

Automated Nuclear Lab and PulseCounter Pro

The Tools for Rapid Nuclear Experimentation

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1. Automated Nuclear Lab

[Automated Nuclear Lab](#) (ANL) by Maximus Energy Corporation is a hardware / software system for rapid nuclear experimentation.

Until recently, nuclear experiments have been difficult to set up and run because each experiment required a unique set of expensive and complex hardware comprising a multitude of detectors, amplifiers, power supplies, and multi-channel analyzers. Calibration, electromagnetic noise reduction, elimination of systematic errors, signal acquisition & processing, and statistical analysis are just a few of many time consuming tasks that must be performed for each experiment and measurement. These tasks are not simple and therefore require hours or days of effort by experienced postdocs and highly trained technicians. Documentation of the measurement process alone may amount to 20-30% of a published paper.

[Automated Nuclear Lab](#) equipped with the [PulseCounter Pro](#) software solves this problem by:

- replacing a multitude of nuclear instrumentation modules with a single compact device capable of acquiring nuclear and auxiliary data on up to 8 channels,
- streamlining calibration, background and experiment data acquisition, and
- automating statistical analysis.

Additionally, ANL allows for:

- cross-referencing and combining counts and spectra obtained from multiple detectors;
- real-time analysis of count rate distributions;
- real-time evaluation of statistical significance of results;
- examination of the raw detector signal to screen for artificial counts due to noise;
- full control over pulse counting and pulse processing algorithm;
- raw detector signal capture with the option for offline reanalysis.

In other words, ANL automates almost all tasks pertaining to nuclear data acquisition, processing and analysis. By freeing up time and resources ANL allows physicists to focus on what is really important: design and execution of an experiment. Thus, ANL increases productivity by allowing you to run more experiments in less time.

1.1 Hardware

ANL hardware comes in a [variety of configurations](#) and generally comprises a multi-channel signal acquisition device combined with a power supply - Fig. 1.

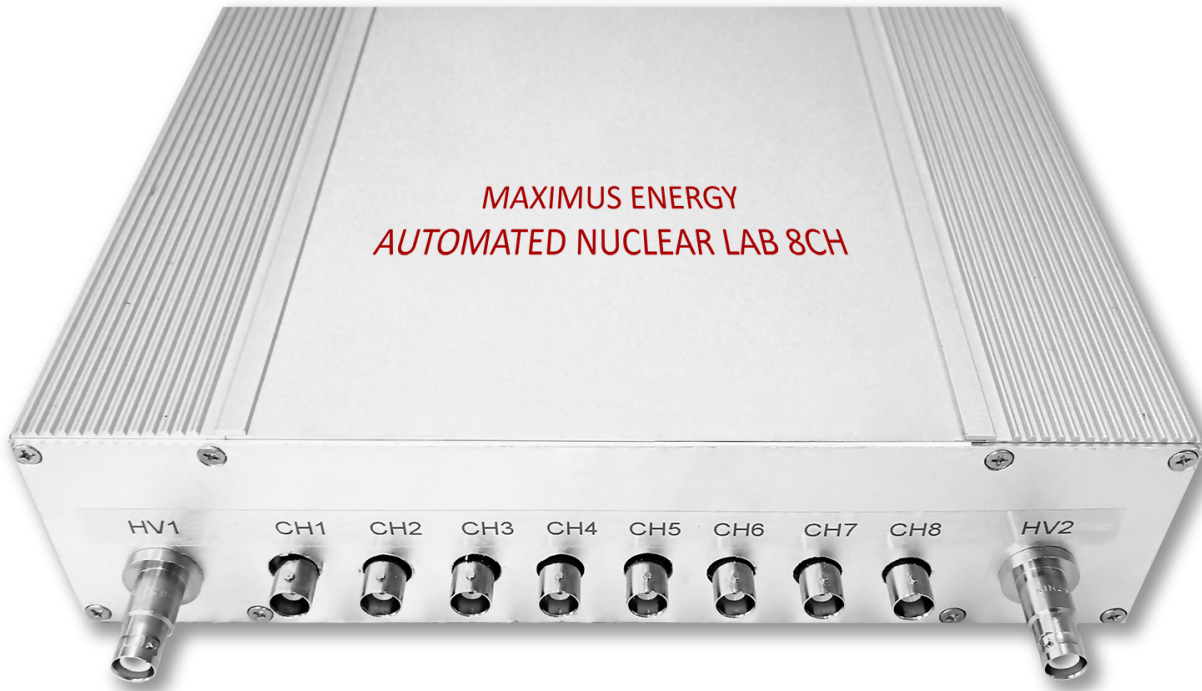


Fig. 1. ANL, the 8-channel configuration.

Typical specifications of an ANL system are as follows:

- Data acquisition channels: 2 to 8;
- Resolution: 12 to 16-bit;
- Sampling rate: 0 to 40 MHz;
- Signal ranges: ± 20 mV to ± 20 V (typical);
- Input impedance: 200 kOhm / 8 pF or 1 MOhm / 19 pF;
- Bias supply: 0 to +3,000 V @ 0.5 mA;
- USB 3.0 connectivity.

High dynamic range of the ANL inputs and ANL's pulse processing capabilities allow connecting most scintillators and proportional counters directly to an ANL device bypassing preamplifiers or shaping amps - Fig. 2.



Fig. 2. A sample ANL configuration with two ^3He proportional neutron counters and two NaI(Tl) gamma scintillation detectors.

Because ANL can function as a pulse processor it can accept signals from a wide variety of nuclear instruments including alpha, beta, gamma, x-ray, neutron detectors and scintillators.

1.2 Input Signals

Most nuclear detectors produce current or voltage pulses corresponding to detected nuclear particles or radiation. Detectors that produce current pulses usually employ preamplifiers to integrate the current pulses and convert them into voltages.

Detectors capable of energy resolution will generate pulses whose magnitude is proportional to energy of the detected particle.

Some detectors will produce pulses with different rise time depending on the type of particle detected (e.g. gamma or neutron).

ANL will work with just about any detector as long as the detector outputs voltage pulses corresponding to one of the following signals:

- **Short unimodal pulses** such as pulses from PMT voltage dividers, SiPM, or proportional counters - Fig. 3;

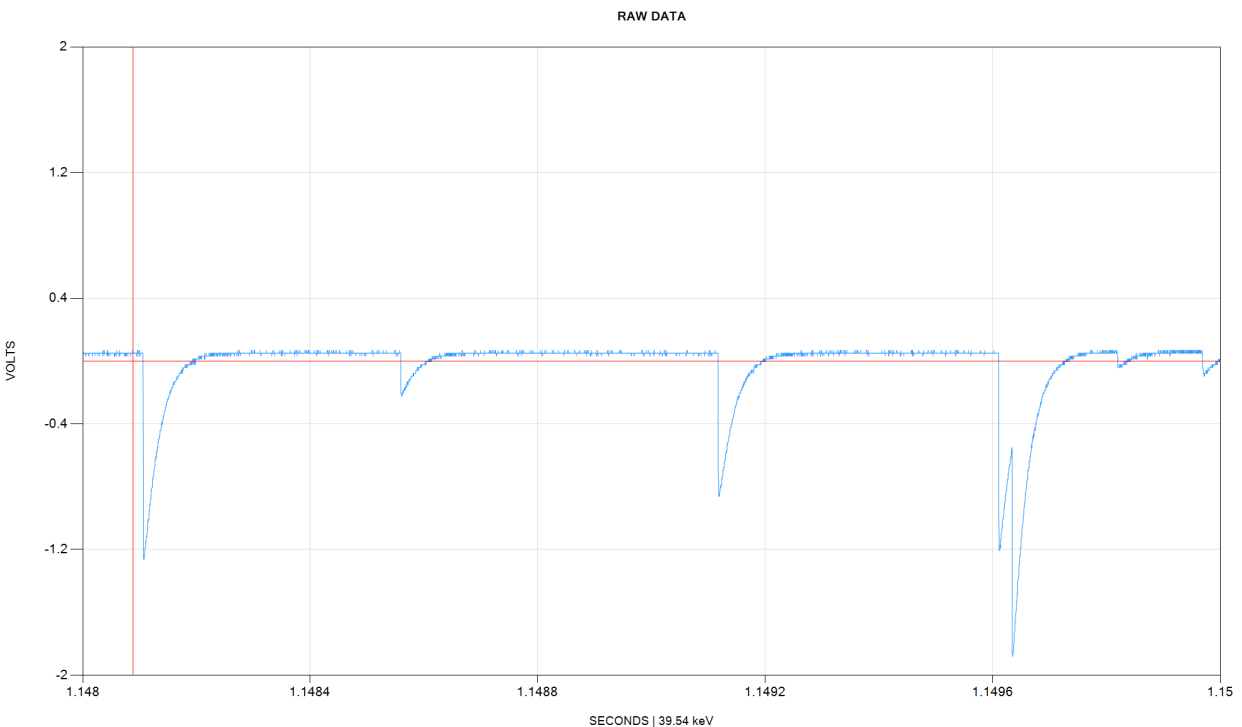


Fig. 3. Short negative pulses from the dynode of a PMT coupled to a NaI(Tl) scintillator.

- **Step-like pulses with long time constant** such as the output of preamplifiers - Fig. 4;

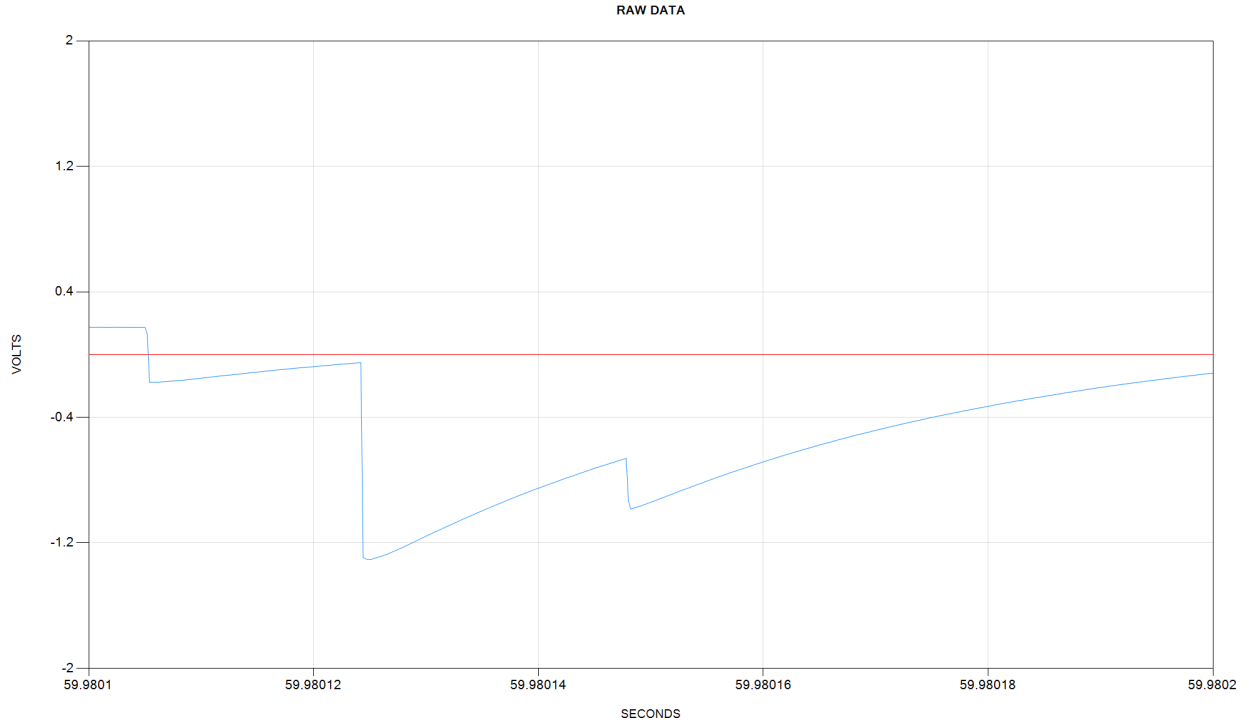


Fig. 4. Long negative step-like pulses from Canberra HPGe preamplifier.

- **Triangular or Gaussian pulses** such as the output of 3rd party shaping amplifiers or pulse processors - Fig. 5;

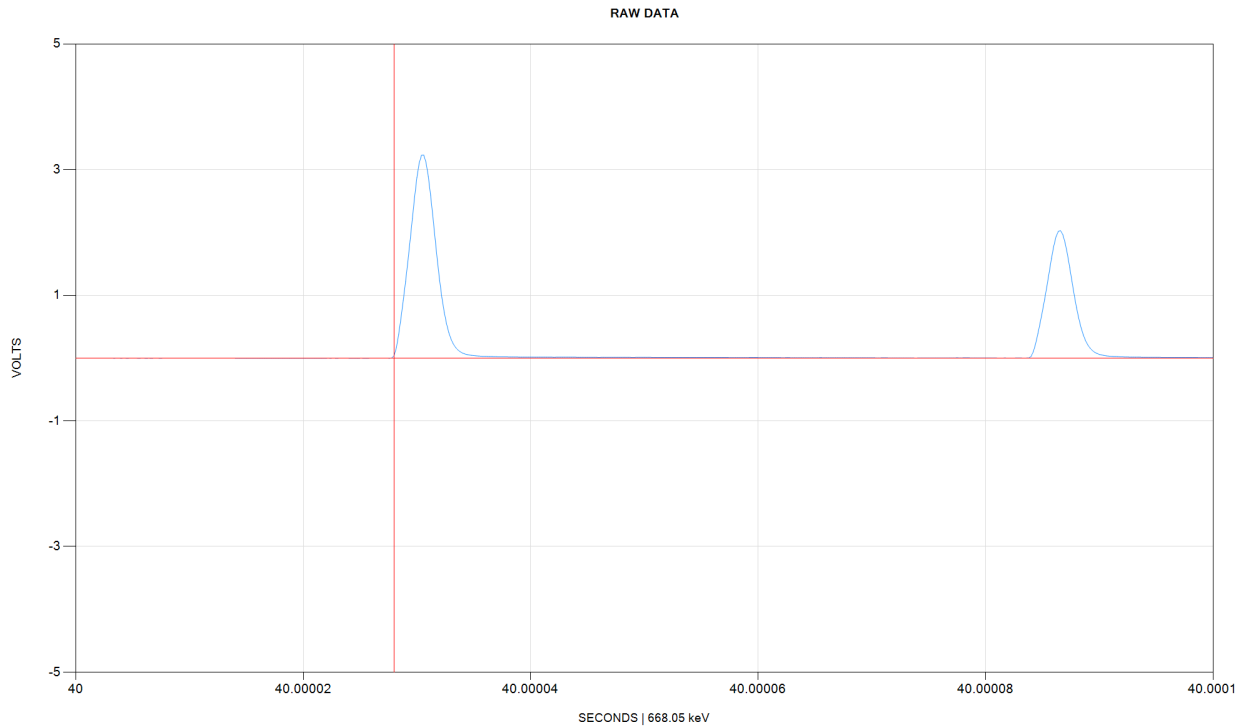


Fig. 5. Positive Gaussian pulses from Canberra 2026 shaping amplifier.

- **Preamplifier ramps** from SDD, SiPIN, or Si(Li) detectors - Fig. 6.

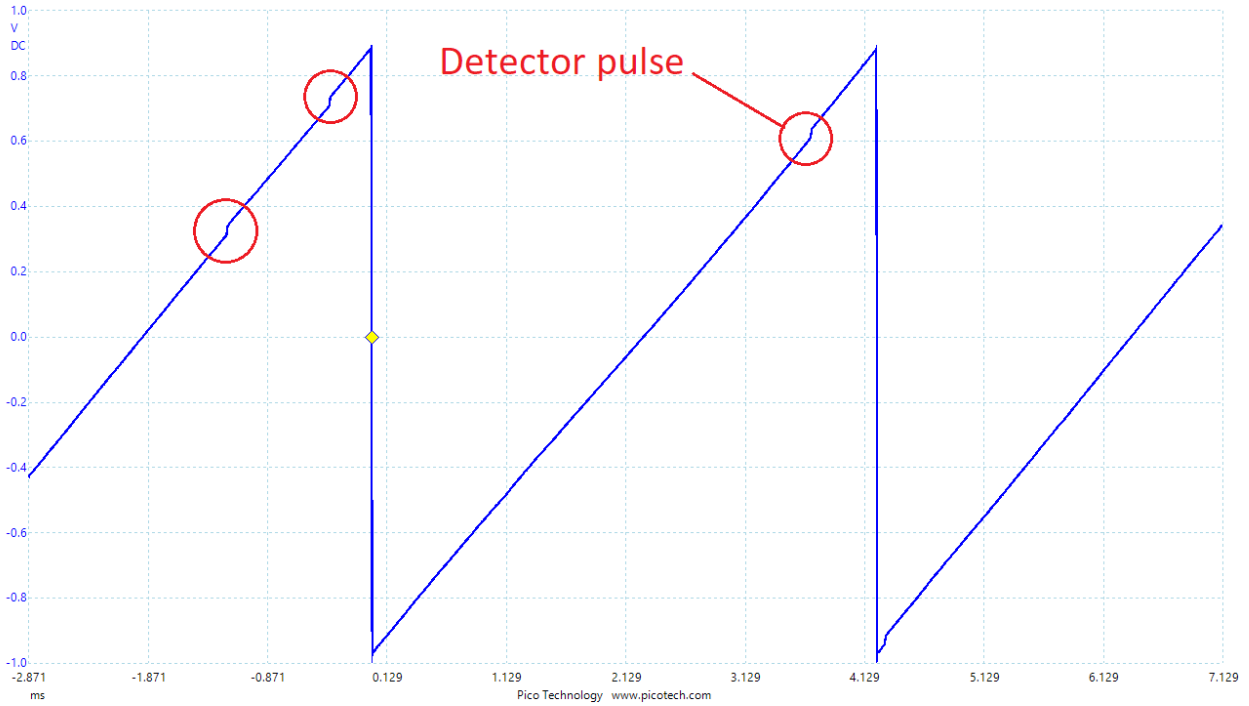


Fig. 6. Preamplifier ramp of an SDD with step-like pulses corresponding to x-rays.

ANL works with both positive or negative pulse polarity and DC-coupled or AC-coupled signals.

1.3 Connecting Detectors

It is possible to use a wide variety of detectors with ANL.

Some detectors come with two connectors: an SHV or an MHV for high voltage bias input and a BNC for signal output - Fig. 7.

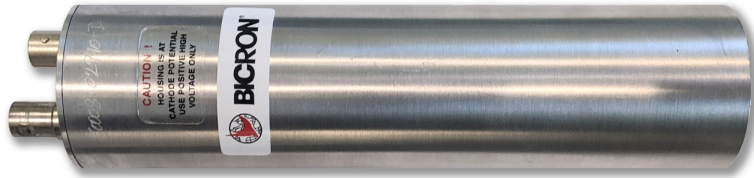


Fig. 7. A gamma detector with an SHV bias-in and a BNC signal-out connectors.

These dual-socket detectors can be connected directly to an ANL device by feeding the detector signal into any available ANL input channel via a BNC cable as shown on Fig. 3, where the detector bias is supplied via a separate SHV cable.

Other detectors come with a single SHV, MHV or BNC connector that combines the high voltage bias with the detector signal - Fig. 8.



Fig. 8. A neutron proportional counter with a single signal / bias SHV connector.

The single-socket detectors can be used with ANL by way of a splitter, which is a simple DC filter separating the HV bias from the low-voltage detector signal - Fig. 9.



Fig. 9. A bias / signal splitter.

ANL provides a built-in power supply that can be used for detector bias. This bias can be shared across multiple detectors provided that all of the detectors can operate at the same bias voltage. When different detectors require different bias voltages external power supplies must be used.

1.4 Software Requirements

ANL requires [PulseCounter Pro](#) software to operate. PulseCounter allows full control over the [pulse processing](#) algorithm for accurate pulse counting, pulse energy extraction and spectral analysis. PulseCounter software requirements are as follows:

- Windows 10 or later, 64-bit;
- [PicoSDK \(64-bit\)](#);
- USB 3.0.

1.5 Software Installation

PulseCounter software requires [PicoSDK \(64-bit\)](#), which must be installed prior to running the software. Once the SDK is installed, copy the *PulseCounter* folder from a flash drive that came with your ANL device to your hard drive and run *PulseCounter.exe* to launch the software.

2. Measurement Basics

Measurement is the most difficult part of any experiment. Measurements involving nuclear instruments are particularly difficult for the following reasons:

- Nuclear instruments are often complex and therefore require detailed understanding of their operating principles including the related physics;
- The analog signals produced by the instruments are usually very small, on the order of millivolts and therefore are easily corrupted by electromagnetic or mechanical noise;
- The changes in counts and count rates obtained from measurements are typically small and therefore require statistical analysis;
- Unlike ordinary measurements of temperature, pressure, length, weight, etc. all nuclear processes are fundamentally random in nature and therefore require solid understanding of random, normally distributed processes in order to interpret the results and derive conclusions.

2.1 Random Processes

There is a big principal difference between measurements of ordinary physical quantities such as temperature or length and activity or count rates reported by nuclear instruments.

For example, when we measure length we obtain a value whose accuracy is limited by the stated accuracy of the instrument. For example, if we use a common ruler graduated in millimeters the typical accuracy is 0.5 mm. Additionally, the measured length may be impacted by systematic errors pertaining to the use of the measurement device such as errors in the ruler positioning, curvature of the object being measured, etc. Yet even a single measurement typically yields a value representative of the true length with some uncertainties that are typically small compared to the value being measured. For instance, if we measure length with a ruler we may find it to be $100 \text{ mm} \pm 1 \text{ mm}$. Therefore in the classical realm a single measurement is usually representative of the value being measured and multiple measurements are necessary only if we wish to further reduce an already small uncertainty. This intuitive approach to measurement is based on our everyday experience with classical physics.

However, the situation is totally different when nuclear instruments are involved because these instruments operate according to the laws of quantum physics and therefore produce measurements pertaining to *random processes*. Randomness and random processes form the foundation of quantum physics, which can only be understood in terms of *probabilities*.

This means that a single measurement in the quantum realm is utterly meaningless because the value it yields is by definition random. Because this value is drawn from a random distribution (in most cases [Normal distribution](#)) it can range from zero to infinity. This situation is very different from measuring length with a ruler, where you always get a certain value close to the true length

100 mm in the example above). When measuring ‘quantum length’ with a ‘quantum ruler’ you can get values such as 0, 22, 311, 65000, etc. This is where our every-day (classical) intuition stops being helpful and we must follow the rules of quantum mechanics and apply appropriate statistical techniques to interpret the results.

In other words, if you wish to determine a neutron or gamma flux associated with a particular process and take a single measurement you will get a meaningless random value that cannot be interpreted in any useful way. To properly measure neutron or gamma flux one must conduct a series of measurements to sample the distribution and subject the results to a statistical analysis. We can make sense of randomness only by way of statistics.

Therefore, any measurement involving nuclear instruments amounts to acquiring multiple count rate samples over an extended period of time until we have a sufficiently large sample representative of the random distribution we are trying to sample.

2.2 Poisson Distribution

Nuclear physics is governed by the laws of quantum mechanics, which teach us that all nuclear processes involving radioactive decay, gamma emission or absorption are [normal processes](#) that follow Gaussian distribution of probabilities.

When we measure signals produced by nuclear processes (which are typically current or voltage pulses resulting from alpha particles, beta particles, neutrons, x-rays or gamma quanta interacting with a detector) we are primarily interested in count rates. A count rate is a number of detected events per unit time. When we count random events and bin them into discrete time intervals we obtain a [Poisson distribution](#), which may look very different from [Normal distribution](#) at low count rates but asymptotically approaches a Normal distribution at high count rates. In fact, at high count rates a Poisson distribution is practically equivalent to a Normal distribution where the distribution mean equals its standard deviation.

Therefore, in the context of this manual conducting a *measurement* constitutes acquisition of a sufficiently large sample of count rates to estimate the sample mean and standard deviation. Here the word ‘estimate’ although synonymous with the word ‘calculate’ means that even though we are calculating the mean and the standard deviation we are only estimating the actual values of the mean and the standard deviation pertaining to the distribution that we are sampling. Although calculated correctly, our estimates may be inaccurate or even totally wrong depending on how many samples we acquired and how ‘broad’ the random process is. Such as the nature of randomness! Therefore we must conduct repeated measurements coupled with statistical analysis to make sense of the results.

To summarize, a measurement is a collection of count rate samples accompanied by the calculated mean and standard deviation.

We can use statistical tools (such as χ^2 test) against the population of our count rate samples to see how well it fits a Poisson distribution - Fig. 10.

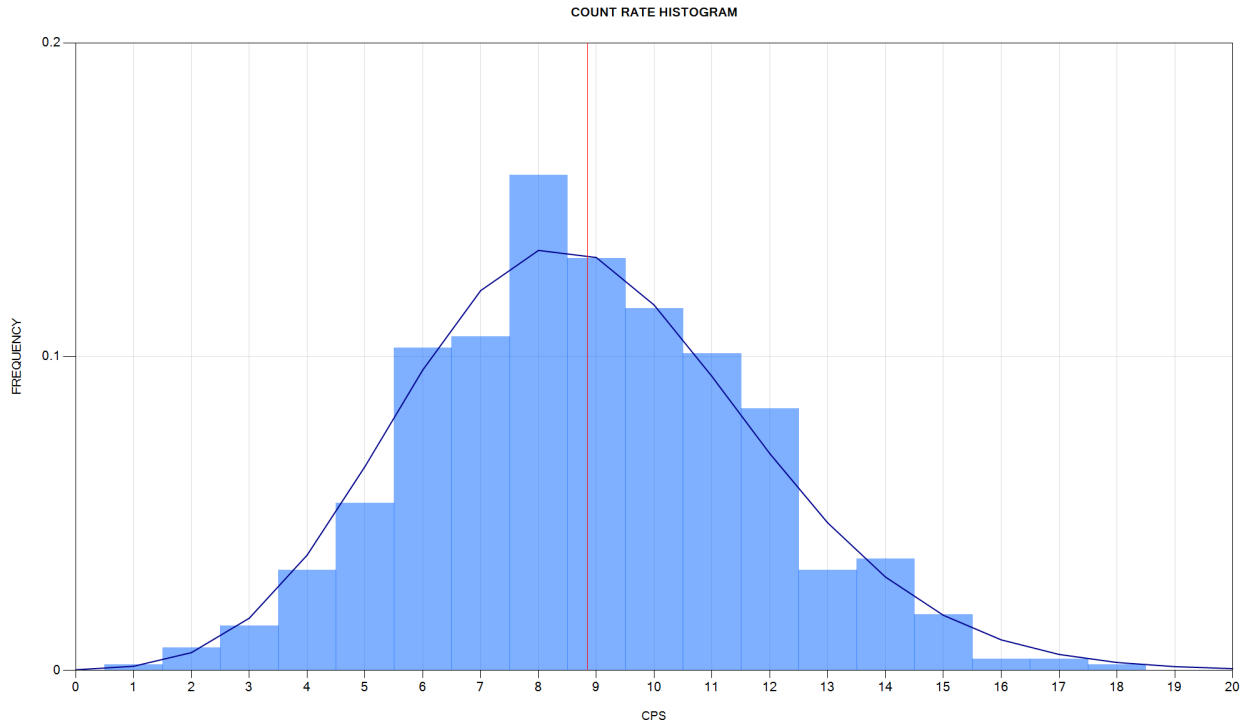


Fig. 10. Count rate histogram fitted to a Poisson distribution.

If the distribution is non-Poisson it can mean one of the two things:

- There is a non-random component to our process;
- The count rate samples are affected by systematic errors or noise.

The non-random component could be a result of the operator's interaction with the experimental setup or with the measurement instrument indicative of systematic errors pertaining to the instrument malfunction, faulty cabling, electromagnetic interference, errors in positioning, etc.

At other times the non-random component could be an indication of control: e.g. by shutting down power to the reactor we are able to reduce the counts and therefore control the random process by subjecting it to our will and thus making it non-random.

In any case, by examining the shape of the count rate distribution (which is referred to as the count rate *histogram*) you can derive useful conclusions pertaining to systematic errors or process control.

2.3 Background Counts

A unique feature of nuclear measurements is their relativity. Once again, consider a length measurement with a ruler. This measurement is absolute in the sense that unless we take the ruler and place it against the object being measured the ruler does not report any measurements. The ruler only reports a measurement when we use it to measure an object. Therefore we deem such measurement an absolute.

The situation is totally different with nuclear instrumentation. As soon as you turn on a nuclear instrument, the instrument will begin reporting counts. The ‘quantum ruler’ begins to measure something as soon as we touch it! The reason this happens is because we are always surrounded by a ‘sea’ of background radiation, some of which originates from outer space (cosmic rays, galactic supernova explosions, solar radiation, magnetosphere events, etc) and some of it originates on Earth due to natural radioactivity of rocks and materials that surround us (granite, radon), human activities, and even weather (electric storms and lightning discharges are known to generate gamma rays, neutrons and even positron radiation).

Hence all nuclear measurements are relative in nature and require two sample populations to be acquired and compared against one another: *background* and *experiment*.

Background measurements pertain to sampling of random processes associated with complex and variable natural phenomena. Proper background sampling must be meticulous yet it is often overlooked or performed incorrectly. Specifically, it is easy to be fooled by randomness and dismiss unexpectedly large background counts as erroneous as they defy our classical intuition. But this is exactly what randomness is! Random numbers are supposed to be surprising and are not supposed to make any sense. In other words, when you turn on a detector to measure background it can and will occasionally report unexpectedly high count rates; this is normal. The longer you sample the background the larger extremes count rates you will obtain. But in the end the count rate histogram of a background measurement must follow a Poisson distribution regardless of how large or small the samples are at their extremes.

Therefore, a singular extreme reading reported by a nuclear instrument should not be interpreted as evidence of something unusual; it is likely to be a manifestation of quantum randomness.

2.3.1 Background Reduction

Because in the course of a nuclear experiment we are always comparing background measurements to experiment measurements it is desirable to reduce the background counts. This is usually accomplished in two ways:

- Lead shielding is commonly used to screen background gammas whereas high density polyethylene (HDPE) or boron-rich shielding is used to screen background neutrons;
- Some experiments are conducted deep underground where the earth itself screens a lot of cosmic radiation such as high-energy muons.

Keep in mind that when using lead shields additional problems may arise such as x-ray fluorescence (XRF) peaks from lead or other elements present in the shield. These peaks arise when the elements of the shield absorb and re-emit x-rays creating a characteristic invisible glow that registers as a distinctive spectral signature on x-ray and gamma detectors. Therefore a lead shield may not always be appropriate; the XRF peaks originating from the shield will be significant when the gamma flux is high and therefore must be accounted for.

2.4 Detector Calibration

Nuclear instruments require regular calibration. In fact most instruments should be calibrated (or at least calibration-checked) before each experiment.

Because most detectors report counts that depend on the physical size of the detector element, its intrinsic sensitivity and orientation it may be necessary to run a sensitivity calibration to establish a relationship between the reported counts and the particle flux (e.g. convert neutron counts to neutron flux per cm²). Alpha, beta and gamma sensitivity calibration can be accomplished by way of [exempt sources](#) available from Spectrum Techniques.

Additionally, such sources can be used for energy calibration of pulse-height spectra to establish the relationship between the magnitude of a detector pulse and the corresponding particle energy. Most commonly used gamma sources for this purpose are:

- ⁵⁷Fe for calibrating x-ray detectors using the 5.9 keV line;
- ¹³⁷Cs for calibrating medium energy gamma detectors using the 661.7 keV line, and
- ⁶⁰Co for calibrating higher energy gamma detectors using the 1.17 and 1.33 MeV lines.

Gamma detectors in general and scintillation detectors in particular require frequent energy calibration due to energy resolution dependency on temperature. Spectral peaks do shift with the ambient temperature changes thus potentially affecting counts.

Calibration of neutron detectors requires neutron sources that in the U.S. generally require an NRC license. Common sources are Po-Be, Pu-Be, Ra-Be or Cf. Such sources are characterized by a known NIST-certified activity on the order of a few curies and therefore can be used to calibrate sensitivity of a neutron detector and in some cases its energy resolution.

2.5 Noise

Every electronic device has intrinsic electronic noise. In the case of nuclear instruments this intrinsic noise can be confused for genuine signal corresponding to particles being counted because detectors output pulses of varying amplitude and some of these pulses can have a very low amplitude. Therefore virtually all nuclear instruments require a choice of a low level discriminator or *threshold* to draw a virtual line below which all pulses are considered noise and above which the pulses are counted - Fig. 11.

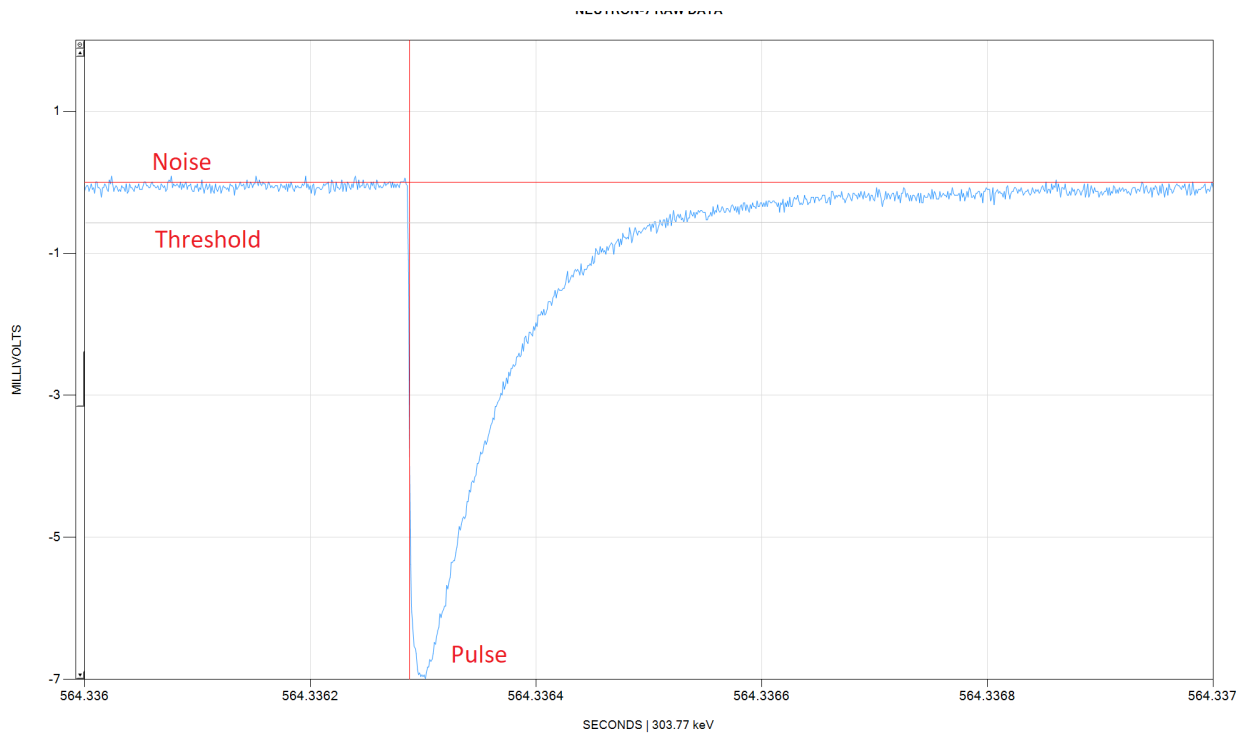


Fig. 11. Detector signal illustrating a genuine pulse, noise and low level threshold.

Ideally the threshold should be set just above the level of noise.

Besides the intrinsic noise there are other sources of interference that may introduce significant levels of noise into the measurement systems. Such noise sources are:

- Electromagnetic waves / RF interference from switching power supplies, plasma discharges, spark gaps, etc;
- Ground loops;
- Mechanical noise due to microphonic effects.

In general no nuclear instrument is immune to noise. In fact nuclear instruments are often very sensitive to noise because of the small magnitude of pulses most detectors produce (few mV or even a fraction of a mV). This noise can be a huge nuisance during an experiment because it is often random in nature and therefore may masquerade as a random process.

In some cases the noise is a side-effect of the experiment itself. For example, suppose that gamma or neutron radiation is expected to spike during a plasma discharge. Yet the discharge may produce copious amounts of EM noise, which may be picked up by gamma and neutron detectors and is reported as a spike in counts. To reduce this possibility measures must be taken to properly screen the detectors from transient EM interference. Regardless of this a manual examination of raw detector signal may be required to confirm authenticity of pulses associated with the count rate spike; pulse rise time and exponential decay time constant must match the detector specification.

In practice follow these steps to reduce or eliminate EM noise:

- use high quality brand name coaxial cables and connectors (no cheap generics);
- troubleshoot and eliminate ground loops;
- use Faraday cages to enclose nuclear instruments (you will get the least amount of interference when you use a battery powered instrument that is completely enclosed in a solid metal box).

2.6 Pulse-Height Spectrum

Examination of the pulse-height spectrum produced by a detector can provide additional clues on whether the counted pulses are genuine or artificial.

For example, some detectors generate pulses of varying amplitude regardless of their ability to discriminate particle energy. Such detectors will always produce the same pulse-height spectrum shape regardless of count rate or particle energy. A ZnS(Ag) scintillation detector for alpha/beta particles is a good example of this behavior - Fig. 12.

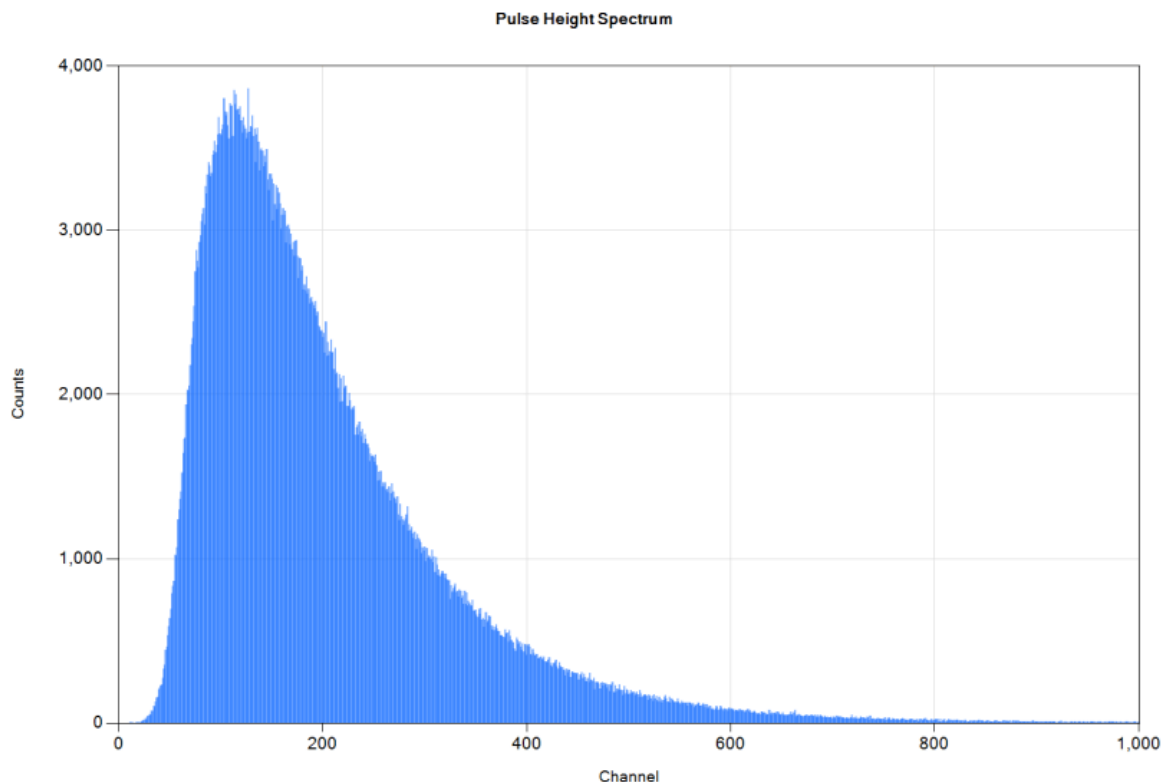


Fig. 12. Pulse height spectrum of a ZnS(Ag) scintillation detector.

Any additional peaks present on the spectrum shown on Fig. 12 will be an indication of artificial counts due to electromagnetic noise.

By the same token ^3He neutron proportional counters always produce thermal neutron energy spectrum regardless of neutron energy - Fig. 13.

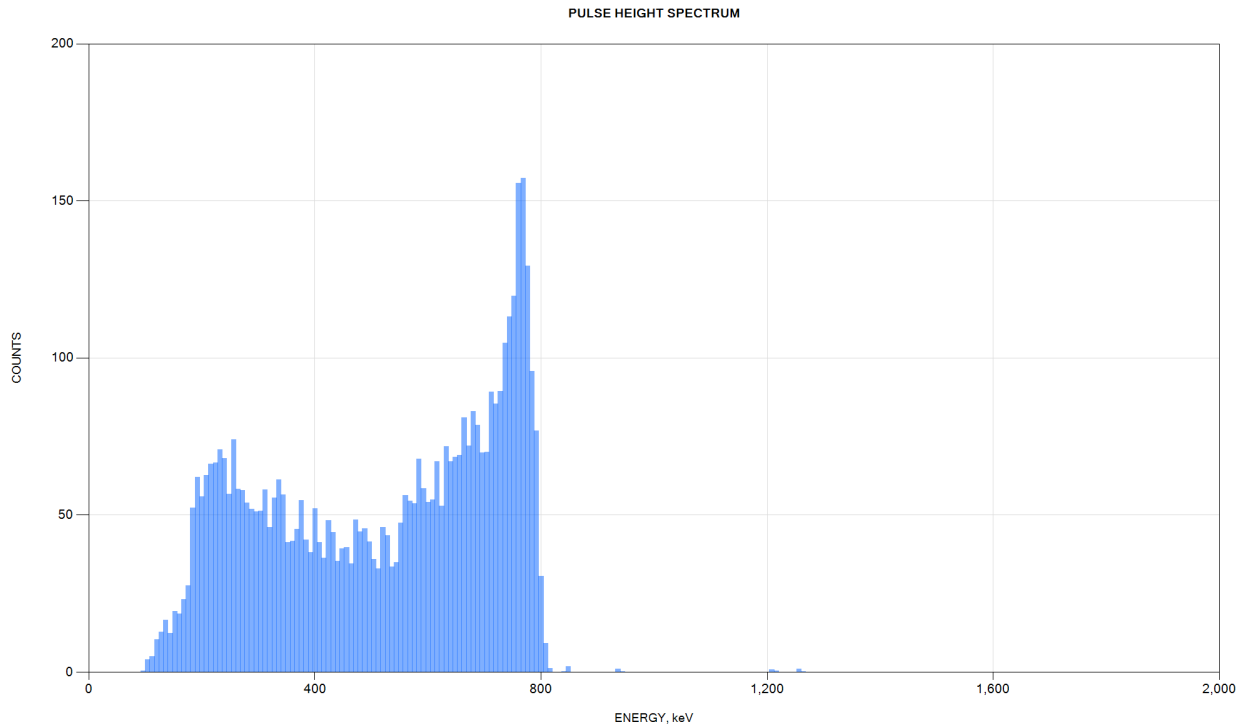


Fig. 13. ^3He proportional counter thermal neutron energy spectrum.

A thermal neutron spectrum is always characterized by the general shape shown on Fig. 13 and any significant deviations from this shape is a good indicator of artificial counts due to electromagnetic or other interference.

Another indicator of noise is spectral peaks that are too high or too low for the detector energy range. For example, most gamma scintillation detectors are packaged in aluminum or steel enclosures and thus are not sensitive to gammas below 20 keV. If a spectrum captured using such a detector exhibits low energy peaks below 20 keV these peaks are likely to be artificial and caused by noise.

By the same token SDD, SiPIN and Si(Li) detectors are generally not sensitive to x-rays above 40 keV. Thus, if an x-ray spectrum acquired using an SDD has significant peaks with energies much greater than 40 keV, those peaks are likely to be artificial in nature.

Therefore having the ability to plot and inspect a pulse-height spectrum provides an important diagnostic tool for evaluating the veracity of the acquired counts.

2.7 Deriving Conclusions

2.7.1 T-Test and P-Value

Once a set of background and experiment measurements is acquired and the corresponding population means and standard deviations are calculated, you can start looking for differences between the experiment and the background count rates. A mere presence of difference in the mean count rates between the two populations, however large, is not an indication of a true difference. Instead a statistical analysis must be conducted in order to determine if the two population means are in fact different (as opposed to merely appearing different due to insufficient sampling of the random processes involved).

One such common tool for comparing populations is [Student's t-test](#). This test yields a numerical measure called *p-value*, which can be used to interpret statistical significance of results. For example, if the background and the experiment counts are evaluated using Student's t-test and the resulting p-value is between 0.05 and 1 the results are considered not *statistically significant* meaning that the observed difference between the experiment and the background count rates is not at all likely to be genuine. This means that the two count rates are essentially the same and the observed numerical difference in the count rates (however large) must be due to insufficient sampling of the random processes involved.

At the same time if the p-value is between 0 and 0.05 indicates *statistically significant* results meaning that the observed difference between the experiment and the background count rates is exceedingly likely to be genuine. This means that the difference between the two count rates (however small) is not at all likely to be an artifact of insufficient sampling of the random processes.

2.7.2 Power of Test

When the number of acquired samples is small the veracity of Student's t-test can be questioned. To provide additional assurance, [power of the test](#) should be also evaluated. For example Lehr's rule of thumb is often used to determine if a Student's t-test calculation was made using enough samples to yield meaningful results.

2.7.3 P-Value Trend

Acquiring additional background and experiment measurements may result in a p-value trend. If p-value is increasing with each additional measurement ($p \rightarrow 1$) this means that there is no difference between the experiment and the background count rates and any initial indication of significance ($p \leq 0.05$) was likely in error.

Conversely, if p-value is decreasing with each additional measurement ($p \rightarrow 0$) this means that there is a genuine difference between the experiment and the background count rates and the initial indication of poor significance ($p > 0.05$) was likely in error.

In other words, any results that are being presented as ‘statistically significant’ must improve in significance ($p \rightarrow 0$) with the increase in the number of measurements. This is a must-have sanity check for presenting high-impact results.

2.7 General Protocol for High-Veracity Measurements

Summarizing the discussion above, a good experimental protocol for high-veracity measurement results involving nuclear instruments is as follows:

1. Properly shield instruments from electromagnetic interference and eliminate ground loops;
2. Calibrate detectors;
3. Acquire a large sample of background count rates;
4. Acquire a large sample of experiment count rates;
5. Perform Student’s t-test and calculate p-value;
6. If the p-value is 0.05 or less than the difference in count rates is statistically significant;
7. To further confirm the purported statistical significance:
 - a. Evaluate power of test to make sure that enough samples were used to determine significance;
 - b. Examine pulse-height spectrum: does it match the expected shape?
 - c. Examine the count rate histogram: does it follow a Poisson distribution?
 - d. Examine the raw detector signal: does it appear free from noise? Are the counted pulses characterized by the expected rise time and decay time?

Following these steps is a tedious but necessary process for reporting high-veracity results. Fortunately, ANL with the help of PulseCounter Pro software automates most of these tasks and makes it easy to acquire quality measurements and to derive real-time conclusions pertaining to the significance of the results.

3. PulseCounter Software

3.1 Purpose

The main purpose of PulseCounter software is to acquire and process a detector signal to obtain an accurate count rate and pulse-height spectrum.

An equally important task of PulseCounter software is to compare experiment and background measurements to determine if there is a statistically significant difference between their respective count rates. This task requires performing multiple repeated measurements over an extended period of time and subjecting the resulting data to a rigorous statistical analysis.

3.2 Data Organization

To accomplish both tasks PulseCounter organizes its data as follows - Fig. 14:

- **Experiment** - is a collection of channels (instruments) and measurements pertaining to each channel (instrument); each ANL experiment is characterized by its own channel configuration set up to acquire and process data from a specific set of instruments;
- **Channel** - is an ANL [data acquisition channel](#) corresponding to a particular nuclear or auxiliary instrument; PulseCounter supports counter, raw data, logger and aggregate channels; each channel has its own set of measurements;
- **Measurement** - is sequence of count rate samples acquired over a specified period of time (duration of the measurement);
- **Summary** - is a channel aggregate of all background and all experiment measurements (all background measurements for the channel are merged into a single composite 'Background' measurement and all experiment measurements for the channel are merged into a single composite 'Experiment' measurement).

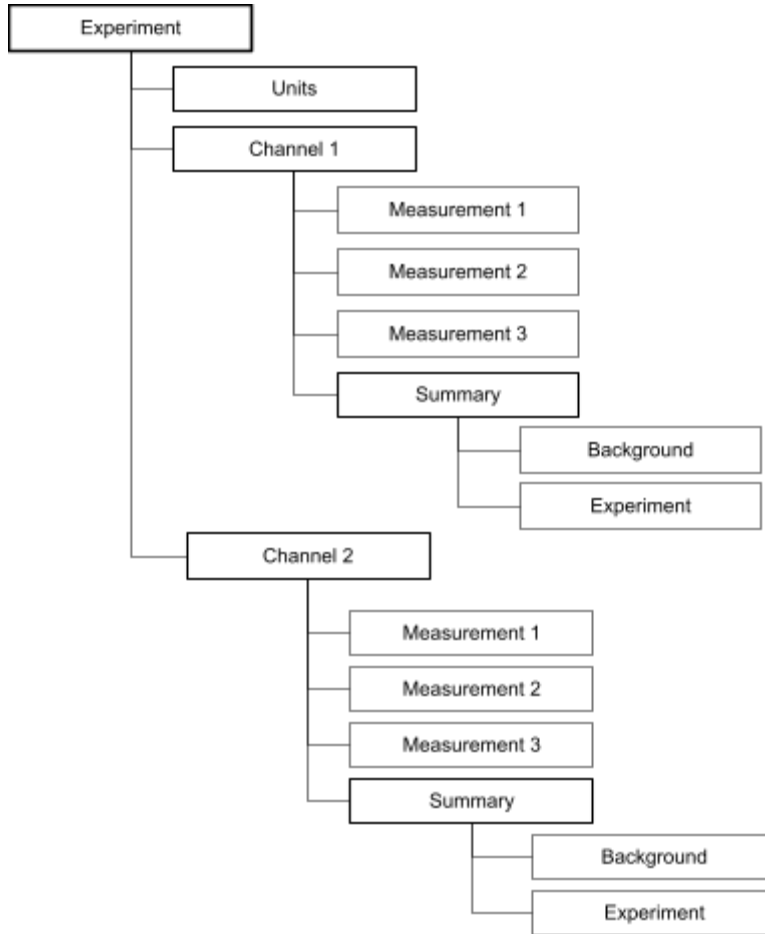


Fig. 14. PulseCounter data organization diagram.

3.3 Units

Basic computational unit of PulseCounter is a count rate sample. PulseCounter can operate on count rates expressed as counts per second (CPS), counts per minute (CPM), counts per hour (CPH), or counts per day (CPD). Each experiment must specify which count rate units are to be used.

Count rate units define the duration of measurements. E.g. if the units are CPM and the measurement duration is 10 samples this means that the measurement took 10 minutes to acquire.

3.4 Measurement Data Structure

PulseCounter classifies measurements as background, experiment, or calibration. Background measurements are compared to experiment measurements to compute statistical significance while calibration measurements are excluded from analysis.

Every PulseCounter measurement contains the following information - Fig. 15:

- Preset - stores information about how the measurement was acquired and processed (hardware channel configuration and pulse processing settings);
- Samples - the number of count rate samples acquired;
- Count rate history - the sequence of count rate samples acquired;
- Mean count rate - the average of the count rate history;
- Standard deviation - computed from the count rate history;
- Total count - the integral (sum) of the count rate history;
- Count rate histogram;
- Pulse-height spectrum (pulse-energy spectrum when energy calibration is present);
- Pulse rise-time histogram;
- Raw detector signal (optional);
- Pulse list - a sequence of all recognized detector pulses including their
 - Start time,
 - Pulse height / pulse energy,
 - Pulse type (accepted, rejected, clipped, and / or piled up),
 - Pulse rise time.

Pulse list allows for swift rebuilding of a measurement (including total count, count rate history, count rate histogram, and spectrum) to accommodate a different counting assumption (e.g. whether to include / exclude pulses of certain rise time, type or energy).

Counted pulses are marked as accepted, not counted pulses (see the [Pulse Rejection](#) section) are marked as rejected. Additionally both accepted and rejected pulses can be marked as clipped or piled up (see the [Pulse Rejection](#) section).

When a measurement contains raw data it is possible to reanalyze the entire measurement using a different set pulse processing parameters.

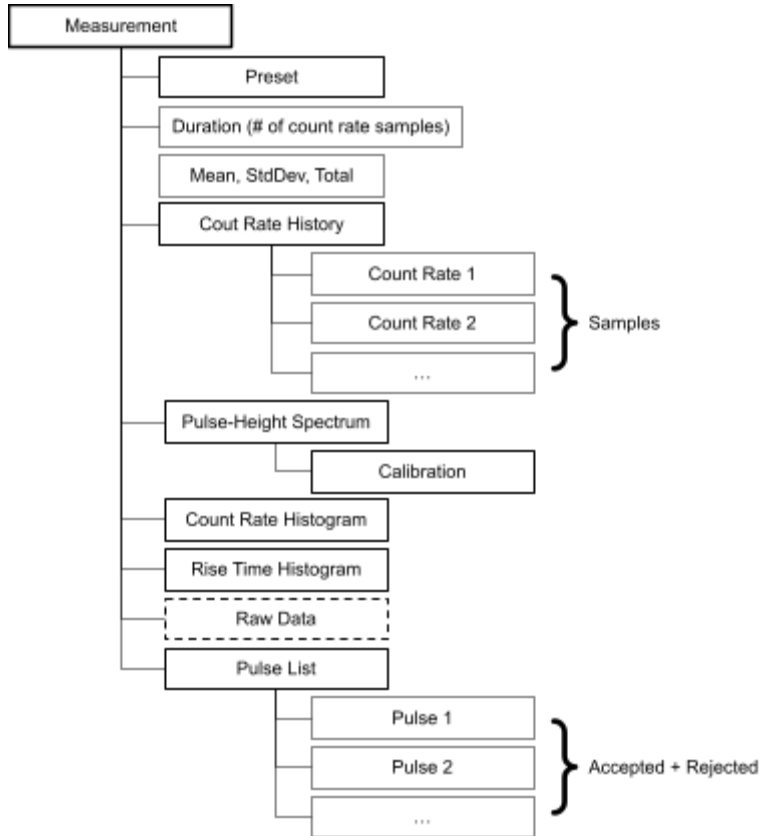


Fig. 15. PulseCounter Measurement data structure.

3.6 Directory Structure

PulseCounter file structure is shown on Fig. 16.

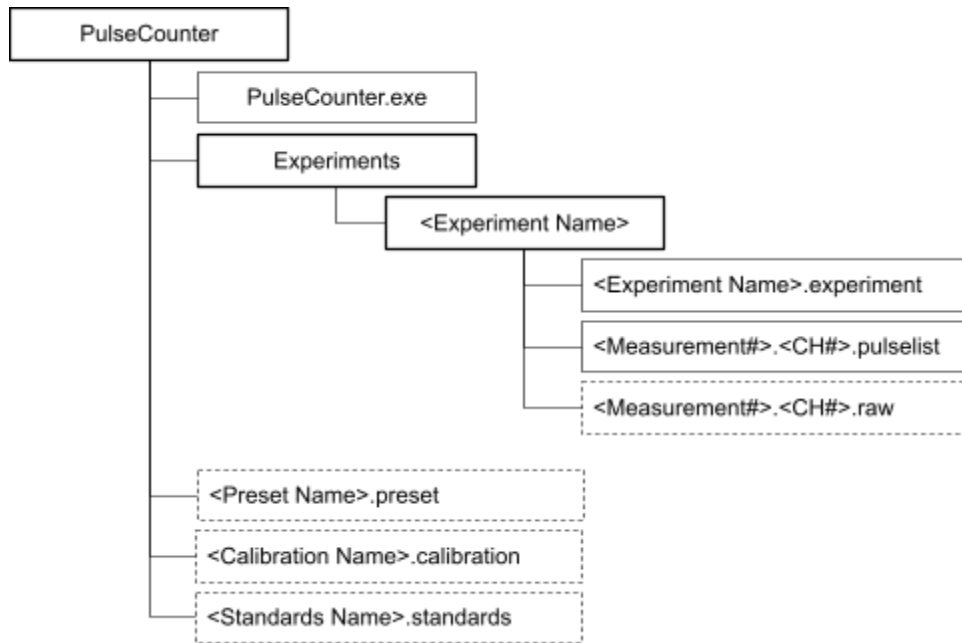


Fig. 16. PulseCounter directory structure.

All experiments are saved in the *Experiments* folder. Each experiment is defined by a corresponding *.experiment* file. Each measurement has a corresponding set of *.pulselist* files, one for each channel. If the raw detector data was captured during a particular measurement then there will be a corresponding set of *.raw* files, one for each channel.

NOTE: Although compressed, the *.raw* data files may occupy gigabytes of disk space.

4. Software Operation

4.1 Main Screen

When PulseCounter Pro launches it displays a list of existing experiments by enumerating directories in the *Experiments* folder - Fig. 17.

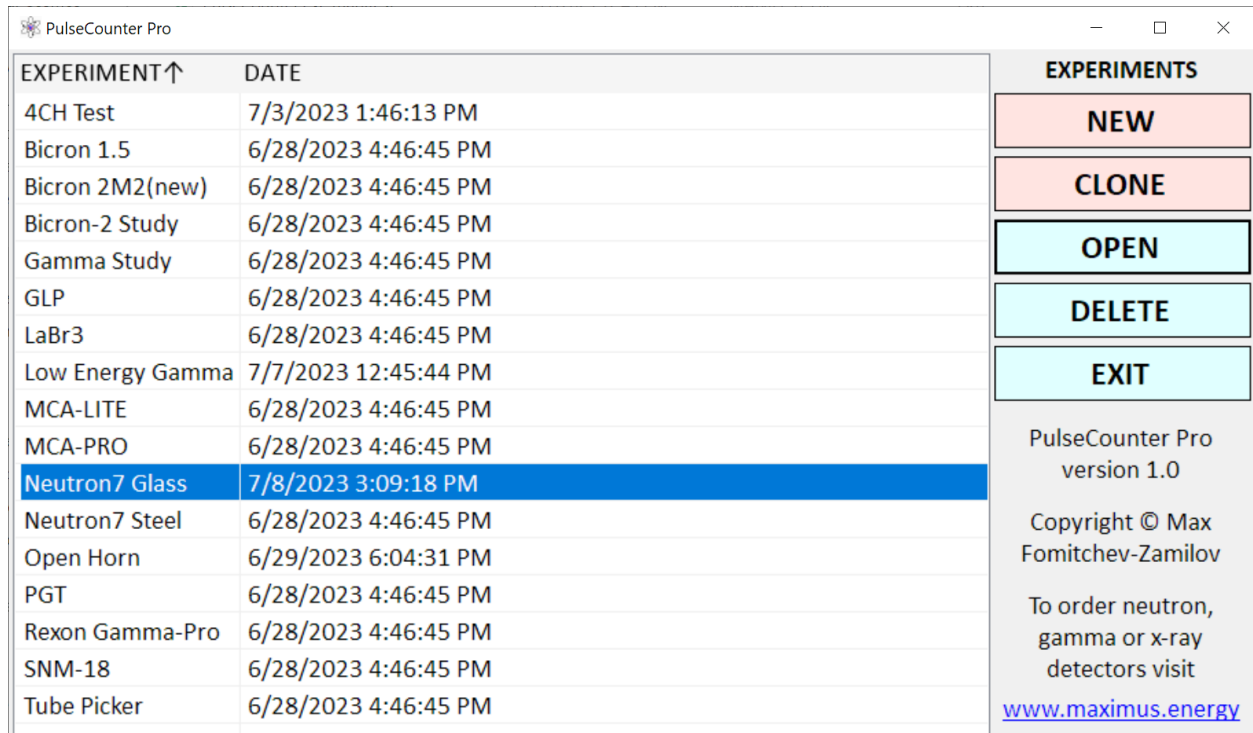


Fig. 17. Main screen of PulseCounter Pro displaying the list of existing experiments.

Click on the **EXPERIMENT** or the **DATE** column header to sort the experiment list by experiment name or by last-modified date.

Click the **NEW** button to create a new experiment or click the **OPEN** button to open an existing experiment.

Use the **CLONE** button to create an empty copy of a selected experiment by duplicating the channel configuration but not the measurements.

4.2 Experiment Screen

When you create a new experiment, PulseCounter opens an Experiment screen displaying a blank **MEASUREMENTS** list, a **CHANNELS** list containing a single default counter channel, and a blank channel **SUMMARY** plot - Fig. 18.

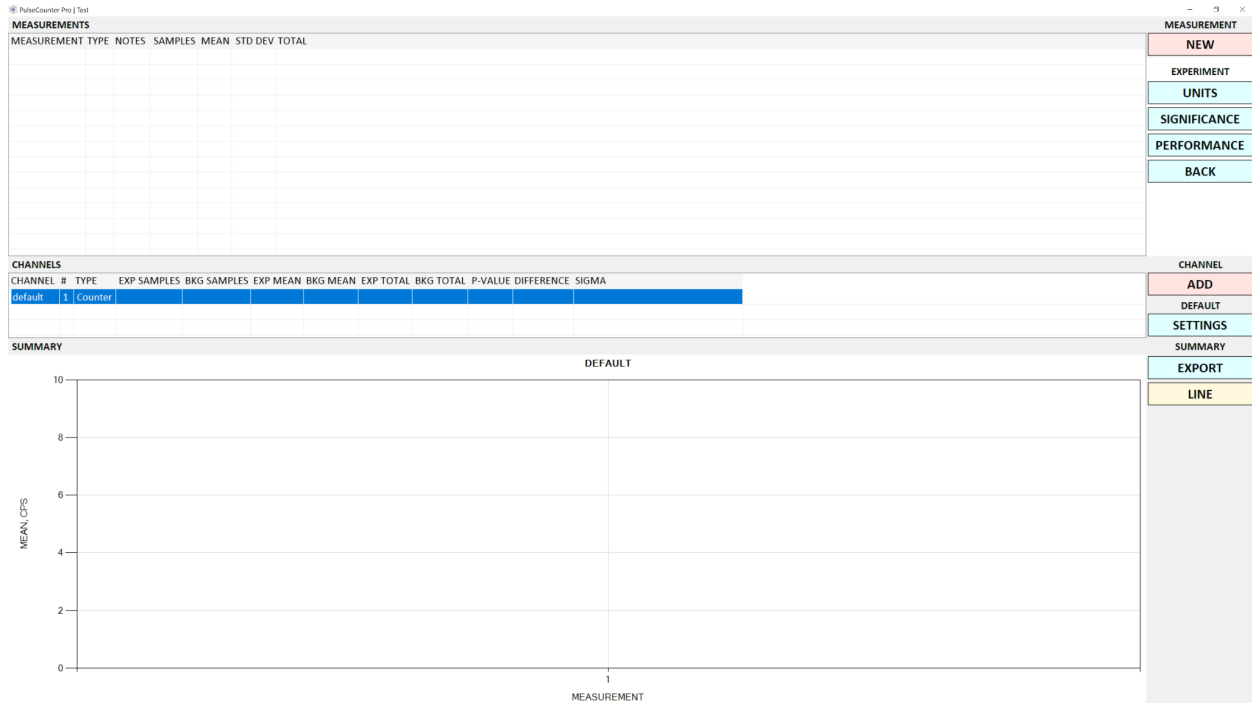


Fig. 18. PulseCounter Experiment screen displaying a new experiment.

4.2.1 Channel List

The first step in the experiment setup is channel configuration. Depending on the ANL hardware variant an experiment can contain up to 8 hardware channels.

The **CHANNEL** column in the **CHANNELS** list is a user-defined channel name, the **#** column contains the ANL hardware channel number, and the **TYPE** column displays the channel type (Counter, RawData, Logger or Aggregate).

To create a new channel click the **ADD** button to open the **CHANNEL SETTINGS** dialog - Fig. 19.

To configure an existing channel select a channel by clicking on the corresponding row in the **CHANNELS** list and click the **SETTINGS** button.

To delete an existing channel select the channel then click the **REMOVE** button.

NOTE: You can delete channels only when the experiment has no measurements.

4.2.1.1 Counter Channel

To create a counter channel select 'Counter' from the **CHANNEL TYPE** drop down list in the **CHANNEL SETTINGS** dialog - Fig. 19.

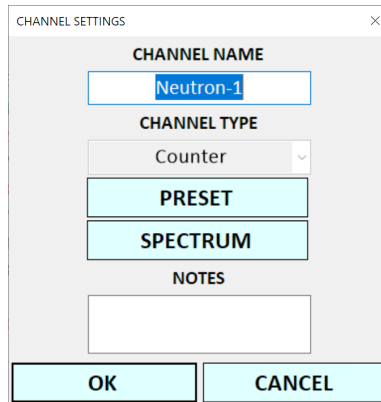


Fig. 19. Counter channel settings in the **CHANNEL SETTINGS** dialog.

Give the channel a friendly name by typing it in the **CHANNEL NAME** box.

You can configure a counter channel by specifying the [data acquisition and pulse processing preset](#) by clicking the **PRESET** button. Additionally you can define the pulse-height spectrum properties by clicking the **SPECTRUM** button. Because the preset and the spectrum properties can be set for each measurement, setting them in the **CHANNEL SETTINGS** dialog is optional.

NOTE: Every experiment must contain at least one counter channel to acquire and process a detector signal. Therefore the first channel of every experiment is always a counter channel and it cannot be removed.

4.2.1.2 RawData Channel

To create a channel for raw data acquisition select 'RawData' from the **CHANNEL TYPE** drop down list in the **CHANNEL SETTINGS** dialog - Fig. 20.

Fig. 20. Raw data channel settings in the **CHANNEL SETTINGS** dialog.

Raw data channels are suitable for acquiring signals from high-frequency instruments such as acoustic sensors, voltage or current probes.

To configure the channel specify the **COUPLING** type (AC or DC) and set the **SIGNAL RANGE** in volts.

To convert from voltages to physical units, specify the unit name in the **UNIT** box and enter volts-to-unit conversion value in the **VOLTS / UNIT** box. For example, if you are using a piezoelectric pressure transducer that reports pressure in psi with the sensitivity of 0.5 mV/psi type 'psi' in the **UNIT** box and enter 0.0005 in the **VOLTS / UNIT** box.

4.2.1.3 Logger Channel

To create a logger channel select 'Logger' from the **CHANNEL TYPE** drop down list in the **CHANNEL SETTINGS** dialog.

A logger channel is similar to a raw data channel except that this channel type is intended for capturing slowly varying signals such as temperature or pressure. Logger channel values are averaged over a time frame defined by the [buffer size](#) divided by the sampling rate specified in the preset.

4.2.1.4 Aggregate Channel

To create an aggregate channel select 'Aggregate' from the **CHANNEL TYPE** drop down list in the **CHANNEL SETTINGS** dialog - Fig. 21.

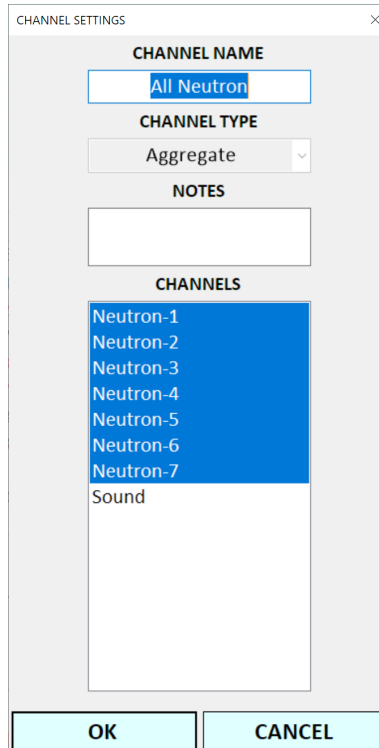


Fig. 21. Aggregate channel settings in the **CHANNEL SETTINGS** dialog.

An aggregate channel allows merging together two or more counter channels to create a virtual channel reporting the combined count rate, history, and spectrum. To set up an aggregate channel create the individual counter channels first then select them in the list of **CHANNELS** when creating an aggregate channel.

NOTE: PulseCounter Pro supports up to eight hardware channels such as counter, raw data or logger and an unlimited number of aggregate channels.

4.2.3 Channel Summary Information

Once you acquire one or more measurements, the **CHANNELS** list will be populated with information pertaining to background and experiment measurements as follows (Fig. 22):

- **EXP SAMPLES** - total count of samples of all experiment measurements;
- **BKG SAMPLES** - total count of all samples of all background measurements;
- **EXP MEAN** - mean count rate across all experiment measurements;
- **BKG MEAN** - mean count rate across all background measurements;
- **EXP COUNT** - the sum of total counts of all experiment measurements;
- **BKG COUNT** - the sum of total counts of all background measurements;

- **P-VALUE** - p-value calculated using the double-tailed Student's t-test using the experiment and the background sample populations;
- **DIFFERENCE** - percentage difference between the **EXP MEAN** and the **BKG MEAN**;
- **SIGMA** - difference between the **EXP MEAN** and the **BKG MEAN** in terms of standard deviations.

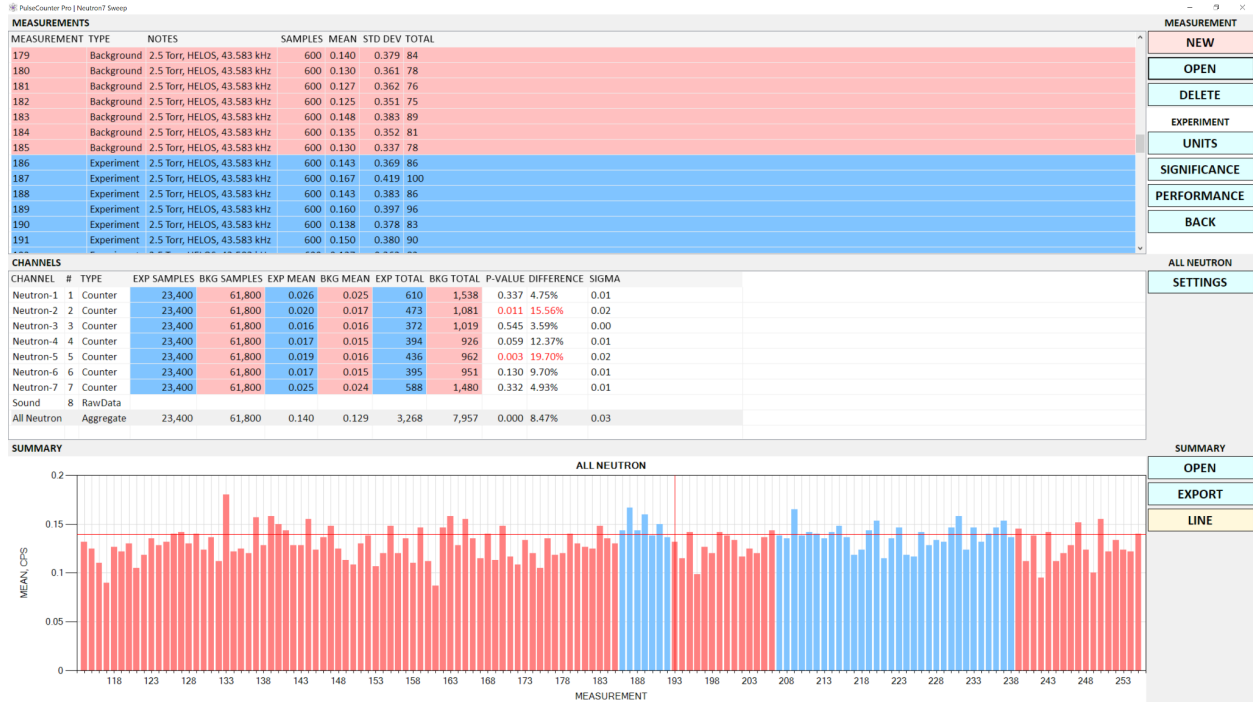


Fig. 22. An experiment with multiple channels and multiple measurements.

NOTE: the **EXP SAMPLES**, the **EXP MEAN** and the **EXP TOTAL** columns are colored blue whereas the **BKG SAMPLES**, the **BKG MEAN** and the **BKG TOTAL** columns are colored pink.

NOTE: If the p-value is significant, the **P-VALUE** and the **DIFFERENCE** column figures are colored red.

4.2.4 Summary Plot

The **SUMMARY** plot at the bottom of the Experiment screen (Fig. 22) displays a bar chart plot of mean count rates corresponding to the experiment (blue) and the background (pink) measurements of the currently selected channel (which is the highlighted channel in the **CHANNELS** list).

The horizontal red line indicates the mean experiment count rate (the figure from the **EXP MEAN** column of the currently selected channel in the **CHANNELS** list).

The vertical red line indicates the currently selected measurement.

The **SUMMARY** plot will refresh when you select a different channel in the **CHANNELS** list.

You can export the summary plot to a PNG or a CSV file by clicking the **EXPORT** button.

The **LINE** button toggles between the bar chart and the line plot representation.

4.2.5 Units

You can specify the [experiment units](#) by clicking the **UNITS** button - Fig. 23.

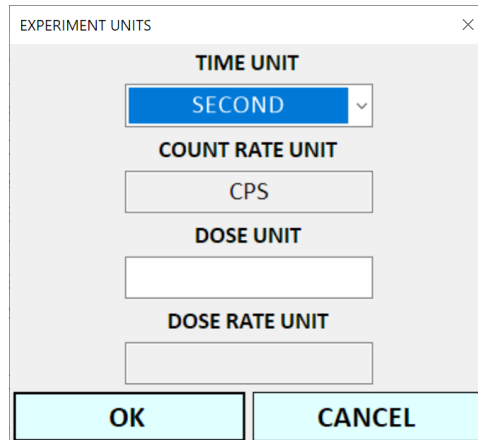


Fig. 23. The **EXPERIMENT UNITS** dialog.

Select a desired time unit from the **TIME UNIT** drop down list; the **COUNT RATE UNIT** box will update to display the corresponding count rate label.

NOTE: Changing time units in an experiment that has measurements will result in the rebuilding of all measurements to accommodate the new units.

To replace counts with dose, type a dose unit designation (such as mrem, Gy, etc.) in the **DOSE UNIT** box. The **DOSE RATE UNIT** box will update automatically with an appropriate dose rate unit corresponding to the selected time unit. For example, if the selected time unit is 'SECOND' and the dose unit is 'mrem' the dose rate unit will read 'mrem/second'.

To complete the count-to-dose calibration you must configure every counter channel to specify a dose per count conversion constant. Once you enter these constants PulseCounter Pro will start reporting doses and the dose rates instead of the counts and the count rates.

4.2.6 Statistical Significance

To modify the significance level applied to p-value analysis to determine the statistical significance of results click the **SIGNIFICANCE** button to display the **STATISTICAL SIGNIFICANCE** dialog - Fig. 24.

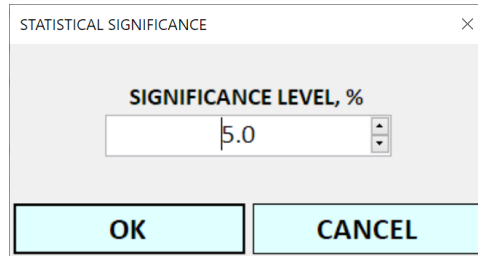


Fig. 24. The **STATISTICAL SIGNIFICANCE** dialog.

The default value is 5%. P-values below the specified significance level are deemed significant and are marked as such.

4.2.7 Performance

To adjust the data acquisition performance of PulseCounter Pro click the **PERFORMANCE** button to open the **DATA ACQUISITION PERFORMANCE** dialog - Fig. 25.

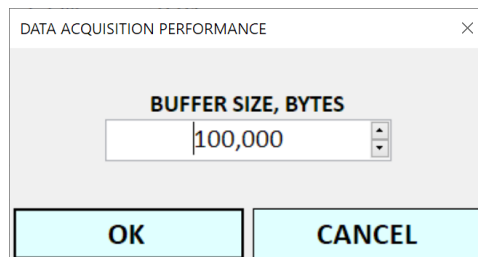


Fig. 25. The **DATA ACQUISITION PERFORMANCE** dialog.

The default **BUFFER SIZE** of 100,000 bytes is suitable for most purposes. If you are experiencing measurement acquisition issues with dropped samples or less than real-time performance try increasing this number.

NOTE: Very large **BUFFER SIZE** values will make PulseCounter Pro screen refresh less responsive to real-time changes in detector signal and counts.

4.2.8 Measurement List

The **MEASUREMENTS** list at the top of the Experiment screen (Fig. 22) summarizes measurements for the currently selected channel as follows:

- **MEASUREMENT** - numerical measurement ID;
- **TYPE** - background, experiment, or calibration;
- **NOTES** - user-entered measurement notes;
- **SAMPLES** - number of acquired measurement samples (measurement duration in time units);

- **MEAN** - mean count rate;
- **STD DEV** - standard deviation;
- **TOTAL** - total counts.

Selecting a different channel in the **CHANNELS** list will refresh the **MEASUREMENTS** list with the measurement data for the selected channel.

To delete a measurement select one or more measurements and click the **DELETE** button.

To open an existing measurement select a single measurement and click the **OPEN** button.

To acquire a new measurement click the **NEW** button to display the Measurement screen - Fig. 26.

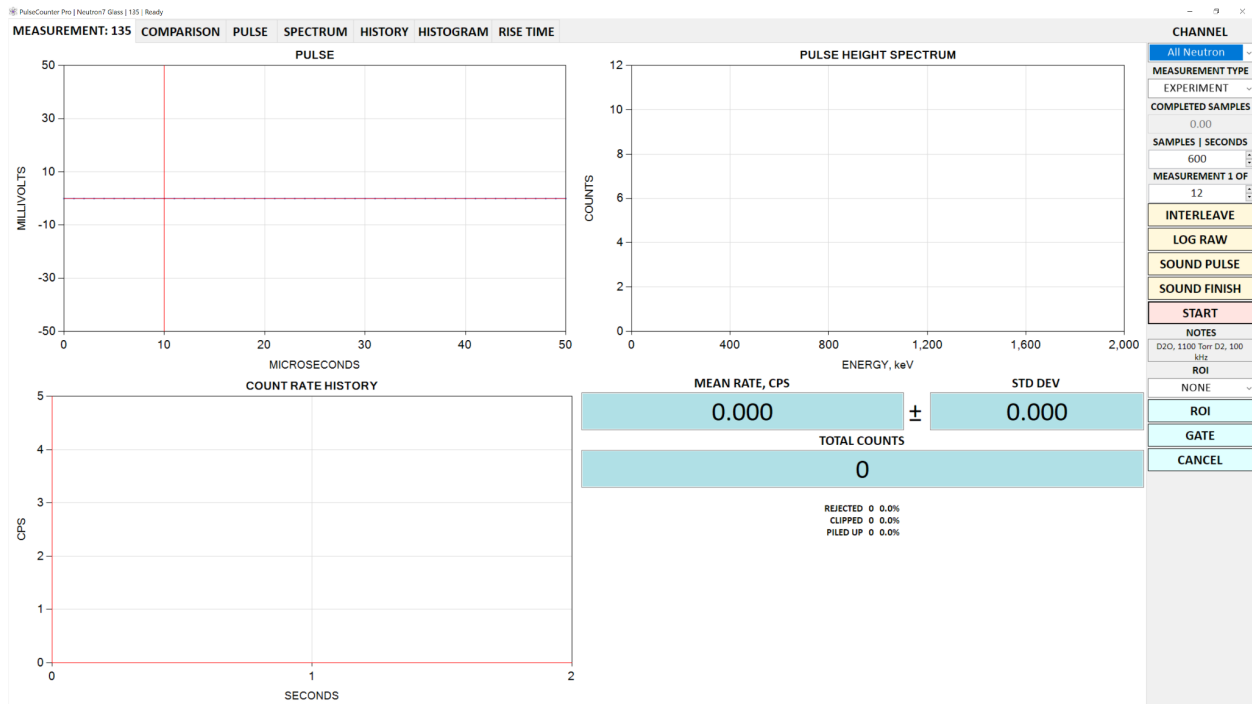


Fig. 26. The Measurement screen.

4.3 Measurement Screen

The Measurement screen (Fig. 26) contains the following pages:

- **MEASUREMENT** - displays the measurement overview, including current detector pulse, pulse-height spectrum, count rate history, mean count rate, and total pulse count;
- **COMPARISON** - allows comparing the current measurement to another previously acquired measurement;

- **PULSE** - allows viewing a recognized detector pulse;
- **SPECTRUM** - displays the pulse-height or pulse-energy spectrum;
- **CALIBRATION** - allows calibrating the pulse-height spectrum by assigning energy values to channels;
- **HISTORY** - displays the count rate history;
- **HISTOGRAM** - displays the count rate distribution histogram;
- **RISE TIME** - displays the detector pulse rise time histogram;
- **RAW** - displays the raw detector signal (available only when the **LOG RAW** button is checked).

4.3.1 Channel List

If the experiment has more than one counter channel or has aggregate channels the Measurement screen will display the **CHANNEL** drop down list in the top right corner - Fig. 27.

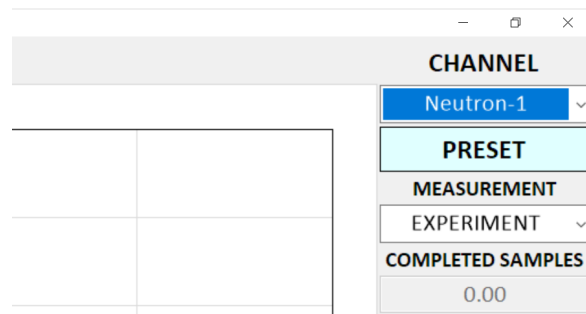


Fig. 27. The **CHANNEL** drop down list.

By selecting a channel from the **CHANNEL** list the Measurement screen refreshes with the selected channel information.

NOTE: Raw data and logger channels do not show in the **CHANNEL** list.

If the selected channel is a counter channel the **PRESET** button will be visible below the **CHANNEL** list. Aggregate channels do not allow editing presets.

4.3.2 Preset

Prior to starting a measurement click the **PRESET** button to open the **PRESET** dialog to specify / inspect hardware channel configuration and pulse processing parameters. The **PRESET** dialog has the following pages:

- **MEASUREMENT** - allows specifying the measurement-wide hardware parameters shared by all channels; these parameters are the **SAMPLE RATE**, the **BIAS VOLTAGE**

and the detector **WARM-UP** time, which is a delay in seconds at the start of the first measurement, Fig. 28;

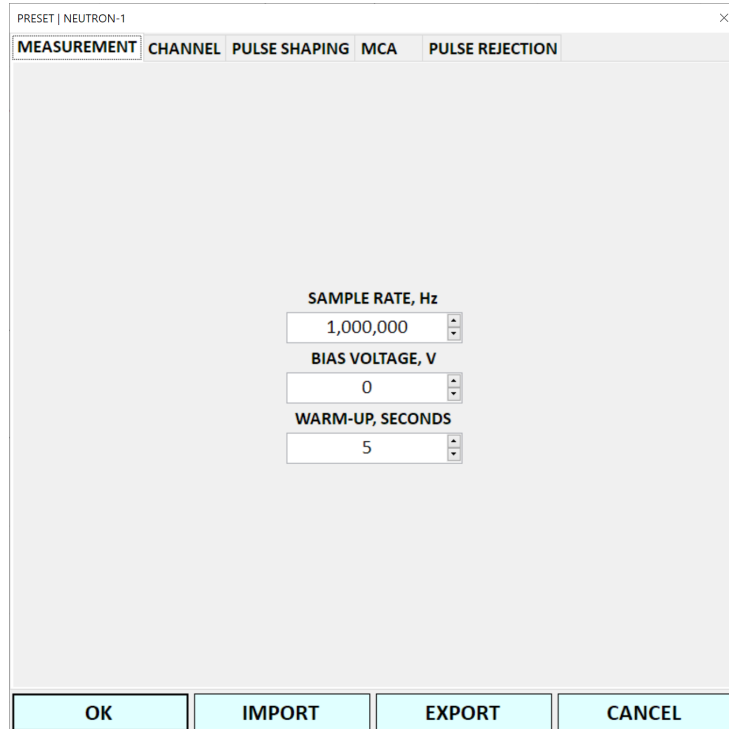


Fig. 28. The **MEASUREMENT** page of the **PRESET** dialog.

- **CHANNEL** - allows specifying the current channel's hardware configuration such as the **COUPLING** (AC or DC) and the **SIGNAL RANGE** in volts, Fig. 29;

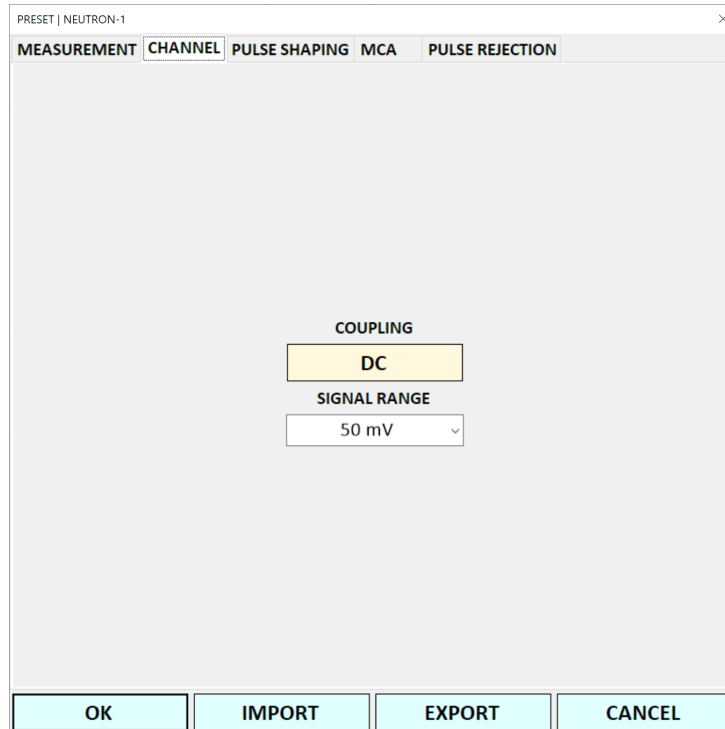


Fig. 29. The **CHANNEL** page of the **PRESET** dialog.

- **PULSE SHAPING** - allows specifying the detector **SIGNAL POLARITY** (positive or negative) and the **PULSE SHAPING MODE**, Fig. 30;

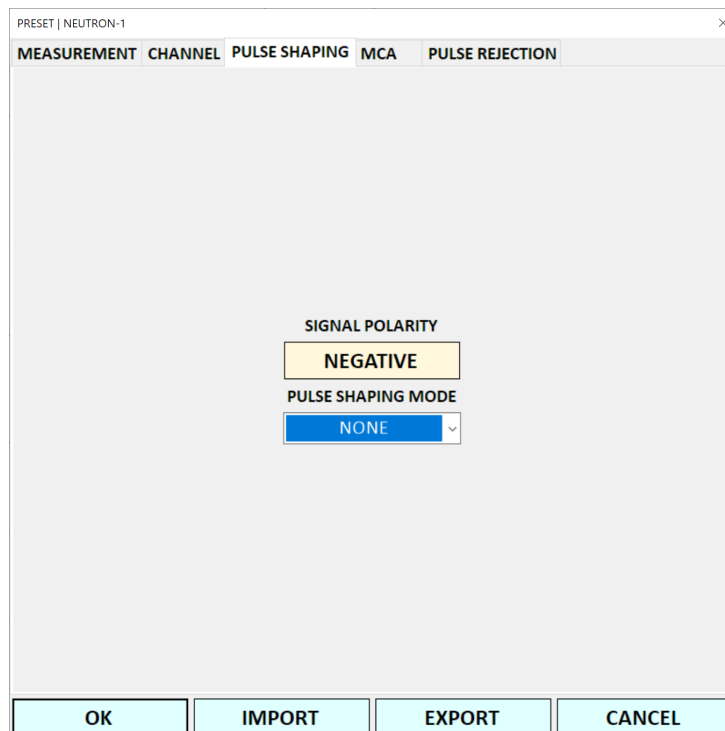


Fig. 30. The **PULSE SHAPING** page of the **PRESET** dialog.

- **MCA** - allows specifying the [pulse height measurement options](#);
- **PULSE REJECTION** - allows specifying the [pulse rejection options](#).

NOTE: In a multi-channel experiment all channels are acquired using the same sampling rate, therefore the sample rate can only be specified for the first counter channel.

NOTE: You can import / export presets to / from .preset file by clicking the **IMPORT / EXPORT** button.

4.3.2.1 Pulse Shaping: None

When you select the 'NONE' option from the **PULSE SHAPING MODE** list on the **PULSE SHAPING** page of the **PRESET** dialog (Fig. 30) it means that the signal that you acquire on this channel has already been shaped and the height of the pulse corresponds to energy. Fig. 31 shows an example of a triangular shaped pulse.

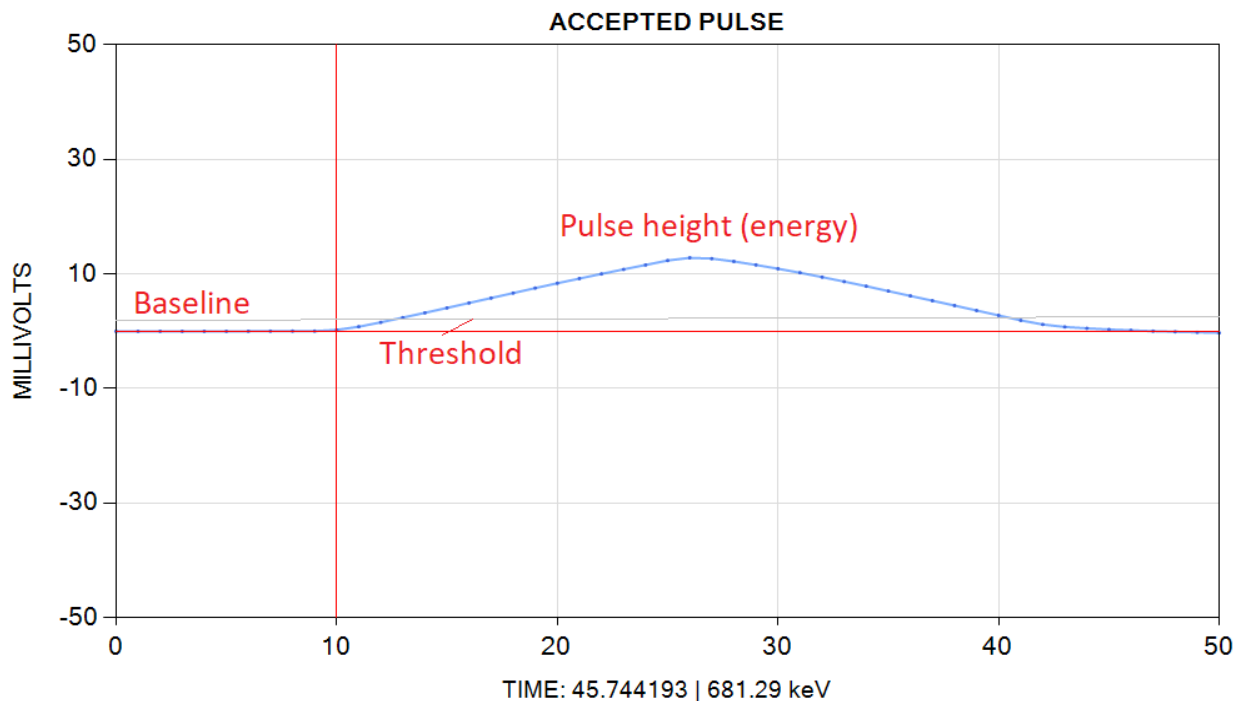


Fig. 31. A triangular shaped pulse.

A shaped pulse can be triangular, or Gaussian, or any other unimodal shape. PulseCounter will simply measure the height of the pulse. The **MCA** page of the **PRESET** dialog (Fig. 32) allows specifying pulse height measurement options.

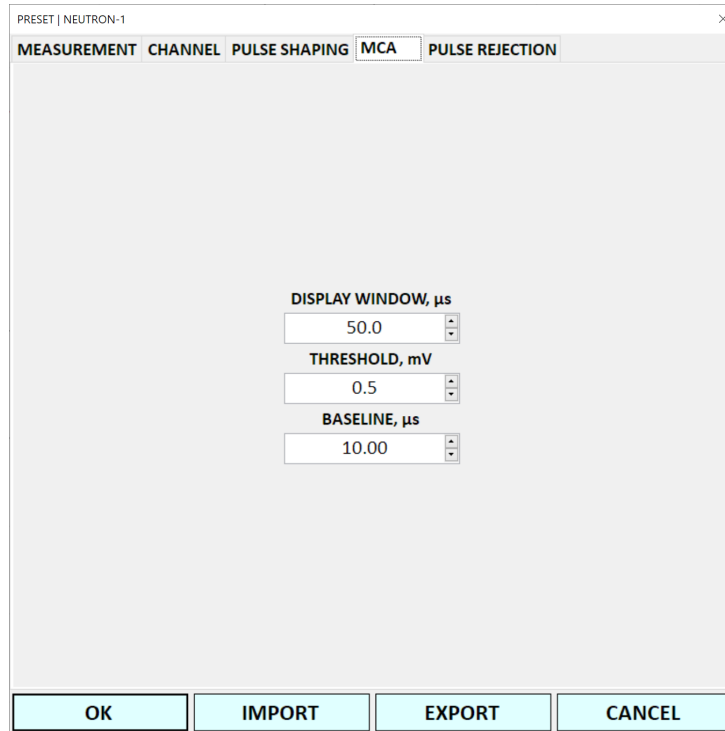


Fig. 32. The **MCA** page of the **PRESET** dialog.

The **DISPLAY WINDOW** allows specifying the duration of the detector pulse displayed by PulseCounter during measurement acquisition. Then **THRESHOLD** (horizontal gray line on Fig. 31) defines the minimum level below which the pulses are considered noise and therefore not counted. The **BASELINE** allows specifying how many baseline samples should be averaged with the resulting DC offset subtracted from the measured pulse height. This option is useful when there is a baseline drift due to low frequency noise or signal processing artifacts resulting from the uncompensated exponential decay. In most cases the value of the **BASELINE** should be set zero (no baseline averaging).

4.3.2.2 Pulse Shaping: Trapezoidal

Most commonly a detector signal is a step with a slow exponential decay - Fig. 33.

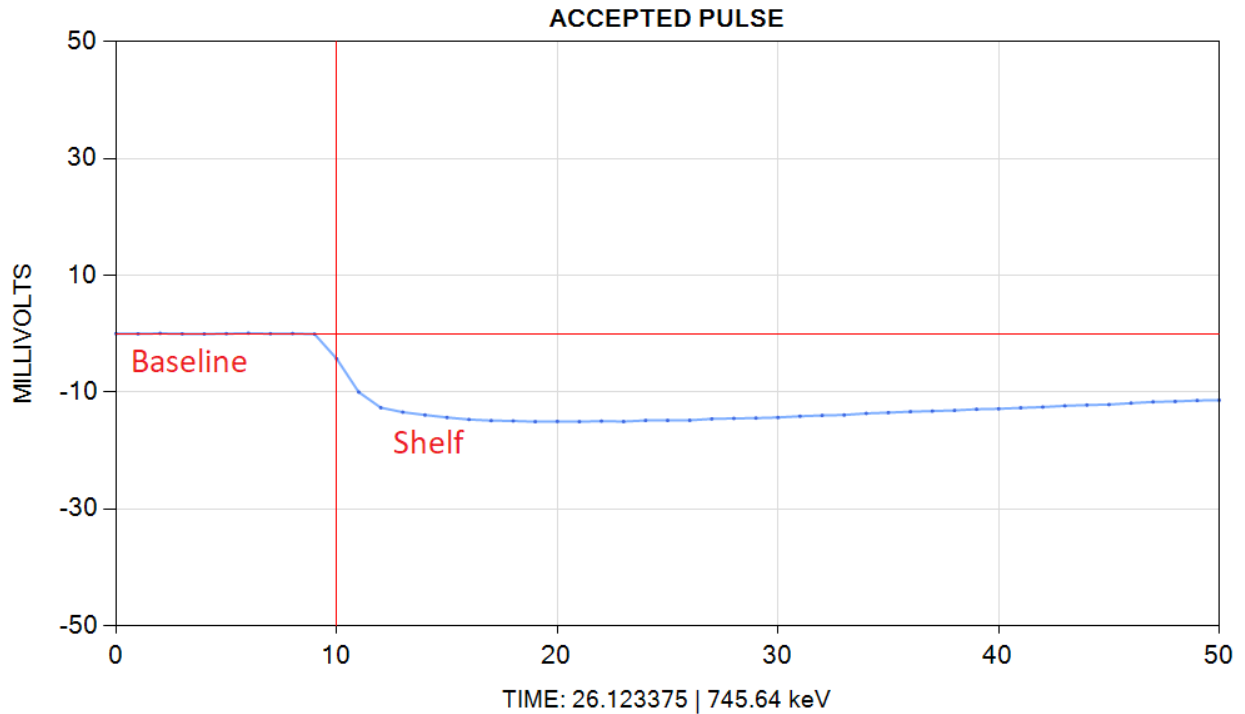


Fig. 33. A detector signal corresponding to a negative step with a slow exponential decay.

To shape such a pulse using a trapezoidal filter, select the 'TRAPEZOIDAL' option from the **PULSE SHAPING MODE** list - Fig. 34.

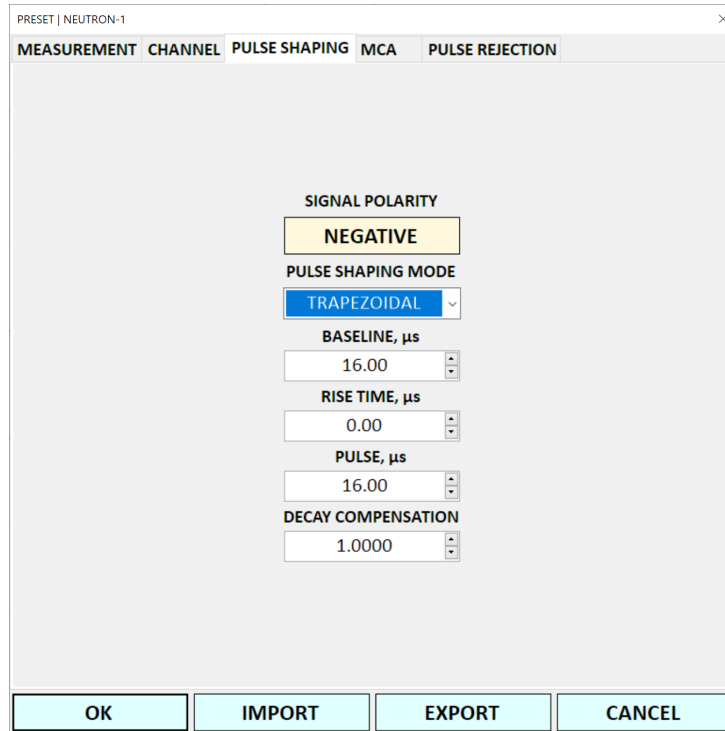


Fig. 34. Trapezoidal pulse shaping options.

A shaped pulse corresponding to the detector signal from Fig. 33 is shown on Fig. 35.

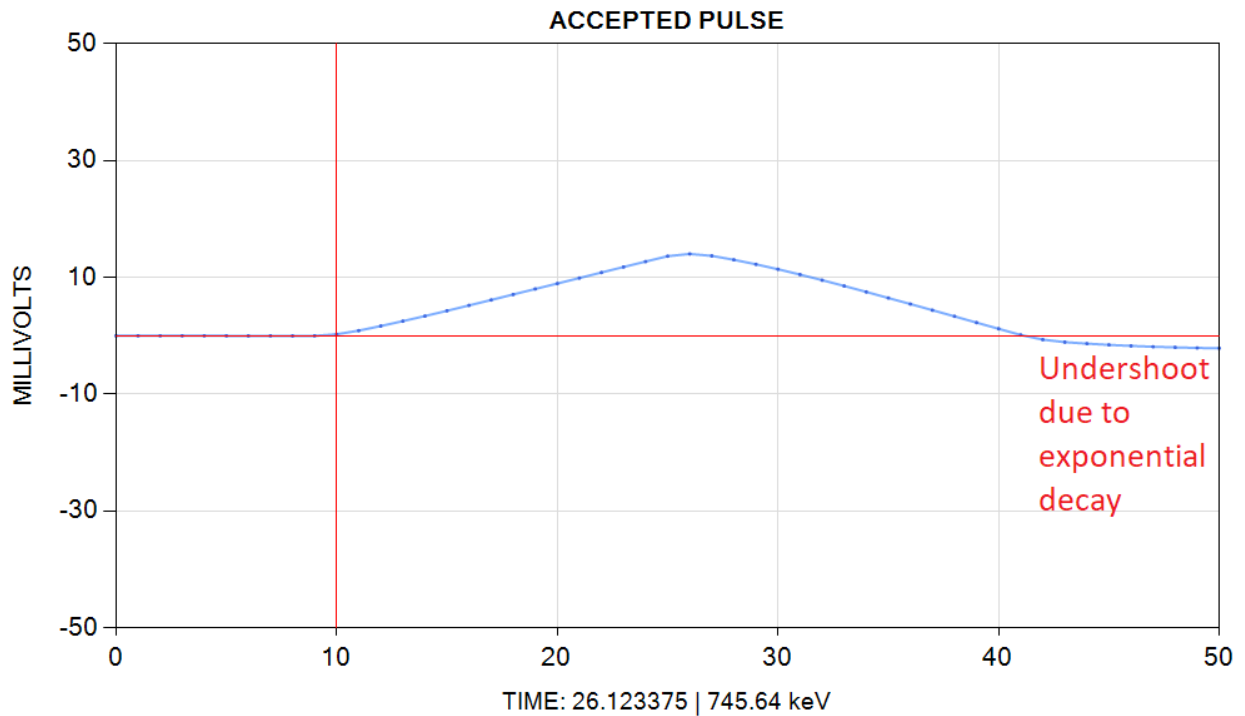


Fig. 35. A triangular pulse, the result of trapezoidal pulse shaping.

For trapezoidal pulse shaping, specify the duration of the baseline averaging (**BASELINE**), the duration of the pulse shelf averaging (**PULSE**, usually the same as the **BASELINE**) and how many samples to skip between the baseline and the shelf to account for rise time (**RISE TIME**, most commonly zero).

NOTE: Larger **BASELINE** and **PULSE** values generally improve energy resolution but only up to a point. An optimal value should be determined experimentally.

NOTE: Larger **BASELINE** and **PULSE** values will result in wider triangular pulses and therefore may increase the pulse pile up probability at high count rates, which may negatively impact the quality of the pulse-height spectrum. High count rates generally require reducing the **BASELINE** and the **PULSE** values to preserve the quality of the pulse-height spectrum.

NOTE: You can specify a **DECAY COMPENSATION** constant (≤ 1) to compensate for exponential decay of the detector pulses. However, this option will require considerably more CPU power to process the signal. Setting this parameter to 1 disables the exponential decay compensation. You can experiment with values just below unity until the baseline undershoot after a triangular shaped pulse disappears - Fig. 36.

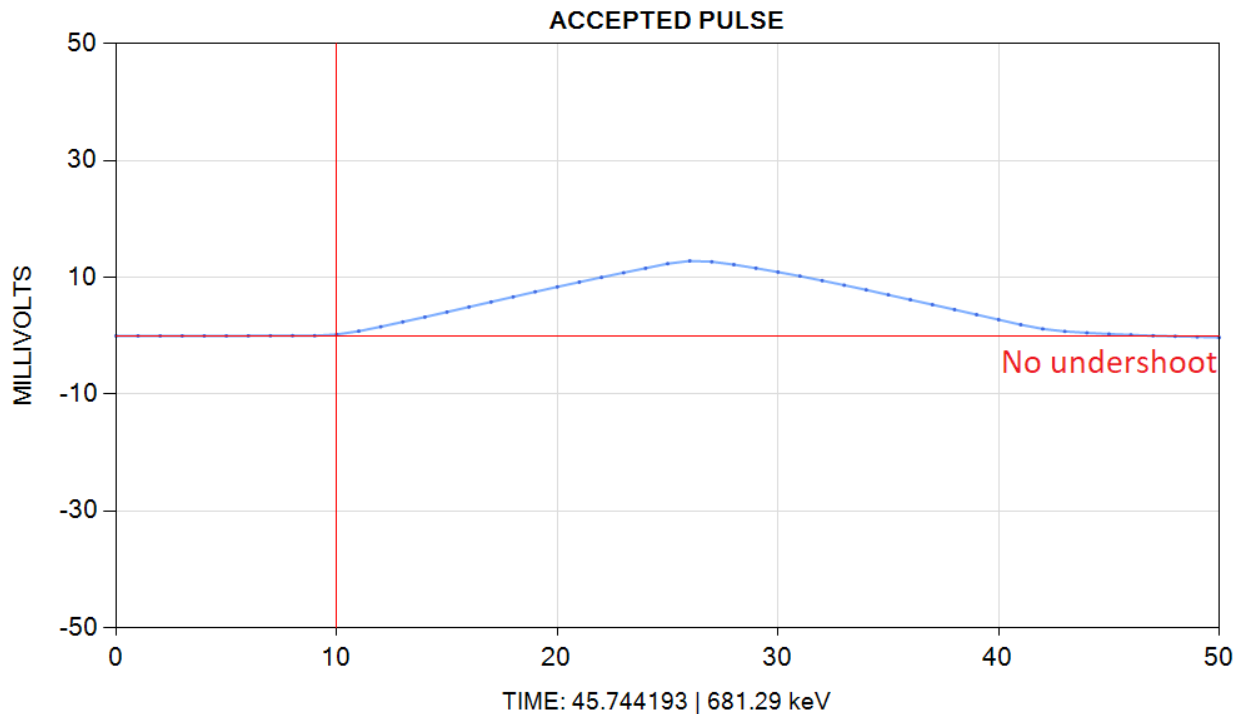


Fig. 36. A triangular pulse without the baseline undershoot (due to **DECAY COMPENSATION**).

4.3.2.3 Pulse Shaping: Differential

Sometimes it may be desirable to recover the energy of the pulse from the edge of the pulse alone ignoring the shelf. For this purpose the detector signal can be differentiated to obtain a pulse corresponding to the edge - Fig. 37.

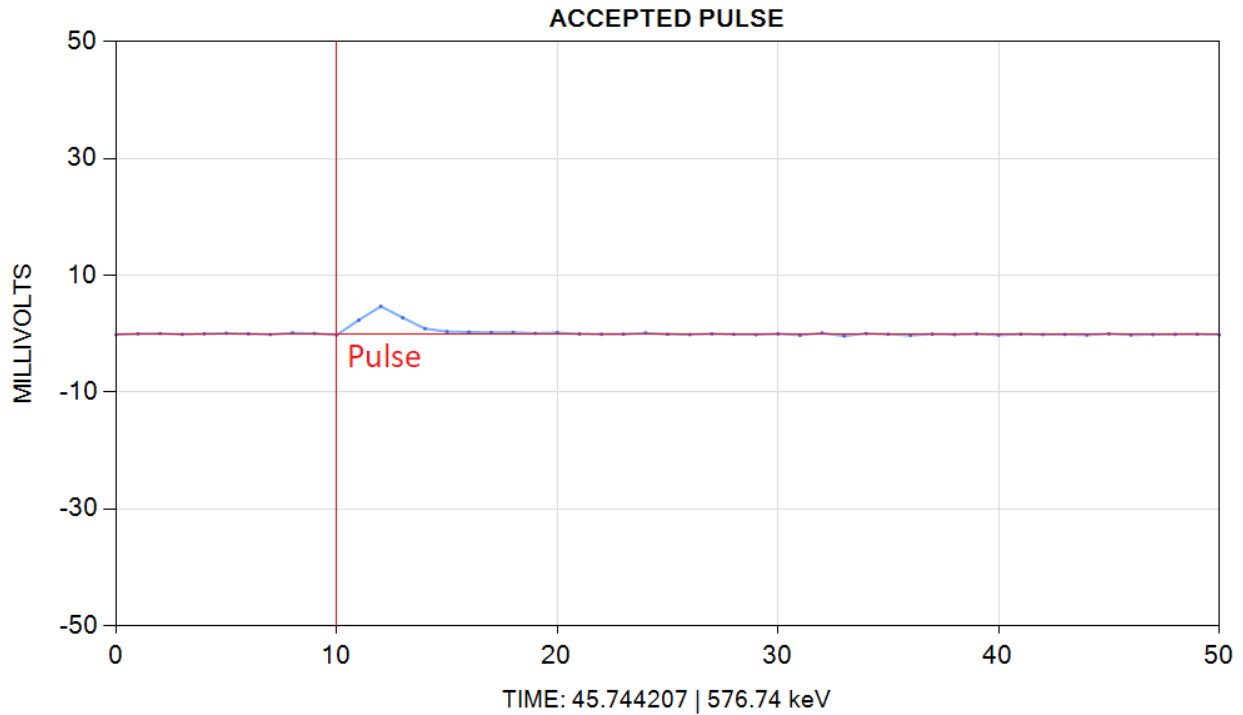


Fig. 37. The differentiated detector pulse from Fig. 33.

To use this algorithm select the 'DIFFERENTIAL' option from the **PULSE SHAPING MODE** list and specify the duration of the pulse to be integrated post differentiation in the **PULSE** box - Fig. 38.

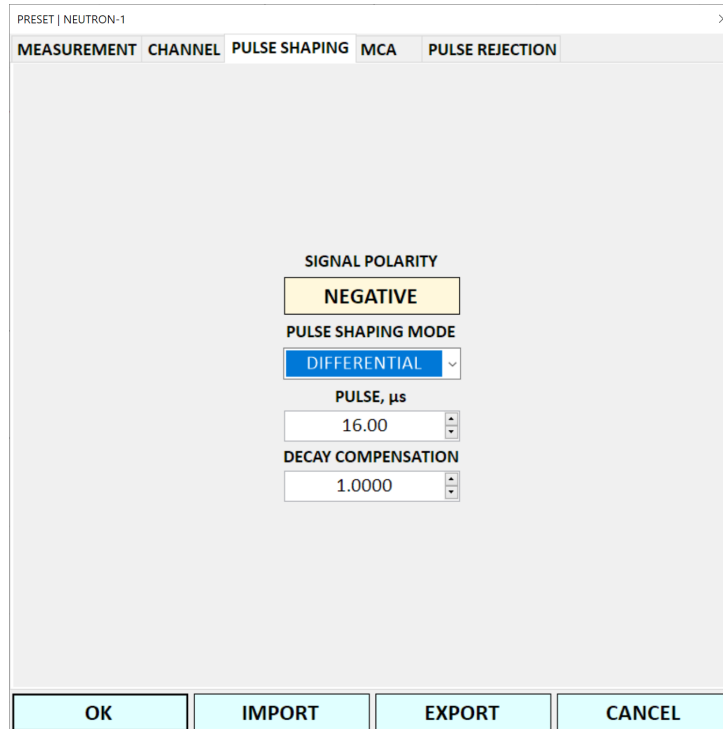


Fig. 38. Differential pulse shaping options.

This integration is necessary to recover the pulse energy from the edge of the pulse.

NOTE: For rapidly decaying detector signals specify a **DECAY COMPENSATION** constant to compensate for exponential decay. The optimal value of the constant will result in differential pulses that return to baseline quickly without overshoot or undershoot. Unlike in the trapezoidal pulse shaping mode there is no associated performance disadvantage. Setting this parameter to 1 disables the exponential decay compensation.

4.3.2.4 Pulse Rejection

PulseCounter signal processing algorithm classifies detector pulses as follows:

- **Accepted** - a genuine detector pulse that was counted and included in the pulse-height spectrum;
- **Rejected** - an artificial / noise pulse that was not counted and therefore was excluded from the pulse-height spectrum;
- **Piled Up** - a pulse that goes through multiple peaks before returning to baseline (Fig. 39) is considered to be made of several genuine pulses that are too closely spaced together and therefore overlap; the piled up pulses are counted but normally excluded from pulse-height spectrum as their energy cannot be accurately evaluated.

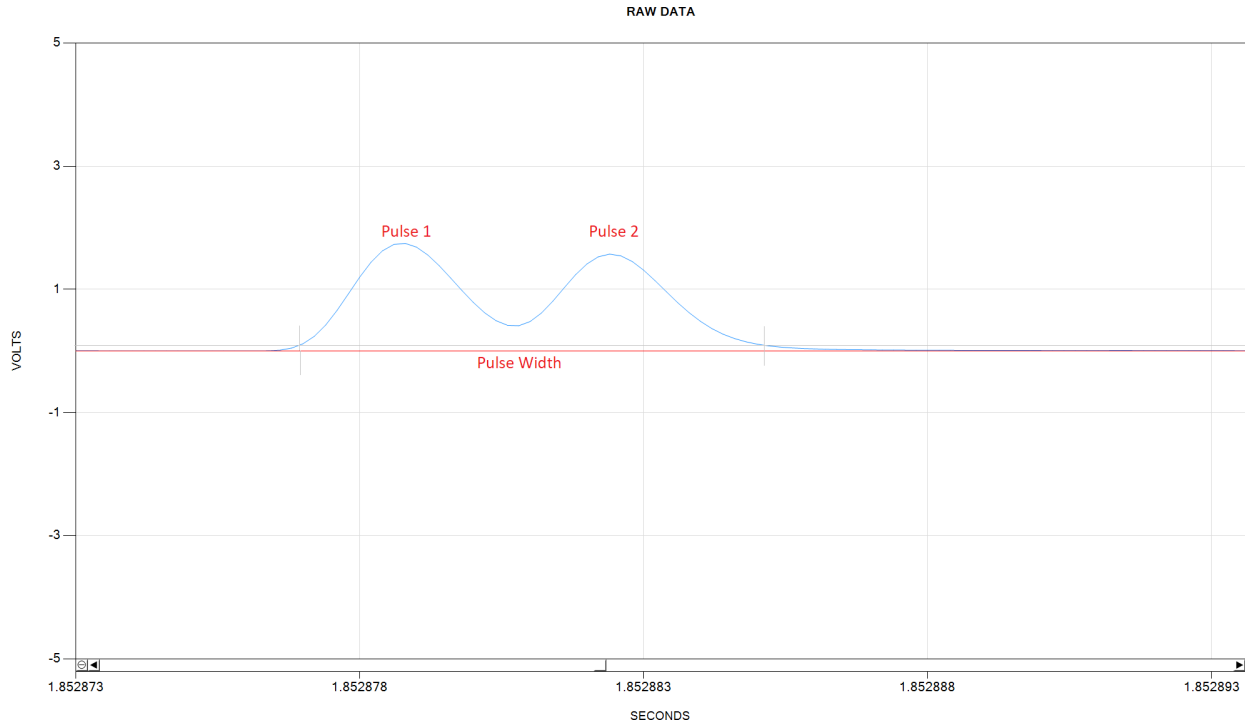


Fig. 39. Piled up detector pulses.

NOTE: When using the [trapezoidal pulse shaping](#), increasing the **BASELINE** and the **PULSE** values will increase the pile up probability due to broadening of the shaped pulses. When using an external pulse-shaping amplifier, increasing the shaping time constant will result in the increase of the pile up probability.

Although PulseCounter automatically classifies pulses as accepted, piled up or rejected it allows specifying custom pulse rejection criteria - Fig. 40.

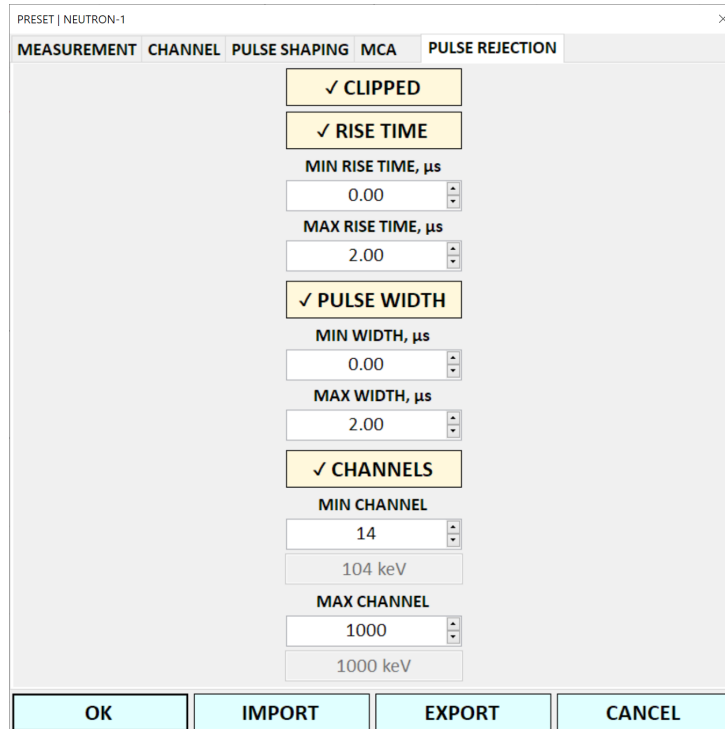


Fig. 40. The **PULSE REJECTION** page of the **PRESET** dialog.

The **CLIPPED** button allows rejecting pulses whose amplitude exceeds the channel range.

The **RISE TIME** button allows rejecting pulses by specifying a range of valid rise time values that cannot be exceeded in order for a pulse to be classified as accepted.

The **PULSE WIDTH** button allows rejecting pulses by specifying a range of valid pulse width values that cannot be exceeded in order for a pulse to be classified as accepted.

The **CHANNELS** button allows rejecting pulses based on their height expressed as energy or spectrum channel number. For example, when the **THRESHOLD** parameter is low, PulseCounter may recognize and count pulses corresponding to noise. These pulses will manifest themselves as an artificial peak in the low spectrum channels - Fig. 41.

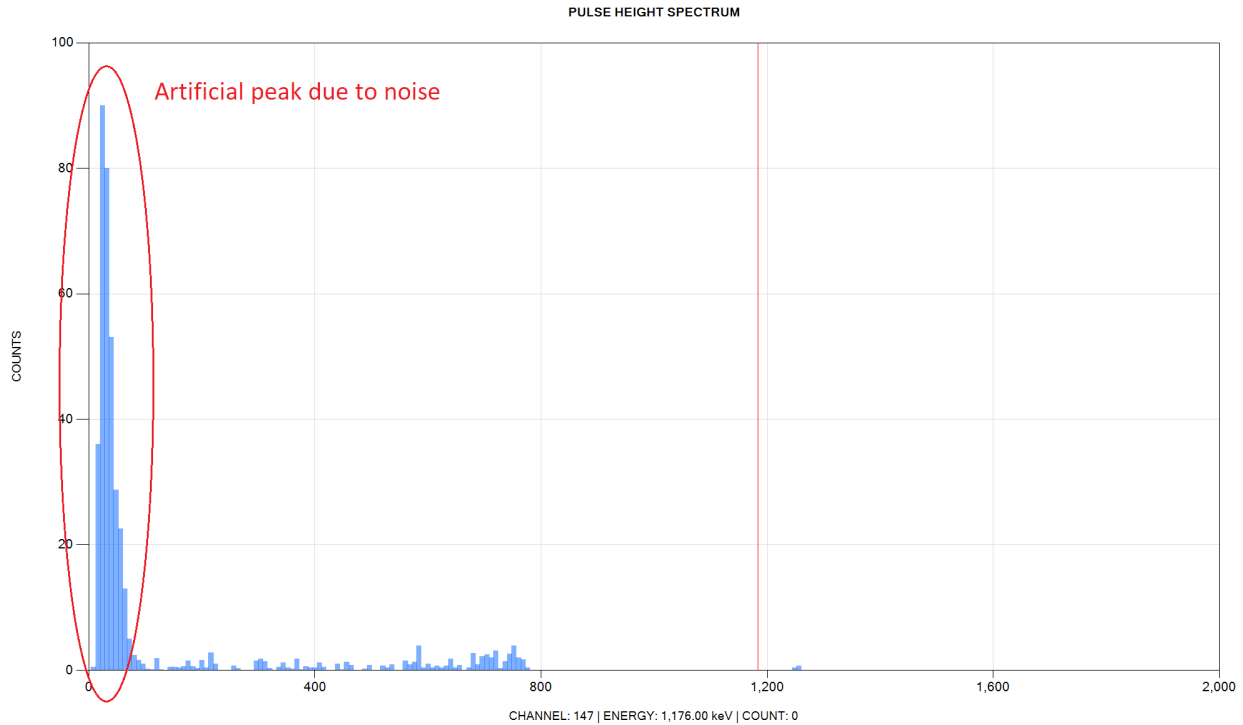


Fig. 41. A pulse-height spectrum with an artificial peak due to noise.

Such an artificial noise peak can be easily eliminated by rejecting pulses corresponding to the first few channels of the pulse-height spectrum.

4.3.3 Starting and Stopping Measurement

To start acquiring a new measurement specify the following information, Fig. 42:

- **MEASUREMENT TYPE** - select the measurement type ('BACKGROUND', 'EXPERIMENT', or 'CALIBRATION');
- **SAMPLES** - specify how many count rate samples to acquire (this is the duration of the measurement);
- **MEASUREMENT 1 OF** - set the number of consecutive measurements to acquire;
- **INTERLEAVE** - check this button to automatically interleave the experiment and the background measurements (good for troubleshooting);
- **LOG RAW** - check this button to acquire and store the raw detector signal;
- **SOUND PULSE** - check this button to play a clicking sound every time a pulse is detected; the clicking sound becomes a continuous tone with pitch indicative of the count rate when the count rate exceeds 60 CPS;

- **SOUND FINISH** - check this button to play a 'tada' sound when the measurement acquisition is complete;
- **NOTES** - click on this field to enter optional measurement information.

CHANNEL
Neutron-1 ▾
PRESET
MEASUREMENT TYPE
BACKGROUND ▾
COMPLETED SAMPLES
0.00
SAMPLES SECONDS
600 ▾
MEASUREMENT 1 OF
4 ▾
INTERLEAVE
LOG RAW
SOUND PULSE
<input checked="" type="checkbox"/> SOUND FINISH
START
NOTES
7E-4 Torr, 100 kHz Sweep

Fig. 42. Measurement acquisition controls.

Click the **START** button to start acquiring the measurement. Once the measurement is started, the **START** button changes to the **STOP** button and the **COMPLETED** field displays the number of the currently acquired count rate samples.

4.3.3.1 Acquisition Performance

During the measurement acquisition PulseCounter title bar will display a percentage figure indicative of the software performance - Fig. 43.

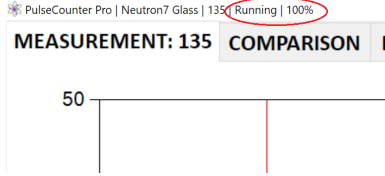


Fig. 43. PulseCounter performance indicator.

The figure close to 100% means satisfactory performance. Figures significantly below 100% indicate less than real-time data acquisition and signal processing performance that may result in dropped samples. To cure the performance problems try increasing the [buffer size](#), decreasing the [sample rate](#), or turning off exponential decay compensation for the [trapezoidal filter](#).

4.3.4 Measurement Page

The **MEASUREMENT** page of the Measurement screen is shown on Fig. 44.

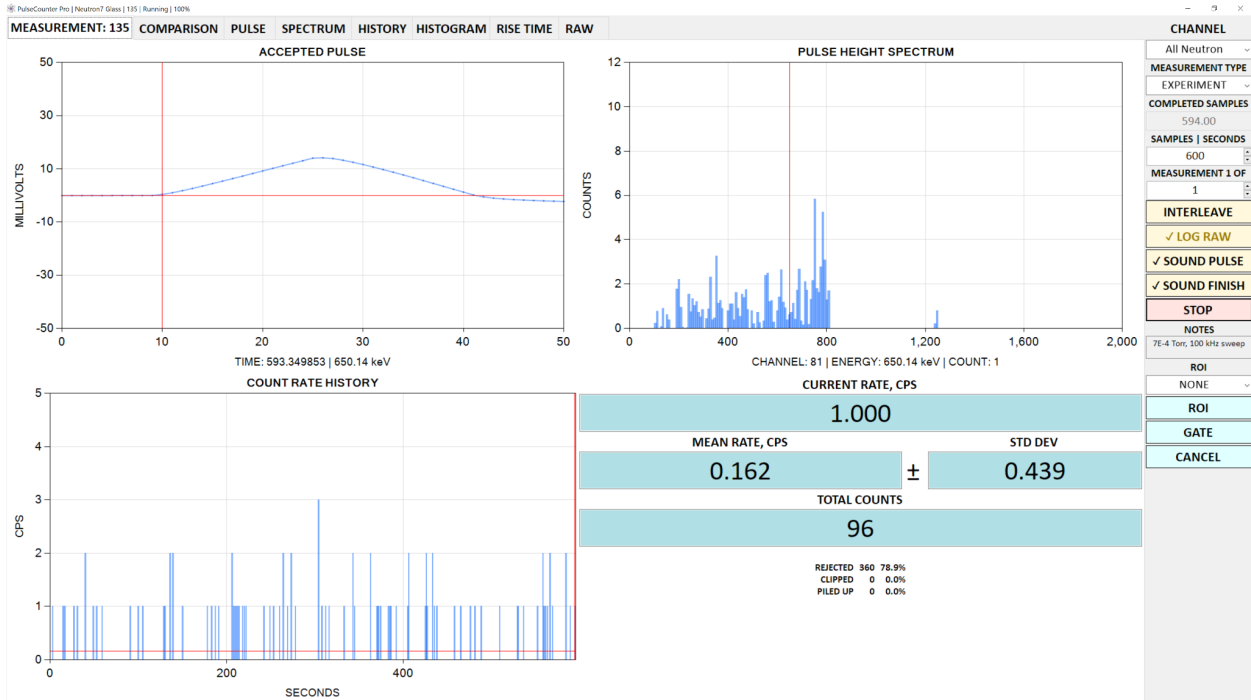


Fig. 44. The **MEASUREMENT** page of the Measurement screen.

During the measurement acquisition, the **MEASUREMENT** page displays the following information:

- **ACCEPTED PULSE** - the plot of the last counted (accepted or rejected) detector pulse (if the pulse shaping mode is trapezoidal or differential the shaped pulse rather than the raw detector pulse is displayed during the measurement acquisition);
- **PULSE HEIGHT SPECTRUM** - last counted (accepted) pulse is marked by the vertical red line;
- **COUNT RATE HISTORY** - the plot of all currently acquired count rate samples; the mean count rate is marked by the horizontal red line;
- **CURRENT RATE** - current instantaneous count rate;
- **MEAN RATE** - average count rate;
- **STD DEV** - standard deviation;
- **TOTAL COUNTS** - total count of accepted pulses;
- **REJECTED, CLIPPED and PILED UP** - statistics pertaining to rejected, clipped and piled up pulses.

4.3.5 Comparison Page

The **COMPARISON** page of the Measurement screen is shown on Fig. 45.



Fig. 45. The **COMPARISON** page of the Measurement screen.

The **COMPARISON** page allows comparing current measurement to another measurement. To load a measurement for comparison click the **LOAD** button. The PulseCounter will display the **LOAD COMPARISON MEASUREMENT** dialog - Fig. 46.

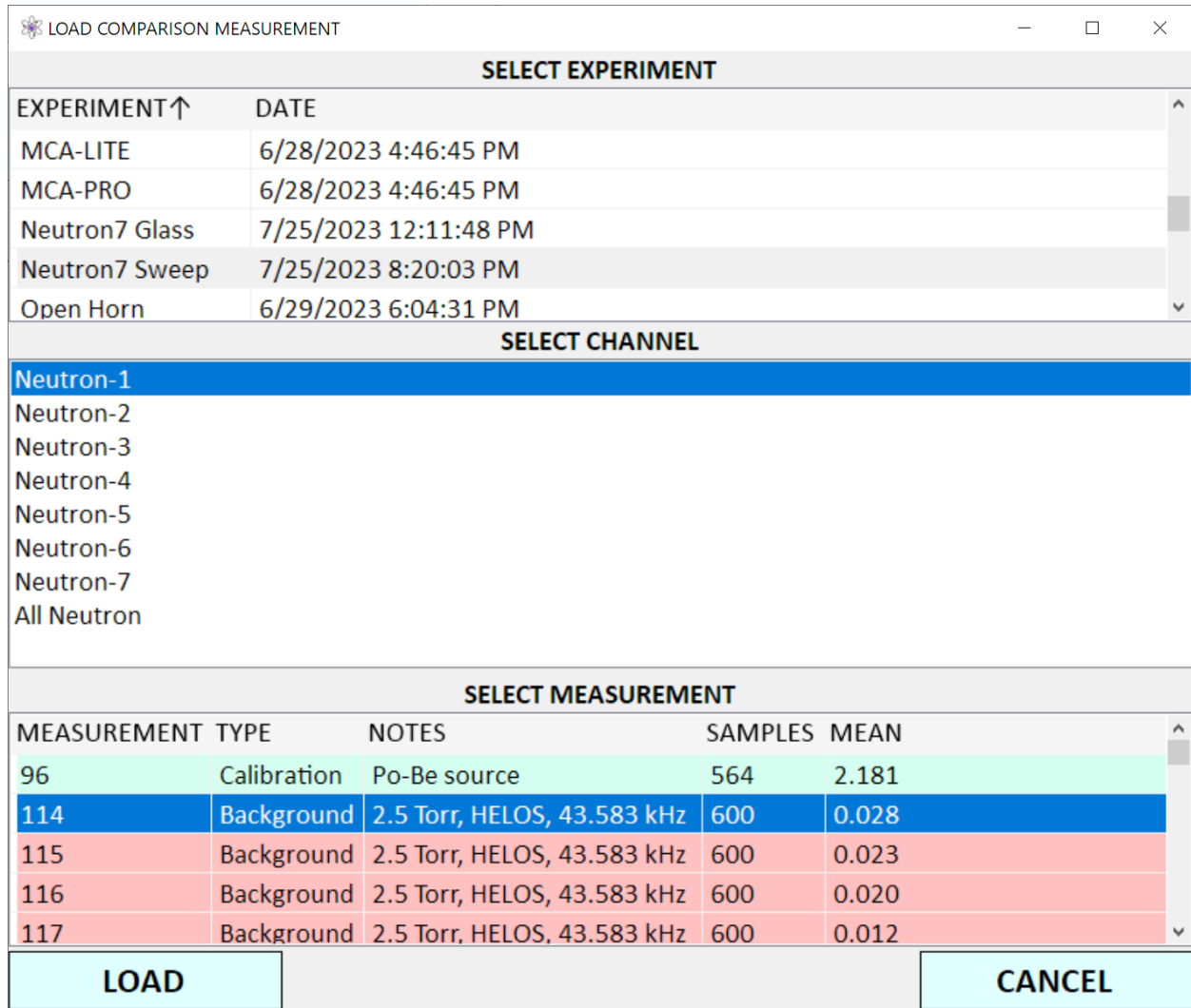


Fig. 46. The **LOAD COMPARISON MEASUREMENT** dialog.

To load a measurement select an experiment, then select a channel, then select a measurement and click the **LOAD** button.

Once a comparison measurement is loaded the **COMP** button will appear on the **HISTORY**, **SPECTRUM**, **HISTOGRAM** and **RISE TIME** pages. When checked this button overlays the corresponding plot (displayed in pink) from the comparison measurement over the plot from the current measurement.

The **COMPARISON** page displays the **P-VALUE**, which is obtained by applying the double-tailed Student's t-test to the count rate sample populations from the current and from the comparison measurements. The **DIFFERENCE** box displays the count rate difference as a percentage figure and in terms of standard deviations (σ). When the reported **P-VALUE**

indicates a statistically significant difference, the **DIFFERENCE BOX** also reports if the power of the test is above or below the 80% level.

4.3.6 Pulse Page

The **PULSE** page of the Measurement screen is shown on Fig. 47.

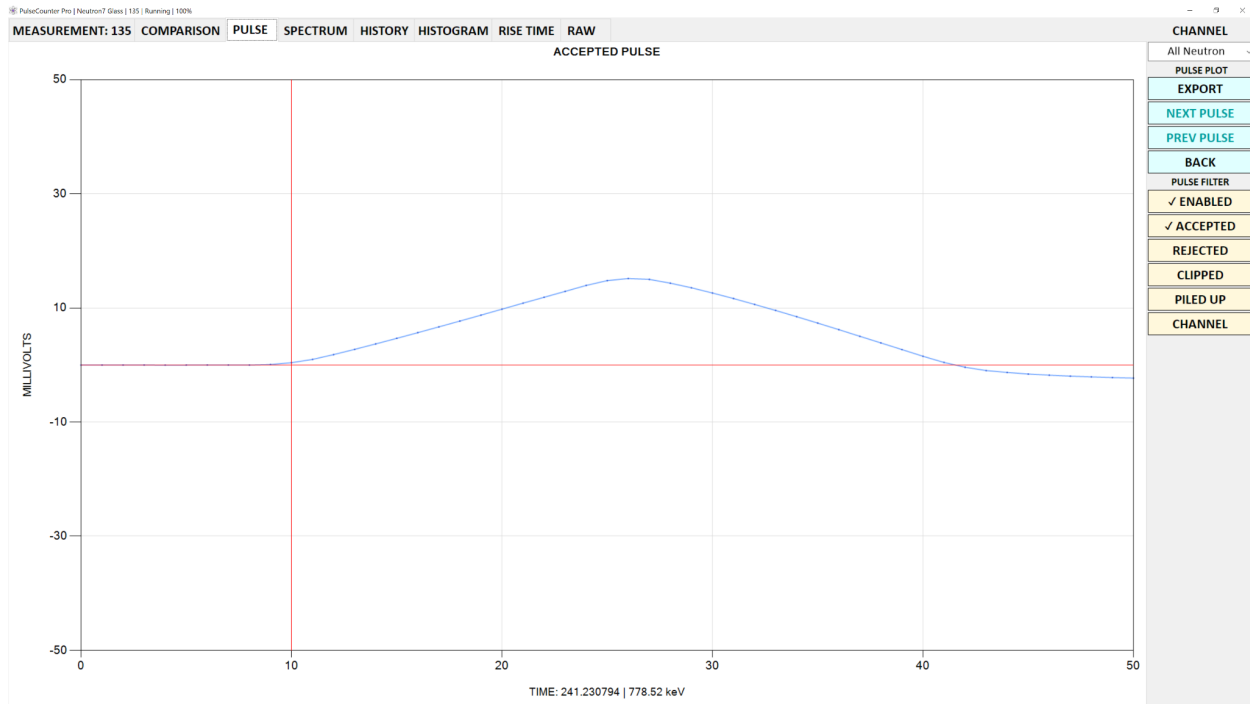


Fig. 47. The **PULSE** page of the Measurement screen.

During the measurement acquisition this screen displays the current detector pulse, which could be either an [accepted or rejected](#) pulse.

The vertical red line marks the end of the baseline and the beginning of the pulse when the **BASELINE** value on the [MCA page](#) of the **PRESET** dialog is greater than zero.

The horizontal axis of the pulse plot displays time in microseconds with the axis title indicating the pulse start time and spectrum channel (or pulse energy if the pulse-height spectrum is energy-calibrated).

During the measurement acquisition if the pulse shaping mode is trapezoidal or differential the shaped pulse rather than the raw detector pulse is displayed during the measurement acquisition.

Once the measurement acquisition is completed and if the measurement was acquired with the **LOG RAW** button checked, you can click the **NEXT PULSE** or the **PREVIOUS PULSE** button to navigate to the next or to the previous pulse. This time the pulse plot will display a raw detector pulse as opposed to a shaped pulse.

The **PULSE FILTER** options allow viewing / browsing only the pulses that meet the specified criteria. The **PULSE FILTER** options operate as follows:

- Check the **ENABLED** button to turn on the pulse filtering;
- Check any combination of the **ACCEPTED**, **REJECTED**, **CLIPPED** and **PILED UP** buttons to indicate which pulses you would like to see;
- Check the **CHANNEL** button to limit the pulse filter to a range of spectrum channels or energies.

The **EXPORT** button allows exporting the pulse plot as a PNG image or as a comma-separated .csv file.

The **BACK** button reverts back to the **MEASUREMENT** page.

4.3.7 Spectrum Page

The **SPECTRUM** page of the Measurement screen is shown on Fig. 48.

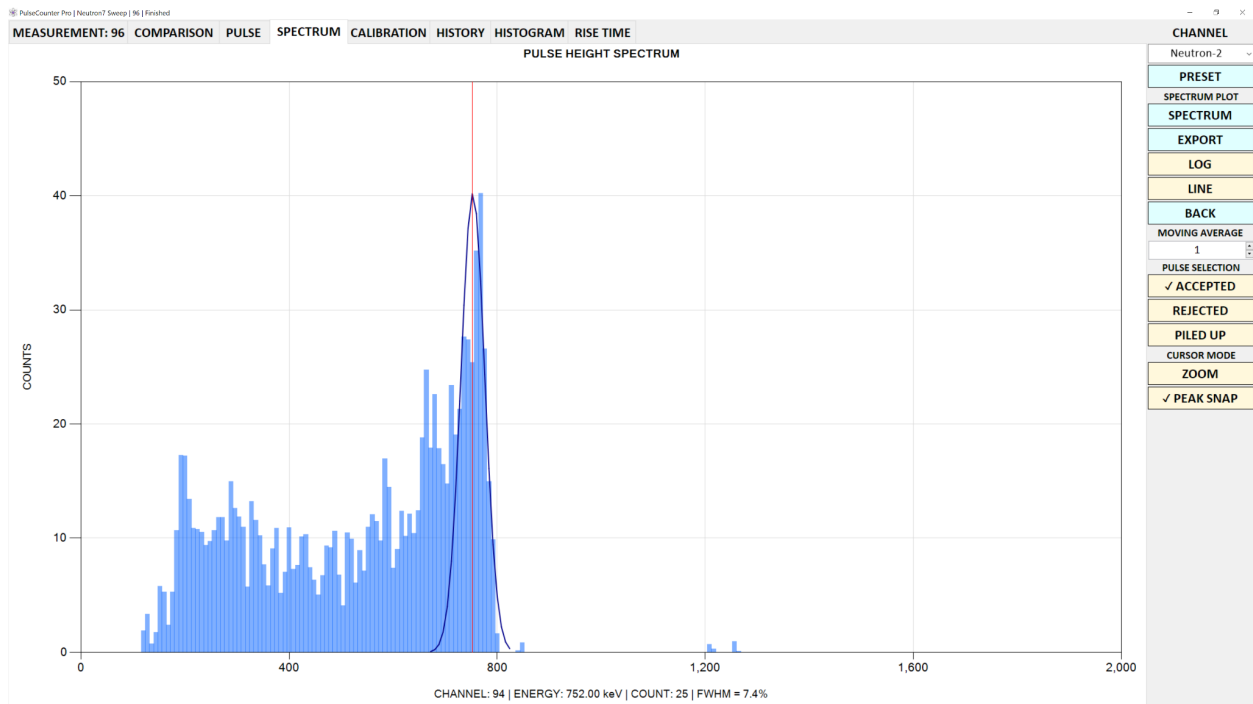


Fig. 48. The **SPECTRUM** page of the Measurement screen.

The pulse-height spectrum can be configured to have an arbitrary number of channels and arbitrary energy range by clicking the **SPECTRUM** button - Fig. 49.

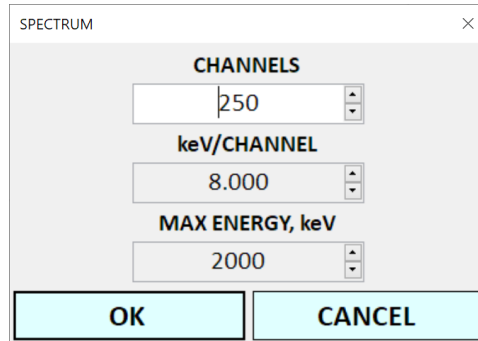


Fig. 49. The **SPECTRUM** dialog.

The **PULSE SELECTION** options (**ACCEPTED**, **REJECTED** and **PILED UP**) allow specifying which pulses must be included in the pulse height spectrum. While in most cases only the accepted pulses should be used, including rejected pulses will make visible artificial peaks due to noise. This may be helpful for tuning noise rejection. Including the piled up pulses may be helpful for tuning the pile up rejection to optimize energy resolution.

The **LOG** button toggles between logarithmic and linear vertical scales, while the **LINE** button toggles between the bar and line plot display mode.

The **CURSOR MODE** options allow toggling between plot zooming (**ZOOM**) and channel selection (**SELECTION**). When a range of channels is selected the **SET FILTER** button appears. Clicking the **SET FILTER** button sets the **CHANNEL** filter of the [PULSE page](#) to the selected range of channels.

NOTE: The channel selection is switched on automatically when one is holding down the **SHIFT** key.

When checked, the **PEAK SNAP** button displays a Gaussian envelope of the peak nearest to the channel cursor position and automatically snaps the cursor to it.

The **MOVING AVERAGE** box allows smoothing the spectrum by computing the moving average of the specified number of channels.

The horizontal axis title of the spectrum plot displays information about the currently selected spectrum channel (the channel at the cursor position) such as the channel number, the channel energy (if the spectrum is calibrated), the number of counts in the channel, and if the peak snap mode is turned on - the peak's full width at half maximum (FWHM) as a percentage figure.

When a comparison measurement is loaded, the **SPECTRUM** page displays additional controls as follows:

- **COMP** - toggles display of spectrum from the comparison measurement (the comparison spectrum is displayed in pink);
- **SUBTRACT** - displays differential spectrum by subtracting the comparison spectrum from the current spectrum;

- **COMP SCALE** - allows adjusting the height of the comparison spectrum for better visual comparison.

4.3.8 Calibration Page

The **CALIBRATION** page of the Measurement screen is shown on Fig. 50.

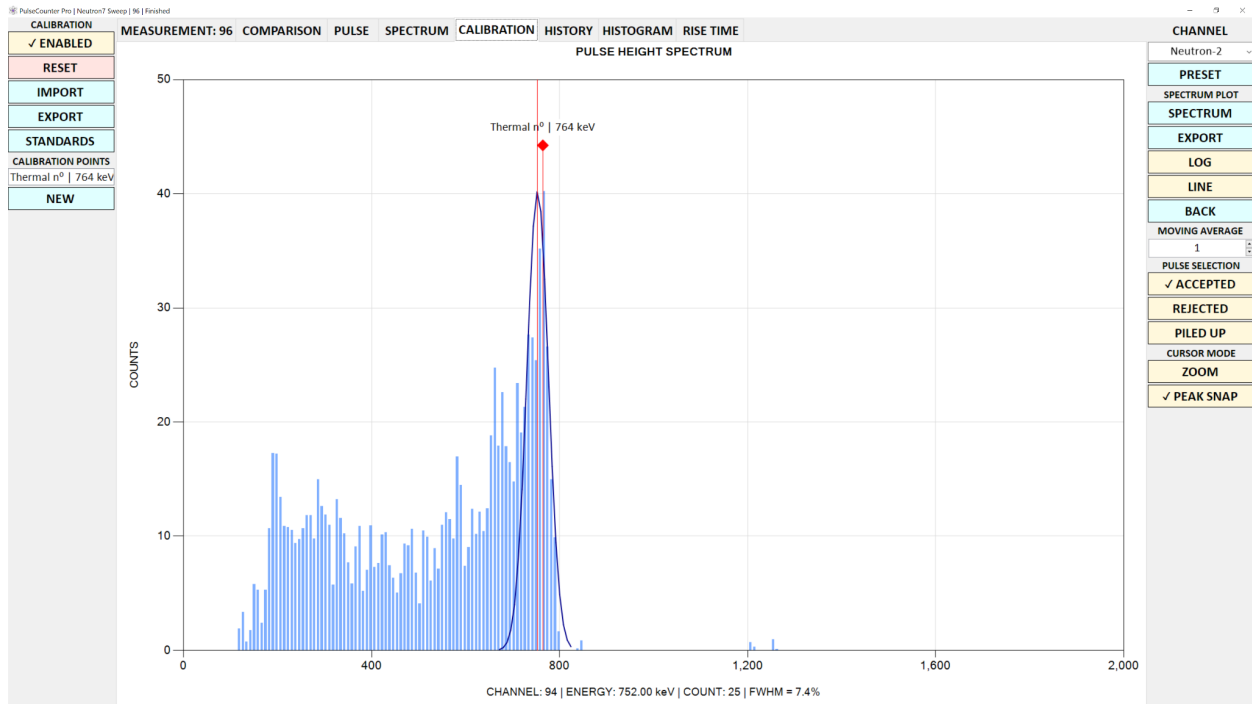


Fig. 50. The **CALIBRATION** page of the Measurement screen.

To assign energy values to channel numbers one has to calibrate the spectrum. To calibrate the spectrum select a peak and click the **NEW** button to display the **CALIBRATION POINT** dialog - Fig. 51.

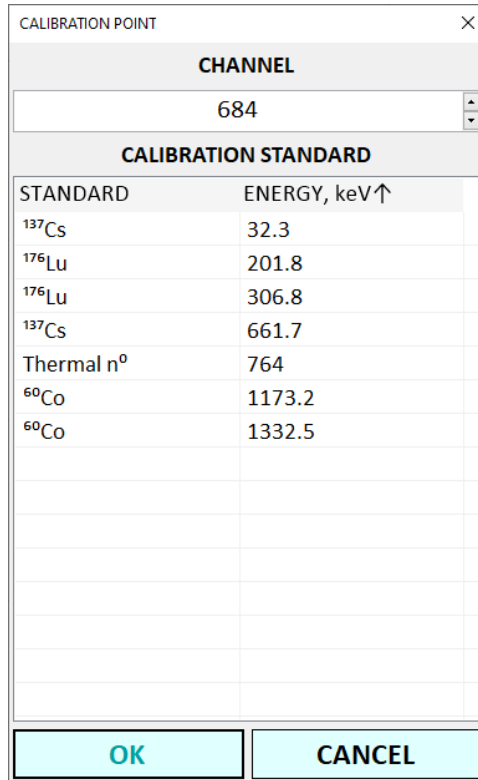


Fig. 51. The **CALIBRATION POINT** dialog.

Click on a **CALIBRATION STANDARD** to assign the corresponding energy value to the selected **CHANNEL**.

To define calibration standards click the **STANDARDS** button to open the **CALIBRATION STANDARDS** dialog - Fig. 52.

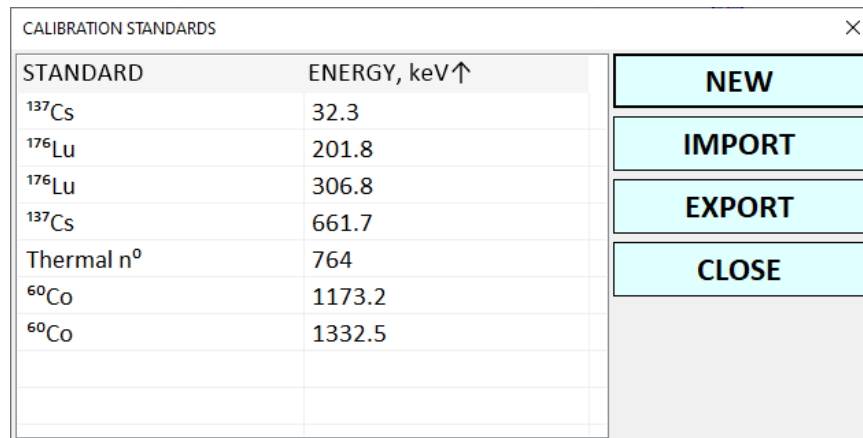


Fig. 52. The **CALIBRATION STANDARDS** dialog.

You can import / export calibration standards to / from a *.standards* file by clicking the **IMPORT / EXPORT** button.

PulseCounter supports multiple calibration points and uses the following interpolation formulas for different number of calibration points:

- **One-point:** linear interpolation, energy = $b \times \text{channel}$;
- **Two-point:** linear interpolation, energy = $b \times \text{channel} + c$;
- **Three-point:** quadratic interpolation, energy = $a \times \text{channel}^2 + b \times \text{channel} + c$;
- **More than three points:** quadratic regression, energy = $a \times \text{channel}^2 + b \times \text{channel} + c$.

The **ENABLE** button allows turning calibration on / off without deleting it.

The **RESET** button deletes all calibration points.

The **DELETE** button deletes a single, currently selected calibration point from the **CALIBRATION POINTS** list.

Double-clicking on a calibration point in the **CALIBRATION POINTS** list opens the **CALIBRATION POINT** dialog and allows editing the selected calibration point.

The **IMPORT / EXPORT** buttons allow importing / exporting the current calibration to / from a *.calibration* file.

You can adjust the position of a calibration point by mouse-dragging the calibration point marker. Alternatively, you can snap the position of a calibration point to peak by selecting the peak using the **PEAK SNAP** button and then shift-clicking on the corresponding calibration point in the **CALIBRATION POINTS** list.

4.3.9 History Page

The **HISTORY** page of the Measurement screen is shown on Fig. 53.

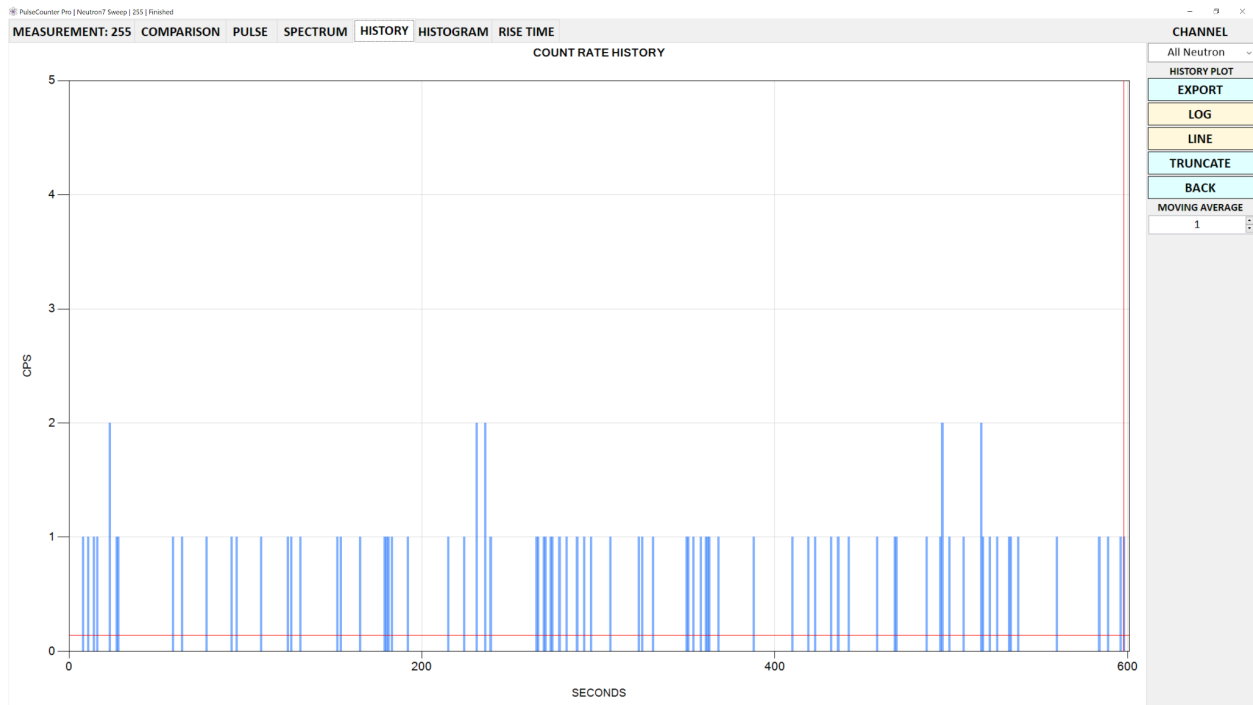


Fig. 53. The **HISTORY** page of the Measurement screen.

The **HISTORY** page displays the count rate history, which is a sequence of the acquired count rate samples versus time. The horizontal red line corresponds to the mean count rate.

During the measurement acquisition the last bar in the history plot corresponds to a partial (i.e. incomplete) sample and therefore is displayed using a different color. If you stop the measurement acquisition prior to completion of sample, the last partial sample must be discarded in order for the measurement to be saved when leaving the Measurement screen.

Once a measurement is acquired, you can click on any bar in the count rate history plot to navigate to the corresponding time unit. The [pulse plot](#) will update with the first pulse from the selected time slot (if present). If the raw data was captured the [raw data plot](#) will refresh with the raw detector signal corresponding to the selected time unit.

The **TRUNCATE** button allows truncating the count rate history at the current cursor position.

4.3.10 Histogram Page

The **HISTOGRAM** page of the Measurement screen is shown on Fig. 54.

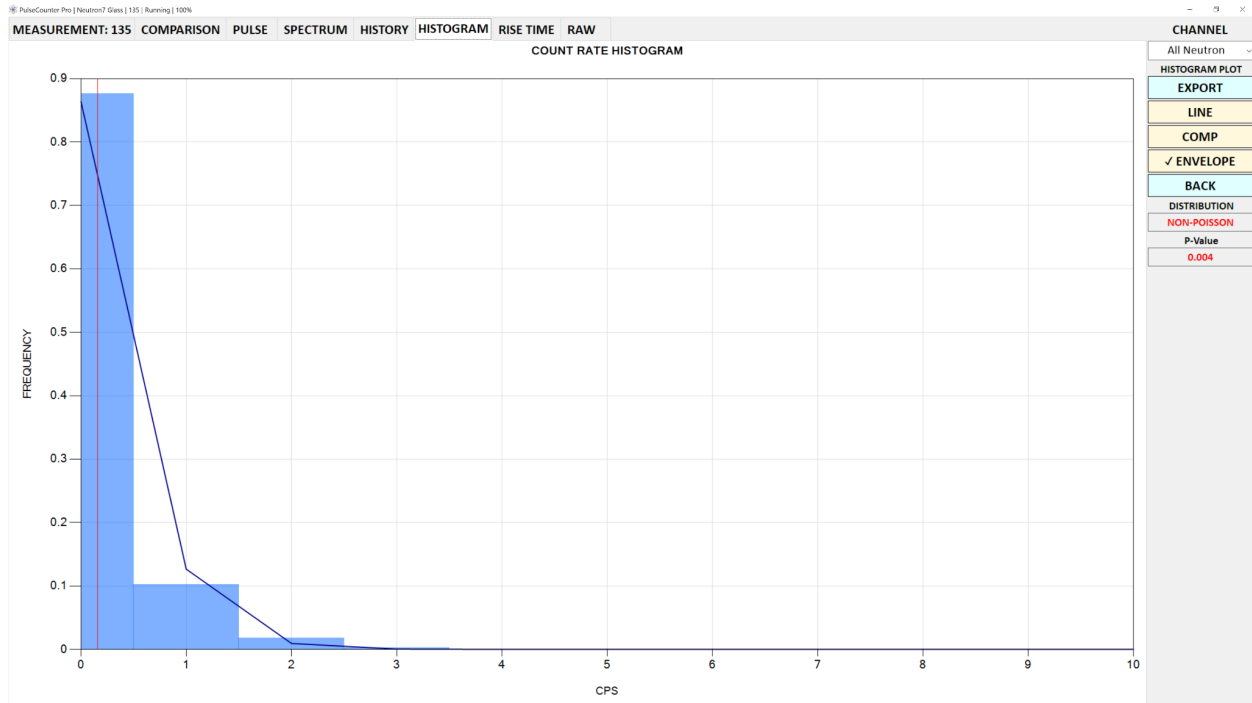


Fig. 54. The **HISTOGRAM** page of the Measurement screen.

The **HISTOGRAM** page displays the histogram of the acquired count rate samples. Under the assumption of a normal process the count rate histogram must follow a Poisson distribution. PulseCounter evaluates the histogram and outputs 'POISSON' in the **DISTRIBUTION** box if the histogram indeed follows a Poisson distribution and reports a corresponding p-value (p-values below 0.05 indicate non-Poisson distributions).

The vertical red line indicates the mean count rate.

The **ENVELOPE** button toggles the Poisson distribution envelope display.

4.3.11 Rise Time Page

The **RISE TIME** page of the Measurement screen is shown on Fig. 55.

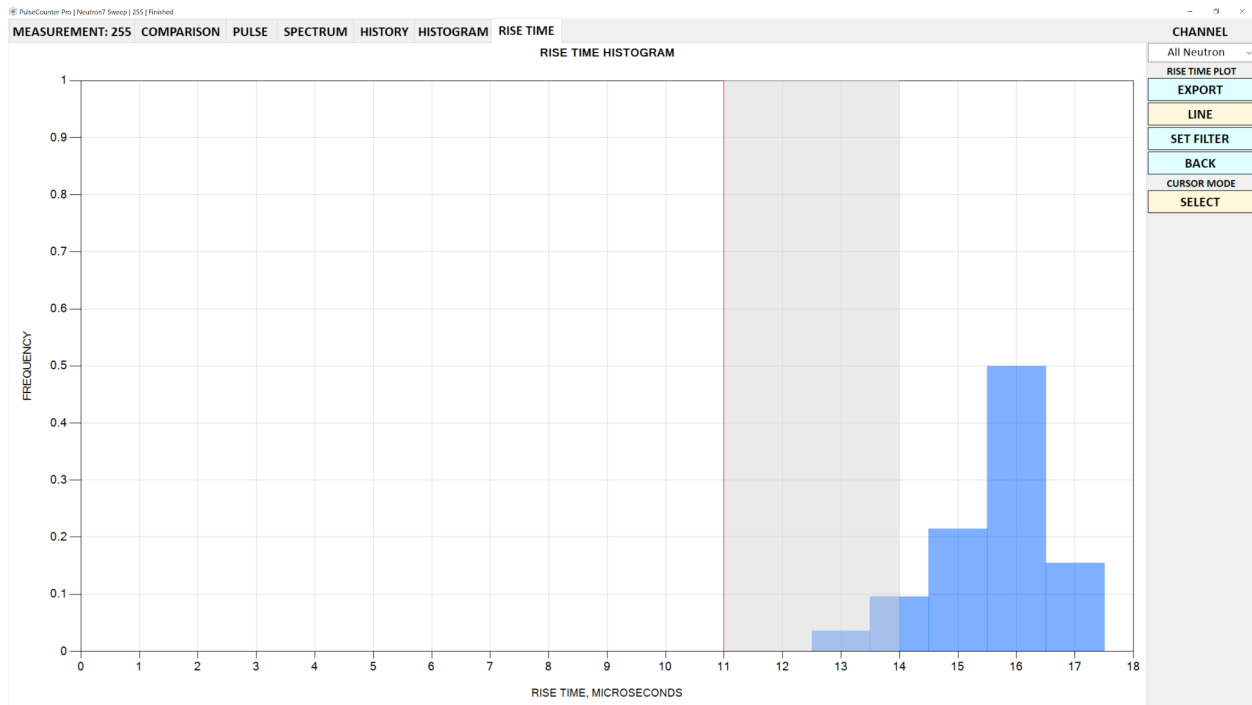


Fig. 55. The **RISE TIME** page of the Measurement screen.

The **RISE TIME** page displays the histogram of rise time of all accepted pulses. If trapezoidal or differential pulse shaping is used the rise time histogram is populated using the rise time of the shaped pulses.

The rise time histogram is useful for rejecting noise pulses that are characterized by extremely short or extremely long rise times. Also, the rise time histogram can be used to reject piled up pulses that were not identified as such because the pulses were spaced too closely to each other and essentially formed a single pulse. However, such pulses might be identified on the rise time histogram by their abnormally large rise time.

The **ZOOM (SELECT)** button toggles between zooming and selection. In selection mode you can select one or more histogram channels as shown on Fig. 55. The **SET FILTER** button appears as soon as the selection is made. Clicking the **SET FILTER** button populates the **RISE TIME** filter on the [REJECTION page](#) in the **PRESET** dialog.

4.3.12 Raw Page

The **RAW** page of the Measurement screen is shown on Fig. 56.

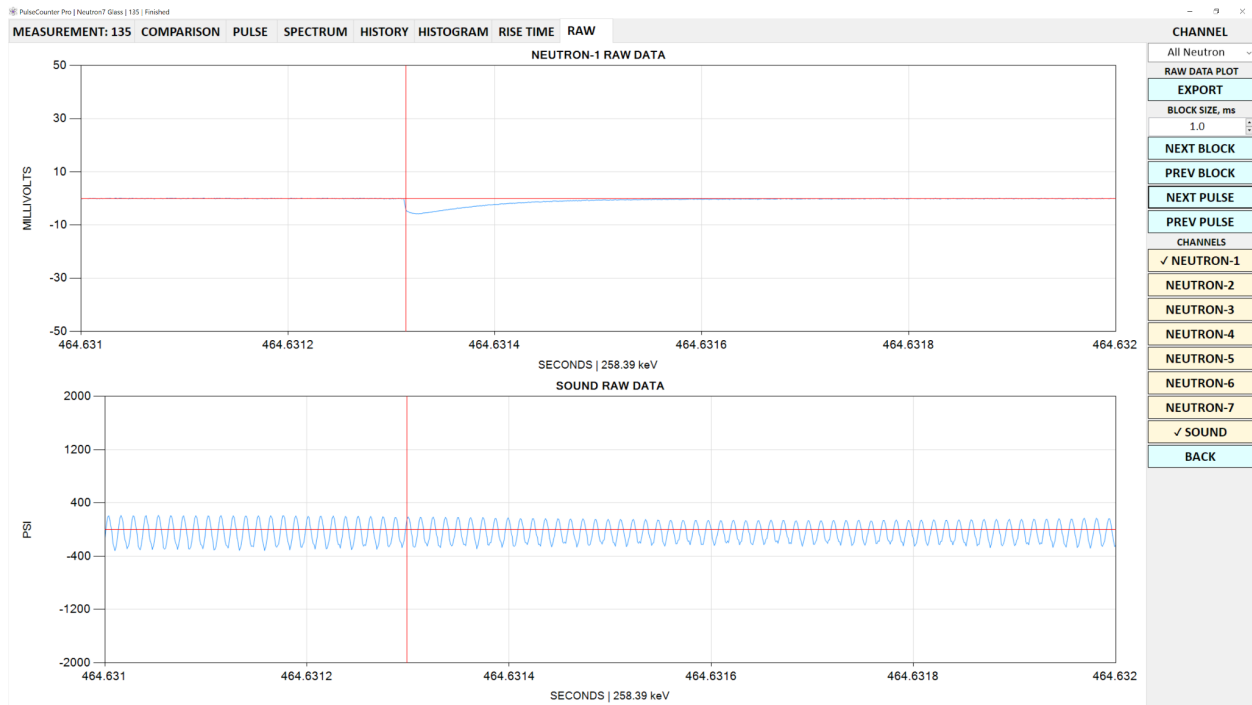


Fig. 56. The **RAW** page of the Measurement screen.

The **RAW** page of the Measurement screen is accessible only if the **LOG RAW** button is checked and it displays the raw detector signal. You can monitor the raw detector signal during the measurement acquisition and inspect it once the measurement is stopped.

The raw detector signal is saved to a **.raw** file in the [Experiments folder](#).

The **BLOCK SIZE** field allows specifying the extent in milliseconds of the raw signal block to display. Values over 10 milliseconds may result in the very slow plot updating especially at high sample rates.

Once a measurement is acquired, you can browse the raw detector signal by clicking the **NEXT BLOCK** or the **PREV BLOCK** buttons.

To navigate to a recognized pulse click the **NEXT PULSE** or the **PREV PULSE** buttons.

If the current channel is an aggregate channel additional buttons corresponding to the compounding channels will appear under the **CHANNELS** label to the right of the plot. Clicking these buttons toggles additional raw signal signal plots corresponding to these channels.

If the experiment has any raw data channels these will also appear under the **CHANNELS** label. The raw signal plot of a raw data channel will be displayed using the physical units if those were set up in the [CHANNEL SETTINGS](#) dialog for the raw data channel.

If the experiment has any logger channels, text boxes displaying the logger values for the current block will be displayed under the **CHANNELS** label.

4.3.13 Measurement Rebuild and Reanalysis

PulseCounter is designed with measurement reanalysis in mind. Specifically, an acquired measurement can be rebuilt by specifying different [pulse rejection](#) parameters in the **PRESET** dialog. When you modify these parameters the **OK** button of the **PRESET** dialog will change to the **REBUILD** button. You can save the rebuilt measurement by clicking the **OK** button on the **MEASUREMENT** page of the Measurement screen or you can discard the rebuilt measurement by clicking the **CANCEL** button.

If the measurement was acquired with the raw data then the acquired measurement can be reanalyzed by modifying the [pulse processing](#) or the [MCA parameters](#) in the **PRESET** dialog. When you modify these parameters the **OK** button of the **PRESET** dialog will change to the **REANALYZE** button, clicking which will initiate a measurement reanalysis process that may take a considerable amount of time depending on the sampling rate and the duration of the measurement. You can save the reanalyzed measurement by clicking the **OK** button on the **MEASUREMENT** page of the Measurement screen or you can discard the reanalyzed measurement by clicking the **CANCEL** button.

4.3.14 Regions of Interest

You can define one or more regions of interest (ROI) corresponding to a range of spectrum channels by clicking the **ROI** button on the **MEASUREMENT** page of the Measurement screen to open the **REGIONS OF INTEREST** dialog - Fig. 57.

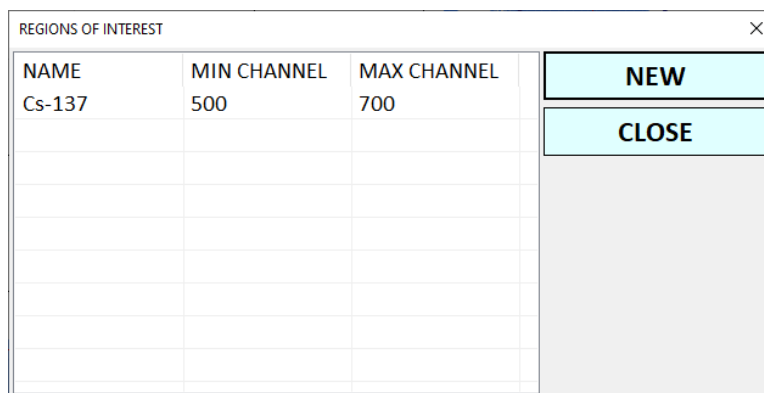


Fig. 57. The **REGIONS OF INTEREST** dialog.

To create a new ROI click the **NEW** button and specify a range of channels.

To edit an existing ROI click the **EDIT** button.

Alternatively, you can use the mouse to select a range of channels on the spectrum plot while holding down the **SHIFT** button and then clicking the **SET ROI** button that appears in response to selection.

To apply a ROI filter to the current measurement, select an ROI from the **ROI** drop-down list on the **MEASUREMENT** page of the Measurement screen.

4.3.15 Gate

PulseCounter allows using a gate channel to control pulse counting. To set up a gate channel click the **GATE** button on the **MEASUREMENT** page of the Measurement screen to open the **GATE** dialog - Fig. 58.

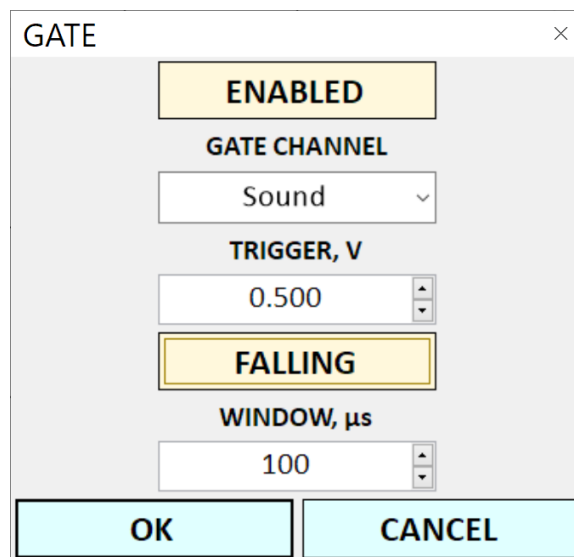


Fig. 58. The **GATE** dialog.

To enable pulse gating check the **ENABLED** button.

To set up a gate condition select a gate channel from the **GATE CHANNEL** list. Any available counter or raw data channel can be used as the gate channel. Then specify a **TRIGGER** in volts level and identify if you want to trigger on the falling or on the rising edge. Lastly specify the duration of the gate **WINDOW** in microseconds.

When the gate is enabled PulseCounter will count pulses only during a gate window, which starts every time the trigger condition on the gate channel is satisfied.

4.4 Measurement Summary

To view a summary measurement, which is a comparative aggregate of all background and all experiment measurements for the currently selected channel click the **OPEN** button under the **SUMMARY** label on the Experiment screen. PulseCounter will display the Measurement screen where the aggregate of all experiment measurements is presented as the current measurement and the aggregate of all background measurements is loaded as the comparison measurement - Fig. 59.

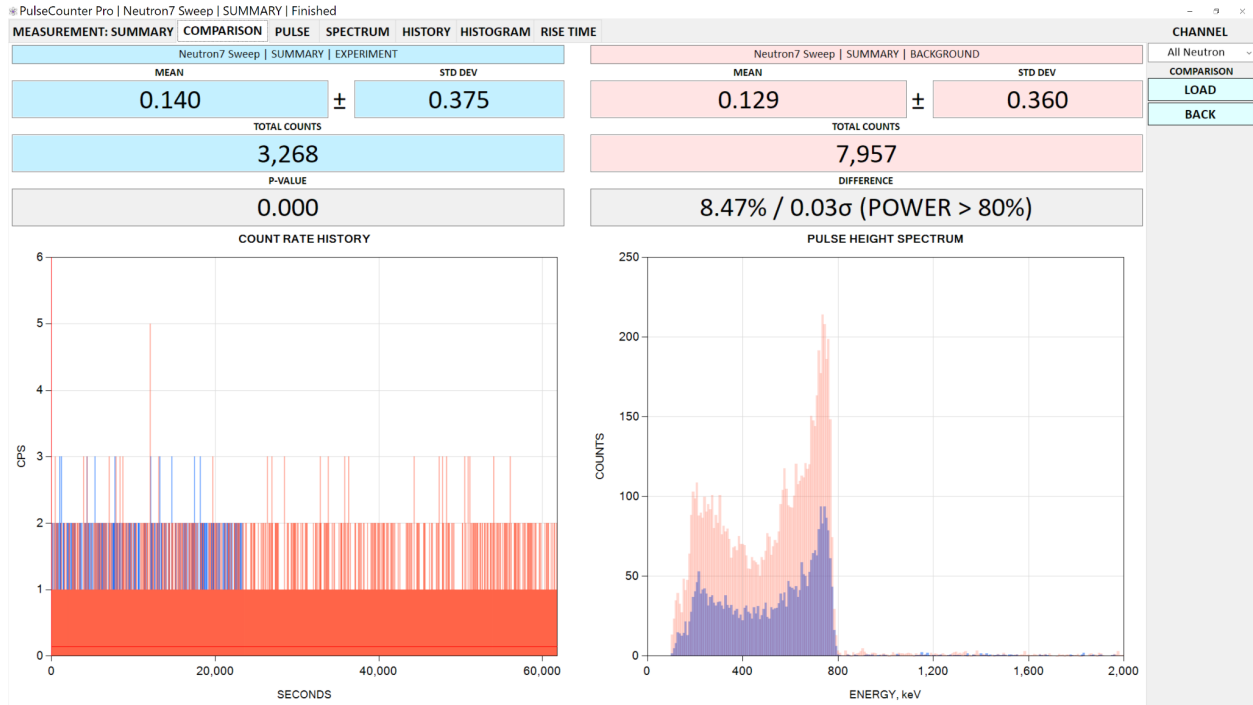


Fig. 59. The summary measurement.

Viewing the summary measurement is useful for comparing merged histories, spectra and histograms of all background and experiment measurements.

5. Resources

For additional information visit the [Neutron Detection](#) and [Gamma Spectroscopy](#) blogs at www.maximus.energy. Specific recommended articles are as follows:

- [Gamma detection best practices](#)
- [Gamma calibration sources](#)
- [Make your own neutron source](#)
- [Neutron detection best practices](#)
- [Thermal neutron spectrum](#)