Headings for Incident Projectile Energy Resolution (EN-RSL etc.)

(N. Otsuka, V. Semkova, 2017-05-16, Memo CP-D/932)

LEXFOR "Resolution" explains the coding of the incident projectile energy resolution as follows:

> The energy resolution describes the distribution curve of the energy spread. It is usually defined as full-width at half-maximum (FWHM), but may be given in other representations. The shape and definition of the resolution function should be given in free text under INC-SPECT, if known. Resolution is coded using the following data headings:
>
> - EN-RSL-FW Incident-particle energy resolution (FWHM)
> - EN-RSL-HW Incident-particle energy resolution (±HWHM)
> - EN-RSL   Incident-particle energy resolution (unspecified)

Accordingly, an energy spread value following ± without further specification (e.g., ± 1 MeV) has to be under EN-RSL. However, a value under this heading (EN-RSL) may have another meaning (e.g., full bin width such as 12924.002). Under this situation, we cannot explain users and tools the meaning of the number properly (See Appendix 1 for two different interpretations of the values under EN-RSL).

I checked the usage of EN-RSL-HW in EXFOR entries compiled from the articles published in 2000 or later, and found three usages:

1. To provide HWHM values
2. To provide values followed by ±
3. To provide FWHM values (!, This must be under EN-RSL-FW).

Sometimes compilers try to explain the details about the heading in free text, but the following two examples would show we need a better coding rule for it:

Example – **22923.001**
```
INC-SPECT  *EN-RSL-FW*.The full width at half-maximum energy
            resolution. Low-energy tail includes 13% of neutrons
          Neutron flux is given on Fig.1 of J,PR/C,73,034611,2006
          -the peak -95.6 MeV, median -95.1 MeV, average 94.0MeV.
```

Example – **40642.001**
```
ERR-ANALYS EN-RSL-FW Width at the bottom of triangular energy
            distribution
```

Proposals

(1) Two change in the expansions of EN-RSL-FW and EN-RSL-HW as follows:
- EN-RSL-FW Incident-particle energy resolution (~~FWHM~~ full width)
- EN-RSL-HW Incident-particle energy resolution (~~±HWHM~~ half width)

- EN-RSL   Incident-particle energy resolution (unspecified)

(2) Change of the format rule to allow free text explanation of the heading followed by the parenthesized heading under INC-SPECT, for example
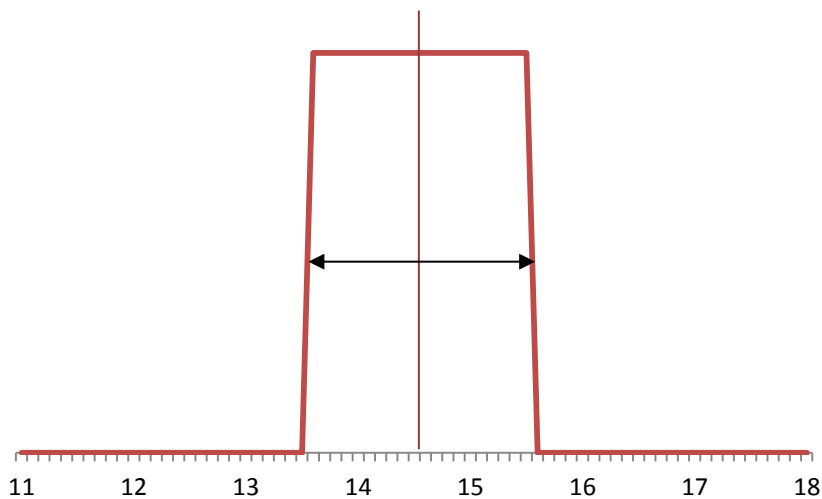
```
INC-SPECT  (EN-RSL-FW) Energy resolution (Full width at half-maximum)
INC-SPECT  (EN-RSL-FW) Width of energy bin
INC-SPECT  (EN-RSL-HW) Energy resolution (Half width at half-maximum)
INC-SPECT  (EN-RSL-HW) Energy resolution (standard deviation)
```

Examples of energy distributions

1) Standard deviation, HWHM and FWHM in normal distribution
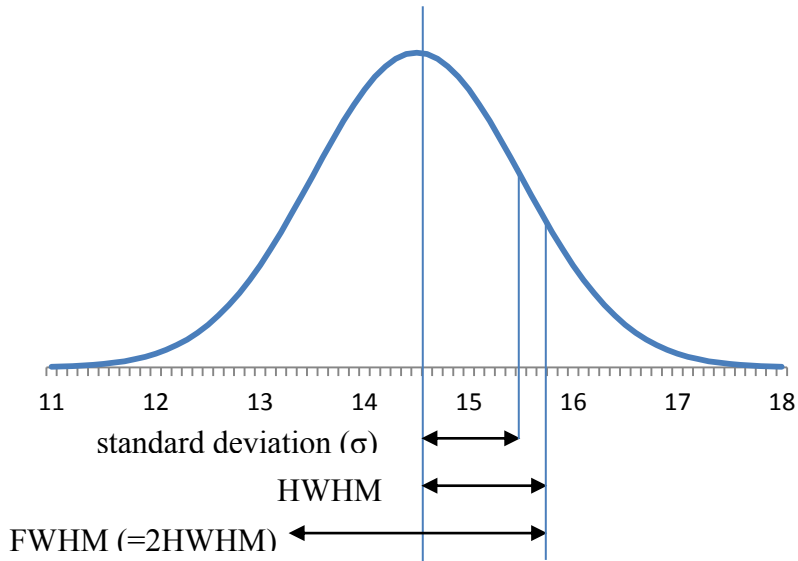
2) Full bin width in uniform distribution

Uncertainty? Resolution?

We would like to remind compilers to distinguish the uncertainty (e.g., EN-ERR) and resolution (e.g., EN-RSL) when possible.

- The uncertainty in the charge particle beam energy is very small. The uncertainty in the neutron beam energy, which is usually much smaller that the energy resolution, depends on the uncertainties in the parameters for neutron production reactions (e.g., cross section, charged-particle beam energy and its loss in the neutron production target). The neutron energy resolution depends on spectral flux distribution of the neutron beam for the actual irradiation geometry (e.g., shape and size of the sample irradiated by the neutron beam).
- The uncertainty can be reduced by repeating measurement of the incident energy, but resolution does not depend on such statistics. For example, the thickness of foils in the stacked foil charged-particle activation determines the incident energy resolution (not uncertainty), and we cannot reduce it by measuring the thickness many times.

Example: **Table XIII of A.Fessler et al., Nucl.Sci.Eng.134(2000)171 (EXFOR 22414)**

The uncertainty and energy spread (HWHM) for D-T neutron energy distribution are tabulated separately. EN-RSL is wrongly used for HWHM in the current EXFOR Master.

TABLE XIII

Measured Reaction Cross Sections and Corresponding Total Uncertainties from the Present Experiment

| E_n[a] (keV)	$\frac{1}{2}$ FWHM[b] (keV)	σ (mb)	E_n[a] (keV)	$\frac{1}{2}$ FWHM[b] (keV)	σ (mb)
$^{19}F(n,p)^{19}O$			$^{23}Na(n,p)^{23}Ne$		
$16\,064 \pm 62$	400	14.55 ± 0.78	$16\,127 \pm 62$	440	35.80 ± 1.67
$17\,026 \pm 40$	300	12.27 ± 0.72	$17\,119 \pm 41$	285	31.16 ± 2.10
$17\,777 \pm 32$	285	9.85 ± 0.56	$17\,887 \pm 32$	230	26.17 ± 1.67
$19\,101 \pm 12$	290	8.37 ± 0.50	$19\,174 \pm 11$	250	24.62 ± 1.98
$20\,310 \pm 10$	295	7.43 ± 0.67	$20\,463 \pm 10$	200	17.27 ± 1.59
$^{23}Na(n,\alpha)^{20}F$			$^{25}Mg(n,p)^{25}Na$		
$16\,127 \pm 62$	440	102.11 ± 4.81	$16\,083 \pm 62$	410	60.95 ± 5.00

[a] Average neutron energy and its uncertainty.
[b] $\frac{1}{2}$ FWHM of the primary $^{3}H(d,n)^{4}He$ neutron spectrum seen by the sample, derived from the calculated spectra.
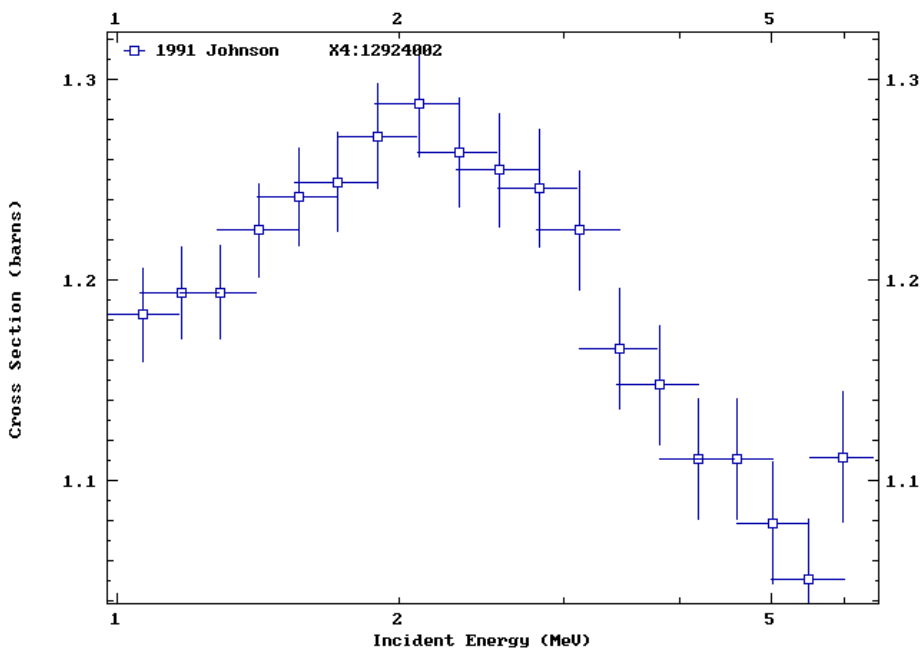
Appendix 1
EXFOR 12924.002 plotted by the NDS EXFOR web retrieval system

Quick plot (as intended by the author)
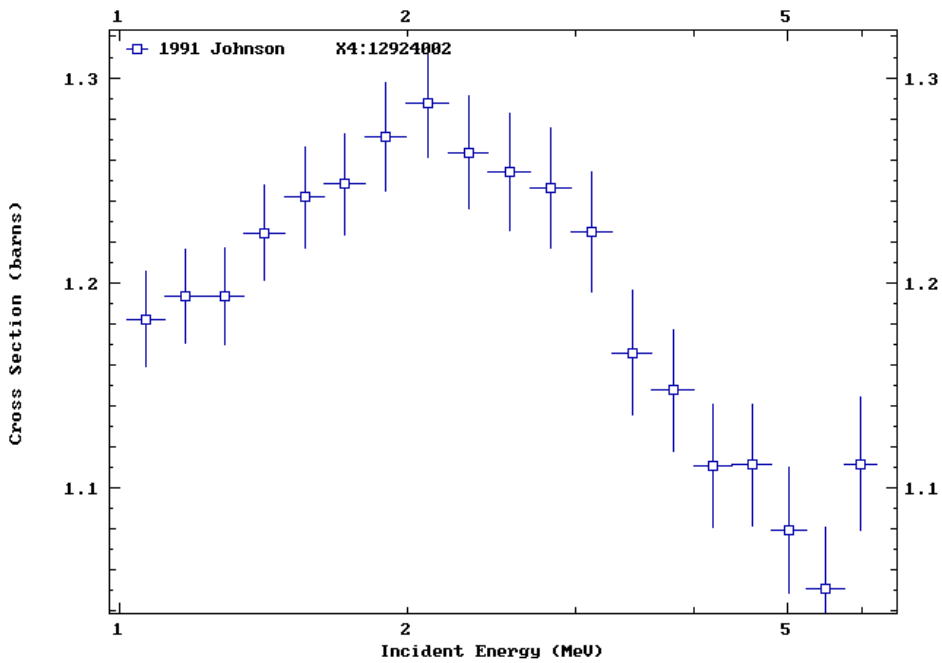
Advanced plot (according to the plotting flag of EN-RSL in Dict.24?)

Extraction from EXFOR 12924.002

EN	EN-RSL	DATA	ERR-S	ERR-T	ERR-9
KEV	KEV	B	PER-CENT	PER-CENT	PER-CENT
5985.9	468.4	1.1118	2.39	2.91	0.35
5504.1	495.2	1.0510	2.26	2.82	0.36
5039.6	433.8	1.0794	2.27	2.82	0.35

...

Appendix 2

Usage of EN-RSL-HW in EXFOR entries from articles published in 2000 or later

Entry	Explanation by authors	Remark	Half width?
22666	FWHM	Must be EN-RSL-FW.	No
22691	Half-width of the peak in the neutron spectrum	Uncertain if HWHM	Yes
22723	?	No such a value in the article	?
22806	FWHM	Must be EN-RSL-FW.	No
22821	95.8 ±0.5 MeV neutrons	Uncertain if HWHM	Yes
22910	Difference between maximum and mean neutron energy	Not HWHM.	Yes
22949	The spread of the neutron energy is estimated to be ±130 keV	Uncertain if HWHM	Yes
23159	Difference between maximum and mean neutron energy	Not HWHM.	Yes
23233	FWHM (V. Semkova, 2017-05-08)	Must be EN-RSL-FW.	No
23288	?	Values received from authors	?
23295	With an energy spread of ±30 keV	Uncertain if HWHM	Yes
31714	FWHM of the monoenergetic peaks	Must be EN-RSL-FW.	No
32205	The estimated energy resolution, 0.5FWHM (MeV)	Ok	Yes
E1831	Beam energy stability was less than ±2.5 keV at 6 MeV	Must be EN-ERR?	?