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Multipurpose Data Acquisition System for Neutron Beam Monitor / Profiler

Contents

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1. Summary

The purpose of this document is to describe the a multipurpose Data Acquisition System that can be used for Neutron Beam Monitors / Profilers. The system is capable of working with traditional point like beam monitors as well as position sensitive beam monitors (Beam Profilers) in both one and two dimensions, with or without Time-of-Flight capabilities.

2. Beam Monitors and Beam Profilers

The traditional role of beam monitors in neutron scattering applications is to provide a means of normalization for measurements especially in conditions where the effective neutron flux can vary during or in between measurements.

The beam monitor is basically a neutron detector with very low efficiency (~0.1%) that is placed into the beam before the sample. The number of neutron hits at the beam monitor (*Monitor Counts*) is thus proportional to the number of neutrons that reach the sample during the measurement.

If the beam monitor is replaced by a Position Sensitive Detector (PSD) tube than one can provide additional information about the beam: the one dimensional profile (corresponding to the orientation of the PSD tube) of the neutron beam can be obtained. At the same time the Monitor Counts can still be utilized in the traditional sense. A beam monitor like this can thus be called a *Beam Profiler* as well.

If the beam monitor is replaced with a two dimensional PSD (e.g. a multi-wire detector) than the two dimensional beam profile can be obtained and the resulting beam monitor is a two dimensional Beam Profiler.

An additional dimension of the data acquisition can be obtained for neutron measurements that utilize chopper systems or pulsed sources. In such a system, if the beam profiler is placed in the beam after (some of) the choppers than the Time-of-Flight (and thus spectral) profile of the beam can be obtained as well.

The Data Acquisition System described in this document when connected to a two dimensional position sensitive beam monitor is capable of operating in any and all of these modes, as described in the next section.

3. Operational Modes

In the following sections we will provide detailed description of all possible modes of operation of the DAQ System. The description of the modes follows the order from most basic to most sophisticated.

3.1. Point Like (0D) Monitor Mode

The very basic operational mode of the system is to use the monitor in the traditional sense as a normalization measurement. In this mode the DAQ system collects all monitor counts in a configurable *Region-Of-Interest* (ROI) of the monitor detector. This *Monitor Counts* value can be used to control measurement termination (when measuring for a specific monitor value) or as a normalization value (when measuring for fixed time value).

An additional measured quantity is the value of *Monitor Counts per Second* corresponding to the current neutron flux in the beam at the point of the monitor detector.

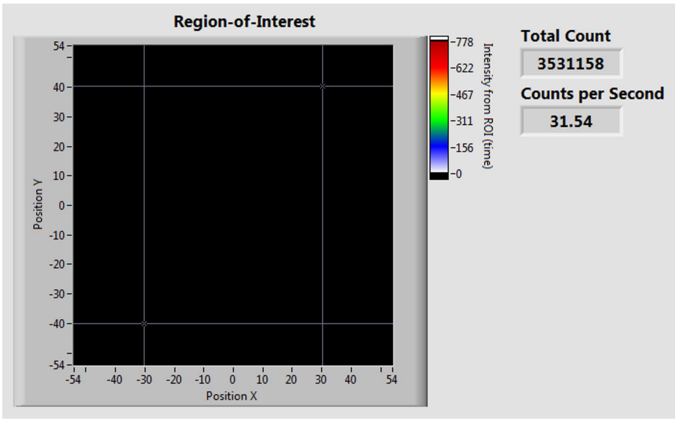

Figure 1. Basic monitor operation with ROI selection, total counts and counts per second indicators

3.1.1. Point Like (0D) Monitor Mode with TOF

If the measurement system has choppers or a pulsed source with a T_0 signal then the DAQ system can provide an additional very useful measurement, namely the Time-of-Flight (TOF) spectrum of the beam at the point of the beam monitor. This provides important data about the wavelength/energy spectrum of the beam itself, which can be correlated with the wavelength/energy spectra of the measurements.

This data takes the form of a graph plotting the number of monitor counts as a function of the Time-of-Flight values.

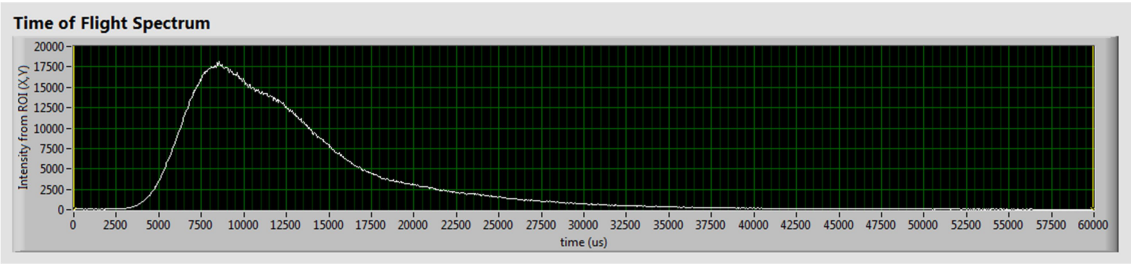

Figure 2 Time-of-Flight spectrum for point like operational mode

3.2. Position Sensitive 1D Monitor Modes

In a more sophisticated measurement setup the DAQ system can be used to provide a one dimensional profile of the neutron beam during the measurement. In this case the neutron intensity can be mapped against one of the cardinal directions X (for horizontal axis) of Y (for vertical axis). This *One Dimensional Beam Profile* can be especially useful for reflectometer instruments to assess the homogeneity of the beam.

This operational mode like the previous ones allows for both measurements for time as well as measurements for monitor counts. In the latter case monitor counts are generated for the easily configurable region of interest (ROI).

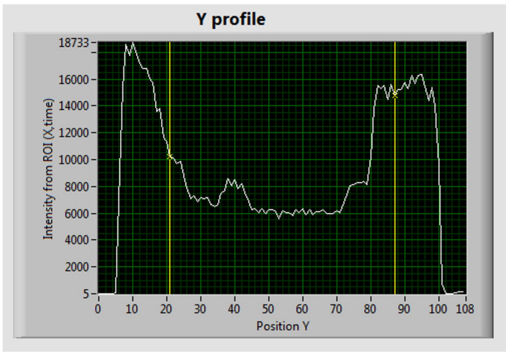

Figure 3 Example of a one dimensional beam profile for the vertical axis with ROI selection

3.2.1. Position Sensitive 1D Monitor Modes with TOF

If the measurement system has choppers or a pulsed source with a T_0 signal then the DAQ system can in addition generate a spectrum in two dimensions: one cardinal axis (X/horizontal or Y/vertical) and the Time-of-Flight values.

The resulting spectrum encodes the number of monitor counts with color gradients and maps them onto a two dimensional plot of cardinal dimension versus TOF values.

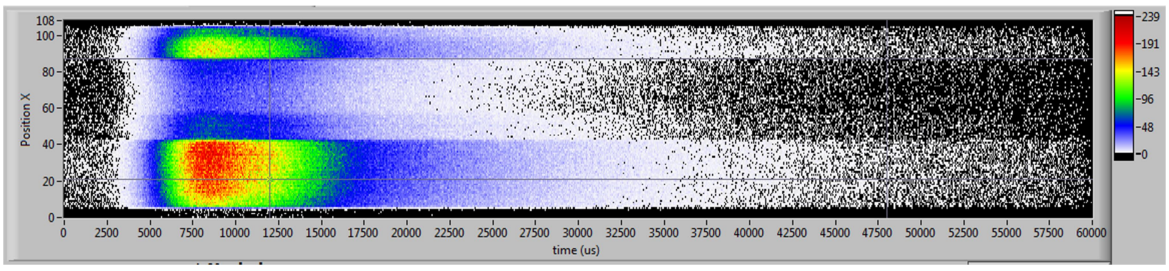

Figure 4 One dimensional beam profile with Time-of-Flight using the X/horizontal axis

3.3. Position Sensitive 2D Monitor Mode

In this mode the monitor detector operates as a true two dimensional Position Sensitive Detector (PSD). This allows for a full two dimensional beam profile.

The *Two Dimensional Beam Profile* encodes the monitor count values with color gradients and maps them onto the two cardinal dimension axes: X/horizontal versus Y/vertical. This two dimensional profile can provide useful information about the homogeneity of the neutron beam, the correct placement of neutron guides, the proper operation of neutron optics in the beam (such as shutters, apertures, focusing mirrors etc.)

This operational mode like the previous ones allows for both measurements for time as well as measurements for monitor counts. In the latter case monitor counts are generated for the easily configurable region of interest (ROI).

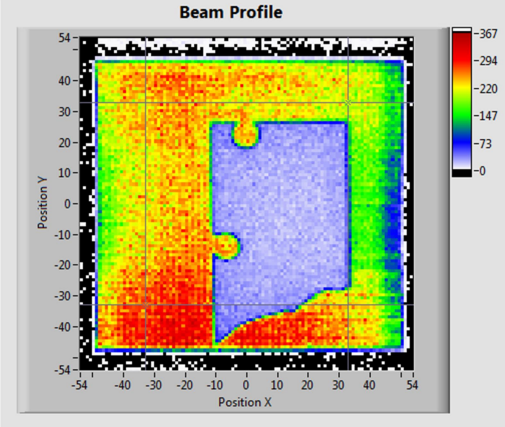

Figure 5 Example of two dimensional Beam Profile with ROI selection

3.3.1. Position Sensitive 2D Monitor Mode with TOF

If the measurement system has choppers or a pulsed source with a T_0 signal then the DAQ system could in theory generate a fully three dimensional (two cardinal directions plus the Time-of-Flight value) spectrum with monitor counts at every point in the three dimensional space.

Such a complex spectrum may contain a wealth of information about the spatial and spectral attributes of the neutron beam. However there is no trivial way to generate. a meaningful representation of such a data set, that could be useful for the experimenter. The representation that we offer in the DAQ System is as follows:

The Time-of-Flight (TOF) axis can be divided into appropriate intervals (preferably only a handful of intervals, see section 4). The user can easily navigate between the resulting TOF slices with the mouse on an isometrically placed TOF axis. At each point the two dimensional spatial Beam Profile is presented for the selected TOF interval.

As an example let us take a measurement with a 2000 RPM chopper. The resulting time of flight will vary from 0 to 30000 µs. We can divide this into four 7500 µs wide intervals. Examples for the resulting beam profile representations can be seen in the figure below.

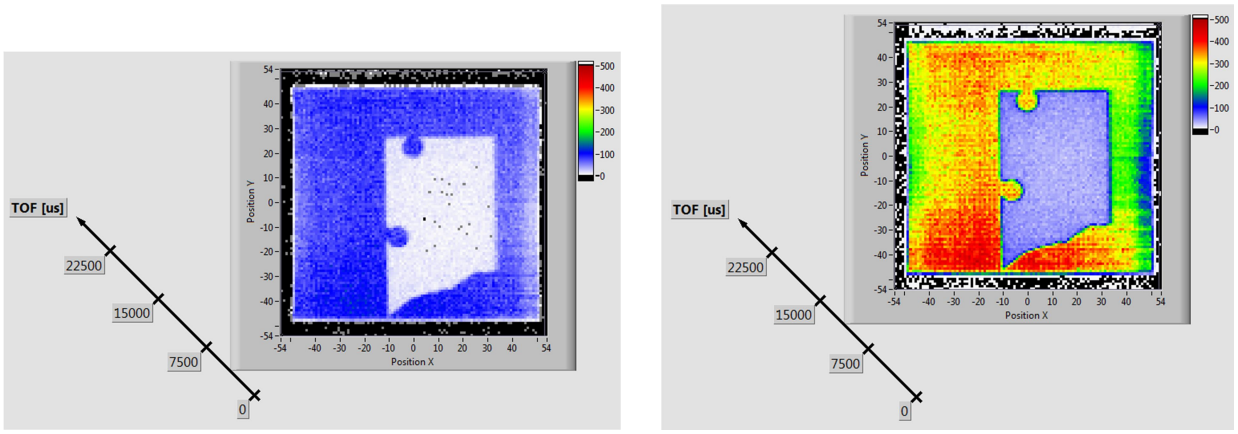

Figure 6 Two positions of the Two Dimensional Beam Profiler Mode with Time of Flight. Figure left shows beam profile in [0-7500 µs] range; figure right shows the same in the [7500-1500 µs] range

4. A Note on Monitor Counts in Different Operational Modes

Please be aware that the total number of monitor counts will typically be the same or similar for all operational modes however the values at each measurement point (e.g. in a specific TOF slice at a specific X-Y coordinate) will be lower whenever there are more measurement points.

For example in a measurement with a spatial resolution of only 20 * 20 pixels with only 4 TOF slices, each measurement point will have on average 1600 times less counts then the total monitor counts value and some points will have significantly less than that. This means that the measurements might appear more "grainy" unless significantly longer measurements are performed.

On the other hand, measurement times can indeed be significantly longer for the beam profiling application in certain cases because the profiling can be performed in parallel with several other measurements as long as the beam and chopper setup at the beam monitor remains constant.