The automatic search two-dimensional of peaks and definition of their characteristics

Contents:

1. The "Bi" code - search two-dimensional of peaks and definition of their characteristics

- Definition of outputs of nuclei rather labor-consuming process: it is necessary to analyze tens matrixes, each of which carries the information on several tens ions. So in case of the experiment with the beam ^{112}Sn the nuclei with mass numbers from 8 up to 53 were identified [Lew94]. For each meaning of magnetic rigidity there were four matrixes for various charging states of products, and in everyone more than five hundred ions. After measurement of outputs all data are brought in to the computer for the further analysis. Enormous volume of work can be estimated:

*500 ions * 4 matrixes for charge states * 10 values of magnetic rigidity = 20 000 values!!*

- It is necessary also to note a high probability of subjective mistakes of the experimenters connected, both with the analysis two-dimensional of peaks, and at carry of the information to the computer. In this connection, for the automated search of two-dimensional peaks and definition of statistical parameters the program "Bi" were created (spelling [bi]).

- There are three versions of the program:

	Operating system	Programming language	Spectrum format
1	VMS 5.1 and higher	Fortran	GANIL Acquisition
2	MS DOS 3.3 and higher	C	The code "Athene" /format "SURFER/
3	Window 95 and higher (in the LISE package)	C++	NSCL, GANIL, Athene

Fig.1. *Principal window of the code"BI" (version for MS-DOS) designed for automatic search of two-dimensional peaks and definition of their characteristics.*
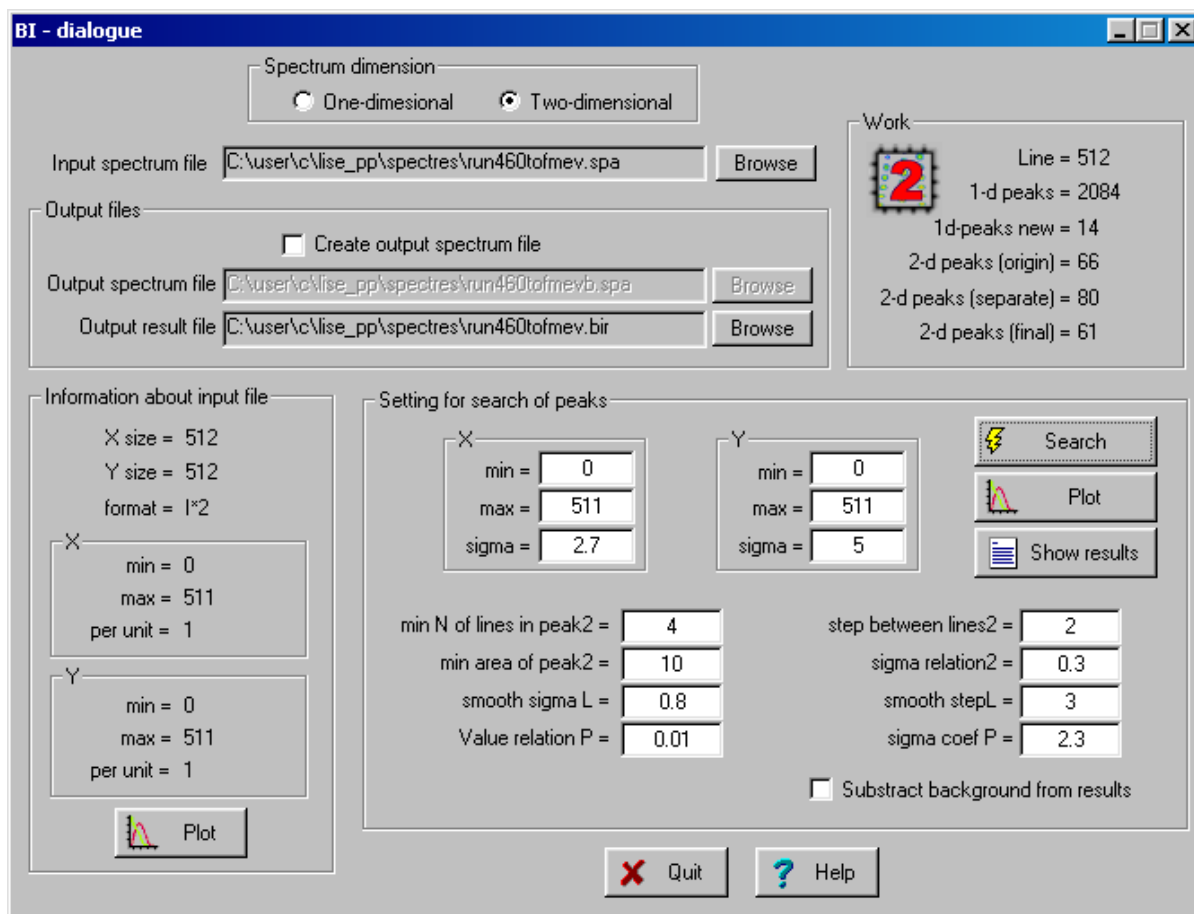

Fig.2. *Principal window of the code"BI" (version for Windows) designed for automatic search of two-dimensional peaks and definition of their characteristics.*

The input of initial model of search consists in the following (according to Fig.2):

- Search window (*xmin, xmax, ymin, ymax*) is defined (window parameters of a researched spectrum are taken by default);

- Important parameters *sigx* and *sigy* (individual for each spectrum) are fixed. Its values should be close to average deviations of researched peaks on horizontal and vertical axes accordingly;

- depending on quality of a spectrum (background, "fuzziness" (low-intense wide peaks), imposition of peaks) search parameters are modified (the internal parameters are taken by default in most cases from experience), which description is given below.

  ❖ *value relationP* - is multiplied on amplitude of peak (by default 0.01). The result value is used for definition of peak borders, if there are points with nonzero y-values up to the next peak or up to the spectrum boundary. It serves to avoid background events not having relation to the given peak and capable to affect its characteristics;

  ❖ *smooth sigma L* and *smooth stepL* – see details below in the text;

  ❖ *min line peak2* – minimum quantity of one-dimensional horizontal peaks in two-dimensional peak (by default 3). If amount of horizontal peaks is less than the given value, the peak is excluded from the list;

  ❖ *min area of peak2* –minimal area of two-dimensional peak (by default is equal to 10). If peak area is less than the given size, the peak is excluded from the list;

  ❖ *step between lines2* –the maximum number of horizontal EMPTY lines between non-zero lines in two-dimensional peak (by default 2).

Algorithm of program work automatically to search two-dimensional peaks and definition of their statistical parameters is shown in Fig.3.
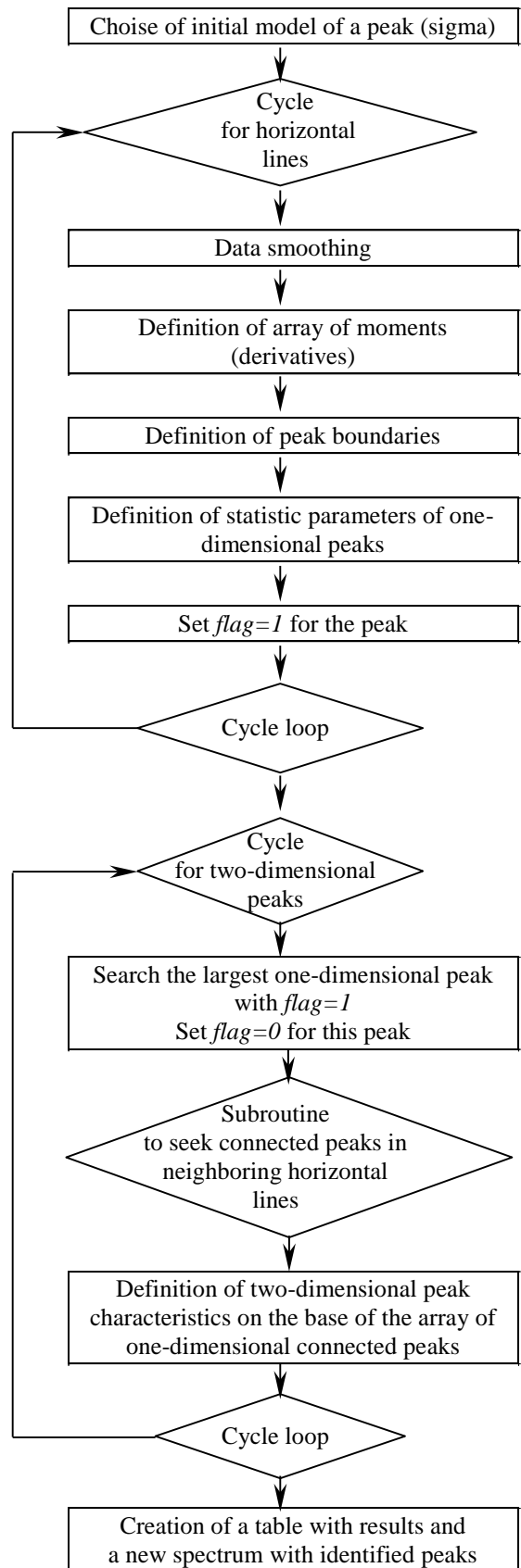

Fig.3. *"BI" code algorithm automatically to search two-dimensional peaks and define their statistical parameters.*
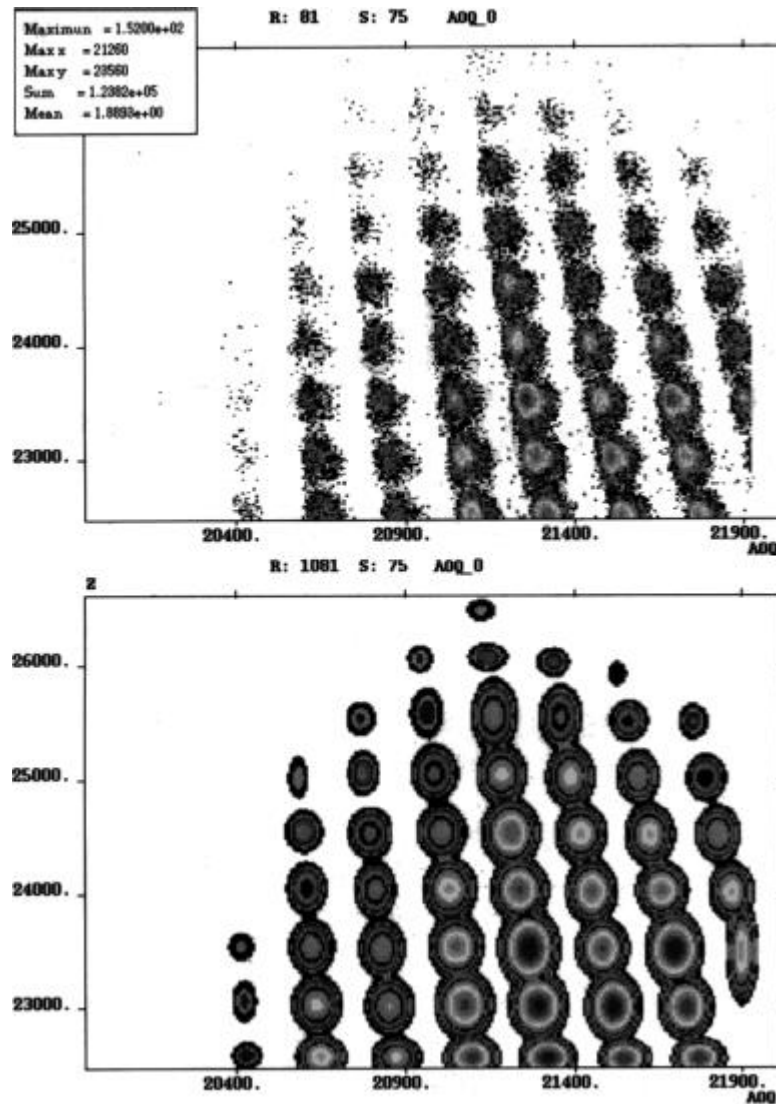
Fig.4. *In the top figure the experimental spectrum of products with Z=45-53 in the reaction 112Sn (58MeV/nucl)+Ni [Lew94] for completely stripped ions (Q=Z) at magnetic rigidity Bρ=1.98835 Tm depending on mass number Z and value A/Q. The spectrum with identified peaks after search peaks by the program "Bi" is shown in the bottom picture.*

The example of results of program work is shown in Fig.3. All versions of the code give out search results in a graphic presentation (new spectrum of the same format. See bottom spectrum in Fig.3) and as the table with all statistical characteristics of the identified peaks. The program can easily without change of its basis be modified to other formats of a spectrum by addition of the new subroutines of reading and record of spectra.

Smoothing is carried out with the help of coefficients received from the normal distribution. Firstly, every c-point gets image:

$$T(x_c) = \sum_{i=c-step}^{c+step} f(x_i) \cdot \exp\left[-\frac{(x_i - x_c)^2}{2 \cdot \sigma_{smooth}^2}\right], \quad /1/$$

where *step* is the number of neighbor points applied to smoothing (according to the menu in Fig.2, this parameter is named *"smooth stepL"*. Default value is equal to 4), σ_{smooth} is the value responsible for width of the normal distribution and equal to *"sigx"* * *"smooth sigmaL"* (by default 0.80). The next step is normalization to save the same number of events as it was before smoothing.

The most important moment of the program is the search of one-dimensional peak and definition of its borders, under condition of, that this search is enough fast and effective. Originally search was carrying out with the help of derivative calculation in each point. Proceeding from extremum:

$$f'(x_c) = 0, \ f''(x_c) < 0 \Rightarrow x_c - minimum,$$
$$f'(x_c) = 0, \ f''(x_c) > 0 \Rightarrow x_c - maximum, \qquad /2/$$

boundaries of peaks (minima) and locations of maxima were determined. Fit by line in the interval $x_c - step^{\#} \div x_c + step^{\#}$ was used to define by derivative in a point *xc*. The $step^{\#}$ value is product *"sigx"* and *"sigma_coef_P"* (see the menu in Fig.2) and has physical meaning of full width on half-height of peak. Parameter of an inclination of the given line was used as derivative. However the fit occupied a lot of time, therefore the simple and effective method was offered on the basis of calculation of the moment of the first order in the point x_c:

$$Mom(x_c) = \sum_{x=x_{c-l}}^{x_{c+l}} f(x) \cdot (x - x_c), \qquad /3/$$

where *l* is equal to integer value of relation $step^{\#}$ to an interval $\Delta x = x_i - x_{i-1}$. The example of results of experimental data smoothing and definition of their "moments" for one-dimensional spectrum is shown in Fig.5. Is it clear from the figure then the crossing of the function of moments with the zero axis and then the sign changes from "+" to "-" it corresponds to maximum of a peak of experimental data, and change of sign "-" to "+" correspond to peak boundaries.
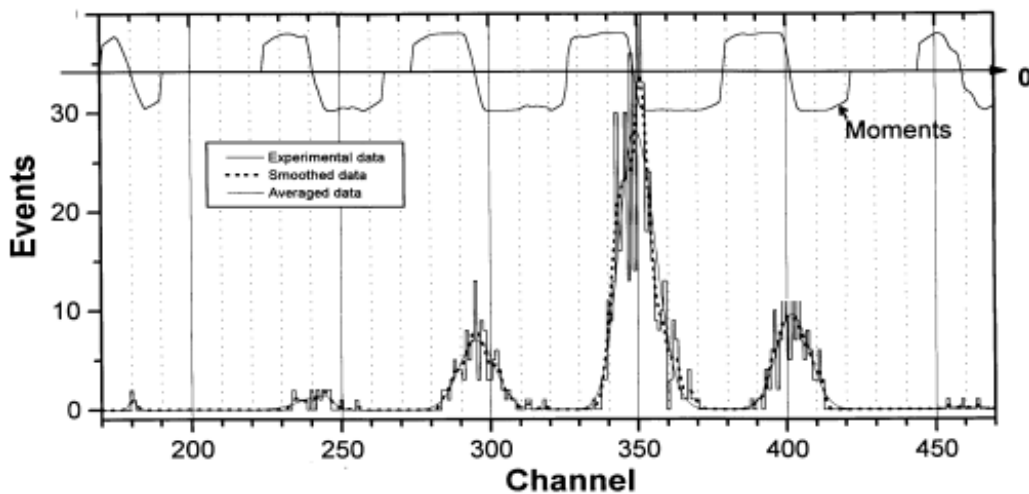

Fig.5. *Results of experimental data smoothing and definition of their "«moments" for one-dimensional spectrum.*

2. version N`5.8: on-line LISE analysis of experimental plots

Into the concept of the program LISE development enters not only input of new tools (new models of reaction mechanisms, etc.) able to help physicists in the prediction of products' outputs, but also further development of the mechanism of experimental data analysis. In the new version the apparatus for work with experimental spectra obtained by the program BI was developed. The analysis of experimental two-dimensional peaks can be divided into 4 stages:

The first stage is reading an experimental spectrum by the program BI. An example of such a spectrum is shown in Fig.2-1. This spectrum is obtained with the spectrometer A1900 (NSCL MSU) in the reaction ^{18}O (120AMeV) + Be (this experiment is discussed in more detail in the chapter "Version 5.5").

Fig.1. *The dialog of ellipse size.*

The second stage is the determination of the program-BI parameters for the analysis of the initial spectrum, and the analysis itself. The program creates a text file with the found peaks and an output spectrum with the found peaks in the format of the initial spectrum (Fig.2-2).

The third stage is the new stage, which helps the user to avoid unnecessary peaks and also to initialize "good" peaks. After search of peaks by clicking on the button "Plot" in the dialog "BI" the user gets an output spectrum (Fig.2-3), where the determined peaks are shown by ellipses with serial numbers. The semi-axes of ellipses by default are equal to three standard deviations (σ) found by the program BI. However, the user can redefine their size pressing the icon $\sigma_3^{1,2}$ (see Fig.1). The double clicking of the right button of the mouse on a peak allows editing this peak. The user can switch off the peak using the checkbox "Available" and/or give a name (see Fig.3). The new spectrum obtained after selection from the previous spectrum (Fig.2-3) is shown in Fig.2-4.

The fourth stage is recording selected peaks on a disk (clicking the icon) and reading them by another program (for example MS Excel).

Within 10 minutes the user gets the table with found selected peaks with the characteristics (average values, standard deviations, area) that can be used for the further analysis (cross sections, momentum distributions, calibrations, etc.).
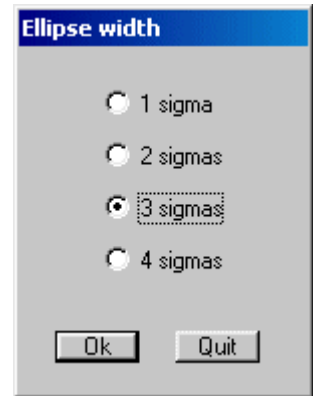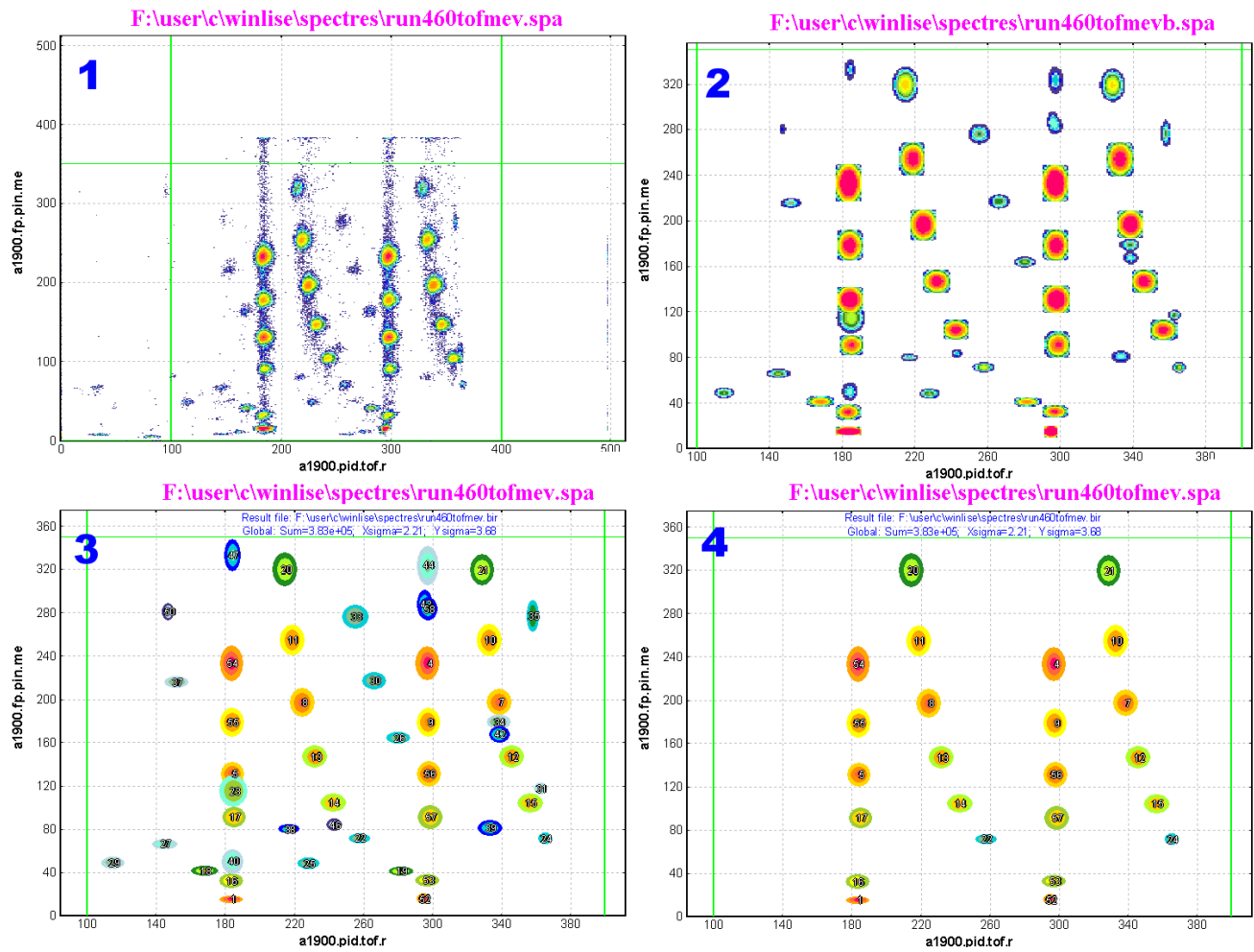
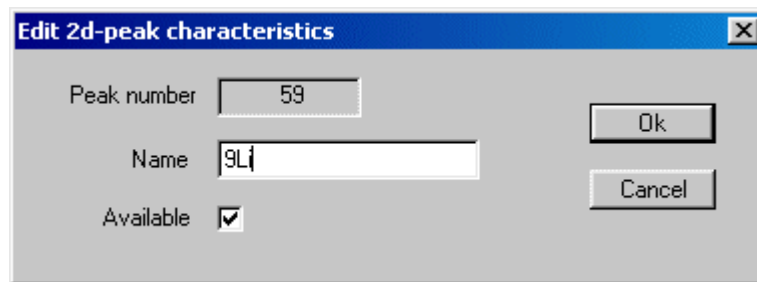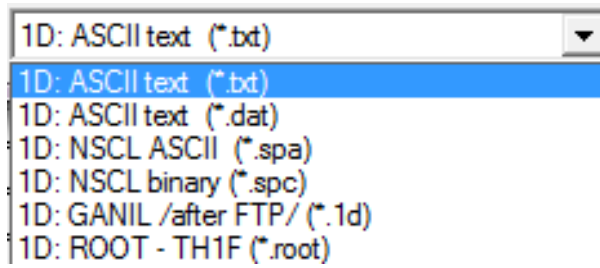*Fig.2. Analysis of an experimental two-dimensional spectrum in the program.*

Fig.3. The dialog of editing peak characteristics.

3. Input data file format

3.1. 1D

```
1D: ASCII text  (*.txt)           ▼
1D: ASCII text  (*.txt)
1D: ASCII text  (*.dat)
1D: NSCL ASCII  (*.spa)
1D: NSCL binary (*.spc)
1D: GANIL /after FTP/ (*.1d)
1D: ROOT - TH1F (*.root)
```

3.2. 2D

```
2D: NSCL ASCII  (*.spa)           ▼
2D: NSCL ASCII  (*.spa)
2D: NSCL binary (*.spc)
2D: SURPHER    (*.grd)
2D: GANIL /after FTP/ (*.2d)
2D: ASCII text  (*.txt)
2D: ASCII text  (*.dat)
2D: ROOT - TH2F (*.root)
```