^{168}Er(d,t)　　1977So08,1978So04,1969Tj01

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	Balraj Singh and Jun Chen	NDS 191,1 (2023)	22-Aug-2023

1977So08, 1978So04: E(d)=17 MeV in 1977So08, and 9, 11, 13, 15 MeV in 1978So04 from the University of Pittsburgh three stage Van De Graaff accelerator. Measured triton spectra and $\sigma(\theta)$ at 18 angles from θ(lab)=8° to 60°, excitation functions using a split-pole magnetic spectrograph, with particle tracks recorded on photographic emulsions. Target was 97.7% enriched ^{168}Er with a thickness of ≈75 μg/cm^2 evaporated on carbon backing. FWHM≈11 keV. Deduced 42 levels up to 1440 keV excitation, L-transfers, spectroscopic factors and Nilsson configurations. The $\sigma(\theta)$ data were analyzed using finite-range non-local DWBA calculations. Measured cross sections were accurate to ≈15%. In an earlier work 1973Ma43, at E(d)=17 MeV, nine levels were reported with L-transfers, spectroscopic factors and Nilsson configurations. 1980Pe07 carried out theoretical analysis of measured $\sigma(\theta)$ distributions at E(d)=11, 13, 15 and 17 MeV incident deuteron energies, especially anomalous ones, employing coupled-channels Born Approximation (CCBA) calculations using CHUCK code for 15 levels (g.s. to 1377 keV) reported in their earlier studies, and compared with DWBA calculations.

1969Tj01: E(d)=12.1 MeV from Niels Bohr Institute FN tandem accelerator. Carbon backed, enriched ^{168}Er target of ≈40 μg/cm^2 thickness on ≈40 μg/cm^2 carbon backing. Measured triton spectra and absolute cross sections at θ=60°, 90°, 125° using a magnetic spectrometer with FWHM≈6 keV, and with analyzed particles recorded on photographic plates. Energy uncertainties were assumed to be 3 keV below 1 MeV and 5 keV above 1 MeV excitation as stated in 1967Tj01, and cross section uncertainties of 15-20% as in 1966Bu16. Nilsson configurations and spins were assigned on the basis of 'fingerprint method' by a comparison of experimental and theoretical cross sections, the latter using DWBA calculations.

^{167}Er Levels

E(level)†	J$^{\pi}$ $^{@}$	L $^{\&}$	C^{2}S^c	Comments
0^d	7/2$^+$	4	0.009	Measured dσ/dΩ (μb/sr): ≈2 (60°), ≈1 (90°), ≈0.6 (125°) (1969Tj01). Measured dσ/dΩ (μb/sr at 30°)=5 (1977So08). C^{2}S=0.009 (15 MeV), 0.013 (13 MeV), 0.012 (11 MeV) (1978So04). C^{2}S<0.009 (1973Ma43) for E(d)=17 MeV, $\sigma(\theta)$ poorly fitted for a weak peak.
79^d 2	9/2$^+$	4	0.13	Measured dσ/dΩ (μb/sr): 41 (60°), 57 (90°), 22 (125°) (1969Tj01). Measured dσ/dΩ (μb/sr at 30°)=84 (1977So08). C^{2}S=0.13 (15 MeV), 0.14 (13 MeV), 0.16 (11 MeV), 0.17 (9 MeV) (1978So04). C^{2}S=13 for 78 3 level (1973Ma43) for E(d)=17 MeV.
177^d 2	11/2$^+$	(6)^a	0.24	Measured dσ/dΩ (μb/sr): ≈1 (60°), ≈2 (90°), ≈1 (125°) (1969Tj01). Measured dσ/dΩ (μb/sr at 30°)=7 (1977So08). C^{2}S=0.27 (15 MeV), 0.28 (13 MeV), 0.32 (11 MeV) (1978So04). C^{2}S<0.24 (1973Ma43) for 179 3 level at E(d)=17 MeV, $\sigma(\theta)$ poorly fitted for a weak peak.
208^e 2	1/2$^-$	1	0.19	Measured dσ/dΩ (μb/sr): 265 (60°), 201 (90°), 72 (125°) (1969Tj01). Measured dσ/dΩ (μb/sr at 30°)=47 (1977So08). C^{2}S=0.19 (15 MeV), 0.19 (13 MeV), 0.20 (11 MeV), 0.21 (9 MeV) (1978So04). C^{2}S=0.18 for 207 3 level (1973Ma43) at E(d)=17 MeV.
264^e 2	3/2$^-$	1	0.008	Measured dσ/dΩ (μb/sr): 9 (60°), 5 (90°), 3 (125°) (1969Tj01). Measured dσ/dΩ (μb/sr at 30°)=20 (1977So08). C^{2}S=0.011 (15 MeV), 0.009 (13 MeV), 0.010 (11 MeV), 0.013 (9 MeV) (1978So04). C^{2}S=0.009 (1973Ma43) for 263 3 level at E(d)=17 MeV.
281^e 2	5/2$^-$	(3)^a	0.10	Measured dσ/dΩ (μb/sr): 32 (60°), 34 (90°), 16 (125°) (1969Tj01). Measured dσ/dΩ (μb/sr at 30°)=40 (1977So08). C^{2}S=0.092 (15 MeV), 0.094 (13 MeV), 0.11 (11 MeV), 0.12 (9 MeV) (1978So04). C^{2}S=0.10 (1973Ma43) for 281 3 level at E(d)=17 MeV, $\sigma(\theta)$ poorly fitted with DWBA calculations.
295^d 2	13/2$^+$	6	1.22	L=6 in 1973Ma43. Measured dσ/dΩ (μb/sr): 37 (60°), 71 (90°), 50 (125°) (1969Tj01). Measured dσ/dΩ (μb/sr at 30°)=42 (1977So08). C^{2}S=1.30 (15 MeV), 1.52 (13 MeV), 1.76 (11 MeV), 2.52 (9 MeV) (1978So04). C^{2}S=1.21 (1973Ma43) for 295 3 level at E(d)=17 MeV.

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^{168}**Er(d,t)**   **1977So08,1978So04,1969Tj01 (continued)**

$\underline{^{167}\text{Er Levels (continued)}}$

E(level)[†]	J$^\pi$ [@]	L[&]	C^{2}S^c	Comments
345^f 2	5/2$^-$	3	0.013	Measured dσ/dΩ (μb/sr): 2 (60°), 1 (90°), ≈0.5 (125°) (1969Tj01). Measured dσ/dΩ (μb/sr at 30°)=7 (1977So08). C^{2}S=0.012 (15 MeV), 0.010 (13 MeV), 0.014 (11 MeV) (1978So04).
414^e 2	7/2$^-$	3	0.14	Measured dσ/dΩ (μb/sr): 60 (60°), 65 (90°), 37 (125°) (1969Tj01). Measured dσ/dΩ (μb/sr at 30°)=115 (1977So08). C^{2}S=0.15 (15 MeV), 0.15 (13 MeV), 0.13 (11 MeV), 0.13 (9 MeV) (1978So04). C^{2}S=0.14 (1973Ma43) for 412 3 level at E(d)=17 MeV.
431^f 2	7/2$^-$	3	0.15	Measured dσ/dΩ (μb/sr): 66 (60°), 82 (90°), 41 (125°) (1969Tj01). Measured dσ/dΩ (μb/sr at 30°)=110 (1977So08). C^{2}S=0.16 (15 MeV), 0.17 (13 MeV), 0.18 (11 MeV), 0.19 (9 MeV) (1978So04).
439^e 2	9/2$^-$	5	0.36	Measured dσ/dΩ (μb/sr): ≈8 (125°) (1969Tj01). E(level): ≈438 (1969Tj01). L=(5) in 1977So08; L=5 in 1978So04 as the peak is better defined. C^{2}S for E(d)=13 and 15 MeV (1978So04). C^{2}S=0.44 (11 MeV) (1978So04).
532^g 2	3/2$^+$	2	0.022	Configuration=ν5/2[512], J$^\pi$=9/2$^-$ (1969Tj01) is inconsistent with L=2. Also, γ-vibrational band and tentative configuration=ν3/2[651] in 1969Tj01. Measured dσ/dΩ (μb/sr): 9 (60°), 13 (90°), 7 (125°) (1969Tj01). Measured dσ/dΩ (μb/sr at 30°)=190 (1977So08). E(level): 534 (1969Tj01). C^{2}S=0.026 (15 MeV), 0.025 (13 MeV), 0.026 (11 MeV) (1978So04).
573^g 2	5/2$^+$	2	0.014	Measured dσ/dΩ (μb/sr): 4 (60°), 5 (90°), 2 (125°) (1969Tj01). Measured dσ/dΩ (μb/sr at 30°)=9 (1977So08). C^{2}S=0.013 (15 MeV), 0.016 (13 MeV), 0.015 (11 MeV) (1978So04).
643^e 2	11/2$^-$	(5)^a	0.063	Measured dσ/dΩ (μb/sr): ≈1 (60°), 5 (90°), 6 (125°) (1969Tj01). Measured dσ/dΩ (μb/sr at 30°)=7 (1977So08). C^{2}S=0.083 (15 MeV), 0.070 (13 MeV), 0.072 (11 MeV) (1978So04).
668^h 2	5/2$^-$	3	0.12	Mixed configurations=ν5/2[512], J$^\pi$=11/2$^-$ and ν5/2[523], J$^\pi$=5/2$^-$ (1969Tj01), but 11/2$^-$ is inconsistent with L=3 from $\sigma(\theta)$ (1977So08). Measured dσ/dΩ (μb/sr): 31 (60°), 28 (90°), 22 (125°) (1969Tj01). Measured dσ/dΩ (μb/sr at 30°)=58 (1977So08). C^{2}S=0.14 (15 MeV), 0.14 (13 MeV), 0.11 (11 MeV) (1978So04).
711^g 2	9/2$^+$	4	0.027	Measured dσ/dΩ (μb/sr): 5 (60°), 7 (90°), 3 (125°) (1969Tj01). Measured dσ/dΩ (μb/sr at 30°)=10 (1977So08). C^{2}S=0.033 (15 MeV), 0.030 (13 MeV), 0.039 (11 MeV) (1978So04).
753^i 2	3/2$^-$	1	0.21	Measured dσ/dΩ (μb/sr): 195 (60°), 200 (90°), 110 (125°) (1969Tj01). Measured dσ/dΩ (μb/sr at 30°)=500 (1977So08). C^{2}S=0.25 (15 MeV), 0.23 (13 MeV), 0.23 (11 MeV), 0.28 (9 MeV) (1978So04).
802^j 2	3/2$^-$	1	0.039	Measured dσ/dΩ (μb/sr): 31 (60°), 31 (90°), 17 (125°) (1969Tj01). Measured dσ/dΩ (μb/sr at 30°)=93 (1977So08). C^{2}S=0.037 (15 MeV), 0.037 (13 MeV), 0.042 (11 MeV) (1978So04).
812^k 2	5/2$^+$	2	0.054	Measured dσ/dΩ (μb/sr): 26 (60°), 31 (90°), 14 (125°) (1969Tj01). Measured dσ/dΩ (μb/sr at 30°)=35 (1977So08). C^{2}S=0.075 (15 MeV), 0.088 (13 MeV), 0.086 (11 MeV) (1978So04).
843^h 2	9/2$^-$	5	1.08	Measured dσ/dΩ (μb/sr): 14 (60°), 38 (90°), 35 (125°) (1969Tj01). Measured dσ/dΩ (μb/sr at 30°)=41 (1977So08). C^{2}S=1.14 (15 MeV), 1.20 (13 MeV), 1.26 (11 MeV), 1.32 (9 MeV) (1978So04).
854$^{\ddagger j}$ 2	5/2$^-$	3	0.042	L=3 in 1977So08 and 1978So04, but peak is better defined in the latter work. C^{2}S from E(d)=15 MeV (1978So04). C^{2}S=0.047 (13 MeV), 0.051 (11 MeV) (1978So04).
895^i 2	7/2$^-$	3	0.53	Measured dσ/dΩ (μb/sr): 150 (60°), 200 (90°), 110 (125°) (1969Tj01). Measured dσ/dΩ (μb/sr at 30°)=290 (1977So08). C^{2}S=0.55 (15 MeV), 0.56 (13 MeV), 0.64 (11 MeV), 0.72 (9 MeV) (1978So04).

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^{168}Er(d,t)   1977So08,1978So04,1969Tj01 (continued)

^{167}Er Levels (continued)

E(level)[†]	J$^{\pi}$ [@]	L[&]	C^{2}S[c]	Comments
911[g] 2	13/2$^+$	b		Measured dσ/dΩ (μb/sr): ≈6 (60°), ≈6 (90°), ≈1 (125°) (1969Tj01).
933[k] 2	9/2$^+$	4	0.28	Measured dσ/dΩ (μb/sr): 42 (60°), 60 (90°), 34 (125°) (1969Tj01).
				Measured dσ/dΩ (μb/sr at 30°)=120 (1977So08).
				C^{2}S=0.30 (15 MeV), 0.32 (13 MeV), 0.30 (11 MeV) (1978So04).
943[j] 2	7/2$^-$	3	0.047	Measured dσ/dΩ (μb/sr): 10 (60°), 13 (90°), 9 (125°) (1969Tj01).
				Measured dσ/dΩ (μb/sr at 30°)=21 (1977So08).
				C^{2}S=0.050 (15 MeV), 0.057 (13 MeV), 0.055 (11 MeV) (1978So04).
967[h] 2	11/2$^-$	(5)[a]	0.36	Measured dσ/dΩ (μb/sr): ≈1 (60°), 3 (90°), 2 (125°) (1969Tj01).
				Measured dσ/dΩ (μb/sr at 30°)=20 (1977So08).
				C^{2}S=0.34 (15 MeV), 0.46 (13 MeV), 0.46 (11 MeV) (1978So04).
1002[i] 2	9/2$^-$	(5)[a]	0.58	Measured dσ/dΩ (μb/sr): ≈2 (60°), 4 (90°), 3 (125°) (1969Tj01).
				Measured dσ/dΩ (μb/sr at 30°)=21 (1977So08).
				C^{2}S=0.50 (15 MeV), 0.60 (13 MeV), 0.63 (11 MeV) (1978So04).
1052 2	11/2$^-$	(5)[a]	1.64	Configuration=ν11/2[505], J$^{\pi}$=11/2$^-$ (1969Tj01).
				Measured dσ/dΩ (μb/sr): 15 (60°), 55 (90°), 46 (125°) (1969Tj01).
				Measured dσ/dΩ (μb/sr at 30°)=62 (1977So08).
				C^{2}S=2.04 (15 MeV), 1.95 (13 MeV), 1.56 (11 MeV) (1978So04). C^{2}S=1.6 (1973Ma43) for 1053 3 level at E(d)=17 MeV, $\sigma(\theta)$ poorly fitted with DWBA calculations.
1086 2	3/2$^+$	2	0.91	Configuration=ν3/2[402], J$^{\pi}$=3/2$^+$ (1969Tj01).
				Measured dσ/dΩ (μb/sr): 242 (60°), 345 (90°), 215 (125°) (1969Tj01).
				Measured dσ/dΩ (μb/sr at 30°)=570 (1977So08).
				C^{2}S=0.92 (15 MeV), 0.93 (13 MeV), 0.86 (11 MeV), 0.52 (9 MeV) (1978So04).
1109[k] 2	13/2$^+$	6	1.89	L=6 in 1977So08 and 1978So04, but peak is better defined in the latter work.
				Measured dσ/dΩ (μb/sr): 13 (60°), 25 (90°), 36 (125°) (1969Tj01).
				C^{2}S for E(d)=15 MeV (1978So04).
				C^{2}S=1.75 (13 MeV), 1.95 (11 MeV) (1978So04).
1135 2	1/2$^+$	0	0.66	Configuration=ν1/2[400], J$^{\pi}$=1/2$^+$ (1969Tj01).
				Measured dσ/dΩ (μb/sr): 269 (60°), 384 (90°), 224 (125°) (1969Tj01).
				Measured dσ/dΩ (μb/sr at 30°)=80 (1977So08).
				C^{2}S=0.66 (15 MeV), 0.66 (13 MeV), 0.55 (11 MeV), 0.40 (9 MeV) (1978So04).
1173[‡] 2	9/2$^-$	(5)[a]	1.02	Configuration=ν7/2[514], J$^{\pi}$=9/2$^-$ (1977So08).
				Measured dσ/dΩ (μb/sr at 30°)=14 (1977So08).
				C^{2}S=1.02 (15 MeV), 1.04 (13 MeV), 0.84 (11 MeV) (1978So04).
1190 2		a		Measured dσ/dΩ (μb/sr): 26 (125°) (1969Tj01).
				Measured dσ/dΩ (μb/sr at 30°)=14 (1977So08).
1205 2		0	0.053	Measured dσ/dΩ (μb/sr): 8 (60°), 21 (90°), 24 (125°) (1969Tj01).
				Measured dσ/dΩ (μb/sr at 30°)=50 (1977So08).
				C^{2}S=0.043 (15 MeV), 0.052 (13 MeV), 0.040 (11 MeV) (1978So04).
1222 2		a		Measured dσ/dΩ (μb/sr): 12 (125°) (1969Tj01).
				Measured dσ/dΩ (μb/sr at 30°)=17 (1977So08).
1247[‡] 2		a		Measured dσ/dΩ (μb/sr at 30°)=14 (1977So08).
1280[‡] 5		b		
1302 2		3	0.054	Measured dσ/dΩ (μb/sr): 44 (60°), 6 (90°), 7 (125°) (1969Tj01).
				Measured dσ/dΩ (μb/sr at 30°)=22 (1977So08).
				C^{2}S=0.052 (15 MeV), 0.042 (13 MeV), 0.050 (11 MeV) (1978So04).
1352 2		a		Measured dσ/dΩ (μb/sr): 3 (60°), 5 (90°), 2 (125°) (1969Tj01).
				Measured dσ/dΩ (μb/sr at 30°)=11 (1977So08).
1377 2		2	0.29	Configuration=ν1/2[530], J$^{\pi}$=3/2$^-$ (1969Tj01) inconsistent with $\sigma(\theta)$ distribution in 1977So08 and 1978So04 which fits better with L=2 rather than L=1 required for 3/2$^-$, 1/2[530] assignment.
				Measured dσ/dΩ (μb/sr): 62 (60°), 75 (90°), 47 (125°) (1969Tj01).
				Measured dσ/dΩ (μb/sr at 30°)=175 (1977So08).

^{168}Er(d,t)　　1977So08,1978So04,1969Tj01 (continued)

^{167}Er Levels (continued)

E(level)[†]	L[&]	C^{2}S[c]	Comments
1426 *2*	0	0.14	C^{2}S=0.38 (15 MeV), 0.35 (13 MeV), 0.29 (11 MeV) (1978So04). Measured dσ/dΩ (μb/sr): 36 (60°), 61 (90°), 52 (125°) (1969Tj01). Measured dσ/dΩ (μb/sr at 30°)=130 (1977So08). C^{2}S=0.13 (15 MeV), 0.13 (13 MeV), 0.12 (11 MeV) (1978So04).
1440[‡] *2*	0	0.015	Measured dσ/dΩ (μb/sr at 30°)=16 (1977So08). C^{2}S=0.016 (15 MeV), 0.018 (13 MeV), 0.020 (11 MeV) (1978So04).
1525[#] *5*			Measured dσ/dΩ (μb/sr): ≈10 (60°), ≈9 (90°), 9 (125°) (1969Tj01).
1536[#] *5*			Measured dσ/dΩ (μb/sr): ≈13 (60°), ≈18 (90°), 10 (125°) (1969Tj01).
1545[#] *5*			Measured dσ/dΩ (μb/sr): ≈13 (60°), ≈27 (90°), 17 (125°) (1969Tj01).
1558[#] *5*			Measured dσ/dΩ (μb/sr): ≈26 (90°), ≈16 (125°) (1969Tj01).
1590[#] *5*			Measured dσ/dΩ (μb/sr): 2 (60°), 2 (90°), 3 (125°) (1969Tj01).
1625[#] *5*			Measured dσ/dΩ (μb/sr): 32 (60°), 36 (90°), 28 (125°) (1969Tj01).
1638[#] *5*			Measured dσ/dΩ (μb/sr): 6 (60°), 11 (90°), 6 (125°) (1969Tj01).
1657[#] *5*			Measured dσ/dΩ (μb/sr): 39 (60°), 51 (90°), 29 (125°) (1969Tj01).
1748[#] *5*			Measured dσ/dΩ (μb/sr): 5 (60°), 5 (90°), 10 (125°) (1969Tj01).
1812[#] *5*			Measured dσ/dΩ (μb/sr): 5 (60°), 4 (90°), 4 (125°) (1969Tj01).
1853[#] *5*			Measured dσ/dΩ (μb/sr): 5 (60°), 4 (90°), 9 (125°) (1969Tj01).
1893[#] *5*			Measured dσ/dΩ (μb/sr): 17 (60°), 28 (90°), 33 (125°) (1969Tj01).
1940[#] *5*			Measured dσ/dΩ (μb/sr): 5 (60°), 10 (90°), 4 (125°) (1969Tj01).

[†] From 1977So08 and 1978So04 unless otherwise indicated. Level energies up to 1440 keV are the same in 1969Tj01 for all the levels, except in a few cases which are noted in comments.

[‡] Level not reported in 1969Tj01.

[#] From 1969Tj01 only, where averages of available values from the measurements at 60°, 90° and 125° were taken, and where energy uncertainty was assumed by evaluators as 5 keV as stated in a similar study by 1967Tj01. As stated by authors, levels from 1657 to 1892 are weakly populated.

[@] As assigned in 1969Tj01 based on 'fingerprint method' for Nilsson states assigned for band members, and in 1977So08 and 1978So04 from $\sigma(\theta)$ distributions.

[&] From DWBA analysis of $\sigma(\theta)$ distributions (1977So08,1978So04).

[a] Shape of $\sigma(\theta)$ distribution is anomalous as compared to DWBA calculations (1977So08,1978So04). See also 1980Pe07.

[b] Meaningful $\sigma(\theta)$ distribution could not be extracted as the level is weakly populated and/or obscured by a stronger transition (1977So08).

[c] dσ/dΩ(exp)/(N dσ/dΩ(DWBA)), where N=3.33. Values are from E(d)=17 MeV data from 1977So08. Corresponding values for E(d)=9, 11, 13, and 15 MeV measurements in 1978So04 are given under comments.

[d] Band(A): ν7/2[633]. Band assignment from 1969Tj01.

[e] Band(B): ν1/2[521]. Band assignment from 1969Tj01.

[f] Band(C): ν5/2[512]. Band assignment from 1969Tj01.

[g] Band(D): 3/2$^+$ γ-vibrational band. Assignment in 1969Tj01; γ-vibrational band, and tentative ν3/2[651].

[h] Band(E): ν5/2[523]. Band assignment from 1969Tj01.

[i] Band(F): ν3/2[521]. Band assignment from 1969Tj01.

[j] Band(G): ν1/2[510]. Band assignment from 1969Tj01.

[k] Band(H): ν5/2[642]. Band assignment from 1969Tj01.

^{168}Er(d,t)   **1977So08,1978So04,1969Tj01**

Band(F): ν3/2[521]

Band(E): ν5/2[523]   9/2$^-$ 1002

Band(D): 3/2$^+$
γ-vibrational band   11/2$^-$ 967

13/2$^+$ 911

7/2$^-$ 895

9/2$^-$ 843

3/2$^-$ 753

9/2$^+$ 711

Band(B): ν1/2[521]   5/2$^-$ 668

11/2$^-$ 643

5/2$^+$ 573

3/2$^+$ 532

Band(C): ν5/2[512]

9/2$^-$ 439   7/2$^-$ 431

7/2$^-$ 414

5/2$^-$ 345

Band(A): ν7/2[633]

13/2$^+$ 295

5/2$^-$ 281

3/2$^-$ 264

1/2$^-$ 208

11/2$^+$ 177

9/2$^+$ 79

7/2$^+$ 0

$^{167}_{68}$Er$_{99}$

<u>^{168}Er(d,t)   1977So08,1978So04,1969Tj01 (continued)</u>

Band(H): ν5/2[642]

13/2$^+$ 1109

Band(G): ν1/2[510]

7/2$^-$ 943

                    9/2$^+$ 933

5/2$^-$ 854

                    5/2$^+$ 812

3/2$^-$ 802

$^{167}_{68}$Er$_{99}$