 25ns

3.2 The main features of Timepix3

Timepix3 readout chip and fast interfaces make possible individual processing of every detected particle. Such event-by-event imaging principle (list-mode) allows for extracting of more information from measured data. Thanks to it the Timepix3 read-out chip allows for suppression of secondary radiation generated inside of high-Z sensors such as CdTe or GaAs via internal XRF or Compton effect. This principle together with reconstruction of charge sharing effect for each particle a significant improvement of spatial resolution down to 14 microns is achieved even for hard X or gamma rays.

Timepix3-based detectors have single energy threshold. All energies below the set value are cut off. Devices are set to a minimal threshold above noise by default. This is typically 5 keV fo CdTe sensor and 3 keV for silicon sensor. The threshold can be adjusted by user in the Event Count & iToT mode.

3.3 Timepix3 operation modes

The Timepix3-based detector offers several operation modes. These modes are summarized in the table below.

Acqisition modes	Readout	Bit depth
ToT& ToA	Data driven based	ToA:14bit ToT: 10bit Fast ToA: 4bit @ 640 MHz (1.56ns)
only ToA	Data driven based	ToA:14bit Fast ToA: 4bit @ 640 MHz (1.56ns)
Event Count & integral ToT	Frame based	Integral ToT: 14bit Hit counter: 10bit

ToT &ToA –Time-Over-Threshold (ToT) & Time-Of- Arrival (ToA) running in data-driven mode is the most complex measuring mode that can be used for fully spectral data acquisition. This mode exploits a 10 bit counter working like a timer that determines the number of events (clks). This number is proportional to deposited energy of particle captured in the sensor. Simultaneously uses the 14 Global Timer to determine the time of arrival.

The time resolution of Timepix3 chip (1.56ns) is given by fast ToA that determines a time of arrival with higher accuracy.

It is important to note that in Timepix3, ToA value is not based on the shutter (like in Timepix) and is taken from a free-running global Gray counter instead. However, ToA values of rising/falling edges of the shutter can be obtained via Global Timer. If acquisition time is shorter than 14b-range * clock period (409.6us @ 40MHz), it is guaranteed that no ambiguities in ToA values exist. The information about the position of hit pixel is noted in the same time.

This all makes it possible to get complex information about each particle detected in the sensitive area.

Only ToT - This mode internally blocks local oscillators and allows faster measurement of ToT in data-driven mode.

Event Count & Integral ToT

Mode of operation Event Count & Integral ToT is one of reasonable and usable mode based on frame readout. It works as a counter of all detected particles and as a timer for energy-dependent measurement. The Event Count measures every detected particle hit in the sensor. The counter is increased if the detected pulse is above the energy level. Integral ToT measures the energy of the particle which is proportional to the length of the pulse. This mode works the same as for Timepix chip with the respect of a number of particles detected in one frame.

To measure energy must be selected the time as low as would be possible to distinguish the particles from each other. In the case the time would be selected inappropriately the particles will be overlapped and then it does not be possible to determine the real energy of the measured particle.

Timepix3 also offers to switch between the additional modes of measurements which are allowed in the menu for modes of measurement. Then is the ability to measure even ToT and ToA or only ToA. The rule of correct acquisition time selection applies here also as well as for using iToT measuring mode.

3.4 Timepix3 data formats

Each pixel in Timepix3 data file is 64bit long. The frames of type u64 are used. Each pixel value in the file contains multiple information - ToT, Toa, iTot, etc. based on the Timepix3 detector measurement settings. The data can be saved and replayed using the following file formats:

- Timepix3 Pixels ASCII File **(*.t3pa)**
- Timepix3 Pixels Binary File **(*.t3r)**
- Timepix3 Raw Data File **(*.t3p)**

The list of the commonly used formats is described in the following section.

ASCII File (*.t3pa)

This file is specific for Timepix3 detector. It contains a stream of pixels received from the detector. It is a ASCII file. The file starts with a header line:

```
Index Matrix Index ToA ToT FToA Overflow
```

Each following line contains a single pixel. Where the values are:

- Index - index of the pixel in the file. Starting from 0
- Matrix Index - position (index) of the pixel in pixel matrix - for single detector 0 - 65535, where 0 – 255 are pixels in first row, 256 - 511 second row, ...
- ToA - ToA value of the pixel (raw detector value)
- ToT - ToT value of the pixel (raw detector value)
- FToA - Fast ToA value of the pixel (raw detector value)
- Overflow - just for internal purpose

The ToA and FToA are raw values from the Timepix3 detector. To convert them in nano seconds use this formula:

```
toa[ns] = toa * 25 – ftoa * 25/16
```

Example:

```
Index   Matrix Index         ToA     ToT  FToA     Overflow
0       40790     198395270     12    9    0
1       40793     198395275     11    7    0
2       40534     198395263     26    11   0
```

Binary File (*.t3r)

Timepix3 Binary Pixels is similar to t3pa file. Just the numbers are not saved as ASCII, but binary. The file contains one pixel after each other. Each pixel in this format:

```
u32 matrixIdx
u64 toa
byte overflow
byte ftoa
u16 tot
```

Raw Data File (*.t3p)

This is a dump of raw communication from the device. The file format is device specific and complex. For more information and code please contact daniel.turecek@advacam.com.

4. Settings of *ADVAPIX* / MINI*PIX* TPX3 device

4.1 Setting operation modes

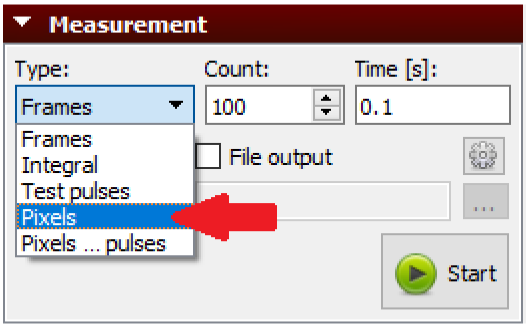
Mode of operation can be selected via drop-down list in the **Detector Settings** panel:

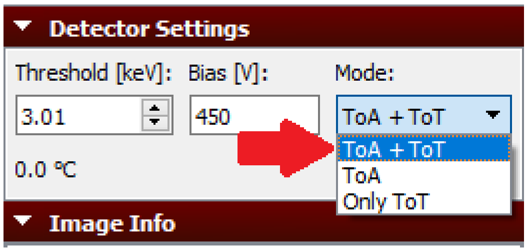
ToT & ToA (Pixels)

Information about the position, the energy and the time of arrival of every detected event is noticed and directly sent to PC. The out-put formats are *.t3pa, *.t3p and *.t3r. Data driven based mode is used.

<u>*Mode setting:*</u>

Click on the **Pixels** measurement type in the drop-down list within the section **Measurement**. After selecting of measurement type check measurement mode that must be set to **ToA &ToT**



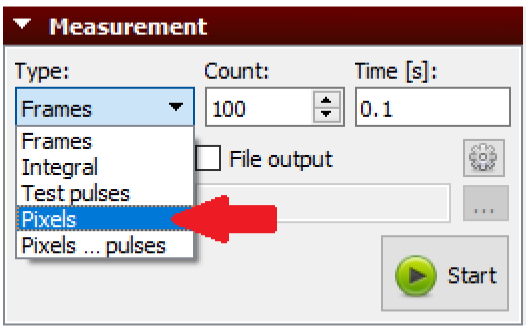


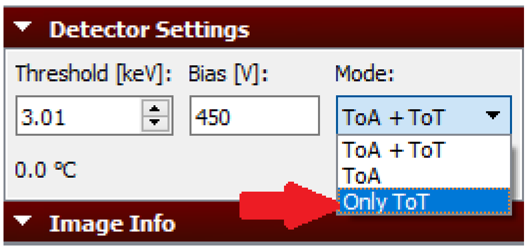
Only ToT (Pixels)

Information about the position and the energy of every detected event is noticed and directly sent to PC. The out-put formats are *.t3pa, *.t3p and *.t3r. Data driven mode is used.

<u>*Mode setting:*</u>

The setting of this mode is same as the setting for **ToT & ToA (Pixels**). Select measurement mode to **Only ToT** instead of option ToT & ToA in the drop-down list for Mode measurement is required.



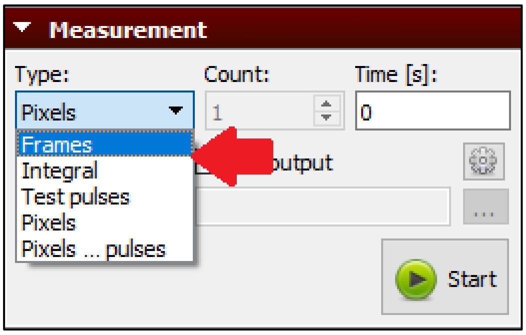


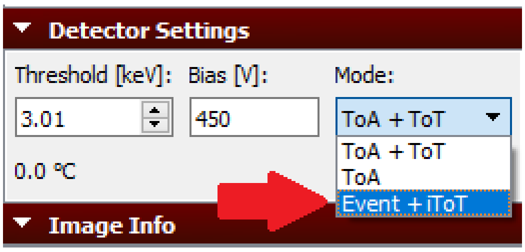
Event + iToT (Frame or Integral)

Frame-based mode measurement. Measurement outputs: one 10-bit image representing the number of events per pixel and one 14-bit image representing integral measured energy. Images can be saved as *.pmf files or *.txt files.

Mode setting:

Click on the **Frame** or **Integral** measurement type in the drop-down list within the section **Measurement**. After selecting of measurement type check measurement mode that must be set to **Event + iToT**



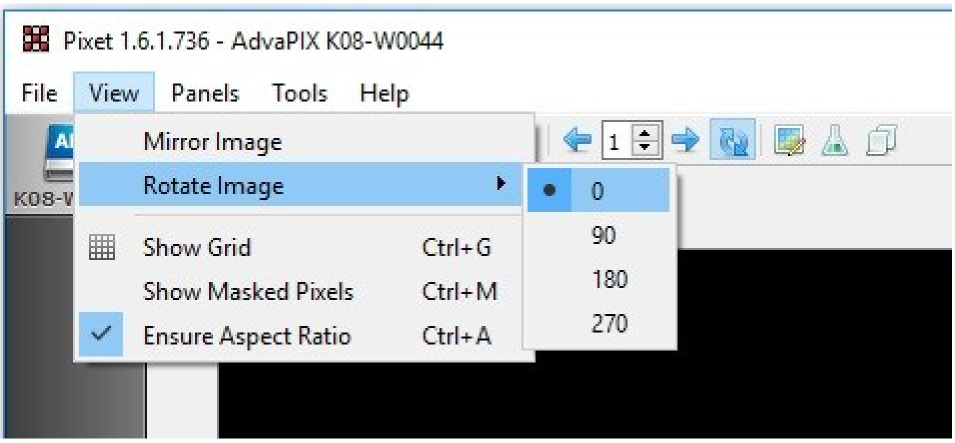


4.2 Useful tips and how-tos

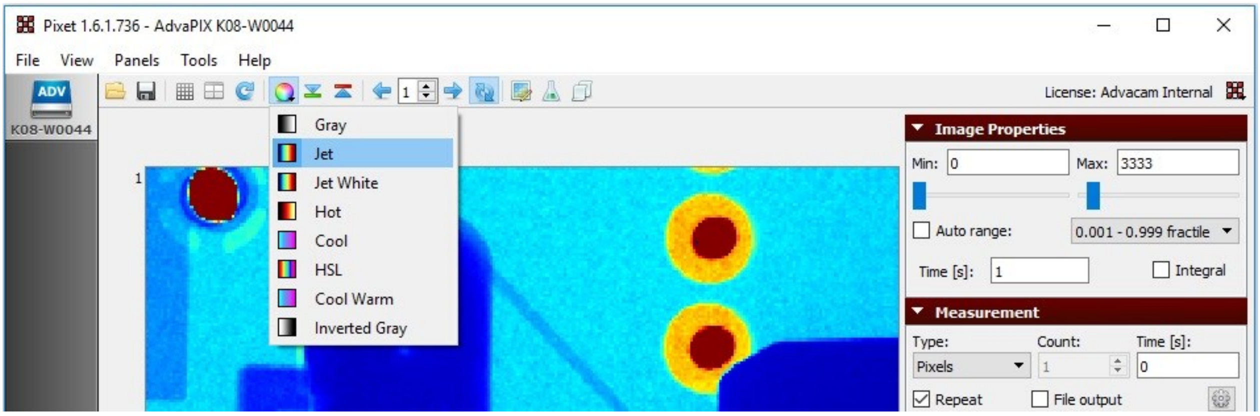
***PIXET* Pro** is being developed in Advacam s.r.o. as desktop application for expert users. It implements full control of the Timepix- / Medipix-based detectors and it is used within manufacturing processes (testing, calibration, …) as well as during the preceding development phase of the devices. Since the application is very powerful, inexperienced user could set the device to non-functioning state. Recovery from such case is loading the factory settings shipped with the detector.

Here are several tips for more effective and comfortable use:

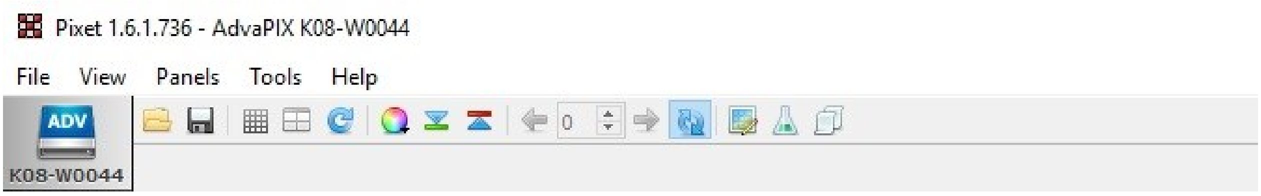
- Composition of panels on the right side of the ***PIXET* Pro** window can be configured in **Panels** in menu bar.
- Orientation of the image (rotation, mirroring) can be customized in **View** drop-down list in menu bar



- To keep the aspect ratio of the image click on **View → Ensure Aspect ratio** menu bar.
- Default colormap is gray. Colormap can be selected via drop-down list under the multicolored icon located in main toolbar.

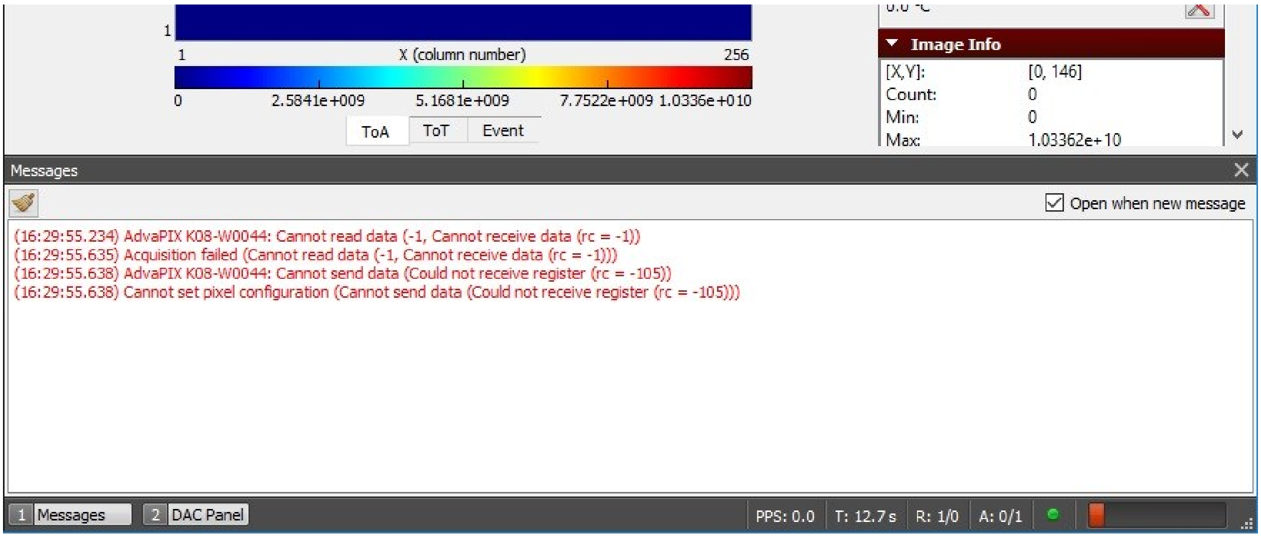


- **Image Properties Panel** allows to adjust brightness and contrast of the displayed images by setting the range to be displayed. **Auto range options** provides automatic adjustment.
- **Advanced Image Properties** anel allows to set **gamma correction** for better visibility of features within measured sample.
- ***PIXET* Pro** allows opening and showing previously saved images by drag and drop into image area of the ***PIXET* Pro** window. When multiple images are drag and dropped, one can browse them using blue arrows in the main toolbar.



- Images can be zoomed by holding the left mouse button in the frame, dragging the mouse to create a selection rectangle and releasing the mouse button. To restore the original frame size, double click on the image.

- Application output including error messages are shown in **Messages** panel.



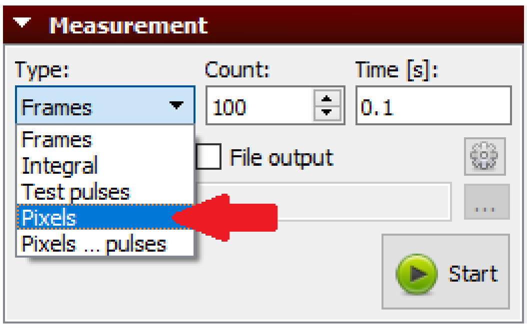
- In case of hardware disconnection, the device can be reconnected by clicking File⍰ Reconnect in menu bar without restarting ***PIXET* Pro** application.

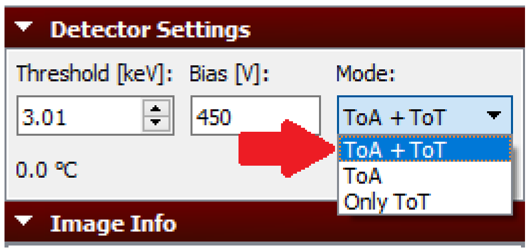
4.3 Practical examples of measurements

<u>Example 1 :</u> Measurement in ToA & ToT

<u>Setting of operation mode:</u>

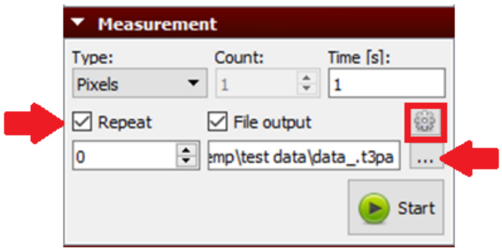
1. Set the device to **Pixels** operation type as described above
2. Check the **mode** in **Dettector Settings**. Mode **ToA & ToT** must be set.





Controlling the measurement parameters via **Measurement** panel:

1. Set the exposure time for measurement in seconds using **Time [s]** text box.

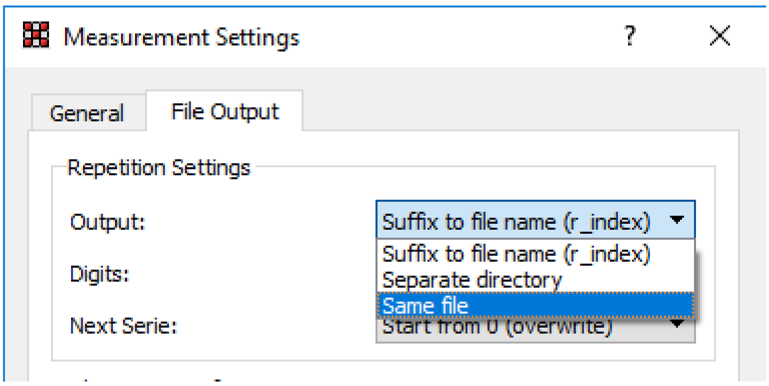


2. Checking the **Repeat** checkbox and setting the number of repetitions using the text box underneath will cause repeating the defined measurement several times. Setting the number of repetitions to zero value means "repeat forever". If the **Repeat** checkbox is unchecked, the number of repetitions is not in use. Every repetition can be saved in several ways. How to save the data into the required file outputs is described below.

Setting the file output

Click on the **More Measurement Settings** (red labeled box above) button in the **Measurement** panel. New window will appear. Select the output form in the drop-down list within the **Repetition Settings → Output:**

- **Suffix to file name (r_index) –** every repetition will be save as a separate file
- **Separate directory –** every repetition will be saved in to its own directory
- **Same file –** all repetitions will be gradually saved into one file



3. Check box **File output** for data saving (if is need)

    Automatic saving of measured data

    Check **File output** in **Measurement panel** for automatic saving. Then click on the button with three dots. A system dialog window will appear to Select the target destination and filename. Confirm it by clicking the **Save** button. Measured data are saved automatically during the measurement. A warning dialog will appear if the file name and destination is used for another measurement.

    Two files are saved by default to each frame:

    1. **data file** (*.t3pa,*.t3r or *.t3p)
    2. **description file** (.info) which contains information about the device, used configuration, measurement settings, etc.

4. Press **Start** measurement

    Starting the measurement

    Start / stop the measurement using **Start / Stop** button on the **Measurement** panel. Progress of the measurement is shown in the status bar at the bottom of the window. Once the measurement is finished, the measured frame is shown in the image preview area of the **PIXET Pro** window.

[1]If you measure with high intensity flux check the following parameters:

Check the following setting before you start the measurement. Uncheck the "ProcessData" and "DummyAcqNegativePolarity" in the tab Readout in More Detector Setting dialog which is accessible from the main ***PIXET* Pro** window on the right side under the panel Detector setting. These two parameters influence the preprocessing of the data and if enable can slow down the data readout.

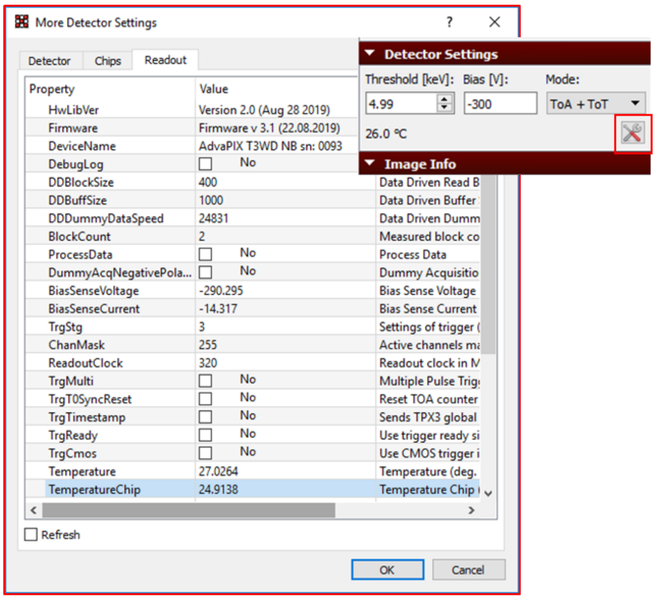


Fig. 3. More detector settings main window

Set value **400** to the field *DDBlockSize* and value **1000** to the field *DDBuffSize.* Set *Pixels* mode in the panel Measurement. The meaning of these parameters is following:

Block size – the data are readout from the device in blocks (chunks) in order to optimize the data throughput. The size of this block is specified by the Block size parameter (in MB). The block size cannot be greater than the Buffer size. The data blocks read from the device are filled with measured data and dummy bytes in case there is no data coming from the chip. Therefore the block size can also influence the speed of the readout. If the block size is big and the radiation intensity is very low, it might take several seconds to read the full block. However, for high intensity measurements, it is neccessary to setup the block size to higher numbers (e.g. 600 MB).

Buffer size - this parameter represents the amount of memory in MB that is reserved for the measured data. This buffer is filled with the data blocks and if saving of the data is enabled the data are saved to disk and the used memory is released for next measured data block. If the saving of the data is not enabled, only data blocks tha t fits into this memory will be measured. If the buffer size is set e.g. to 1000 MB

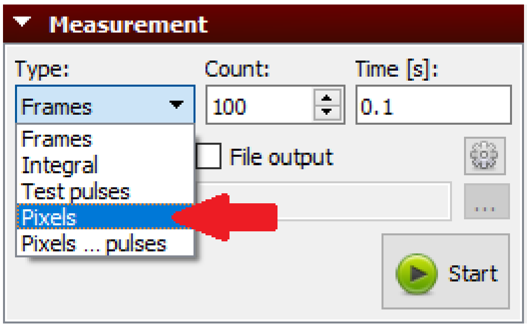
The data must be read out to the memory. The data are saved to disk after the measurement and later processed.

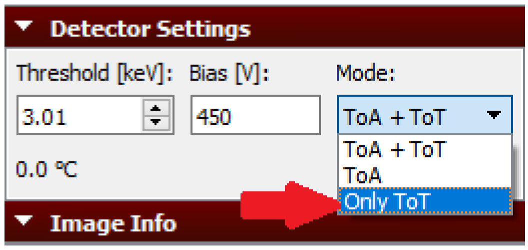
[1] These parameters are available and enabled only for AdvaPIX TPX3. Mini PIX TPX3 has these parameters partially preselected.

Example 2: Measurement in only ToT

Setting of operation mode:

1. Set the device to **Pixels** operation type as described above
2. Check the **mode** in **Dettector Settings**. Mode **only ToT** must be set.





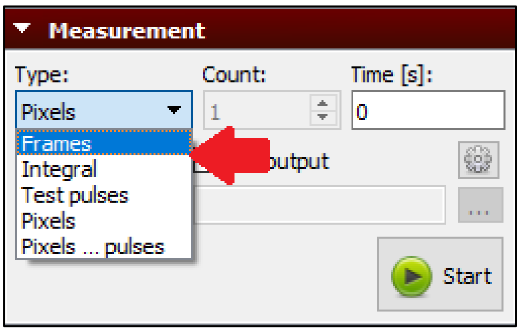
Controlling the measurement parameters via **Measurement** panel:

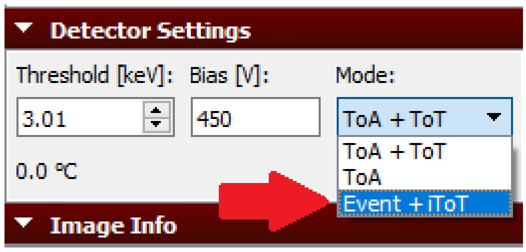
See. Example 1.

Example 3: Measurement in Event Count & Integral ToT

Setting of operation mode:

1. Set the device to **Frames (a)** or **Integral (b)** operation type:
2. Check the **mode** in **Dettector Settings**. Mode **Event + iToT** must be set.





<u>Controlling the measurement parameters via **Measurement** panel:</u>

1. Select type of measurement in **Type** drop-down list
   - **a.** For single acquisition select **Frames** and set parameter **Count** to 1.
   - **b.** **Integral** - several acquisitions are added to one frame. Number of acquisitions to be added is defined by parameter **Count.**
2. Set the exposure time of individual frame acquisitions in seconds using **Time[s]** text box.
3. Checking the **Repeat** checkbox and setting the number of repetitions using the text box underneath will cause repeating the defined measurement several times. Setting the number of repetitions to zero value means "repeat forever". If the **Repeat** checkbox is unchecked, the number of repetitions is not in use.
4. Check box **File output** for data saving (if is need)

   <u>Automatic saving of measured data</u>

   Check **File output** in **Measurement panel** for automatic saving. Then click on the button with three dots. A system dialog window will appear to Select the target destination and filename. Confirm it by clicking the **Save** button. Measured data are saved automatically during the measurement. A warning dialog will appear if the file name and destination is used for another measurement.

   Two files are saved by default to each frame:

   1. data file (*.txt) that contains two sub-frames: The first one represents number of counts in every pixels and the second one frames represent integral measured energy in every pixel
   2. description file (*.dsc) which contains information about the device, used configuration, measurement settings, etc.

   <u>Manual saving of measured data</u>

   Click on **Save Data** option. A pop-up window will appear. Save the data to the required form according to forms descriptions.

5. Press **Start** measurement

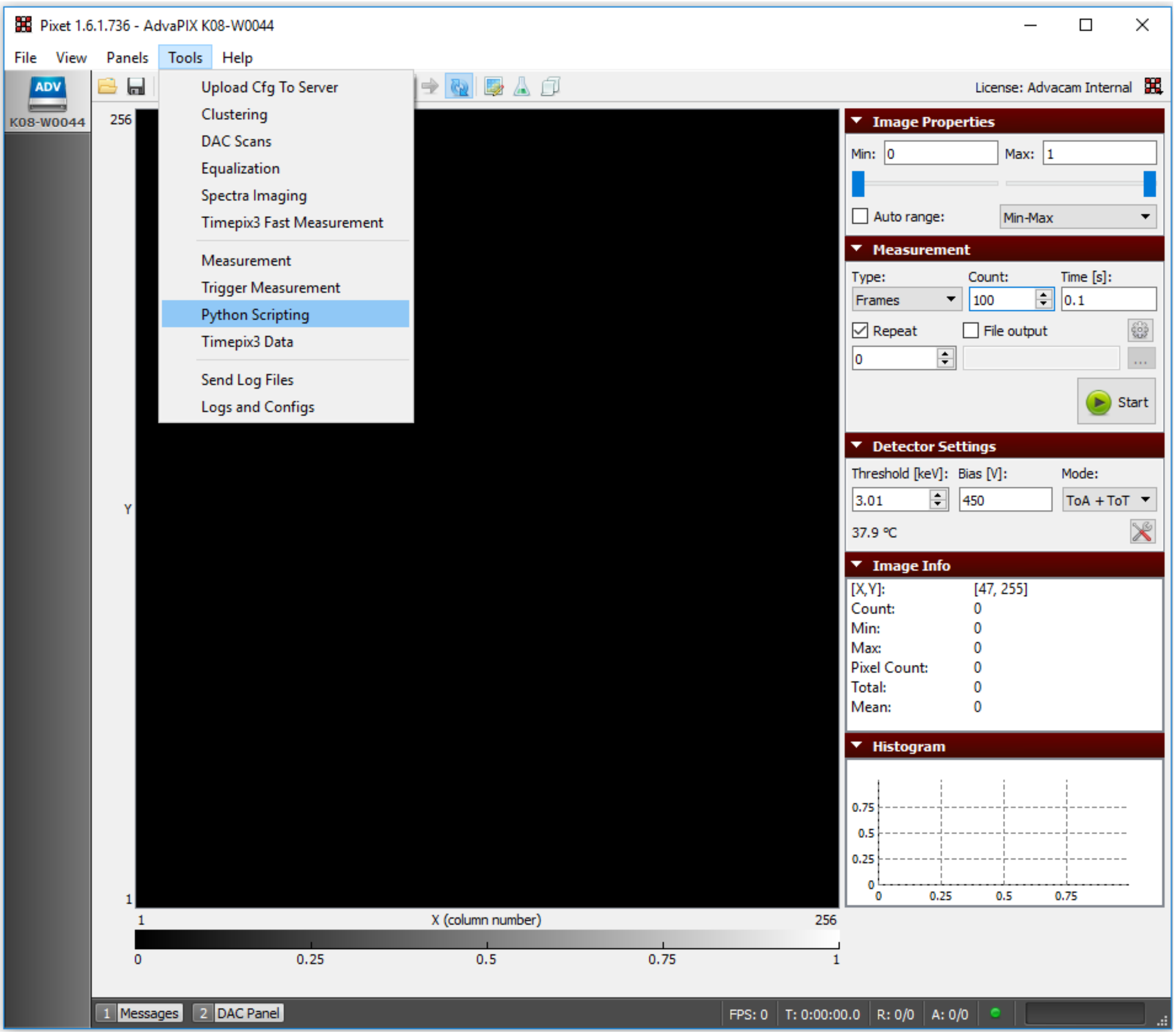
   <u>Starting the measurement</u>

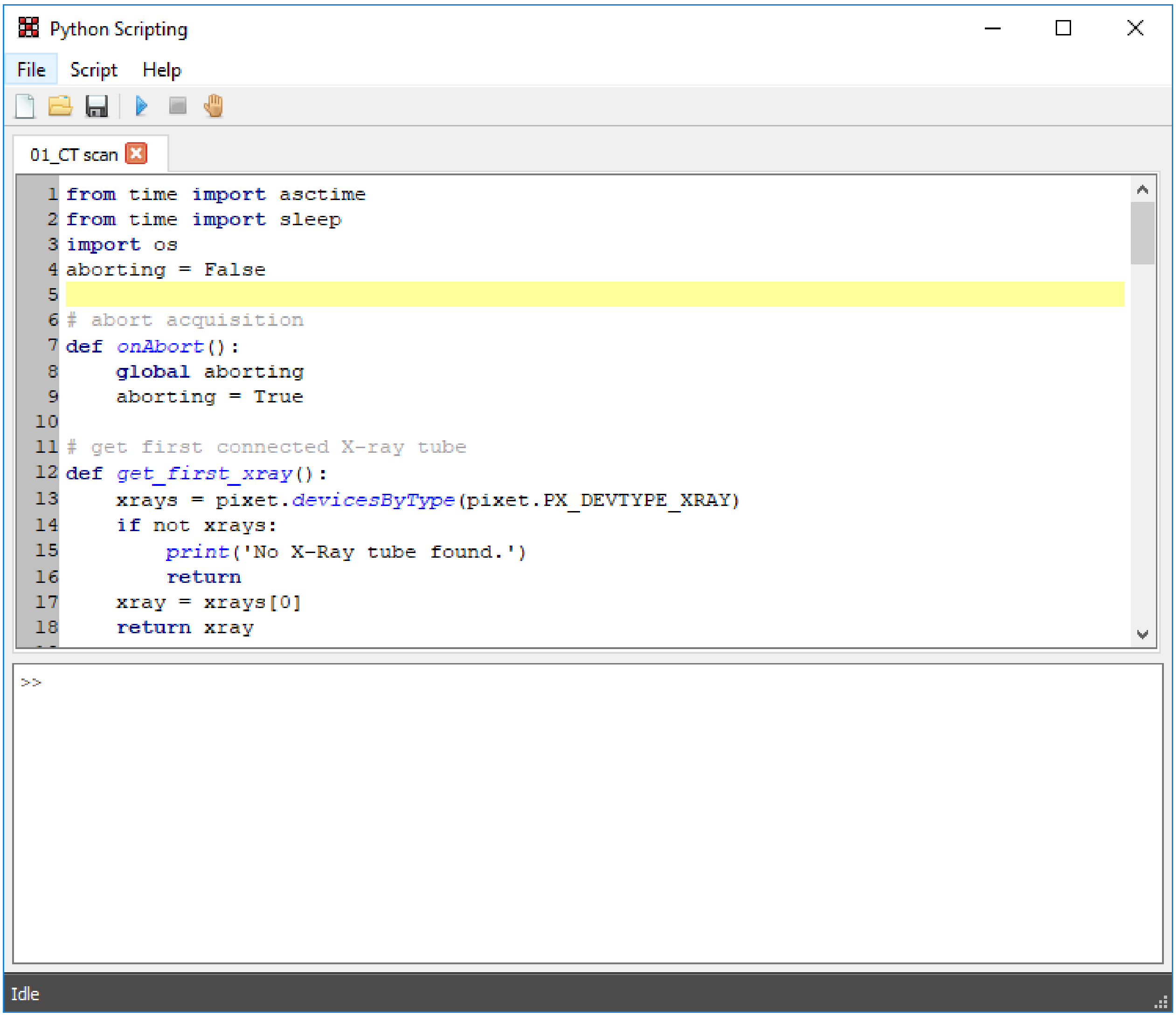
   Start / stop the measurement using **Start / Stop** button on the **Measurement** panel. Progress of the measurement is shown in the status bar at the bottom of the window. Once the measurement is finished, the measured frame is shown in the image preview area of the **PIXET Pro** window.

5. Advanced control using Python Scripting plugin

Python Scripting plugin allows the user to perform complex measurements controlling the detectors automatically via Python commands and scripts. The **Python Scripting** embeds a full python 2.7 interpreter including the standard python libraries. All standard functionality of python is threfore accessible. Please refer to www.python.org or www.learnpython.org for more information about Python programming language.

Click on the icon on the right edge of the main toolbar to start the **Python Scripting** plugin. Choose **Python Scripting** from the list. A new window with simple editor will open. The bottom part of the plugin window contains a python console, where python commands can be run one by one with immediate output. The console also contains the output of executed python script.





The ***PIXET* Pro** API (Application Programming Interface) is accessible in the scripts via a **pixet** variable. This variable represents the **IPixet** object that provides all the necessary methods to get information about all connected devices, log messages to log file, access the ***PIXET* Pro** menu, etc. A list of all available objects, methods and constants of the ***PIXET* Pro** API can be displayed by clicking **Help →Function List...** in the main menu of the **Python Scripting** window.

5.1 Practical examples

Script #1

Detector settings for acquisition measured in data driven mode **ToT & ToA**

```
import time
import os
import copy
aborting = False


# get first Timepix3 device:
devices = pixet.devicesByType(pixet.PX_DEVTYPE_TPX3)
dev = devices[0]


# set Timepix3 operation mode:
dev.setOperationMode(pixet.PX_TPX3_OPM_TOATOT)

print " Start to measure"

# Measuring conditions

acqTimes = 1

projCount = 6
OUTPUT_DIR = "o:\\Data"


for i in range(0,projCount):
    print "Measurement %d" % i
    filename = os.path.join(OUTPUT_DIR, "frame_%03s.t3pa" % i )
    dev.doAdvancedAcquisition(1, acqTimes, pixet.PX_ACQTYPE_DATADRIVEN, 0, pixet.PX_FTYPE_AUTODETECT, 0, filename)


print "Measurement is done"
```

Script #2

Detector settings for acquisition measured in **Event mode (Event & iToT)**

```
import time
import os
import copy
aborting = False

# get first Timepix3 device:
devices = pixet.devicesByType(pixet.PX_DEVTYPE_TPX3)
dev = devices[0]


# set Timepix3 operation mode:
dev.setOperationMode(pixet.PX_TPX3_OPM_EVENT_ITOT)

print " Start to measure"

# Measuring conditions

ACQ_COUNT = 1
acqTimes = 1

projCount = 6
OUTPUT_DIR = "o:\\Data"


for i in range(0,projCount):
    print "Measurement %d" % i
    filename = os.path.join(OUTPUT_DIR, "frame_%03s.txt" % i )
    dev.doSimpleIntegralAcquisition(ACQ_COUNT, acqTimes, pixet.PX_FTYPE_AUTODETECT, filename)

print "Measurement is done"
```

6. Plugins for proccesing and evaluation of the data

The ***PIXET* Pro** software provides three data processing tools for data generated by TPX3. These tools allow visualizing different types of spectra, identifying various types of particles and also displaying and saving images, maps and histograms. One of these tools makes it possible to convert the data from complicated coded format to much clearly arranged format. The spectral data processing are the following:

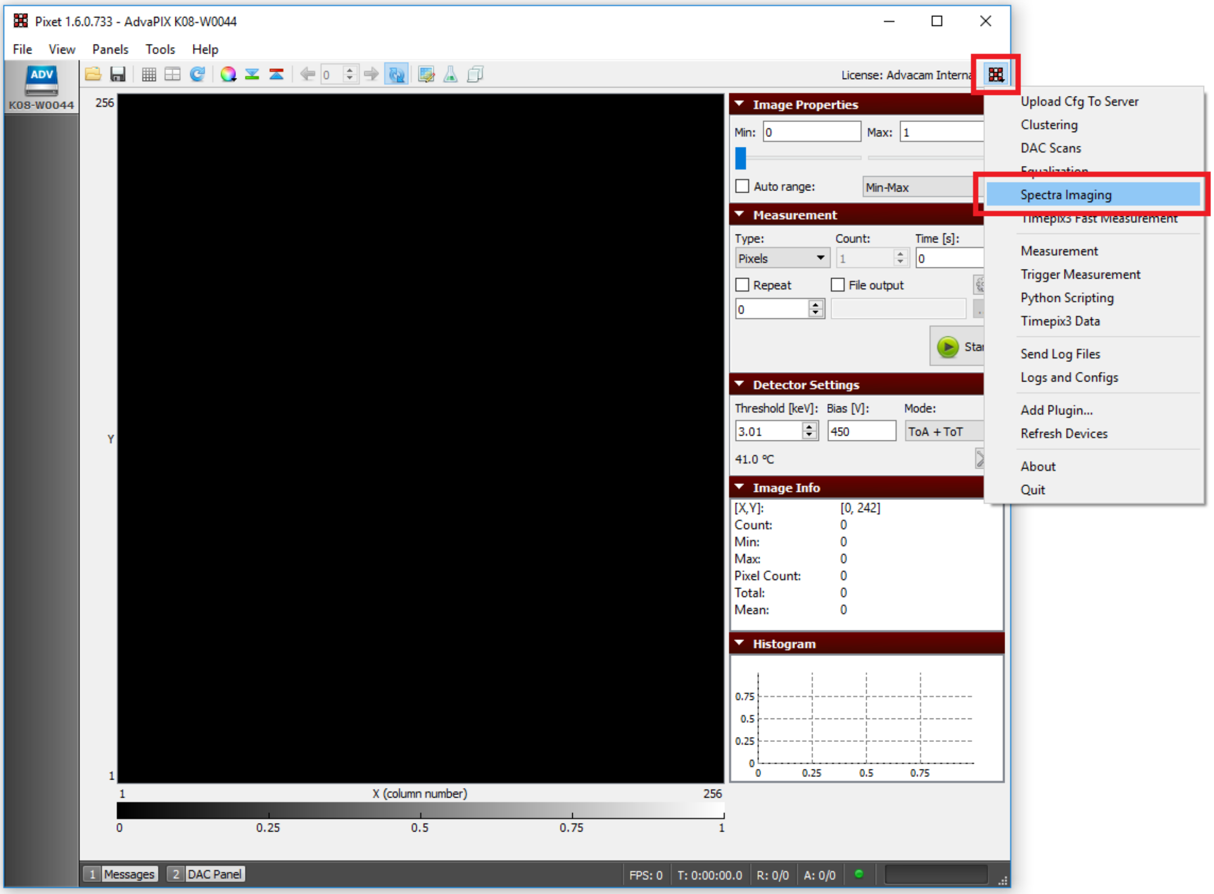
1. **Clustering** for advanced data processing
2. **Spectral imaging** for easy processing of the spectra
3. **TPX3 Data Converter**

How to set and control these tools is explained and described in the text below.

6.1 Spectral Imaging

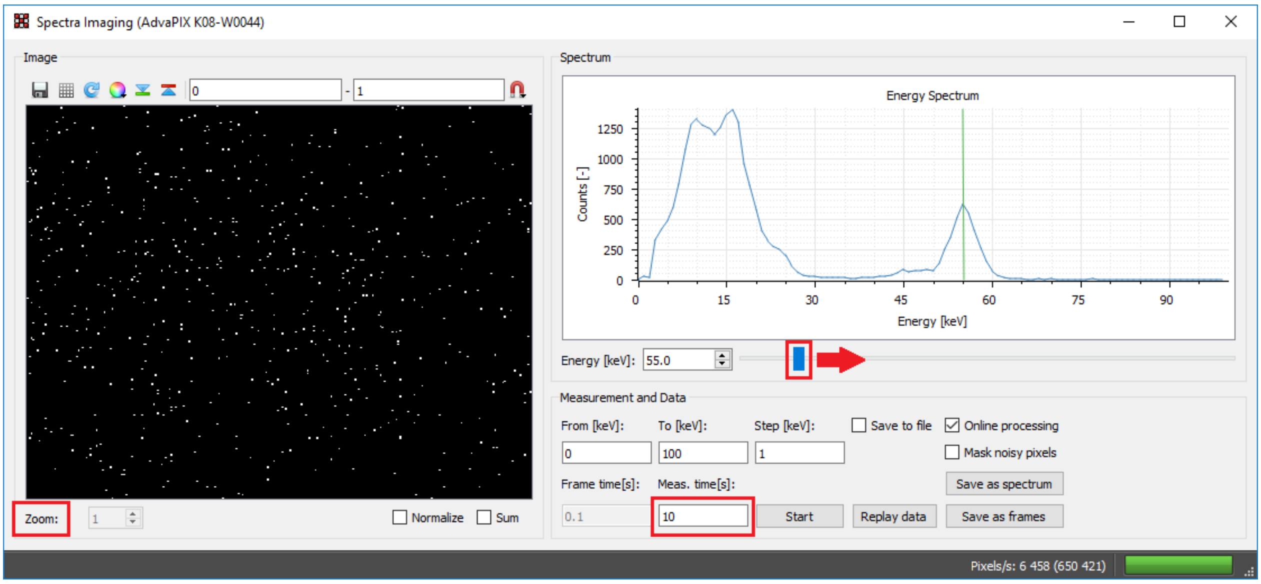
The following text describes the use of spectral imaging with Timepix3 detectors operated in the "Pixels" mode.

Connect the detector, start ***PIXET* Pro** Under the "icon is the list of installed plugins. Select the "Spectra imaging plugin"



Switch the type measurement from Frames to Pixels in the main window of the ***PIXET* Pro**. The spectra imaging plugin activates automatically the required calibrations. However, it is necessary to make sure that the default energy discrimination threshold is entered in the main ***PIXET* Pro** window.

The Timepix3 device measures directly a stream of events which are subsequently added to the spectrum. Each hit or particle track is recognised and all the energy deposited by each particle often into several pixels is summed. The result is the total deposited energy in the sensor. This value is then added into the global spectrum as well as to the local spectrum of each individual pixel. The total spectrum can be inspected within the plugin window. The slider under the spectrum plot allows selecting the image at given energy to be show in the preview on the lefthand side. The following images show incorrect and correct settings.



The plugin window allows selecting the minimum energy in the measured spectrum, number of

energy bins and the total measurement time. The "zoom" option allows splitting the acquired image into sub-pixels (NxN where N is the value

of the zoom parameter). It is available only for the sum image (the "sum" checkbox selected)

The measurement is started simply by pressing the start button in the spectra plugin. Checking

the "Save to file" check box saves data to Timepix3 required file format. This file can be replayed later on for instance to change the spectrum binning settings. A name of file is has to be selected each time the measurement is started.

The processed spectra could be saved after the measurement by clicking "Save as spectrum"

which saves the results into a text single file. Each line of the file contains spectrum of a single

pixel. Clicking "Save as frames" allows saving the measured spectrum as a sequence of images where each image corresponds to a single energy bin.

6.2 Clustering

The **Clustering** module preforms on-line or off-line identification of the particle traces in images recorded by ***PIXET* Pro**, performs their energy calibration, shape analysis and sorting. The module generates various types of results: Histograms, images, 2D maps, lists, logs.

6.2.1 Features of the software

- Processes images of radiation taken by ***PIXET* Pro** software
- Identifies particle traces in images = Clusters
- Performs data calibration (for each pixel independently)
- Calculates measures describing properties of particle traces
- Applies predefined sorting criteria
- Saves identified traces to “Cluster log” file
- Generates histograms, images, maps
- Supports “Energy mode” (ToT) and “Time mode” (TPX) of Timepix detector

Using Track Processing Tool

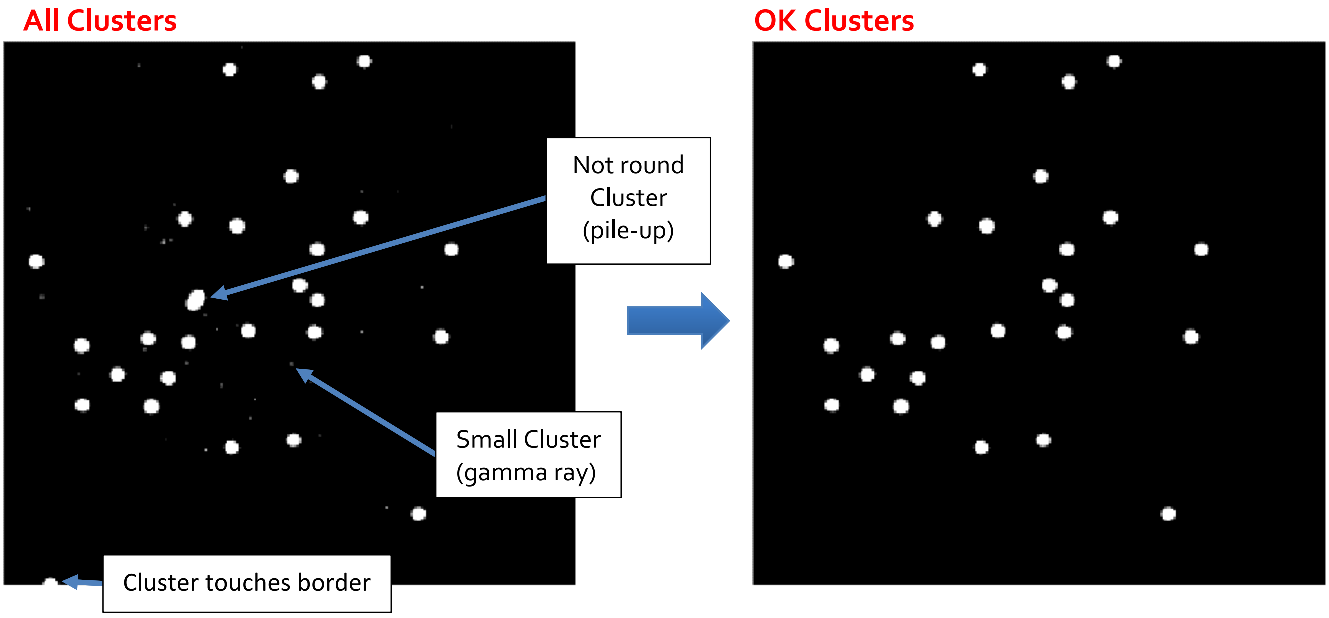
The Clustering tool processes frames provided by preselected device via ***PIXET* Pro** software. The parameters of the device such as exposure time or triggering are controlled by ***PIXET* Pro**. The track processing tool therefore doesn’t control the data taking. Whenever ***PIXET* Pro** takes the new frame it is automatically send for processing to the “Clustering” tool.

Clusters

The Timepix3 data files passed to the track processing tool contain traces of ionizing particles. Each particle track is identified as continuous area of neighboring pixels in the frame. Such set of pixels is called “Cluster”. The tool identifies individual clusters and process them according to preselected criteria.

Clusters analysis parameters and OK Clusters

The “Clustering“ tool can evaluate a number of parameters for each identified cluster. User can specify certain acceptance criteria for selected parameters. Typically the criteria are given as a range of allowed parameter values. Clusters which are positively evaluated are assigned with “OK” flag and they are often referred as “OK clusters” in the software. An example of this method is shown in following figure.



There are many parameters describing shape of clusters. The analysis would be very slow if all of them would have to be evaluated for each cluster. Thus the inactive parameters, which are not needed since no criterion is defined for them, are not calculated. All active parameters are calculated in sequence from the most simple to the most complicated. Validity of each acceptance criterion is tested immediately when the corresponding parameter is determined. If such criterion is negative evaluated then all other (more complicate) parameters and criteria are not evaluated.

Generating of cluster log files

The identified clusters can be saved to special output files called “cluster logs”. The cluster log is ASCII file containing many frames. For each of them there is list of clusters. Each cluster is described by single row where a list of pixels belonging to that cluster are listed. Each pixel is described by three numbers “[X,Y,value]” where X,Y are pixel coordinates (integer) and value (double) is the pixel value (usually energy or time). The Cluster log file format is very simple so that these files are often used as an input for further analysis by other software (Matlab or Python scripts …). Saved Cluster log file can be replayed many times later refining sorting criteria.

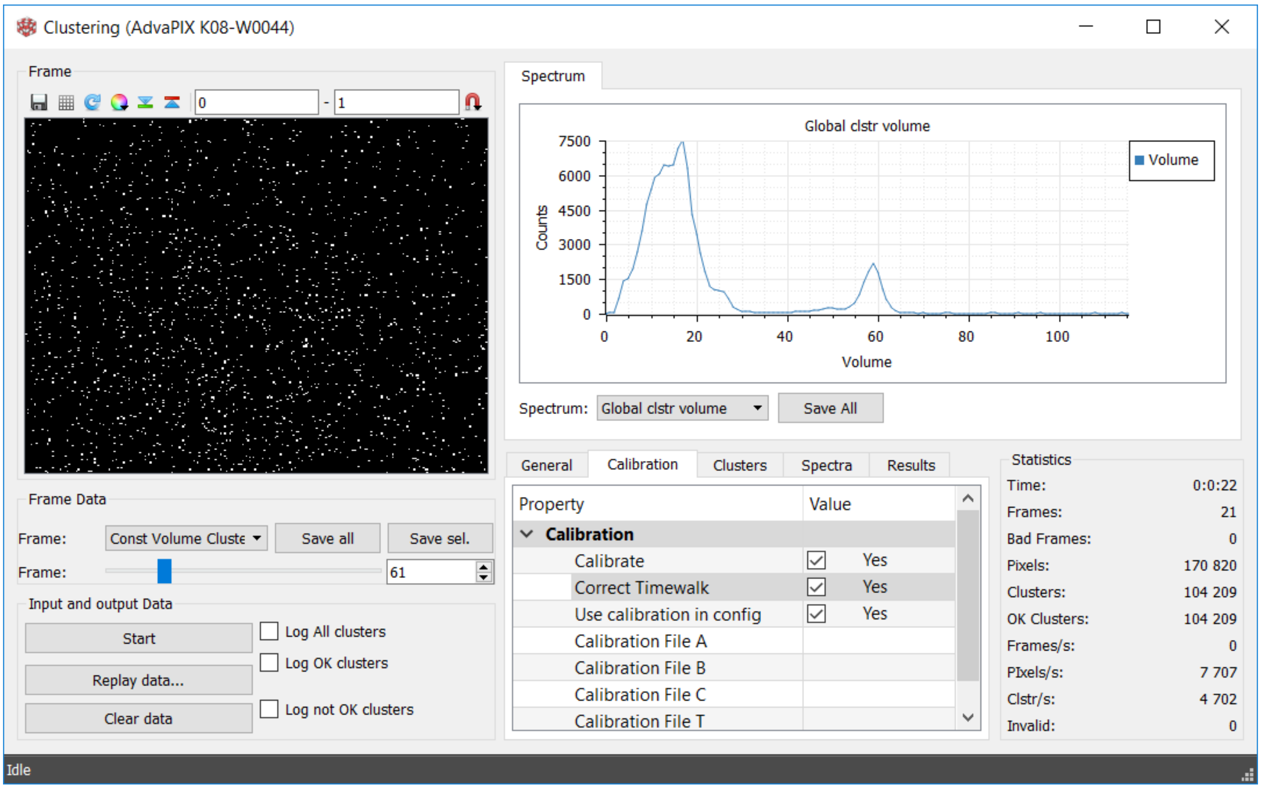
```
Frame 1 (1398164179.3519452 s, 0.01 s)
[173, 19, 6.59206] [174, 19, 9.087] [175, 19, 6.17943] [17
[42, 21, 6.35027] [43, 21, 8.71867] [44, 21, 9.3065] [45,
[242, 27, 5.78606] [243, 27, 6.05694] [243, 28, 36.27] [24
[12, 28, 6.51167] [13, 28, 8.7182] [14, 28, 6.83723] [14,
[94, 54, 5.68778] [95, 54, 8.22142] [96, 54, 10.4038] [97,
[56, 60, 5.88473] [57, 60, 6.90327] [58, 60, 5.21698] [58,
[181, 70, 5.27222] [182, 70, 8.16933] [183, 70, 11.4169] [
[205, 80, 5.9662] [206, 80, 8.80709] [207, 80, 6.54822] [2
[155, 86, 3.66322] [156, 86, 7.33663] [157, 86, 9.24677] [
[109, 111, 4.88881] [110, 111, 10.0502] [111, 111, 12.4426
[60, 114, 5.81477] [61, 114, 6.68157] [62, 114, 4.1726] [6
[122, 116, 3.28308] [123, 116, 5.0673] [123, 117, 28.9069]
[214, 119, 3.41926] [214, 120, 16.3998] [215, 120, 14.3808
[86, 124, 6.84526] [87, 124, 11.4726] [88, 124, 10.0176] [
[113, 125, 4.32642] [114, 125, 5.13926] [114, 126, 22.6586
[169, 149, 4.56991] [170, 149, 7.92599] [171, 149, 7.953]
[143, 196, 4.89416] [144, 196, 4.31856] [144, 197, 17.9045
[147, 210, 2.75662] [148, 210, 3.40553] [148, 211, 14.5885
[239, 212, 4.9568] [240, 212, 8.5968] [241, 212, 9.58238]

Frame 2 (1398164179.3732529 s, 0.01 s)
[172, 1, 5.36533] [173, 1, 3.56842] [173, 2, 19.8978] [174
[68, 4, 4.82454] [69, 4, 3.93045] [69, 5, 26.0541] [70, 5,
[27, 21, 8.2784] [28, 21, 18.2643] [29, 21, 19.9869] [30,
[127, 51, 5.63121] [128, 51, 12.1259] [129, 51, 10.9083] [
[78, 63, 5.52731] [79, 63, 6.82945] [80, 63, 5.38501] [80,
```

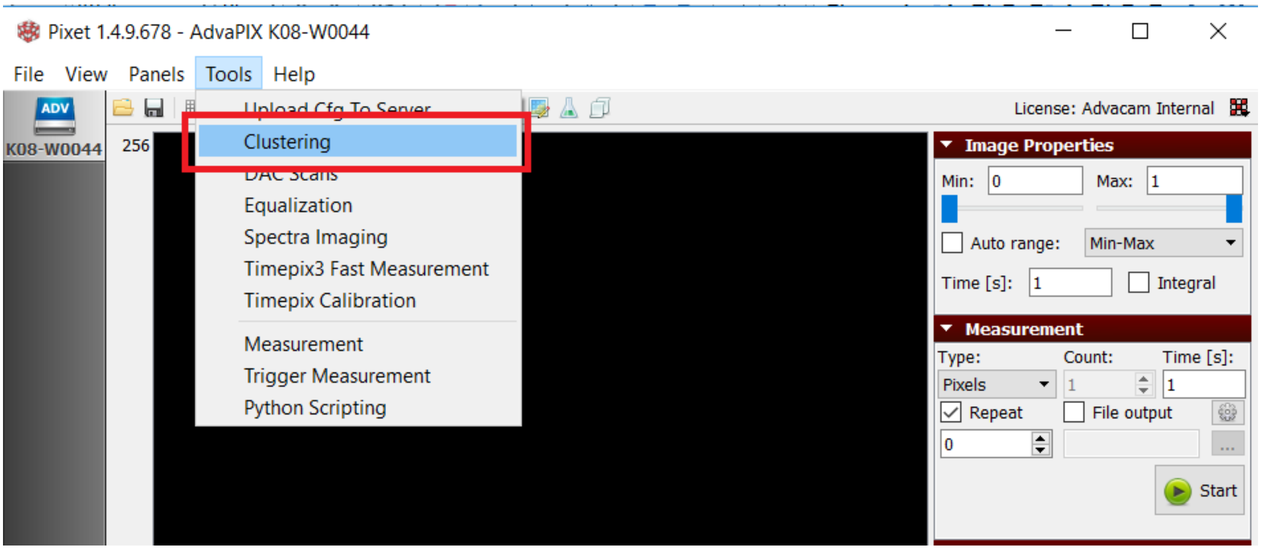
Cluster log file structure. Frames are separated by "Frame" row with frame number, frame time stamp (in seconds) and frame exposure time in seconds. Each row following the Frame row contains single cluster which is given as list of its pixels [X,Y,value], where "X,Y" are pixel coordinates (integers) and "value" is pixel value (double).

Main window

The "Clustering" tool is opened always for one particular imaging device. The device can be either real physical detector (e.g. Timepix) connected to the computer or virtual device such as "Dummy device" or "File device". The name of the used device is displayed in caption of "Clustering" window as shown in figure below.



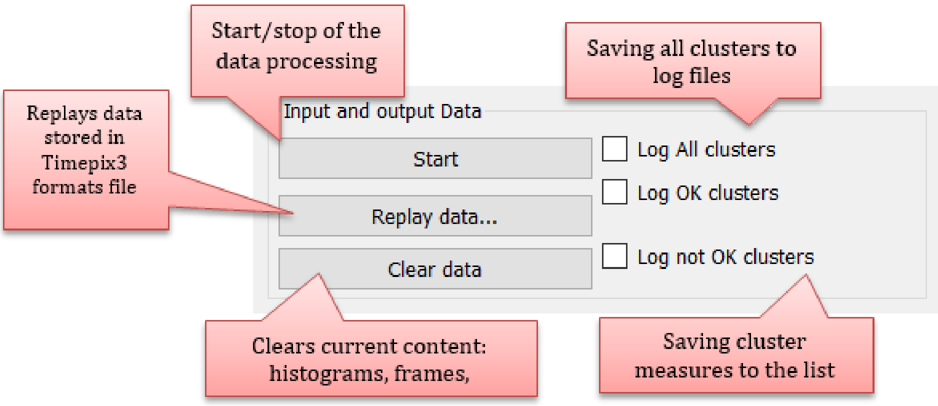
The main window of the Clustering plugin can be opened from menu of the **PIXET Pro** software main window as illustrated in the following figure: Select the device which will act as a source of the data in the tab bar, go to "Tools" menu and select "Clustering".



*Part of the **PIXET Pro** main window with highlighted menu item used for opening of the "Clustering" plugin for selected device.*

Control panel

The control panel allows to start/stop processing of the events being collected by the device. Before **start** it is possible to check what log files should be saved during the data processing.



Control:

Button "Start/stop":

When started, then the "Clustering" tool waits for events being measured by device. Each event measured by ***PIXET*** **Pro** is directed to this tool and processed according to criteria.

Button "Clear data"

All data within the tool are erased. All histograms, spectra, images and statistics are cleared. The button doesn't change the start/stop state.

Saving:

Check box "Log all clusters"

When checked the "file save as window" appears where user has to choose the name and location for the log file. All identified clusters will be saved to the log file. This check box has to be selected before starting with start button. The check box is cleared automatically when processing is finished pressing "stop" button.

Check box "Log OK clusters"

When checked the "file save as window" appears where user has to choose the name and location for the log file. Only clusters evaluated as OK will be saved to this log file. This option has to be selected before starting with start button. The check box is cleared automatically when processing is finished pressing "stop" button.

Check box "Log not OK clusters"

When checked the "file save as window" appears where user has to choose the name and location for the log file. Only clusters evaluated as not OK will be saved to this log file. This option has to be selected before starting with start button. The check box is cleared automatically when processing is finished pressing "stop" button.

Replaying:

Button "Replay cluster log"

When clicked the "file open window" appears where user has to choose the cluster log file. The file will be replayed processing all stored data. The execution can be stopped by stop button. The device has to be stopped during replaying of the log files. Otherwise the data being measured by ***PIXET* Pro** would be processed as well.

6.2.2 Image display

Some processing results are generated in form of images. These images are visualized in image display. The control of this display is simple not requiring special description.

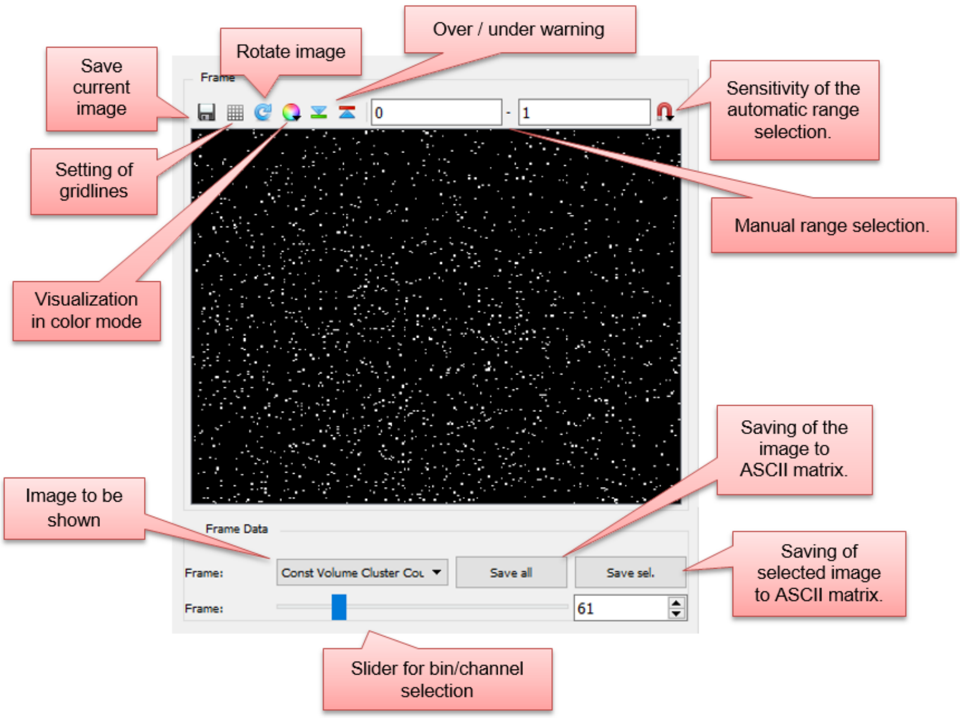


Image display visualizes images generated automatically during data processing. The generated image to be shown is selected in combobox (bottom-left). The image range is controlled automatically by the red button (top-right) if "Auto" pushbutton is checked. If auto option is unchecked then pair of edit boxes (top-right) are used for image range selection. The selected image can be saved as ASCII matrix pressing "Save selected image" button.

The current image data can be saved anytime to ASCII matrix pressing one of two buttons below the image:

Save all – save all "Frame options"

Save sel – saves selected "Frame option". If the current image represents one of series of images of the same type then the message box is displayed asking whether just displayed complete series should be saved as a spectra or images.

The selection of the image to be shown is done in the “Image” combo-box. The available items are:

OK data	Frame of OK clusters (bad clusters are removed)
Bad Data	Frame of Bad clusters (not complying the conditions)
Raw sum	Sum of all raw frames
OK sum	Sum of all OK clusters
Bad sum	Sum of all Bad clusters
Cluster count	In this image the pixel corresponding to cluster center is incremented by one for each OK cluster.
Average cluster size	Every pixel of this image contains average cluster size (number of cluster pixels) for all clusters with center in this pixel.
Average cluster volume	Every pixel of this image contains average cluster volume (energy) for all clusters with center in this pixel.
Average cluster height	Every pixel of this image contains average cluster height (maximal pixel) for all clusters with center in this pixel.
Const Height cluster count	Per pixel cluster height spectrum. For each cluster height the image of number of such clusters is generated. The height range is defined in parameter group “Generated results” item “Generate per pixel spectra” and its sub-items. The image to be shown is selected by item “Show per pixel spectral image”.
Const volume cluster count	Per pixel cluster volume spectrum. For each cluster volume the image of number of clusters with equal volume is generated. The volume range is defined in parameter group “Generated results” item “Generate per pixel spectra” and its sub-items. The image to be shown is selected by item “Show per pixel spectral image”.
Const volume cluster size sum	Auxiliary image for “Const volume avrg cluster size”
Const volume avrg cluster size	Maps average cluster size for clusters of the same volume (energy). The volume range is defined in parameter group “Generated results” item “Generate per pixel spectra” and its sub-items. The image to be shown is selected by item “Show per pixel spectral image”.

6.2.3 Cluster Analysis display

The multipurpose area in the right part of the main window serves for displaying of various spectra types.

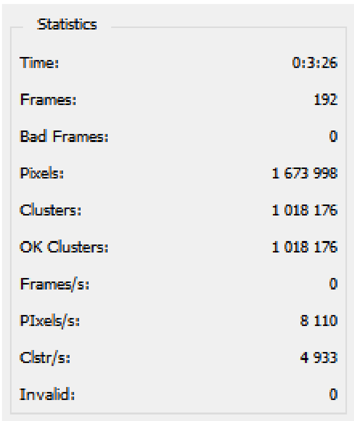
Spectrum

In "Spectrum mode" It is possible to select one or several of many different spectra generated. The available options are:

Global clstr size	Cluster size spectrum for All clusters and OK clusters (cluster size = number of pixels in the cluster)
Global clstr volume	Cluster volume spectrum for All and OK clusters (cluster volume = sum of values of all pixels in the cluster = total energy)
Global clstr height	Cluster height spectrum for All and OK clusters (cluster height = maximal pixel value in the cluster)
Per clstr size volume	Cluster volume spectra shown independently for several cluster sizes. It is shown for All clusters (not for OK only). The number of these spectra is set in "Generated results", item "Number of per clstr size spectra".
Pixel clstr volume	Cluster volume spectrum for single specific pixel (pixel is selected clicking to the image display or by coordinates in "Generated results", item "Selected pixel".
Cluster count	Spectrum of number of clusters in the image.

6.2.4 Statistical panel

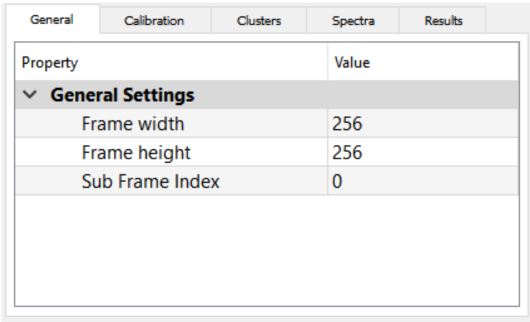
Statistics panel shows current status/progress of data processing and displays statistical data, parameters of device and cluster analysis parameters. The fields in the statistical panel are self-explanatory.



6.2.5 Cluster analysis parameters

This is the most important part of the “Clustering” tool. The set of parameters is divided to several parameter groups:

- General
- Calibrations
- Clusters
- Spectra
- Results



Each item in the parameter list represents either some processing parameter or discrimination criterion for decision on the cluster quality (bad or OK cluster). Whenever the discrimination criterion is defined as a comparison of some value with custom threshold level (e.g. Min cluster size = 10) then software uses no sharp inequality for decision - greater or equal or smaller or equal

General

This parameter group doesn’t need to be changed.

Frame width

defines width of an active matrix.

Frame height

defines height of an active matrix

Sub Frame Index

Specifies data measured in frame mode to be processed (if needed)

Calibration

This is the important part of parameters. All parameters here deal with corrections of the input data. Per pixel energy calibration is applied here.

Calibrate

If switched on then the data will be calibrated using calibration matrices below.

Correct Timewalk

It anabeles the time walk correction. The devices are not standardly calibrated for a Timewalk correction

Use calibration in config

data will be calibrated using matrices taht are part of the detector configuration. Detector must be connected int this case.

Calibration File A B C T

Matrices of calibration coeficients A,B,C,T. The sizes of these matrices have to fit to size of the frames being processed. Use browse button to fill these fields.

Clusters

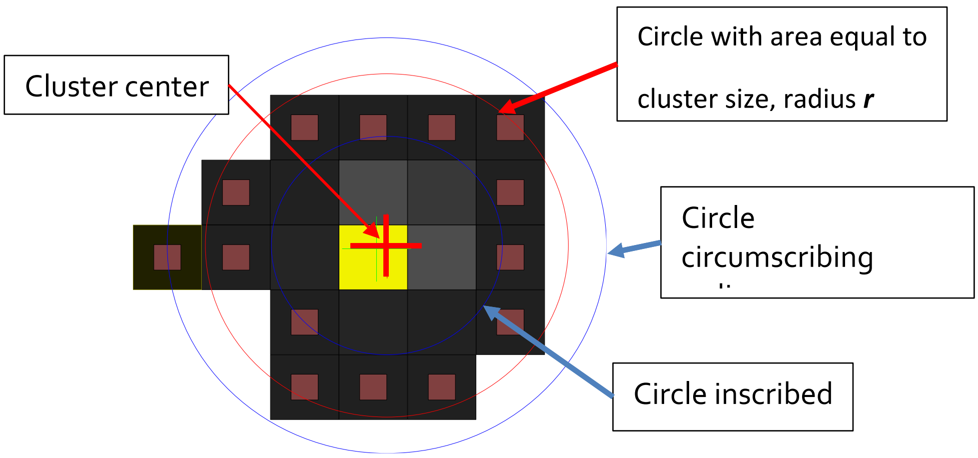
This parameter group allows to separate clusters according to basic integral cluster measures such as their size (number of pixels in the cluster), total energy (volume of the cluster), maximal energy deposited in one pixel (cluster height) or maximal distance of the pixels within the cluster (Cluster Length).

Min cluster height, Max cluster height

Restriction to the minimal/maximal cluster height: Cluster height is the value of the pixel with biggest signal within the cluster. This value corresponds to largest deposited energy in ToT mode or to biggest Time-stamp in Time mode.

Min clstr roudness, Max cluster roudness

Minimal and maximal cluster roudness. Roudness ranges from zero (not round) to one (perfect circle). Good value for recognition of alpha particles is 0.9.



Cluster roudness is expressed as ratio $\mathbf{r/r_{max}}$.

Min cluster size, Max cluster size

Minimal/Maximal number of pixels within the cluster.

Min cluster volume, Max cluster volume

Minimal/maximal deposited energy calculated as sum of values of all pixels of the cluster.

Min border pixels, Max border pixels

Minimal and maximal distance of any border pixel from circle with area equal to cluster size

Min inner pixels, Max inner pixels

Number of inner pixels can be restricted. Some clusters are composed only of border pixels (e.g. some electron tracks or muon tracks).

Spectra

Global Cluster size, Clobal Cluster volume, Global Cluster Height, Per Cluster Volume, Cluster Count, Per Pixel Spectra

The limits for value of properties. These limits are used for ranges of spectrum

Results

Generate Per Pixel Spectra

For per pixel energy calibration, for XRF imaging or for spectroscopic transmission imaging it is often needed to measure/generate the energy spectrum for each pixel. Such processing is enabled here. Number of channels is given below.

Max TOA Diff for new frame

Is the maximal value in time betweem clusters to create new frame to cluster log –virtual „frame“. Basically you can control grouping of clusters by the time setting

Timepix3 XRF

If check the **Correction Enabled** the inner XRF events generated by the sensor (CdTe) itself will be reconstructed.

Min. And **Max Volume** set the range of energies for the clusters that correspond with internal XRF of Cd and Te.

ToA difference set the maximum time window in there the coincidences are detected.

Two clusters are considered to be coincident if their time stamp doesn't differ more than time window width. This number is specified in time periods and depends on the clock frequency.

Distance is the distance of each coincidence partner from the pivot (the cluster that was detected early) is evaluated and its value is checked with given range.

Remove (no=reconstruct) enabled a remove of XRF clusters from the original spectrum.

Timepix3 XRF		
Correction Enabled	☐	No
Min volume	18	
Max volume	32	
ToA difference	100	
Distance	50	
Remove (no=reconstruct)	☑	Yes

Timepix3 Compton

If check the **Correction Enabled** the Compton scattering clusters will be removed from the originally measured spectrum. The removed clusters are in coincidences and they have energy that corresponds with a value that is calculated based on Compton Scattering formula.

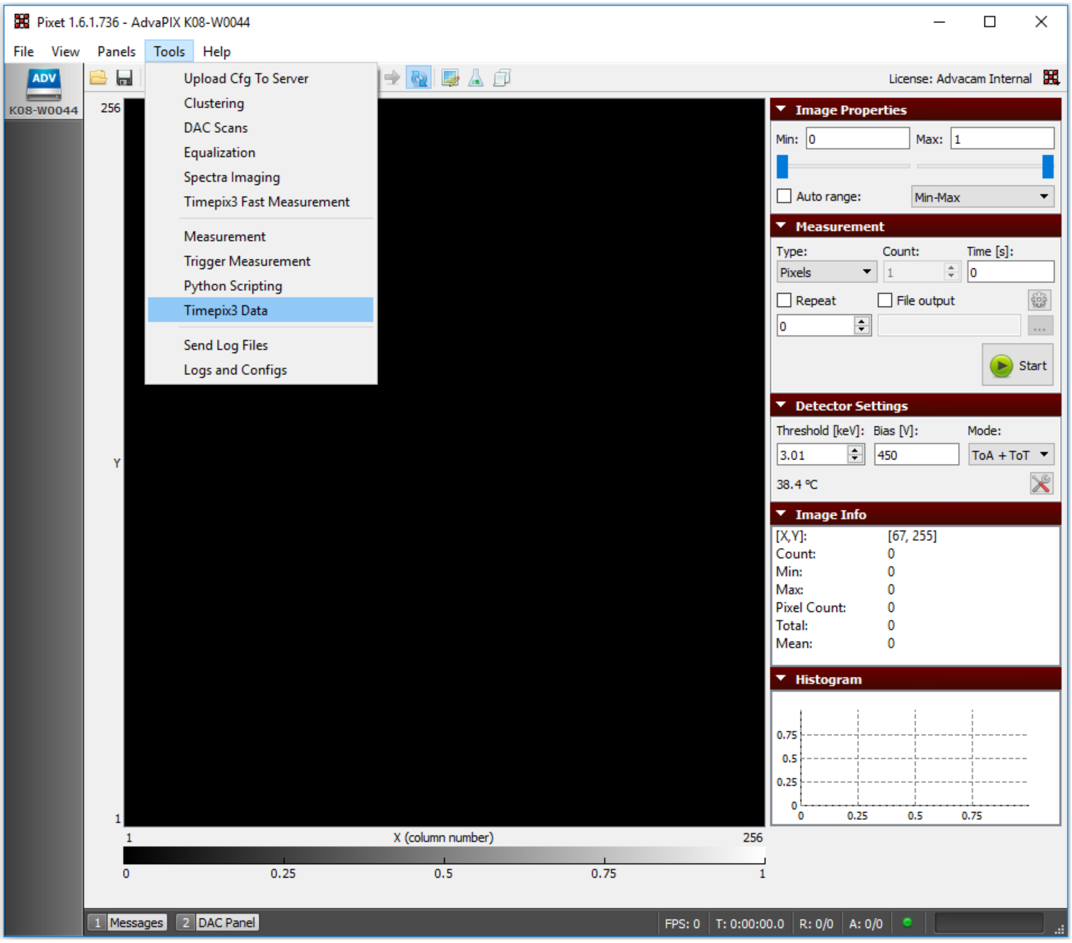
Timepix3 Compton		
Correction Enabled	☐	No
ToA difference	100	

ToA difference set the maximum time window in there the coincidences are detected.

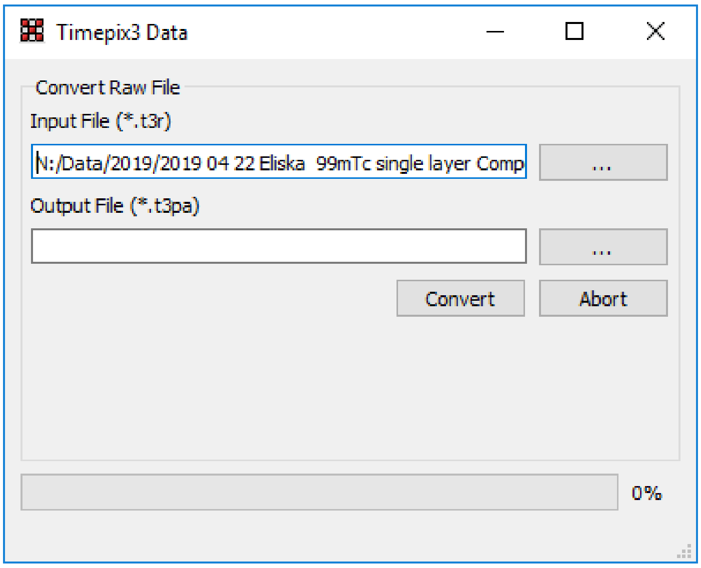
6.3 Timepix3 data converter

Data converter is suitable tools for data conversion from a coded data file *.t3r into much clearly arrange format *.t3pa. This tool is useful if you want to process the data outside the ***PIXET* Pro** in another Software such as Matlab or Python.

The converter is hidden under the bookmark Tools. The pop-up window will appear when you click on **Timepix3 Data** in the mentioned bookmark above.



Select the file for conversion and find the path where the data will be stored. Press **Convert.** The processed data you find in the terminal folder in the *.t3pa format. How the structure of *.t3pa data format looks like it is described in the section TPX3 data formats.



7. Release history

Date	Changes
20/04/27	Release

8. Copyright

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