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An Automated Neutron Monitor Maintenance System

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AN AUTOMATED NEUTRON MONITOR MAINTENANCE SYSTEM (U)

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Savannah River Technology Center, WSRC

ABSTRACT

Neutron detectors are commonly used by the nuclear materials processing industry to monitor fissile materials in process vessels and tanks. The proper functioning of these neutron monitors must be periodically evaluated. We have developed and placed in routine use a PC-based multichannel analyzer (MCA) system for on-line BF_3 and He-3 gas-filled detector function testing. The automated system: 1) acquires spectral data from the monitor system, 2) analyzes the spectrum to determine the detector's functionality, 3) makes suggestions for maintenance or repair, as required, and 4) saves the spectrum and results to disk for review. The operator interface has been designed to be user-friendly and to minimize the training requirements of the user. The system may also be easily customized for various applications.

INTRODUCTION

Neutron detection systems (neutron monitors) are used in the nuclear material separation processes of the Savannah River Site (SRS) to monitor the relative inventory of fissile material in the mixer-settler tanks of the solvent extraction process. Because of the importance of the neutron monitors as secondary safety control systems, maintenance and reliability problems can have a serious negative effect on the operations of the solvent extraction processes at the SRS. For this reason, the Analytical Development Section has been working closely with the Nuclear Materials Stabilization Department for several years to improve the reliability and performance of the neutron monitors and to simplify the preventive maintenance programs to reduce costs and enhance system reliability.

INSTALLATION AND ELECTRONICS

The neutron monitors used in the nuclear materials processing buildings (canyons) are stainless steel $^{10}BF_3$- or ^{3}He- filled proportional counter tubes, one inch in diameter and 10 inches long. Six of the total of eight mixer settler banks in the two canyon buildings at SRS use a single neutron detector tube at each measurement point. The two mixer-settler banks in the F Canyon Second Plutonium Cycle use three neutron detector tubes connected in series to improve sensitivity and to provide better coverage of the bank. In addition, ^{3}He tubes are used on the F Canyon Second Pu Cycle to further enhance the neutron sensitivity.

The exact mounting arrangement differs from bank to bank and canyon

to canyon. In general each detector is located in a polyethylene moderator block in a detector housing adjacent to the mixer-settler bank. For redundancy each bank contains two independent neutron monitor systems, called points. Technical specifications permit operation with only one operational detector. Operations are generally not undertaken with only one point , since failure of this point would result in process shutdown.

Each neutron detector housing is connected to the second level of the canyon building through a section of pipe called a jumper. Signals from the neutron monitor detector are transmitted by a coaxial cable in the jumper to a through pipe located in the canyon wall and then to the counting electronics on the second level of the canyon building. Cable lengths are typically around 60 feet. The neutron monitor tubes are inserted into the jumper and pushed down into position using the coaxial cable. Removal is the reverse process. This procedure places potentially damaging stresses on the cable and connectors, but it has the advantage of permitting rapid insertion and removal without the risk of contamination.

Standard nuclear counting electronics are used to process the pulses. Figure 1 is a schematic diagram of the process. Pulses from the detector tubes are transmitted via the coaxial cable to the preamplifier on the second level of the canyon and thence to the amplifier/single channel analyzer (Amp/SCA) module. The output logic pulses from the SCA are sent to the count rate meter(CRM). Since the count rate is monitored in the canyon control room, the 0- 10V output of the CRM is converted to a 4-20 ma signal and sent to the control room. All of the electronics are mounted together in a NIM bin on the canyon's second level.

As mentioned earlier, ADS has been working for several years to improve the reliability of the neutron monitor systems, and to simplify and improve the preventive maintenance of the neutron monitor systems.[1] Although only the gross neutron count rate is used for process control, it was recognized that the energy loss mechanism of the reaction products produced a distinctive signature which could be used for system setup and diagnosis. In the case of BF_3 for example, either the alpha particle or the Li nucleus may strike the tube wall, limiting the energy deposition in the tube. Thus the energy spectrum in the MCA has a unique structure.

Figure 2 shows this characteristic spectrum. It is composed of three parts corresponding to three events. First, if the alpha particle collides with the wall, the energy deposited in the tube is the total reaction energy minus the contribution lost when the alpha particle collides with the wall. The minimum value is obtained when the alpha collides immediately after the neutron capture reaction. If the Li nucleus collides with the wall, there is a similar distribution whose minimum is the energy of the alpha particle alone. There is an additional feature, the full energy peak when the particles move parallel to the tube axis and the entire reaction energy is deposited in the gas. Figure 3 is an actual spectrum taken from the neutron monitor system. Figures 4

through 7 show used, marginal, and bad tubes. The ^3He reaction yields similar spectra.

When properly set up, the lower level discriminator of the SCA is set in the valley between the gamma ray and electronic noise low energy rise and the beginning of the true neutron events. Changing the amplifier gain, high voltage, or lower level will change the count rate. Unless the maintenance person is experienced, properly setting these three variables may become a "dial-a-value" exercise with no assurance the counts come from neutrons rather than gamma rays or noise.

Additionally, determining when a detector tube has reached the end of its useful lifetime is difficult. It was originally done by inserting the tube into a neutron source and determining if the expected count rate was obtained. This method is compromised by the variability in the settings of the lower level, amplifier gain, and high voltage. If any variable is set incorrectly, a good tube may be rejected or a bad tube retained in service.

DESCRIPTION OF THE MCA BASED FUNCTIONAL TEST

To minimize these problems, ADS developed a new functional test which facilitates correct setup and identifies the detector condition. The key component in this new functional test is the use of a portable multichannel analyzer (MCA). The MCA, when connected to the amplifier output of the Amp/SCA collects and displays the neutron detector spectrum. This spectrum (FIG 3) is not duplicated by any noise or other radiation source. This offers the following advantages in setup and maintenance.

(1) Use of the MCA gives direct visual assurance that the various parameters, amplifier gain and high voltage, have been set correctly. From the number of channels in the display, and the location of the valley, one can compute a value for the lower level discriminator. For example, if one is using a 512 channel display, and the minimum in the valley is around channel 50, then setting the lower level at 1 Volt will the correct. If the detector is defective, the characteristic shape will be absent.

(2) The MCA based test can often be performed with the detectors in situ. This reduces the stress on the cables and connectors in removal and reinsertion, and can be performed with the system in operation.

(3) Using a computer based MCA means that the spectra may be saved on disk and/or printed. Detectors with questionable spectra may be referred to the system engineer for later evaluation without delaying testing of the remaining monitors.

The MCA functional test is based around the PCA II board from Oxford Instruments[2] installed in a portable IBM compatible computer. This MCA board was used for the following reasons.

(1) This board contains it's own built in analog to digital converter (ADC). There is no need to add one to the electronics in the NIM bin.

(2) The PCA II board can be used in coincidence mode, which is useful in setting up the neutron monitor system.

In the original version of the MCA based functional test the procedure calls for the maintenance person to acquire a spectrum and then to compare the spectrum to an example spectrum shown in the procedure. If the spectrum does not contain all the expected features, the tube was declared defective and replaced. The spectrum was saved on disk for review if it seemed marginal.

Software was then written for an improved version in which the analysis of the detector spectrum was done automatically. The software looks for the expected features in the spectrum and based on which ones are not found, makes troubleshooting suggestions. The program computes and plots the point by point derivative of the data. Peaks and valleys in this computed spectrum correspond to points in the data where the slope of the data changes and zeroes to flat regions in the data.

The locations and numbers of these features are used to determine if the tube is good or bad. If, for example the negative peak in the derivative plot expected at the end of the spectrum is missing, the amplifier gain or the high voltage may be set too high. The program then suggests that the gain or high voltage may be too high, or the tube may be bad. If the valley between the noise and the first feature is extremely narrow or missing, it will suggest increasing the gain or high voltage, rather than simply saying replace the tube. If the total count in the spectrum is too low for a meaningful analysis, the program will display that message. Figures 8 through 11 show the actual spectra and derivatives of a good and a bad tube. The troubleshooting suggestions may be seen on the display of the spectrum of a bad tube.

The current version of the software includes some additional functionality. The initial screen (Figure 12) asks the user to enter the number corresponding to the monitor point he wishes to test. Once this has been entered the software feeds back this information and asks the user to confirm that it is the desired point. It then creates the filename, date and time to be used to save the spectrum on disk and counts for the preset time. After the count has been completed, the program saves the data, and runs the analysis program. The analysis program then determines the condition of the detector, replots the spectrum on the computer screen, tells the operator if the tube is good, and suggests possible problems if the spectrum is bad.

The initial screen is the only location-specific portion of the software. It calls a series of short files to tell the rest of the software what to do. All that is required to revise the program for another neutron monitor application is to modify this routine, and

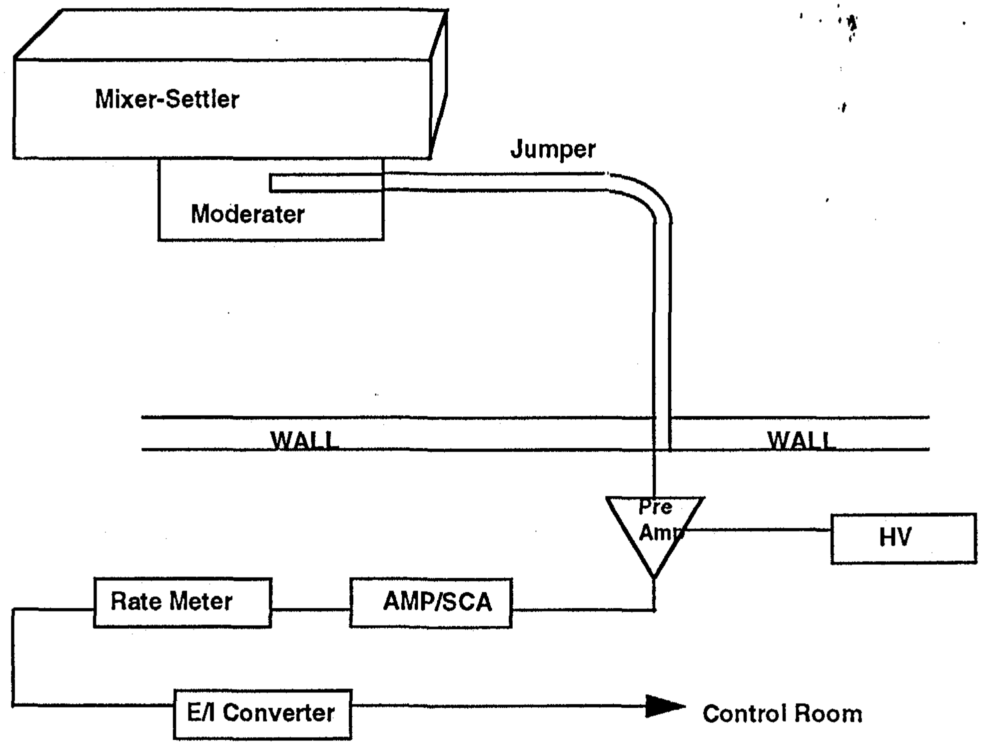
add the appropriate input file. The software works equally well with BF_3 and $_3He$ gas-filled tubes.

The "manual operation" selection on the initial screen is for maintenance and setup use. If a detector tube has been replaced, it is necessary to properly set the gain and high voltage. When replacement is required, a gate and delay generator and a delay amplifier are carried in a portable NIM bin to the counting electronics. After initiating a count, either the gain or high voltage is adjusted to put the high energy peak of the spectrum around channel 800 to 850. The MCA's cursor is then moved to the minimum in the valley above the noise. At this time the coincidence input to the MCA is connected as shown in Figure 13. The MCA now displays only those amplifier pulses which exceed the SCA's lower level discriminator and produce an output from the SCA. By alternately clearing the MCA's display, adjusting the lower level discriminator on the AMP/SCA, and recounting until the spectrum begins at the MCA's cursor, the proper lower level can be quickly set to ensure that only neutrons are counted. Figures 14 and 15 show the respective spectra with coincidence disabled and enabled.

With the canyons being brought back into use, the neutron monitor functional test program is being reinstituted. Currently efforts are being directed to simplifying and combining the functional test procedures in the two canyons to reduce the number of procedures in use in the canyons.

1.J.C. Griffin; IMPROVED NEUTRON MONITOR SYSTEM FOR SAVANNAH RIVER SITE SEPARATIONS FACILITIES (U), 1989 Plutonium/Uranium Recovery Operations Conference, Oak Ridge Tenn, 1989.

2. Oxford Instruments Inc. P.O. Box 2560, Oak Ridge Tenn,37831-2560



Mixer-Settler
Jumper
Moderater
WALL
WALL
Pre
Amp
HV
Rate Meter
AMP/SCA
E/I Converter
Control Room

FIGURE 1

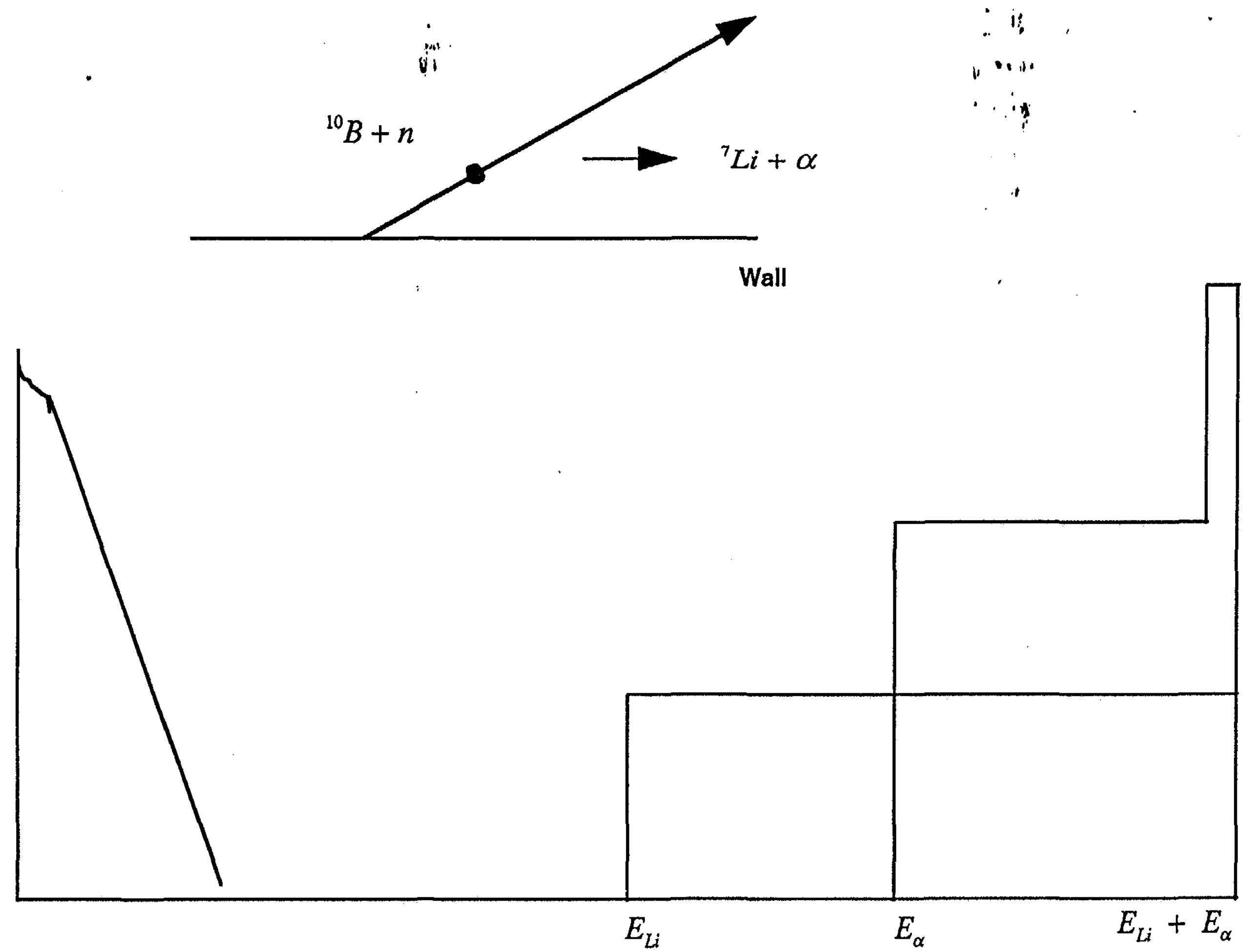


FIGURE 2

Good BF-3 Tube

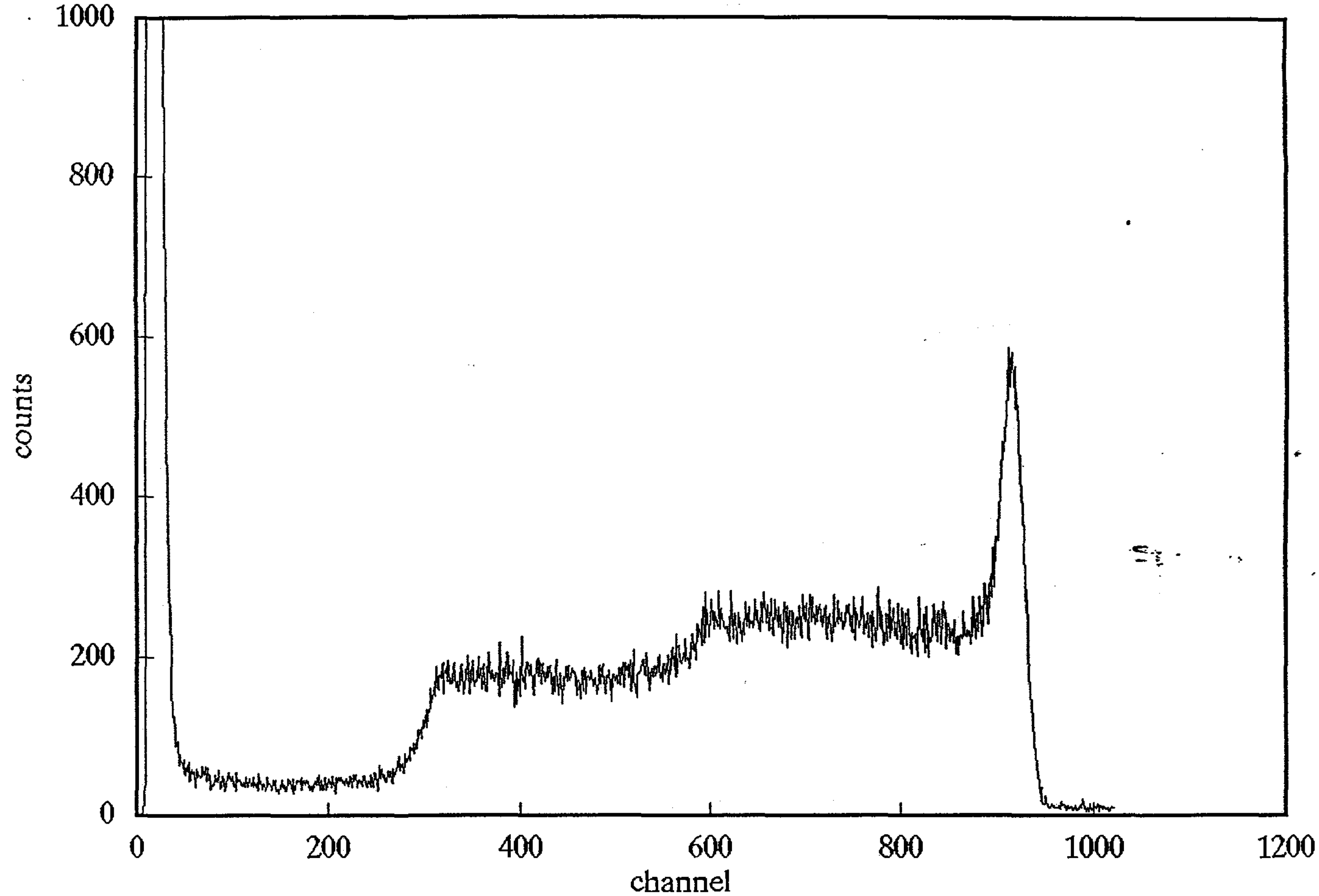


FIGURE 3

Fig-3

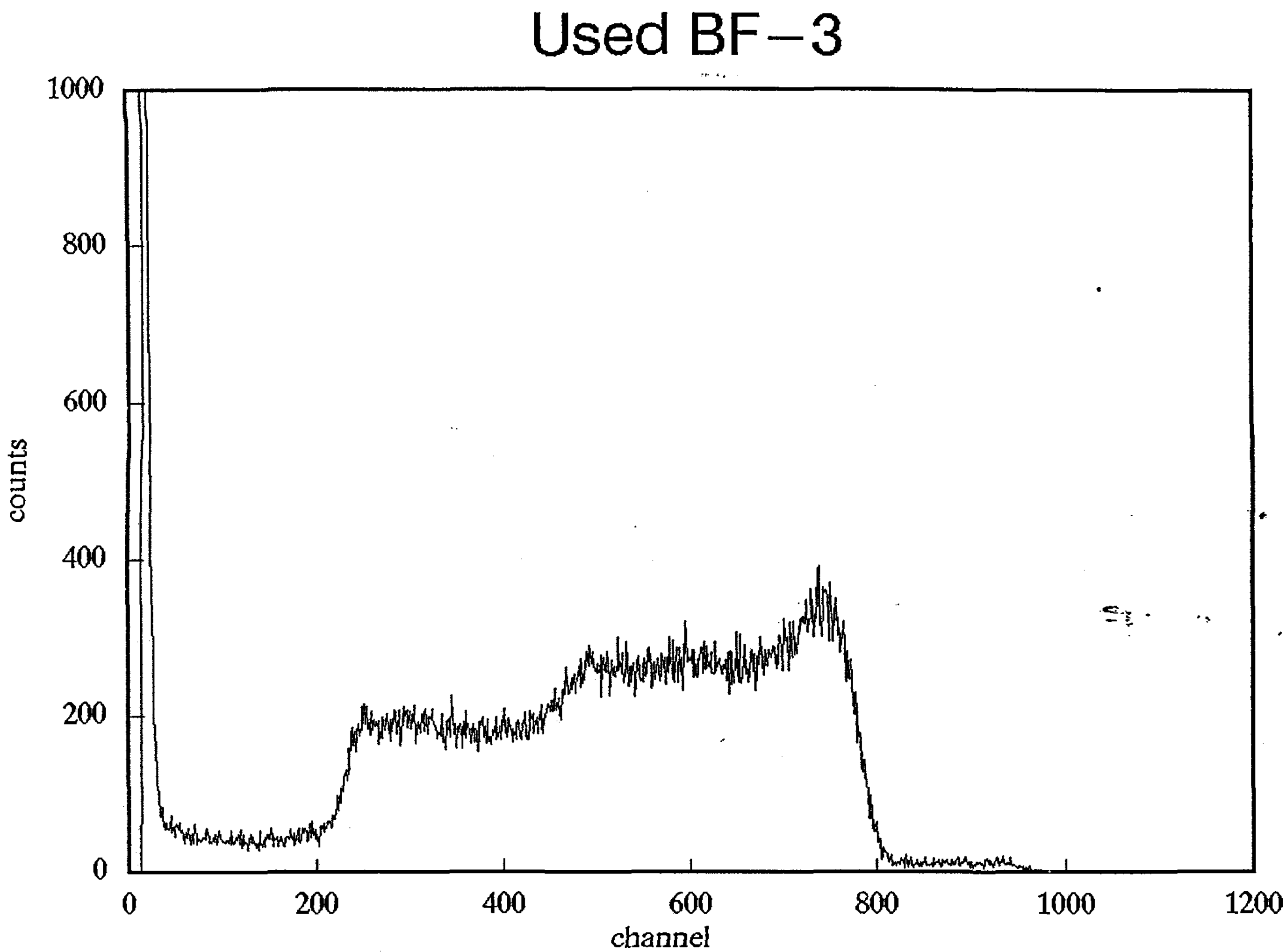


FIGURE 4

Fig -4

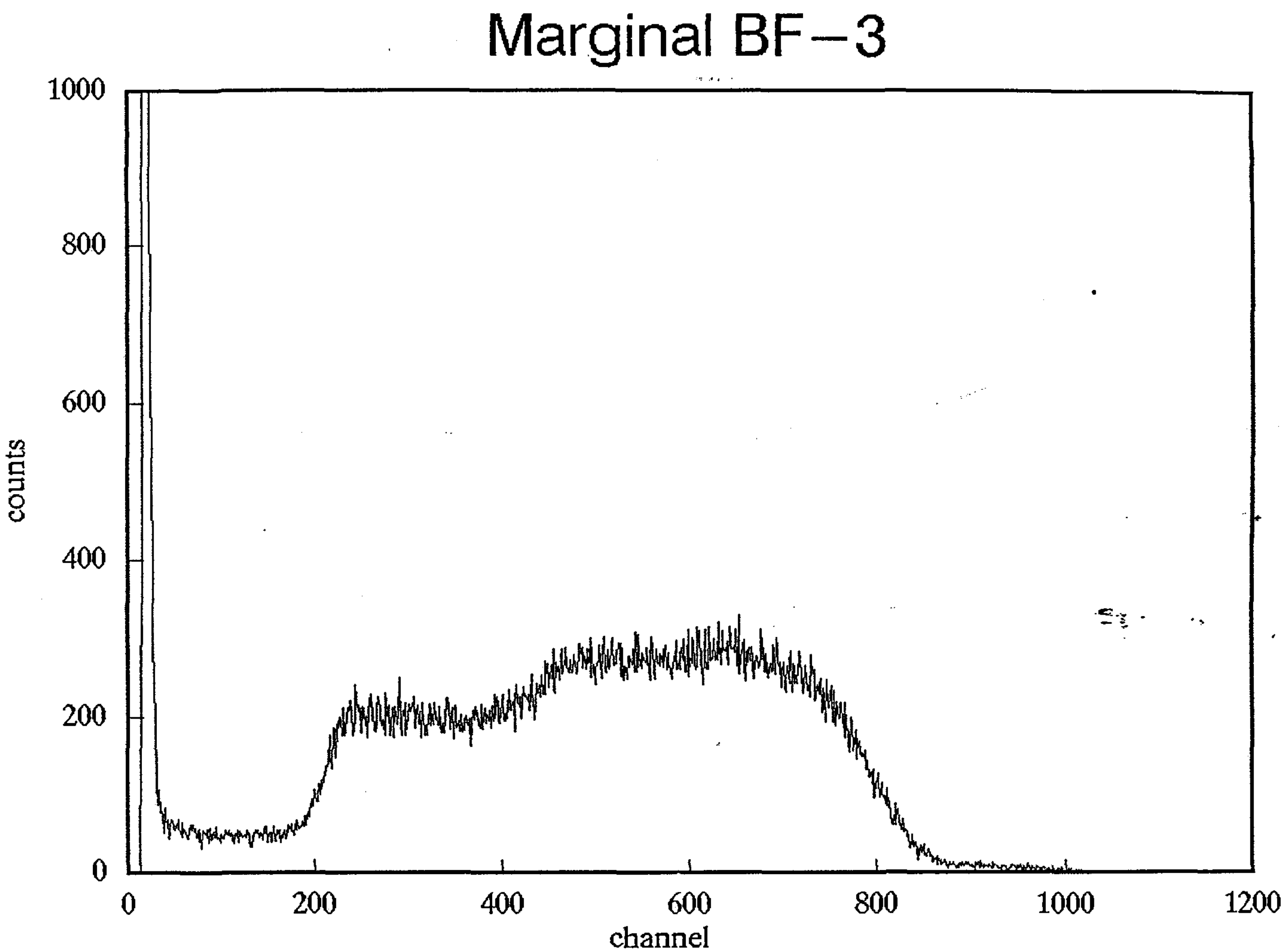


FIGURE 5

Fig - 5

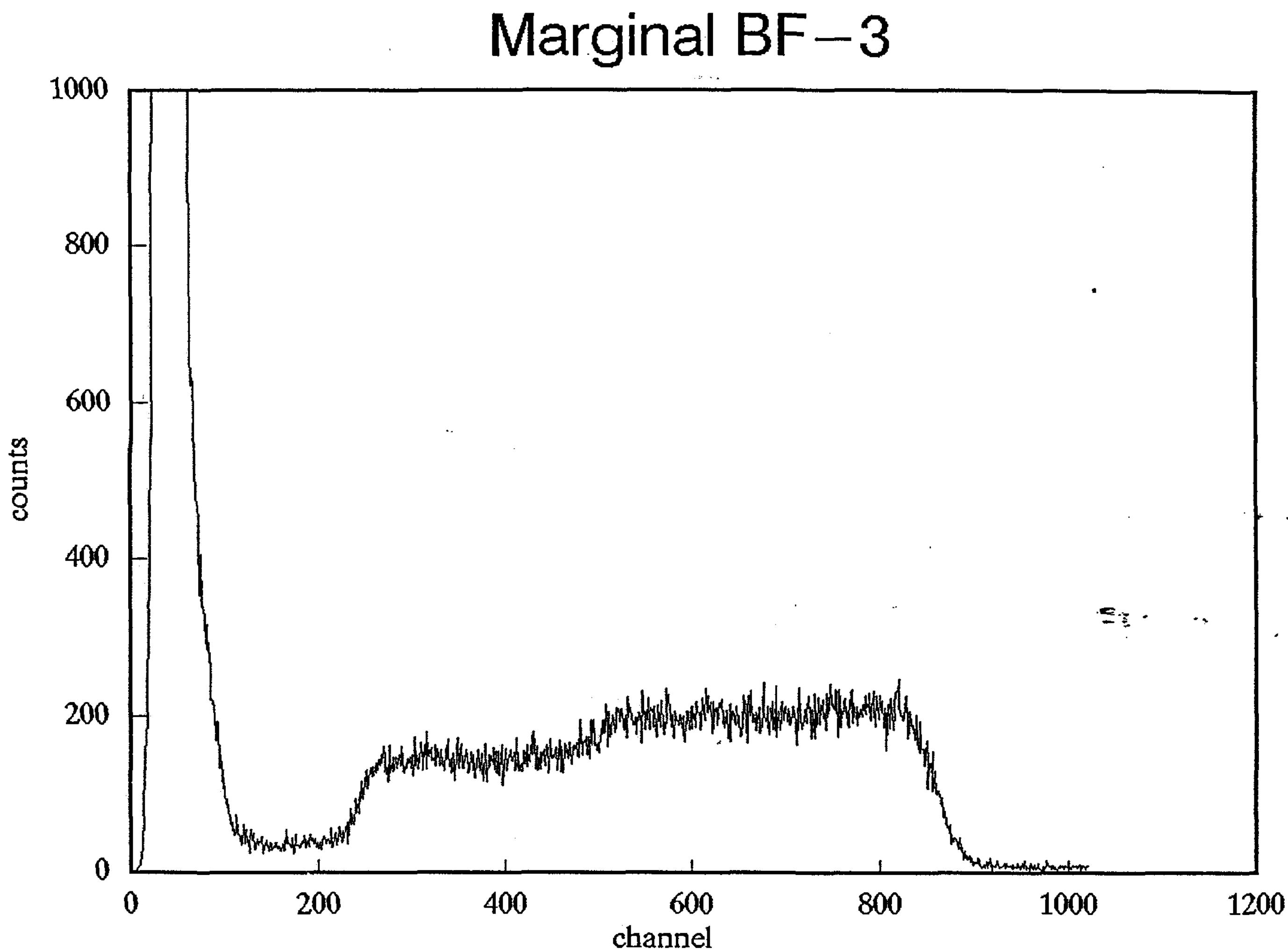


FIGURE 6

Fig - 6

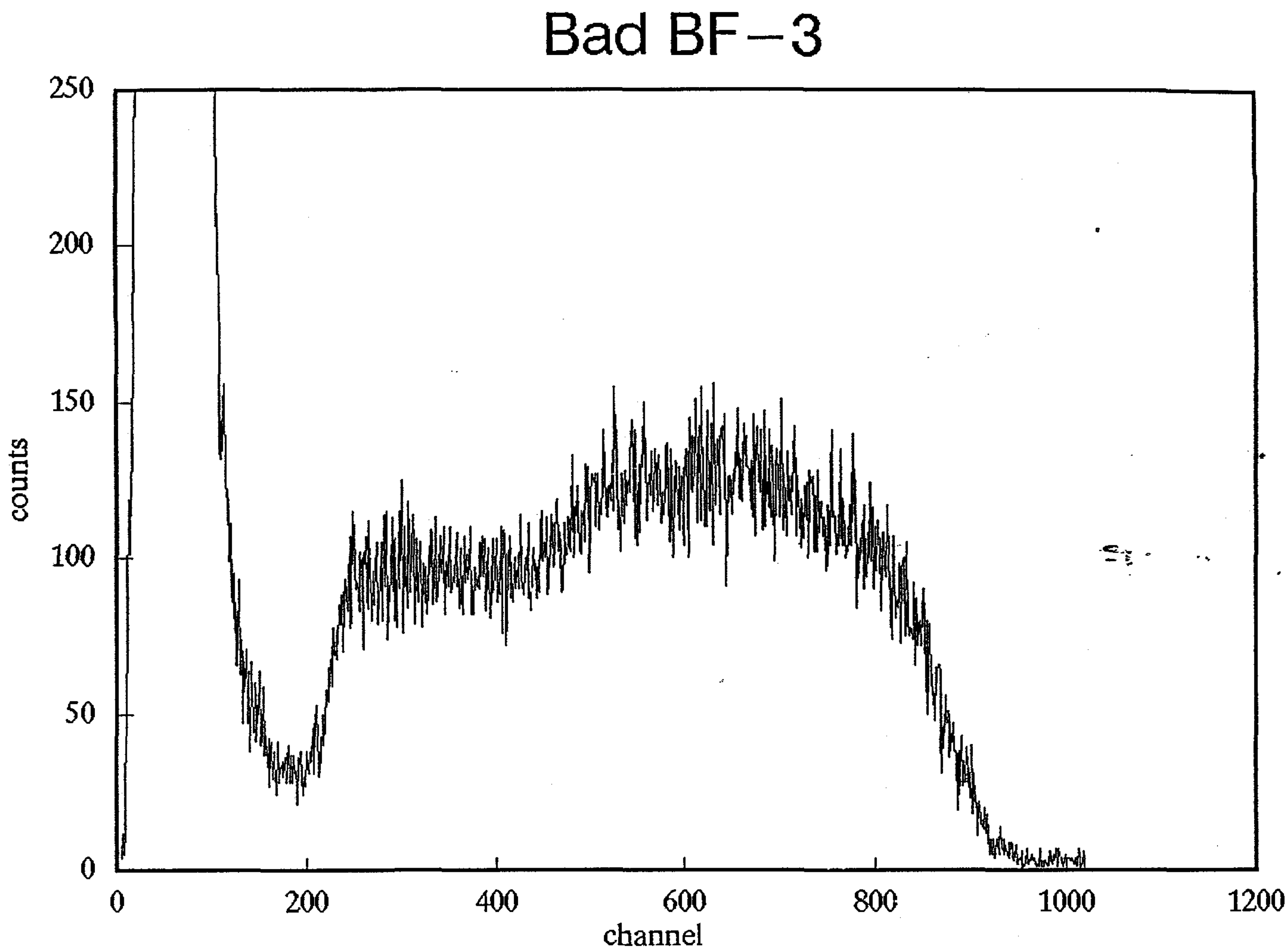

Bad BF−3
counts
channel
250
200
150
100
50
0
0
200
400
600
800
1000
1200

FIGURE 7

through 7 show used, marginal, and bad tubes. The ^{3}He reaction yields similar spectra.

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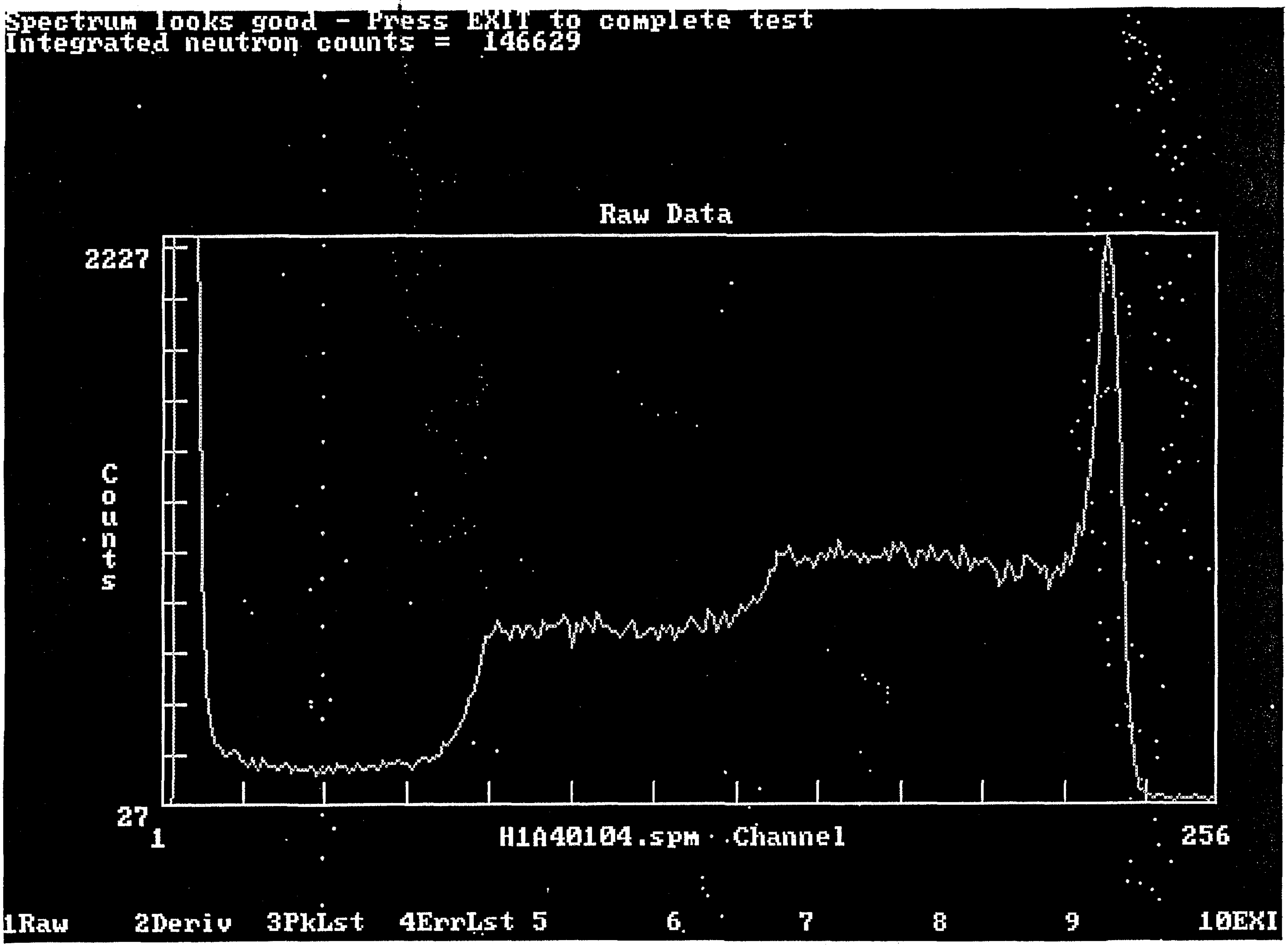

Spectrum looks good - Press EXIT to complete test
Integrated neutron counts = 146629
Raw Data
2227
Counts
27
1
H1A40104.spm Channel
256
1Raw
2Deriv
3PkLst
4ErrLst 5
6
7
8
9
10EXI

FIGURE 8

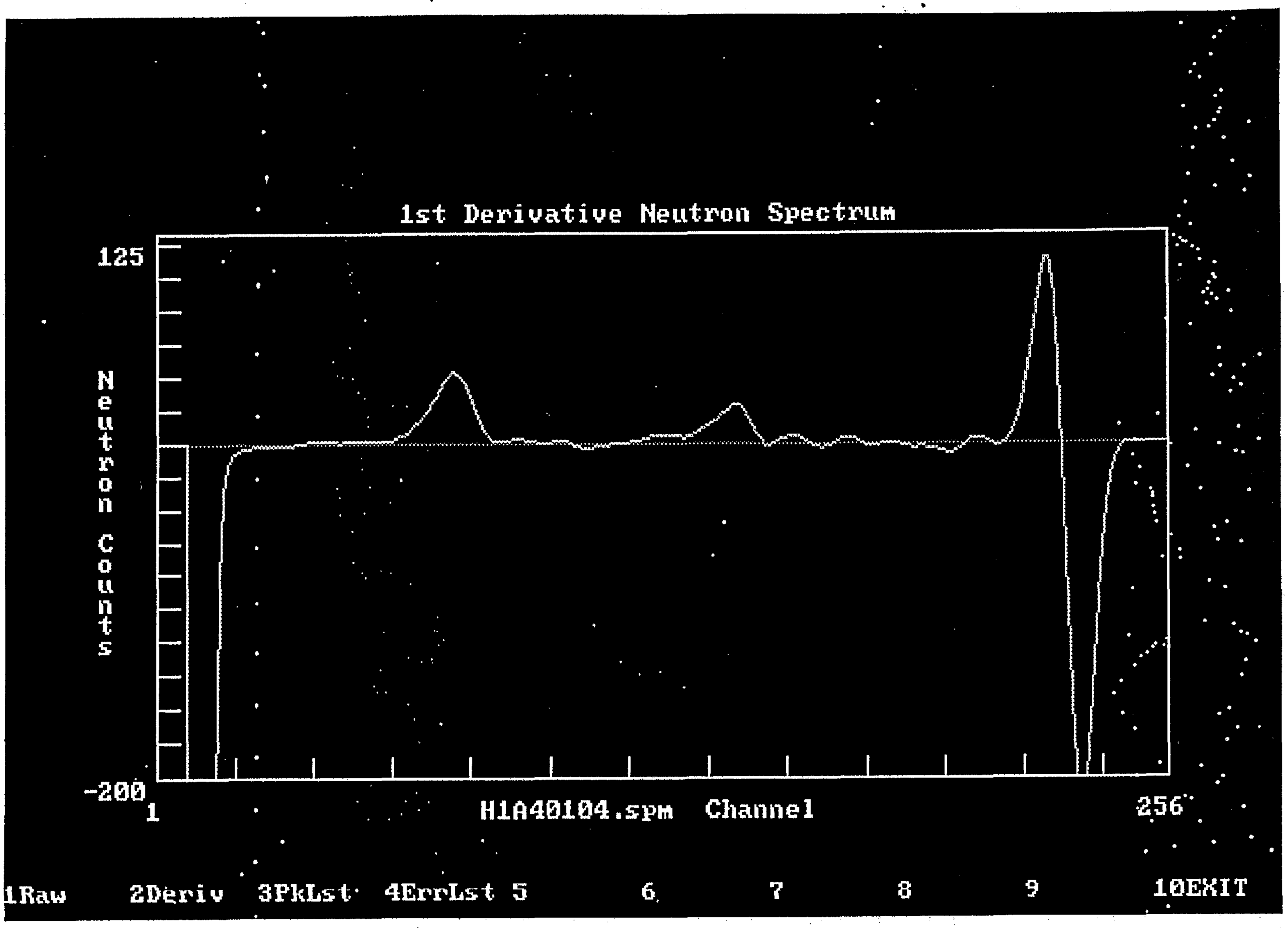


FIGURE 9

Fig 9

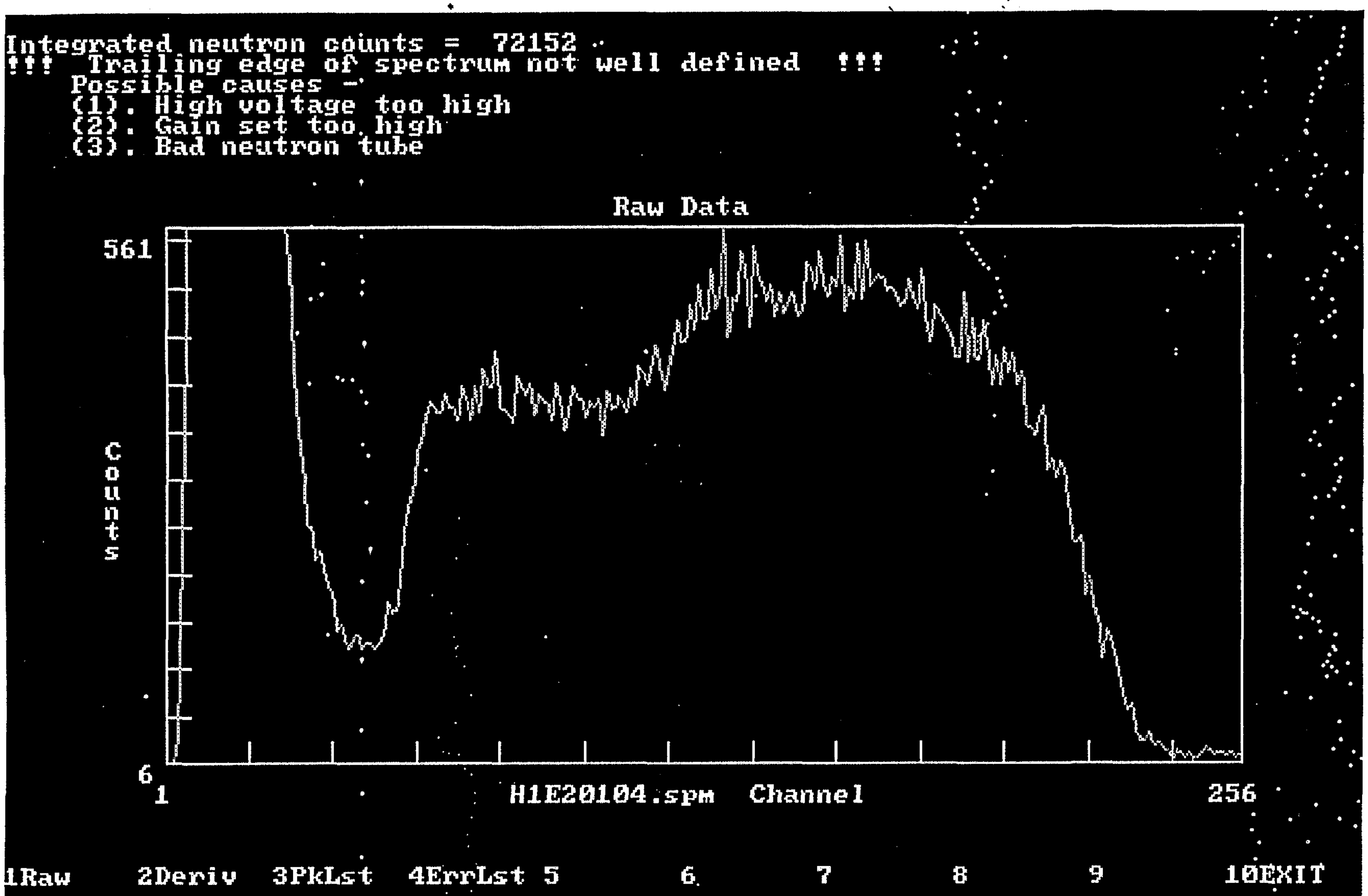
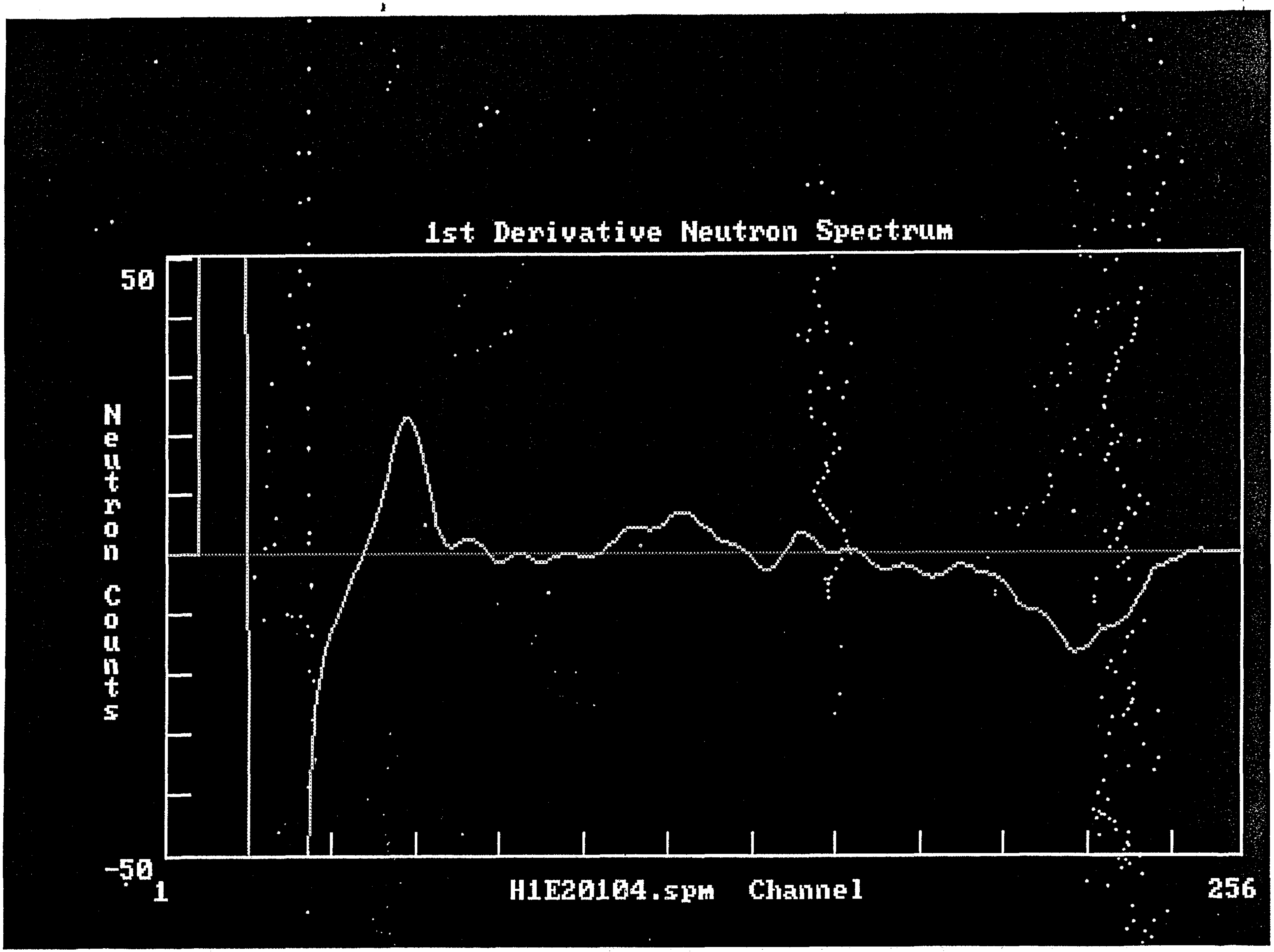


FIGURE 10

Fig 10



1st Derivative Neutron Spectrum
50
-50
Neutron Counts
1
H1E20104.spm Channel
256

FIGURE 11

```
***********************************************************************
*
*     F CANYON NEUTRON MONITOR
*  FUNCTIONAL VERIFICATION PROGRAM
*          pre-release version 0.1, 12/2/93
*             FOR EVALUATION USE ONLY
***********************************************************************
*
*      Select the bank and point that you want to verify:
*
*  1. 1B, pt. 1        3. 2A, pt. 1       5. 2B, pt. 1
*
*  2. 1B, pt. 2        4. 2A, pt. 2       6. 2B, pt. 2
*
*               7. manual operation
*
*               8. return to DOS
***********************************************************************

Enter your selection, please:
```

FIGURE 12

Fig-12

(1) This board contains it's own built in analog to digital converter (ADC). There is no need to add one to the electronics in the NIM bin.

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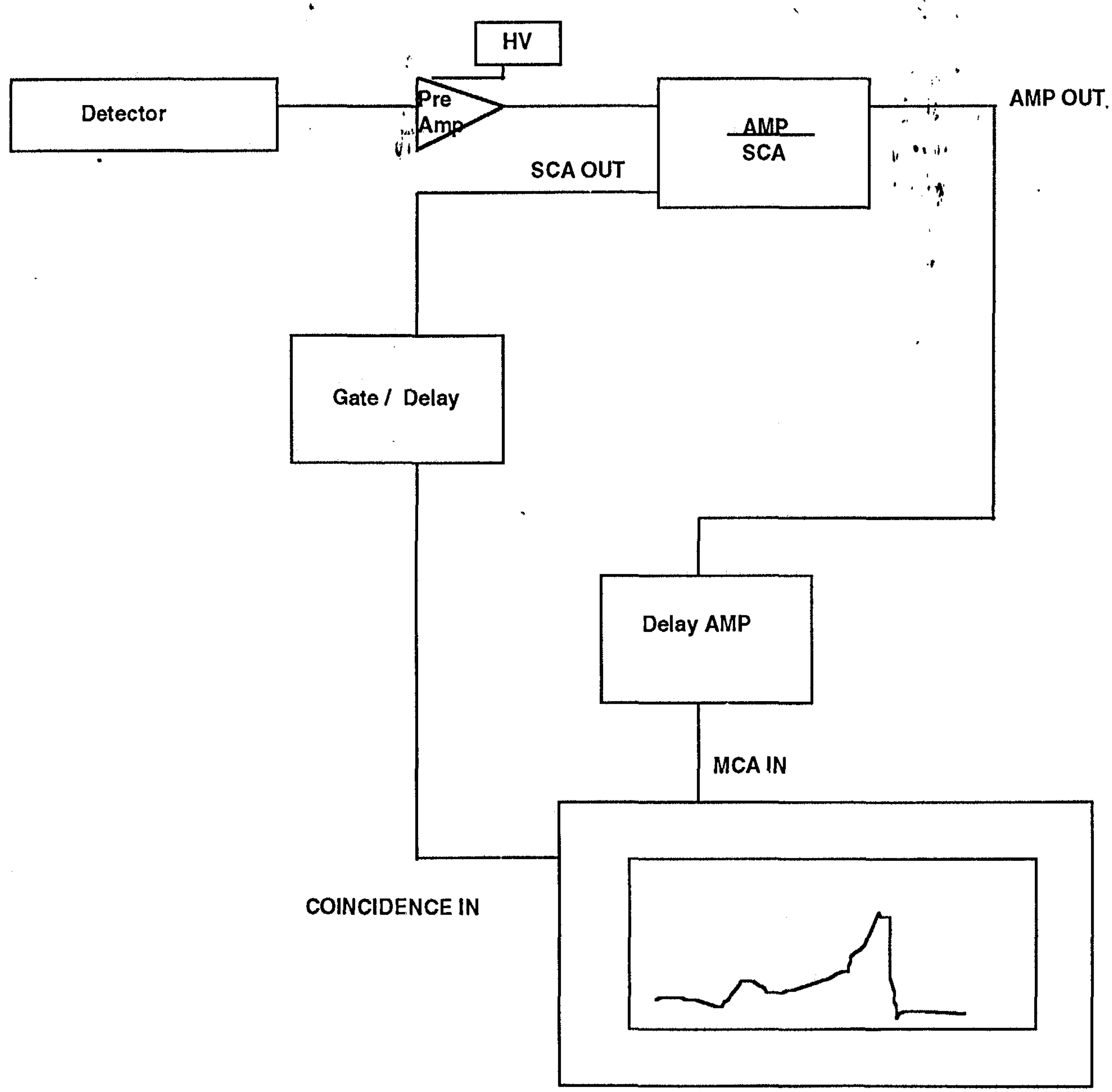
HV
Detector
Pre
Amp
AMP
SCA
AMP OUT
SCA OUT
Gate / Delay
Delay AMP
MCA IN
COINCIDENCE IN

FIGURE ~~IX~~ 13

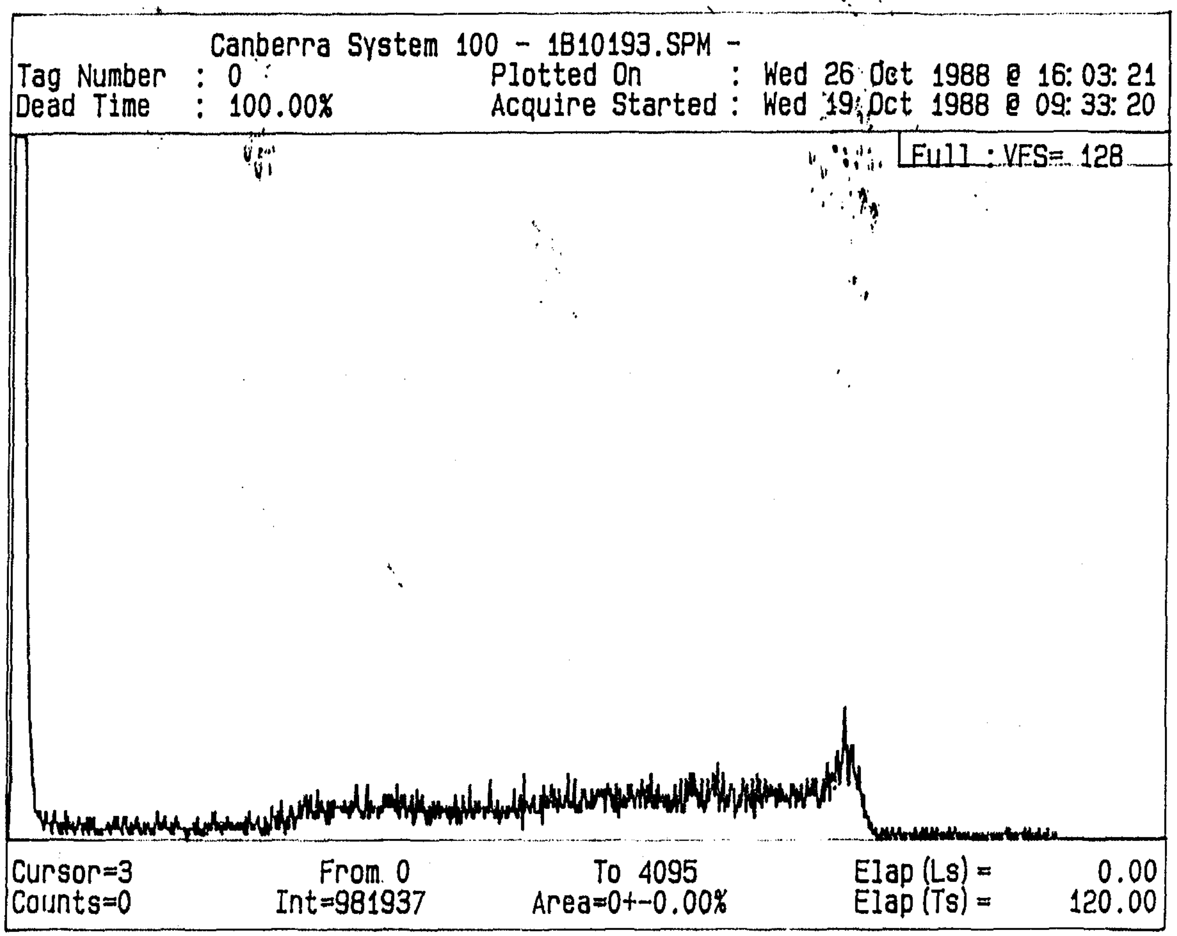

fig 14

FIGURE 14

RF of 1 B 221-F normal :

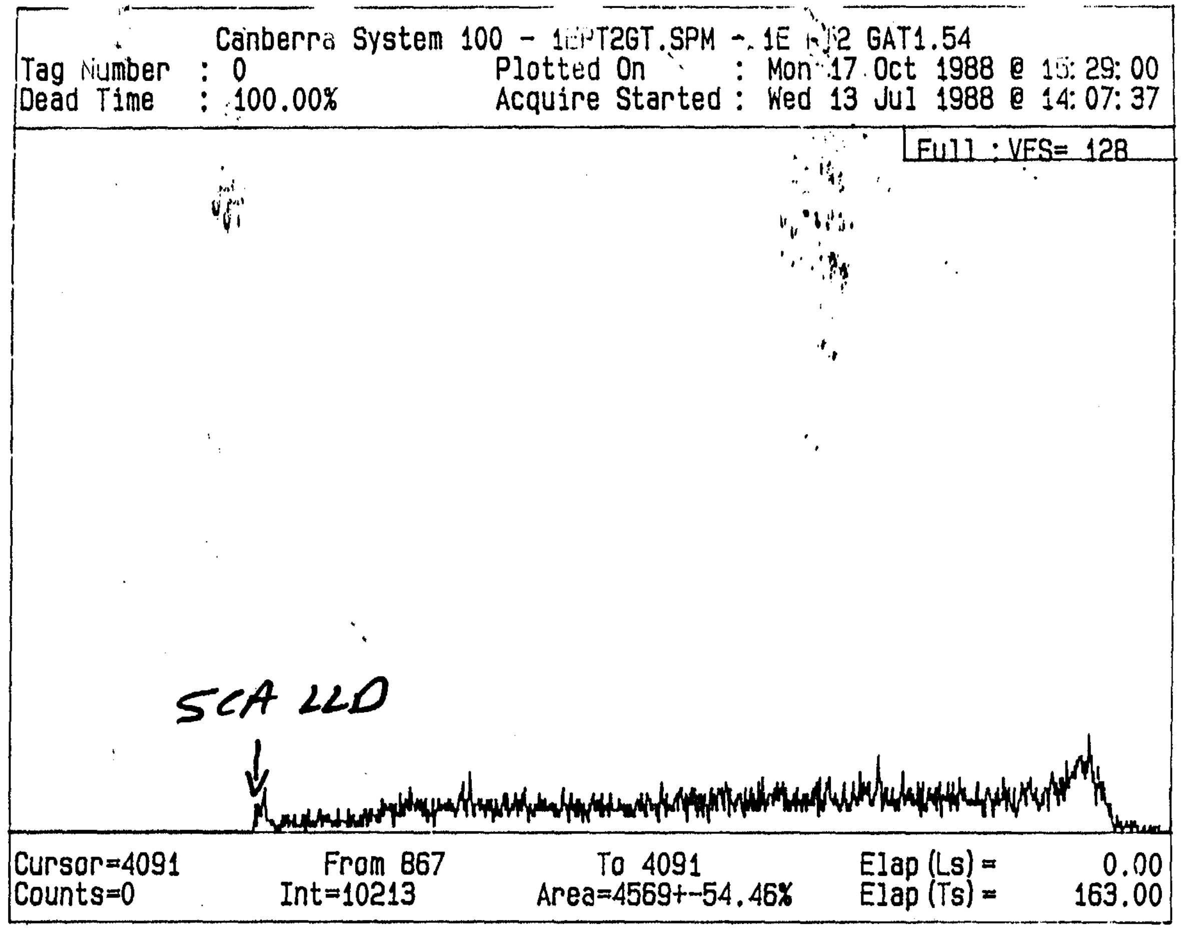

FIGURE 15

221H 1E PT2

add the appropriate input file. The software works equally well with BF_3 and $_3He$ gas-filled tubes.

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