Radiation Spectroscopy Using Seeded Localized Averaging ("SLA")

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***Abstract*– A new technique for acquiring radiation spectra was developed. This technique is called Seeded Localized Averaging ("SLA"). A principal feature of the SLA method and the fundamental difference from the conventional spectrum-building method is the use of more than one pulse-height measurement to obtain the address of the channel that increments. That is, two or more pulse-height measurements are averaged to obtain an average channel address.**

The average channel address is used to increment the corresponding channel in the spectrum memory. The counting statistics is preserved by using pipeline based pulse-height recycling scheme. SLA technique works in real time by averaging pulse-height measurements in localized windows. The use of average channel addresses reduces the FWHM of the recorded spectral peaks. The technique has been applied to various detectors and applications.

I. Introduction

THE salient feature of the traditional technique to acquire radiation spectra is the fact that the increment of the spectroscopy channels is based on a single pulse height measurement. That is, every time a channel address is received, the corresponding channel content increments. A new technique for acquiring radiation spectra was developed. This technique is called Seeded Localized Averaging ("SLA"). A principal feature of the SLA method and the fundamental difference from the conventional spectrum-building method is the use of more than one pulse-height measurement to obtain the address of the channel whose content increments.

II. SLA TECHNIQUE

This is a brief description of the SLA technique due to page limitation. A detailed paper will be published elsewhere. In addition, a patent disclosure has been written which contains all technical details.

The block diagram of a spectroscopy system using the SLA method is shown in Fig. 1.

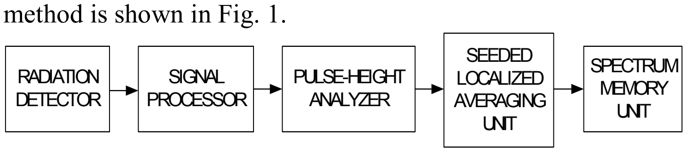

Fig. 1. Spectroscopy system based on SLA.

Patent Pending.

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The SLA unit is placed between Pulse-Height Analyzer (PHA) and the spectrum memory. The SLA unit receives pulse-height measurements referred to as channel address also known as channel number. After receiving multiple channel addresses the SLA unit computes the average channel address derived as the average of channel addresses within narrow averaging window. The average channel address is fed to the spectrum memory as in the conventional spectroscopy.

The SLA function can be implemented either as dedicated hardware or as software routine. The later can be used in real time DSP/embedded based systems or as an off-line spectrum processing routine. The SLA requires only one parameter specific to the radiation detector and the associated electronics. This parameter is the FWHM as function of the channel number and it is used to calculate the width of the averaging window. There is no presumption on the type of the detector and/or its response function. SLA is not a detector-response deconvolution technique.

Fig. 2 depicts the block diagram of the SLA unit. The averaging window is supplied by the WINDOW LOOK-UP TABLE. The CONTROL UNIT synchronizes the operation of all units. The AVERAGING MEMORY is organized in channels similarly to the spectrum memory. Each channel of the AVERAGING MEMORY holds two values: average sum and average number. The SLA calculations are performed by the AVERAGING ARITHMETIC UNIT.

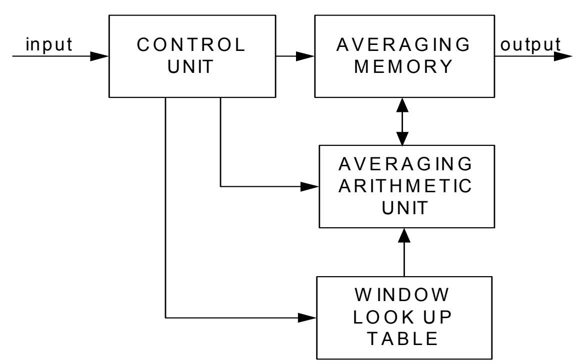


Fig. 2. Block diagram of the SLA unit.

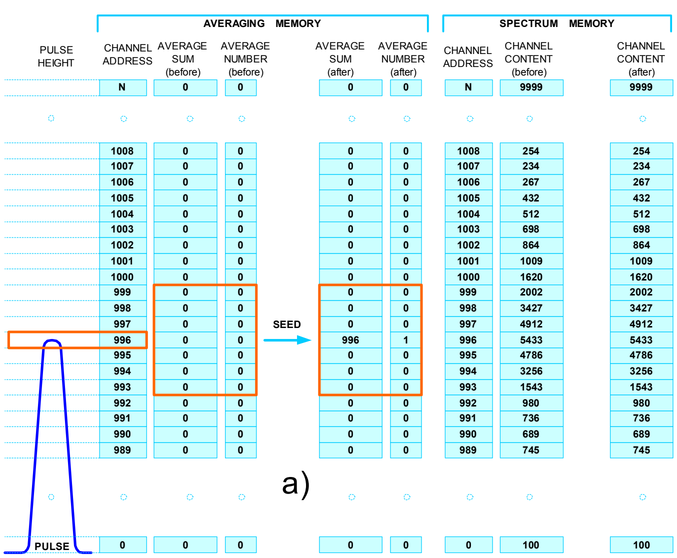
Using simple pulse-height-measurement averaging over the full range of all pulse heights will destroy the differential pulse-height information and will be quite useless. Therefore, a selective approach to carry out the averaging must be implemented.

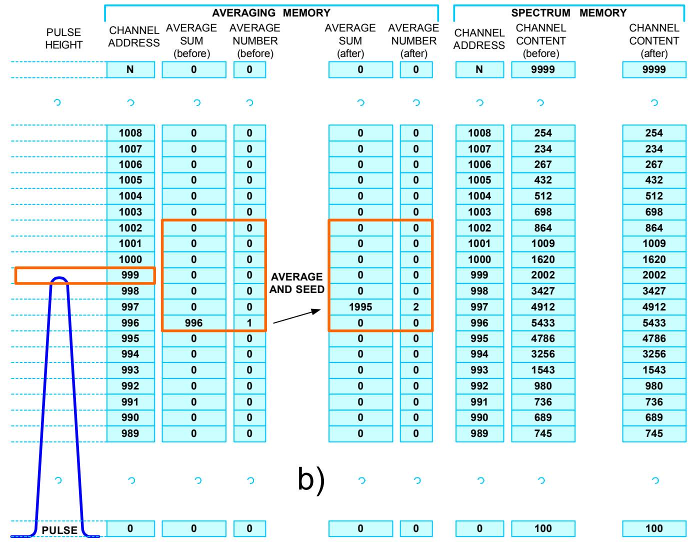
The SLA method solves this problem by performing AVERAGING only over a narrow averaging window.

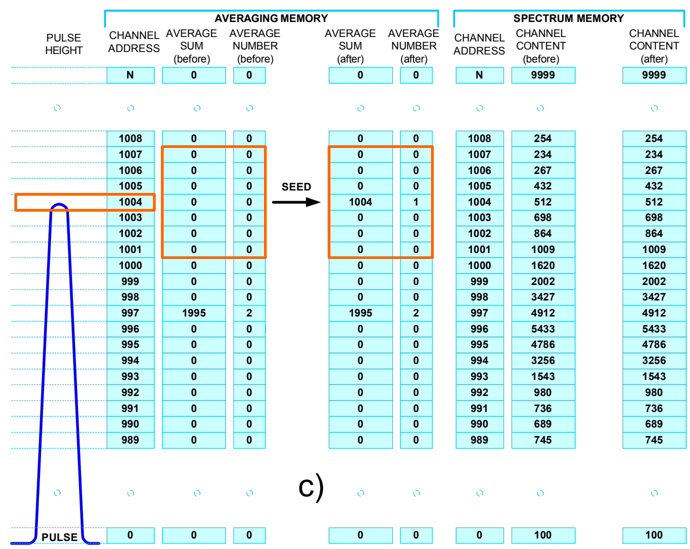
Selection of a narrow averaging window is not sufficient by itself. It is necessary to select the position of the averaging window. The averaging window is centered on the pulse-height measurement that is being processed. Thus, the averaging is always LOCALIZED around the currently-processed pulse-height measurement – channel address.

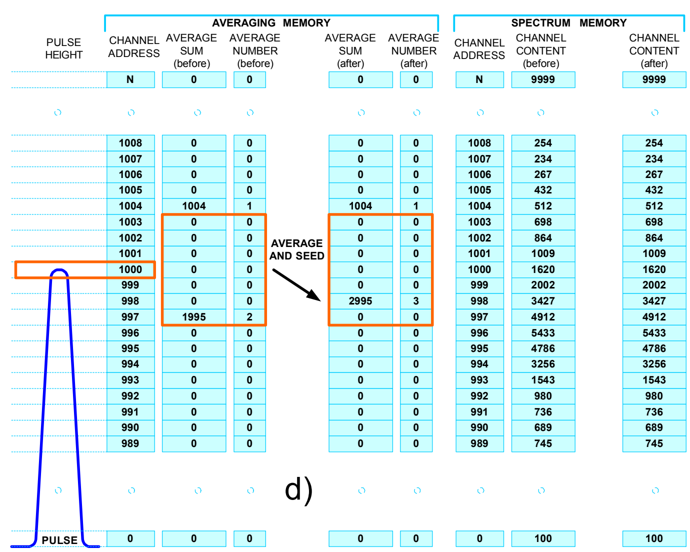
Initially, the entire content of the averaging memory is set to zero. When a pulse-height measurement is received, it is used to position the averaging window. Next, the average numbers of all channels within the averaging window are scanned and compared with zero. If all channels within the averaging window hold zero, then the pulse-height measurement is stored in the average sum of the channel pointed by the processed pulse-height measurement. This pulse-height measurement becomes a SEED of a new average sum. Along with the seeding of the average sum, the corresponding average number increments by one. Once the averaging memory is seeded, average sum can be built until the number of the pulse heights in the sum (average number) reaches the maximum average number required to calculate the average channel address.

The LSA operation is illustrated in Fig. 3 a) to e). For simplicity the averaging window size is the same for all pulse height measurements. The contents of the averaging memory and the spectrum memory are shown before and after a single pulse-height measurement. In this particular example the maximum average number is set to 4. The seeding operation is shown in Fig. 3a and Fig. 3c. The averaging process is depicted in Fig. 3b and Fig. 3d. The computation of the average channel address is shown in Fig. 3e. Note that after the average channel address is computed, the average sum and the average number are removed from the averaging memory.









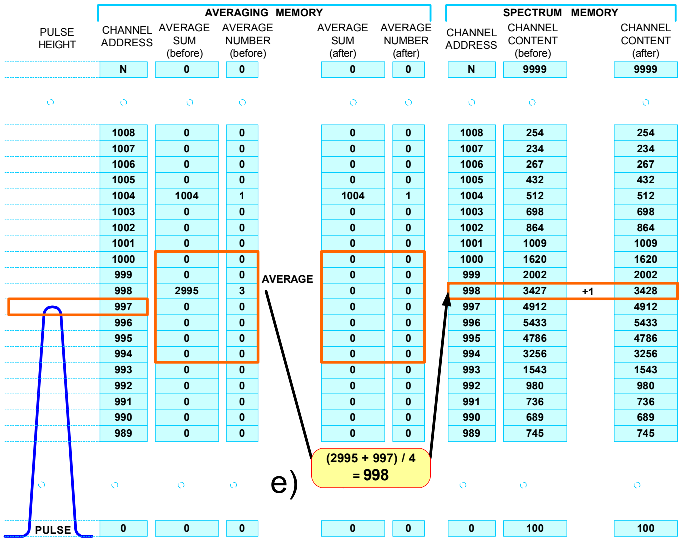


Fig. 3. Illustration of the SLA operation.

From the SLA algorithm it is evident that the total number of counts in the SLA spectrum is reduced by a factor equal to the maximum average number. For example, the SLA spectrum obtained as illustrated in Fig. 3 will have four times less counts compared to the conventional spectrum acquired from the same set of channel addresses. To compensate for this count loss a randomizing pipelines are used. The randomizing pipelines recycle each channel address N-1 times, where N is the maximum average number.

III. Randomizing Pulse Recycler

Fig. 4 shows a simplified diagram of the RNDOMIZING PULSE RECYCLER ("RPR").

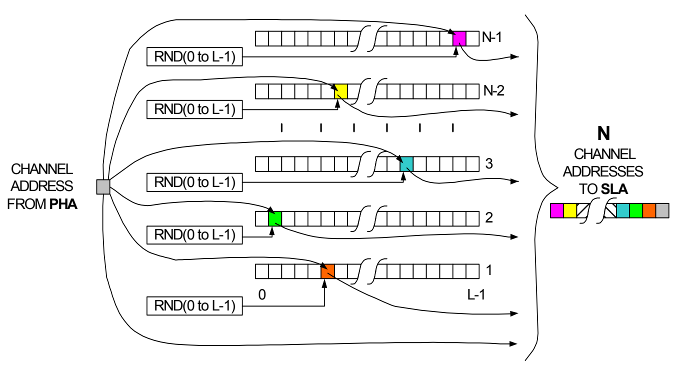


Fig. 4. Randomizing Pulse Recycler.

The RPR is comprised of N-1 pipelines. Each pipeline has L cells that are linearly addressed. L must be sufficiently large to reduce the correlation effects in calculating the average channel address. The cell addresses are derived from a random generator.

The RPR receives channel address from the PHA. When the channel address is received it replaces randomly the content of one cell in every pipeline. The old content (replaced value) together with channel address from the PHA are sent for processing by the SLA unit. Thus, a single channel address from PHA causes SLA to process N channel addresses. Although the channel addresses are scrambled efficiently the correlation effects can not be eliminated completely due to the finite length of the pipelines.

Fig 5. shows a comparison of three spectra that have the same total number of counts. These spectra are obtained from the same set of channel addresses. The detector is HPGE and a portion of gamma-spectrum is chosen that exhibits relatively poor statistics. The spectrum in Fig. 5a is the conventional spectrum. The spectrum in Fig. 5b is the SLA spectrum obtained with SLA, without RPR. The maximum average number is equal to 8. Therefore, the counts of each channel are multiplied by 8 to compensate for the counting losses due to the averaging. Fig. 5c shows a spectrum obtained with SLA and with RPR.

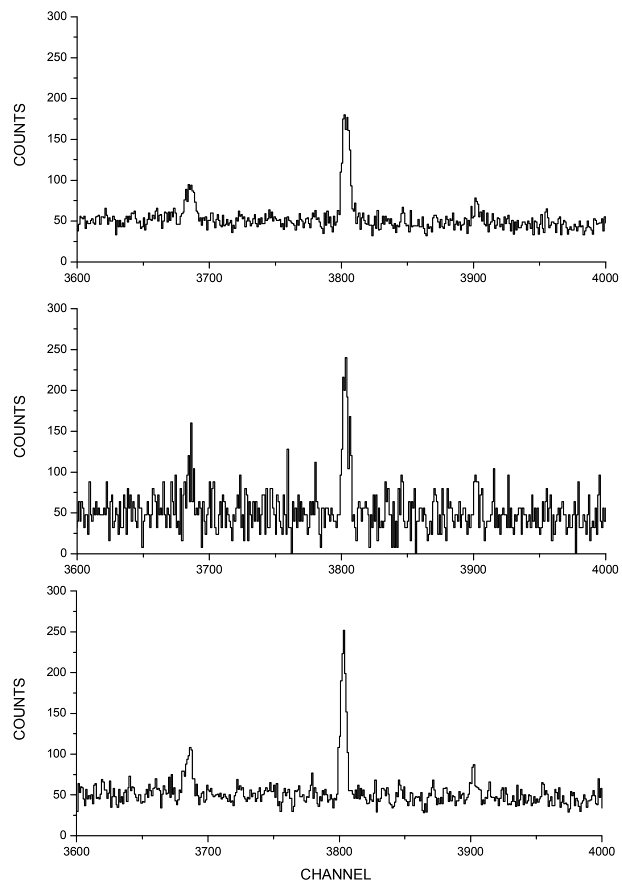


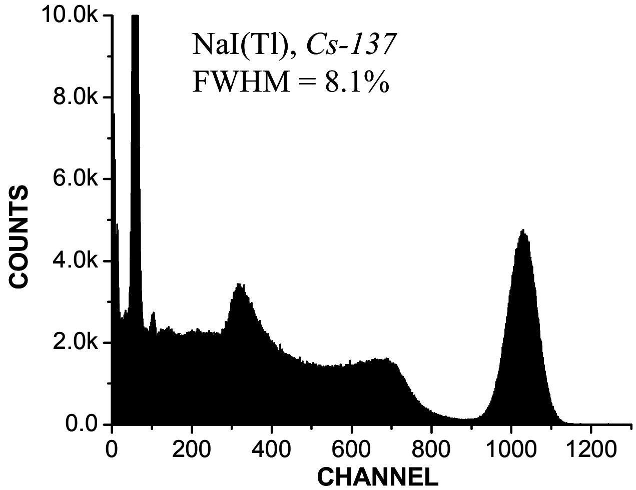
Fig. 5. Spectra with and without RPR; a)-top, b)-middle; c)-bottom.

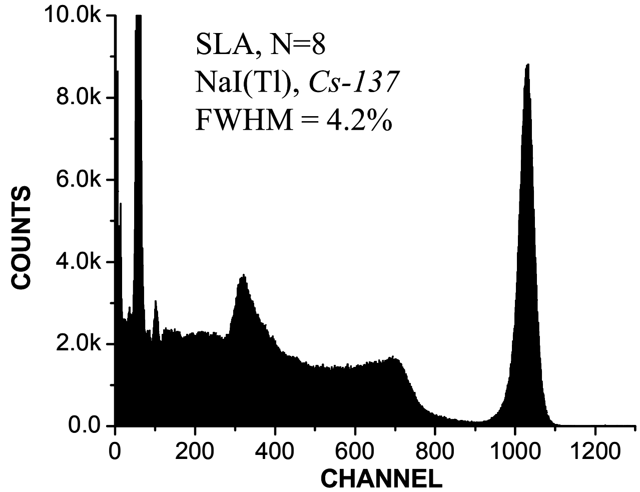
In the Appendix comparison is shown between conventional (left) and SLA (right) spectra. The Co-60 SLA spectrum is taken without RPR and it shows higher statistical variation than the conventional counterpart. One important observation is that the spectral line shape is not Gaussian in the case of SLA. The shape is well fitted with Voigt line shape which represents superposition of independent Lorentzian and Gaussian line broadening mechanisms.

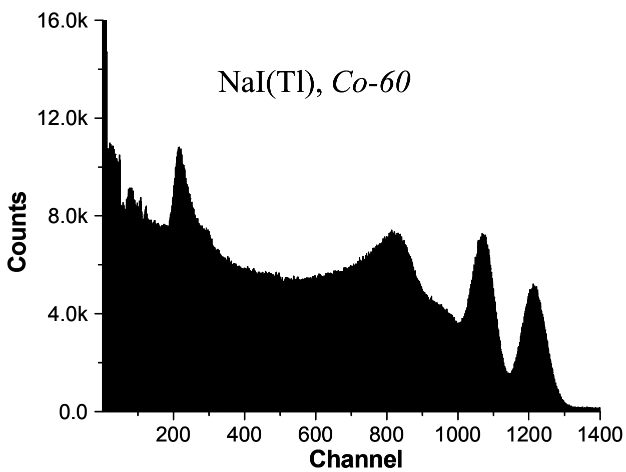
IV. Conclusion

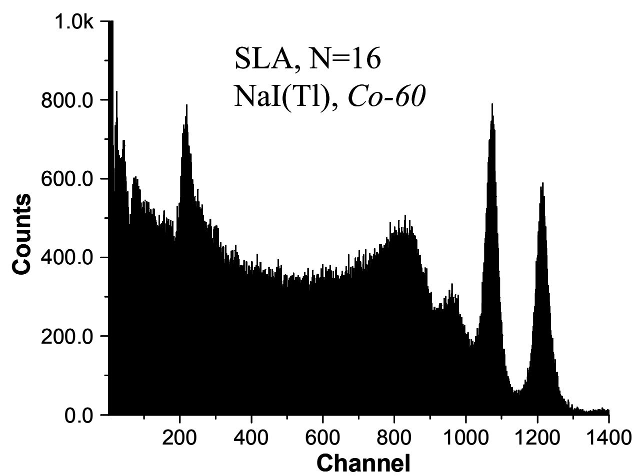
The SLA technique sharpens the spectral peaks and improves the FWHM. The spectral data shown here is preliminary and the analytical performance has not been studied yet. Other effects such as spectrum distortion need to be investigated before a final conclusion about the usefulness of this technique can be drawn.

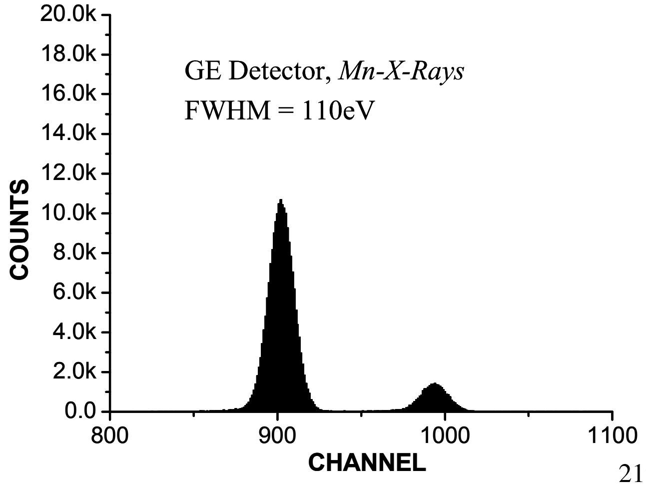
Appendix

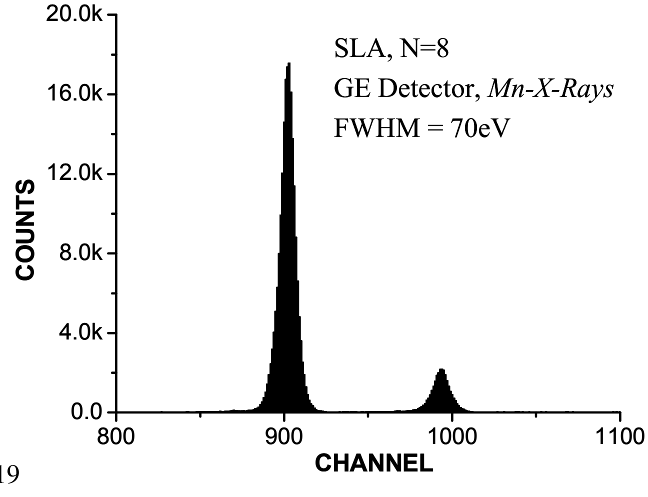


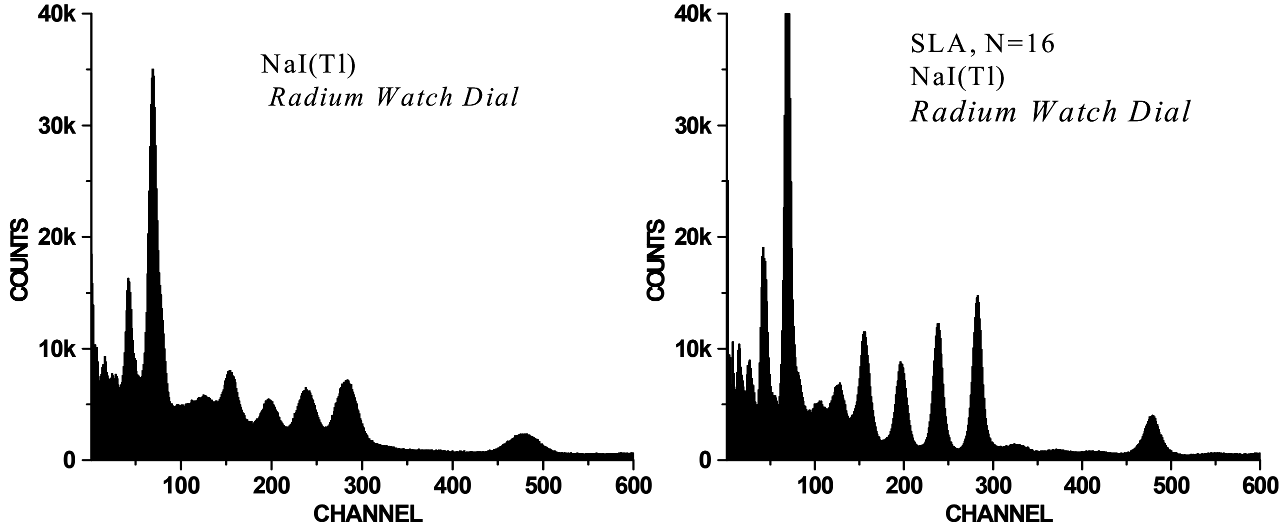


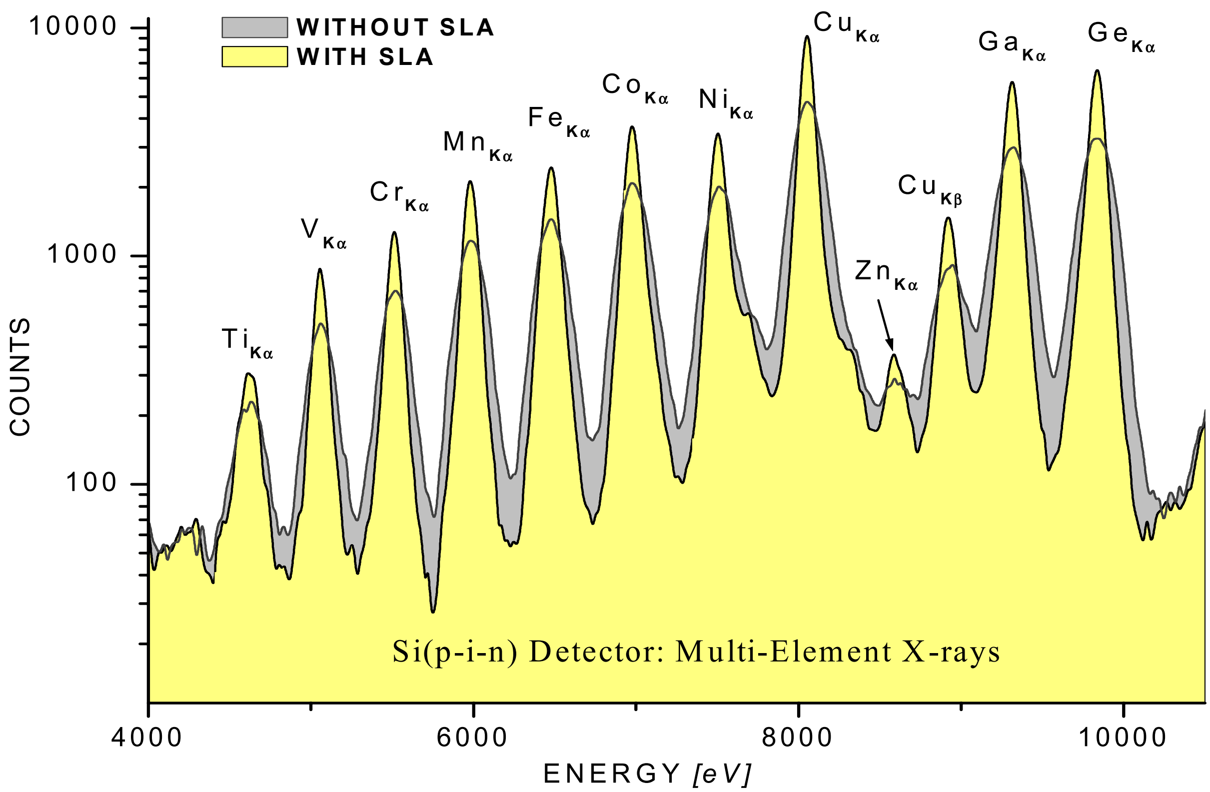












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