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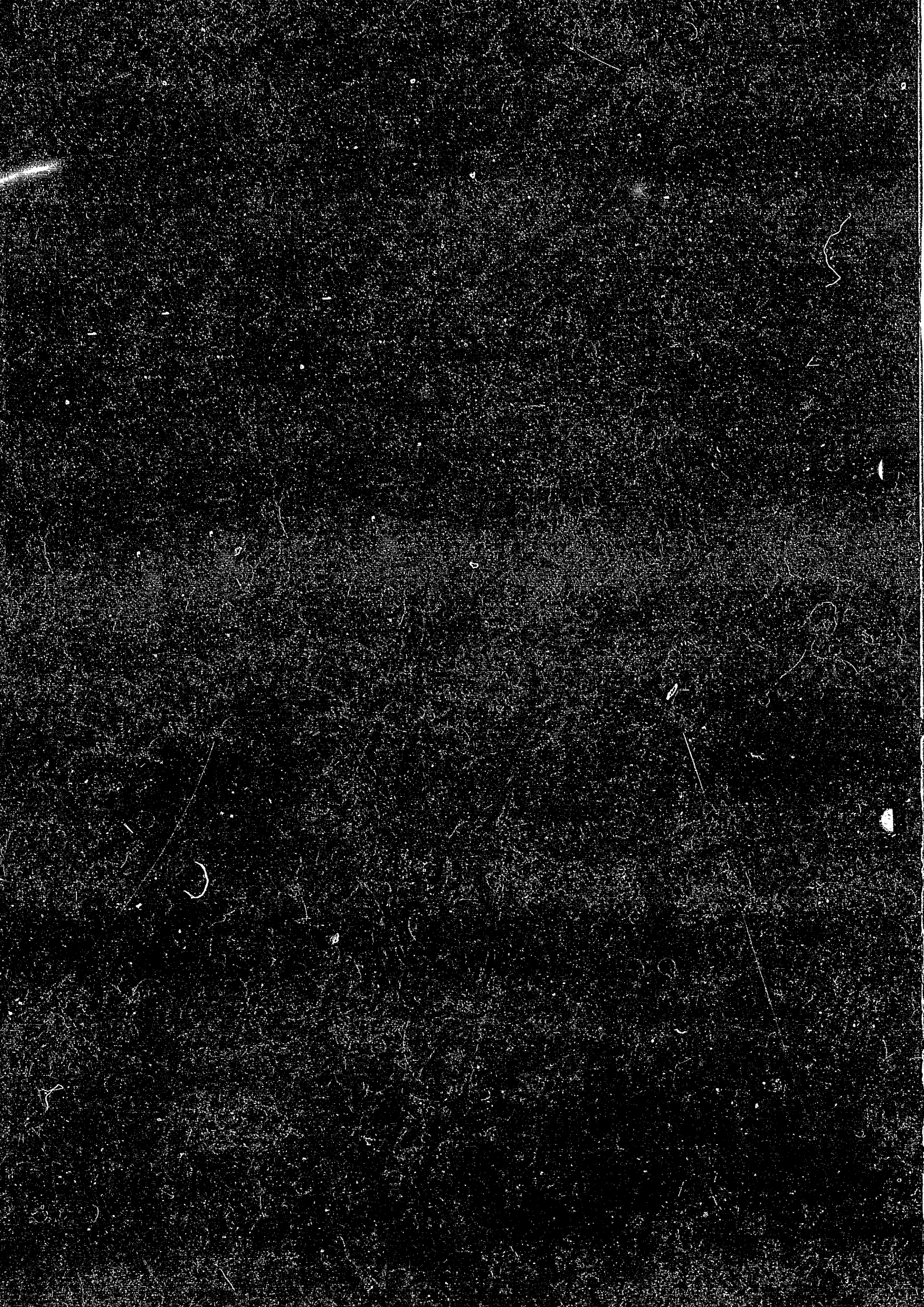

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I. Introduction

Experimental data of sputtering of solids by ion bombardment have been accumulated for these three decades.[1] Current needs for the sputtering data have accelerated the experimental measurements of the sputtering yield particularly by light ions. For better understanding of the phenomena[2] and for the extensive use of the sputtering data for the design of the fusion reactors, we need comparison of the experimental data with empirical formula for varieties of combination of the incident ions and targets.

This paper present a compilation of the experimental data of the energy dependence of the sputtering yield at the normal incidence for all available combinations of the incident ions and target atoms. For each combination, the data are fitted to the empirical equation suggested by the present authors.[3] The best fit values of two empirical parameters in the empirical equation are tabulated. Best fit values are also plotted as a function of M_2/M_1, where M_1 and M_2 are the atomic masses of the incident ions and the target atoms respectively. It is shown that the value of these parameters for a given value of M_2/M_1 falls within $\pm$ 30% of the average for most cases. Thus using the averaged relation between the values of these parameters for a given value of M_2/M_1, the approximate sputtering yield of any combination as a function of energy is easily attainable.

II. Empirical Equation - Scaling Rule

A theoretical equation for the sputtering yield Y has been derived by Sigmund.[4] Sigmund equation, which predicts that the sputtering yield is proportional to the elastic stopping power, is known to account for the experimental data for heavy ion bombardments over a wide energy range. However, it has been shown recently that the straight line pertaining the plots of the energy dependence

of the sputtering yield approaches to zero at a finite incident energy.[5), 6)] This result has been attributed to the threshold effect in displacement of atoms at crystal surfaces and at lattice points. According to the recently suggested modified Sigmund equation,[3)] which takes the threshold effect into account, the sputtering yield is given by

$$Y = \frac{0.42}{U_s}\alpha S_n\{1 - (\frac{Eth}{E})^{1/2}\} \qquad (1)$$

where α is a factor depending on M_2/M_1, U_s is the sublimation energy,[7)] S_n is the elastic stopping cross section in unit of eV $cm^2/ 10^{15}$atoms, E is the energy and E_{th} is an energy factor relevant to the threshold effect. If the last factor is dropped in Eq (1), one gets the Sigmund equation. Parameters α and E_{th} were chosen so that Eq (1) was fitted to the experimental energy dependence of the sputtering yield. The elastic stopping cross section was obtained, using an analytical approximation of the Lindhard-Scharff-Schiott relation between the reduced elastic stopping cross section s_n and the reduced energy ε(Appendix A). The stopping cross section S_n is given by

$$S_n = Ks_n = \frac{4\pi a Z_1 Z_2 e^2 M_1}{M_1 + M_2} s_n \quad (\text{eV cm}^2/ 10^{15}\text{atoms}) \qquad (2)$$

where Z_1 and Z_2 are atomic number of incident ions and target atoms, and a is the Thomas-Fermi in the unit of Å and is given by

$$a = \frac{0.8853 a_0}{\sqrt{Z_1^{2/3} + Z_2^{2/3}}}, \qquad (3)$$

using Bohr radius a_0.

Examples of fitting of experimental data to Eq (1) are shown in Figs. 1 and 2. Figure 1 is the result for the nickel targets and Fig. 2 for self sputtering of several metal targets. The deviation of the experimental values from the best fit curves is remarkable

for heavier incident ions and for heavier target atoms. This deviation may be ascribed to (1) the subthreshold effects and (2) the overestimation of the threshold energy because of the non-linear effect.[9)]

III. Compilation of the Data on the Energy Dependence of the Sputtering Yield

The energy dependence of the sputtering yield of all available combinations of the incident ions and target atoms upto the end of 1978 have been compiled and stored in the computer. The compiled combinations are shown in Table I, where * indicates the combinations for which the numerical analysis was made and x indicates those for which the available data are insufficient for the numerical analysis.

Numerical values of the parameters α and E_{th} are shown in Table II. In the table we also show the numerical values of some other important quatities. The dependence of α as well as E_{th}/Us ($=\xi$) on M_2/M_1 is shown in Fig. 3 and 4, respectively. The values of the sublimation energy are listed in Appendix B. The solid lines in these figures denote the averages, and the broken lines show the $\pm 30\%$ deviation.

The plots of the energy dependence of the sputtering yields of various combinations of the incident ions and the target atoms are shown in Figs. 5 to 208. The solid lines in these figures are the best fit curves to the empirical equation. The broken lines show the result calculated by putting average values of α and ξ into Eq (1). The references for each experimental points are shown in the figures and all the references are listed chronologically and alphabetically in each year at the end of the report.

1) For current data compilation see for example H. H. Andersen and H. L. Bay,in Sputtering by Ion Bombardment (ed. R. Behrish) Chap. 4 (to be published)

2) For the review of the theoretical aspects, see P. Sigmund, ibid Chap 1.

3) N. Matsunami et al., Radiation Effect Letters (to be published).

4) P. Sigmund, Phys. Rev. 184, 383 (1969) and 187, 768 (1969).

5) P. Behrish, G. Maderlechner and B. M. U. Shertger, Applied Physics 18, 391 (1979).

6) J. Bohdansky, J. Roth and H.L. Bay, J. Appl. Phys.

7) K. A. Gschneidner, Jr., Solid State Physics, eds. F. Seitz and D. Turnbull, (Academic Press, New York, 1964) Vol. 16, p. 275.

8) J. Lindhard, V. Nielsen and M. Scharff, Mat. Fyz. Medd. Dan. Vid. Selsk. 36, No. 10 (1968).

9) W. O. Hofer, Nucl. Inst.and Methods, (to be published).

Table I Ion-target combinations in the present data compilation

Target \ Ion	H 1	D 1	He 2	Li 3	N 7	O 8	Ne 10	Ar 18	Zn 30	Kr 36	Xe 54	Cs 55	Gd 64	Hg 80	Pb 82	+
Be 4			*				*	*		*	*					
B 5			x													
C 6	x	*	*					*		*	*			*		
Al 13			*				*	*		*	*			*		*
Si 14			*				*	*		*	*				*	
Ti 22	x		*				*	*		*	*			*		
V 23			*				*	*		*	*			*		
Cr 24			*				*	*		*	*			*		x
Mn 25										x	x					
Fe 26			*		*		*	*		*	*	*		*	*	
Co 27			*				*	*		*	*			*		*
Ni 28	*	*	*			*	*	*		*	*			*		*
Cu 29		*	*		*		*	*	x	*	*	*		*	*	*
Zn 30								x								x
Ge 32			*				*	*		*	*			*		
Zr 40			*	*			*	*		*	*			*		
Nb 41	x	*	*	*			*	*		*	*	*		*		*
Mo 42	*	*	*				*	*		*	*	*		*	*	
Ru 44							*	*		*	*					
Rh 45			*				*	*		*	*			*		
Pd 46			*				*	*		*	*			*		
Ag 47	*	*	x				*	*	x	*	*		x	*		*
Cd 48								x								
In 49														x		
Sn 50							x	*		x	x					*
Hf 72			x				*	*		*	*			*		
Ta 73			x				*	*		*	*			*		
W 74			*				*	*		*	*	*		*	x	
Re 75							*	*		*	*			*		
Os 76			*				*	*		*	*					
Ir 77			*				*	*		*	*			*		
Pt 78			*				*	*		*	*			*		
Au 79	*	*	*		*		*	*		*	*			*		*
Pb 82			x													
Th 90							*	*		*	*					
U 92							*	*		*	*			*		

Target		Na 11	Si 14	P 15	S 16	Cl 17	K 19	Ni 28	Cd 48	Tl 81
Cu	29	x	x	x	x	x	x	x	x	x

+ Self-sputtering

Table II. The best fit values of α and E_{th} to Eq (1).

$$C_e = \frac{a}{Z_1 Z_2 e^2} \frac{M_2}{M_1 + M_2} \qquad (eV^{-1})$$

$$K = \frac{4\pi a Z_1 Z_2 e^2 M_1}{M_1 + M_2} \qquad (eV\ cm^2/10^{15} atoms)$$

$$P = \frac{0.42 \alpha K}{U_s}$$

$$\xi = \frac{E_{th}}{U_s}$$

$$\gamma = \frac{4 M_1 M_2}{(M_1 + M_2)^2}$$

$$a = \frac{0.8853 a_o}{(Z_1^{2/3} + Z_2^{2/3})^{1/2}}$$

M_1 and M_2: masses of incident ions and target atoms

Z_1 and Z_2: atomic numbers of incident ions and target atoms

U_s: sublimation energy

α: a factor depending on M_2/M_1

		C_e	K	P	E_{th}	M_2/M_1	α	ξ	γ
Be	He	1.389E-3	10.29	0.9835	89.52	2.251	0.769	26.5	0.8519
	Ne	9.382E-5	87.60	2.682	98.27	0.4465	0.246	29.1	0.8536
	Ar	2.715E-5	162.5	3.620	73.10	0.2256	0.179	21.6	0.6008
	Kr	5.988E-6	300.9	5.346	89.39	0.1075	0.143	26.4	0.3507
	Xe	2.360E-6	418.0	7.536	138.8	0.06864	0.145	41.1	0.2404
C	D	2.239E-3	3.522	0.1092	31.88	5.964	0.547	4.30	0.4919
	He	9.196E-4	11.50	0.4505	167.4	3.000	0.691	22.6	0.7499
	Ar	2.184E-5	220.7	6.768	348.9	0.3007	0.541	47.1	0.7109
	Kr	5.010E-6	425.0	1.936	93.73	0.1433	0.0804	12.6	0.4386
	Xe	2.007E-6	600.1	1.485	18.07	0.09148	0.0437	2.44	0.3071
	Hg	8.189E-7	821.0	12.44	286.5	0.05988	0.267	38.7	0.2132
Al	He	4.085E-4	10.68	0.9009	151.4	6.740	0.675	45.1	0.4500
	Ne	4.489E-5	147.9	4.565	93.17	1.337	0.247	27.7	0.9792
	Al	2.895E-5	215.4	4.748	39.44	1.0	0.176	11.7	1.0
	Ar	1.592E-5	336.3	6.936	71.28	0.6754	0.165	21.2	0.9625
	Kr	4.177E-6	740.4	11.85	81.07	0.3220	0.128	24.1	0.7370
	Xe	1.775E-6	1109.	15.34	86.28	0.2055	0.111	25.7	0.5656
	Hg	7.556E-7	1583.	23.74	133.6	0.1345	0.120	39.8	0.4180
Si	He	3.740E-4	10.89	0.4875	85.02	7.016	0.501	18.1	0.4367
	Ne	4.183E-5	153.5	2.835	90.95	1.392	0.207	19.4	0.9732
	Ar	1.497E-5	352.3	3.987	64.20	0.7031	0.127	13.7	0.9696
	Kr	3.964E-6	782.8	6.912	92.71	0.3352	0.0988	19.7	0.7520
	Xe	1.692E-6	1178.	11.59	159.3	0.2139	0.110	33.9	0.5806
	Pb	6.810E-7	1725.	15.52	2.435	0.1356	0.101	0.52	0.4205
Ti	He	2.221E-4	9.364	0.2605	56.38	11.97	0.324	11.5	0.2847
	Ne	2.944E-5	156.4	2.725	61.79	2.373	0.203	12.6	0.8343
	Ar	1.168E-5	397.9	3.933	57.15	1.199	0.115	11.7	0.9918
	Kr	3.450E-6	986.5	6.948	86.89	0.5716	0.0820	17.8	0.9257
	Xe	1.556E-6	1568.	10.37	118.6	0.3648	0.0770	24.3	0.7834
	Hg	6.933E-7	2343.	13.84	106.2	0.2388	0.0688	21.7	0.6224
V	He	2.108E-4	9.134	0.2536	90.93	12.73	0.352	17.1	0.2702
	Ne	2.840E-5	155.1	3.415	79.57	2.524	0.279	14.9	0.8130
	Ar	1.139E-5	398.9	3.899	44.73	1.275	0.124	8.39	0.9854
	Kr	3.409E-6	1002.	8.466	79.38	0.6079	0.107	14.9	0.9405
	Xe	1.548E-6	1604.	12.38	83.06	0.3880	0.0979	15.6	0.8056
	Hg	6.936E-7	2410.	19.18	160.2	0.2540	0.101	30.1	0.6460

		C_e	K	P	Eth	M_2/M_1	α	ξ	γ
Cr	He	1.999E-4	9.241	0.7059	74.46	12.99	0.749	18.1	0.2655
	Ne	2.712E-5	158.0	6.471	62.70	2.576	0.402	15.2	0.8057
	Ar	1.093E-5	408.3	9.284	41.78	1.302	0.223	10.1	0.9828
	Kr	3.289E-6	1031.	19.10	66.76	0.6205	0.182	16.2	0.9451
	Xe	1.498E-6	1655.	30.33	84.17	0.3960	0.180	20.4	0.8128
	Hg	6.727E-7	2493.	21.28	96.38	0.2592	0.0838	23.4	0.6539
Fe	He	1.814E-4	9.159	0.5800	67.71	13.95	0.654	15.6	0.2496
	N	4.053E-5	87.74	5.994	407.7	3.987	0.706	93.9	0.6412
	Ne	2.509E-5	159.7	4.504	35.85	2.767	0.291	8.26	0.7800
	Ar	1.025E-5	418.3	9.133	52.56	1.398	0.226	12.1	0.9725
	Kr	3.134E-6	1073.	17.23	81.77	0.6664	0.166	18.8	0.9599
	Xe	1.440E-6	1739.	27.00	96.42	0.4253	0.160	22.2	0.8375
	Cs	1.396E-6	1771.	37.56	348.9	0.4202	0.219	80.4	0.8333
	Hg	6.515E-7	2638.	29.28	164.7	0.2784	0.115	37.9	0.6814
	Pb	6.162E-7	2707.	38.45	25.37	0.2695	0.147	5.84	0.6690
Co	He	1.734E-4	8.949	0.5597	89.25	14.72	0.660	20.1	0.2382
	Ne	2.430E-5	158.1	6.902	81.92	2.920	0.460	18.5	0.7601
	Ar	1.002E-5	417.9	11.64	65.54	1.475	0.294	14.8	0.9631
	Co	5.260E-6	728.4	5.886	41.87	1.0	0.0852	9.45	1.0
	Kr	3.098E-6	1084.	15.47	86.61	0.7033	0.150	19.6	0.9696
	Xe	1.433E-6	1768.	22.70	82.71	0.4488	0.135	18.7	0.8553
	Hg	6.515E-7	2696.	34.86	146.8	0.2938	0.136	33.1	0.7021
Ni	H	3.573E-4	1.253	0.05155	82.13	58.24	0.437	18.4	0.06638
	D	3.514E-4	2.463	0.1168	58.71	29.15	0.504	13.2	0.1283
	He	1.654E-4	9.218	0.5689	54.52	14.67	0.655	12.2	0.2390
	O	3.139E-5	111.8	1.670	82.86	3.670	0.159	18.6	0.6732
	Ne	2.322E-5	163.1	5.311	39.09	2.909	0.346	8.77	0.7615
	Ar	9.577E-6	431.3	12.69	53.94	1.470	0.312	12.1	0.9638
	Ni	4.832E-6	773.9	10.43	52.65	1.0	0.143	11.8	1.0
	Kr	2.964E-6	1120.	17.53	75.63	0.7006	0.166	17.0	0.9690
	Xe	1.371E-6	1827.	24.35	93.92	0.4471	0.141	21.1	0.8541
	Hg	6.239E-7	2787.	36.43	115.4	0.2927	0.139	25.9	0.7006

		C_e	K	P	E_{th}	M_2/M_1	α	ξ	γ
Cu	D	3.366E-4	2.338	0.2694	406.3	31.55	0.966	115.0	0.1191
	He	1.589E-4	8.775	0.8420	49.10	15.87	0.804	13.9	0.2230
	N	3.629E-5	85.88	4.756	22.06	4.537	0.464	6.27	0.5920
	Ne	2.269E-5	157.9	8.678	37.07	3.148	0.460	10.5	0.7318
	Ar	9.477E-6	423.0	16.01	33.93	1.591	0.317	9.64	0.9480
	Cu	4.452E-6	820.5	22.27	44.46	1.0	0.227	12.6	1.0
	Kr	2.980E-6	1116.	31.52	56.50	0.7583	0.237	16.1	0.9811
	Xe	1.391E-6	1837.	49.07	79.87	0.4840	0.224	22.7	0.8791
	Cs	1.350E-6	1871.	68.60	186.1	0.4781	0.307	52.9	0.8753
	Hg	6.375E-7	2822.	63.21	122.1	0.3168	0.188	34.7	0.7308
	Pb	6.035E-7	2899.	68.25	111.3	0.3067	0.197	31.6	0.7185
Ge	He	1.411E-4	8.302	0.8502	79.96	18.13	0.390	20.6	0.1981
	Ne	2.073E-5	153.8	5.178	67.53	3.597	0.311	17.4	0.6809
	Ar	8.850E-6	421.1	8.296	29.12	1.817	0.182	7.50	0.9159
	Kr	2.862E-6	1142.	14.82	72.07	0.8662	0.120	18.6	0.9949
	Xe	1.358E-6	1911.	20.54	83.73	0.5529	0.0993	21.6	0.9171
	Hg	6.310E-7	2978.	24.89	110.8	0.3619	0.0772	28.6	0.7805
Zr	He	1.069E-4	7.823	0.1647	163.3	22.79	0.317	25.8	0.1611
	Li	6.788E-5	19.38	0.6451	101.8	13.15	0.502	16.1	0.2628
	Ne	1.648E-5	152.0	3.008	70.80	4.520	0.298	11.2	0.5934
	Ar	7.294E-6	431.5	6.061	53.12	2.283	0.212	8.39	0.8472
	Kr	2.477E-6	1230.	6.196	60.16	1.089	0.0760	9.50	0.9982
	Xe	1.211E-6	2120.	12.75	89.15	0.6947	0.0906	14.1	0.9676
	Hg	5.777E-7	3390.	12.60	91.80	0.4548	0.0560	14.5	0.8595
Nb	D	2.163E-4	2.054	0.02584	52.37	46.13	0.227	6.90	0.08307
	He	1.036E-4	7.822	0.2386	191.0	23.21	0.551	25.2	0.1584
	Li	6.585E-5	19.39	0.8341	128.0	13.39	0.777	16.9	0.2587
	Ne	1.603E-5	152.6	2.896	63.97	4.603	0.343	8.43	0.5865
	Ar	7.118E-6	434.4	7.456	75.26	2.326	0.310	9.92	0.8411
	Kr	2.427E-6	1243.	10.75	90.38	1.109	0.156	11.9	0.9973
	Nb	1.984E-6	1461.	10.39	367.5	1.0	0.129	48.4	1.001
	Xe	1.190E-6	2148.	25.50	207.5	0.7076	0.214	27.3	0.9707
	Cs	1.156E-6	2192.	22.39	4.010	0.6990	0.185	0.53	0.9686
	Hg	5.690E-7	3444.	12.41	105.9	0.4632	0.0651	14.0	0.8654

		C_e	K	P	E_{th}	M_2/M_1	α	ξ	γ
Mo	H	2.119E-4	1.024	8.914E-3	327	95.18	0.142	47.9	0.04116
	D	2.098E-4	2.024	0.01602	131.5	47.64	0.129	19.2	0.08055
	He	1.006E-4	7.714	0.1457	99.28	23.97	0.307	14.5	0.1538
	Ne	1.565E-5	151.3	3.848	59.02	4.754	0.413	8.64	0.5744
	Ar	6.980E-6	432.8	5.405	39.32	2.402	0.203	5.76	0.8302
	Kr	2.396E-6	1247.	9.982	44.13	1.145	0.130	6.46	0.9954
	Xe	1.179E-6	2163.	19.59	73.07	0.7307	0.147	10.7	0.9758
	Cs	1.146E-6	2208.	31.21	253.7	0.7218	0.230	37.1	0.9739
	Hg	5.659E-7	3481.	19.81	135.0	0.4783	0.0926	19.8	0.8755
	Pb	5.374E-7	3587.	31.26	135.1	0.4631	0.142	19.8	0.8653
Ru	Ne	1.490E-5	150.1	4.774	72.74	5.008	0.506	10.9	0.5550
	Ar	6.696E-6	432.6	10.55	58.70	2.530	0.389	8.77	0.8121
	Kr	2.323E-6	1259.	21.83	86.21	1.206	0.276	12.9	0.9913
	Xe	1.152E-6	2201.	28.50	91.43	0.7698	0.206	13.7	0.9831
Rh	He	9.221E-5	7.571	0.2683	90.57	25.71	0.488	15.7	0.1442
	Ne	1.454E-5	150.4	6.251	75.52	5.099	0.572	13.1	0.5483
	Ar	6.549E-6	434.6	13.88	68.49	2.576	0.440	11.8	0.8058
	Kr	2.281E-6	1270.	24.30	76.39	1.228	0.263	13.2	0.9895
	Xe	1.133E-6	2225.	31.30	80.13	0.7838	0.194	13.9	0.9853
	Hg	5.485E-7	3610.	41.58	96.42	0.5130	0.158	16.7	0.8964
Pd	He	8.973E-5	7.446	0.6540	75.61	26.58	0.818	19.3	0.1398
	Ne	1.422E-5	148.7	6.440	41.67	5.272	0.403	10.7	0.5361
	Ar	6.435E-6	431.6	13.96	41.77	2.663	0.301	10.7	0.7938
	Kr	2.256E-6	1269.	28.52	49.03	1.270	0.209	12.5	0.9859
	Xe	1.126E-6	2234.	43.72	63.04	0.8104	0.182	16.1	0.9890
	Hg	5.468E-7	3638.	52.60	78.25	0.5304	0.135	20.0	0.9059
Ag	H	1.831E-4	0.9851	0.1271	268.3	107.0	0.912	90.3	0.03669
	D	1.815E-4	1.950	0.2666	44.60	53.56	0.966	15.0	0.07197
	Ne	1.387E-5	149.4	13.09	45.34	5.345	0.619	15.3	0.5311
	Ar	6.292E-6	434.6	24.67	23.39	2.700	0.401	7.87	0.7889
	Kr	2.212E-6	1282.	60.33	84.88	1.287	0.333	28.6	0.9842
	Ag	1.443E-6	1835.	89.25	89.07	1.0	0.344	30.0	1.0
	Xe	1.106E-6	2260.	94.51	95.93	0.8216	0.296	32.3	0.9904
	Hg	5.384E-7	3688.	140.	123.6	0.5378	0.269	41.6	0.9096

		C_e	K	P	E_{th}	M_2/M_1	α	ξ	γ
Sn	Ar	5.982E-6	425.0	10.44	51.82	2.971	0.182	16.6	0.7536
	Sn	1.249E-6	2034	26.60	56.43	1.0	0.0971	18.1	1.0
Hf	Ne	8.665E-6	132.4	3.125	63.57	8.844	0.355	10.1	0.3651
	Ar	4.172E-6	408.7	7.804	39.20	4.468	0.287	6.21	0.5977
	Kr	1.608E-6	1322.	16.92	68.16	2.130	0.192	10.8	0.8697
	Xe	8.578E-7	2485.	30.57	118.3	1.359	0.185	18.8	0.9768
	Hg	4.440E-7	4314.	22.56	109.0	0.8898	0.0786	17.3	0.9966
Ta	Ne	8.527E-6	132.1	2.457	54.64	8.965	0.359	6.75	0.3611
	Ar	4.112E-6	408.4	5.801	50.15	4.530	0.274	6.19	0.5926
	Kr	1.589E-6	1324.	17.35	81.60	2.159	0.253	10.1	0.8653
	Xe	8.488E-7	2494.	22.93	86.49	1.378	0.177	10.7	0.9747
	Hg	4.402E-7	4336.	19.56	99.34	0.9021	0.0870	12.3	0.9974
W	He	4.908E-5	6.100	0.05713	165.3	45.93	0.194	19.0	0.08342
	Ne	8.395E-6	131.5	3.031	57.92	9.109	0.476	6.67	0.3565
	Ar	4.054E-6	407.3	7.493	65.92	4.602	0.380	7.59	0.5866
	Kr	1.571E-6	1324.	16.32	73.80	2.194	0.255	8.50	0.8603
	Xe	8.408E-7	2498.	32.15	95.61	1.400	0.266	11.0	0.9722
	Cs	8.191E-7	2556.	30.21	51.47	1.383	0.244	5.93	0.9741
	Hg	4.369E-7	4353.	16.31	92.18	0.9165	0.0774	10.6	0.9981
Re	Ne	8.264E-6	131.3	3.864	77.98	9.226	0.567	9.64	0.3529
	Ar	3.996E-6	407.2	11.18	71.67	4.661	0.529	8.86	0.5818
	Kr	1.552E-6	1326.	24.96	85.87	2.222	0.362	10.6	0.8562
	Xe	8.319E-7	2507.	33.11	96.64	1.418	0.254	11.9	0.9701
	Hg	4.330E-7	4375.	32.46	105.6	0.9283	0.143	13.1	0.9986
Os	He	4.744E-5	6.010	0.1555	187.0	47.51	0.501	23.0	0.08075
	Ne	8.144E-6	130.1	3.839	80.74	9.424	0.571	9.93	0.3469
	Ar	3.946E-6	404.1	12.11	84.66	4.761	0.580	10.4	0.5738
	Kr	1.537E-6	1321.	25.67	91.50	2.270	0.376	11.3	0.8492
	Xe	8.261E-7	2503.	35.74	95.12	1.449	0.276	11.7	0.9664

		C_e	K	P	E_{th}	M_2/M_1	α	ξ	γ
Ir	He	4.664E-5	6.003	0.07918	180.1	48.01	0.217	26.1	0.07994
	Ne	8.018E-6	130.1	4.323	64.22	9.523	0.546	9.31	0.3440
	Ar	3.889E-6	404.7	12.39	57.87	4.812	0.503	8.39	0.5699
	Kr	1.518E-6	1325.	22.01	74.44	2.294	0.273	10.8	0.8457
	Xe	8.169E-7	2514.	42.31	92.65	1.464	0.276	13.4	0.9646
	Hg	4.268E-7	4404.	46.20	88.30	0.9582	0.172	12.8	0.9995
Pt	He	4.588E-5	5.969	0.2193	179.3	48.74	0.513	30.6	0.07881
	Ne	7.900E-6	129.6	5.177	56.34	9.666	0.558	9.61	0.3399
	Ar	3.837E-6	403.6	14.84	54.99	4.884	0.513	9.38	0.5643
	Kr	1.501E-6	1325	32.93	83.10	2.328	0.347	14.2	0.8408
	Xe	8.093E-7	2518	50.28	92.13	1.486	0.279	15.7	0.9618
	Hg	4.236E-7	4420	67.79	112.3	0.9726	0.214	19.2	0.9998
Au	H	9.300E-5	0.7740	0.05583	372.8	195.4	0.653	98.1	0.02026
	D	9.253E-5	1.539	0.1261	152.0	97.80	0.741	40.0	0.04008
	He	4.513E-5	5.966	0.4742	68.88	49.21	0.719	18.1	0.07809
	N	1.169E-5	66.25	4.327	30.89	14.06	0.591	8.13	0.2479
	Ne	7.780E-6	129.6	7.831	28.05	9.759	0.547	7.38	0.3372
	Ar	3.783E-6	404.3	26.05	62.12	4.931	0.583	16.3	0.5607
	Kr	1.482E-6	1329.	76.97	97.73	2.350	0.524	25.7	0.8375
	Xe	8.003E-7	2530.	126.0	105.2	1.500	0.451	27.7	0.9600
	Au	4.259E-7	4360.	221.0	120.7	1.0	0.459	31.8	1.0
	Hg	4.194E-7	4446.	134.6	86.26	0.9820	0.274	22.7	0.9999
Th	Ne	6.688E-6	122.8	3.436	82.55	11.50	0.395	13.9	0.2945
	Ar	3.300E-6	388.6	7.758	53.79	5.809	0.282	9.07	0.5012
	Kr	1.325E-6	1309.	20.21	78.22	2.769	0.218	13.2	0.7797
	Xe	7.292E-7	2540.	28.84	83.14	1.767	0.160	14.0	0.9231
U	Ne	6.517E-6	121.9	5.008	70.40	11.79	0.530	13.0	0.2882
	Ar	3.223E-6	386.5	11.79	63.84	5.958	0.394	11.8	0.4922
	Kr	1.299E-6	1307.	27.14	75.83	2.840	0.268	14.0	0.7703
	Xe	7.169E-7	2543.	27.44	122.3	1.813	0.139	22.6	0.9165
	Hg	3.844E-7	4572.	35.55	69.28	1.187	0.100	12.8	0.9927

Figure 1. Energy dependence of the sputtering yields of Ni targets for H (×), He (□), Ni (o), Ar (Δ) and Xe (▽) ions. The yield and energy are normalized by $P \cdot s_n$ and E_{th}, respectively. The values of P and E_{th} are given in Table II. The dashed line is the best fit curve.

Figure 2. Energy dependence of the self sputtering yields for Al (Δ), Cu (□), Nb (▽), Ag (x) and Au (o). The yield and energy are normalized by $P \cdot s_n$ and E_{th}, respectively. The dashed line is the best fit curve.

Figure 3. The α-parameter as a function of the mass ratio M_2/M_1, where M_2 and M_1 are the masses of target atoms and incident ions, respectively. The solid line is drawn by smoothing the averaged values. Multiplying the averaged values by 1.3 and 0.7, broken lines are drawn. The dot-dashed line is the Sigmund curve for α.

Figure 4. The $\xi = E_{th}/U_s$ parameter as a function of the mass ratio M_2/M_1, where M_2 and M_1 are the masses of target atoms and incident ions, respectively. The solid line is drawn by smoothing the averaged values. Multiplying the averaged values by 1.3 and 0.7, broken lines are drawn.

Figure 5-208. Sputtering yield vs energy. A,B,C,··· indicate the experimental values. The solid line is the curve best fit to the experimental data. The dashed line shows the result calculated by the empirical formula (Eq. (1)) with the average values of the parameter ξ and α , which are indicated by the solid curve in Figs. 3 and 4.

The graphs are arranged first in order of increasing atomic number of the target (Z_2) and, under each Z_2, in order of increasing atomic number of the projectile(Z_1).

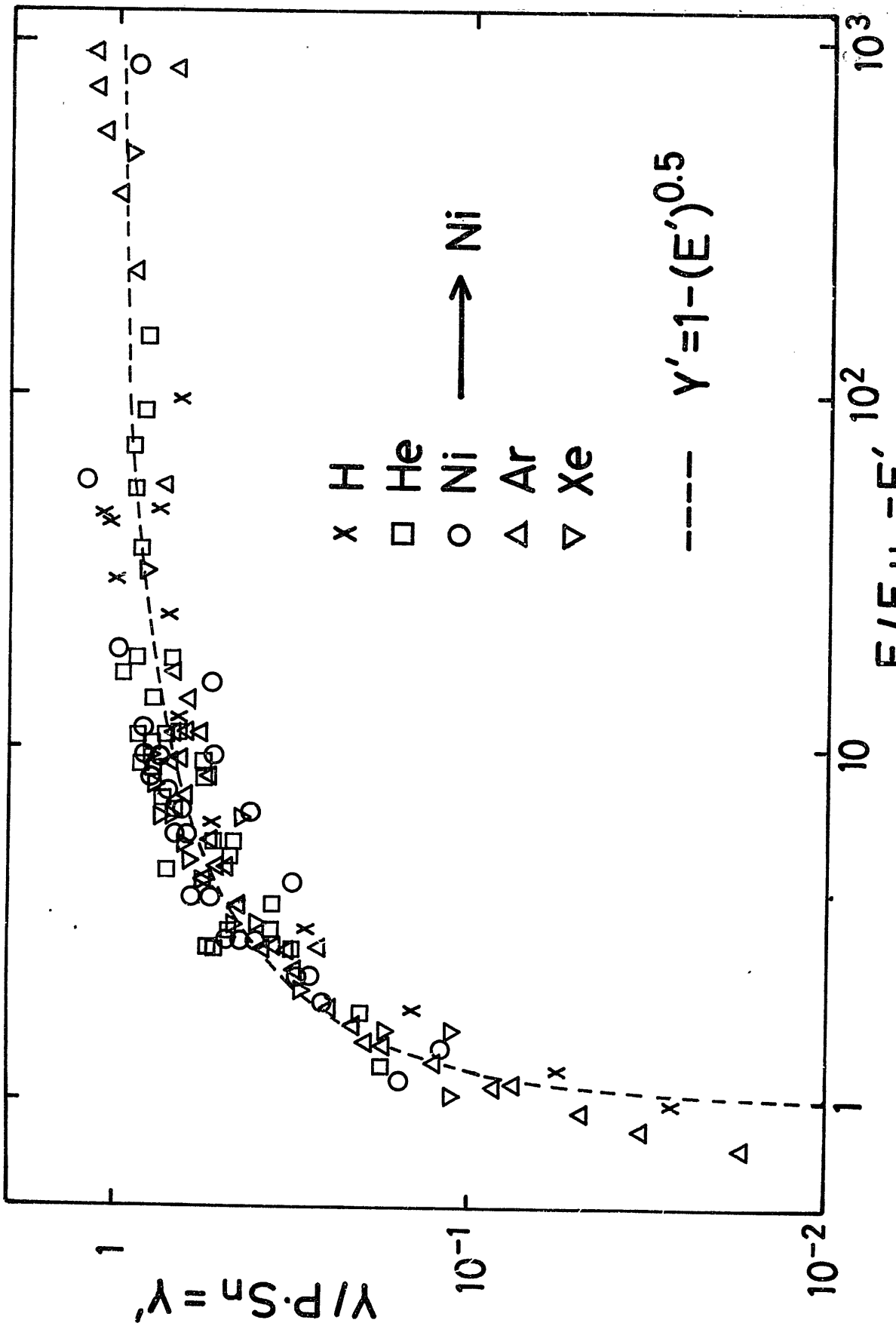


Fig. 1

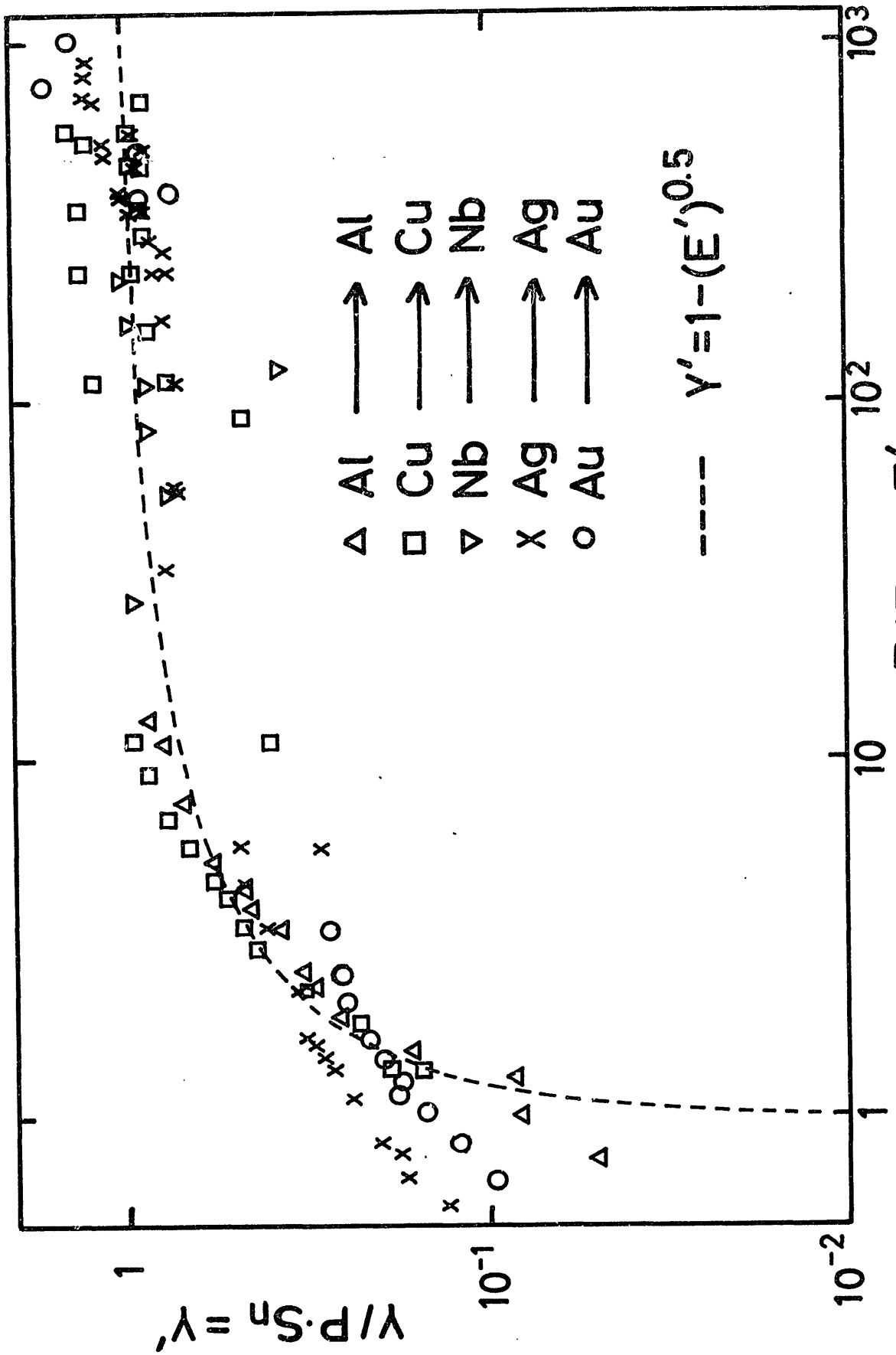


Fig. 2

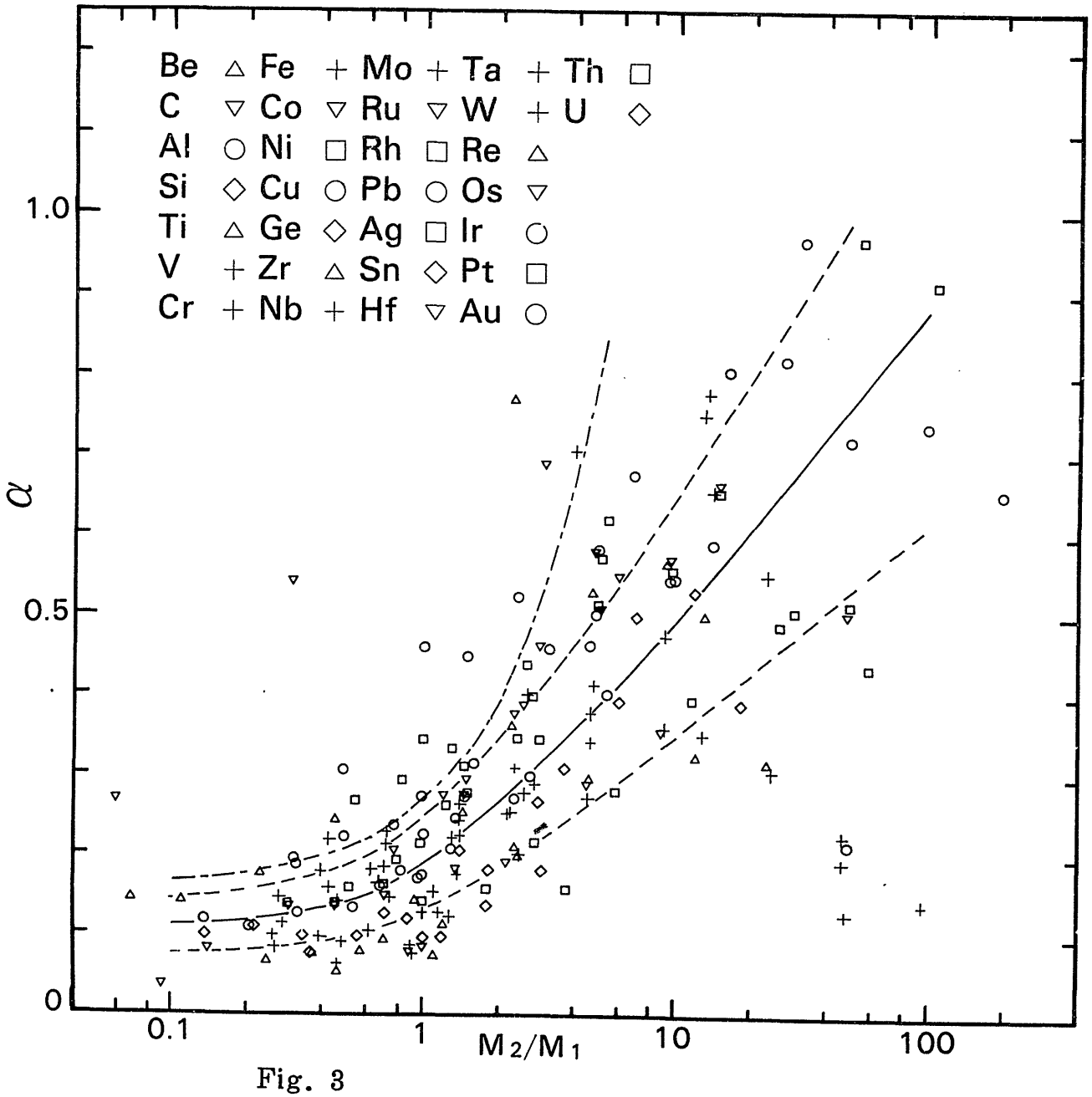

Be △ Fe + Mo + Ta + Th □
C ▽ Co ▽ Ru ▽ W + U ◇
Al ○ Ni □ Rh □ Re △
Si ◇ Cu ○ Pb ○ Os ▽
Ti △ Ge ◇ Ag □ Ir ○
V + Zr △ Sn ◇ Pt □
Cr + Nb + Hf ▽ Au ○
α
1.0
0.5
0
0.1
1
10
100
M2/M1

Fig. 3

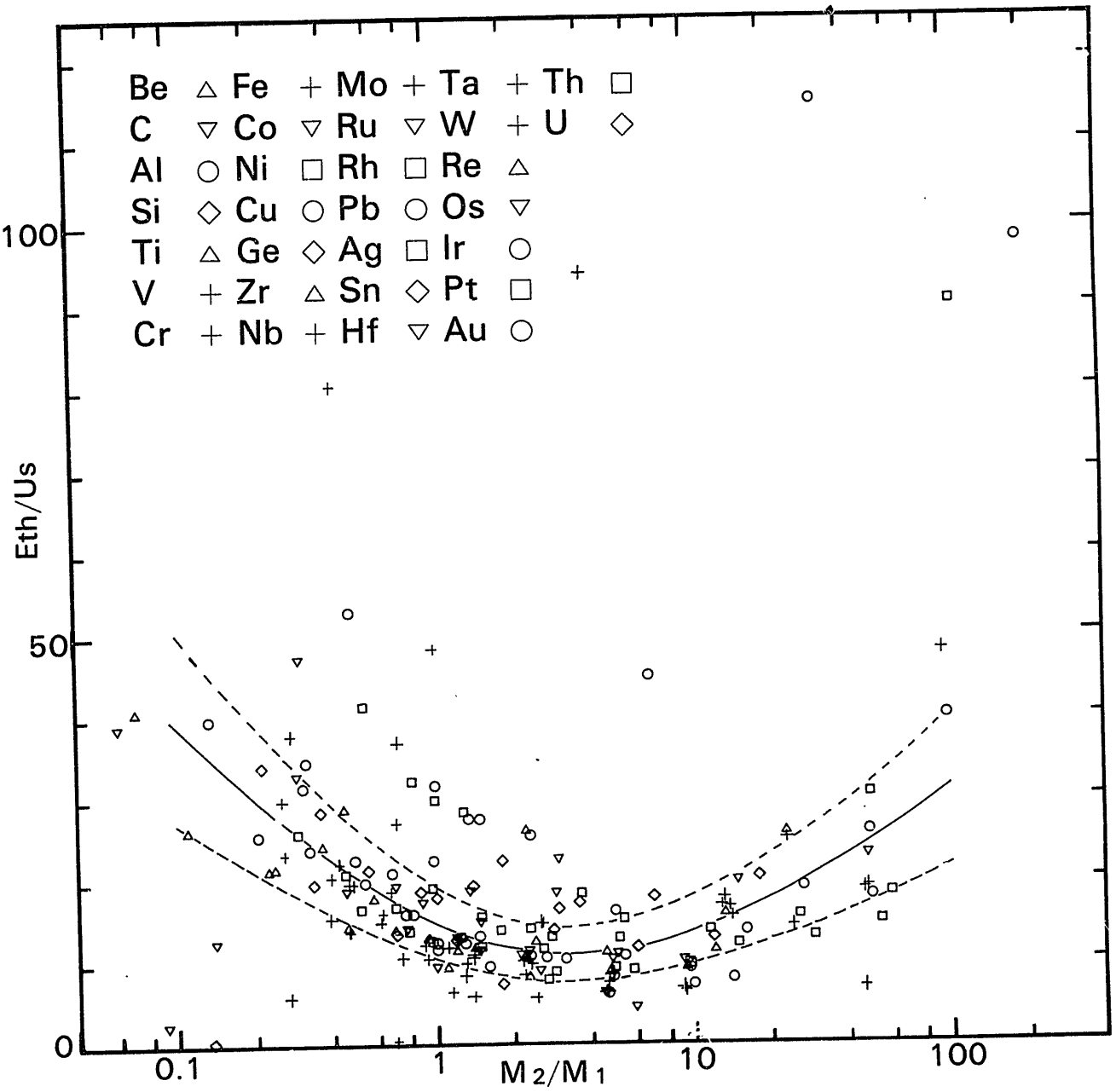
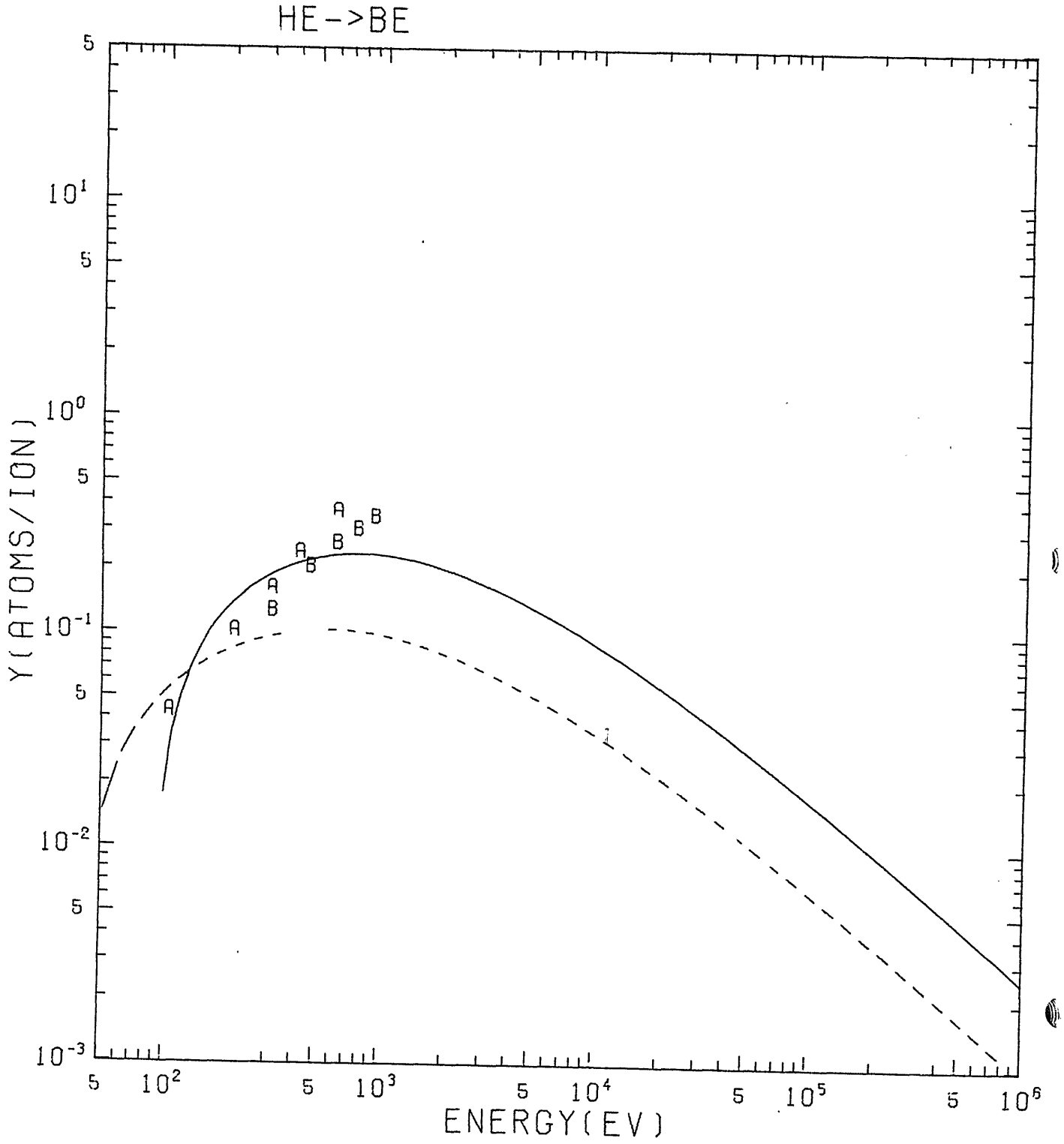
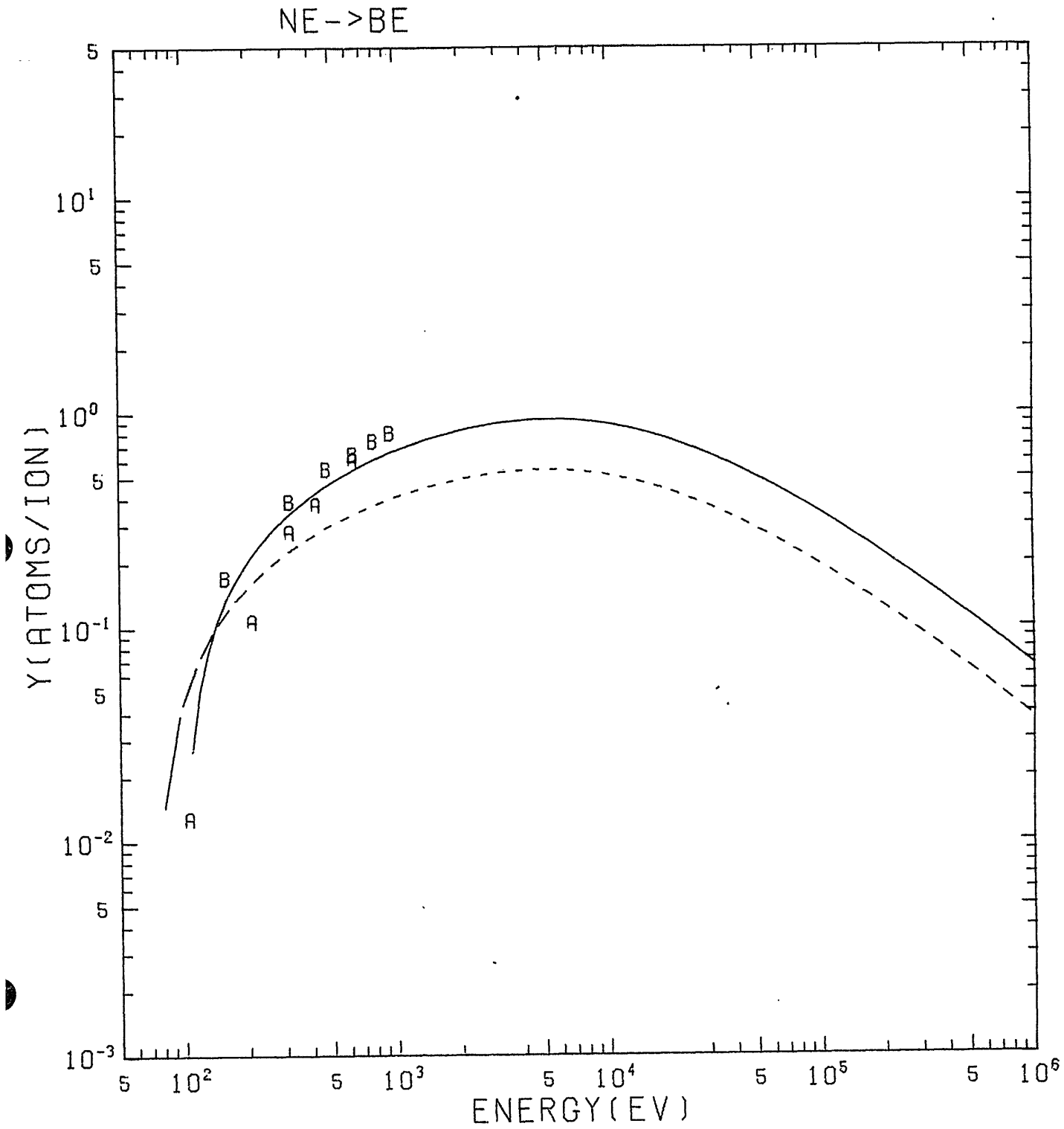

Be △ Fe + Mo + Ta + Th □
C ▽ Co ▽ Ru ▽ W + U ◇
Al ○ Ni □ Rh □ Re △
Si ◇ Cu ○ Pb ○ Os ▽
Ti △ Ge ◇ Ag □ Ir ○
V + Zr △ Sn ◇ Pt □
Cr + Nb + Hf ▽ Au ○
100
50
0
Eth/Us
0.1
1
10
100
M2/M1

Fig. 4



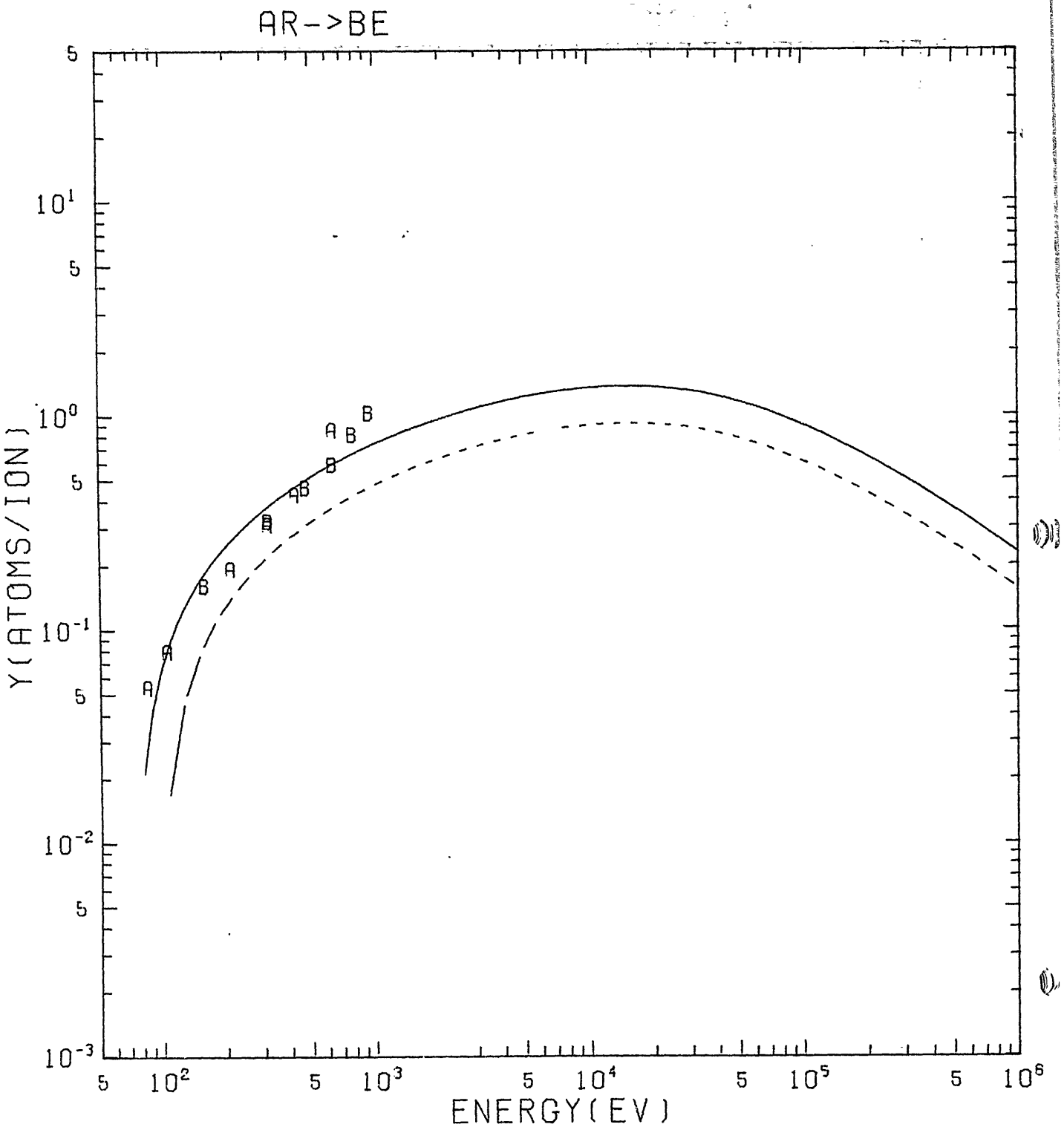
HE->BE
A ROSENBERG.WEHNER (1962)
B FETZ.OECHSNER (1963)

Fig.5



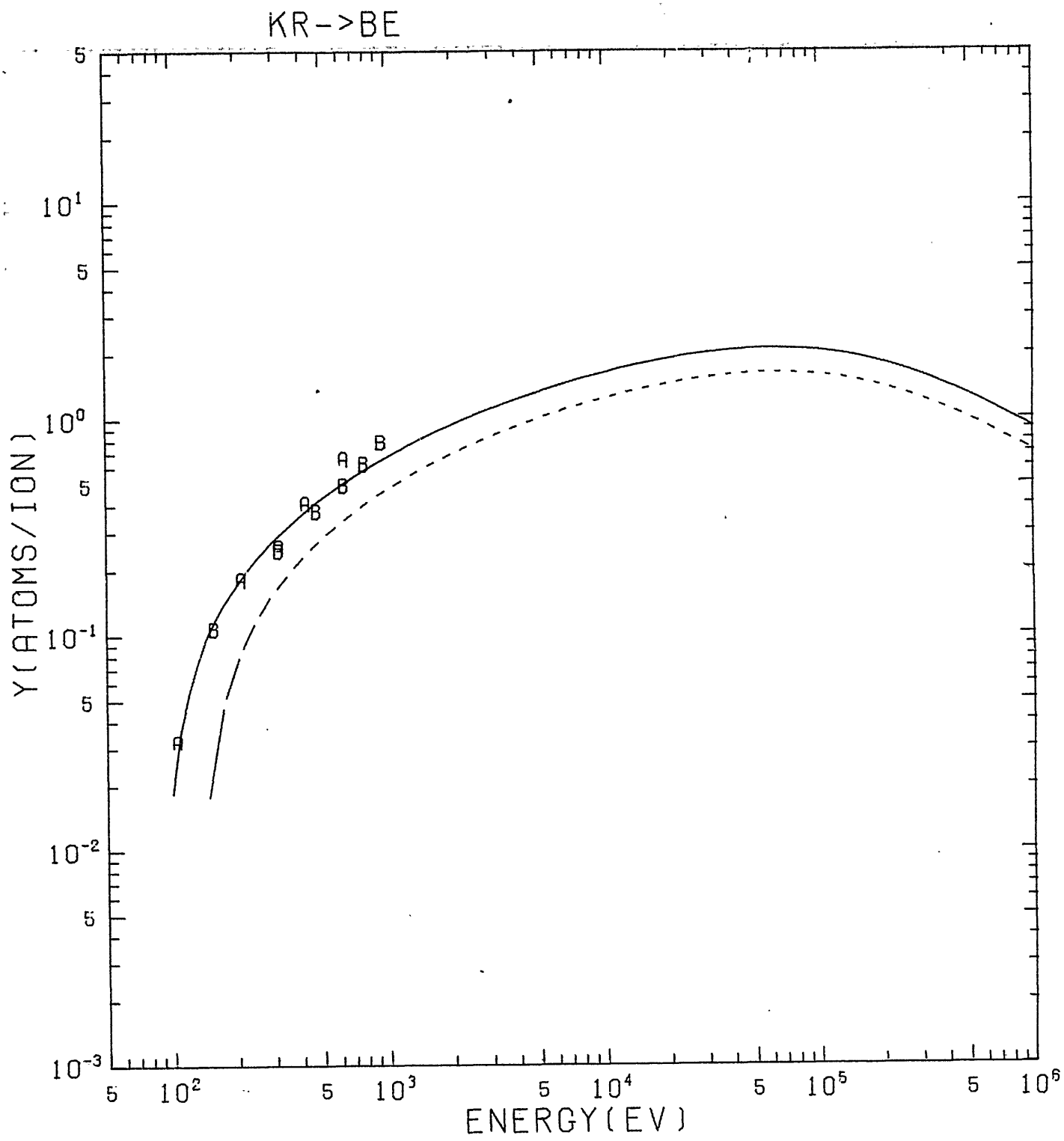
NE->BE
A LAEGREID,WEHNER (1961)
B FETZ,OECHSNER (1963)

Fig. 6



AR->BE
A LAEGREID,WEHNER (1961)
B FETZ,OECHSNER (1963)

Fig. 7



KR->BE
A ROSENBERG,WEHNER (1962)
B FETZ,OECHSNER (1963)

Fig. 8

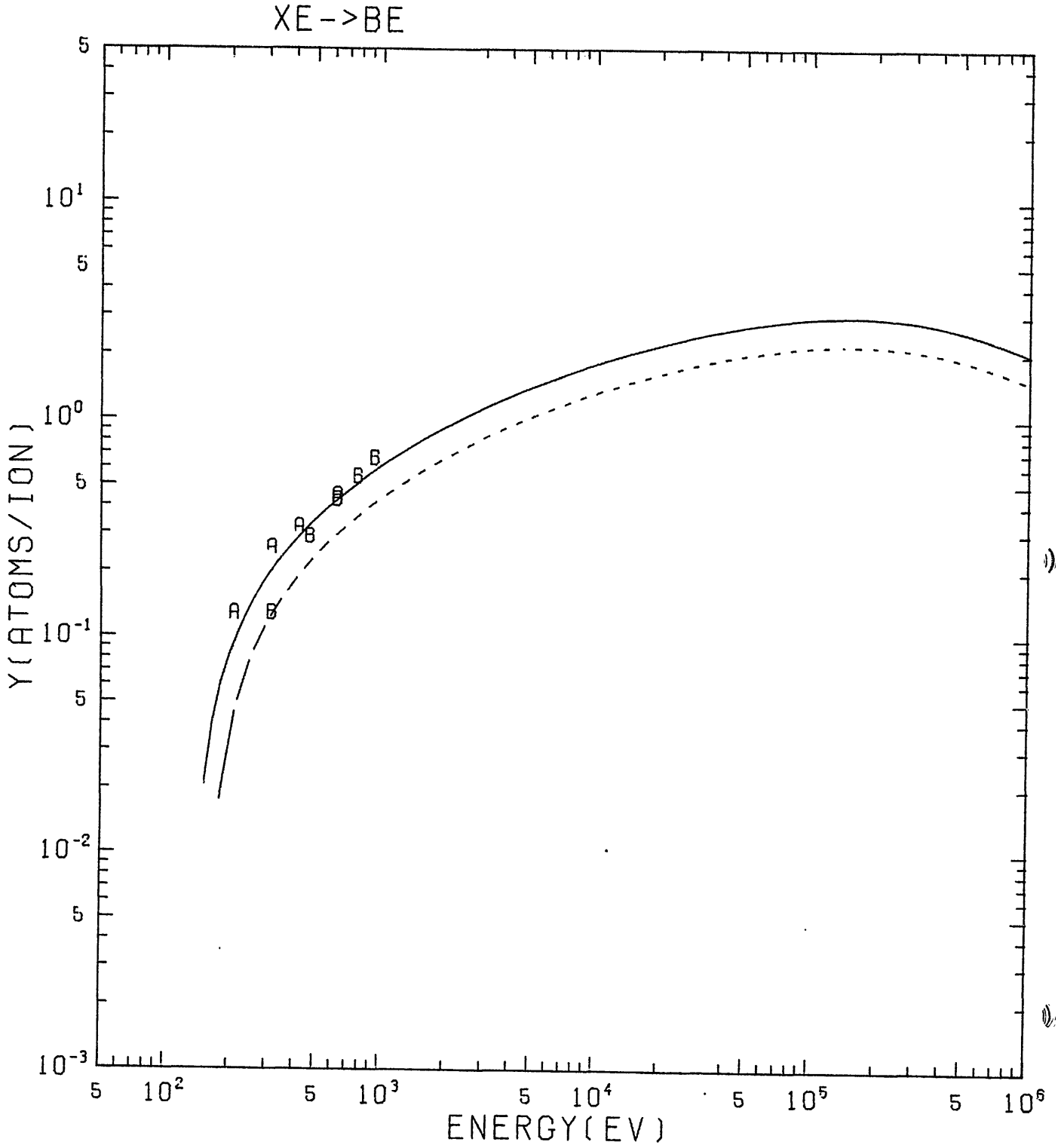
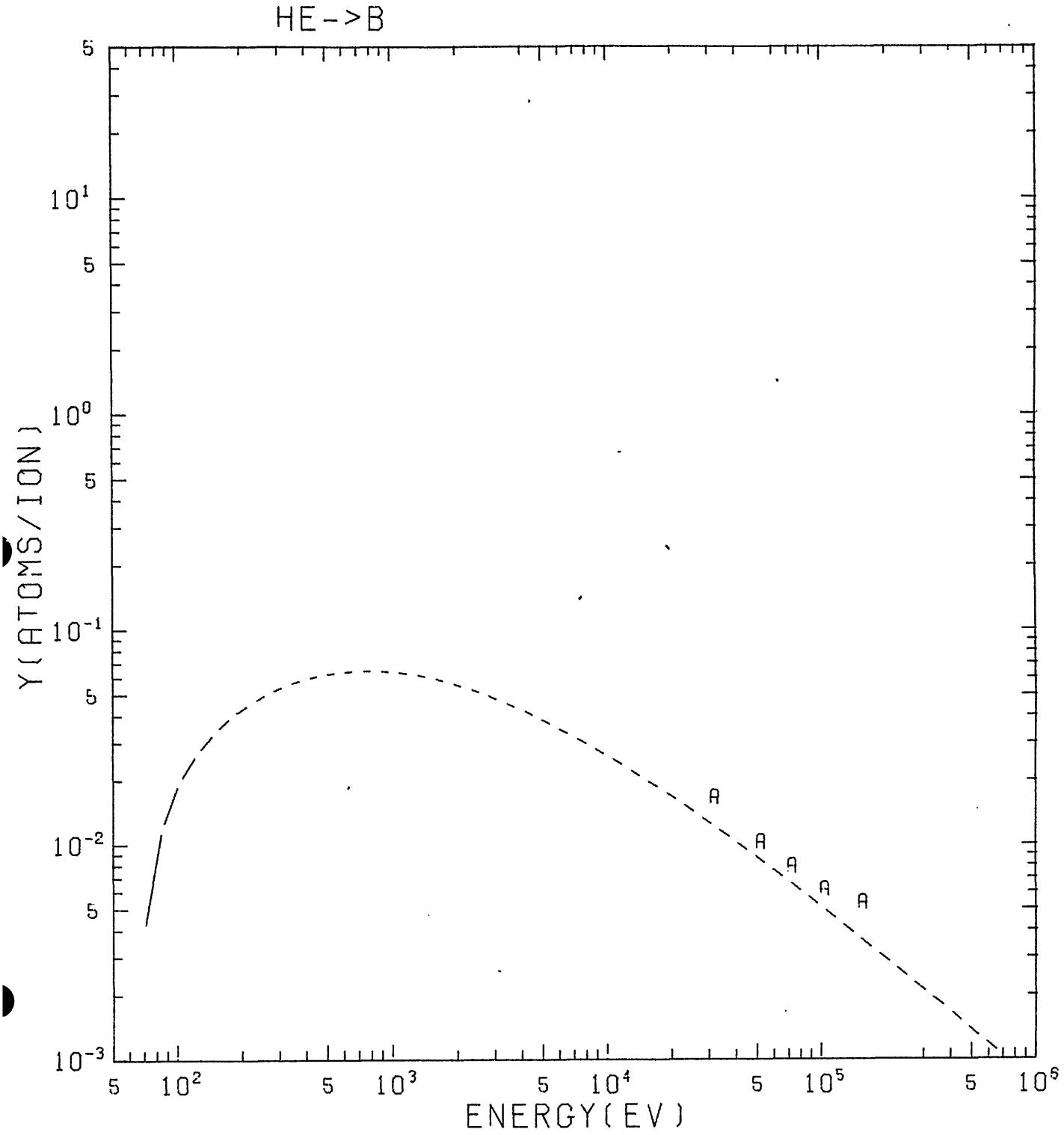
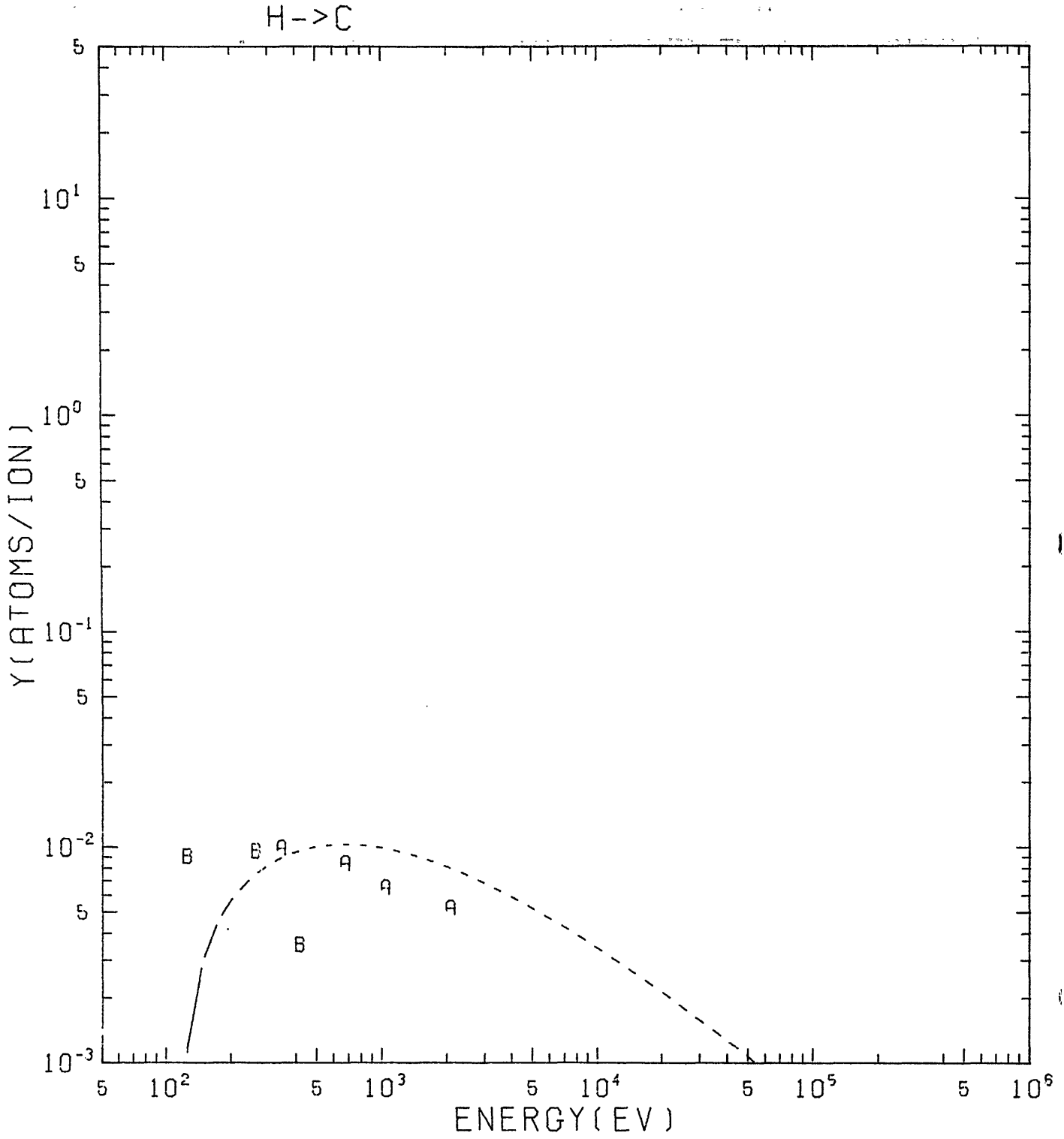

XE->BE
Y(ATOMS/ION)
ENERGY(EV)
5
10¹
10⁰
10⁻¹
10⁻²
10⁻³
5 10² 5 10³ 5 10⁴ 5 10⁵ 5 10⁶
A
B
XE->BE
A ROSENBERG,WEHNER (1962)
B ETZ,OECHSNER (1963)

Fig. 9



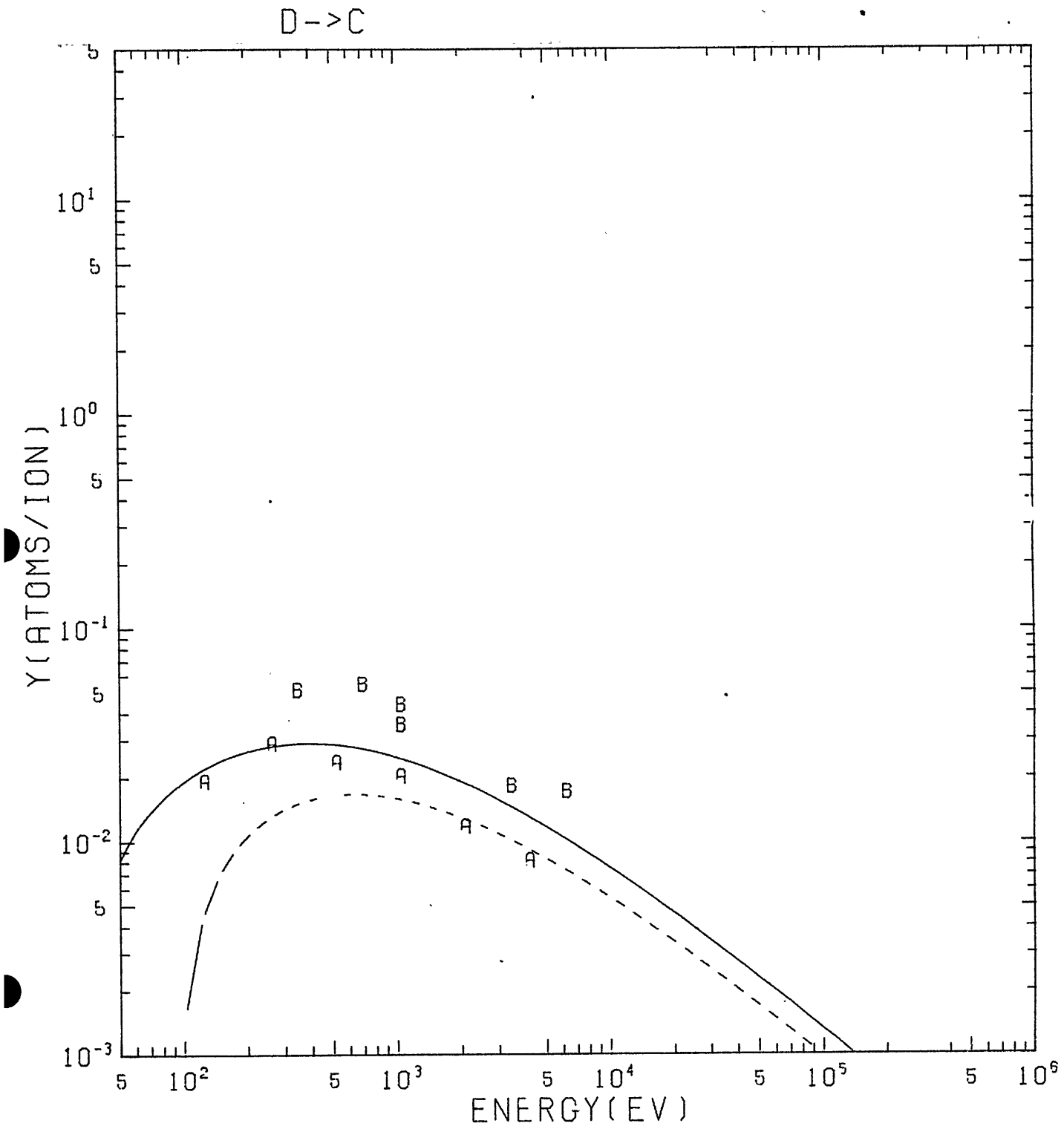
HE->B
A MIYAGAWA,ATO,MORIYA (1978)

Fig. 10



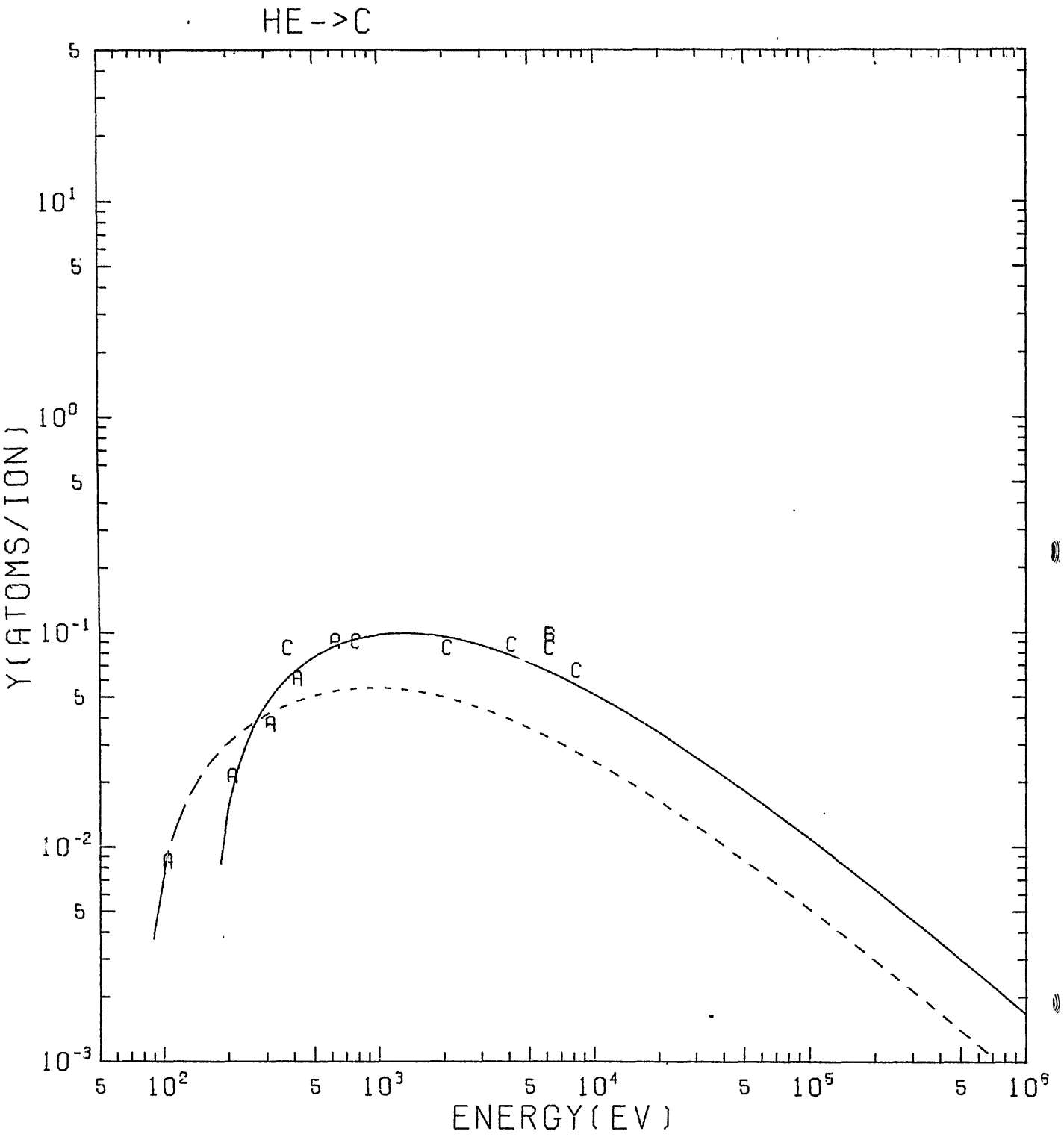
H->C
A BOHDANSKY.ROTH.SINHA (1976)
B BOHDANSKY.BAY.OTTENBERGER (1978)

Fig. 11



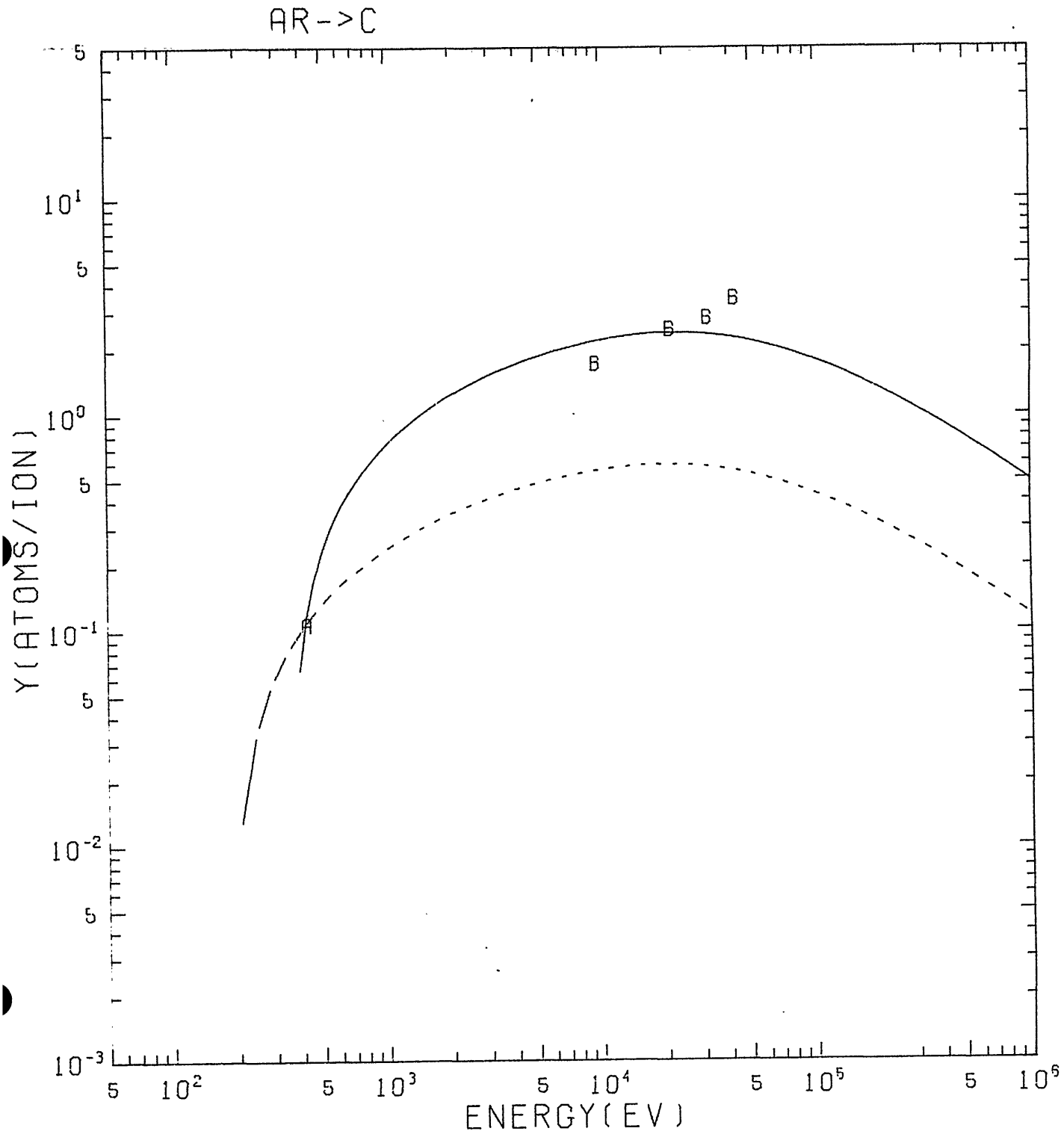
D->C
A BOHDANSKY.BAY.OTTENBERGER (1978)
B BORDERS.LANGLEY.WILSON (1978)

Fig. 12



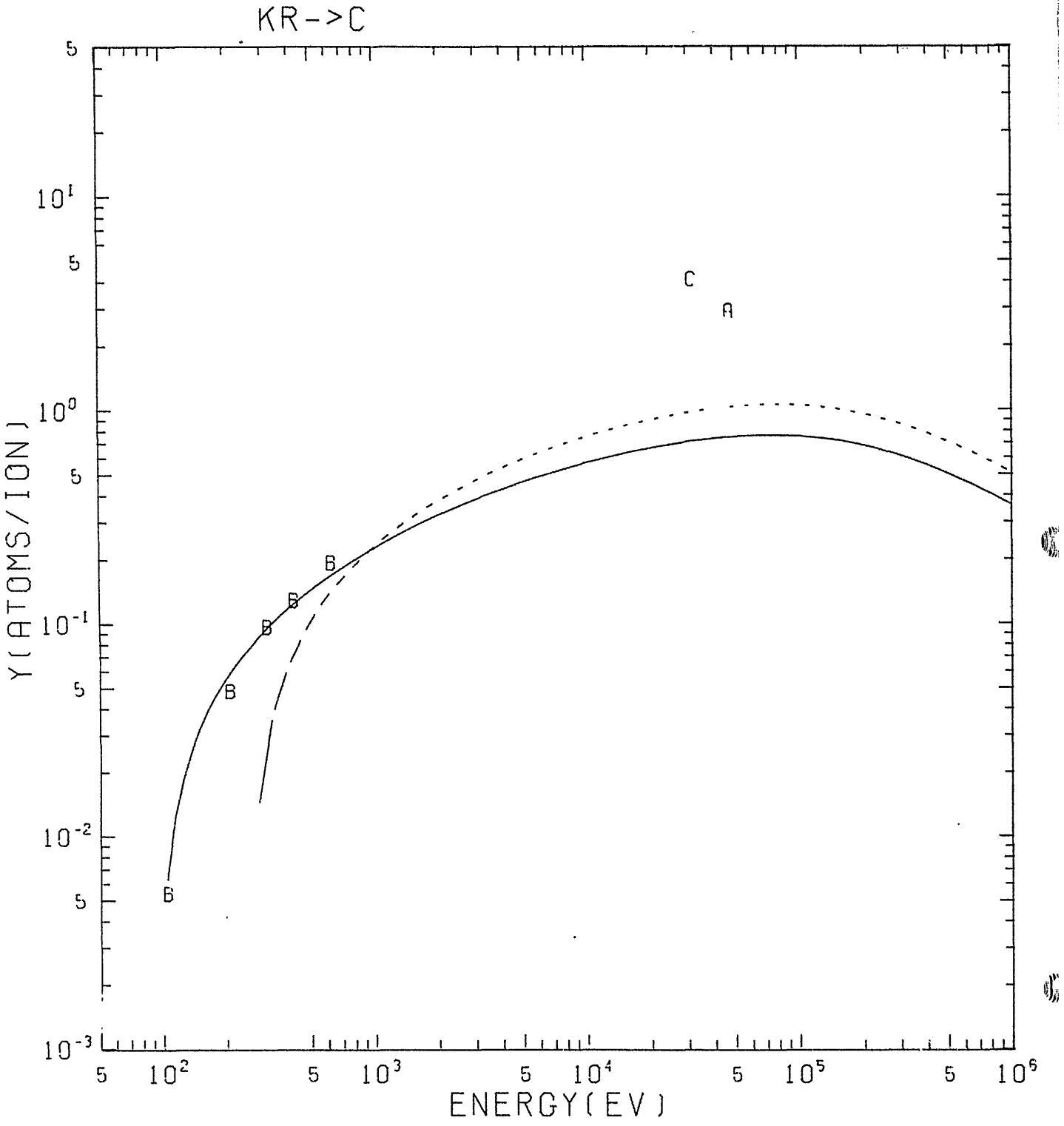
HE->C
A ROSENBERG,WEHNER (1962)
B ROTH,BOHDANSKY (1976)
C BOHDANSKY,BAY,OTTENBERGER (1978)

Fig. 13



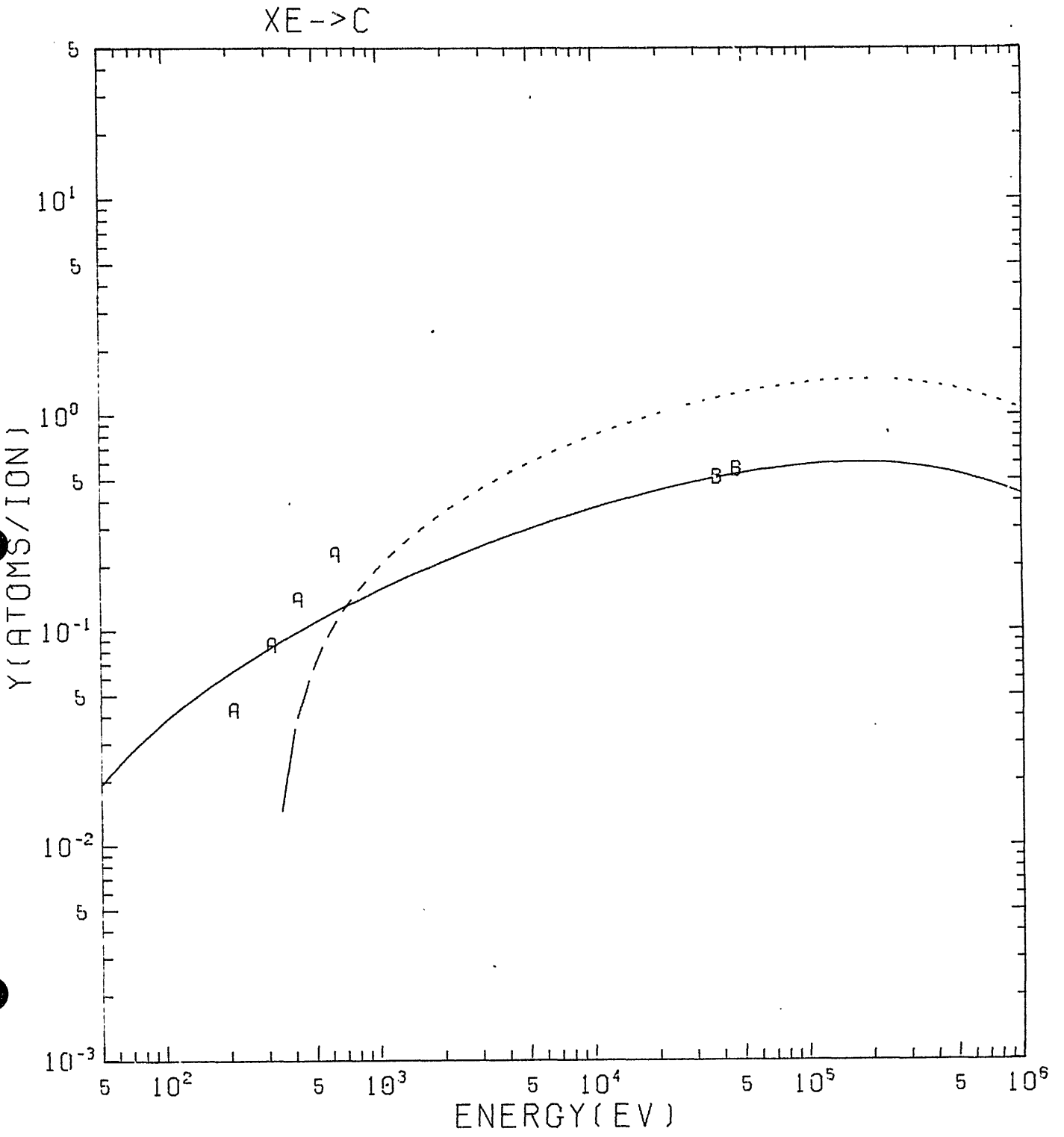
AR->C
A LAEGREID,WEHNER (1961)
B BETZ,DOBROZEMSKY,VISHBCCK (1969)

Fig. 14



KR->C
A ALMEN.BRUCE (1961A)
B ROSENBURG.WEHNER (1962)
C BETZ.DOBROZEMSKY.VISHBCCK (1969)

Fig. 15



XE->C
A ROSENBERG,WEHNER (1962)
B BETZ,DOBROZEMSKY,VISHBCCK (1969)

Fig. 16

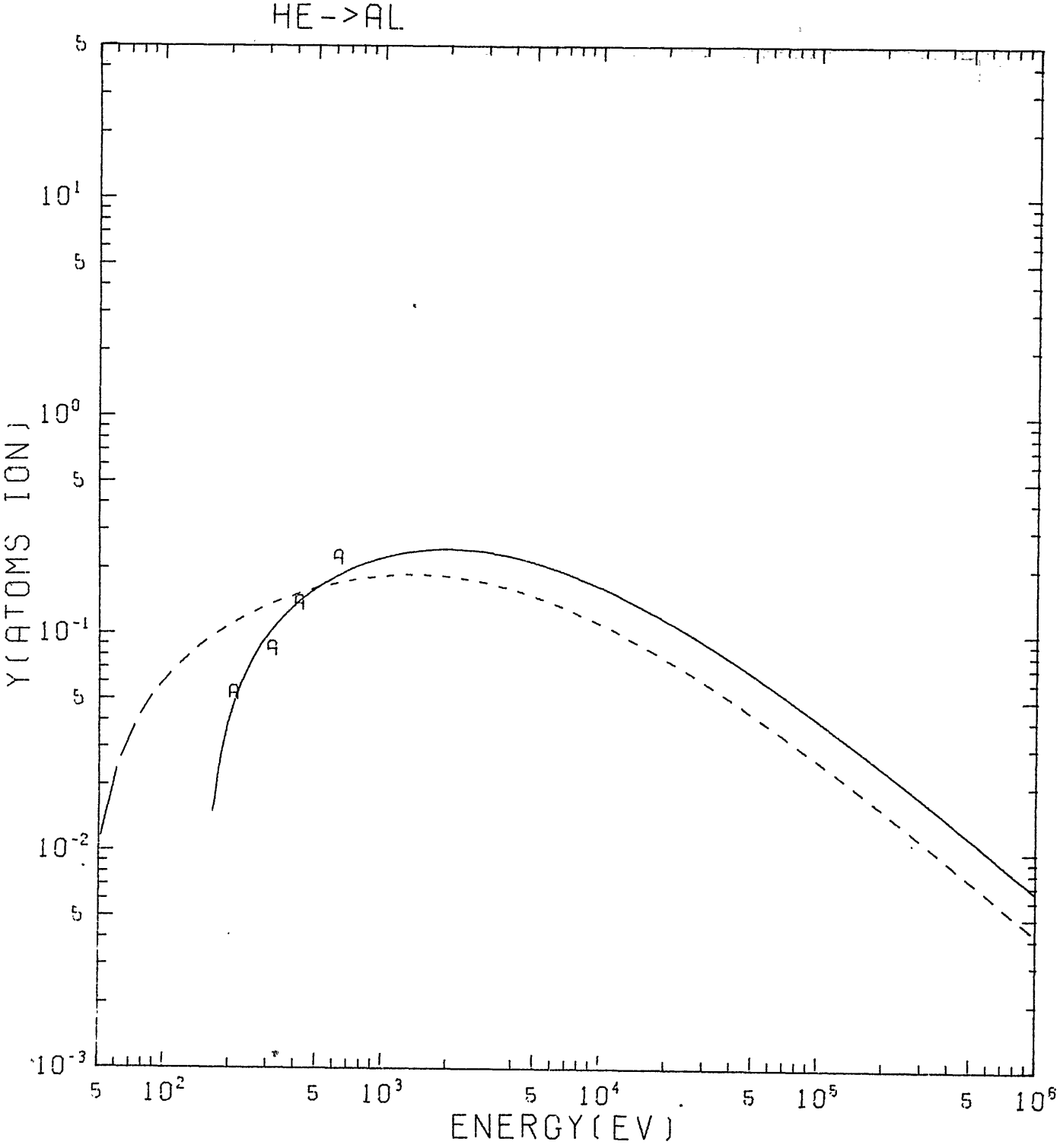
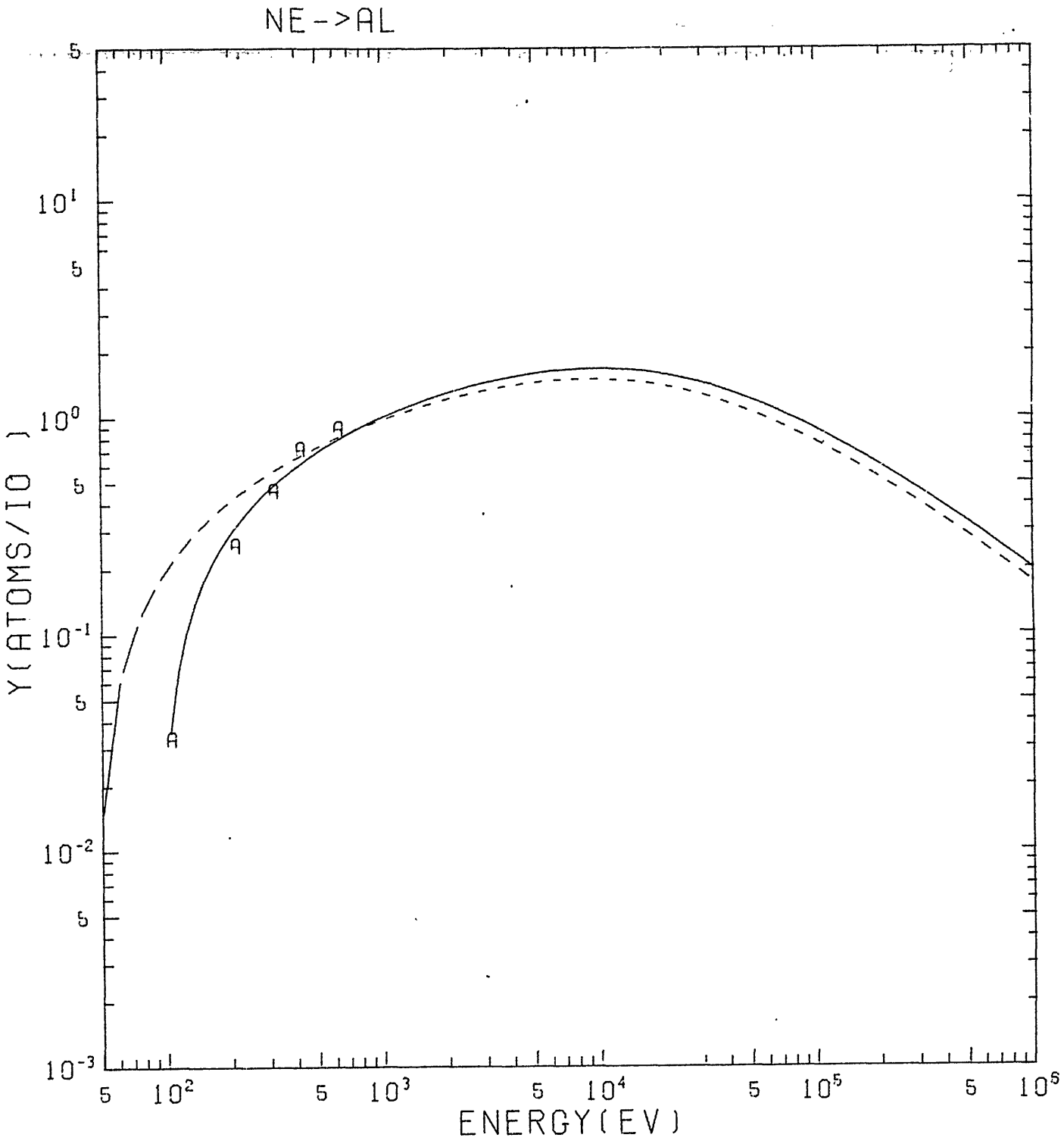
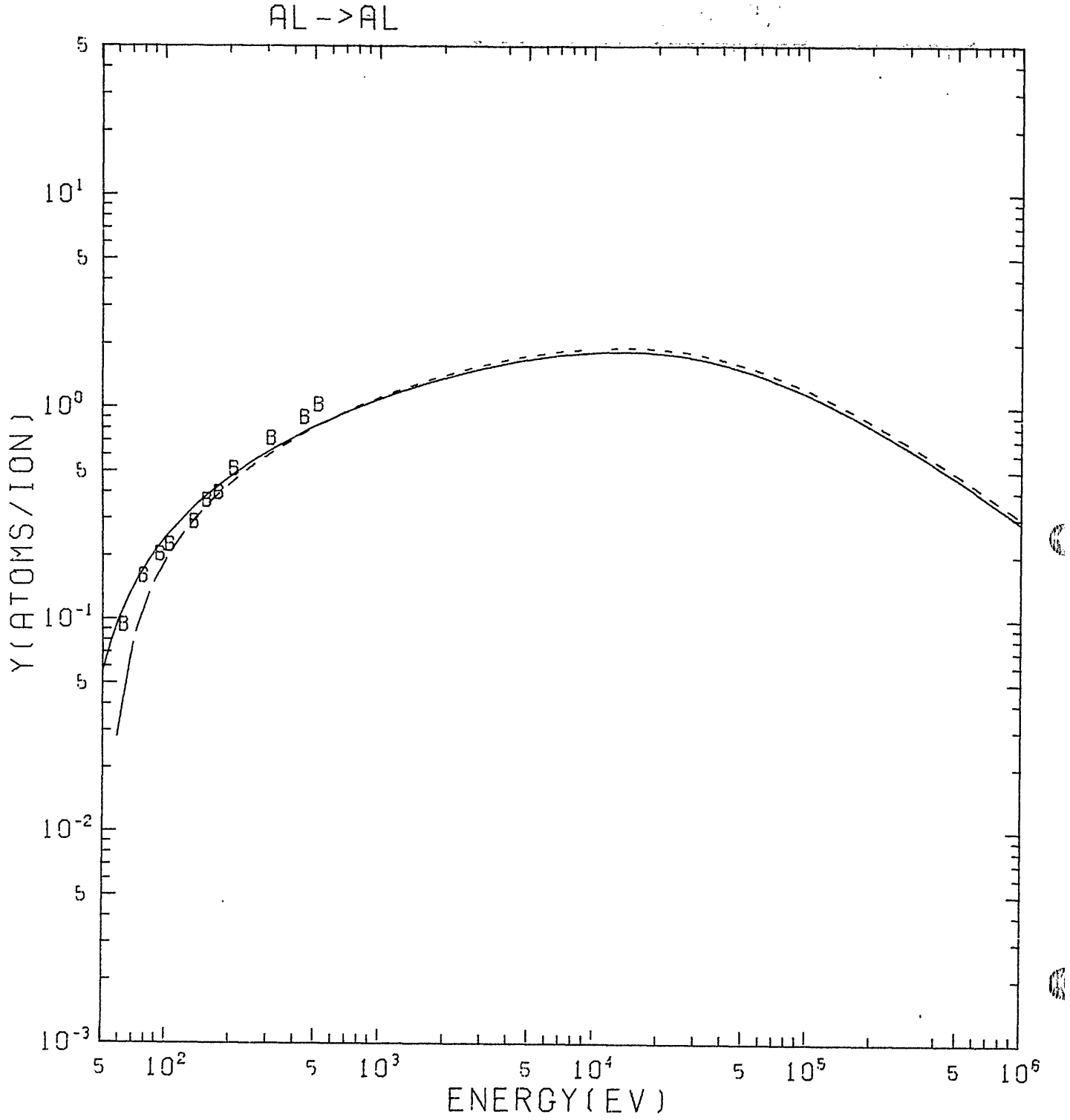


Fig. 17



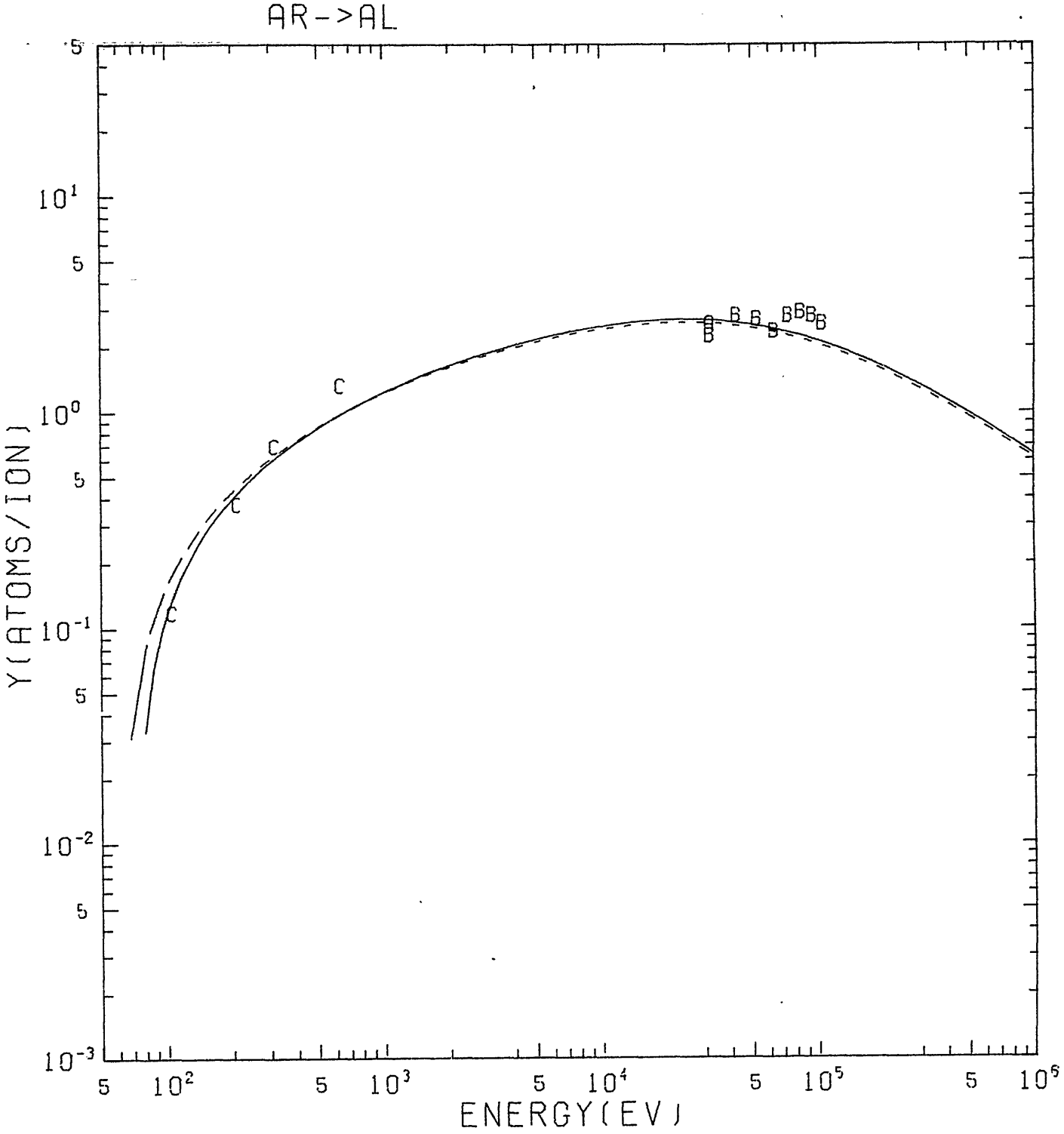
NE->AL
A LAEGREID,WEHNER (1961)

Fig. 18



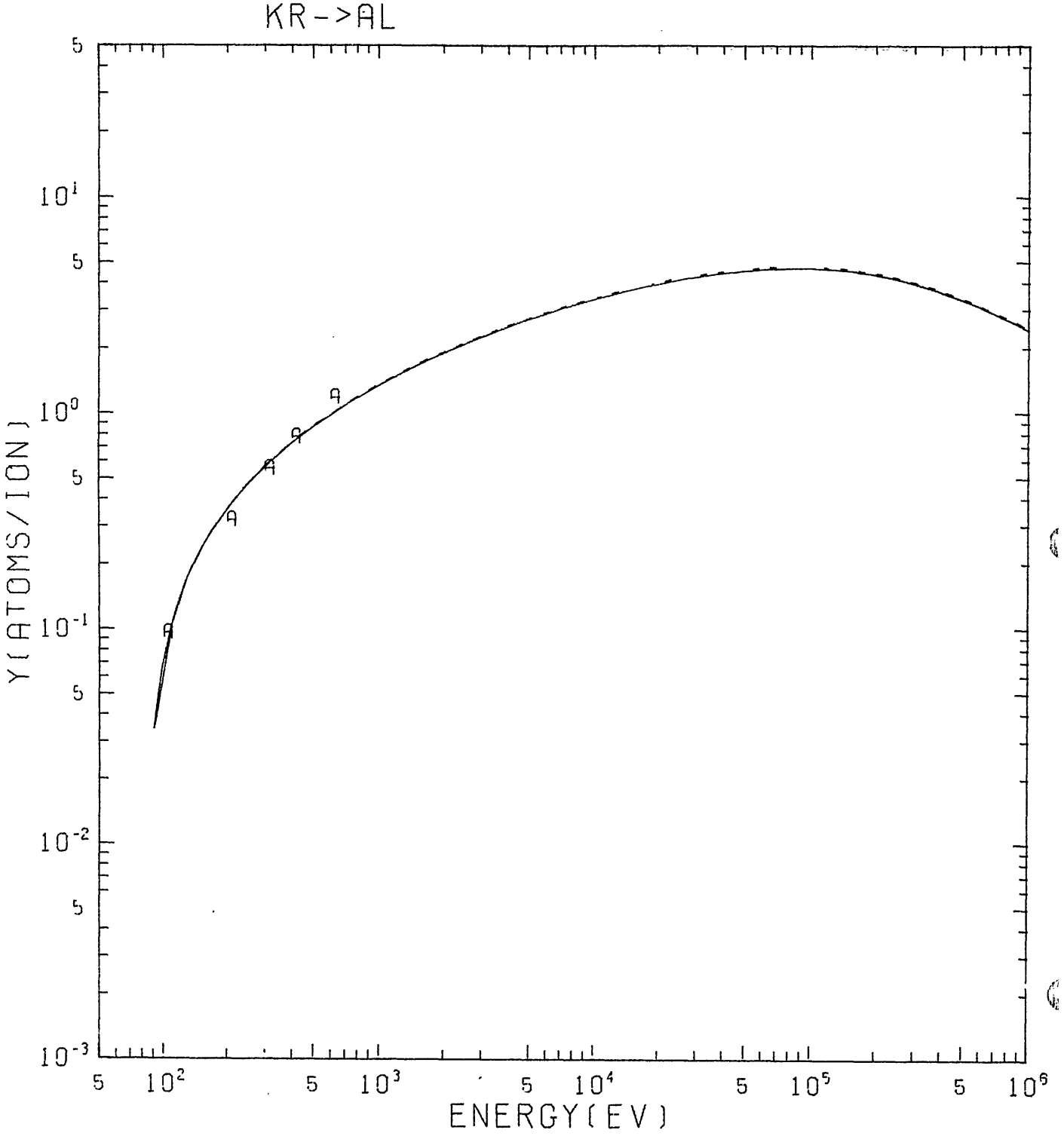
AL->AL
A ALMEN.BRUCE (1961B)
B HAYWARD.WOLTER (1969)

Fig. 19



AR->AL
A YONTS,NORMAND,HARRISON (1960)
B ERT,COLOMBIE,FAGOT (1961)
C LAEGREID,WEHNER (1961)

Fig. 20



KR->AL
A ROSENBERG,WEHNER (1962)

Fig. 21

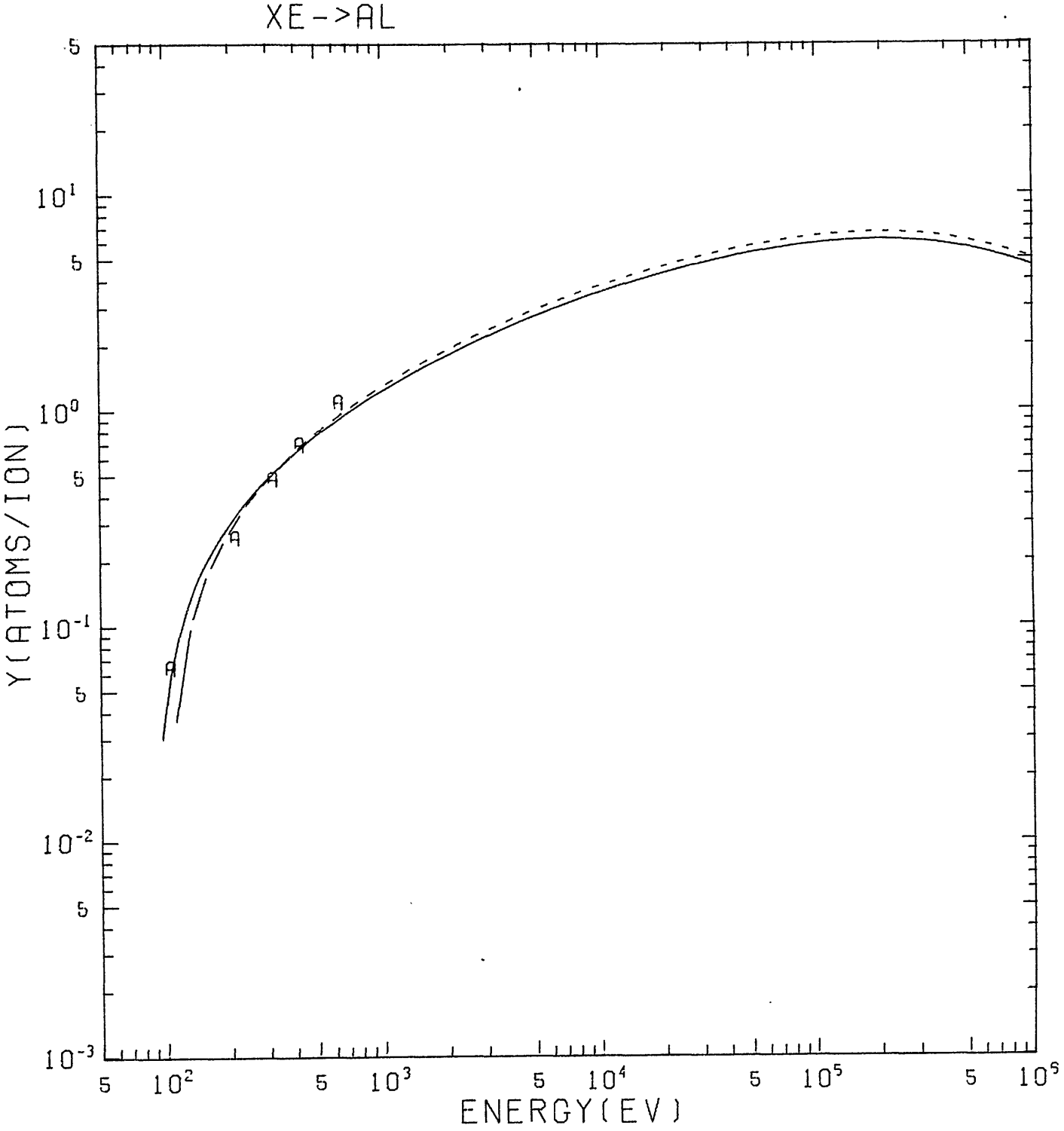
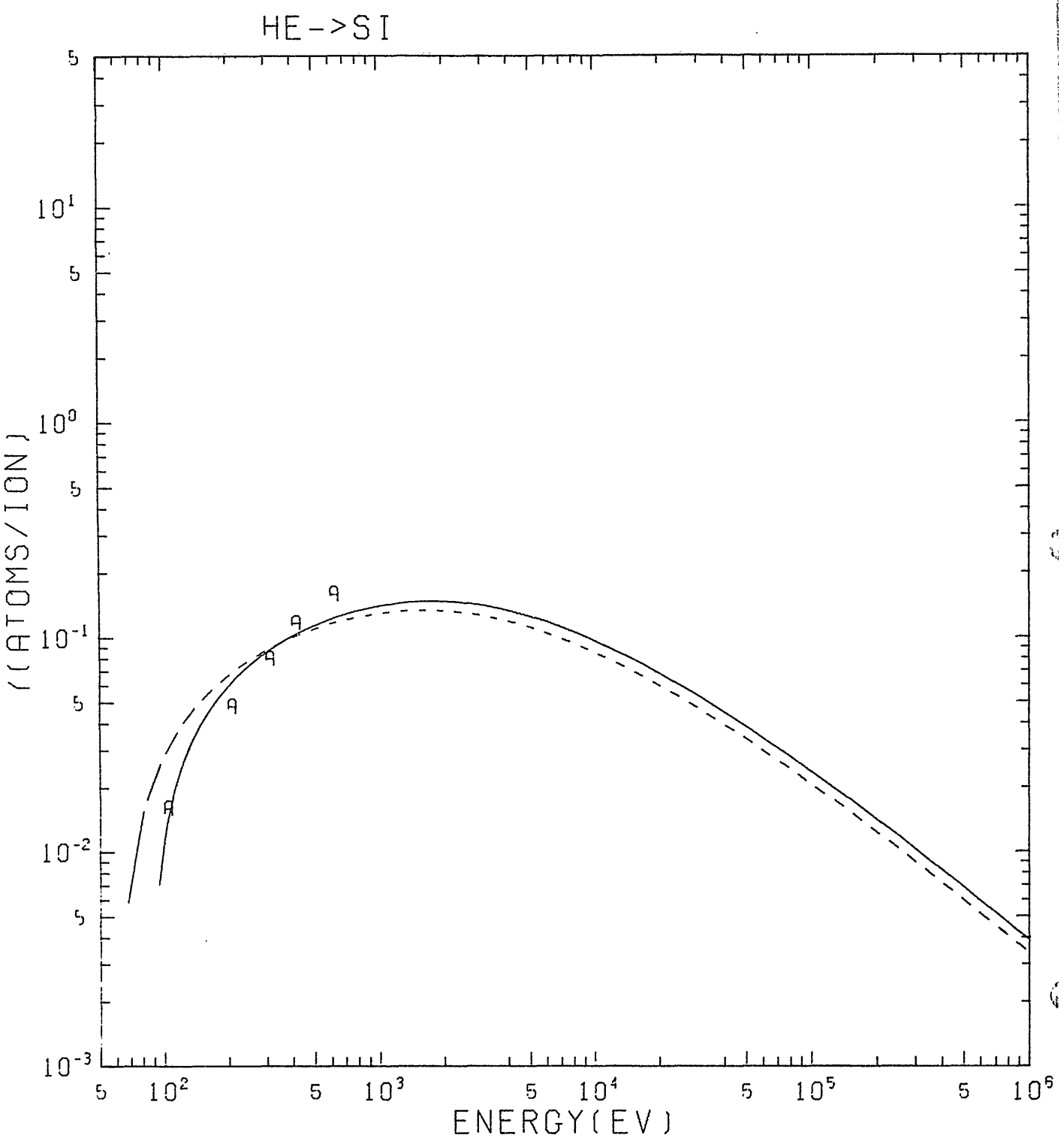
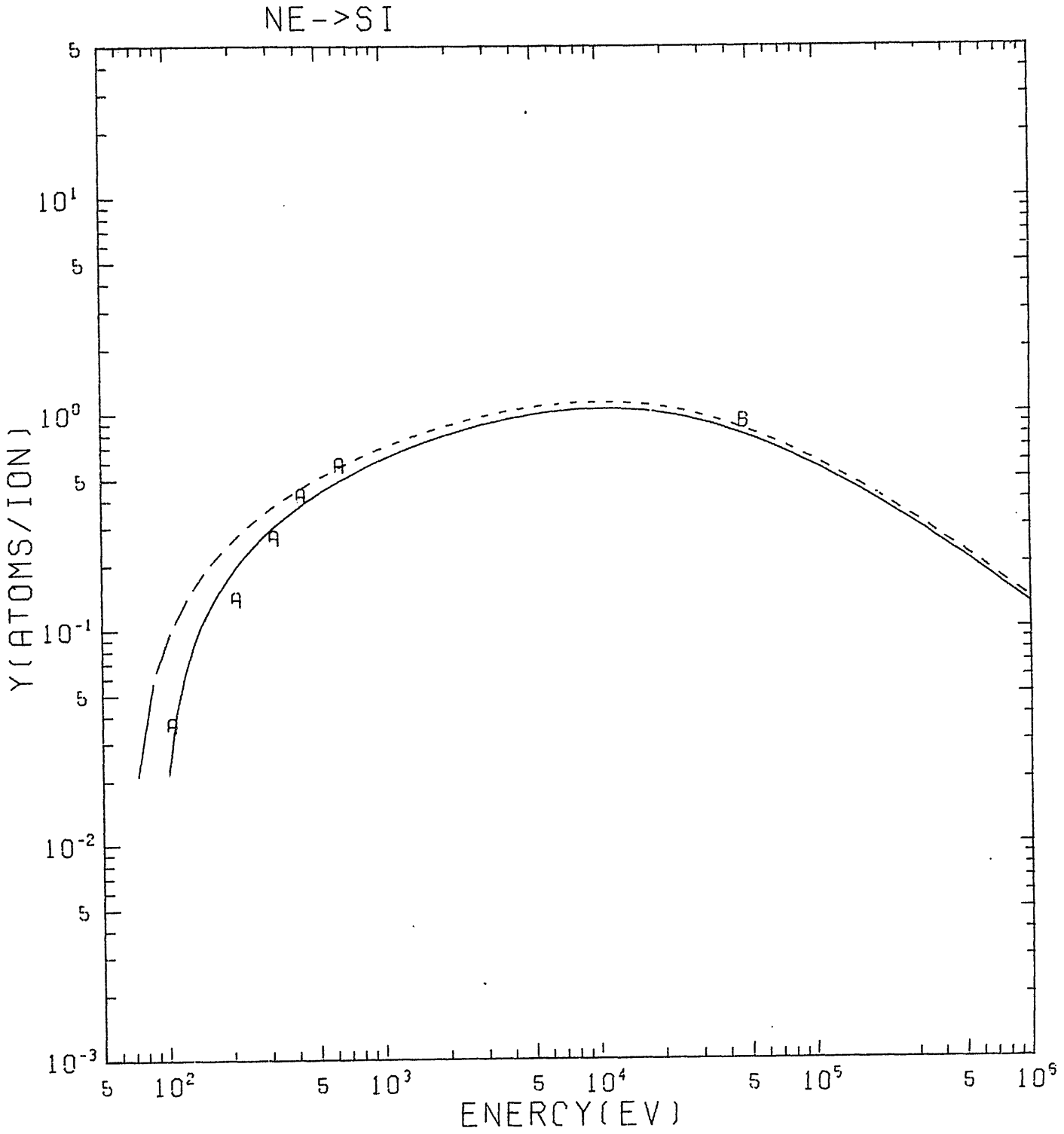


Fig. 22



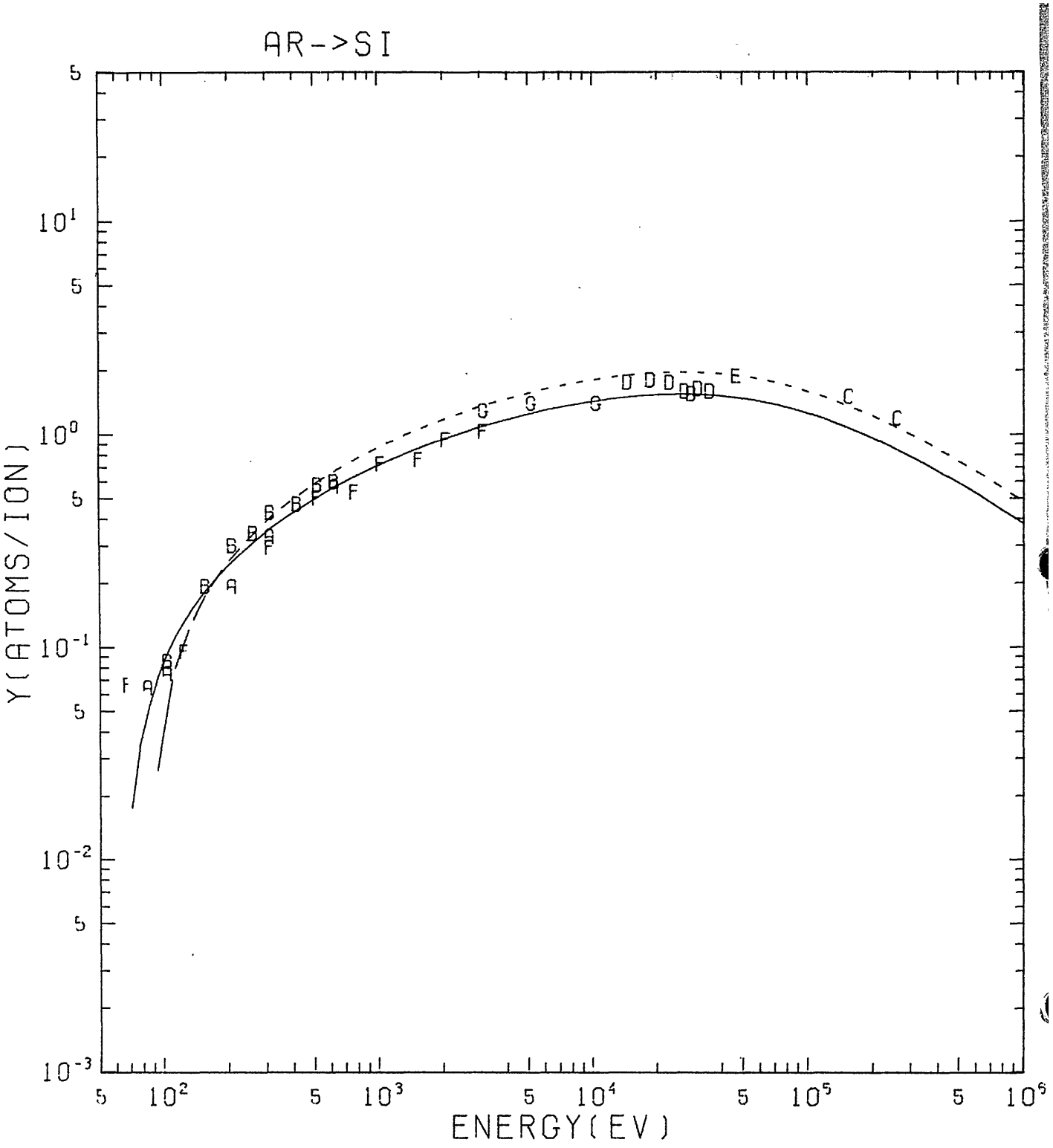
HE->SI
A ROSENBERG,WEHNER (1962)

Fig. 23



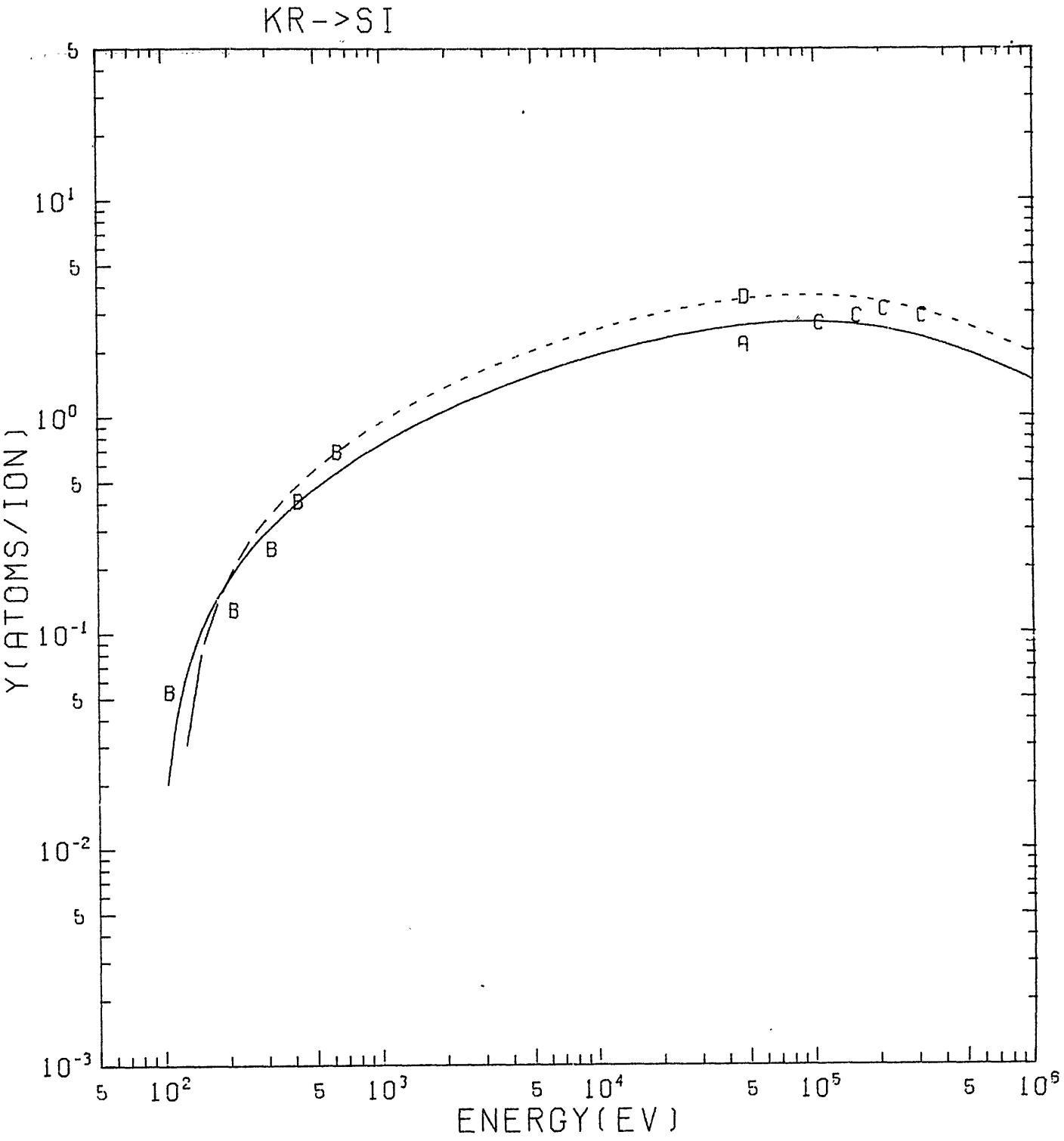
NE->SI
A LAEGREID.WEHNER (1961)
B ANDERSEN.BAY (1975)

Fig. 24



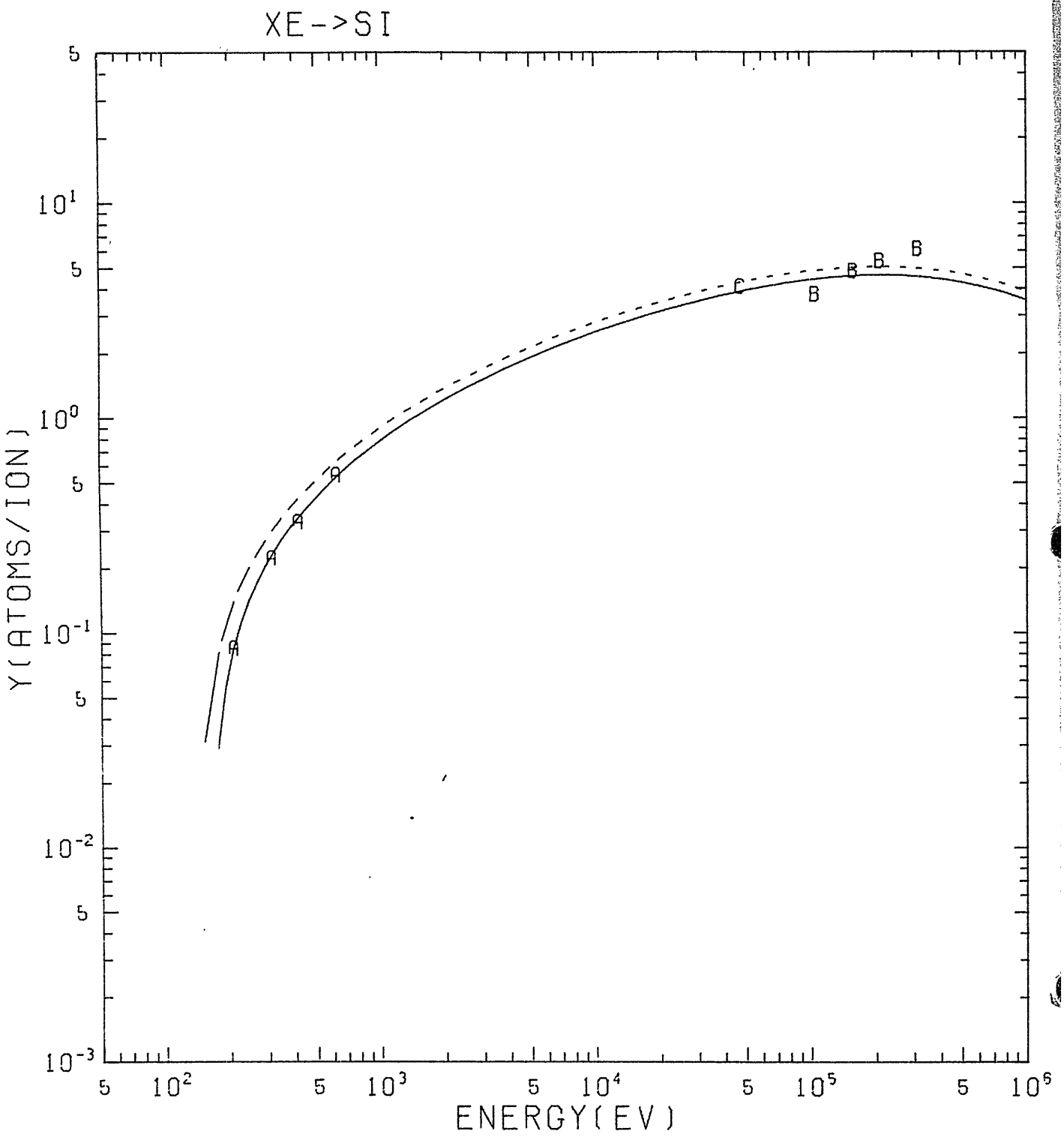
AR->SI
A ' AEGREID.WEHNER (1961)
B WEHNER.STUART.ROSENBERG (1961)
C EERNISSE (1971)
D SOMLERFIDT (1972)
E ANDERSEN.BAY (1975)
F COBURN.WINTERS.CHUANG (1977)
G KANG.OKUTANI.SHIMIZU (1979)

Fig. 25



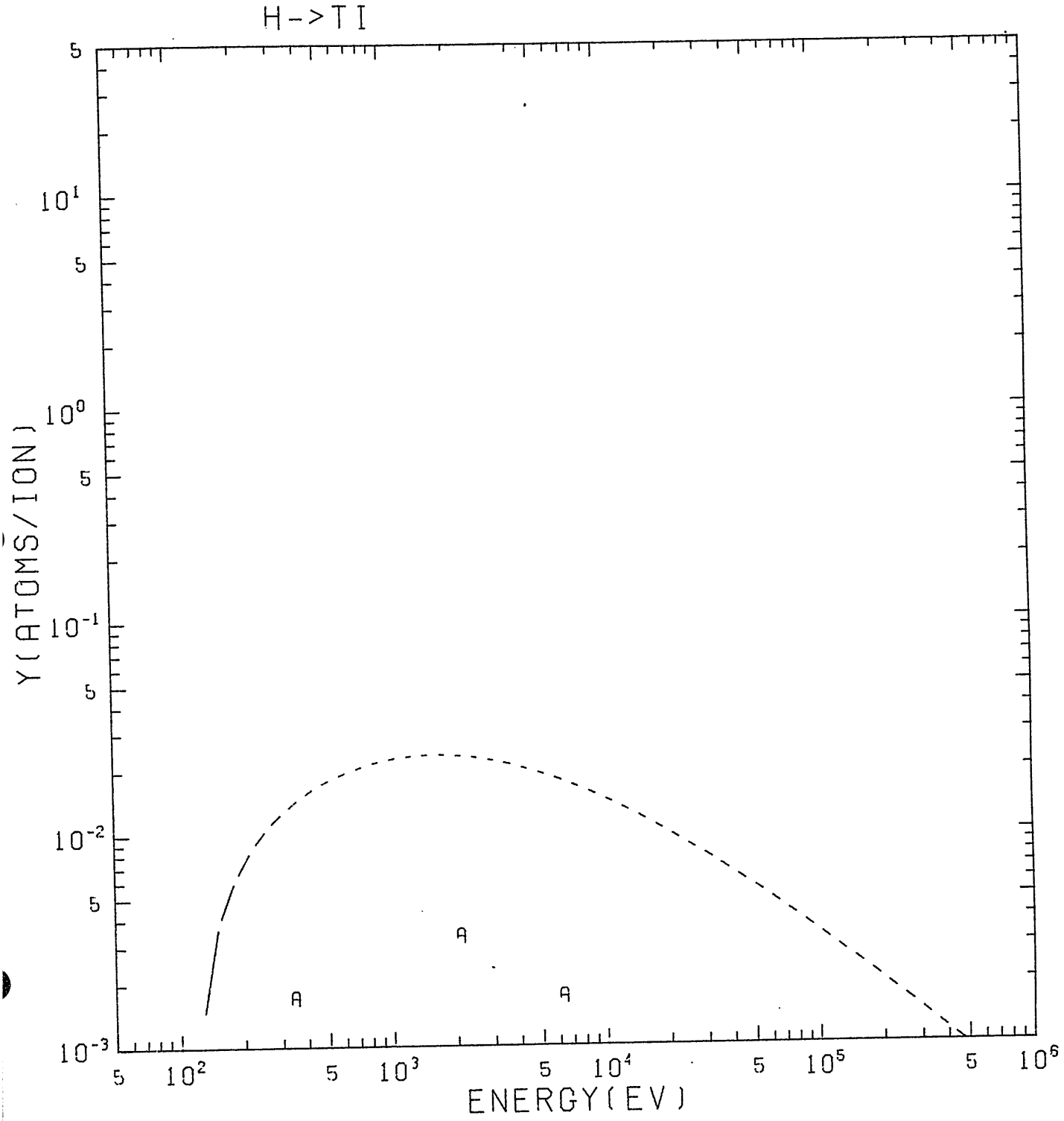
KR->SI
A ALMEN.BRUCE (1961B)
B ROSENBERG.WEHNER (1962)
C EERNISSE (1971)
D ANDERSEN.BAY (1975)

Fig. 26



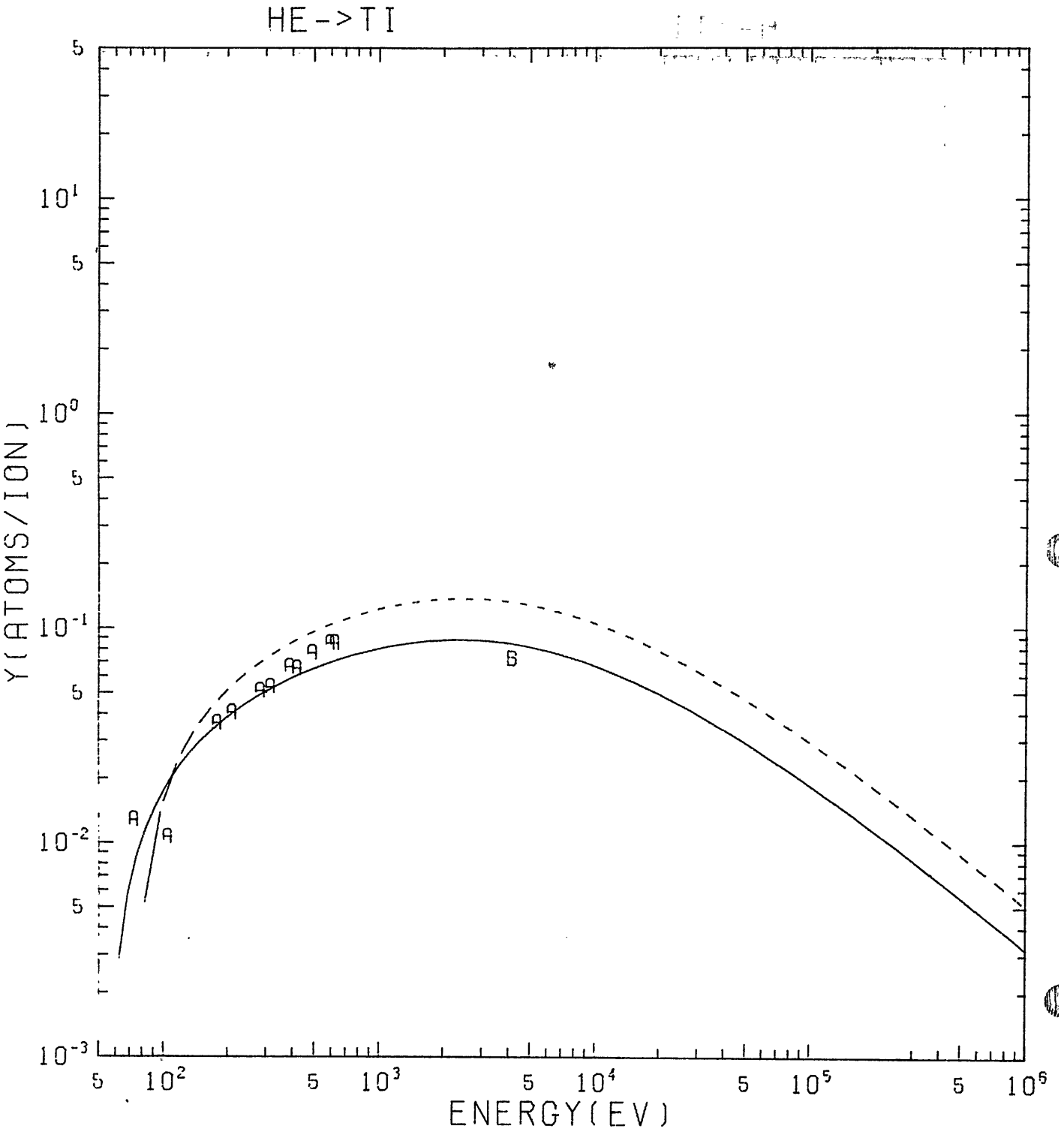
XE->SI
A ROSENBERG,WEHNER (1962)
B EERNISSE (1971) .
C ANDERSEN,BAY (1975)

Fig. 27



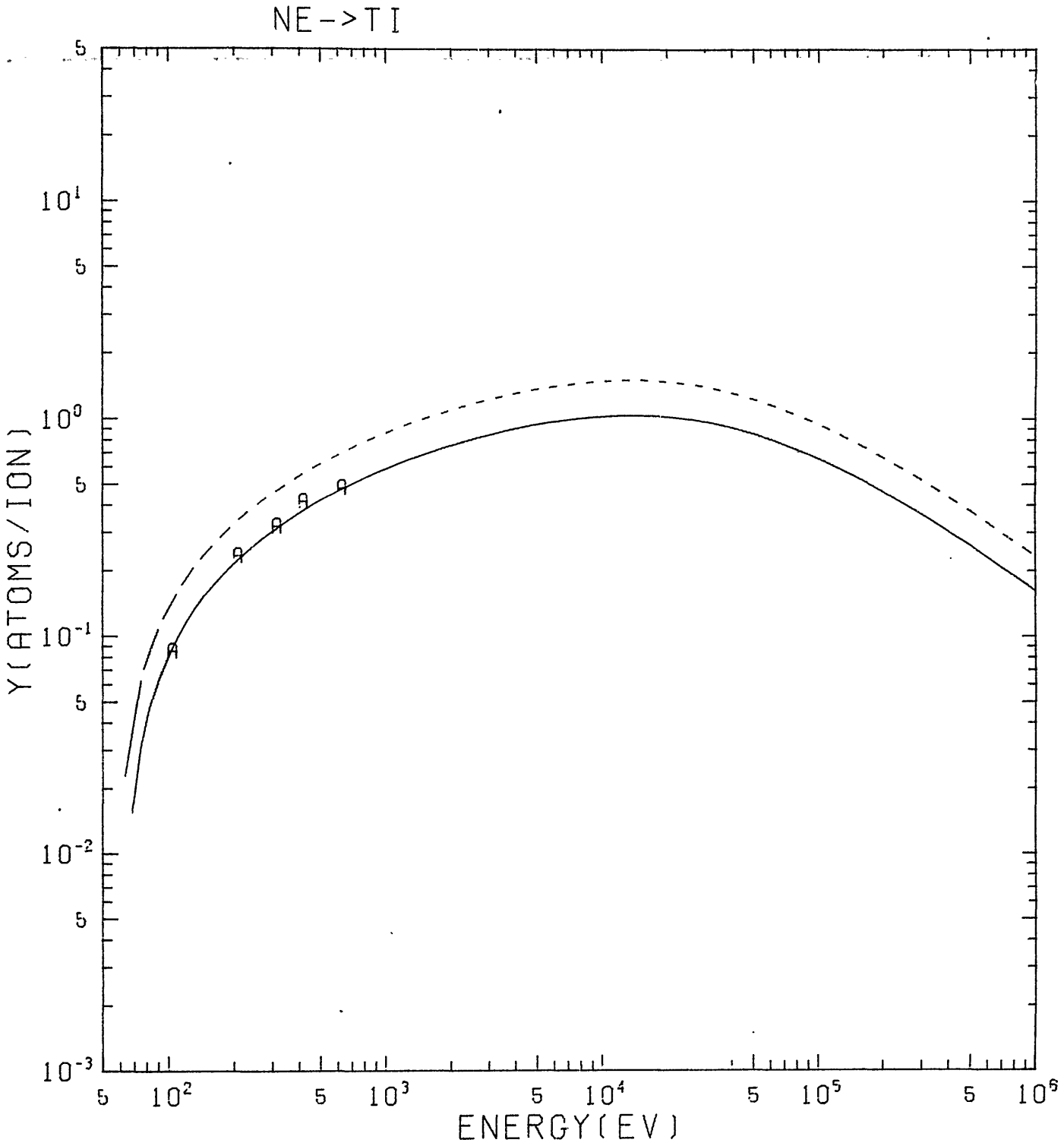
H->TI
A BOHDANSKY,ROTH,SINHA (1976)

Fig. 28



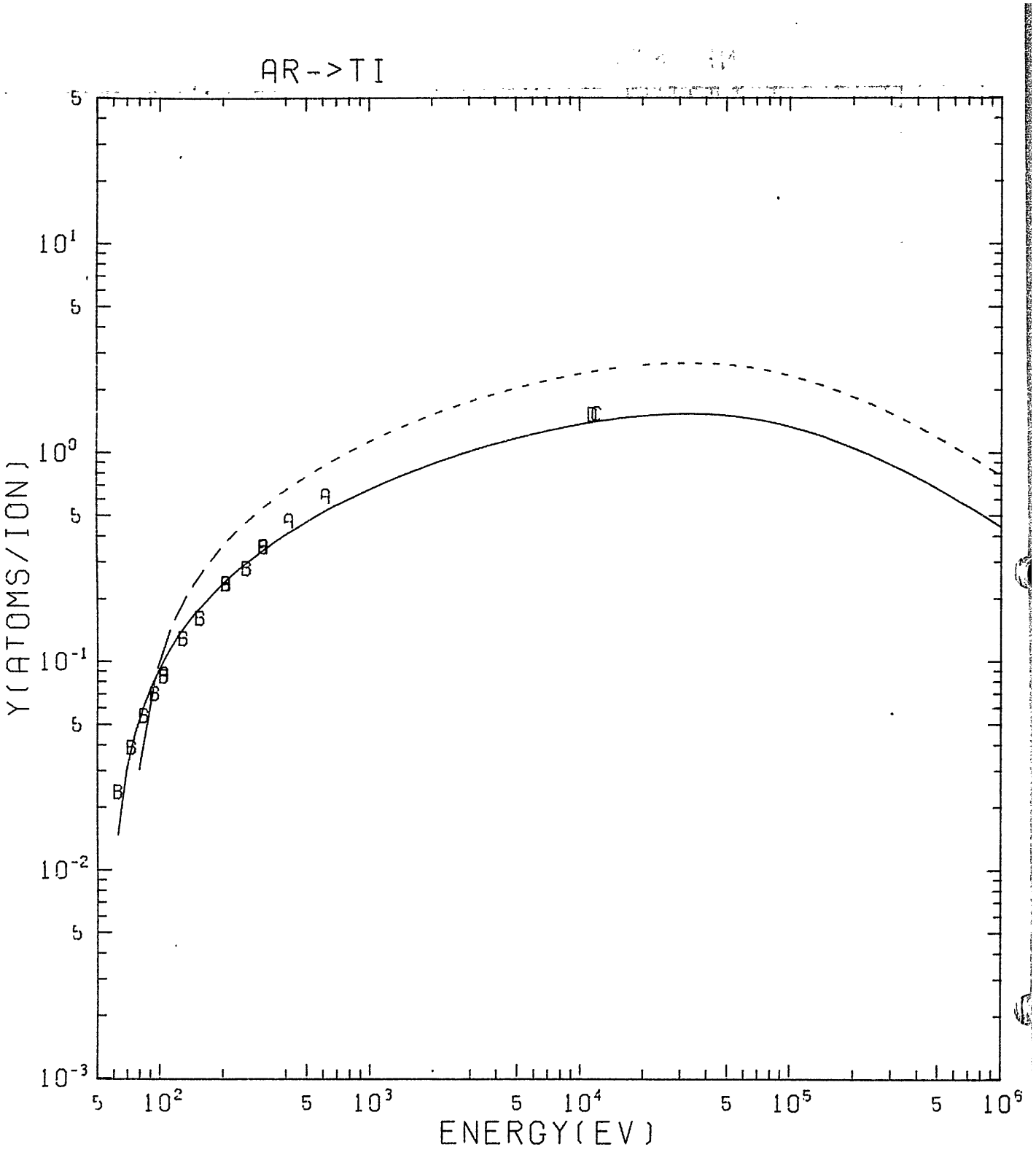
HE->TI
A ROSENBERG,WEHNER (1962)
B HOFER,BAY,MARTIN (1978)

Fig. 29



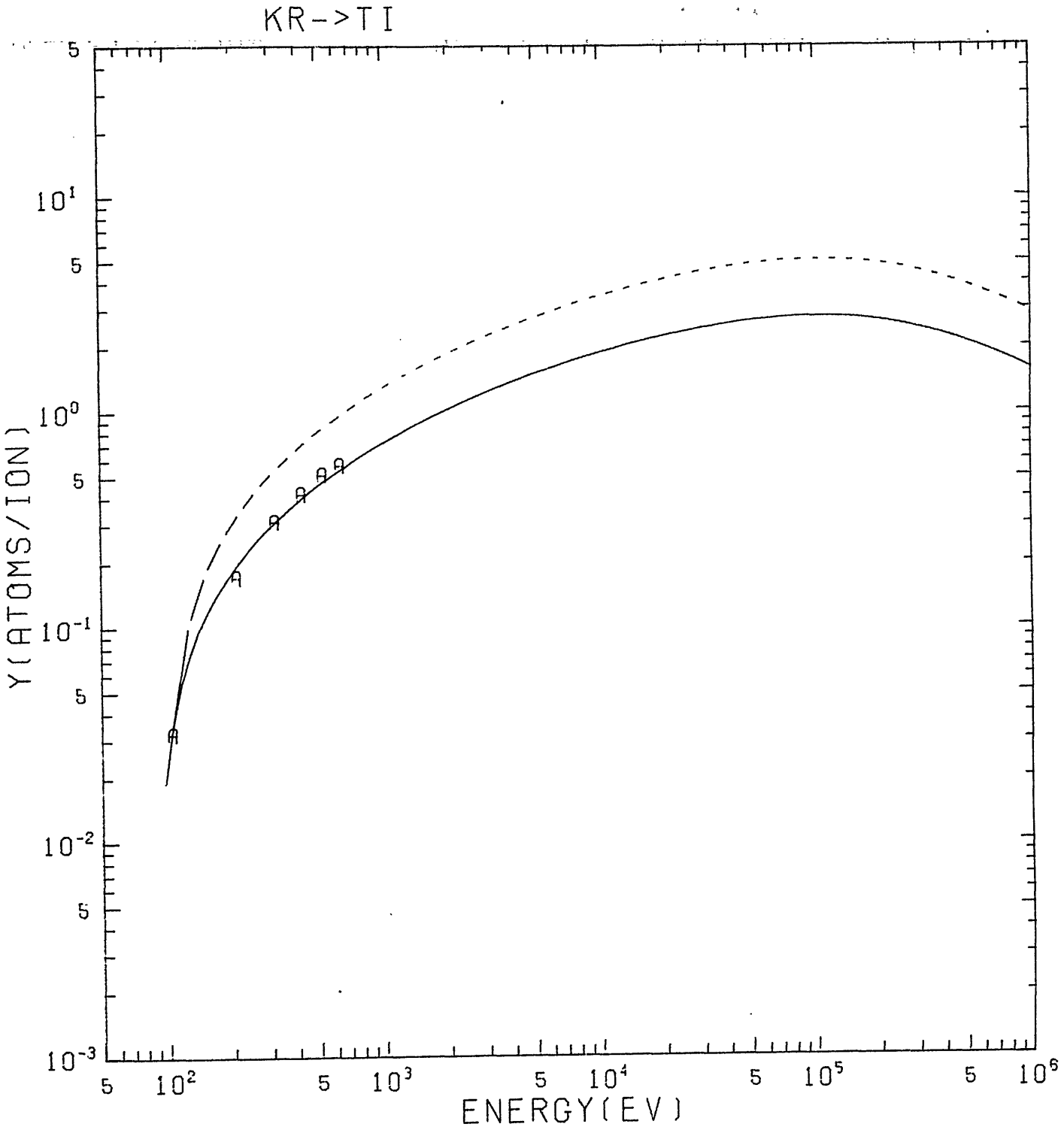
NE->TI
A LAEGREID,WEHNER (1961)

Fig. 30



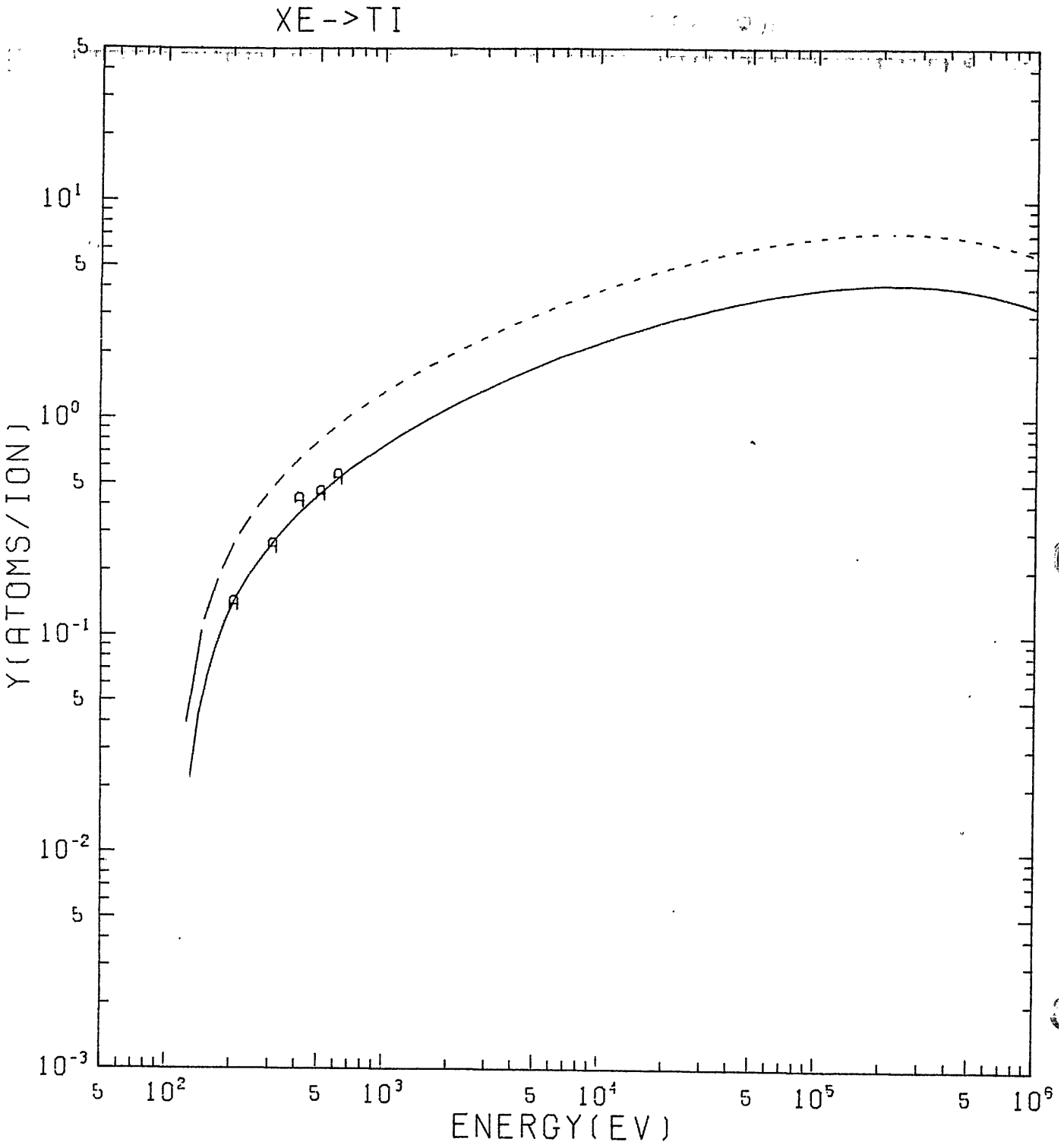
AR->TI
A LAEGREID,WEHNER (1961)
B STUART,WEHNER (1962)
C HOFER,LIEBLE (1976)
D HOFER,BAY,MARTIN (1978)

Fig. 31



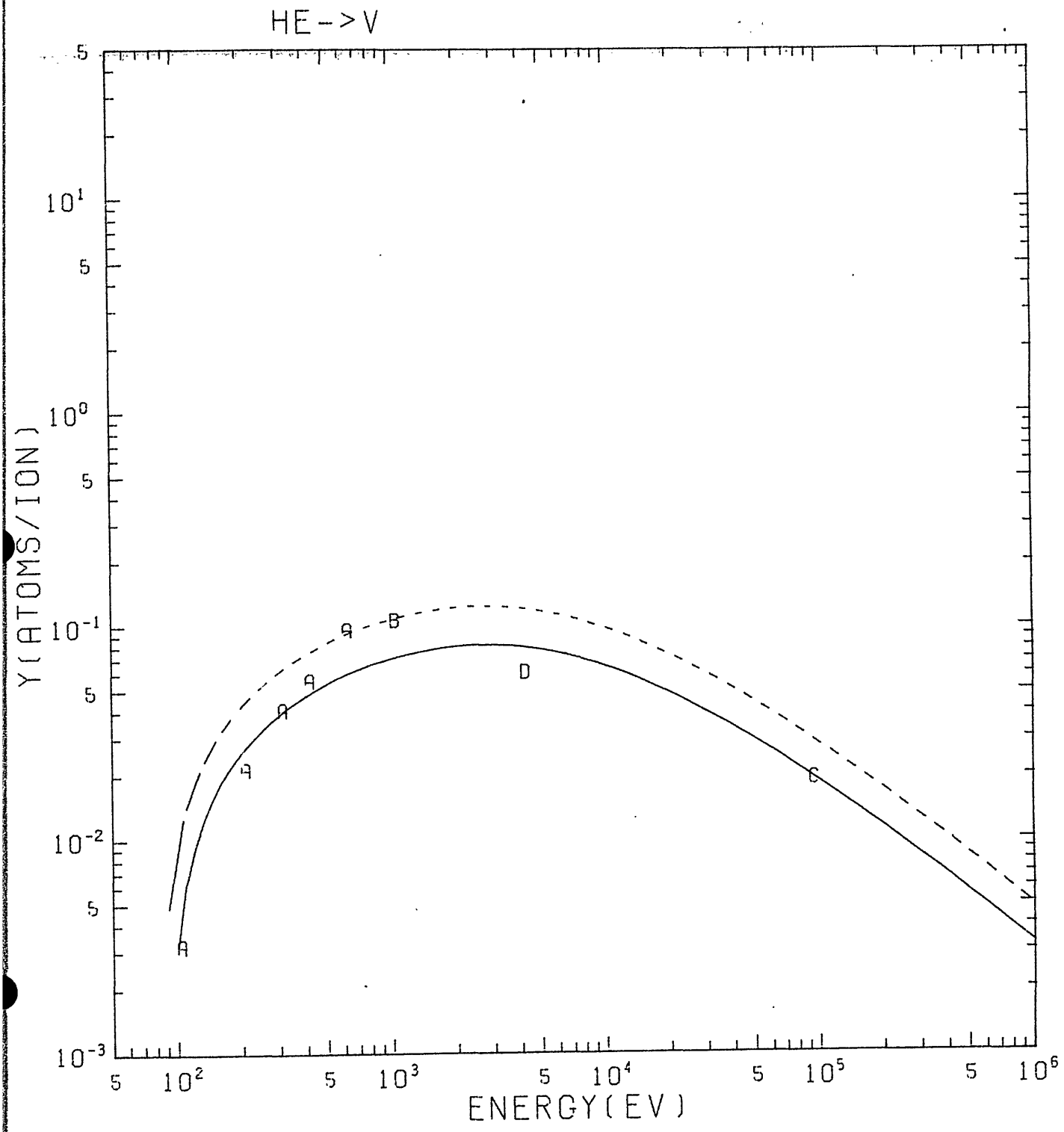
KR->TI
A ROSENBERG,WEHNER (1962)

Fig. 32



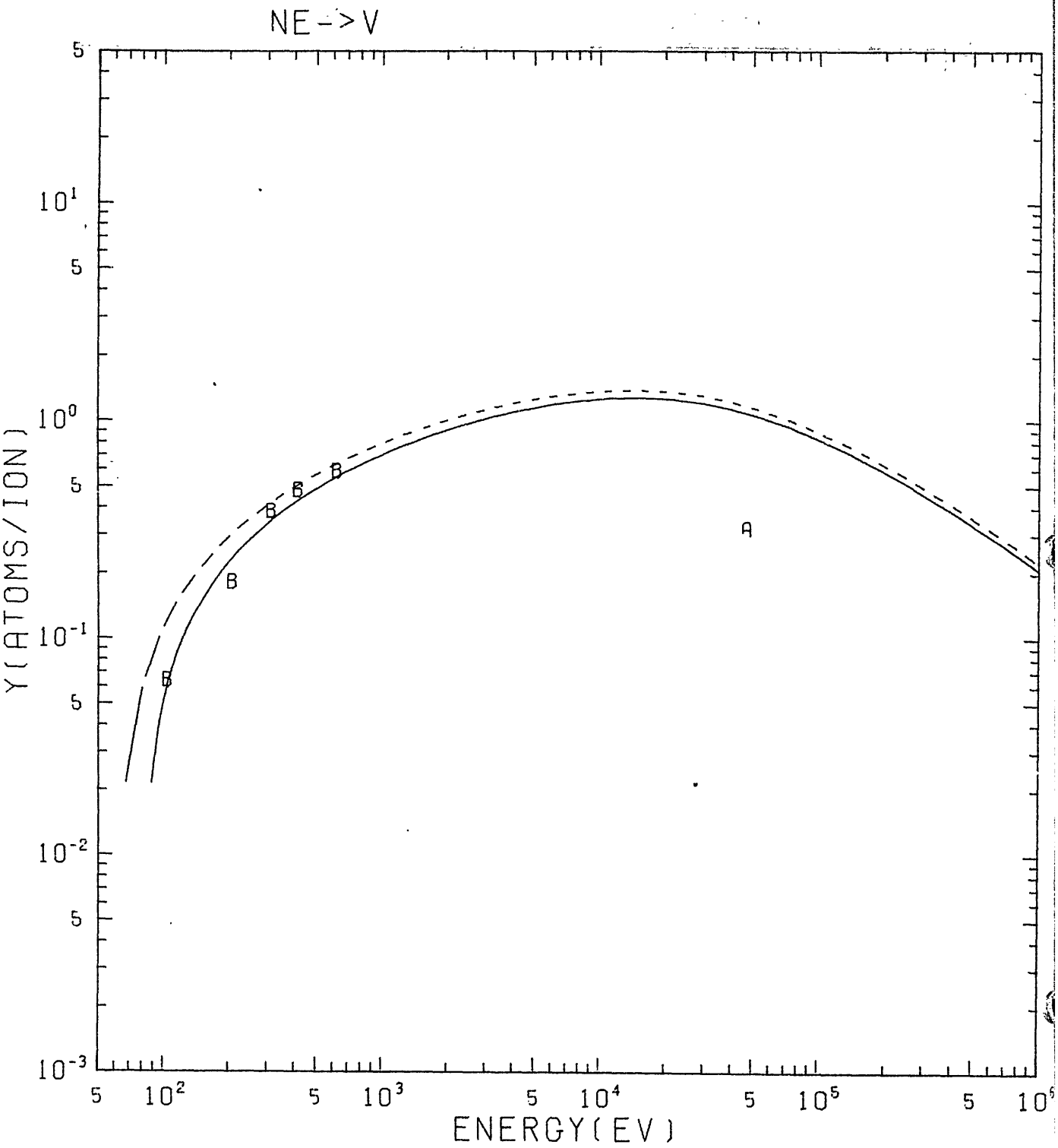
XE->TI
A ROSENBERG,WEHNER (1962)

Fig. 33



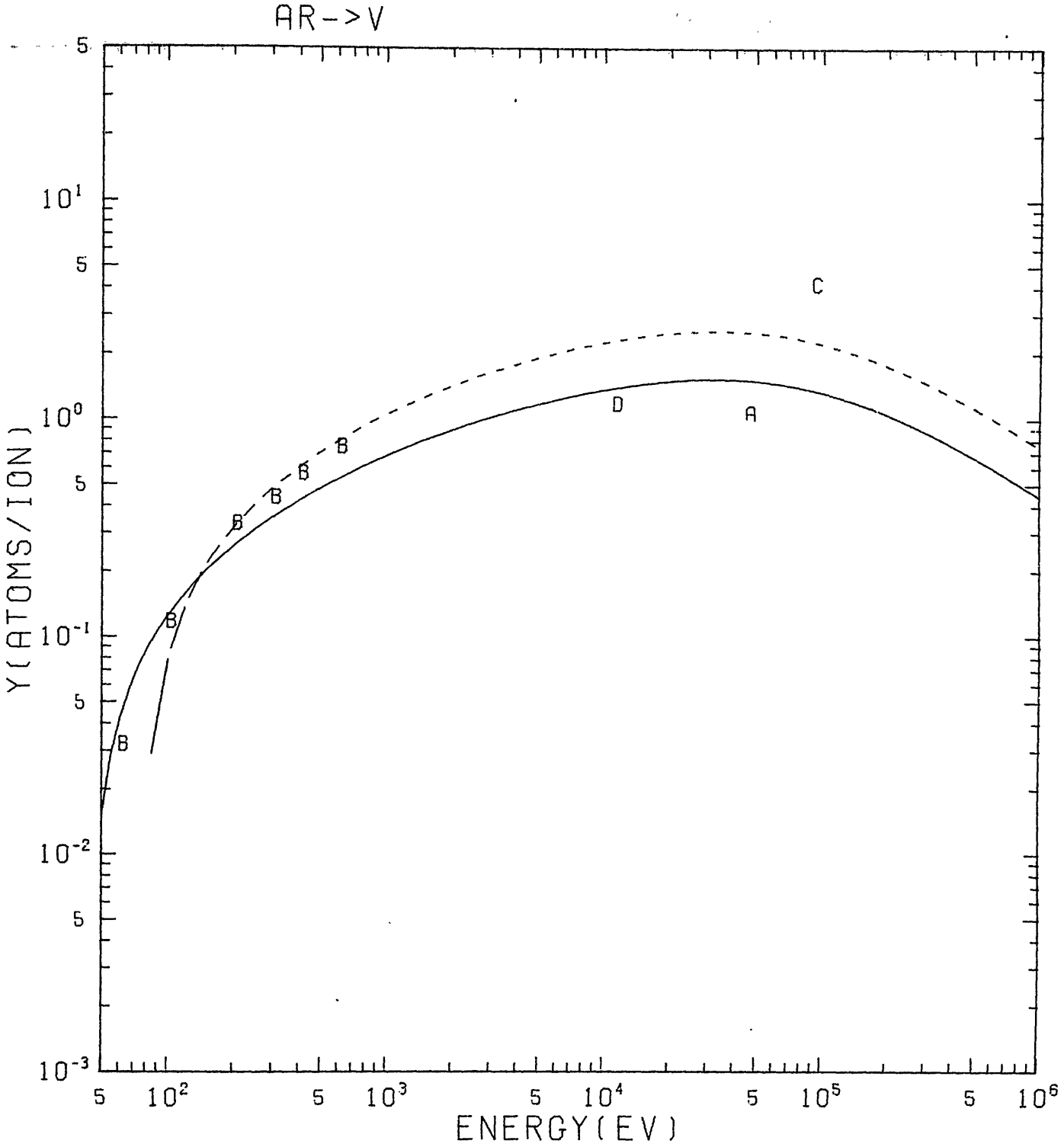
HE->V
A ROSENBERG,WEHNER (1962)
B GUSEVA,MARTYNENKO (1976)
C SWITKOWSKI,MANN,KNEFF (1976)
D HOFER,BAY,MARTIN (1978)

Fig. 34



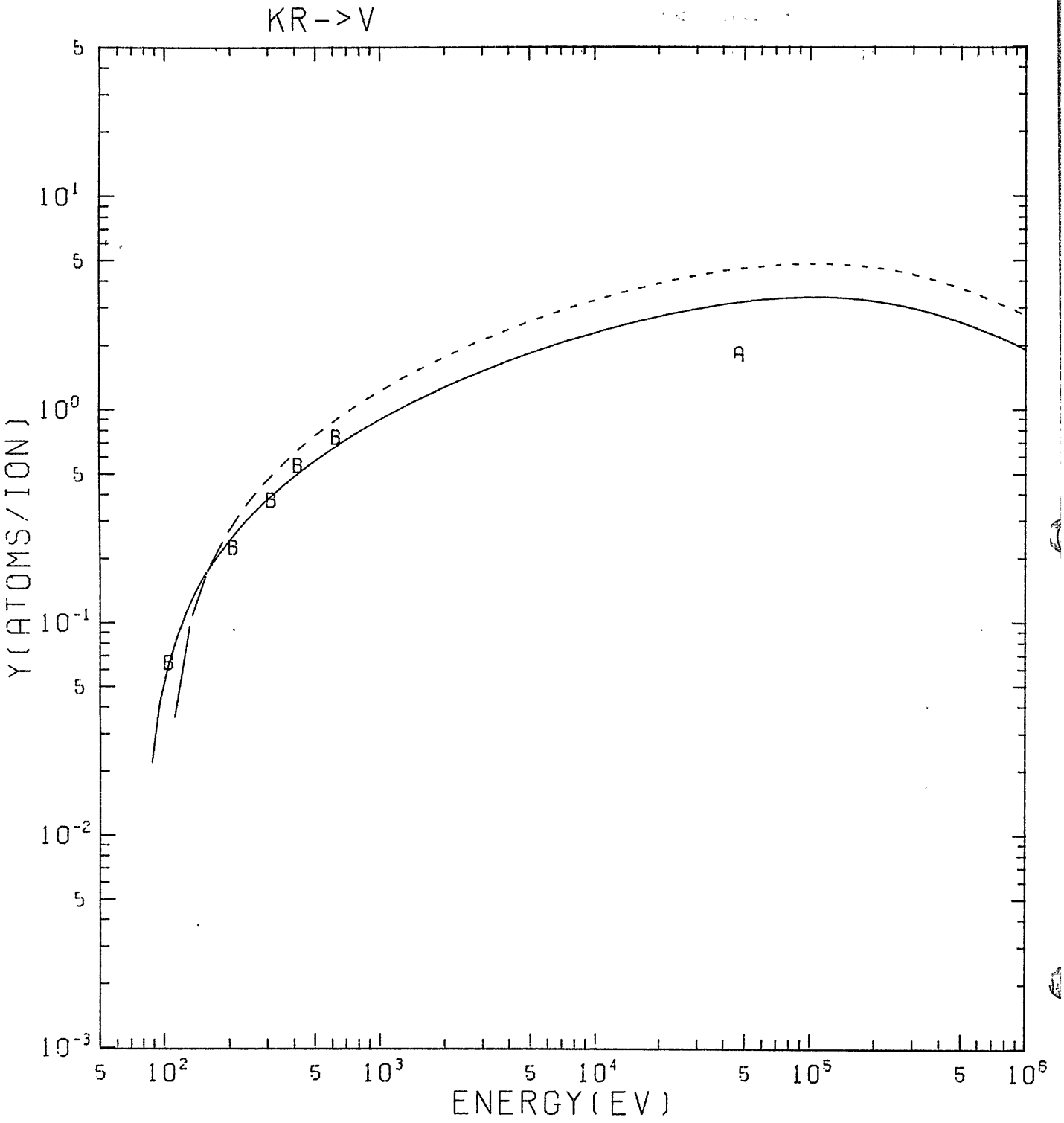
NE->V
A ALMEN.BRUCE (1961A)
B LAEGREID.WEHNER (1961)

Fig. 35



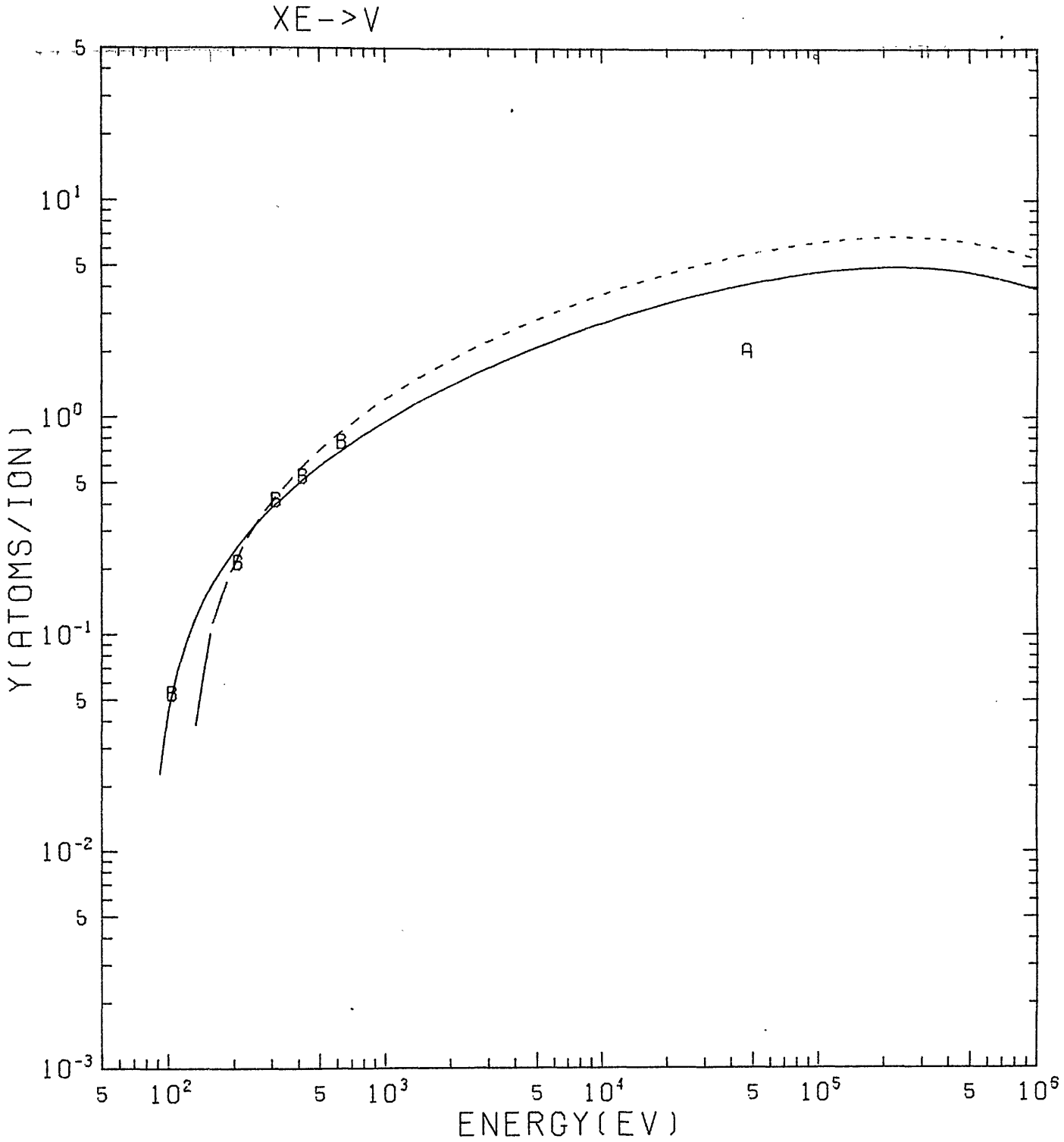
AR->V
A ALMEN.BRUCE (1961A)
B LAEGREID.WEHNER (1961)
C SWITKOWSKI.MANN.KNEFF (1976)
D HOFER.BAY.MARTIN (1978)

Fig. 36



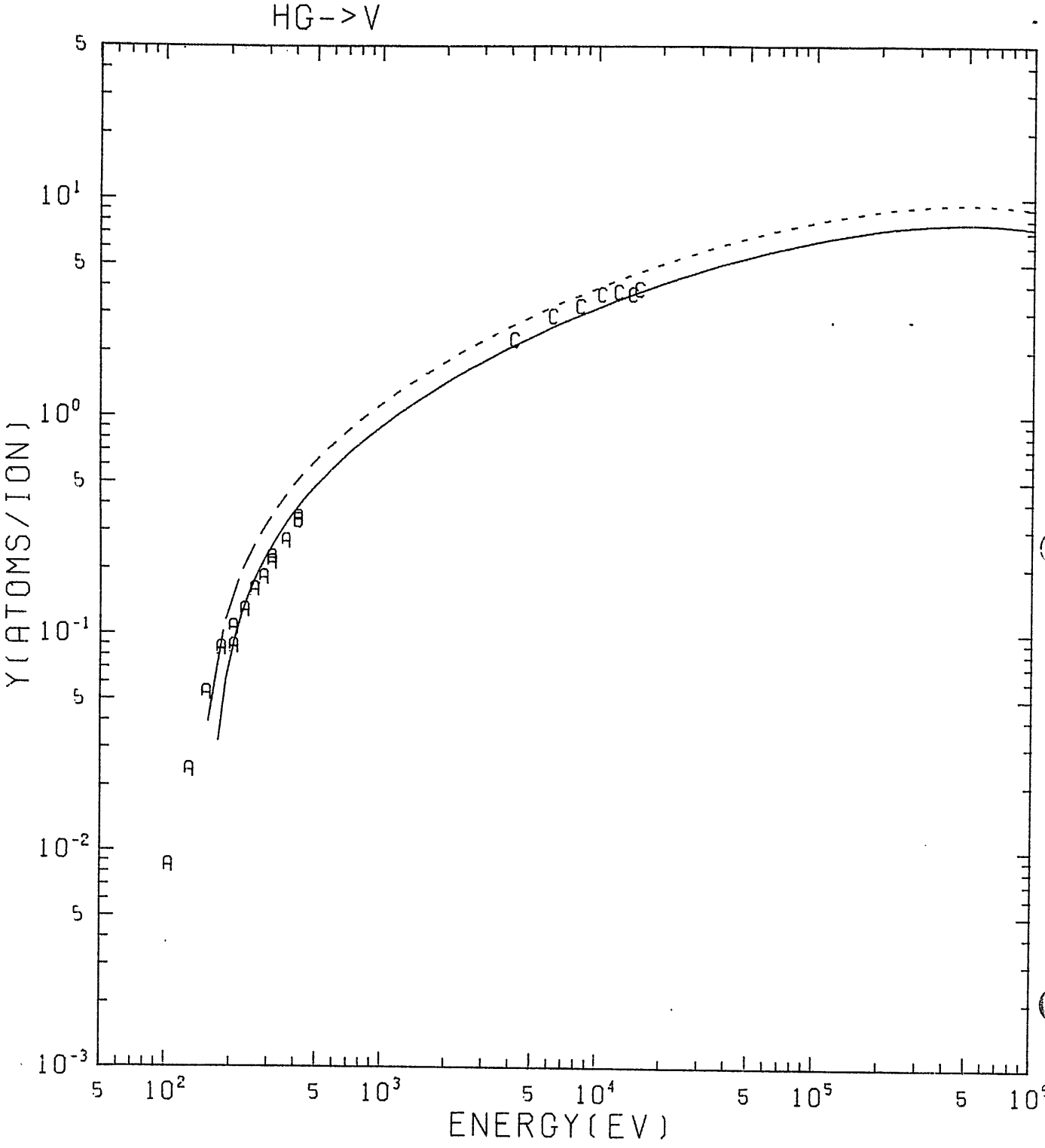
KR->V
A ALMEN,BRUCE (1961A)
B ROSENBERG,WEHNER (1962)

Fig. 37



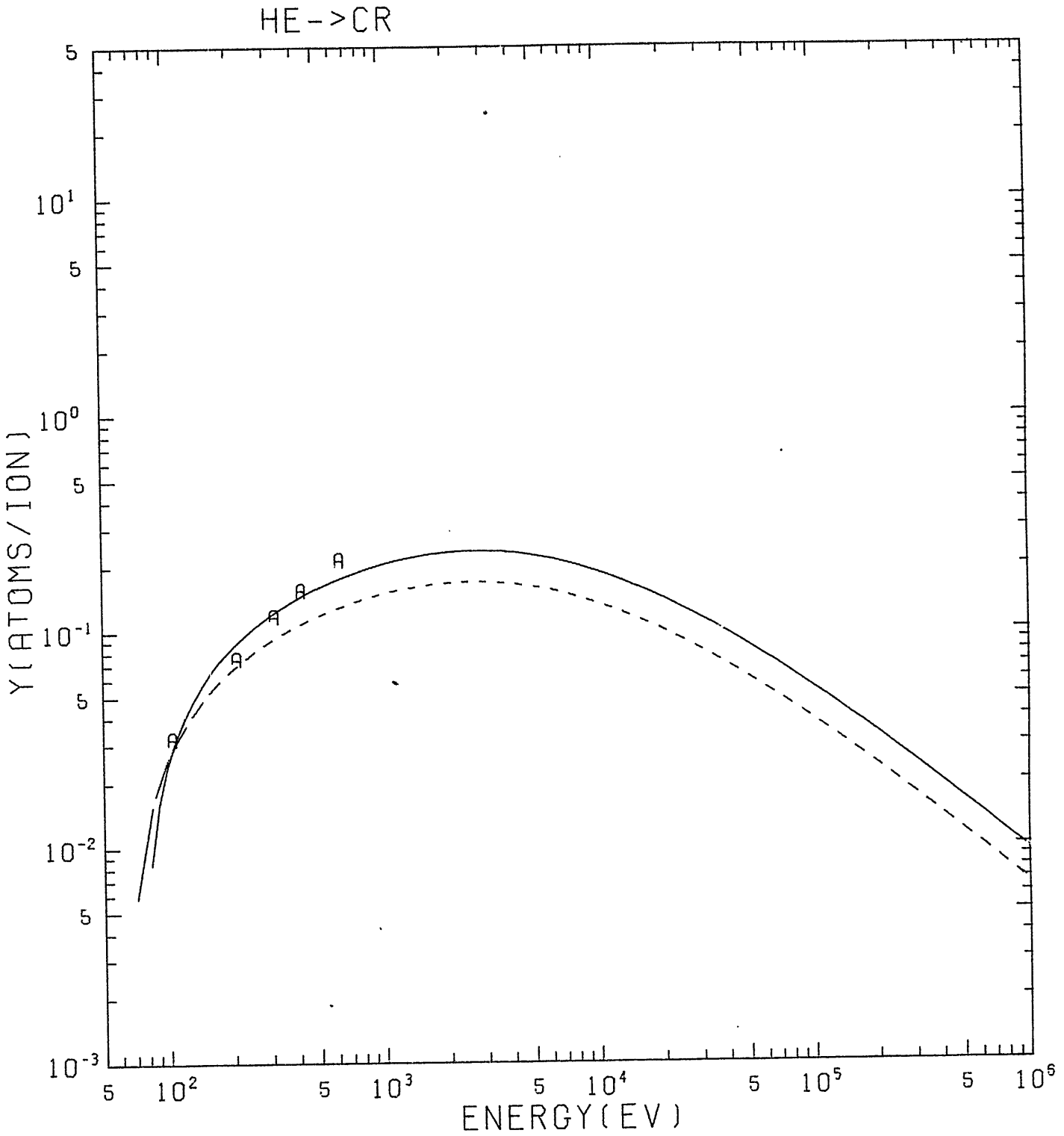
XE->V
A ALMEN.BRUCE (1961A)
B ROSENBERG.WEHNER (1962)

Fig. 38



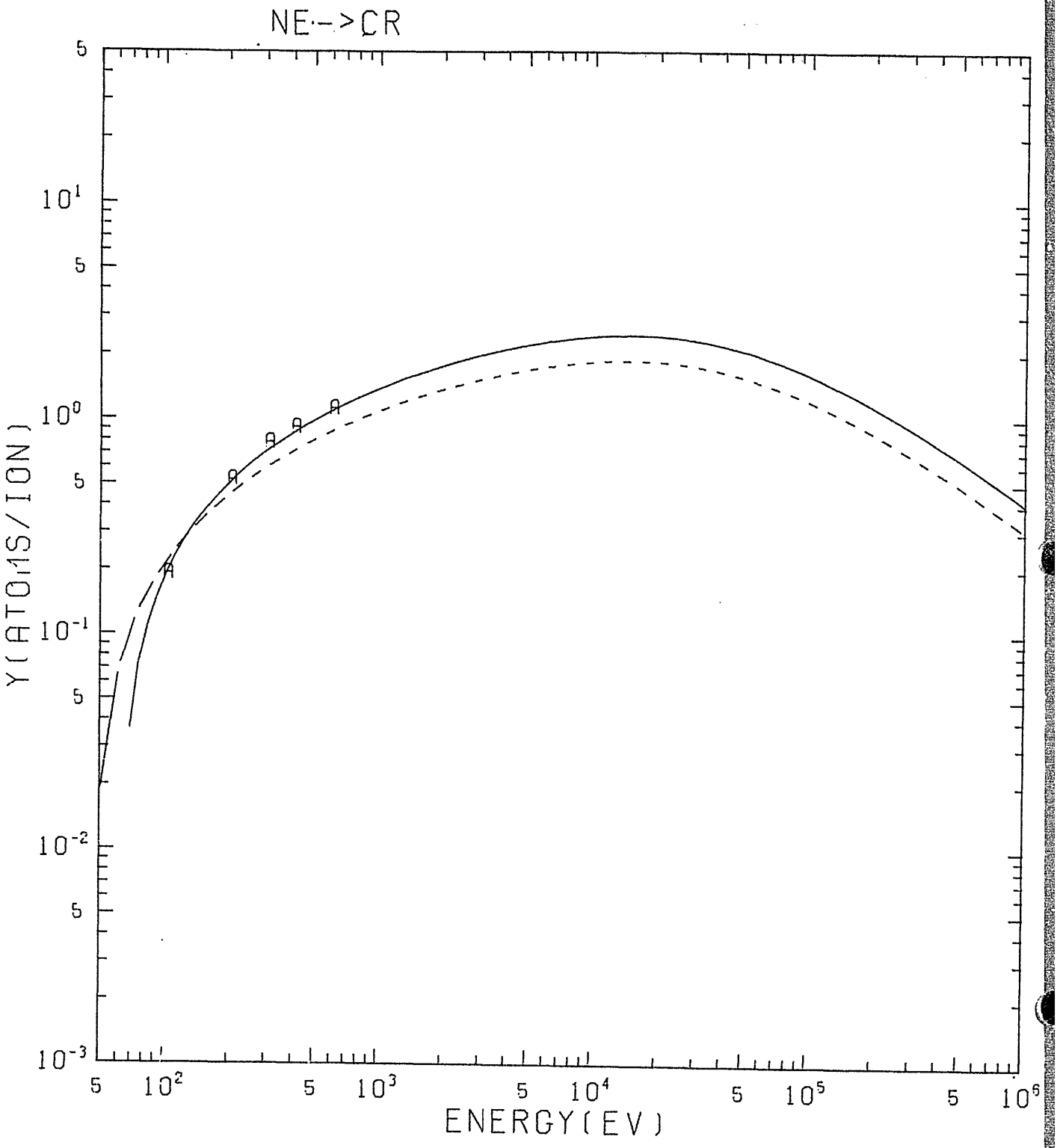
HG->V
A WEHNER (1957)
B LAEGREID,WEHNER (1961)
C WEHNER,ROSENBERG (1961)

Fig. 39



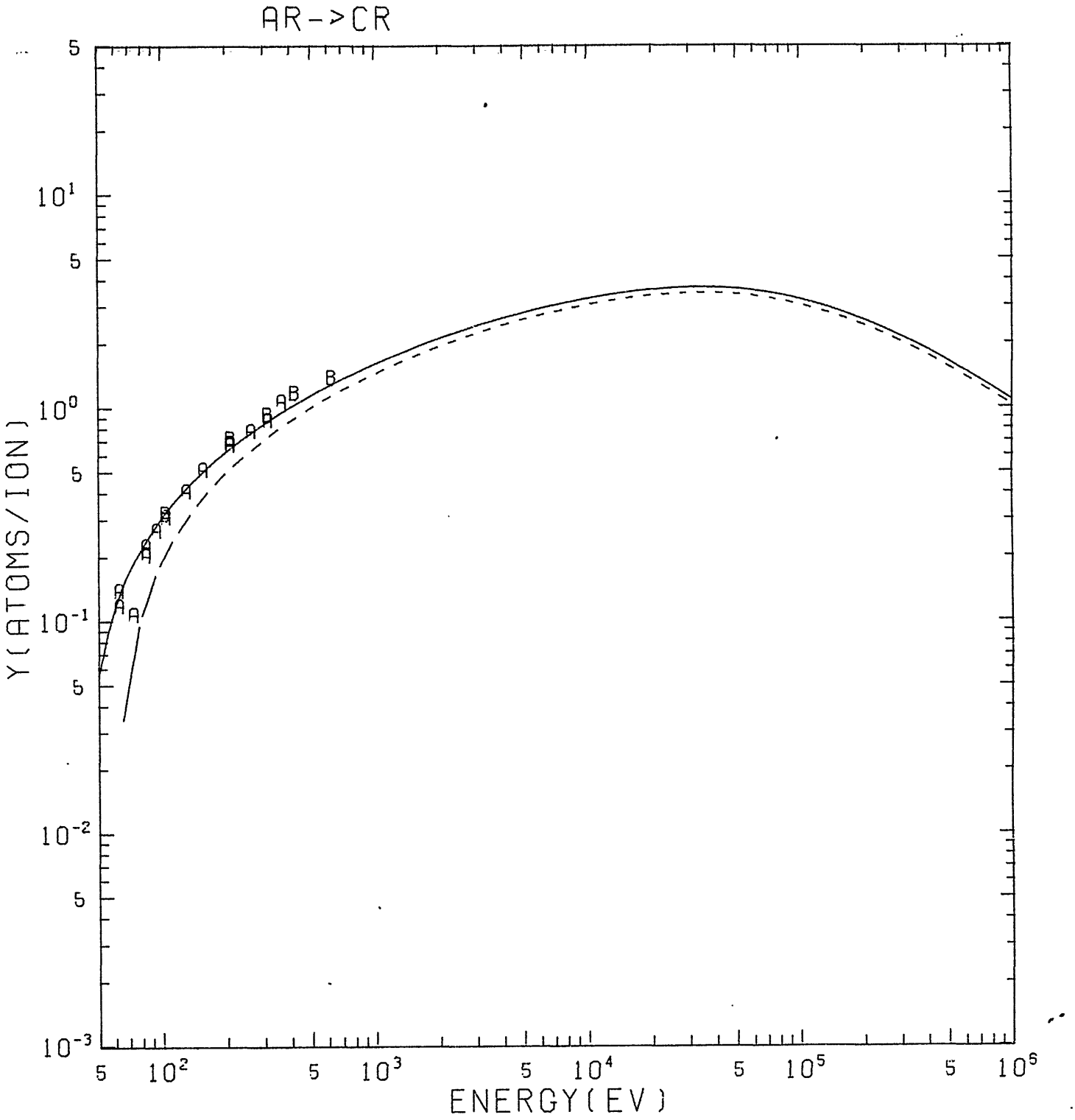
HE->CR
A ROSENBERG,WEHNER (1962)

Fig. 40



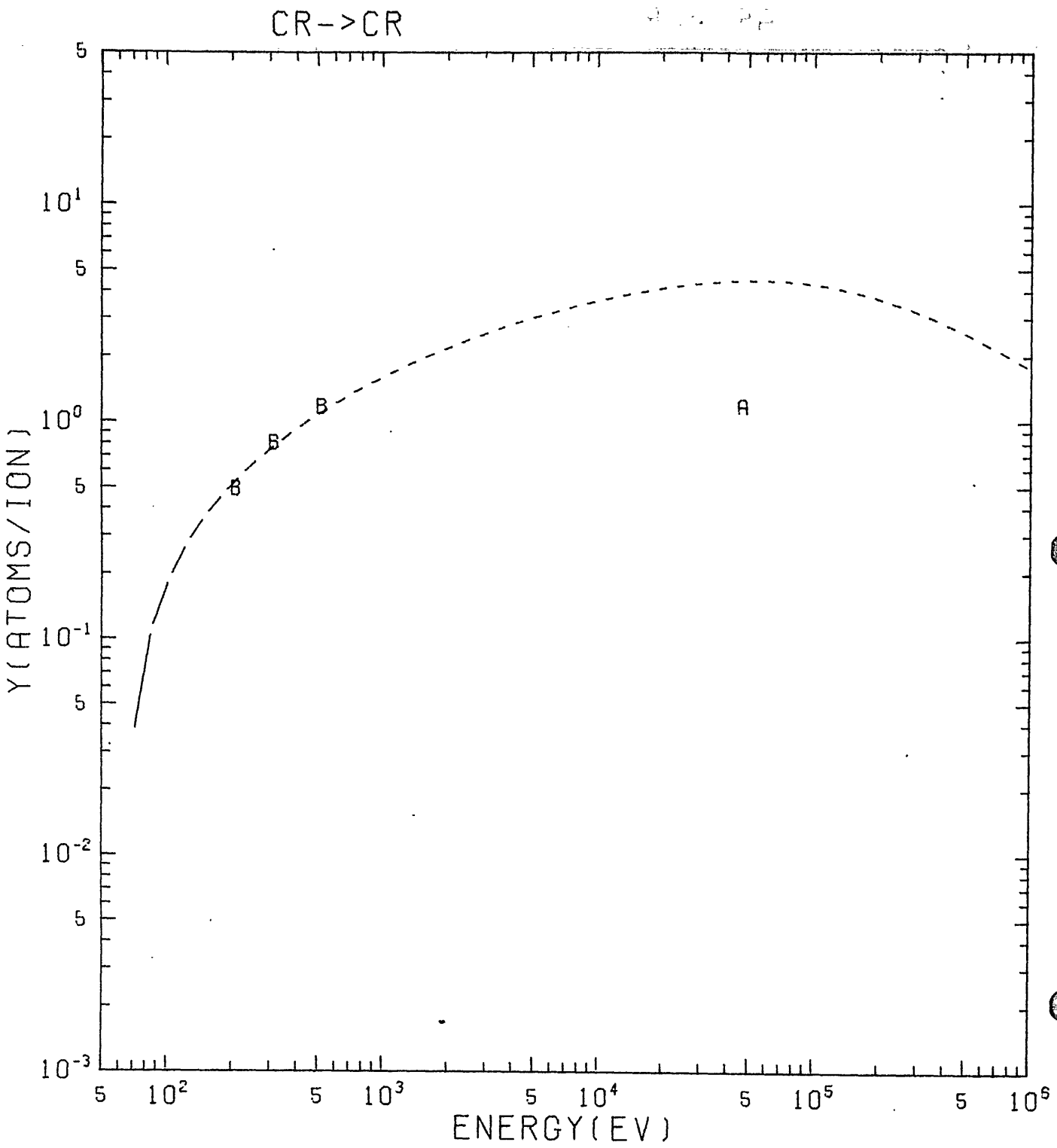
NE->CR
A LAEGREID,WEHNER (1961)

Fig. 41



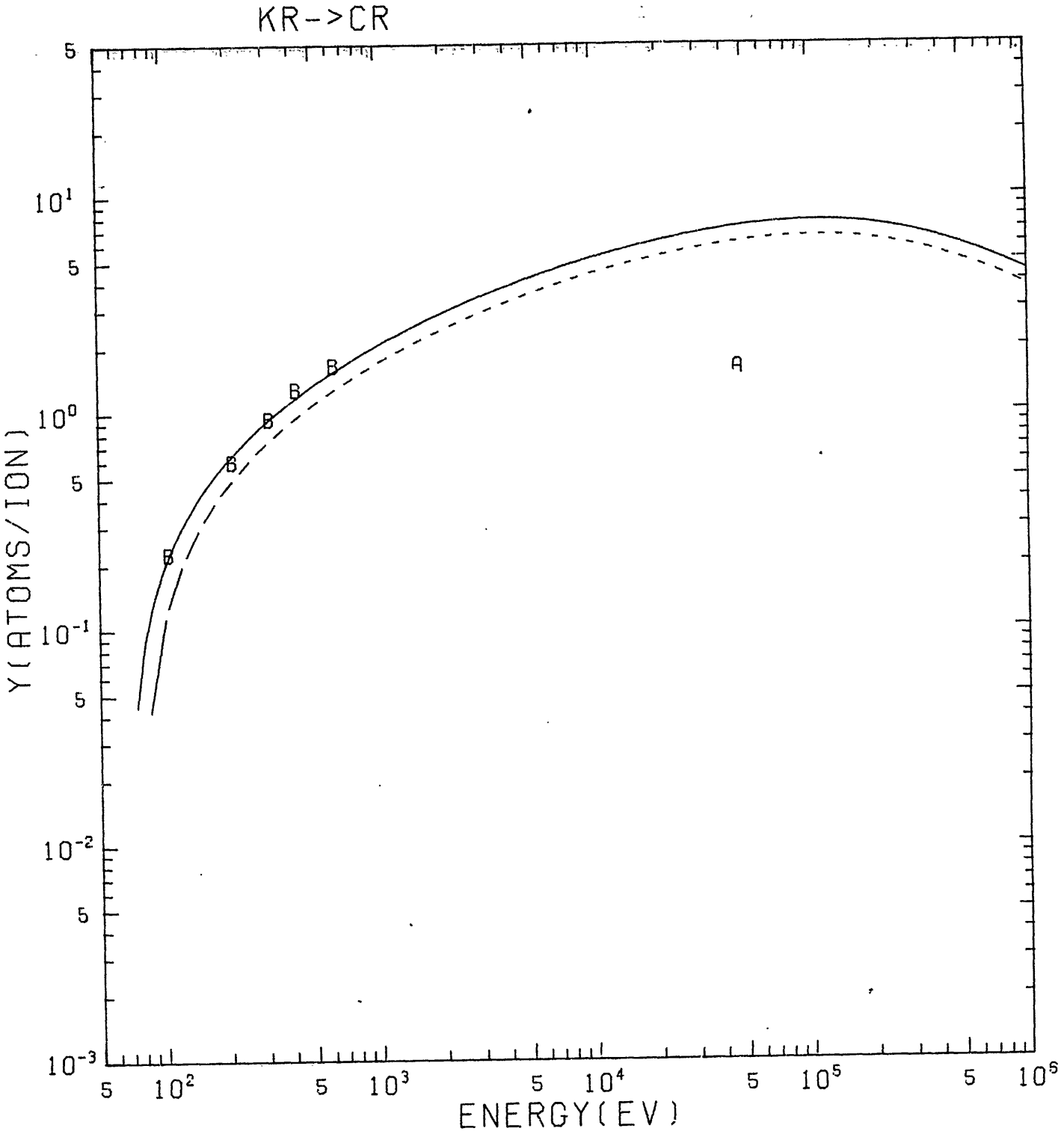
AR->CR
A STUART.WEHNER (1960)
B LAEGREID.WEHNER (1961)

Fig. 42



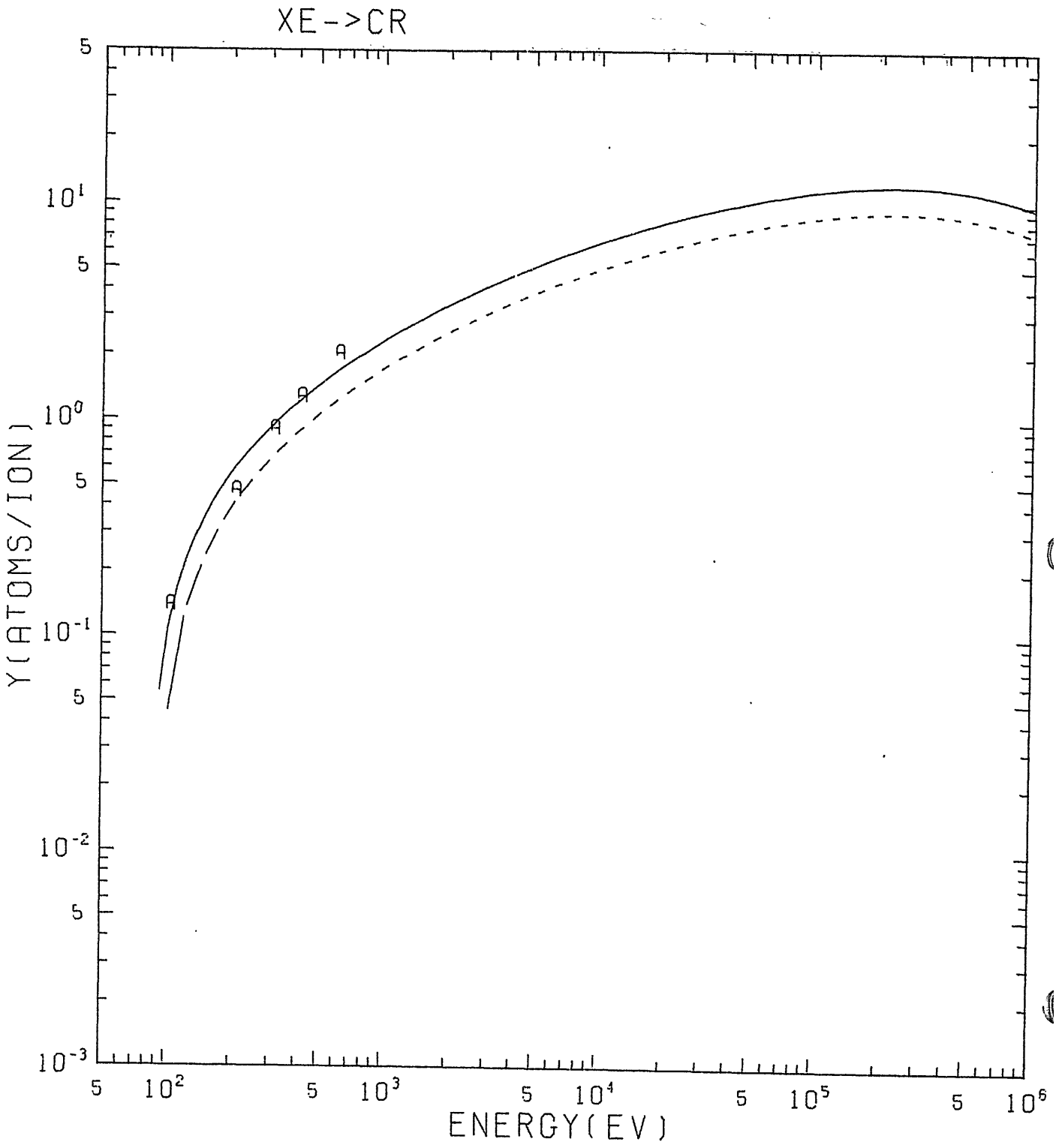
CR->CR
A ALMEN.BRUCE (1961B)
B HAYWARD.WOLTER (1969)

Fig. 43



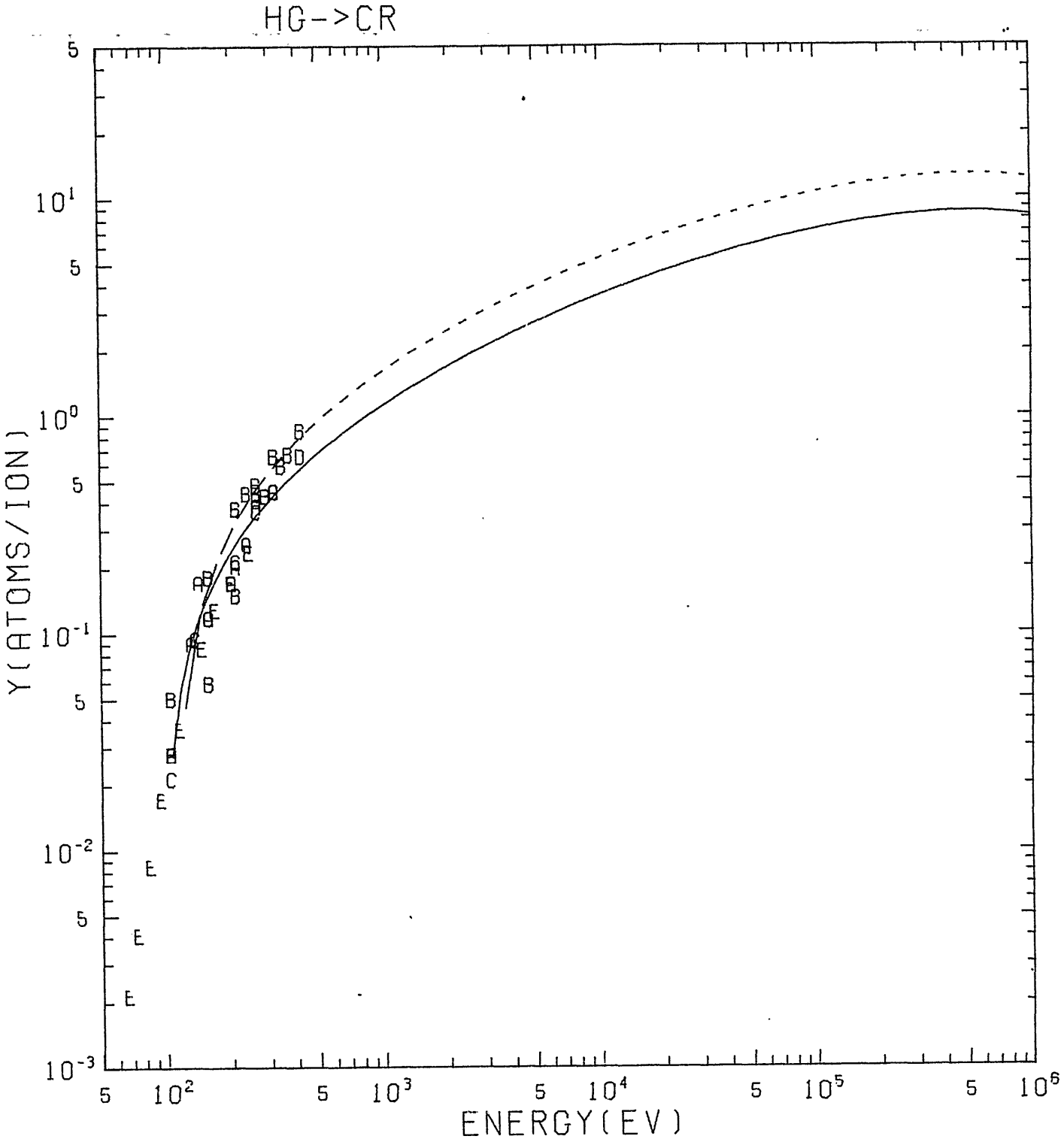
KR->CR
A ALMEN.BRUCE (1961A)
B ROSENBERG.WEHNER (1962)

Fig. 44



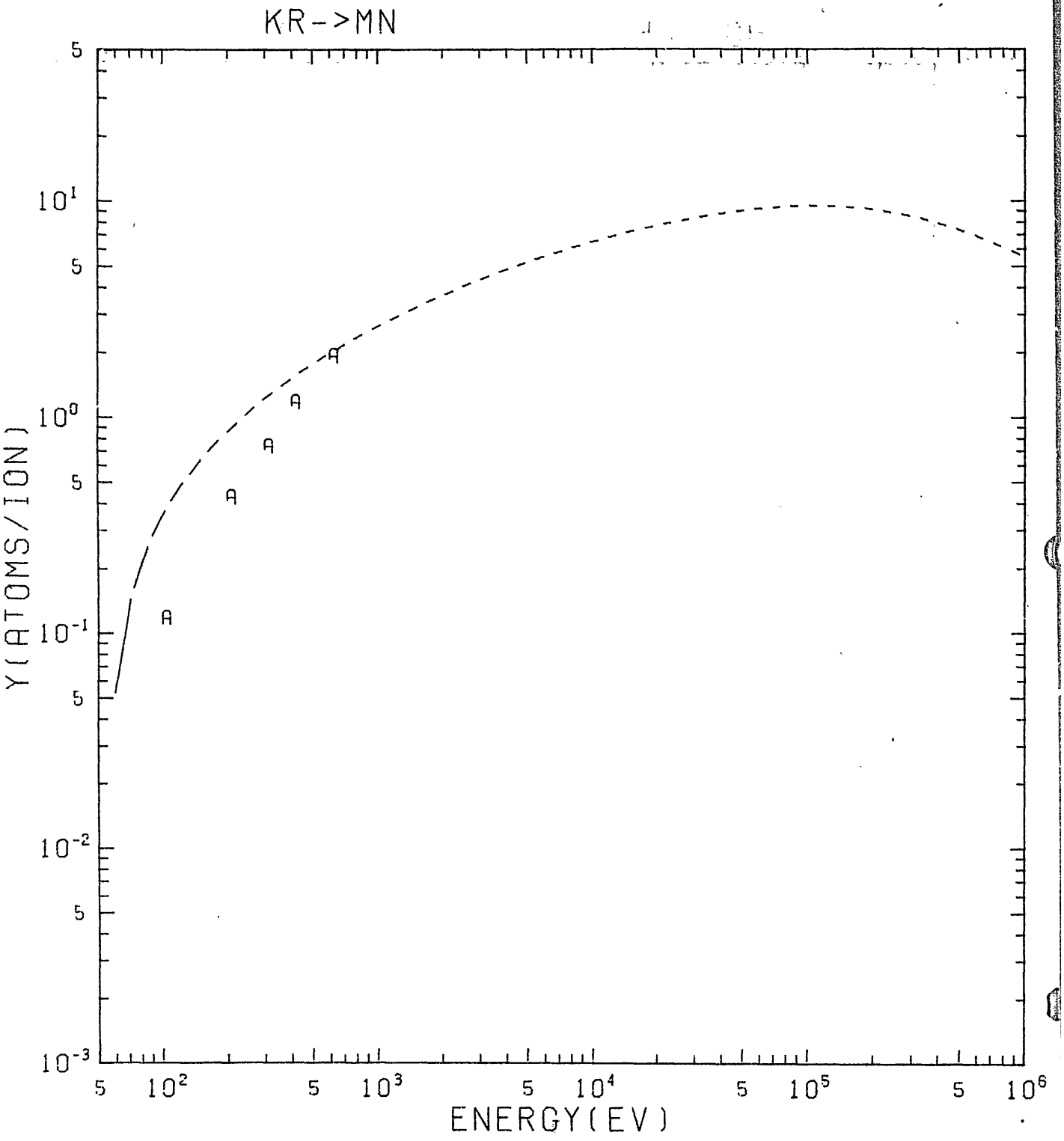
XE->CR
A ROSENBERG,WEHNER (1962)

Fig. 45



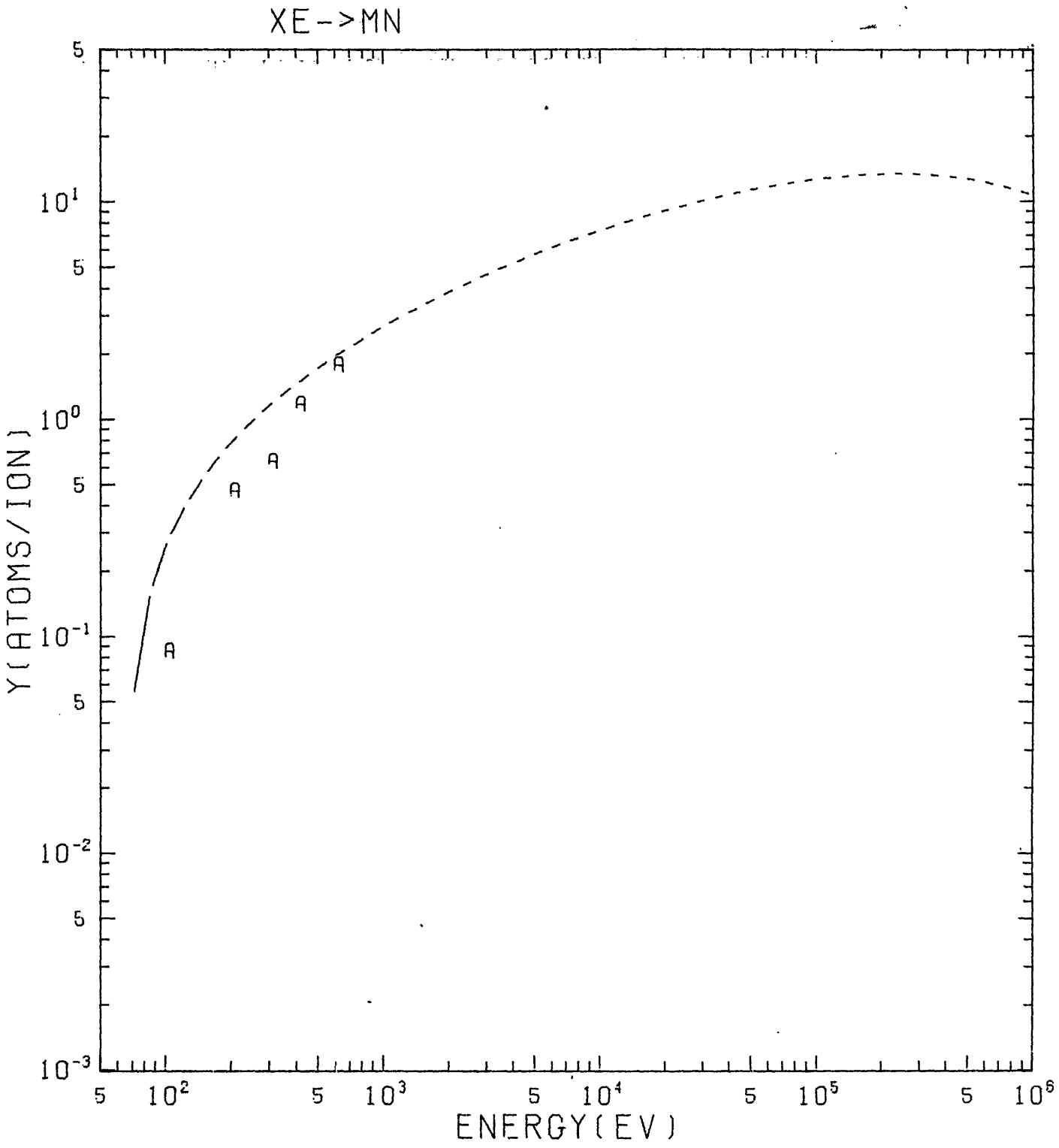
HG->CR
A WEHNER (1957)
B WEHNER (1958)
C STUART.WEHNER (1960)
D LAEGREID.WEHNER (1961)
E ASKEROV.SENA (1969)

Fig. 46



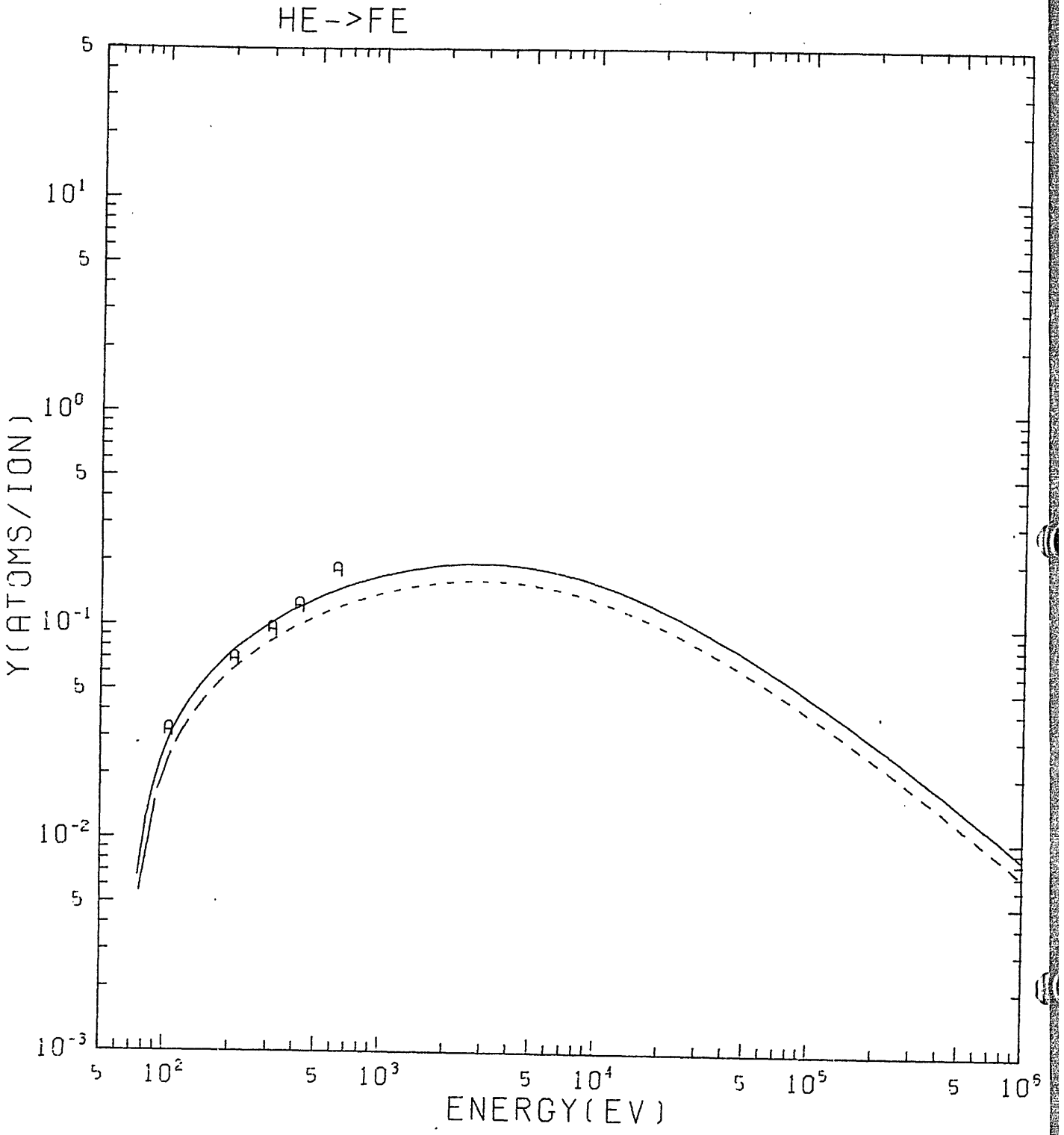
KR->MN
A ROSENBERG,WEHNER (1962)

Fig. 47



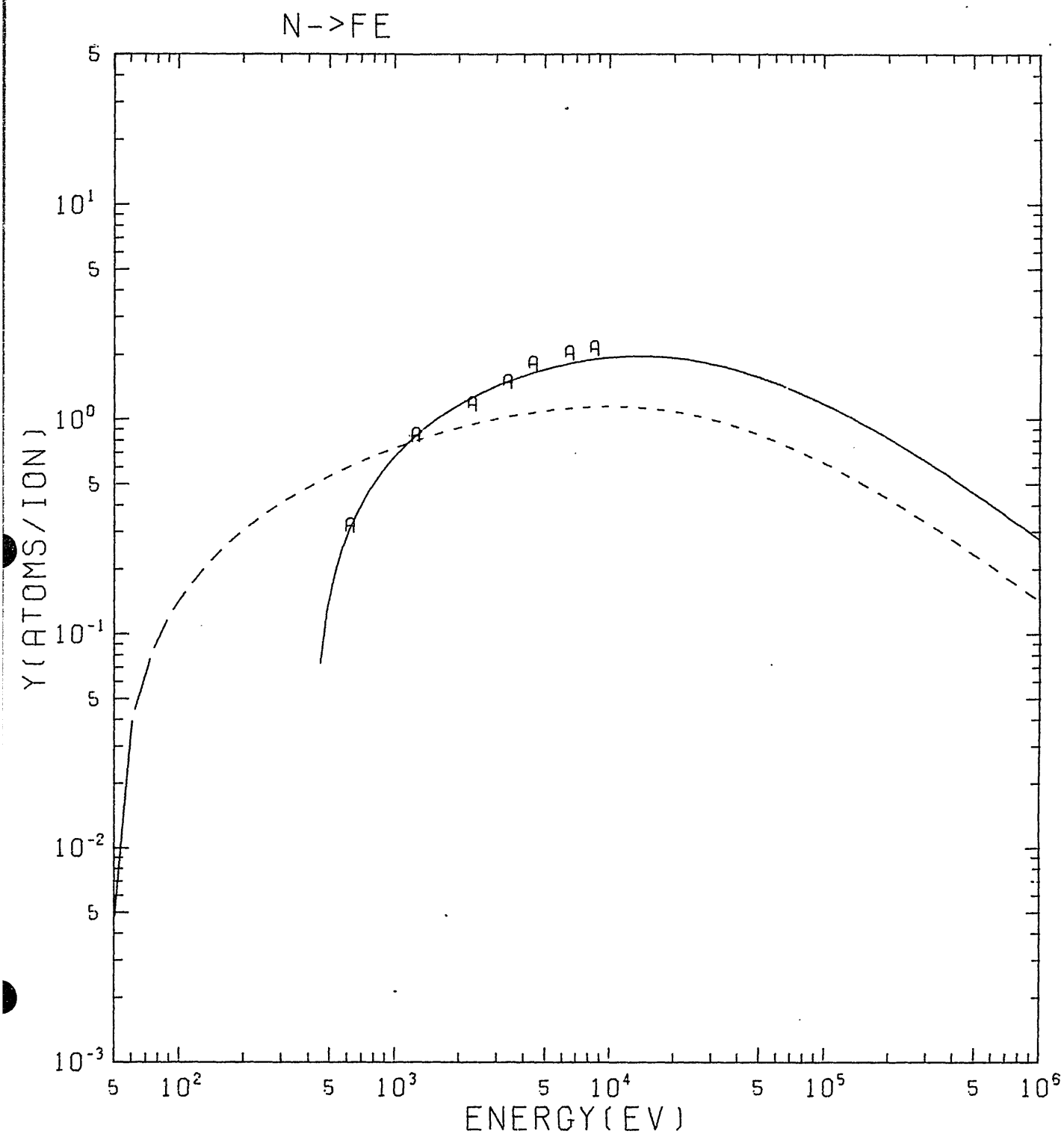
XE->MN
A ROSENBERG,WEHNER (1962)

Fig. 48



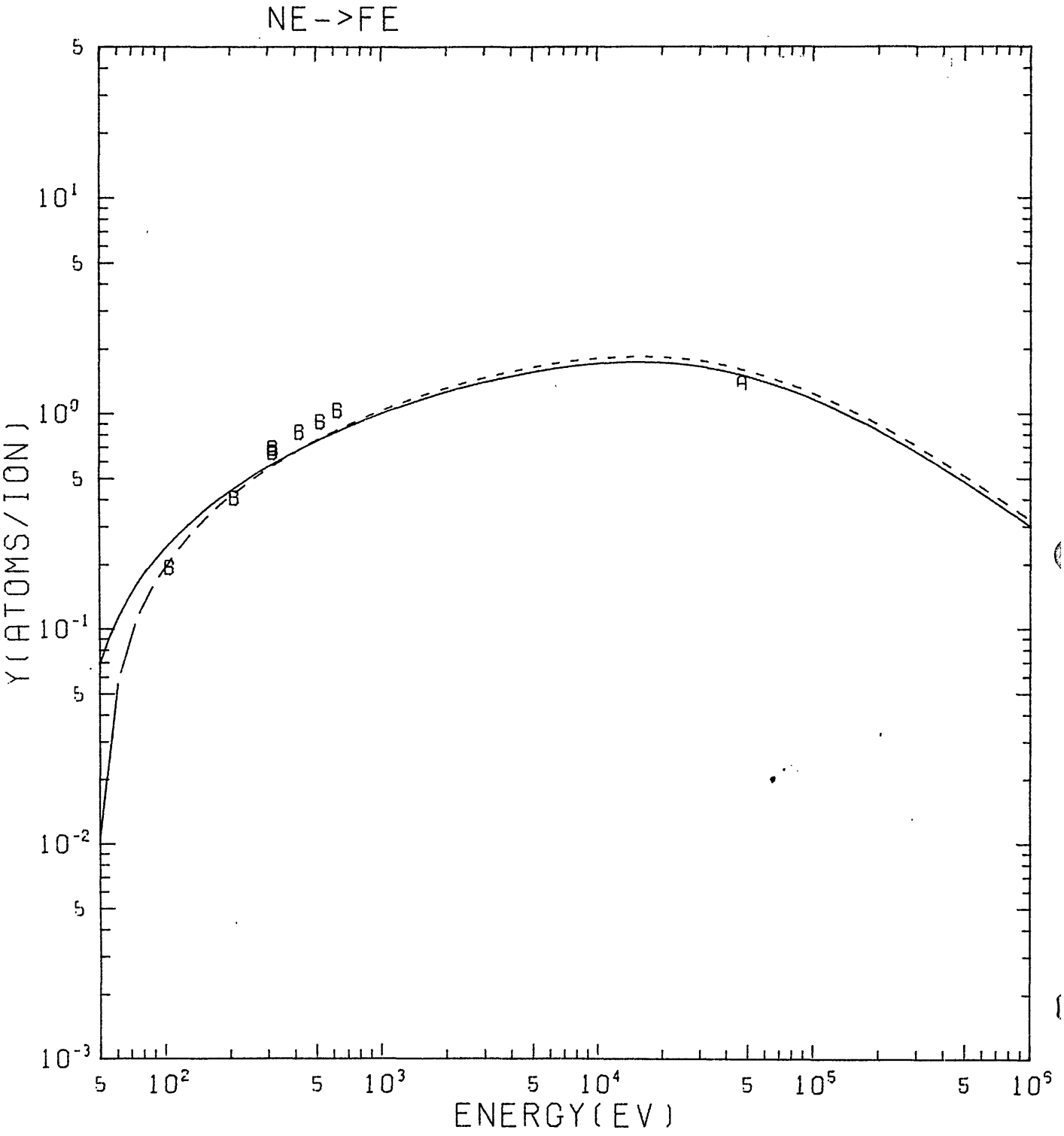
HE->FE
A ROSENBERG,WEHNER (1962)

Fig. 49



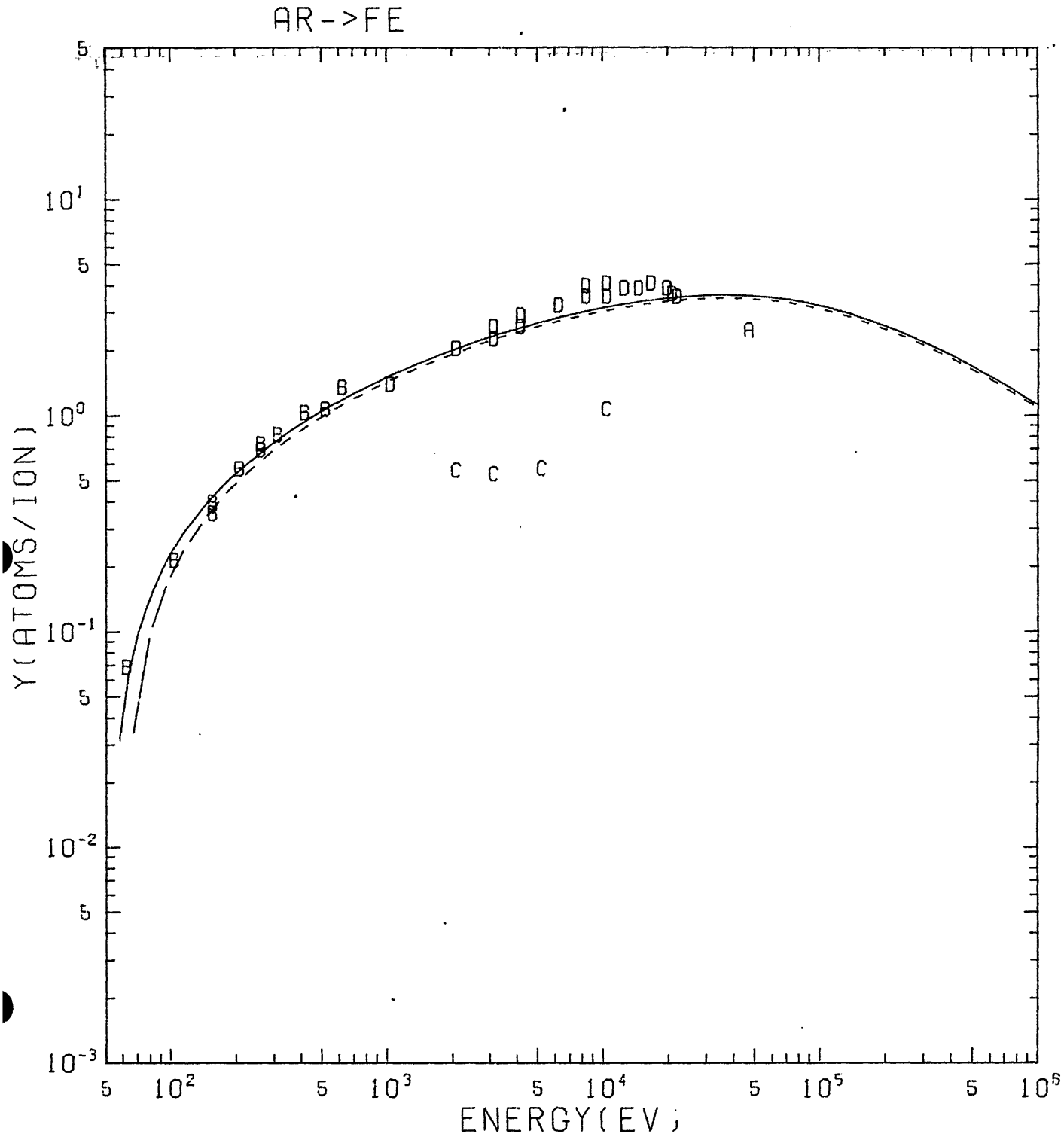
N->FE
A BADER,WITTEBONE,SNCUSE (1960)

Fig. 50



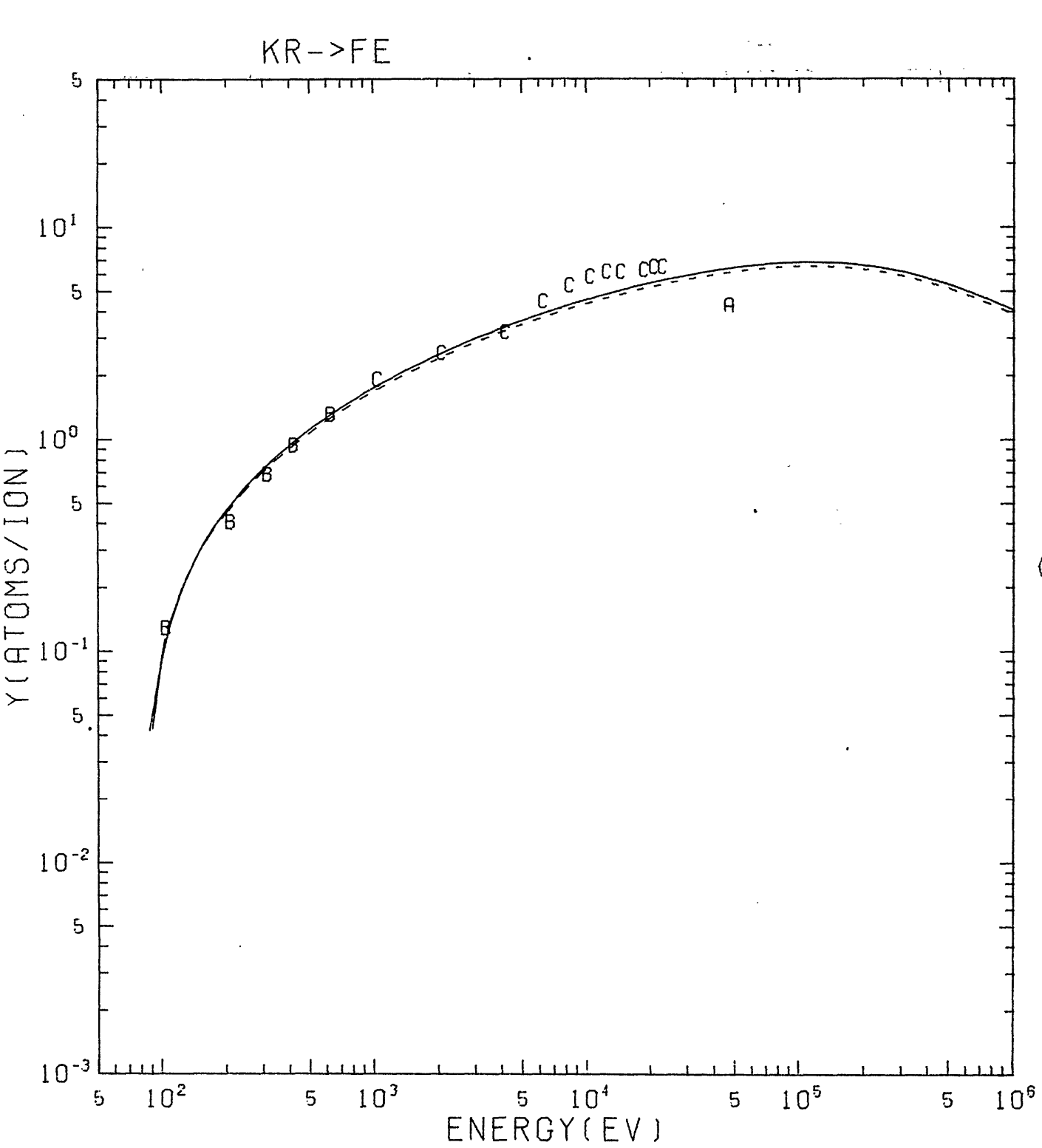
NE->FE
A ALMEN.BRUCE (1961A)
B LAEGREID.WEHNER (1961)

Fig. 51



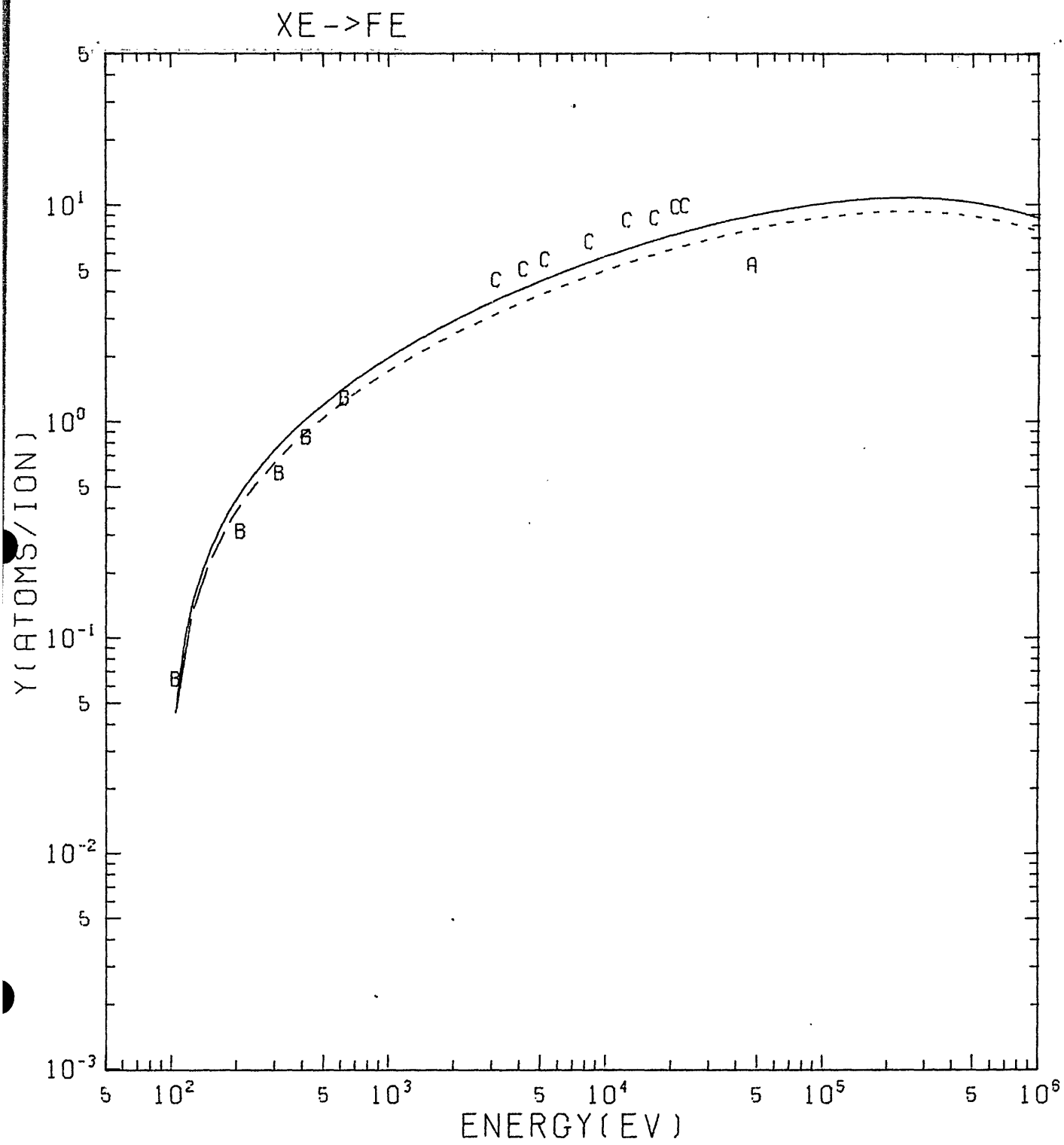
AR->FE
A ALMEN.BRUCE (1961A)
B LAEGREID.WEHNER (1961)
C PATTERSON.TOMLIN (1962)
D KOSHKIN.RYSOV.SHKARBAN (1969)

Fig. 52



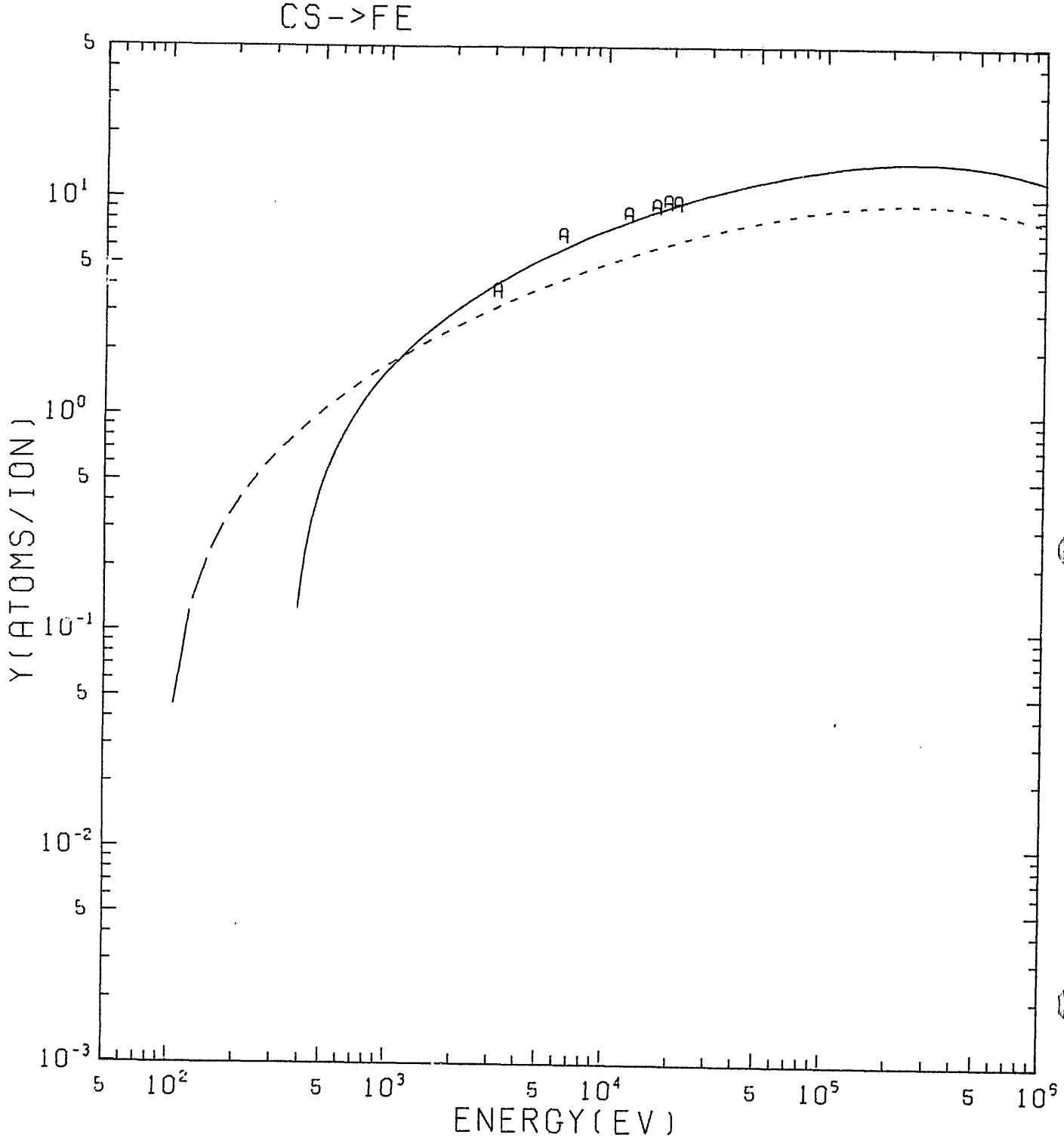
KR->FE
A ALMEN.BRUCE (1961A)
B ROSENBERG.WEHNER (1962)
C KOSHKIN.RYSOV.SHKARBAN (1969)

Fig. 53



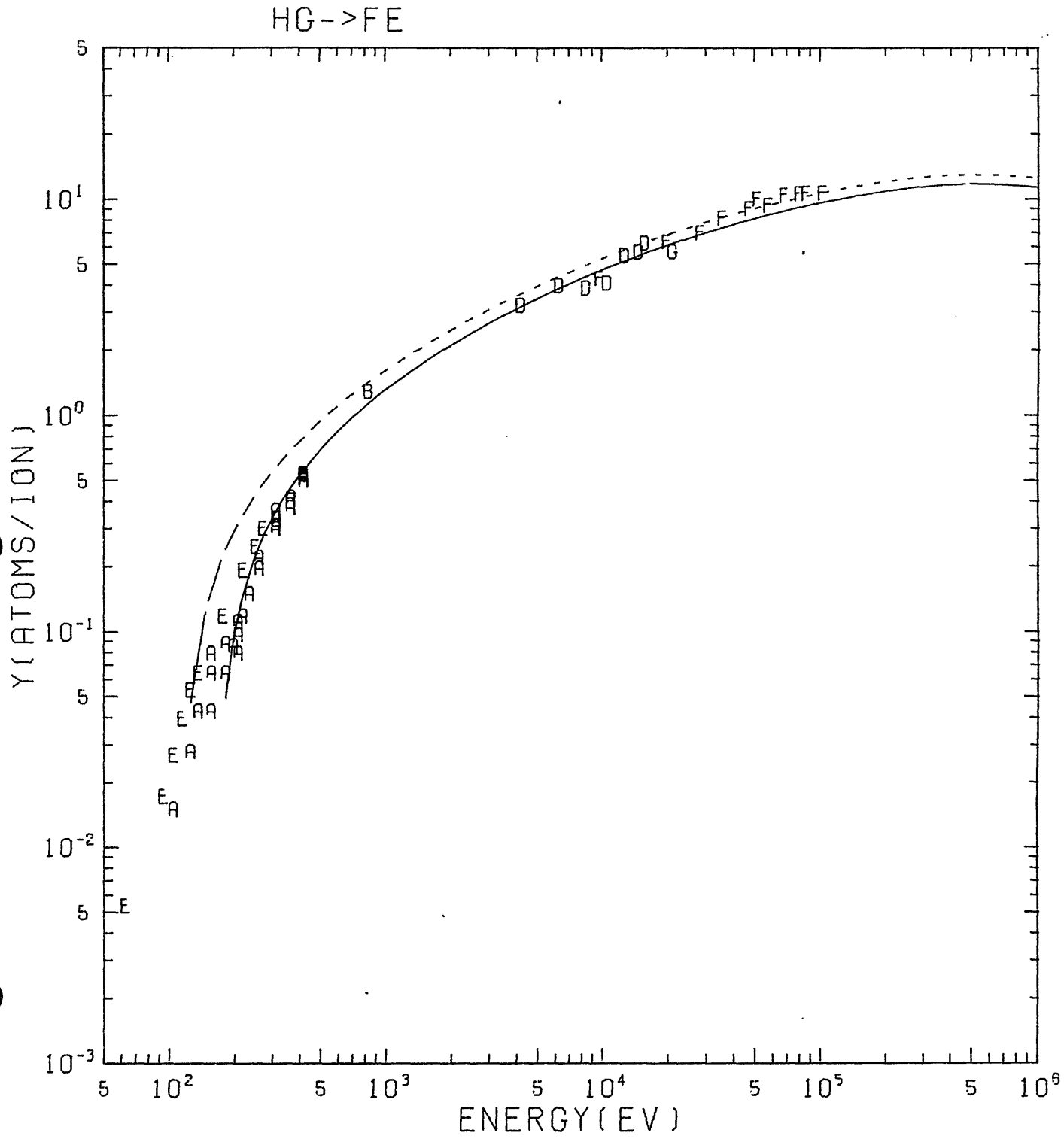
XE->FE
A ALMEN.BRUCE (1961A)
B ROSENBERG.WEHNER (1962)
C KOSHKIN.RYSOV.SHKARBAN (1969)

Fig. 54



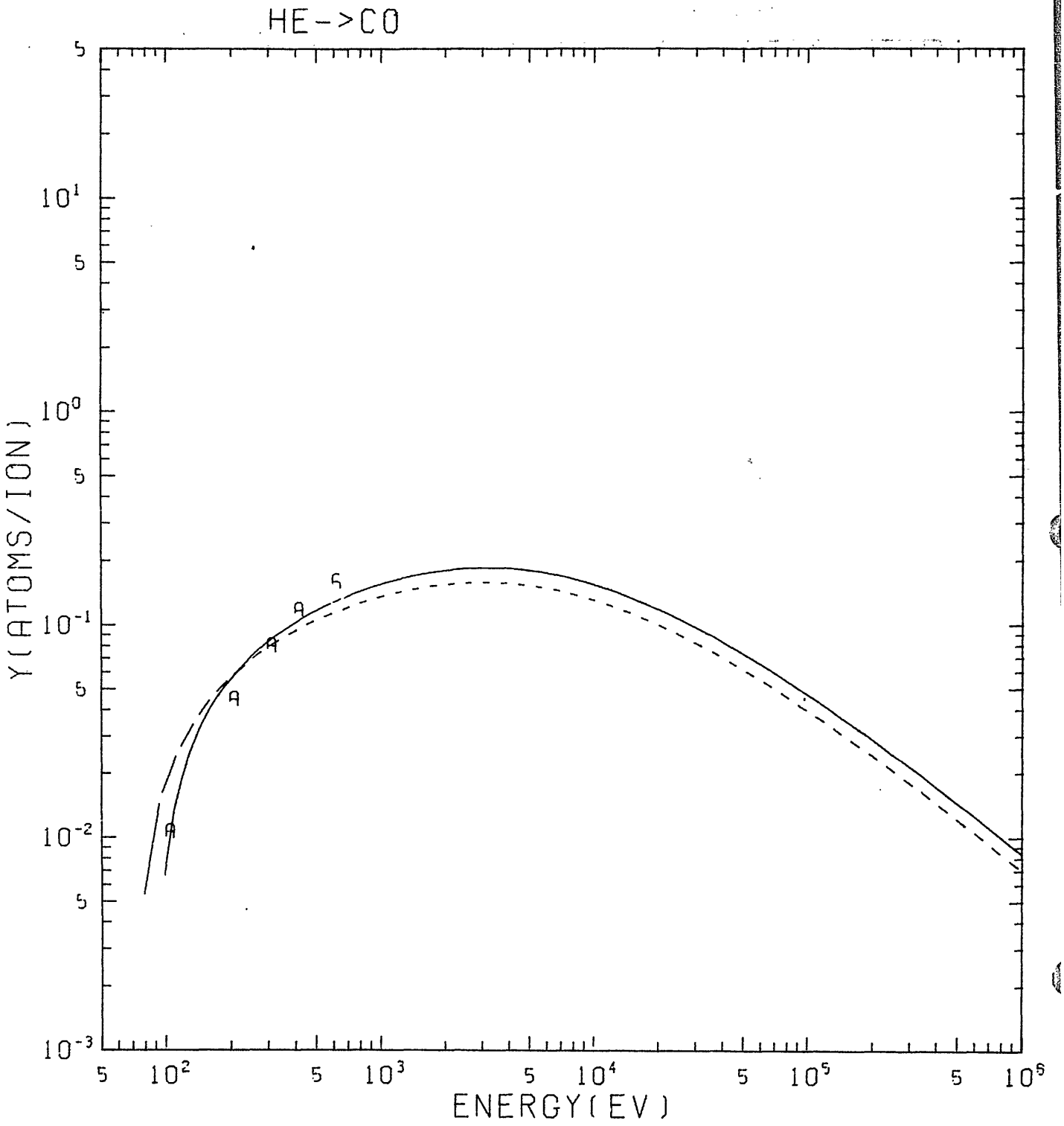
CS->FE
A KOSHKIN.RYSOV.SHKARBAN (1969)

Fig. 55



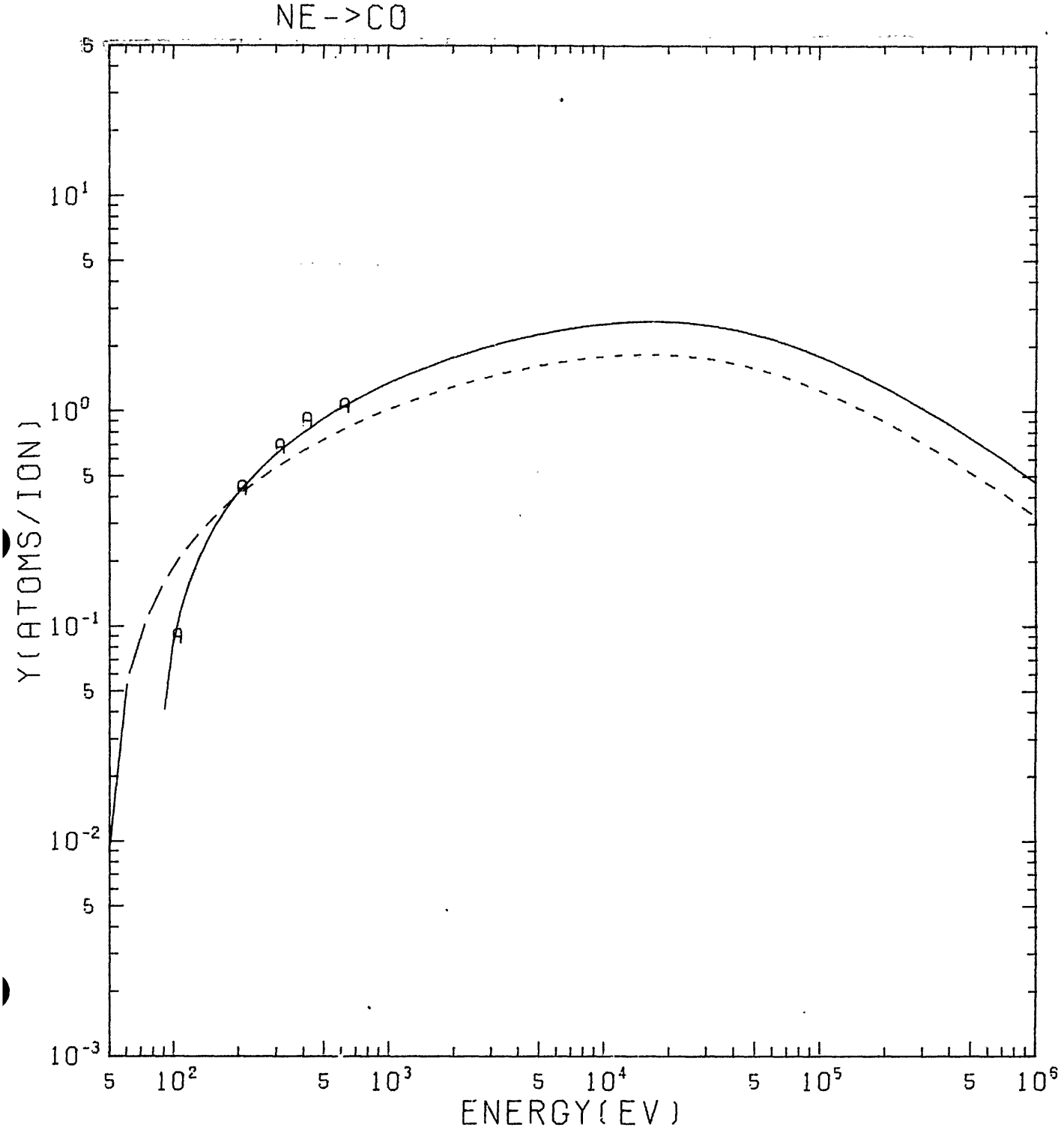
HG->FE
A WEHNER (1957)
B WEHNER (1959)
C LAEGREID,WEHNER (1961)
D WEHNER,ROSENBERG (1961)
E ASKEROV,SENA (1969)
F HOLMEN,ALMEN (1969)
G ISMAIL (1970)

Fig. 56



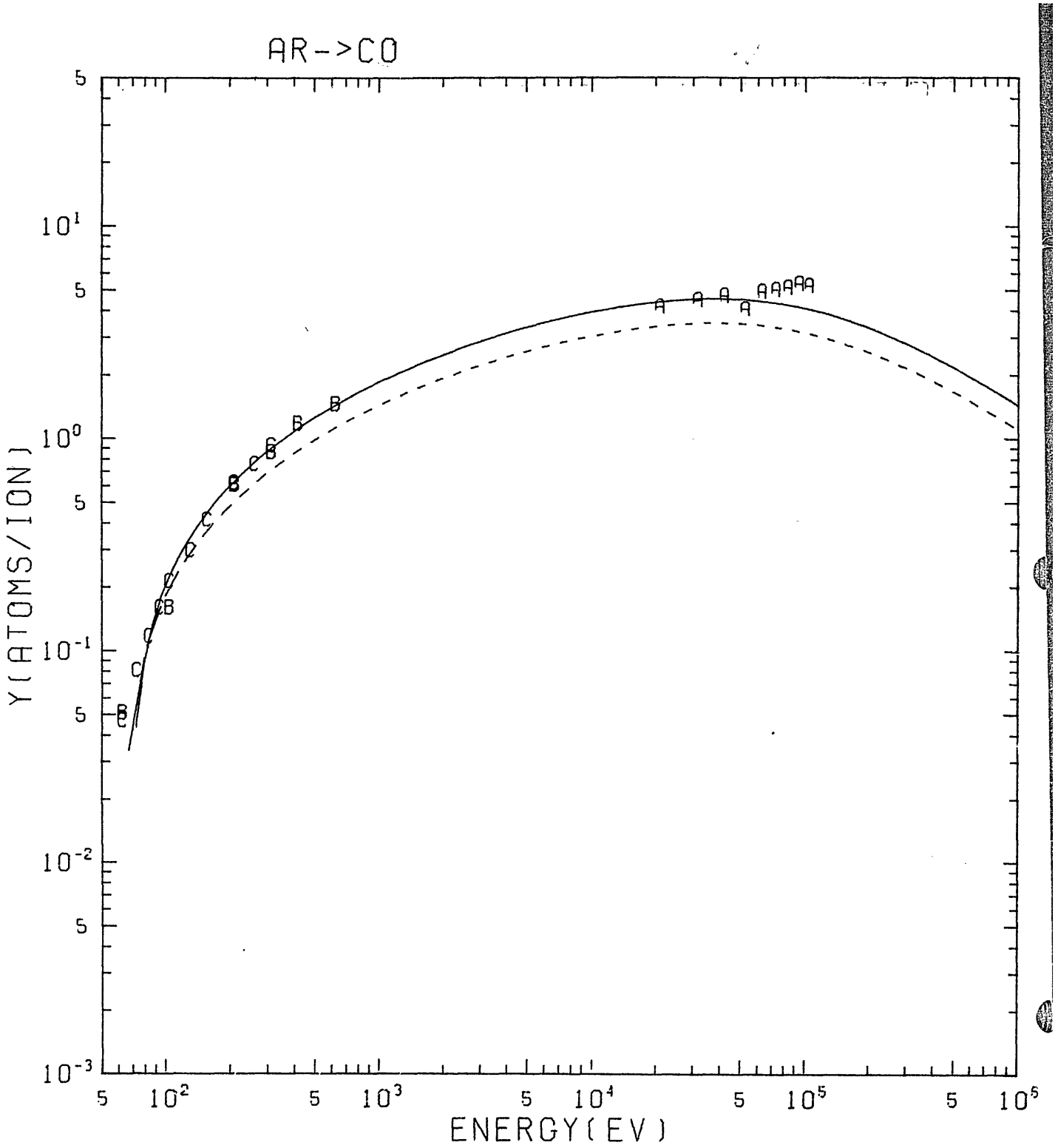
HE->CO
A ROSENBERG,WEHNER (1962)

Fig. 57



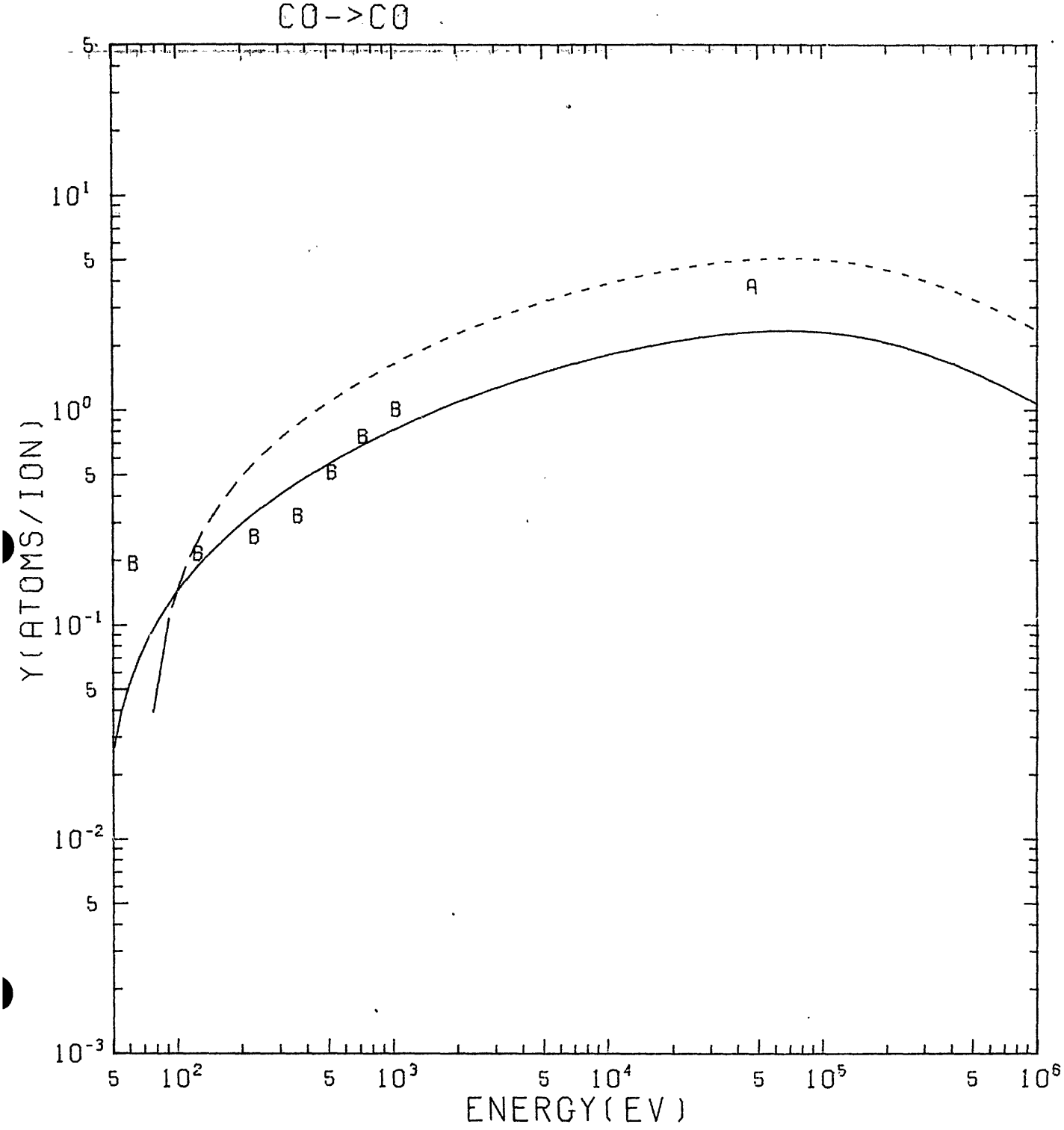
NE->CO
A LAEGREID.WEHNER (1961)

Fig. 58



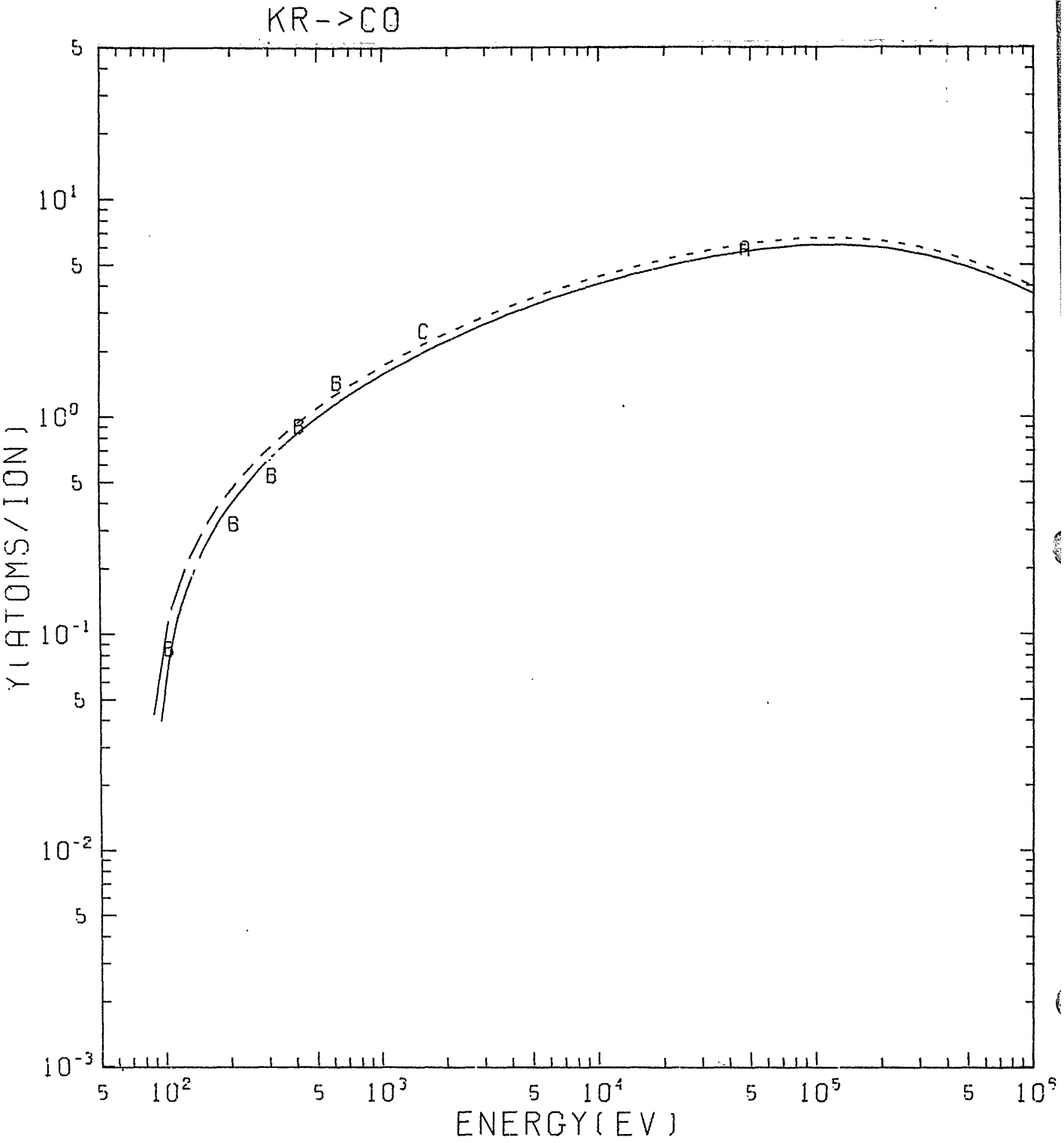
AR->CO
A FERT.COLOMBIE.FAGOT (1961)
B LAEGREID.WEHNER (1961)
C STUART.WEHNER (1962)

Fig. 59



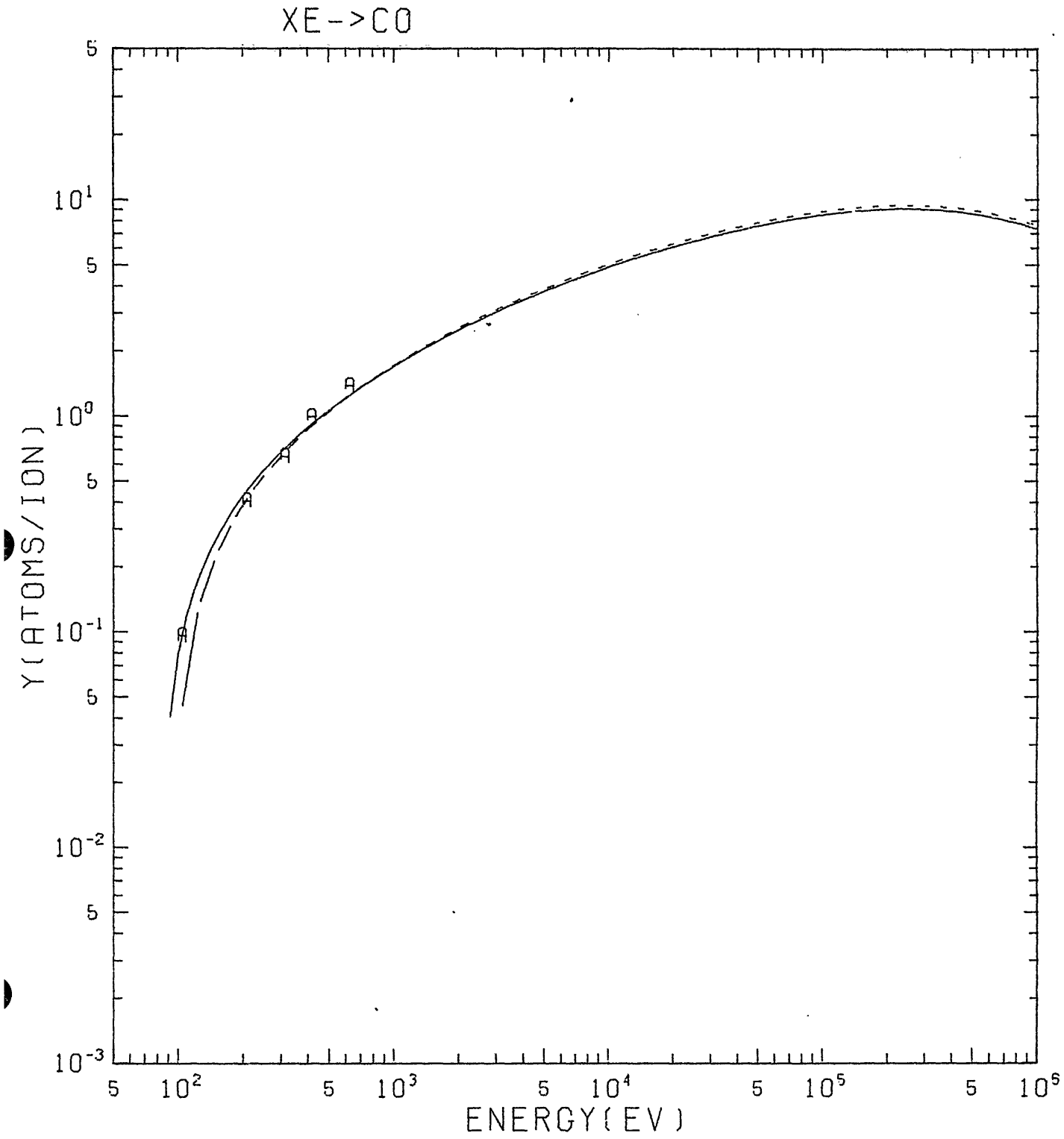
CO->CO
A ALMEN.BRUCE (1961B)
B FONTELL.ARMINEN (1969)

Fig. 60



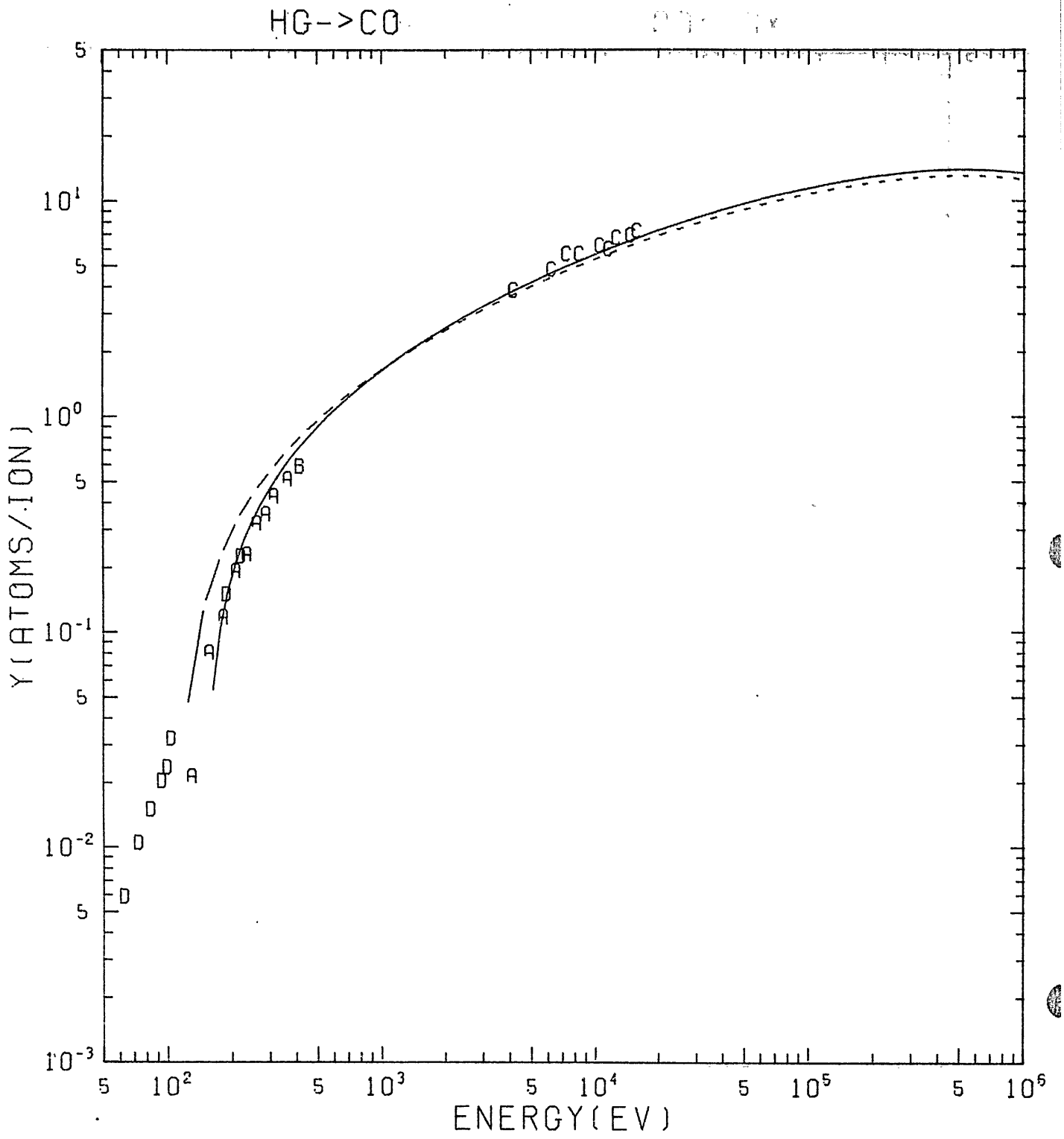
KR->CO
A ALMEN,BRUCE (1961A)
B ROSENBERG,WEHNER (1962)
C DAHLGREN,MCCLANAHAN (1972)

Fig. 61



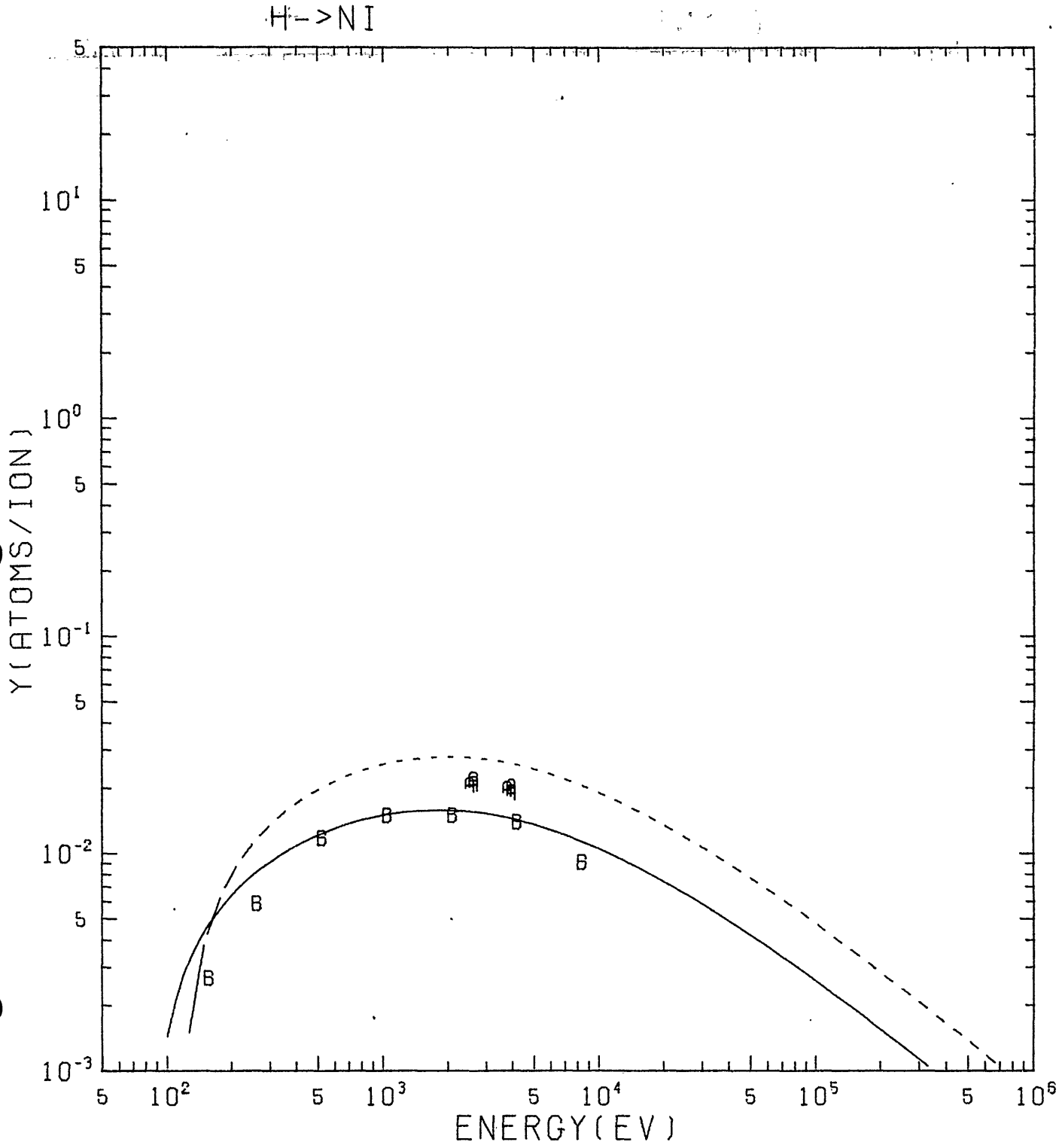
XE->CO
A ROSENBERG,WEHNER (1962)

Fig. 62



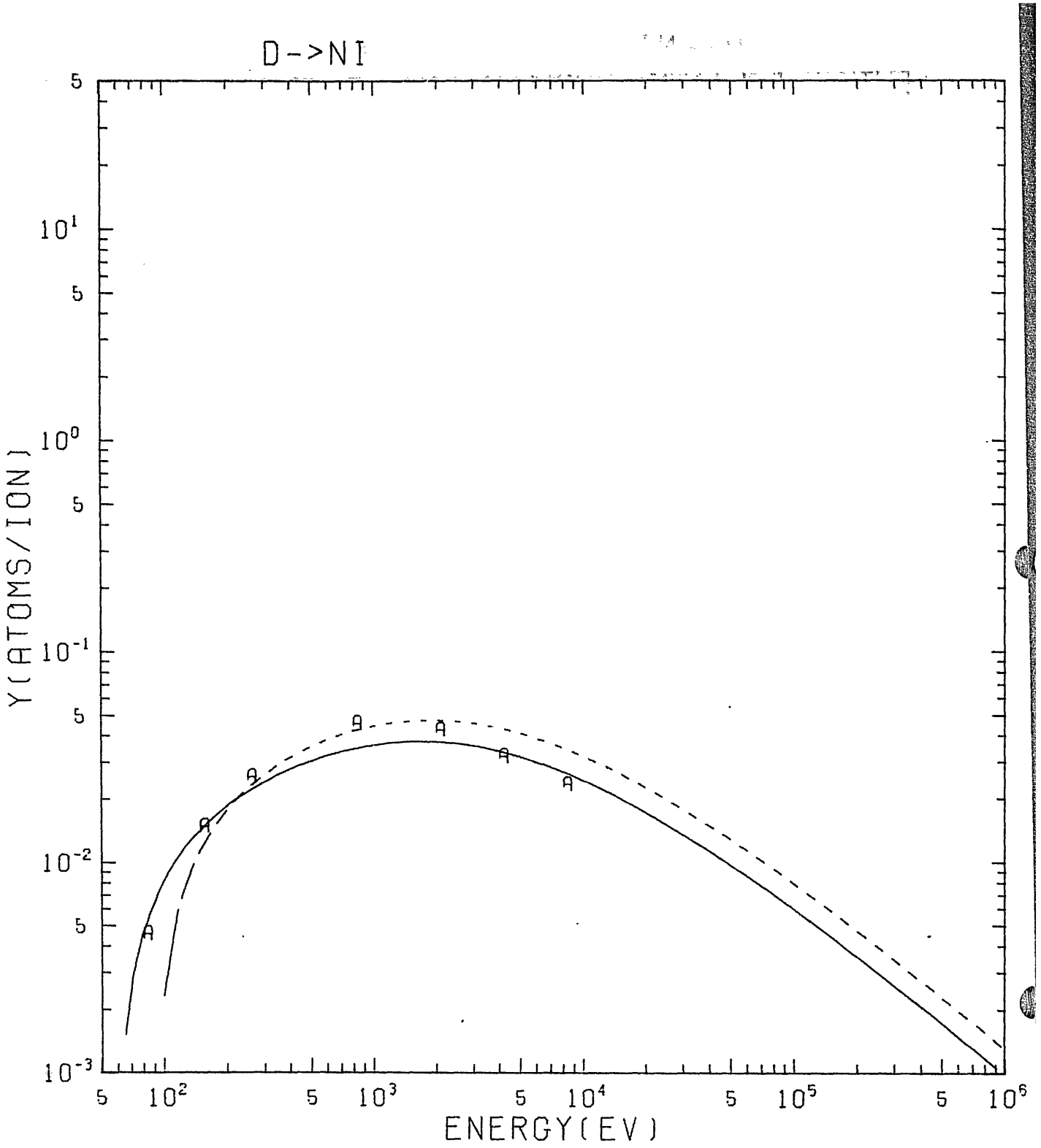
HG->CO
A WEHNER (1957)
B LAEGREID,WEHNER (1961)
C WEHNER,ROSENBERG (1961)
D ASKEROV,SENA (1969)

Fig. 63



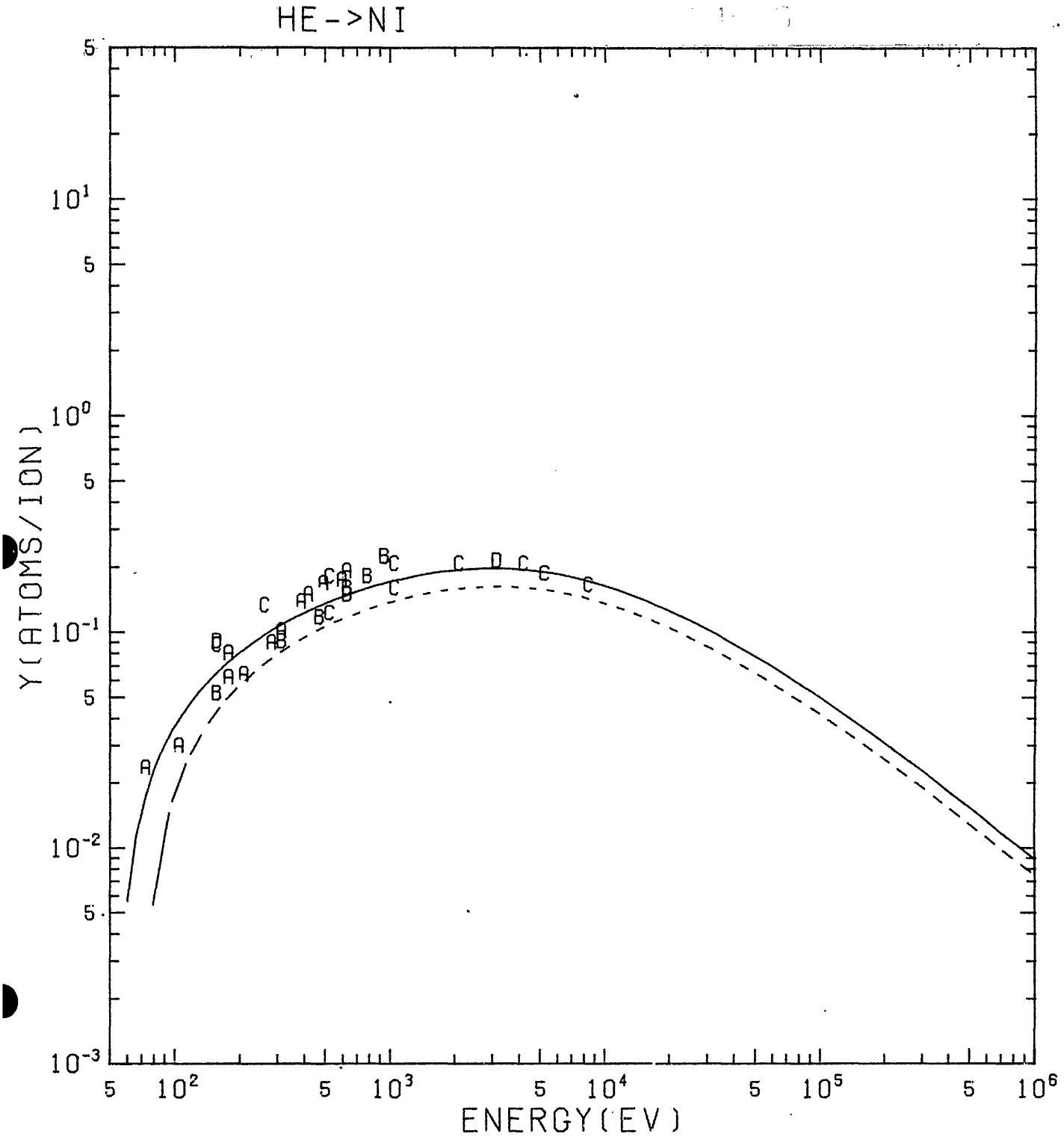
H->NI
A KENKNIGHT,WEHNER (1964)
B BOHDANSKY,BAY,ROTH (1977)

Fig. 64



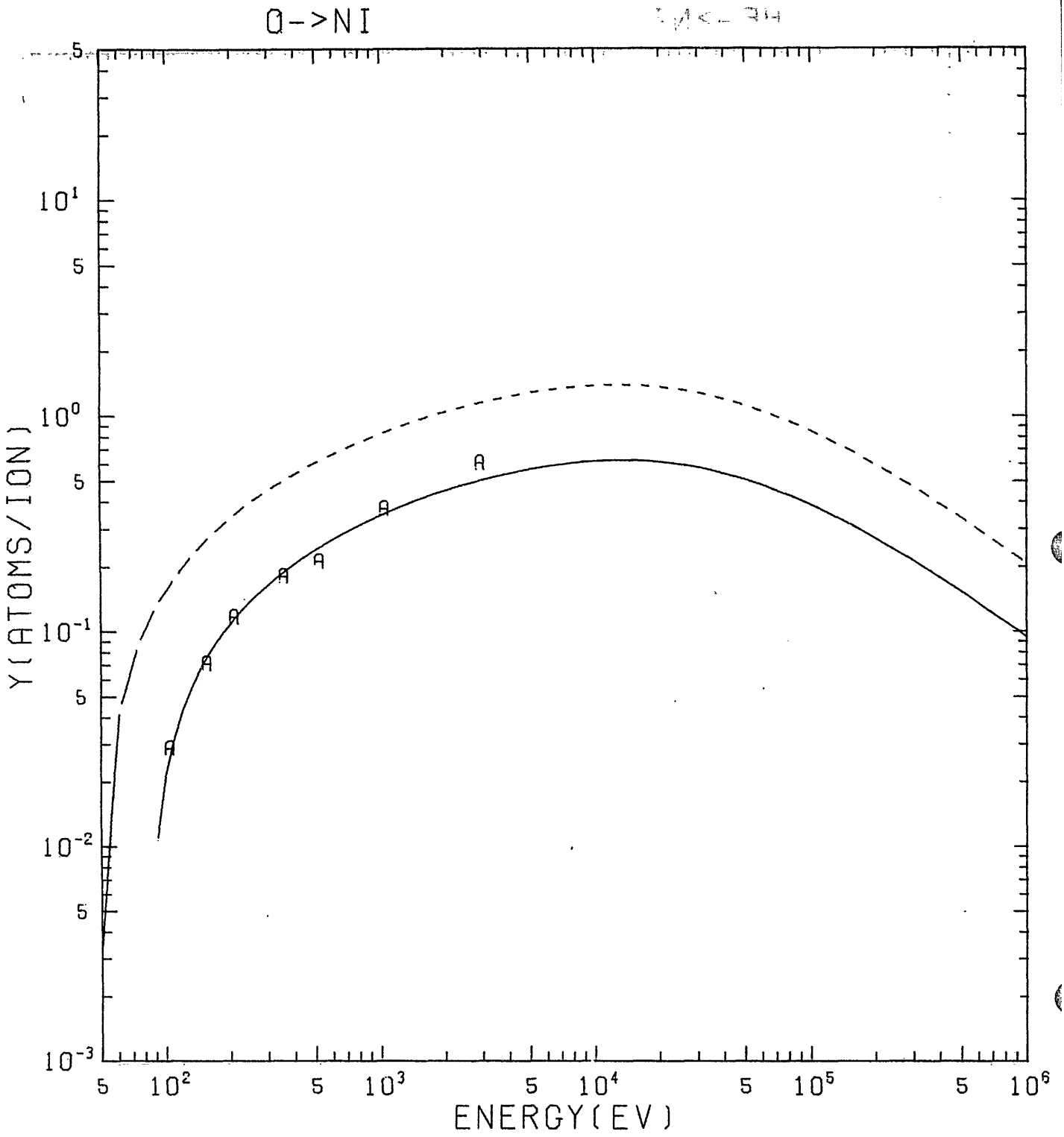
D->NI
A BOHDANSKY,BAY,ROTH (1977)

Fig. 65



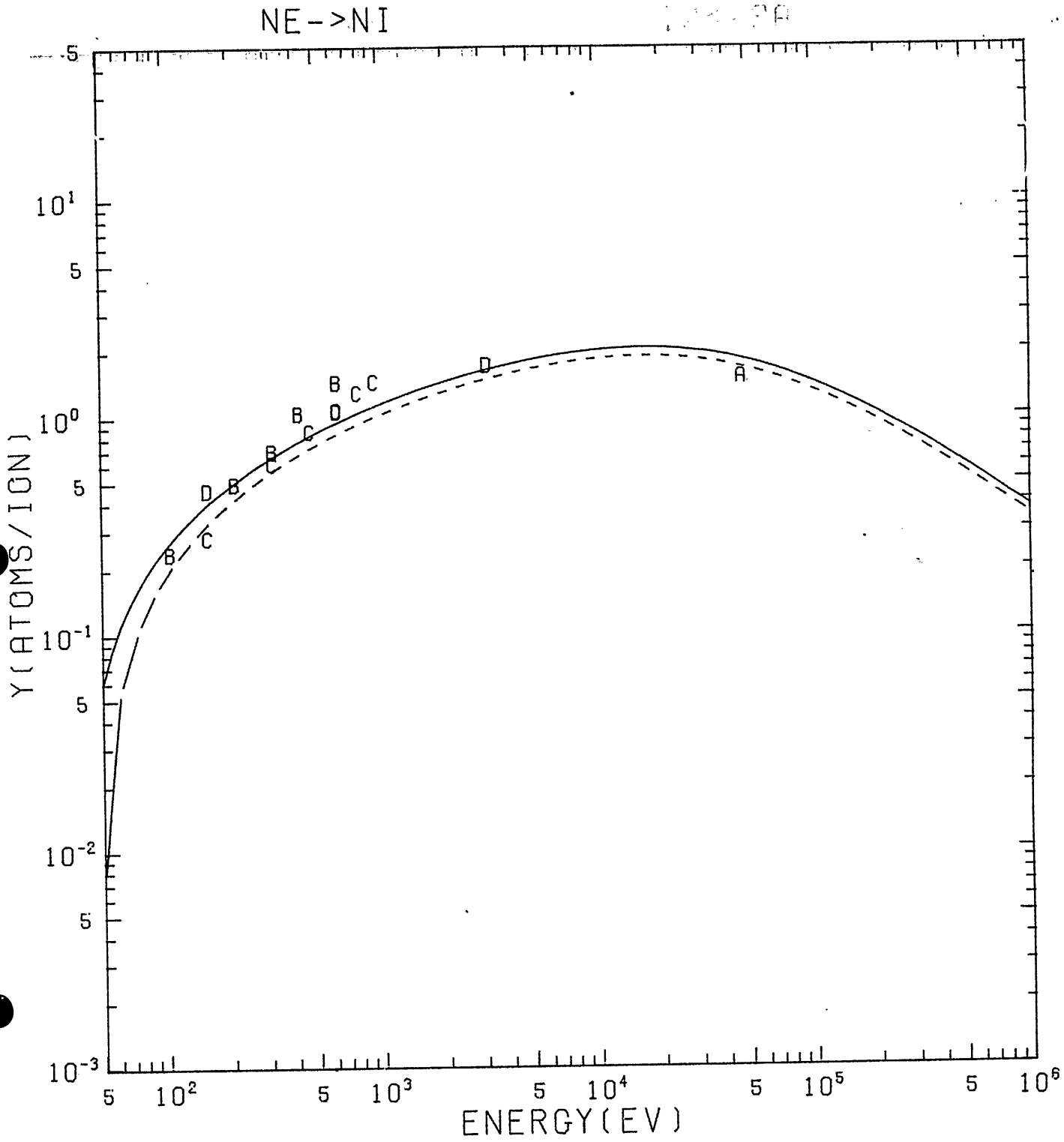
HE->NI
A ROSENBERG,WEHNER (1962)
B FETZ,OECHSNER (1963)
C BOHDANSKY,BAY,ROTH (1977)
D BAY,BOHDANSKY,HECHTL (1979)

Fig. 66



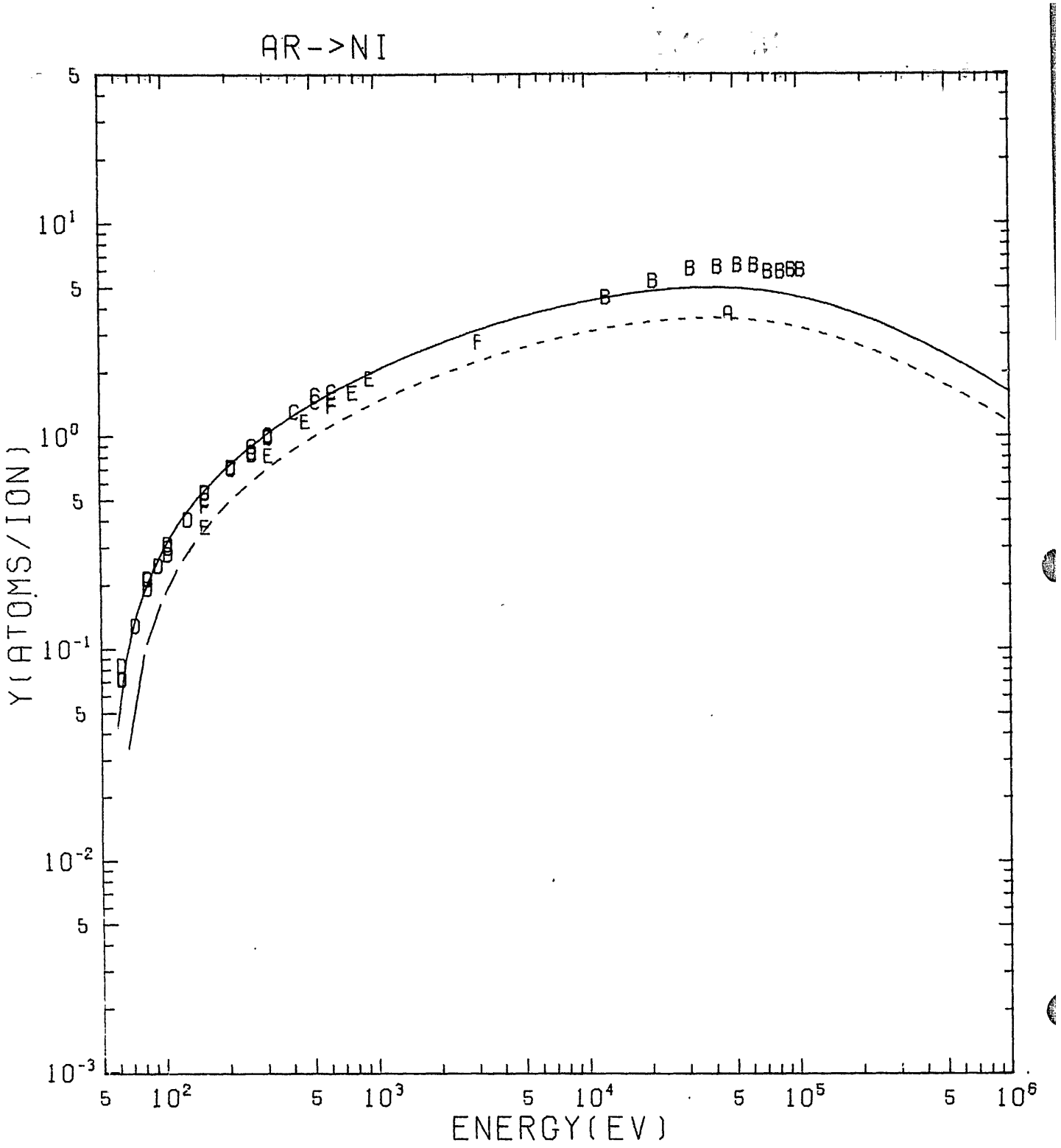
O->NI
A BAY.BOHDANSKY.HECHTL (1979)

Fig. 67



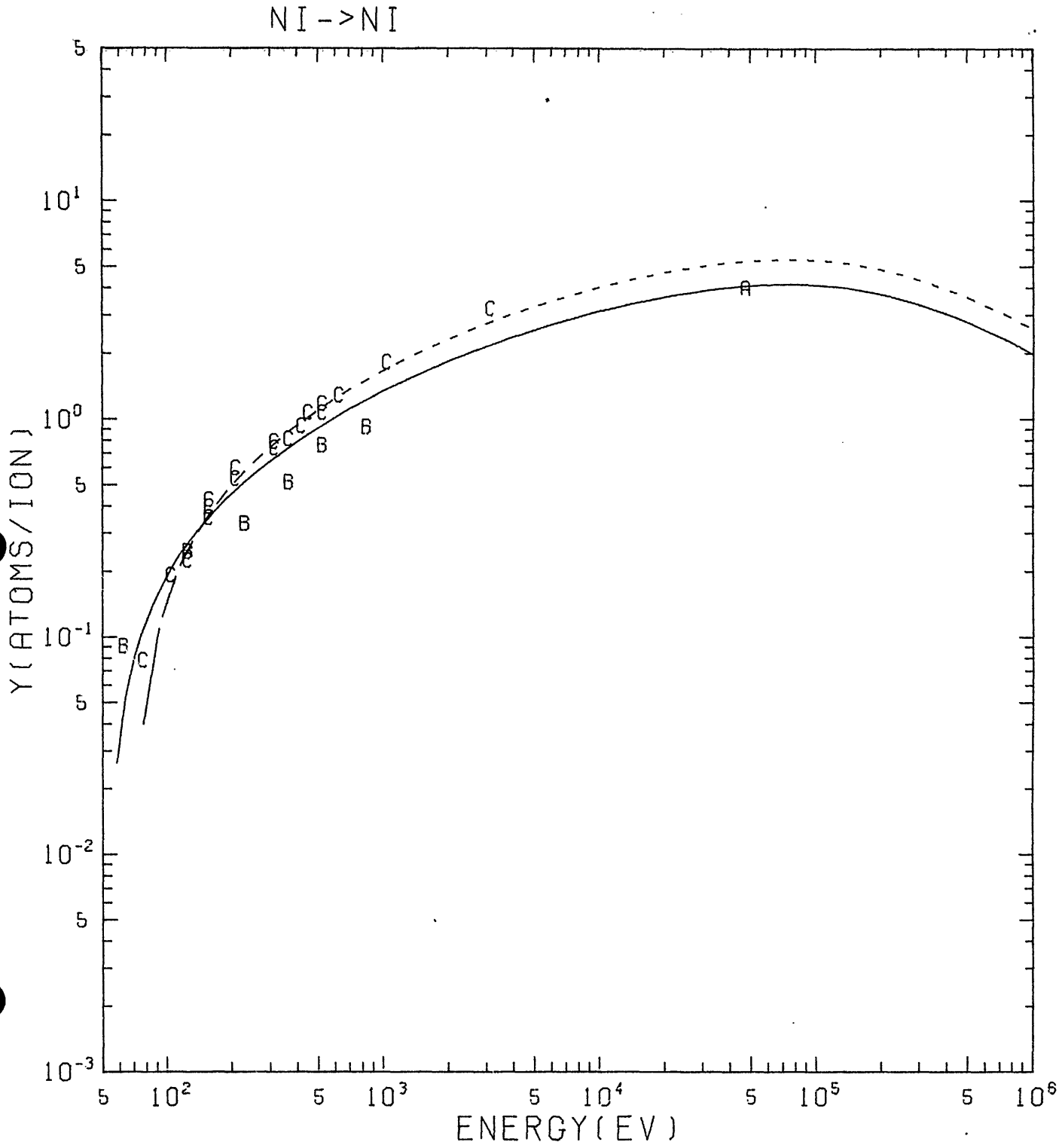
NE->NI
A ALMEN.BRUCE (1961A)
B LAEGREID.WEHNER (1961)
C FETZ,OECHSNER (1963)
D BAY.BOHDANSKY.HECHTL (1979)

Fig. 68



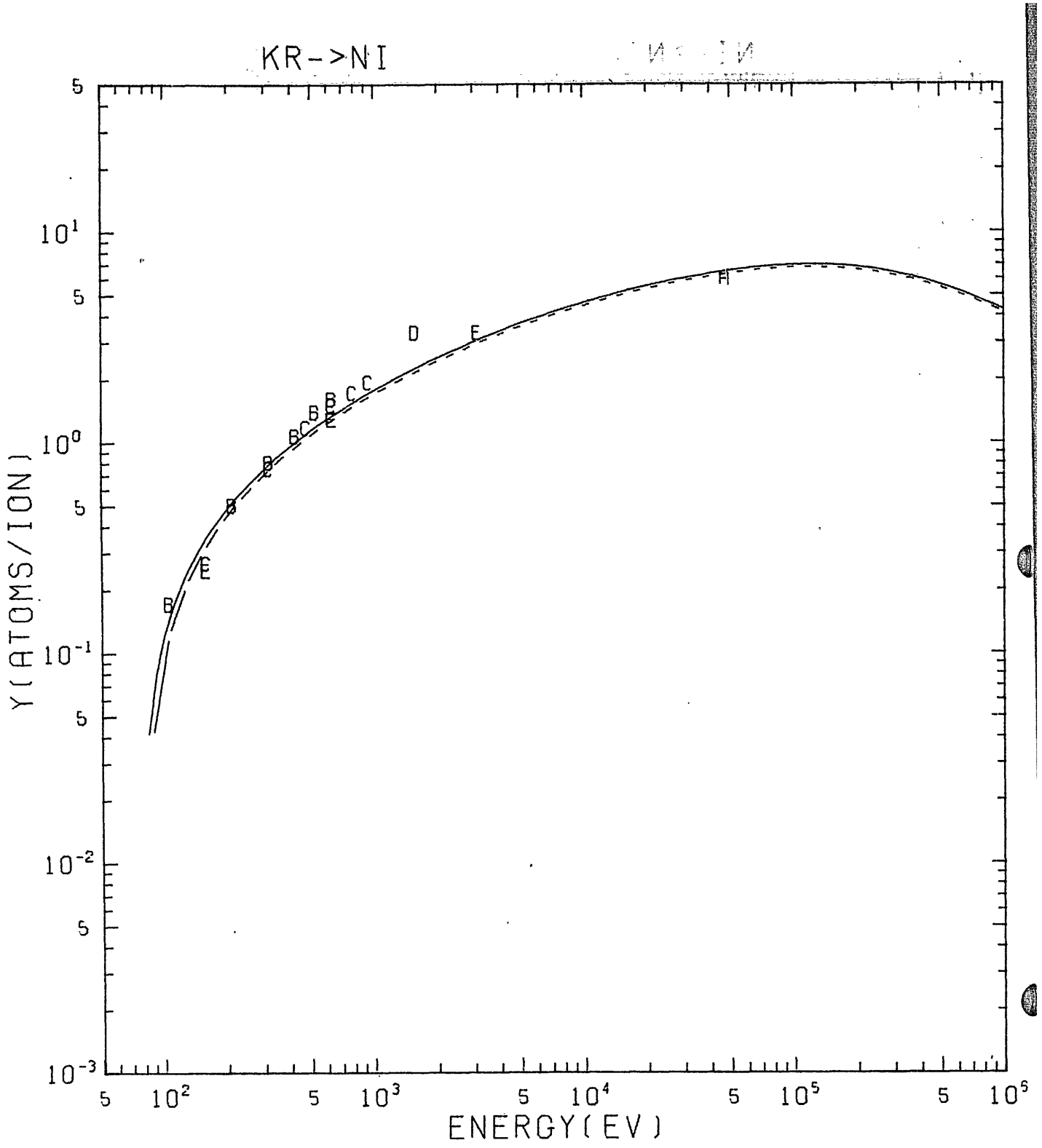
AR->NI
A ALMEN.BRUCE (1961A)
B FERT.CLOMBIE.CHUONG (1961)
C LAEGREID.WEHNER (1961)
D STUART.WEHNER (1962)
E FETZ.OECHSNER (1963)
F BAY.BOHDANSKY.HECHTL (1979)

Fig. 69



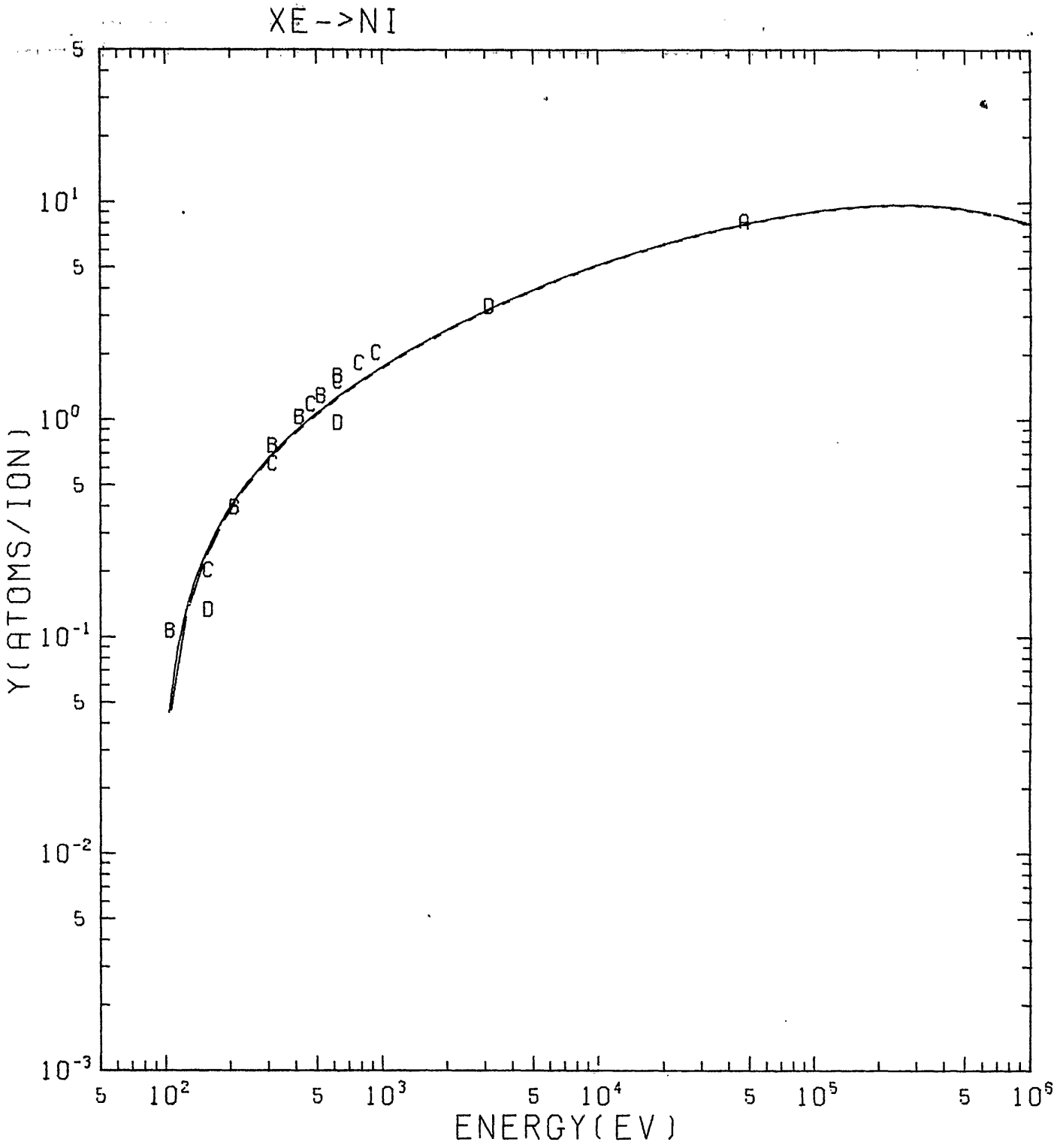
NI->NI
A ALMEN.BRUCE (1961B)
B FONTELL.ARMINEN (1969)
C HECHTL.BAY.BOHDANSKY (1978)

Fig. 70



KR->NI
A ALMEN.BRUCE (1961A)
B ROSENBERG.WEHNER (1962)
C FETZ.OECHSNER (1963)
D DAHLGREN.MCCLANAHAN (1972)
E BAY.BOHDANSKY.HECHTL (1979)

Fig. 71



XE->NI

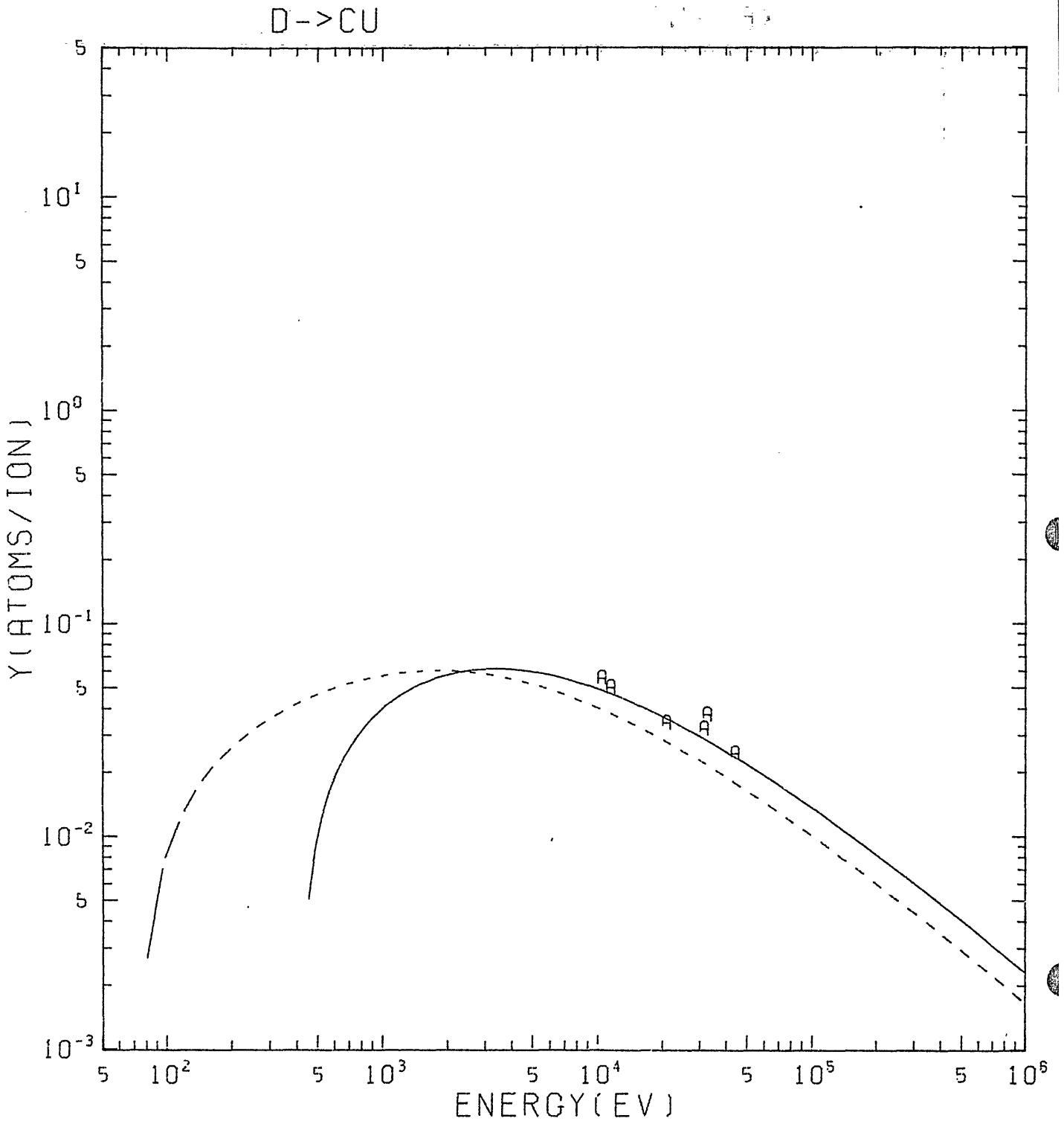
A ALMEN.BRUCE (1961A)

B ROSENBERG.WEHNER (1962)

C FETZ.OECHSNER (1963)

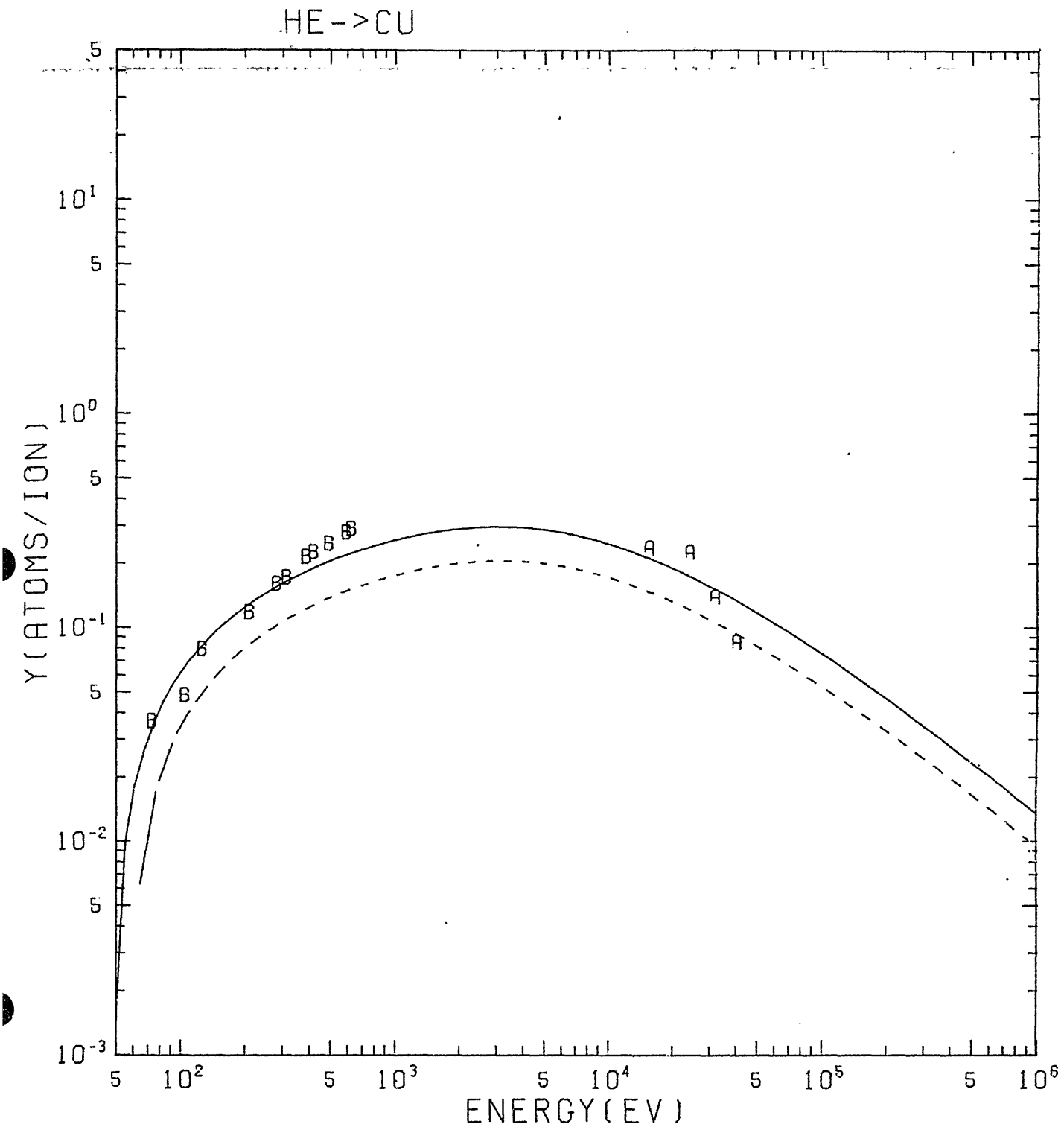
D BAY.BOHDANSKY.HECHTL (1979)

Fig. 72



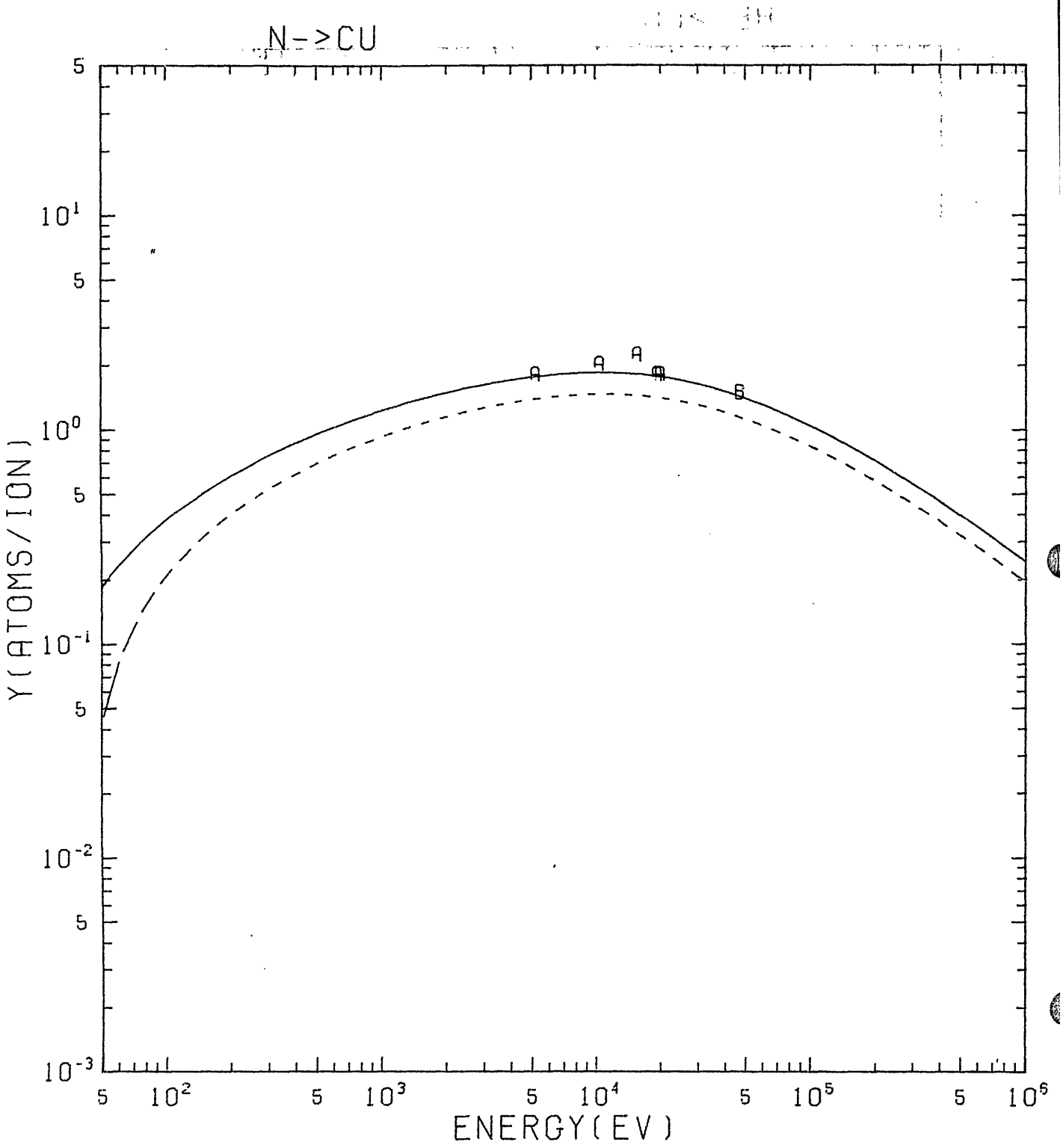
D->CU
A YONTS,NORMAND,HARRISON (1960)

Fig. 73



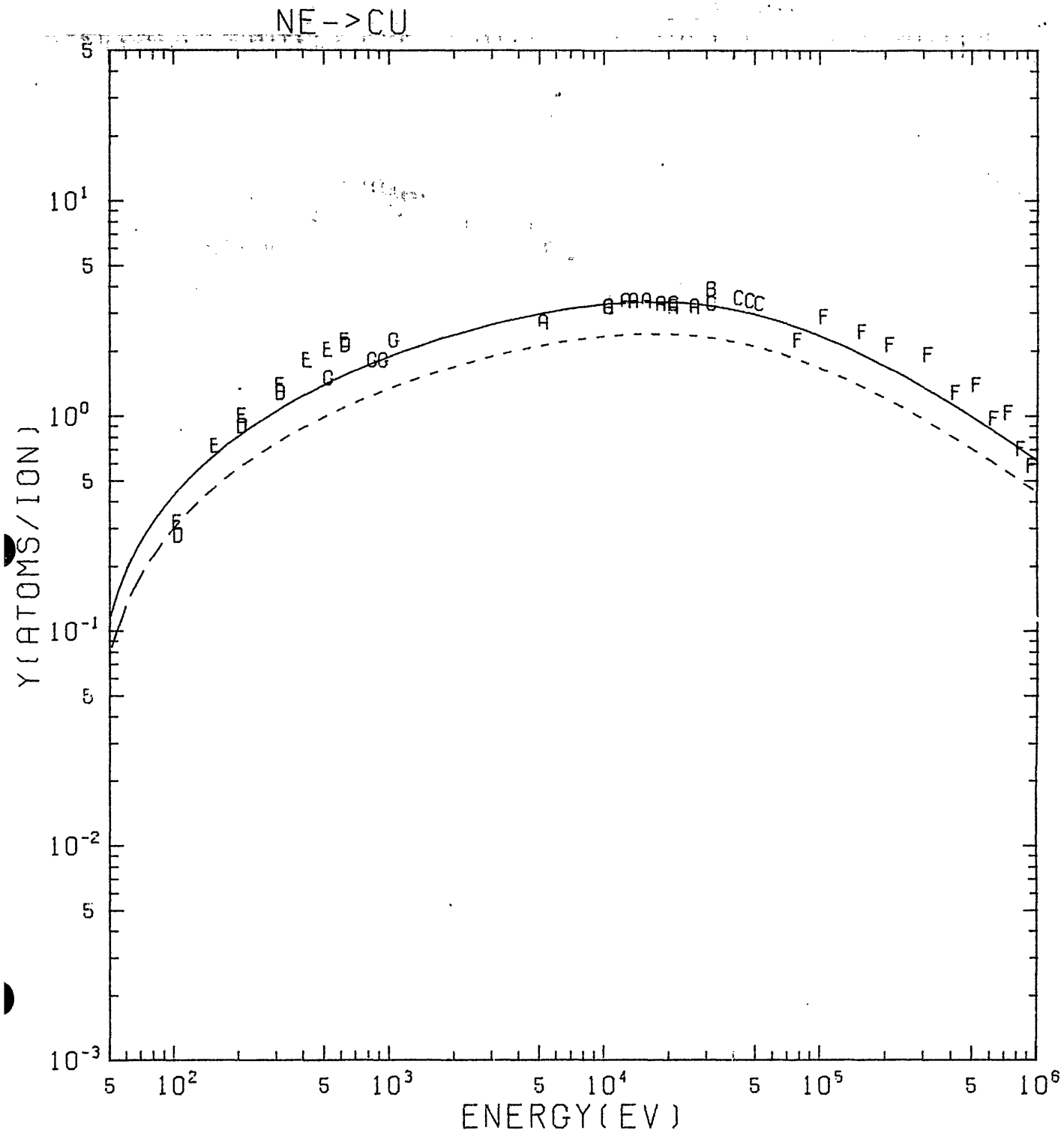
HE->CU
A YONTS.NORMAND.HARRISON (1960)
B ROSENBERG.WEHNER (1962)

Fig. 74



N->CU
A ROL.FLUIT.KISTEMAKER (1960)
B ALMEN.BRUCE (1961B)

Fig. 75



NE->CU
A ROL.FLUIT.KISTEMAKER (1960)
B YONTS.NORMAND.HARRISON (1960)
C ALMEN.BRUCE (1961A)
D LAEGREID.WEHNER (1961)
E WEHNER.STUART.ROSENBERG (1961)
F DUPP.SCHARMANN (1966)
G WEIJSENFELD (1966)

Fig. 76

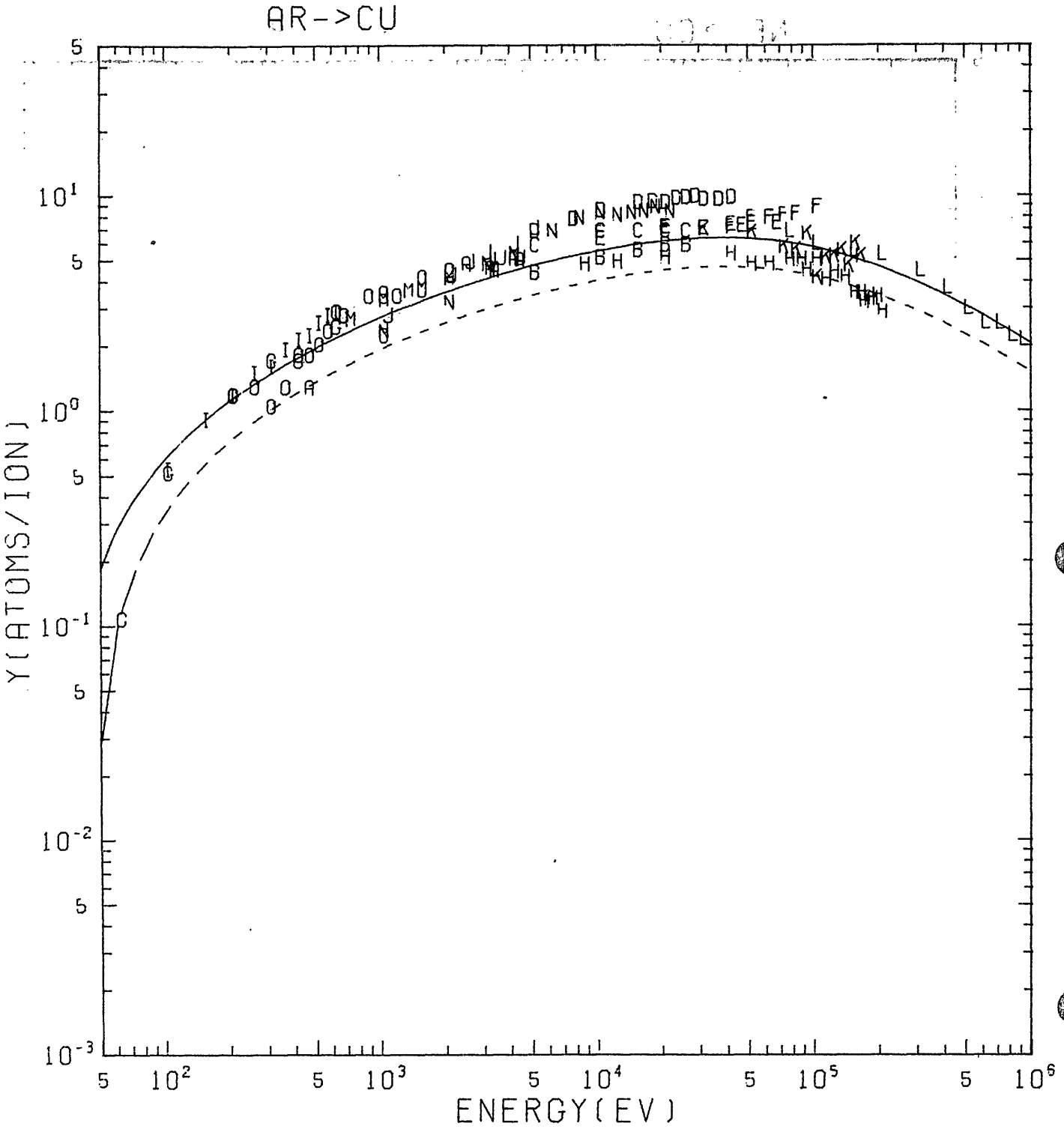
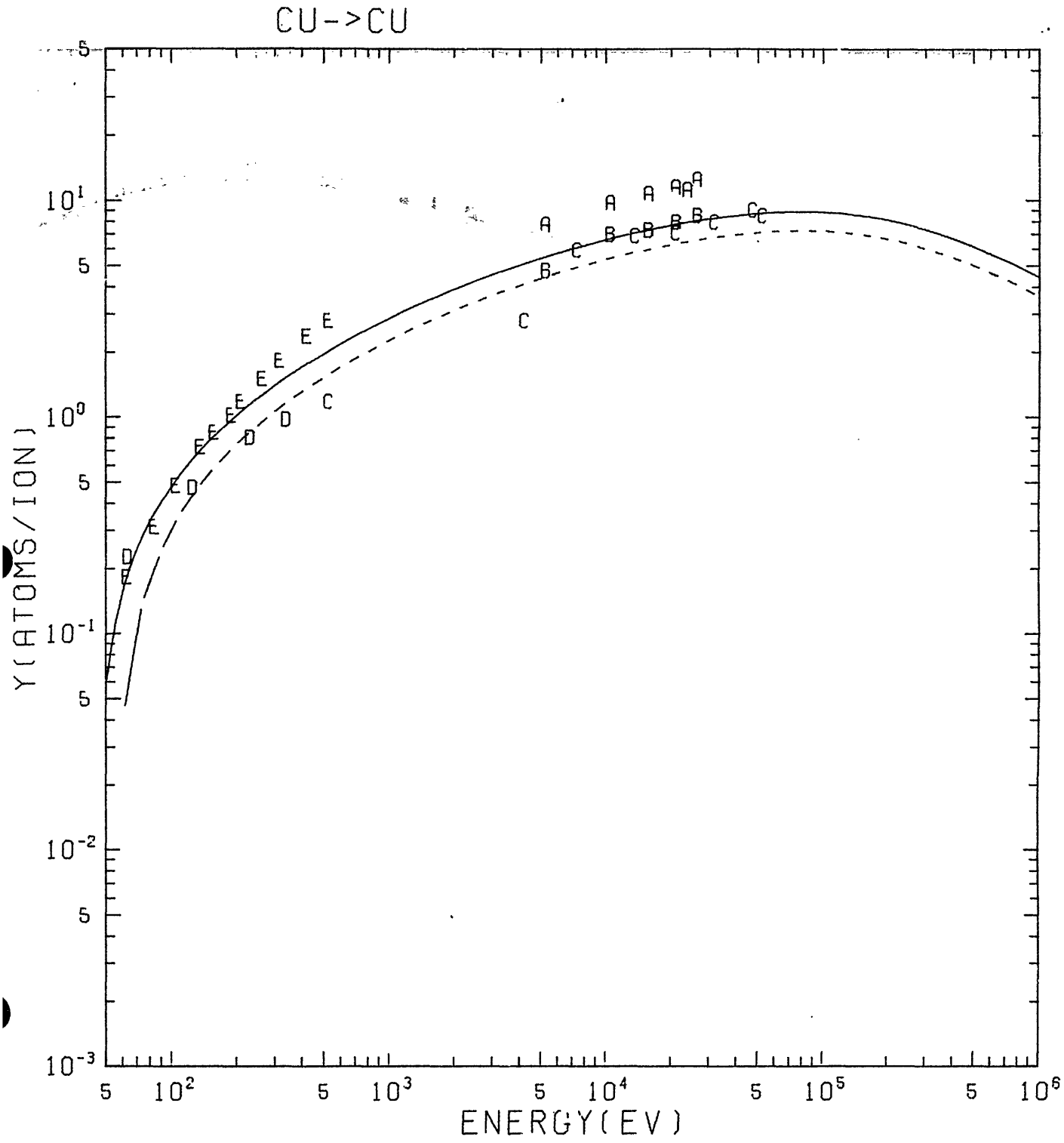


Fig. 77

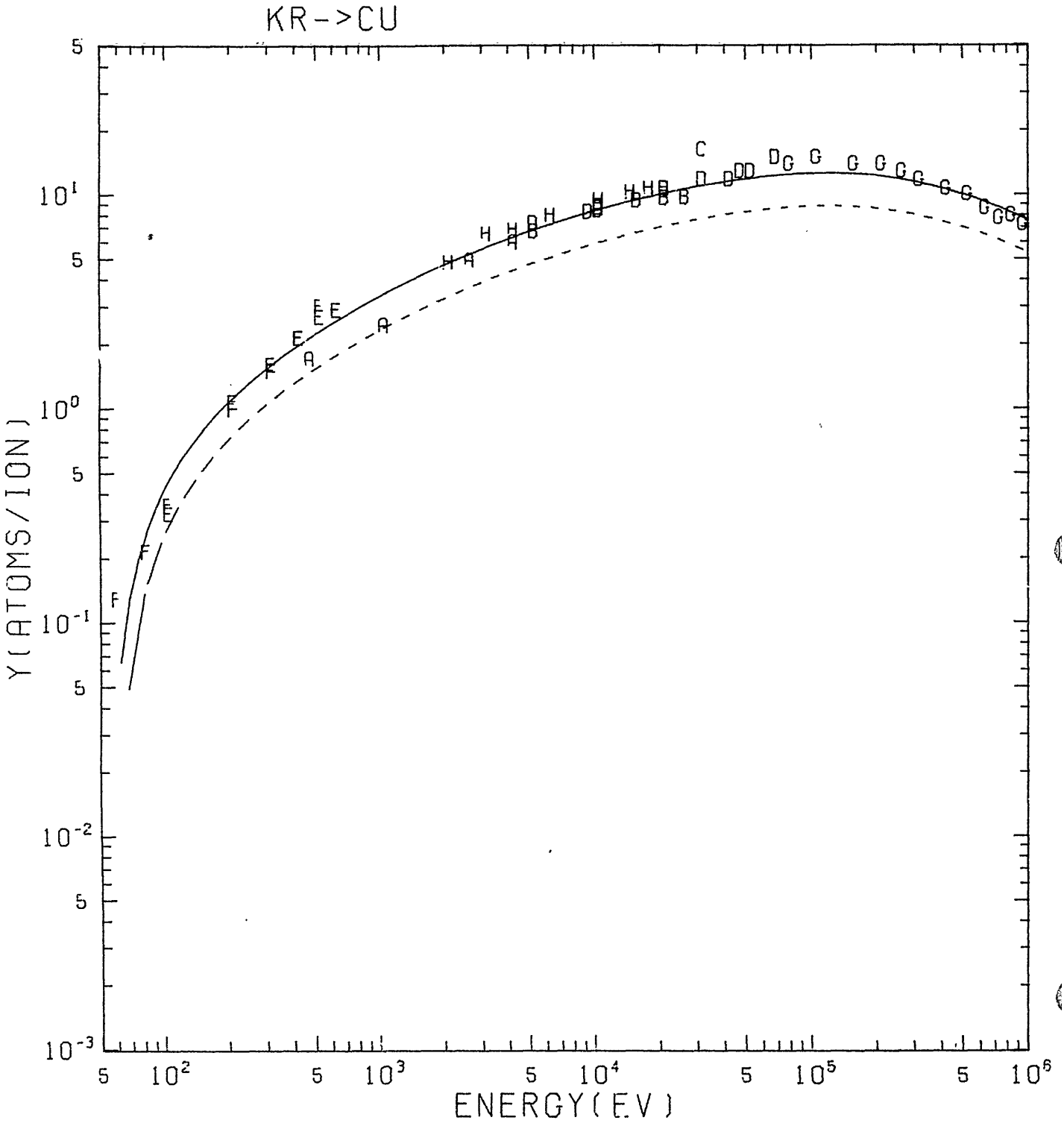
AR->CU

A KEYWELL (1955)
B GUSEVA (1960)
C ROL.FLUIT.KISTEMAKER (1960)
D YONTS.NORMAND.HARRISON (1960)
E ALMEN.BRUCE (1961A)
F FERT.COLOMBIE.FAGOT (1961)
G LAEGREID.WEHNER (1961)
H PEROVIC.COBIC (1961)
I WEHNER.STUART.ROSENBERG (1961)
J SOUTHERN.WILLIS.ROBINSON (1963)
K RAMER.NARASIMHAM.REYNOLDS (1964)
L DÜPP.SCHARMANN (1966)
M WEIJSENFELD (1966)
N KOSHKIN.RYSOV.SHKARBAN (1969)
O AKAISHI.MIYAHARA.KABEYA (1977)



CU->CU
A GUSEVA (1960)
B ROL.FLUIT.KISTEMAKER (1960)
C ALMEN.BRUCE (1961B)
D FONTELL.ARMINEN (1969)
E HAYWARD.WOLTER (1969)

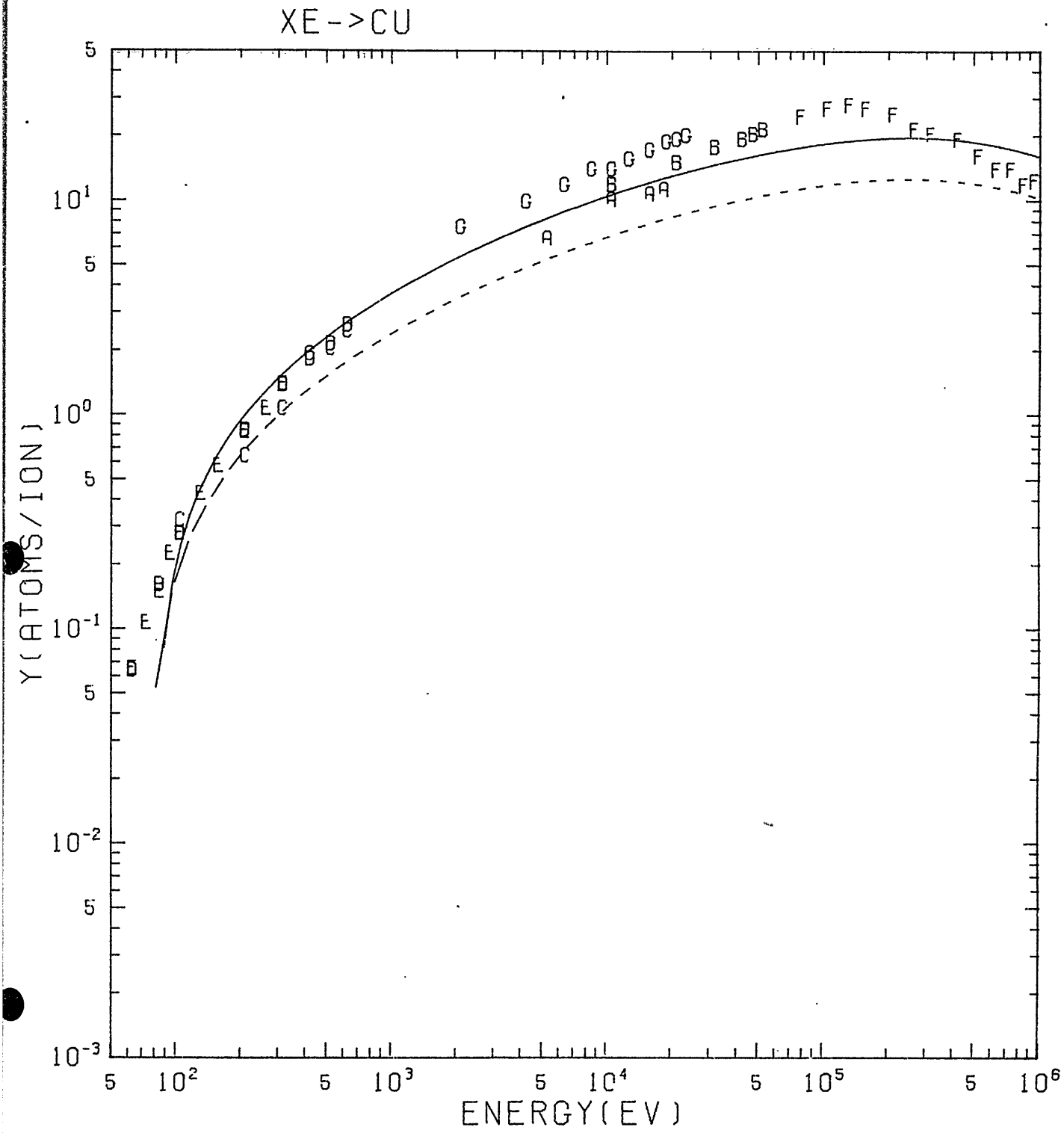
Fig. 78



KR->CU

A KEYWELL (1955)
B GUSEVA (1960)
C YONTS,NORMAND,HARRISON (1960)
D ALMEN,BRUCE (1961A)
E WEHNER,STUART,ROSENBERG (1961)
F ROSENBERG,WEHNER (1962)
G DUPP,SCHARMANN (1966)
H KOSHKIN,RYSOV,SHKARBAN (1969)

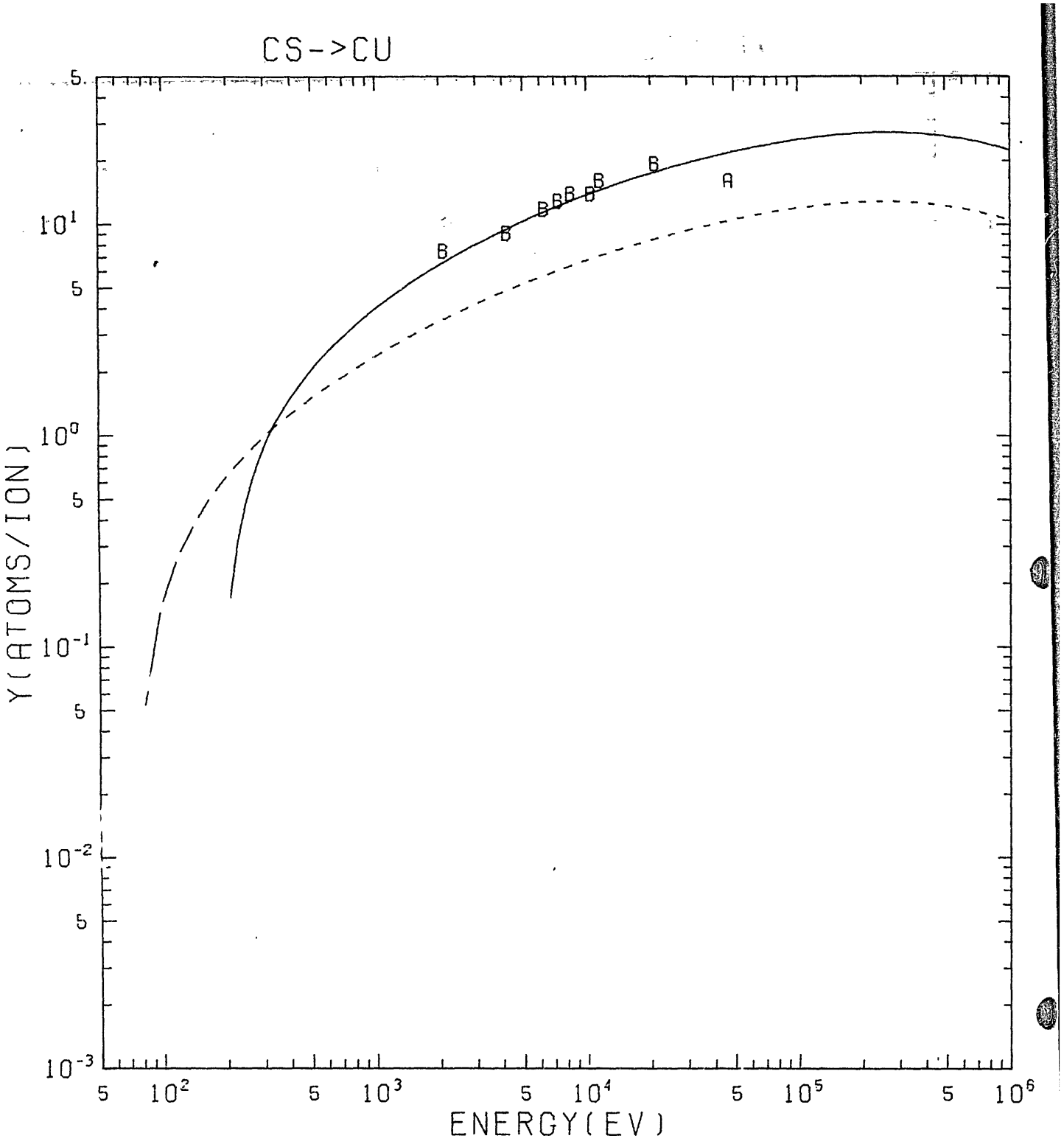
Fig. 79



XE->CU

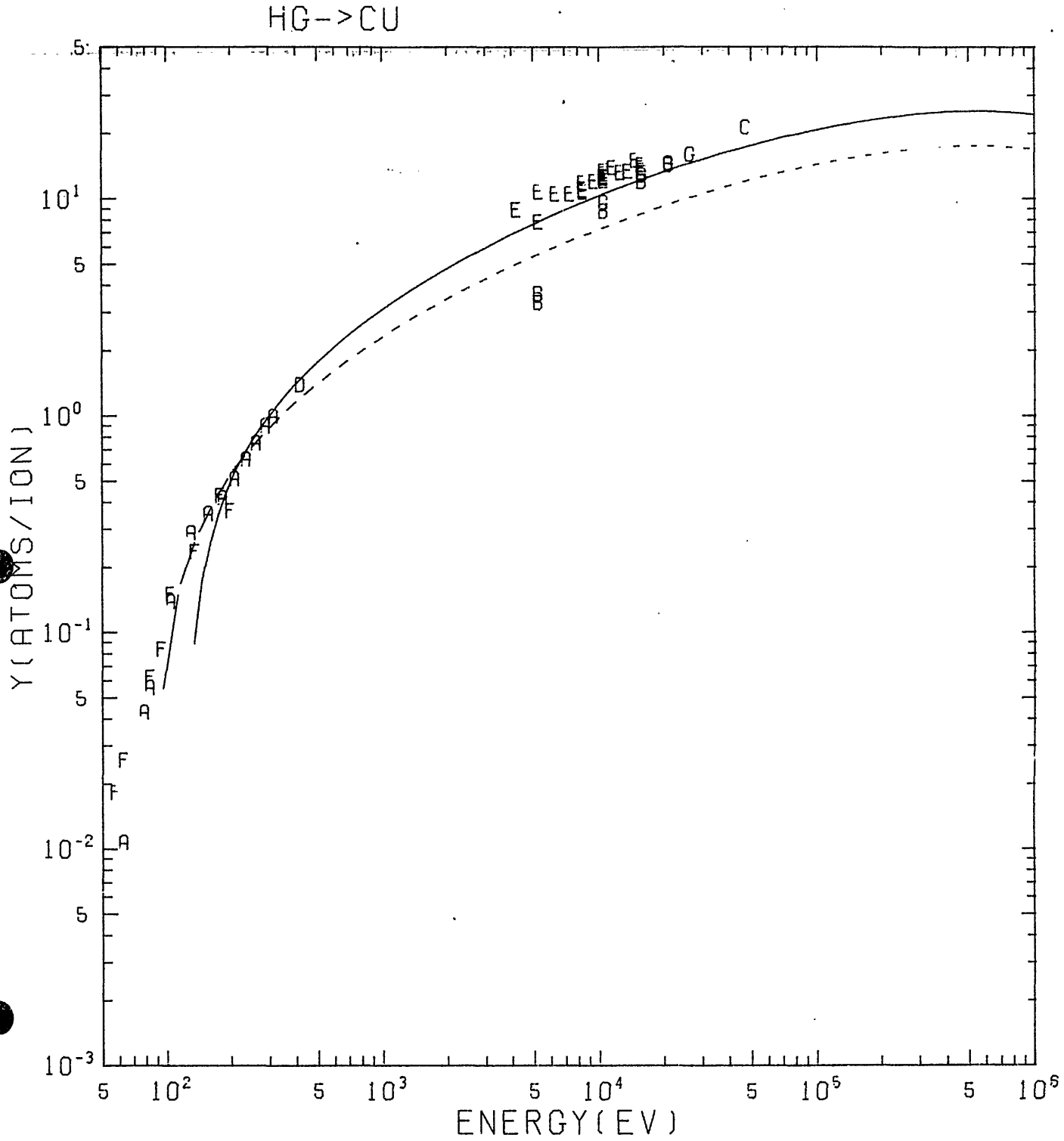
A GUSEVA (1960)
B ALMEN,BRUCE (1961A)
C WEHNER,STUART,ROSENBERG (1961)
D ROSENBERG,WEHNER (1962)
E STUART,WEHNER (1962)
F DUPP,SCHARMANN (1966)
G KOSHKIN,RYSOV,SHKARBAN (1969)

Fig. 80



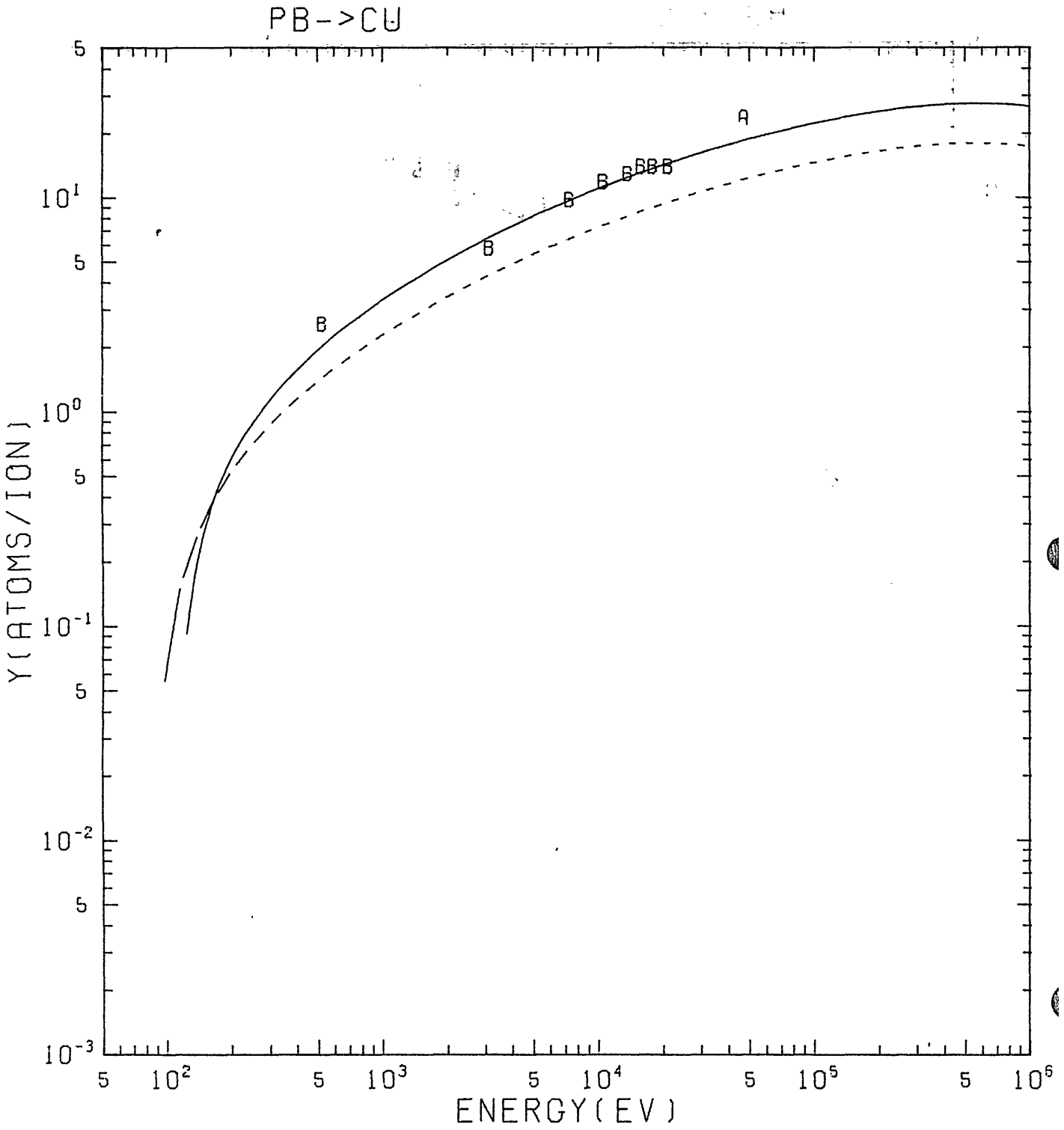
CS->CU
A ALMEN.BRUCE (1961B)
B KOSHKIN.RYSOV.SHKARBAN (1969)

Fig. 81



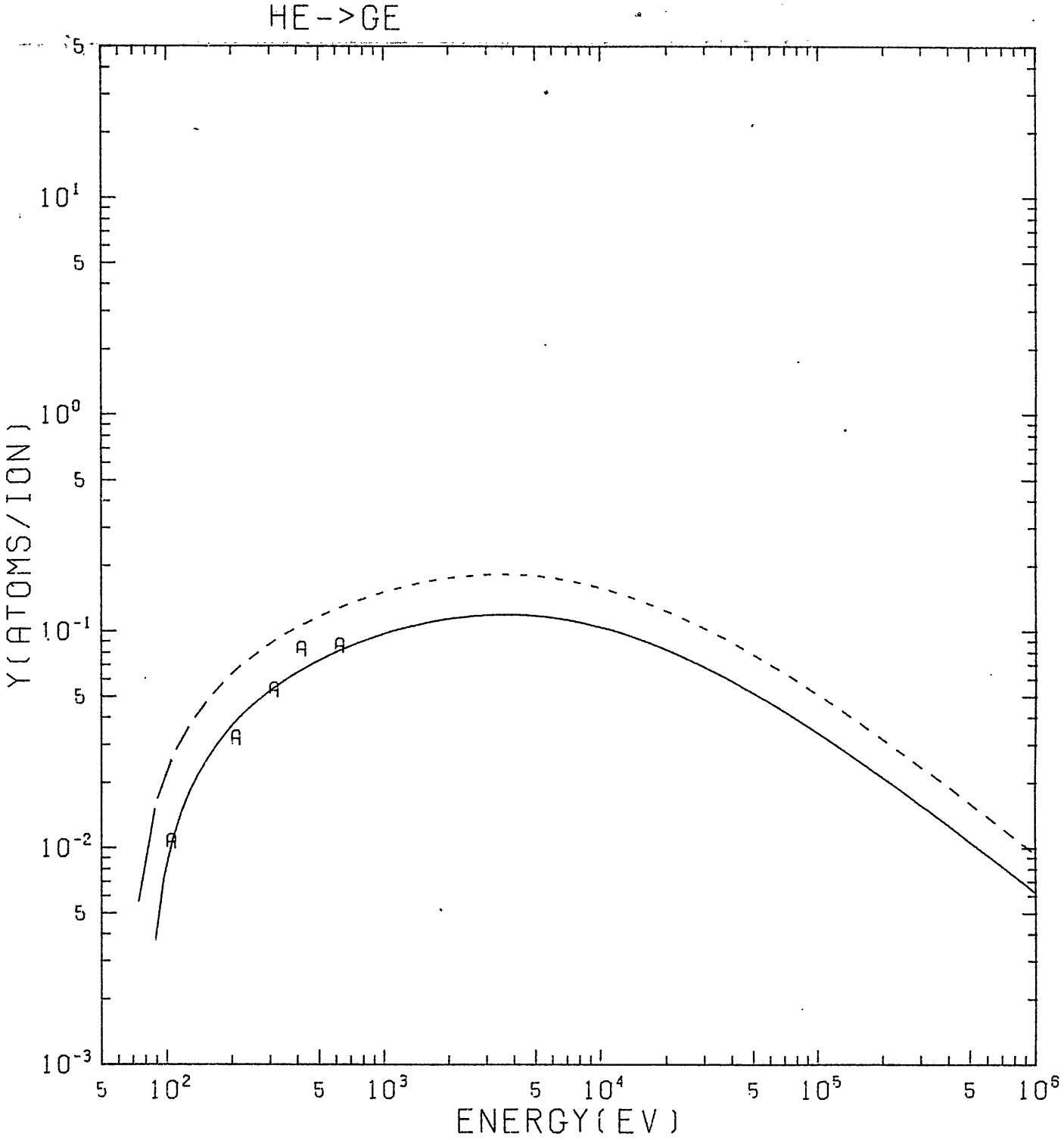
HG->CU
A WEHNER (1957)
B ROL.FLUIT.KISTEMAKER (1960)
C ALMEN.BRUCE (1961B)
D LAEGREID.WEHNER (1961)
E WEHNER.ROSENBERG (1961)
F ASKEROV.SENA (1969)
G ISMAIL (1970)

Fig. 82



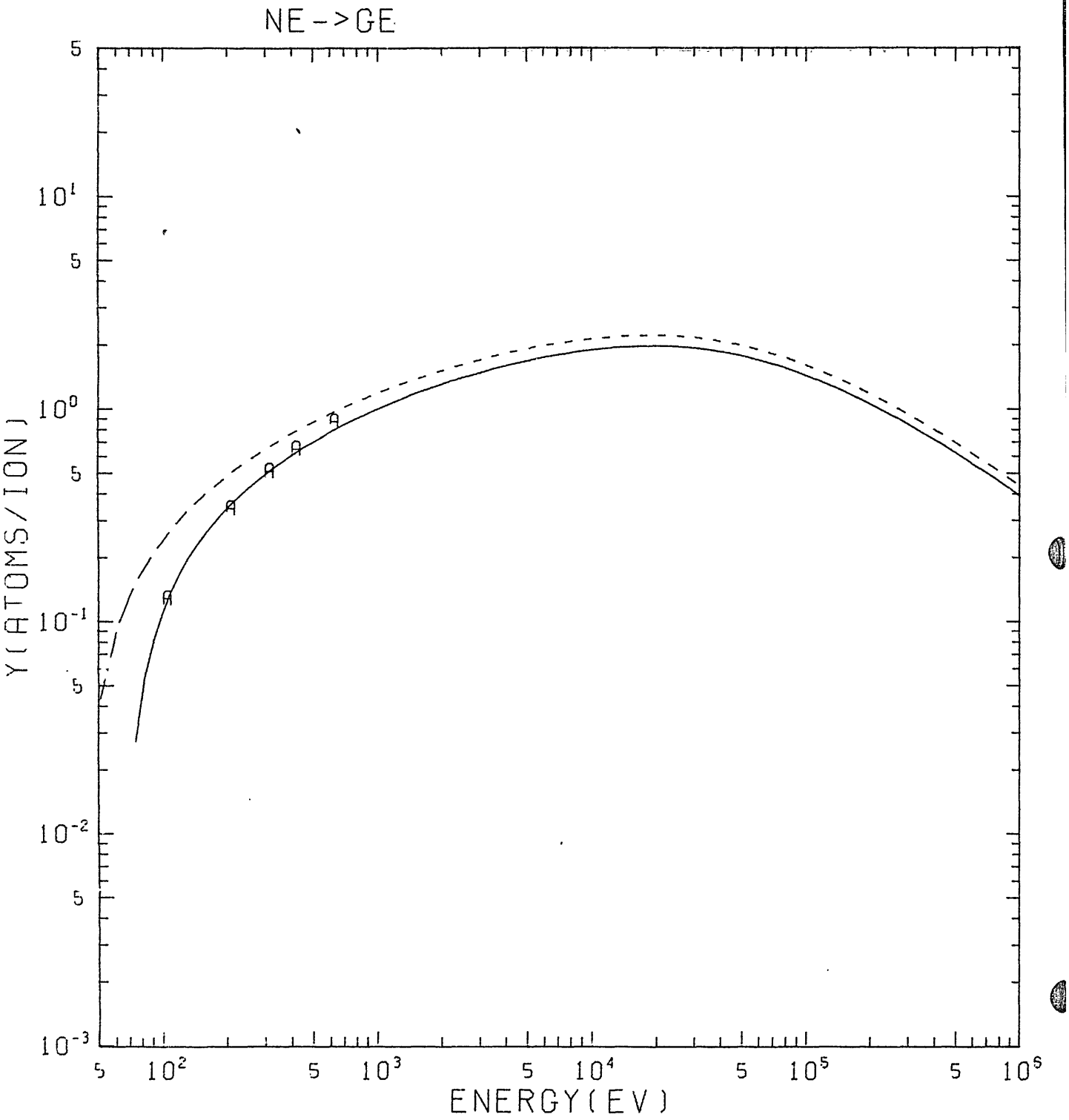
PB->CU
A ALMEN.BRUCE (1961B)
B KOSHKIN.RYSOV.SHKARBAN (1969)

Fig. 83



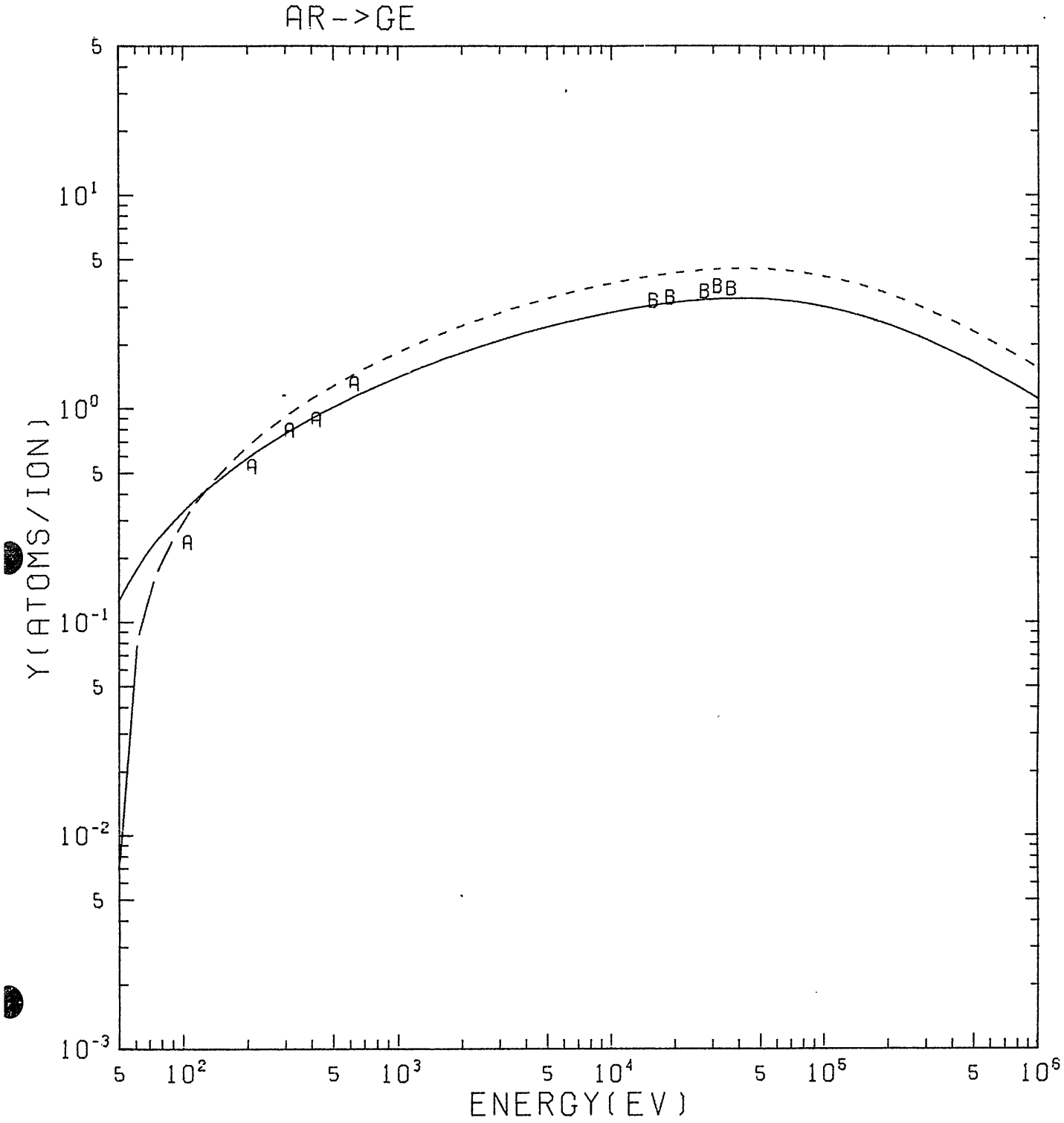
HE->GE
A ROSENBERG,WEHNER (1962)

Fig. 84



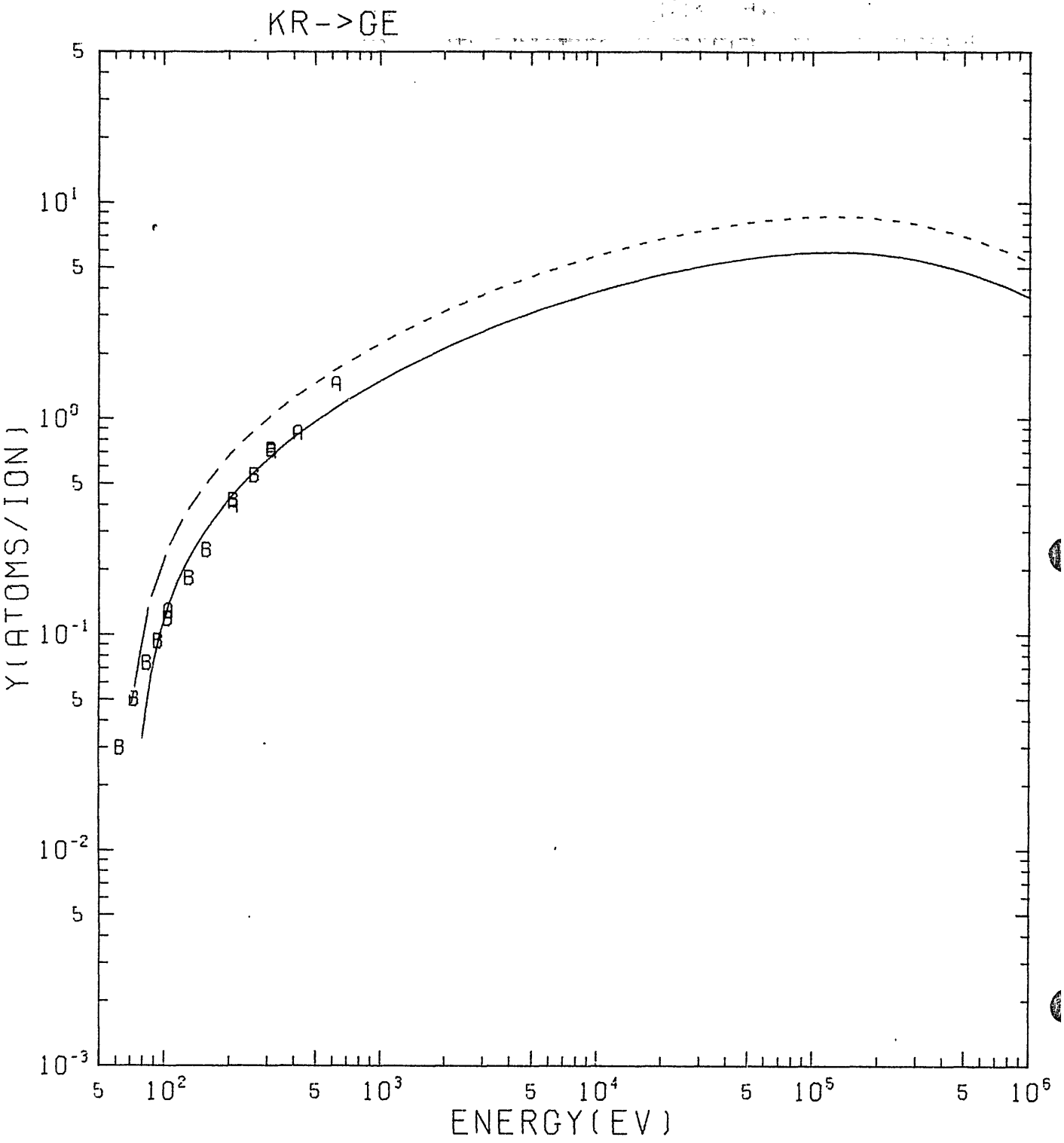
NE->GE
A LAEGREID.WEHNER (1961)

Fig. 85



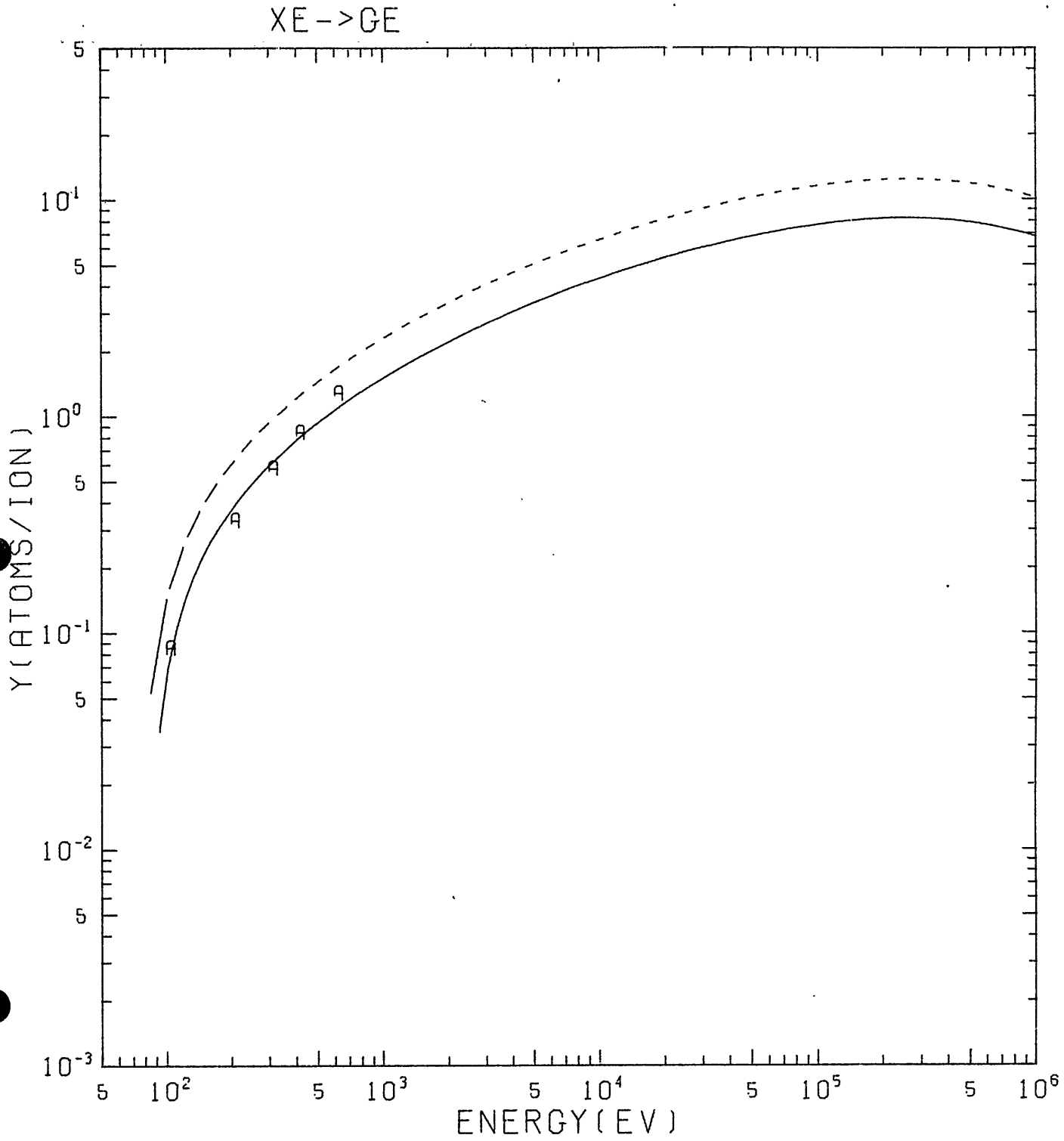
AR->GE
A LAEGREID,WEHNER (1961)
B SOMMERFELDT,MASHKOVA (1972)

Fig. 86



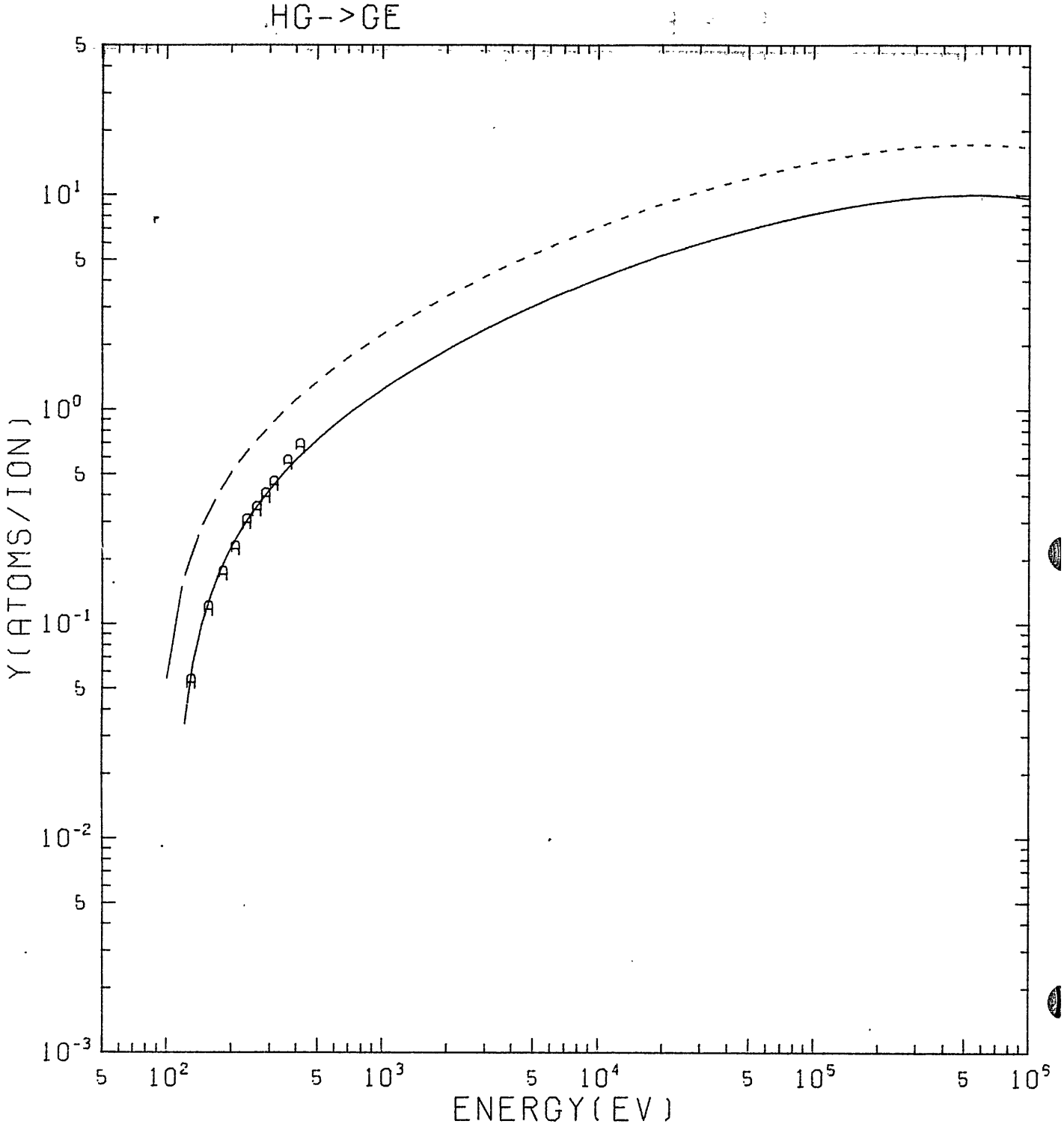
KR->GE
A ROSENBERG,WEHNER (1962)
B STUART,WEHNER (1962)

Fig. 87



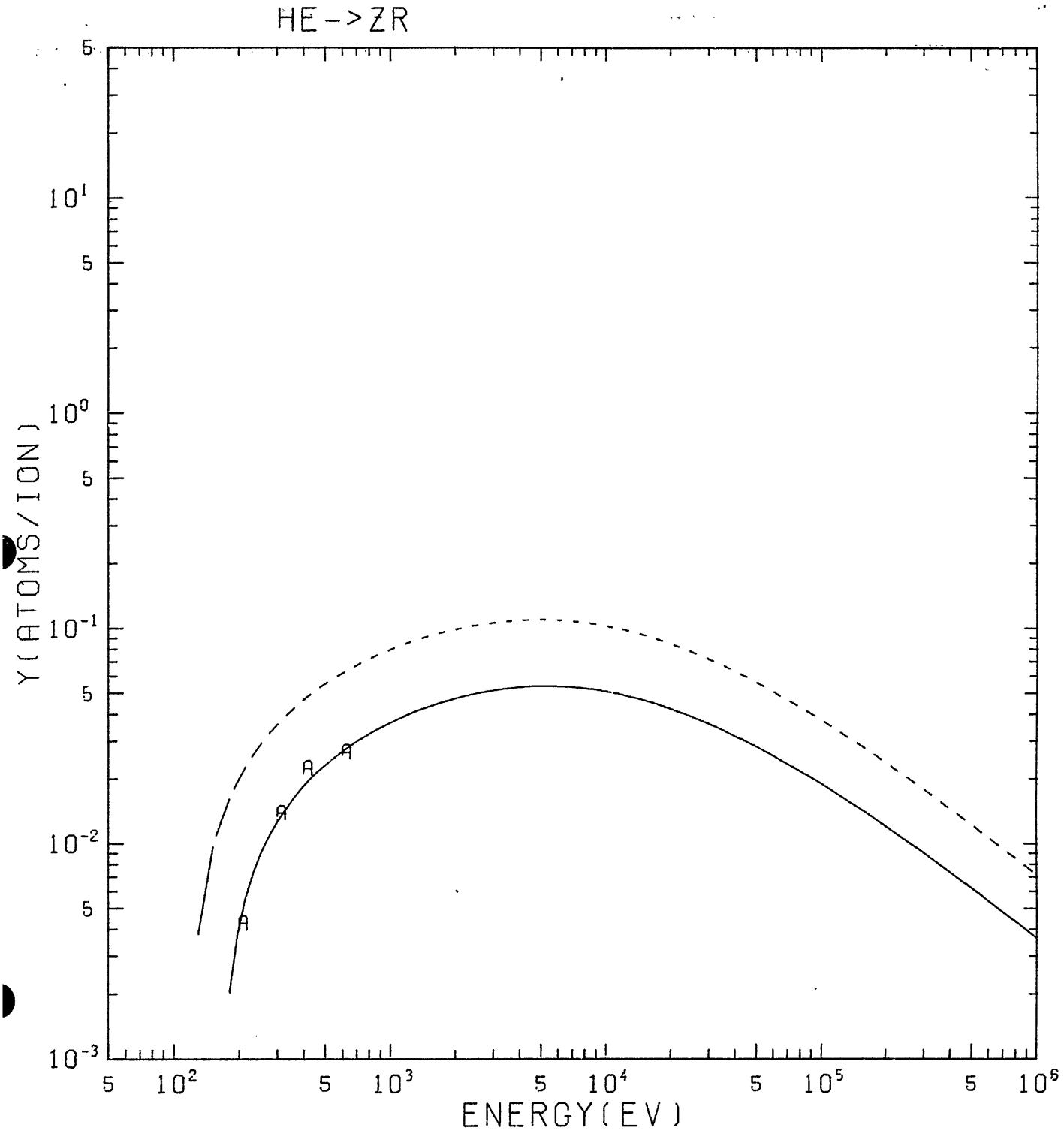
XE->GE
A ROSENBERG,WEHNER (1962)

Fig. 88



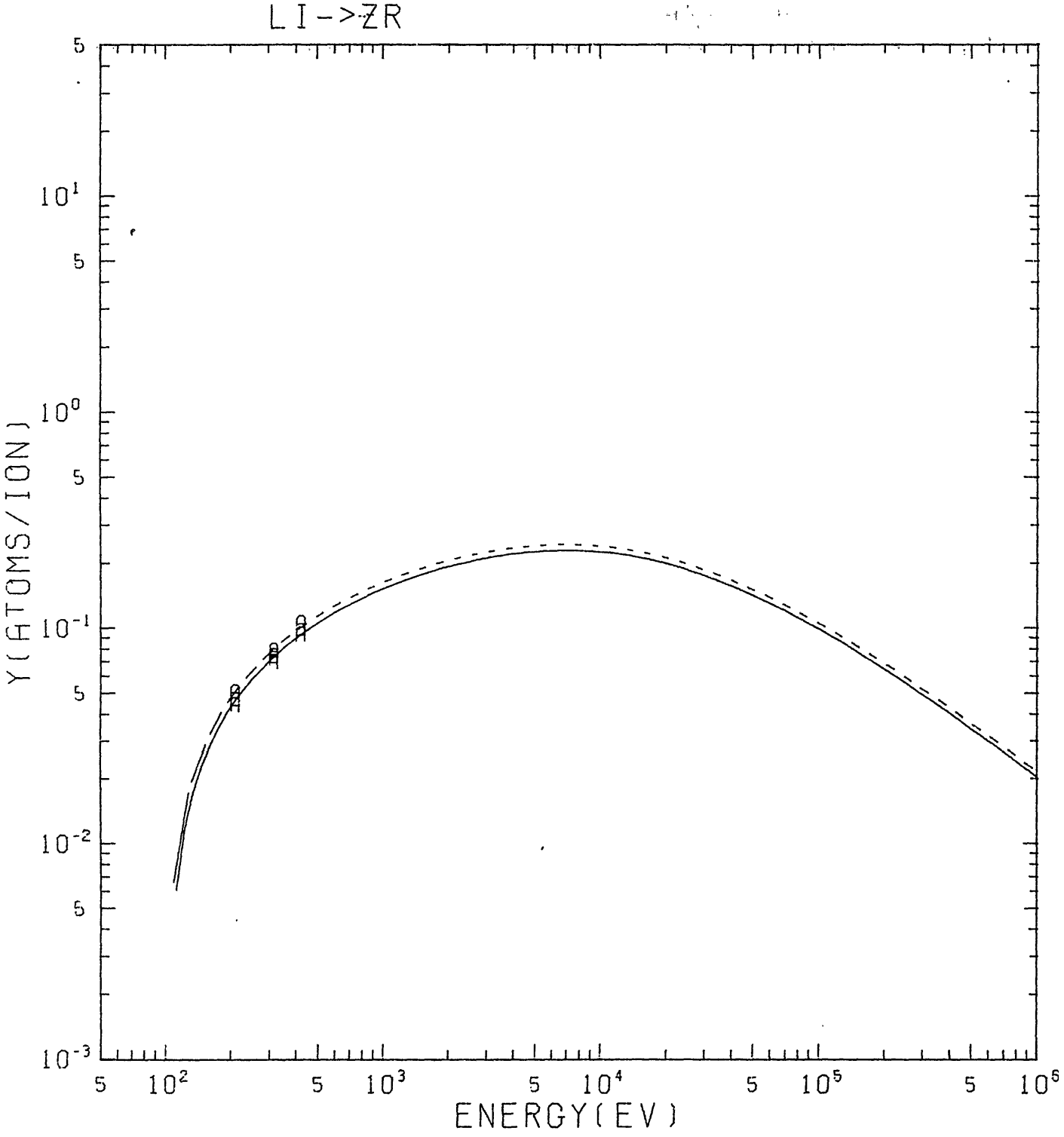
HG->GE
A WEHNER (1957)

Fig. 89



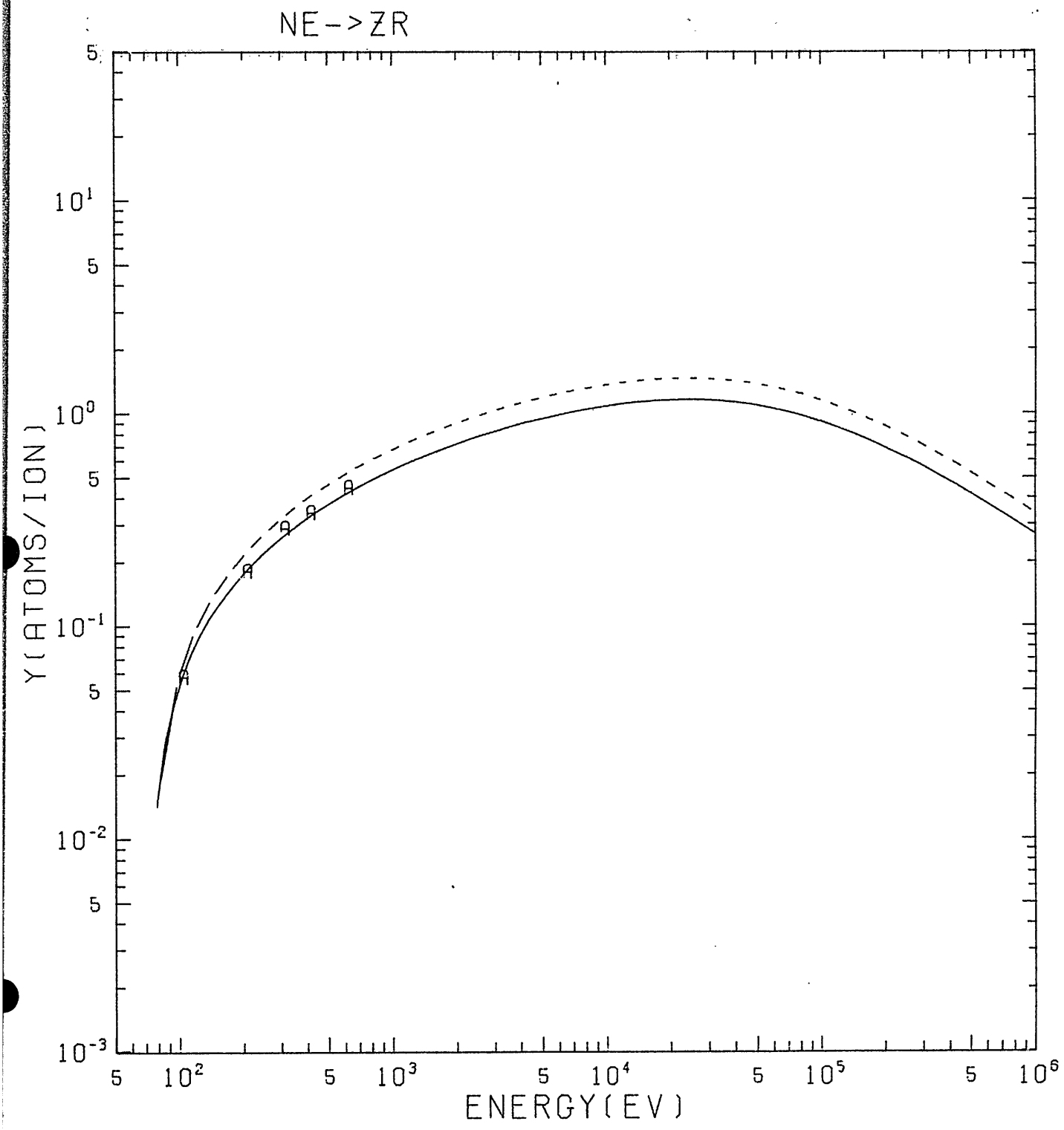
HE->ZR
A ROSENBERG,WEHNER (1962)

Fig. 90



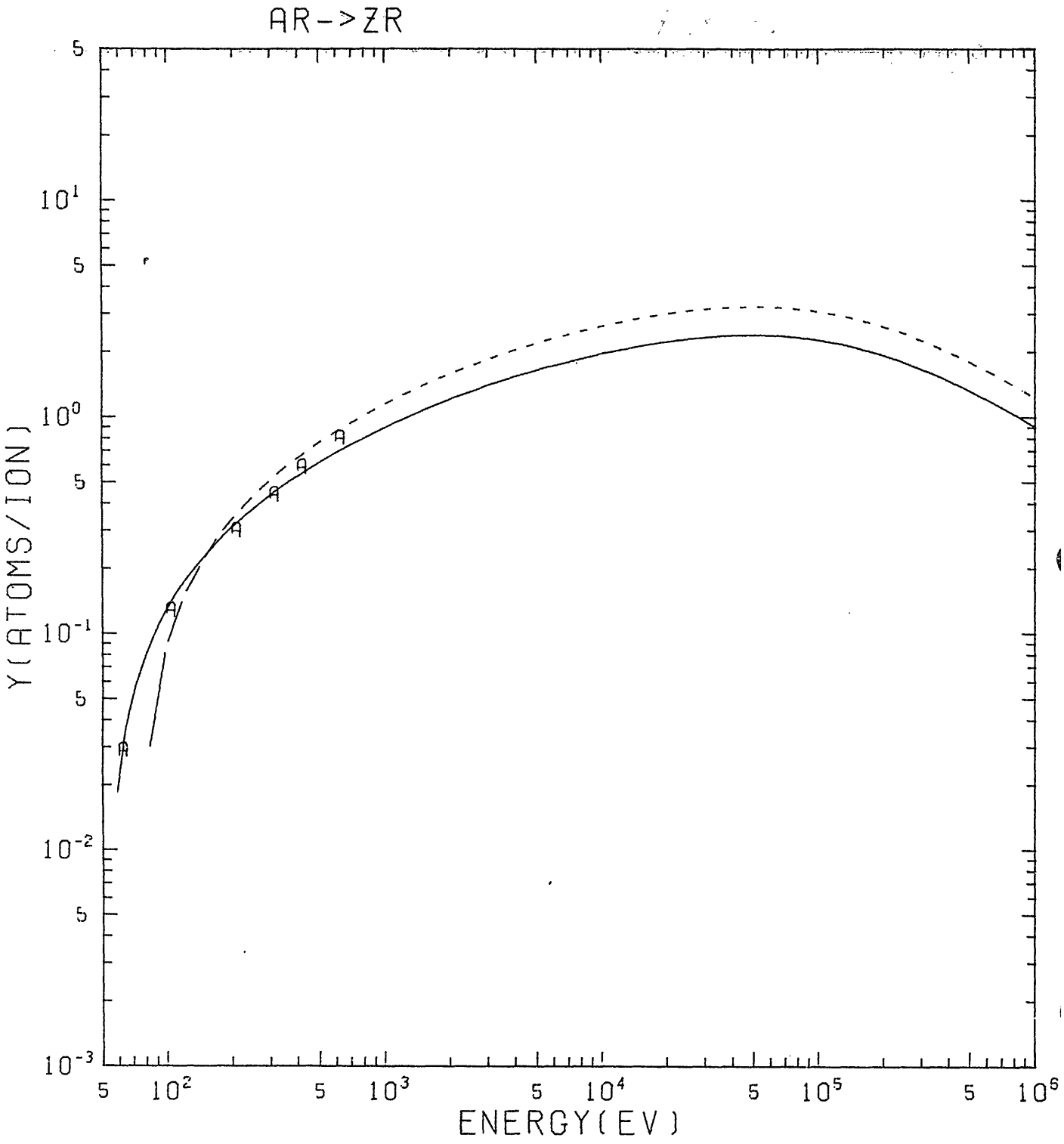
LI->ZR
A MARTYNENKO (1969)

Fig. 91



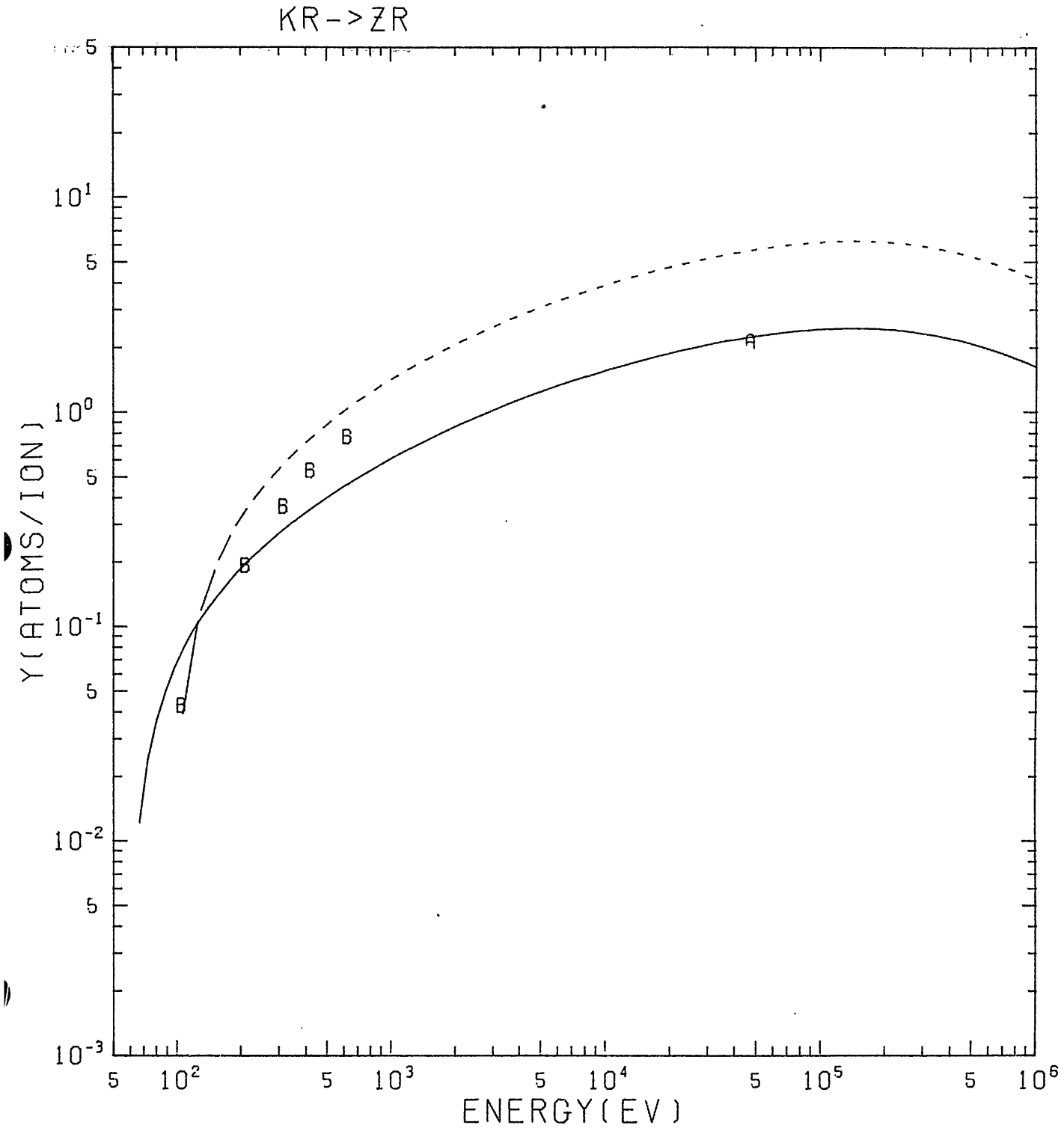
NE->ZR
A LAEGREID,WEHNER (1961)

Fig. 92



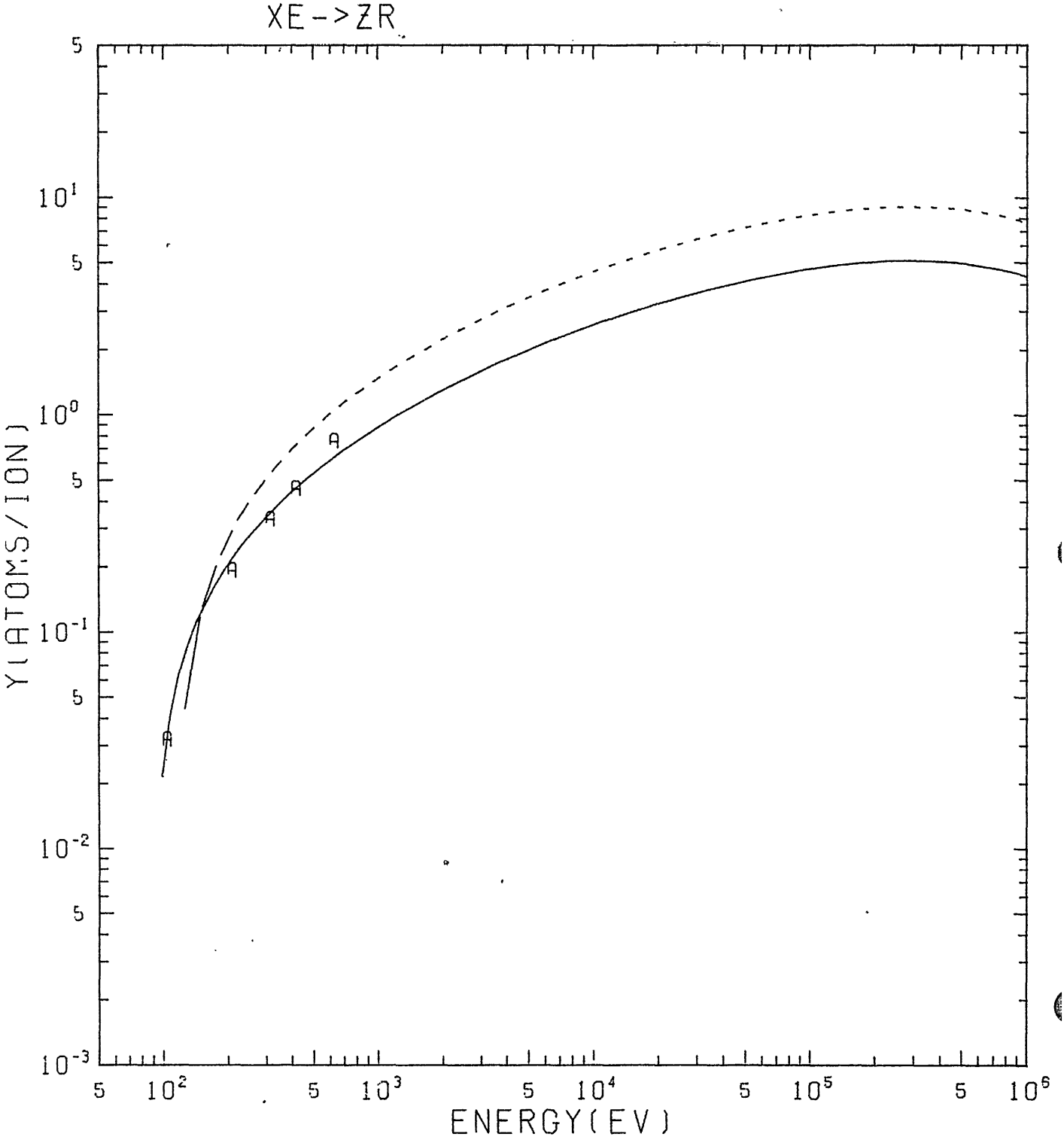
AR->ZR
A LAEGREID,WEHNER (1961)

Fig. 93



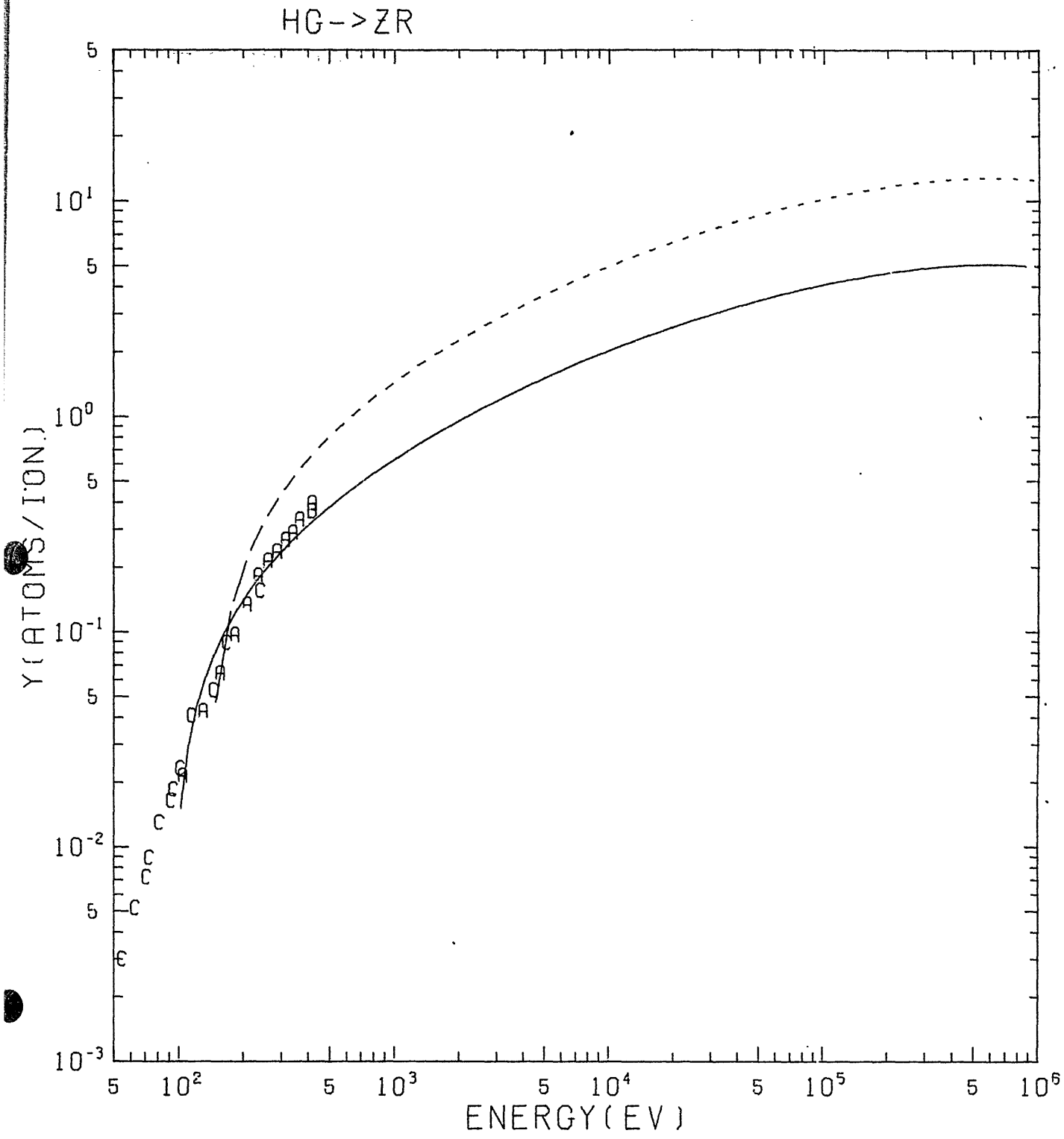
KR->ZR
A ALMEN.BRUCE (1961A)
B ROSENBERG.WEHNER (1962)

Fig. 94



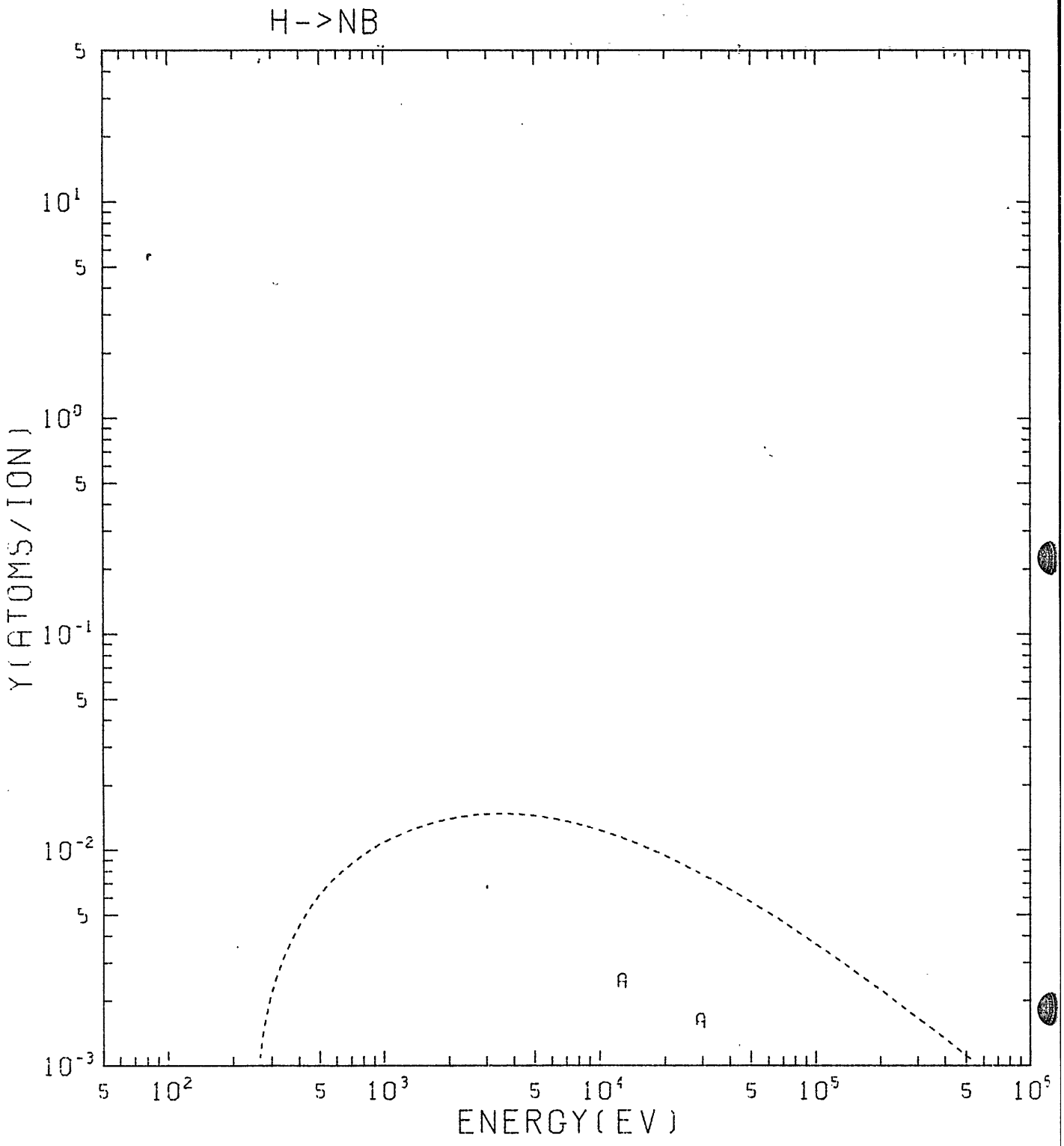
XE->ZR
A ROSENBERG,WEHNER (1962)

Fig. 95



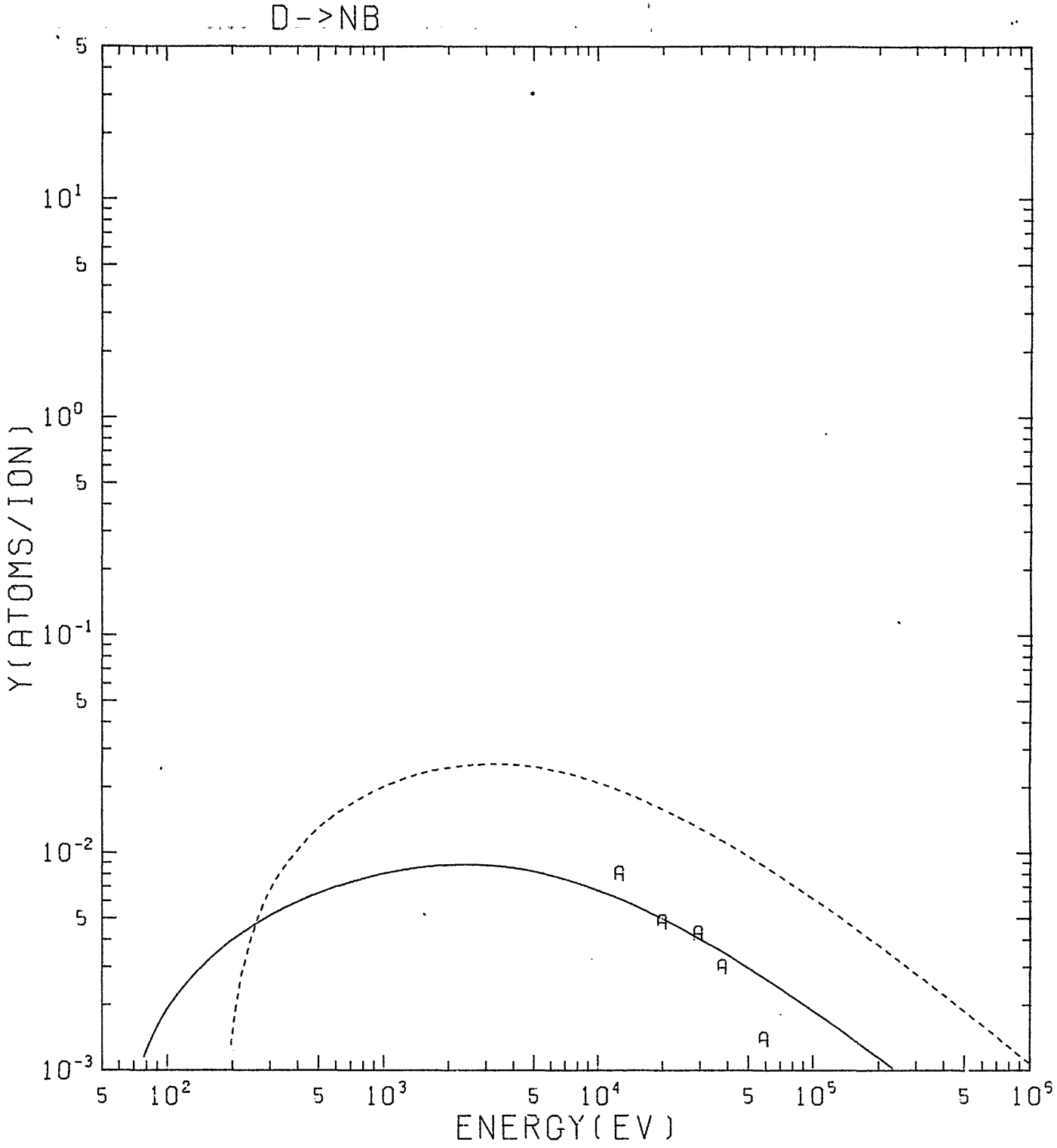
HG->ZR
A WEHNER (1957)
B LZEGREID.WEHNER (1961)
C ASKEROV.SENA (1969)

Fig. 96



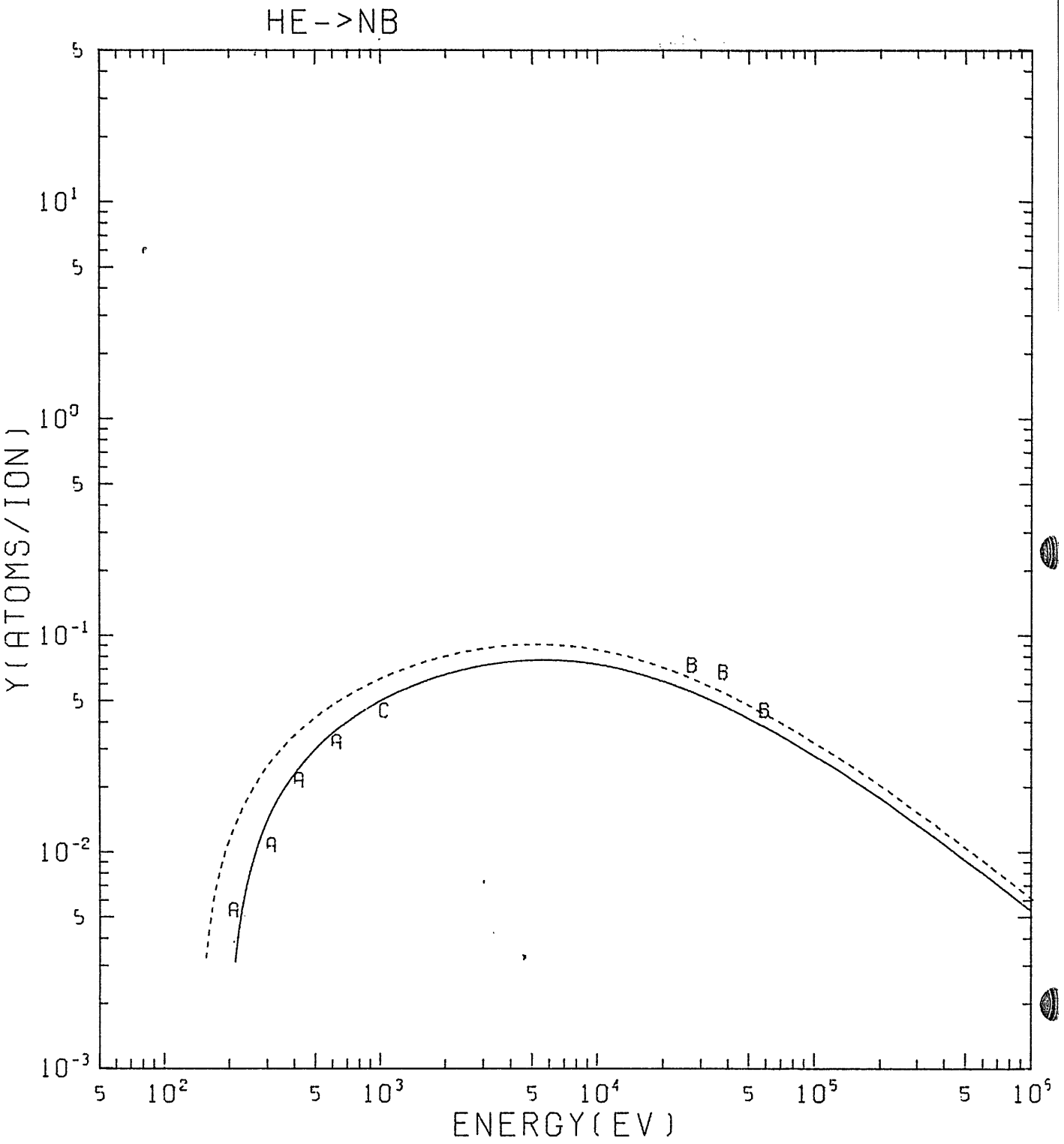
H->NB
A SUMMERS.FREEMAN.DALY (1971)
B OLLERHEAD.MANN.KNEFF (1976)

Fig. 97



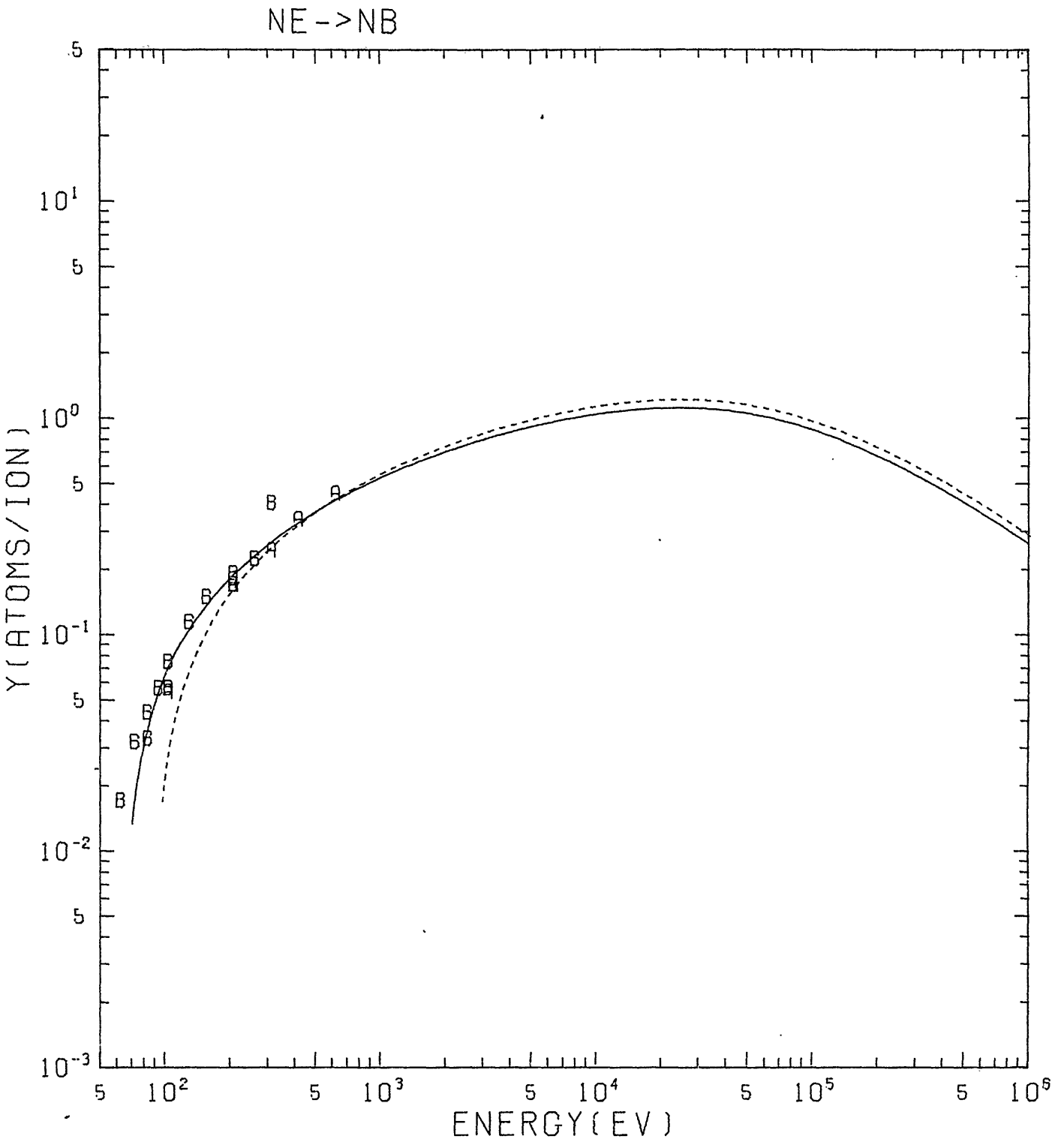
D->NB
A SUMMERS,FREEMAN,DALY (1971)

Fig. 98



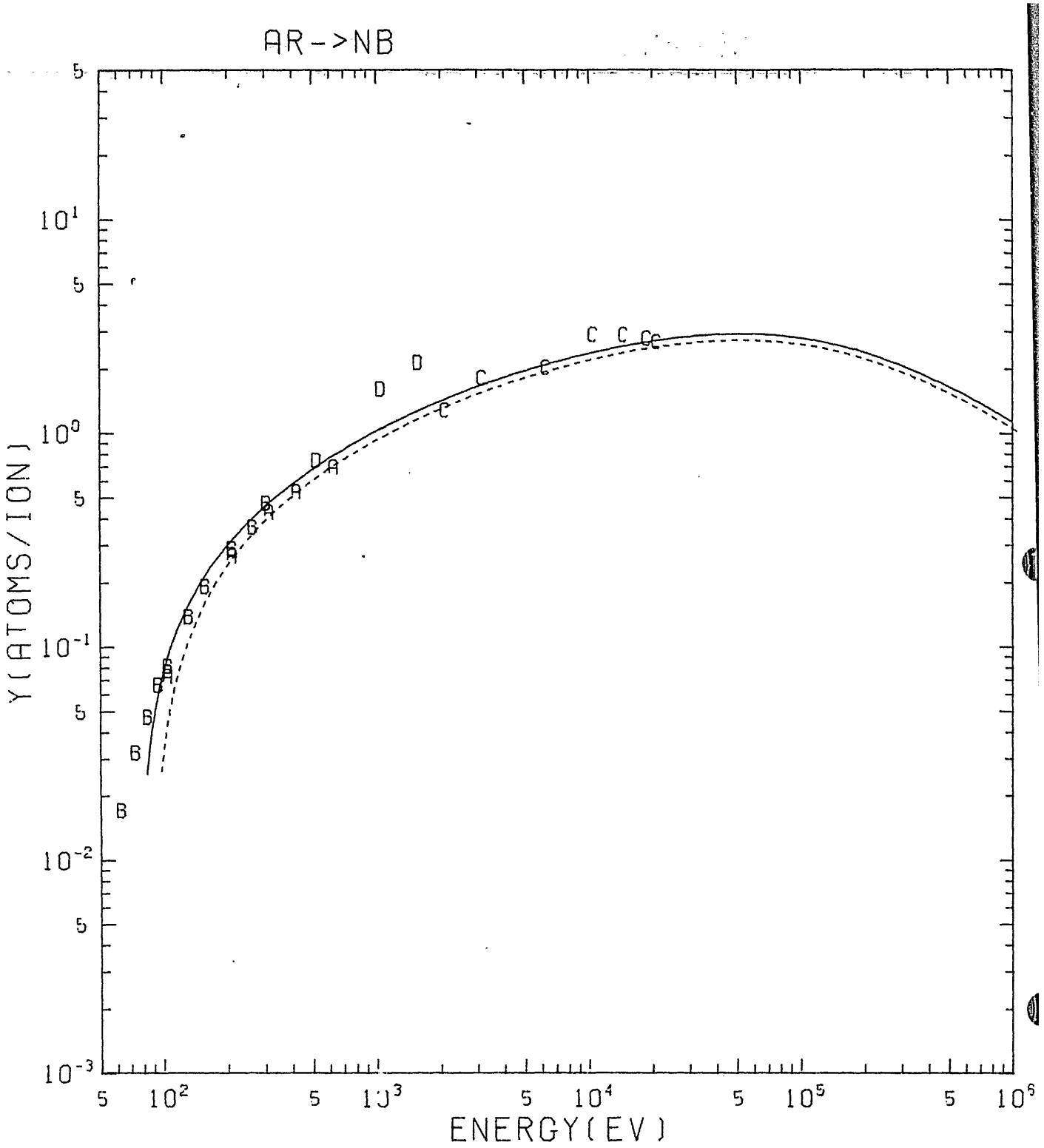
HE->NB
A ROSENBERG.WEHNER (1962)
B SUMMERS.FREEMAN.DALY (1971)
C GUSEVA.MARTYNENKO (1976)

Fig. 99



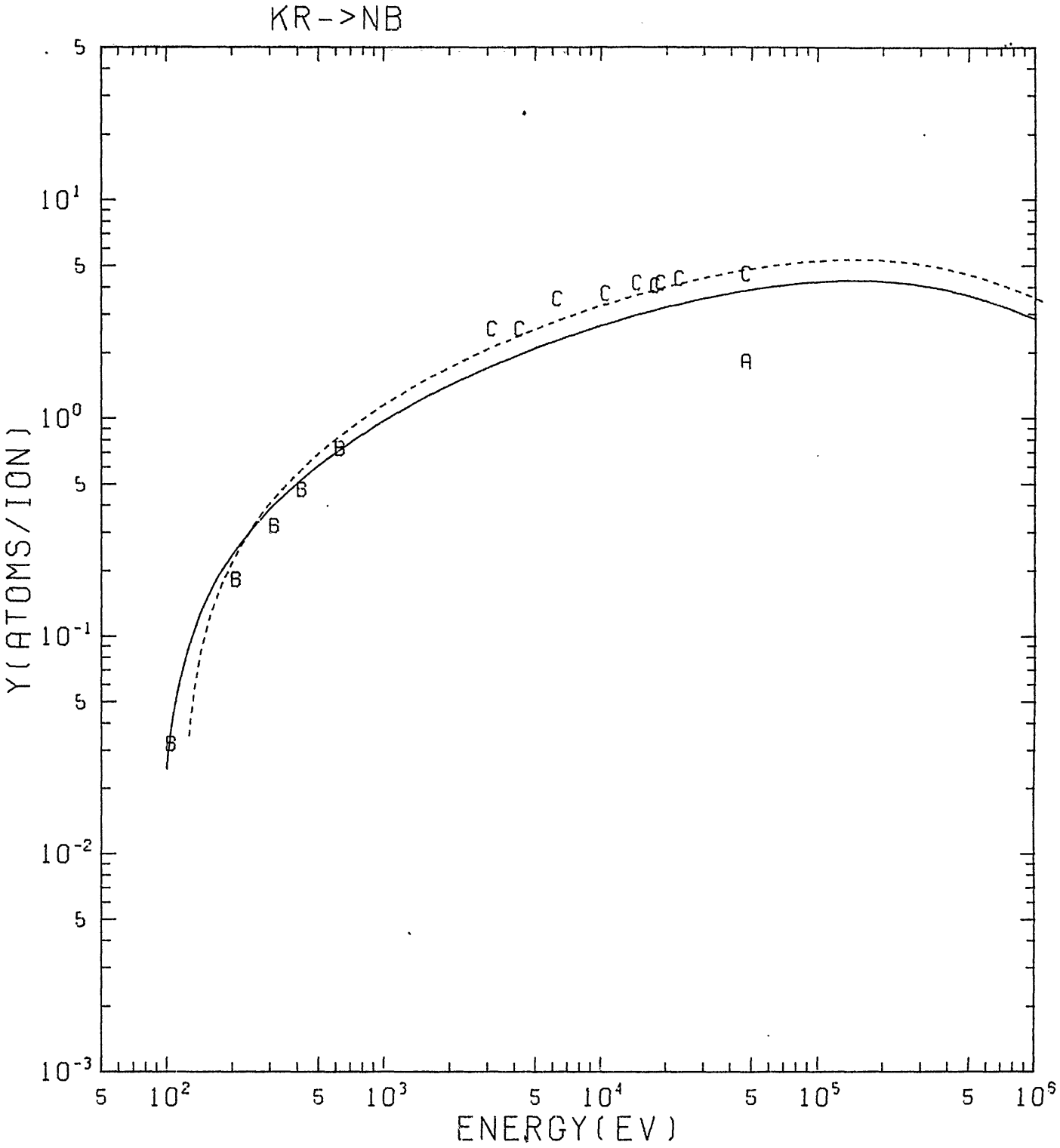
NE->NB
A LAEGREID,WEHNER (1961)
B STUART,WEHNER (1962)

Fig. 100



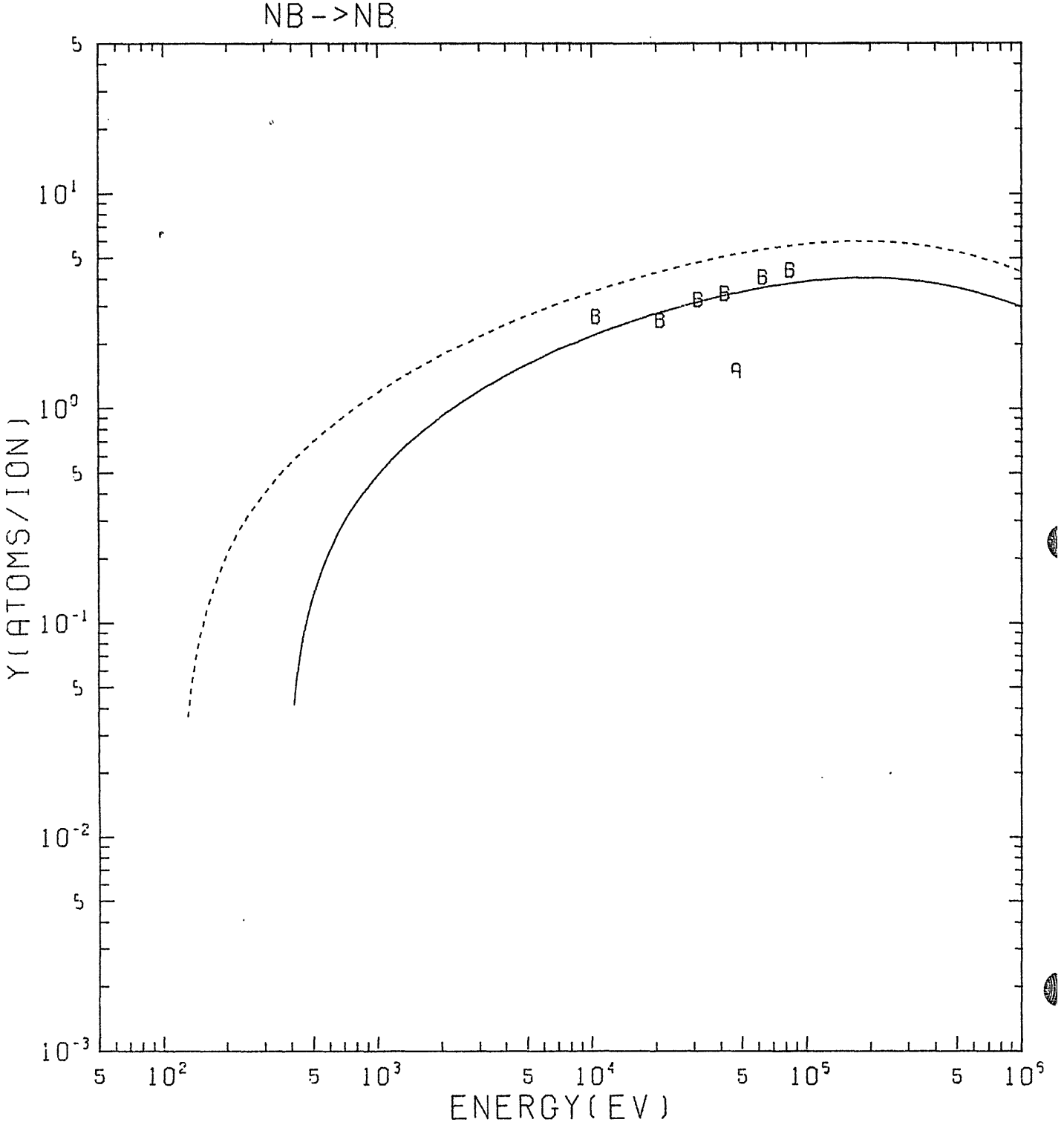
AR->NB
A LAEGREID.WEHNER (1961)
B STUART.WEHNER (1962)
C KOSHKIN.RYSOV.SHKAVBAN (1969)
D SMITH.MEYER.LAYTON (1975)

Fig. 101



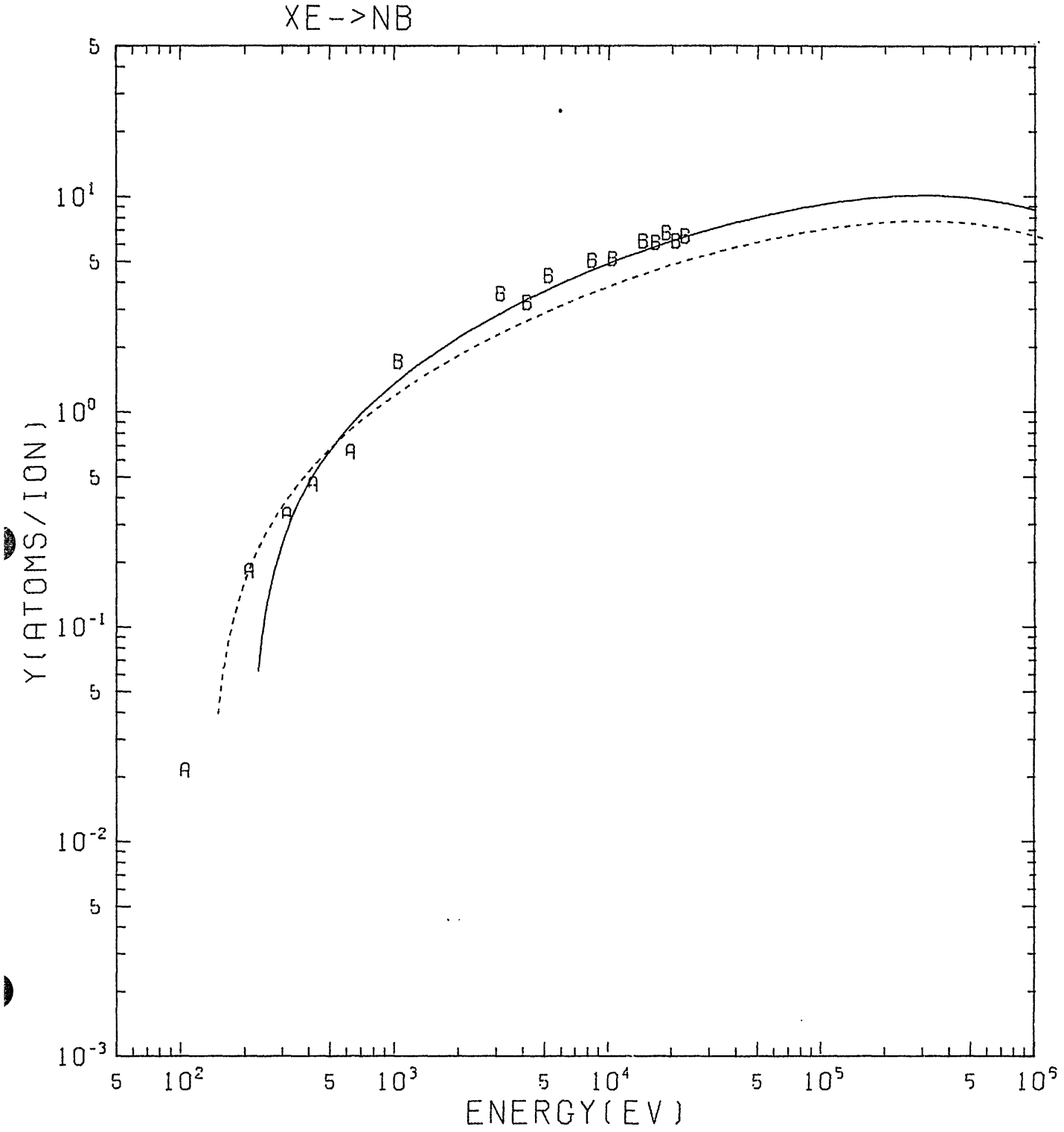
KR->NB
A ALMEN.BRUCE (1961B)
B ROSENBERG.WEHNER (1962)
C KOSHKIN.RYSOV.SHKARBAN (1969)

Fig. 102



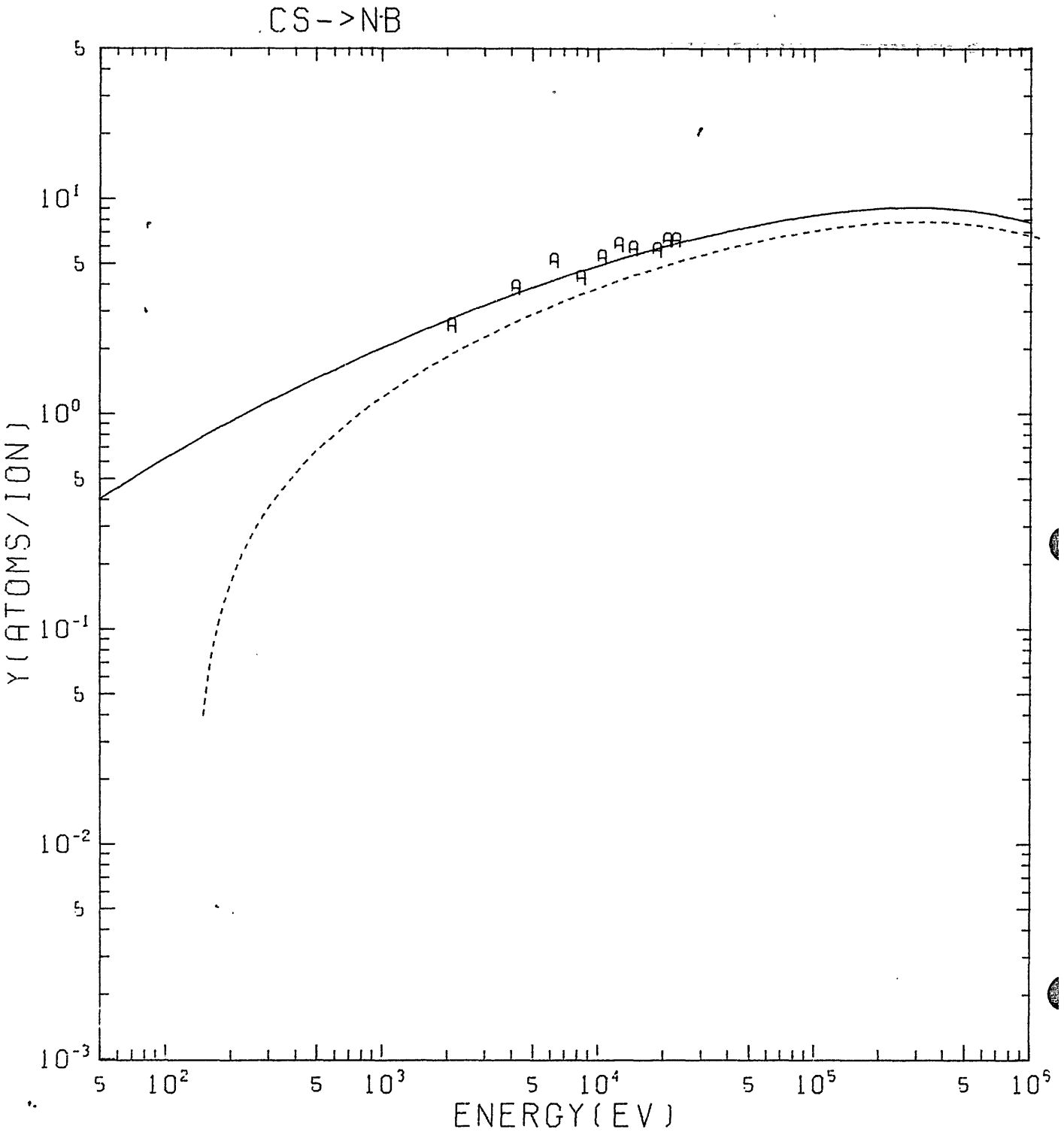
NB->NB
A ALMEN.BRUCE (1961B)
B SUMMERS.FREEMAN.DALY (1971)

Fig. 103



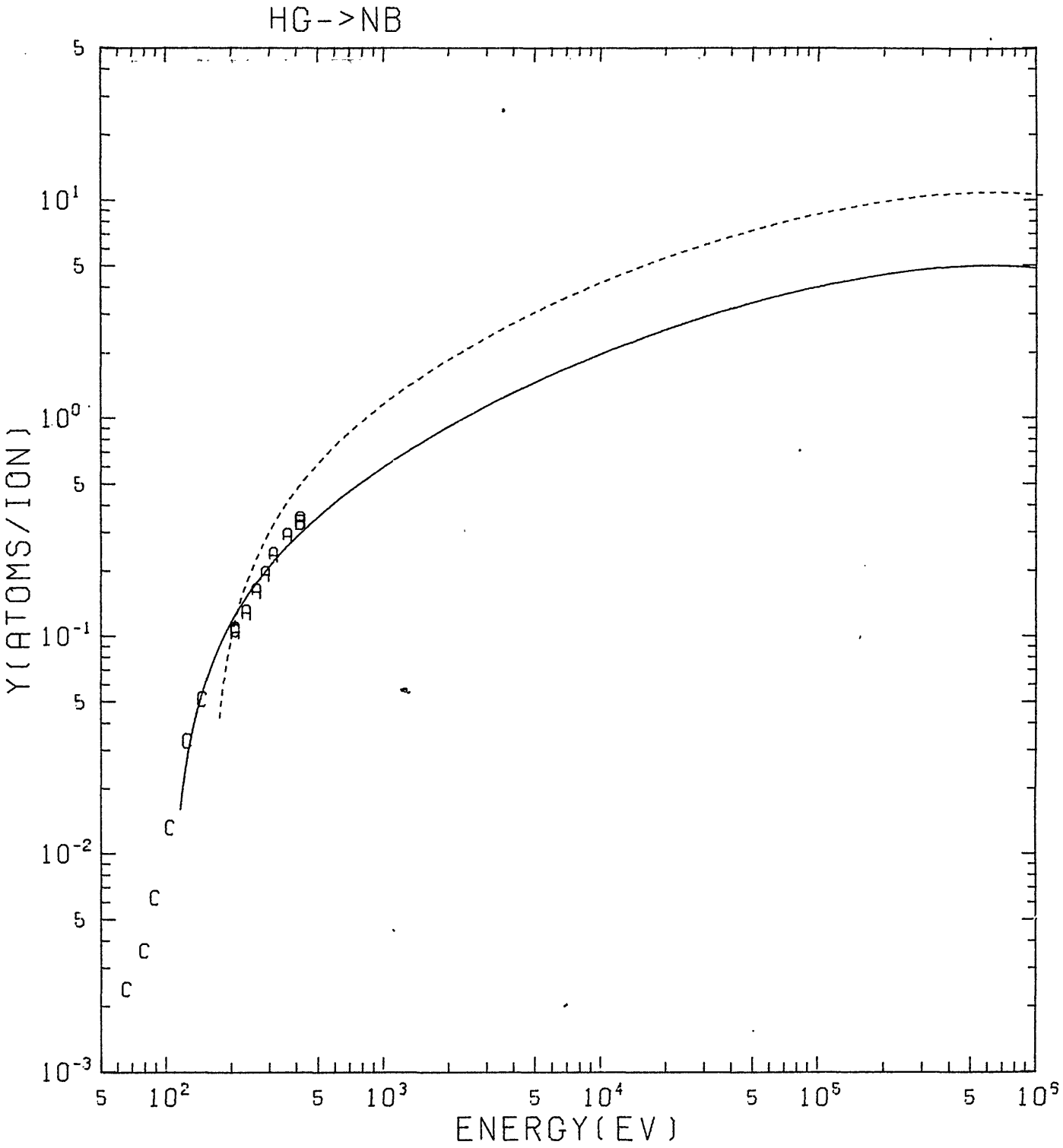
XE->NB
A ROSENBERG,WEHNER (1962)
B KOSHKIN,RYSOV,SHKARBAN (1969)

Fig. 104



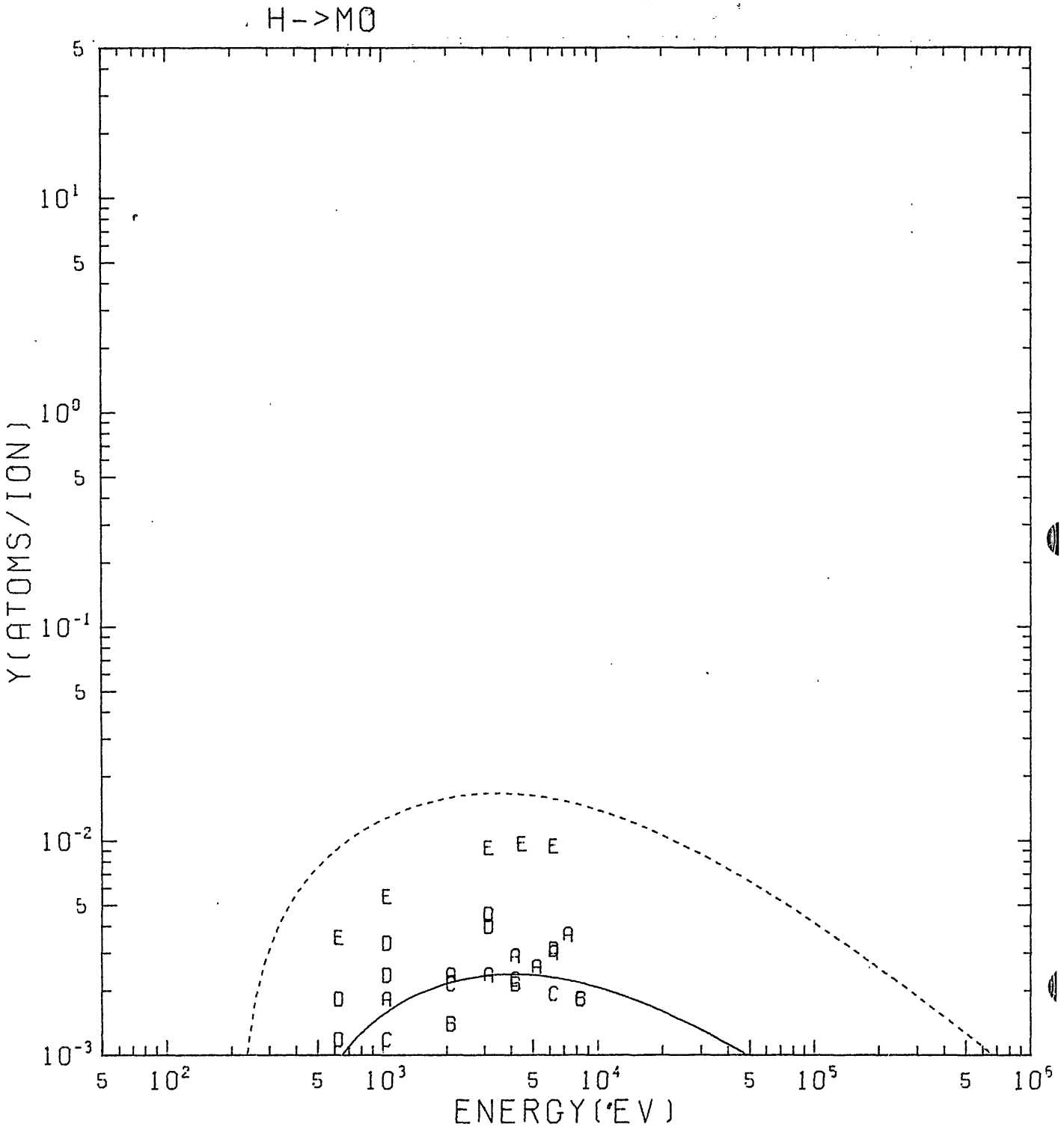
CS->NB
A KOSHKIN.RYSOV.SHKARBAN (1969)

Fig. 105



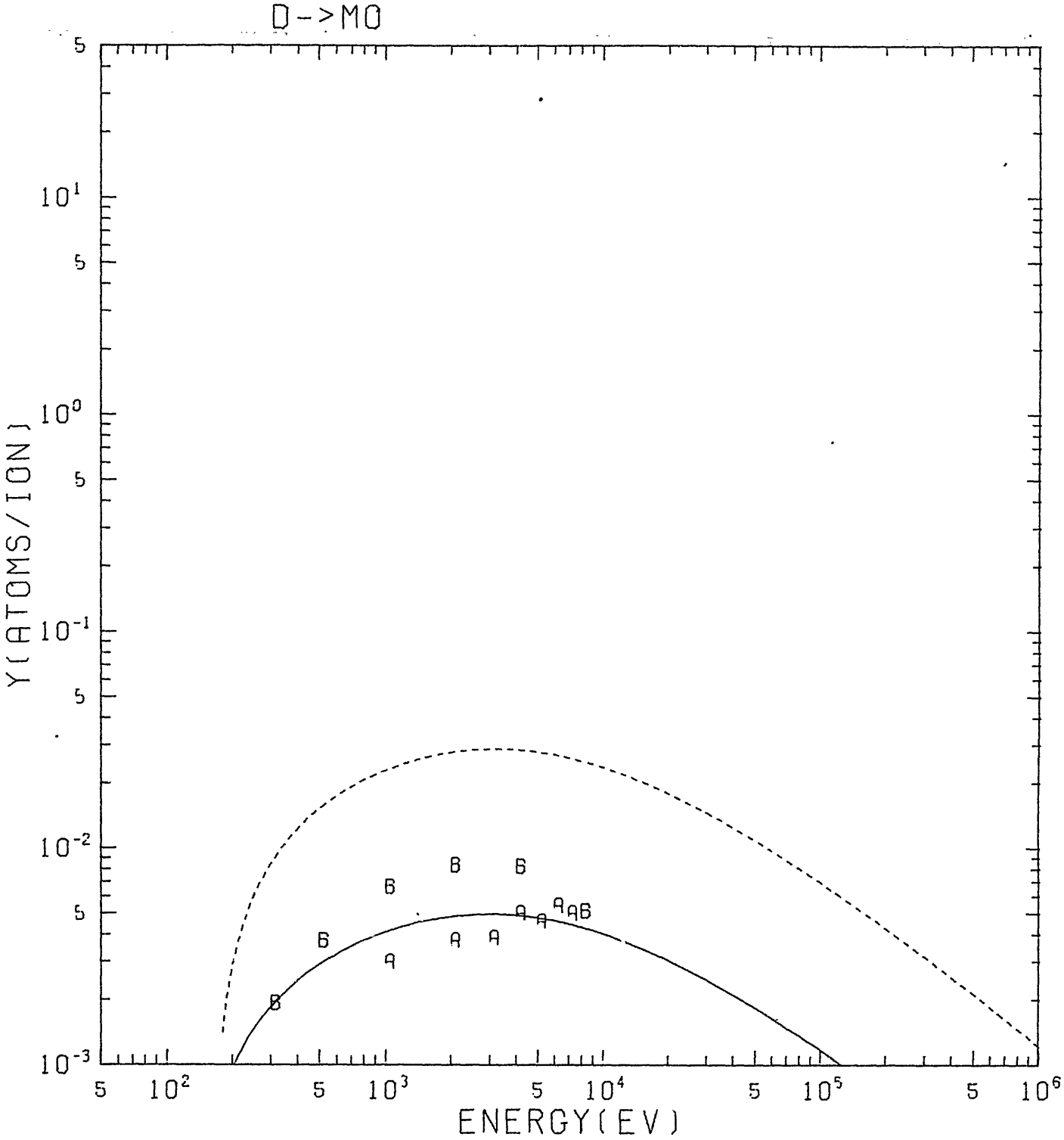
HG->NB
A WEHNER (1957)
B LZEGREID.WEHNER (1961)
C ASKEROV.SENA (1969)

Fig. 106



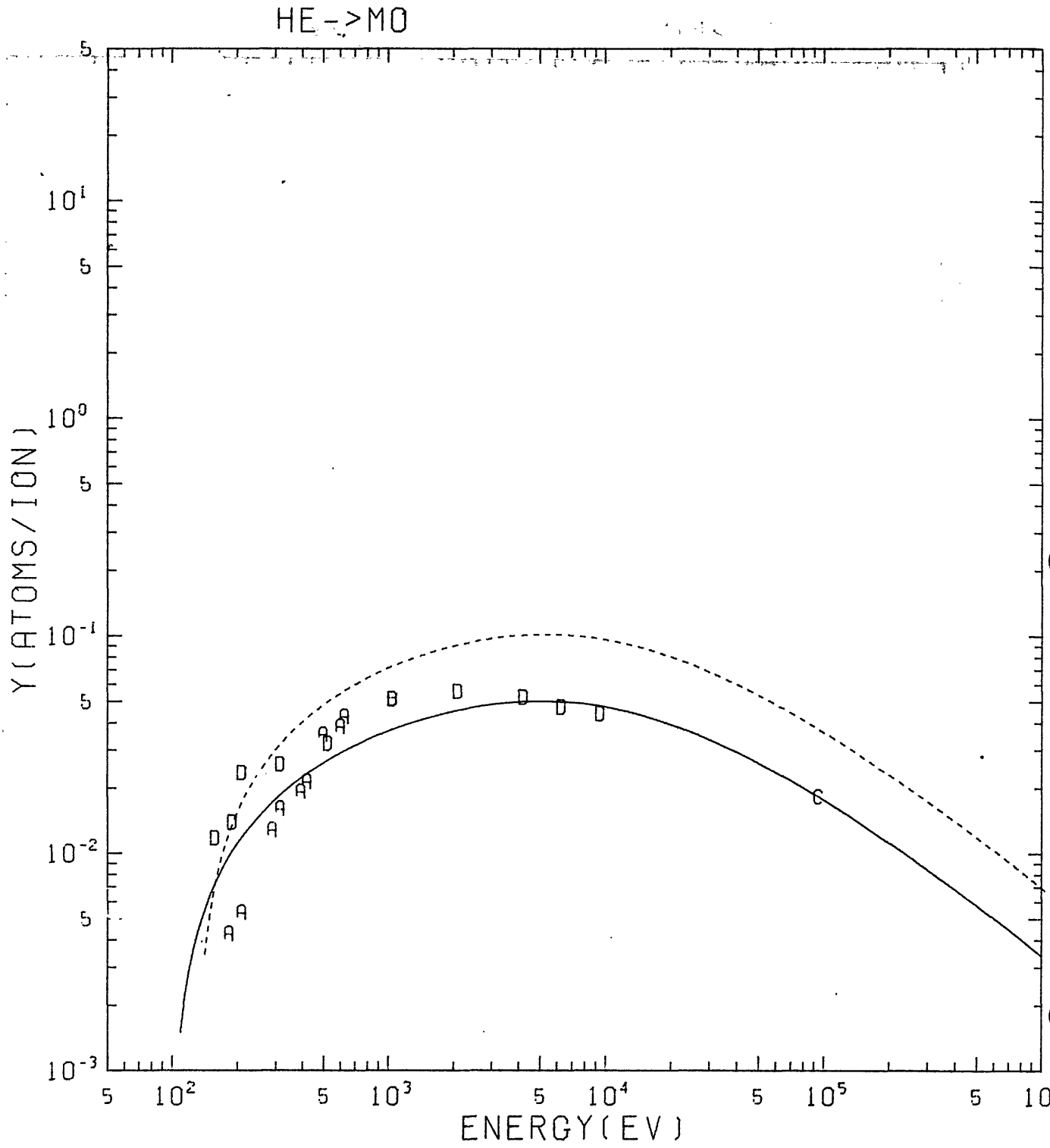
H->MO
A FINFGELD (1975)
B BOHDANSKY,ROTH,SINHA (1976)
C BAY,ROTH,BOHDANSKY (1977)
D OHTSUKA,YAMADA,SONE (1978)
E SONE,OHTSUKA,ABE (1977)

Fig. 107



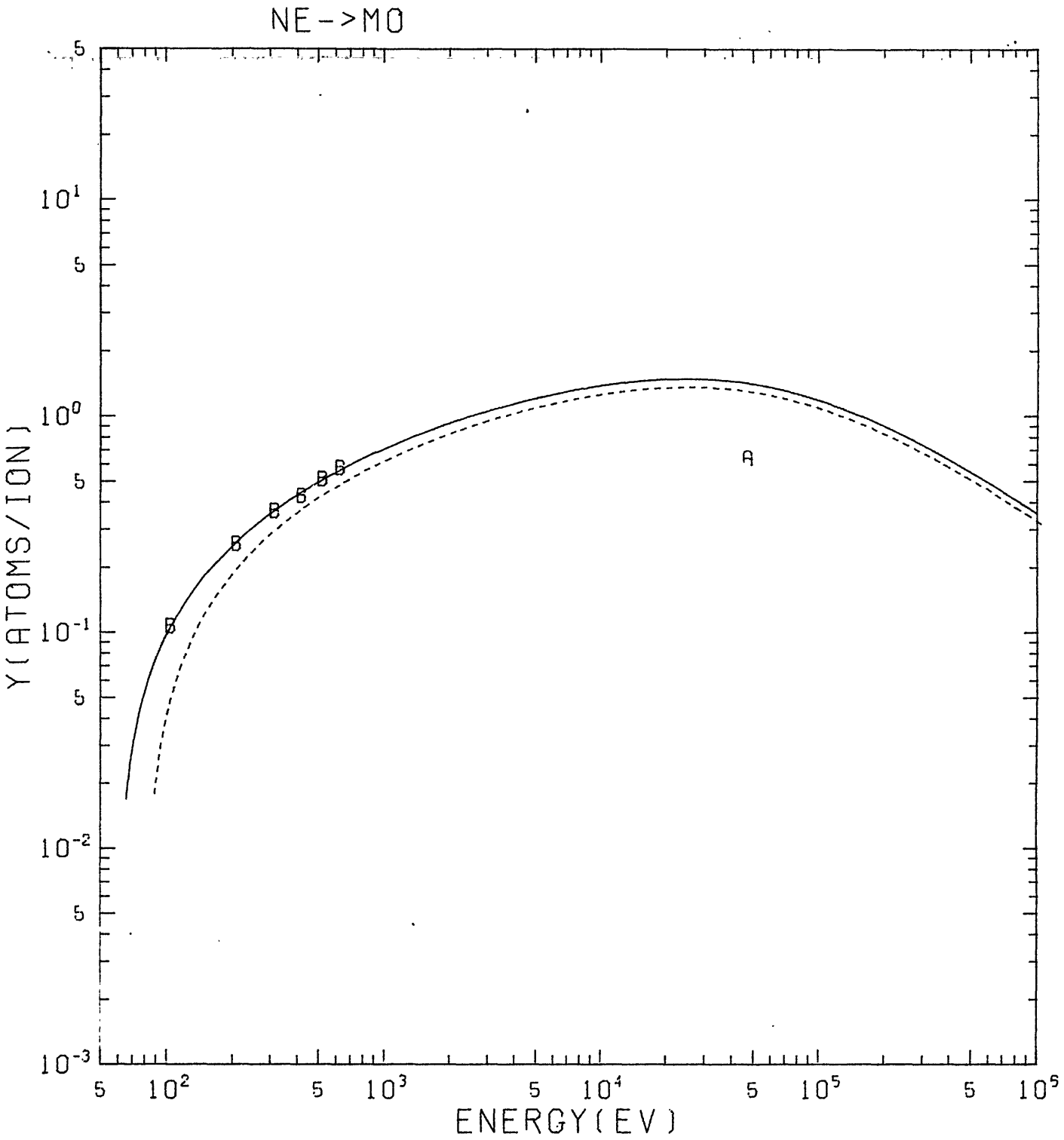
D->MO
A FINFGELD (1975)
B BAY,ROTH,BOHDANSKY (1977)

Fig. 108



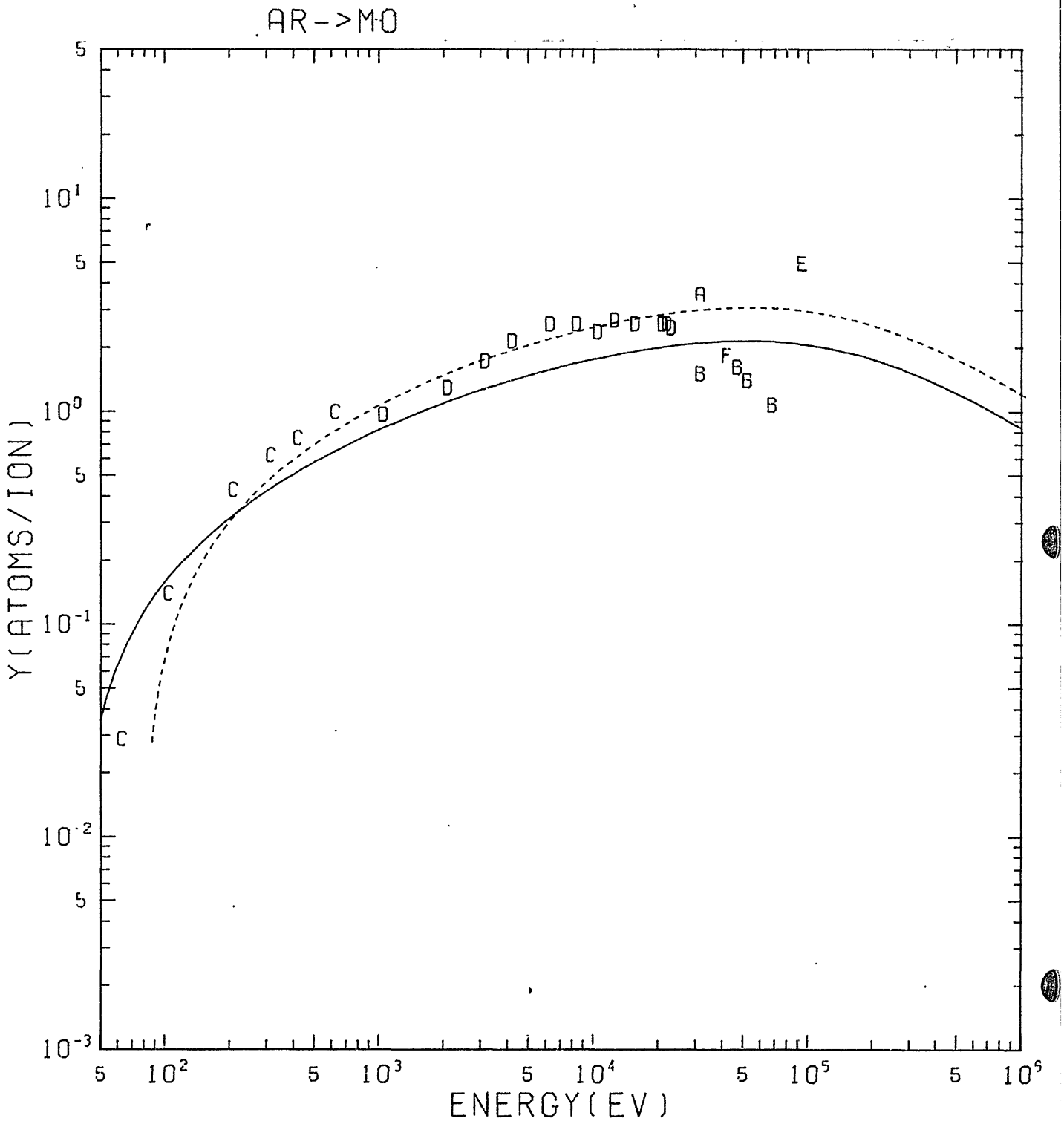
HE->MO
A ROSENBERG,WEHNER (1962)
B GUSEVA,MARTYNENKO (1976)
C SWITKOWSKI,MANN,KNEFF (1976)
D BAY,ROTH,BORDANSKY (1977)

Fig. 109



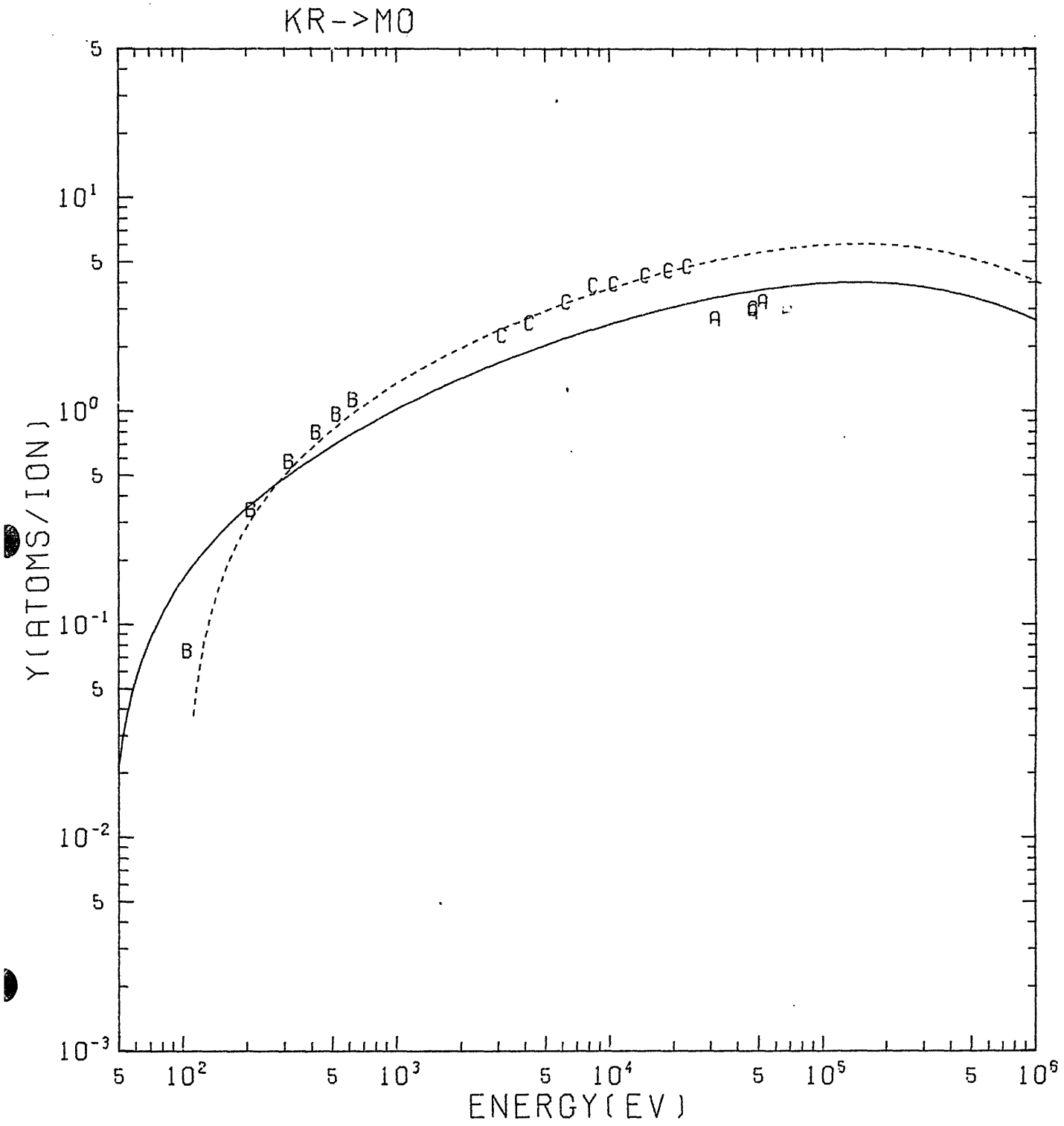
NE->MO
A ALMEN.BRUCE (1961A)
B LAEGREID.WEHNER (1961)

Fig. 110



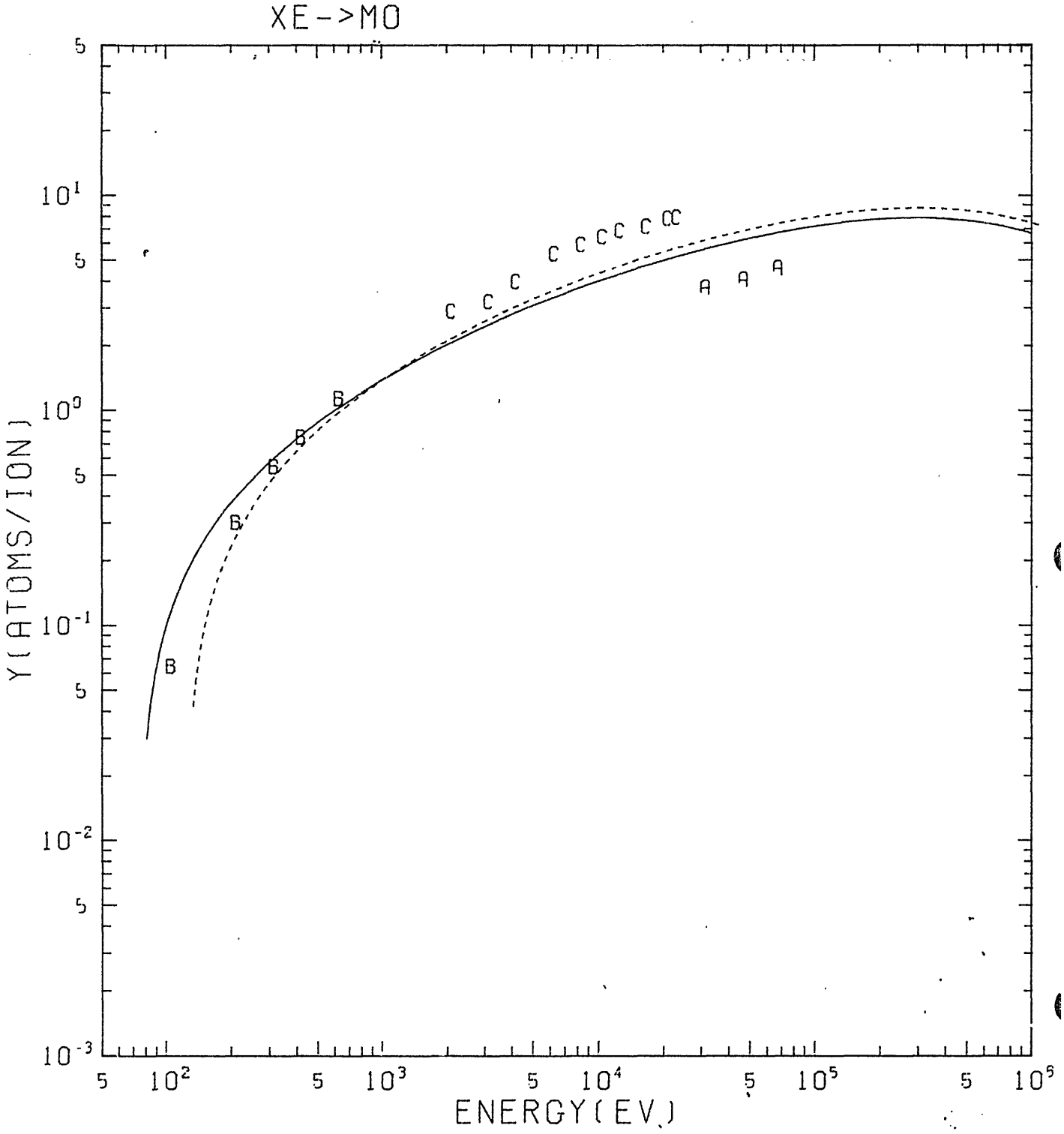
AR->MO
A YONTS.NORMAND.HARRISON (1960)
B ALMEN.BRUCE (1961A)
C LAEGREID.WEHNER (1961)
D KOSHKIN.RYSOV.SHKARBAN (1969)
E SWITKOWSKI.MANN.KNEFF (1976)
F EMMOTH.FRIED.BRAUN (1978)

Fig. 111



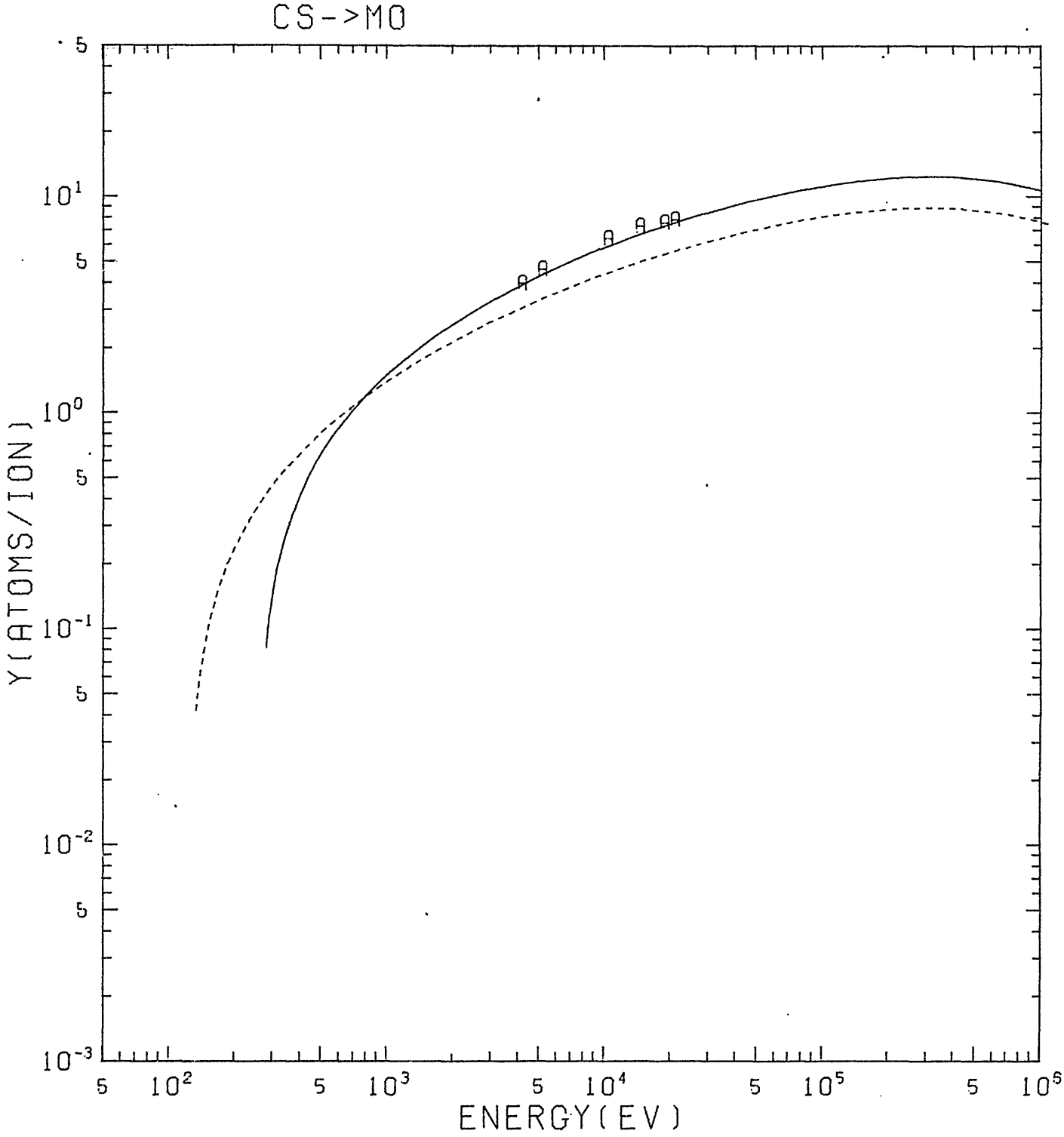
KR->MO
A ALMEN.BRUCE (1961A)
B ROSENBERG.WEHNER (1962)
C KOSHKIN.RYSOV.SHKARBAN (1969)

Fig. 112



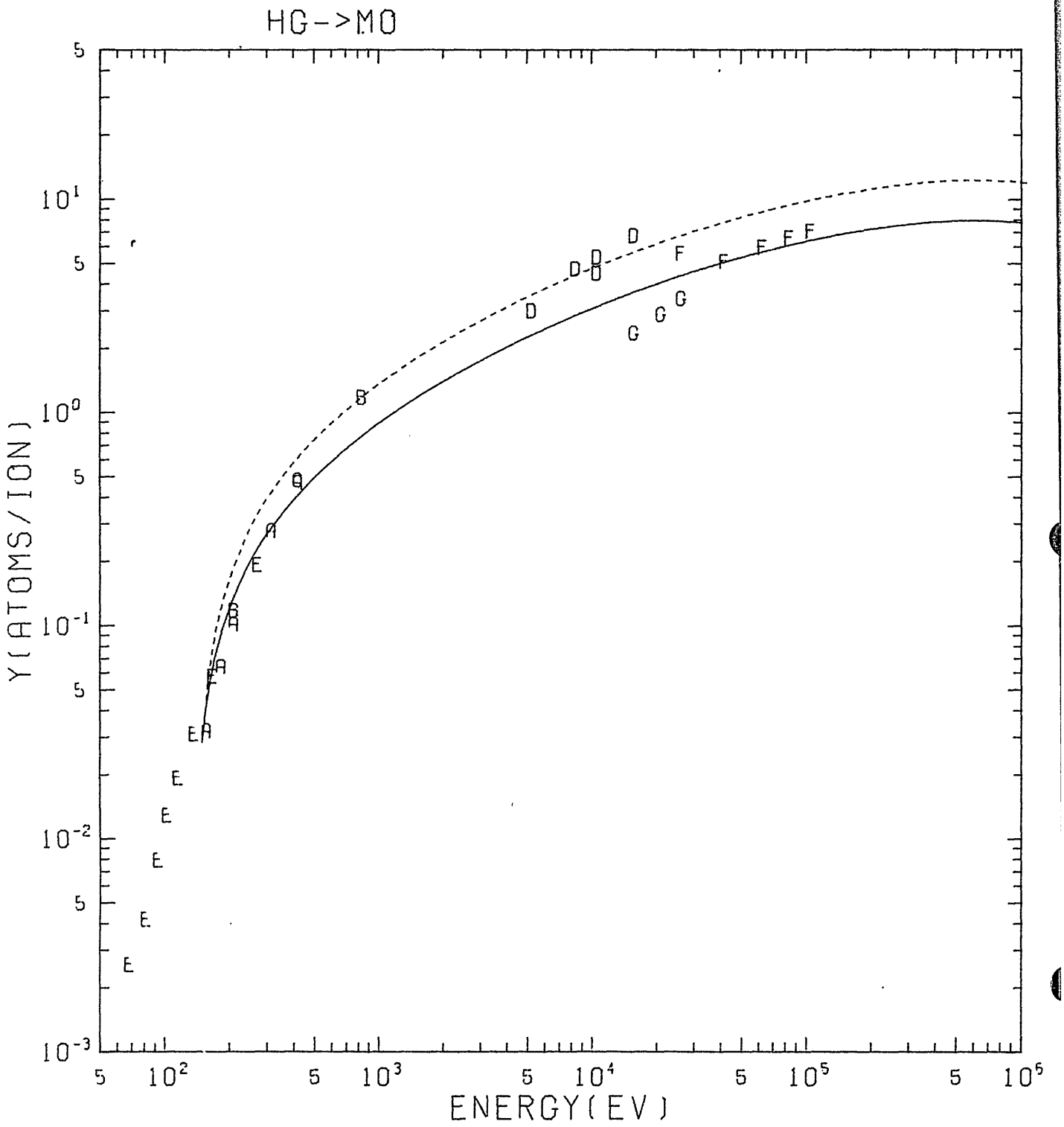
XE->MO
A ALMEN.BRUCE. (1961A)
B ROSENBERG.WEHNER (1962)
C KOSHKIN.RYSOV.SHKARBAN (1969)

Fig. 113



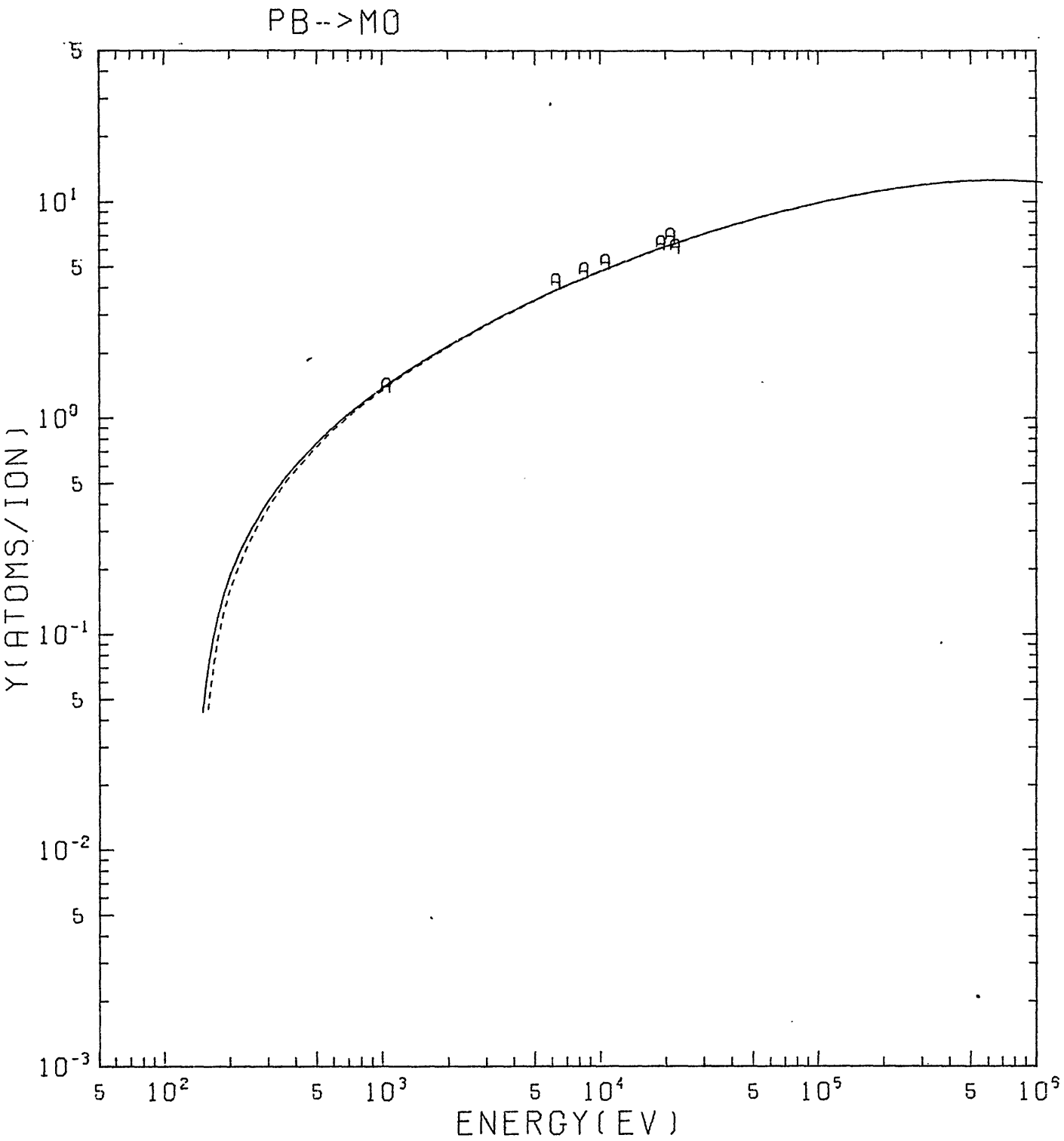
CS->MO
A KOSHKIN.RYSOV.SHKARBAN (1969)

Fig. 114



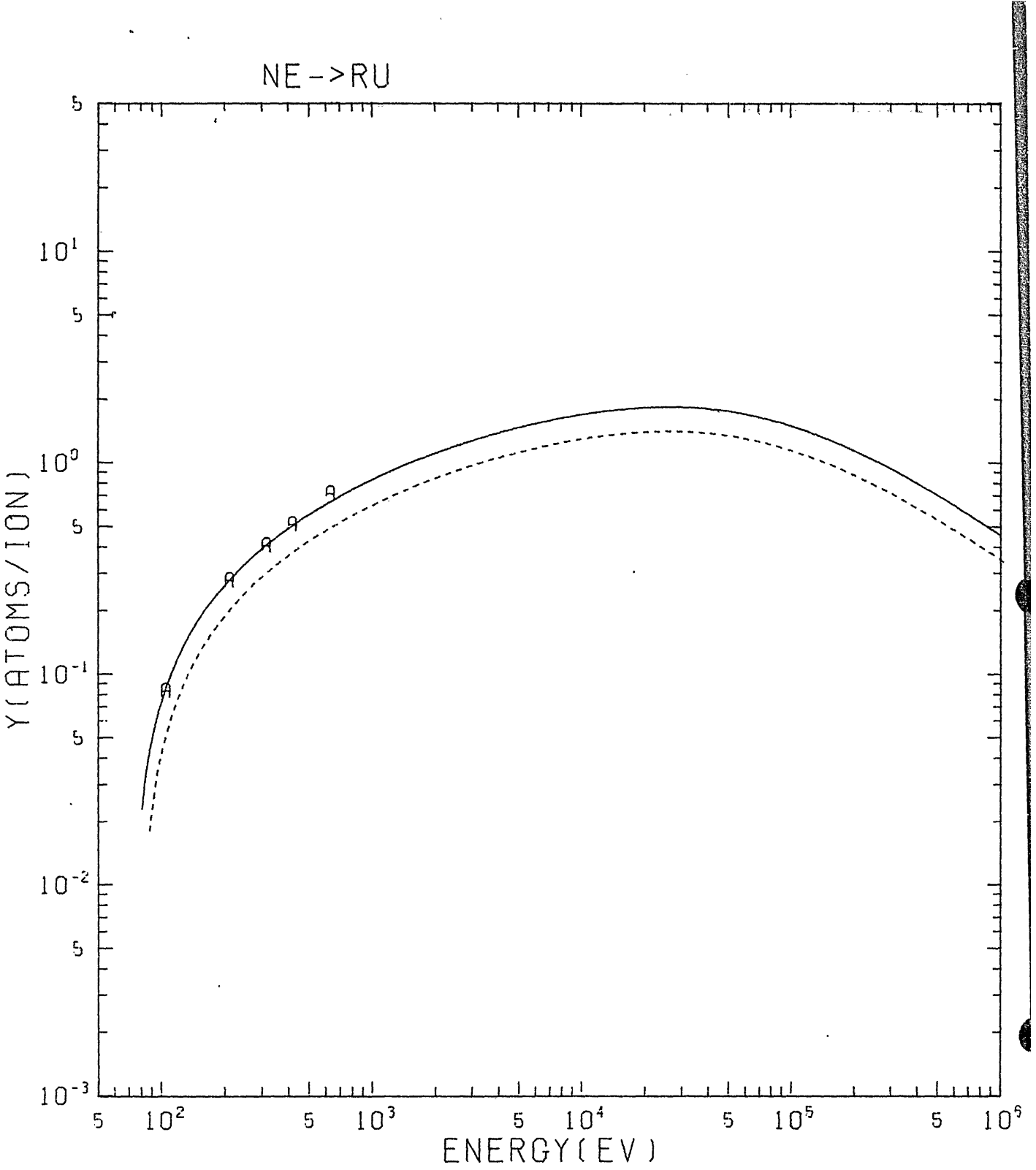
HG->MO
A WEHNER (1957)
B WEHNER (1959)
C LZEGREID.WEHNER (1961)
D WEHNER.ROSENBERG (1961)
E ASKEROV.SENA (1969)
F HEPWORTH (1970)
G ISMAIL (1970)

Fig. 115



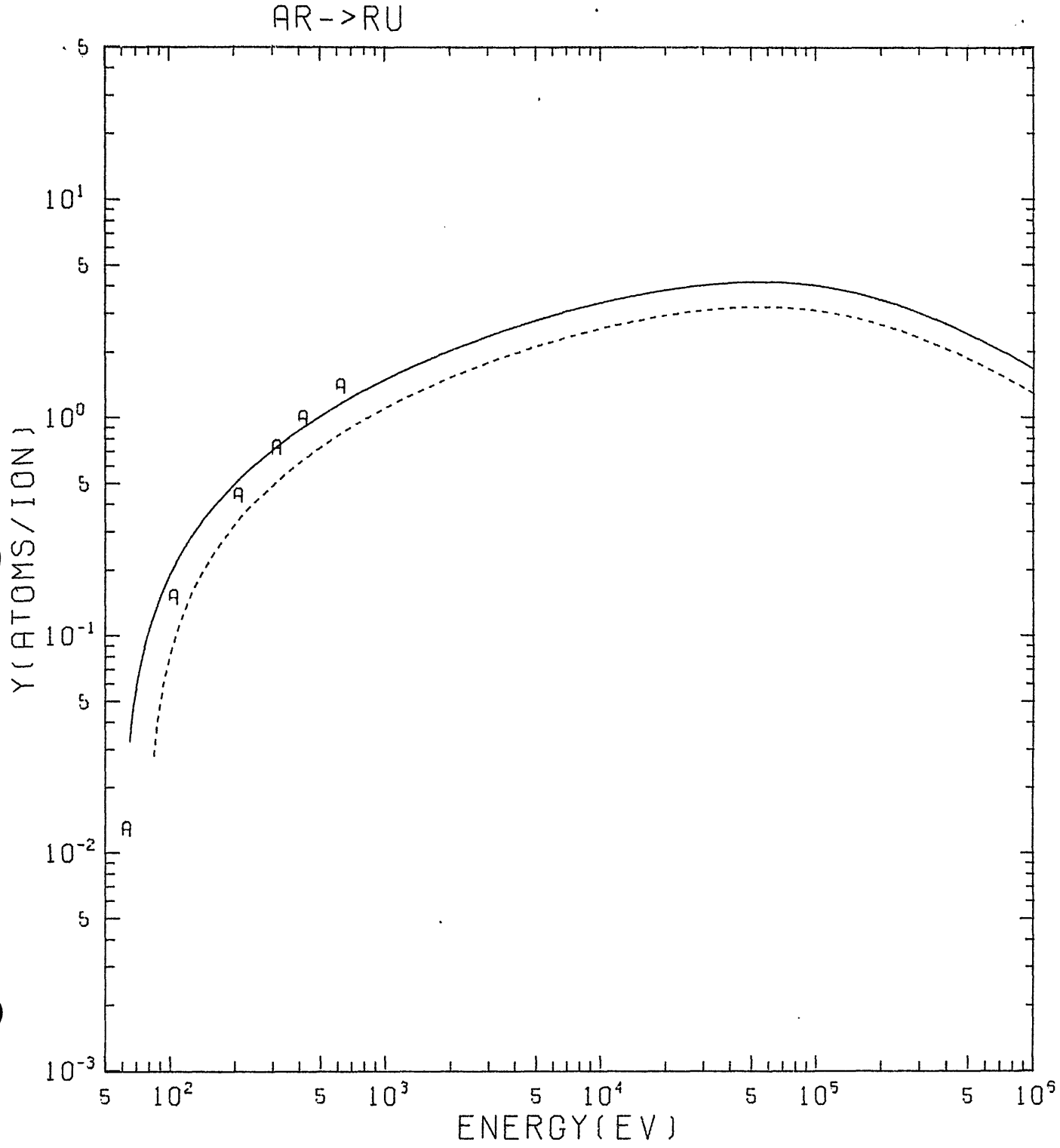
PB->MO
A KOSHKIN.RYSOV.SHKARBAN (1969)

Fig. 116



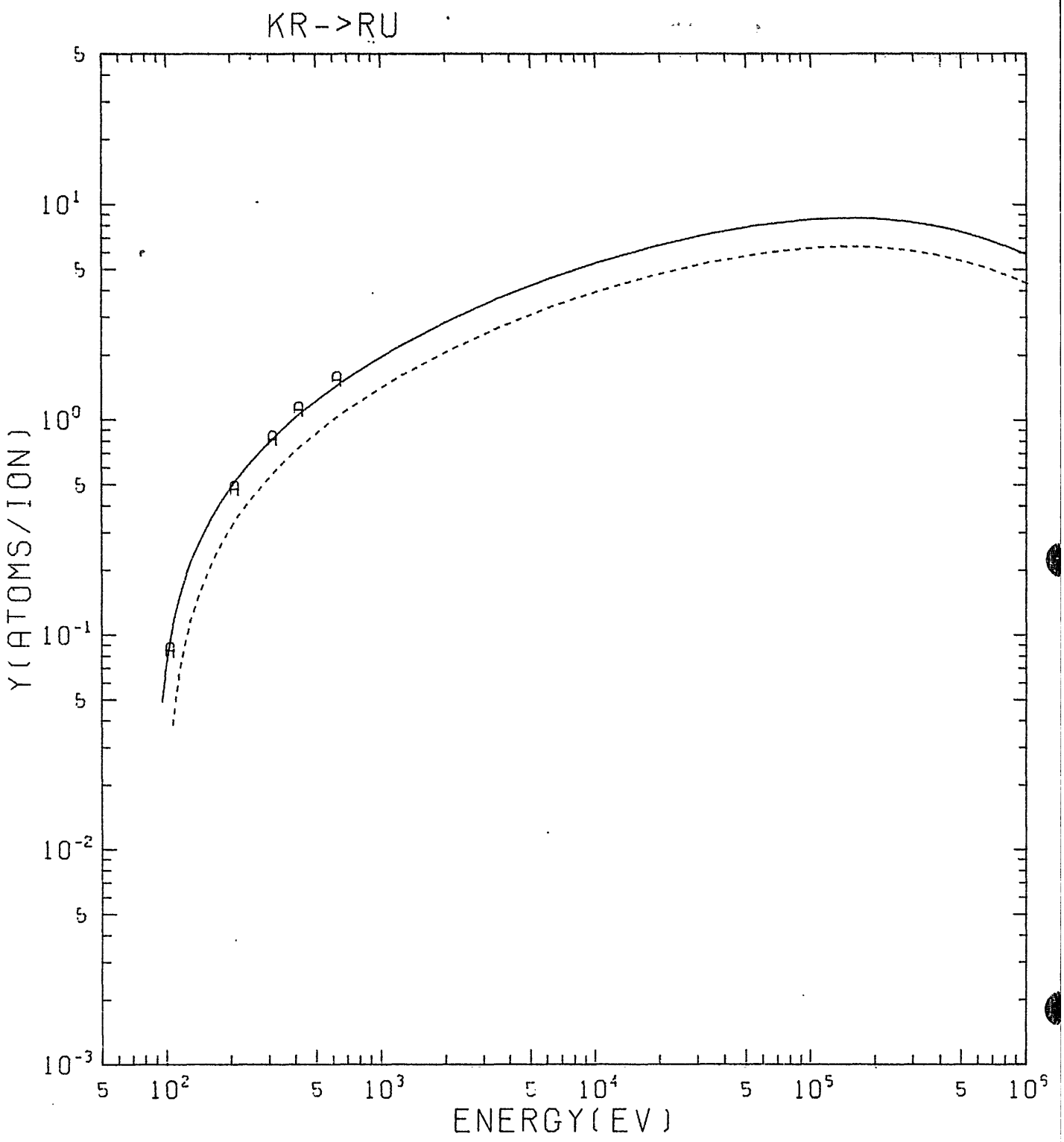
NE->RU
A LAEGREID.WEHNER (1961)

Fig. 117



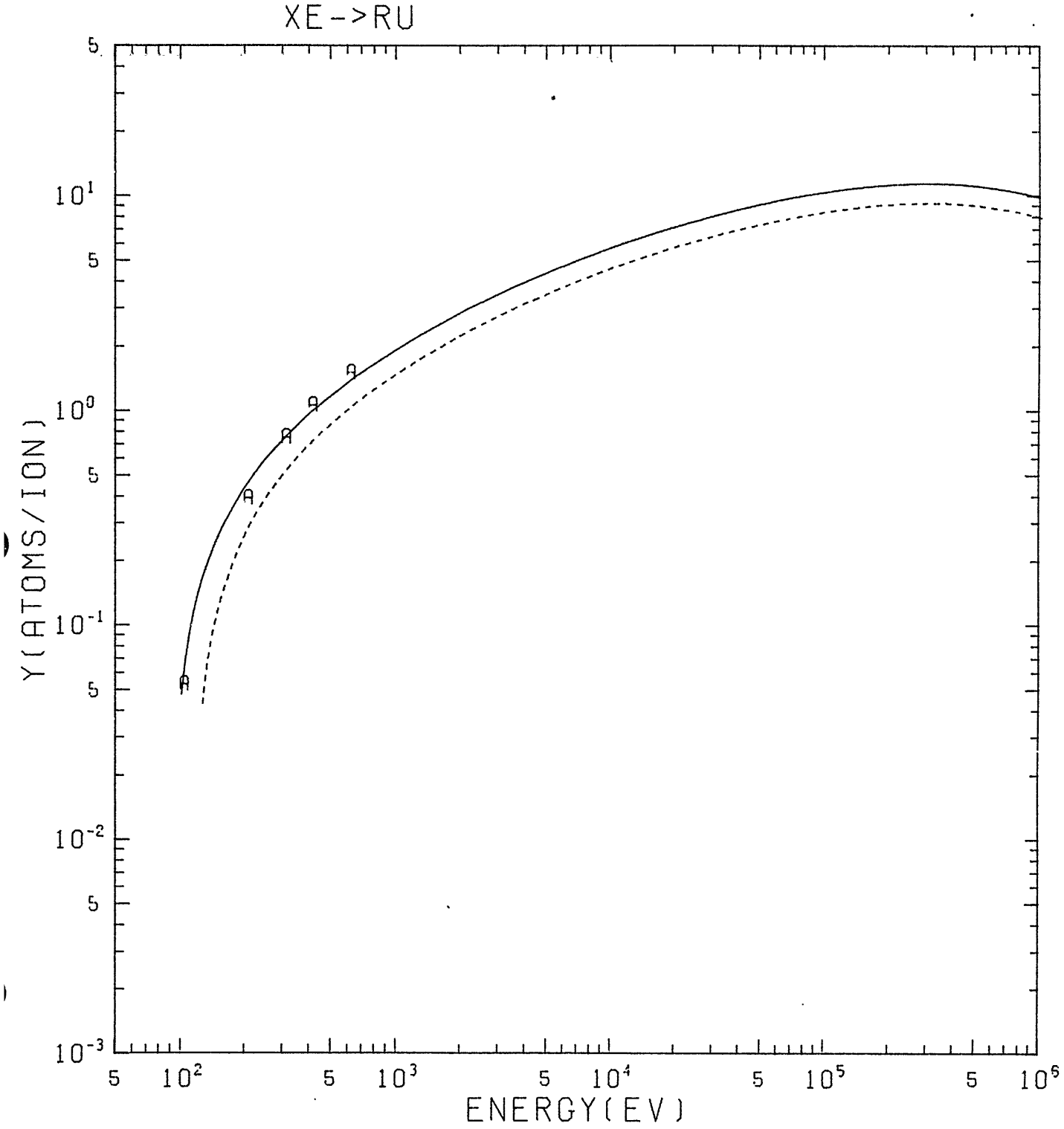
AR->RU
A LAEGREID,WEHNER (1961)

Fig. 118



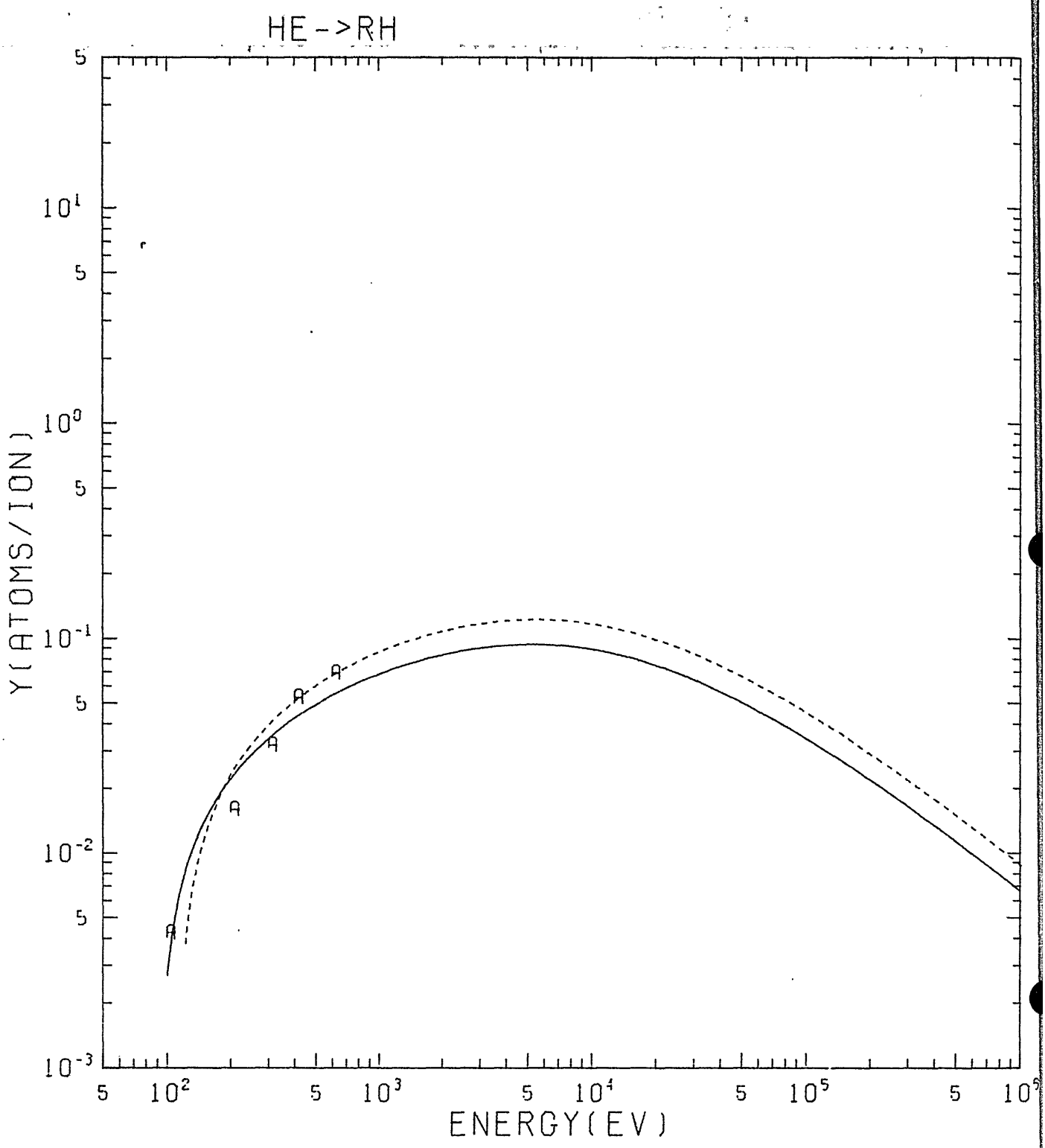
KR->RU
A ROSENBERG,WEHNER (1962)

Fig. 119



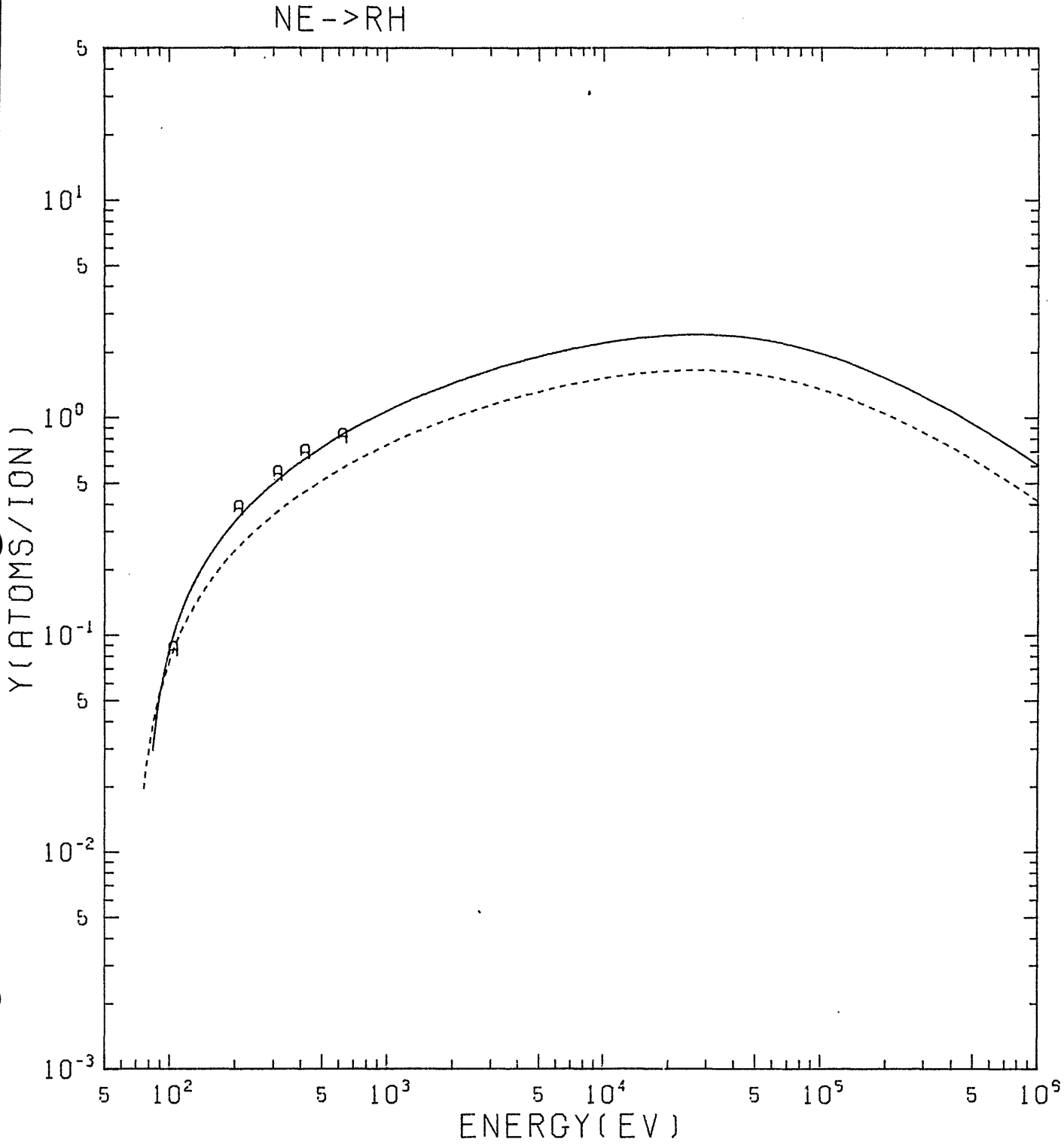
XE->RU
A ROSENBERG,WEHNER (1962)

Fig. 120



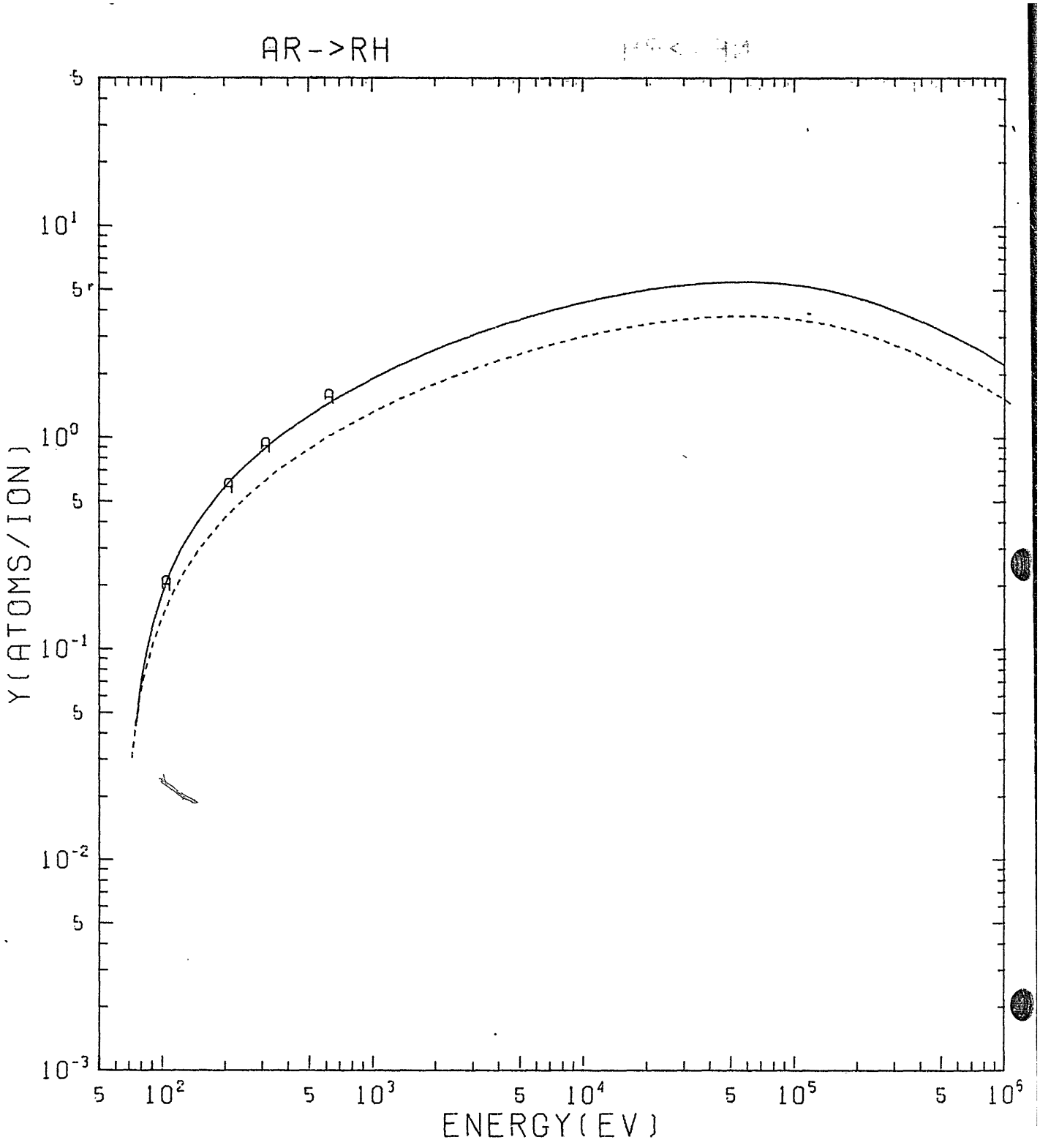
HE->RH
A ROSENBERG,WEHNER (1962)

Fig. 121



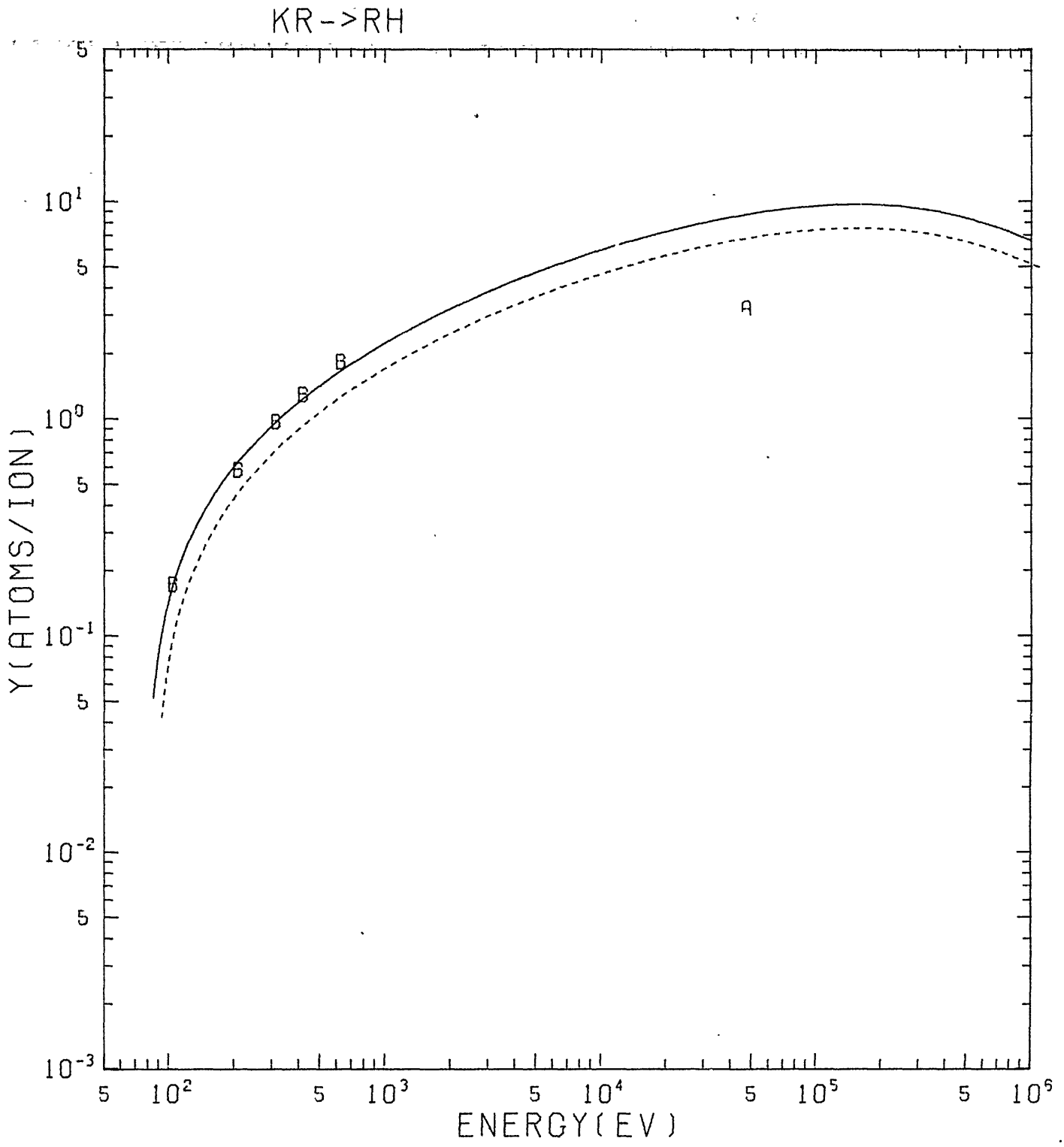
NE->RH
A LAEGREID,WEHNER (1961)

Fig. 122



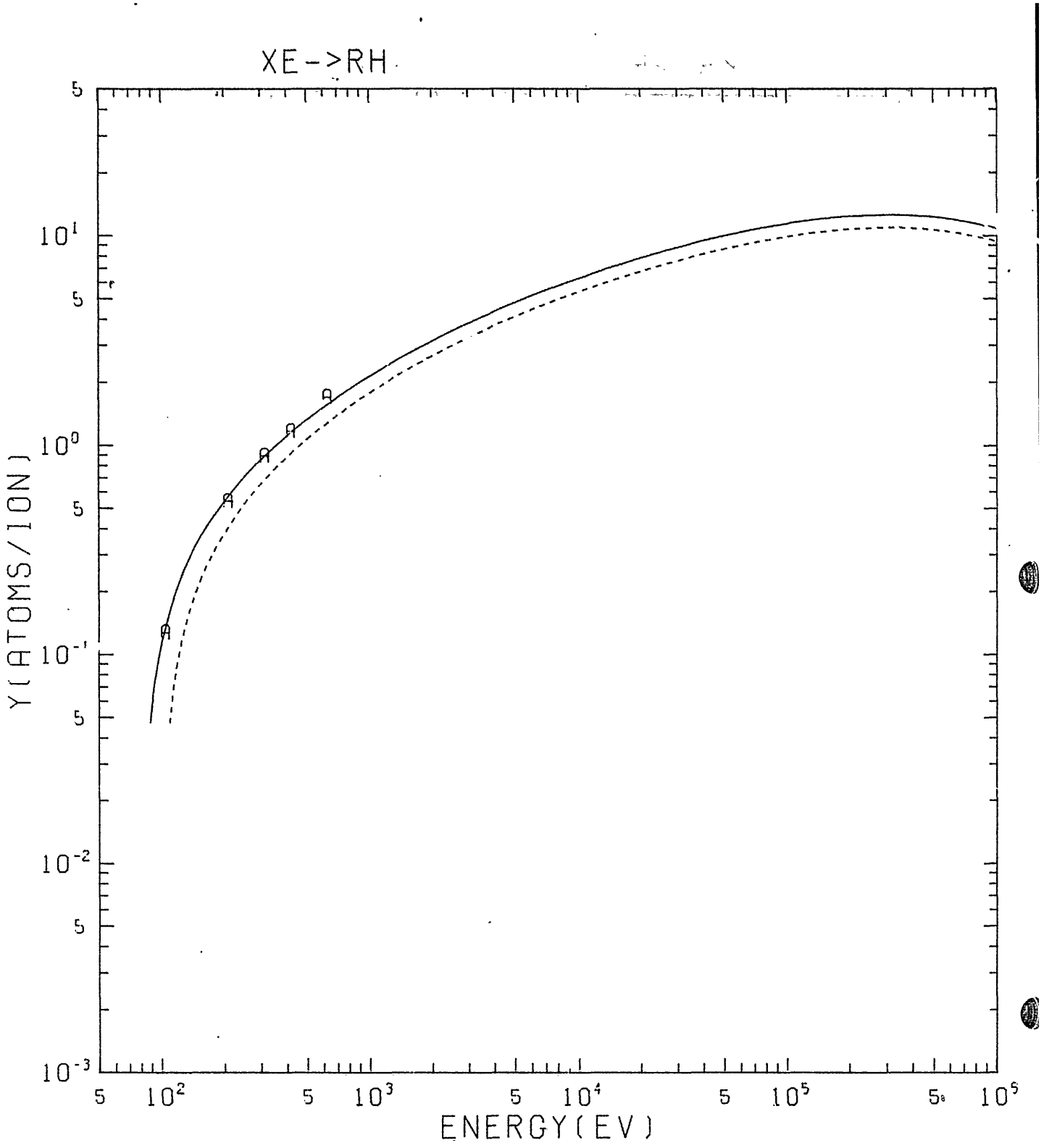
AR->RH
A LAEGREID.WEHNER (1961)

Fig. 123



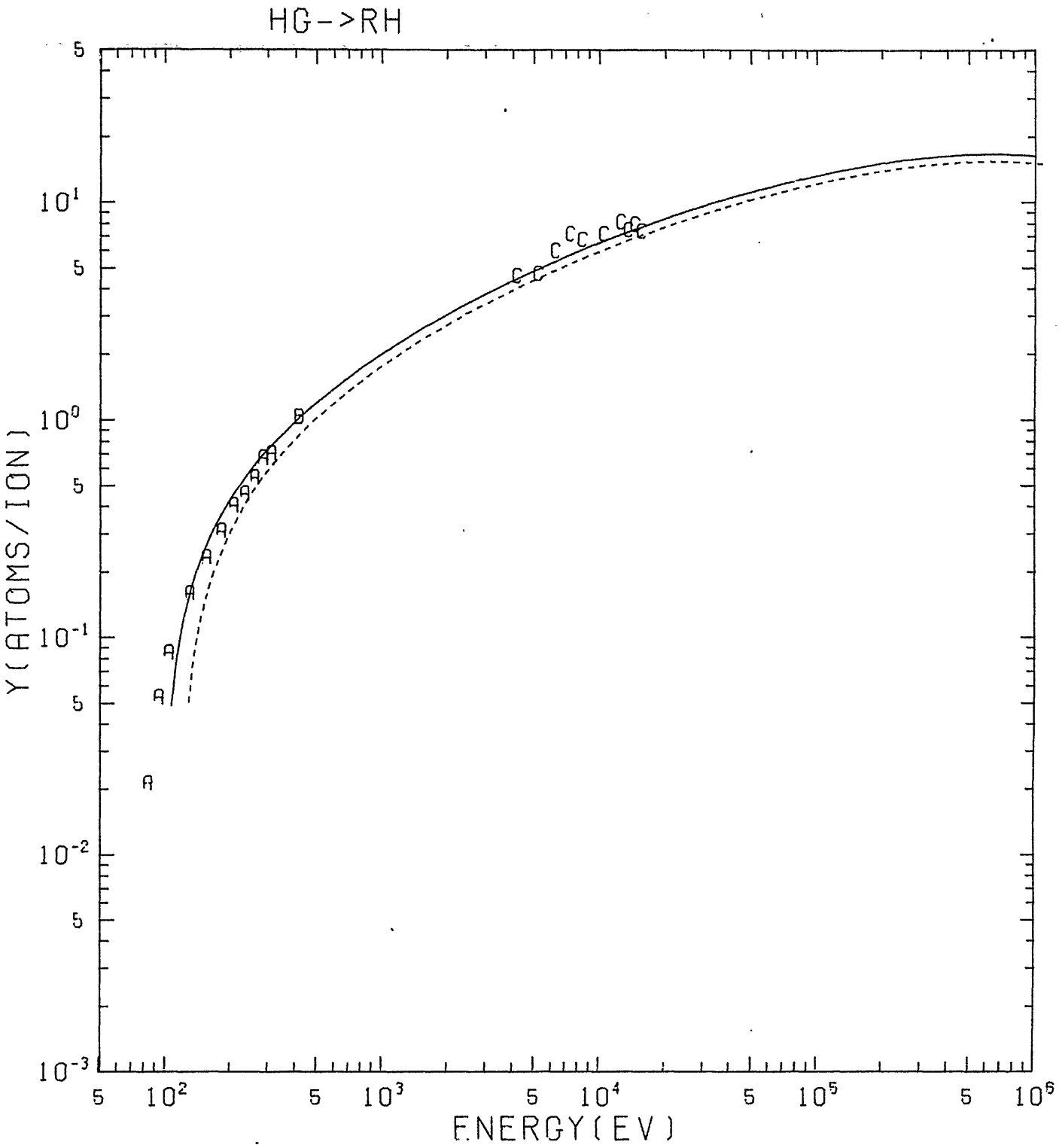
KR->RH
A ALMEN.BRUCE (1961A)
B ROSENBERG.WEHNER (1962)

Fig. 124.



XE->RH
A ROSENBERG,WEHNER (1962)

Fig. 125



HG->RH
A WEHNER (1957)
B LAEGREID,WEHNER (1961)
C WEHNER,ROSENBERG (1961)

Fig. 126

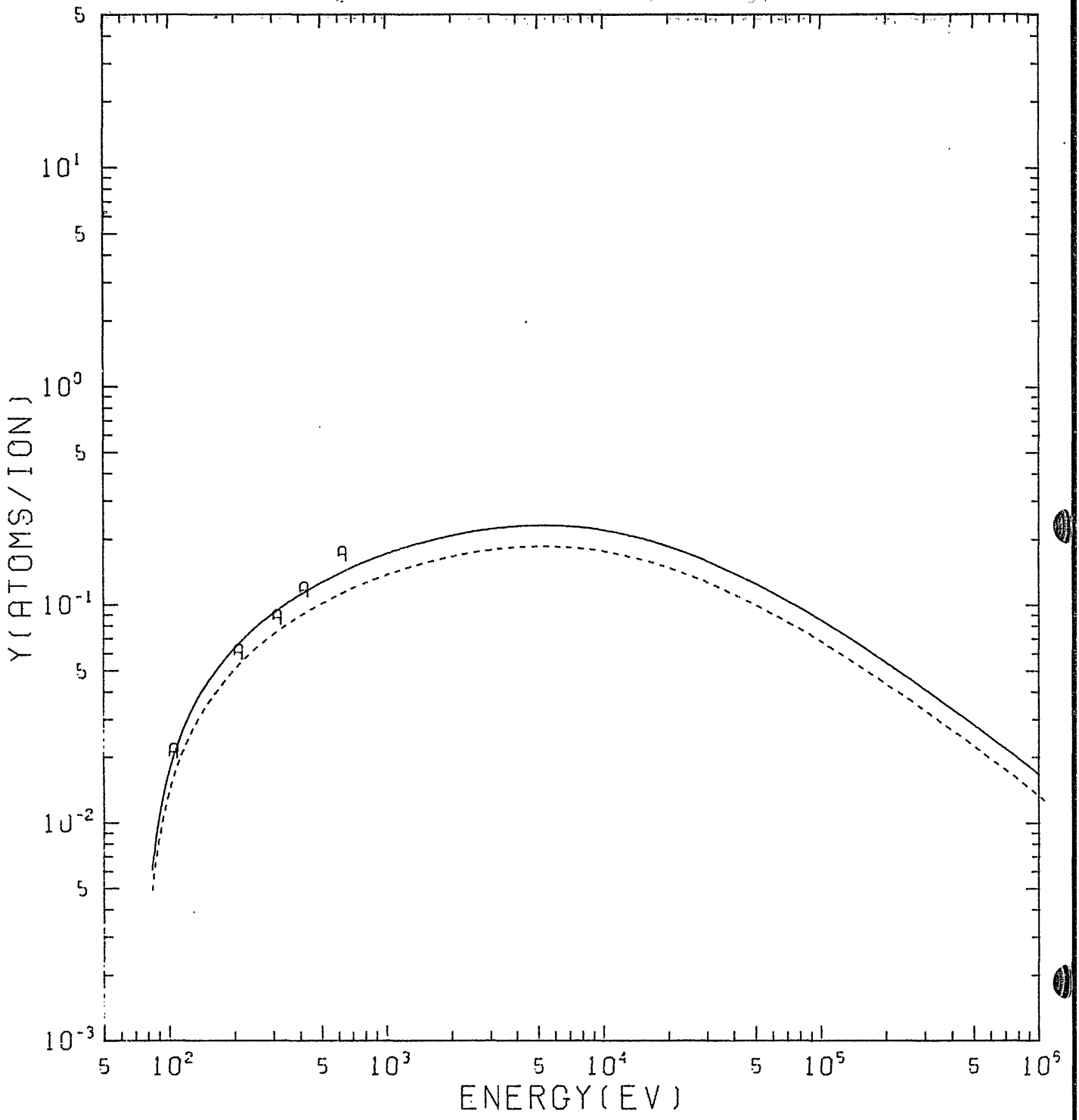
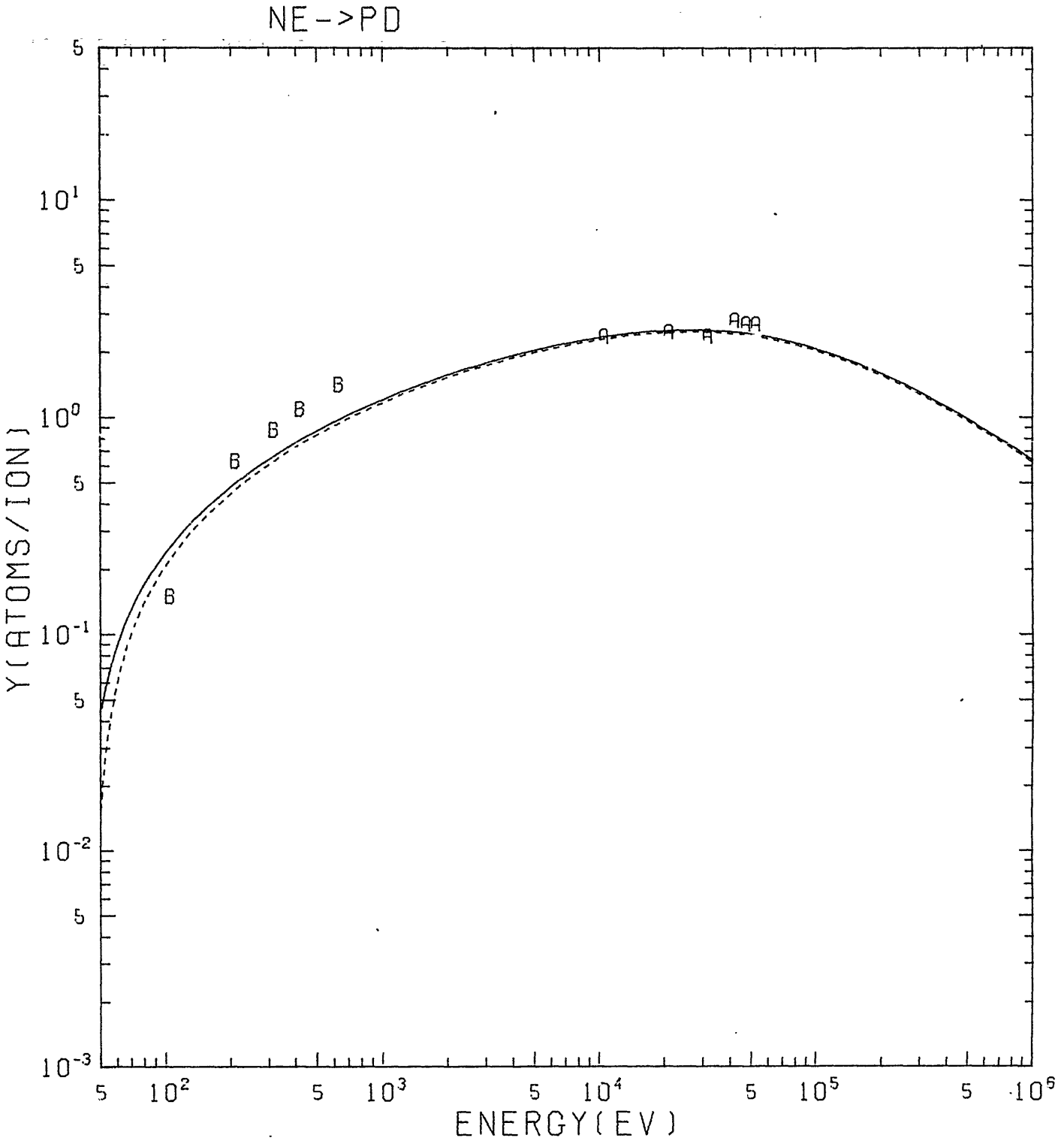
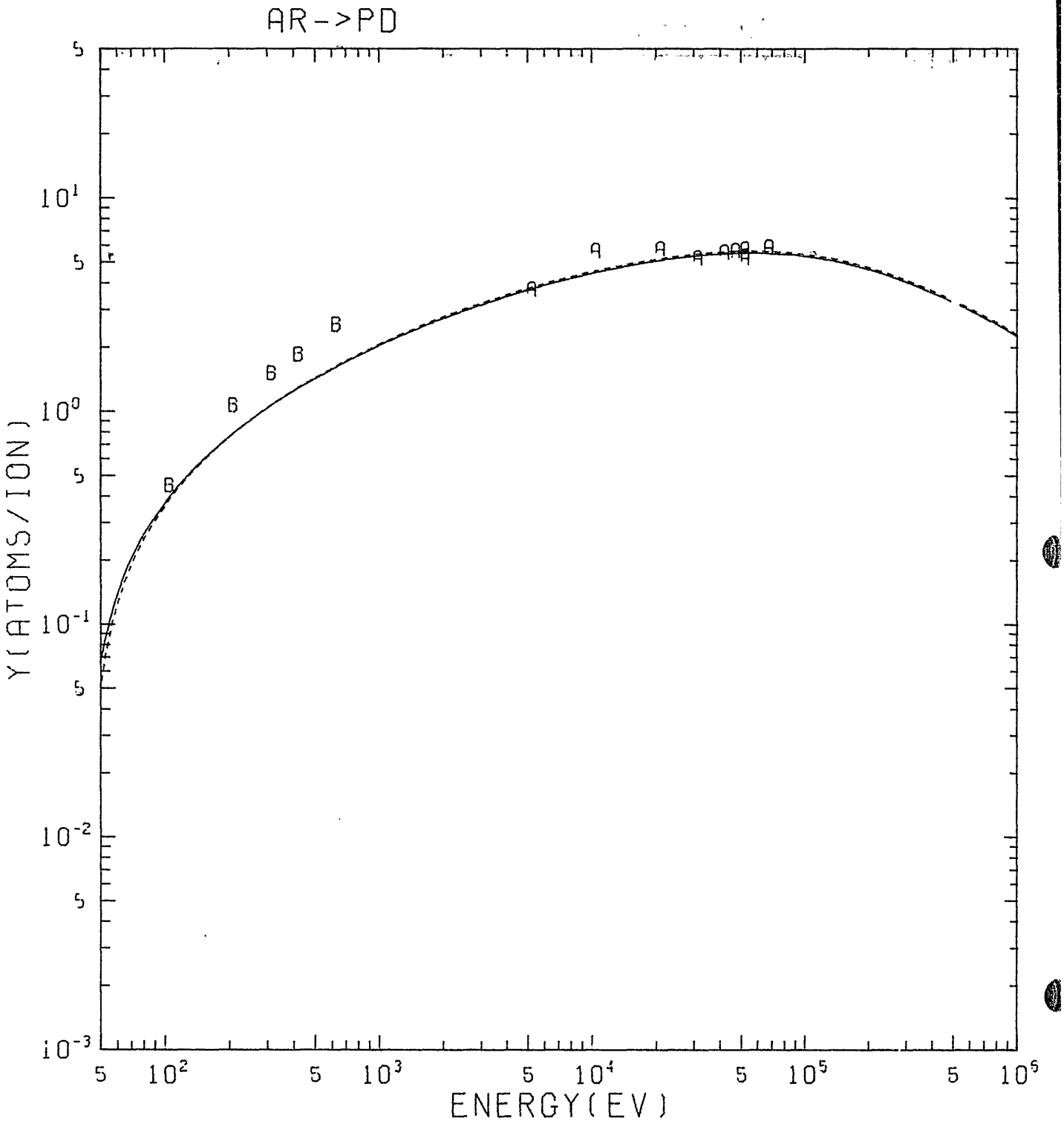


Fig. 127



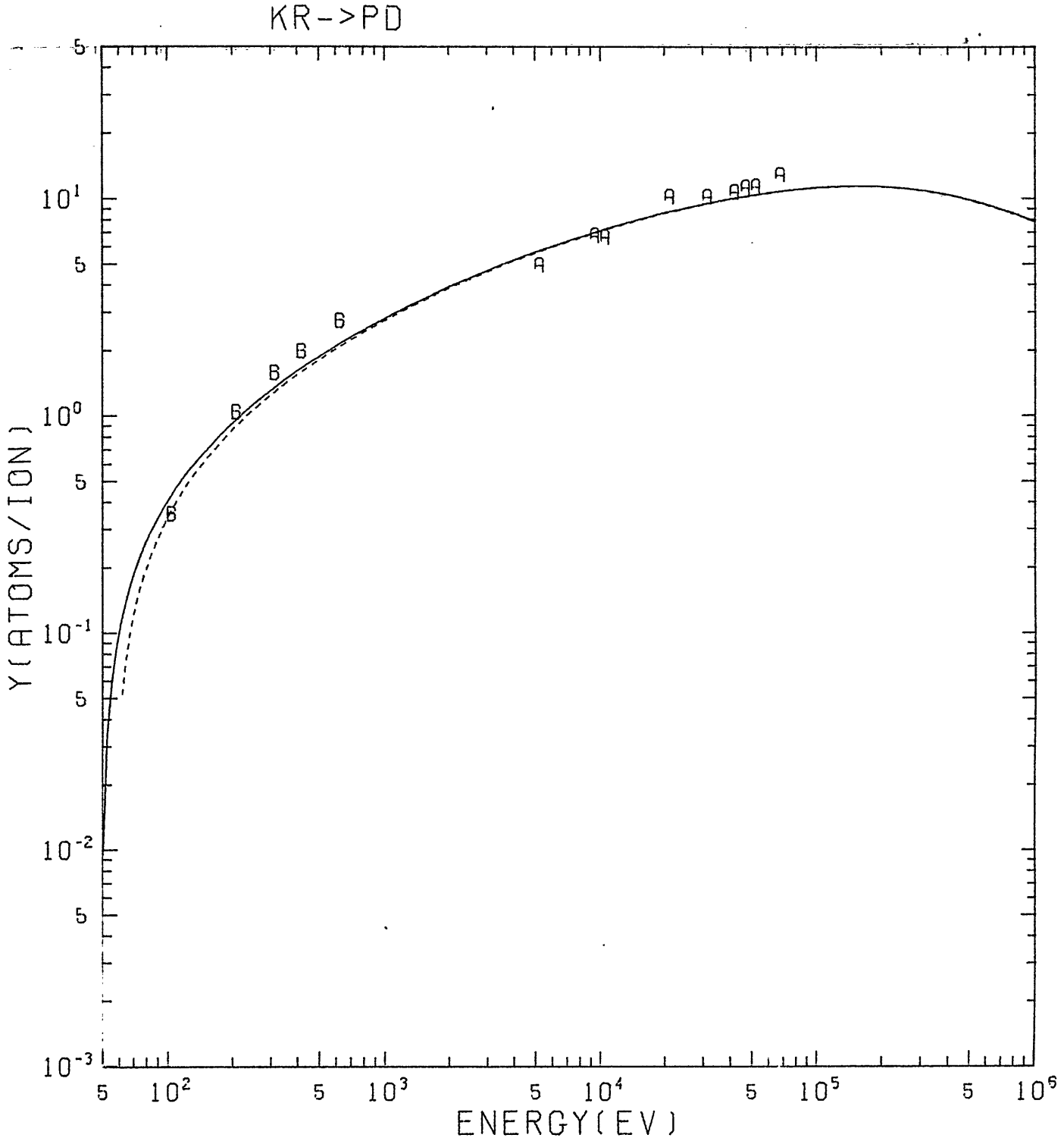
NE->PD
A ALMEN.BRUCE (1961A)
B LAEGREID.WEHNER (1961)

Fig. 128



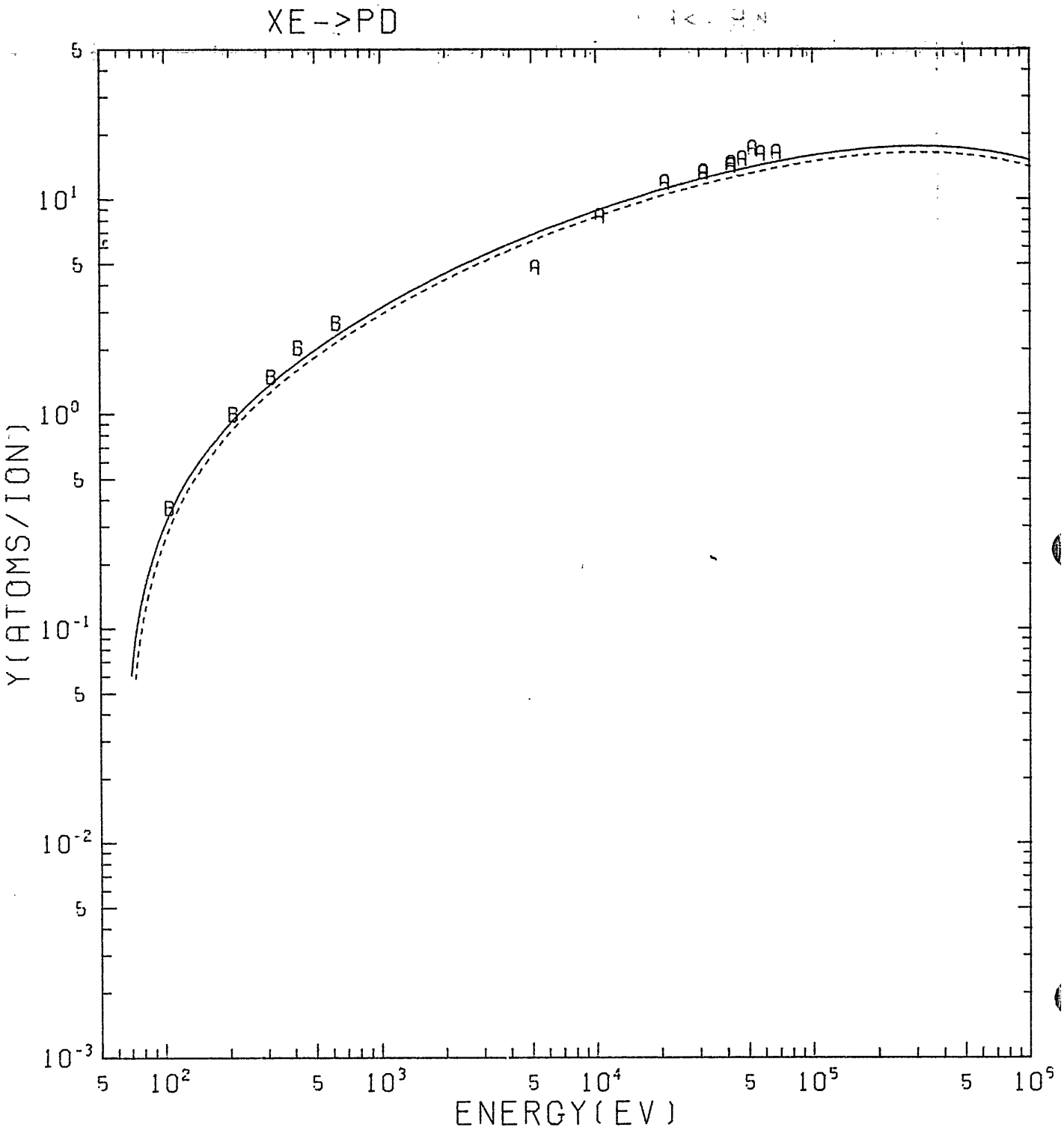
AR->PD
A ALMEN.BRUCE (1961A)
B LAEGREID.WEHNER (1961)

Fig. 129



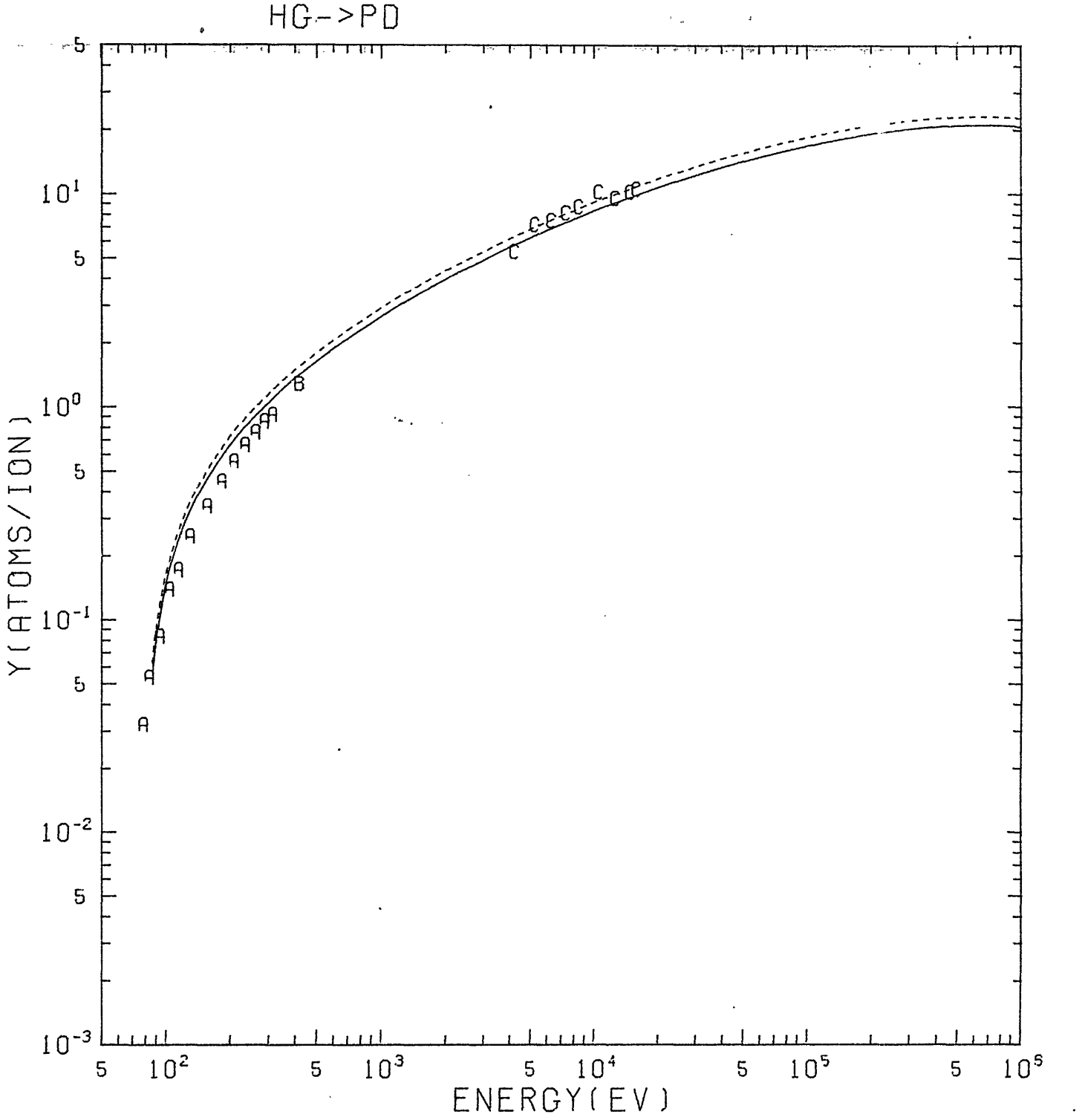
KR->PD
A ALMEN.BRUCE (1961A)
B ROSENBERG.WEHNER (1962)

Fig. 130



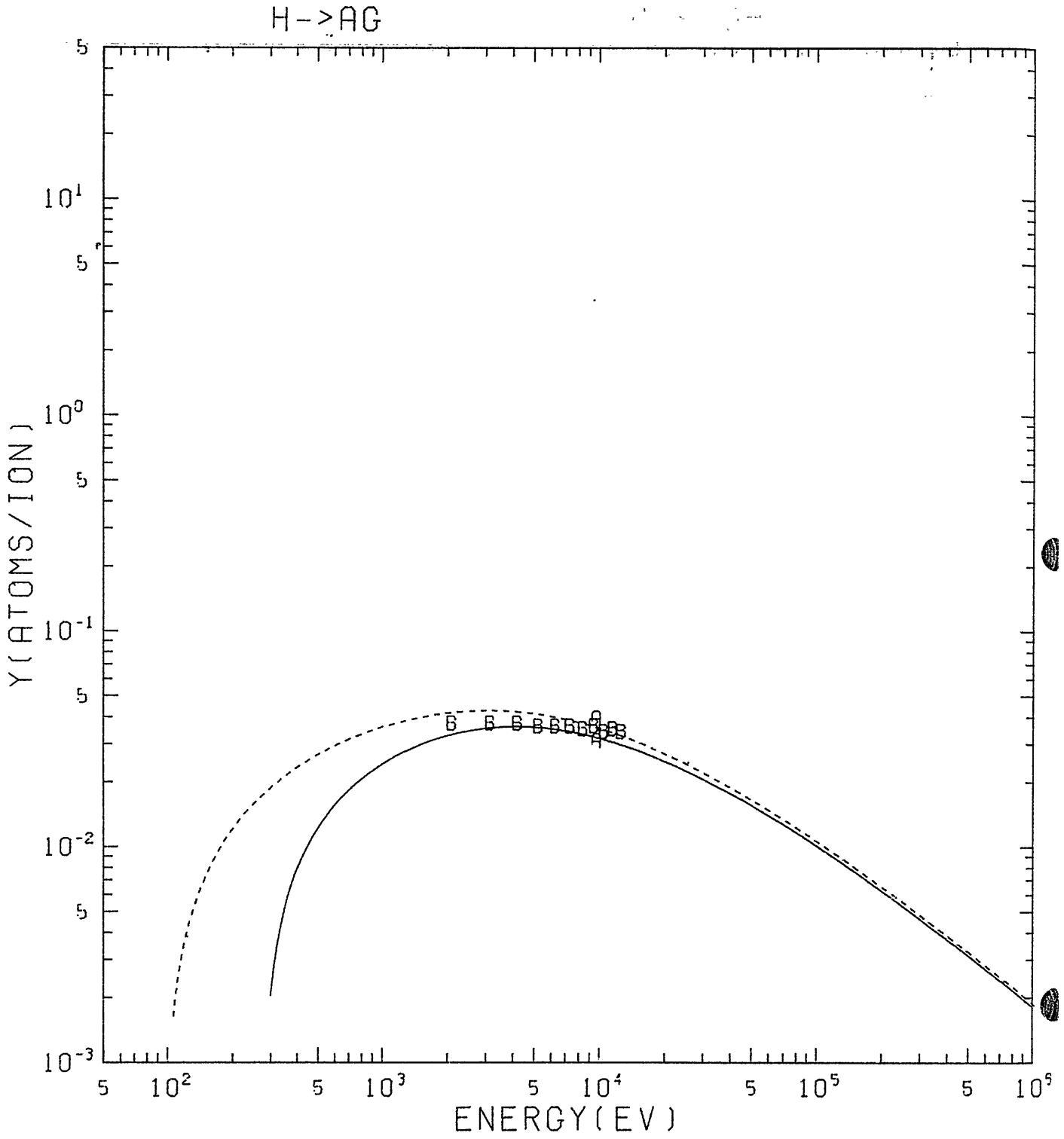
XE->PD
A ALMEN.BRUCE (1961A)
B ROSENBERG.WEHNER (1962)

Fig. 131



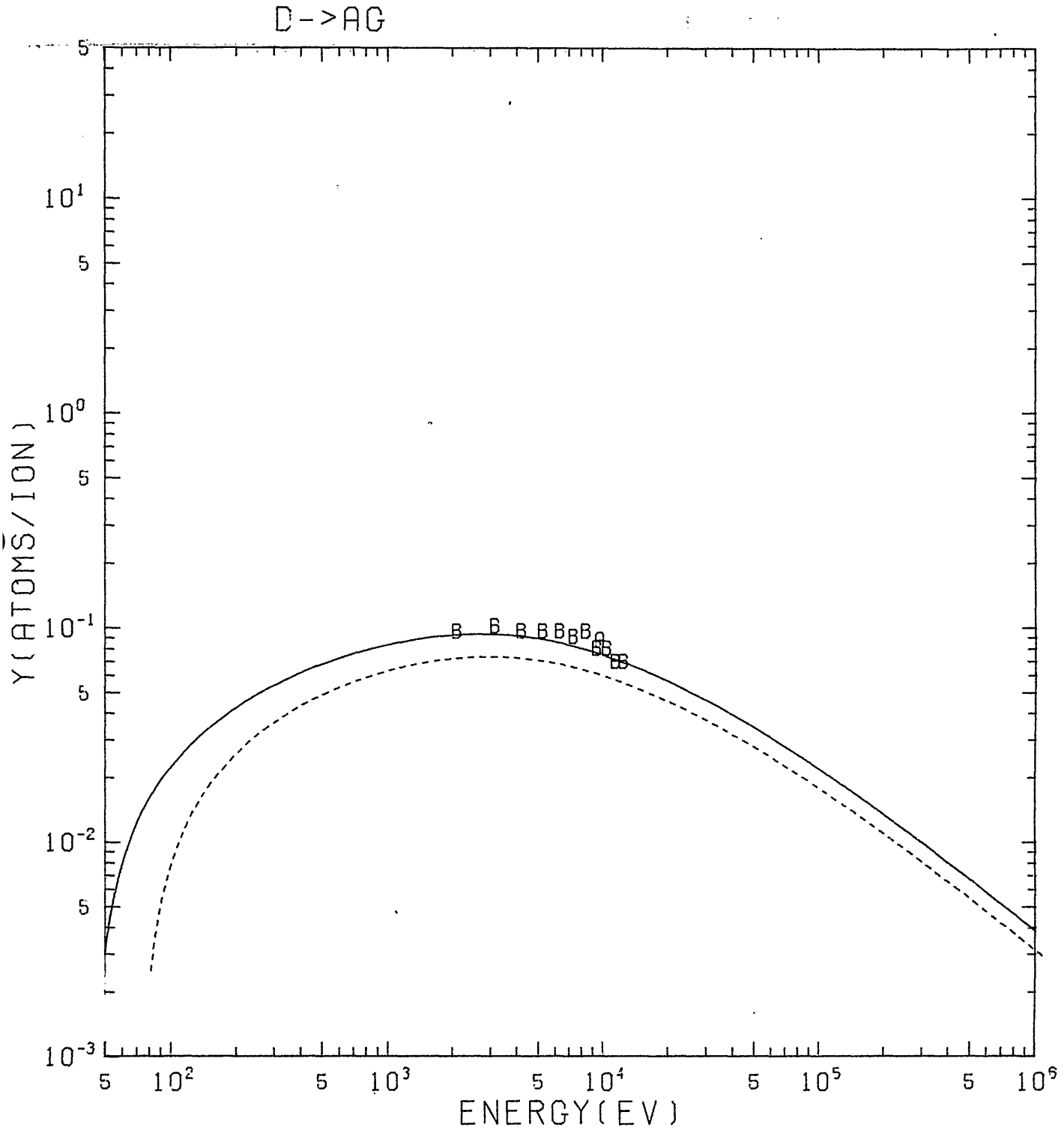
HG->PD
A WEHNER (1957)
B LAEGREID,WEHNER (1961)
C WEHNER,ROSENBERG (1961)

Fig. 132



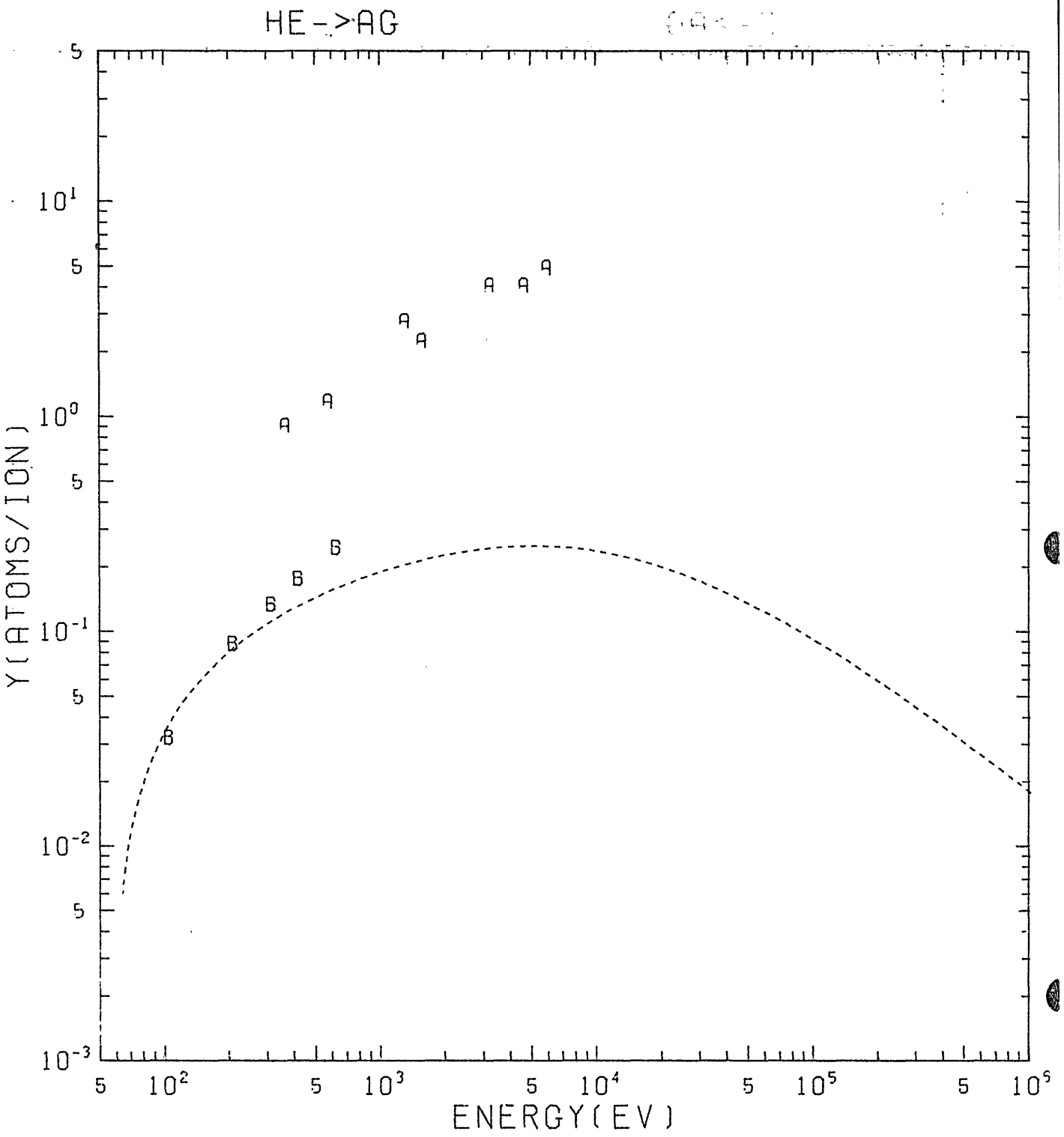
H->AG
A O'BRIAIN.LINDNER.MOORE (1958)
B GRONLUND.MOORE (1960)

Fig. 133



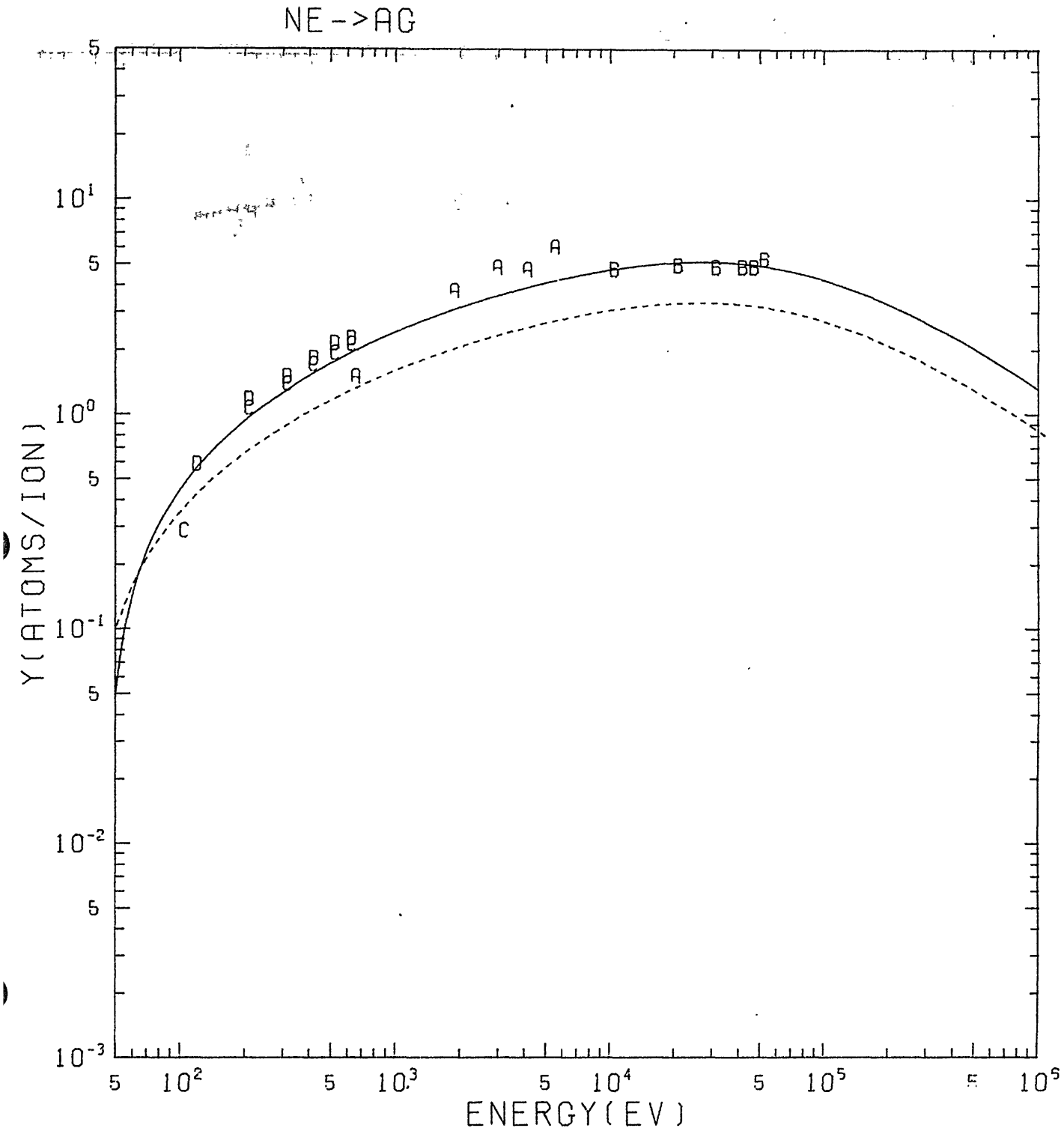
D->AG
A O'BRIAIN.LINDNER.MOORE (1958)
B GRONLUND.MOORE (1960)

Fig. 134



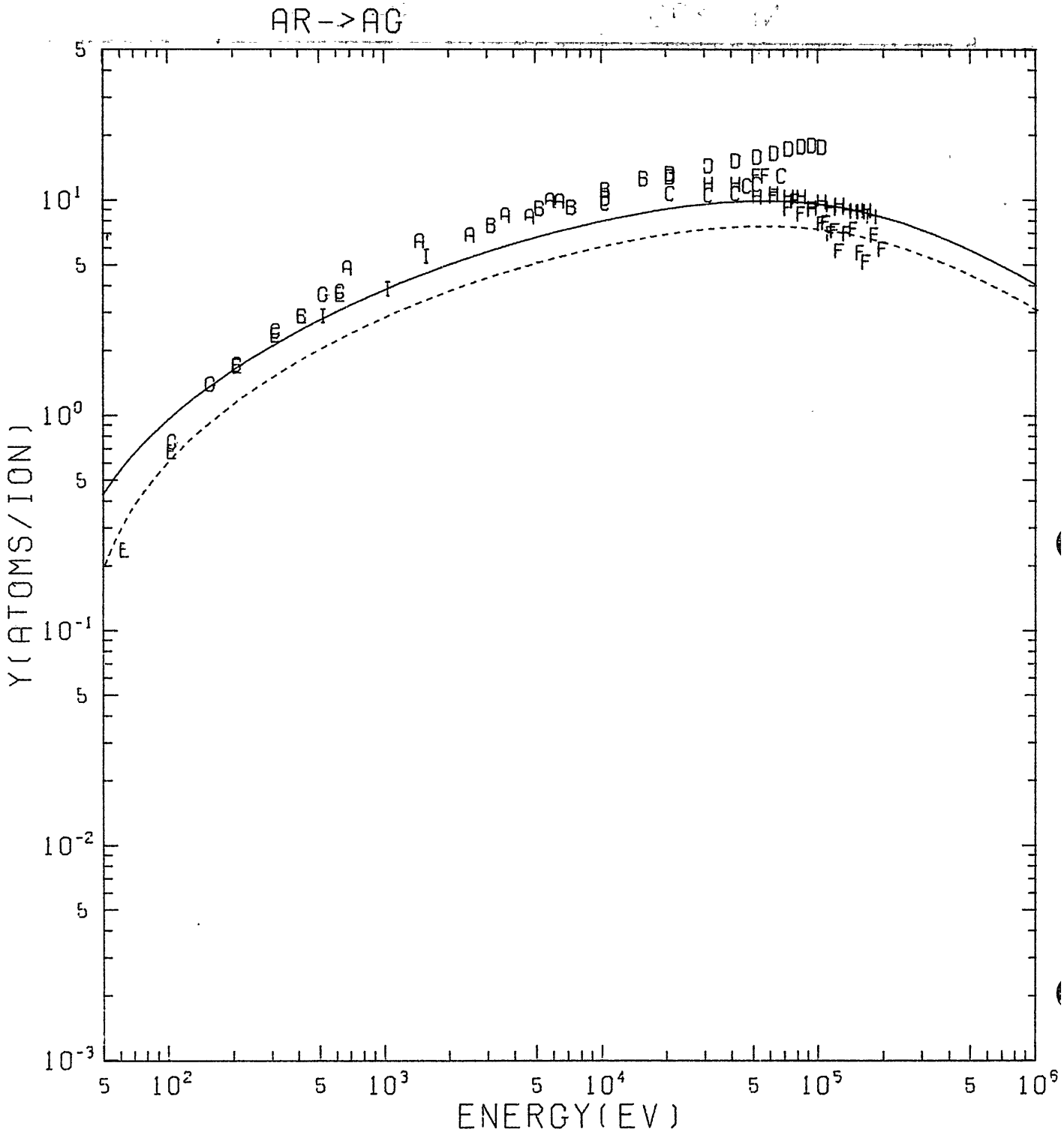
HE->AG
A KEYWELL (1955)
B ROSENBERG,WEHNER (1962)

Fig. 135



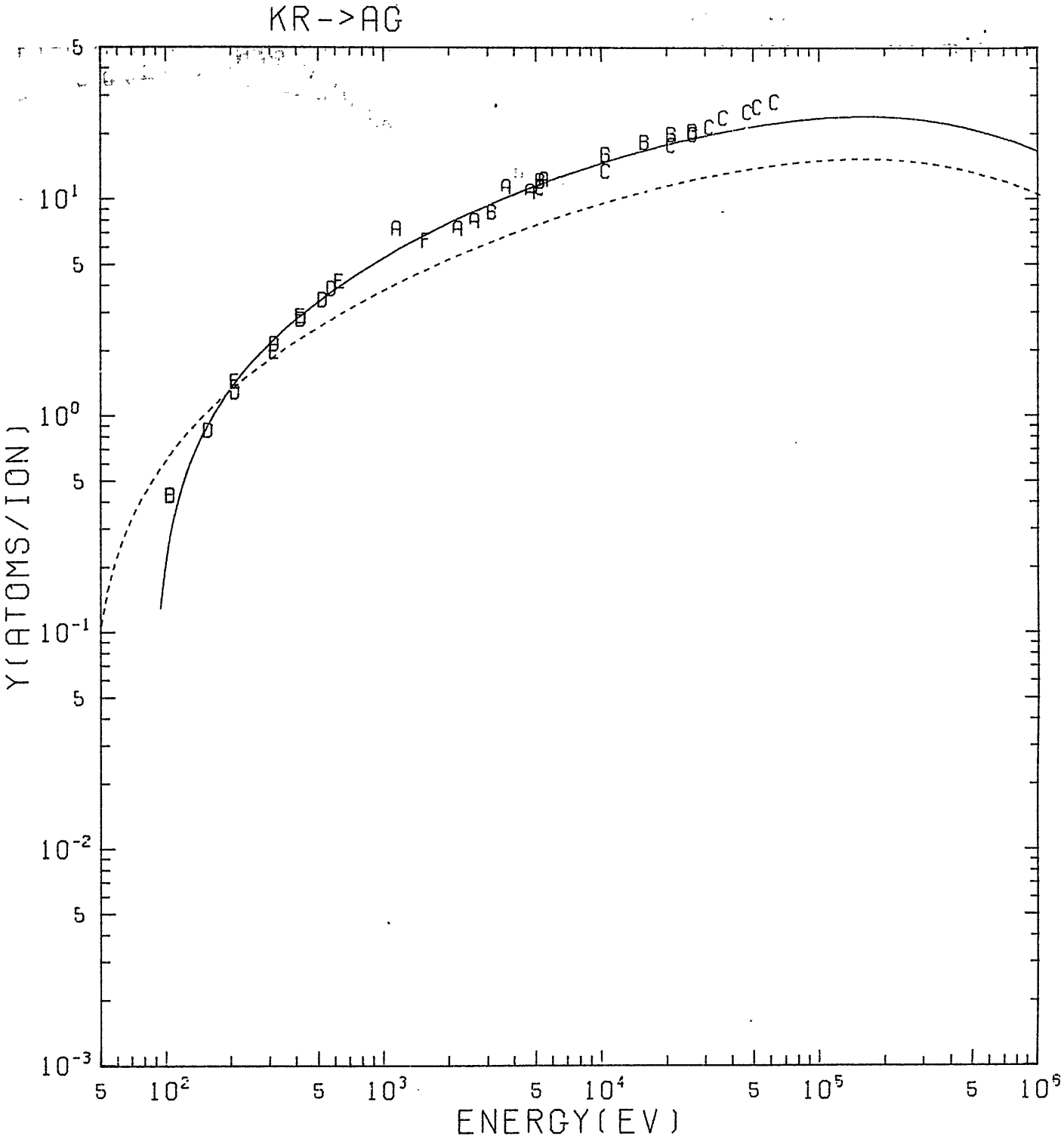
NE->AG
A KEYWELL (1955)
B ALMEN,BRUCE (1961A)
C LAEGREID,WEHNER (1961)
D WEHNER,STUART,ROSENBERG (1961)

Fig. 136



AR->AG
A KEYWELL (1955)
B GUSEVA (1960)
C ALMEN,BRUCE (1961A)
D FERT,COLOMBIE,FAGOT (1361)
E LAEGREID,WEHNER (1961)
F PEROVIC,COBIC (1961)
G WEHNER,ROSENBERG (1961)
H RAMER,NARASIMHAM,REYNOLDS (1964)
I SMITH,MEYER,LAYTON (1975)

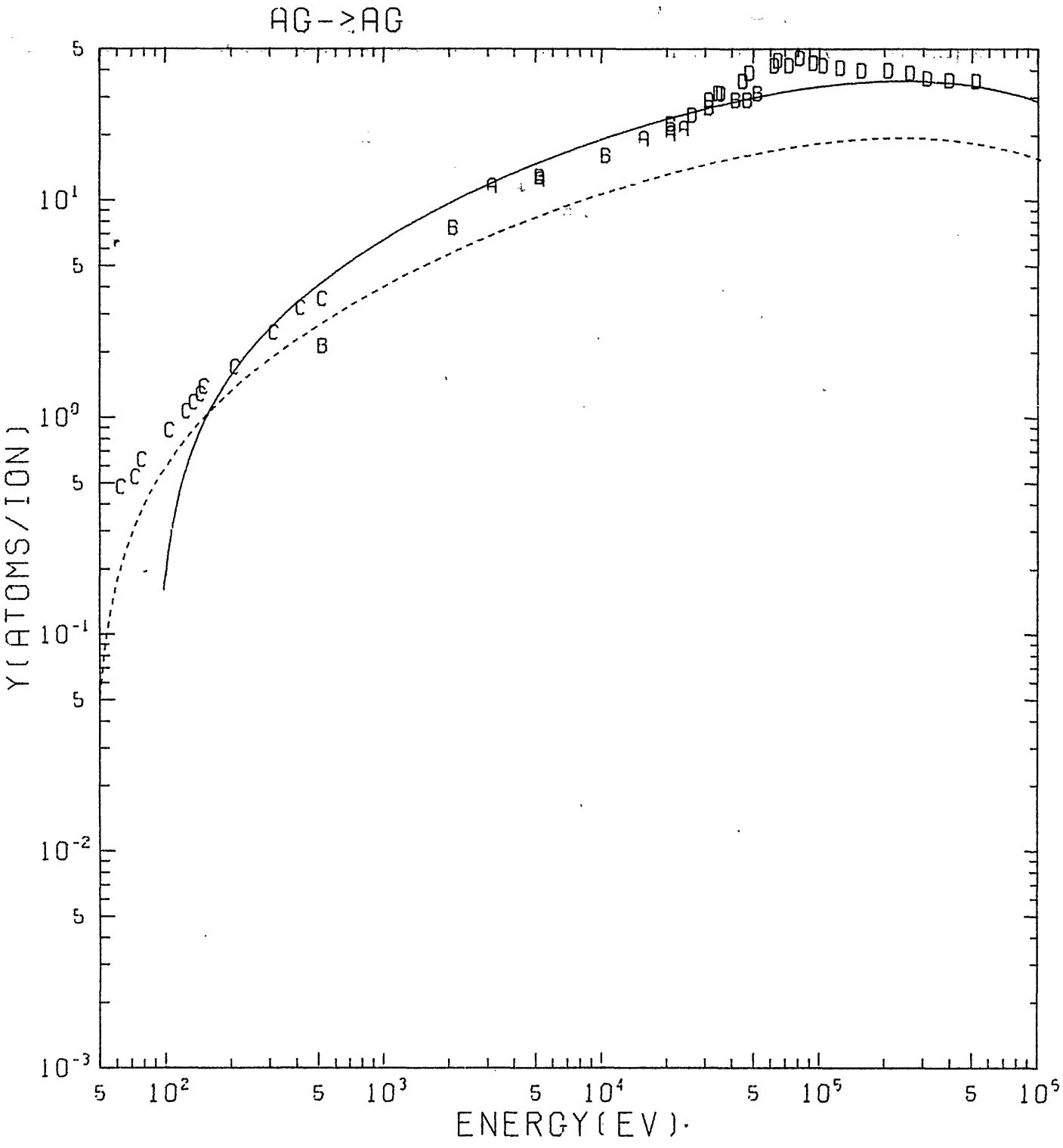
Fig. 137



KR->AG

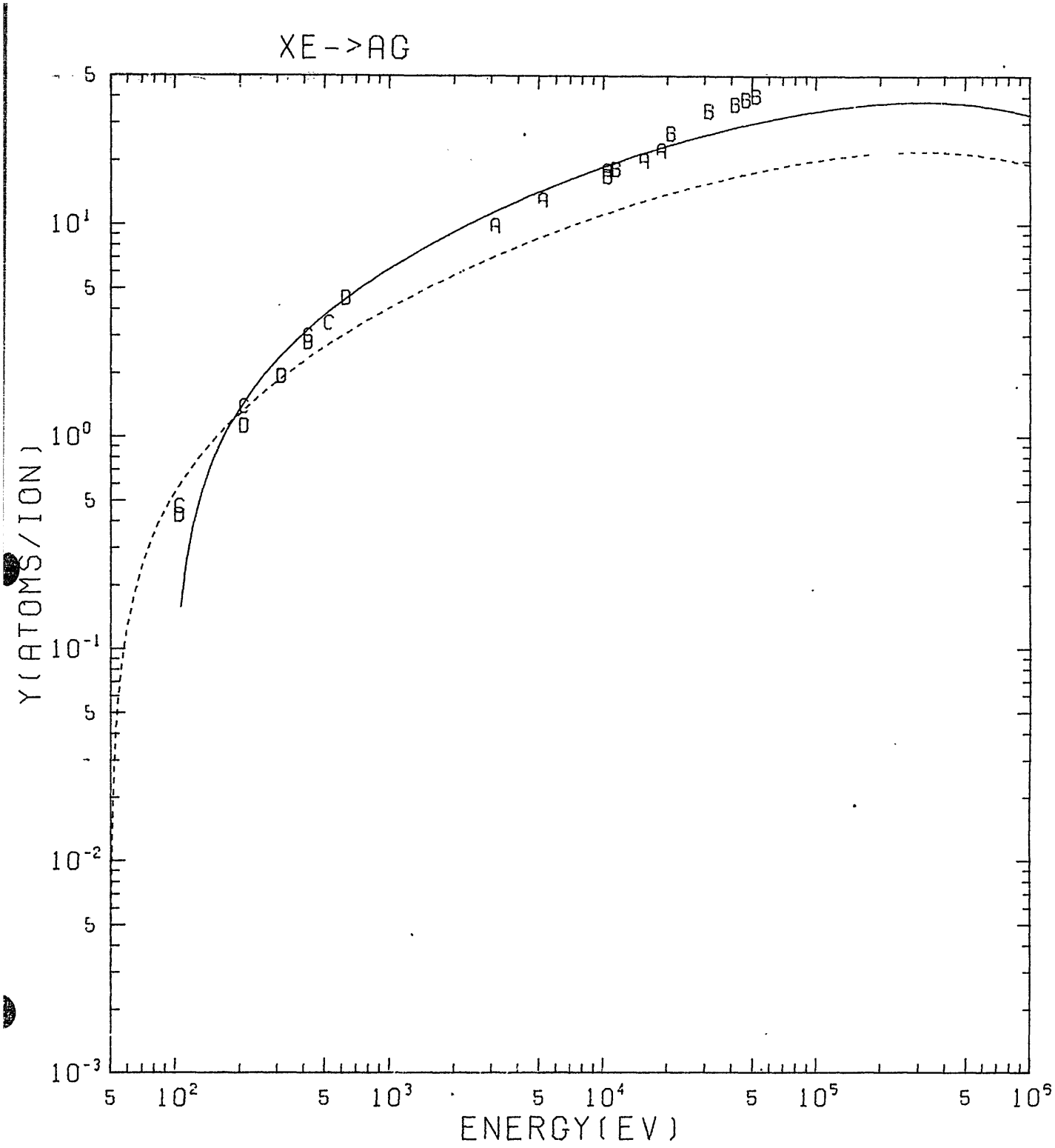
A KEYWELL (1955)
B GUSEVA (1960)
C ALMEN.BRUCE (1961A)
D WEHNER.STUART.ROSENBERG (1961)
E ROSENBERG.WEHNER (1962)
F DAHLGREN.MCCLANAHAN (1972)

Fig. 138



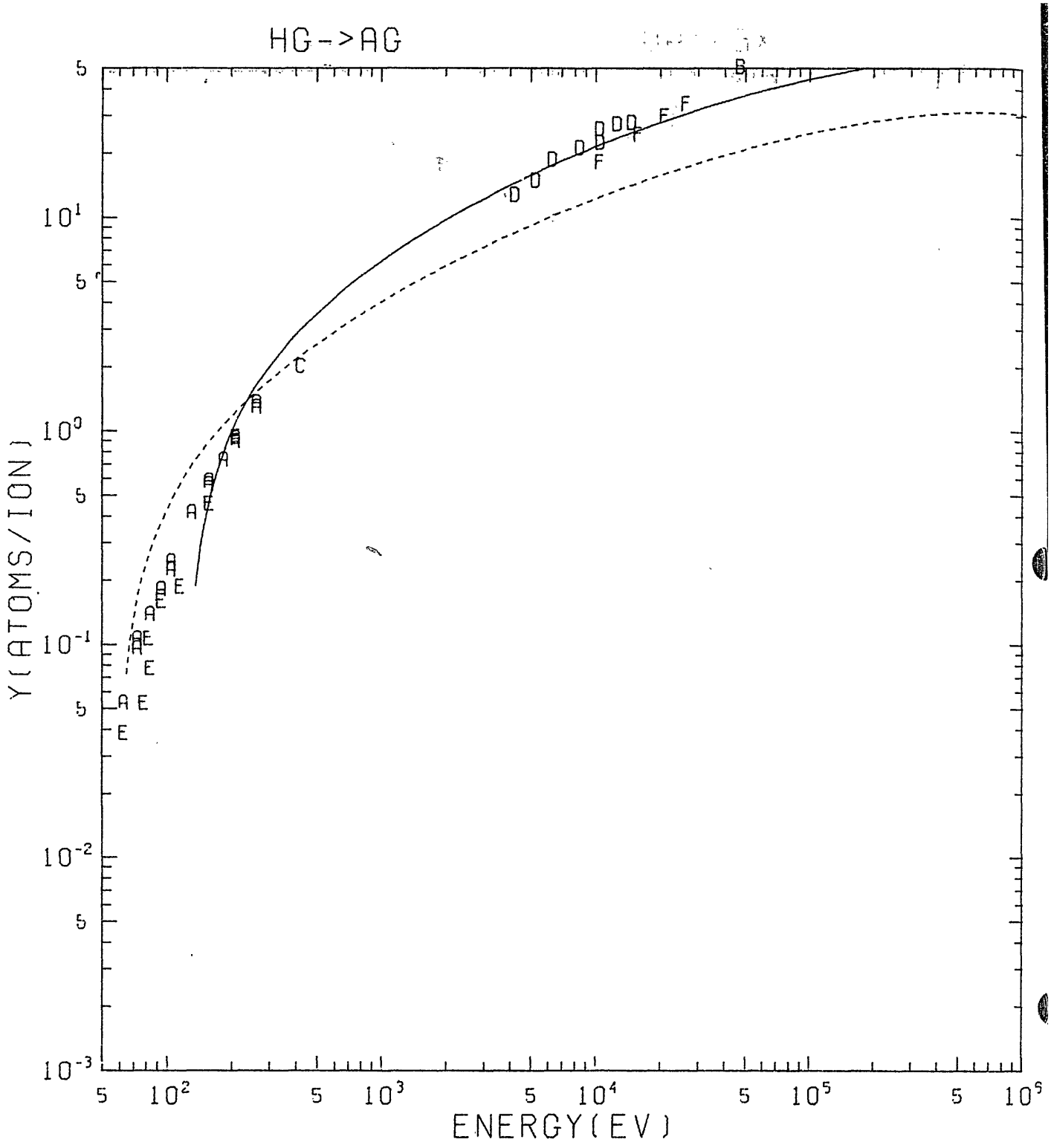
AG->AG
A GUSEVA (1960)
B ALMEN,BRUCE (1961B)
C HAYWARD,WOLTER (1969)
D ANDERSEN,BAY (1973)

Fig. 139



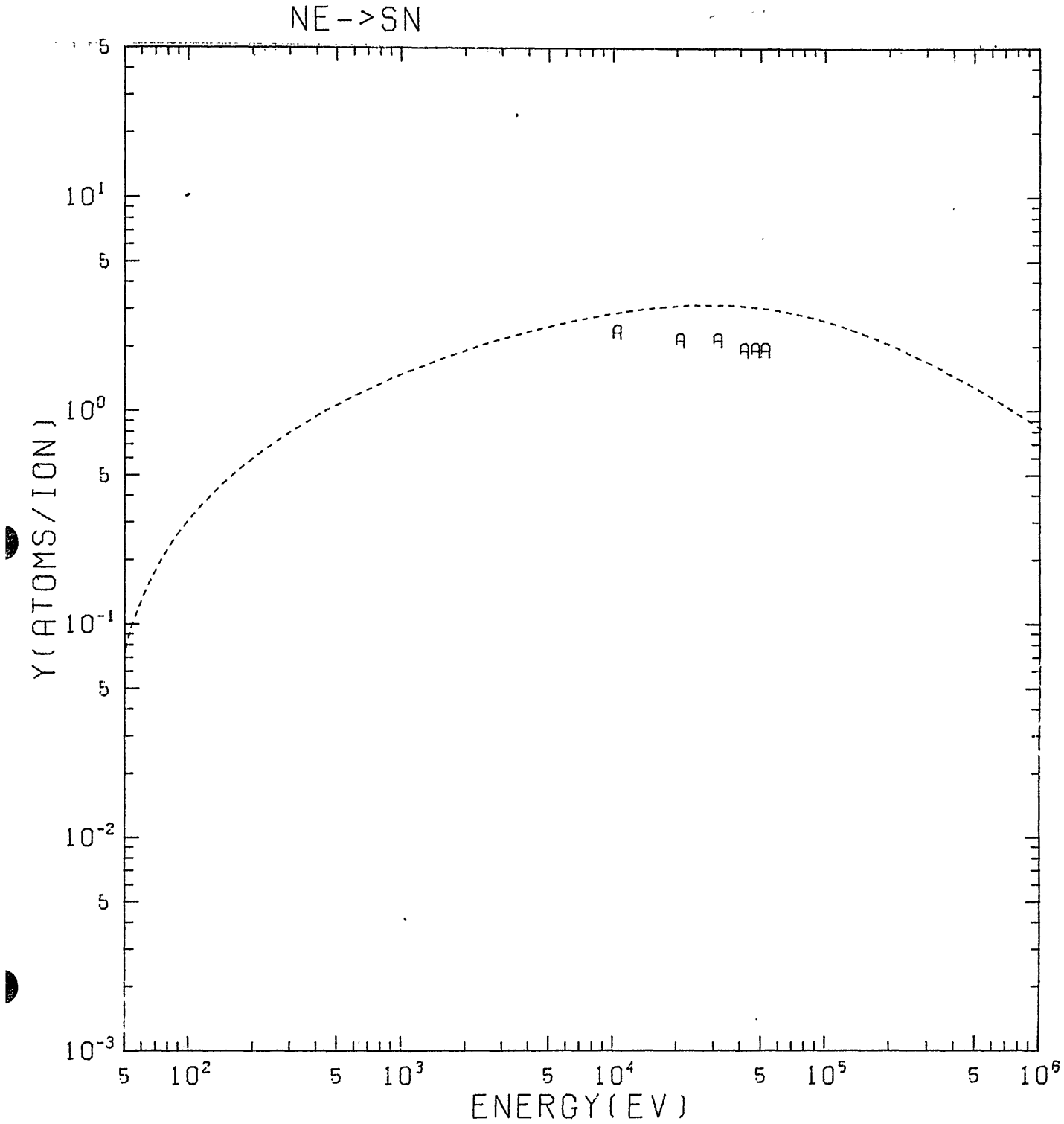
XE->AG
A GUSEVA (1960)
B ALMEN,BRUCE (1961A)
C WEHNER,STUART,ROSENBERG (1961)
D ROSENBERG,WEHNER (1962)

Fig. 140



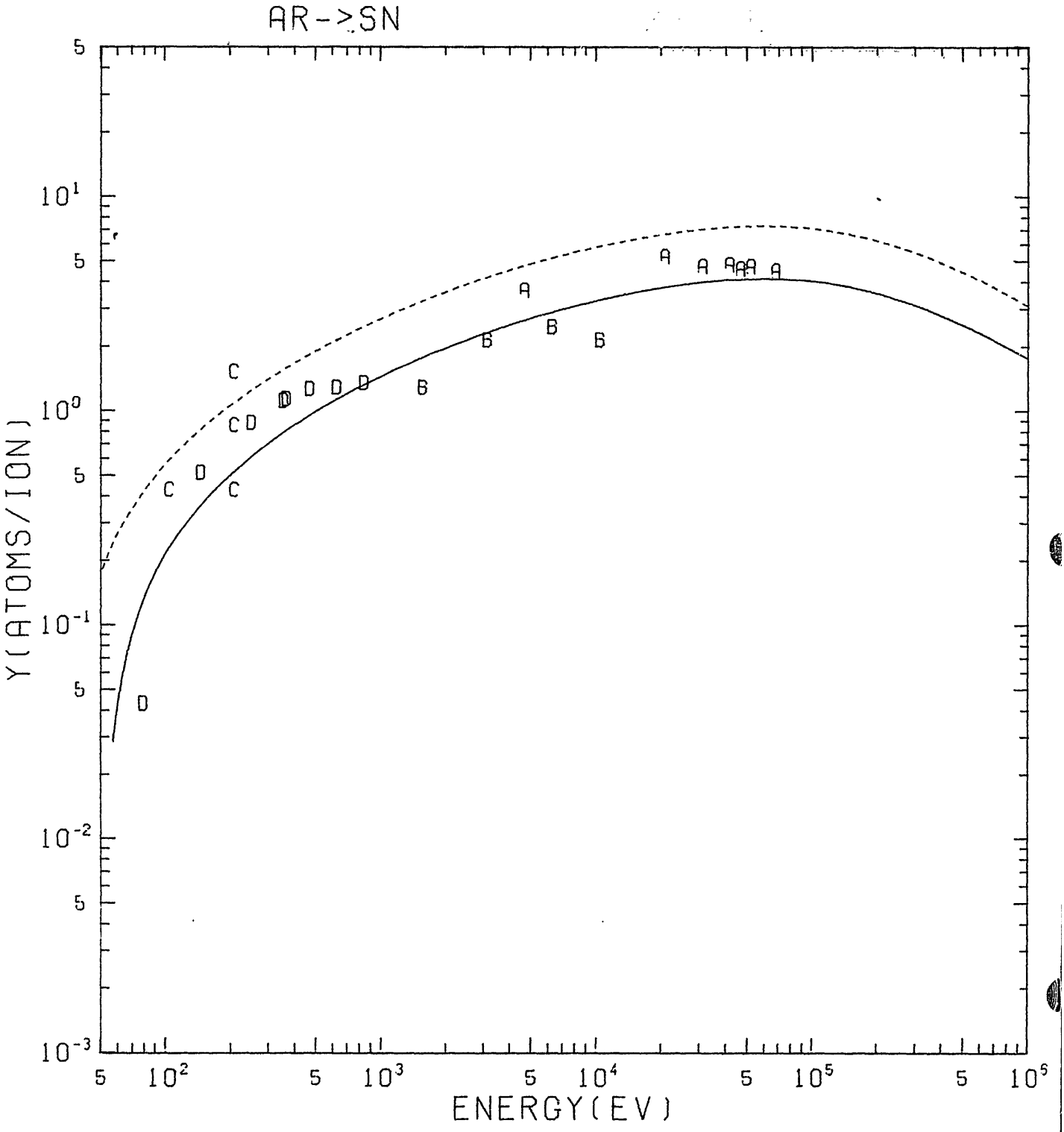
HG->AG
A WEHNER (1957)
B ALMEN.BRUCE (1961B)
C LZEGREID.WEHNER (1961)
D WEHNER.ROSENBERG (1961)
E ASKEROV.SENA (1969)
F ISMAIL (1970)

Fig. 141



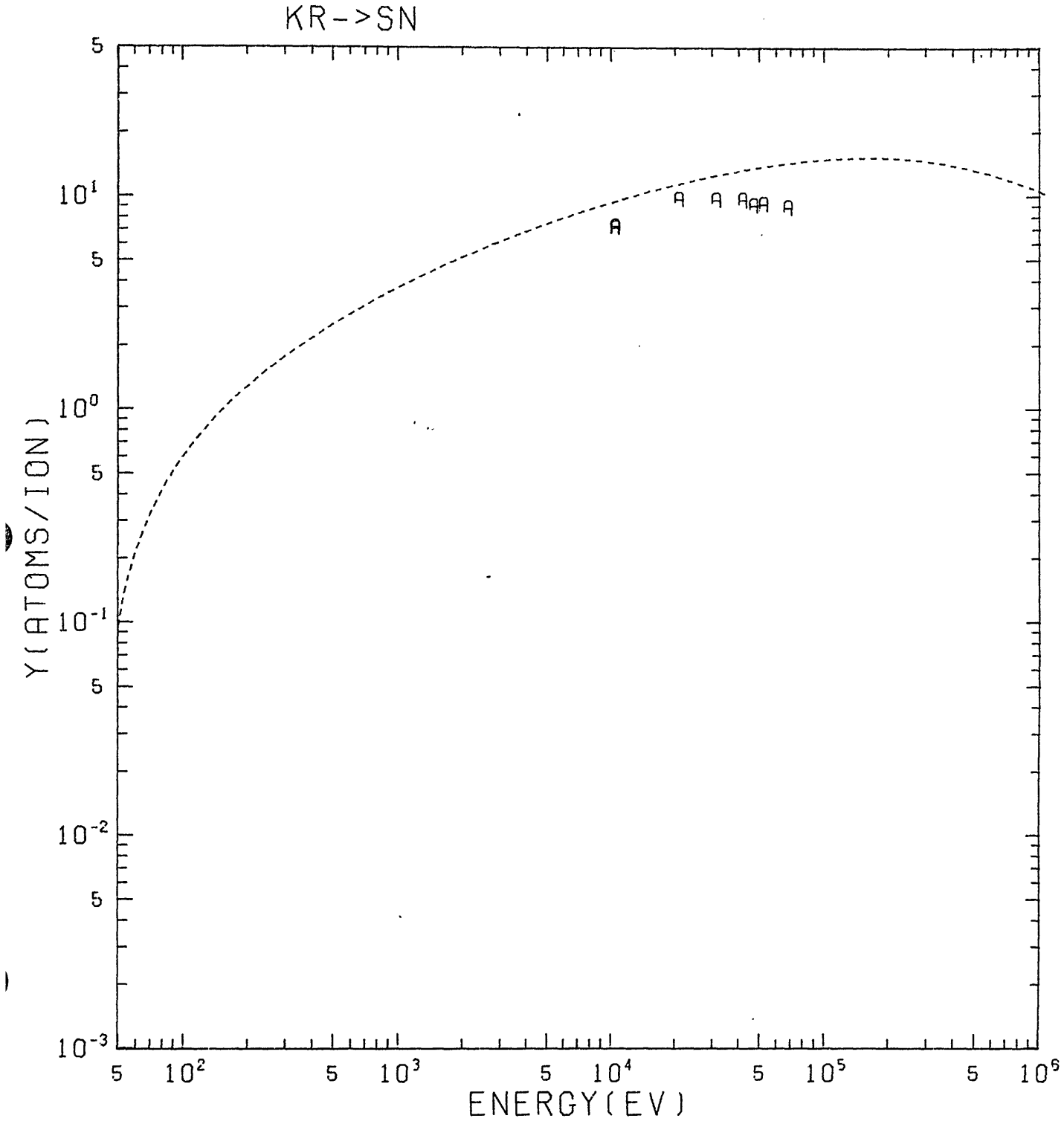
NE->SN
A ALMEN.BRUCE (1961A)

Fig. 142



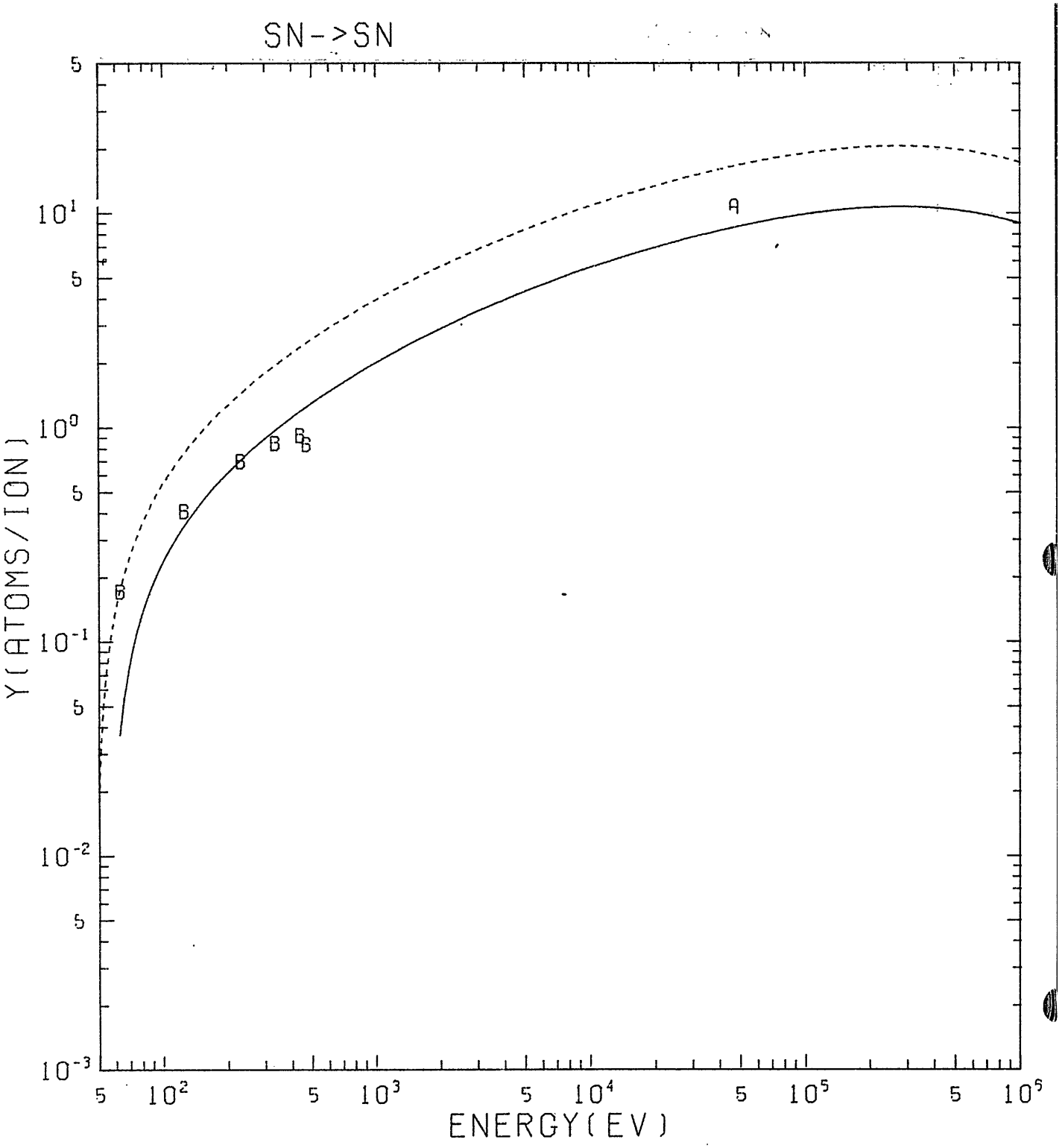
AR->SN
A ALMEN.BRUCE (1961A)
B PATTERSON.TOMLIN (1962)
C WEHNER.STUART.ROSENBERG (1962)
D KRUTENANT.PANZERA (1970)

Fig. 143



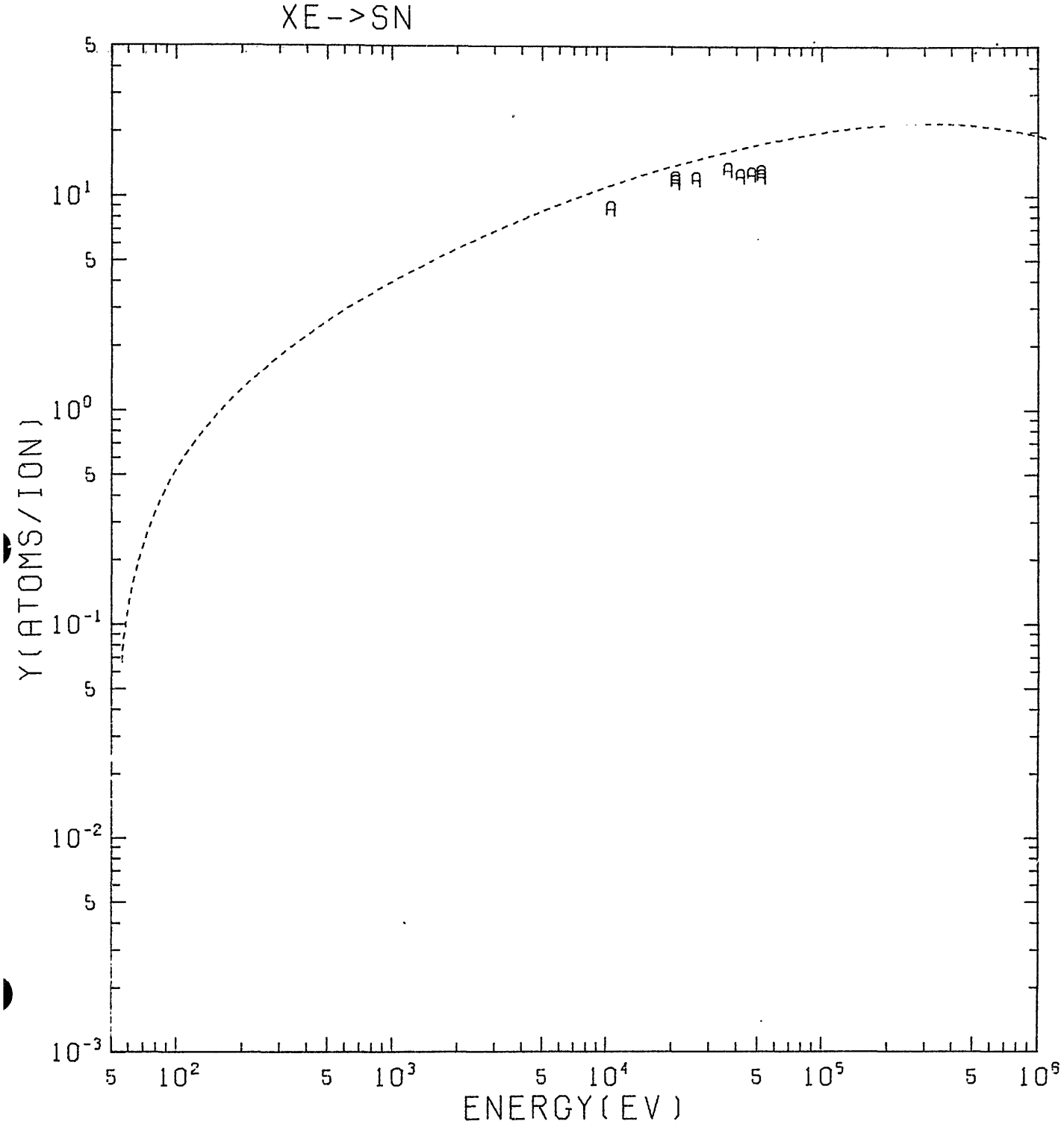
KR->SN
A ALMEN.BRUCE (1961A)

Fig. 144



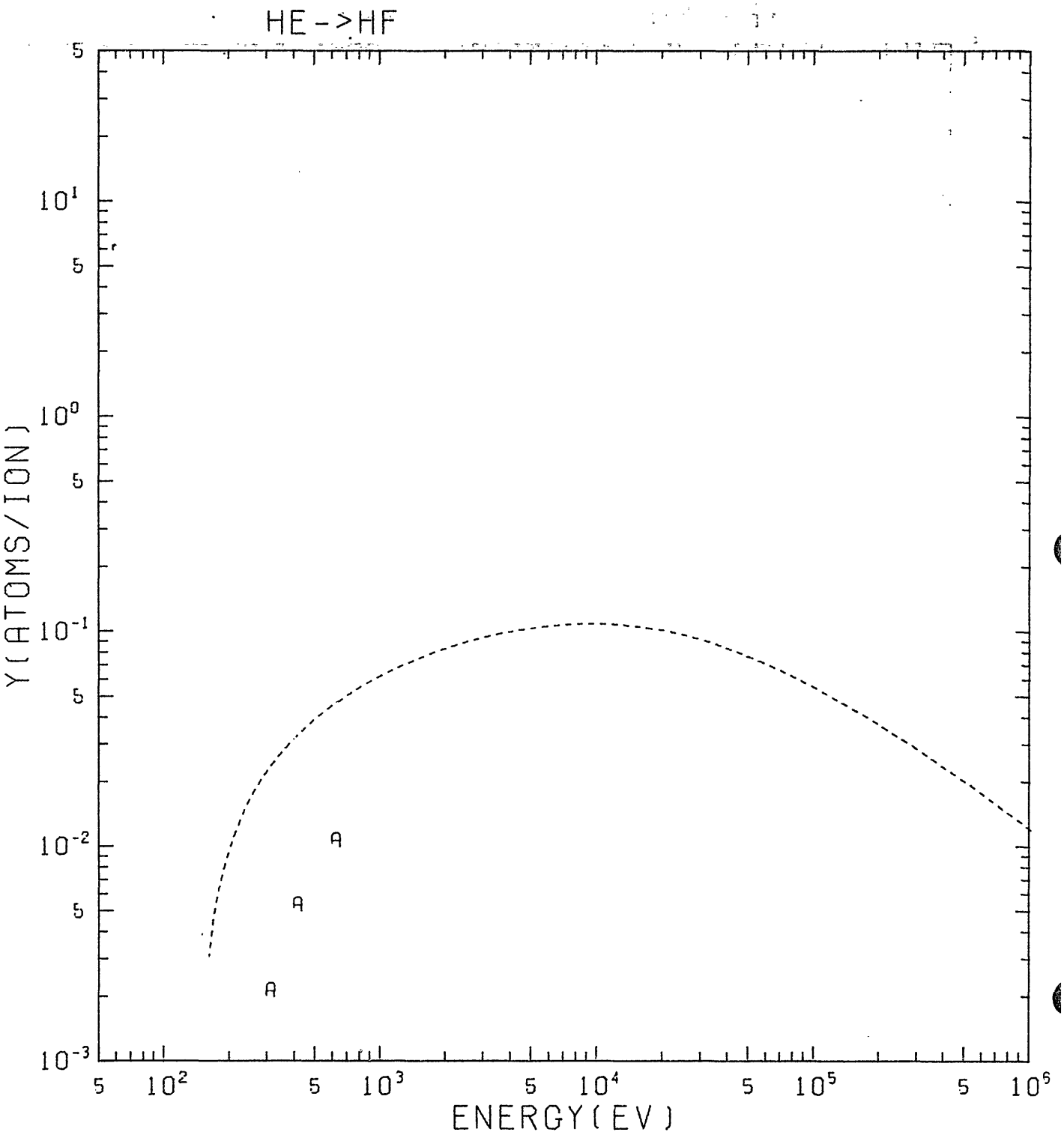
SN->SN
A ALMEN.BRUCE (1961B)
B FONTELL.ARMINEN (1969)

Fig. 145



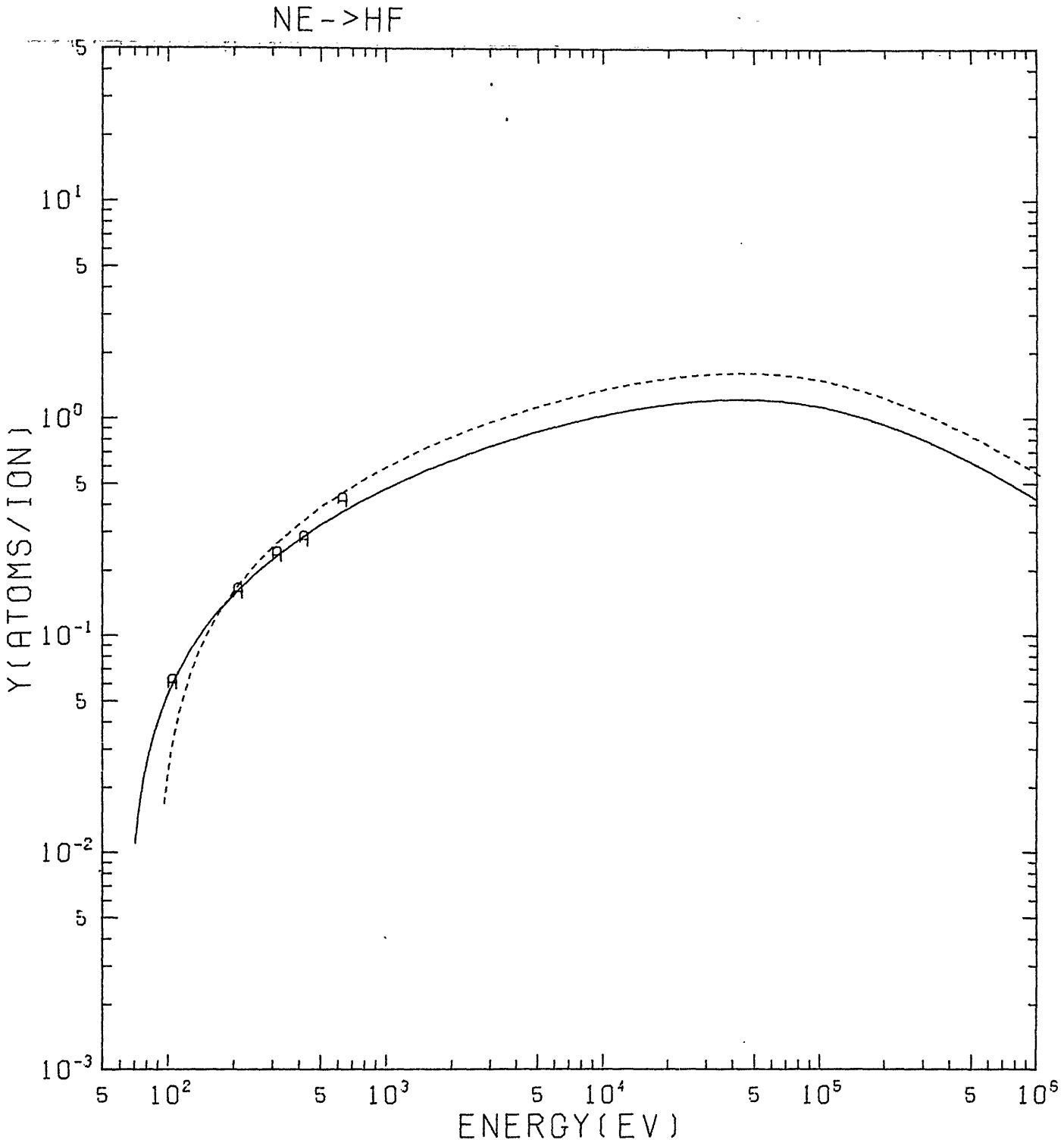
XE->SN
A ALMEN.BRUCE (1961A)

Fig. 146



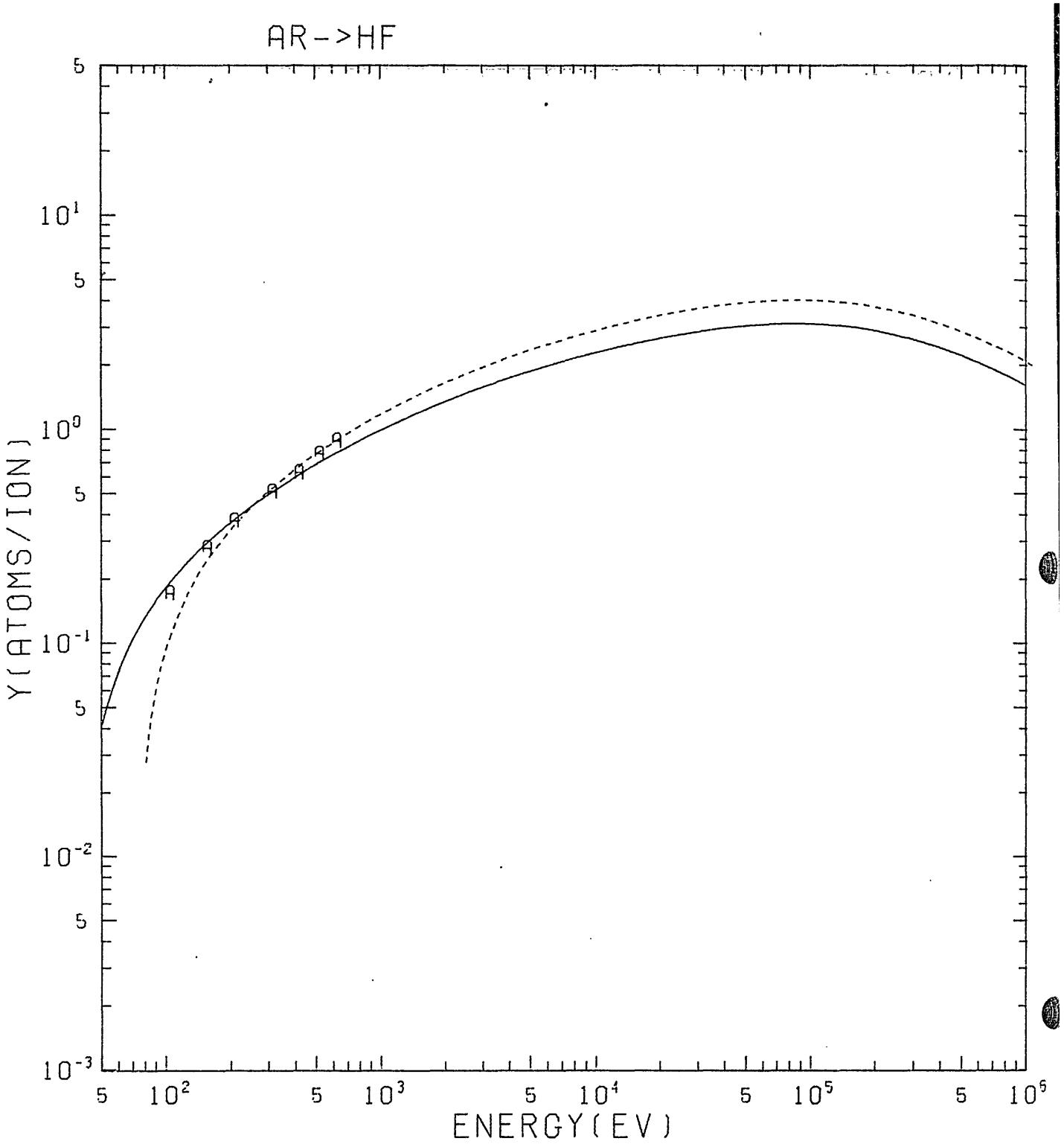
HE->HF
A ROSENBERG.WEHNER (1962)

Fig. 147



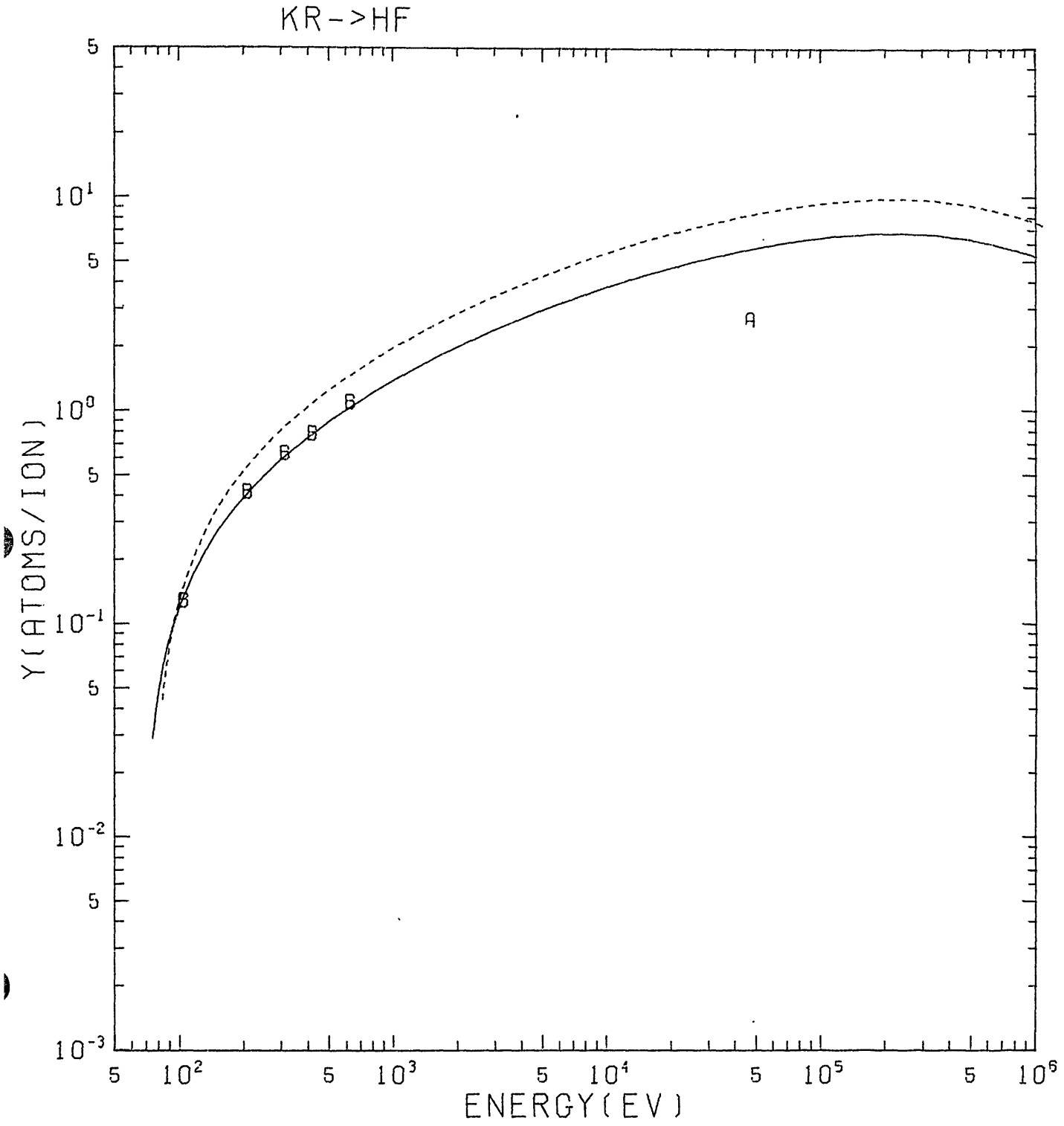
NE->HF
A LAEGREID.WEHNER (1961)

Fig. 148



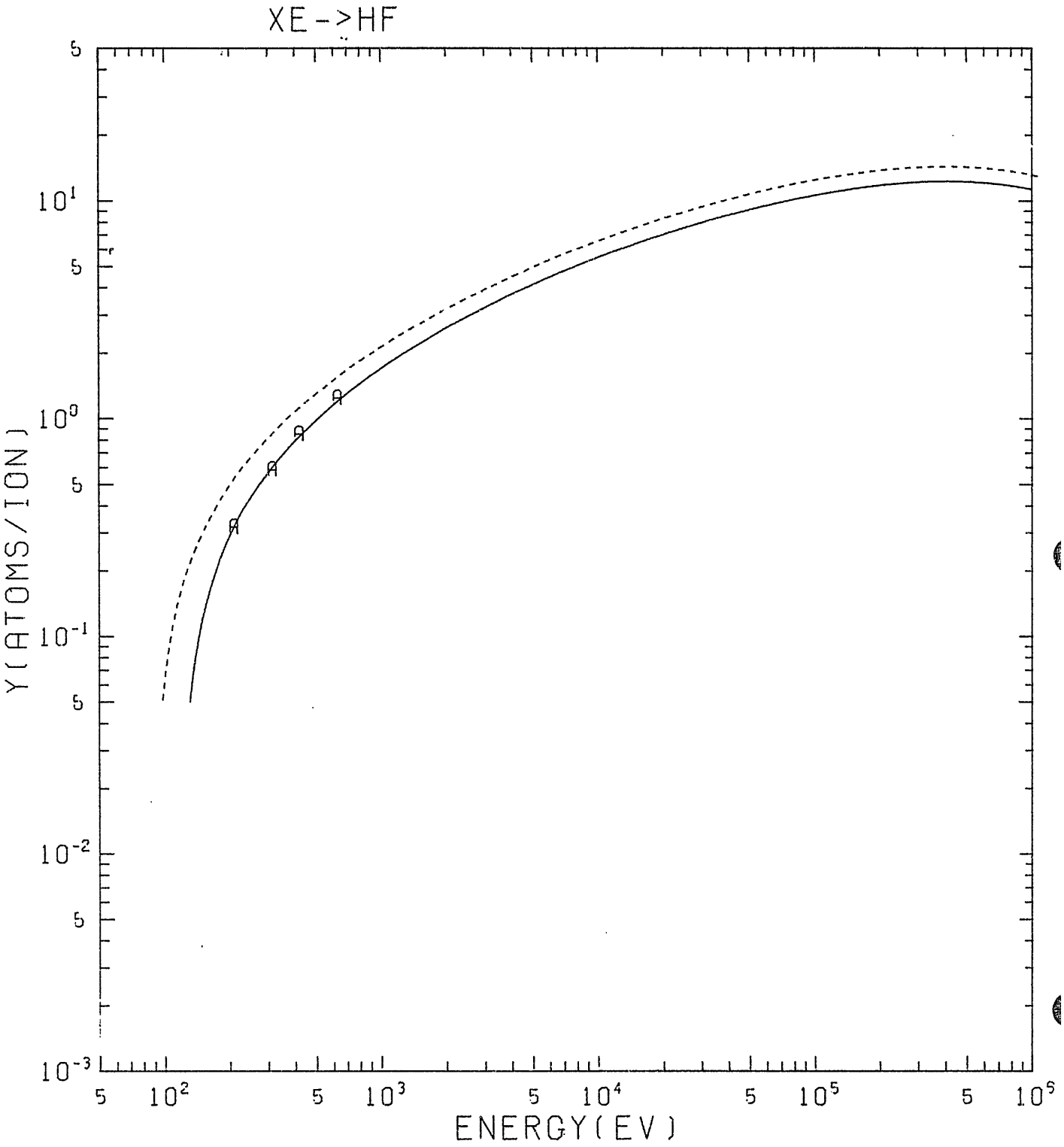
AR->HF
A LAEGREID,WEHNER (1961)

Fig. 149



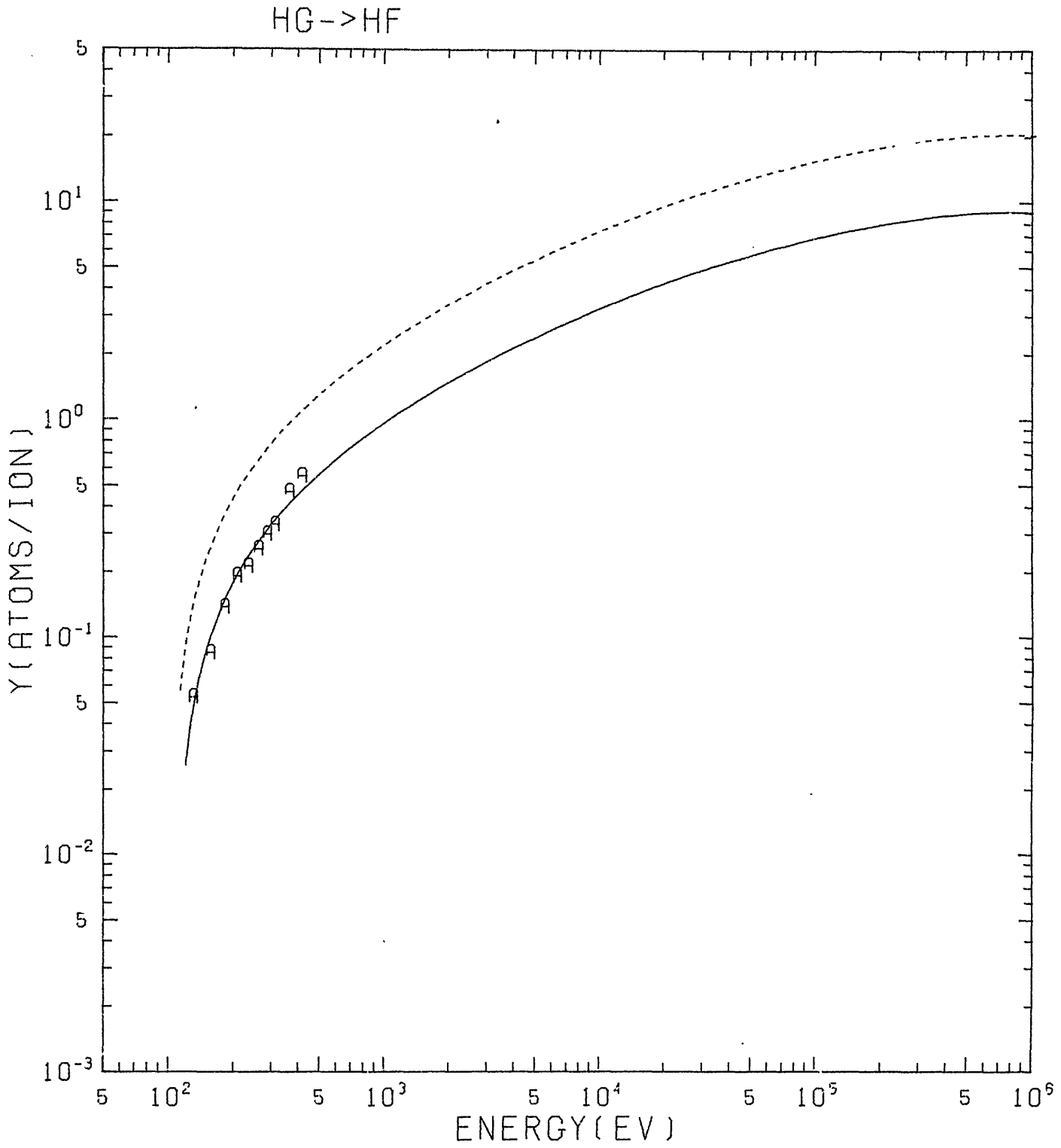
KR->HF
A ALMEN.BRUCE (1961B)
B ROSENBERG.WEHNER (1962)

Fig. 150



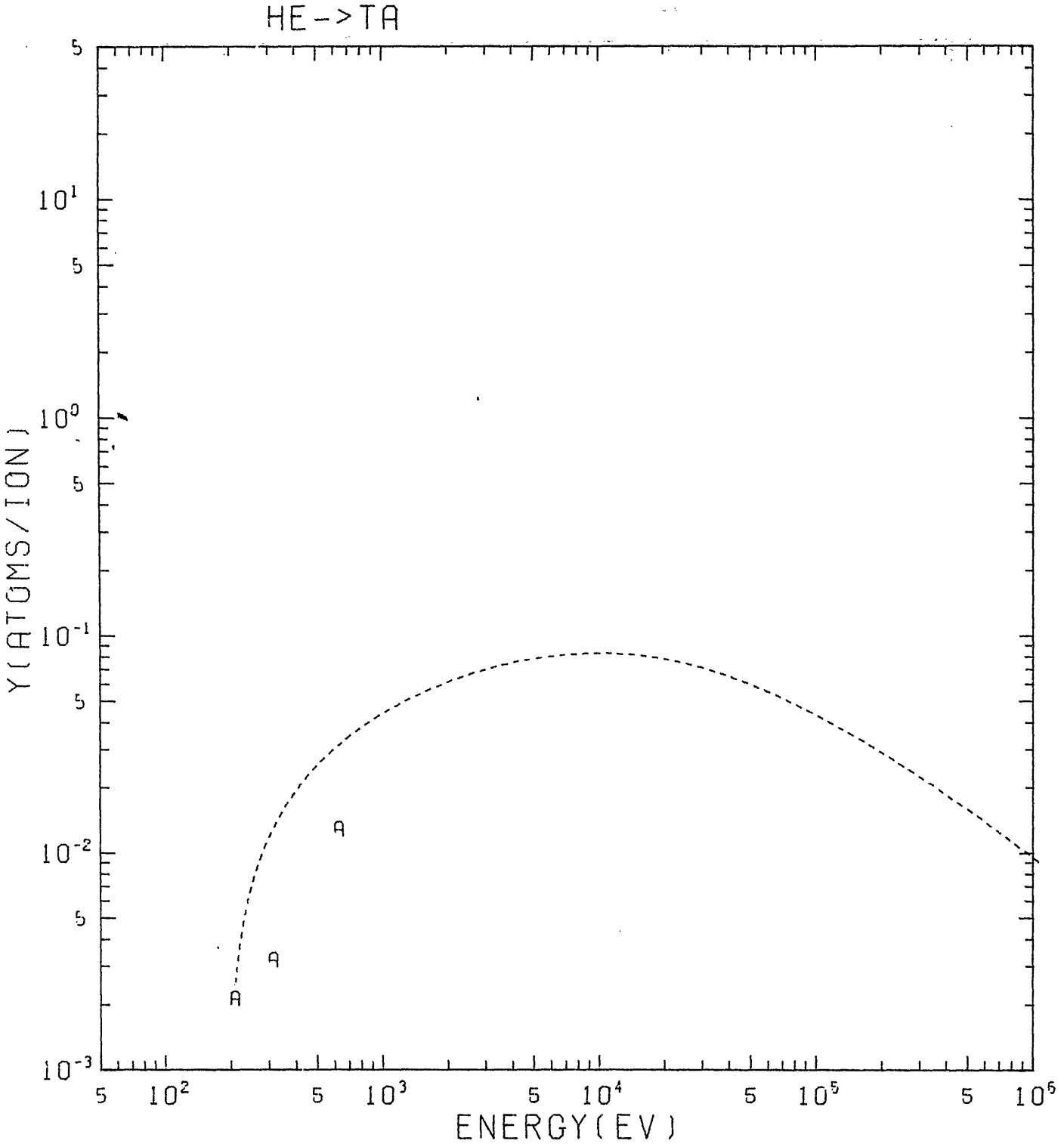
XE->HF
A ROSENBERG,WEHNER (1962)

Fig. 151



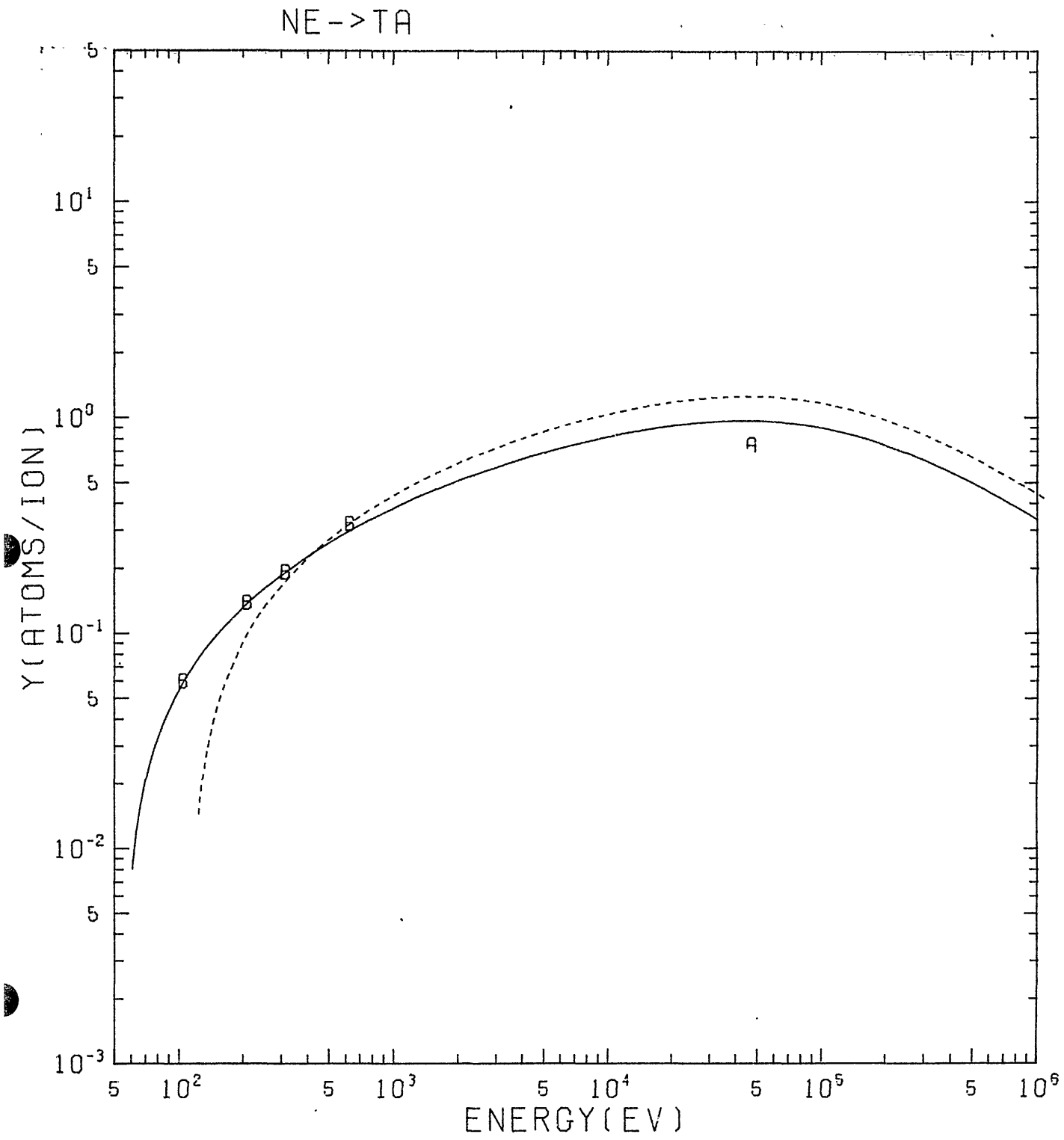
HG->HF
A WEHNER (1957)

Fig. 152



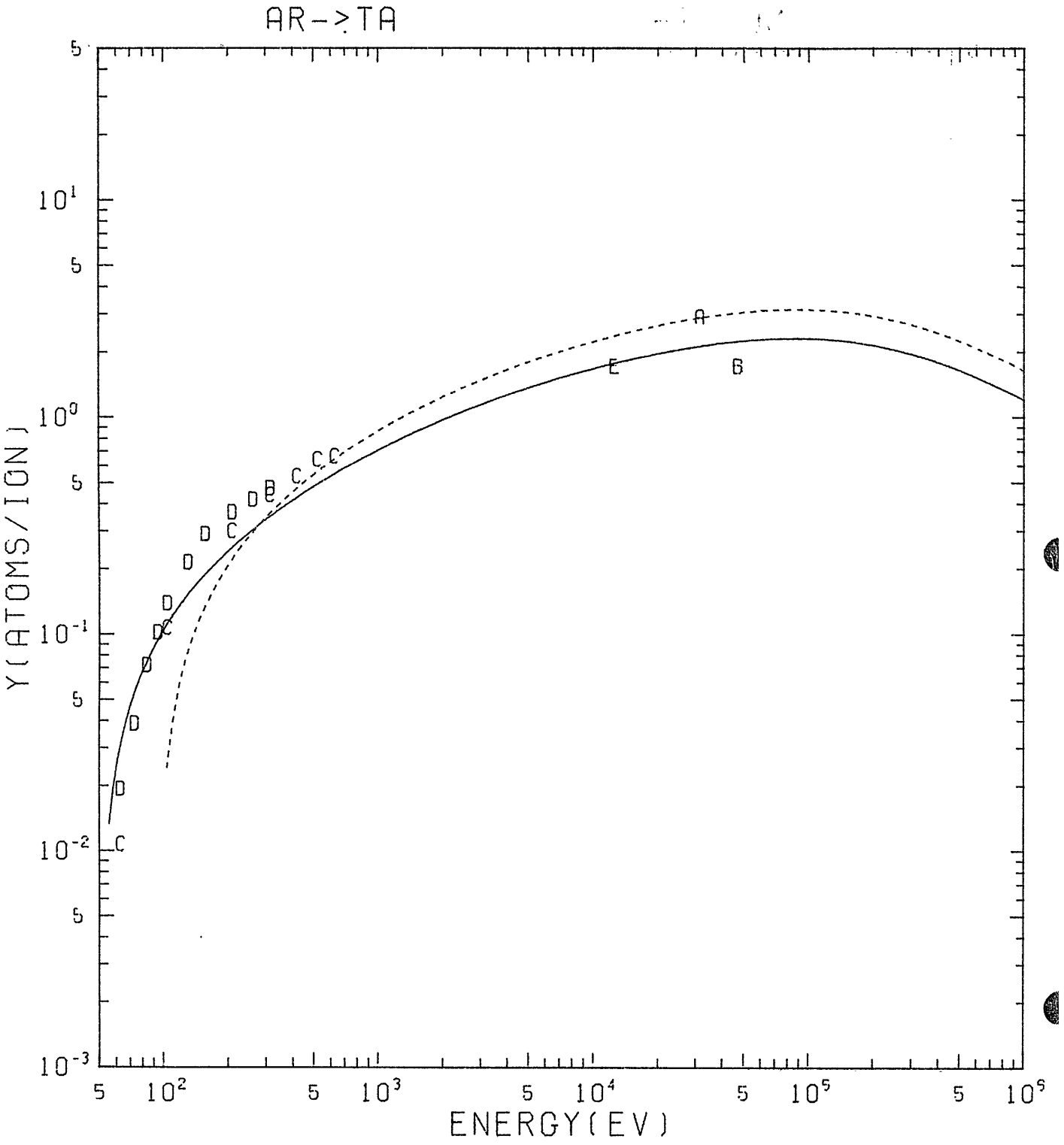
HE->TA
A ROSENBERG,WEHNER (1962)

Fig. 153



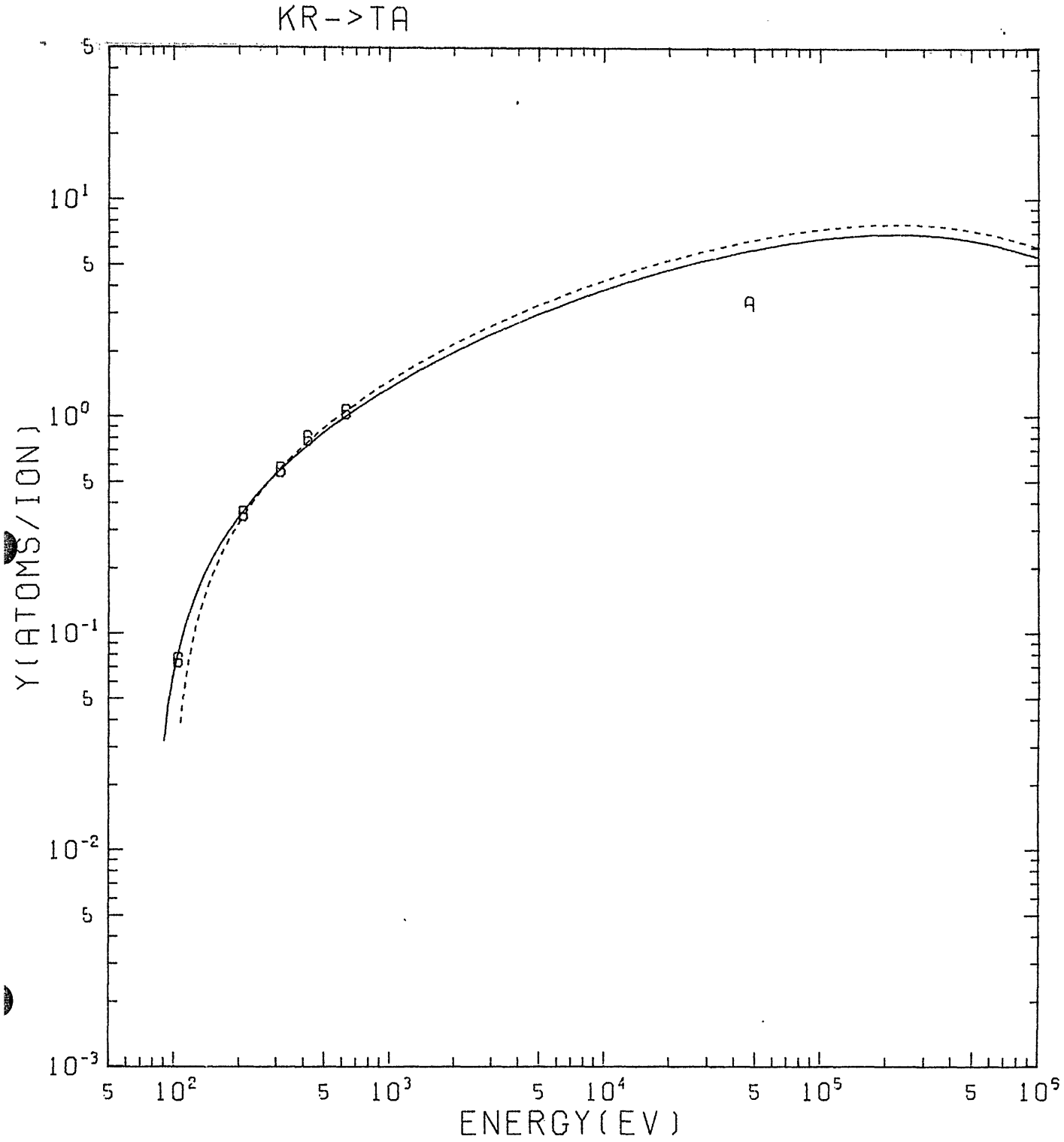
NE->TA
A ALMEN.BRUCE (1961A)
B LAEGREID.WEHNER (1961)

Fig. 154



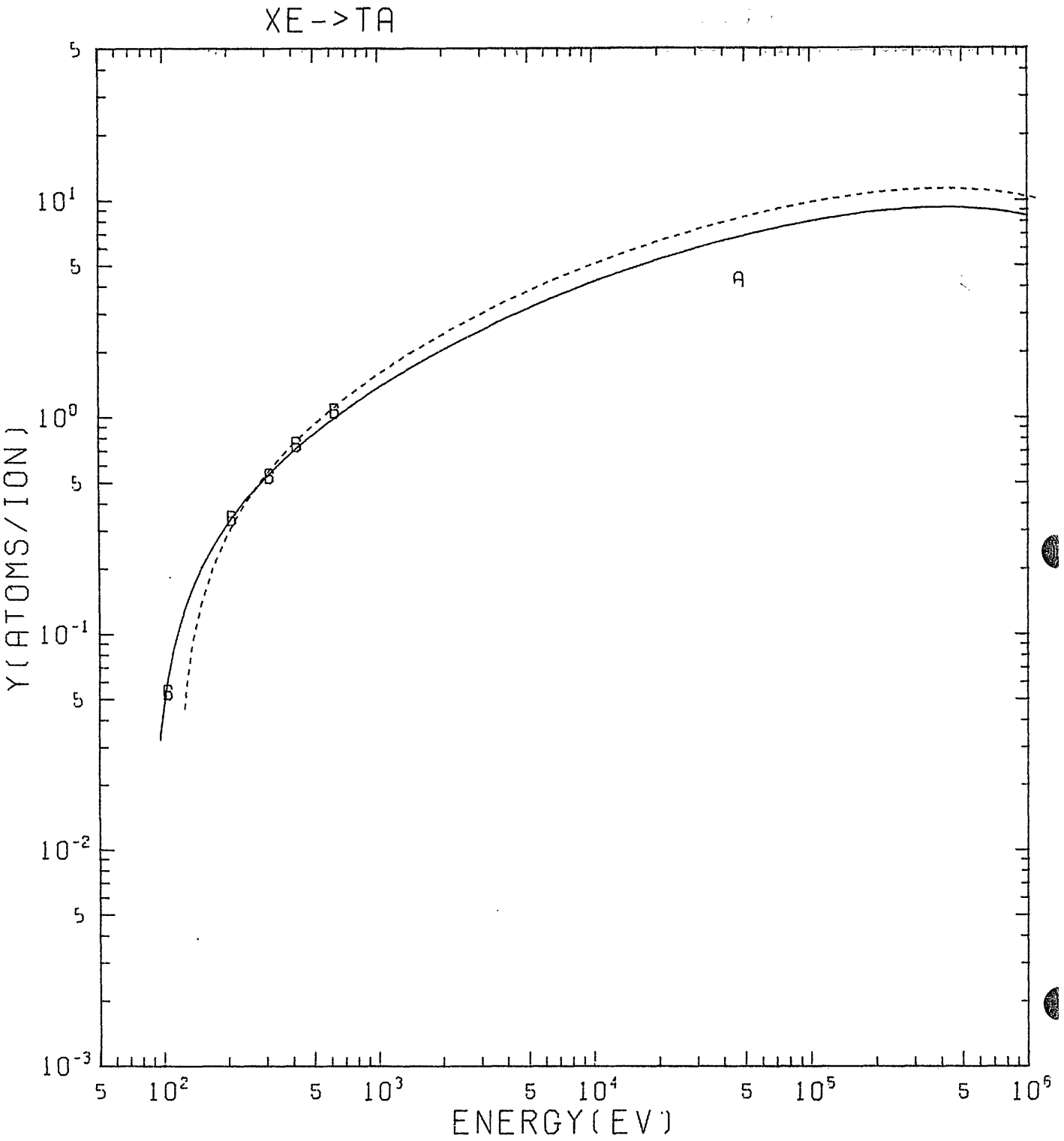
AR->TA
A YONTS.NORMANN.HARRISON (1960)
B ALMEN.BRUCE (1961A)
C LAEGREID.WEHNER (1961)
D STUART.WEHNER (1962)
E WITTMAACK (1975)

Fig. 155



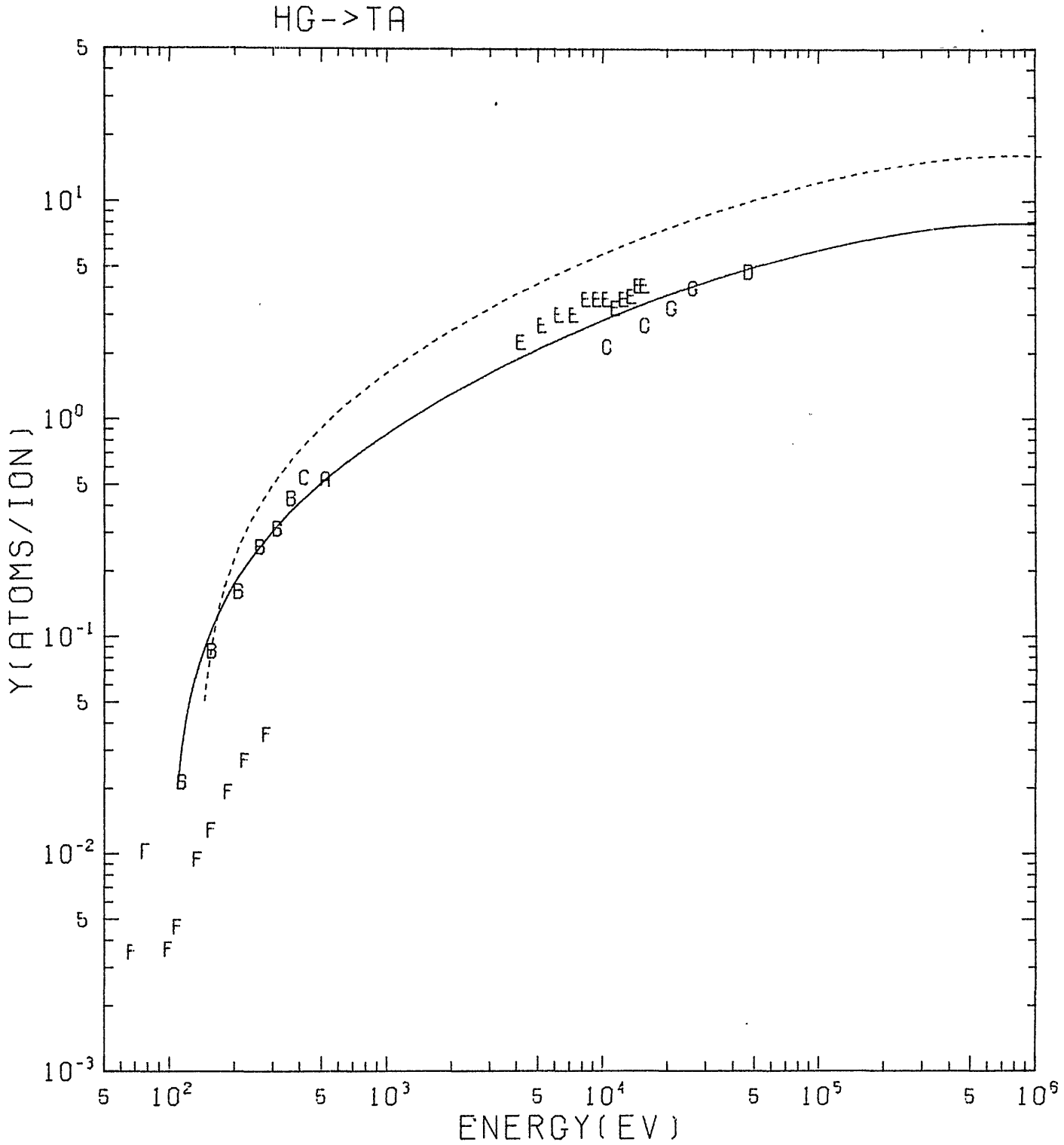
KR->TA
A ALMEN.BRUCE (1961A)
B ROSENBERG.WEHNER (1962)

Fig. 156



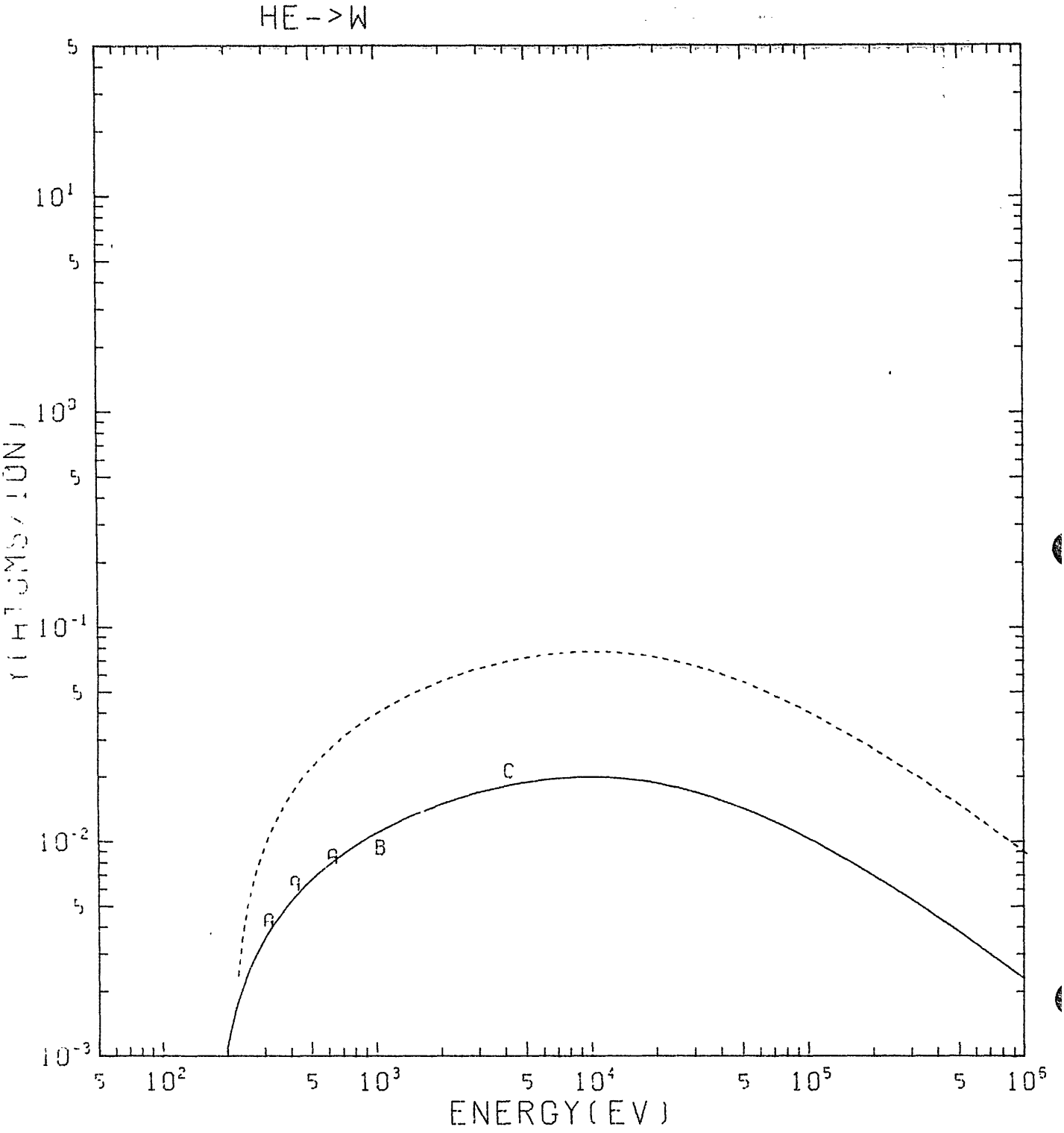
XE->TA
A ALMEN.BRUCE (1961A)
B ROSENBERG,WEHNER (1962)

Fig. 157



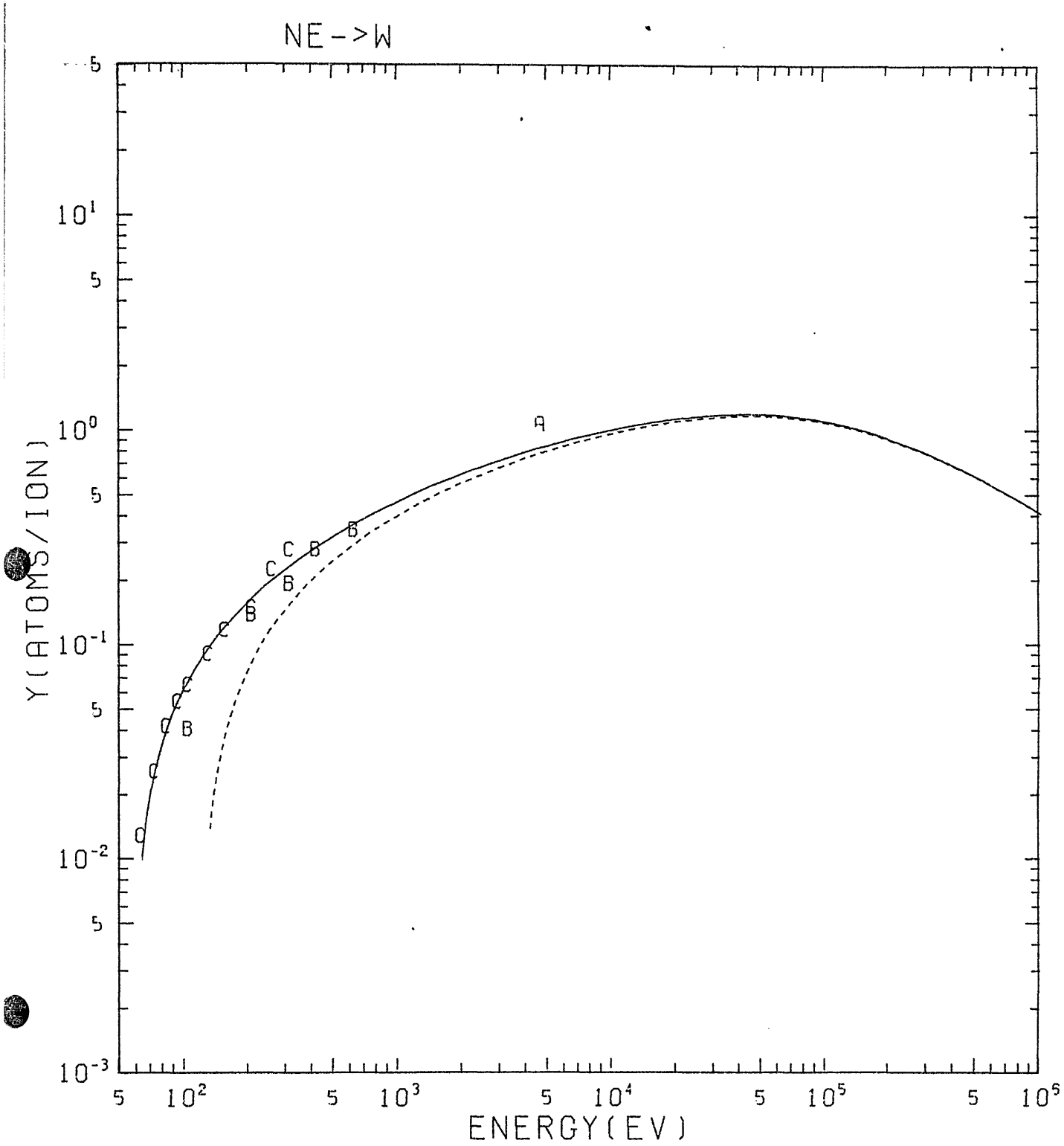
HG->TA
A MEYER,GUENTHERSCHULZE (1931)
B WEHNER (1957)
C WEHNER (1959)
D ALMEN,BRUCE (1961)
E WEHNER,ROSENBERG (1961)
F ASKEROV,SENA (1969)
G ISMAIL (1970)

Fig. 158



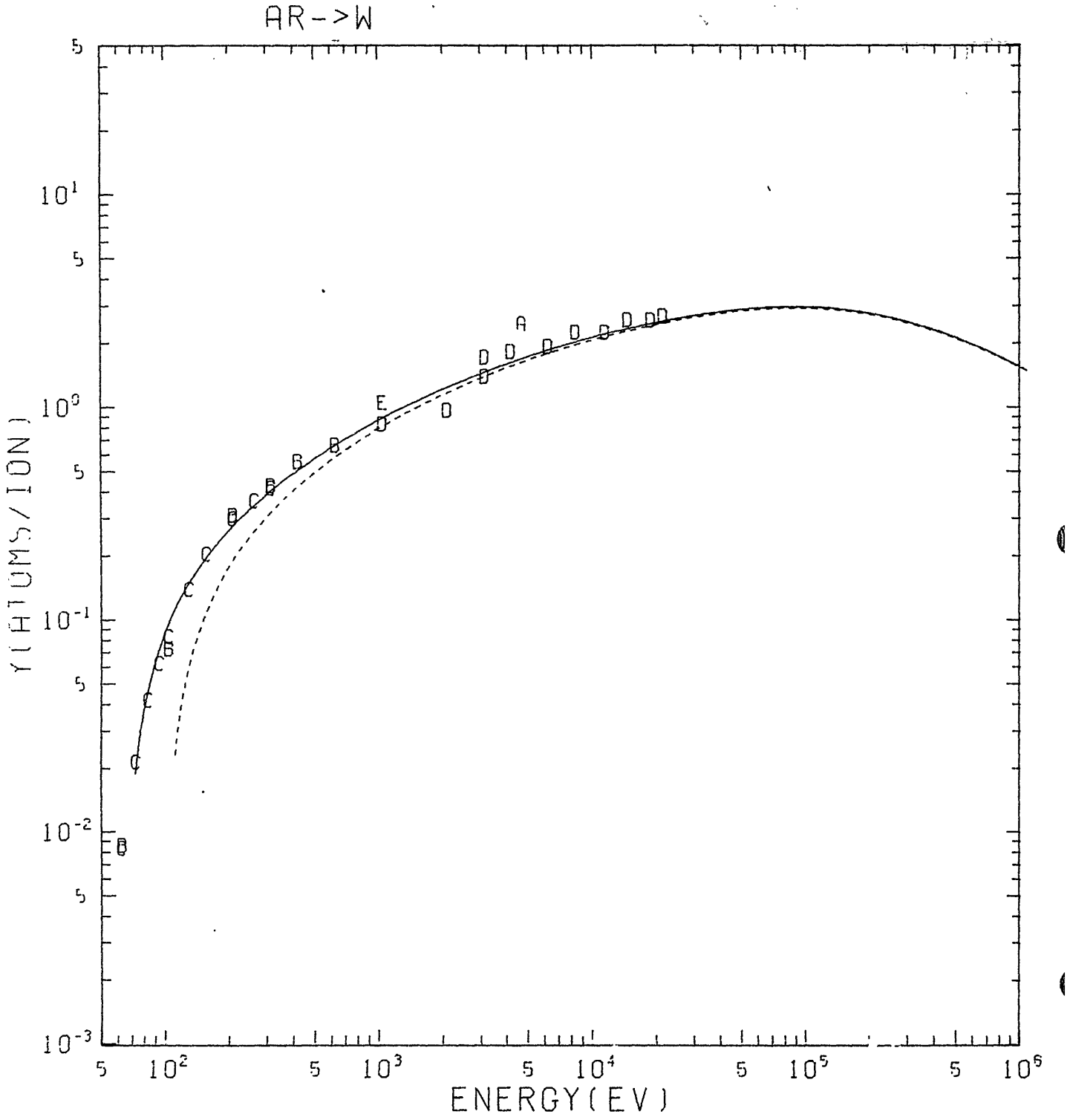
HE->W
A ROSENBERG,WEHNER (1962)
B GUSEVA,MARTYNENKO (1976)
C ZIEGLER,CUOMO,ROTH (1977)

Fig. 159



NE->W
A ALMEN.BRUCE (1961A)
B LAEGREID.WEHNER (1961)
C STUART.WEHNER (1962)

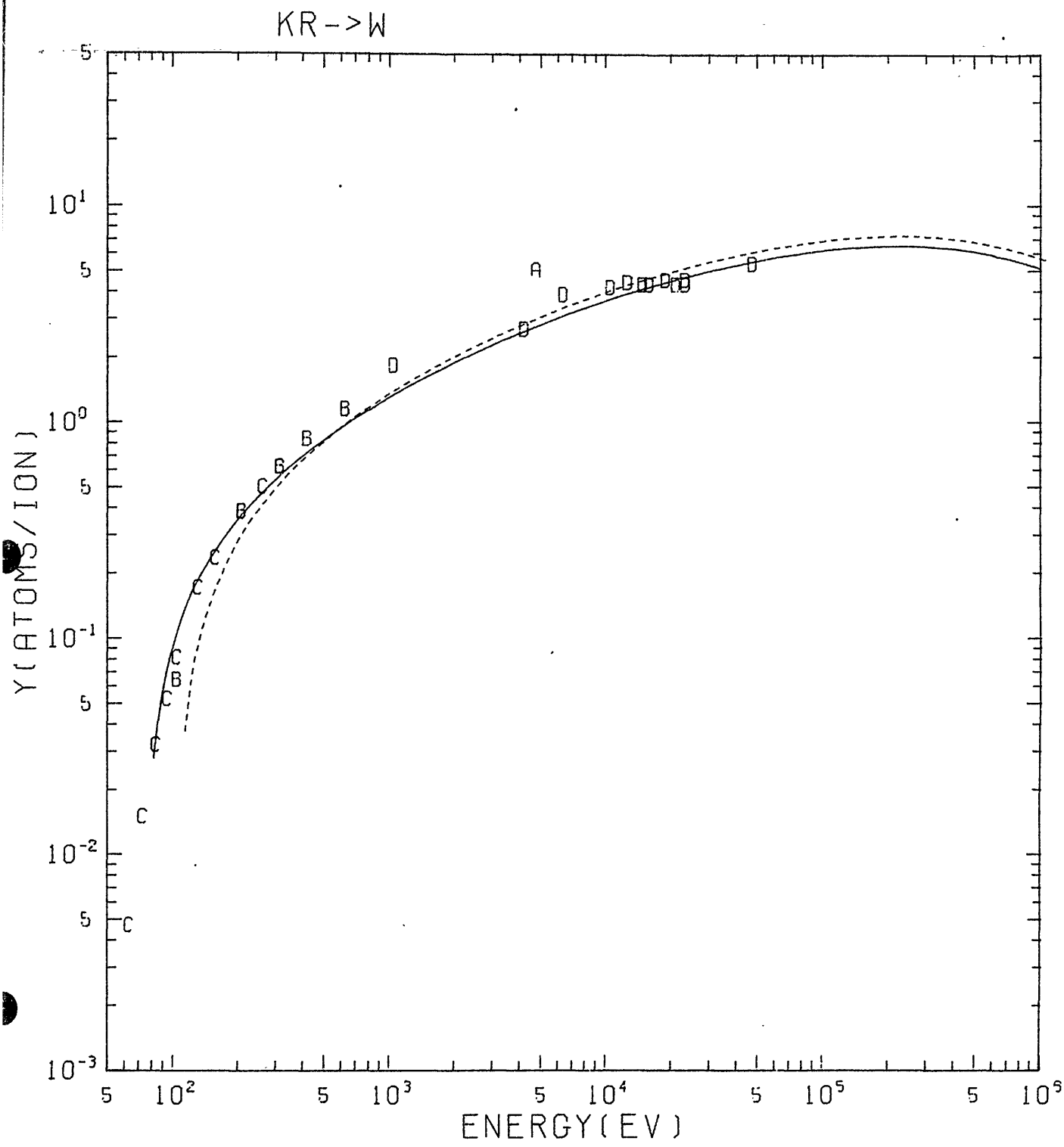
Fig. 160



AR->W

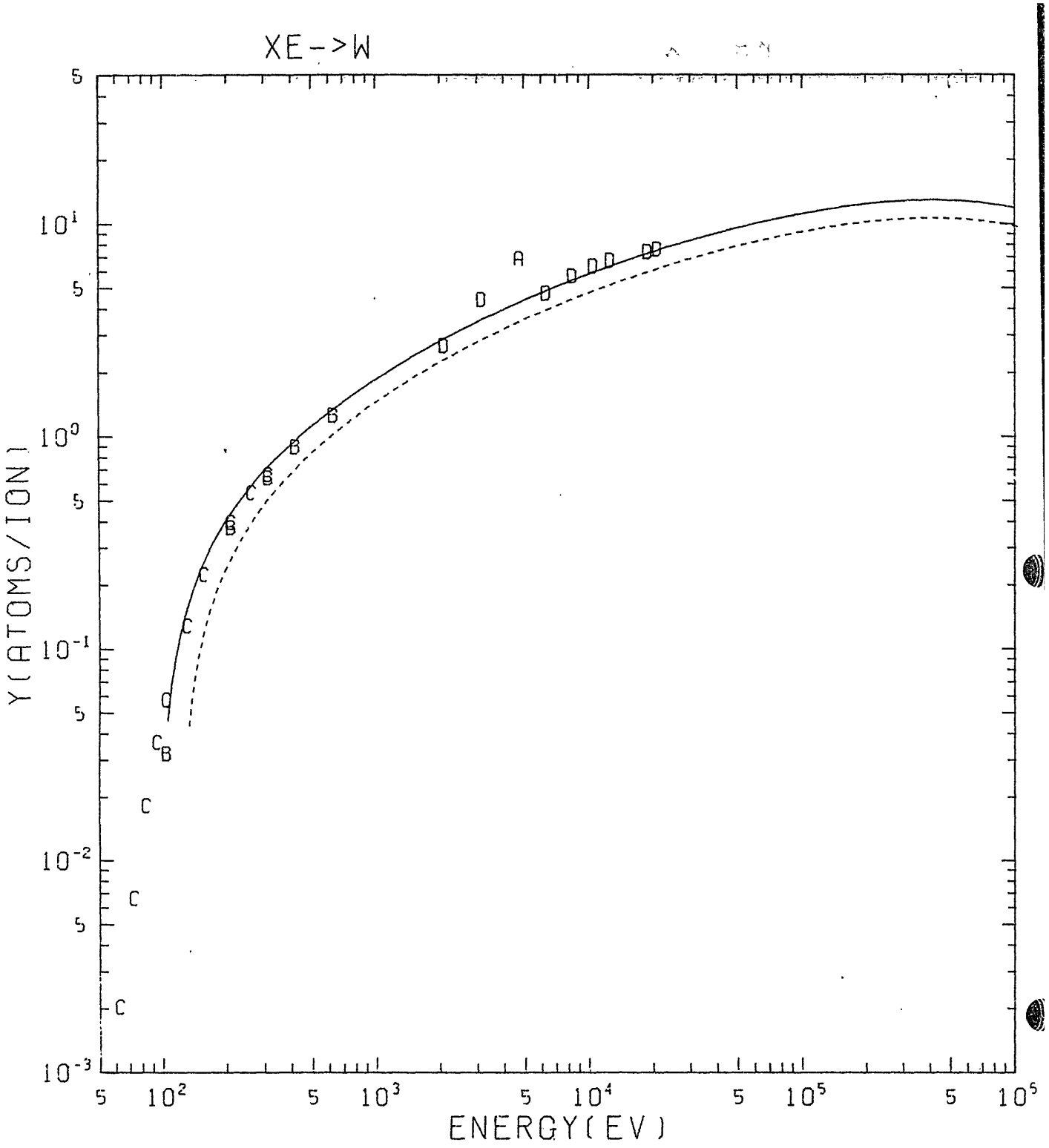
A ALMEN.BRUCE (1961A)
B LAEGREID.WEHNER (1961)
C STUART.WEHNER (1962)
D KOSHKIN.RYSOV.SHKARBAN (1969)
E SMITH.MEYER.LAYTON (1975)

Fig. 161



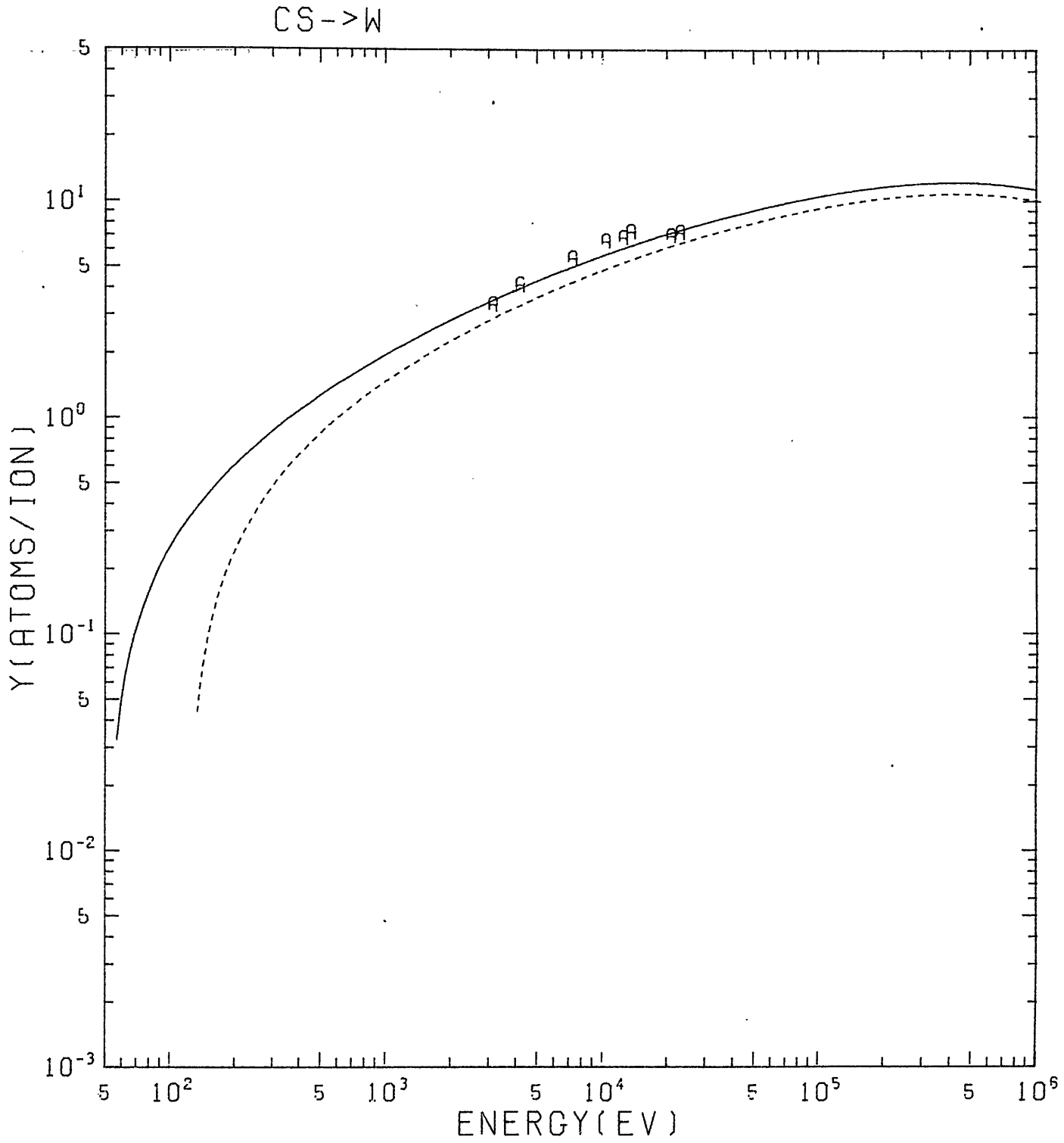
KR->W
A ALMEN.BRUCE (1961A)
B ROSENBERG.WEHNER(1962)
C START.WEHNER (1962)
D KOSHKIN.RYSOV.SHKARBAN (1969)

Fig. 162



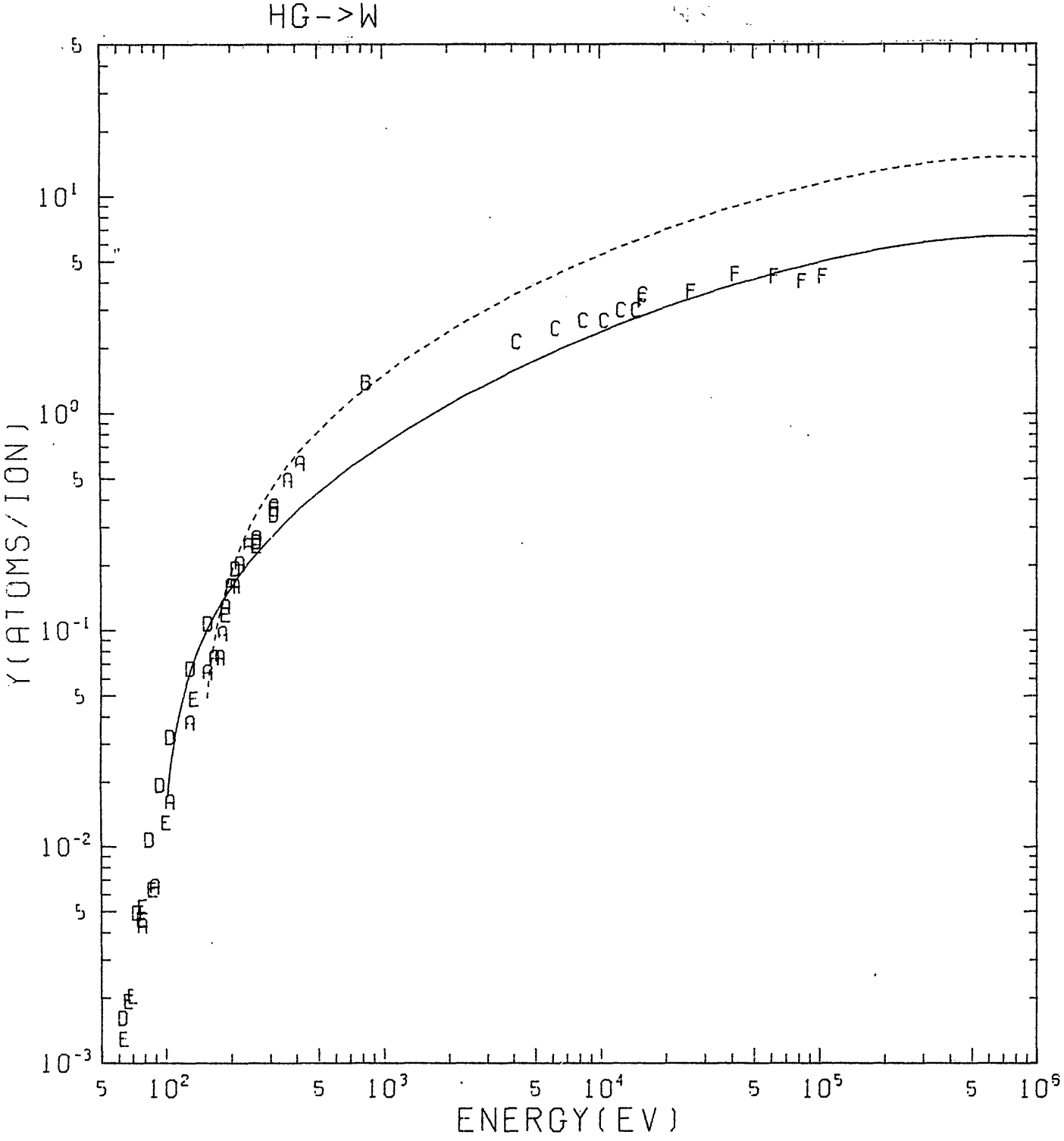
XE->W
A ALMEN.BRUCE (1961A)
B ROSENBERG.WEHNER (1962)
C STUART.WEHNER (1962)
D KOSHKIN.RYSOV.SHKAVBAN (1969)

Fig. 163



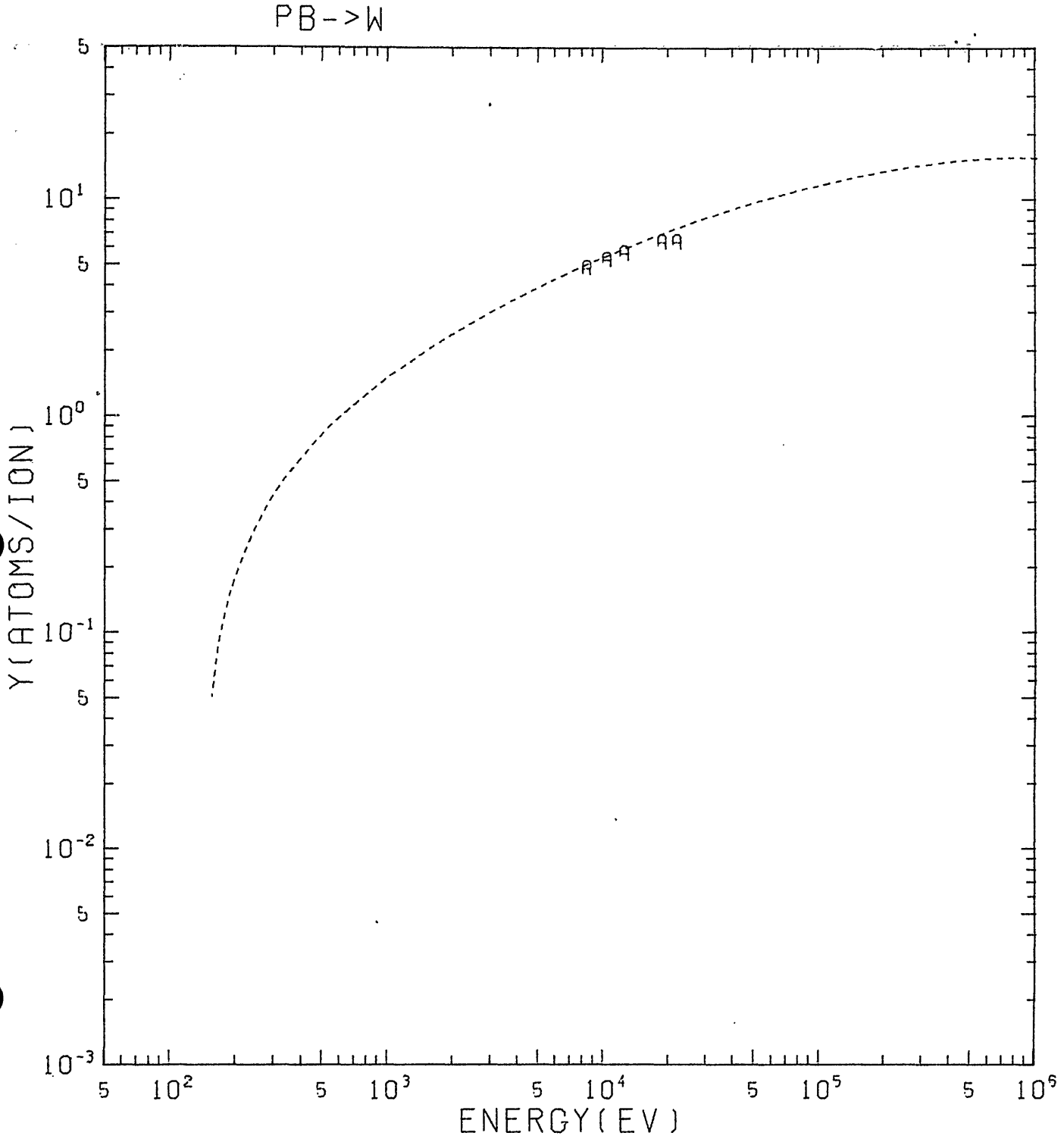
CS->W
A KOSHKIN.RYSOV.SHKAVBAN (1969)

Fig. 164



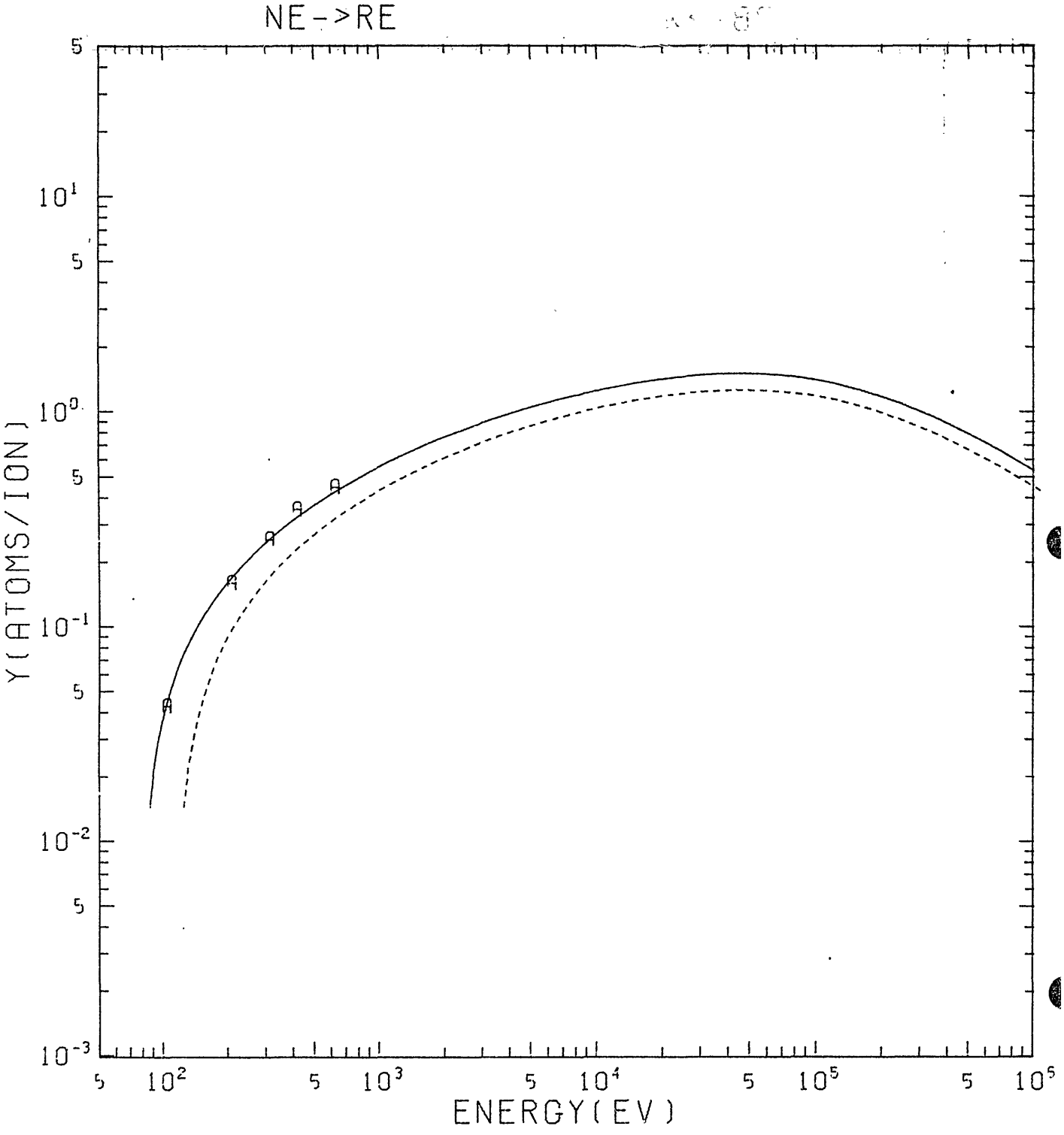
HG->W
A WEHNER.(1957)
B WEHNER (1959)
C WEHNER.ROSENBERG (1961)
D STUART.WEHNER (1962)
E ASKEROV.SENA (1969)
F HEPWORTH (1970)

Fig. 165



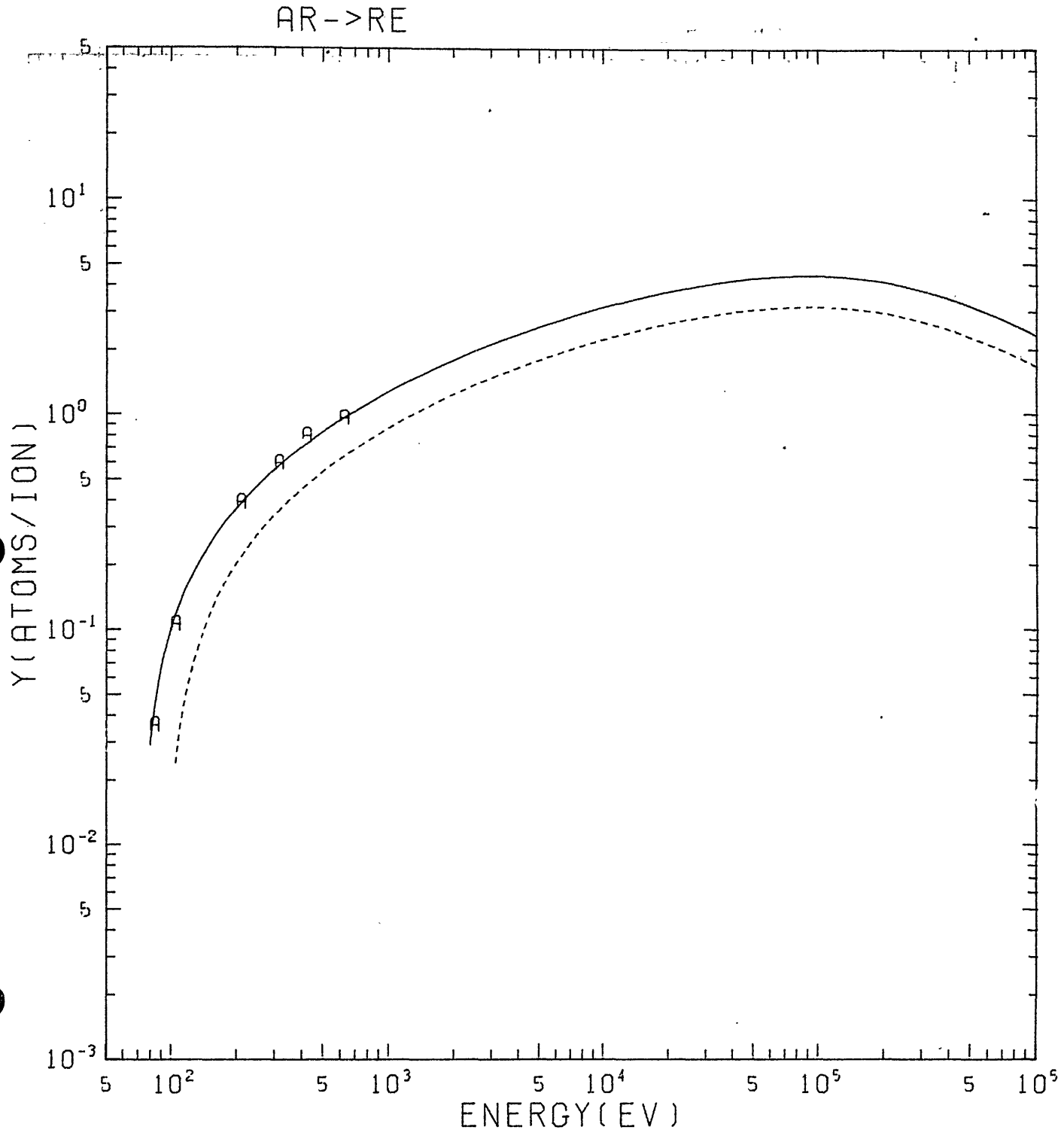
PB->W
A KOSHKIN,RYSOV,SHKARBAN (1969)

Fig. 166



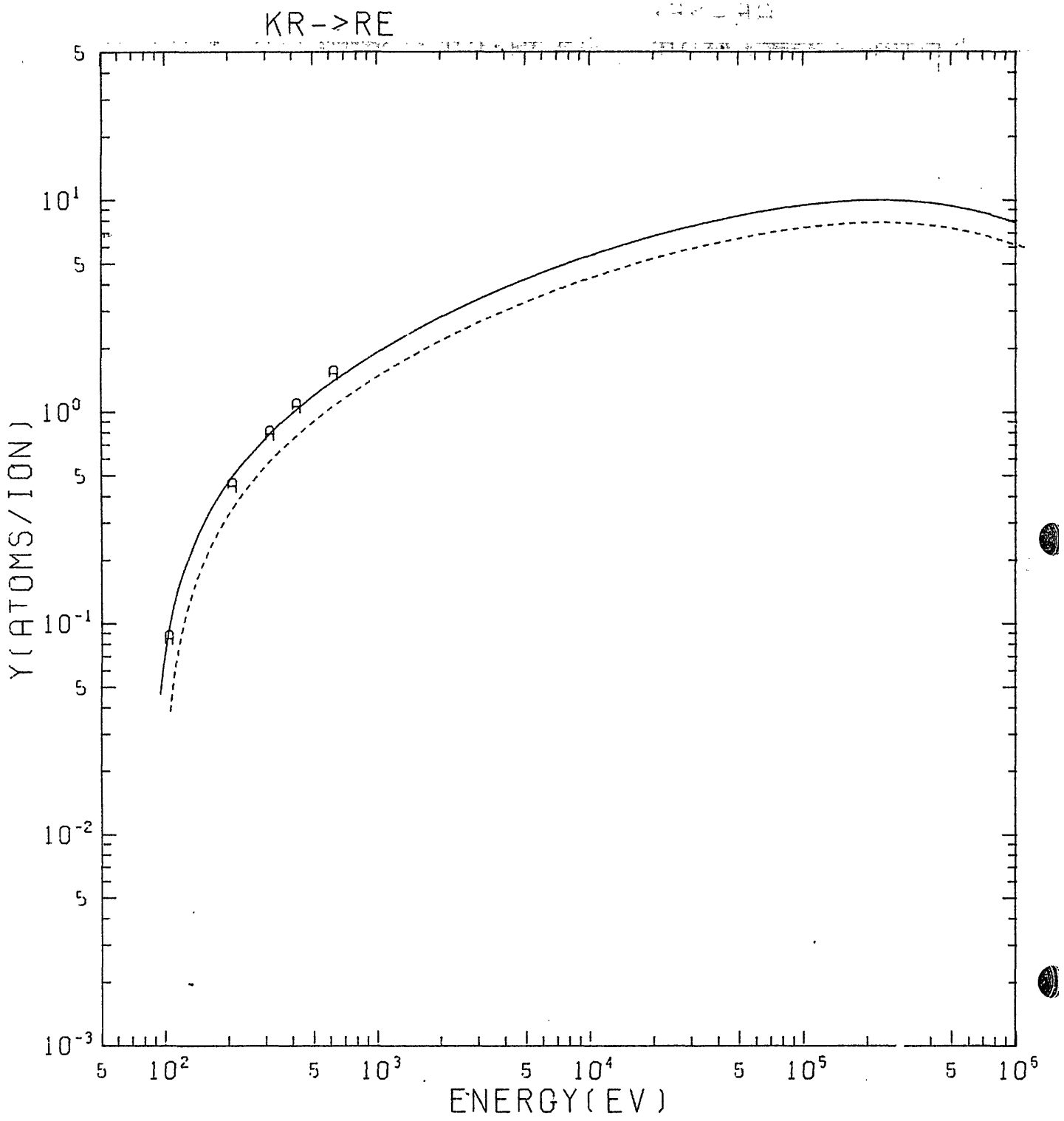
NE->RE
A LAEGREID,WEHNER (1961)

Fig. 167



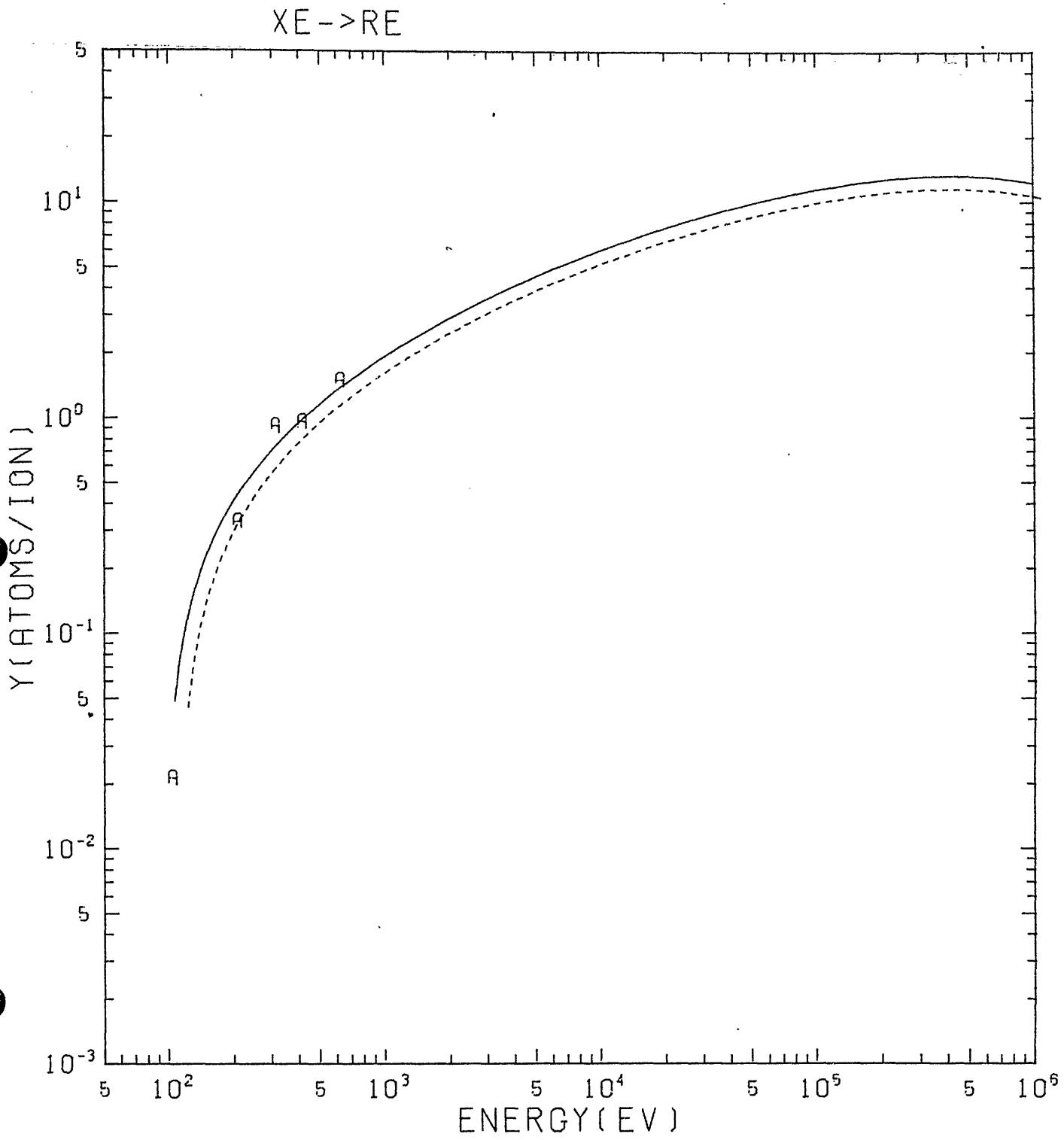
AR->RE
A LAEGREID,WEHNER (1961)

Fig. 168



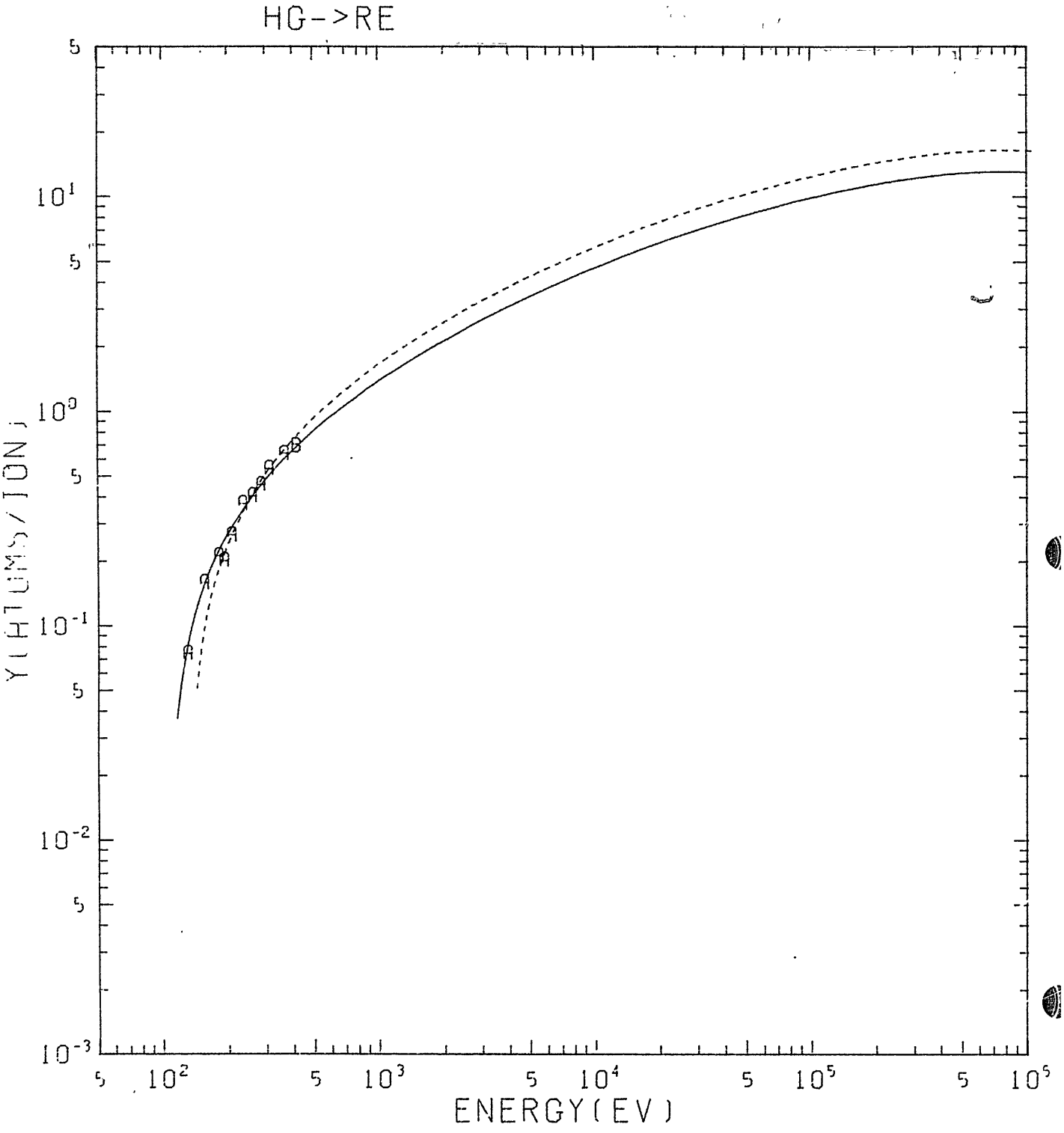
KR->RE
A ROSENBERG,WEHNER (1962)

Fig. 169



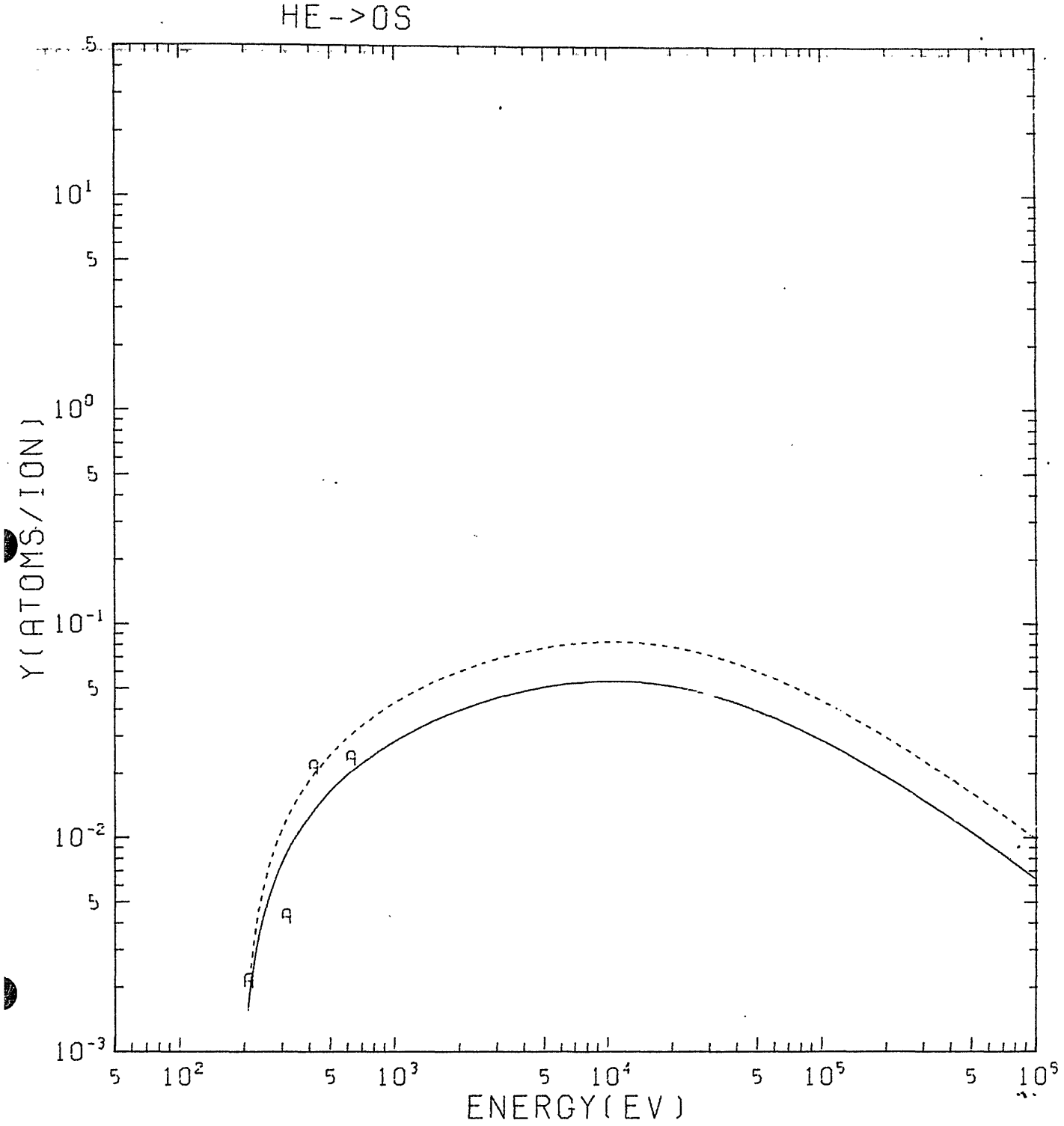
XE->RE
A ROSENBERG,WEHNER (1962)

Fig. 170



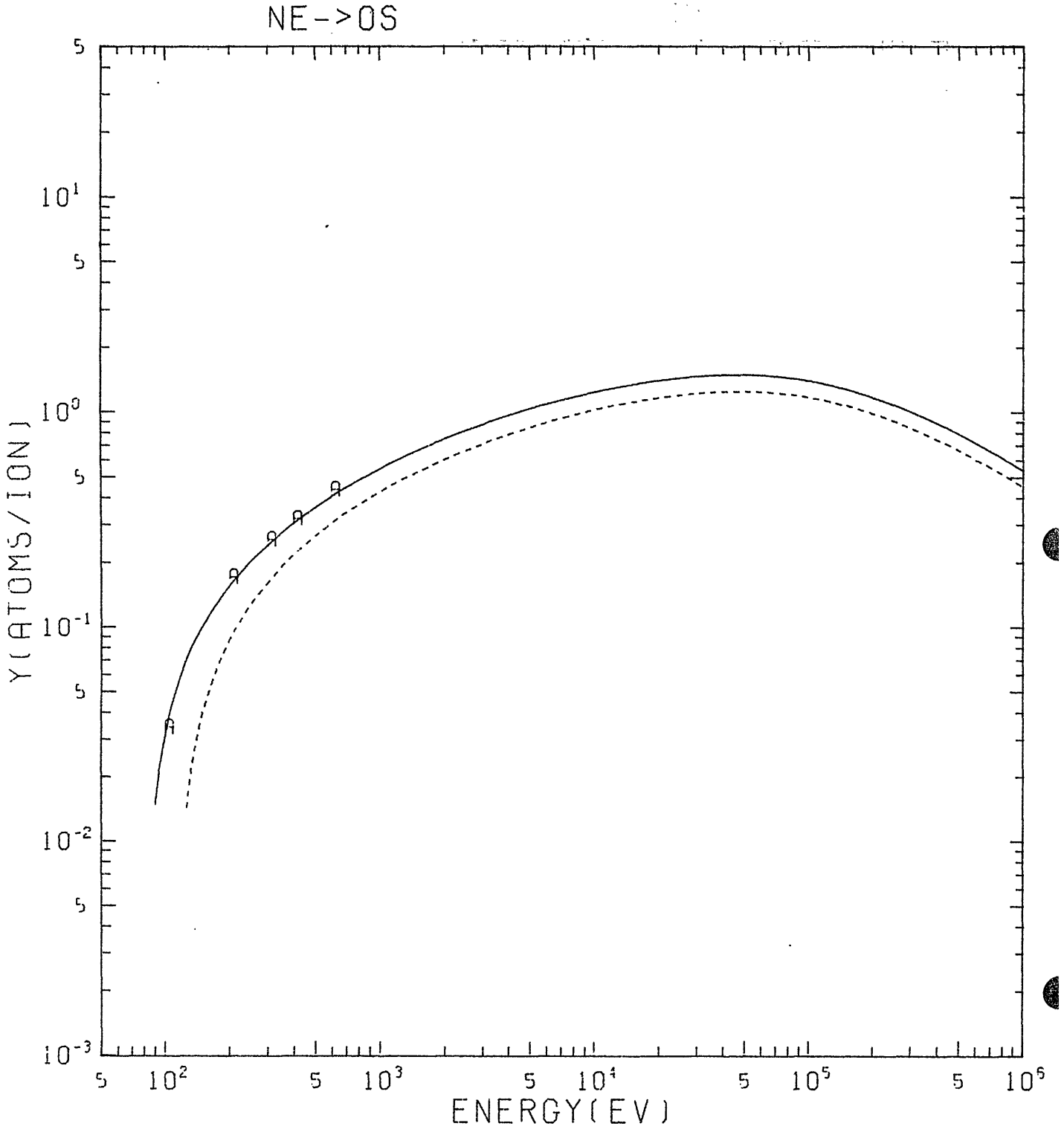
HG->RE
9 WEHNER (1957)
5 LAEGREID,WEHNER (1961)

Fig. 171



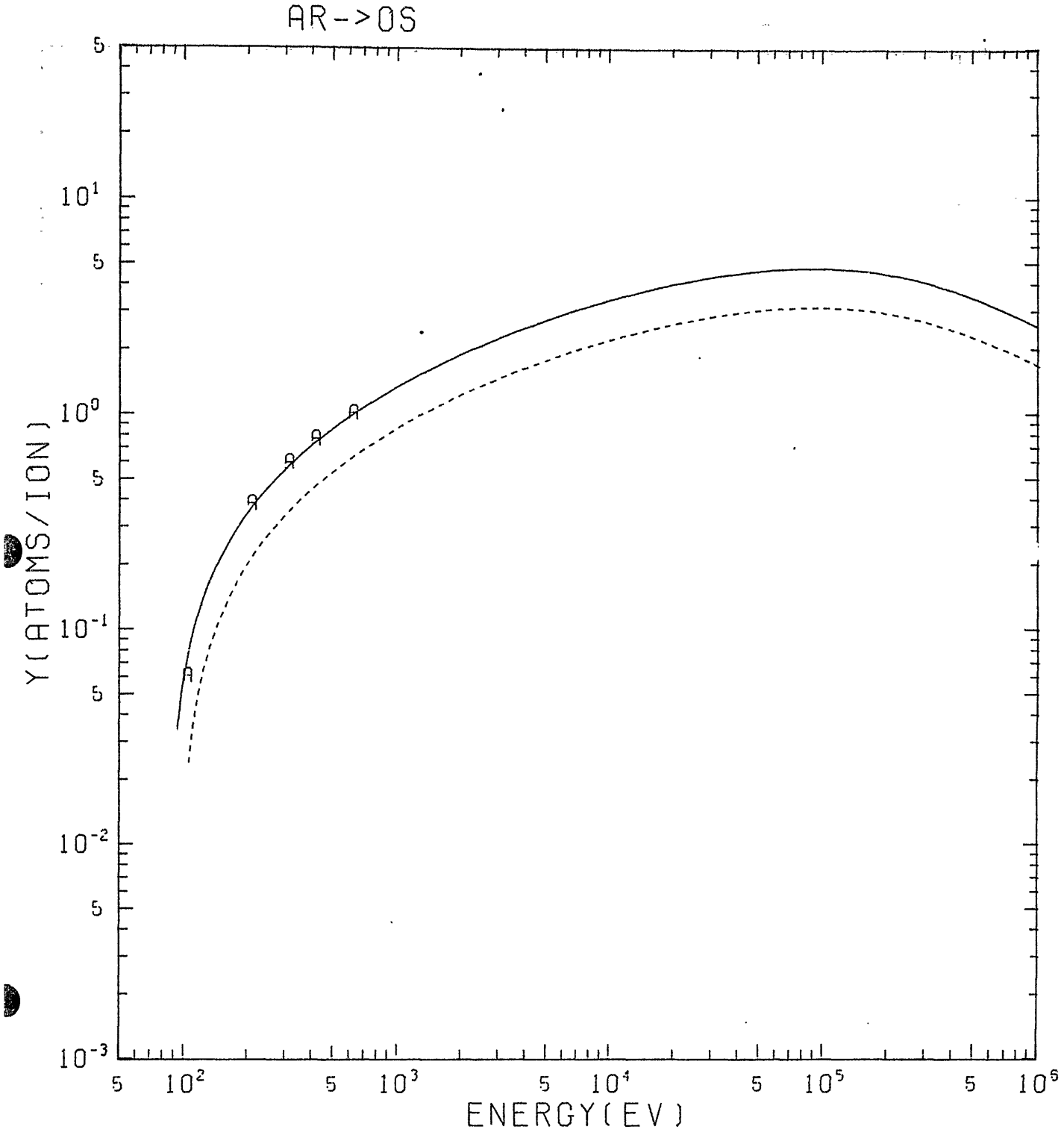
HE->OS
A ROSENBERG,WEHNER (1962)

Fig. 172



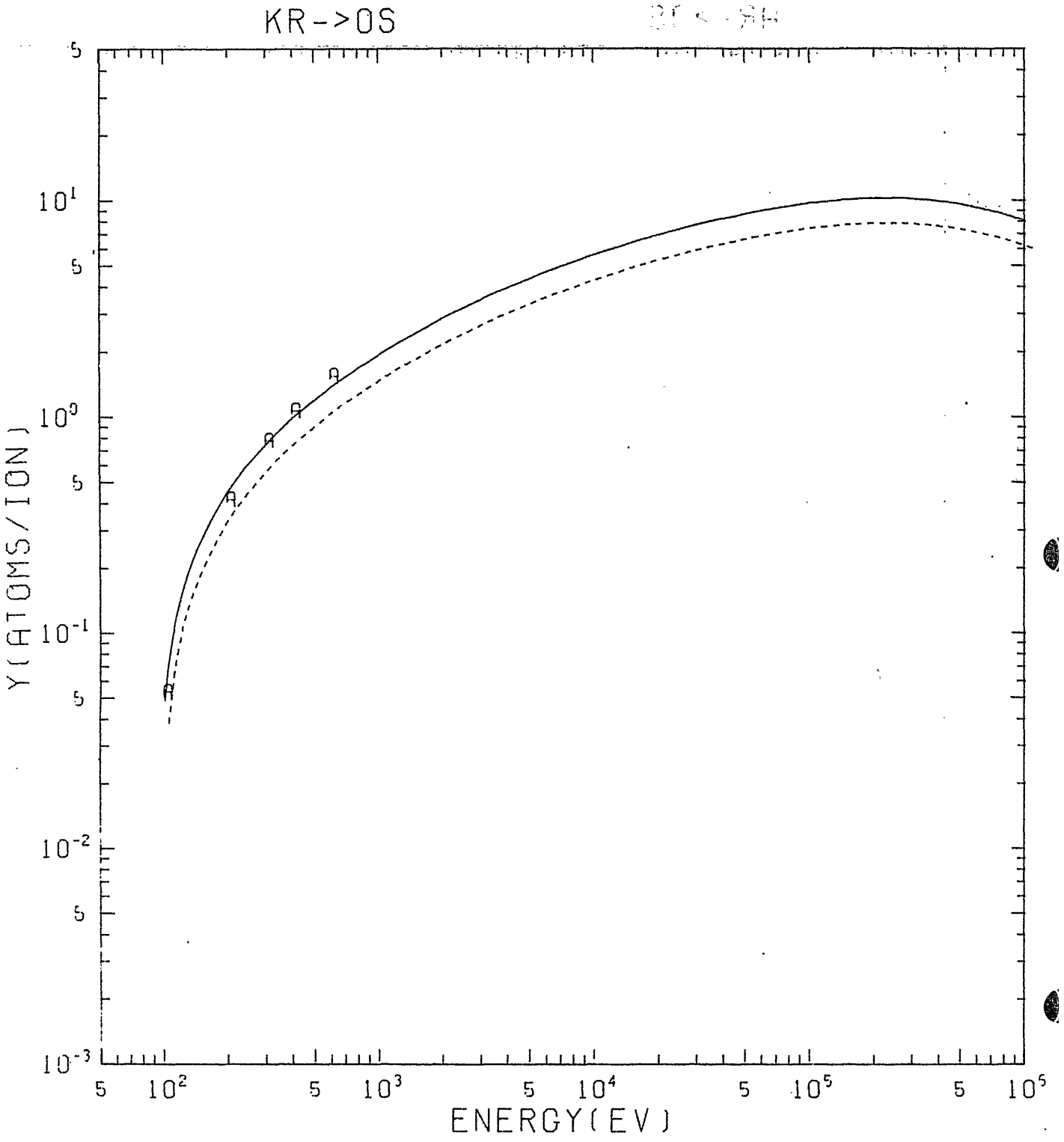
NE->OS
A LAEGREID,WEHNER (1961)

Fig. 173



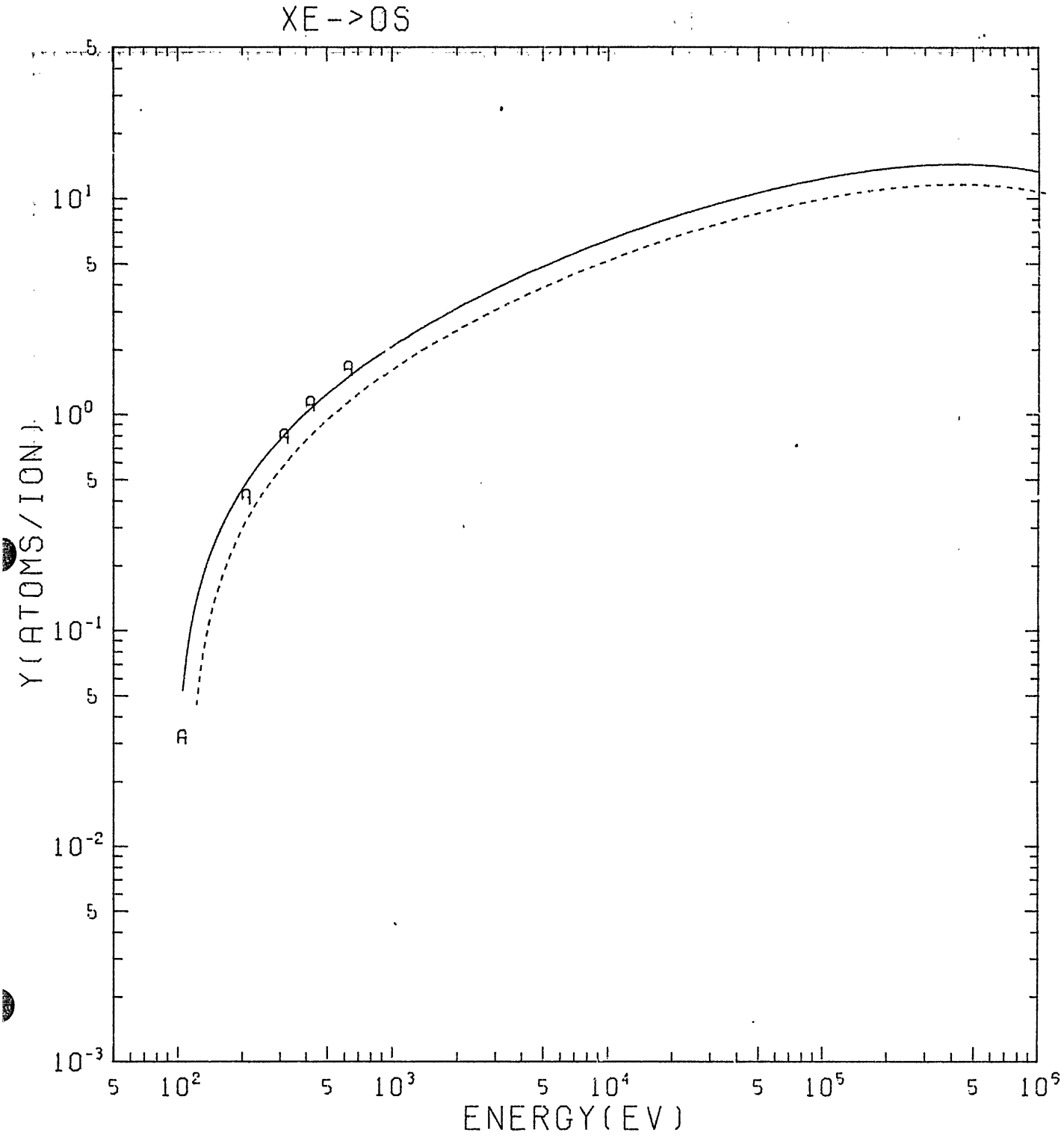
AR->OS
A LAEGREID,WEHNER (1961)

Fig. 174



KR->OS
A ROSENBERG,WEHNER (1962)

Fig. 175



XE->OS
A ROSENBERG,WEHNER (1962)

Fig. 176

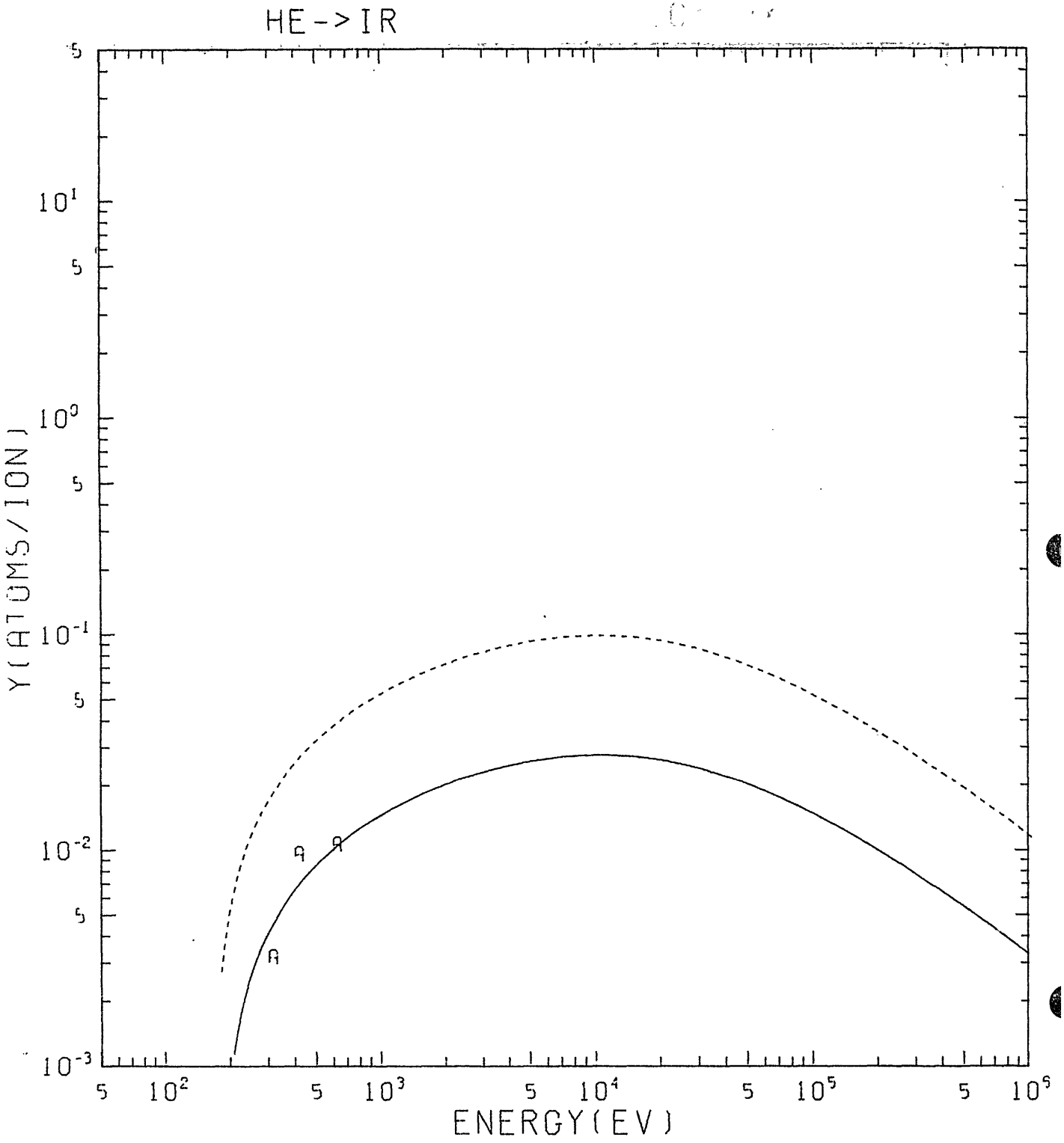
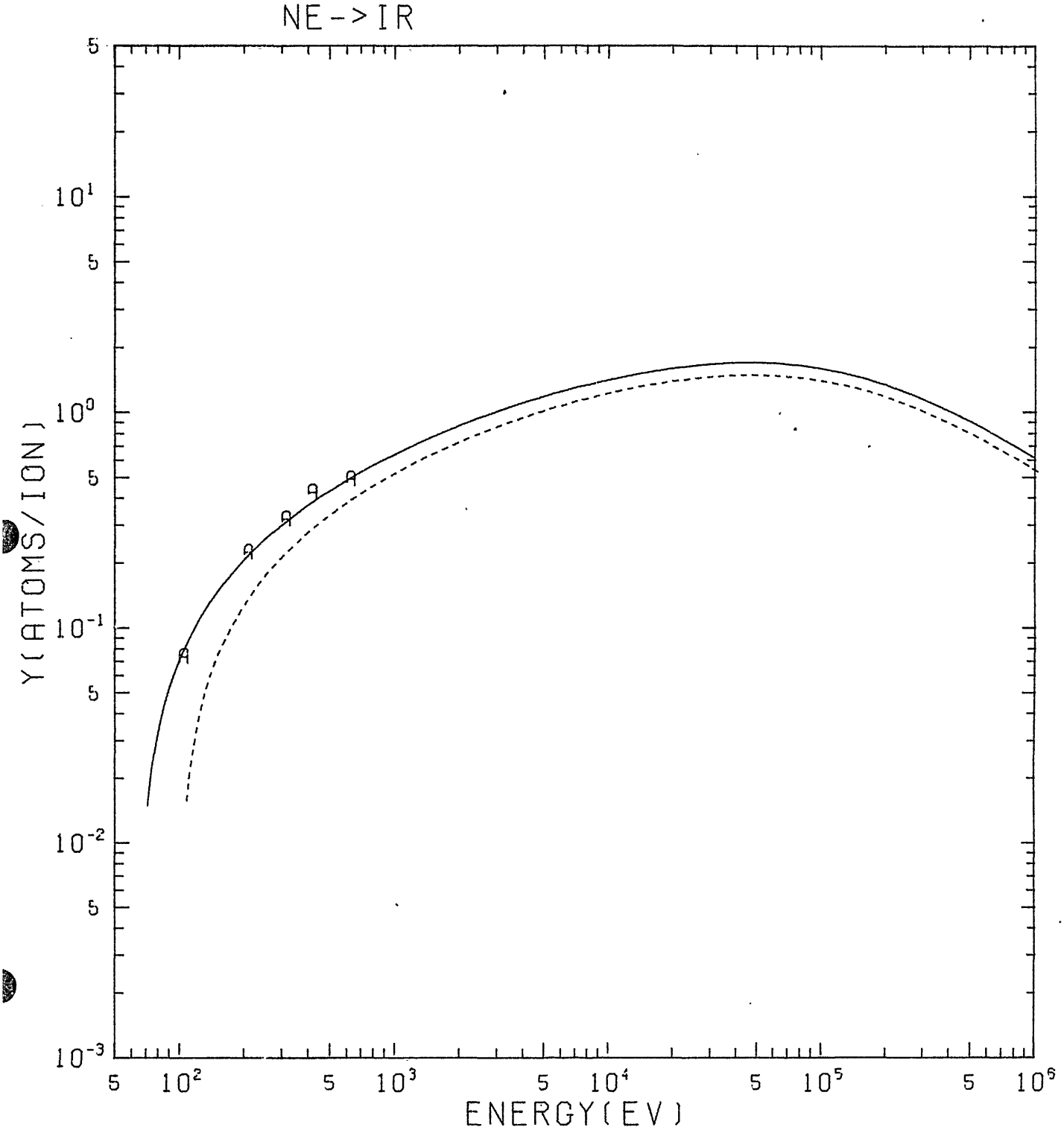
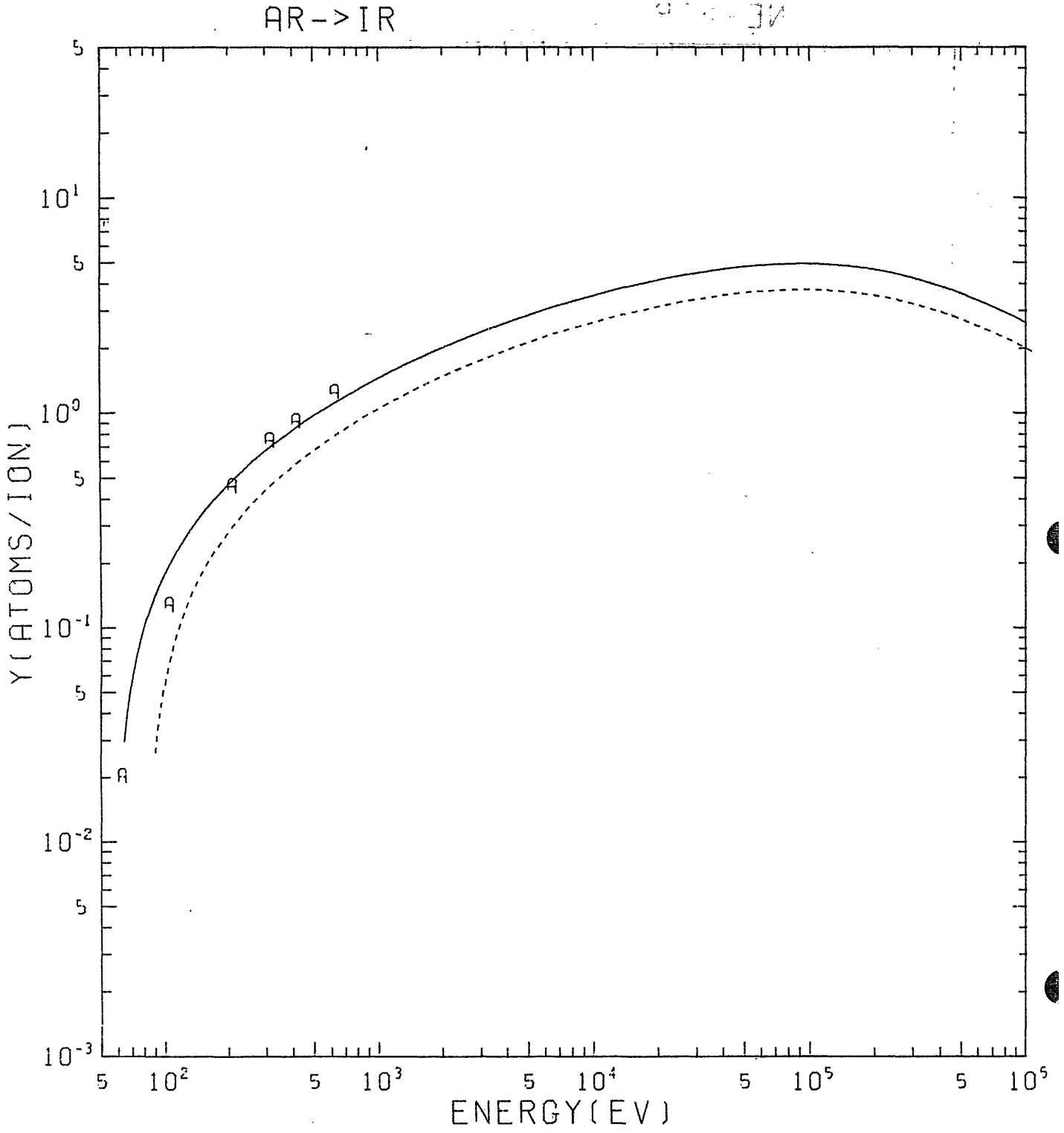


Fig. 177



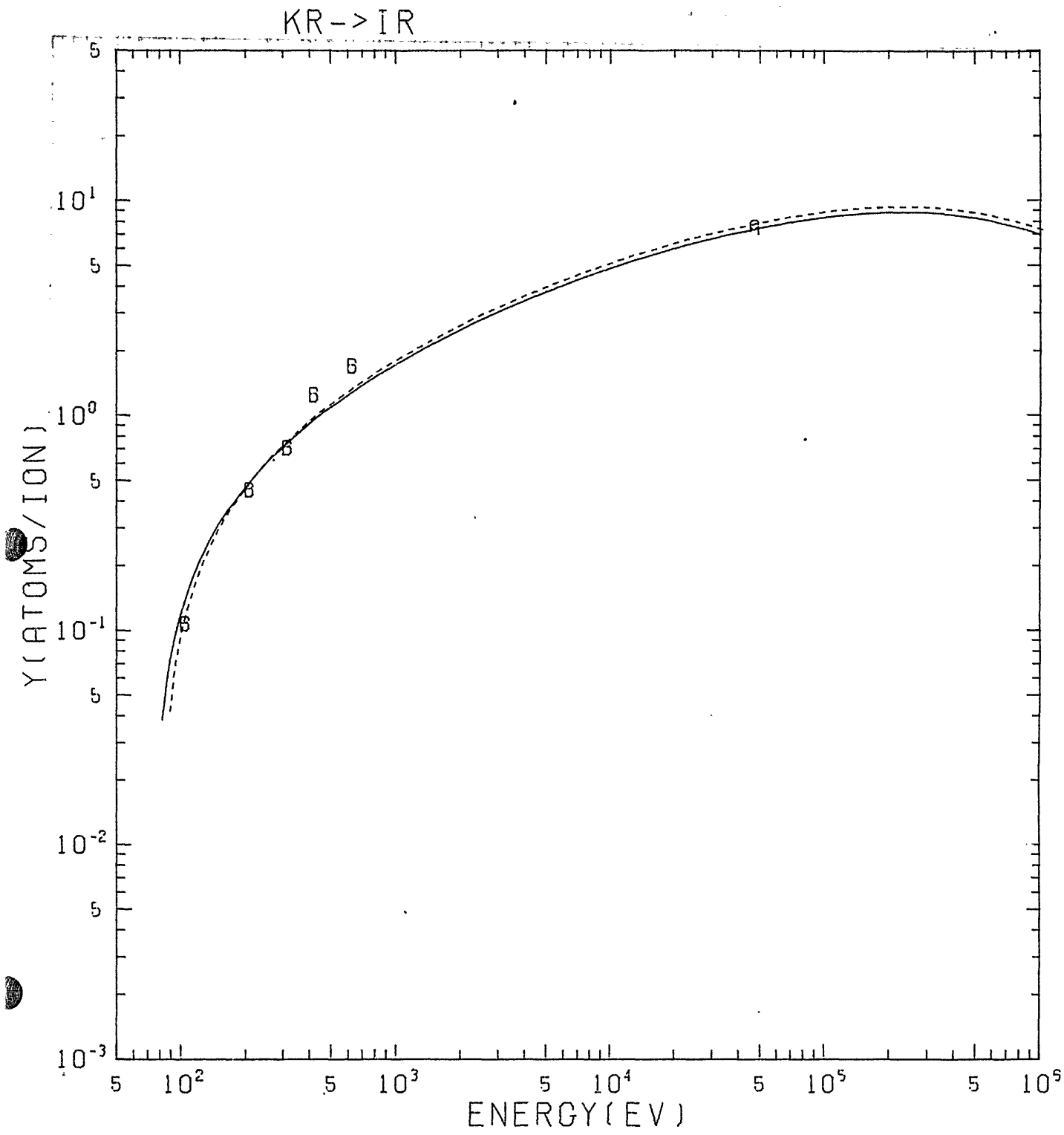
NE->IR
A LAEGREID,WEHNER (1961)

Fig. 178



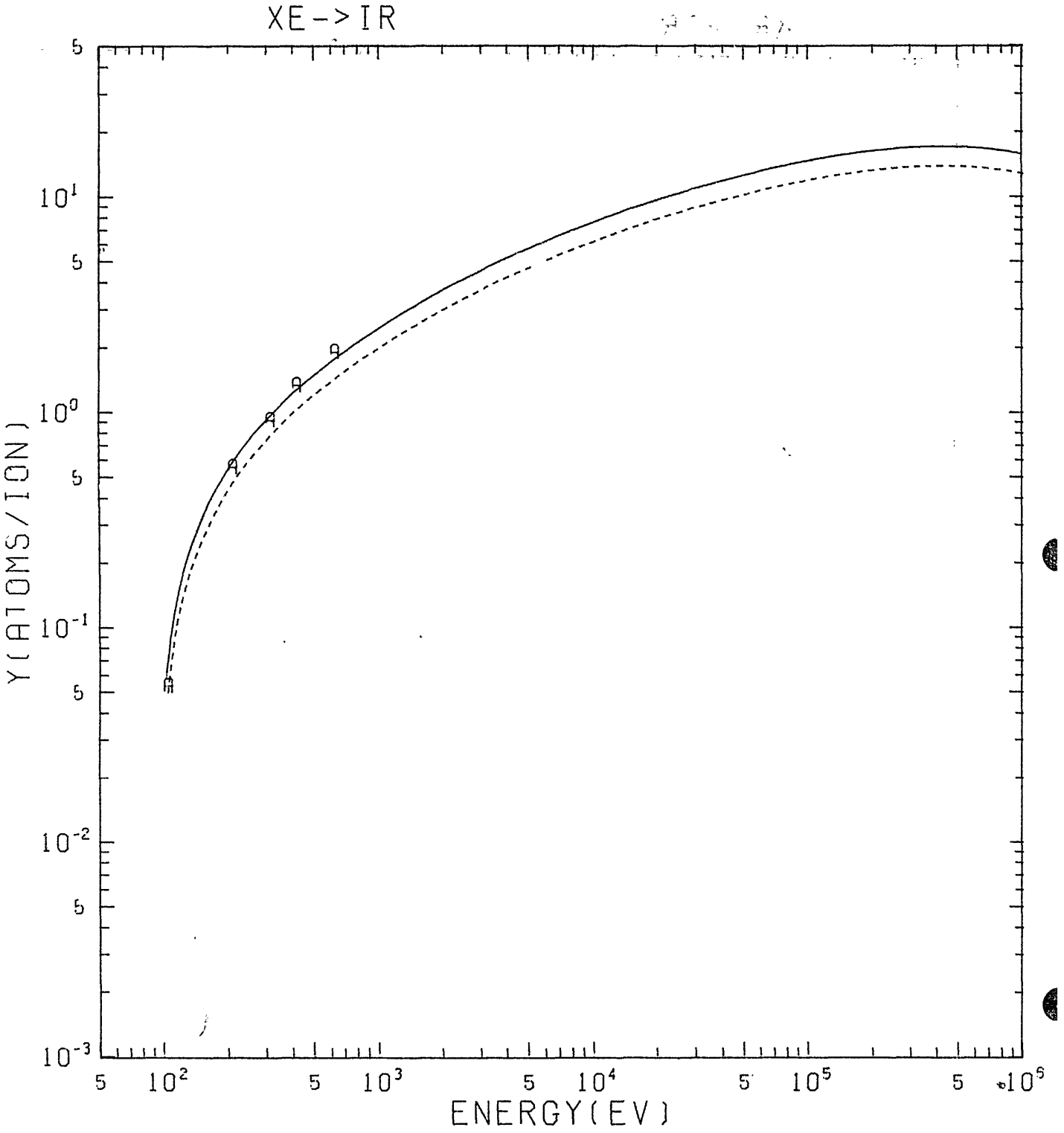
AR->IR
A LAEGREID,WEHNER (1961)

Fig. 179



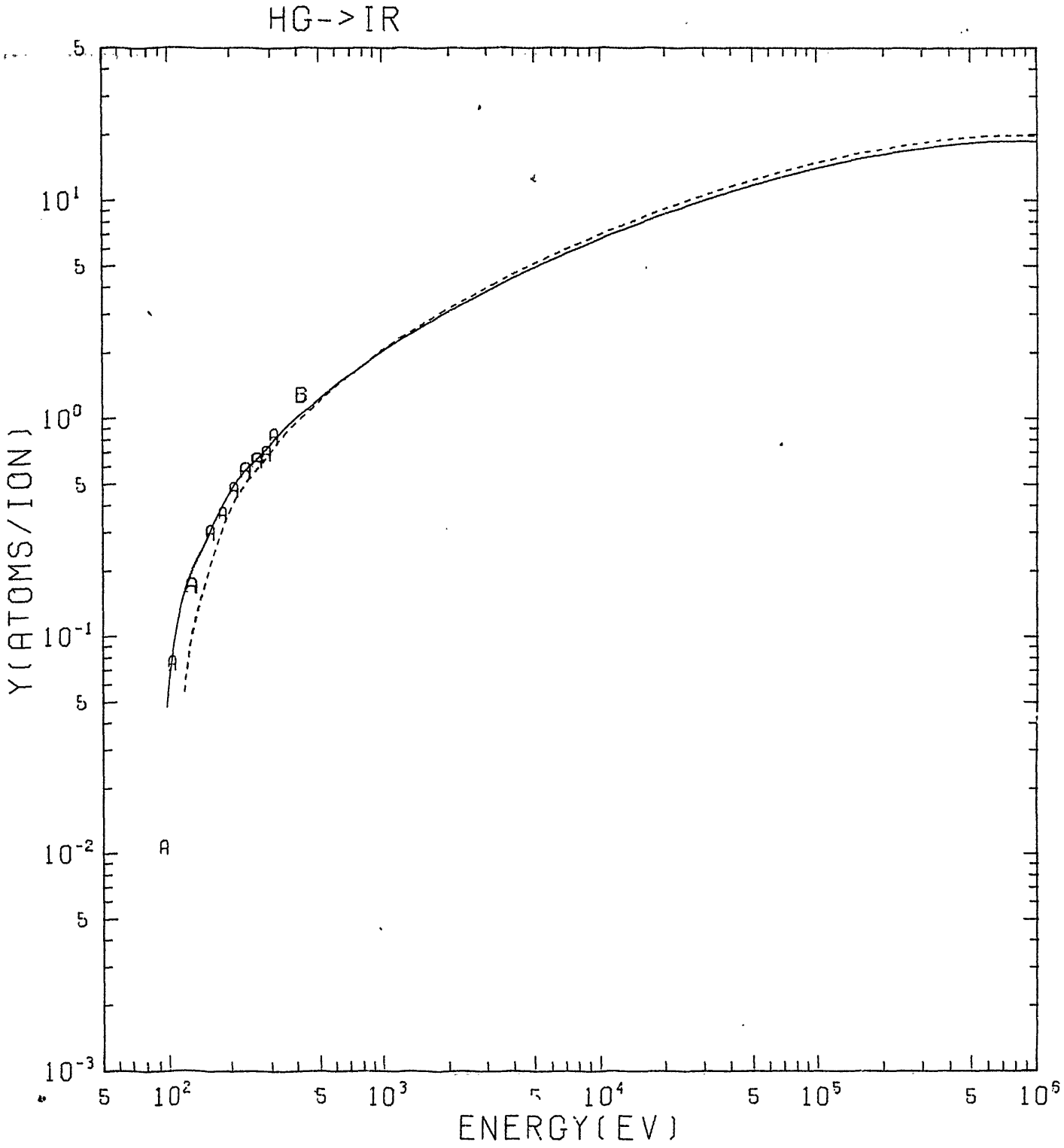
KR->IR
A ALMEN.BRUCE (1961B)
B ROSENBERG.WEHNER (1962)

Fig. 180



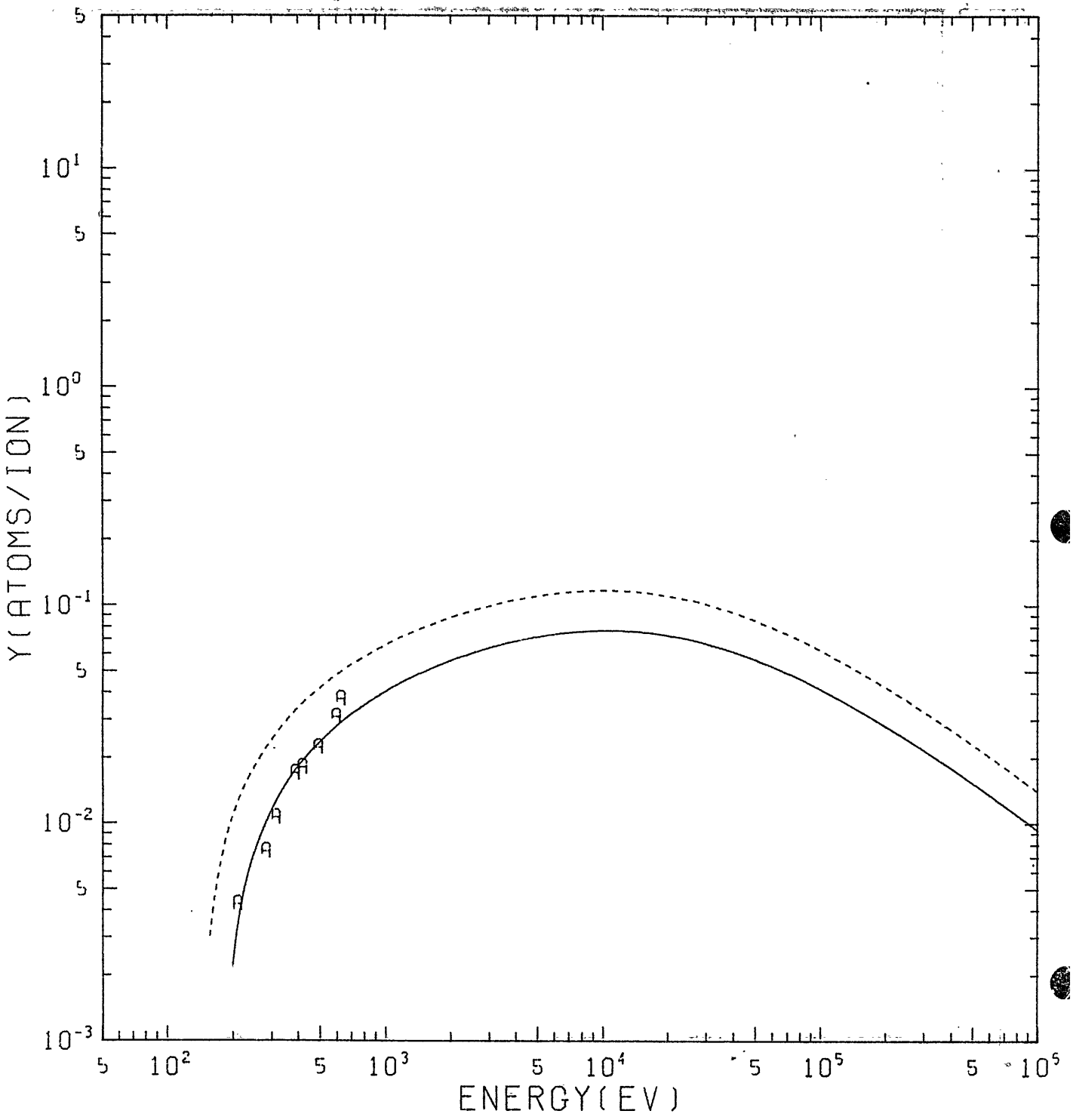
XE->IR
A ROSENBERG,WEHNER (1962)

Fig. 181



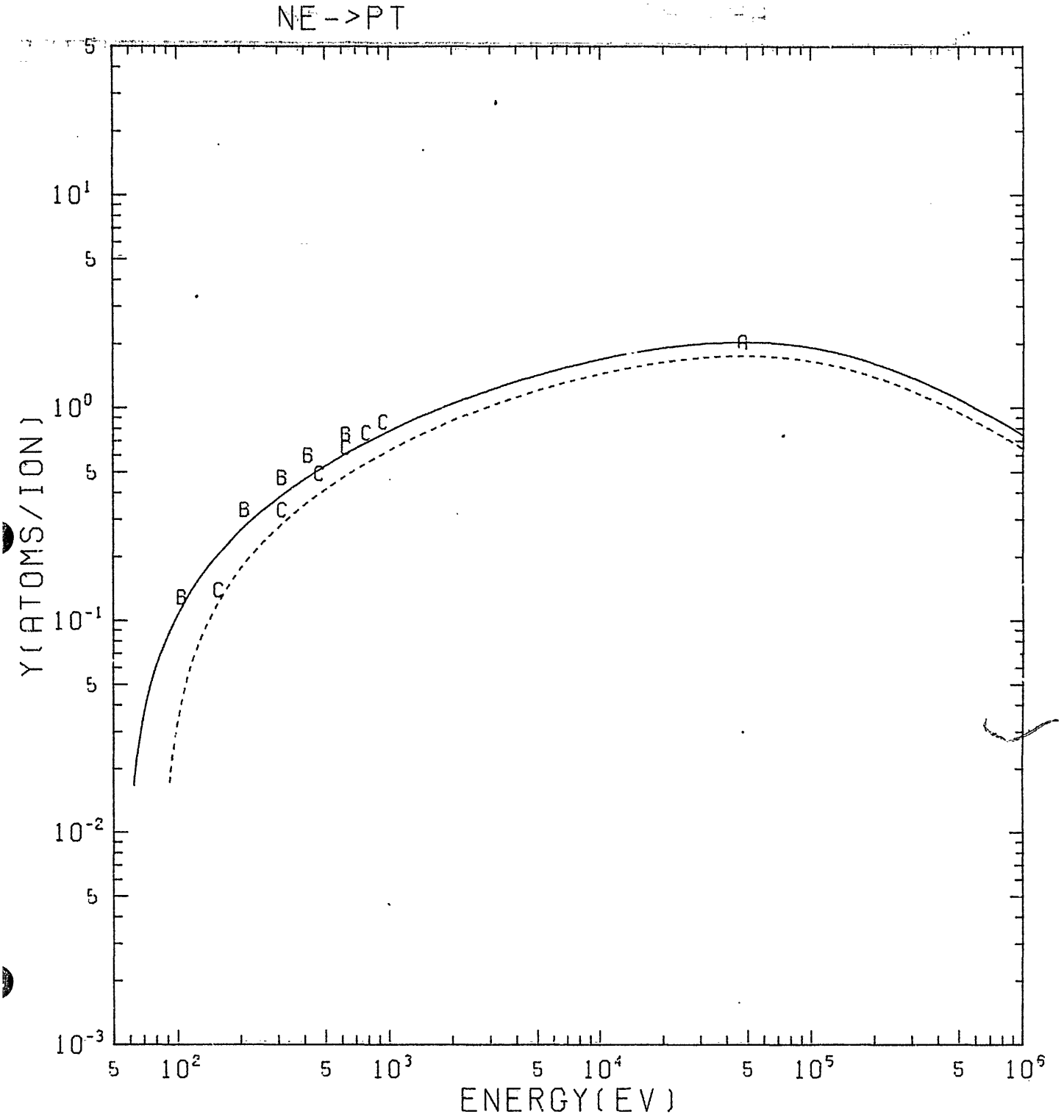
HG->IR
A WEHNER (1957)
B LAEGREID,WEHNER (1961)

Fig. 182



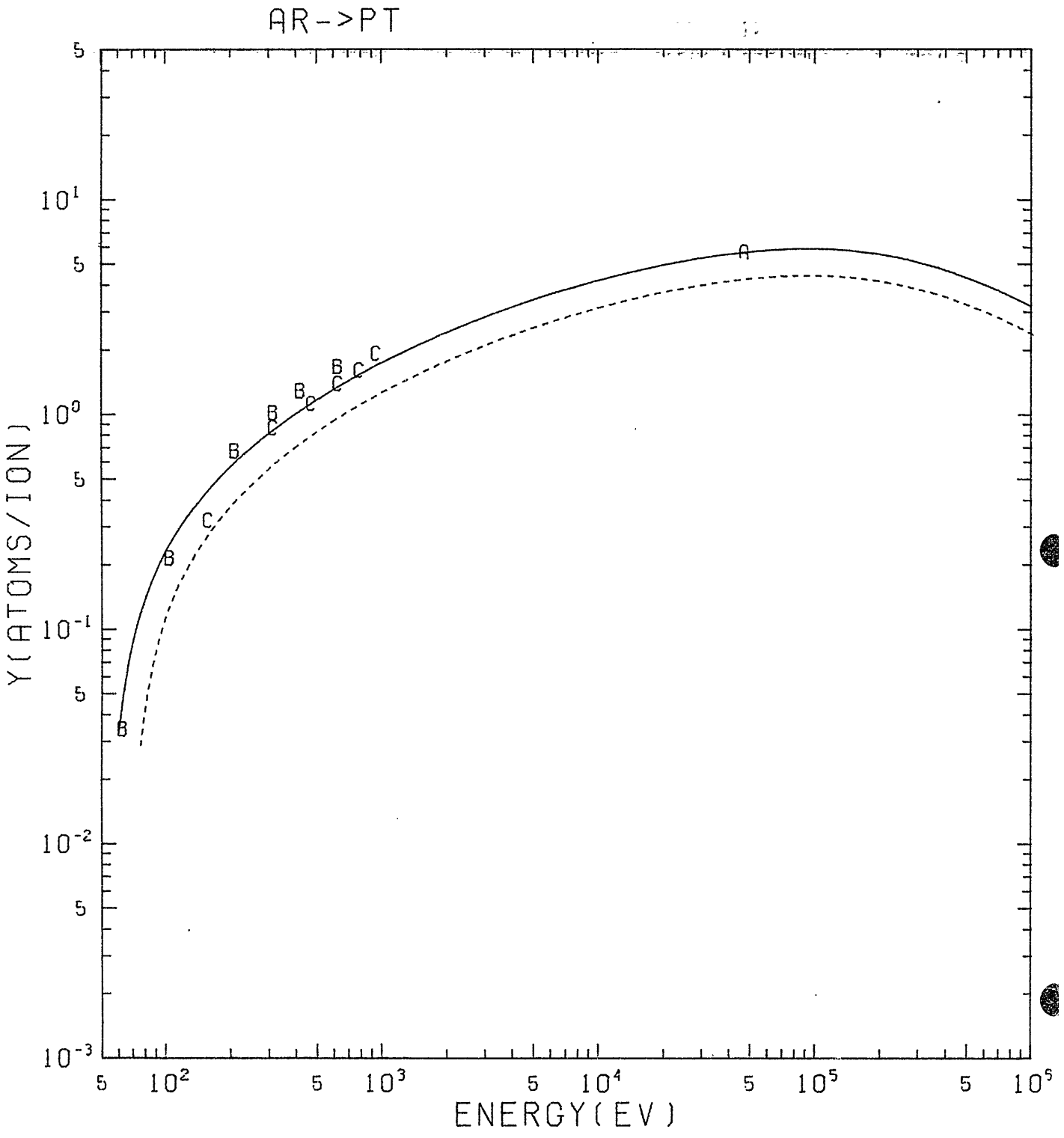
HE->PT
A ROSENBERG,WEHNER (1962)

Fig. 183



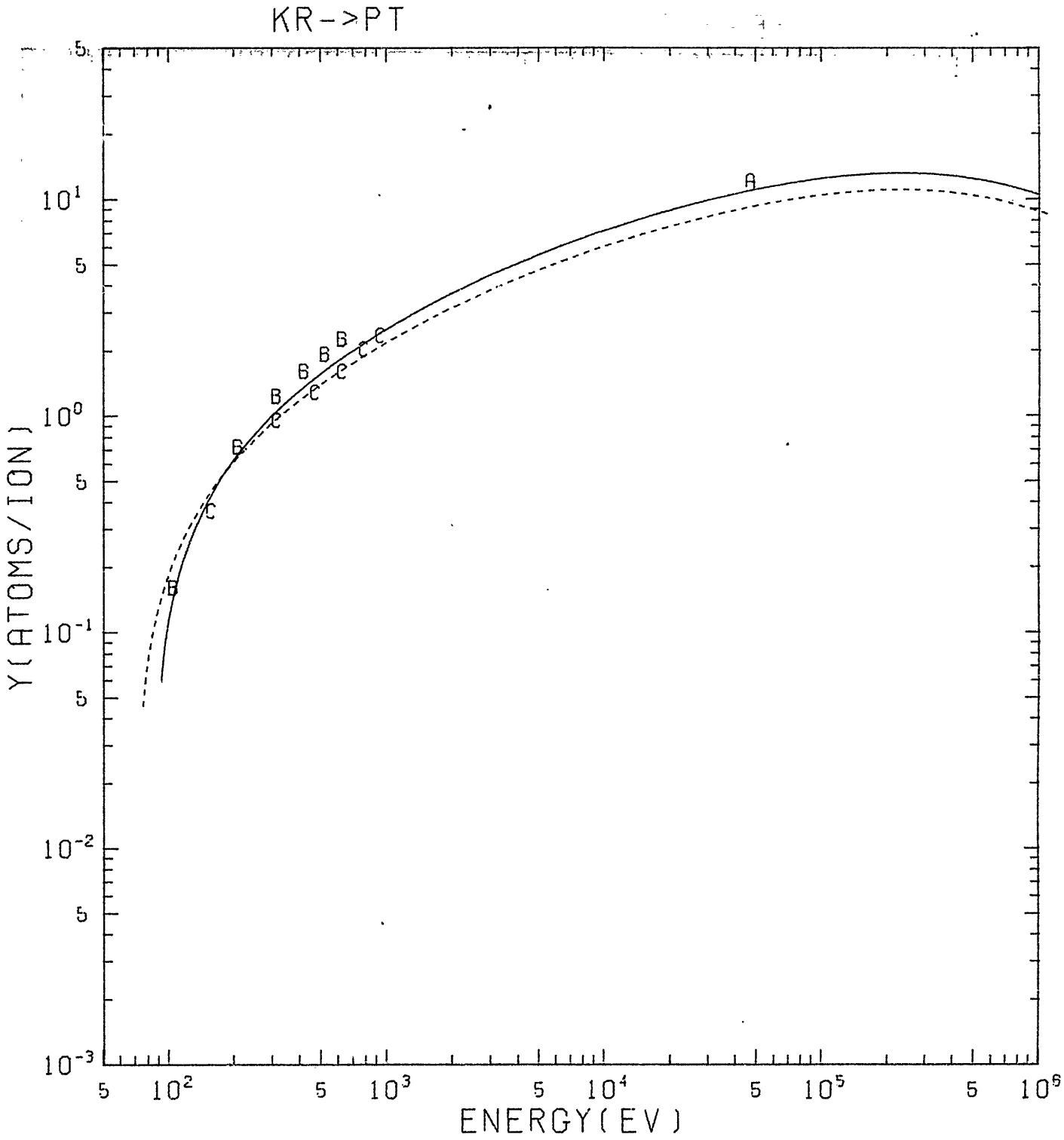
NE->PT
A ALMEN.BRUCE (1961A)
B LAEGREID.WEHNER (1961)
C FETZ.OECHSNER (1963)

Fig. 184



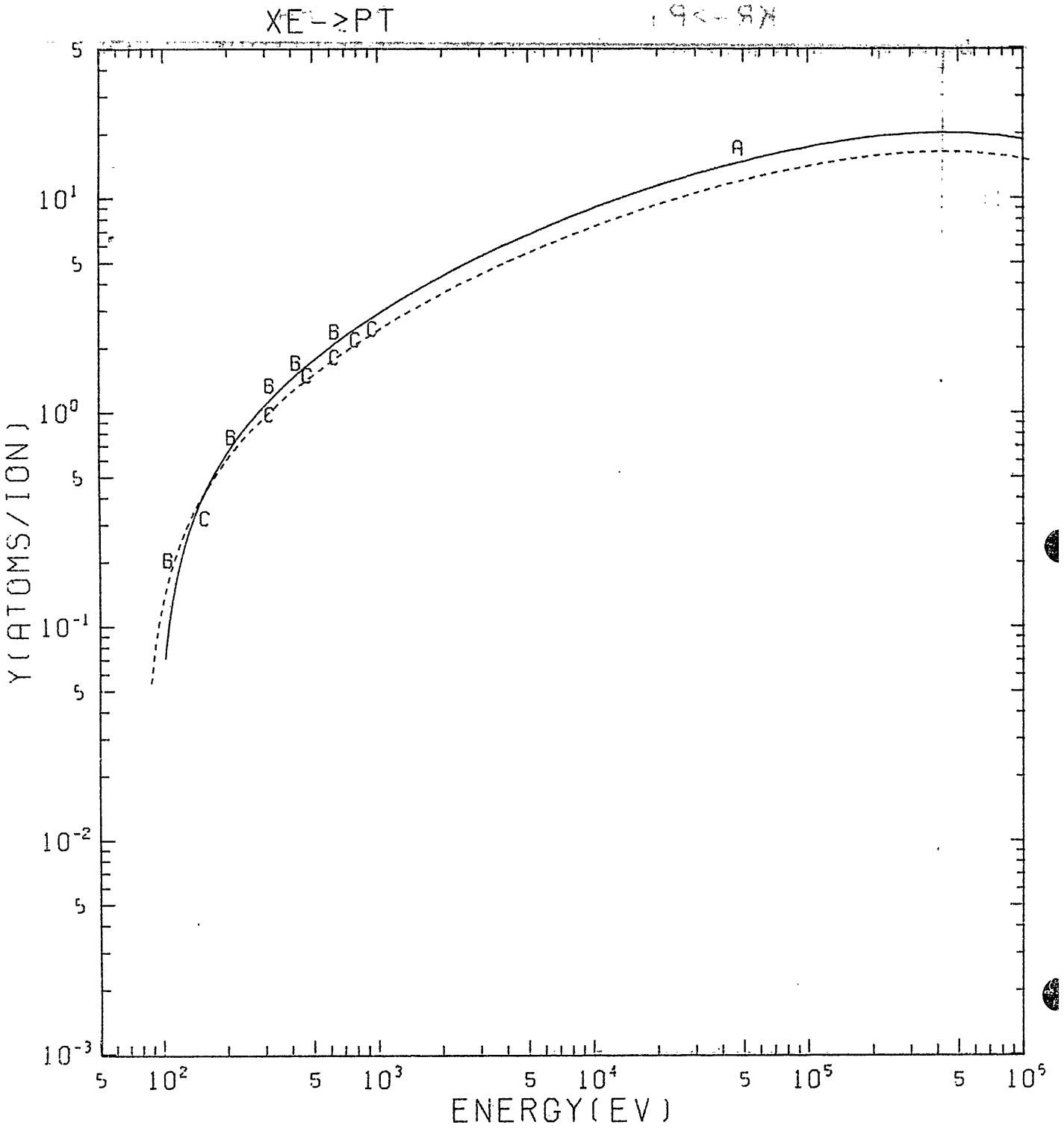
AR->PT
A ALMEN.BRUCE (1961A)
B LAEGREID.WEHNER (1961)
C FETZ.OECHSNER (1963)

Fig. 185



KR->PT
A ALMEN.BRUCE (1961A)
B ROSENBERG.WEHNER (1962)
C FETZ.OECHSNER (1963)

Fig. 186



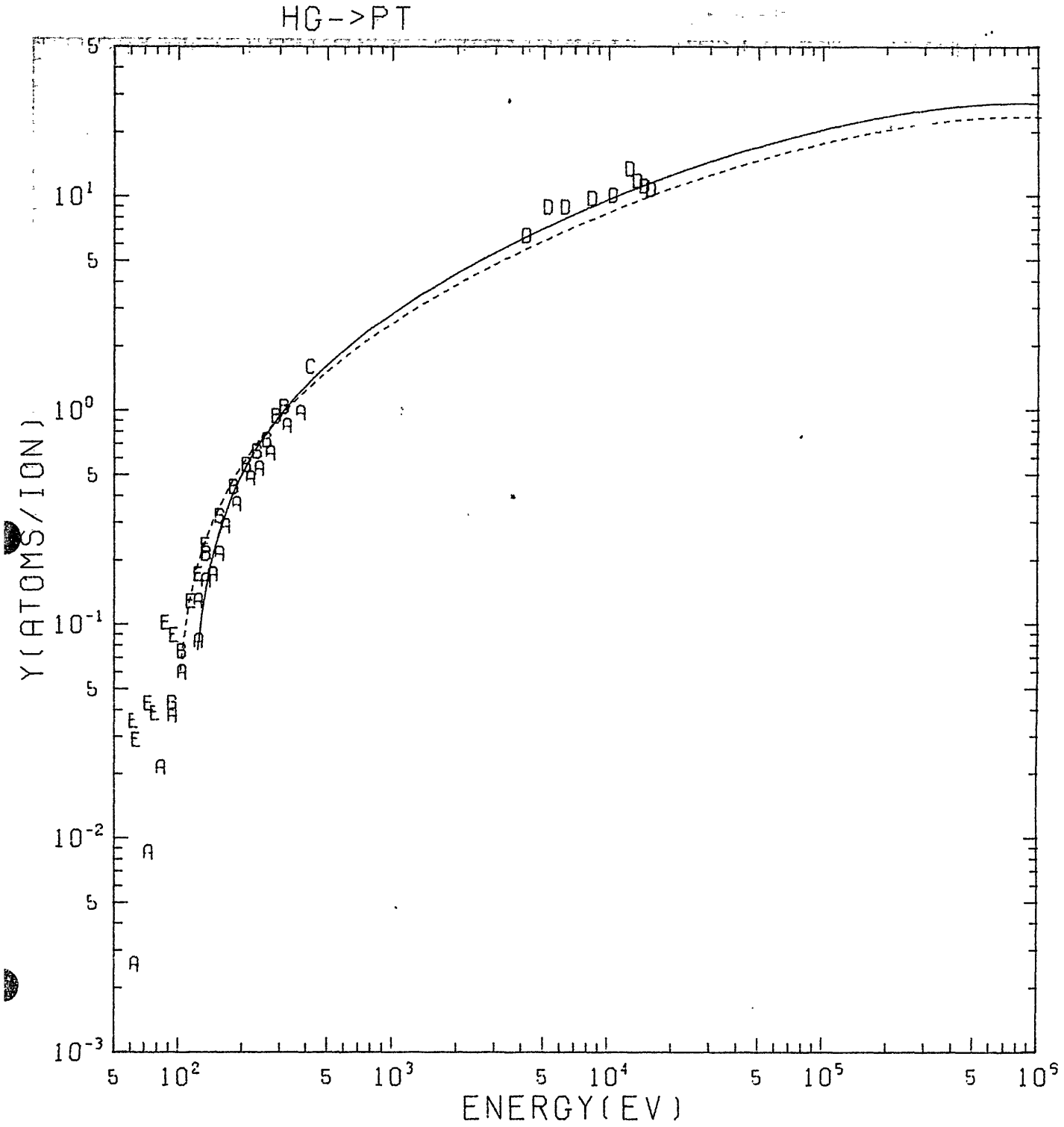
XE->PT

A ALMEN,BRUCE (1961A)

B ROSENBERG,WEHNER (1962)

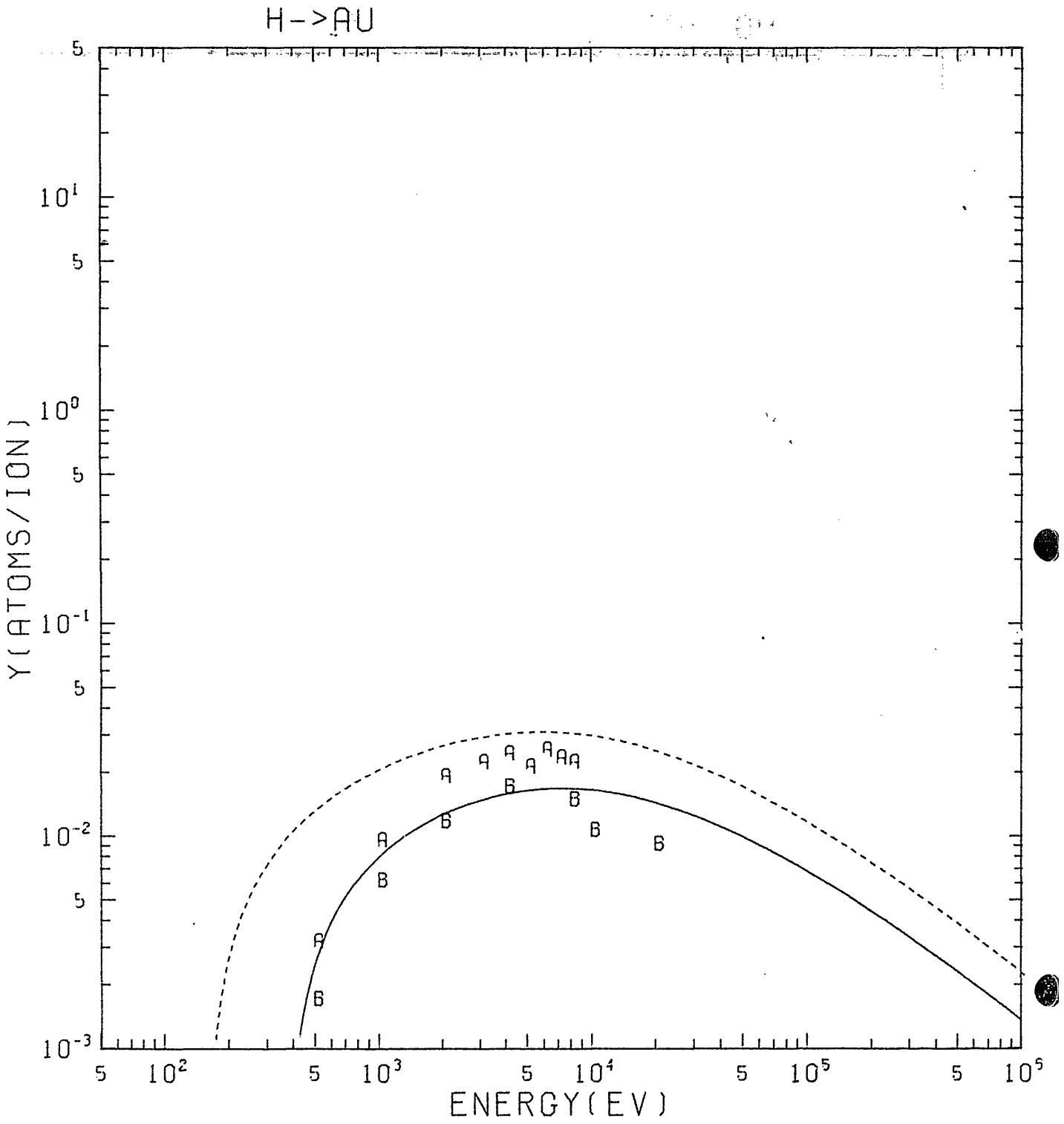
C FETZ,OECHSNER (1963)

Fig. 187



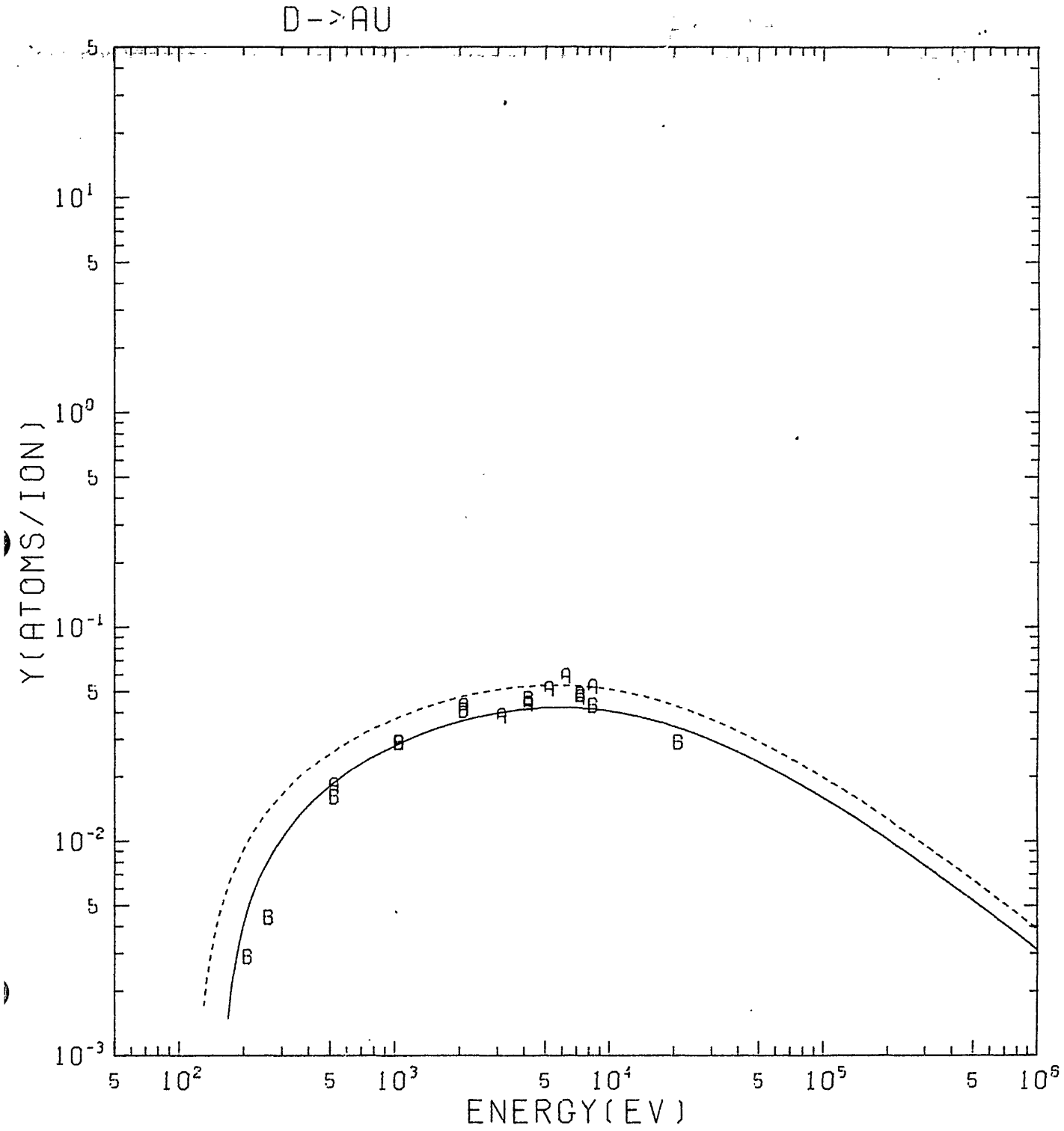
HG->PT
A WEHNER (1956)
B WEHNER (1957)
C LAEGREID.WEHNER (1961)
D WEHNER.ROSENBERG (1961)
E ASKEROV.SENA (1969)

Fig. 188



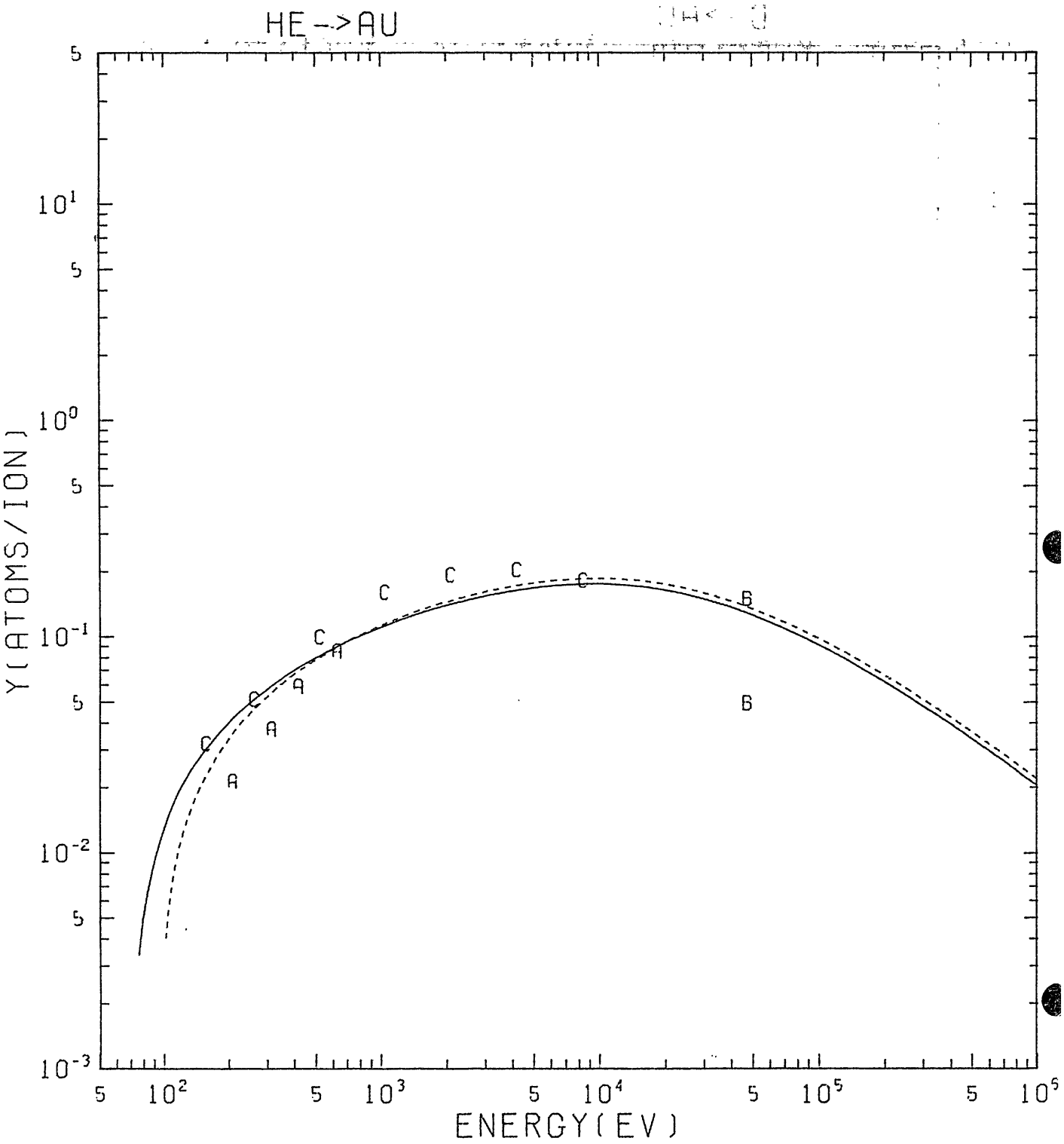
H->AU
A FURR,FINFGELD (1970)
B BAY,ROTH,BOHDANSKY (1977)

Fig. 189



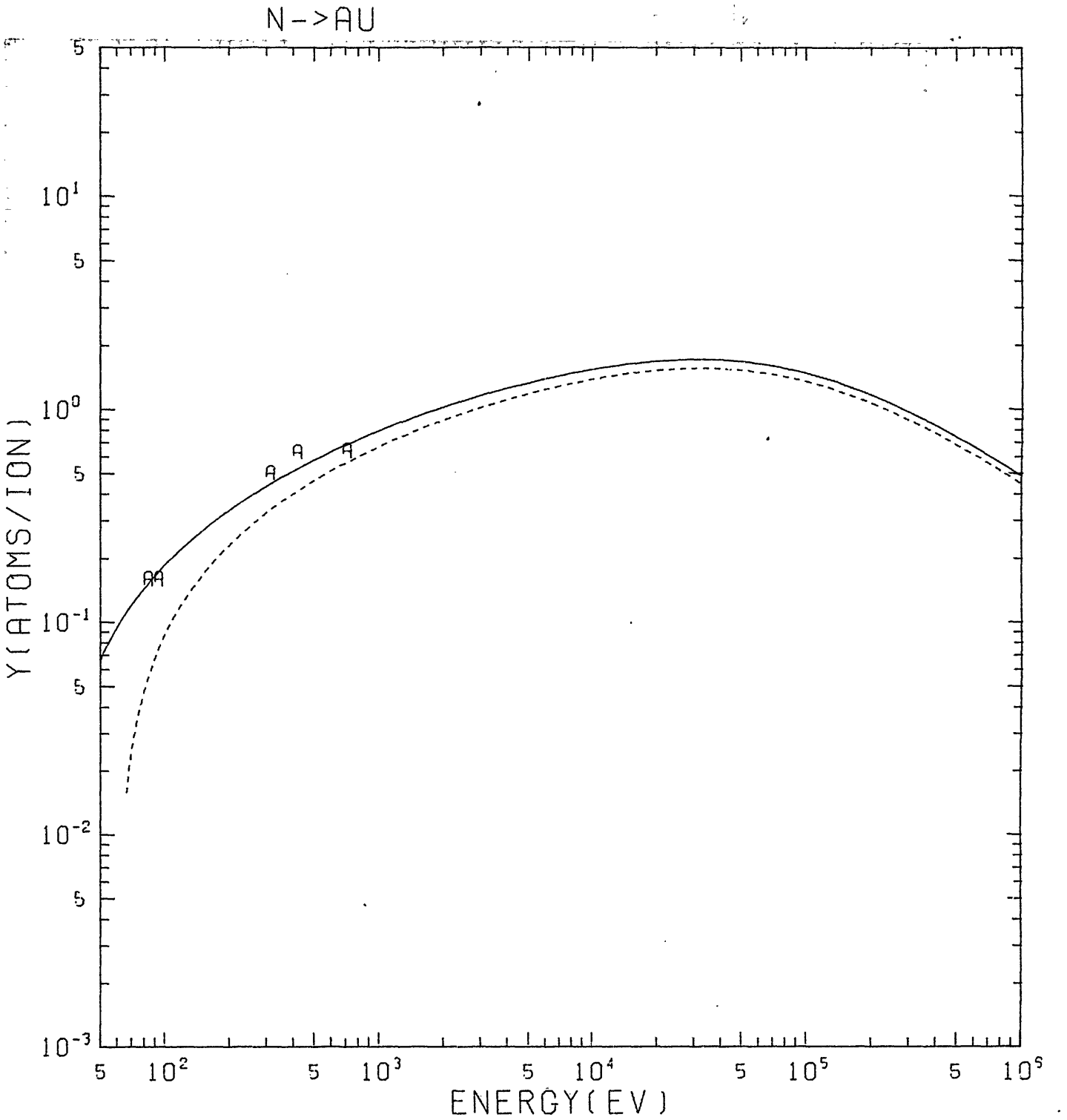
D->AU
A FURR,FINFGELD (1970)
B BAY,ROTH,BOHDANSKY (1977)

Fig. 190



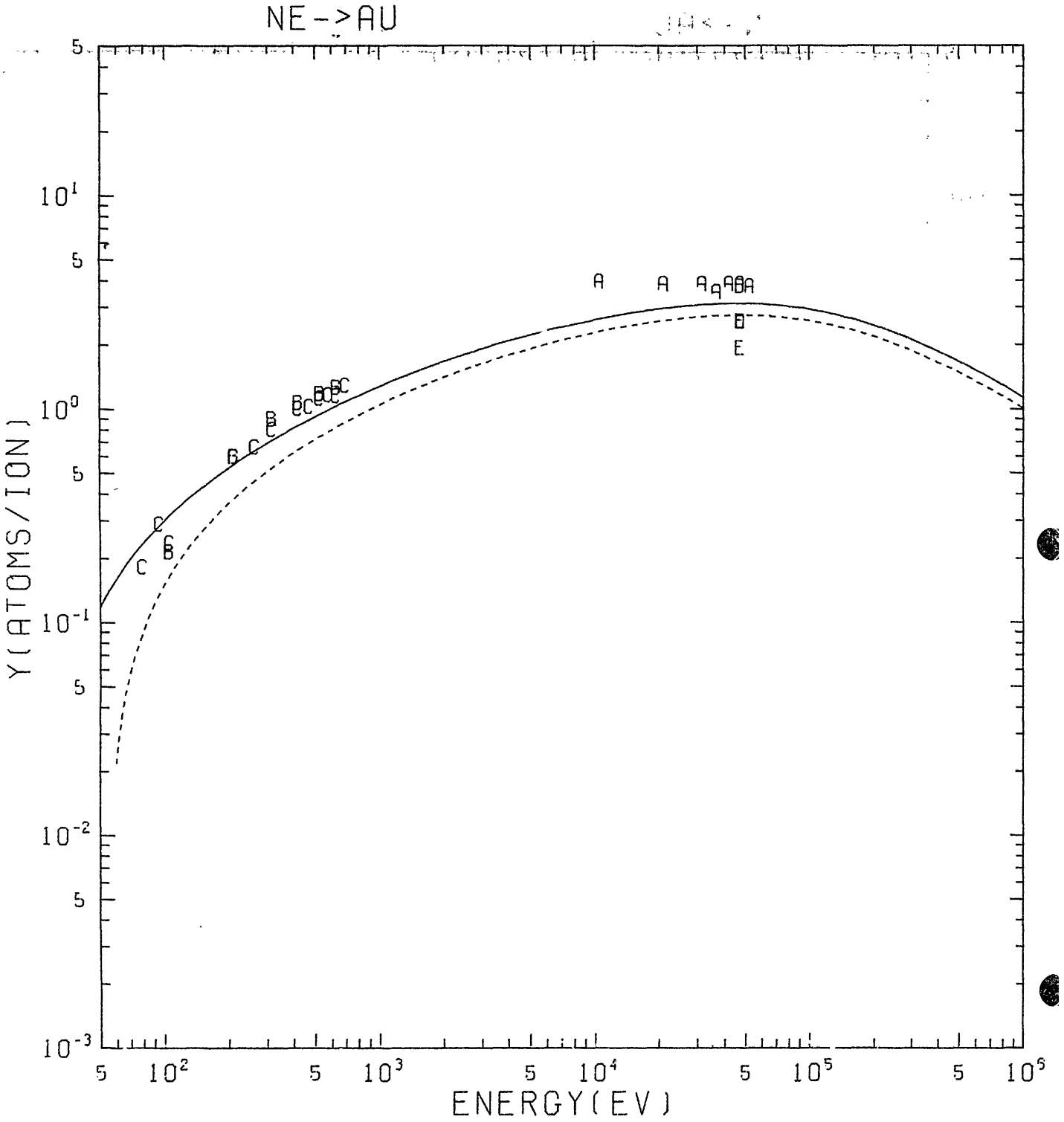
HE->AU
A ROSENBERG,WEHNER (1962)
B EERNISSE (1976)
C BAY,ROTH,BOHDANSKY (1977)

Fig. 191



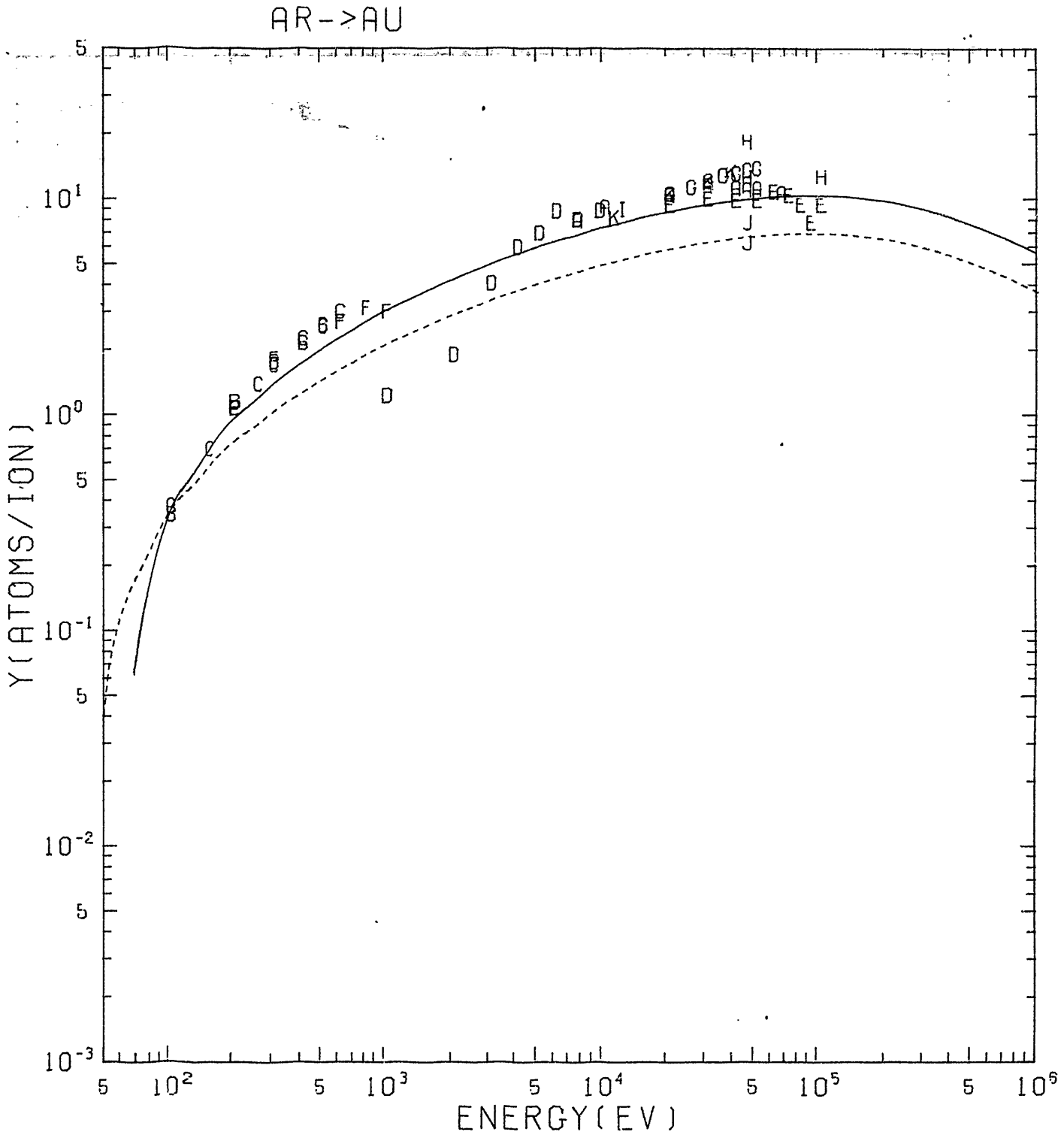
N->AU
A COLLIGON.BRAMHAM (1970)

Fig. 192



NE->AU
A ALMEN.BRUCE (1361A)
B LAEGREID.WEHNER (1961)
C COLLICON.BRAMHAM (1970)
D ANDERSEN.BAY (1975)
E EERNISSE (1976)

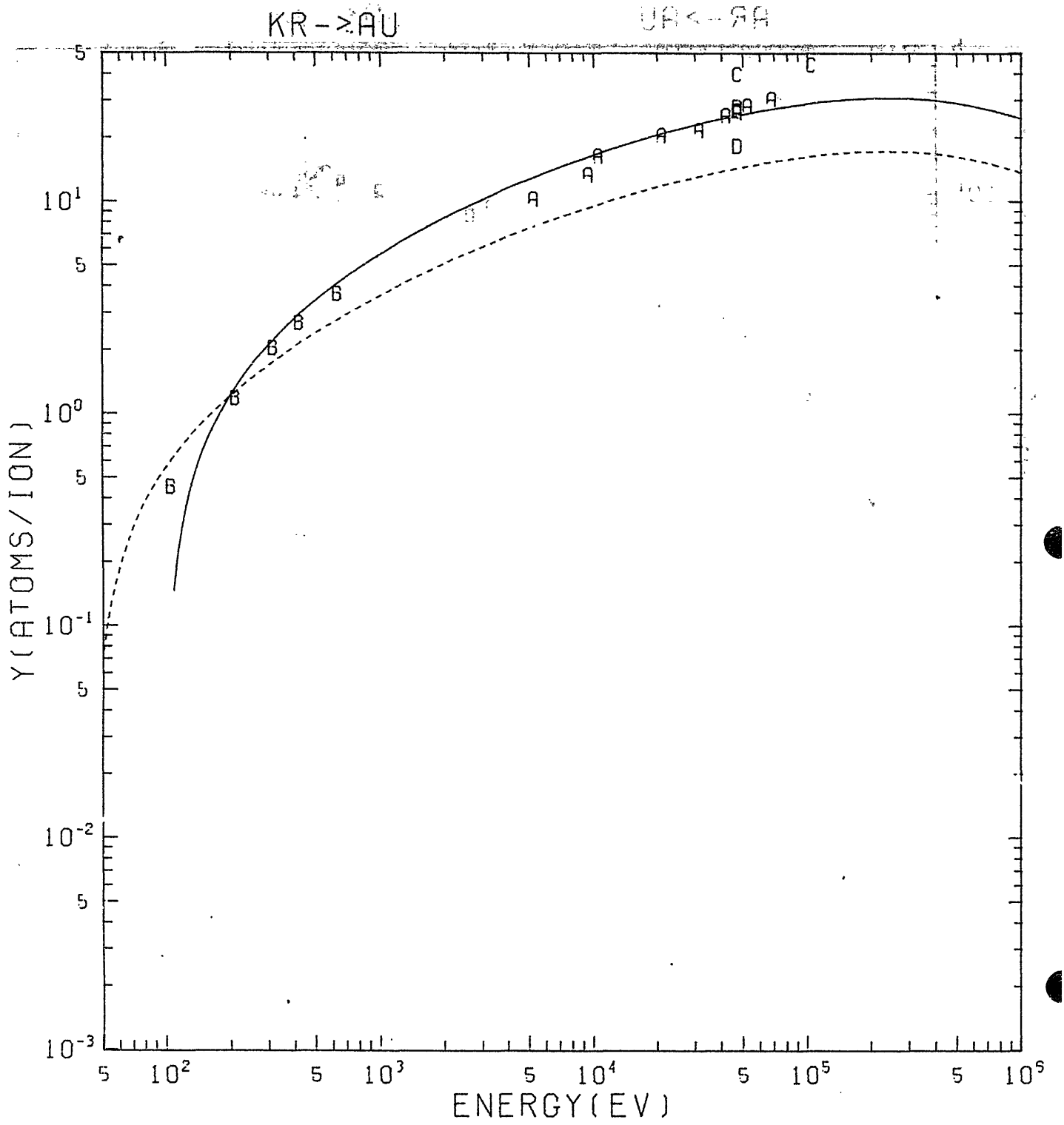
Fig. 193



AR->AU

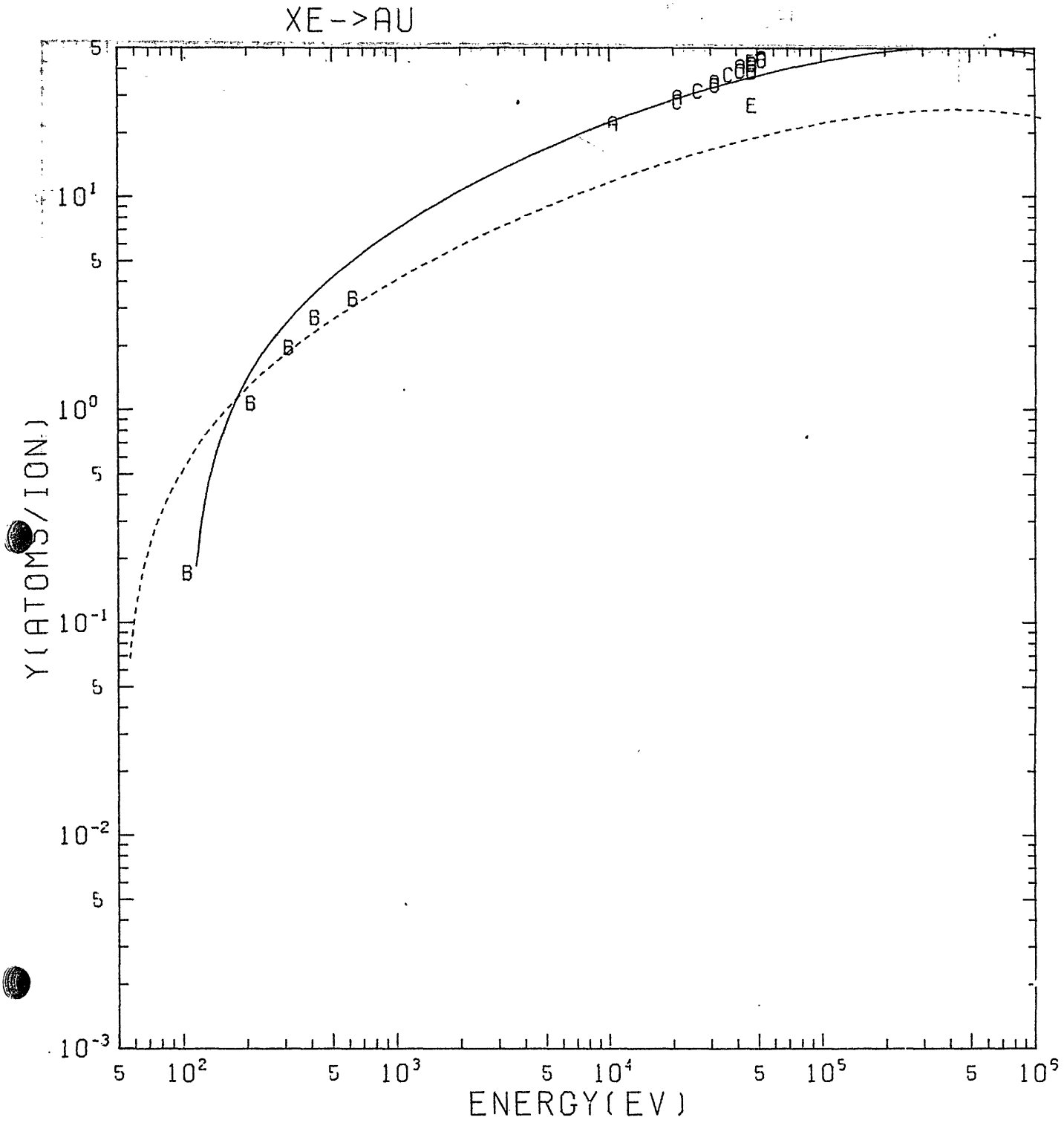
A ALMEN,BRUCE (1961A)
B LAEGREID,WEHNER (1961)
C WEHNER,STUART,ROSENBERG (1961)
D PATTERSON,TOMLIN (1962)
E COLOMBIE (1964)
F WEIJSENFELD (1966)
G NENADOVIC,POTIRIC (1972)
H ANDERSEN,BAY (1975)
I WITTMAACK (1975)
J EERNISSE (1976)
K COLLIGON,PATEL (1977)

Fig. 194



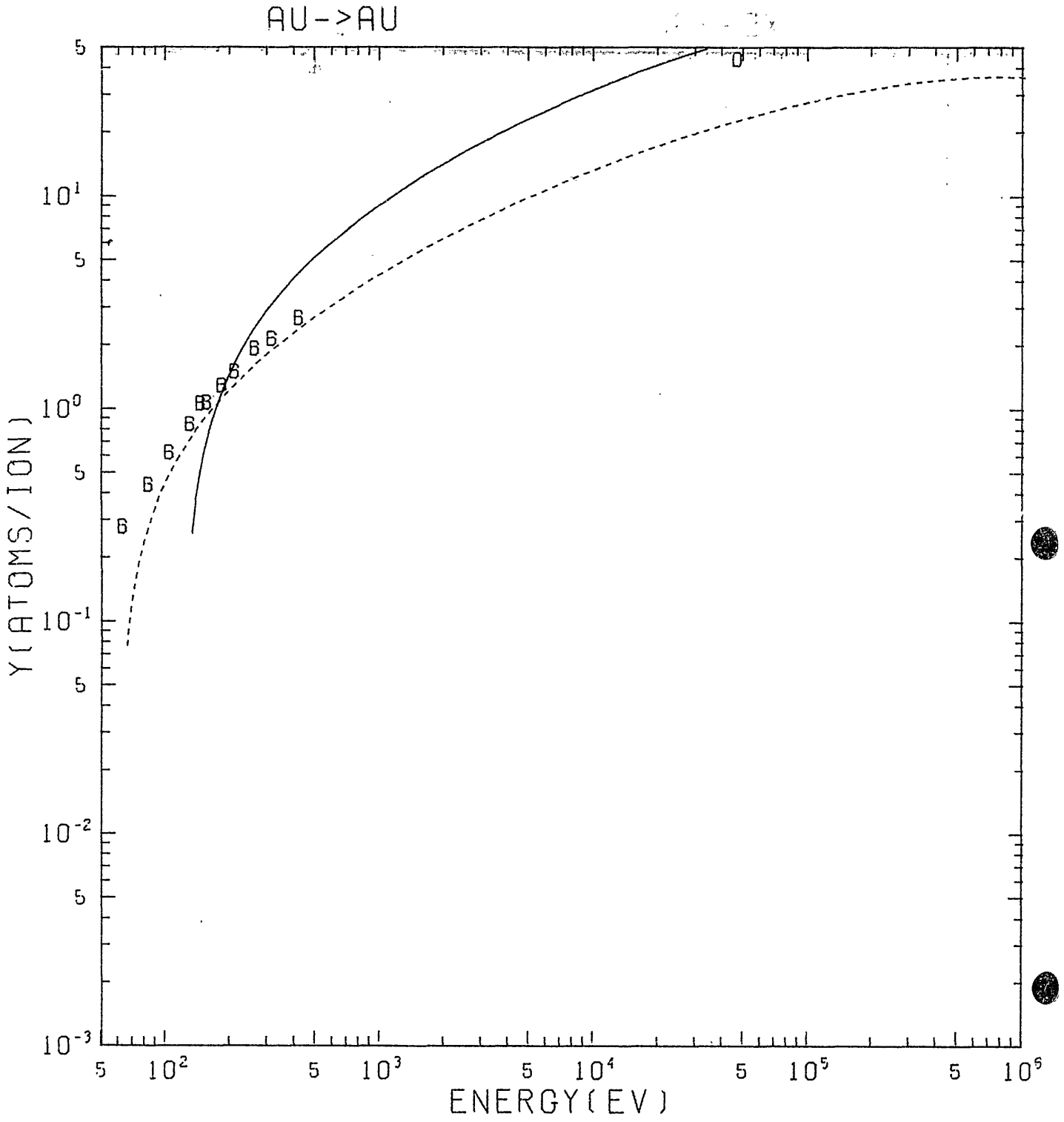
KR->AU
A ALMEN,BRUCE (1961A)
B ROSENBERG,WEHNER (1962)
C ANDERSEN,BAY (1975)
D EERNISSE (1976)

Fig. 195



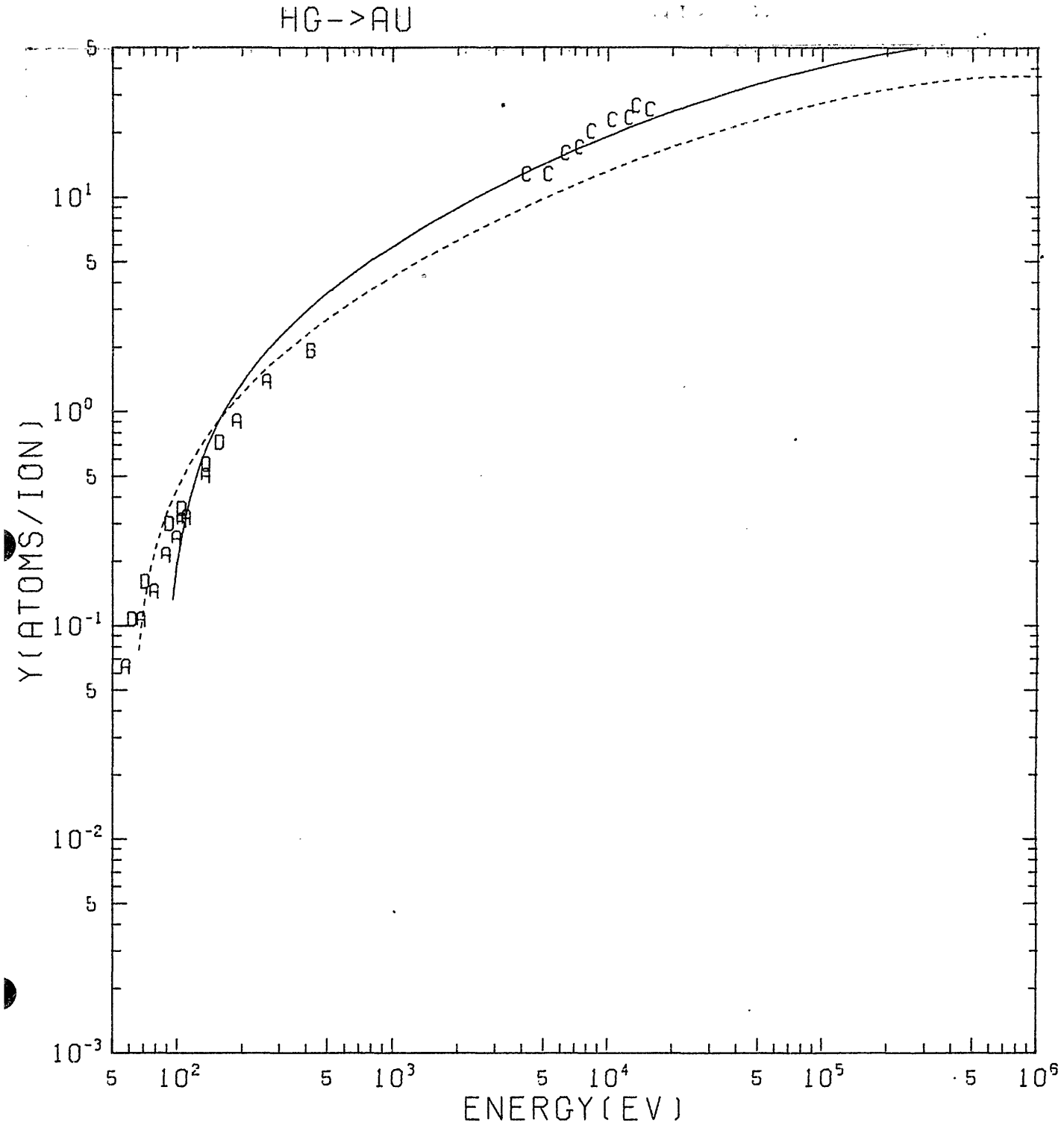
XE->AU
A ALMEN.BRUCE (1961A)
B ROSENBERG.WEHNER (1962)
C NENADOVIC.JURELA (1969)
D ANDERSEN.BAY (1975)
E EERNISSE (1976)

Fig. 196



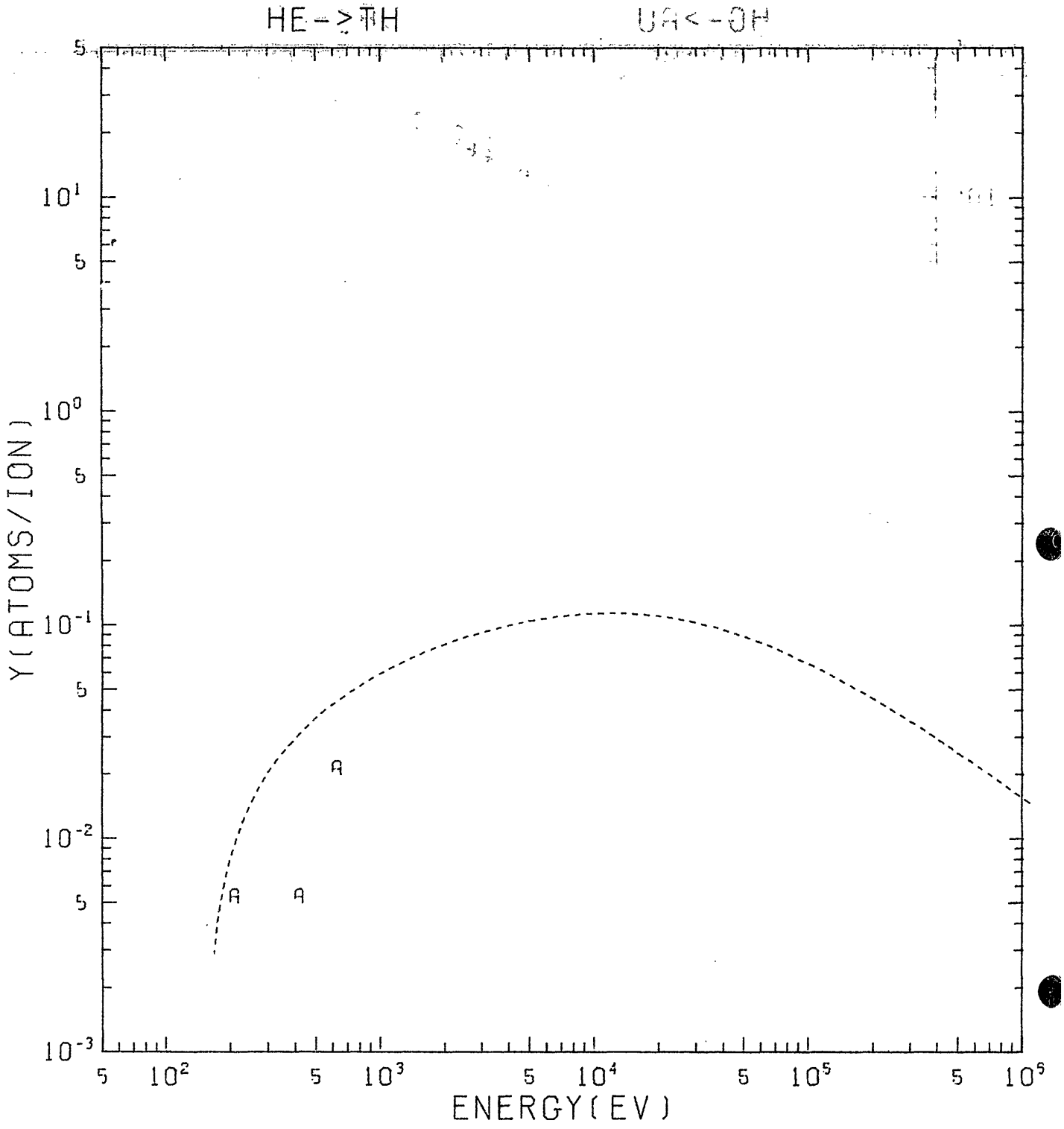
AU->AU
A ALMEN.BRUCE (1961B)
B HAYWARD.WOLTER (1969)
C BAY.ANDERSEN.HOFER (1976)
D EERNISSE (1976)

Fig. 197



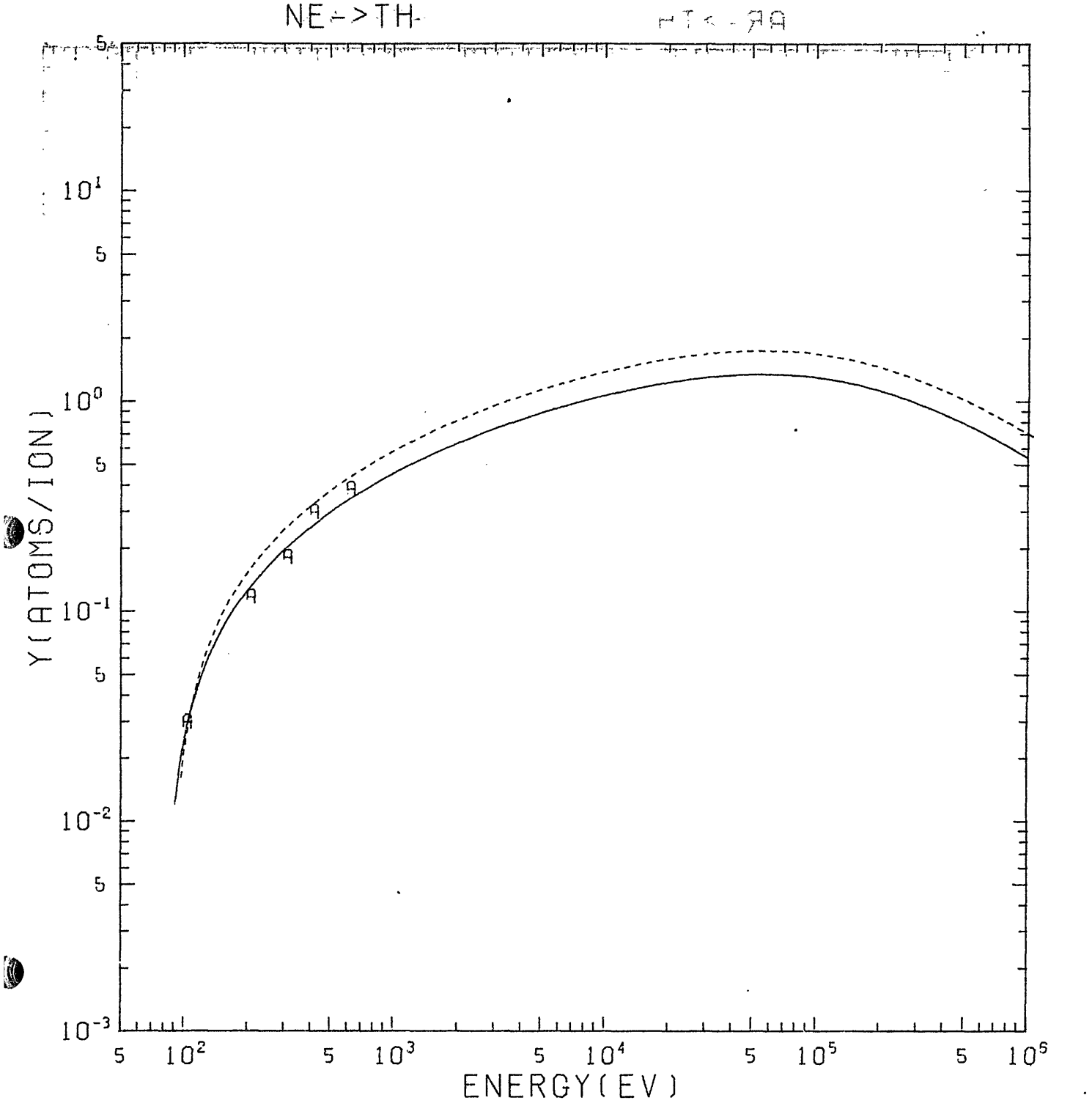
HG-->AU
A WEHNER (1957)
B LAEGREID,WEHNER (1961)
C WEHNER,ROSENBERG (1961)
D ASKEROV,SENA (1969)

Fig. 198



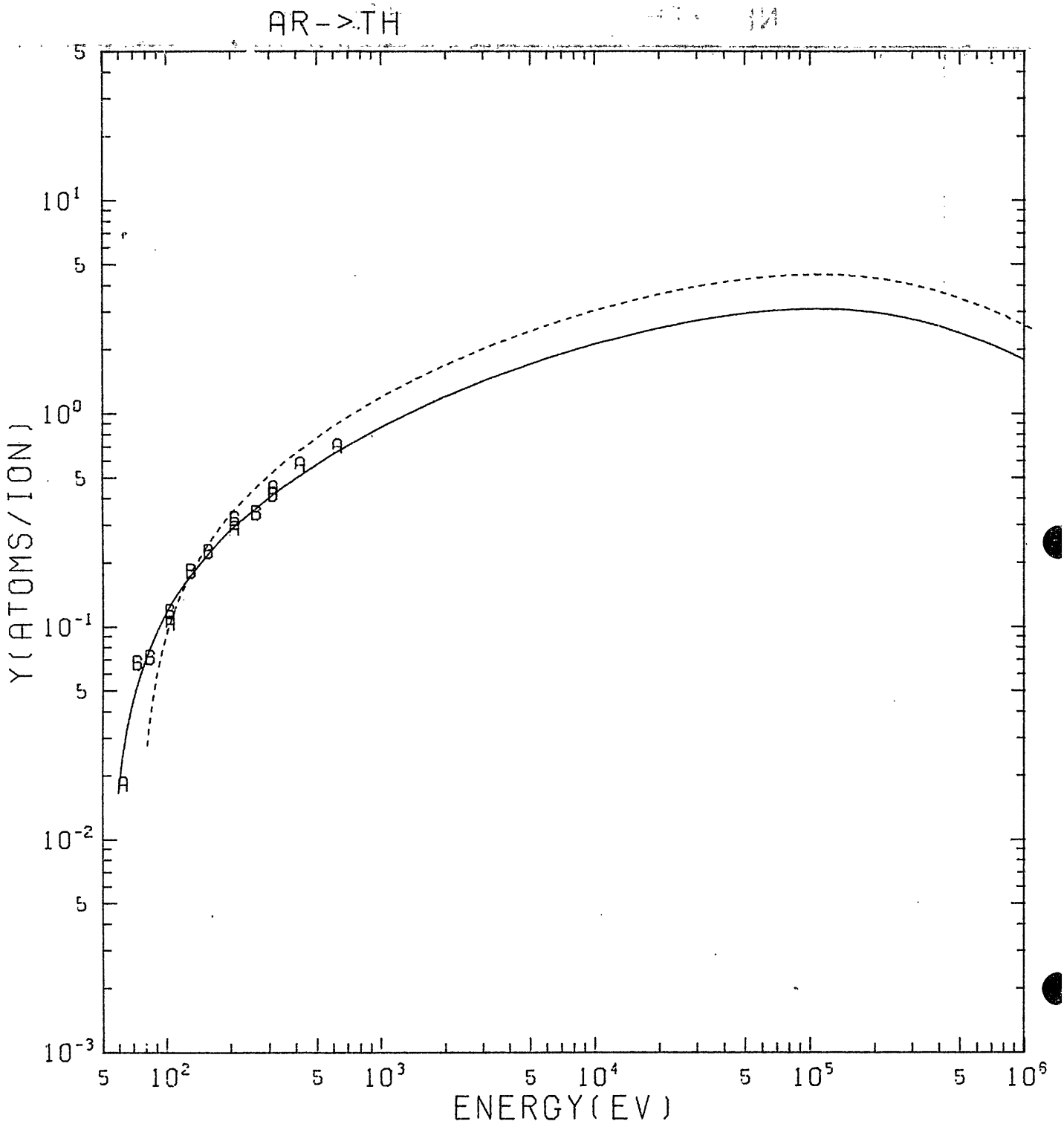
HE->TH
A ROSENBERG,WEHNER (1962)

Fig. 199



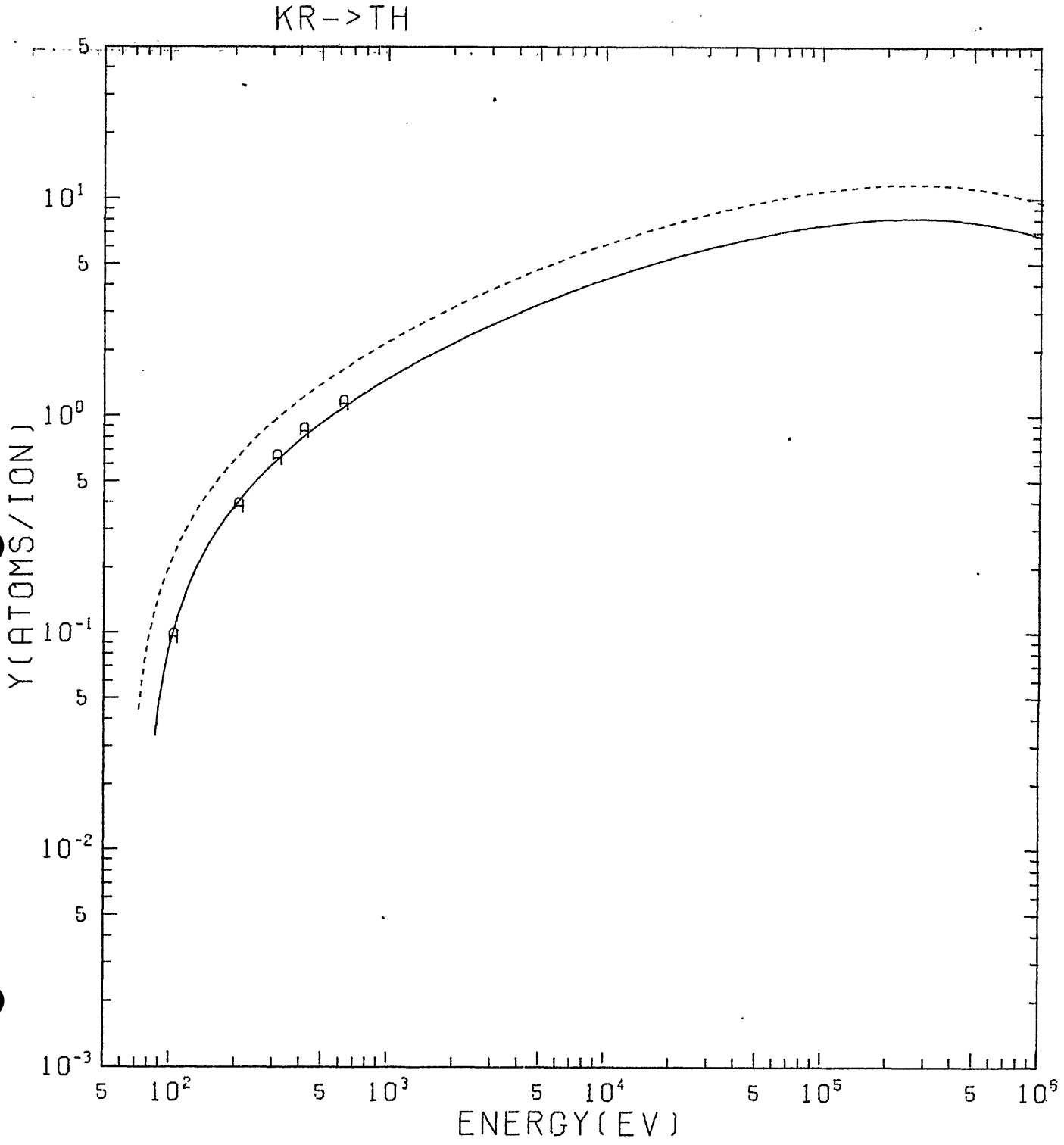
NE->TH
A LAEGREID,WEHNER (1961)

Fig. 200



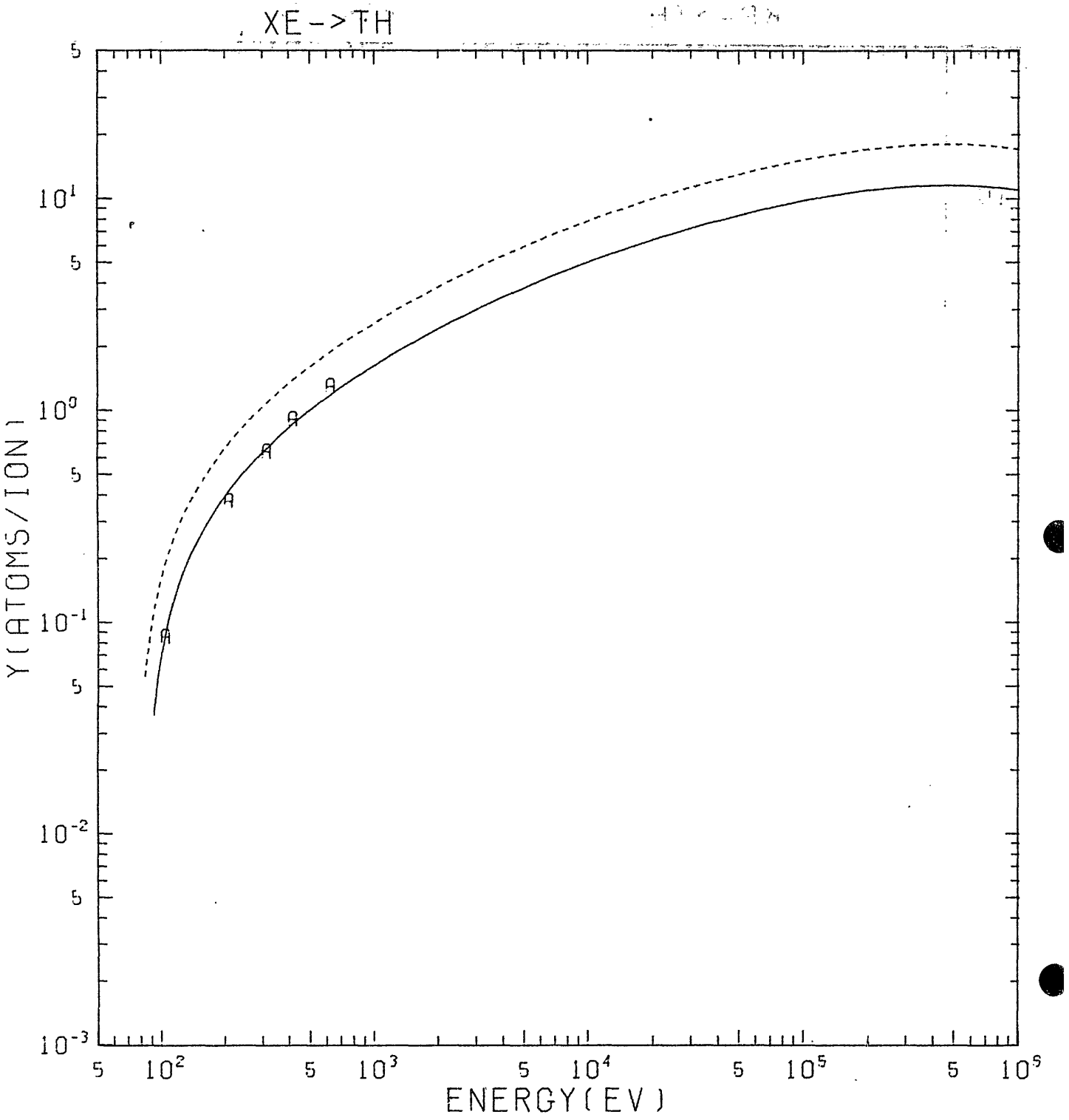
AR->TH
A LAEGREID,WEHNER (1961)
B STUART,WEHNER (1962)

Fig. 201



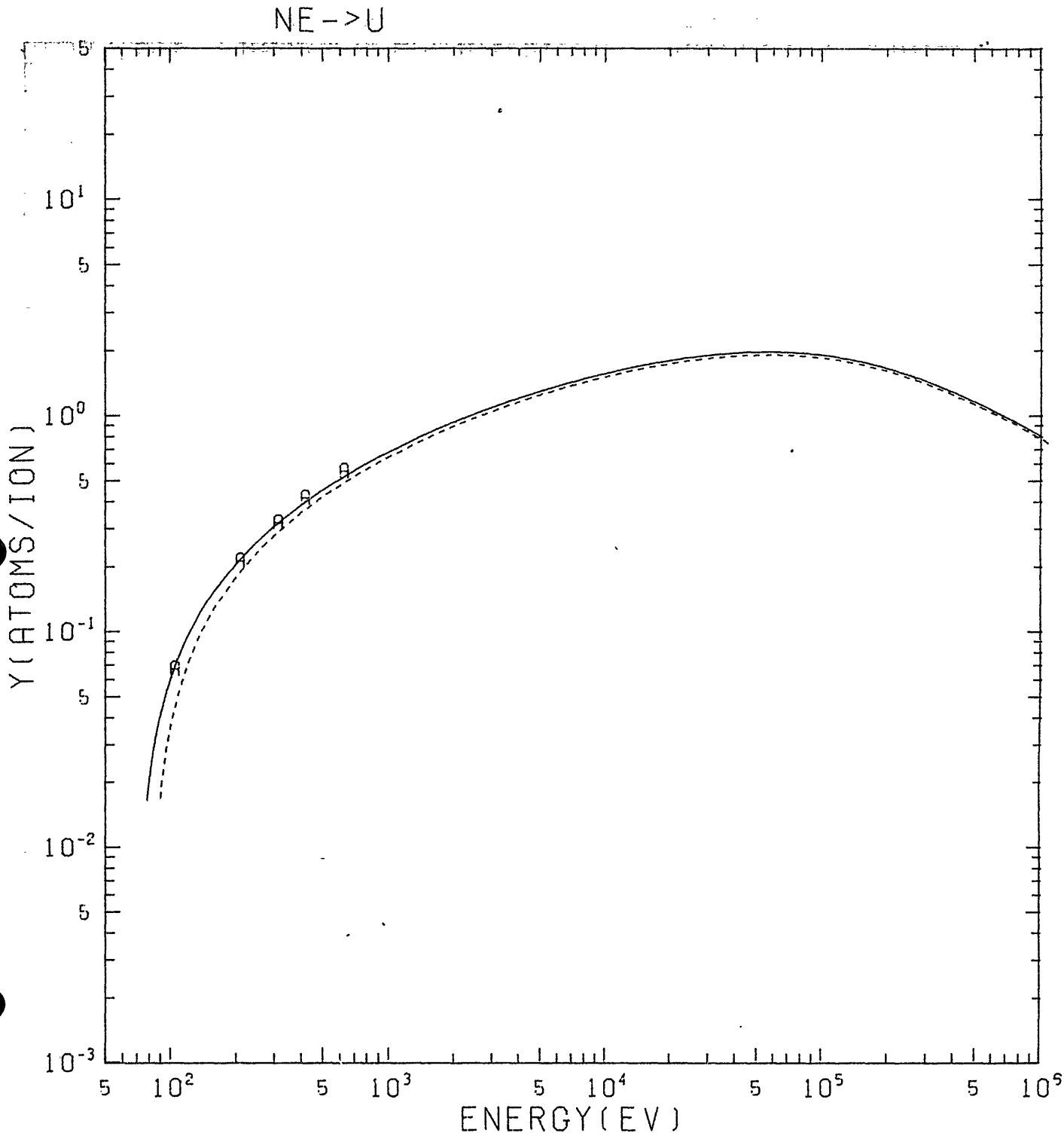
KR->TH
A ROSENBERG,WEHNER (1962)

Fig. 202



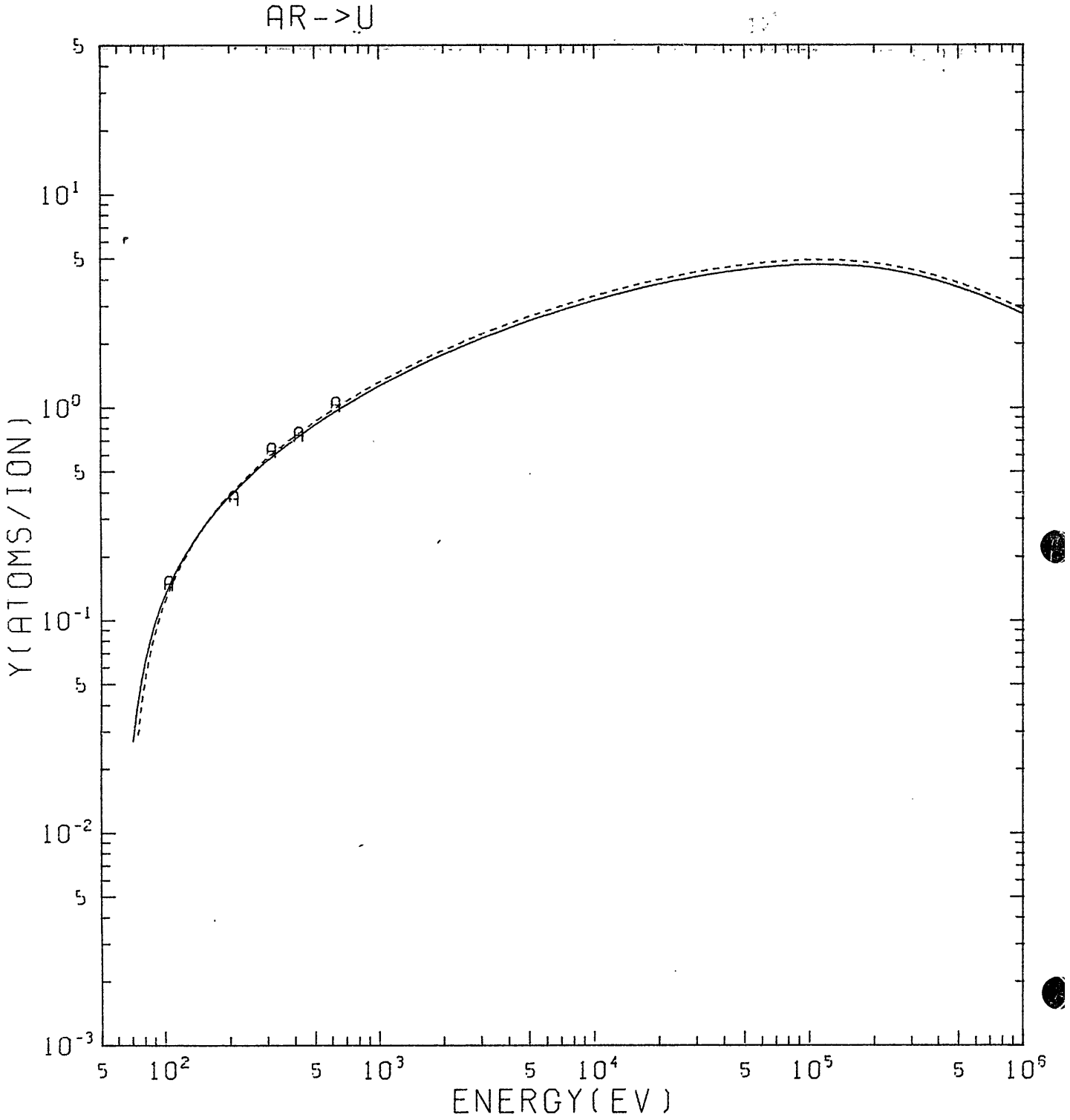
XE->TH
A ROSENBERG,WEHNER (1962)

Fig. 203



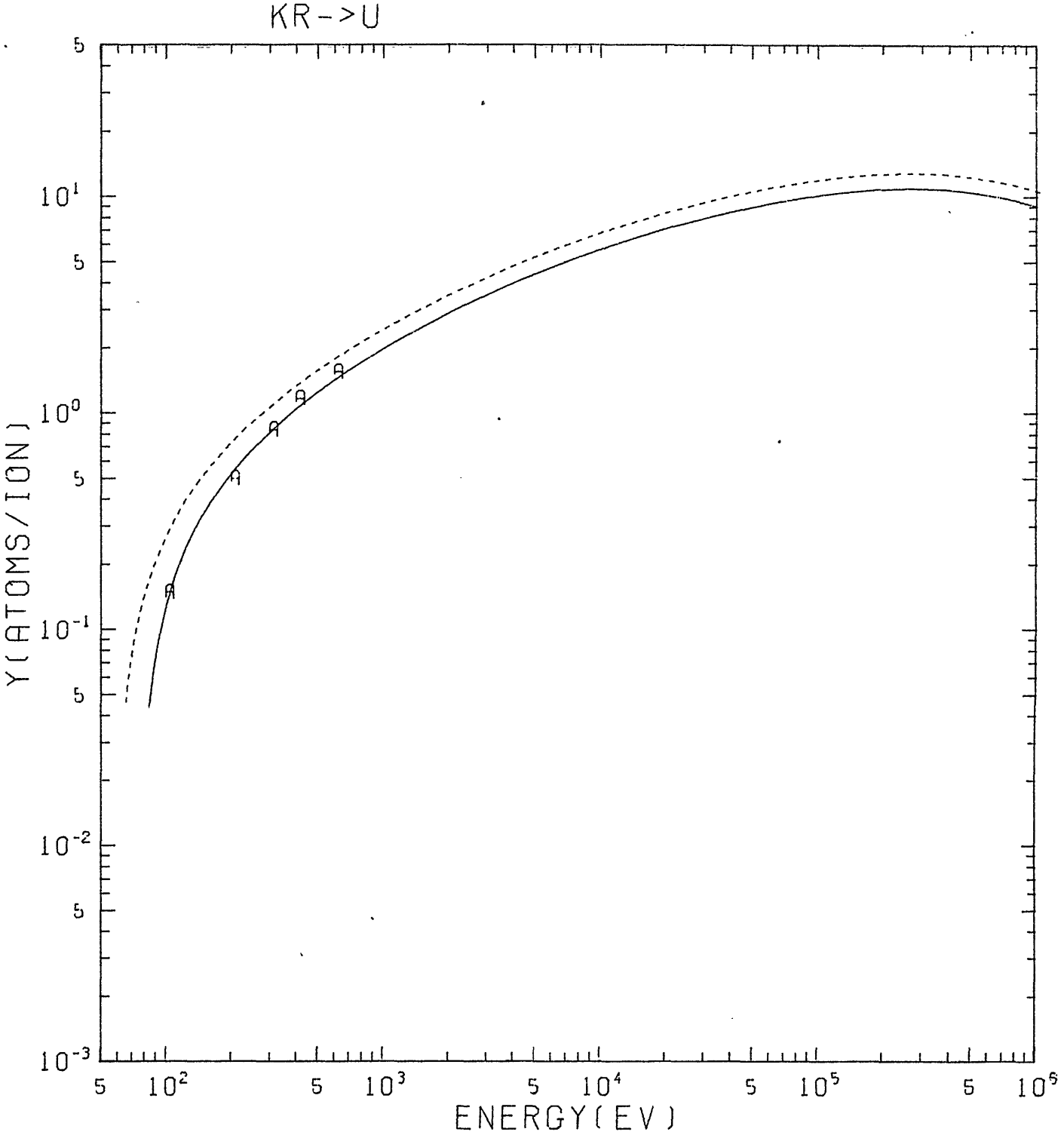
NE->U
A LAEGREID,WEHNER (1961)

Fig. 204



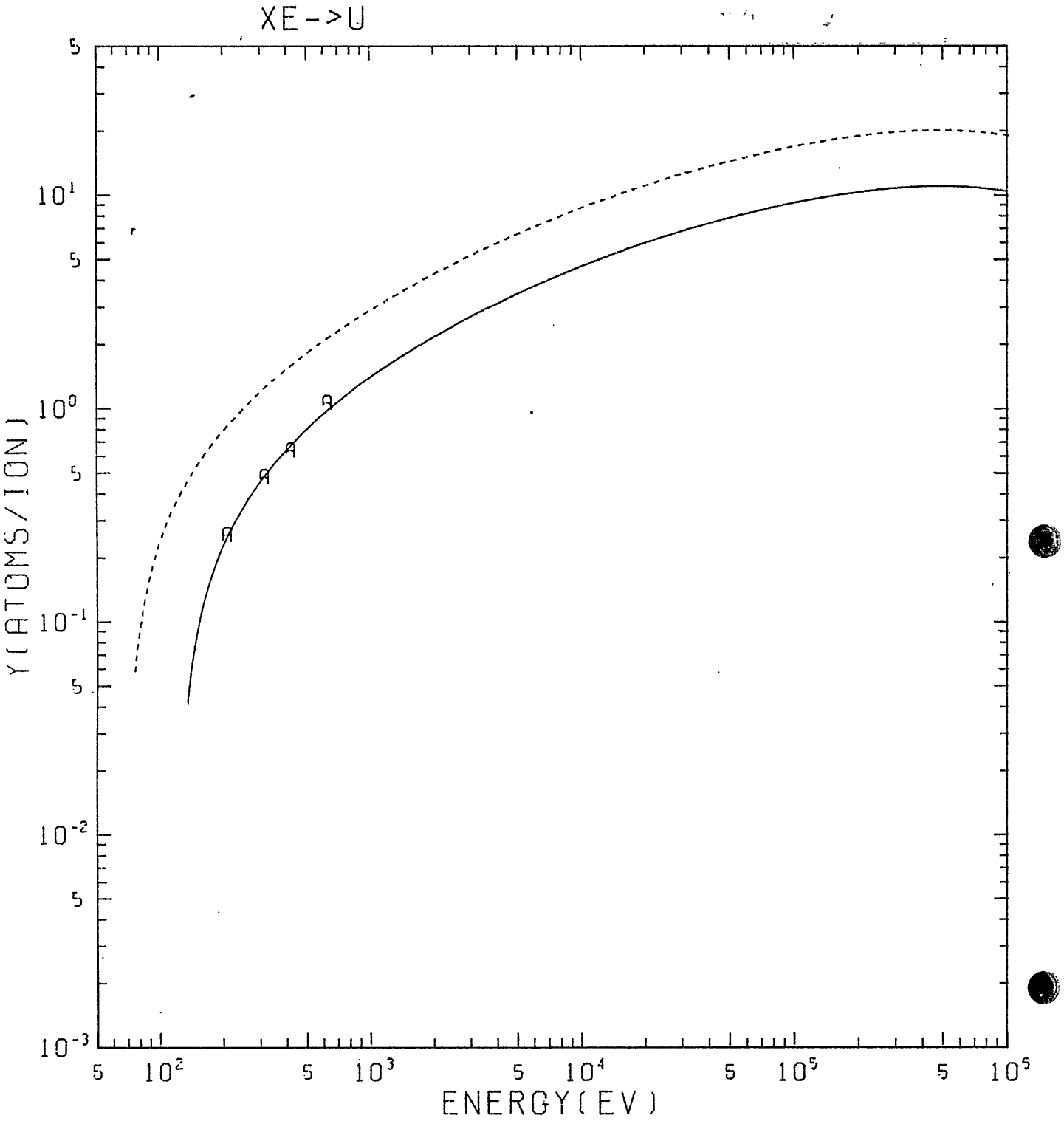
AR->U
A LAEGREID,WEHNER (1961)

Fig. 205



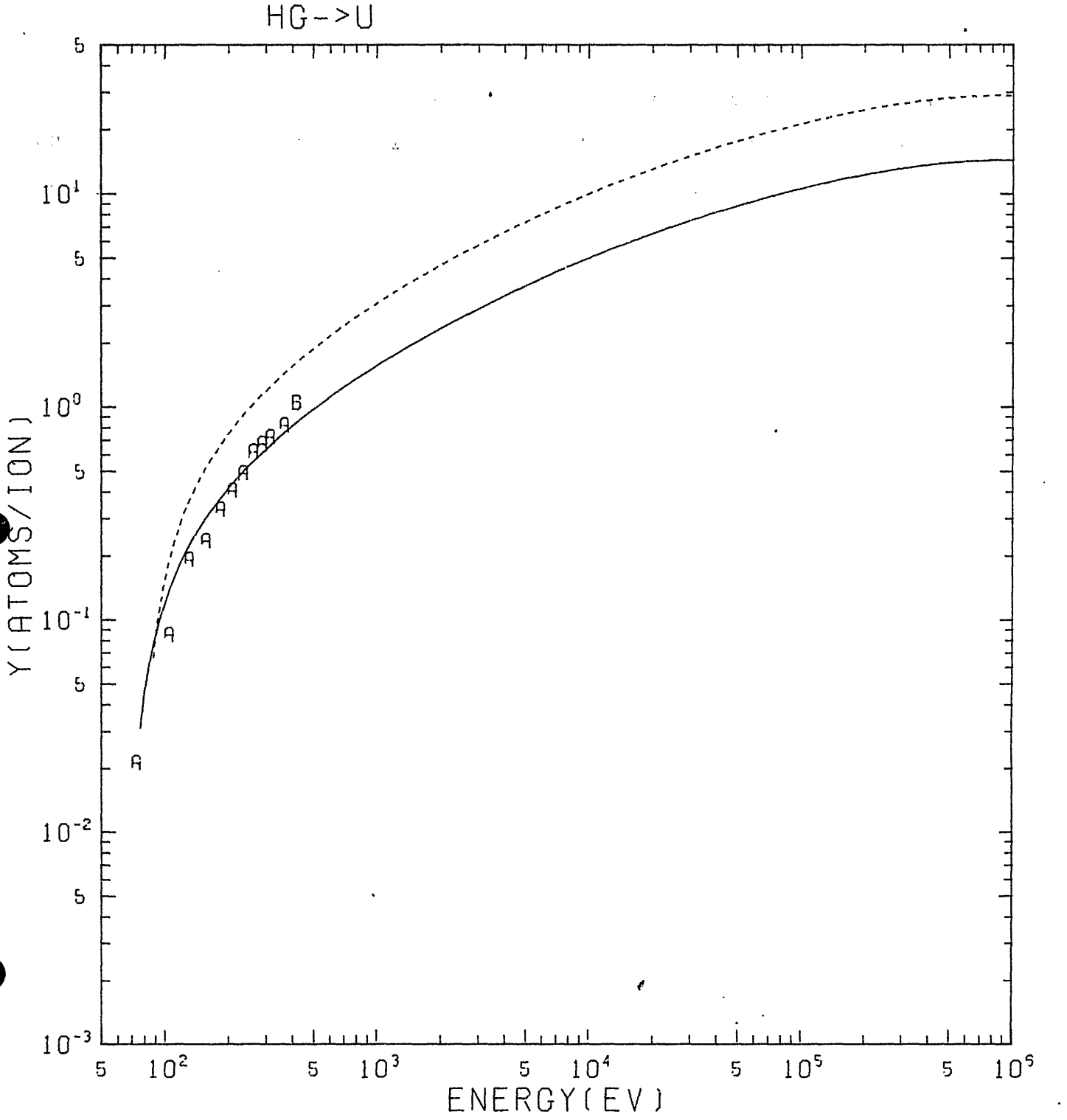
KR->U
A ROSENBERG,WEHNER (1962)

Fig. 206



XE->U
A ROSENBERG,WEHNER (1962)

Fig. 207



HG->U
A WEHNER (1957)
B LAEGREID.WEHNER (1961)

Fig. 208

Appendix A. Elastic Stopping Cross Section.

According to Lindhard, Scharff and Schiott, the elastic stopping cross sections in the reduced unit is a universal function of energy ε in the reduced unit:

$$\varepsilon \equiv C_e E = \frac{aE}{Z_1 Z_2 e^2} \frac{M_2}{M_1 + M_2} . \qquad \text{(A1)}$$

This function has been given only numerically. An analytical form,

$$s_n = \frac{3.441\sqrt{\varepsilon} \log (\varepsilon + 2.718)}{1 + 6.355\sqrt{\varepsilon} + \varepsilon (-1.708 + 6.882\sqrt{\varepsilon})} , \qquad \text{(A2)}$$

was used in the present paper. The comparison between the results calculated using the Lindhard-Scharff-Schiott equation and those using Eq (A2) is shown in Fig. A1.

Figure A1. Relation between the reduced stopping cross section S_n and the reduced energy ε calculated using the Lindhard-Scharff-Schiott equation (o) and using Eq A2 (solid line).

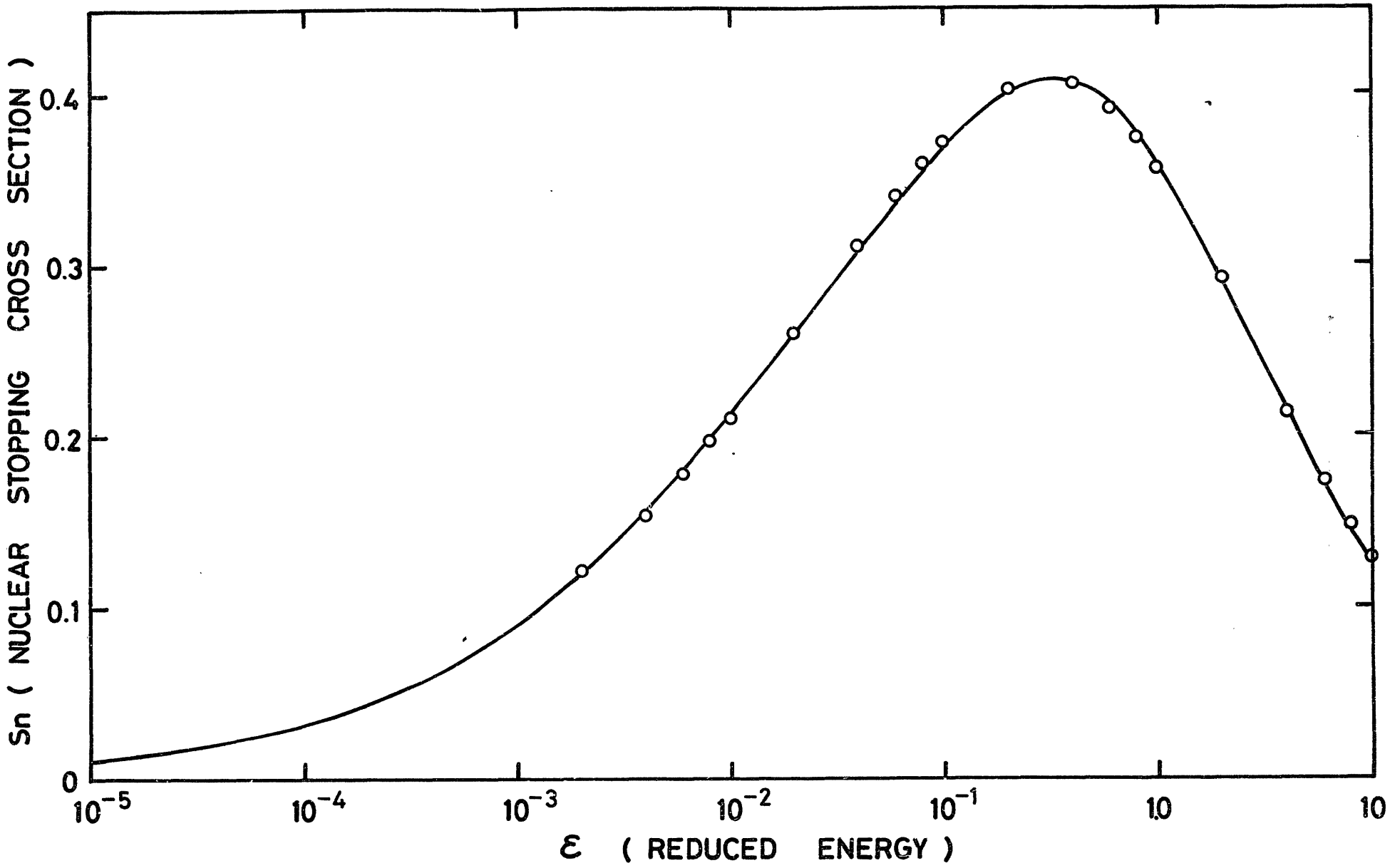

Sn (NUCLEAR STOPPING CROSS SECTION)
0.4
0.3
0.2
0.1
0
10^{-5}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
1.0
10
ε (REDUCED ENERGY)

Fig. A 1

Appendix B. Atomic Weights and Sublimation Energy.

Atomic weight and sublimation energy of target atoms is shown in Table B1.

Table B1

Atomic weight M and sublimation energy Us (eV)

		M	Us			M	Us			M	Us
1	H	1.008		35	Br	79.909		70	Yb	173.04	1.74
1	D	2.014		36	Kr	83.80		71	Lu	174.97	4.29
2	He	4.003		37	Rb	85.47	8.63	72	Hf	178.49	6.31
3	Li	6.939	1.67	38	Sr	87.62	1.70	73	Ta	180.95	8.10
4	Be	9.012	3.38	39	Y	88.905	4.24	74	W	183.85	8.68
5	B	10.811	5.73	40	Zr	91.22	6.33	75	Re	186.2	8.09
6	C	12.011	7.41	41	Nb	92.906	7.59	76	Os	190.2	8.13
7	N	14.007		42	Mo	95.94	6.83	77	Ir	192.2	6.90
8	O	15.999		43	Tc	98.00		78	Pt	195.09	5.86
9	F	18.998		44	Ru	101.07	6.69	79	Au	196.97	3.80
10	Ne	20.183		45	Rh	102.91	5.78	80	Hg	200.59	6.36
11	Na	22.990	1.12	46	Pd	106.40	3.91	81	Tl	204.37	1.88
12	Mg	24.312	1.54	47	Ag	107.87	2.97	82	Pb	207.19	2.03
13	Al	26.982	3.36	48	Cd	112.40	1.16	83	Bi	208.98	2.17
14	Si	28.086	4.70	49	In	114.82	2.49	84	Po	210.0	1.50
15	P	30.974	3.27	50	Sn	118.69	3.12	85	At	210.0	
16	S	32.064	2.88	51	Sb	121.75	2.72	86	Rn	222.0	
17	Cl	35.453		52	Te	127.60	2.02	87	Fr	223.0	
18	Ar	39.948		53	I	126.90		88	Ra	226.0	
19	K	39.102	0.932	54	Xe	131.30		89	Ac	227.0	
20	Ca	40.080	1.83	55	Cs	132.91	0.817	90	Th	232.4	5.93
21	Sc	44.956	3.49	56	Ba	137.34	1.84	91	Pa	231.0	
22	Ti	47.900	4.89	57	La	138.91	4.42	92	U	238.03	5.42
23	V	50.942	5.33	58	Ce	140.12	4.23	93	Np	237.0	
24	Cr	51.996	4.12	59	Pr	140.91	3.71	94	Pu	242.0	3.98
25	Mn	54.938	2.92	60	Nd	144.24	3.28	95	Am	243.0	
26	Fe	55.847	4.34	61	Pm	147.		96	Cm	247.0	
27	Co	58.933	4.43	62	Sm	150.35	2.16	97	Bk	247.0	
28	Ni	58.71	4.46	63	Eu	151.96	1.85	98	Cf	249.0	
29	Cu	63.546	3.52	64	Gd	157.25	3.57	99	Es	254.0	
30	Zn	65.37	1.35	65	Tb	158.92	3.89	100	Fm	253.0	
31	Ga	69.72	2.82	66	Dy	162.50	2.89				
32	Ge	72.59	3.88	67	Ho	164.93	3.05				
33	As	74.922	1.26	68	Er	167.26	3.05				
34	Se	78.96	2.14	69	Tm	168.93	2.52				

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