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DELPHI: A GAMMA SPECTRUM ANALYSIS CODE PROGRAM'S STRUCTURE AND USER'S GUIDE

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DELPHI

A gamma spectrum analysis code
Program's structure and user's guide

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ABSTRACT

DELPHI is a program written to perform the fit of gamma ray spectra from high resolution detectors. The language is VAX-11 FORTRAN, the Digital extension of the standard FORTRAN-77, and it is written to be used interactively on VT125, or compatible, graphic terminals. In addition to searching and fitting single and multiple peaks the code performs the energy, efficiency and line shape calibrations and the computation of the errors of the fit parameters. The organization of the program is in a menu structure to allow the user to manage the code according to his own needs. An automatic analysis option is provided. The possibility to have plots, during the analysis, of the fitted shares increases the performances of the procedure and allows to control the goodness of the fit for each peak. In spite of its origin this program was successfully used to analyse other types of spectra with peaks.

1. - INTRODUCTION

The need to get analysis of complex gamma rays spectra, namely to have the exact channel locations, the areas of photopeaks even if overlapping, their energies and intensities, brought on the development of techniques of numerical analysis, that not only provide considerable savings in time but also on a better accuracy in results.

The big development that in these last years has been realized in computer technique and that has yielded to a comparative easy availability of large memory machines with the possibility to be used interactively, at the same time, by several users has brought on a reproposal in an "updated" version of the old code SAMPO [1,2], a FORTRAN IV program written to analyse gamma spectra.

A new code, DELPHI(*), has been realized and it can be considered a simplified and, to a certain extent, an extended interactive version of the old code. As SAMPO, DELPHI is divided into two big shares: shape analysis and peak fitting. Reasons for this structure are described in [1] and here are briefly summarized.

The difficulties to compute in details the physical and statistical phenomena determining the response of a semiconductor detector and the fact that the peak shapes could be sensitive to small variations in the electronic set-up, force to define a suitable functional representation of the peak shapes from measured data.

On the basis of some considerations on the performancies of semiconductor detectors the mathematical representation of a photopeak should include a central gaussian shape and provisions for tailing effects by simple exponential smoothly joined to the gaussian. In this representation the shape parameters (the width of the gaussian and the distances from the centroid to the junction points of the tails) vary

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(*) This name is referred to the ancient Greek sanctuary in the meaning that responsibility in managing the responses of this oracle is left to users.

smoothly with energy and therefore their values for any line in the spectrum may be found by interpolation between parameters of neighbouring lines. This experimental situation allows to perform the analysis in a particular fashion.

Located high intensity and well isolated peaks along the whole spectrum, a shape analysis is performed for these peaks and parameters characterizing FWHM and tails position are stored with the channel corresponding to the gaussian centroid. Shape parameters for any peak in the spectrum may be found by interpolation between neighbouring shape calibration peaks. Thus the unknown parameters are those describing the continuum approximation and the height and position of the peaks.

This means that a shape calibration can be performed only once, e.g. at the beginning of the acquisition stage, and the analysis of unknown peaks can be performed in a separate run, later. In other way it may be used to control, during the experiment, the eventual variation of shapes due to varied performances of electronic set-up.

The program allows to work according to some options that may be choosen from a menu table appearing on the terminal screen. Options deal with peak searching, plot of the spectrum, automatic analysis, shape calibration and peak fitting. A secondary menu allows to choose for energy and/or efficiency calibrations or reading the automatic analysis output file. All these options are described in sect. 4 while shape analysis and peak fitting in sects. 2 and 3. The reasons to have separate options for automatic analysis and peak fitting lie in the structure of the automatic fit. In fact this option gets the program executed a peak search. The found channel locations enter the analysis routines and results are stored. If a peak has more components these are resolved only by a fit and residuals inspection. Fit option may be now used to refit shares where peaks with more components are present.

2. - Shape calibration

The continuum under a peak or a cluster of peaks, due to Compton from higher energy gamma rays and to a general background, may be considered, except for statistical fluctuations, a continuum smoothly energy dependent. A good functional approximation is then a straight line or a parabola according to the extension of the region of interest. In the case of peaks choosen for shape calibration a very good approximation for this continuum is a straight line; the shape parameters are then defined by fitting the experimental data with this continuum and the functional representation of the peak.

The fit is performed by minimizing the following expression (3)

$$G = -\sum_i (Y_i \ln F_i - F_i) \qquad (1)$$

where the sum is extended to the channels specifying the fitting interval. Y_i is the count at the channel i and F_i is the functional representation of the peak defined as:

$$\begin{aligned}
F_i &= b_i + p_3 \exp[p_6^2 (2i - 2p_4 + p_6^2)/2p_5^2)] && \text{for} \quad i < p_4 - p_6^2 \\
F_i &= b_i + p_3 \exp[-(i-p_4)^2 /2p_5^2)] && \text{for} \quad p_4 - p_6^2 \leq i \leq p_4 + p_7^2 \qquad (2) \\
F_i &= b_i + p_3 \exp[p_7^2 (2p_4 - 2i + p_7^2)/2p_5^2)] && \text{for} \quad i > p_4 + p_7^2
\end{aligned}$$

where

$$b_i = p_1 + p_2 (i - p_4) \qquad (3)$$

is the continuum background approximation. The minimization is performed with respect to the parameters p_1 - p_7 which, respectively, have the

following meaning:

p_1 = constant in the continuum approximation

p_2 = slope of the continuum approximation

p_3 = height of the gaussian

p_4 = position of the peak

p_5 = width of the gaussian (FWHM = 2.355 p_5)

p_6 = square root distance in channel to the lower junction point

p_7 = square root distance in channel to the higher junction point

The straight line approximation helps to stabilize the solution of tailing parameters and for the same reason they are squared in the fit function.

The choice to minimize the function G, instead of the most common χ^2 function, lies in the fact that in this way, as it is pointed out in (3), the total area under the fitting functions equals the total number of counts; this situation is not respected using the χ^2 function as in this case the two quantities differ of about the minimum χ^2 value.

This result is not very important if the area under a peak is large, but may be critical if this area is small. Using the χ^2 function there is the possibility that peaks with poor statistics cannot be analysed or are analysed with a significant error about the extimation of the area.

Once the fit is performed the values of p_4, p_5, p_6^2, p_7^2, their errors, the starting and ending channel of the fitting share, peak area and its error are stored, for each shape calibration peak, in the file CAL.OUT from which they are read at the moment to fix the line shape parameters in any part of the spectrum.

The number of calibration lines is related to the real presence of intense and well isolated lines and depends on the range of the spectrum. Nevertheless the program DELPHI is dimensioned to store up to 20 lines, one for about a 200 keV energy interval in a spectrum of 4 MeV energy range.

The minimization is performed by an iterative algorithm with variable metric defined in the routine VARM. This routine uses the Davidon's method [4], an alternative approach to the Newton's one; the lenght of the step toward the minimization depends on the value of the function to minimize and at each iteration an approximation of the inverse of the matrix of second derivatives is computed in such a way to ensure this inverse matrix be positive definite.

Because of the slowness of the convergence instead of the G function a χ^2 one has been used in the step lenght expression calculation. The gradient and the approximation of the inverse of the second derivatives matrix of G and the χ^2 function value are used to predict the size and the direction of the next iteration. The initial parameters' values necessary to start the routine are calculated by geometrical considerations on the shape of the peak, according to its functional representation.

A minimization session ends when three successive χ^2 values are equal or if 100 iterations are completed; χ^2 decreasing values are written on the interactive terminal screen. When four minimization sessions are completed the program prompts a message to allow the user to continue or to stop the procedure. If the user chooses to continue, the routine starts for a new minimization session then prompts again the message. It was decided to adopt this solution to stop the iterative procedure as sometimes the minimization stops during a χ^2 values descending session and the possibility to reach the (or a) minimum for this function is lost. In this way sometimes a change of a factor 2 or 3 in the χ^2 values has been obtained. This result is important as the shape calibration sets at a certain energy the shape parameters of the peak through which, by linear interpolation with other calibration peaks, the shape parameters of peaks or clusters of peaks in the spectrum are calculated. The better the shape parameters are known the better peaks or clusters of peaks are analysed.

3. - Fitting of single peaks or clusters of peaks

The analysis of a single peak or cluster of peaks is performed in the same way as shape calibration. The function to minimize is always

$$G = -\sum_i (Y_i \ln F_i - F_i) \qquad (4)$$

where the sum is extended to the share containing the peaks to analyse.

The functional representation obviously changes; so

$$F_i = b_i + \sum_{j=1}^{n} f_{ij} \qquad (5)$$

where

$$b_i = p_1 + p_2(i-k) + p_3(i-k)^2 \qquad (6)$$

is the background function. The possibility that the parameter p_3 be equal to zero is left to the user as, according to the extension of the fitting range, the continuum background approximation may be linear or parabolic. k is a reference channel for background polynomial, choosen as the mean value of the fitting range; f_{ij} is the functional representation of the j-th peak in the fitting range and n is the number of peaks in this range:

$$f_{ij} = p_{2+2j} \exp[l_j (2i - 2p_{3+2} + l_j)/2w_j^2] \quad \text{for} \quad i < p_{3+2j} - l_j$$

$$f_{ij} = p_{2+2j} \exp[-(i-p_{3+2j})^2/2w_j^2] \quad \text{for} \quad p_{3+2j} - l_j \leqslant i \leqslant p_{3+2j} + h_j \qquad (7)$$

$$f_{ij} = p_{2+2j} \exp[h_j (2p_{3+2j} - 2i + h_j)/2w_j^2] \quad \text{for} \quad i > p_{3+2j} + h_j$$

Here p_{2+2j} and p_{3+2j} are respectively the height and the centroid of the central gaussian of the j-th peak while l_j , h_j and w_j represent the j-th peak shape parameters obtained by linear interpolation of shape analysis results.

Again minimization is performed by the routine VARM. To obtain the initial parameters' values the program executes a fast linear least-square routine where the height of the peak and the parameters of the continuum are computed. The user has to supply with the channel location of the peak(s) in the fitting interval. To avoid negative height value, as sometimes it happens in the analysis of overlapping lines when one of them has a small area, these parameters were squared in fitting procedure. The height parameters were not squared in the fit function representation to save the use of the linear least-square routine to find the initial parameters. The convergence criteria are the same as in shape analysis. When four minimization sessions are completed the program prompts a message to allow the user to continue or to stop it. Unlike shape analysis the fit continuation replay returns the program to the least-squares routine to get a better approximation of the initial parameters. Normally results are unchanged but sometimes an improvement is obtained.

4. - DELPHI's features

The program is structured in a main and a secondary menu. The actual version works interactively on VT125 or compatible graphic terminals even if it is possible to run it on non graphic ones. In this case however it is not possible to have plots of analysed shares and then to control the goodness of the fit, by comparison of graphical and numerical outputs.

The executable code is stored in the VAX-11/780 of the Acquisition Data Service at the Laboratorio Nazionale del Sud and informations on running it may be obtained by typing the command

VAXLNS::DRA2:[ANALDAT.GAMMA]DELPHI.DOC

In this documentation file the operations the user has to do to access the code are described. In particular the code is run with the command DELPHI.COM. In the user area this command file asks the user for the name of the data file, copies it into the file FILE.IN, deletes all preceding versions of FILE.IN then deletes output file generated from preceding runs of DELPHI and prepares itself to begin the analysis. When the user decides to stop the analysis the command file prints on the printer the output file containing all the informations about the performed interactive analysis session.

The first thing DELPHI does is the reading of the file FILE.IN, containing the experimental data. FILE.IN is a formatted file: a first line containing a string up to 80 characters with user informations and file identification; a second line with the indication of channels' number, type of file (if mono- or bi-dimensional), the matrix dimensions (in case of mono-dimensional file the second matrix dimension is 1) in the format I9,1X,A1,2(1X,I9). DELPHI can handle only mono files; then the first matrix dimension equals the channels' number. At last experimental data are read in the format 8(I9,1X). This format is the same as partial output files of the acquisition program developed by the Acquisition Data Service of the Laboratorio Nazionale del Sud.

Reading is performed by the routine READIN. In case the input file has not the requested format the routine prompts a message and stops DELPHI.

Once the spectrum has been read the main menu is prompted. Fig. 1 shows this output:

```
------------------------------------------------------------------
                D E L P H I :   main   option   menu
------------------------------------------------------------------
  H - TERMINAL *** linked [not linked] *** to a hardcopier
  N - New shape calibration
  U - Updating old shape calibration
  P - Peak fit
  A - Automatic fit
  F - Peaks in the spectrum: output on printer
  S - Plot of the spectrum
        CTRL/Z  to  stop
```

Fig. 1 - Main options; see text for more details.

Digiting N,U,P,A appears the secondary menu (see fig. 4) that allows the user to choose among energy and/or efficiency calibration, no further option or reading the automatic analysis output file.

During the execution of the analysis the program, as needed, prompts messages regarding local options to be settled by the user. Normally the replay is Y for yes and N for not and it is sufficient to digit the letter. Default answers are enclosed in square brackets and it is enough to press RETURN on the keyboard. By pressing CTRL/Z at any prompting the user has the possibility to go back to the preceeding prompting till the main menu. Here a new option may be choosen or the program stopped.

Three plot routines are provided: plot of the spectrum, plot of the fit of shape calibration peaks, plot of the fitted peaks with their residuals. Each routine calculates the maximum value of the spectrum in the share of interest, rounds it to a multiple of the magnitude order of this maximum and uses this last result to scale the ordinate axis. All plots are set linear in both axes. The ReGis Graphics Library (RGL) implemented by Digital on VAX computers was used to realize these plot routines.

4.1. - Main option menu

A file FIT.DAT is created for each stored fitted share and holds the fit parameters and the spectrum of this share. The purpose of this file is to provide the user with the possibility to have on a plotter the graphic of the fitted share with the identification of the spectrum where the peak was taken from, the energy range of the fitted share and the possibility to have a logarithmic scale for the ordinate axis. In this connection some plotting programs have been carried out. Their performances are reported in the appendix.

4.1.1. - Option H: TERMINAL linked or not to a hardcopier.

In the main menu appears a message that the terminal is linked or not to a hardcopier. By digiting the letter H it is possible to change this feature in such a way that copies of the graphics can be printed on the hardcopier or stored in the file HARDC.DAT to be plotted later on a terminal linked to a hardcopier.

4.1.2. - Option F: peaks in the spectrum.

It allows the possibility to have a file on the printer with the positions and the approximate heights of the peaks in the spectrum. A generalized second difference in channel i and its standard deviation are used to set the significance of a peak. This option asks the user for the significance limit; in this way it is possible to select the shape

calibration peaks (peaks with a high significance) and in a later run all other peaks.

4.1.3. - Option S: plot of the spectrum.

It performs the plot of the spectrum or a share of it on the terminal screen according to the user's choice. If the share to be drawn is greater or equal to 60 channels the data points are connected with a straight line. On the contrary they are plotted point by point and marked by a circle.

F and S options are useful to a better identification of the peaks to be used in the shape analysis session or in the identification of single peaks or clusters of peaks.

4.1.4. - Option N: new shape calibration.

The program opens a file CAL.OUT where shape analysis results are stored. The fitting interval may be choosen in two ways, by giving the bordering channels or by giving the channel location of the peak or its energy (in this case a preliminary energy calibration has to be ready): a 14 channels interval is set and it may be eventually modified. From tests on simulated and real spectra it was seen that the fit is very sensitive to the choice of the fitting interval. Sometimes a change of one channel in its extension may improve considerably the results. So, many cares and much patience is necessary in this first stage of the analysis.

Once the fit has been completed the program plots, on request, the experimental data with the fit. If the result is satisfactory, fit parameters, peak area, FWHM and other information are prompted on the terminal screen and, again on request, stored in the output file FITPAR.DAT.

It is not necessary that peaks choosen for shape calibration be fitted according to the increasing value of their channel locations. In the end of the shape analysis session shape parameters (gaussian cutoff, low and high tails positions and their errors) are rearranged according to the increasing channel locations. These rearranged parameters are stored respectively in the arrays w, l and h (see peak functional representation in sect. 3); the channels of the fitted peaks are prompted in increasing order on the terminal screen.

Now if a secondary option (energy and/or efficiency) was set the program prompts a message and waits for the introduction of the energies and/or the efficiencies of the analysed peaks. In this case the file ENECAL.OUT and/or EFFICAL.OUT is prepared to be used for energy and/or efficiency calculation of the other peaks in the spectrum.

4.1.5. - Option U: updating of file calibration.

This option allows the user to modify the content of the file CAL.OUT deleting or adding some lines. With this option the program prompts first the channel locations of the peaks fitted for shape calibration then asks for further action. Lines can be deleted in any order, one by one or in a cluster. If some line has been deleted a new CAL.OUT file is created with the new situation and the old CAL.OUT is not deleted. Energy and efficiency output files are updated according to the lines deleted in shape calibration output file. New energy and efficiency output files are created and the old ones are not deleted (it is user's care to control and eventually to purge his own working area). By means of this option it is possible to introduce an energy and/or an efficiency calibration or to modify the old ones.

4.1.6. - Option P: peak fitting

Once shape calibration file CAL.OUT (toghether with an eventual energy and efficiency calibration) is ready, it is possible to perform peak fitting. If the user has used the option F a table of peaks in the spectrum is available. To fit a certain peak the user may supply with the position or the energy of the peak (if it is known) and the program chooses automatically the fitting interval on the basis of the local value of the gaussian cutoff w at the peak location, obtained by extrapolating between neighbouring shape calibration peaks; the background is choosen linear if the extension of this interval is less than 30 channels. The fitting share is plotted (on request) on the terminal screen and the user may change its boundaries. In this case he has to supply besides with the starting and ending channels with the value of a flag according to he chooses a linear or a parabolic functional representation for the continuum background.

The results of the peak fitting are shown on the terminal screen and, on request, stored in the output file FITPAR.DAT. Again on request, the fit with experimental data, continuum, single peaks contributions are plotted toghether with residuals in standard deviation units.

This graphical and numerical informations make convenient to establish the goodness of the fit and the presence of previously unobserved peaks. In fig. 2 a case is shown where an unobserved peak reveals itself both from fit plot and from residuals behaviour.

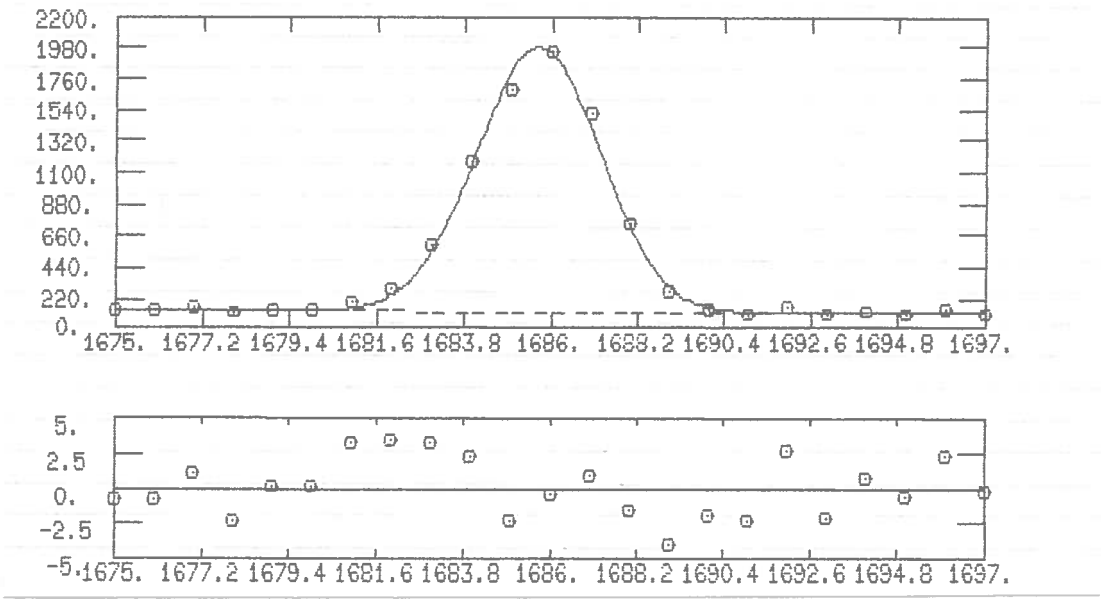

Fig. 2 - Analysis of a peak centered about channel 1686 in a ^{152}Eu and ^{60}Co source spectrum, collected by a 15% high purity germanium detector. The dashed line is the fit of the background and the full line is the total fit.

The fit has been performed with a FWHM obtained from extrapolation from neighbouring shape calibration lines. On the left of the peak, residuals show a bump indicating that at least two components are present.

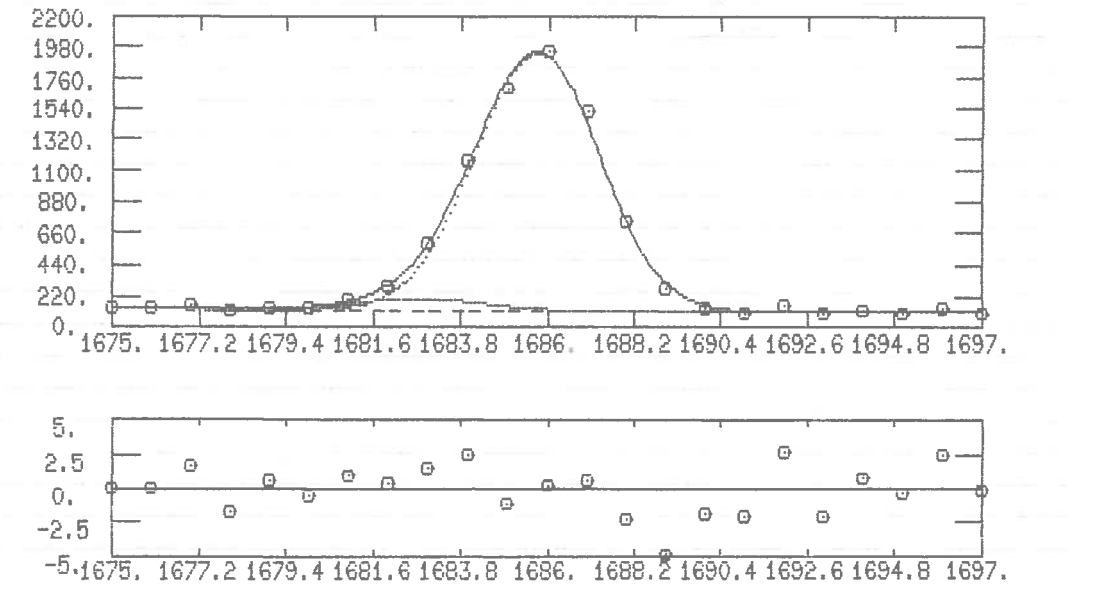

Fig. 3 - Analysis of the peak in Fig. 2 with the two components centered about the residuals zero level, namely about channels 1684 and 1686.

Their centroids lie near the zero of the residuals. So, for this peak the two components have their centroids respectively about channel 1684 and 1686. The analysed line is the 964 keV one in a ^{152}Eu gamma spectrum; this line has two components of which that at lower energy has a very weak intensity. Fig. 3 shows the same peak analysed with these two components.

In corrispondence of the peak the residual behaviour is now almost flat. Output of the fit will show, apart from background parameters, the areas, FWHM's, channel locations and heights of the component lines.

An option is provided to analyse peaks that have been feeded in some way. In this case the peak width is different from the value that could be obtained from interpolation. To avoid difficulties in analysis, on request, it is possible to supply with a FWHM variation to change the interpolated value. On output the FWHM value from fit and the interpolated one will be prompted.

4.1.7. - Option A: automatic fit

This option allows the user to have saving in time during the analysis. In fact the program automatically finds the channel locations of the peaks in the spectrum with a significance level of 3; subtracts from this list the shape calibration peaks locations, calculates for any peak or cluster of peaks the extension of the fitting interval, on the basis of the FWHM in that share, then calls for the fit routines (the program is dimensioned to select up to 8 peaks for each fitting share).

Results are stored in the file AUTODELPHI.DAT in the same way as interactive analysis stores results in the file FITPAR.DAT. The word "automatic" in the first line of each output and the lack of feeded FWHM are the only differences.

The user may choose to execute this automatic analysis interactively or by sending the program to a batch queue. In the first case the program prompts for the number of peaks to be fitted and during the analysis the extension of the fitting share and the number of the peaks therein. In the second case in the file AUTODELPHI.LOG will appear the file identification and the number of analysed peaks.

About 30 seconds of CPU time is necessary to analyse about 15 peaks in a 1000 channels spectrum.

Before running this analysis it is possible to modify the list of the found peaks. New channel locations may be added and old channel locations may be deleted. Lines to be added or to be deleted may be entered in any order, positive those to be added and negative those to be deleted. The program separately orders the two sets according to the increasing channel locations and builds a new list.

To exit the program it is necessary to return to the main option menu. All working files are closed and program stops letting further commands in the command file to be executed. The output file FITPAR.DAT is printed and the command file terminates execution.

4.2. - Secondary option menu

Fig. 4 shows the output of the secondary option menu. This menu allows to choose an energy calibration, an efficiency calibration, both calibrations, no further option or reading the automatic session output file.

```
-----------------------------------------------------------------
                D E L P H I :   secondary   option   menu
-----------------------------------------------------------------
   N - No other option
   E - Energy calibration and calculation
   F - Efficiency calibration and calculation
   B - Energy and efficiency calibration and calculation
  [R - Reading of the automatic fit results]

   CTRL/Z  to  stop
-----------------------------------------------------------------
```

Fig. 4 - Secondary options; see text for more details

Again it is enough to digit the letter relative to the choosen option to set the program to execute that option.

4.2.1. - Option N: no further option

By choosing this option the program executes the main option without any energy or efficiency calculation. On output only informations on shape parameters.

4.2.2. - Option E: energy calibration and calculation

Some tests were made about the best functional form of the function needed to approximate the relation channel-energy. It was choosen to use the interpolation Lagrange polynomial

$$E(c) = \sum_{i=1}^{n} E_i \prod_{j \neq i} \frac{c - c_j}{c_i - c_j} \qquad (8)$$

where E(c) is the unknown energy at the channel c. E_i and c_i are the n couples energy-channel set for energy calibration and stored in the file ENECAL.OUT. This file is created in the end of the shape analysis session

when the program prompts the message to supply with the energies of the calibration peaks.

As interpolation Lagrangian polynomial may give erroneous values for energy in case of extrapolation, channels external to the shape calibration peaks locations range are converted in energy by means of a parabolic approximation obtained by a least square reduction of the n couples energy-channel set for energy calibration. The three parameters are stored in the file ENECAL.OUT,too.

When this option is called from P and A options in the main menu, the program calculates the energy of a peak by means of the Lagrange polynomial or the parabolic approximation according to the channel location of the peak.

4.2.3. - Option F: efficiency calibration and calculation

The interpolation Lagrange polynomial is used to interpolate logarithmically among calibration points. The n couples efficiency-channel set for efficiency calibration are stored in the file EFFICAL.OUT. This file is created in the end of the shape analysis session when the program prompts the message to supply with the gamma rate of the calibration peaks.

As in energy calibration option a functional representation of the efficiency curve is used in case of peaks external to the shape calibration peaks locations range. The parameters of this functional representation, effective down to about 100 keV,

$$F_i = p_1 \exp(p_2 \ln c_i + p_3 \ln^2 c_i) \qquad (9)$$

are determined by the least square method; c_i is the channel peak location. The three parameters p_j are stored in the file EFFICAL.OUT, too.

As in the energy calculation when this option is called from P and A options in the main menu, the program calculates the efficiency of a peak by means of the Lagrange polynomial or the functional approximation according to the channel location of the peak.

4.2.4. - Option B: Energy and efficiency calibration and calculation

Energy and efficiency calibrations are performed together. In the end of the shape analysis session the program prompts a message to inform the user to supply with energies and efficiencies of the peaks. This option called from P or A, calculates the energy and the efficiency of the fitted peak.

4.2.5. - Option R: reading the automatic output file

This option appears in the secondary menu only if the option A has been choosen in the main menu and allows the reading of the automatic fit output file AUTODELPHI.DAT. All fit informations are prompted on the screen for any analysed share. User, on request, may store these informations in the output file FITPAR.DAT with the indication that they come from the automatic session, and may draw the fit; on the basis of these informations he may decide to refit the share. By pressing CTRL/Z he returns to the main menu and here invokes P option. In the end of this stage the program returns to the main menu and by pressing A the user may continue reading from the last read share.

5. - Conclusion

A list of the files opened by DELPHI in the user area is reported with their contents and the action that user may do on them. All the files created by DELPHI are formatted files to allow their direct inspection and their eventual printing.

ADPEAK.OUT	holds the channel locations of the peaks that the user wants to add or to delete from the list

found in the automatic search. It has to be deleted in the end of the analysis.

AUTODELPHI.DAT holds parameters from the automatically analyzed shares. It can be deleted by the user after its reading.

AUTODELPHI.LOG holds the file identification and the number of analysed peaks. It is created in case of a request of a batch automatic analysis. This file is not printed in the end of the batch process and it will be user's care to act on it after printing or inspection.

CAL.OUT holds shape parameters of the peaks picked out for shape calibration. If a new shape calibration acts it may be purged by the user.

ENECAL.OUT holds couples energy-channel for energy conversion of the channel locations of fitted peaks and the parameters of the parabolic approximation of the continuum. If a new energy calibration acts it may be purged by the user.

EFFICAL.OUT holds couples efficiency-channel for efficiency conversion of fitted peaks and the coefficients for efficiency calibration. If a new efficiency calibration acts it may be purged by the user.

EFFEN.OUT holds the values of the flags related to the energy and/or efficiency calculations. It is created only if the automatic analysis is sent to a batch queue. It is deleted by a new run of

DELPHI.

FIND.OUT — holds the list of the channel locations of the peaks found with the option F. As this file is printed it may be deleted.

FITPAR.DAT — holds all informations about fitted peaks. Shape parameters for each peak calibration, FWHM, area, peak position, total experimental yield and total theoretical yield. This file is printed when the user decides to exit DELPHI. The file is deleted by a new run of DELPHI.

FILE.IN — holds the copy of the original file containing the data to be analysed. The file is deleted by a new run of DELPHI.

FIT.DAT — holds the parameters related to the fitted share and the experimental yield in that share to be drawn, with ad-hoc programs on whatever plotter (Up to now two programs are ready; one for the graphic station at the Dipartimento di Fisica of Catania University and one for the HP7475-Plotter of the Acquisition Data Service at the Laboratorio Nazionale del Sud). If the user decides not to use these files they have to be deleted in the end of the analysis session.

HARDC.DAT — holds the plots of the fitted shares. It may be printed on a terminal linked to a hardcopy if it is necessary to store on paper the draws of the fits. It has to be deleted when the printing is finished.

The list of the options described in section 4 allows the user to manage the code according to his own needs. Obviously it is not intended that this list may be exhaustive of all needs but it may give an useful tool in the analysis of complex gamma rays spectra. The provisions of tails allows the use of this code also for non gamma rays spectra. Fig. 5 shows an example of this versatility; a TPHC spectrum was analysed with this code to extract the shape parameters and the FWHM, the coincidence time interval among several detectors.

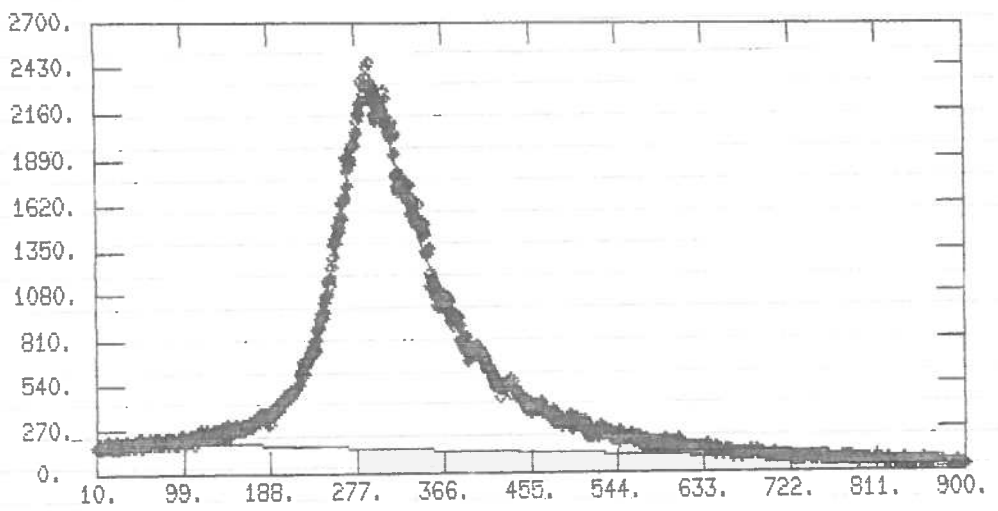

Fig. 5 - Analysis of a TPHC spectrum from an operation test of coincidences between a high purity Germanium detector and one of a 12 NaI(Tl) detectors assembly.

APPENDIX

The file FIT.DAT is read by a program that starting from the read parameters builds fit functions and plots them together with experimantal points. Some options are provided, some of them automatic according to the type of peaks to plot; e.g., residuals are not drawn if the peak to plot is a calibration one. Non automatic options deal with:

abscisse scale: plot versus channel or energy. In this last case the program uses the file ENECAL.OUT to convert channels in energies. Energies, in keV, are shown in the upper abscisse scale.

ordinate scale: option between linear and logarithmic scale (in this last case the eventual residuals are plotted in linear scale). In logarithmic scale functions are plotted between a minimum and a maximum that automatically are choosen as powers of ten.

Informations on running these programs may be found in the file

VAXLNS::DRA2:[ANALDAT.GAMMA]DELPHI.DOC

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