

CHARGE CHANGING CROSS SECTIONS
FOR HEAVY-PARTICLE COLLISIONS IN
THE ENERGY RANGE FROM 0.1 eV TO 10 MeV

I. INCIDENCE OF H, Li, Be, B AND THEIR IONS

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December 1978

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Introduction

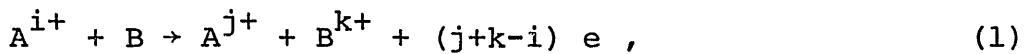
This paper presents a compilation of the experimental works on charge changing cross sections for neutral atoms, negative- and positive-atomic ions of atomic numbers $Z = 2 - 5$ in collisions with atoms and simple molecules. A systematic survey of the literature has been made through October 1977. Some recent data are also included. The result is summarized in graphical forms with reference lists attached.

Note on Reference List and Graphs

There are some review articles¹⁻⁷⁾ on the charge changing cross sections of atoms and ions in gases. Generally, they deal with the electron loss cross sections of projectiles and the ionization cross sections of targets. The energy ranges are rather high, where the electron capture processes are not dominant. Here we compile the experimental works on the charge changing cross sections of projectiles in a wide energy range down to 0.1 eV. In the low-energy region, the electron capture process becomes dominant. The charge changing cross section data on hydrogen atom and ion in various gases and vapors were covered by Tawara and Russek⁶⁾ and Tawara⁷⁾, so that they are not included here.

Some review papers^{1,6)} have already discussed fully about the charge changing process, experimental methods and accuracy of the data. Here only the explanation of the symbols used in this paper is described.

In the charge changing process, an atomic projectile colliding with atomic or molecular targets may capture or lose one or more electrons at the collision. The process can be written as



irrespective of the excitation of the colliding particles. Here, i, j and k are the initial and final charge states of the projectile (A) and the final state of the target (B), respectively. Then $(j+k-i)$ electrons are released after the collision. Of course, i, j and k cannot be larger than the atomic numbers of the respective particles and $j+k-i \geq 0$. The elementary cross section of the

process (1) is represented by σ_{ij}^{0k} (or $\sigma_{ij}^{0(k0)}$) for a diatomic molecular target to be dissociated). The summation over k of the elementary cross sections, $\sigma_{ij} \equiv \sum_k \sigma_{ij}^{0k}$, means the charge changing cross section of the projectile when i is not equal to j : σ_{ij} ($i > j$) is the electron capture cross section and σ_{ij} ($i < j$) is the electron loss cross section. When $j = i$, the cross section σ_{ii} means the total pure ionization cross section of the target particle and is denoted by $\sigma_i^i \equiv \sum_k \sigma_{ii}^{0k}$. In the condenser method using parallel plates, the cross sections of slow ion and electron productions are obtained. They are denoted by $\sigma_i^+ \equiv \sum_{jk} k \sigma_{ij}^{0k}$ and $\sigma_i^- \equiv \sum_{jk} (j+k-i) \sigma_{ij}^{0k}$, including ionization of projectiles. The cross sections obtained by the condenser method or projectile-beam attenuation method are some sort of sum of the elementary cross sections. Therefore, one cannot determine the charge changing cross section only by the total charge collection or the beam attenuation unless sufficient information about the charge changing mechanism is available.

In this paper, experimental data are divided into three groups:
 (A) Electron capture cross sections of projectile, (B) Electron loss cross sections of projectile, and (C) Ionization cross sections of target and production cross sections of slow ions and electrons. Some of the literature dealing with excited states, angular distribution of scattered particles, energy loss spectra of the projectile and so on, rather than cross sections themselves, are also included in the present lists and tables. The graphs are separated into two energy ranges: from 0.1 eV to 1.0 keV and 1.0 keV to 10 MeV. The energy scale is given in the laboratory

systems. For the data on isotopes, the energy scale has been corrected by multiplying a scale factor. The cross sections obtained for molecular targets are all presented in the unit of cm^2 per molecule in this paper.

The present author should like to thank W. Shearer-Izumi and T. Watanabe (Faculty of Engineering, University of Tokyo) for the proffer of their reference library (1967-1975) and also should like to thank K. Takayanagi (Institute of Space and Aeronautical Science, University of Tokyo) for making his bibliographies^{8,9)} available.

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Charge Changing Cross Sections of Helium
Atoms and Ions, Z=2.

- I. Lists of Reference
- II. Tables of Experimental Data
 - A) Electron Capture Cross Sections
 - B) Electron Loss Cross Sections
 - C) Cross Sections of Ionization, Slow ions
Productions and Electron productions
- III. Graphs of Charge Changing Cross Sections

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II. Table of Experimental Data

A) Electron Capture Cross Sections of Helium Atom and Ions;

He^0 , He^+ and He^{2+} .

Author	year	Energy (eV)	Target	Reference
$(\sigma_0)_l$				
Fogel' <u>et al.</u>	1960	10,000-60,000	Ne,Ar,Kr,Xe	43
Jorgensen <u>et al.</u>	1965	50,000-200,000	H_2	69
Collins,Stroud	1967	100,000	H_2	26
Dounally,Thoeming	1967	2,000	Cs	35
Schlachter <u>et al.</u>	1968	1,500-25,000	Cs	128
Baragiola <u>et al.</u>	1973	90,000	Li,Mg,Pb	8
Baragiola,Salvatelli	1975	20,000-40,000	Mg,Pb	11
(σ_{10})				
Rudnick	1931	7,500-21,000	He	123
Massey,Smith	1933		He	92
Smith	1934	2,000-12,000	He	140
Rostagni	1935	10-900	He	122
Wolf	1937	25-1,000	He, N_2 , Ne, Ar	157
Meyer	1937	35,000-200,000	H_2 , He, Air	95
Keeene	1949	3,000-35,000	H_2 , He	71
Hasted	1951	25-900	He	55
Snitzer	1953	100,000-480,000	H_2 , He, Ar, Air	142
Stedeford,Hasted	1955	100-4,000	He, Ne, Ar, Kr, Xe	149
Dillon <u>et al.</u>	1955	50-735	He	32
Allison <u>et al.</u>	1956	100,000-450,000	H_2 , He, Ar	4
Fedorenko <u>et al.</u>	1956	3,000-980,000	He, Ne, Ar, Kr	38
Cramer,Simons	1957	4-400	He	28
DeHeer <u>et al.</u>	1957	10,000-20,000	H_2 , Ar	29

Gilbody, Hasted	1957	100-3,600	H ₂ , He, Ne, Ar	47
Ghosh, Sherian	1957	100-800	He	46
Allison	1958	150,000-450,000	H ₂ , He, Air	5
Barnett, Stier	1958	4,000-200,000	H ₂ , He, N ₂ , O ₂ , Ne, Ar	14
Windham <u>et al.</u>	1958	17,500	H ₂	154
Jones <u>et al.</u>	1959	25,000-100,000	He, Ne, Ar	68
Gustafsson, Lindholm	1960		He, N ₂	54
Nikolaev <u>et al.</u>	1961	300,000-1,300,000	He, N ₂ , Ar, Kr	103
Pivovar <u>et al.</u>	1962	200,000-1,450,000	He, N ₂ , Ar, Kr	118
Gilbody <u>et al.</u>	1963	100,000-400,000	H ₂ , He, Ne, Ar, Kr	48
Stebbins <u>et al.</u>	1963	100-7,700	N ₂ , O ₂	147
Solv'ev <u>et al.</u>	1964	15,000-180,000	H ₂ , He, N ₂ , Ar	143
Hayden, Utterback	1964	30-1,000	He	57
Sayers, Smith	1964	195-503°K	N ₂ , O ₂	148
Lipeles <u>et al.</u>	1965	5-500	Ne, Ar, Kr, Xe	85
Stebbins <u>et al.</u>	1965	3-600	N ₂ , O ₂	127
Fehsenfeld <u>et al.</u>	1966	300°K	O ₂	39
DeHeer <u>et al.</u>	1966	10,000-140,000	H ₂ , He, N ₂ , O ₂ , Ne, Ar, Kr	30
Collins, Strroud	1967	100,000	H ₂	26
Koopman	1967	100-1,050	Ar, Kr, Xe	77
Donnally, Thoeming	1967	2,000	Cs	35
Wittkower <u>et al.</u>	1967	60,000-330,000	H ₂ , He	155
Beryaev <u>et al.</u>	1968	7-100	He	18
Dunkin <u>et al.</u>	1968	82-600°K	Ne	36
Gilbody <u>et al.</u>	1968	7,500-250,000	H ₂	49
Champion, Doverspike	1968	1.6-50	N ₂	24
Maier	1968	0.5-400	N ₂ , O ₂	89

Schlachter <u>et al.</u>	1968	1,500-25,000	Cs	128
Koopman	1968	40-1,500	N ₂ , O ₂ , H ₂ O, CO ₂	78
Mahadevan, Magnuson	1968	1-100	He, N ₂ , O ₂ , Ar	88
Il'in <u>et al.</u>	1969	30,000-180,000	Na, Mg	63
Champion, Doverspike	1969	30-200	Ar	24
Koopman	1959	120-1,000	H ₂ , N ₂ , O ₂ , H ₂ O, NH ₃ , CH ₄ , CO ₂	79
Lockwood	1969	5,000-100,000	N ₂ , O ₂	87
Nagy <u>et al.</u>	1969	400-2,000	He	101
Ong, Hasted	1969	0.04-0.25	N ₂	107
Peterson, Lorents	1969	11-1,550	K, Rb, Cs	117
Schlumbohm	1969	3-200	Ar, Kr, N ₂ , O ₂	129
Gaily, Harrison	1970	200-1,200	H ⁻	44
Latypov <u>et al.</u>	1970	200-3,200	He	101
Lockwood	1970	10,000-100,000	N ₂	87
Muller, DeHeer	1970	300-150,000	He, Ne, Ar, Kr, Xe	100
Olson <u>et al.</u>	1970	3-300	H ⁻	106
Smith <u>et al.</u>	1970	65-300	Ar	141
Taylor <u>et al.</u>	1970	120,000-830,000	He, Ne, Ar	151
Il'in <u>et al.</u>	1971	15,000-180,000	Na, Mg	64
Gilbody <u>et al.</u>	1971	10,000-200,000	H ₂ , He, N ₂ , Ne, Ar, Kr	51
Gusev <u>et al.</u>	1971	3,000-50,000	CO	53
Lipeles	1971	10-1,000	Ar	86
Ormrod, Michel	1971	125,000	H ₂	110
Salop <u>et al.</u>	1971	50-1,600	K, Rb	126
Shelton, Stoycheff	1971	2,000-22,000	He	135
Tawara	1971	14,000-50,000	H ₂	150
Aleinikov, Ushakov	1972	300°K	Zn, Cd, Te, Hg	3

Latypov, Shaporenko	1972	400-3,200	He	83
Maier	1972	0-100	Kr,Xe	90
Tolmachev	1972	300°K	I	152
Barat <u>et al.</u> :	1973	300-3,000	Ne	12
Haugh	1973	2,500	HBr,HCl	56
Johnsen <u>et al.</u>	1973	0.04-0.34	Hg	67
Kemper,Bowers	1973	0.04-1.0	N ₂	72
Montmagnon <u>et al.</u>	1973	5,000-20,000	Cs	98
Moran,Courads	1973	1,000-3,000	H ₂	99
Turner-Smith <u>et al.</u>	1973	300°K	Zn,Cd,Se	153
Coplan,Ogilvie	1974	200-1,500	CO	27
Isler	1974	4.7-10,000	Ar	65
Meyer,Anderson	1974	500-41,000	Cs	27
Baragiola,Salvatelli	1975	9,000-40,000	Mg,Pb	10
Brenot <u>et al.</u>	1975	800-3,000	He,Ne,Ar,Kr,Xe	21,22,137
Kano <u>et al.</u>	1975	300°K	I	172
Kikiani <u>et al.</u>	1975	200-4,000	He	76
Latypov	1975	150-3,300	He	84
Shah,Gilbody	1975	15,000-60,000	H ₂	132
Eisel,Nagy	1976	500-5,000	He	37
Eisel,Nagy	1977	500-5,000	Ne,Ar	158
Helm	1977	0.3-8.0	He	159
Jones <u>et al.</u>	1977	100	Xe	160
Meyer <u>et al.</u>	1977	40,000-160,000	Cs	161
Hegerberg <u>et al.</u>	1978	1,000-10,000	He	58
(σ ₁ ⁻¹ ₁)				
Schlachter <u>et al.</u>	1978	1,500-25,000	C _s	128

(σ_{21})

Rutherford	1924	650,000-6,800,000	Air	124
Snitzer	1953	100,000-480,000	H ₂ ,He,Ar,Air	142
Allison	1958	150,000-450,000	H ₂ ,He,Air	5
Nikolaev <u>et al.</u>	1961	350,000-1,000,000	He,N ₂ ,Ar,Kr	103
Fite <u>et al.</u>	1962	100-32,500	H	42
Pivovar <u>et al.</u>	1962	200,000-1,500,000	H ₂ ,He,N ₂ ,Ar,Kr	118
Hertel, Koski	1964	1,000-8,000	He	60
Collins,Stroud	1967	100,000	H ₂	26
Berkner <u>et al.</u>	1968	7,200-181,000	He	19
Stearns <u>et al.</u>	1968	7,700-166,000	N ₂	146
Puckett <u>et al.</u>	1969	150,000-1,000,000	H ₂ ,He,N ₂ ,Ar	121
Gilbody <u>et al.</u>	1970	4,000-30,000	Ar	50
Chen <u>et al.</u>	1971	400-1,000	Ne	25
Ormrod,Michel	1971	125,000	H ₂	138
Siegel <u>et al.</u>	1972	200-1,000	He,Ne,Ar	110
Afrosimov <u>et al.</u>	1973	2,000-100,000	He,Xe	1
Baragiola,Nemirovsky	1973	55,000-400,000	H ₂ ,Ne,Ar	9
Bayfield,Khayrallah	1973	15,000-125,000	H ₂ ,He,N ₂ ,Ar	15
Graham <u>et al.</u>	1973	6,700-85,000	H ₂ ,CO	52
Shah,Gilbody	1974	10,000-60,000	H ₂ ,He,N ₂ ,O ₂ ,Ar,Kr	131
Shah, Gilbody	1974	6,000-60,000	H	131
Shah, Gilbody	1974	10,000-60,000	K	131
Afroaimov <u>et al.</u>	1975	10,360	He	2
Ast <u>et al.</u>	1975	8,000	He,Ne,Ar,Kr,Xe	6
Bayfield,Khayrallah	1975	15,000-125,000	H ₂ ,He,N ₂ ,Ar	16
Bayfield,Khayrallah	1975	7,000-144,000	H	17
Khayrallah,Bayfield	1975	7,000-70,000	H ₂ ,He,N ₂ ,Ar	75

Schrey, Huber	1975	50-540	Ar	130
Hvelplund <u>et al.</u>	1976	1,000,000-8,000,000	H ₂ , He, Ar	105
Shah, Gilbody	1976	10,000-60,000	H, H ₂ , He, N ₂ , O ₂ , Ar, Kr	133
Nutt <u>et al.</u>	1978	400-10,000	H, H ₂	105
Shah, Gilbody	1978	4,000-343,000	H	134
(σ_{20})				
Rutherford	1924	650,000-6,800,000	Air	124
Allison <u>et al.</u>	1956	100,000-450,000	H ₂ , He, Air	4
Allison	1958	150,000-450,000	H ₂ , He, Air	5
Nikolaev <u>et al.</u>	1962	330,000-1,300,000	He, N ₂ , Ar, Kr	104
Pivovar <u>et al.</u>	1962	200,000-1,500,000	H ₂ , He, N ₂ , Ar, Kr	118
Collins, Stroud	1967	100,000	H ₂	26
Berkner <u>et al.</u>	1968	7,200-181,000	He	19
Stearns <u>et al.</u>	1968	7,700-166,000	N ₂	146
Afrosimov <u>et al.</u>	1973	2,000-100,000	He, Xe	1
Baragiola, Nemirovsky	1973	55,000-400,000	H ₂ , Ne, Ar	9
Bayfield, Khayrallah	1973	15,000-125,000	H ₂ , He, N ₂ , Ar	15
Graham <u>et al.</u>	1973	6,700-85,000	CO	52
Shah, Gilbody	1974	10,000-60,000	He, N ₂ , O ₂ , Ar, Kr	131
Shah, Gilbody	1974	10,000-60,000	K	131
Bayfield, Khayrallah	1975	15,000-125,000	H ₂ , He, N ₂ , Ar	16
Bayfield, Khayrallah	1975	7,000-144,000	H	17
Schrey, Huber	1975	50-540	He	130
Shah, Gilbody	1978	4,000-343,000	H	134

B) Electron Loss Cross Sections of Helium Negative Ion, Atom and Positive Ion; He⁻, He⁰ and He⁺.

(σ_{10})

Windham <u>et al.</u>	1958	175,000	H ₂	154
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Jorgensen <u>et al.</u>	1965	50,000-300,000	H ₂	69
Collins,Stroud	1967	100,000	H ₂	26
Nicholas <u>et al.</u>	1968	20,000-75,000	He	102
Ryding <u>et al.</u>	1968	480,000-1,500,000	H _e ,He,Ne	125
Schlachter <u>et al.</u>	1968	1,500-25,000	Cs	128
Simpson,Gilbody	1972	4,000-30,000	H ₂ ,He,Ar	139
Heinemeier <u>et al.</u>	1975	100,000-3,000,000	H ₂ ,He,Ar	59
$(\sigma_{\bar{1}1})$				
Collins,Stroud	1967	100,000	H ₂	26
Ryding <u>et al.</u>	1968	400,000-1,500,000	H ₂ ,He,Ne	125
Schlachter <u>et al.</u>	1968	1,5000-25,000	Cs	128
Heinemeier <u>et al.</u>	1975	100,000-3,000,000	H ₂ ,He,Ar	59
(σ_{01})				
Rudnick	1931	5,000-21,000	He	123
Snitzer	1953	100,000-480,000	H ₂ ,He,Ar,Air	142
Krasner	1955	100,000-450,000	H ₂ ,He,Ar	80
Barnett,Stier	1955	30,000-200,000	H ₂ ,He,N ₂ ,O ₂ ,Ne	13
Allison <u>et al.</u>	1956	100,000-450,000	H ₂ ,He,Air	4
DeHeer <u>et al.</u>	1957	10,000	Ar	29
Allison	1958	100,000-450,000	H ₂ ,He,Air	5
Barnett,Stier	1958	4,000-200,000	H ₂ ,He,N ₂ ,O ₂ ,Ne,Ar	14
Windham <u>et al.</u>	1958	17,500	H ₂	154
Fogel' <u>et al.</u>	1960	10,000-100,000	He,Ne,Ar,Kr,Xe	43
Pivovar <u>et al.</u>	1962	200,000-1,500,000	H ₂ ,He,N ₂ ,Ar,Kr	118
Solv'ev <u>et al.</u>	1964	15,000-180,000	H ₂ ,He,N ₂ ,Ar	143
Collins,Stroud	1967	100,000	H ₂	26
Wittkower <u>et al.</u>	1967	60,000-400,000	H ₂ ,He,N ₂ ,Ne,Ar, Kr, CO ₂	155

Gilbody <u>et al.</u>	1968	60,000-450,000	H ₂	49
Schlachter <u>et al.</u>	1968	1,500-25,000	C _s	128
Punkett <u>et al.</u>	1969	150,000-1,000,000	H ₂ ,He,N ₂ ,Ar	121
Gilbody <u>et al.</u>	1970	10,000-350,000	H ₂ ,He,N ₂ ,Ne,Ar,Kr	50
Ormrod, Michel	1971	125,000	H ₂	110
Pedersen,Hvelplund	1971	20,000-2,000,000	H ₂ ,He	113
Tawara	1971	14,000-50,000	H ₂	150
Baragiola <u>et al.</u>	1973	90,000	Li,Mg,Pb	8
Dmitriev <u>et al.</u>	1973	1,330,000-8,300,000	He,N ₂ ,Ne,Ar	34
Pedersen	1973	500-10,000	H ₂	114
Peart <u>et al.</u>	1977	3,000-28,500	H ⁺	112
Pedersen	1977	25,000-450,000	H ₂ ,He,N ₂ ,Ne,Ar	161
Hegerberg <u>et al.</u>	1978	1,000-10,000	He	58
(σ ₀₂)				
Allison	1958	150,000-450,000	H ₂ ,He,Air	5
Collins,Stroud	1967	100,000	H ₂	26
Baragiola <u>et al.</u>	1973	90,000	Mg,Pb	8
Dmitriev <u>et al.</u>	1973	1,330,000-8,300,000	He,N ₂ ,Ne,Ar	34
Hvelplund,Pedersen	1974	200,000-4,000,000	H ₂ ,He,Ne,Ar,Kr	61
(σ ₁₂)				
Snitzer	1953	340,000	He	142
Fedorenko <u>et al.</u>	1954	3,000-180,000	He,N ₂ ,Ne,Ar	38
Allison <u>et al.</u>	1956	100,000-450,000	H ₂ ,He,Air	4
DeHeer <u>et al.</u>	1957	10,000	Ar	29
Jones <u>et al.</u>	1959	25,000-100,000	He,Ne,Ar	68
Dmitriev <u>et al.</u>	1962	320,000-6,000,000	He,N ₂ ,Ar,Kr	33
Pivovar <u>et al.</u>	1962	200,000-1,500,000	H ₂ ,He,N ₂ ,Ar,Kr	112

Collins, Stroud	1967	100,000	H ₂	26
Taylor <u>et al.</u>	1970	120,000-830,000	He, Ne, Ar	151
Ormrod, Michel	1971	125,000	H ₂	110
Shah, Gilbody	1975	15,000-48,000	H ₂ , He, N ₂ , O ₂ , Ar	132
Mitchell <u>et al.</u>	1977	70,000-400,000	H ⁺	97
Peart <u>et al.</u>	1977	3.0-28.5	H ⁺	112

C) Ionization Cross Section, Slow Ion and Electron Productions
by Helium Atom and Ion; He° and He⁺.

$$(\sigma_0^i, \sigma_0^+, \sigma_0^-)$$

Solov'ev <u>et al.</u>	1964	15,000-180,000	H ₂ , He, N ₂ , Ar	143
Hayden, Utterback	1964	30-1,000	He, Ne, N ₂	57
Puckett <u>et al.</u>	1969	150,000-1,000,000	H ₂ , He, N ₂ , Ar	121
Browning <u>et al.</u>	1970	5,000-45,000	H ₂ , N ₂ , O ₂ , CO, CO ₂ , CH ₄	23
Polyakova <u>et al.</u>	1970	30,000-40,000	H ₂	120
Gerber <u>et al.</u>	1972	100-5,000	Ne, Ar, Kr, Xe	125
($\sigma_1^i, \sigma_1^+, \sigma_1^-$)			.	
Fedorenko <u>et al.</u>	1956	3,000-180,000	He, Ne, Ar, Kr	38
Gilbody, Hasted	1957	25-3,600	H ₂ , He, Ne, Ar	47
Gilbody <u>et al.</u>	1963	100,000-400,000	H ₂ , He, Ne, Ar	48
Solov'ev <u>et al.</u>	1964	15,000-180,000	H ₂ , He, N ₂ , Ar	143
Langley <u>et al.</u>	1964	133,000-1,000,000	H ₂ , He, N ₂ , O ₂ , Ne, Ar, CO	81
Martin <u>et al.</u>	1964	200,000-1,000,000	H ₂ , He, N ₂ , Ar	91
Pivovar <u>et al.</u>	1968	200,000-1,800,000	H ₂ , He, N ₂ , Ne, Ar, Kr	119
Geber <u>et al.</u>	1972	100-5,000	He, Ne, Ar, Kr, Xe	45

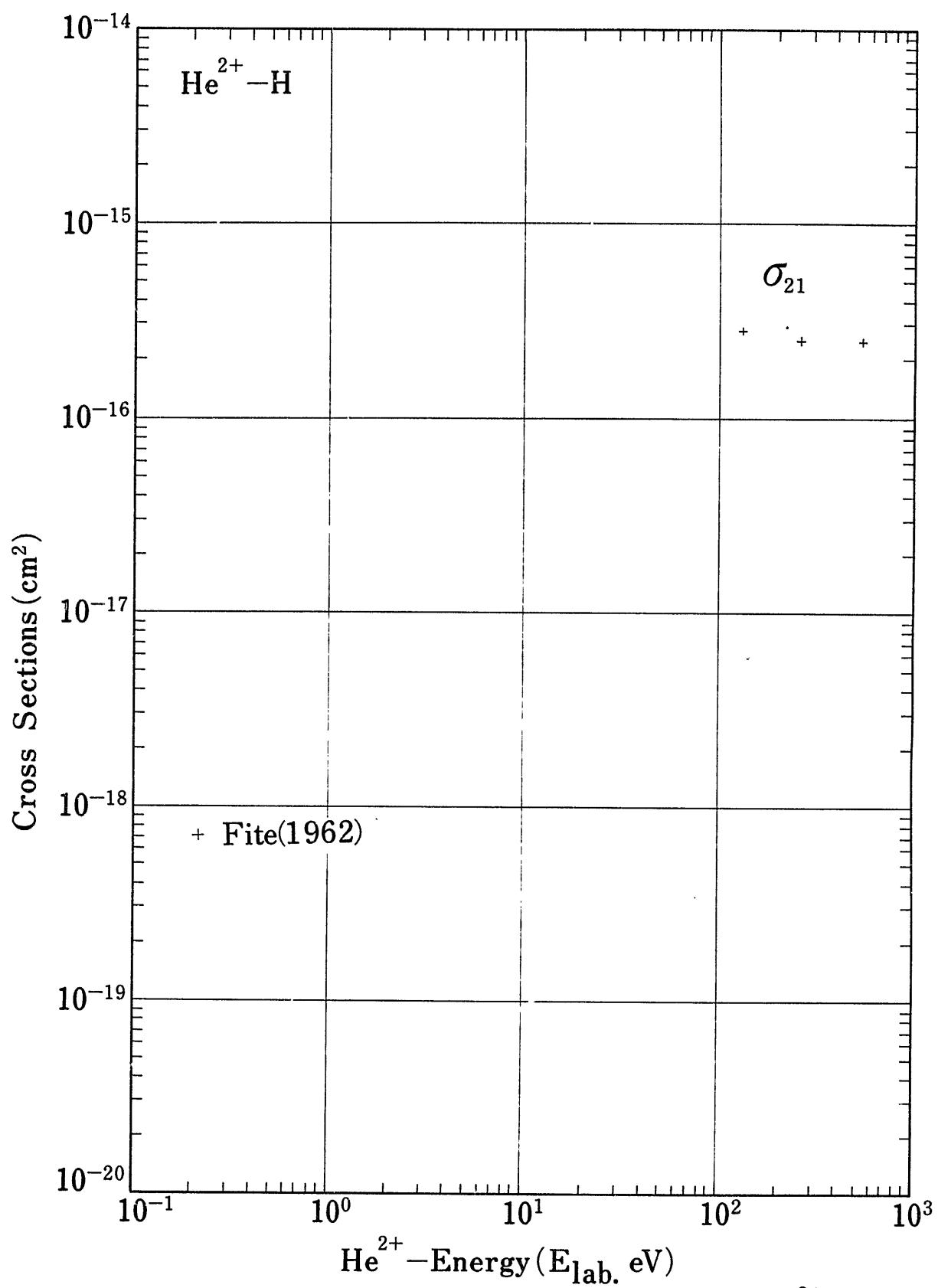


Fig.1-a Charge Changing Cross Sections of He^{2+} in H

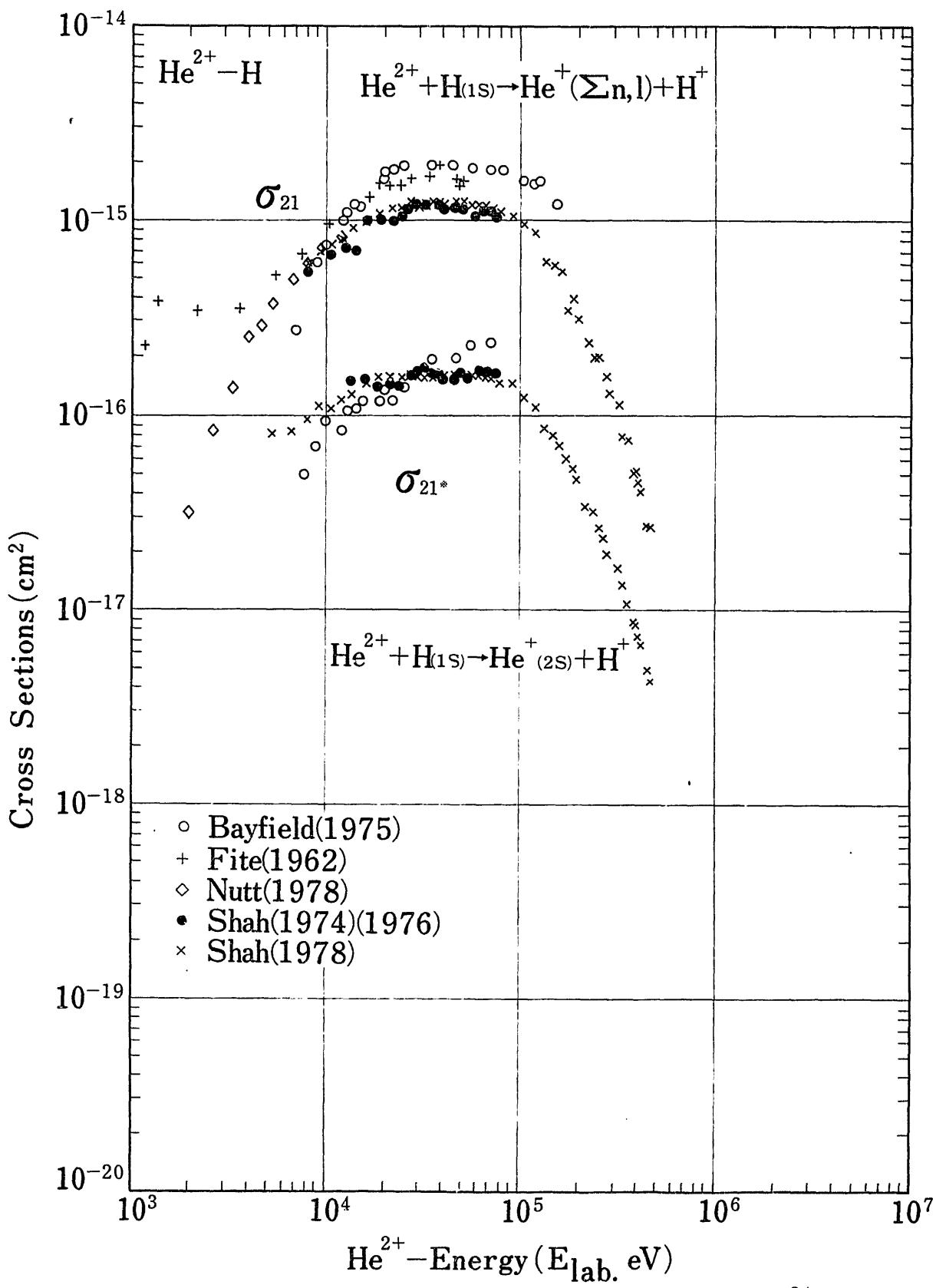


Fig.1-b Charge Changing Cross Sections of He^{2+} in H

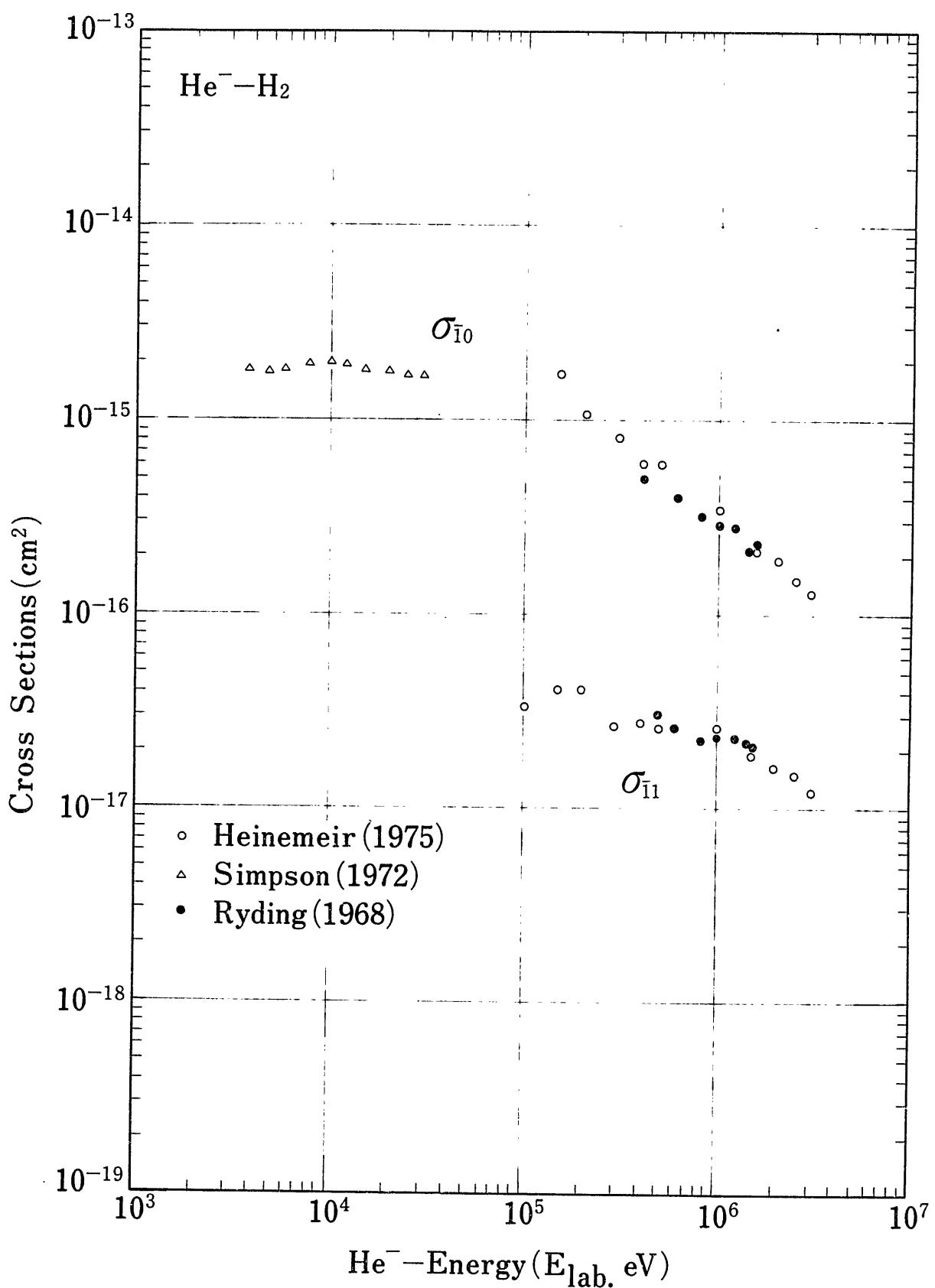


Fig.2 Charge Changing Cross Sections of He^- in H_2

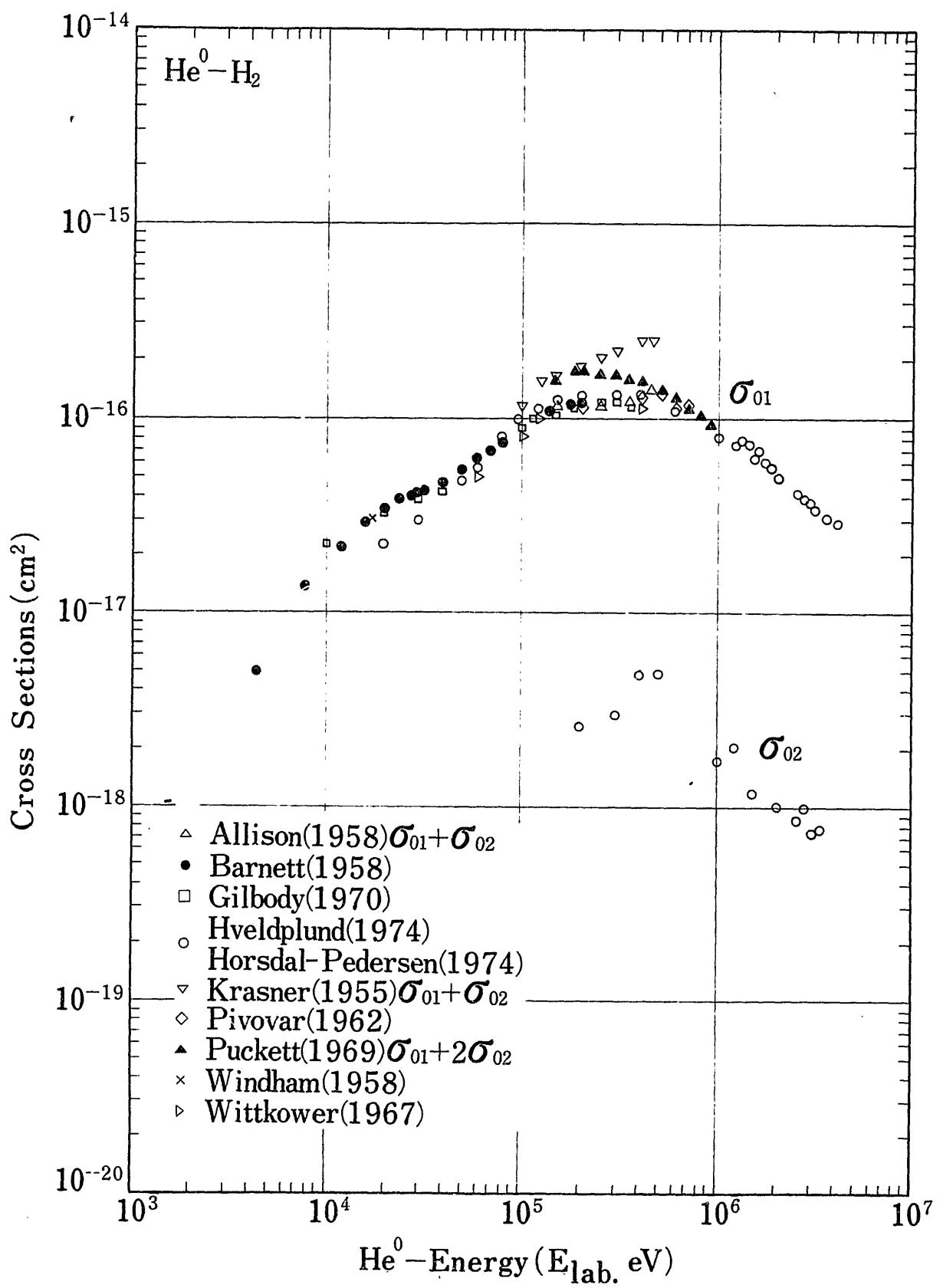


Fig.3 Charge Changing Cross Sections of He^0 in H_2

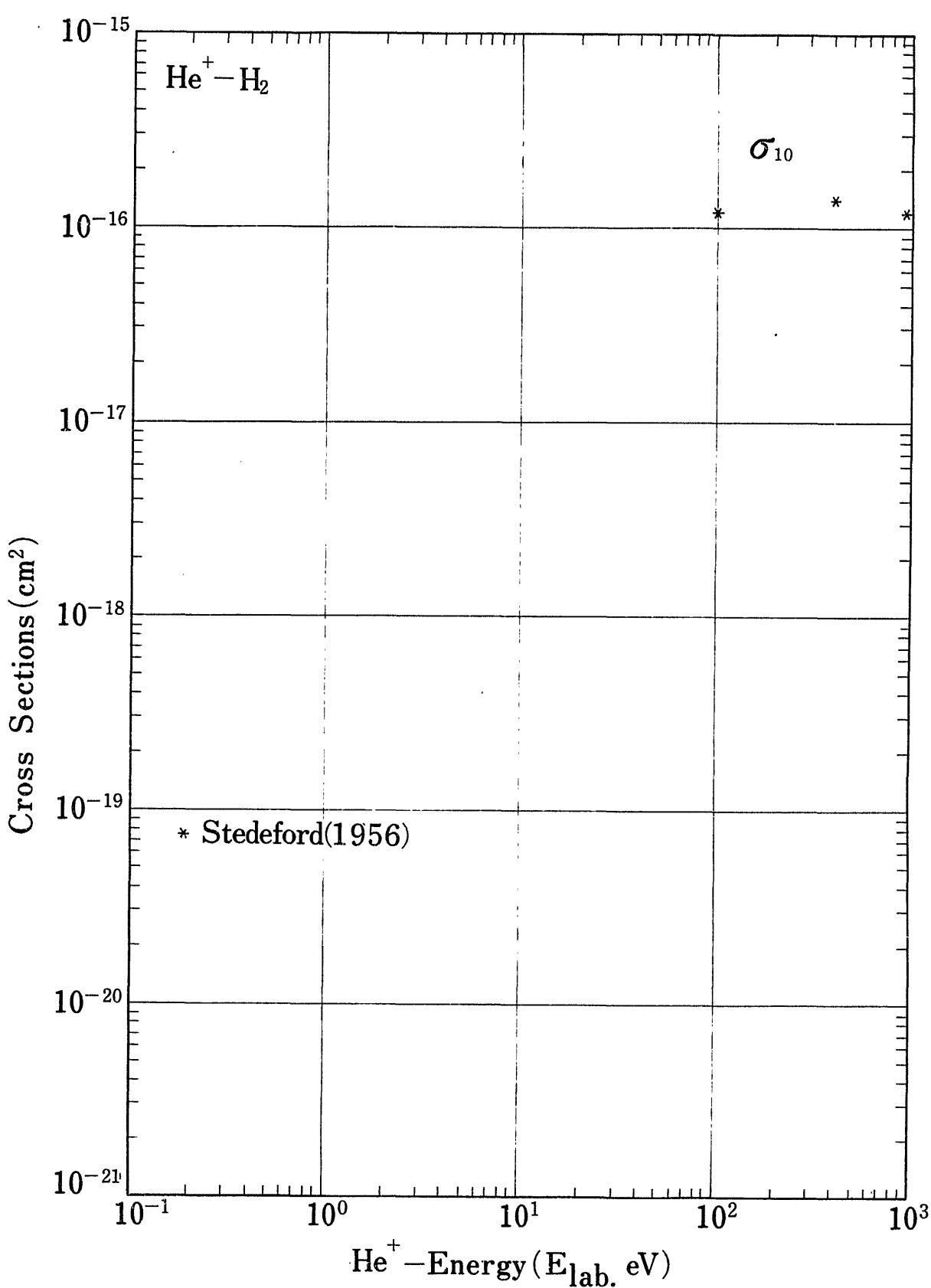


Fig.4-a Charge Changing Cross Sections of He^+ in H_2

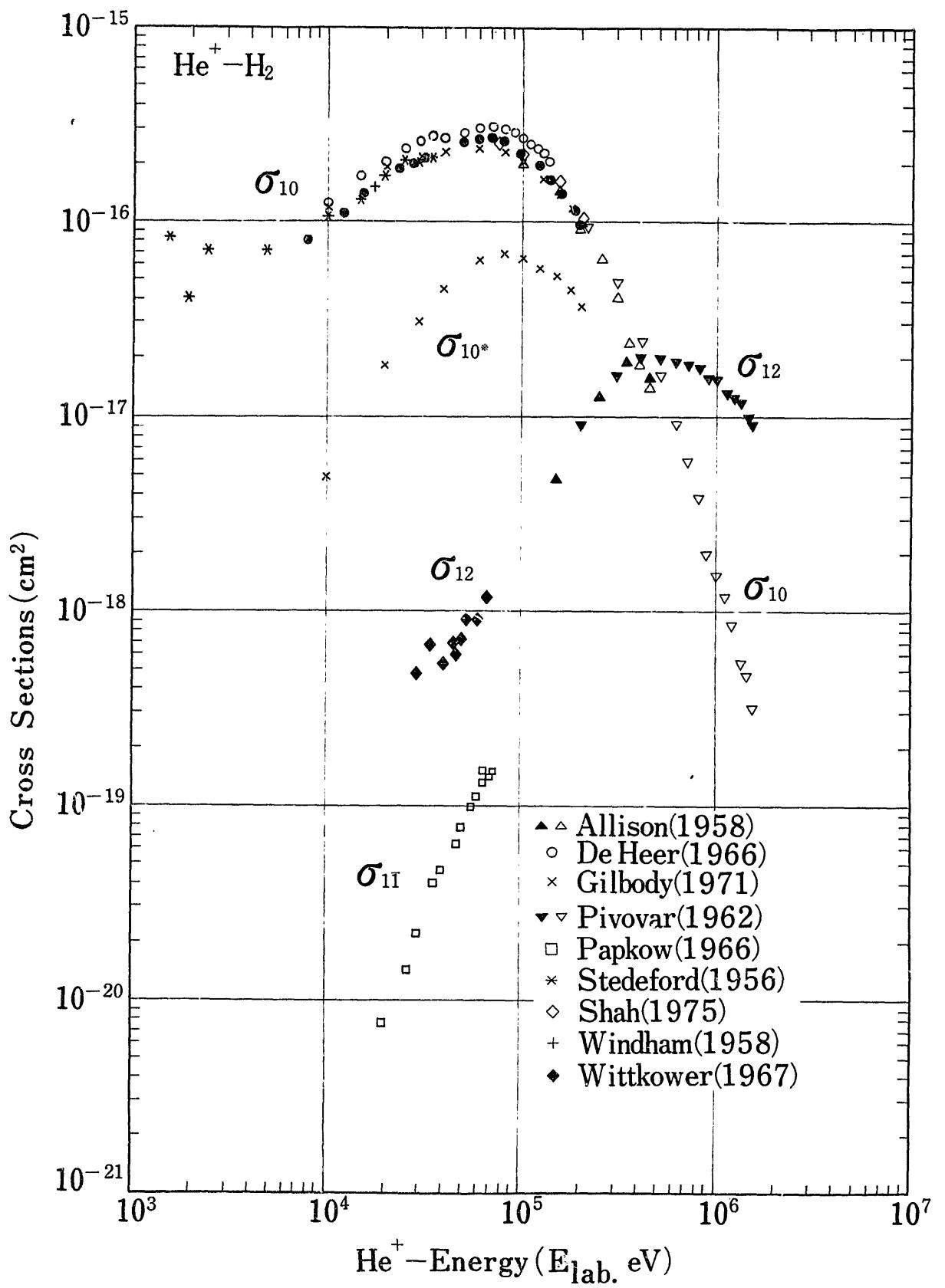


Fig.4-b Charge Changing Cross Sections of He^+ in H_2

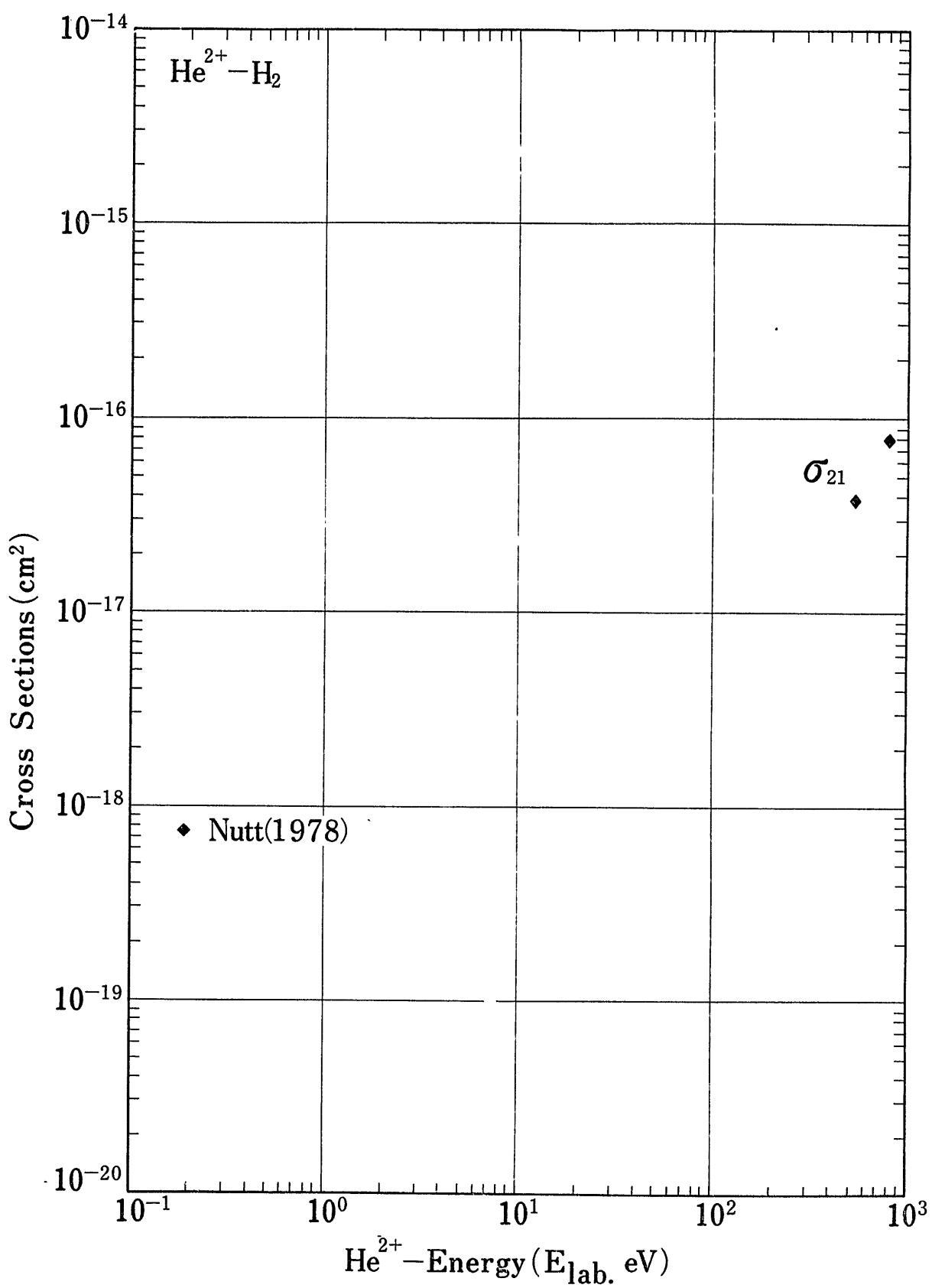


Fig.5-a Charge Changing Cross Sections of He^{2+} in H_2

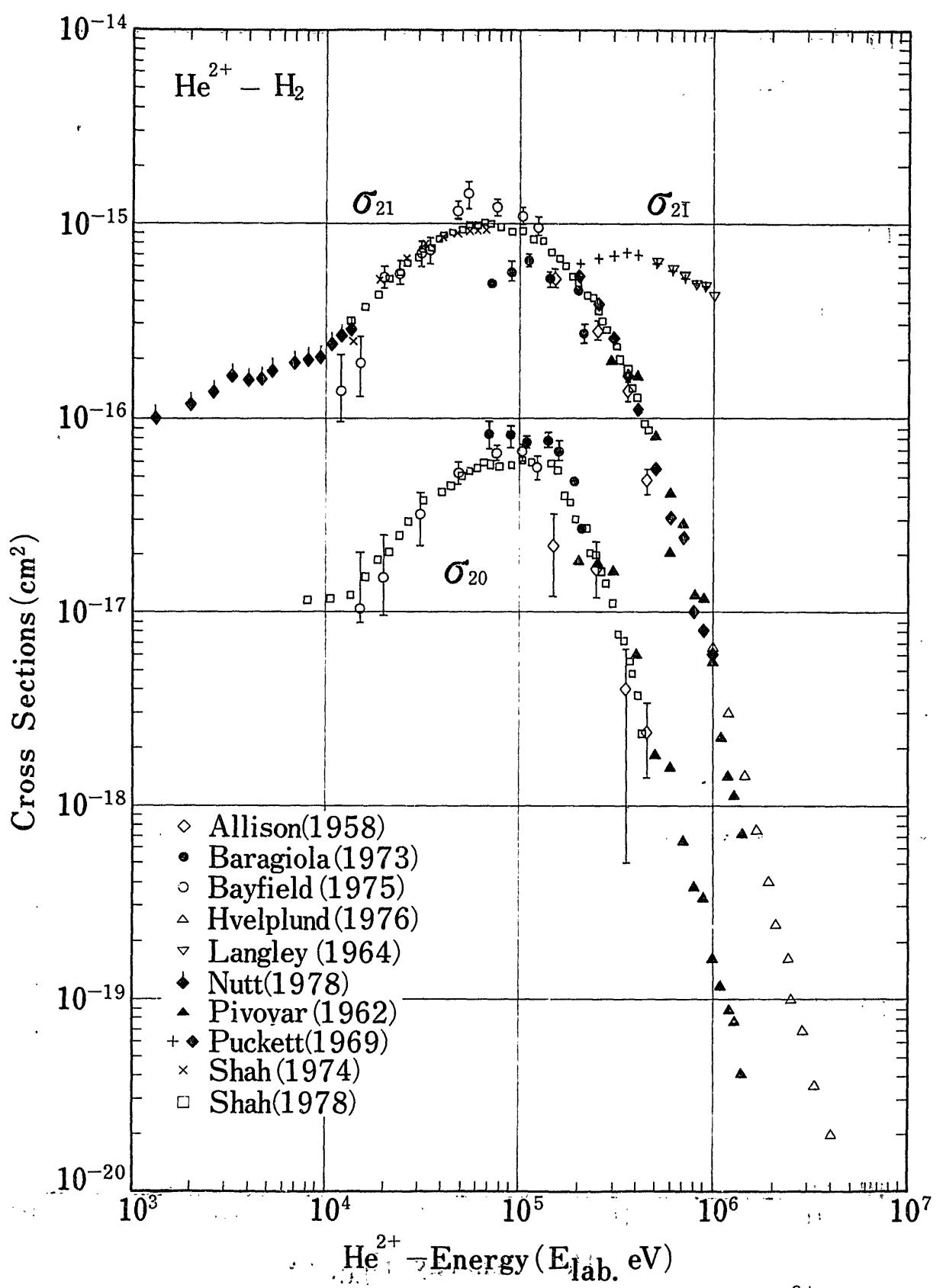


Fig.5-b Charge-Changing Cross Sections of He^{2+} in H_2

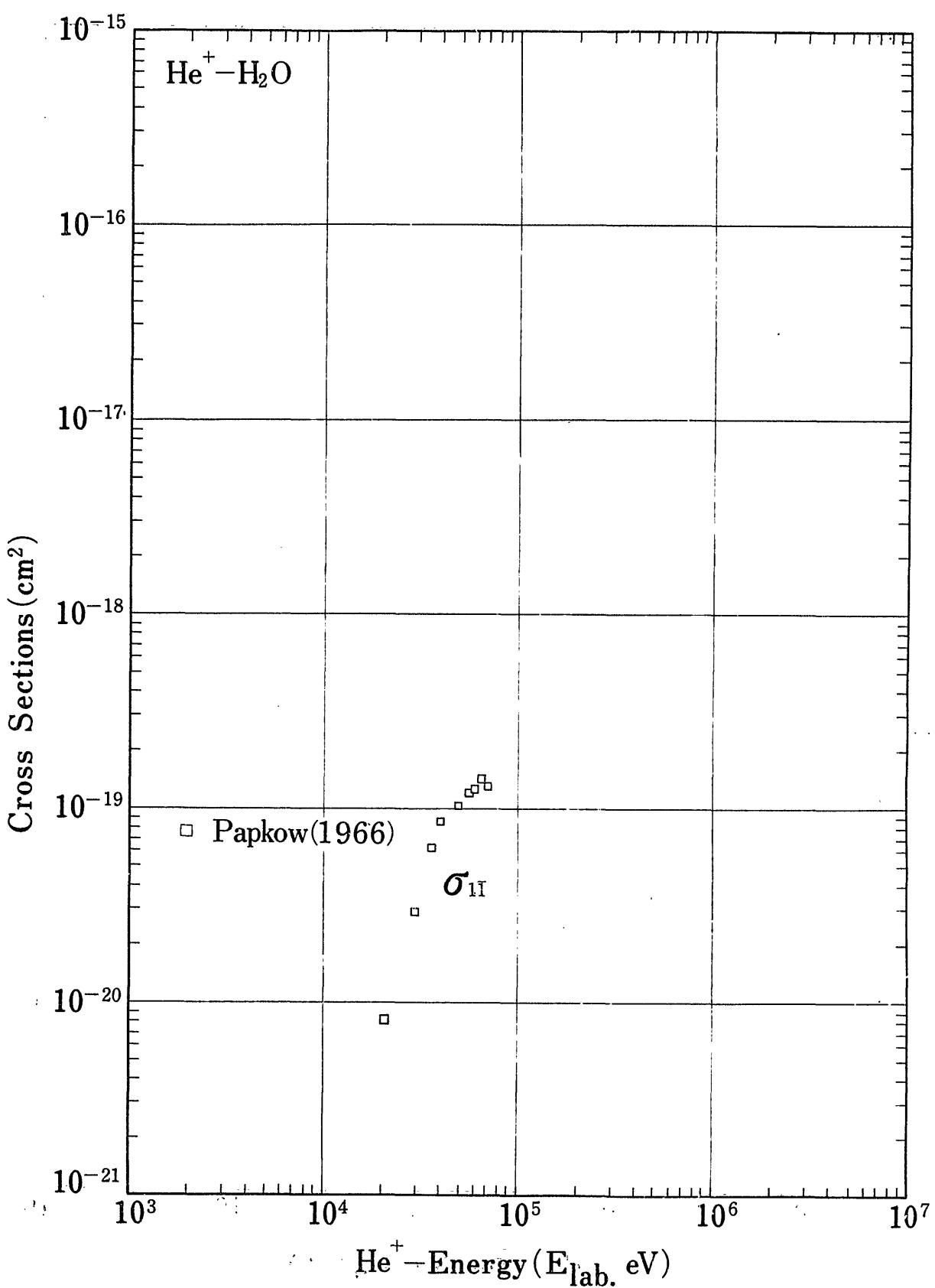


Fig. 6 Charge Changing Cross Sections of He^+ in H_2O

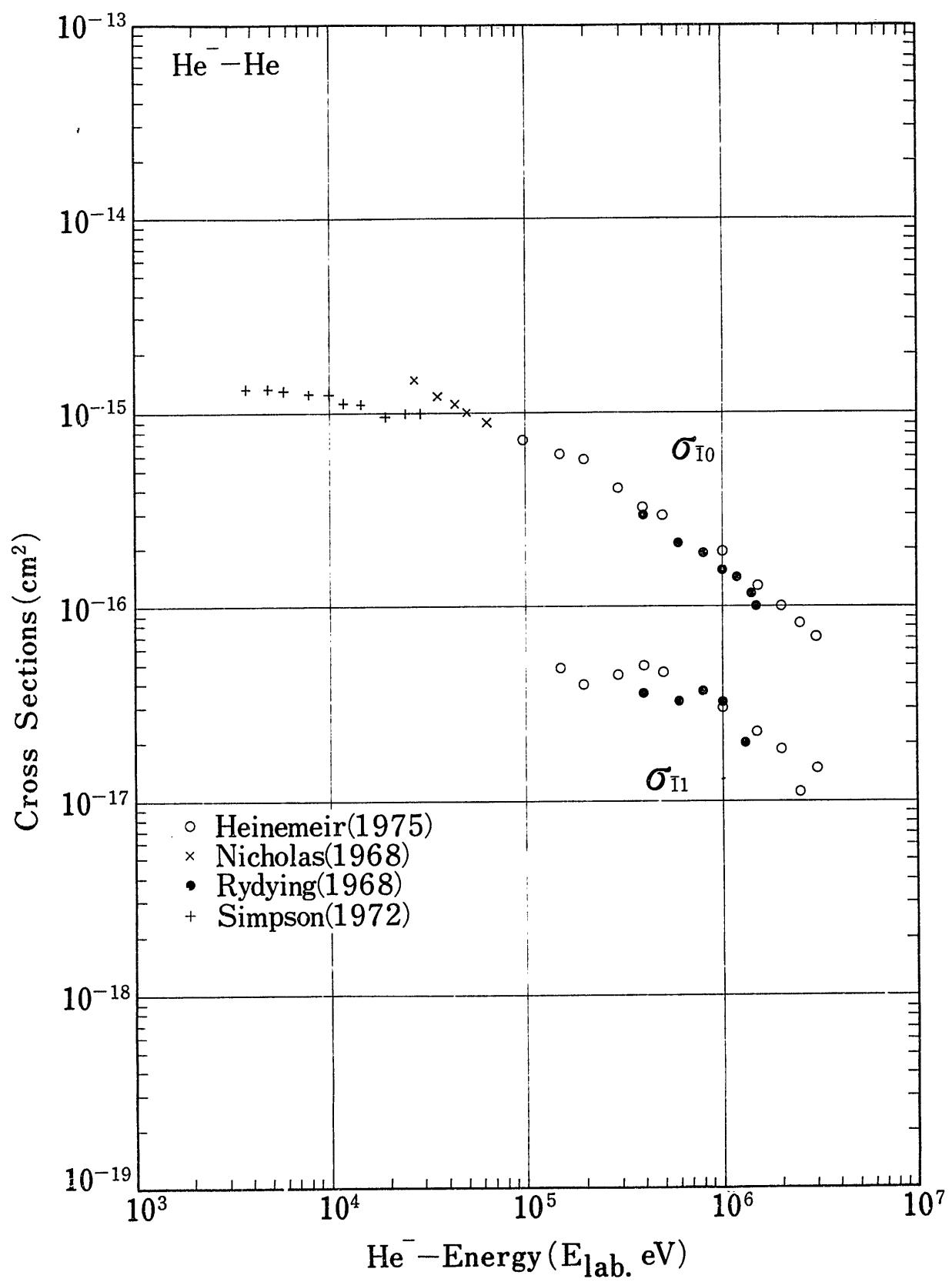


Fig. 7 Charge Changing Cross Sections of He^- in He

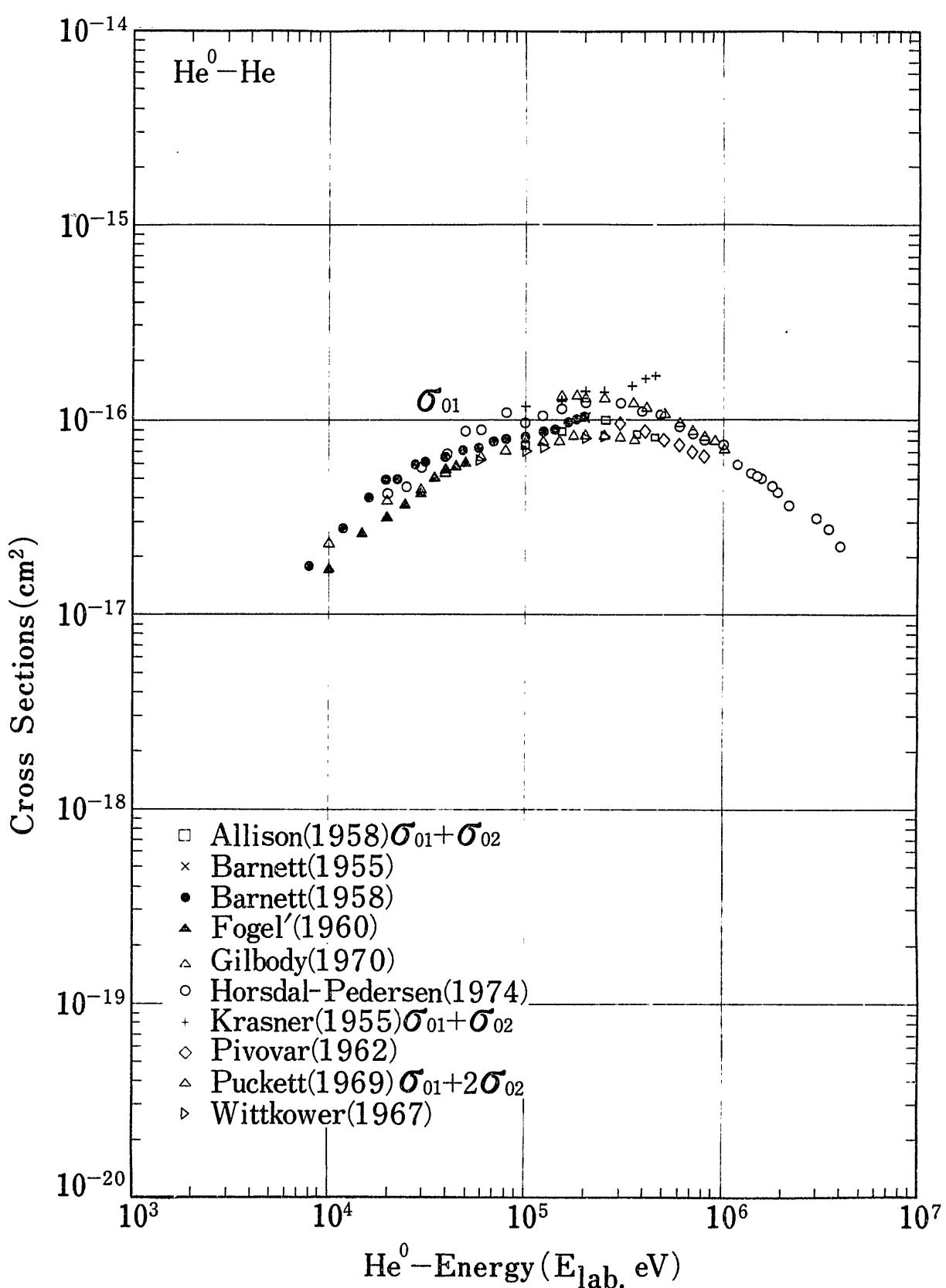


Fig.8 Charge Changing Cross Sections of He^0 in He

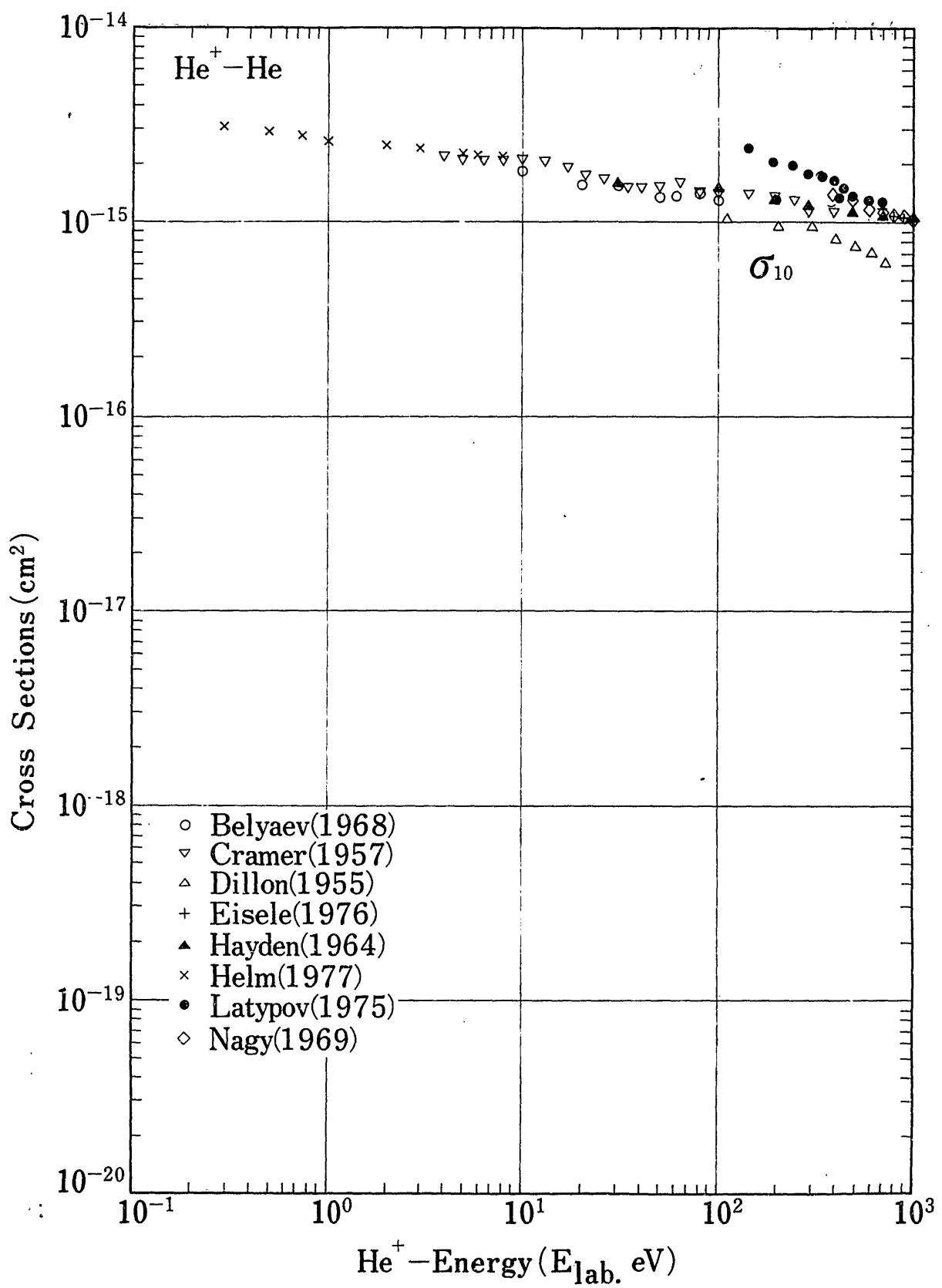


Fig.9-a Charge Changing Cross Sections of He^+ in He

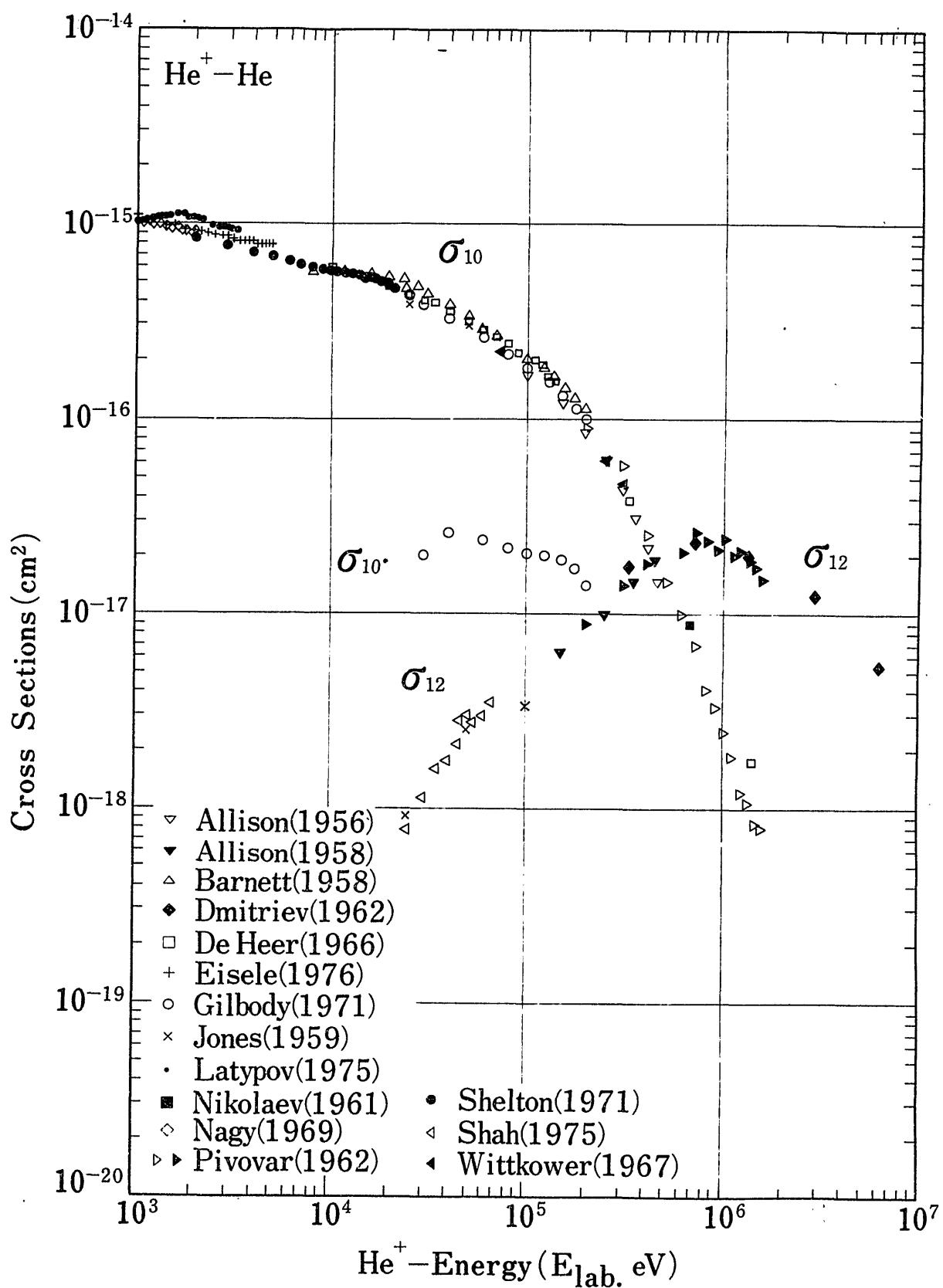


Fig.9-b Charge Changing Cross Sections of He^+ in He

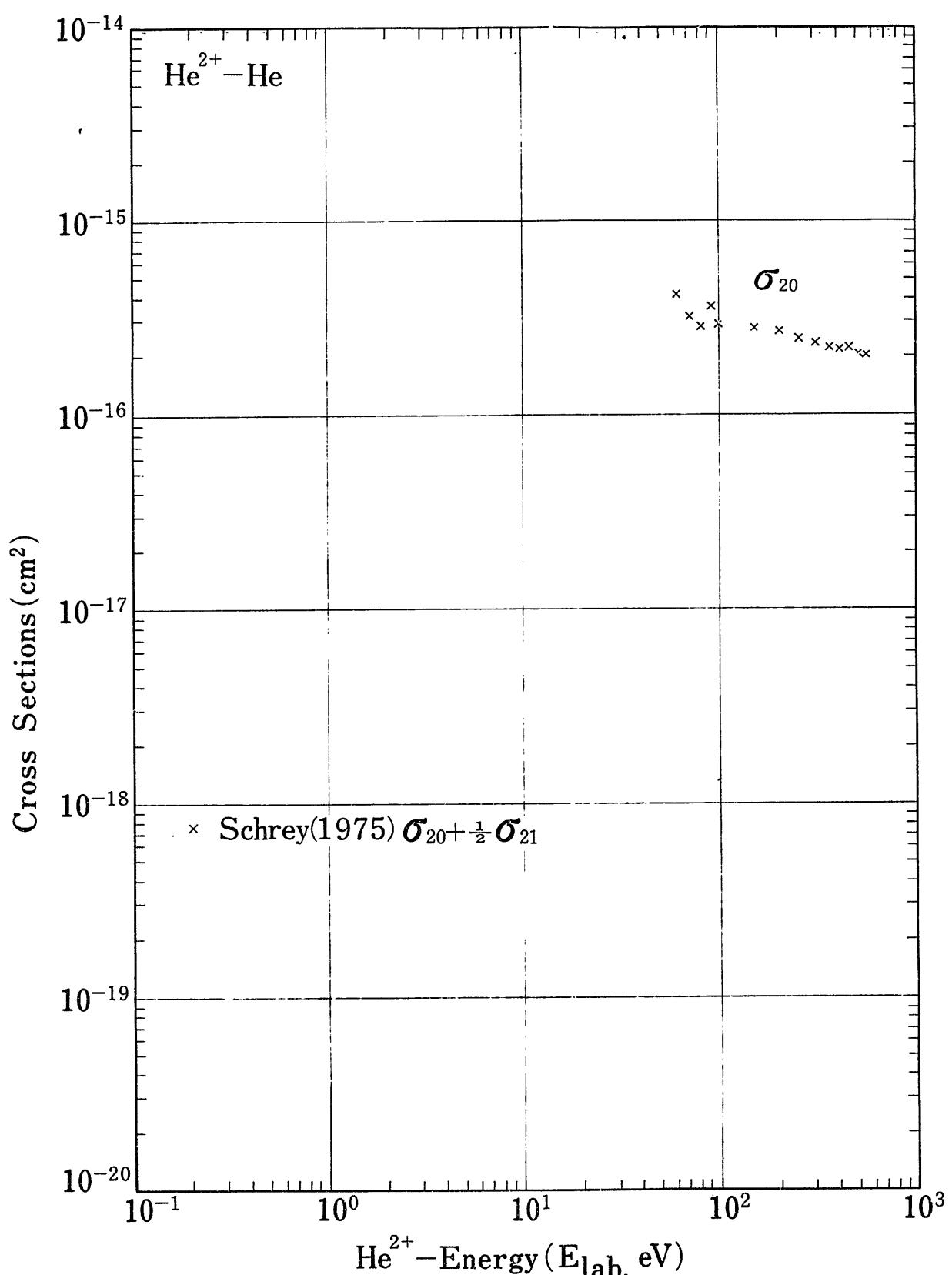


Fig.10-a Charge Changing Cross Sections of He^{2+} in He

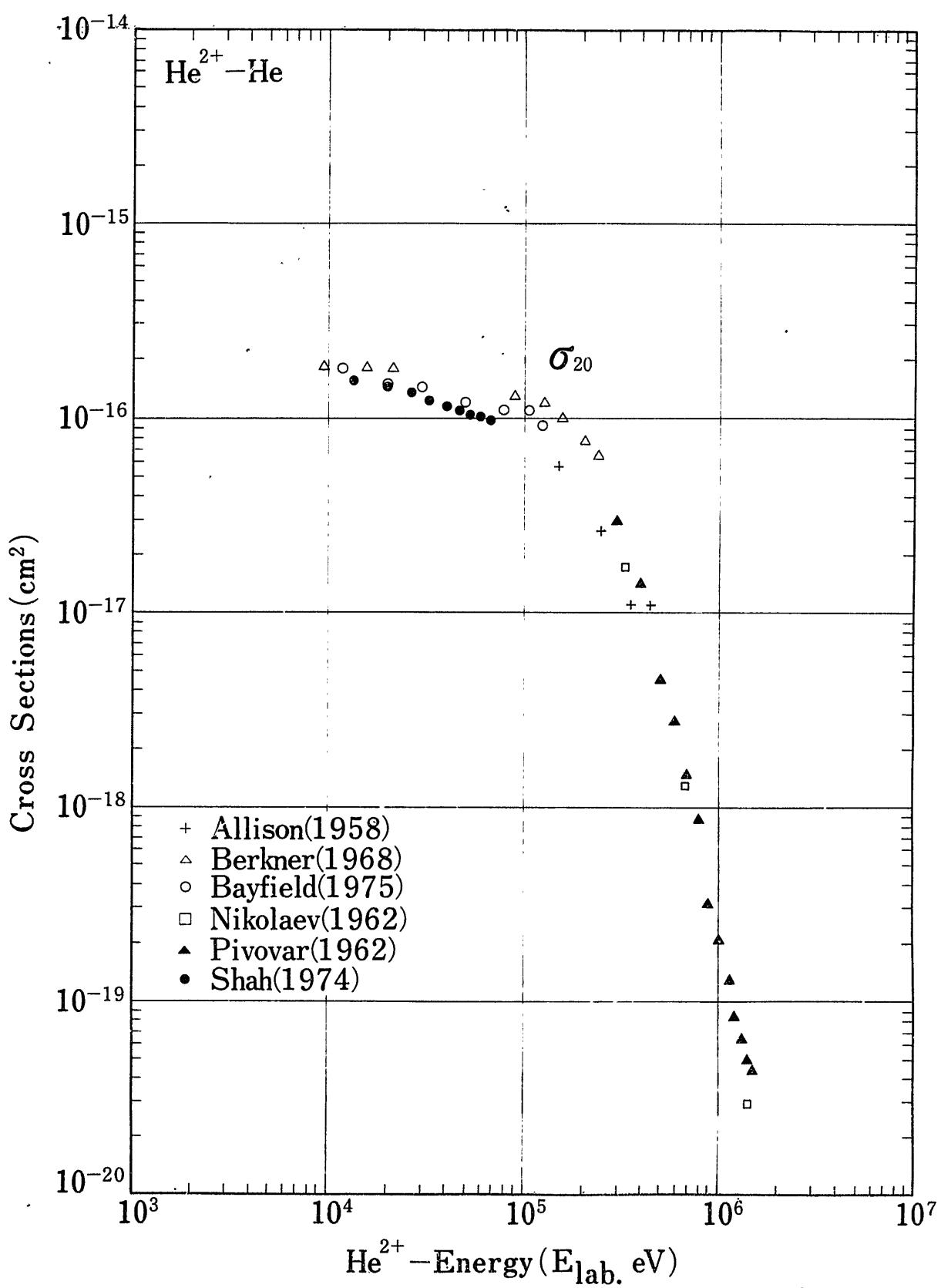


Fig.10-b Charge Changing Cross Sections of He^{2+} in He

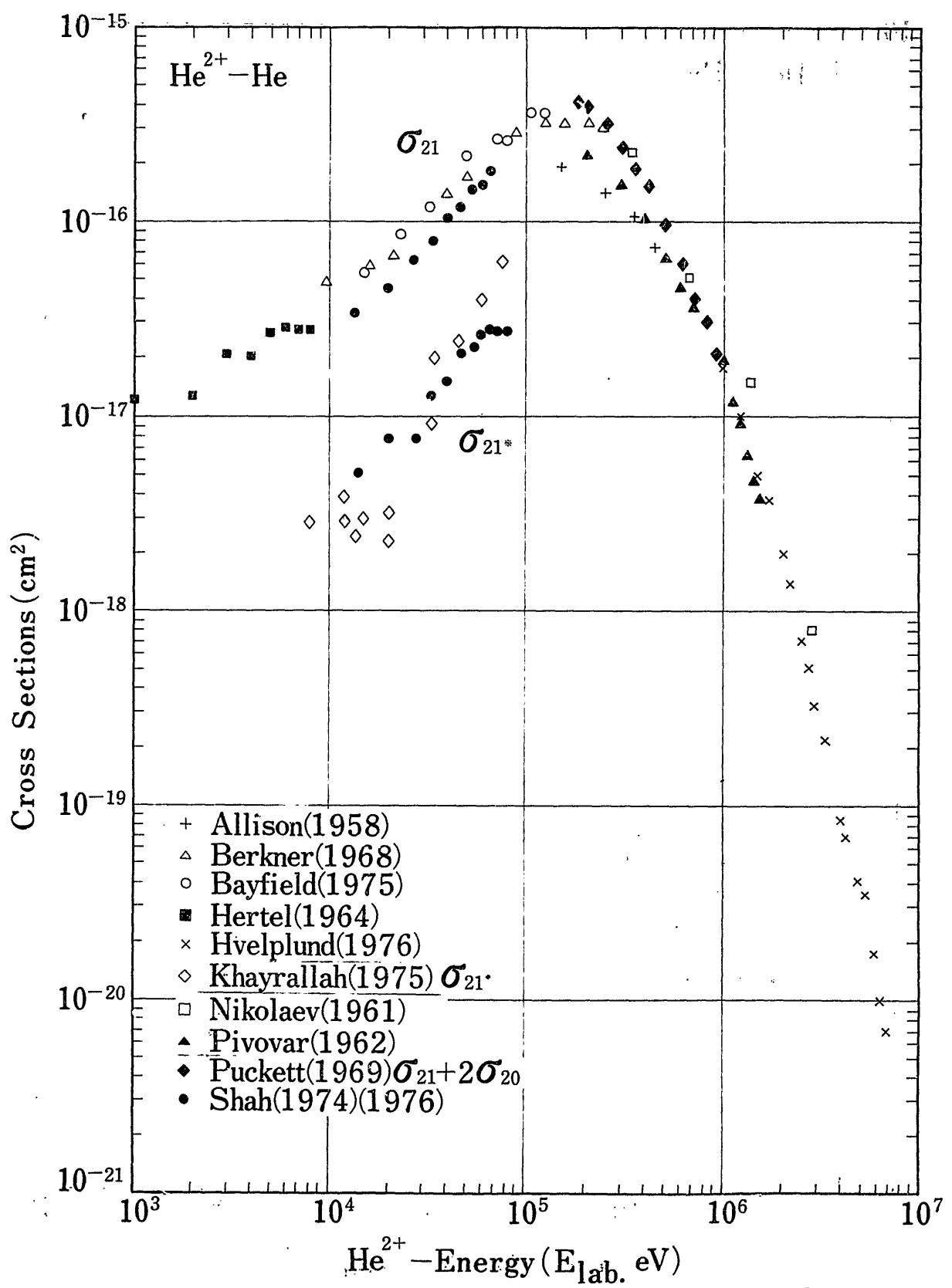


Fig.11 Charge-Changing Cross Sections of He^{2+} in He

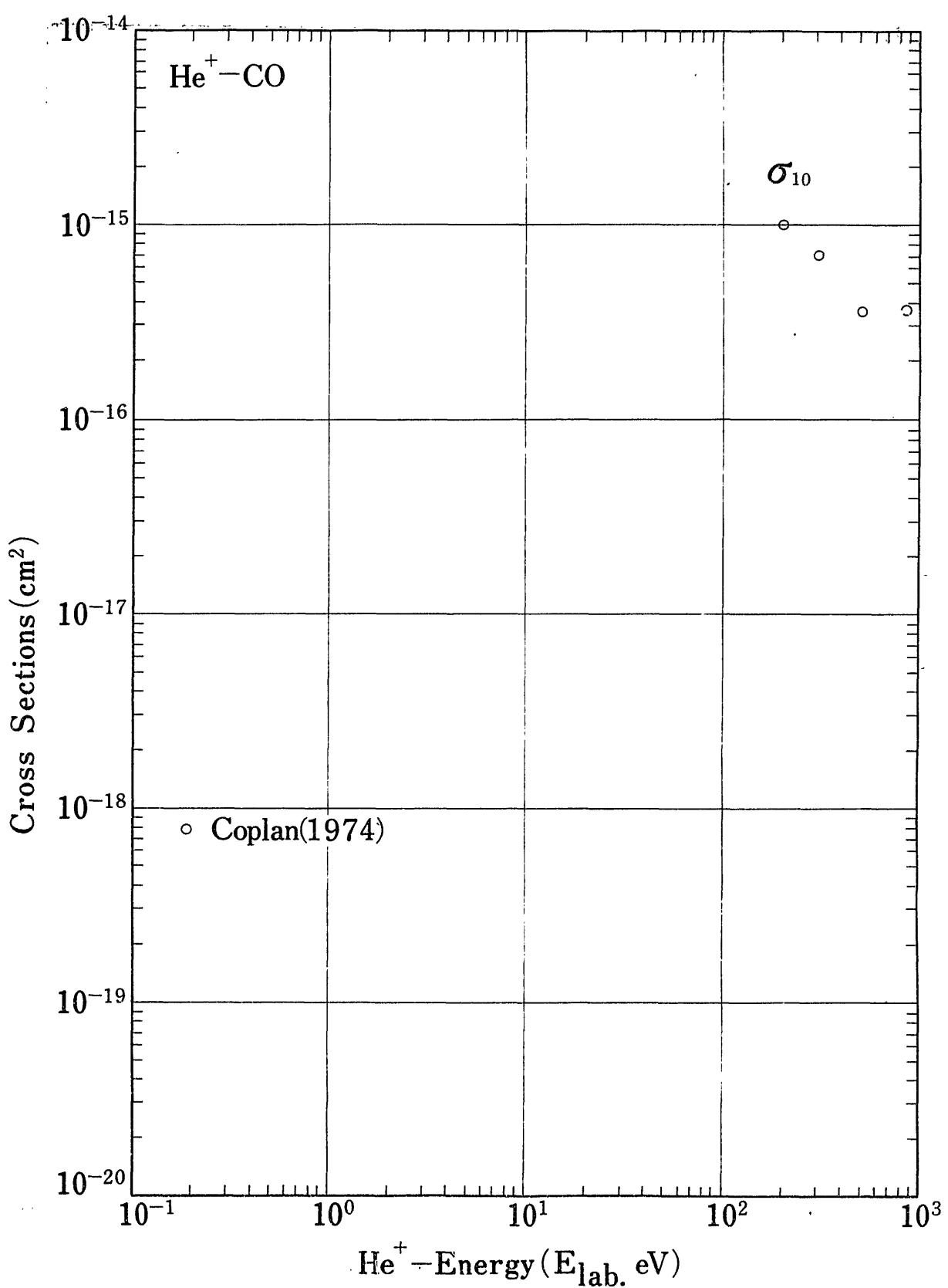


Fig.12-a Charge Changing Cross Sections of He^+ in CO

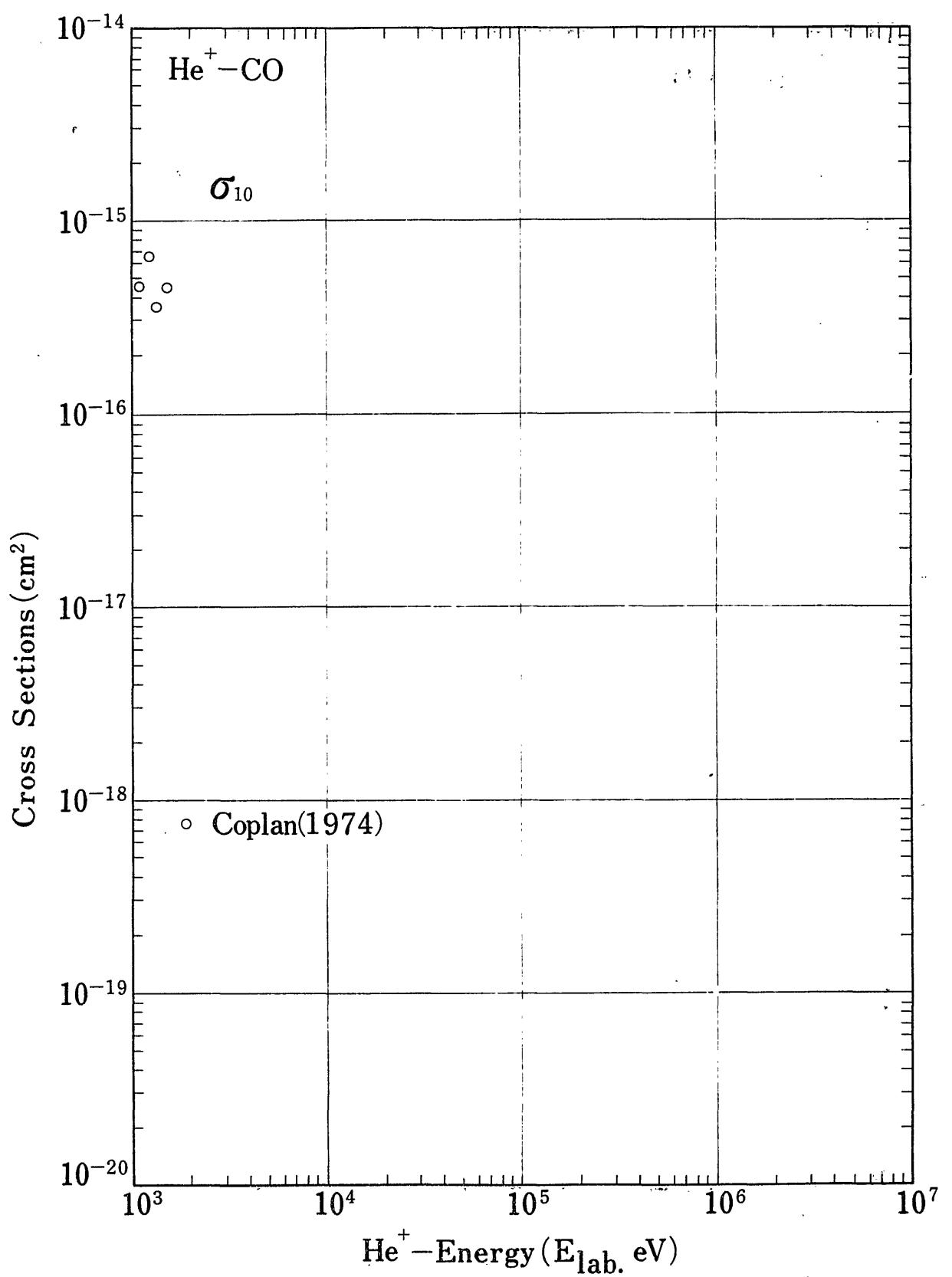


Fig.12-b Charge Changing Cross Sections of He^+ in CO

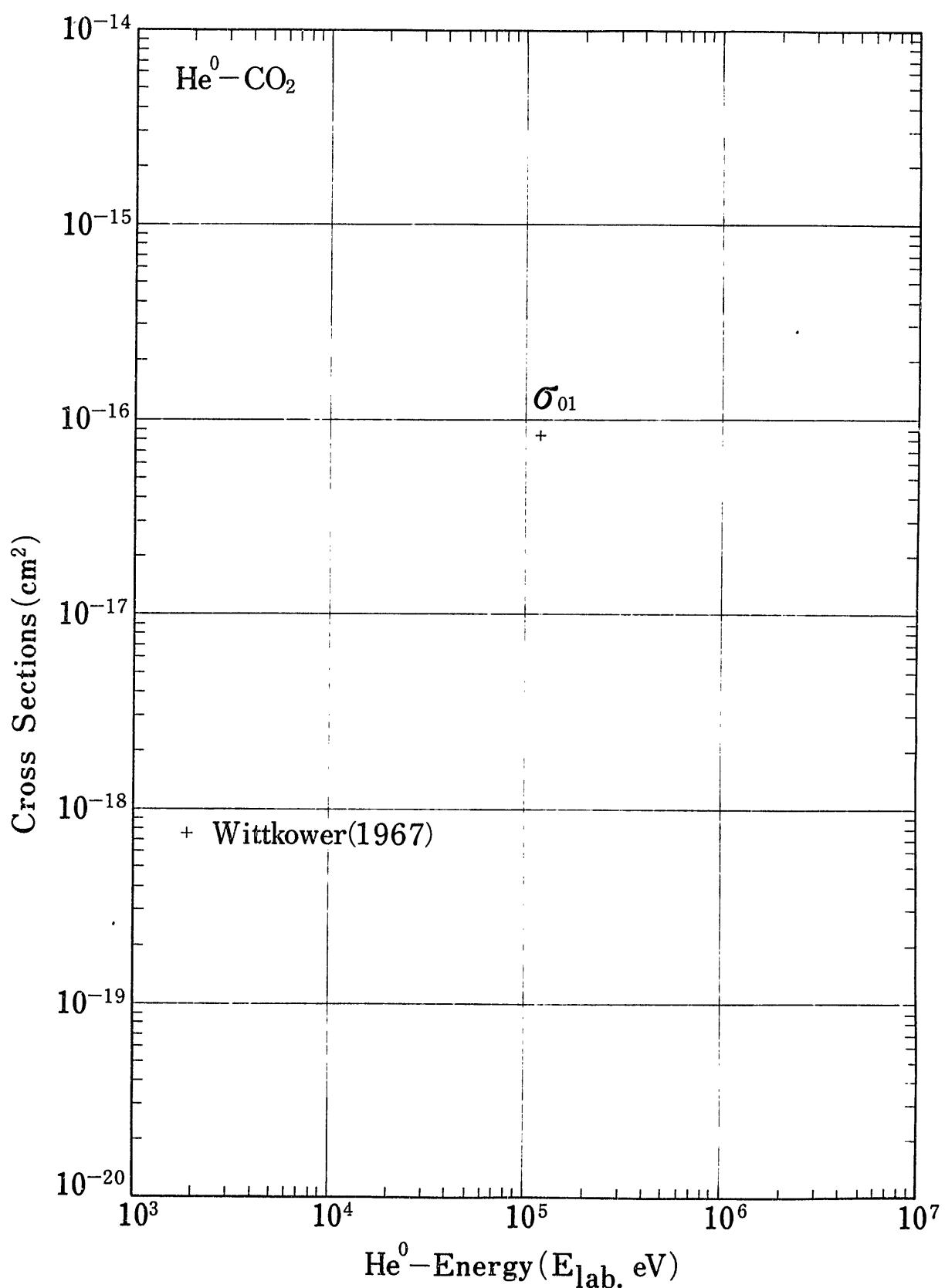


Fig.13 Charge Changing Cross Sections of He^0 in CO_2

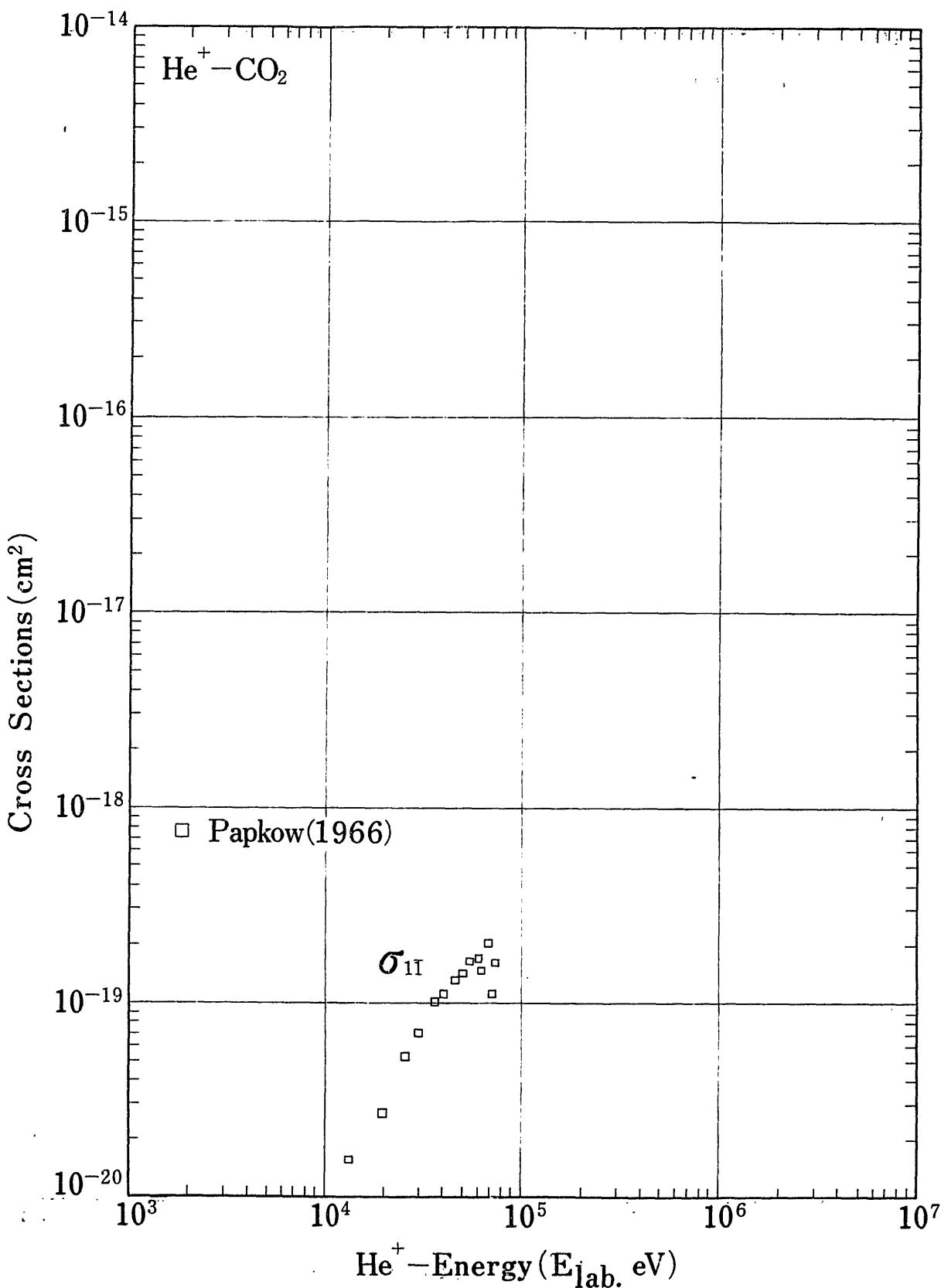


Fig.14 Charge Changing Cross Sections of He^+ in CO_2

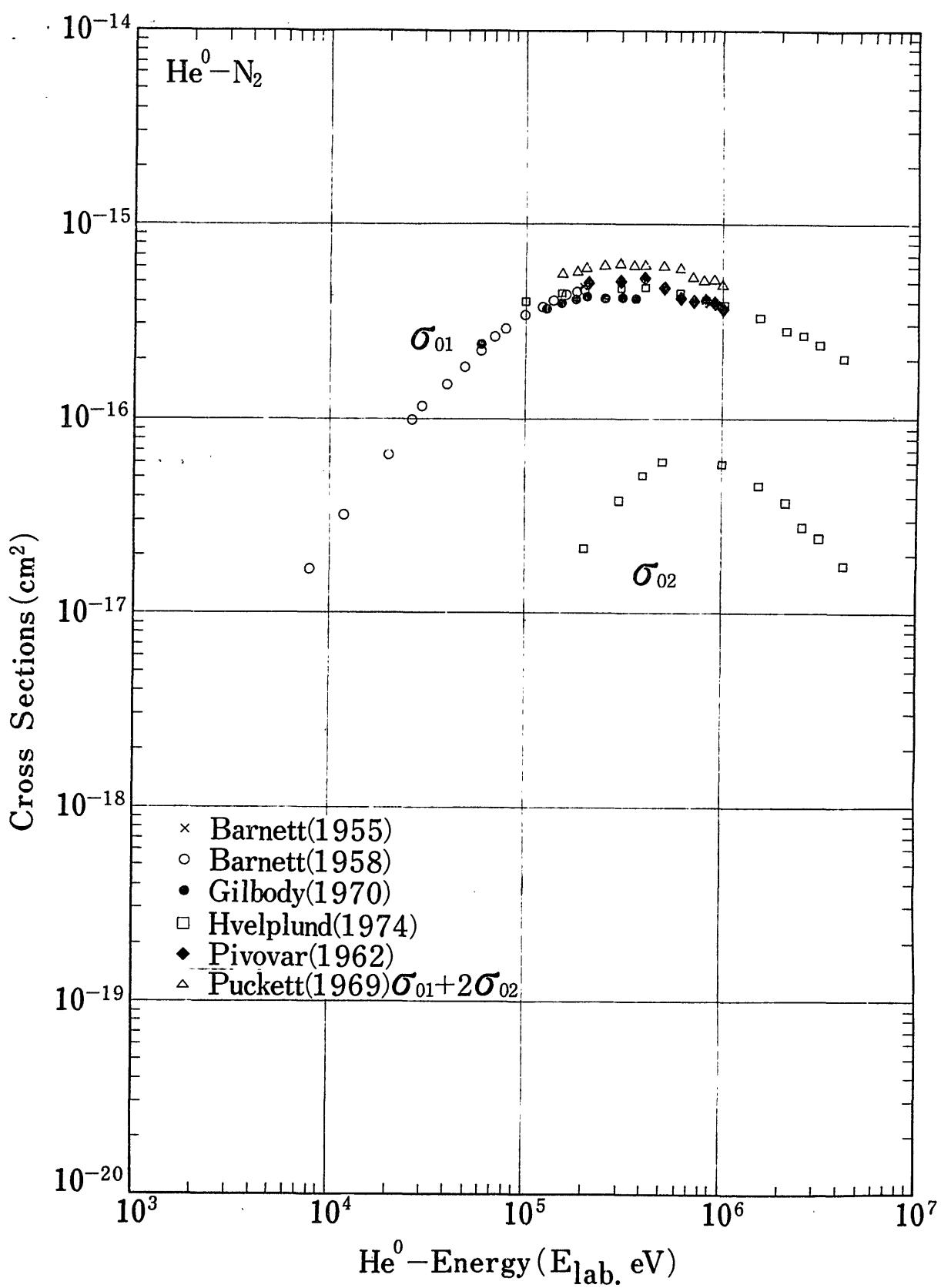


Fig.15 Charge Changing Cross Sections of He^0 in N_2

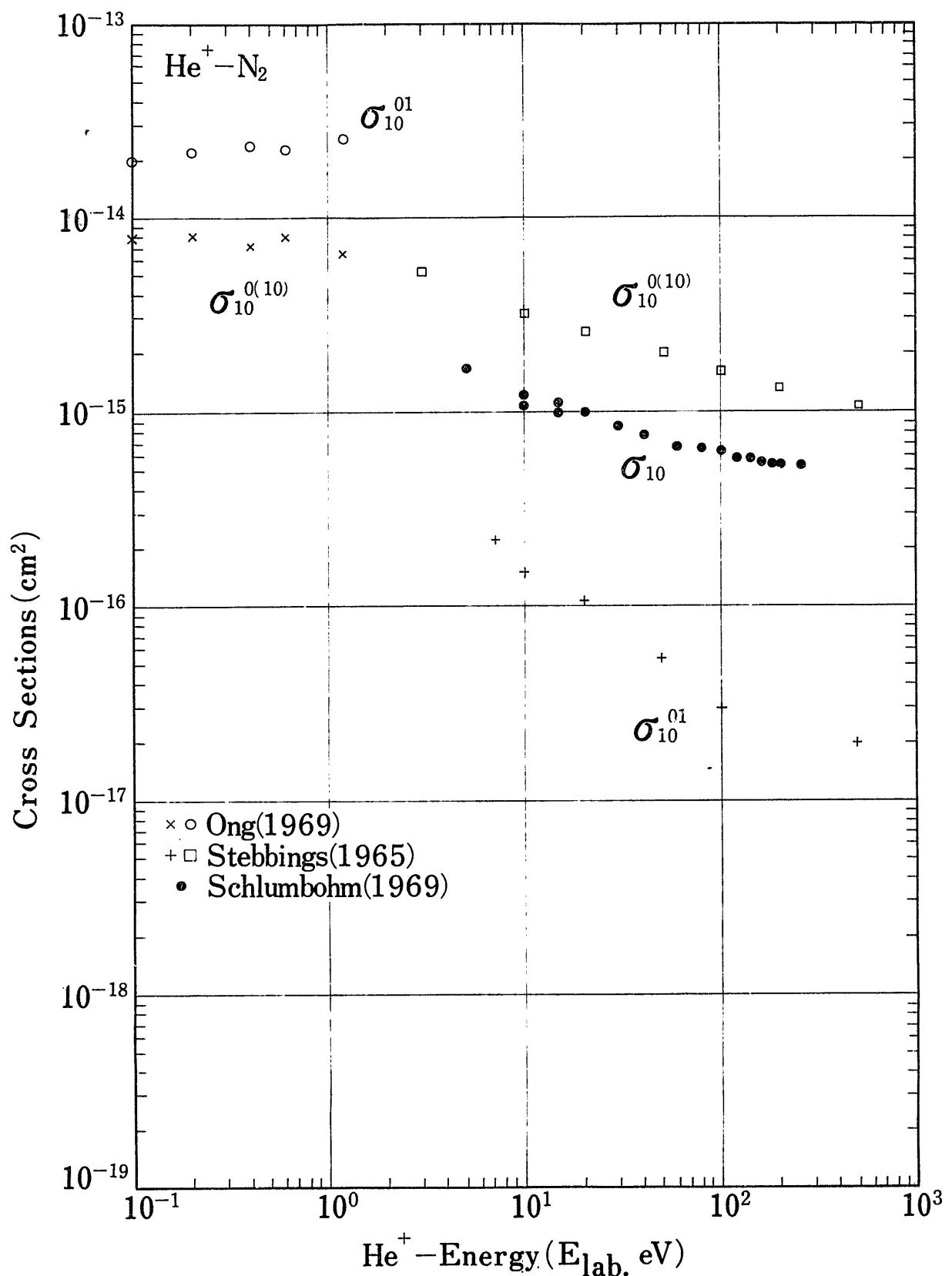


Fig.16-a Charge Changing Cross Sections of He^+ in N_2

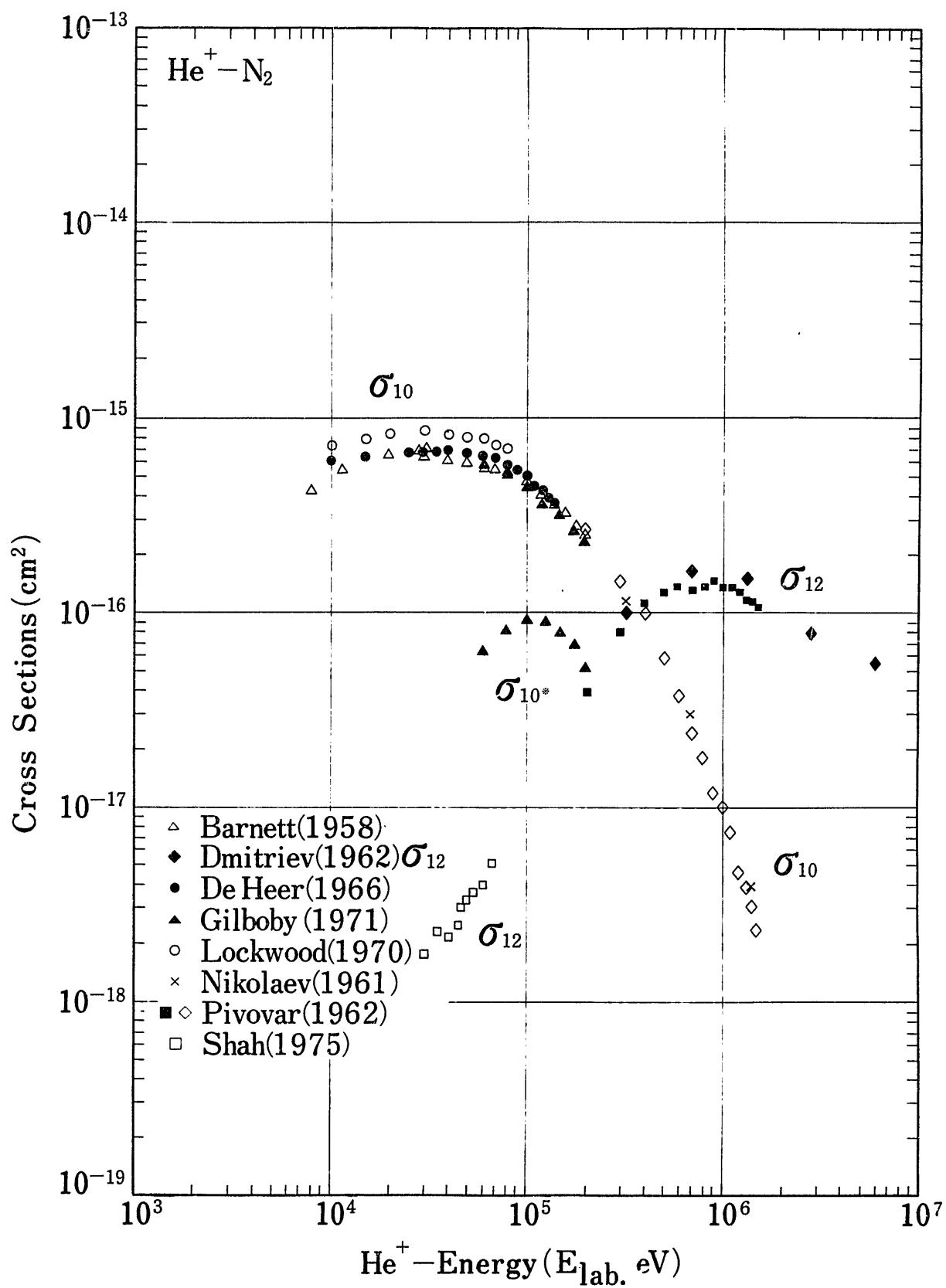


Fig.16-b Charge Changing Cross Sections of He^+ in N_2

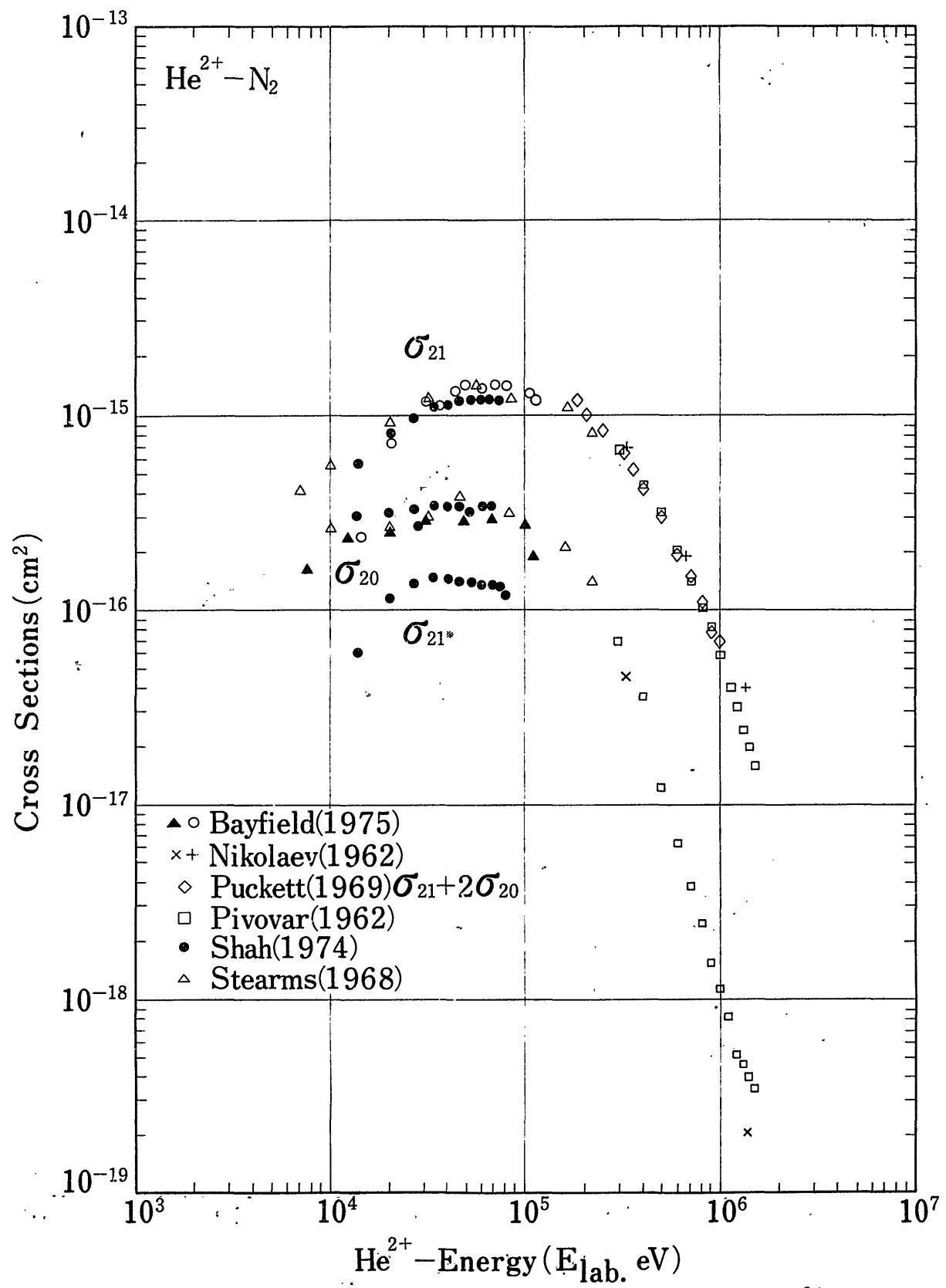


Fig.17 Charge Changing Cross Sections of He^{2+} in N_2

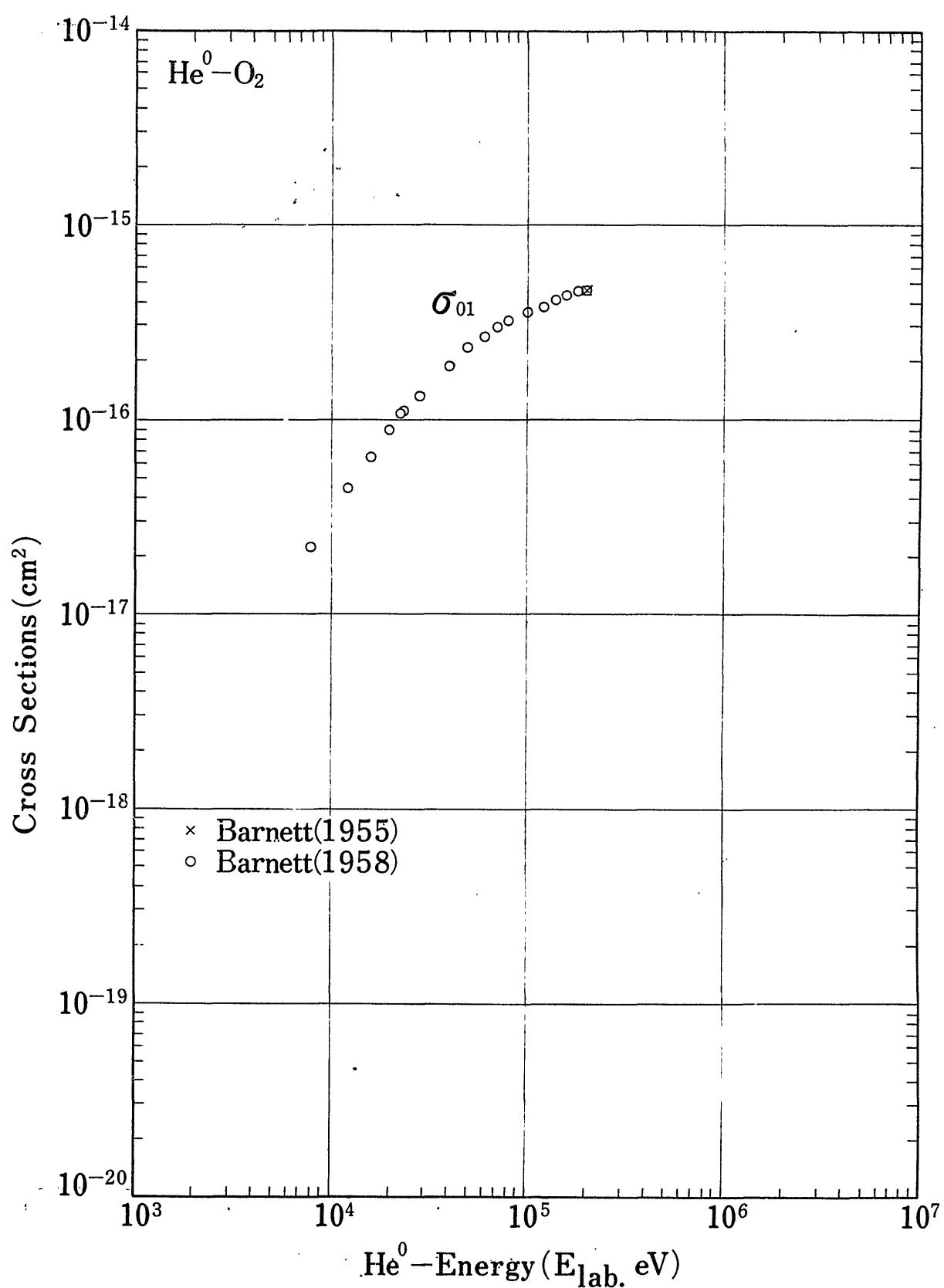


Fig.18 Charge Changing Cross Sections of He^0 in O_2

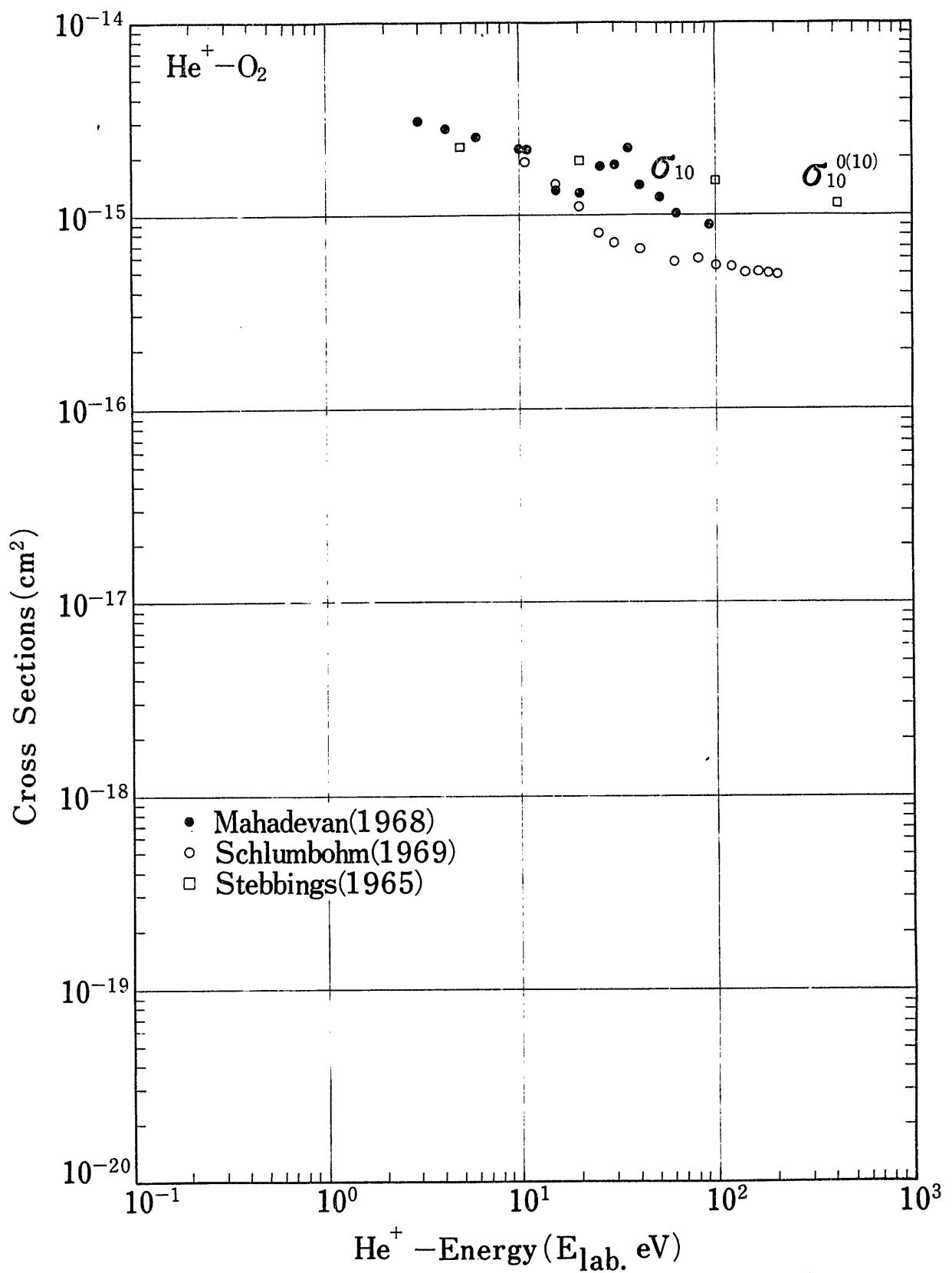


Fig.19-a Charge Changing Cross Sections of He^+ in O_2

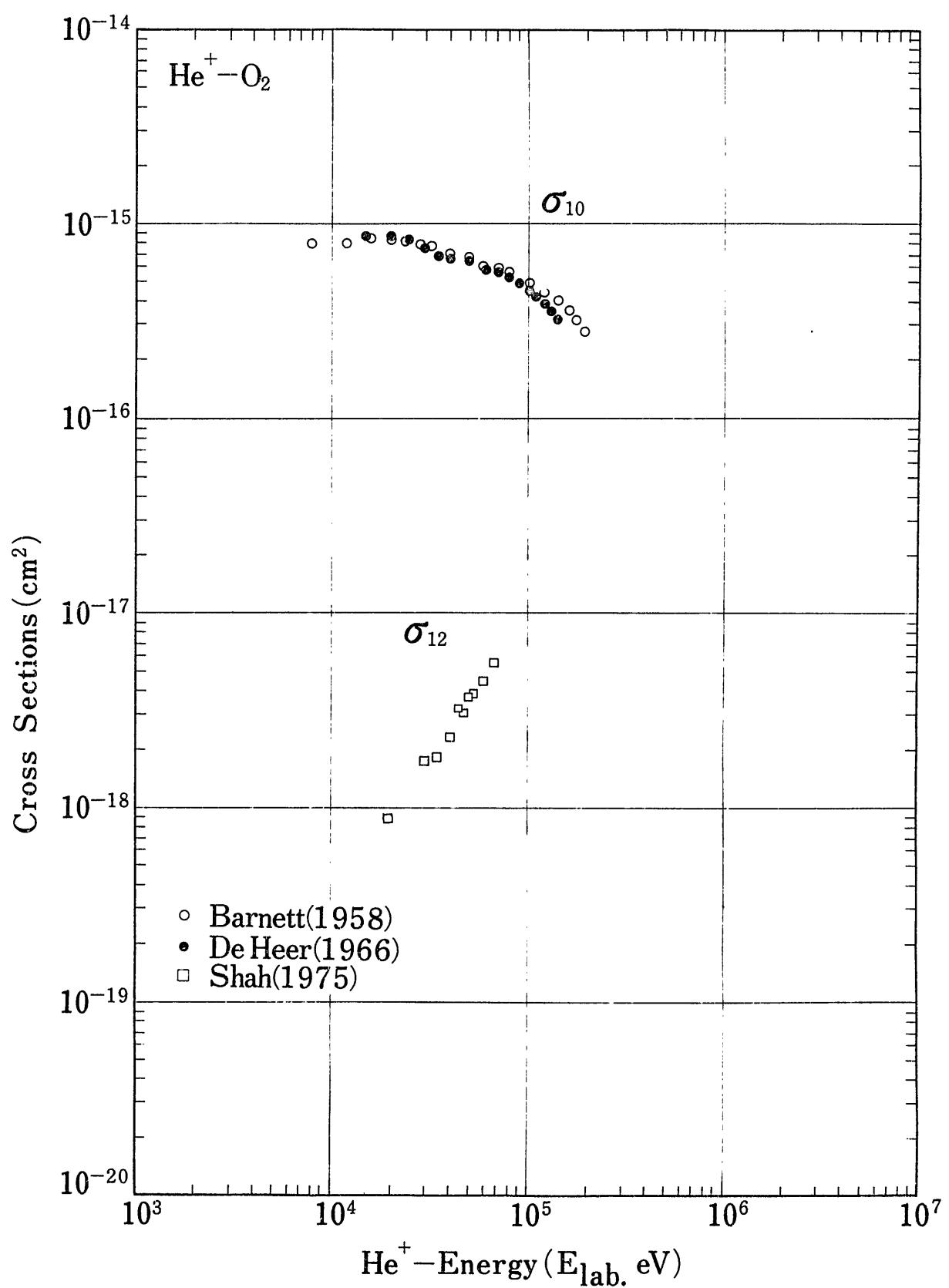


Fig.19-b Charge Changing Cross Sections of He^+ in O_2

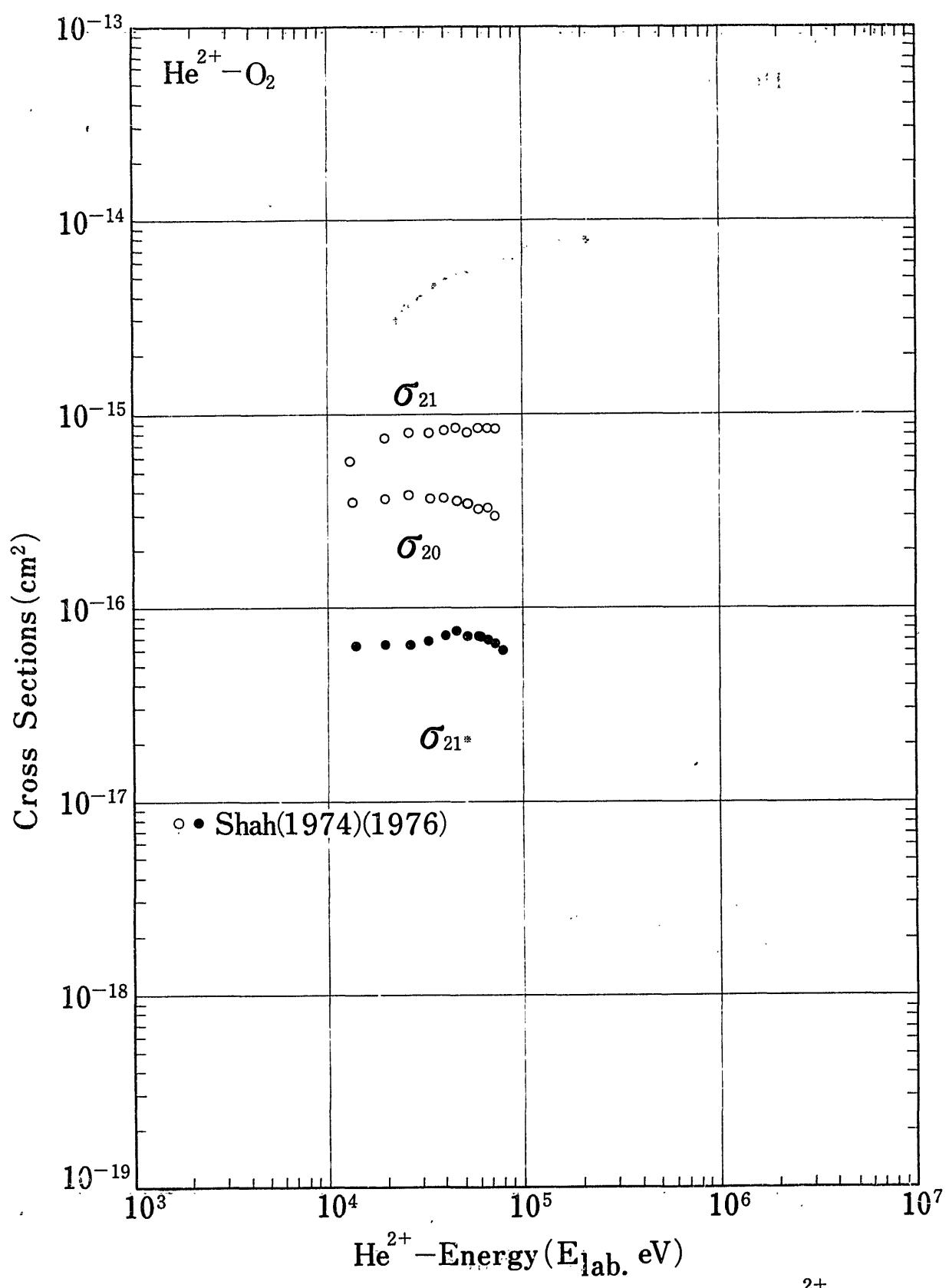


Fig. 20 Charge Changing Cross Sections of He^{2+} in O_2

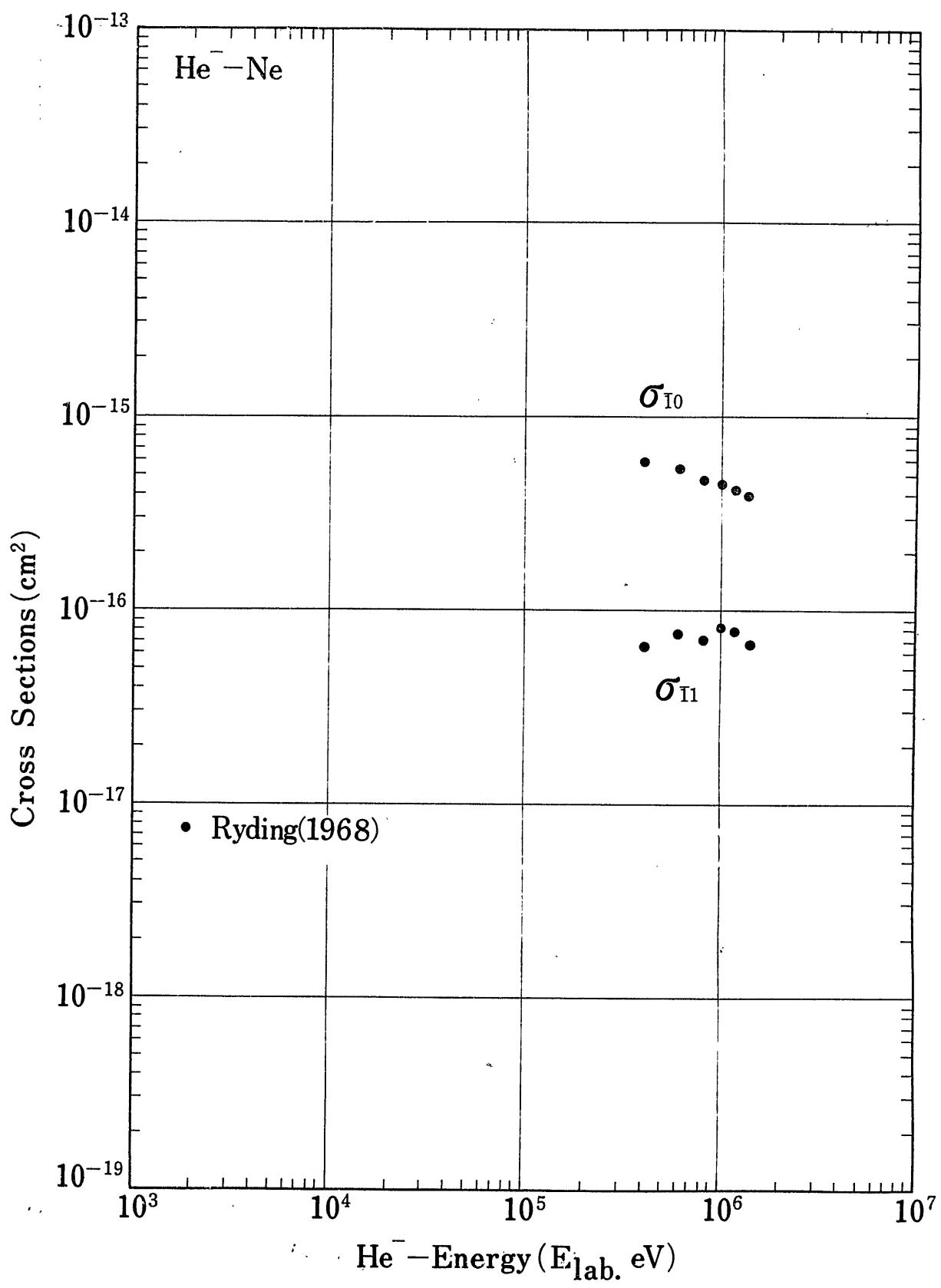


Fig.21 Charge Changing Cross Sections of He^- in Ne

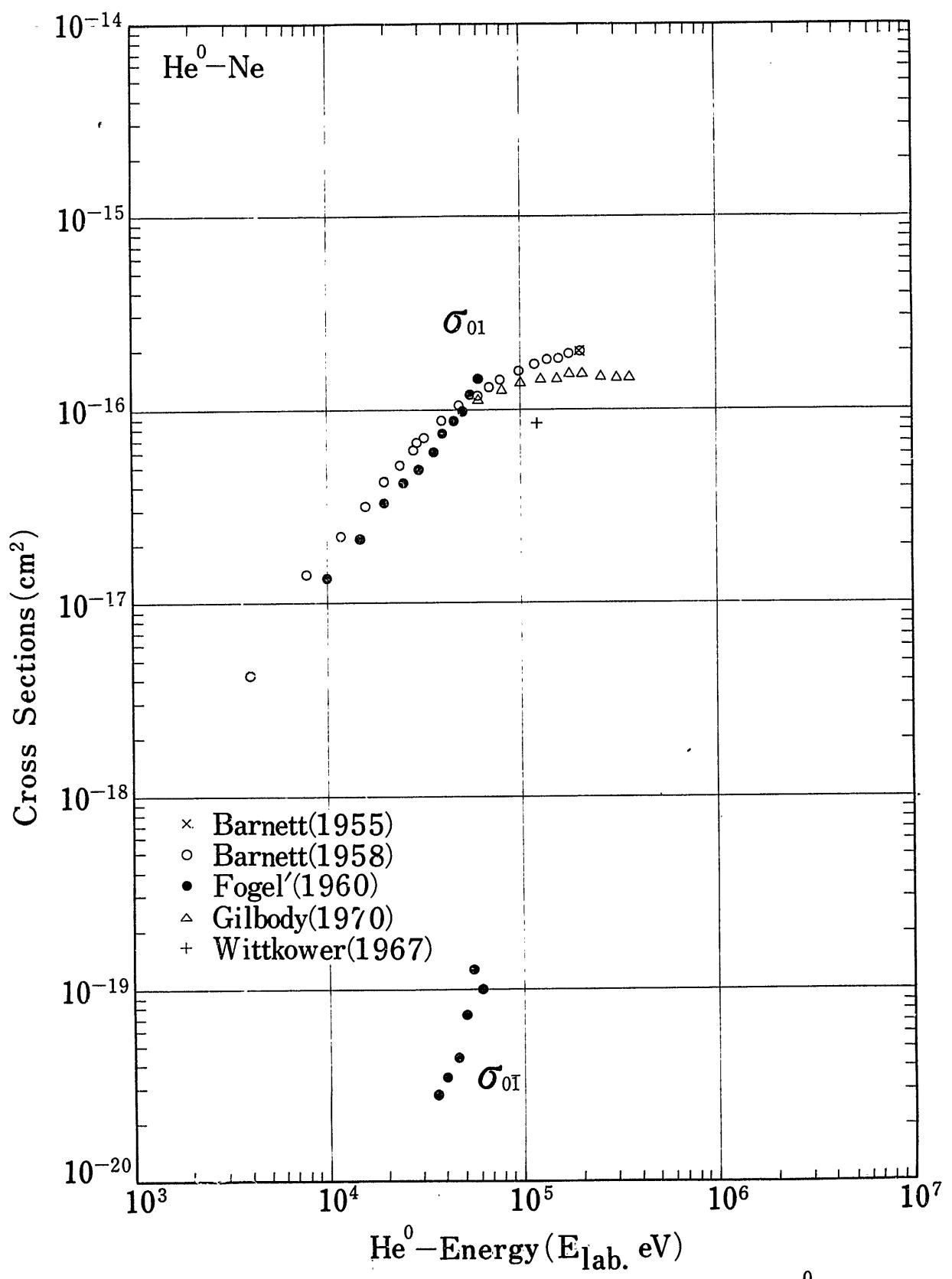


Fig.22 Charge Changing Cross Sections of He^0 in Ne

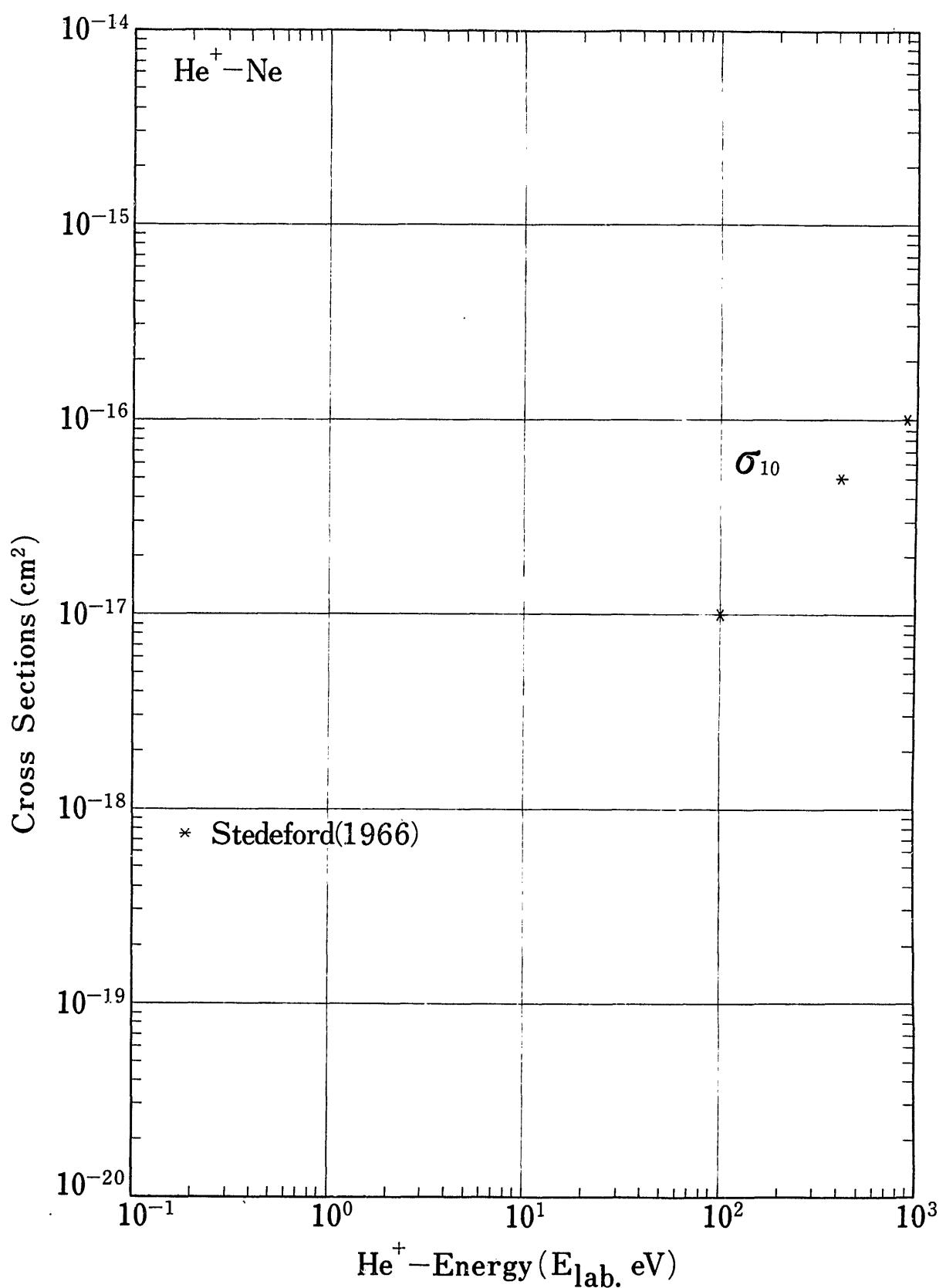


Fig.23-a Charge Changing Cross Sections of He^+ in Ne

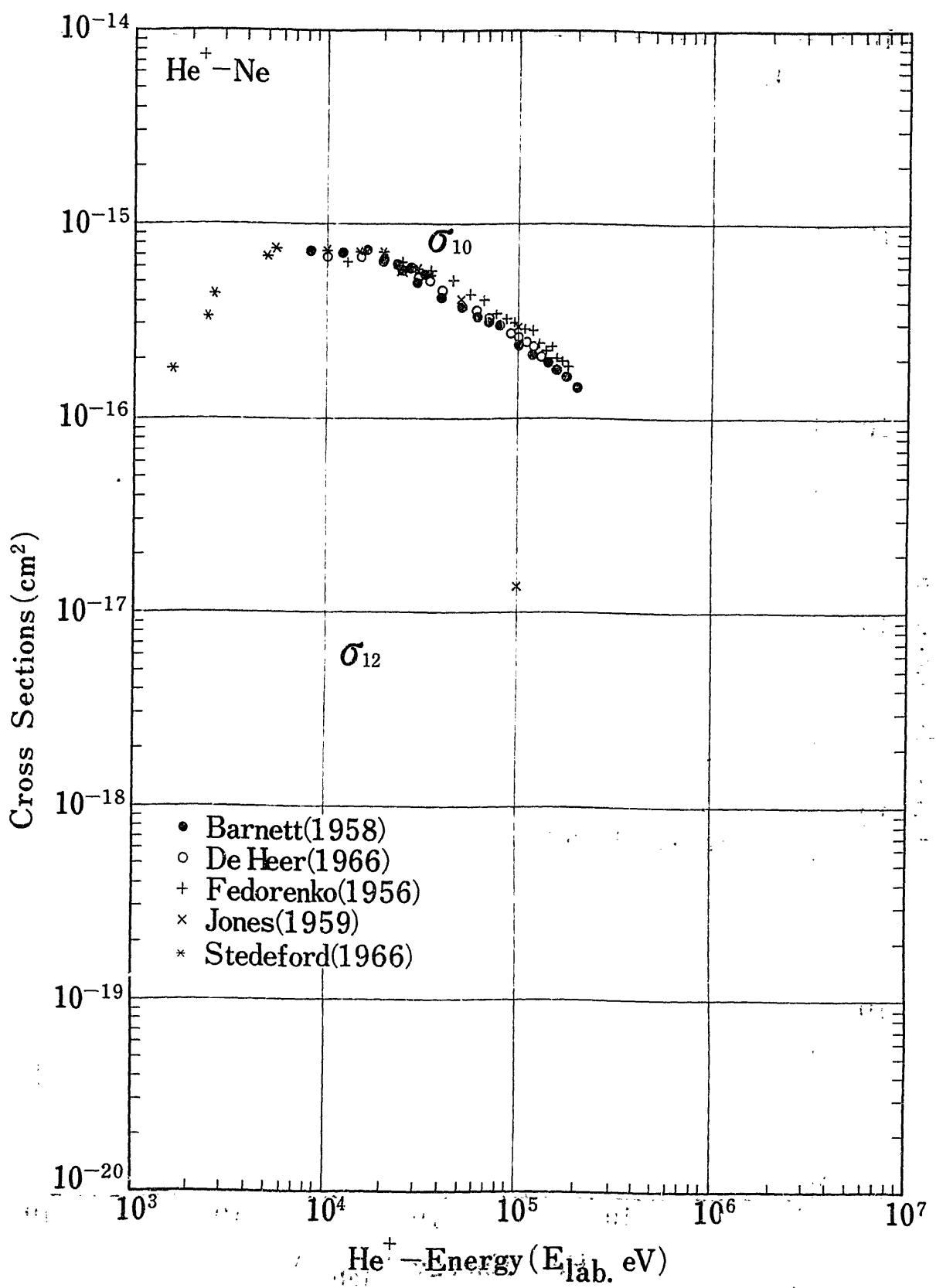


Fig. 23-b. Charge Changing Cross Sections of He^+ in Ne

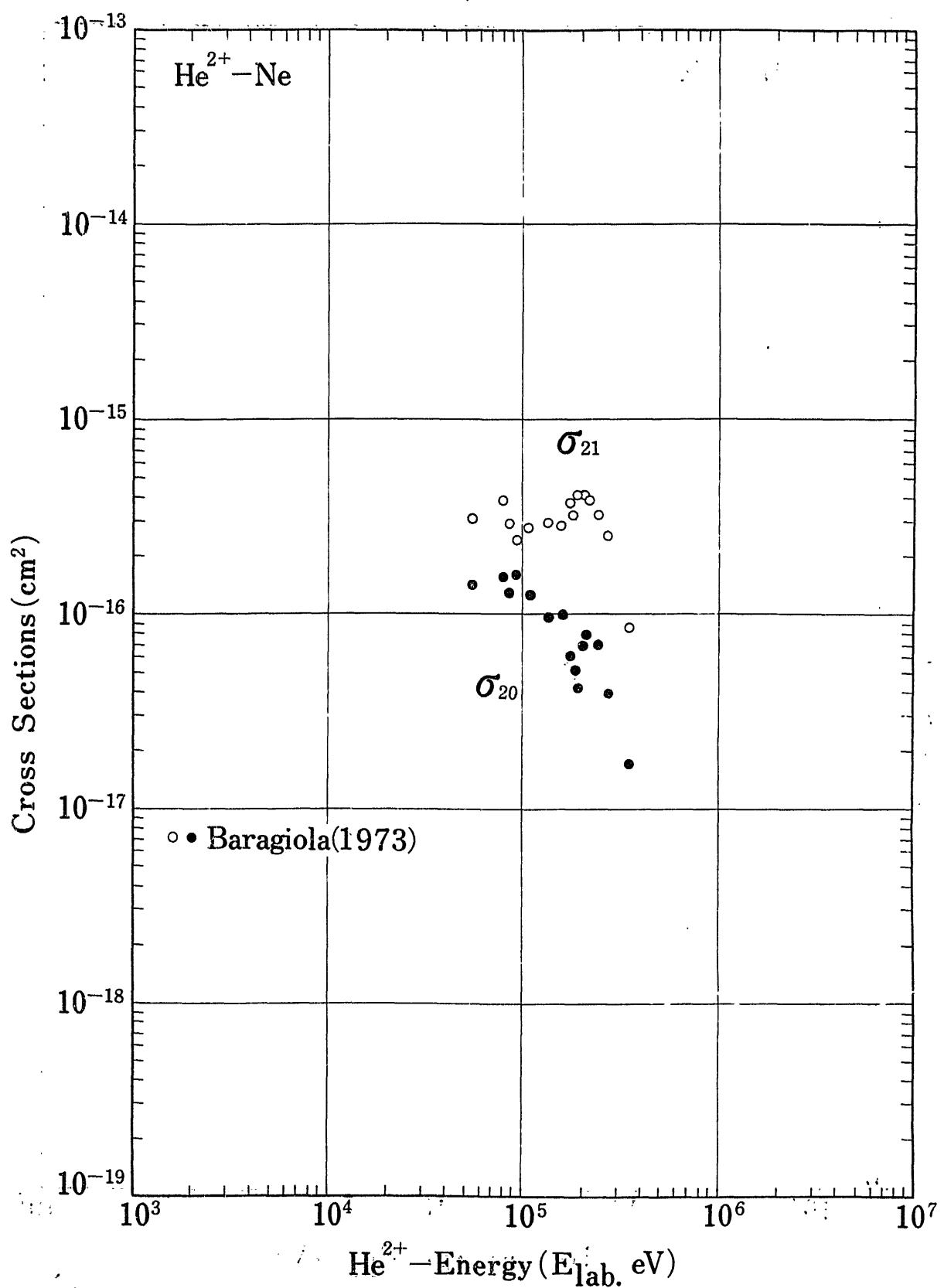


Fig. 24 Charge Changing Cross Sections of He^{2+} in Ne

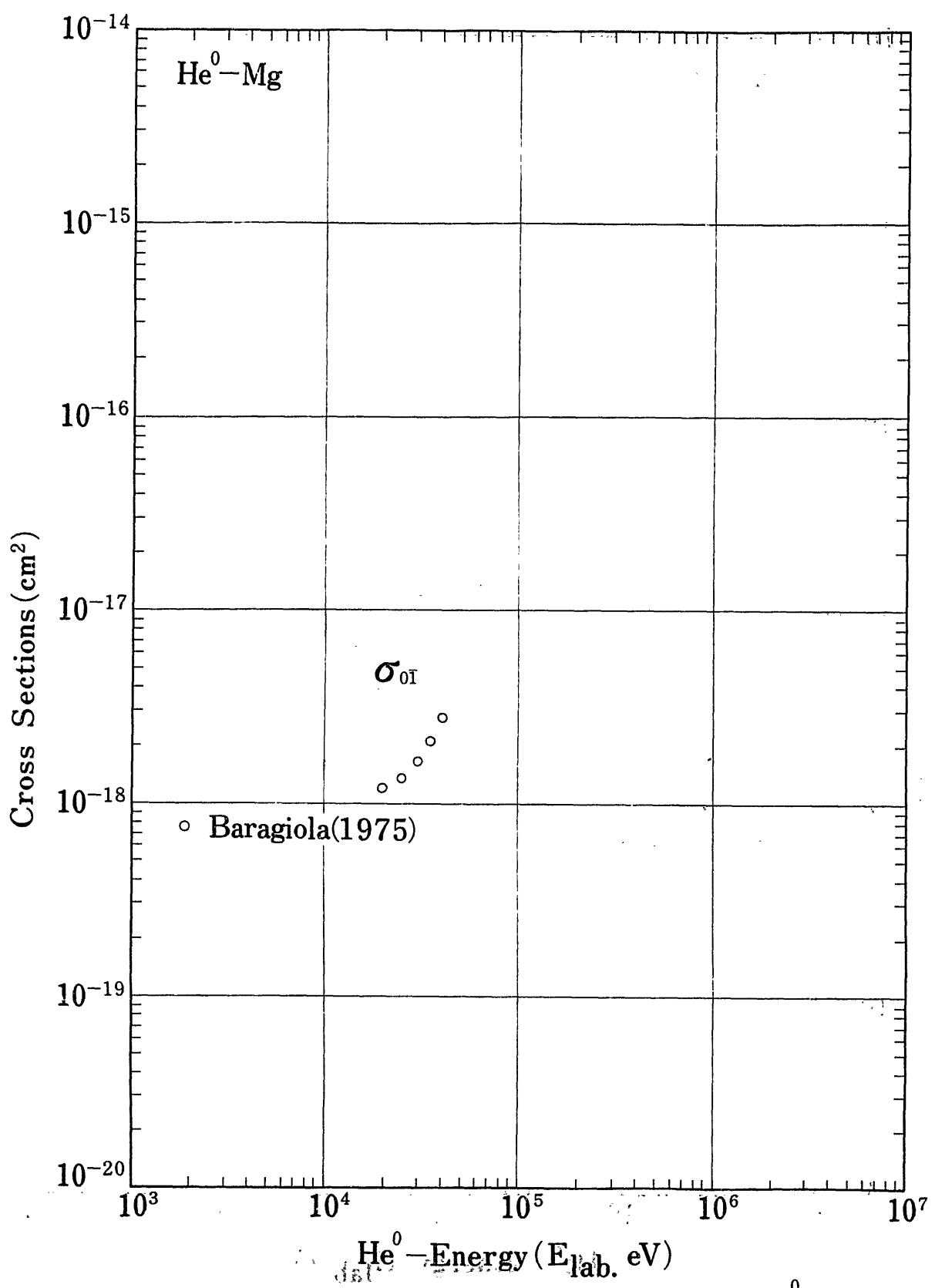


Fig. 25 Charge-Changing Cross Sections of He^0 in Mg

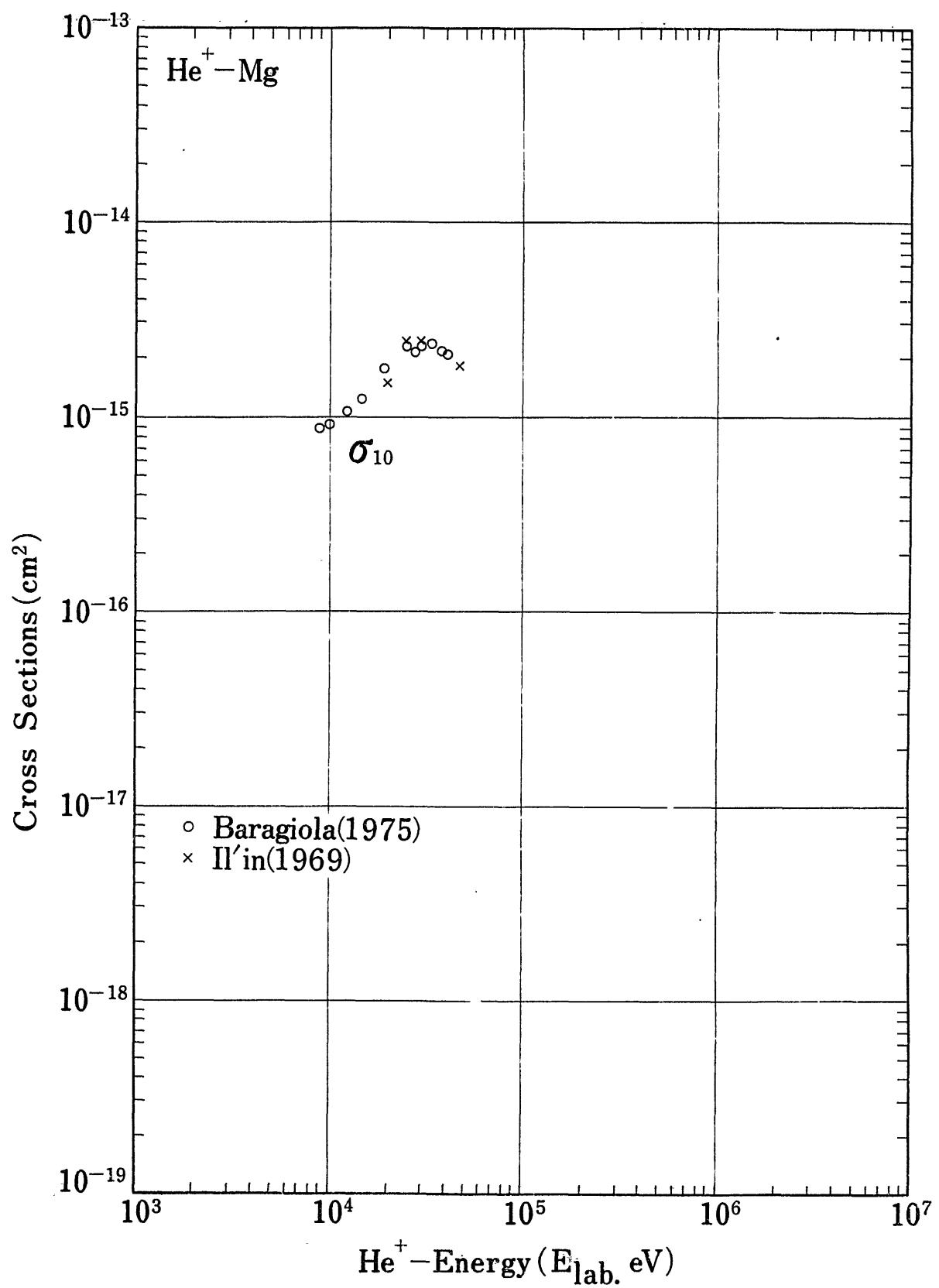


Fig.26 Charge Changing Cross Sections of He^+ in Mg

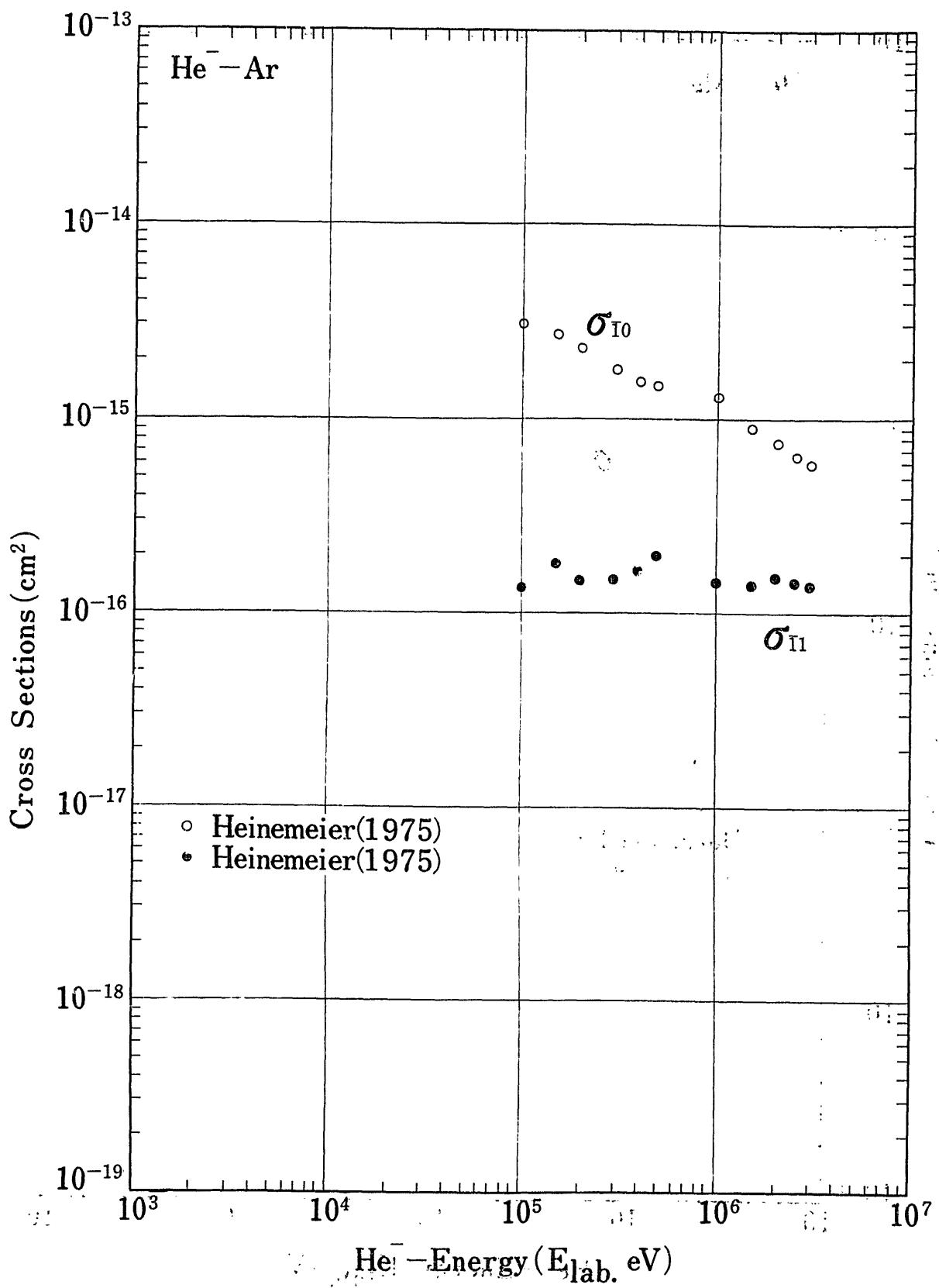


Fig. 27. Charge Changing Cross Sections of He^- in Ar

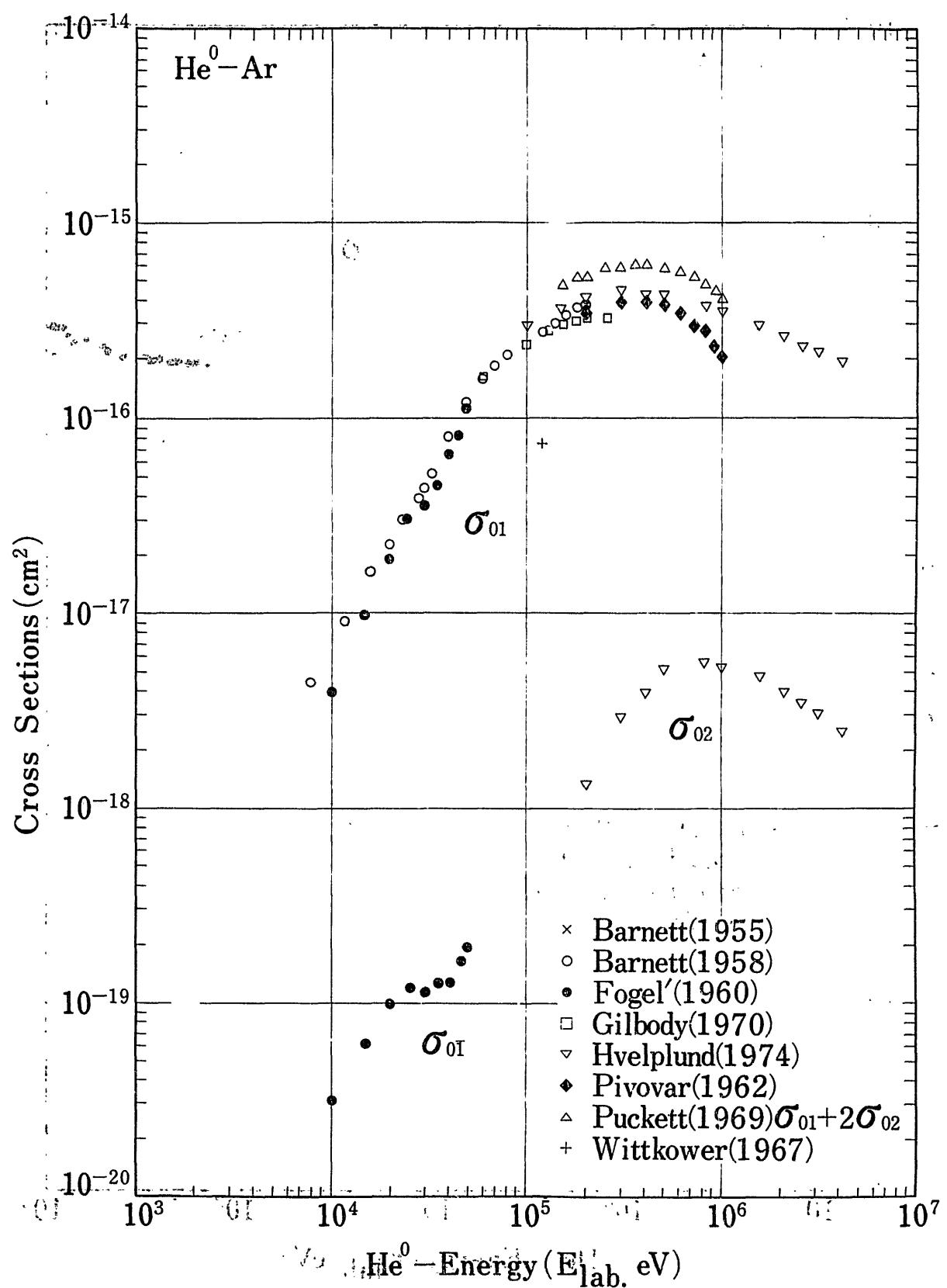


Fig. 28 Charge Changing Cross Sections of He^0 in Ar

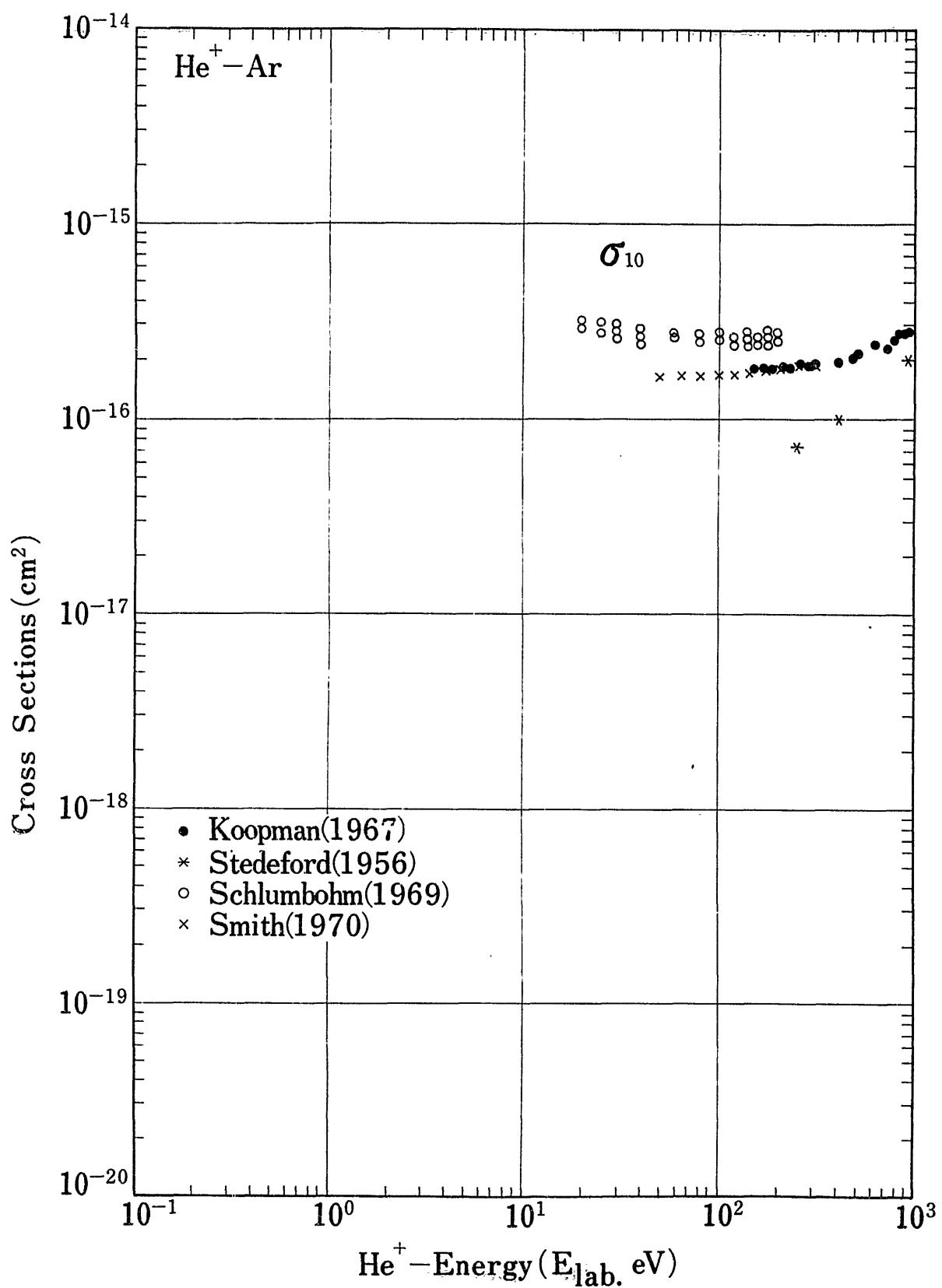


Fig.29-a Charge Changing Cross Sections of He^+ in Ar

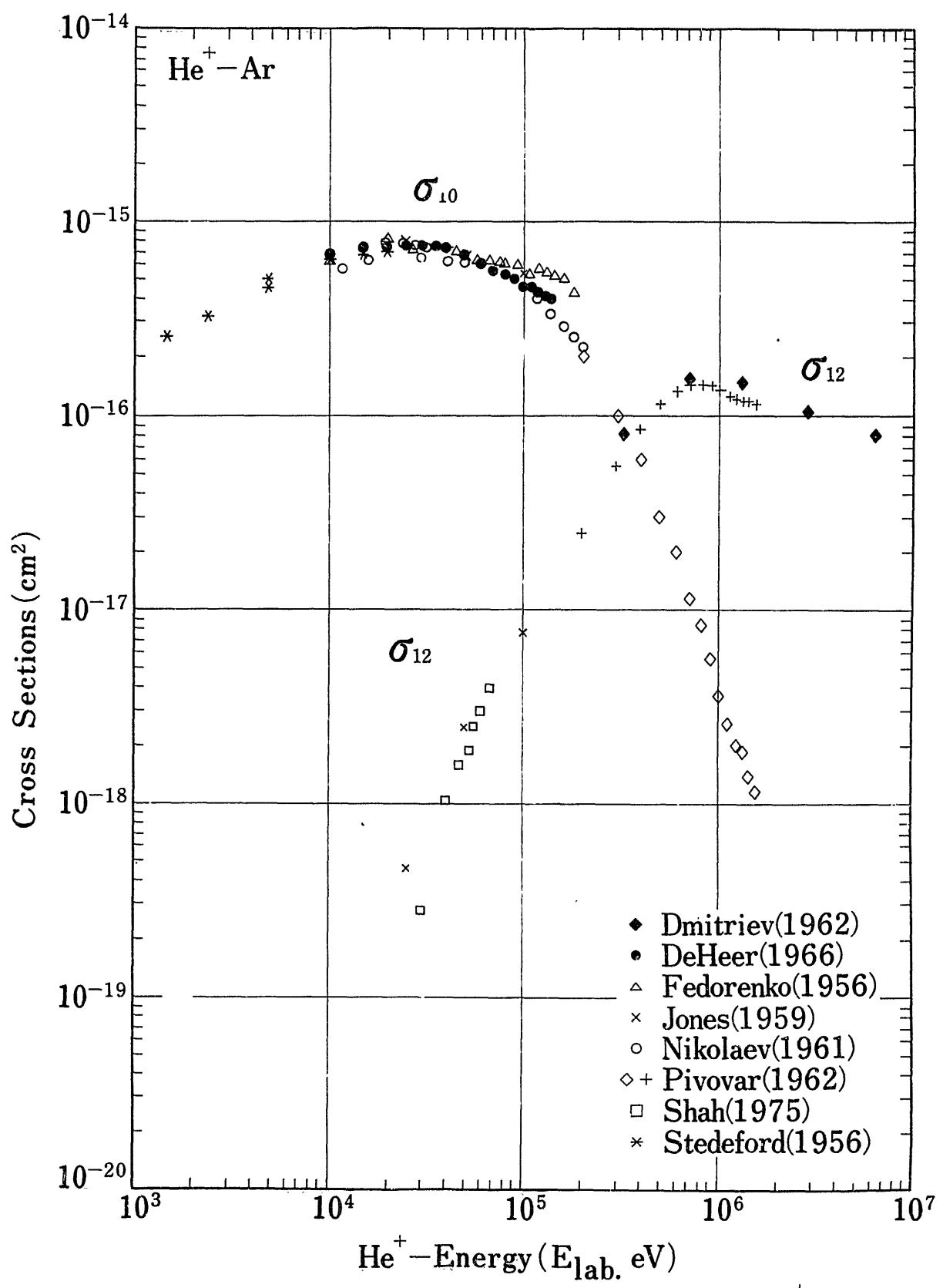


Fig.29-b Charge Changing Cross Sections of He^+ in Ar

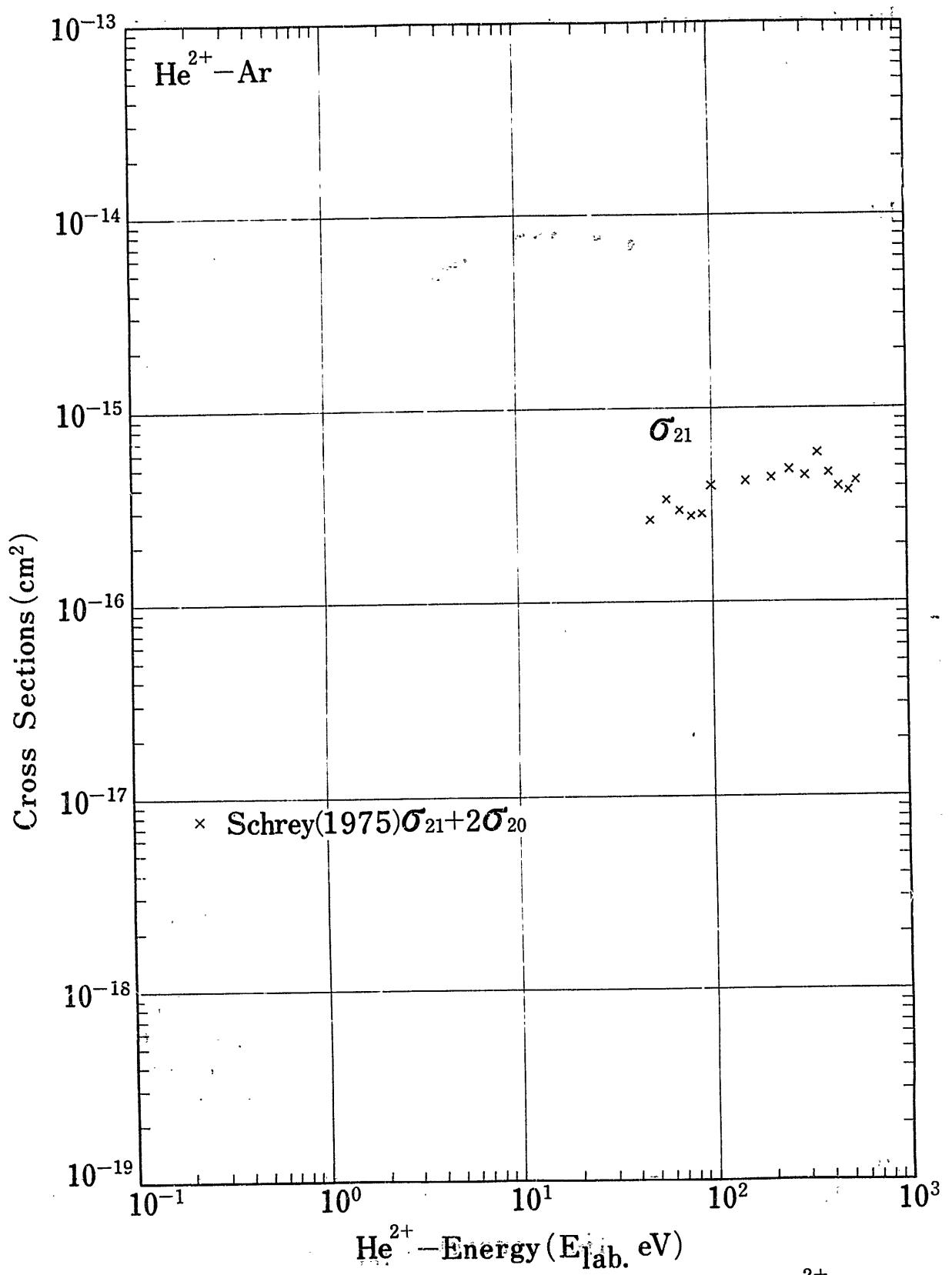


Fig. 30-a Charge-Changing Cross Sections of He^{2+} in Ar

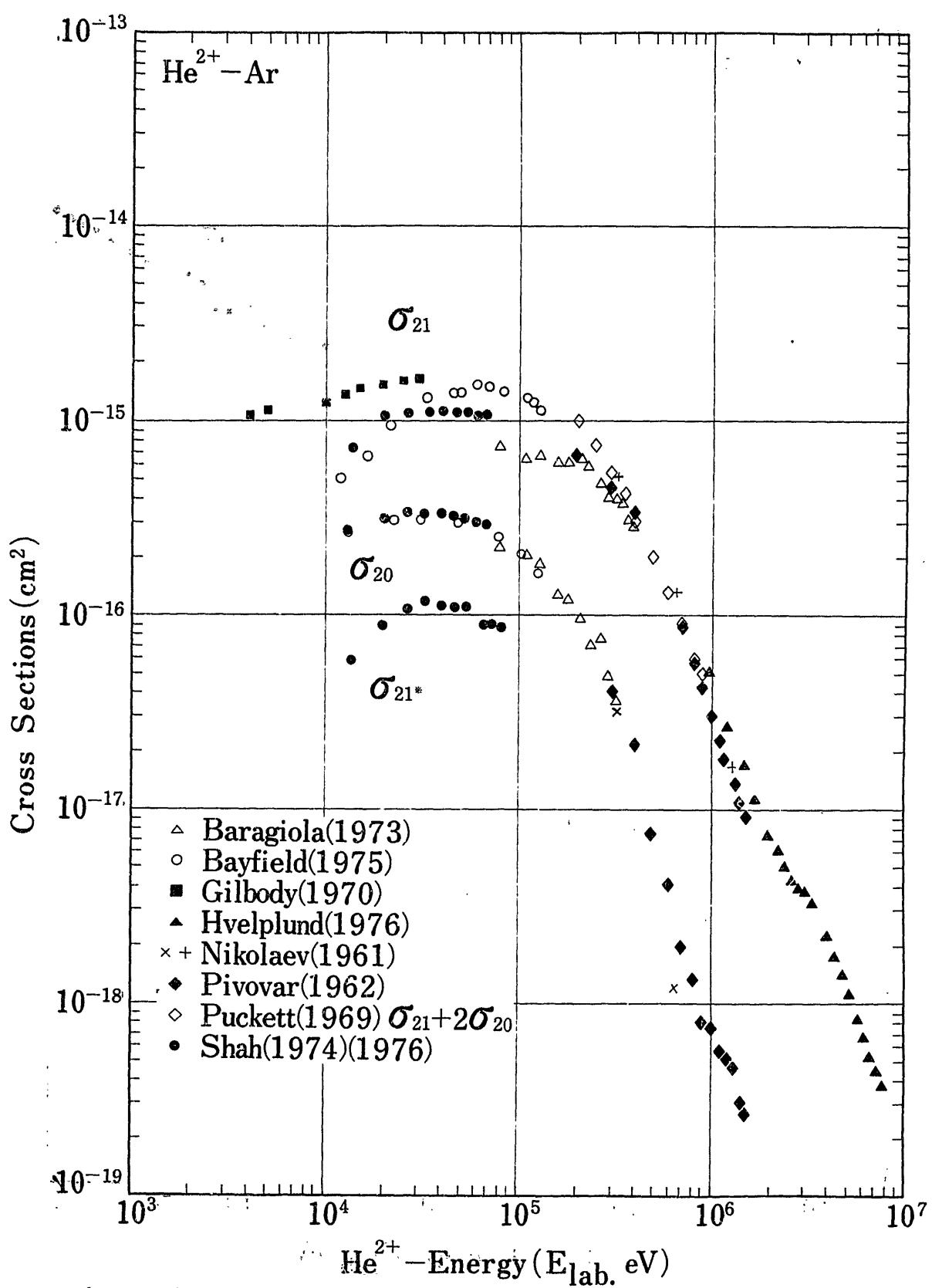


Fig.30-b Charge Changing Cross Sections of He^{2+} in Ar

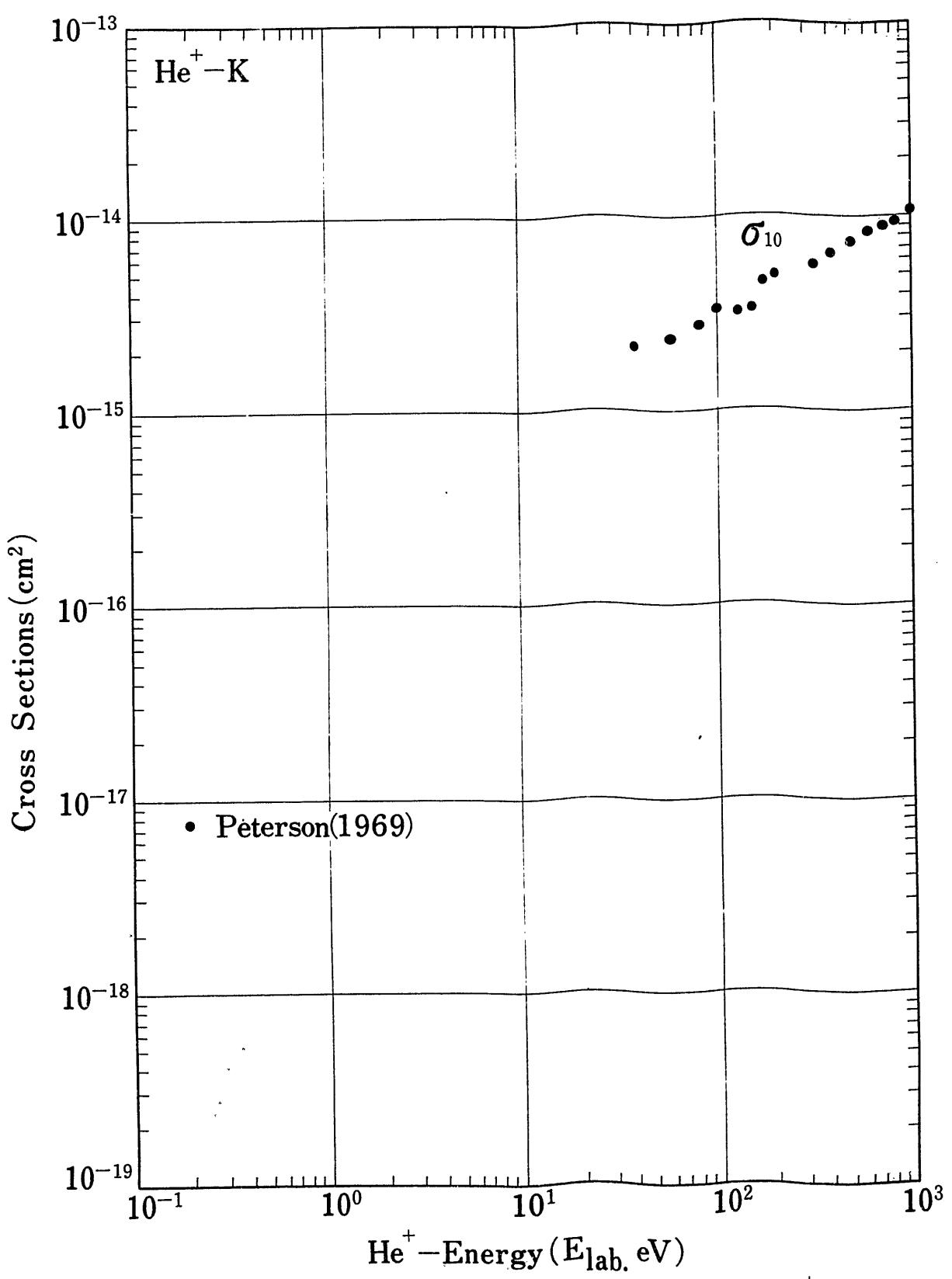


Fig.31-a Charge Changing Cross Sections of He^+ in K

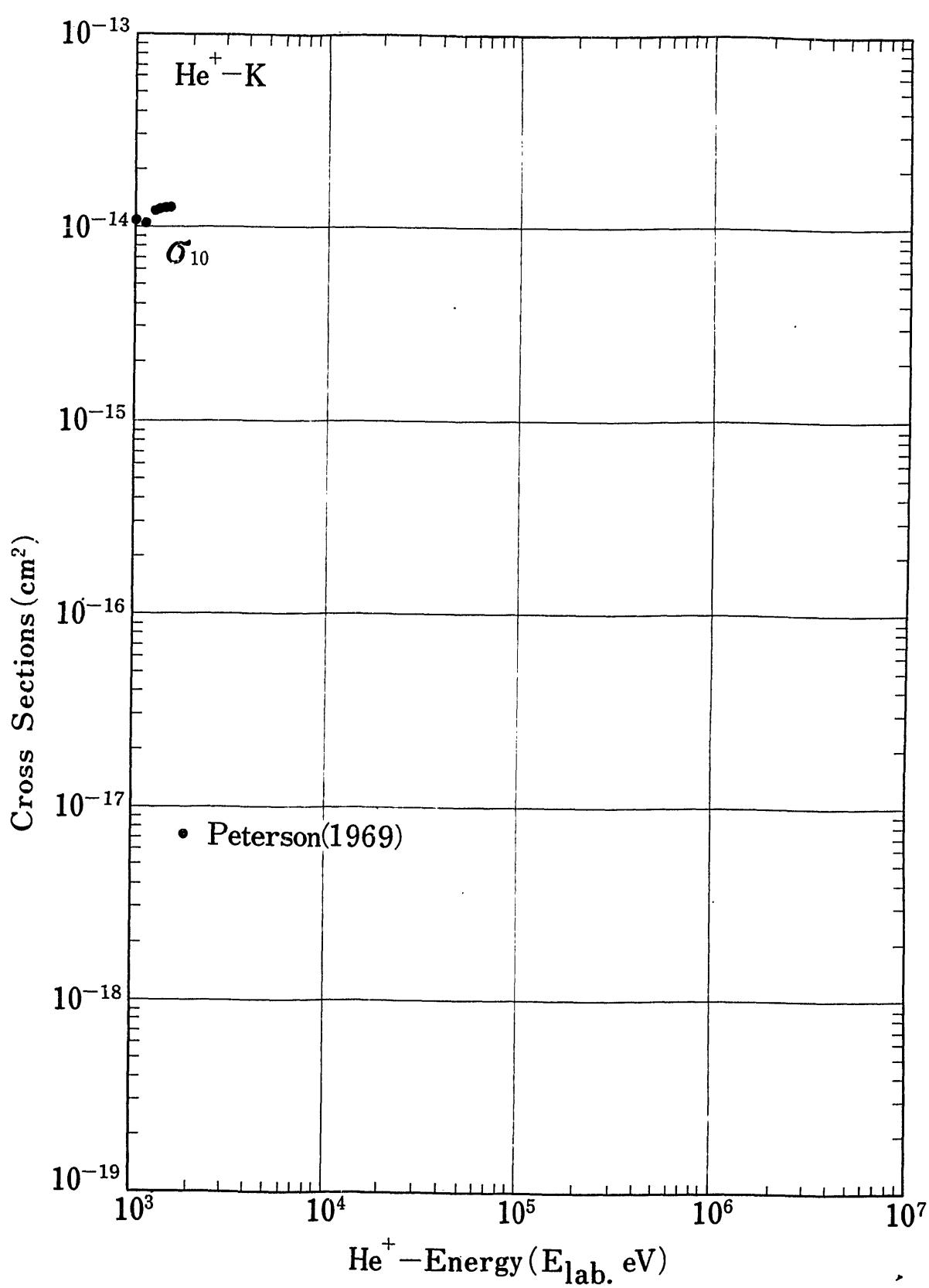


Fig.31-b Charge Changing Cross Sections of He^+ in K

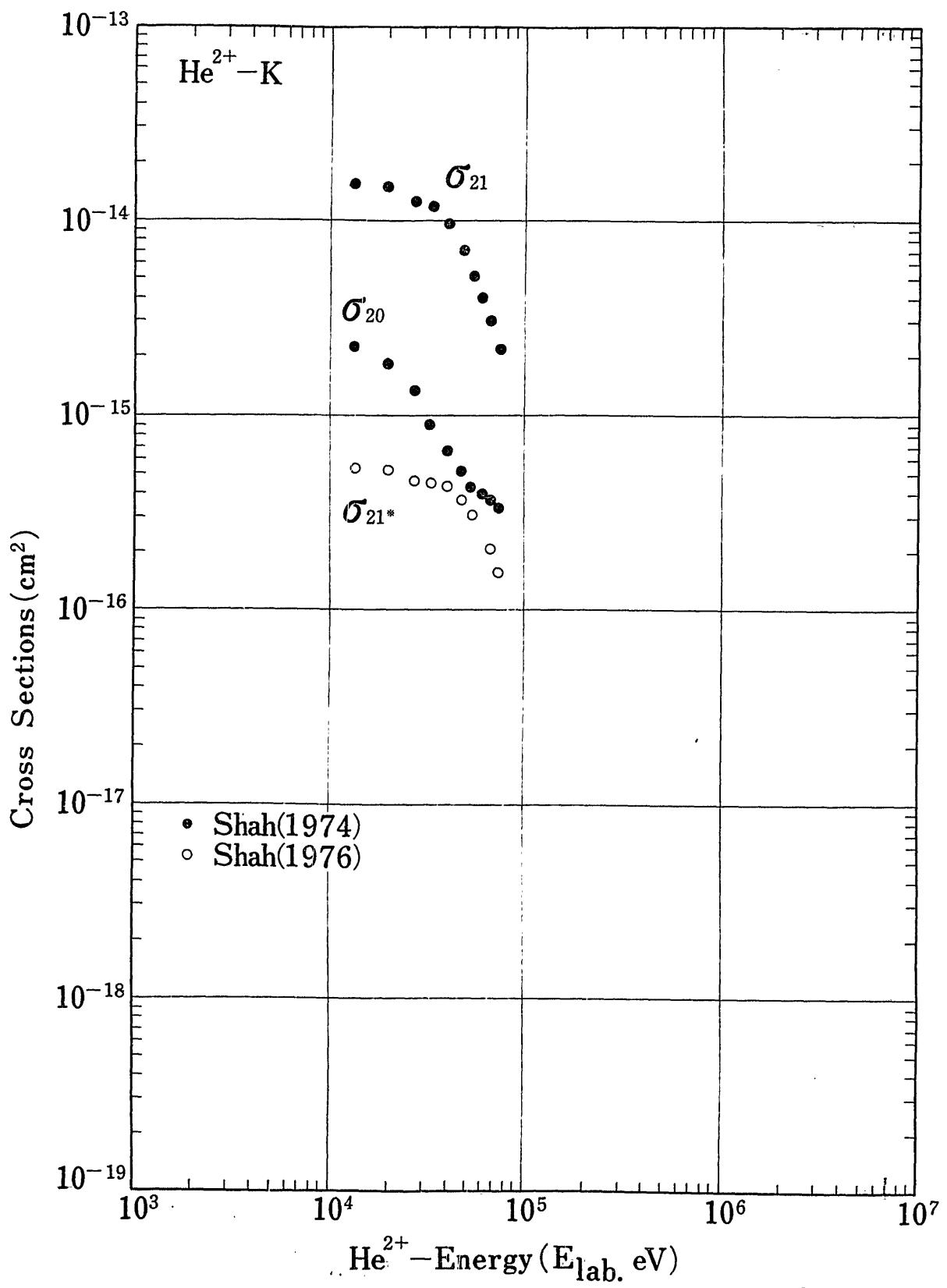


Fig.32 Charge Changing Cross Sections of He^{2+} in K

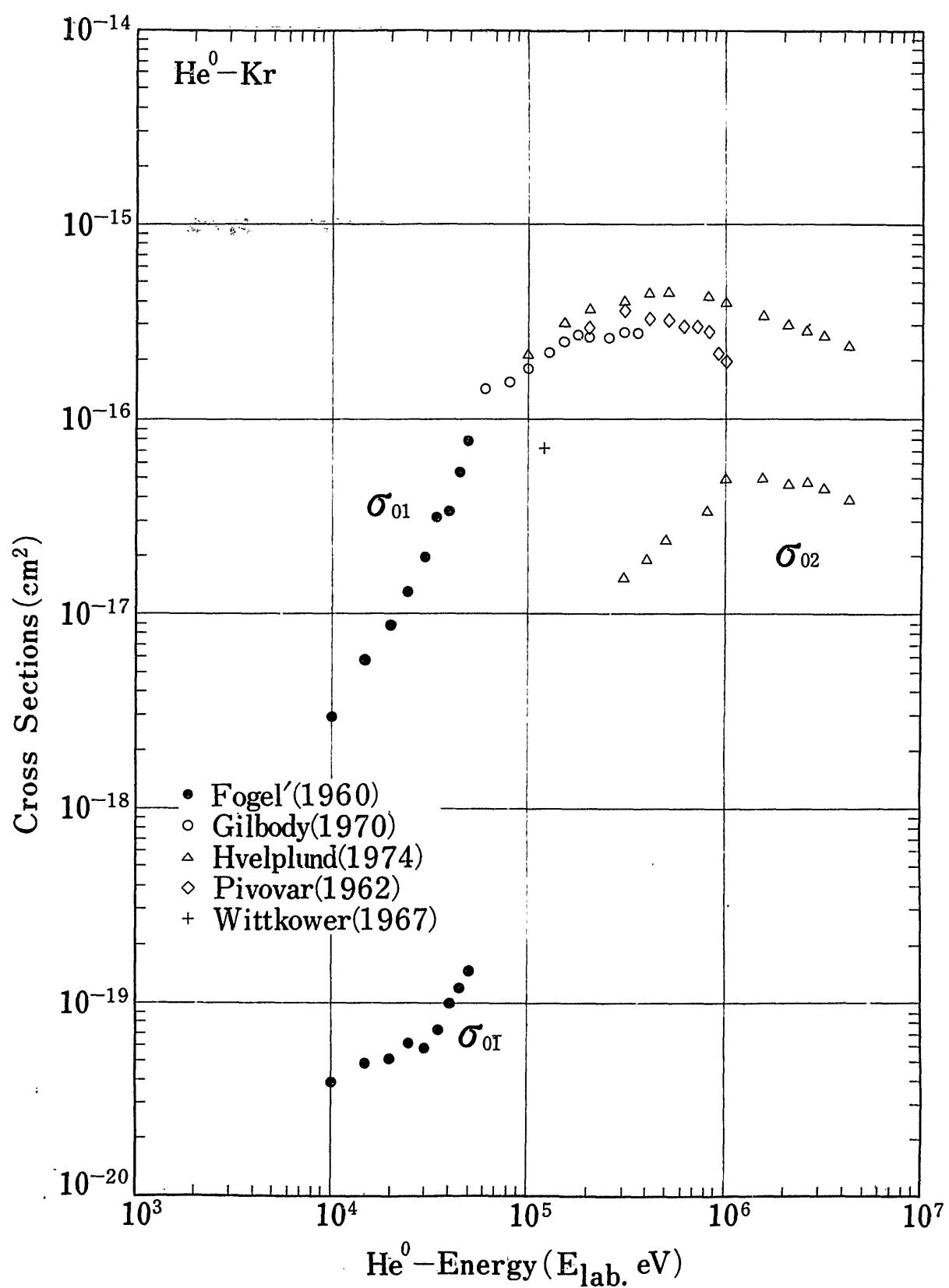


Fig.33 Charge Changing Cross Sections of He^0 in Kr

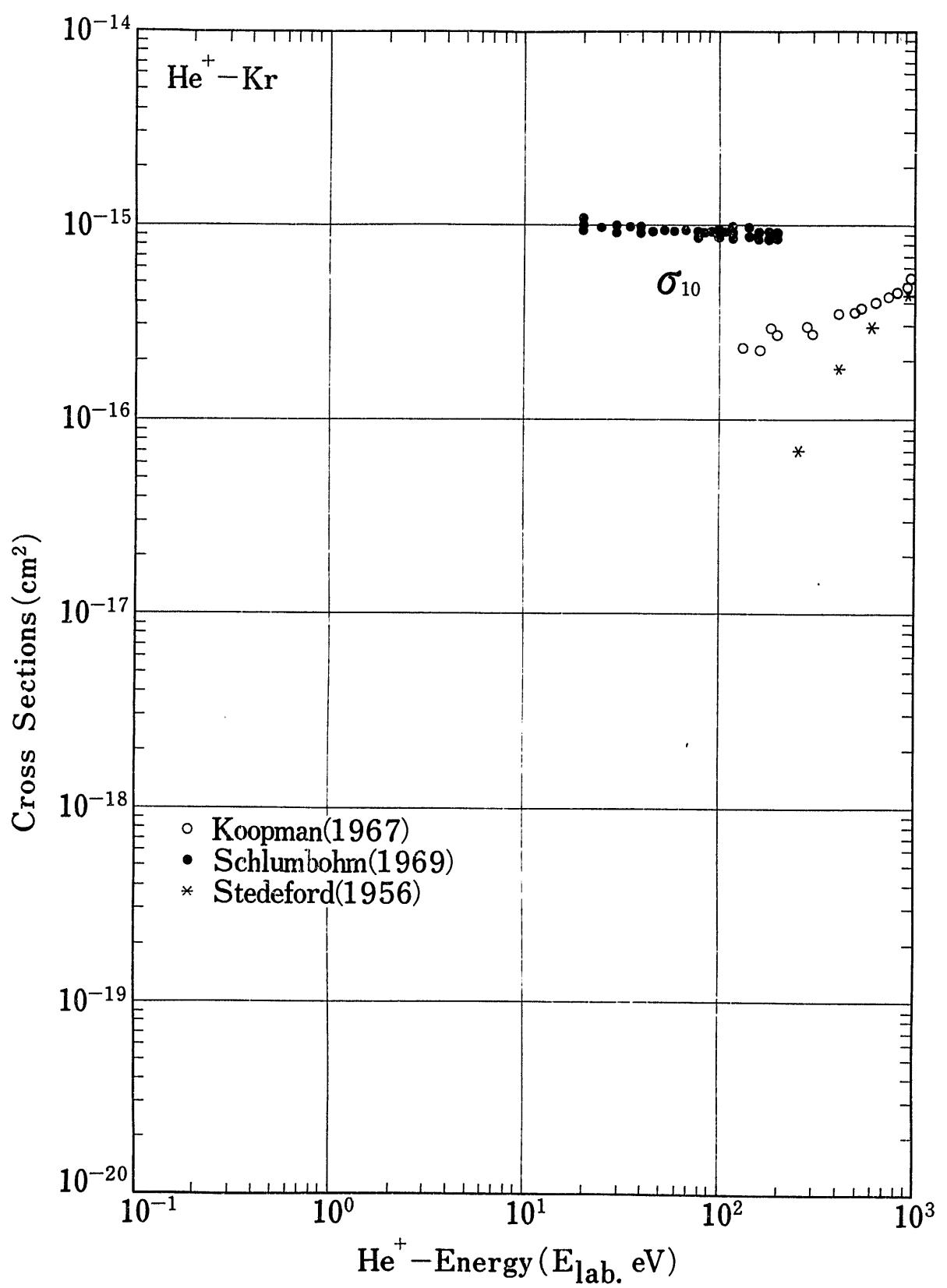


Fig.34-a Charge Changing Cross Sections of He^+ in Kr

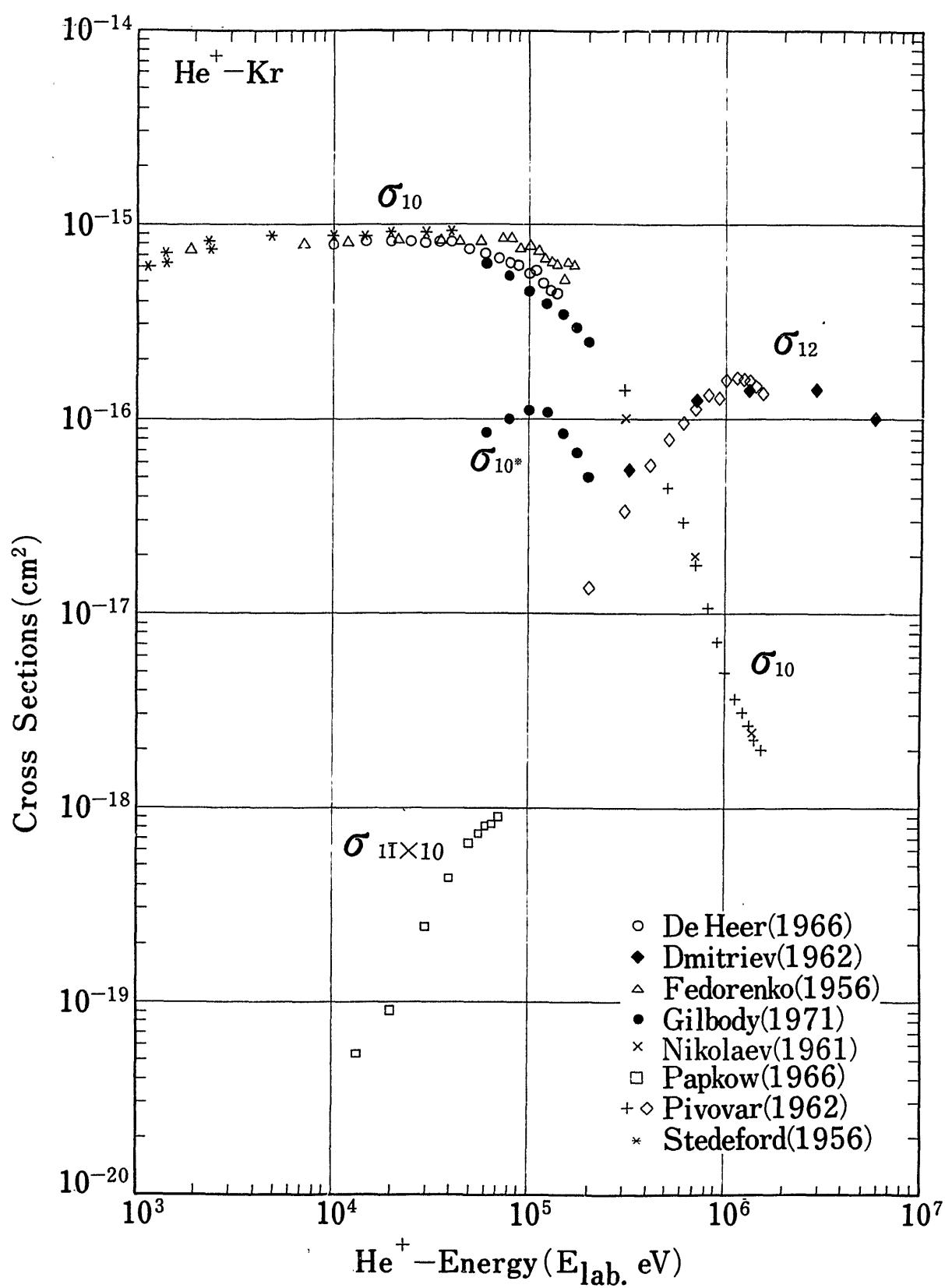


Fig.34-b Charge Changing Cross Sections of He^+ in Kr

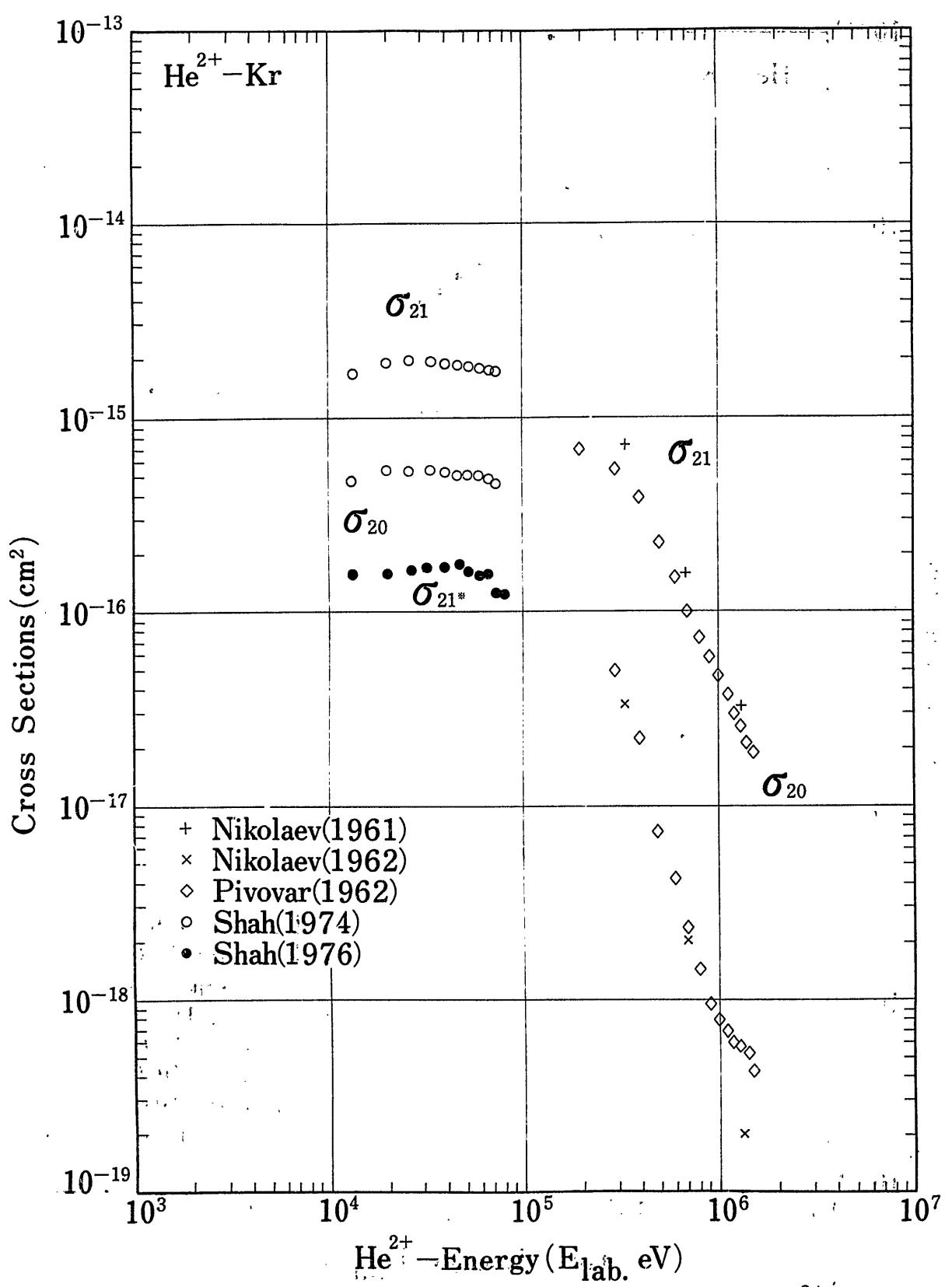


Fig:35 Charge Changing Cross Sections of He^{2+} in Kr

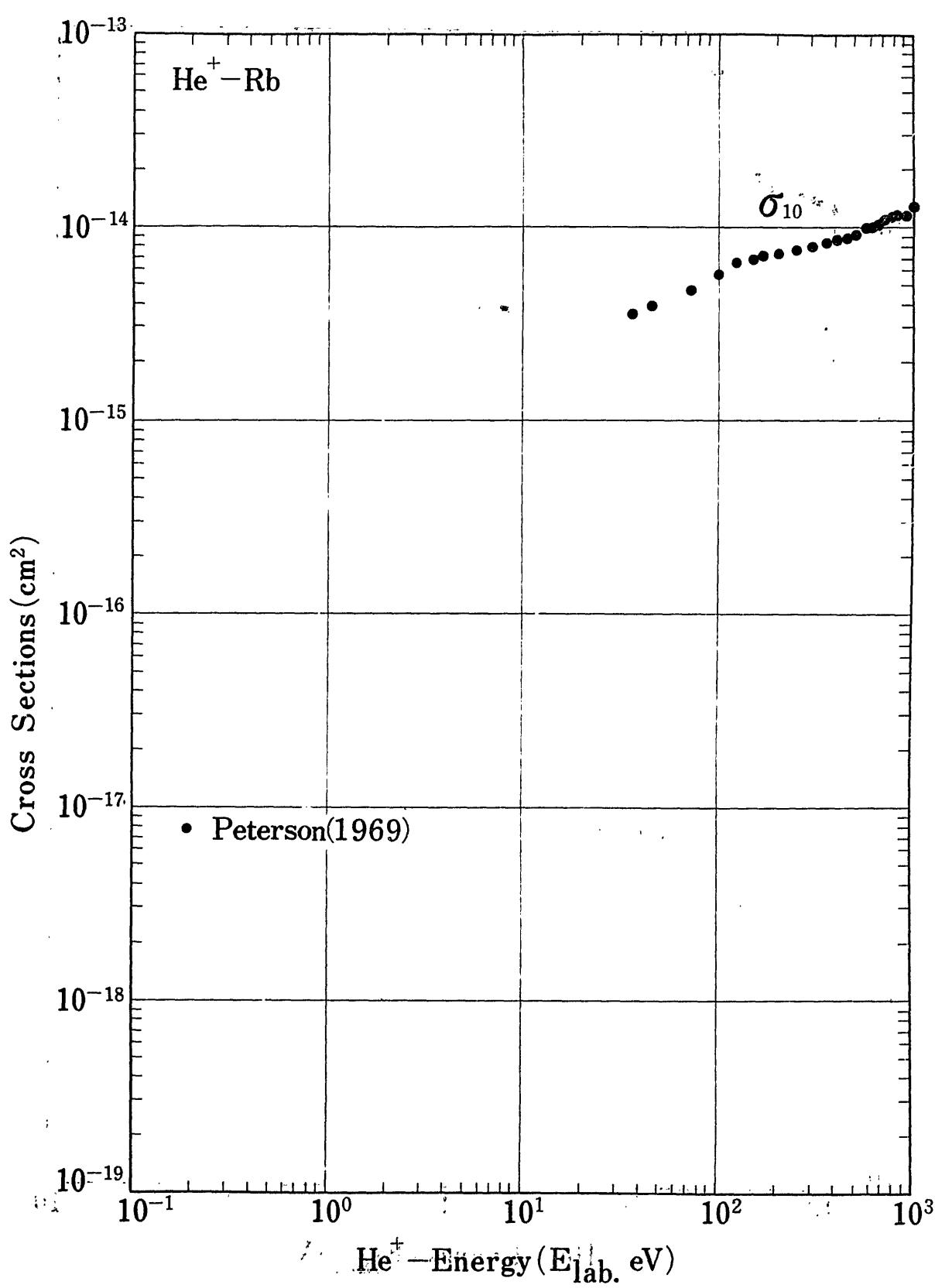


Fig. 36-a Charge Changing Cross Sections of He^+ in Rb

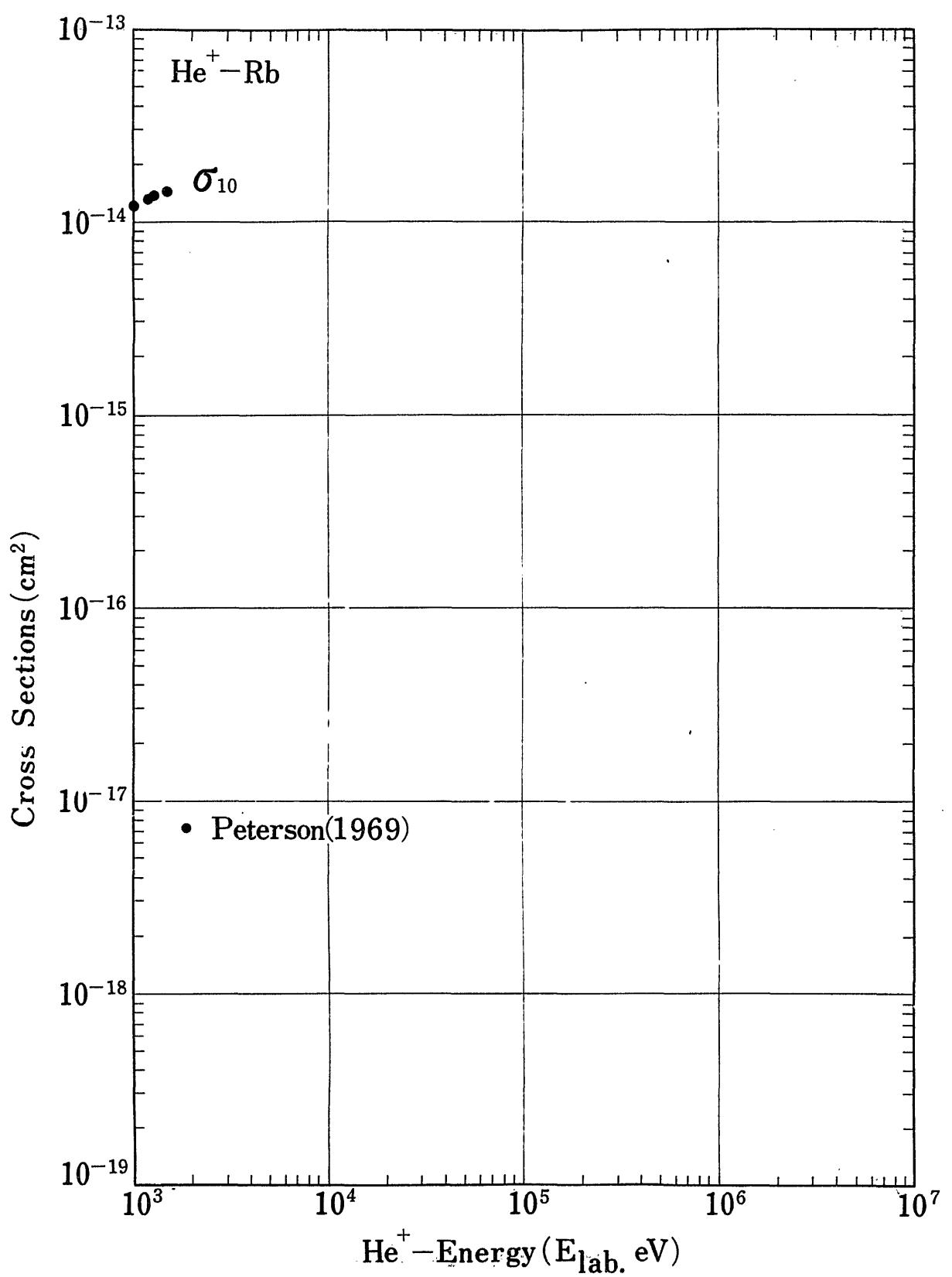


Fig.36-b Charge Changing Cross Sections of He^+ in Rb

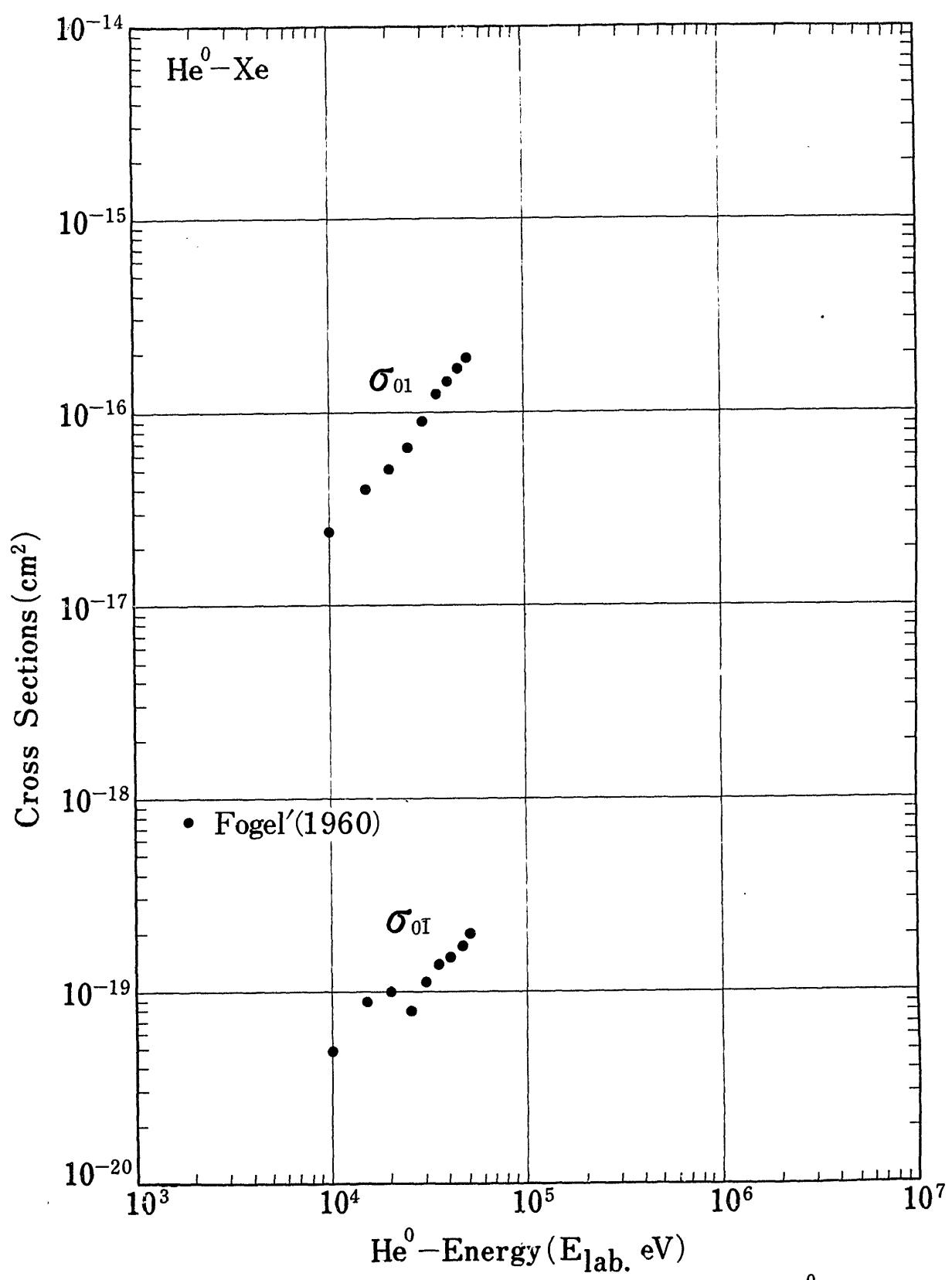


Fig.37 Charge Changing Cross Sections of He^0 in Xe

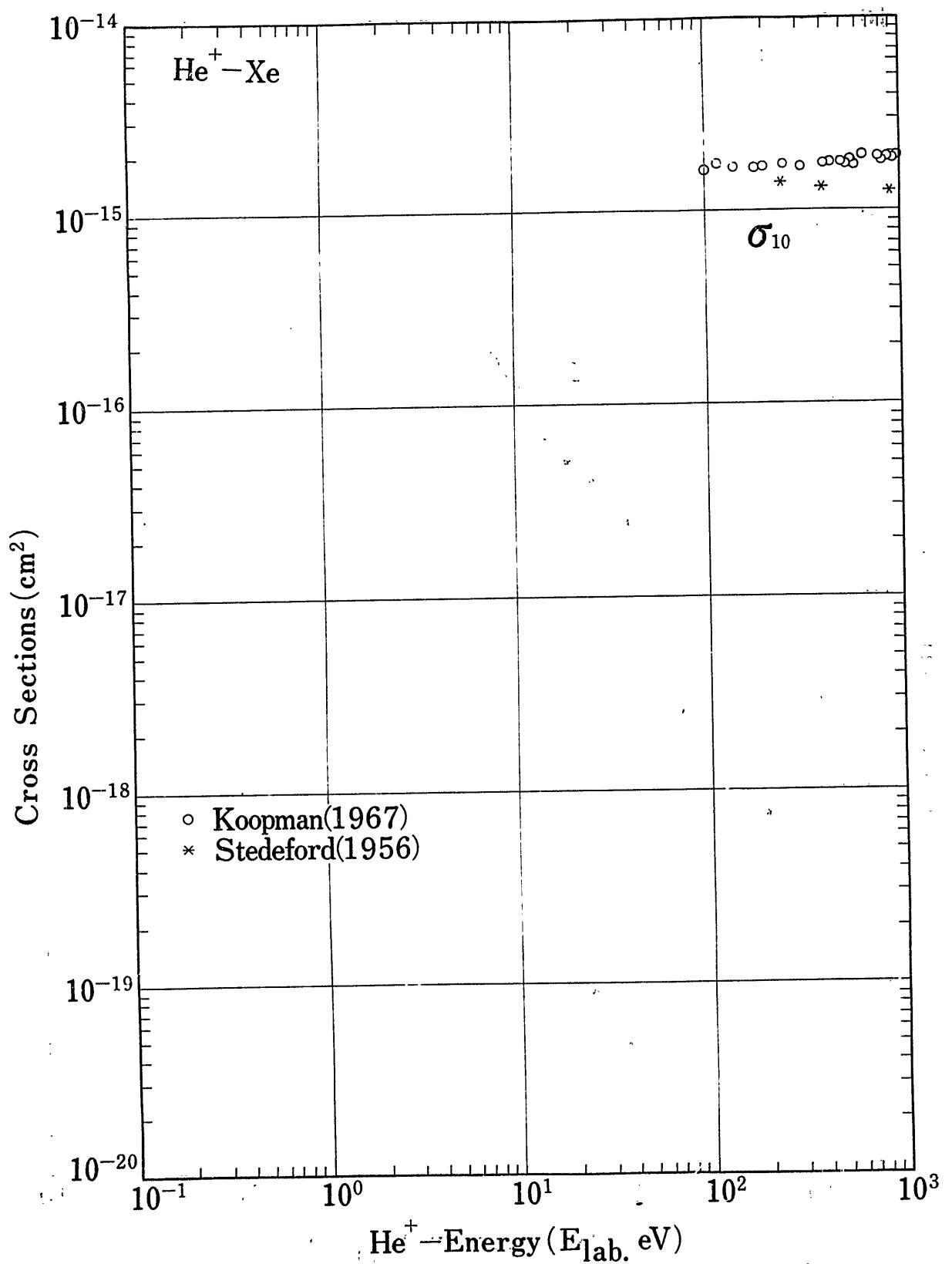


Fig.38-a Charge Changing Cross Sections of He^+ in Xe

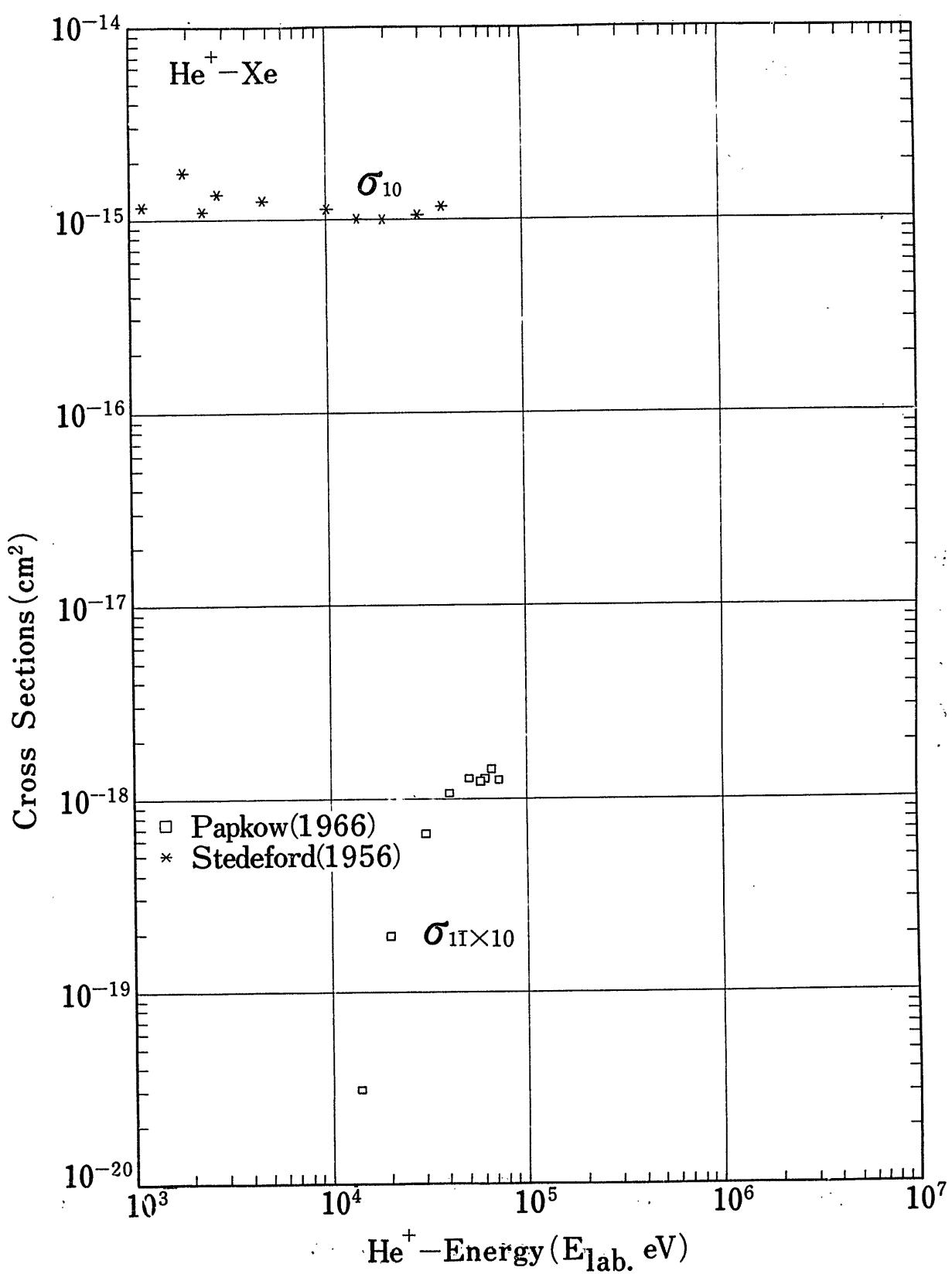


Fig. 38-b Charge Changing Cross Sections of He^+ in Xe

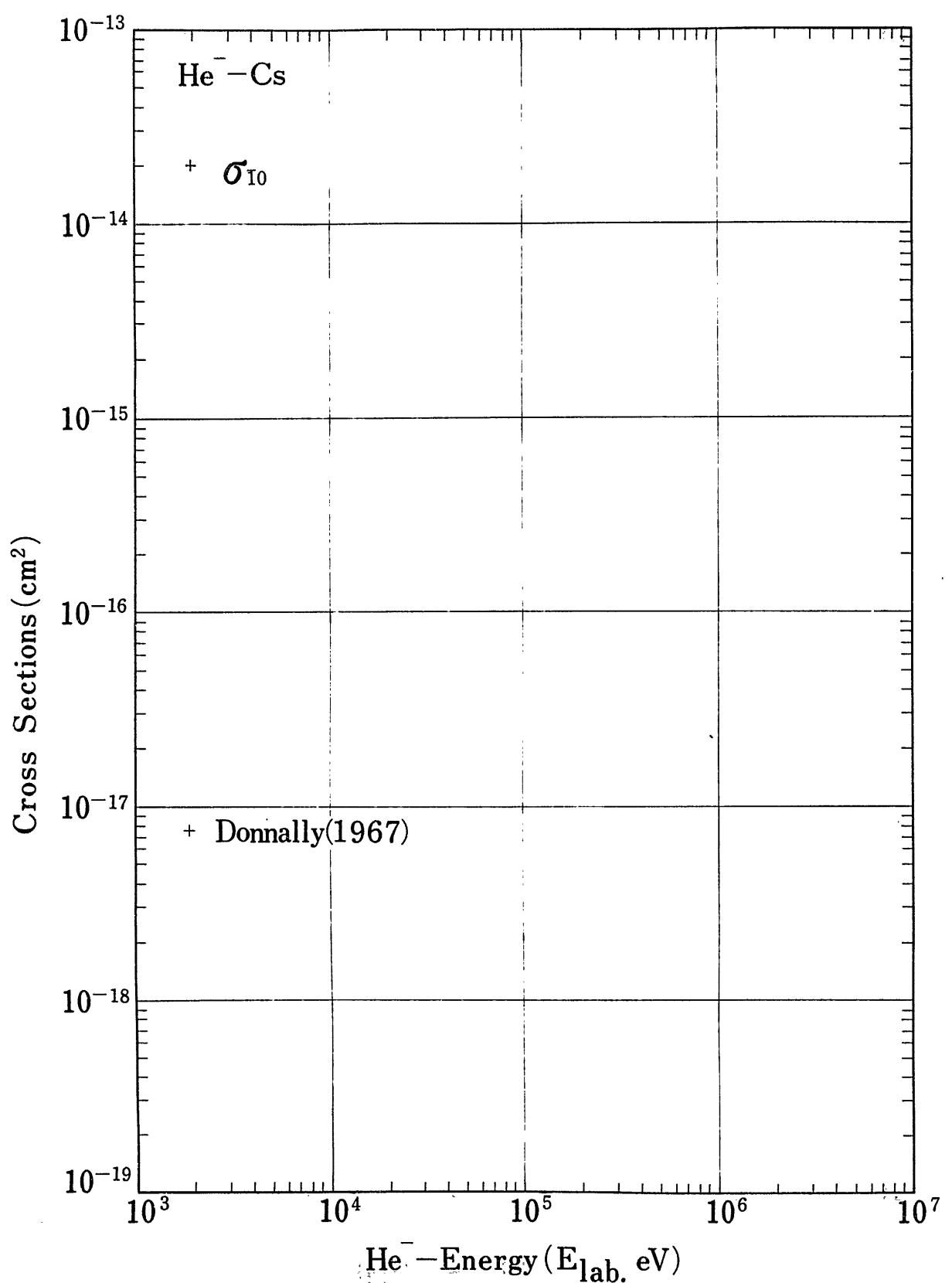


Fig.39 Charge Changing Cross Sections of He^- in Cs

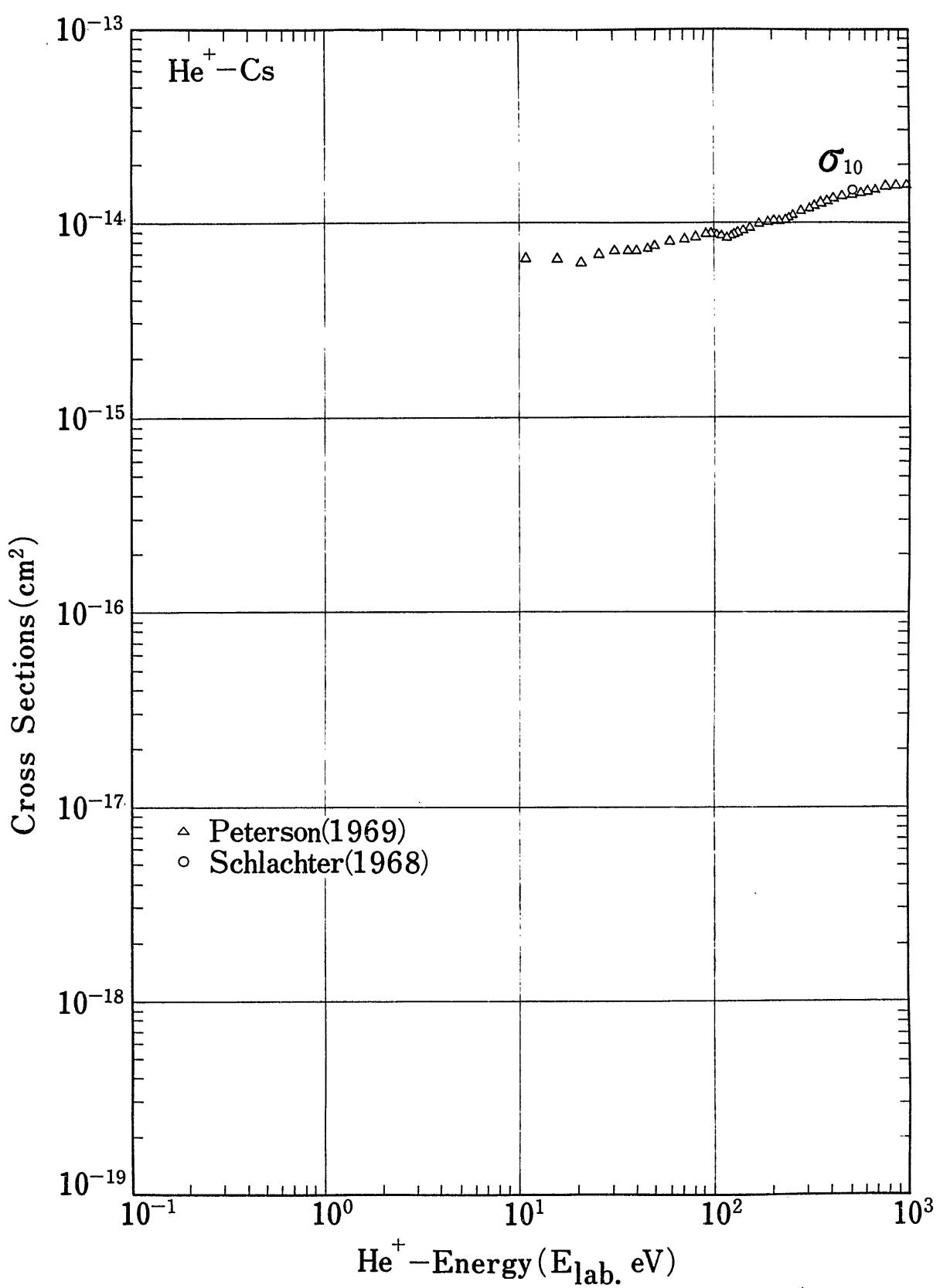


Fig.40-a Charge Changing Cross Sections of He^+ in Cs

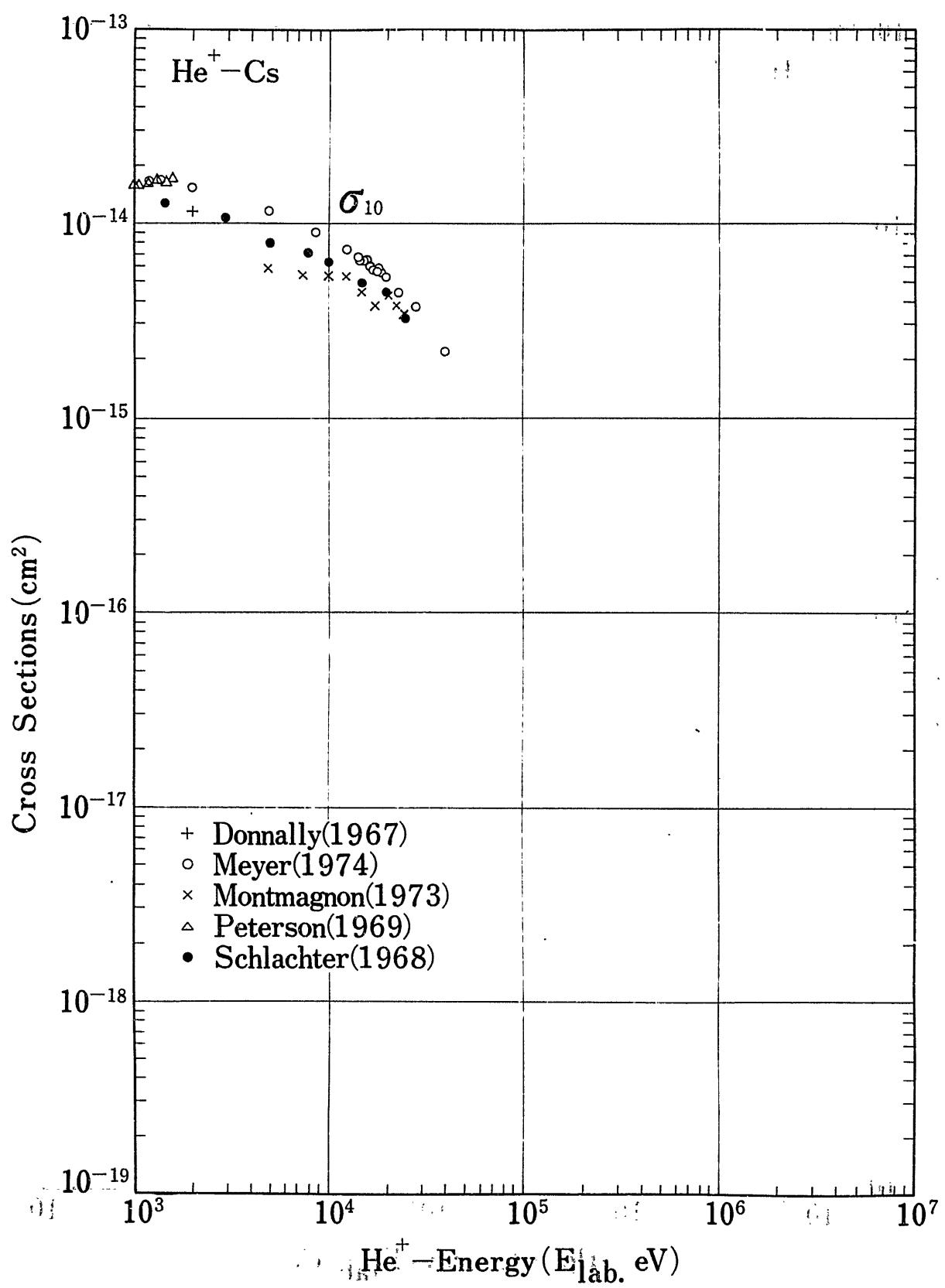


Fig. 40-b Charge-Changing Cross Sections of He^+ in Cs

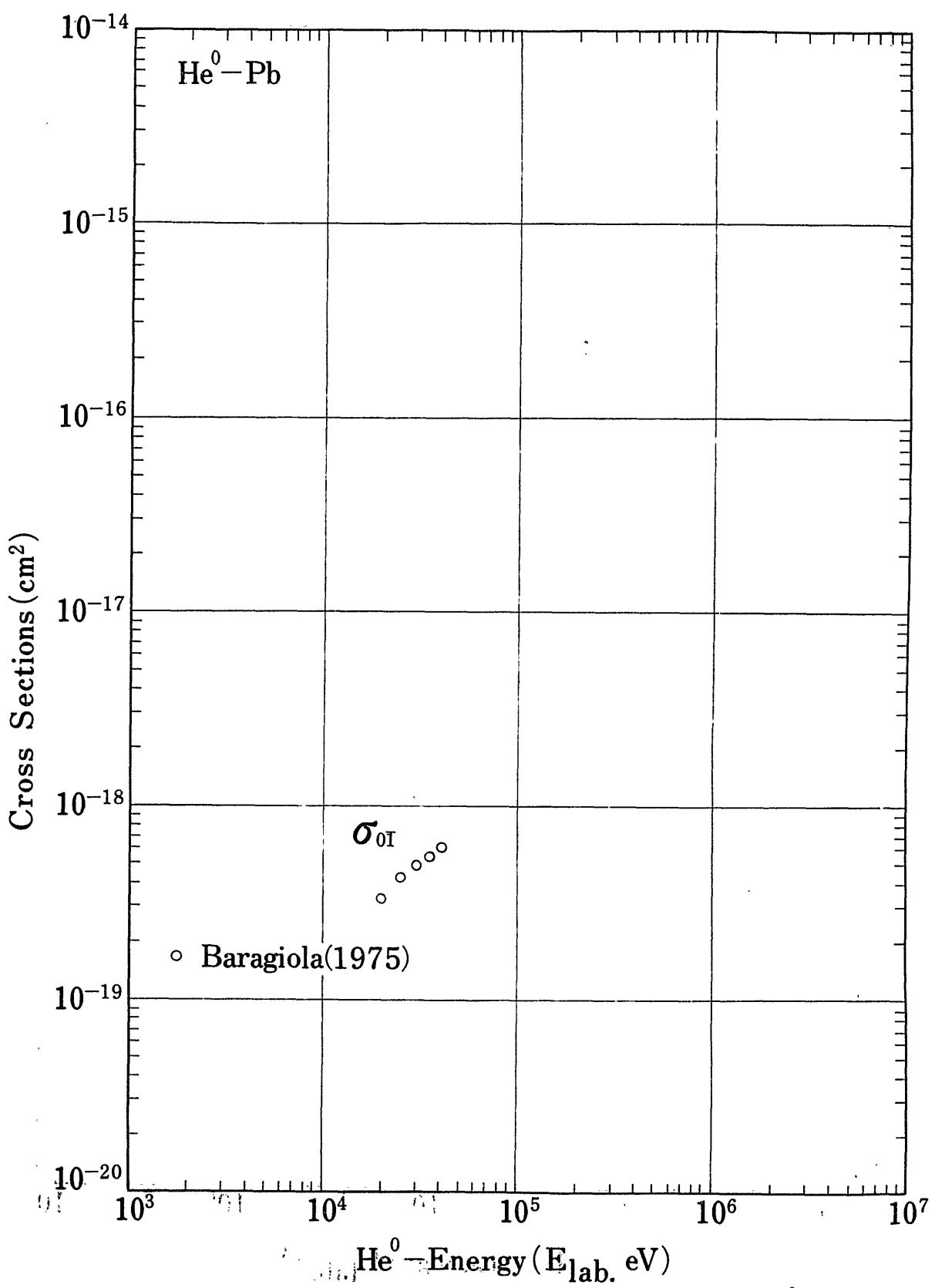


Fig. 41 Charge-Changing Cross Sections of He^0 in Pb

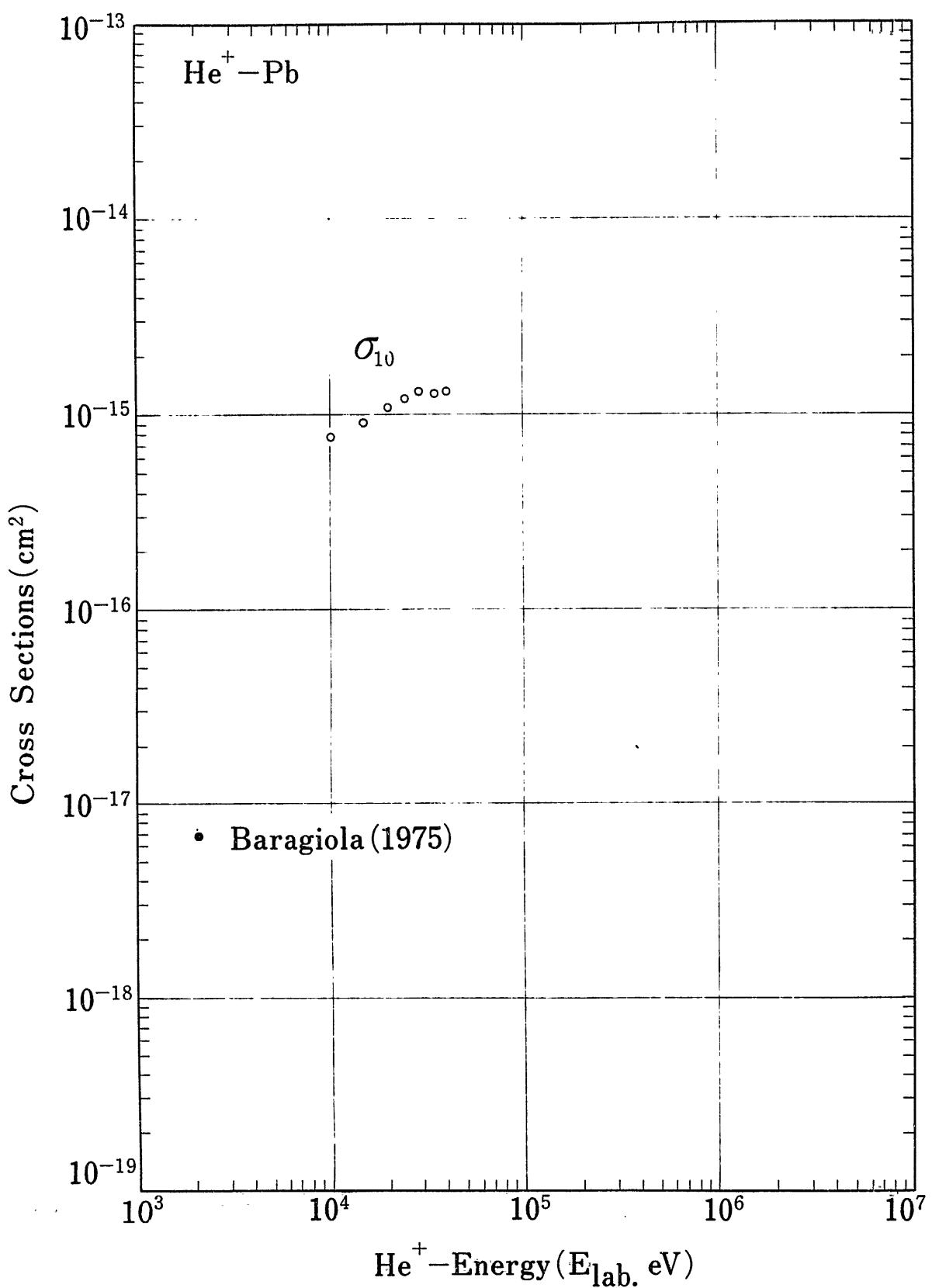


Fig.42 Charge Changing Cross Sections of He^+ in Pb

Charge Changing Cross Sections of Lithium
Atoms and Ions, Z=3.

- I. Lists of Reference
- II. Tables of Experimental Data
 - A) Electron Capture Cross Sections
 - B) Electron Loss Cross Sections
 - C) Cross Sections of Ionization, Slow ions
Productions and Electron productions
- III. Graphs of Charge Changing Cross Sections

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II. Table of Experimental Data

A) Electron Capture Cross Sections of Lithium Ions: Li^+ , Li^{2+} and Li^{3+} .

Author (σ_{10})	Year	Energy (eV)	Target	Reference
Allison <u>et al.</u>	1960	10,000-475,000	$\text{H}_2, \text{He}, \text{N}_2$	1
VanEck, Kistemaker	1960	5,000-24,000	H_2, He	46
Nikolaev <u>et al.</u>	1961	600,000-1,200,000	$\text{H}_e, \text{N}_2, \text{Ar}, \text{Kr}$	32
Lorentz <u>et al.</u>	1965	14-1,000	Li	27
Marino	1966	50-4,000	C_s	30
Ogurtsov <u>et al.</u>	1966	1,000-30,000	$\text{H}_2, \text{He}, \text{N}_2, \text{Ne}, \text{Ar}, \text{Kr}, \text{Xe}$	35
Perel <u>et al.</u>	1969	500-22,000	Li	36
Perel, Daley	1969	500-25,000	Na, Cs	37
Pivovar <u>et al.</u>	1969	20,000-155,000	$\text{Ne}, \text{Na}, \text{Ar}, \text{K}$	40
Lockwood	1969	25,000-100,000	N_2	26
Daley, Perel	1969	500-24,000	Li, Na	10
Pivovar <u>et al.</u>	1970	20,000-155,000	$\text{He}, \text{Ne}, \text{Na}, \text{Ar}, \text{K}$	41
Pivovar <u>et al.</u>	1971	200,000-2,000,000	$\text{H}_2, \text{He}, \text{N}_2, \text{Ne}, \text{Ar}, \text{Kr}$	44
Perel, Daley	1971	500-20,000	$\text{K}, \text{Rb}, \text{Cs}$	38
Latpov, Shaporenko	1972	600-2,800	He	22, 23
Lorentz, Conklin	1972	1,000-2,000	He	28
Francois <u>et al.</u>	1972	600-2,000	He	16
Barat <u>et al.</u>	1973		$\text{Ne}, \text{Ar}, \text{Kr}, \text{Xe}$	9
Aquilanti, Bellu	1974	60 -1,500	Na, K	5
Dmitriev <u>et al.</u>	1975	580,000-5,200,000	He, N_2	13
Teplova <u>et al.</u>	1975	230,000	N_2	45

Blaney <u>et al.</u>	1976		H ₂	7
Hvelplund	1976	40,000-90,000	He,Ar	18
Odom <u>et al.</u>	1976	200-3,000	H ₂	34

($\sigma_{1\bar{1}}$)

Fogel' <u>et al.</u>	1959	5,000-60,000	H ₂ ,He,Kr	14
Fogel' <u>et al.</u>	1961	5,000-60,000	H ₂ ,Ar,Kr	15
Kozlov,Bondar	1966	150-6,000	H ₂ ,Ar,Kr	20
Dmitriev <u>et al.</u>	1975	580,000	He	13

(σ_{21})

Allison <u>et al.</u>	1960	10,000-475,000	H ₂ ,He,N ₂	1
Nikolaev <u>et al.</u>	1961	600,000-5,000,000	He,N ₂ ,Ar,Kr	32
Nikolaev <u>et al.</u>	1962	1,200,000-5,000,000	N ₂ ,Ar,Kr	33
Pivovar, Nikolaichuk	1970	16,000-145,000	Ne	43
Pivovar <u>et al.</u>	1971	600,000-2,000,000	H ₂ ,He,N ₂ ,Ne,Ar,Kr	44
Teplova <u>et al.</u>	1975	230,000	N ₂	45

(σ_{20})

Nikolaev <u>et al.</u>	1962	600,000-2,400,000	He,N ₂ ,Ar,Kr	33
Pivovar <u>et al.</u>	1971	600,000-2,000,000	He,N ₂ ,Ar,Kr	44

(σ_{32})

Allison <u>et al.</u>	1960	10,000-475,000	H ₂ , He,N ₂	1
Nikolaev <u>et al.</u>	1961	1,200,000-5,000,000	He,N ₂ ,Ar,Kr	32
Pivovar <u>et al.</u>	1971	1,200,000-2,000,000	H ₂ ,He,N ₂ ,Ne,Ar,Kr	45
Teplova <u>et al.</u>	1975	230,000	N ₂	45

(σ_{31})

Nikolaev <u>et al.</u>	1962	1,200,000-2,400,000	He,N ₂ ,Ar,Kr	33
Pivovar <u>et al.</u>	1971	1,200,000-2,000,000	Ne,Ar,Kr	44

B) Electron Loss Cross Sections of Lithium Negative Ion, Atom
and Positive Ion: Li⁻, Li⁰, Li⁺, Li²⁺.

(σ_{10})

Allison et al. 1960 10,000-475,000 H_e, He, N₂ 1

(σ_{01})

Allison et al. 1960 10,000-475,000 H₂, He, N₂ 1,2

VanEck,Kistemaker 1960 5,000-22,500 H₂, He 46

Dmitriev et al. 1960 600,000-1,200,000 Ne, Ar, N₂, Kr 11

Kikiani et al. 1966 3,000-30,000 H₂, He, N₂, Ne, Ar, Kr, Xe 19

Pivovar,Nikolaichuk 1970 16,000-145,000 Ne, Na, Ar, K 43

(σ_{12})

Liviant et al. 1955 85,000-250,000 Air 25

Dmitriev et al. 1962 600,000-2,400,000 Ne, N₂, Ar, Kr 11

Pivovar,Nikolaichuk 1970 16,000-145,000 He, Ne 43

Pivovar et al. 1971 200,000-2,000,000 H₂, He, N₂, Ne, Ar, Kr 44

Dmitriev et al. 1975 580,000-5,200,000 He, N₂ 13

Teplova et al. 1975 230,000 N₂ 45

Hvelplund 1976 40,000-90,000 He, Ar 18

(σ_{13})

Leviant et al. 1955 85,000-250,000 Air 25

Dmitriev et al. 1963 600,000-2,400,000 He, N₂, Ar, Kr 12

Pivovar et al. 1971 200,000-2,000,000 He, N₂, Ne, Ar, Kr 44

Dmitriev et al. 1975 580,000-5,200,000 He, Ne 13

(σ_{23})

Dmitriev et al. 1962 600,000-5,200,000 He, N₂, Ar, Kr 11

Pivoval <u>et al.</u>	1971	600,000-2,000,000	H ₂ ,He,N ₂ ,Ne,Ar,Kr	44
Tepløva <u>et al.</u>	1975	230,000	N ₂	45

C) Cross Sections of Ionization, Slow ion and Electron Production
by Lithium Atom and Ion.

(σ_1^i , σ_1^+ , σ_1^-)

VanEck,Kistemaker	1960	5,000-50,000	H ₂ ,He	46
Kikiani <u>et al.</u>	1966	3,000-30,000	H ₂ ,He,N ₂ ,Ne,Ar, Kr,Xe	19
Pivovar <u>et al.</u>	1971	200,000-2,000,000	H ₂ ,He,N ₂ ,Ne,Ar,Kr	44

(σ_2^i , σ_2^+ , σ_2^-)

Pivovar <u>et al.</u>	1971	600,000-2,000,000	H ₂ ,He,N ₂ ,Ne,Ar,Kr	44
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(σ_3^i , σ_3^+ , σ_3^-)

Pivovar <u>et al.</u>	1971	1,200,000-2,000,000	H ₂ ,He,N ₂ ,Ne,Ar,Kr	44
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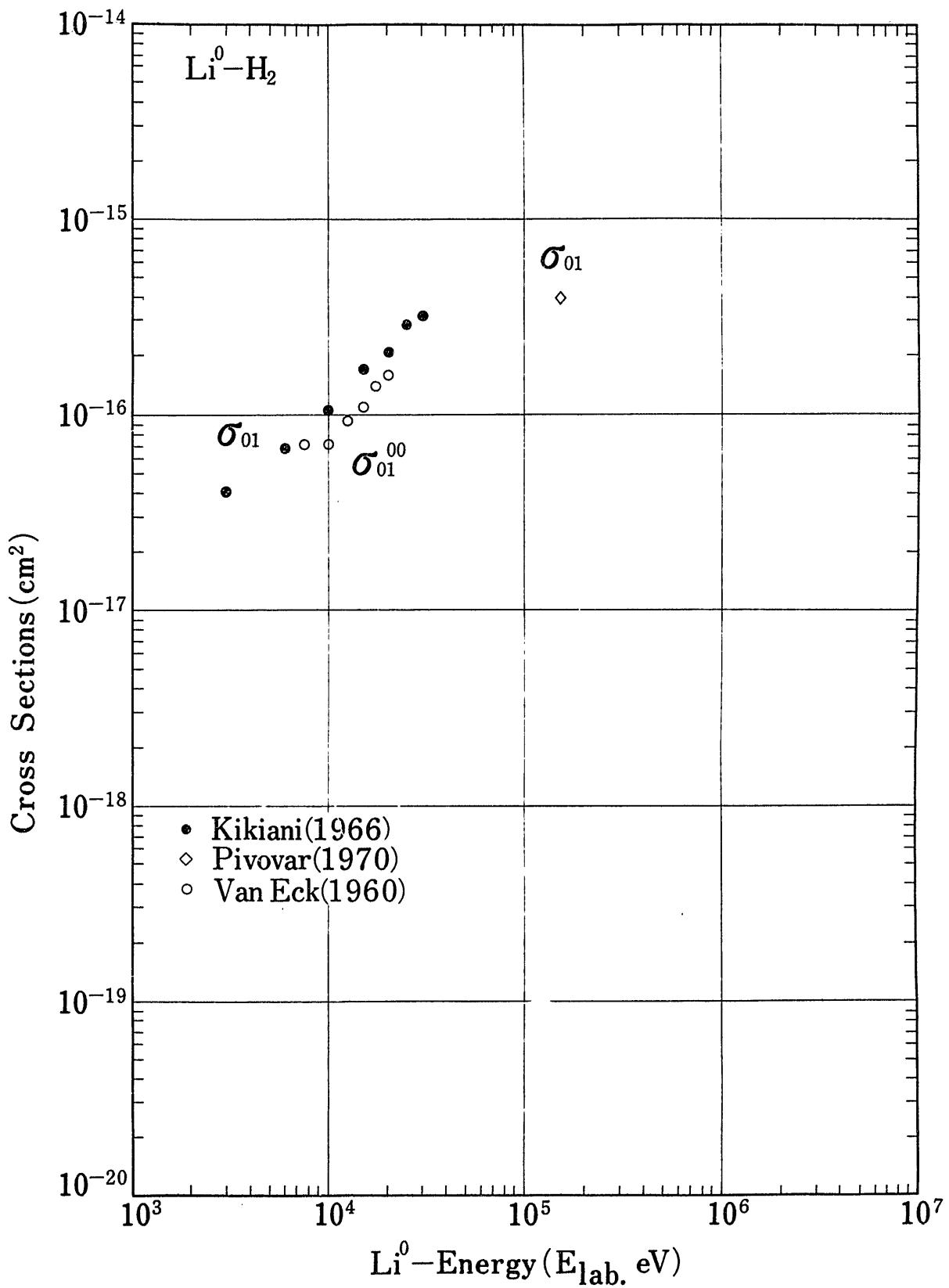


Fig.1 Charge Changing Cross Sections of Li^0 in H_2

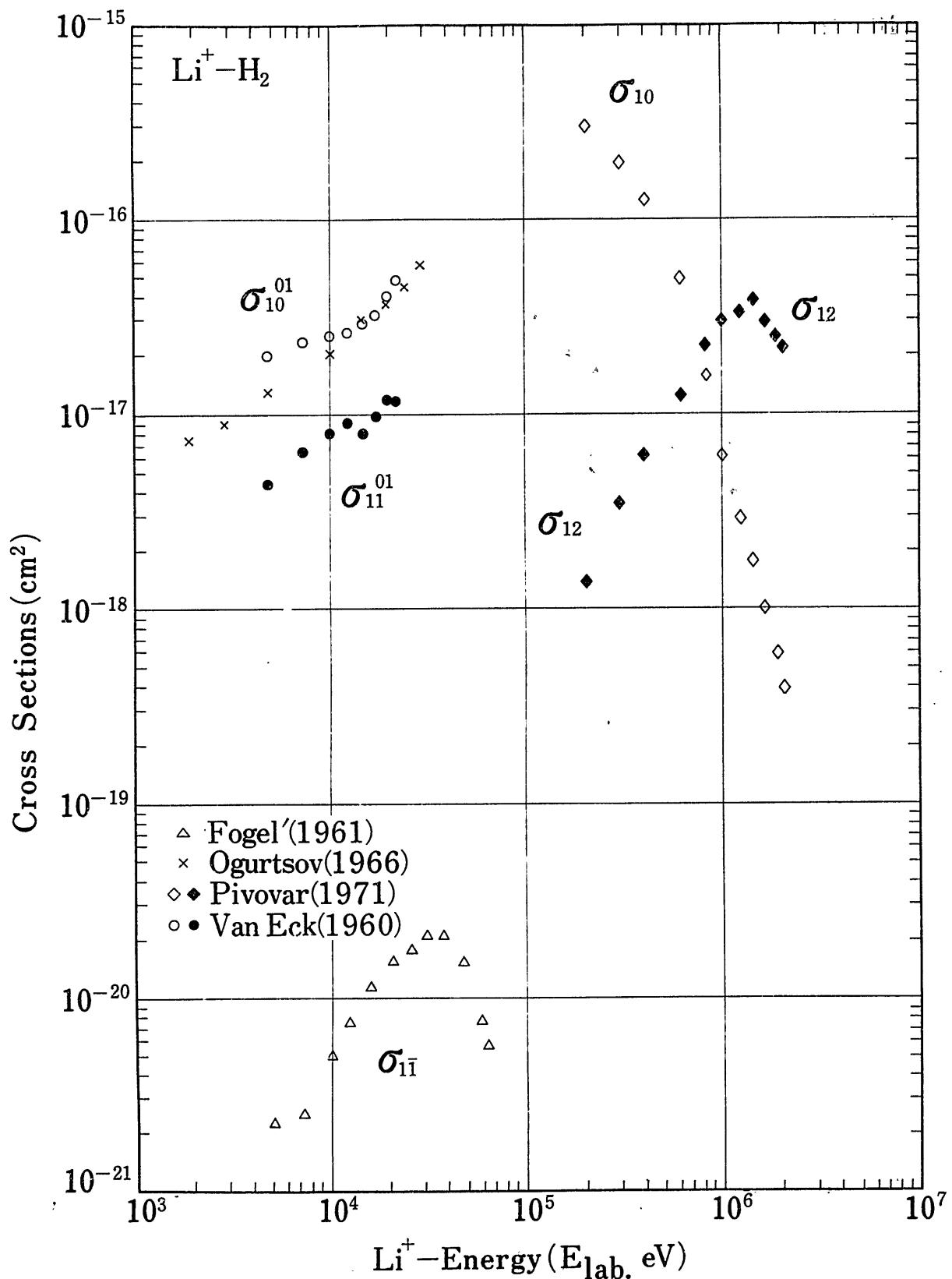


Fig.2 Charge Changing Cross Sections of Li^+ in H_2

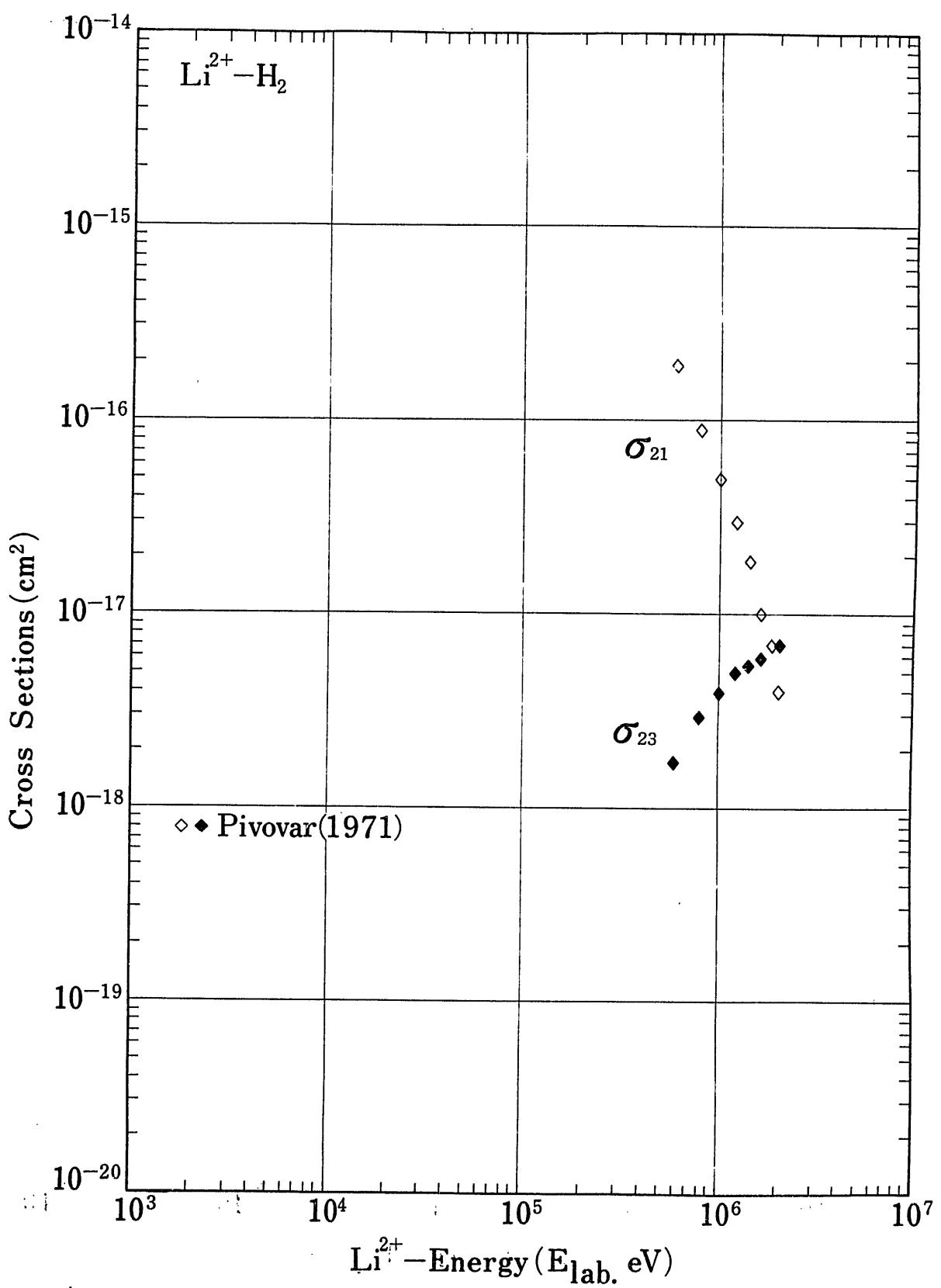


Fig.3 Charge Changing Cross Sections of Li^{2+} in H_2

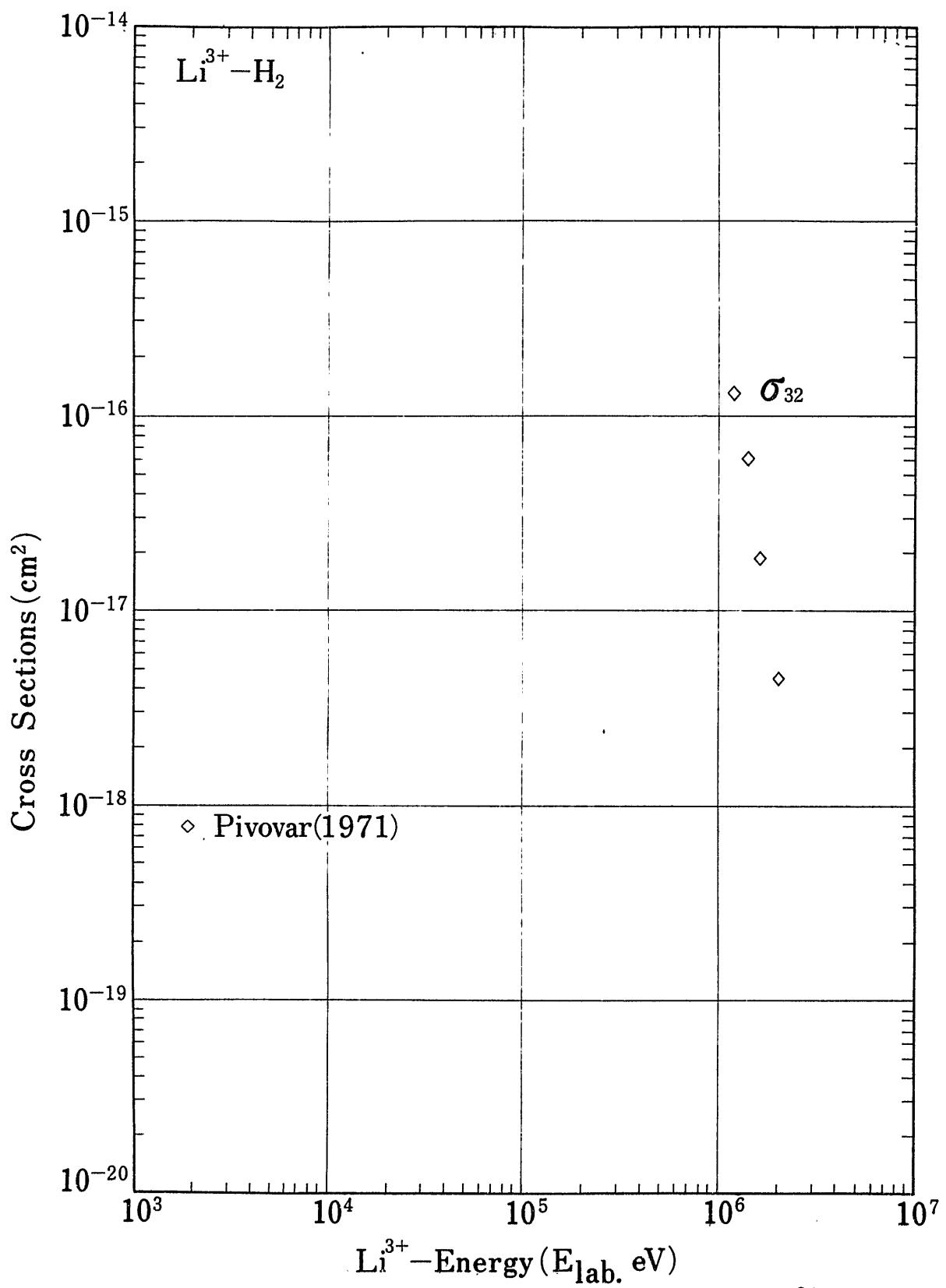


Fig.4 Charge Changing Cross Sections of Li^{3+} in H_2

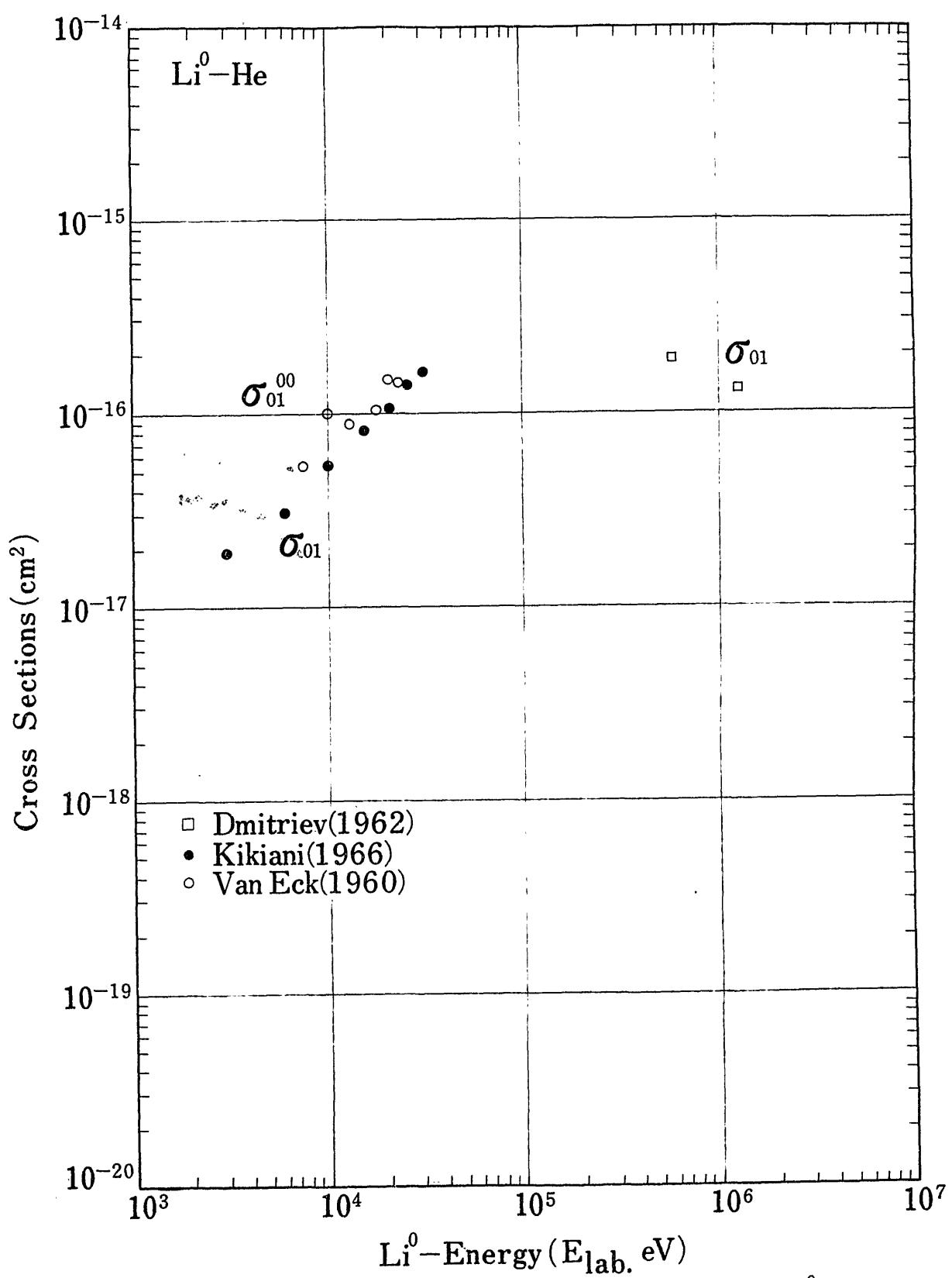


Fig.5 Charge Changing Cross Sections of Li^0 in He

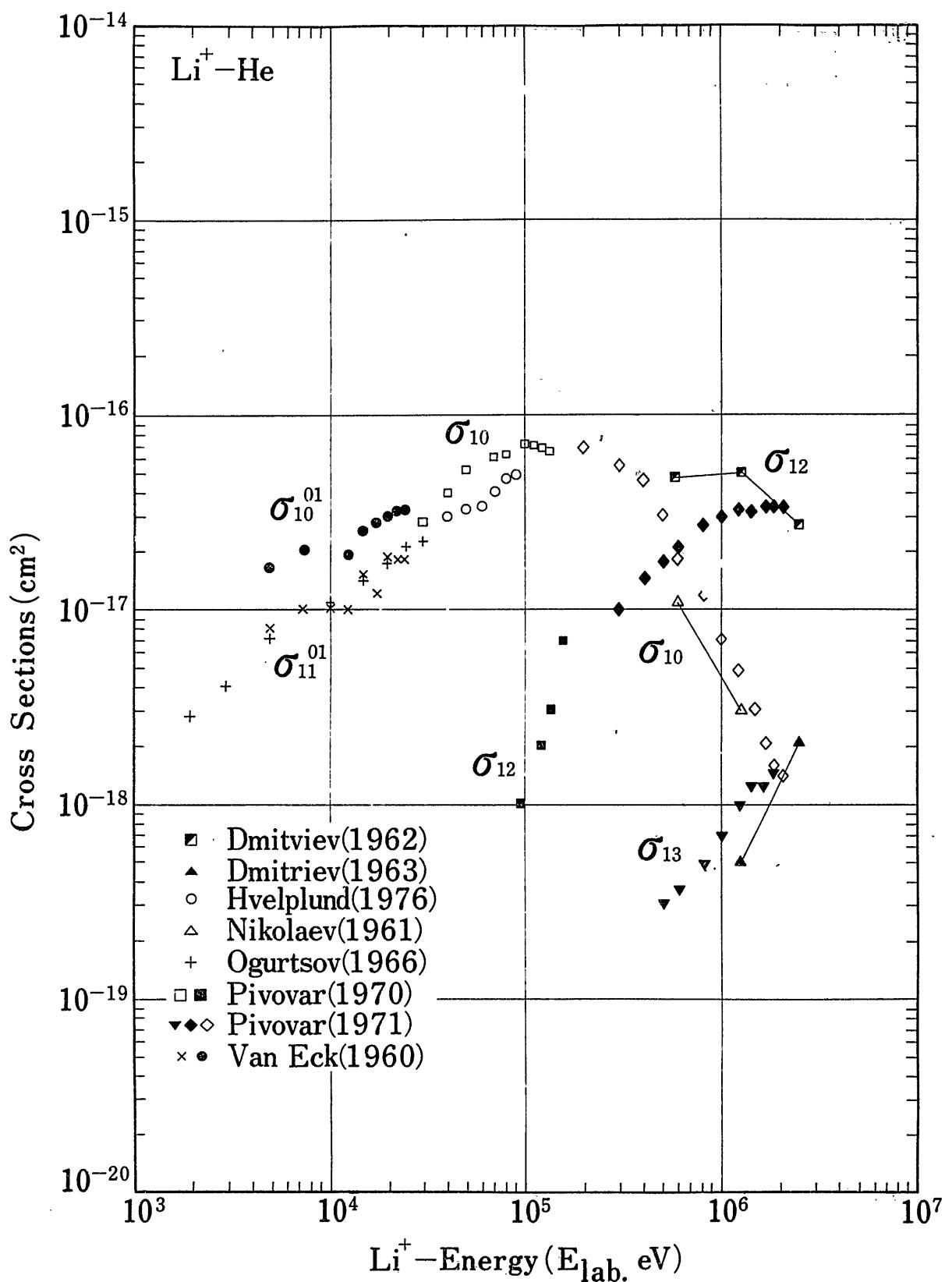


Fig.6 Charge Changing Cross Sections of Li^+ in He

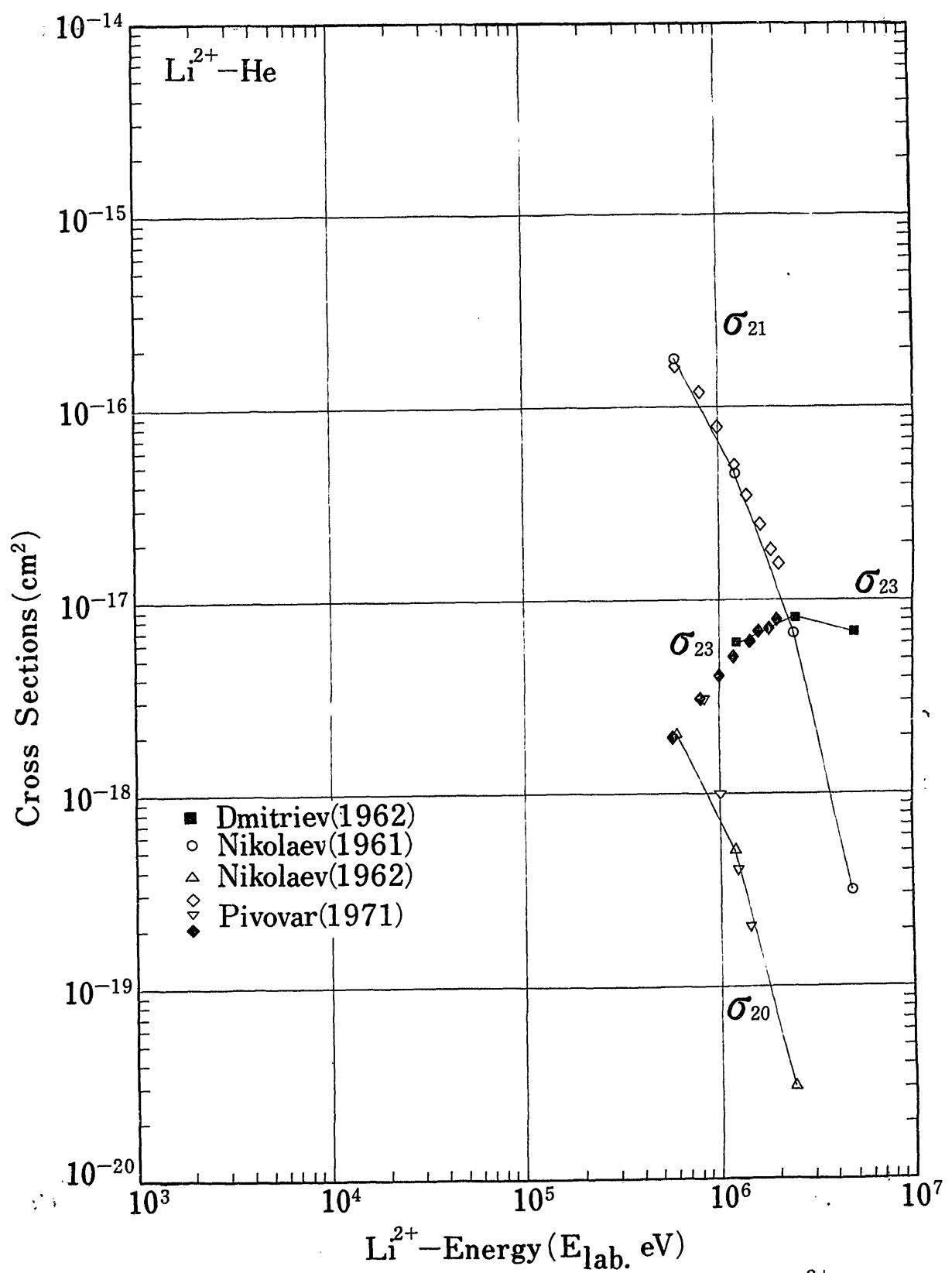


Fig. 7 Charge Changing Cross Sections of Li^{2+} in He

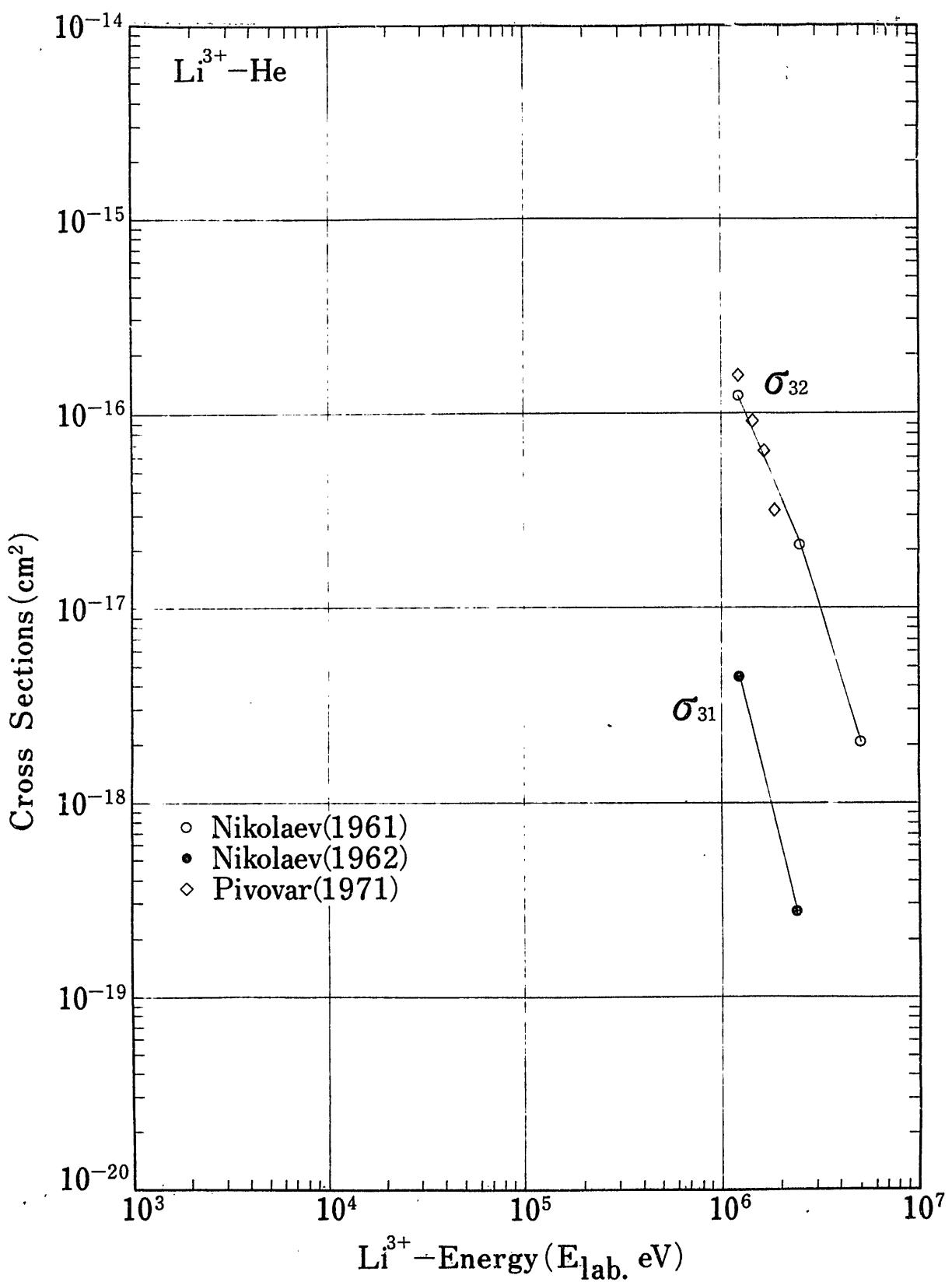


Fig. 8 Charge Changing Cross Sections of Li^{3+} in He

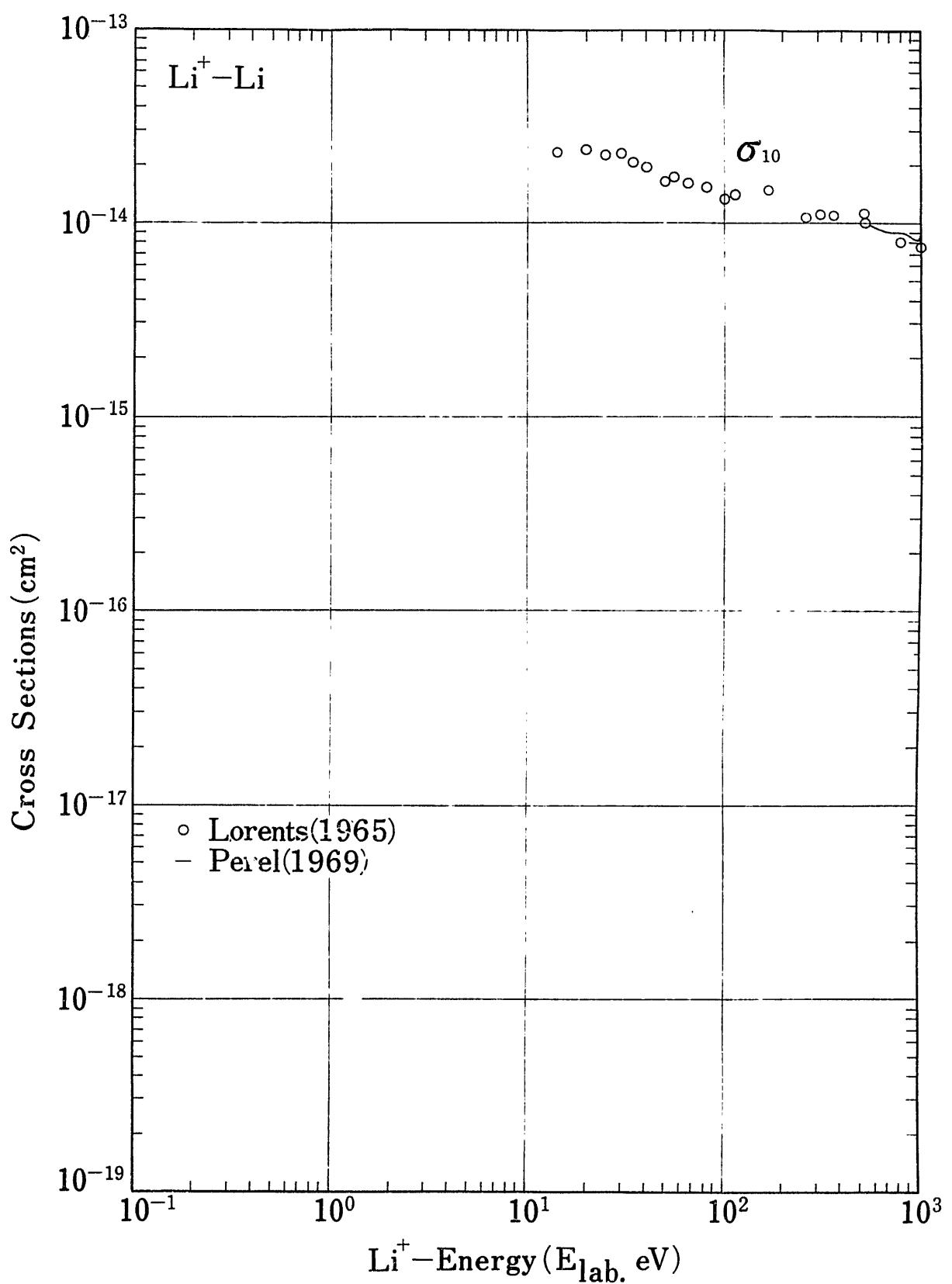


Fig. 9-a Charge Changing Cross Sections of Li^+ in Li

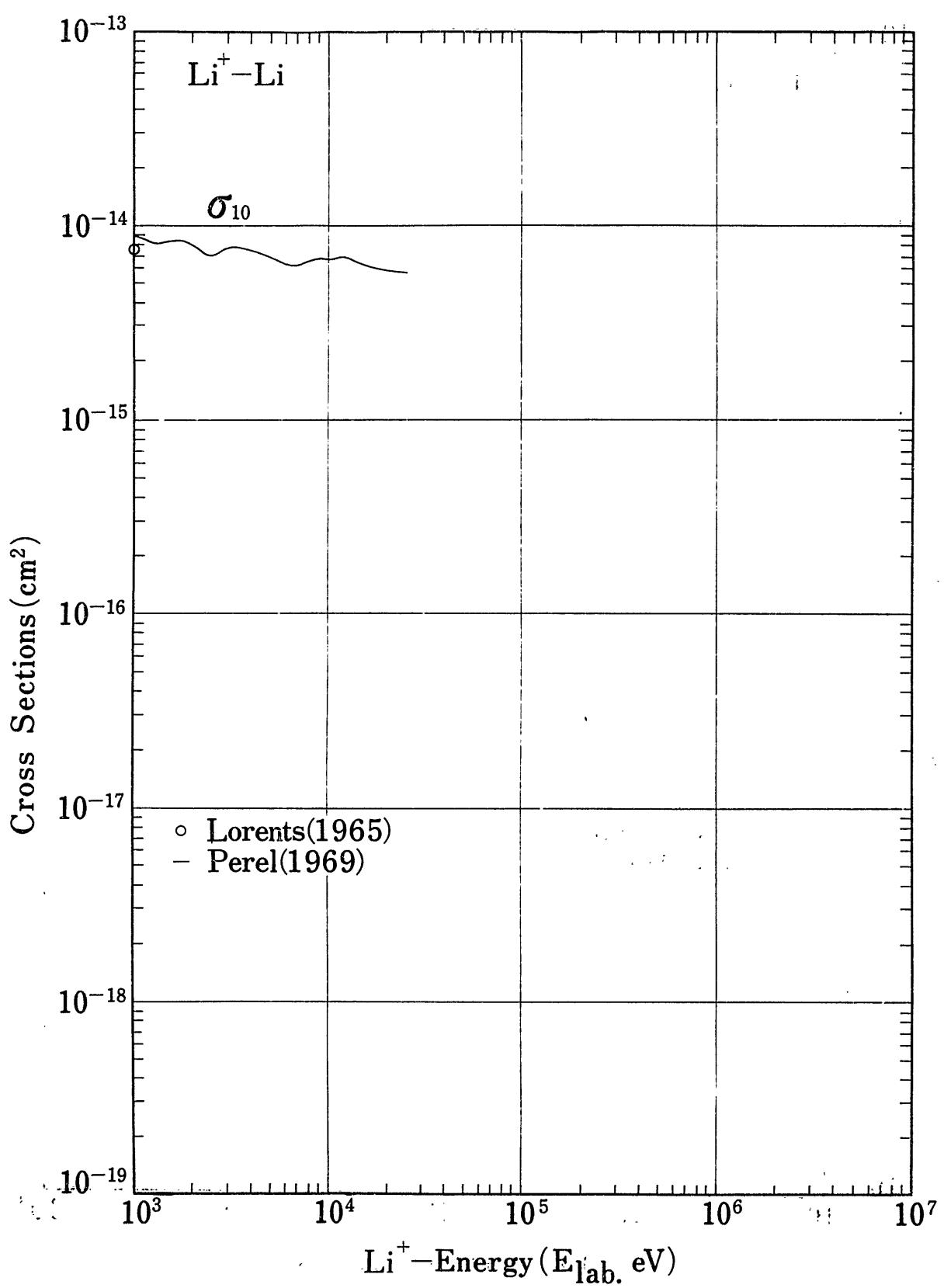


Fig. 9-b Charge Changing Cross Sections of Li^+ in Li

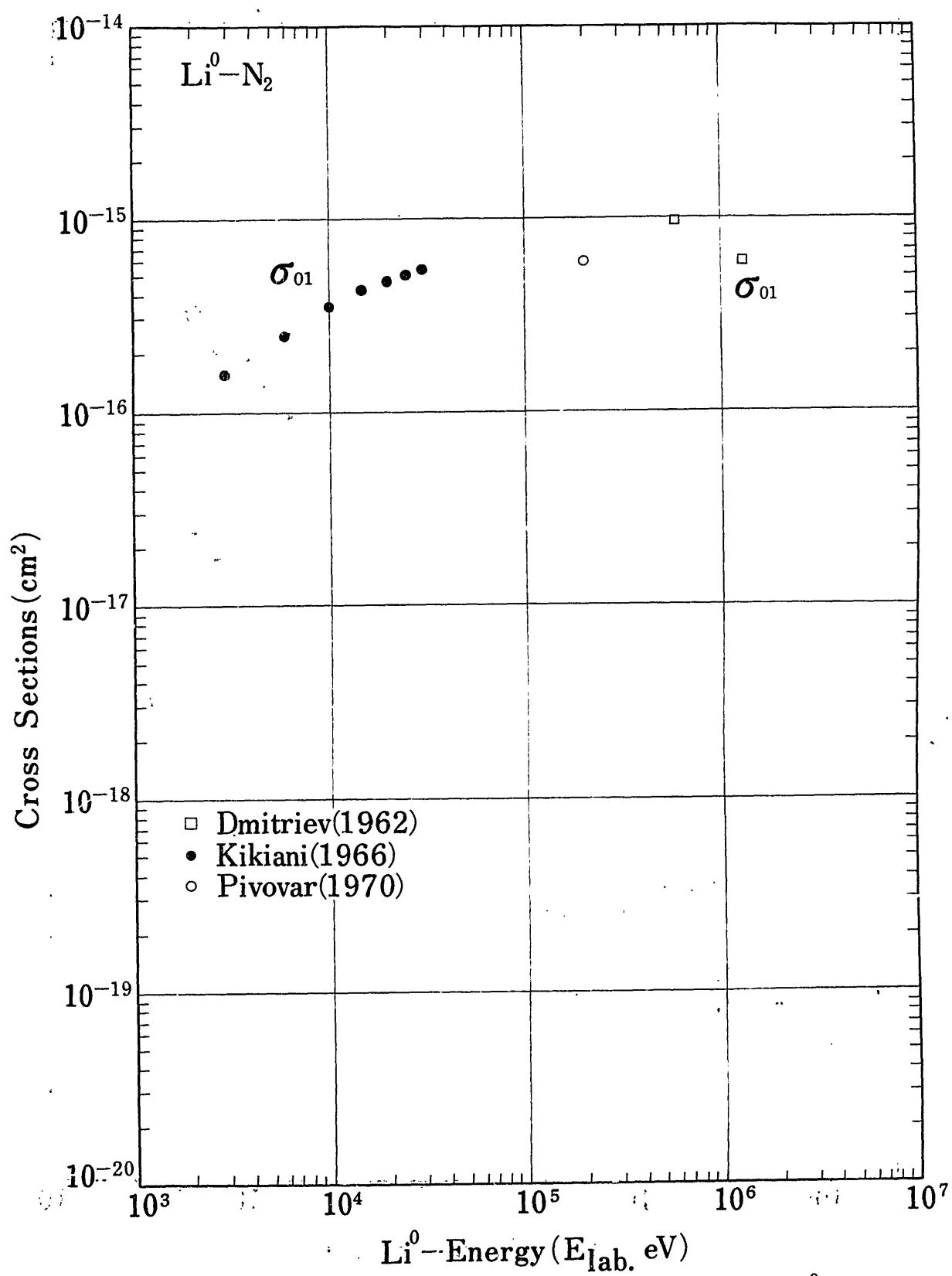


Fig.10 Charge Changing Cross Sections of Li^0 in N_2

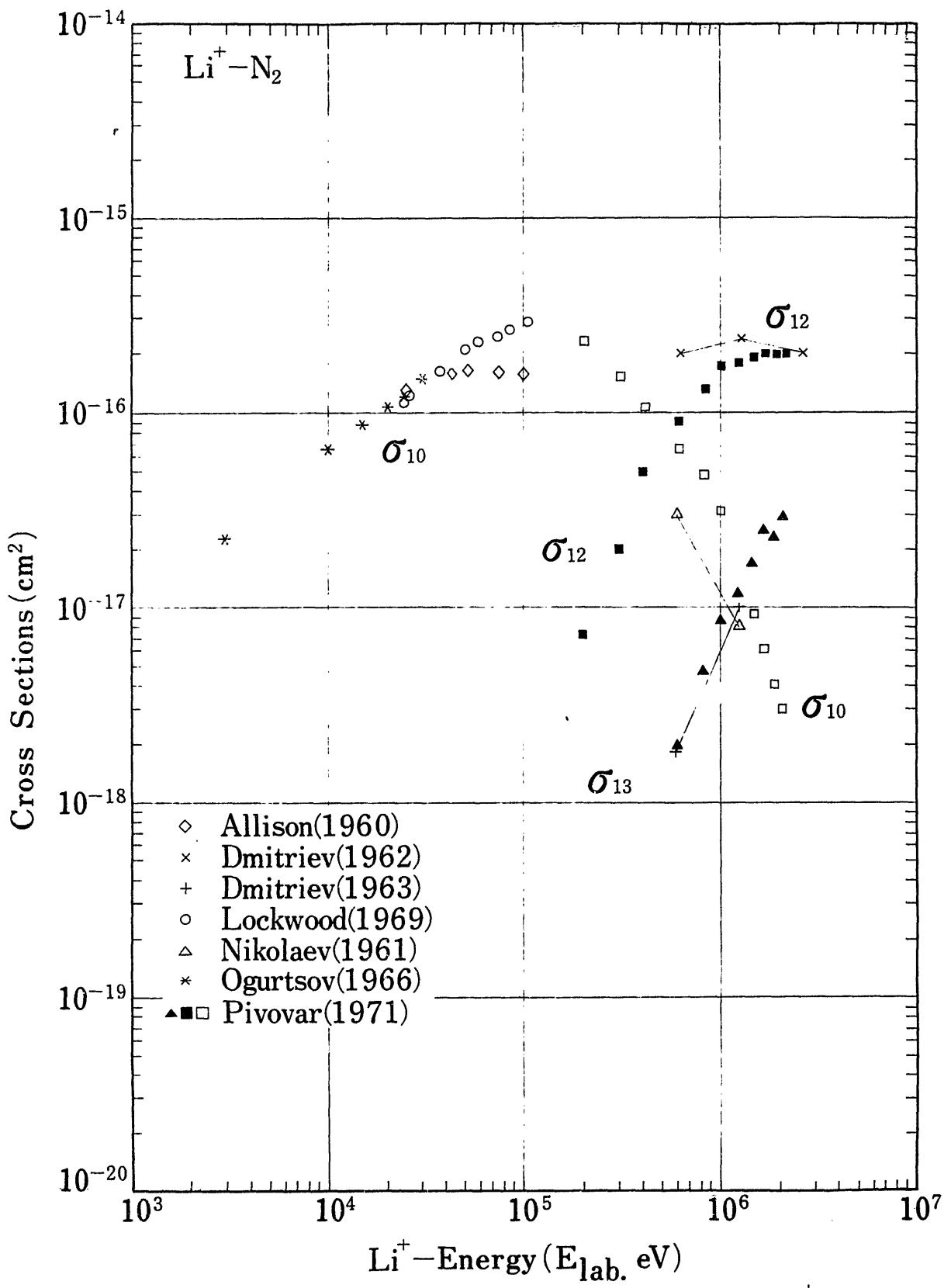


Fig. 11 Charge Changing Cross Sections of Li^+ in N_2 .

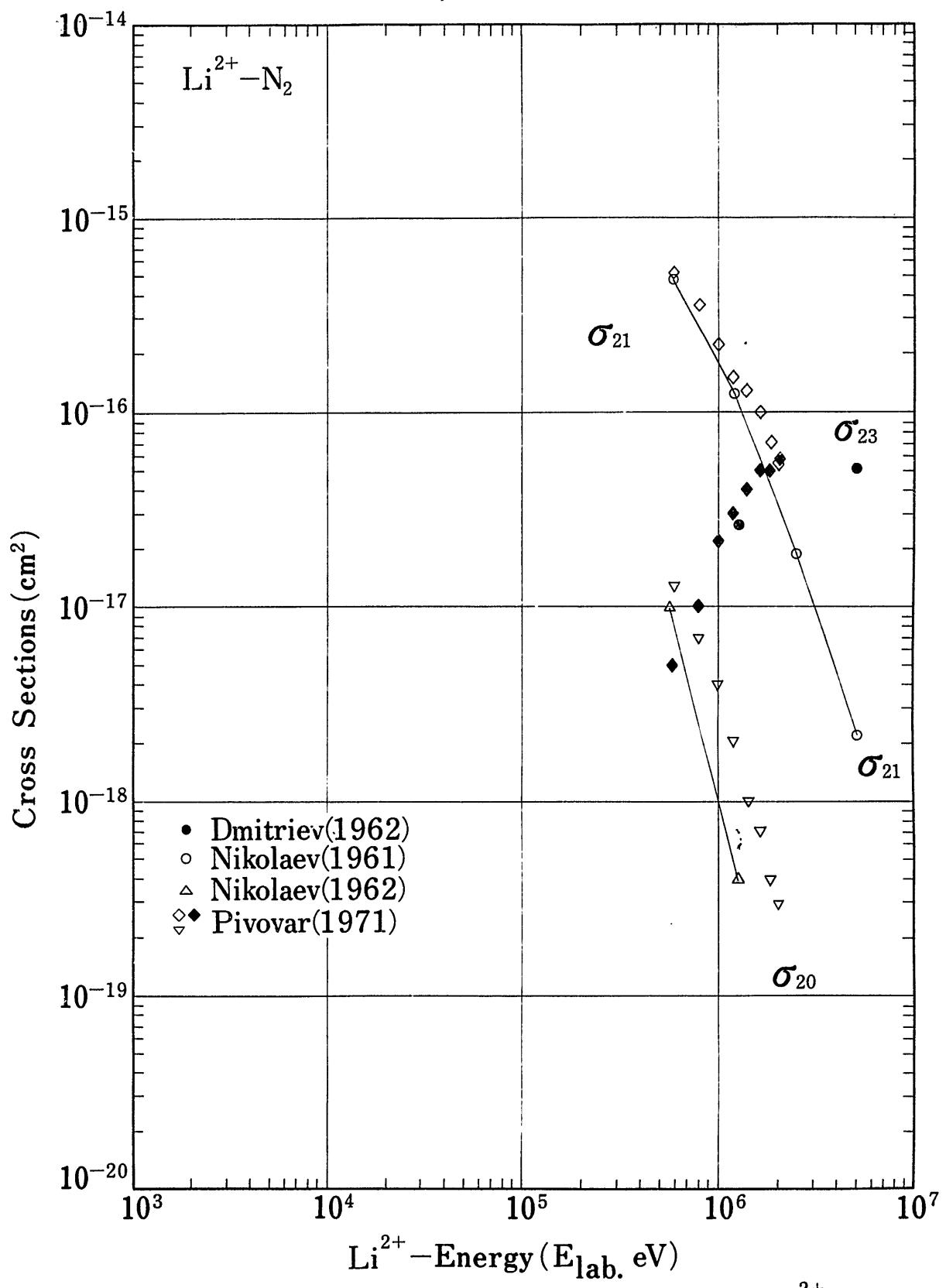


Fig.12 Charge Changing Cross Sections of Li^{2+} in N_2

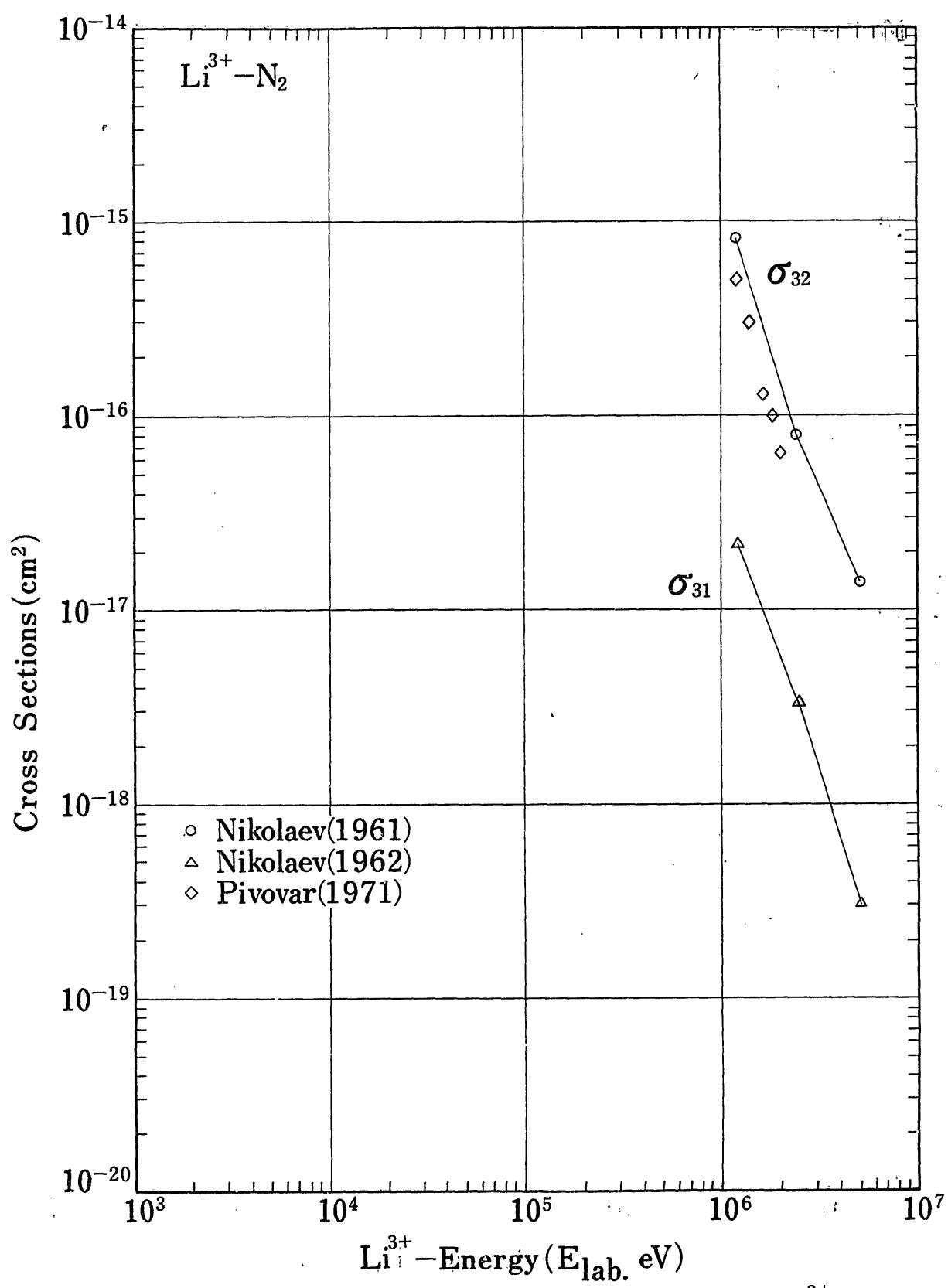


Fig. 13 Charge Changing Cross Sections of Li^{3+} in N_2

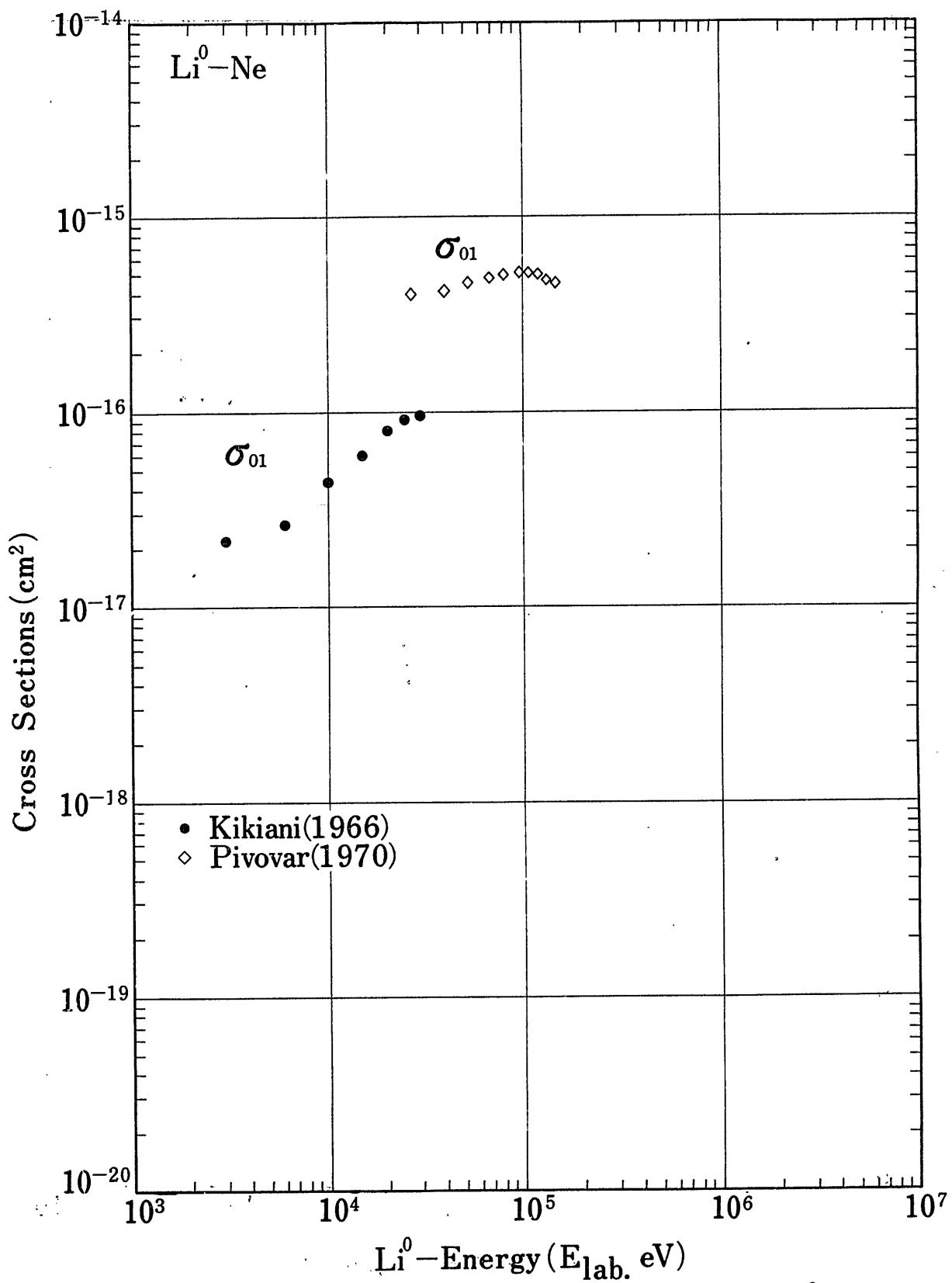


Fig.14: Charge Changing Cross Sections of Li^0 in Ne

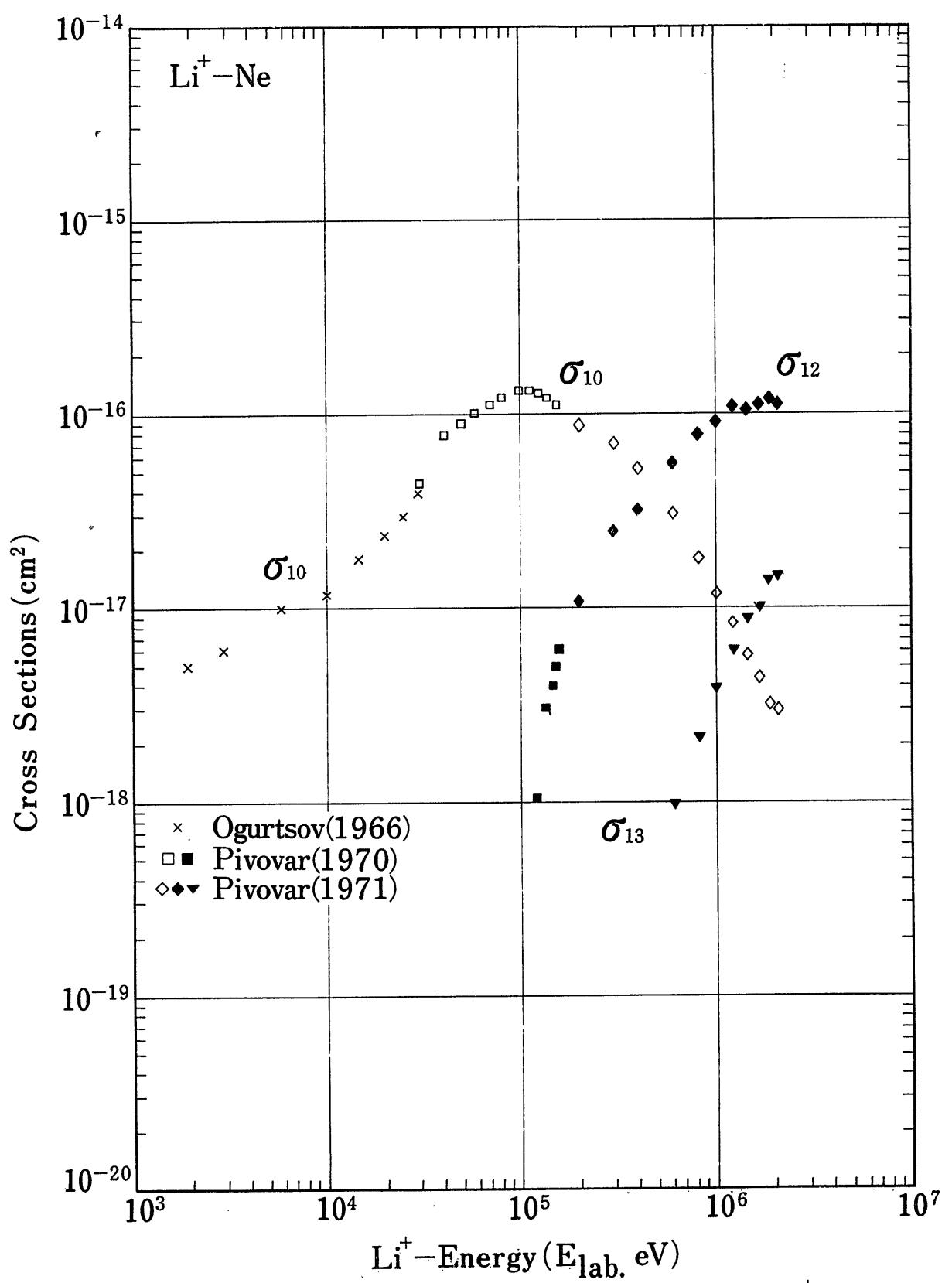


Fig.15 Charge Changing Cross Sections of Li^+ in Ne

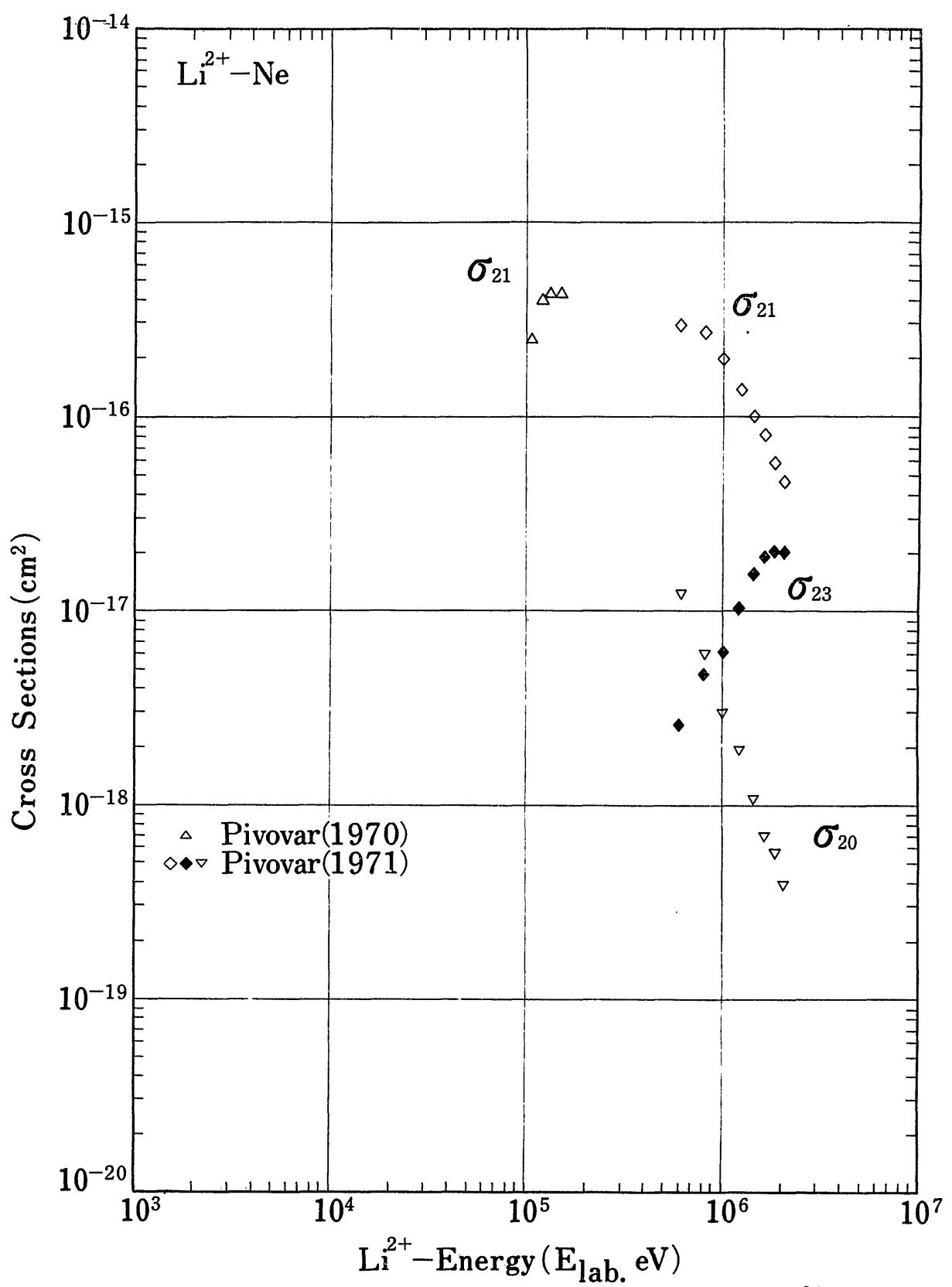


Fig.16 Charge Changing Cross Sections of Li^{2+} in Ne

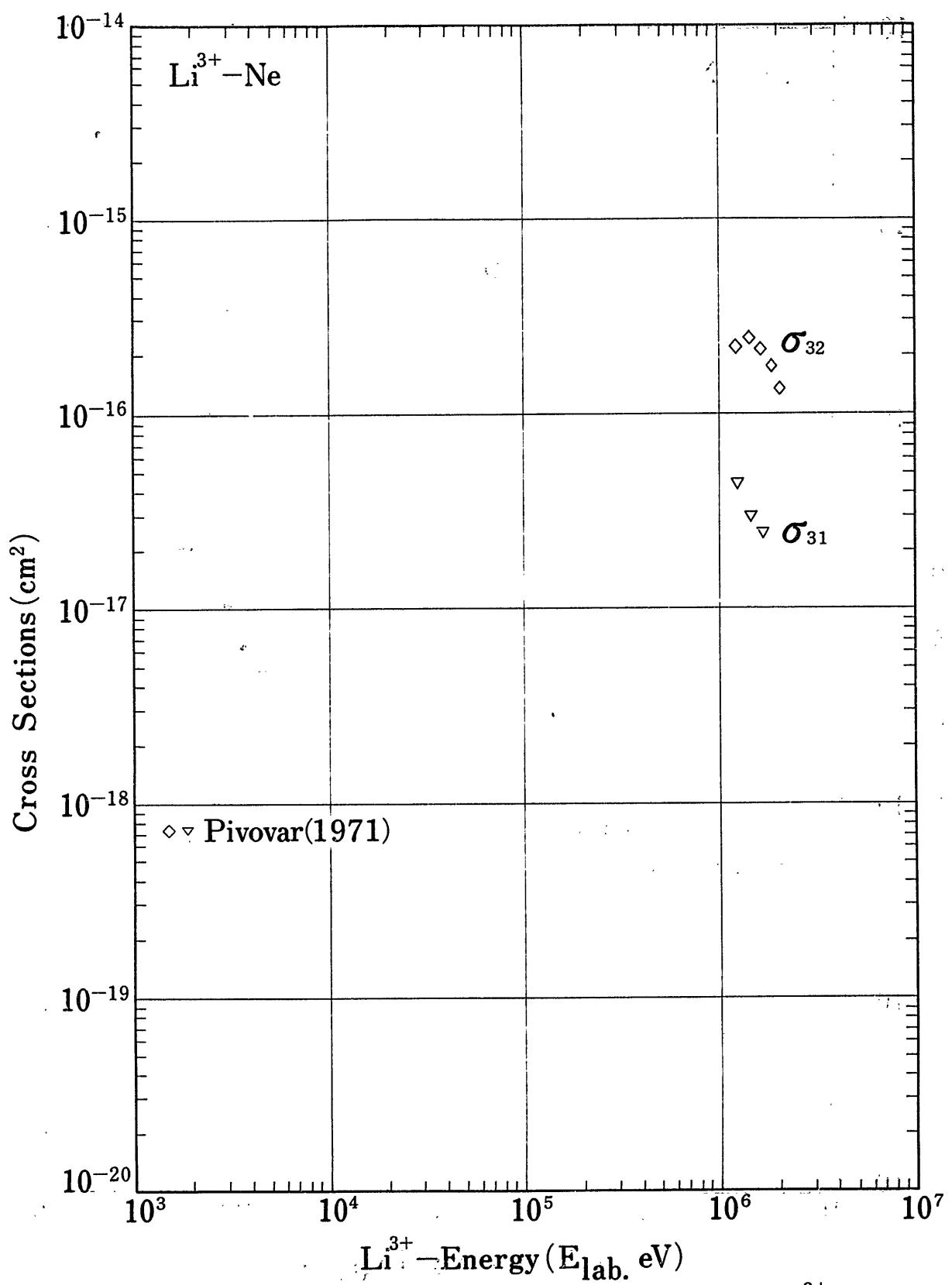


Fig.17 Charge Changing Cross Sections of Li^{3+} in Ne

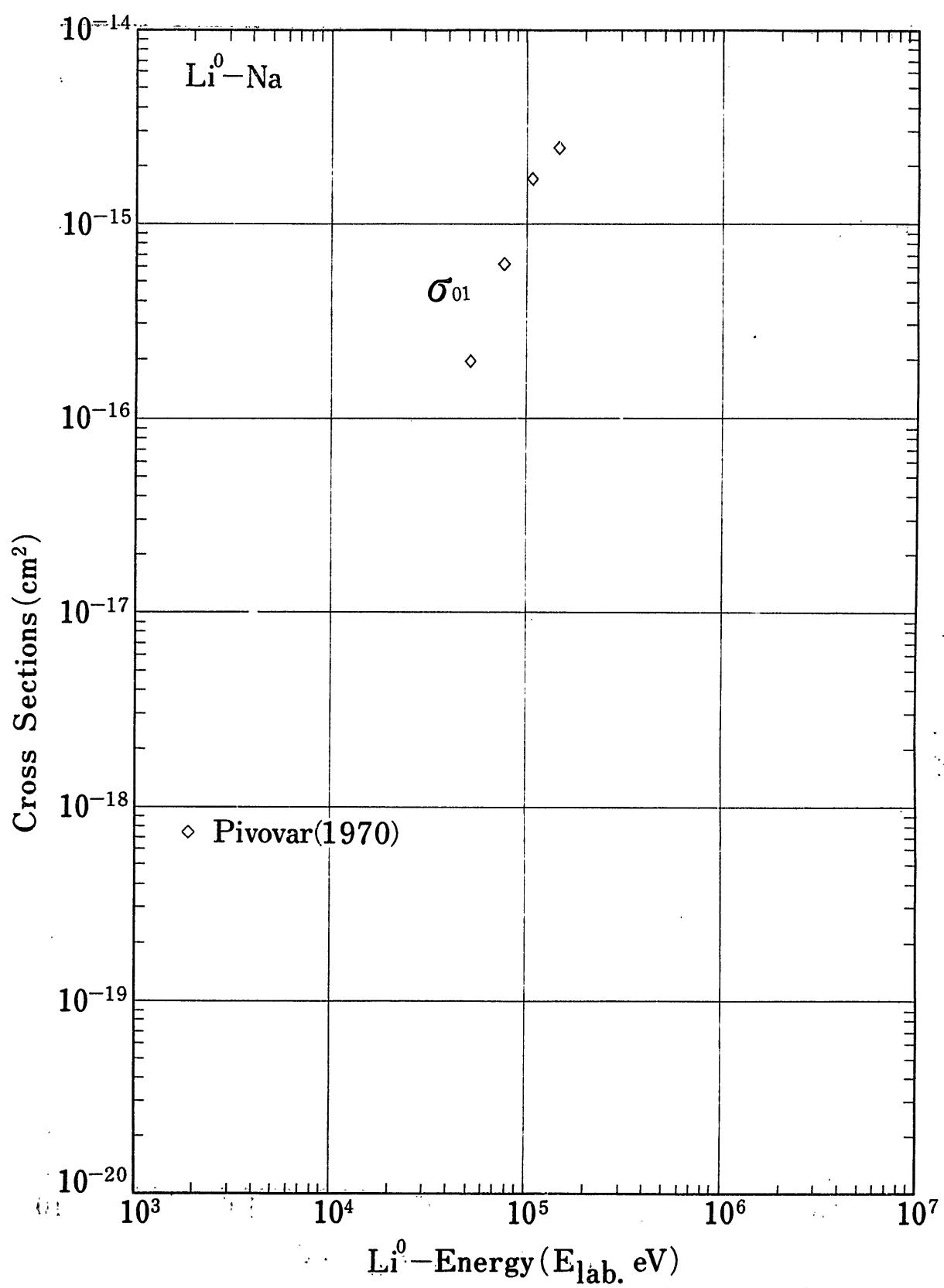


Fig.18 Charge Changing Cross Sections of Li^0 in Na

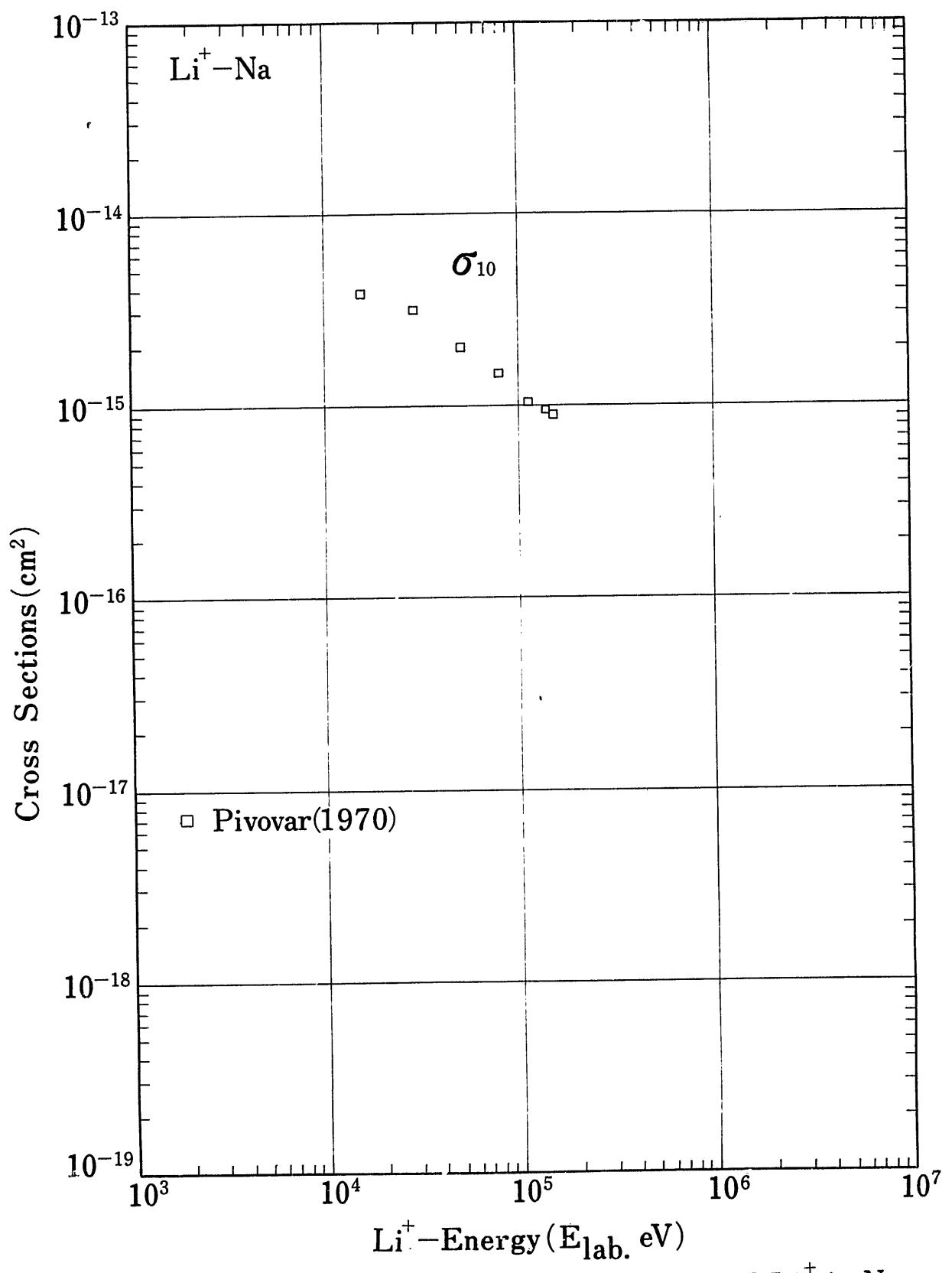


Fig. 19 Charge Changing Cross Sections of Li^+ in Na

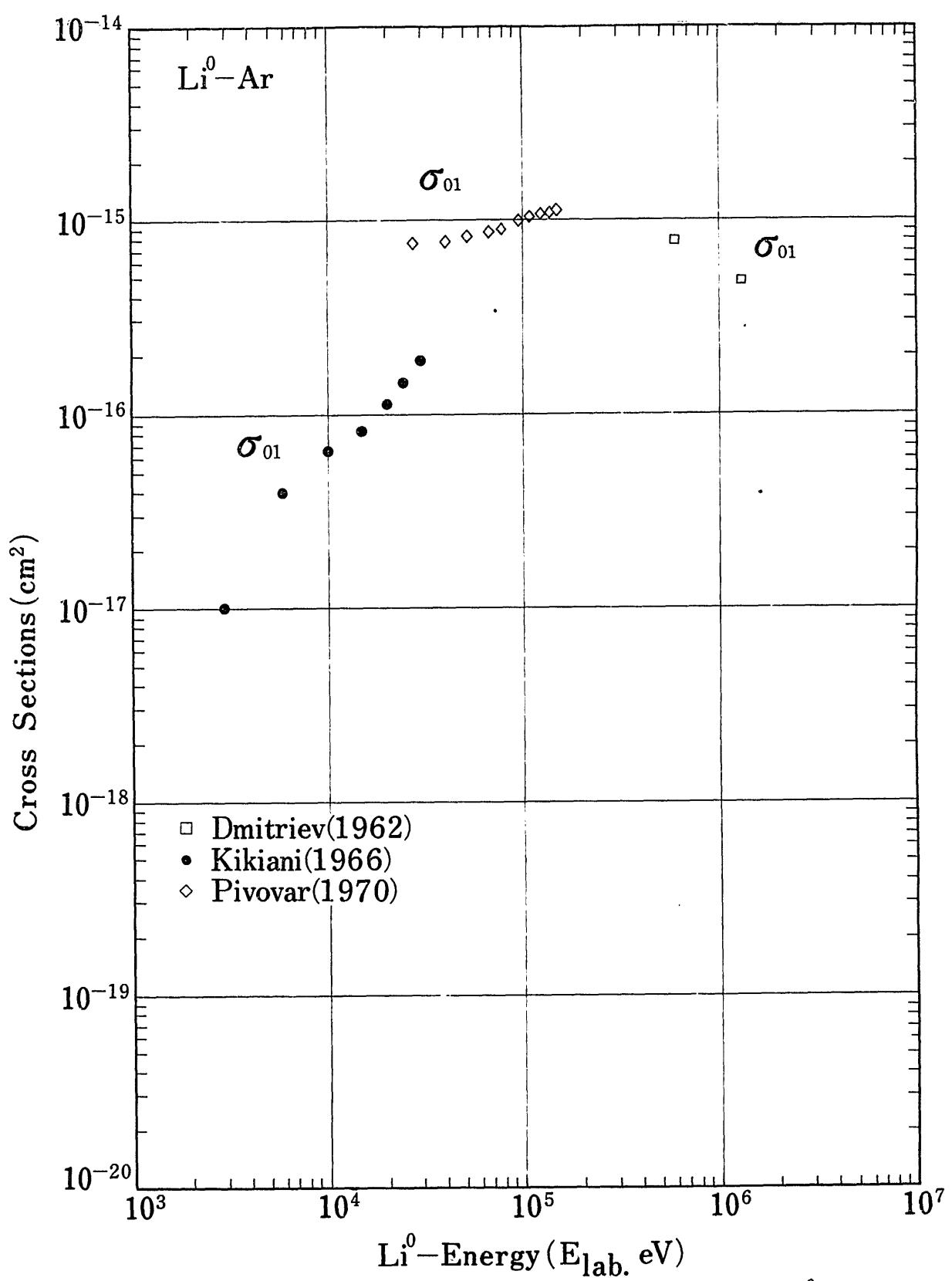


Fig.20 Charge Changing Cross Sections of Li^0 in Ar

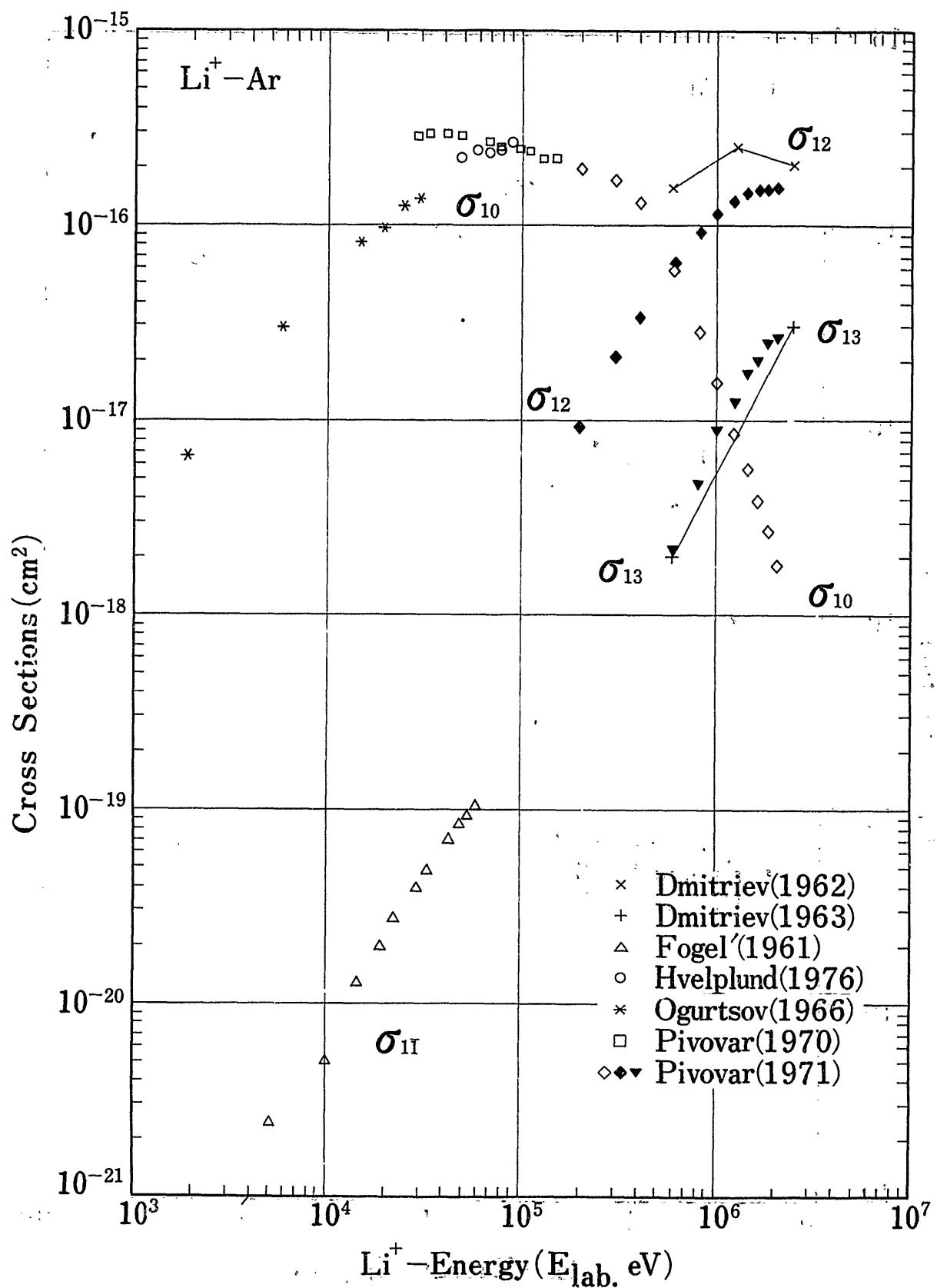


Fig. 21. Charge Changing Cross Sections of Li^+ in Ar

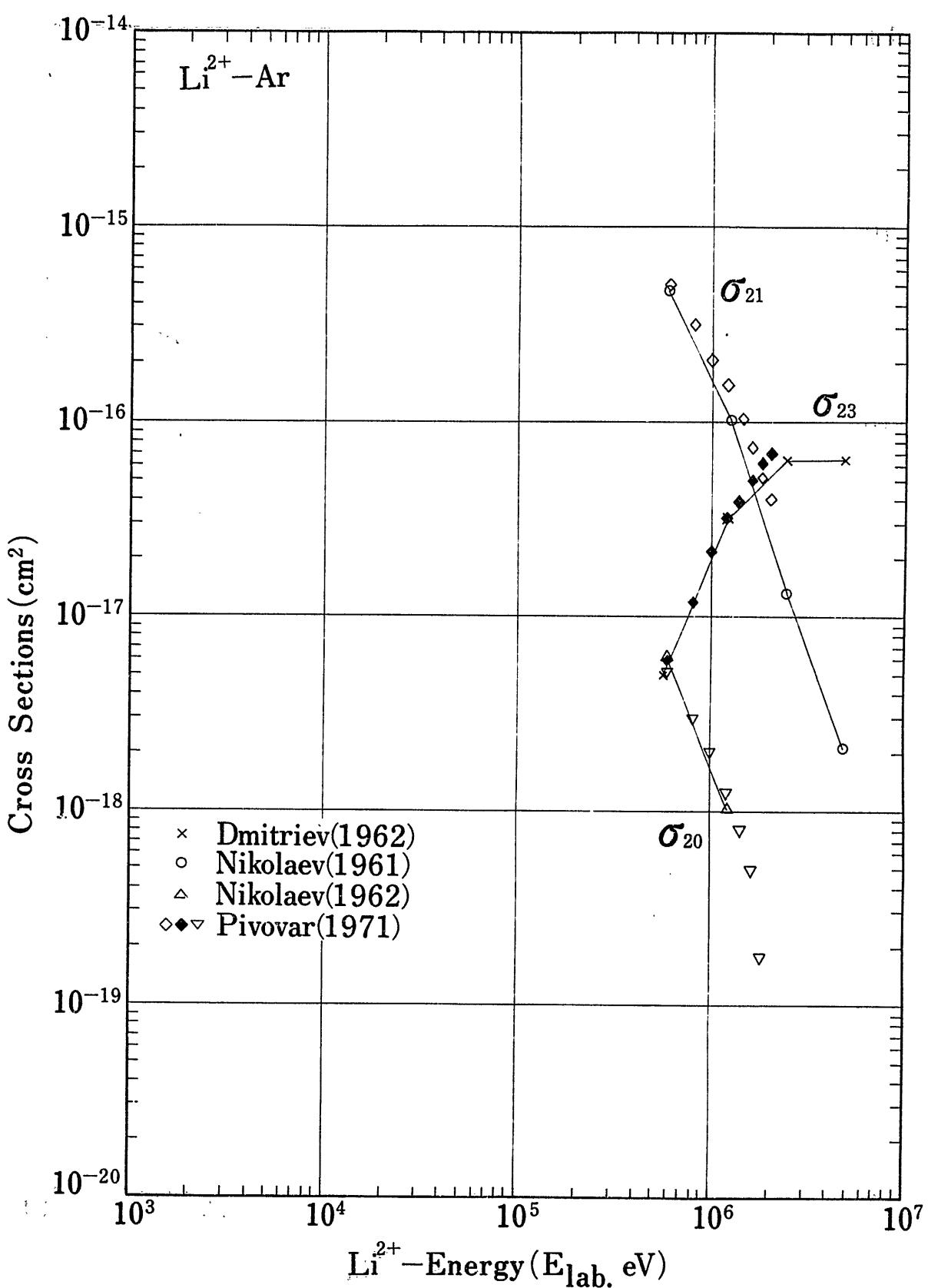


Fig.22 Charge Changing Cross Sections of Li^{2+} in Ar

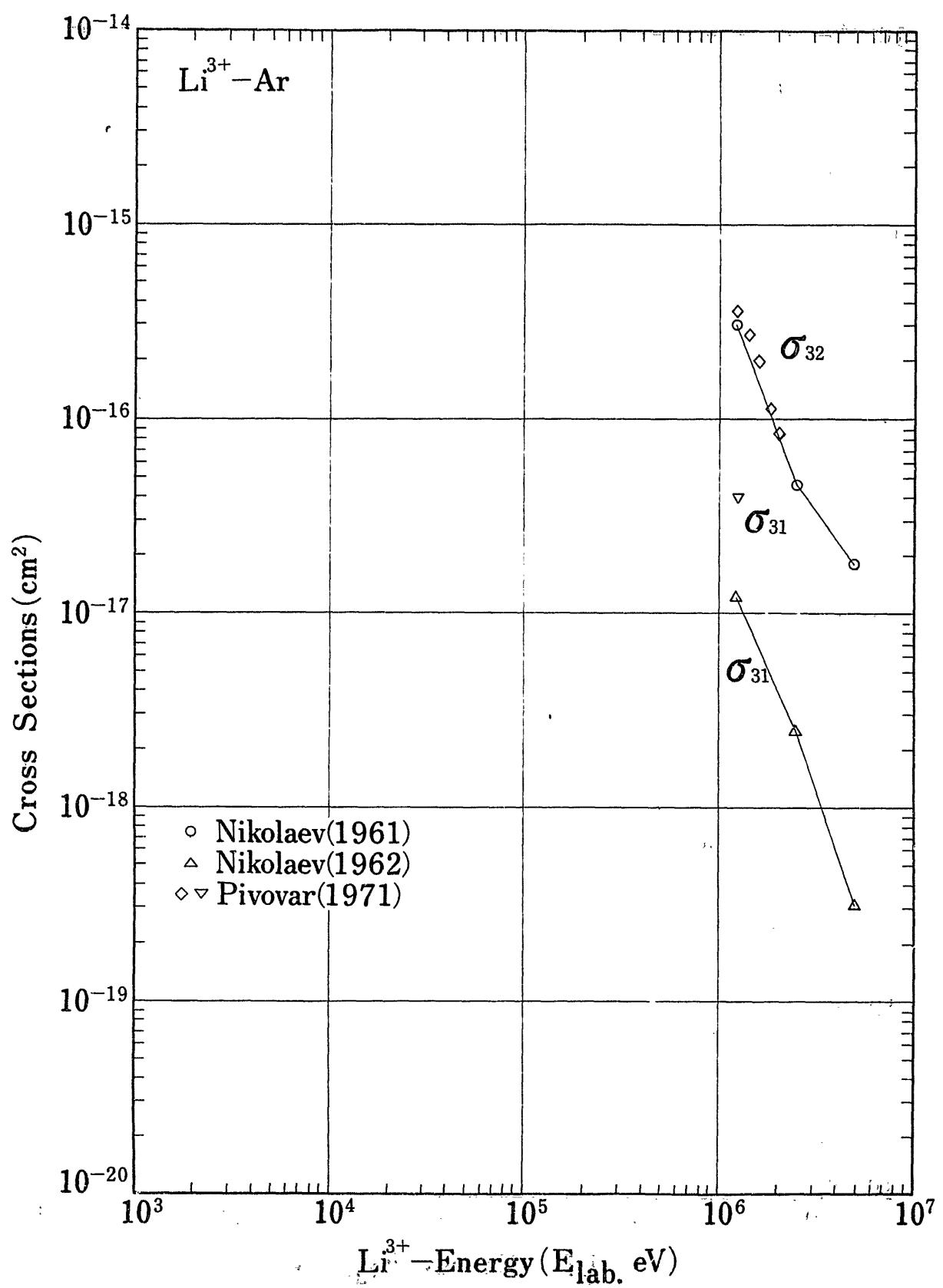


Fig.23 Charge-Changing Cross Sections of Li^{3+} in Ar

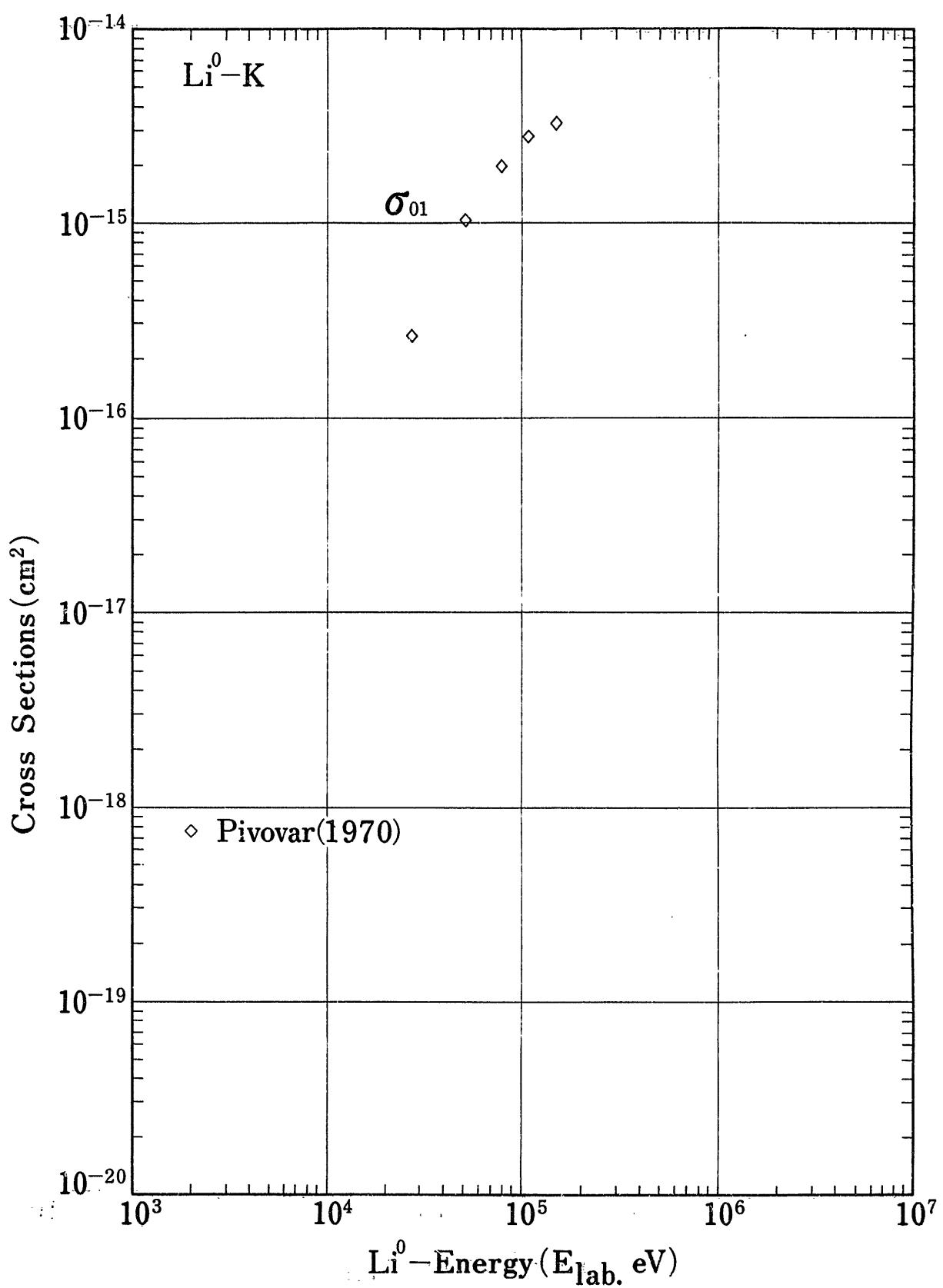


Fig.24 Charge Changing Cross Sections of Li^0 in K

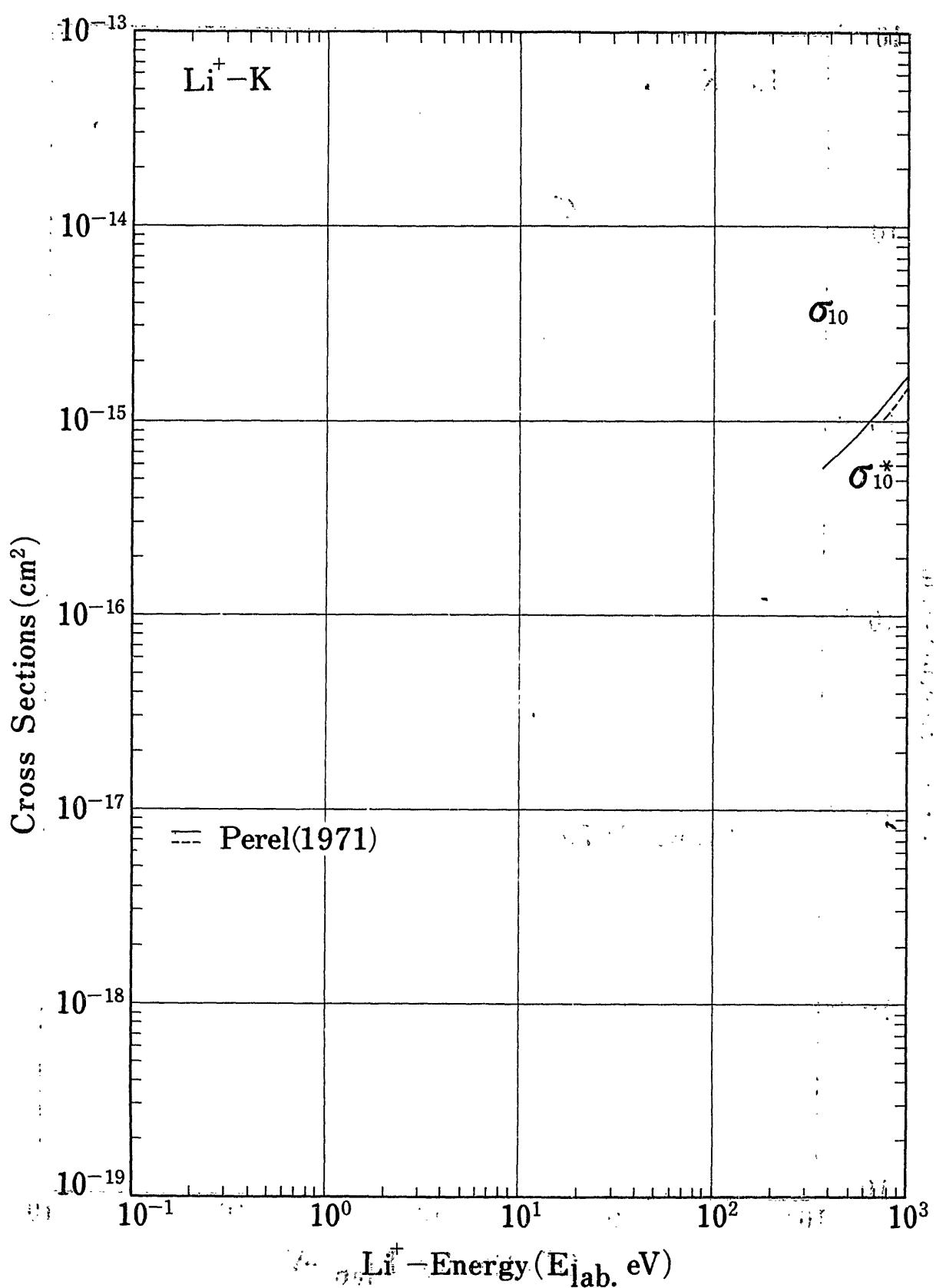


Fig. 25-a Charge-Changing Cross Sections of Li⁺ in K

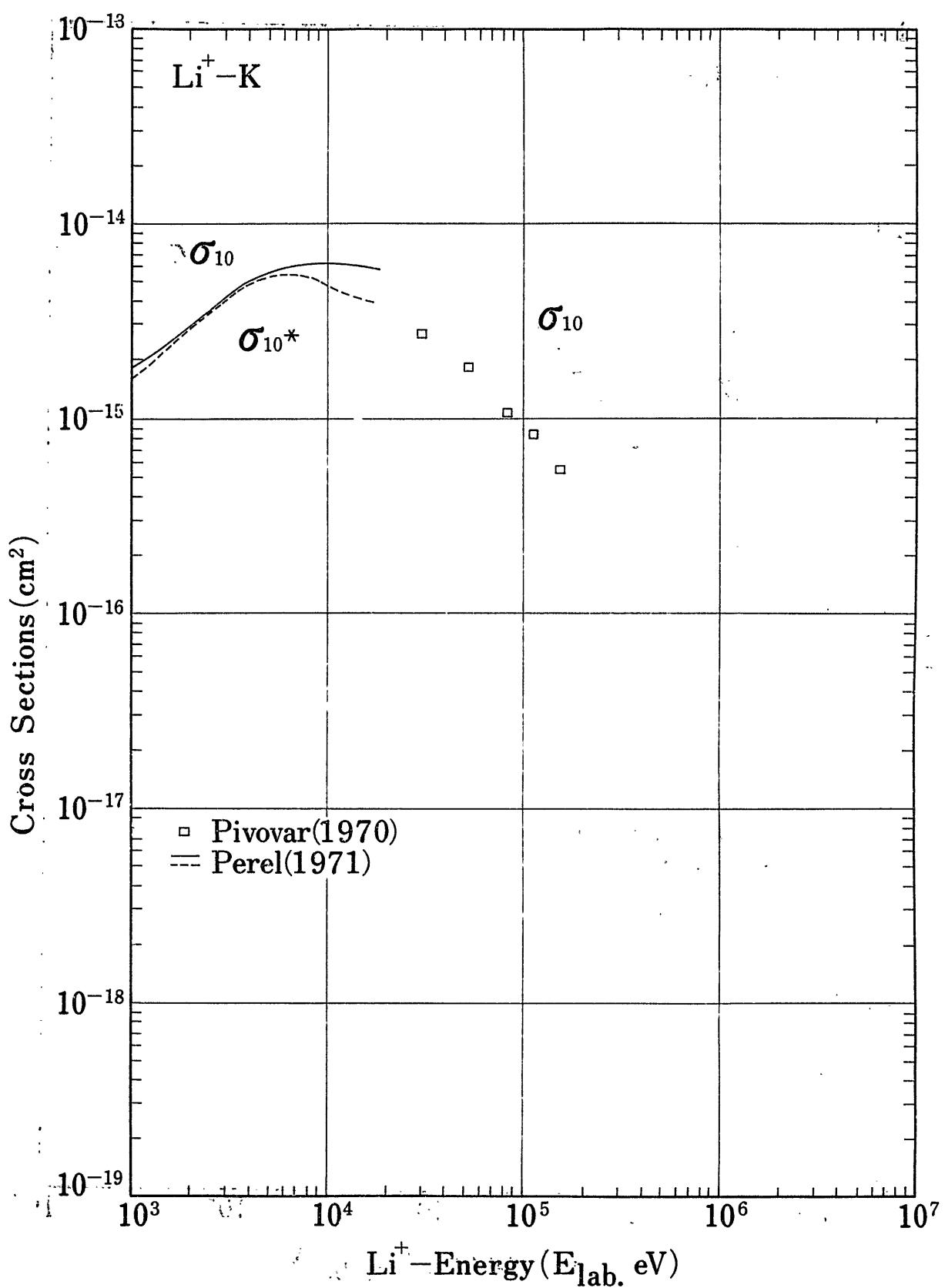


Fig. 25-b Charge Changing Cross Sections of Li^+ in K

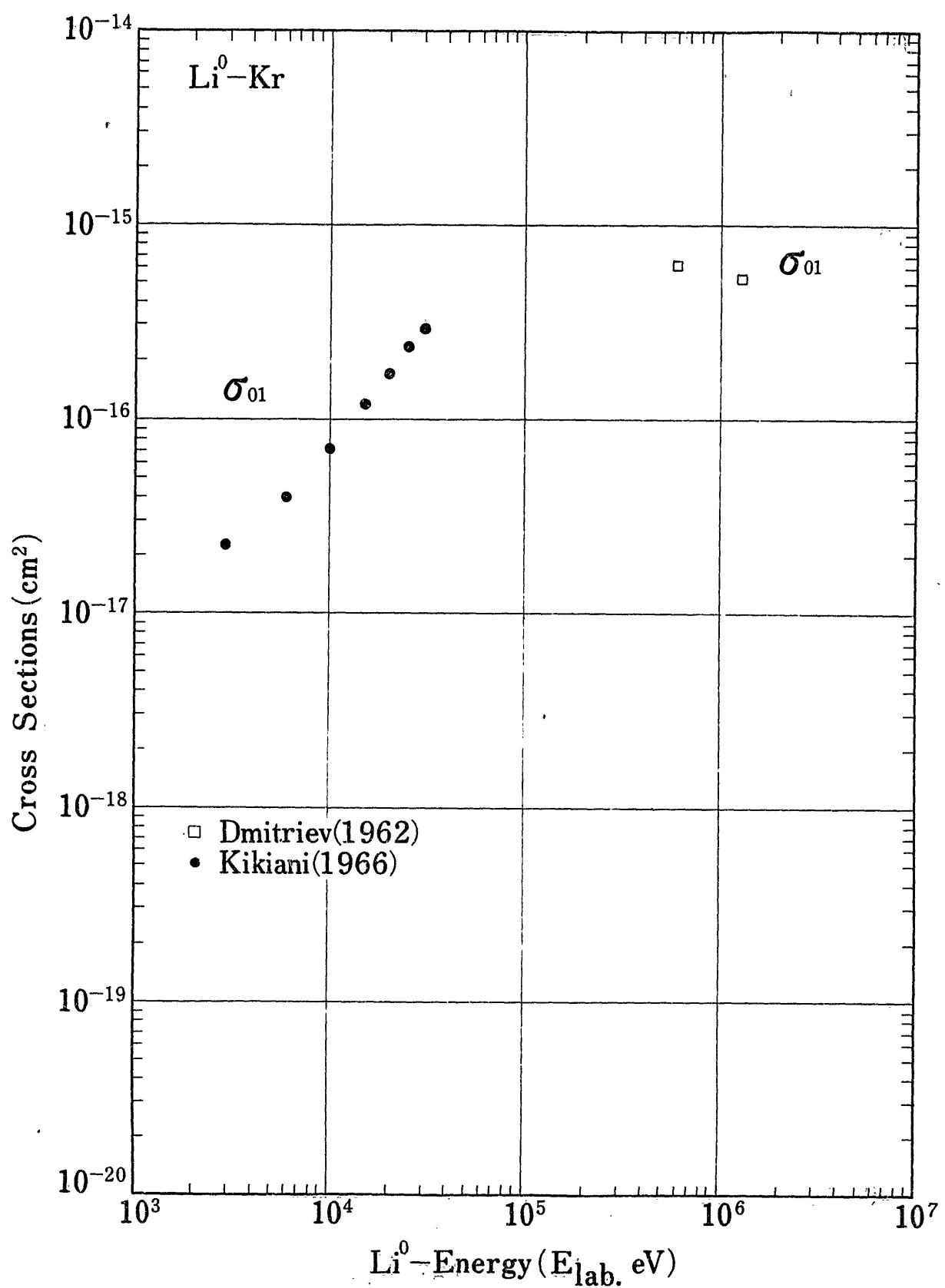


Fig.26 Charge-Changing Cross Sections of Li^0 in Kr

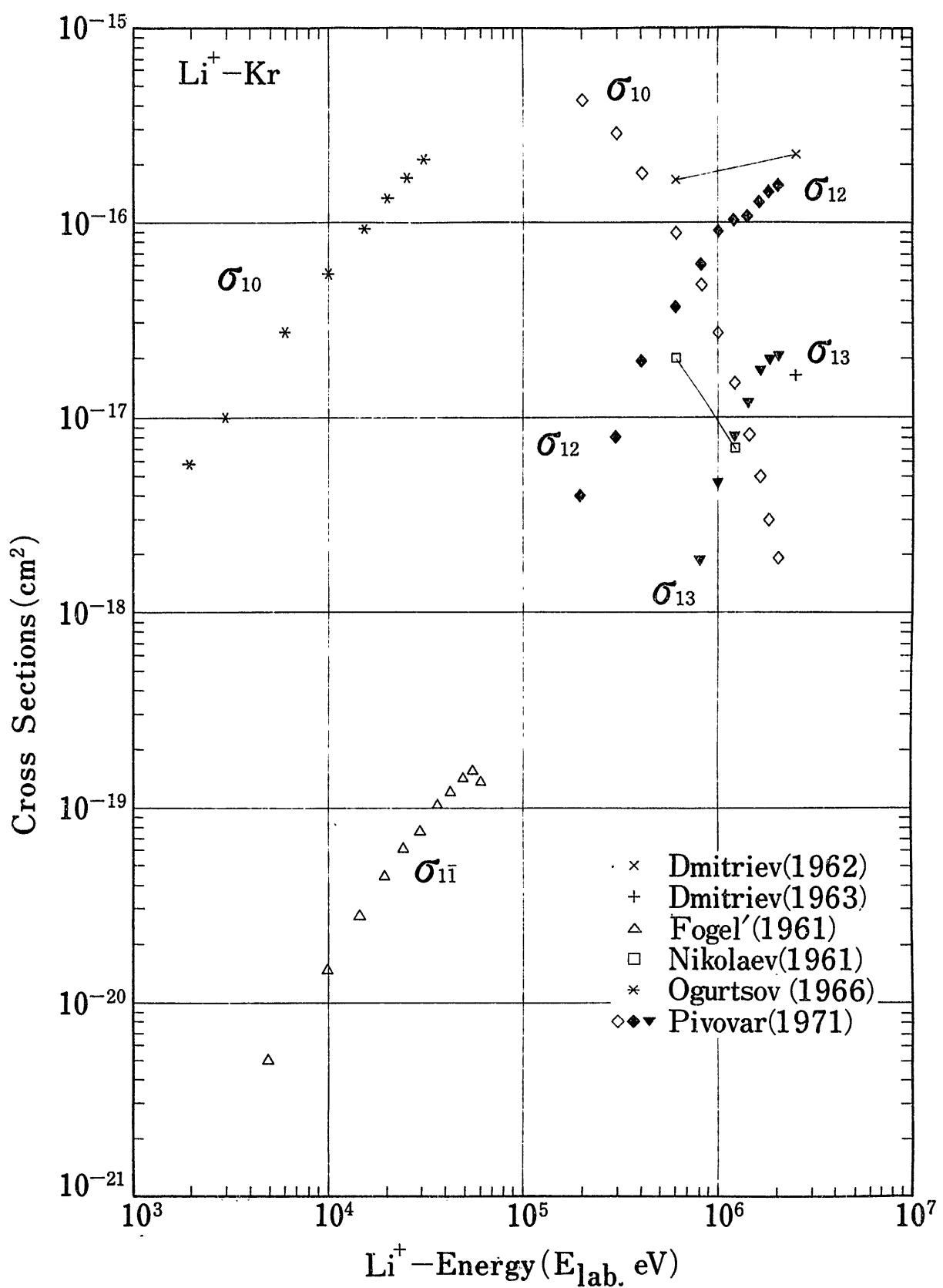


Fig. 27 Charge Changing Cross Sections of Li^+ in Kr

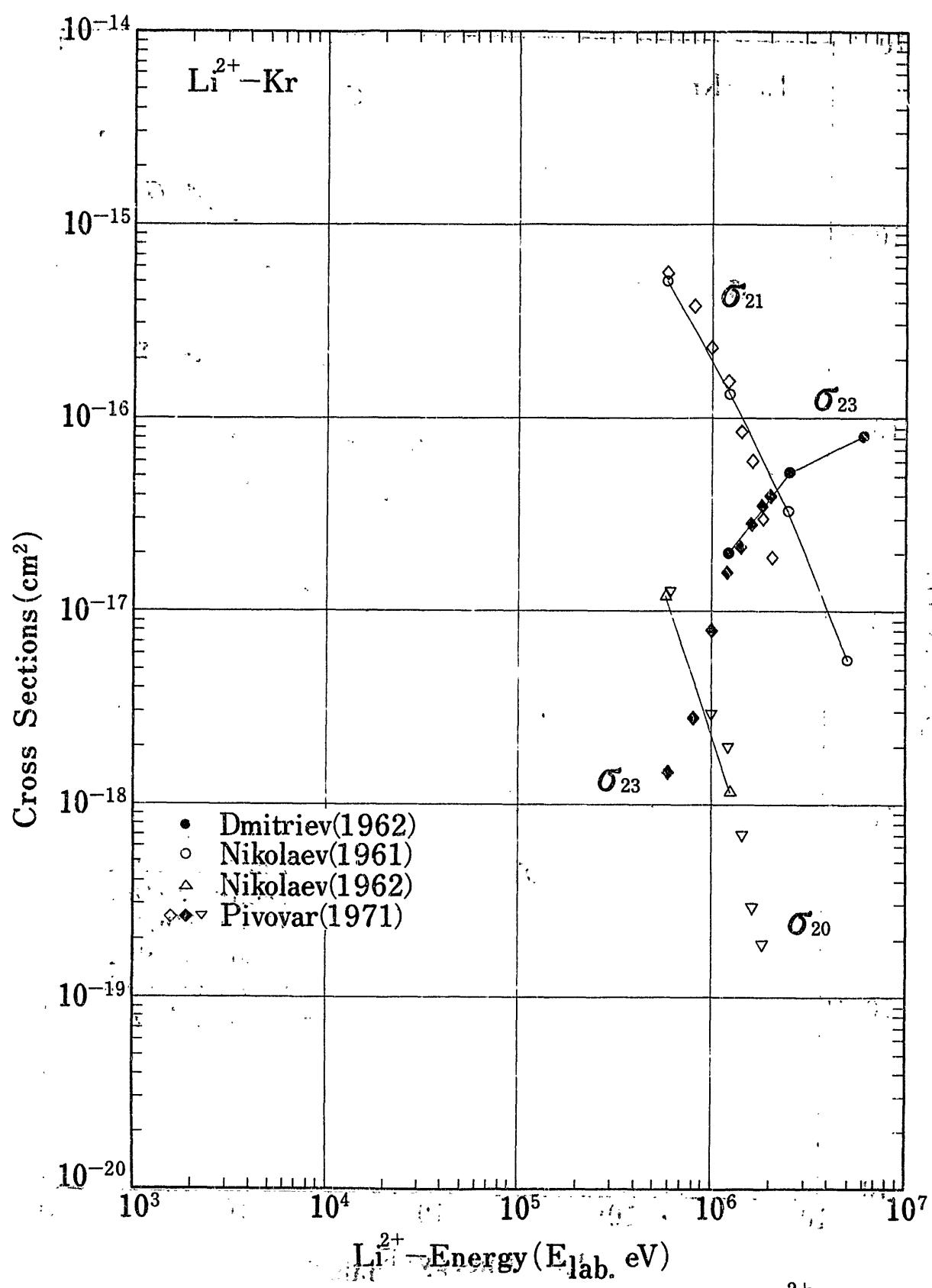


Fig. 28 Charge Changing Cross Sections of Li^{2+} in Kr

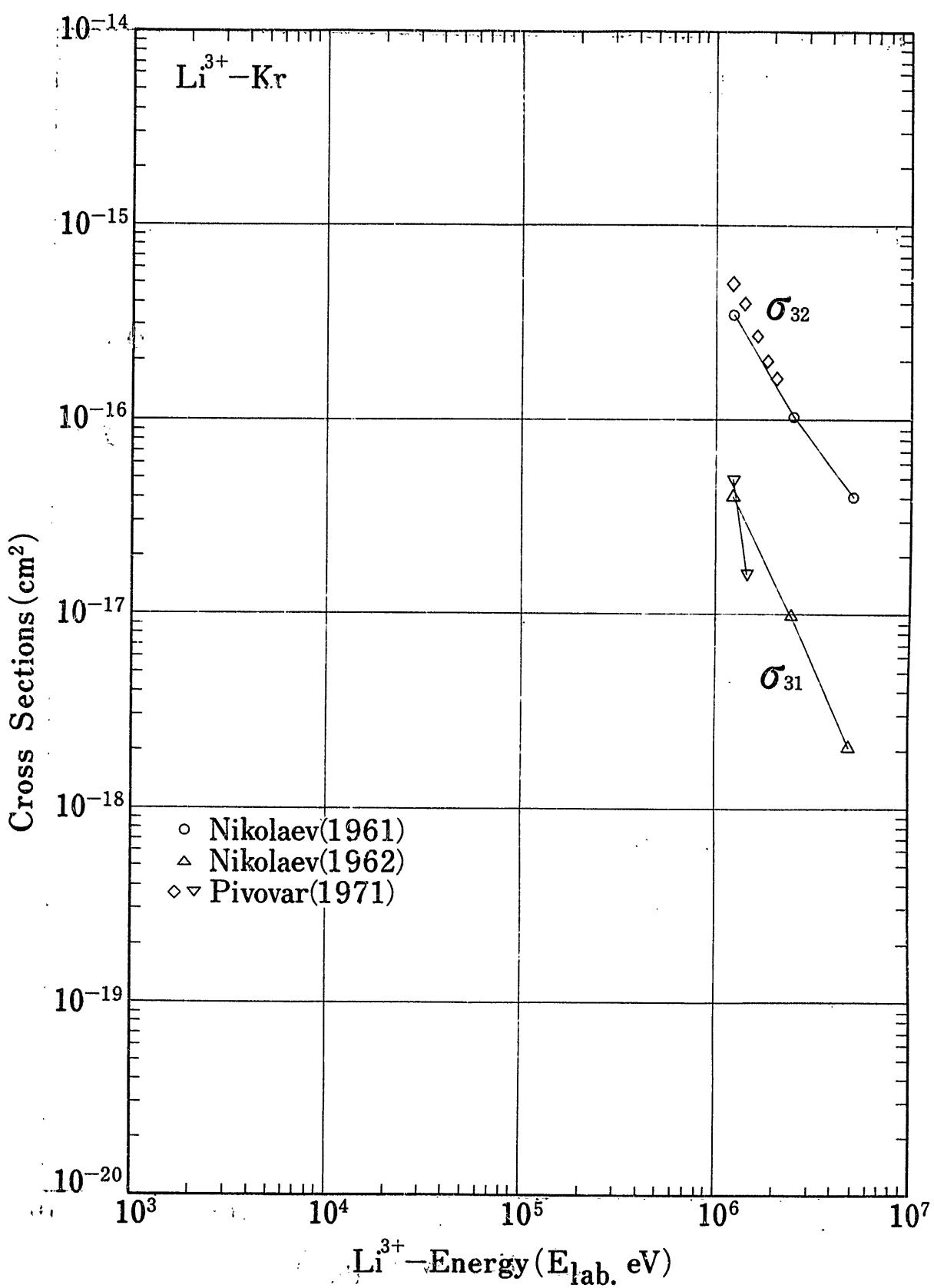


Fig. 29 Charge-Changing Cross Sections of Li^{3+} in Kr

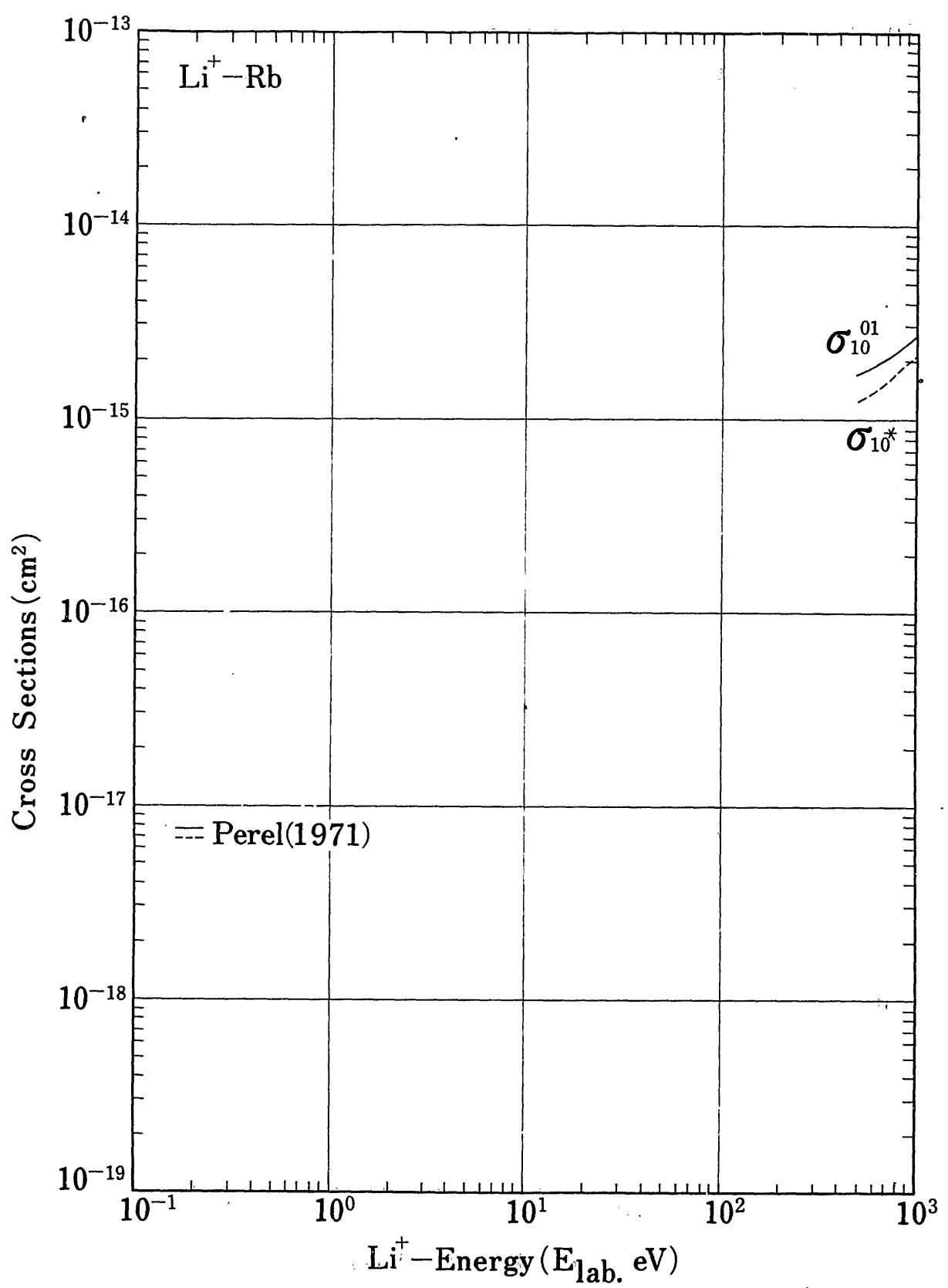


Fig.30-a Charge Changing Cross Sections of Li^+ in Rb

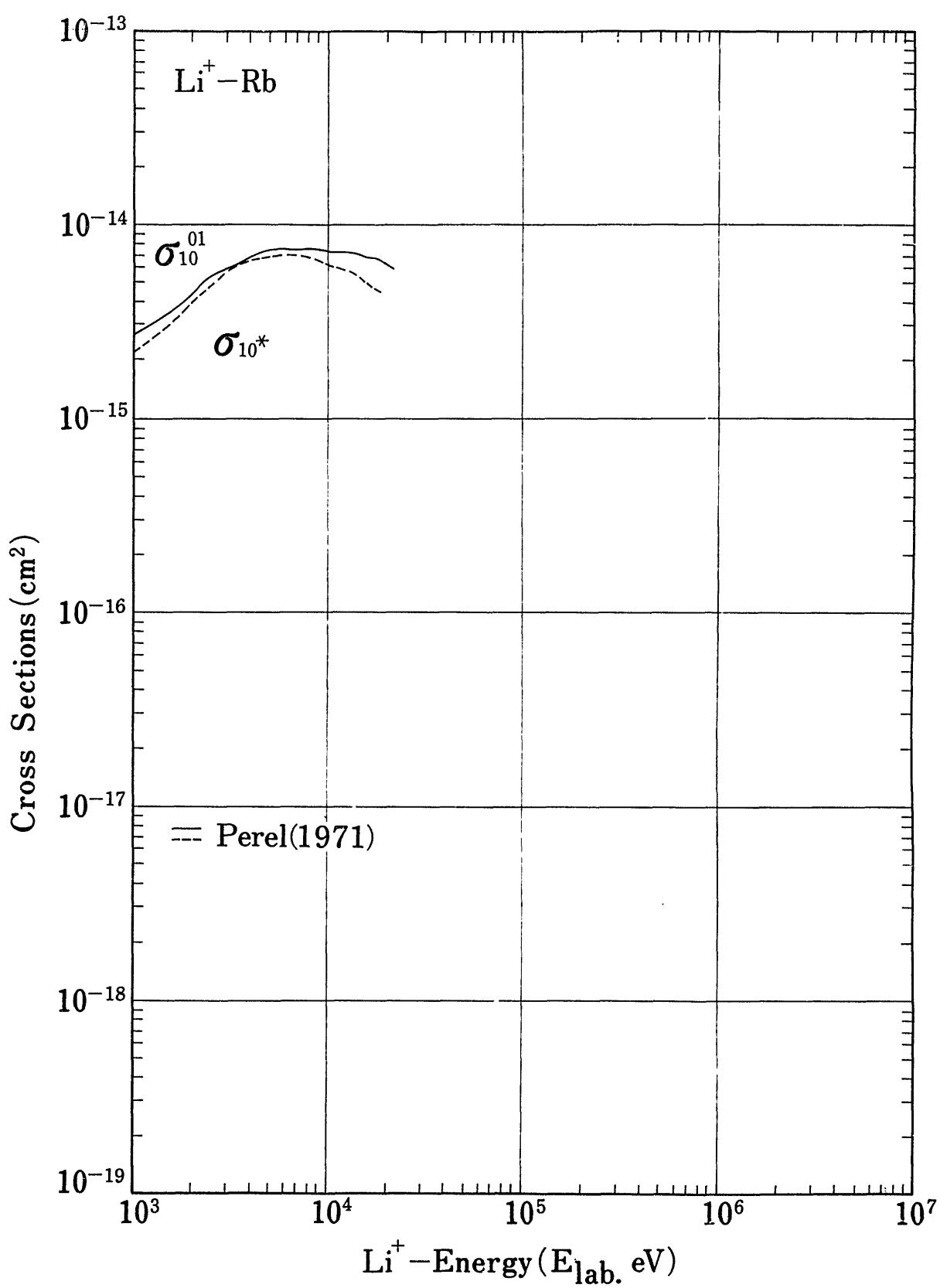


Fig.30-b Charge Changing Cross Sections of Li^+ in Rb

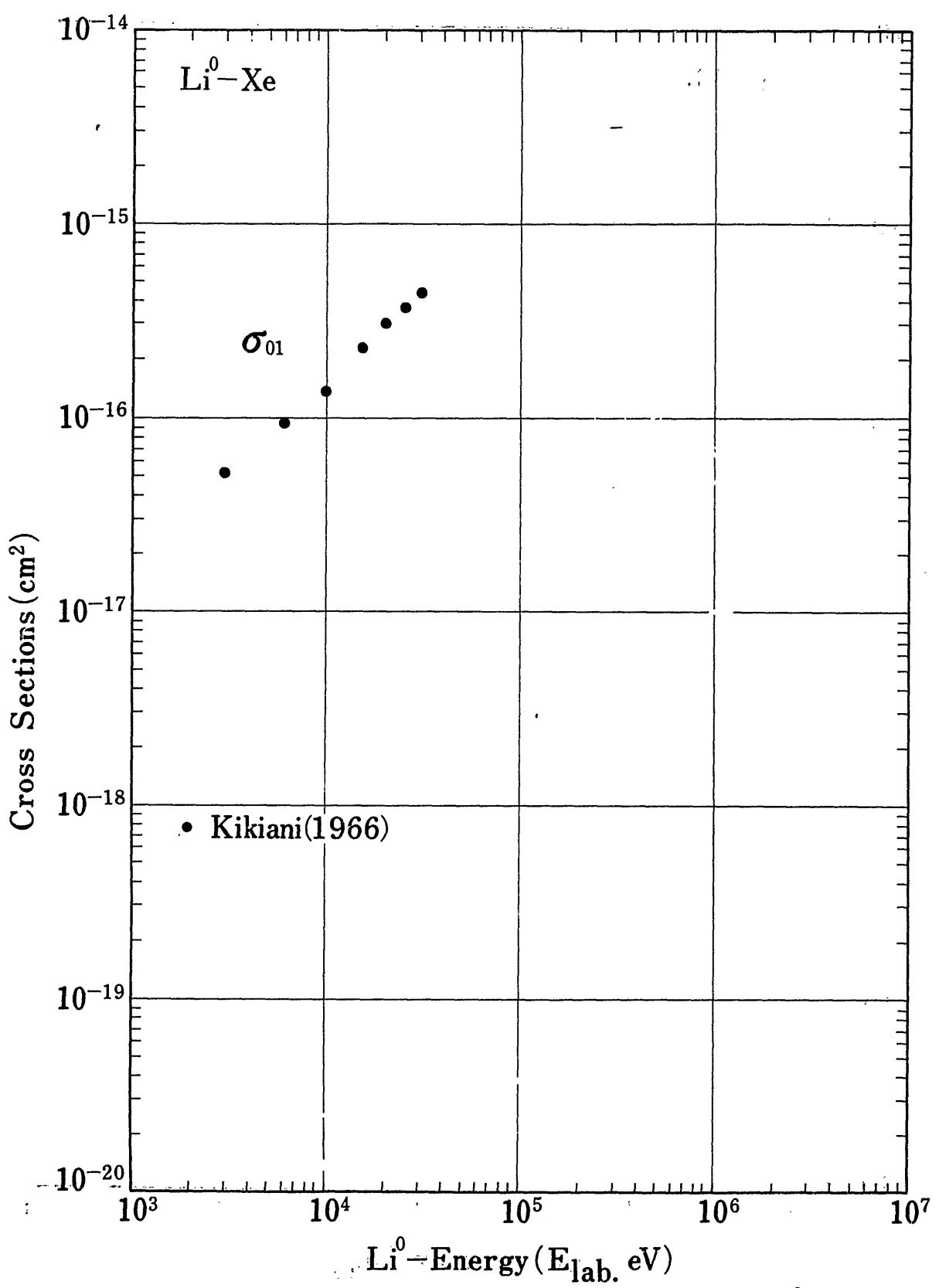


Fig.31 Charge Changing Cross Sections of Li^0 in Xe

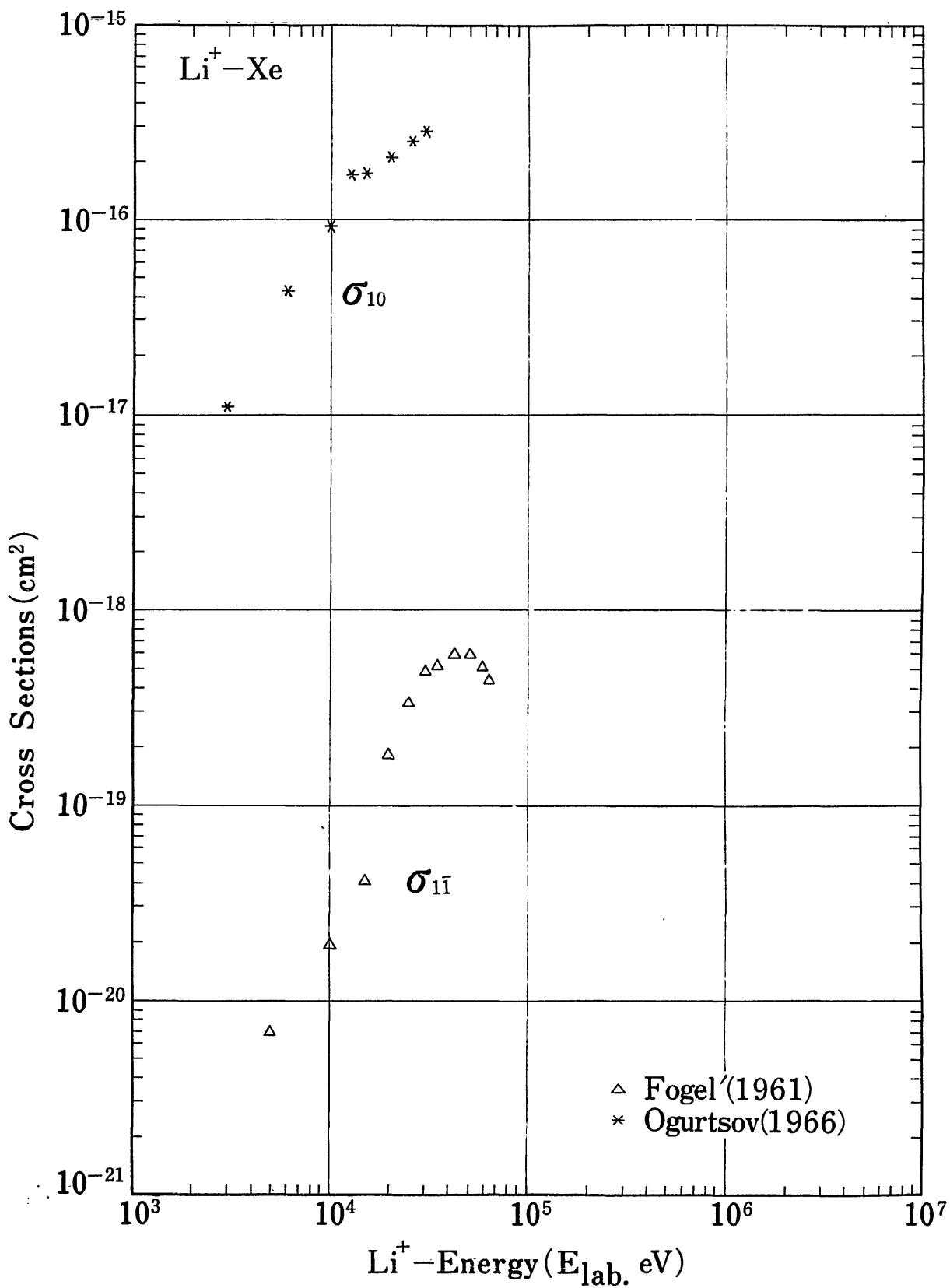


Fig.32 Charge Changing Cross Sections of Li^+ in Xe

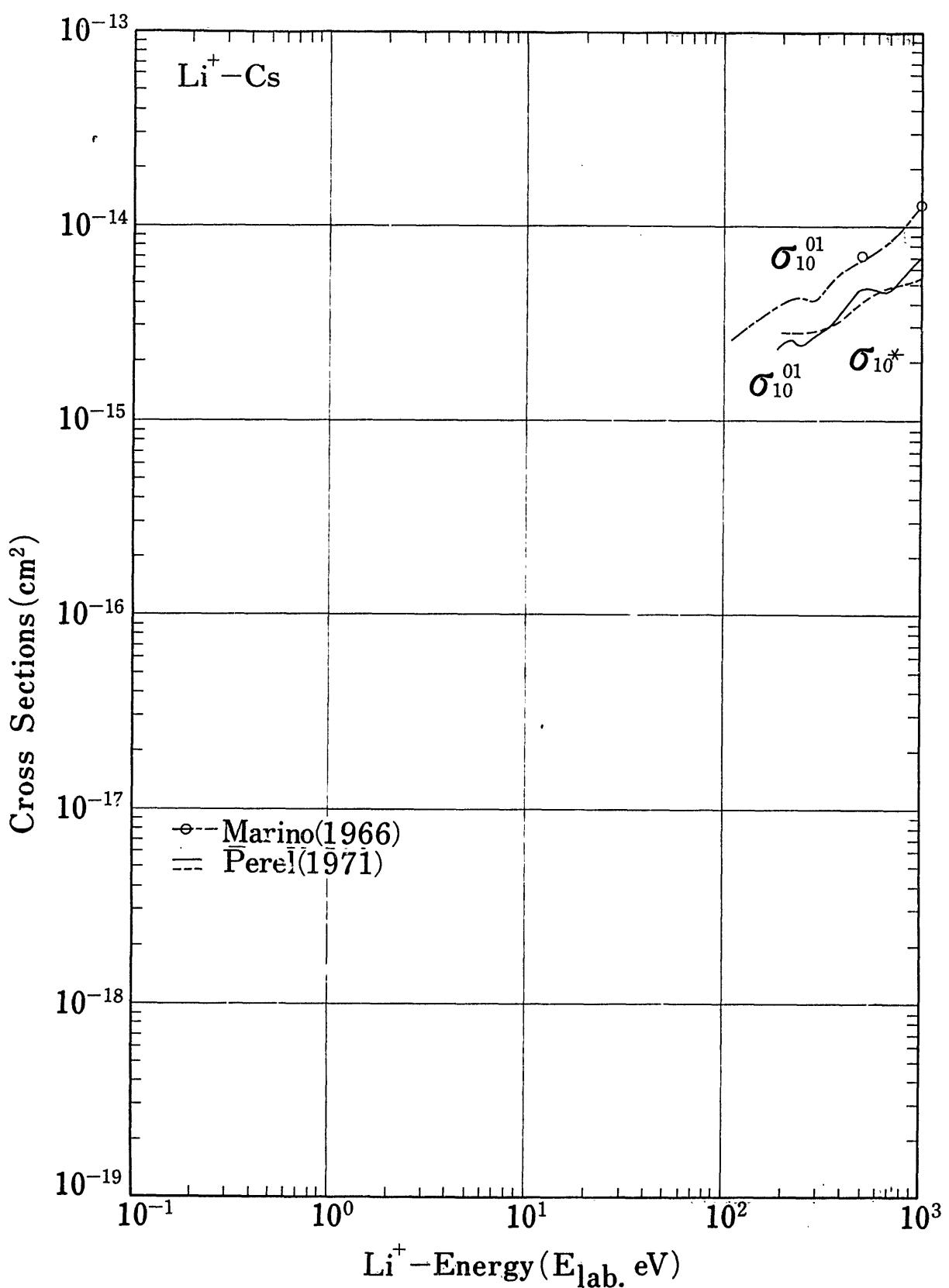


Fig. 33--a Charge Changing Cross Sections of Li^+ in Cs

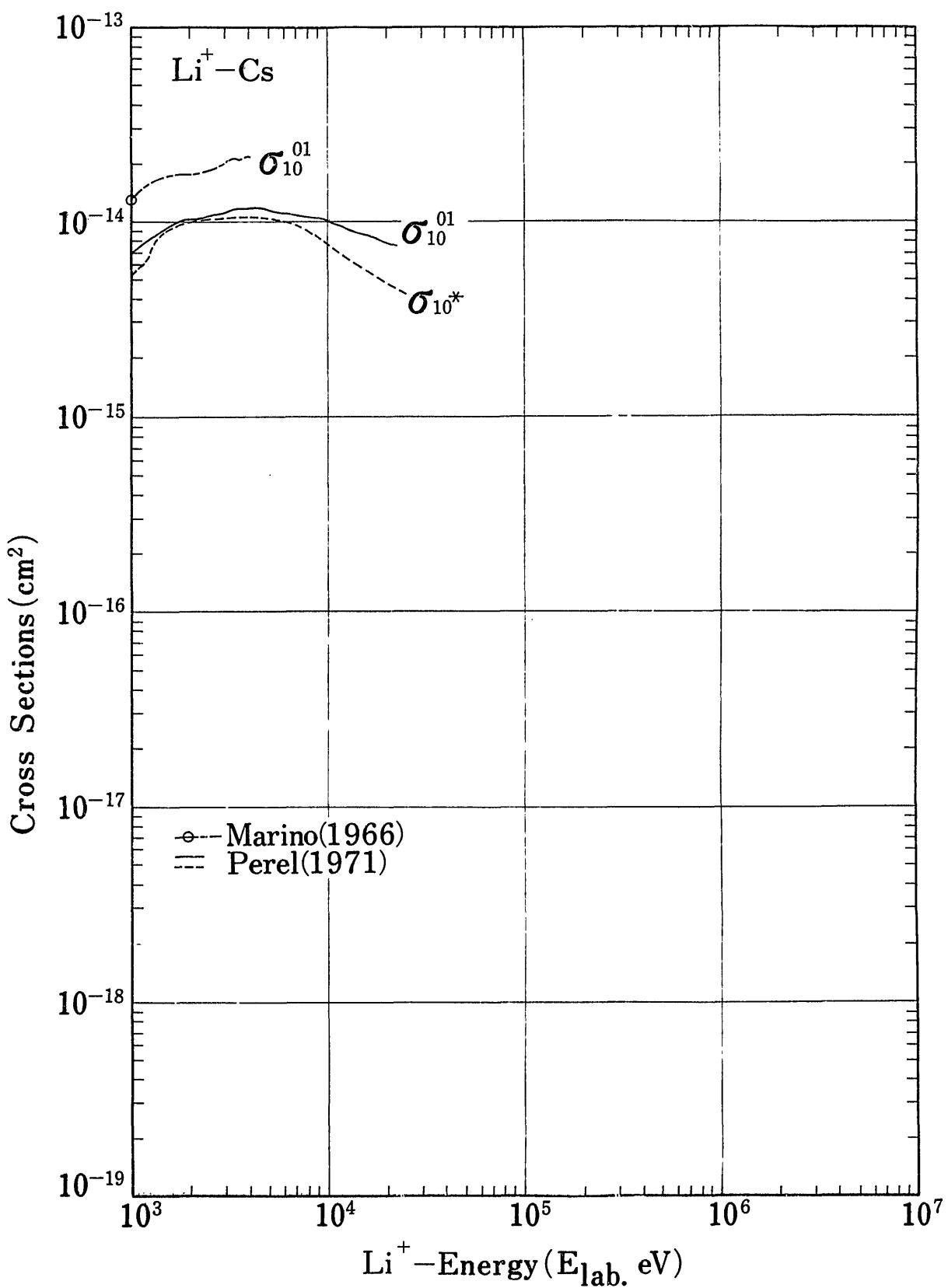


Fig.33-b Charge Changing Cross Sections of Li^+ in Cs

OR 101 01 '01 '01 '01
for all 3 years - 11
and all the remaining years required until the end of

Charge Changing Cross Sections of Beryllium

Atoms and Ions, Z=4.

I. Lists of Reference

II. Tables of Experimental Data

A) Electron Capture Cross Sections

B) Electron Loss Cross Sections

C) Cross Sections of Ionization, Slow ions Productions
and Electron productions

III. Graphs of Charge Changing Cross Sections

I. References for Experimental Data of Be (Z=4)

1. I.S.Dmitriev, V.S.Nikolaev, L.N.Fateeva and Ya.A.Teplova, Sov. Phys. JETP 15, 11 (1962)
2. I.S.Dmitriev, V.S.Nikolaev, Ya.A.Teplova and B.A. Prigodin, Proc. 6th ICPEAC, Cambridge, (1969) p.460
3. I.S.Dmitriev, Ya.A.Teplova and V.S.Nikolaev, Sov. Phys. JETP 34, 723 (1972)
4. I.S.Dmitriev, V.S.Nikolaev, Yu.A.Tashaev and Ya.A. Teplova, Sov. Phys. JETP 40, 1017 (1975)
5. J.K.Layton, R.F.Stebbins, R.T.Brackmann, W.L.Fite, W.R. Ott, C.E.Carlston, A.R.Comeaux, G.D.Magnuson and P.Mahadevan, Phys. Rev. 161, 73 (1967); J.K.Layton and W.L.Fite, AFWL-TR-67-2
6. V.S.Nikolaev, L.N.Fateeva, I.S.Dmitriev and Ya.A. Teplova, Sov. Phys. JETP 13, 695 (1961)
7. C.W.Sherwin, Phys. Rev. 57, 814 (1940)
8. Ya.A.Teplova, V.S.Nikolaev, I.S.Dmitriev and Yu.A. Tashaev, Proc. 9th ICPEAC, Seattle, (1975) p.187

II. Tables of Experimental Data

A) Electron Capture Cross sections of Beryllium Ions; Be^+ , Be^{2+} , Be^{3+} .

(σ_{10})

Sherwin	1940	6,000-24,000	H_2	7
Layton <u>et al.</u>	1967	10,000-60,000	$\text{N}_2, \text{O}_2, \text{Ar}$	5

(σ_{21})

Nikolaev <u>et al.</u>	1961	3,000,000	H_2, He	6
Dmitriev <u>et al.</u>	1962	3,000,000	He, N_2	1
Teplova <u>et al.</u>	1975	3,000,000	N_2	8
Dmitriev <u>et al.</u>	1975	750,000-3,000,000	He, N_2	4

(σ_{20})

Dmitriev <u>et al.</u>	1975	750,000	He, N_2	4
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(σ_{32})

Nikolaev <u>et al.</u>	1961	3,000,000	H_2, He	6
Dmitriev <u>et al.</u>	1962	3,000,000	He, N_2	1
Teplova <u>et al.</u>	1975	3,000,000	N_2	8

B) Electron Loss Cross Sections of Beryllium Ions, Be^+ , Be^{2+} , Be^{3+} .

(σ_{12})

Layton <u>et al.</u>	1967	30,000-60,000	$\text{N}_2, \text{O}_2, \text{Ar}$	5
Teplova <u>et al.</u>	1975	3,000,000	N_2	8

(σ_{23})

Dmitriev <u>et al.</u>	1962	3,000,000	He, N ₂	1
Teplova <u>et al.</u>	1975	3,000,000	N ₂	8
Dmitriev <u>et al.</u>	1975	746,000-3,000,000	He, N ₂	4

(σ_{24})

Dmitriev <u>et al.</u>	1975	3,000,000	He, N ₂	4
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(σ_{34})

Dmitriev <u>et al.</u>	1962	3,000,000	He, N ₂	1
Teplova <u>et al.</u>	1975	3,000,000	N ₂	4

C) Ionization Cross Sections by Beryllium Ion

(σ_1^i)

Sherwin	1940	6,000-24,000	H ₂ , He	7
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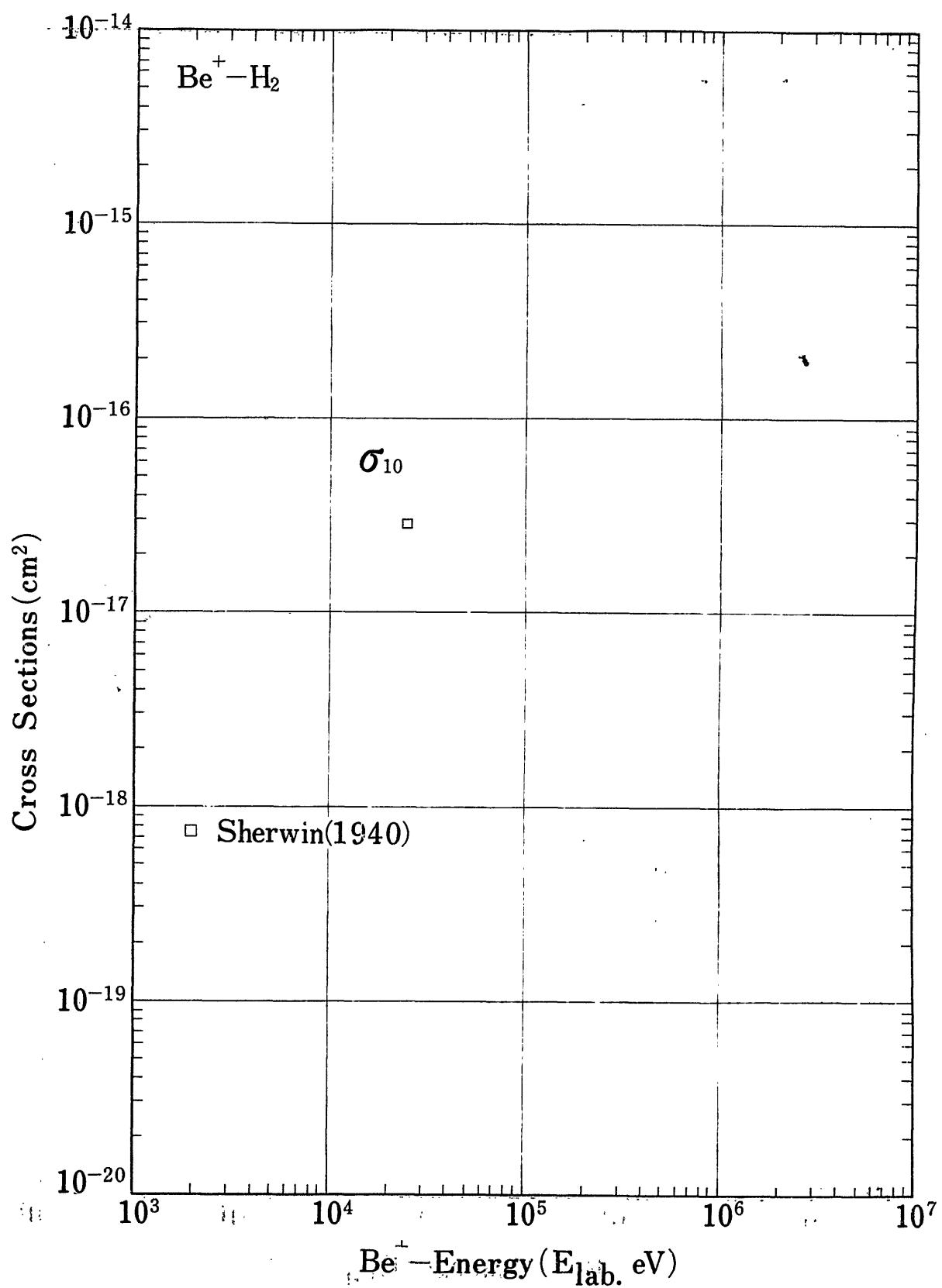


Fig.1 Charge-Changing Cross Sections of Be^+ in H_2

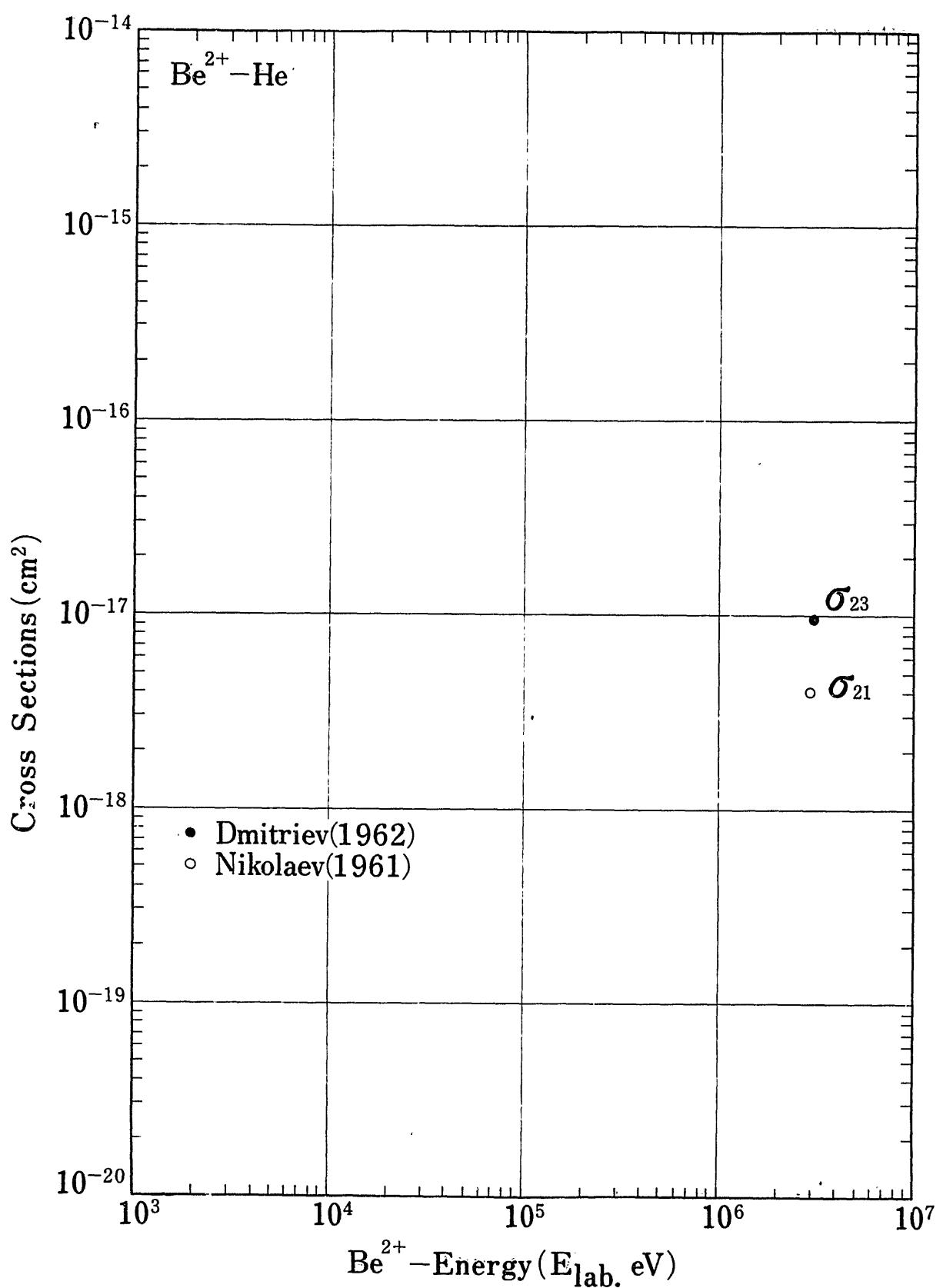


Fig.2 Charge Changing Cross Sections of Be^{2+} in He

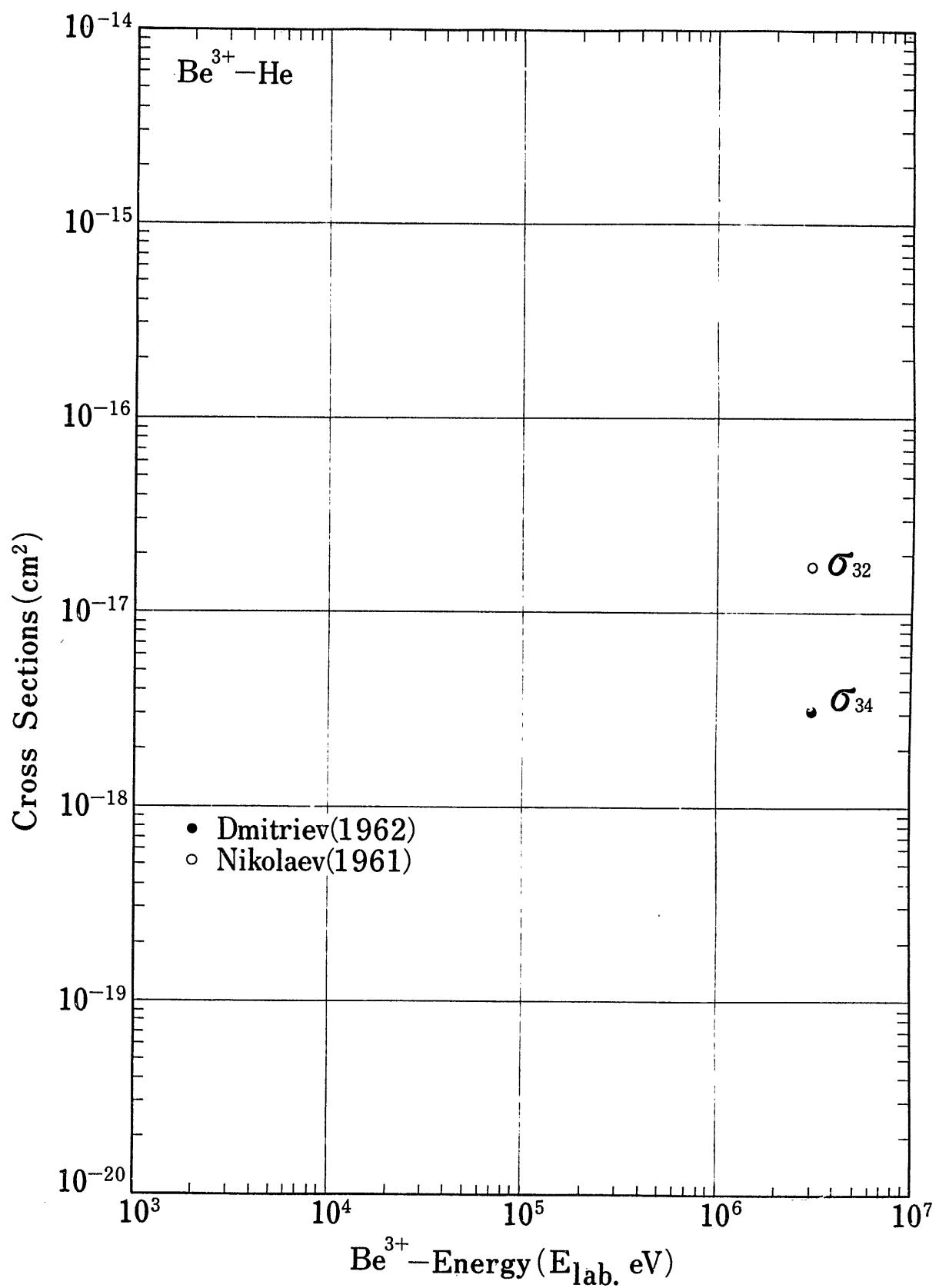


Fig.3 Charge Changing Cross Sections of Be^{3+} in He

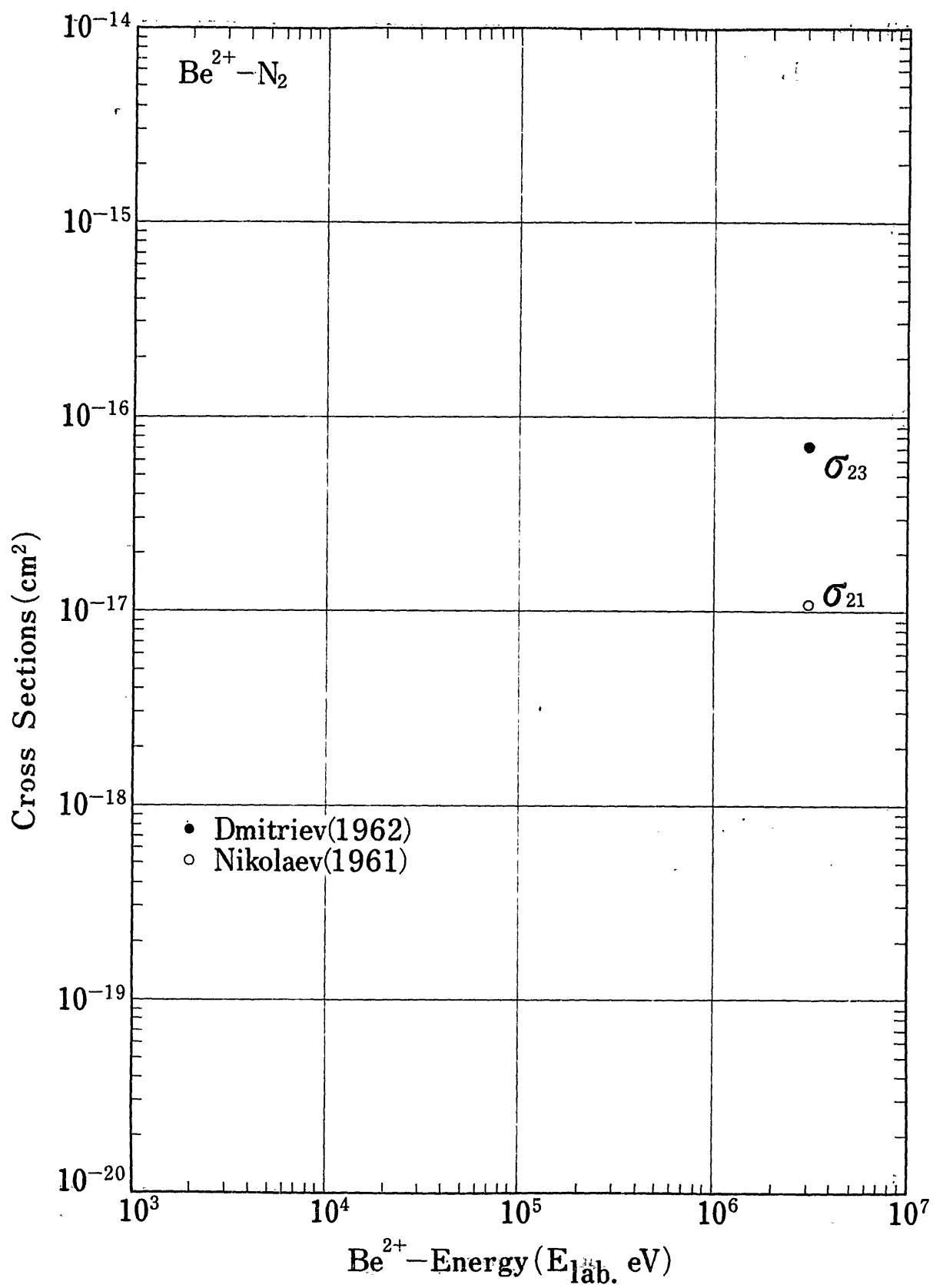


Fig.4 Charge Changing Cross Sections of Be^{2+} in N_2

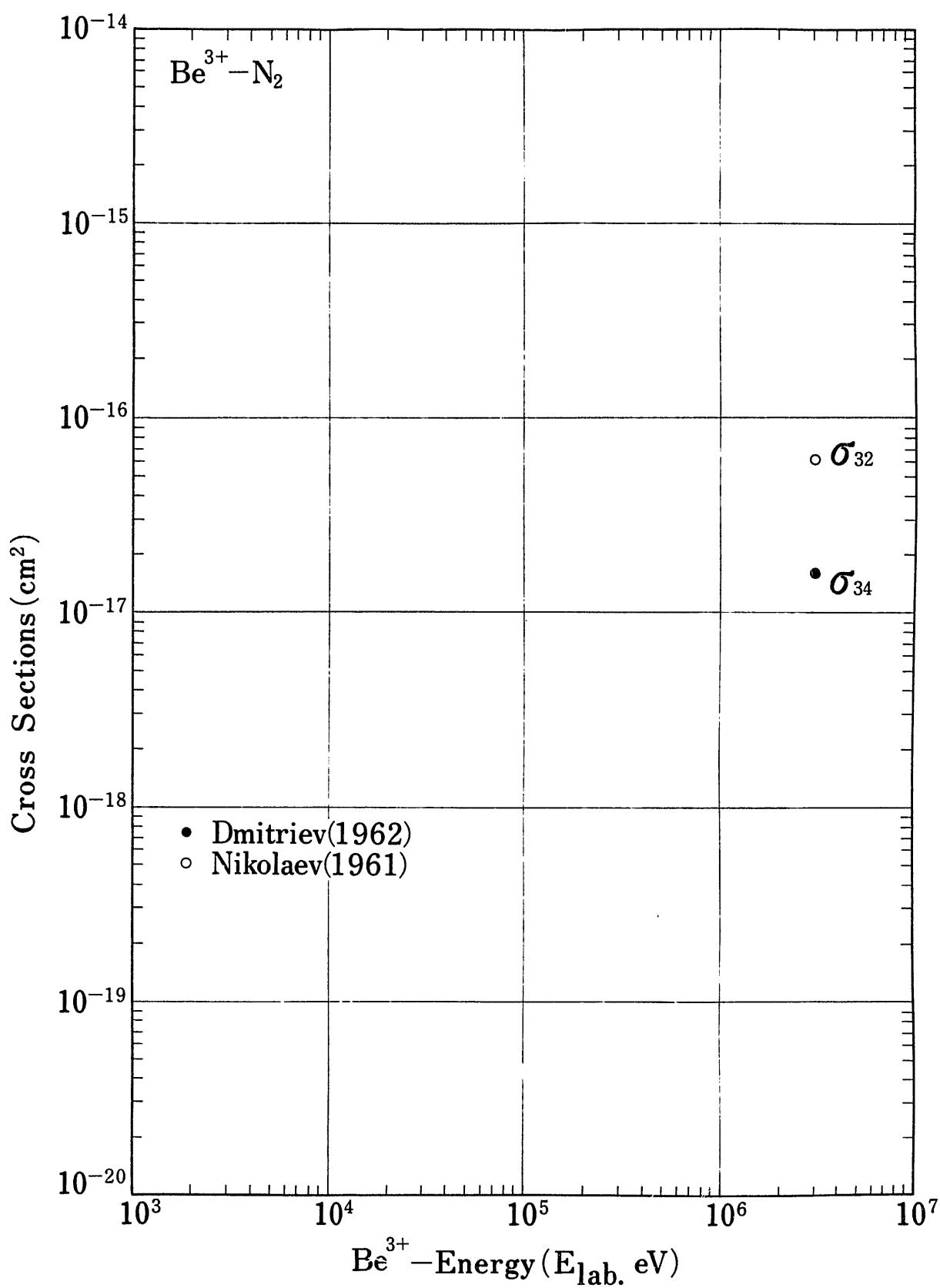


Fig. 5 Charge Changing Cross Sections of Be^{3+} in N_2

Charge Changing Cross Sections of Boron

Atoms and Ions, Z=5

I. Lists of Reference

II. Tables of Experimental Data

A) Electron Capture Cross Sections

B) Electron Loss Cross Sections

C) Cross Sections of Ionization, Slow ions Productions
and Electron productions

III. Graphs of Charge Changing Cross Sections

I. References for Experimental Data of B (Z=5)

1. P.G.Cable and H.J.Zwally, Proc. 7th ICPEAC, Amsterdam (1971) p.141
2. D.H.Crandall, Phys. Rev. A 16, 958 (1977)
3. I.S.Dmitriev, V.S.Nikolaev, L.N.Fateeva and Y.A.Teplova, Sov. Phys. JETP 15, 11 (1962)
4. I.S.Dmitriev, V.S.Nikolaev, L.N.Fateeva and Y.A.Teplov, Sov. Phys. 16, 259 (1963)
5. I.S.Dmitriev, V.S.Nikolaev, Ya.A.Teplova and B.A. Prigodin, Proc. 6th ICPEAC, Cambridge, (1969) p.460
6. I.S.Dmitriev, V.S.Nikolaev and Ya.A.Teplova, Proc. 7th ICPEAC, Amsterdam, (1971) p.510
7. I.S.Dmitriev, Ya.A.Teplova and V.S.Nikolaev, Sov. Phys. JETP 34, 723 (1972)
8. I.S.Dmitriev, V.S.Nikolaev, Yu.A.Tashaev and Ya.A. Teplova, Sov. Phys. JETP 40, 1017 (1975)
9. Ya.M.Fogel', V.F.Kozlov, A.A.Kalmykov and V.J.Murator, Sov. Phys. JETP 9, 929 (1959)
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11. V.S.Nikolaev, L.N.Fateeva, I.S.Dmitriev and Ya.A.Teplova, Sov. Phys. JETP 13, 695 (1961)
12. V.S.Nikolaev, L.N.Fateeva, I.S.Dmitriev and Ya.A.Teplova, Sov. Phys. JETP 14, 67 (1962)
13. J.H.Ormrod and W.L.Michel, Canad. J. Phys. 49, 606 (1971)
14. C.W.Sherwin, Phys. Rev. 57, 814 (1940)
15. H.J.Zwally and P.G.Cable, Phys. Rev. A 4, 2301 (1971)

II. Tables of Experimental Data

A) Electron Capture Cross Sections of Boron Atom and Ions,
 $B^0, B^+, B^{2+}, B^{3+}, B^{4+}, B^{5+}$.

$(\sigma_{0\bar{1}})$

Fogel <u>et al.</u>	1960	15,000-60,000	He, Ne, Ar, Kr, Xe	10
Ormrod, Michel	1971	15,000-100,000	Ar	13

$(\sigma_{1\bar{0}})$

Sherwin	1940	6,000-24,000	H ₂	14
Nikolaev <u>et al.</u>	1961	440,000-2,800,000	Ne, N ₂ , Ar, Kr	11
Ormrod, Michel	1971	15,000-100,000	N ₂ , Ar	13

$(\sigma_{1\bar{1}})$

Fogel <u>et al.</u>	1959	5,000-60,000	H ₂ , Kr, Xe	9
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$(\sigma_{2\bar{1}})$

Sherwin	1940	6,000-24,000	H ₂ , He	14
Nikolaev <u>et al.</u>	1961	440,000-3,500,000	He, N ₂ , Ar, Kr	11
Ormrod, Michel	1971	40,000-90,000	N ₂ , Ar	13

$(\sigma_{2\bar{0}})$

Nikolaev <u>et al.</u>	1962	450,000-900,000	He, N ₂ , Ar, Kr	12
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$(\sigma_{3\bar{2}})$

Nikolaev <u>et al.</u>	1961	860,000-3,500,000	He, N ₂ , Ar, Kr	11
Zwally, Cable	1971	300-31,500	He	15

Dmitriev <u>et al.</u>	1975	900,000-8,200,000	He,N ₂	8
Crandall <u>et al.</u>	1977	14,300-83,000	He	2

(σ_{31})

Nikolaev <u>et al.</u>	1962	900,000-2,800,000	He,N ₂ ,Ar,Kr	12
Dmitriev <u>et al.</u>	1975	900,000-3,600,000	He,N ₂	8

(σ_{43})

Nikolaev <u>et al.</u>	1961	2,800,000-7,800,000	He,N ₂ ,Ar,Kr	11
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(σ_{42})

Nikolaev <u>et al.</u>	1962	2,800,000-7,700,000	N ₂ ,Ar,Kr	12
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(σ_{54})

Nikolaev <u>et al.</u>	1961	3,500,000-7,800,000	He,N ₂ ,Ar,Kr	11
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(σ_{53})

Nikolaev <u>et al.</u>	1962	3,500,000	N ₂ ,Ar,Kr	12
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B) Electron Loss Cross Sections of Boron Atom and Ions,
 B^0 , B^+ , B^{2+} , B^{3+} , B^{4+}

(σ_{01})

Fogel' <u>et al.</u>	1960	15,000-60,000	He,Ne,Ar,Kr Xe	10
Dmitriev <u>et al.</u>	1962	425,000-2,800,000	He,N ₂ ,Ar,Kr	3
Ormrod, Michel	1971	15,000-80,000	N ₂ ,Ar	13

(σ_{12})

Dmitriev et al. 1962 425,000-3,600,000 He,N₂,Ar,Kr 3

(σ_{13})

Dmitriev et al. 1963 450,000-3,600,000 He,N₂,Ar,Kr 4

(σ_{23})

Dmitriev et al. 1962 425,000-3,600,000 He,N₂,Ar,Kr 3

(σ_{24})

Dmitriev et al. 1963 2,800,000-3,600,000 He,N₂,Ar,Kr 4

(σ_{34})

Dmitriev et al. 1962 800,000-3,600,000 He,N₂,Ar,Kr 3

Dmitriev et al. 1975 900,000-8,200,000 He,N₂ 8

(σ_{35})

Dmitriev et al. 1963 2,800,000-3,500,000 He,N₂,Ar,Kr 4

Dmitriev et al. 1975 3,600,000-8,200,000 He,N₂ 8

(σ_{45})

Dmitriev et al. 1962 2,750,000-7,500,000 He,N₂,Ar,Kr 3

C) Ionization Cross Sections by Boron Ion

(σ_1^i)

Sherwin 1940 6,000-24,000 H₂,He 14

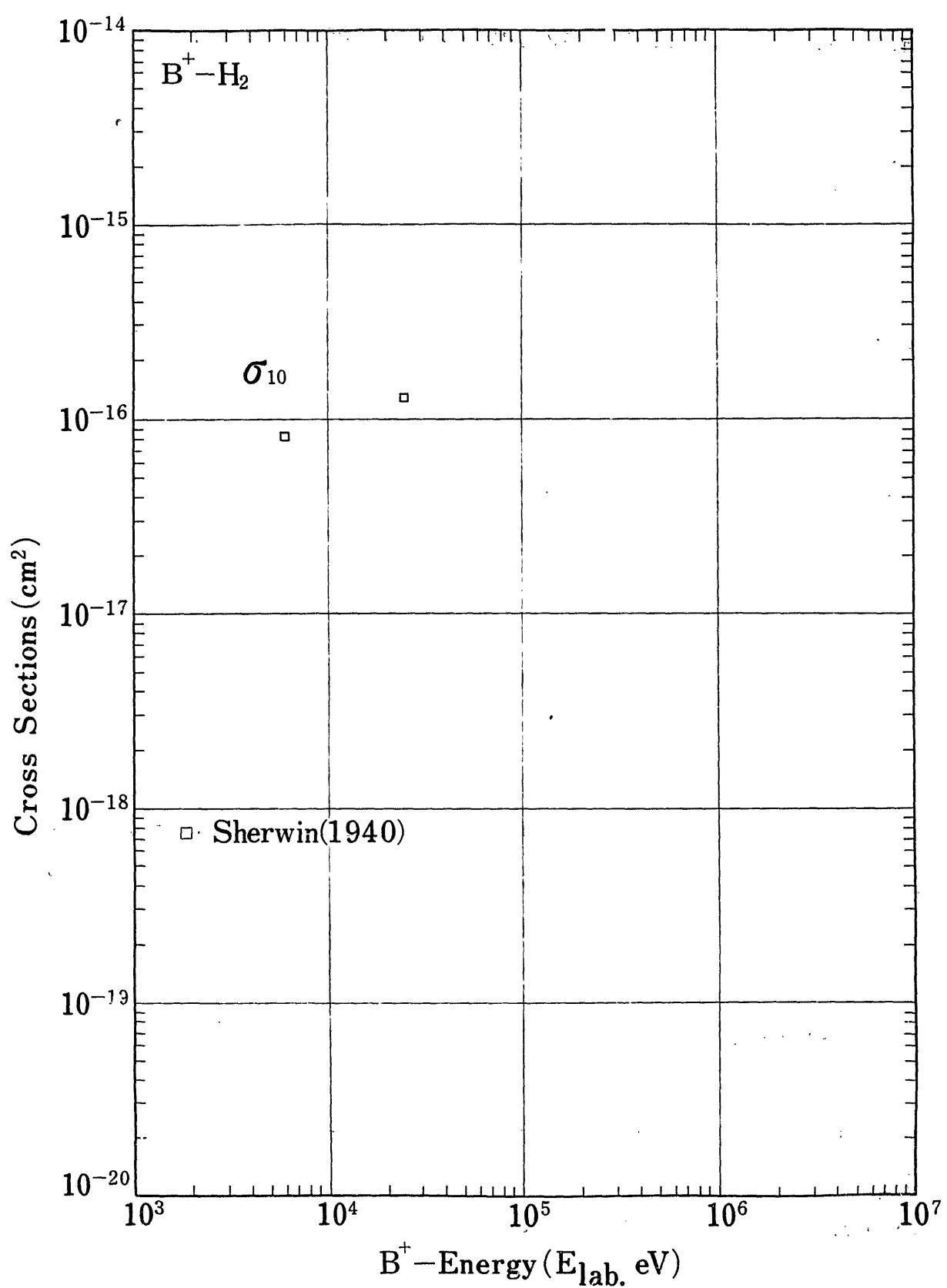


Fig.1 Charge Changing Cross Sections of B^+ in H_2

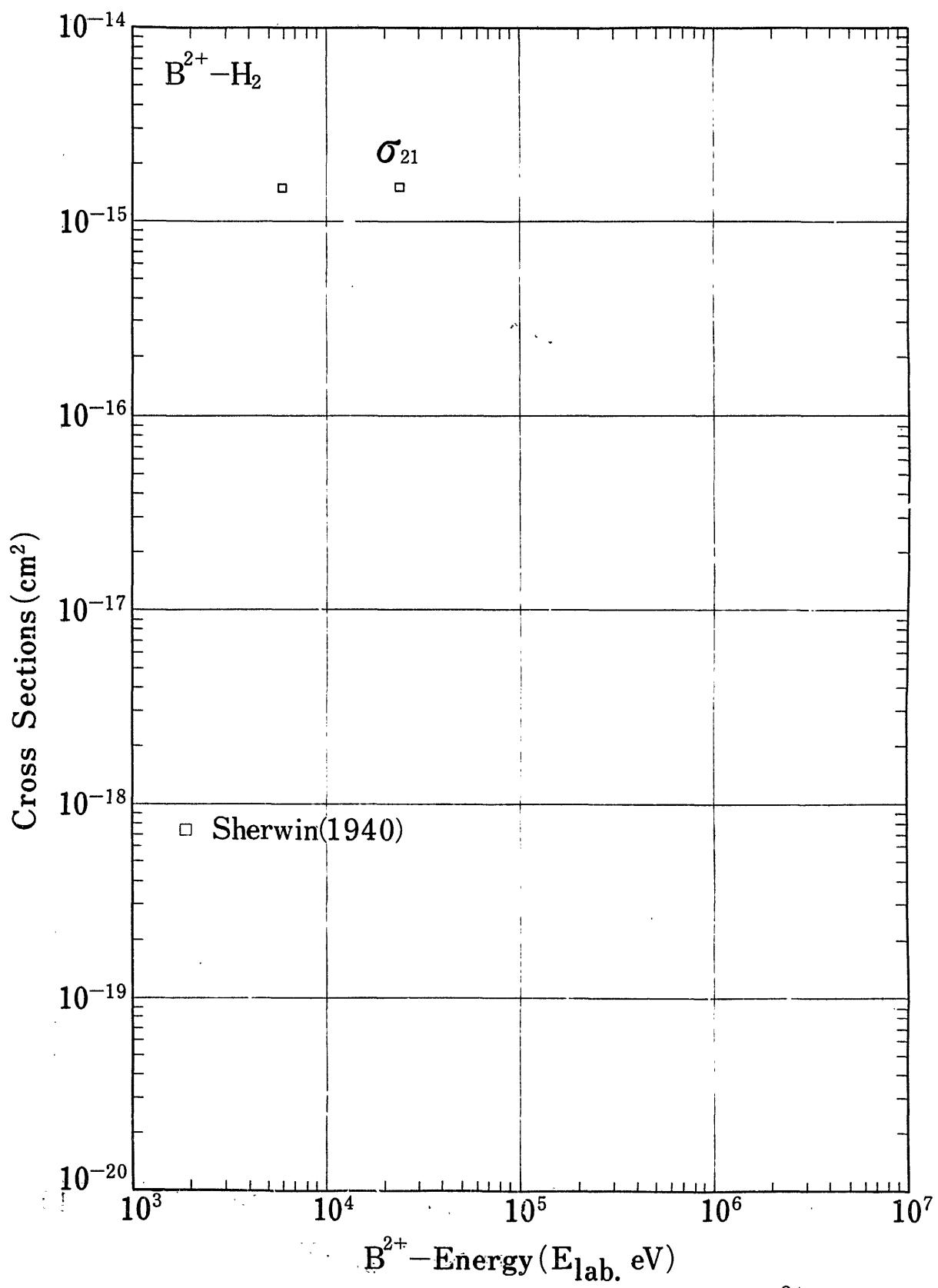


Fig.2 Charge Changing Cross Sections of B²⁺ in H₂

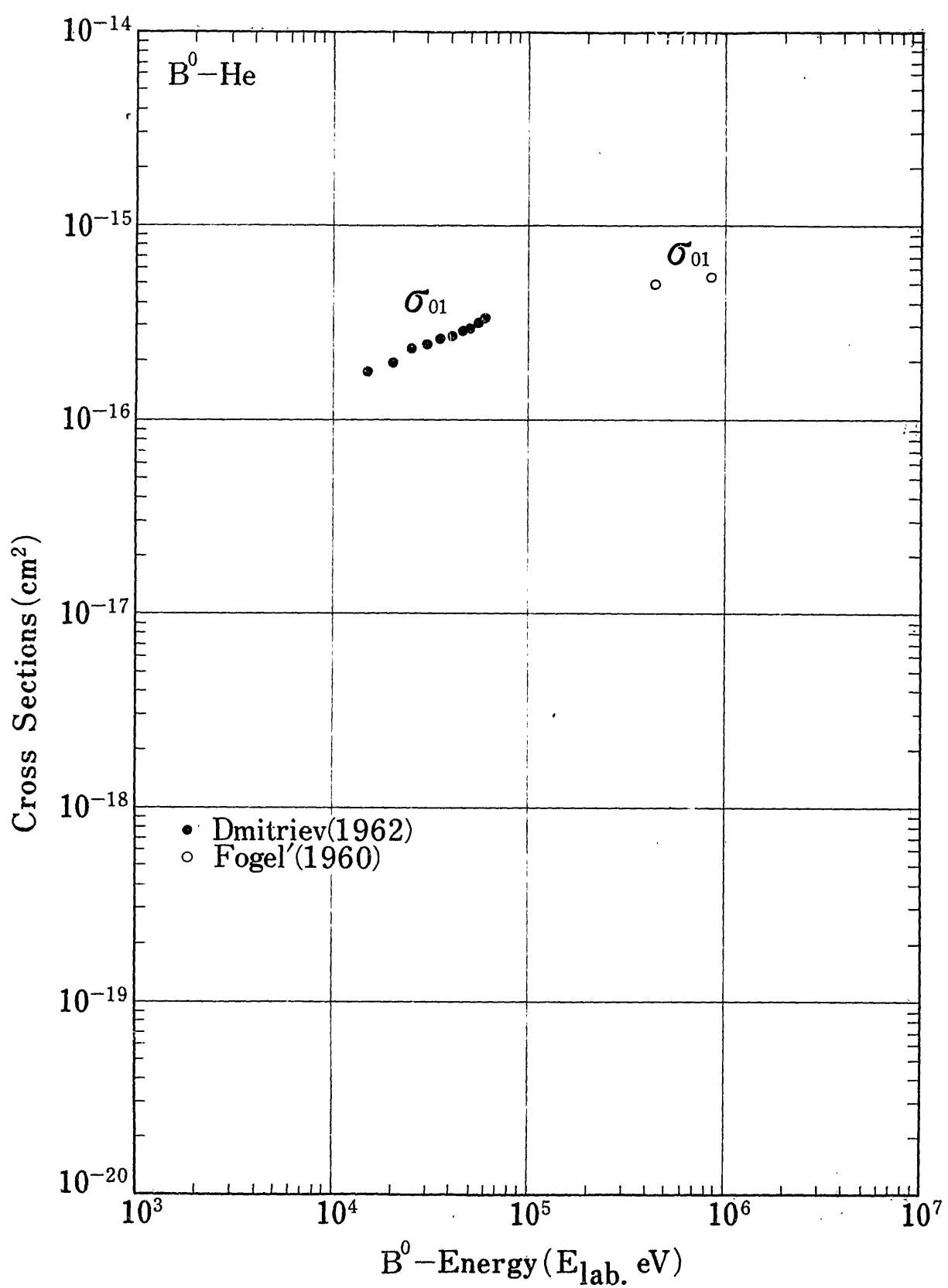


Fig. 3 Charge Changing Cross Sections of B^0 in He

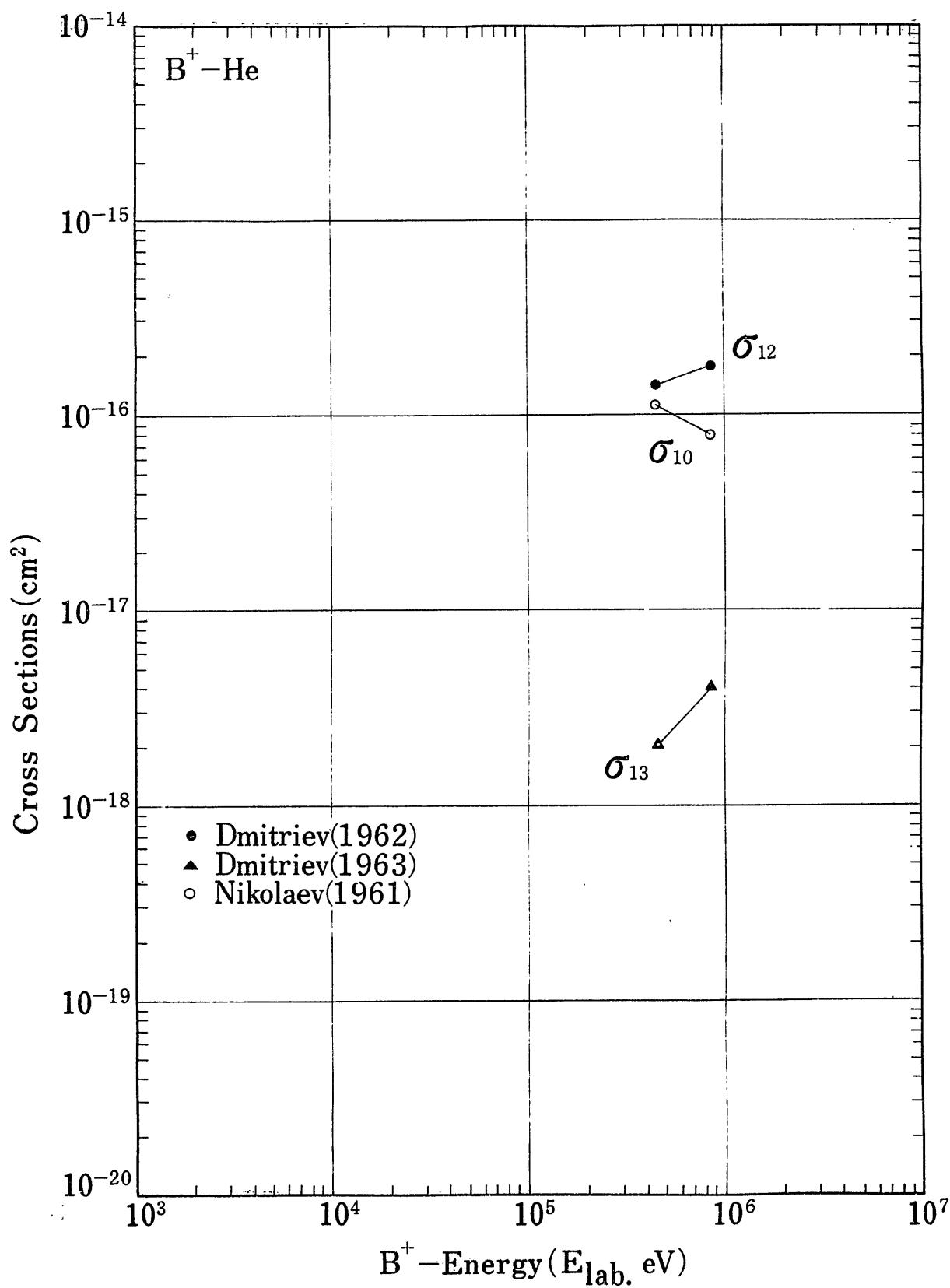


Fig.4 Charge Changing Cross Sections of B⁺ in He

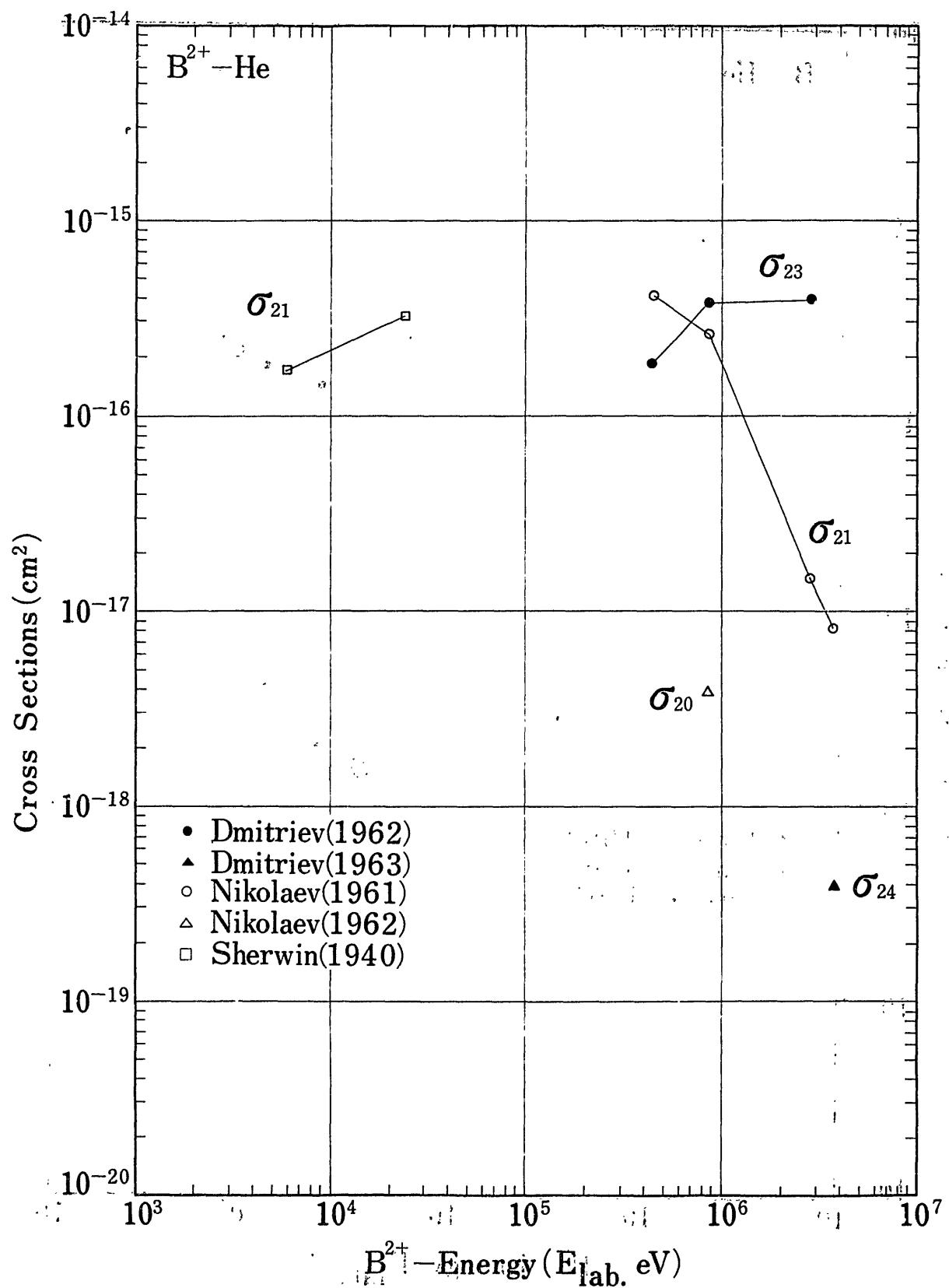


Fig.5 Charge-Changing Cross Sections of B^{2+} in He

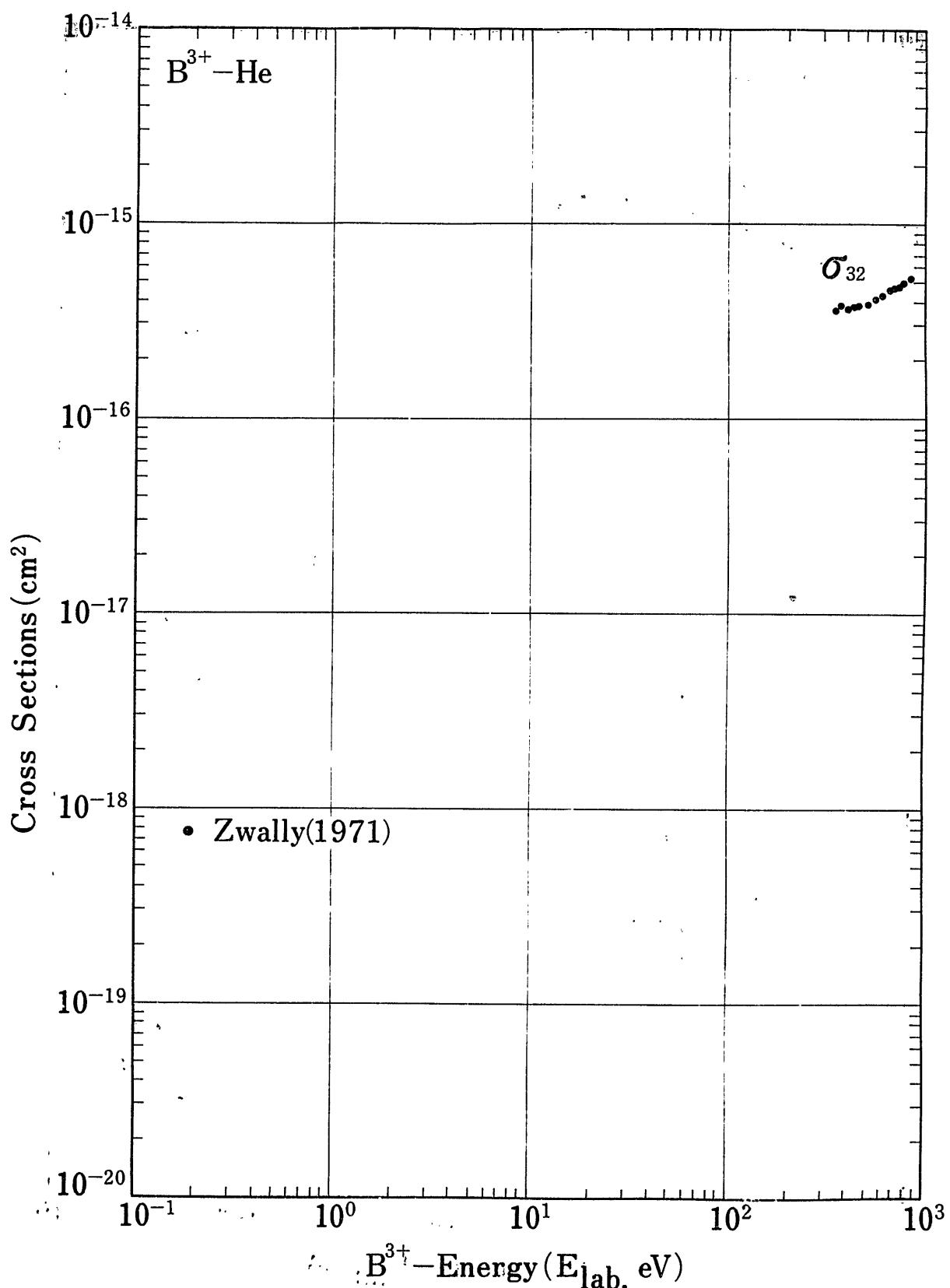


Fig. 6-a Charge Changing Cross Sections of B^{3+} in He

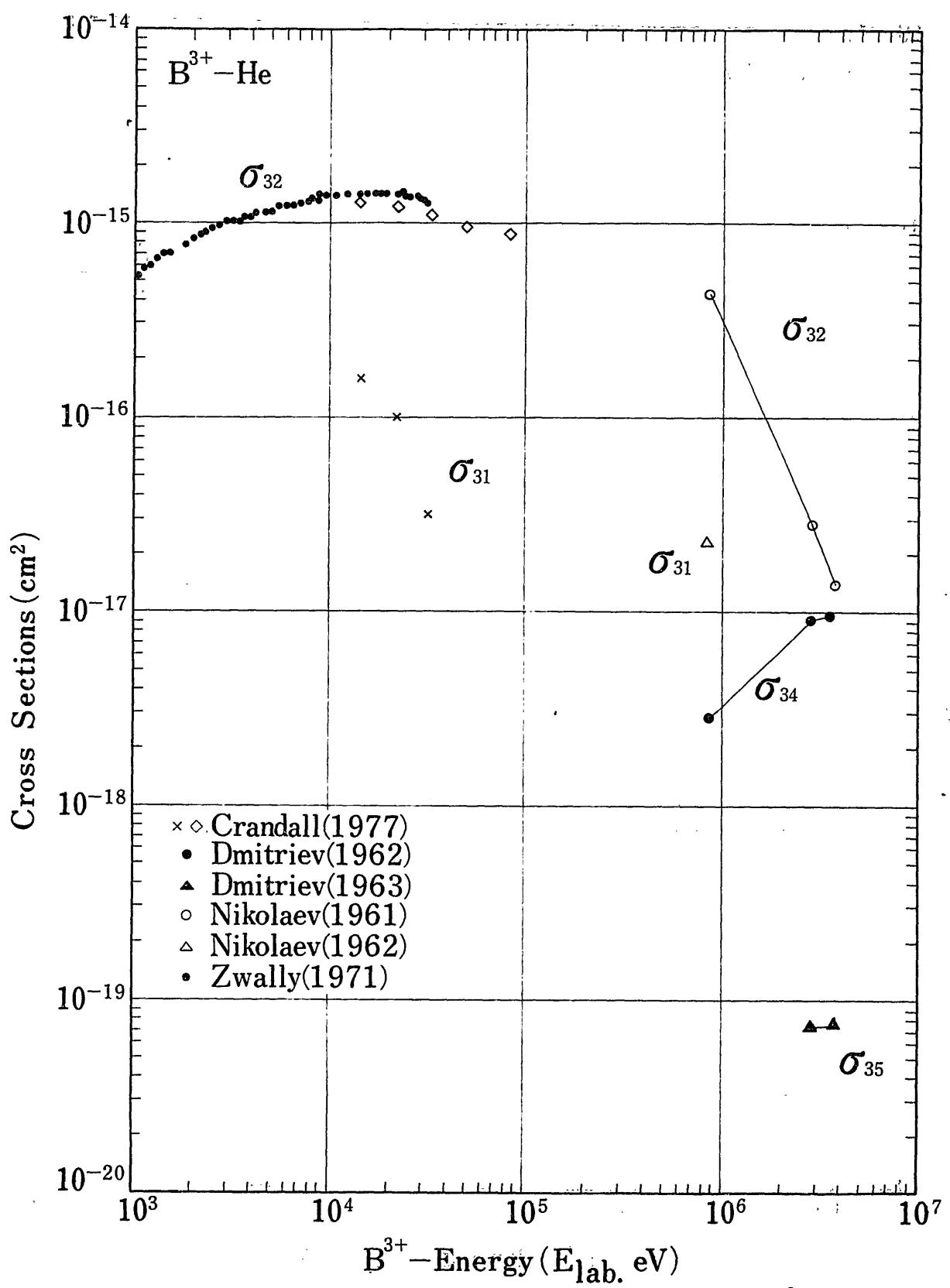


Fig.6-b Charge Changing Cross Sections of B^{3+} in He

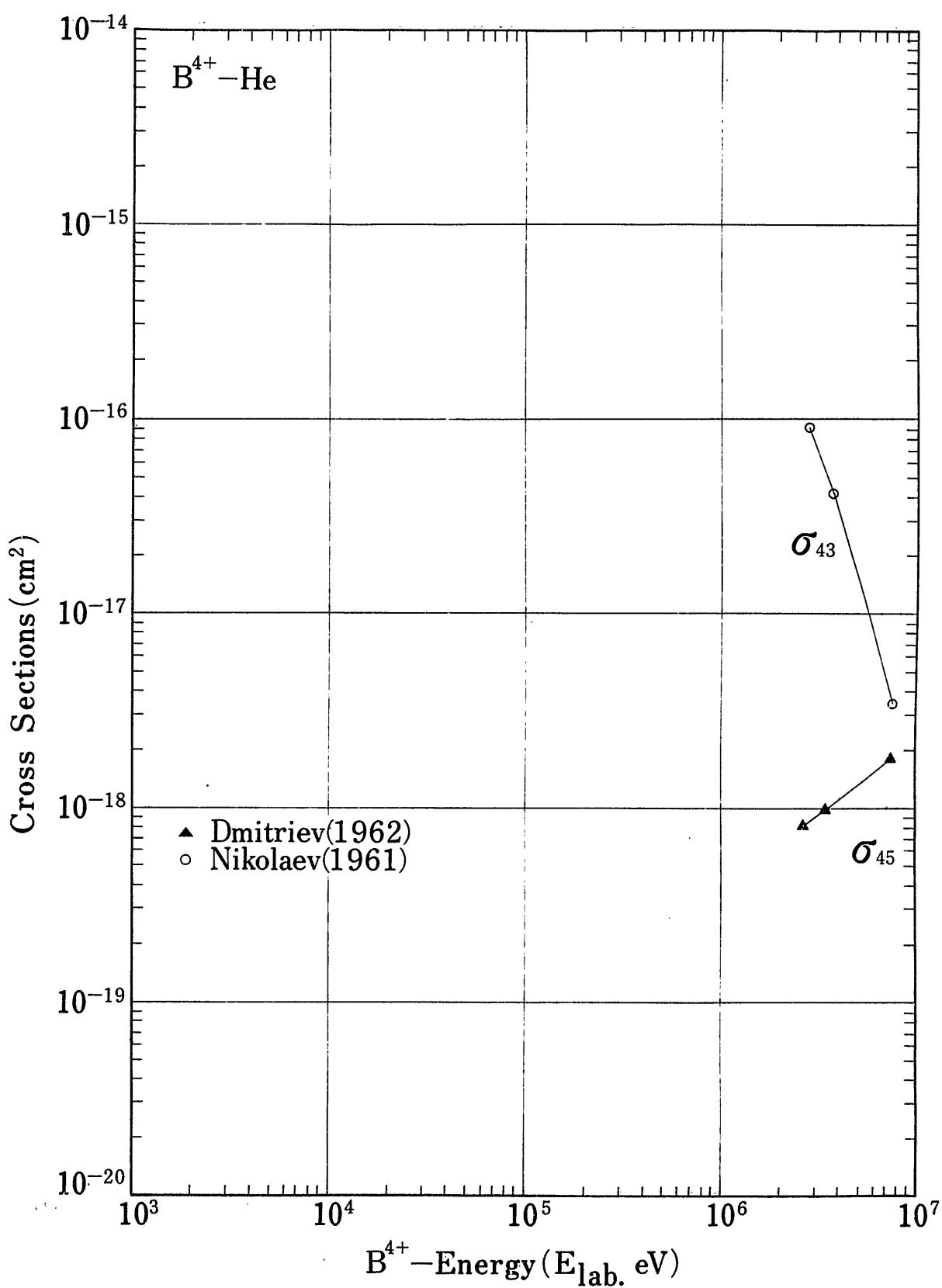


Fig. 7 Charge Changing Cross Sections of B^{4+} in He

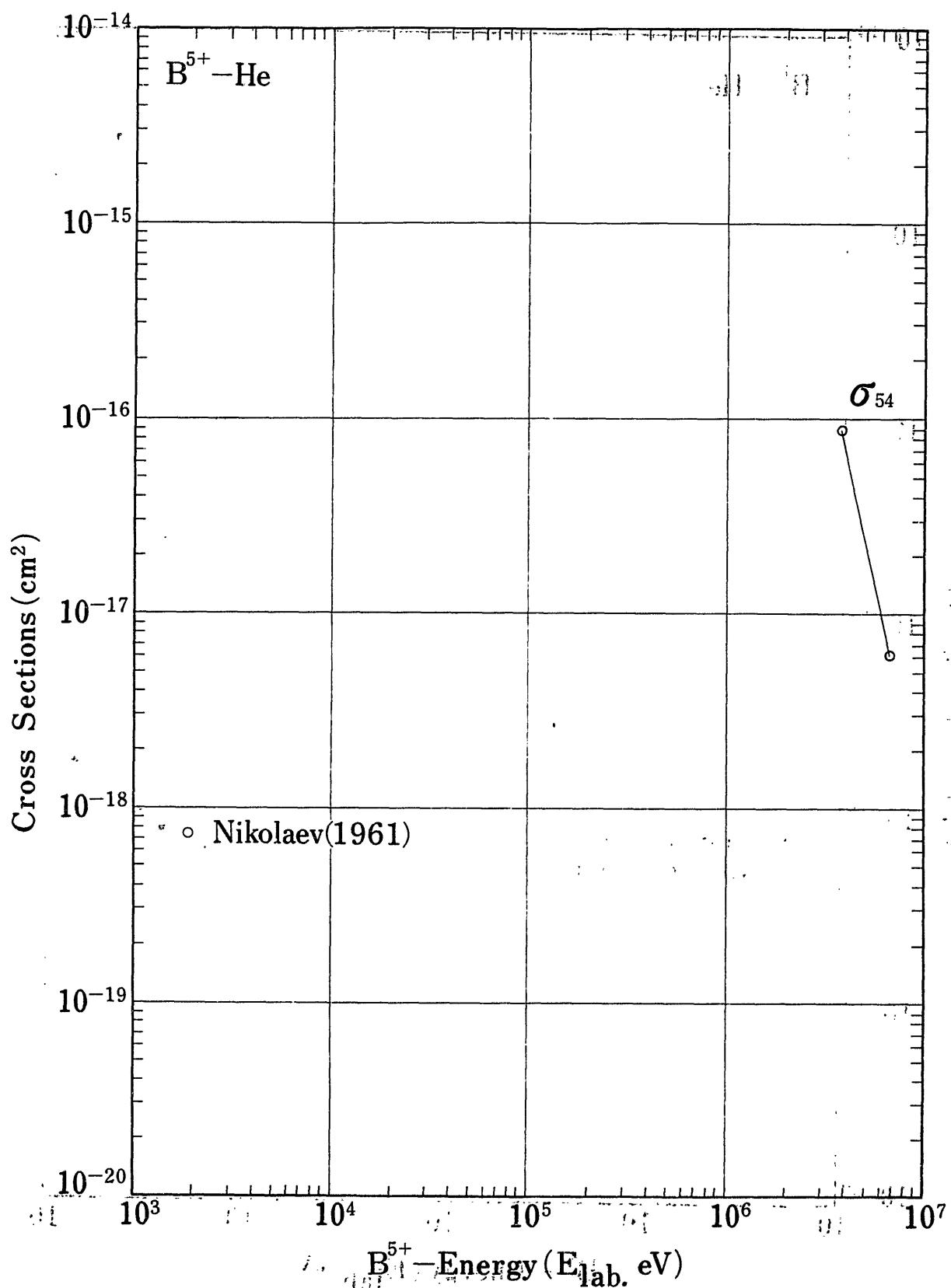


Fig. 8 Charge-Changing Cross Sections of B^{5+} in He

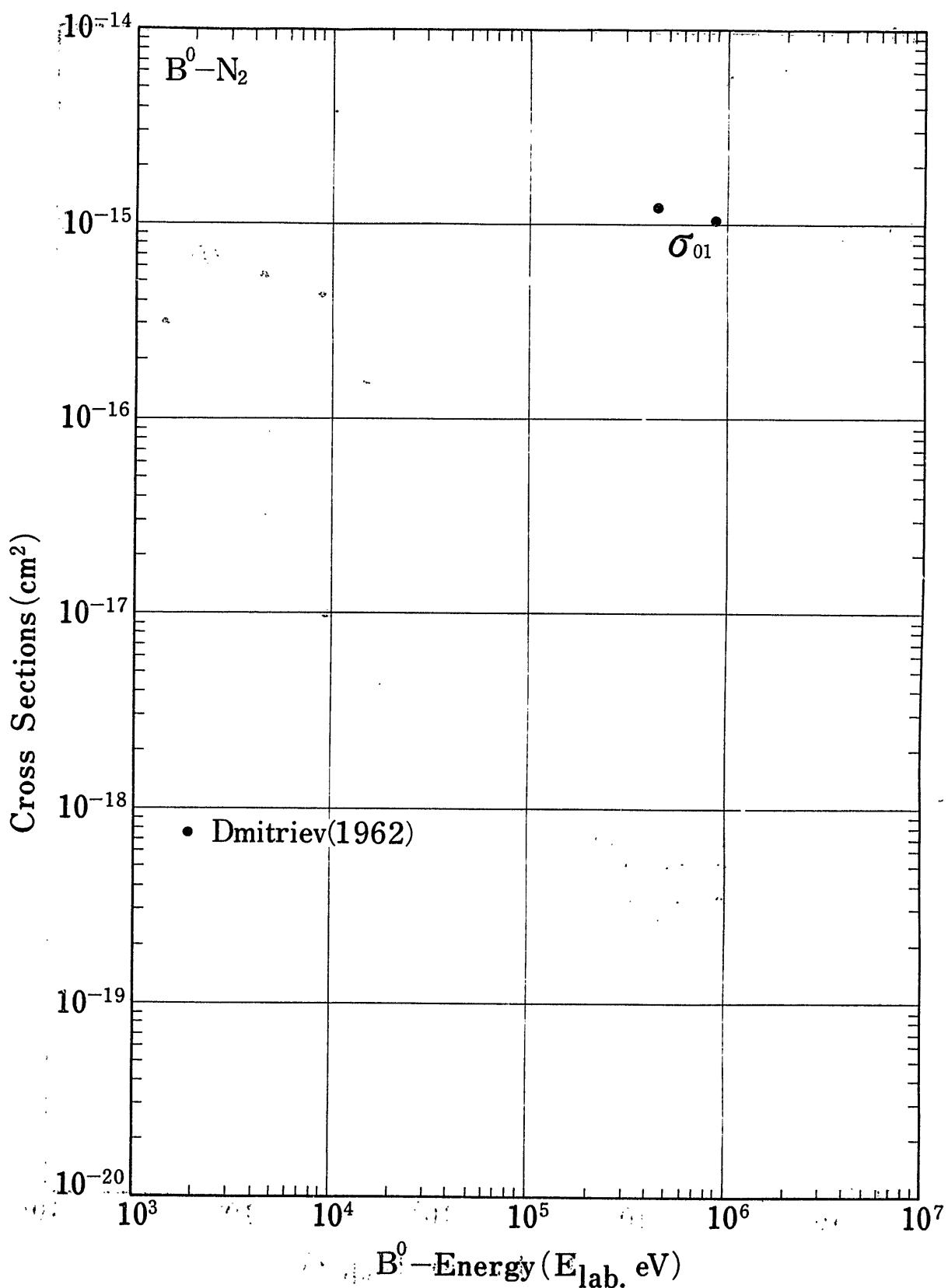


Fig.9 : Charge Changing Cross Sections of B^0 in N_2

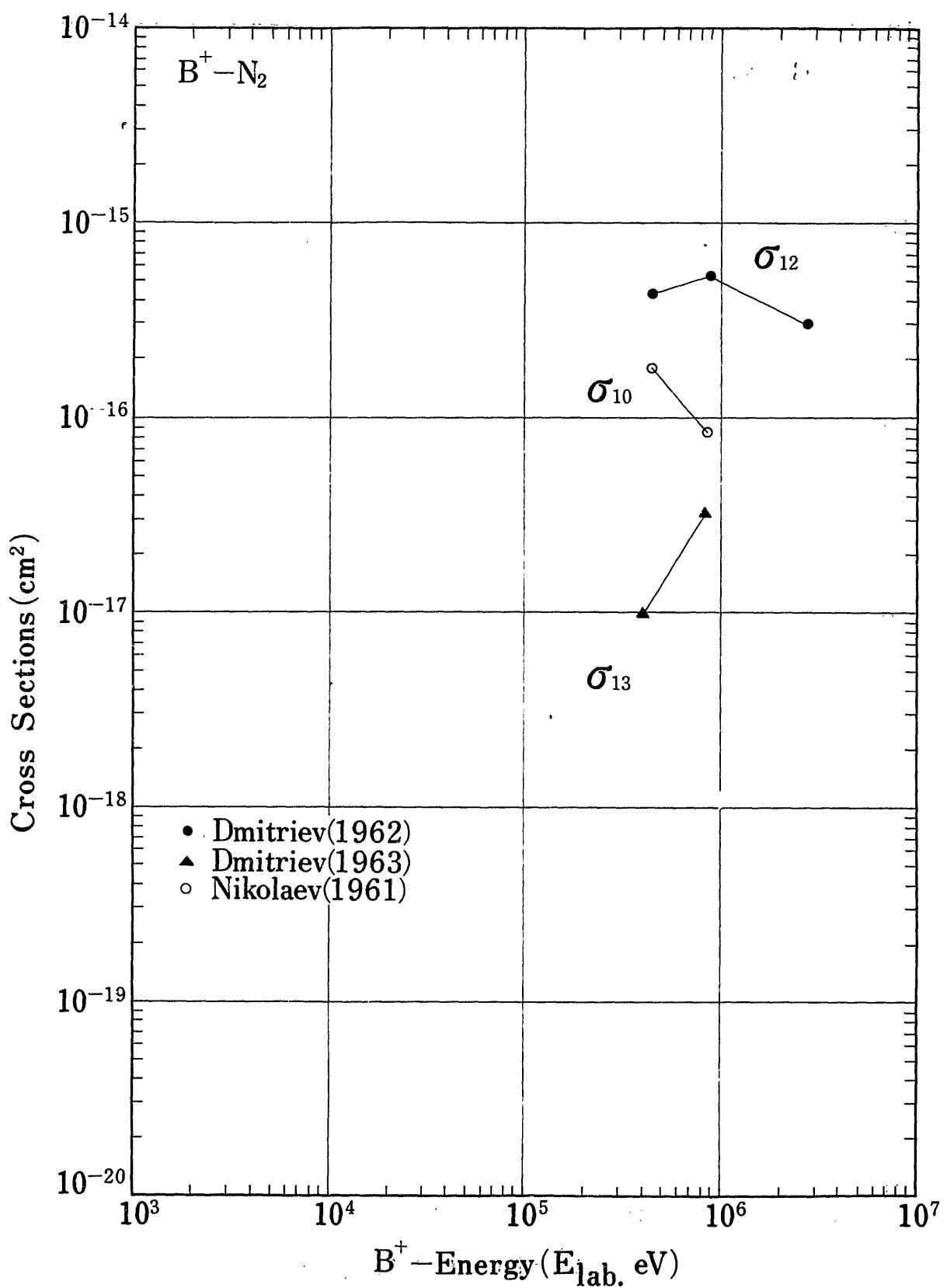


Fig.10 Charge Changing Cross Sections of B^+ in N_2

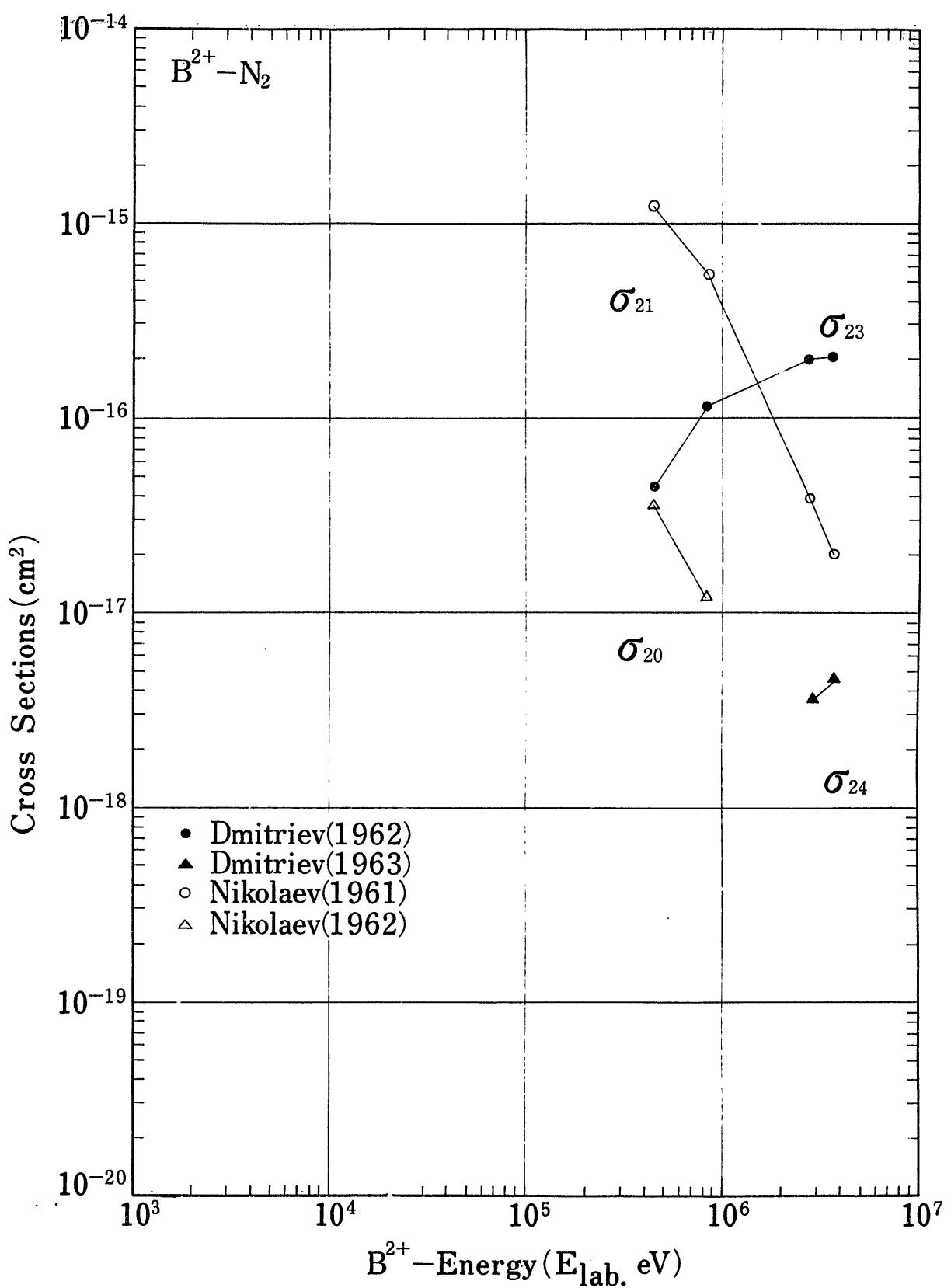


Fig.11 Charge Changing Cross Sections of B^{2+} in N_2

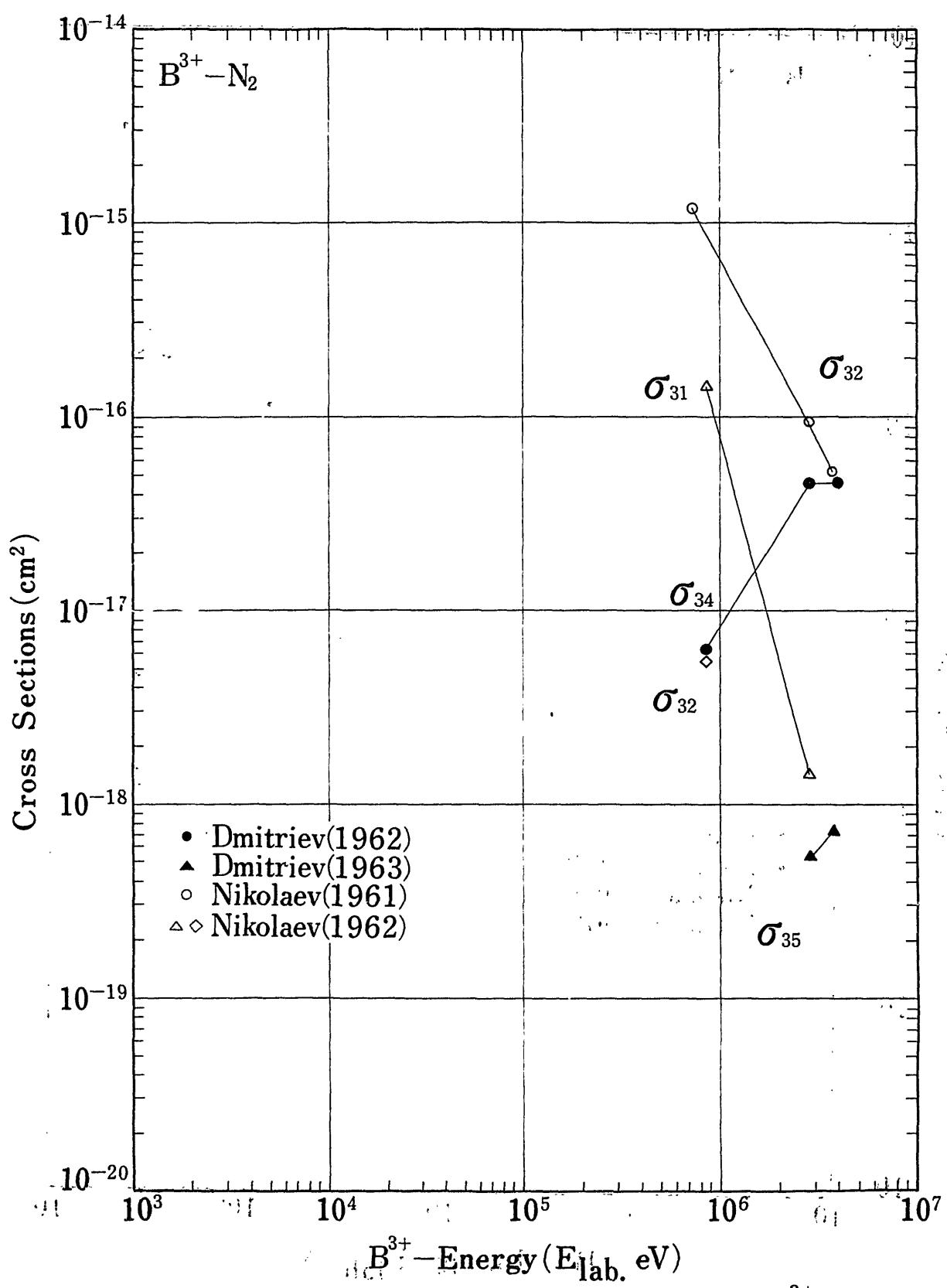


Fig.12 Charge-Changing Cross Sections of B^{3+} in N_2

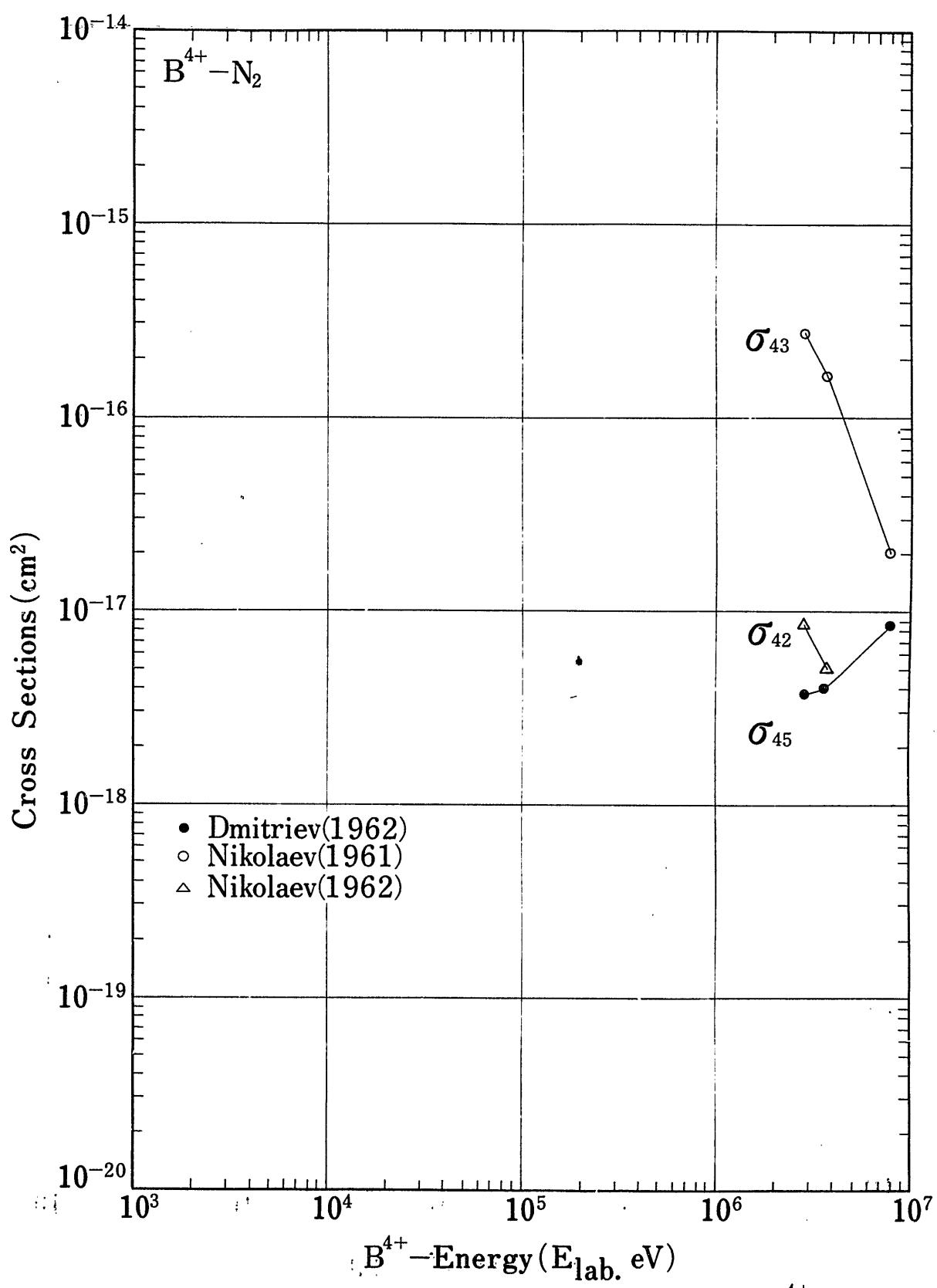


Fig.13 Charge Changing Cross Sections of B^{4+} in N_2

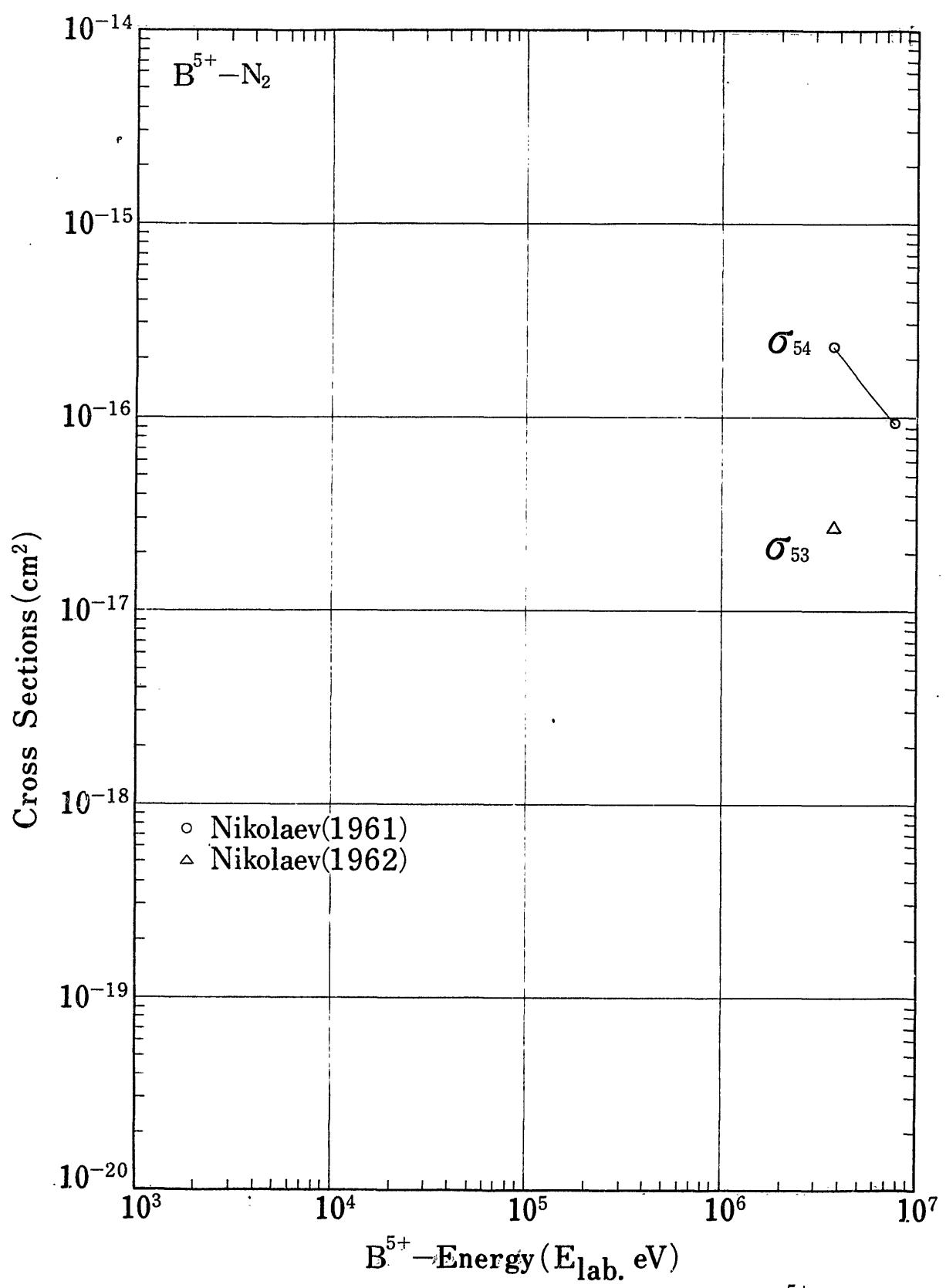


Fig.14 Charge Changing Cross Sections of B^{5+} in N_2

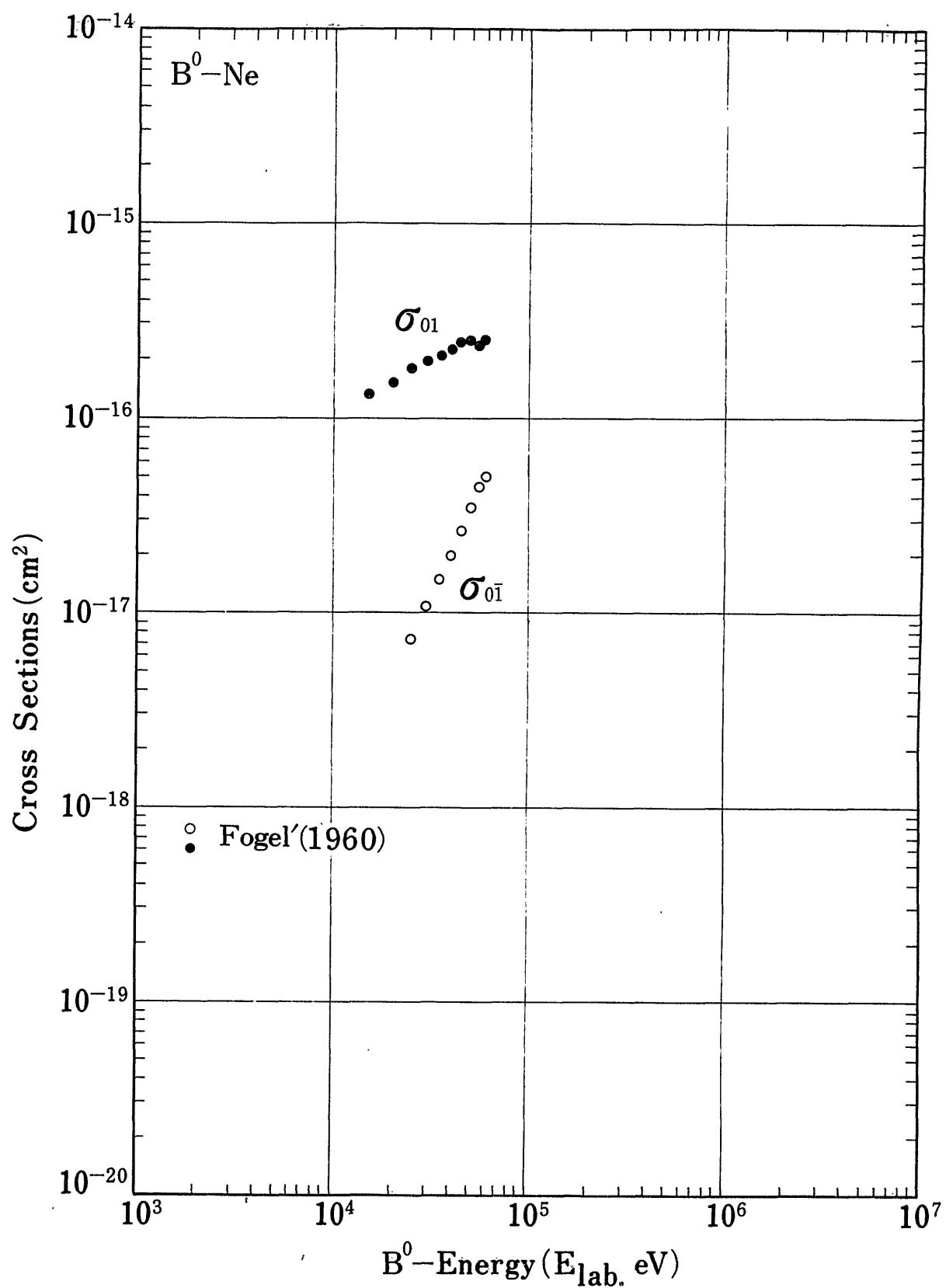


Fig.15 Charge Changing Cross Sections of B^0 in Ne

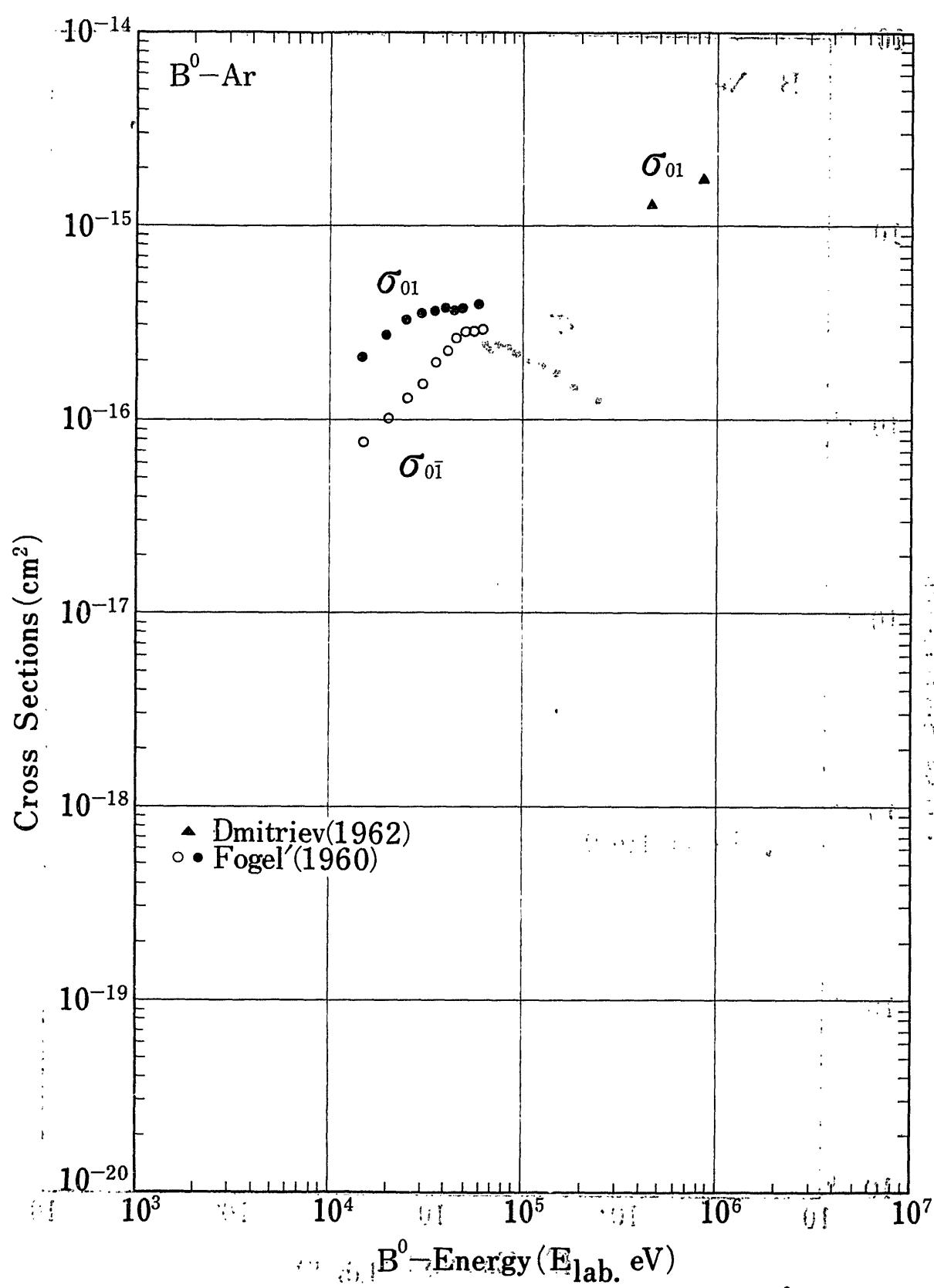


Fig.16 Charge Changing Cross Sections of B^0 in Ar

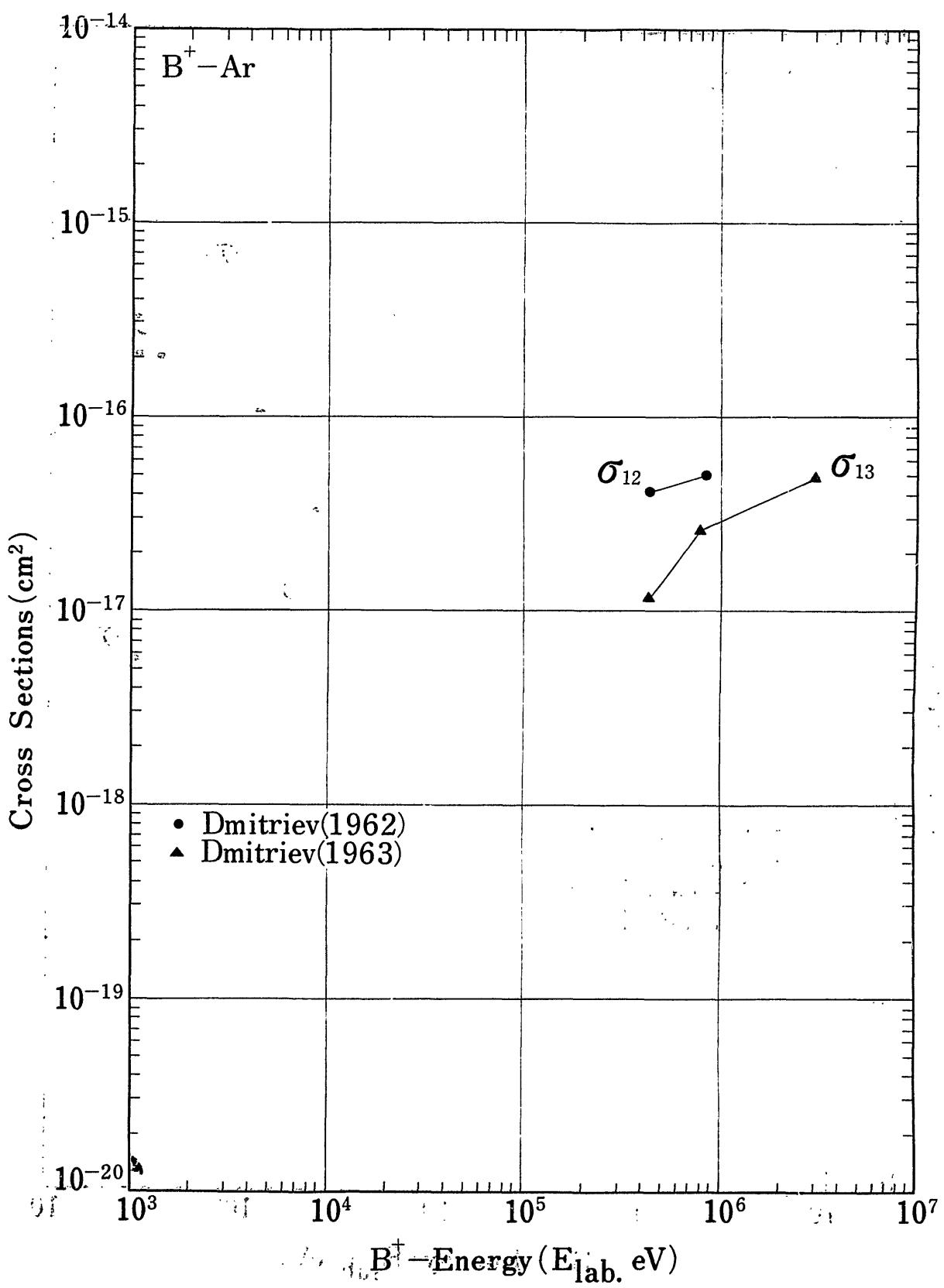


Fig. 17 Charge-Changing Cross Sections of B^+ in Ar

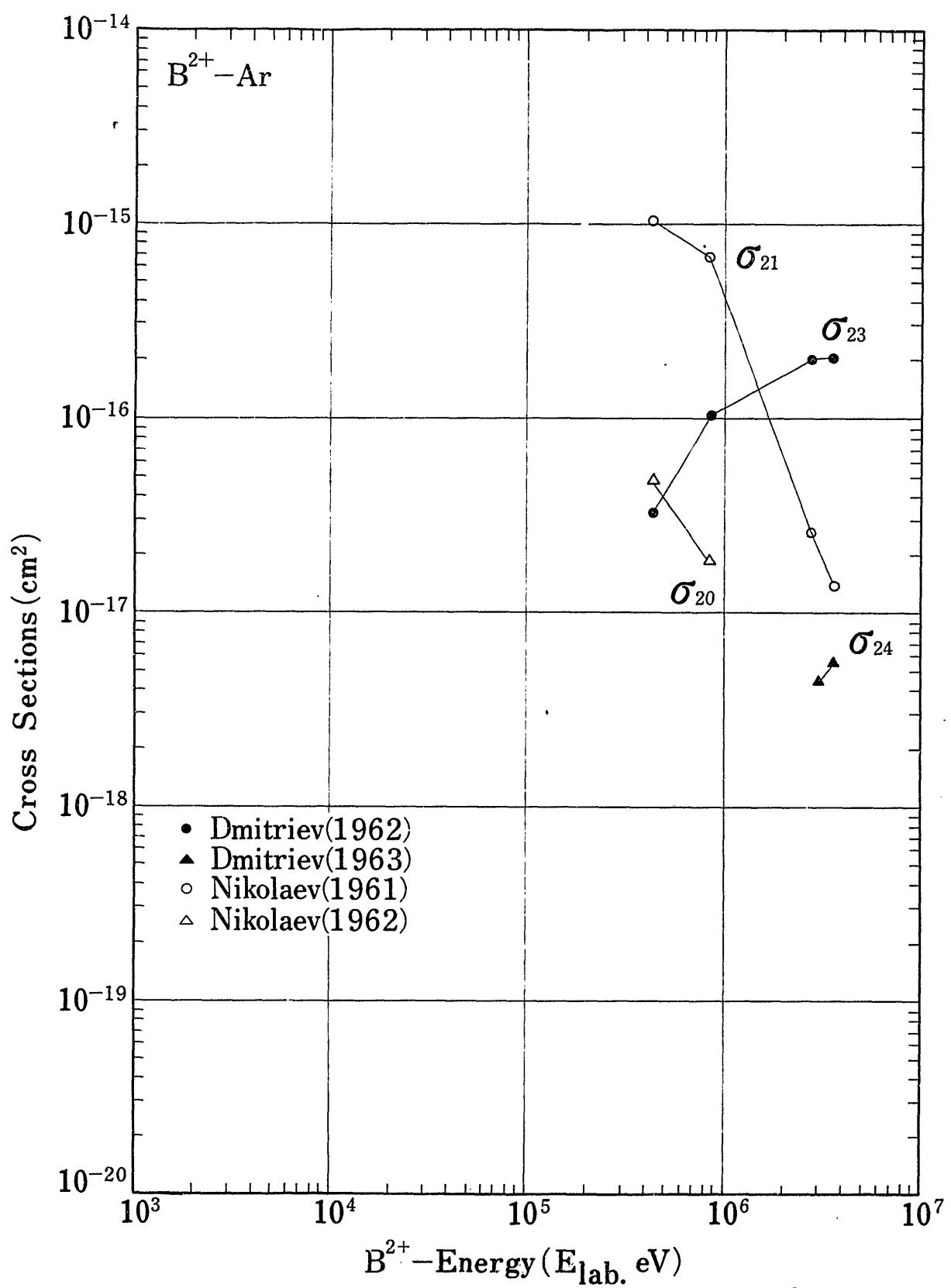


Fig.18 Charge Changing Cross Sections of B^{2+} in Ar

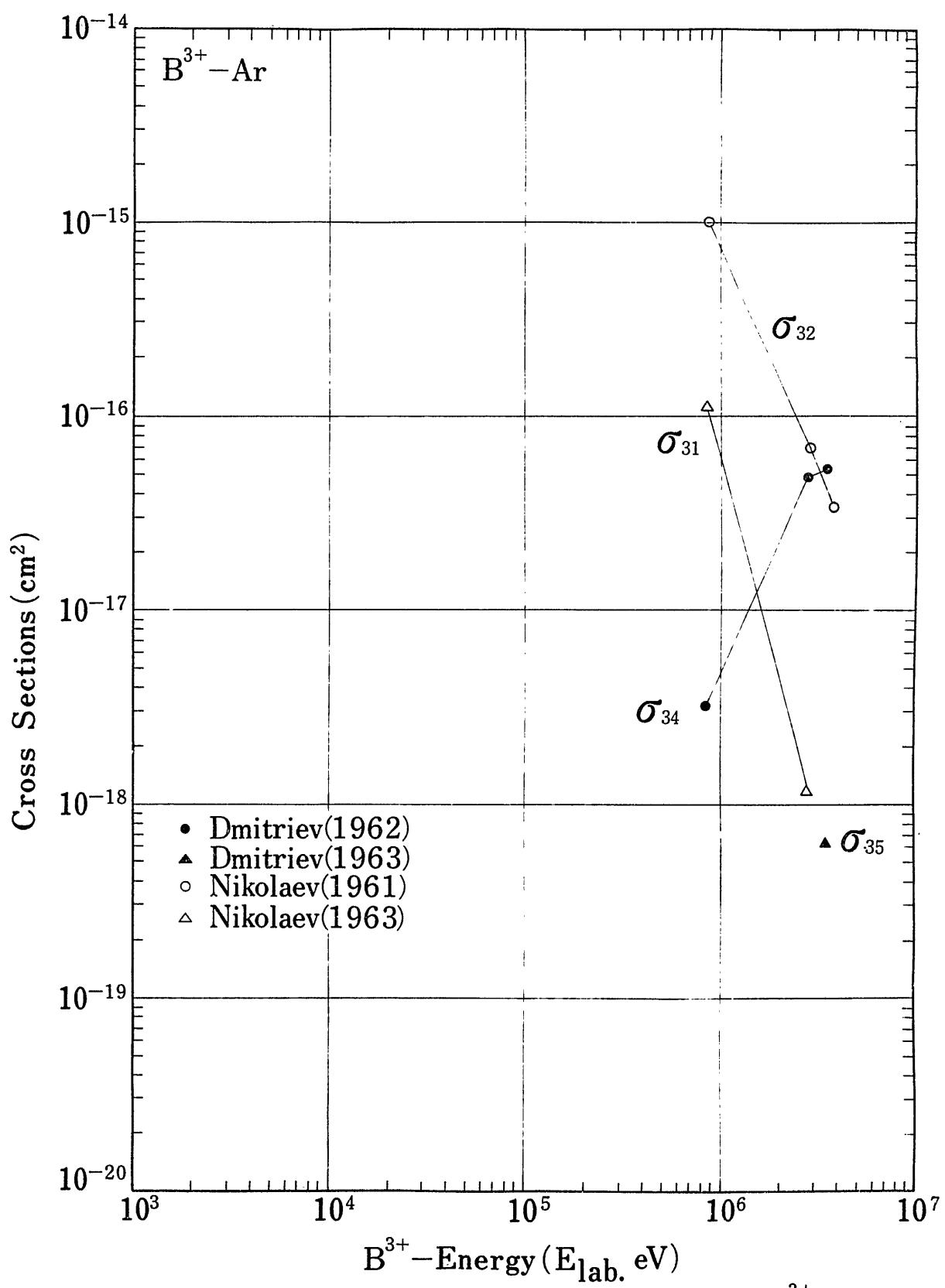


Fig.19 Charge Changing Cross Sections of B^{3+} in Ar

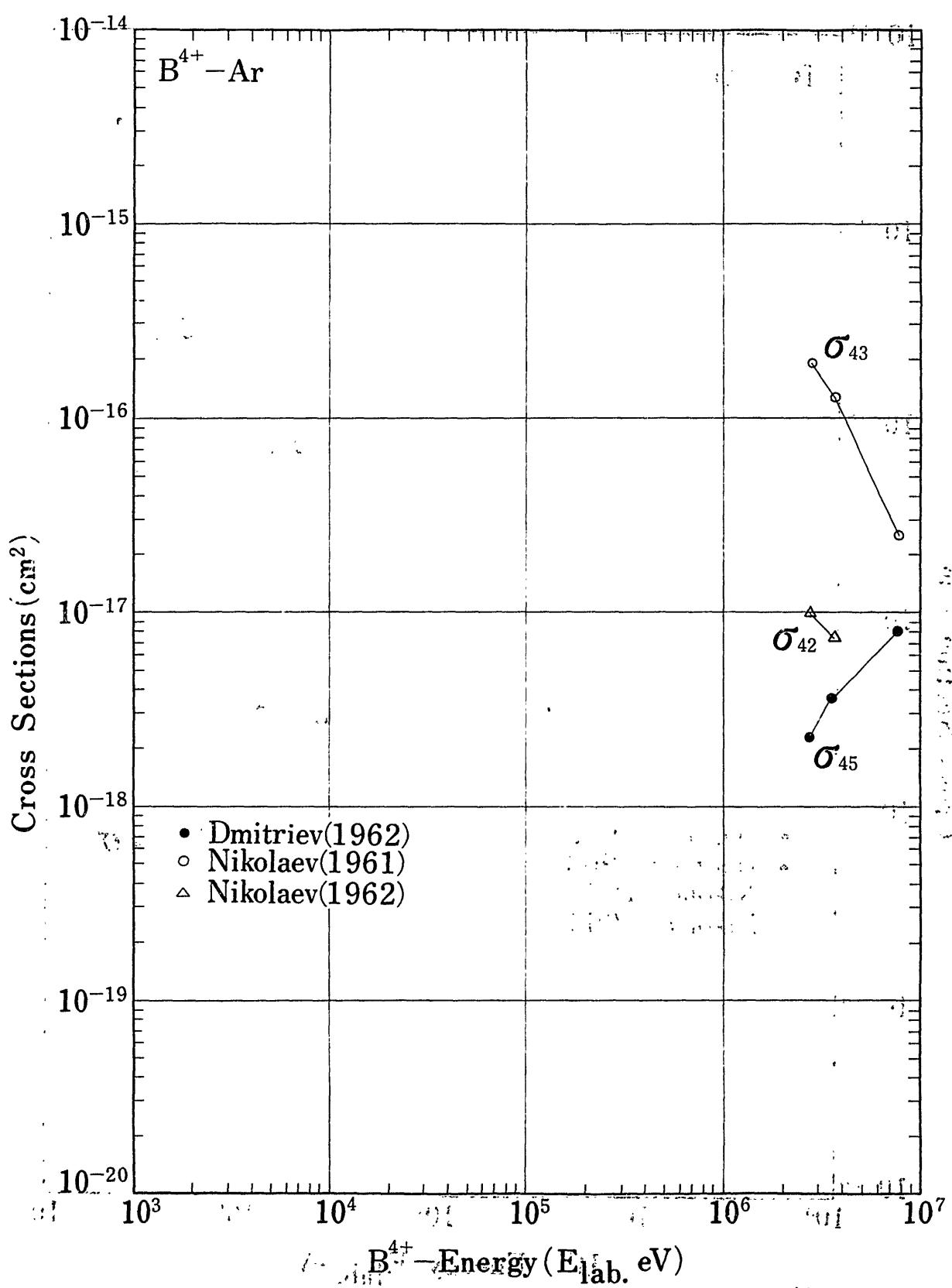


Fig. 20 Charge Changing Cross Sections of B^{4+} in Ar

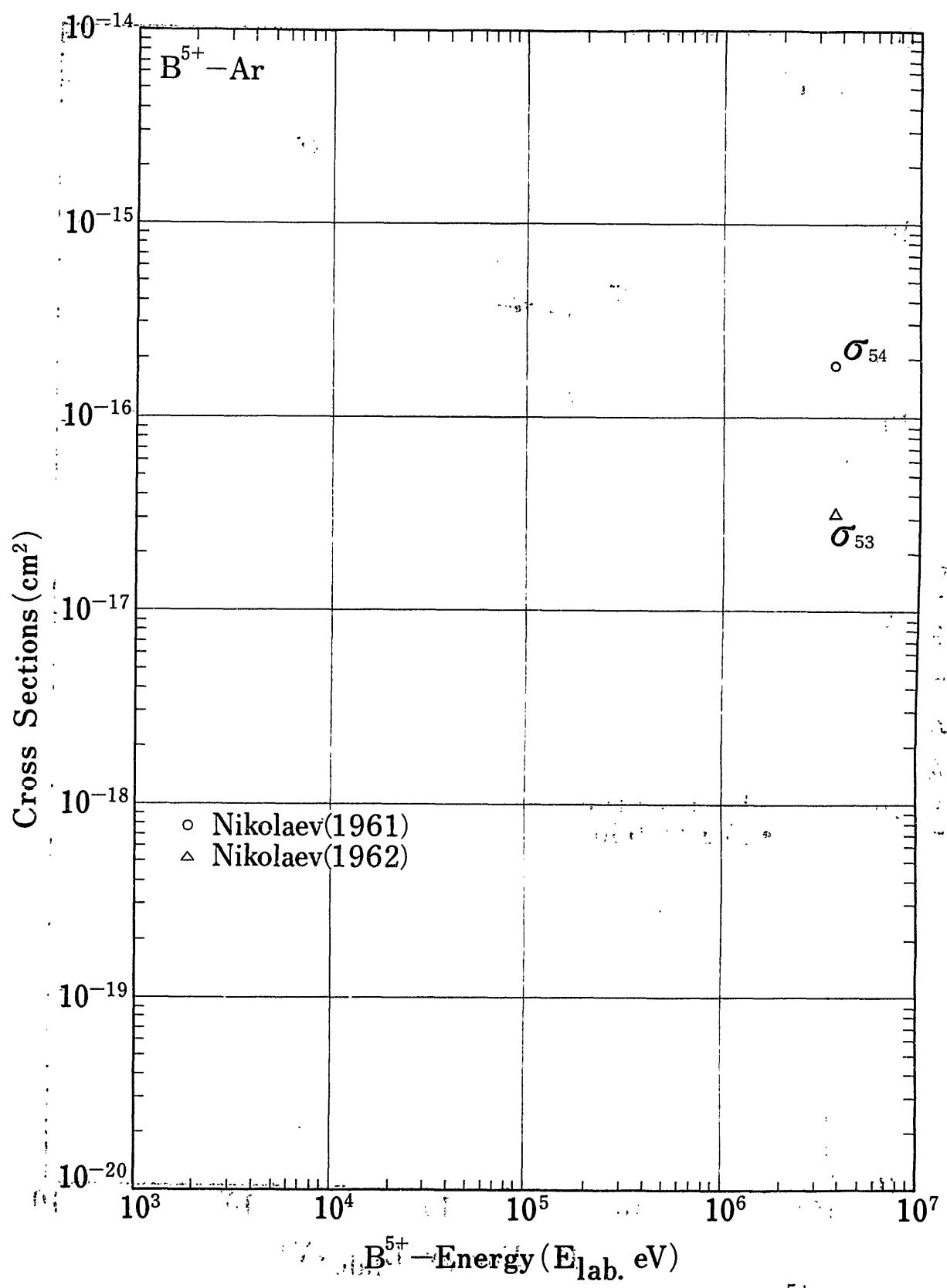


Fig. 21 Charge Changing Cross Sections of B^{5+} in Ar

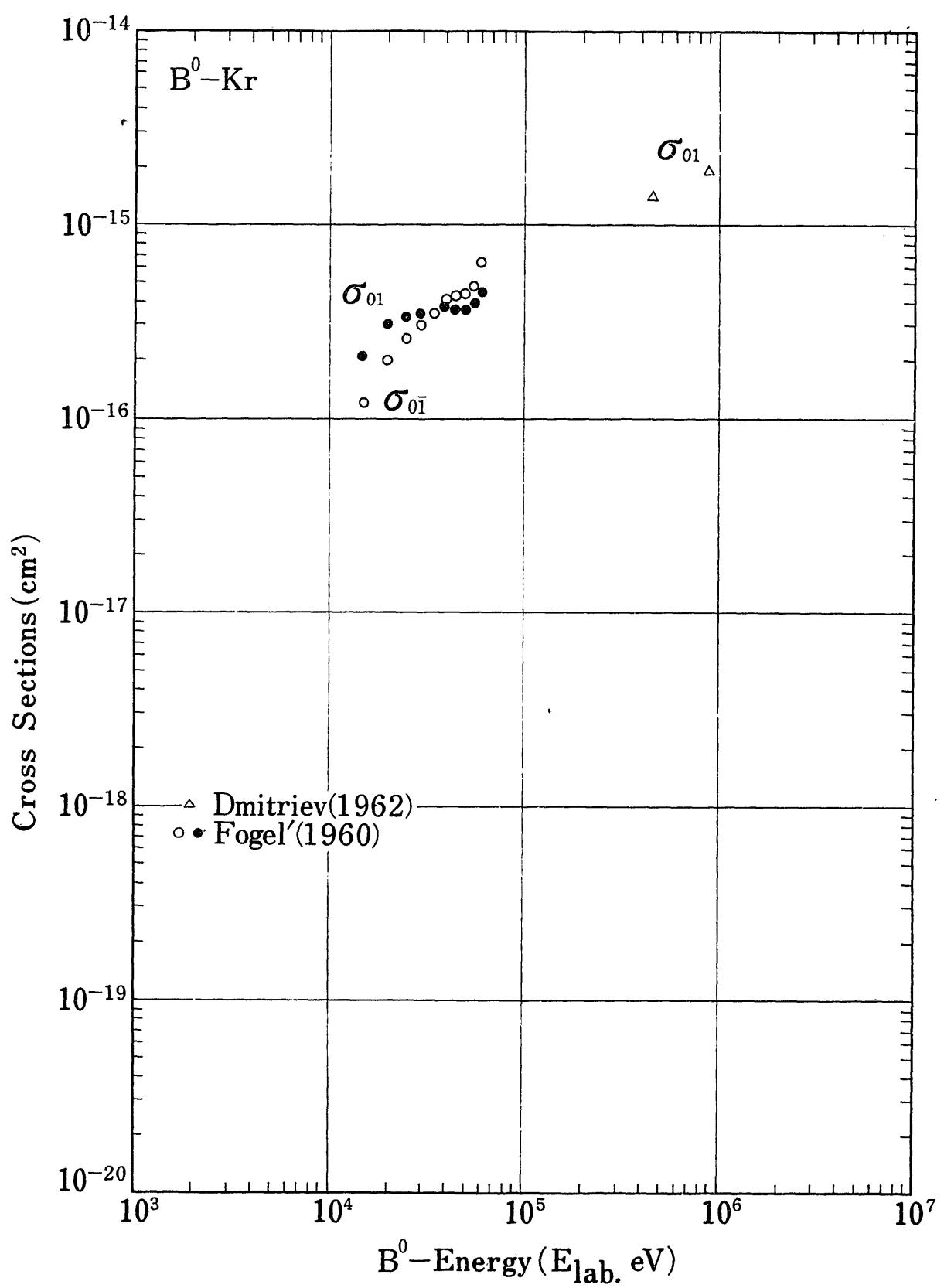


Fig.22 Charge Changing Cross Sections of B^0 in Kr

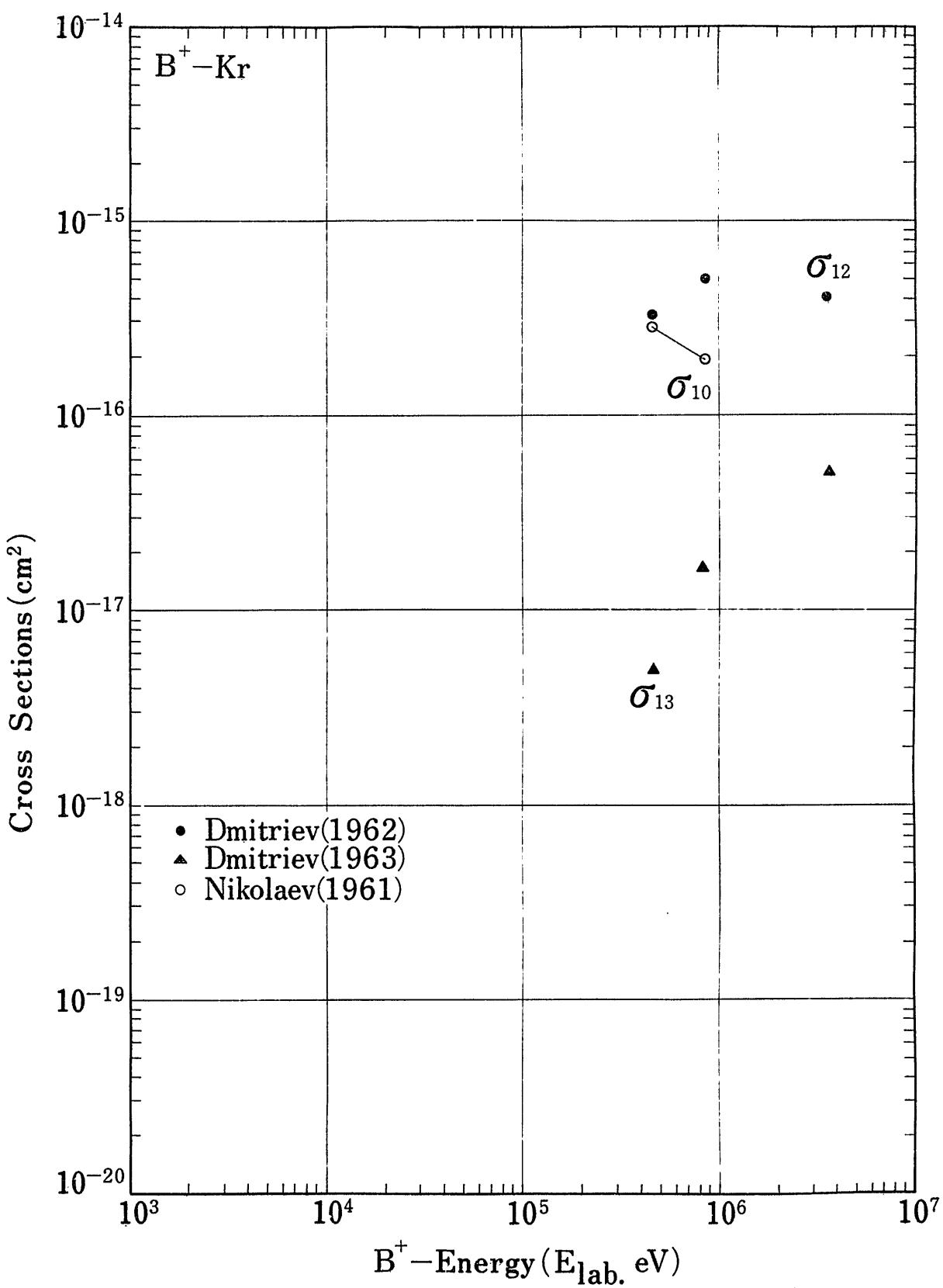


Fig.23 Charge Changing Cross Sections of B^+ in Kr

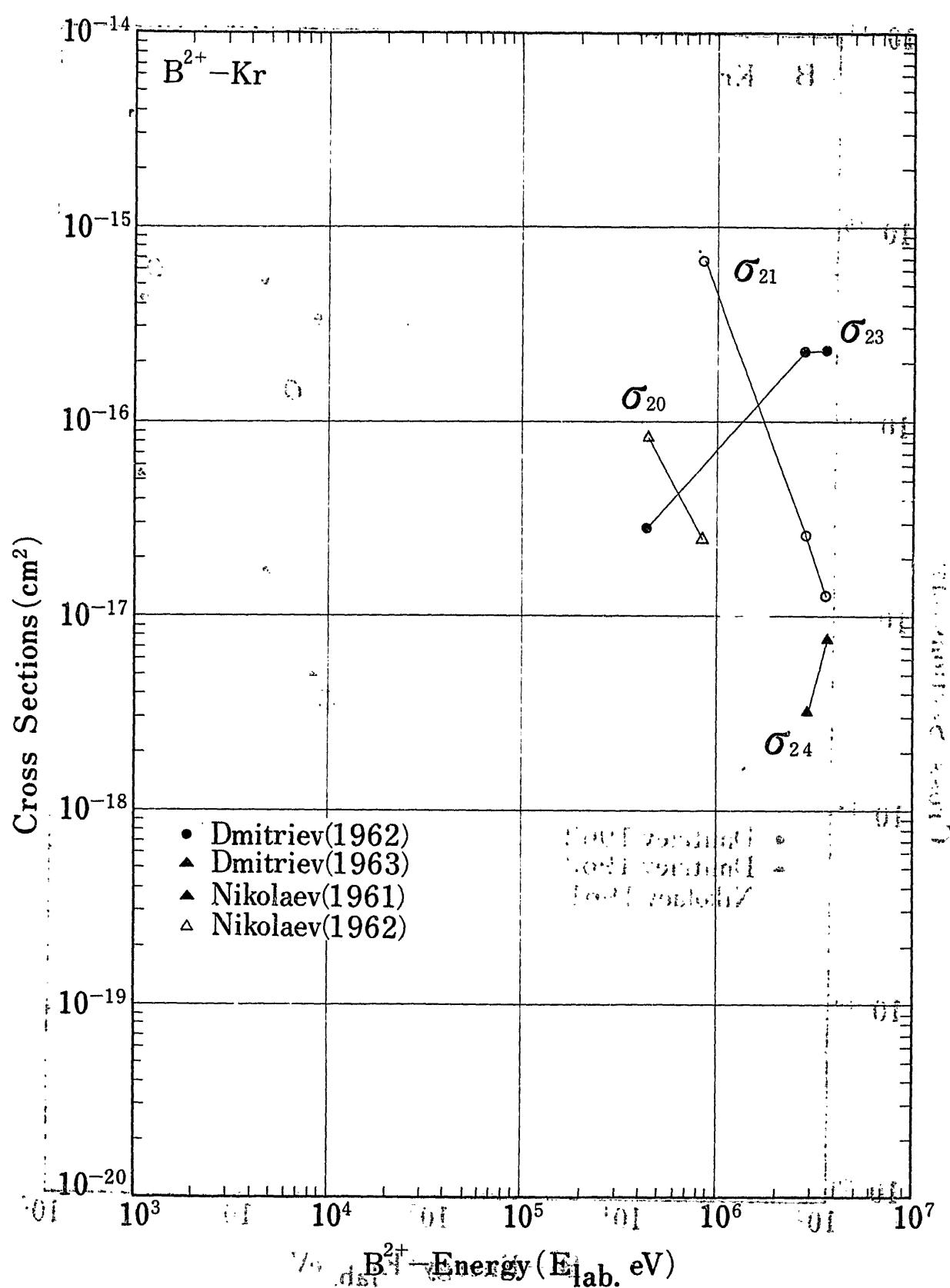


Fig.24 Change-Changing Cross Sections of B^{2+} in Kr

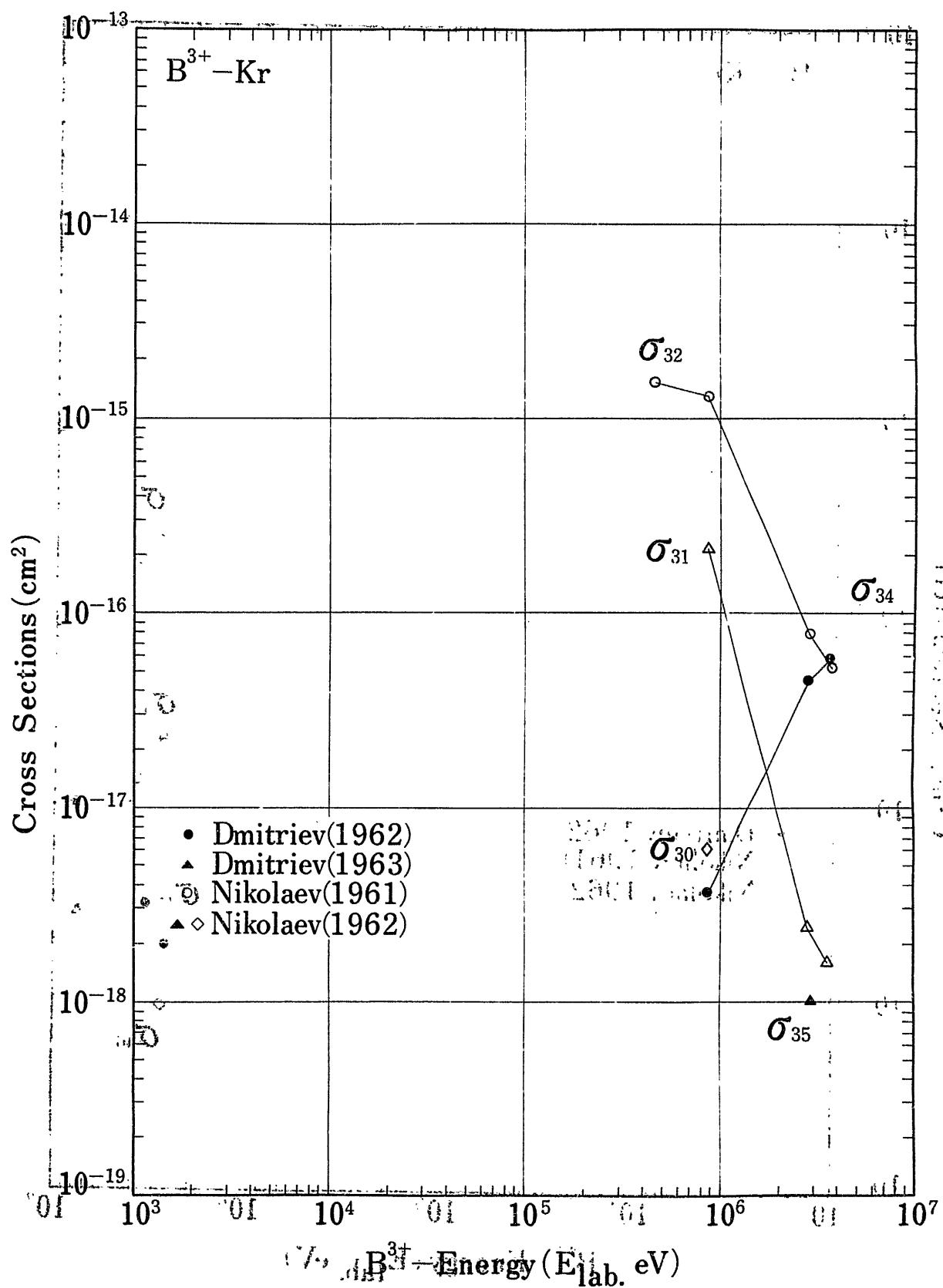


Fig. 25 Charge Changing Cross Sections of B^{3+} in Kr

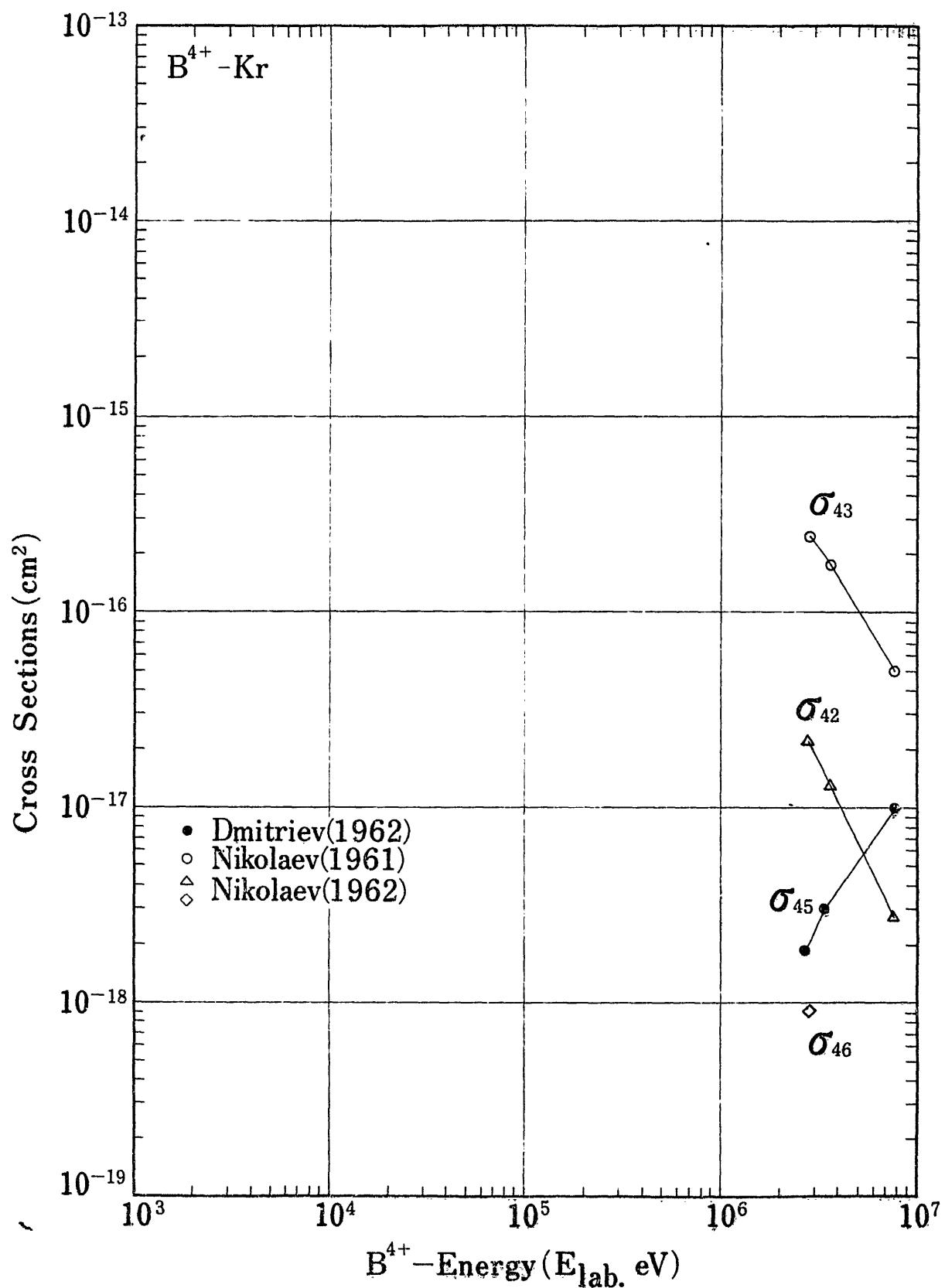


Fig.26 Charge Changing Cross Sections of B^{4+} in Kr

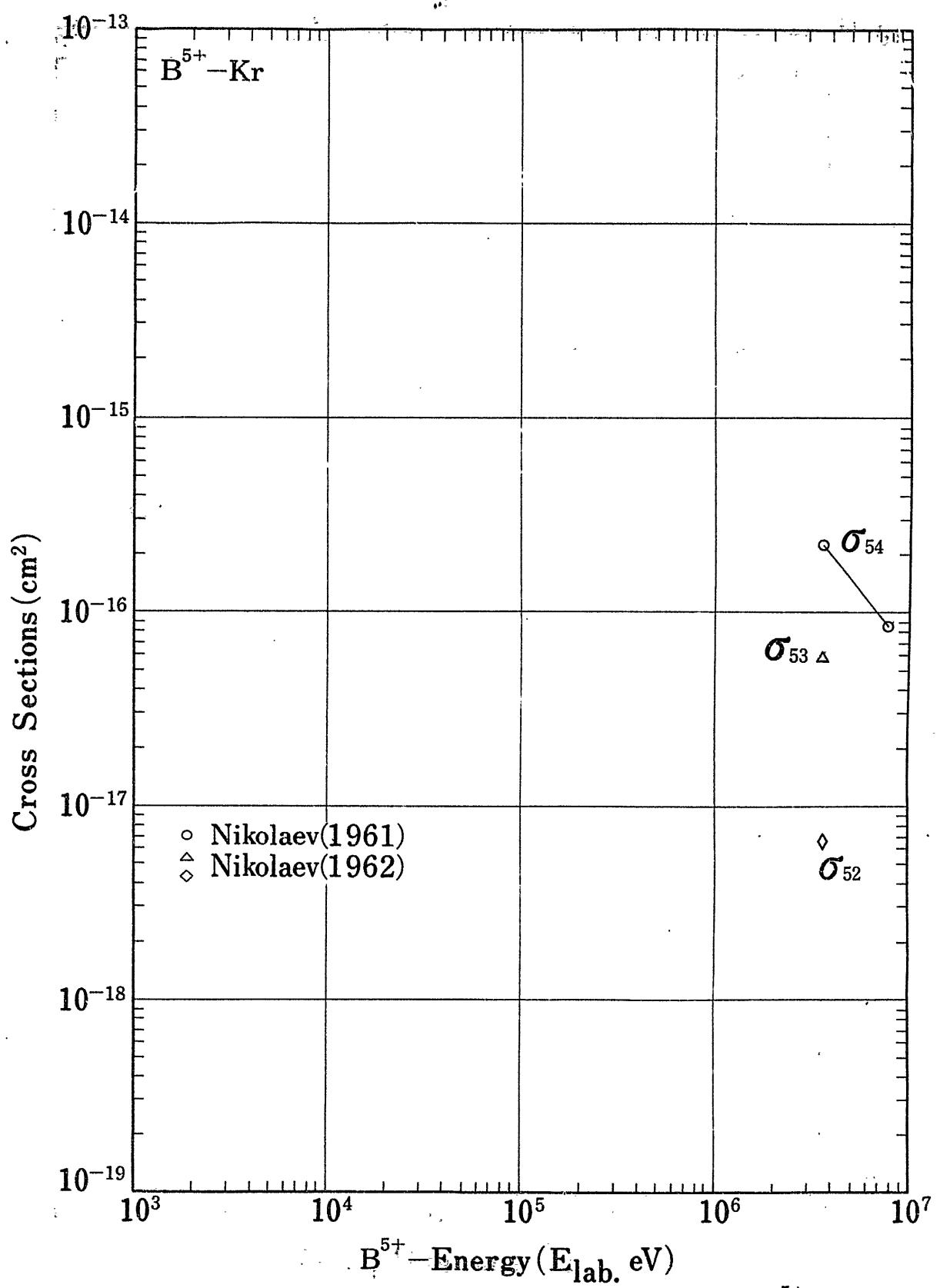


Fig. 27 Charge Changing Cross Sections of B^{5+} in Kr

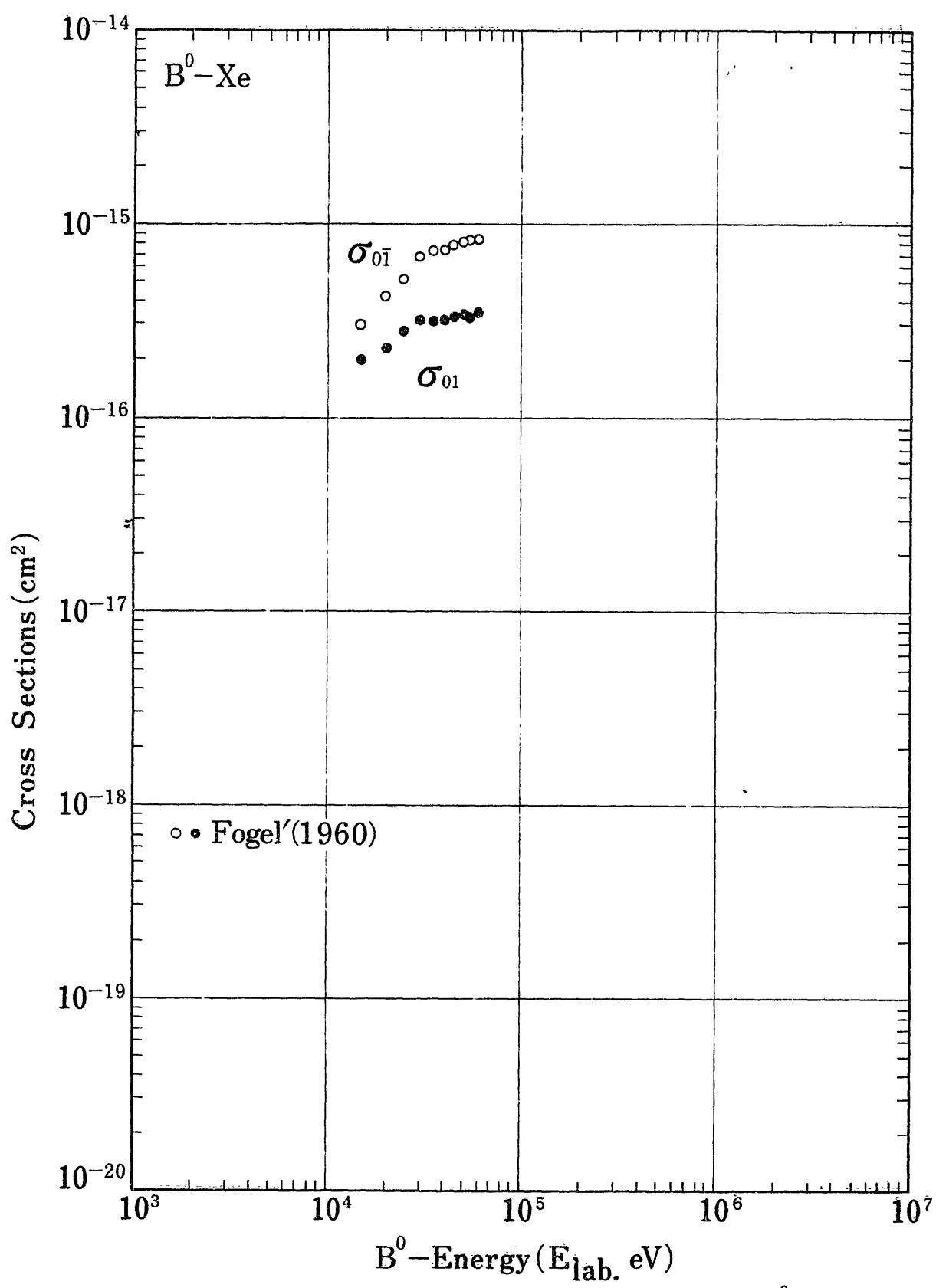


Fig.28 Charge Changing Cross Sections of B^0 in Xe

