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COVFILS

A 30-Group Covariance Library Based on ENDF/B-V

University of California

LOS ALAMOS SCIENTIFIC LABORATORY
Post Office Box 1663 Los Alamos, New Mexico 87545

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D. W. Muir
R. J. LaBauve

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by

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ABSTRACT

A library of 30-group cross sections and covariances called COVFILS has been prepared from ENDF/B-V data using the NJOY code system. COVFILS includes data on the total cross sections, scattering cross sections, and the most important absorption cross sections for ^{1}H, ^{10}B, C, ^{16}O, Cr, Fe, Ni, Cu, and Pb. This report contains detailed descriptions of various features of the library, a listing of a FORTRAN retrieval program, and 143 plots of the multigroup cross-section uncertainties and their correlations.

I. INTRODUCTION

A library of 30-group multigroup cross sections and covariance data designed for use in sensitivity studies has been prepared from ENDF/B-V[1] data with the NJOY[2] code system. The selection of the contents of the library, called COVFILS, is based largely on a recent Los Alamos National Laboratory report.[3] This report provides the sensitivities of neutronic responses (in a Tokamak Experimental Power Reactor designed by Argonne National Laboratory) to various nuclear cross sections. The neutronic responses considered in Ref. 3 were related to toroidal-field-coil (TFC) integrity and activation of the TFC's outermost dewar. In particular, these included (1) neutron and gamma-ray heating in the TFC; (2) absorbed dose in the Mylar insulation of the TFC; (3) radiation damage, i.e., displacements per atom (dpa), in copper in the TFC; and (4) copper transmutation in the TFC.

The investigation reported in Ref. 3 revealed the scattering cross sections in the stainless steel (in particular, the iron in stainless steel) and copper and the absorption cross sections of the ^{10}B in boron carbide to be the most significant contributors to the integral sensitivities of the responses studied in this design. Of lesser importance were the scattering cross sections of ^{1}H, C, and Fe. Data for ^{16}O were needed for a subsequent sensitivity and uncertainty analysis[4] of the General Atomic Power Generating Fusion Reactor design. Thus, in the COVFILS covariance library we have included data for ^{1}H, ^{10}B, C, ^{16}O, Cr, Fe, Ni, Cu, and Pb. Since the ENDF/B-V evaluation for Cu (MAT 1329) does not contain formatted uncertainty files,[5] we have generated an approximate data set for Cu by combining cross sections from MAT 1329 with relative uncertainties taken from the ENDF/B-V evaluation for Fe (MAT 1326). Reactions in COVFILS include total cross sections, elastic and inelastic scattering cross sections, nonelastic (total minus elastic) cross sections, and all cross sections making a significant contribution to the total absorption cross section for each nuclide.

The COVFILS library is described in detail in the following sections. The data itself can be obtained on magnetic tape, either from the authors of this report or from the Radiation Shielding Information Center at Oak Ridge National Laboratory. The data are also available to users of the National Magnetic Fusion Energy Computer Center, which is located at Lawrence Livermore National Laboratory.

II. DEFINITIONS

COVFILS contains both multigroup cross sections and associated multigroup relative covariance matrices. The covariances describe both the uncertainty in the multigroup cross sections and the correlations between them. To be more specific, let x_i be the multigroup cross section for reaction "x" in energy group i, and let y_j be the cross section for reaction "y" in group j. Let Δx_i be the uncertainty (standard deviation) in x_i. We denote by $\mathrm{Corr}(x_i,y_j)$, the correlation coefficient between the two cross sections, a number whose absolute magnitude lies between 0 and 1. Then the relative covariance of x_i with y_j is

$$R(x_i,y_j) \equiv \frac{\mathrm{Cov}(x_i,y_j)}{x_i y_j} = \mathrm{Corr}(x_i,y_j)\,\frac{\Delta x_i}{x_i}\,\frac{\Delta y_j}{y_j} \quad . \tag{1}$$

We see here that relative covariance is a ratio, a dimensionless quantity. The set of values of $R(x_i,y_j)$ obtained by fixing x and y, but letting i and j range over all energy groups, is the relative covariance matrix of reaction "x" with reaction "y." By convention, i is the row index of the matrix and j the column index.

The energy group structure used in COVFILS is listed in Table I. Note that the group indexing used internally in the COVFILS library runs from low energies to high energies, the reverse of the high-to-low ordering normally used in neutronics calculations.

Reactions are identified in the library by a set of "MT-numbers." The MT-numbers follow ENDF/B definitions, and they are listed in Table II.

III. CONTENTS OF THE LIBRARY

A complete list of the relative covariance matrices that are included in the library is given in Table III. To illustrate the organization of this table, we note that for ^{1}H, for example, the relative covariance matrix of the total cross section (MT=1) with the radiative capture cross section (MT=102) is present, but all correlation coefficients are less than 0.20, as indicated by status code "B."

A COVFILS retrieval program COVARD (covariance reader) is listed in Table IV. Note that the only input required by COVARD is the material identifier MAT and the desired reaction-pair MT-MT1 (see Table III). The requested relative covariance matrix is retrieved from COVFILS, assumed to be on logical unit NIN, and stored into the array CF(I,J). The multigroup cross sections for reactions MT and MT1 are also retrieved and stored into XX(I) and XY(I), respectively. If desired, one can convert the relative covariances into absolute covariances, $Cov(x_i,y_j)$ in Eq. (1), with a FORTRAN statement of the form ACF(I,J) = XX(I) * XY(J) * CF(I,J). Note that COVARD automatically reverses the energy group ordering to produce the "normal" group sequence listed in Table I.

For readers who wish to scan the numerical data "by eye" or who want to construct their own retrieval program, the following section contains a detailed description of the library format.

TABLE I

ENERGY BOUNDS FOR THE 30-GROUP STRUCTURE

Group Index		Group Upper Energy (eV)
"Normal"	COVFILS	
1	30	2.00+7*
2	29	1.50+7
3	28	1.35+7
4	27	1.20+7
5	26	1.00+7
6	25	7.79+6
7	24	6.07+6
8	23	3.68+6
9	22	2.865+6
10	21	2.232+6
11	20	1.738+6
12	19	1.353+6
13	18	8.23+5
14	17	5.00+5
15	16	3.03+5
15	15	1.84+5
17	14	6.76+4
18	13	2.48+4
19	12	9.12+3
20	11	3.35+3
21	10	1.235+3
22	9	4.54+2
23	8	1.67+2
24	7	6.14+1
25	6	2.26+1
26	5	8.32+0
27	4	3.06+0
28	3	1.13+0
29	2	4.14-1
30	1	1.52-1/1.39-4

*To be read as $2.00 \times 10^{+7}$.

TABLE II

MT-NUMBER DEFINITIONS

MT=1	total cross section
MT=2	inelastic scattering cross section
MT=3	nonelastic cross section
MT=4	total inelastic scattering cross section
MT=16	(n,2n) cross section
MT=17	(n,3n) cross section
MT=22	(n,n'α) cross section
MT=28	(n,n'p) cross section
MT=51-90	cross sections for excitation of discrete levels 1-40
MT=102	(n,γ) radiative capture cross section
MT=103	(n,p) cross section
MT=104	(n,d) cross section
MT=105	(n,t) cross section
MT=106	(n,^{3}He) cross section
MT=107	(n,α) cross section
MT=111	(n,2p) cross section

TABLE III

ENDF/B-V COVARIANCE DATA PROCESSED WITH NJOY/ERRORR

Nuclide	ENDF/B[a] MAT-Number	Status[b] of Processed Reaction-Pairs

^{1}H — 1301

	1	2	102
1	A	A	B
2		A	C
102			A

^{10}B — 1305

	1	2	107	780	781
1	A	A	A	A	A
2		A	A	A	A
107			A	A	A
780				A	A
781					A

C — 1306

	1	2	3	4	102	103	104	107
1	A	A	A	A	B	C	C	C
2		A	A	A	C	C	C	C
3			A	A	A	C	C	C
4				A	B	B	B	A
102					A	C	C	C
103						A	C	C
104							A	C
107								A

^{16}O — 1276

	1	2	4	103	107
1	A	A	A	B	B
2		A	A	B	A
4			A	B	A
103				A	C
107					A

Cr — 1324

	1	2	3	4	16	17	22	28	102	103	104	105	106	107
1	A	A	A	C	C	C	C	C	A	C	C	C	C	C
2		A	A	A	C	C	C	C	C	C	C	C	C	C
3			A	A	C	C	C	C	A	C	C	C	C	C
4				A	A	B	B	B	A	A	B	B	B	B
16					A	C	C	C	C	C	C	C	C	C
17						A	C	C	C	C	C	C	C	C
22							A	C	C	C	C	C	C	C
28								A	C	C	C	C	C	C
102									A	C	C	C	C	C
103										A	C	C	C	C
104											A	C	C	C
105												A	C	C
106													A	C
107														A

Fe — 1326

	1	2	3	4	16	22	28	102	103	104	105	106	107
1	A	A	A	C	C	C	C	A	C	C	C	C	C
2		A	A	A	C	C	C	B	C	C	C	C	C
3			A	A	C	C	C	A	C	C	C	C	C
4				A	A	B	A	B	B	B	B	B	B
16					A	C	C	C	C	C	C	C	C
22						A	C	C	C	C	C	C	C
28							A	C	C	C	C	C	C
102								A	C	C	C	C	C
103									A	C	C	C	C
104										A	C	C	C
105											A	C	C
106												A	C
107													A

TABLE III (cont.)

Nuclide	ENDF/B[a] MAT-Number
Ni	1328

Status[b] of Processed Reaction-Pairs

	1	2	4	16	22	28	102	103	104	107	111
1	A	C	C	C	C	C	C	C	C	C	C
2		A	C	C	C	C	C	C	C	C	C
4			A	C	C	C	C	C	C	C	C
16				A	C	C	C	C	C	C	C
22					A	C	C	C	C	C	C
28						A	C	C	C	C	C
102							A	C	C	C	C
103								A	C	C	C
104									A	C	C
107										A	C
111											A

Nuclide	ENDF/B[a] MAT-Number
Cu	1329

	1	2	3	4	18	22	28	102	103	104	105	106	107
1	A	A	A	C	C	C	C	A	C	C	C	C	C
2		A	A	A	C	C	C	B	C	C	C	C	C
3			A	A	C	C	C	A	C	C	C	C	C
4				A	A	B	A	B	B	B	C[c]	B	B
16					A	C	C	C	C	C	C	C	C
22						A	C	C	C	C	C	C	C
28							A	C	C	C	C	C	C
102								A	C	C	C	C	C
103									A	C	C	C	C
104										A	C	C	C
105											C[c]	C	C
106												A	C
107													A

Nuclide	ENDF/B[a] MAT-Number
Pb	1382

	1	2	3	4	16	17	51	52	64	102
1	A	A	B	C	C	C	C	C	C	B
2		A	A	A	C	A	C	C	C	C
3			A	A	C	A	C	C	C	A
4				A	A	A	C	C	C	B
16					A	A	C	C	C	C
17						A	C	C	C	B
51							A	C	C	C
52								A	C	C
64									A	C
102										A

[a] Ref. 1.

[b] Status explanations:

A. The covariances are nonzero and at least some correlation coefficients are significant, i.e., above 0.20.

B. The covariances are nonzero, but all correlation coefficients are below 0.20.

C. The covariance matrix is present but contains only zeros.

[c] Covariances were zeroed for these reaction-pairs because σ(MT=105) is negligible for Cu.

TABLE IV

RETRIEVAL PROGRAM FOR COVFILS

```
      SUBROUTINE COVARD (MAT,MT,MT1)
C
C     FUNCTION OF ROUTINE.  READ COVARIANCE DATA IN THE ENDF-LIKE
C     FORMAT OF COVFILS AND TRANSFORM IT INTO ENGINEERING FORMAT.
C     THAT IS, RECONSTRUCT FULL MATRICES (INCLUDING ZEROES) AND REVERSE
C     THE GROUP ORDERING TO THE NORMAL HIGH-ENERGY TO LOW-ENERGY ORDER.
C
      COMMON/COV/CF(30,30),SIG(30),SIG1(30),EMIN(31),IG,IGP
      COMMON/UNITS/NIN,NOUT
      COMMON/ZERO/IZERO
      DIMENSION A(17), CT(30)
      MF1=3
      MF2=33
      MFA=1
      MTA=451
      REWIND NIN
C
C     READ GROUP STRUCTURE
   10 READ (NIN,20) (A(I),I=1,17),MATH,MFH,MTH
   20 FORMAT (16A4,A2,I4,I2,I3)
      IF (MATH.EQ.MAT) GO TO 30
      IF (MATH.LT.MAT) GO TO 10
      WRITE (NOUT,40) MAT,NIN,MATH
   40 FORMAT ( 1H0,*   SORRY,REQUESTED MAT=*I4,* NOT ON TAPE *I3,
     1        * LAST MAT READ WAS *I4)
      STOP1
   30 CONTINUE
      READ (NIN,50) C1,C2,L1,L2,L3,L4,MATH,MFH,MTH
   50 FORMAT (2E11.4,4I11,I4,I2,I3)
      IF (MFH.EQ.MFA) GO TO 70
      WRITE (NOUT,60) NIN,MFH,MTH
   60 FORMAT (1H0,*  SORRY,TAPE *I3,* BAD.  MFH=*I3, * MTH=*I4)
      STOP2
   70 IF (MTH.EQ.MTA) GO TO 80
      WRITE (NOUT,60) NIN,MFH,MTH
      STOP3
   80 CONTINUE
      IG=L1
      IGP=L3
      READ (NIN,90) (CT(I),I=1,IGP)
   90 FORMAT (6E11.4)
      DO 85 I=1,IGP
      IR=IGP+1-I
   85 EMIN(IR)=CT(I)
C
C     READ CROSS SECTIONS FOR MT AND MT1.
  100 READ (NIN,20) (A(I),I=1,17),MATH,MFH,MTH
      IF (MFH.LT.MF1) GO TO 100
      IF (MFH.EQ.MF1) GO TO 110
      WRITE (NOUT,60) NIN,MFH,MTH
      STOP4
  110 CONTINUE
      IF (MTH.LT.MT) GO TO 100
      IF (MTH.EQ.MT) GO TO 120
      WRITE (NOUT,60) NIN,MFH,MTH
      STOP5
  120 CONTINUE
      READ (NIN,90) (CT(I),I=1,IG)
      DO 115 I=1,IG
      IR=IG+1-I
  115 SIG(IR)=CT(I)
      IF (MT.NE.MT1) GO TO 130
      DO 125 I=1,IG
      SIG1(I)=SIG(I)
  125 CONTINUE
      GO TO 150
```

TABLE IV (cont.)

```
  130 READ (NIN,20) (A(I),I=1,17),MATH,MFH,MTH
      IF (MTH.LT.MT1) GO TO 130
      IF (MTH.EQ.MT1) GO TO 140
      WRITE (NOUT,60) NIN,MFH,MTH
      STOP6
  140 READ (NIN,90) (CT(I),I=1,IG)
      DO 145 I=1,IG
      IR=IG+1-I
  145 SIG1(IR)=CT(I)
  150 CONTINUE
C
C     READ COVARIANCES.
  160 READ (NIN,20) (A(I),I=1,17),MATH,MFH,MTH
      IF (MFH.LT.MF2) GO TO 160
      IF (MTH.NE.MT) GO TO 160
      IF (MFH.EQ.MF2) GO TO 170
      WRITE (NOUT,60) NIN,MFH,MTH
      STOP7
  170 CONTINUE
      READ (NIN,50) C1,C2,L1,L2,L3,L4,MATH,MFH,MTH
      IF (MTH.LT.MT) GO TO 160
      IF (MTH.EQ.MT) GO TO 180
      WRITE (NOUT,60) NIN,MFH,MTH
      STOP10
  180 CONTINUE
      MTX=L2
      KGP=L4
      DO 155 N=1,KGP
      DO 155 K=1,KGP
  155 CF(K,N)=0.
      DO 190 K=1,KGP
      READ (NIN,50) C1,C2,L1,L2,L3,L4
      LGP1=L2
      LGP2=L2+L3-1
      NGNO=L4
      KL=L4
      READ (NIN,90) (CT(L),L=LGP1,LGP2)
      LR1=KGP+1-KL
      DO 185 L=LGP1,LGP2
      LR2=KGP+1-L
  185 CF(LR1,LR2)=CT(L)
      IF (NGNO.GE.KGP) GO TO 200
  190 CONTINUE
  200 IF (MTX.LT.MT1) GO TO 170
      IF (MTX.EQ.MT1) GO TO 210
      WRITE (NOUT,60) NIN,MFH,MTH
      STOP11
  210 CONTINUE
C
C     ELIMINATE SPURIOUS COVARIANCES IN REGIONS OF ZERO XSEC,
C     AND TEST FOR A NULL COVARIANCE MATRIX.
      IPFLAG=0
      IZERO=0
      DO 230 K=1,IG
      DO 230 N=1,IG
      IF (SIG(K)*SIG1(N).NE.0.) GO TO 270
      IF (CF(K,N).EQ.0.) GO TO 230
      CF(K,N)=0.
      IPFLAG=IPFLAG+1
      IF (IPFLAG.EQ.1) WRITE (NOUT,250) MT,K,MT1,N
  250 FORMAT (/,50H ***** WARNING FROM COVARD.  COVARIANCE ZEROED FOR,
     1 /,5H MT =,I4,6H, IG =,I4,11H WITH MT1 =,I4,7H, IG1 =,I4,
     2 /,32H BECAUSE OF ZERO CROSS SECTIONS.)
      IF (IPFLAG.EQ.2) WRITE (NOUT,260)
  260 FORMAT (43H ADDITIONAL WARNING DIAGNOSTICS SUPPRESSED.)
      GO TO 230
  270 IF (CF(K,N).NE.0) IZERO=1
  230 CONTINUE
      RETURN
```

IV. THE COVFILS CARD-IMAGE FORMAT

The particular module of the NJOY[2] code system that was used to produce the COVFILS library is the ERRORR module. The multigroup output of ERRORR is produced in an ENDF-like format, a sample of which is given in Table V.

The data in Table V are given in standard ENDF/B BCD card-images consisting of 80 columns divided into 10 fields. The first 6 fields are 11 characters wide and are used for either floating-point numbers or integers. The seventh, eighth, ninth, and tenth fields are 4, 2, 3, and 5 characters wide, respectively, and are used for integers only. The four digits in field 7 are the MAT or "material" number of the isotope or element; the two digits in field 8 are the MF or "file" number that indicates the general type of data (for example, cross-section data vs. covariance data); the three digits in field 9 are the MT or "section" number that indicates the particular nuclear reaction; and finally, the five digits in the field 10 are the card sequence number. Sections are terminated by zeros in the MT field, files by zeros in the MF field, and materials by zeros in the MAT field.

The first card shown in Table V is the first card for the material MAT 1326, which is elemental iron. Note that on this card the number 2.6×10^4 appears in the first field and 55.365 is the second field. These are the "ZA" ($1000 \times Z + A$) and "AWR" (atomic weight ratio, i.e., atomic weight of the material divided by the weight of the neutron), numbers taken by the NJOY code directly from the ENDF/B file. The fact that ZA is 26 000 (implying that $A = 0$) is a convention that means that the data is for the element Fe rather than for a single isotope.

Also note that MF=1 and MT=451 on cards 1 to 8. This MF-MT combination is normally used in the ENDF/B formats for descriptive Hollerith information, but it is used here for the boundaries of the multigroup structure used for the processed data to follow. On card 2, note the number 30 in field 3 and the number 31 in field 5, which indicate, respectively, the number of energy groups and the number of energy-group boundaries in the multigroup set. The values of the group boundaries, given in eV from low to high energy, follow on cards 3 through 8. Cards 9 and 10 are section and file terminators, respectively.

Multigroup cross-section data are given in barns on cards 11 through 101. This file, denoted by MF=3, corresponds to the smooth cross-section file in ENDF/B. The MT-numbers (field 9) can be identified with particular nuclear reactions by consulting Table II.

TABLE V

SAMPLE OF COVFILS DATA

```
2.60000+ 4 5.53650+ 1          0          0          0          01326 1451     1
0.00000+ 0 0.00000+ 0         30          0         31          01326 1451     2
1.00001- 1 1.52000- 1 4.14000- 1 1.13000+ 0 3.06000+ 0 8.32000+ 01326 1451     3
2.26000+ 1 6.14000+ 1 1.67000+ 2 4.54000+ 2 1.23500+ 3 3.35000+ 31326 1451     4
9.12000+ 3 2.48000+ 4 6.76000+ 4 1.84000+ 5 3.03000+ 5 5.00000+ 51326 1451     5
8.23000+ 5 1.35300+ 6 1.73800+ 6 2.23200+ 6 2.86500+ 6 3.68000+ 61326 1451     6
6.07000+ 6 7.79000+ 6 1.00000+ 7 1.20000+ 7 1.35000+ 7 1.50000+ 71326 1451     7
2.00000+ 7                                                       1326 1451     8
                                                                 1326 1  0     9
                                                                 1326 0  0    10
0.00000+ 0 0.00000+ 0          0          0         30          01326 3  1    11
1.35541+ 1 1.22016+ 1 1.18821+ 1 1.16911+ 1 1.15747+ 1 1.15004+ 11326 3  1    12
1.14473+ 1 1.13890+ 1 1.08615+ 1 9.81159+ 0 7.48915+ 0 1.03051+ 11326 3  1    13
2.37348+ 0 9.85481+ 0 4.41598+ 0 3.68858+ 0 3.78846+ 0 3.06211+ 01326 3  1    14
2.67145+ 0 2.98232+ 0 3.06996+ 0 3.34555+ 0 3.40099+ 0 3.67215+ 01326 3  1    15
3.58365+ 0 3.28614+ 0 2.98118+ 0 2.72494+ 0 2.57176+ 0 2.33063+ 01326 3  1    16
                                                                 1326 3  0    17
0.00000+ 0 0.00000+ 0          0          0         30          01326 3  2    18
1.15197+ 1 1.14101+ 1 1.14035+ 1 1.14006+ 1 1.13984+ 1 1.13946+ 11326 3  2    19
1.13848+ 1 1.13521+ 1 1.08378+ 1 9.56700+ 0 7.48389+ 0 1.02890+ 11326 3  2    20
2.36615+ 0 9.84028+ 0 4.40579+ 0 3.68150+ 0 3.78343+ 0 3.05551+ 01326 3  2    21
2.35213+ 0 2.28275+ 0 2.22931+ 0 2.43413+ 0 2.20602+ 0 2.14129+ 01326 3  2    22
2.04250+ 0 1.77500+ 0 1.49848+ 0 1.30110+ 0 1.17171+ 0 9.82526- 11326 3  2    23
                                                                 1326 3  0    24
0.00000+ 0 0.00000+ 0          0          0         30          01326 3  3    25
2.03435+ 0 7.91472- 1 4.78657- 1 2.90519- 1 1.76230- 1 1.05795- 11326 3  3    26
6.25256- 2 3.69154- 2 2.37323- 2 2.44582- 1 5.26174- 3 1.60700- 21326 3  3    27
7.32804- 3 1.45286- 2 1.01936- 2 7.08119- 3 5.03364- 3 6.59400- 31326 3  3    28
3.19314- 1 6.99575- 1 8.40647- 1 9.11424- 1 1.19498+ 0 1.53086+ 01326 3  3    29
1.54115+ 0 1.51114+ 0 1.48270+ 0 1.42384+ 0 1.40006+ 0 1.34810+ 01326 3  3    30
                                                                 1326 3  0    31
0.00000+ 0 0.00000+ 0          0          0         30          01326 3  4    32
0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 01326 3  4    33
0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 01326 3  4    34
0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 01326 3  4    35
3.16090- 1 6.97516- 1 8.37997- 1 9.06140- 1 1.18417+ 0 1.50336+ 01326 3  4    36
1.47693+ 0 1.40533+ 0 1.32806+ 0 1.07065+ 0 7.06491- 1 3.81651- 11326 3  4    37
                                                                 1326 3  0    38
0.00000+ 0 0.00000+ 0          0          0         30          01326 3 16    39
0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 01326 3 16    40
0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 01326 3 16    41
0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 01326 3 16    42
0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 01326 3 16    43
0.00000+ 0 0.00000+ 0 2.89441- 3 1.65433- 1 4.65000- 1 6.24670- 11326 3 16    44
                                                                 1326 3  0    45
0.00000+ 0 0.00000+ 0          0          0         30          01326 3 22    46
0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 01326 3 22    47
0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 01326 3 22    48
0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 01326 3 22    49
0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 01326 3 22    50
0.00000+ 0 0.00000+ 0 2.00000- 6 1.27543- 4 4.08366- 3 4.22890- 21326 3 22    51
                                                                 1326 3  0    52
0.00000+ 0 0.00000+ 0          0          0         30          01326 3 28    53
0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 01326 3 28    54
0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 0 0.00000+ 01326 3 28    55
```

TABLE V (cont.)

0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	1326 3 28	56
0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	1326 3 28	57
0.00000+ 0	0.00000+ 0	3.32449- 3	1.02461- 2	4.34896- 2	1.55290- 1	1326 3 28	58
						1326 3 0	59
0.00000+ 0	0.00000+ 0	0	0	30	0	1326 3102	60
2.03435+ 0	7.91472- 1	4.78657- 1	2.90519- 1	1.76230- 1	1.05795- 1	1326 3102	61
6.25256- 2	3.69154- 2	2.37323- 2	2.44582- 1	5.26174- 3	1.60700- 2	1326 3102	62
7.32804- 3	1.45286- 2	1.01936- 2	7.08119- 3	5.03364- 3	6.59077- 3	1326 3102	63
3.20207- 3	1.87146- 3	1.52351- 3	1.24692- 3	1.01854- 3	7.77897- 4	1326 3102	64
6.66572- 4	6.35742- 4	6.48990- 4	7.13011- 4	8.13104- 4	9.53248- 4	1326 3102	65
						1326 3 0	66
0.00000+ 0	0.00000+ 0	0	0	30	0	1326 3103	67
0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	1326 3103	68
0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	1326 3103	69
0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	3.23000- 6	1326 3103	70
2.22100- 5	1.87870- 4	1.12710- 3	4.03744- 3	9.77153- 3	2.60238- 2	1326 3103	71
5.64685- 2	8.63289- 2	1.13654- 1	1.28663- 1	1.20209- 1	7.33574- 2	1326 3103	72
						1326 3 0	73
0.00000+ 0	0.00000+ 0	0	0	30	0	1326 3104	74
0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	1326 3104	75
0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	1326 3104	76
0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	1326 3104	77
0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	1326 3104	78
0.00000+ 0	1.80996- 5	2.25000- 3	9.13333- 3	1.99333- 2	2.86600- 2	1326 3104	79
						1326 3 0	80
0.00000+ 0	0.00000+ 0	0	0	30	0	1326 3105	81
0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	1326 3105	82
0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	1326 3105	83
0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	1326 3105	84
0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	1326 3105	85
0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	5.60000- 4	1.44000- 2	1326 3105	86
						1326 3 0	87
0.00000+ 0	0.00000+ 0	0	0	30	0	1326 3106	88
0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	1326 3106	89
0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	1326 3106	90
0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	1326 3106	91
0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	1326 3106	92
0.00000+ 0	0.00000+ 0	0.00000+ 0	8.33334- 6	3.91667- 4	5.31000- 3	1326 3106	93
						1326 3 0	94
0.00000+ 0	0.00000+ 0	0	0	30	0	1326 3107	95
0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	1326 3107	96
0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	1326 3107	97
0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	1326 3107	98
0.00000+ 0	0.00000+ 0	0.00000+ 0	0.00000+ 0	1.98577- 5	6.90973- 4	1326 3107	99
7.08327- 3	1.88243- 2	3.18674- 2	3.88640- 2	3.90835- 2	2.15230- 2	1326 3107	100
						1326 3 0	101
						1326 0 0	102
2.60000+ 4	5.53650+ 1	0	0	0	13	1326 33 1	103
0.00000+ 0	0.00000+ 0	0	1	0	30	1326 33 1	104
0.00000+ 0	0.00000+ 0	8	1	8	1	1326 33 1	105
1.81487- 3	1.99084- 3	2.04160- 3	2.07346- 3	2.09334- 3	2.10578- 3	1326 33 1	106
2.11317- 3	2.11788- 3					1326 33 1	107
0.00000+ 0	0.00000+ 0	8	1	8	2	1326 33 1	108
1.99084- 3	2.18787- 3	2.24470- 3	2.28039- 3	2.30263- 3	2.31657- 3	1326 33 1	109
2.32507- 3	2.33026- 3					1326 33 1	110

TABLE V (cont.)

```
 0.00000+ 0 0.00000+ 0          0        102          0          30132633  4  911
 0.00000+ 0 0.00000+ 0          5         17          5          19132633  4  912
-1.63835- 5-3.27826- 5-1.22710- 4-2.07985- 4-1.15466- 4            132633  4  913
 0.00000+ 0 0.00000+ 0          3         19          3          20132633  4  914
-5.50855- 5-1.07321- 4-5.95814- 5                                  132633  4  915
 0.00000+ 0 0.00000+ 0         12         19         12          21132633  4  916
-2.07223- 5-4.03725- 5-4.37136- 5-5.03268- 5-5.43578- 5-6.11663- 5132633  4  917
-6.59791- 5-6.76100- 5-6.68902- 5-6.37887- 5-5.99185- 5-5.58653- 5132633  4  918
 0.00000+ 0 0.00000+ 0         10         21         10          22132633  4  919
-3.80925- 5-9.04449- 5-9.83828- 5-1.11790- 4-1.21267- 4-1.24479- 4132633  4  920
-1.23061- 4-1.16954- 4-1.09333- 4-1.01351- 4                       132633  4  921
 0.00000+ 0 0.00000+ 0         10         21         10          23132633  4  922
-2.57173- 5-6.14953- 5-6.75694- 5-7.78287- 5-8.50809- 5-8.75384- 5132633  4  923
-8.64538- 5-8.17804- 5-7.59485- 5-6.98409- 5                       132633  4  924
 0.00000+ 0 0.00000+ 0         10         21         10          24132633  4  925
-1.74088- 5-4.20357- 5-4.68202- 5-5.49012- 5-6.06136- 5-6.25493- 5132633  4  926
-6.16950- 5-5.80138- 5-5.34202- 5-4.86094- 5                       132633  4  927
 0.00000+ 0 0.00000+ 0         10         21         10          25132633  4  928
-1.63792- 5-3.97730- 5-4.46431- 5-5.28688- 5-5.86834- 5-6.06538- 5132633  4  929
-5.97842- 5-5.60371- 5-5.13613- 5-4.64644- 5                       132633  4  930
 0.00000+ 0 0.00000+ 0         10         21         10          26132633  4  931
-1.68233- 5-4.09220- 5-4.60402- 5-5.46850- 5-6.07958- 5-6.28666- 5132633  4  932
-6.19527- 5-5.80147- 5-5.31006- 5-4.79542- 5                       132633  4  933
 0.00000+ 0 0.00000+ 0         10         21         10          27132633  4  934
-1.79797- 5-4.37020- 5-4.91180- 5-5.82658- 5-6.47322- 5-6.69235- 5132633  4  935
-6.59564- 5-6.17893- 5-5.65893- 5-5.11434- 5                       132633  4  936
 0.00000+ 0 0.00000+ 0         10         21         10          28132633  4  937
-2.33664- 5-5.66009- 5-6.33190- 5-7.46662- 5-8.26873- 5-8.54054- 5132633  4  938
-8.42057- 5-7.90368- 5-7.25866- 5-6.58314- 5                       132633  4  939
 0.00000+ 0 0.00000+ 0         10         21         10          29132633  4  940
-3.79314- 5-9.14425- 5-1.01624- 4-1.18819- 4-1.30975- 4-1.35094- 4132633  4  941
-1.33276- 4-1.25443- 4-1.15668- 4-1.05431- 4                       132633  4  942
 0.00000+ 0 0.00000+ 0         10         21         10          30132633  4  943
-7.67502- 5-1.83961- 4-2.02808- 4-2.34640- 4-2.57142- 4-2.64767- 4132633  4  944
-2.61401- 4-2.46901- 4-2.28806- 4-2.09856- 4                       132633  4  945
 0.00000+ 0 0.00000+ 0          0        103          0          30132633  4  946
 0.00000+ 0 0.00000+ 0          7         18          7          19132633  4  947
-1.71773- 7-1.71773- 7-1.71773- 7-1.71773- 7-1.71773- 7-1.71773- 7132633  4  948
-1.31582- 8                                                        132633  4  949
 0.00000+ 0 0.00000+ 0          7         18          7          20132633  4  950
-6.73354- 7-6.73354- 7-6.73354- 7-6.73354- 7-6.73354- 7-6.73354- 7132633  4  951
-5.15804- 8                                                        132633  4  952
 0.00000+ 0 0.00000+ 0         13         18         13          21132633  4  953
-3.36247- 6-3.36247- 6-3.36247- 6-1.17786- 4-7.13781- 5-3.14654- 5132633  4  954
-1.08098- 5-4.86305- 6-3.18096- 6-2.41618- 6-2.13432- 6-2.28442- 6132633  4  955
-3.74344- 6                                                        132633  4  956
 0.00000+ 0 0.00000+ 0         13         18         13          22132633  4  957
-1.11391- 5-1.11391- 5-1.11391- 5-2.36460- 4-1.45074- 4-6.64790- 5132633  4  958
-2.16325- 5-9.57623- 6-6.26389- 6-4.75790- 6-4.20287- 6-4.49844- 6132633  4  959
-7.37151- 6                                                        132633  4  960
 0.00000+ 0 0.00000+ 0         13         18         13          23132633  4  961
 2.06295- 5-2.06295- 5-2.06295- 5-1.93048- 4-1.23118- 4-6.29763- 5132633  4  962
-1.74808- 5-7.32785- 6-4.79321- 6-3.64081- 6-3.21609- 6-3.44227- 6132633  4  963
-5.64078- 6                                                        132633  4  964
 0.00000+ 0 0.00000+ 0         13         18         13          24132633  4  965
```

The multigroup covariance data for MAT 1326 (Fe) begin with card 103. The designation of MF=33 in field 8 is the same as that for covariance data in ENDF/B. Card 103 repeats the ZA and AWR numbers in fields 1 and 2, and the number 13 in field 6 indicates that covariance matrices for 13 reaction-pairs follow. The number "1" in the MT field (field 9) indicates that all 13 reaction-pairs have MT=1 as the "first" reaction.

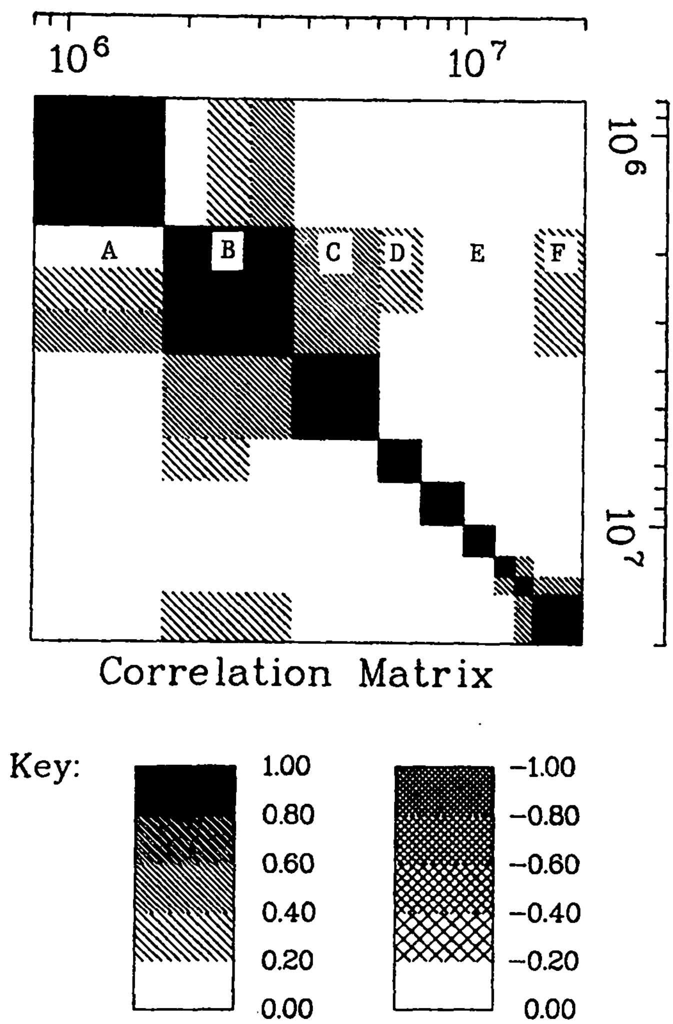
The data for one typical reaction-pair begin at card 911. In this section, note that the "first" reaction is MT=4. Field 4 of card 911 contains the number "102," so the "second" reaction is MT=102. In other words, the data to follow refer to the covariance matrix of the iron inelastic scattering reaction (MT=4) with the iron radiative capture reaction (MT1=102). The number "21" occurring in field 6 of card 916 indicates that these data refer to group 21 of MT=4, i.e., the twenty-first row of the covariance matrix. The number "12" in field 3 of card 916 indicates that there are 12 consecutive groups of MT1=102 for which covariances are non-zero. The first non-zero value occurs in group 19 of MT1=102, as indicated by the number "19" in field 4. Then, in referring to the entry in the sixth field of card 917, for example, one would say that "the relative covariance of the iron inelastic cross section in group 21 (1.738-2.232 MeV) with the iron radiative capture cross section in group 24 (3.68-6.07 MeV) is -6.11663×10^{-5}."

Any row of the covariance matrix, or any part of a row, which is not specified explicitly should be set to zero. The last row (group 30) is always given explicitly in COVFILS, even it it contains only zeros. The occurrence of the last row terminates a given covariance matrix and signals that the next card will name a new reaction-pair.

V. PLOTS OF THE DATA

Rather than simply listing the contents of the library, it is probably more helpful to plot the data. To do this, the computer program CPL[6] was employed. This program uses COVARD, Table IV, to read the data and Eq. (1) to extract the relative standard deviations ($\Delta x_i/x_i$) and the correlation coefficients $Corr(x_i,y_j)$ from the tabulated relative covariances $R(x_i,y_j)$. All covariance matrices in the library that contain "plottable" data (i.e., those that have status "A" in Table III) are plotted in Figs. 1-143. For convenience in locating a particular reaction-pair, a complete list of figures precedes Fig. 1. In each figure, the correlation matrix is plotted as a "countour map," where the shading density is proportional to the magnitude of the correlation coefficient in a given region.

Probably the best way to read these correlation plots is to fix one's attention on some energy in the reaction whose uncertainties are plotted vertically on the right side of the plot. For example, suppose one chooses 2 MeV in the sample plot shown below. Then the correlation coefficient between the "right" reaction at 2 MeV and the "top" reaction can be read as a function of the energy of the top reaction. Thus, in energy regions A, B, C, D, E, and F, the correlation coefficients vary in magnitude as follows: between -0.2 and 0.2, then 0.8 to 1.0, 0.4 to 0.6, 0.2 to 0.4, -0.2 to 0.2, and 0.2 to 0.4, respectively. Interestingly, the right reaction at 2 MeV is more strongly correlated with the top reaction at 18 MeV than with the same reaction at 10 MeV.



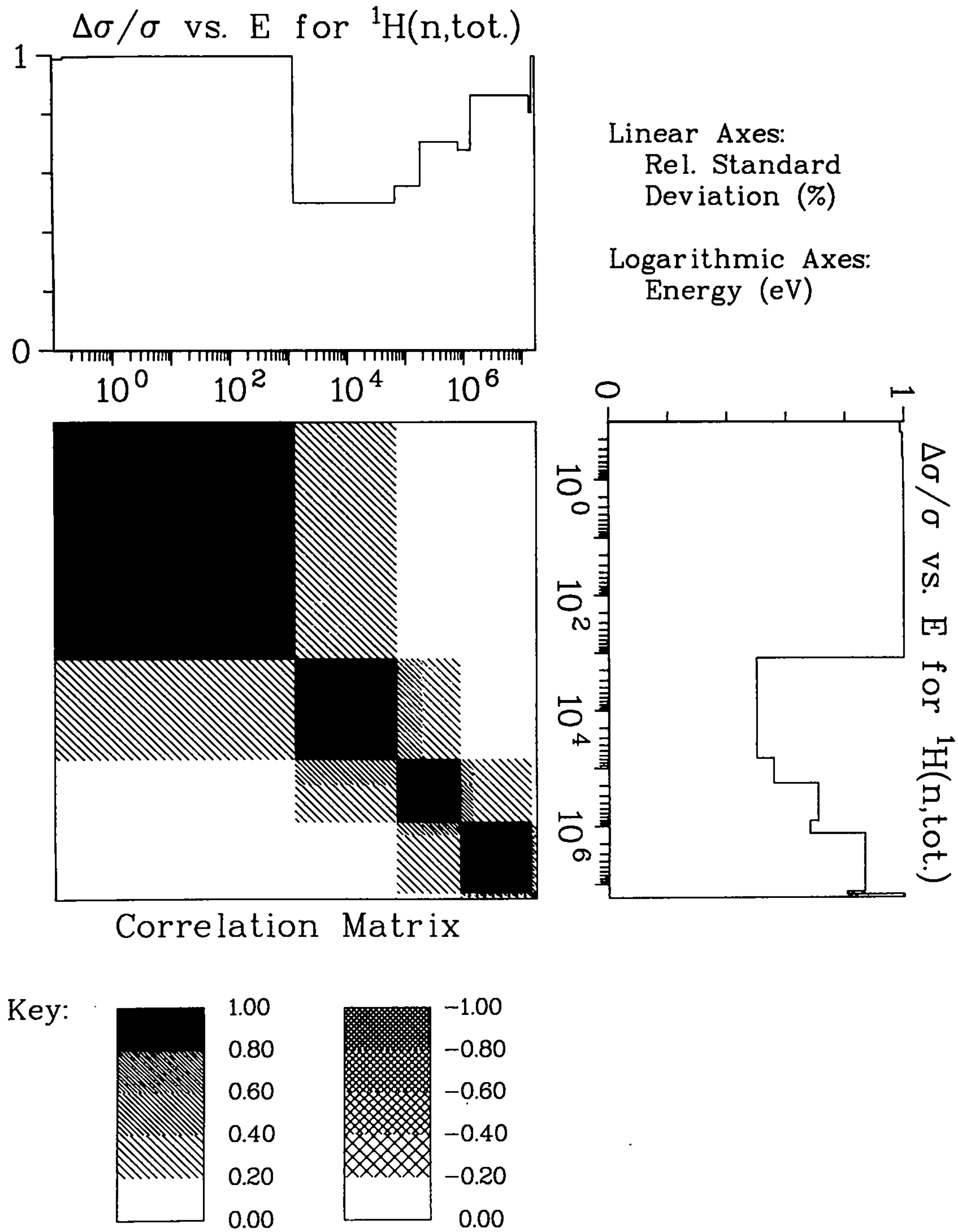


Fig. 1.

Covariance data for ^{1}H(n,tot.) with ^{1}H(n,tot.).

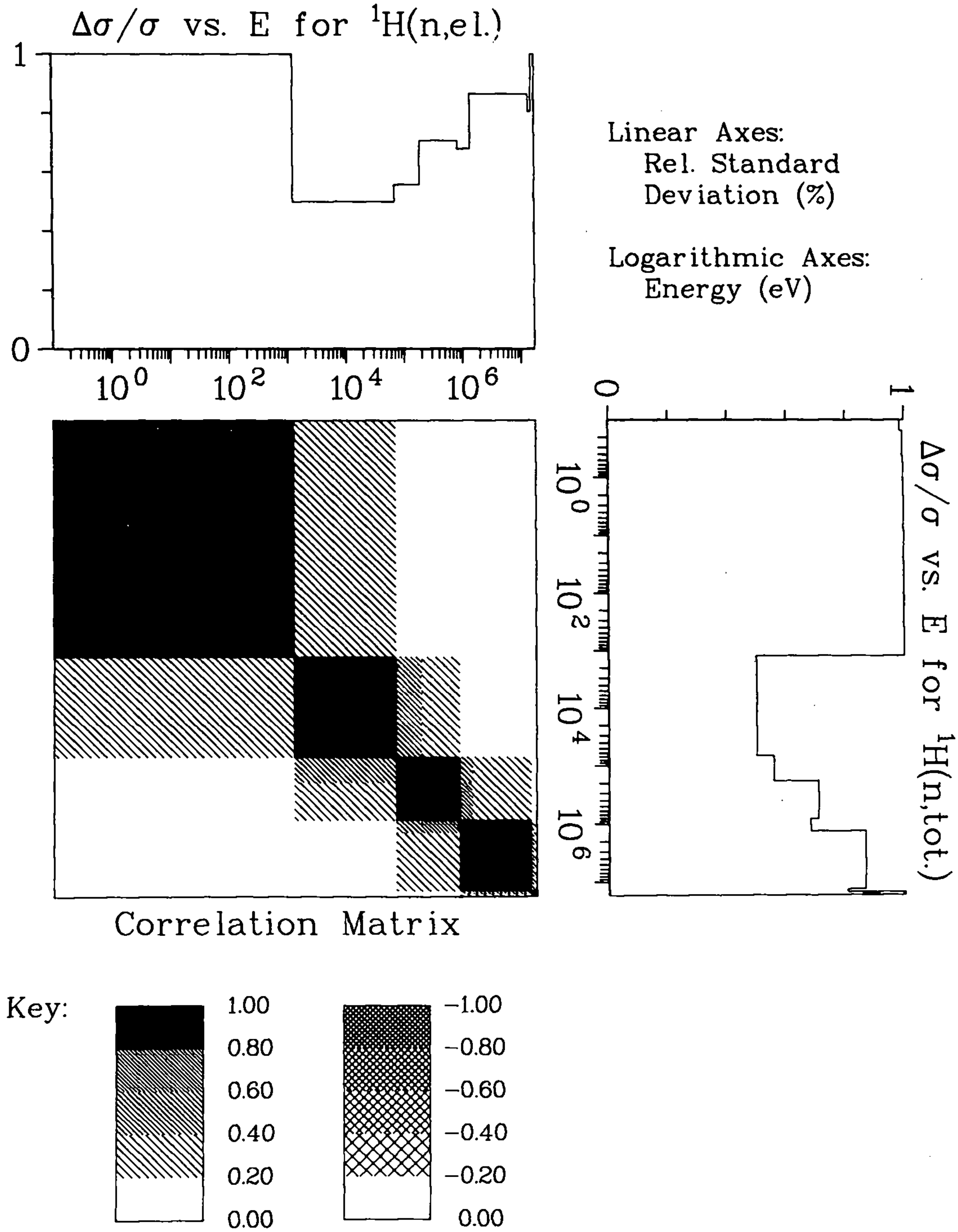


Fig. 2.

Covariance data for ^{1}H(n,tot.) with ^{1}H(n,el.).

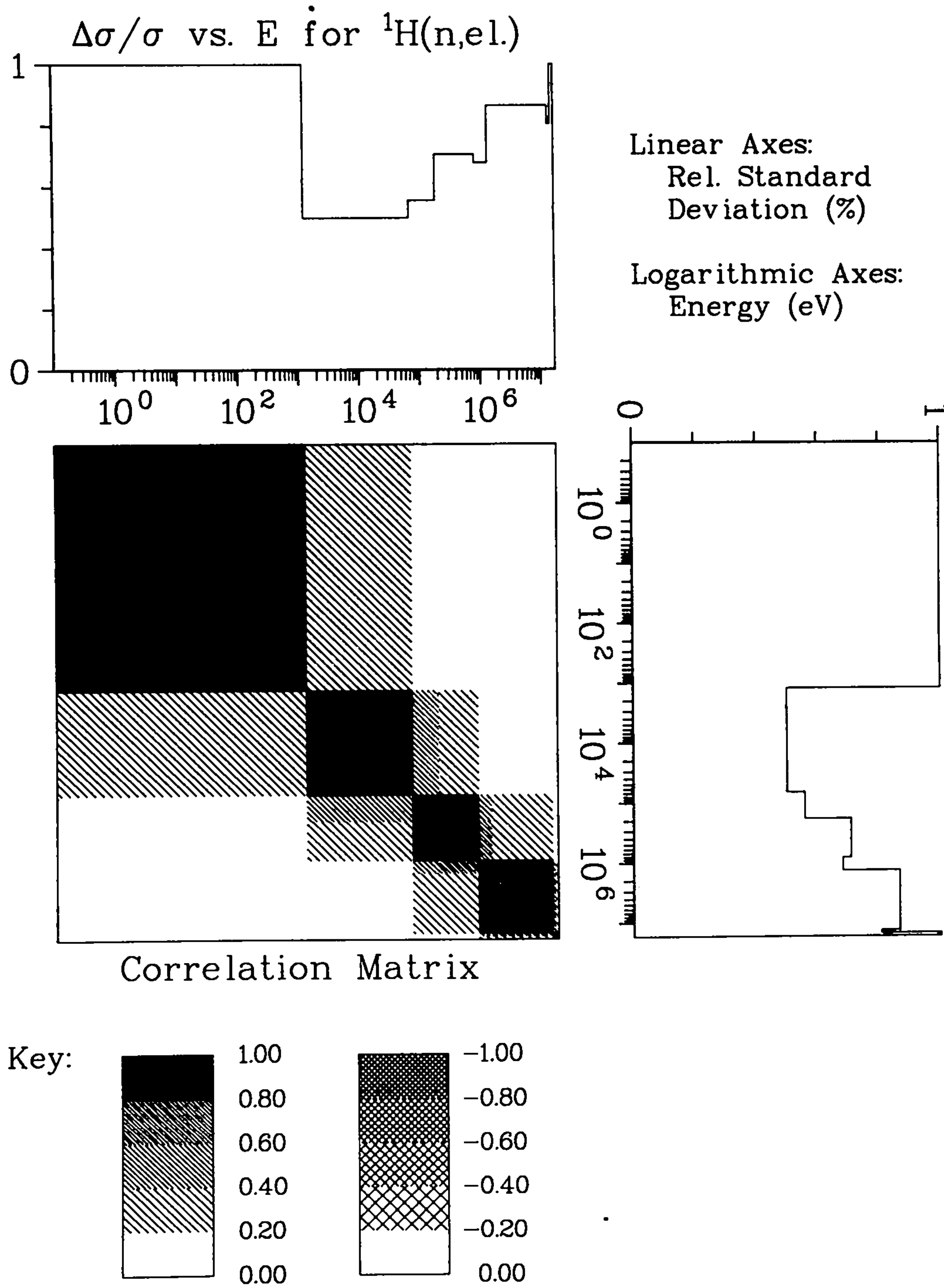


Fig. 3.
Covariance data for ^{1}H(n,el.) with ^{1}H(n,el.).

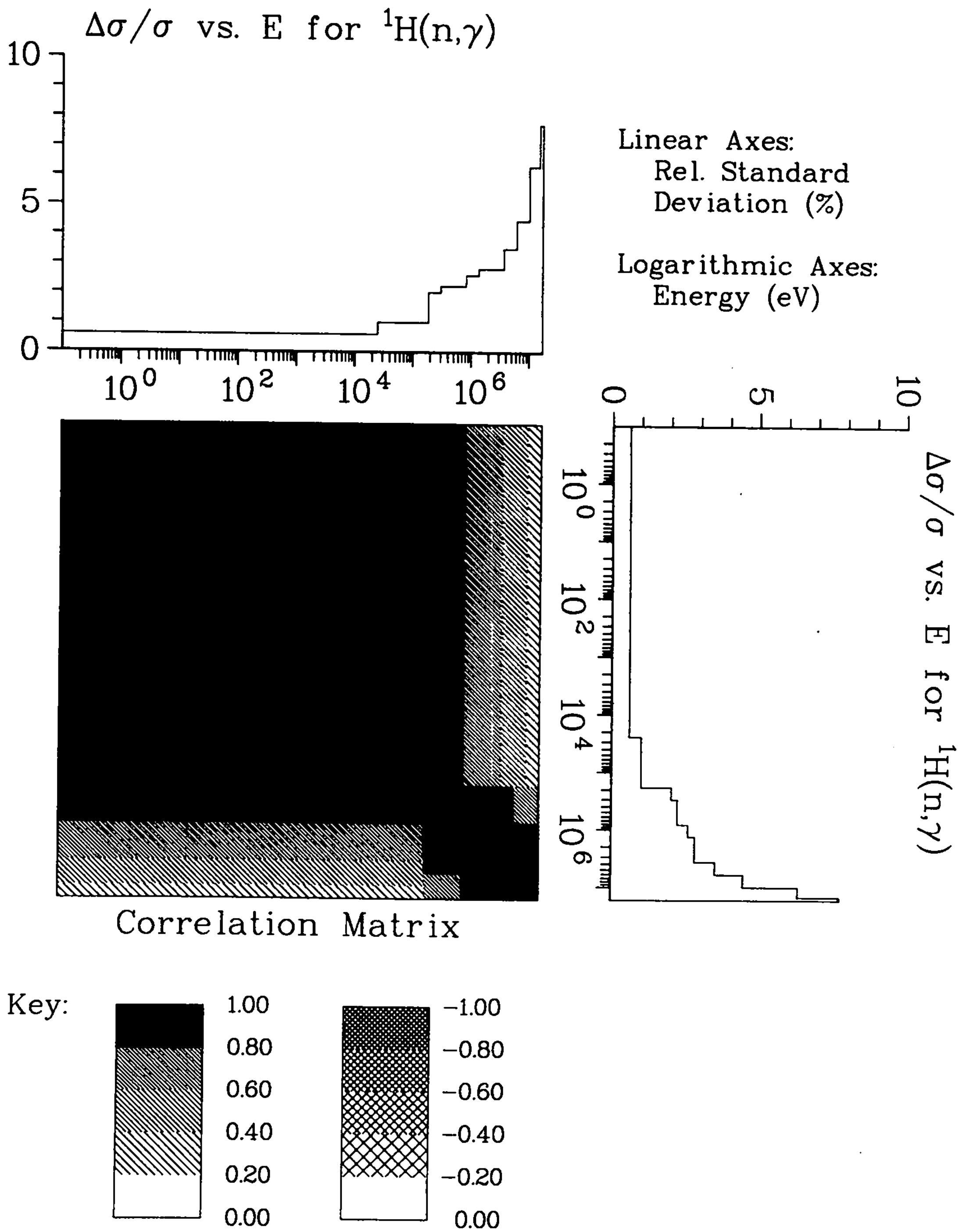


Fig. 4.
Covariance data for $^1H(n,\gamma)$ with $^1H(n,\gamma)$.

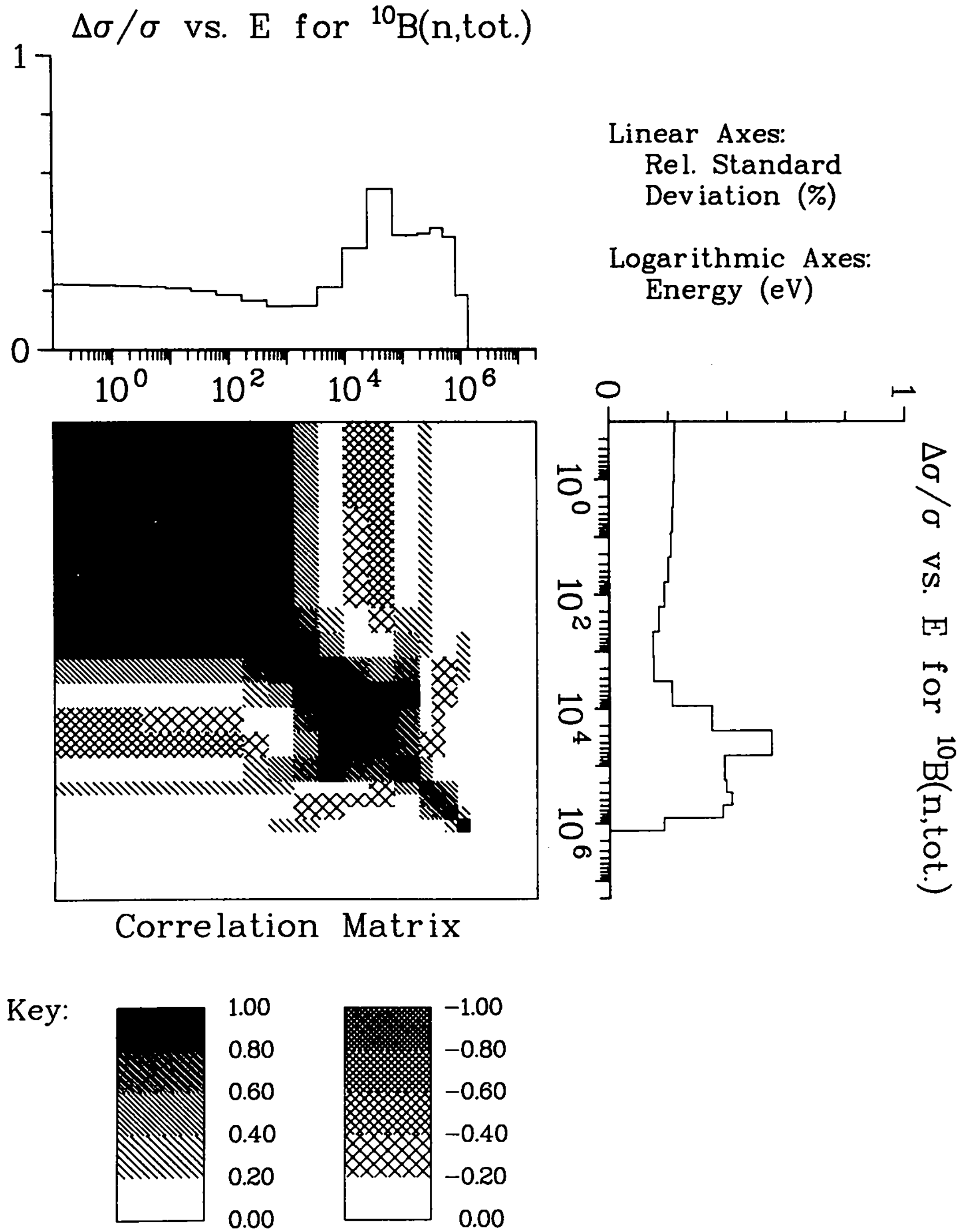


Fig. 5.
Covariance data for ^{10}B(n,tot.) with ^{10}B(n,tot.).

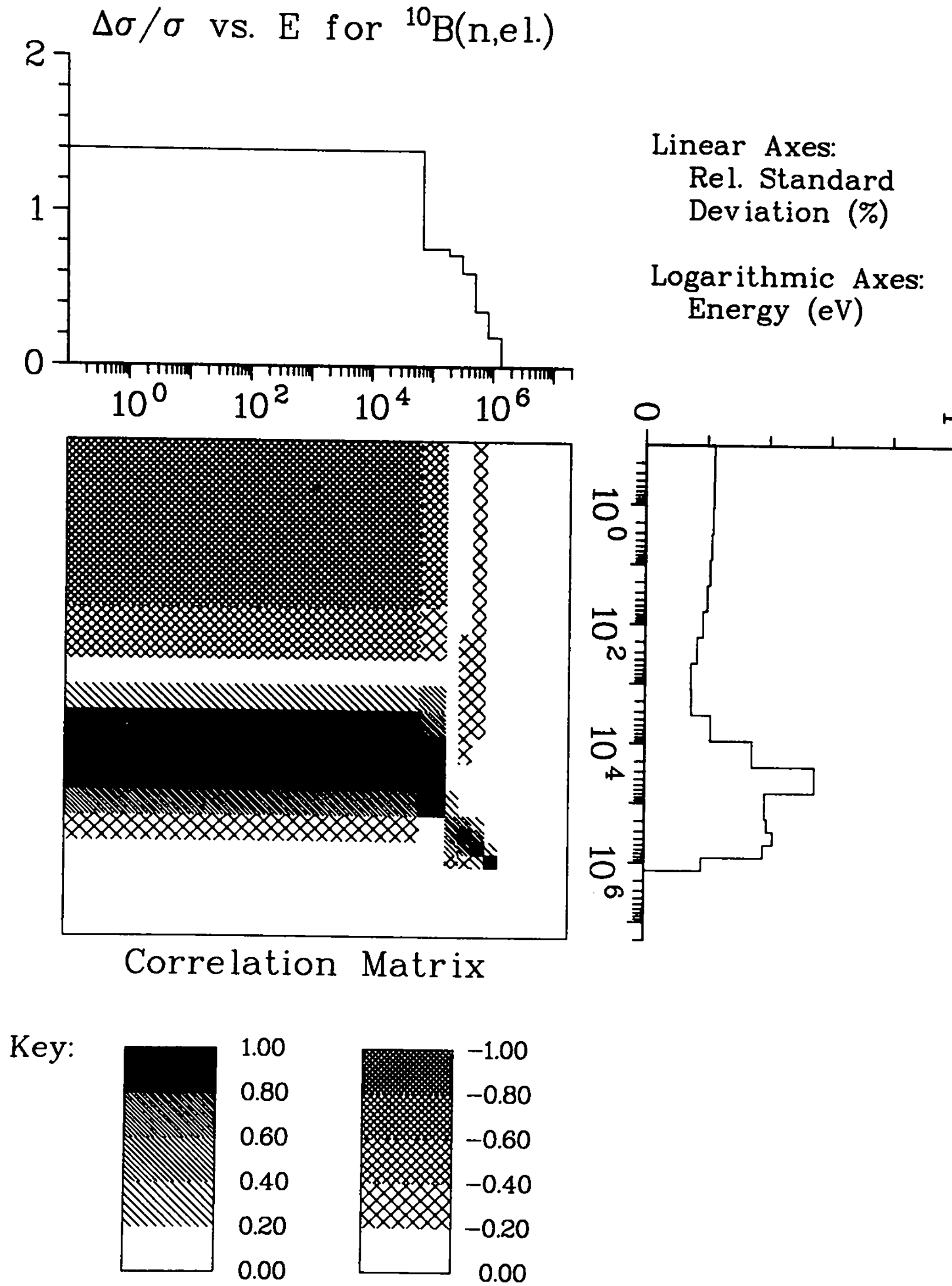


Fig. 6.
Covariance data for ^{10}B(n,tot.) with ^{10}B(n,el.).

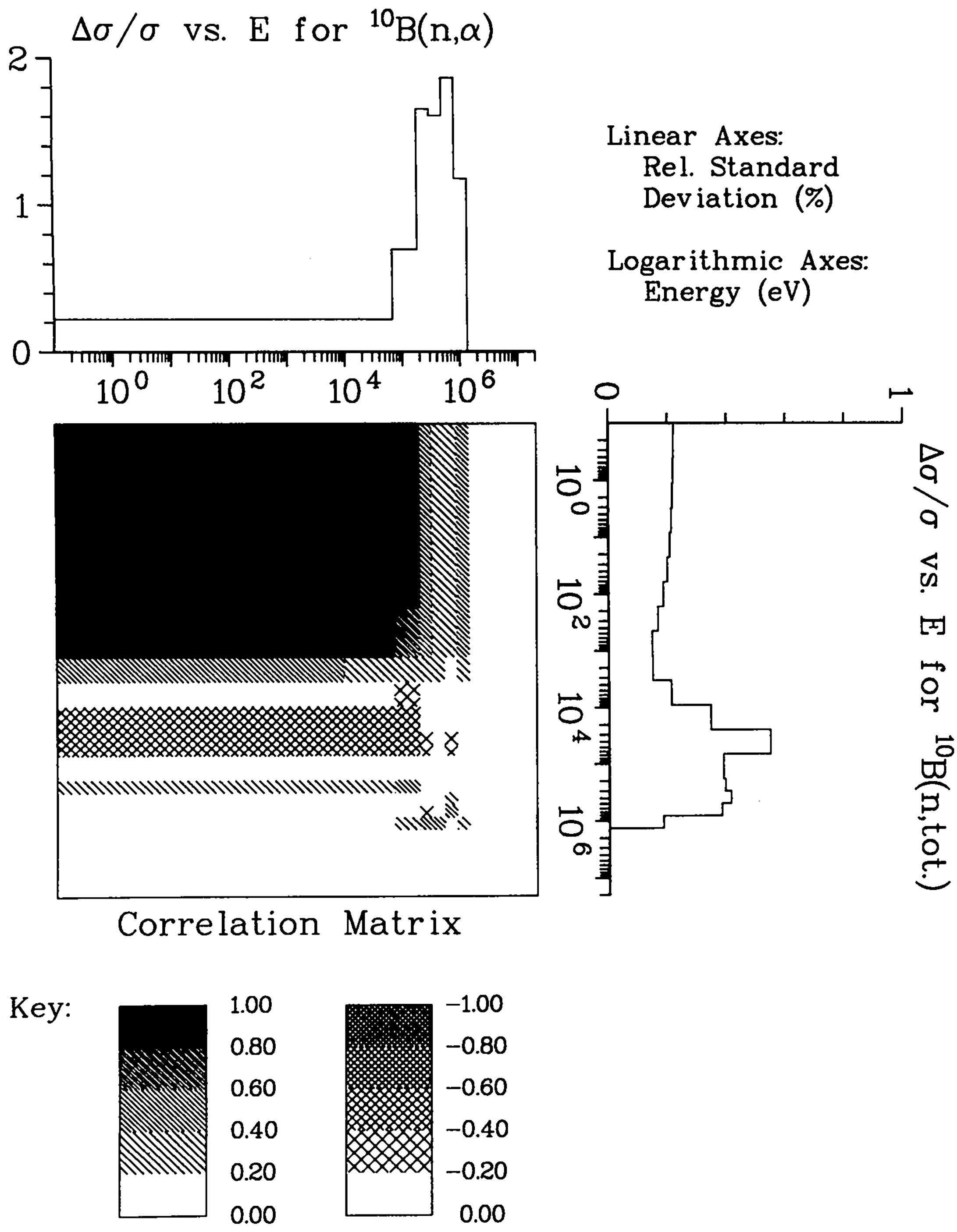


Fig. 7.
Covariance data for ^{10}B(n,tot.) with $^{10}B(n,\alpha)$.

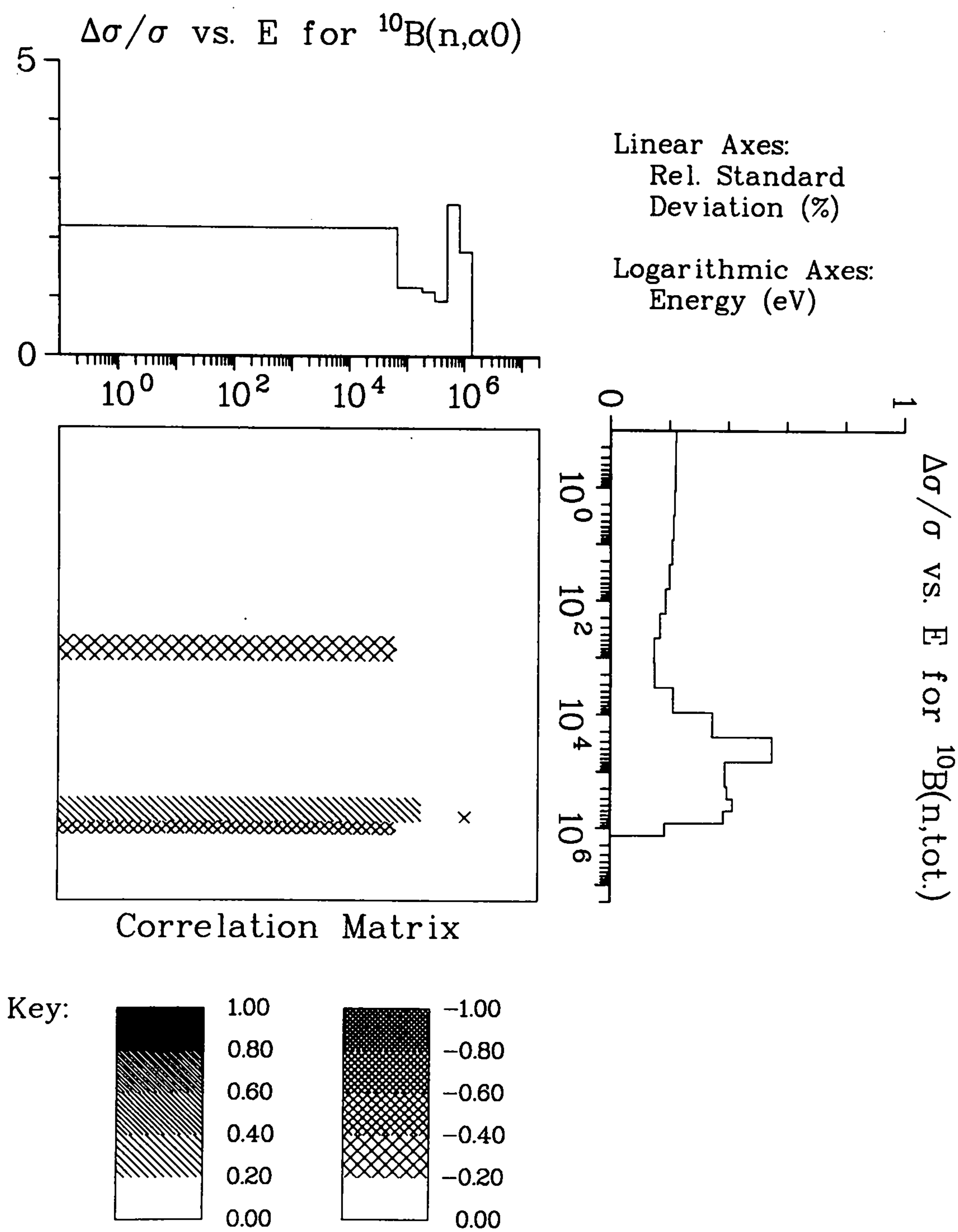


Fig. 8.
Covariance data for $^{10}B(n,tot.)$ with $^{10}B(n,\alpha 0)$.

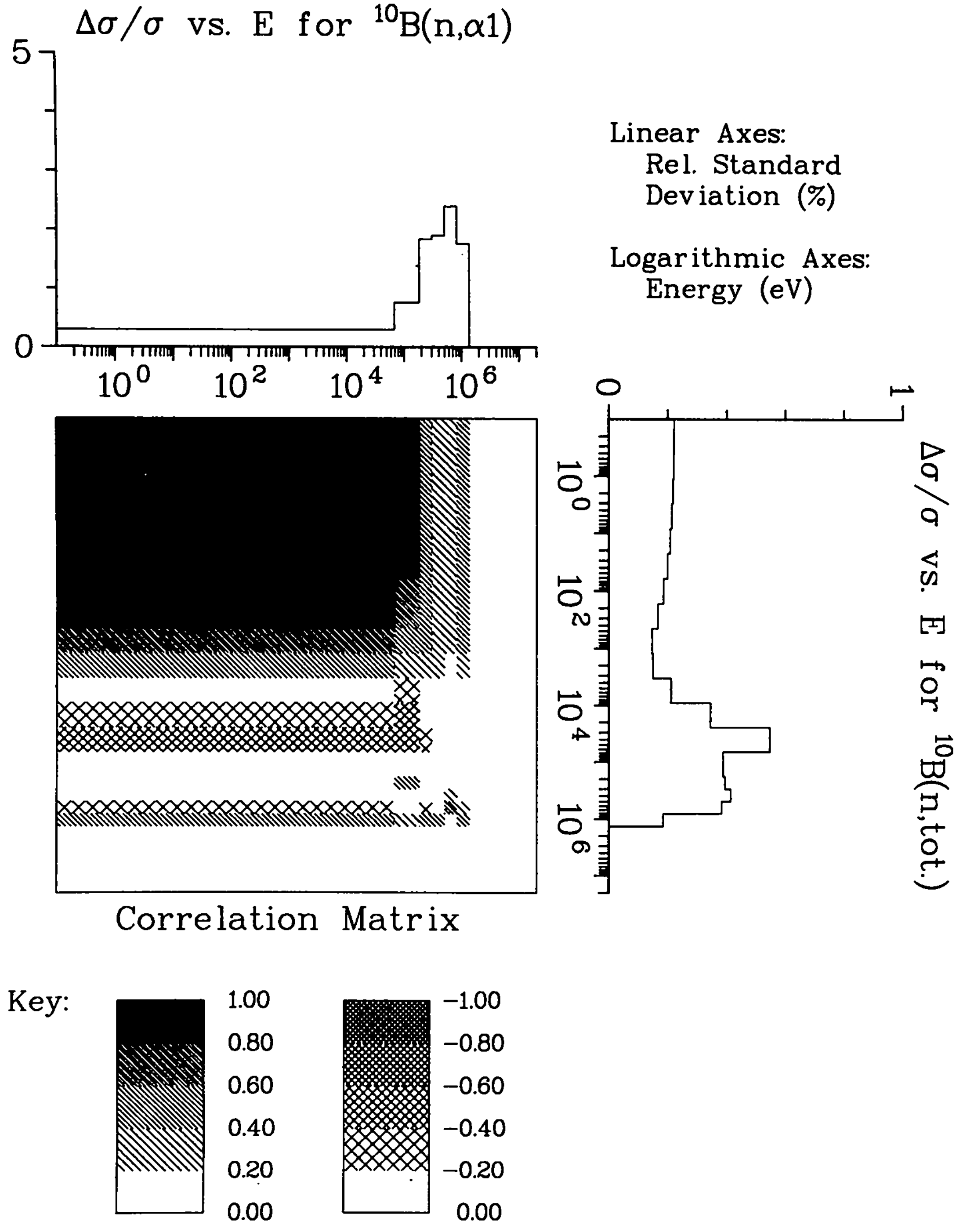


Fig. 9.
Covariance data for $^{10}B(n,tot.)$ with $^{10}B(n,\alpha 1)$.

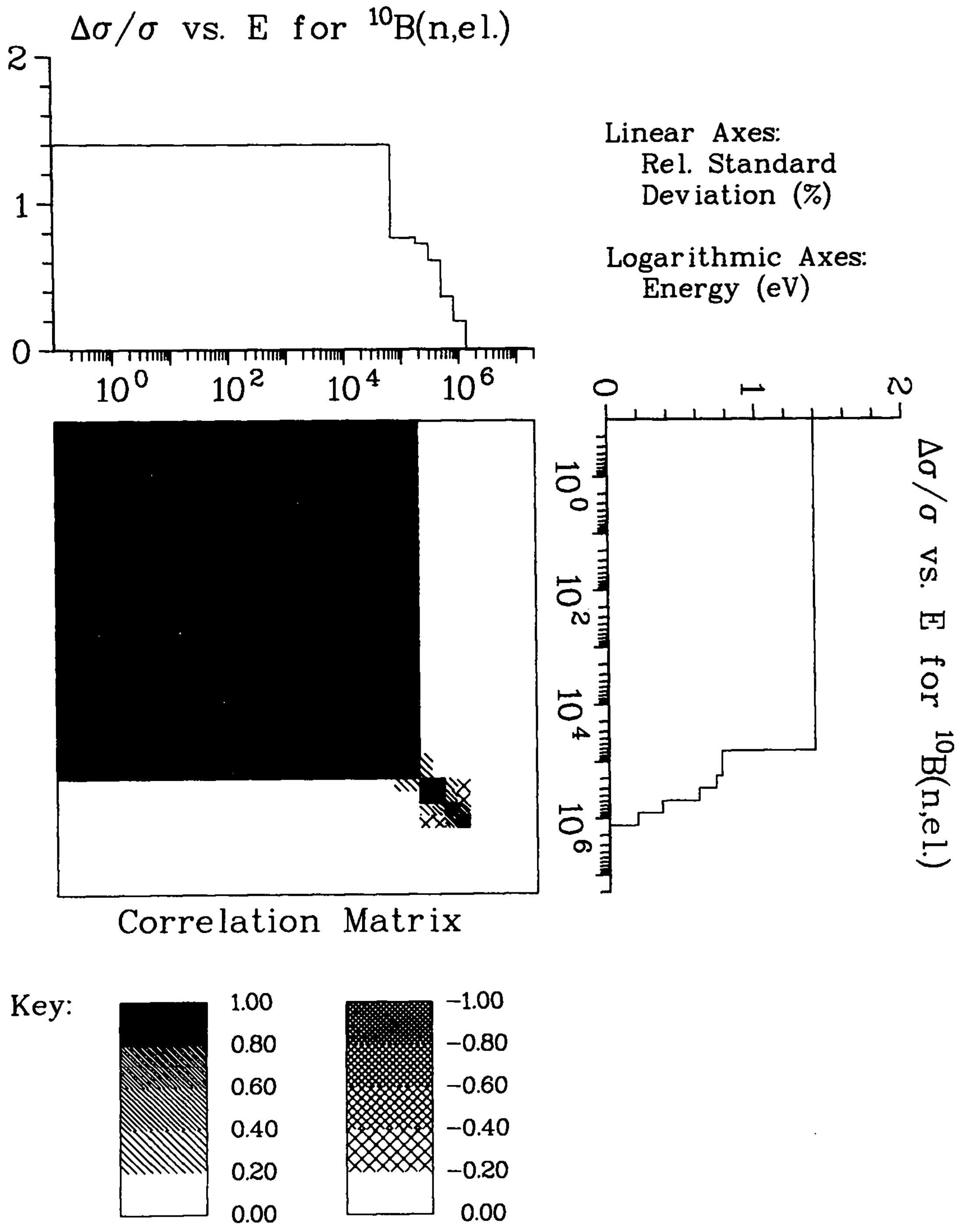


Fig. 10.
Covariance data for ^{10}B(n,el.) with ^{10}B(n,el.).

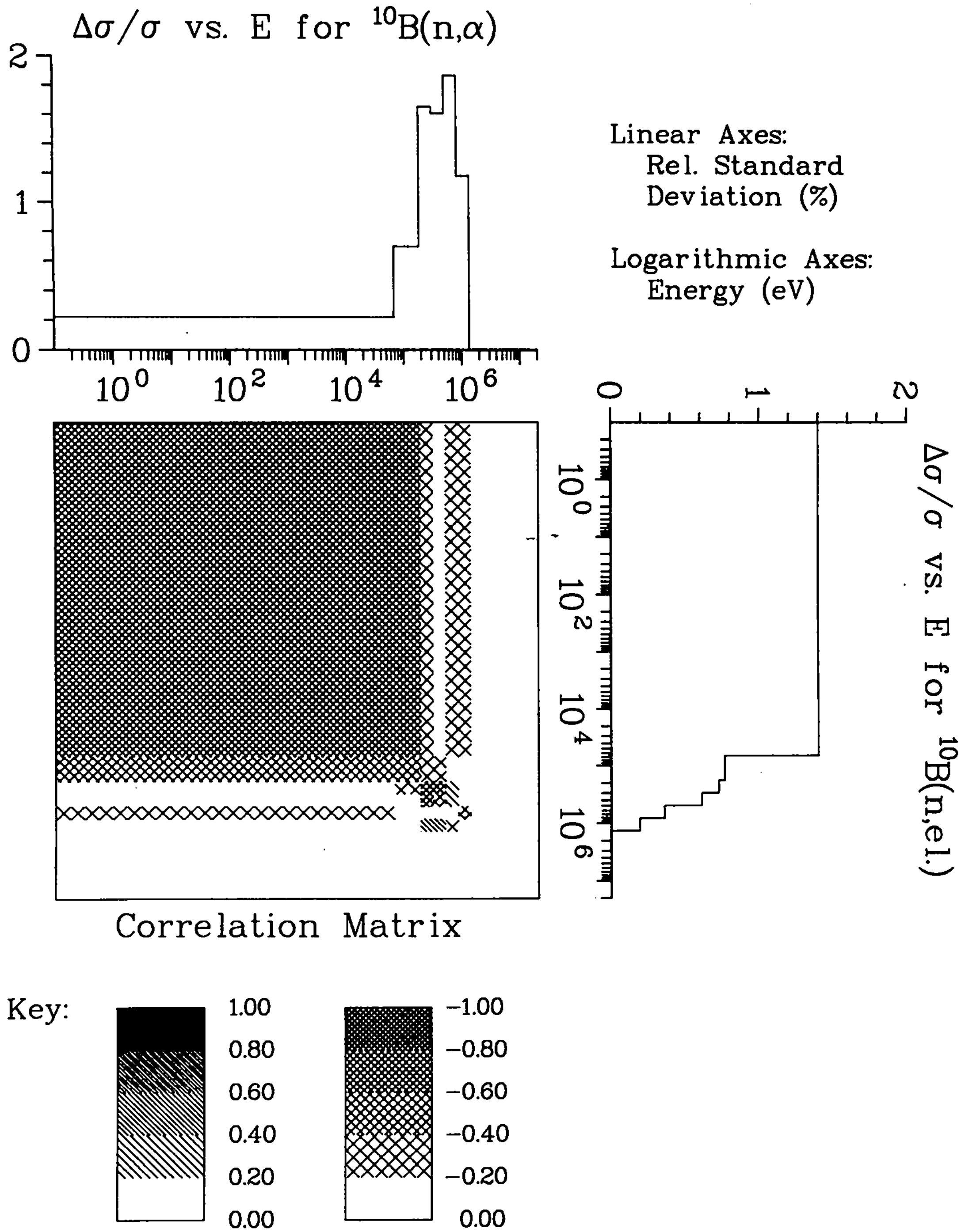


Fig. 11.
Covariance data for $^{10}B(n,el.)$ with $^{10}B(n,\alpha)$.

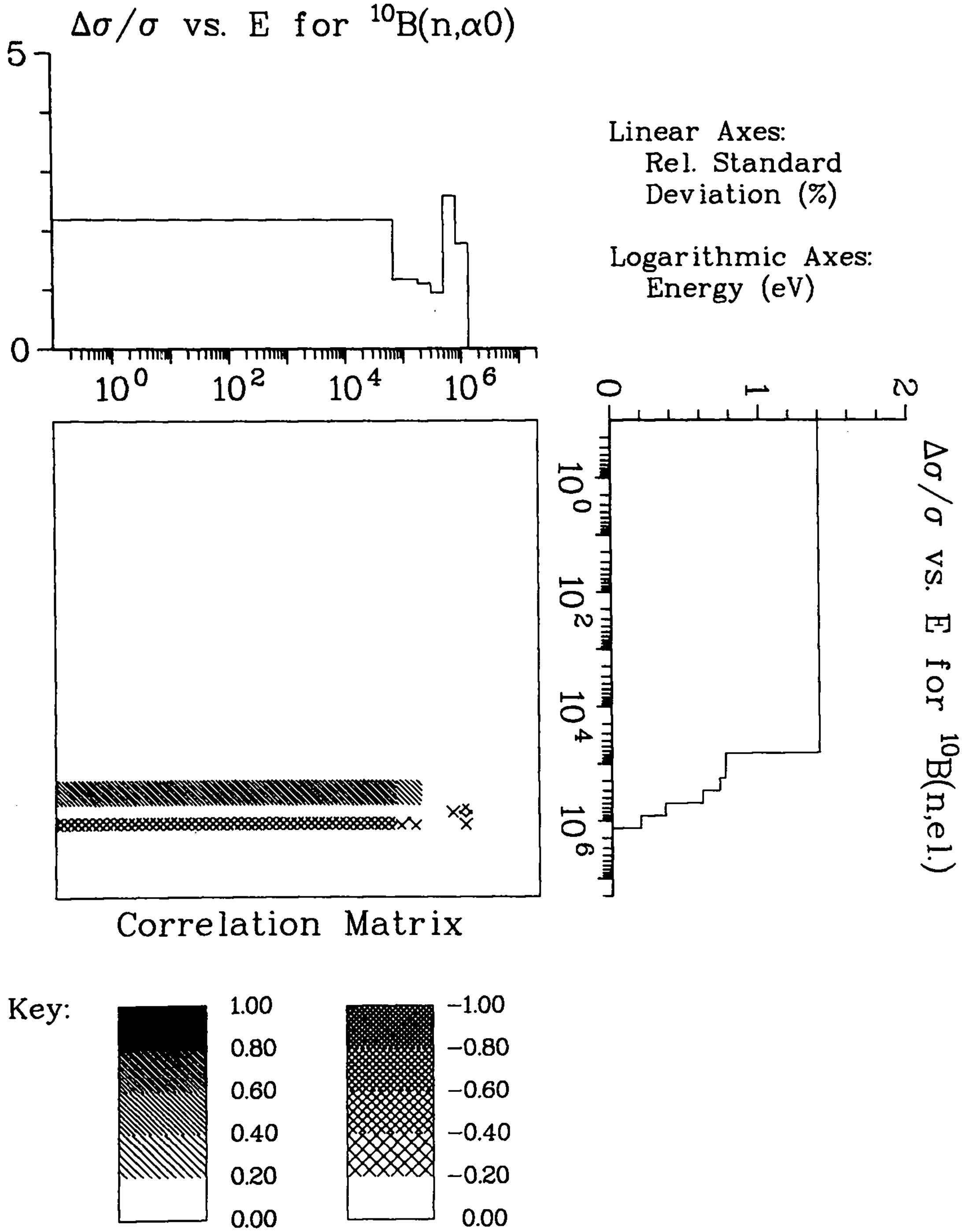


Fig. 12.
Covariance data for ^{10}B(n,el.) with $^{10}B(n,\alpha 0)$.

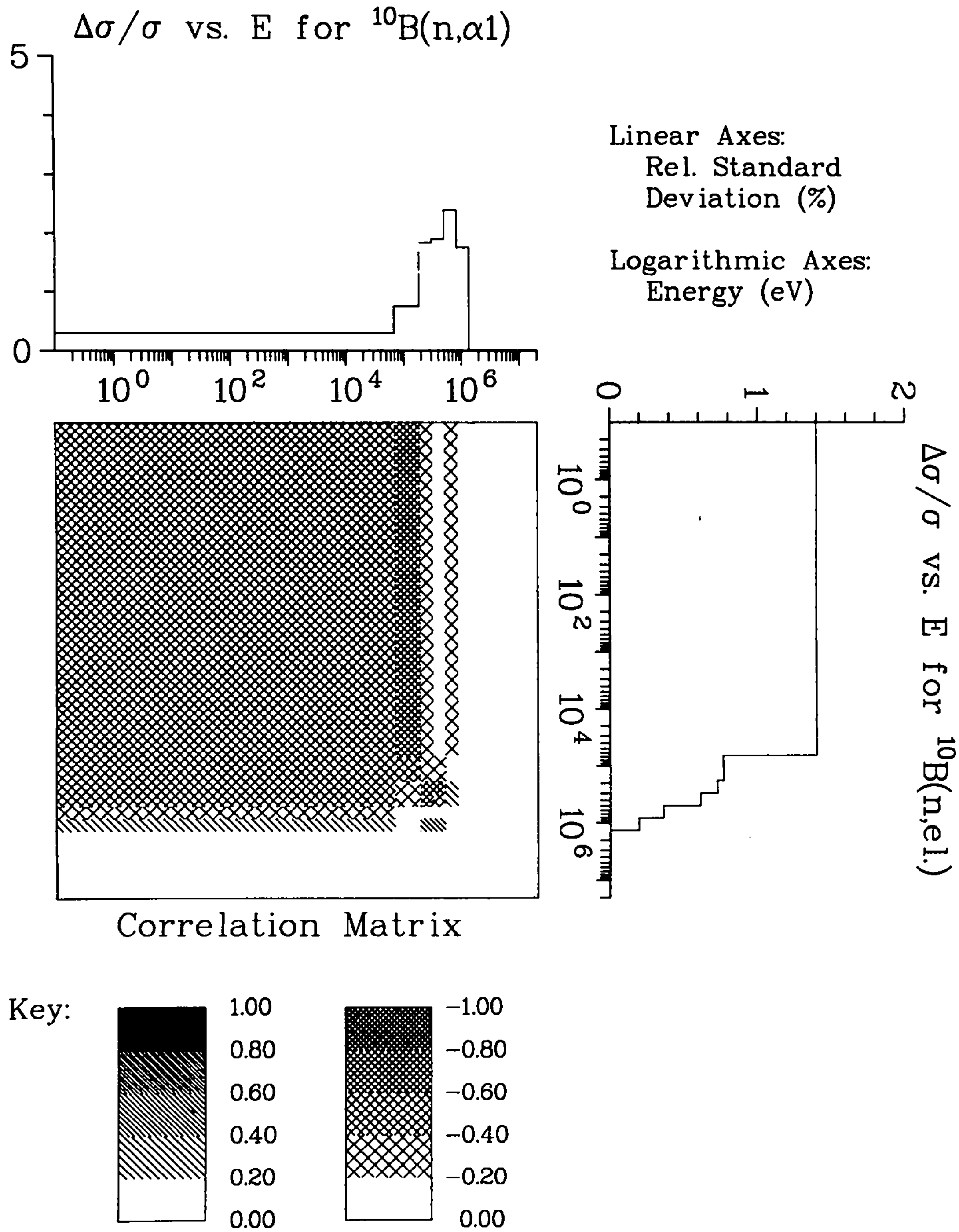


Fig. 13.
Covariance data for $^{10}B(n,el.)$ with $^{10}B(n,\alpha 1)$.

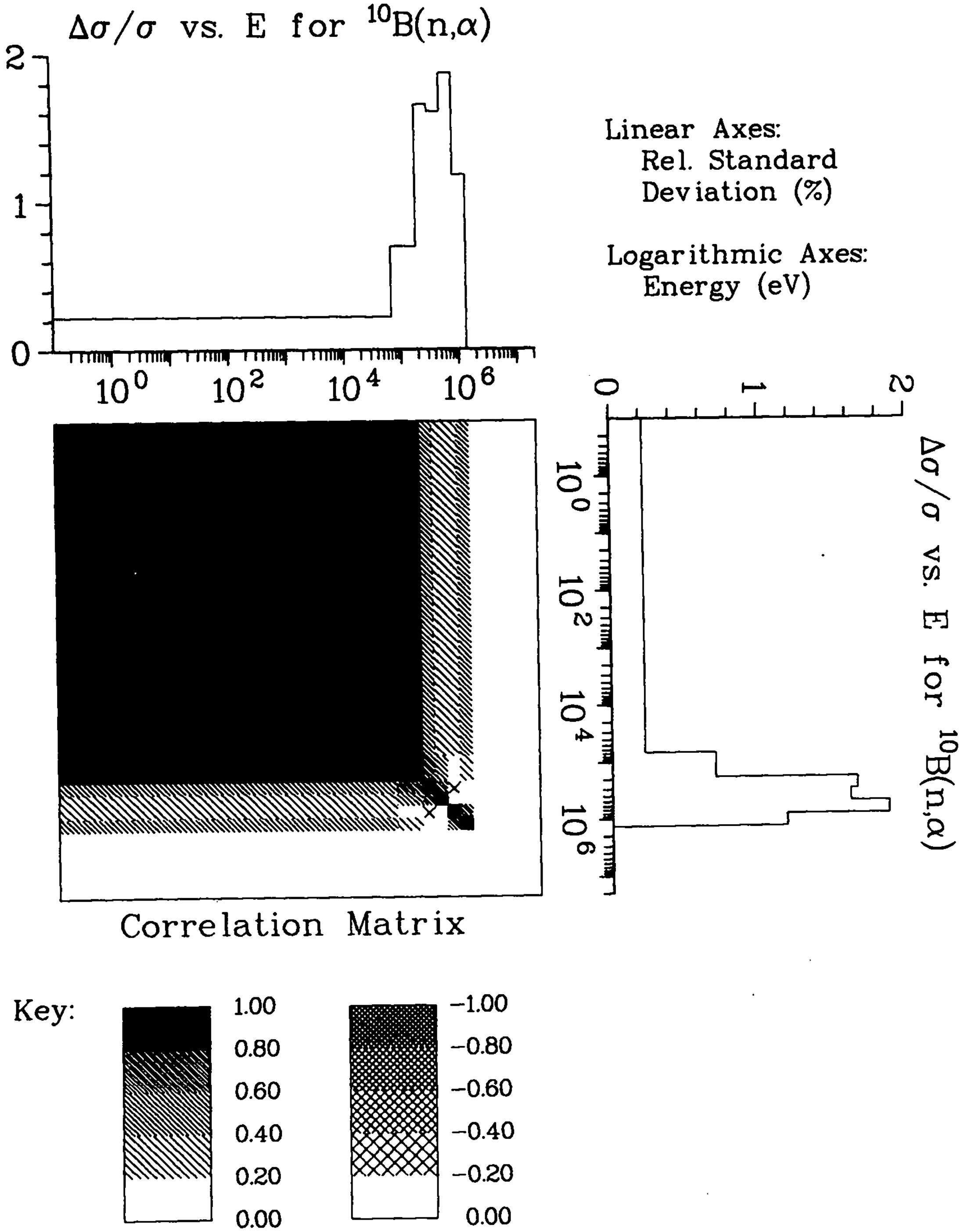


Fig. 14.
Covariance data for $^{10}B(n,\alpha)$ with $^{10}B(n,\alpha)$.

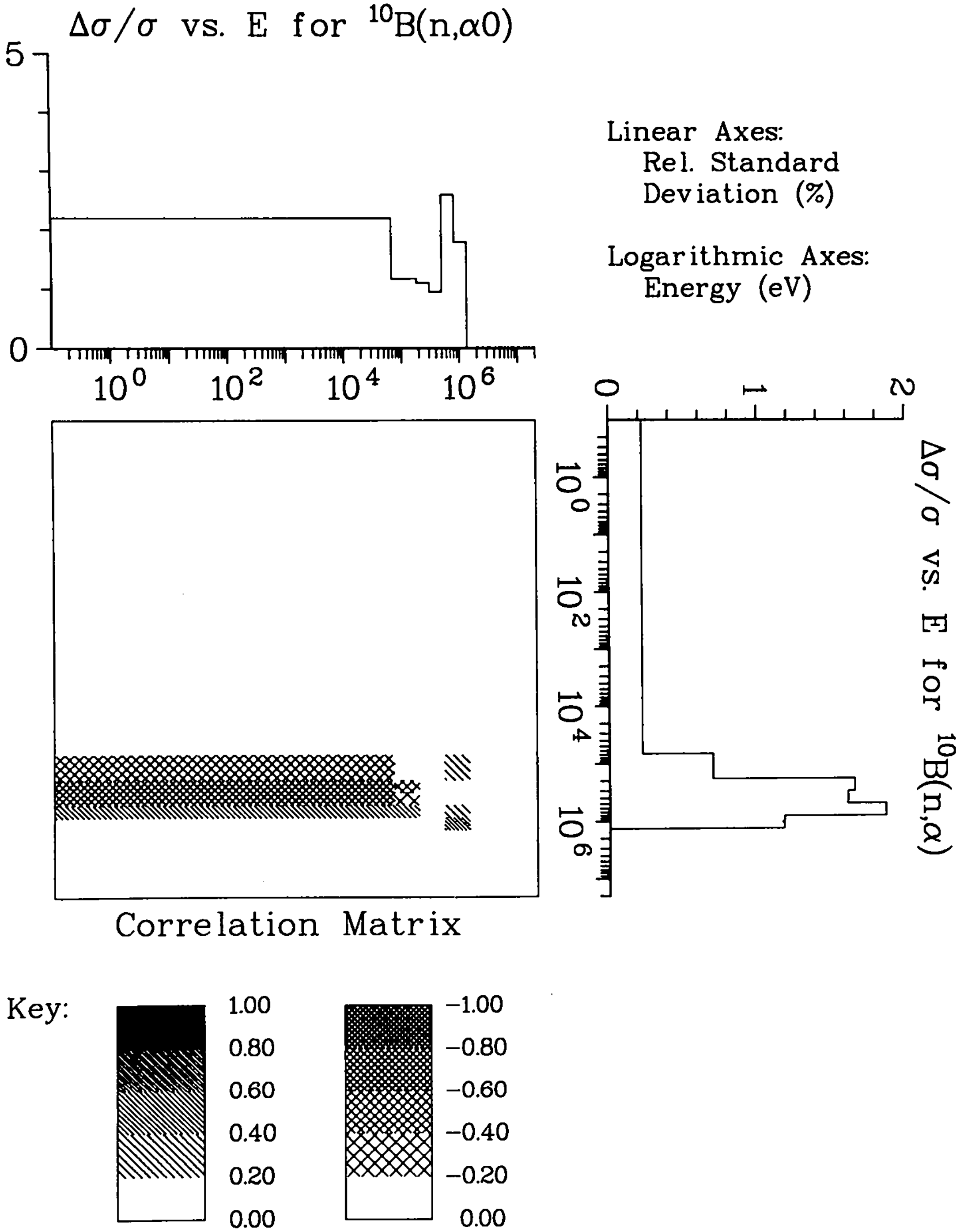


Fig. 15.
Covariance data for $^{10}B(n,\alpha)$ with $^{10}B(n,\alpha 0)$.

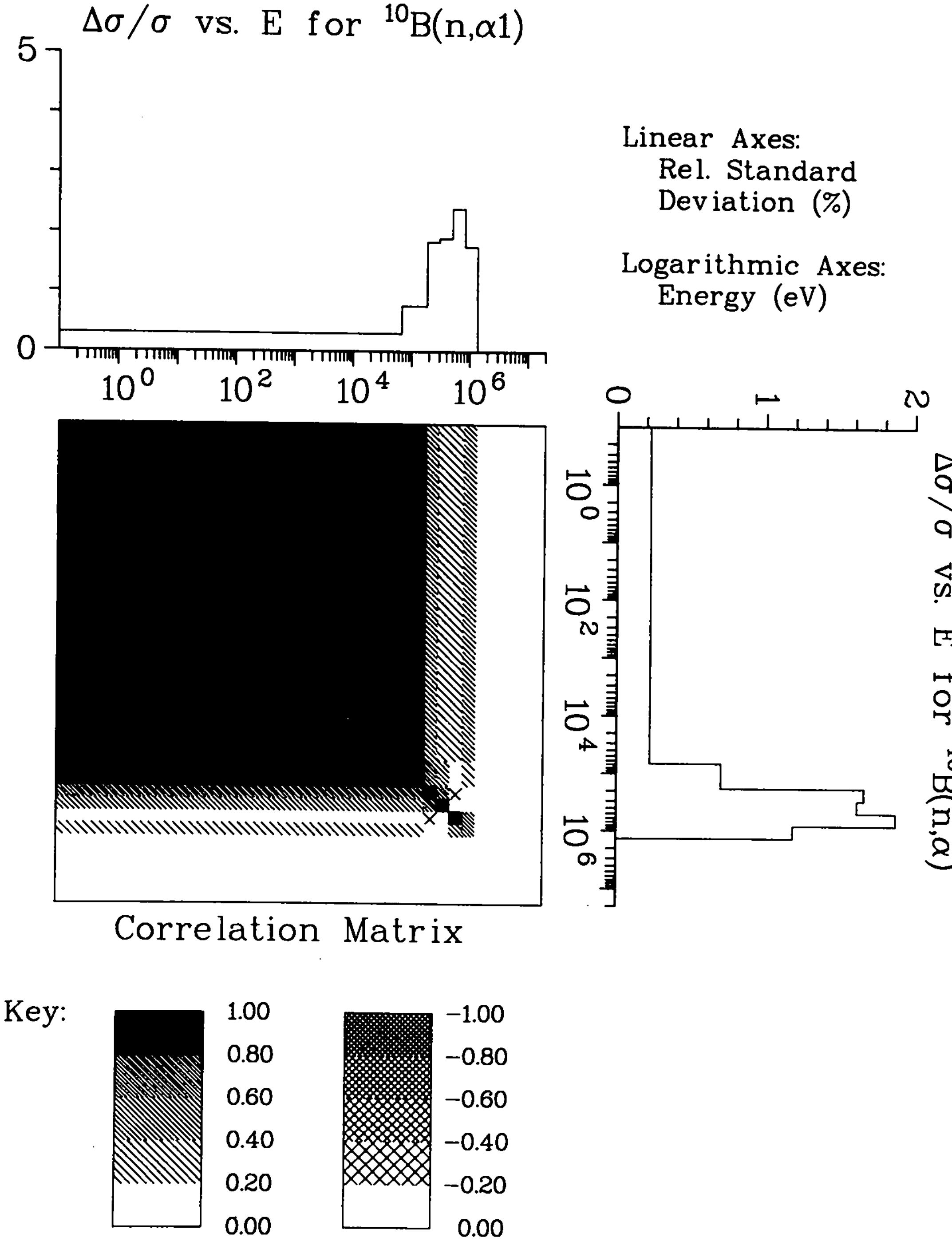


Fig. 16.
Covariance data for $^{10}B(n,\alpha)$ with $^{10}B(n,\alpha1)$.

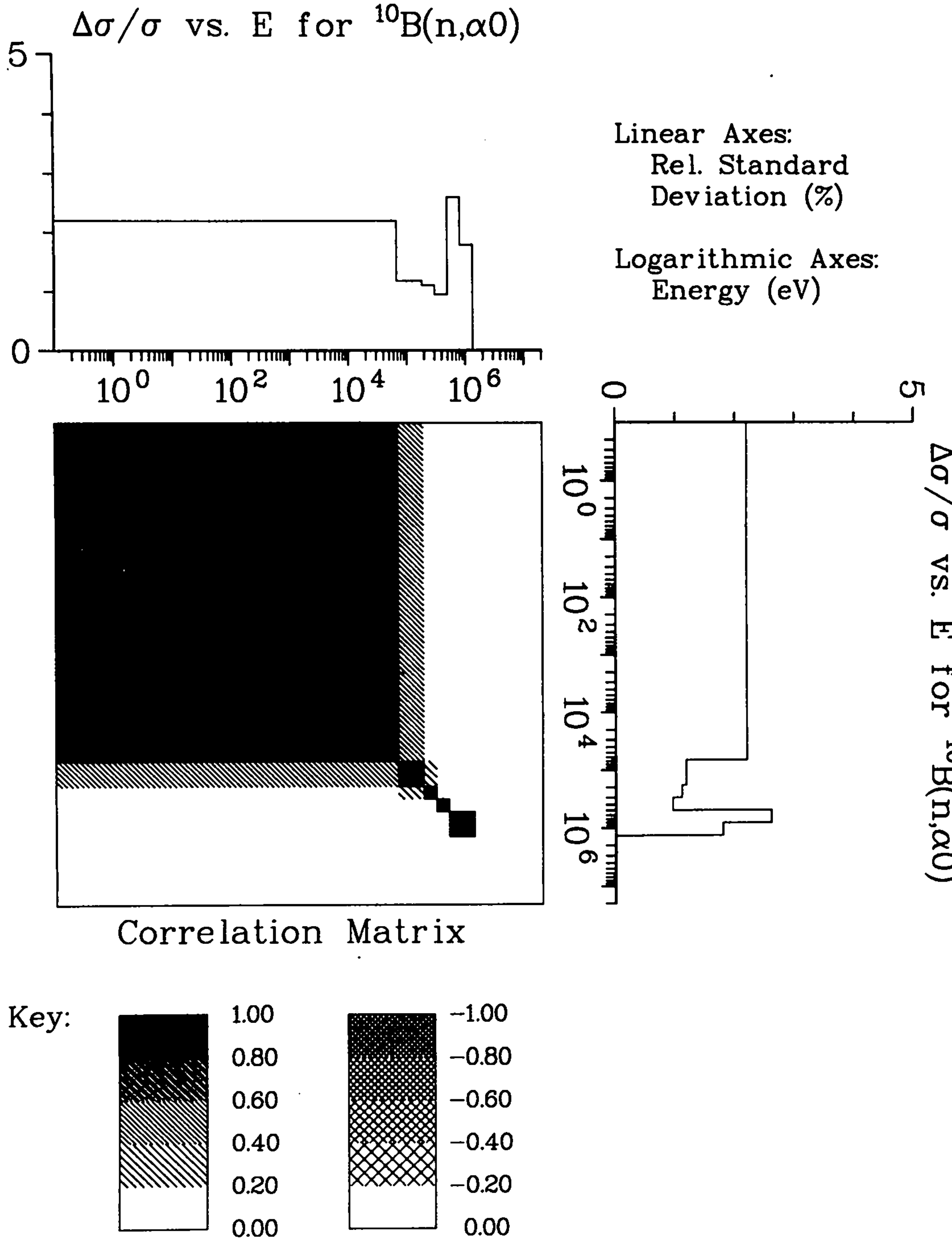


Fig. 17.
Covariance data for $^{10}B(n,\alpha0)$ with $^{10}B(n,\alpha0)$.

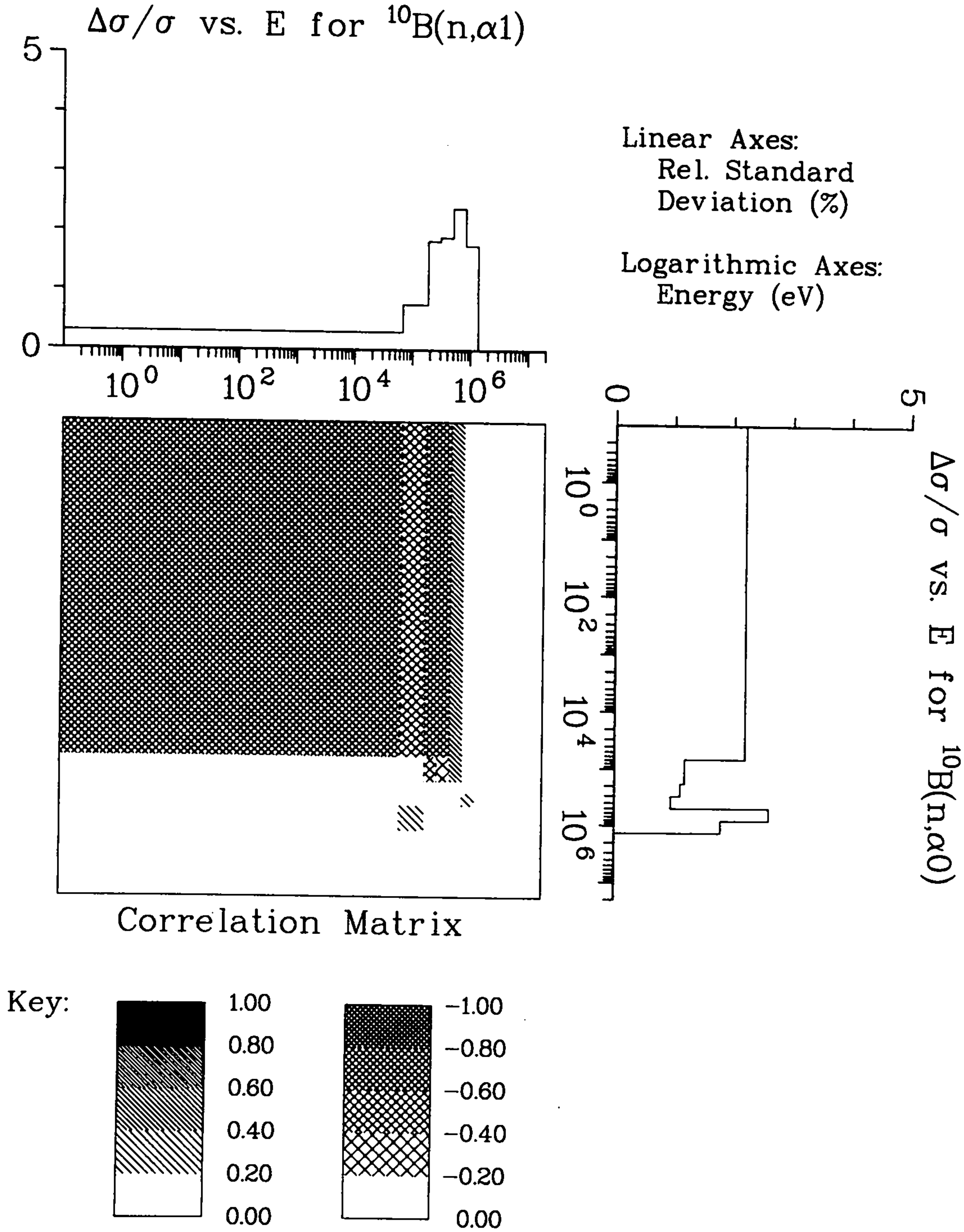


Fig. 18.
Covariance data for $^{10}B(n,\alpha 0)$ with $^{10}B(n,\alpha 1)$.

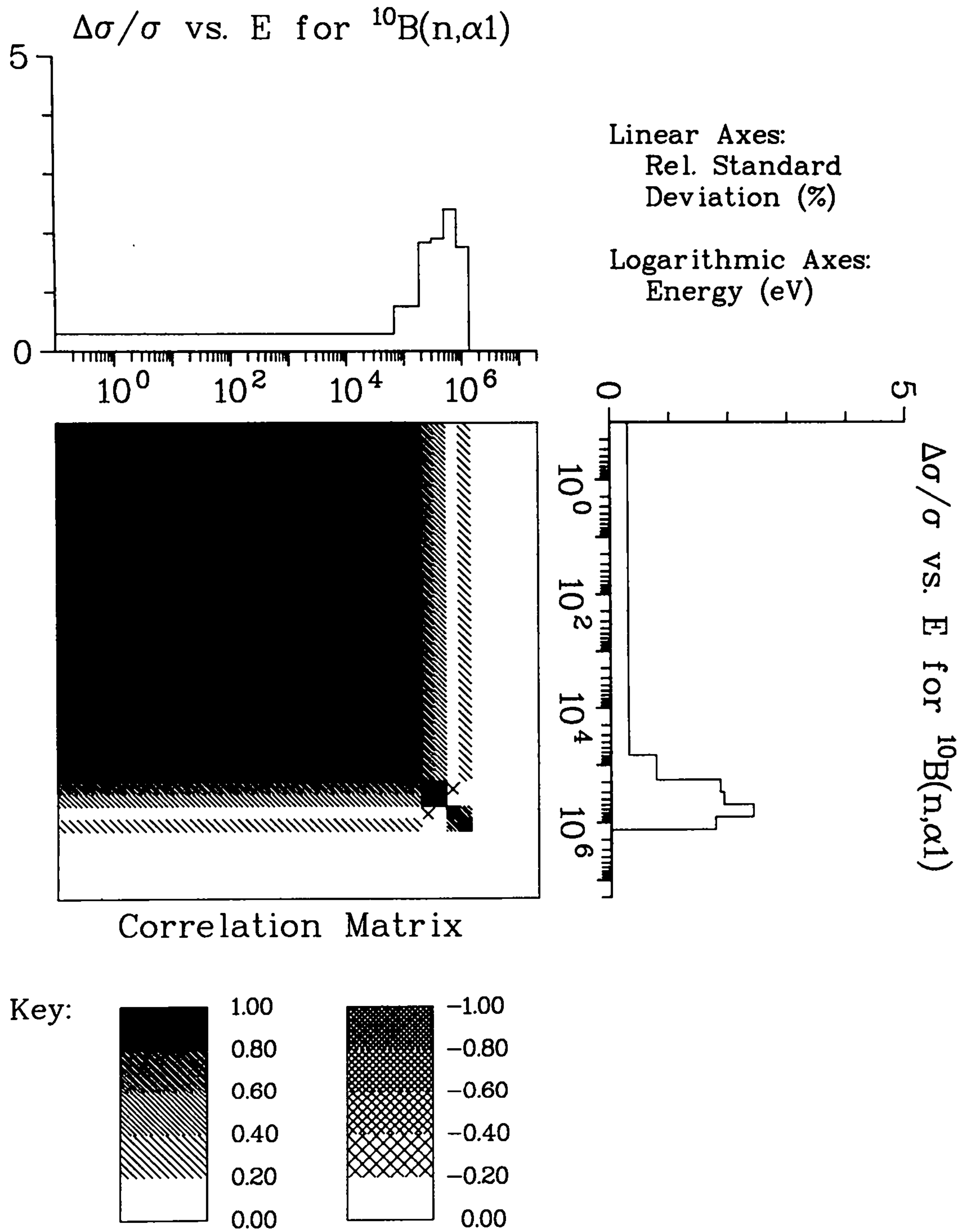


Fig. 19.
Covariance data for $^{10}B(n,\alpha 1)$ with $^{10}B(n,\alpha 1)$.

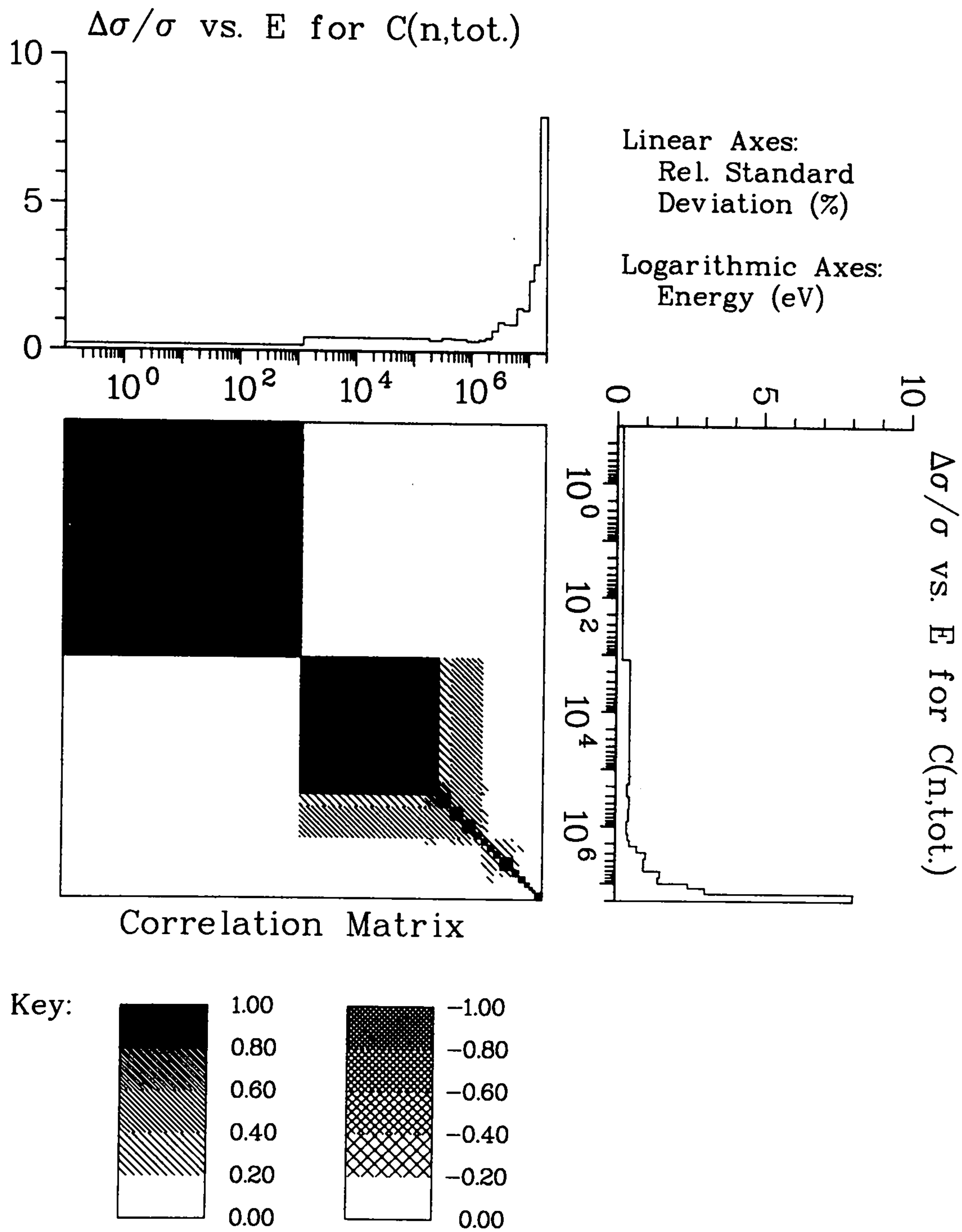


Fig. 20.
Covariance data for C(n,tot.) with C(n,tot.).

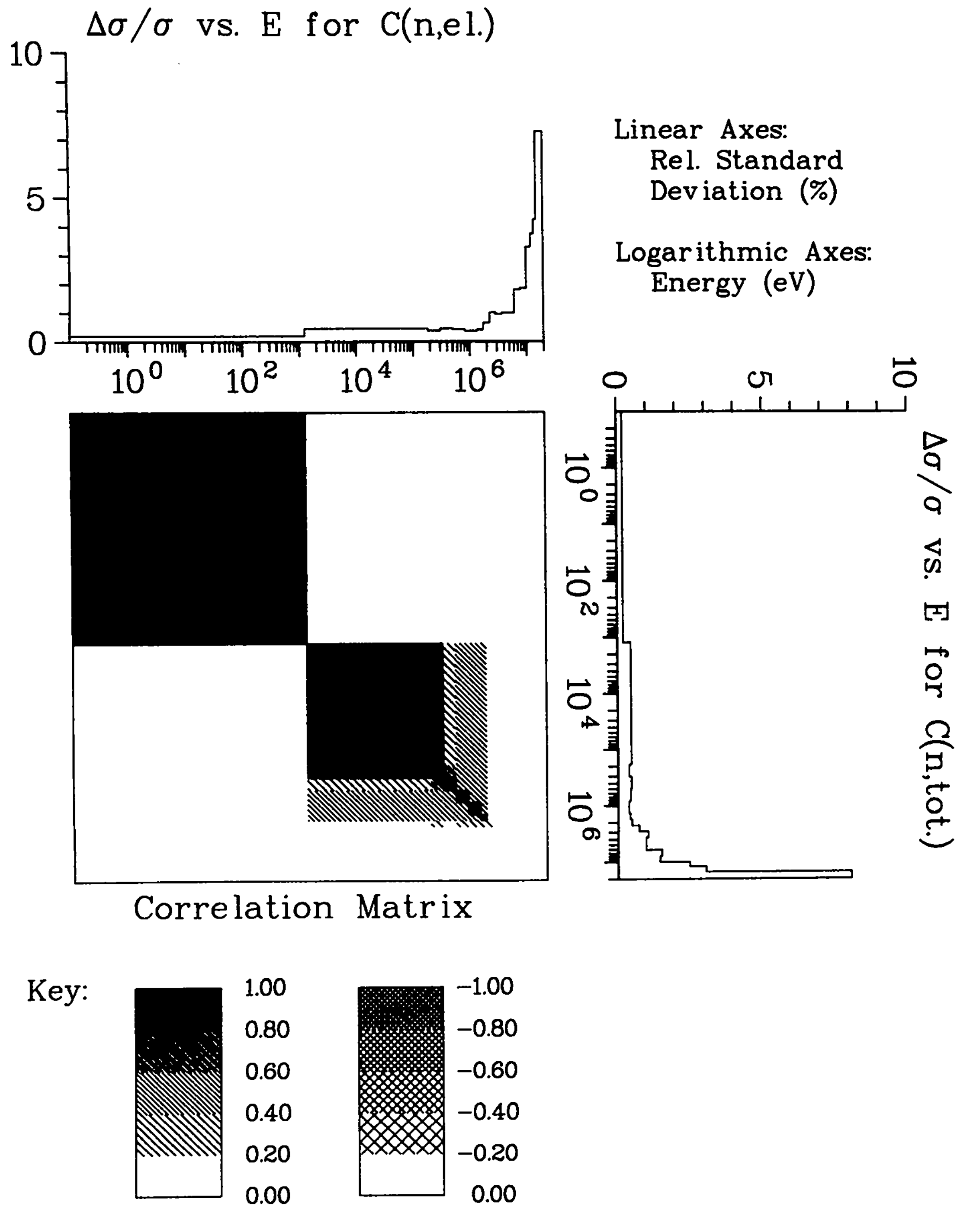


Fig. 21.
Covariance data for C(n,tot.) with C(n,el.).

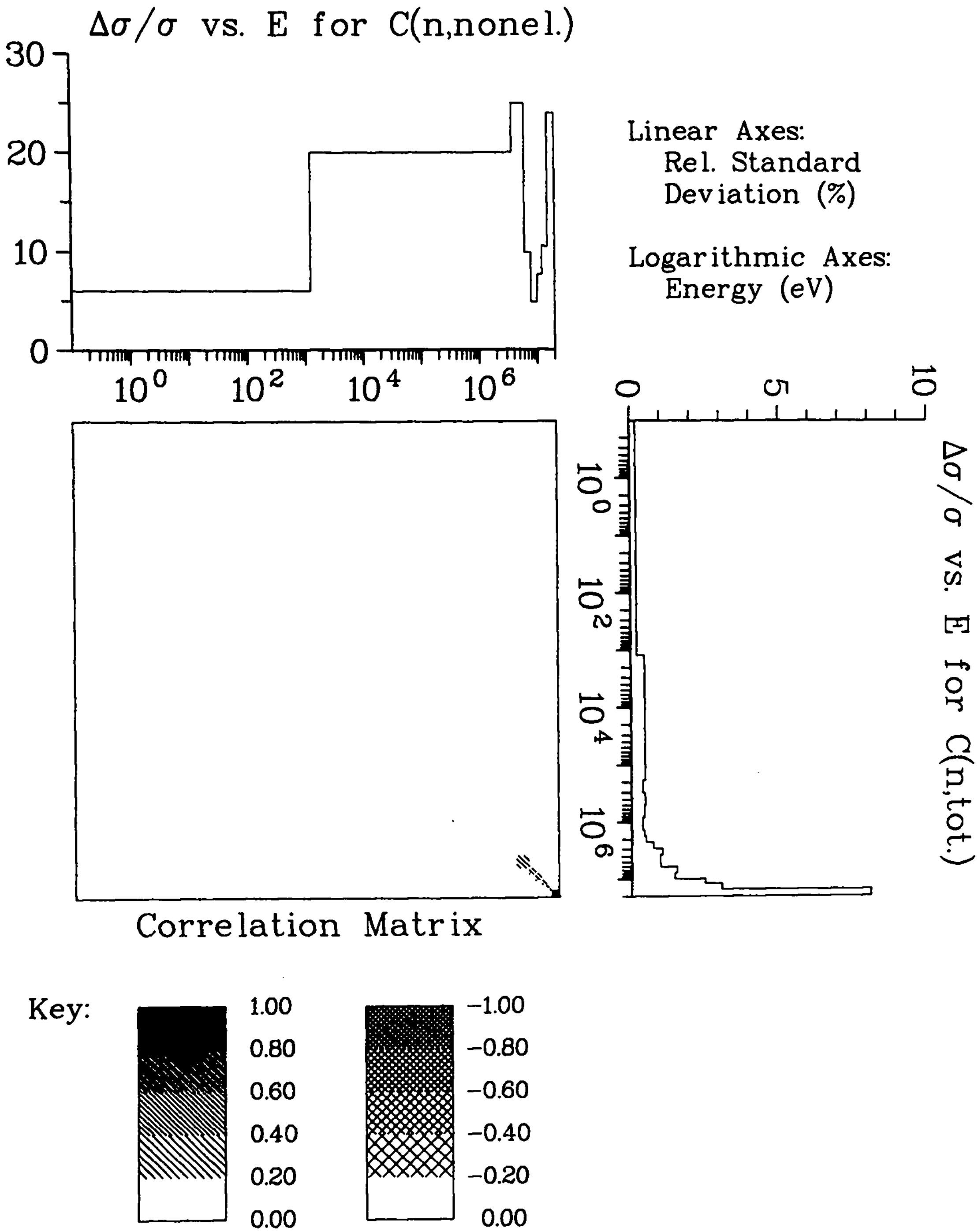


Fig. 22.
Covariance data for C(n,tot.) with C(n,nonel.).

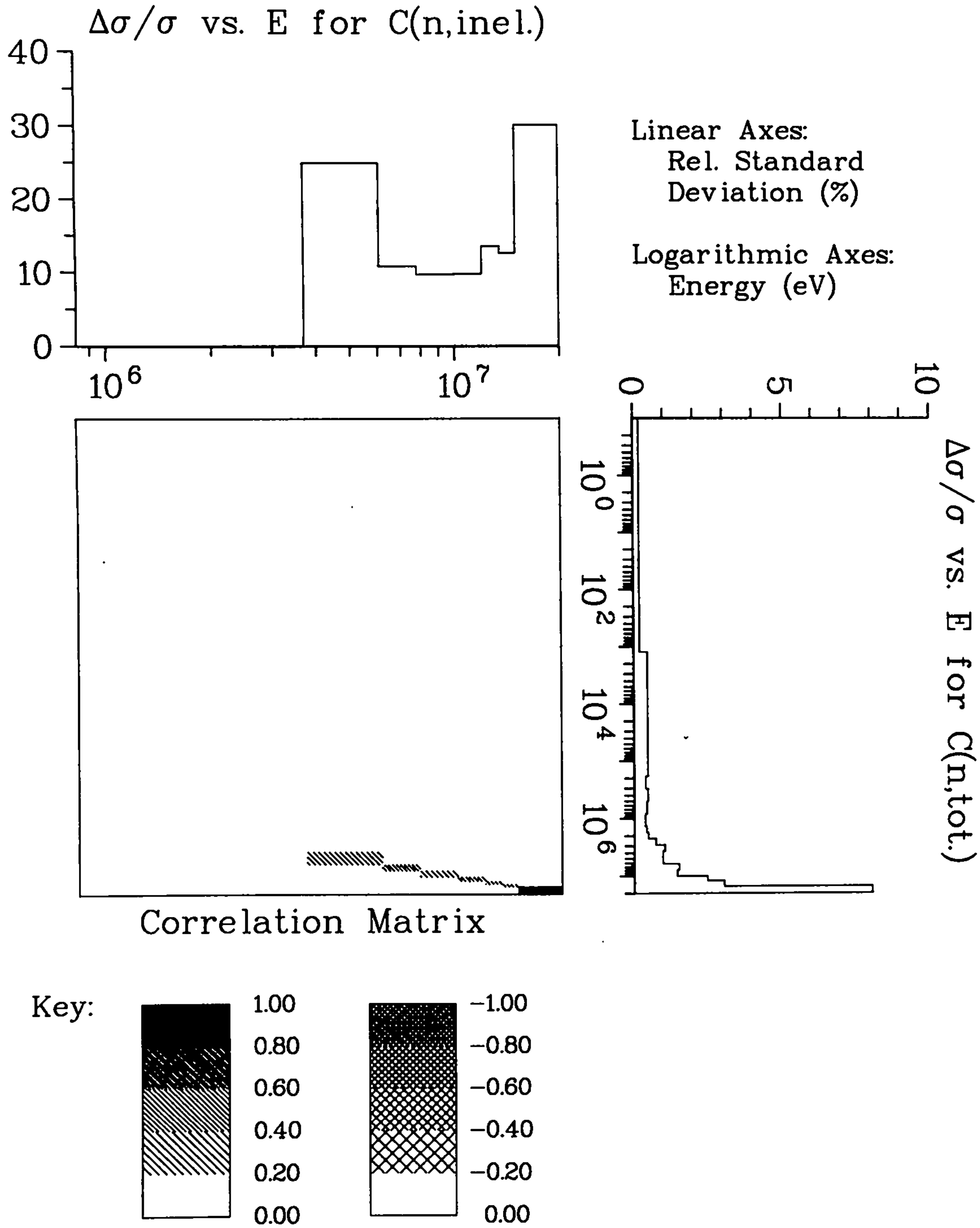


Fig. 23.
Covariance data for C(n,tot.) with C(n,inel.).

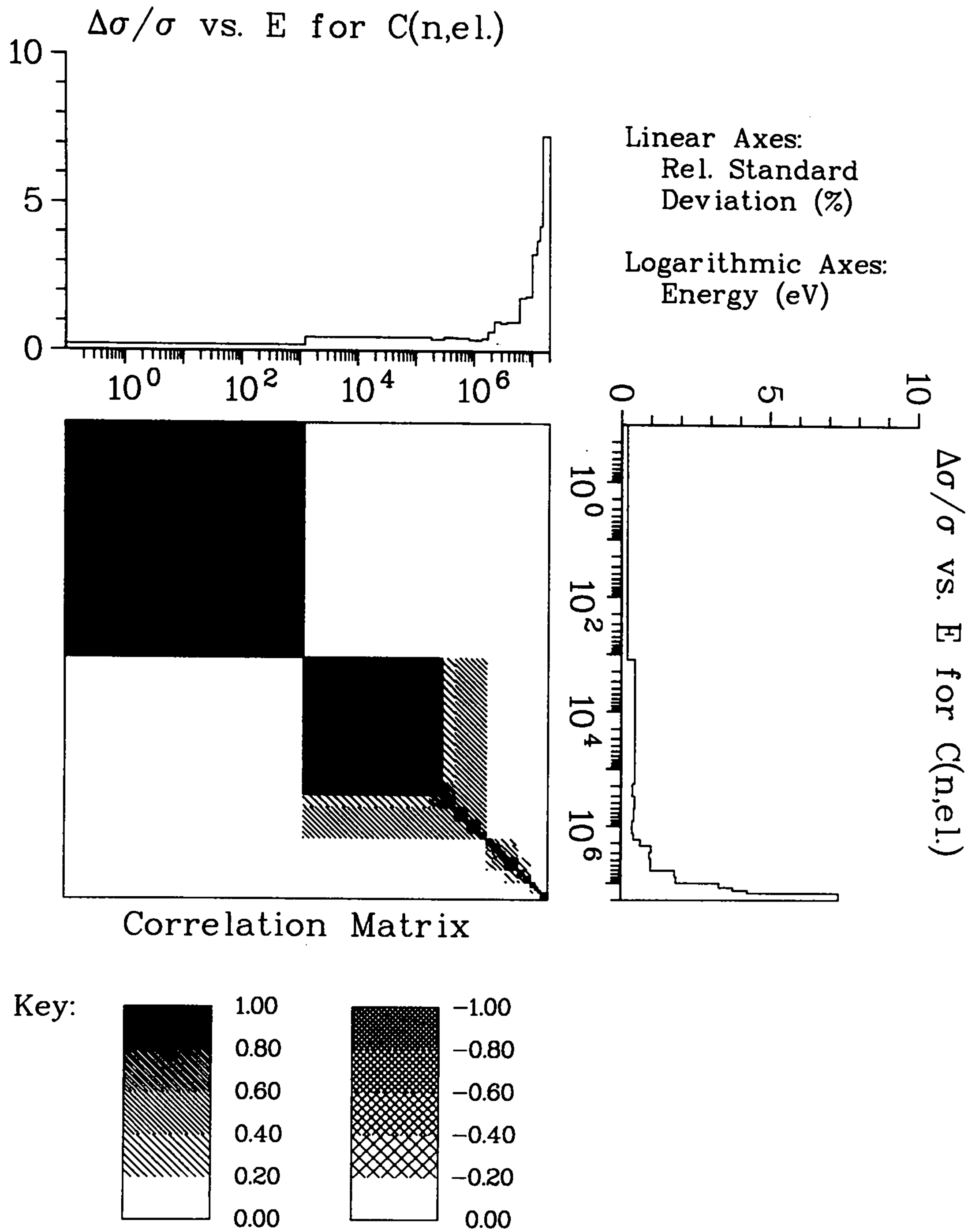


Fig. 24.
Covariance data for C(n,el.) with C(n,el.).

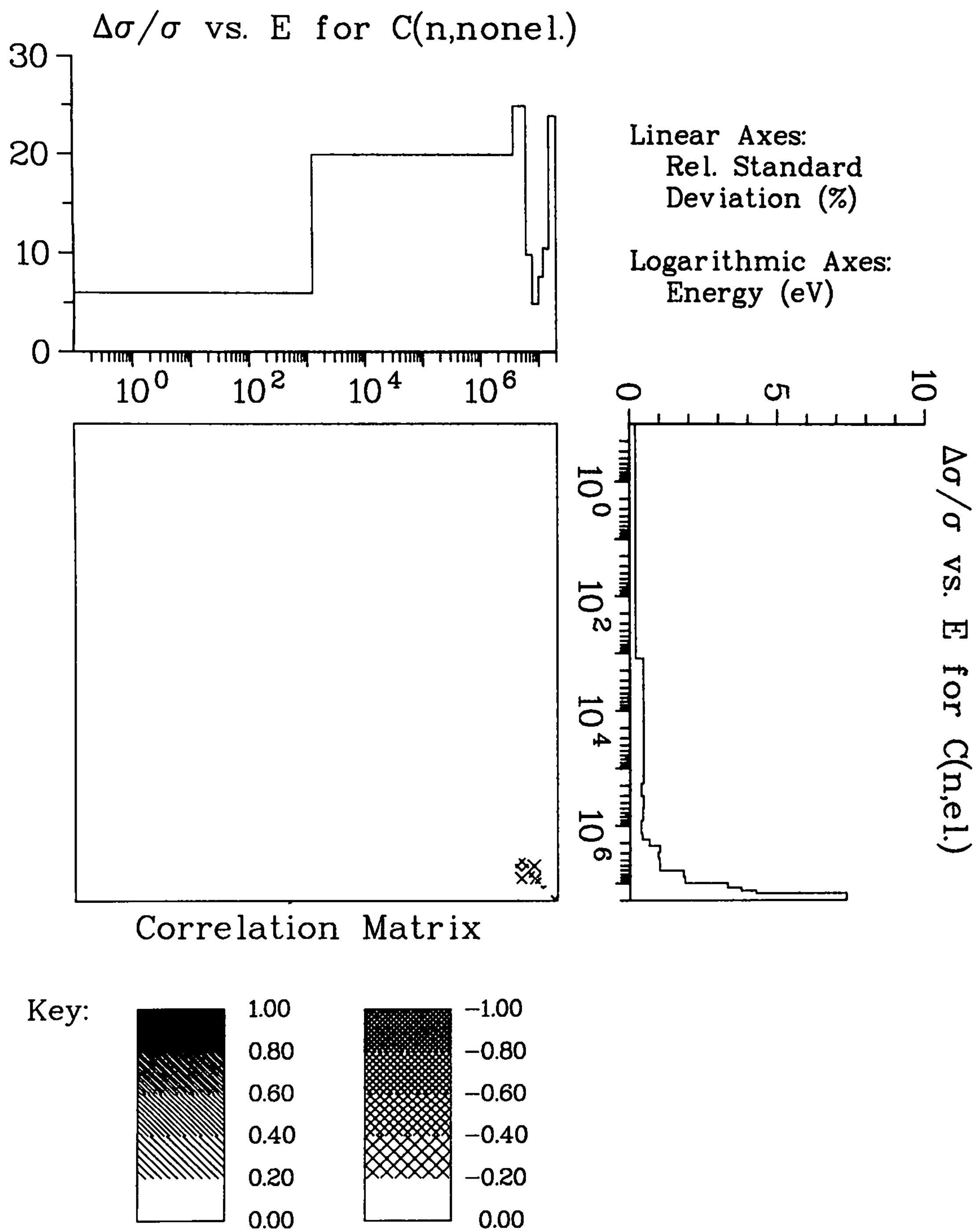


Fig. 25.
Covariance data for C(n,el.) with C(n,nonel.).

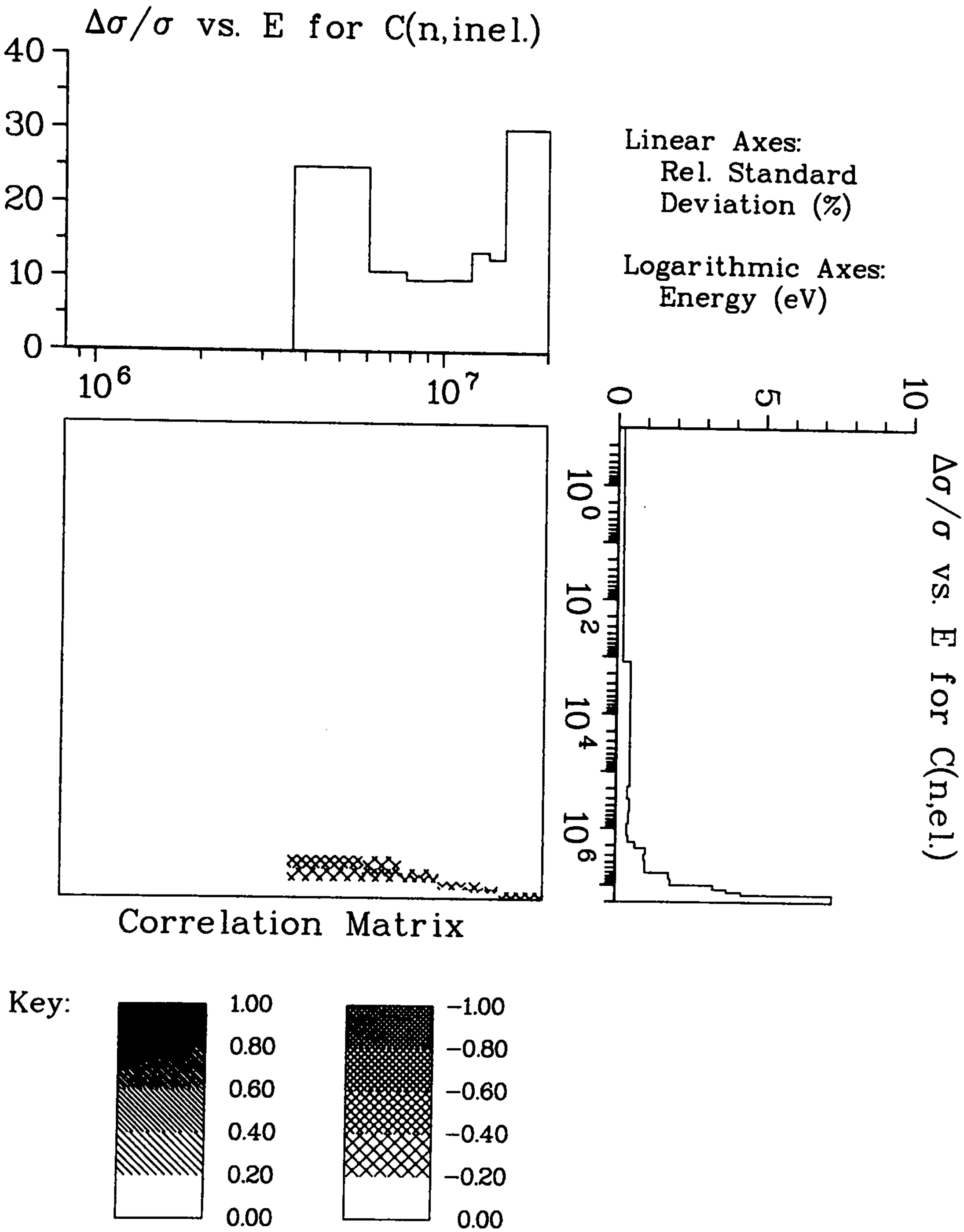


Fig. 26.
Covariance data for C(n,el.) with C(n,inel.).

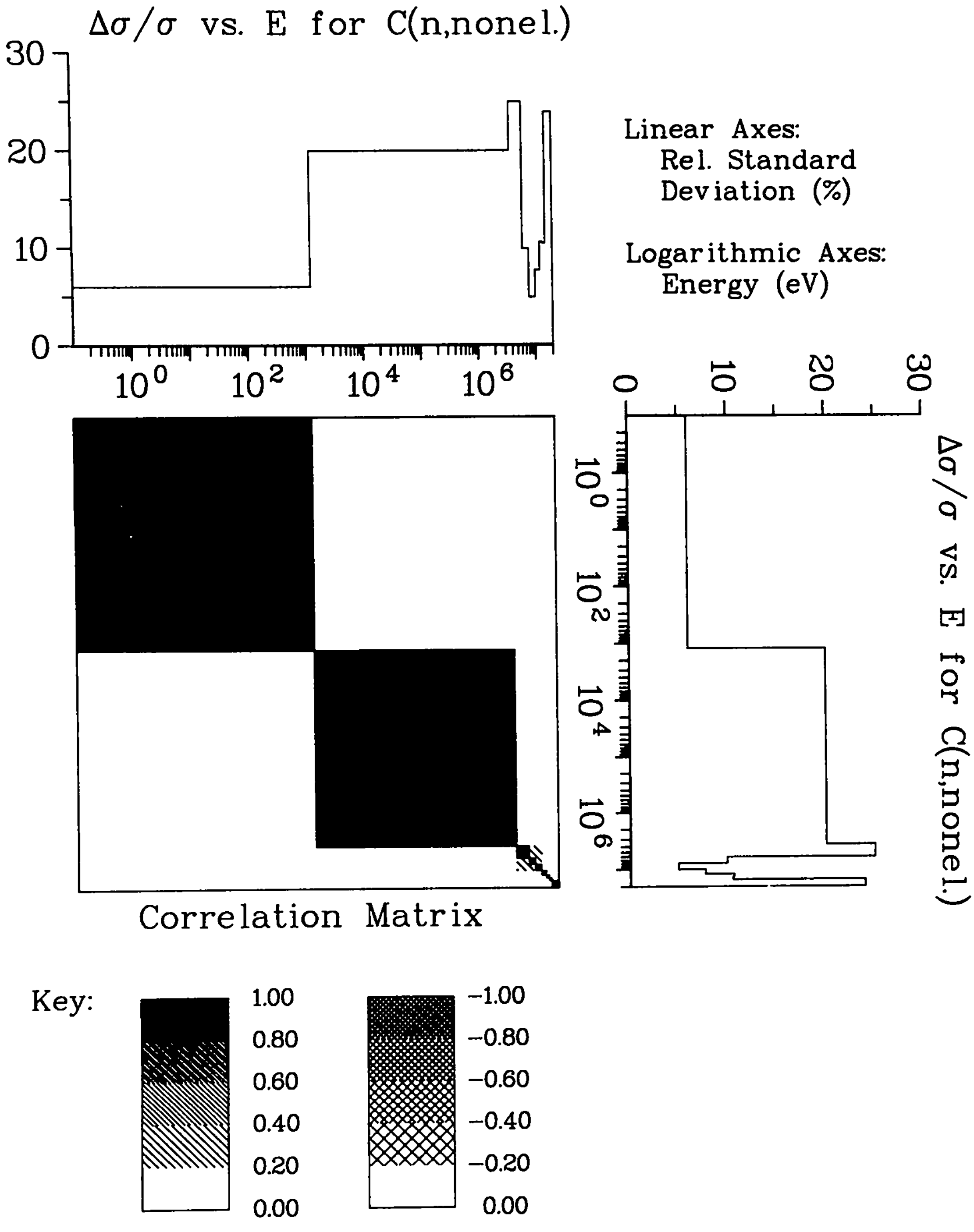


Fig. 27.
Covariance data for C(n,nonel.) with C(n,nonel.).

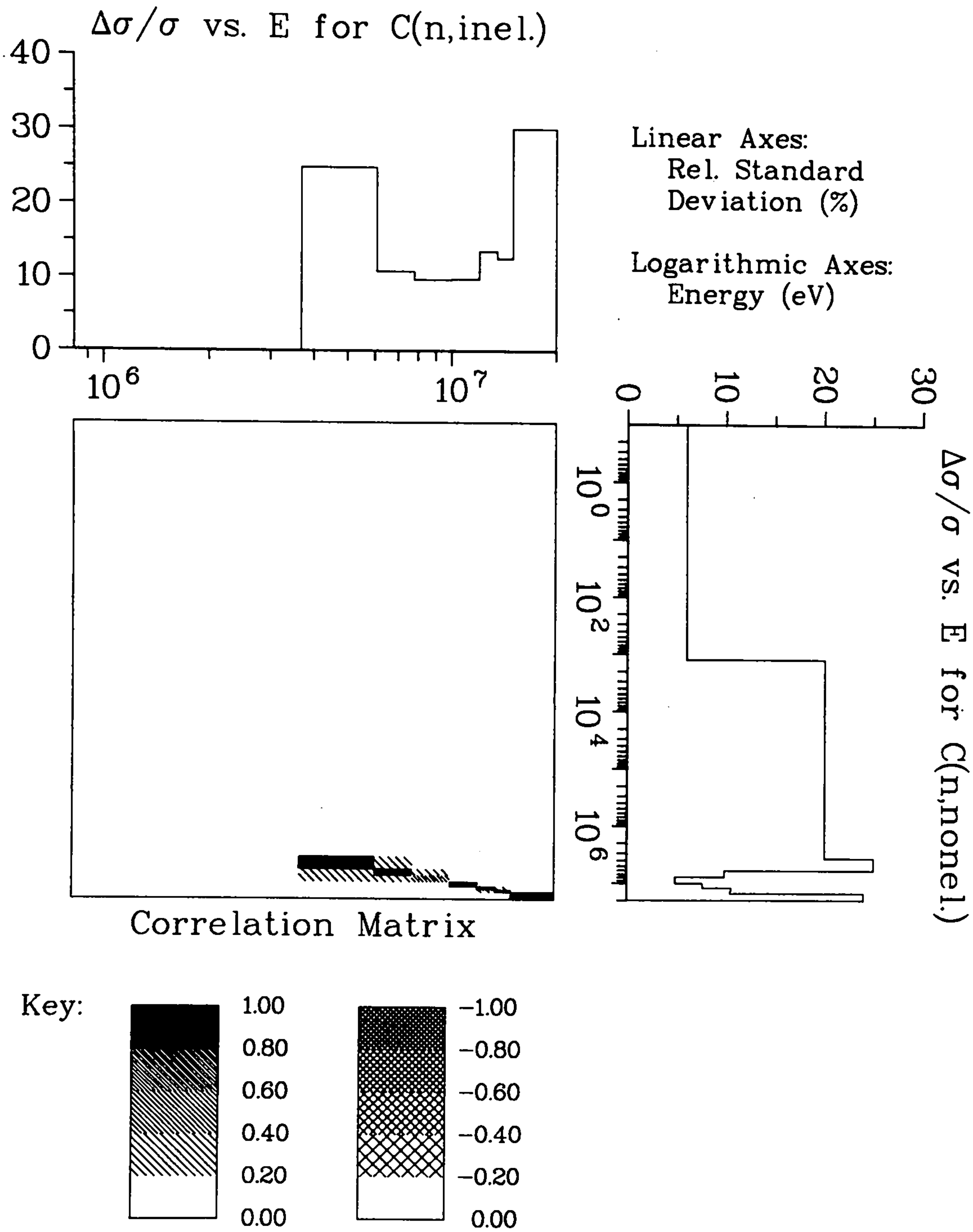


Fig. 28.
Covariance data for C(n,nonel.) with C(n,inel.).

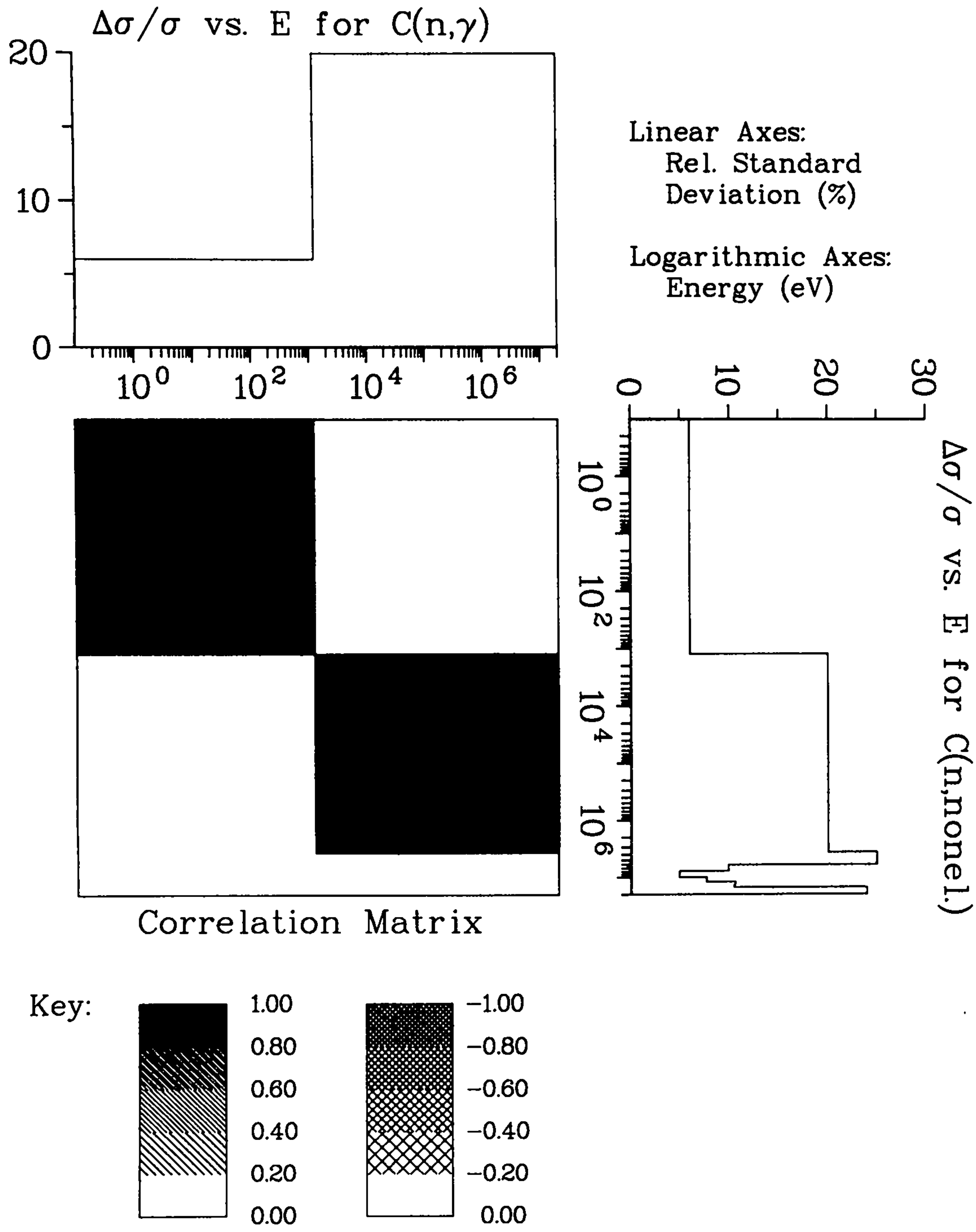


Fig. 29.
Covariance data for C(n,nonel.) with C(n,γ).

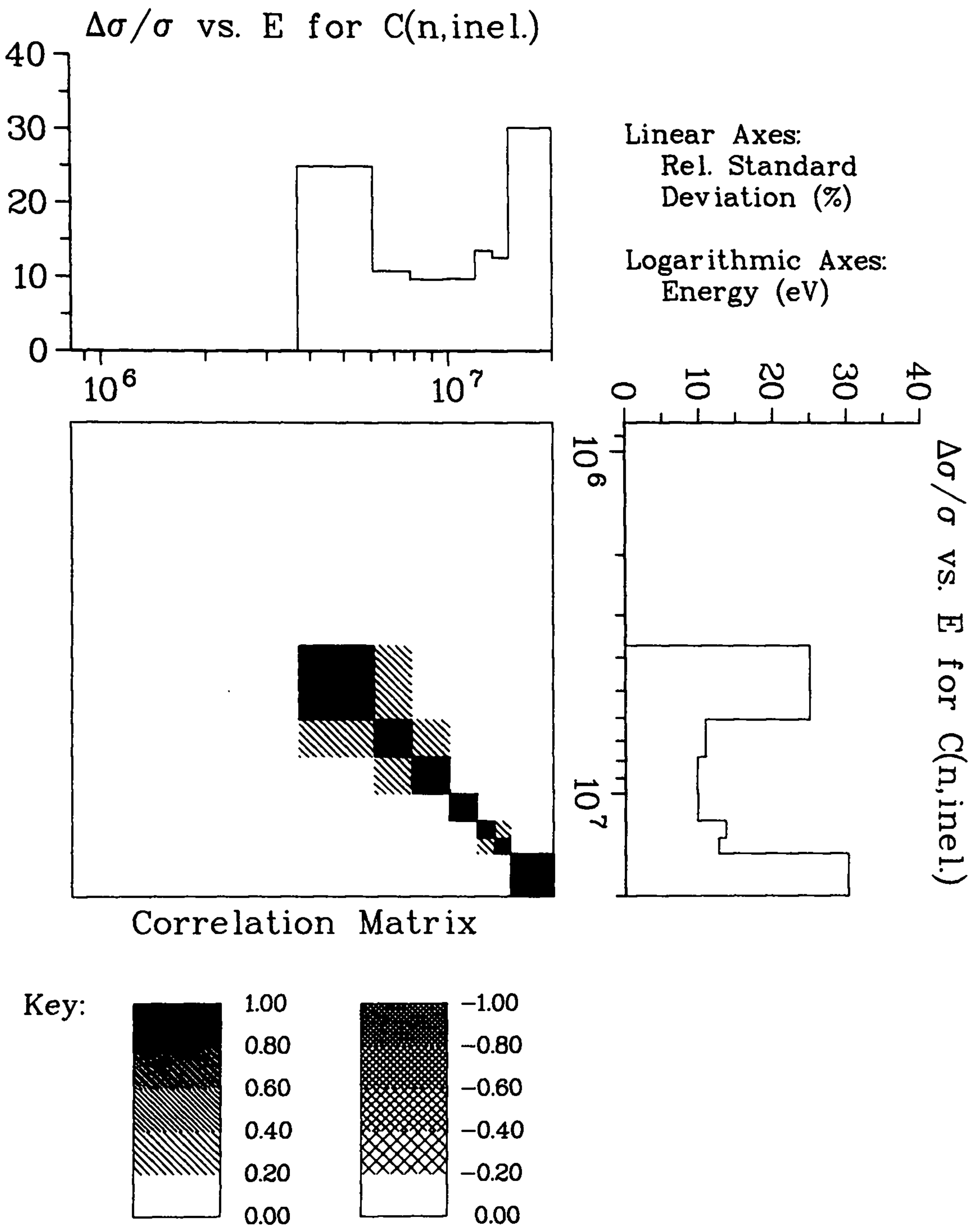


Fig. 30.
Covariance data for C(n,inel.) with C(n,inel.).

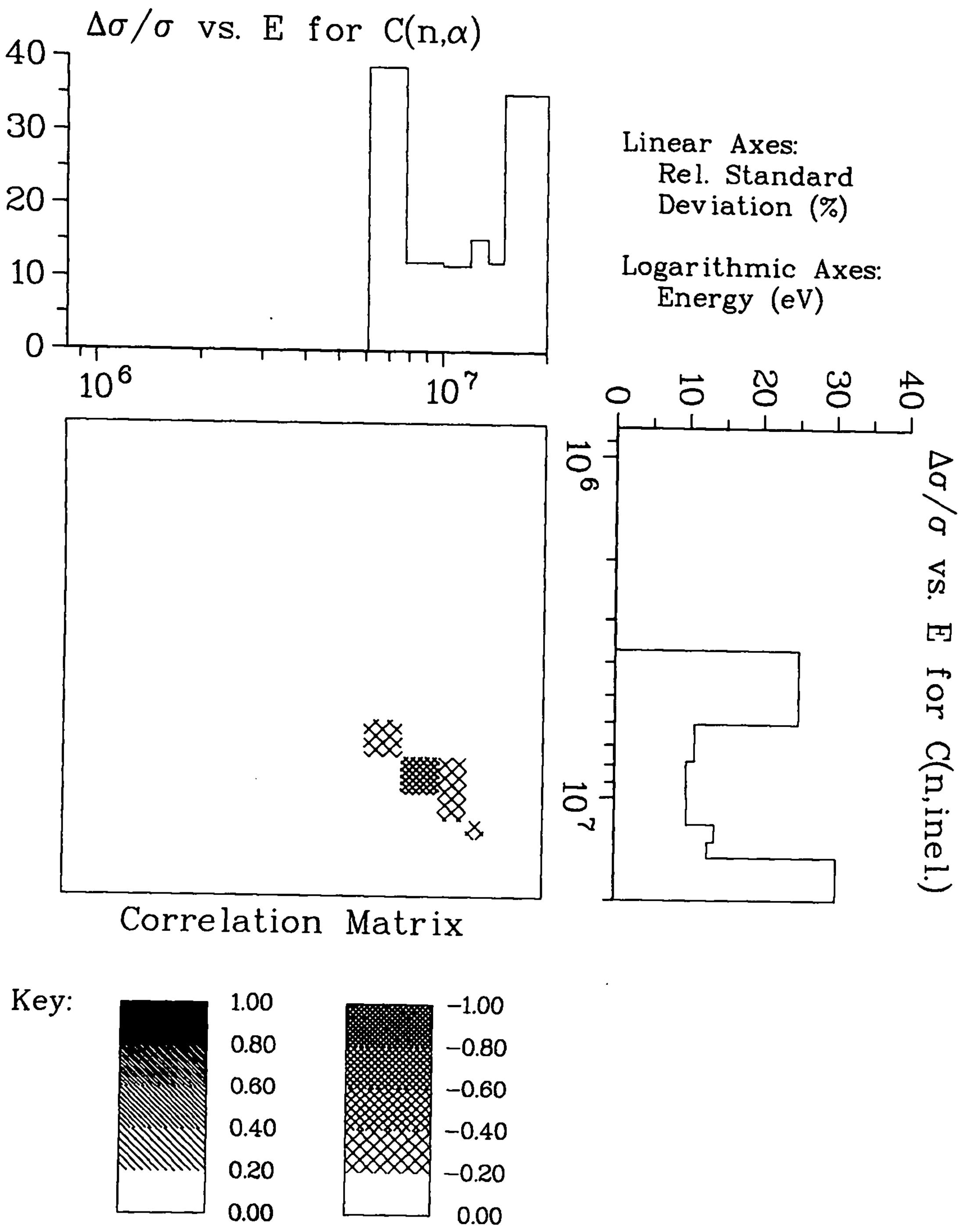


Fig. 31.
Covariance data for C(n,inel.) with C(n,α).

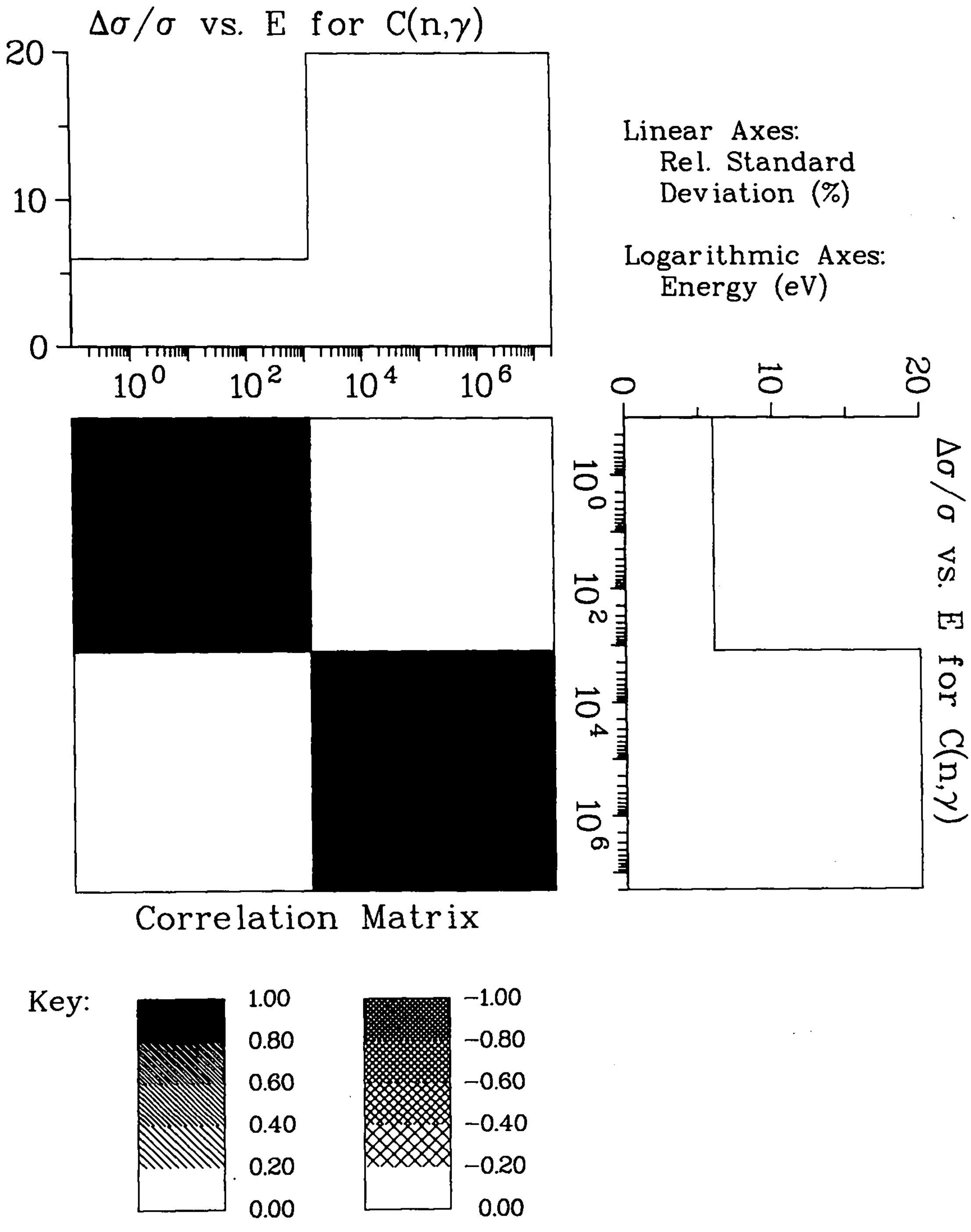


Fig. 32.

Covariance data for C(n,γ) with C(n,γ).

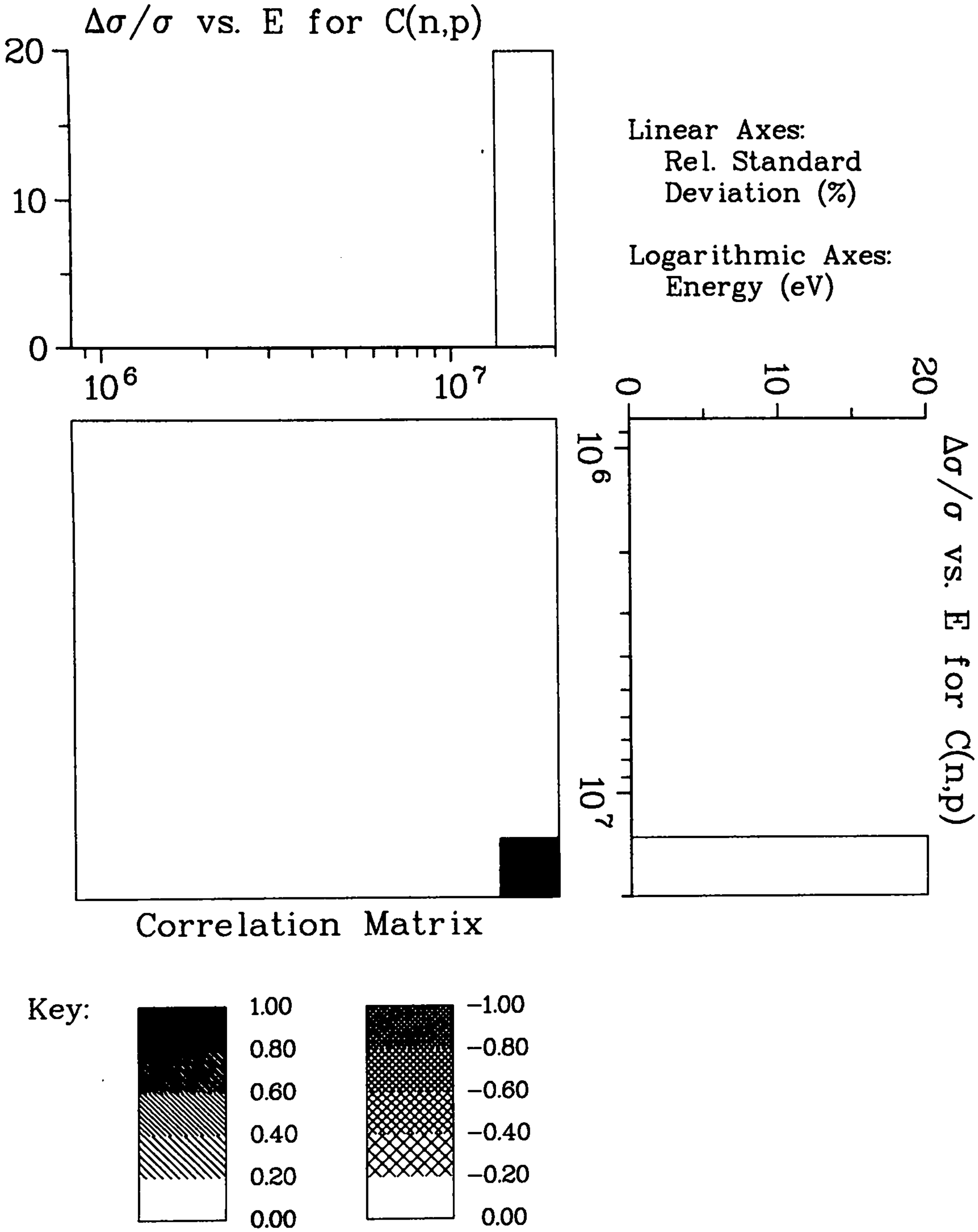


Fig. 33.
Covariance data for C(n,p) with C(n,p).

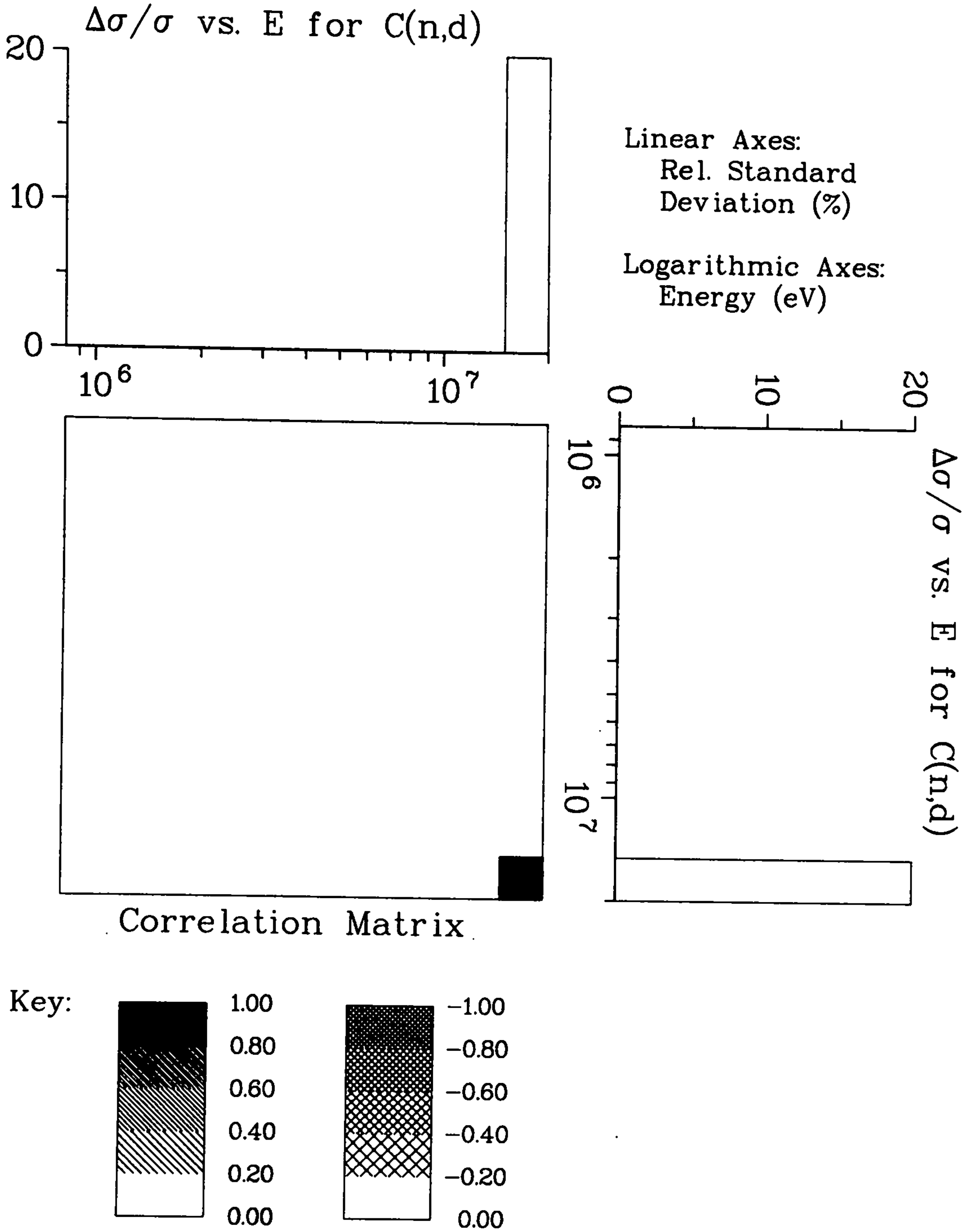


Fig. 34.
Covariance data for C(n,d) with C(n,d).

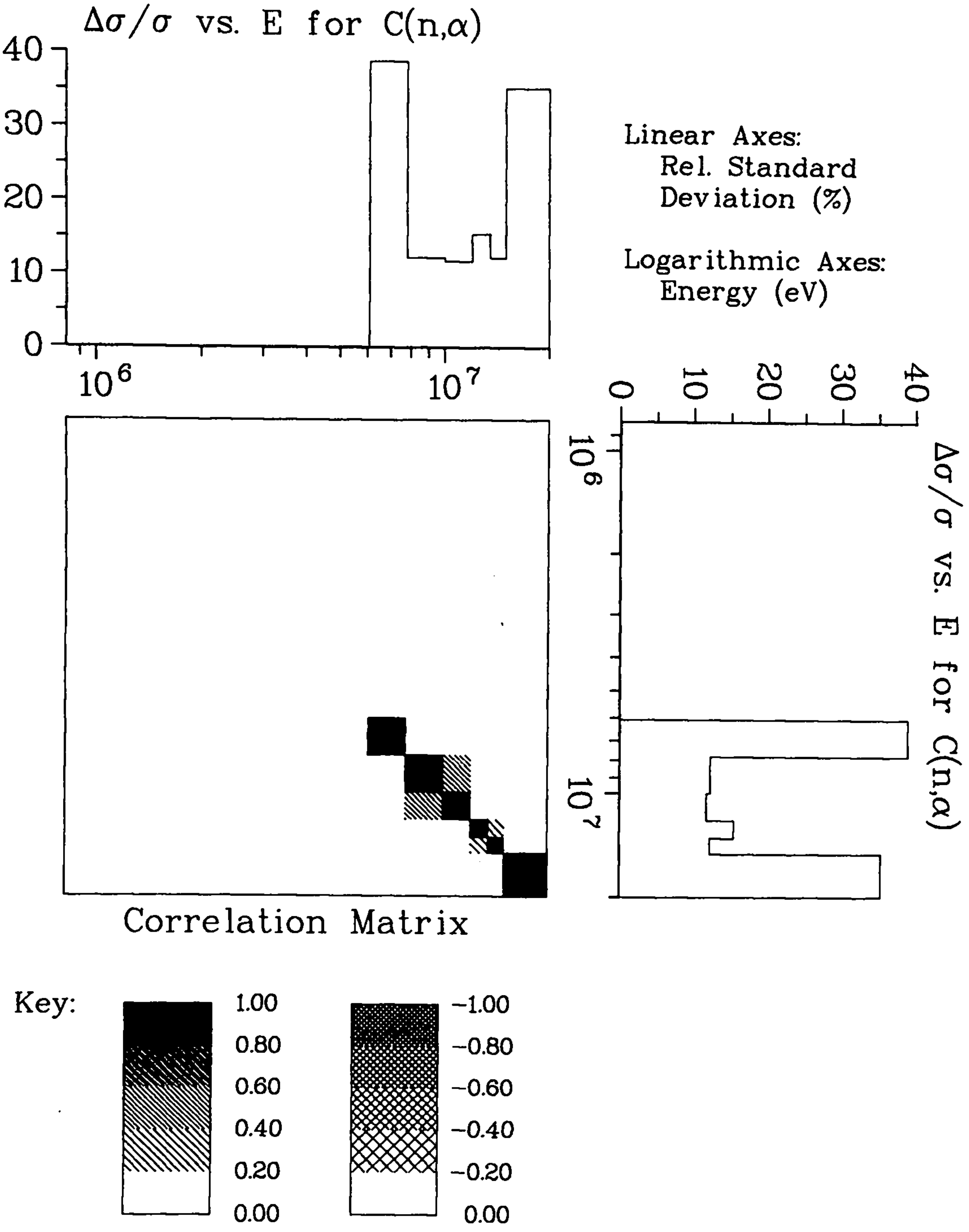


Fig. 35.
Covariance data for C(n,α) with C(n,α).

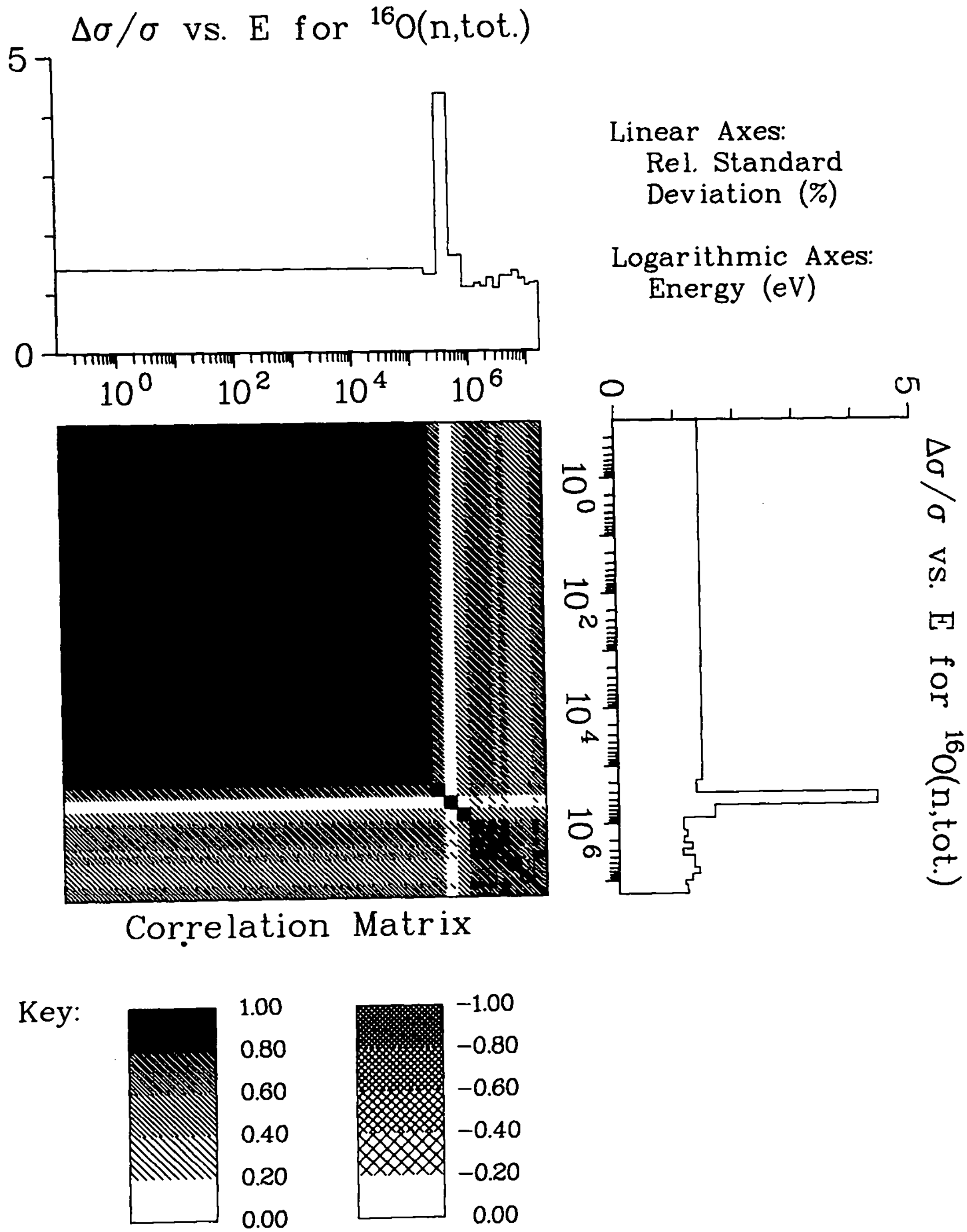


Fig. 36.
Covariance data for ^{16}O(n,tot.) with ^{16}O(n,tot.).

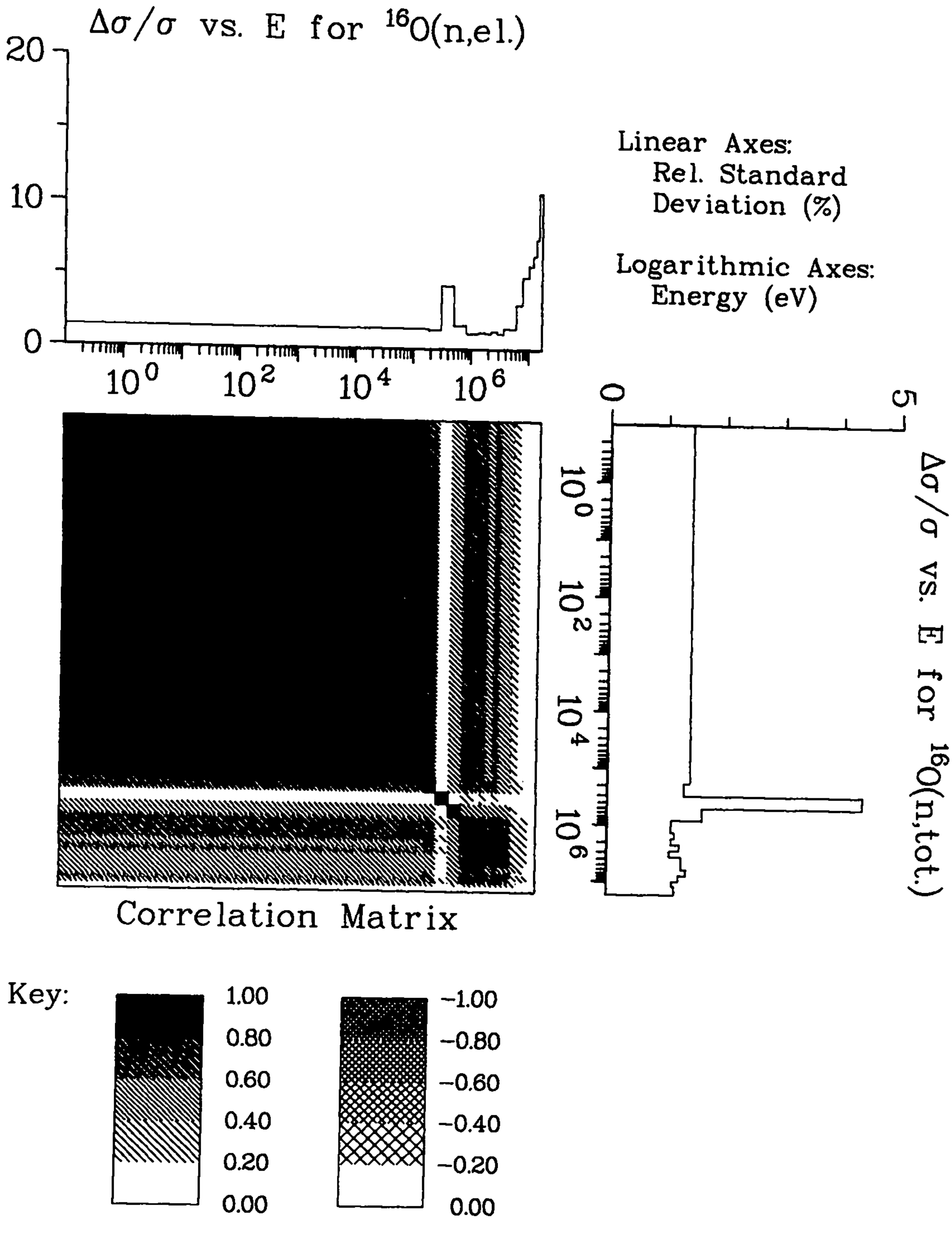


Fig. 37.
Covariance data for ^{16}O(n,tot.) with ^{16}O(n,el.).

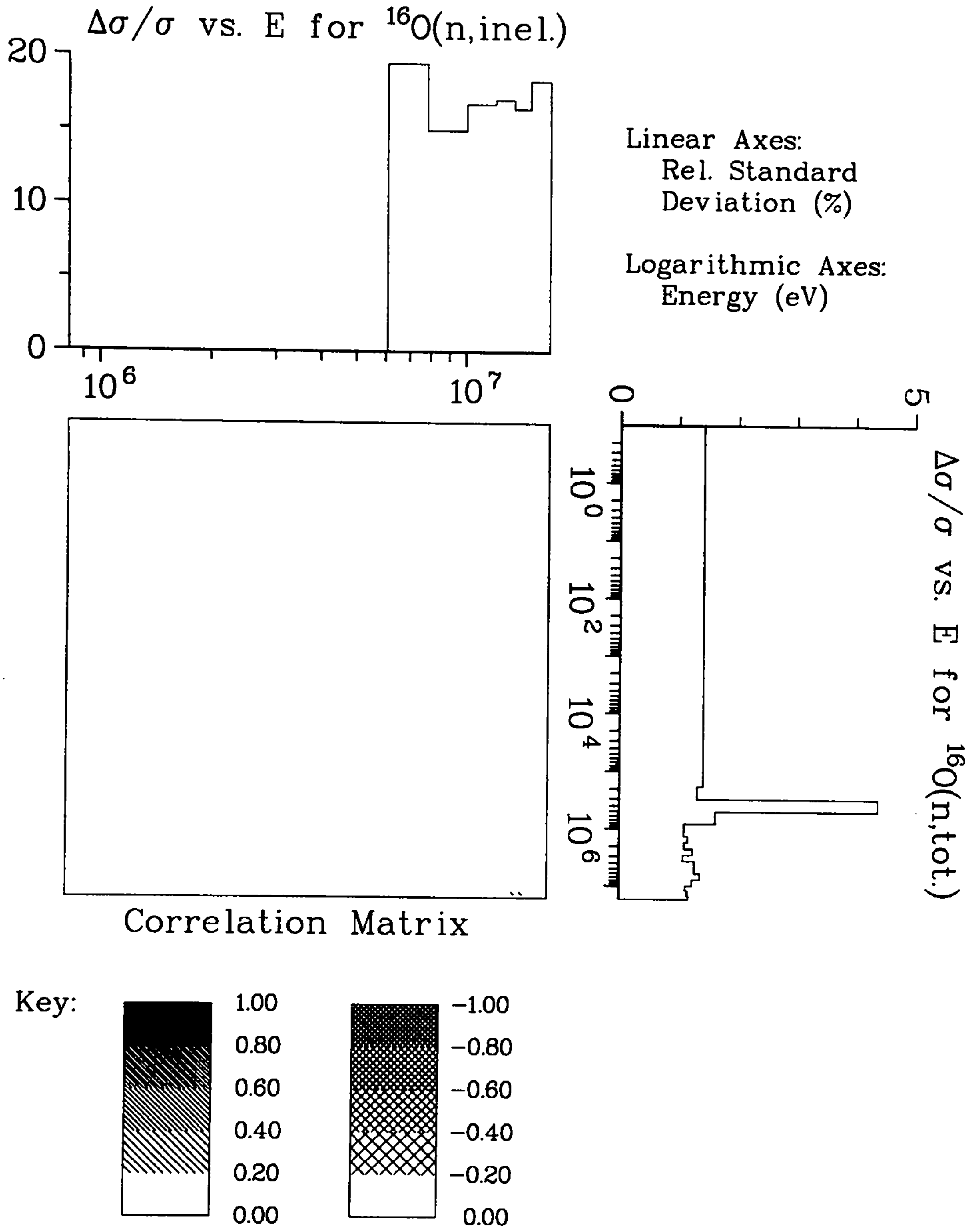


Fig. 38.
Covariance data for $^{16}O(n,tot.)$ with $^{16}O(n,inel.)$.

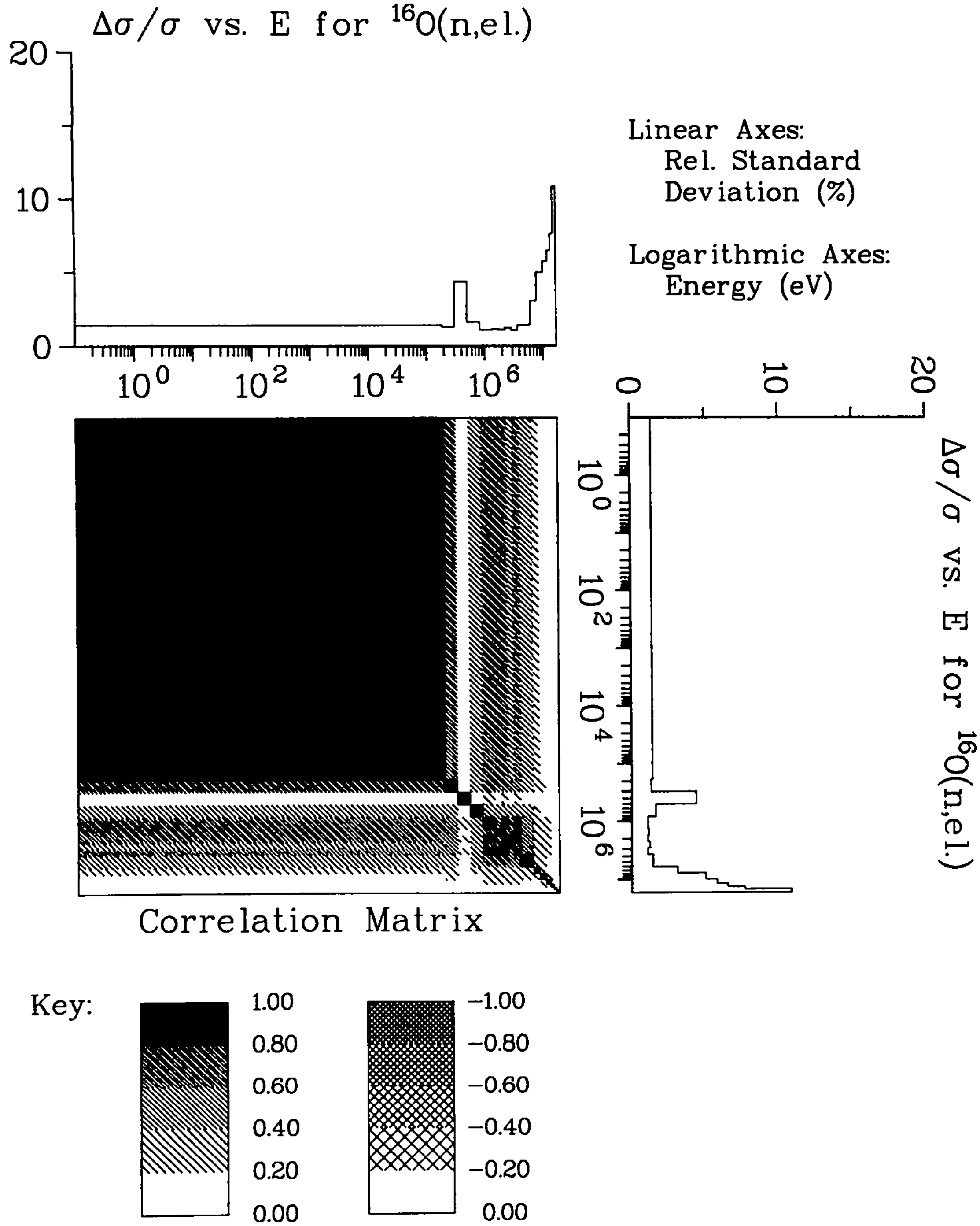


Fig. 39.
Covariance data for ^{16}O(n,el.) with ^{16}O(n,el.).

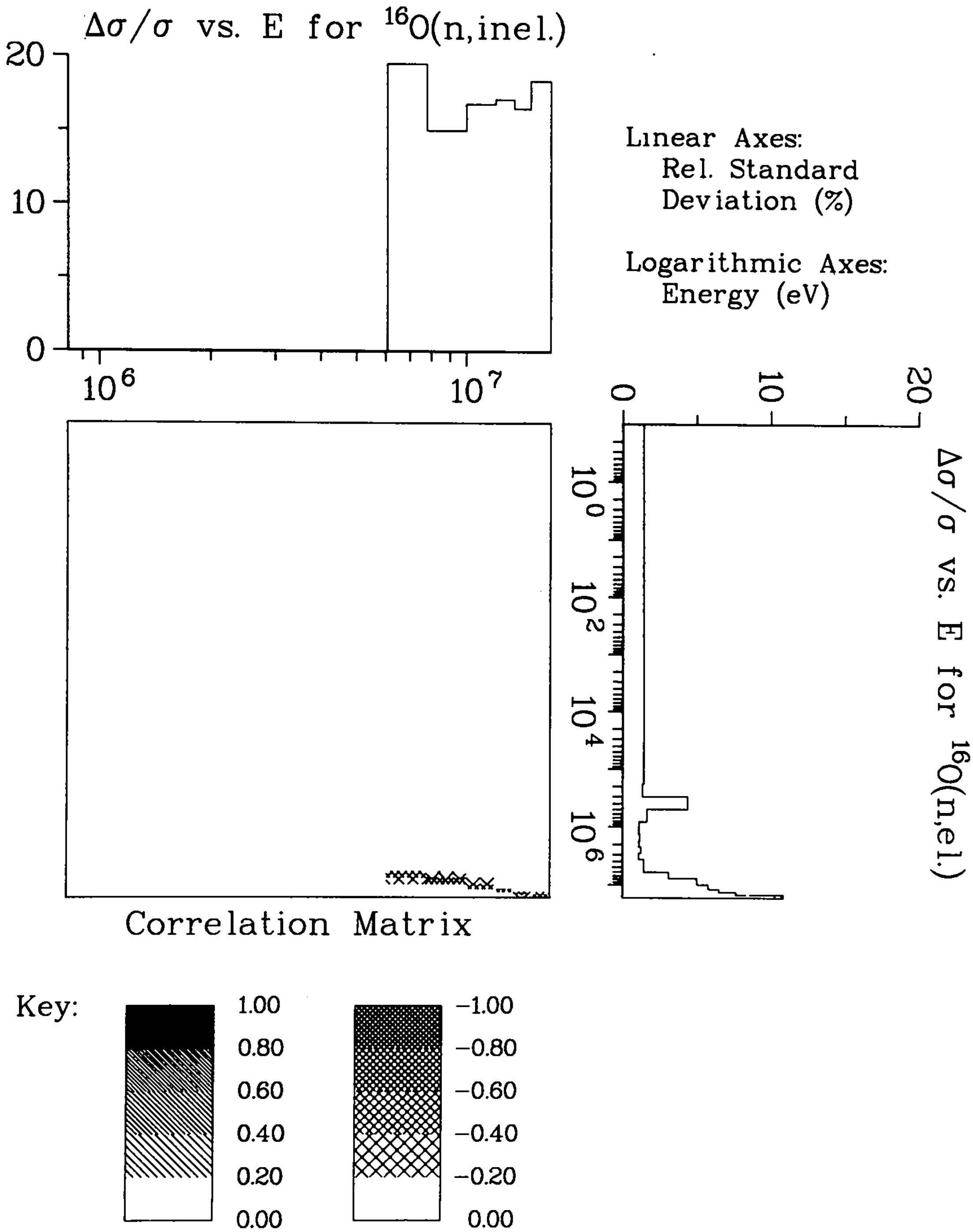


Fig. 40.

Covariance data for $^{16}O(n,el.)$ with $^{16}O(n,inel.)$.

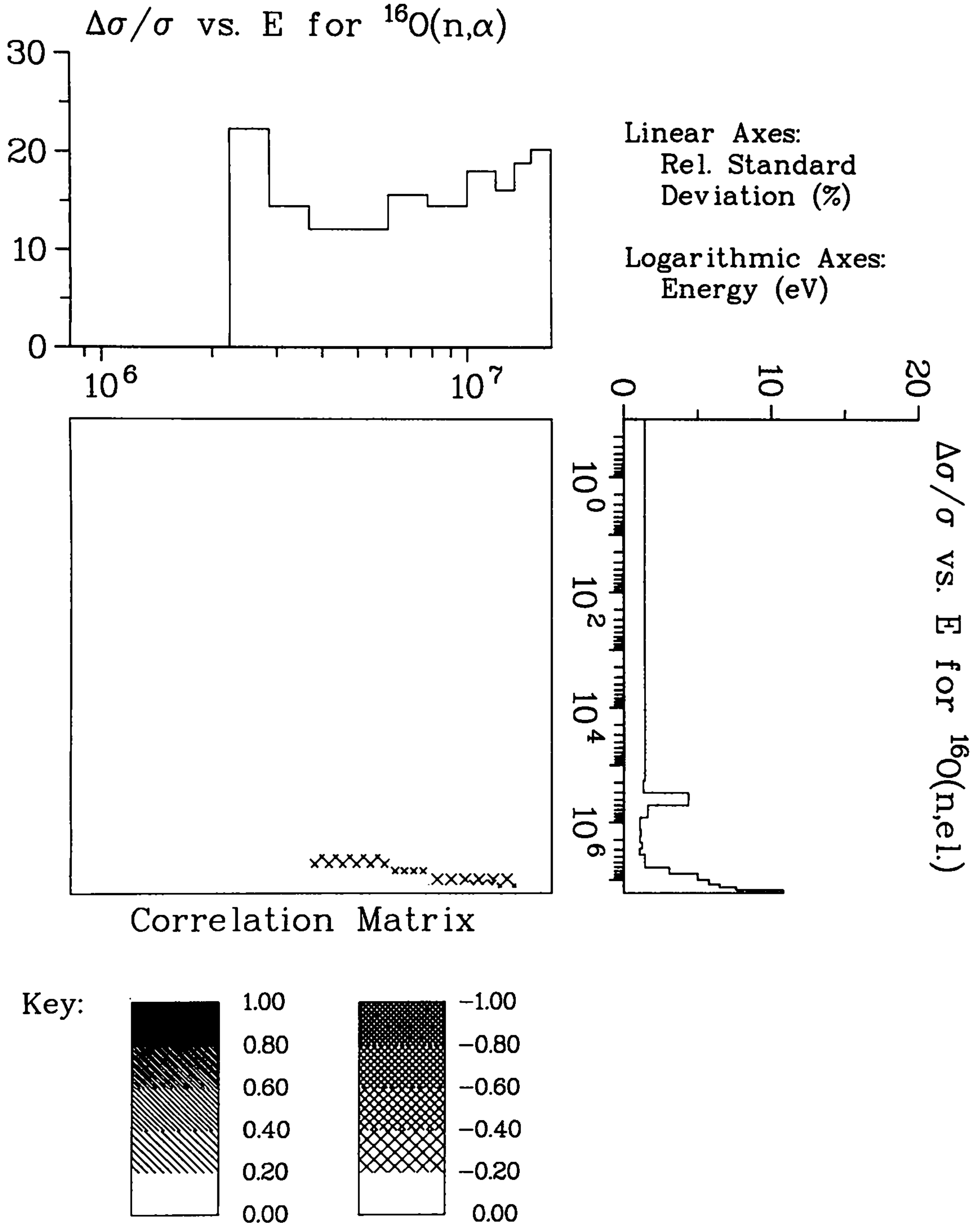


Fig. 41.
Covariance data for ^{16}O(n,el.) with ^{16}O(n,α).

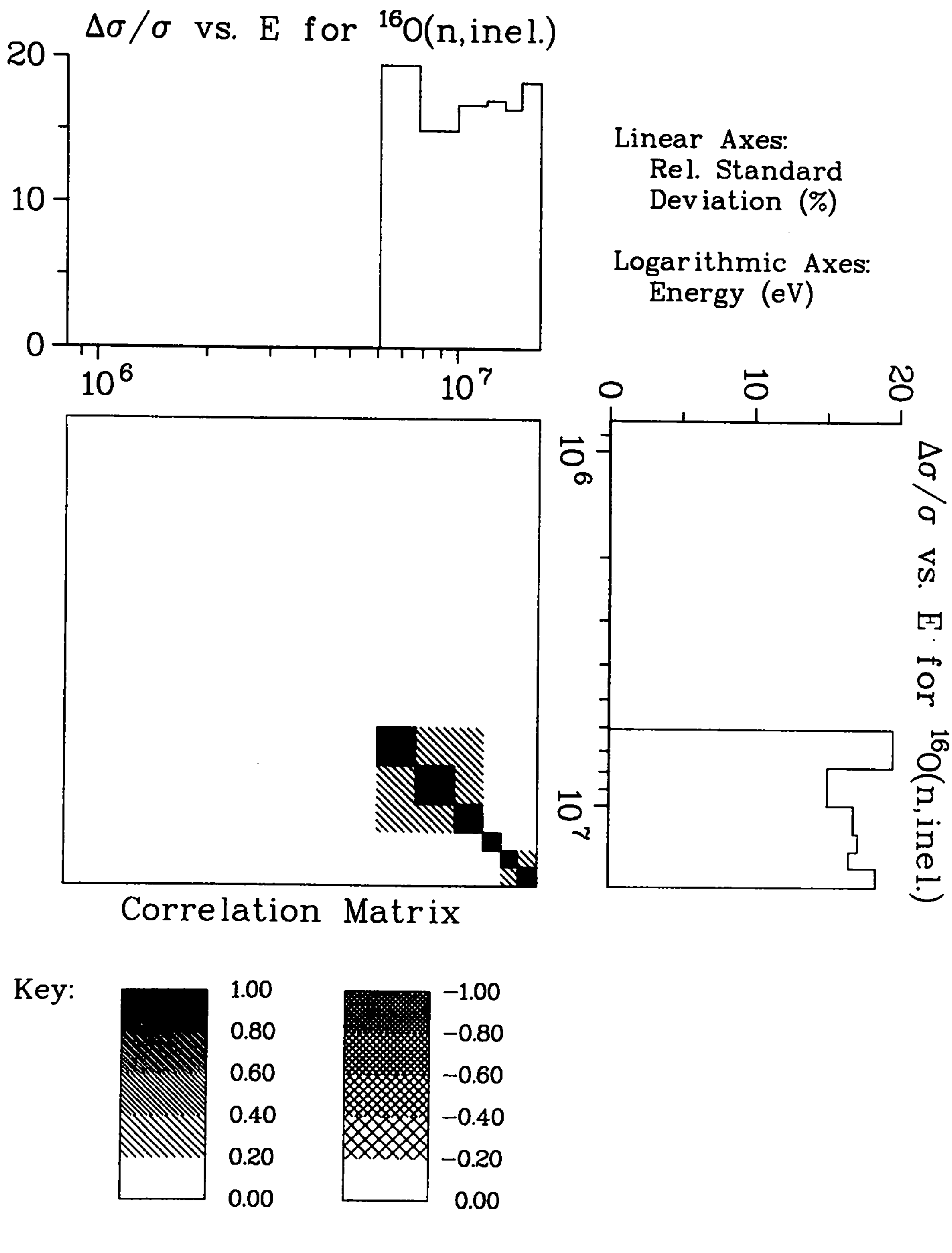


Fig. 42.
Covariance data for ^{16}O(n,inel.) with ^{16}O(n,inel.).

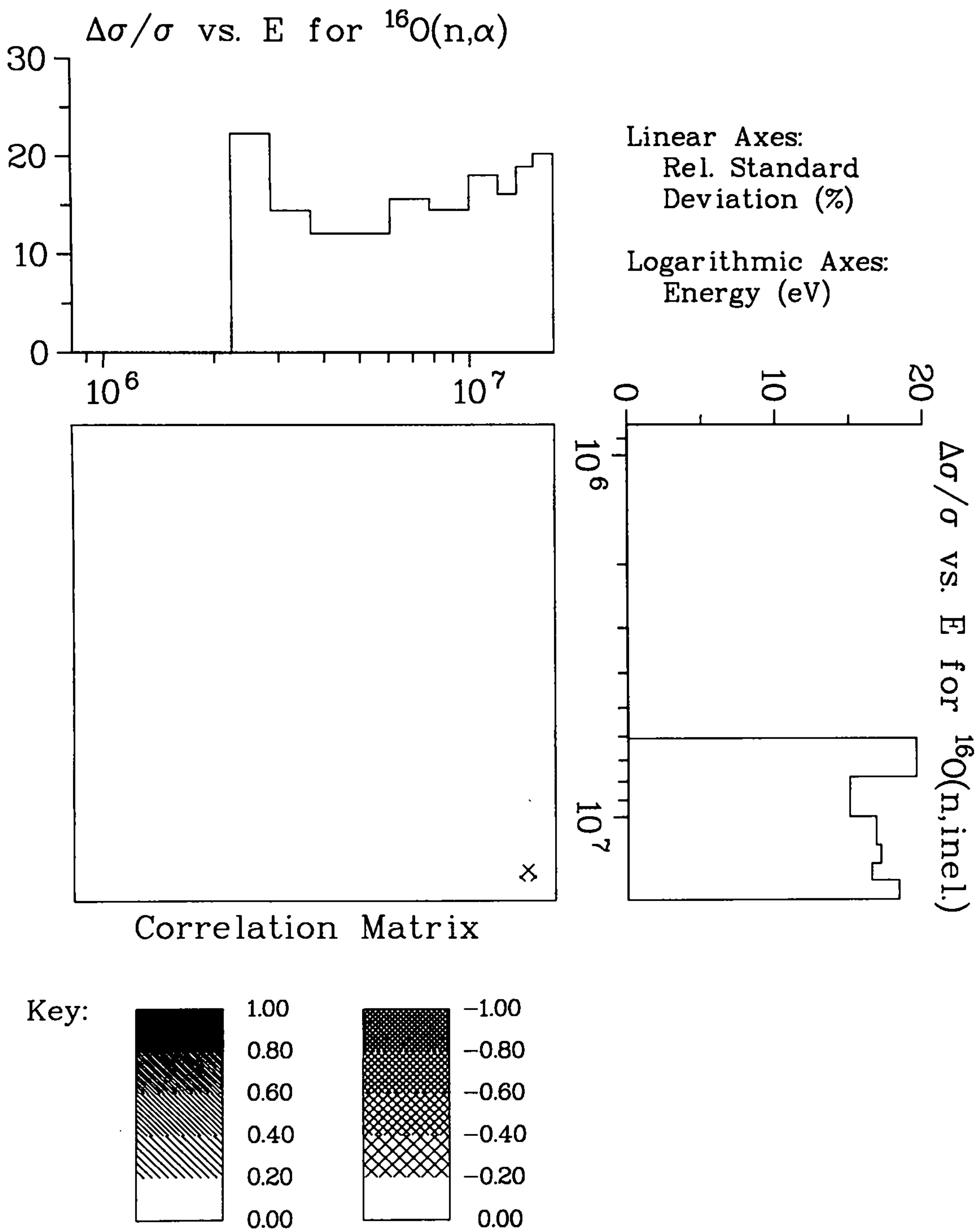


Fig. 43.
Covariance data for $^{16}O(n,inel.)$ with $^{16}O(n,\alpha)$.

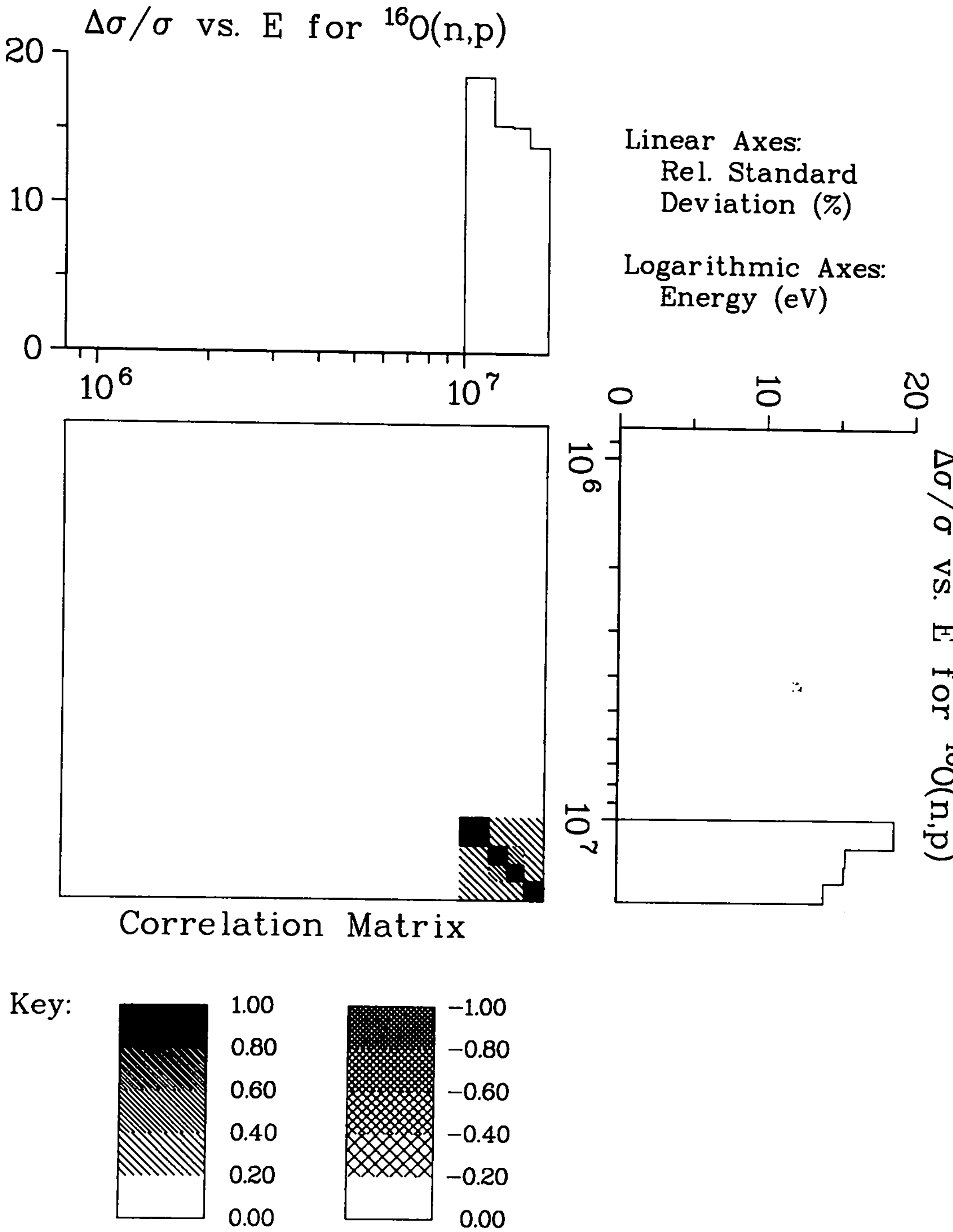


Fig. 44.
Covariance data for $^{16}O(n,p)$ with $^{16}O(n,p)$.

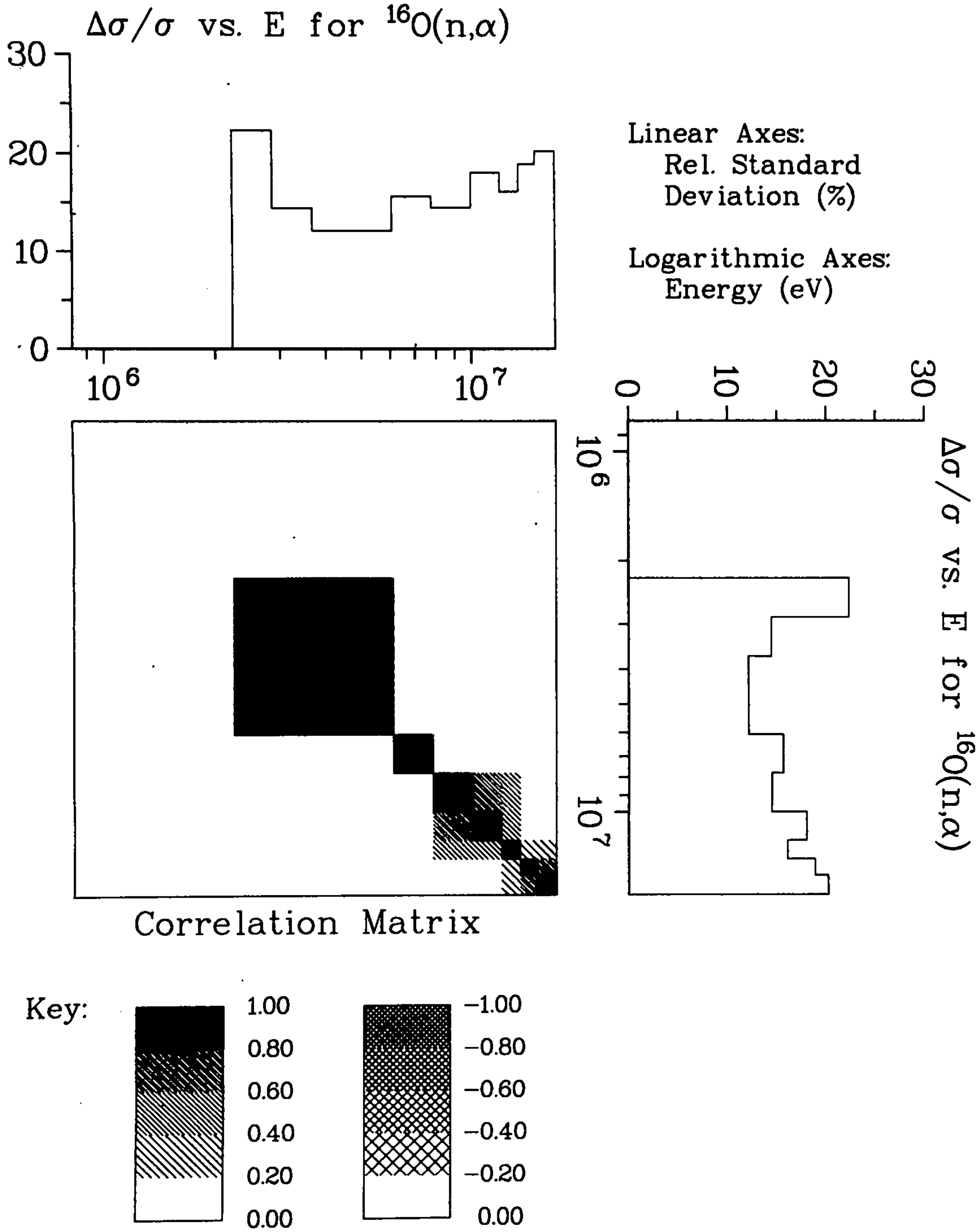


Fig. 45.
Covariance data for $^{16}O(n,\alpha)$ with $^{16}O(n,\alpha)$.

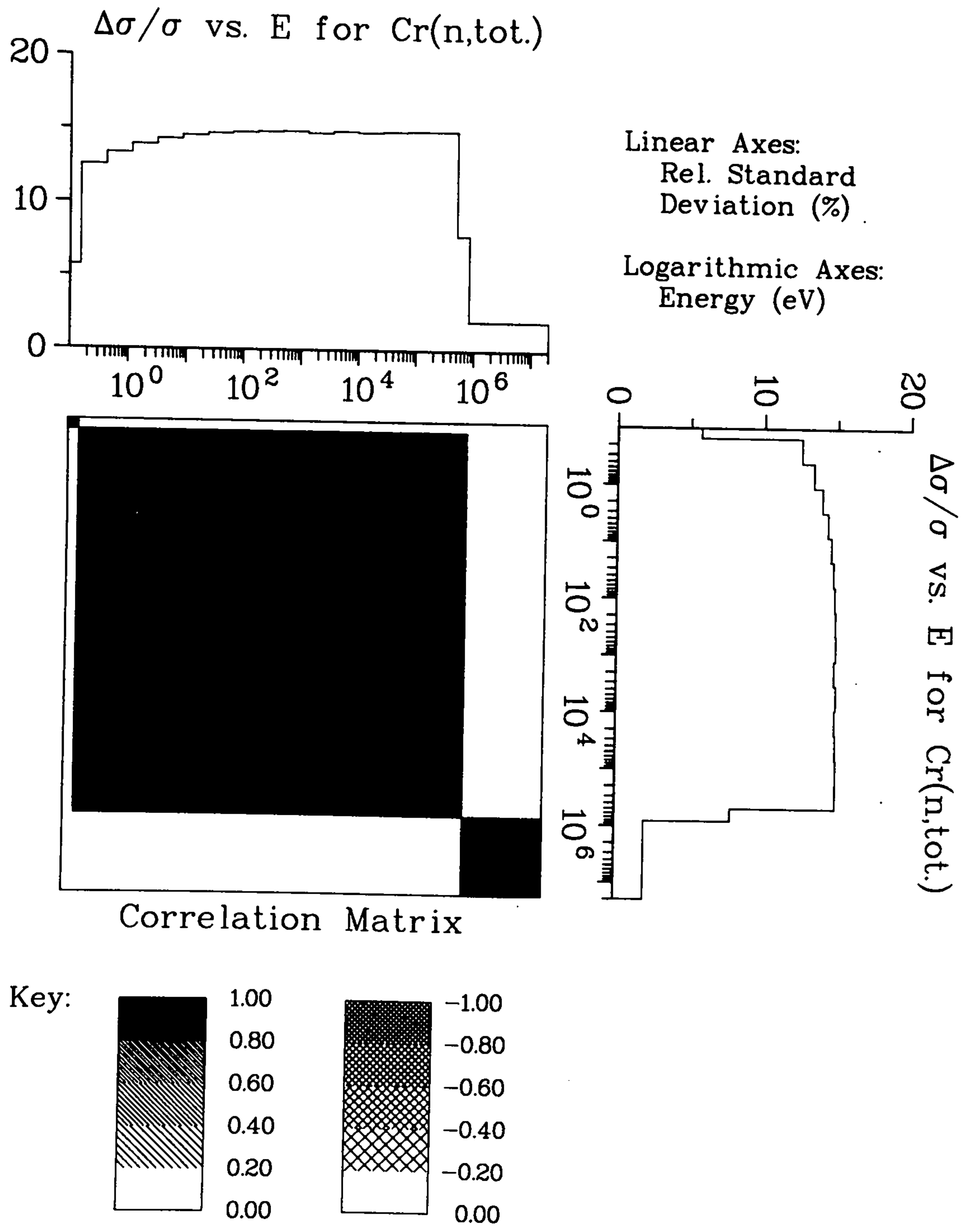


Fig. 46.
Covariance data for Cr(n,tot.) with Cr(n,tot.).

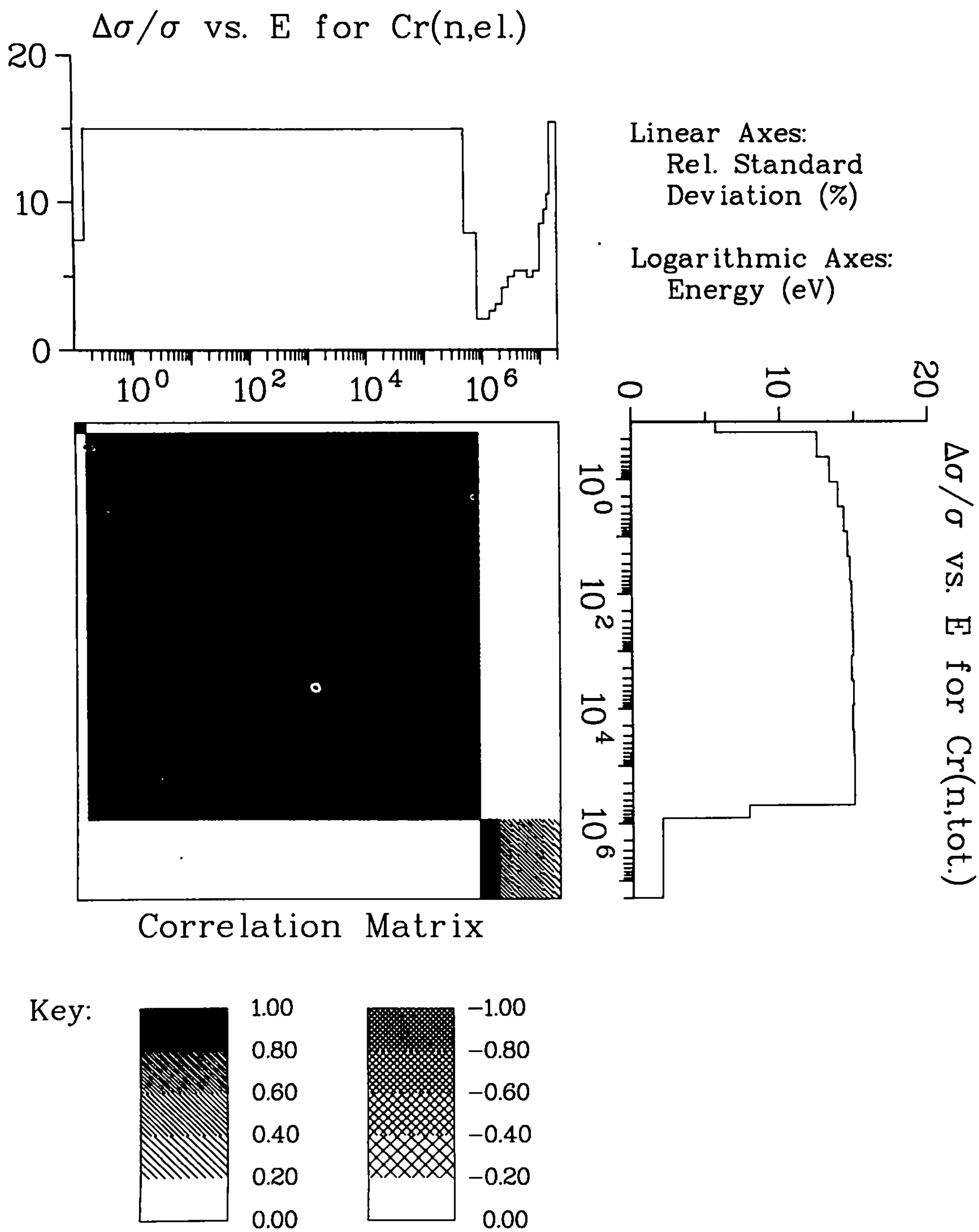


Fig. 47.
Covariance data for Cr(n,tot.) with Cr(n,el.).

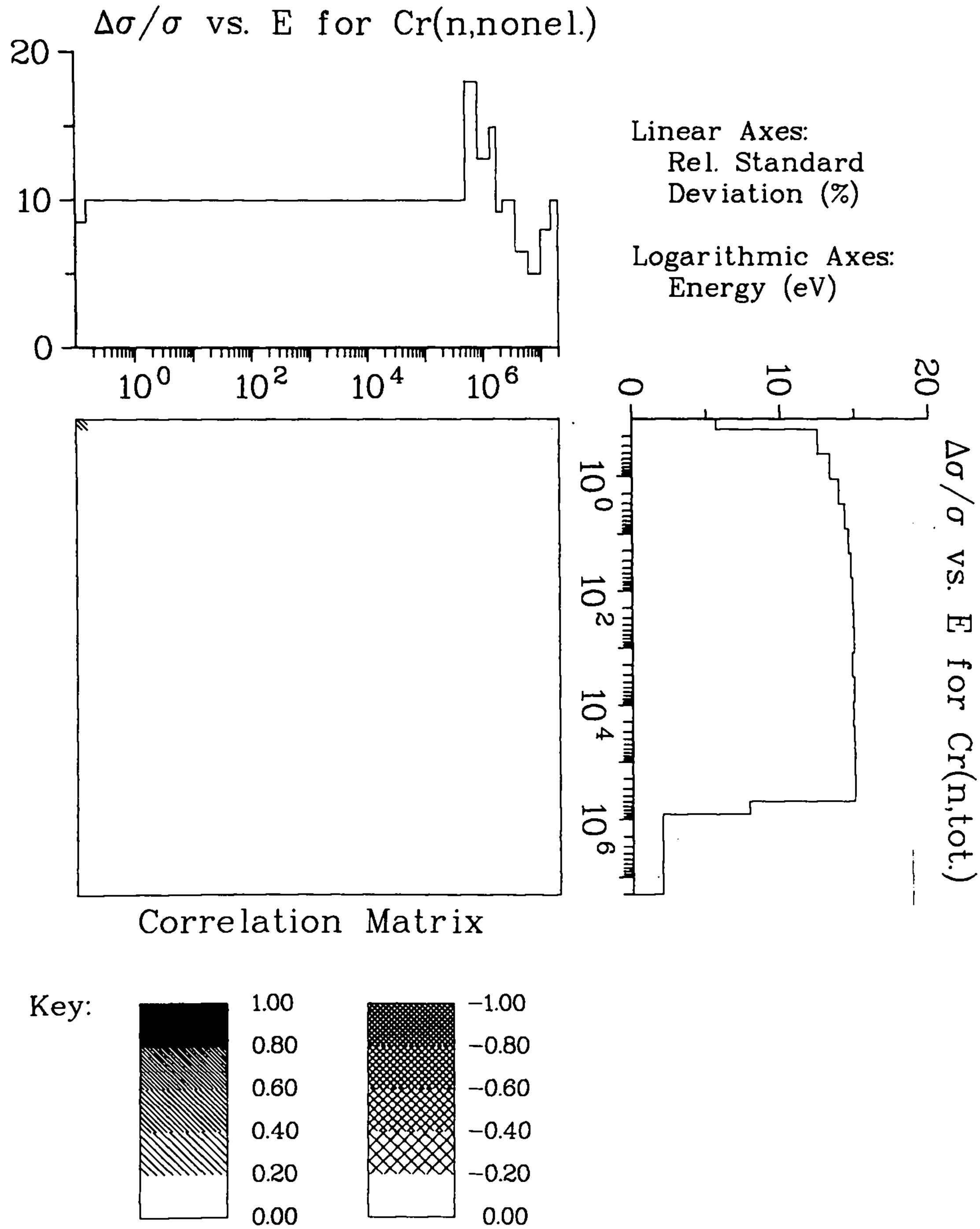


Fig. 48.
Covariance data for Cr(n,tot.) with Cr(n,nonel.).

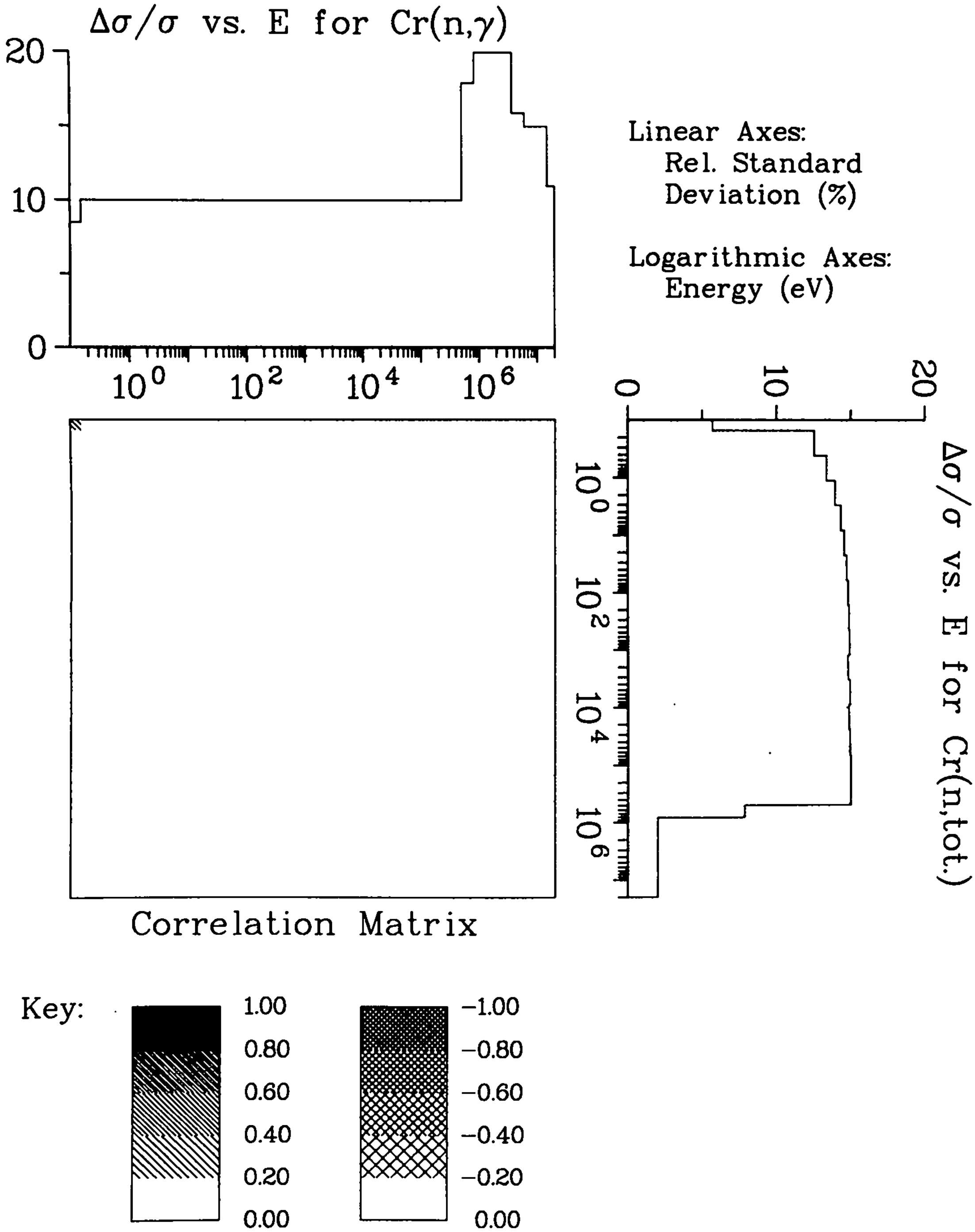


Fig. 49.
Covariance data for Cr(n,tot.) with Cr(n,γ).

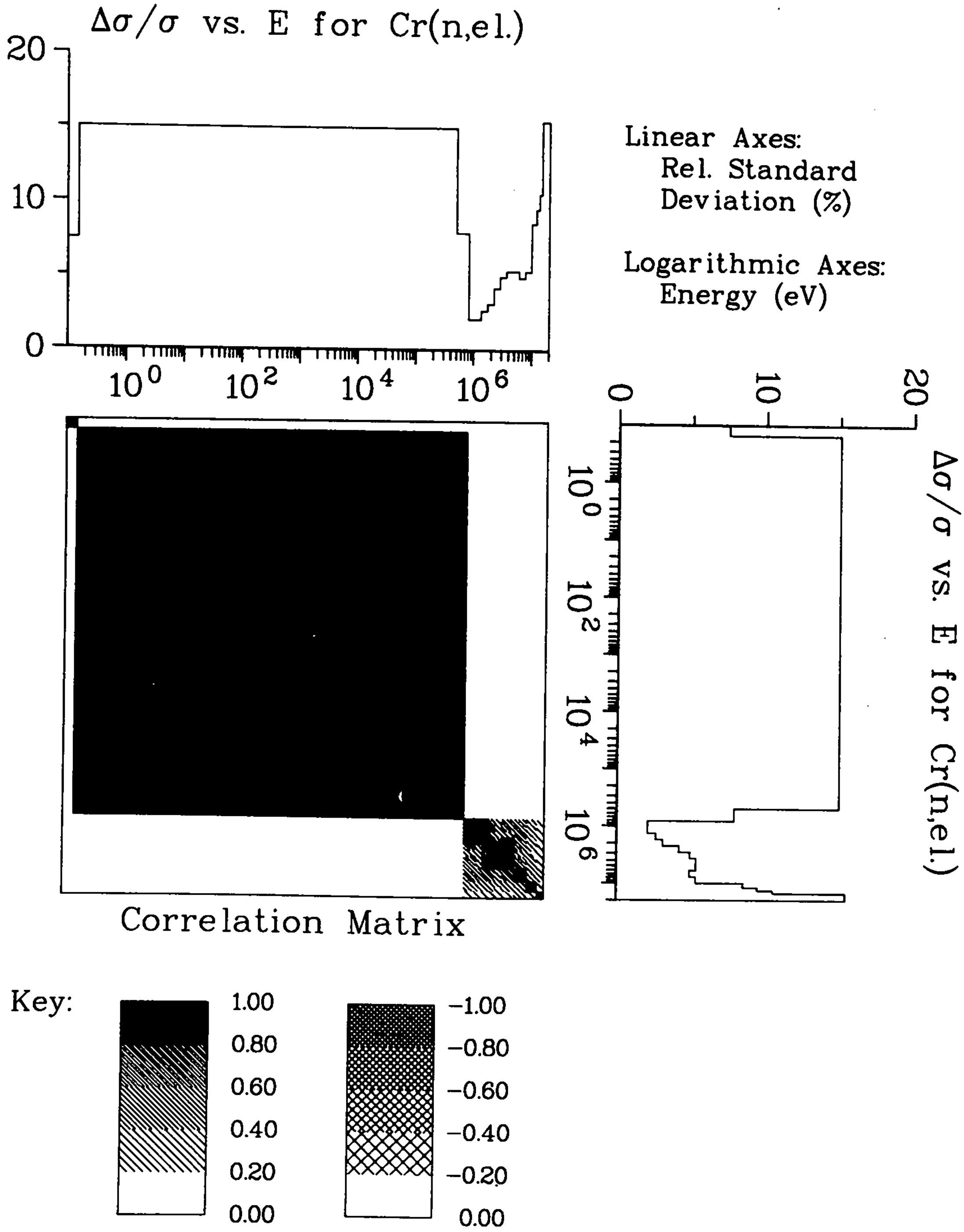


Fig. 50.
Covariance data for Cr(n,el.) with Cr(n,el.).

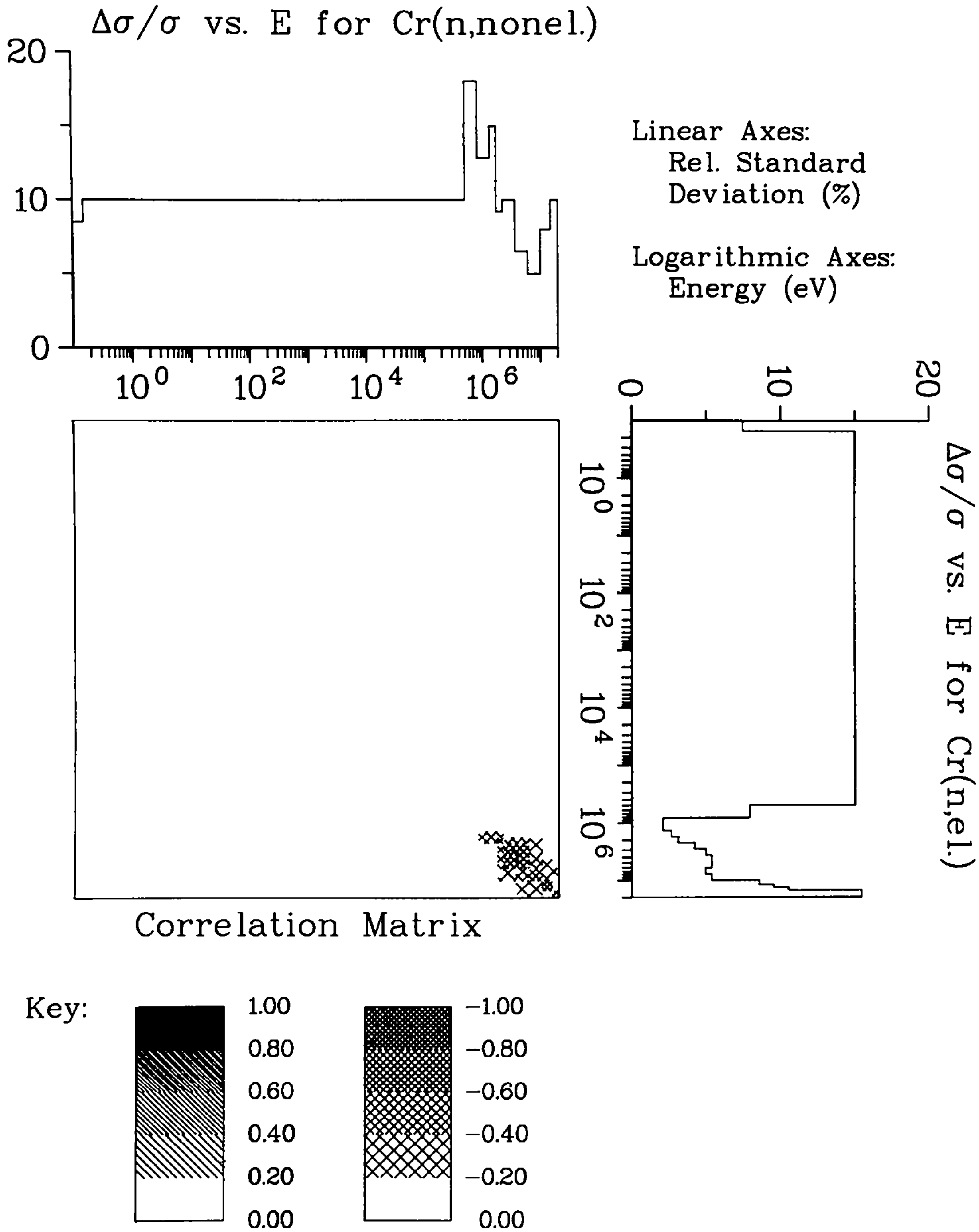


Fig. 51.
Covariance data for Cr(n,el.) with Cr(n,nonel.).

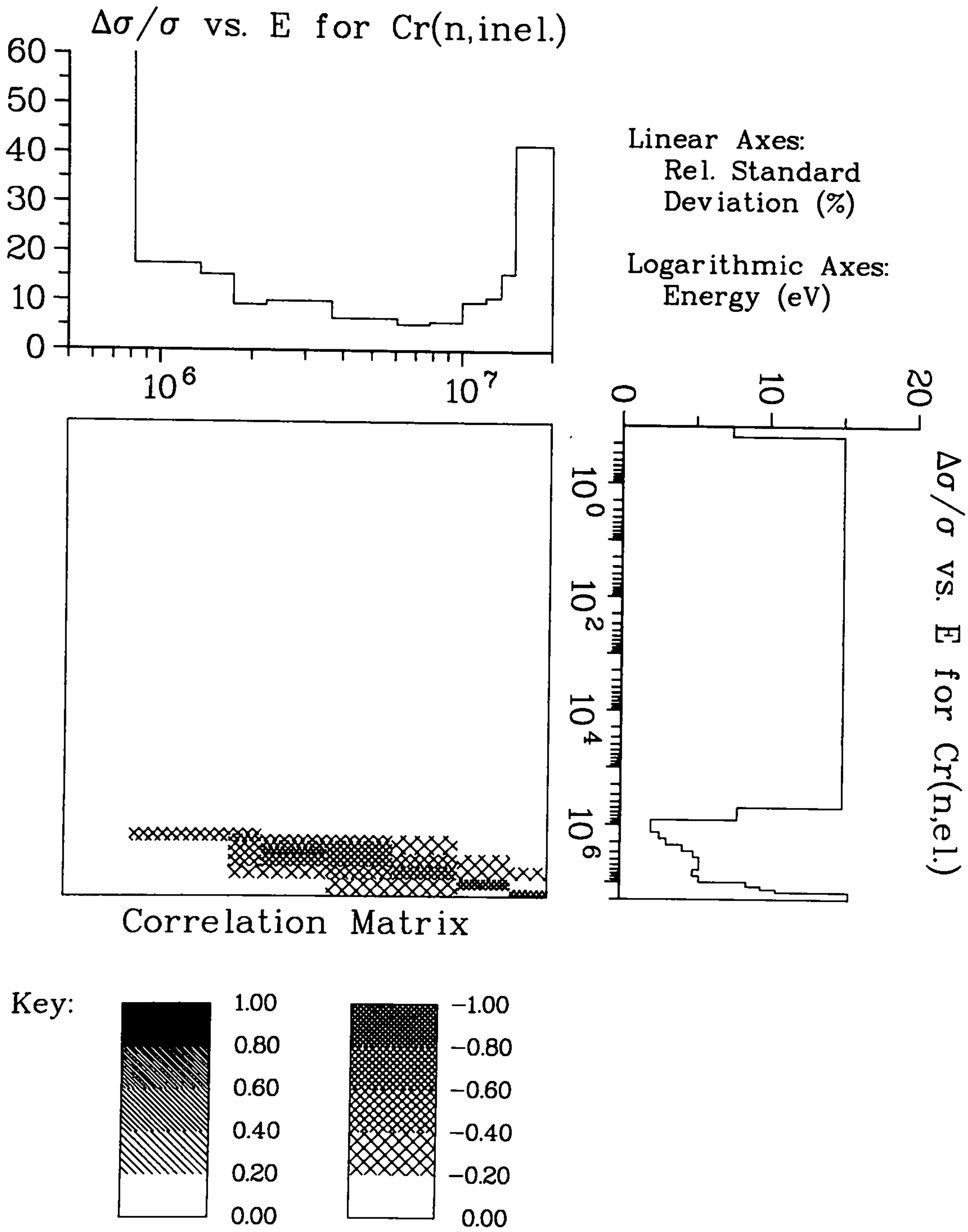


Fig. 52.
Covariance data for Cr(n,el.) with Cr(n,inel.).

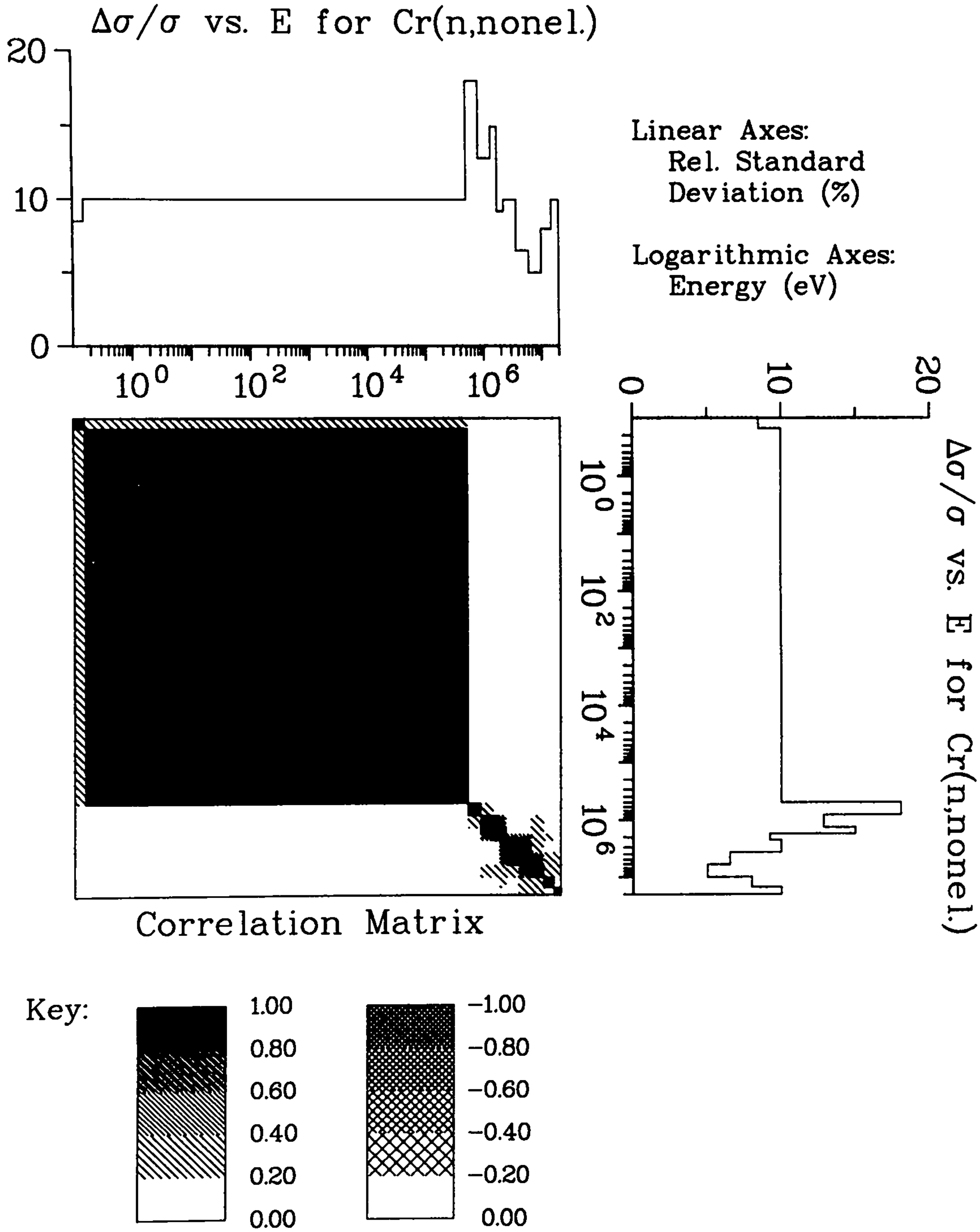


Fig. 53.
Covariance data for Cr(n,nonel.) with Cr(n,nonel.).

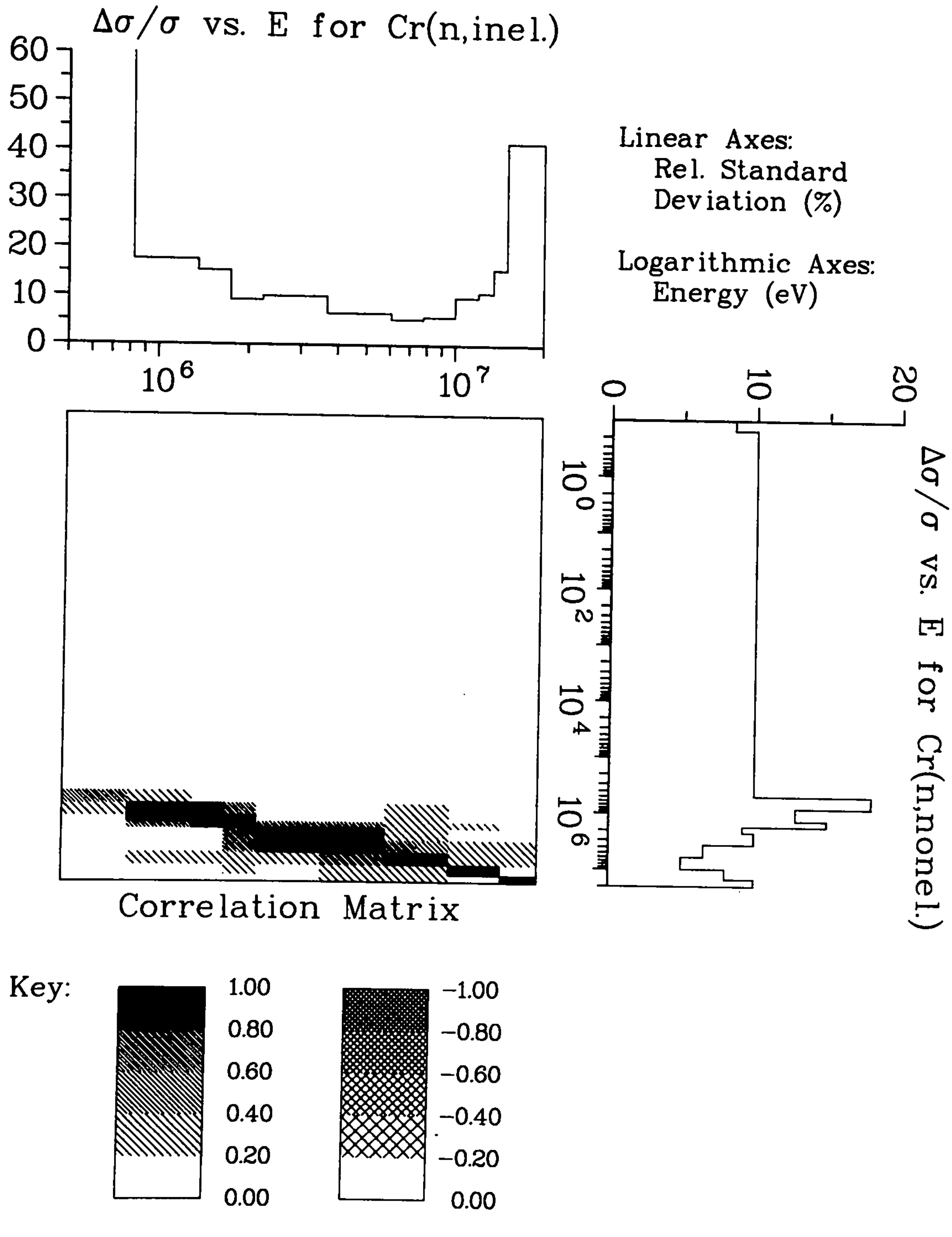


Fig. 54.
Covariance data for Cr(n,nonel.) with Cr(n,inel.).

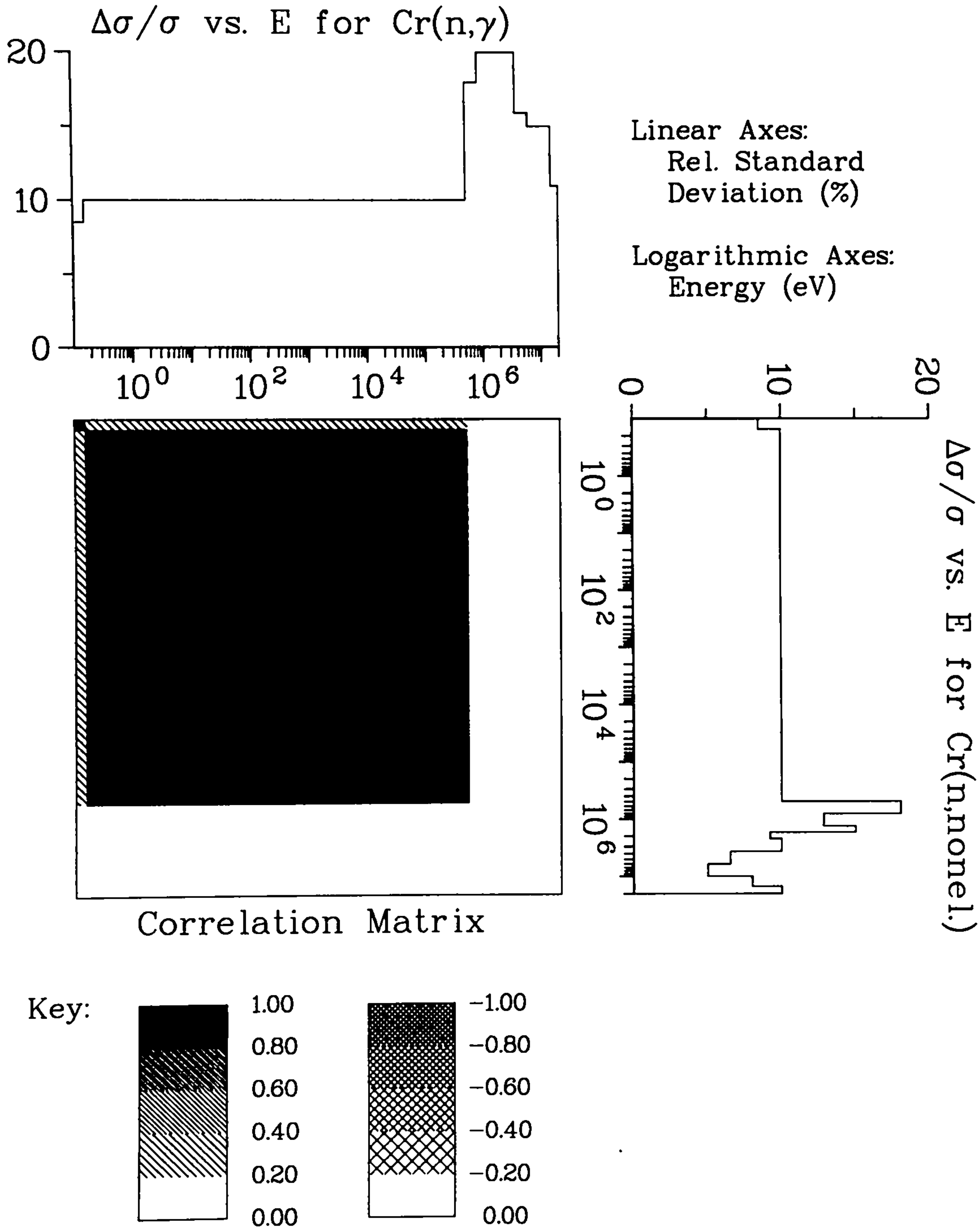


Fig. 55.
Covariance data for Cr(n,nonel.) with Cr(n,γ).

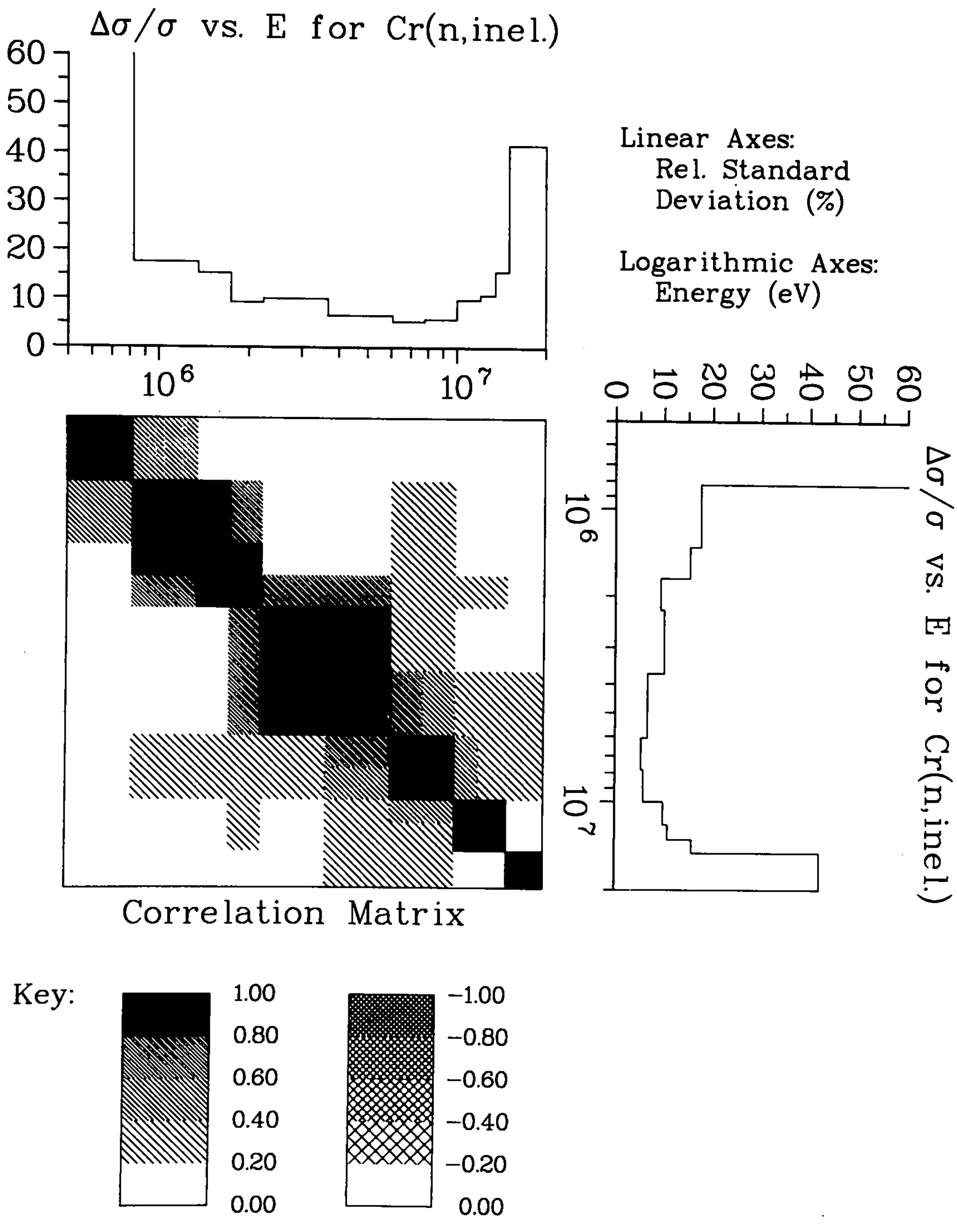


Fig. 56.
Covariance data for Cr(n,inel.) with Cr(n,inel.).

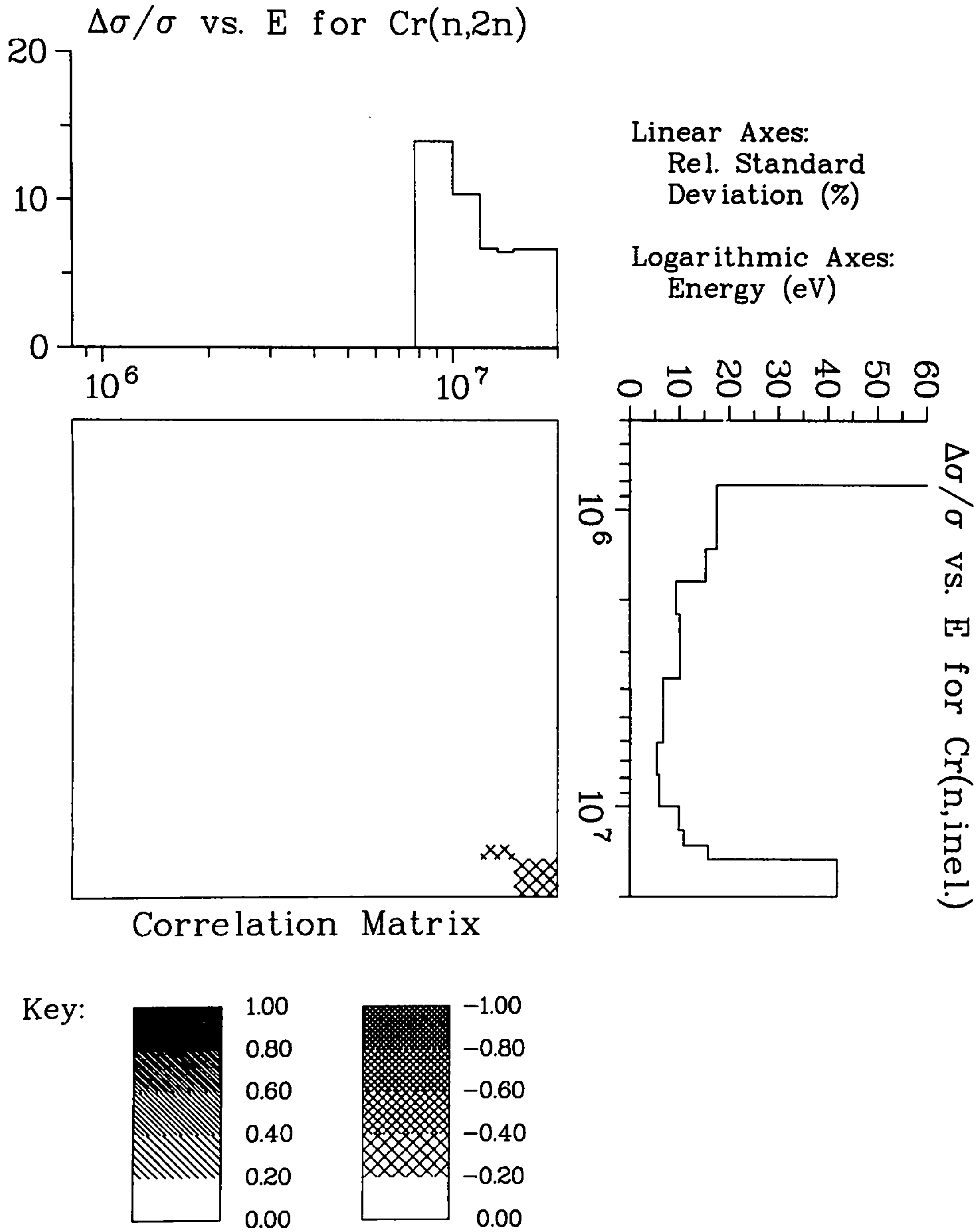


Fig. 57.
Covariance data for Cr(n,inel.) with Cr(n,2n).

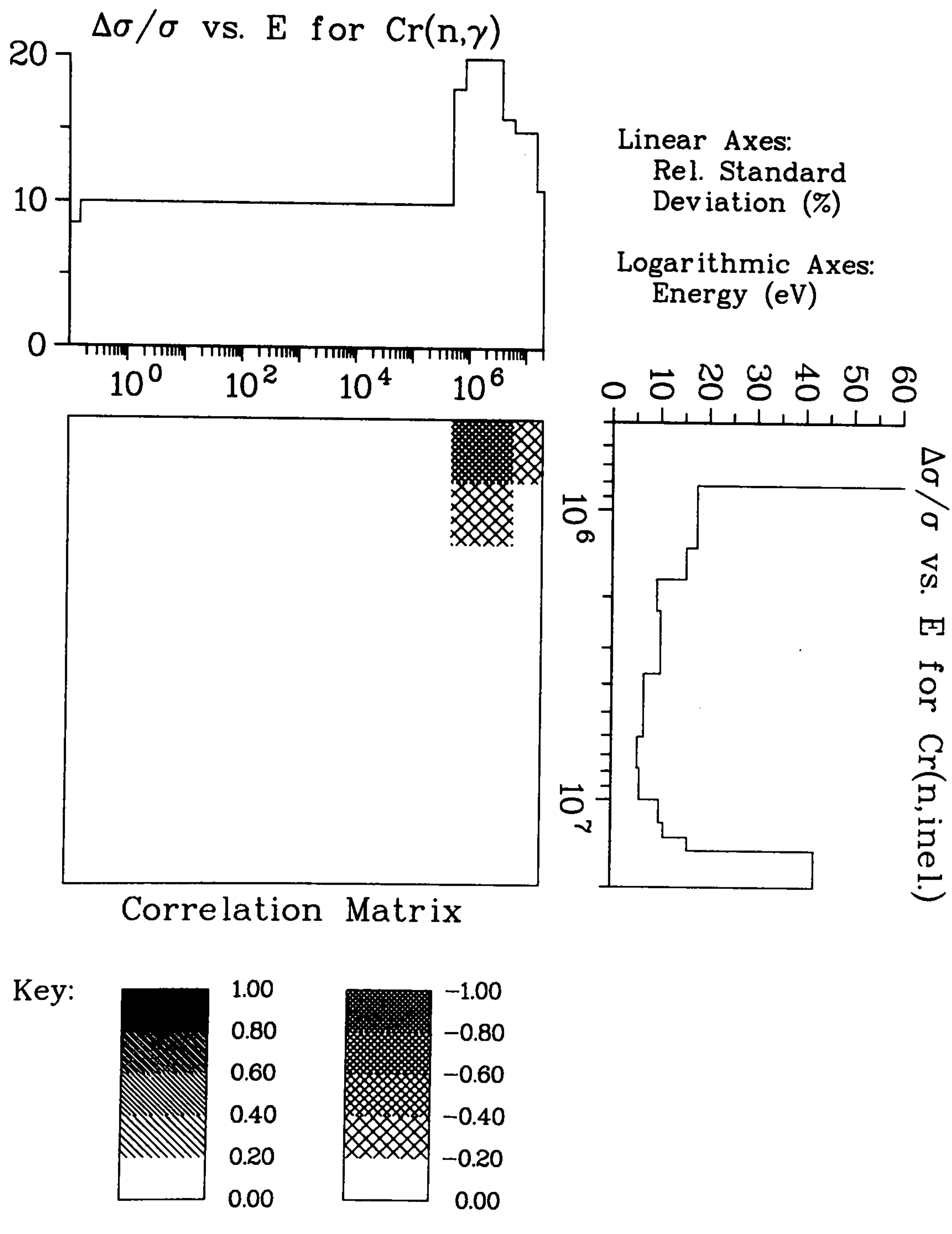


Fig. 58.
Covariance data for Cr(n,inel.) with Cr(n,γ).

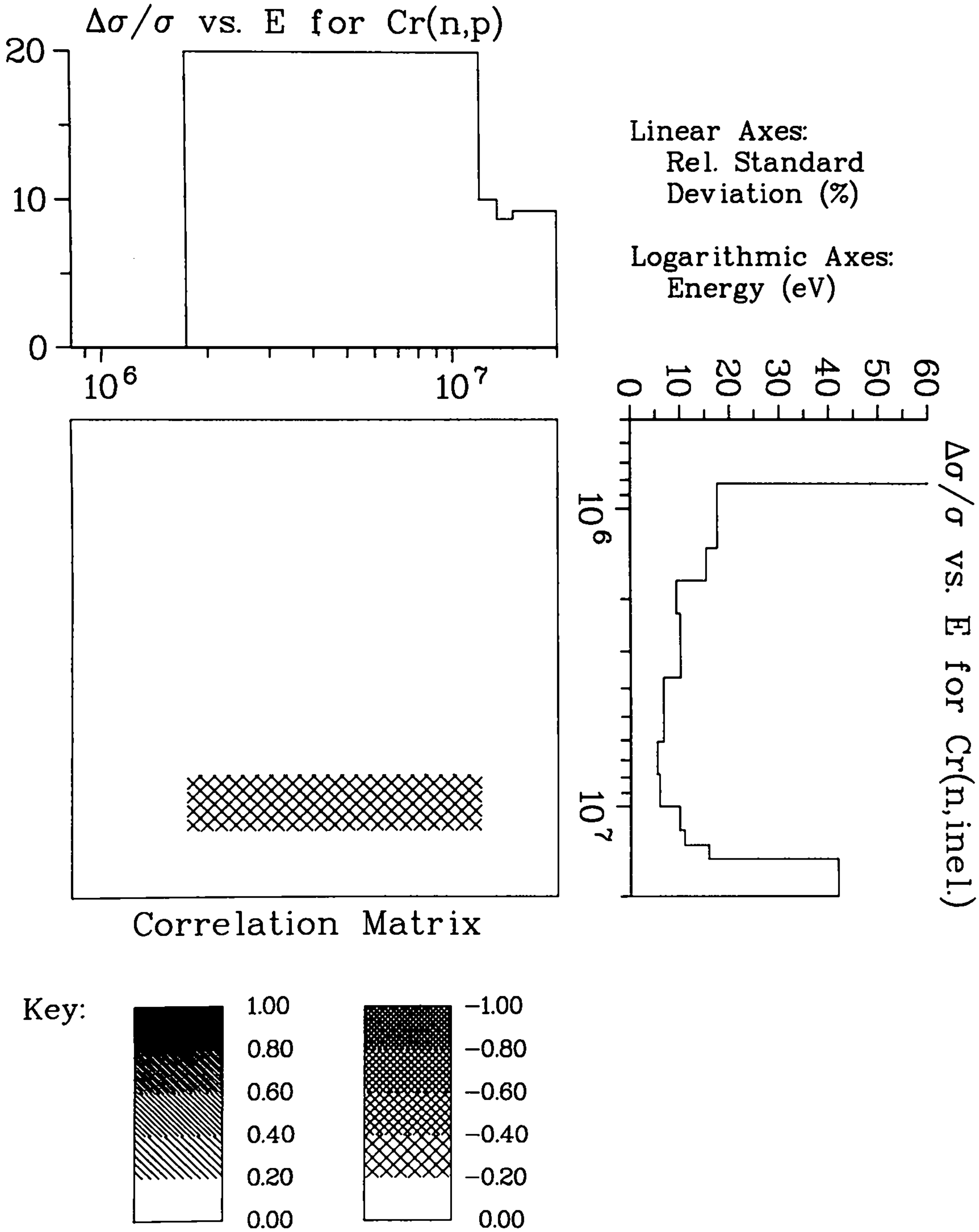


Fig. 59.

Covariance data for Cr(n,inel.) with Cr(n,p).

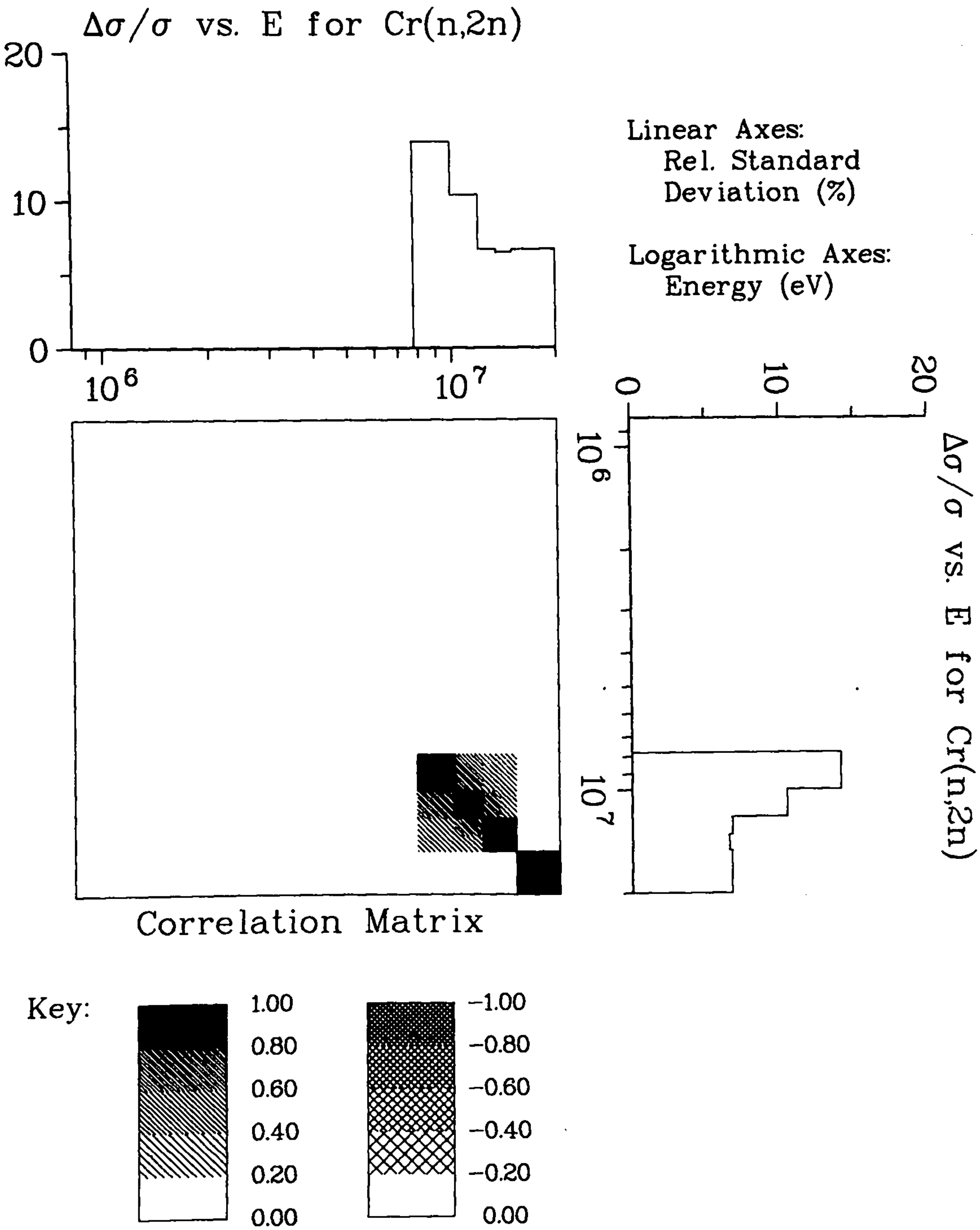


Fig. 60.
Covariance data for Cr(n,2n) with Cr(n,2n).

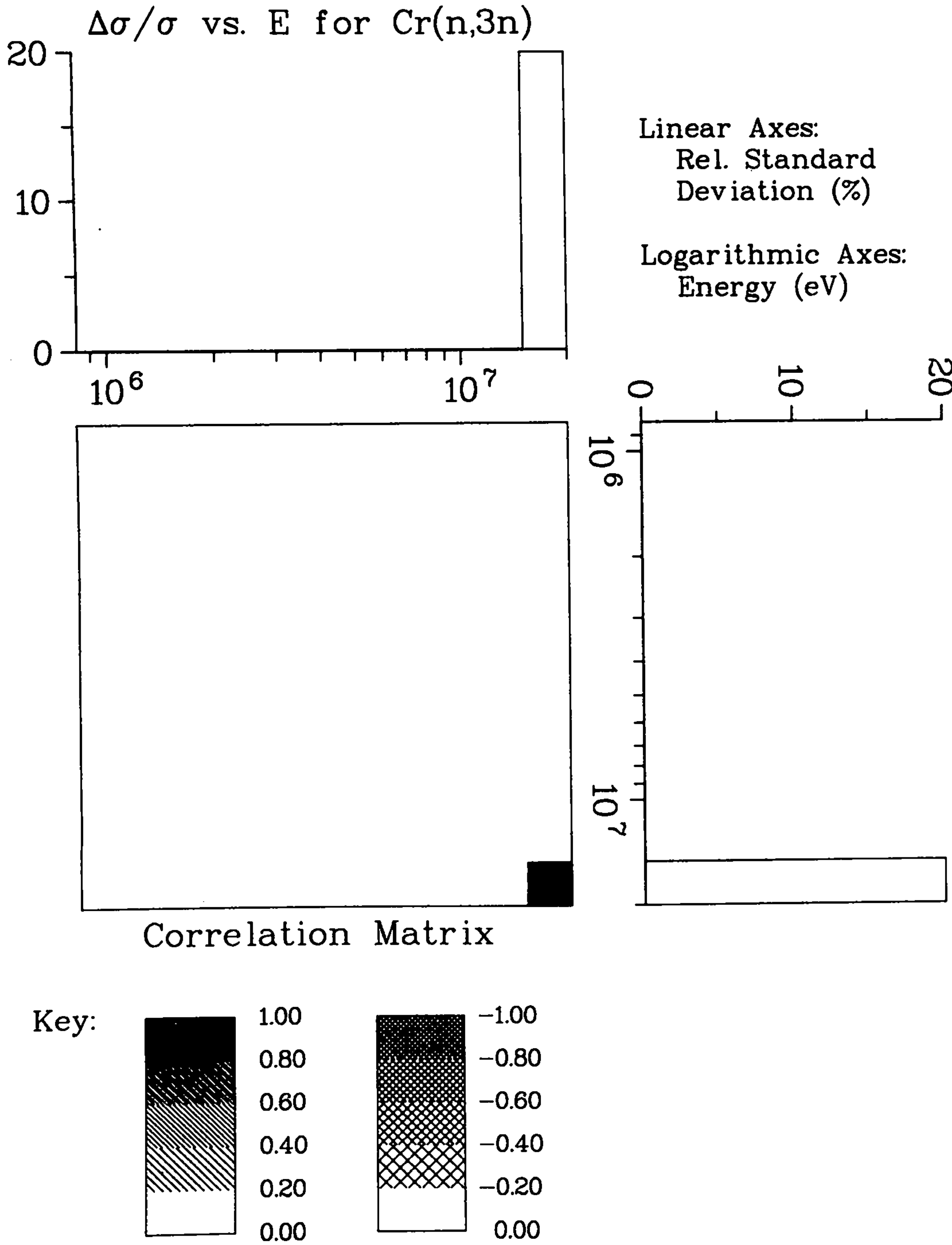


Fig. 61.

Covariance data for Cr(n,3n) with Cr(n,3n).

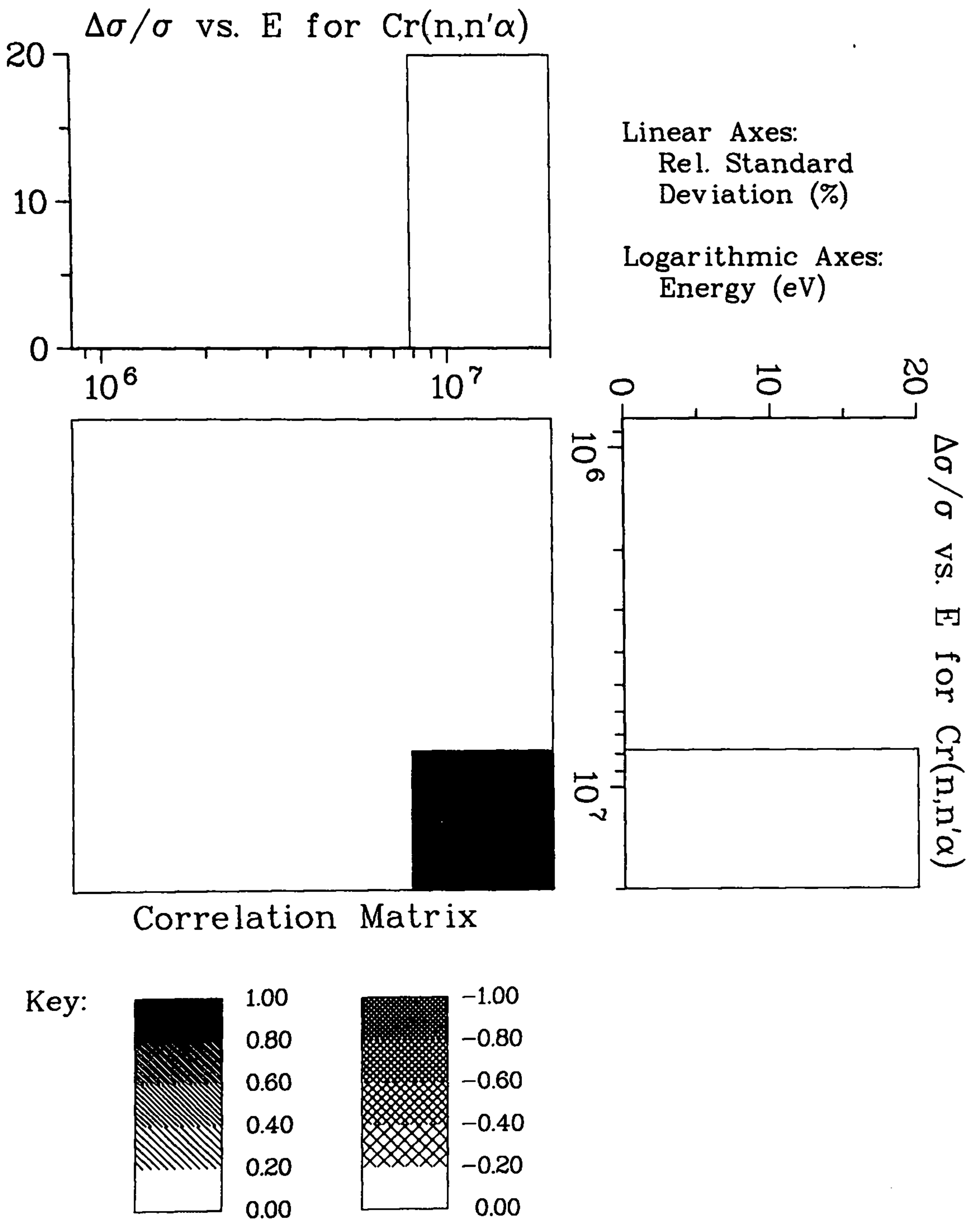


Fig. 62.

Covariance data for Cr(n,n'α) with Cr(n,n'α).

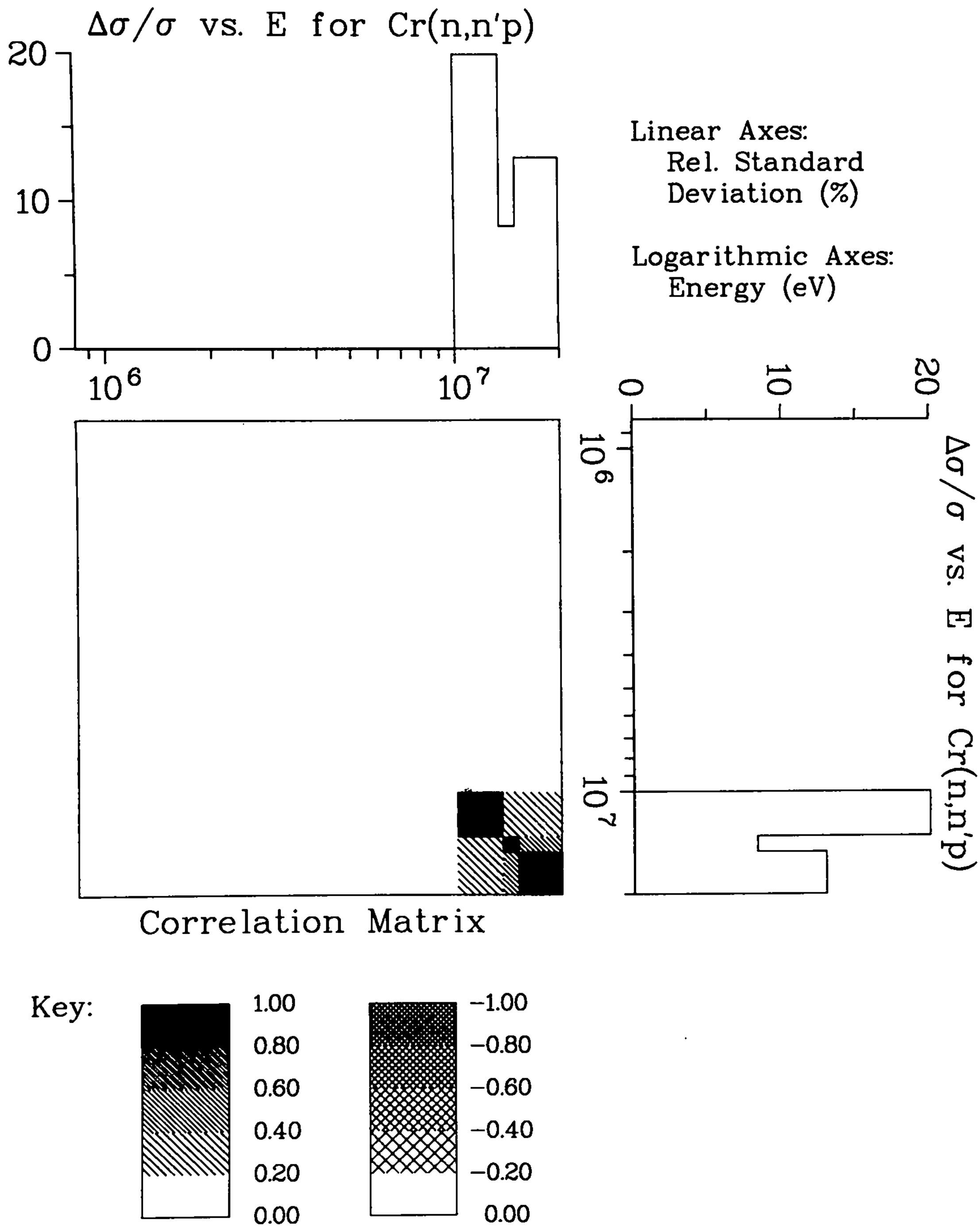


Fig. 63.

Covariance data for Cr(n,n'p) with Cr(n,n'p).

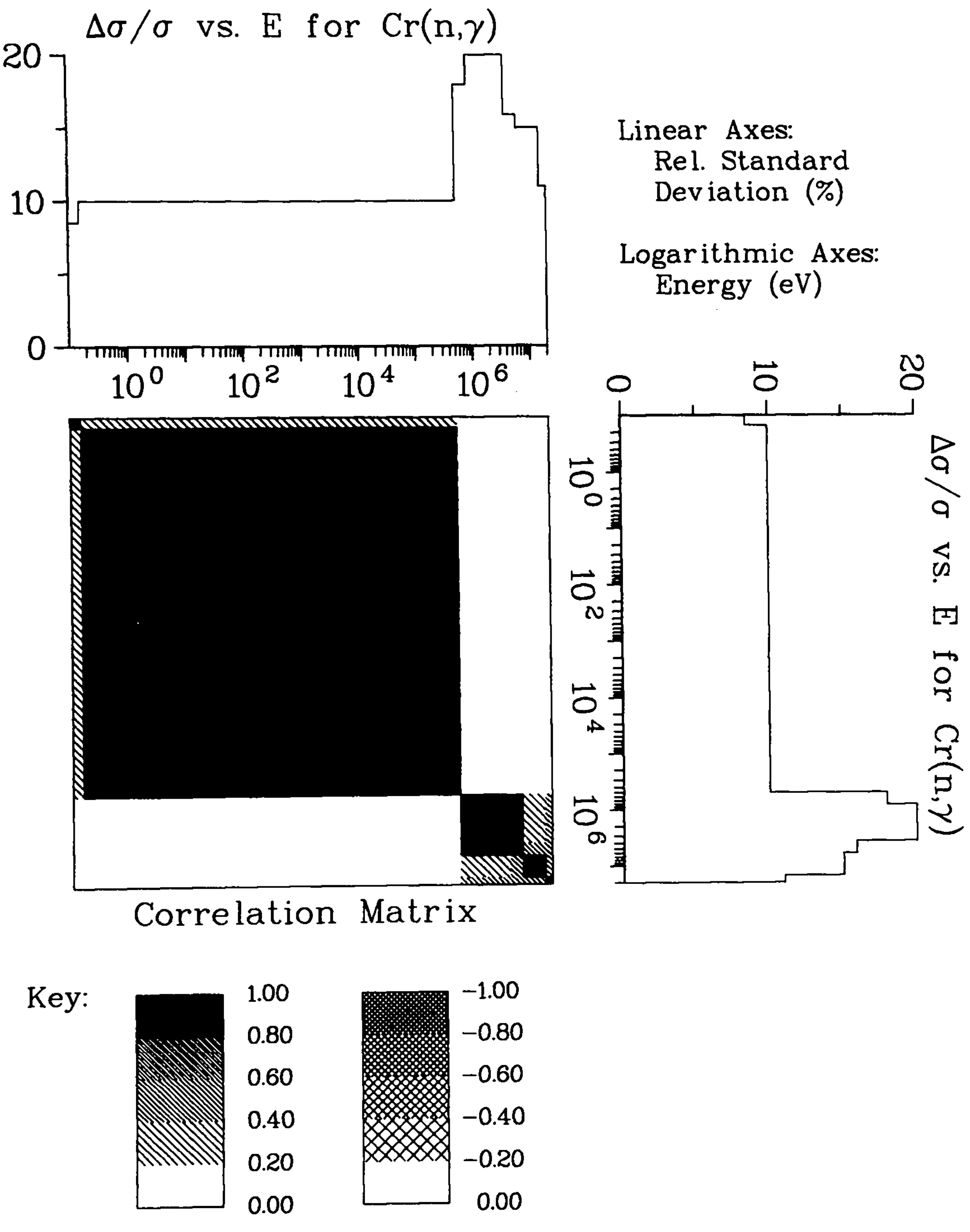


Fig. 64.
Covariance data for Cr(n,γ) with Cr(n,γ).

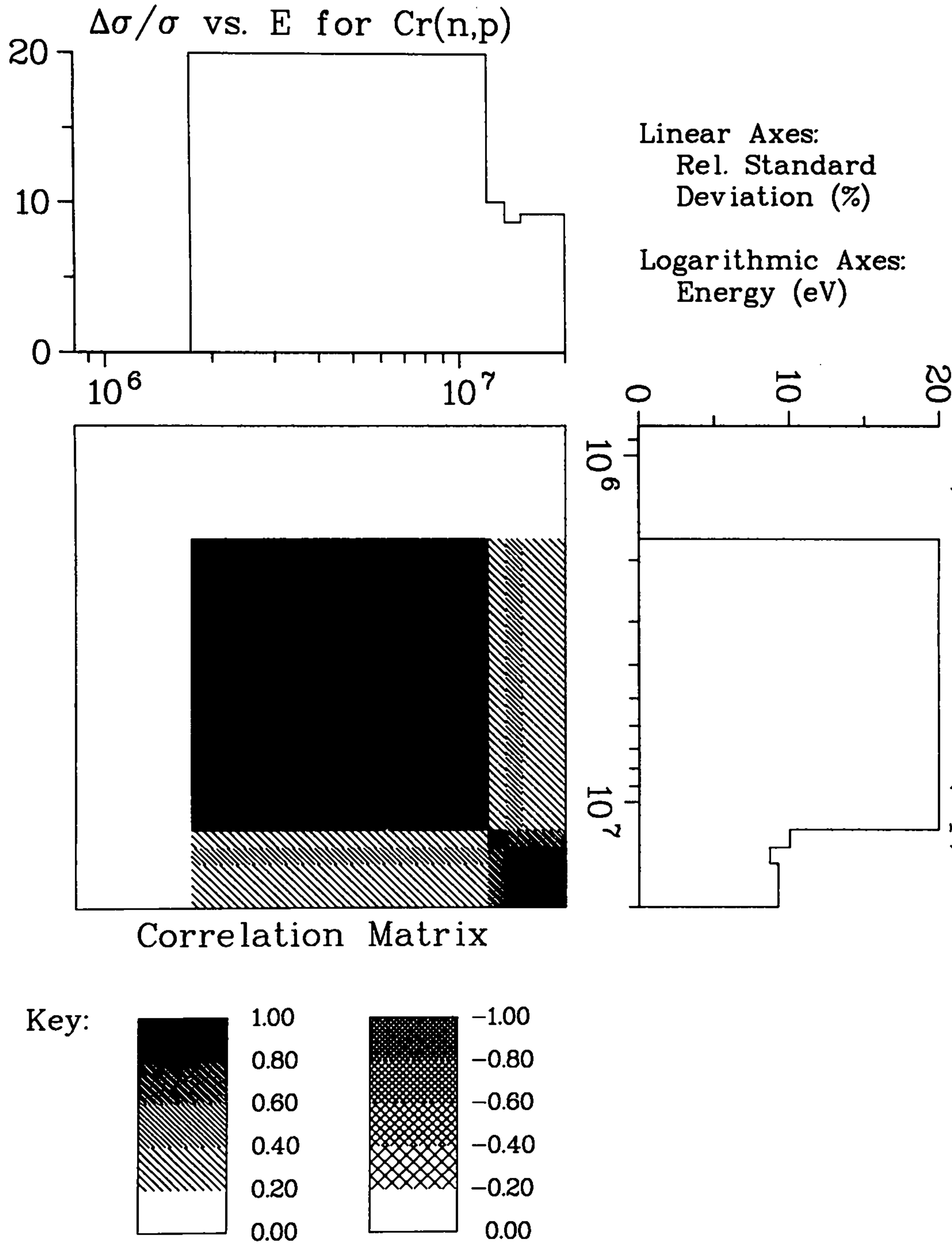


Fig. 65.
Covariance data for Cr(n,p) with Cr(n,p).

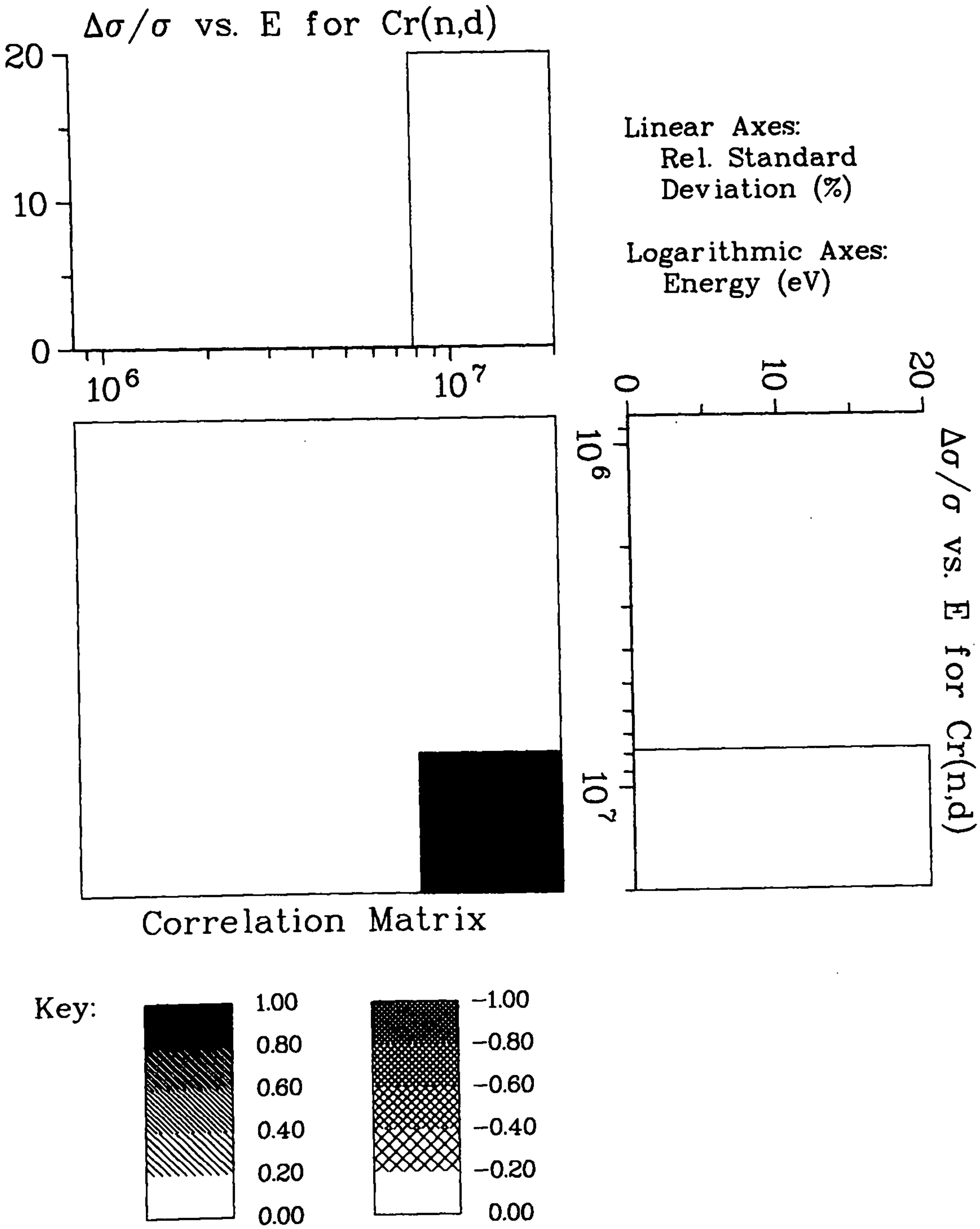


Fig. 66.

Covariance data for Cr(n,d) with Cr(n,d).

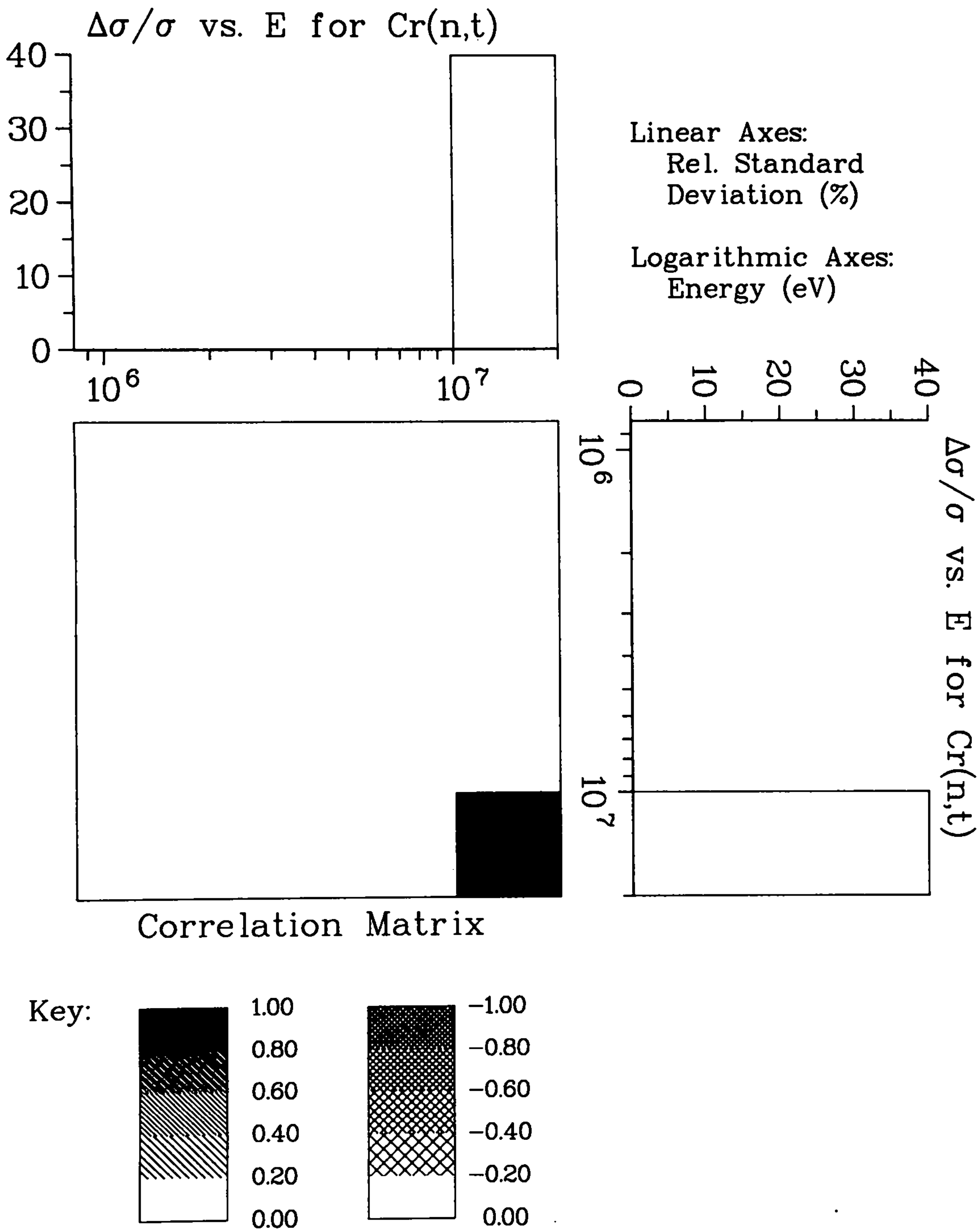


Fig. 67.
Covariance data for Cr(n,t) with Cr(n,t).

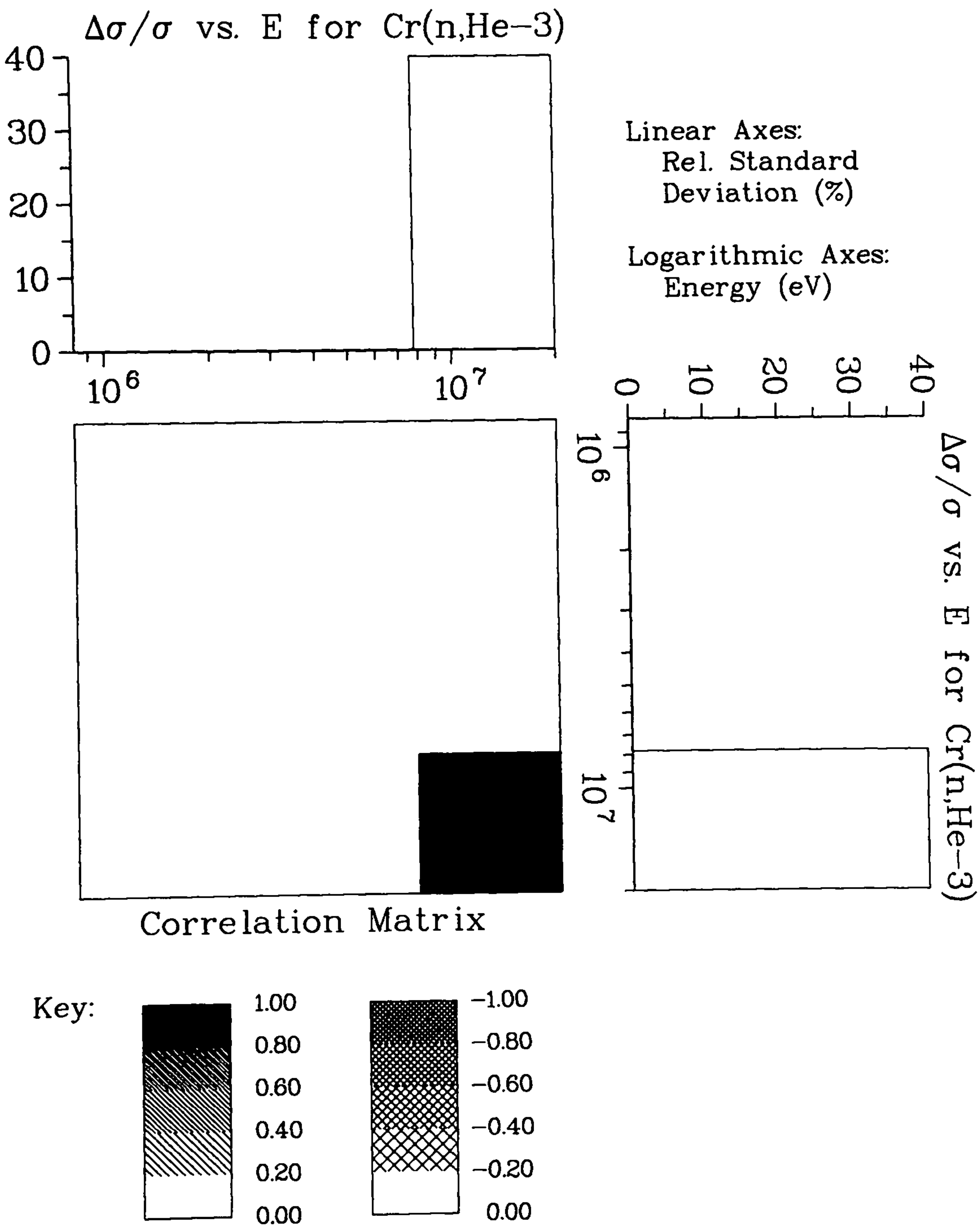


Fig. 68.
Covariance data for Cr(n,He−3) with Cr(n,He−3).

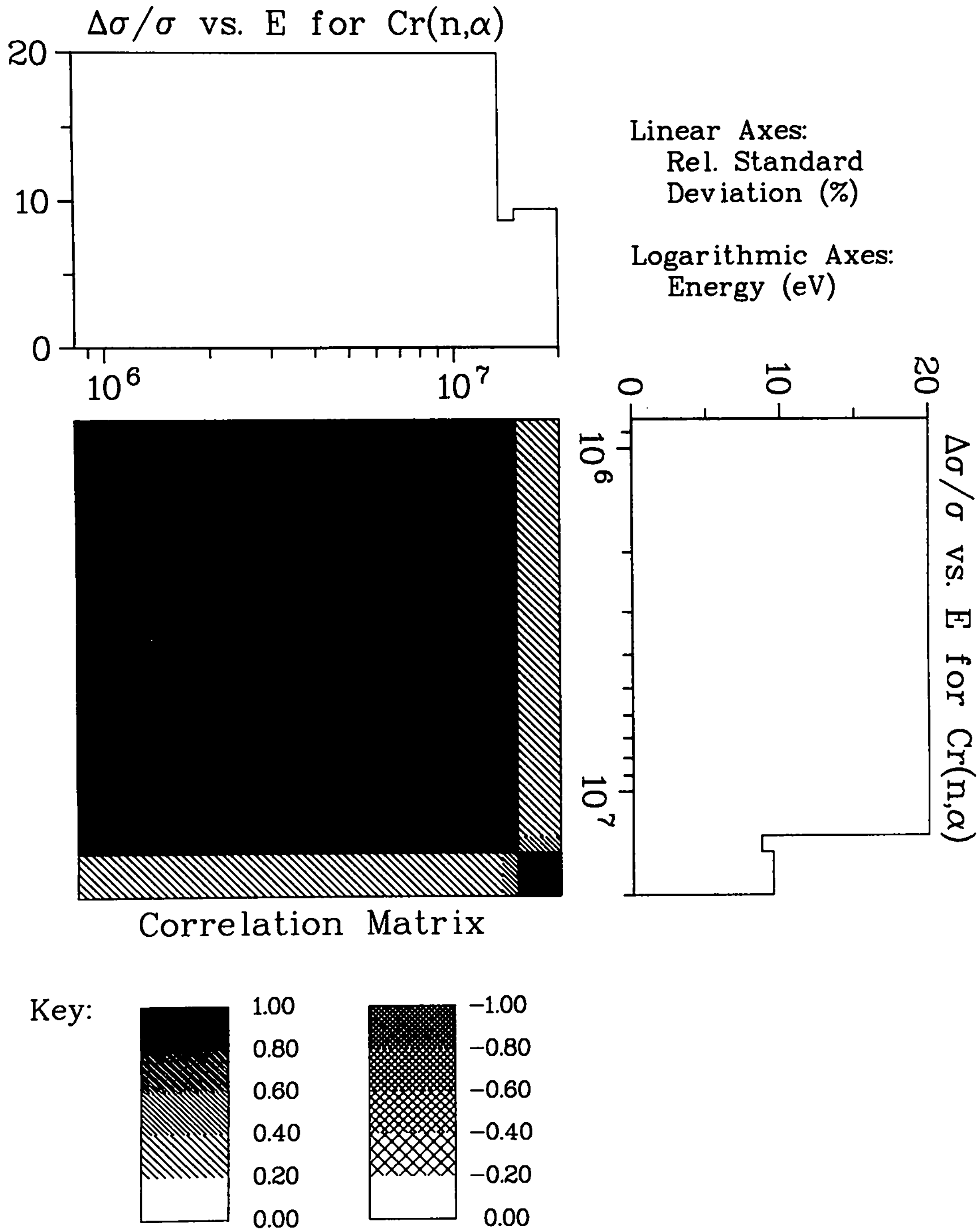


Fig. 69.
Covariance data for Cr(n,α) with Cr(n,α).

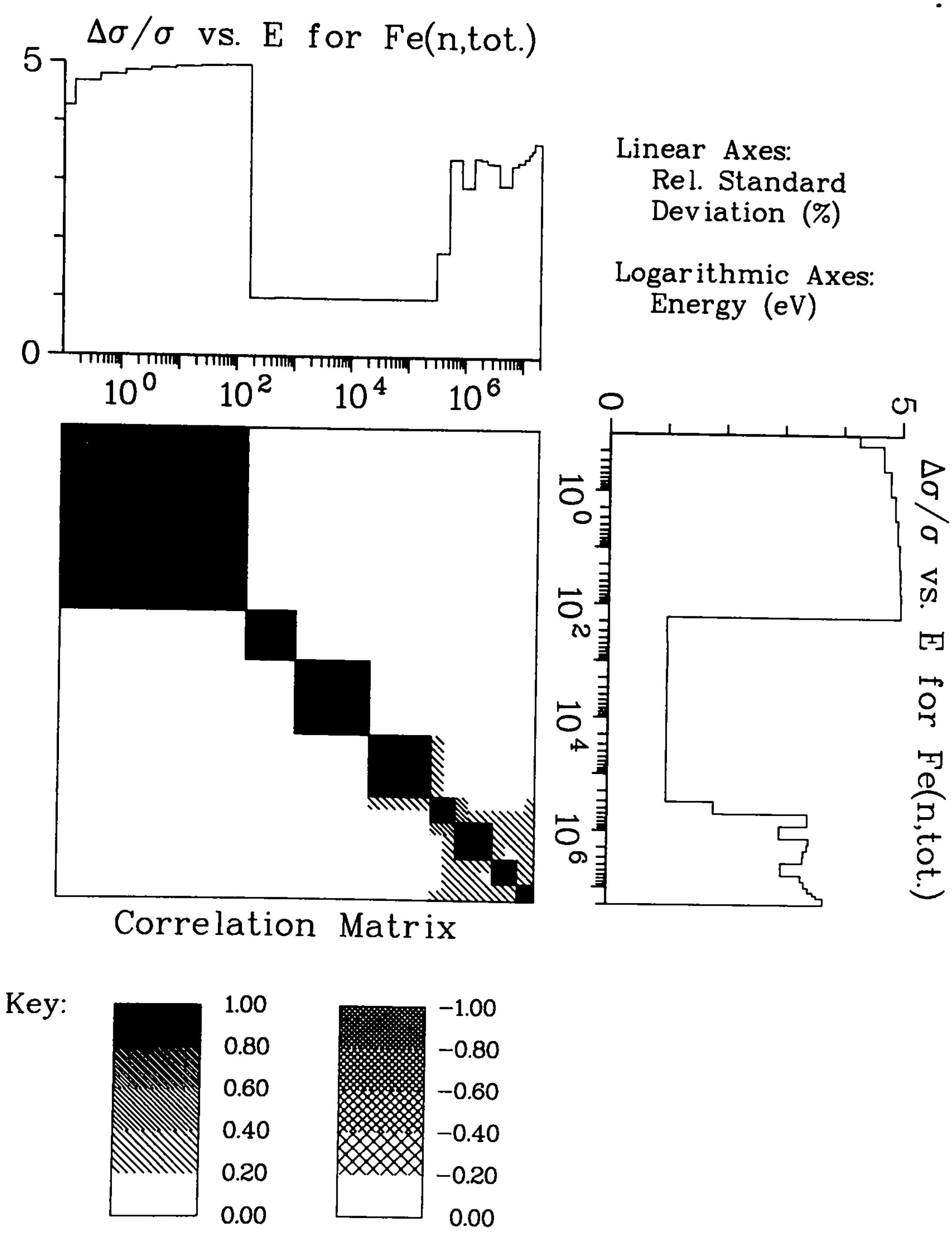


Fig. 70.

Covariance data for Fe(n,tot.) with Fe(n,tot.).

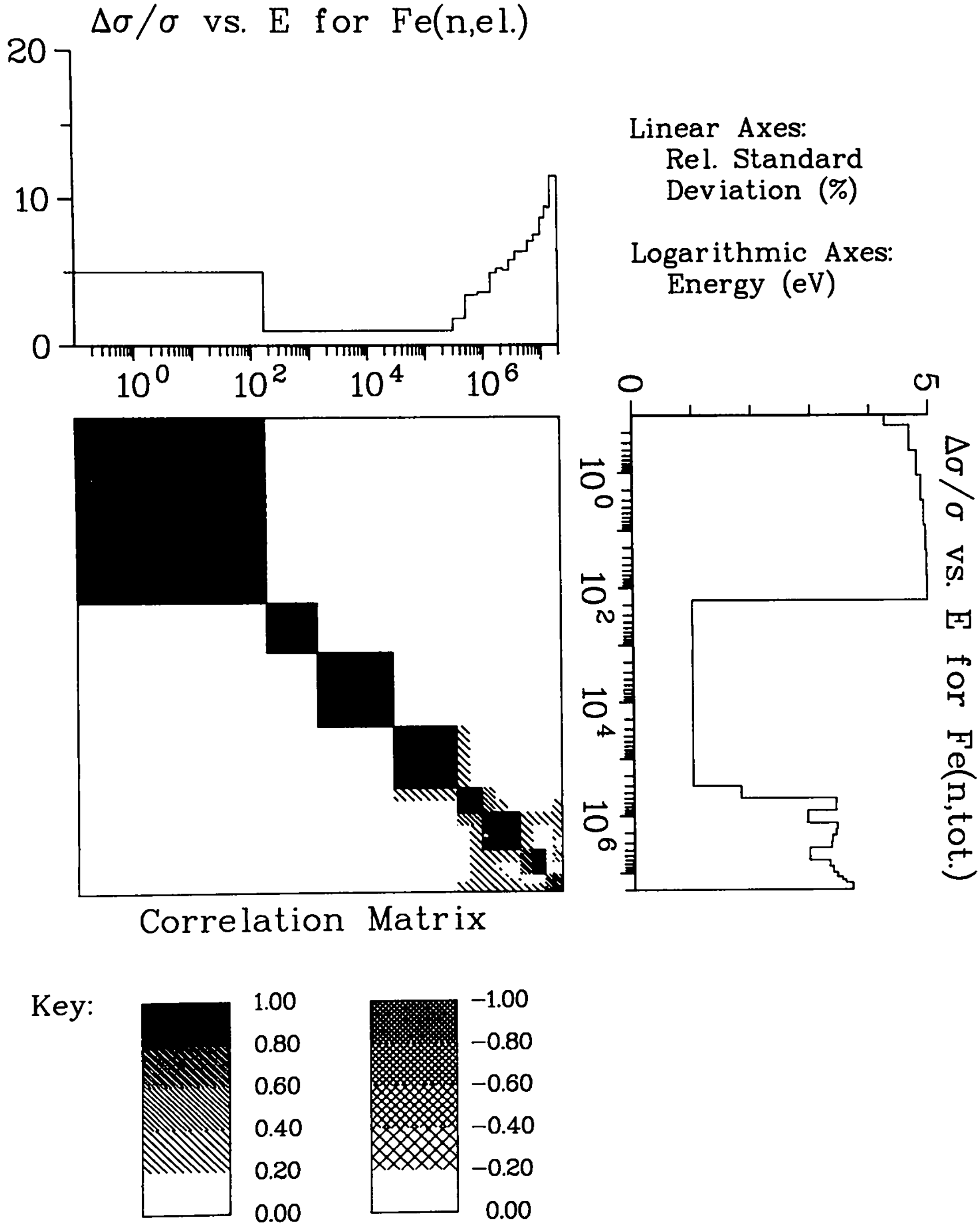


Fig. 71.
Covariance data for Fe(n,tot.) with Fe(n,el.).

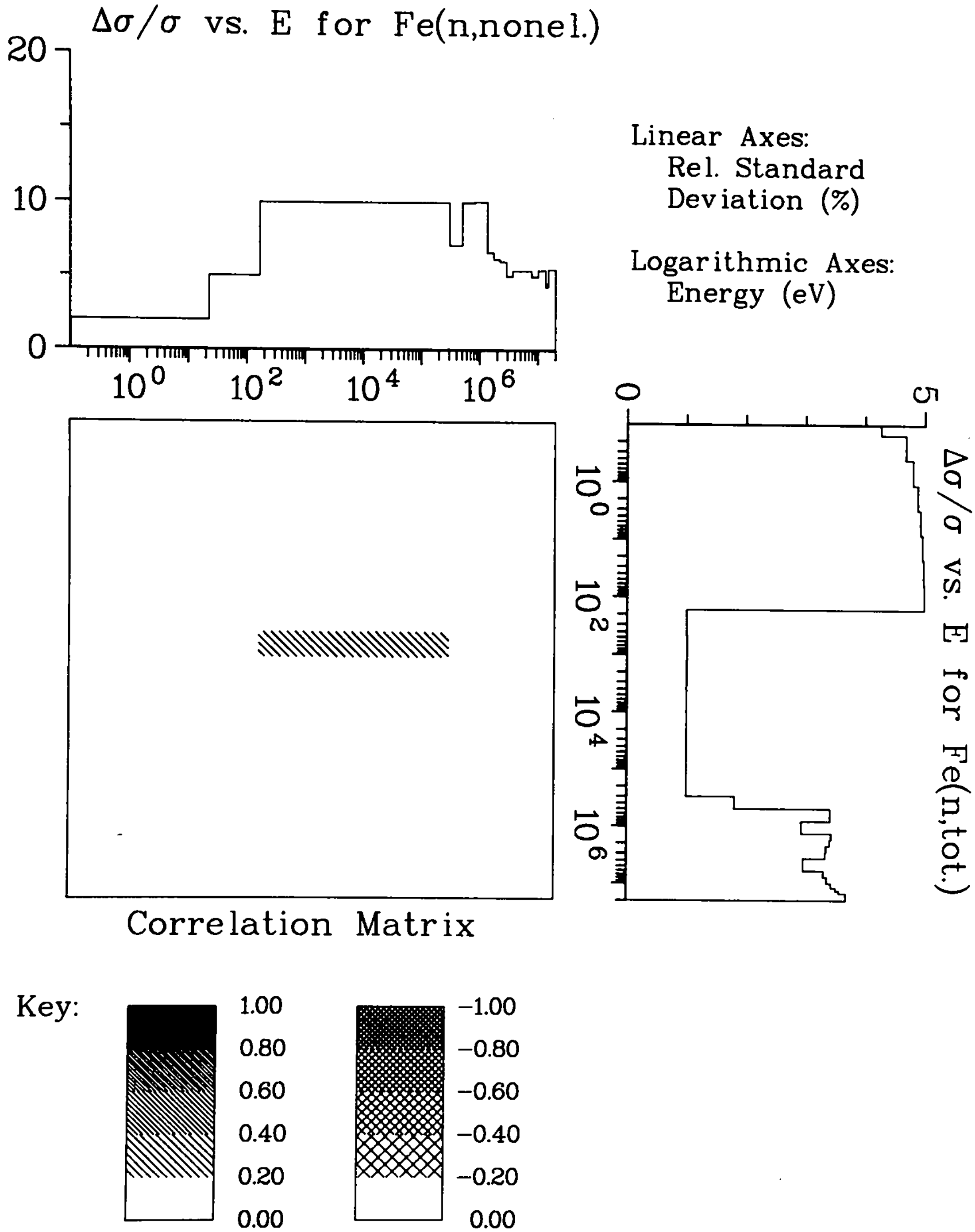


Fig. 72.
Covariance data for Fe(n,tot.) with Fe(n,nonel.).

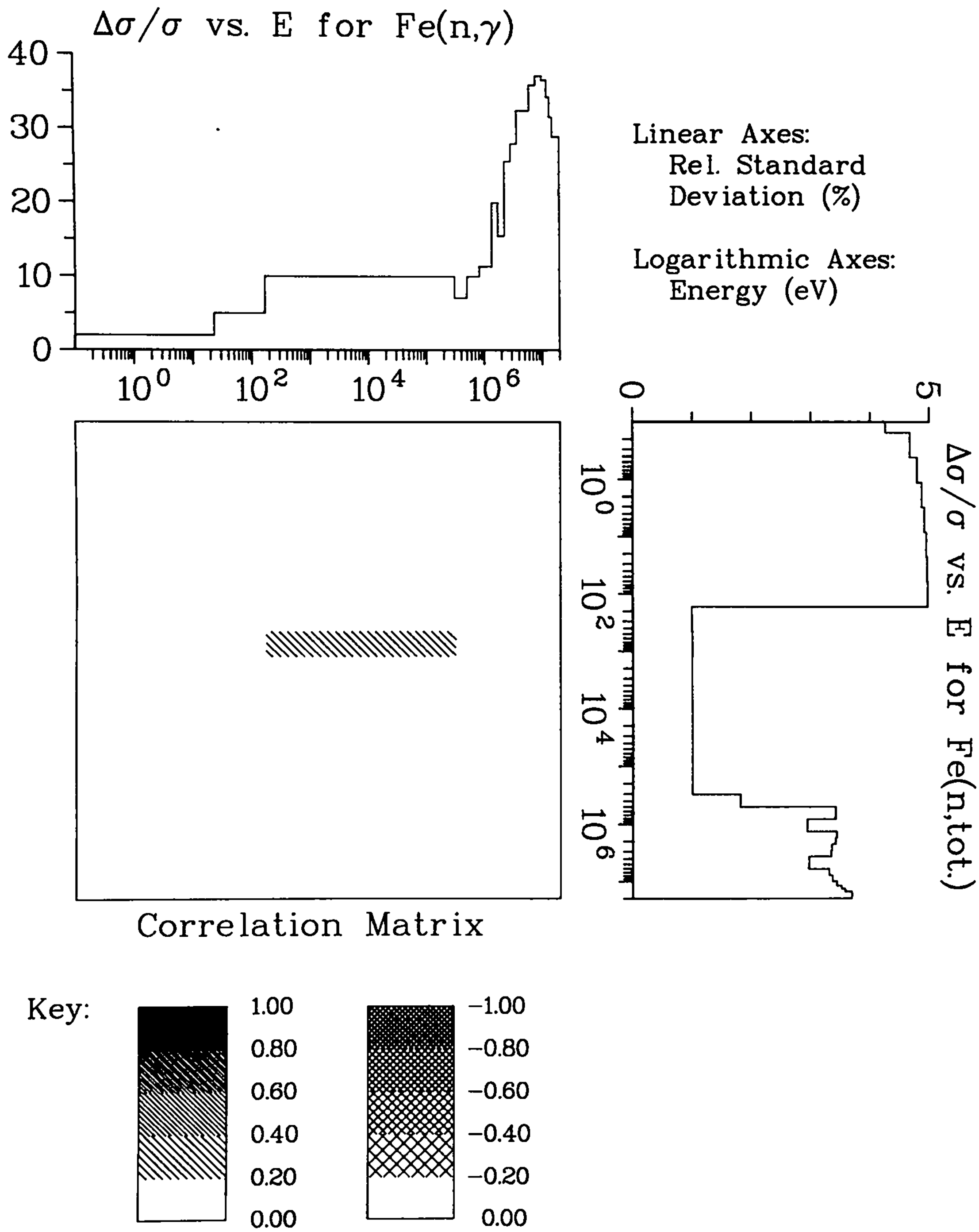


Fig. 73.
Covariance data for Fe(n,tot.) with Fe(n,γ).

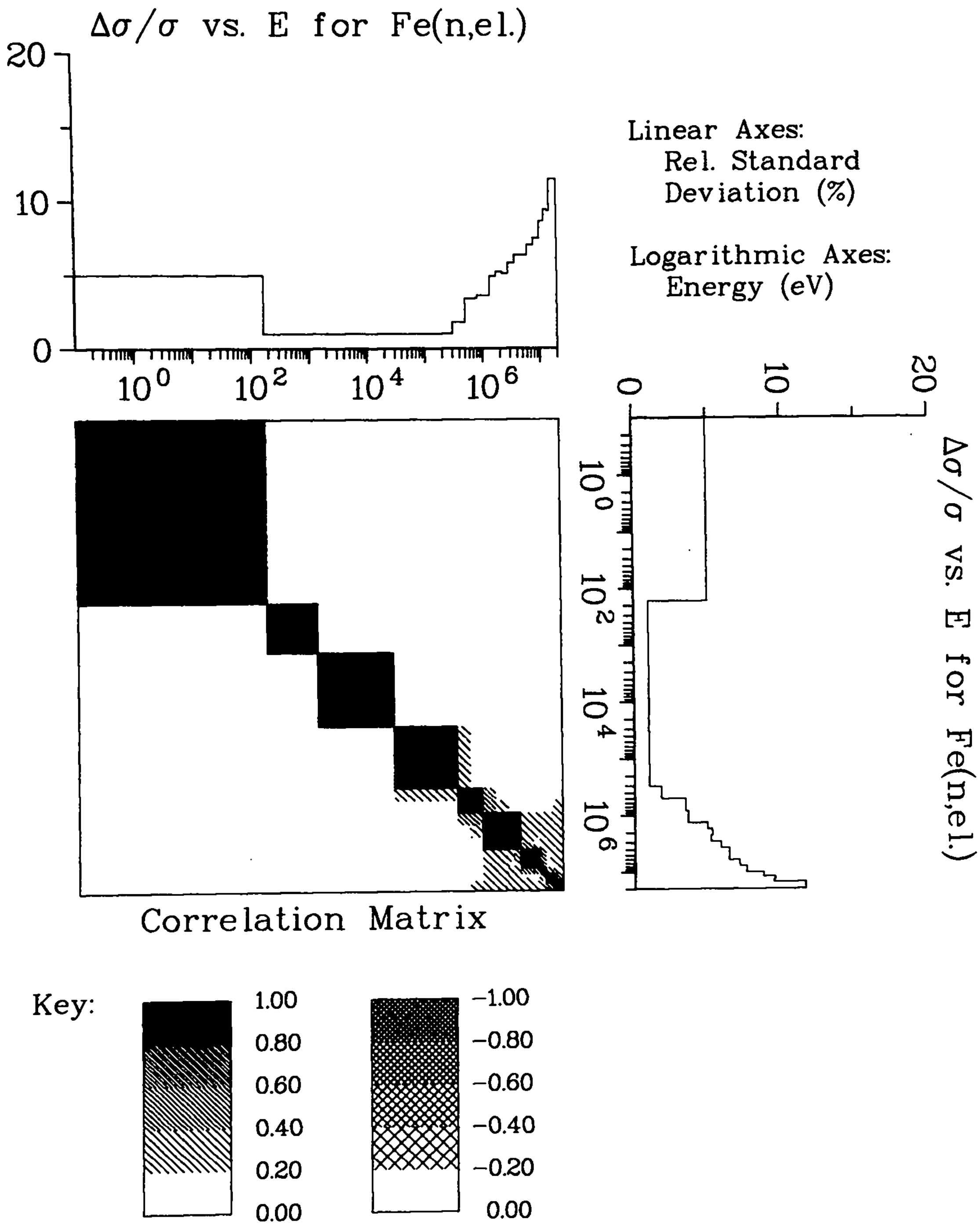


Fig. 74.
Covariance data for Fe(n,el.) with Fe(n,el.).

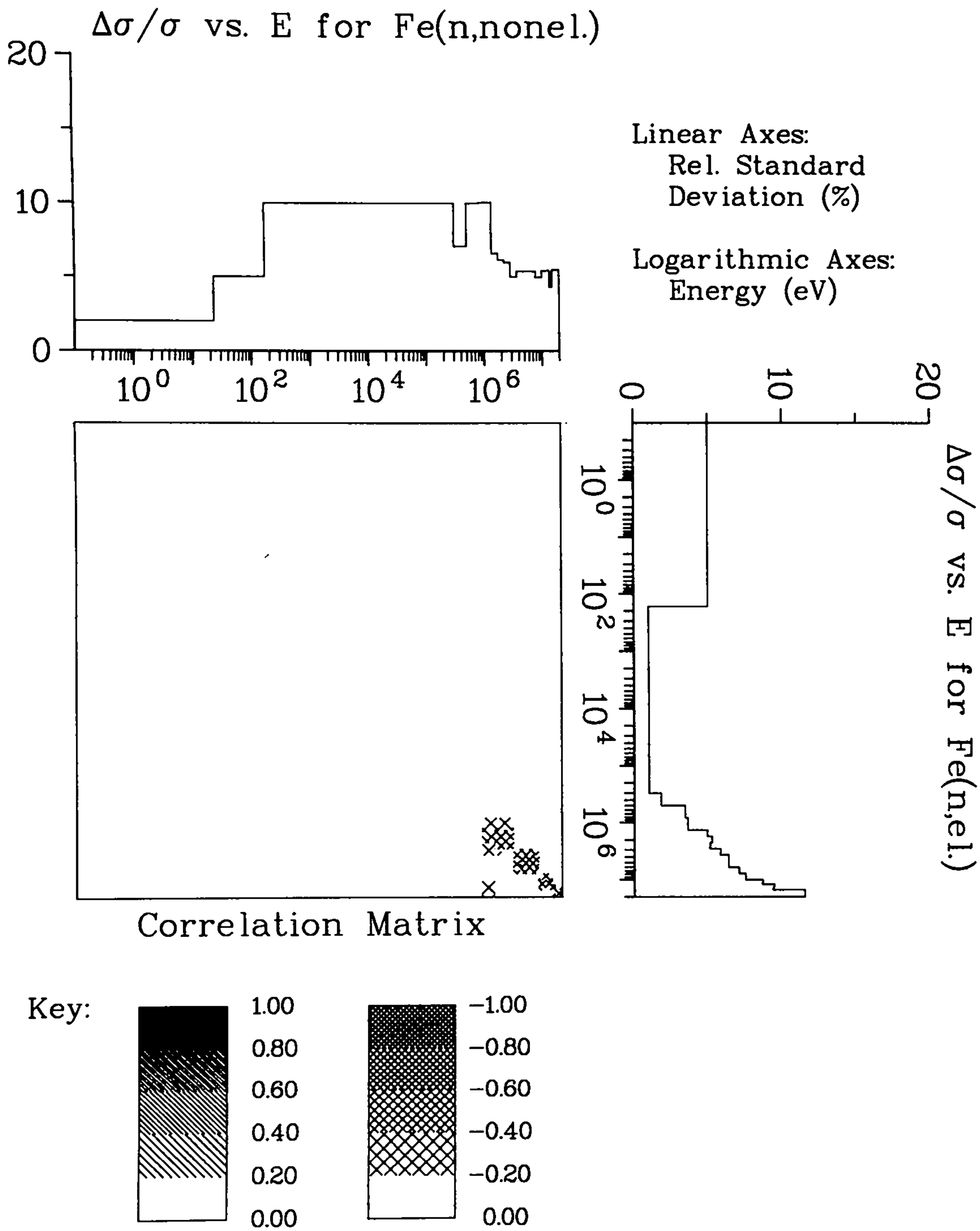


Fig. 75.
Covariance data for Fe(n,el.) with Fe(n,nonel.).

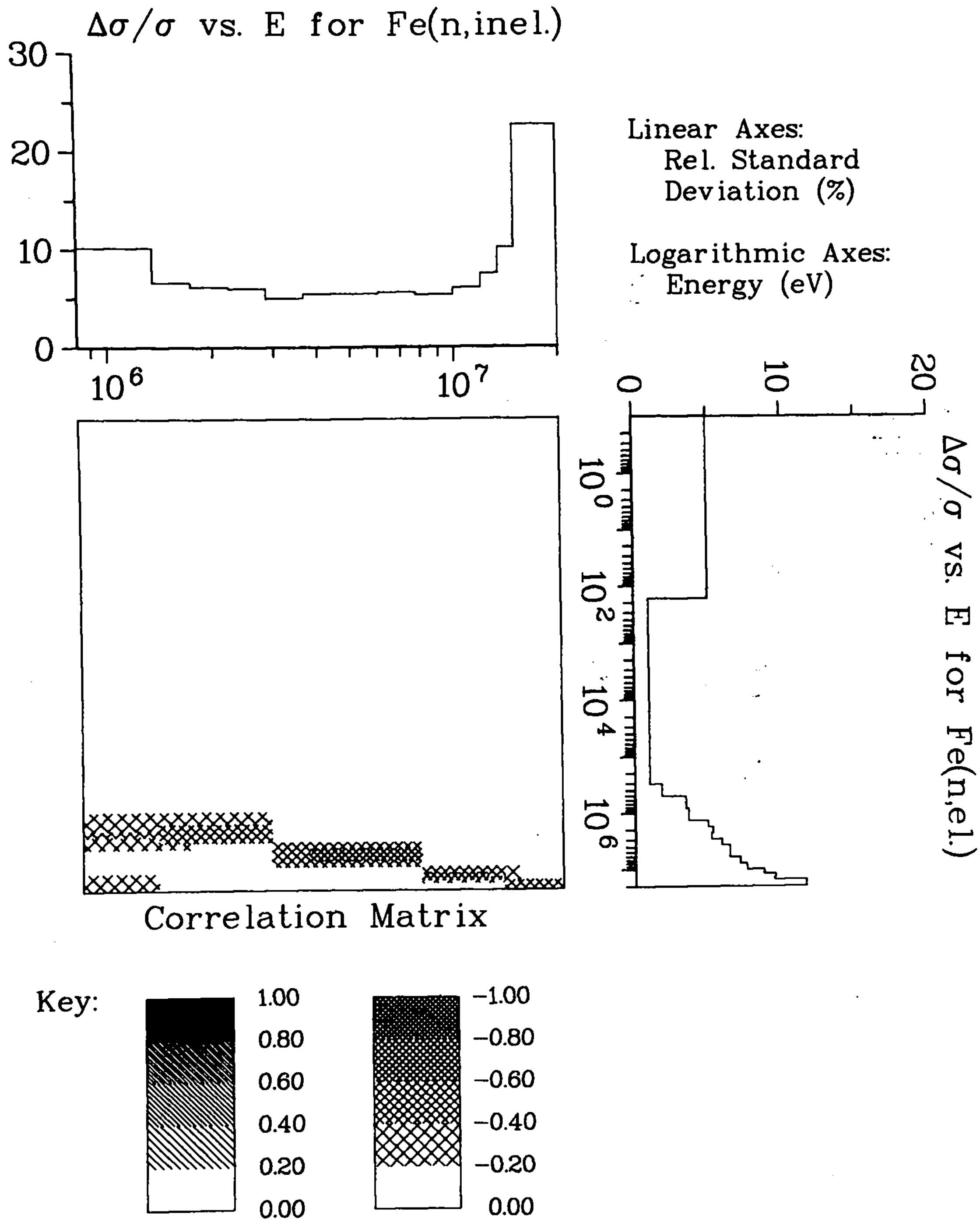


Fig. 76.
Covariance data for Fe(n,el.) with Fe(n,inel.).

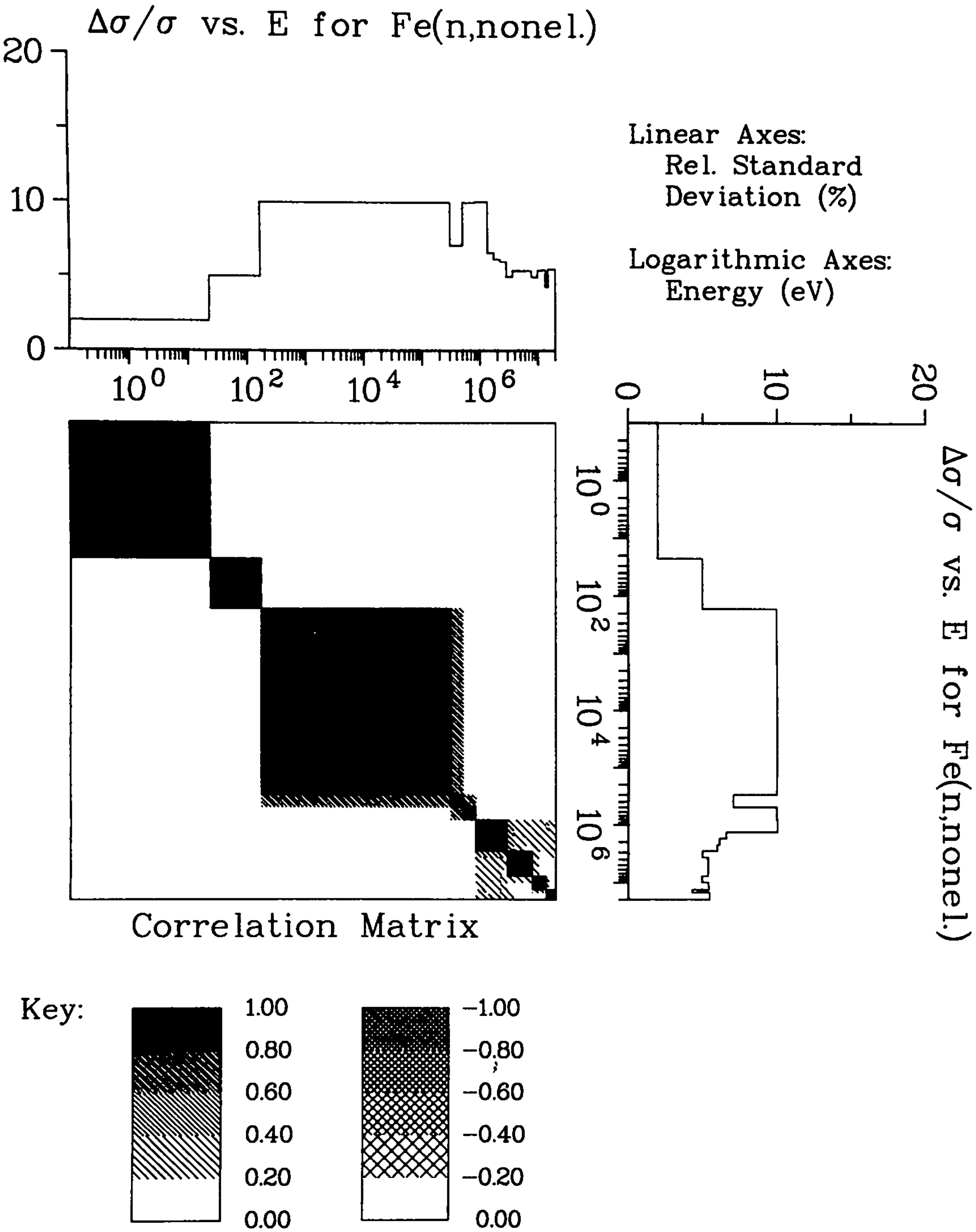


Fig. 77.
Covariance data for Fe(n,nonel.) with Fe(n,nonel.).

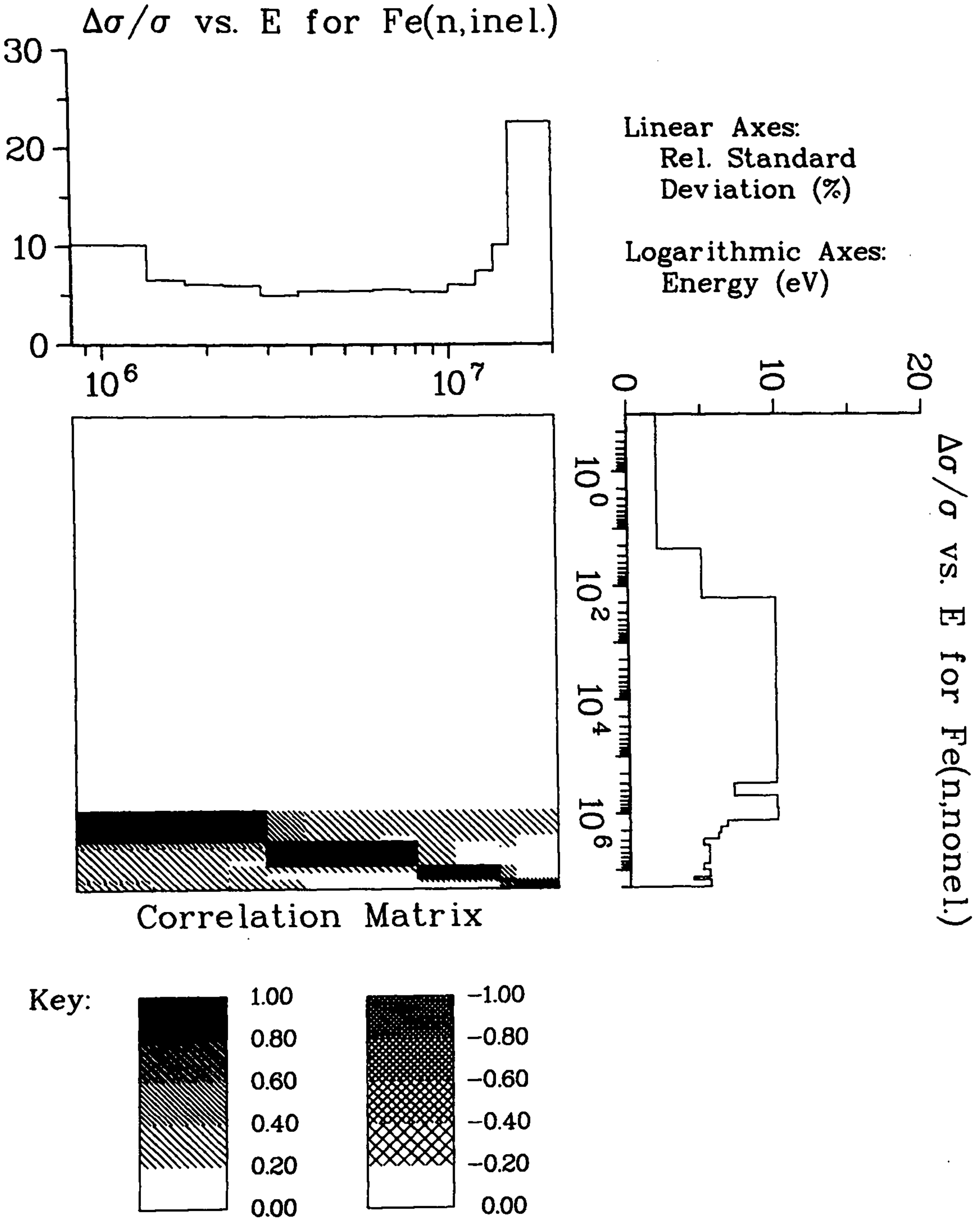


Fig. 78.

Covariance data for Fe(n,nonel.) with Fe(n,inel.).

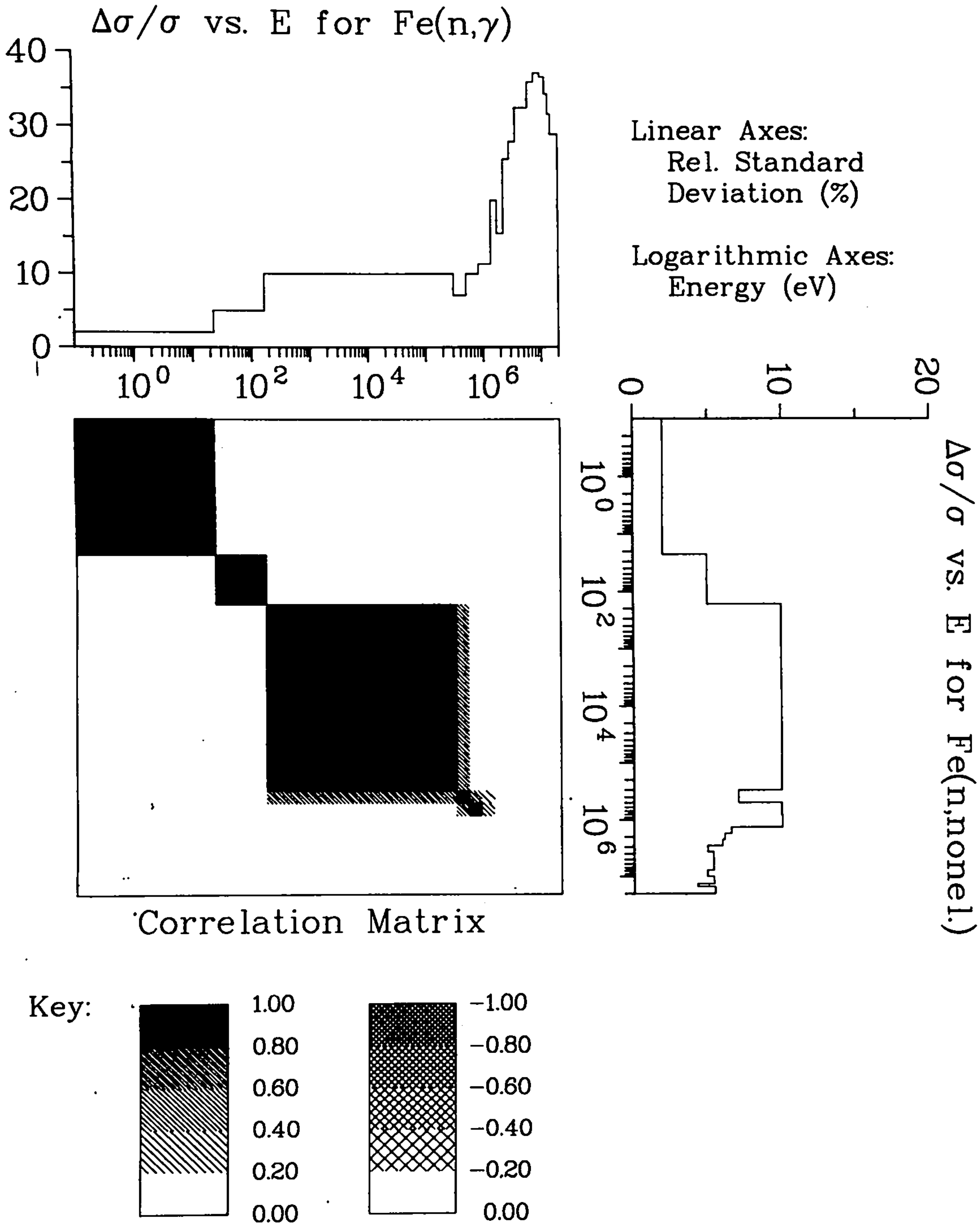


Fig. 79.
Covariance data for Fe(n,nonel.) with Fe(n,γ).

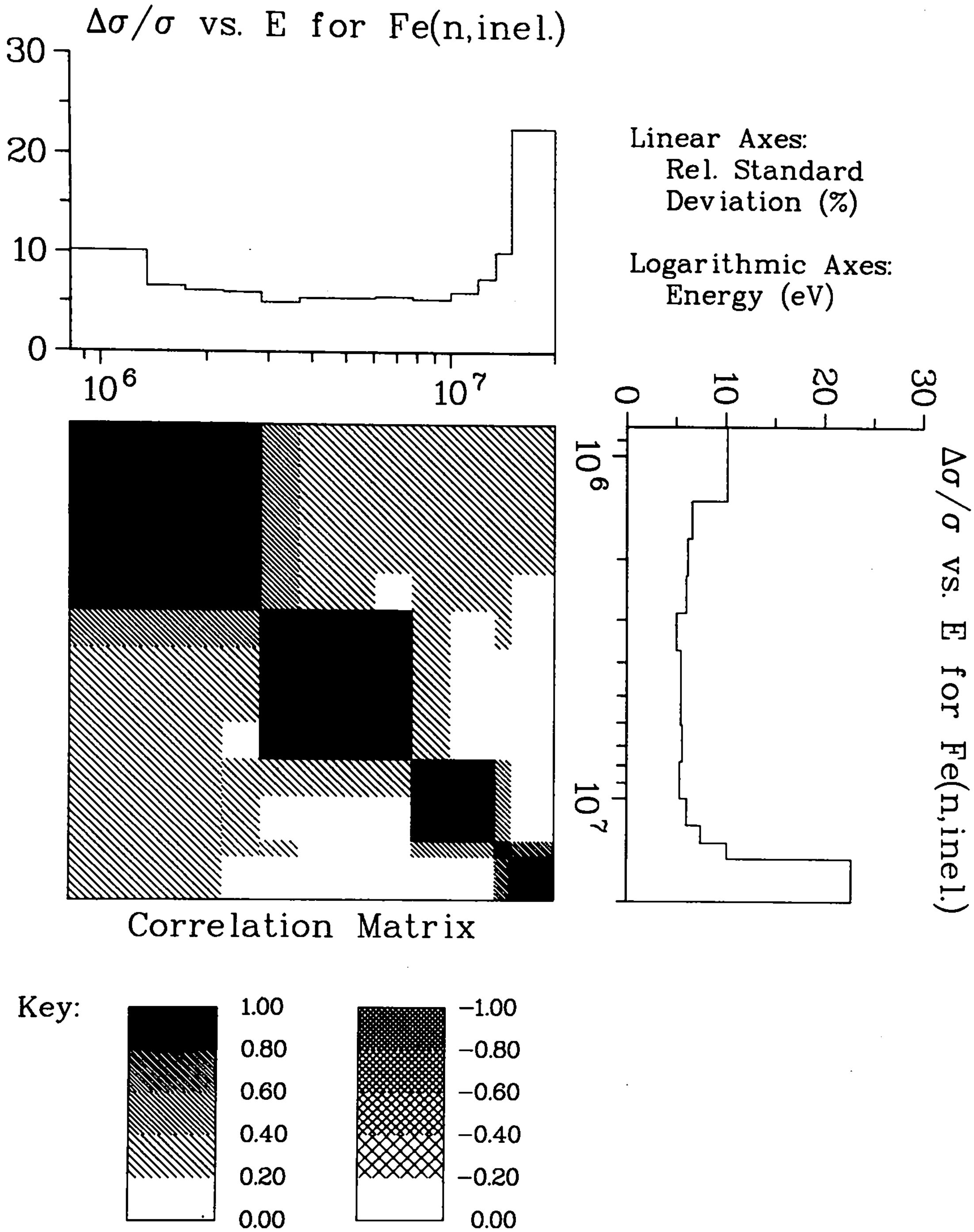


Fig. 80.
Covariance data for Fe(n,inel.) with Fe(n,inel.).

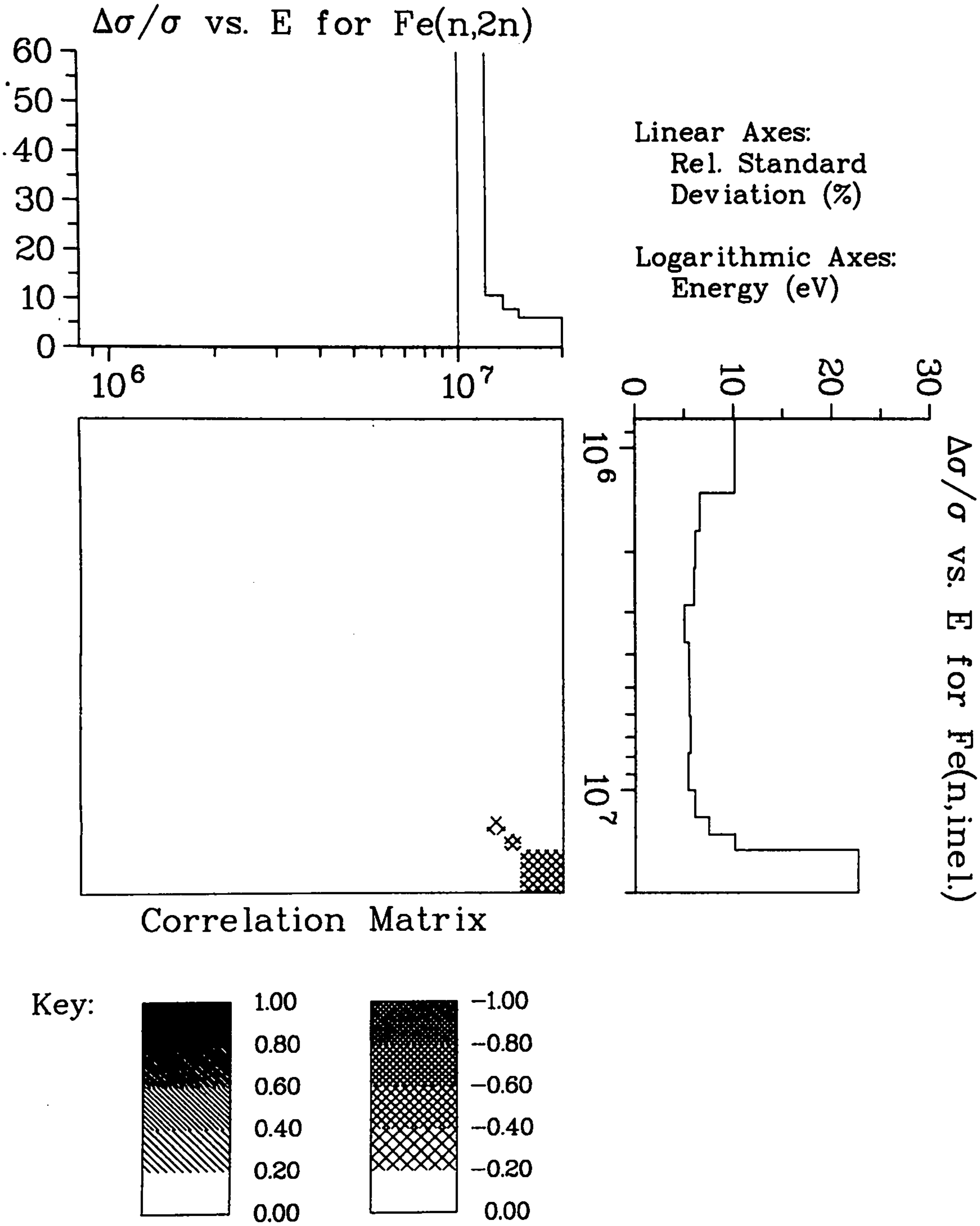


Fig. 81.
Covariance data for Fe(n,inel.) with Fe(n,2n).

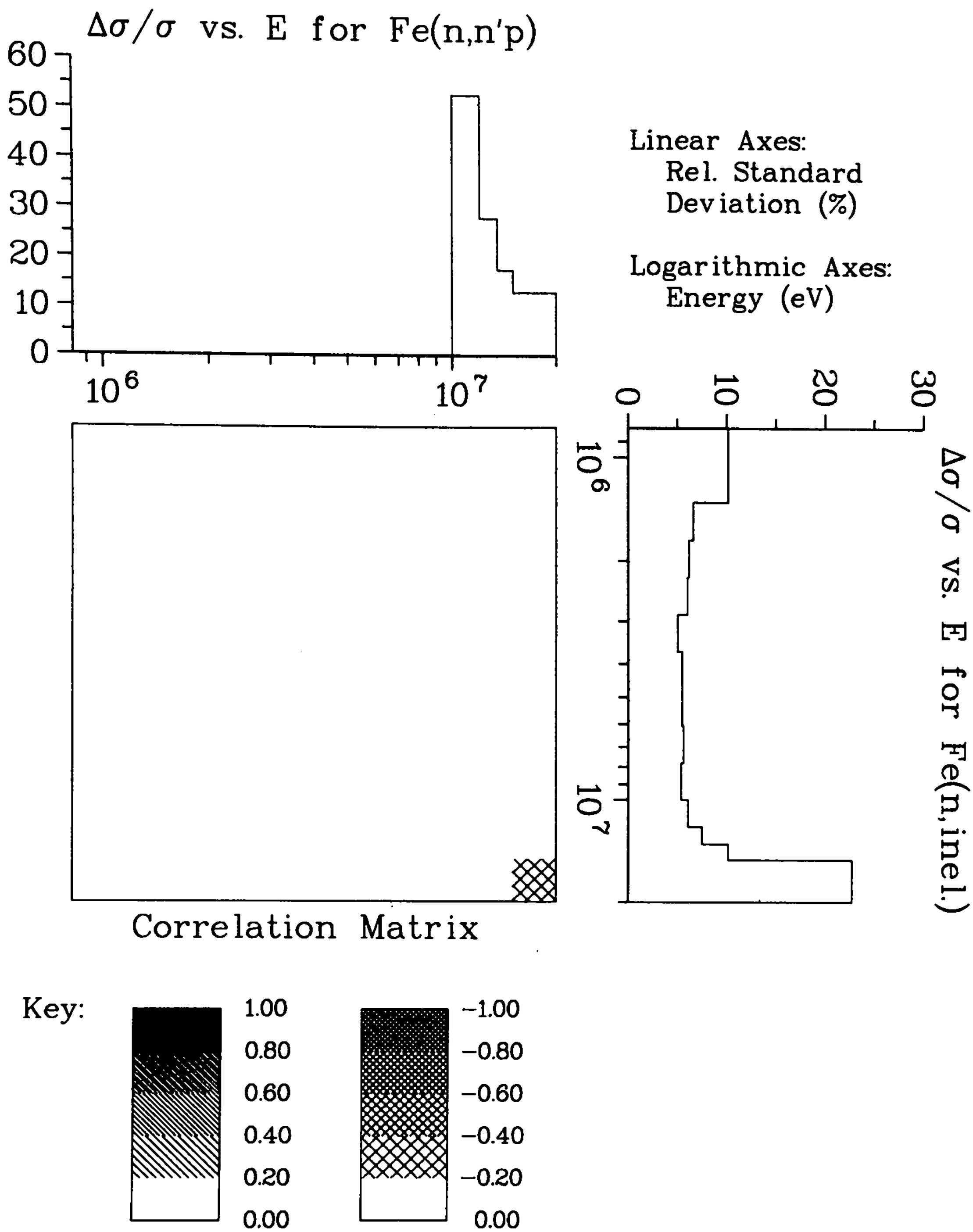


Fig. 82.
Covariance data for Fe(n,inel.) with Fe(n,n'p).

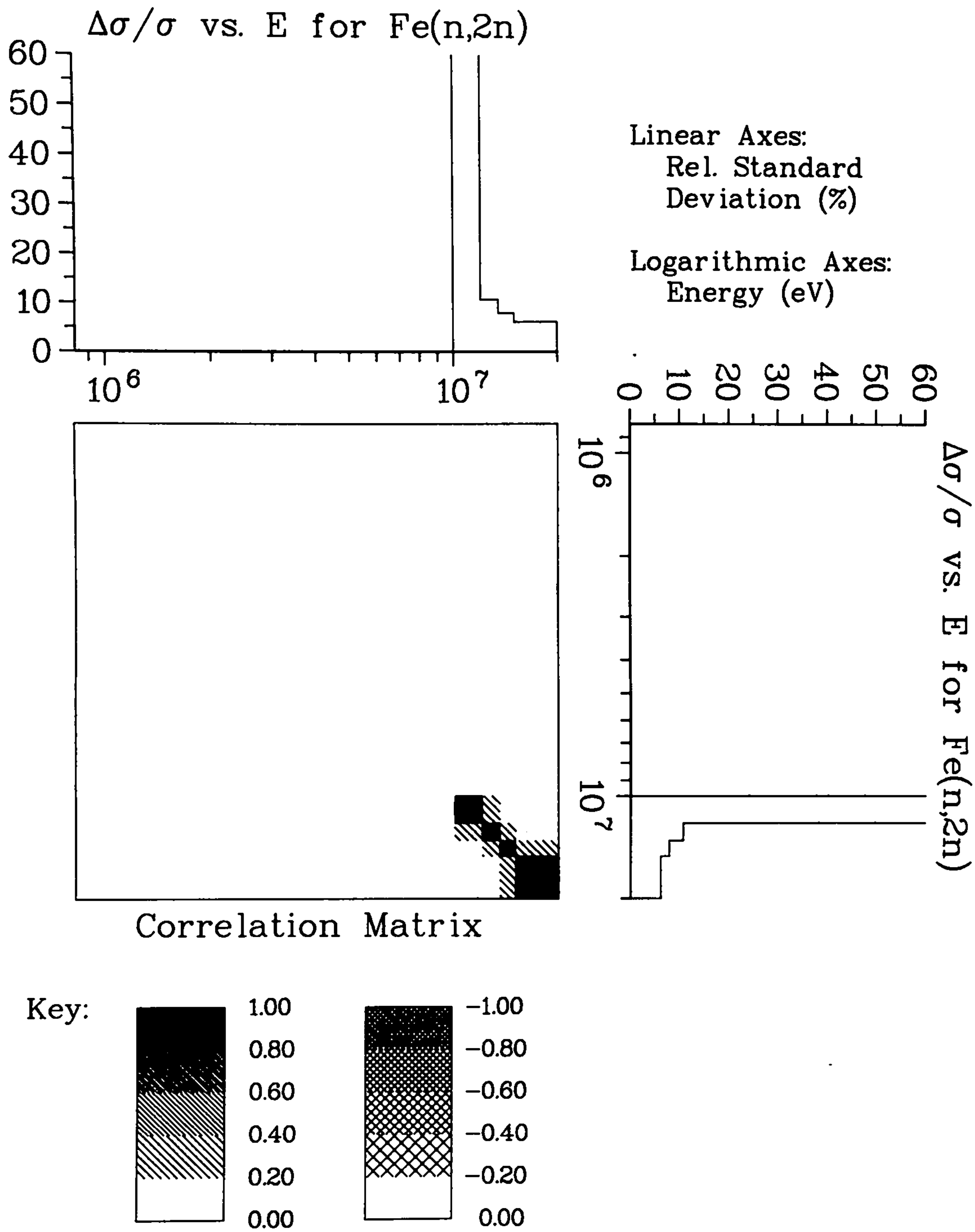


Fig. 83.
Covariance data for Fe(n,2n) with Fe(n,2n).

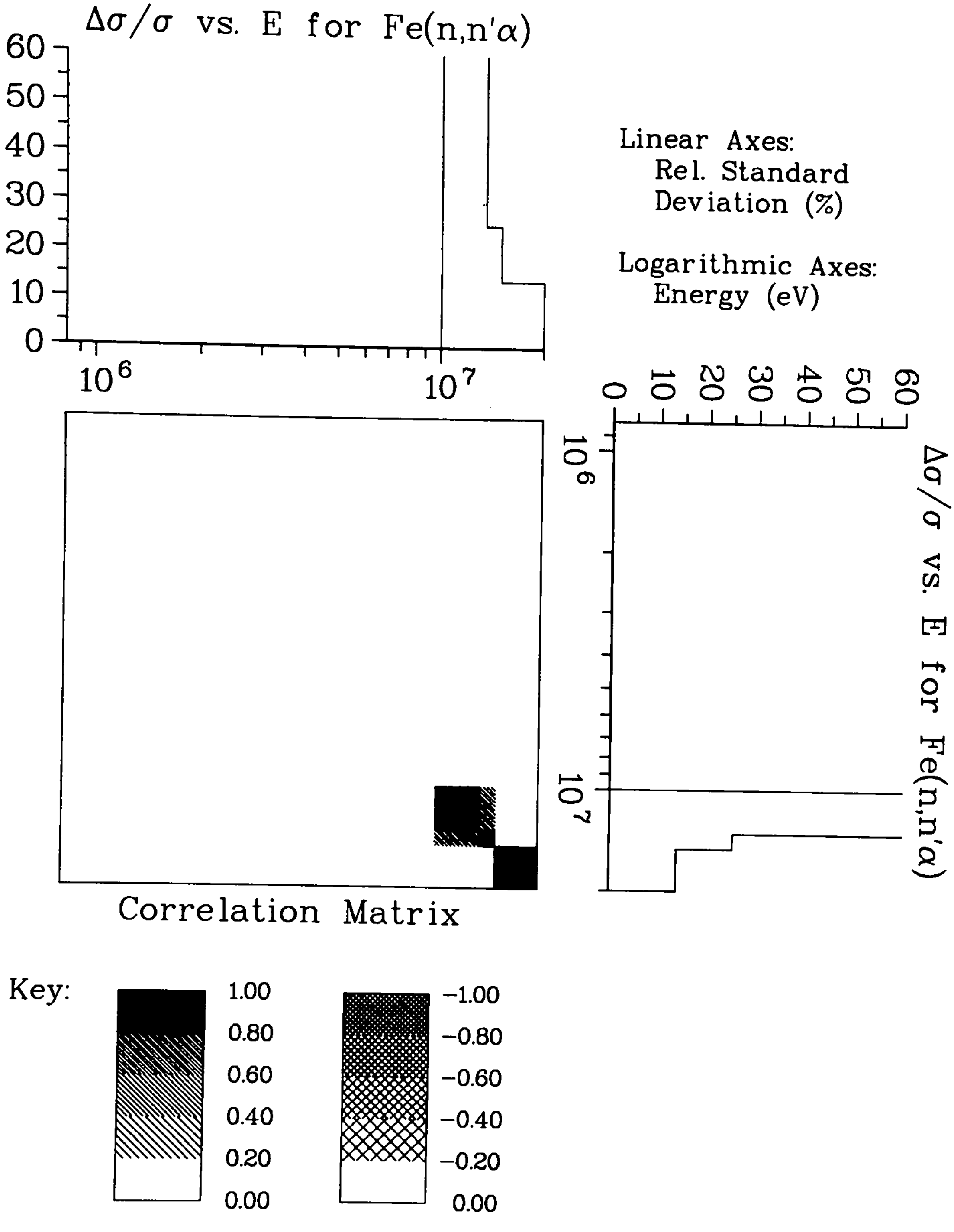


Fig. 84.
Covariance data for Fe(n,n'α) with Fe(n,n'α).

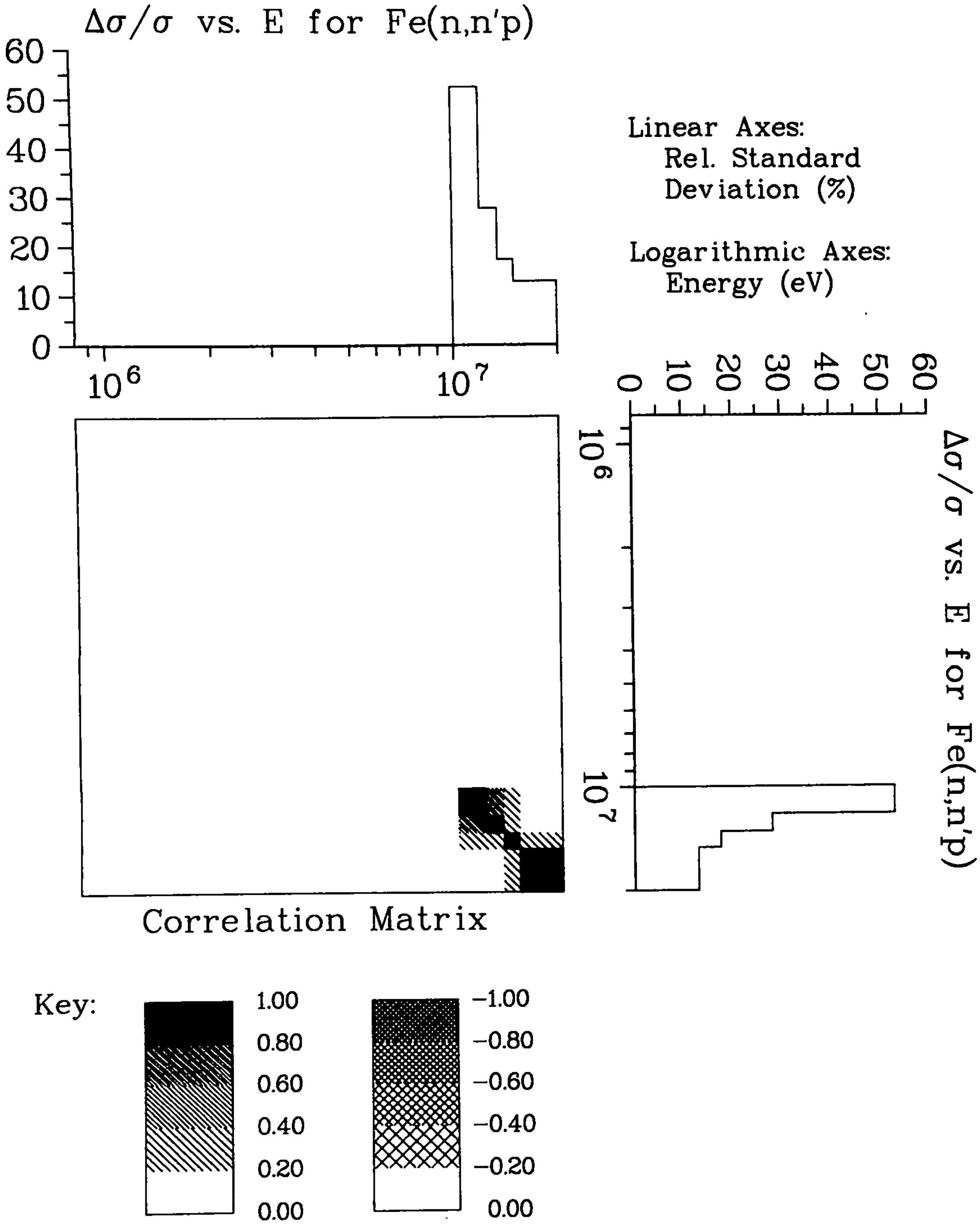


Fig. 85.
Covariance data for Fe(n,n'p) with Fe(n,n'p).

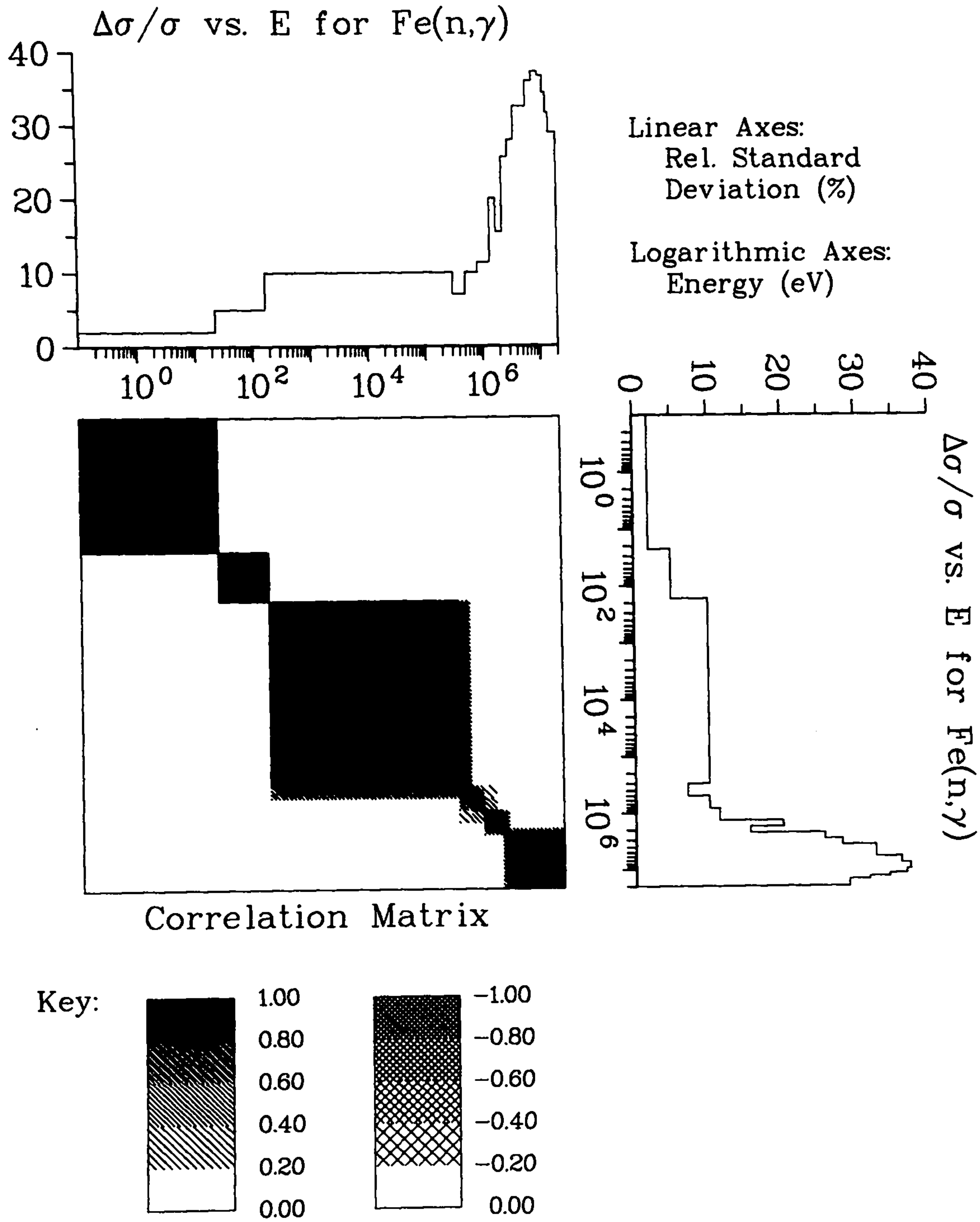


Fig. 86.

Covariance data for Fe(n,γ) with Fe(n,γ).

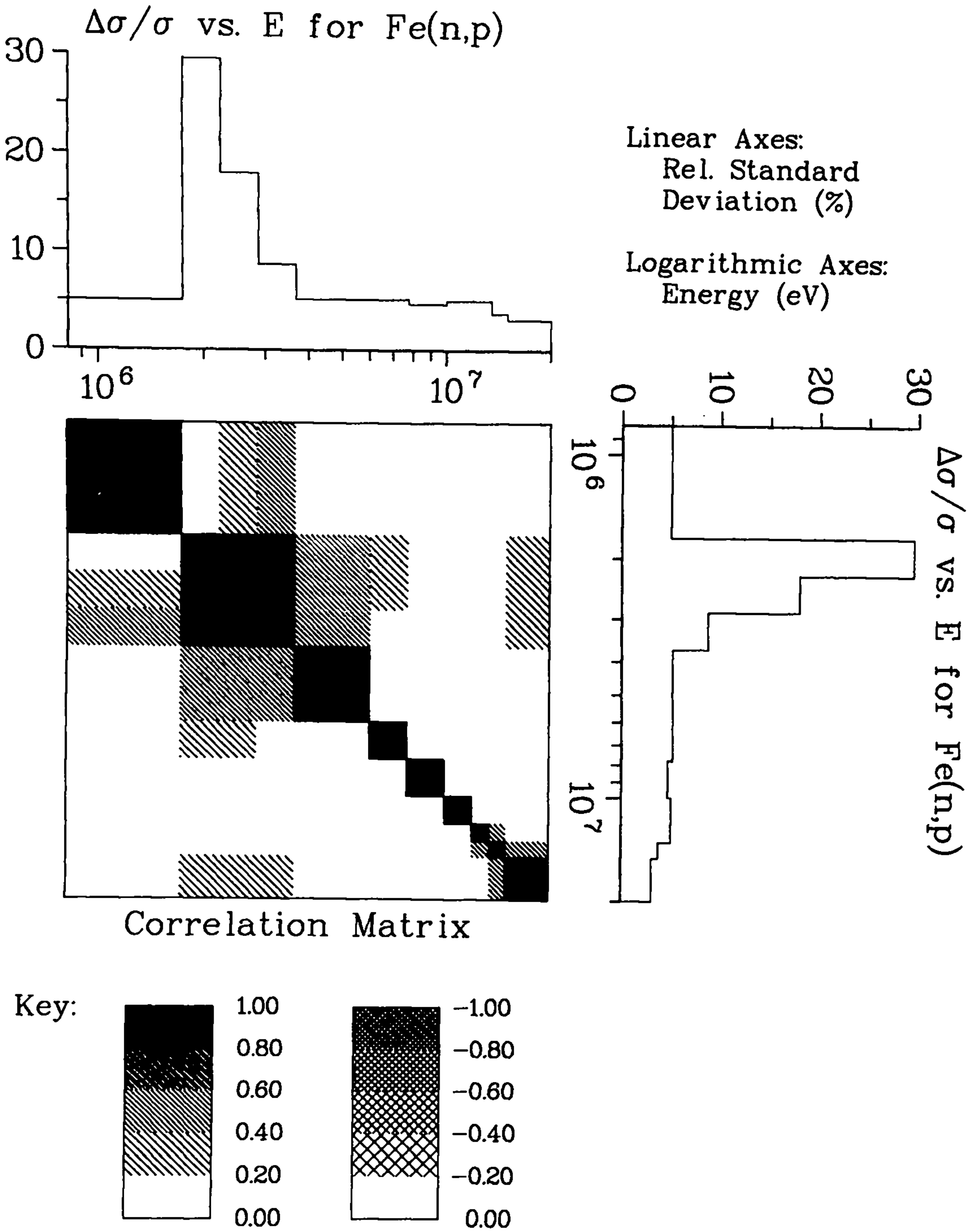


Fig. 87.
Covariance data for Fe(n,p) with Fe(n,p).

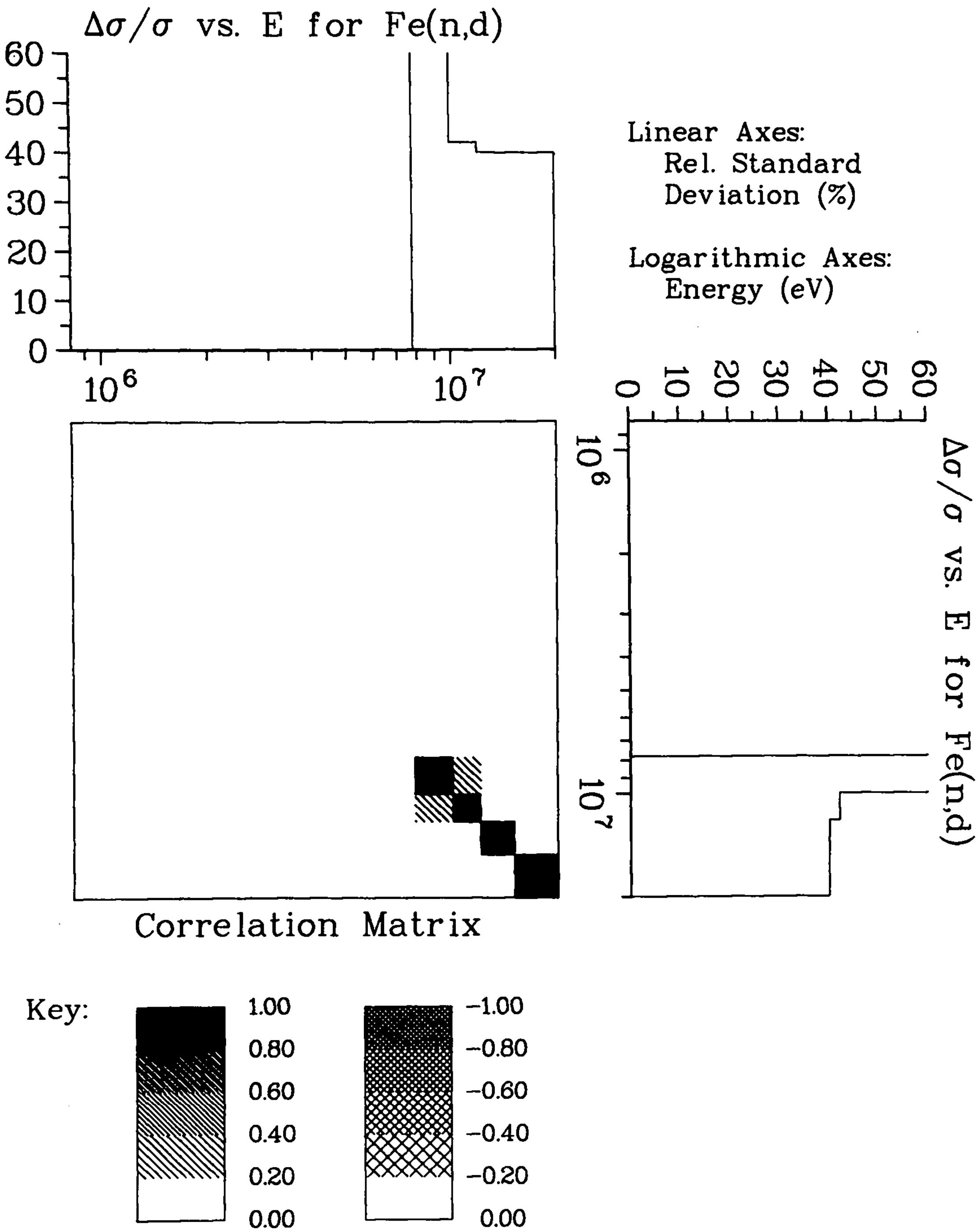


Fig. 88.
Covariance data for Fe(n,d) with Fe(n,d).

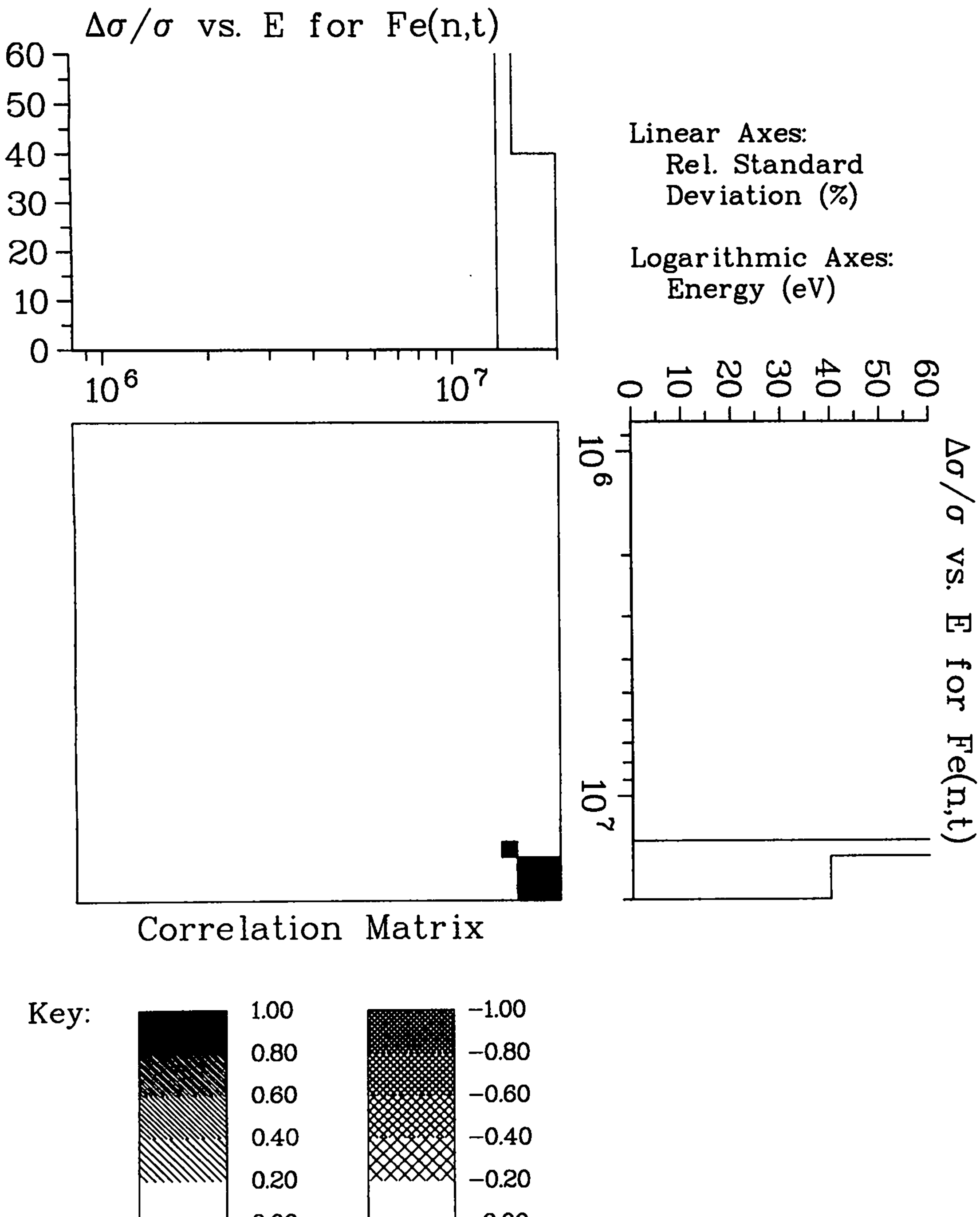


Fig. 89.
Covariance data for Fe(n,t) with Fe(n,t).

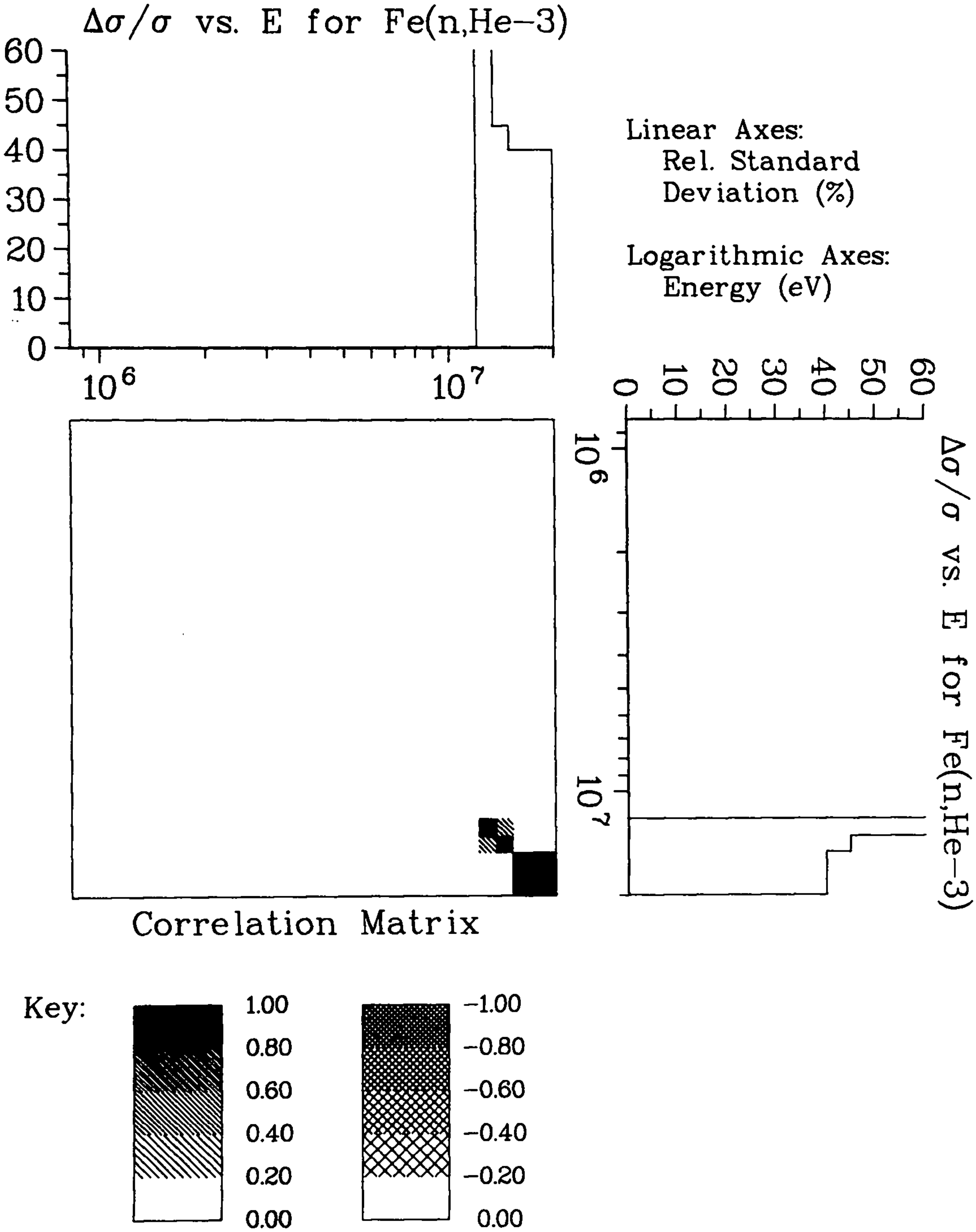


Fig. 90.

Covariance data for Fe(n,He−3) with Fe(n,He−3).

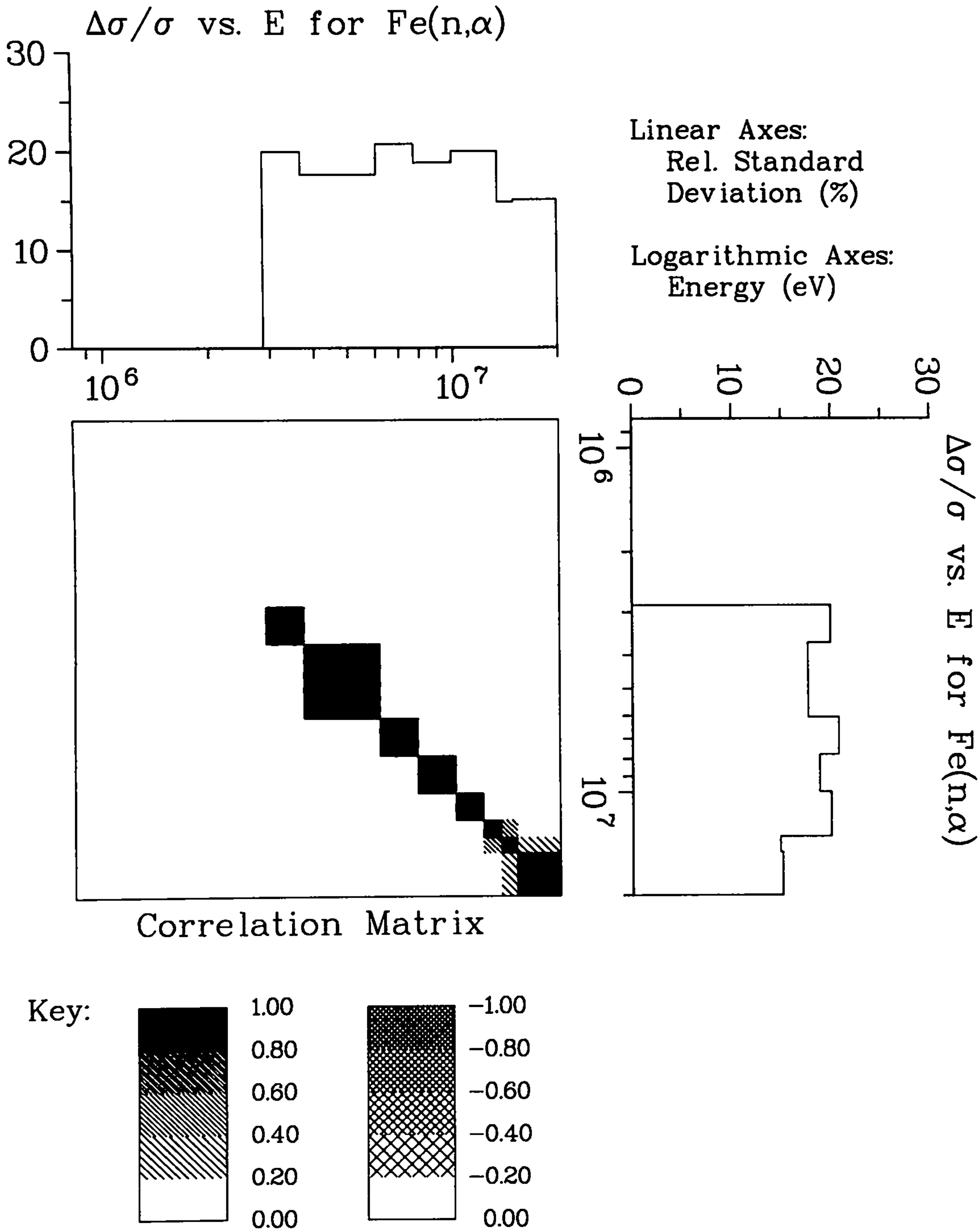


Fig. 91.
Covariance data for Fe(n,α) with Fe(n,α).

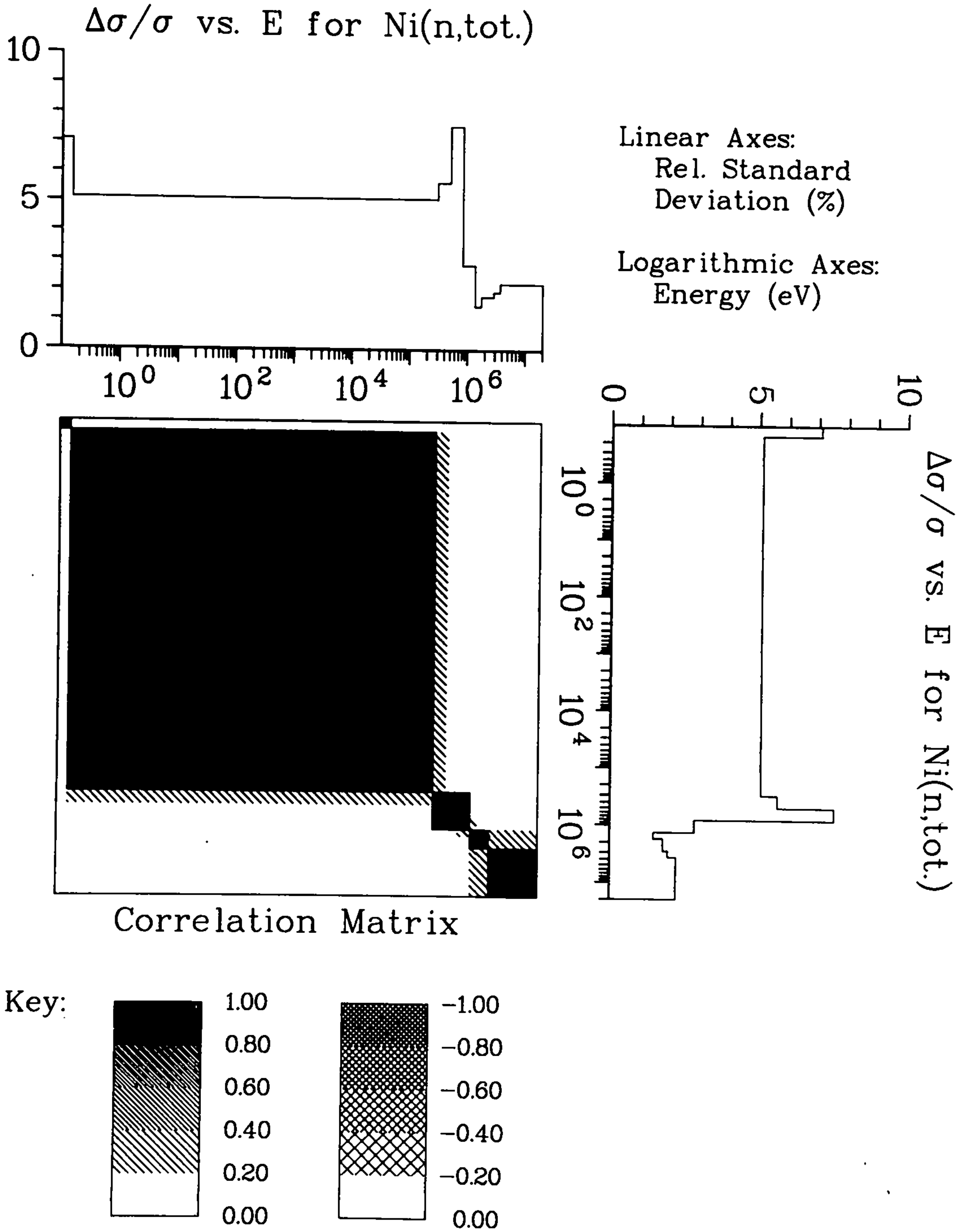


Fig. 92.
Covariance data for Ni(n,tot.) with Ni(n,tot.).

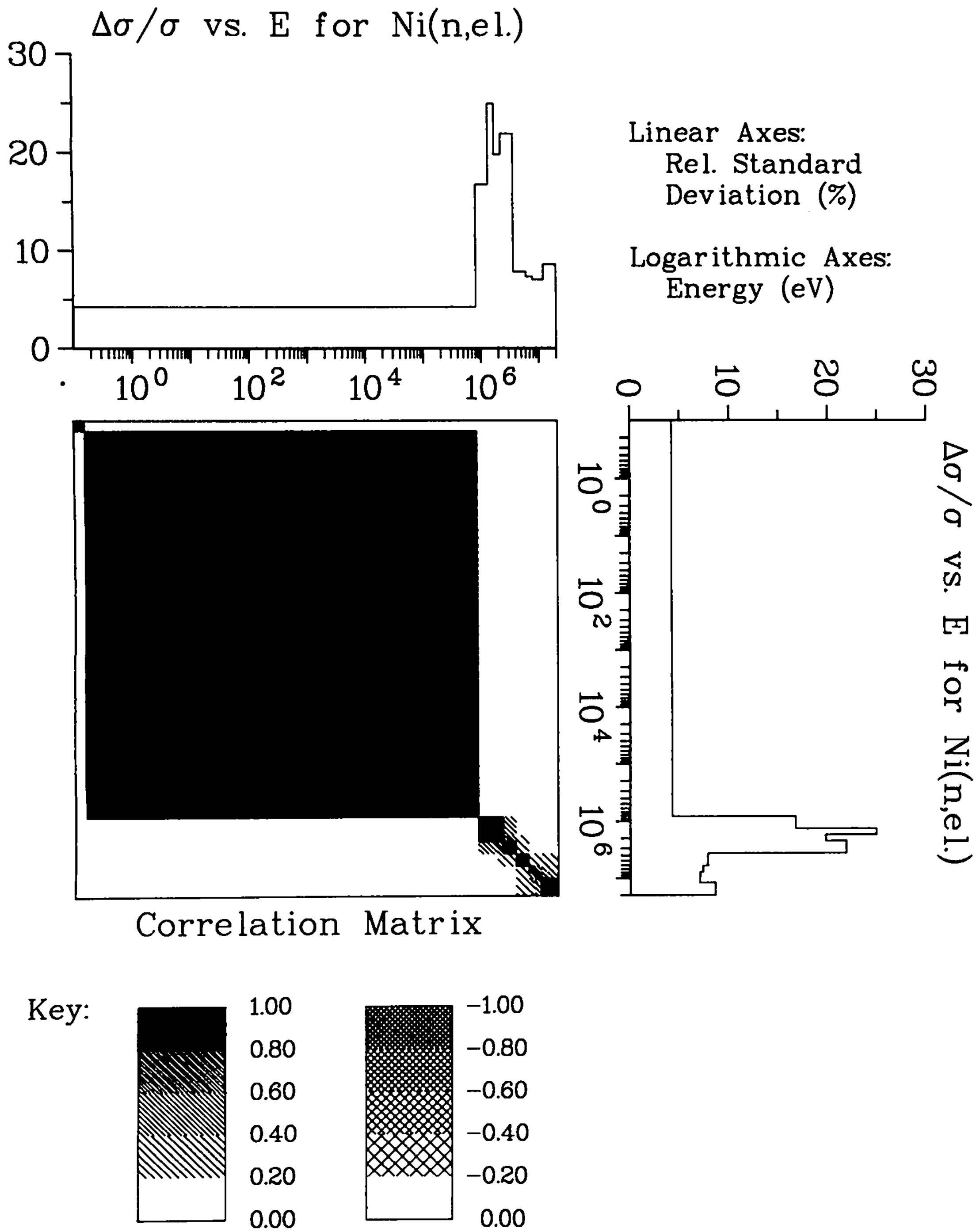


Fig. 93.
Covariance data for Ni(n,el.) with Ni(n,el.).

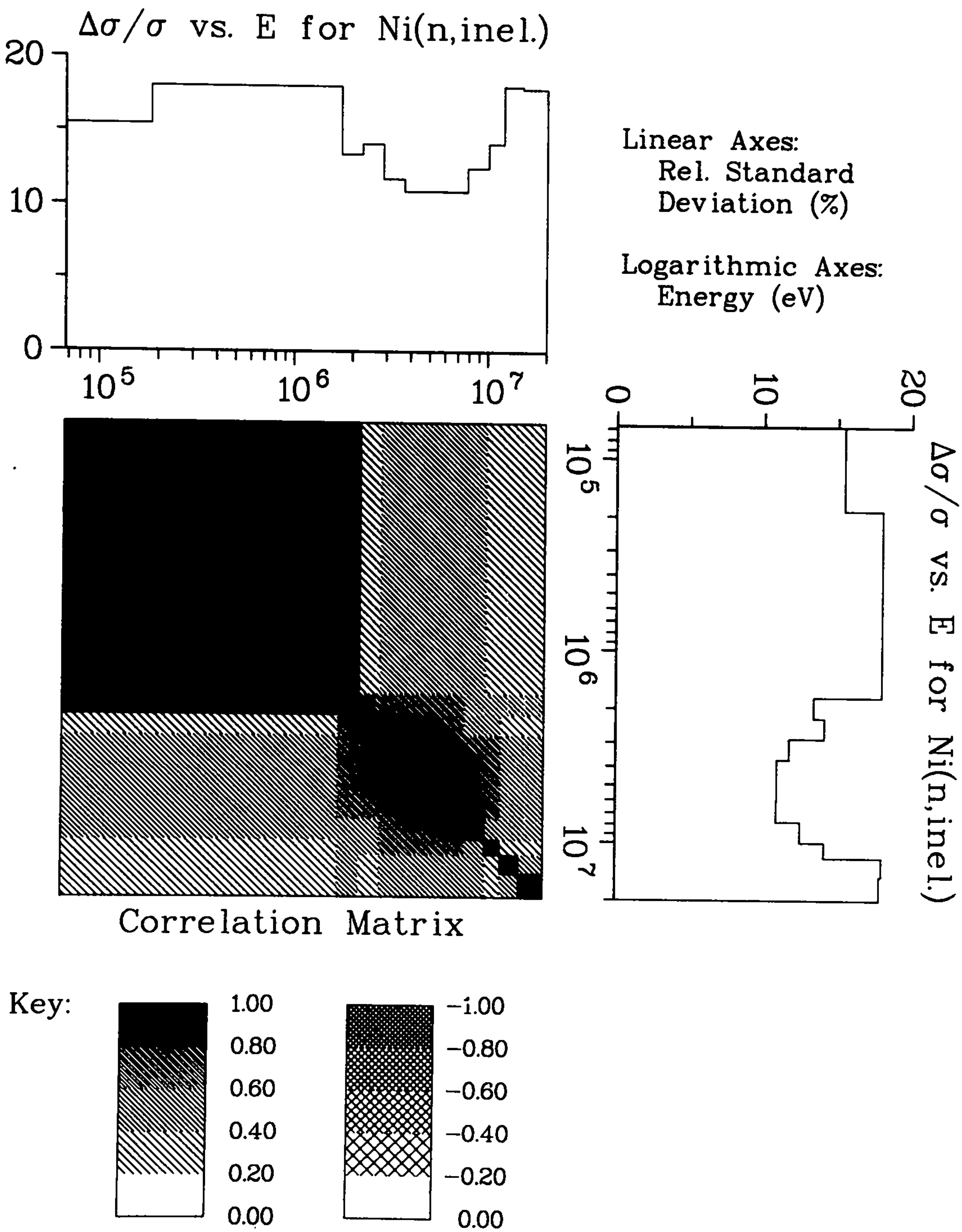


Fig. 94.
Covariance data for Ni(n,inel.) with Ni(n,inel.).

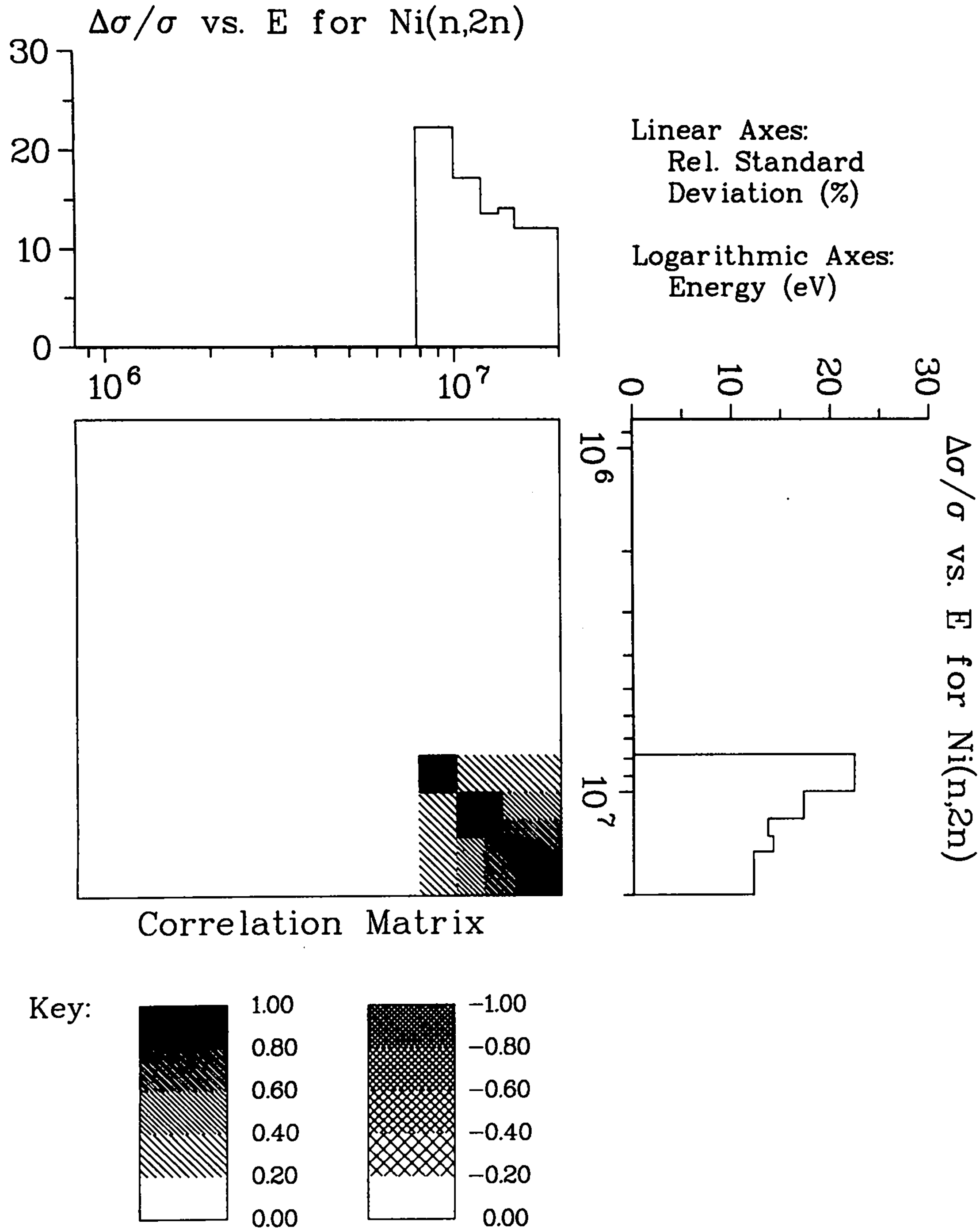


Fig. 95.
Covariance data for Ni(n,2n) with Ni(n,2n).

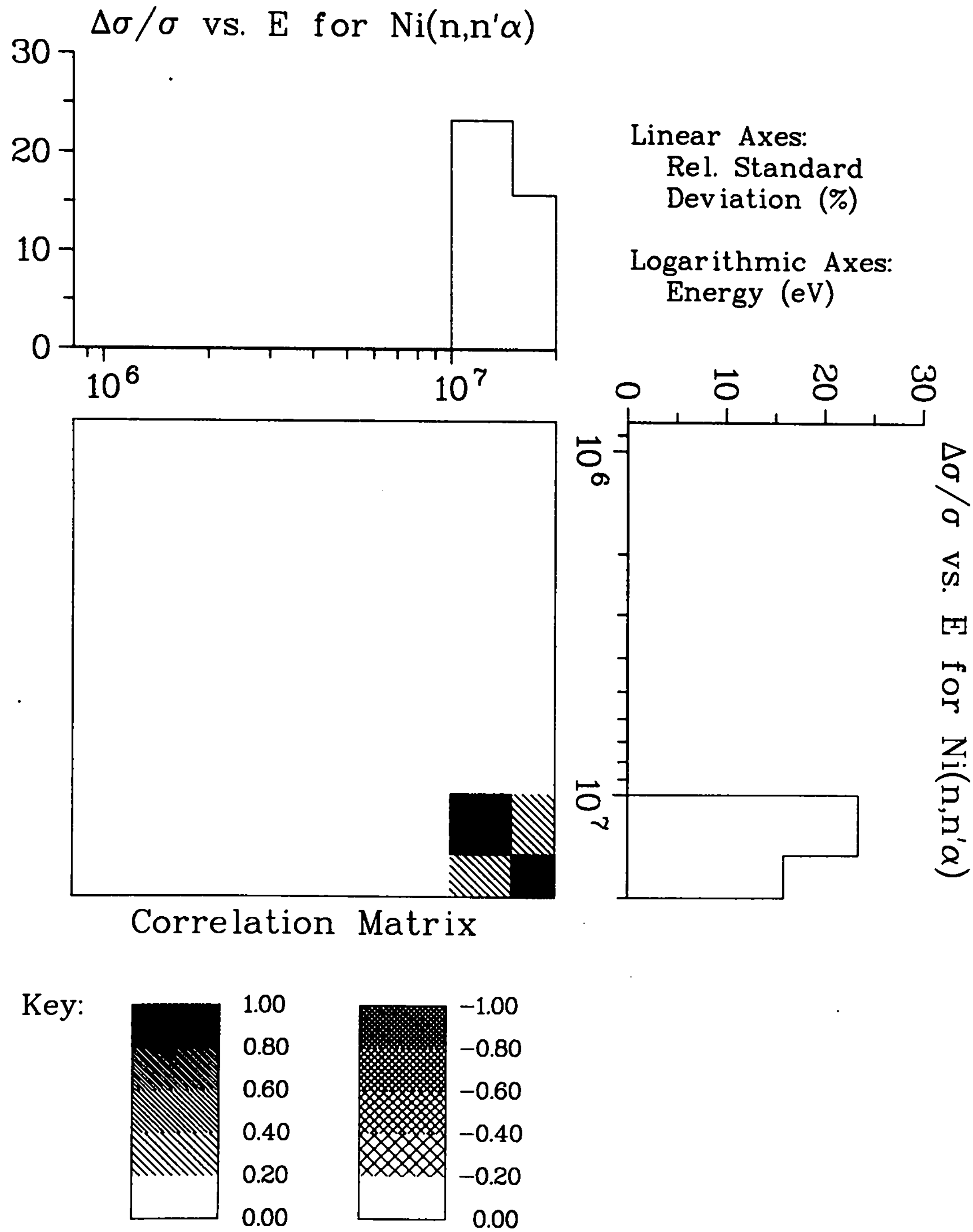


Fig. 96.
Covariance data for Ni(n,n'α) with Ni(n,n'α).

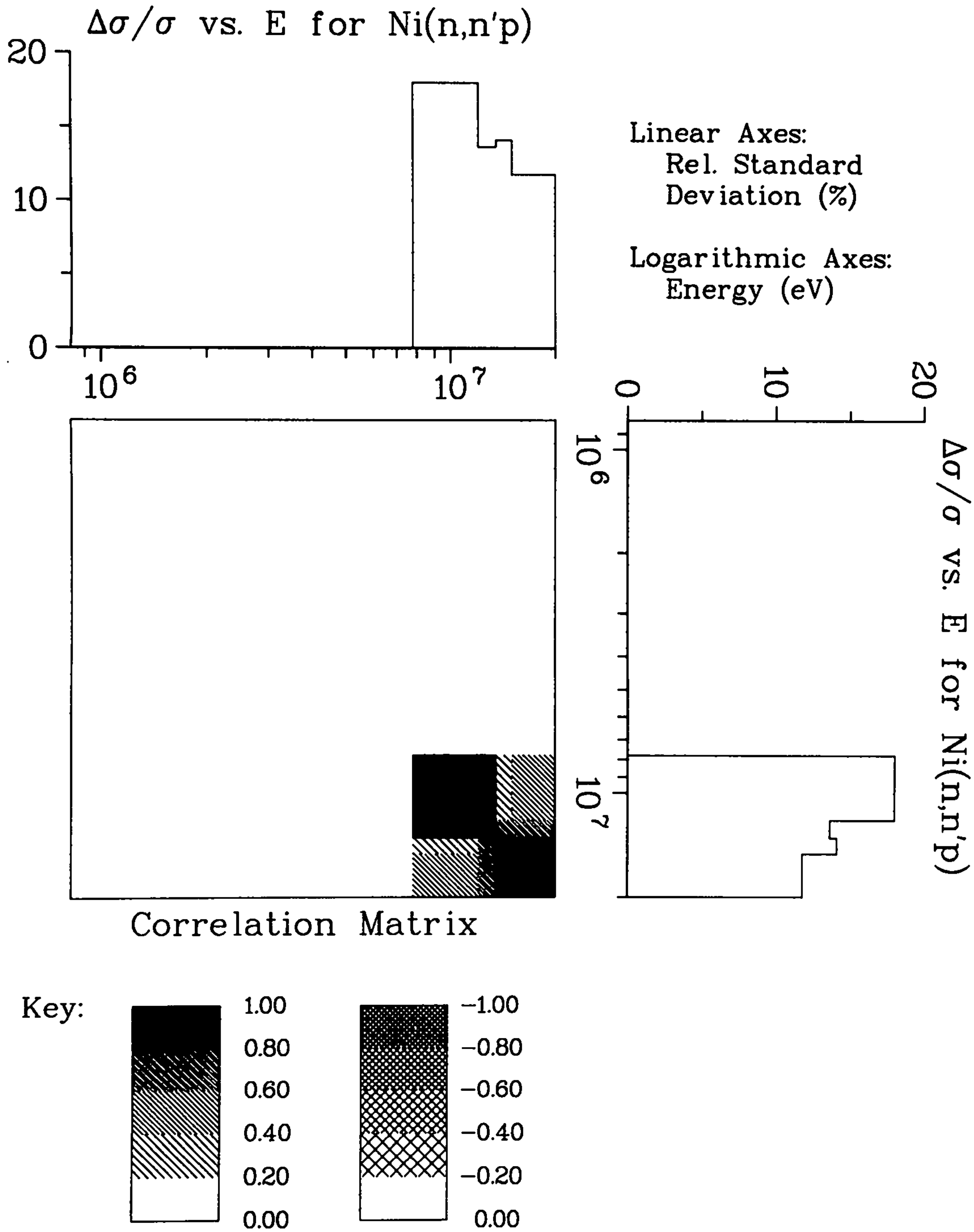


Fig. 97.
Covariance data for Ni(n,n'p) with Ni(n,n'p).

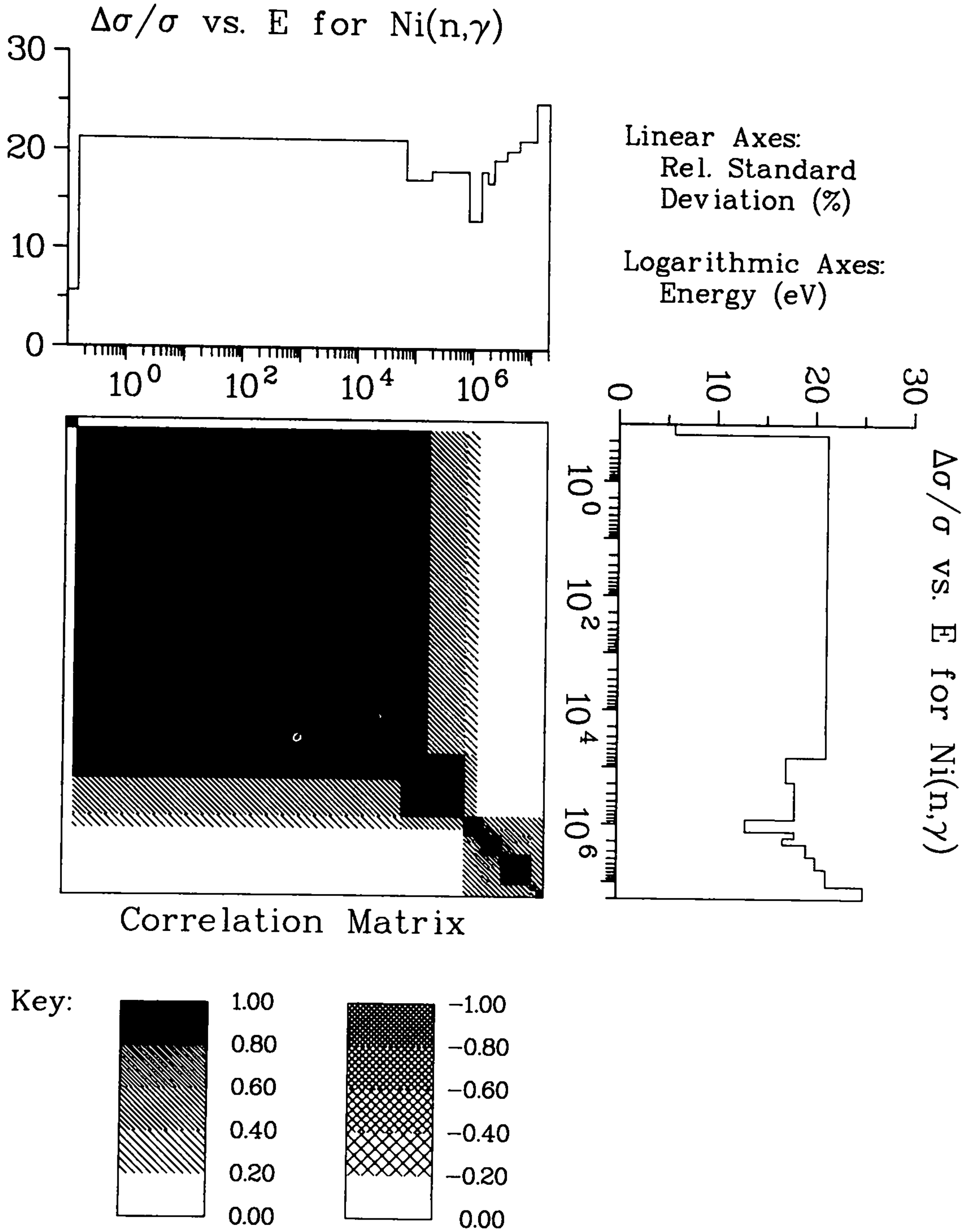


Fig. 98.
Covariance data for Ni(n,γ) with Ni(n,γ).

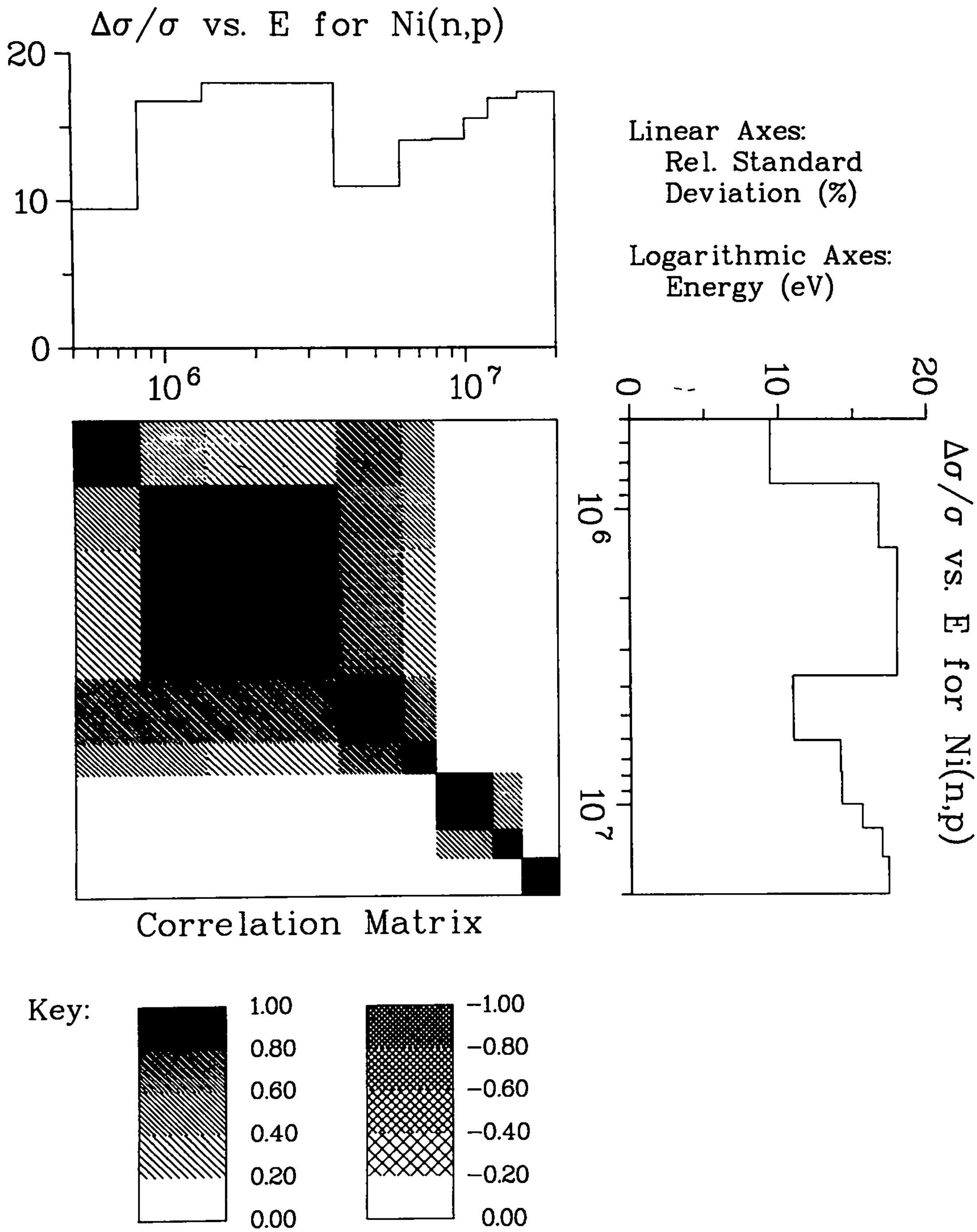


Fig. 99.
Covariance data for Ni(n,p) with Ni(n,p).

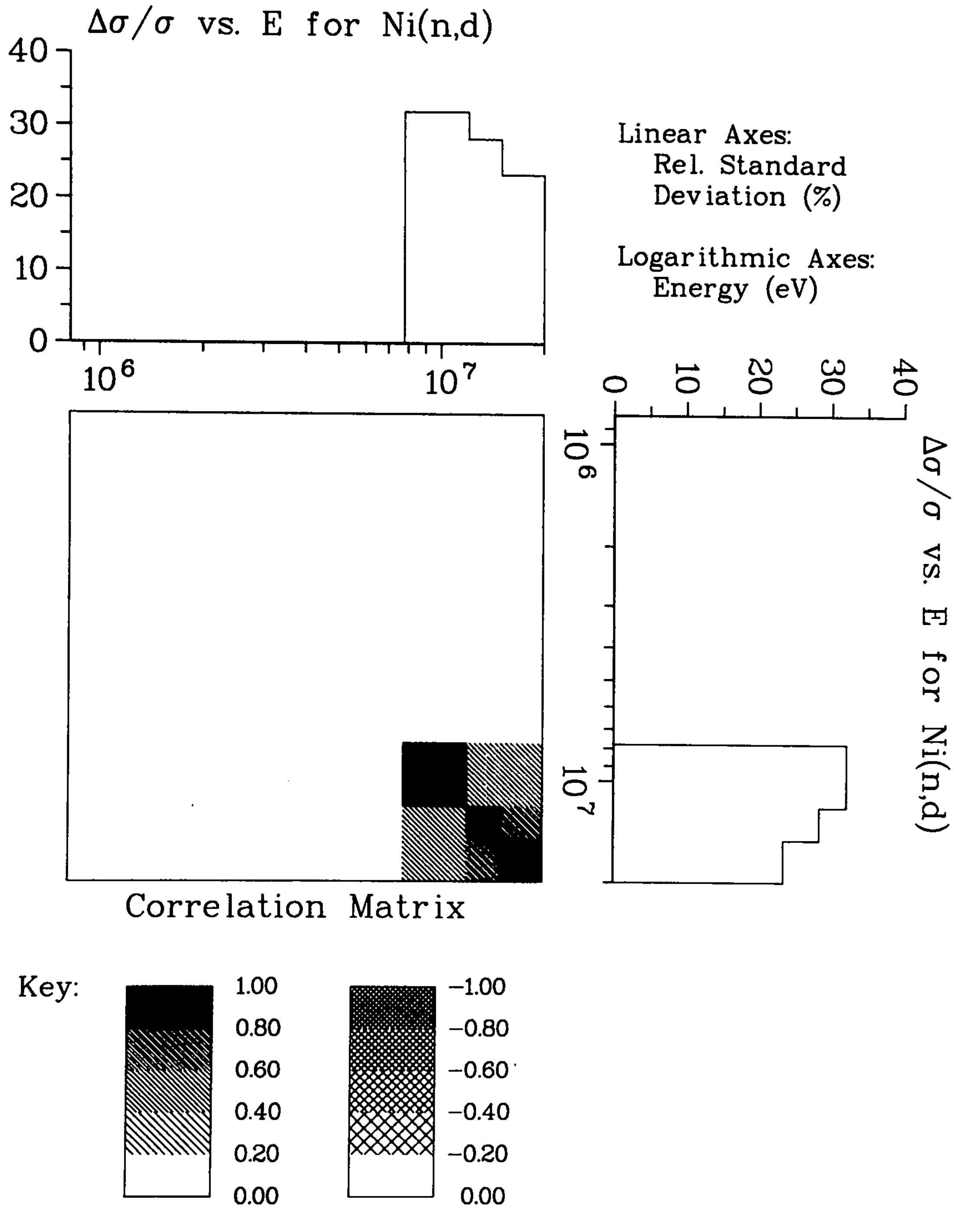


Fig. 100.
Covariance data for Ni(n,d) with Ni(n,d).

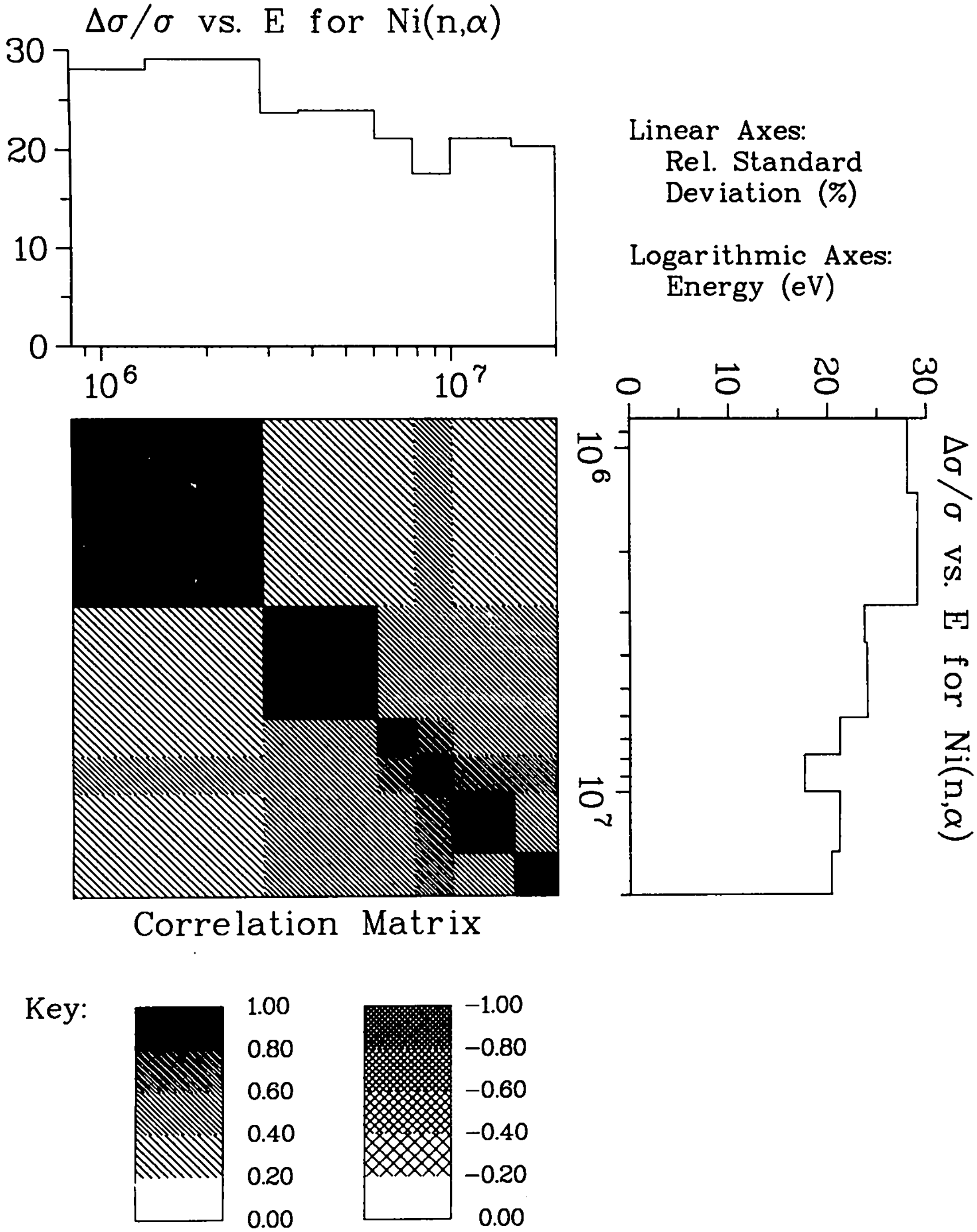


Fig. 101.
Covariance data for Ni(n,α) with Ni(n,α).

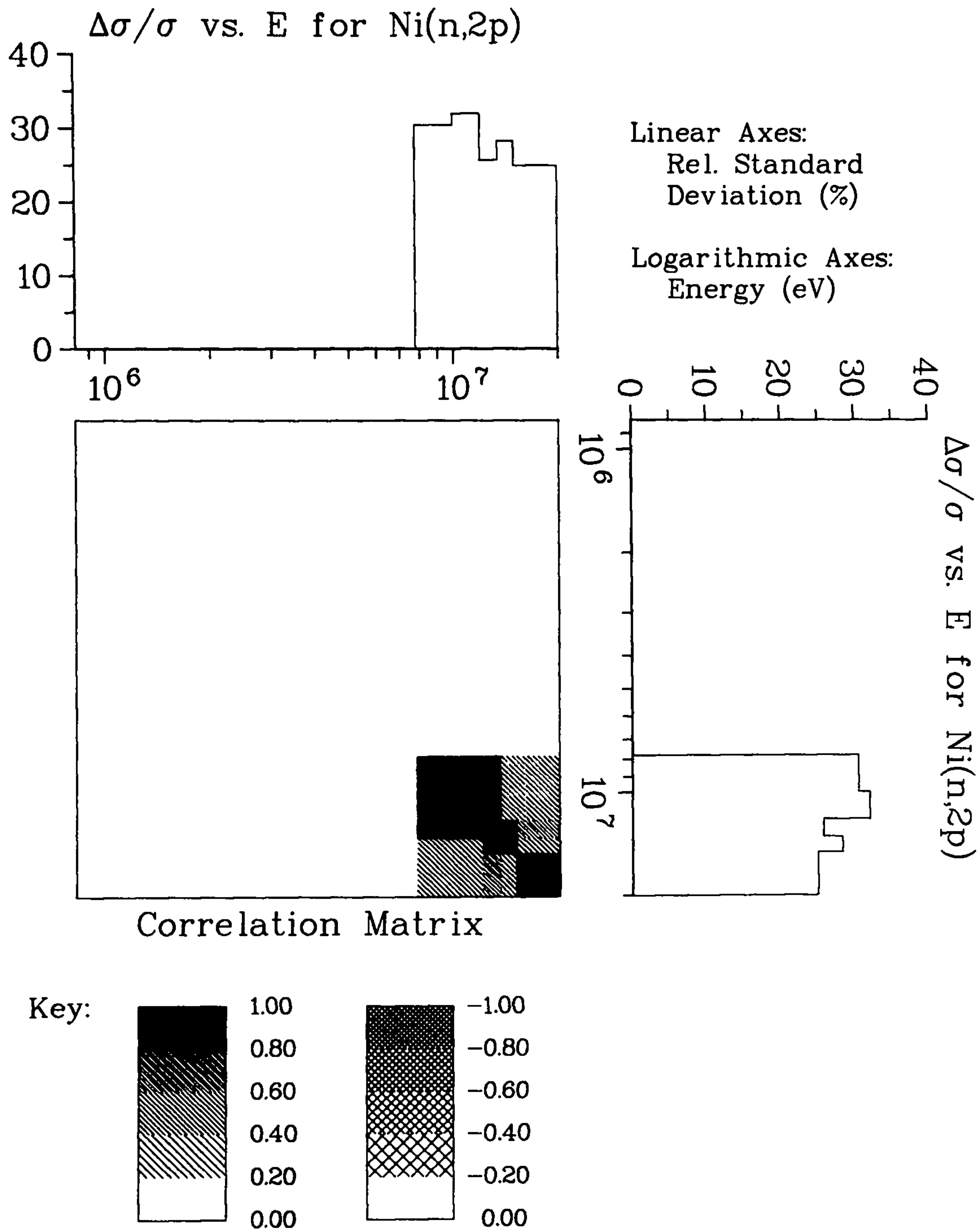


Fig. 102.
Covariance data for Ni(n,2p) with Ni(n,2p).

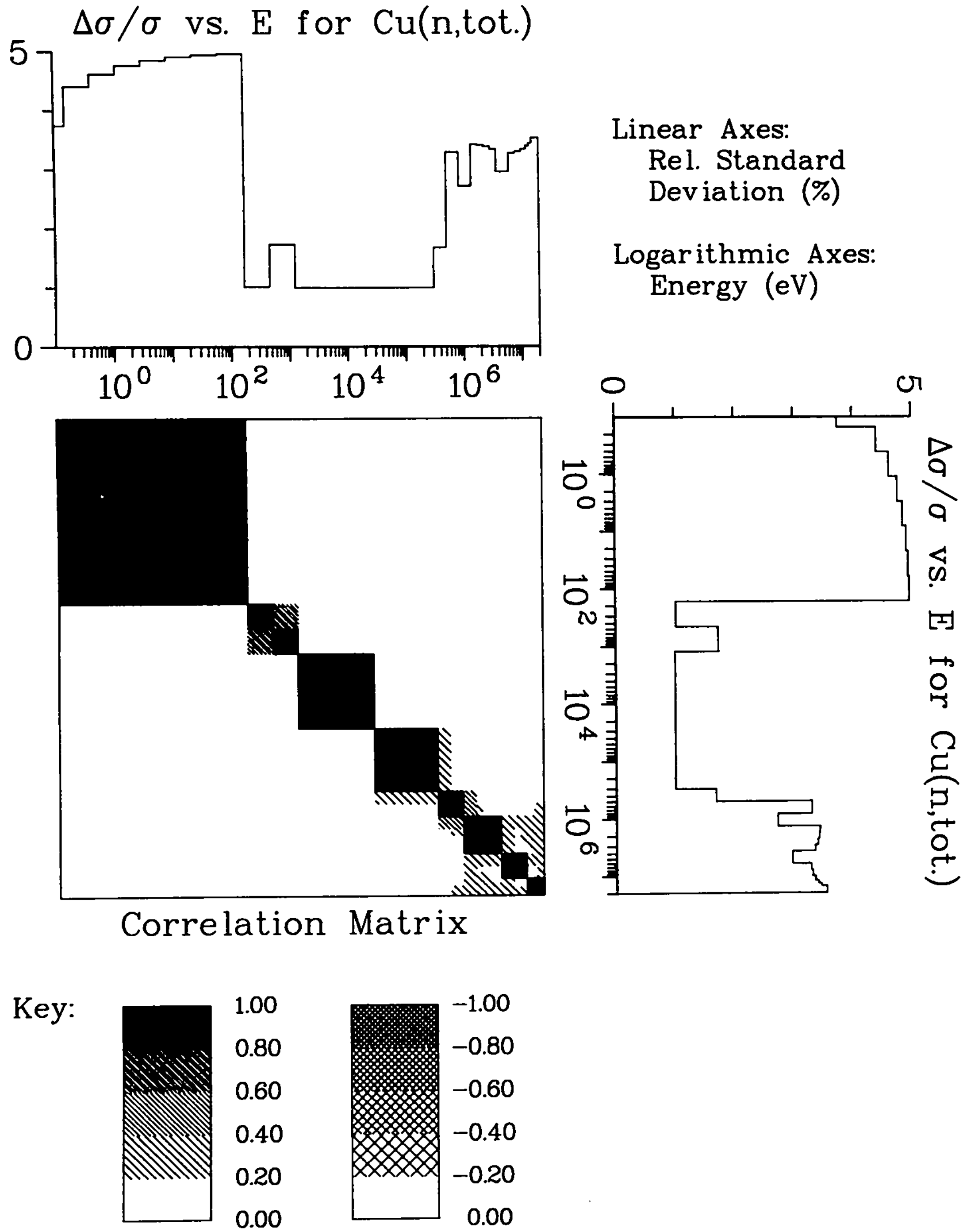


Fig. 103.
Covariance data for Cu(n,tot.) with Cu(n,tot.).

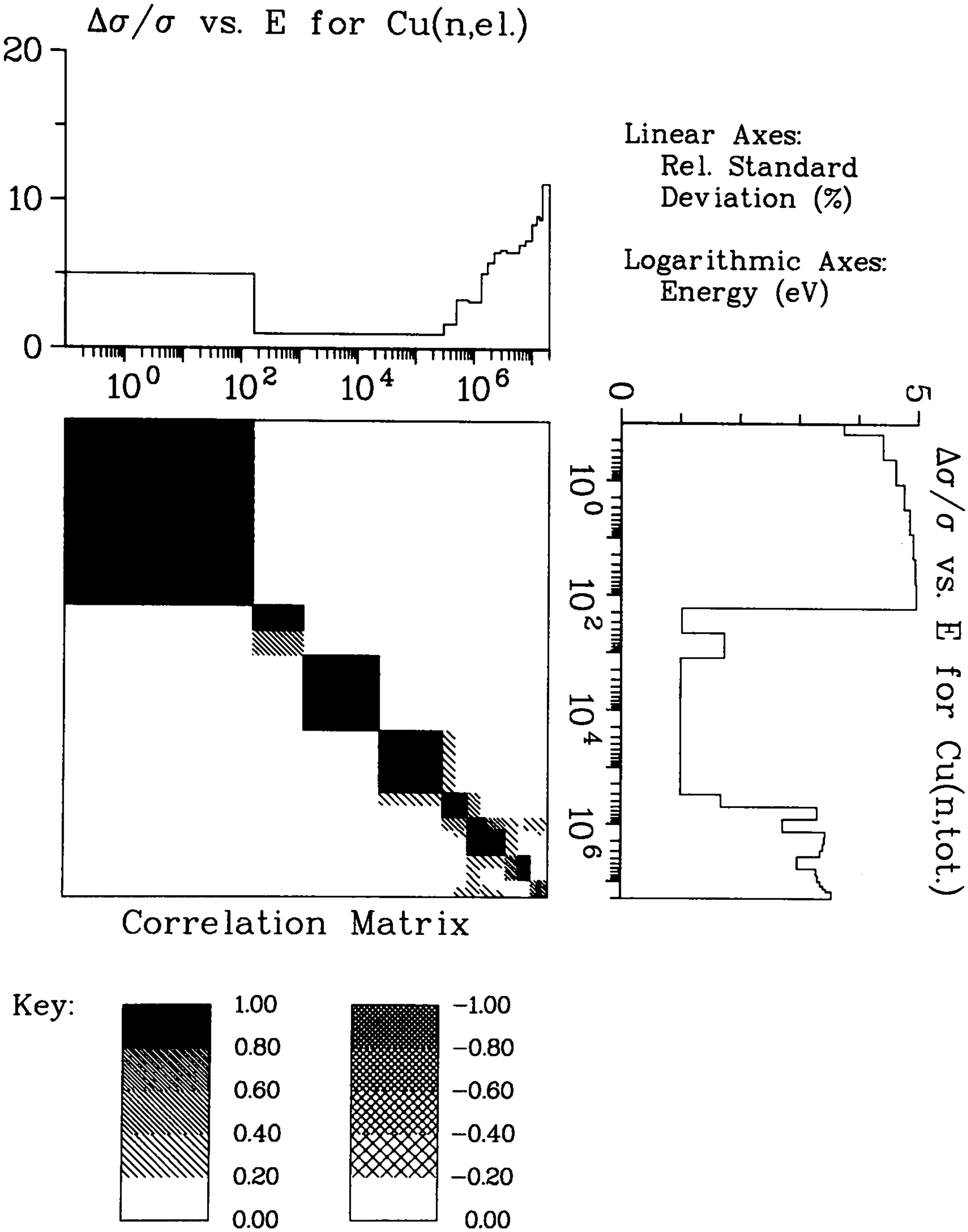


Fig. 104.

Covariance data for Cu(n,tot.) with Cu(n,el.).

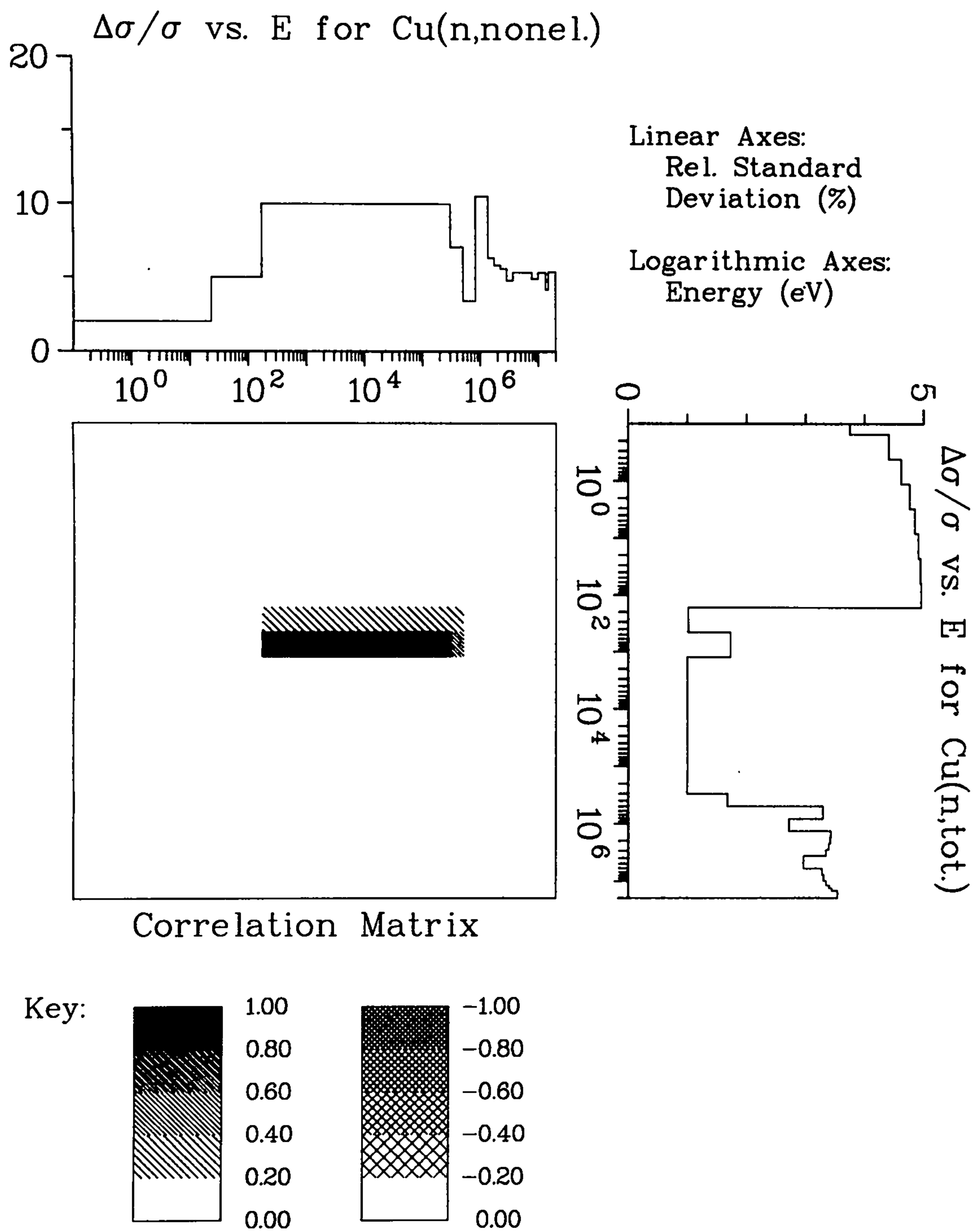


Fig. 105.

Covariance data for Cu(n,tot.) with Cu(n,nonel.).

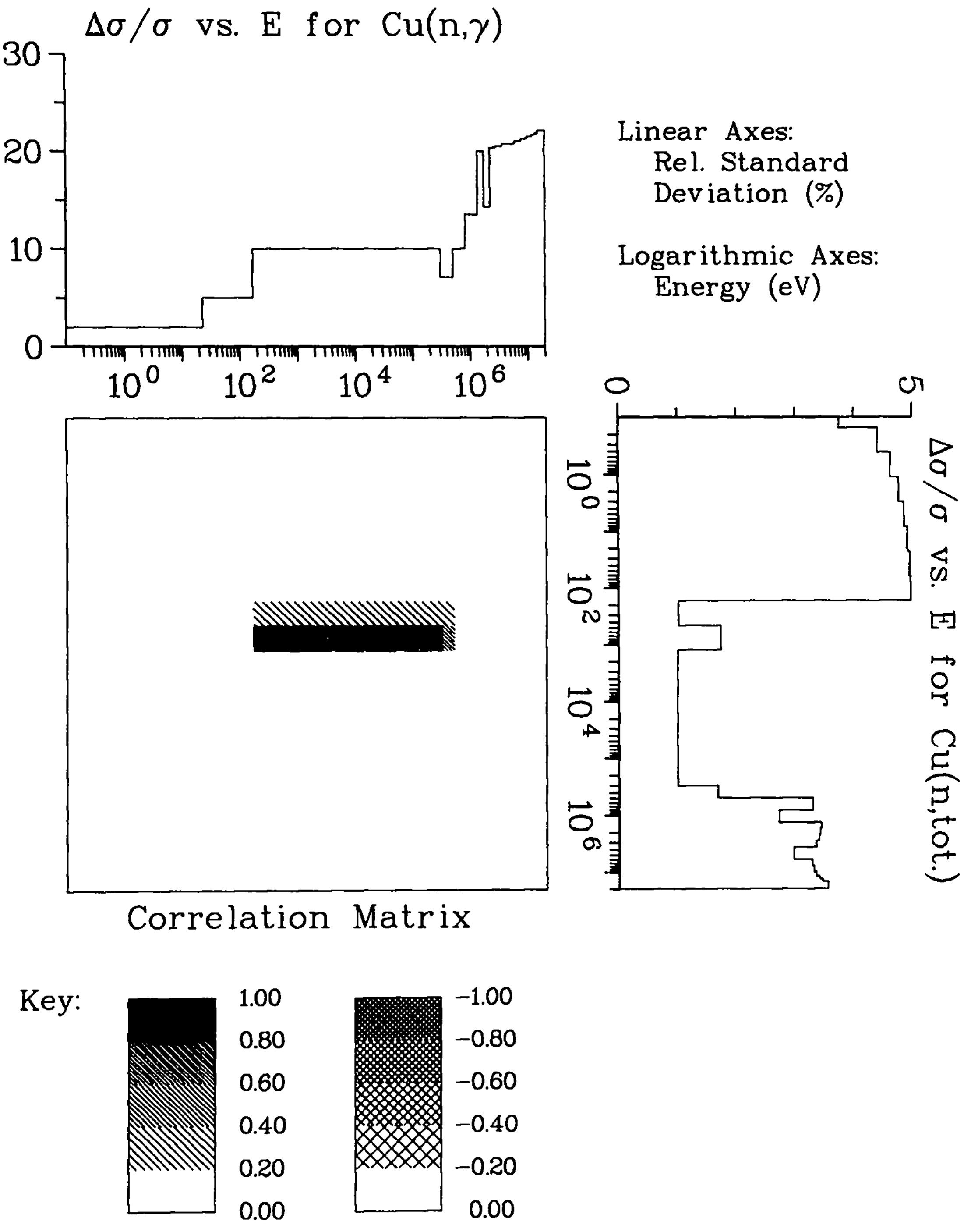


Fig. 106.

Covariance data for Cu(n,tot.) with Cu(n,γ).

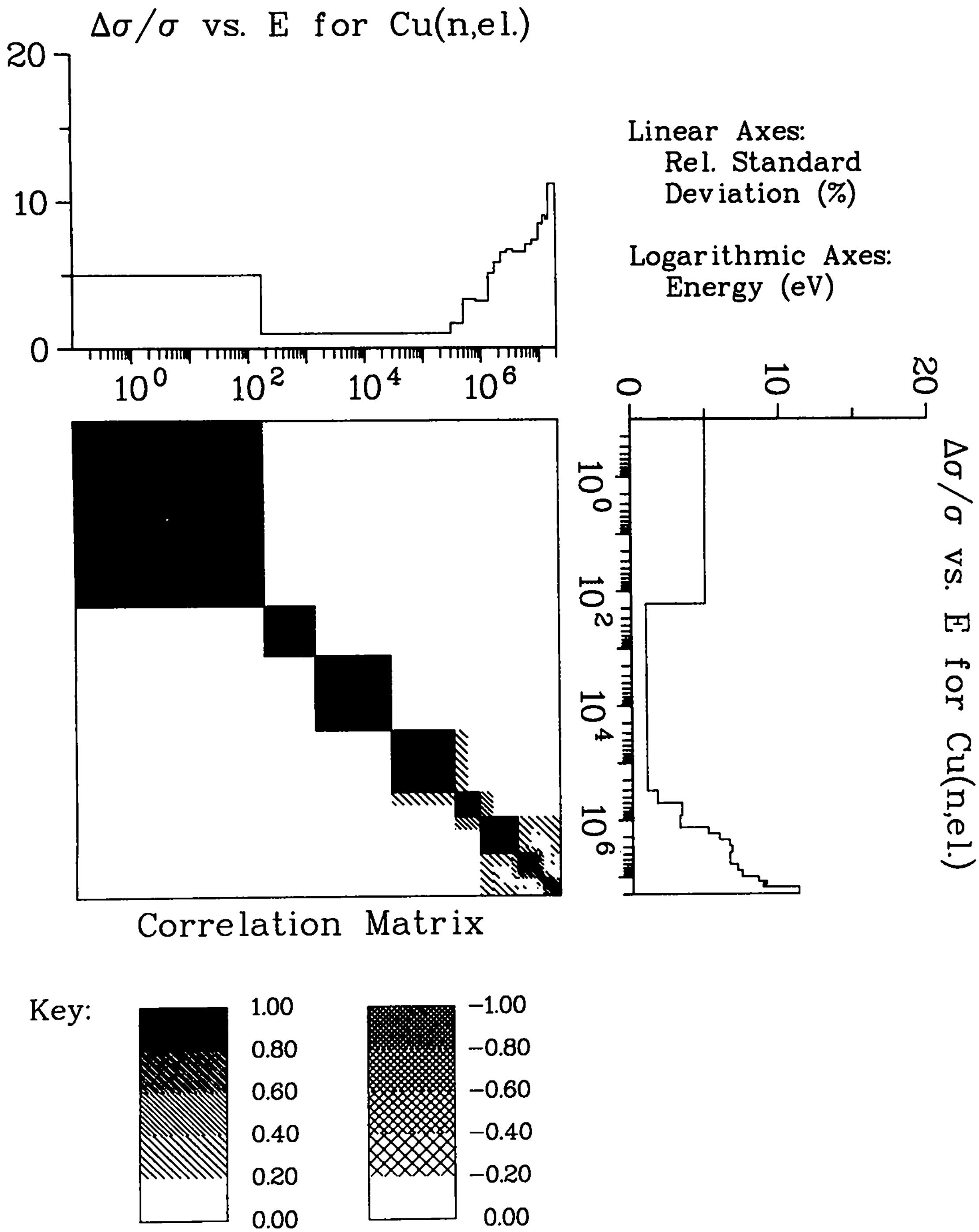


Fig. 107.
Covariance data for Cu(n,el.) with Cu(n,el.).

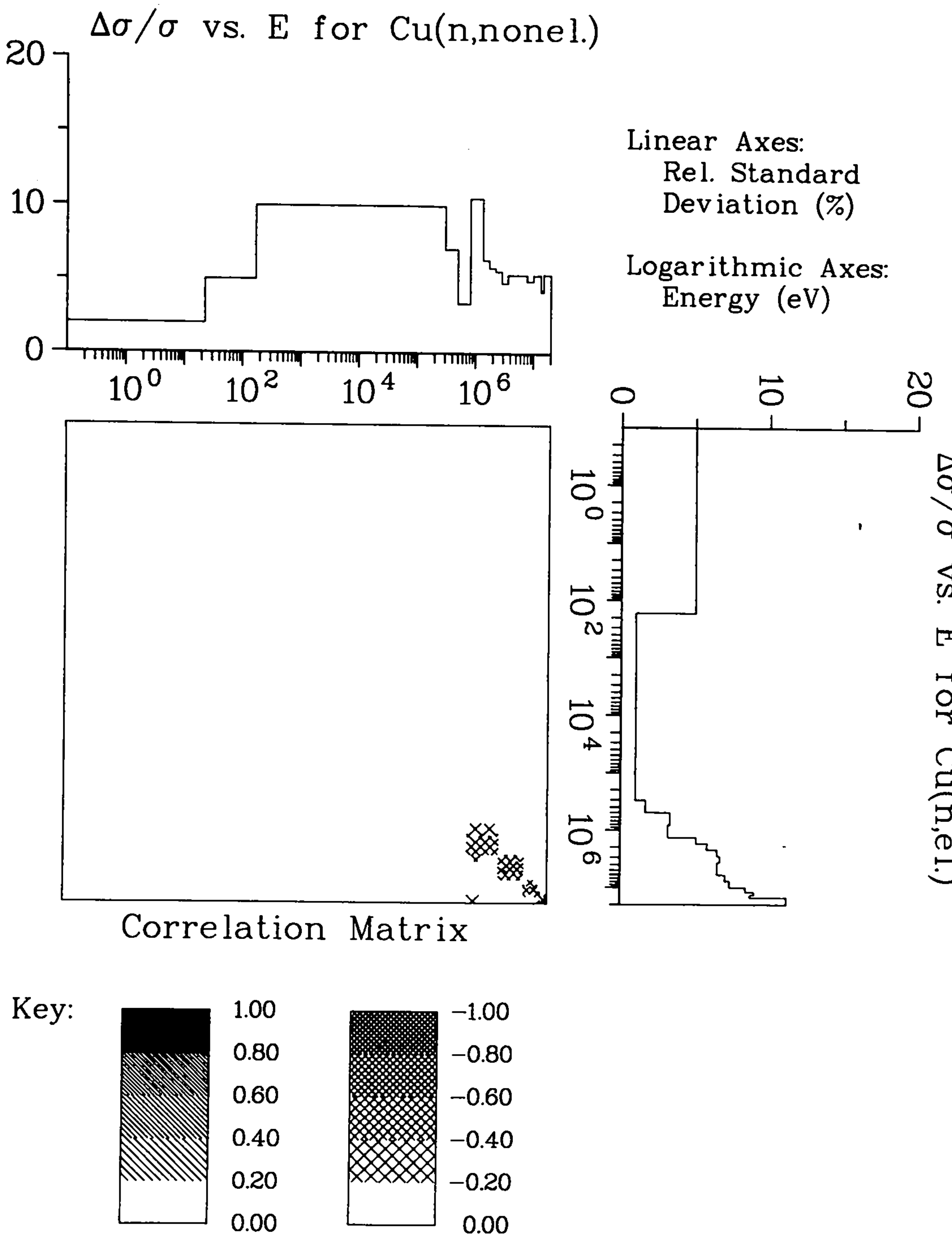


Fig. 108.
Covariance data for Cu(n,el.) with Cu(n,nonel.).

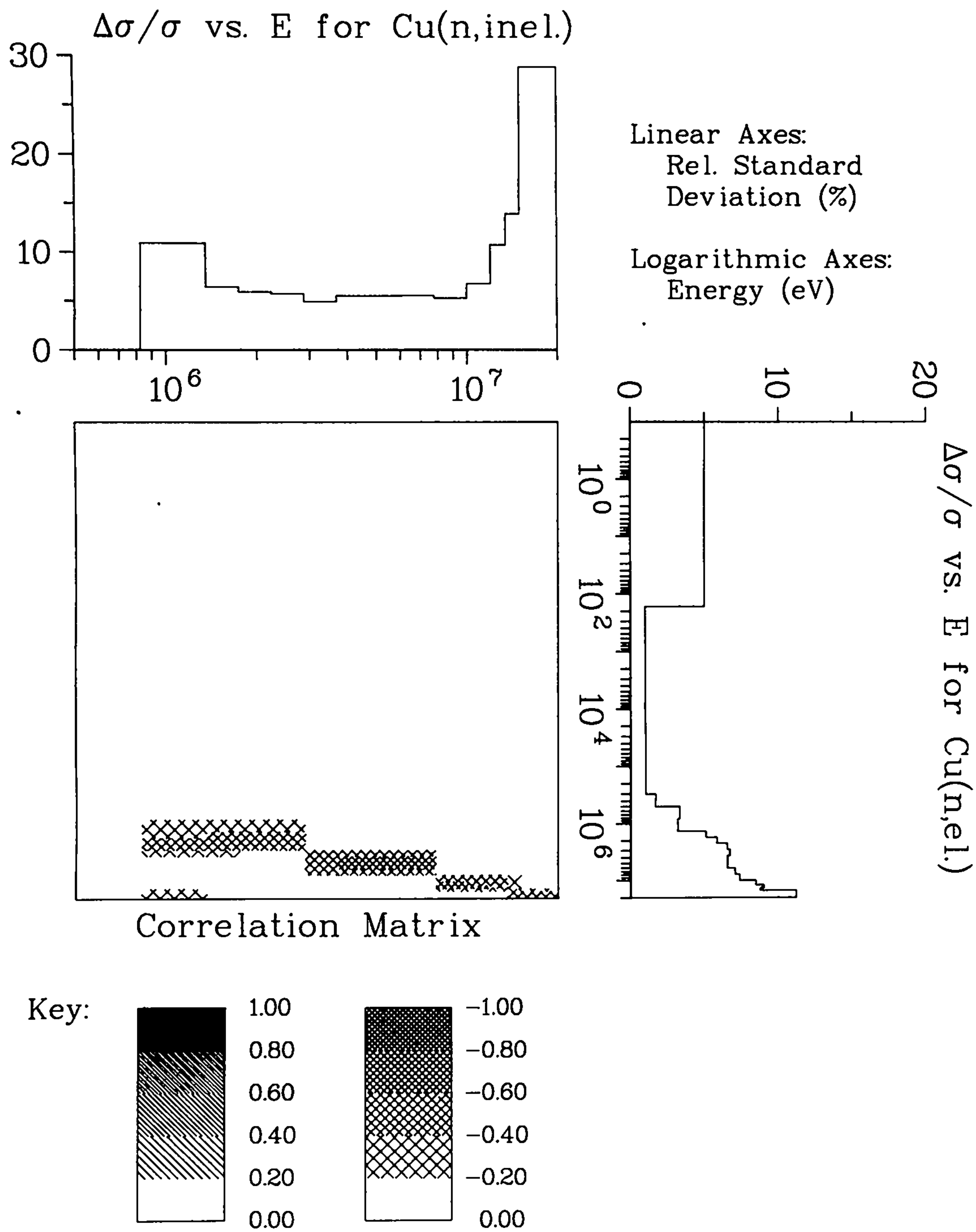


Fig. 109.
Covariance data for Cu(n,el.) with Cu(n,inel.).

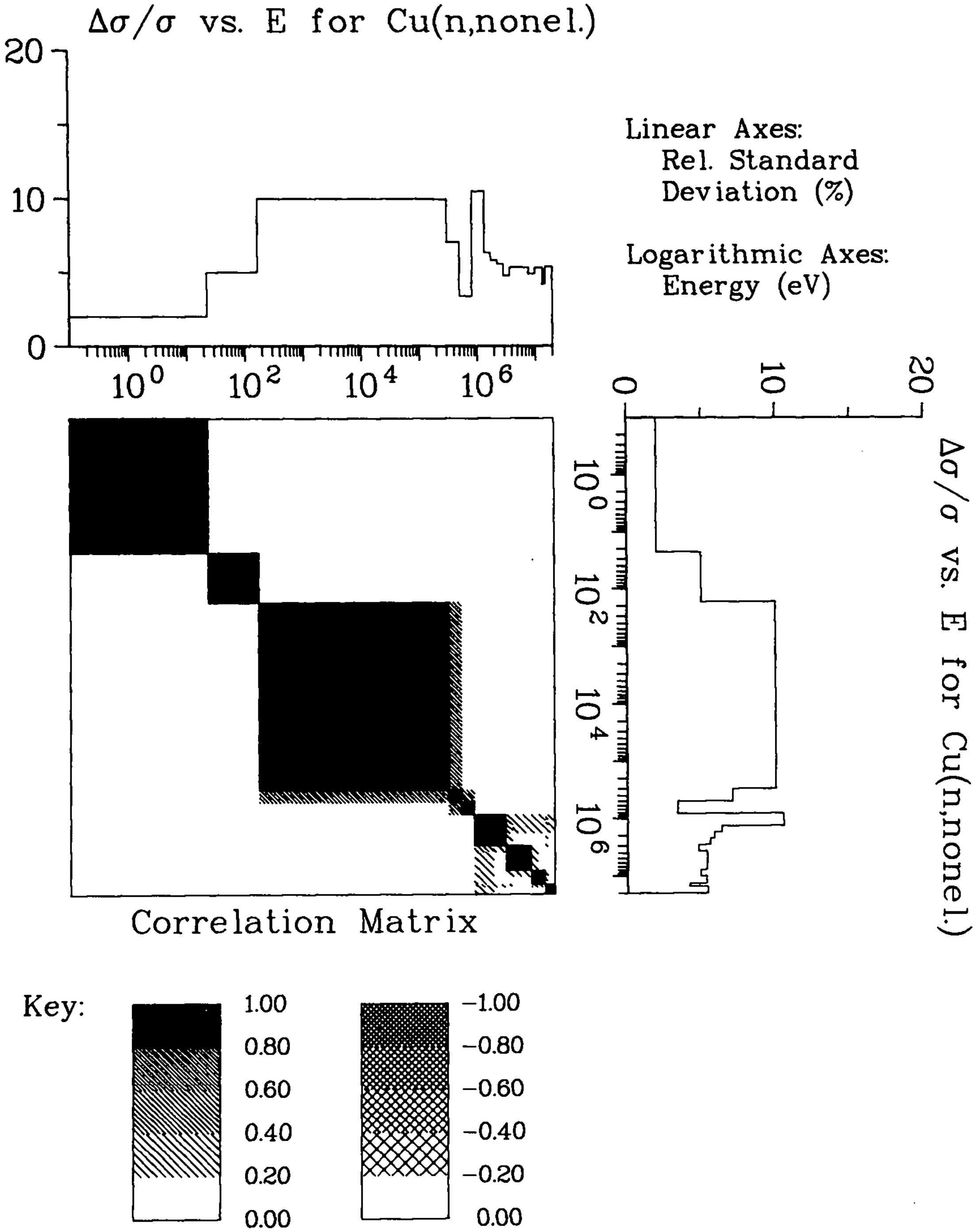


Fig. 110.

Covariance data for Cu(n,nonel.) with Cu(n,nonel.).

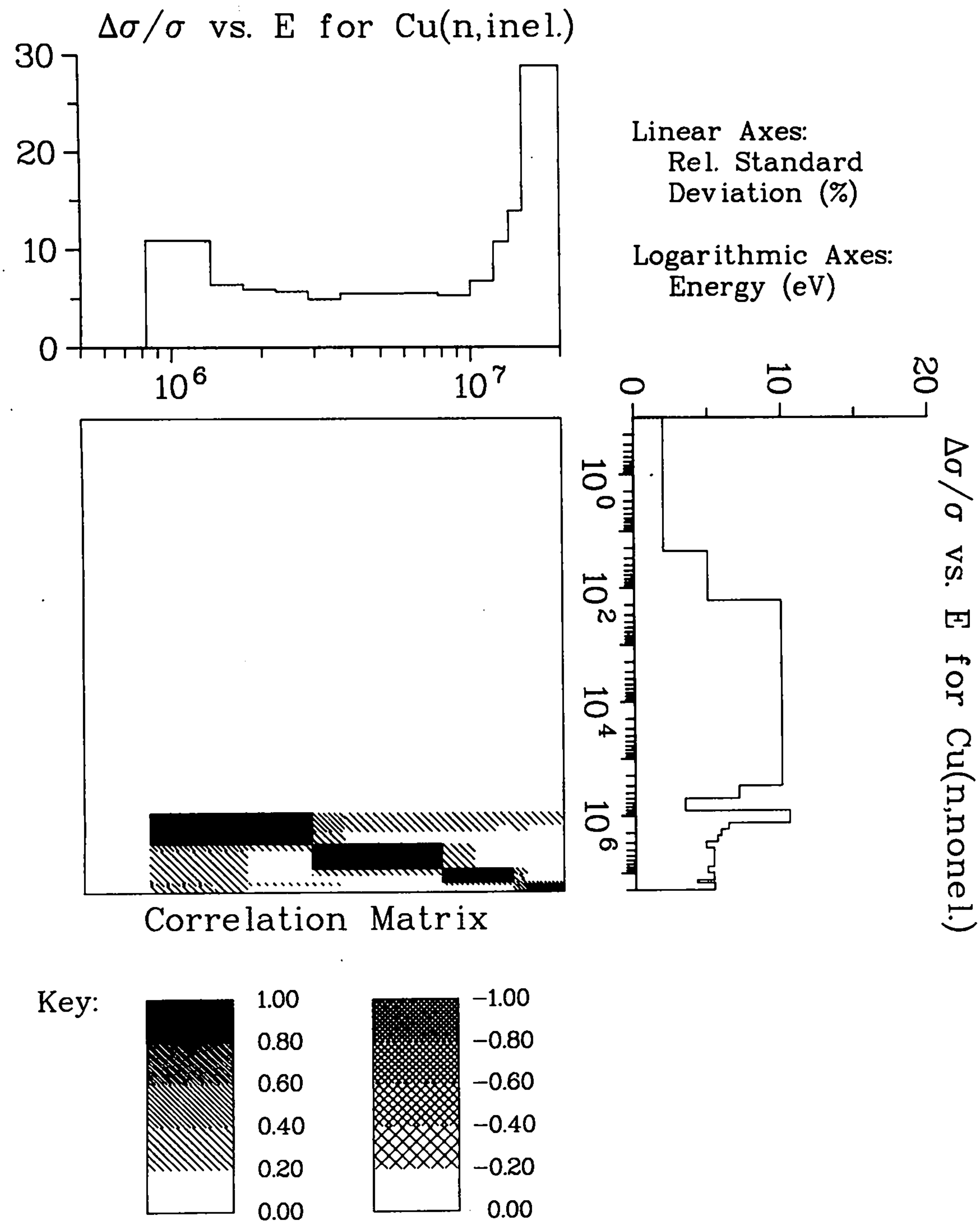


Fig. 111.
Covariance data for Cu(n,nonel.) with Cu(n,inel.).

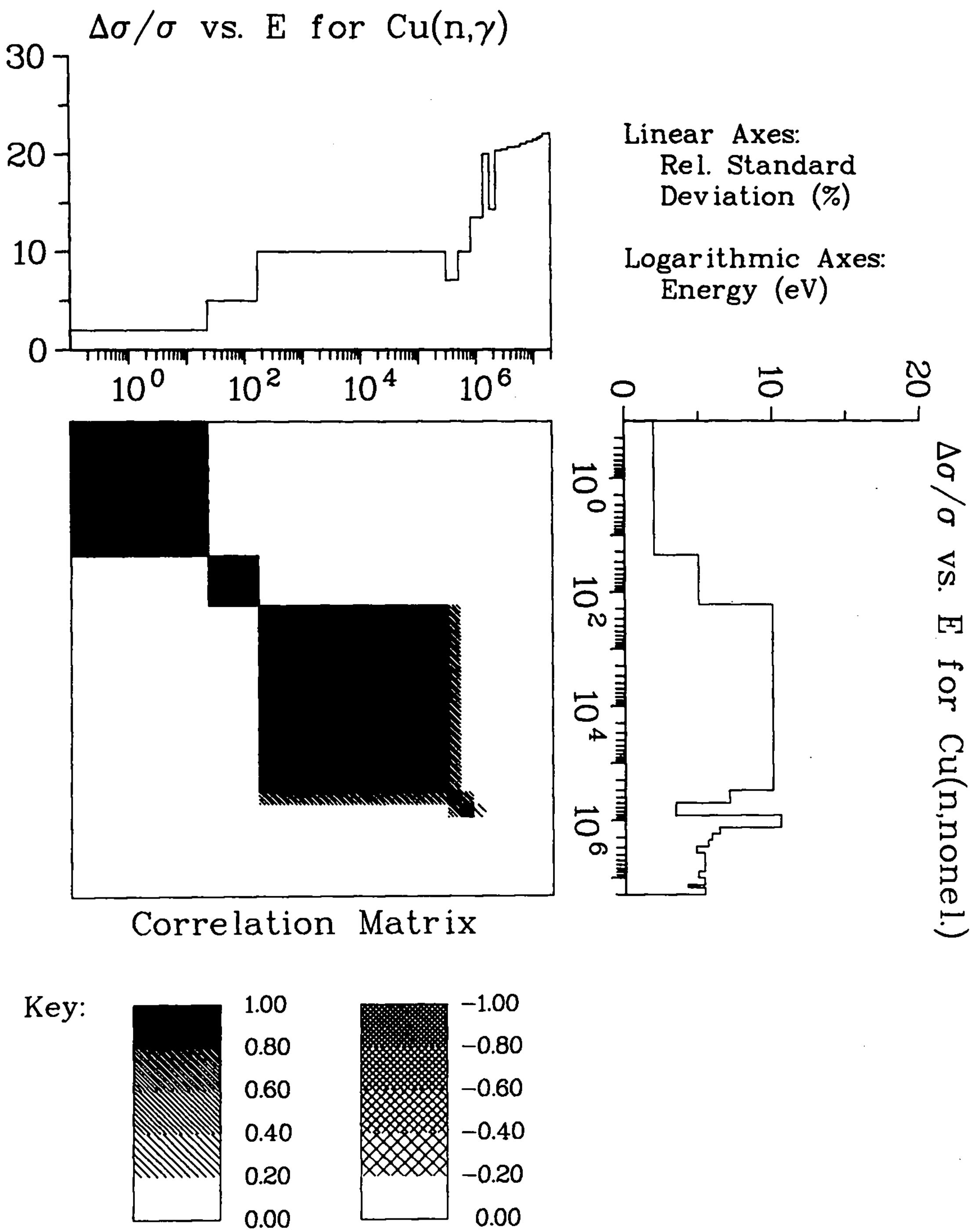


Fig. 112.

Covariance data for Cu(n,nonel.) with Cu(n,γ).

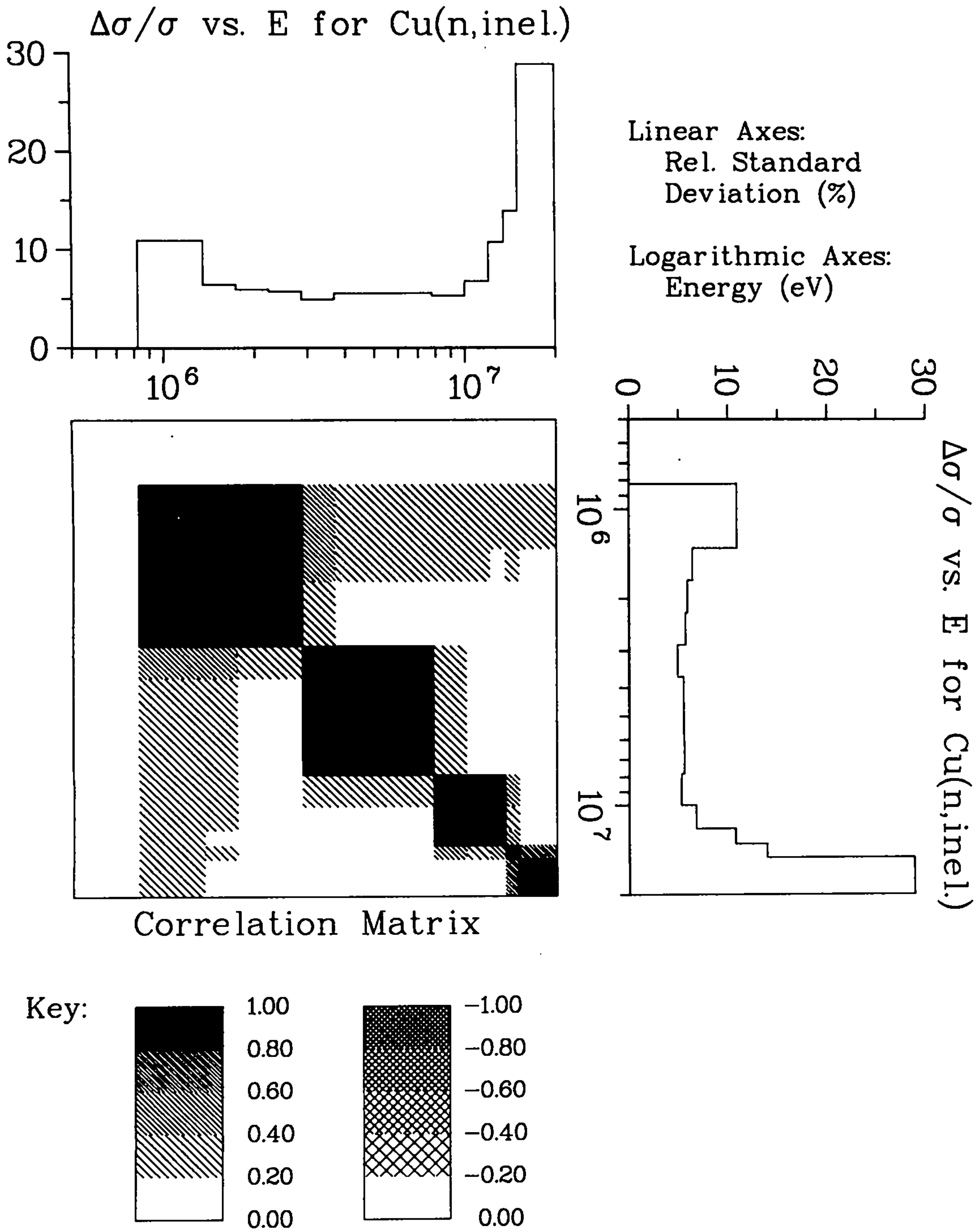


Fig. 113.
Covariance data for Cu(n,inel.) with Cu(n,inel.).

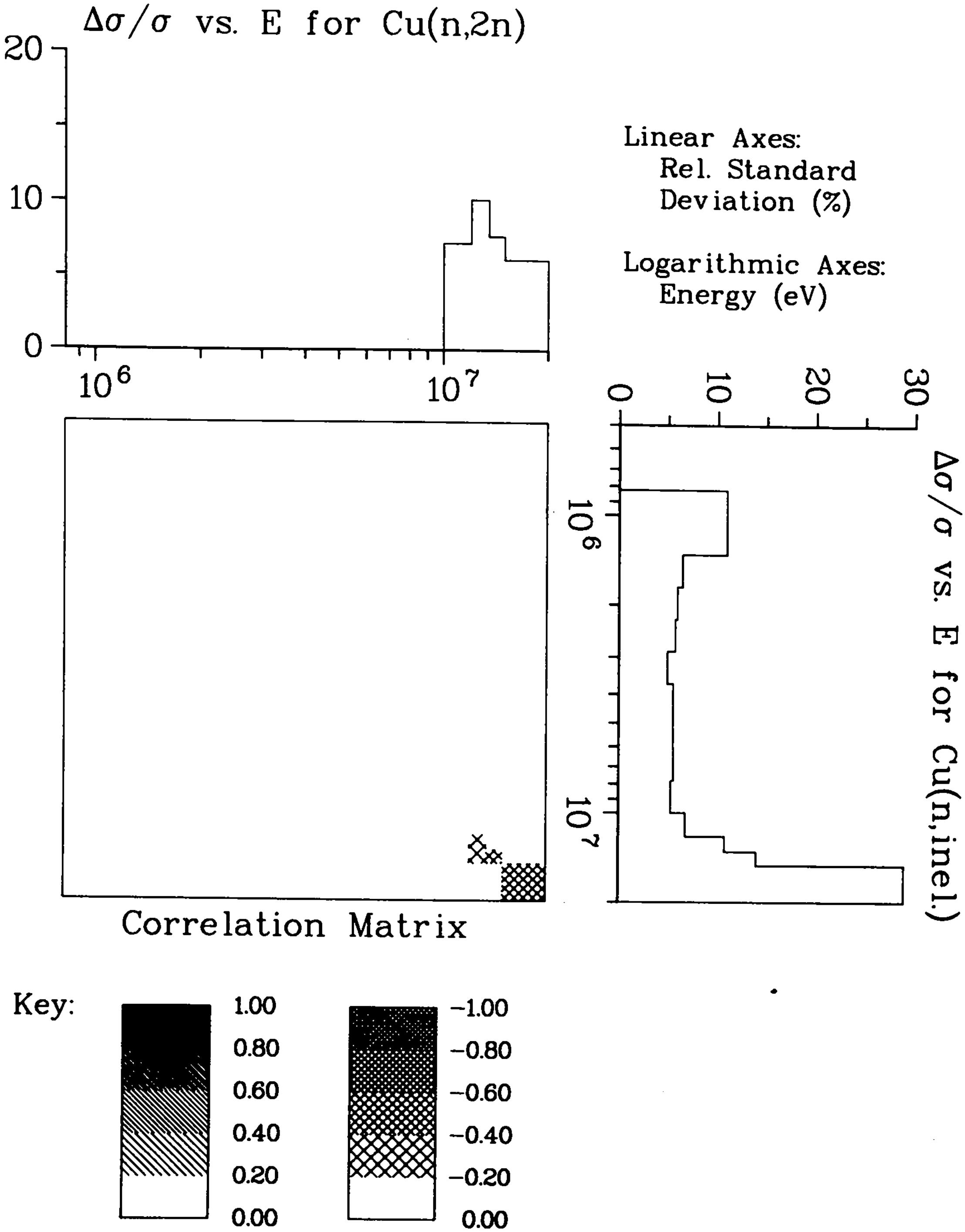


Fig. 114.
Covariance data for Cu(n,inel.) with Cu(n,2n).

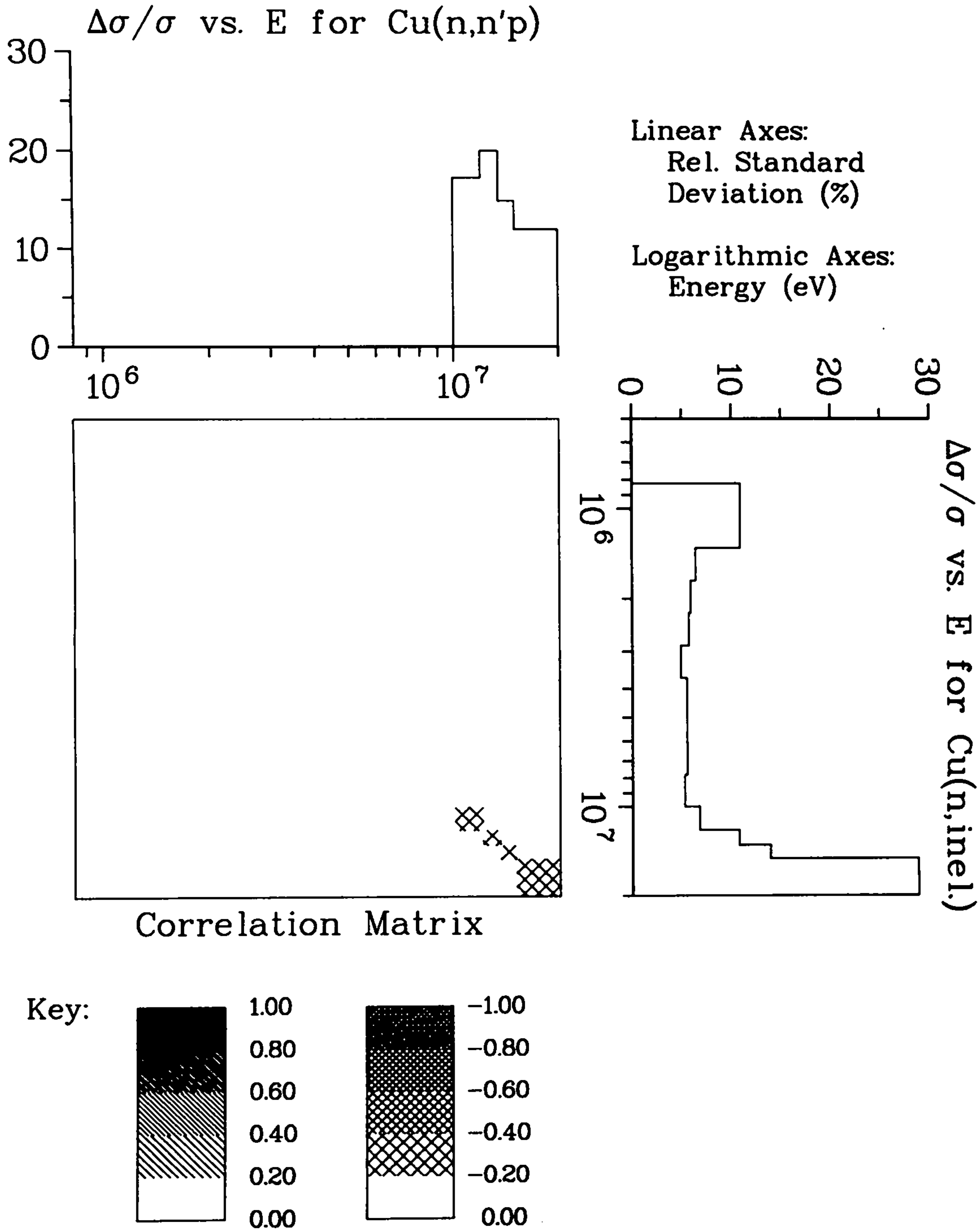


Fig. 115.

Covariance data for Cu(n,inel.) with Cu(n,n'p).

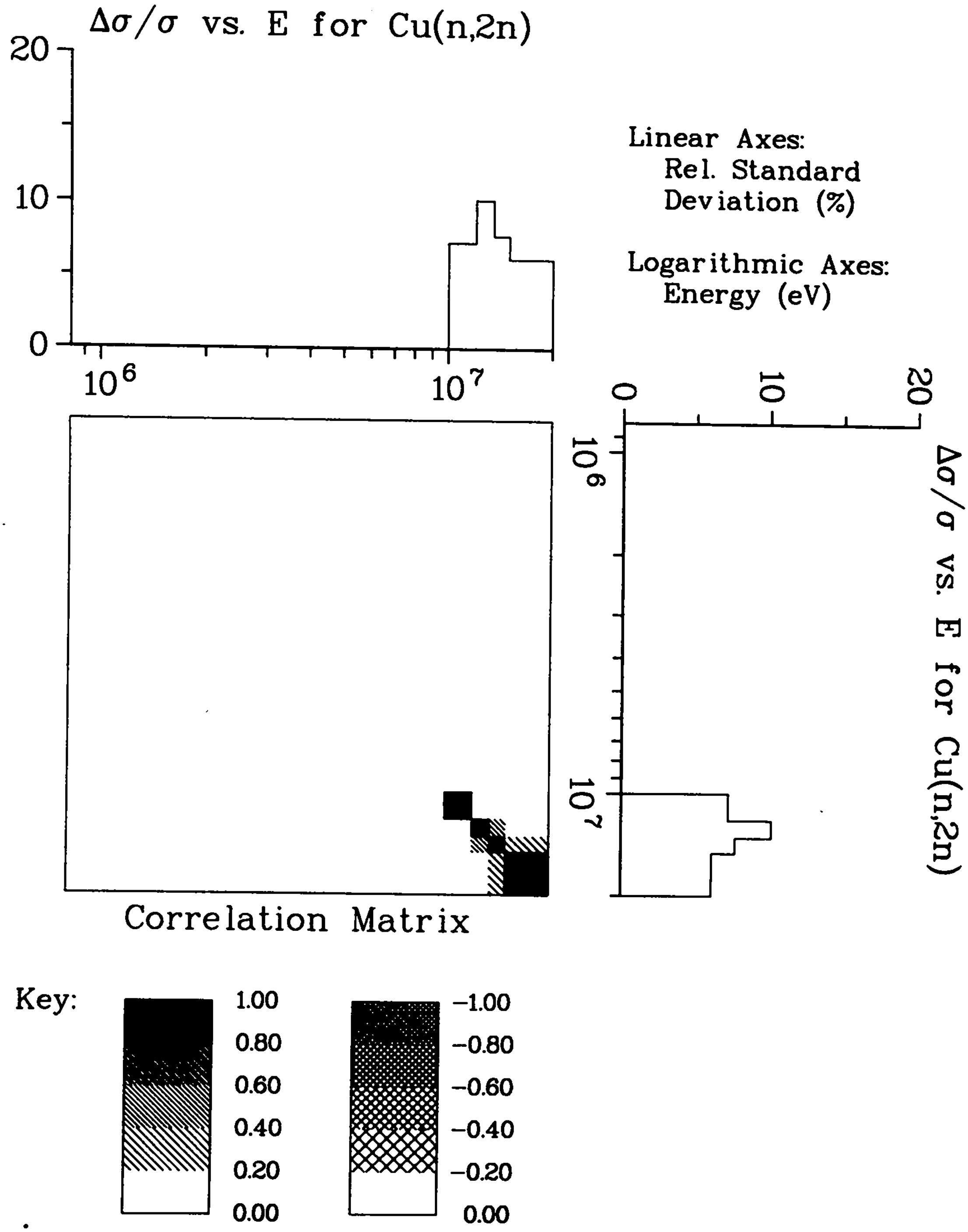


Fig. 116.
Covariance data for Cu(n,2n) with Cu(n,2n).

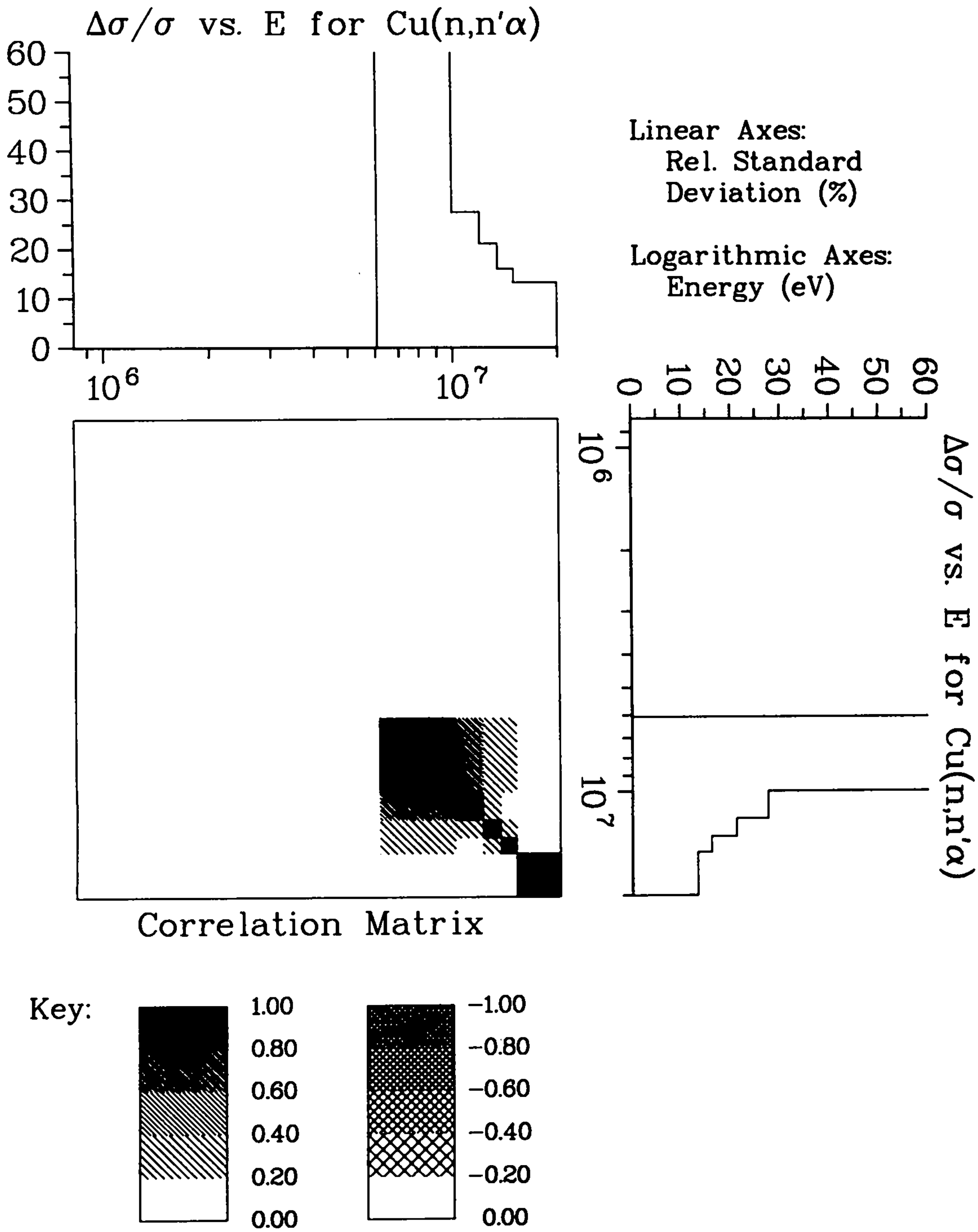


Fig. 117.
Covariance data for Cu(n,n'α) with Cu(n,n'α).

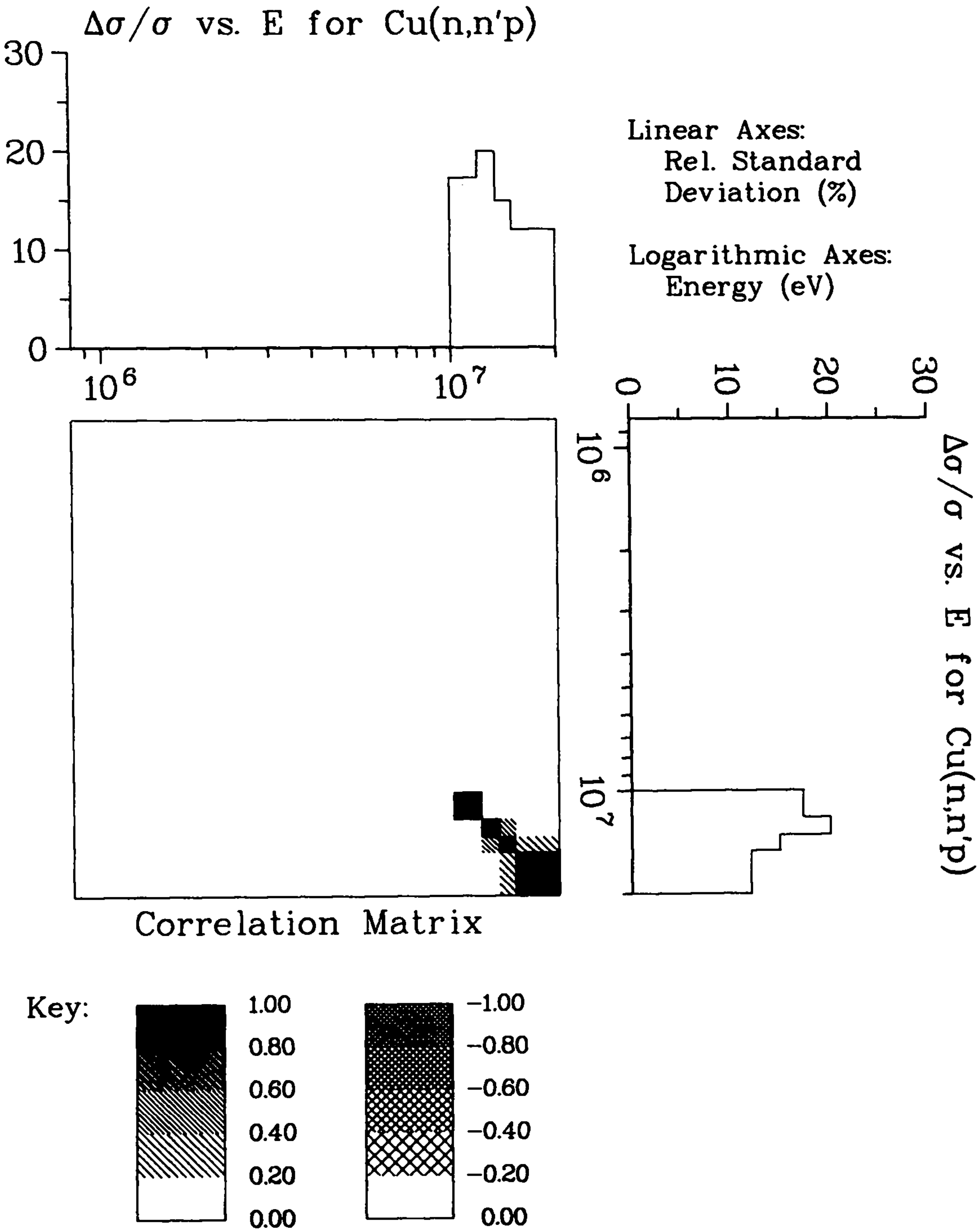


Fig. 118.
Covariance data for Cu(n,n'p) with Cu(n,n'p).

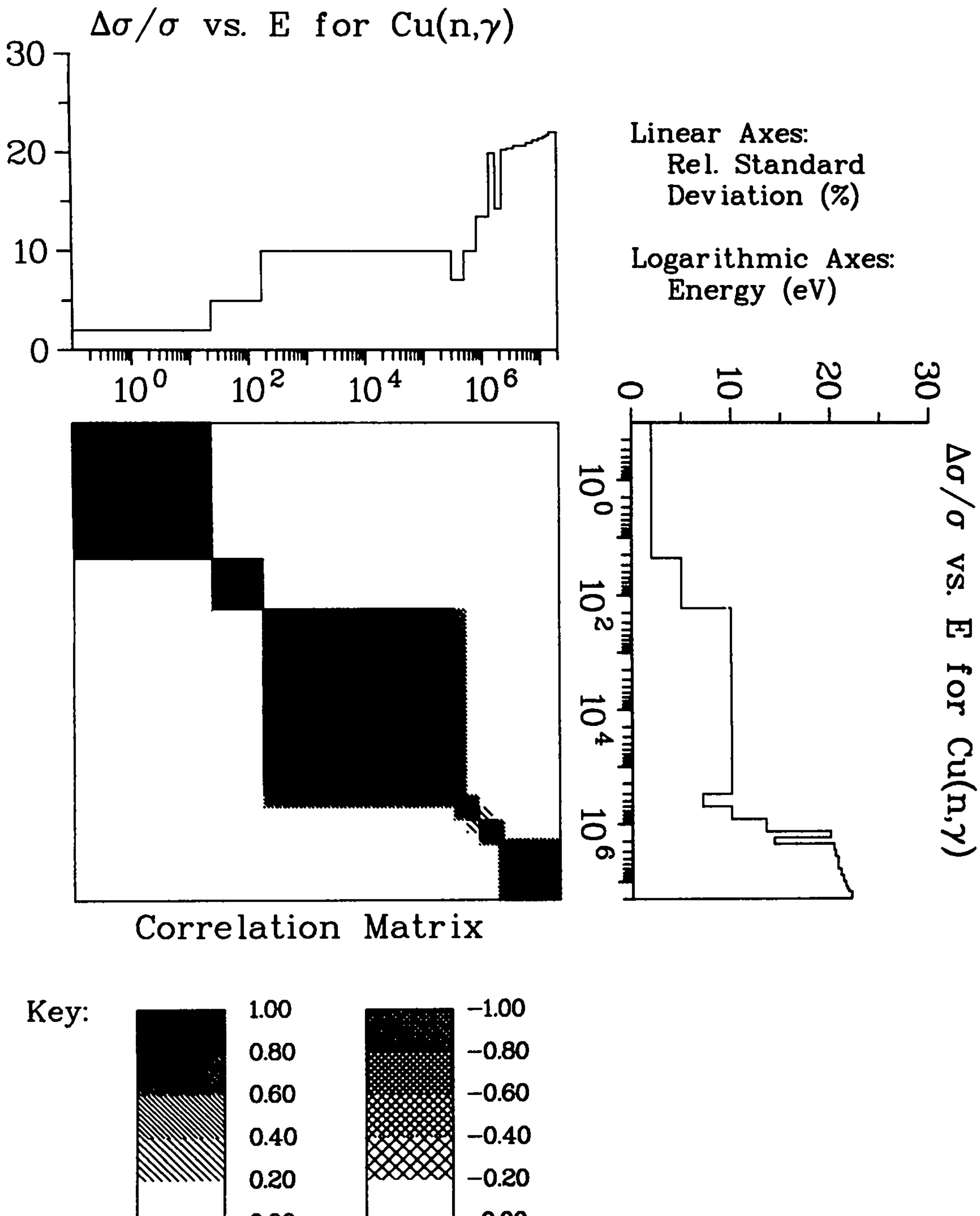


Fig. 119.
Covariance data for Cu(n,γ) with Cu(n,γ).

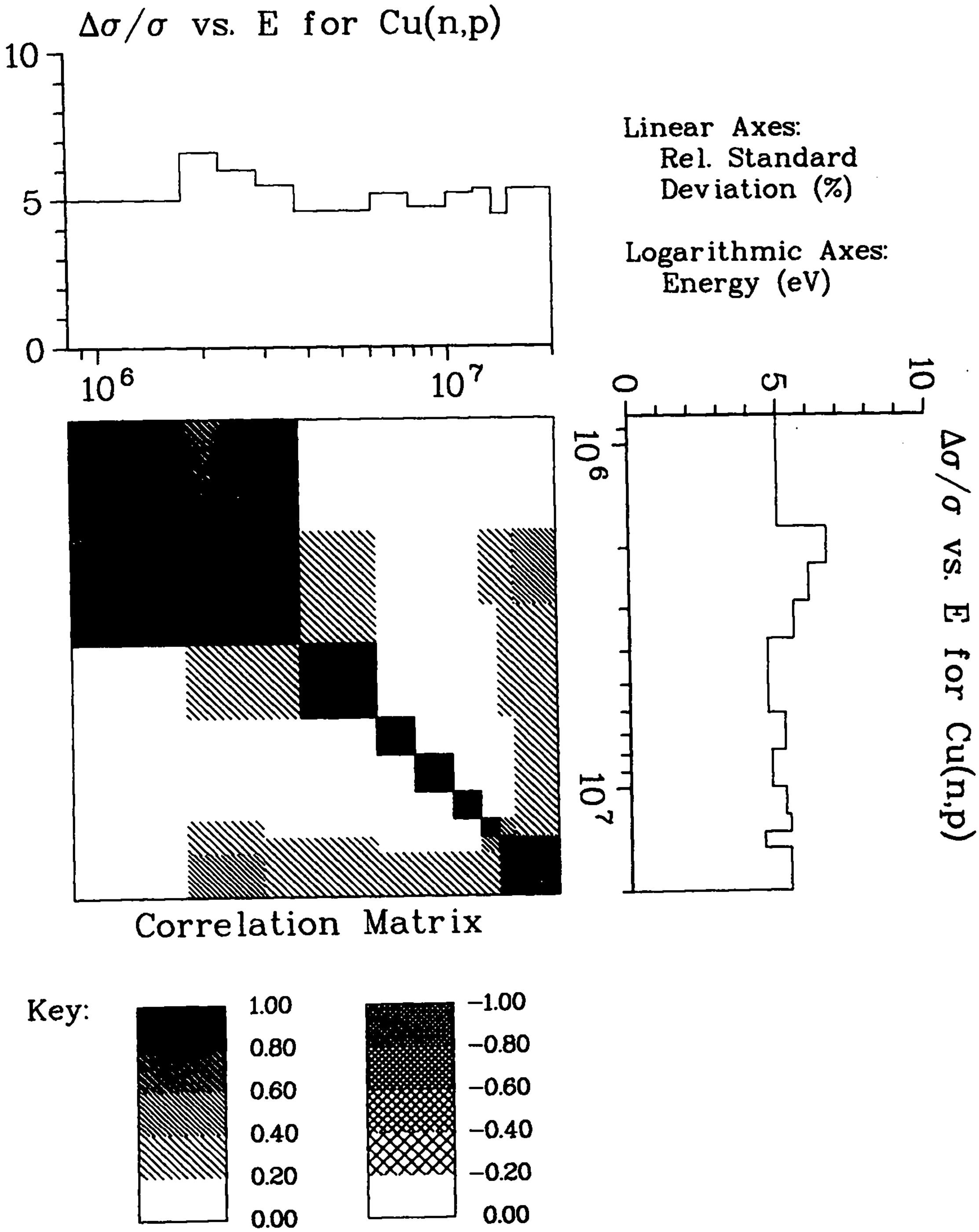


Fig. 120.

Covariance data for Cu(n,p) with Cu(n,p).

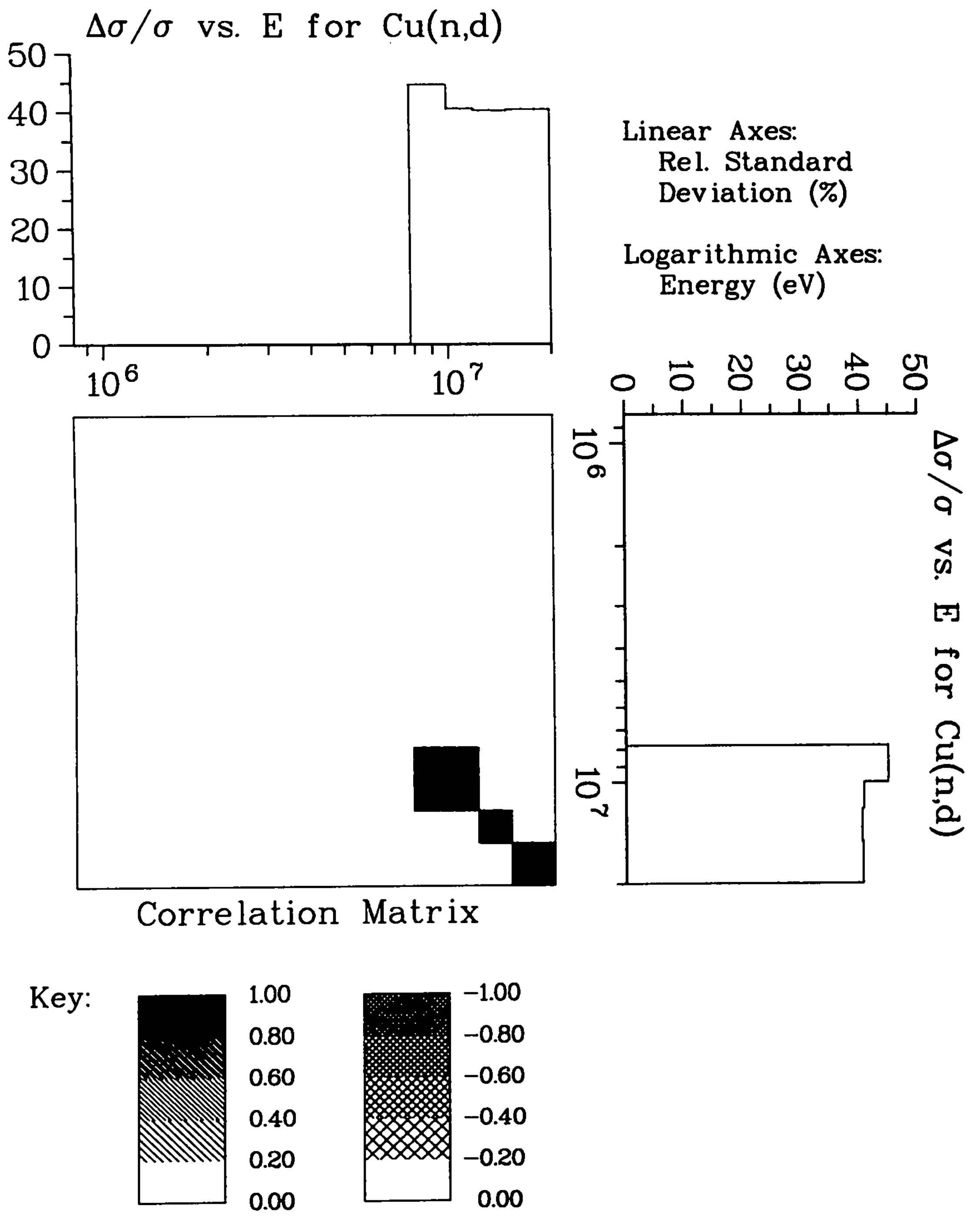


Fig. 121.
Covariance data for Cu(n,d) with Cu(n,d).

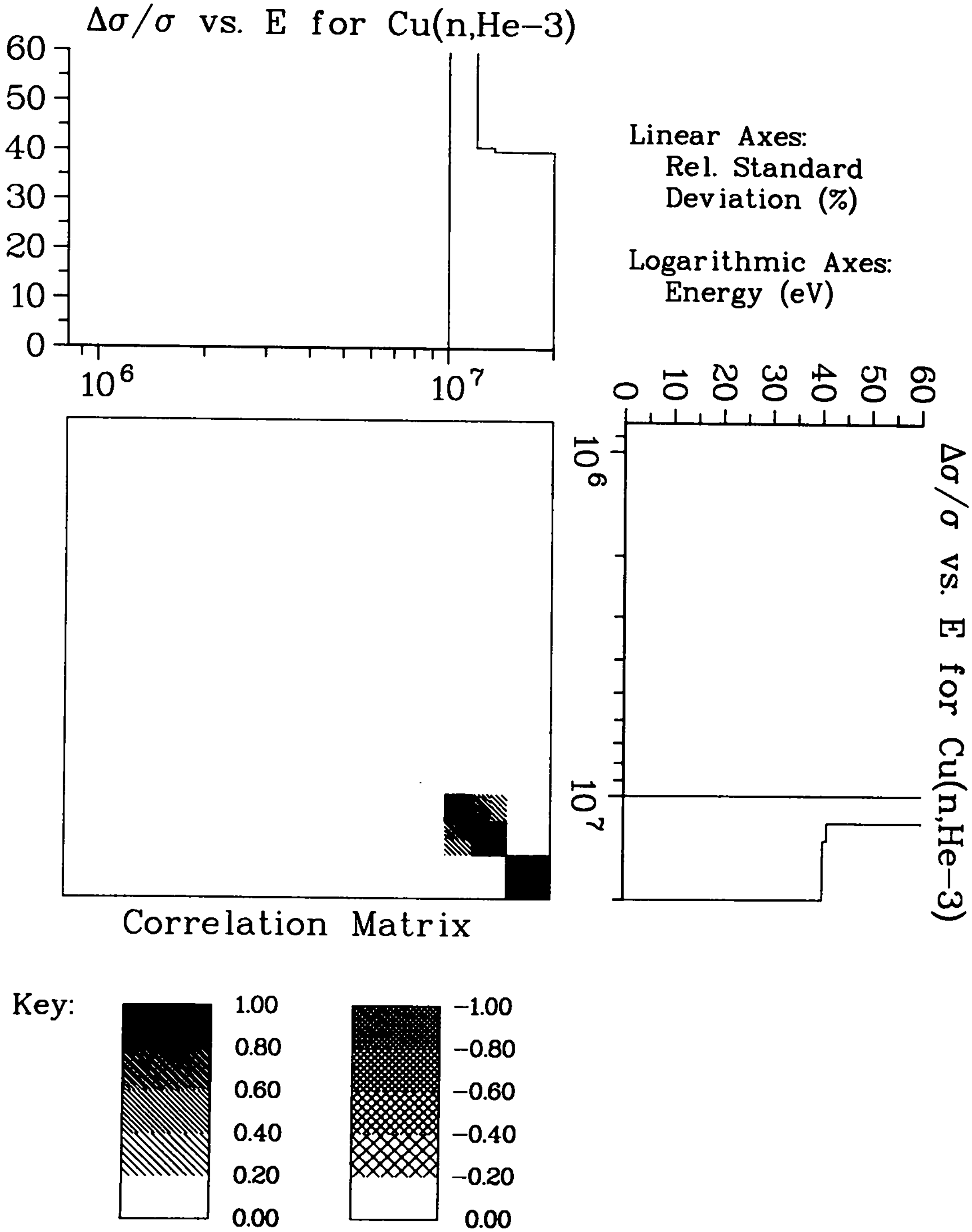


Fig. 122.
Covariance data for Cu(n,He–3) with Cu(n,He–3).

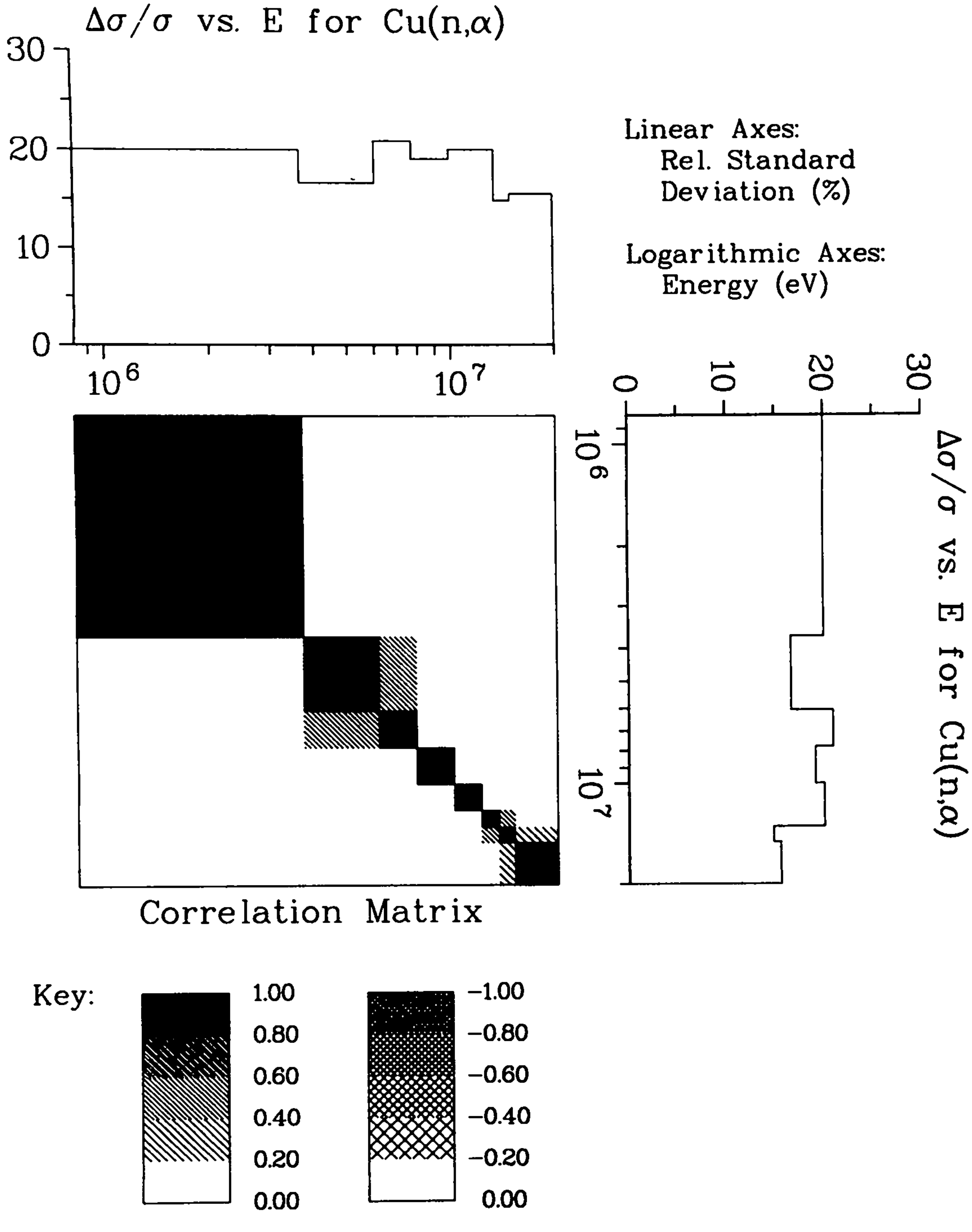


Fig. 123.
Covariance data for Cu(n,α) with Cu(n,α).

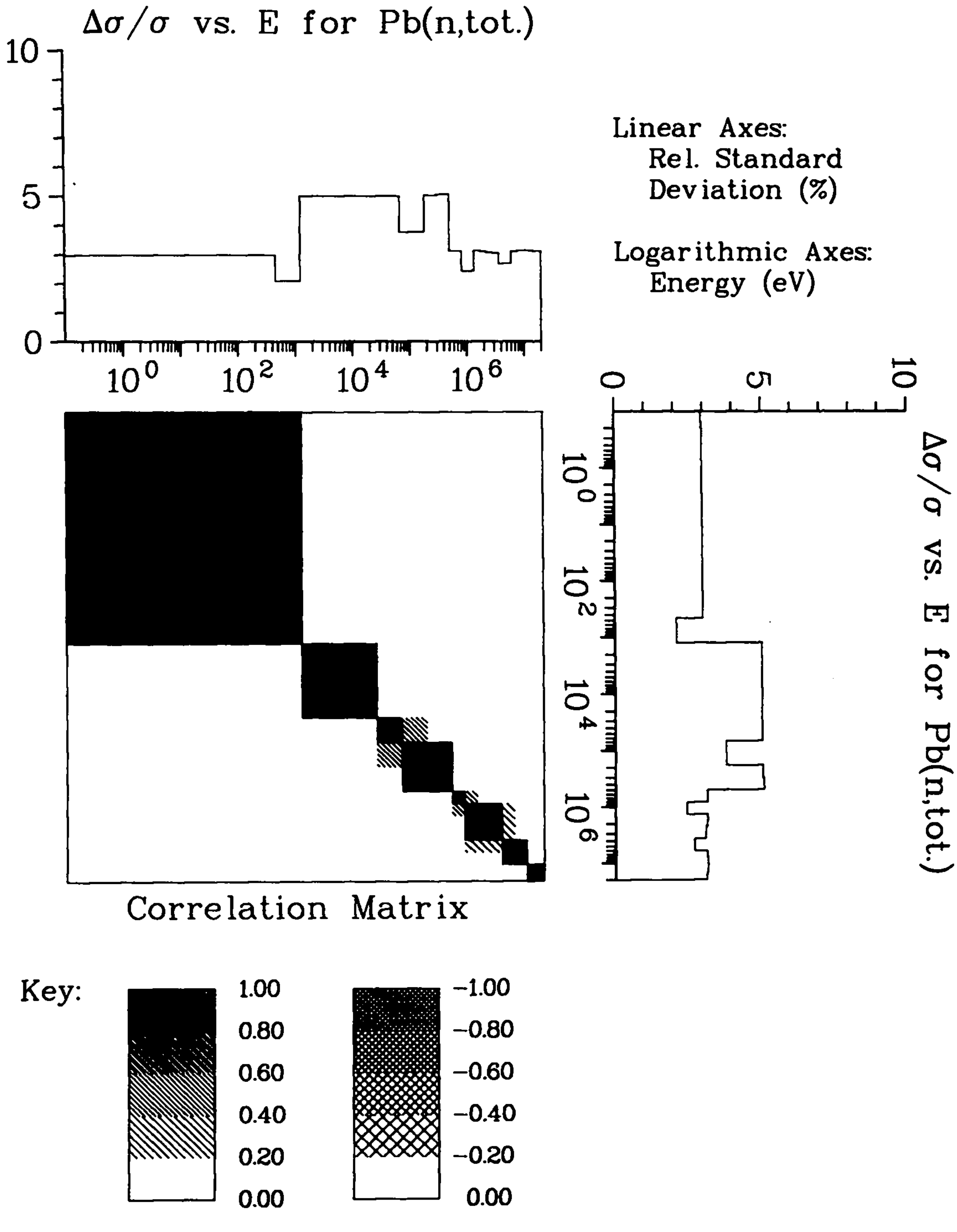


Fig. 124.

Covariance data for Pb(n,tot.) with Pb(n,tot.).

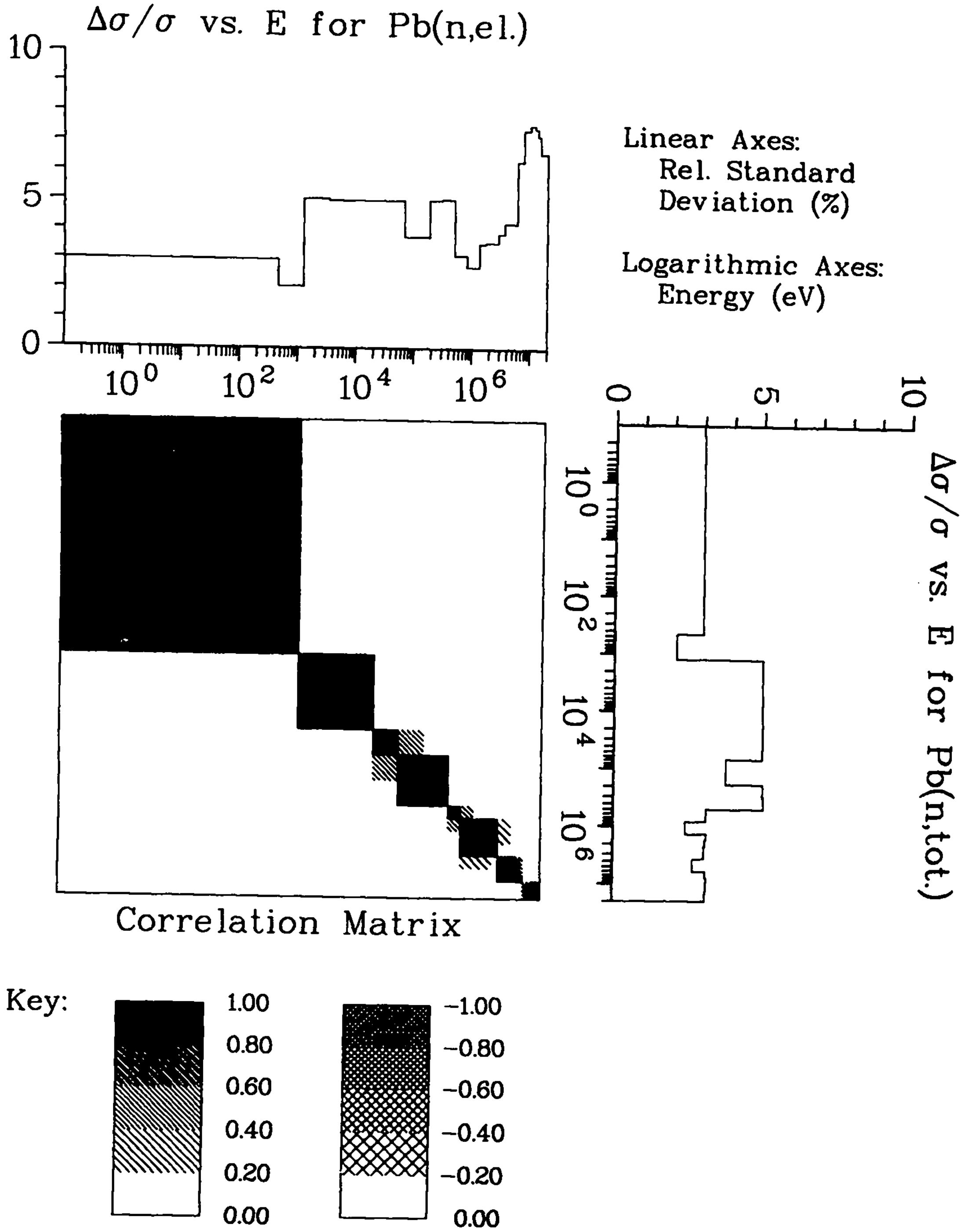


Fig. 125.
Covariance data for Pb(n,tot.) with Pb(n,el.).

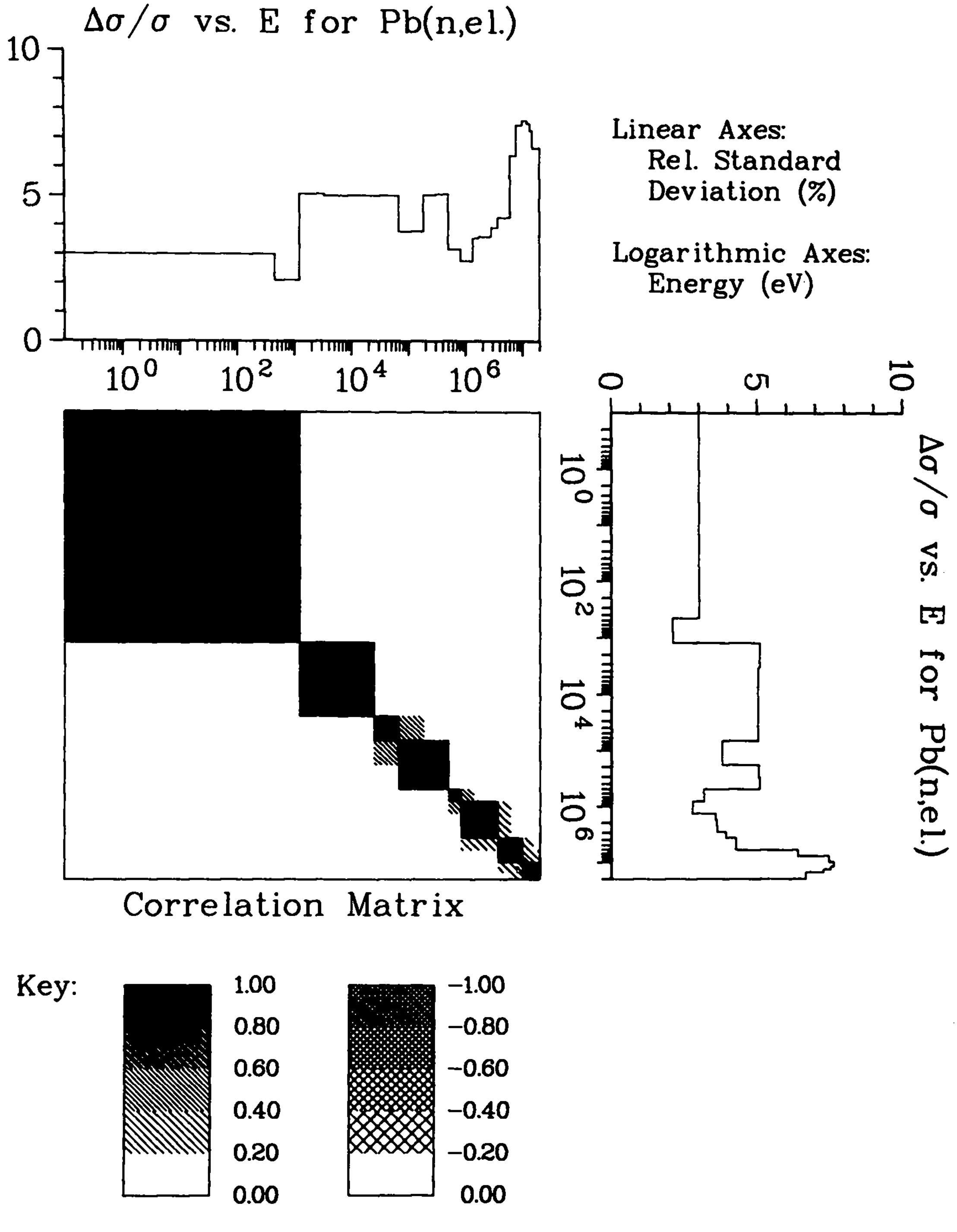


Fig. 126.
Covariance data for Pb(n,el.) with Pb(n,el.).

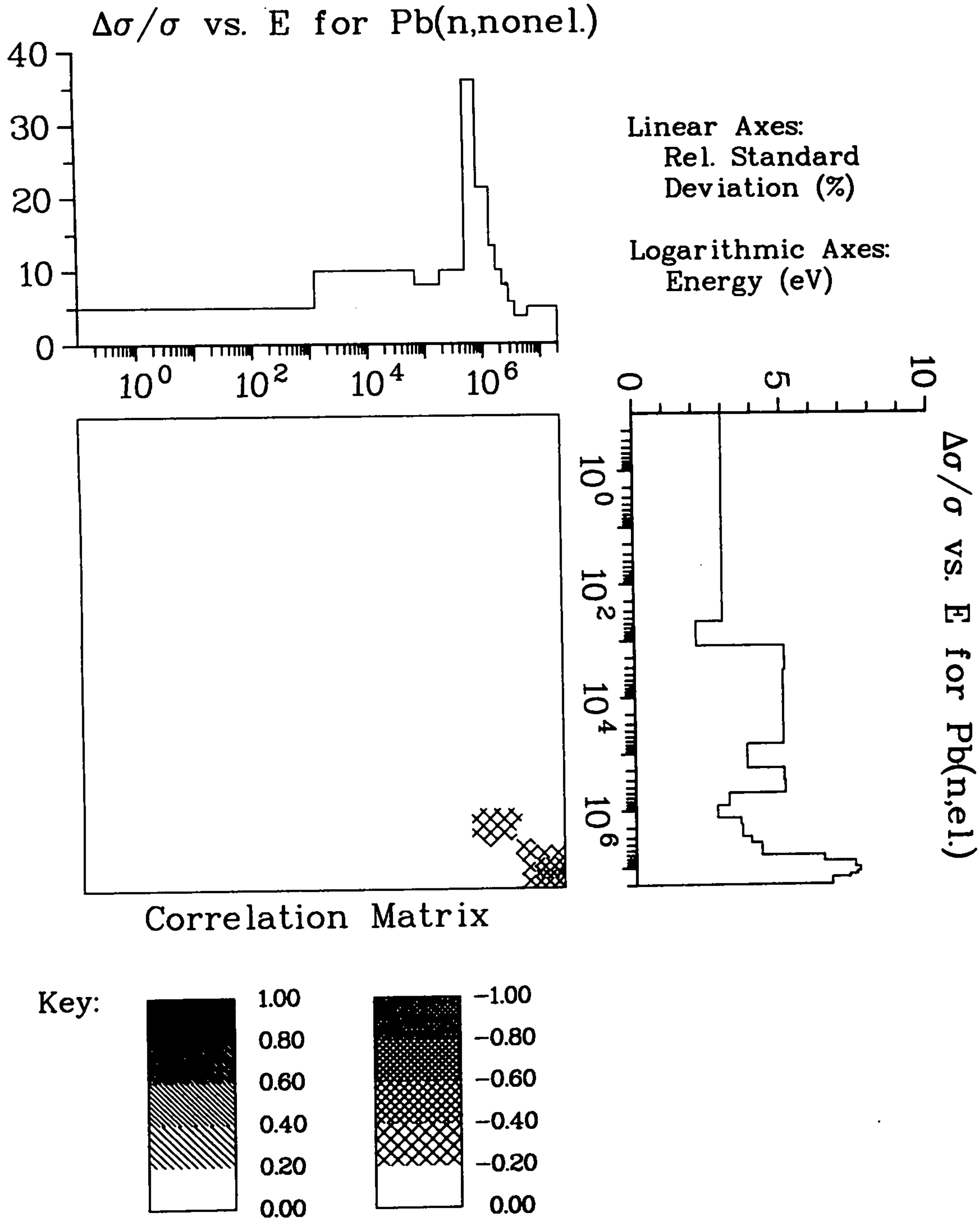


Fig. 127.
Covariance data for Pb(n,el.) with Pb(n,nonel.).

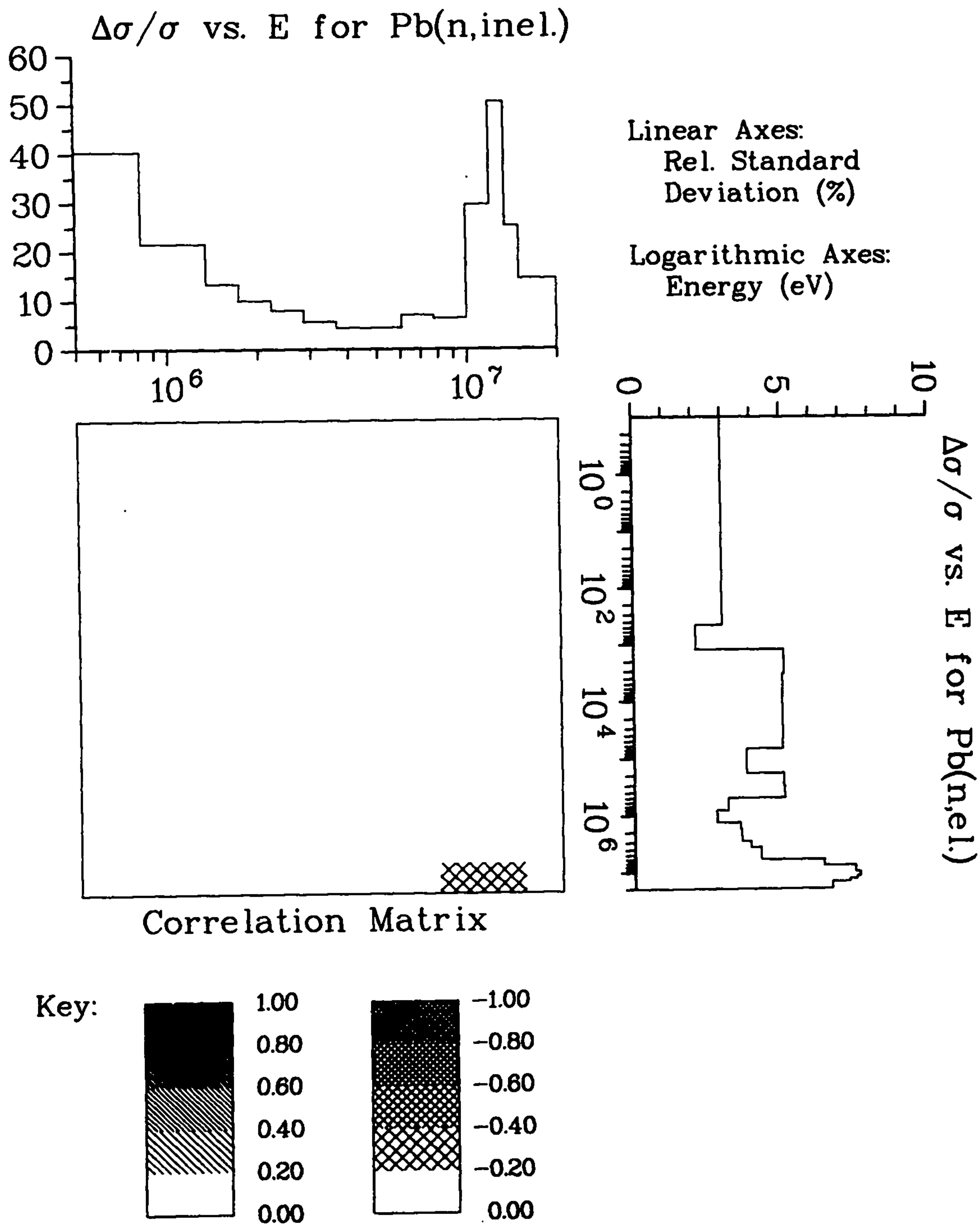


Fig. 128.

Covariance data for Pb(n,el.) with Pb(n,inel.).

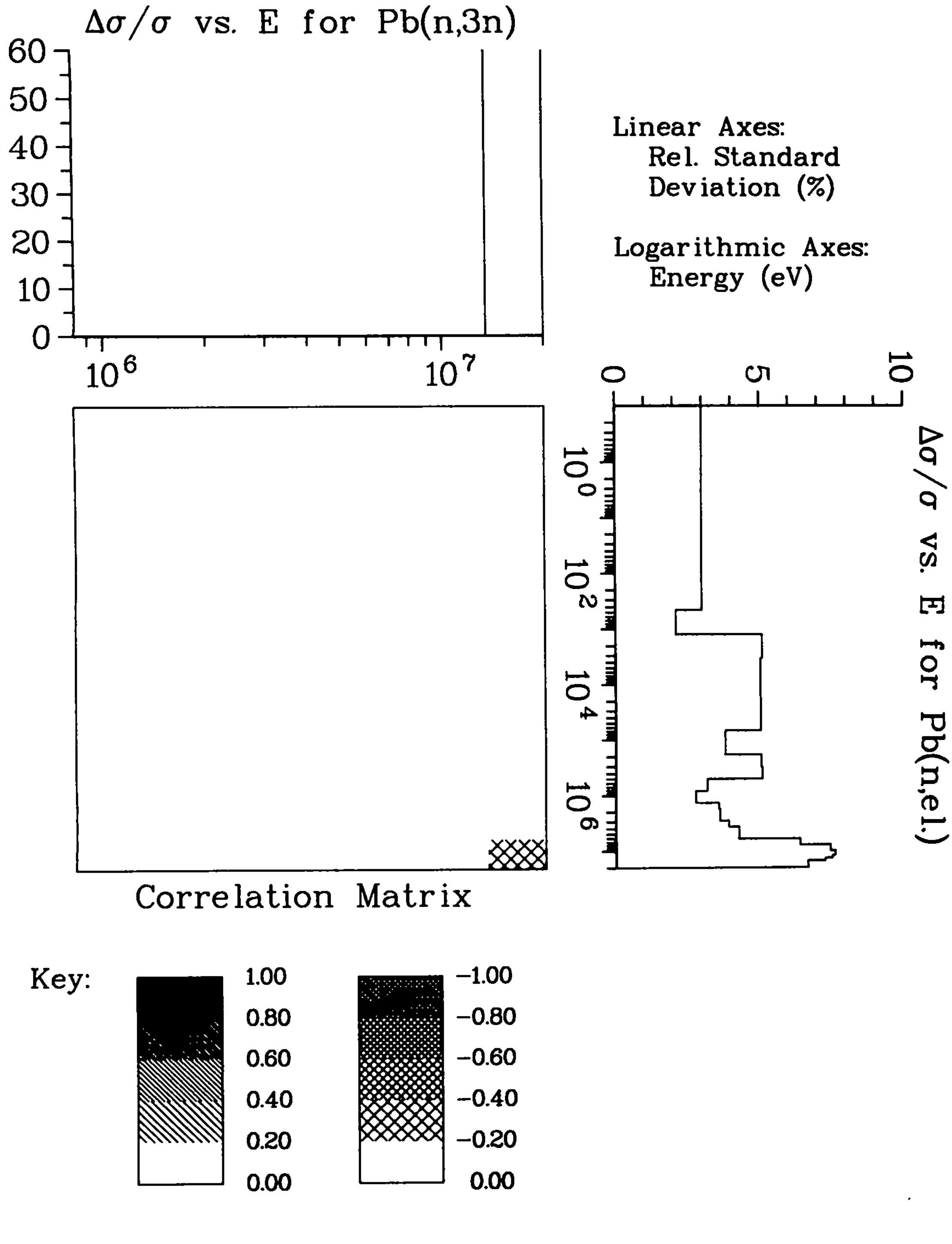


Fig. 129.
Covariance data for Pb(n,el.) with Pb(n,3n).

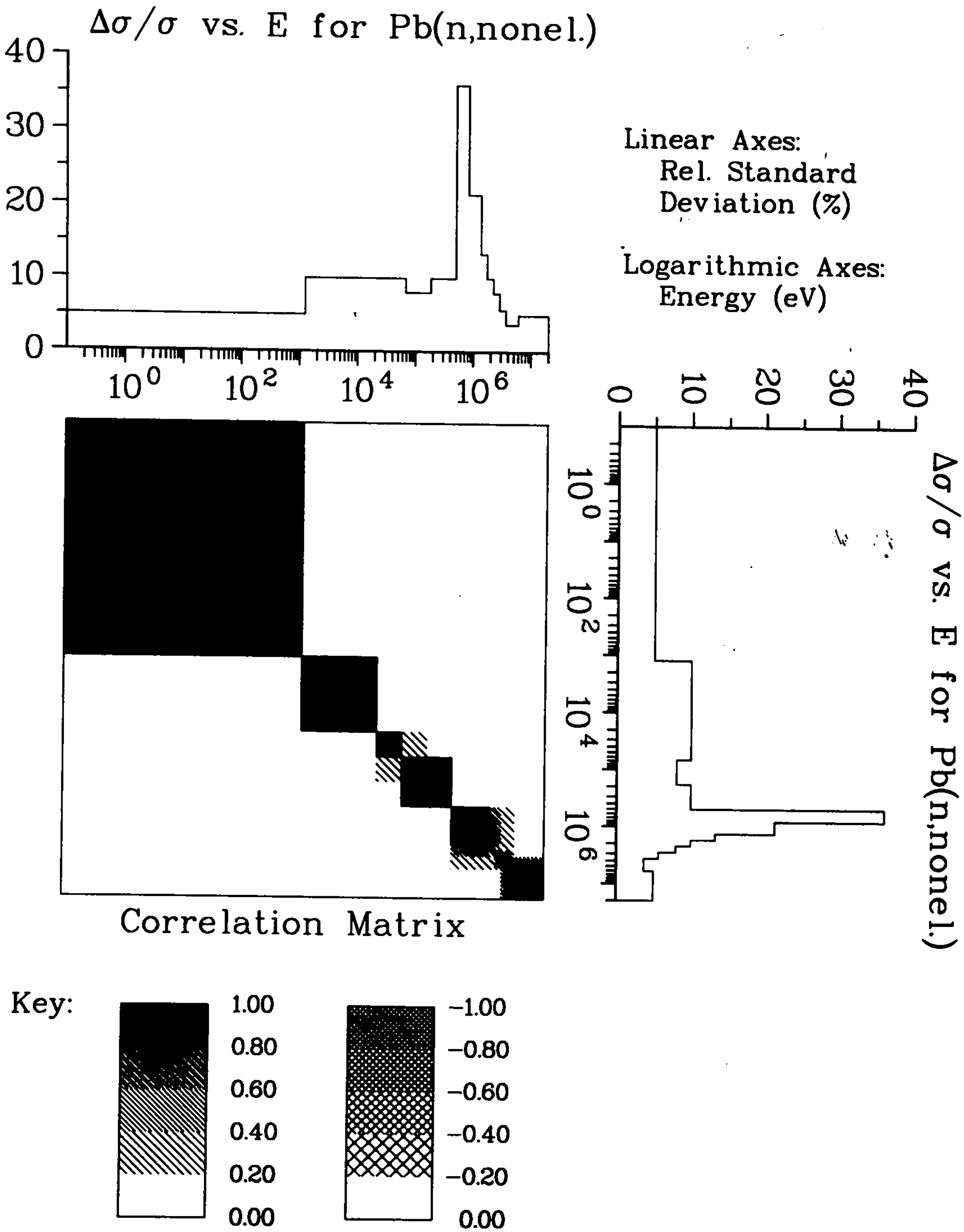


Fig. 130.
Covariance data for Pb(n,nonel.) with Pb(n,nonel.).

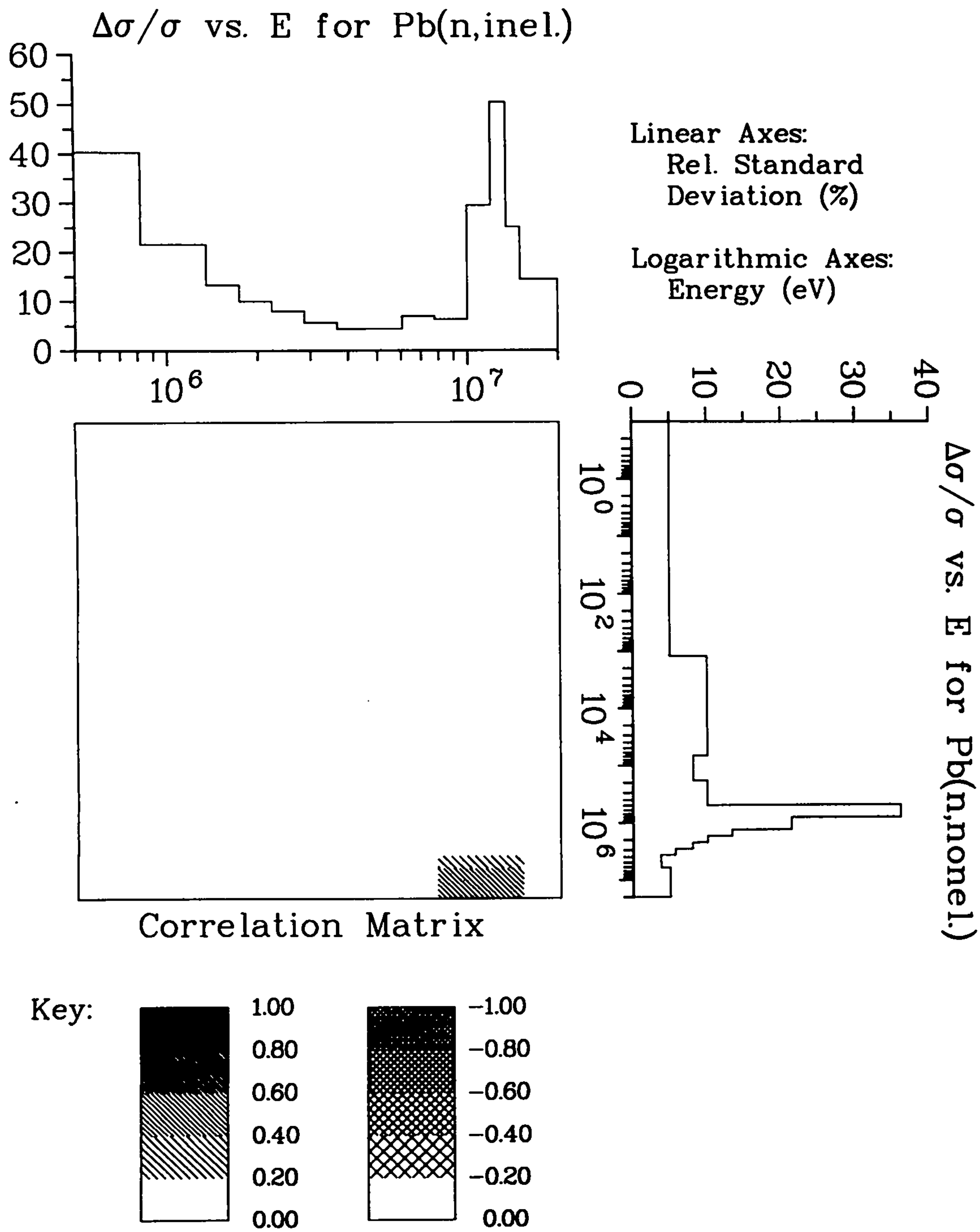


Fig. 131.

Covariance data for Pb(n,nonel.) with Pb(n,inel.).

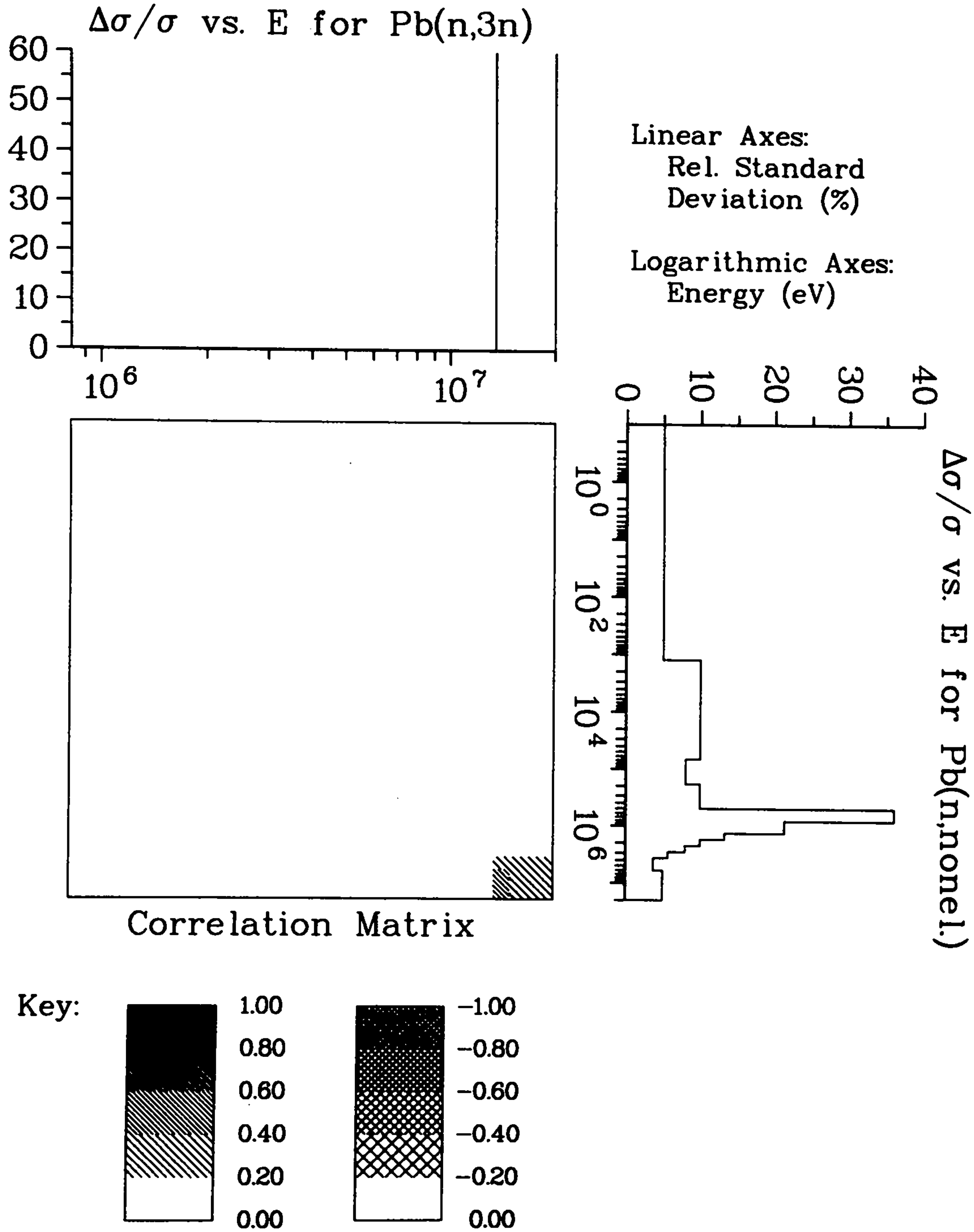


Fig. 132.
Covariance data for Pb(n,nonel.) with Pb(n,3n).

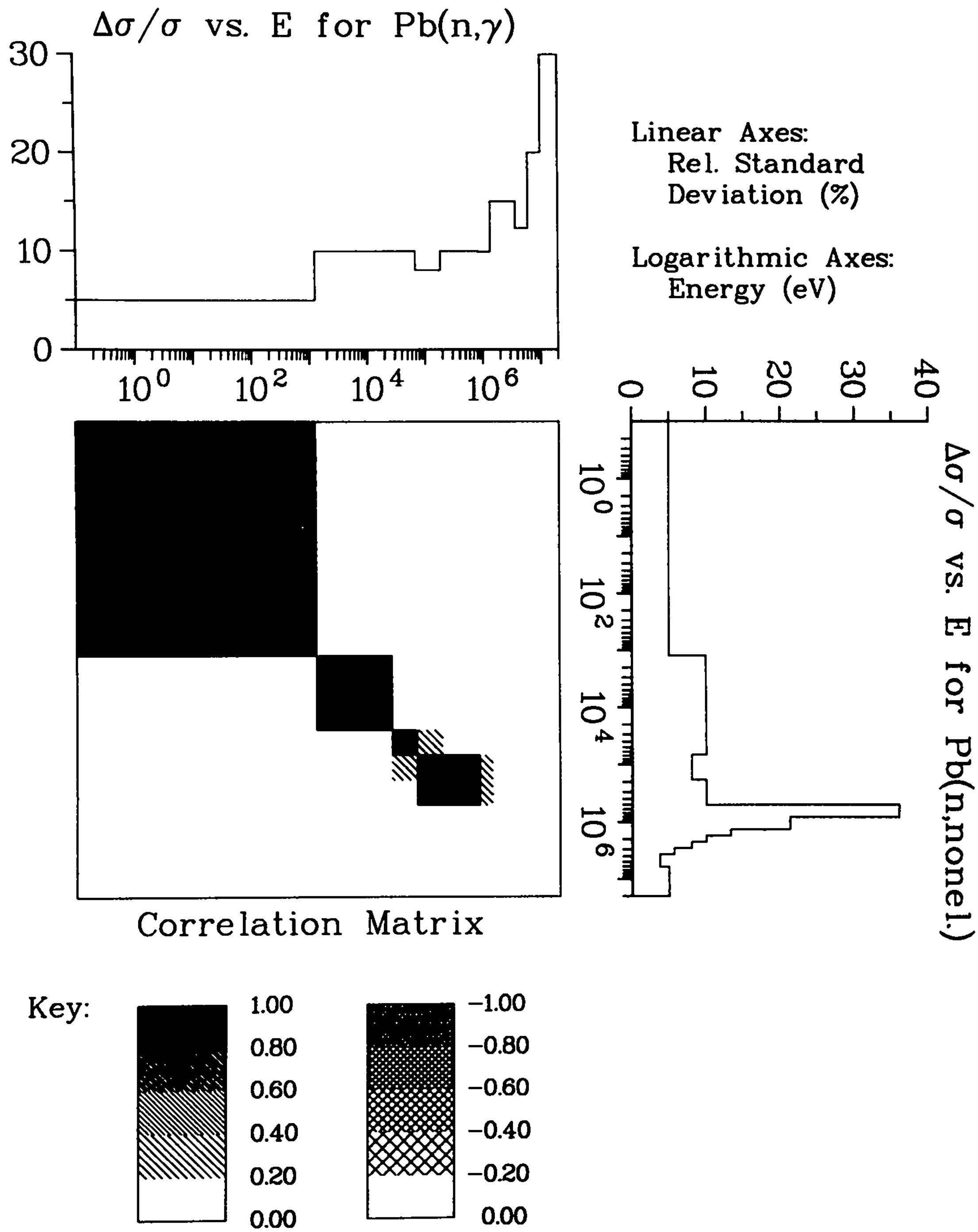


Fig. 133.
Covariance data for Pb(n,nonel.) with Pb(n,γ).

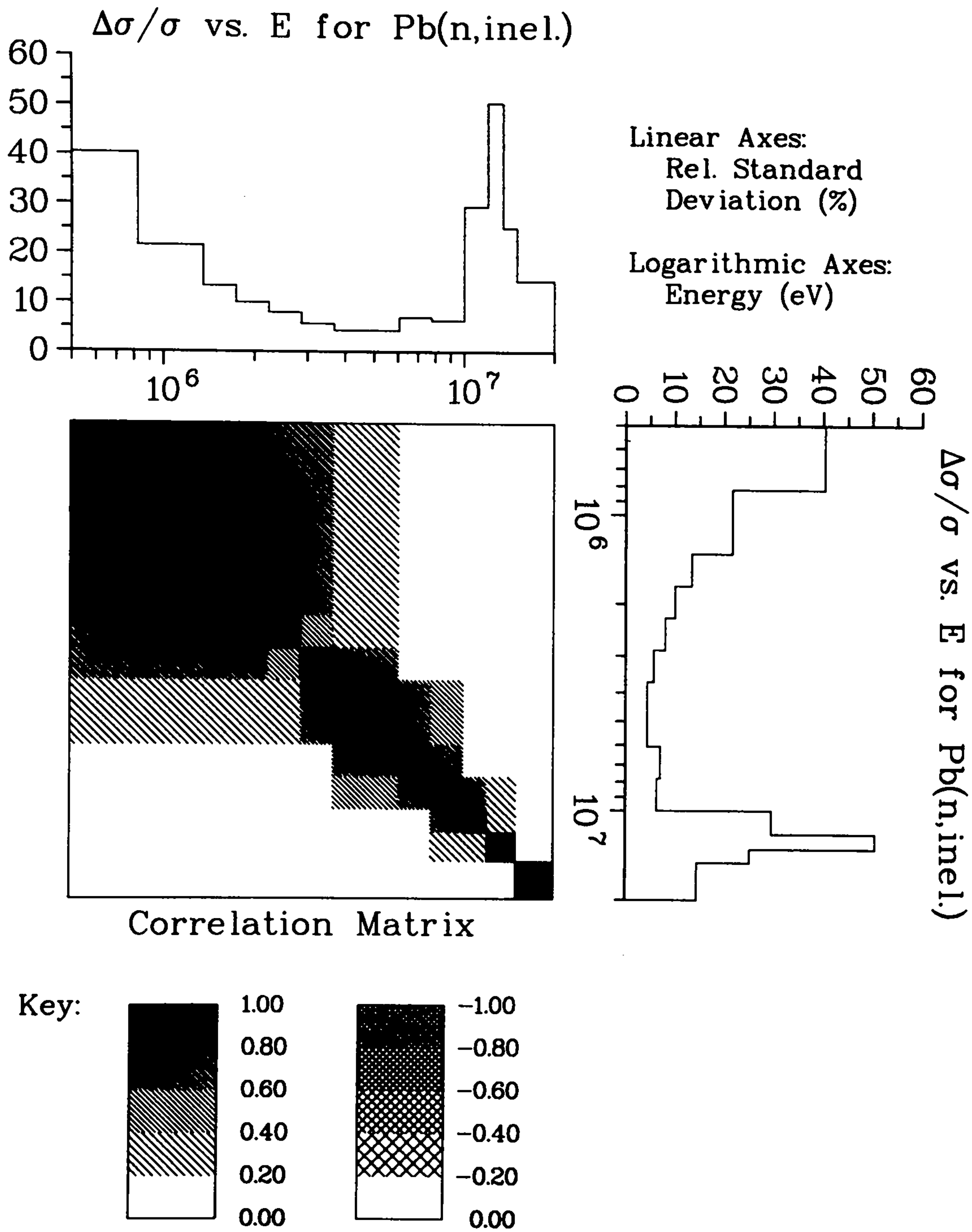


Fig. 134.
Covariance data for Pb(n,inel.) with Pb(n,inel.).

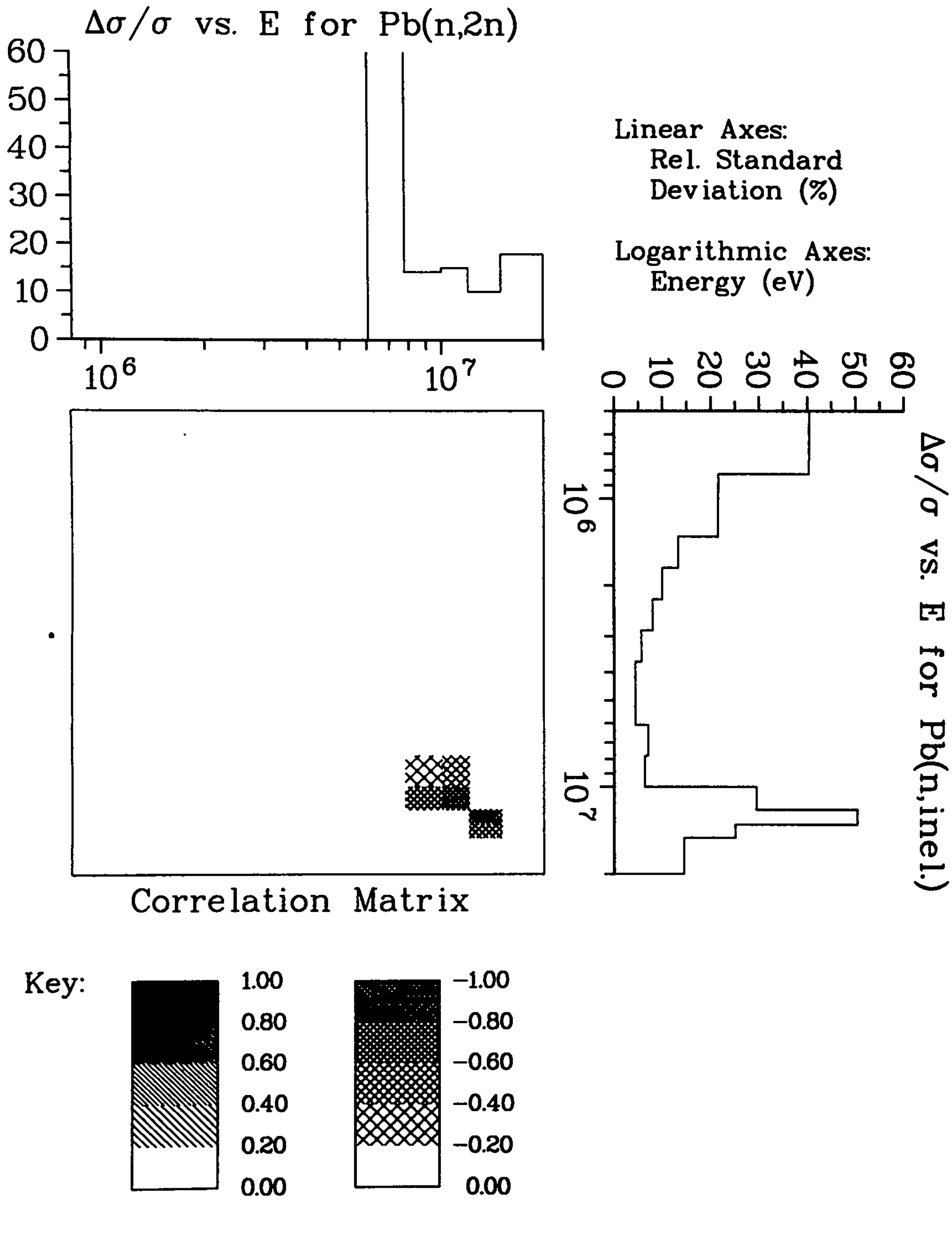


Fig. 135.
Covariance data for Pb(n,inel.) with Pb(n,2n).

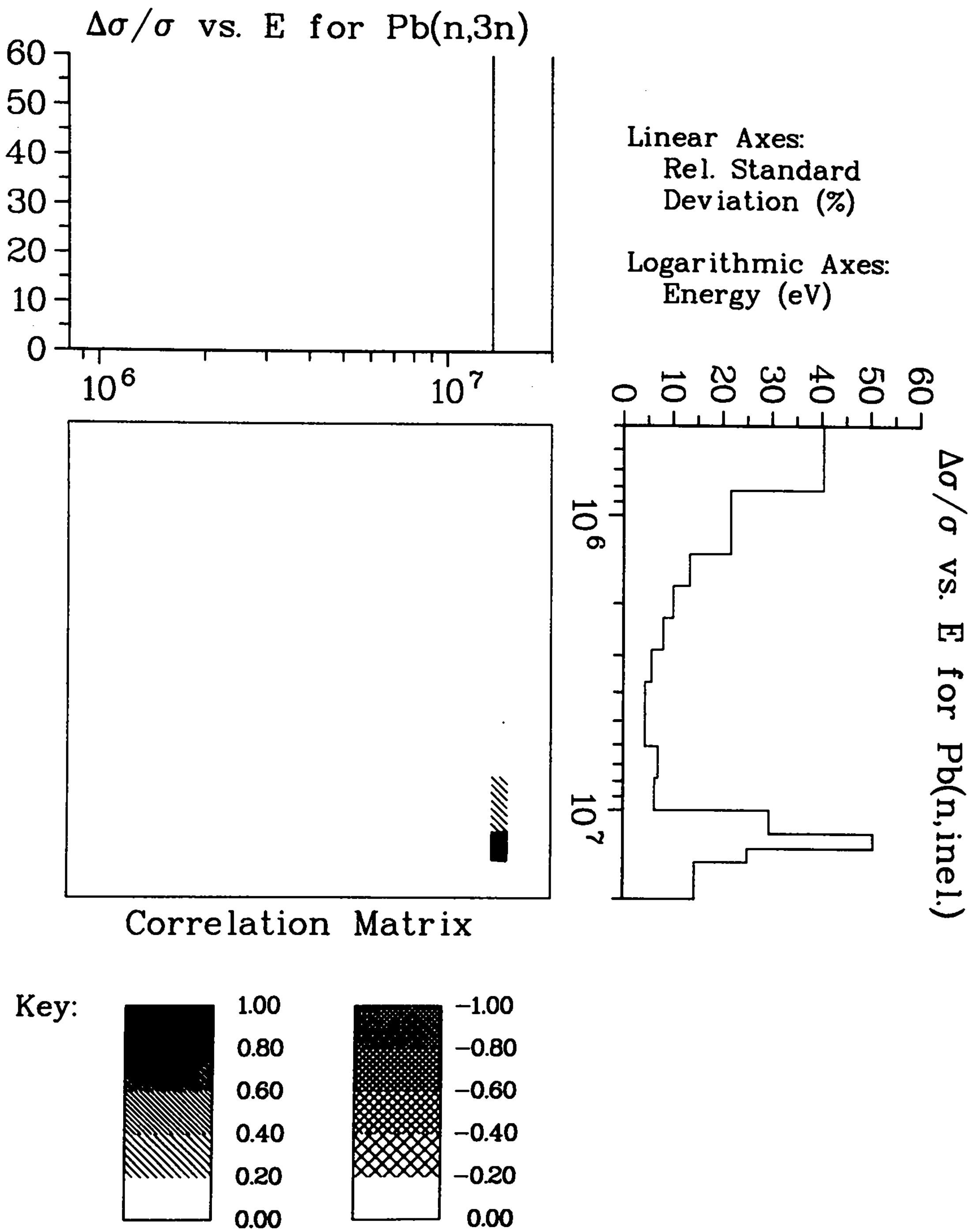


Fig. 136.

Covariance data for Pb(n,inel.) with Pb(n,3n).

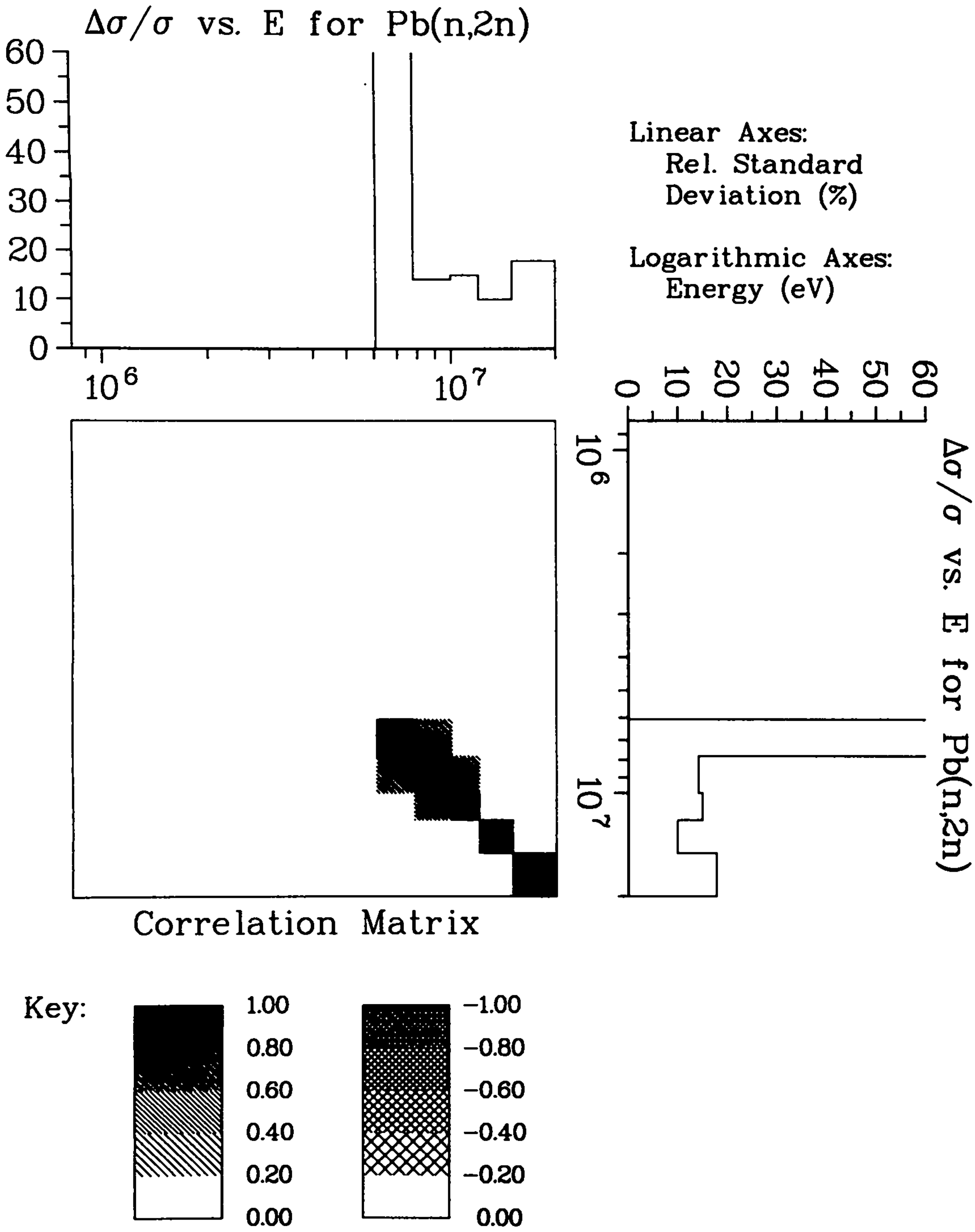


Fig. 137.
Covariance data for Pb(n,2n) with Pb(n,2n).

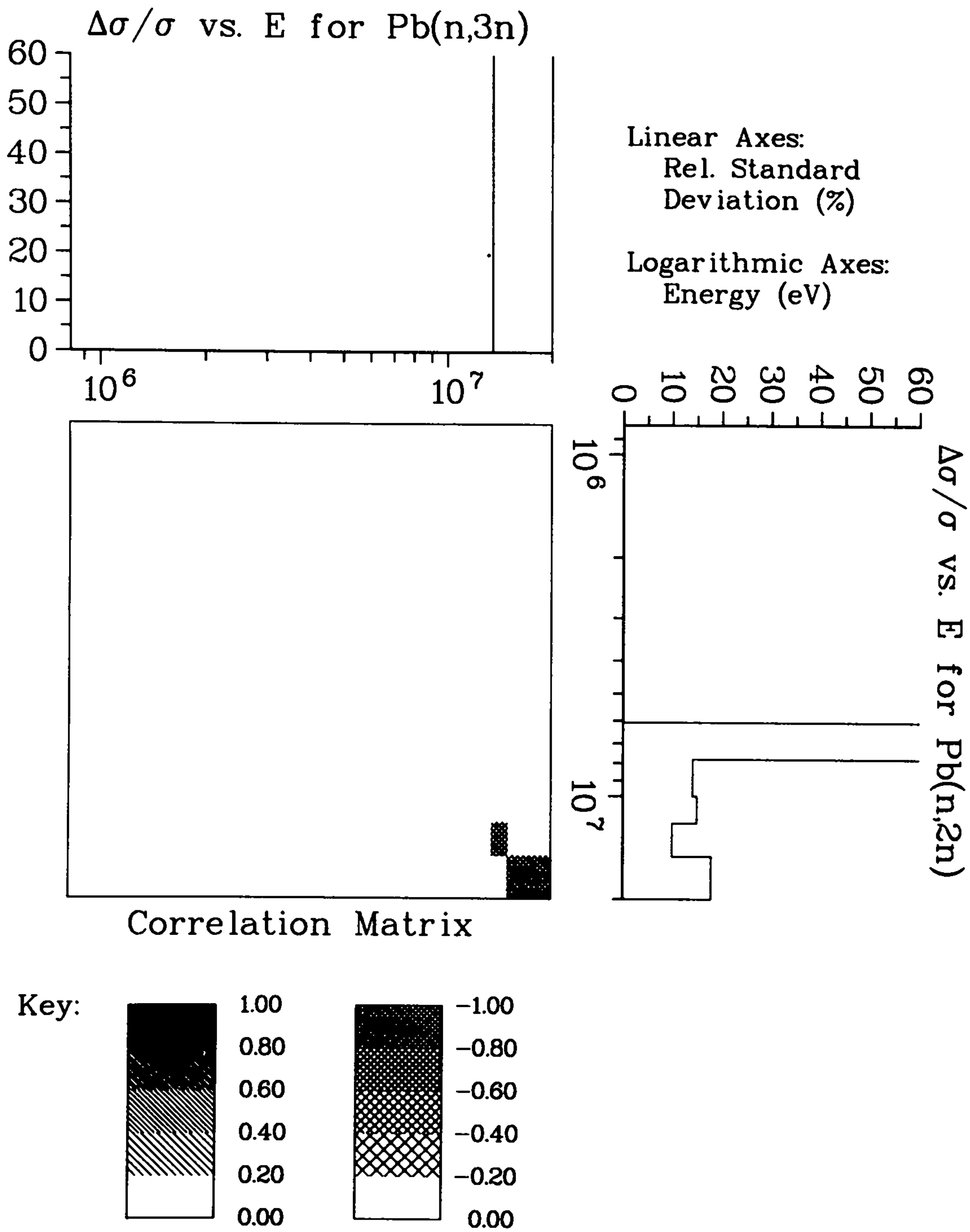


Fig. 138.
Covariance data for Pb(n,2n) with Pb(n,3n).

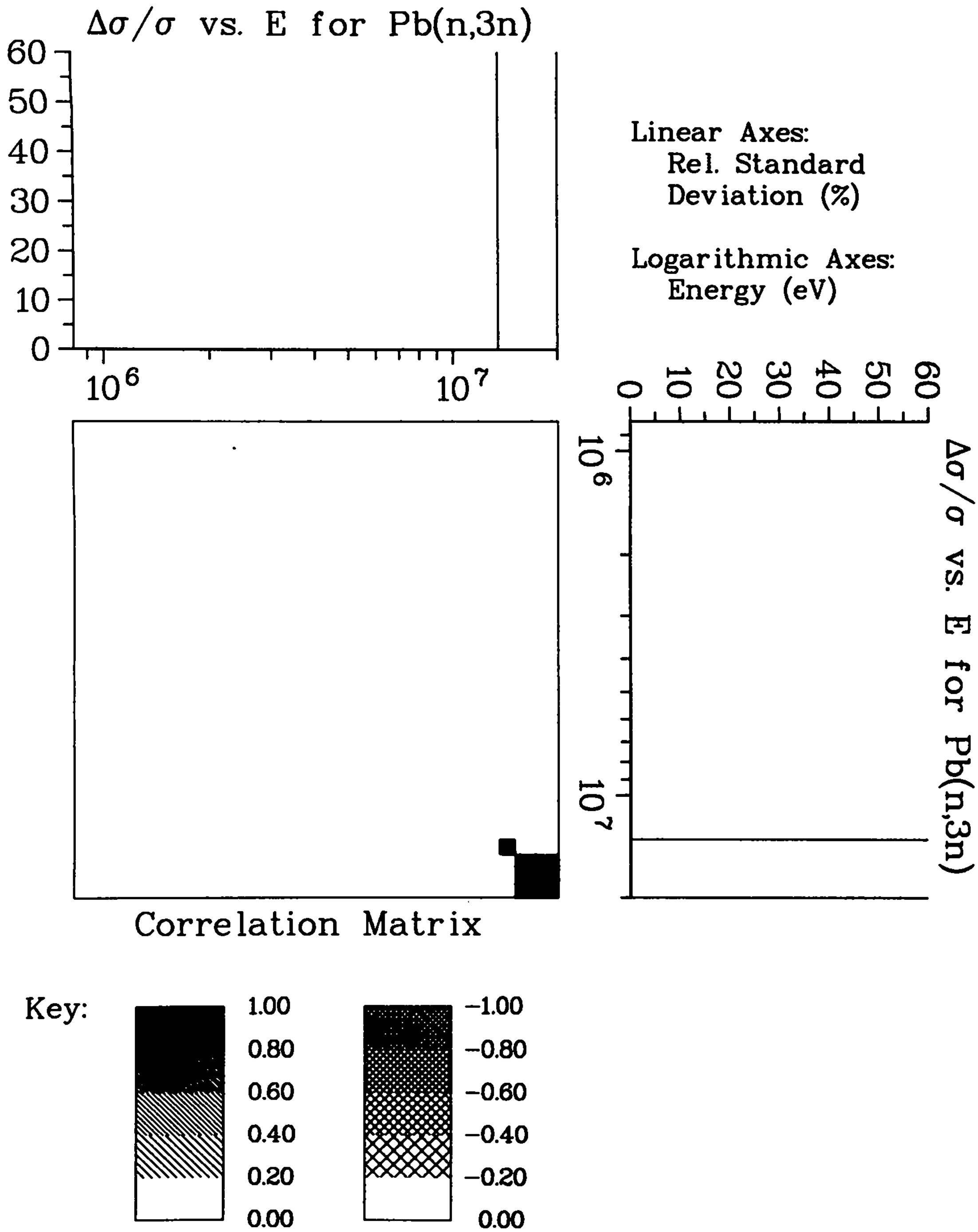


Fig. 139.
Covariance data for Pb(n,3n) with Pb(n,3n).

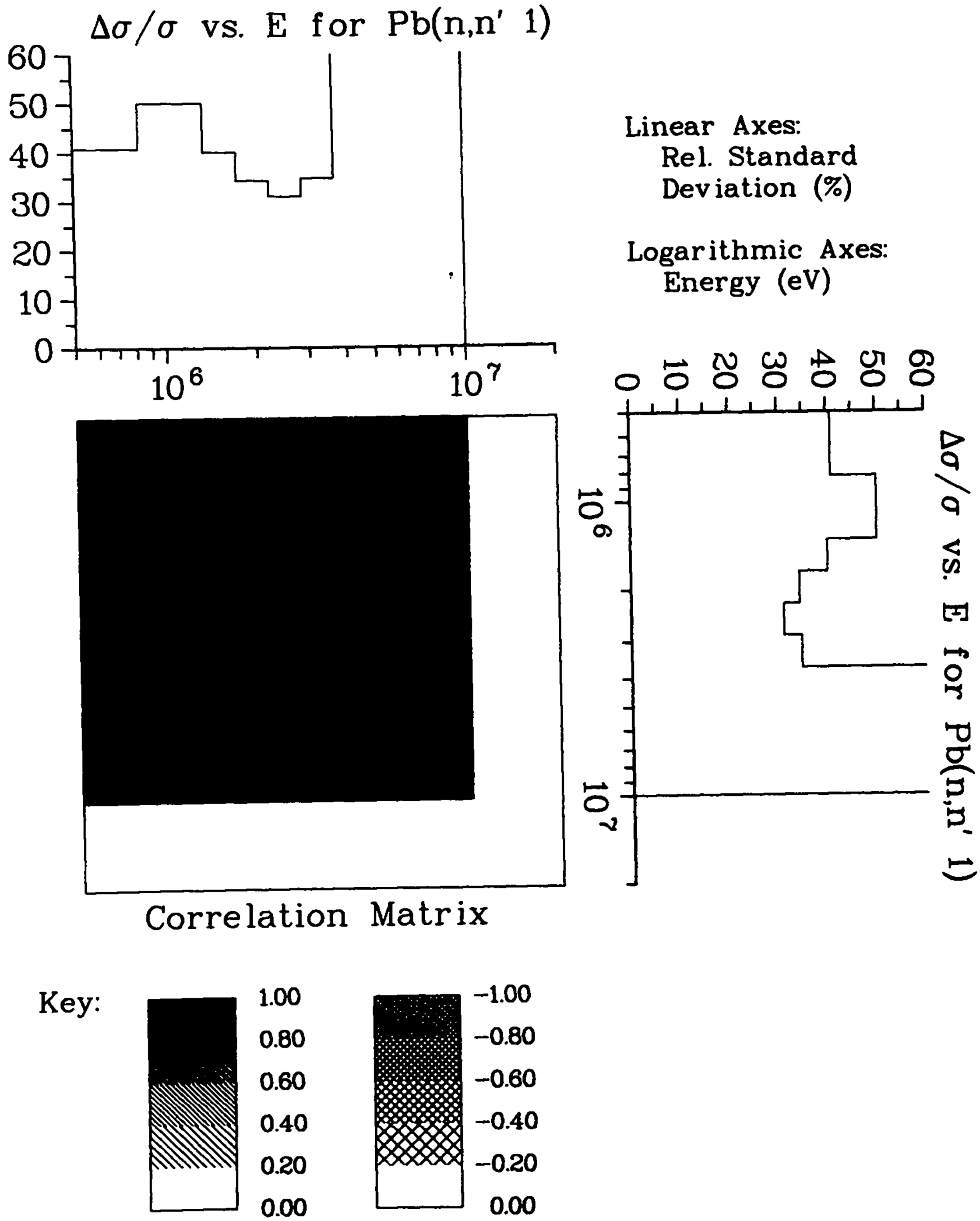


Fig. 140.
Covariance data for Pb(n,n' 1) with Pb(n,n' 1).

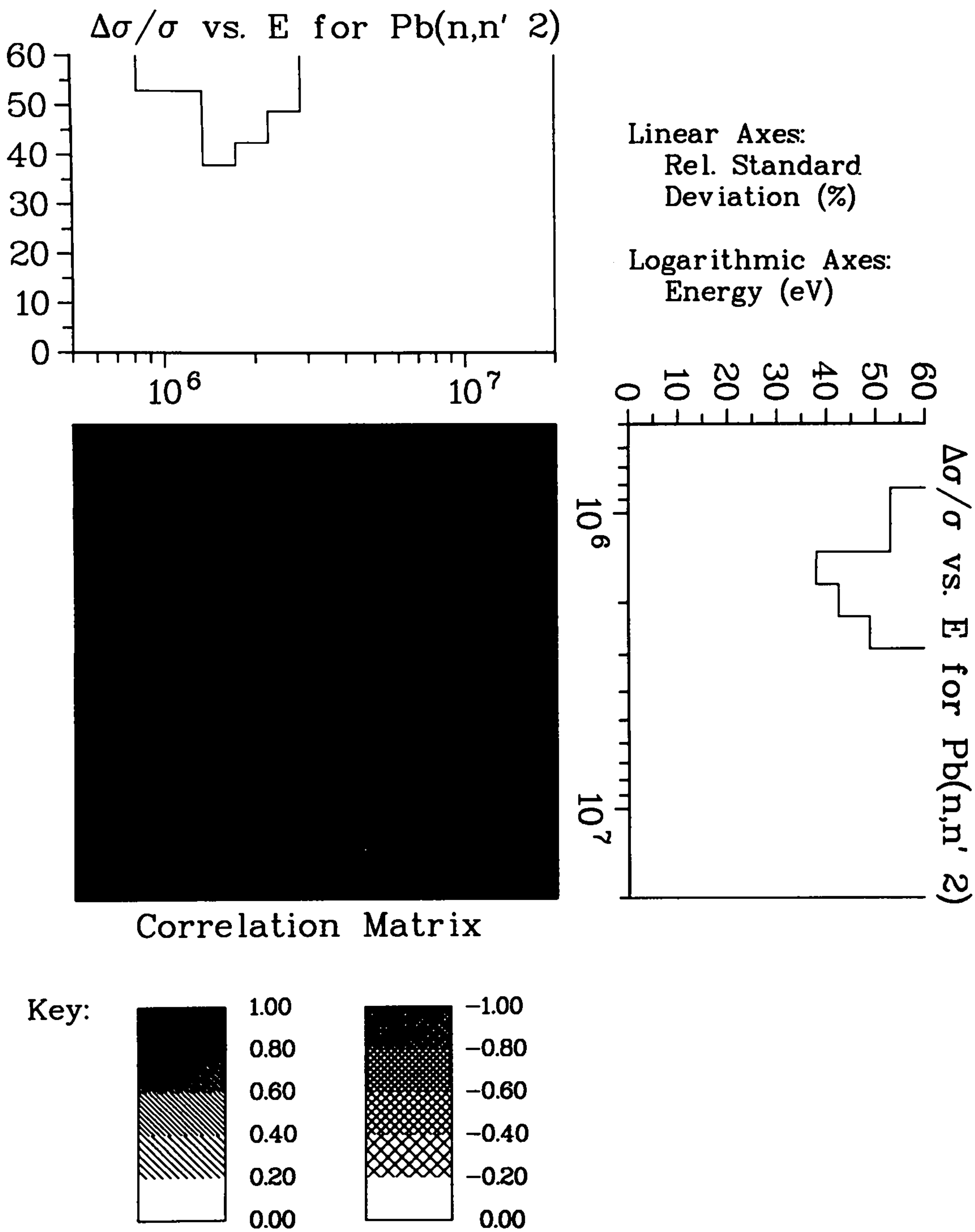


Fig. 141.
Covariance data for Pb(n,n' 2) with Pb(n,n' 2).

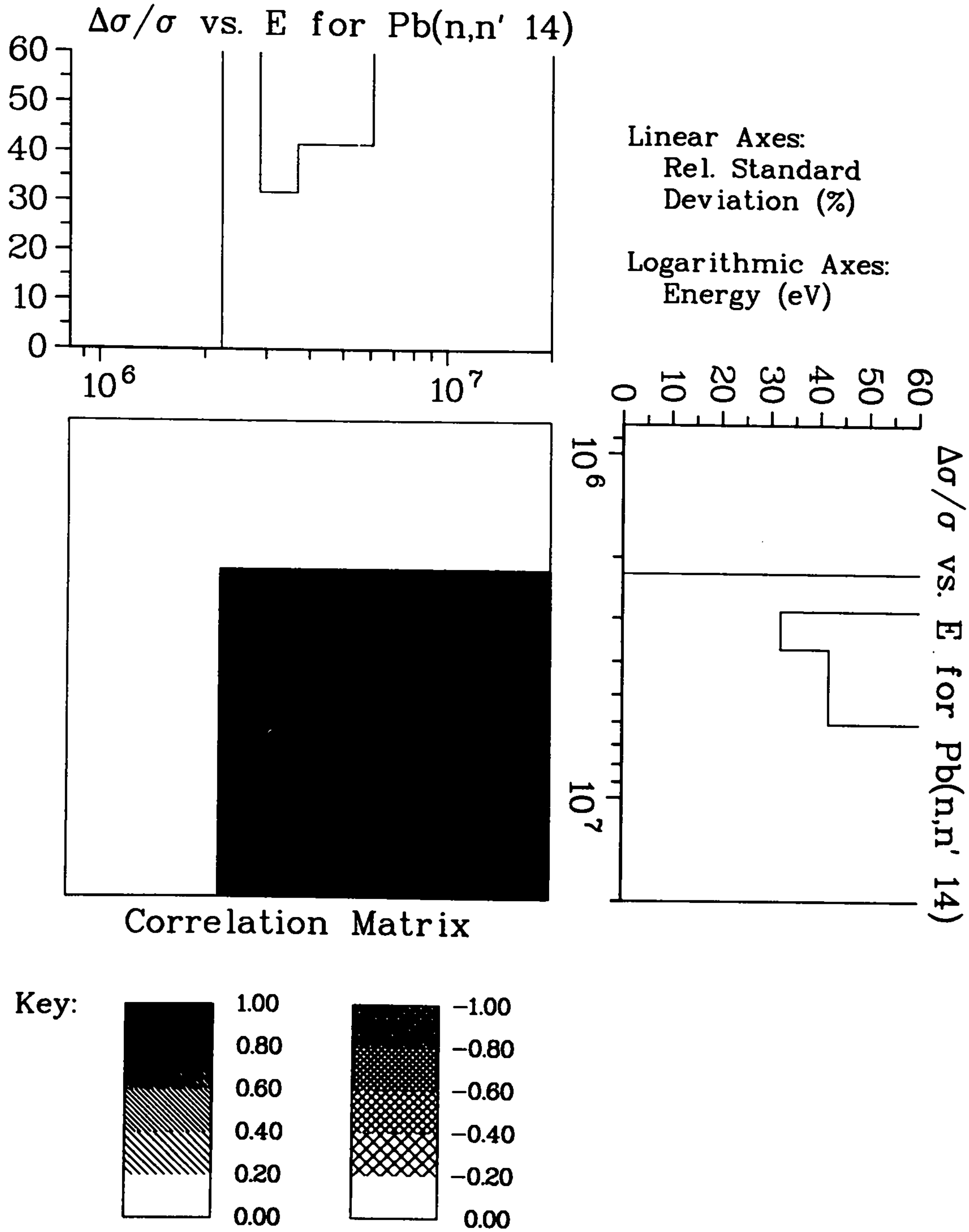


Fig. 142.

Covariance data for Pb(n,n' 14) with Pb(n,n' 14).

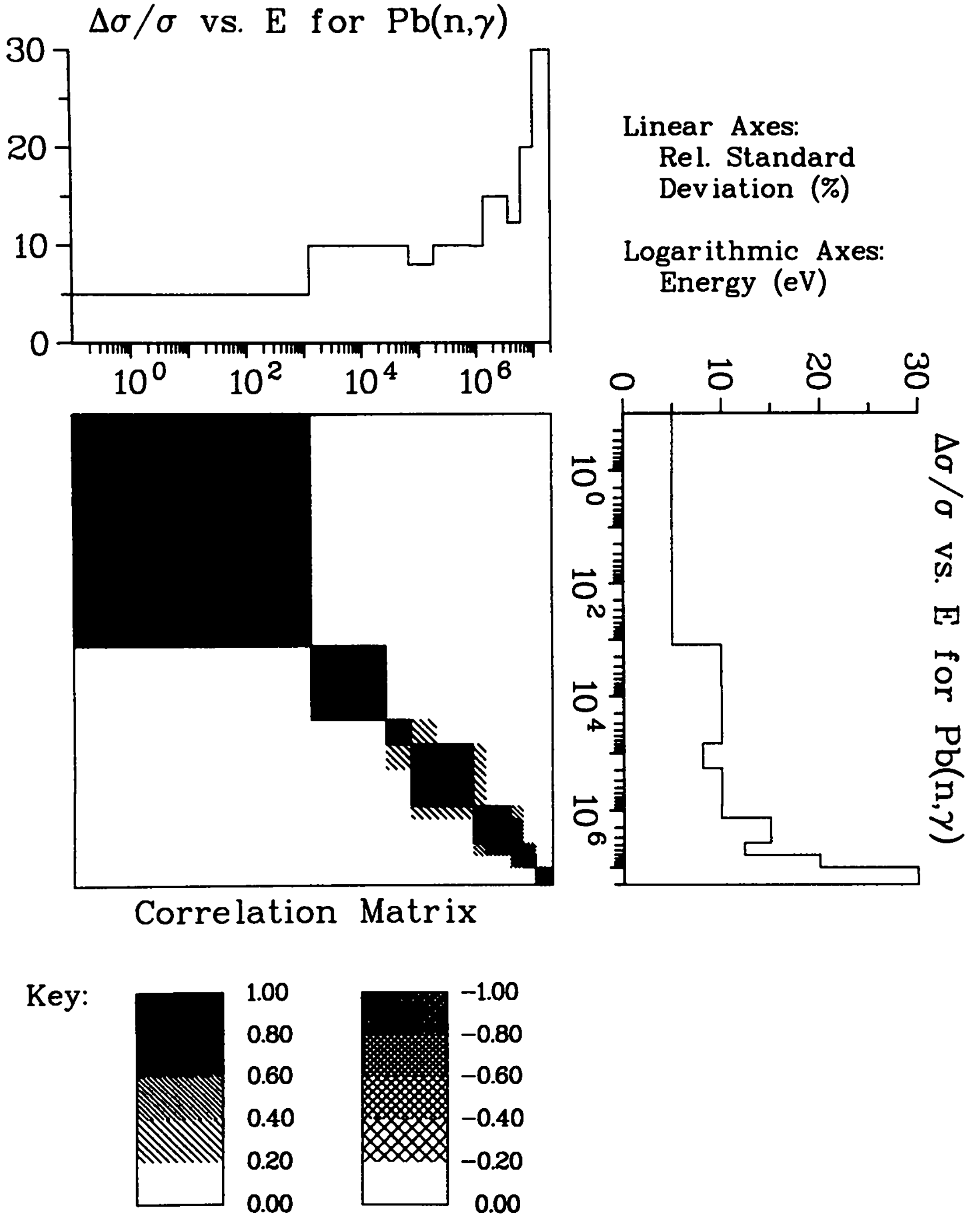


Fig. 143.
Covariance data for Pb(n,γ) with Pb(n,γ).

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