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

III. INCIDENCE OF F, Ne, Na 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 $Z = 9 - 11$ in collisions with atoms and simple molecules. A systematic survey of the leterature 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 articles[1-7] 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 Russek[6] and Tawara[7], 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

$$A^{i+} + B \rightarrow A^{j+} + B^{k+} + (j+k-i)\ e\ , \qquad (1)$$

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 groupes: (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.

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Charge Changing Cross Sections of Fluorine Atoms and Ions, Z=9.

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 F (z=9)

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II. Table of Experimental Data

A) Electron Capture Cross Sections of Fluorine Atom and Positive Ions F°, F^{+}, F^{2+}, F^{4+}, F^{5+}, F^{6+}, F^{7+}, F^{8+}, F^{9+}.

authors	year	energy(eV)	target	reference
($\sigma_{0\,\bar{1}}$)				
Fogel' et al.	1960	10,000-60,000	He,Ne,Ar,Kr,Xe	3
Ormrod,Michel	1971	20,000-75,000	N_2,Ar	8
(σ_{10})				
Ormrod,Michel	1971	15,000-80,000	N_2,Ar	8
Lockwood	1974	13,700-100,400	H_2,He,N_2,Ne,Ar	6
(σ_{21})				
Ormrod,Michel	1971	40,000-90,000	N_2,Ar	8
(σ_{43})				
Ferguson et al.	1973	7,980,000-28,500,000	Ar	1
(σ_{42})				
Ferguson et al.	1973	7,980,000	Ar	1
(σ_{54})				
Ferguson et al.	1973	7,980,000-39,400,000	Ar	1
(σ_{53})				
Ferguson et al.	1973	7,980,000-25,200,000	Ar	1
(σ_{65})				
Ferguson et al.	1973	7,980,000-39,400,000	Ar	1

authors	year	energy(eV)	target	reference
(σ_{64})				
Ferguson et al.	1973	7,980,000-39,400,000	Ar	1
(σ_{63})				
Ferguson et al.	1973	7,980,000-25,200,000	Ar	1
(σ_{76})				
Ferguson et al.	1973	7,980,000-52,100,000	Ar	1
(σ_{75})				
Ferguson et al.	1973	7,980,000-52,100,000	Ar	1
(σ_{74})				
Ferguson et al.	1973	7,980,000-31,900,000	Ar	1
(σ_{73})				
Ferguson et al.	1973	7,980,000-25,200,000	Ar	1
(σ_{87})				
Ferguson et al.	1973	7,980,000-52,100,000	Ar	1
(σ_{86})				
Ferguson et al.	1973	7,980,000-52,100,000	Ar	1
(σ_{85})				
Ferguson et al.	1973	7,980,000-52,100,000	Ar	1
(σ_{84})				
Ferguson et al.	1973	7,980,000-35,500,000	Ar	1
(σ_{98})				
Ferguson et al.	1973	7,980,000-52,100,000	Ar	1

authors	year	energy(eV)	target	references
(σ_{97})				
Ferguson et al.	1973	7,980,000-52,100,000	Ar	1
(σ_{96})				
Ferguson et al.	1973	7,980,000-52,100,000	Ar	1
(σ_{95})				
Ferguson et al.	1973	7,980,000-52,100,000	Ar	1

B) Electron Loss Cross Sections of Fluorine Negative Ion, Atom and Positive Ions; F^-, F°, F^{3+}, F^{4+}, F^{5+}, F^{6+}, F^{7+}, F^{8+}.

authors	year	energy(eV)	target	references
($\sigma_{\bar{1}0}$)				
Ormrod,Michel	1971	25,000-85,000	N_2,Ar	8
(σ_{01})				
Forgel' et al	1960	10,000-60,000	He,Ne,Ar,Kr,Xe	3
Ormrod,Michel	1971	20,000-80,000	N_2,Ar	8
(σ_{34})				
Ferguson et al.	1973	9,850,000-14,200,000	Ar	1
(σ_{35})				
Ferguson et al.	1973	9,850,000-14,200,000	Ar	1
(σ_{36})				
Ferguson et al.	1973	9,850,000-14,200,000	Ar	1
(σ_{37})				
Ferguson et al.	1973	9,850,000-14,2000,000	Ar	1

authors	year	energy (eV)	target	references
(σ_{45})				
Ferguson et al.	1973	7,980,000-30,200,000	Ar	1
(σ_{46})				
Ferguson et al.	1973	7,980,000-30,200,000	Ar	1
(σ_{47})				
Ferguson et al.	1973	7,980,000-30,200,000	Ar	1
(σ_{48})				
Ferguson et al.	1973	7,980,000-19,300,000	Ar	1
(σ_{56})				
Ferguson et al.	1973	7,980,000-39,400,000	Ar	1
(σ_{57})				
Ferguson et al.	1973	7,980,000-39,400,000	Ar	1
(σ_{58})				
Ferguson et al.	1973	9,850,000-39,400,000	Ar	1
(σ_{59})				
Ferguson et al.	1973	19,300,000-22,200,000	Ar	1
(σ_{67})				
Ferguson et al.	1973	7,980,000-39,400,000	Ar	1
(σ_{68})				
Ferguson et al.	1973	7,980,000-39,400,000	Ar	1

authors	year	energy(eV)	target	references
(σ_{69})				
Ferguson et al.	1973	14,200,000-39,400,000	Ar	1
(σ_{78})				
Ferguson et al.	1973	7,980,000-52,100,000	Ar	1
(σ_{79})				
Ferguson et al.	1973	7,980,000-52,100,000	Ar	1
(σ_{89})				
Ferguson et al.	1973	14,200,000-52,100,000	Ar	1

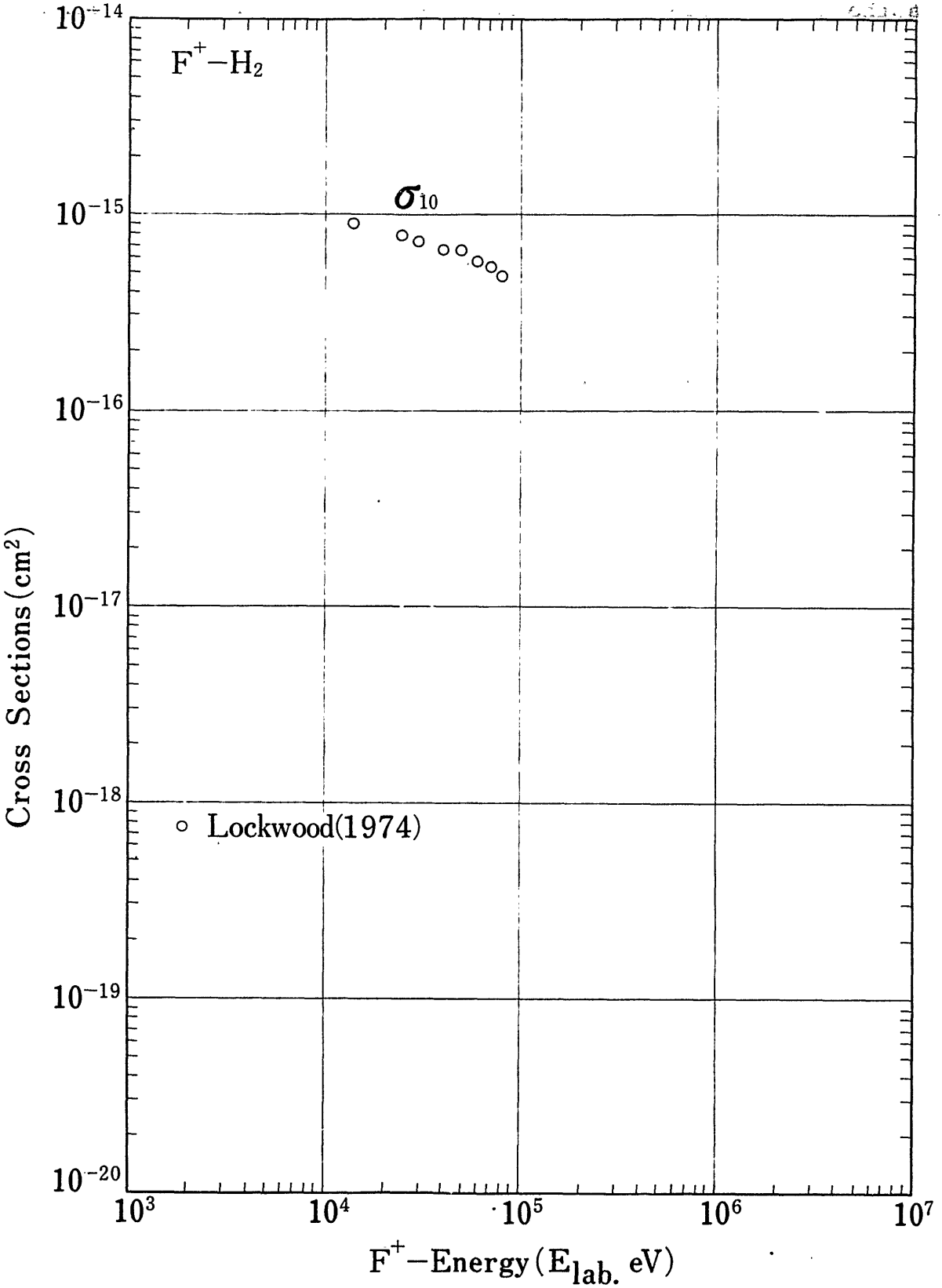

Fig.1 Charge Changing Cross Sections of F^+ in H_2

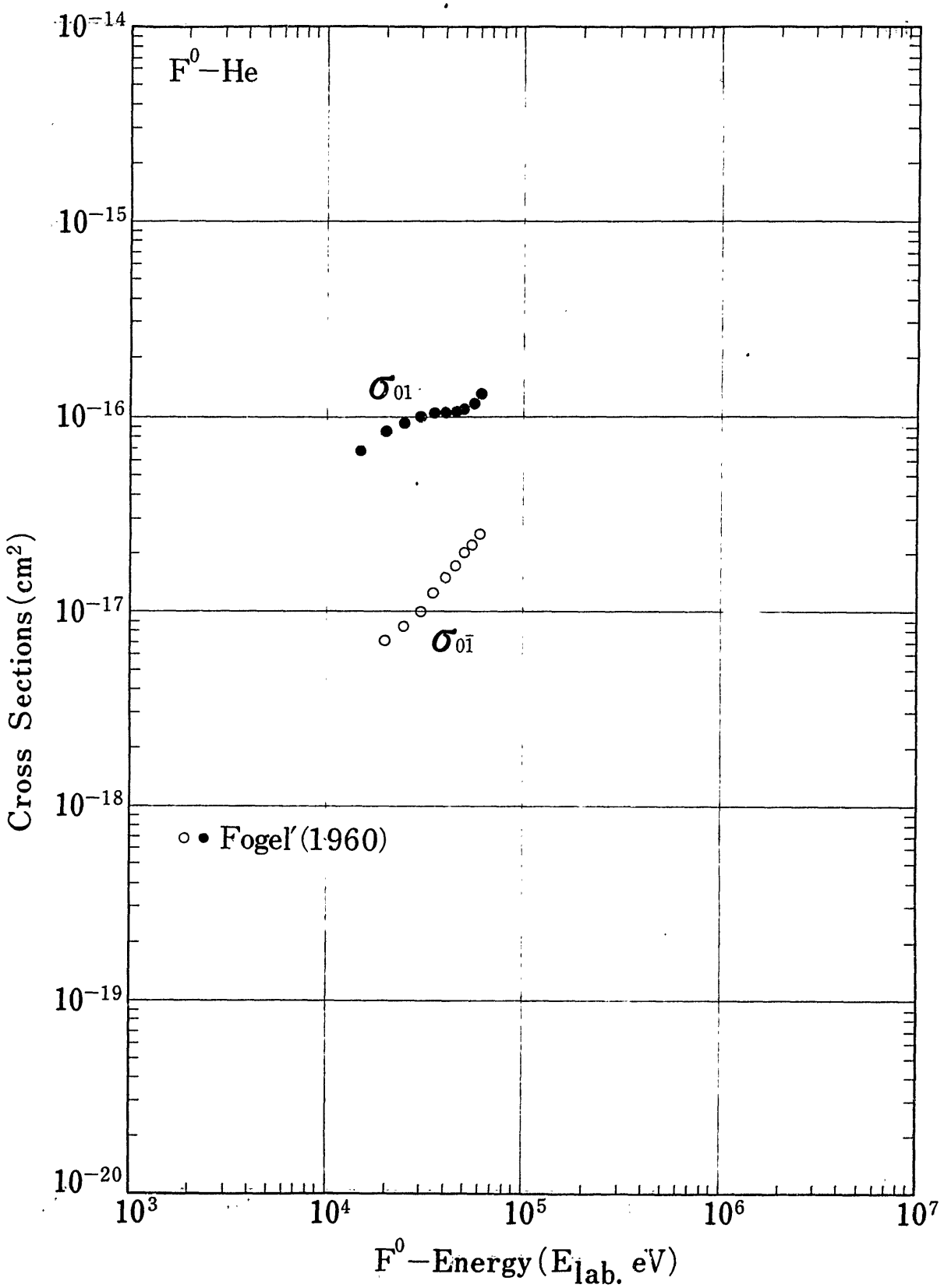

Fig.2 Charge Changing Cross Sections of F^0 in He

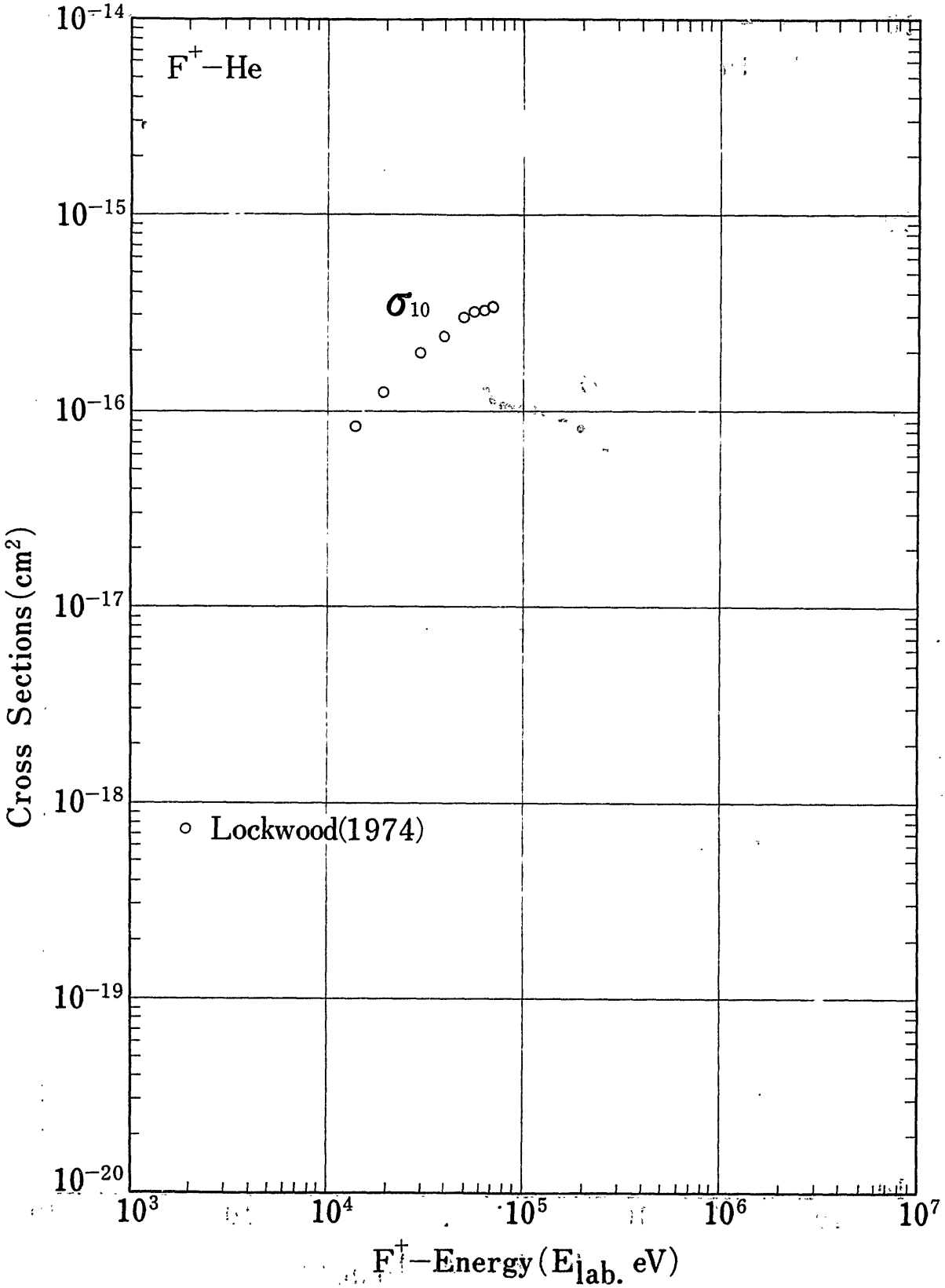

Fig.3 Charge Changing Cross Sections of F^+ in He

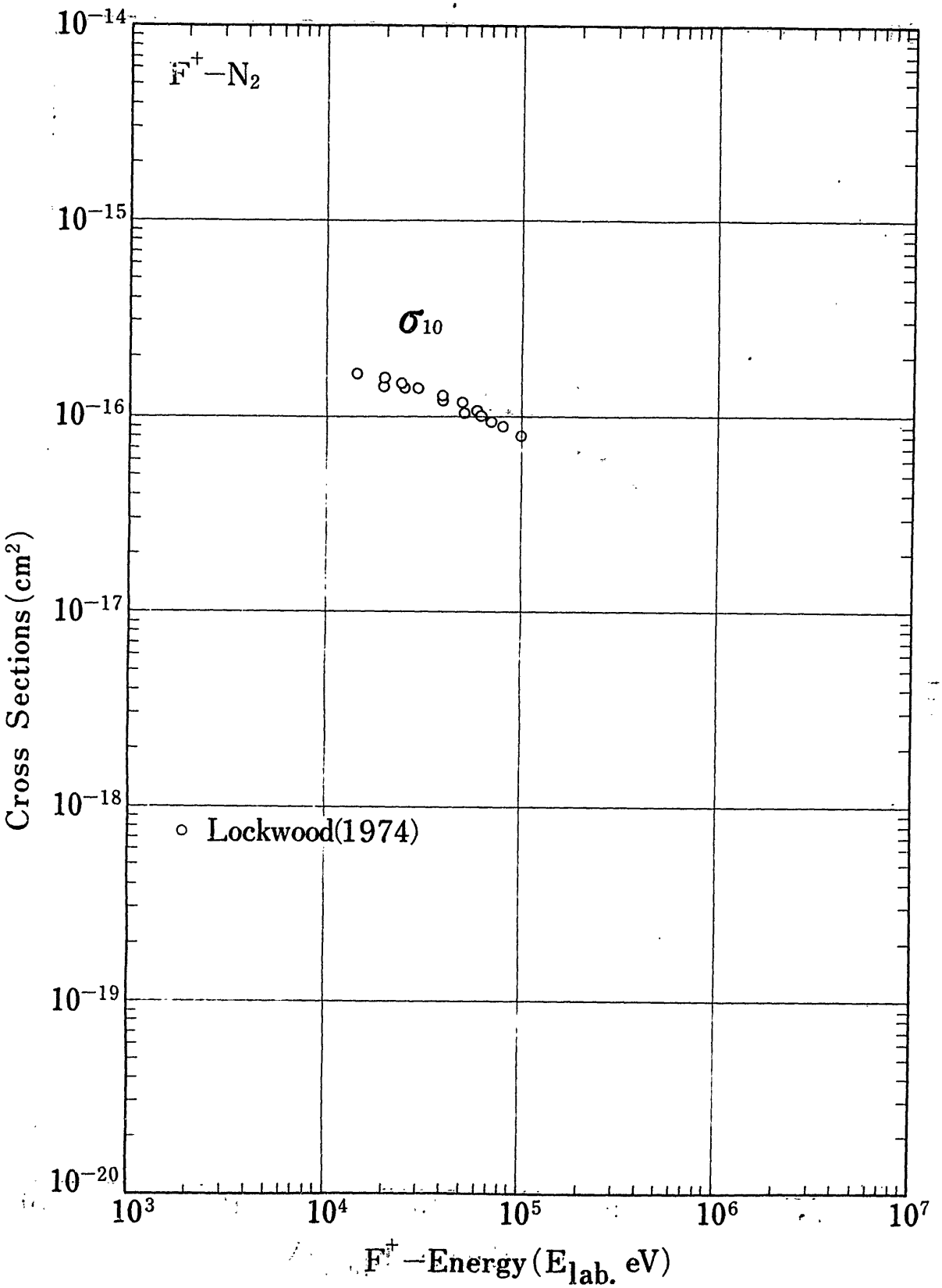

Fig.4 Charge Changing Cross Sections of F^+ in N_2

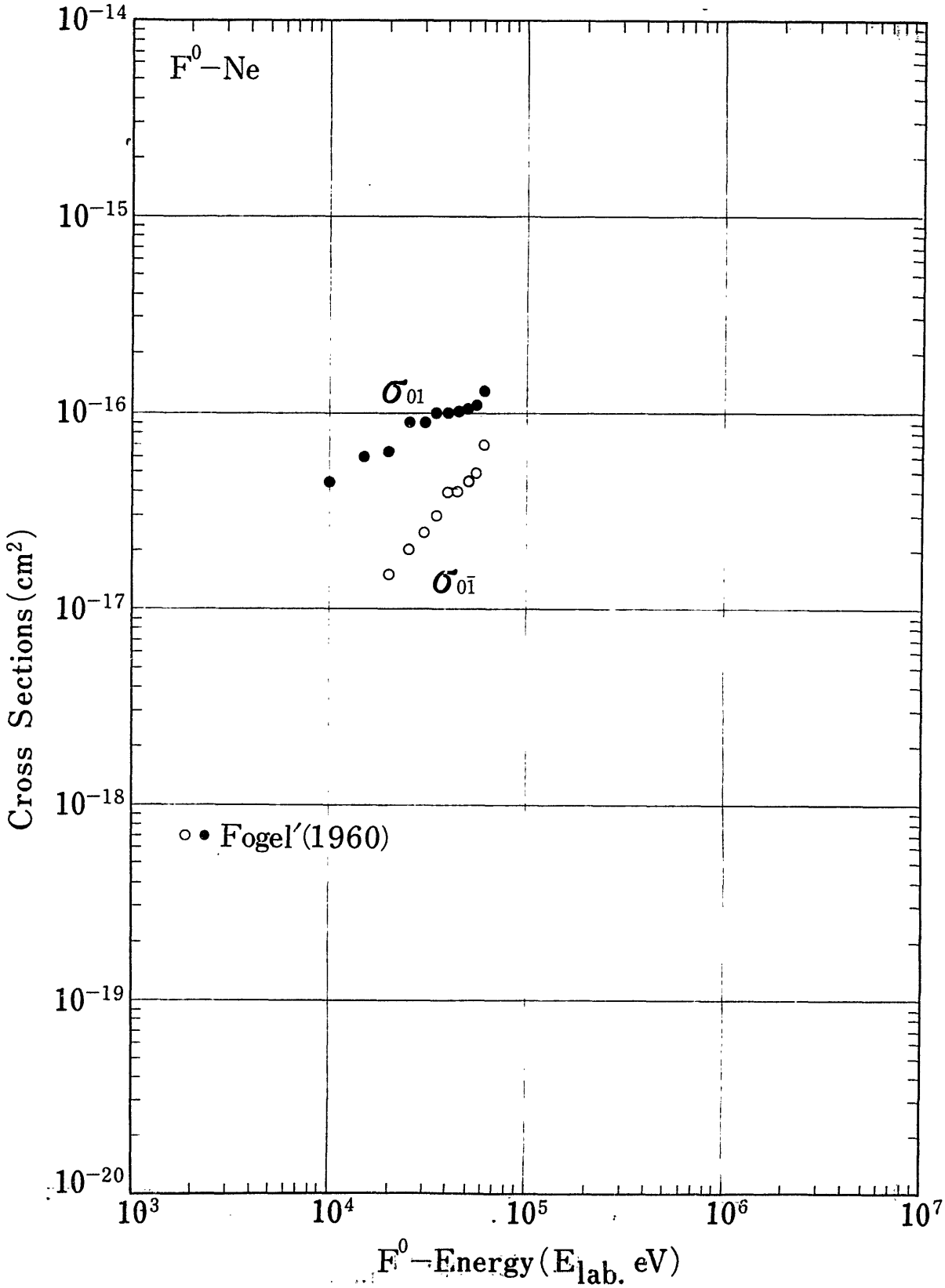

Fig. 5 Charge Changing Cross Sections of F^0 in Ne

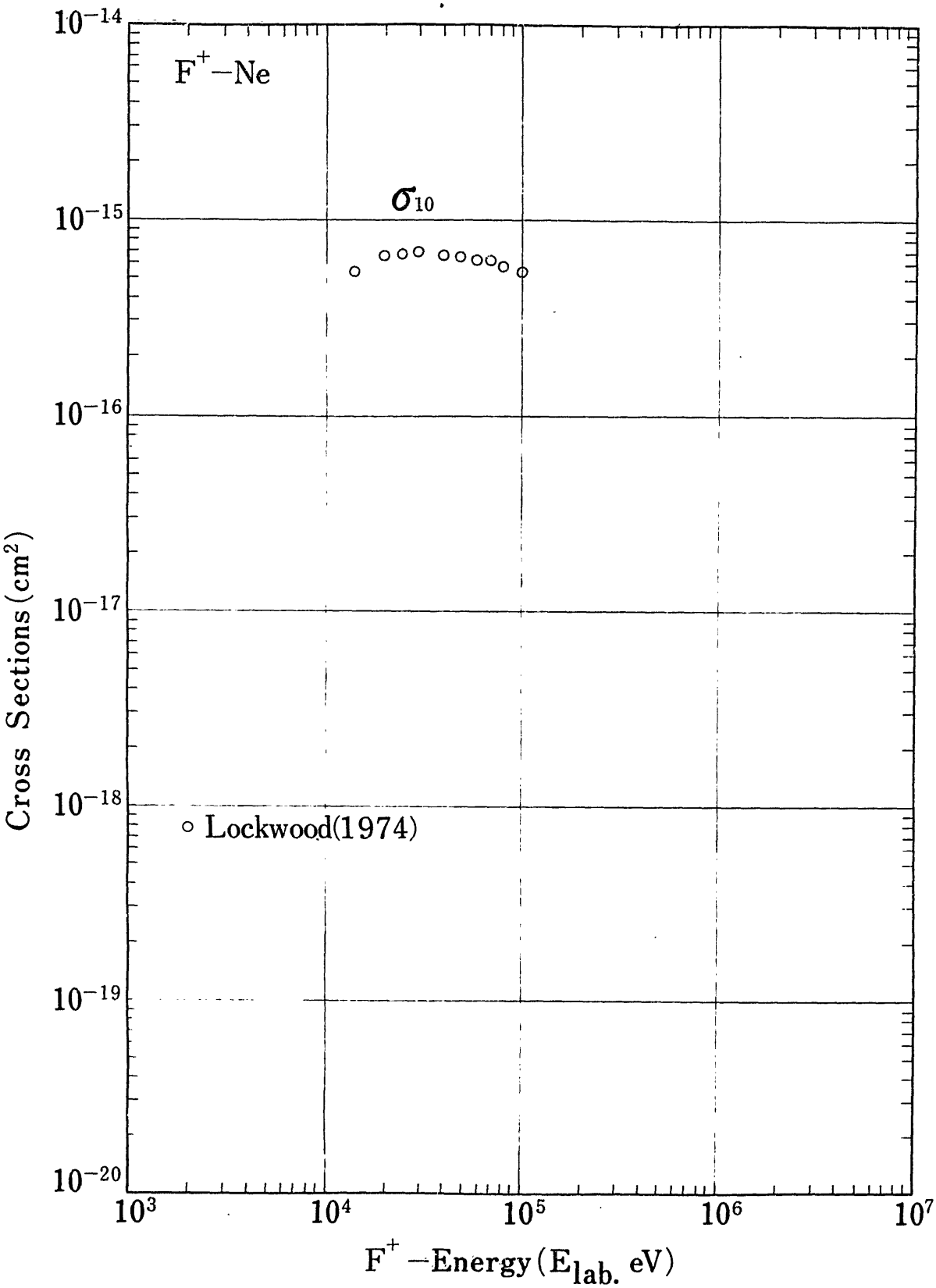

Fig.6 Charge Changing Cross Sections of F^+ in Ne

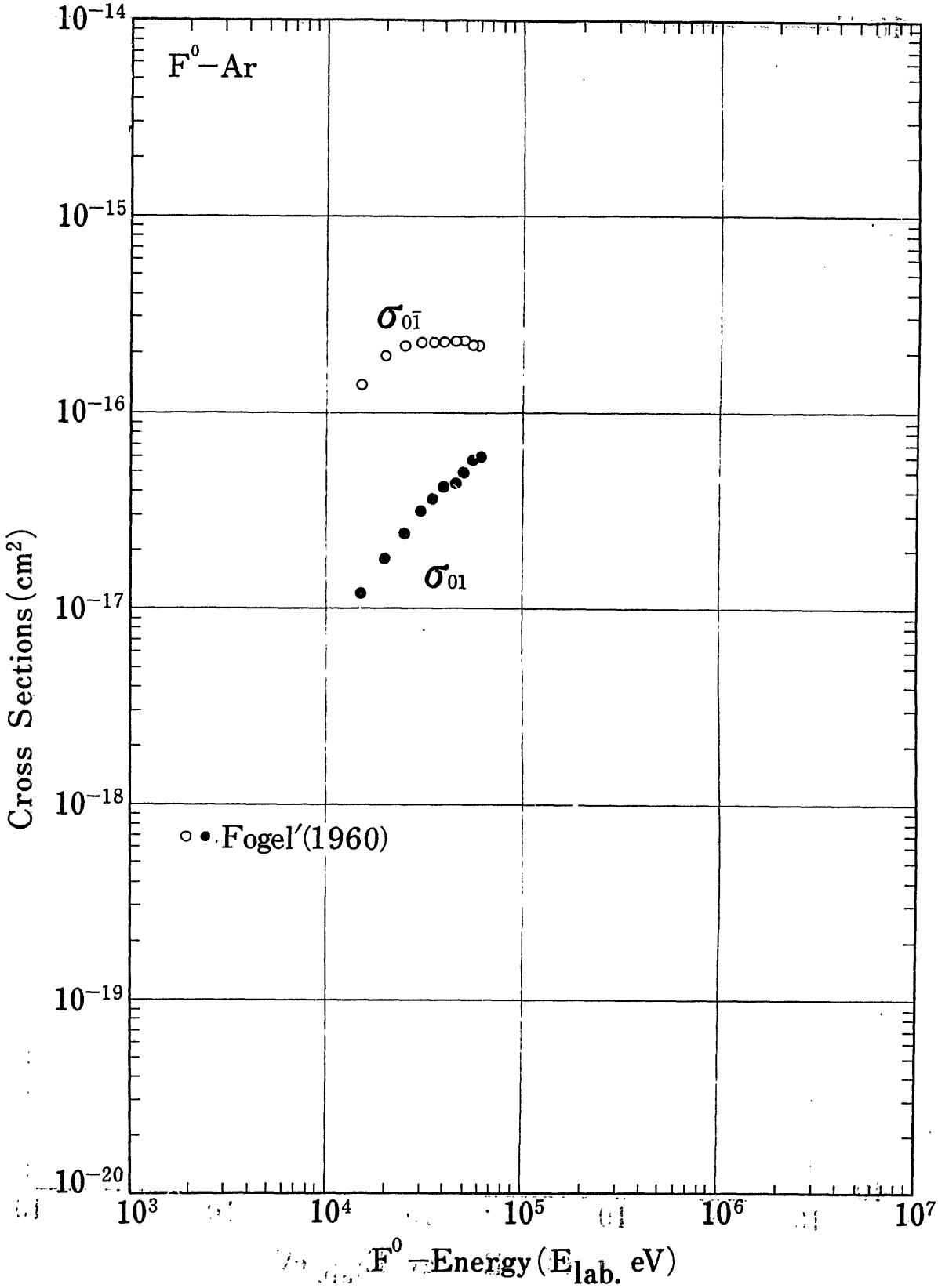

Fig.7 Charge Changing Cross Sections of F^0 in Ar

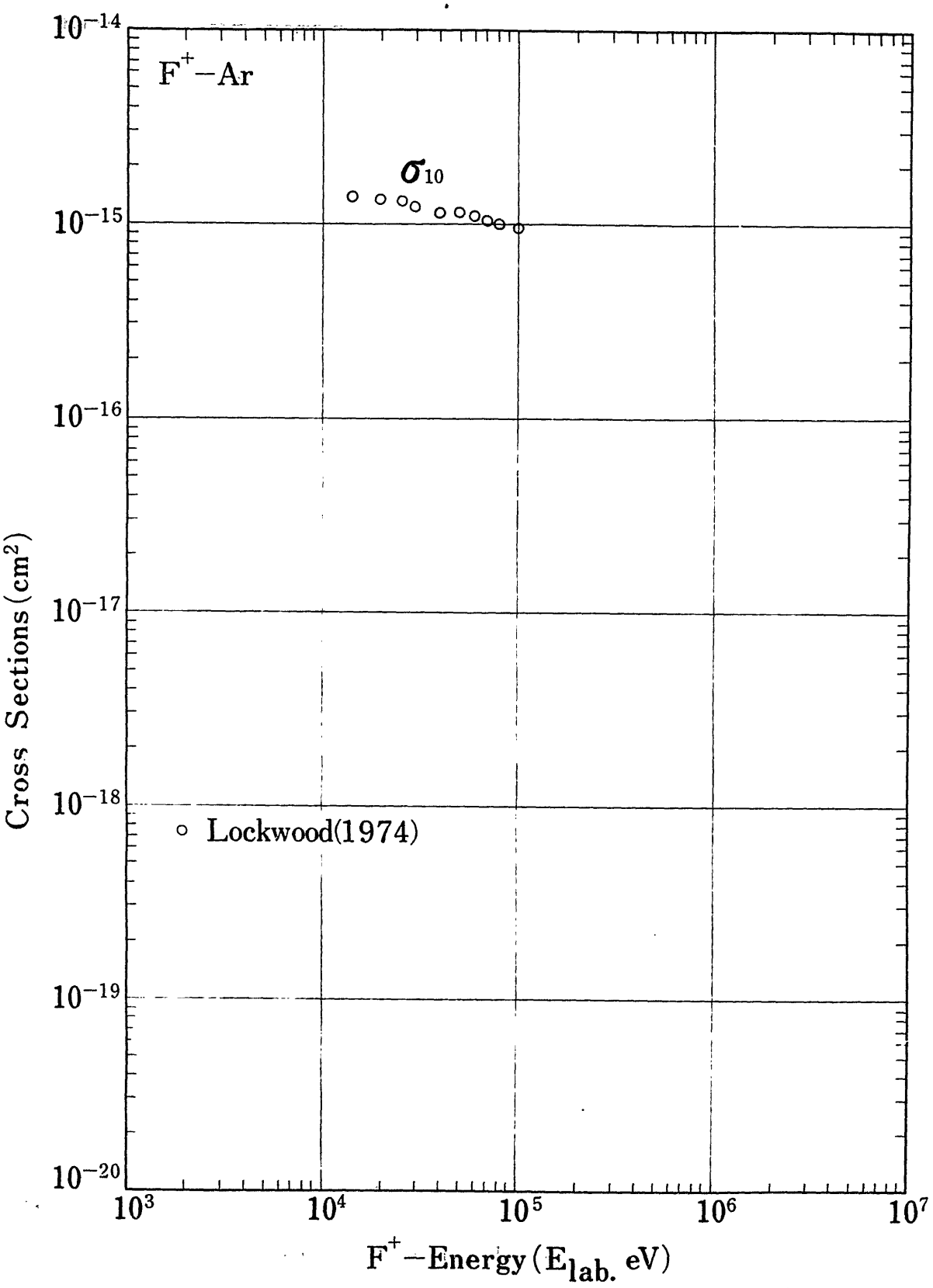

Fig.8 Charge Changing Cross Sections of F^+ in Ar

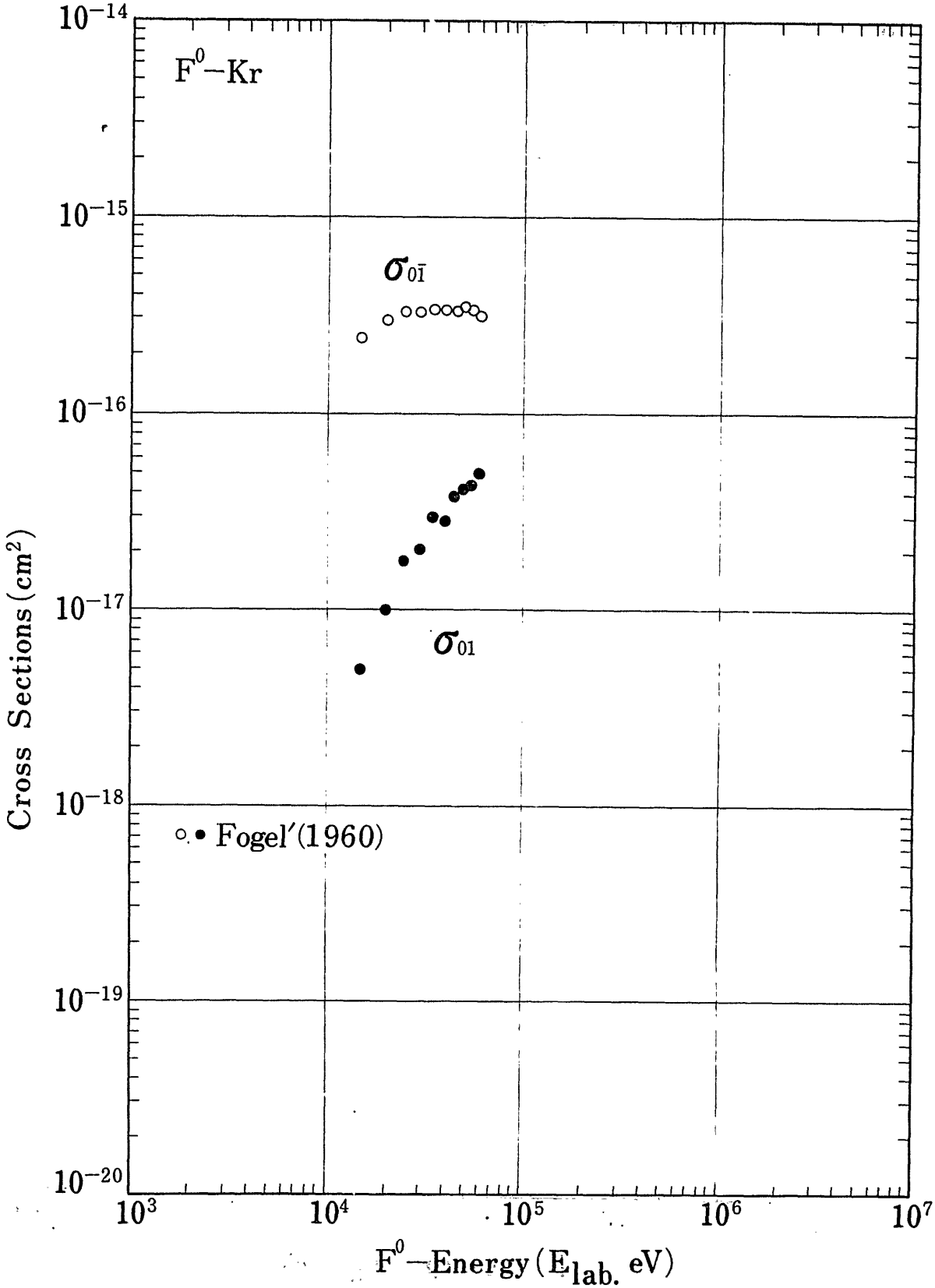

Fig.9 Charge Changing Cross Sections of F^0 in Kr

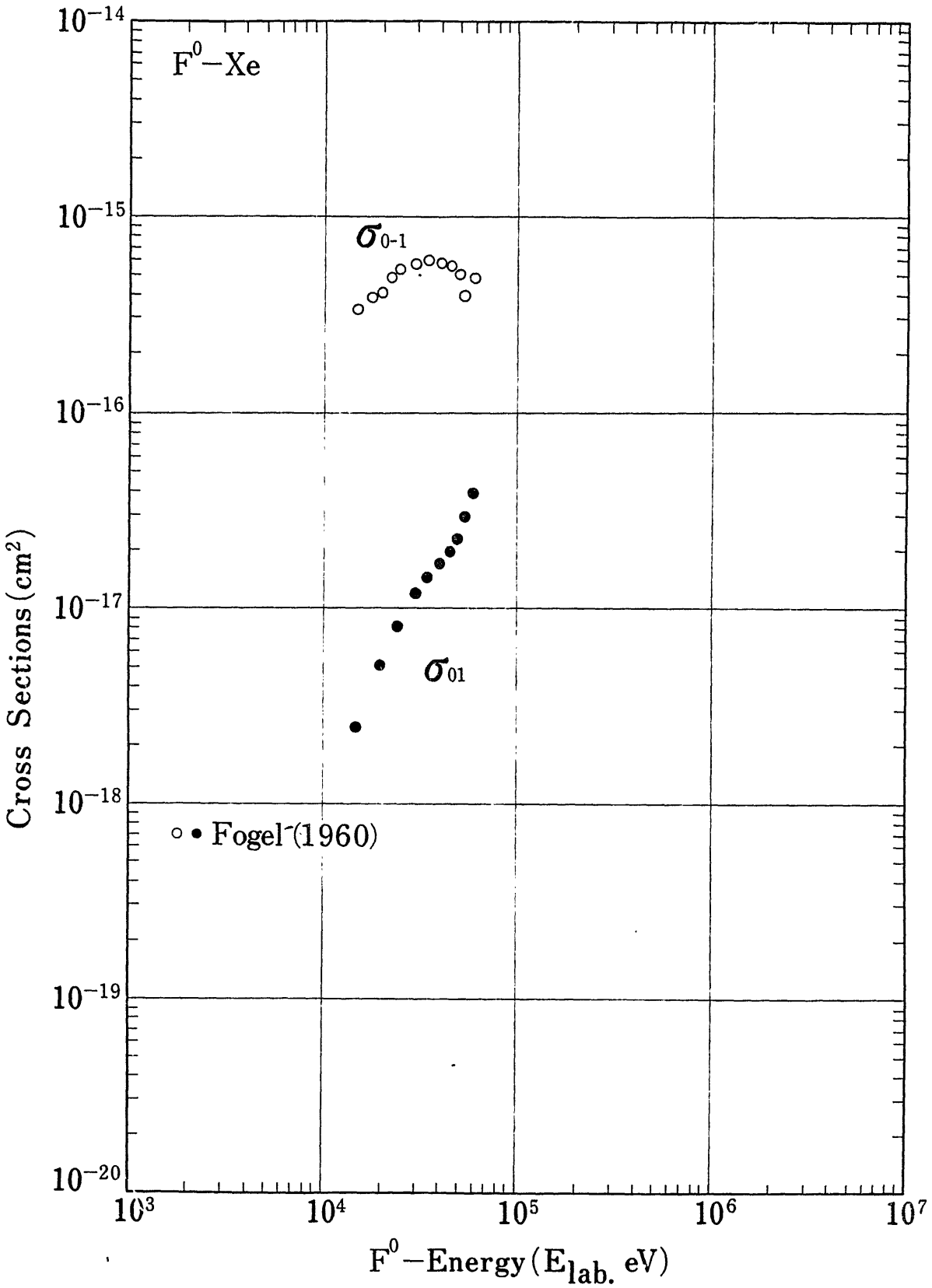

Fig.10 Charge Changing Cross Sections of F^0 in Xe

Charge Changing Cross Sections of Neon Atoms and Ions, Z=10.

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 Neon Positive Ions; Ne^{+}, Ne^{2+}, Ne^{3+}, Ne^{4+}, Ne^{5+}, Ne^{6+}, Ne^{7+}

authors	year	energy (eV)	target	reference
(σ_{10})				
Rostagni	1935	10-900	Ne	57
Dillon et al.	1955	50-850	Ne	10
Gilbody,Hasted	1956	10-40,000	Ne,Ar	27
Gilbody,Hasted	1956	50-2,500	H_2,He,Ne,Ar	28
DeHeer et al.	1957	5,000-20,000	H_2,Ne,Ar	9
Flaks,Solov'ev	1958	6,000-30,000	Ne	17
Cramer	1959	4-400	Ar	7
Jones et al.	1959	25,000-100,000	Ne,Ar	37
Flaks	1961	3,000-30,000	He,Ne,Ar,Kr,Xe	20
Nikolaev et al.	1961	700,000	He,N_2,Ar,Kr	51
Gilbody et al.	1963	100,000-400,000	He,Ne,Ar,Kr	29
Pivovar et al.	1966	250,000-1,400,000	Ne,Ar,Kr	55
Wittkower,Gilbody	1967	60,000-450,000	H_2,He,Ne,Ar,Kr	66
Kaneko et al.	1969	0.04-1.3	Ne	39
Lockwood	1969	5,000-100,000	N_2,O_2	44
Latypov et al.	1969	750-2,000	Ne	42
Schlumbohm	1969	4-200	Co_2,N_2,O_2,Ar,Kr	59,60
Lockwood	1970	10,000-100,000	N_2	45
Ormrod,Michel	1971	15,000-75,000	N_2,Ar	54
Maier	1972	3-95	Kr,Xe	46
Kobayashi	1972	0.04-1.5	Ne	41
Meyer,Anderson	1974	1,720-40,200	Cs	49

authors	year	energy (eV)	target	reference
Kikiani et al.	1975	200-4,000	Ne	40
Meyer et al.	1977	40,000-200,000	C_s	50
Winter et al.	1977	100,000	H_2,He,Ar	64
Winter et al.	1977	25,000-400,000	He,Ar	65
(σ_{21})				
Flaks Solov'ev	1958	6,000-60,000	Ne	17
Flaks Solov'ev	1958	6,000-60,000	He,Ar,Kr,Xe	18
Nikolaev et al.	1961	700,000-3,370,000	He,N_2,Ar,Kr	51
Islam et al.	1962	19,000-90,000	Ne	36
Hertel, Koski	1964	1,000-1,250,000	Ne	34
Hasted,Hussain	1964	850-4,000	Ne	32
Ormrod,Michel	1971	40,000-90,000	N_2,Ar	54
Maier	1974	1-96	Kr	47
Winter et al.	1977	100,000	H_2,He,Ar	64
Winter et al.	1977	25,000-400,000	He,Ar	65
Suk et al.	1978	58,000-200,000	He,Ne,Ar,Kr,Xe	62
(σ_{20})				
Wolf	1939	360-1,450	Ne	68
Flaks, Solov'ev	1958	6,000-60,000	Ne	17
Flaks,Solov'ev	1958	6,000-60,000	He,Ar,Kr,Xe	18
Islam et al.	1962	19,000-90,000	Ne	36
Nikolaev et al.	1962	700,000-3,370,000	He,N_2,Ar	52
Hasted,Hussain	1964	850-4,000	Ne	32
Latypov et al.	1969	630-6,000	Ne	42
(σ_{32})				
Flaks,Filippenko	1960	6,000-90,000	Ne,Kr	19
Nikolaev et al.	1961	700,000-3,370,000	He,N_2,Ar,Kr	51

authors	year	energy (eV)	target	references
Winter et al.	1977	100,000	H_2,He,Ar	64
Winter et al.	1977	25,000-400,000	He,Ar	65
(σ_{31})				
Flaks,Filippenko	1960	6,000-90,000	Ne,Kr	19
Nikolaev et al.	1962	700,000-3,370,000	He,N_2,Ar	52
(σ_{30})				
Flaks, Filippenko	1960	6,000-90,000	Ne,Kr	19
Latypov et al.	1969	800-10,000	Ne	42
(σ_{43})				
Nikolaev et al.	1961	1,830,000-3,370,000	He,N_2,Kr	51
Winter et al.	1977	100,000	He,Ar	64
Winter et al.	1977	25,000-400,000	He,Ar	65
(σ_{42})				
Nikolaev et al.	1962	1,830,000-3,370,000	He,N_2,Kr	52
(σ_{54})				
Nikolaev et al.	1961	1,830,000-3,370,000	He,N_2,Ar,Kr	51
(σ_{53})				
Nikolaev et al.	1962	1,830,000-3,370,000	He,N_2,Ar,Kr	52
(σ_{65})				
Nikolaev et al.	1961	1,830,000-3,370,000	He,N_2,Ar,Kr	51
(σ_{64})				
Nikolaev et al.	1962	1,830,000-3,370,000	He,N_2,Ar,Kr	52
(σ_{76})				
Nikolaev et al.	1961	3,370,000	Ar,Kr	51

authors	year	energy (eV)	target	reference
(σ_{75})				
Nikolaev et al.	1962	3,370,000	Ar,Kr	52

B) Electron Loss Cross Sections of Neon Atom and Positive Ions; Ne°, Ne^{+}, Ne^{2+}, Ne^{3+}.

(σ_{01})				
DeHeer et al.	1957	10,000	Ne,Ar	8,9
Flaks	1961	3,000-30,000	He,Ne,Ar,Kr,Xe	20
Dmitriev et al.	1962	700,000-1,750,000	He,N_2,Ar,Kr	11
Wittkower et al.	1967	120,000	H_2,Ne,Ar,Kr	67
Ormrod,Michel	1971	25,000-75,000	N_2,Ar	54
(σ_{12})				
Fedorenko	1954	20,000	He	14
Jones et al.	1959	25,000-100,000	Ne,Ar	37
Dmitriev et al.	1962	700,000-1,750,000	He,N_2,Ar,Kr	11
Lee, Gilbody	1963	100,000-420,000	Ne,Ar,Kr	43
Pivovar et al.	1966	250,000-1,400,000	Ne,Ar,Kr	55
(σ_{13})				
Jones et al.	1959	25,000-100,000	Ne,Ar	37
Dmitriev et al.	1963	700,000-1,750,000	He,N_2,Ar,Kr	12
Lee, Gilbody	1963	150,000-430,000	Ne,Ar,Kr	43
Pivovar et al.	1966	250,000-1,400,000	Ne,Ar,Kr	55
(σ_{14})				
Jones et al.	1959	50,000-100,000	Ne,Ar	37
Dmitriev et al.	1963	700,000-1,750,000	He,N_2,Ar,Kr	12

authors	year	energy (eV)	target	reference
Pivovar et al.	1966	250,000-1,400,000	Ne,Ar,Kr	55
(σ_{15})				
Jones et al.	1959	50,000-100,000	Ne,Ar	37
Dmitriev et al.	1963	700,000-1,750,000	Ar,N_2,Kr	12
Pivovar et al.	1966	500,000-1,400,000	Ne,Ar,Kr	55
(σ_{16})				
Pivovar et al.	1966	1,200,000-1,400,000	Ne,Ar,Kr	55
(σ_{23})				
Dmitriev et al.	1962	700,000-3,370,000	He,N_2,Kr,	11
(σ_{24})				
Dmitriev et al.	1963	700,000-3,370,000	He,N_2,Ar,Kr	12
(σ_{25})				
Dmitriev et al.	1963	700,000-3,370,000	N_2,Ar	12
(σ_{26})				
Dmitriev et al.	1963	1,750,000	Ar	12
(σ_{34})				
Dmitriev et al.	1962	700,000-3,370,000	He,N_2,Ar,Kr	11
(σ_{35})				
Dmitriev et al.	1963	700,000-3,370,000	He,N_2,Ar,Kr	12
(σ_{36})				
Dmitriev et al.	1963	700,000-3,370,000	He,N_2,Ar,Kr	12
(σ_{45})				
Dmitriev et al.	1962	1,750,000-3,370,000	He,N_2,Ar,Kr	11

authors	year	energy (eV)	target	reference
(σ_{46})				
Dmitriev et al.	1963	1,750,000-3,370,000	N_2,Ar,Kr	12
(σ_{56})				
Dmitriev et al.	1962	3,370,000	N_2,Ar,Kr	11
(σ_{57})				
Dmitriev et al.	1963	3,370,000	Ar	12

C) Cross Sections of Ionization, Slow Ion Production and Electron Production by Neon Atom and Positive Ions; Ne°, Ne^+, Ne^{2+}, Ne^{3+}, Ne^{4+}.

(σ_0^i, σ_0^{0n}, σ_0^+, σ_0^-)				
Flaks	1961	3,000-30,000	He,Ne,Ar,Kr,Xe	20
Flaks et al.	1962	3,000-30,000	Xe	22
Flaks et al.	1962	3,000-30,000	Ne,Ar,Kr,Xe	21
Polyakova et al.	1970	100-30,000	H_2	56
(σ_1^i, σ_1^{0n}, σ_1^+, σ_1^-)				
Fedorenko et al.	1956	10,000-180,000	Ar	15
Fedorenko,Afrosimov	1956	3,000-180,000	Ar	16
DeHeer et al.	1957	5,000-20,000	H_2,Ne,Ar	9
Flaks et al.	1962	3,000-30,000	Xe	22
Flaks et al.	1962	3,000-30,000	Ne,Ar,Kr,Xe	21
Gilbody et al.	1963	100,000-450,000	He,Ne,Ar,Kr	29
Polyakova et al.	1970	100-30,000	H_2	56
Gusev et al.	1971	120-30,000	CO	30
Maier	1972	3-95	Kr,Xe	46
Hippler,Schartner	1975	150,000-1,800,000	Ne,Ar,Kr	35
Kikiani et al.	1975	200-4,000	Ne	40

authors	year	energy (eV)	target	reference
$(\sigma_2^i, \sigma_2^{0n}, \sigma_2^+, \sigma_2^-)$				
Wolf	1936	360-1,450	Ne	68
Flaks et al.	1962	6,000-60,000	Xe	22
Flaks et al.	1962	6,000-60,000	Ne,Ar,Kr,Xe	21
Islam et al.	1962	19,000-90,000	Ne	36
Maier	1974	1-96	Kr	47
Hippler, Schartner	1975	300,000-1,800,000	Ne	34
$(\sigma_3^i, \sigma_3^{0n}, \sigma_3^+, \sigma_3^-)$				
Flaks et al.	1962	9,000-90,000	Xe	22
Flaks et al.	1962	9,000-90,000	Ne,Ar,Kr,Xe	21
Ogurtsov et al.	1970	21,000-45,000	Ar	53
(σ_4^-)				
Flaks et al.	1962	12,000-120,000	Xe	22

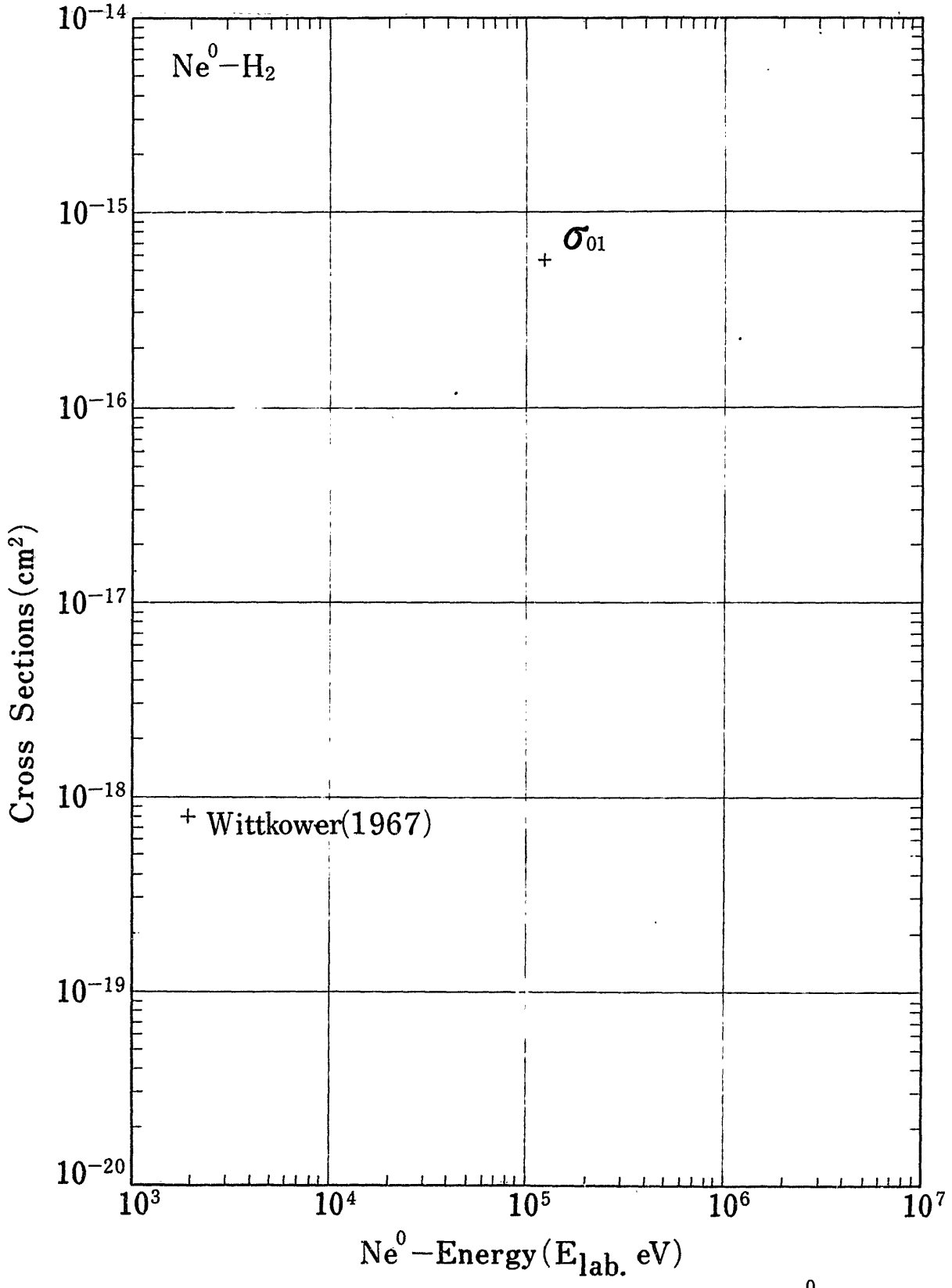

Fig.1 Charge Changing Cross Sections of Ne^0 in H_2

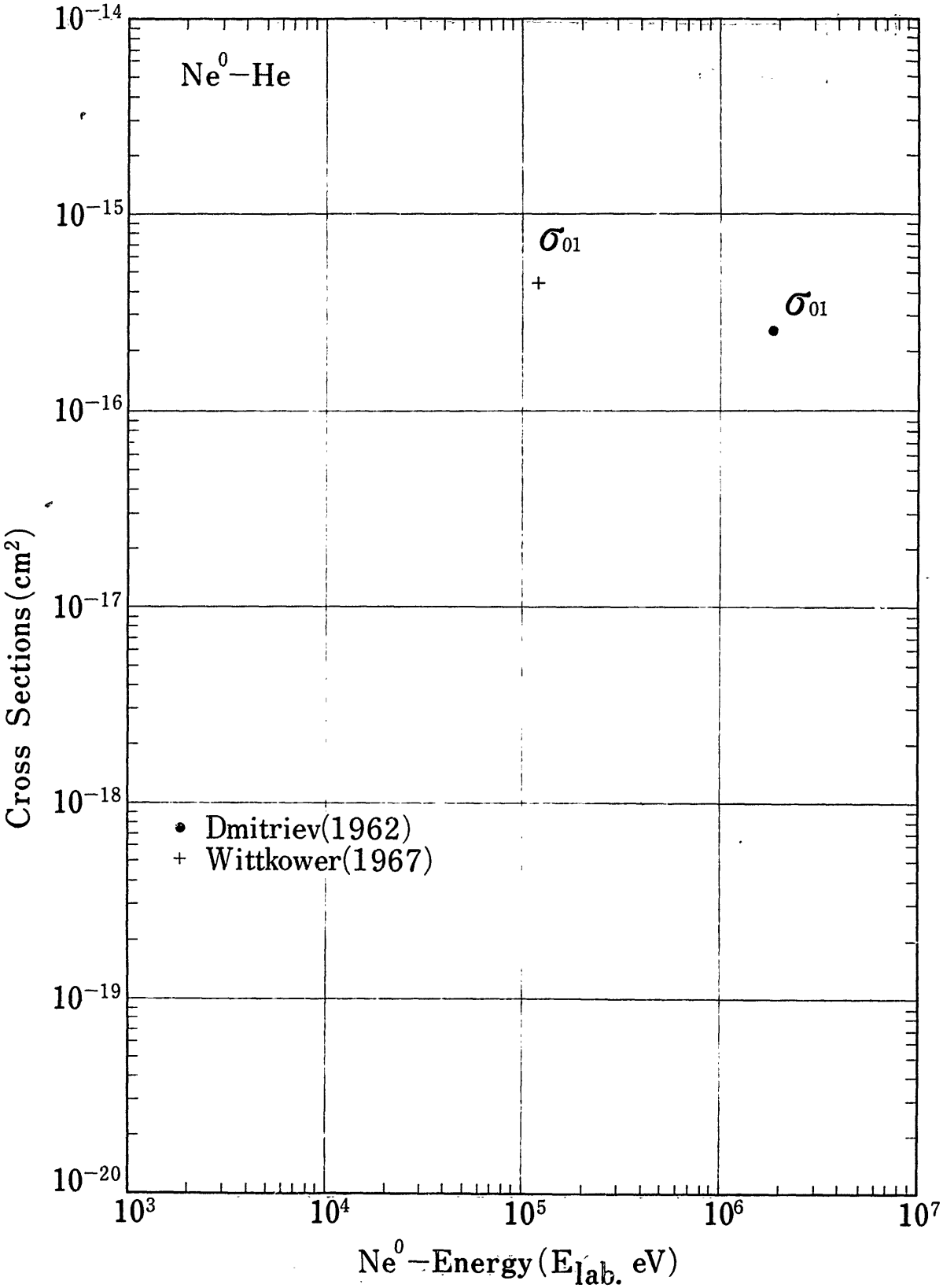

Fig.2 Charge Changing Cross Sections of Ne^0 in He

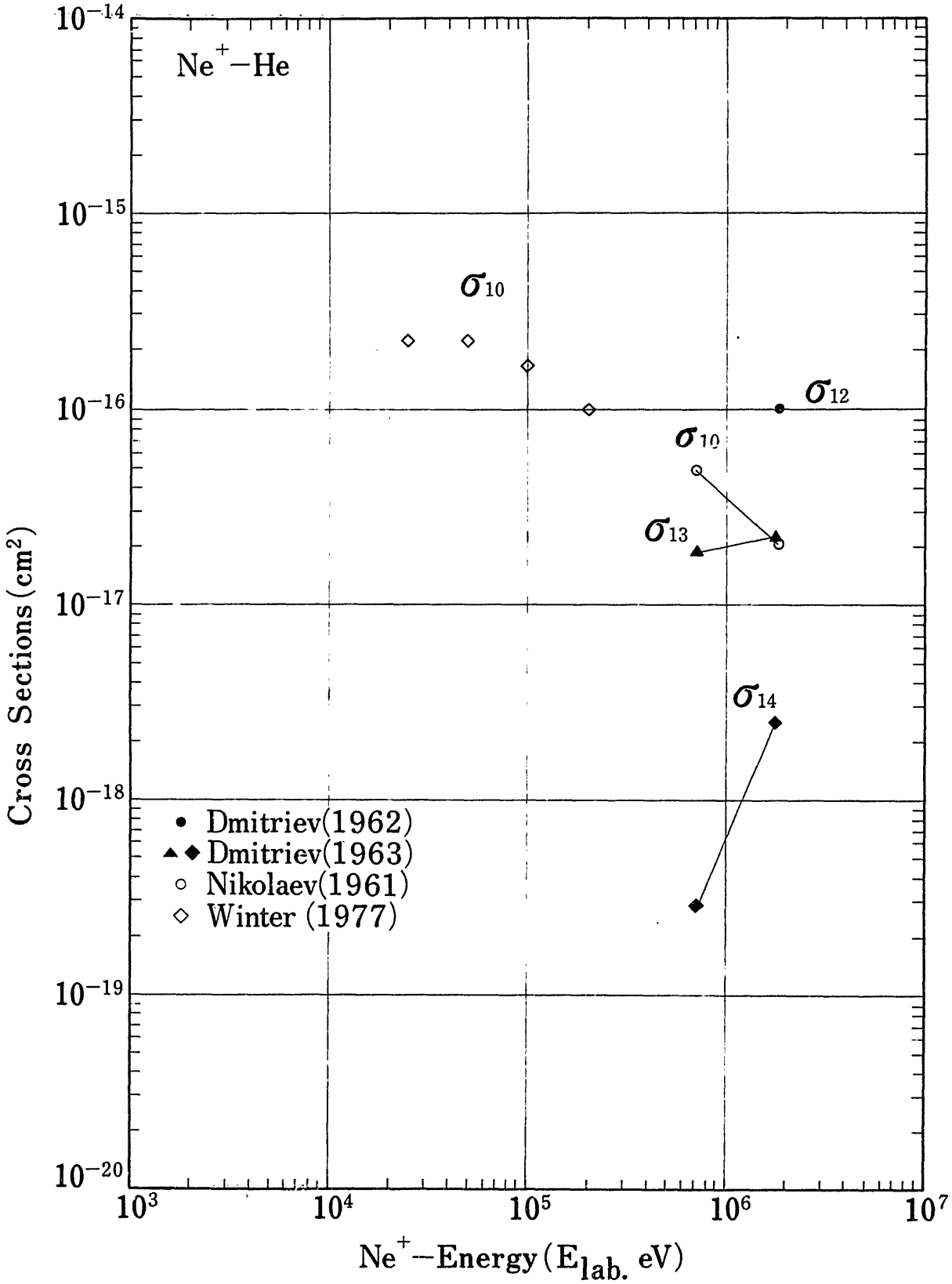

Fig.3 Charge Changing Cross Sections of Ne^+ in He

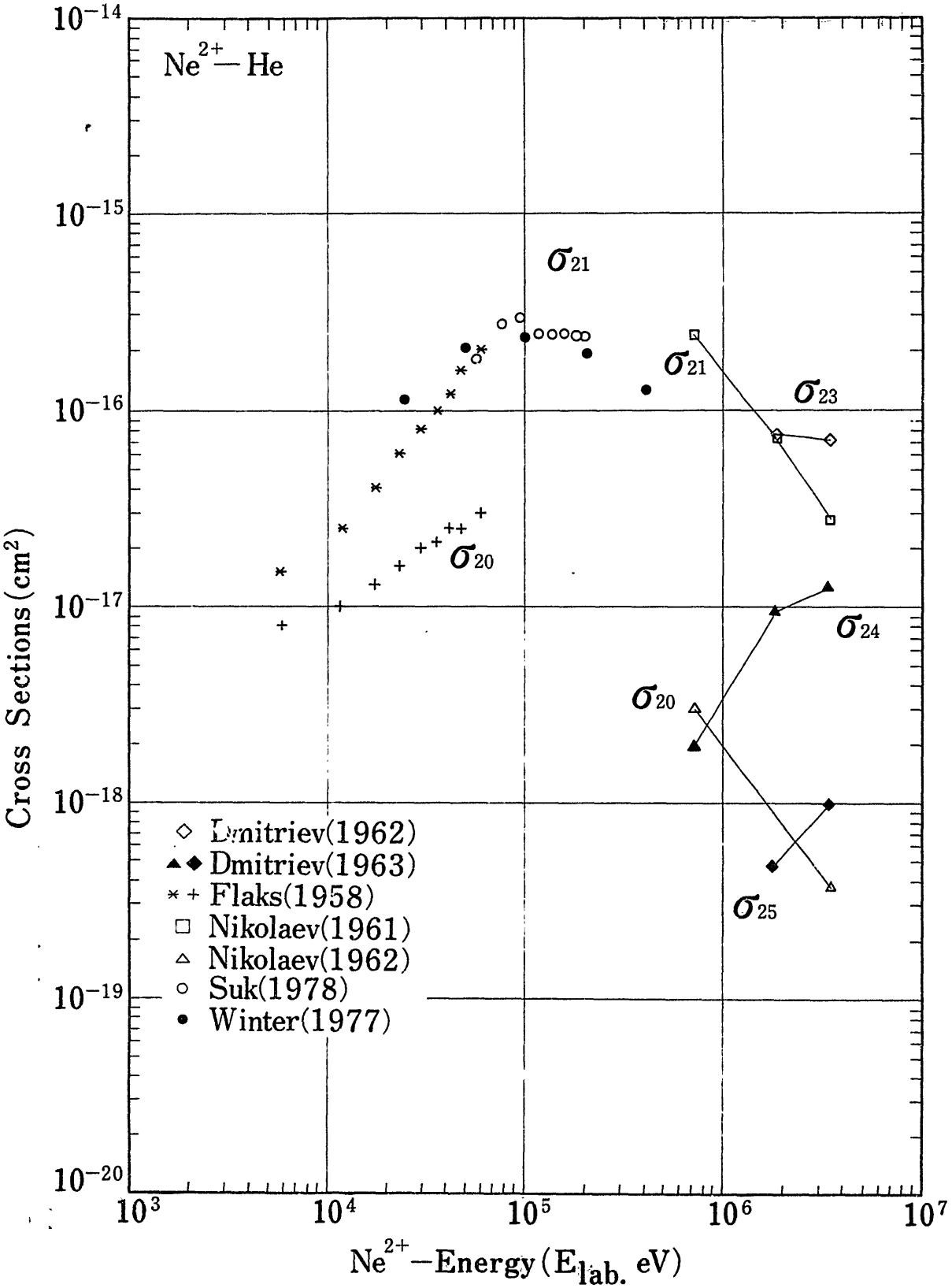

Fig.4 Charge Changing Cross Sections of Ne^{2+} in He

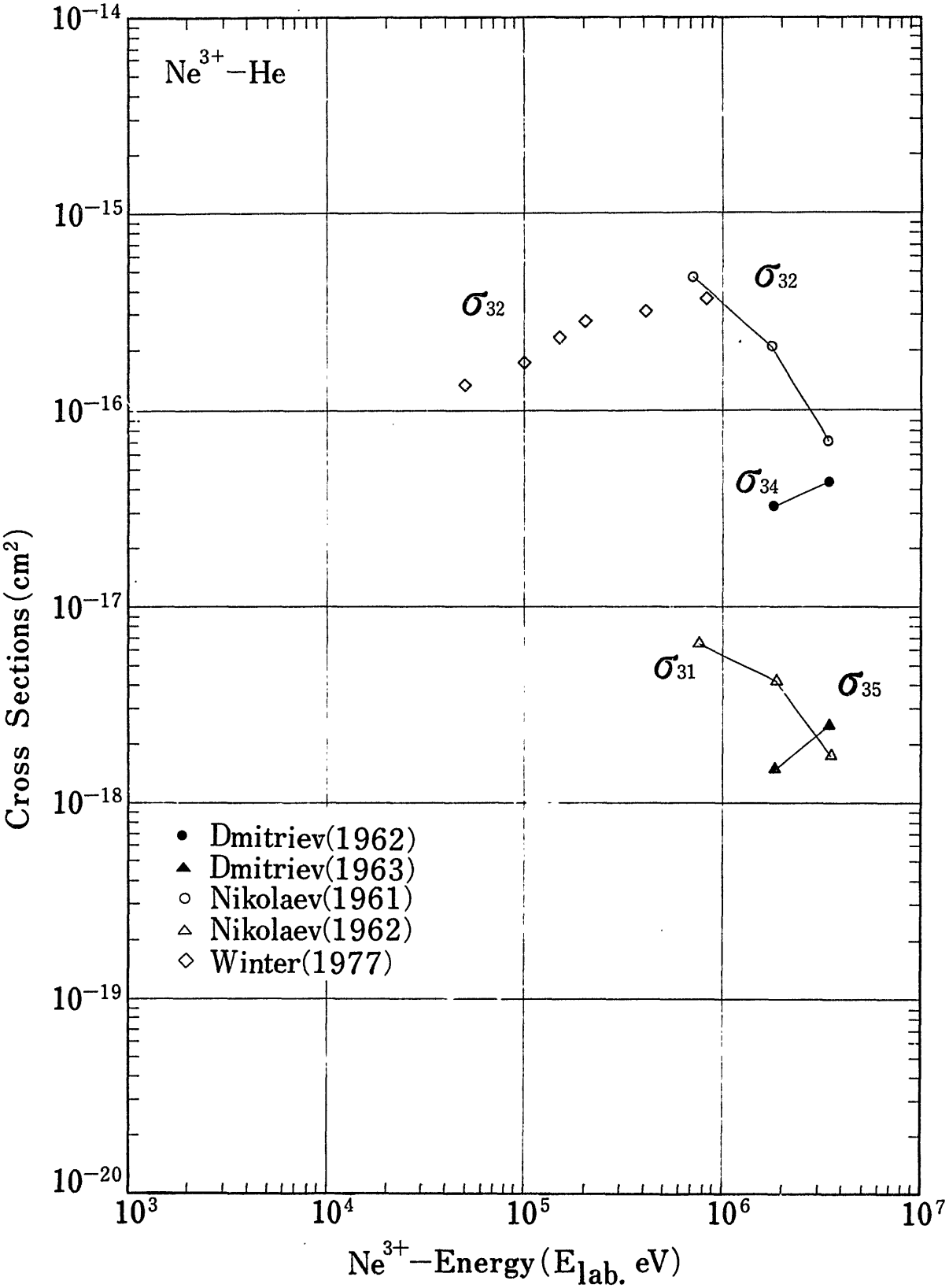

Fig.5 Charge Changing Cross Sections of Ne^{3+} in He

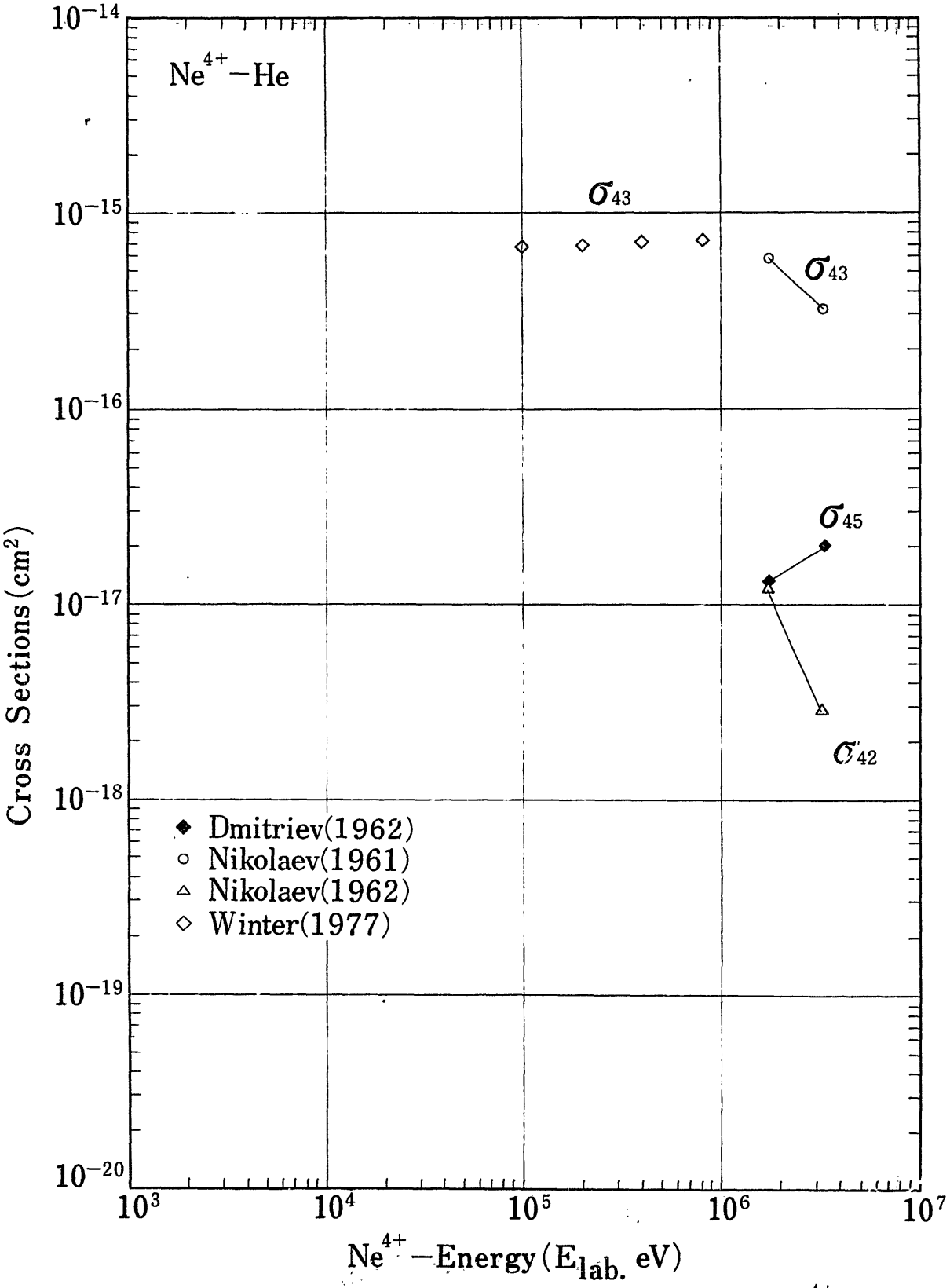

Fig.6 Charge Changing Cross Sections of Ne^{4+} in He

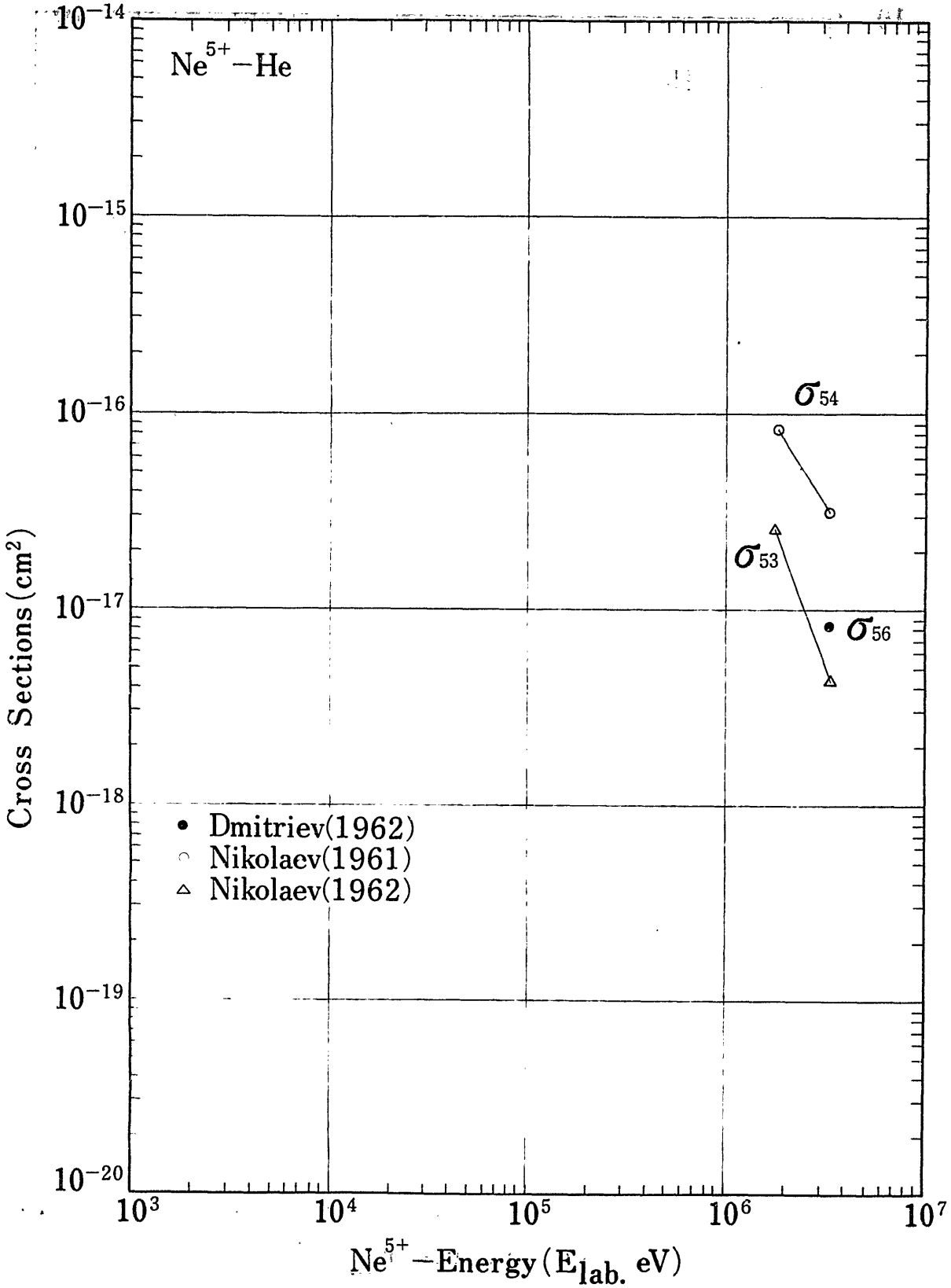

Fig. 7 Charge Changing Cross Sections of Ne^{5+} in He

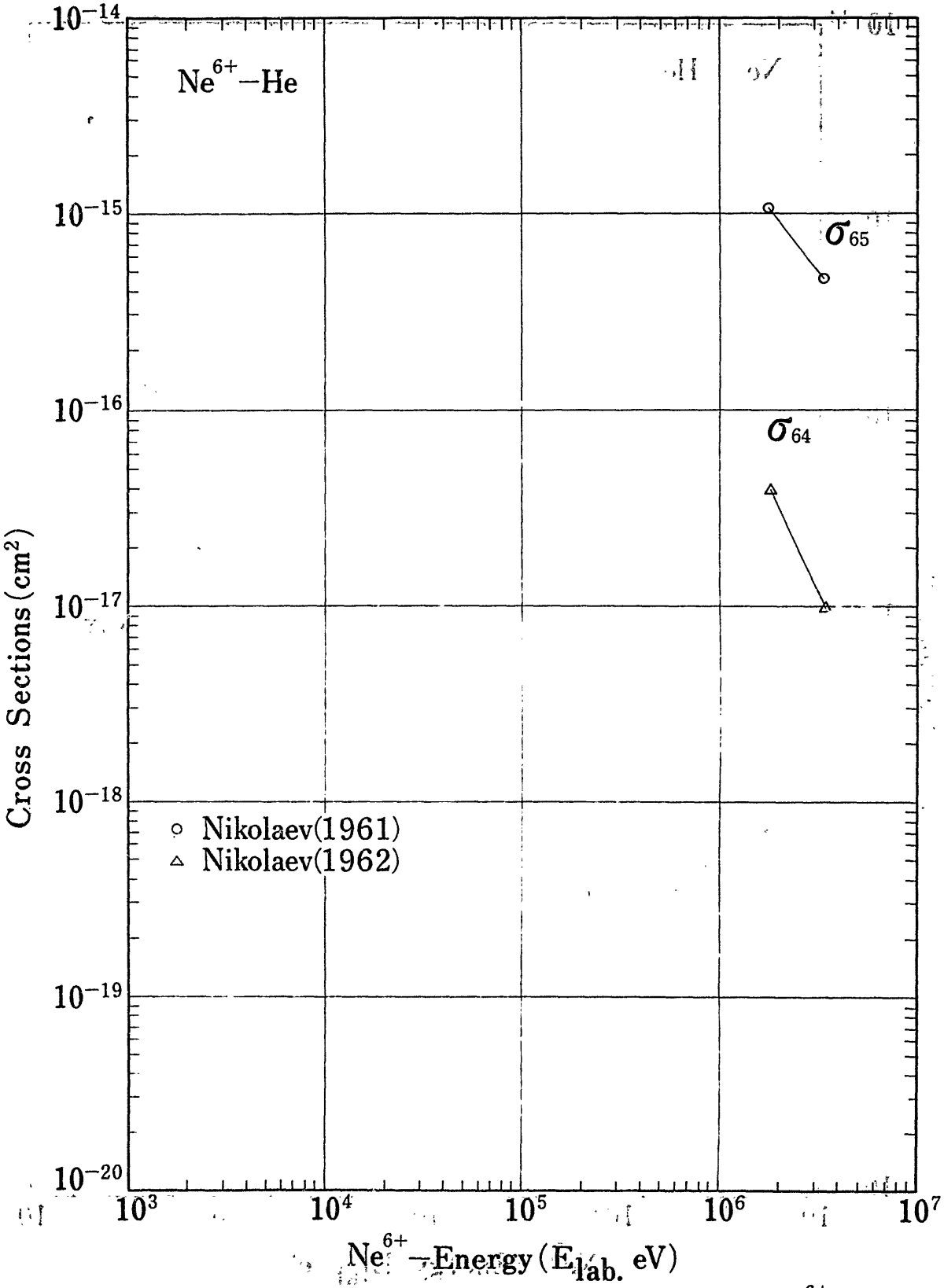

Fig. 8 Charge Changing Cross Sections of Ne^{6+} in He

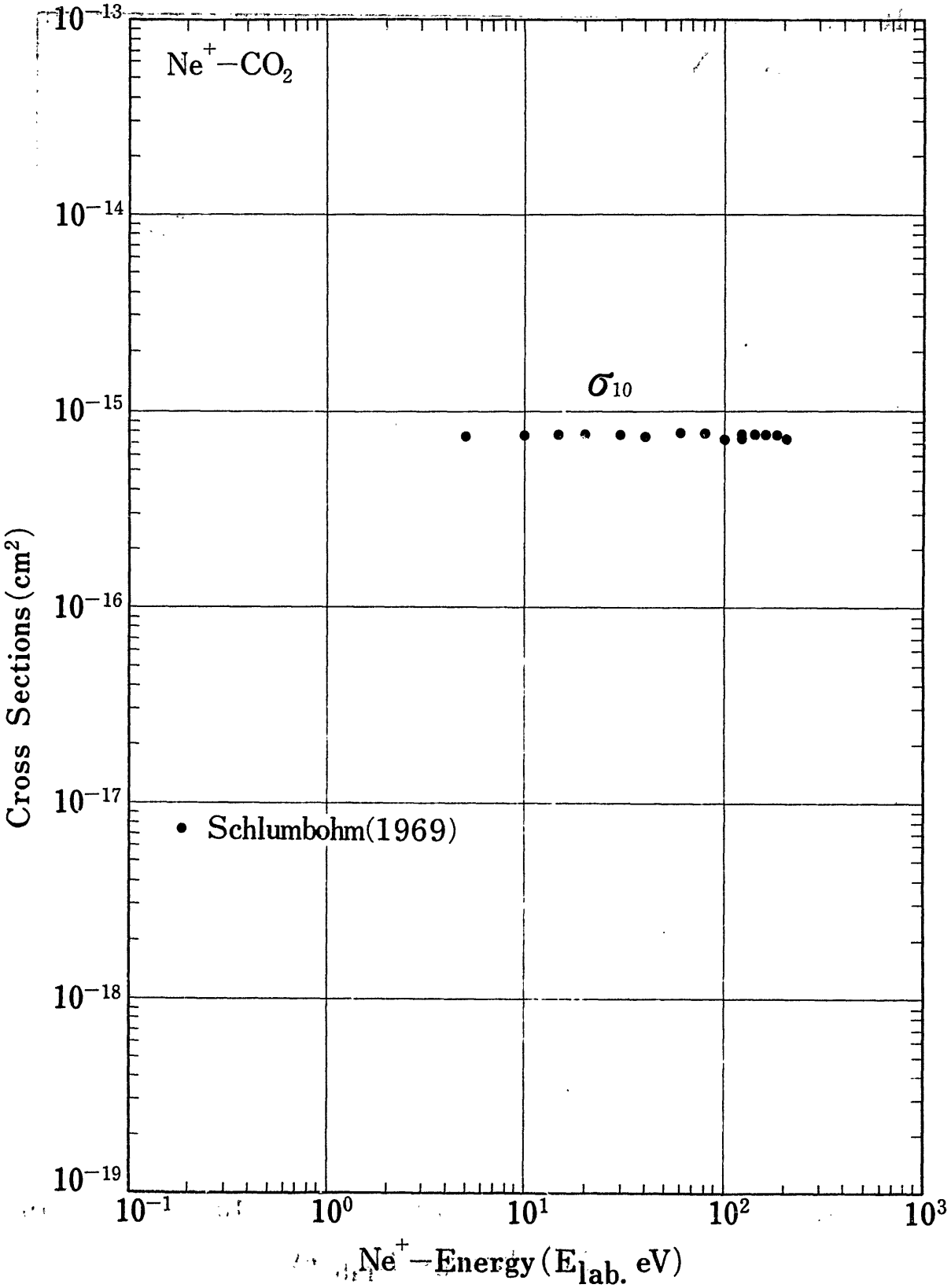

Fig. 9 Charge Changing Cross Sections of Ne^+ in CO_2

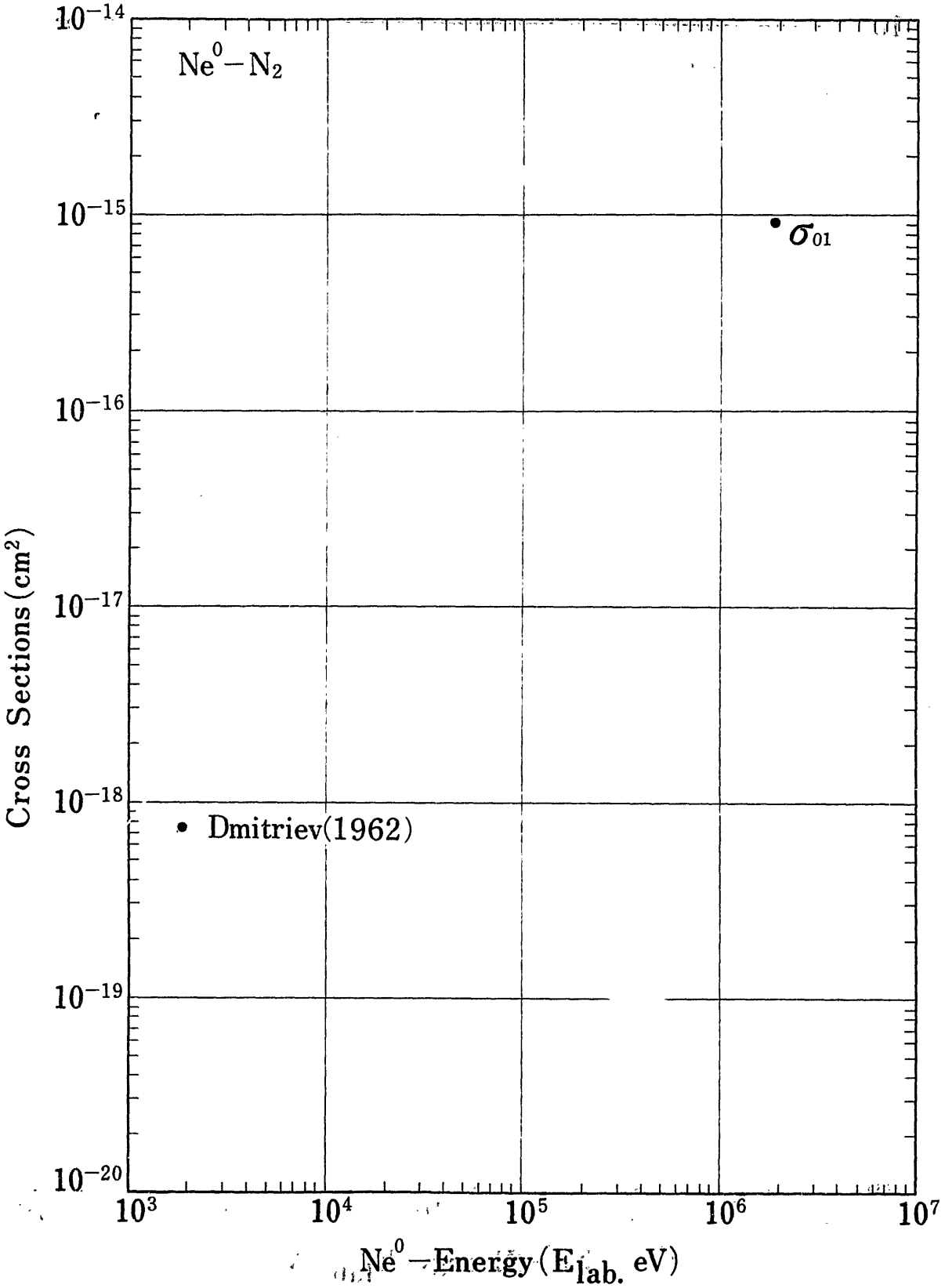

Fig.10 Charge Changing Cross Sections of Ne^0 in N_2

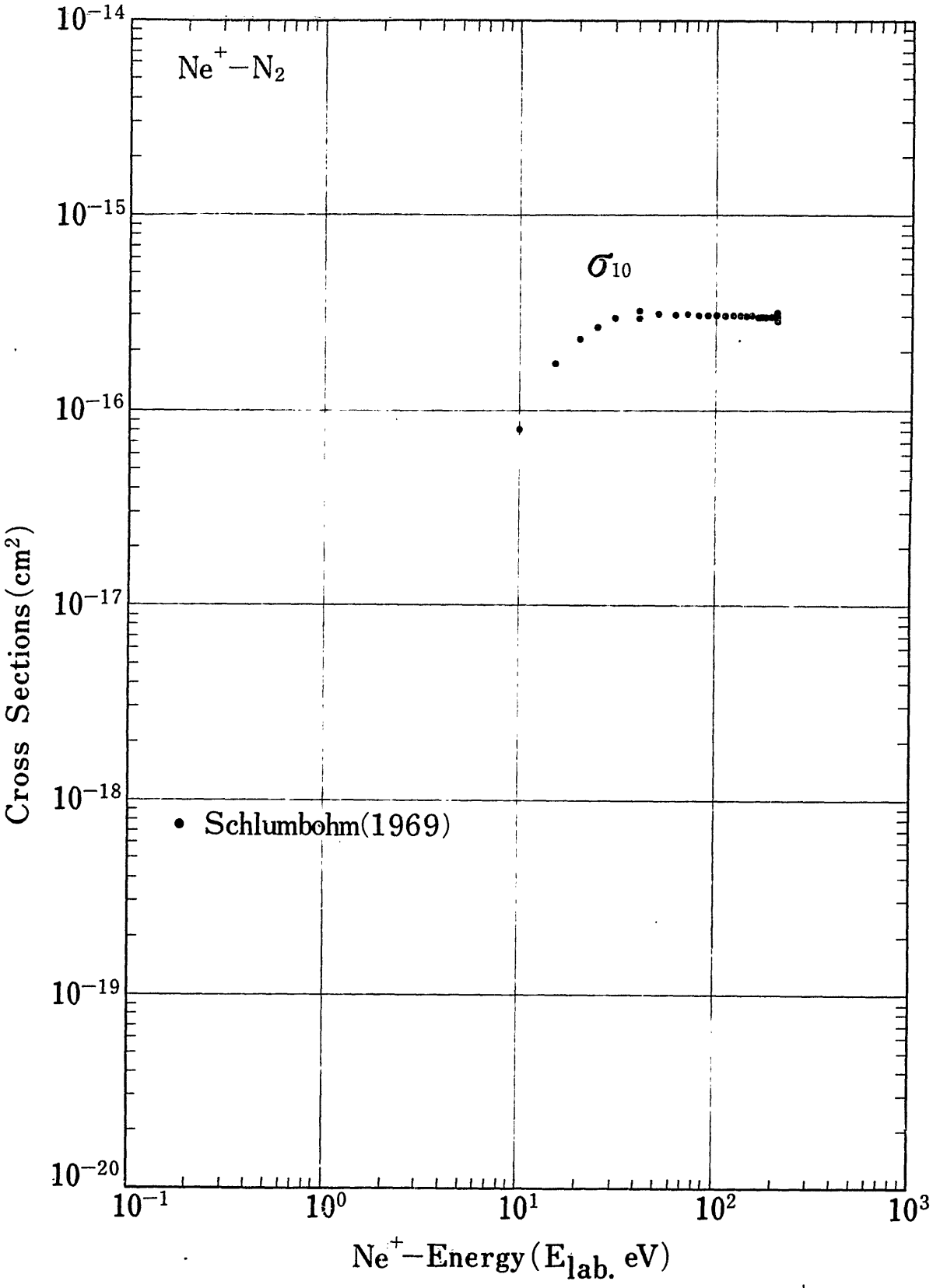

Fig.11−a Charge Changing Cross Sections of Ne^+ in N_2

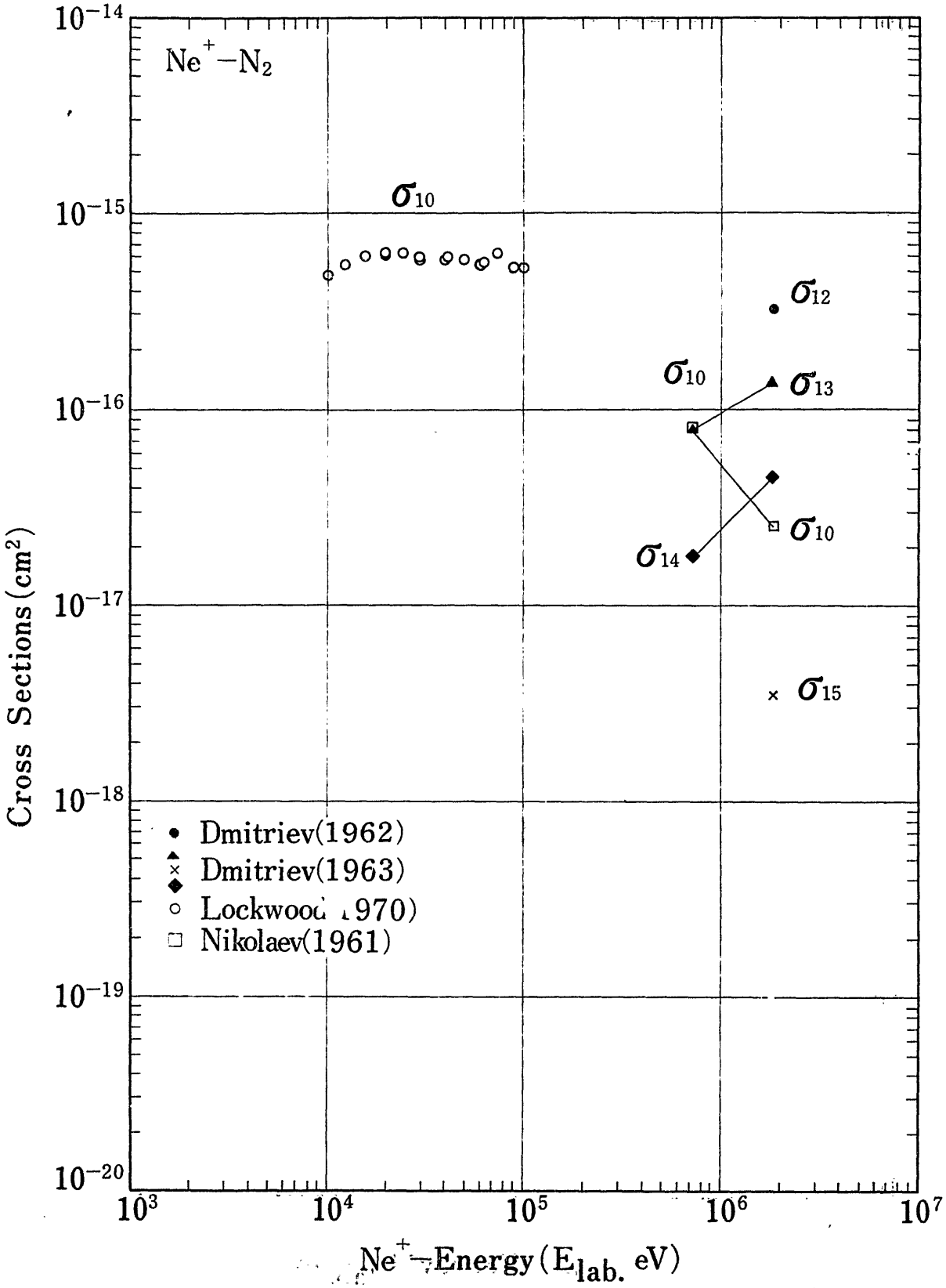

Fig.11-b Charge Changing Cross Sections of Ne^+ in N_2

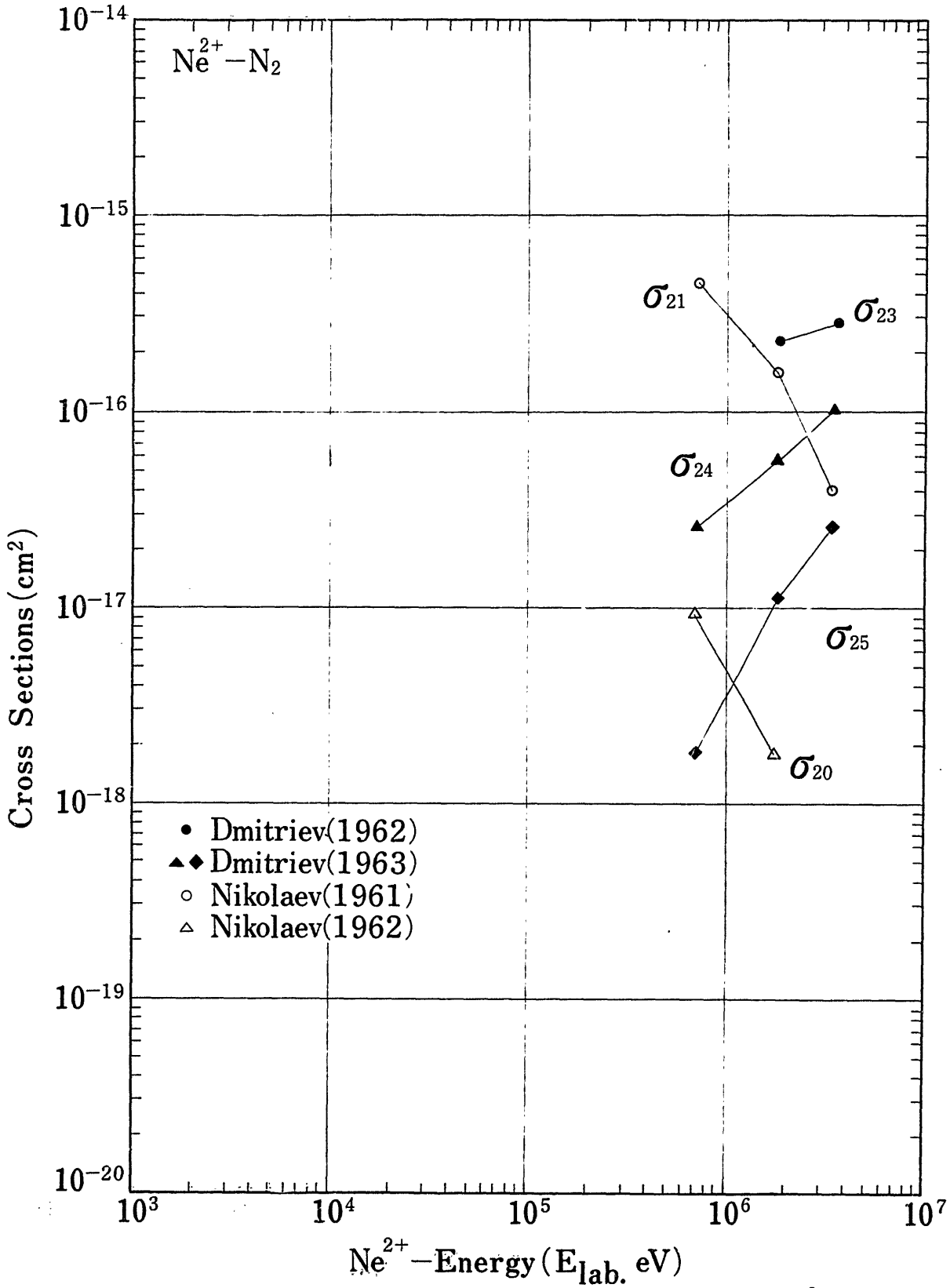

Fig.12 Charge Changing Cross Sections of Ne^{2+} in N_2

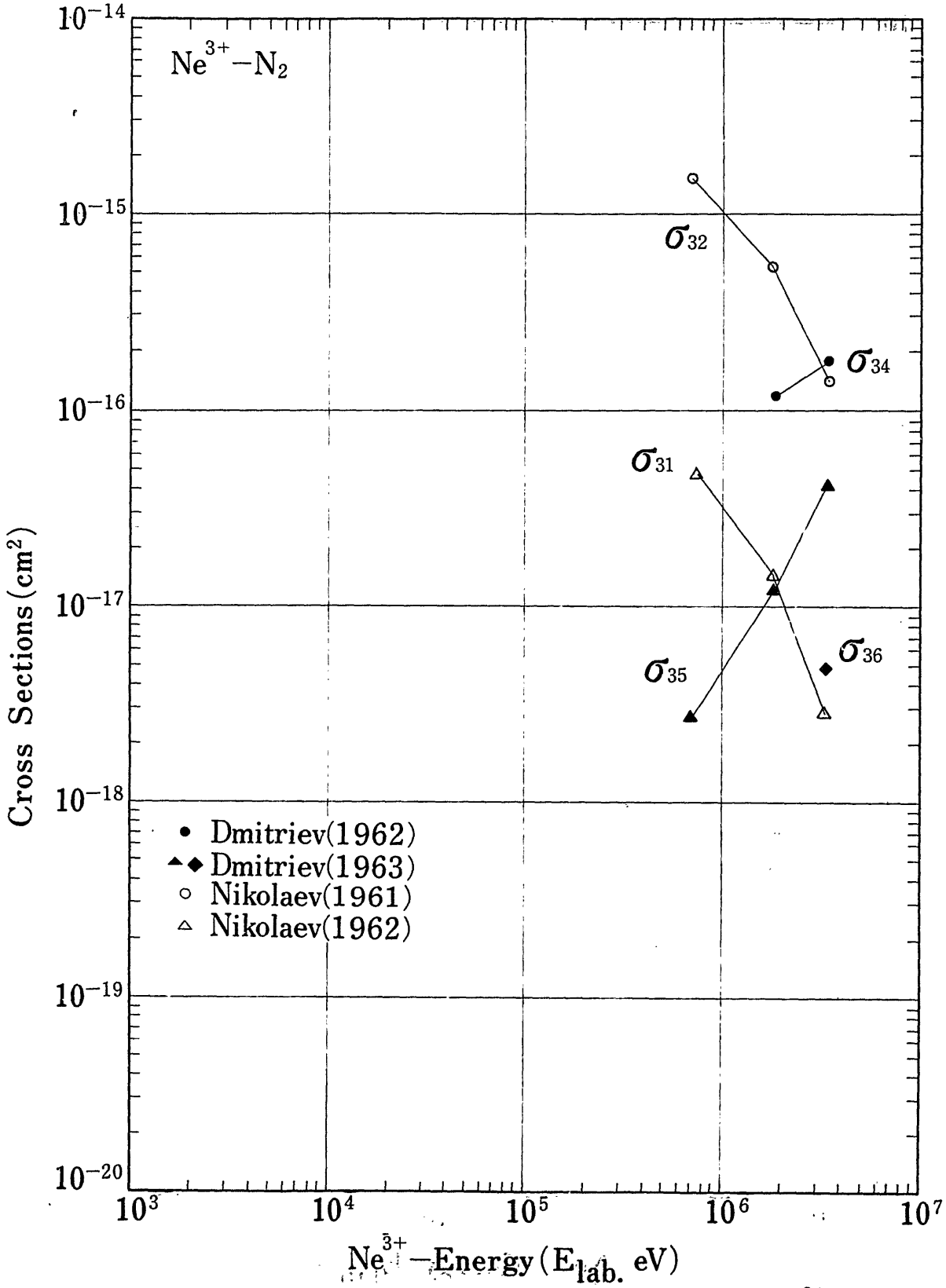

Fig.13 Charge Changing Cross Sections of Ne^{3+} in N_2

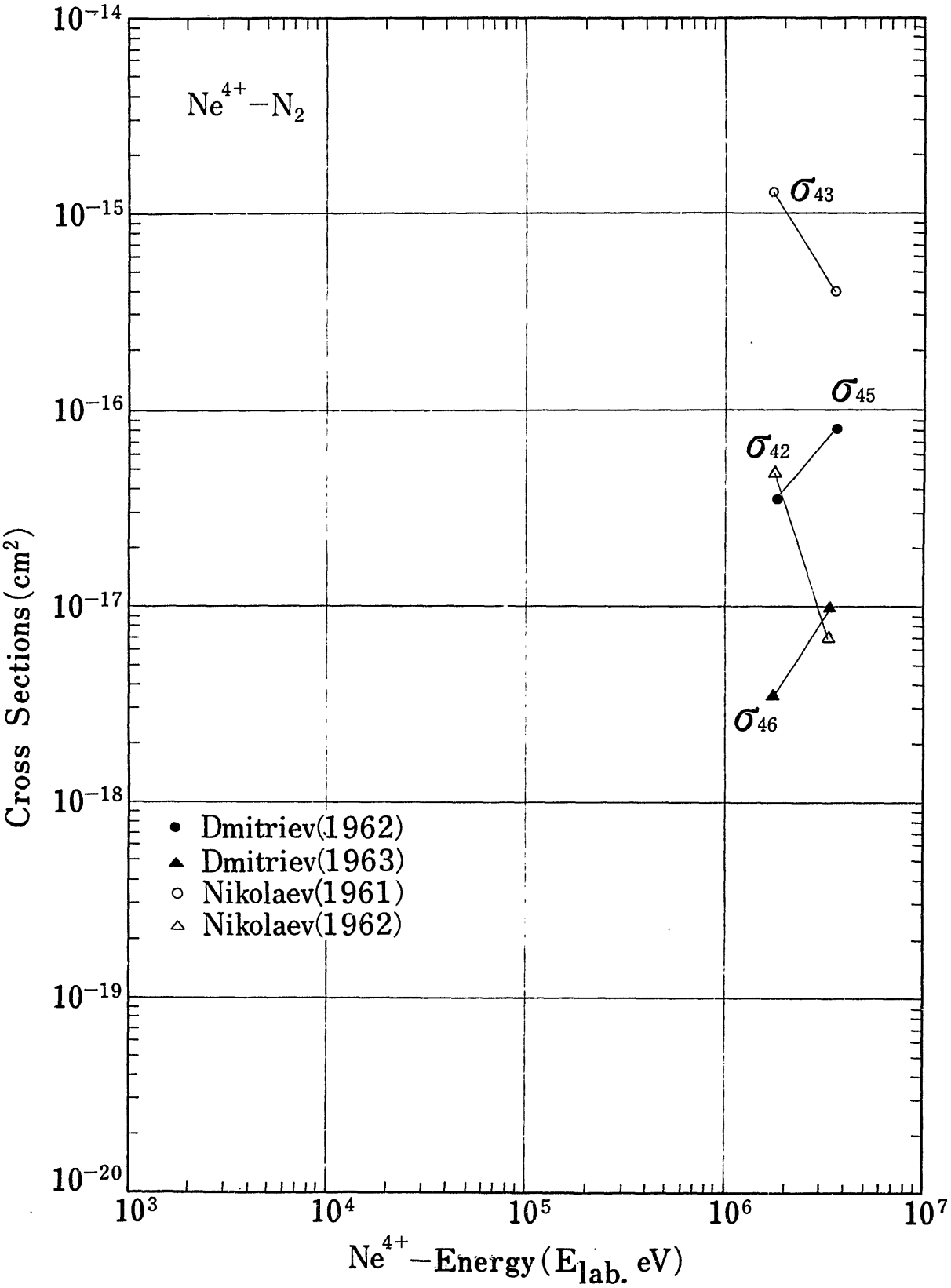

Fig.14 Charge Changing Cross Sections of Ne^{4+} in N_2

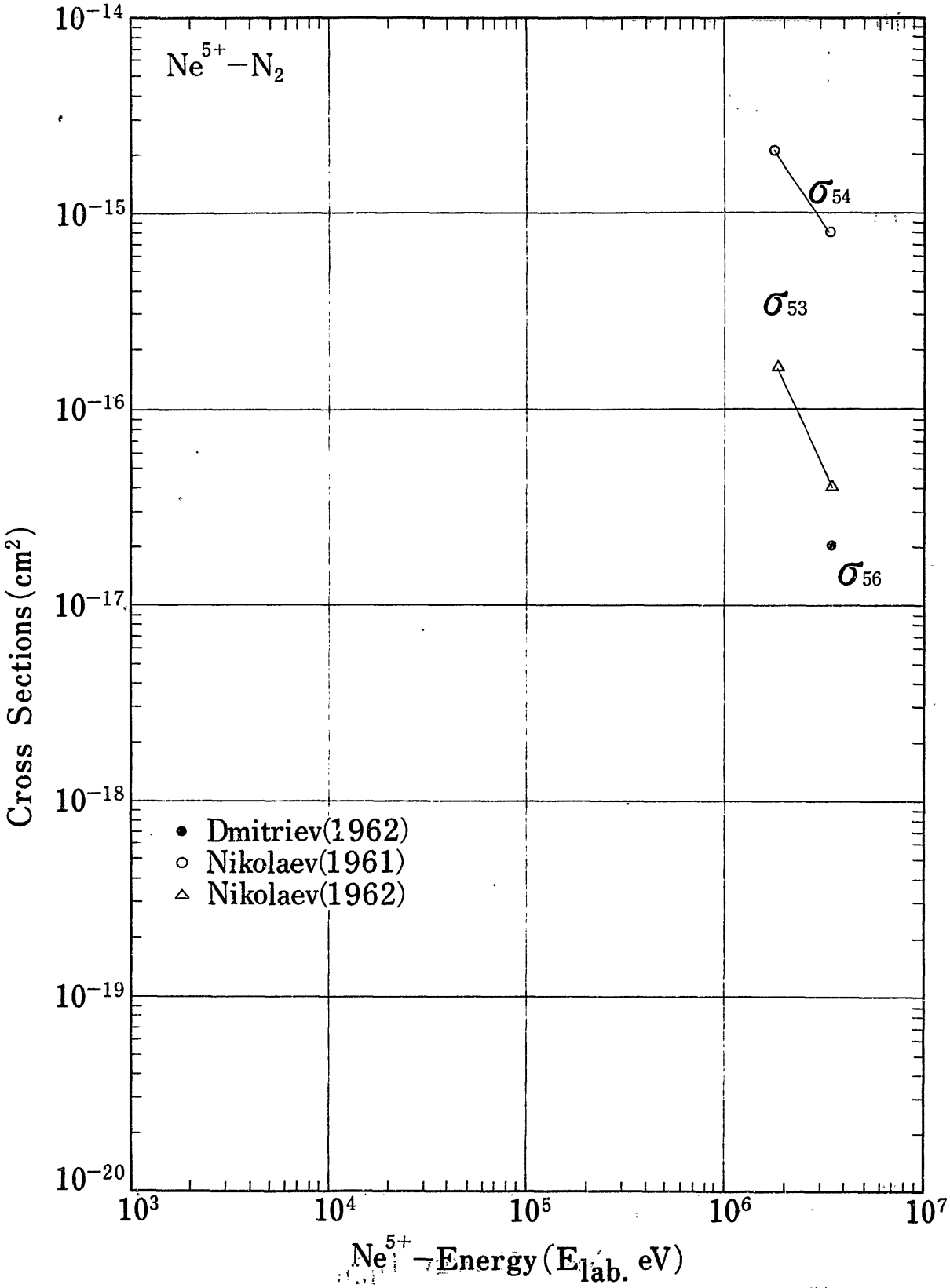

Fig.15 Charge-Changing Cross Sections of Ne^{5+} in N_2

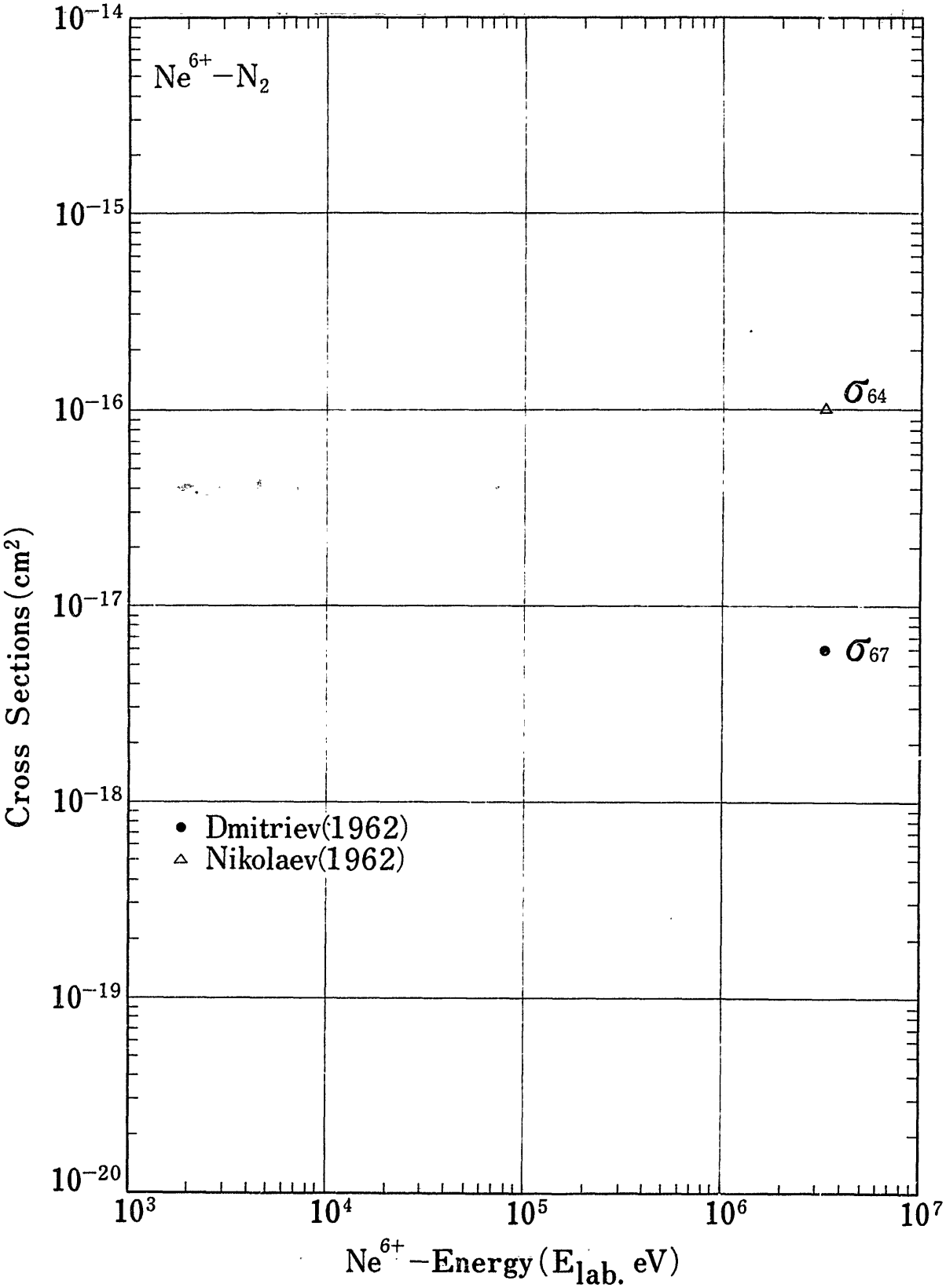

Fig.16 Charge Changing Cross Sections of Ne^{6+} in N_2

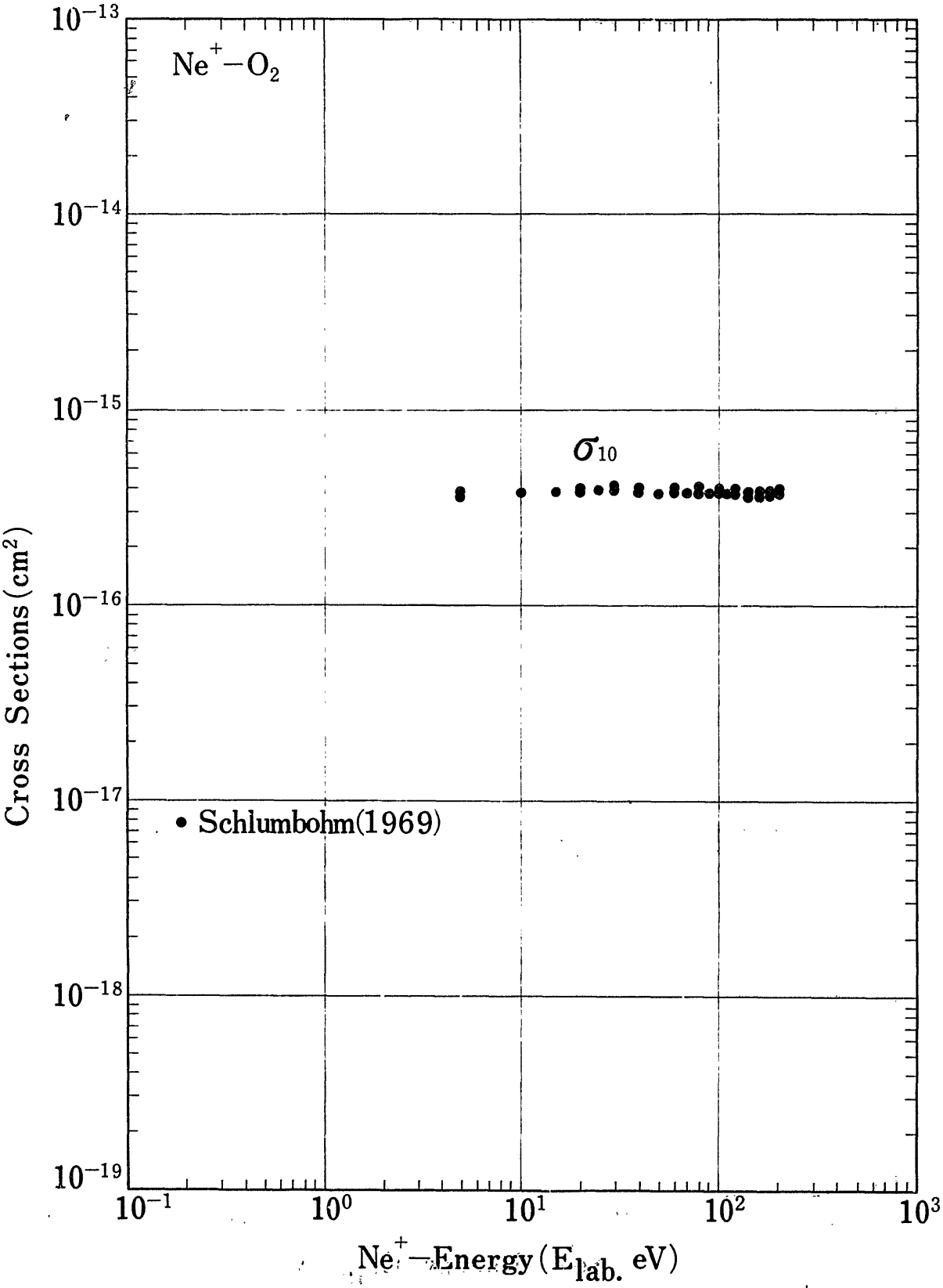

Fig.17 Charge Changing Cross Sections of Ne^+ in O_2

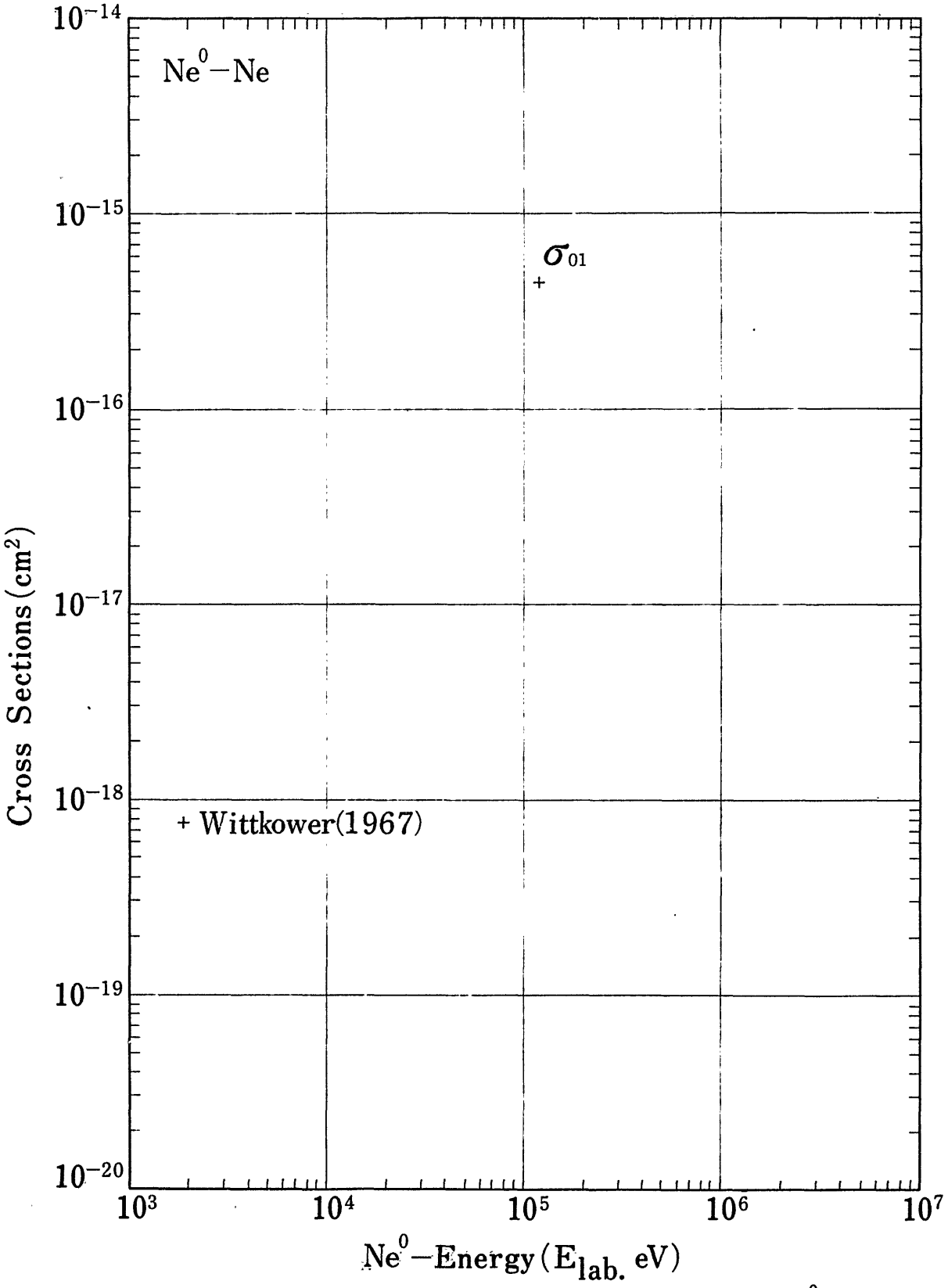

Fig. 18 Charge Changing Cross Sections of Ne^0 in Ne

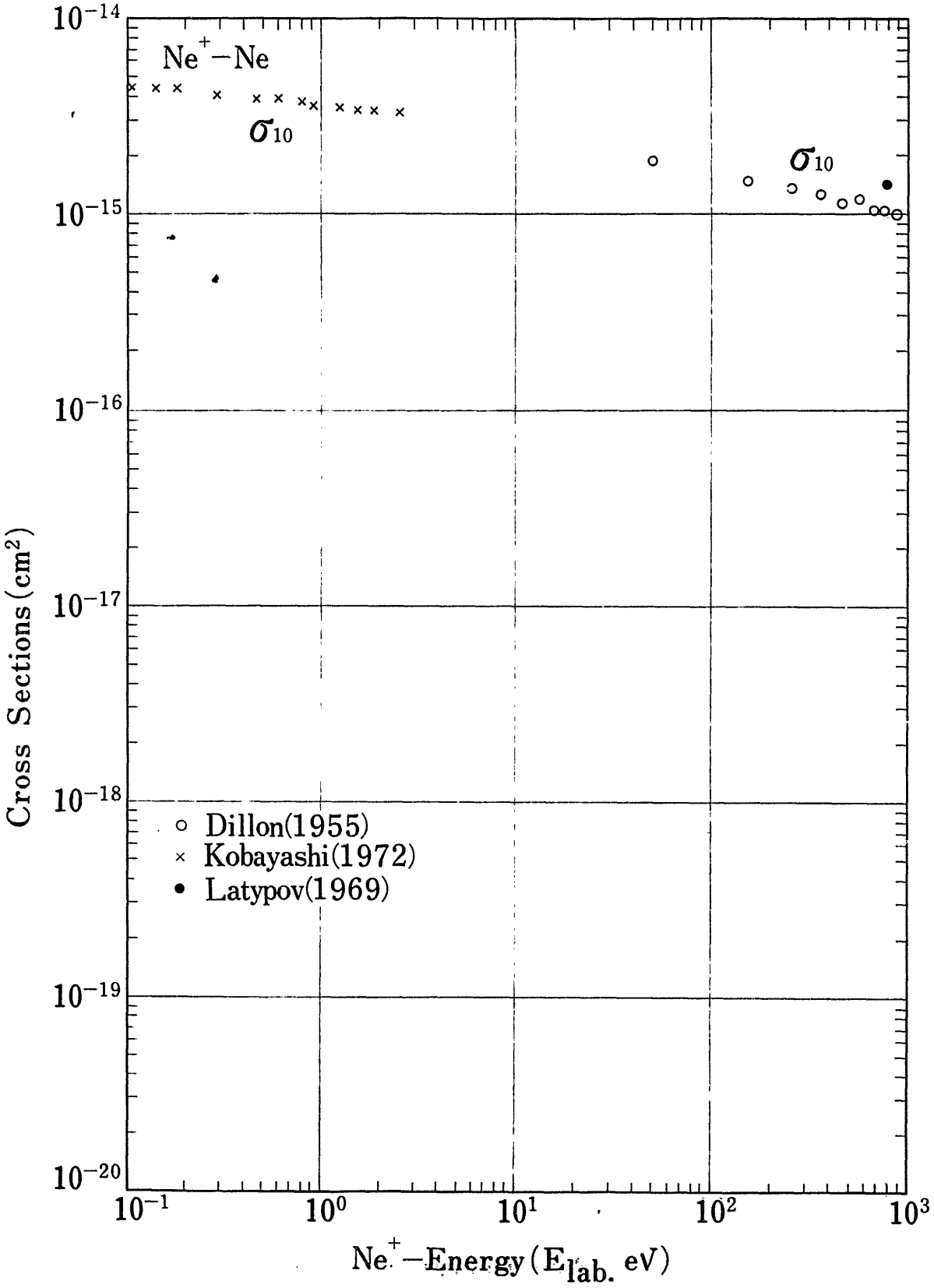

Fig.19—a Charge Changing Cross Sections of Ne^+ in Ne

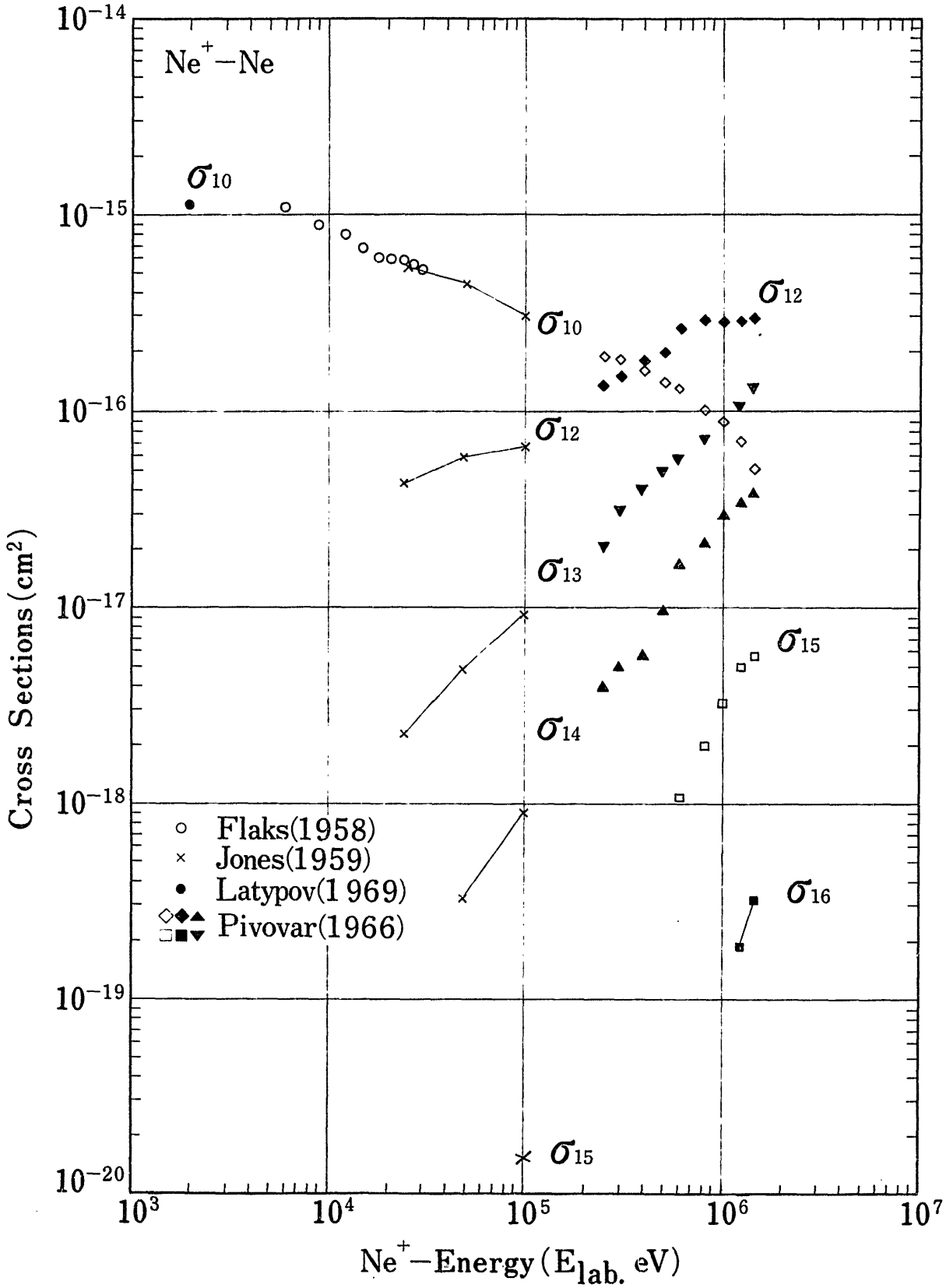

Fig.19−b Charge Changing Cross Sections of Ne^+ in Ne

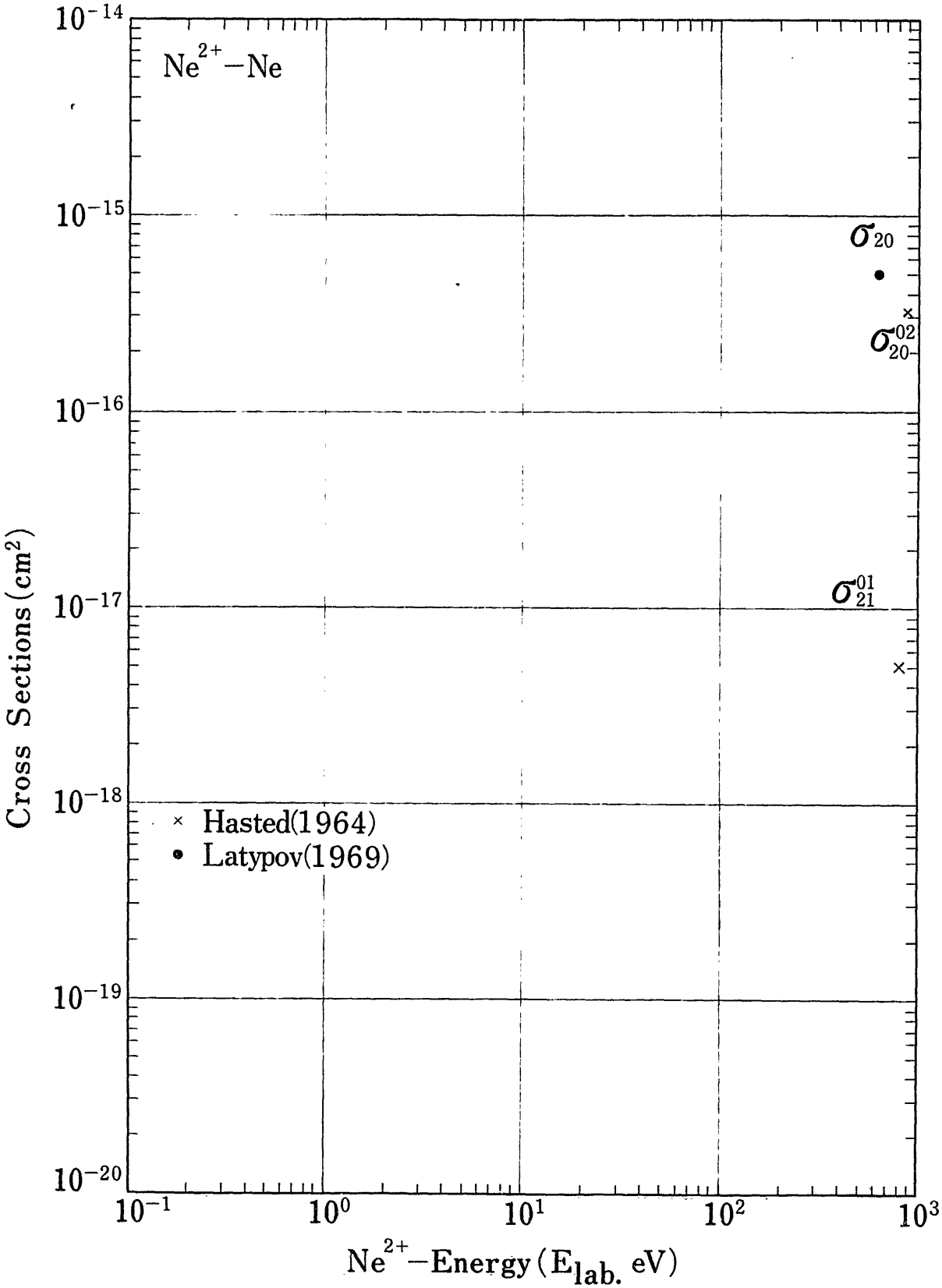

Fig.20–a Charge Changing Cross Sections of Ne^{2+} in Ne

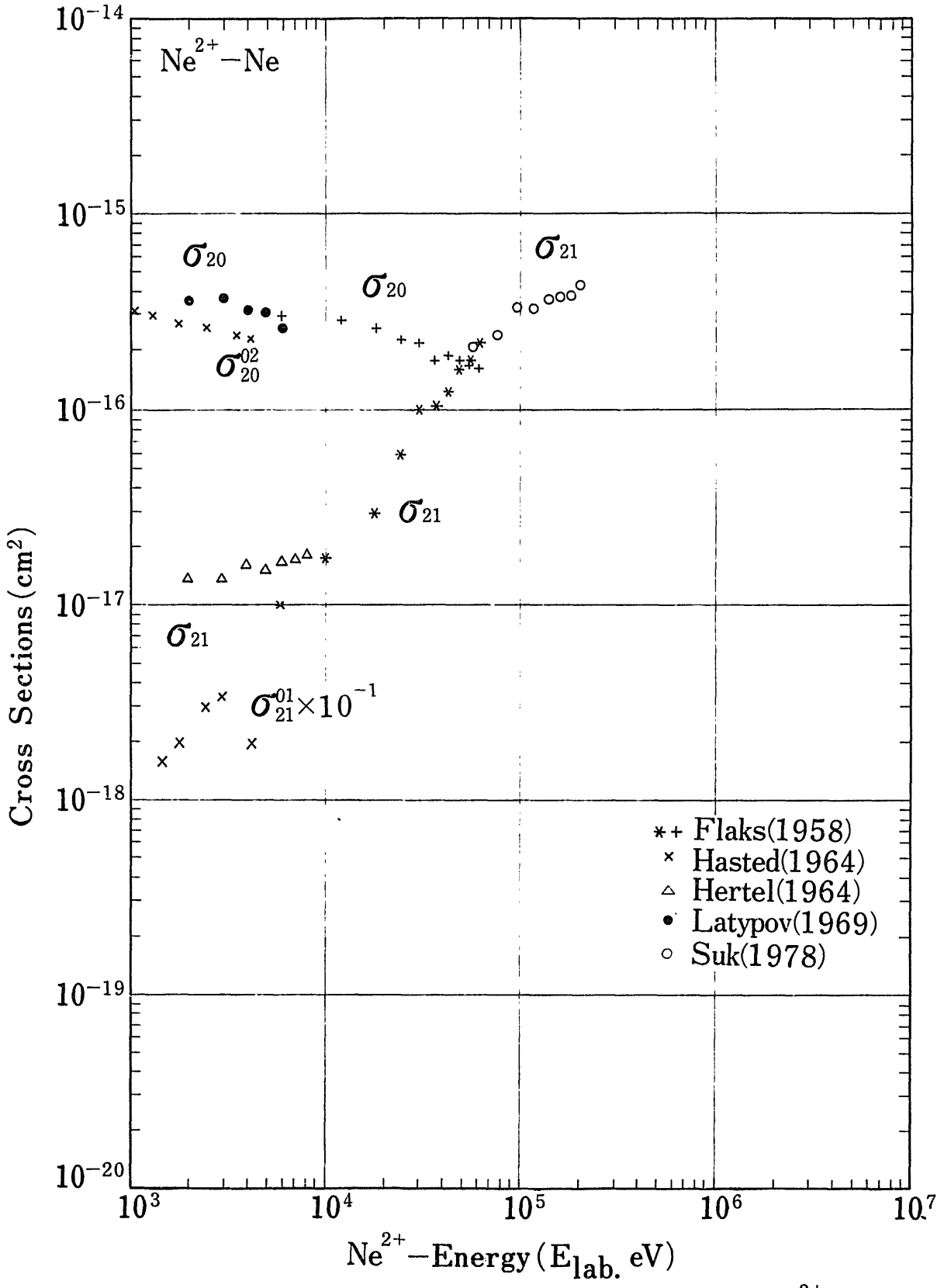

Fig.20—b Charge Changing Cross Sections of Ne^{2+} in Ne

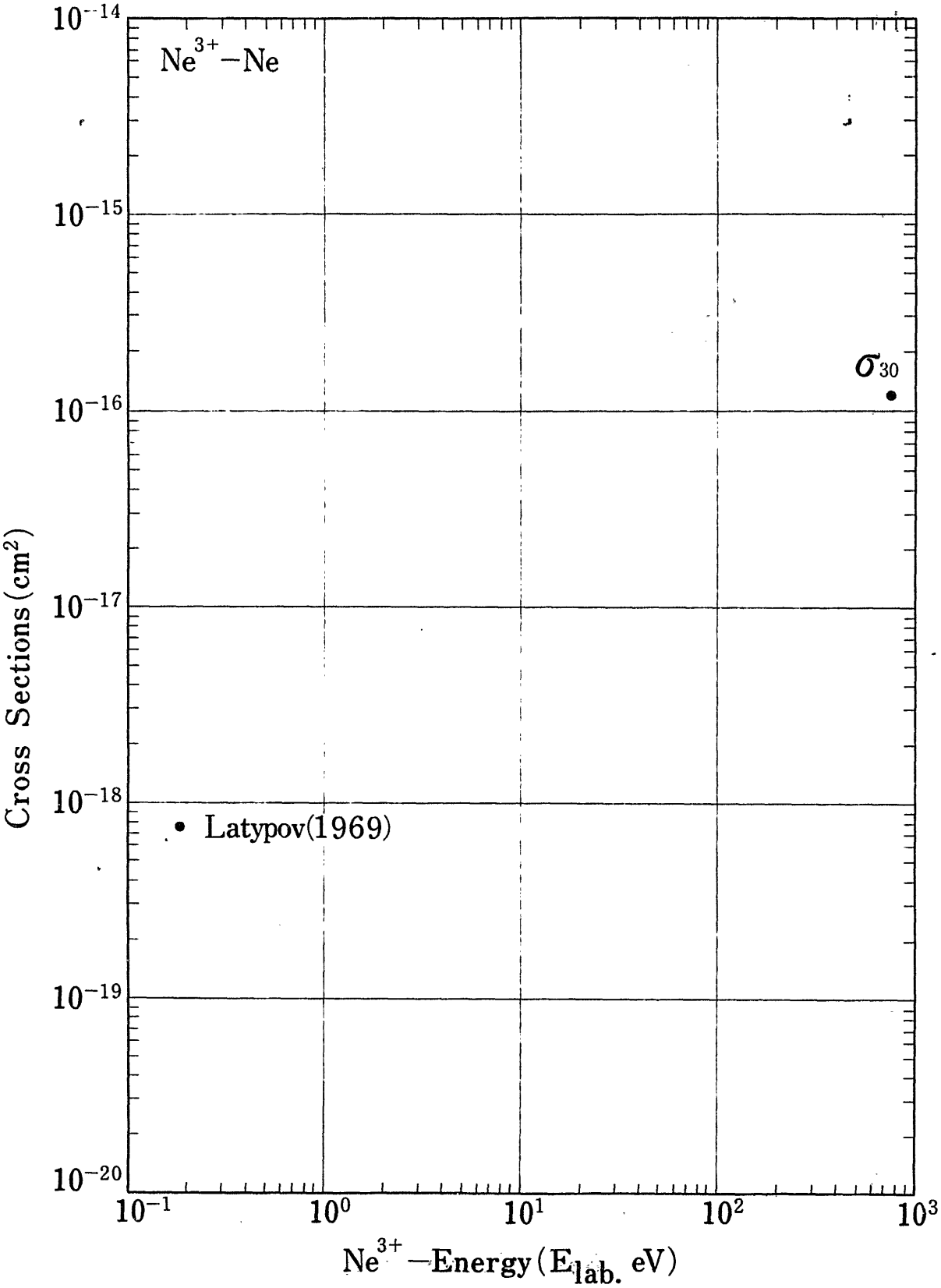

Fig. 21−a Charge Changing Cross Sections of Ne^{3+} in Ne

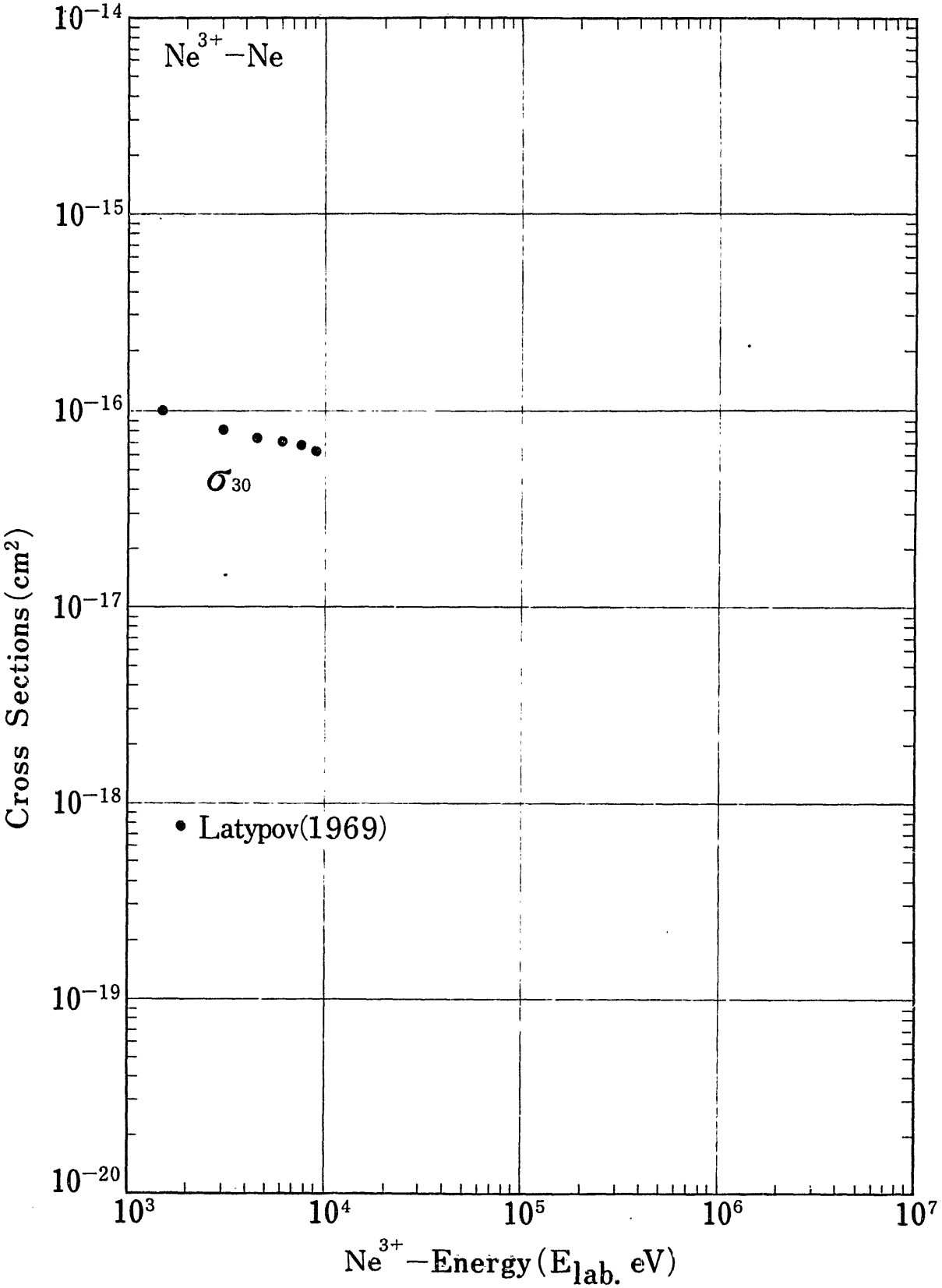

Fig.21−b Charge Changing Cross Sections of Ne^{3+} in Ne

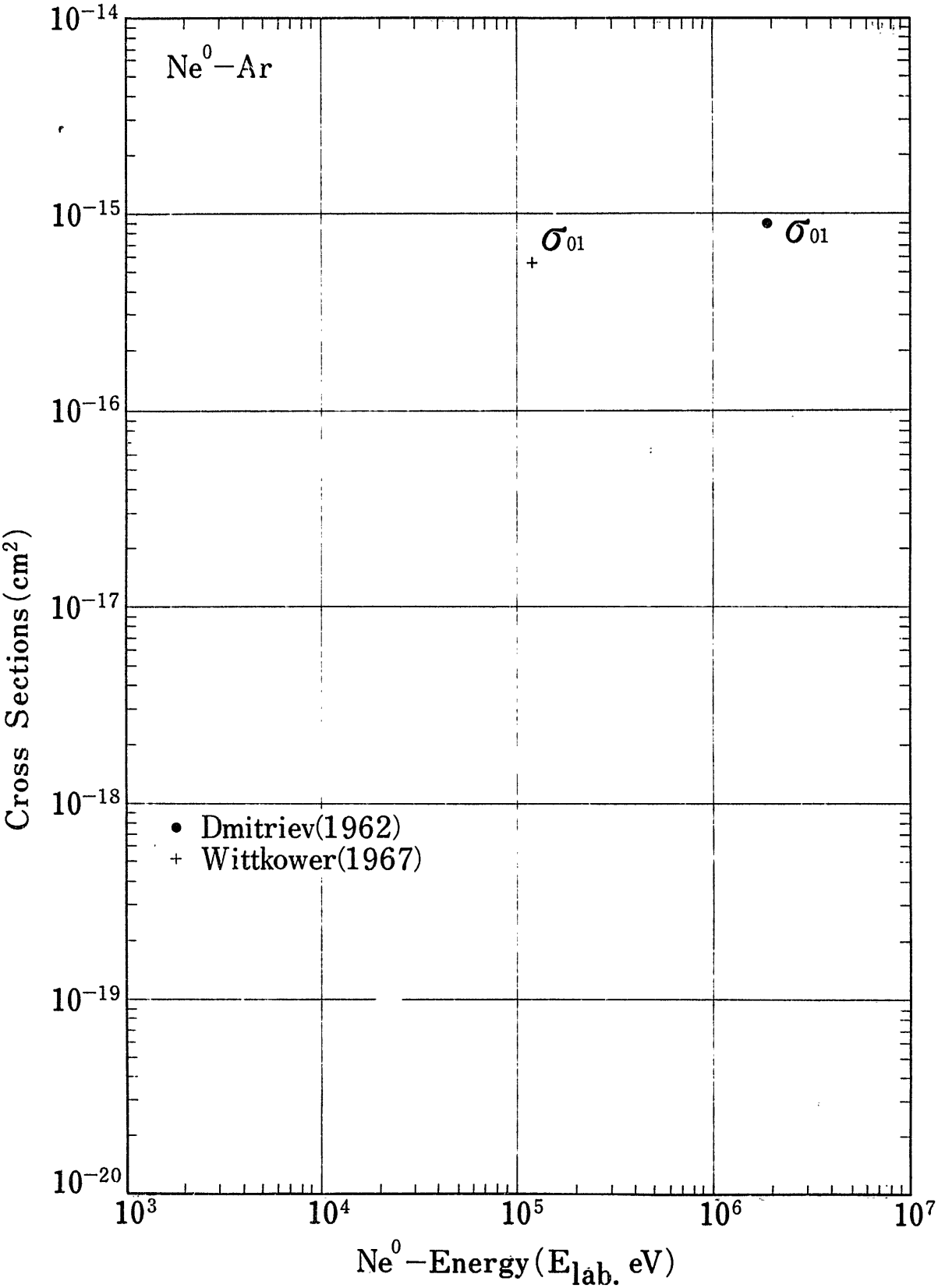

Fig.22 Charge Changing Cross Sections of Ne^0 in Ar

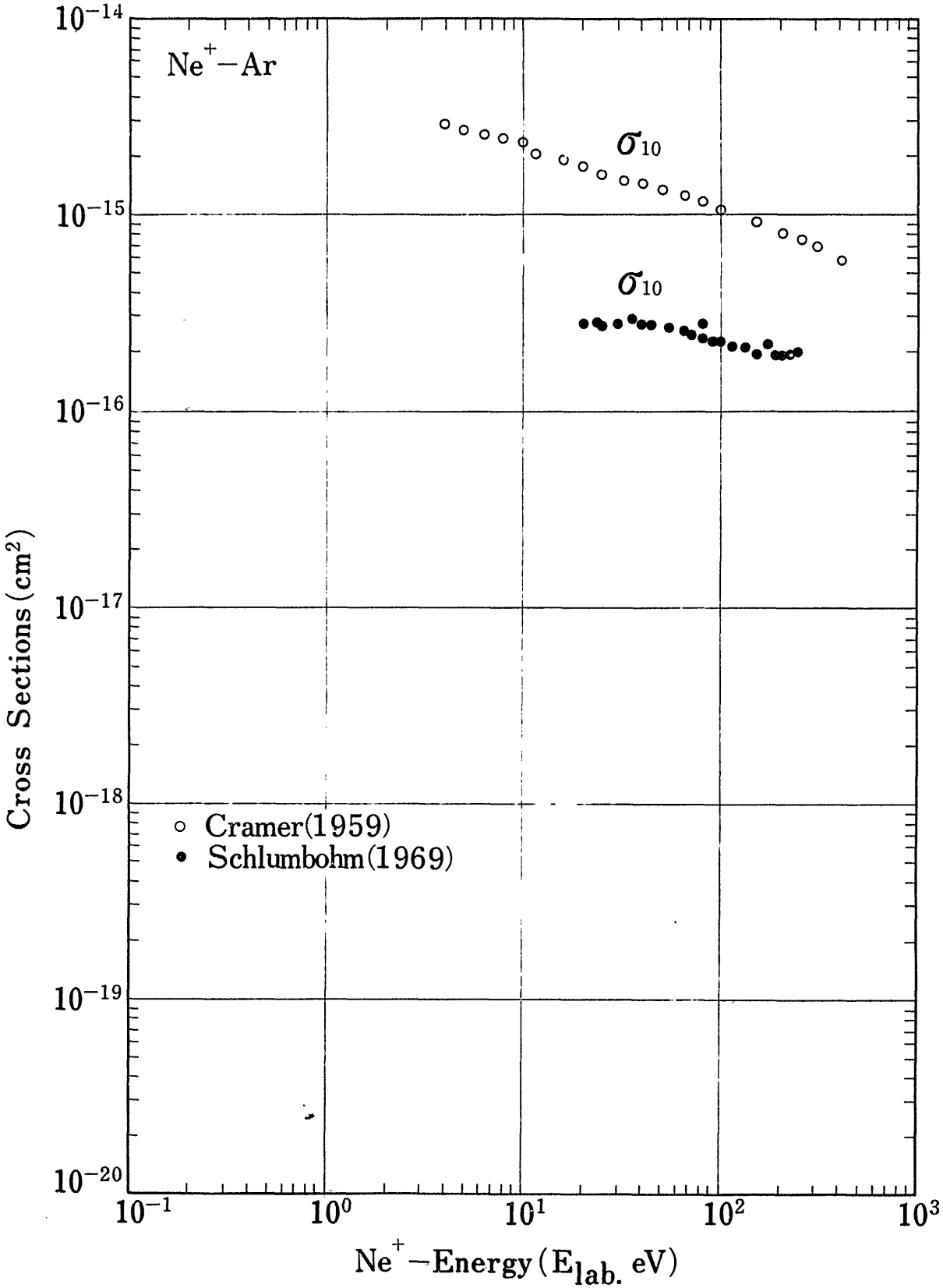

Fig.23—a Charge Changing Cross Sections of Ne^+ in Ar

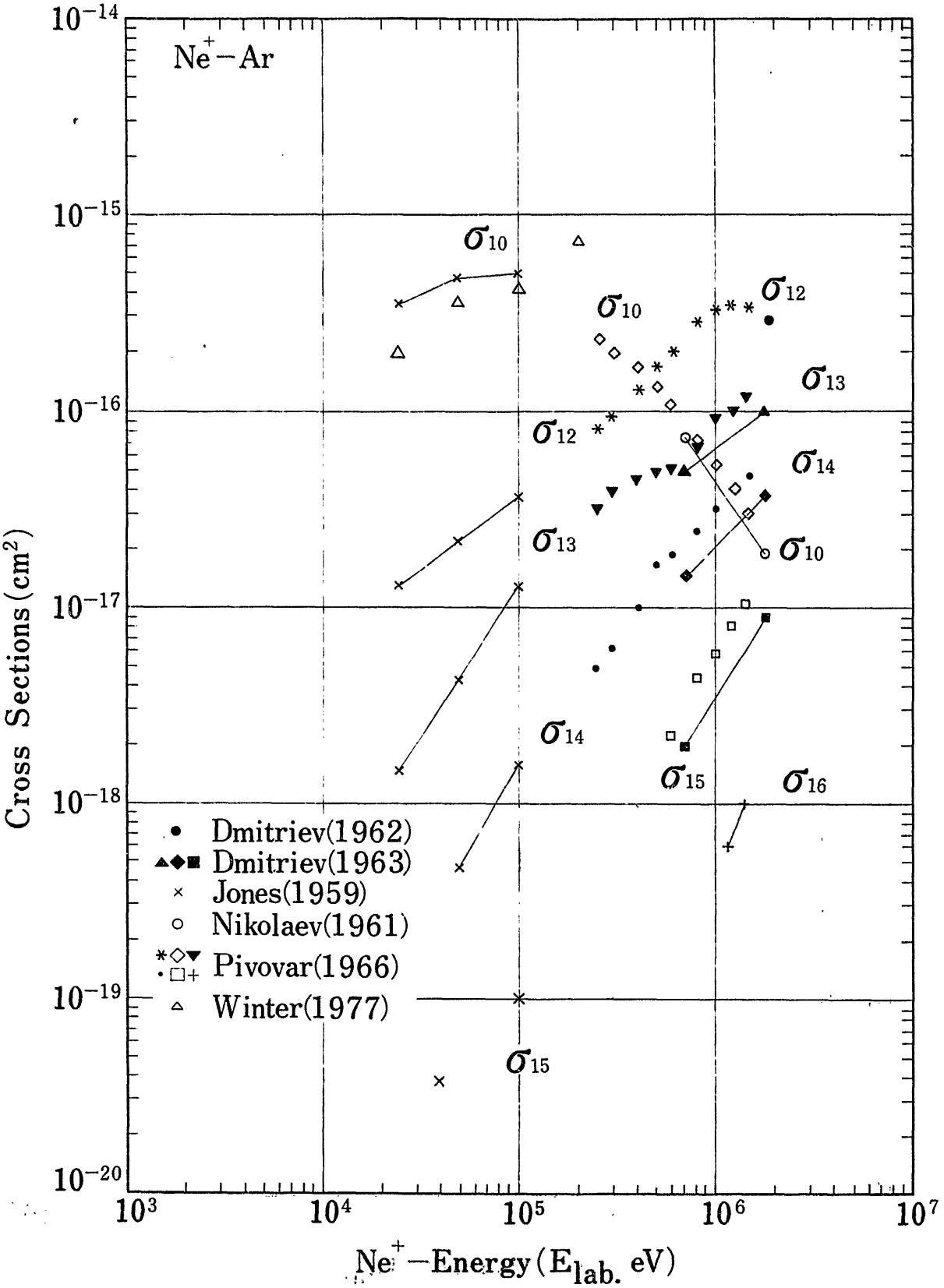

Fig.23—b Charge Changing Cross Sections of Ne^+ in Ar

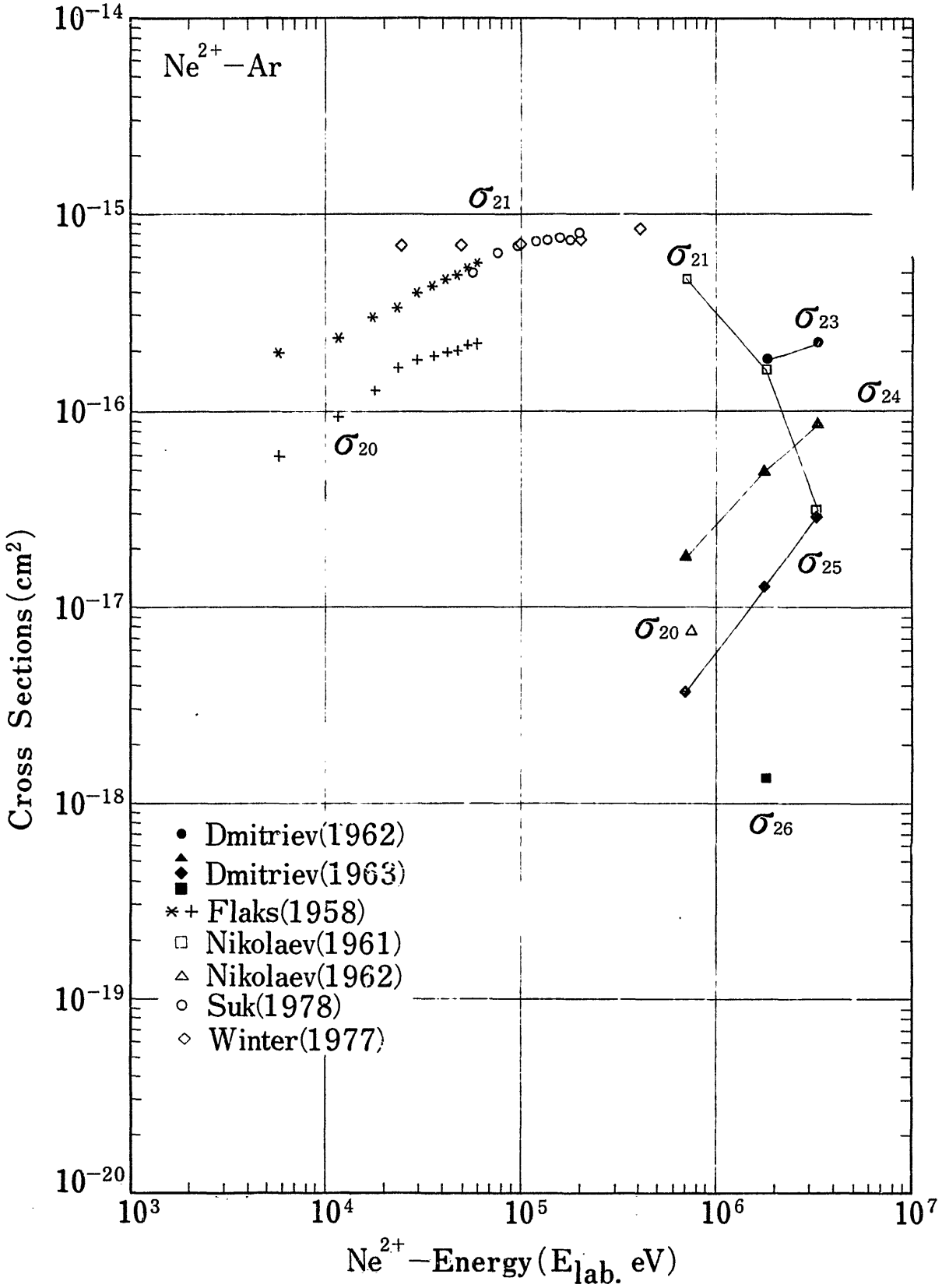

Fig.24 Charge Changing Cross Sections of Ne^{2+} in Ar

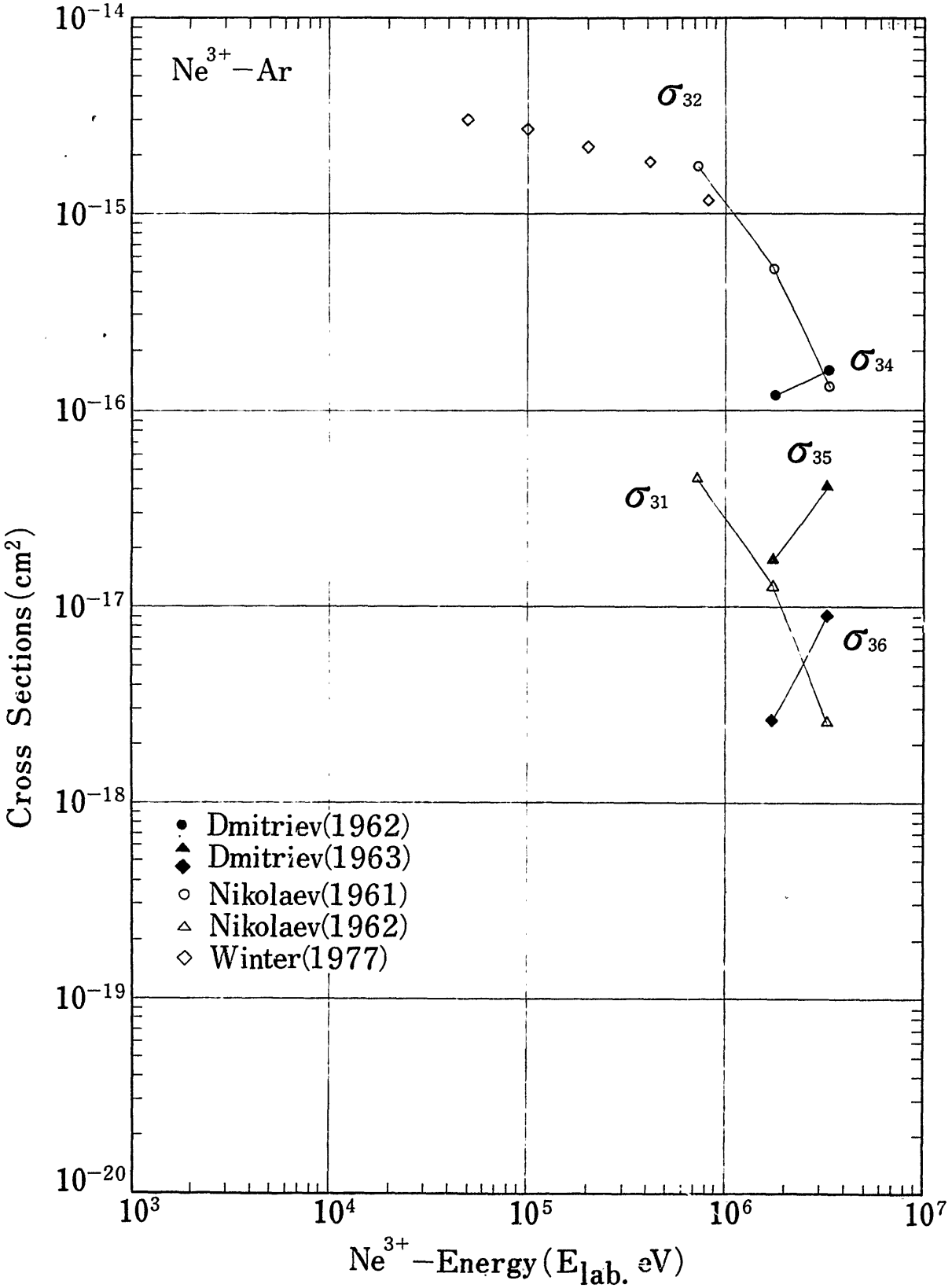

Fig. 25 Charge Changing Cross Sections of Ne^{3+} in Ar

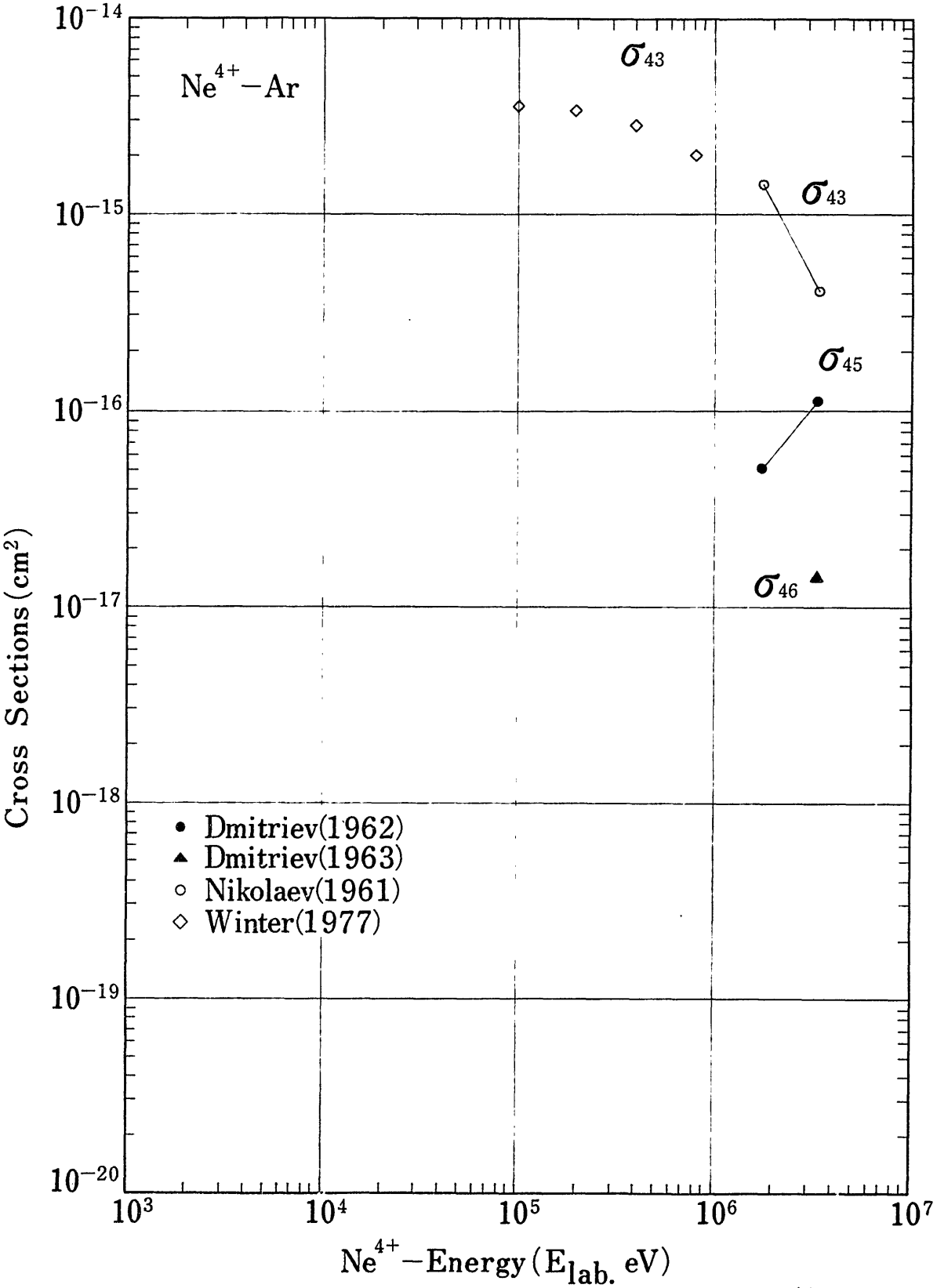

Fig.26 Charge Changing Cross Sections of Ne^{4+} in Ar

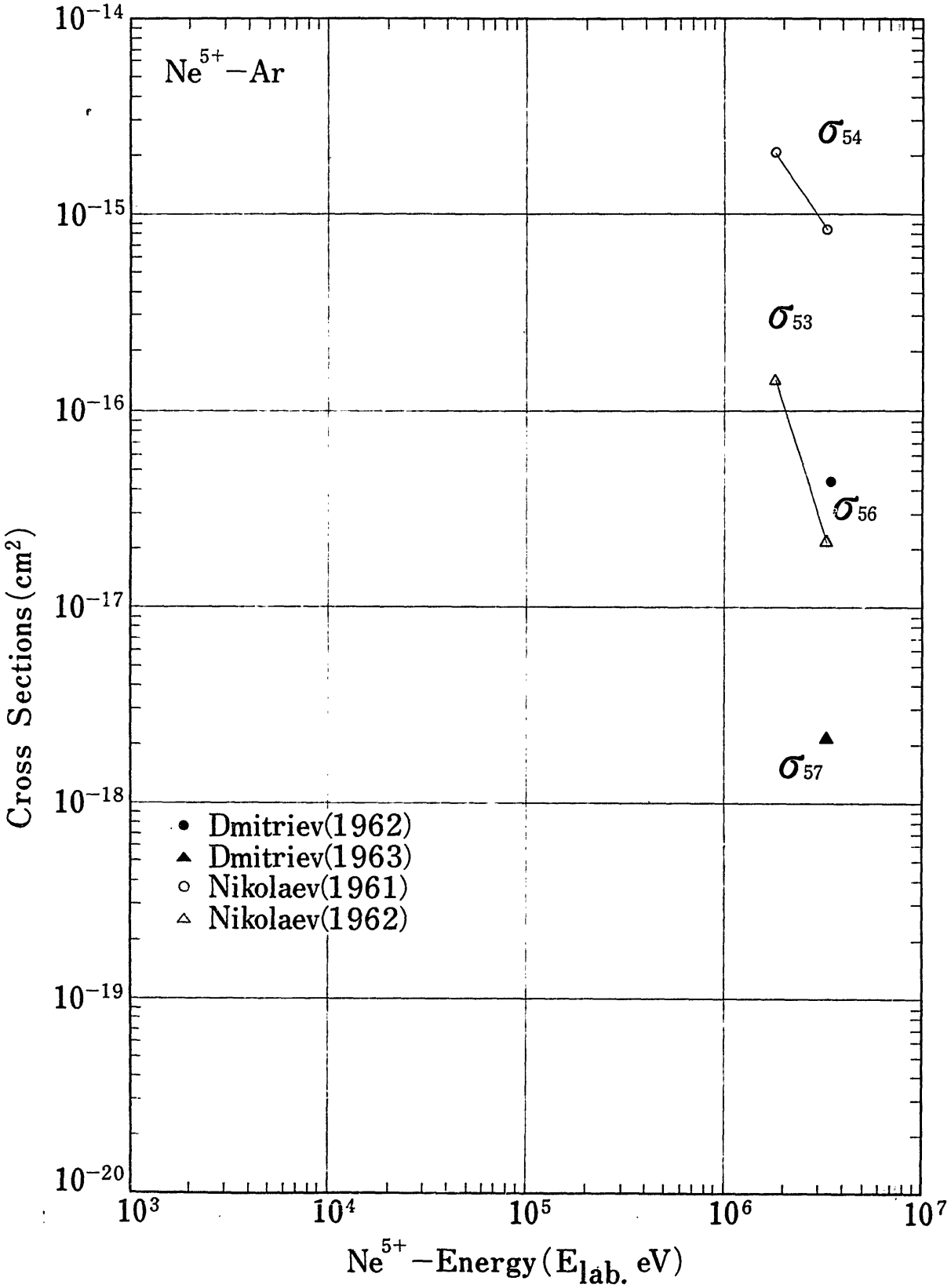

Fig. 27 Charge Changing Cross Sections of Ne^{5+} in Ar

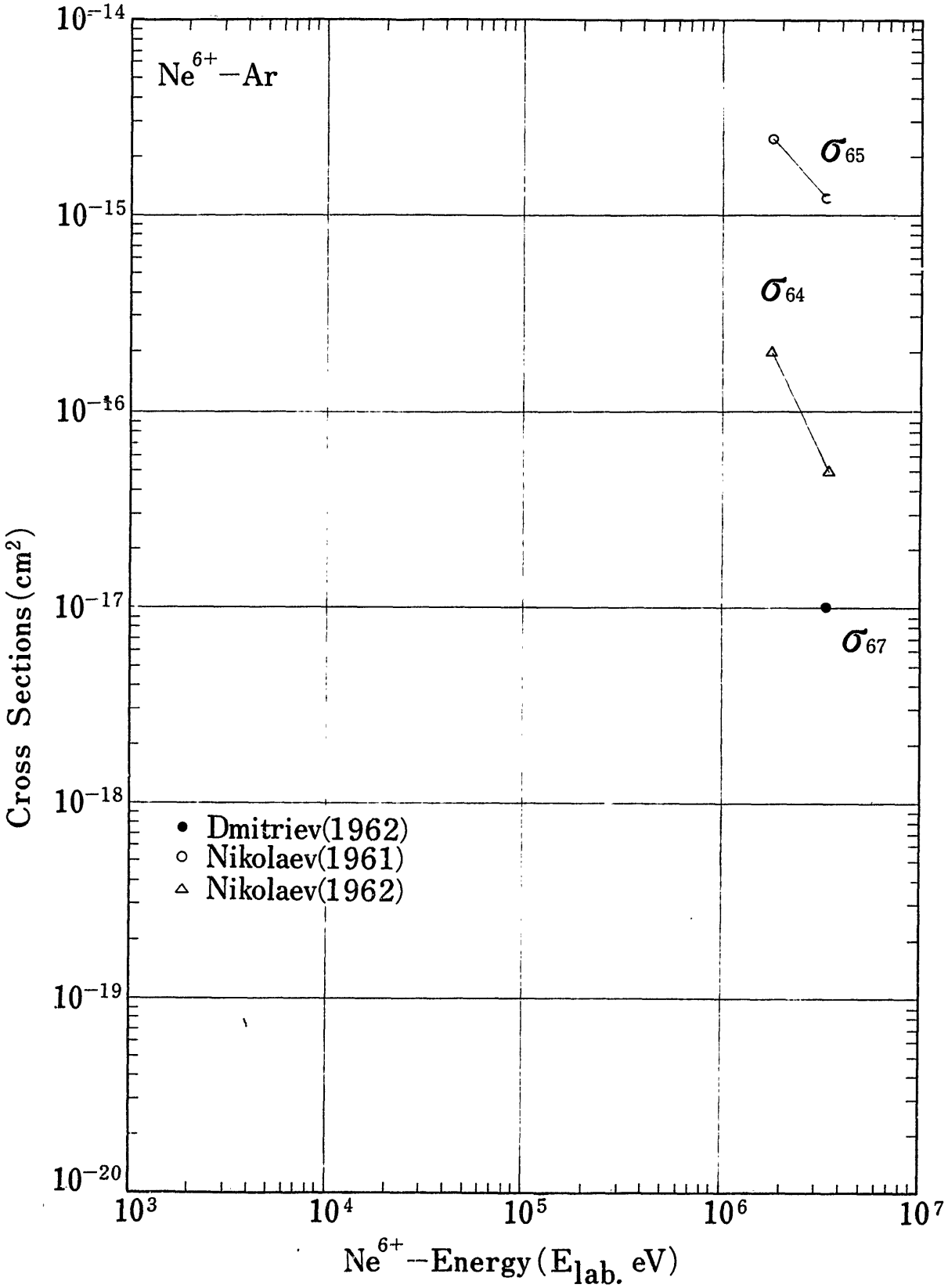

Fig.28 Charge Changing Cross Sections of Ne^{6+} in Ar

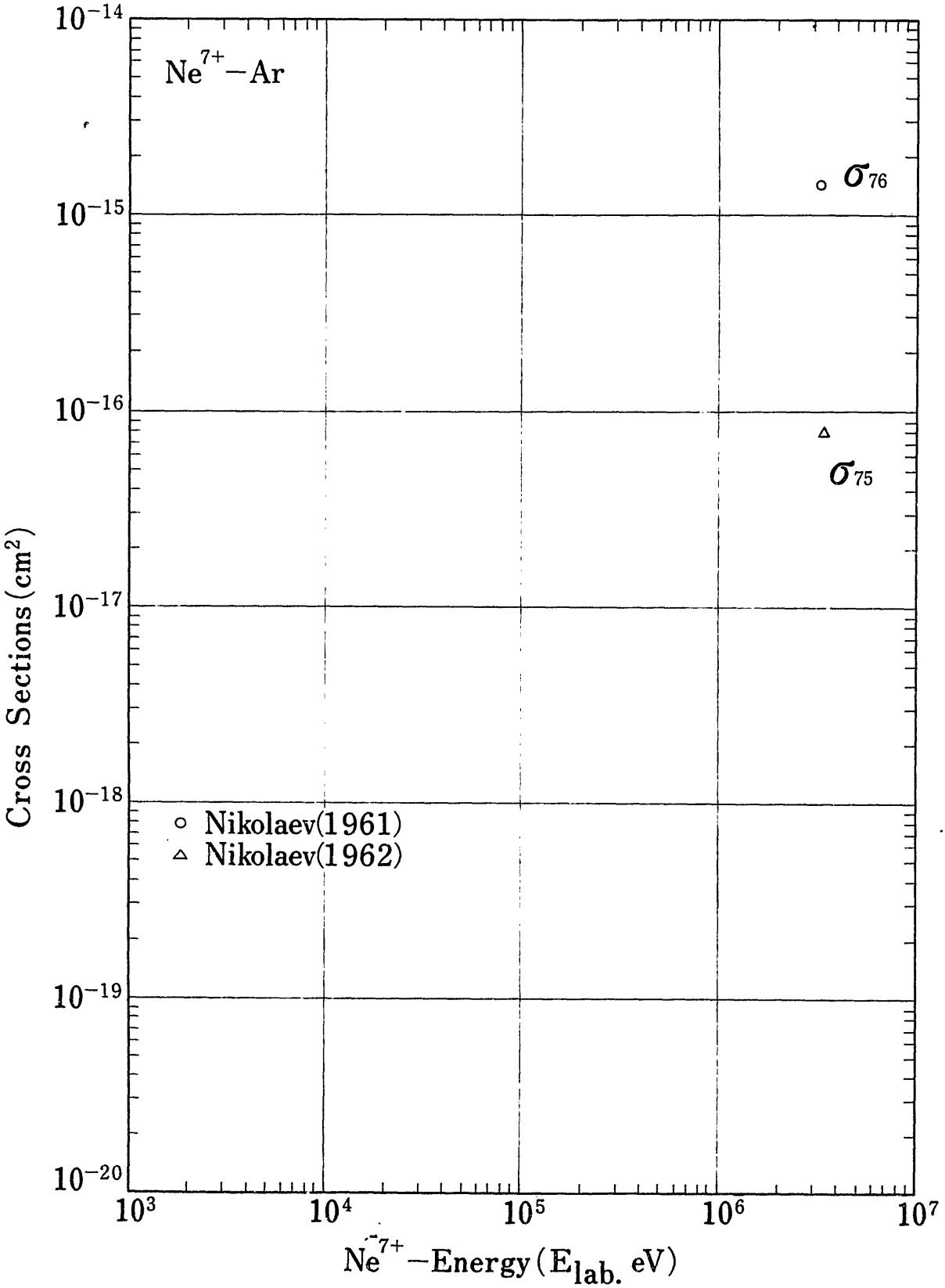

Fig.29 Charge Changing Cross Sections of Ne^{7+} in Ar

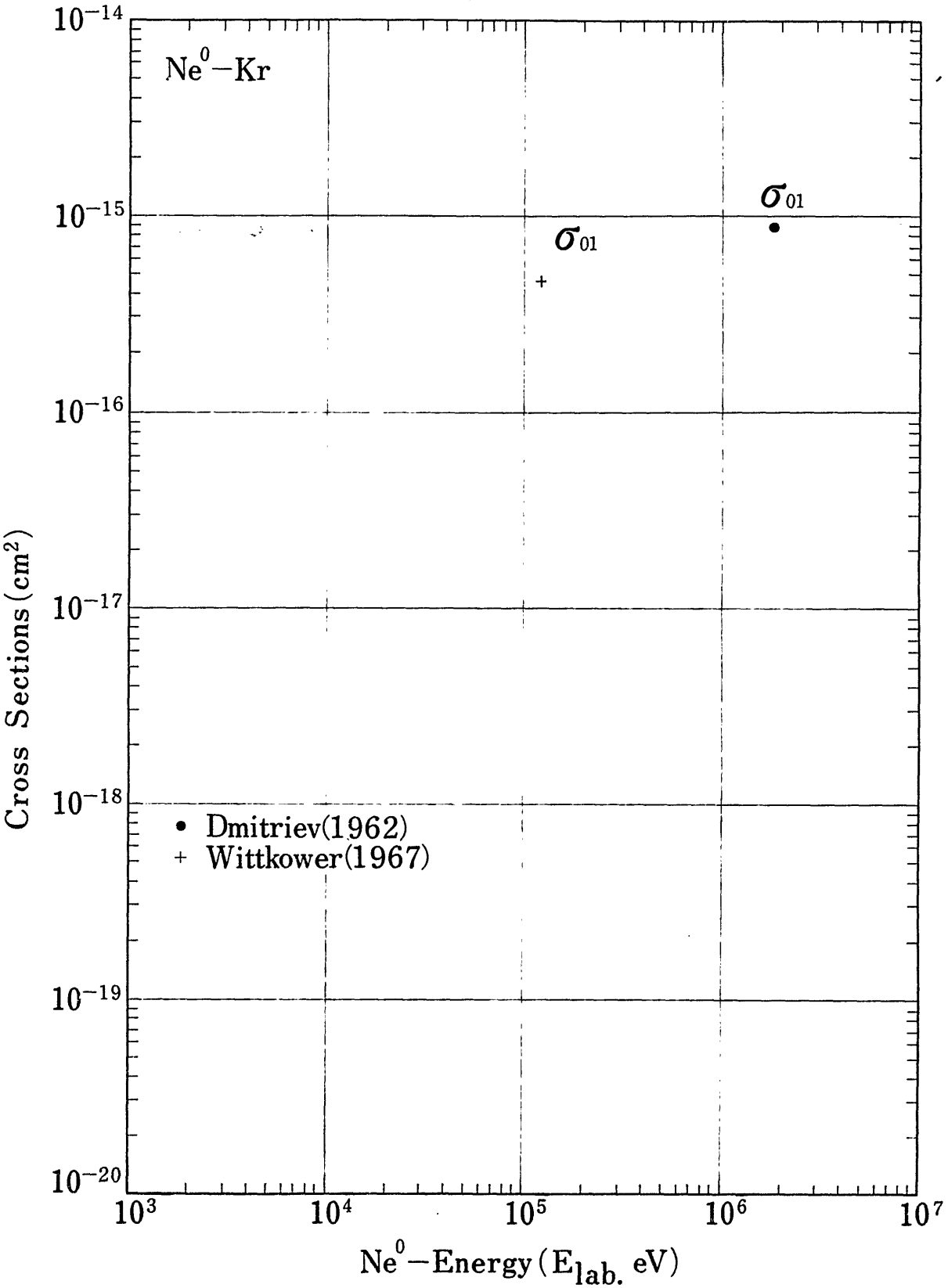

Fig.30 Charge Changing Cross Sections of Ne^0 in Kr

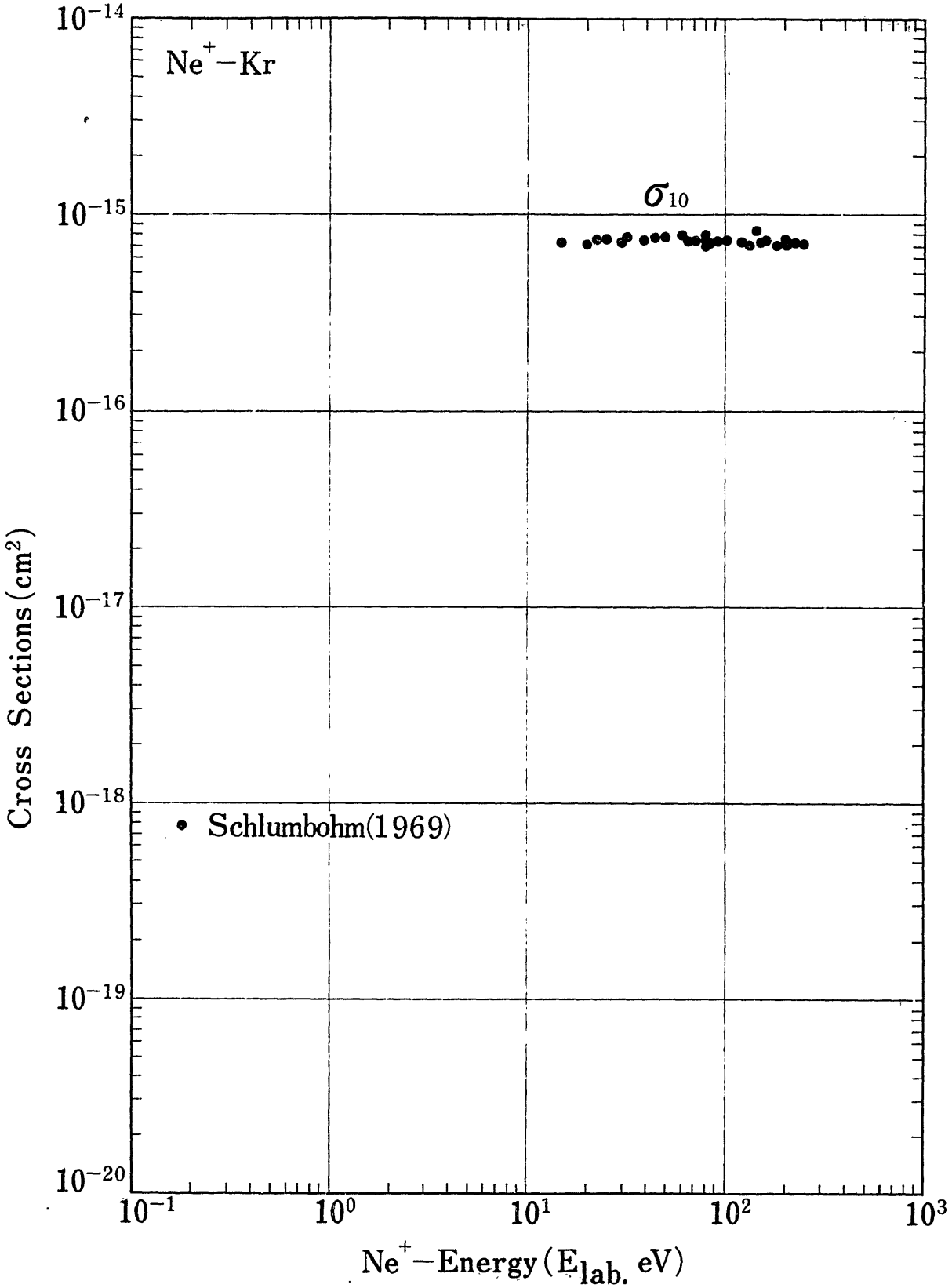

Fig. 31−a Charge Changing Cross Sections of Ne^+ in Kr

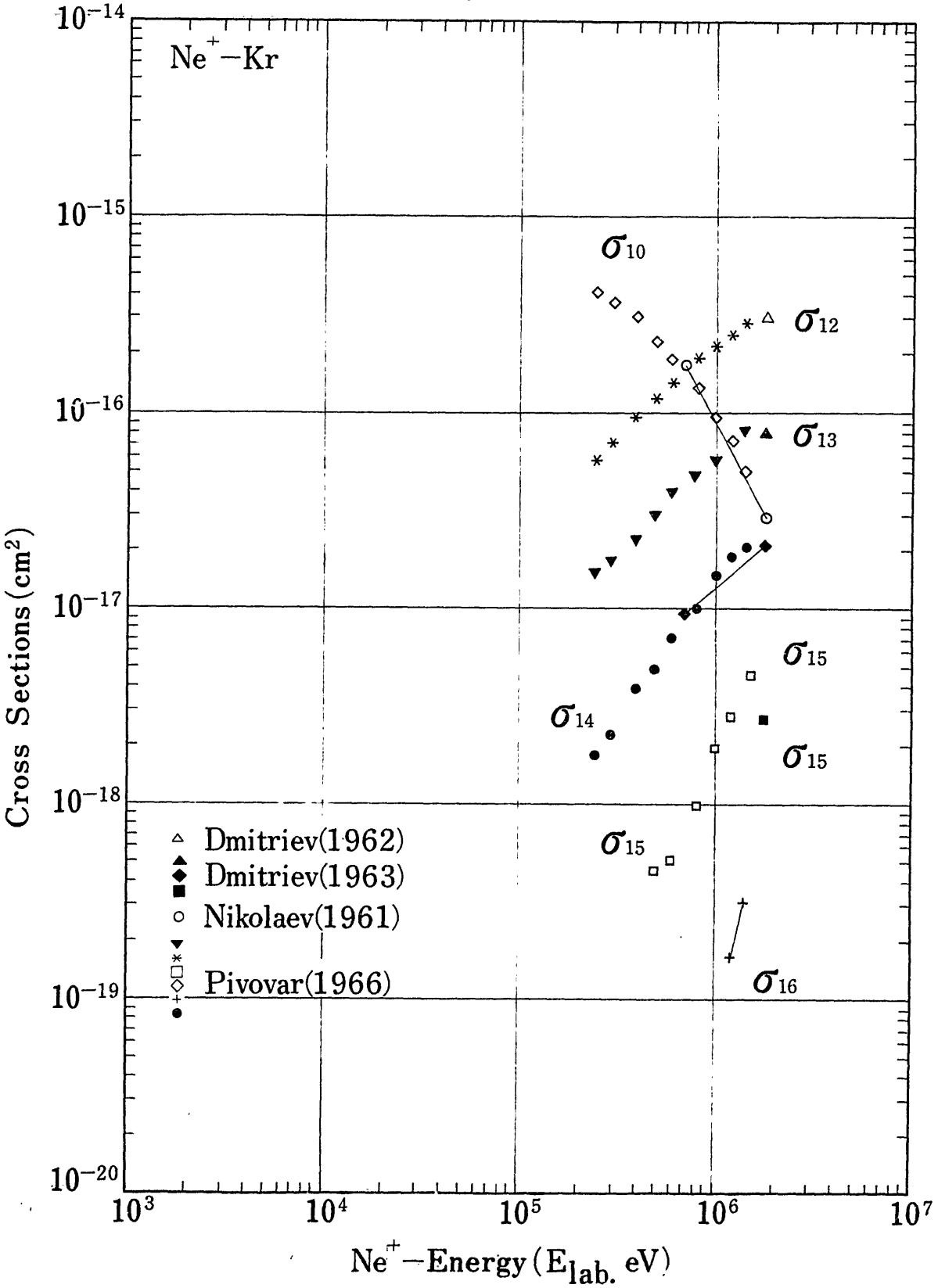

Fig. 31−b Charge Changing Cross Sections of Ne^+ in Kr

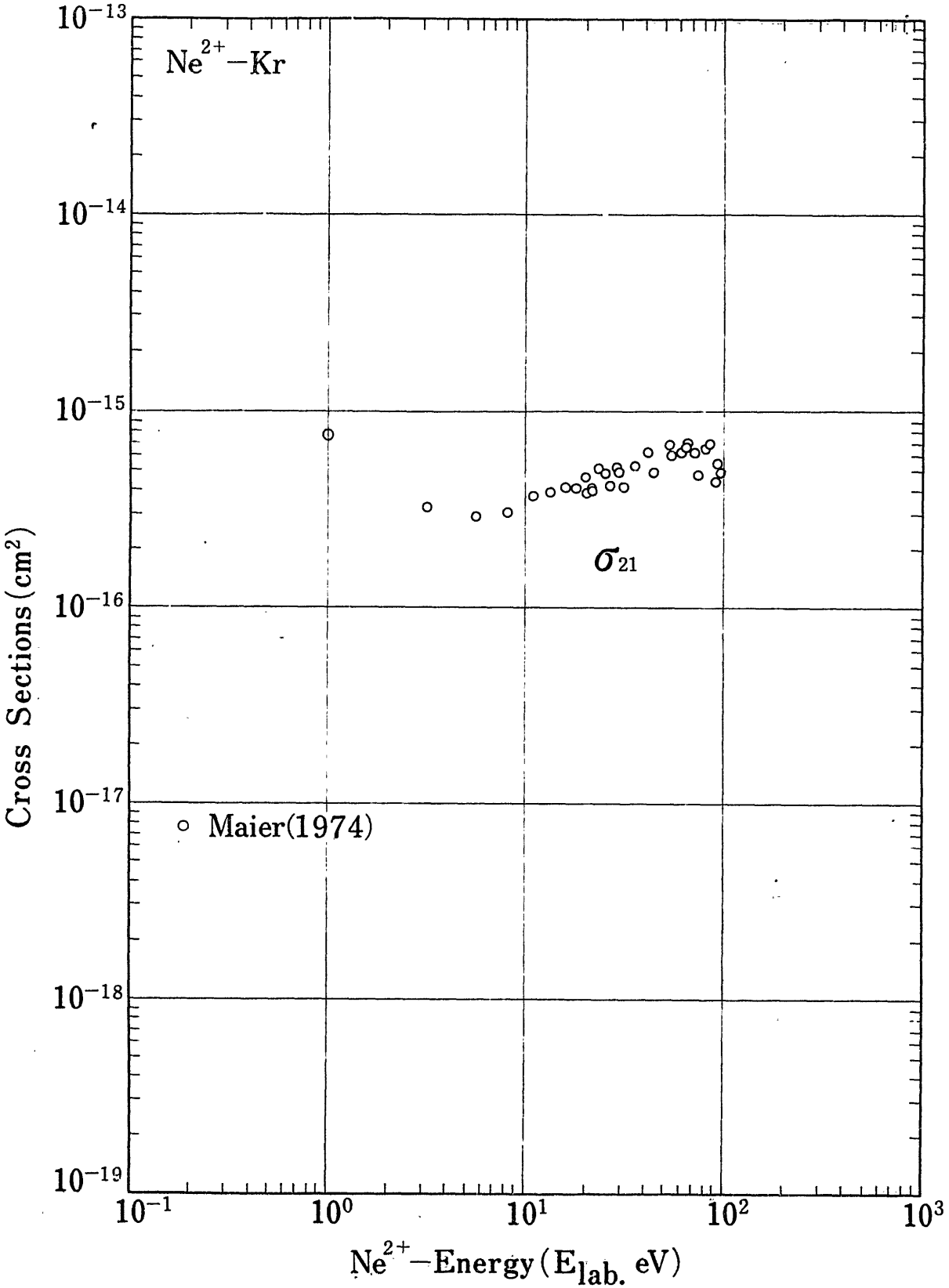

Fig.32—a Charge Changing Cross Sections of Ne^{2+} in Kr

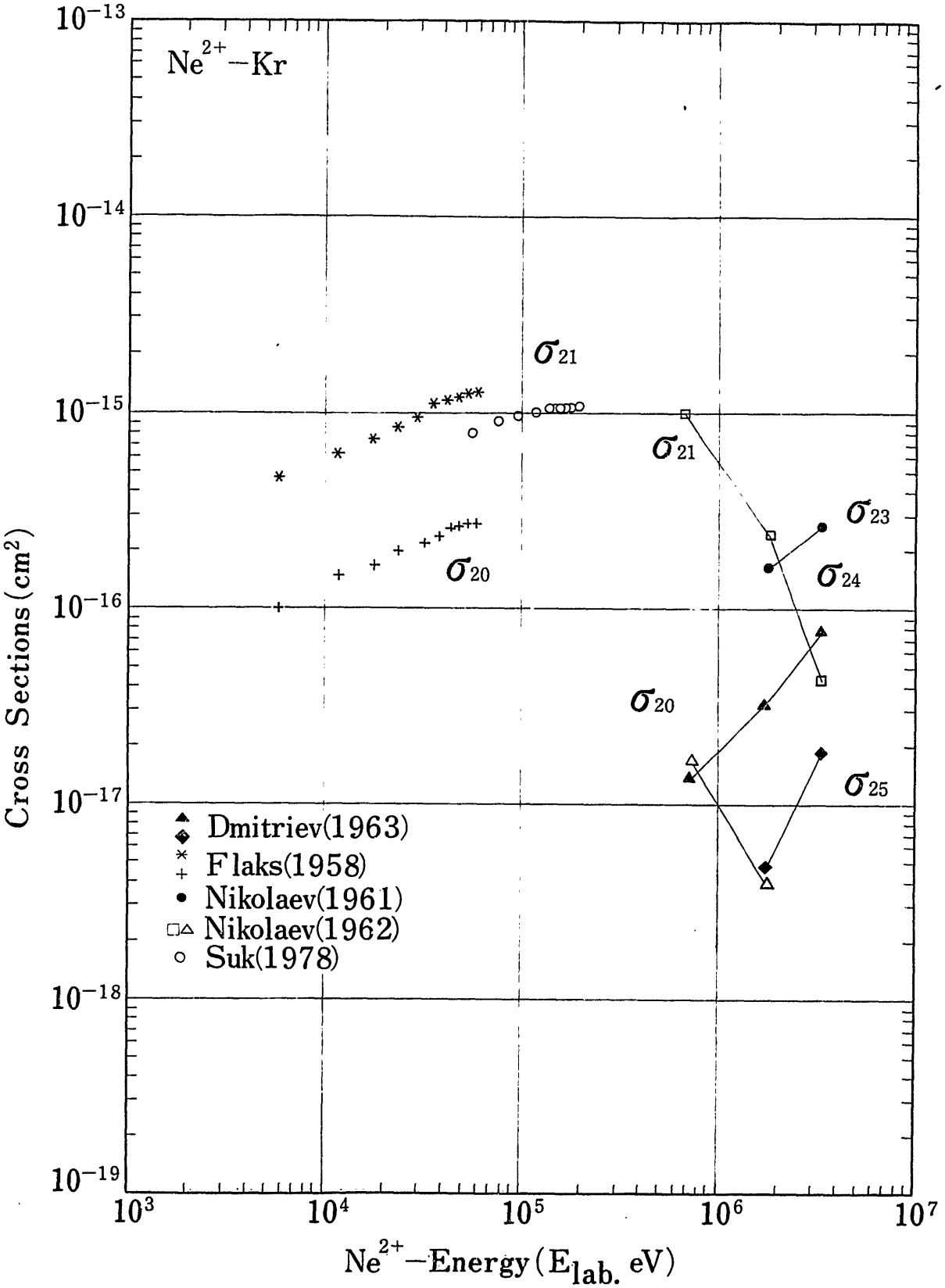

Fig.32–b Charge Changing Cross Sections of Ne^{2+} in Kr

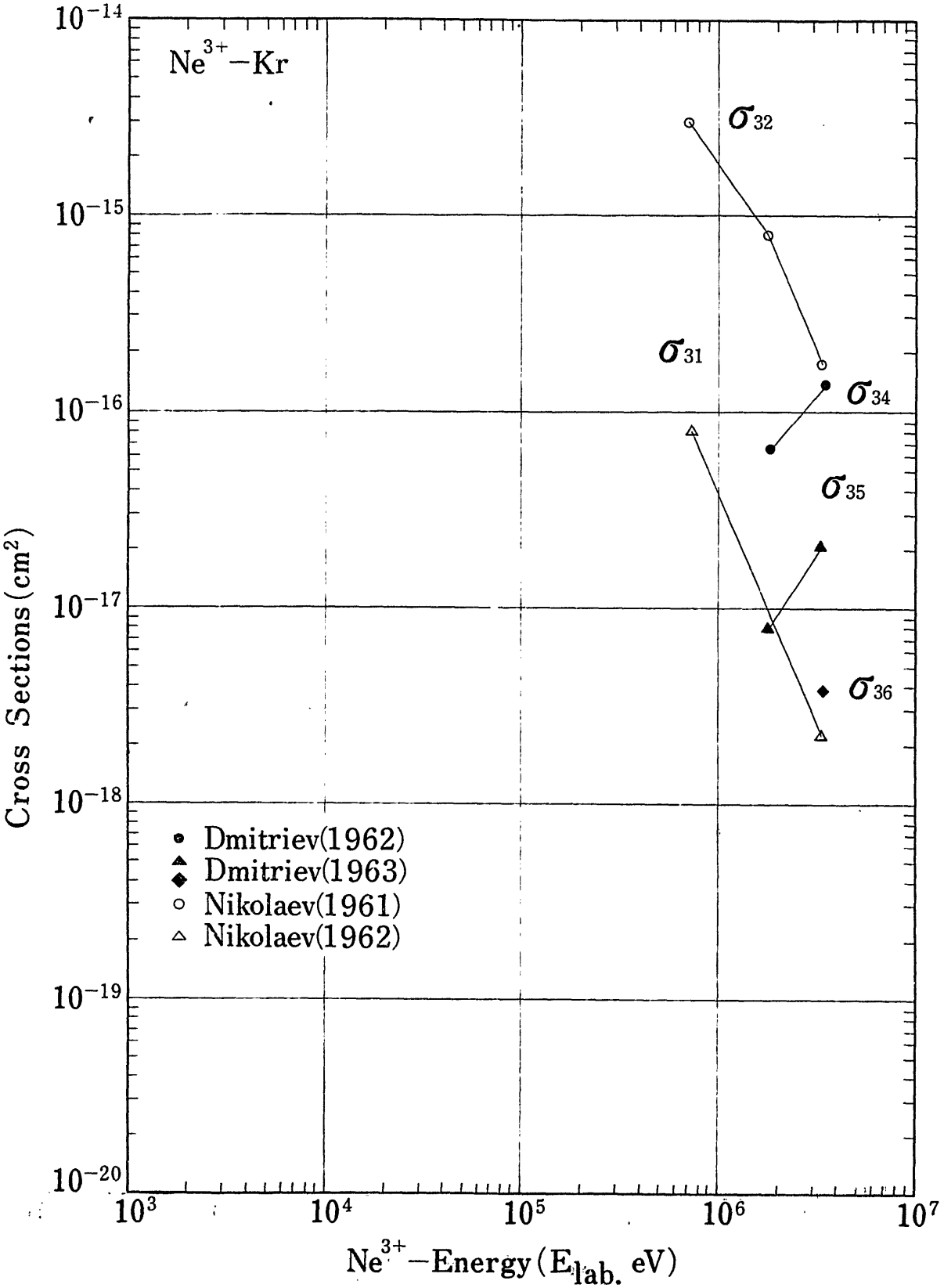

Fig. 33 Charge Changing Cross Sections of Ne^{3+} in Kr

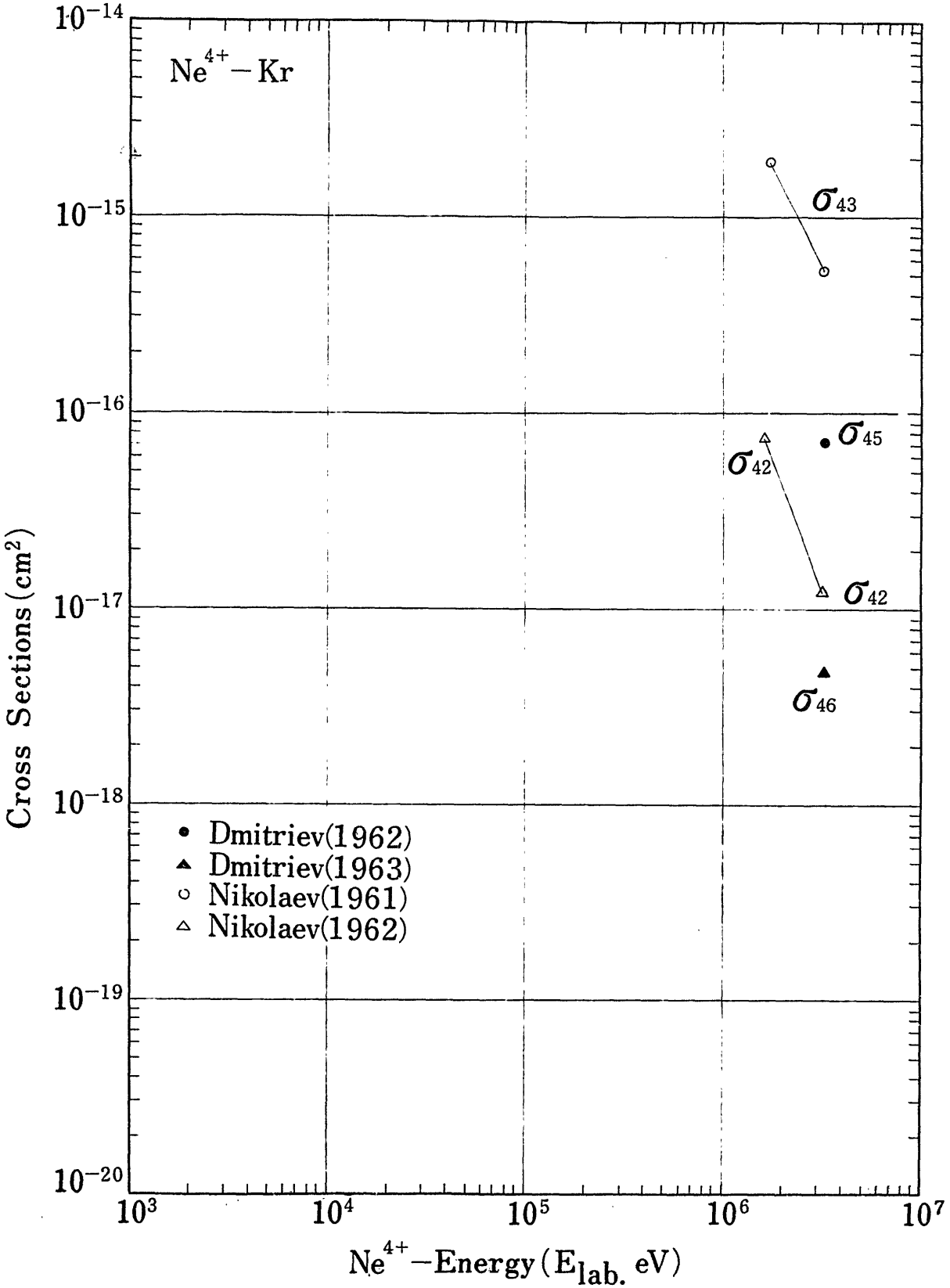

Fig. 34 Charge Changing Cross Sections of Ne^{4+} in Kr

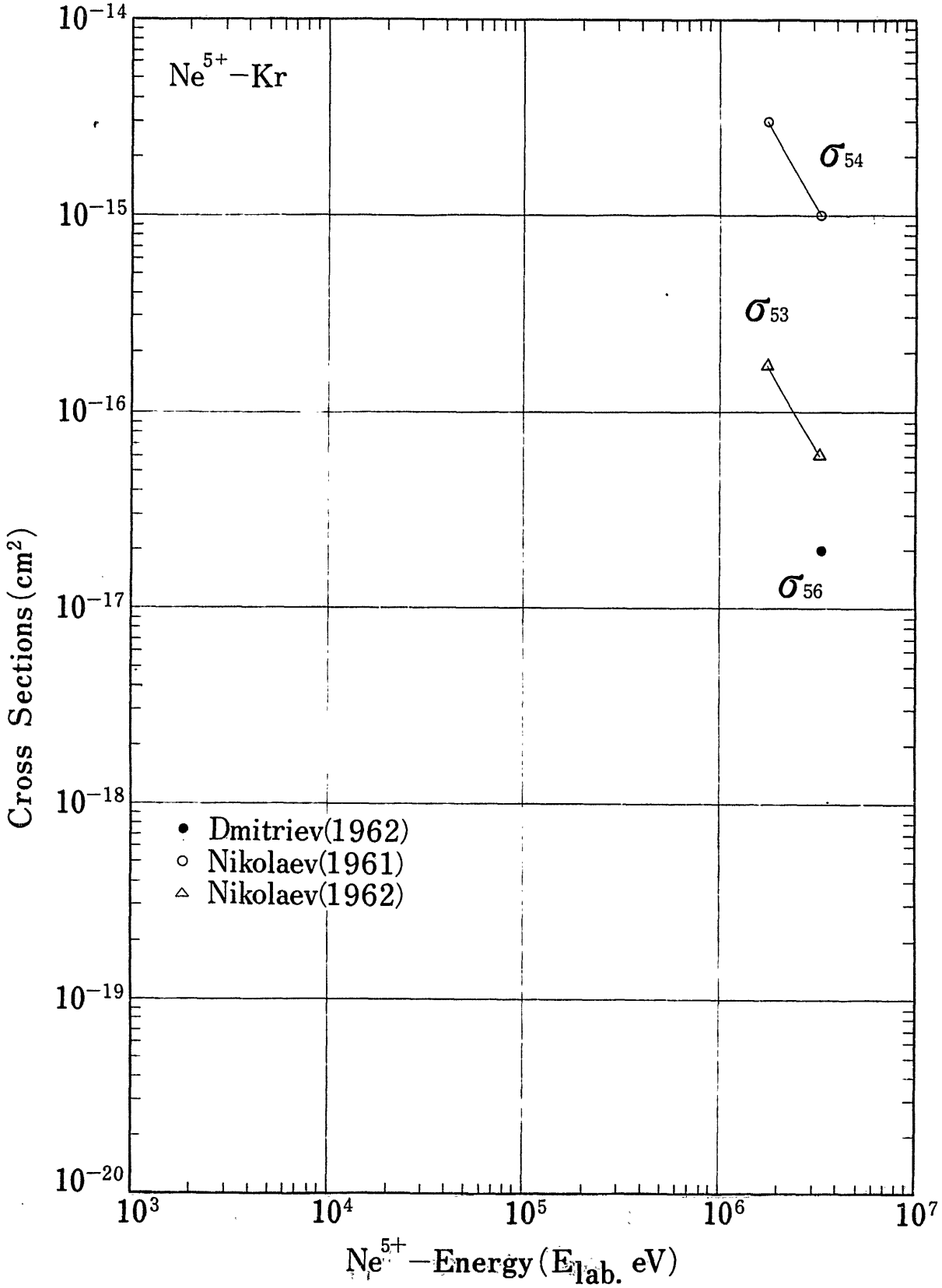

Fig.35 Charge Changing Cross Sections of Ne^{5+} in Kr

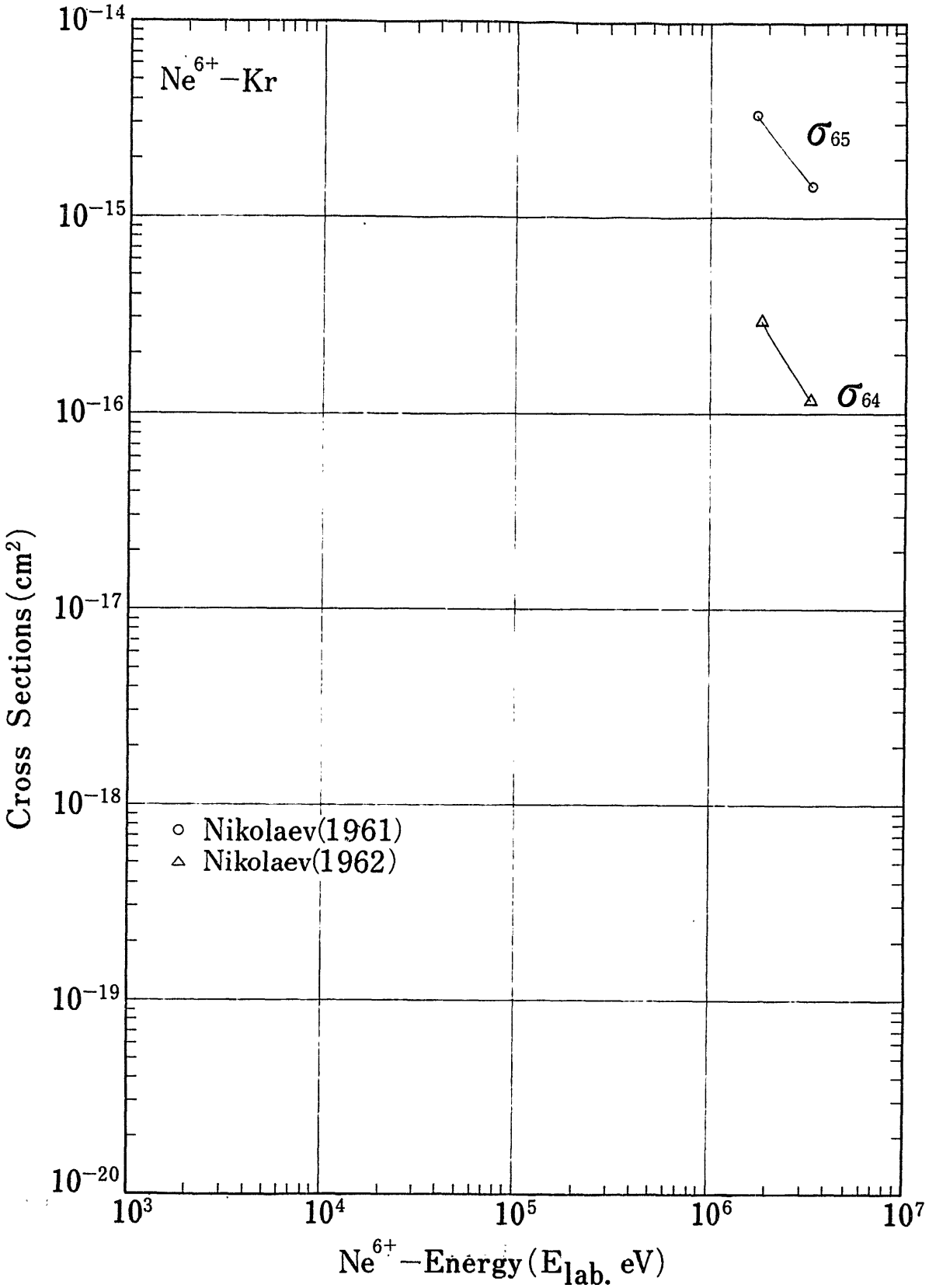

Fig.36 Charge Changing Cross Sections of Ne^{6+} in Kr

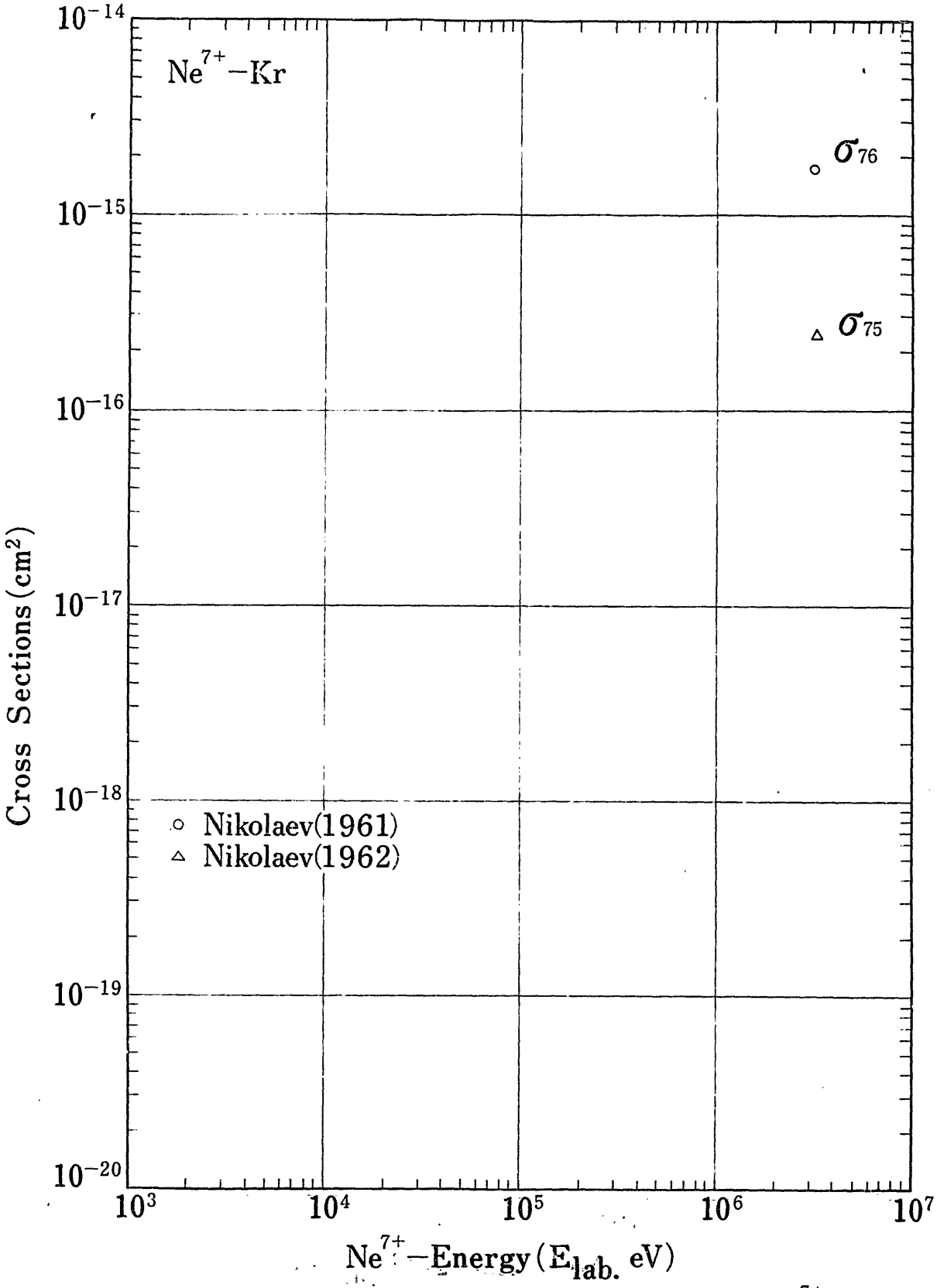

Fig.37 Charge Changing Cross Sections of Ne^{7+} in Kr

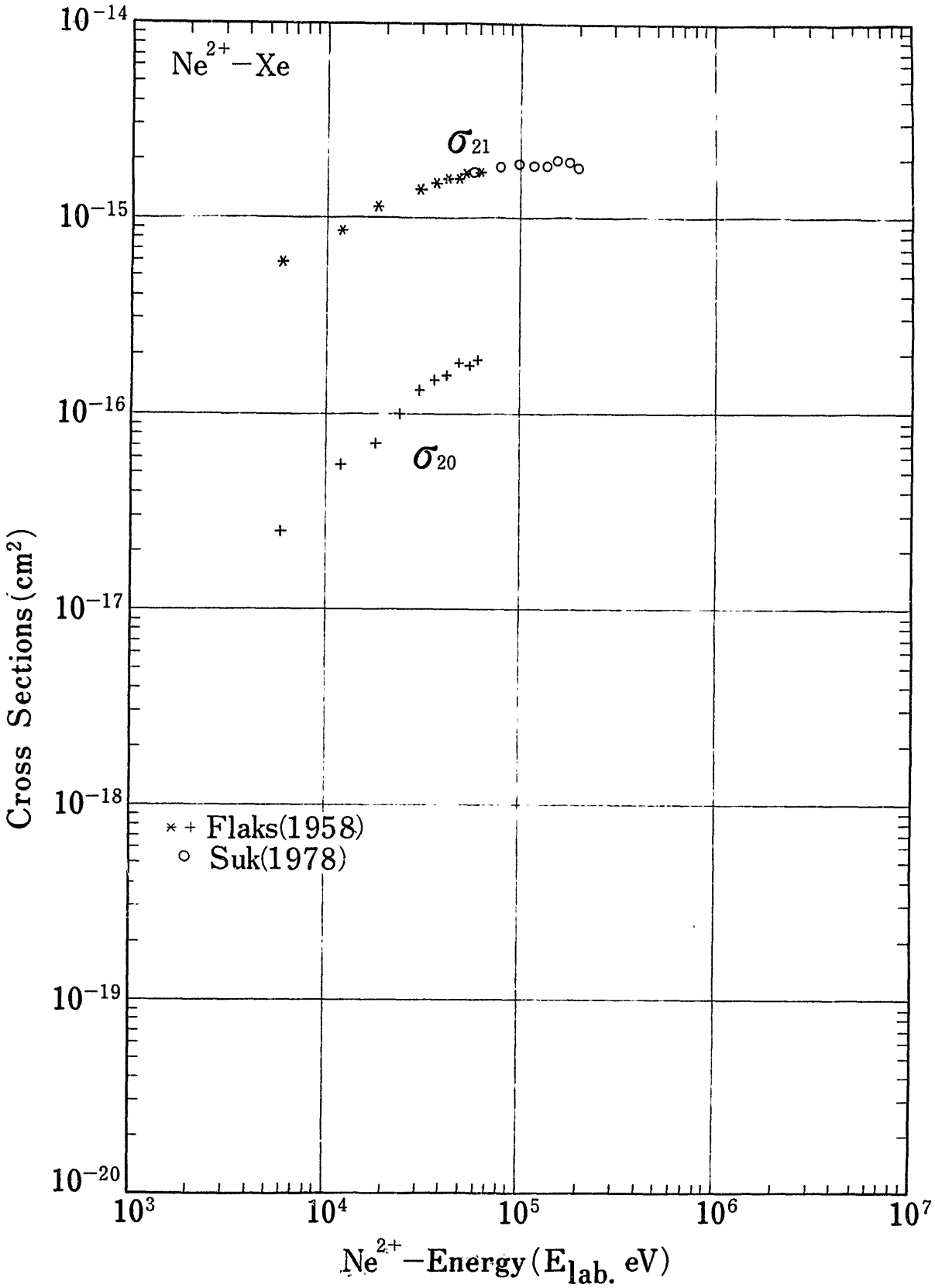

Fig.38 Charge Changing Cross Sections of Ne^{2+} in Xe

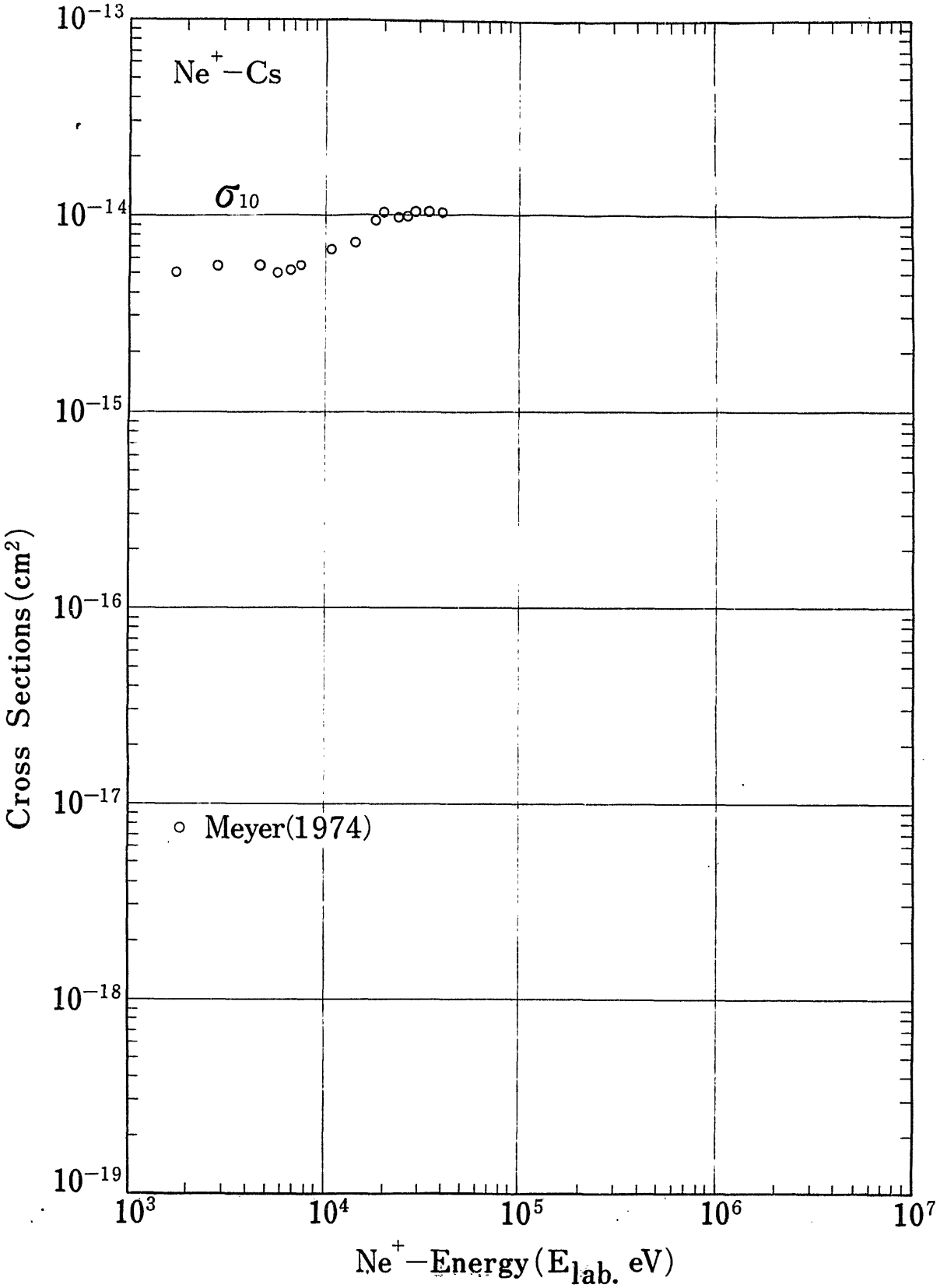

Fig.39 Charge Changing Cross Sections of Ne^+ in Cs

Charge Changing Cross Sections of Sodium Atoms and Ions, Z=11

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. Craphs of Charge Changing Cross Sections

I. References for Experimental Data of Na (Z=11)

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II. Tables of Experimental Data

A) Electron Capture Cross Sections of Sodium Positive Ions; Na^+, Na^{2+}, Na^{3+}.

authors	year	energy(eV)	target	references
(σ_{10})				
Nikolaev et al.	1961	806,000	He,N_2,Kr	22
Ogurtsov et al.	1966	1,000-30,000	H_2,He,N_2,Ne, Ar,Kr,Xe	24
Marino	1966	50-4,000	Cs	21
Lockwood	1969	25,000-100,000	N_2	18
Perel, Daley	1969	500-25,000	Li,K	28
Pivovar et al.	1969	20,000-155,000	Ne,Na,Ar,K	29
Daley,Perel	1969	500-24,000	Li,Na	7
Lockwood	1969	25,000-100,000	Ar	19
Pivovar et al.	1970	30,000-150,000	Ne,Na,Ar,K	30
Ormrod,Michel	1971	25,000-70,000	N_2,Ar	27
Aquilanti,Bellu	1974	50-1,500	K	3
($\sigma_{1\,\bar{1}}$)				
Fogel' et al.	1961	10,000-55,000	H_2,Ar,Kr,Xe	12
Kozlov, Boudar	1966	2,000-6,000	H_2,Ar,Kr	14
Weiner et al.	1971	0.1-7.0	O^-	34
(σ_{21})				
Nikolaev et al.	1961	806,000	He,N_2,Kr	23
Pivovar,Nikolaichuk	1970	20,000-155,000	Ne,Ar	31
(σ_{20})				
Nikolaev et al.	1962	806,000	N_2	24

authors	year	energy (eV)	target	reference
(σ_{32})				
Nikolaev et al.	1961	806,000	He,N_2,Kr	23
(σ_{31})				
Nikolaev et al.	1962	806,000	N_2	24

B) Electron Loss Cross Sections of Sodium Atom and Positive Ions; Na°, Na^+, Na^{2+}, Na^{3+}.

(σ_{01})				
Dukelsky et al.	1959	420-2,060	He,Ne,Ar,Kr,Xe	10
Bydin,Bukhteev	1960	250-2,200	H_2,D_2,N_2,O_2	6
Dmitriev et al.	1962	806,000	N_2	9
Kikiani et al.	1966	3,000-30,000	H_2,He,N_2,Ne Ar,Kr,Xe	13
Pivovar, Nikolaichuk	1970	20,000-155,000	Ne,Na,Ar,K	31
Ormrod, Michel	1971	30,000-70,000	N_2,Ar	27
Hvelplund, Horsdal	1971	60,000-1,000,000	H_2	8
(σ_{12})				
Levient et al.	1955	85,000-215,000	Air	17
Dmitriev et al.	1962	806,000	He,N_2,Ar,Kr	9
Pivovar,Nikolaichuk	1970	20,000-155,000	Ne,Ar	31
(σ_{13})				
Levient et al.	1955	85,000-235,000	Air	17
Dmitriev et al.	1963	806,000	He,N_2,Kr	9
(σ_{14})				
Levient et al.	1955	135,000-215,000	Air	17

authors	year	energy (eV)	target	reference
Dmitriev et al.	1963	806,000	N_2	9
(σ_{15})				
Levient et al.	1955	235,000	Air	17
(σ_{23})				
Dmitriev et al.	1962	806,000	He,N_2,Ar	9
(σ_{24})				
Dmitriev et al.	1963	806,000	He,N_2,Kr	9
(σ_{34})				
Dmitriev et al.	1962	806,000	He,N_2	9

C) Cross Sections of Ionization, Slow Ion Production and Electron Production by Sodium Atom: Na°

(σ_0^i, σ_0^+, σ_0^-)

Bydin, Bukhteev	1960	150-2,200	H_2,D_2,N_2,O_2	6
Kikiani et al.	1966	3,000-30,000	H_2,He,N_2,Ne Ar,Kr,Xe	13
(σ_{54})				
Nikolaev et al.	1961	1,830,000-3,370,000	He,N_2,Ar,Kr	51
(σ_{53})				
Nikolaev et al.	1962	1,830,000-3,370,000	He,N_2,Ar,Kr	52
(σ_{65})				
Nikolaev et al.	1961	1,830,000-3,370,000	He,N_2,Ar,Kr	51
(σ_{64})				
Nikolaev et al.	1962	1,830,000-3,370,000	He,N_2,Ar,Kr	52

authors	year	energy (eV)	target	reference
(σ_{76})				
Nikolaev et al.	1961	3,370,000	Ar,Kr	51

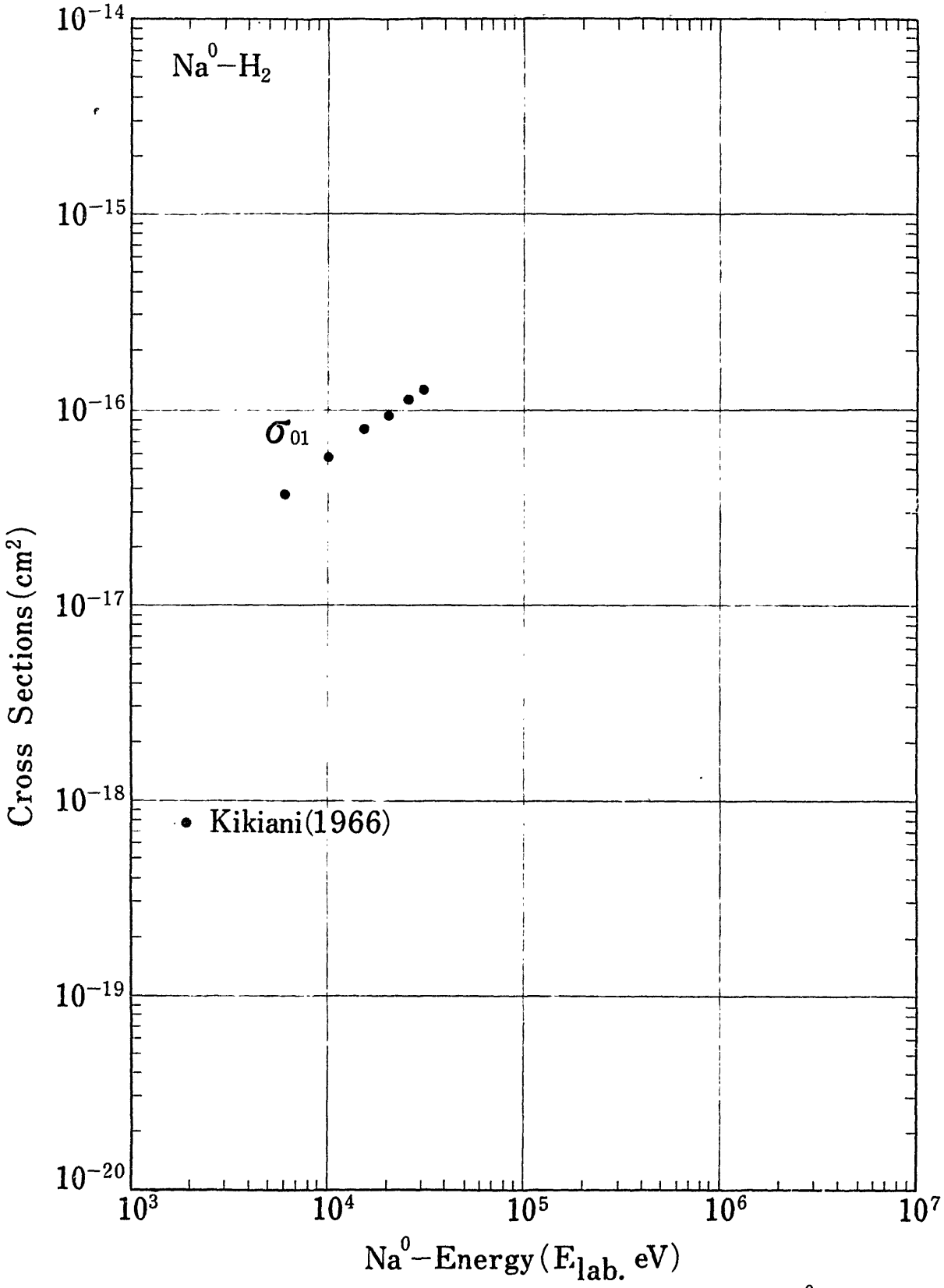

Fig.1 Charge Changing Cross Sections of Na^0 in H_2

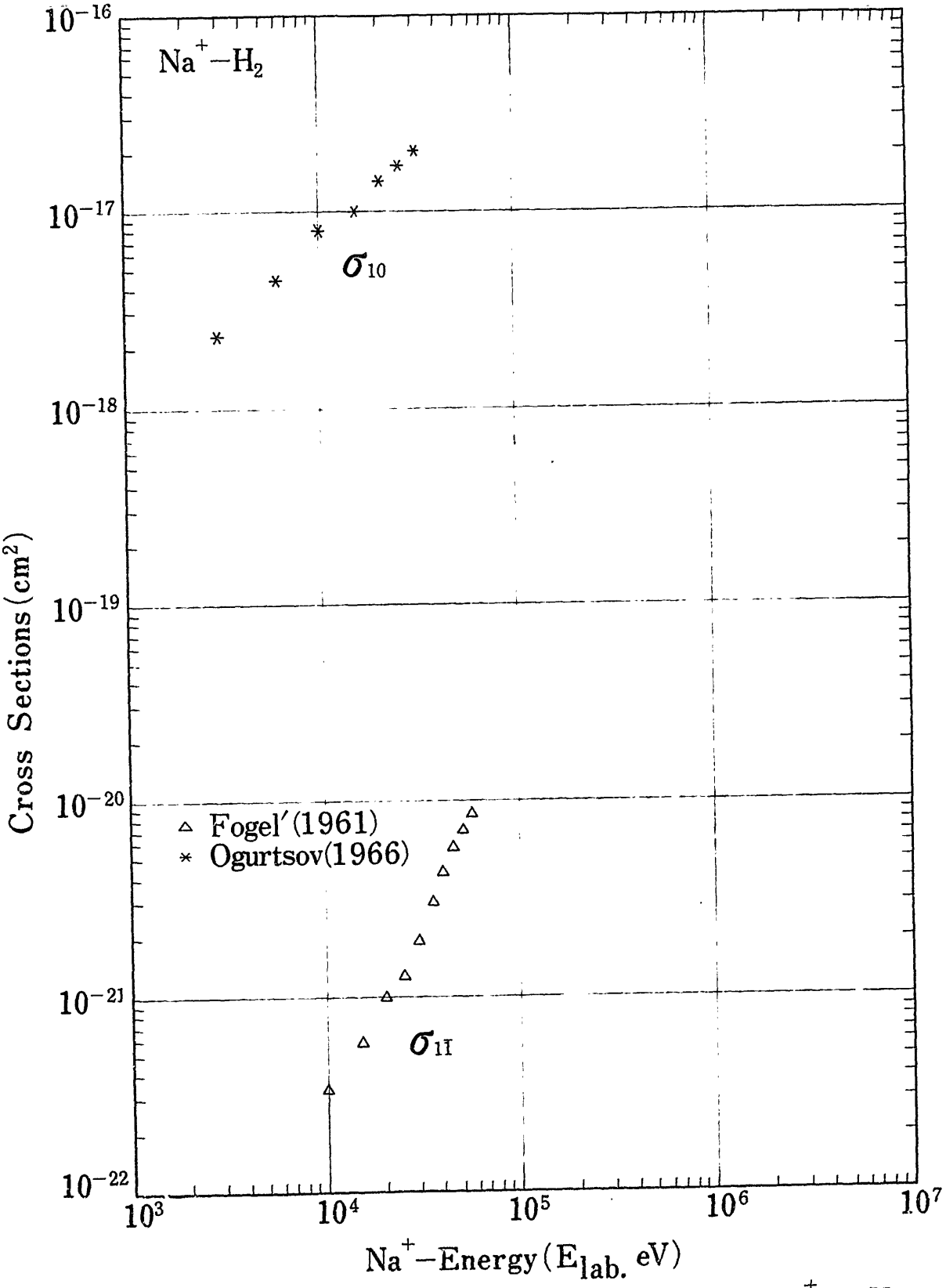

Fig.2 Charge Changing Cross Sections of Na^+ in H_2

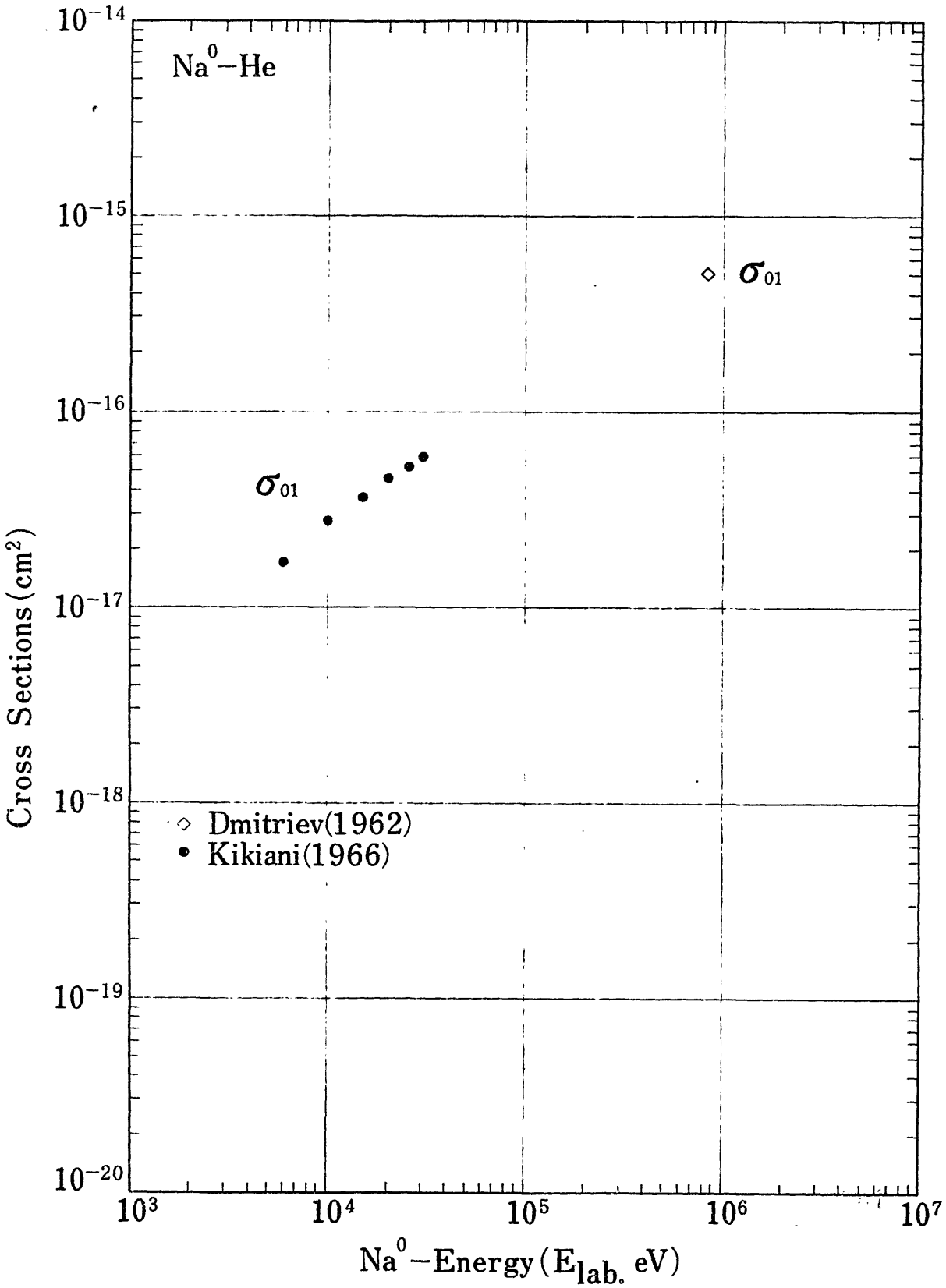

Fig.3 Charge Changing Cross Sections of Na^0 in He

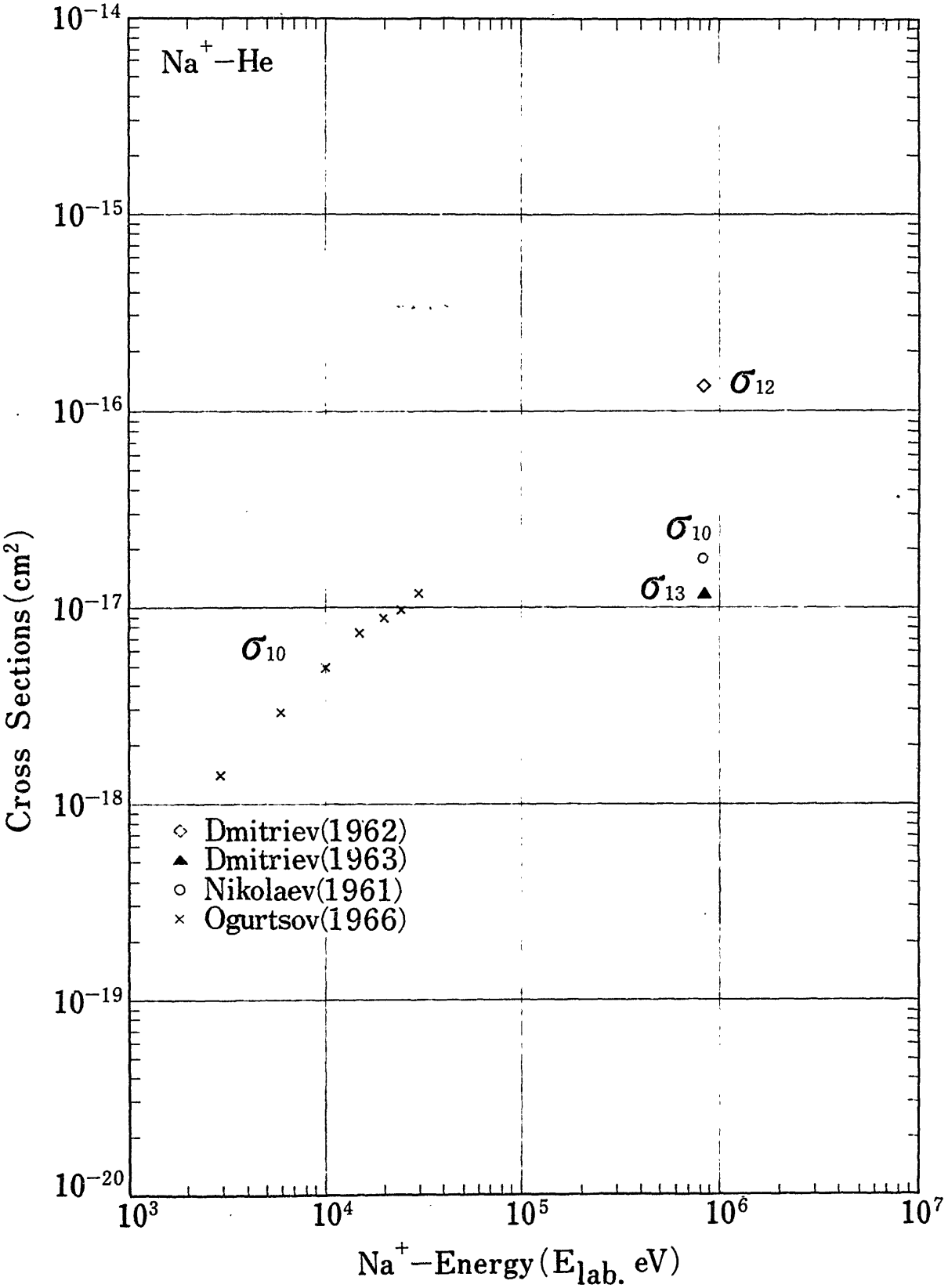

Fig.4 Charge Changing Cross Sections of Na^+ in He

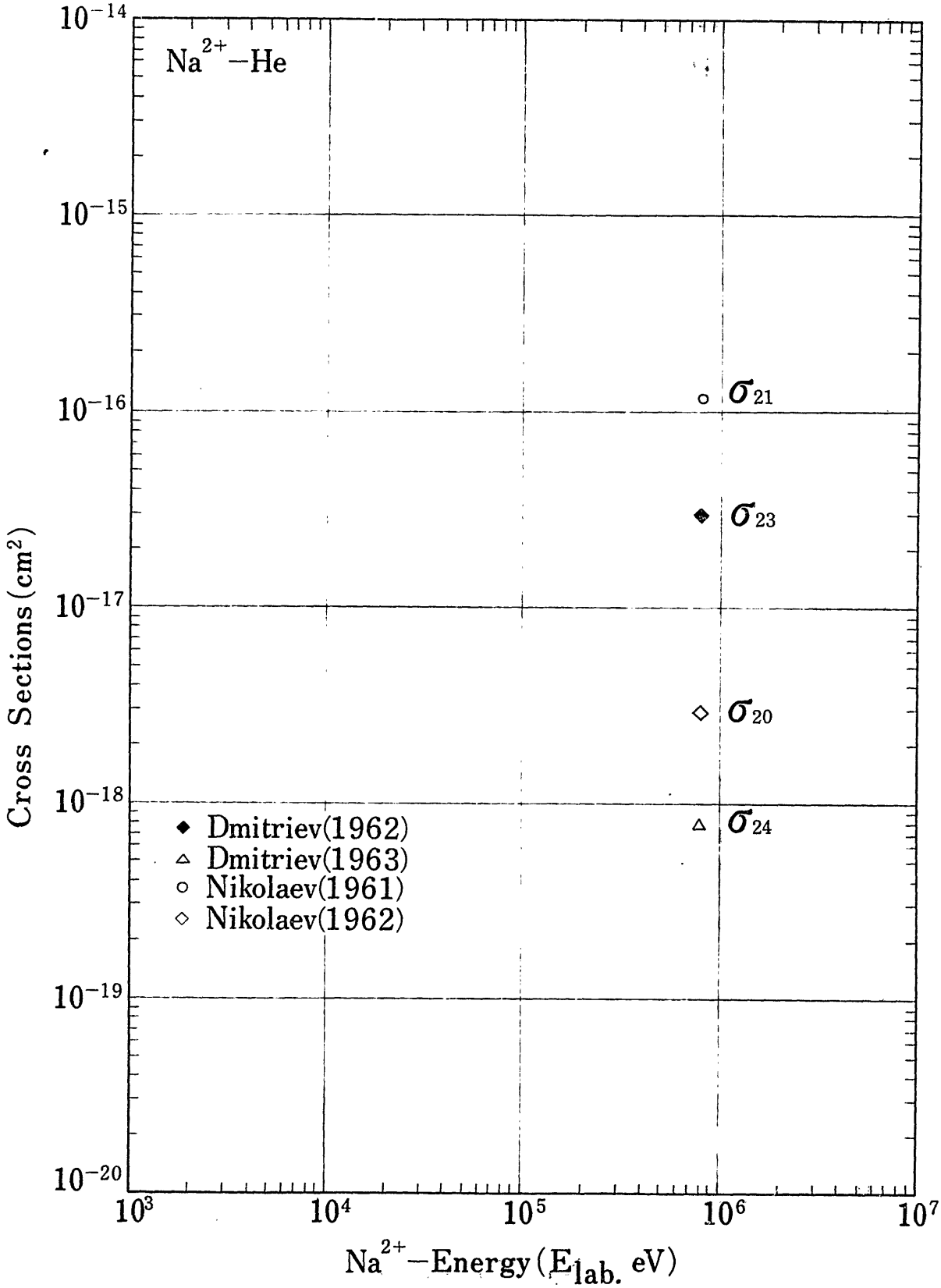

Fig.5 Charge Changing Cross Sections of Na^{2+} in He

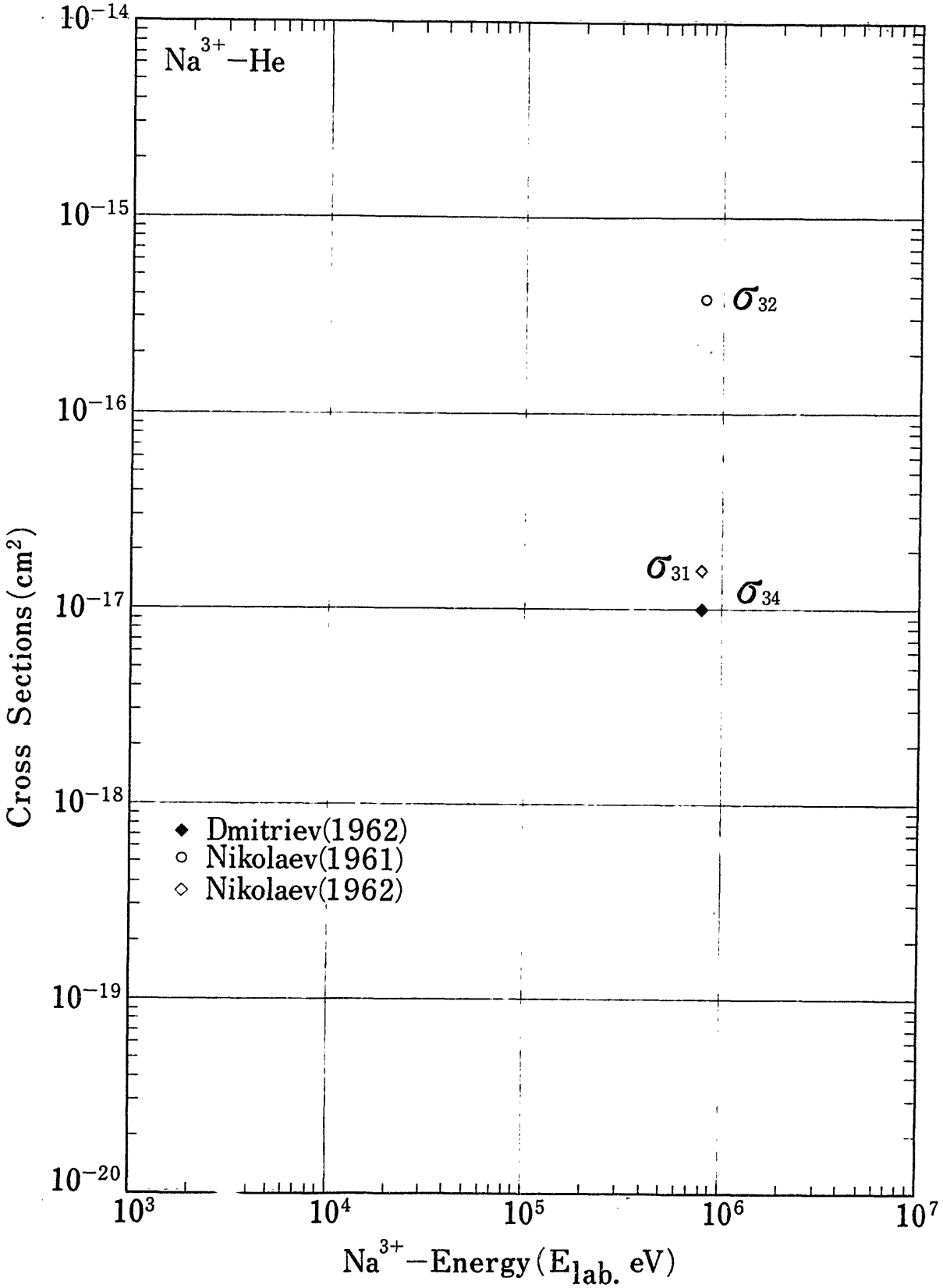

Fig.6 Charge Changing Cross Sections of Na^{3+} in He

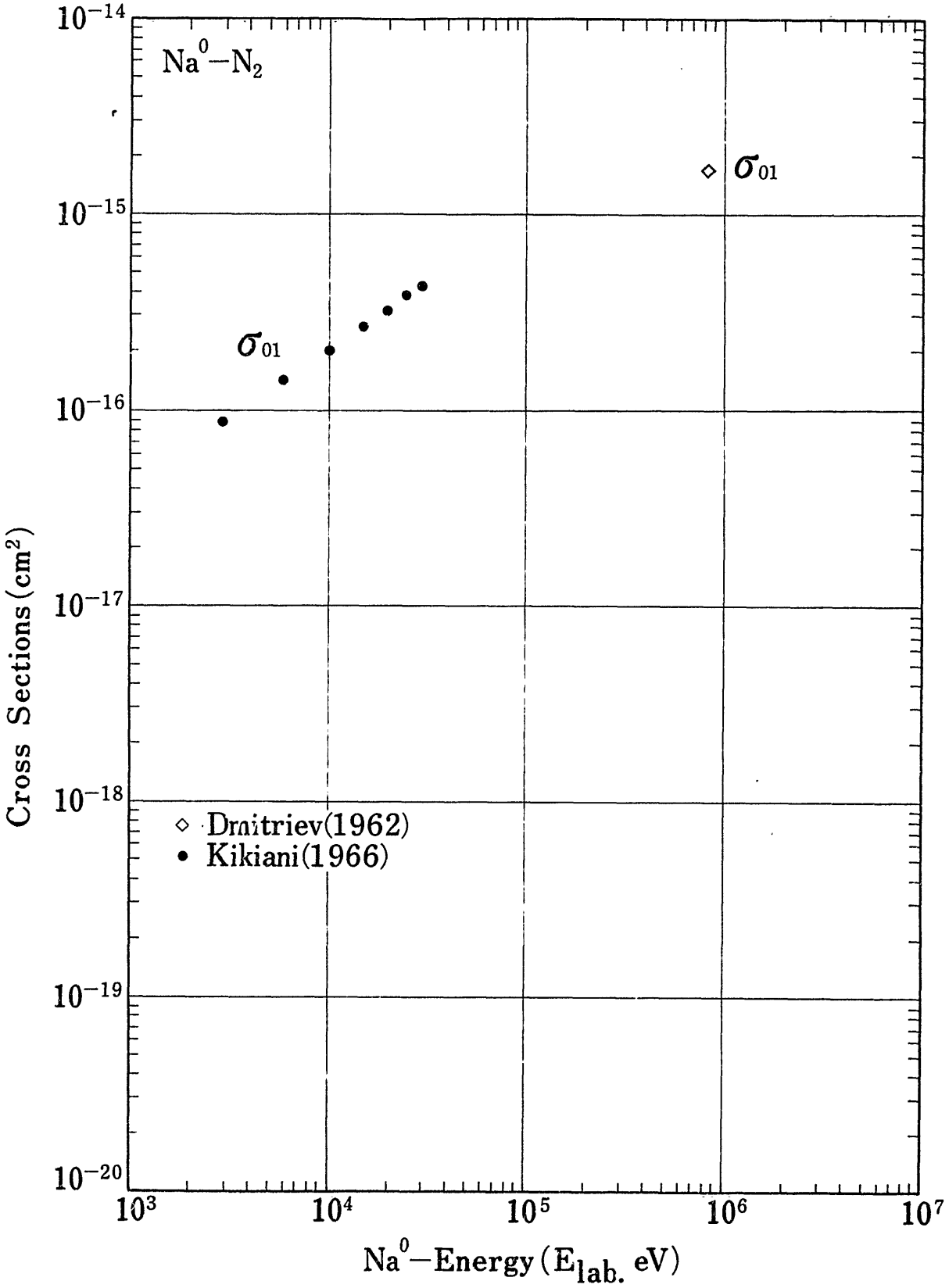

Fig.7 Charge Changing Cross Sections of Na^0 in N_2

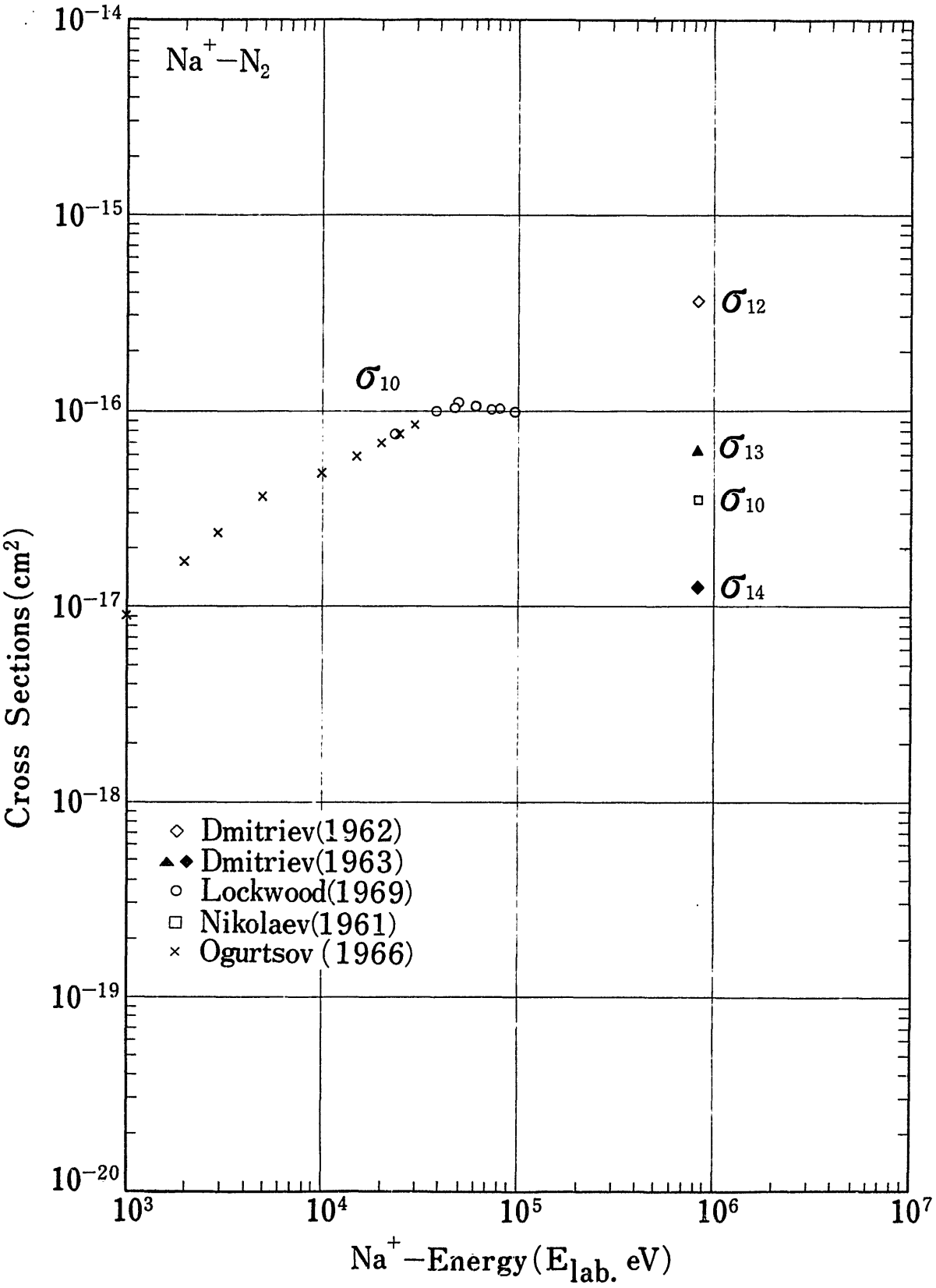

Fig.8 Charge Changing Cross Sections of Na^+ in N_2

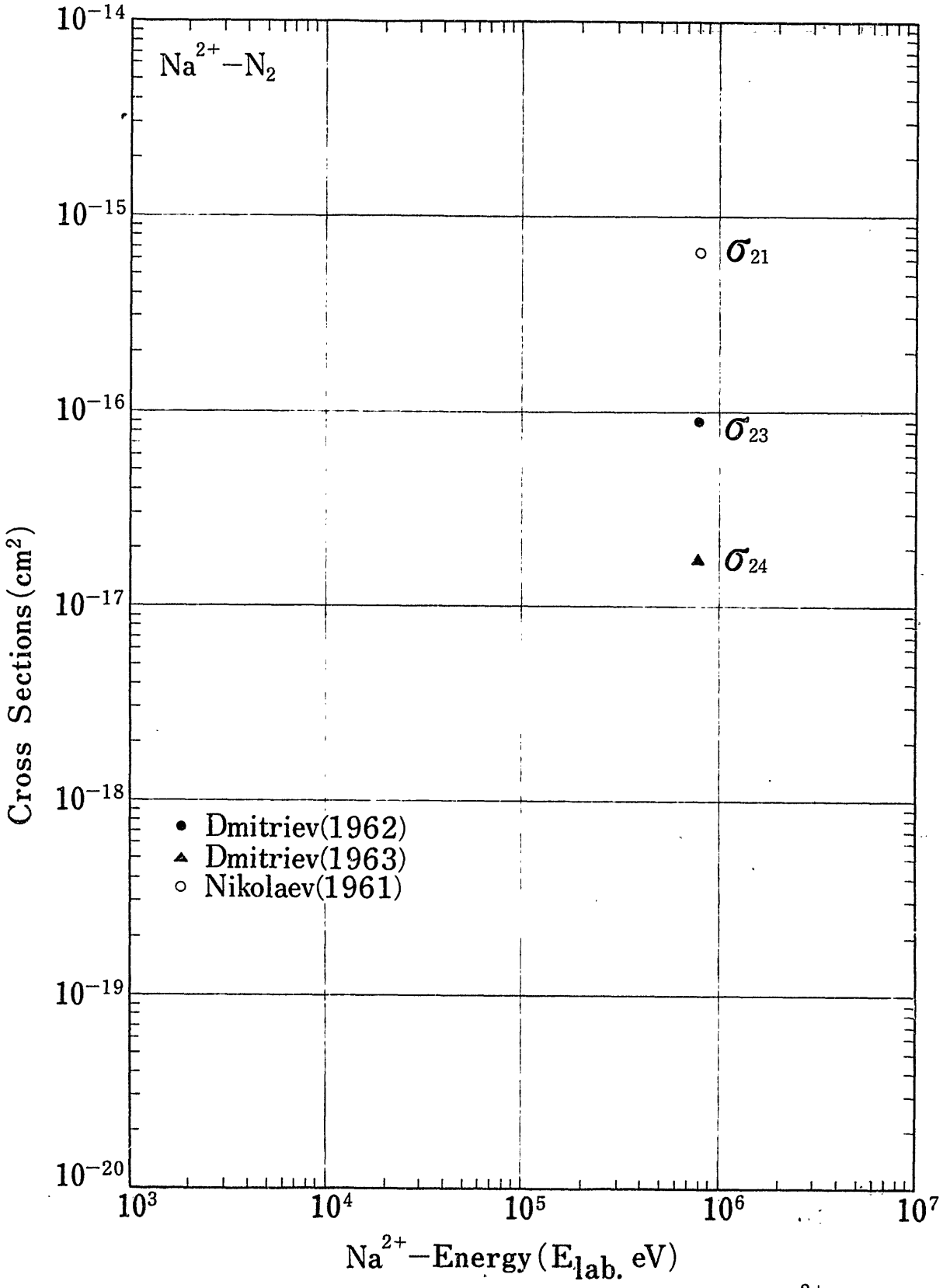

Fig.9 Charge Changing Cross Sections of Na^{2+} in N_2

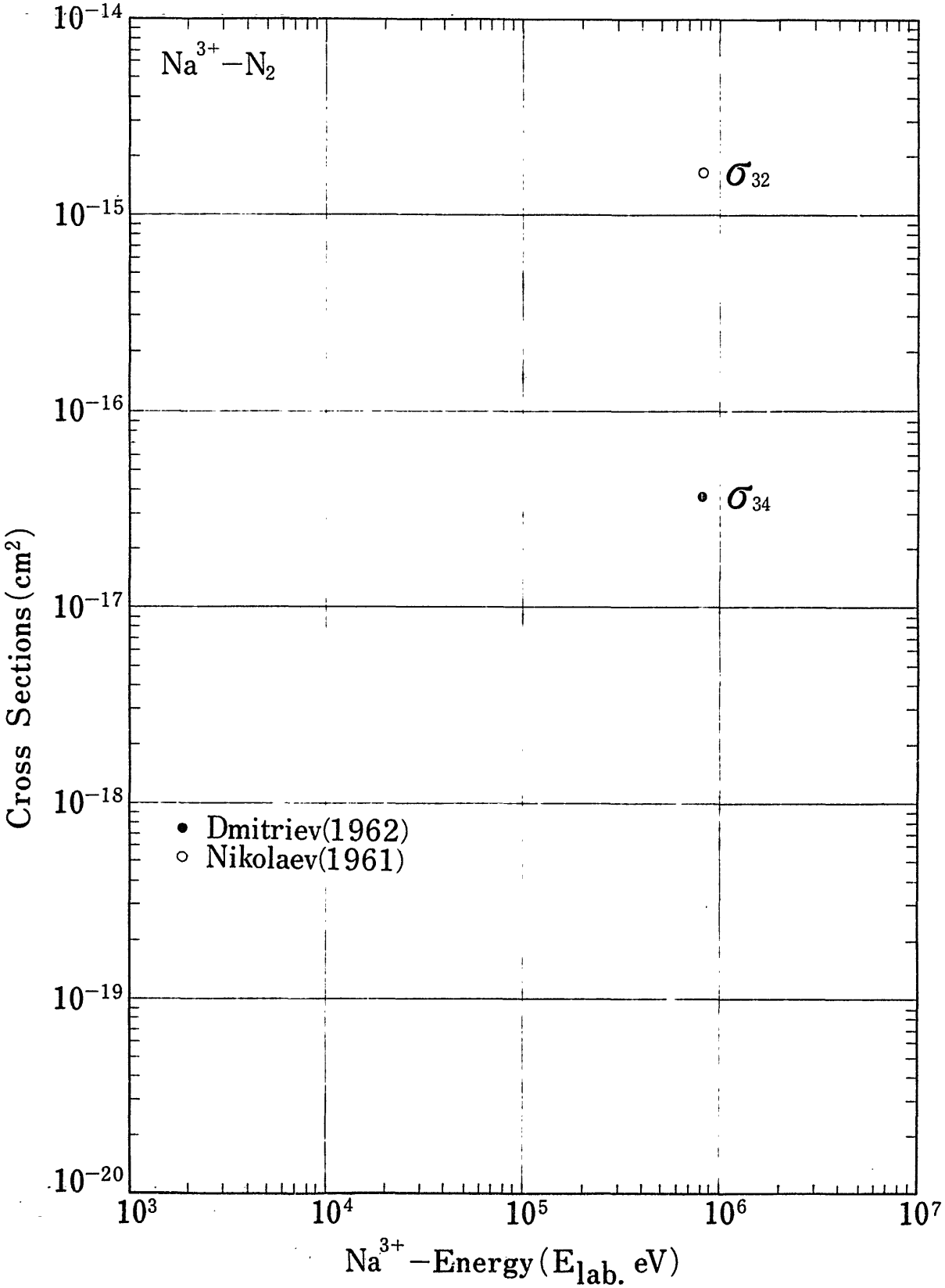

Fig.10 Charge Changing Cross Sections of Na^{3+} in N_2

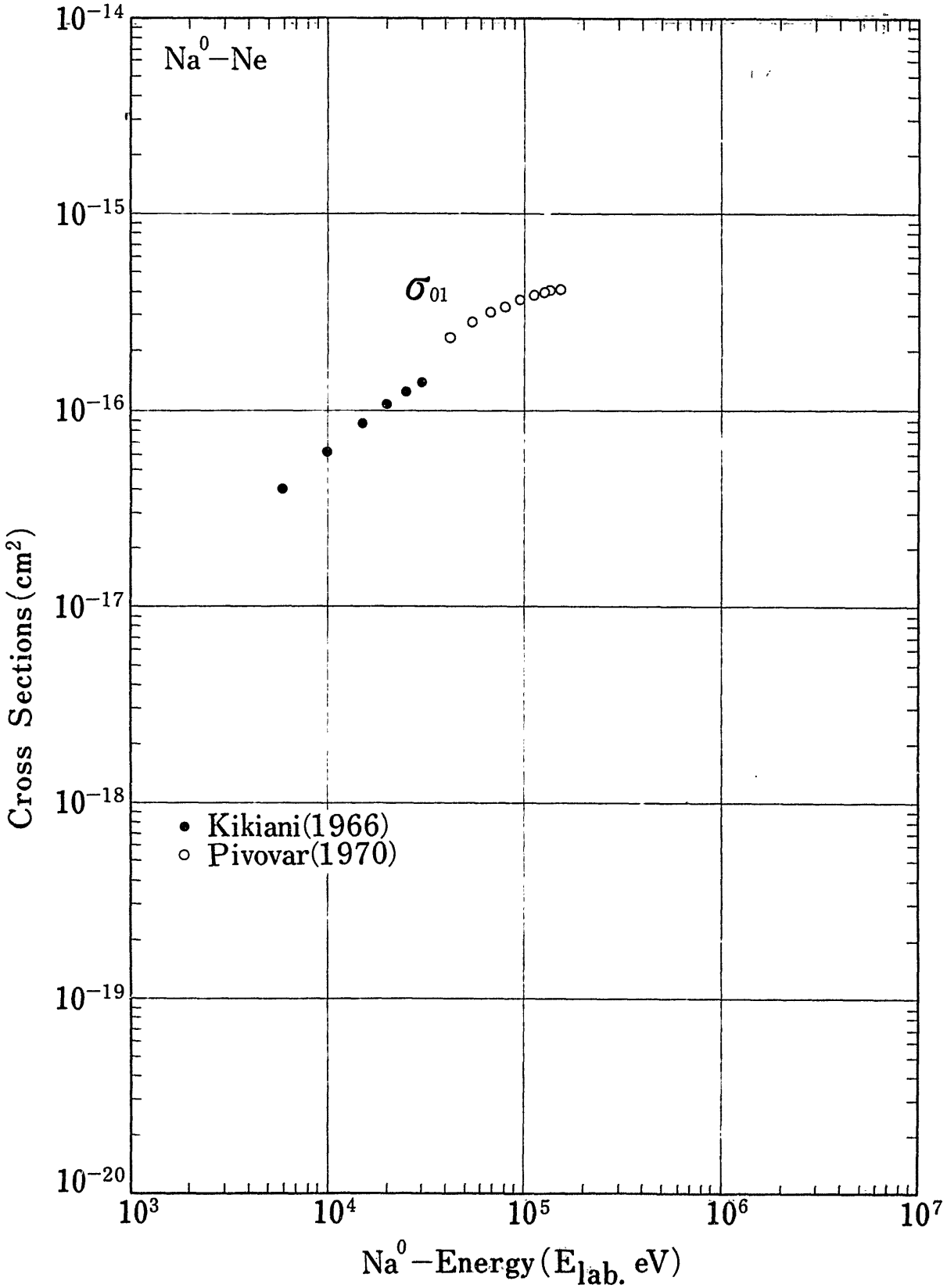

Fig.11 Charge Changing Cross Sections of Na^0 in Ne

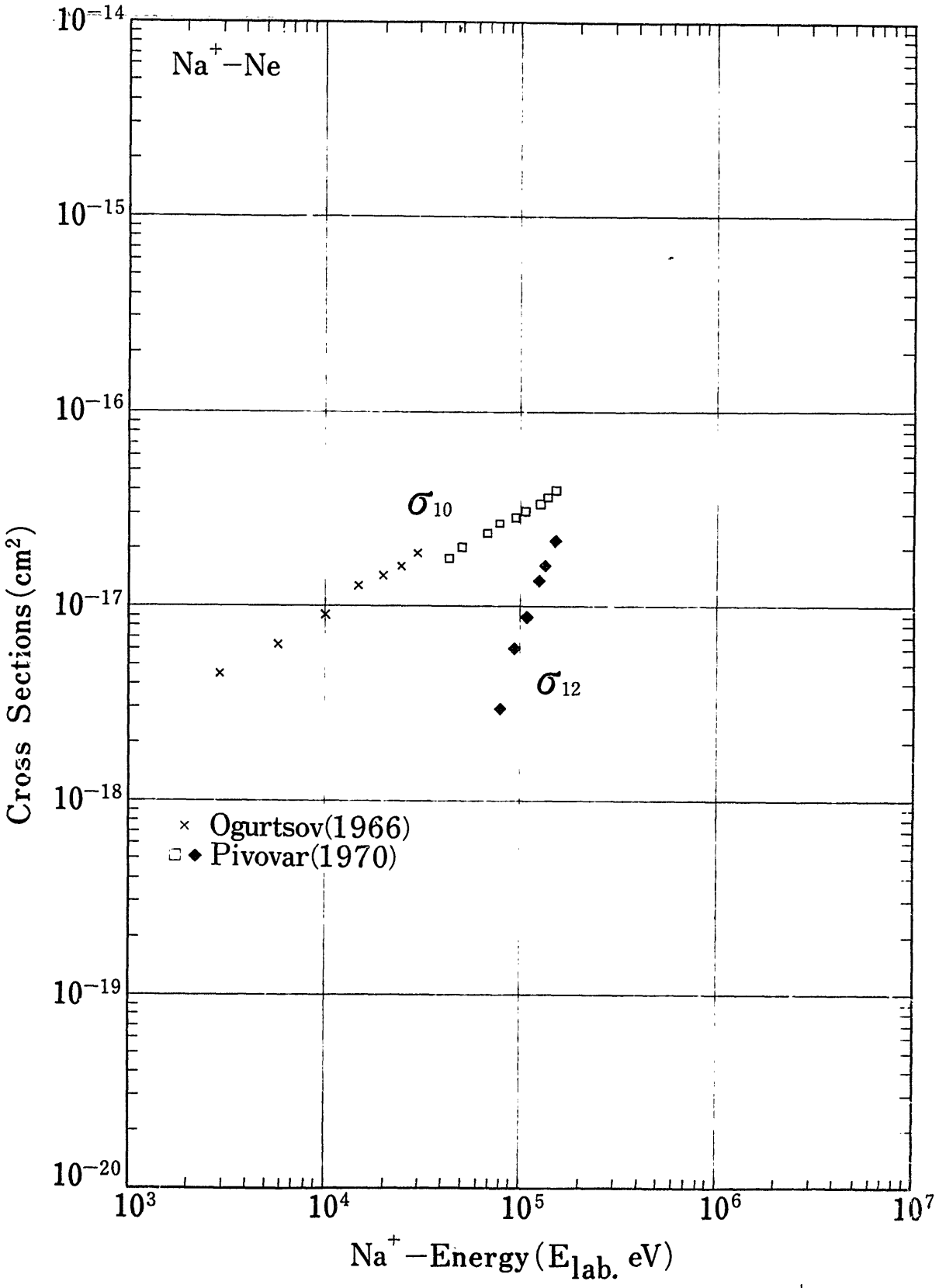

Fig.12 Charge Changing Cross Sections of Na^+ in Ne

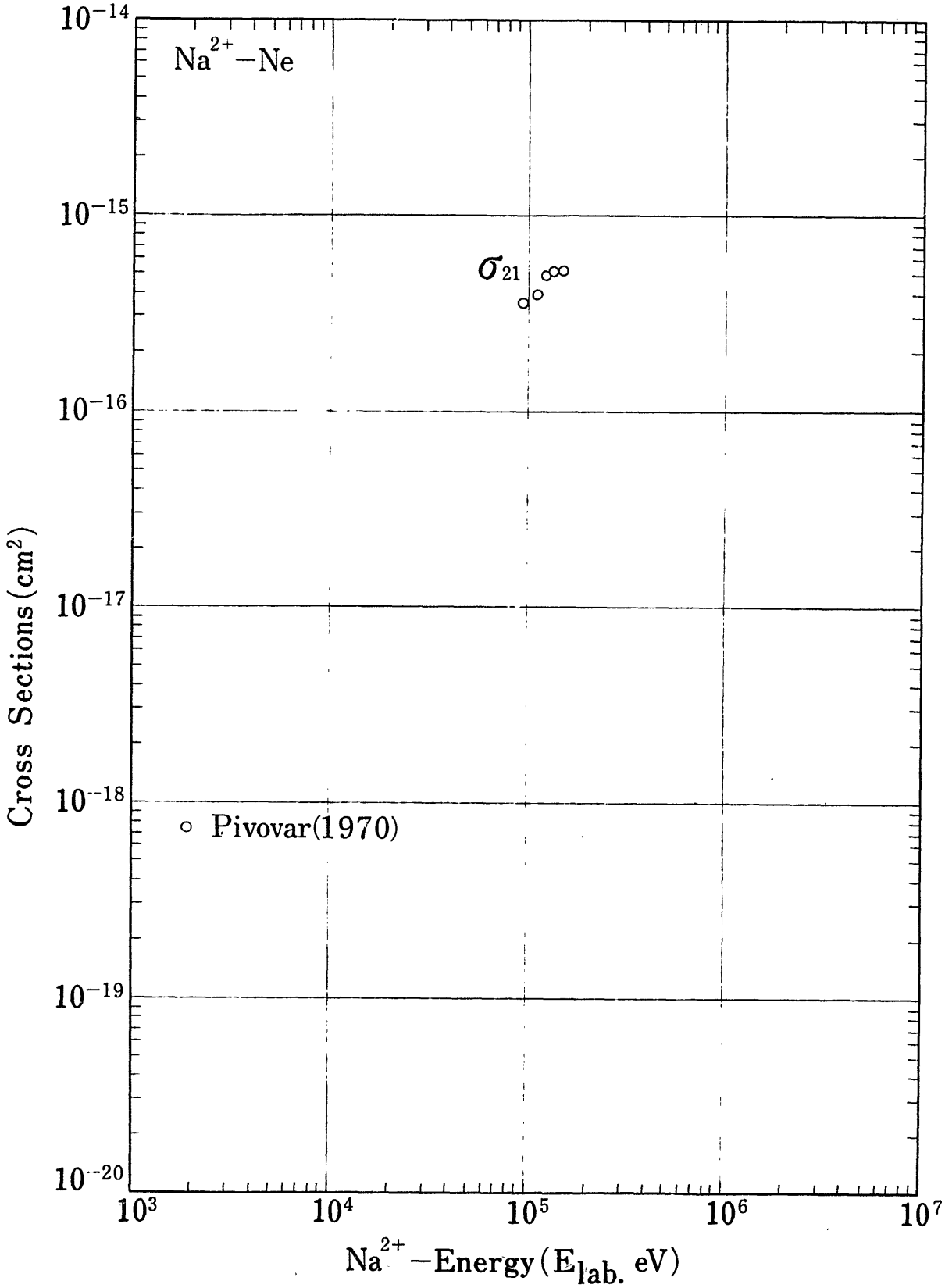

Fig.13 Charge Changing Cross Sections of Na^{2+} in Ne

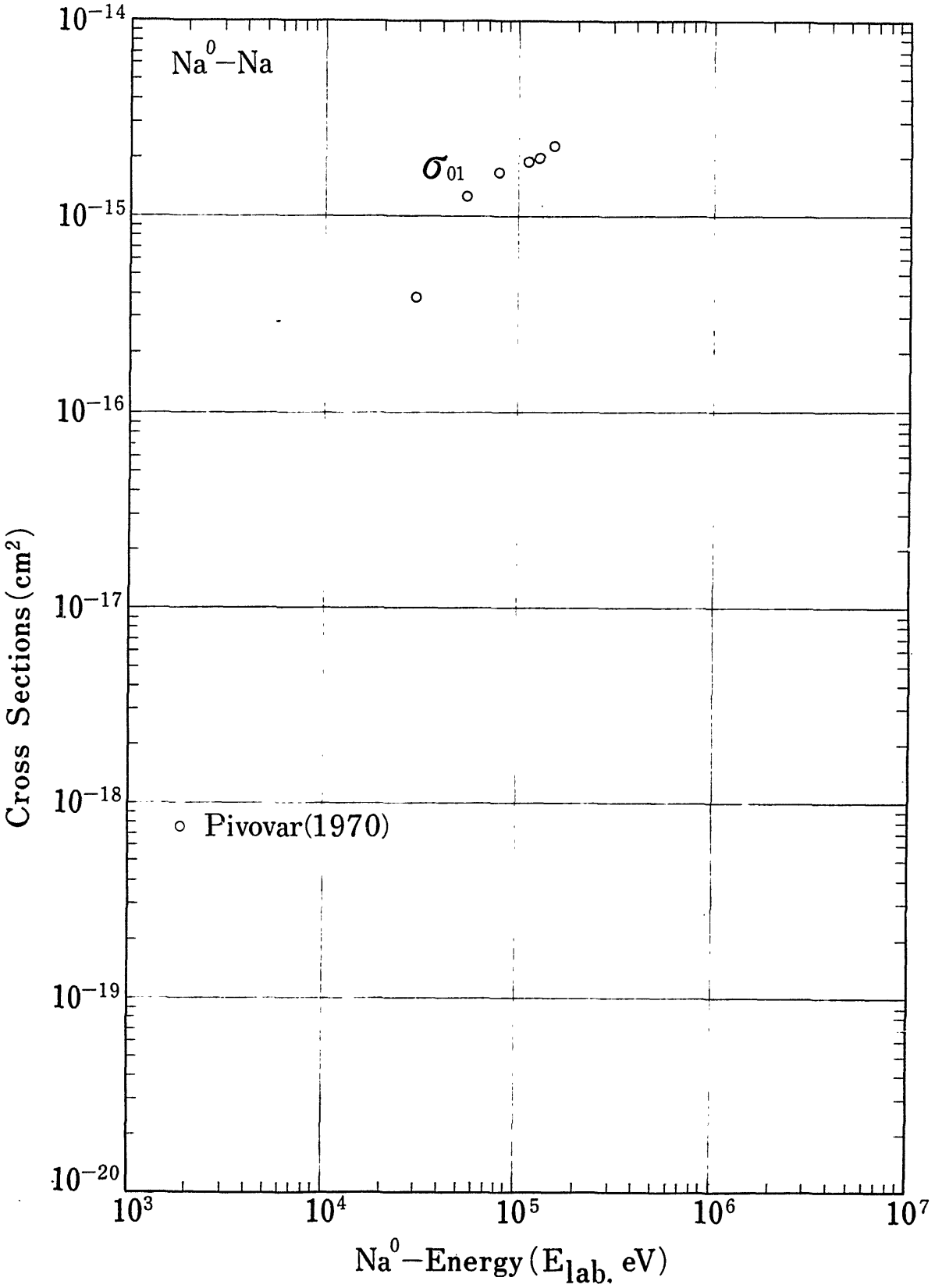

Fig.14 Charge Changing Cross Sections of Na^0 in Na

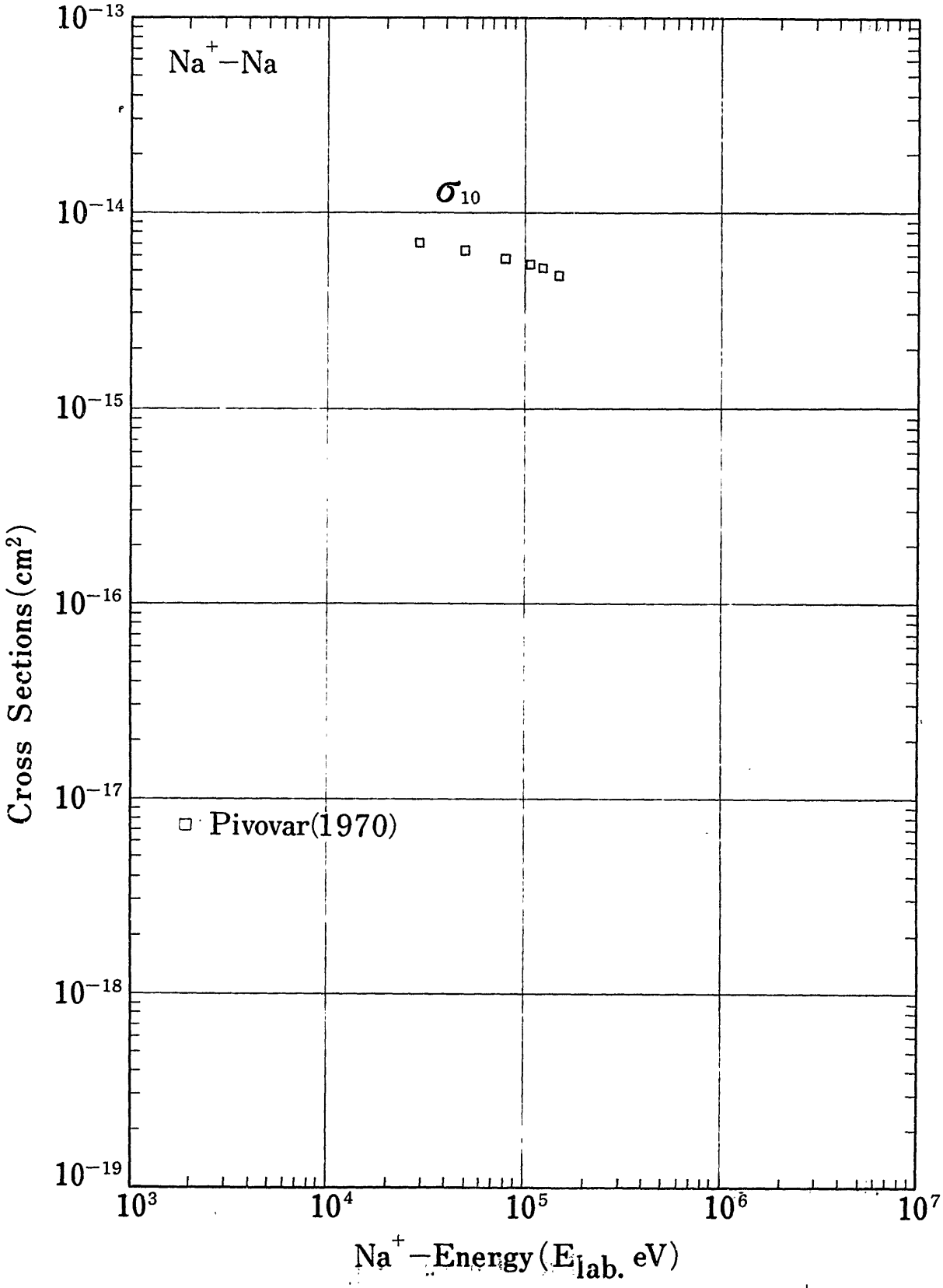

Fig.15 Charge Changing Cross Sections of Na^+ in Na

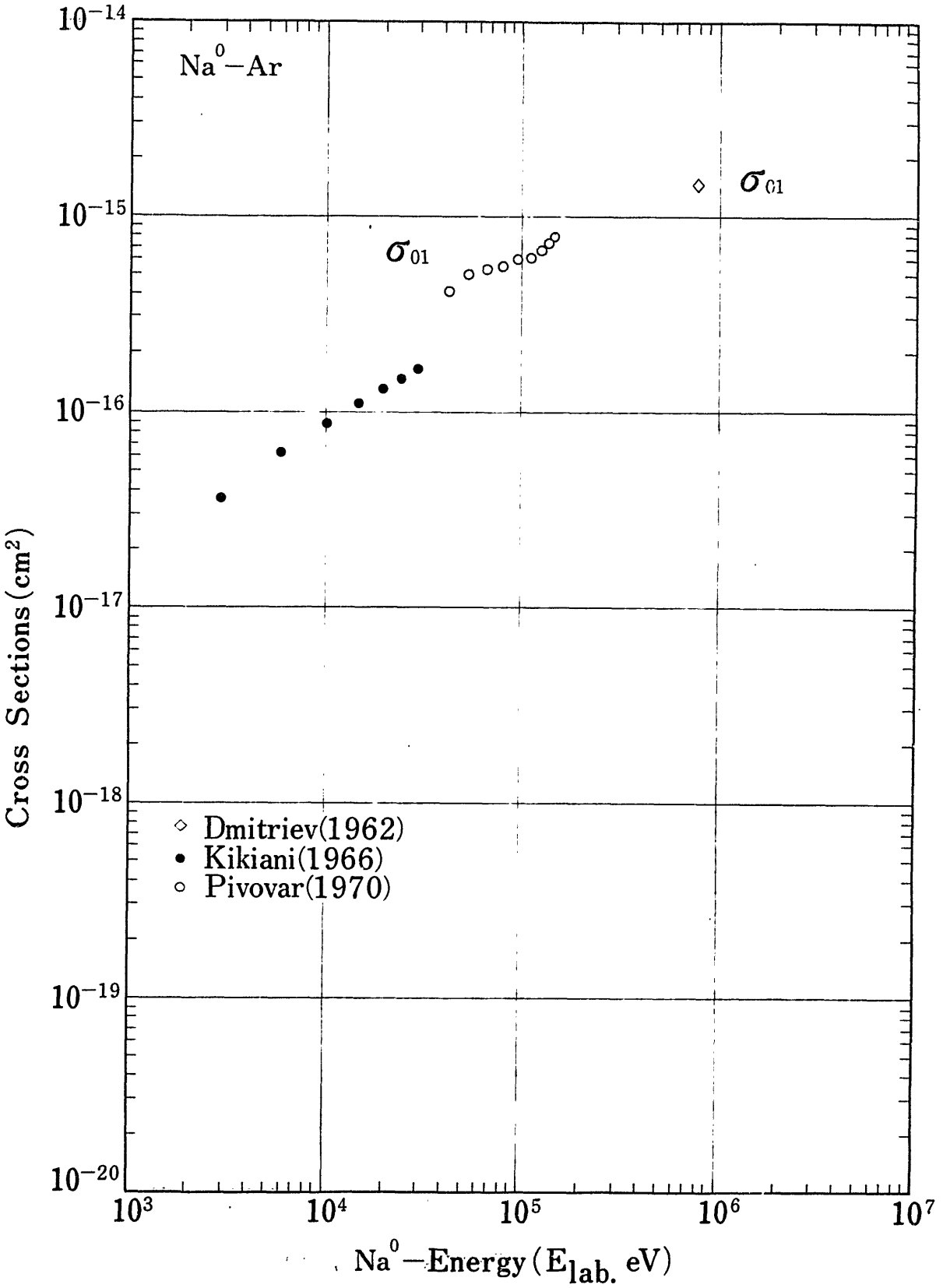

Fig.16 Charge Changing Cross Sections of Na^0 in Ar

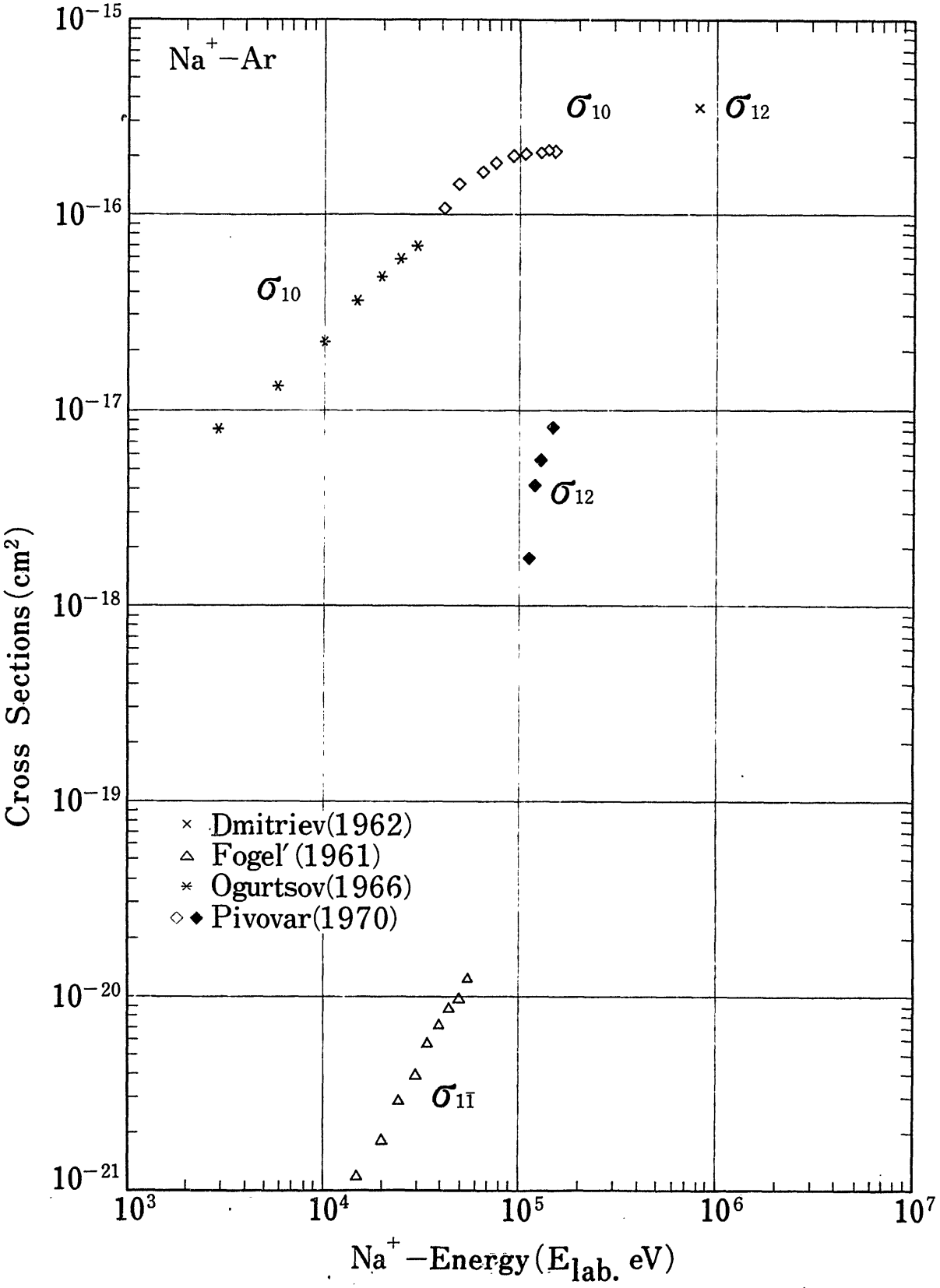

Fig.17 Charge Changing Cross Sections of Na^+ in Ar

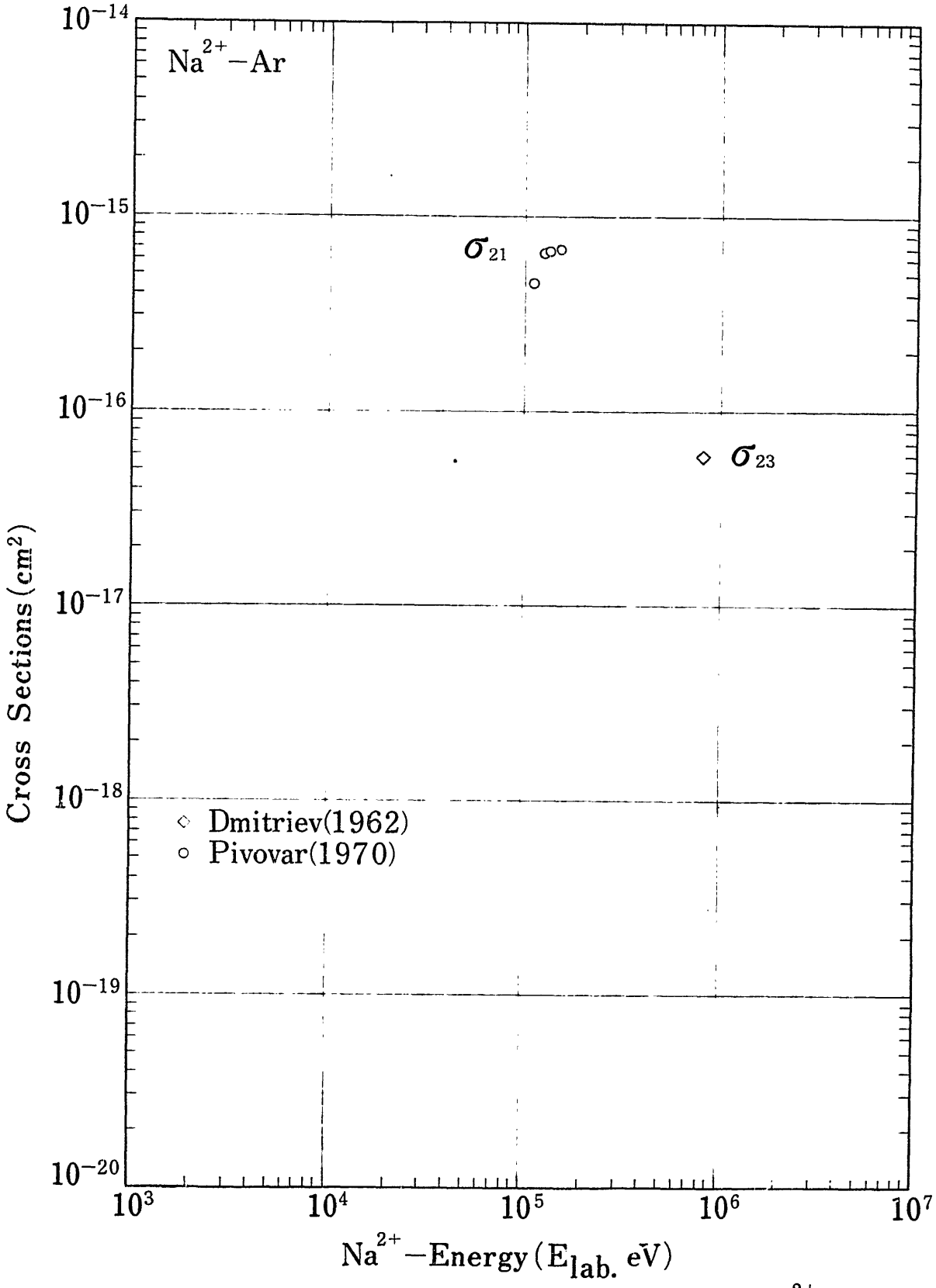

Fig.18 Charge Changing Cross Sections of Na^{2+} in Ar

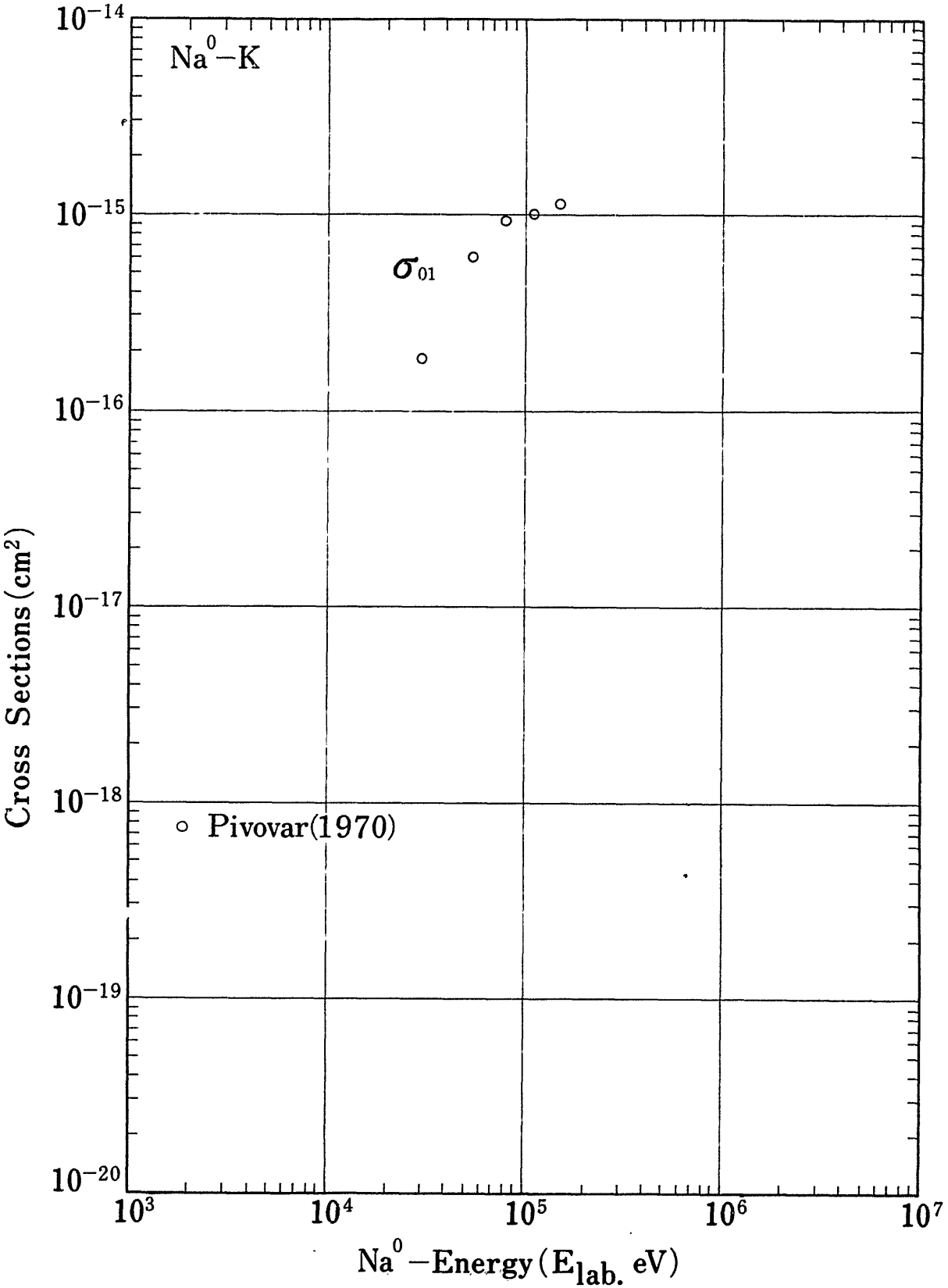

Fig.19 Charge Changing Cross Sections of Na^0 in K

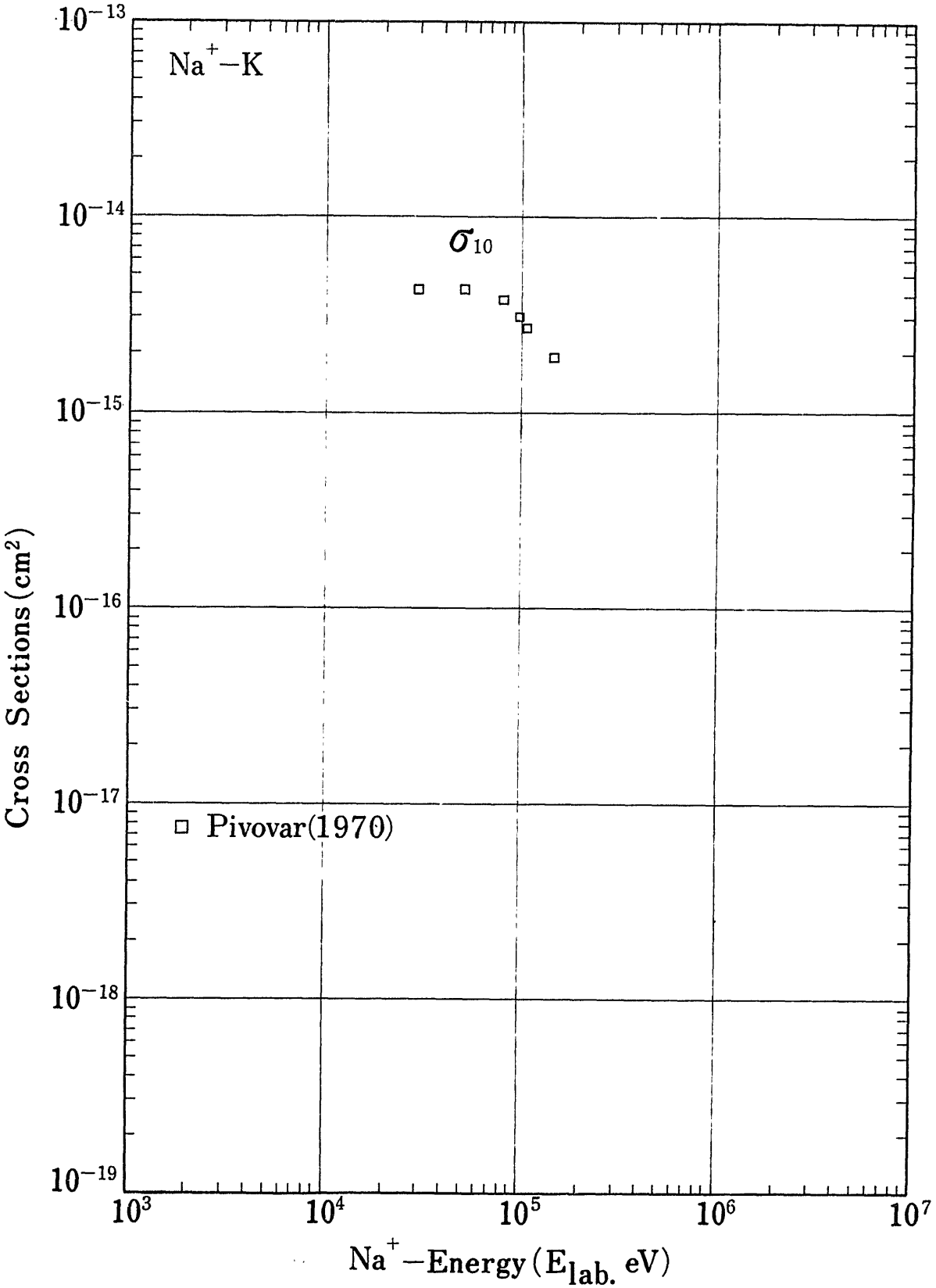

Fig.20 Charge Changing Cross Sections of Na^+ in K

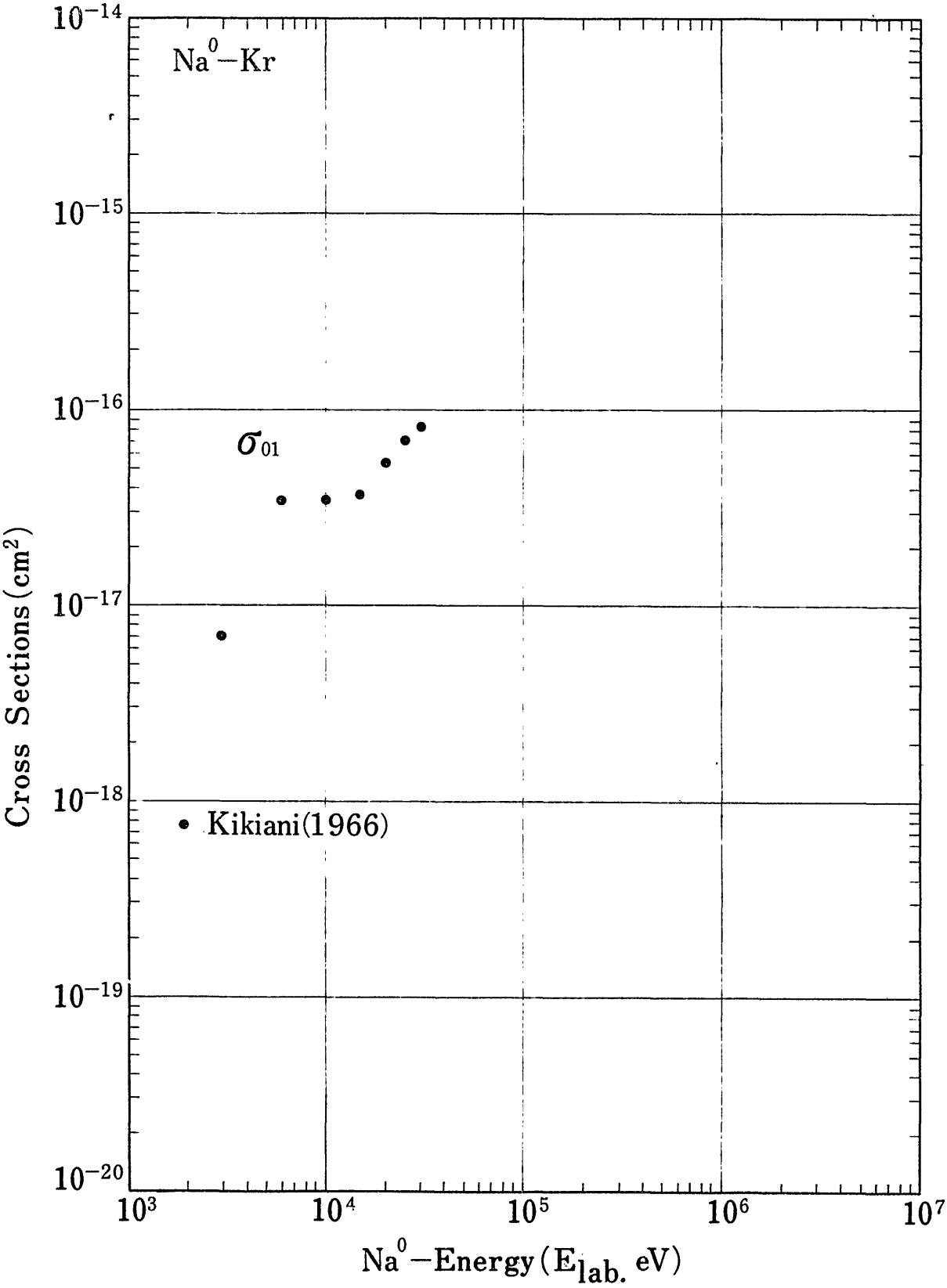

Fig.21 Charge Changing Cross Sections of Na^0 in Kr

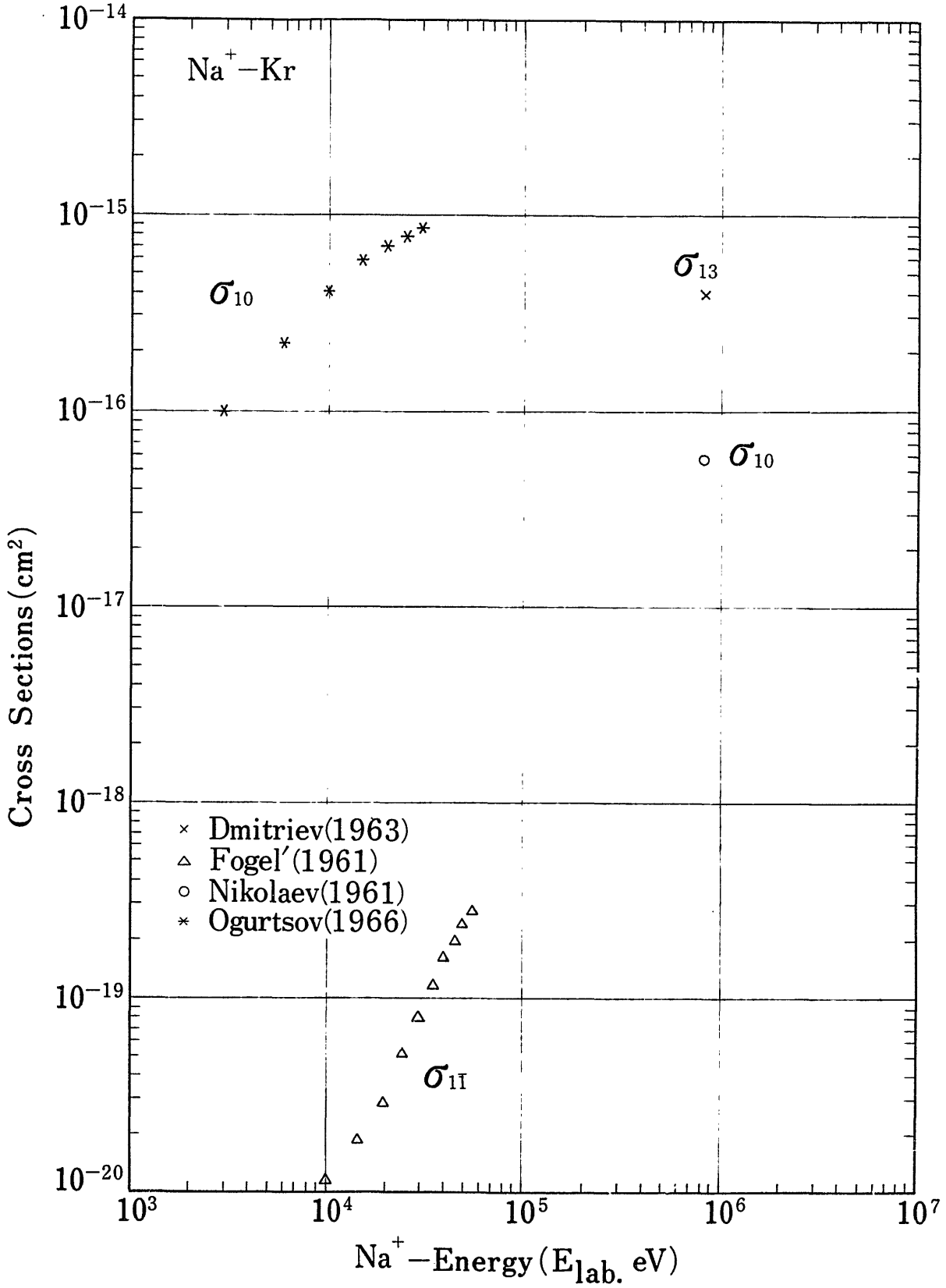

Fig.22 Charge Changing Cross Sections of Na^+ in Kr

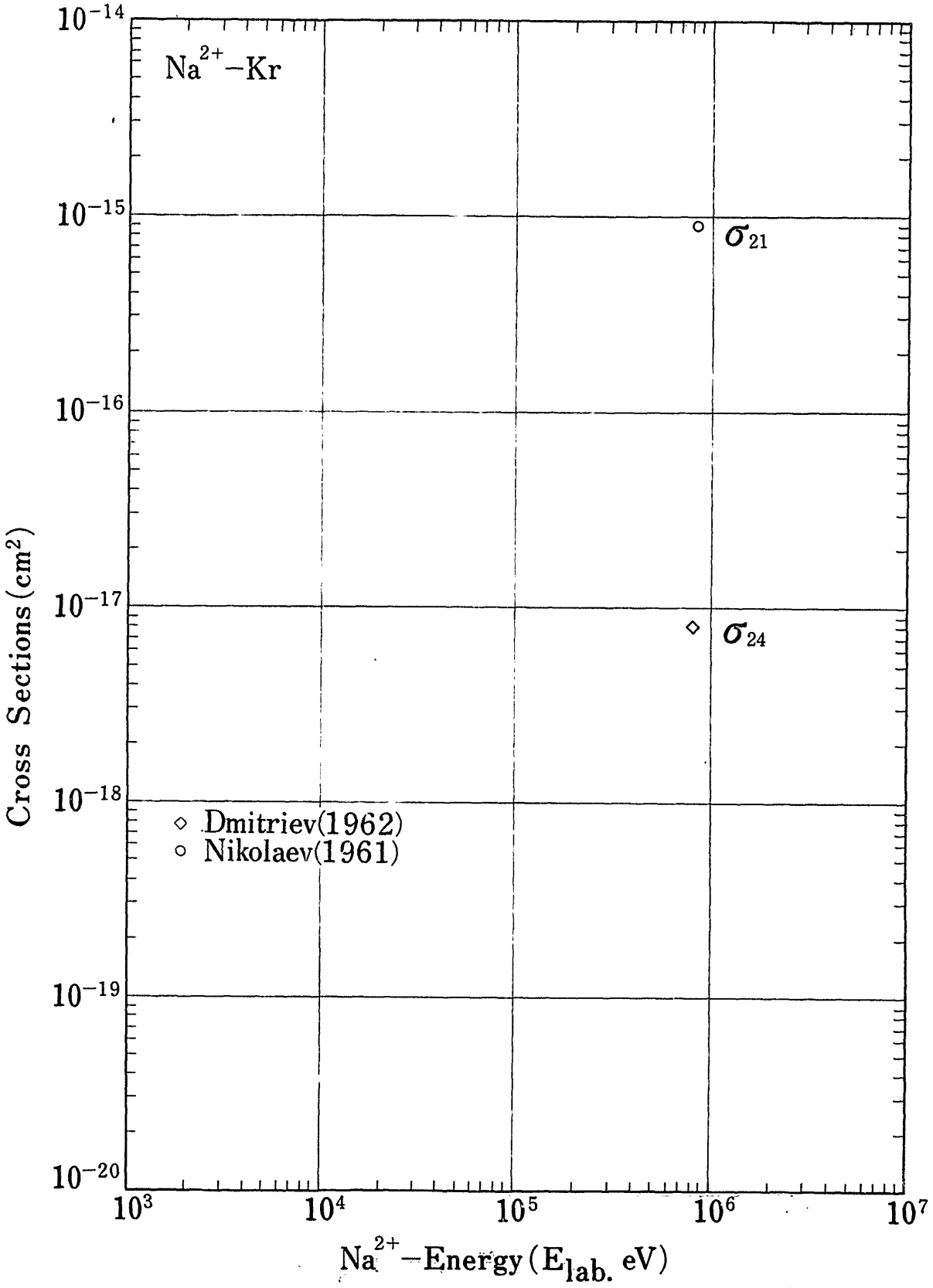

Fig. 23 Charge Changing Cross Sections of Na^{2+} in Kr

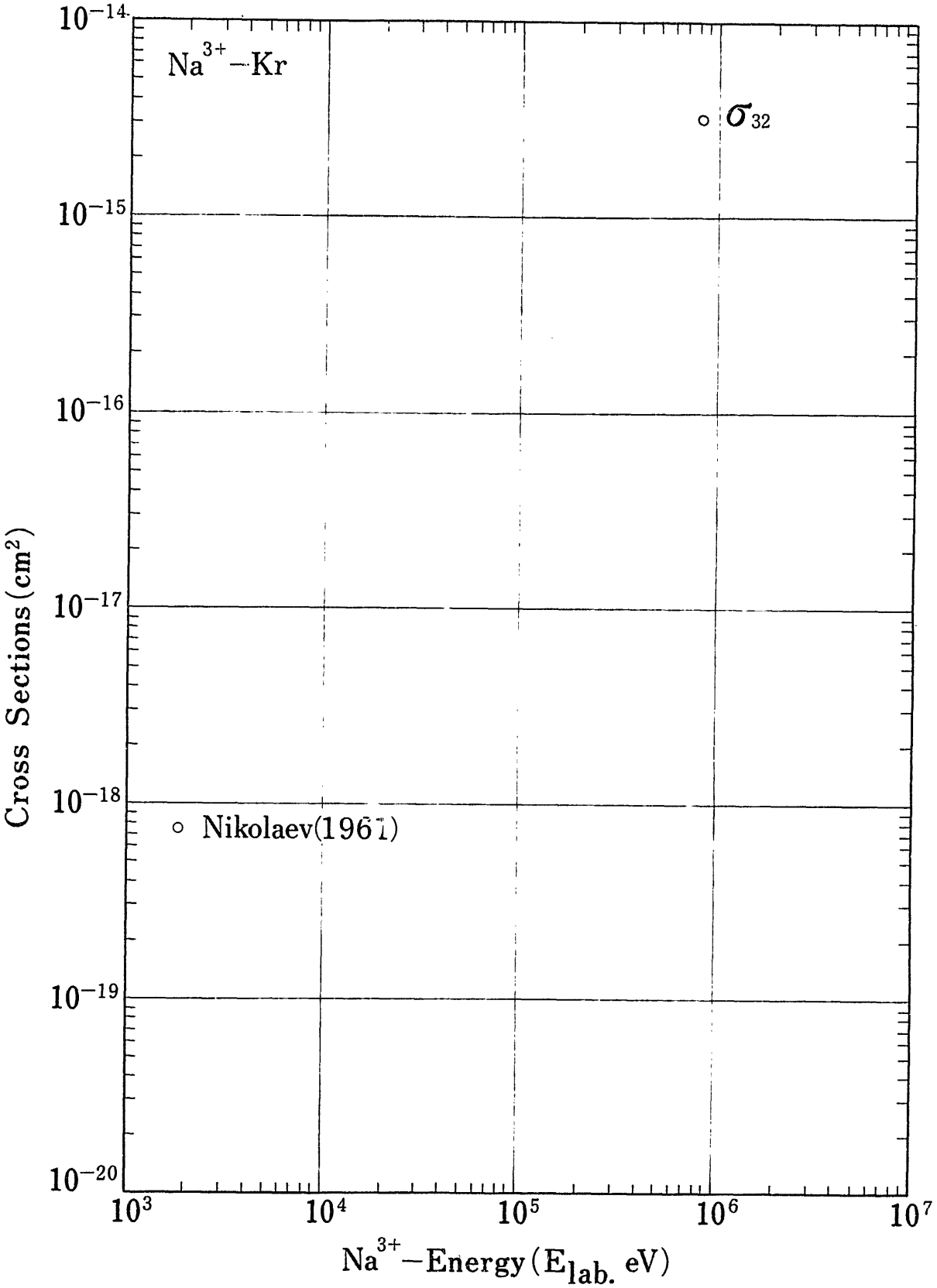

Fig.24 Charge Changing Cross Sections of Na^{3+} in Kr

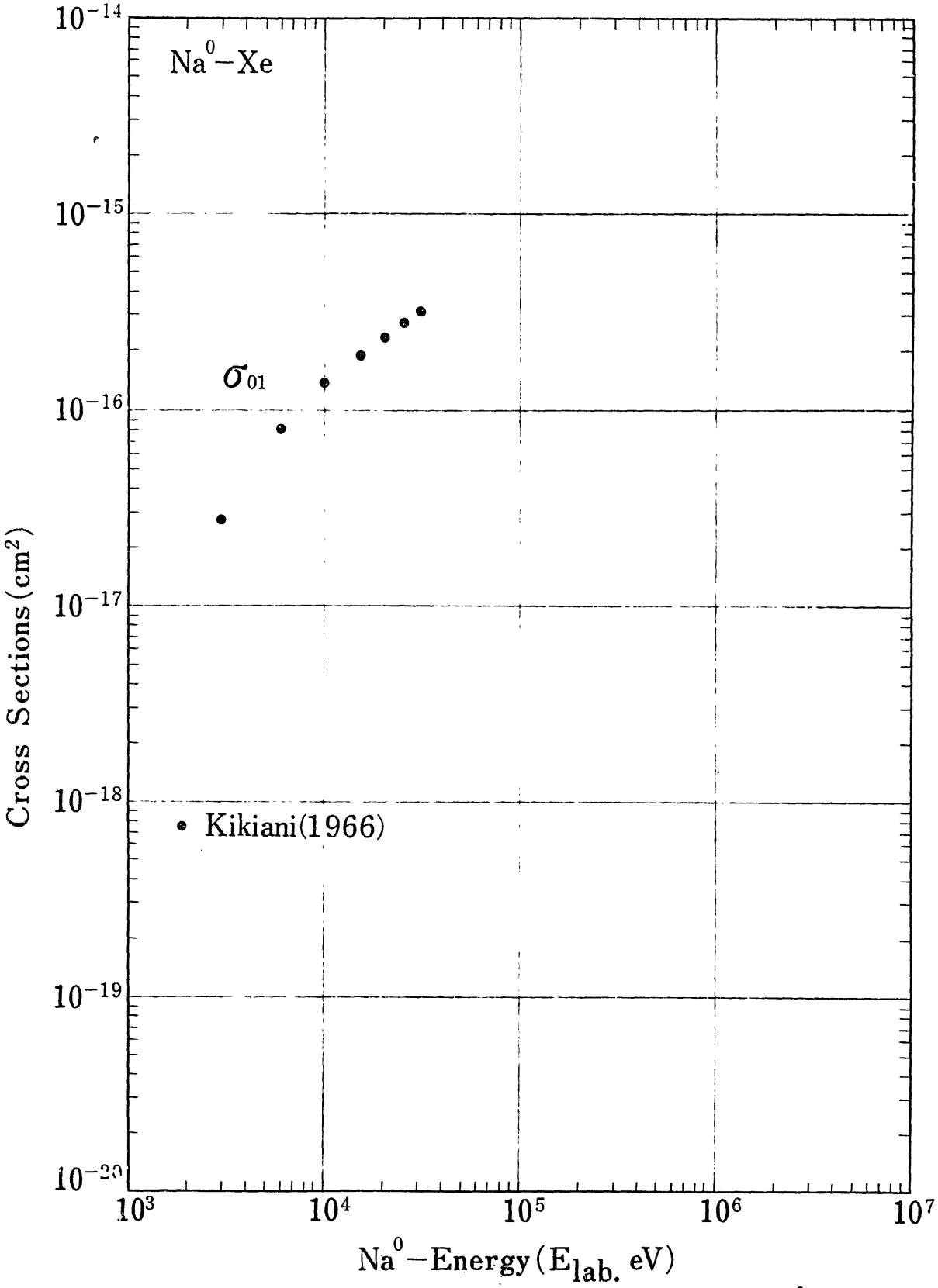

Fig.25 Charge Changing Cross Sections of Na^0 in Xe

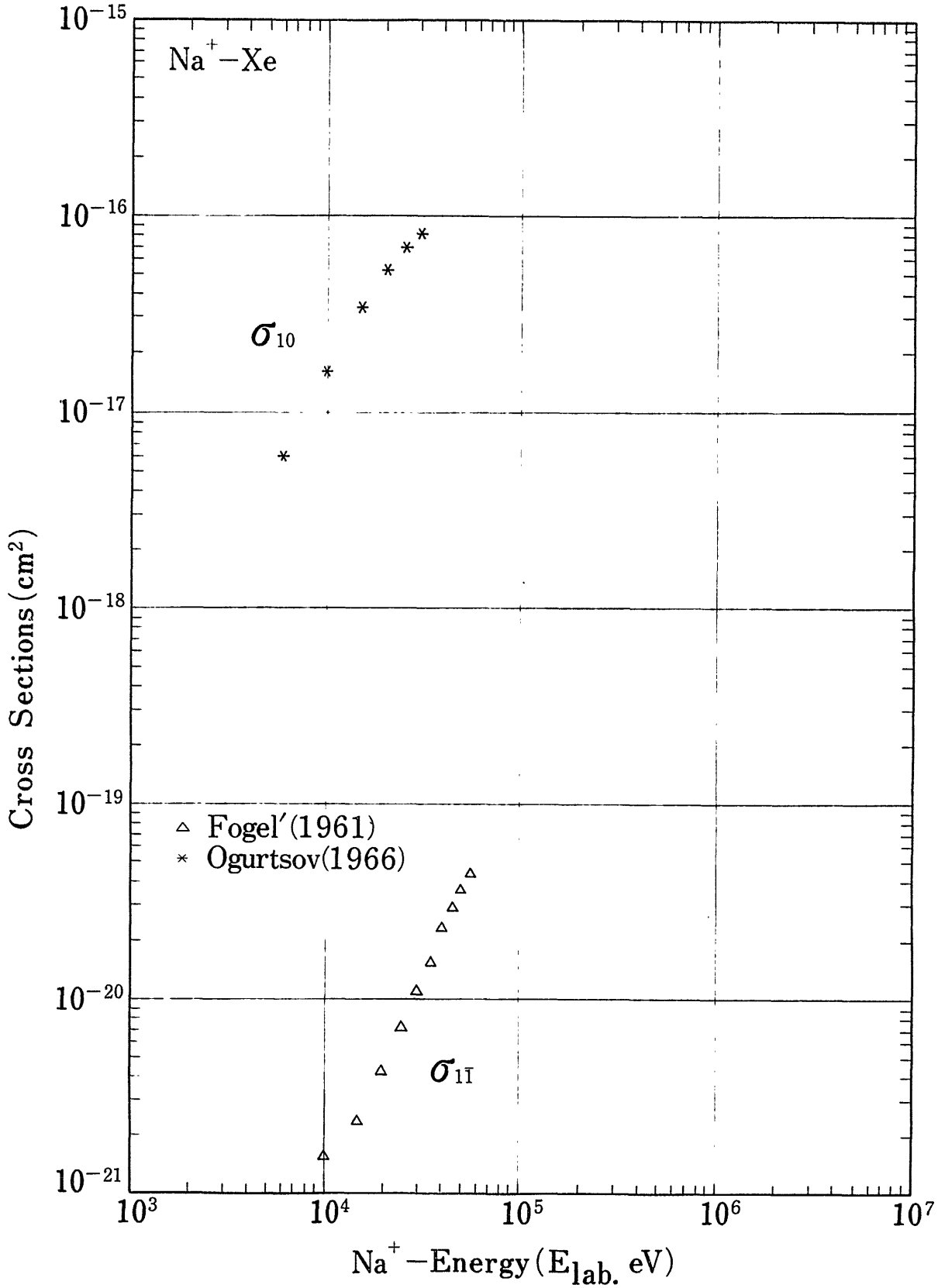

Fig.26 Charge Changing Cross Sections of Na^+ in Xe

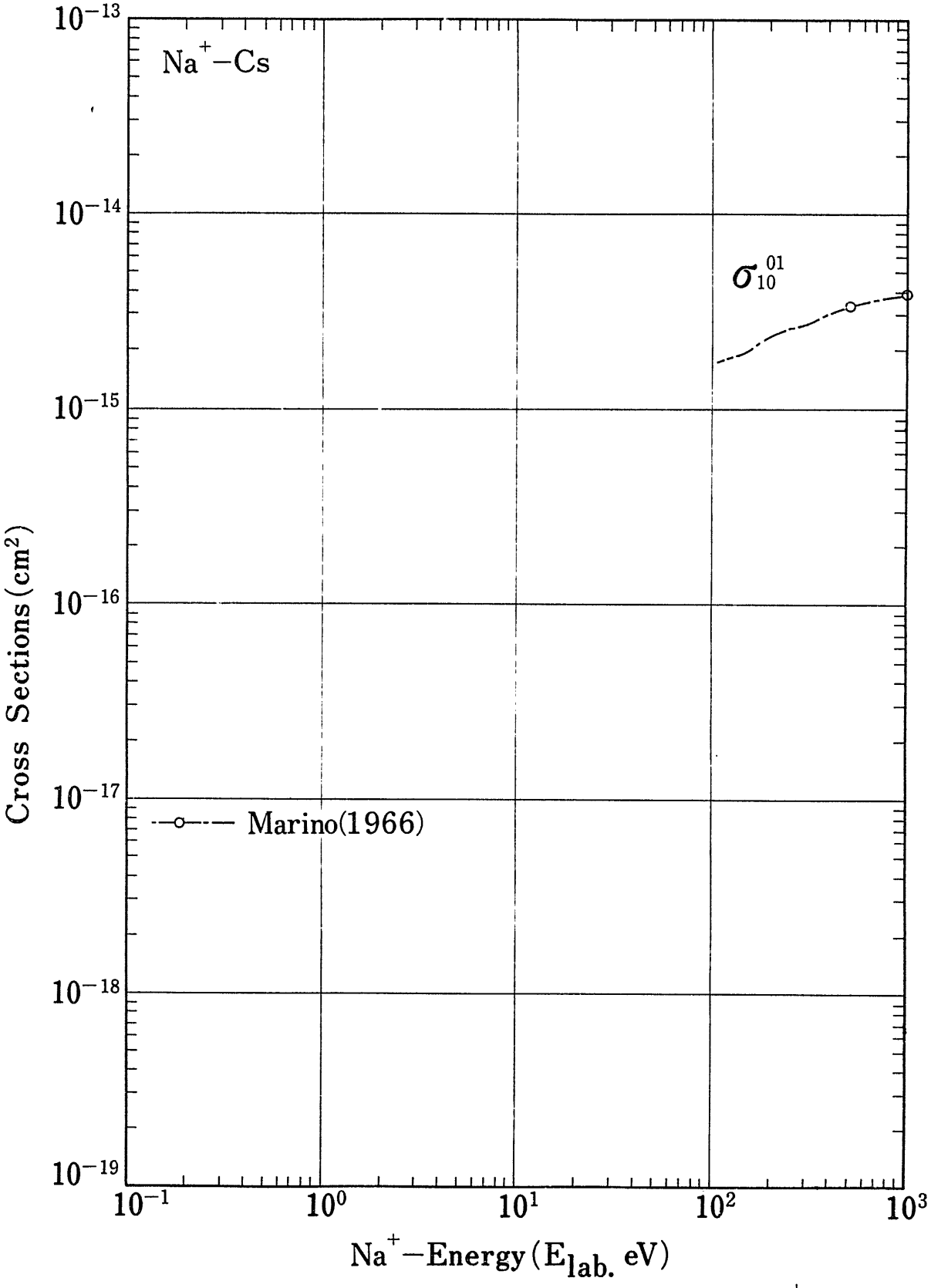

Fig.27−a Charge Changing Cross Sections of Na^+ in Cs

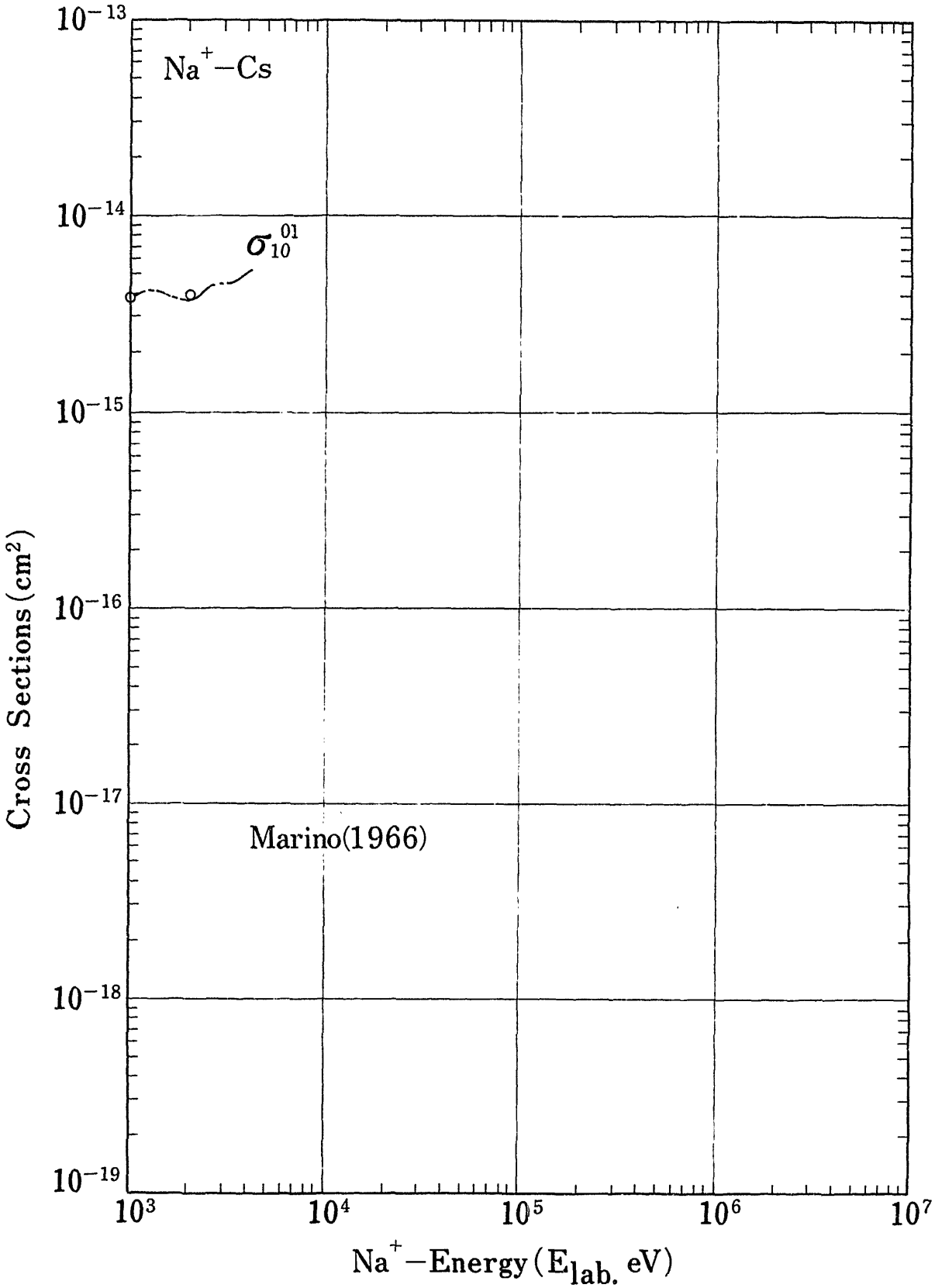

Fig.27–b Charge Changing Cross Sections of Na^+ in Cs