

Analysis of suspicious E-LVL values (Appendix of Memo CP-D/1043)

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1 Purpose

Although EXFOR contains a lot of experimental nuclear reaction data (about 24,000 experiments), there are a lot of coding errors that should be corrected. In this work, we focused on the level energy (E-LVL) rather than excitation energy (E-EXC) that should be modified in order to reflect what is reported by experimentalists.

2 Process

EXFOR contains a lot of data, and it is time-consuming to check all of them manually. Therefore, we developed a program which extracts the data with the high possibility of error by setting the allowance to 5%. This program selected the data registered in EXFOR whose E-LVL value is more than 5% far from any values registered in ENSDF. It should be noted that there may be an E-LVL value more than 5% away from any ENSDF value but do not need to be corrected, and there may be an E-LVL value less than 5% away but need to be corrected. We were not able to investigate the latter in this study.

Among the data existing in EXFOR, the present survey covers all reactions where the incident particles are neutrons, protons, deuteron, triton, helium-4, helium-3, and γ rays, and spontaneous fission reactions.

3 Results

There were 933¹E-LVL values more than 5% far from any values registered in ENSDF. Table 1 shows the number of suspicious E-LVL values extracted by the program for each projectile and spontaneous fission reaction.

Table 1: Number of E-LVL values for each reaction and incident particle

Reactions, Projectile	Number of E-LVL values (Fraction (%))	Fraction of experiments in EXFOR (%)
Proton	273 (29)	20
Deuteron	270 (29)	9
Helium-3	143 (15)	3
Neutron	117 (13)	46
Helium-4	96 (10)	8
Gamma ray	24 (3)	6
Triton	9 (1)	1
Spontaneous Fission	1 (0)	3
Total	933 (100)	100

It should be noted that the number extracted by the program depends on the reaction and incident particle, but it also depends on the number of data originally recorded in EXFOR. Proton and Helium-3 is a good example.

EXFOR is built on the cooperation of various data centers. Table 2 shows the number of suspicious E-LVL values extracted by the program for each center / projectile.

Table 2: Number of suspicious E-LVL values per data center/projectile

Center / projectile	O	E	F	2	D	A	1	4	C	M	T	L	3	S	K	R
Number of E-LVL values (Fraction (%))	439 (47)	138 (15)	106 (11)	56 (6)	36 (4)	30 (3)	28 (3)	26 (3)	25 (3)	12 (1)	11 (1)	11 (1)	8 (1)	5 (1)	1 (0)	1 (0)
Fraction of experiments in EXFOR (%)	10	5	6	15	8	5	19	7	10	4	1	1	8	1	0	0

¹If the same subentry had multiple E-LVL values in the Data or Common sections, they were counted separately.

It should be noted that the number of experiments for each data center / projectile originally included in EXFOR is also different, as explained in Table 1.

Next, we checked the original paper for the 933 suspicious E-LVL values extracted by the program. As a result, it became clear that there were some cases that needed to be corrected. Table 3 shows the number of suspicious E-LVL values that are related coding mistakes.

Table 3: Number of data with and without correction

Decision	Number of E-LVL values
Not necessary (N)	470
Necessary (Y)	412
Not necessary but not certain (N?)	34
Necessary but not certain (Y?)	2
Data source unknown (?)	15
Total	933

The number of suspicious E-LVL values that needed to be corrected and not needed were about the same. Table 4 shows which need to be corrected.

Table 4: Number of coding errors

Correction point	Number of errors
Unit	159
Heading	90
Number in Data	60
Number in Common	54
REACTION	48
EN-SEC	5
Total	416

There were a total of 416^{2 3} pieces that needed to be fixed. It became clear that there were various modifications. The following is a detailed explanation of each modification.

3.1 Unit

The first is a correction regarding units. In EXFOR, "keV" and "MeV" are used as the units of E-LVL. There were some data where the units were likely to have been mistaken during the data input to EXFOR.

As an example, Figure 1 shows the current EXFOR data of F1146.007.

#/Legend				
E-LVL	E-LVL	ANG-CM	DATA-CM	DATA-ERR
MEV	MEV	ADEG	MU-B/SR	MU-B/SR
1.073	1.081	10.299	2.3545	1.2282
1.073	1.081	12.704	1.9657	0.8674
1.073	1.081	17.733	1.2678	0.7995
1.073	1.081	20.127	1.944	1.0378
1.073	1.081	22.975	1.1746	0.5752
1.073	1.081	35.533	0.9705	0.3534
1.073	1.081	37.944	0.564	0.2448
1.073	1.081	45.704	0.3412	0.1737
1.073	1.081	50.393	0.46	0.2641
140.5	142.6	2.845	802.18	
140.5	142.6	5.55	1311.	
140.5	142.6	7.83	1436.	
140.5	142.6	10.232	963.57	
140.5	142.6	12.973	381.03	
140.5	142.6	15.701	255.7	
140.5	142.6	22.771	175.06	

Figure 1: EXFOR:F1146.007

In the current EXFOR, MeV is used as the unit for E-LVL values. It also describes 1.073 MeV, 1.081 MeV, 140.5 MeV, and 142.6 MeV as E-LVL values⁴.

Next, we checked the original paper for F1146.007. Figure 2 shows the data that F1146.007 referred to.

²In addition to the 412 data whose decision is "Y", the following two data are included. Data 20935.003 has the decision of "?" and F1351.006 has the decision of "Y?".

³22532.010 and 22532.020 has two errors, (REACTION and Number in Common) respectively.

⁴It is only the latter two energies that have been extracted in this program. 1.073 MeV and 1.081 MeV are not more than 5% far from the values in ENSDF.

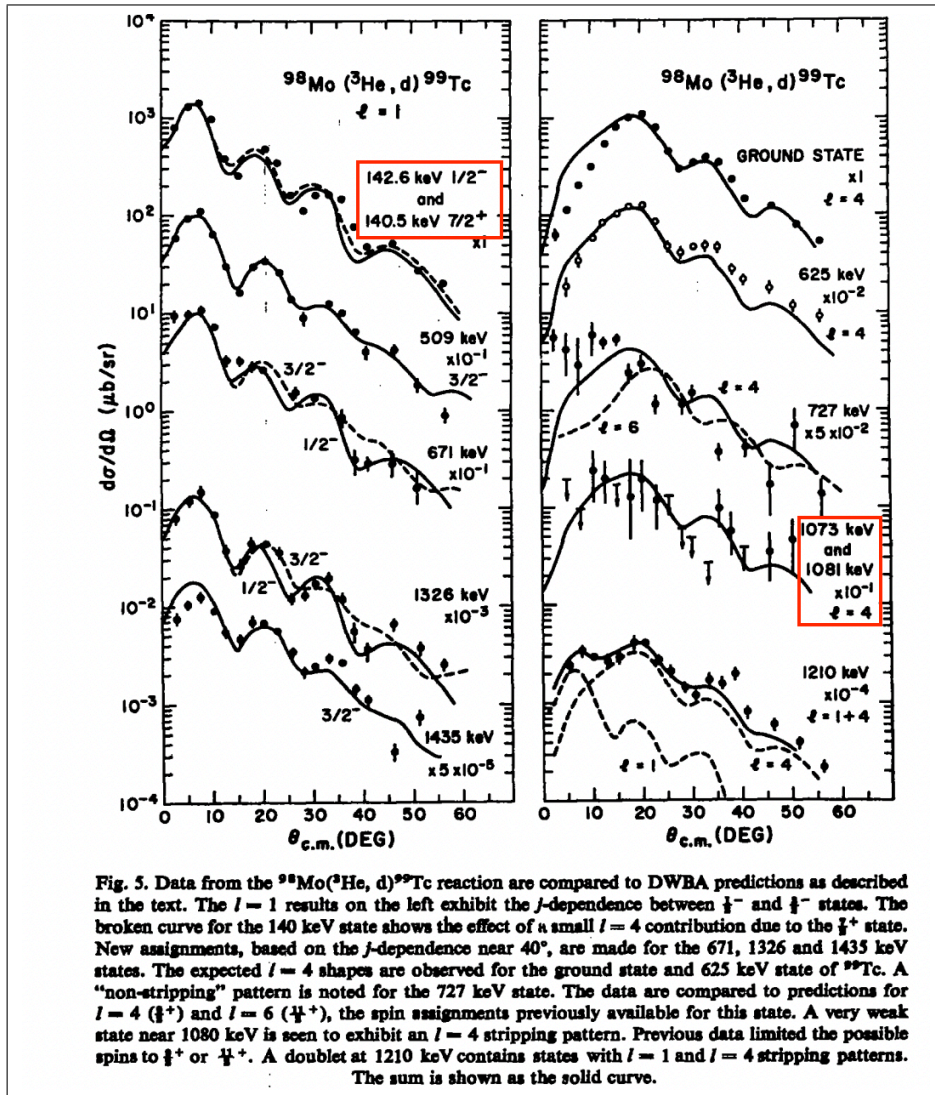


Figure 2: Data referenced in F1146.007

The E-LVL is described as 1073 keV, 1081 keV, 140.5 keV, and 142.6 keV, and "keV" is used as the unit. Therefore, it is necessary to revise the unit of EXFOR from MeV to keV. In addition, if the unit is changed to keV, it is necessary to change 1.073 and 1.081 in Data to 1073 and 1081.

The above can be summarized as shown in Table 5.

Table 5: Fix of F1146.007

Item	Current	Modified
Unit	MeV	keV
Data	1.073	1073
Data	1.081	1081

3.2 Heading

The second is a correction regarding headings. There are various headings in EXFOR. However, it was found that some of the data had the wrong heading. One of the mistakes in the heading is that the outgoing energy ("E") should have been used, but "E-LVL" is used.

As an example, Figure 3 shows the current EXFOR data of O2158.008.

EN	#/Legend	DATA	DATA-ERR
MEV	E-LVL	NO-DIM	NO-DIM
14.	232.	-0.20	0.03
14.	265.	0.57	0.06
14.	1030.	-0.44	0.13
14.	1111.	0.63	0.06
14.	1221.	0.21	0.06
14.	1395.	0.22	0.27
14.	1658.	0.52	0.17
18.	232.	-0.28	0.04
18.	991.	-0.76	0.11
18.	1111.	0.55	0.04
18.	1289.	0.63	0.13
18.	1426.	0.66	0.21

Figure 3: EXFOR:O2158.008

In the current EXFOR, heading is "E-LVL".

Next, I checked the original paper for O2158.008. Figures 4 and 5 show the data that O2158.008 refers to.

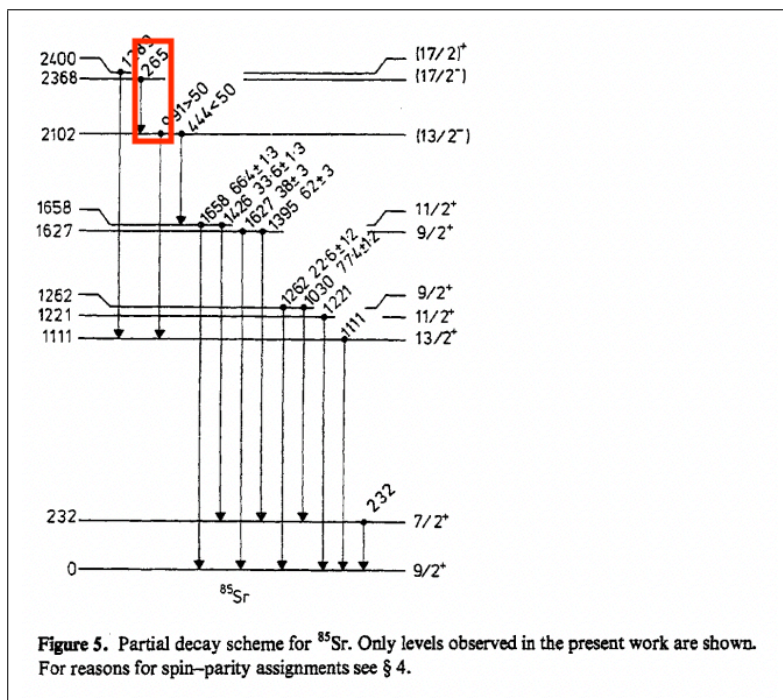


Figure 4: Data referenced in O2158.008 (1)

Table 4. Results of the angular distribution and polarisation measurements with the $^{82}\text{Kr}(\alpha, xn)^{84,85}\text{Sr}$ reactions.

Nucleus	E_γ^a (keV)	$E_\alpha = 14 \text{ MeV}$				
		Relative intensity	a_2^b	a_4^b	$P(90^\circ)$	Relative intensity
^{84}Sr	793	—	—	—	—	1000 ± 40
	974	—	—	—	—	354 ± 14
^{85}Sr	232	—	0.03 ± 0.04	0.03 ± 0.05	-0.20 ± 0.03	—
	265	120 ± 5	0.30 ± 0.03	-0.11 ± 0.04	0.57 ± 0.06	280 ± 11
	444	<200	—	—	—	<200
	991	≈ 190	—	—	—	233 ± 9
	1030	240 ± 9	-0.66 ± 0.02	0.03 ± 0.03	-0.44 ± 0.13	—
	1111	1000 ± 40	0.32 ± 0.03	-0.09 ± 0.03	0.63 ± 0.06	1000 ± 40
	1221	500 ± 20	-0.90 ± 0.02	0.11 ± 0.02	0.21 ± 0.06	—
	1262	70 ± 4	-0.45 ± 0.08	-0.05 ± 0.09	—	—
	1289	—	—	—	—	171 ± 7
	1395	140 ± 7	-0.67 ± 0.03	0.04 ± 0.04	0.22 ± 0.27	—
	1426	110 ± 5	0.43 ± 0.04	-0.11 ± 0.04	—	92 ± 4
	1627	87 ± 9	—	—	—	—
1658	220 ± 9	-0.93 ± 0.03	0.21 ± 0.06	0.52 ± 0.17	179 ± 7	

^a For accurate γ -ray energies see Arnell *et al* (1977) and Lederer and Shirley (1978).
^b Corrected for finite solid angle.

Figure 5: Data referenced in O2158.008 (2)

Here, we focus on the data where the E-LVL is 265 keV in EXFOR. In Figure 4, the arrows are written from the excitation energy 2368 keV to 2102 keV, indicating that the value of 265 keV is not E-LVL. In Figure 6, the value of E_γ is 265 keV, indicating that the value of 265 keV is the observed γ -ray energy. Therefore, the heading of EXFOR needs to be changed to "E" instead of "E-LVL".

Figure 5 shows the data registered in the LiveChart which is one of the interactive charts of ENSDF.

#	Nuclide	Initial Level			Final Level		E_γ [keV]	I_γ (rel) [%]	Mult.
		E_i [keV]	J^π (initial)	$T_{1/2}$	E_f [keV]	J^π (final)			
1	$^{85}_{38}\text{Sr}_{47}$	231.79 4	7/2+	0.21 ns 5	0.0	9/2+	231.77 5	100	M1+E2
2	$^{85}_{38}\text{Sr}_{47}$	238.79 5	1/2-	67.63 min 4	231.79 4	7/2+	7.00 S 6		[E3]
3	$^{85}_{38}\text{Sr}_{47}$	238.79 5	1/2-	67.63 min 4	0.0	9/2+	238.78 5		M4
98	$^{85}_{38}\text{Sr}_{47}$	2351.74 9	(7/2)+ 3		231.79 4	7/2+	2120.2 3	66 6	
99	$^{85}_{38}\text{Sr}_{47}$	2351.74 9	(7/2)+ 3		0.0	9/2+	2351.7 2	47 4	
100	$^{85}_{38}\text{Sr}_{47}$	2367.1 3	(17/2)-	1.2 ns 4	2102.06 23	13/2-	265.1 3	100	E2
101	$^{85}_{38}\text{Sr}_{47}$	2400.1 3	(17/2)+	2.25 ps 27	1111.46 27	13/2+	1288.8 3	100	E2

Figure 6: Livechart : Sr-85

In Sr-85, there was a transition with E_γ of 265 keV. This transition has an initial level of 2367 keV and a final level of 2102 keV, which might correspond to the arrows shown in Figure 4.

The above can be summarized as shown in Table 6.

Table 6: Fix of O2158.008

Item	Current	Modified
Heading	E-LVL	E

There were other headings errors, such as data that reversed the incident energy EN with E-LVL.

3.3 Values in Data and Common sections

The third is the correction regarding values in Data and Common sections. Some E-LVL values of Date and Common sections in EXFOR were different from those in the paper, and some E-LVL values for which only a level number (LVL-NUMB) was written in the paper.

3.3.1 E-LVL values different from the values in the paper

There were some E-LVL values different from those in the paper.

As an example, Figure 7 shows the current EXFOR data of C0925.016.

#/Legend			
E-LVL	ANG-CM	DATA-CM	ERR-S
MEV	ADEG	MB/SR	PER-CENT
0.00	14.8	0.85	5.0
0.00	18.2	0.30	10.0
0.00	25.1	0.18	11.0
0.00	30.1	0.32	8.0
0.00	36.0	0.29	5.0
0.00	42.0	0.179	3.0
0.00	47.7	0.042	18.0
0.00	53.5	0.022	8.0
0.00	59.3	0.021	19.0
0.00	64.9	0.049	11.0
0.00	70.5	0.046	5.0
0.00	76.0	0.029	14.0
0.00	81.5	0.013	30.0
0.00	86.7	0.0069	21.0
3.61	15.1	0.28	10.0
3.61	18.3	0.30	10.0
3.61	25.3	0.21	11.0
3.61	30.3	0.13	13.0
3.61	36.4	0.077	10.0

Figure 7: EXFOR:C0925.016

The current EXFOR describes data with E-LVL of 0.0 MeV (Ground State) and 3.61 MeV.

Next, I checked the original paper for C0925.016. Figure 8 shows the data that C0925.016 refers to.

c.m. Angle (deg)	Cross Section c.m. (mb/sr)	Statistical Uncertainty (%)
<u>Ground State</u>		
14.8	0.85	5
18.2	0.30	10
25.1	0.18	11
30.1	0.32	8
36.0	0.29	5
42.0	0.179	5
47.7	0.042	18
53.5	0.022	8
59.3	0.021	19
64.9	0.049	11
70.5	0.046	5
76.0	0.029	14
81.5	0.013	30
86.7	0.0069	21
<u>3.36-MeV Level</u>		
15.1	0.28	10
18.3	0.30	10
25.3	0.21	11
30.3	0.13	13
36.4	0.077	10
42.4	0.065	8

Figure 8: Data referenced in C0925.016

Figure 8 shows the data for Ground State and 3.36 MeV cross sections, and the value of 3.61 was not found. The angles and cross sections are consistent with the 3.36 MeV data in EXFOR. We can conclude that E-LVL=3.61 MeV described in the current EXFOR is a typo for 3.36 MeV.

Figure 9 shows the data registered in ENSDF.

#	Nuclide	E_x [keV]	J^π order	Band	$T_{1/2}$	$T_{1/2}$ [s]	Decay modes BR [%]	Isospin
1	$^{10}_6\text{C}_4$	0.0	0+		19.290 s 12	19.290 12	ec β^+ 100	1
2	$^{10}_6\text{C}_4$	3353.7 6	2+		107 fs 17	107E-15 17	IT 100	
3	$^{10}_6\text{C}_4$	5220 40			225 keV 45	2.0E-21 4		
4	$^{10}_6\text{C}_4$	5380 70			300 keV 60	1.5E-21 3		
5	$^{10}_6\text{C}_4$	6580 20	(2+)		190 keV 35	2.4E-21 4		

Figure 9: Livechart : C-10

There was a value of 3353 keV, which is close to the 3.36 MeV value described in Figure 8, but there was no value close to the 3.61 MeV value described in EXFOR.

The above results can be summarized as shown in Table 7.

Table 7: Fix of C0925.016

Item	Current	Modified
Data	3.61	3.36

3.3.2 LVL-NUMB

In the paper, only the number of the excited level (LVL-NUMB) was written, but in EXFOR, there existed data with the value of the excitation energy (E-LVL).

As an example, Figure 10 shows the current EXFOR data of 21672.004.

EN	#/Legend	E-LVL	E-LVL	DATA	ERR-S
MEV	EN-RSL	MEV	MEV	MB	MB
1.3470e+01	1.7500e-01	0.0000e+00		2.2200e+01	4.4000e+00
1.3470e+01	1.7500e-01	1.0710e+00		1.2700e+01	4.0000e+00
1.3470e+01	1.7500e-01	1.7020e+00	1.8230e+00	9.8000e+00	3.6000e+00
1.3930e+01	7.5000e-02	0.0000e+00		1.7700e+01	3.1000e+00
1.3930e+01	7.5000e-02	1.0710e+00		1.0500e+01	2.8000e+00
1.3930e+01	7.5000e-02	1.7020e+00	1.8230e+00	1.5400e+01	2.7000e+00
ENDDATA					
ENDSUBENT	18				
ENENTRY					

Figure 10: EXFOR:21672.004

The current EXFOR describes data with E-LVL of 0.0 MeV and 1.071 MeV, 1.702 MeV, and 1.823 MeV. Next, we checked the original paper for 21672.004. Figure 11 shows the data that 21672.004 refers to.

Table 3. Comparison between Hauser-Feshbach and experimental angle-integrated cross sections

Transition group	Neutron energy E_n (MeV)	Hauser-Feshbach cross section σ_{HF} (mb)	Experimental cross section σ_{EXP} (mb)
$^{24}\text{Mg}(n, \alpha_0, 1)^{21}\text{Ne}$	13.19	32.13	37.8 ± 3
	13.93	26.92	37.0 ± 2.2
	14.33	24.93	33.3 ± 2.2
$^{24}\text{Mg}(n, \alpha_2)^{21}\text{Ne}$	13.19	17.03	23.7 ± 3
	13.93	15.10	16.7 ± 2.5
	14.33	14.25	16.5 ± 3.2
$^{24}\text{Mg}(n, \alpha_{3, 4, 5})^{21}\text{Ne}$	13.19	27.83	32.3 ± 6
	13.93	25.23	27.9 ± 5
	14.33	24.14	28.3 ± 4.4
$^{25}\text{Mg}(n, \alpha_0)^{22}\text{Ne}$	13.93	2.51	1.4 ± 0.3
	14.33	2.27	1.7 ± 0.4
$^{25}\text{Mg}(n, \alpha_1)^{22}\text{Ne}$	13.93	12.06	4.4 ± 0.4
	14.33	10.82	5.1 ± 0.7
$^{25}\text{Mg}(n, \alpha_2)^{22}\text{Ne}$	13.93	16.67	8.9 ± 0.7
	14.33	15.03	6.1 ± 0.9
$^{26}\text{Mg}(n, \alpha_0)^{23}\text{Ne}$	13.47	18.60	22.2 ± 4.4
	13.93	18.15	17.7 ± 3.1
$^{26}\text{Mg}(n, \alpha_1)^{23}\text{Ne}$	13.47	6.92	12.7 ± 4.0
	13.93	6.82	10.5 ± 2.8
$^{26}\text{Mg}(n, \alpha_{2, 3})^{23}\text{Ne}$	13.47	24.74	9.8 ± 3.6
	13.93	24.70	15.4 ± 2.7

Figure 11: Data referenced in 21672.004

The table does not contain any level energy values, only α_0 , α_1 , $\alpha_{2,3}$ using the level numbers. The specific values of the level energies were not given elsewhere in the paper either. Therefore, we need to change the E-LVL value of EXFOR to the number of the excited level. In that case, heading should also be modified to LVL-NUMB instead of E-LVL.

The above can be summarized in Table 8.

Table 8: Fix of 21672.004

Item	Current	Modified
Data	0.0000e+00	0
Data	1.0710e+00	1
Data	1.7020e+00	2
Data	1.8230e+00	3
Heading	E-LVL	LVL-NUMB

3.4 REACTION

The fourth is the modification of reactions. EXFOR contains data on various reactions of various nuclides. However, there were some data that were highly likely to contain reactions other than those described in the paper. In the present program, E-LVL values of residual nuclide or nuclide specified under EN-SEC is compared between EXFOR and ENSDF. Therefore, if the reaction between the paper and EXFOR is different and the nuclide considered is different, the E-LVL values to be compared are also different.

As an example, figure 12 shows the current EXFOR data of R0015.008.


```

SUBENT      R0015008      20040830      20050926
BIB          3          5
REACTION    (40-ZR-90 (A, INL) 40-ZR-90, PAR, DA)
            # (40-ZR-90(A,INL)40-ZR-90,PAR,DA)
            # Target:ZR-90 #Projectile:A #Reaction:A,INL #Process
            # Product: [40-ZR-90]
SAMPLE      Thickness of target was 75 mg/cm**2.
ERR-ANALYS No error analysis is given by the authors.
            Data errors indicated in graphs by the authors
            were read by compilers.
ENDBIB      5
COMMON      2          1          12
            #Legend: 2 x 1 x 12 : data columns * lines * column w
            #EN          Energy of incident projectile, laboratory s
            #E-LVL      Level energy
            #/Legend
EN          E-LVL
MEV        MEV
205.       1.09
ENDCOMMON
DATA        3          15          12
            #Legend: 3 x 15 x 12 : data columns * lines * column 1

```

Figure 12: EXFOR:R0015.008

EXFOR shows that the reaction is an inelastic scattering reaction of alpha particles and the residual nucleus is Zr-90. Next, we checked the original paper of R0015.008. Figure 13 shows the data that R0015.008 referred to.

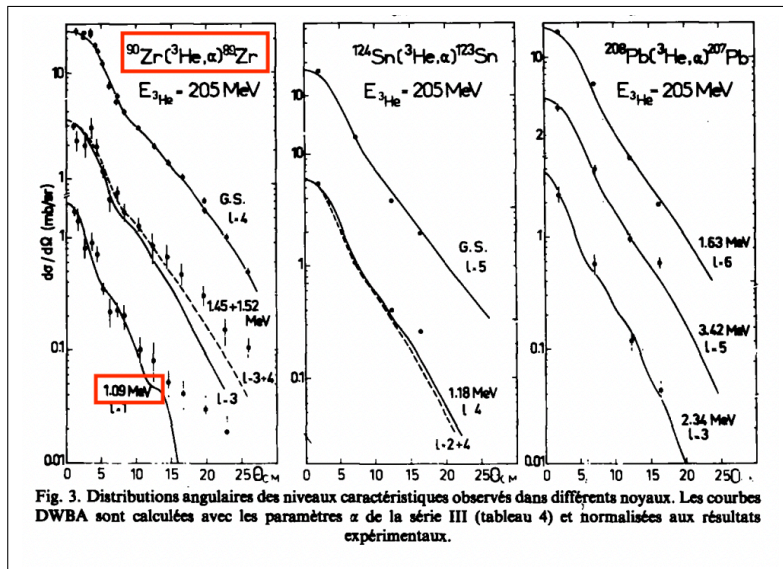


Figure 13: Data referenced in R0015.008

Unlike the REACTION registered in EXFOR, Figure 13 shows a $(\text{He-3}, \alpha)$ reaction data, and the residual nuclide is Zr-89. Therefore, the E-LVL value was compared with Zr-90 by the program instead of Zr-89, and it was extracted as E-LVL values with high possibility of error in this program.

Figures 14 and 15 show the data of Zr-89 and Zr-90 registered in ENSDF.

#	Nuclide	E_x [keV]	J^π order	Band	$T_{1/2}$	$T_{1/2}$ [s]
1	$^{89}_{40}\text{Zr}_{49}$	0.0	9/2+	1	78.41 h 12	282276 432
2	$^{89}_{40}\text{Zr}_{49}$	587.82 10	1/2-		4.161 min 10	249.7 6
3	$^{89}_{40}\text{Zr}_{49}$	1094.91 18	3/2-		0.05 ps	50E-15
4	$^{89}_{40}\text{Zr}_{49}$	1451.23 18	5/2-		3.5 ps	3.5E-12
5	$^{89}_{40}\text{Zr}_{49}$	1511.79 17	(9/2)+		0.53 ps 10	530E-15 10

Figure 14: Livechart : Zr-89

#	Nuclide	E_x [keV]	J^π order	Band	$T_{1/2}$	$T_{1/2}$ [s]
1	$^{90}_{40}\text{Zr}_{50}$	0	0+		STABLE	
2	$^{90}_{40}\text{Zr}_{50}$	1760.74 14	0+ 2		61.3 ns 25	61E-9 3
3	$^{90}_{40}\text{Zr}_{50}$	2186.273 14	2+		87.9 fs 21	87.9E-15 21
4	$^{90}_{40}\text{Zr}_{50}$	2319.000 9	5-		809.2 ms 20	0.8092 20
5	$^{90}_{40}\text{Zr}_{50}$	2739.29 5	(4)-			

Figure 15: Livechart : Zr-90

Livechart shows presence of a level of 1.094 MeV, which is close to the E-LVL value registered in EXFOR, while Livechart does not show such a level of ZR-90.

The above can be summarized as shown in Table 9.

Table 9: Fix of R0015.008

Item	Current	Modified
Reaction	40-ZR-90(A,INL)40-ZR-90	40-ZR-90(HE3,A)40-ZR-89

3.5 EN-SEC

It has already been explained that EXFOR contains data for various nuclides of various reactions. Various keywords are used in EXFOR to record the data of each experiment. One of them is "EN-SEC", which indicates the nuclide which energy is considered. There were some data that could be solved by implementing "EN-SEC".

As an example, Figure 16 shows the current EXFOR data of F0025.003.

```

D.L.D
REACTION (3-LI-7(P,A)2-HE-4,PAR,DA)
# (3-LI-7(P,A)2-HE-4,PAR,DA)
# Target:LI-7 #Projectile:P #Reaction:P,A #Quantity:PAR,DA:DAP:Partial differential cross section d/dA
# Product: [2-HE-4]
ERR-ANALYS (DATA-ERR) Errors from graphic bars. No information
about source of uncertainty
COMMENT For the Li-7(p,gamma,2+alpha)He-4 reaction, with
gamma,2 transition from the excited initial state to
the final excited state of Be-8 at 7.56MeV (for gamma1)
and 13.91MeV (for gamma2) breaking up in two
alpha-particles.
STATUS (CURVE) Fig. 4 b,c from Nucl.Phys.,36(1962)597
# (CURVE) Data read from a curve
HISTORY (20200122A) SD: SF9=EXP deleted from REACTION code.
EN-ERR -> EN-ERR-DIG. EN-SEC deleted. ERR-ANALYS,
STATUS updated.
ENDBIB
COMMON 12 1 12
#Legend: 2 x 1 x 12 : data columns * lines * column width
#ANG Angle, laboratory system ADEG angular Degrees
#EN-ERR-DIG Digitizing error of incident particle energy MEV MeV
#/Legend
ANG EN-ERR-DIG
ADEG MEV
90. 0.013
ENDCOMMON
DATA 4 27 12
#Legend: 4 x 27 x 12 : data columns * lines * column width
#E-LVL Level energy MEV MeV
#EN Energy of incident projectile, laboratory system MEV MeV
#DATA Partial differential cross section d/dA
# + 3-LI-7(P,A)2-HE-4,PAR,DA MB/SR millibarns per steradian
#DATA-ERR Error in value of quantity, defined under ERR-ANALYS MB/SR millibarns per steradian
#/Legend
E-LVL EN DATA DATA-ERR
MEV MEV MB/SR MB/SR
7.56 0.441 0.0027 0.0013
7.56 0.518 0.0026 0.0013
7.56 0.605 0.0048 0.0054
7.56 0.716 0.0330 0.0076
7.56 0.784 0.0710 0.0065
7.56 0.831 0.1449 0.0076
7.56 0.877 0.1883 0.0076
7.56 0.928 0.1263 0.0087
7.56 0.955 0.0068 0.0043
13.91 0.577 0.0088 0.0065
13.91 0.698 0.0283 0.0087
13.91 0.752 0.0369 0.0109
13.91 0.796 0.0412 0.0130

```

Figure 16: EXFOR:F0025.003

EXFOR describes the (p,α) reaction of Li-7. The residual nuclide is He-4.

Next, I checked the original paper of F0025.003. Figures 17, 18 and 19 show the data that F0025.003 refers to.

Abstract: The $\text{Li}^7 + p$ interaction has been extensively studied and its various products analysed. The results confirm the presence of the well known levels of Be^8 at 2.9, 17.63 and 18.15 MeV and give clear evidence for the existence of the discussed 7.56 MeV level. Three new levels of Be^8 have been discovered at the energies 13.91, 17.9 and 18.0 MeV. Widths, angular momenta, parities and isobaric spins of several levels have been determined. Some anomalies of the $\text{Li}^7 + p$ interaction, previously observed by others, are explained.

Figure 17: Data referenced in F0025.003 (1)

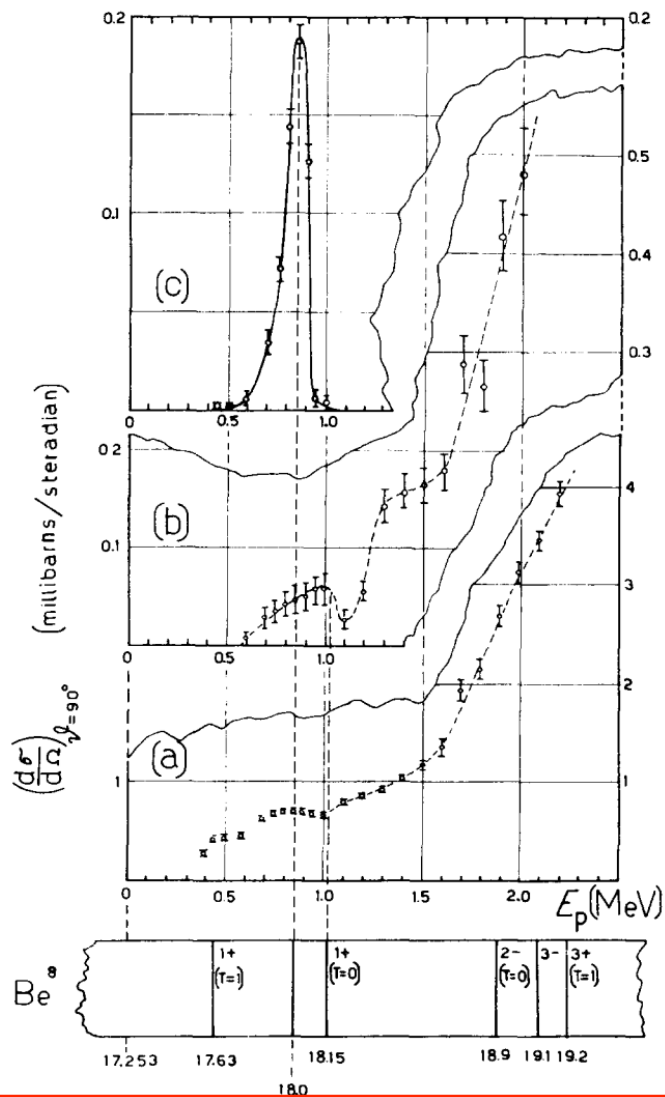


Fig. 4. Differential cross sections at $\theta = 90^\circ$: a) for the $\text{Li}^7(p, \alpha)\text{He}^4$ reaction, b) for the $\text{Li}^7(p, \gamma_2 \alpha)\text{He}^4$ reaction, with γ_2 transition from the excited initial state to the final excited state of Be^8 at 13.91 MeV, breaking up in two α -particles, c) for the $\text{Li}^7(p, \gamma_1 \alpha)\text{He}^4$ reaction with γ_1 transition from the excited initial state to the final excited state of Be^8 at 7.56 MeV breaking up in two α -particles.

Figure 18: Data referenced in F0025.003 (2)

Analysing the yields of the α peaks observed in the energy spectra as a function of proton energy, we can obtain the differential cross sections at $\theta = 90^\circ$

for the $\text{Li}^7(p, \alpha)\text{He}^4$ reaction and for the $\text{Li}^7(p, \gamma\alpha)\text{He}^4$ reactions involving the 7.56 MeV and 13.91 MeV excited states of Be^8 .

Figure 19: Data referenced in F0025.003 (3) (text on pp 602-603)

The experiment shows that the measurement was made in a reaction where Li^7 was bombarded with a proton to become Be^8 once, and then Be^8 split into two α . Thus, the paper describes a two-step reaction. Therefore, the problem can be solved by adding a new entry (E-LVL,4-BE-8) in the EXFOR data.

Figures 20 and 21 show the data of He^4 and Be^8 registered in ENSDF.

#	Nuclide	E_x [keV]	J^π order	Band	$T_{1/2}$	$T_{1/2}$ [s]
1	${}^4_2\text{He}$	0.0	0+		STABLE	
2	${}^4_2\text{He}$	20210	0+ 2		0.50 MeV	912.4754301427714E-24
3	${}^4_2\text{He}$	21010	0-		0.84 MeV	543.1401369897449E-24

Figure 20: Livechart : He-4

#	Nuclide	E_x [keV]	J^π order	Band	$T_{1/2}$	$T_{1/2}$ [s]
1	${}^8_4\text{Be}$	0.0	0+		5.57 eV 25	82E-18 4
2	${}^8_4\text{Be}$	3030 10	2+		1513 keV 15	302E-24 3
3	${}^8_4\text{Be}$	11.35×10^3 15	4+		3.5 MeV	130.35363287753876E-24
4	${}^8_4\text{Be}$	16626 3	2+ 2		108.1 keV 5	4.221E-21 20

Figure 21: Livechart : Be-8

The authors assumed two levels 7.56 and 13.91 MeV, but such levels are unknown nowadays. The above can be summarized in Table 10.

Table 10: Fix of F0025.003

Item	Current	Modified
EN-SEC		E-LVL,4-BE-8

4 Statistics of errors

The following will be brief discussion on the statistics of errors.

4.1 Counting

To conduct the analysis, we organized the 933 data extracted by the program. First of all, for the data that needed to be modified, the data with the "Keyword" of "Unit", "Heading", "REACTION", and "EN-SEC" were considered as one data if the subentries were the same. We will explain why we did this process using O2445.013.

Figure 22 shows the current EXFOR data.

#/Legend			
ANG	E-LVL	DATA	ERR-S
ADEG	MEV	MB/SR	MB/SR
10.	0.	0.756	0.006
10.	478.	0.005	0.001
10.	659.	0.463	0.004
10.	682.	0.061	0.002
10.	719.	0.062	0.002
10.	887.	0.003	0.001
10.	1028.	0.107	0.002
10.	1118.	0.216	0.003
10.	1279.	0.152	0.003
10.	1437.	0.401	0.004
10.	1514.	0.075	0.003
10.	1628.	0.018	0.001
10.	1701.	0.043	0.001
10.	1787.	0.030	0.001
10.	1865.	0.020	0.001
10.	1960.	0.101	0.002
10.	2043.	0.666	0.005
10.	2089.	0.079	0.002
10.	2155.	0.022	0.002
10.	2198.	0.014	0.002
10.	2247.	0.034	0.002
10.	2317.	0.065	0.002
10.	2384.	0.057	0.002
10.	2410.	0.010	0.002
10.	2510.	1.269	0.007
10.	2830.	0.023	0.002
10.	2873.	0.037	0.002
10.	2935.	0.020	0.003
10.	2974.	0.012	0.001
10.	3009.	0.061	0.002
10.	3049.	0.038	0.002
10.	3110.	0.030	0.002
10.	3157.	0.073	0.008
10.	3175.	0.20	0.09
10.	3235.	0.040	0.002
10.	3403.	0.501	0.005
10.	3573.	0.114	0.004
10.	3655.	0.183	0.004
15.	0.	0.709	0.004

Figure 22: EXFOR:O2445.013

In the current EXFOR, the unit is MeV. In this program, 37 suspicious E-LVL values are extracted except for 0.0 MeV (Ground state). In this way, the program generates 37 error messages even though there is only one "Unit" to be modified. We need to prevent this kind of duplication.

If the subentries were the same but had multiple revisions, they were separated into different data. This was the case for "22532.010" and "22532.020". Each of them requires two corrections, "REACTION" and "Common".

In addition, we decided to analyze only data where our decision is "Y" and "N". By doing this, the number of items became 665.

4.2 Result

After applying the above process, the histogram for each mass number is shown in Figure 23 on each 25 mass numbers.

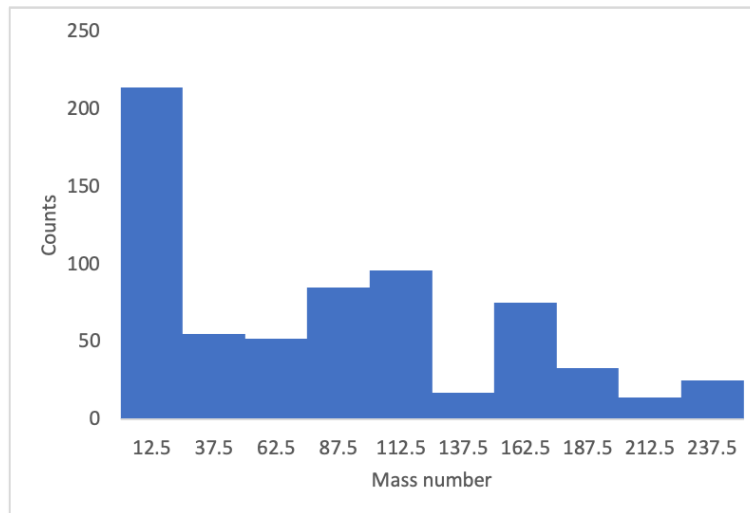


Figure 23: Histogram of items

In addition, Figure 24 shows fraction of the need for correction.

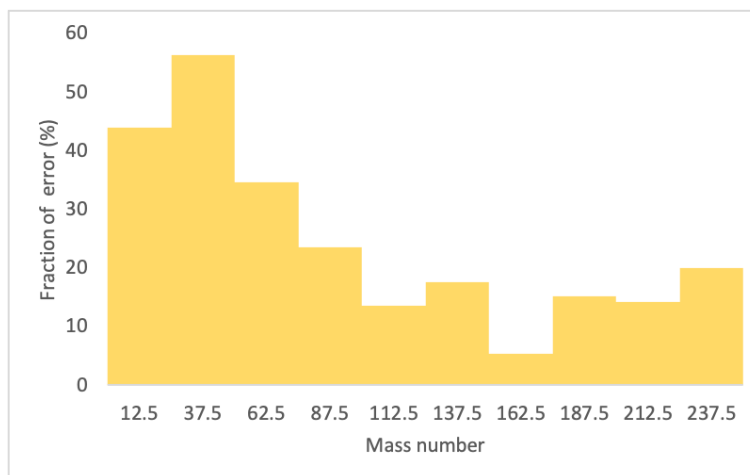


Figure 24: Fraction of error

For the data with mass number up to 75, the percentage of data that need to be corrected is relatively high. However, as explained in the process section, it should be noted that there may be data for which the difference is less than 5% but for which correction is necessary.

It may be possible to improve the results by trying to change the allowance of the data to be extracted as show in Table 11.

Table 11: Data regarding error range

Allowance	Number of E-LVL values	Number of items	Number of errors	Fraction of error (%)
5%	933	665	195	29.3
10%	691	470	164	34.9
20%	541	362	141	39.0
30%	489	315	119	37.8

Brooding the allowance reduces the amount of data extracted by the program. In addition, it increases the fraction of error, but reduces the number of items which need to be corrected.