

Report on the Review of Production Cross-Section of α , d, g, h, p, and t Induced Reactions for Validating TENDL-2021 Curves

V. Devi and N. Otsuka

Objective:

The purpose of this review is to validate TENDL-2021 by examining the production cross-section of α , d, g, h, p, and t induced reactions. This review aims to improve the quality of EXFOR data.

Current Situation:

We have completed the analysis of α , d, g, and h induced reactions, and a few common EXFOR outliers were discussed in the last NRDC-2022 meeting. All corrections have been posted to the feedback list, and many of the entries have already been corrected based on the feedback list. We are currently evaluating the p-induced reactions. However, due to the enormous amount of data for p-induced reactions in EXFOR, we have not completed the checking of p-induced reactions yet. At this point, we have finished checking up to Hf nuclei.

Method:

Examined each plot that Arjan Koning sent us individually, as well as the original article and web retrieval system.

Regenerated the curve using the IAEA EXFOR web retrieval site to verify any questionable subentries found during the review. If any questionable subentries are found in a subentry, we check the entire entry. This is because an error in the subentry has impact on other subentries. In many cases, we discover errors that are hidden in the curve.

This TENDL-2021 curve contains the data up to 2021. By regenerating the curve, we sometimes find new data sets available for that reaction. We can easily compare whole data available in EXFOR till now for that reaction. In some case, we also find error in new data sets that are not available in TENDL-2021.

Results:

All errors found during these checking have already been mentioned in the feedback list for the correction. The main issues found during this analysis are as follow:

- Wrong selections of the REACTION code.
- Inclusion of incorrect data points during compilation.
- Wrong unit selection is also evident in many entries.
- Duplicate entries or certain data for a specific subentry. We found about 12 duplicate entries during the ongoing review of p-induced reaction.

Future Plan:

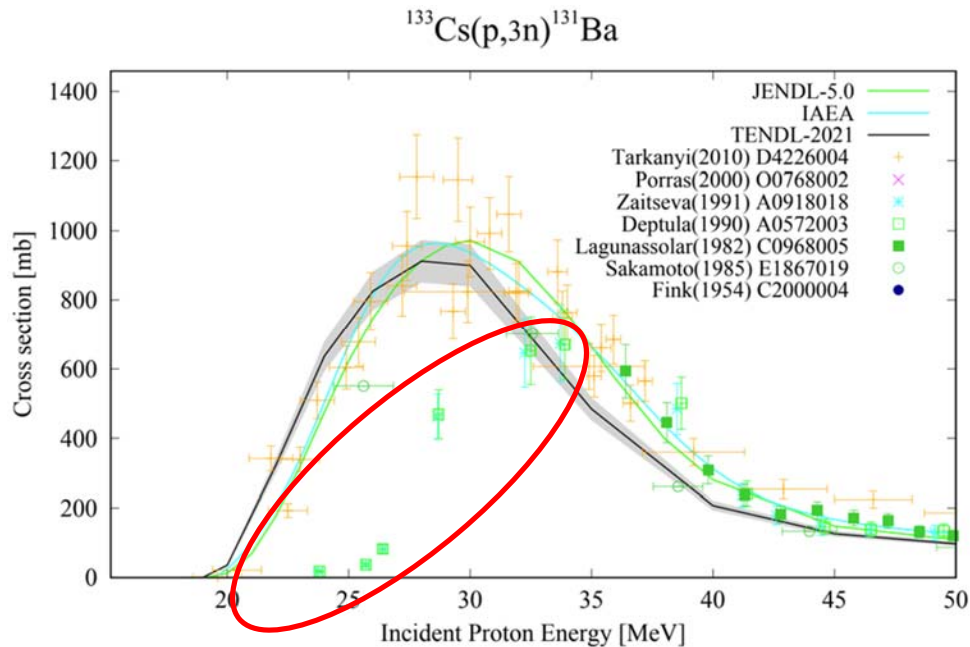
We will complete the review of the remaining p and t-induced reactions. Any errors or discrepancies found during the review will be compiled into a correction list, which will be uploaded to the feedback list for further action.

Acknowledgement:

I would like to thank Arjan and Viktor for the fruitful discussion.

Example 2: Wrong uncertainty and duplicate entry for $^{133}\text{Cs}(p,3n)^{131}\text{Ba}$

- C2000.004: 48.0 mb \rightarrow 4.8 mb at 80 MeV (not in the TENDL plot)
- A0918.018/A0572.003 and A0918.014/A0572.002 (not in the TENDL plot) look pairs of duplication.



```

SUBENT      C2000004      20130416      20130819      20130726
BIB          3          3
REACTION    (55-CS-133(P,3N)56-BA-131,,SIG)
            # (55-CS-133(P,3N)56-BA-131,,SIG)
            # Target:CS-133 #Projectile:P #Reaction:P,3N #QI
            # Product: [56-BA-131]
STATUS      (TABLE) Data taken from tab. 1 of the refer
            # (TABLE) Data presented by authors
DECAY-DATA  (56-BA-131,12.5D)
            # Decay-data: [56-BA-131]
ENDBIB      3
NOCOMMON
DATA        2          5          12
            #Legend: 2 x 5 x 12 : data columns * lines * colu
            #EN      Energy of incident projectile, laborat
            #DATA    Cross section
            #+ 55-CS-133(P,3N)56-BA-131,,SIG
    
```

```

#Legend
EN      DATA
MEV     MB
60.0    20.0
80.0    48.0
100.0   15.0
150.0   3.0
240.0   5.3
ENDDATA
ENDSUBENT      15
ENDENTRY
    
```

TABLE I. Absolute production cross sections of spallation products resulting from irradiation of cesium with protons at various energies.^a

Nominal half-life	Nuclide	Counting efficiency	Yields in millibarns				
			60 Mev	80 Mev	100 Mev	150 Mev	240 Mev
2.4 days	Ba ¹²⁸	1.0	0	67	58	14	8.1
2.0 hr	Ba ¹²⁹	1.0	173	3.1	4.7	11	3.6
12.5 days	Ba ¹³¹	0.72	20	4.8	13	3	—
42.5 hr	Ba ^{133m}	0.78	31	—	—	—	—

Example 3: Incorrect ERR-T value and duplicate subentry for $^{75}\text{As}(p,n)^{75}\text{Se}$

- T0126.019/T0122.010 look a pair of duplication.
- C2702.022: ERR-T=19 mb \rightarrow 1.9 mb at 51.44 MeV (not shown in the TENDL plot)

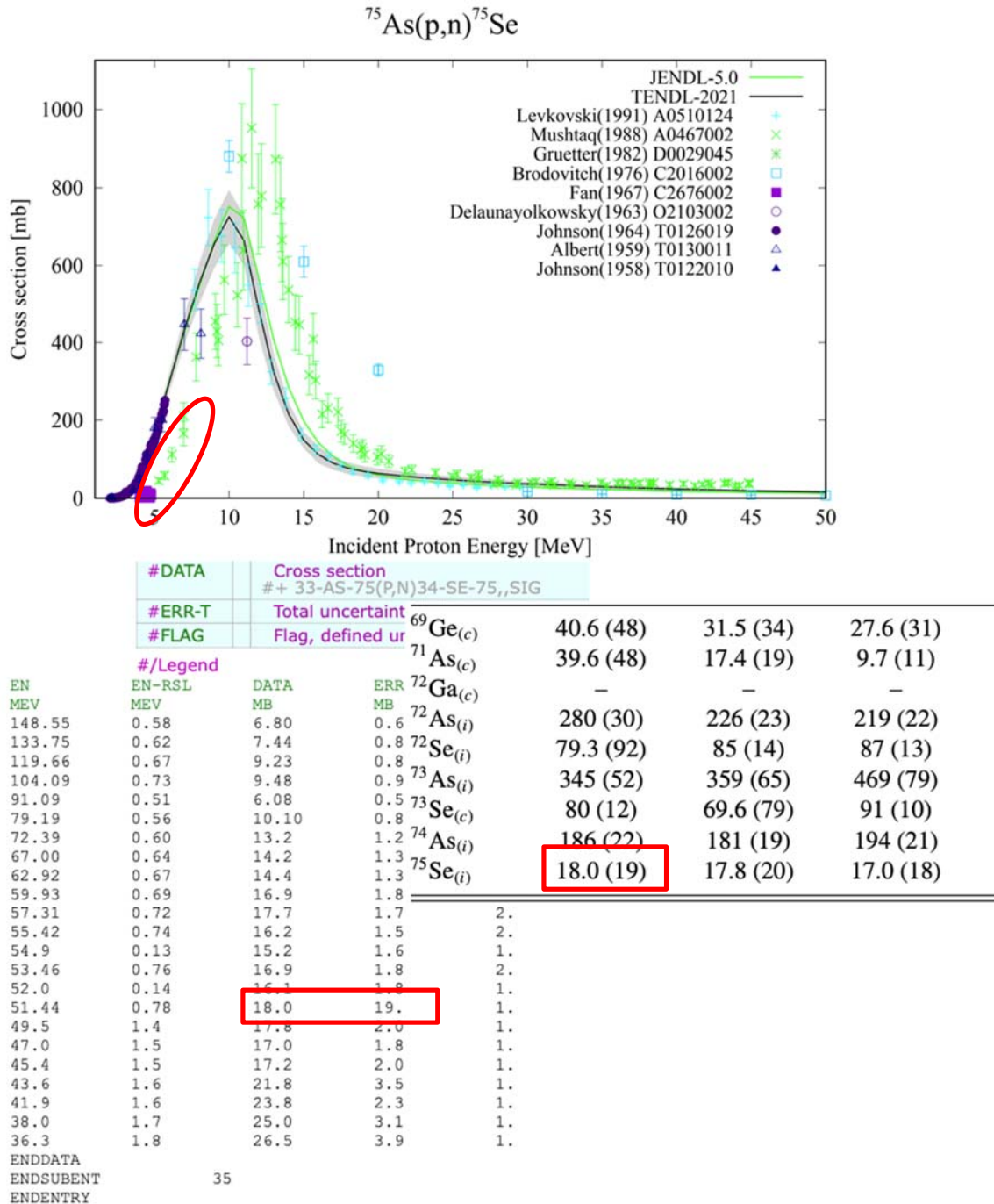


Table: The list of errors during this checking already posted on feedback list.

Dataset ID	Keyword	Comment
23032.008	Data	EN: 0.93 MeV -> 5.93 MeV (Confirmed by Michihiro Shibata, 2022-06-01)
30644.001	Data	Check the relation with the datasets in 30978. Some datasets must be superseded (revision) or deleted (duplication).
40577.002	REACTION	SF3: P+N is illegal.
A0154.006	REACTION	SF3: N+A -> X
A0154.007	REACTION	SF3: A -> X
A0240.003.4	REACTION	SF3: A -> X
A0240.003.4	REACTION	SF3: A -> X
A0240.004.K	REACTION	SF3: A -> X
A0347.003.2	REACTION	SF4: -M -> -G (c.f. Fig.2)
A0347.003.3	REACTION	SF4: -G -> -M (c.f. Fig.2)
A0347.003.5	REACTION	SF4: -M -> -G (c.f. Fig.2)
A0347.003.6	REACTION	SF4: -G -> -M (c.f. Fig.2)
A0347.006.5	REACTION	SF3: N+A -> X
A0347.006.6	REACTION	SF3: 2A -> X
A0347.007.5	REACTION	SF3: N+A -> X
A0347.007.6	REACTION	SF3: 2A -> X
A0347.009.6	REACTION	SF3: A -> X
A0347.010.1	REACTION	SF3: 2A -> X
A0602.002	Data	DATA: 0.4 -> 10.4 mb at 62.1 MeV?(c.f. figure)
A0602.006	REACTION	SF3: N+A -> X
A0618.005	ERR-ANALYS	Check if DATA-ERR1 -> ERR-S.
A0618.006	ERR-ANALYS	Check if DATA-ERR1 -> ERR-S.
A0618.007	ERR-ANALYS	Check if DATA-ERR1 -> ERR-S.
A0618.008	ERR-ANALYS	Check if DATA-ERR1 -> ERR-S.
A0618.009	ERR-ANALYS	Check if DATA-ERR1 -> ERR-S.
C0062.004	STATUS	Table 1 -> Table 3
C0062.013	Data	DATA: 34 mb -> 33 mb at 5.7 GeV
C0348.002	REACION	Use SF3=X.
C0348.003	REACION	Use SF3=X.
C0348.004.2	REACION	SF3=N+P -> X.
C0348.005.2	REACION	SF3=N+P -> X.
C0357.002	REACTION	Use SF3=X.
C0720.004	ADD-RES	Mention presence of 0.04+/-0.07 ub at 0.0 MeV in Table 2.
C0720.007	ADD-RES	Mention presence of 0.6+/-0.8 ub at 0.0 MeV in Table 5.
C1101.001	Data	The same datasets are compiled in EXFOR C2330.
C2323.002	REACTION	SF3: A -> X

C2330.001	Data	The same datasets are compiled in EXFOR C1101.
C2342.002	REACTION	SF3: A -> X
C2342.003	REACTION	SF3: A -> X
C2702.022	Data	ERR-T=19 mb -> 1.9 mb at 51.44 MeV
D0337.001	Data	Analyze their relation with D0314.006, 009 and 015.
D0737.007	REACTION	SF3 must be 2P.
D4072.002	Data	Delete. Digitized data superseded by D4006.002.
D4134.002.1	Data	Asymmetric errors are compiled as symmetric errors.
D4134.002.2	Data	Asymmetric errors are compiled as symmetric errors.
D4327.005	Data	Swap DATA and DATA-ERR? (Typo in Table 4?)
D5057.011	REACTION	SF3: P+A -> X.
E1306.001	METHOD	Add ACTIV.
E1306.010	REACTION	SF3 must be X.
E1306.011	REACTION	SF3 must be X.
E1306.012	REACTION	SF3 must be X.
E1306.013	REACTION	SF3 must be X.
E1306.014	REACTION	SF3 must be X.
E1306.015	REACTION	SF3 must be X.
E1306.020	REACTION	SF3 must be X.
E1306.021	REACTION	SF3 must be X.
E1306.022	REACTION	SF3 must be X.
E1370.001	METHOD	Add ACTIV.
E1370.001	METHOD	Add ACTIV
E1370.004	REACTION	SF3 must be X.
E1370.004	REACTION	SF3: N+A -> X
E1370.005	REACTION	SF3 must be X.
E1370.005	REACTION	SF3: N+A -> X
E1370.006	REACTION	SF3 must be X.
E1370.006	REACTION	SF3: N+A -> X
E1370.011	REACTION	SF3 must be X.
E1370.011	REACTION	SF3: N+A -> X
E1370.016	REACTION	SF3 must be X.
E1370.016	REACTION	SF3 must be X.
E1370.016	REACTION	SF3: N+A -> X
E1961.012	REACTION	SF5: CUM -> (CUM) (c.f. A0210.003/006)
E1967.009	REACTION	SF4: Delete -G (IT=100% with short-lived m.s.)
E2394.002	REACTION	SF3: X -> 2A
E2394.004	REACTION	SF3: X -> 3A
E2394.005	REACTION	SF3: X -> 3A
F0011.004	REACTION	SF1: 3-LI-7 -> 3-LI-0 for the data points coded with FLAG=2.
F0207.002	REACTION	SF3: A -> X
F0207.003	REACTION	SF3: A -> X

F0207.004	REACTION	SF3: A -> X
F0207.005	REACTION	SF3: A -> X
F0207.006	REACTION	SF3: T -> X
F0207.007	CRITIQUE	Add "S.N.Abramovich+: Brill's dataset is 10-15 times less than the rest of the best works".
F0207.007	REL-REF	Add "(C,A0166002,S.N.Abramovich+,J,YK,,(2/56),55,1984)".
F0207.011	REACTION	SF3 must be X.
F0207.011	REACTION	SF3: 2A -> X
F0207.014	REACTION	SF3: 2P+A -> X
F0207.016	REACTION	SF3: T -> X
F0307.005	REACTION	SF3: X -> N
K2164.002.3	REACTION	Add SF8=AV.
M0406.003	Data	Same dataset is in M0515.003.
O0103.001	Data	Duplication of EXFOR T0149.
O0276.455	REACTION	SF4: Remove -G.
O0277.028	REACTION	SF3: N+P -> X
O0345.004	REACTION	SF4: Remove -G.
O0690.001	Data	sigma (300 GeV)/sigma (11.5 GeV) given by the author must be compiled without conversion by the compiler.
O1123.007	REACTION	SF4-5: Delete -G,M+.
O1169.005	Data	Values in Table 2 are not compiled correctly.
O1169.007	Data	Values in Table 2 are not compiled correctly.
O1339.002	Data	Replace the DATA value with those tabulated under "Target" of Table 2. SF8=RAW could be added (cross section not corrected for products moved to catcher foil).
O1339.003	Data	Replace the DATA value with those tabulated under "Target" of Table 2. SF8=RAW could be added (cross section not corrected for products moved to catcher foil).
O1339.004	Data	Replace the DATA value with those tabulated under "Target" of Table 2. SF8=RAW could be added (cross section not corrected for products moved to catcher foil).
O1339.005	Data	Replace the DATA value with those tabulated under "Target" of Table 2. SF8=RAW could be added (cross section not corrected for products moved to catcher foil).
O1339.006	Data	Replace the DATA value with those tabulated under "Target" of Table 2. SF8=RAW could be added (cross section not corrected for products moved to catcher foil).

O1339.007	Data	Replace the DATA value with those tabulated under "Target" of Table 2. SF8=RAW could be added (cross section not corrected for products moved to catcher foil).
O2070.005	Unit	MB -> B
O2124.002	REACTION	SF3: X -> P
O2124.005	REACTION	SF3: X -> 2P
P0069.004	Data	DATA: about 1000 times too low.
P0069.005	Data	DATA: about 1000 times too low. (Digitized with the y-axis on the left side instead of the right side?)
R0041.001	ADD-RES	Mention presence of a tabulated cross section for each gamma line.
R0041.003	REACTION	SF3: A -> X
R0041.007	REACTION	SF3: N+A -> X
R0041.010	REACTION	SF3: P+2A -> X
R0041.011	REACTION	SF3: 5-B-10 -> X
R0041.012	REACTION	SF3: 3-LI-7 -> X
R0041.013	REACTION	SF3: 4-BE-10 -> X
R0046.002	Data	Delete DATA-ERR in DATA section and add the constant uncertainties in COMMON section.
R0049.001	Data	Averaging of two data points at the same energy by the compiler must be cancelled. Also, the constant %-uncertainty must be given instead of point-wise uncertainty calculated by the compiler.
R0049.002	REACTION	SF3: N+A -> X
R0049.003	REACTION	SF3: N+A -> X
R0053.007.1	REACTION	SF3: A -> X
R0053.008	REACTION	SF3: A -> X
R0053.009	REACTION	SF3: A -> X
R0053.011	REACTION	SF3: 2N+A -> X
T0120.009	REACTION	SF3: N+A -> X
T0120.009	REACTION	SF3: N+A -> X
T0120.010	REACTION	SF3: N+A -> X
T0120.010	REACTION	SF3: N+A -> X
T0120.021	REACTION	SF3: T -> X
T0120.021	REACTION	SF3: T -> X
T0149.001	Data	Duplication of EXFOR O0103.
33159.001	Common	0.025 eV -> 0.5 eV
A0347.009.6	REACTION	SF3:A -> X (Other channels open above !12 MeV)
C1159.012	REACTION	SF3:2N+A -> X (Other channels open above ~24 MeV)
C2004.005	Data	10 times too low.
D4061.005.2	Data	One data point (0.33 mb@17.9 MeV) must be added.

D4061.005.2	REACTION	Delete (M).
D4174.006.G	REACTION	SF4: -G+L -> -G
D4287.002	REACTION	SF5: Add CUM (c.f. Sect.5.1.1 of the source article)
D4372.018	Data	Last five data points of 019 are wrongly repeated.
D4374.004	Data	Delete the data point at 26.7 MeV (not in Table 2)
D4374.005	Data	Add 0.19+/-0.07 mb at 26.7 MeV in Table 2.
M0269.002	REACTION	Add SF8=REL with MB -> ARB-UNITS
M0515.003	Data	Same dataset is in M0406.003.
M0665.003	Unit	MICRO-B -> MB
O2124.008	REACTION	SF3: X -> 4N
O0689.002	REACTION	SF4: Delete -G.
O0920.041	REACTION	SF4-SF5: Delete -G,M+.
B0038.006	REACTION	SF4-SF5: Delete -G,M+.
D0116.002	REACTION	SF8: Add (A).
D0116.003	REACTION	SF8: Add (A).
D0116.004	REACTION	SF8: Add (A).
O2015.025	Data	DATA-ERR: 2.11 mb -> 2.1 mb at 2.5 GeV. Also, Table 2 -> Table III in STATUS.
T0123.003	REACTION	SF3: HE3 -> X
A0500.002.3	Data	DATA: 2.3 mb -> 72.3 mb at 10.7 MeV.
D0516.009	REACTION	SF4-SF6: -M1,CUM,SIG -> -M1+M2,,SIG
O1099.269	FLAG	Explain that the data point at 111 MeV (460 mb) is confirmed by Rolf Michel (2023-01-10).
A0085.029	REACTION	Add (M) in SF5?
A0135.003	Data	DATA:279 mb -> 249 mb at 9.1 MeV
C1868.001	Data	The same article is compiled in F1165.
F1165.001	Data	The same article is compiled in C1868.
A0299.003	REACTION	SF5: Delete CUM?
D4293.002	Data	Data points above 60 MeV close to those in D4255.006.
D4293.008	Data	Data points above 60 MeV close to those in D4255.007.
D4293.007	Data	Data points close to those in D4255.005.
D4293.006	Data	Data points above 60 MeV close to those in D4255.004.
D4293.007	Data	Data points close to those in D4255.005.
D4293.005	Data	Data points close to those in D4255.003.
D4293.004	Data	Data points close to those in D4255.002.
C2705.002	Unit	MeV -> keV
C2705.003	Unit	MeV -> keV
A0918.014	Data	Data similar to those compiled in A0572.002.
A0918.018	Data	Data similar to those compiled in A0572.003.
C2000.004	Data	DATA: 48.0 mb -> 4.8 mb at 80 MeV.
C2000.013	Data	DATA :0.1 mb -> 0.05 mb at 60 MeV, 0.9 mb -> 0.94 mb at 80 MeV
O2315.022	Data	Delete the last data point which is for ^{58}Co production.

O2315.018	STATUS	Table 6 -> Table 7
O2315.019	STATUS	Table 6 -> Table 7
O2315.020	STATUS	Table 6 -> Table 7
O2315.021	STATUS	Table 6 -> Table 7
O2315.022	STATUS	Table 6 -> Table 7
O2315.023	STATUS	Table 6 -> Table 7
O2315.024	STATUS	Table 6 -> Table 7
O2315.025	STATUS	Table 6 -> Table 7
O2315.026	STATUS	Table 6 -> Table 7
O2315.027	STATUS	Table 6 -> Table 7
A0580.002	Data	ERR-T: 8mb -> 0.08mb.
A0580.007	Data	ERR-T: 0.7mb -> 0.07mb.
A0580.032	Data	DATA: 0.15 mb -> 0.159 mb
D0422.002	Data	Data point at 13.1 MeV is for D0422.003?
D0422.003	Data	Data point at 13.1 MeV is for D0422.004?
T0126.037	Data	This dataset and T0135.002 look very similar.
T0126.034	Data	This dataset and T0135.003 look very similar.
T0126.011	Data	This dataset and T0135.004+T0122.008 look very similar.
T0126.036	Data	This dataset and T0135.005+T0122.011 look very similar.
T0126.038	Data	This dataset and T0135.006 look very similar.
T0126.041	Data	This dataset and T0135.007 look very similar.
T0126.040	Data	This dataset and T0135.008 look very similar.
T0126.035	Data	This dataset and T0135.009 look very similar.
T0126.039	Data	This dataset and T0135.010 look very similar.
T0126.029	Data	This dataset and T0122.002 look very similar.
T0126.004	Data	This dataset and T0122.003 look very similar.
T0126.005	Data	This dataset and T0122.004 look very similar.
T0126.006	Data	This dataset and T0122.005 look very similar.
T0126.007	Data	This dataset and T0122.006 look very similar.
T0126.009	Data	This dataset and T0122.007 look very similar.
T0126.016	Data	This dataset and T0122.009 look very similar.
T0126.019	Data	This dataset and T0122.010 look very similar.
T0126.021	Data	This dataset and T0122.013 look very similar.
C2018.006	REACTION	SF4: 67-HO-159 -> 66-DY-159. 159Ho production cross section must be compiled additionally.
C2018.018	REACTION	SF4: 67-HO-161 -> 67-HO-162.
C2018.004	REACTION	SF4: -M1+M2 -> -M1 (M2 does not decay into M1).
C2018.009	REACTION	SF4: -M1+M2 -> -M1 (M2 does not decay into M1).
C2018.013	REACTION	SF4: -M1+M2 -> -M1 (M2 does not decay into M1).
C2018.017	REACTION	SF4: -M1+M2 -> -M1 (M2 does not decay into M1).
C0400.004	Data	Delete. Data for an enriched Er target but its mass number is unknown.
A0397.002	REACTION	Add RES in SF8 (c.f. Table 1)

A0397.003	REACTION	Add RES in SF8 (c.f. Table 1)
A0397.005	REACTION	Add RES in SF8 (c.f. Table 1)
A0397.006	REACTION	Add RES in SF8 (c.f. Table 1)
P0030.011	Data	Do not corresponding to open triangles in Fig.3. Digitization required.
D4343.008	REACTION	Delete SF5=CUM. ^{69}mZn is free from feeding by ^{69}Cu .
O2515.002	REACTION	SF4: Add -G. (No IT transitions.)
O2515.004	REACTION	SF4-SF5
D4329.003	COMMENT	Add "By author: TALYS predicts the ^{152}mTb decay contribution is less than 0.9%."