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CROSS SECTIONS FOR CHARGE TRANSFER OF HYDROGEN BEAMS IN GASES AND VAPORS IN THE ENERGY RANGE 10 EV-10 KEV

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Introduction

It has been recognized that the charge transfer processes of hydrogen beams play an important role in plasma physics, radiation physics and astrophysics. In plasma physics, especially in fusion reactor experiment, the injection of neutral hydrogen beam is one of the most promising methods for effective trapping of the beam into toroidal plasma which is shaped with strong magnetic fields. These neutral beams are generally produced through the electron capture to proton beams. Similarily, the production of intense negative hydrogen ion beam is important because the injection of the negative ion beam is thought to be an alternative and effective method. Also the neutral particles escaping from the plasma contain some useful informations on the plasma and can be used for diagnosing characteristics of the plasma. For these purposes, data are prerequisite on the charge transfer of hydrogen beams especially at energies lower than a few keV. There are some reviews[1-6] on these charge transfer processes but their energy is generally limited down to a few keV from some tens MeV. Meanwhile, there are a number of measurements of the cross sections for the charge transfer at lower energies but there are no systematic compilation of data at lower energies.

In this paper, we compile in graphical forms experimental data on the (up to June, 1976) charge transfer of hydrogen ion (proton, H^+), hydrogen atom (H°) and negative hydrogen ions (H^-) in various gases and vapors in the incident energy between 10 and 10,000 eV.

Some detail on the charge transfer processes has already been given in some references.[1,6] Here only a short description is given. In hydrogen beams, the following charge transfer processes take place (B is target atom, B^+ and B^{2+} are slow target ions and e is slow electron):

1. H^+ impact

$H^+ + B \to H^+ + B^+ + e$	$(\sigma_{11} \equiv \sigma_1^i)$	:	pure ionization
$\to H^\circ + B^+$	(σ_{10})	:	one-electron capture
$\to H^- + B^{2+}$	(σ_{1-1})	:	two-electron capture

2. H° impact

$H^\circ + B \to H^\circ + B^+ + e$	$(\sigma_{00} \equiv \sigma_0^i)$	:	pure ionization
$\to H^+ + B + e$	(σ_{01})	:	one-electron stripping
$\to H^- + B^+$	(σ_{0-1})	:	one-electron capture

3. H^- impact

$H^- + B \to H^- + B^+ + e$	$(\sigma_{-1-1} \equiv \sigma_{-1}^i)$	:	pure ionization
$\to H^\circ + B + e$	(σ_{-10})	:	one-electron stripping
$\to H^+ + B + 2e$	(σ_{-11})	:	two-electron stripping.

Here σ_{ij} denotes the cross section for the charge transfer process from the initial charge state i to the final charge state j. σ_k^i means the ionization cross section for the incident ions with the charge state k. To determine the cross section for the charge transfer process, the following three methods are negerally used: the attenuation, the growth and the condenser methods. In the first two methods, only the fast beams are observed, neglecting the charge state of secondary slow ions and electrons, meanwhile in the third method, the secondary slow ions and electrons are measured, neglecting the charge state of the incident projectiles after collision. Some times the equilibrium and retardation methods are also used.[6]

In Table 1 are summarized the cross sections which can be determined from various experimental methods for various incident ion beams. In some methods, for example in the attenuation and the condenser methods, the measured cross sections are not always those for a single process but those for the sum of two or more processes. However, in many collision processes, the cross sections for two electron transfer processes are small, compared with those for single electron transfer processes. In Fig.1 are shown the cross sections for charge transfer of hydrogen beams in H_2 gas over a wide range of the energy to give an idea of the sizes of the cross sections for various processes. In Tables 2-7 are given lists of experiments for various charge transfer processes which include the names of authors, energy range, target and measuring method. In a series of the figures are shown the cross sections for various charge transfer processes. The cross section is given in the unit of cm^2 per collision. The following are important when these data are used:

1. In some measurements using the condenser method, only slow electron or ion production cross sections (σ_-, σ_+) are determined. However, these cross sections are, in many cases, the sum of the ionization cross sections (σ^i) and the charge transfer cross sections. It is possible to estimate the cross section for the charge transfer processes from this measurement only in such processes that the ionization cross section is small, like in He target. In some collisions such as H^o + Xe, the slow electron and ion production cross sections are nearly equal (1-25 keV). Therefore, it is not possible to determine the charge transfer

cross section without measuring both slow electrons and ions. For such data, σ_- or σ_+ is shown to distinguish that from the pure charge transfer cross section. In such cases, σ_- or $_+$ should be taken as an upper limit of the charge transfer cross section σ_{01} or σ_{10}.

2. In most measurements, no detailed descriptions are given of the effect of scattering processes which becomes significantly important at energies lower than a few hundred eV. Due to the scattering loss of the incident beams or of beam charge-transferred in the collision the observed cross sections might be too high or too low, depending on the measuring geometry, as seen in the scattering of data at lower energies. In appendix, some descriptions on the scattering are given.

3. Some meaurements have shown that there is some finite difference (5 %) in the charge transfer cross sections between H and D beams at energies less than 200 eV. This is thought to be due to the difference in scattering cross sections. However, more systematic measurements should be done before finite conclusions on the difference are drawn from the observations.

4. To avoid complication, no error bars are shown in the figures. Usually most experimental data have uncertainty of 10 - 30 %, depending on experimental situations, though some have much larger errors.

Appendix - Scattering in Charge Transfer

Generally the most charge transfer processes take place in collisions with large impact parameters. Therefore, the scattering of the incident ions and of the charge-transferred ions is rather small. Experiments on such scatterings in the charge transfer processes are very limited.[1-7] From these limited experimental observations, some general trends on the scattering processes are deduced:

1. The scattering of ions in electron loss processes is comparatively large, meanwhile that in electron capture processes is relatively small.

2. The differential scattering cross sections for charge transfer processes decrease monotonically and rapidly with increasing the scattering angle. Therefore no structures in the angular distributions are usually observed, though there are some oscillations due to molecular curve crossings in some collisions like H^+ + Kr.

3. At a fixed energy, the width of the angular distribution does not vary significantly with target gases. Only the slight increase of the width is observed for heavy target atoms.

4. The width of the angular distribution decreases with increasing the incident energy, namely proportional to 1/E.

For H° impact, the product of the scattering angle θ and the incident beam energy E is nearly independent of the beam energy. For the half-cone-angle θ_{50} and θ_{75}, into which 50 % and 75 %, respectively, of the total stripped protons are scattered, for example, the following relations are observed:

$$E \cdot \theta_{50} \simeq 1 \text{ keV. deg.}$$

$$E \cdot \theta_{75} \simeq 4 \text{ keV. deg.}$$

Roughly speaking, these relations hold down to 100 eV. These are only approximate to give an impression to the scattering. Actually, the width of the scattering angles increases slightly at lower energies.

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Table 1

The cross sections obtainable from various experimental methods

experimental method	incident particle H^+	H^0	H^-
Growth	σ_{10} , σ_{1-1}	σ_{01} , σ_{0-1}	σ_{-10} , σ_{-11}
Attenuation	$\sigma_{10} + \sigma_{1-1}$	$\sigma_{01} + \sigma_{0-1}$	$\sigma_{-10} + \sigma_{-11}$
Condenser			
slow ion	$\sigma_1^i + \sigma_{10} + 2\cdot\sigma_{1-1}$	$\sigma_0^i + \sigma_{0-1}$	σ_{-1}^i
slow electron	σ_1^i	$\sigma_0^i + \sigma_{01}$	$\sigma_{-1}^i + \sigma_{-10} + 2\cdot\sigma_{-11}$
total charge	$\sigma_{10} + 2\cdot\sigma_{1-1}$	$\sigma_{01} - \sigma_{0-1}$	$\sigma_{-10} + 2\sigma_{-11}$

Table 2

A list of measurements of σ_{10}

authors	year	energy range	target	method	reference
Hasted	1951	10-800	Ar,Kr,Xe	C	34
Hasted	1952	100-1.000	Ar	C	35
Whittier	1954	4.000-70.000	H_2	A	79
Stedeford,Hasted	1955	100-40.000	H_2,He,Ne,Ar, Kr,Xe	C	73
Stier,Barnett	1956	3.000-200.000	H_2,He,N_2,O_2, Ne.Ar	G+E	74
Gilbody,Hasted	1957	10-40.000	N_2,CO,NH_3	C	30
Curran *et al.*	1959	2.400-60.000	H_2	C	17
Gustaffson, Lindholm	1960	25-900	H_2,N_2,CO	MS	33
Cramer,Marcus	1960	4-400	$D_2(D^+)$	C	15
Cramer	1961	50-400	H_2	C	16
Stebbings *et al.*	1964	40-10.000	O_2,O	C	72
Gordeev,Panov	1964	1.000-40.000	H_2,N_2,Ar	C	31
Höllricher	1965	1.500-30.000	H_2,D_2	C	37
McClure	1966	2.000-117.000	H_2,H	G	47
Williams	1966	2.000-50.000	H_2,He,Ne,Ar, Kr,Xe	G	80
Koopman	1967	70-1050	H_2,Ar,Kr,Xe	C	39
Cable	1967	180-460	H_2O	C	11
Futch,Moses	1967	4.000-50.000	Mg	G	29
Koopman	1968	40-1.500	N_2,O_2,CO_2,H_2O	C	40
Koopman	1968	100-1.500	CH_4,NH_3	C	41
McNeal,Clark	1969	1.000-25.000	N_2	C(σ_{-1}, σ_+)	49
Becker,Scharman	1969	1.500-30.000	He-3,He-4	C	7
Schlachter *et al.*	1969	500-20.000	Cs	G	67

Berkner et al.	1969	5.000-70.000	Mg	G	8
Dagnac et al.	1970	2.000-60.000	H_2O	G+E	19
Coplan, Ogilvie	1970	30-500	H_2O, CO_2, NH_3	DC	13
Berkner et al.	1970	300-70.000	$CO, CH_4, H_2O, C_8F_{16}$	C	9
Gruebler et al.	1970	1.000-20.000	Li, Na, K, Cs	G	32
Spiess et al.	1970	2.500	Cs	G	70
McNeal	1970	1.000-25.000	CO, CO_2, NH_3, CH_4	C(σ_-, σ_+)	51
Spiess et al.	1972	500-3.000	Cs	G	71
Inoue	1972	150-8.000	K	G	38
Maier	1972	0.5-100	Kr, Xe	MS	44
Baragiola, Salvatelli	1973	7.500-40.000	Pb	G	4
Monnom et al.	1975	100-2.500	N_2, Ne, Ar	G	52

Notes: A: Attenuation method, C: Condenser method, G: Growth method, E: Equilibrium method, MS: Mass-separation method, DC: Differential cross section measurement, R: Retardation method.

σ_-: Cross section of electron production, σ_+: Cross section of slow ion production.

The energy is given in the unit of eV.

Table 3

A list of measurements of σ_{1-1}

authors	year	energy range	Target	method	reference
Fogel *et al.*	1956	9.500-29.000	H_2,He,N_2,O_2, Ne,Ar	G	25
Fogel *et al.*	1959	5.000-50.000	H_2,He,Ne,Ar, Kr,Xe	G	28
Afrosimov *et al.*	1960	5.000-180.000	Ar	G	2
Kozlov *et al.*	1963	500-5.000	H_2,Ar,Kr	R	42
McClure	1963	6.000-50.000	H_2	G	45
Williams	1966	2.000-50.000	H_2,He,Ne,Ar, Kr,Xe	G	81
Futch-Moses	1967	4.000-50.000	Mg	G	29
Schlachter *et al.*	1969	500-20.000	Cs	G	67
Gruebler *et al.*	1970	1.000-20.000	Li,Na,K,Cs	G	32
Spiess *et al.*	1970	2.500	Cs	G	70
Baragiola, Salvatelli	1973	7.500-40.000	Pb	G	4

Table 4

A list of measurements of σ_{01}

anthors	year	energy range	target	method	reference
Stier, Barnett	1956	3.000-200.000	H_2, He, N_2, O_2, Ne, Ar	G+E	74
Fogel *et al*.	1958	5.000-40.000	H_2, He, N_2, O_2, Ne, Ar, Kr, Xe	G	27
Curran, Donahue	1960	4.000-35.000	H_2	C+A	18
Donahue, Hushfar	1961	8.000-40.000	Ar, CO	C+A	22
Pilipenko, Fogel	1962	5.000-20.000	H_2, N_2, O_2, CO	G	58
Pilipenko, Fogel	1963	5.000-30.000	NO	G	59
Williams	1967	2.000-50.000	H_2, He, Ne, Ar, Kr, Xe	G	82
Futch, Moses	1967	4.000-50.000	Mg	G	29
McClure	1968	1.250-117.000	H_2	G	48
Schlachter *et al*.	1969	500-20.000	Cs	G	67
Berkner *et al*.	1969	5.000-70.000	Mg	G	8
Fleishmann, Young	1969	50-1.000	H_2, He, Ne, Ar	C(σ_-)	23
Fleishmann, Young	1969	50-800	N_2, O_2	C(σ_-)	22
McNeal, Clark	1969	1.000-25.000	N_2	C(σ_-, σ_+)	49
McNeal *et al*.	1970	1.000-25.000	H_2, He, O_2, Ne, Ar, Kr, Xe	C(σ_-, σ_+)	50
McNeal	1970	1.000-25.000	CO, Co_2, CH_4, NH_3	C(σ_-, σ_+)	51
Dagnac *et al*.	1970	2.000-60.000	H_2O	G+E	19
Barnett, Ray	1972	300-10.000	H_2, N_2	G	6
Baragiola, Salvatelli	1973	7.500-40.000	Pb	G	4
Dehmel *et al*.	1973	80-2.000	Ar, Kr, Xe, CO, CO_2, CH_4	C(σ_-)	20
Pradel *et al*.	1974	500-3.000	HI	G	61
Monnom *et al*.	1975	100-2.500	N_2, Ne, Ar	G+E	
Noda	1976	200-5.000	H_2, N_2	G	55

Table 5

A list of measurements of σ_{0-1}

authors	years	energy range	targets	method	reference
Stier, Barnett	1956	3.000-200.000	H_2, He, N_2, O_2, Ne, Ar	G+E	74
Curran, Donahue	1960	4.000-35.000	H_2	C	18
Donahue, Hushfar	1961	8.000-40.000	Ar, CO	C	22
Pilipenko, Fogel	1962	5.000-50.000	H_2, N_2, O_2, CO	G	58
Pilipenko, Fogel	1965	5.000-35.000	NO	G	59
McClure	1964	6.000-120.000	H_2	G	46
Williams	1967	2.000-50.000	H_2, He, Ne, Ar, Kr, Xe	G	82
Schlachter _et al._	1969	500-20.000	Cs	G	67
Berkner _et al._	1969	5.000-70.000	Mg	G	8
Spiess _et al._	1970	2.500	Cs	G	70
Baragiola, Salvatelli	1973	7.500-40.000	Pb	G	4
Pradel _et al._	1974	500-3.000	HI	G	61

Table 6

A list of measurements of σ_{-10}

authors	year	energy range	target	method	reference
Hasted	1952	100-2.500	He,Ne,Ar,Kr, Xe	C	35
Whittier	1954	4.000-70.000	H_2	A	79
Stedeford-Hasted	1955	100-40.000	He,Ne,Ar,Kr, Xe	C	73
Hasted,Smith	1956	10-2.700	H_2	C	36
Stier,Barnett	1956	4.000-300.000	H_2,He,N_2,O_2, Ne,Ar	G	74
Muschlitz <u>et</u> <u>al</u>.	1956	4-400	H_2	C	53
Muschlitz <u>et</u> <u>al</u>.	1957	4-400	H_2	C	54
Bailey <u>et</u> <u>al</u>.	1957	5-350	He,Ne,Ar	C	3
Pilipenko	1966	3.000-30.000	O_2,NO,CO	C	60
Bydin	1966	200-7.000	He,Ne,Ar,Kr,Xe	C	10
Williams	1967	2.000-50.000	H_2,He,Ne,Ar,Kr, Xe	G	83
Berkner <u>et</u> <u>al</u>.	1969	5.000-70.000	Mg	G	8
Spiess <u>et</u> <u>al</u>.	1970	2.500	Cs	G	70
Bailey <u>et</u> <u>al</u>.	1970	10-350	O_2	C	5
Leslie <u>et</u> <u>al</u>.	1971	2.000-30.000	Cs	G	43
Simpson,Gilbody	1972	4.000-30.000	H_2,He,Ar	A	68
Risley,Geballe	1974	200-10.000	H_2,He,N_2,O_2,Ar	A	63
Risley	1974	200-10.000	H_2,He,N_2,O_2,Ar	A	64
Champion <u>et</u> <u>al</u>.	1976	2-100	He,N_2,Ne,Ar	C	12

Table 7

A list of measurements of σ_{-11} :

authors	year	energy range	target	method	reference
Fogel *et al.*	1957	5.000-40.000	H_2,He,N_2,O_2, Ne,Ar,Kr,Xe	G	26
Tisone *et al.*	1965	500-4.000	H_2	G	75,76
Williams	1967	2.000-50.000	H_2,He,Ne,Ar	G	83
Leslie *et al.*	1971	2.000-30.000	Cs	G	43

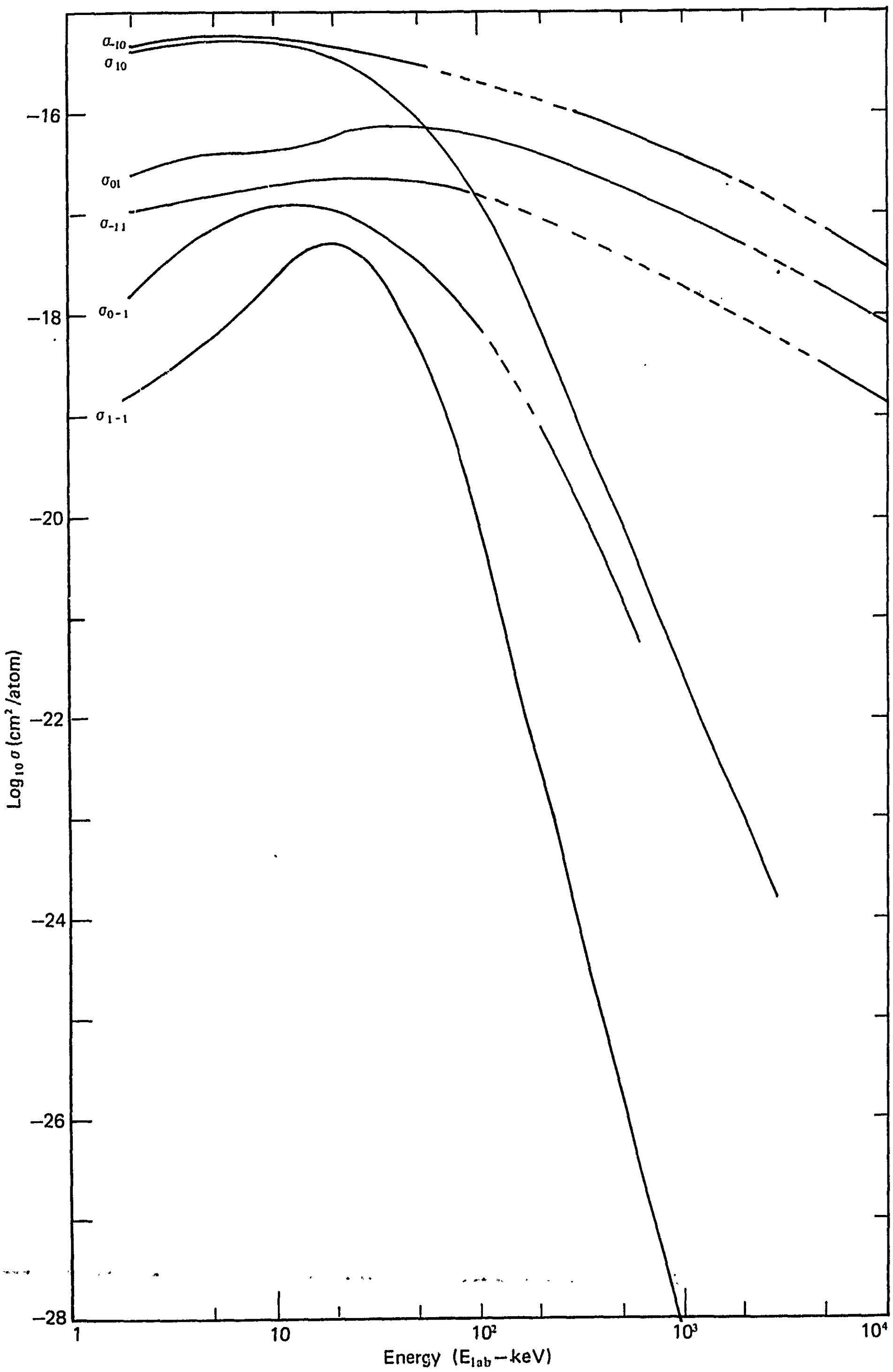

Fig. 1 Charge transfer cross sections of hydrogen beams in H_2 in a wide range of the energy showing the sizes of the cross sections for various processes.

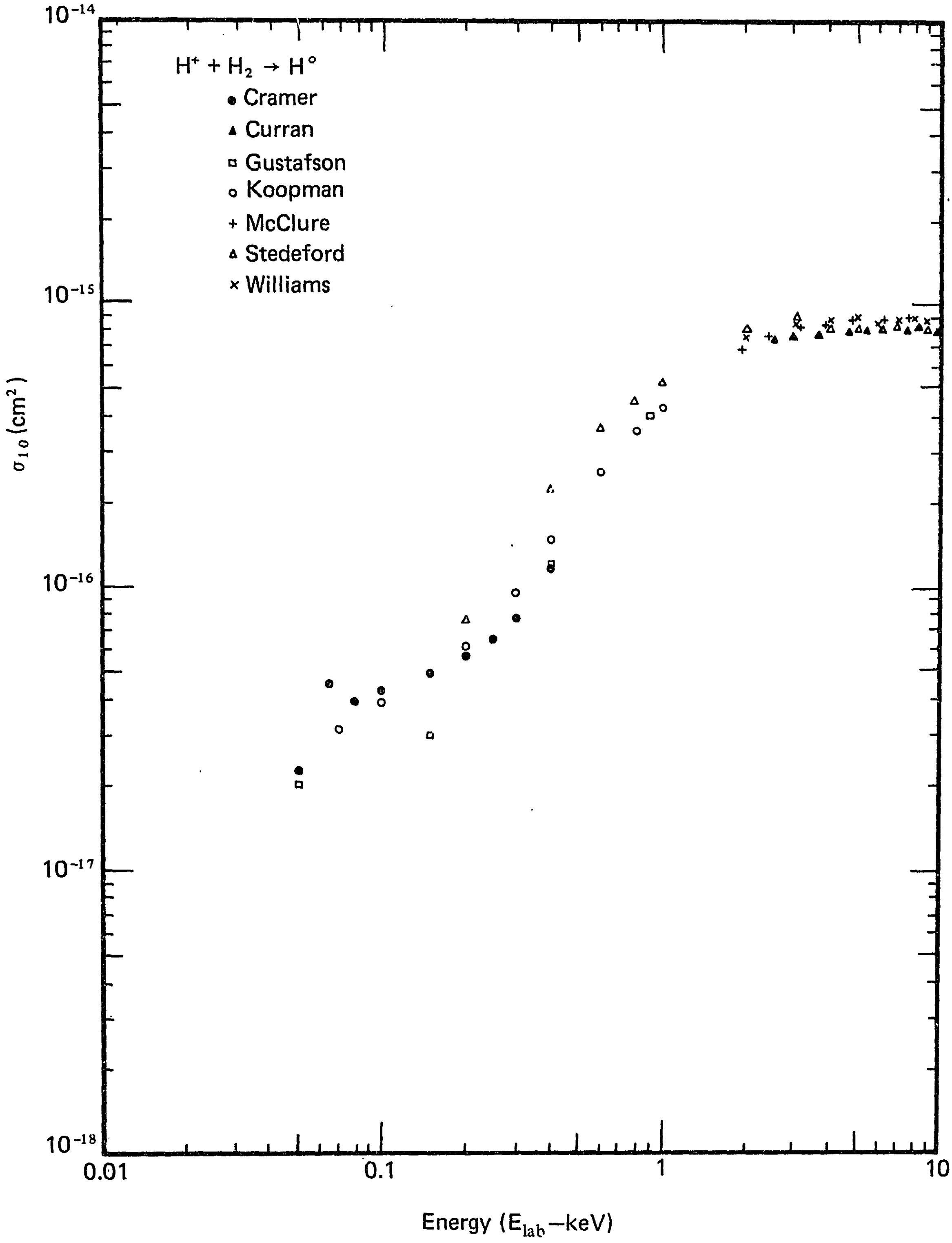

Fig. 2 Cross sections for one-electron capture of H^+ beams in H_2

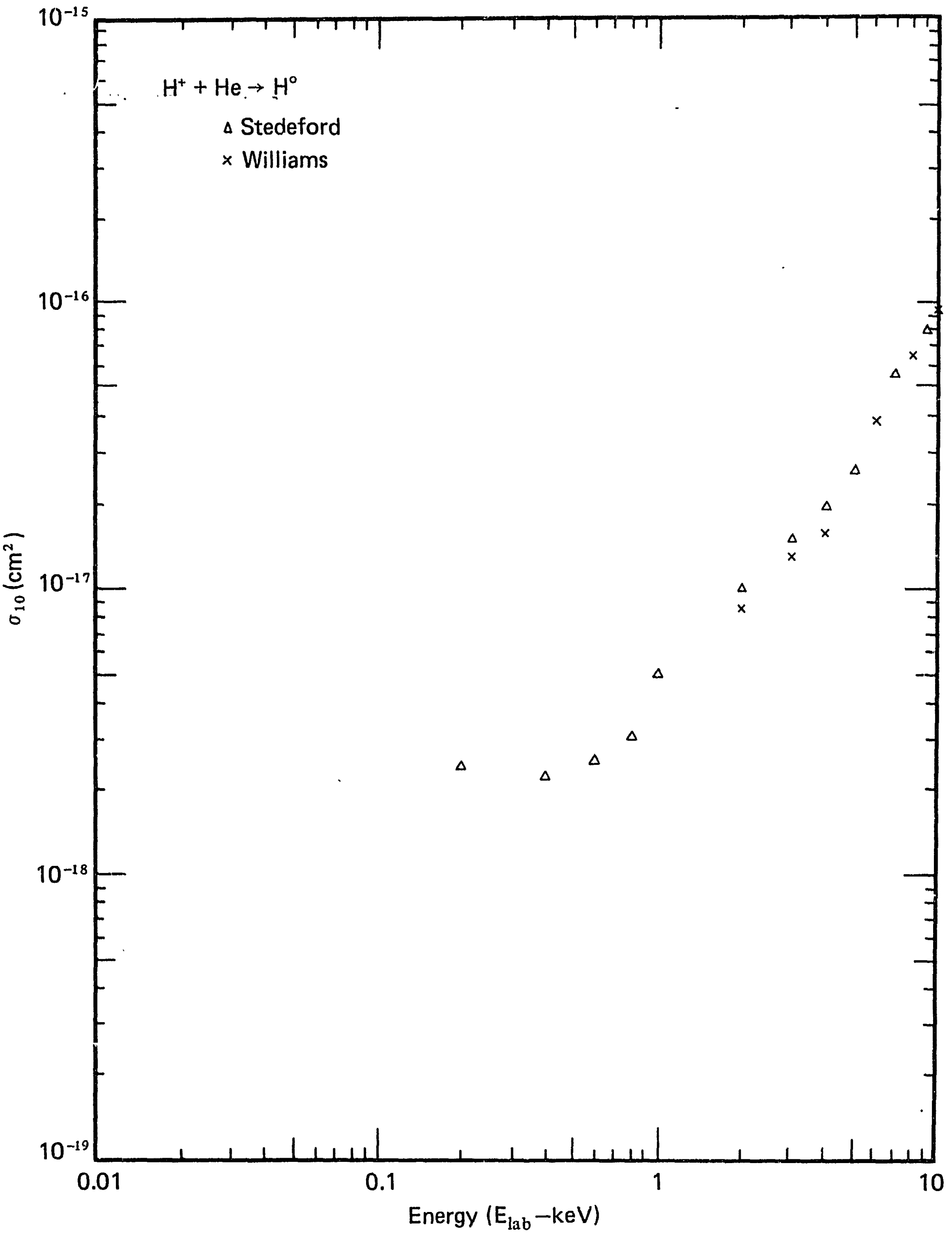

Fig. 3 Cross sections for one-electron capture of H^+ beams in He

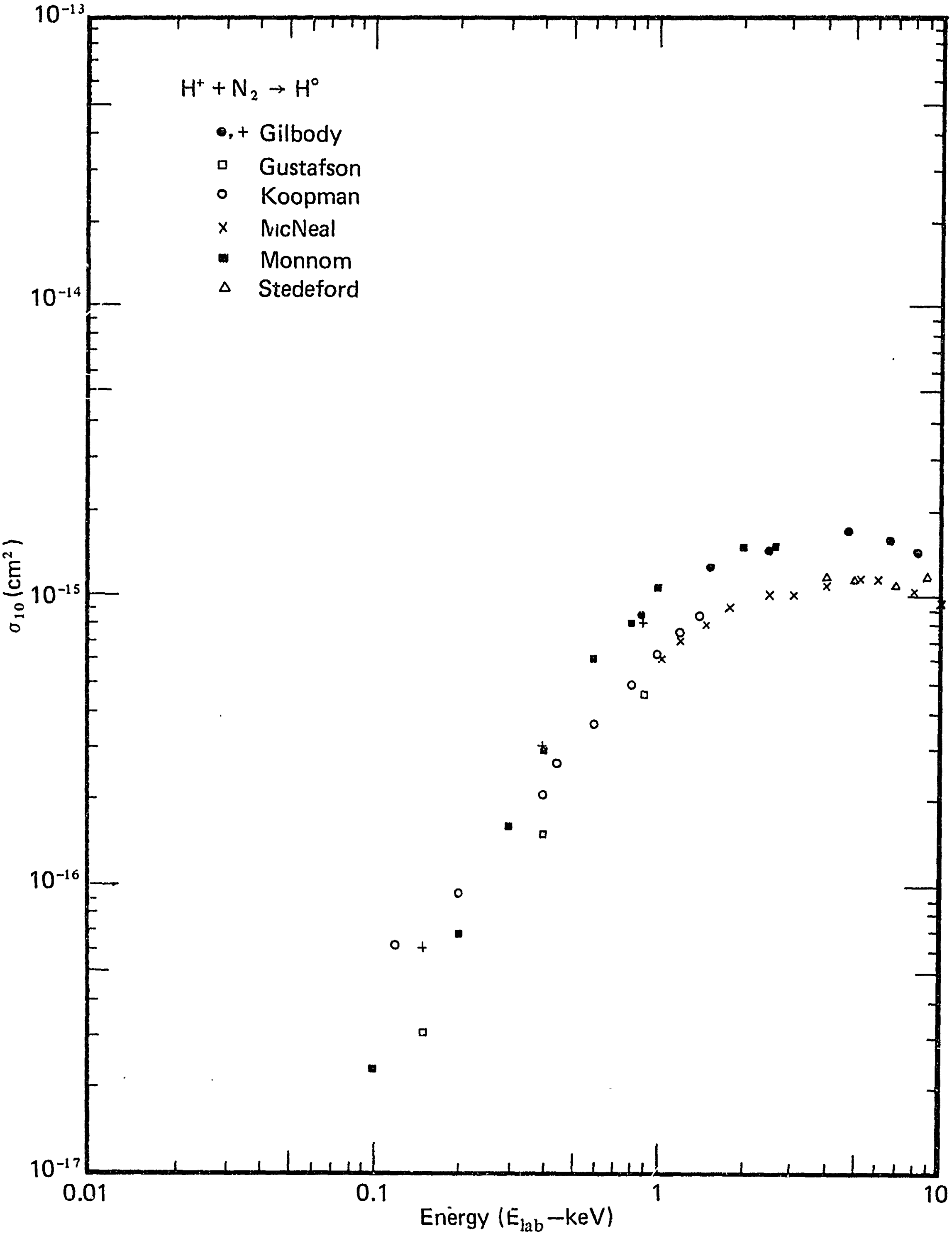

Fig. 4 Cross sections for one-electron capture of H^+ beams in N_2

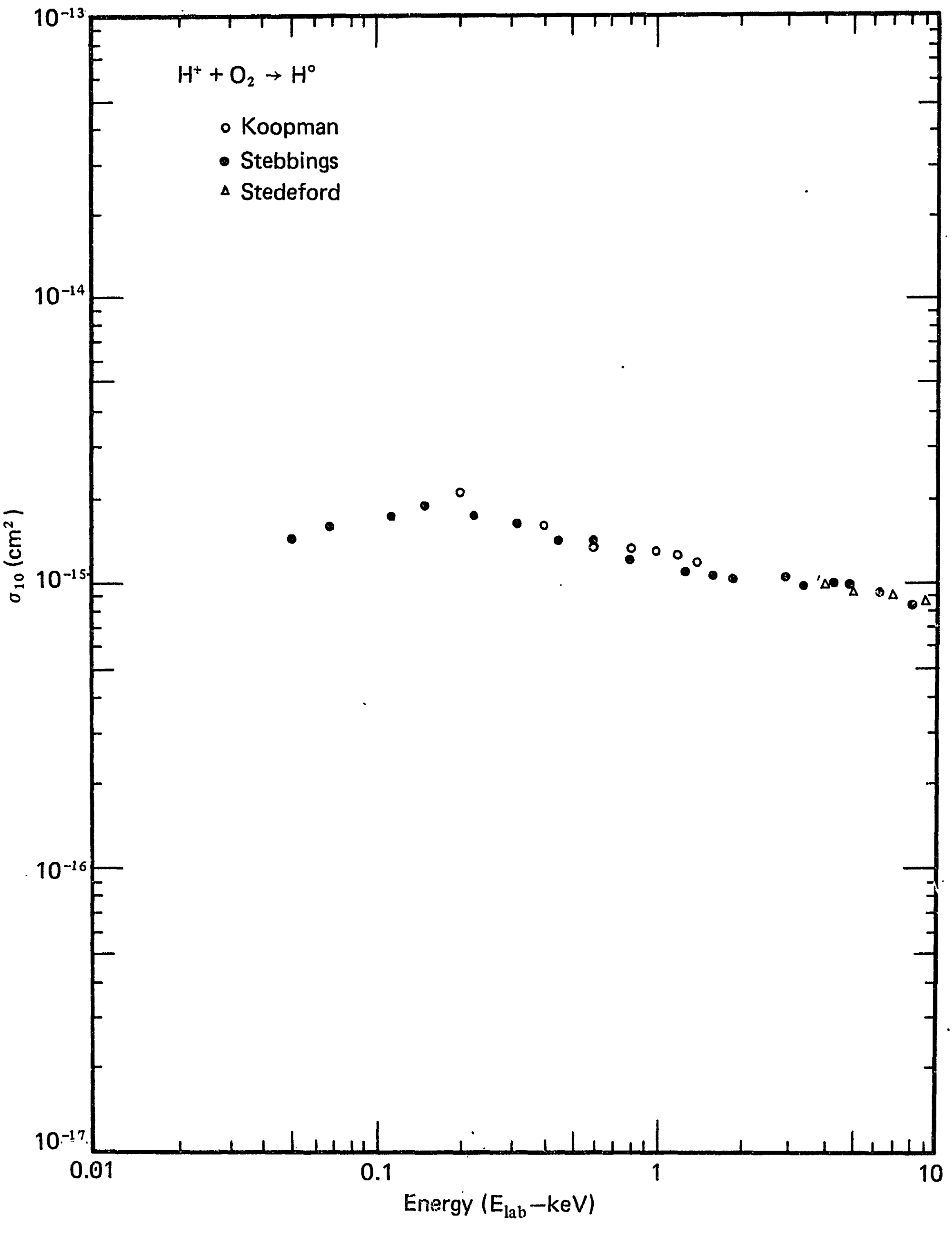

Fig. 5 Cross sections for one-electron capture of H^+ beams in O_2

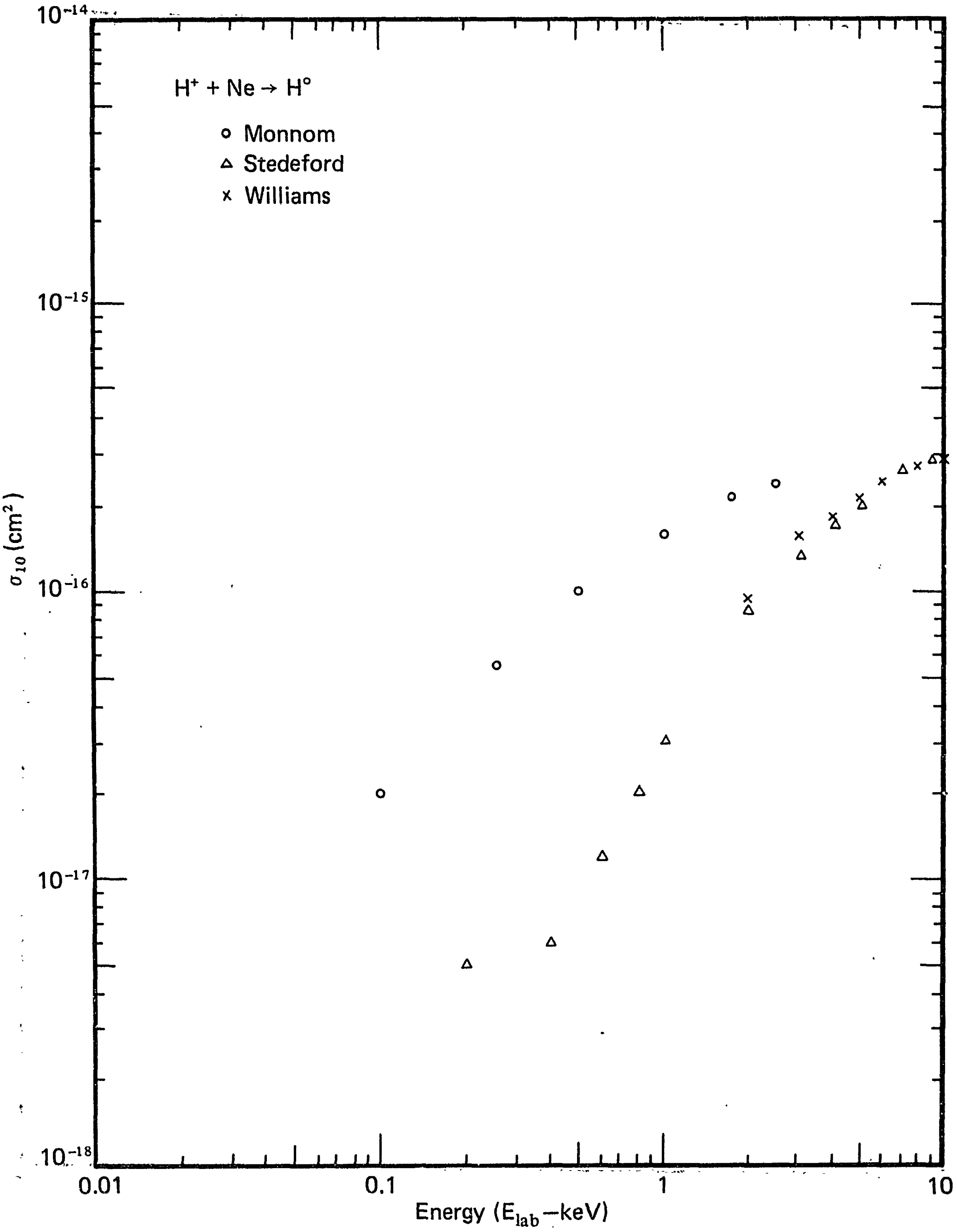

Fig. 6 Cross sections for one-electron capture of H^+ beams in Ne

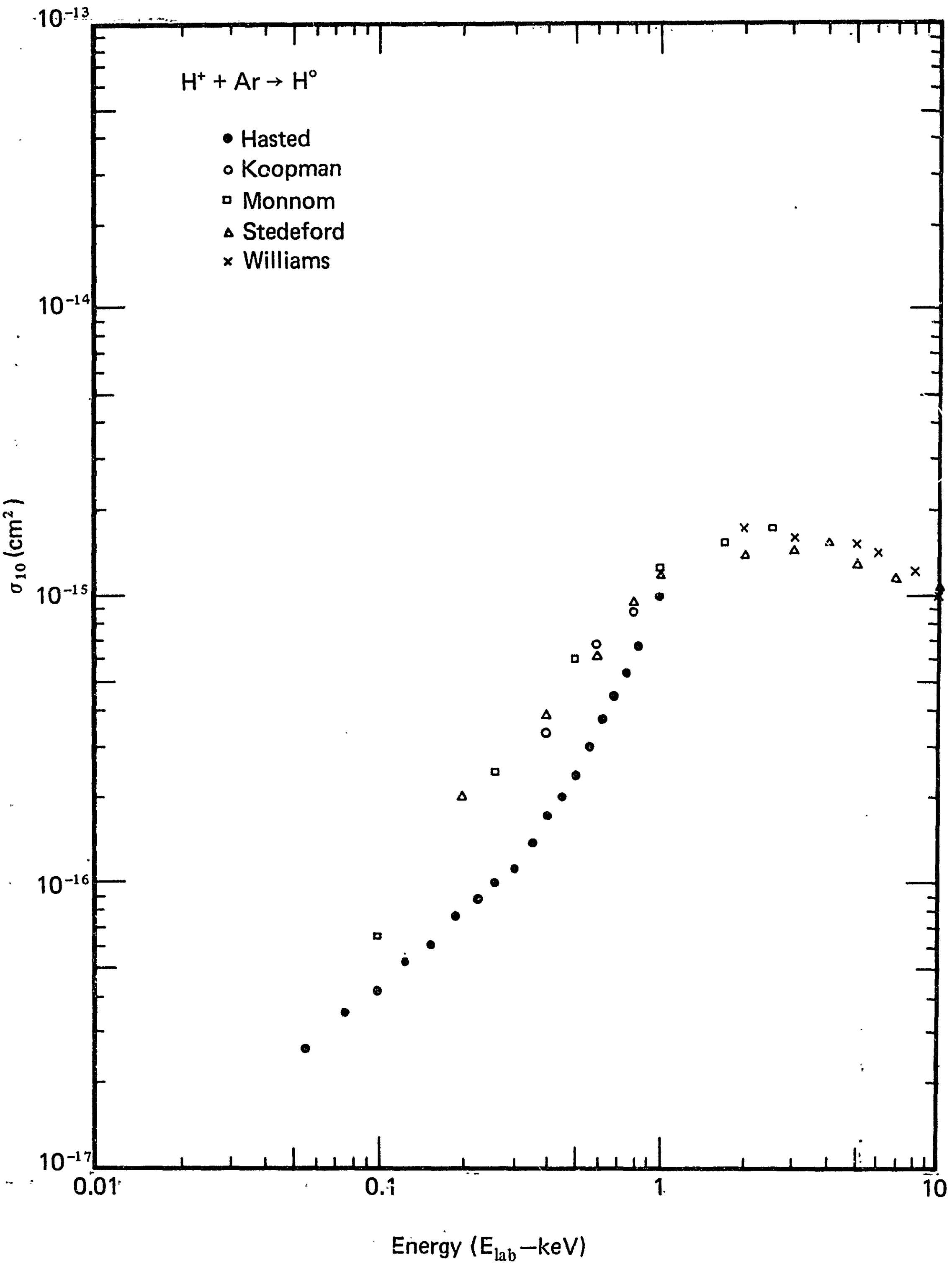

Fig. 7 Cross sections for one-electron capture of H^+ beams in Ar

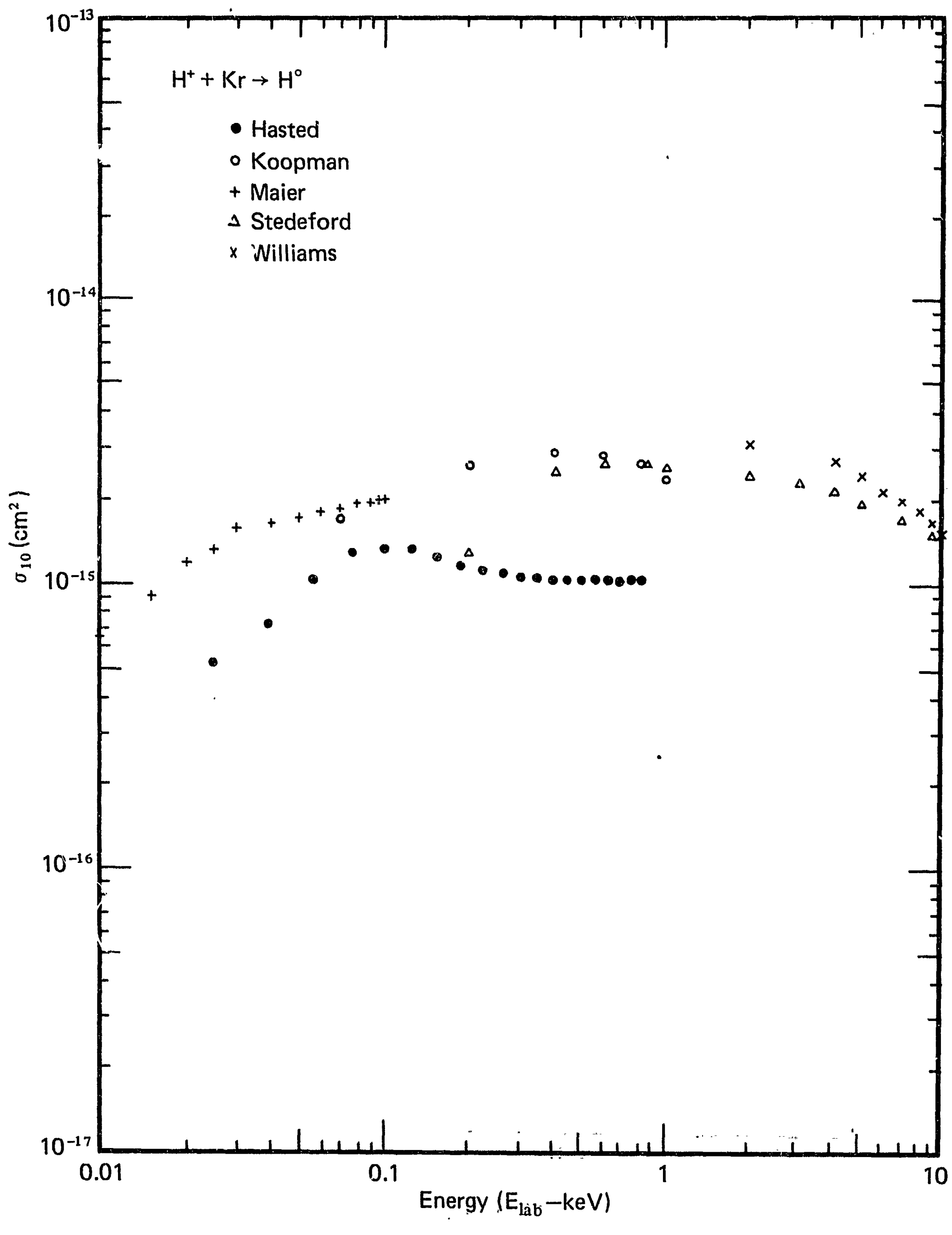

Fig. 8 Cross sections for one-electron capture of H^+ beams in Kr

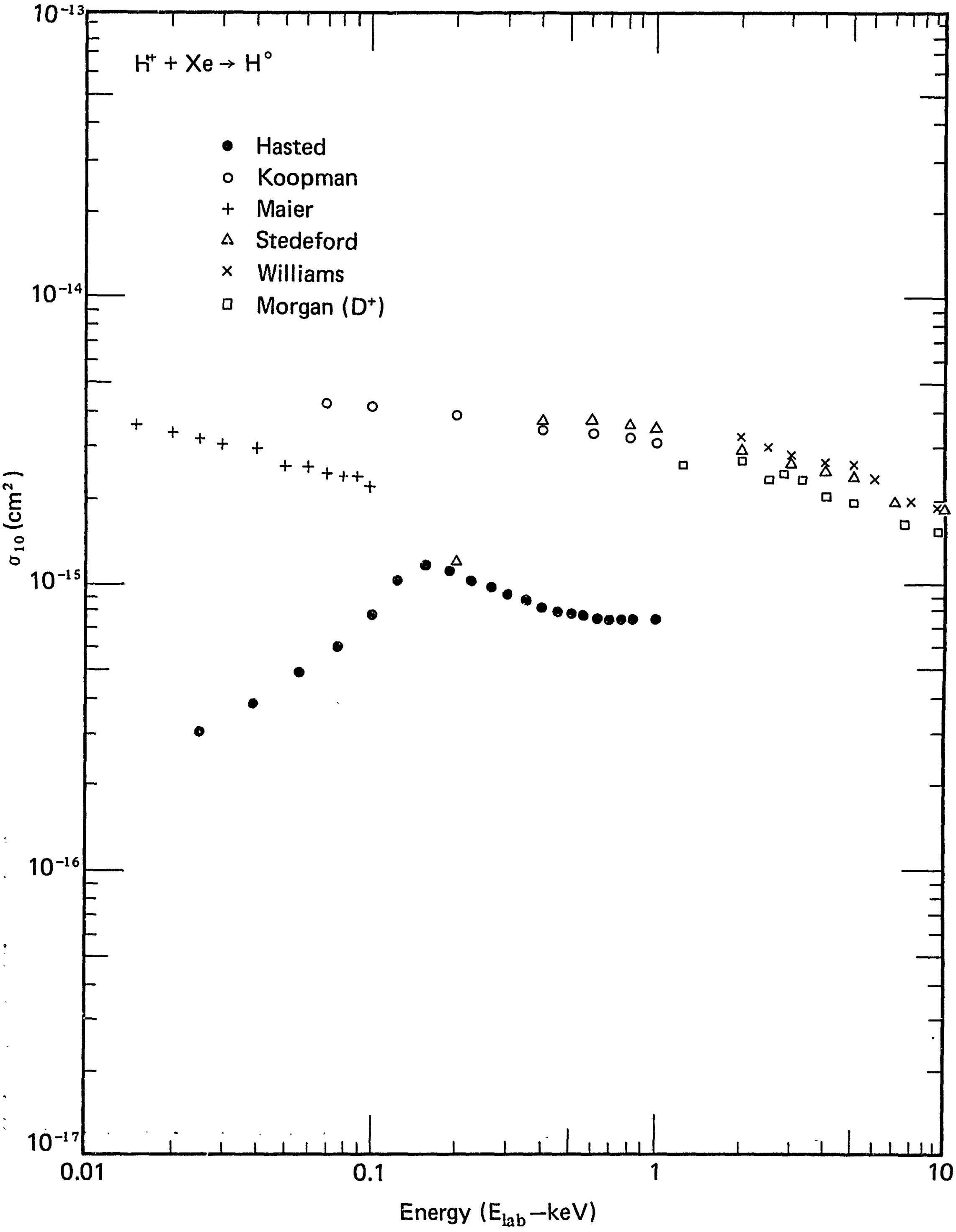

Fig. 9 Cross sections for one-electron capture of H^+ beams in Xe

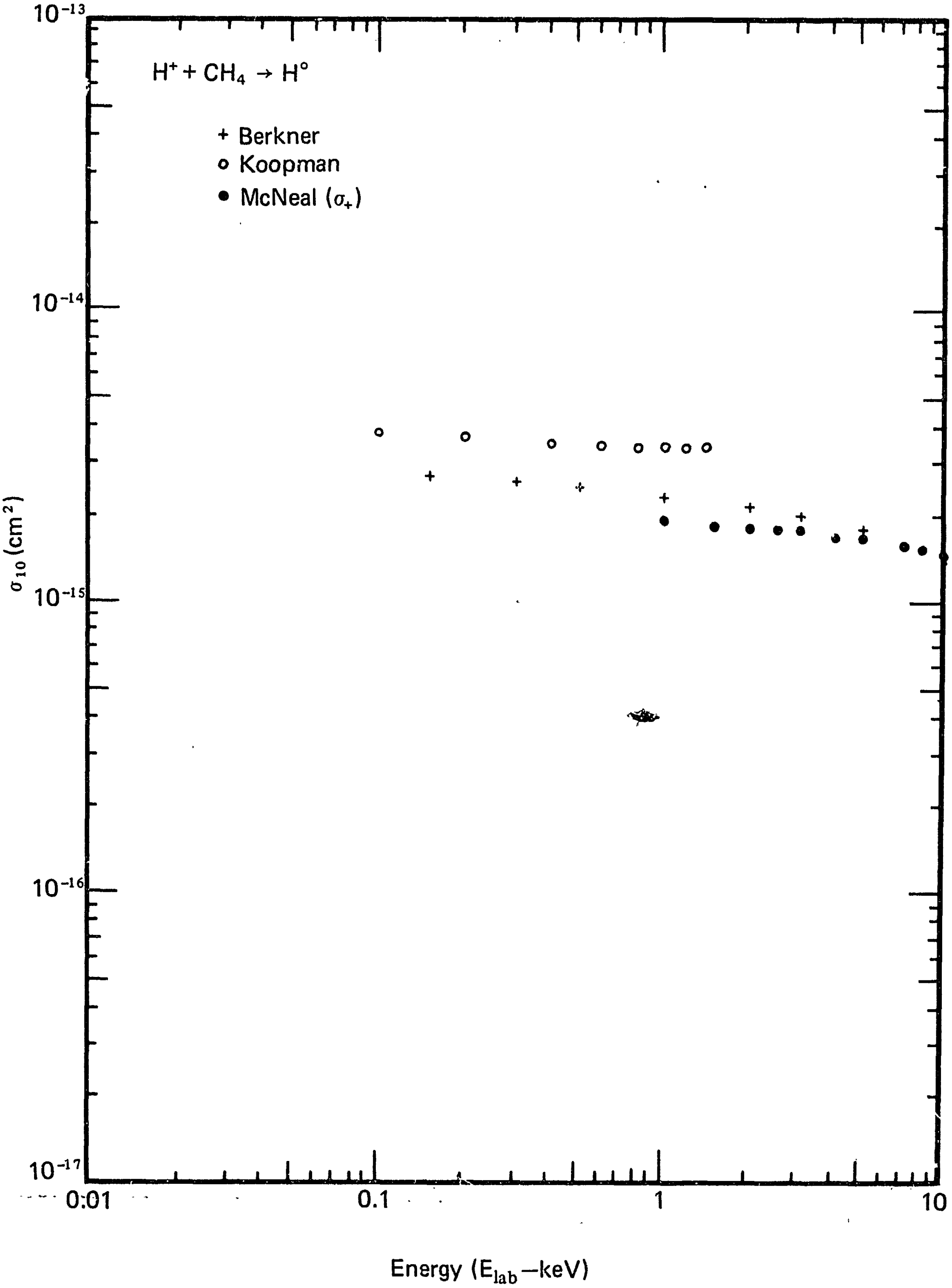

Fig. 10 Cross sections for one-electron capture of H^+ beams in CH

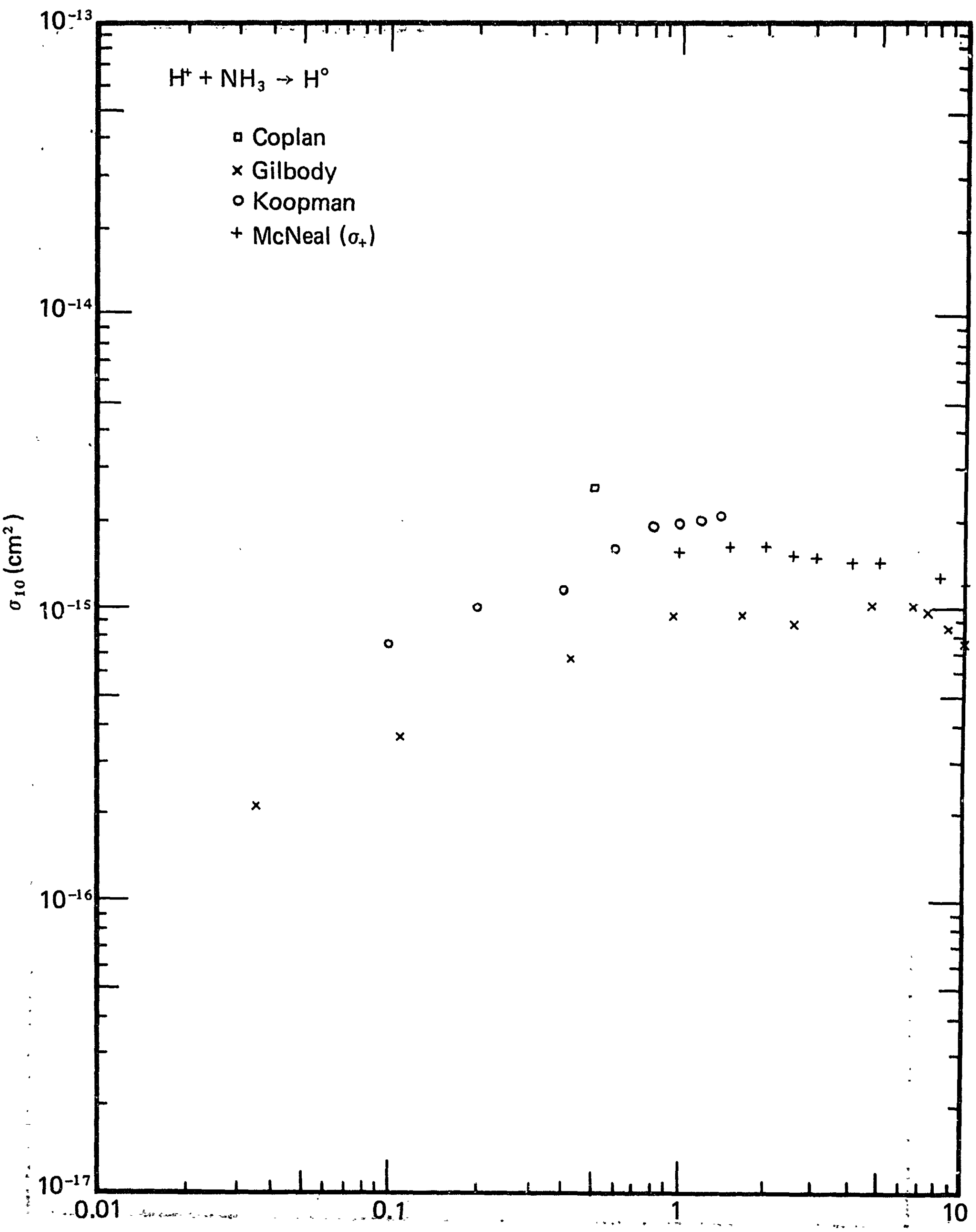

Fig. 11 Cross sections for one-electron capture of H^+ beams in NH_3

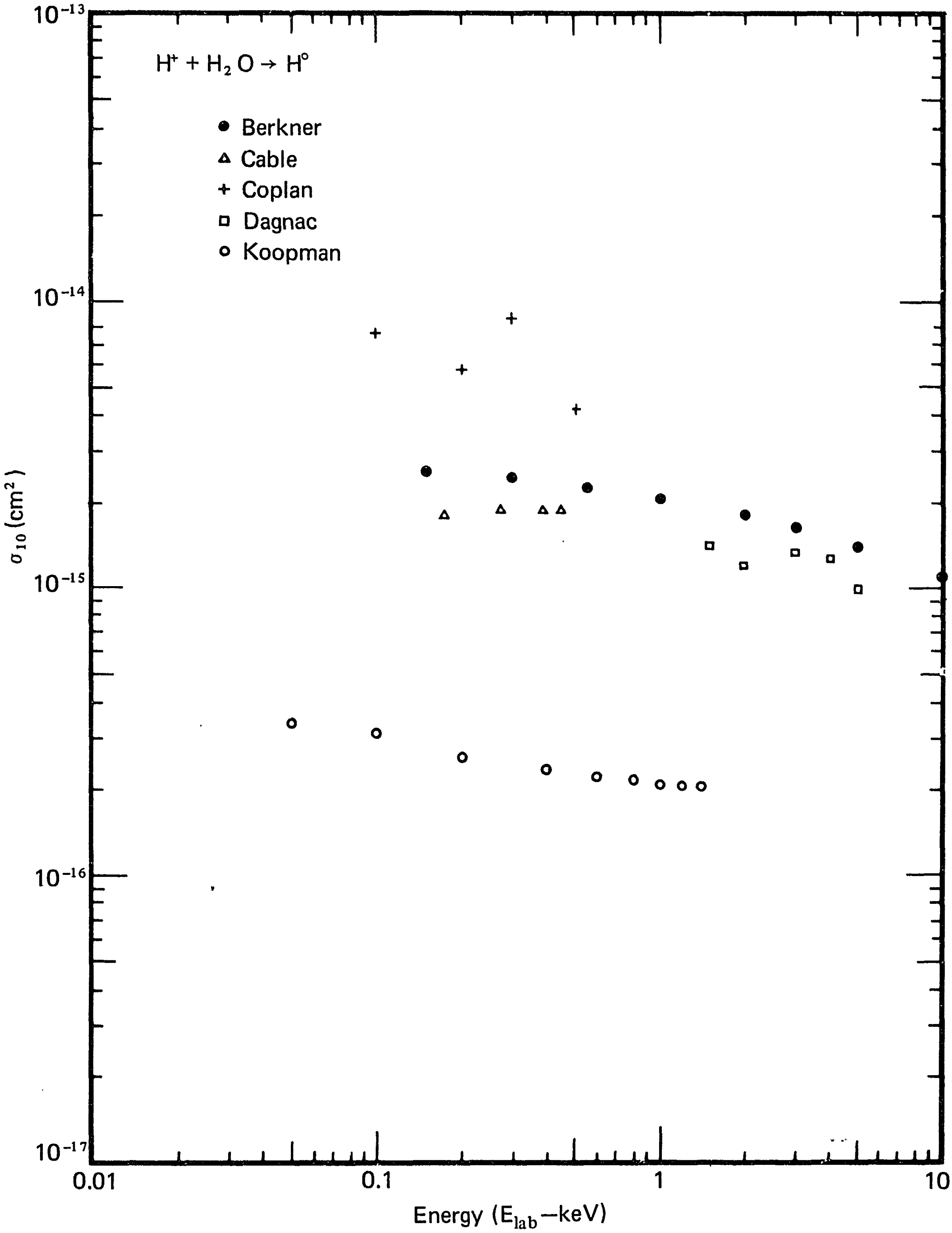

Fig. 12 Cross sections for one-electron capture of H^+ beams in H_2O

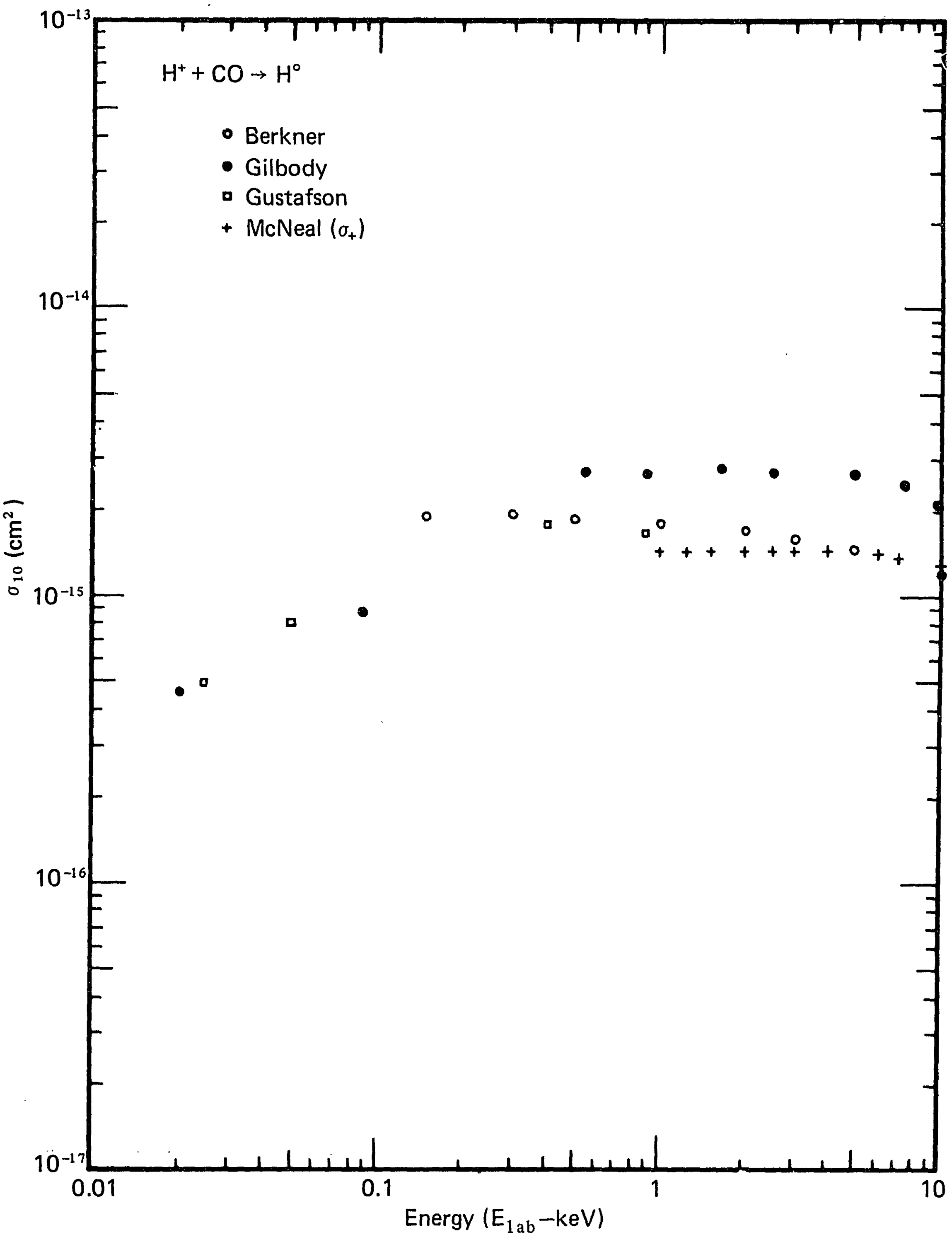

Fig. 13 Cross sections for one-electron capture of H^+ beams in CO

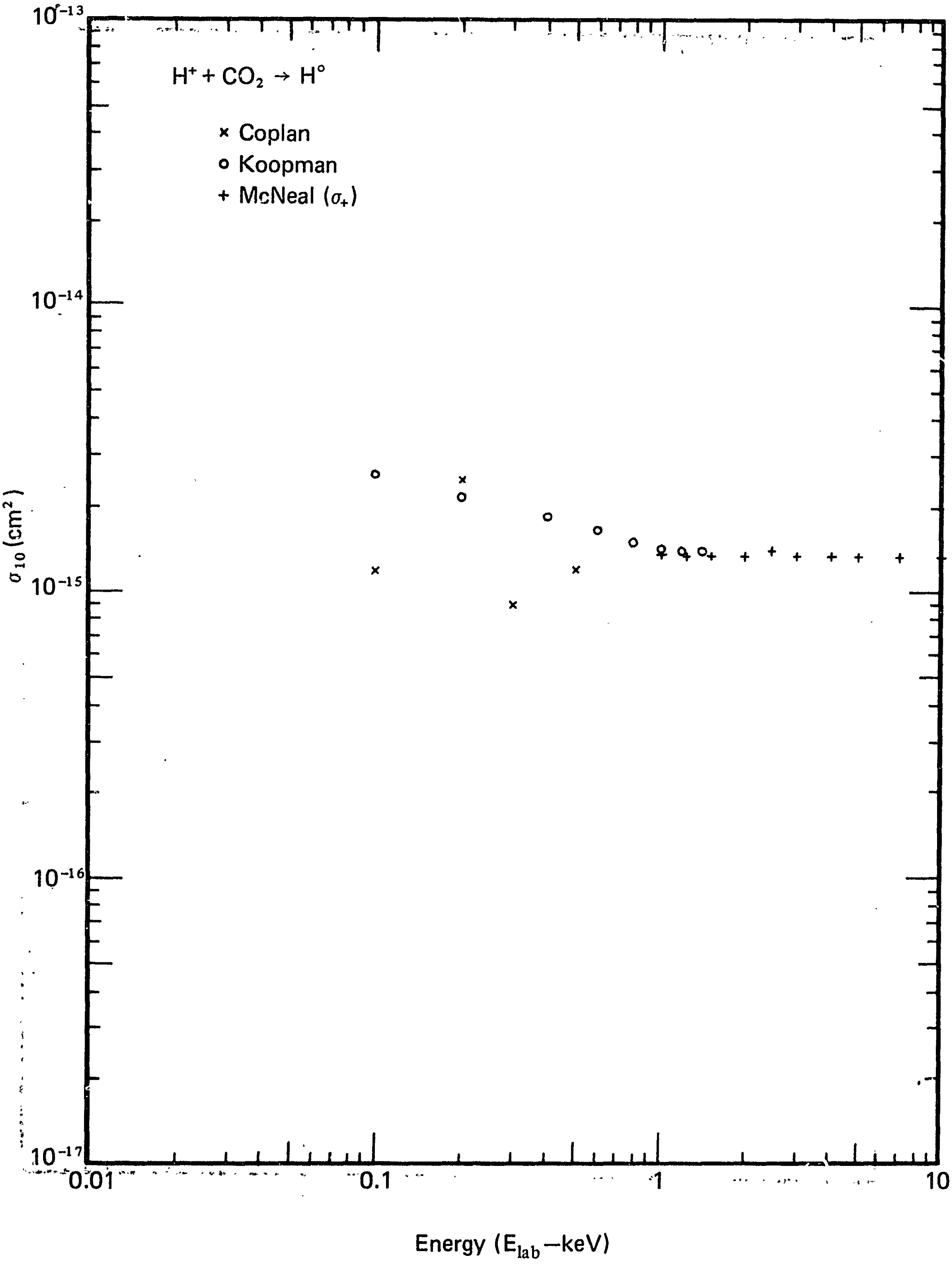

Fig. 14 Cross sections for one-electron capture of H^+ beams in CO_2

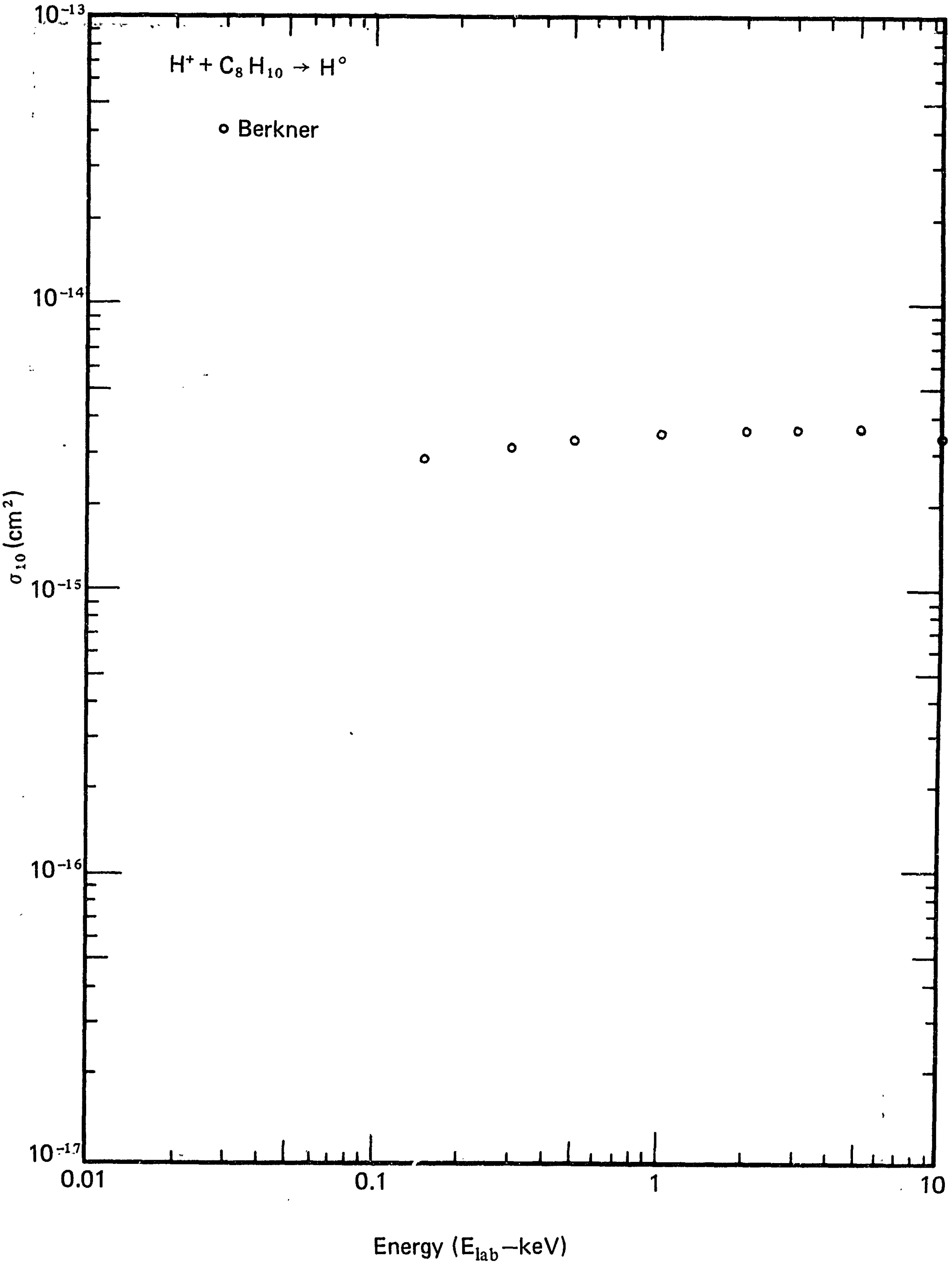

Fig. 15 Cross sections for one-electron capture of H^+ beams in C_8H_{10}

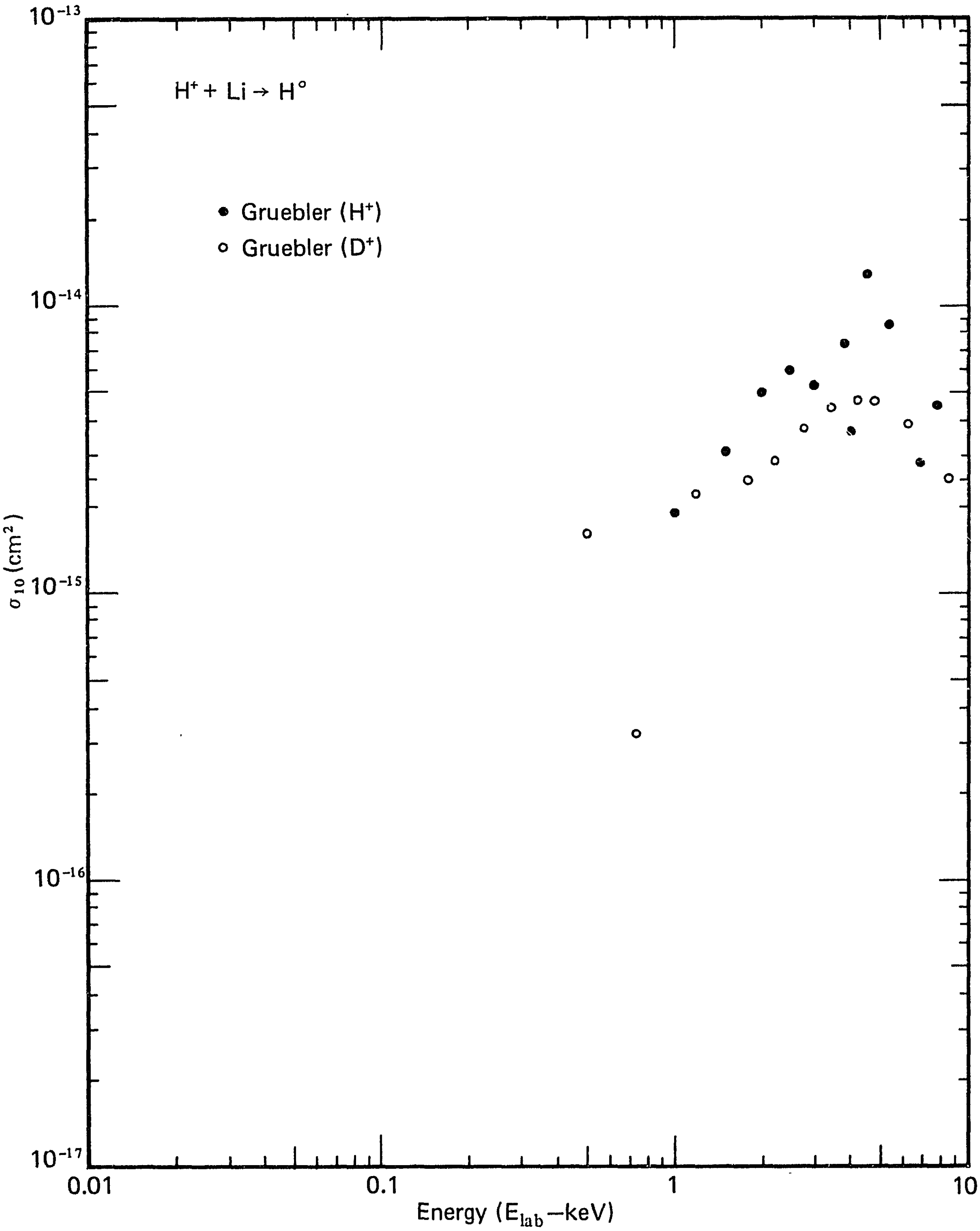

Fig. 16 Cross sections for one-electron capture of H^+ beams in Li

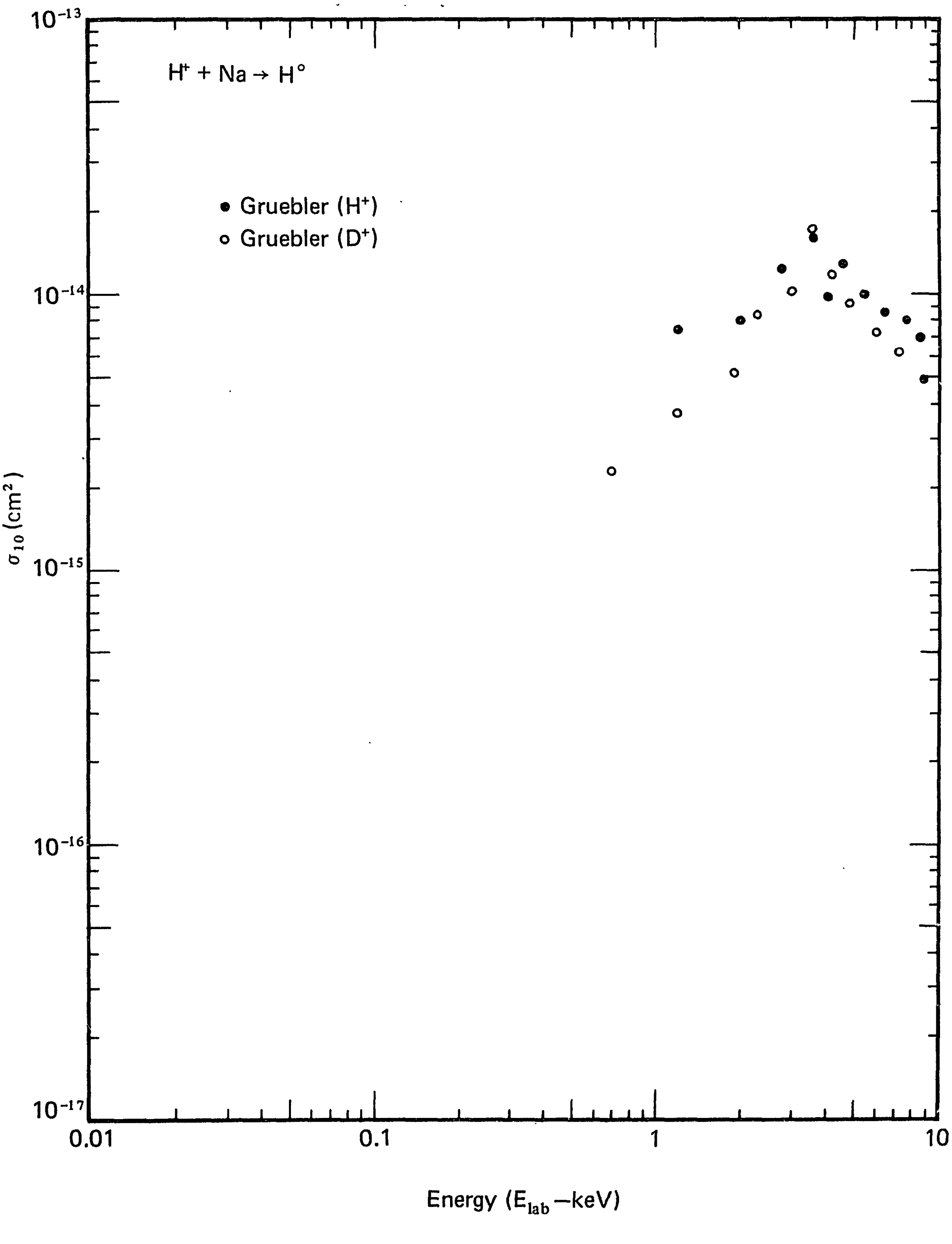

Fig. 17 Cross sections for one-electron capture of H^+ beams in Na

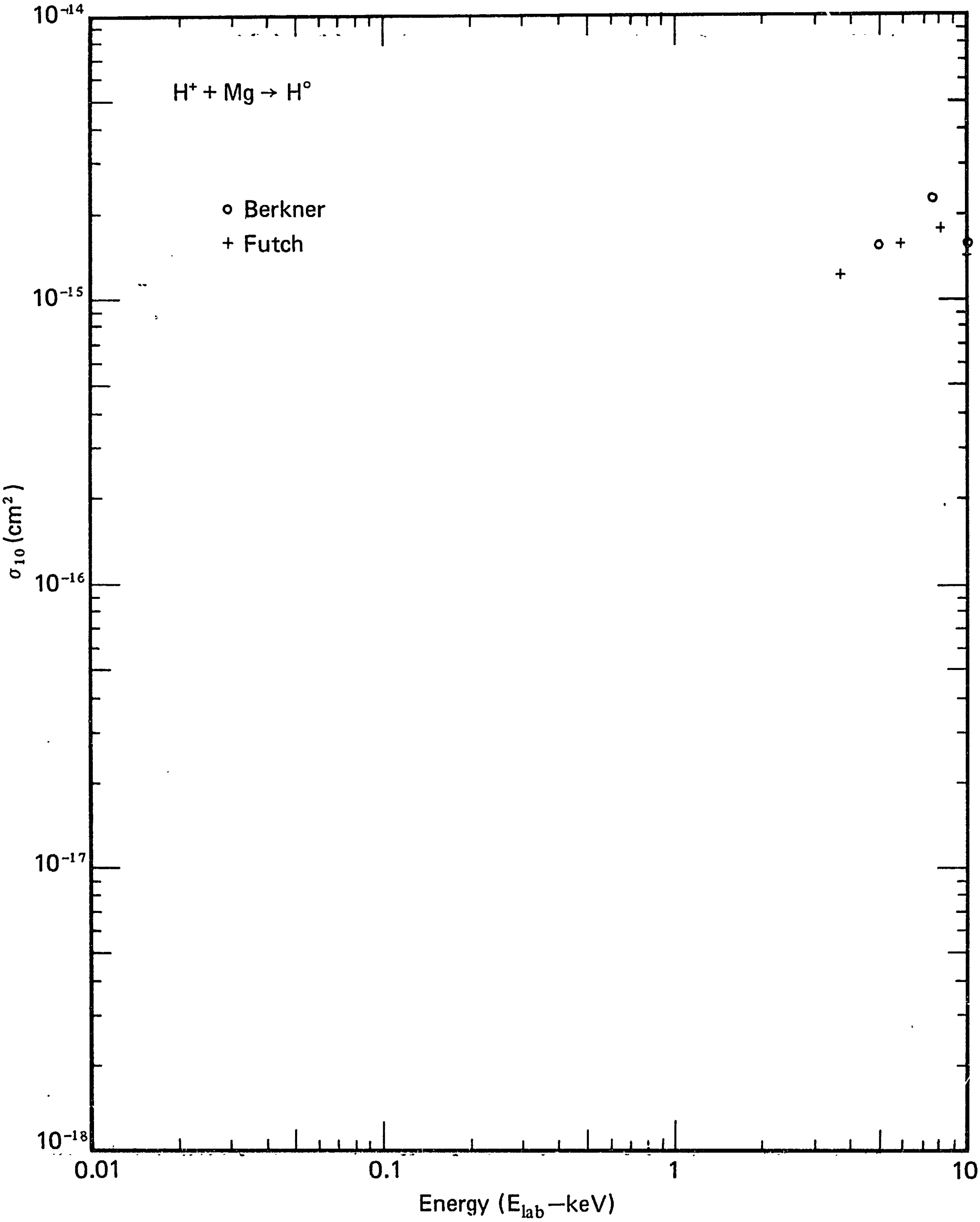

Fig. 18 Cross sections for one-electron capture of H^+ beams in Mg

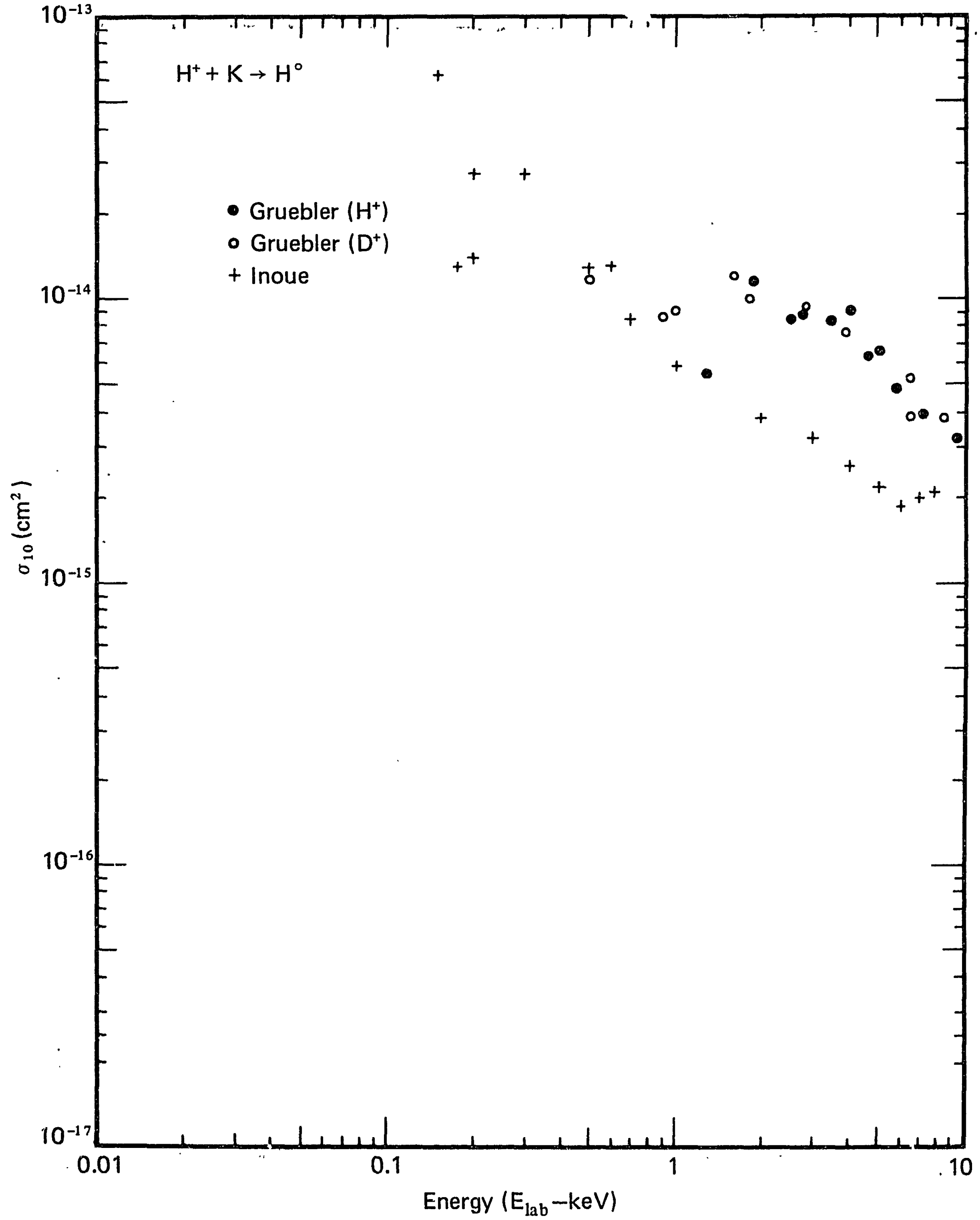

Fig. 19 Cross sections for one-electron capture of H^+ beams in K

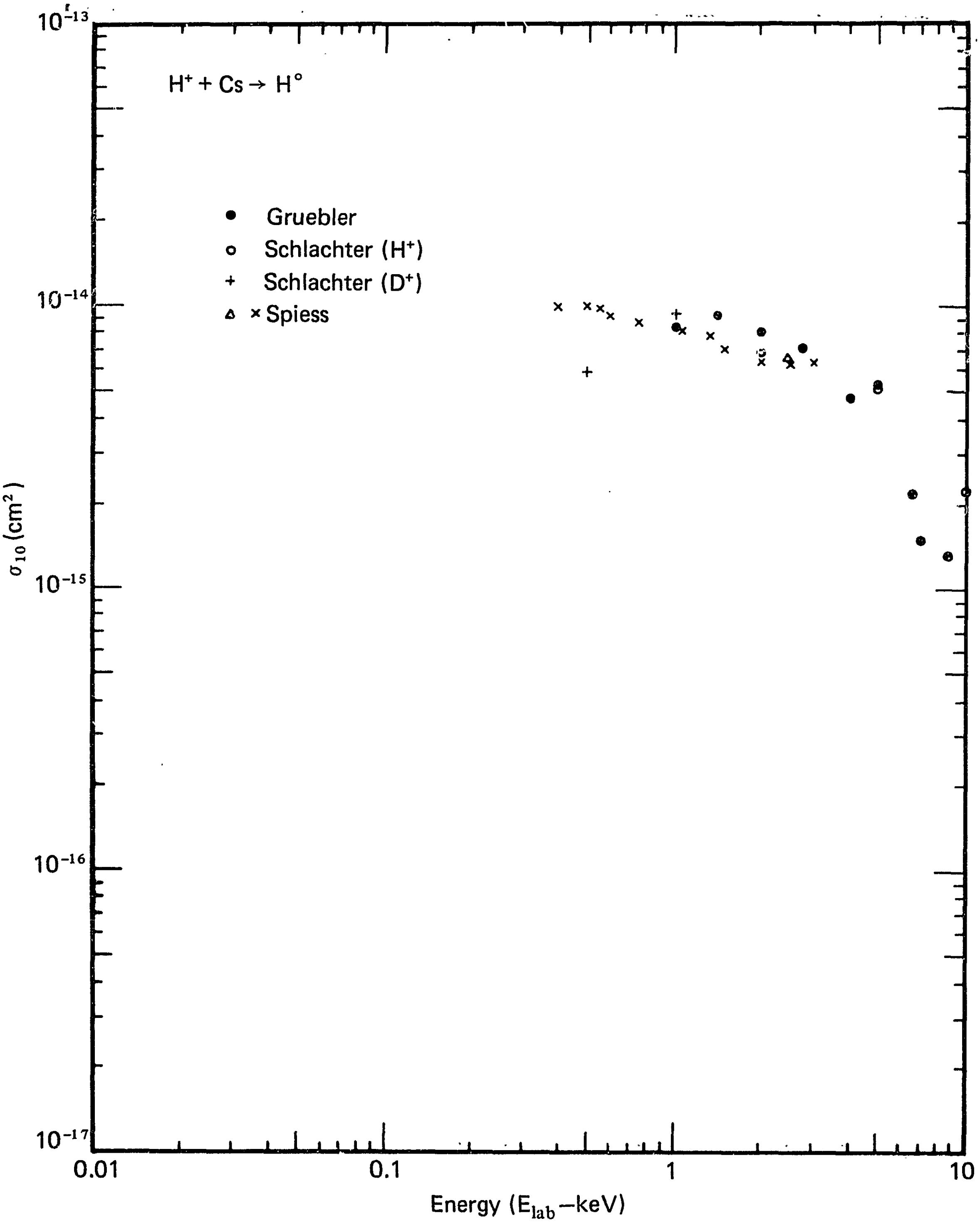

Fig. 20 Cross sections for one-electron capture of H^+ beams in Cs

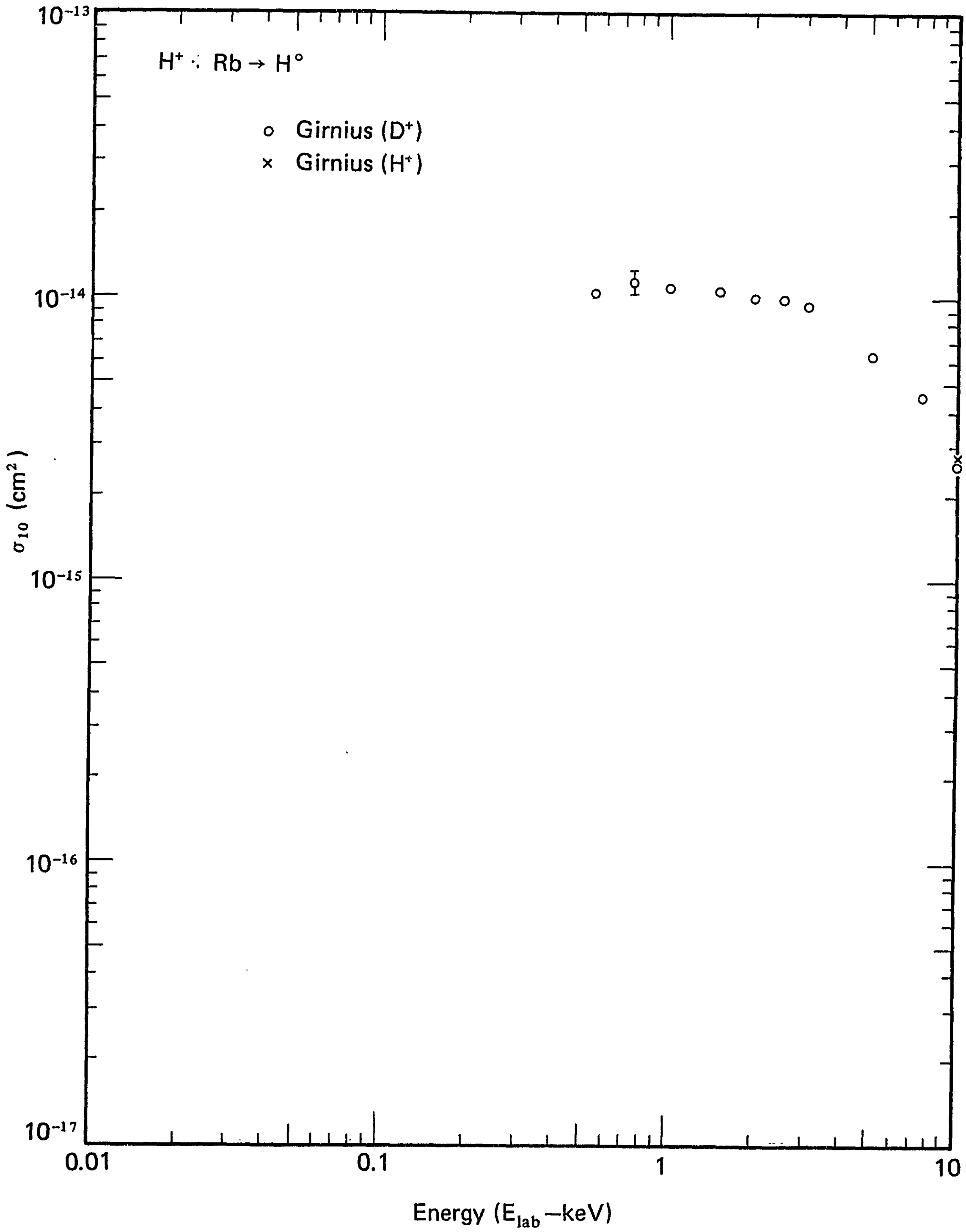

Fig. 21 Cross sections for one-electron capture of H^+ beams in Rb

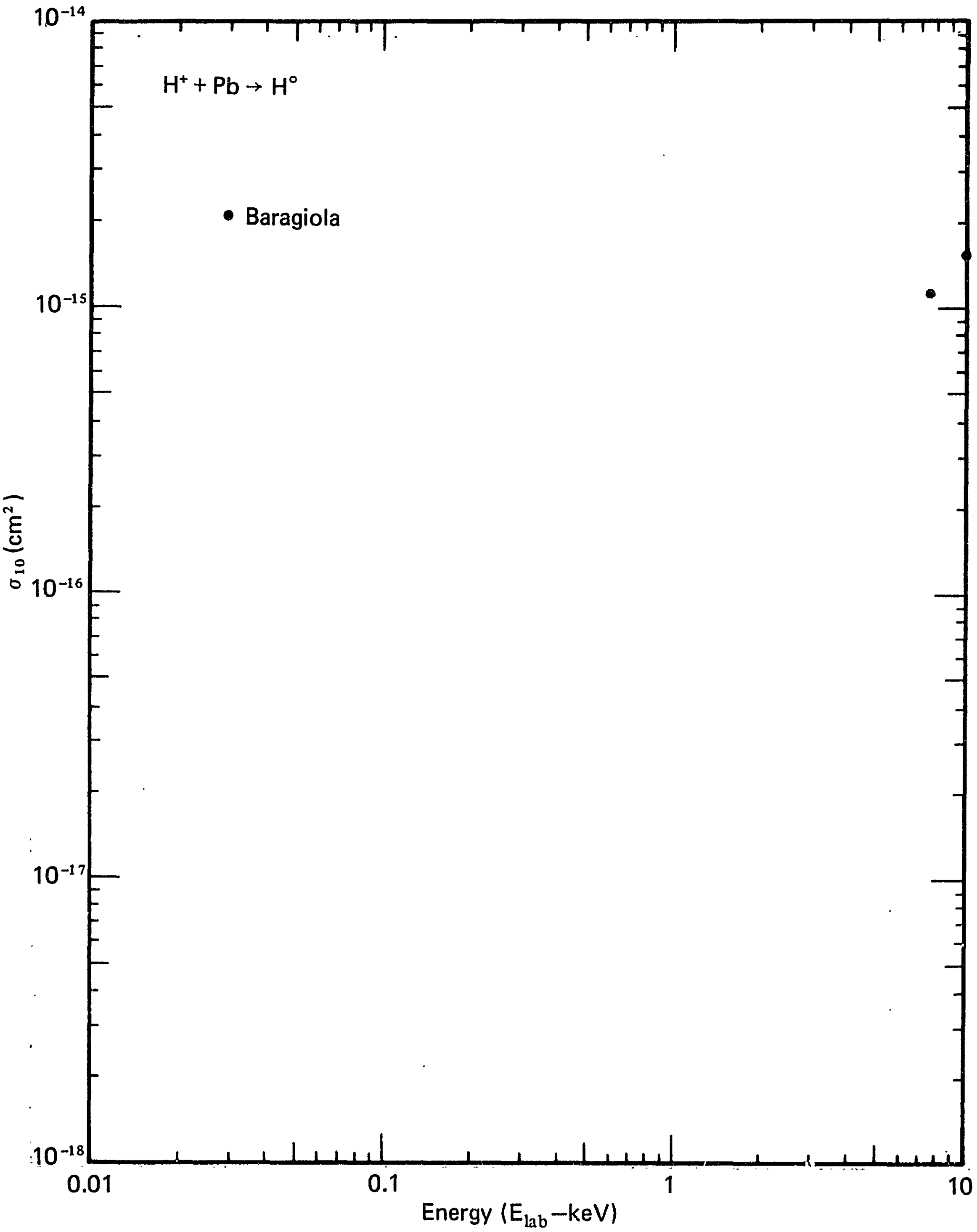

Fig. 22 Cross sections for one-electron capture of H^+ beams in Pb

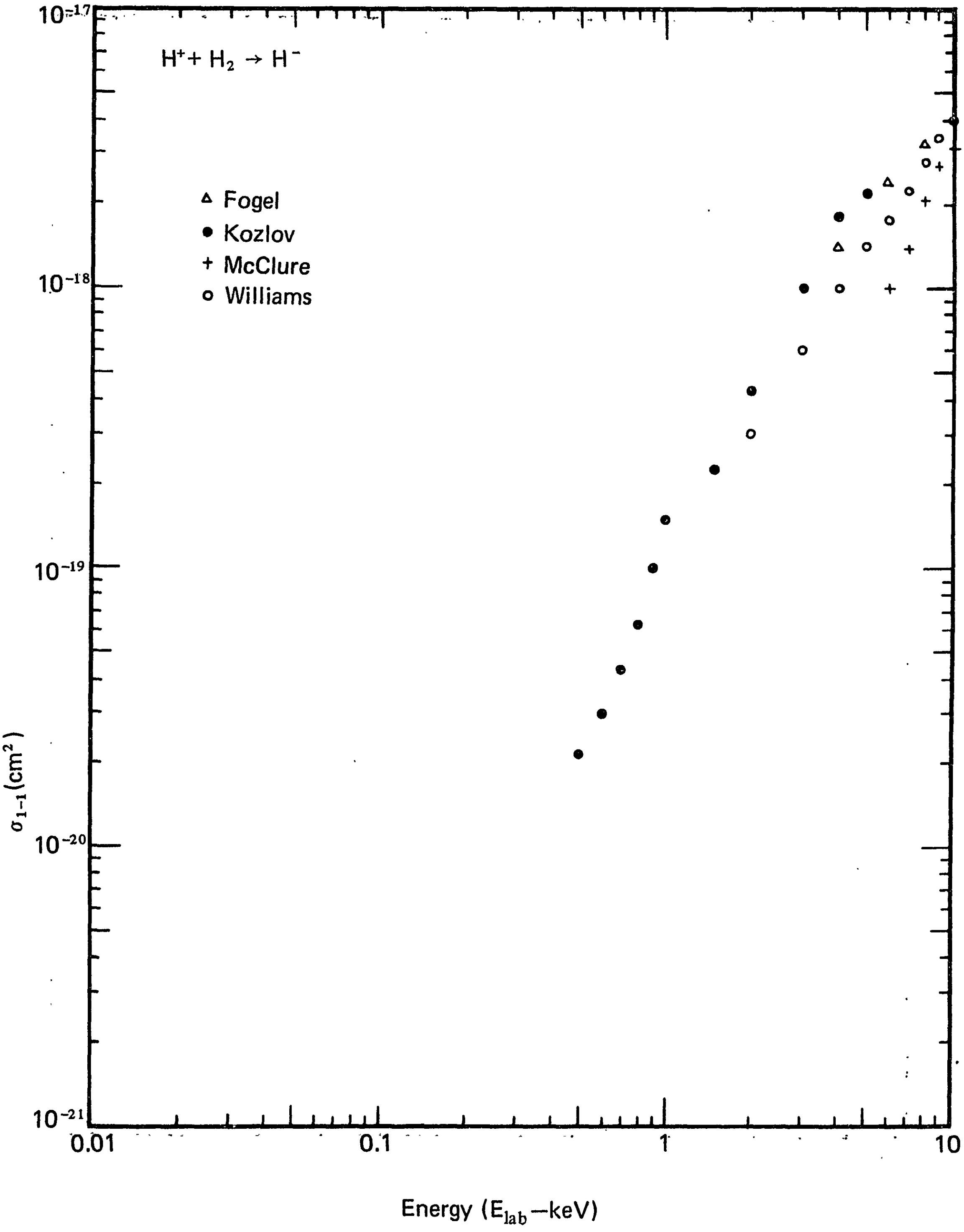

Fig. 23 Cross sections for two-electron capture of H^+ beams in H_2

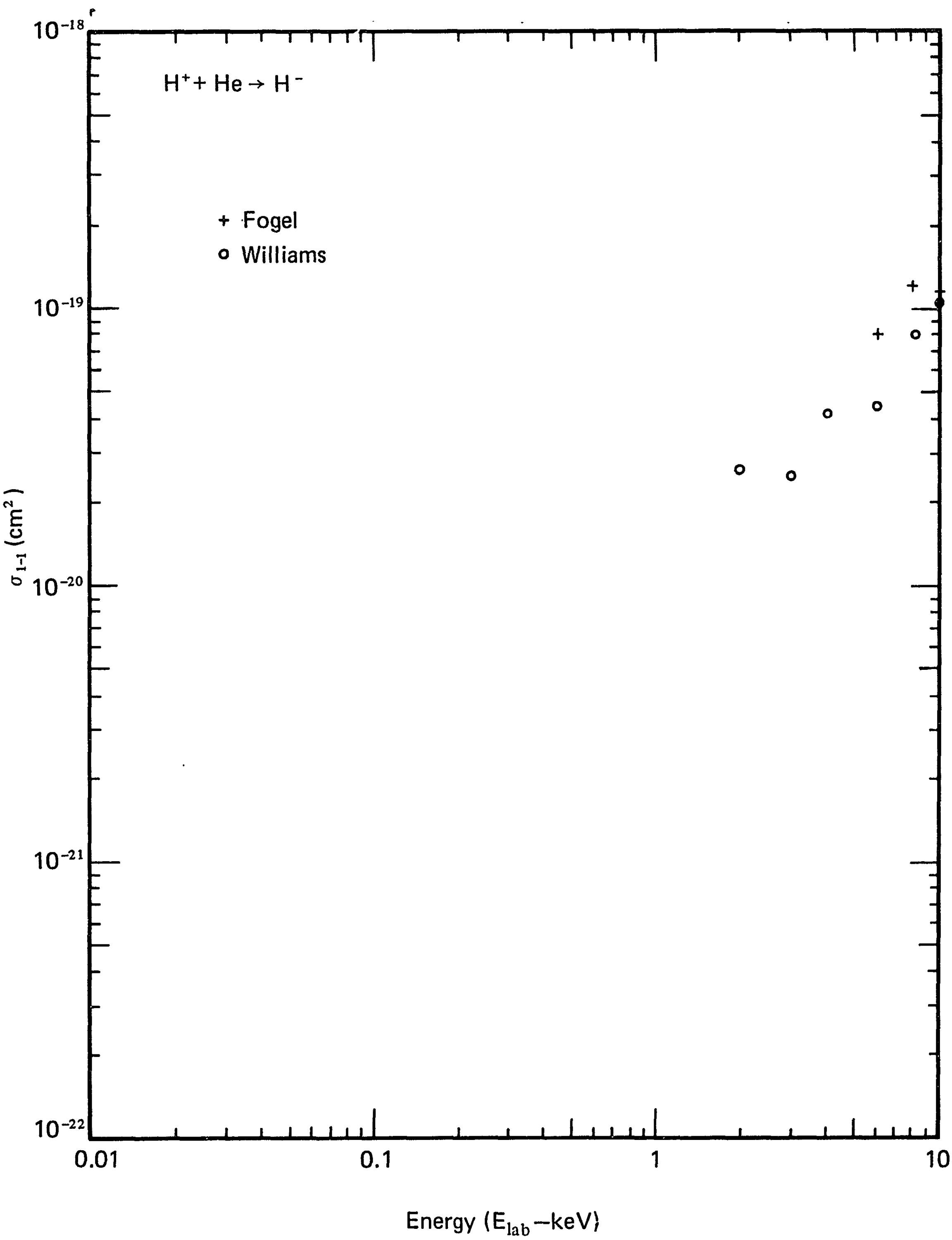

Fig. 24 Cross sections for two-electron capture of H^+ beams in He

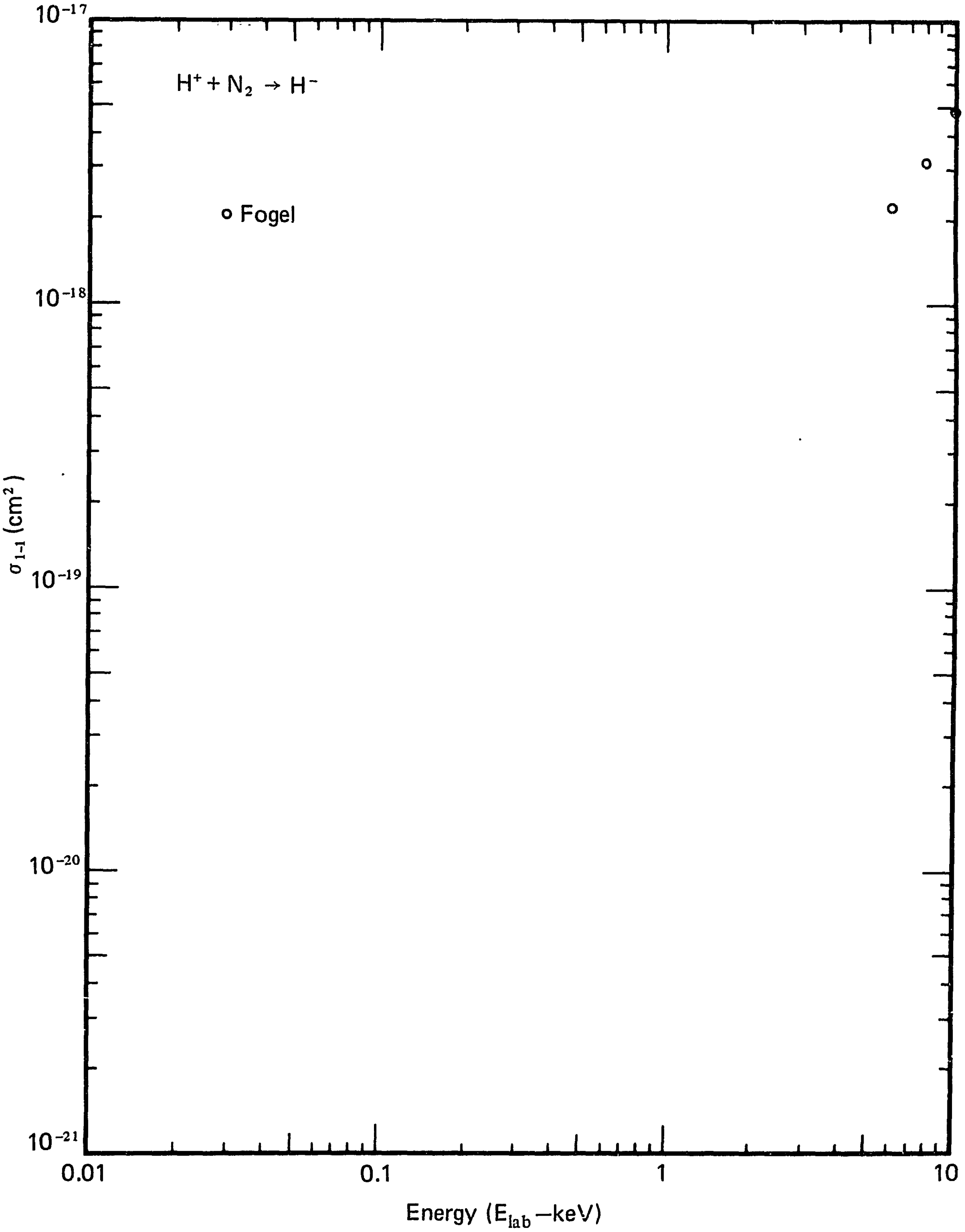

Fig. 25 Cross sections for two-electron capture of H^+ beams in N_2

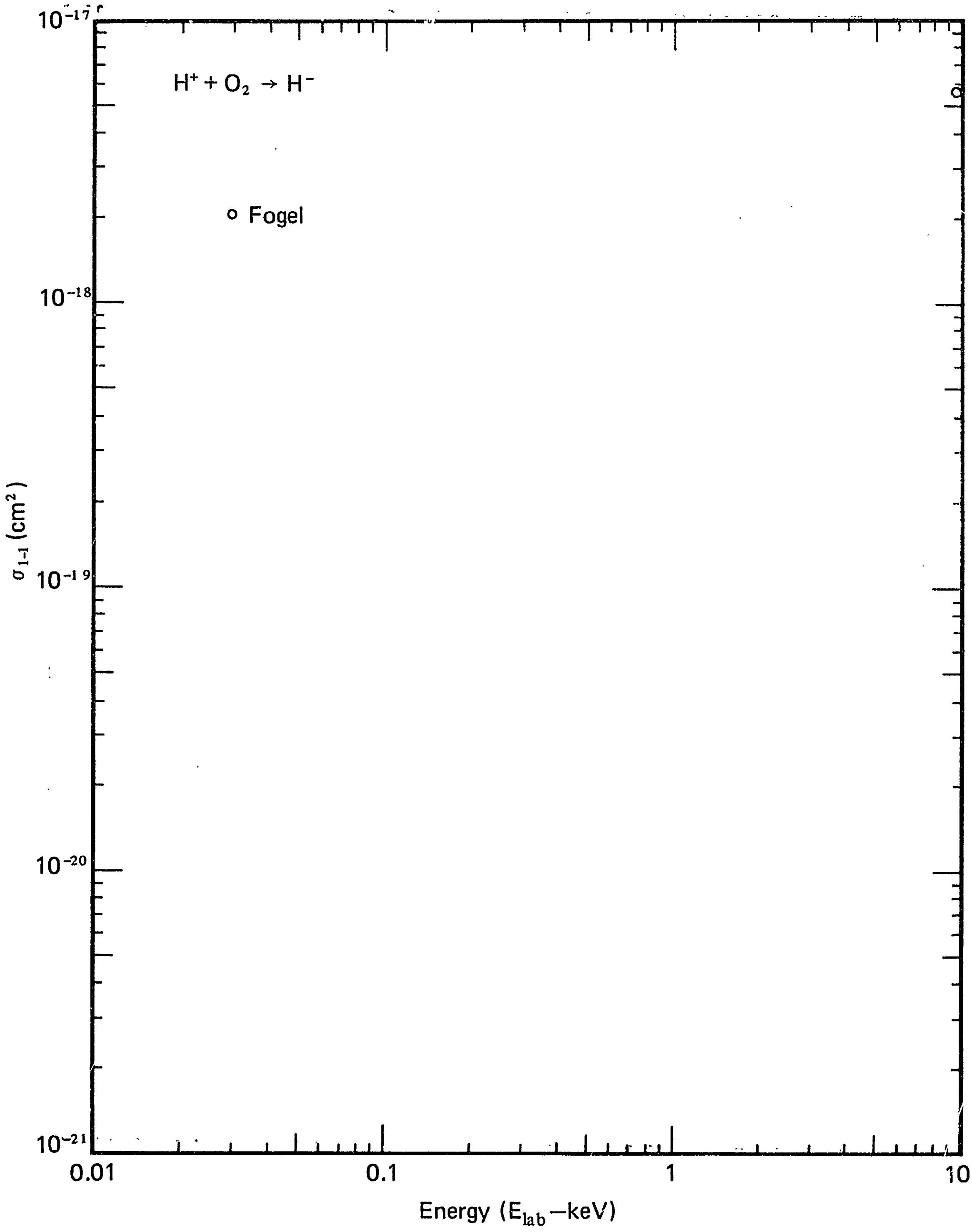

Fig. 26 Cross sections for two-electron capture of H^+ beams in O_2

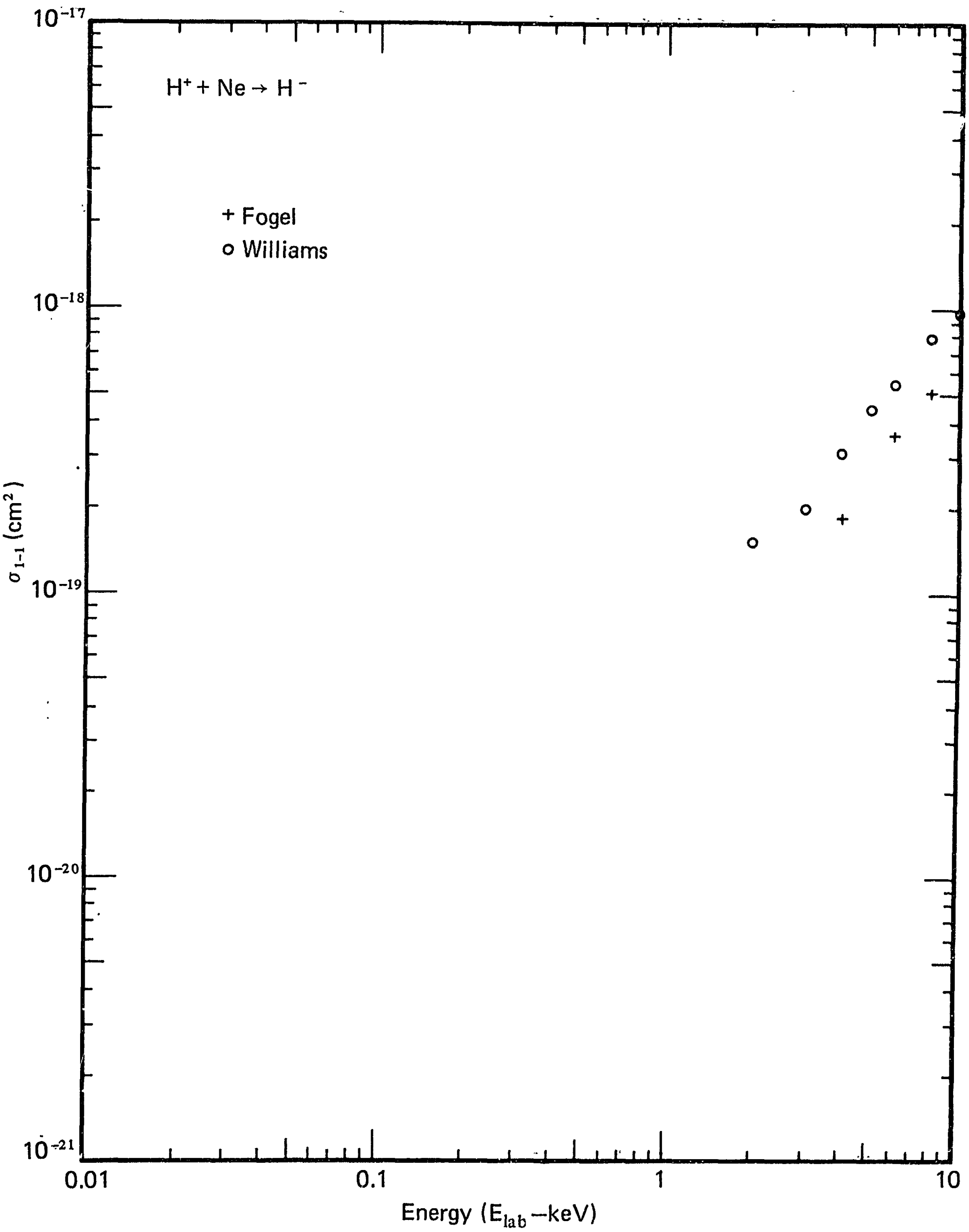

Fig. 27 Cross sections for two-electron capture of H^+ beams in Ne

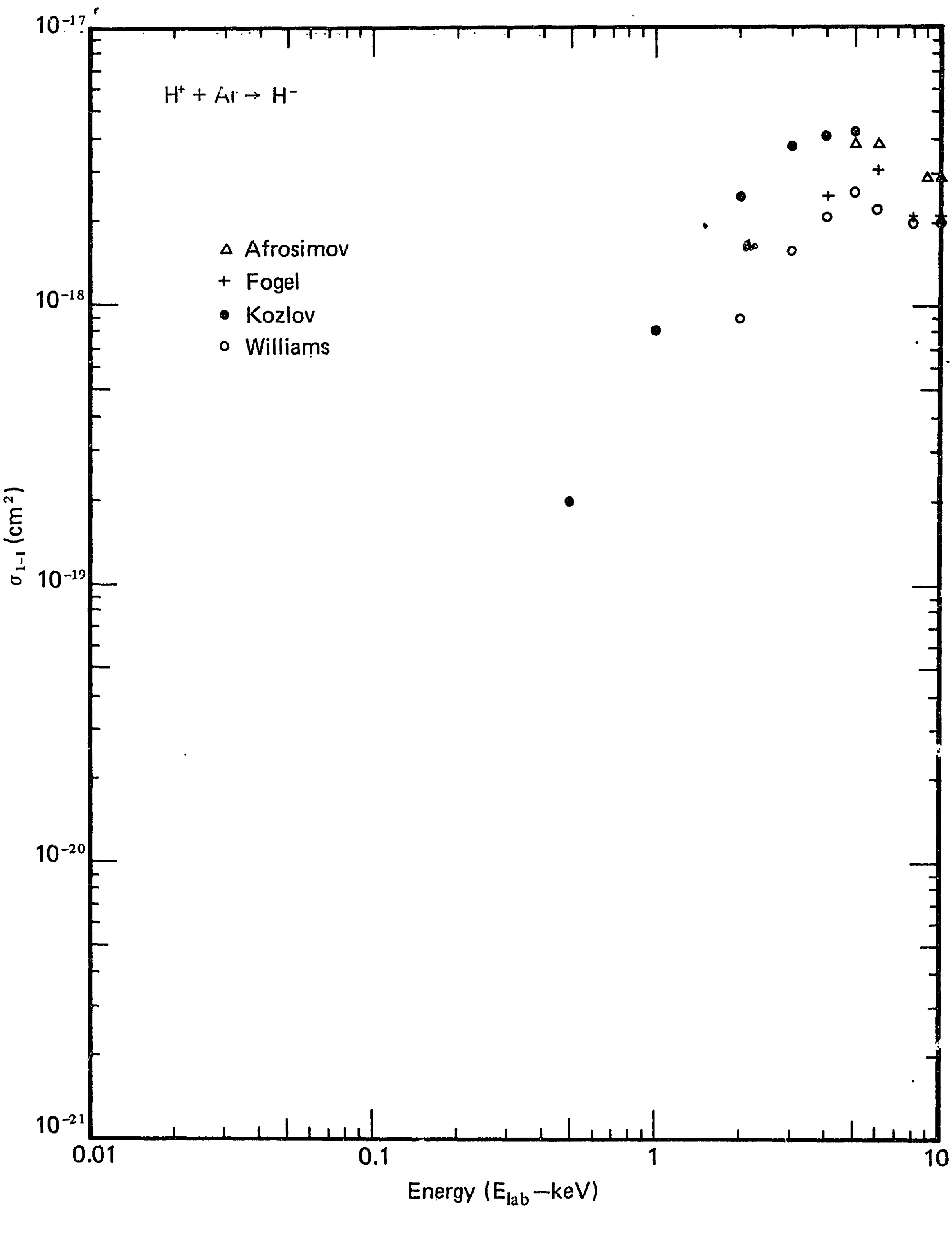

Fig. 28 Cross sections for two-electron capture of H^+ beams in Ar

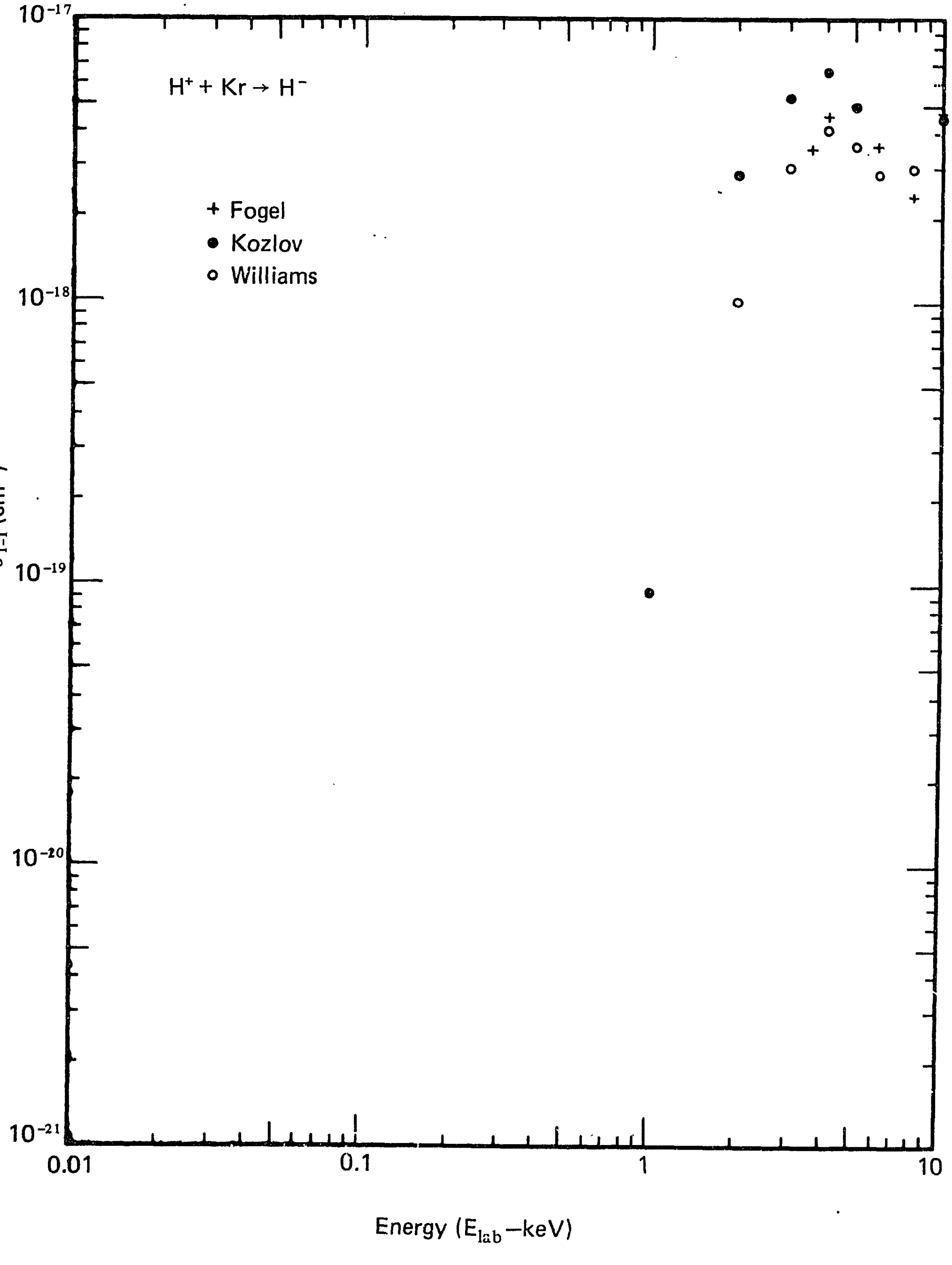

Fig. 29 Cross sections for two-electron capture of H^+ beams in Kr

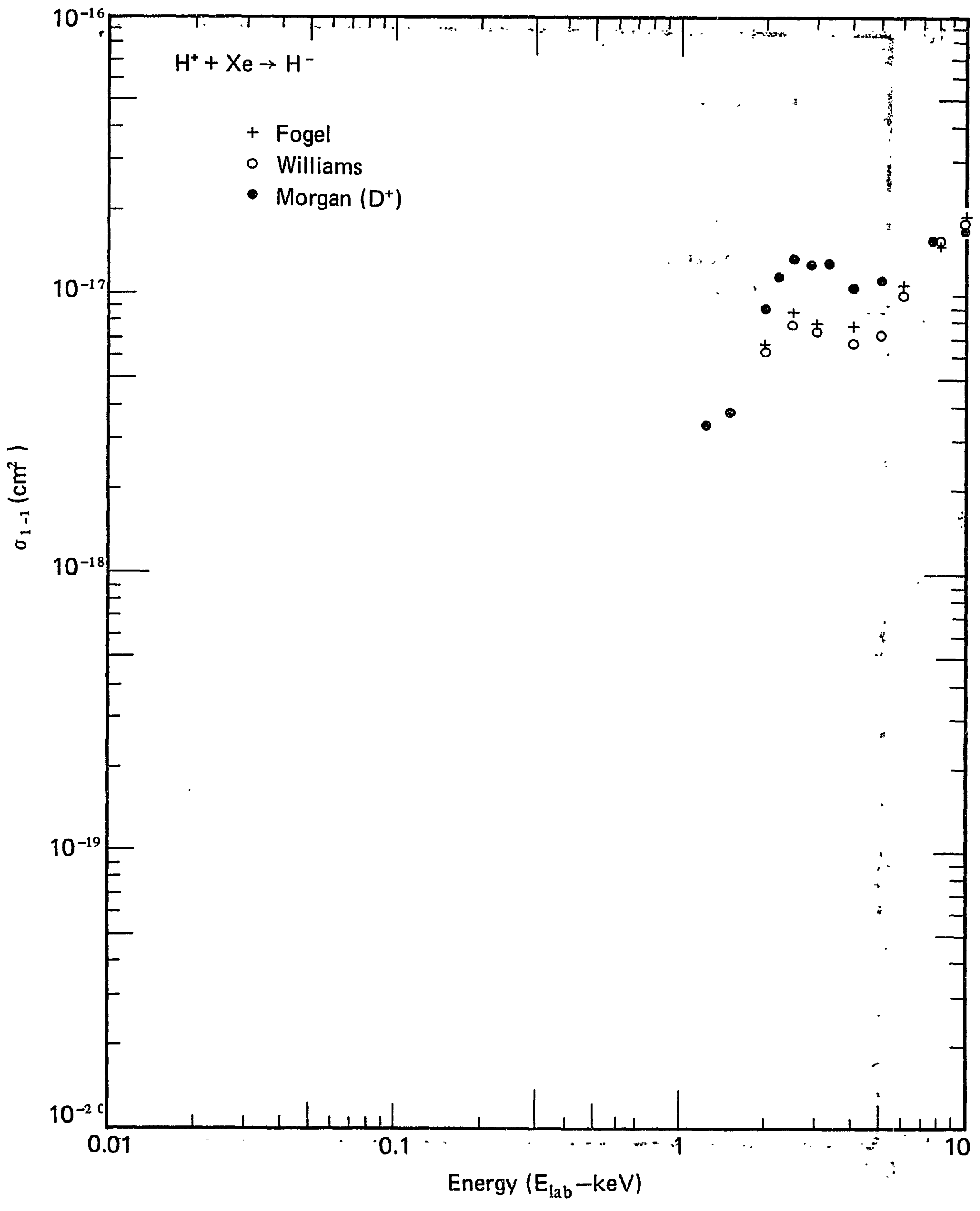

Fig. 30 Cross sections for two-electron capture of H^+ beams in Xe

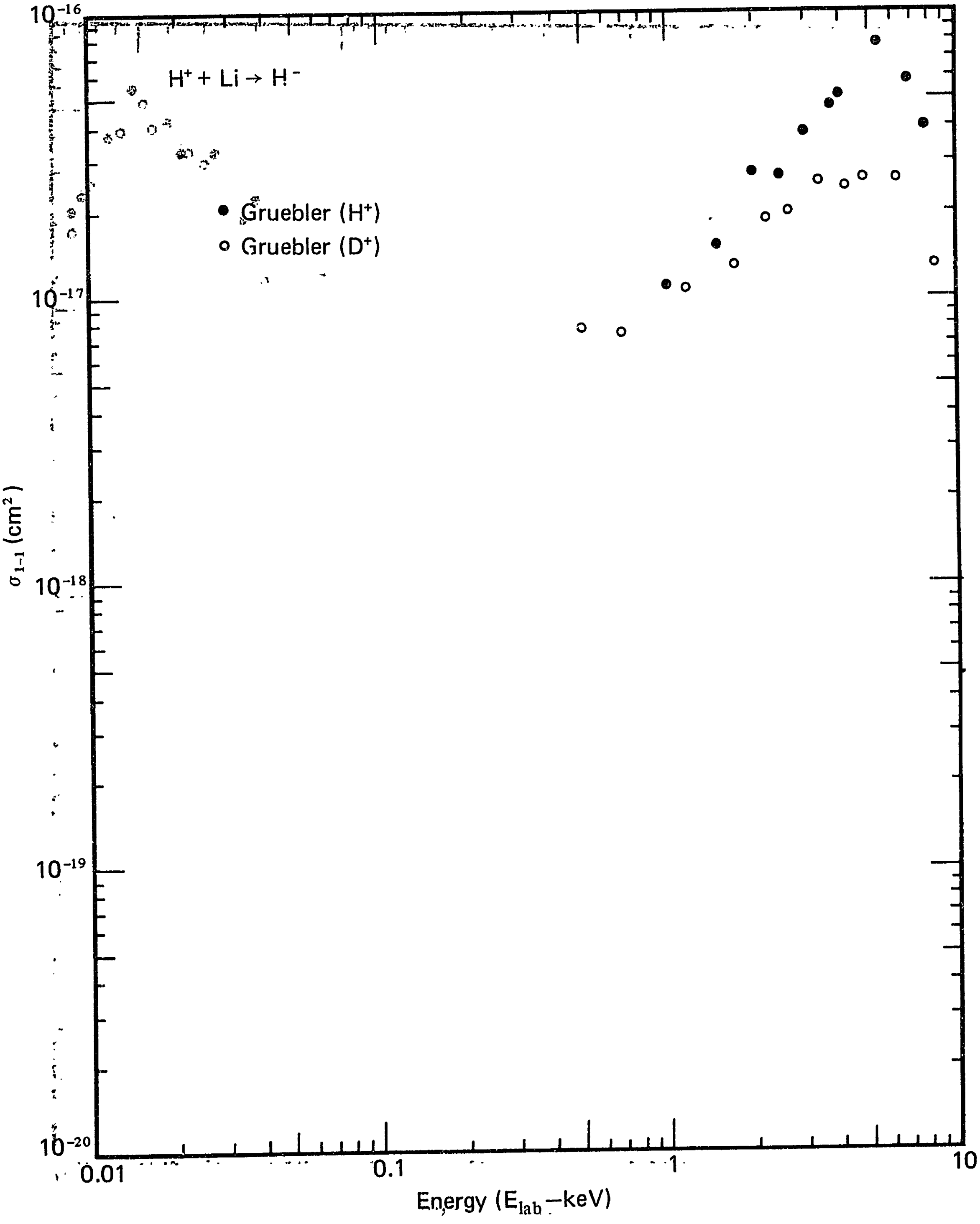

Fig. 31 Cross-sections for two-electron capture of H^+ beams in Li

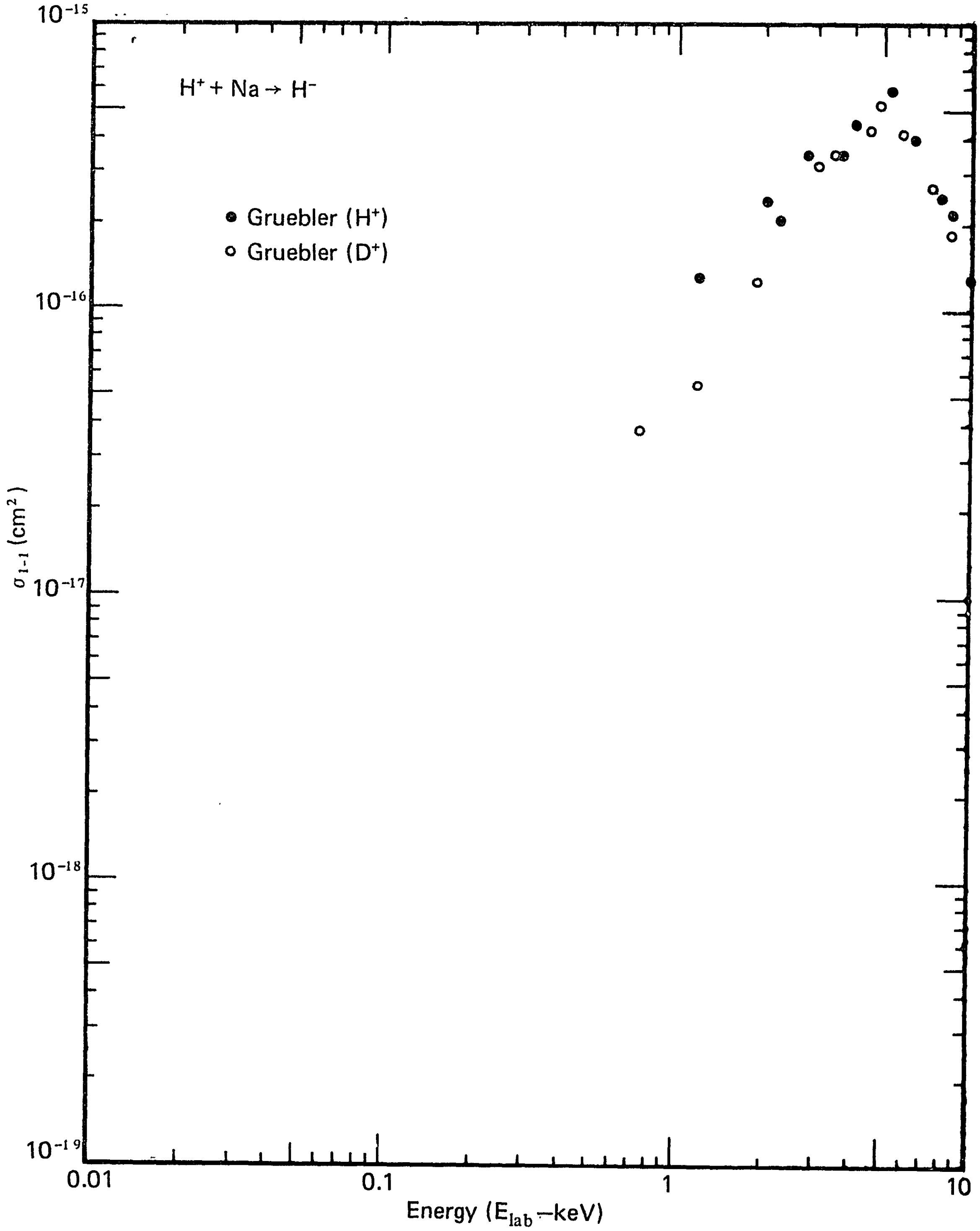

Fig. 32 Cross sections for two-electron capture of H^+ beams in Na

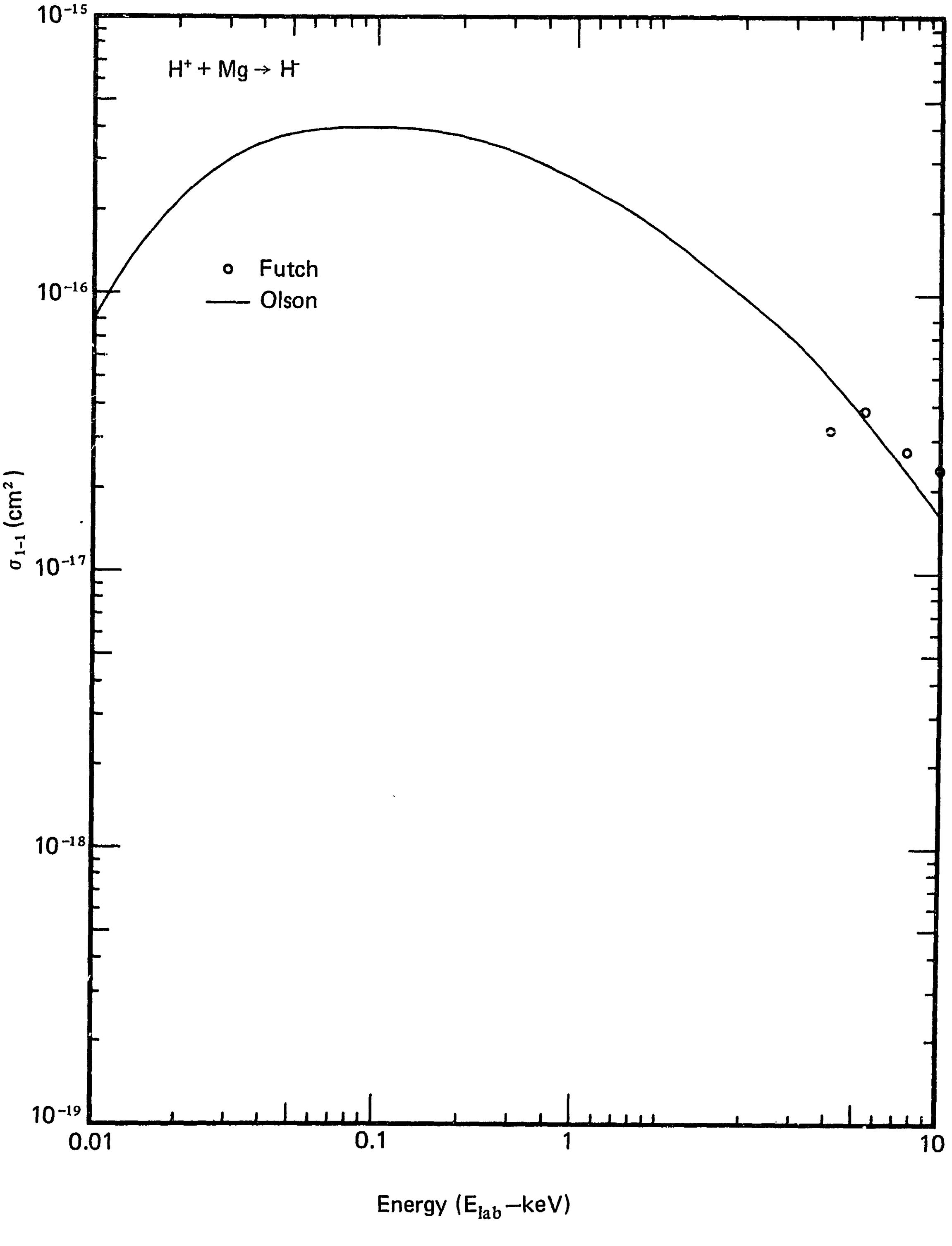

Fig. 33 Cross sections for two-electron capture of H^+ beams in Mg

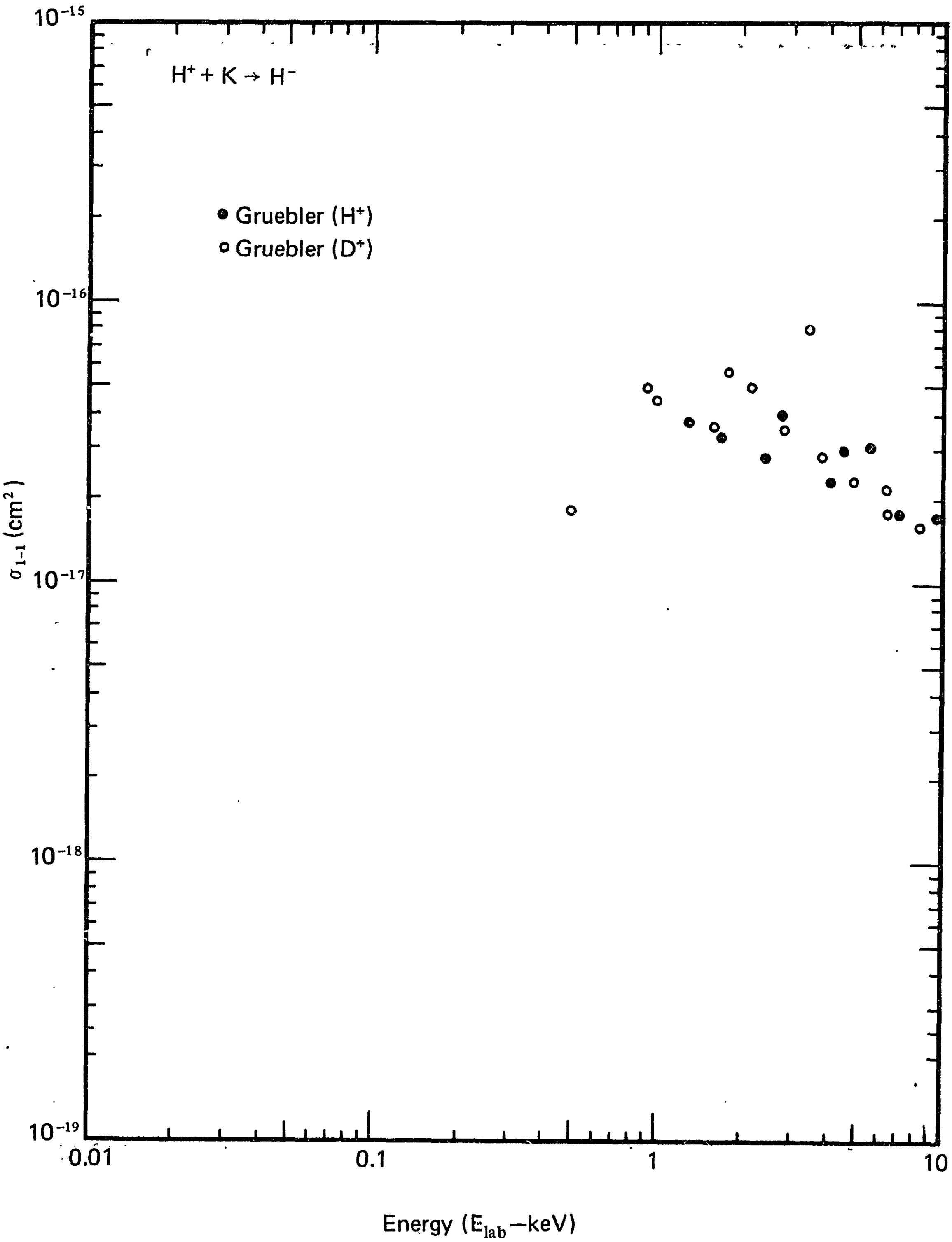

Fig. 34 Cross sections for two-electron capture of H^+ beams in K

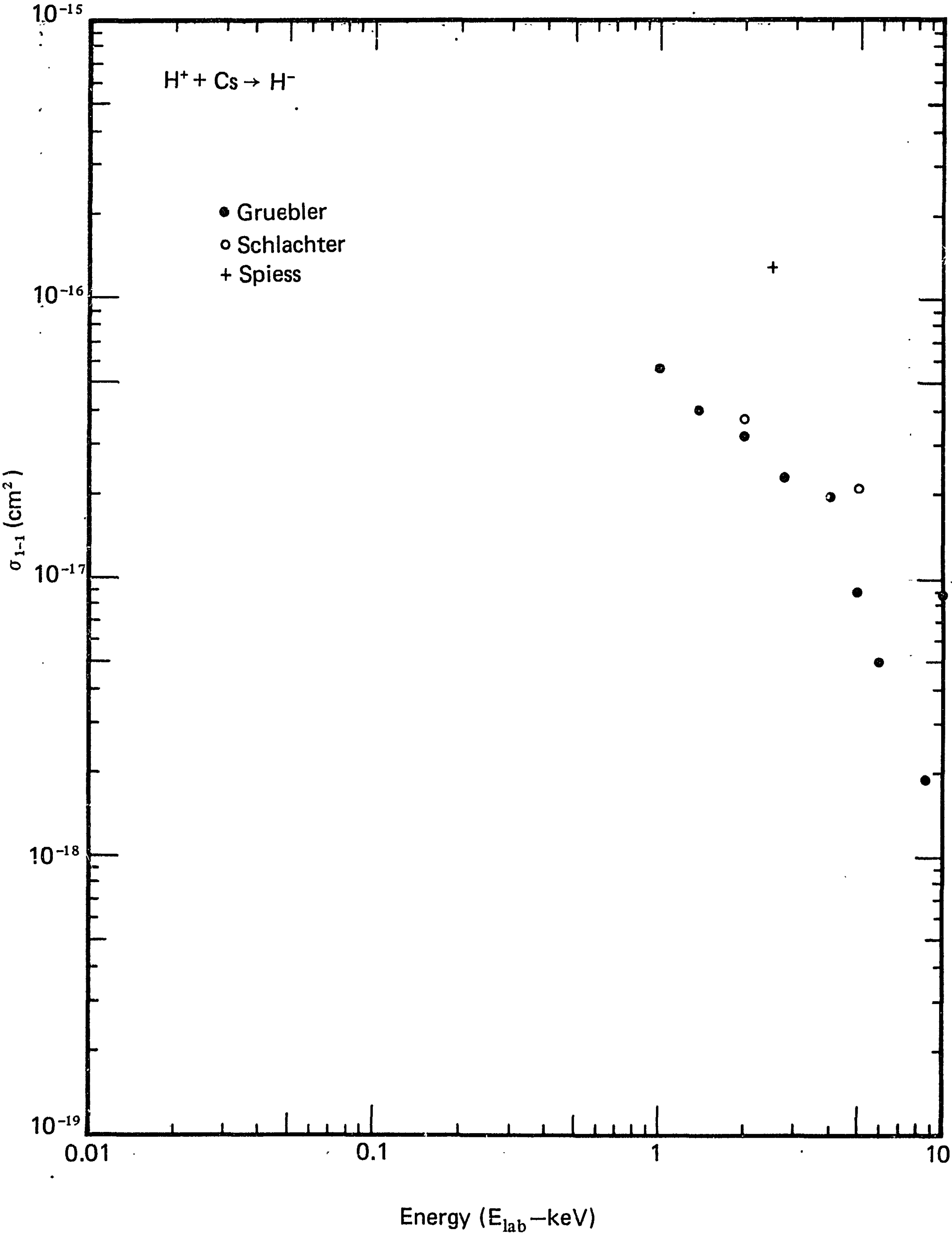

Fig. 35 Cross sections for two-electron capture of H^+ beams in Cs

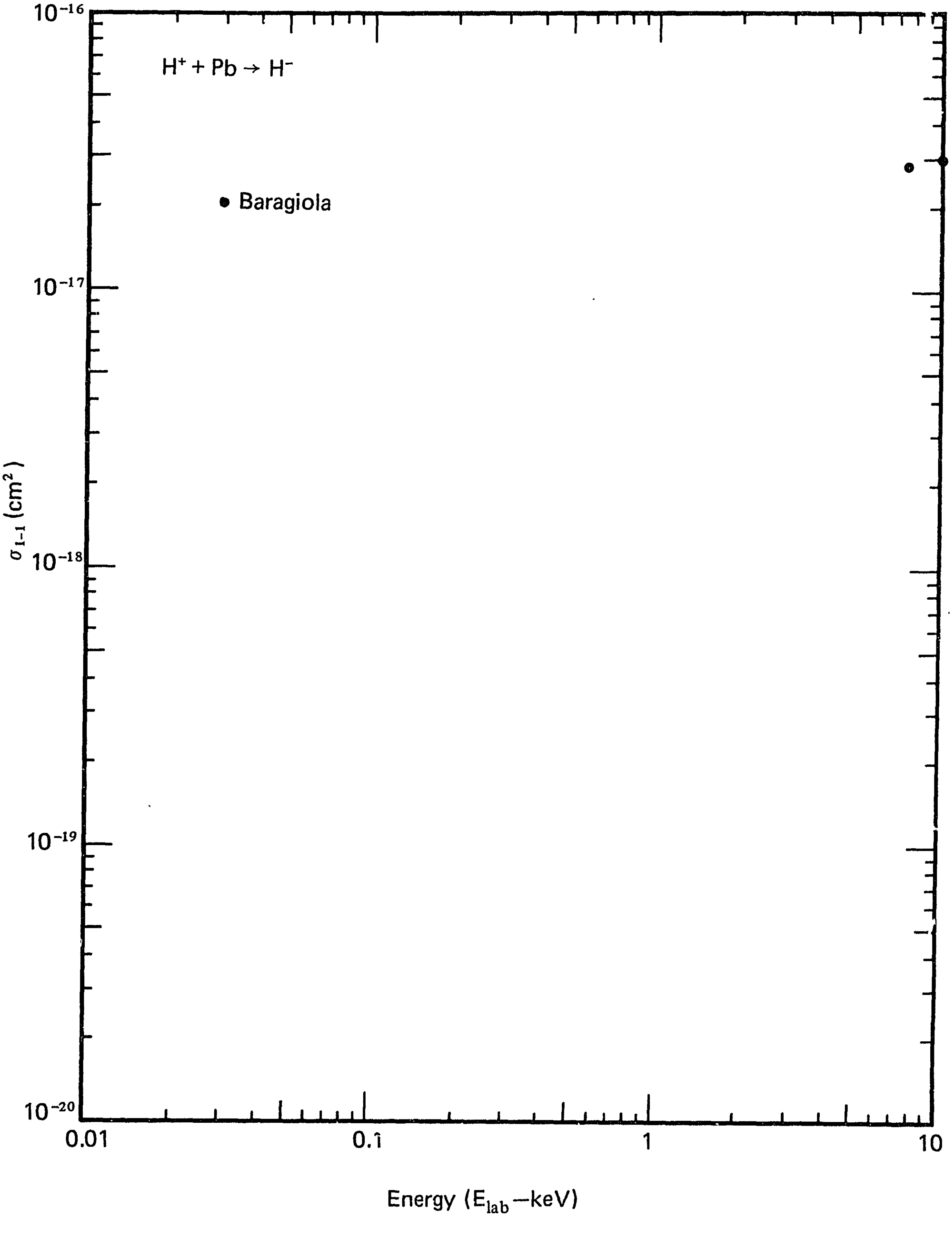

Fig. 36 Cross sections for two-electron capture of H^+ beams in Pb

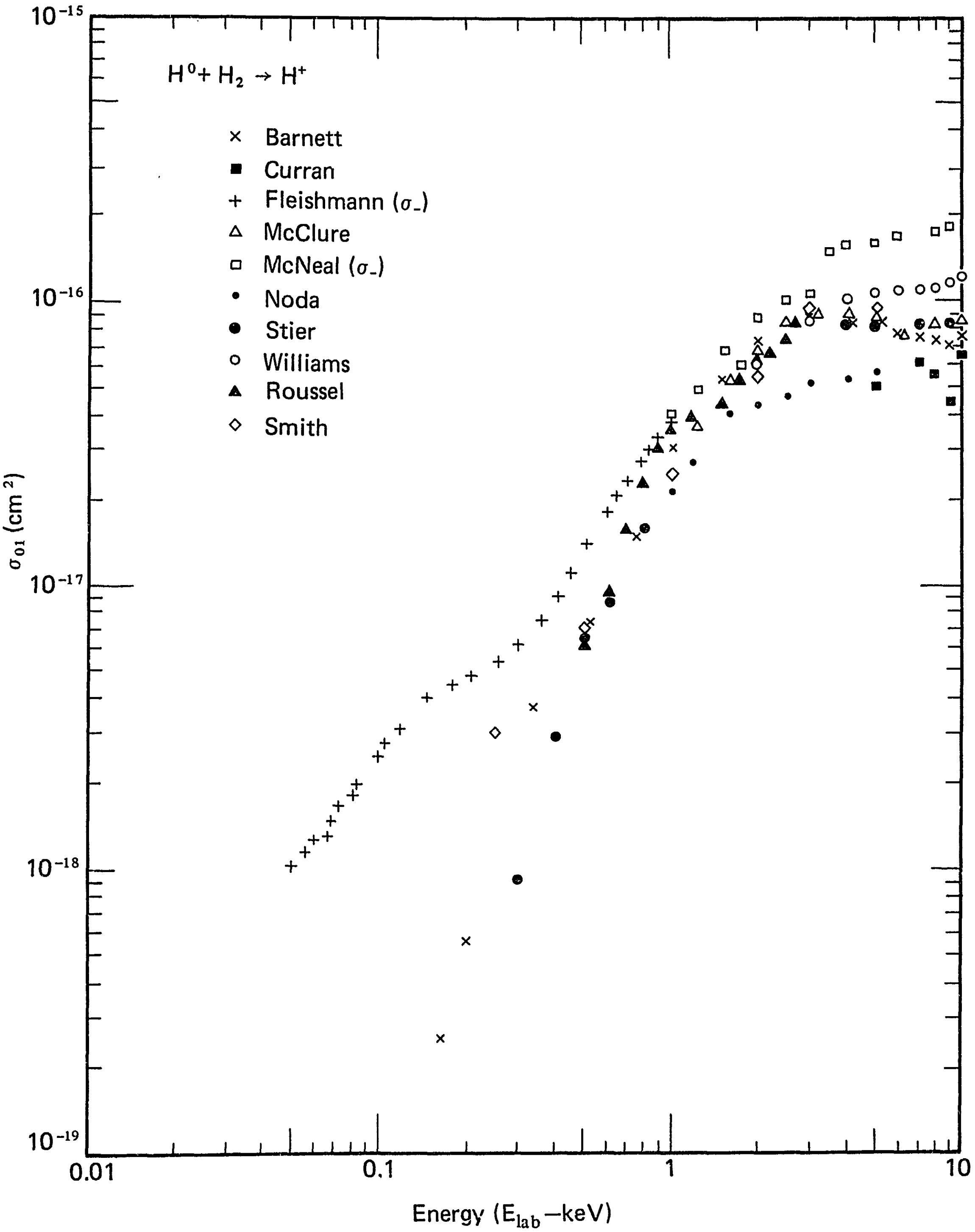

Fig. 37 Cross sections for one-electron loss of H^0 beams in H_2

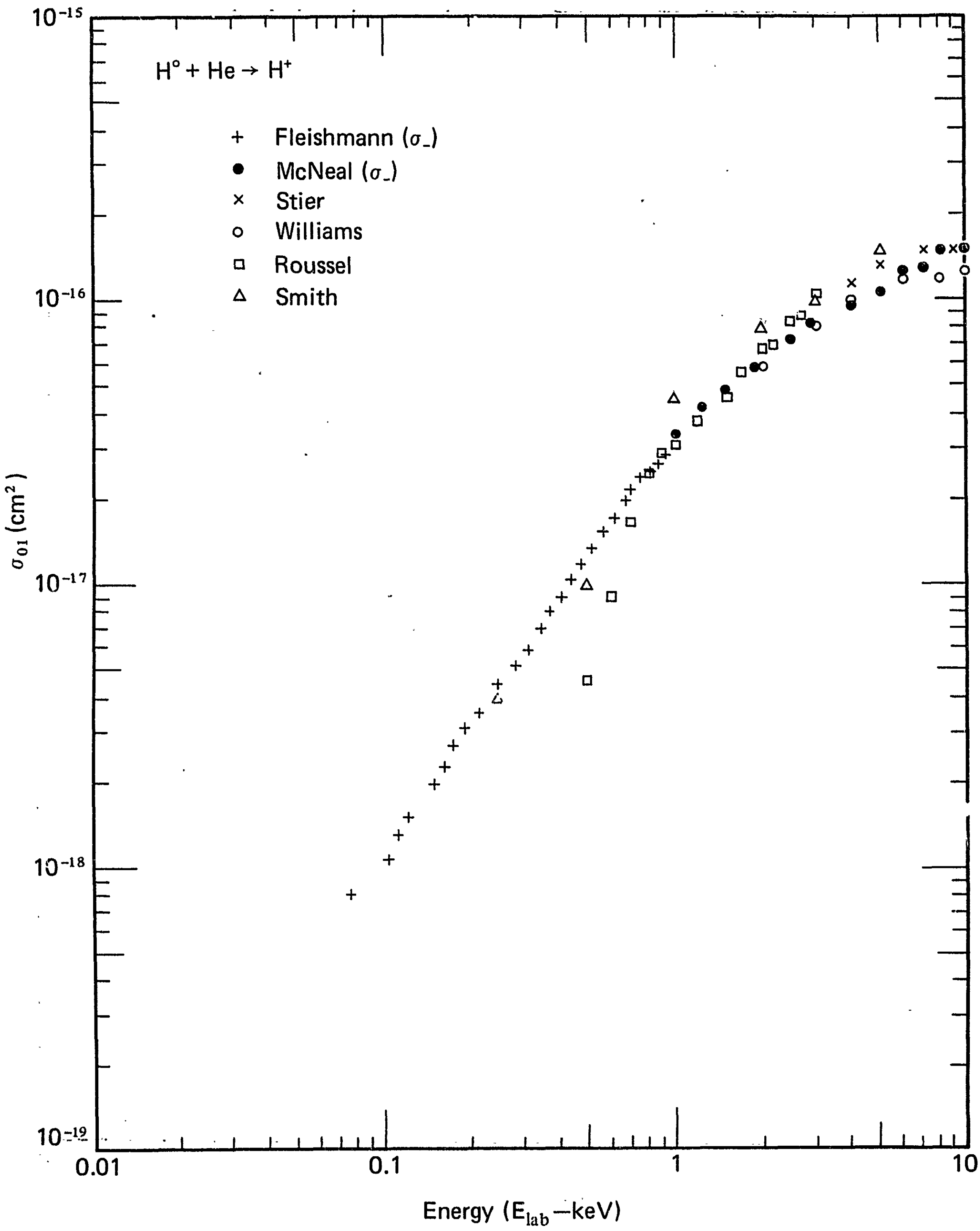

Fig. 38 Cross sections for one-electron loss of H^0 beams in He

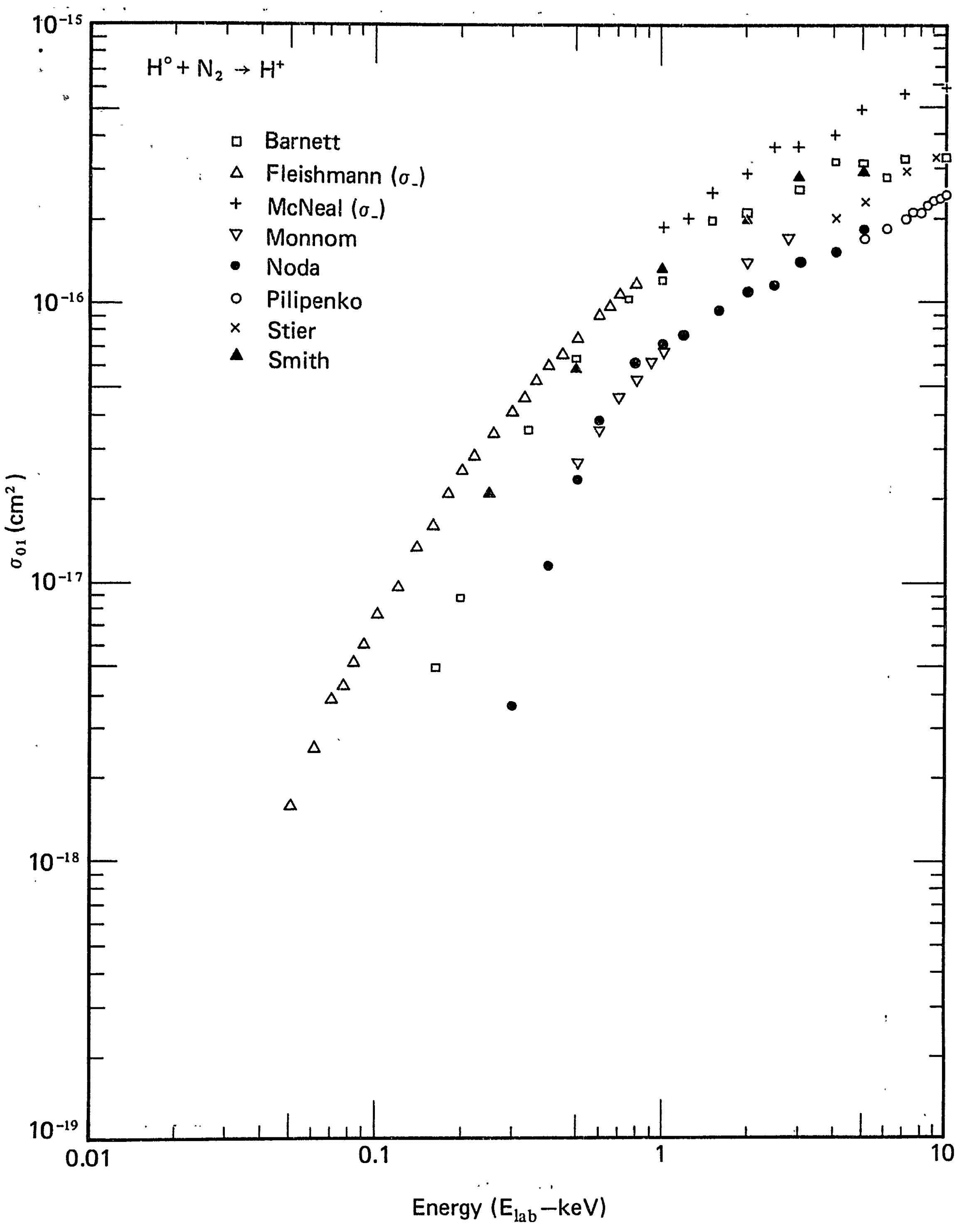

Fig. 39 Cross sections for one-electron loss of H^0 beams in N_2

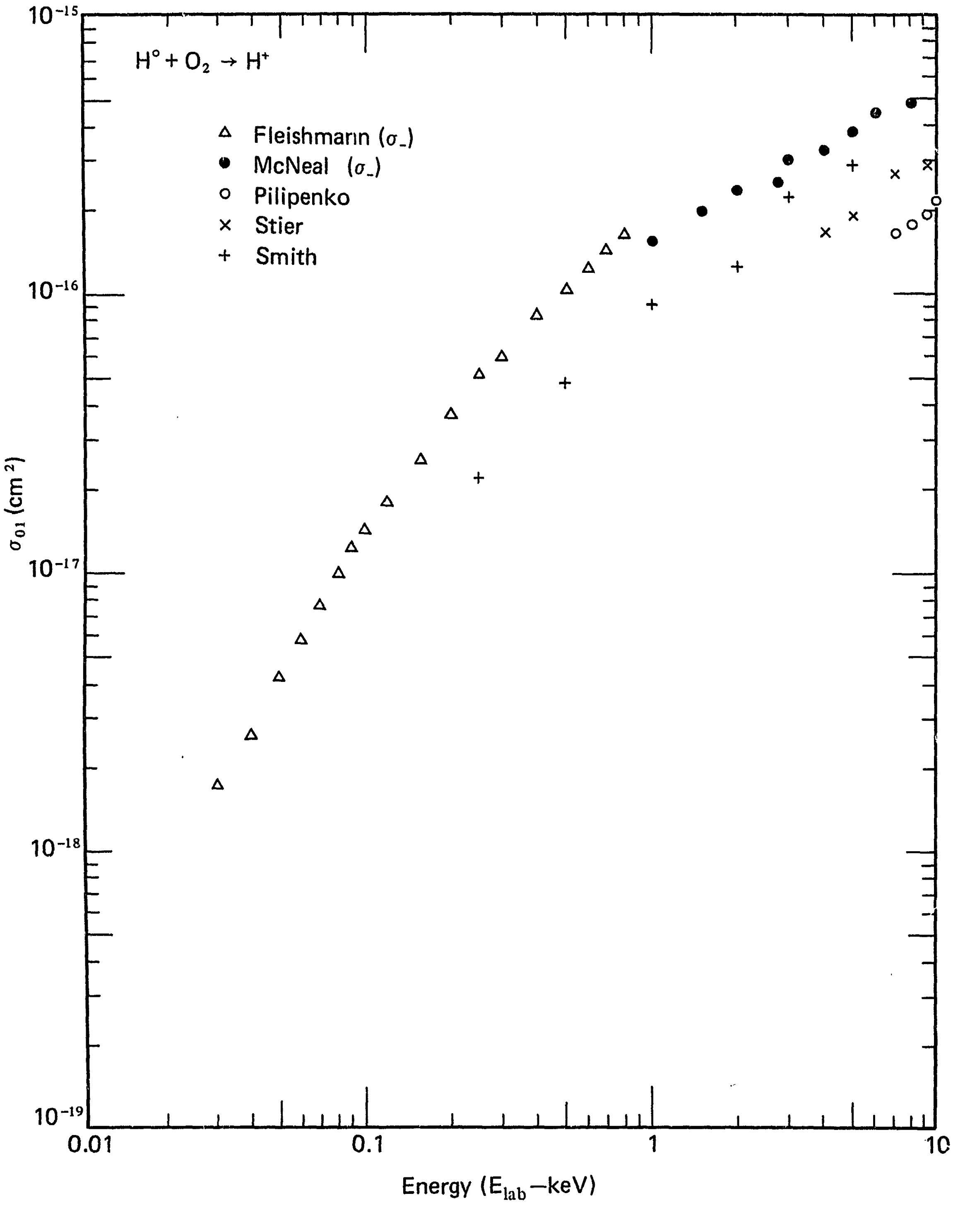

Fig. 40 Cross sections for one-electron loss of H^0 beams in O_2.

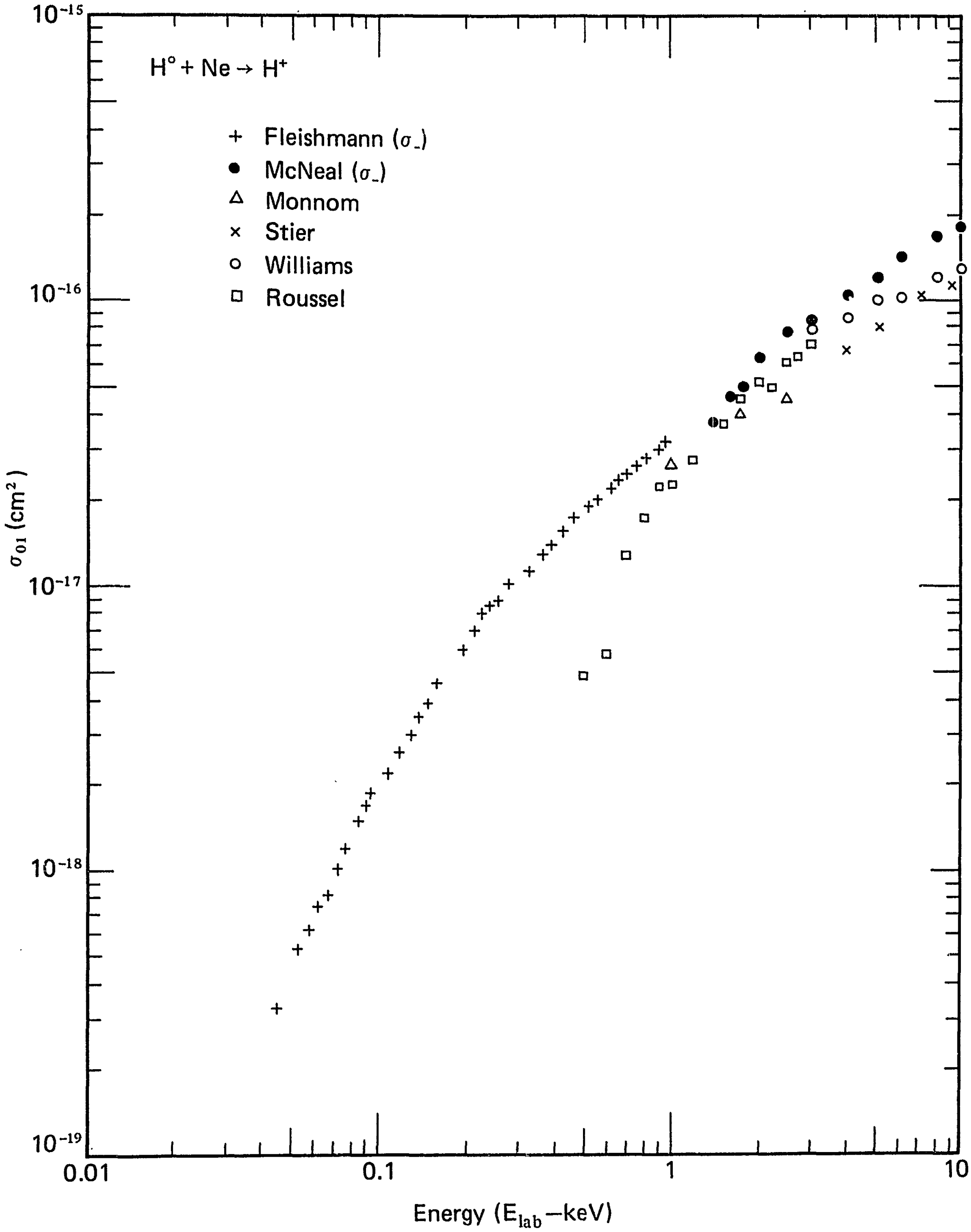

Fig. 41 Cross sections for one-electron loss of H^0 beams in Ne

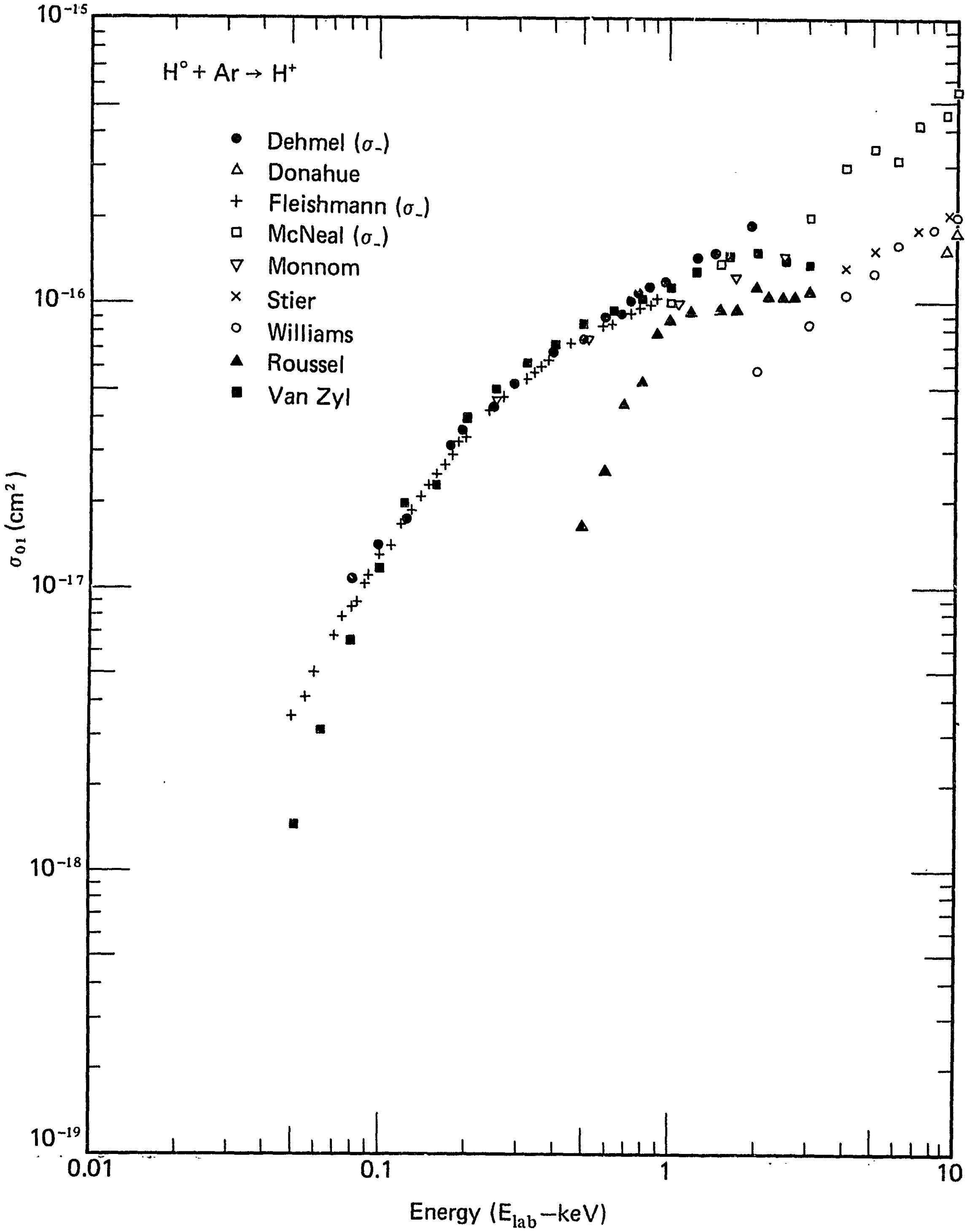

Fig. 42 Cross sections for one-electron loss of H^0 beams in Ar

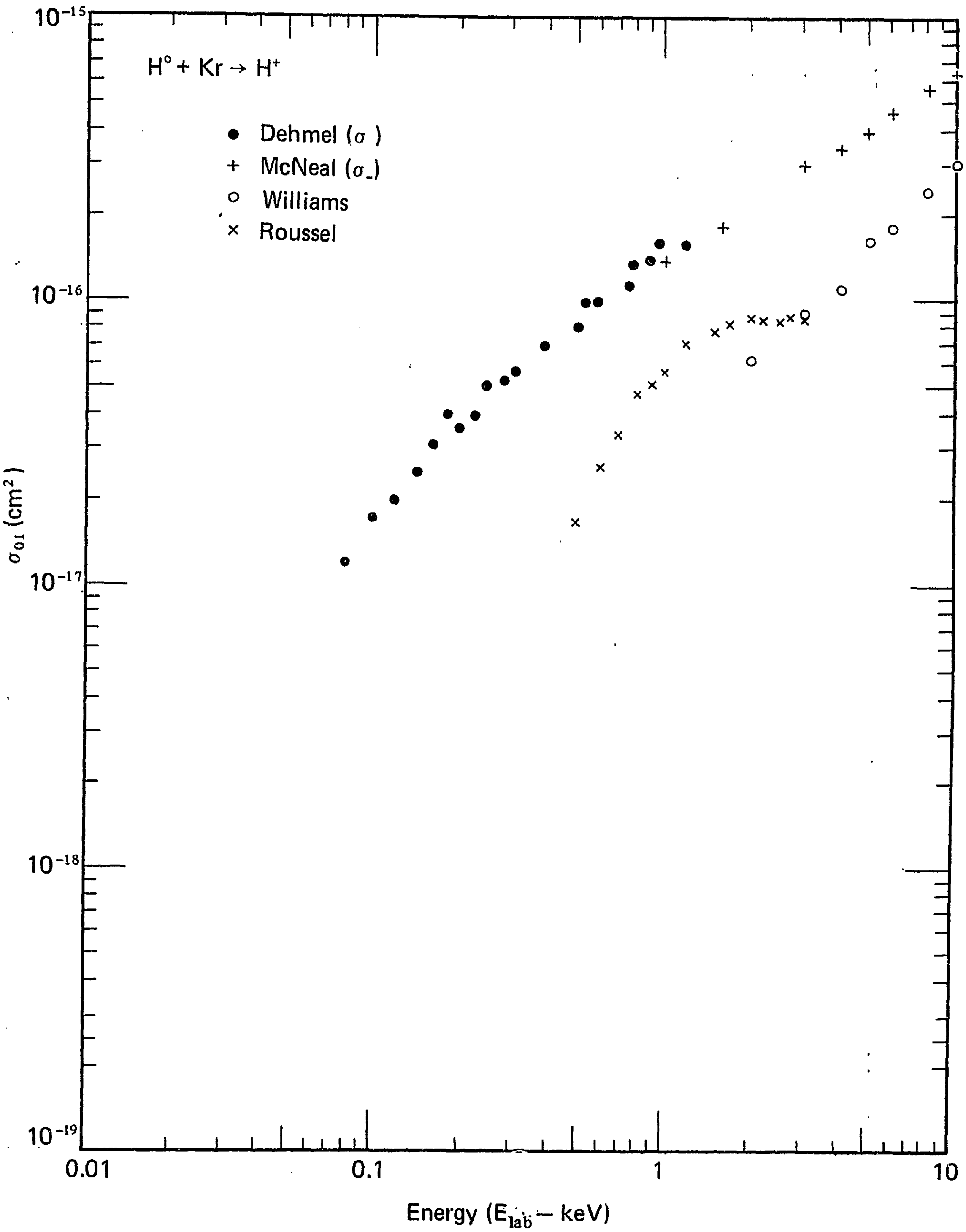

Fig. 43 Cross sections for one-electron loss of H^0 beams in Kr

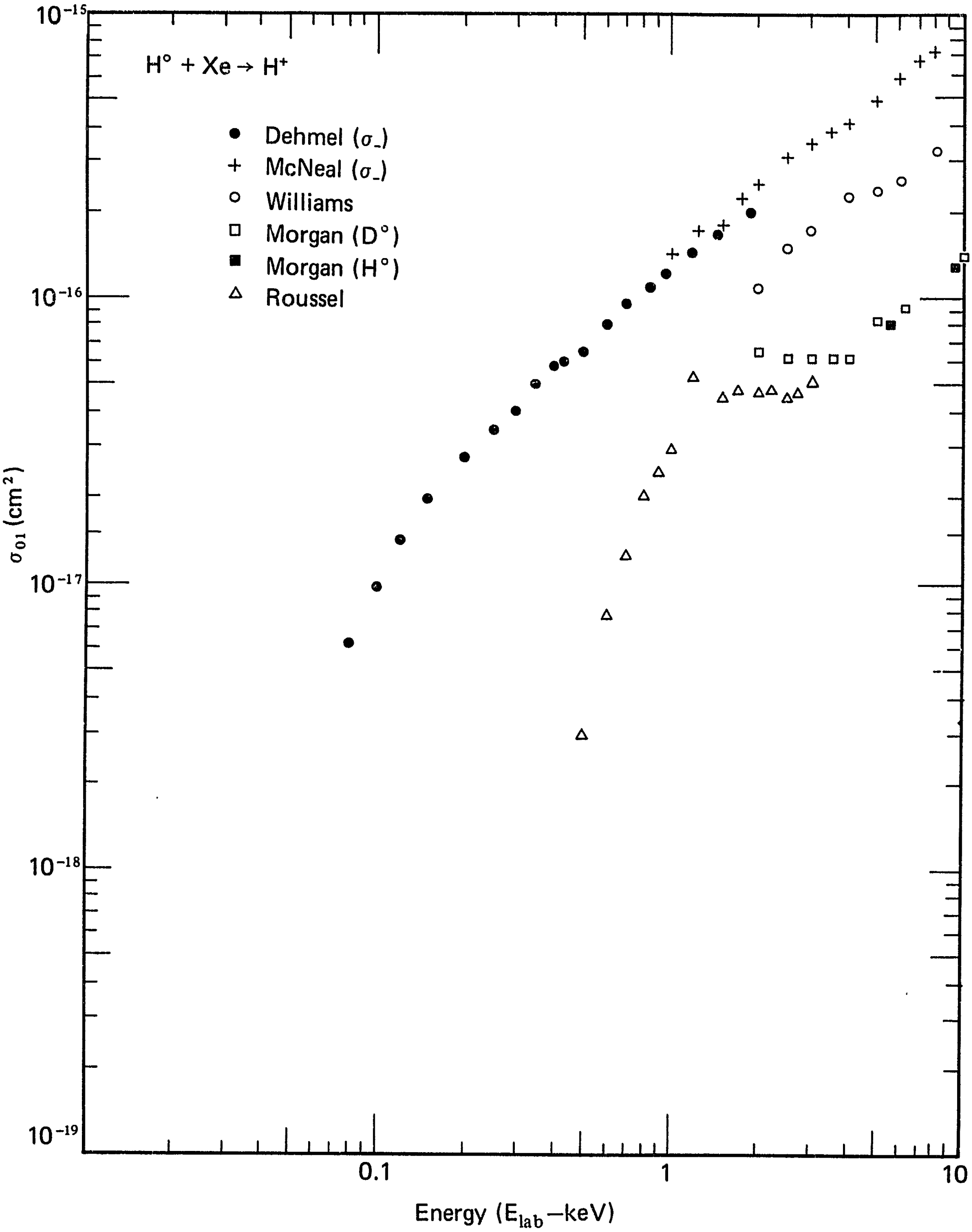

Fig. 44 Cross sections for one-electron loss of H^0 beams in Xe

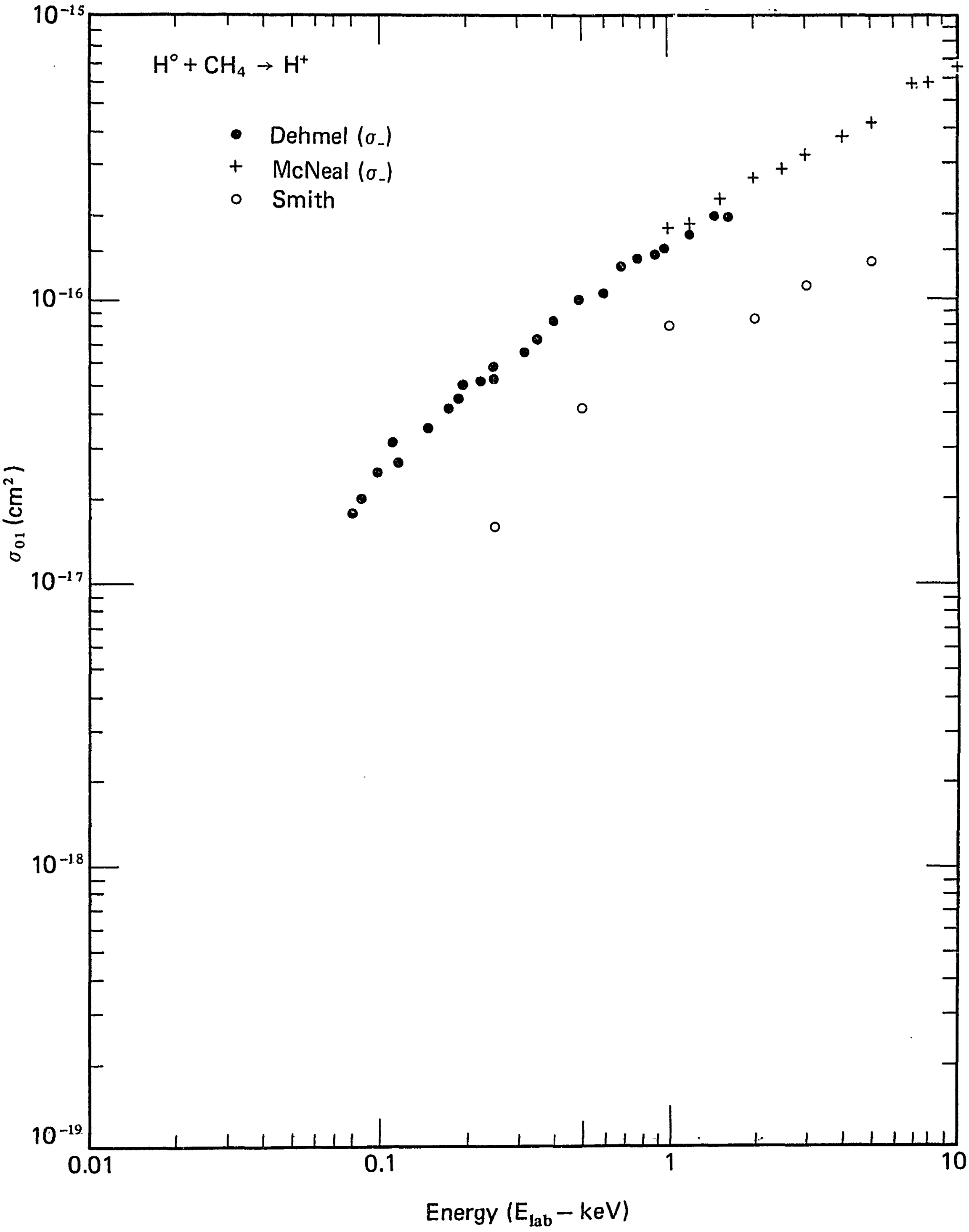

Fig. 45 Cross sections for one-electron loss of H^0 beams in CH_4

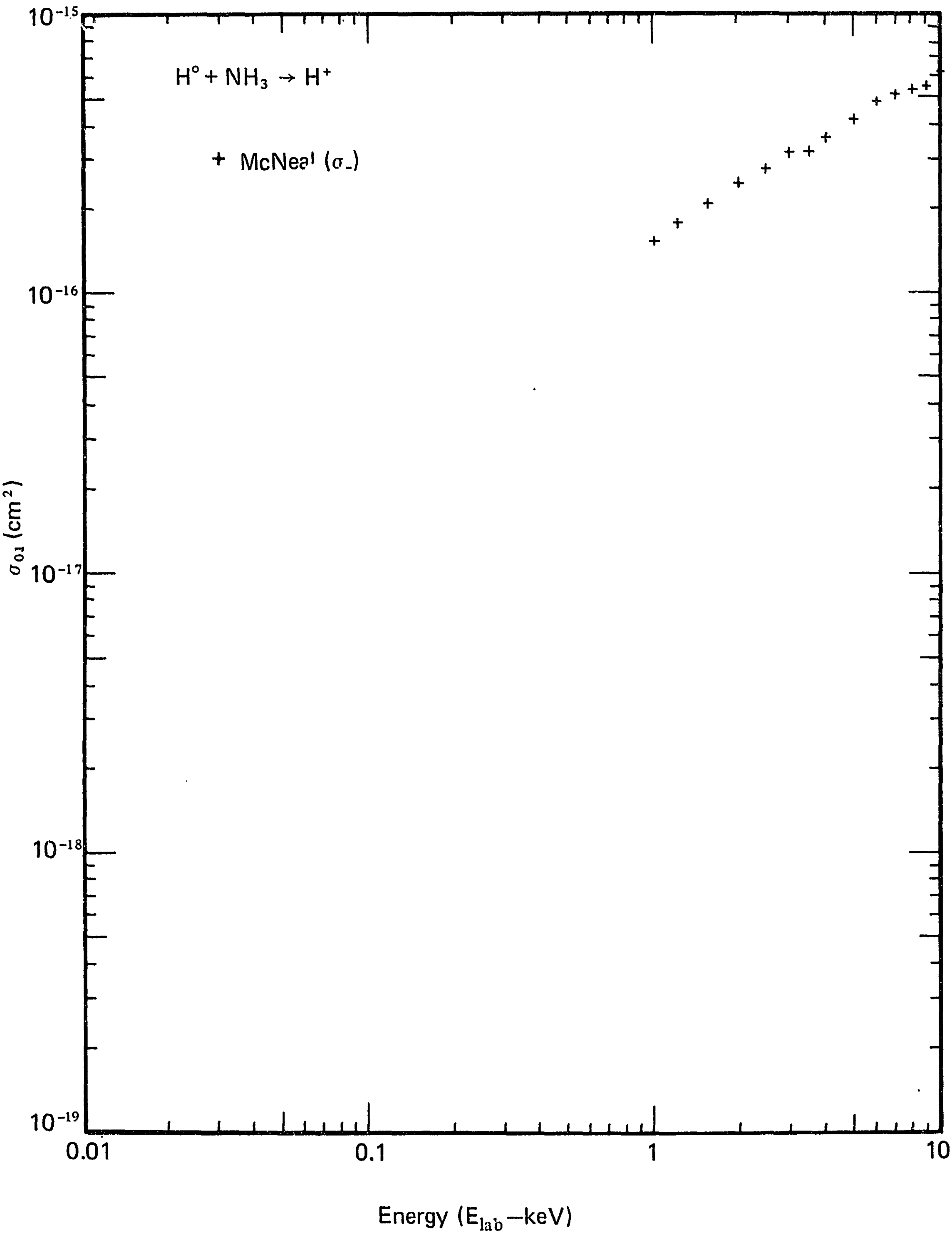

Fig. 46 Cross sections for one-electron loss of H^0 beams in NH_3

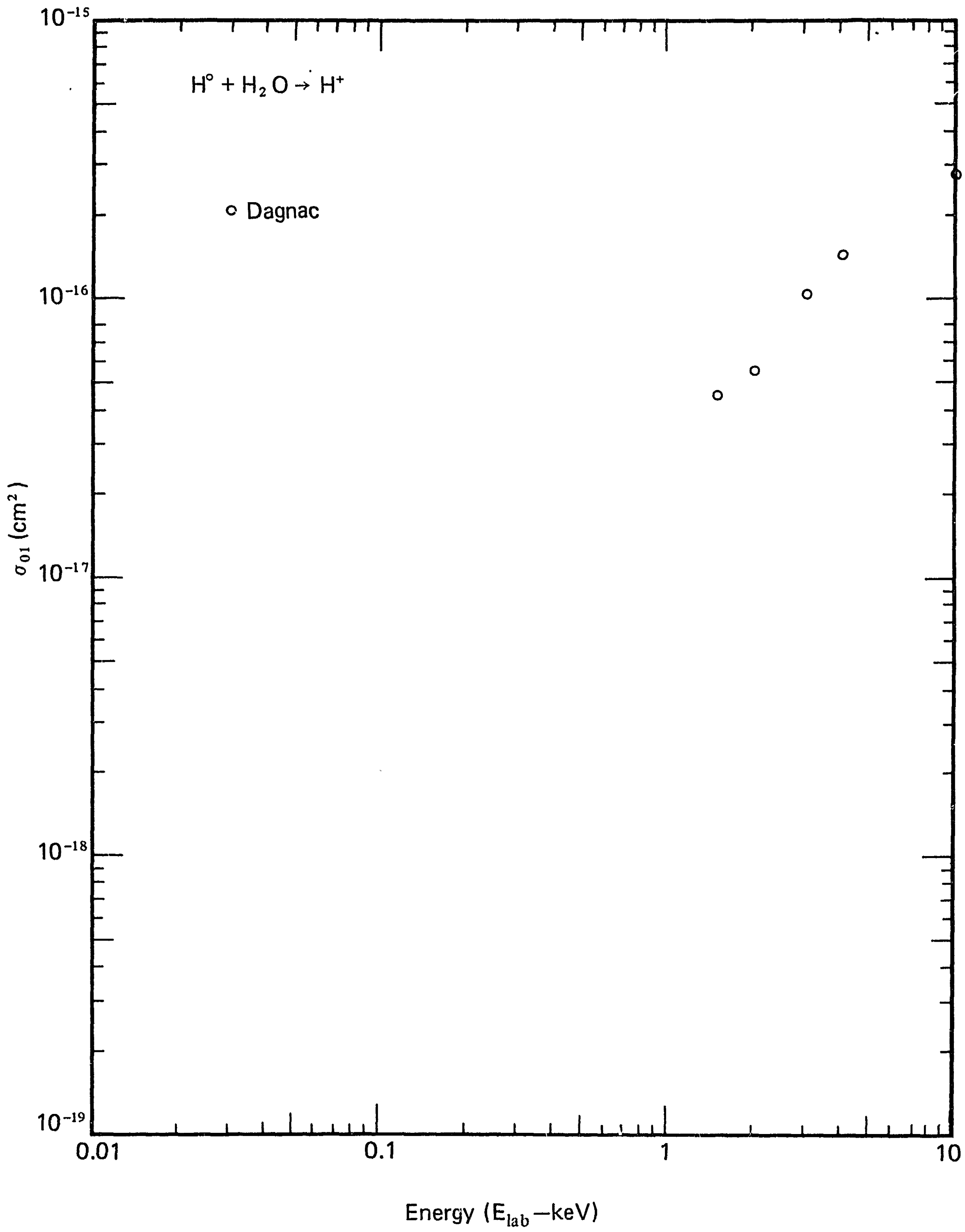

Fig. 47 Cross sections for one-electron loss of H^0 beams in H_2O

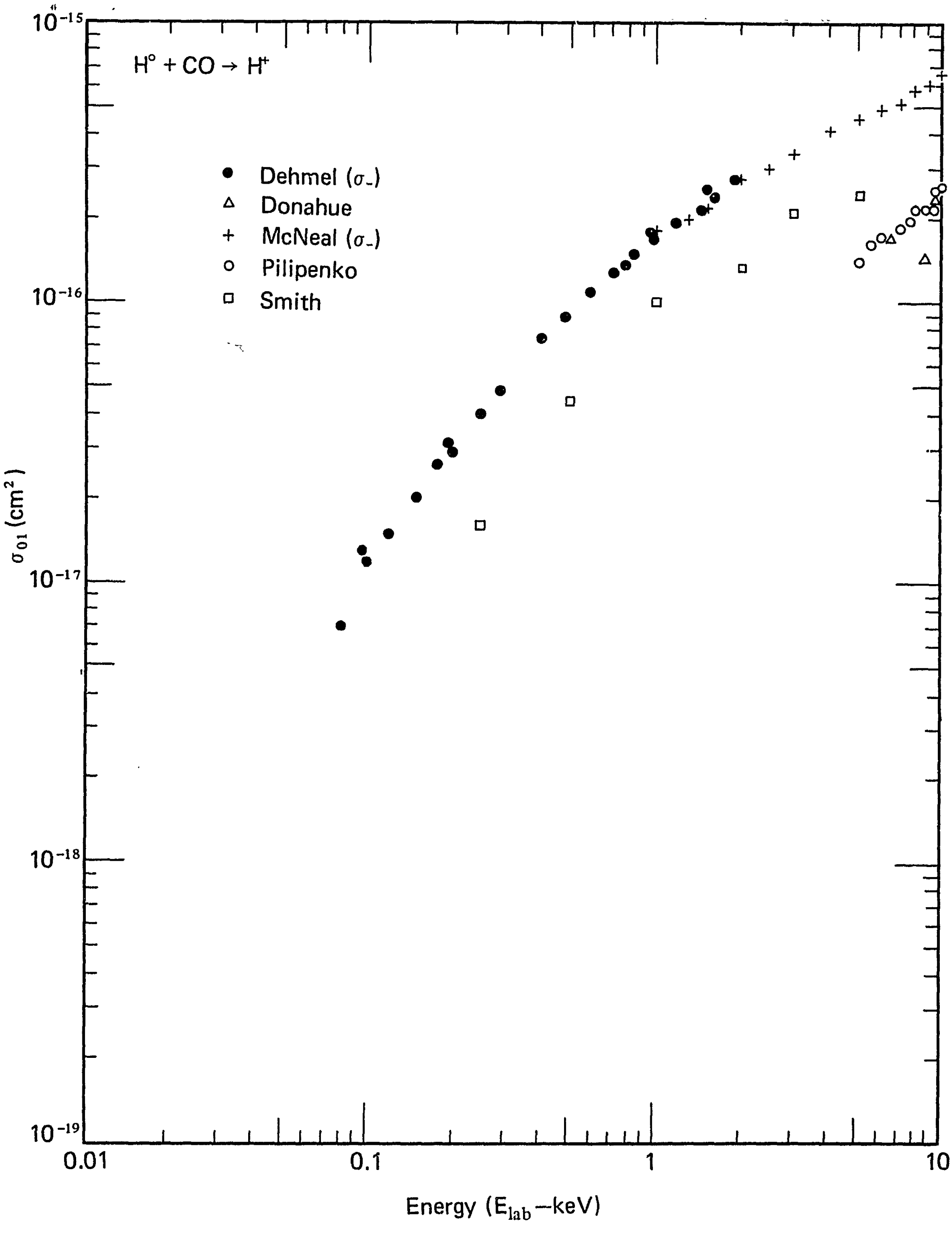

Fig. 48 Cross sections for one-electron loss of H^0 beams in CO

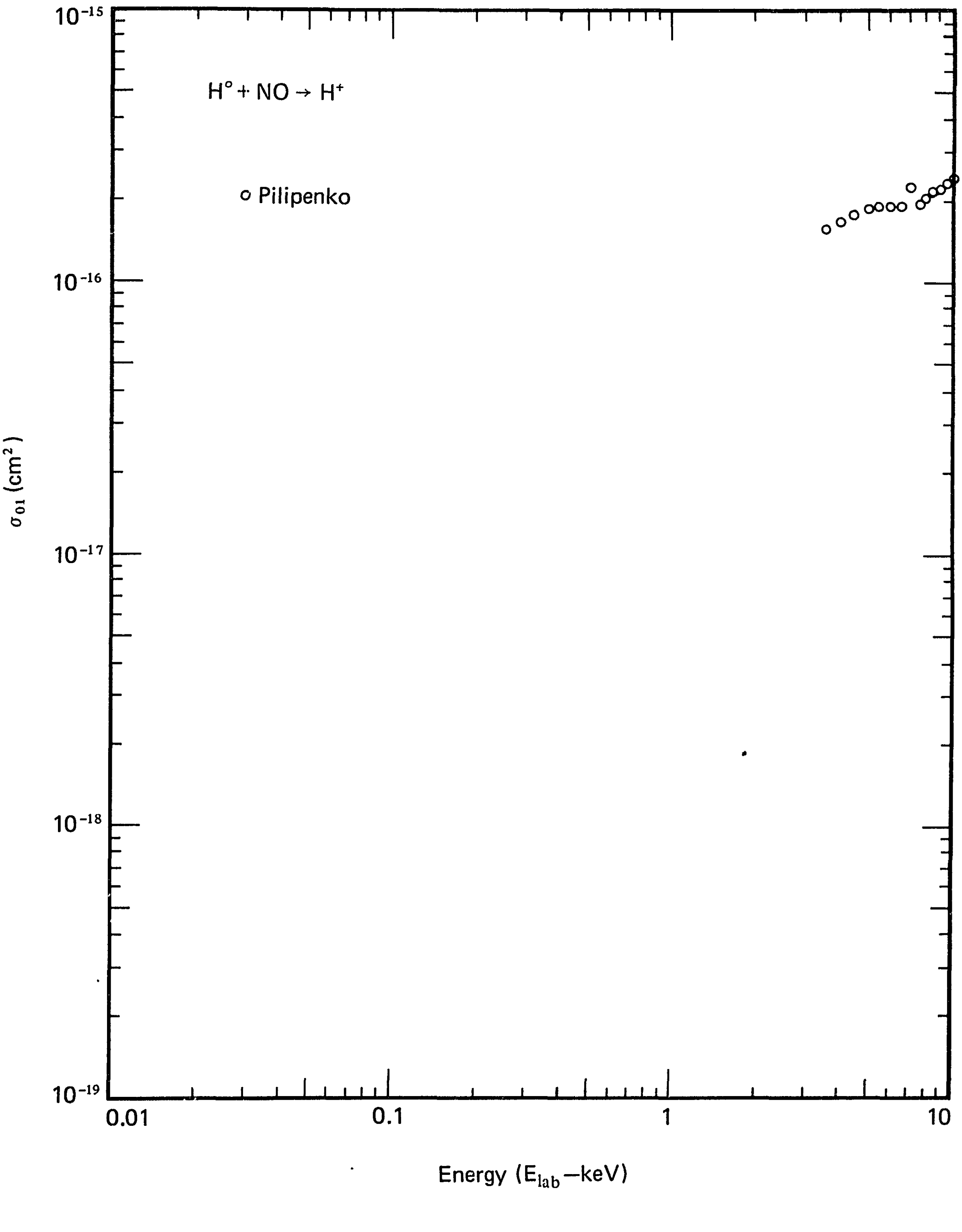

Fig. 49 Cross sections for one-electron loss of H^0 beams in NO

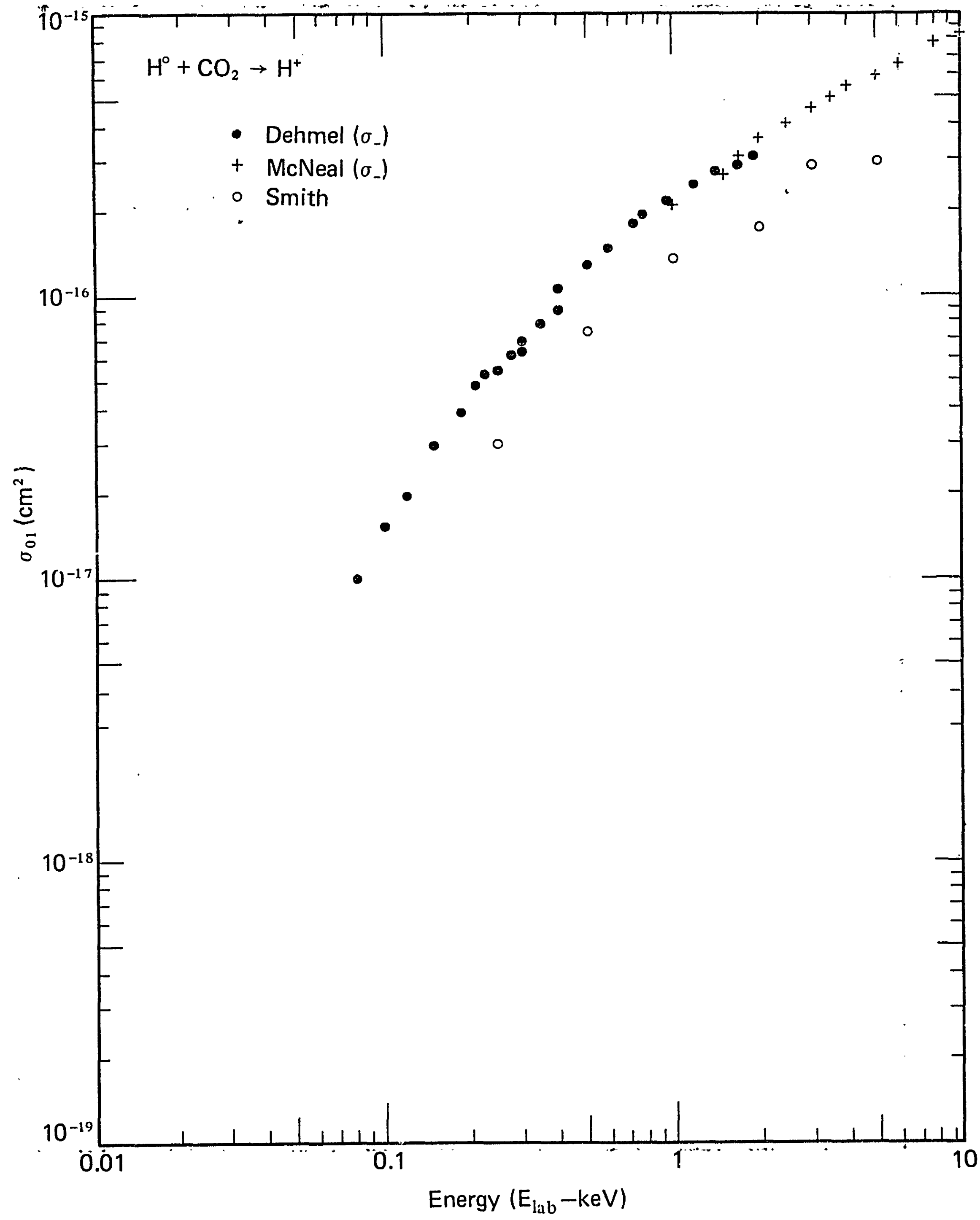

Fig. 50 Cross sections for one-electron loss of H^0 beams in CO_2

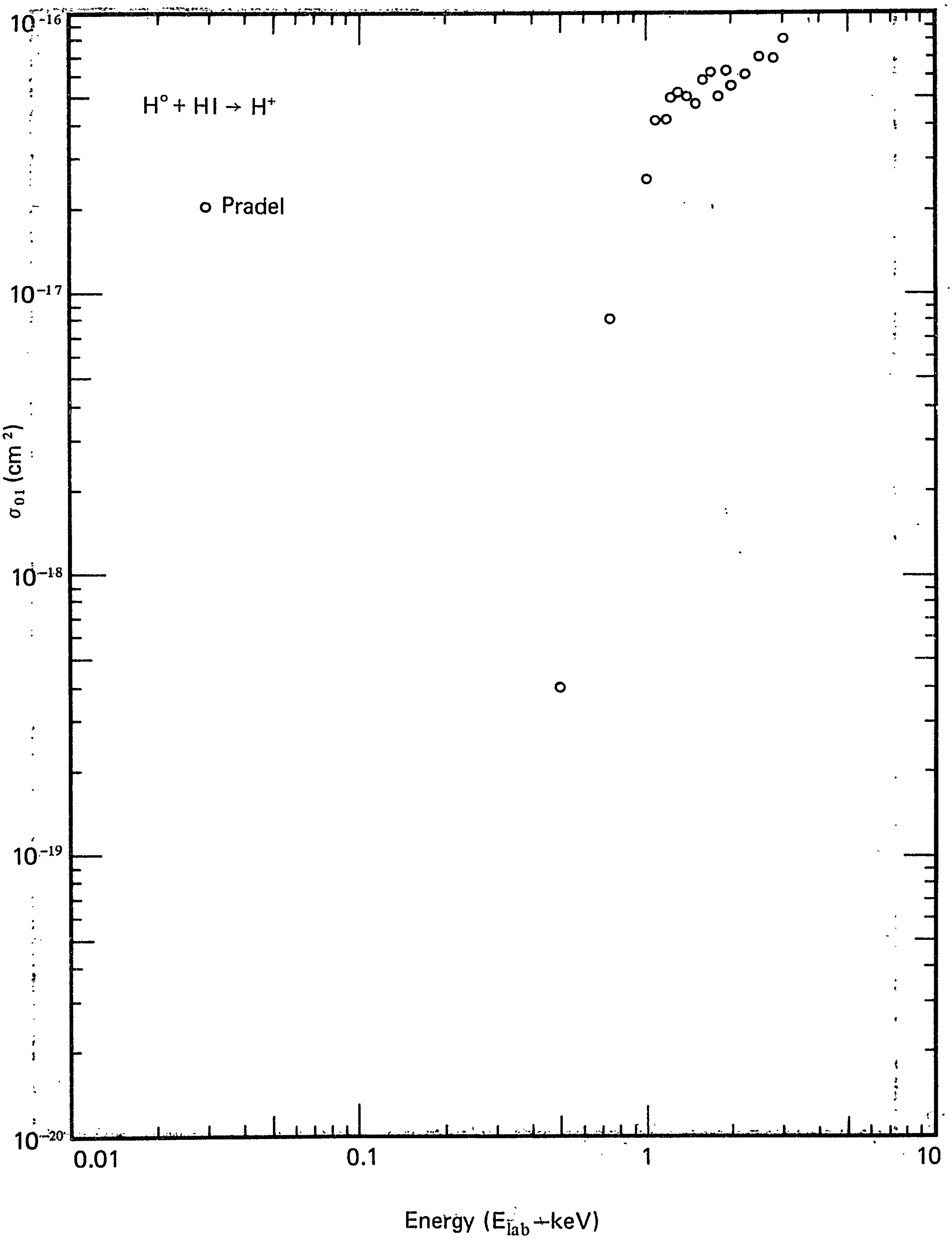

Fig. 51 Cross sections for one-electron loss of H^0 beams in HI

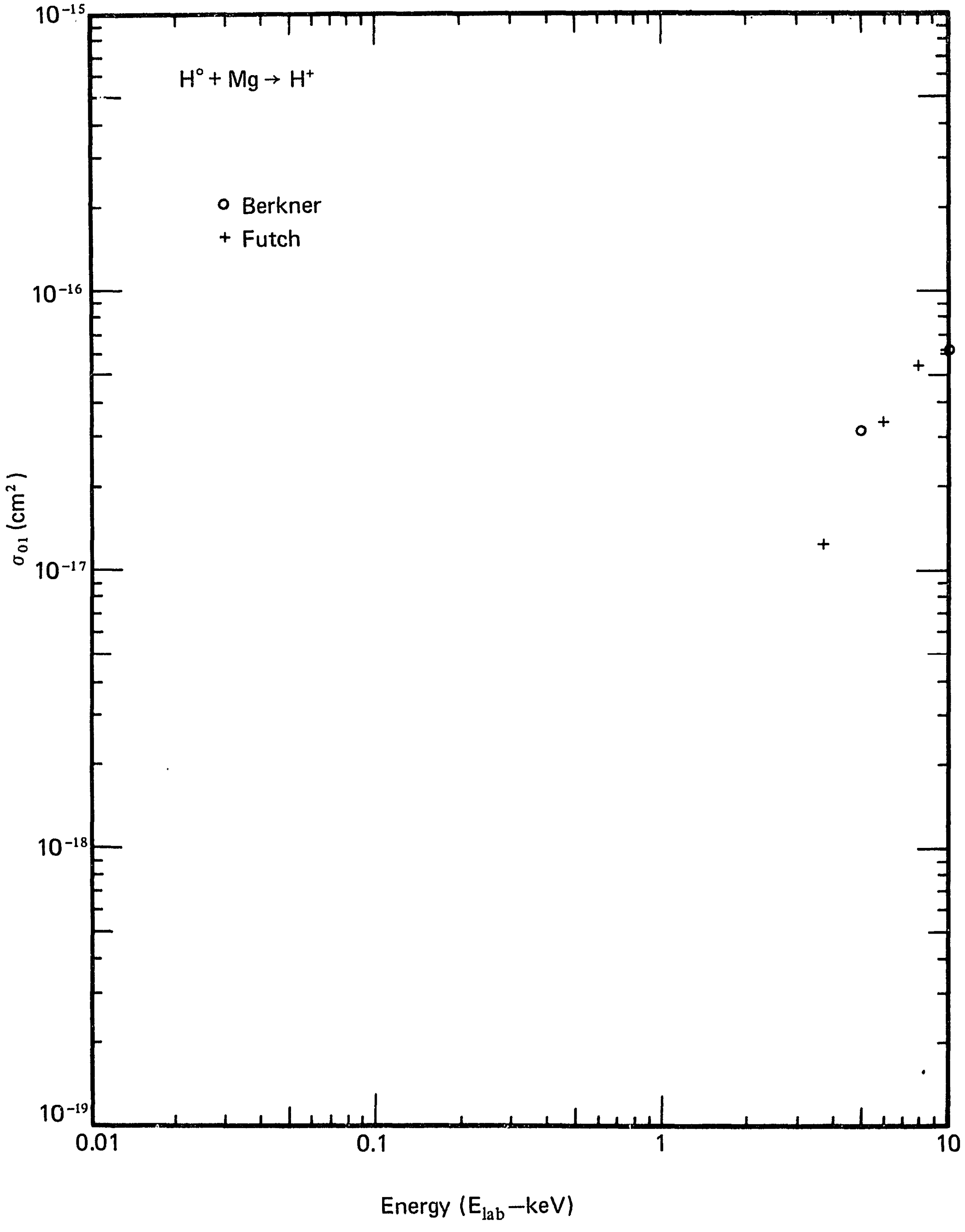

Fig. 52 Cross sections for one-electron loss of H^0 beams in Mg

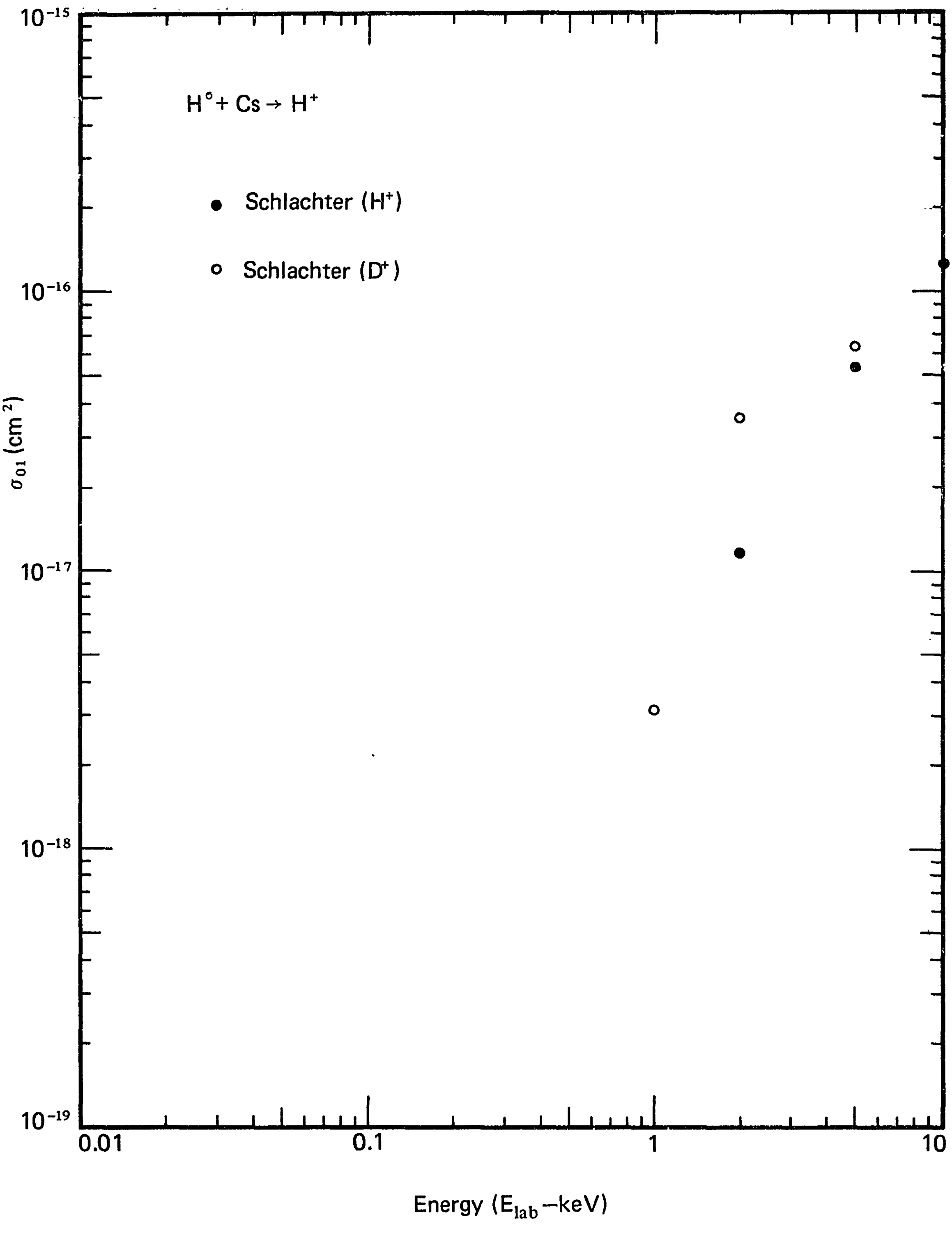

Fig. 53 Cross sections for one-electron loss of H^0 beams in Cs

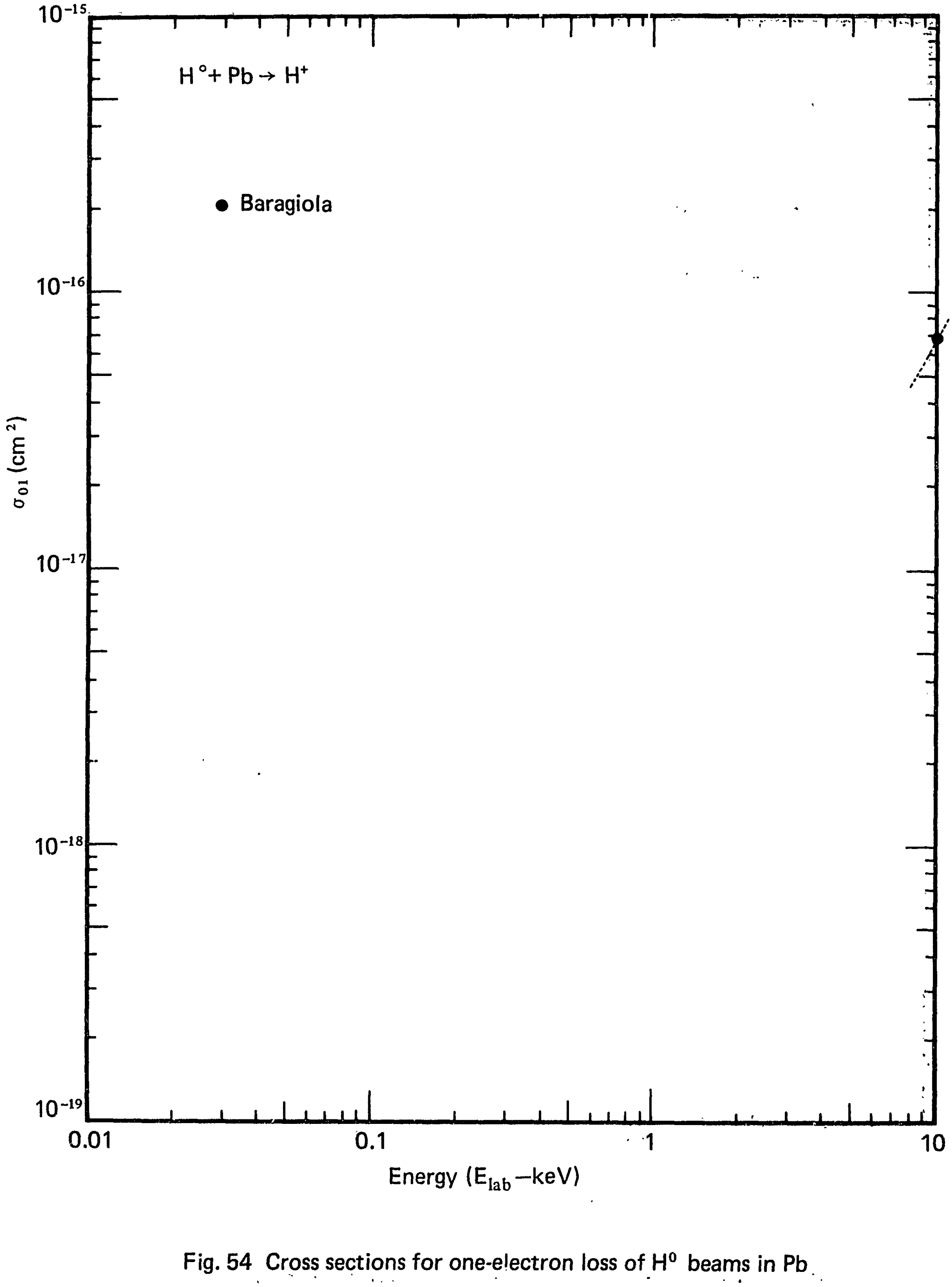

Fig. 54 Cross sections for one-electron loss of H^0 beams in Pb

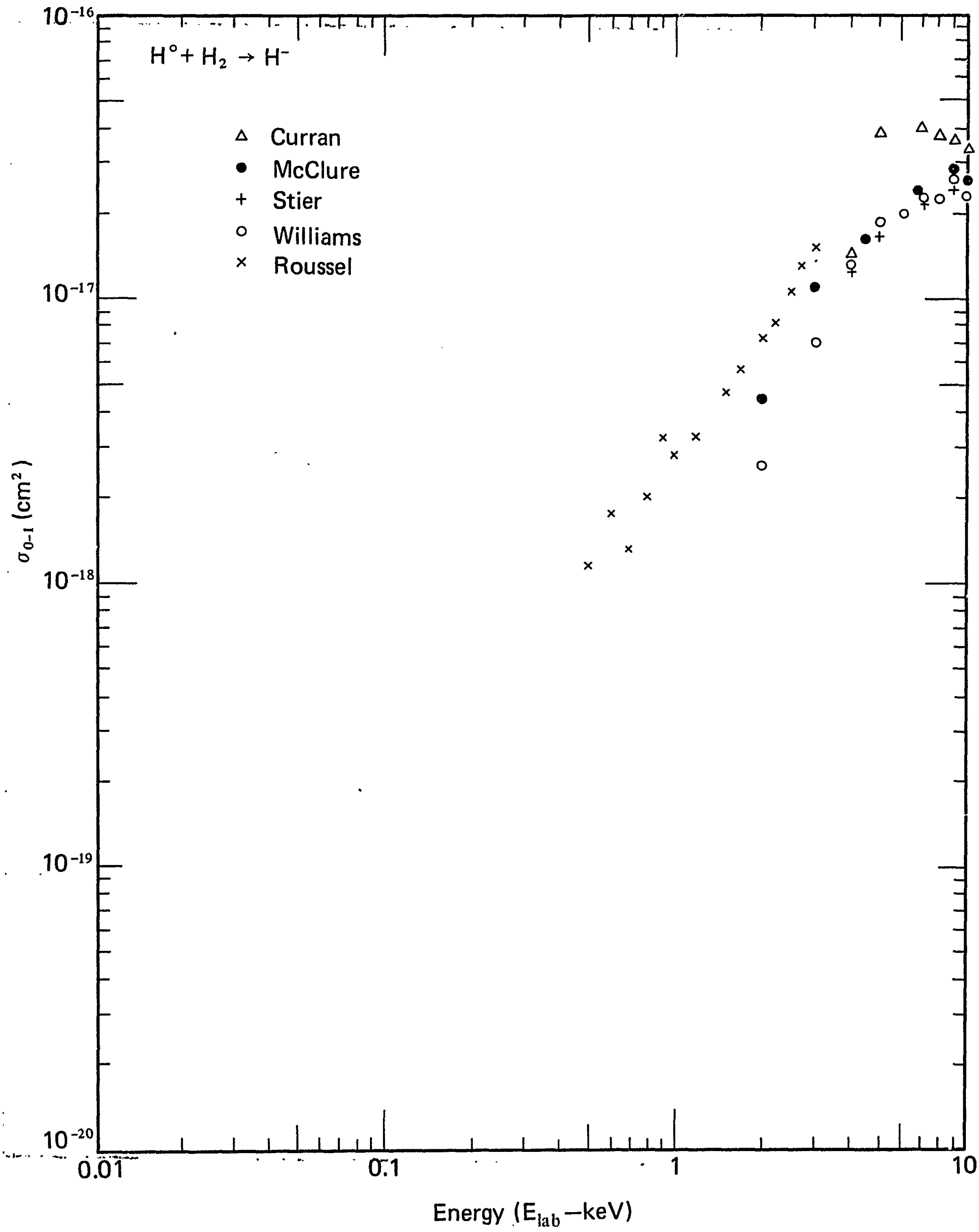

Fig. 55 Cross sections for one-electron capture of H^0 beams in H_2

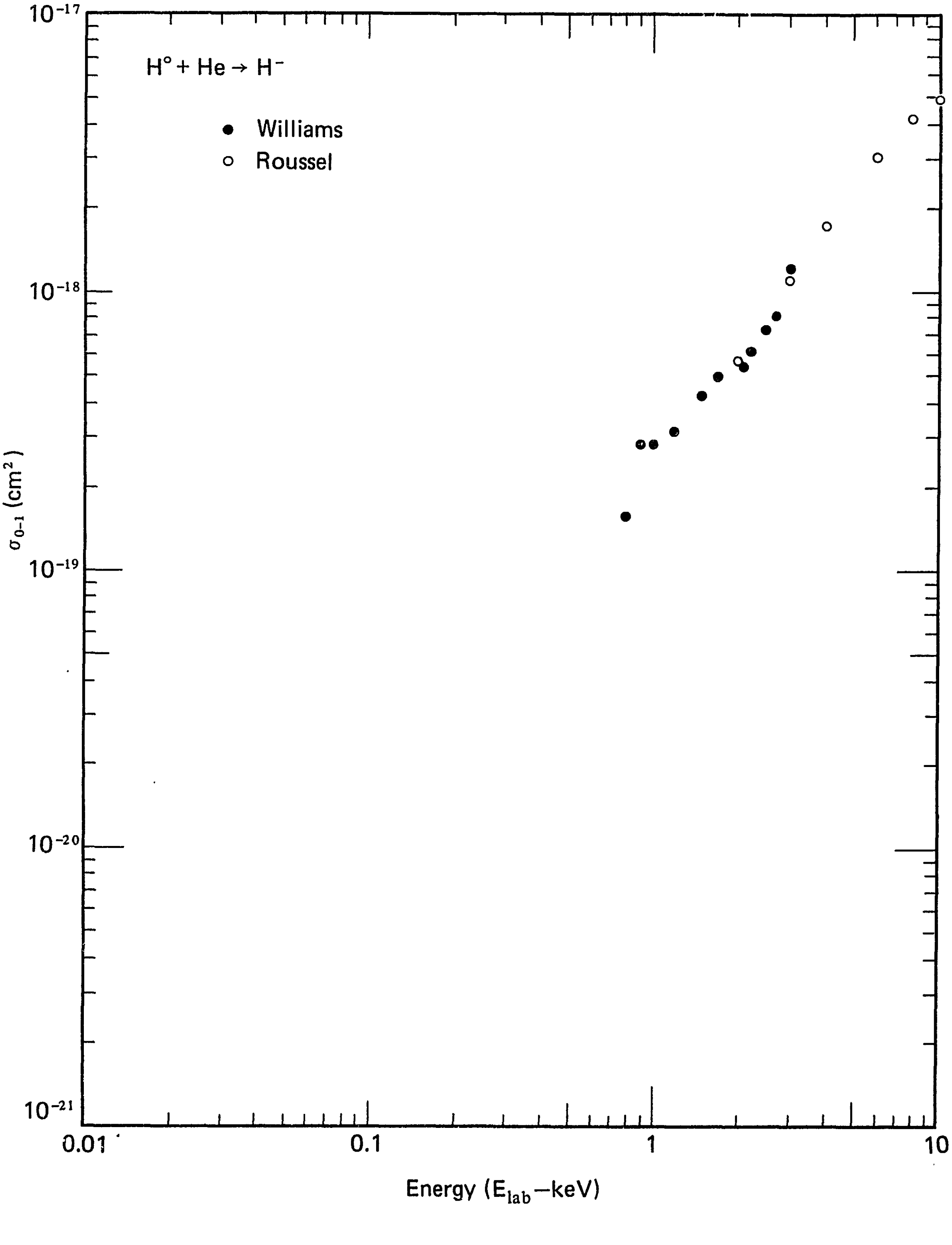

Fig. 56 Cross sections for one-electron capture of H^0 beams in He

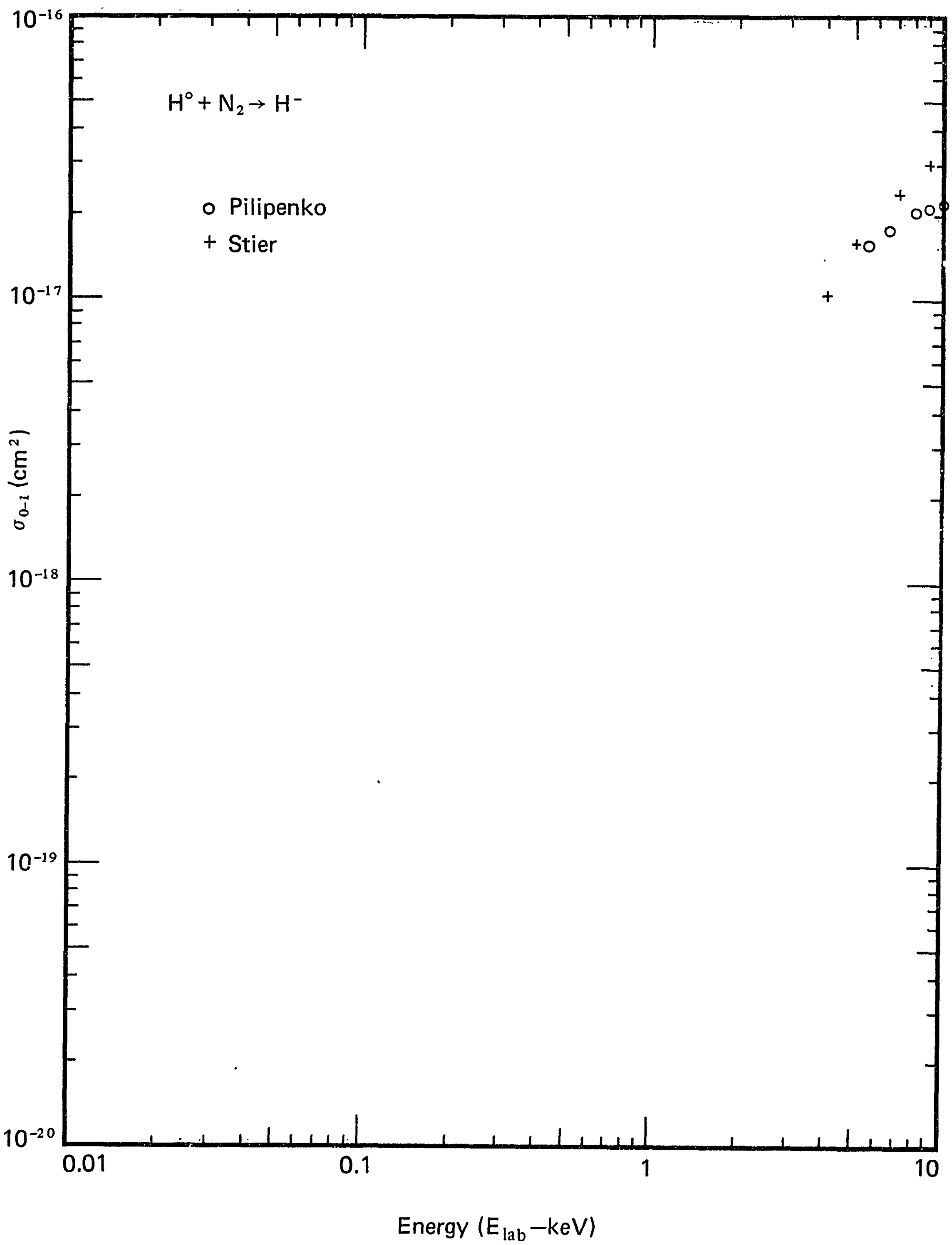

Fig. 57 Cross sections for one-electron capture of H^0 beams in N_2

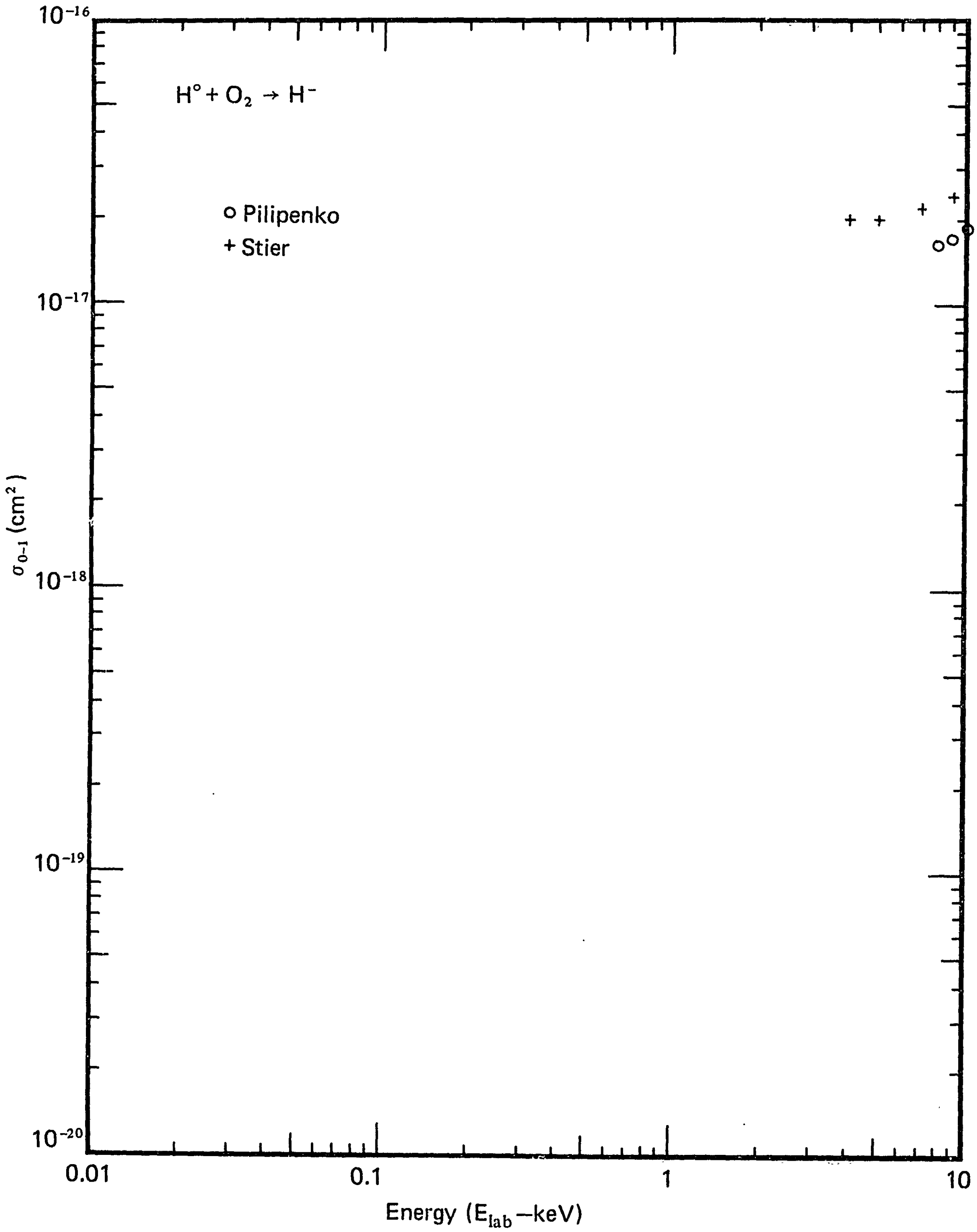

Fig. 58 Cross sections for one-electron capture of H^0 beams in O_2

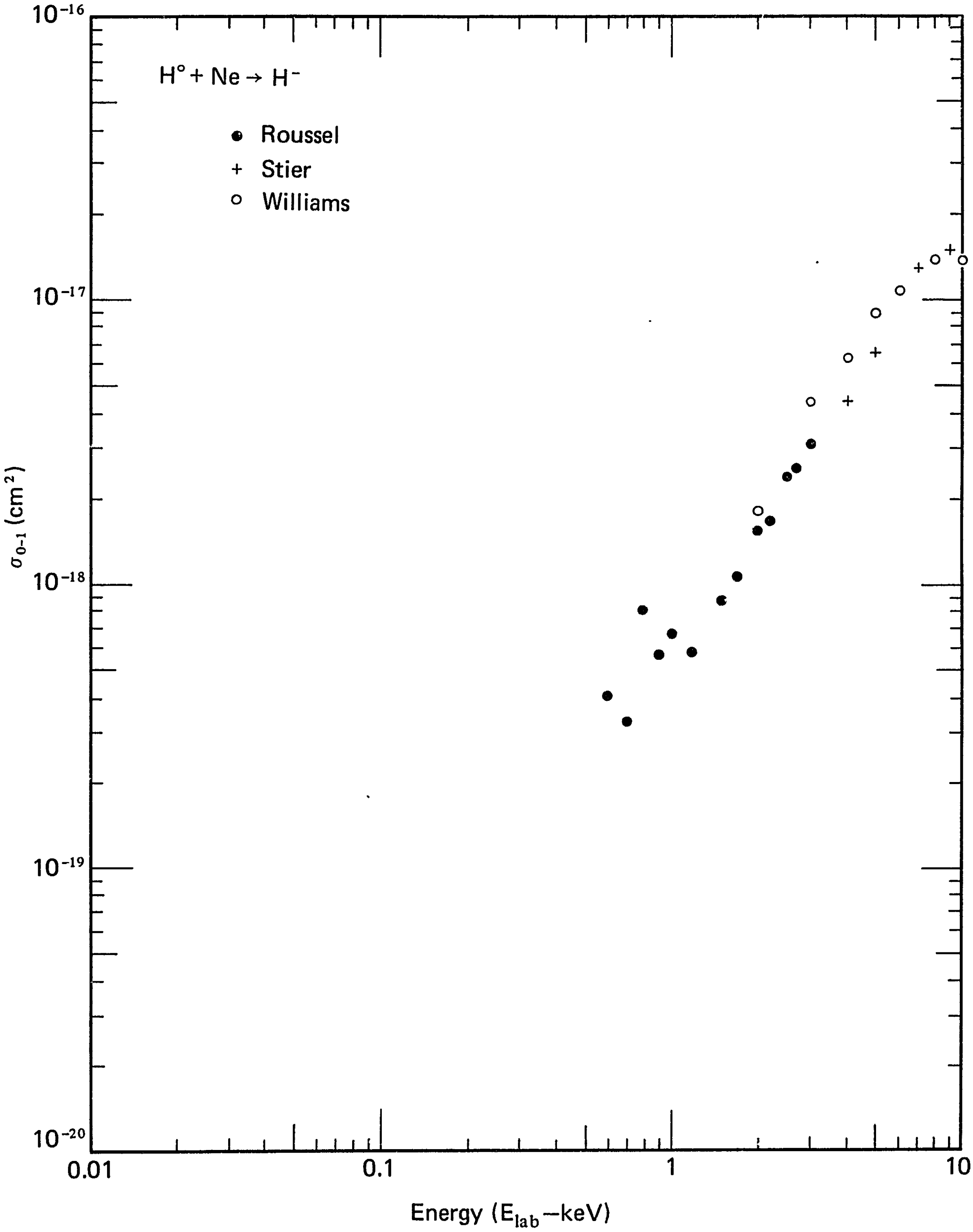

Fig. 59 Cross sections for one-electron capture of H^0 beams in Ne

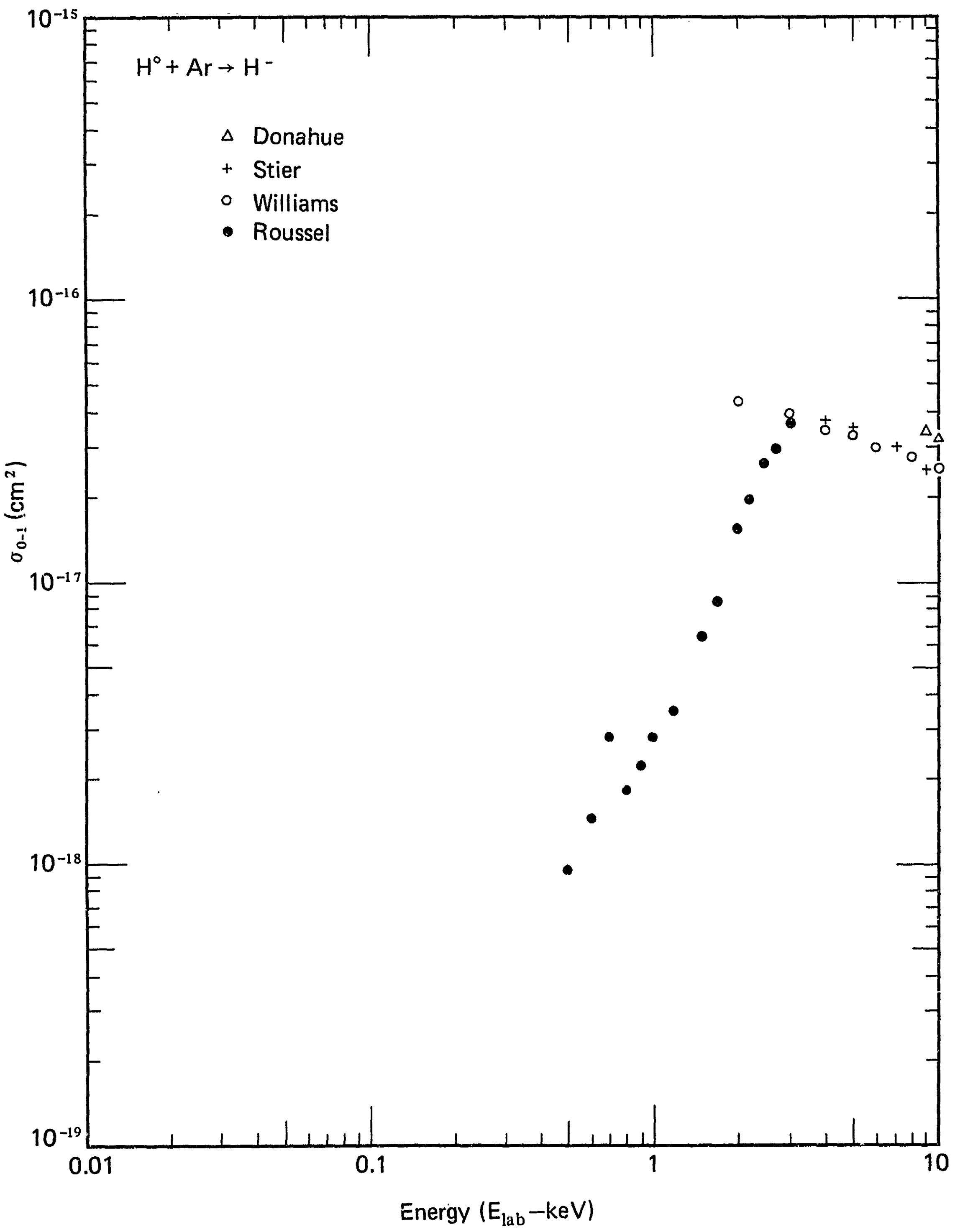

Fig. 60 Cross sections for one-electron capture of H^0 beams in Ar

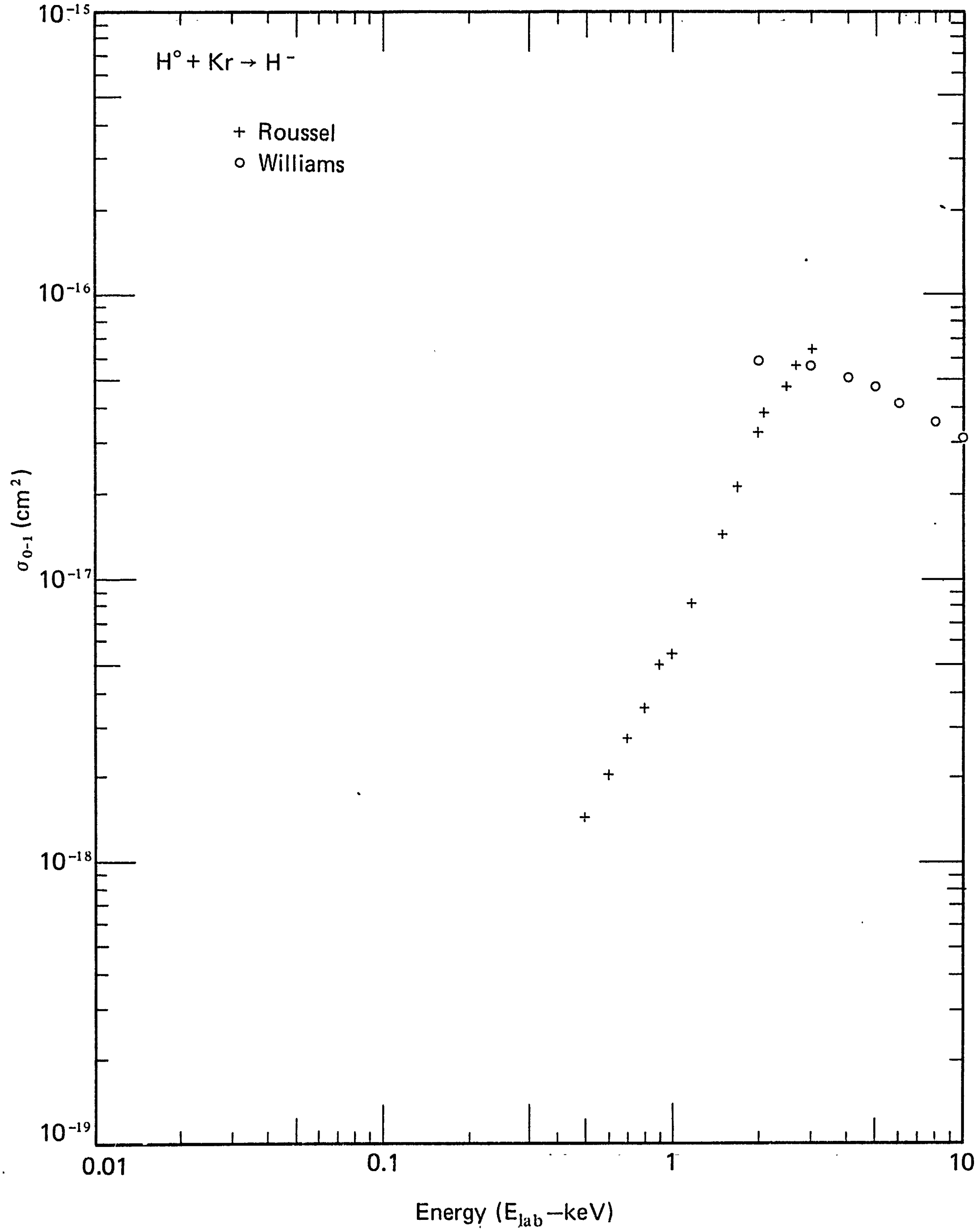

Fig. 61 Cross sections for one-electron capture of H^0 beams in Kr

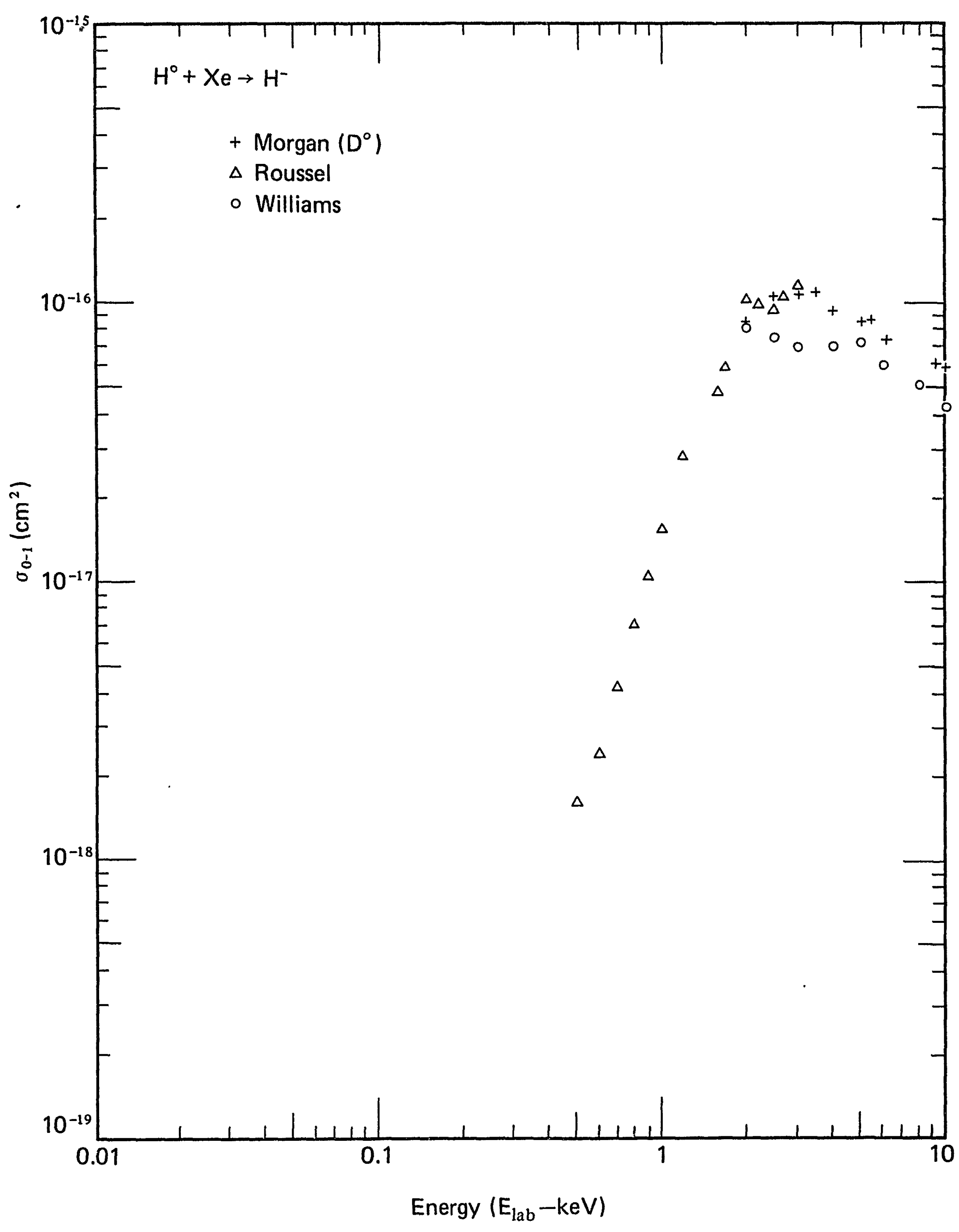

Fig. 62 Cross sections for one-electron capture of H^0 beams in Xe

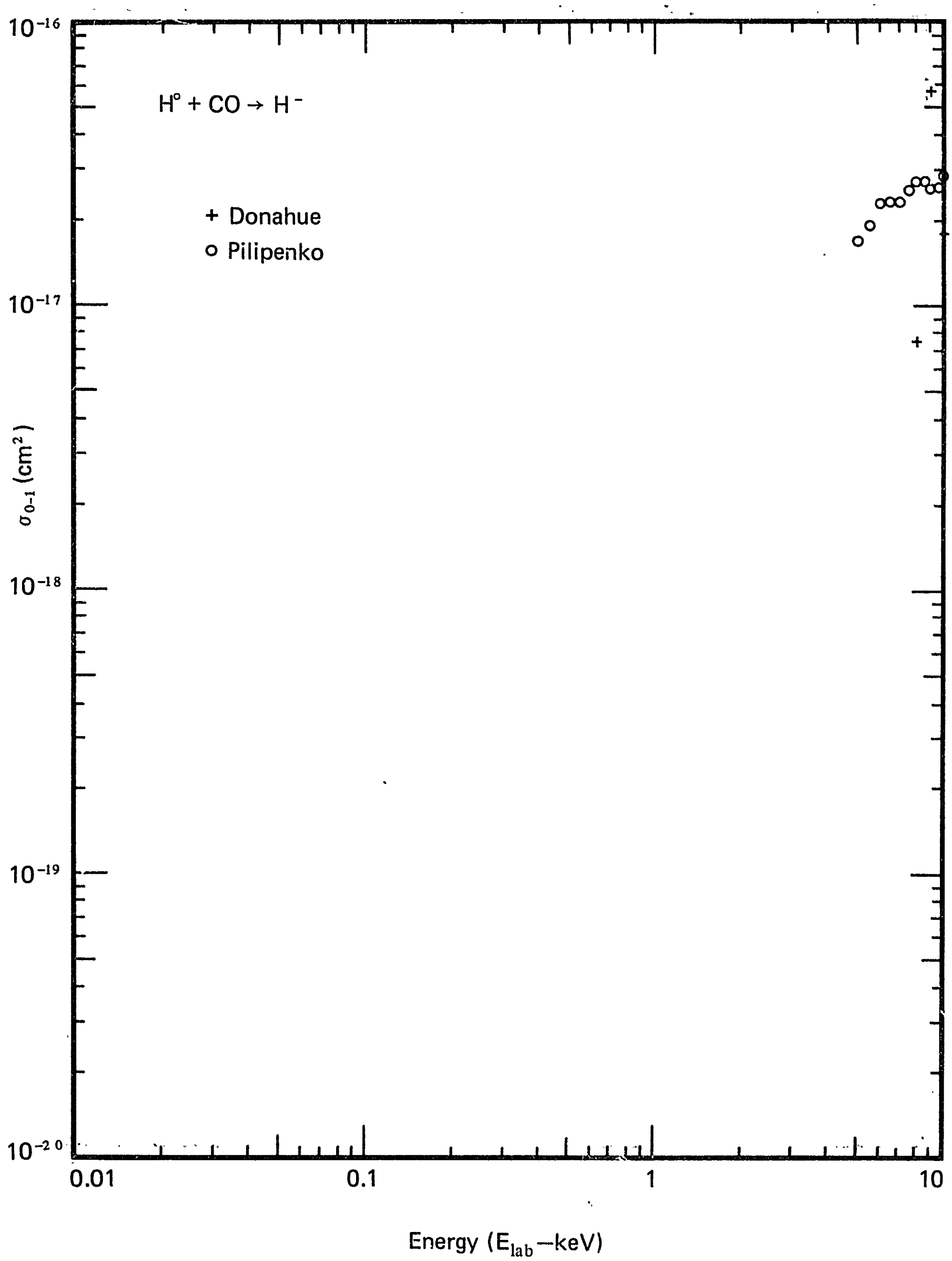

Fig. 63 Cross sections for one-electron capture of H^0 beams in CO

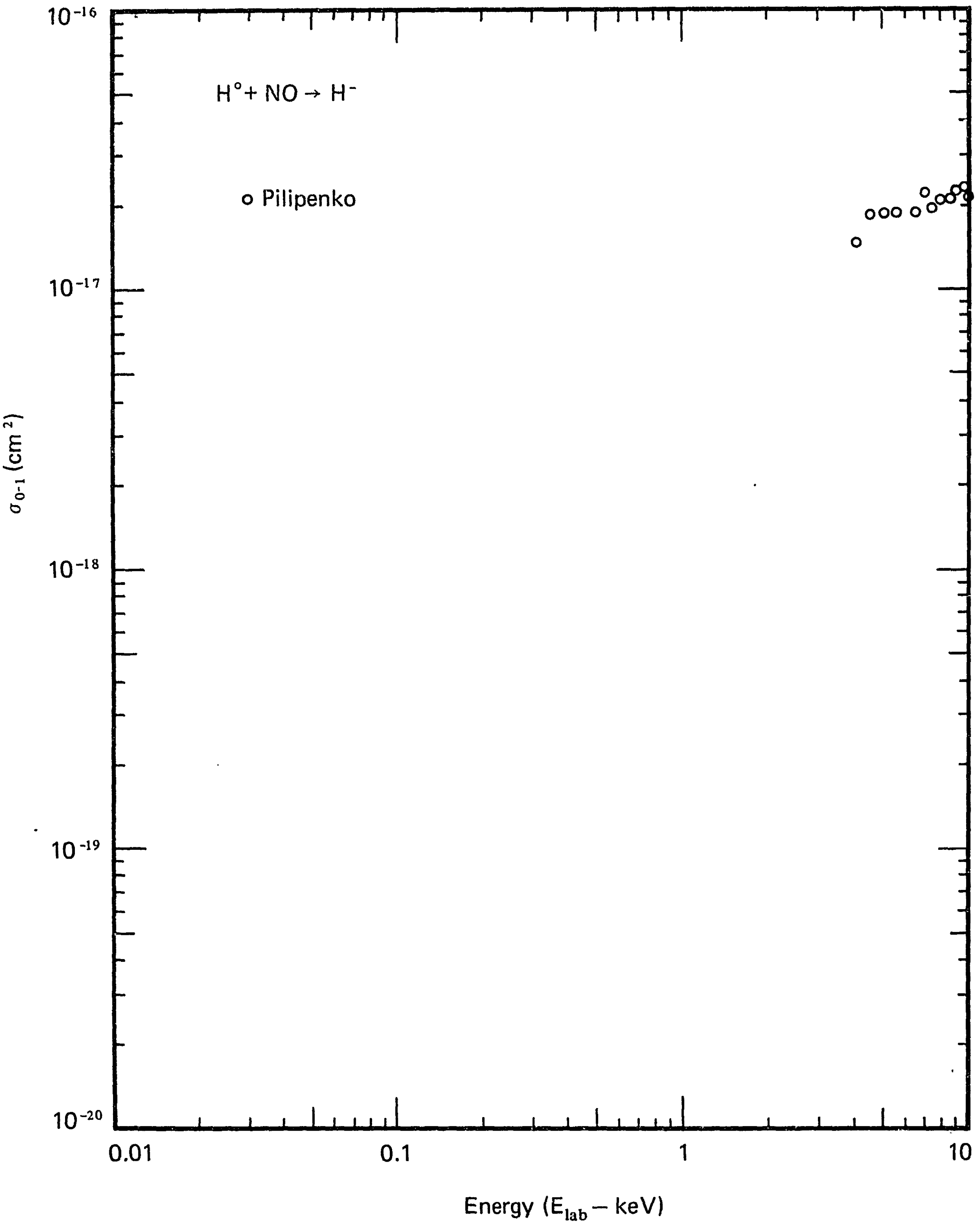

Fig. 64 Cross sections for one-electron capture of H^0 beams in NO

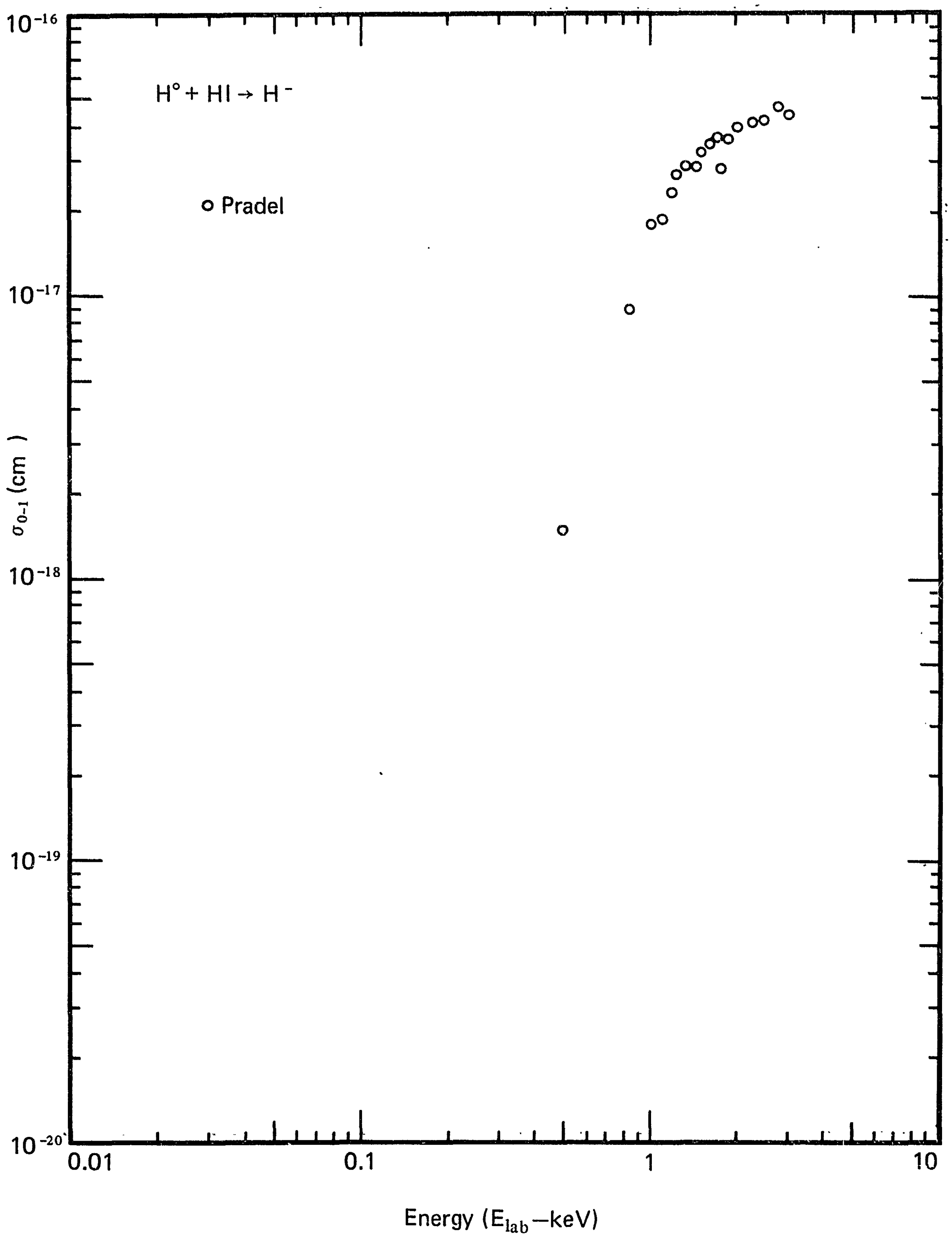

Fig. 65 Cross sections for one-electron capture of H^0 beams in HI

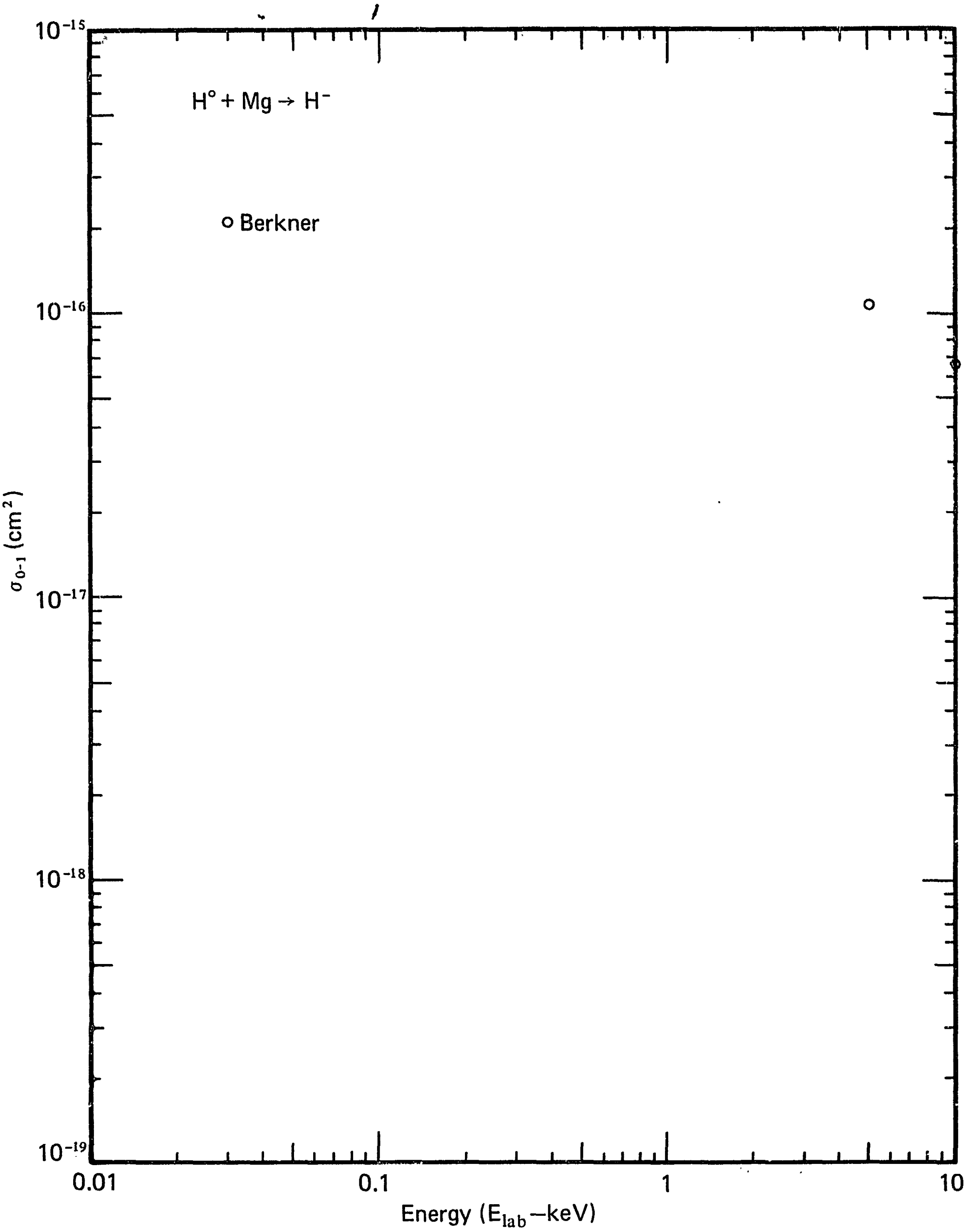

Fig. 66 Cross sections for one-electron capture of H^0 beams in Mg

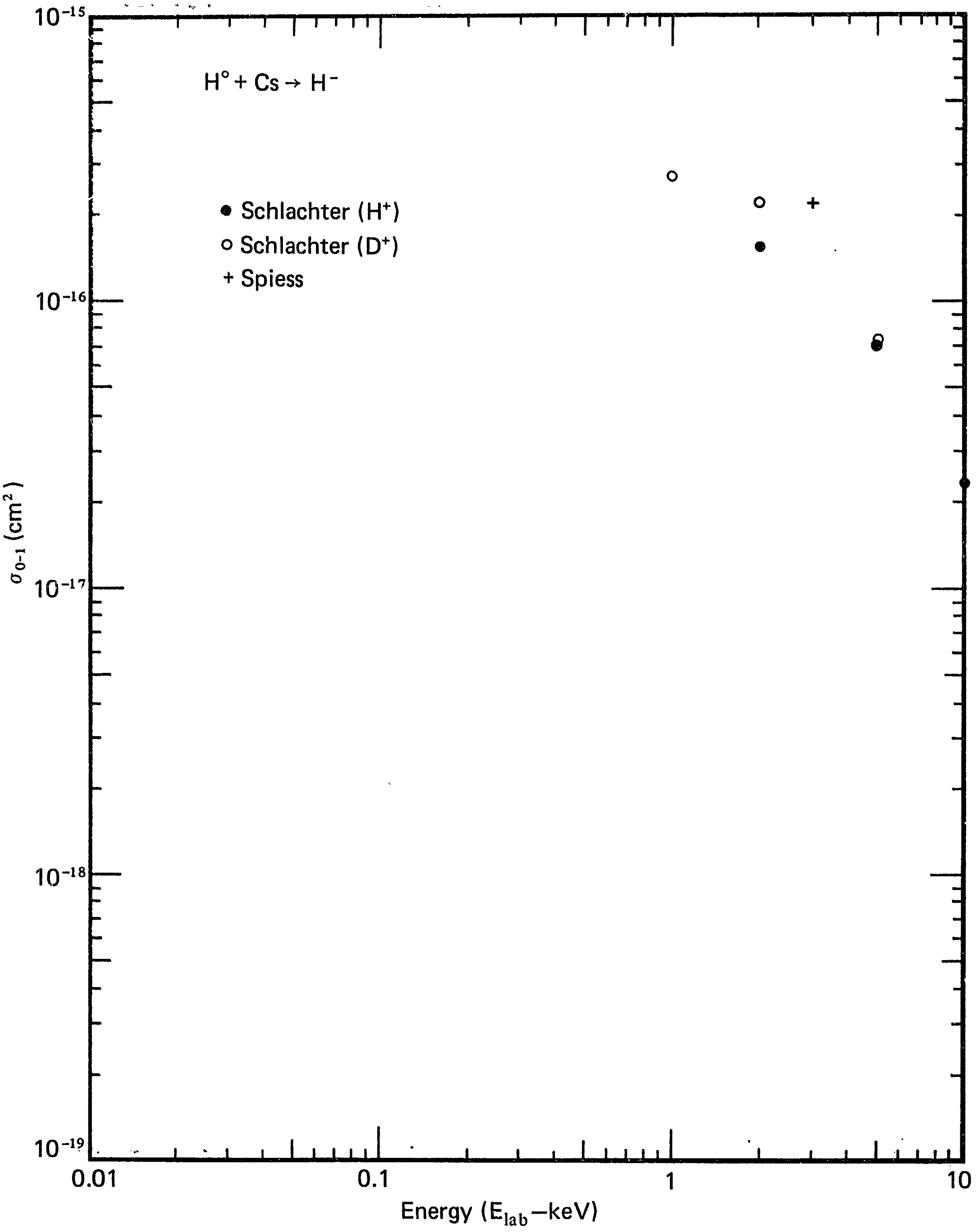

Fig. 67 Cross sections for one-electron capture of H^0 beams in Cs

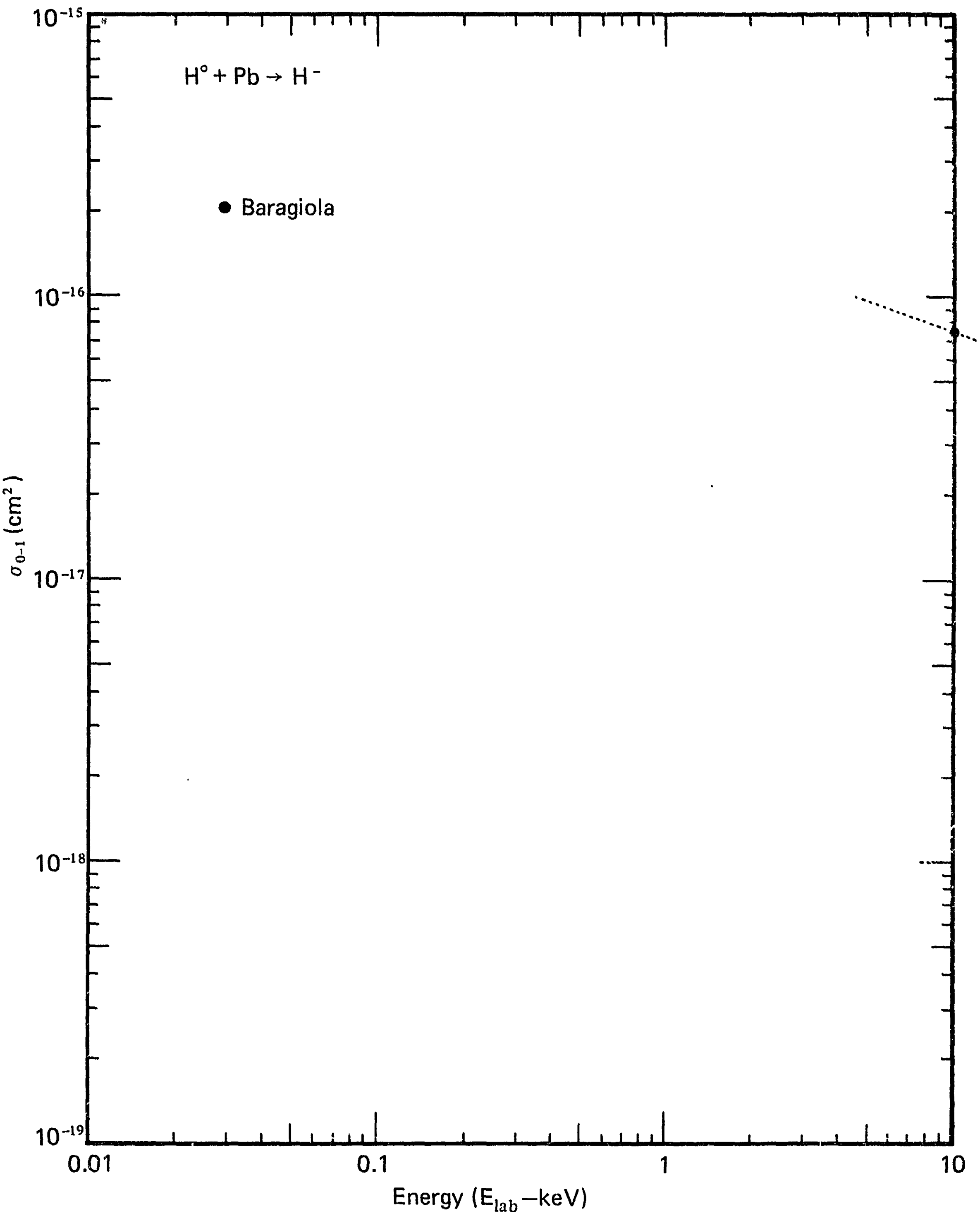

Fig. 68 Cross sections for one-electron capture of H^0 beams in Pb

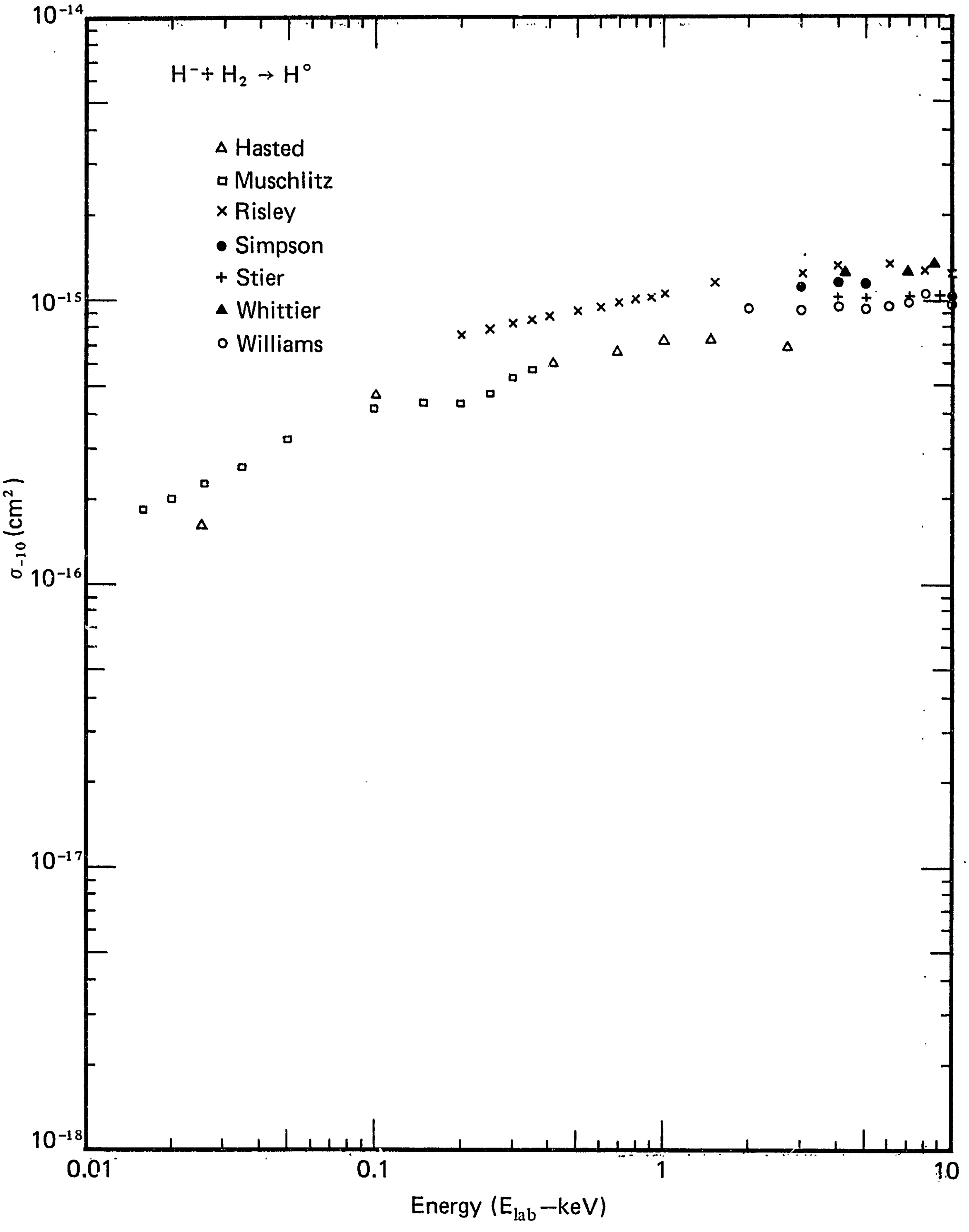

Fig. 69 Cross sections for one-electron loss of H^- beams in H_2

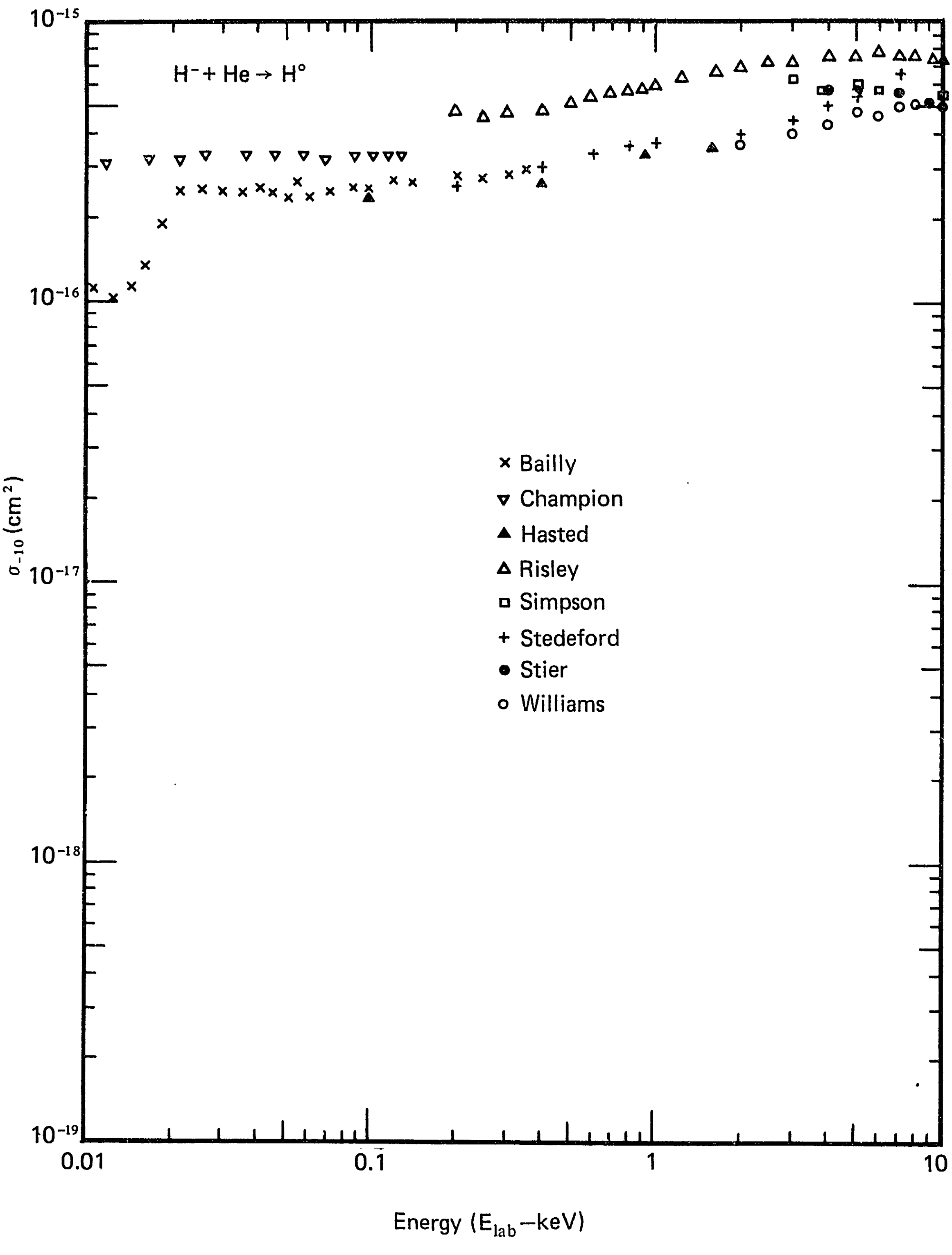

Fig. 70 Cross sections for one-electron loss of H^- beams in He

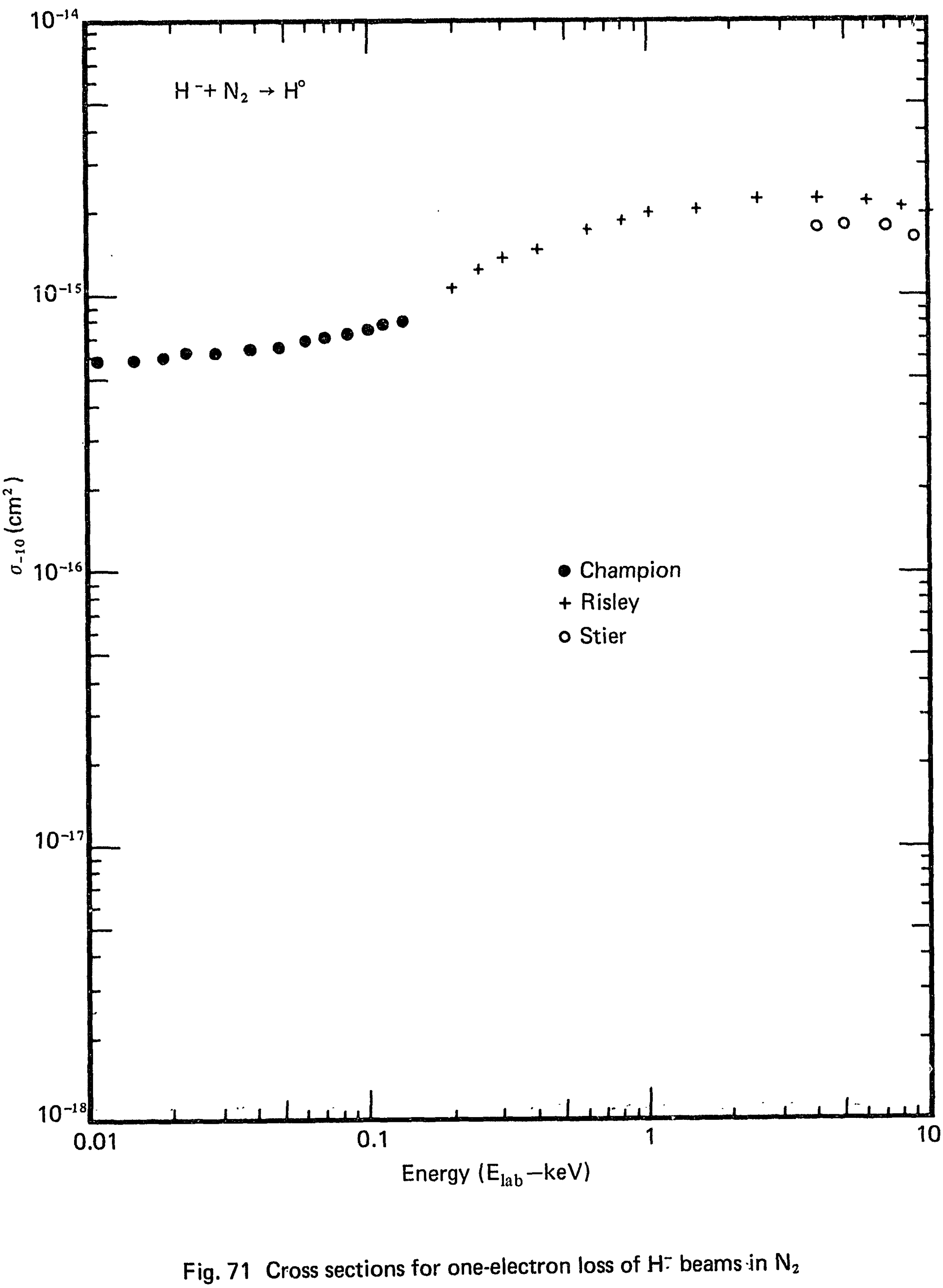

Fig. 71 Cross sections for one-electron loss of H^- beams in N_2

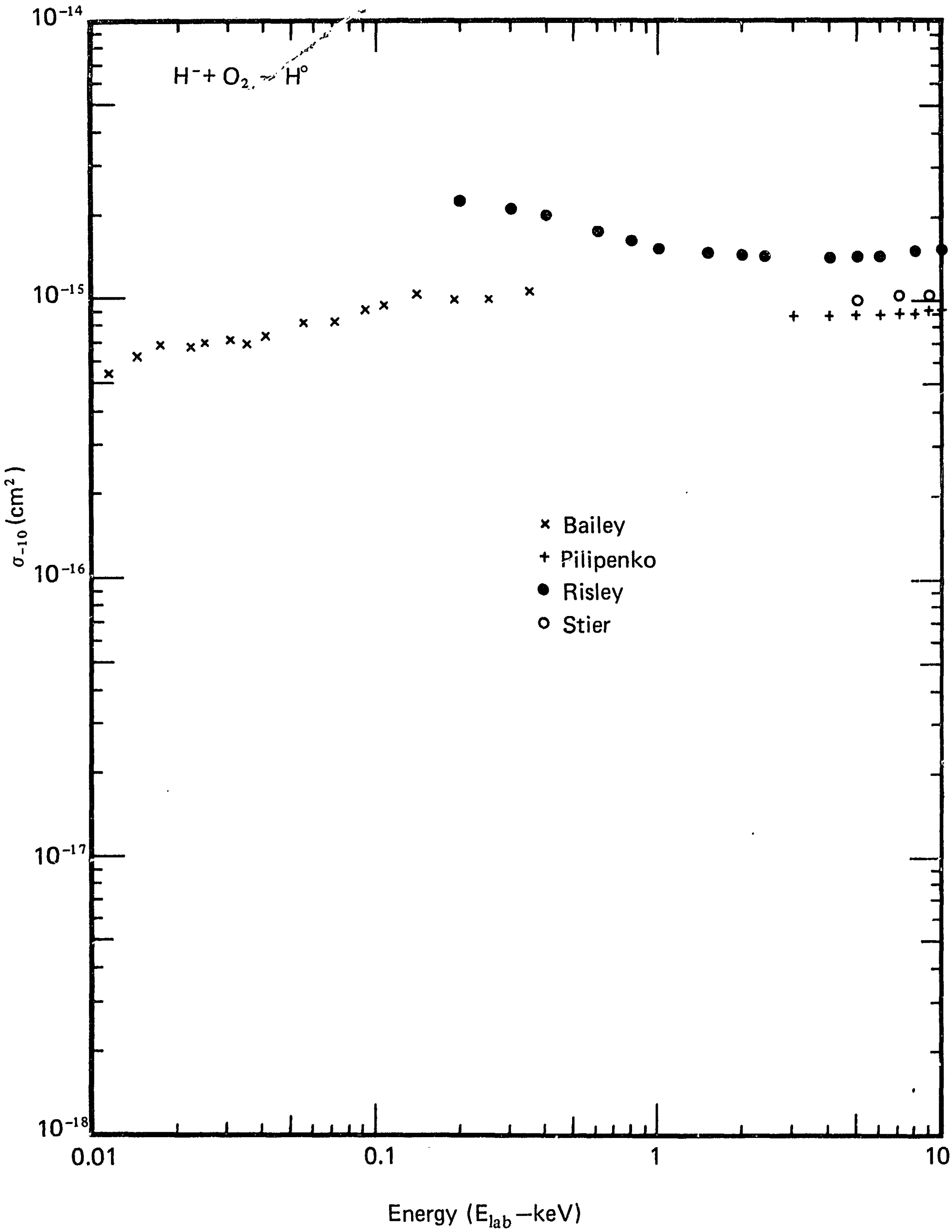

Fig. 72 Cross sections for one-electron loss of H^- beams in O_2

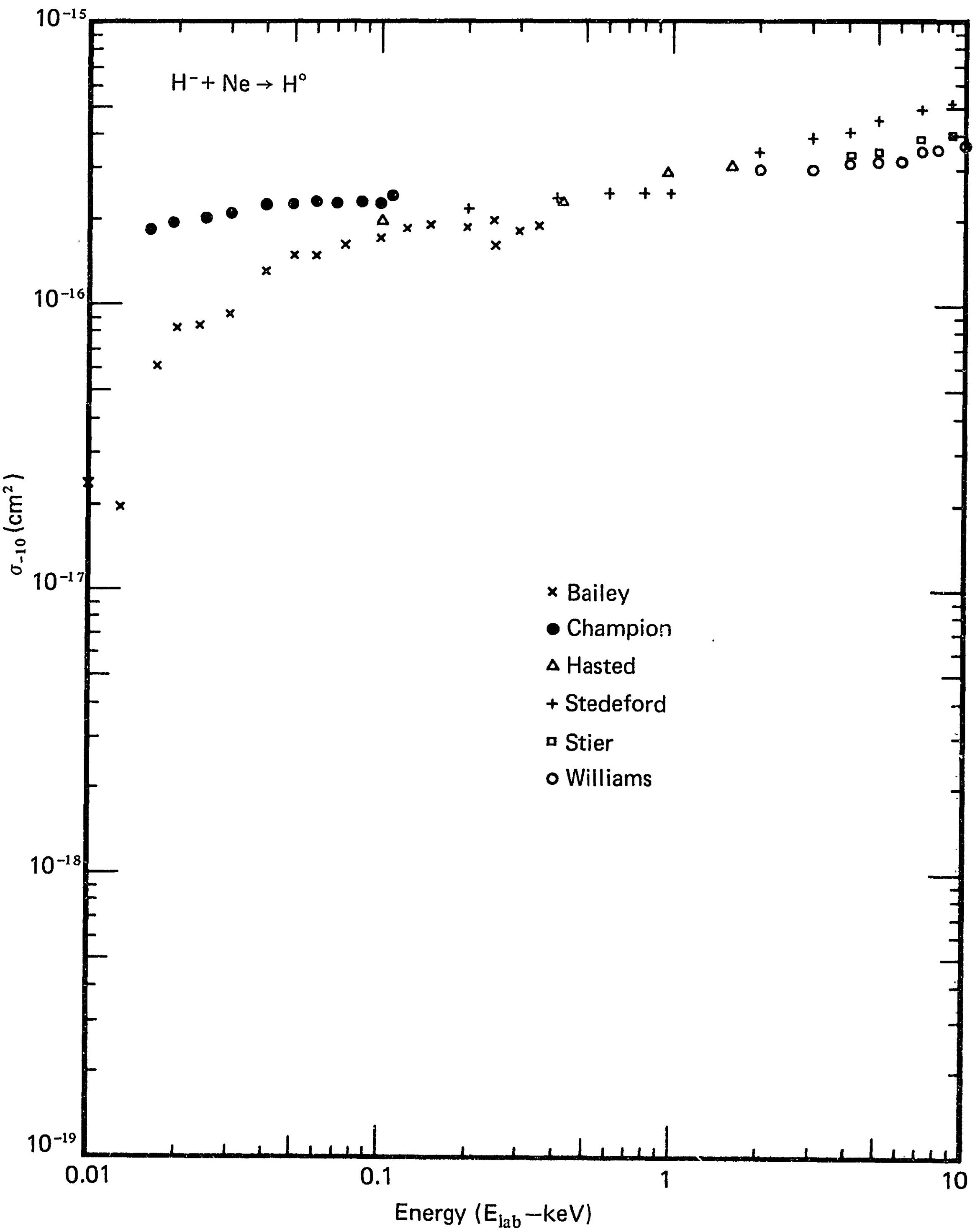

Fig. 73 Cross sections for one-electron loss of H^- beams in Ne

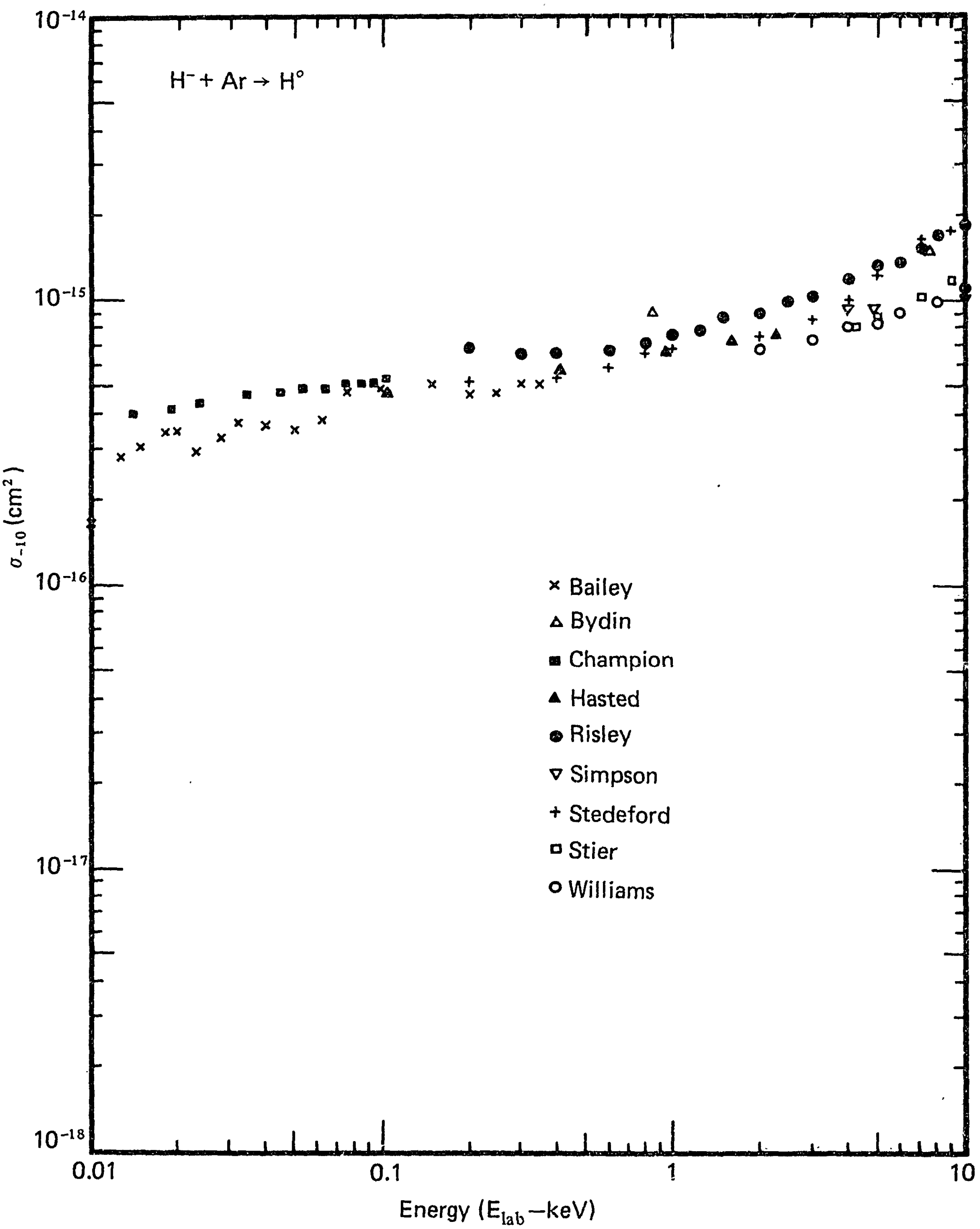

Fig. 74 Cross sections for one-electron loss of H^- beams in Ar

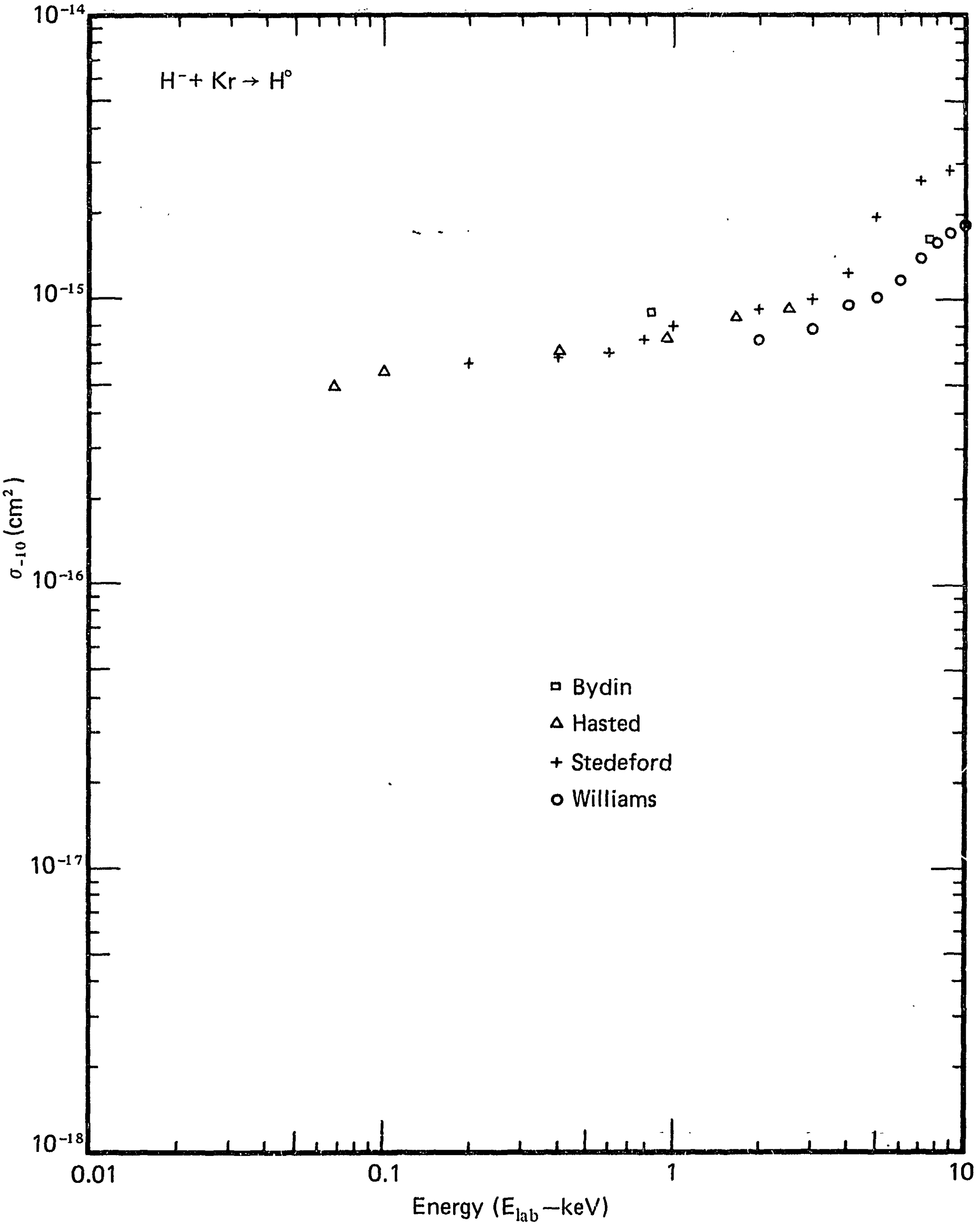

Fig. 75 Cross sections for one-electron loss of H^{-} beams in Kr

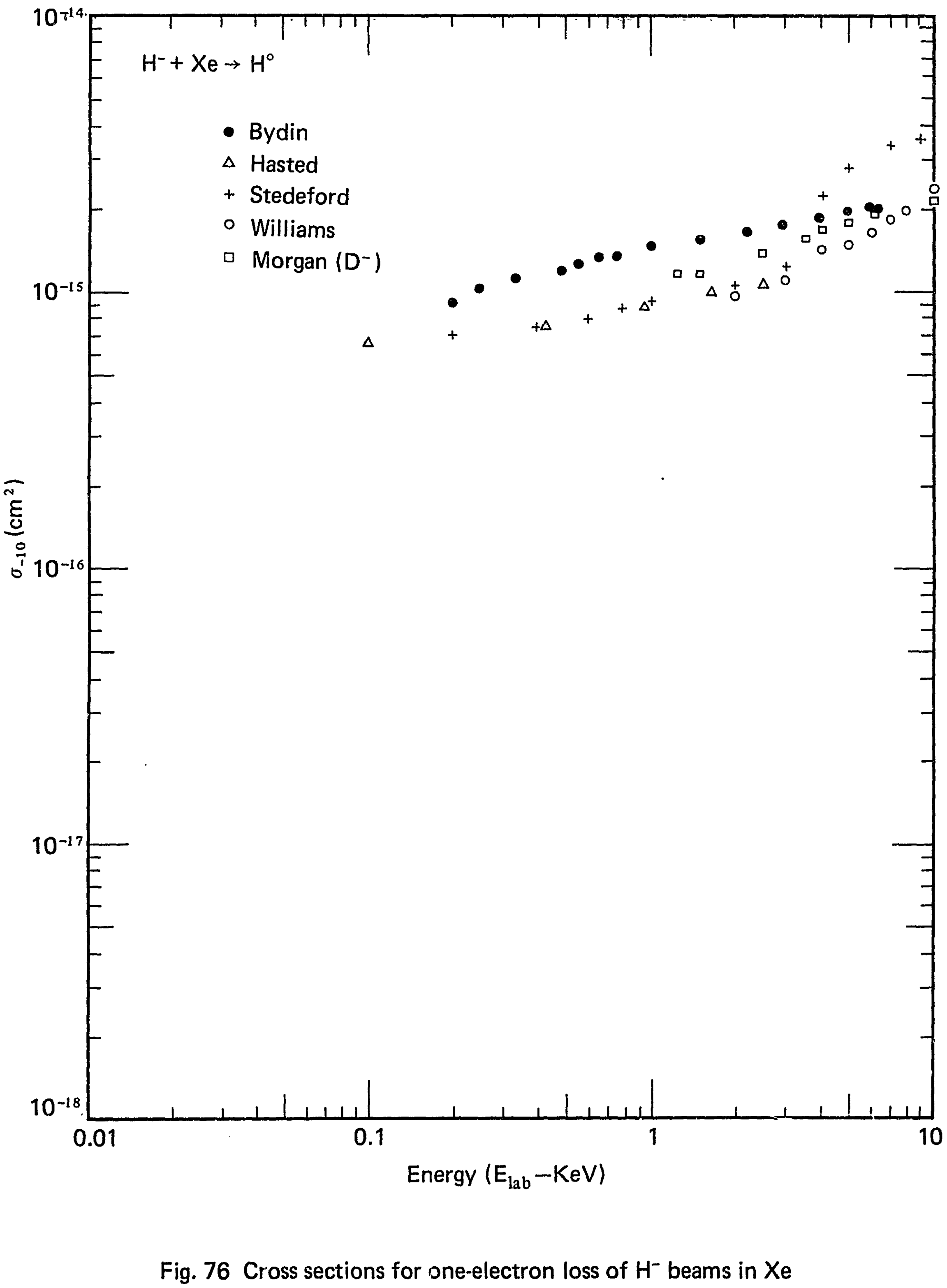

Fig. 76 Cross sections for one-electron loss of H^- beams in Xe

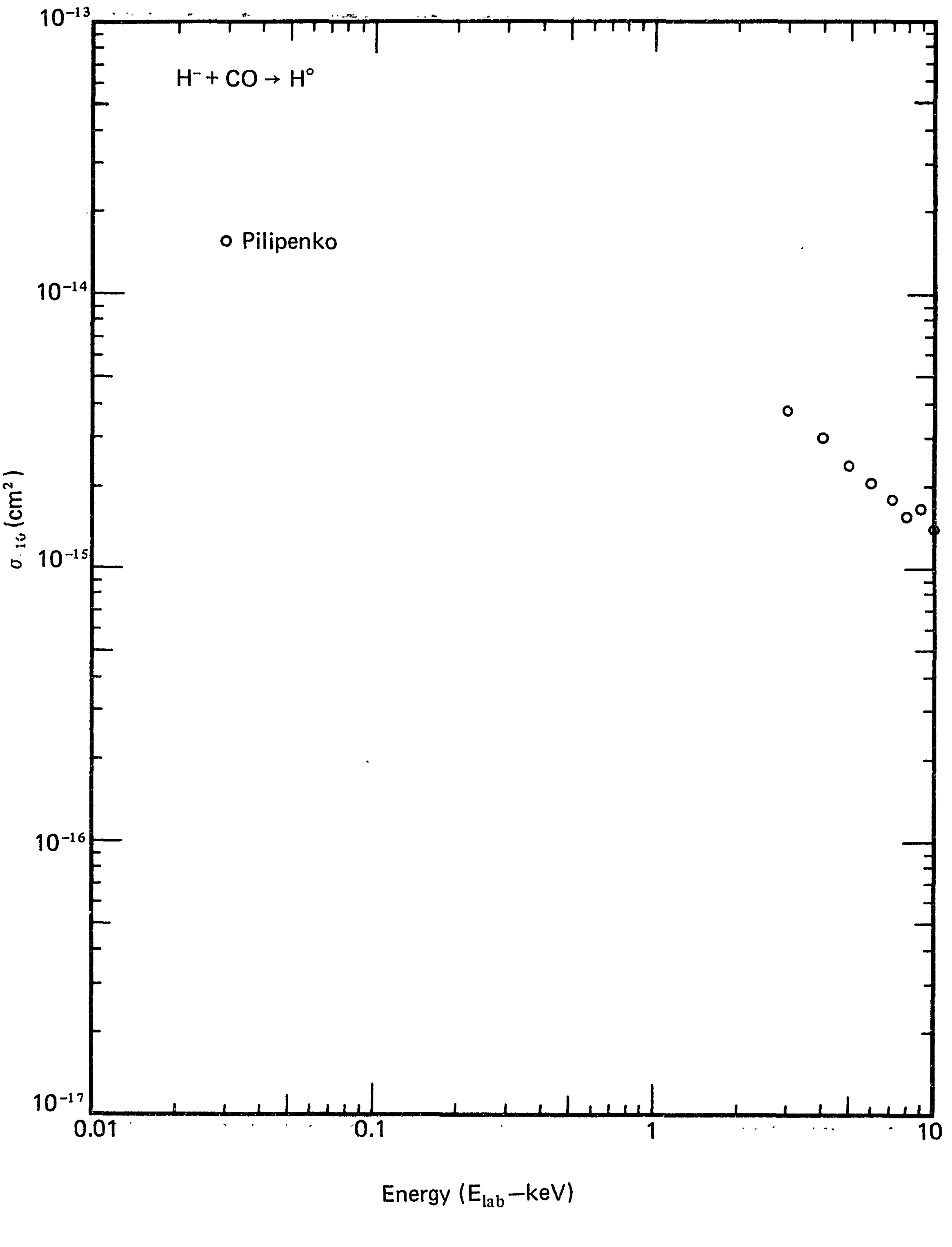

Fig. 77 Cross sections for one-electron loss of H^- beams in CO

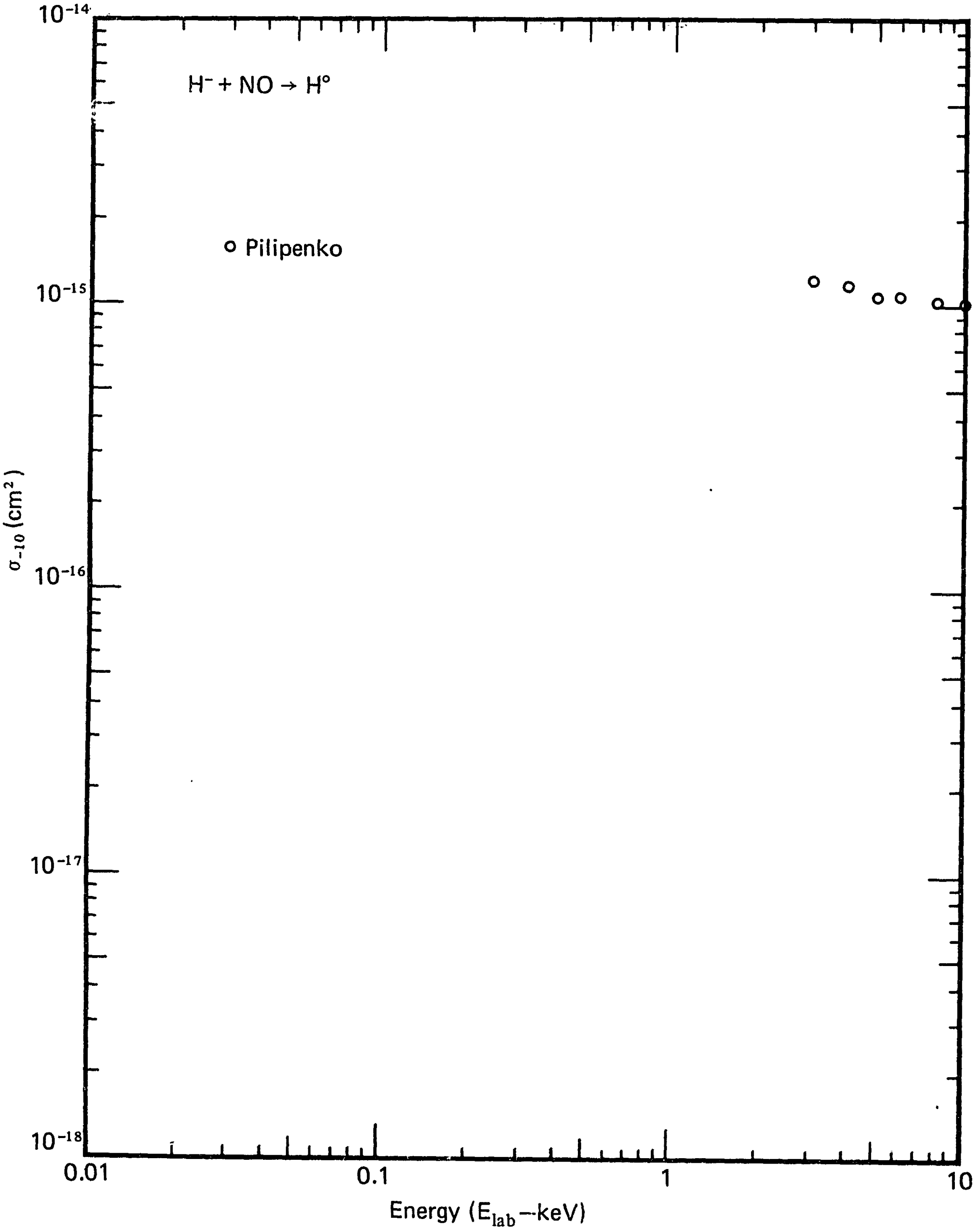

Fig. 78 Cross sections for one-electron loss of H^- beams in NO

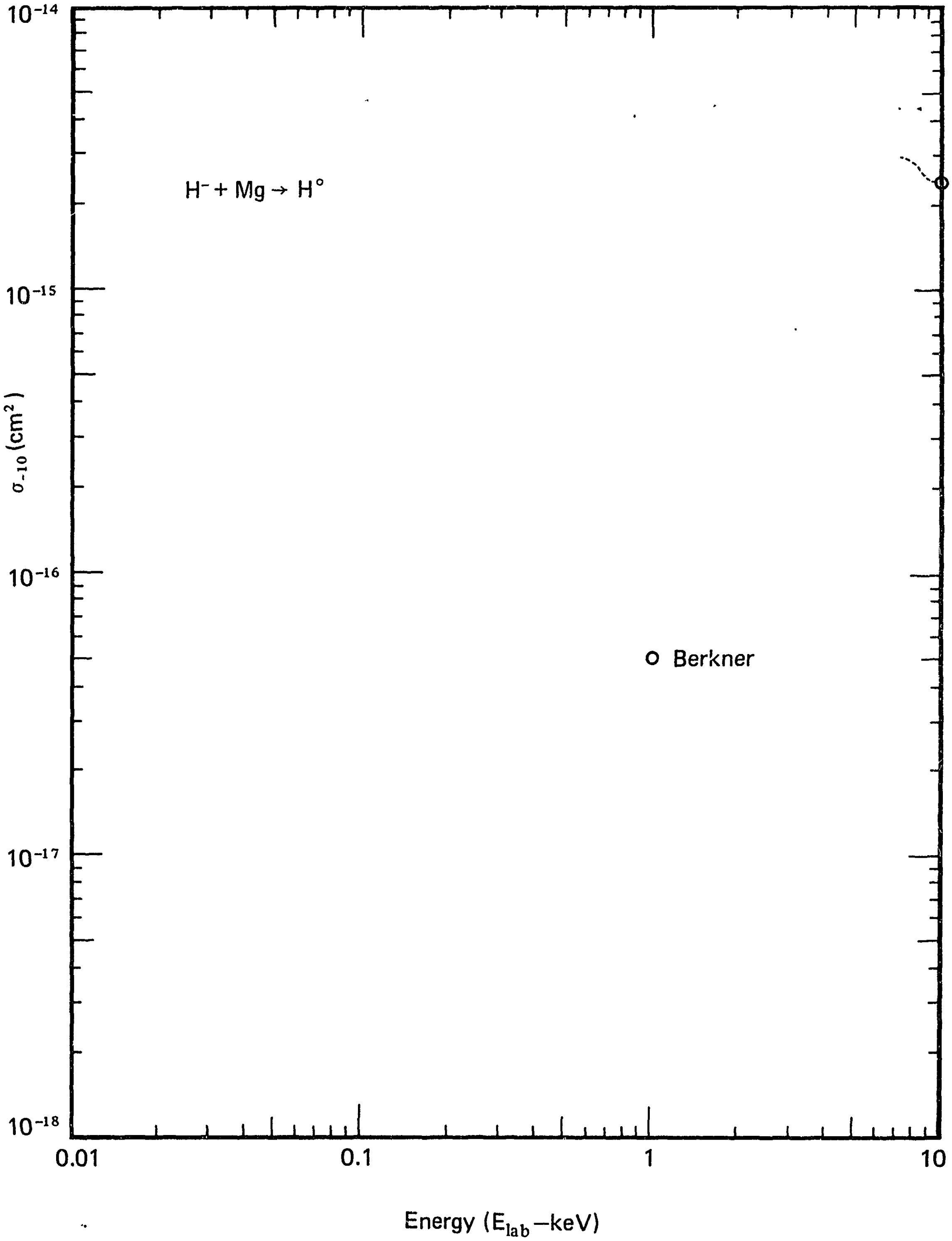

Fig. 79 Cross sections for one-electron loss of H^- beams in Mg

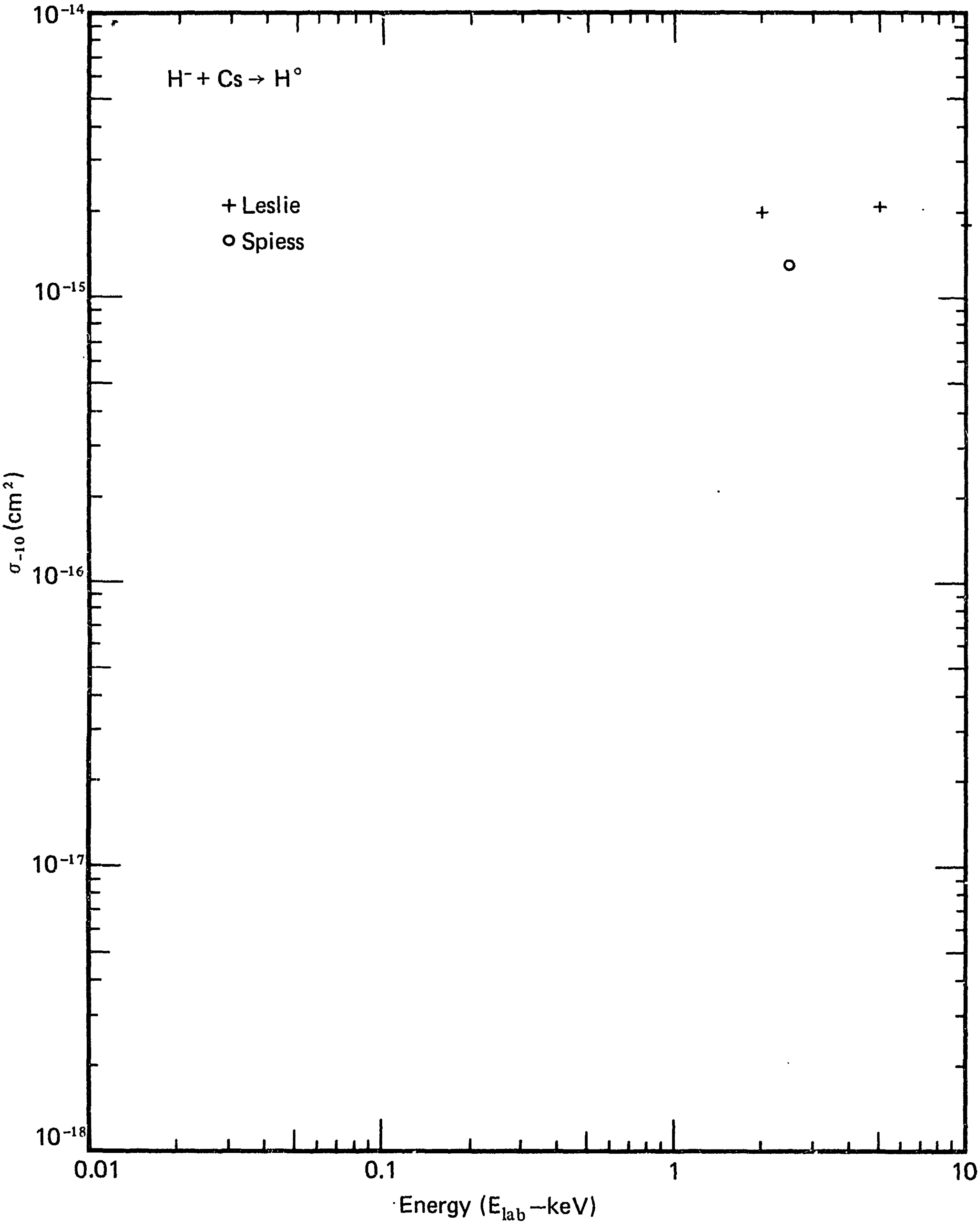

Fig. 80 Cross sections for one-electron loss of H^- beams in Cs

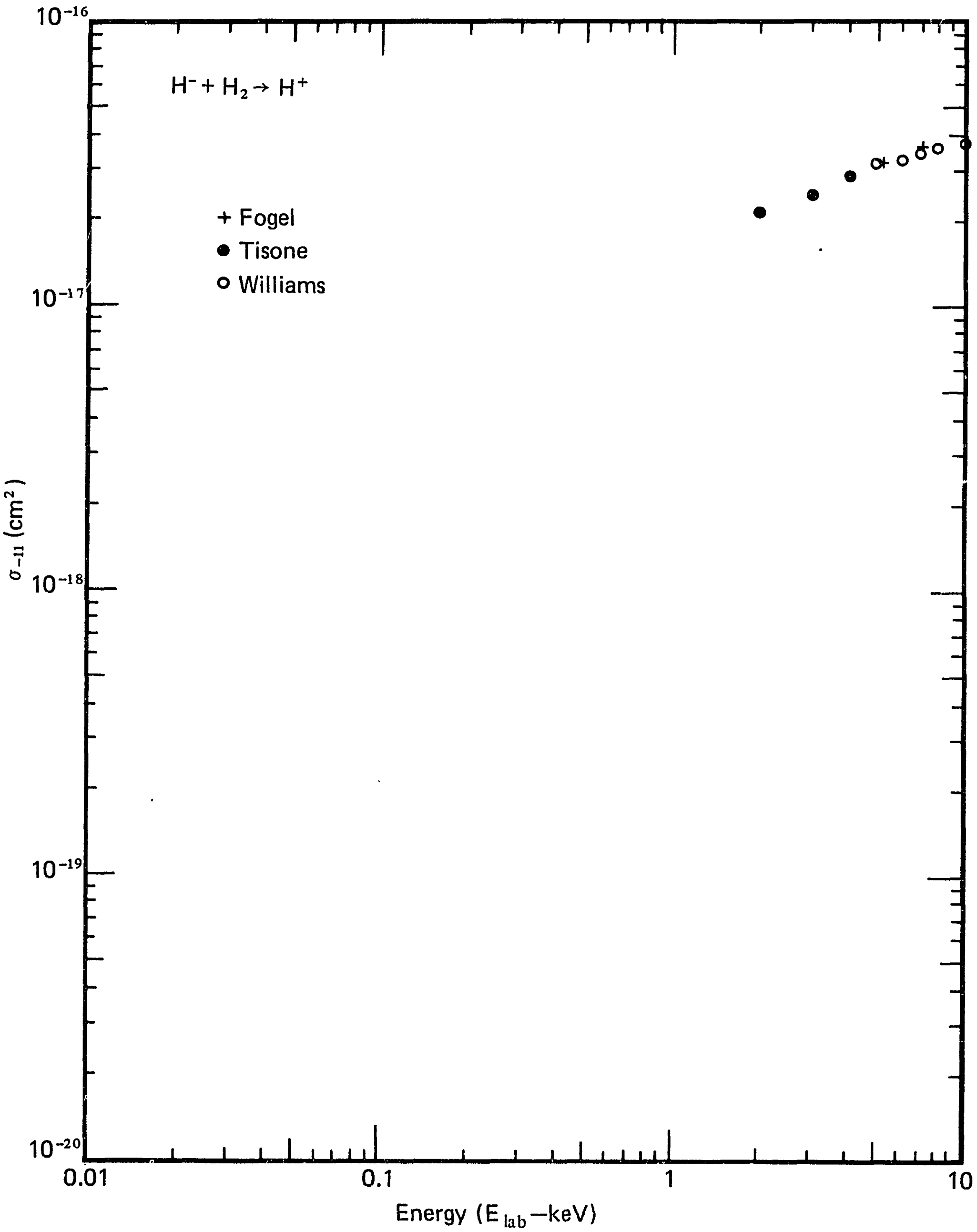

Fig. 81 Cross sections for two-electron loss of H^- beams in H_2

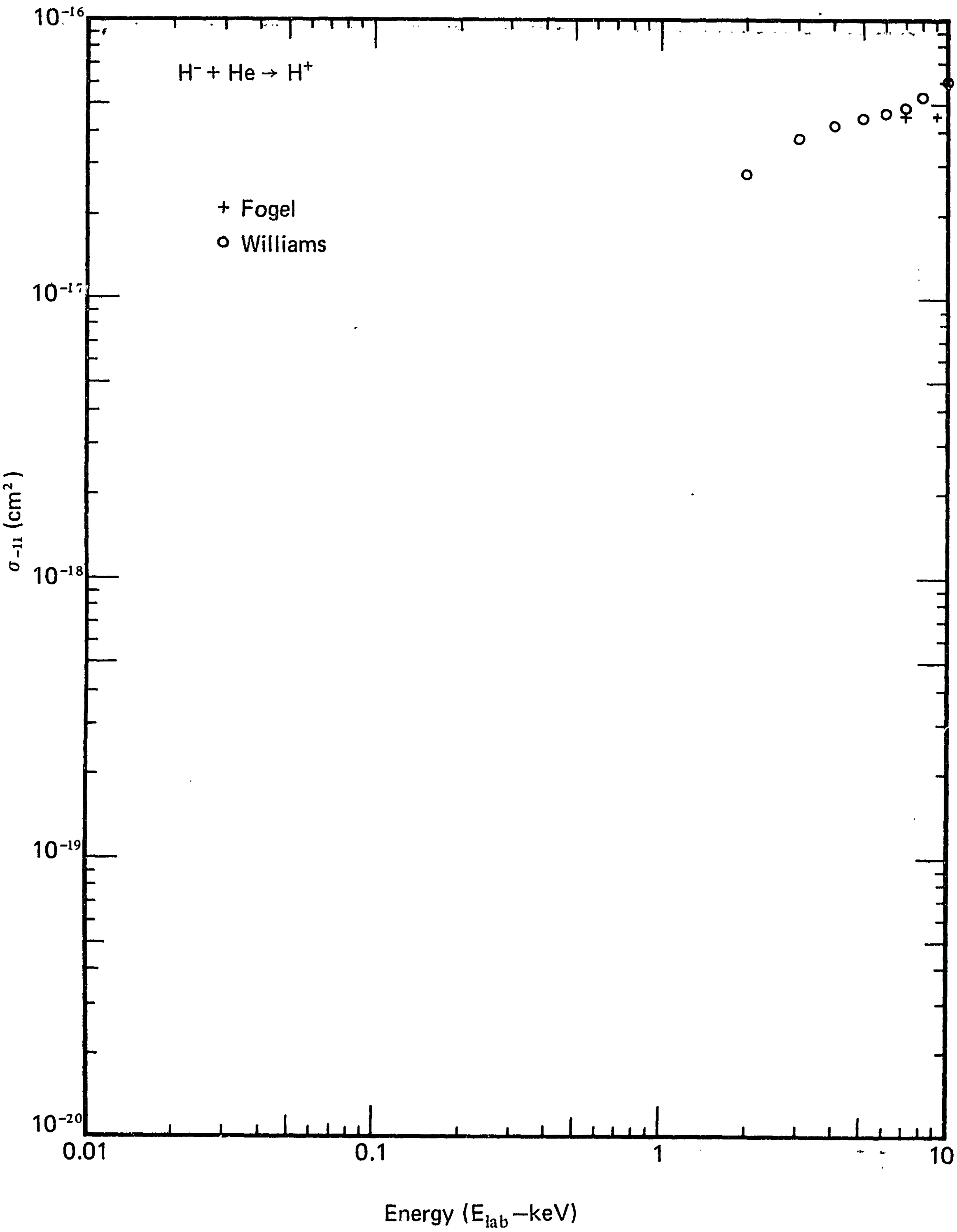

Fig. 82 Cross sections for two-electron loss of H^- beams in He

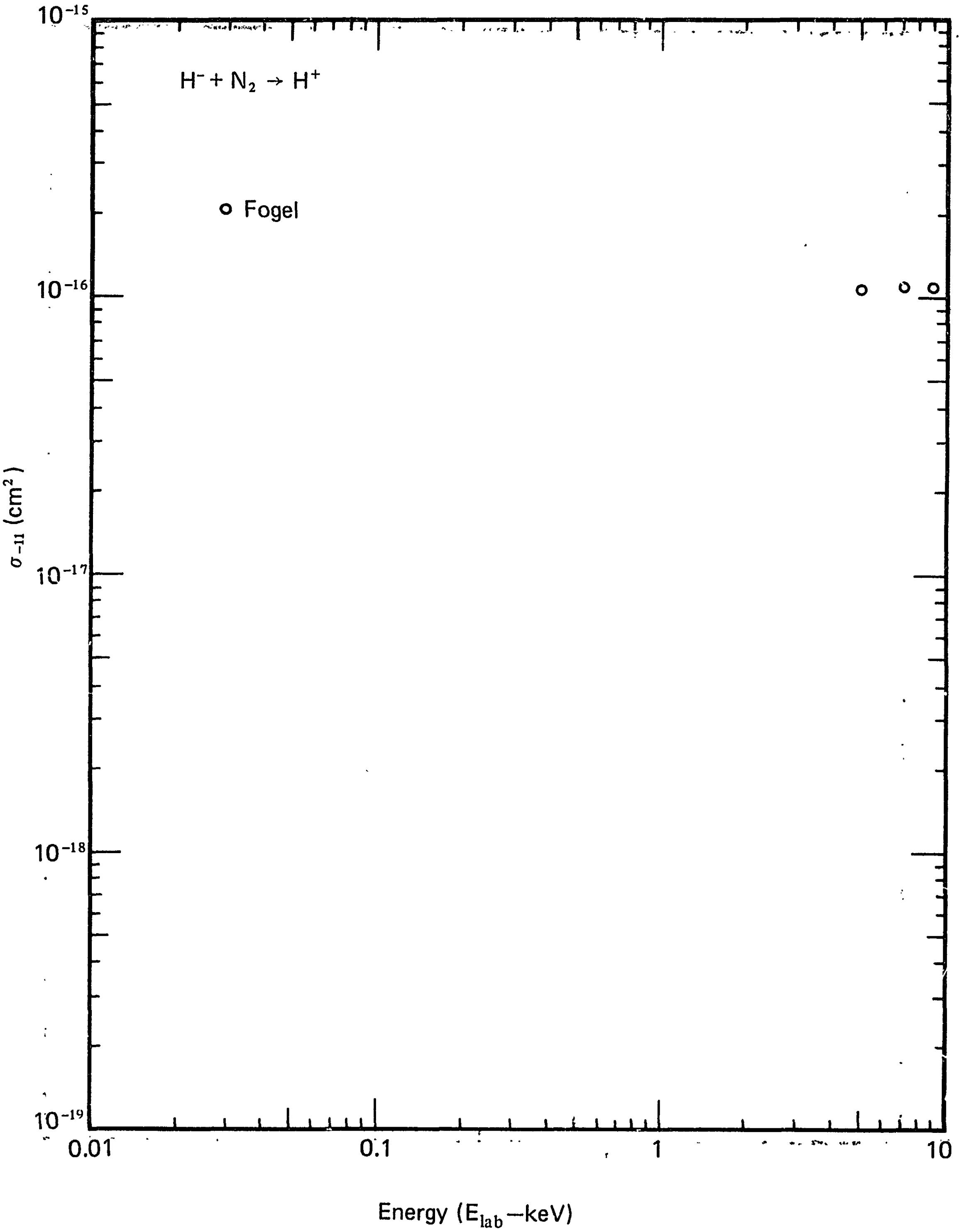

Fig. 83 Cross sections for two-electron loss of H^- beams in N_2

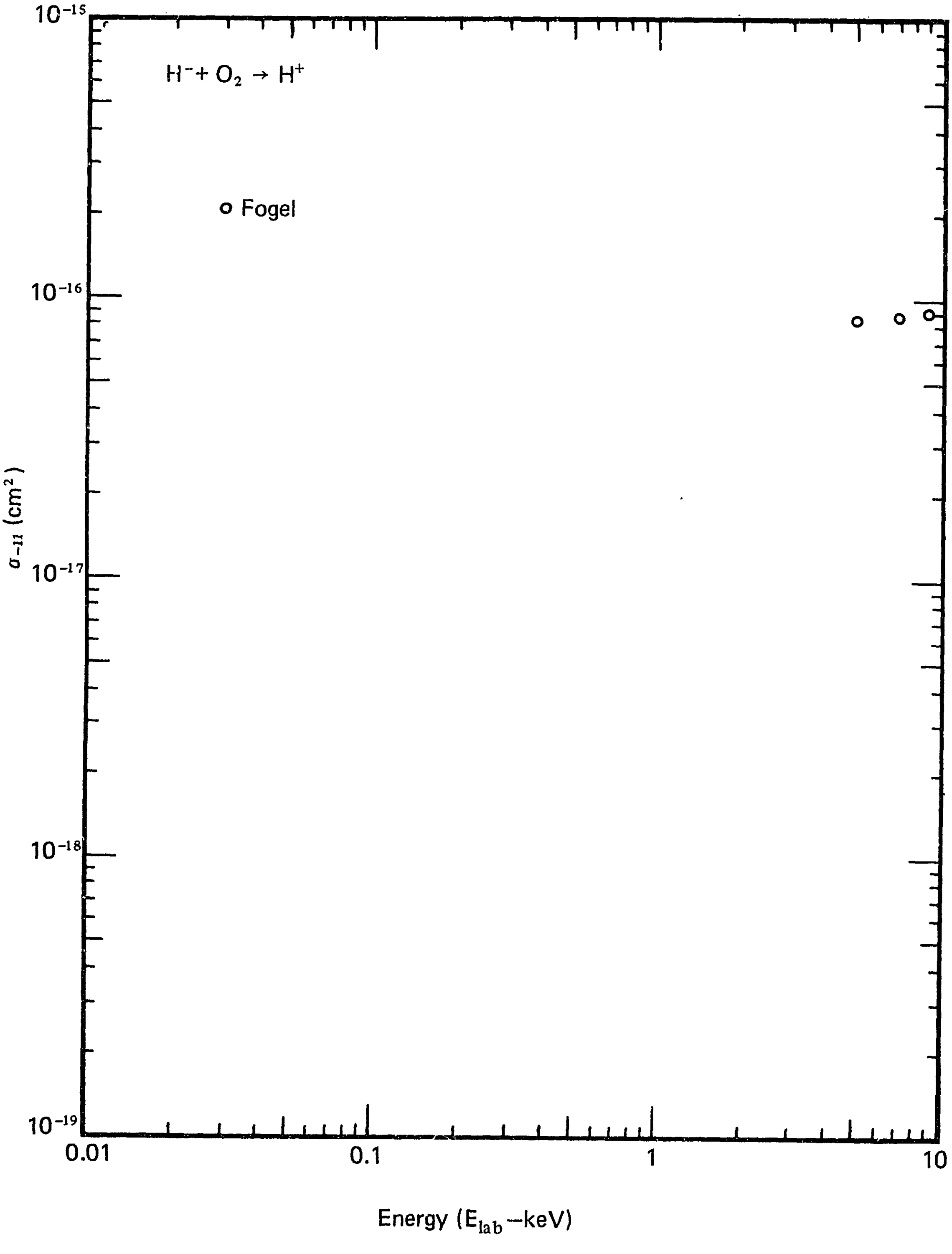

Fig. 84 Cross sections for two-electron loss of H^- beams in O_2

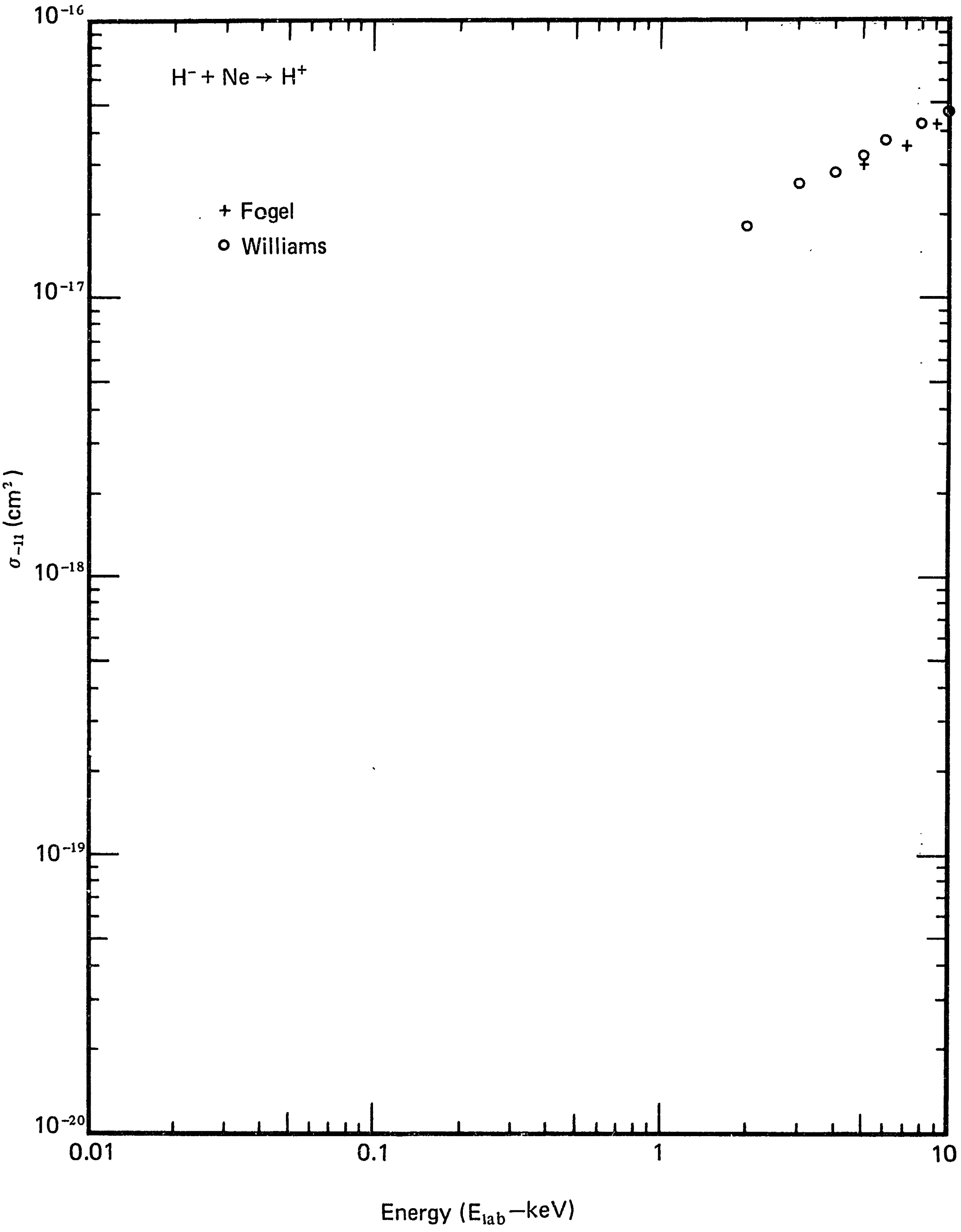

Fig. 85 Cross sections for two-electron loss of H^- beams in Ne

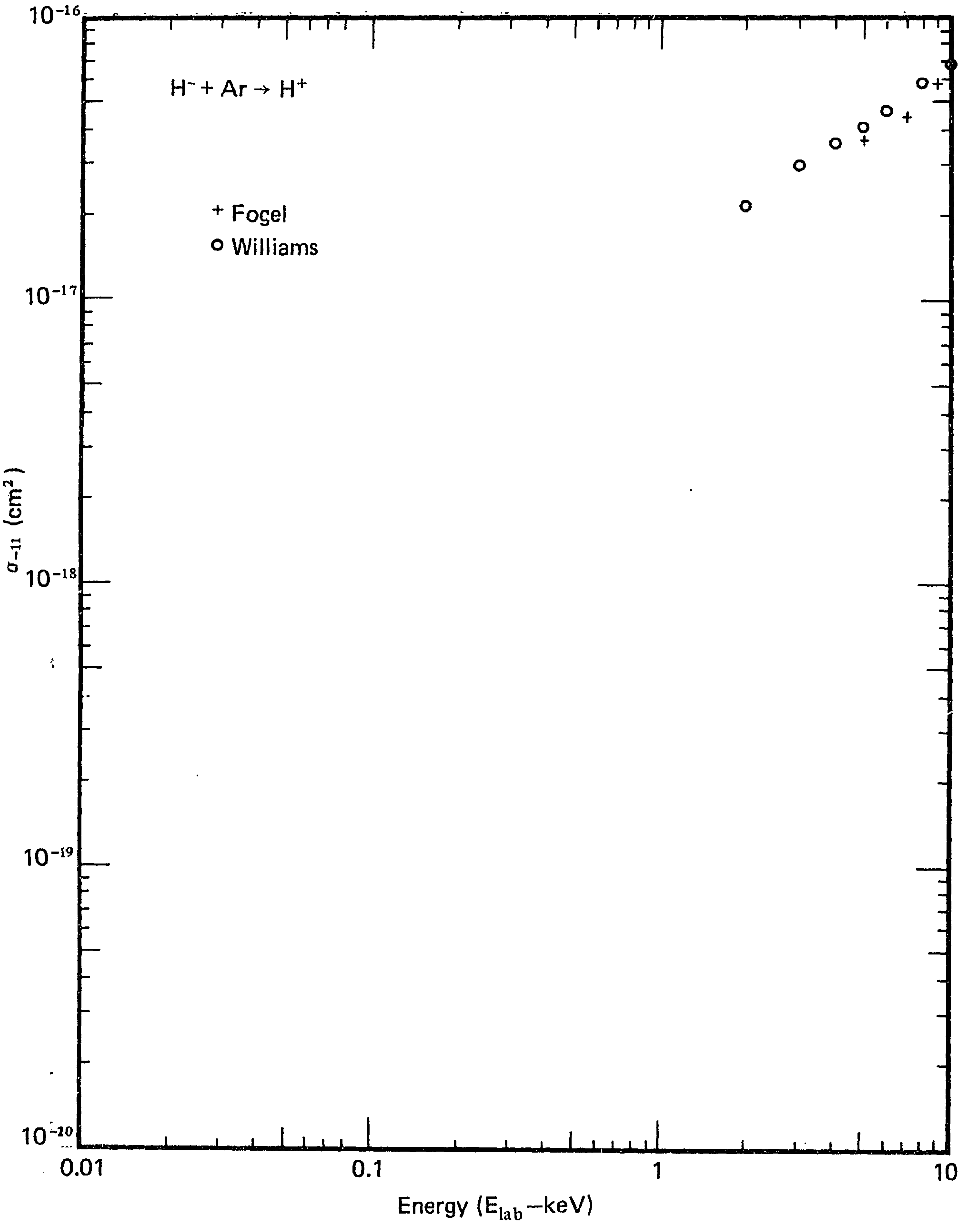

Fig. 86 Cross sections for two-electron loss of H^- beams in Ar

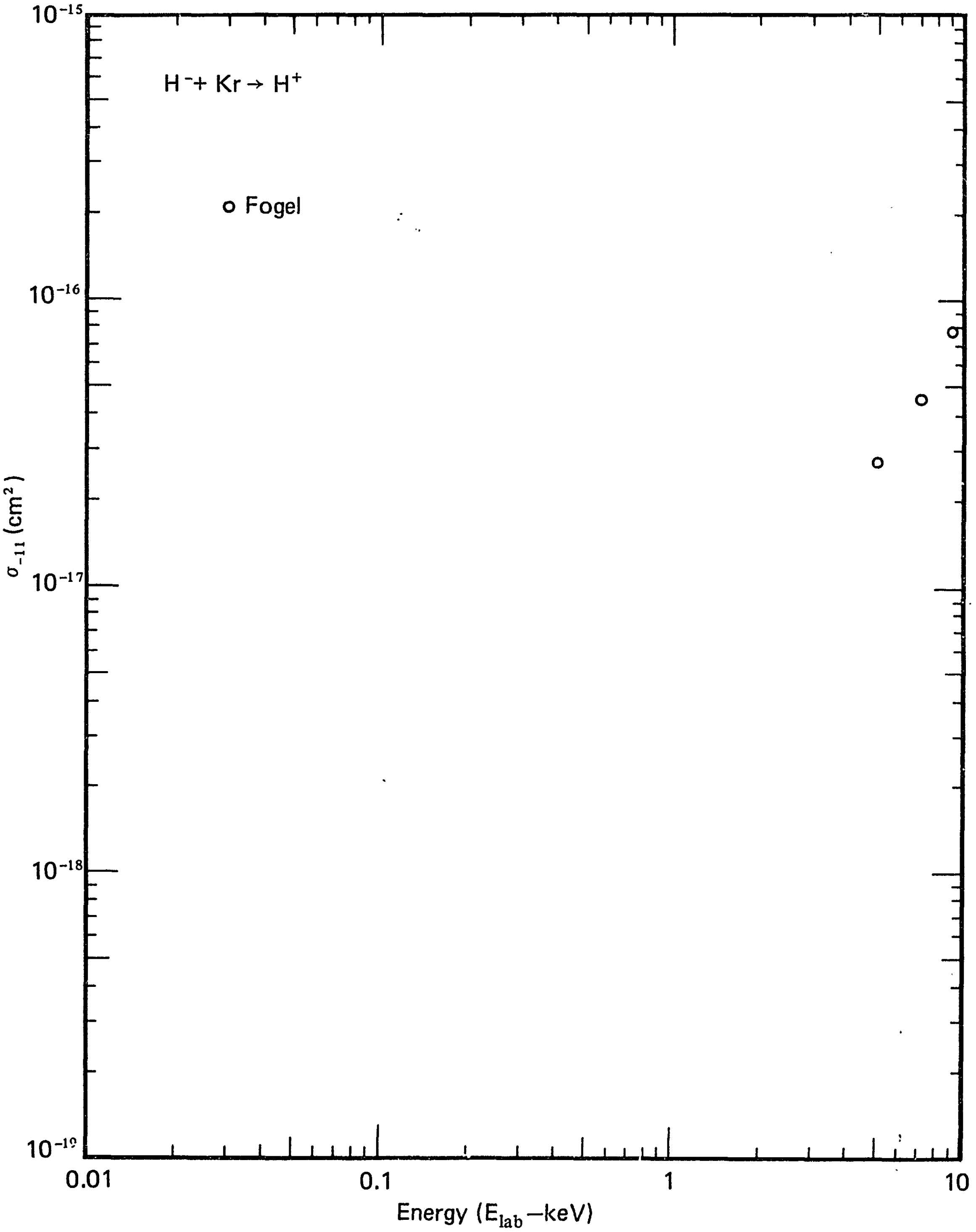

Fig. 87 Cross sections for two-electron loss of H^- beams in Kr

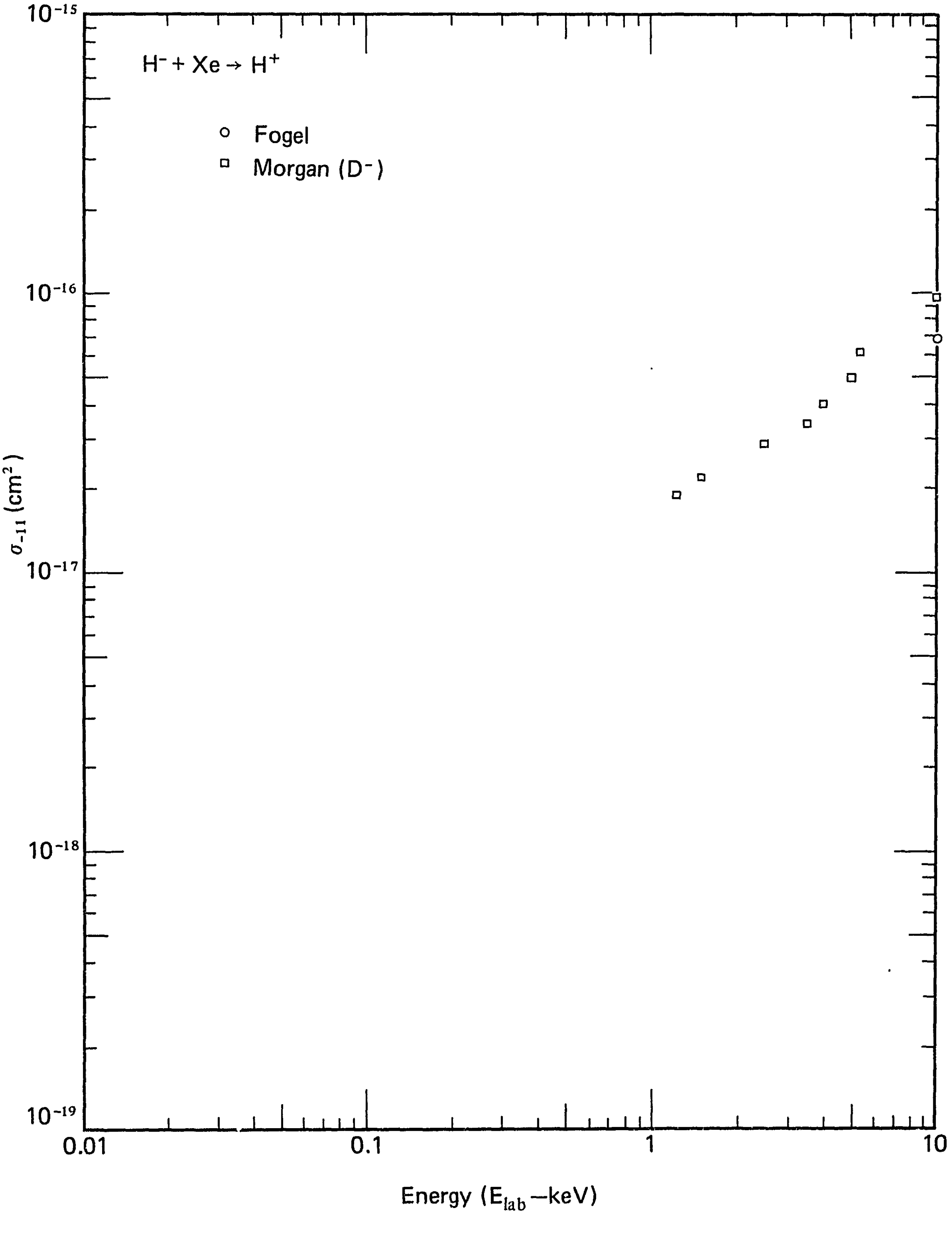

Fig. 88 Cross sections for two-electron loss of H^- beams in Xe

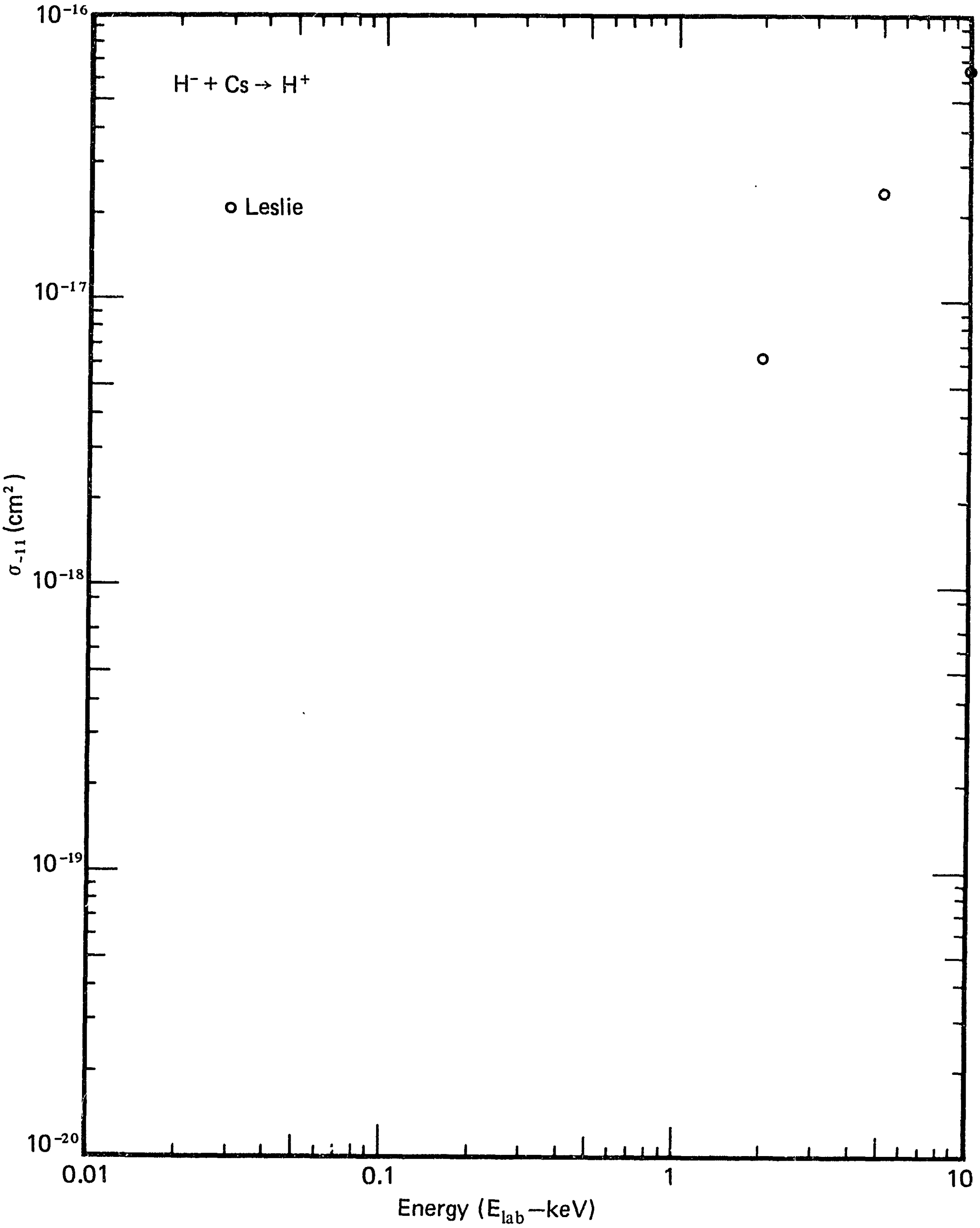

Fig. 89 Cross sections for two-electron loss of H^- beams in Cs