

**Control and Evaluation Programs
for
TANSY-KM5**

by

**Gudmar Grosshög, Dan Aronsson,
Magnus Hoek, Ryszard Rydz,
Lennart Norberg, and Lasse Urholm**

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1. Introduction

No computer suitable to serve as a host computer was available at our department at the time of the start of the TANSY project. Our first task was to purchase a computer and to create a basic software library for the preliminary tests of the components. Our choice was a Starburst system from CES¹. The computer was a PDP-11/70 on a chip. It is the same computer as the ones used by the auxiliary CAMAC crate controllers in the TANSY system [3]. However, the host has a 256 kbyte memory instead of the 64 kbyte memory used in the crate controllers.

The operation system is RSX11-M. It is a real time system with properties suitable for laboratory works. However, the computer works in 64 kbyte partitions which limits the size of the programs. An overlay technique can be used in order to enlarge the size. We tested that technique but found it impractical. Instead we use small programs and use command sequences or chaining in order to link them together. A special COMMON area is sometimes used in order to transfer information between the programs.

A CAMAC software library was delivered with the computer. It is based on the ESONE standard. One reason for the fact that it is not possible to write programs that can be directly transferred to JET is that the CAMAC library at JET does not follow the standard. Another reason is that the NORSK DATA computers at JET may be substituted by another type of computers at the time of the installation of TANSY. Therefore, we present in this document the programs as they were used during the test period. They have to be rewritten at JET but we hope that the ideas hidden in the program system can be used and simplify the software work at JET.

We start this report by pointing out some differences between the CAMAC library used here and the JET CAMAC library, " 2. The CAMAC Library", page 5. At the beginning of the project we needed some basic tools. Four program systems were written. The two first were one-parameter systems for amplitude and time measurements using the ADCs and TDCs which later should be included in the TANSY system. These systems were supplemented with two two-parameter systems, one for time and amplitude measurements and one for time measurements on 16 detectors simultaneously. The display capabilities of these program systems have been used extensively by the TANSY programs. Therefore, a brief description has been included in the chapter: " 3. Display Programs", page 9.

The programs needed for the manipulation of the system are described in the chapter: " 4. Control Programs", page 12. The programs described give the user a possibility to manually run the system without any intervention from the normal CODAS control system. The programs have been used for calibration measurements as well as tests of the TANSY system.

The evaluation programs, " 5. Evaluation Programs", page 15, use the output file from a normal measurement. The data file may be tested for errors. The true events can be sorted into different configurations. The final one is the neutron energy sort program, which gives the neutron energy distribution.

The programs are listed in the appendix. It extends over about 130 pages and, therefore, it is included only if requested.

¹Creative Electronic Systems S.A. route Du Point-Butin 70, CH-1213 Petit-Lancy, Switzerland.

2. The CAMAC Library

We use only some of the CAMAC routines delivered by CES. The number of programs has been limited in order to simplify a transport of the programs to JET. Only three routines are necessary. However, only one-word transfers can be done then. A fourth routine has been used in order to speed up the transfers.

A main difference between a normal system and the JET system is that we use the full 24-bit words incorporated in the CAMAC system. The CODAS data taking system uses only 16-bit words. However, it is possible to collect all the 24 bits in user written routines for the NORSK DATA computers. This possibility should be used in order to have the best use of the calibration programs.

2.1. The CAMAC library start routine

Our first routine defines the position of the host computer. It is defined by CES as follows:

```

;
;CDSET - Declare channel
;
;
;   CDSET assigns an integer number to CHAN, which depends on the unit
;   number specified in the integer UNITNR. (At the moment, CDSET is
;   always set to 1.) UNITNR must equal the CAMAC slot holding the
;   ACC. CDSET must be called before any CAMAC action is started;
;   otherwise, the program will abort with CAMAC Error 6.
;
;
;   Calling sequence:
;       CALL CDSET(CHAN,UNITNR)
;
;
;   Call parameters:
;       INTEGER CHAN  = Channel identifier
;       INTEGER UNITNR = CAMAC slot holding the ACC.
;
;

```

The parameter CHAN must be defined in the calling program. The slot number of our Starburst host has been 21.

A corresponding routine does not exist at JET.

2.2 One-Word Transfers

Before any transfers can be done the branch number, the crate number, the station number, and the sub-address must be combined into a two-byte word. This is done by the subroutine CDREG, which is defined as:

;CDREG - Encode BCAN

; CDREG combines the branch number B, the crate number C, the station
 ; number N and the sub-address A into a system dependent form and stores
 ; the result in EXT. Since the method of encoding depends on the
 ; implementation, the contents of EXT should not be modified by the
 ; program.

; Calling sequence:

; CALL CDREG(EXT,B,C,N,A)

; Call parameters:

; INTEGER EXT = External address
 ; INTEGER B = Branch number
 ; INTEGER C = Crate number
 ; INTEGER N = Station number
 ; INTEGER A = Subaddress

The obtained variable EXT is now used in the routine CFSA for a three-byte transfer of data into a four-byte word or by the routine CSSA for a two-byte transfer. The routine is defined as:

;CFSA,CSSA - Execute a single CAMAC command

; CFSA causes the CAMAC action specified by the function code F to be
 ; performed at the CAMAC address specified by EXT. If F contains a
 ; READ or WRITE code, a 24 bit data transfer occurs between the CAMAC
 ; register addressed by EXT and the computer storage location INT.
 ; Otherwise INT is ignored. The state of Q resulting from the
 ; operation is stored in Q, "TRUE" if Q=1, "FALSE" if Q=0. CSSA
 ; performs the same function as CFSA except that INT contains a
 ; 16 bit data word.

; Calling sequence:

; CALL CSSA(F,EXT,INT,Q)
 ; CALL CFSA(F,EXT,INT,Q)

; Call parameters:

; INTEGER F = CAMAC function in range 0-31
 ; INTEGER EXT = Encoded BCNA from CDREG call
 ; INTEGER INT = Single or double length data or target
 ; LOGICAL Q = Q response target

The corresponding routines at JET are CMDMOD and CMFMSA, respectively. However, the variable EXT does not contain the subaddress. The subaddress is included as a separate variable in the word transfer program. The commands are:

CALL CMDMOD(BCS,B,C,S)
 and
 CALL CMFMSA(BCS,A,F,INT)

where BCS is a combination of the branch, the crate and the station.

2.3 Burst Transfers

The above routines are useful for CAMAC commands. However, the routine must be called for each transfer which is time consuming and unnecessary if the same command is done repeatedly. The burst transfer routines or repeat block transfers, as they are called in the CES package, are useful for reading or writing to CAMAC memories. In the CES package the CDREG routine is used again for the combination of the branch, the crate, the station, and the subaddress. A four-word control block is used to transfer information about the transfer to the transfer routine. The first word of the block contains the number of words to be transferred. The routine is defined by CES as:

```

;
;CFUBR,CSUBR - Repeat mode block transfer
;
;
; CFUBR causes the single CAMAC function specified by the contents of
; F to be executed at the CAMAC address specified by the contents of
; EXTB with the usage of the Q response. In the repeat mode the CAMAC
; address is never changed, but the single address is expected to
; supply or accept many words of data. Q is used as a timing signal.
; Q=1 indicates that the previously executed function succeeded. Q =0
; indicates that the module was not ready to execute the function and
; that the controller should try again. Any data words transferred are
; placed into or taken from the array INTC. If the response is Q=0, no
; transfer took place, and the index into the array INTC is not
; changed. The number of Q=1 responses is given by the contents of the
; second element of CB. If the third element of CB contains zero, the
; process is initiated immediately, if it contains a LAM identifier,
; the process is initiated only when the specified LAM is recognised.
;
;
; CSUBR performs the same function as CFUBR except that the array INTC
; contains truncated data (16 bit words instead of 24). Note that
; INTC is assumed to be a 16 bit integer array.
;
; Calling sequence:
; CALL CFUBR(F,EXTB,INTC,CB)
; CALL CSUBR(F,EXTB,INTC,CB)
;
; Call parameters:
; INTEGER F = CAMAC function in range 0-31
; INTEGER EXTB = Encoded BCNA from CDREG call
; INTEGER INTC = Single or double length data or target array
; INTEGER CB = Control block
; CB(1) = Repeat count to be executed in words
; CB(2) = Actually executed repeat count in words
; CB(3) = LAM identifier to start by LAM
; (Not implemented)
; CB(4) = Chan identifier to stop transfer by lam
; and clear it.
; (Not implemented)

```

The method at JET is identical to the above. Here a routine called CMDREG corresponds to CDREG and CMFUBC corresponds to CFUBR. The calls are

```
CALL CMDREG(EXTB,B,C,S,A,)  
and  
CALL CMFUBC(F,EXTB,INTC,CB)
```

where the parameters are the same as those defined by CES.

3. Display Programs

Display programs are needed for the presentation of the large data areas created by the TANSY system. A problem with a small computer system, as the Starburst system used here as a host computer, is that the data areas can not be kept in the computer memory. One way to solve this problem is to use the data disks and shuffle the data to and from the memory. However, this is tedious. We have instead chosen to use the CAMAC memories as temporary storage of data. This method shall of course be abandoned as soon as a computer with a larger memory is available.

The display programs used were written in order to create basic laboratory instruments out of the CAMAC system. Four program packages have been written. The AD1 package uses one ADC and one 64 kword CAMAC memory as an amplitude multi-channel analysis system. The TD1 uses one TDC and one memory for a multi-channel time analysis system. The TA1 uses one ADC, one TDC, and one memory for a two-parametric time-amplitude system and TM1 uses one TDC with up to 16 detectors for a multi-detector time analysis system.

The systems were used for basic studies of parts of the TANSY system during the early days of the project. Later, only the display capabilities have been used together with data from the complete TANSY system.

The systems are written for the Starburst computer controlled through the TEKTRONIX terminals model 4207. They can not be transported to JET. Therefore, we do not give the listings of the programs. The purpose of this chapter is to explain those features that are of importance for the understanding of the programs written for TANSY. Another display system must be used at JET.

3.1 AD1 - Amplitude Analysis

The AD1 package is written for the LeCroy High Performance Buffered Spectroscopy ADC, model 3512. The ADC is by an external cable connected to the CES histogramming memory model HM-2161.

The memory is divided into 8 parts containing 8192 channels each. The first part is the ADC storage area. The remaining 7 parts can be used for storage of old spectra. Any part of the memory can be displayed on the terminal screen. 8 regions can independently be defined and simultaneously be displayed on the screen. Each region may contain up to 8192 channels. Compress factors are included in order to decrease the display time.

The display abscissa can be defined in channels or energy. The energy conversion is linear, i.e. only an energy offset and the energy per channel are used in the conversion. The ordinate may be linear or logarithmic. The maximum value of the scale may either be fixed by a preset value or automatically set by the maximum value of the displayed region. See figure 11, "The Neutron Spectrum", page 25.

The package contains several features which will not be described here. However, one feature often used in the TANSY system is the peak analysis option. A subregion is defined by the cursor. It is assumed that the subregion contains a peak. Several features of the peak are calculated. Among them are the FWHM value of the peak. It is defined as the difference between the outermost half-maximum values of the peak. The search for the limits is done from the outside which means that the FWHM value will be overestimated (and uncertain) at small intensities. See figure 13,

"An Analysis of the Final Spectrum", page 26, figure 1, "The Proton Detector Amplitude Distribution in Experiment B377", page 19, and figure 14, "An Analysis of the Direct Spectrum", page 26.

The first 8192 channels may be stored in a data file. The data file named exp.A1D is written in blocks of 128 four-byte words. The open statement is:

```
OPEN(UNIT=2,FILE=F,STATUS='NEW',RECL=128,BLOCKSIZE=1024,  
& FORM='UNFORMATTED',ERR=900)
```

and the write statement repeated 64 times is:

```
WRITE(2) (ID(K),K=1,128)
```

A parameter area called exp.A1P is stored at the same time. It contains experiment as well as display parameters.

3.2 TD1 - Time Analysis

The TD1 package is written for the LeCroy High Precision Wide Range Fast Encoding TDC model 4204. The TDC is by hardware connected to the CES histogramming memory model HM-2161.

The display part of the TD1 system is mainly the same as the AD1 display system. The only difference is that the scale on the abscissa is changed from energy to time. The memory and storage organisation correspond to each other. The same routines can be used for the storage files. They are named using the extensions .T1D and .T1P for the data files and the parameter files, respectively.

Examples are given in figure 2, "Direct Time Distribution", page 20 and figure 3, "Synchronized Time Distribution", page 20.

3.2 TA1 - Time-Amplitude Analysis

The TA1 package is written for the LeCroy ADC and TDC mentioned above. They are connected together by a special cable. The eight lower bits of the data word taken from the ADC are substituted by the eight lowest bits of the TDC. Therefore, the memory will be organized as a 256 by 256 channel data array with the time channel number as the fast going index.

The resolution of the ADC-data is decreased by a factor of 256. The time resolution of the TDC-data is the same as the TDC resolution but the range is decreased by a factor of 256.

The display part of the package has three options. The data may be displayed as a number of time curves each representing an amplitude interval, as a number of amplitude curves each representing a time interval, or as a time-amplitude map with colour-coded intensity levels. The display can be enlarged by defining any time-amplitude sub-region as the part of the data area to be displayed.

For examples see figure 4, "The Full Time-Amplitude Distribution", page 21, figure 5, "The Interesting Part of the Time-Amplitude Distribution", page 21, figure 10, and "Another View of the Neutron Ridge", page 24

The curves in the two first options are displayed parallel to the plotting plane, the terminal screen. However, they are displaced so that the plot gives an impression of a three-dimensional display which can be viewed from any direction.

The data storage file is written in 256 blocks of 256 four-byte words. It is defined by the open statement:

```
OPEN(UNIT=2,FILE=F,STATUS='NEW',RECL=256,RECORDTYPE='FIXED',  
& FORM='UNFORMATTED',ERR=900)
```

The data files are named with the extension .TAD and the corresponding parameter file names have the extension .TAP.

3.4 TM1 - Multi-detector Time Analysis

The TM1 package makes use of the multi-detector capacity of the LeCroy TDC model 4204. The memory is organised as 16 time spectra with 4096 channels each.

The display part of the package has only one option. The data from each detector are displayed as time curves. The curves are displaced as the curves in the TA1 package.

The pattern in the data file is the same as in the TA1 package. The same open definition is used. The data file is named with the extension .TMD and the parameter file name has the extension .TMP.

An example is figure 15, "Display of the Neutron Detector Scaler Data", page 28.

4. Control Programs

A control program must be available in the host computer in order to manipulate the Starburst auxiliary crate controllers from a host terminal. Two control programs have been used during the test period, one for the control of calibration and test measurement and another one for writing of the parameters into the parameter area in the Starburst. They have been given the names CON and SETUP and exist in two versions, one for each branch. Furthermore, some programs are needed for fetching the results of calibration measurements.

4.1 Starburst Control

The Starburst control program contains a number of options. The most important of them are presented in the following menu:

| |
|---|
| <p>Starburst slave A control</p> <p>I = Initialize crate P = Prepulse B = Begin= Start of pulse M = Manual control, (QM=quit) W = Write the memory content S = Status Q = Quit</p> |
|---|

Option I initializes the crate. A Z control signal is sent to the crate and the inhibit control signal is set to its off-state.

Option P followed by option B simulates a CODAS start. The modules are set to values given in a parameter file CON.PAR as they will be set by the GAP tree during normal operation. The memories are cleared in order to have a well defined state of the system. Option B gives a start of CTM1 by a CAMAC command. This simulates the external start signal normally provided by CODAS.

Option M opens a direct command channel to the Starburst. The host terminal behaves as a terminal connected directly to the controller. It is now possible to set parameters and give all the commands defined in the Starburst data collection program [3]. This option is normally used during calibration measurements and tests of the instrument. Note that the modules are set by the controller calibration programs to predetermined values which can not be changed. However, at the time of measurement the CODAS takes over the responsibility of the settings of the modules. The command "QM" is used to leave this sequence and return to the main menu.

Sometimes it is valuable to get a quick check of some part of the memory content. This can be done by option W which prints any part of the three memories on the terminal screen. Option S gives the state of the system. The Starburst state, the CTM1 state, and the CPG3 state are reported as follows:

```

Option ? S
Kernel    ÇÇ
User      ÇÇ
Set       ÇÇ
Source    ÇÇ
Control   ÇÇ

Time interval    32896
Timer states    0 0 0-2
Timer outputs    0 0 0 0

CPG3 status =           0
CPG3 IN UNDEFINED STATE

```

Neither the slave Starburst, the CTM1, nor the CPG3 were available at this print-out. Finally, option Q terminates the program.

4.2 Starburst Setup

All Starburst parameters are undefined until they have been set either manually or by a parameter set-up routine. The purpose of the SETUP program is to transfer the parameters from a file in the host to the Starburst.

The parameters are stored in a file which can be easily edited by the host computer editor. The first part of a data file used during the laboratory tests is given below:

```

;Data after experiment 348, 31-MAY-90
;
; Parameters for KM5 branch A
; Syntax: ; in first position = comment line
;         Three letters in the first positions = parameter name
;         a / in position 4 after the name = parameters on 2 lines
;         The parameters are capital letters or figures separated by
;         anything else.
; Branch AA or BB, ASCII.
;BRN    AA
; Option of data, date or some other identification of the data,
OPT     19
; Number of memories in the system, 1, 2, or 3
MSY     3
; Number of kwords stored in JPF, 64 kbytes/memory
MJP     192
; Memory number in use, 4= end of memory
MEN     0
; A pointer to memory position
MPO     0
; Automatic amplitude calibration
; Lower levels of intervals, channels.
;     lower limit channel included but not upper
CLL     2000    7200    0
; Higher levels of intervals, channels.
CLH     2200    7500    0
;
; Data for the neutron detectors
;
; Identification numbers for the neutron detectors
NDI/    12941    12943    12908    12952    12953    12922    12923    13023
        13020    12924    12927    12918    12917    12949    12951    12912
-----

```

4.3 Fetch of Test and Calibration Results

The display packages, " 3. Display Programs", page 9, use different data formats. Therefore, different routines must be used for the different calibration modes.

The result of an amplitude calibration measurement is saved in the files Aiexp.A1D and corresponding parameters in Aiexp.A1P where exp is the experiment number and i is 0, 1, and 2 for the A branch and 3, 4, and 5 for the B branch. The results can be displayed by the AD1 package.

The result of a time calibration measurement is saved in the files Tiexp.TMD and corresponding parameters in Tiexp.TMP. The results can be displayed by the TM1 package.

The result in the Starburst calibration areas is saved in the files Siexp.A1D and corresponding parameters in Siexp.A1P. The results can be displayed by the AD1 package.

The result of a measurement is in a special shape and can not be directly displayed. It is saved in the files Miexp.KMD and corresponding parameters in Miexp.KMP where exp is the experiment number and i is A for the A branch and B for the B branch. The result in the scaler memories is saved in the files Miexp.KMS. The scaler results are saved only in some of the test measurements.

Four programs are written for numerical inspection of the memories and the Starburst. The programs REM and DREM read and display any part of the memories in octal and decimal format, respectively. The programs RE and REB read and display any part of the Starburst memory in octal word and byte format, respectively. All the programs have an option to store the result in a file for later inspection.

5. Evaluation Programs

Several programs have been written for the presentation and the evaluation of the result of a TANSY measurement. The programs use the data file with the extension .KMD which should be the same as the file stored by CODAS in the JPF (Jet Pulse File). The data file contains the parameters, the amplitude calibration areas, and the events. The parameters may be changed during the evaluation in order to correct errors that might be inserted in the parameter part of the file.

We will use the test experiment no. 377 in order to illustrate the process and its options. Experiment no. 377 was performed on 29th of June 1990. A 2.4 mg/cm² foil gave by the evaluation done at that time a resolution of 330 keV FWHM at an energy of 14.075 MeV. The proton detector count rate was about 40 c/s and the sum of the neutron detector pulse frequencies was about 2.4 MHz.

5.1 A First Test of the Measurement Data

Our first task is to inspect the file. We use PRTEV and get the following print-out for some of the events, see [3]:

```
>R PRTEV
Include time-markers (Y/N)?Y
Include true events (Y/N)?Y
Include false events (Y/N)?Y
Experiment number (xxxx) B377
From event number 930
To event number 960
```

| Event: | Octal words | Pdet | Ampl. | Ndet | Time | Pattern | Error |
|--------|-------------|--------|-------|------|-------------|---------|--------|
| 931: | 51523 | 32341 | 2 | 4947 | 3 | 1249 | 0 |
| 932: | 126336 | 21616 | 1 | 3294 | 2 | 910 | 177 2 |
| 933: | 46625 | 32661 | 2 | 3477 | 3 | 1457 | 0 |
| 934: | 10107 | 63411 | 0 | 4167 | 6 | 1801 | 0 |
| 935: | 126336 | 22506 | 1 | 3294 | 2 | 1350 | 177 2 |
| 936: | 11021 | 53061 | 0 | 4625 | 5 | 1585 | 0 |
| 937: | 11302 | 112606 | 0 | 4802 | 9 | 1414 | 0 |
| 938: | 11274 | 143276 | 0 | 4796 | 12 | 1726 | 0 |
| 939: | 47337 | 73205 | 2 | 3807 | 7 | 1669 | 0 |
| 940: | 10015 | 22451 | 0 | 4109 | 2 | 1321 | 0 |
| 941: | 51376 | 72775 | 2 | 4862 | 7 | 1533 | 0 |
| 942: | 11470 | 131660 | 0 | 4920 | 11 | 944 | 0 |
| 943: | 126556 | 22173 | 1 | 3438 | 2 | 1147 | 200 2 |
| 944: | 126556 | 22077 | 1 | 3438 | 2 | 1087 | 200 2 |
| 945: | 50771 | 12112 | 2 | 4601 | 1 | 1098 | 0 |
| 946: | 126556 | 23243 | 1 | 3438 | 2 | 1699 | 200 2 |
| 947: | 126556 | 23152 | 1 | 3438 | 2 | 1642 | 201 2 |
| 948: | 126556 | 22503 | 1 | 3438 | 2 | 1347 | 201 2 |
| 949: | 147253 | 12135 | 2 | 3755 | 1 | 1117 | 5000 1 |
| 9: | 71074 | 8 | 10 | 5 | Time marker | | |
| 951: | 50434 | 72345 | 2 | 4380 | 7 | 1253 | 0 |
| 952: | 126556 | 22731 | 1 | 3438 | 2 | 1497 | 201 2 |
| 953: | 126556 | 23452 | 1 | 3438 | 2 | 1834 | 201 2 |
| 954: | 51207 | 123106 | 2 | 4743 | 10 | 1606 | 0 |
| 955: | 46172 | 22536 | 2 | 3194 | 2 | 1374 | 0 |
| 956: | 126556 | 22575 | 1 | 3438 | 2 | 1405 | 201 2 |
| 957: | 126556 | 23060 | 1 | 3438 | 2 | 1584 | 201 2 |
| 958: | 47661 | 133423 | 2 | 4017 | 11 | 1811 | 0 |
| 959: | 47272 | 142635 | 2 | 3770 | 12 | 1437 | 0 |
| 960: | 126556 | 22340 | 1 | 3438 | 2 | 1248 | 202 2 |

Event 931, the first one on the list, is caused by a coincidence between proton detector 2 and neutron detector 3. It is a correct event with a proton energy corresponding to channel 4947 and a time corresponding to channel 1249. Event 932 is erroneous. It is error no. 2 indicating that the amplitude is wrong. The hit pattern is undefined. Error no. 1 is indicated in event 949. Here we see from the hit pattern that we have a double hit. The hits are coming from neutron detectors 9 and 11. The decoder in the TDC has given it the value 1 which is completely unreliable.

The event 950 is the time marker no. 9. The number of time ticks in the Starburst internal clock was 71074. During the last time interval there have 8, 10, and 5 events with times lower than the software time limits of proton detector line 0, 1, and 2, respectively.

The large number of type 2 errors indicates that something is wrong. A check of the proton detector discriminators showed that the errors were caused by too low discriminator levels.

5.2 The Parameter Fetch

Our next step is to fetch the parameters from the parameter area and put them in a shape suitable for the analysis programs. The GMEPAR program, used during the test runs, fetches only the parameters used in the evaluation programs described later. The program determines the energy calibration parameters from the stored calibration spectra. The corresponding default values from the parameter file are displayed and it is left to the user to choose either the default or the new values. The status of the proton detectors can be judged upon from the calculated widths. From our experiment B377 we get:

```

>R GMEPAR
Experiment number (xnnn) B377
Result in file DU1:MB377.MPR
Proton energy calibration
Analysis of detector      0
Am at channel  2101.78, width      54.808 keV.
PG at channel  7352.84, width      49.476 keV.
Default E0, ED  -6.580000      2.611300
New      E0, ED  -8.922363      2.611089
Shall we use new (N) or default (D) values ? N
Analysis of detector      1
Am at channel  2070.09, width      50.417 keV.
PG at channel  7378.31, width      42.609 keV.
Default E0, ED  -34.08000      2.666200
New      E0, ED  -56.73633      2.674153
Shall we use new (N) or default (D) values ? N
Analysis of detector      2
Am at channel  2222.79, width      51.215 keV.
PG at channel  7348.41, width      41.045 keV.
Default E0, ED  -7.510000      2.471700
New      E0, ED  -46.29785      2.485749
Shall we use new (N) or default (D) values ? N

```

The position of the detectors is given in the file parameter list. However, the evaluation programs need the mean flight lengths of the proton and the neutron. GMEPAR calculates these distances. For the measurements at our laboratory we use a

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routine which takes into consideration that we have a point source (" A4.5 CTHUNDERP.FTN", page 114). Another routine must be used for the almost parallel beam at JET. Such a routine is supplied in the program listings (" A4.6 JETUNDERP.FTN", page 116).

GMEPAR creates a file with the extension .MPR. It looks as follows:

```

; Parameters from DU1:MB377.KMD
VRS 0 0 (I3) 6          Version
BRN 0 0 (A1)B          Branch
OPT 0 0 (I3)375        Option of data
CLL 0 0 (I6) 2000      Low level of calibration region
CLL 1 0 (I6) 7200
CLL 2 0 (I6) 0
CLH 0 0 (I6) 2300      High level of calibration region
CLH 1 0 (I6) 7500
CLH 2 0 (I6) 0
CSN 0 0 (I6) 3          Number of calibration/2
CSN 1 0 (I6) 1
CSN 2 0 (I6) 4
TLL 0 0 (I6) 70        Lower level time limits
TLL 1 0 (I6) 70
TLL 2 0 (I6) 70
TUL 0 0 (I6) 150       Upper level time limits
TUL 1 0 (I6) 150
TUL 2 0 (I6) 150
FTH 0 0 (F7.2) 2.40    Foil thickness
TMP 0 0 (I6) 1006      Number of time markings
NSC 0 0 (I6) 20        Number of scalers used
CDO 0 0 (I6) 256       Count down factor of scalers
ERC 0 0 (I11) 16918    Number erroneous events
CMC 0 0 (I6) 52410     Measurement, calibration time
CMV 0 0 (I6) 3524      wait after calibration time
CMP 0 0 (I6) 10091     pulse measurement time
CMW 0 0 (I6) 0         wait after pulse time
; Neutron flight lengths
LND 0 0 (F7.2) 99.84
-----
LND 2 15 (F7.2) 101.15
; Proton flight lengths
LPD 0 0 (F7.2) 15.39
-----
LPD 2 15 (F7.2) 19.57
; Neutron det calibration times, ns
NDT 0 0 (F7.2) 70.00
-----
PDT 2 0 (F7.2) 2.68
; Proton energy calibration
PDE 0 0 (E14.6) 0.261109E+01
PE0 0 0 (E14.6) -0.892236E+01
PDE 1 0 (E14.6) 0.267415E+01
PE0 1 0 (E14.6) -0.567363E+02
PDE 2 0 (E14.6) 0.248575E+01
PE0 2 0 (E14.6) -0.462979E+02

```

The file is written in a special format. Comments are marked by a ";" in the first position. Otherwise the three first positions of a line is the parameter name. It is followed by two three-position indices. Next is the format within parenthesis and finally the value formatted according to the given format. Keeping the format as a part of the line gives a great freedom at the time the file is written or edited. Some part of the parameter list coming from the data file might be incorrect. Here is the place where such errors can be corrected simply by editing the file.

5.3 The Sort Program Package

The result of a measurement is a long row of events. These shall be sorted and arranged into histograms in order to obtain readable information. The histograms may present different aspects of the measurement. However, the goal is a neutron energy distribution.

A package of programs has been written for the presentation of the data. They are collected and controlled by a command routine which has a menu as follows:

```

-----
Sort Starburst list data
CL = Clear memory
PA = Set parameters, edit
D = Display result
Q = Quit
AD = Proton amplitudes
TD = Neutron times
TA = Neu. time and prot. ampl.
EG = Neu energy vs Geom factor
NE = Neutron energy
-----

```

Only the most important options are given in the above list. They were added to the list in the order of creation. Here they are arranged in a more logical succession.

5.3.1 Sort Control Options

Four options are used for the control of the package.

The package uses one CAMAC memory for the building of histograms. The memory is not cleared by the different options. We may want to add information from different experiments. Therefore, the clearing of the memory must be done by the CL-option at the beginning of each new building of a histogram.

The parameters of the evaluation and sorting are set by the PA-option. It calls the editor with the parameter file "A5.4 SRT.PAR". The parameter file looks as follows:

```

; SRT parameters
FIL 0 0      (A19)DU1:[6,67]MB377.XXX
;
; Neutron detector combinations
NCO 0 0      (A16)IIIIIIIIIIIIIIII  Neutrontdetectors I=included
;NCO 0 0      (A16)XXXXXXXXXIIIIIIII  Neutrontdetectors I=included
;NCO 0 0      (A16)IIIIIIIIIXXXXXXXX  Neutrontdetectors I=included
;NCO 0 0      (A16)XXXXXXXXXXXXXXXXXI  Neutrontdetectors I=included
;
;                                0123456789012345
PCO 0 0      (A3)III                    Protontdetectors I=included
;PCO 0 0      (A3)IXX                   Protontdetectors I=included
;PCO 0 0      (A3)XIX                   Protontdetectors I=included
;PCO 0 0      (A3)XXI                   Protontdetectors I=included
;
; Memory crate and station

```

```

MEC 0 0      (I3)000      Memory crate
MES 0 0      (I3)008      Memory station
;
TAD 0 0      (F6.2)-21.00  Common time adjuster, ns
;
; Neutron bias and channel width
DEN 0 0      (F4.0)010.    Neutron energy per channel
ENO 0 0      (F7.3)000.000 Neutron energy offset
;
; End of parameters
;

```

The syntax is the same as in the parameter file `SETUP.PAR`, "4.2 Starburst Setup", page 13. The first parameter, `FIL`, gives the experiment name. `NCO` is the neutron detector combination. The neutron detectors to be included are marked by "I". `PCO` uses the same rule for the proton detector. The position of the used memory is given in `MEC` and `MES`. `TAD` is the common time adjuster which could not be determined during the calibration process [9]. We will discuss this parameter later. `DEN` and `ENO` give the resolution and the energy offset of the eventual neutron spectrum.

Option `D` in the list starts the display package. The command routine chooses the display package according to the last used sort option.

The command routine is left by the `Q` command.

5.3.2 Proton Detector Amplitudes

Option `AD` sorts the data into three histograms, one for each proton detector. They are stored in the three first 8K memory intervals in a shape suitable for the `AD` display programs.

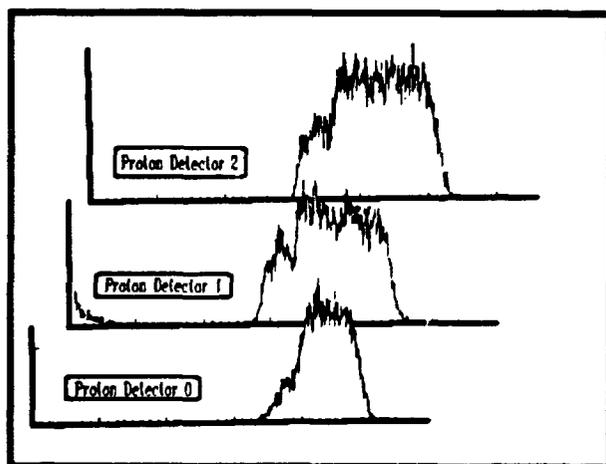


Fig.1. The Proton Detector Amplitude Distribution in Experiment B377

The three distributions in figure 1 are not the best ones that have been obtained. The discriminator level of detector 0 is higher than that of detector 1 and 2. An extra peak can be seen at the low end of detector 1 and 2. Very low amplitudes are seen in the detector 1 distribution. The experiment B377 is not clean.

5.3.3 The Time Distributions

The TD option gives two possibilities, the calibration synchronization may or may not be used.

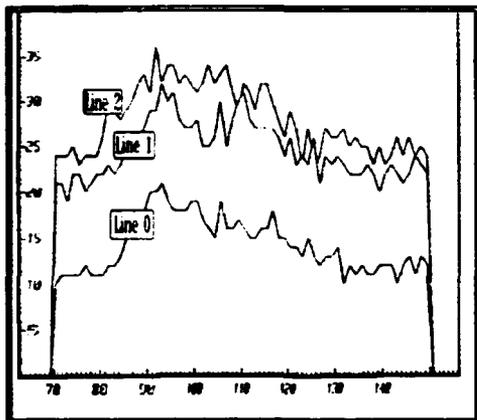


Fig.2. Direct Time Distribution

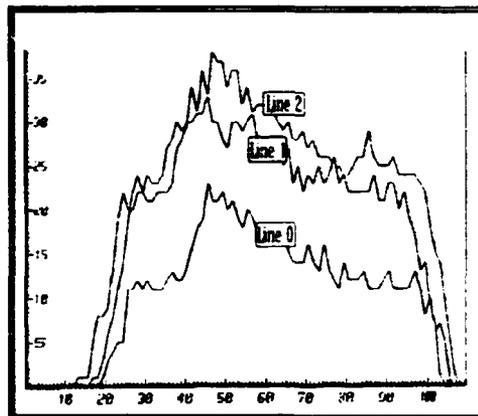


Fig.3. Synchronized Time Distribution

In the direct time distribution, figure 2, we see that the time limits are well defined. When the cobalt calibration values are used the limits will be blurred. However, the peaks are more dominant. This experiment contains a lot of background. Therefore, the peaks are obscured by the noise of the background. The high background is an obstacle that we had to fight all the time during the laboratory tests. Actually, at the time we first saw this distributions we were afraid that the method did not work. However, we will see later that we get good results even from this rather bad experiment.

5.3.4 The Amplitude and Time Distribution

The time distributions are sums over all amplitudes and the amplitude distributions are sums over all times. But the time and the amplitude are connected. A three dimensional plot is needed in order to resolve the connection between time and amplitude. This is done by the TA-option.

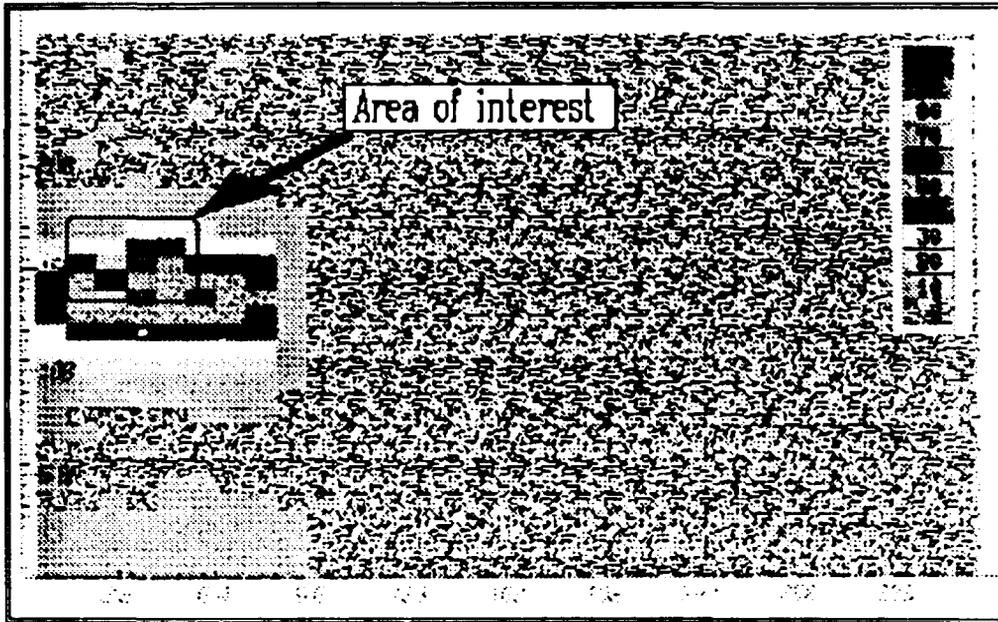


Fig.4. The Full Time-Amplitude Distribution

The time-amplitude distribution shown in figure 4 covers the entire field of information. The figure is a map over the time-amplitude field with the intensities originally coded by colour. The gray map shown in the figure can not represent the colours very well. However, it is possible to see that only a small part of the time-amplitude field is used. The part containing the interesting information is enlarged in the next figure.

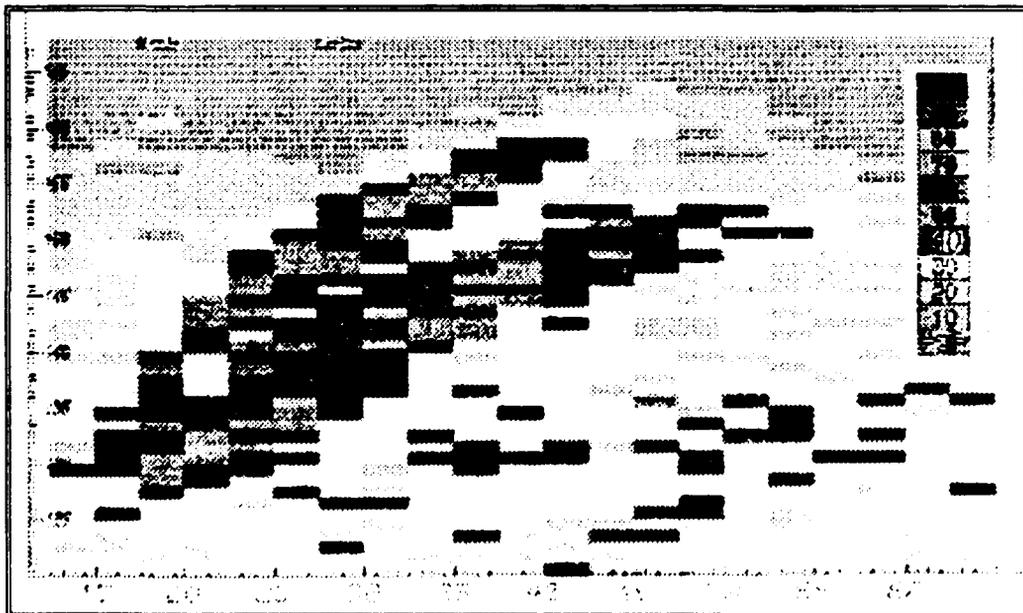


Fig.5. The Interesting Part of the Time-Amplitude Distribution

Each proton detector line creates a banana-like pattern in the time-amplitude distribution. The different lines are now synchronized in time but not in amplitude. Therefore, in figure 5 appears two bananas, one thin and one thick. The thin one comes from proton detector line 2 which has a somewhat higher amplification than the other ones. The thick one is a composition of the results from line 0 and line 1.

We could of course include amplitude calibration in the above figures. However, we prefer to see the details of the different lines here and save the energy calibration for the next step of our inspection tour.

5.3.5 The Neutron Energy - Geometric Factor Distribution

The relation between the neutron energy, the proton energy and the elapsed time between the arrival of the proton and the neutron has been presented in reference [2]. The formulae are:

$$E_n = E_p \left[1 + \left(\frac{L_n}{L_p + L_v} \right)^2 \right] \quad (1)$$

$$L_v = t v_p = t c \sqrt{\frac{2E_p}{m_p}} \quad (2)$$

where

E_n is the initial neutron energy,

E_p is the proton energy,

L_n is the neutron flight-length,

L_p is the proton flight-length,

L_v is a virtual proton flight-length,

v_p is the proton velocity,

t is the time difference between the arrival of the proton and the neutron,

c is the velocity of light in vacuum, and

m_p is the proton rest-mass in energy units.

Equation 1 can be written

$$E_n = \frac{E_p}{\cos^2(\Theta)} = E_p G \quad (3)$$

which shows that E_n is a product of two factors, the proton energy and a factor which depends on the proton recoil angle (Θ). The last factor depends only on the geometry of the system. We call it the geometric factor.

The point is that a distribution based on the parameters E_n and G is separable. Therefore, we transform our distribution into a space defined by these parameters.

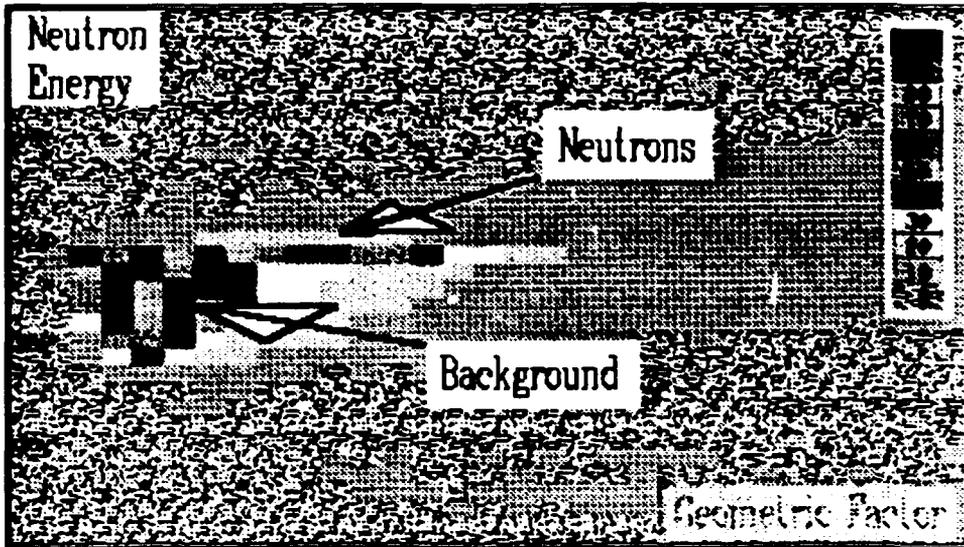


Fig.6. The Full EG Distribution

Again we start with a map, figure 6, showing a large part of the distribution. The neutron events gather into a line shaped area. The vertical width of the area is determined by the resolution of the system.

The background is concentrated to the low left part of the distribution. It is rather well separated from the neutron distribution, a fact that simplifies the background subtraction.

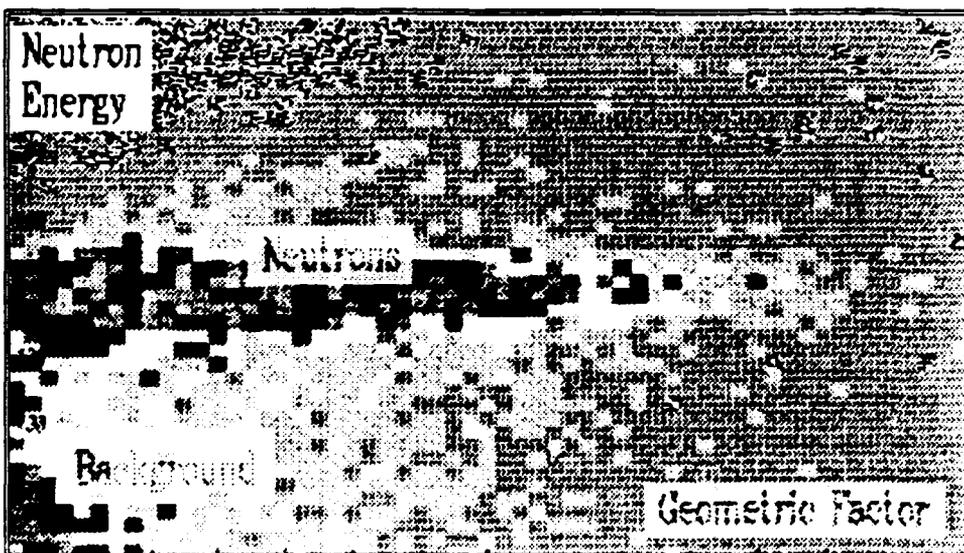


Fig.7. The Neutron Part of the EG-distribution

Figure 7 is an enlarged part of figure 6. The neutron distribution can be studied in more detail here. This presentation can be used for the determination of the time calibration parameter TAD mentioned in the chapter " 5.3.1 Sort Control

Options", page 18. A wrong value of TAD will give a positive or negative slope for the energy mean value of the neutron distribution ridge.

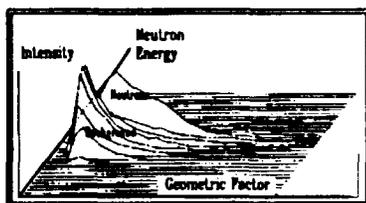


Fig.8. A View of the Full EG-Distribution

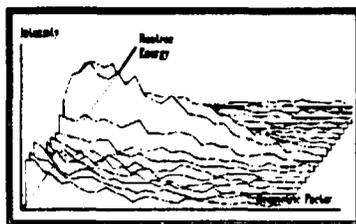


Fig.9. The Neutron Ridge

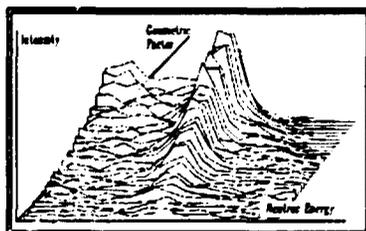


Fig.10. Another View of the Neutron Ridge

However, the distribution obtained will then contain background. We will deal with this problem in our next chapter.

5.3.6 The Neutron Energy Distribution

Before we present the final neutron distribution we will discuss two problems. The first is the background subtraction, the second is a correction for the proton energy loss in the foil.

The background is created by random events, i.e. starts of the measurement cycle that are not stopped by the detection of a true neutron. A proton detection is not followed by the detection of a corresponding neutron.

First consider an accidental start. A reaction occurs in the proton detector but it is not a proton reaction. No corresponding neutron exists and the time will run out. The event cycle will be stopped by the TDC internal stop signal. The event will not be recorded as the time is outside the software time limits. From the electronics point

The maps are suitable tools for the work with the distribution at a computer terminal. Any deviations from a good distribution can readily be seen. However, it is not a good presentation for the understanding of the distribution. The lack of colours in a publication makes it even more difficult.

Three-dimensional views are easier to understand. Therefore, we here present three 3-D views of the same distribution as in the maps. The first one, figure 8, represents the full distribution. Closest to the viewer is the background mountain. Behind it we can see the neutron ridge.

The neutron ridge is more detailed in figure 9 which is an enlarged part of figure 8. There is a valley between the ridge and the background mountain. Actually, the neutron ridge is resting on the tails of the background distribution, a fact that is more evident in the next figure.

Turning the distribution 90 degrees anti-clockwise gives us figure 10. The neutron energy axis is parallel to the paper surface and the geometric factor decreases as we step into the figure. The neutron ridge is parallel to the geometric factor axis. Therefore, it is possible to get a neutron distribution simply by summing over all geometric factors for each neutron energy.

of view this type of event is identical to a true start which is not followed by any neutron detection. The sensitivity of the neutron detectors is only about 20 percent. Only 1 out of 5 proton events will end up with a neutron detection.

The event was not recorded. That means that we use some system time, the efficiency goes down a little but otherwise we could forget everything about it. That is true as long as the neutron detectors detect only true neutrons. Unfortunately, the neutron detectors are sensitive to background. They may also pick up neutrons from events which did not start the system because the system was engaged by a previous event. We may record uncorrelated random events. The neutron detector background was the dominating part during the laboratory experiments. It is very difficult to protect the neutron detectors from neutrons coming directly from the source when the source is close to the foil.

The uncorrelated events may occur anywhere on the time scale. Those occurring after the true stop are of no interest. However, those occurring before the true event will create stops which obscure the true stops. Wrong times are recorded. The effect is often called time shielding. As a matter of fact the uncorrelated events will at high count rates obscure each other. A time distribution for an experiment with entirely random events is described not by a constant but by a function which decreases exponentially with time.

The time shielding has been investigated for KM3 and a correction program has been written for this one-dimensional case. The situation is more complicated in TANSY because we work in a two-dimensional space, time and amplitude.

The method used during the laboratory tests is based on a measurement of the random distribution. The time interval is chosen to be twice the length of the time span of the correlated events. The first half is considered to contain true and random events, the second half is considered to contain only random events. It is evaluated in the same way as the first part but the common time adjuster (TAD) is increased with a time equal to half the time interval. The time shielding effect is estimated from a comparison of time-energy areas not containing neutron interactions.

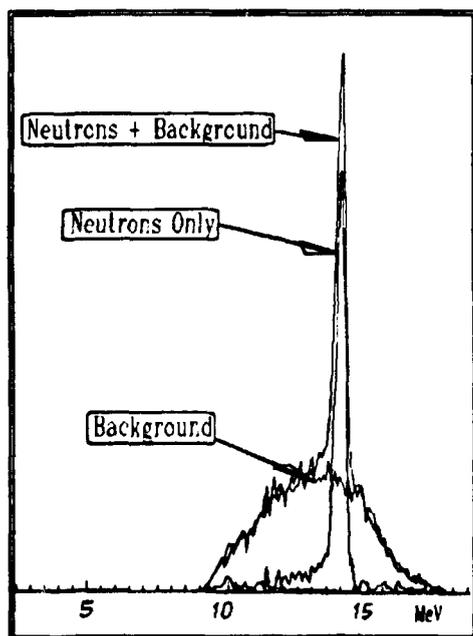


Fig.11. The Neutron Spectrum

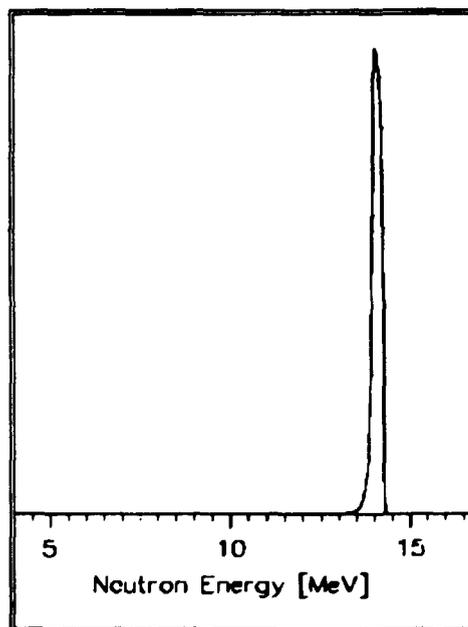


Fig.12. The Calculated Neutron Spectrum

The protons lose energy in the foil. The proton energy loss is about 30 keV per mg/cm². We do not know the place of the interaction. As an estimate we assume that all interactions take place at the centre plane of the foil and correct for the proton energy loss created by half the foil. The correction is small and its essential effect is a shift in the mean energy of the obtained spectra. The method has after the experimental time period been elaborated upon by Magnus Hoek and Ninos Garis. Their code, SPOWER, is included in the listings (" A4.7 SPOWER.FTN", page 117) but has not been used for the evaluations presented in this document.

The resulting neutron spectrum is shown in figure 11. In spite of all the troubles we have encountered in the preceding paragraphs the experiment results in a nice spectrum. Three curves are shown in the figure, a direct result including the background, the background calculated according to the above mentioned method, and the final background-subtracted spectrum. A comparison between the direct spectrum and the background shows that they coincide well outside the neutron peak. A tail can be seen in the final spectrum. It is caused by multiple scattering in the neutron detectors.

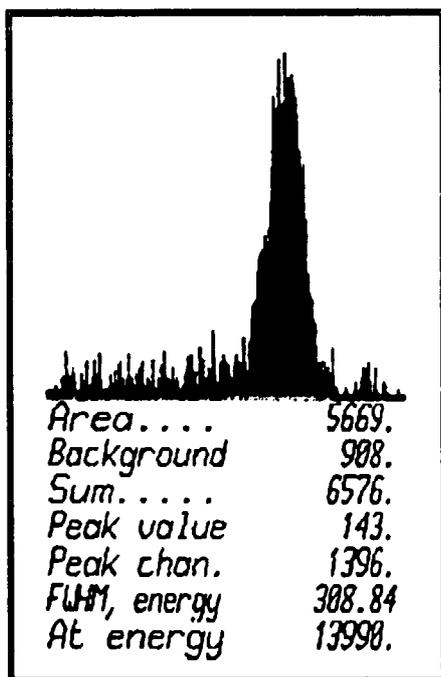


Fig.13. An Analysis of the Final Spectrum

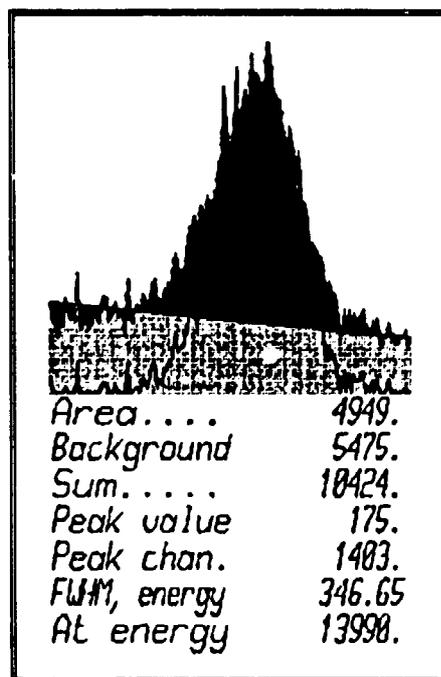


Fig.14. An Analysis of the Direct Spectrum

The AD display package used here contains a peak analysis option. Using this for the final and the direct spectrum gives the results presented in figure 13 and 14, respectively. The energy scales in the figures are not equal. Background is subtracted in the direct spectrum simply by drawing a straight line between the outermost spectrum values. The background area is marked in the figure with a gray pattern.

The resulting FWHMs are not equal. Partly this is caused by the used background subtraction method. However, The FWHM routine is sensitive to the statistical scatter of the data. All channels are used and the outermost crossing of the peak half-value defines the ends of the FWHM region. Therefore, the correct value of

FWHM is expected to be about 320 keV, a value that agrees well with the estimated resolution for a system using a 2.4 mg/cm² foil.

The result can be compared with a preliminary result from a Monte-Carlo calculation done by Magnus Hoek and Ninos Garis [10], figure 12. They got a resolution of 331 keV. A small tail can be seen in the spectrum.

5.4 The Scaler Program Package

The scalers were incorporated in the system at a rather late time of the project. However, they have been used extensively for the neutron detector energy calibration. Those programs have been reported elsewhere [7, 8, 9].

A scaler presentation program package used during the last part of the project will be presented here. It is constructed in the same way as the sort program package described above. A command file controls the package. It has the following menu:

```
-----  
Scaler presentation  
P = Set parameters, edit  
S = Sort scalers  
D = Display result  
T = Type result  
O = Output result on printer  
Q = Quit  
-----
```

Option P calls the editor with the file SRTSC.PAR as a parameter. Option S is the call to the program which rearranges the data and loads them into a CAMAC memory in a shape suitable for the TM display package. The TM package is called by option D. A summary result is produced. Option T types this on the screen and option O prints it on the printer. Option Q is the exit from the package.

The parameter file has the following shape:

```

; SRTSC parameters
FIL 0 0      (A19)DU1:[6,67]MB377.MPR
;
; Scaler selection, the position in the string selects
one of
; the possible scalers. It is put into a position
determined
; by the hexadecimal value of the marked position.
; Unselected positions are marked by X.
PSC 0 0      (A32)0123456789ABCDEFXXXXXXXXXXXXXXXXXX
; Neutron scalers
; PSC 0 0      (A32)XXXXXXXXXXXXXXXXXX012XXXXXXXXXXXXXXXXXX
; Proton scalers
; PSC 0 0      (A32)XXXXXXXXXXXXXXXXXXXX0XXXXXXXXXXXXXXXXXX
; Monitor
; PSC 0 0      (A32)XXXXXXXXXXXXXXXXXX0123XXXXXXXXXXXXXXXXXX
; Proton scalers + Mon.
;
; Time interval milliseconds
STI 0 0      (I5)10000
;
; Memory crate and station
MEC 0 0      (I3)000      Memory crate
MES 0 0      (I3)008      Memory station
;
; End of parameters for SCSORT

```

The syntax is the same as in the parameter file used in the sort programs, see " 5.3.1 Sort Control Options", page 18. The scaler file may contain up to 32 scaler vectors. Only 16 of these can at one time be displayed by the TM display package. The selection is done in the string PSC. A hexadecimal number in a position indicates that the scaler given by the position shall be placed in the display position determined by the hexadecimal number. The time interval and the display memory position is given in the file. Other parameters are fetched from the parameter file given by the experiment number followed by the extension MPR, " 5.2 The Parameter Fetch", page 16.

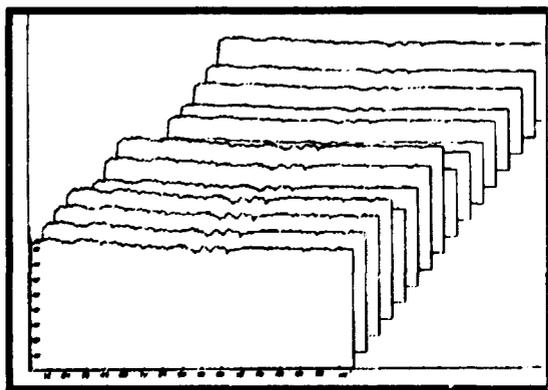


Fig.15. Display of the Neutron Detector Scaler Data

figure, have a poorer shielding than the detectors 8 to 15.

A display of the neutron detector scaler data for experiment B377 is given in figure 15. The intensity has been almost constant during the 168 minutes long measurement. Some small variations coming from readjustments of the neutron generator can be seen in the middle of the experiment. The intensity varies between the detectors. Most of the counts come from background and the shielding is not homogeneous. It can be observed that detectors 0 to 7, the traces in the front of the

A summary of the scaler result is stored in a file named M.SCR. A print-out of this file for experiment B377 is given below.

| | | | | | | | | | | |
|-----------------------------|------------------------------------|----|---------|----|----|----|----|----|----|--|
| Parameter file..... | DU1:[6,67]MB377.MPR | | | | | | | | | |
| Scaler selection..... | 0123456789ABCDEFXXXXXXXXXXXXXXXXXX | | | | | | | | | |
| Total time length, minutes. | 167.6667 | | | | | | | | | |
| Time interval length..... | 10000 | | | | | | | | | |
| Number of time intervals... | 1006 | | | | | | | | | |
| Memory crate and station... | 0 | | | | | | | | 8 | |
| Neutron scaler count down.. | 256 | | | | | | | | | |
| Number of scalers used..... | 20 | | | | | | | | | |
| SCPOS | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | |
| 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | |
| SCORD | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | |
| 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | |
| Scaler | Mean rate | | Std dev | | | | | | | |
| 0 | 207940. | | 299. | | | | | | | |
| 1 | 188376. | | 266. | | | | | | | |
| 2 | 170609. | | 243. | | | | | | | |
| 3 | 167638. | | 240. | | | | | | | |
| 4 | 163170. | | 233. | | | | | | | |
| 5 | 170269. | | 241. | | | | | | | |
| 6 | 179055. | | 254. | | | | | | | |
| 7 | 184804. | | 260. | | | | | | | |
| 8 | 116376. | | 166. | | | | | | | |
| 9 | 117650. | | 170. | | | | | | | |
| 10 | 105966. | | 151. | | | | | | | |
| 11 | 114685. | | 156. | | | | | | | |
| 12 | 106845. | | 153. | | | | | | | |
| 13 | 113909. | | 163. | | | | | | | |
| 14 | 115229. | | 164. | | | | | | | |
| 15 | 133435. | | 185. | | | | | | | |
| 16 | 9. | | 0. | | | | | | | |
| 17 | 18. | | 0. | | | | | | | |
| 18 | 19. | | 0. | | | | | | | |
| 19 | 1030. | | 1. | | | | | | | |
| Ndto | 2355962. | | | | | | | | | |

Some information about the experiment is given in the beginning of the file. 20 scalers have been used. The first 16 of these represent the neutron detectors. They have count rates ranging from 100 to 200 kHz. Most important is the sum of these. The total intensity, 2.4 MHz, is above the 1 MHz level stipulated for the instrument. The proton detector discriminator counts are registered in the scalers 16, 17, and 18. The count rate is very low. The lowest value is registered for proton detector 0. It is only half the value of the other detectors, a fact we already noted in figure 1, "The Proton Detector Amplitude Distribution in Experiment B377", page 19.

The last scaler, scaler no. 19, has been used to register counts from a monitor which we used in some experiment for measurement of the relative intensity of the neutron generator.

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