Berlin, 18th April 2024

BH-PMS800

4 Channel Gated Photon Counter

USER GUIDE

Content

Thank you…

… for choosing a quality product from Becker & Hickl. This guide will lead you through the installation process of the BH-PMS800 application and some simple operating commands to get even more out of your hardware.

Use BH-PMS800 if you…

… have purchased a B&H PMS-800 photon-counter and multiscaler card and want to control its hardware parameters, perform gated photon counting measurements, record events, display it to the screen of your PC and export it for later data analysis.

Recorded events can be electric impulses created by a wide range of devices like photomultipliers or pulse generators. Each channel of the PMS-800 can record events with a rate of up to 800 MHz with a time resolution down to 4 ns.

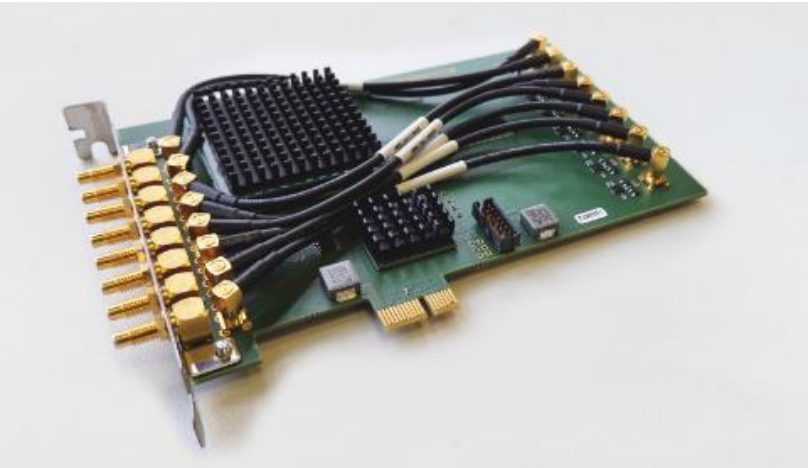
Each of the 4 input channels has a separate gate input. When used, only events occurring within the gate window will be recorded. The channel 4 gate can additionally be used as a trigger input or time reference for the input channels.

The software offers three standard measurement modes:

1. **Multiscaler** displays the counted events of the channels over time with the possibility to repeat and accumulate the events after the end of the measurement time.
2. **Triggered Accumulation** displays the accumulated events of the channels over time in correlation with an external trigger signal. Unlike in *Multiscaler mode*, in *Triggered Accumulation Mode* the measurement will be restarted and accumulated with each trigger signal.
3. **Event Threshold** registers the events in time bins, only when the event count in a time bin exceeds the user-defined event threshold. The threshold can be set individually for each channel.

Pre-Requisites

A PC running Windows 10 or newer, 32 GB RAM and at least logical 10 Cores.
An installed Becker & Hickl PMS-800 Photon Counter card.
Signal sources connected to the PMS-800 inputs via SMC-connectors on the front panel.

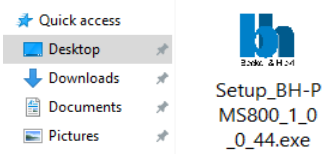


Software Installation

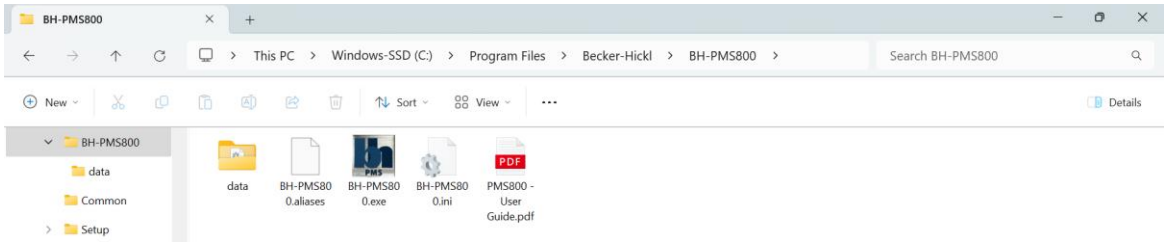
The BH-PMS800 application installer comes with your PMS-800 card or can be downloaded from www.becker-hickl.com.

Run Installer

- Execute the Setup_BH-PMS800.exe to run the installer.

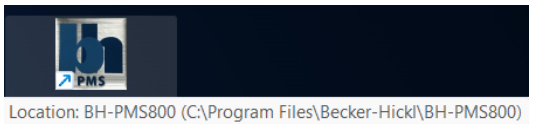


- The default installation path is C:\Program Files\Becker-Hickl\BH-PMS800.



The required **LabView Runtime Engine 2017 SP1** is also installed. The runtime can be used to operate software written with LabVIEW without needing a LabVIEW license. It can also be downloaded from www.ni.com.
The default destination is C:\Program Files\National Instruments\

- The BH-PMS800 software shortcut is now available on your desktop. Another link can be found in the start menu.



Using the BH-PMS800 Application

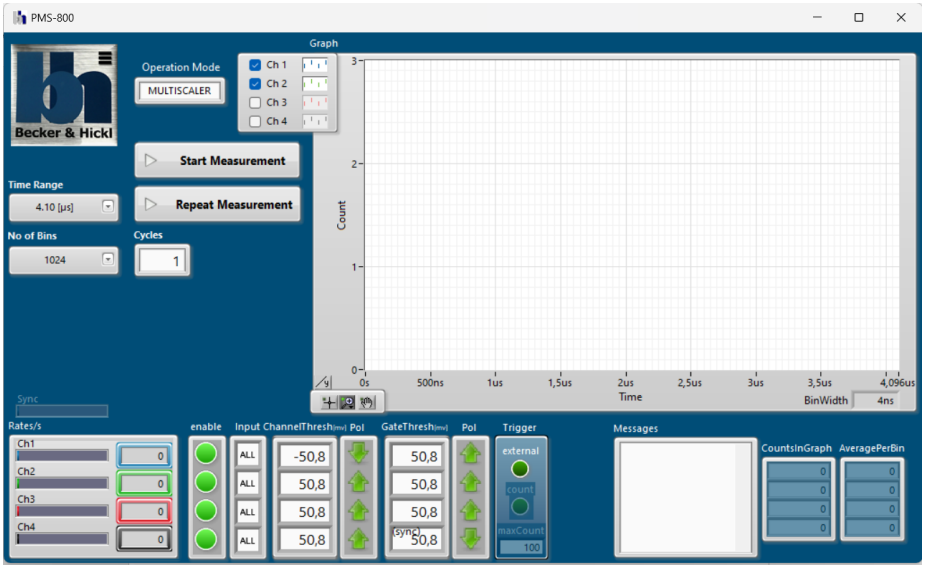
BH-PMS800.exe allows you to configure the B&H PMS-800 event recording card and initiate a measurement in three different measurement modes. The raw event data can be exported to file as well as the processed data in the graphs, allowing you to read a previous measurement back into the application or to perform a post-analysis in your personal software.

The application window is resizable in a Windows standard fashion and can be configured to display various pieces of information at the same time.

BH-PMS800 was developed to handle large amounts of data and count rates making use of at least 32 GB RAM and using up to 16 logical processors in parallel.

Starting BH-PMS800

Double-click the desktop icon or use the link provided in the start menu to open the application.



First appearance of the BH-PMS800 application

The BH-PMS800 window starts first in the default configuration, but will remember all configuration changes (including window size and position) when you close the application and start with its last configuration when opened again.

GUI Components

Positioned in the top left corner is the B&H company logo acting as the **main menu** button.

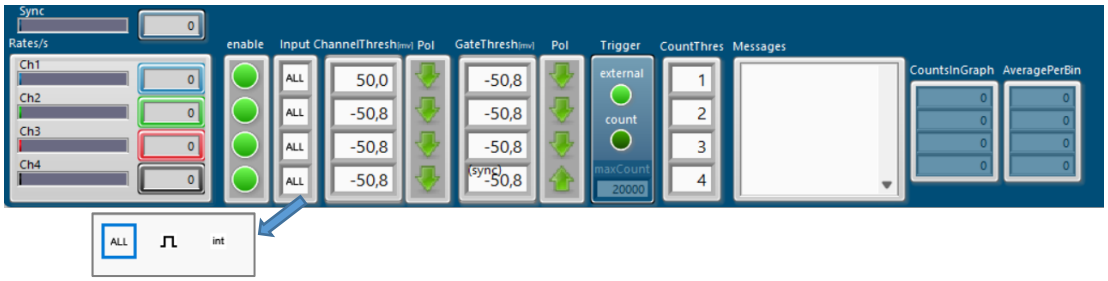
To the right of it you will find a drop list to switch between the **Measurement Modes**. Below that the **Start Measurement** and the **Repeat Measurement** buttons are located. Followed by the **measurement timing** settings.

The **Rates** display shows the currently detected events averaged per second. The colouring of the channels matches the plot colours in all graphs.

In the lower left corner of the graphs there are three **tool buttons** to zoom and scroll the plots in the graphs.

The axis range can be adjusted by modifying the minimum or maximum tick-labels respectively. The Y-axis will automatically be adjusted to the new data range when performing a measurement – unless you right-click on the scale and un-check AutoScale. The graph possesses a button  to toggle between logarithmic and linear scale on the Y-axis.

Setting Up a Measurement

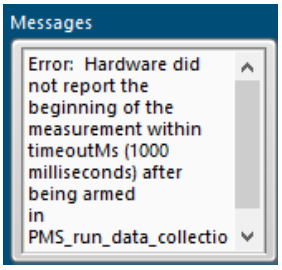


Connect your signal sources and adapt your channel configuration as needed. Then verify that you see the expected event rate in the Rates display. This display samples all channels every second and is continuously updated regardless of a running measurement. Rates can vary due to signal polarization and threshold level of the inputs.

By toggling the **enable** button of each channel, the channel can be activated or deactivated respectively. The **input** list allows the user to choose between either ***ALL***, ⎍ or ***int.*** The option ***ALL*** means that all input pulses will be registered on that channel, while ⎍ will register events only inside the gate. The last option ***int*** activates the internal pulse generator of each channel.

The **channel and gate threshold** can be adjusted in a rage of -500 to +500 mV with 4 mV steps.

The arrows on the **Pol** panel can be used to set detection edge polarity of the input channels and the polarity of the gates. Note that registering the wrong edge of a pulse can change the timing result.

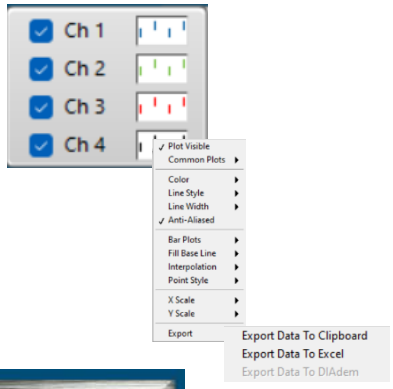


Gate 4 can be used to gate pulses for channel 4 or as an external trigger signal. By activating the **external Trigger button** on the **Trigger** panel, it will turn bright green. The PMS-800 card will wait for a trigger signal on gate 4 to start a measurement. If no signal was detected on gate 4 within 1 s, a timeout will occur and an error message will be displayed.

When using the external trigger in a measurement, it is possible to stop the measurement automatically after a set number of trigger pulses. To do that, activate the **count** button on the **Trigger** panel and set the value of **max Count** to the desired number of trigger pulses.

The **CountThres** panel is available only in the **Event_Thresh** mode. Here you can define the minimum counts to be registered in each bin. More about the different measurement modes can be found in the Measurement Modes section.

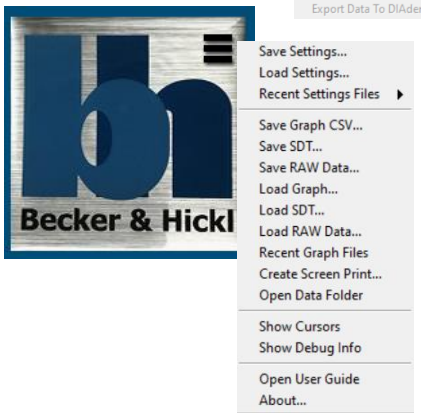
The last two panels on the right – **CountsInGraph** and **AveragePerBin** – show the total number of counts and the average counts per bin in each channel respectively.



The **Plot Legend** can be found on the top-left corner of the graph. In this panel the channels to be displayed can be selected as well as renamed by clicking on the channel name. To adjust the plot style, click on the plot style button on the right of the channel name. A drop-down list with the adjustable settings will be opened.

The last option of the drop-down list ***"Export"*** allows to export the plot data to the clipboard or directly into an Excel file.

The BH-PMS800 Main Menu



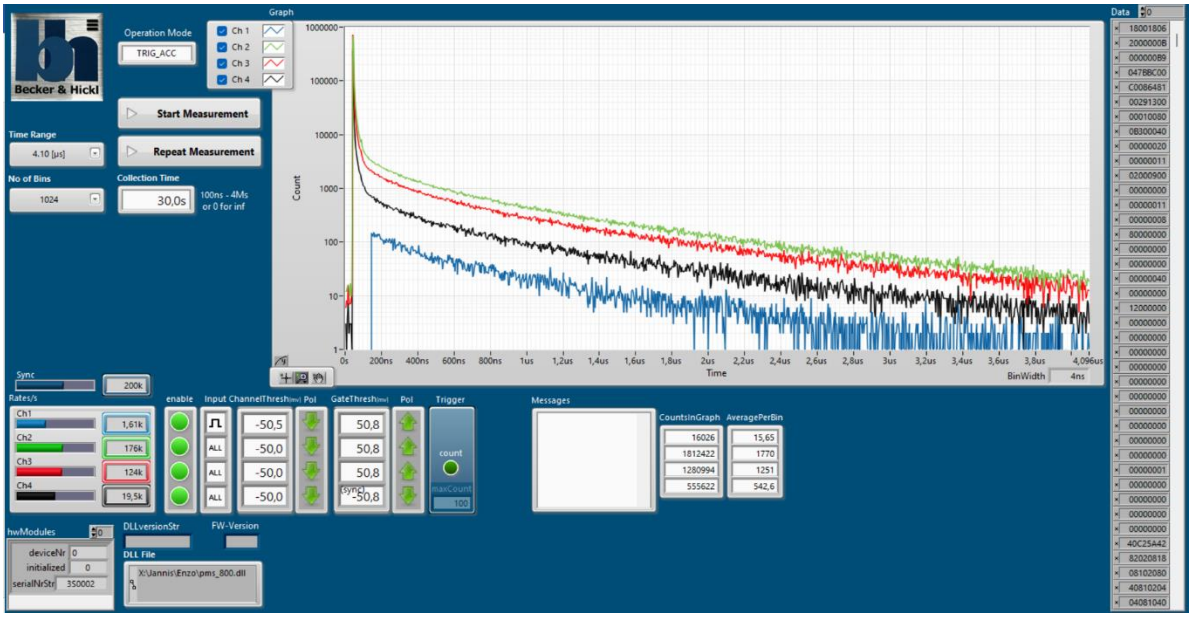
Clicking on the B&H company logo in the top-left corner will bring up the main menu of the application, where you can save/load data and settings from/to the application, activate the cursors and show the debug information. To find out more about the save/load option, please see the Handling Data section.

In the main menu you will find an item named **Show Debug Info**. By selecting it the application window size increases and makes space for more information about the internal workings.

Use this information to track errors or provide hardware information to Becker & Hickl when requesting support.

The **Data** column on the right of the graphs shows the raw data as received from the PMS-800 card prior to processing through the BH-PMS800 application. The raw data is not easily interpreted by the human eye, unless you live in the Matrix.

hwModules, **DLLversionStr** and **FW-Version** refer to the PMS-800 card. **DLL File** shows the path to the dynamic link library used to communicate with the card.



BH-PMS800 application with 4 channels and one gate applied on channel 1 registering the luminescence decay of an LCD-Display sample with 4 ns resolution

The About Box

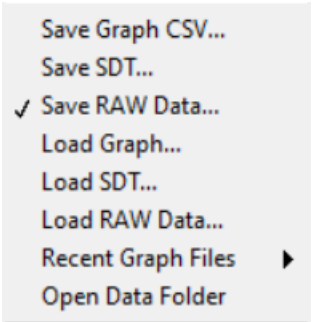
By selecting **About** you can open the about box window. The Becker & Hickl company logo and the copyright information is displayed, alongside with contact details, the version and build date of the application and the open VI Server port for remote controlling the application from other customer apps.

Dismiss this window by clicking into it.

Handling Data

The Becker & Hickl PMS-800 event recording card uses a highly compressed event data format to maximize its performance during high count rates. The BH-PMS800 application offers several export and re-import functions of the raw data as well as of the processed data to convert the compressed data stream to a more easily accessible format.

Export Options



The main menu (accessible by clicking on the B&H company logo) offers options to save the processed data as comma separated value files (CSV) or in the B&H standard data container file (SDT).

Use **Save Graph CSV** if you want to further process the data plotted in graphs, e.g. perform custom fits.

Use **Save SDT** in TRIG_ACC Mode to create files readable by applications like B&H's SPCImage to do elaborate decay curve analysis.

Use ***Save RAW Data*** if you want to save the raw recorded data in a binary file, to be able to read it back into BH-PMS800 at a later time.

Note: Save Graph CSV and Save RAW Data are automatically saving an additional settings file in CFG format. This is needed when importing the data back into BH-PMS800.

Note: Save Graph CSV and Save SDT are storing processed data, meaning absolute timing information of single events are not retrievable from these formats.

Note: The menu item ***Save RAW Data*** Has to be selected before a measurement is started. A check mark next to the menu item indicates if the raw data of the following measurement will be stored. You will be asked for a filename after completion of the measurement.

You can deactivate saving the raw data by deselecting the corresponding menu item again.

The CSV format is an ASCII coded comma separated value format. You can open and read those files in any text editor, but note, that German based Excel versions can get confused with the comma as separator.

Import Options

Processed graph and SDT data as well as PMS-800 raw data can be read back from file.

Load Graph will read previously saved graph data back into the application. To succesfully set the time axis a matching CFG-file at the same location is needed.

Load SDT will read a previously saved measurement back into the graph window. All measurement parameters are loaded from the SDT-file itself.

Load RAW Data will read a previously saved measurement fully back into the application. To succesfully set the time axis a matching CFG-file at the same location is needed.

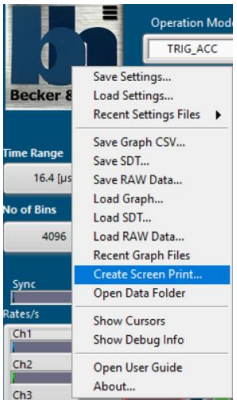
Convenience Options

The main menu offers a memory of the last 10 used data files. Use **Recent Graph Files** to quickly manoeuvre through your file history.

Open Data Folder will open the location of the last handled data file in your standard file browser.

Creating a Screen Print

Use the **Create Screen Print** option from the main menu to conveniently archive your measurement to a PNG- file.



Measurement Settings

While the data export options **Save Graph CSV** and **Save RAW Data** automatically create a settings file (the SDT-format includes the setting in the file itself), you might want to save the current measurment parameters so you can quickly return to those parameters at a later stage for new measurements.

Use the **Save Settings** item in the main menu to save all current parameters to a CFG-file in ASCII format. If desired, you can edit this file in Notepad or a similar editor. The default location for settings files is *C:\Users\<username>\AppData\Local\BH* but you can choose any location on your file system.

Use the main menu item **Load Settings** to read a previously saved CFG parameter file back into the application. This could be a manually saved file, the BH-PMS.cfg auto-save file or any CFG-file saved when saving measurement data.

The menu item **Recent Settings Files** gives you quick access to load any of the last 10 used settings files.

Anytime a parameter is changed, the BH-PMS800 application updates a settings file named BH-PMS.cfg to allow a restart of the application with the last used parameters.

The menu item **Auto Saved Settings** under **Recent Settings Files** will load this setting file. This comes in handy when a previous measurement file loaded back in has changed your setting parameters.

Note: in the unlikely event of a corrupted settings file it is safe to completely delete the *C:\Users\<username>\AppData\Local\BH\BH-PMS.cfg* file. All measurement parameters will be returned to their default values and you will have to set them again to your requirement. A new file will be generated automatically.

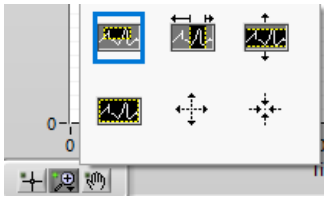
Display Settings

The BH-PMS-800 application offers several options to customize its front end to give you the best possible insight to your measurement. Take some time and choose the settings that will display just the information you need.

The Measurement Graphs

The graph possesses a button  to toggle between logarithmic and linear scale on the Y-Axis.

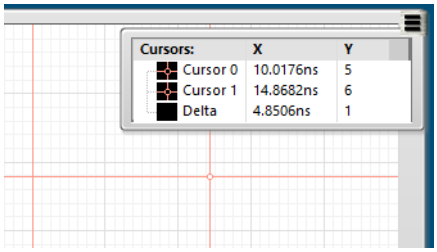
Zoom and Pan Tools



The magnifying glass button in the lower left corner of the graph brings up the zoom tools. Use the top 3 tools for zooming in on a range, only x-axis or only y-axis. Clicking the bottom left tool zooms back to full scale. Stepwise zoom in or out with the arrow tools.

The hand tool allows panning of the graph.

Show Cursors



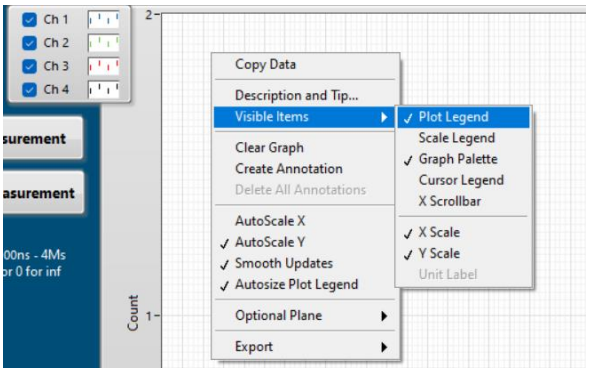
The application offers the option to display two crosshair cursors in the graph window. Selecting **Show Cursors** in the main menu will bring up the red cursors with a small circle at their hotspots. Their positions are listed in the cursor legend. The cursor distance is listed as **Delta**.

Use the graph tool  to move the cursors around. The listed position will be updated in real time. When releasing the cursor it will attempt to snap to the closest data point and the listed Delta will be updated. Dismiss the cursors and legend by selecting **Hide Cursors** in the main menu.

Autoscale

By right-clicking on any scale you can toggle between autoscale and fixed scale. The default is autoscale, but you might want to switch to fixed when trying to observe signal changes in **Repeat Measurement** mode.

The Plot Legend



The Plot legend panel is activated by default. If not visible, it can be reactivated by right-clicking in a graph and selecting **Plot Legend** in the **Visible Items** section. This brings up the plot legend where you can change settings like plot visibility, plot colour or line- or point-style.

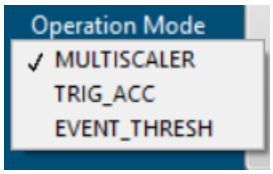
Note: Changes to these settings are temporary and are not stored in the settings file. A restart will return the application to the default values.

Closing the BH-PMS800 Application

You can terminate the BH-PMS800 application, as you are used to from any other Windows application, by clicking on the red X in the top right corner. The current settings will be stored to disk and reloaded when you start BH-PMS-800 again.

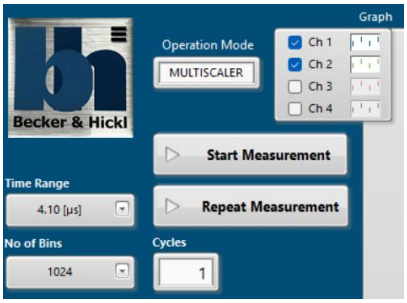
The Measurement Modes

Currently BH-PMS800 offers three different measurement modes. With 4 channels an extremely high rate of events can be registered over the measurement time or in a specific time gate, correlated to an external trigger signal if desired. We are certain, that you can come up with even more possibilities of what to do with your data, nevertheless here are three ways already implemented that might get you started on your job.



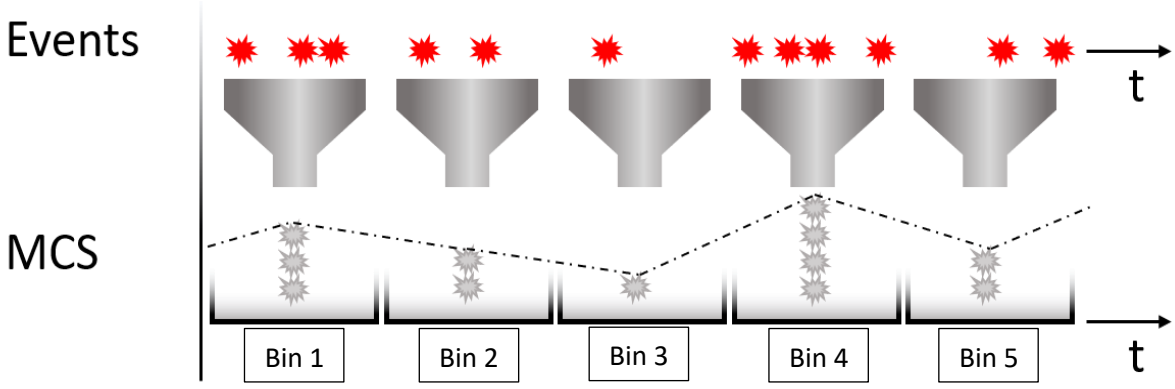
Click on the **Operation Mode** menu to choose the desired mode.

Multiscaler Mode



In multiscaler mode the events are recorded over a specified time range and saved in associated bins as shown in the schematic below. The **Time Range** defines the length of the histogram, which is in this mode equivalent to the collection time. The time range can vary between 256 ns and 1.07 s. The **No of Bins** determines the number of bins in the histogram, in which the recorded events will be stored. The resulting **Bin Width** is displayed in the lower right corner of the graph.

Note: if the required time range is not selectable, then the **No of Bins** needs to be adjusted under consideration that the smallest possible bin width is 4 ns and the maximum number of bins is 65536 bins. For example, a time range of 256 ns can have maximum 64 bins reaching the finest resolution of 4 ns. To increase the bin number in this case, the time range must be increased.



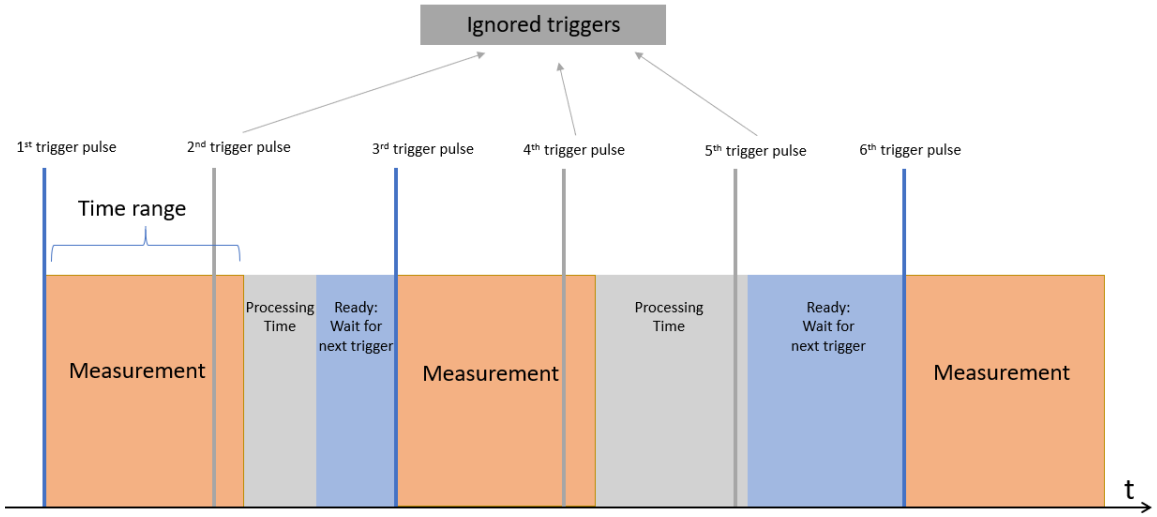
Schematic of the MCS measuring mode

Under **Cycles** the number of accumulation cycles can be set between 1 and 4 million cycles to be accumulated in a repeated measurement. After the end of the time range a new measurement will be started and the events will be accumulated in the corresponding bins.

When the external trigger is activated in this mode, a trigger source like a laser synchronisation signal must be connected to the gate 4. The measurement will start with the first trigger pulse and run until the end of the defined time range. Then the BH-PMS800 software will rearm the PMS-

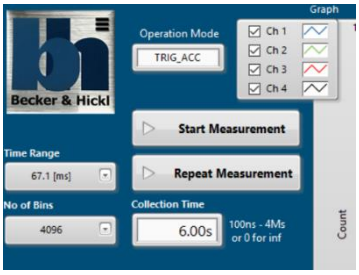
800 card which in turn waits for the next trigger signal to start a new measurement. The recorded data will be added to existing measurements until the set number of cycles is met.

If a trigger pulse occurs before the end of the time range, it will be ignored and the measurement will continue until the end of the set time range. After that the PMS-800 can be armed to wait for the next trigger signal and starts counting again.

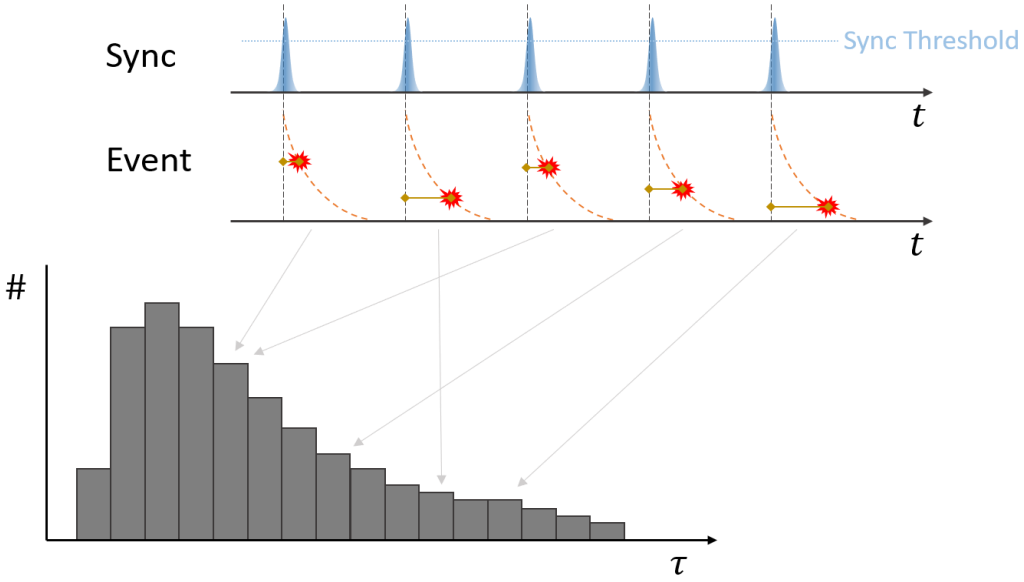


Schematic of the MCS accumulation with external trigger. The 2nd and 4th trigger pulses were ignored, as they arrived before the end of the time range. In practice, the waiting time depends on the software processing time, so that a trigger pulse after the end of the time range, like the 5th pulse, will be skipped, because the software was not ready for the next cycle.

TRIG_ACC Mode



The **TRIG_ACC Mode** (Triggered Accumulation) is available only with an external trigger signal and aimed at decay curve recording. Using gate 4 as an external trigger input, you will record incoming pulses from the 4 input channels referenced to the last trigger. Typically, the trigger can be a synchronization signal (sync) from a laser source and the events on input channels could be output pulses of a photomultiplier. The time difference between sync and photomultiplier pulses is calculated and stored in a histogram.



Schematic of the TRIG_ACC measuring mode

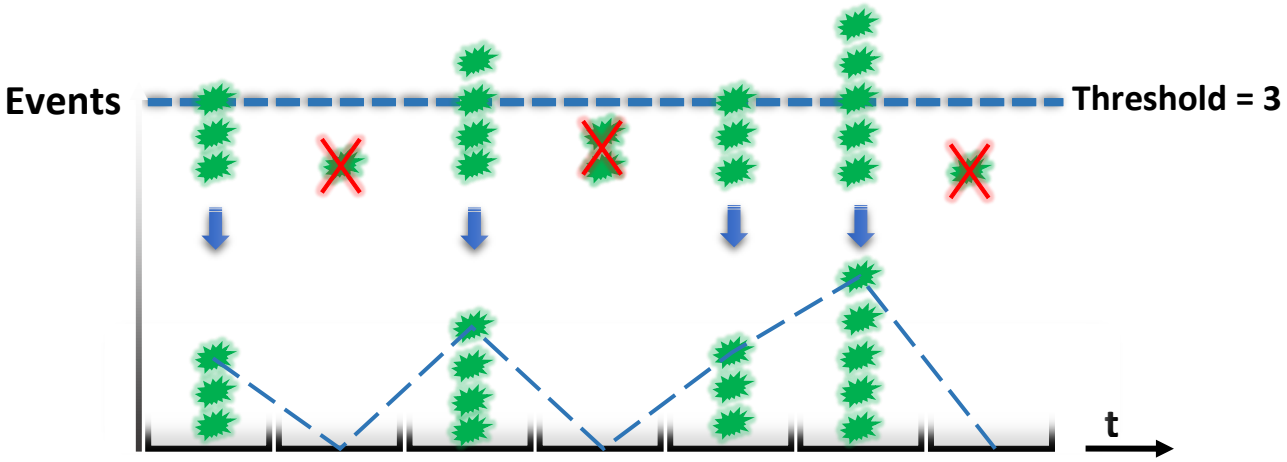
Important parameters are the **No of Bins**, the **Time Range** and the **Collection Time**. The latter is the overall time in which events are recorded. It can vary between 100 ns and 4Ms. Setting the collection time to 0 will keep the measurement running until the user clicks the **Stop Measurement** button.

The **Time Range** is the length of the histogram and should roughly match the period of your repeating trigger signal. The **No of Bins** describes the number of bins in the histogram. In **TRIG_ACC** Mode the highest **No of Bins** is 4096. The bin width can range from 4 ns to 16.4 µs, depending on the set time range.

Event_THRESH mode

The event threshold mode is aimed to register events only when the pulse count within a time bin reaches the set threshold. This threshold can be chosen for every channel individually.

The **Time Resolution** can be set to between 4 ns and 128 ns with a **Collection Time** between 100 ns and 4 Ms. For longer measurement times a value of 0 s can be set and the measurement will stop only by clicking the **Stop Measurement** button.



Schematic of the Event Threshold mode

The maximum number of data points on the graph can be found in the lower-right corner of the graph and varies depending on the chosen time resolution and the collection time. For an infinite collection time a value of 0 will be shown in the maximum number of data points.

By clicking on **Repeat Measurement**, the measurement will be repeated automatically after the end of the collection time.

Note: by repeating the measurement, there will be no accumulation. The repeated one will simply replace the previous measurement.

Internal Signal Generator

Sometimes it can be hard to determine which part of an experiment does not work. Is it the signals, the hard- or software? Or sometimes there might be a sync signal missing during setup.

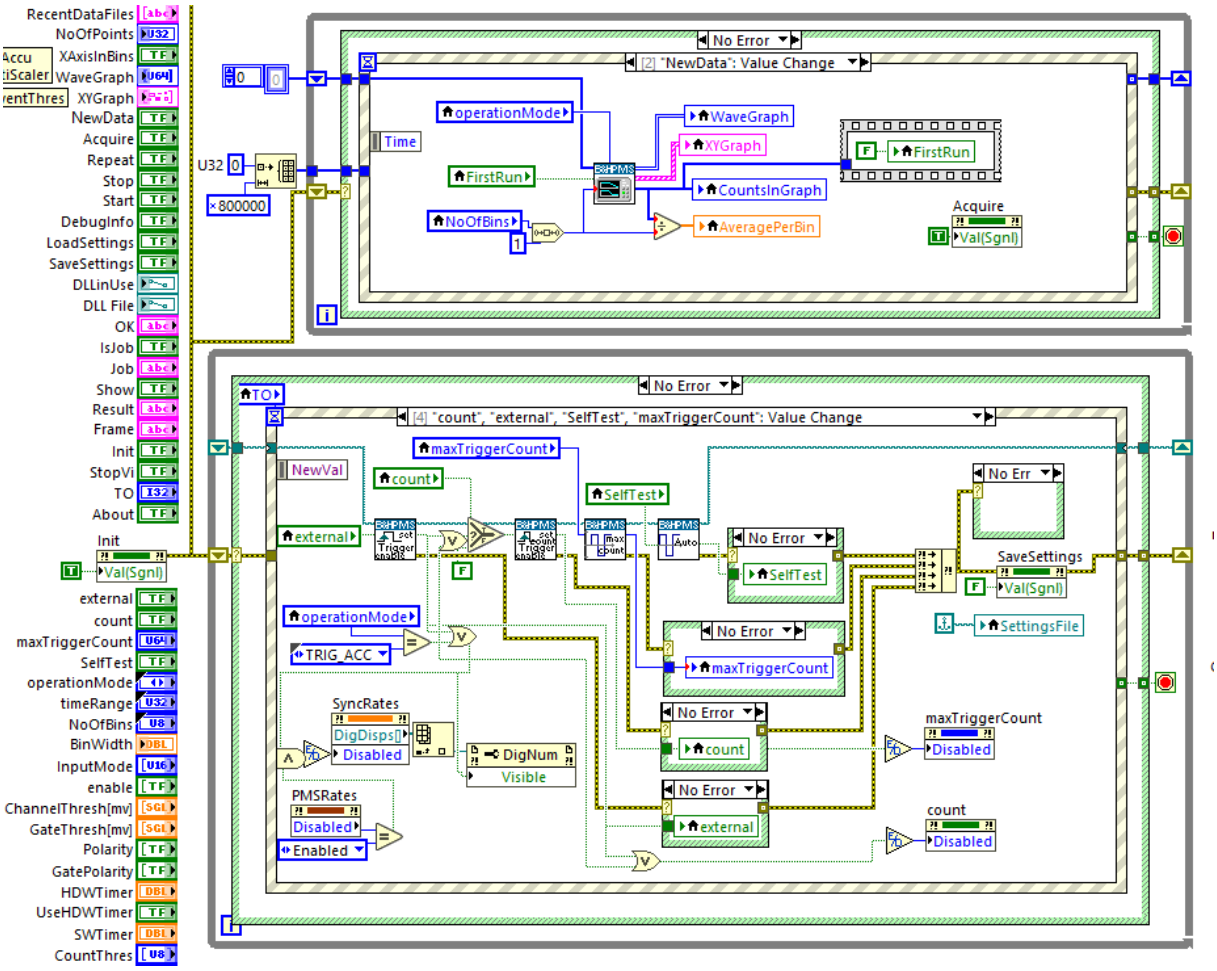
For test purposes you can use the **internal Pulse Generator** by clicking on the input box of the channels and choosing **int**. The PMS-800 card will start generating an internal signal, which can be fed to the application, used and displayed like any life-signal on the channel inputs.

Remote Controlling BH-PMS800

The Remote Controlling of the BH-PMS800 is still under construction and will be available with the next update.

Source Code Distribution

For developers the complete LabVIEW 2017 source code (Virtual Instruments) of the BH-PMS800 application is available for your modification requirements. Please contact info@becker-hickl.com for pricing and licenses.



Where to go from here…

We at Becker & Hickl hope you will get the most out of your PMS-800 card and the control application BH-PMS800. A lot of analysis features and the graphs are readily available to be used in documentation or publications. You might use collected data saved to file for further specialized analysis specific to your setup.

But since we at B&H are continuously progressing our development of user inspired hard- and software, you can expect new features in the future. Some of which will cater to your needs. To do so we are thankful for your feedback and of course bug-reports.

Please feel free to contact us at info@becker-hickl.com with suggestions or collaboration offers.

Troubleshooting

The backdrop of the application flashes red	Check the message window for error messages
I started a measurement but the graphs are not updating.	Too many events have been recorded for a speedy computation. Try reducing the event rate, Collection Time and/or No of Bins. A task kill in the task manager might be necessary.
I received an “Out of memory” error.	The histograms have become too large for your PC RAM. Try reducing Collection Time and/or No of Bins. A task kill in the task manager might be necessary.
I connected a SYNC signal to the gate 4, but the SYNC Rates is dimmed and no value in displayed.	Make sure that the External Trigger button in Trigger Panel is activated.
I connected a signal to an input, but do not see any Rates displayed.	• Ensure to have the corresponding channel enabled. • Check the Threshold and Polarity settings in the Card Settings. Positive and negative values are possible. • If a gate signal is connected, check that the events are inside the gate window.
I do have Rates in a channel but do not see the signal in the graph.	The signal might be outside the currently selected time range. Try to choose another time range.
The Rates panel is dimmed, it shows counts but the values are not updated.	You have loaded a previously saved measurement file and the Rates panel shows the rates values of the loaded file. Click on the Rates panel to turn it live again.
I have stopped a measurement by clicking on “Stop Measurement” and now a green lit “Start Measurement” is visible but the application is not responsive.	Patience!
I have an old measurement saved to a file, but cannot reload it to the app because I lost the corresponding CFG-file.	It is possible to create a CFG file with matching parameters via Save Settings and name it corresponding to your measurement file.
I received an error: “Hardware did not report the beginning of the measurement”.	Check the setting of external Trigger in the Card Settings and the Sync Rate. Check the Threshold of the SYNC channel (Gate 4).
I tried everything but my problem persists.	Feel free to contact info@becker-hickl.com with a detailed description of your issue together with a screenshot of BH-PMS800. Consider to email us in addition a copy of your BIN / CFG pair.

Appendix

PMS-800 Datasheet

Input Channels	
Counter Channels	4
Frequency Range	0 to 800 MHz
Dead Time	1.25 ns
Gate Channels	4 (1 Trigger Optional)
Principle	Threshold Discriminator
Discriminator Input Bandwidth	4 GHz
Maximum Pulsed (<1 ms) Input Voltage Range	-5.5 V to +5.5 V
Maximum DC Input Voltage Range	-3.3 V to +3.3 V
Min. Input Pulse Width	0.625 ns
Min. Gate Width	1 ns
Min. Trigger Pulse Width	1 ns
Discriminator Threshold (All Inputs)	-500 to 500 mV in Steps of 4 mV
Input Connectors	SMC, 50 Ohm
Time-Measurement Circuitry	
Principle	Time-to-Digital Converter
Resolution	4 ns
Time Range	4 ms (Software Limited)
Data Acquisition	
Max. Count Rate	800 MHz / Channel
Online Display	Hardware Multiscaler, Triggered Accumulation, Multiscaler Stream
Hardware Multiscaler	
No. of Time Bins	64 to 65,536
Time / Bin	4 ns to 16,384 ns
Max. Counts / Bin	65,535
Time Range	256 ns to 1.07 s
Sustained Count Rate	800 MHz / Channel
Triggered Accumulation	
No. of Time Bins	64 to 4,096
Time / Bin	4 ns to 16,384 ns
Max. Counts / Bin	65,535
Time Range	256 ns to 67.1 ms
Sustained Count Rate	800 MHz / Channel
Max. Trigger Rate	50 MHz
Multiscaler Stream	
Max. No. of Time Bins	Unlimited
Time / Bin	4 ns to 128 ns
Max. Counts / Bin	127
Count Threshold	1 to 127 Counts
On-Board FIFO Buffer Capacity	3,500,000 Bins
Sustained Bin Transfer Rate	160 MHz (All Channels Combined)
Operating Environment	
Operating System	Windows 10, Windows 11
Bus Connector (Slot Type)	PCI-ex
Total Power Consumption	approx. 12 W from +3.3 V, 3 W from +12 V
Dimensions	165 mm x 110 mm x 20 mm

Data Format in PMS-800 RAW Stream

Deeper understanding of the raw data format is not required for users of the BH-PMS800 application. The information is included here for developers interested in interpreting the stream directly for further analysis.

The data protocol changes depending on the mode, the card is operated in. As mentioned above, the user can choose between three different operating modes: Multiscaler, Triggered Accumulation and Event Threshold mode. The incoming data will be structured as follows.

In Multiscaler and Triggered accumulation mode

The histograms accumulated in hardware in the two modes are transferred in 32bit vectors. The first 3 vectors contain header information as depicted in the table below.

Vector	Name	Bits					
1	Header 1	31 – 28: Channel ID	27 – 24: Transfer condition	23-20: Time-rollover	19 – 7: N_bins	6 – 4: 0x0	3 – 0: MSB_idx = N_bits-1
2	Header 2	31 – 24: N_occ		23 – 12: 0x0 (Reserved)		11 – 0: N_data	
3	Header 3	31 – 0: event count					
4 – 4+N_occ	Occupancy array	Occupancy vectors (big endian)					
5+N_occ – 5+N_occ+N_data	Data vectors	Data vectors (big endian)					
6+N_occ+N_data	Final Padding 1	31 – 0: 0xffffffff					
7+N_occ+N_data (optional)	Final Padding 2 (optional)	31 – 0: 0xffffffff					

Header 1:

1. **Channel ID:** The channel number associated with the transmitted data
2. **Transfer condition:** The condition which triggered the transfer of the histogram. This could be:
    a. Bit3: Due to a trigger
    b. Bit2: Due to the end of the measurement
    c. Bit1: Due to a time-rollover (Multiscaler mode only)
    d. Bit0: Reserved
3. **Time-rollover:** During a Multiscaler measurement, these are the bits 15-12 of the time measurement for the transferred memory block. NOTE: The memory blocks can only hold 4096 bins each. A measurement, containing more bins will be segmented into the appropriate number of 4096-bin blocks. There can be up to 16 blocks.
4. **N_bins:** The number of occupied bins in the transferred memory block
5. **MSB_idx:** This is the index of the MSB of the maximum bin count. The total number of necessary bits to encode the value in the memory block is MSB_idx+1.

Header 2:

1. **N_occ**: The number of occupancy vectors, to be transferred (see below for details).
2. **N_data**: The number of data vectors to be transferred (see below for details)

Header 3: The total event count in the transferred memory block.

The memory content is compressed before transfer. An array of occupancy bits is sent first to indicate which memory addresses have a content larger than 0. This array has one bit for each memory location and is packed into 32bit vectors.
After that, the content of those memory bins which are not empty is transferred, encoded with the bits necessary to contain the maximum count in the histogram. This data is also packed into 32bit vectors. The last vector is padded with zeros if necessary.
Finally, one or two padding vectors of 0xffffffff are sent in the end of the transfer. These are making sure that every transfer contains an even number of 32bit vectors, which simplifies the memory interface usage. If the number of data vectors is odd, two padding vectors are sent, otherwise one suffices.

Example

If a 64-bin memory of channel 0 has been transferred upon an incoming trigger and has the following hit content:

Bin 10	Count = 10
Bin 15	Count = 5
Bin 20	Count = 3
Bin 25	Count = 1
Bin 29	Count = 9
All other bins are empty	

The three header vectors will be:

Vector	Bits					
1	31 – 28: 0x0	27 – 24: 0x4	23-20: 0x0	19 – 7: 0x5	6 – 4: 0x0	3 – 0: 0x3
2	31 – 24: 0x2		23 – 12: 0x0		11 – 0: 0x1	
3	31 – 0: 0x1C					

The occupancy array will be 2 x 32bit vector (Big endian):

Vector	Bit 31	Bit 30	…																												Bit 0
4	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

The data will be encoded with 4 bits (10 = 1010) and we have 5 bins with content. The data vectors will be:

Vector	Bits 31-20	Bits 19-16	Bits 15-12	Bits 11-8	Bits 7-4	Bits 3-0
6	0x0 (Padding)	0x9	0x1	0x3	0x5	0xA

Now there will be two padding vectors since we have an odd number of data vectors:

Vector	Bits 31-0
7	0xffffffff
8	0xffffffff

This completes the transfer.

In Event Threshold Mode

In this mode, “events” and Macrotime-Overflows are transferred individually as 16bit vectors with the following structure:

Type	Header: 15 - 12				Bin count: 11 – 5	Event time: 4 – 0
Event	MTOF	GAP	Channel_ID[1]	Channel_ID[0]	Count in given time bin Is always >0	Event time after last MTOF
MTOF	1	GAP	0	0	0x0	0x0

1. **Header:**
   - **MTOF:** Indicates a Macrotime-Overflow. Such an event will be sent regularly after 32 times the set bin width has passed and is used to keep track of the event time.
   - **GAP:** Indicates if the data transfer has been interrupted and the time offset of all following events is not guaranteed anymore.
   - **Channel_ID:** The channel in which the transferred Bin count has been recorded
2. **Bin count** indicates the number of hits, occurring within the transferred time bin. Up to 127 hits per bin can be stored in this mode.
3. **Event time:** The elapsed time T_i since the last Macrotime-Overflow.

With the above information, the timing of every event can be calculated relative to the beginning of the measurement by counting the events with MTOF set high and adding the event time as follows

$$T_{event} = N_{MTOF} \cdot 32 + T_i.$$

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Becker & Hickl GmbH
Nunsdorfer Ring 7-9, 12277 Berlin, Germany
Tel. +49 / 30 / 212 800 20 Fax. +49 / 30 / 212 800 213
email: info@becker-hickl.com
www.becker-hickl.com