Data Analysis and Evaluation with SAMMY

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Outline

Data Preparation for SAMMY

Description of input files for SAMMY

a. Input File *XXX.inp*

Experimental conditions, Spin assignment, etc.

b. Input File *XXX.par*

Resonance parameters

c. Input file *XXX.dat*

Experimental data.

Evaluation "from scratch"

In general for starting an evaluation SAMMY requires 3 input files:

a) xxx.inp: this file contains information regarding the experimental conditions including flight paths, temperatures, samples thickness, resonance spin information, etc.

b) xxx.par: this file is the initial estimation of the resonance parameters. For a Reich-Moore evaluation, users will give in general the spin of the resonance (J), the resonance energy (E_r), neutron widths (Γ_n), gamma width (Γ_γ) and two more channels for describing the fission process, Γ_{c1} and Γ_{c2}.

Only two fission channels will be used.

c) xxx.dat: this file contains the data to be evaluated such as transmission data (total cross section), fission cross section, capture cross section, elastic cross section, etc.

These files will be created based on the ^{235}U total cross section data.

General Information for ^{235}U

A	235
Z	92
Target Spin and Parity*, I^B	$7/2^-$
Nuclear Radius	9.6 fm

*Note: neutron spin and parity: 1/2+

Spin information

s= *I*+*i*, where |*I*-*i*| # *s* #|*I*+*i*|;

J= *l*+*s*, where |*l*-*s*| # *J* #|*l*+*s*|; and

(&1)**^{l} B" ' (&1)^{l} B"′ ;

" and "′ are the incoming and outgoing channels, respectively.

Spin and Parity of the Compound Nucleus

*I*B$_0$	*l*	*s*	*J*B					Spectroscopic Notation
7/2$^-$	0	3	3-					s
		4	4-					
	1	3	2+	3+	4+			p
		4	3+	4+	5+			
	2	3	1-	2-	3-	4-	5-	d
		4	2-	3-	4-	5-	6-	

Experimental Conditions:

Information on Total Cross Section Measurements for ^{235}U

Measurement Descriptions	
Material	^{235}U
Data type:	Total Cross Section
Laboratory:	ORNL
Experimentalist:	J. Harvey et al.
Run Number:	10409
Date of Experiment:	7/7/1986

Experimental Conditions	
Flight Path Length ± Dispersion (m)	80.394 ± 0.022
Neutron Overlap Filter	0.60 cm Pb 150 mg/cm^2 ^{10}B
Permanent Background Sample	(Not applicable)
Sample for the Determination of Background	(Not applicable)
Linac Burst Width (ns)	20
Repetition Rate (sec^{-1})	347
Power (kW)	13
Moderator	(Not applicable)
Moderator Thickness	(Not applicable)
Detector Type	Glass scintillatior

Information on Total cross section Measurements for ^{235}U

Time-of-Flight Analyzer	
Energy Range (eV)	**Channel Width (ns)**
E < 13.8	512
13.8 < E < 35.3	128
35.3 < E < 114.3	64
114.3 < E < 408.0	32
408.0 < E < 1325.0	16
1325.0 < E < 9380.0	8
9380.0 < E < 4	2

Sample Characteristics	
Weight (grams)	(Not needed)
Thickness (atom/barn)	0.03294
Isotopic Composition	99.6 % enriched ^{235}U
Sample Composition (Impurities, etc)	^{151}Ta, ^{234}U, ^{236}U, ^{238}U
Size (cm)	1.47-cm diameter 0.69 cm thick
Temperature (K)	Liquid Nitrogen (77 K)

Resolution Broadening information

Flight-path, time-of-flight and energy relation:

$$E_n = \mu^2 \frac{L^2}{t_n^2}$$, where μ = 72.3 eV$^{1/2}$ μsec/m.

Energy resolution in a TOF experiment:

$$\left(\frac{\Delta E}{E}\right)^2 = 2\left[\left(\frac{\Delta t_n}{t_n}\right)^2 + \left(\frac{\Delta L}{L}\right)^2\right]$$

Where:

Δt_n is the time-of-flight uncertainty;

ΔL is the flight-path uncertainty (dispersion);

Details on the calculation of the resolution function are found in SAMMY user manual on page 63(R4), section IV-A-2.

The resolution in the TOF Δt_n can be expressed as

$$\Delta t_n^2 = \sum_i \Delta t_i^2$$

where Δt_i represents the different contributions to the time uncertainty Δt_n mainly due to:

$\Delta t_{cw,}$ the TOF analyzer width;

$\Delta t_{bw,}$ the width of the neutron burst; and

Δt_{ed}, the instability of the electronic device (jitter), etc.

Conversion from square distribution to an equivalent Gaussian distribution:

$\Delta t_G = 0.67978 \, \Delta t_n$, where

Δt_G is the parameter entered in the input file for SAMMY.

The resolution in the TOF length ΔL

The uncertainty (dispersion) in the flight-path length is the combination of the uncertainty due to the neutron moderator (if any) ΔL_m and the uncertainty due to the detector ΔL_d, so the total flight-path resolution parameter is

$$\Delta L^2 = \Delta L_m^2 + \Delta L_d^2 \; ;$$

ΔL is the input parameter to SAMMY.

SAMMY Input file xxx.inp

Input for SAMMY, the *.inp* file

```
 92-U-235 total cross section data (Harvey et al. 1986)
      U235      235.
use new spin group format
csisrs
chi squared is wanted
generate plot file a
use free gas model of

    77.00     80.394      .022      .0       -.0136
       1.0     7
      13.8     0.512      35.3     0.128     114.3     0.064     408.0     0.032
    1325.0     0.016    9380.0     0.008  100000.0     0.002
   9.6       .03294
total cross section
      -3.5        0.    0    1
  1       1    2  -3.        1. -3.5  U235                 S3- (s=3)
    1    1    0    0       -3.        0.     0.000
    2    0    0    0       -3.        0.     0.000
    3    0    0    0       -3.        0.     0.000
  2       1    2  -4.        1. -3.5  U235                 S4- (s=4)
    1    1    0    0       -4.        0.     0.000
    2    0    0    0       -4.        0.     0.000
    3    0    0    0       -4.        0.     0.000
  3       1    2   2.        1. -3.5  U235                 P2+ (s=3)
    1    1    0    1       -3.        0.     0.000
    2    0    0    1       -3.        0.     0.000
    3    0    0    1       -3.        0.     0.000
  4       1    2   3.        1. -3.5  U235                 P3+ (s=3)
    1    1    0    1       -3.        0.     0.000
    2    0    0    1       -3.        0.     0.000
    3    0    0    1       -3.        0.     0.000
  5       1    2   4.        1. -3.5  U235                 P4+ (s=3)
    1    1    0    1       -3.        0.     0.000
    2    0    0    1       -3.        0.     0.000
    3    0    0    1       -3.        0.     0.000
  6       1    2   3.        1. -3.5  U235                 P3+ (s=4)
    1    1    0    1       -4.        0.     0.000
    2    0    0    1       -4.        0.     0.000
    3    0    0    1       -4.        0.     0.000
  7       1    2   4.        1. -3.5  U235                 P4+ (s=4)
    1    1    0    1       -4.        0.     0.000
    2    0    0    1       -4.        0.     0.000
    3    0    0    1       -4.        0.     0.000
  8       1    2   5.        1. -3.5  U235                 P5+ (s=4)
    1    1    0    1       -4.        0.     0.000
```

```
    2    0    0    1       -4.         0.      0.000
    3    0    0    1       -4.         0.      0.000
```

SAMMY Input file xxx.dat

This file contains data to be evaluated such as:

Transmission (total cross section);

Fission cross section;

Capture cross section;

Elastic scattering cross sections, etc.

Nuclear Data Centers:

Name	Location	URL
IAEA Nuclear Data Section (NDS)	Vienna/Austria	www-nds.iaea.or.at
OECD NEA Data Bank	Paris/France	www.nea.fr/html/dbdata
US National Nuclear Data Center	Brookhaven/US	www.nndc.bnl.gov
Russian Nuclear Data Center	Obninsk/Russia	www.ippe.obninsk.ru

Data are available in the Cross-Section Information Standard Retrieval System (CSISRS) in the EXFOR, EXchange FORmat, form. Additional

information available in the Computer Index of Neutron Data (CINDA).

Total cross section information as given in the EXFOR format of CSISRS system

```
REQUEST           1001   20000217         5                             0  0     0
ENTRY            13632   20000127                                   13632000     1
SUBENT        13632001   20000114                                   13632001     1
BIB                  9         12                                   13632001     2
INSTITUTE  (1USAORL)                                                13632001     3
REFERENCE  (C,88MITO,,115,198805)                                   13632001     4
AUTHOR     (J.A.HARVEY,N.W.HILL,F.G.PEREY,G.L.TWEED,L.LEAL)         13632001     5
TITLE      High-Resolution Neutron Transmission Measurements on     13632001     6
            235U, 239Pu, 238U                                       13632001     7
FACILITY   (LINAC) ORELA                                            13632001     8
INC-SOURCE (EVAP)                                                   13632001     9
ERR-ANALYS (DATA-ERR) Absolute uncertainty                          13632001    10
STATUS     (APRVD) Approved by D. Wiarda, 10 May 1999.              13632001    11
           Data produced from J. Harvey files by D. Wiarda.         13632001    12
HISTORY    (19990302C) VM                                           13632001    13
           (20000114A) TK BIB corrections                           13632001    14
ENDBIB              12                                              13632001    15
NOCOMMON             0          0                                   13632001    16
ENDSUBENT            0                                              1363200199999
SUBENT        13632002   19990810                                   13632002     1
BIB                  5         10                                   13632002     2
REACTION   (92-U-235(N,TOT),,SIG,,RAW)                              13632002     3
            Run 10409, uncorrected for impurities.                  13632002     4
SAMPLE     99.6% enriched 235U at liquid nitrogen temperature.      13632002     5
           Areal density 0.03294 atom/b for cooled U sample,        13632002     6
            corrected for Ta impurities.                            13632002     7
METHOD     (TOF) 80.394-m flight path                               13632002     8
DETECTOR   (GLASD) Glass scintillator.                              13632002     9
CORRECTION Corrected for deadtime and background.                   13632002    10
           In contrast to the paper: corrections for Ta, 234U,      13632002    11
            236U and 238U have not been made.                       13632002    12
ENDBIB              10                                              13632002    13
NOCOMMON             0          0                                   13632002    14
DATA                 3      27855                                   13632002    15
EN         DATA       DATA-ERR                                      13632002    16
EV         B          B                                             13632002    17
           .
           .
           Several data omitted
           .
           .

 4.6204E+00 2.0675E+01 3.1774E-01                                   1363200227863
 4.5995E+00 2.0488E+01 3.1435E-01                                   1363200227864
 4.5787E+00 1.8817E+01 3.1641E-01                                   1363200227865
 4.5581E+00 1.9213E+01 3.1455E-01                                   1363200227866
 4.5376E+00 1.9278E+01 3.1634E-01                                   1363200227867
 4.5172E+00 1.9270E+01 3.1824E-01                                   1363200227868
 4.4970E+00 1.8852E+01 3.2018E-01                                   1363200227869
 4.4769E+00 1.9290E+01 3.2024E-01                                   1363200227870
 4.4569E+00 1.9433E+01 3.2122E-01                                   1363200227871
 4.4371E+00 1.9987E+01 3.2583E-01                                   1363200227872
ENDDATA          27857                                              1363200227873
```

```
ENDSUBENT            3                                          1363200299999
ENDENTRY             2                                          1363299999999
ENDREQUEST           1                                          Z999999999999
```

SAMMY Input file xxx.par

This file is the initial estimation of the resonance parameters. For a Reich-Moore evaluation, users will give in general the spin of the resonance (J), the resonance energy (E_r), neutron widths (Γ_n), gamma width (Γ_γ) and two more channels for describing the fission process, Γ_{c1} and Γ_{c2}.

1. Initial Resonance Parameter Set

A. Search open literature:

Physics Review, Journal of Nuclear Science and Engineering, etc.

Mughabghab book (BNL-325).

B. If no Information is available

Choose best high-resolution data and look for resonance energy position.

Assign widths according to some method:

Mariscotti Method built in the RSAP computer code:

Searches the total cross section and extract information on maximum, peak height and areas.

$$4Bg\,'_{n}\,'\,F_{0}k^{2}\,'$$

$$'_{f}\,'\;'\,\&\,'_{(}\,\&\,'_{n}$$

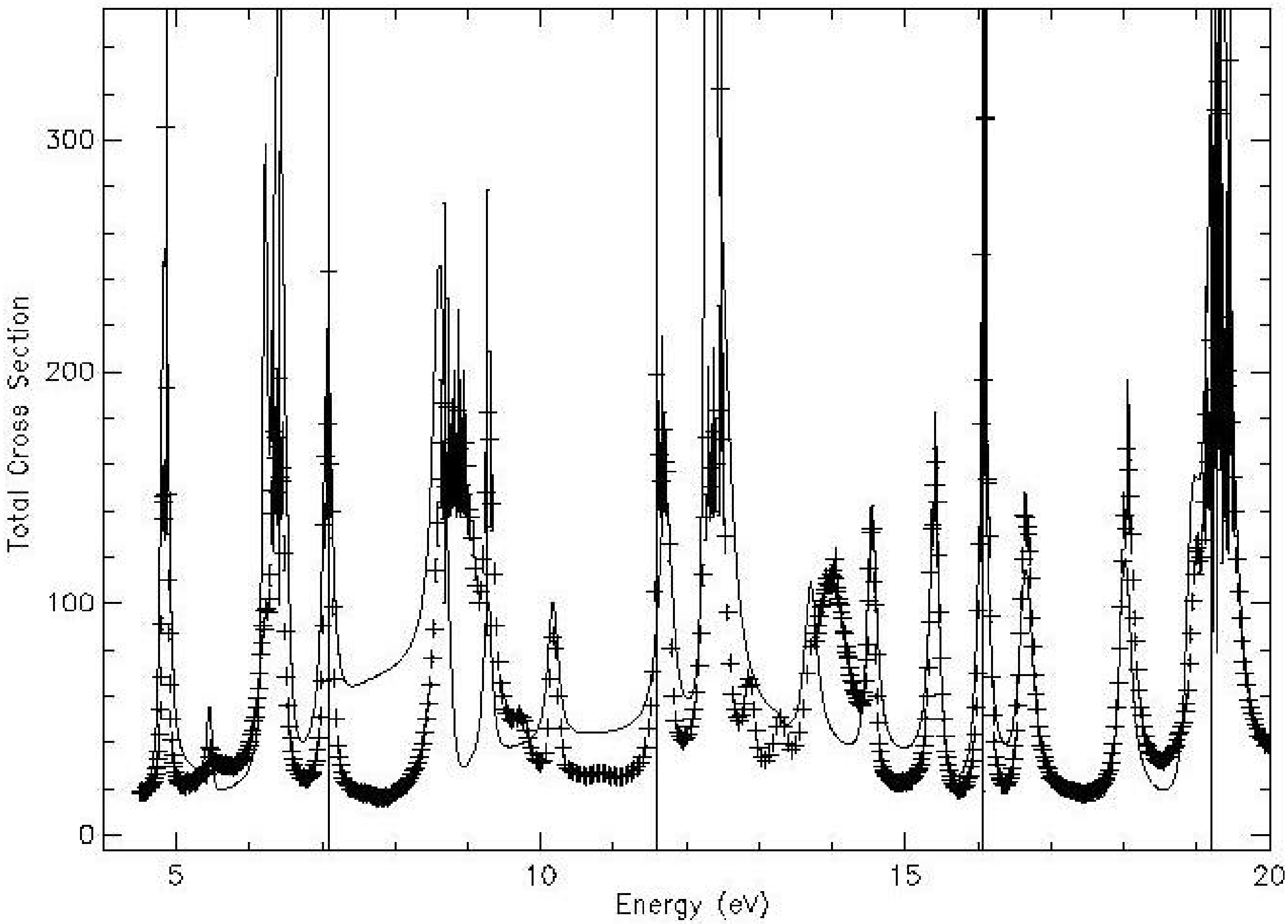
Parameters are equivalent to Single-Level Breit-Wigner cross section representation.

Resonance spins are assigned randomly.

Fission widths signs are assigned randomly.

Initial set of resonance parameters in the SAMMY format generated by RSAP in the energy range from 4 eV to 20 eV for *l*=0 (s-wave).

E_r	$'_{(}$	$'_{n}$	$'_{f1}$	$'_{f2}$						SG
4.810	3.8000E+01	4.4764E-02	2.063E+01	-2.063E+01	0	0	0	0	0	1
4.871	3.8000E+01	4.8218E-02	2.638E+01	-2.638E+01	0	0	0	0	0	2
5.164	3.8000E+01	1.9562E-02	-2.118E+02	2.118E+02	0	0	0	0	0	1
5.466	3.8000E+01	9.8105E-03	8.095E+00	8.095E+00	0	0	0	0	0	2
6.206	3.8000E+01	6.3603E-02	4.772E+01	4.772E+01	0	0	0	0	0	1
6.336	3.8000E+01	6.1664E-02	-4.507E+01	-4.507E+01	0	0	0	0	0	1
6.396	3.8000E+01	5.8226E-02	3.082E+01	3.082E+01	0	0	0	0	0	1
6.468	3.8000E+01	1.1635E-01	5.274E+01	5.274E+01	0	0	0	0	0	2
6.675	3.8000E+01	2.1521E-01	-1.014E+03	-1.014E+03	0	0	0	0	0	1
7.081	3.8000E+01	1.0638E-01	4.120E+01	4.120E+01	0	0	0	0	0	2
8.608	3.8000E+01	1.4457E-01	6.203E+01	6.203E+01	0	0	0	0	0	2
8.713	3.8000E+01	1.2215E-01	9.959E+01	9.959E+01	0	0	0	0	0	1
9.283	3.8000E+01	6.8630E-02	3.112E+01	3.112E+01	0	0	0	0	0	1
10.172	3.8000E+01	6.5080E-02	4.997E+01	4.997E+01	0	0	0	0	0	2
11.715	3.8000E+01	2.2957E-01	7.989E+01	7.989E+01	0	0	0	0	0	1
12.291	3.8000E+01	3.5522E-01	1.198E+02	-1.198E+02	0	0	0	0	0	1
12.484	3.8000E+01	3.5296E-01	1.198E+02	1.198E+02	0	0	0	0	0	2
12.864	3.8000E+01	2.2692E+00	2.480E+03	2.480E+03	0	0	0	0	0	1
13.289	3.8000E+01	2.9070E-02	6.649E+01	6.649E+01	0	0	0	0	0	1
13.697	3.8000E+01	1.2236E-01	6.344E+01	-6.344E+01	0	0	0	0	0	2
14.546	3.8000E+01	1.5165E-01	3.942E+01	3.942E+01	0	0	0	0	0	2
15.417	3.8000E+01	1.8825E-01	-4.541E+01	4.541E+01	0	0	0	0	0	2
16.075	3.8000E+01	2.6288E-01	-4.937E+01	4.937E+01	0	0	0	0	0	2
16.656	3.8000E+01	2.9711E-01	7.735E+01	-7.735E+01	0	0	0	0	0	1
18.040	3.8000E+01	3.3474E-01	7.583E+01	7.583E+01	0	0	0	0	0	1
18.973	3.8000E+01	4.5320E-01	9.827E+01	9.827E+01	0	0	0	0	0	1
19.163	3.8000E+01	5.3121E-01	-1.147E+02	1.147E+02	0	0	0	0	0	1
19.279	3.8000E+01	3.9626E-01	1.608E+02	1.608E+02	0	0	0	0	0	2
19.469	3.8000E+01	7.4532E-01	1.466E+02	-1.466E+02	0	0	0	0	0	1



Comparison of the experimental high-resolution total cross section (crosses) and SAMMY calculations using the initial set of resonance parameters (solid line) generated with RSAP.

2. Resonance Evaluation

A. Begin evaluation of the total cross section. Allow SAMMY to search for the resonance energy (E_r) and the neutron width (Γ_n)

```
 4.810 3.8000E+01 4.4764E-02  2.063E+01 -2.063E+01 1 0 1 0 0 1
 4.871 3.8000E+01 4.8218E-02  2.638E+01 -2.638E+01 1 0 1 0 0 2
 5.164 3.8000E+01 1.9562E-02 -2.118E+02  2.118E+02 1 0 1 0 0 1
 5.466 3.8000E+01 9.8105E-03  8.095E+00  8.095E+00 1 0 1 0 0 2
 6.206 3.8000E+01 6.3603E-02  4.772E+01  4.772E+01 1 0 1 0 0 1
 6.336 3.8000E+01 6.1664E-02 -4.507E+01 -4.507E+01 1 0 1 0 0 1
 6.396 3.8000E+01 5.8226E-02  3.082E+01  3.082E+01 1 0 1 0 0 1
 6.468 3.8000E+01 1.1635E-01  5.274E+01  5.274E+01 1 0 1 0 0 2
 6.675 3.8000E+01 2.1521E-01 -1.014E+03 -1.014E+03 1 0 1 0 0 1
 7.081 3.8000E+01 1.0638E-01  4.120E+01  4.120E+01 1 0 1 0 0 2
 8.608 3.8000E+01 1.4457E-01  6.203E+01  6.203E+01 1 0 1 0 0 2
 8.713 3.8000E+01 1.2215E-01  9.959E+01  9.959E+01 1 0 1 0 0 1
 9.283 3.8000E+01 6.8630E-02  3.112E+01  3.112E+01 1 0 1 0 0 1
10.172 3.8000E+01 6.5080E-02  4.997E+01  4.997E+01 1 0 1 0 0 2
11.715 3.8000E+01 2.2957E-01  7.989E+01  7.989E+01 1 0 1 0 0 1
12.291 3.8000E+01 3.5522E-01  1.198E+02 -1.198E+02 1 0 1 0 0 1
12.484 3.8000E+01 3.5296E-01  1.198E+02  1.198E+02 1 0 1 0 0 2
12.864 3.8000E+01 2.2692E+00  2.480E+03  2.480E+03 1 0 1 0 0 1
13.289 3.8000E+01 2.9070E-02  6.649E+01  6.649E+01 1 0 1 0 0 1
13.697 3.8000E+01 1.2236E-01  6.344E+01 -6.344E+01 1 0 1 0 0 2
14.546 3.8000E+01 1.5165E-01  3.942E+01  3.942E+01 1 0 1 0 0 2
15.417 3.8000E+01 1.8825E-01 -4.541E+01  4.541E+01 1 0 1 0 0 2
16.075 3.8000E+01 2.6288E-01 -4.937E+01  4.937E+01 1 0 1 0 0 2
16.656 3.8000E+01 2.9711E-01  7.735E+01 -7.735E+01 1 0 1 0 0 1
18.040 3.8000E+01 3.3474E-01  7.583E+01  7.583E+01 1 0 1 0 0 1
18.973 3.8000E+01 4.5320E-01  9.827E+01  9.827E+01 1 0 1 0 0 1
19.163 3.8000E+01 5.3121E-01 -1.147E+02  1.147E+02 1 0 1 0 0 1
19.279 3.8000E+01 3.9626E-01  1.608E+02  1.608E+02 1 0 1 0 0 2
19.469 3.8000E+01 7.4532E-01  1.466E+02 -1.466E+02 1 0 1 0 0 1
```

This procedure will improve the estimation of the resonance energy and neutron width.

B. Fit the fission cross section. One is advised to fit the fission cross section by searching alternatively for one fission channel at a time.

4.810	3.8000E+01	4.4764E-02	2.063E+01	-2.063E+01	0	0	0	1	1	1
4.871	3.8000E+01	4.8218E-02	2.638E+01	-2.638E+01	0	0	0	1	1	2
5.164	3.8000E+01	1.9562E-02	-2.118E+02	2.118E+02	0	0	0	1	1	1
5.466	3.8000E+01	9.8105E-03	8.095E+00	8.095E+00	0	0	0	1	1	2
6.206	3.8000E+01	6.3603E-02	4.772E+01	4.772E+01	0	0	0	1	1	1
6.336	3.8000E+01	6.1664E-02	-4.507E+01	-4.507E+01	0	0	0	1	1	1
6.396	3.8000E+01	5.8226E-02	3.082E+01	3.082E+01	0	0	0	1	1	1
6.468	3.8000E+01	1.1635E-01	5.274E+01	5.274E+01	0	0	0	1	1	2
6.675	3.8000E+01	2.1521E-01	-1.014E+03	-1.014E+03	0	0	0	1	1	1
7.081	3.8000E+01	1.0638E-01	4.120E+01	4.120E+01	0	0	0	1	1	2
8.608	3.8000E+01	1.4457E-01	6.203E+01	6.203E+01	0	0	0	1	1	2
8.713	3.8000E+01	1.2215E-01	9.959E+01	9.959E+01	0	0	0	1	1	1
9.283	3.8000E+01	6.8630E-02	3.112E+01	3.112E+01	0	0	0	1	1	1
10.172	3.8000E+01	6.5080E-02	4.997E+01	4.997E+01	0	0	0	1	1	2
11.715	3.8000E+01	2.2957E-01	7.989E+01	7.989E+01	0	0	0	1	1	1
12.291	3.8000E+01	3.5522E-01	1.198E+02	-1.198E+02	0	0	0	1	1	1
12.484	3.8000E+01	3.5296E-01	1.198E+02	1.198E+02	0	0	0	1	1	2
12.864	3.8000E+01	2.2692E+00	2.480E+03	2.480E+03	0	0	0	1	1	1
13.289	3.8000E+01	2.9070E-02	6.649E+01	6.649E+01	0	0	0	1	1	1
13.697	3.8000E+01	1.2236E-01	6.344E+01	-6.344E+01	0	0	0	1	1	2
14.546	3.8000E+01	1.5165E-01	3.942E+01	3.942E+01	0	0	0	1	1	2
15.417	3.8000E+01	1.8825E-01	-4.541E+01	4.541E+01	0	0	0	1	1	2
16.075	3.8000E+01	2.6288E-01	-4.937E+01	4.937E+01	0	0	0	1	1	2
16.656	3.8000E+01	2.9711E-01	7.735E+01	-7.735E+01	0	0	0	1	1	1
18.040	3.8000E+01	3.3474E-01	7.583E+01	7.583E+01	0	0	0	1	1	1
18.973	3.8000E+01	4.5320E-01	9.827E+01	9.827E+01	0	0	0	1	1	1
19.163	3.8000E+01	5.3121E-01	-1.147E+02	1.147E+02	0	0	0	1	1	1
19.279	3.8000E+01	3.9626E-01	1.608E+02	1.608E+02	0	0	0	1	1	2
19.469	3.8000E+01	7.4532E-01	1.466E+02	-1.466E+02	0	0	0	1	1	1

After some iterations vary both fission channels.

C. Fit the total and fission cross sections.

```
  4.810 3.8000E+01 4.4764E-02  2.063E+01 -2.063E+01 1 0 1 1 1 1
  4.871 3.8000E+01 4.8218E-02  2.638E+01 -2.638E+01 1 0 1 1 1 2
  5.164 3.8000E+01 1.9562E-02 -2.118E+02  2.118E+02 1 0 1 1 1 1
  5.466 3.8000E+01 9.8105E-03  8.095E+00  8.095E+00 1 0 1 1 1 2
  6.206 3.8000E+01 6.3603E-02  4.772E+01  4.772E+01 1 0 1 1 1 1
  6.336 3.8000E+01 6.1664E-02 -4.507E+01 -4.507E+01 1 0 1 1 1 1
  6.396 3.8000E+01 5.8226E-02  3.082E+01  3.082E+01 1 0 1 1 1 1
  6.468 3.8000E+01 1.1635E-01  5.274E+01  5.274E+01 1 0 1 1 1 2
  6.675 3.8000E+01 2.1521E-01 -1.014E+03 -1.014E+03 1 0 1 1 1 1
  7.081 3.8000E+01 1.0638E-01  4.120E+01  4.120E+01 1 0 1 1 1 2
  8.608 3.8000E+01 1.4457E-01  6.203E+01  6.203E+01 1 0 1 1 1 2
  8.713 3.8000E+01 1.2215E-01  9.959E+01  9.959E+01 1 0 1 1 1 1
  9.283 3.8000E+01 6.8630E-02  3.112E+01  3.112E+01 1 0 1 1 1 1
 10.172 3.8000E+01 6.5080E-02  4.997E+01  4.997E+01 1 0 1 1 1 2
 11.715 3.8000E+01 2.2957E-01  7.989E+01  7.989E+01 1 0 1 1 1 1
 12.291 3.8000E+01 3.5522E-01  1.198E+02 -1.198E+02 1 0 1 1 1 1
 12.484 3.8000E+01 3.5296E-01  1.198E+02  1.198E+02 1 0 1 1 1 2
 12.864 3.8000E+01 2.2692E+00  2.480E+03  2.480E+03 1 0 1 1 1 1
 13.289 3.8000E+01 2.9070E-02  6.649E+01  6.649E+01 1 0 1 1 1 1
 13.697 3.8000E+01 1.2236E-01  6.344E+01 -6.344E+01 1 0 1 1 1 2
 14.546 3.8000E+01 1.5165E-01  3.942E+01  3.942E+01 1 0 1 1 1 2
 15.417 3.8000E+01 1.8825E-01 -4.541E+01  4.541E+01 1 0 1 1 1 2
 16.075 3.8000E+01 2.6288E-01 -4.937E+01  4.937E+01 1 0 1 1 1 2
 16.656 3.8000E+01 2.9711E-01  7.735E+01 -7.735E+01 1 0 1 1 1 1
 18.040 3.8000E+01 3.3474E-01  7.583E+01  7.583E+01 1 0 1 1 1 1
 18.973 3.8000E+01 4.5320E-01  9.827E+01  9.827E+01 1 0 1 1 1 1
 19.163 3.8000E+01 5.3121E-01 -1.147E+02  1.147E+02 1 0 1 1 1 1
 19.279 3.8000E+01 3.9626E-01  1.608E+02  1.608E+02 1 0 1 1 1 2
 19.469 3.8000E+01 7.4532E-01  1.466E+02 -1.466E+02 1 0 1 1 1 1
```

3. External Levels

Describes the potential scattering cross section effects for the energy region where the evaluation is performed.

Methods:

A. SAMMY users manual section III.A.1.a "Logarithmic parameterization of external R-function"

> **Contribution of the external levels to the R-matrix in terms of average resonance parameters (strength functions, radius, etc.)**

B. Fröhner method: Two external resonance one below and one above the energy region where the evaluation is performed.

C. H. Derrien method: Consists of shifting resonances in the region where the evaluation is made into the external region below and above the resonance region.

GOOD LUCK !!