International Atomic Energy Agency

Heading for Incident Projectile Energy Resolution

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Example of Beam Energy Resolution (D-T source)

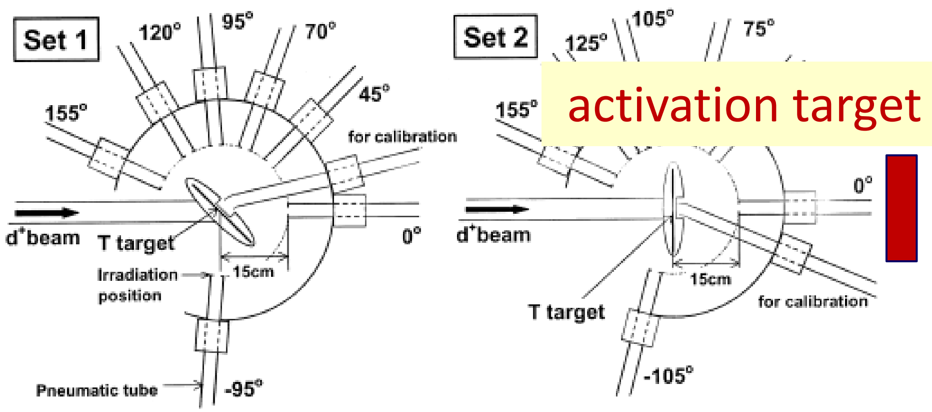


Fig. 1. Pneumatic sample transport system at OKTAVIAN. Samples were irradiated at the angles of 0, 45, 70, 95, 120 and 155° (Set 1) or at the angles of 0, 50, 75,

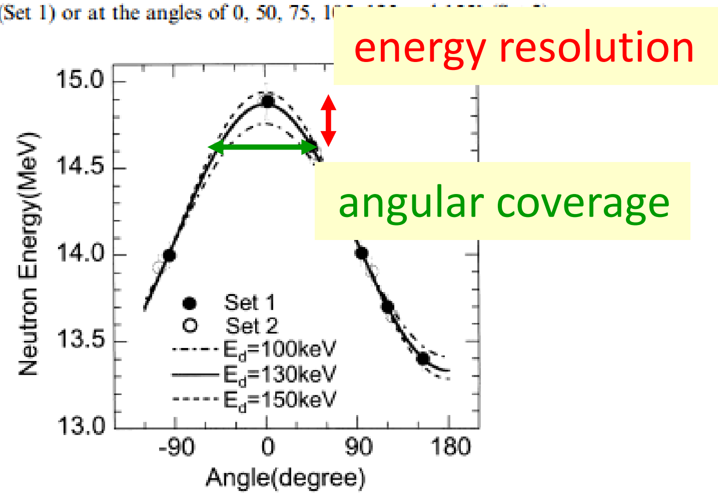
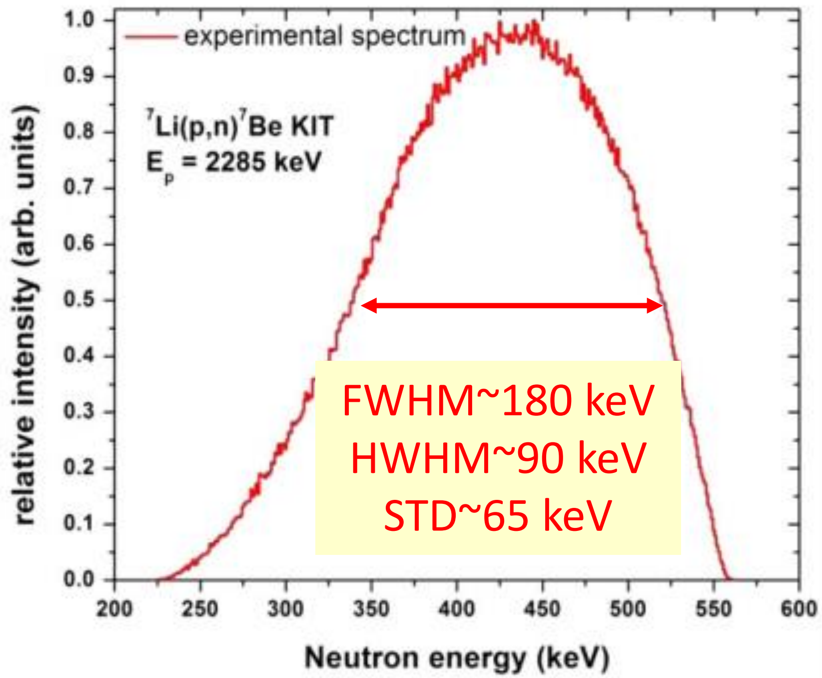


Fig. 2. Angular dependence of D–T neutron energy. The calculated neutron energies for incident deuteron energies (E_d) = 100, 130 and 150 keV are shown. The measured neutron energies show a good agreement with a calculated value with E_d = 130 keV.

- The neutron energy of D-T source depends on the angle of the sample relative to the deuteron beam.
- The highest energy at 0 degree.
- The energy range depends on the angle covered by the sample.
- Larger spread for larger sample.

H. Sakane+, J,ANE,28,1175,2001

Example of Beam Energy Resolution (Li-p source)



Neutron activation under a broad neutron spectrum (SPA)

A. Wallner+, J,PRL,112,192501,2014

Example of Beam Energy Resolution (TOF)

energy resolution of each bin (bin width)

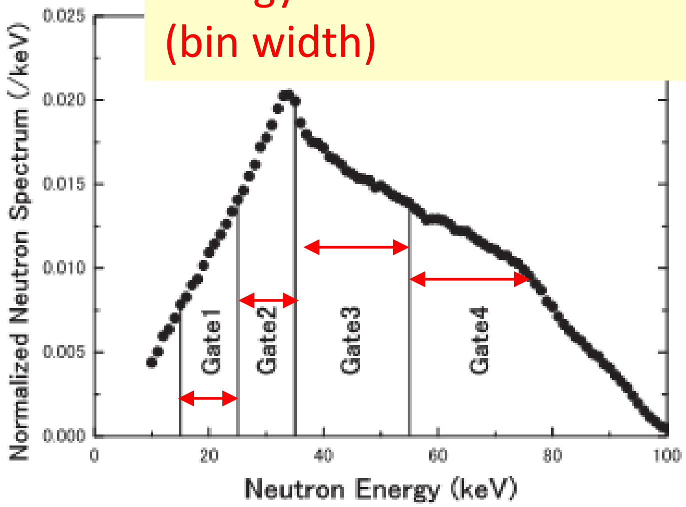
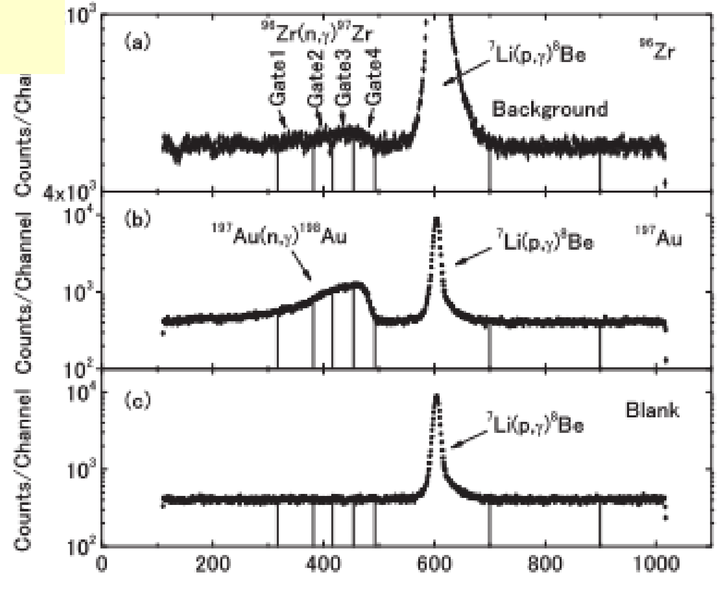


Fig. 2 Incident neutron spectrum. Neutron energy regions for analysis are shown as Gates 1 to 4. The average neutron energy



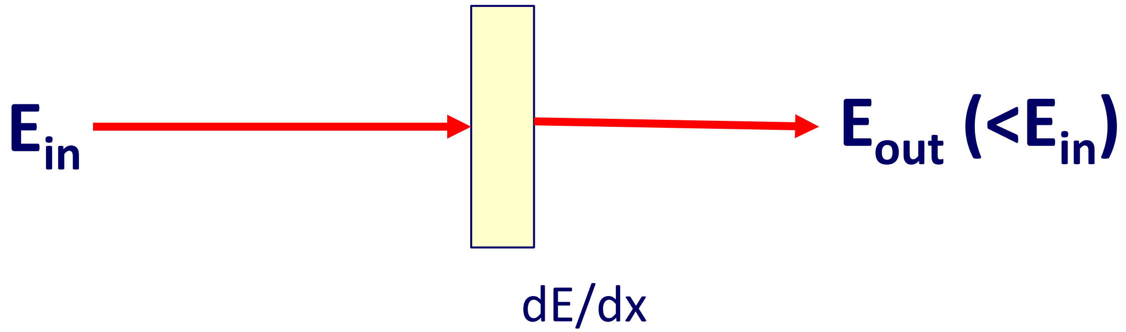
$^{7}Li(p,n)$ neutron field divided to four bins (gates)

Capture events at each TOF channel divided to four bins (gates).

Energy resolution can be adjusted by gate setting (balance with statistics)

T. Katabuchi+, J,NST,48,744,2011

Example of Beam Energy Resolution (CP Beam)



- Energy resolution ($E_{in} – E_{out}$) due to energy loss of charged particle (calculated by using a stopping power table)

- Thinner foil gives narrower energy resolution (balance with statistics)

LEXFOR “Resolution”

Resolution

<u>Incident-Projectile Energy Resolution</u>

Incident-projectile energy resolution is the energy spread or channel width (or a combination) of the incident projectile.

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)

Headings for Energy Resolution

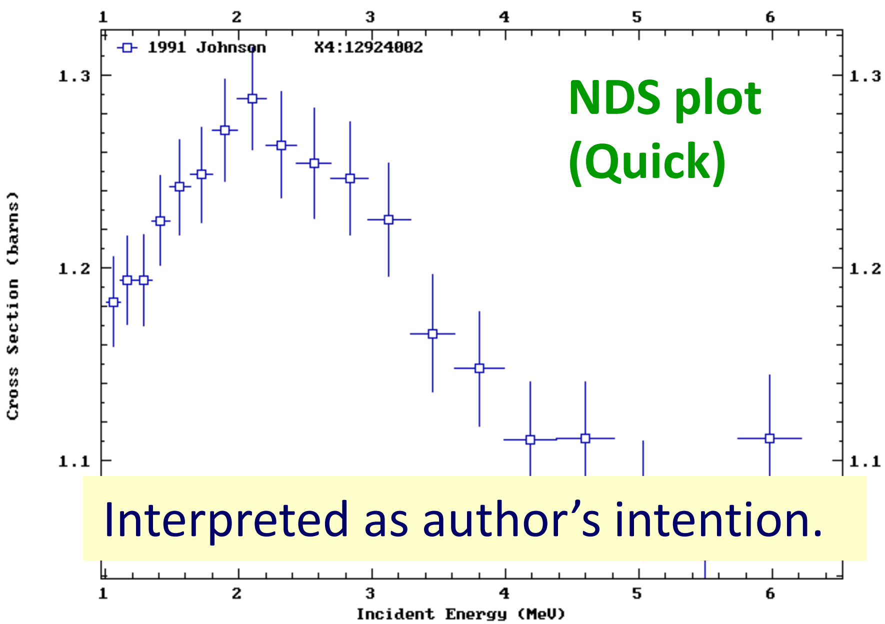
Code	Expansion (explanation)	Derivatives
EN-RSL	Incident projectile energy resolution (unspecified)	+EN-RSL, -EN-RSL etc.
EN-RSL-FW	Incident projectile energy resolution (FWHM)	
EN-RSL-HW	Incident projectile energy resolution (HWHM)	+EN-RSL-HW, -EN-RSL-HW

The following expressions of energy resolution are therefore for EN-RSL:

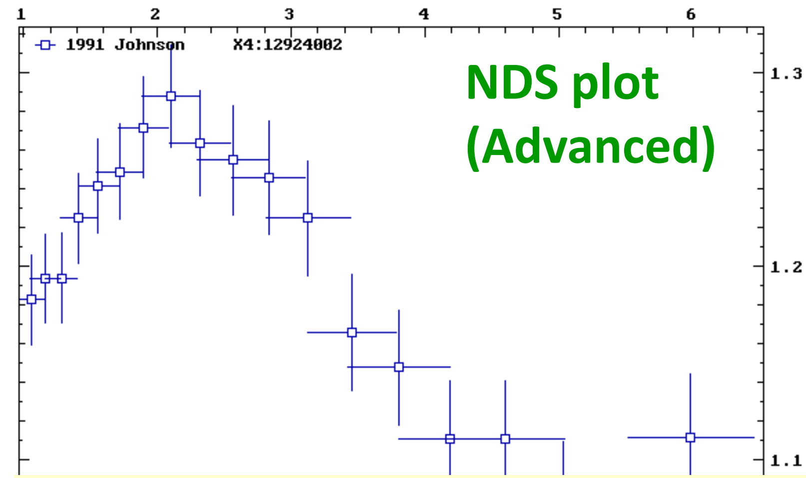
- Standard deviation
- Numbers followed by ± (e.g., "±1.2 MeV") without further specification
- Bin width

We cannot explain plotting tools their treatment properly.

Plotting of Cross Sections with Bin Width



Interpreted as author's intention.



Interpreted in a consistent manner with plotting flag of EN-ERR in Dict.24.

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

…

Should "half-maximum" be Computer Readable?

- In the current definition of EN-RSL-FW (FWHM) and -HW (HWHM), we cannot instruct plotting tools length of the horizontal error-bar properly in many cases.

- Distinction between various half-width (HWHM, standard deviation, half of bin-width) becomes important if we want to use beyond plotting (e.g., folding of evaluated cross section by spectrum). But it requires more details of the spectrum shape.

$$\langle\sigma\rangle = \int dE\, \sigma(E)\, \phi(E) \,/\, \int dE\, \phi(E)$$

Actual Usage of EN-RSL-HW in EXFOR

(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
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
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?	?

- **We have already used EN-RSL-HW for HW but not HWHM.**
- **Use of EN-RSL-HW for FWHM is not acceptable!!**

Proposal 1

To delete "HM" (half-maximum) from expansions

Code	Expansion (explanation)
EN-RSL	Incident projectile energy resolution (unspecified)
EN-RSL-FW	Incident projectile energy resolution (FW~~HM~~)
EN-RSL-HW	Incident projectile energy resolution (HW~~HM~~)

Free Text Explanation on EN-RSL

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
```

We can standardize free text description of EN-RSL related headings by allowing headings as coded information of INC-SPECT:

```
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.

INC-SPECT  (EN-RSL-FW) Width at the bottom of triangular energy
            distribution
```

Proposal 2

Allow energy resolution headings as coded information of INC-SPECT.

Reminder: Resolution and Uncertainty

Distinguish the *uncertainty* (e.g., EN-ERR) and *resolution* (e.g., EN-RSL) when possible. They are different concepts!!

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		
16064 ± 62	400	14.55 ± 0.78	16127 ± 62	440	35.80 ± 1.67
17026 ± 40	300	12.27 ± 0.72	17119 ± 41	285	31.16 ± 2.10
17777 ± 32	285	9.85 ± 0.56	17887 ± 32	230	26.17 ± 1.67
19101 ± 12	290	8.37 ± 0.50	19174 ± 11	250	24.62 ± 1.98
20310 ± 10	295	7.43 ± 0.67	20463 ± 10	200	17.27 ± 1.59
^{23}Na$(n,\alpha)^{20}$F			^{25}Mg$(n,p)^{25}$Na		
16127 ± 62	440	102.11 ± 4.81	16083 ± 62	410	60.95 ± 5.00
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

A.Fessler et al., Nucl.Sci.Eng.134(2000)171 (EXFOR 22414)