S.F. BIAGI

SIMULATION OF GAS AVALANCHE DETECTORS AND MOLECULAR PHYSICS EFFECTS

1) COMPUTER PROGRAMS TO SOLVE ELECTRON TRANSPORT IN GASES

2) REFINEMENT OF ELECTRON SCATTERING X-SECTIONS USING INPUT DATA FROM HIGH ACCURACY DRIFT AND DIFFUSION EXPERIMENTS

3) PHYSICAL EFFECTS ON DETECTOR PERFORMANCE FROM PENNING AND ATTACHMENT PROCESSES

4) SOME PREVIOUS SUCCESSES AND SOME OPEN QUESTIONS

1) COMPUTER PROGRAMS

PROBLEM IS SPLIT INTO 2 AREAS

A) CREATE FINITE ELEMENT GRID FOR $\vec{E}$ AND $\vec{B}$ FIELD SOLUTIONS. IN A UNIT CELL. (GARFIELD, MAXWELL OR USER SOFT)

B) CALCULATE ARRAY OF SOLUTIONS FOR TRANSPORT PARAMETERS OVER THE MAX AND MIN VALUES OF $\vec{E}$ AND $\vec{B}$

THEN CREATE IONISATION TRACKS THROUGH UNIT CELL AND DRIFT FREE ELECTRONS THROUGH LATTICE.

ONLY 2 ASSUMPTIONS

1) DRIFTING ELECTRONS ARE IN EQUILIBRIUM WITH THE $\vec{E}$ AND $\vec{B}$ FIELDS

2) SPACE CHARGE BUILD UP IS NEGLECTED.

1 IS SATISFIED AT 760 TORR IN MOST COUNTING GAS MIXTURES.
(THERMALISATION DISTANCE ~ 1 μm)

AT LOW PRESSURE DISTANCE $\propto 1/P$
∴ CLOSE TO THE ANODE WIRE NON-EQUILIBRIUM EFFECTS ARE SEEN AT ~ 100 TORR:
C.F: SEGUR ET AL RAD PROT. DOS. 52 (1994) 65
29 (1989) 23

2 SPACE CHARGE BUILD UP NOT IMPORTANT IN PROPORTIONAL MODE. NEED TO USE COUPLED POISSON SOLVER AT HIGH GAIN. (10^5)

LIST OF TRANSPORT PARAMETERS

FROM ELECTRON ATOM / MOLECULE X-SECTIONS

CAN CALCULATE:

α	TOWNSEND IONISATION COEFICIENT
η	TOWNSEND ATTACHMENT COEFICIENT
$\lvert D \rvert$	DIFFUSION TENSOR
$\vec{V}$	DRIFT VELOCITY VECTOR
$\langle E_{ION} \rangle$	AVERAGE IONISATION ENERGY

MIPS:

N_P	CLUSTER PRIMARY DENSITY
N_C	CLUSTER SIZE DISTRIBUTION
$\langle \tau_0 \rangle$	THERMALISATION TIME
R_0	TRACK WIDTH (RANGE)
R_σ	TRACK WIDTH FLUCTUATION

X RAYS:

F_0, F_1, F_2, F_N	FANO FACTORS
τ_0	THERMALISATION TIME
R_0	RANGE OF ELECTRON CLOUD
$R_1 \cdots R_N$	HIGHER MOMENTS (SHAPE) OF CLOUD.

FROM ATOM / MOLECUAR LEVELS AND COLLISION FREQUENCY CAN ESTIMATE: MAXIMUM AND MINIMUM VALUES OF PENING TRANSFERS AND THEIR EFFECTS ON α, N_p AND FANO FACTORS.

FROM X-RAY TABLES : X RAY ABSORPTION LENGTH.

PROBLEM: CAN NOT YET CALCULATE:

ION TRANSPORT.

$\mu_{ION}(\vec{E}, E^2)$ ION MOBILITY FUNCTION OF $\vec{E}$ AND $|E^2|$

$|D_{ION}|$ ION DIFFUSION TENSOR

THERE ARE SOME TABULATED VALUES FOR μ_{ION} IN LITERATURE BUT NOT MANY.

$|D_{ION}|$ IS NORMALLY TAKEN AS $\rightarrow kT$ WITH SUFFICIENT ACCURACY.

PROGRAMS FOR GAS TRANSPORT CALCULATION

BOLTZMANN SOLUTIONS

1) A. PHELPS 1960 — 2 TERM LEGENDRE EXPANSION

2) PITCHFORD + PHELPS 1982 — $\vec{E}$ ONLY MULTITERM LEGENDRE

3) ROBSON + NESS 1988 — $\vec{E}$ ONLY MULTITERM SPHERICAL HARMONICS

4) BIAGI 1989 — $\vec{E}$ AND $\vec{B}$ 3 TERM LEGENDRE 2 TERM WITH $\vec{B}$

5) NESS 1993 — $\vec{E}$ AND $\vec{B}$ AT 90° ONLY MULTI TERM SPHERICAL HARM.

6) WHITE ROBSON NESS 1999 — $\vec{E}$ AND $\vec{B}$ AT ANY ANGLE (LIMITED TO LOW $|E|$)

MONTE CARLO SOLUTIONS

1) SKULLERUD 1968 — $\vec{E}$ ONLY "NULL COLLISIONS"

2) REID 1979 — $\vec{E}$ ONLY "STANDARD MODELS"

3) FRASER AND MATHEISON 1986 — $\vec{E}$ ONLY LIMITED TO LOW $\vec{E}$

4) BIAGI 1998 — $\vec{E}$ AND $\vec{B}$ AT ANY ANGLE ANGULAR DISTRIBUTIONS ALLOWED

PROGRAMS 6 AND 4 HAVE BEEN CHECKED AND GIVE SIMILAR ANSWERS TO 0.01%

MONTE CARLO INTEGRATOR MAGBOLTZ

SOLVES TRANSPORT EQUATIONS IN $\vec{E}$ AN $\vec{B}$

GIVEN X SECTIONS FROM DATA BASE.

SOLUTION GIVEN IN N.I.M: A421 (1999) 234

DETAILS NOT MENTIONED IN PAPER:

A) CALCULATION OF TOWNSEND COEFICIENTS ARE DONE FOR BOTH (SST) SPATIALLY SEPARATED PLANES.
AND ALSO FOR PULSED TOWNSEND (PT) AND TIME OF FLIGHT (TOF) ON TIME SEPARATED PLANES.
PROCEDURE AND PROGRAM NOMENCLATURE SAME AS IN: TAGASHIRA ETAL
J. PHYS D 10 (1977) 1035

B) IMPLEMENTATION OF ANGULAR DISTRIBUTIONS FOR HIGHLY ANISOTROPIC SCATTERING.

IN MORE DETAIL :-

ANGULAR DISTRIBUTIONS IN MONTE CARLO

ELASTIC SCATTERING:

$$\sigma_{MT} = \int_0^{\pi} \sigma(\theta)\,(1-\cos\theta)\,\sin\theta\,d\theta$$

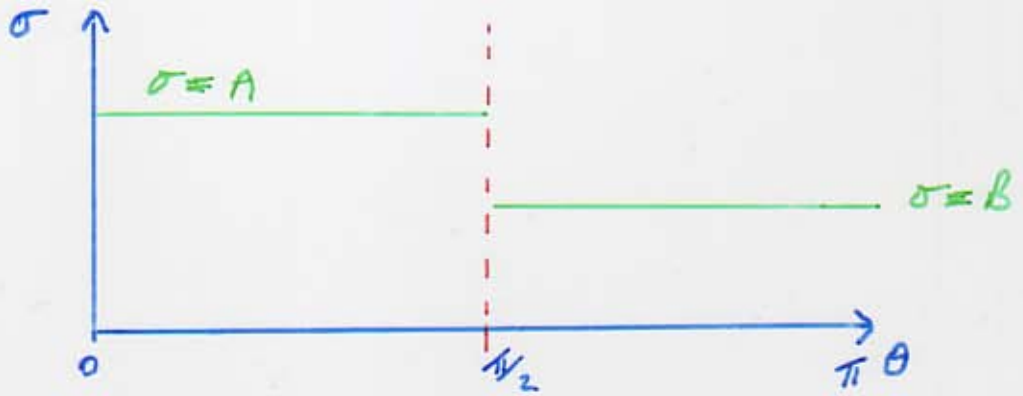
$$\sigma_T = \int_0^{\pi} \sigma(\theta)\,\sin\theta\,d\theta$$

$$\langle \cos\theta \rangle = (\sigma_T - \sigma_{MT})/\sigma_T$$

LONGO AND CAPITELLI : PLASMA CHEMISTRY AND PLASMA PROC. 14 (1993) 1

$\Downarrow$

ASSUMED ISOTROPIC FORWARD SCATTERING AND ISOTROPIC BACKWARD SCATTERING



9)

$$\langle \cos\theta \rangle = \frac{\int_0^{\pi/2} A \sin\theta \cos\theta \, d\theta + \int_{\pi/2}^{\pi} B \sin\theta \cos\theta \, d\theta}{\int_0^{\pi/2} A \sin\theta \, d\theta + \int_{\pi/2}^{\pi} B \sin\theta \, d\theta}$$

$$\langle \cos\theta \rangle = \frac{A-B}{2(A+B)}$$

PROBABILITY OF FORWARD SCATTERING = P

$$P = \frac{\int_0^{\pi/2} A \sin\theta \, d\theta}{\int_0^{\pi/2} A \sin\theta \, d\theta + \int_{\pi/2}^{\pi} B \sin\theta \, d\theta} = \frac{A}{(A+B)}$$

EXPAND P $\quad P = \frac{A+B}{2(A+B)} + \frac{A-B}{2(A+B)} = \boxed{\frac{1}{2} + \frac{(\sigma_T - \sigma_M)}{\sigma_T}}$

SIMPLE TO IMPLEMENT IN A MONTE CARLO

REQUIRES 2 RANDOM NUMBERS

1) PICK FORWARD OR BACKWARD SCATTERING
2) GIVES SCATTERING ANGLE IN FORWARD OR BACKWARD DIR.

EXTENSION TO INELASTIC SCATTERING:

$$P = 0.5 + \frac{(\sigma_T - \sigma_M)}{\sigma_T \sqrt{1 - E_i/E}}$$

WHERE E_i = ENERGY LOSS

E = INCIDENT ENERGY

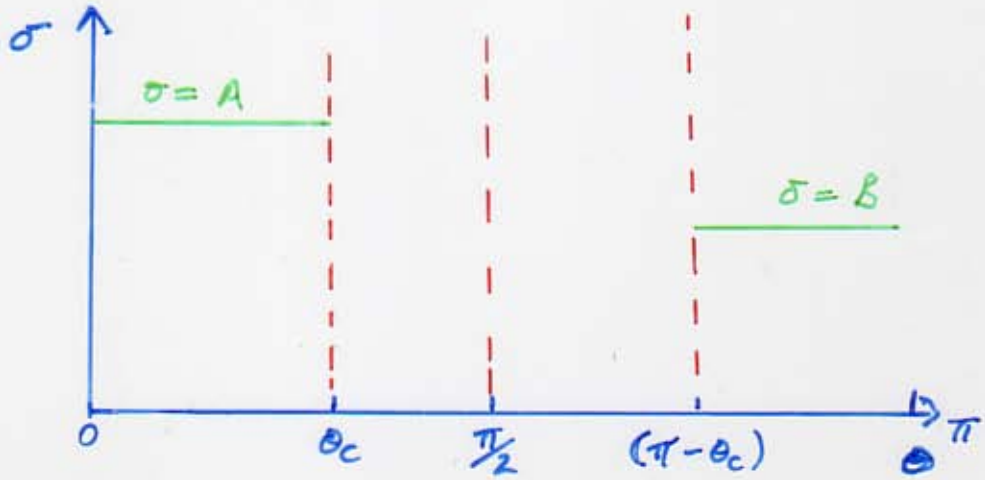
CONSISTENT WITH HUXLEY AND CAMPTON BUT NOT NECESSARY IF USING MEASURED DISTRIBUTIONS.

MONTECARLO TRANSPORT PROGRAM (1999)

INTRODUCED EXTENSION TO LONGO + CAPITELLI ANGULAR DISTRIBUTION ALGORITHM. (CUT OFF ANGLE)

PREVIOUS ALGORITHM FAILS IN RAMSAUER DIP REGION IN SOME GASES AND AT HIGH ENERGY IN ALL GASES. $\because$ $P > 1$ IN THESE REGIONS.

NEW ANGLE CUT OFF ALGORITHM



IF $P > 1$ THEN FIX θ_c SO THAT $P = 1$

NEW FORMALISM:

$$\langle \cos\theta \rangle = \frac{\int_0^{\theta_c} A \sin\theta \cos\theta \, d\theta + \int_{\pi-\theta_c}^{\pi} B \sin\theta \cos\theta \, d\theta}{\int_0^{\theta_c} A \sin\theta \, d\theta + \int_{\pi-\theta_c}^{\pi} B \sin\theta \, d\theta}$$

$$= \frac{A-B}{2(A+B)} \left[\frac{\sin^2\theta_c}{1-\cos\theta_c} \right] = \frac{\sigma_T - \sigma_{MT}}{\sigma_T}$$

$$P = \frac{A}{A+B} = \frac{A+B}{2(A+B)} + \frac{A-B}{2(A+B)} = 0.5 + \frac{(\sigma_T - \sigma_{MT})}{\sigma_T} \frac{(1-\cos\theta_c)}{\sin^2\theta_c}$$

ALGORITHM: A) IF $P > 1$

THEN $\theta_c = \sin^{-1}\sqrt{\frac{2F-1}{F^2}}$ FOR $P = 1$

WHERE $F = \frac{1-\cos\theta_c}{\sin^2\theta_c}$ (F CALCULATED FROM σ DATA).

B) IF $P \leq 1$ $\theta_c = \pi/2$

ALGORITHM IMPLEMENTED IN MONTE CARLO

WORKS WELL IN ARGON RAMSAUER DIP REGION.

SHOULD ALLOW MORE ACCURATE ELECTRON RANGE PARAMETERS FROM X-RAY INTERACTIONS IN GASES.

2) EXTRACTION OF ELECTRON SCATTERING CROSS SECTIONS

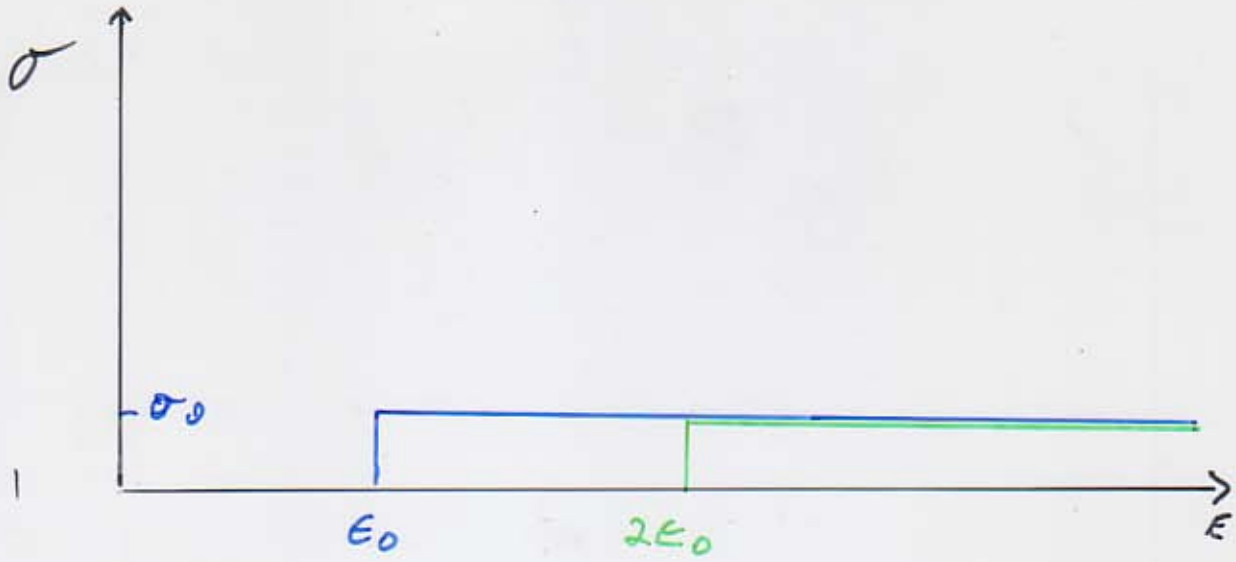
MODERN SCATTERING DATA (1990 – 2003) IS MORE ACCURATE THAN CAN BE DEDUCED FROM DRIFT AND DIFFUSION FITING (EXCEPT BELOW 1eV)

STATE OF THE ART:	TOTAL X-SECTION	± 1%
	IONISATION	± 2%
	EXCITATION	± 5–10%
(ABOVE 2eV)	ELASTIC AND VIBRATION	± 5–10%
(BELOW 2eV)	ELASTIC AND VIBRATION	± 10–25%
(ABOVE 2eV)	ELASTIC MOMENTUM TRANS.	± 10–20%
(BELOW 2eV)		± 20–30%

PROCEDURE: ONLY ALLOW X-SECTIONS ABOVE 2eV TO VARY WITHIN EXPERIMENTAL ERRORS

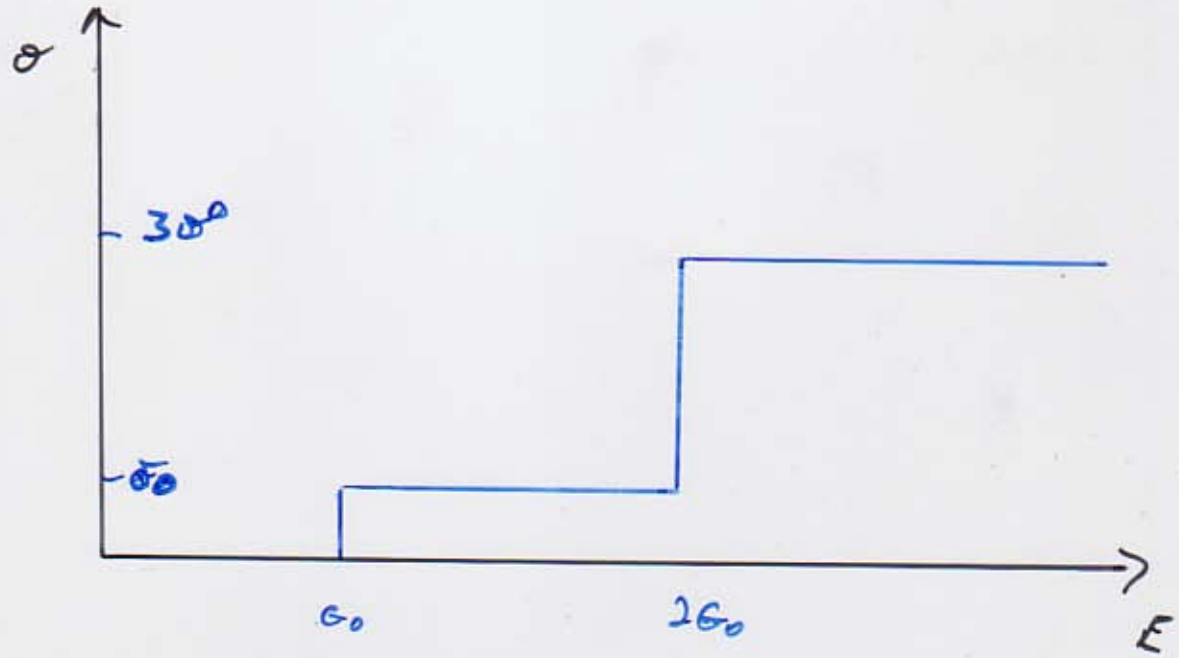
BELOW 1eV: VARY ELASTIC X-SECTION
VARY VIBRATION X-SECTION WITH SHAPE FUNCTION GIVEN BY BORN DIPOLE APPROXIMATION OR DIRECT SCATTERING WHERE APPROPRIATE.

AMBIGUITY IN X-SECTION EXTRACTION



EFFECT ON V_D AND $|D|$

$$\propto \sum_{1}^{N} \epsilon_{LOSS}\, \sigma$$



BOTH X-SECTIONS ARE EQUIVALENT.

EXAMPLES :

1989 CH_4 VIBRATION AND ELASTIC FROM HADDAD BELOW 2eV.

1994 CH_4 SCHMIDT INTRODUCED ENHANCED X-SECTION AT THRESHOLD FOR VIBRATION (REQUIRES SOME RESONANCE PROCESS)

2002 CH_4 VIBRATIONAL X-SECTION SHAPE FUNCTION FITTED TO THEORETICAL X-SECTION OF ALTHORPE ET AL J. PHYS B28 (1995) 1165

NOW ELASTIC X-SECTION IS IN AGREEMENT WITH DATA DOWN TO 0.6eV AND VIBRATION IS ALSO MORE REALISTIC.

THERE IS ONLY SMALL CHANGES IN THE DRIFT AND DIFFUSION CALCULATIONS BETWEEN 1994 AND 2002 IN PURE CH_4 BUT 2002 PRODUCES BETTER AGREEMENT IN XENON MIXTURES.

POSSIBLE EXPLANATION FOR NON-PHYSICAL X-SECTION EXTRACTED IN (1994) IS THE LARGE CORELLATION BETWEEN HIGHER MOMENTS IN THE ANALYSIS OF SCHMIDT.

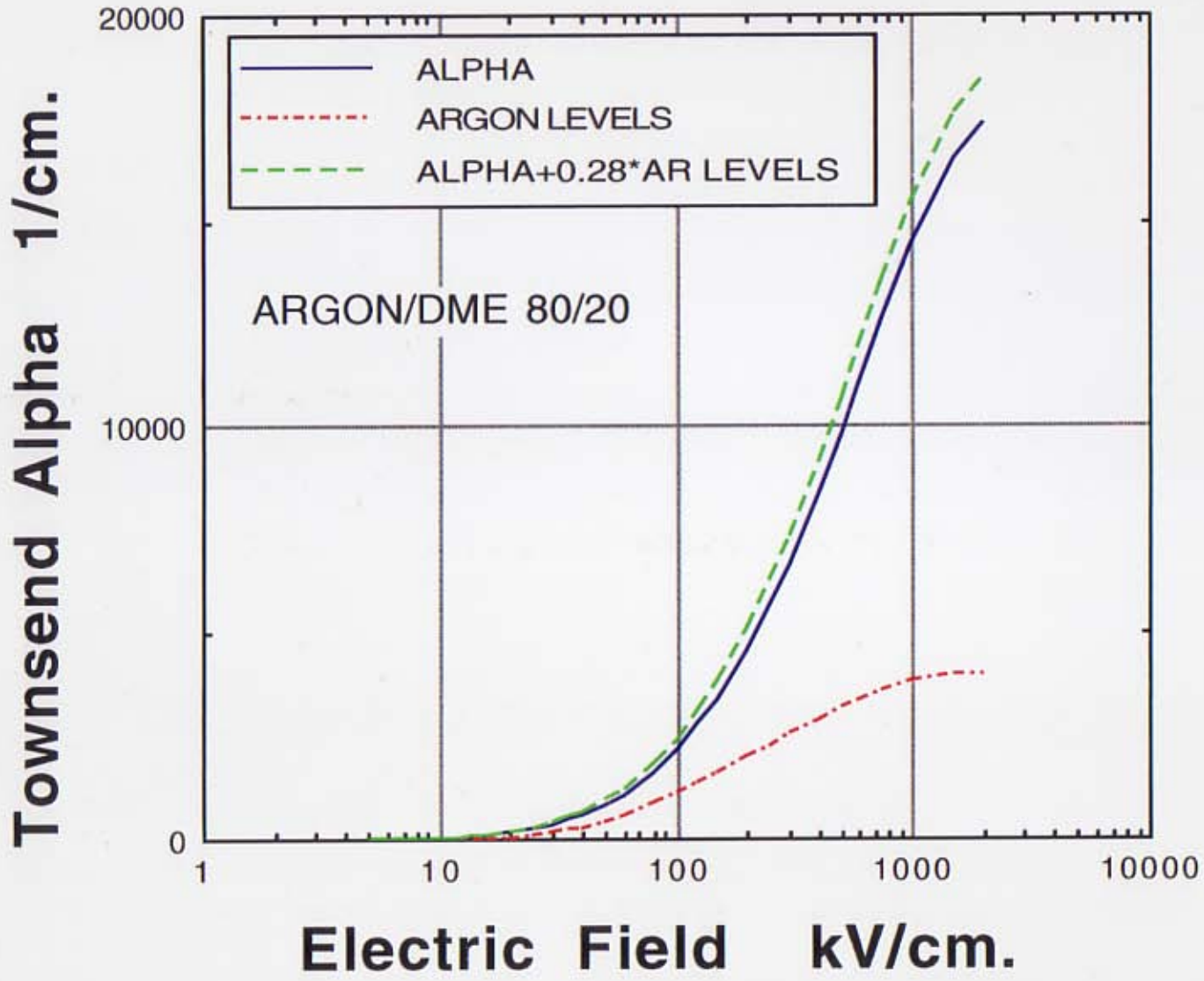
NOBLE GASES He Ne Ar Kr Xe

ANISOTROPIC SCATTERING HAS BEEN EXTENDED TO ALL NOBLE GASES

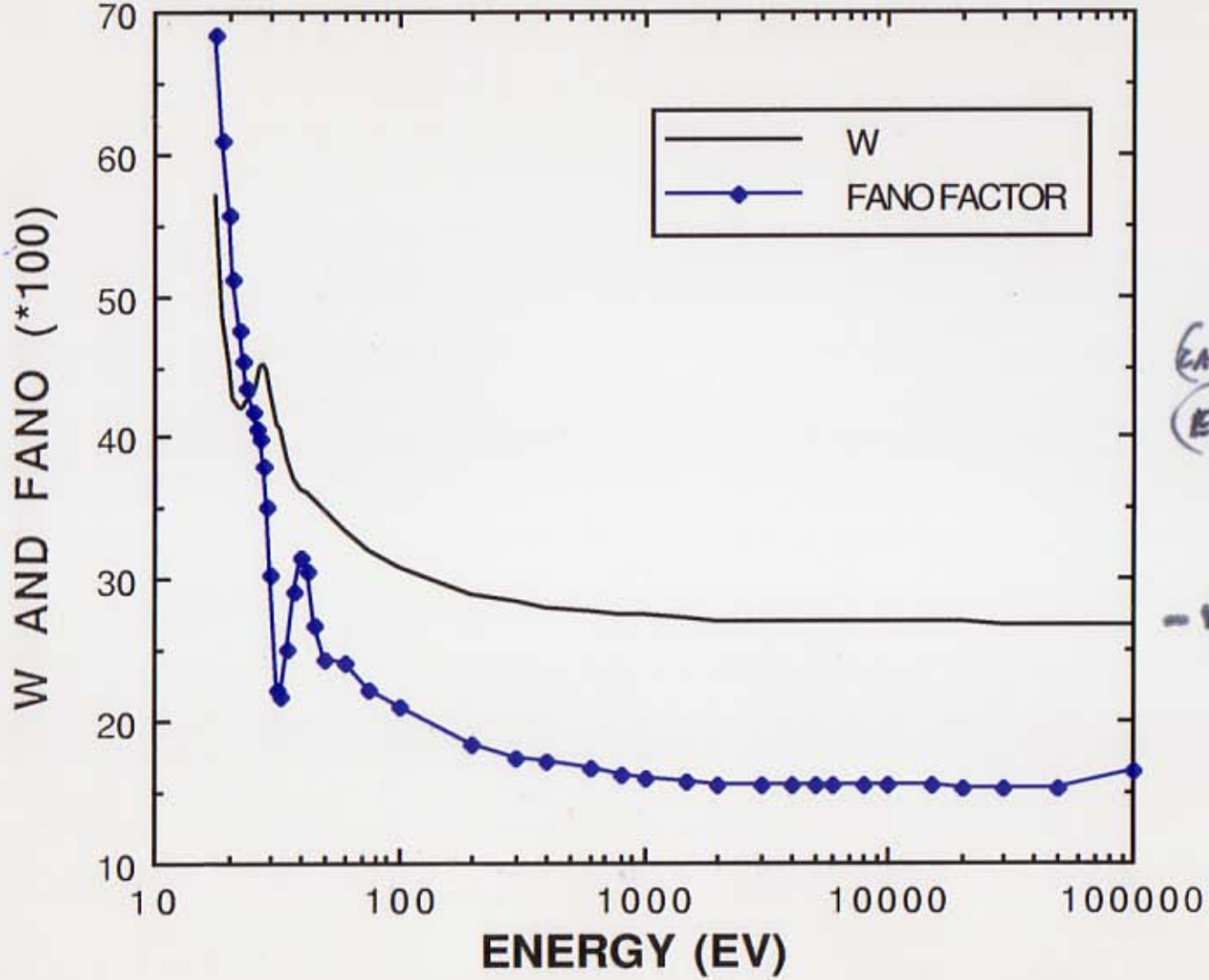
THE DATA BASE CONTAINS BOTH THE OLD ISOTROPIC AND NEW ANISOTROPIC VERSIONS

FOR He Ne AND Ar THE ANISOTROPIC AND ISOTROPIC VERSIONS PRODUCE SIMILAR RESULTS IN MIXTURES (WITHIN ~1%) BOTH FILES ARE RETAINED AND GIVE AN ESTIMATE OF CALCULATION ERRORS

THE Kr AND Xe ANISOTROPIC FILES ARE NOT YET ACCURATE ENOUGH TO COMPARE WITH THE ISOTROPIC FILES. ∴ ONLY THE ISOTROPIC FILES FOR Kr AND Xe SHOULD BE USED.


ALPHA
ARGON LEVELS
ALPHA+0.28*AR LEVELS
ARGON/DME 80/20
20000
10000
0
1
10
100
1000
10000
Townsend Alpha 1/cm.
Electric Field kV/cm.

FANO FACTOR AND EV/ION PAIR IN ARGON



(CALC) $F_1 = 0.17$

(EXP) $F_1 = 0.18(1)$

$-W = 26.8$ eV $= F_0$

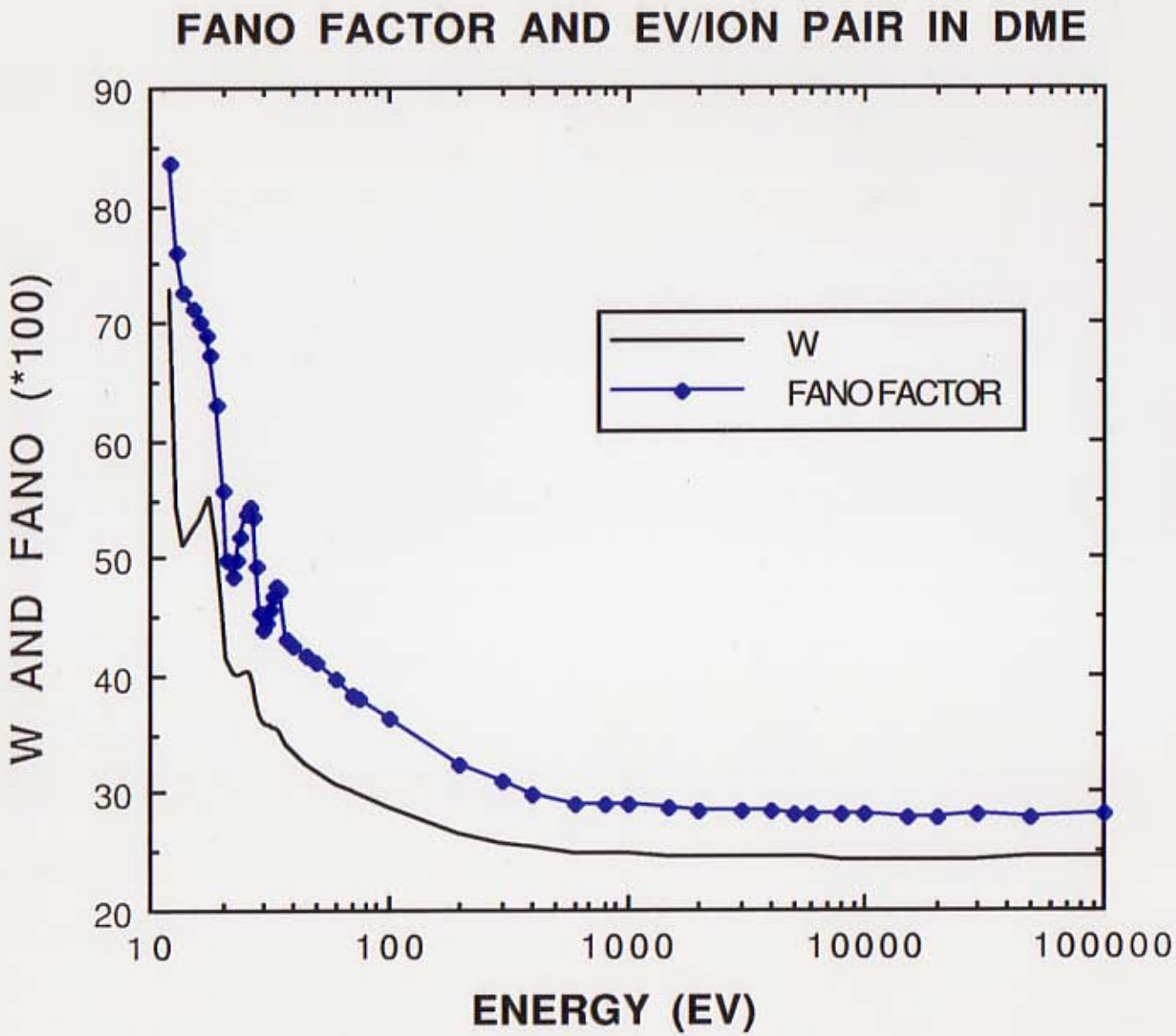
$W_{eff} = 26.4$ eV.

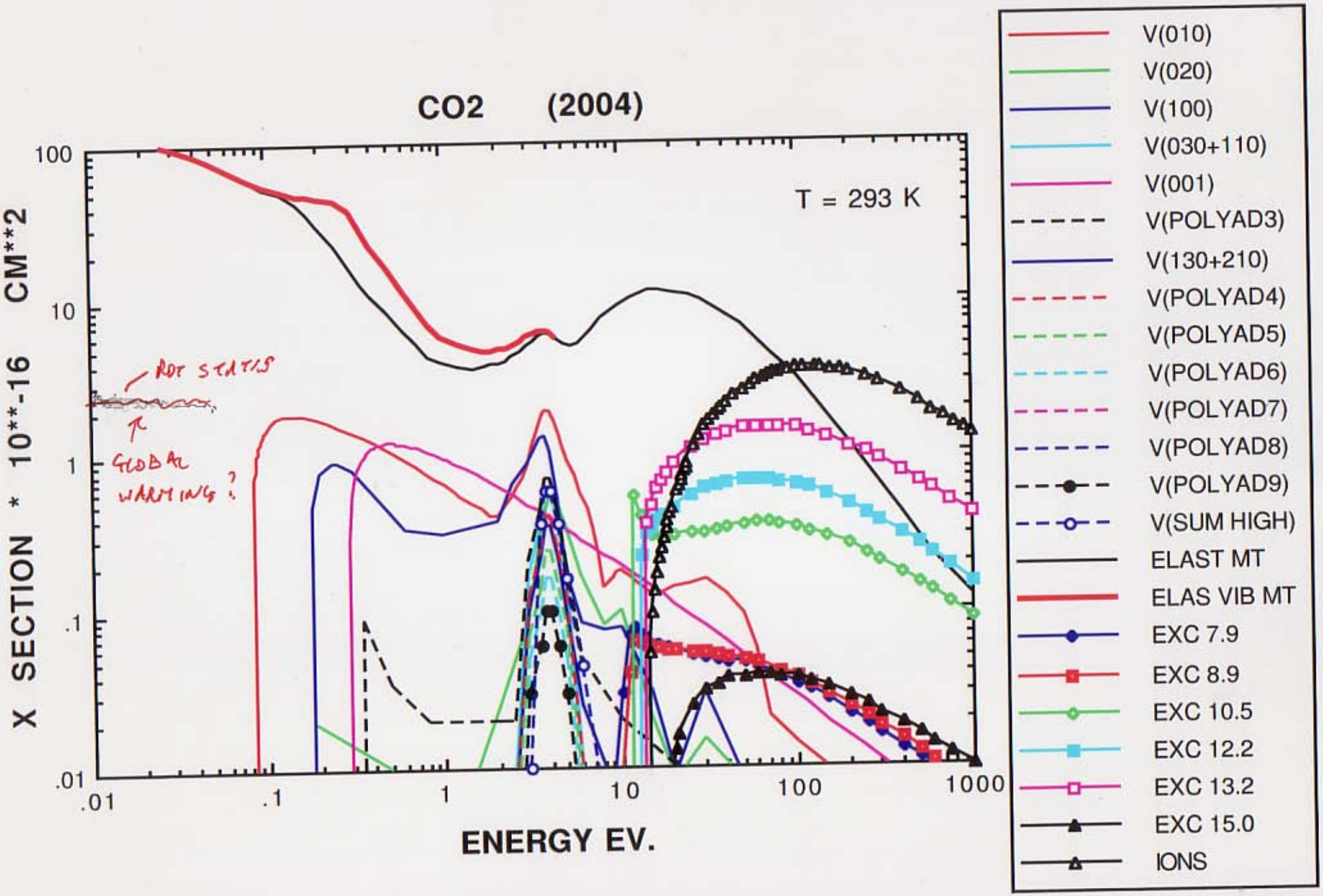
$Ar^{+} + Ar \rightarrow Ar_2^{+} + e^{-}$

$\sim 1-2\%$

AT

760 TORR


FANO FACTOR AND EV/ION PAIR IN DME
W AND FANO (*100)
90
80
70
60
50
40
30
20
10
100
1000
10000
100000
ENERGY (EV)
W
FANO FACTOR


CO2 (2004)
T = 293 K
X SECTION * 10**-16 CM**2
ENERGY EV.
100
10
1
.1
.01
.01
.1
1
10
100
1000
ROT STATES
GLOBAL WARMING ?
V(010)
V(020)
V(100)
V(030+110)
V(001)
V(POLYAD3)
V(130+210)
V(POLYAD4)
V(POLYAD5)
V(POLYAD6)
V(POLYAD7)
V(POLYAD8)
V(POLYAD9)
V(SUM HIGH)
ELAST MT
ELAS VIB MT
EXC 7.9
EXC 8.9
EXC 10.5
EXC 12.2
EXC 13.2
EXC 15.0
IONS

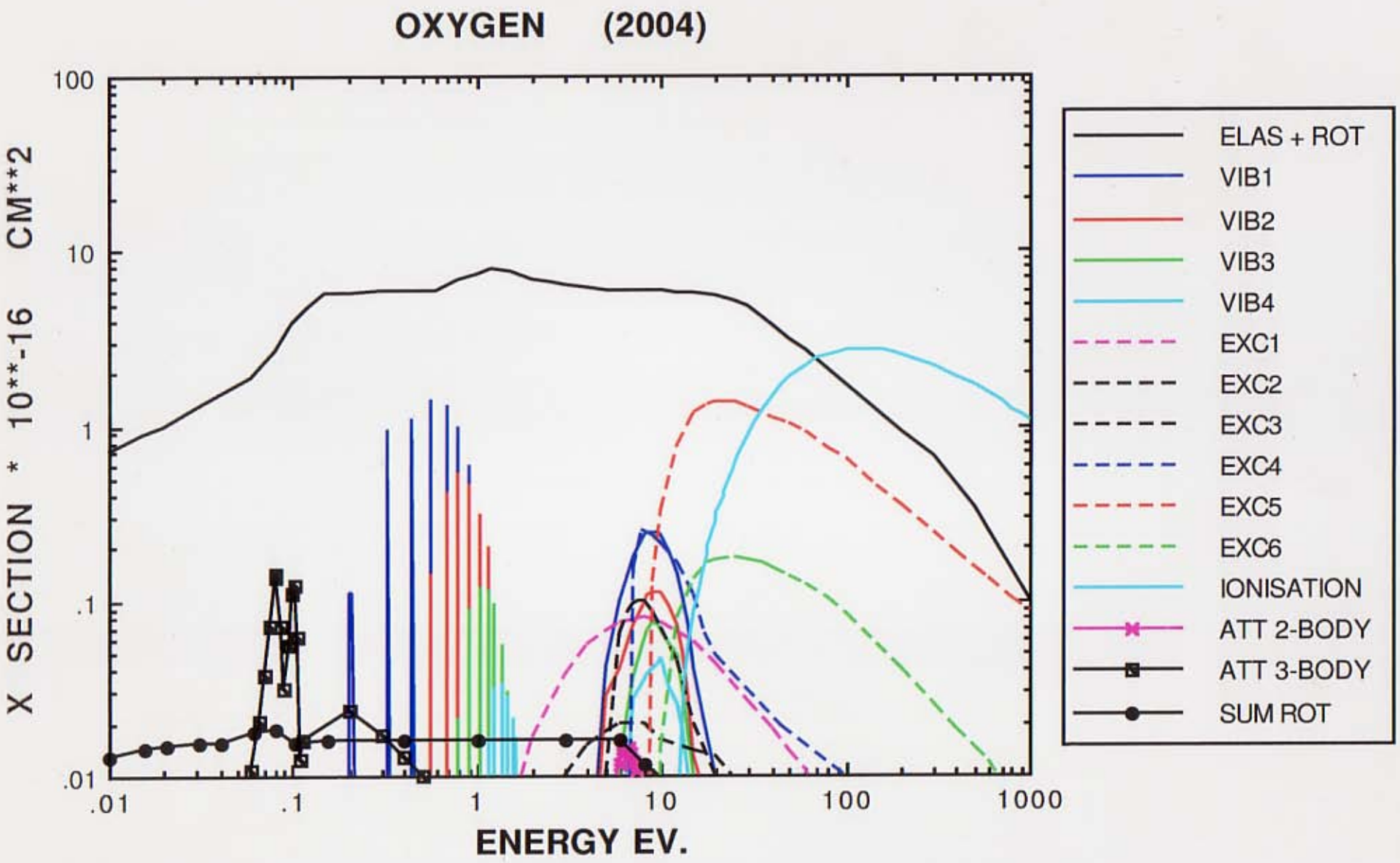

OXYGEN (2004)
X SECTION * 10**-16 CM**2
100
10
1
.1
.01
.01
.1
1
10
100
1000
ENERGY EV.
ELAS + ROT
VIB1
VIB2
VIB3
VIB4
EXC1
EXC2
EXC3
EXC4
EXC5
EXC6
IONISATION
ATT 2-BODY
ATT 3-BODY
SUM ROT

TABLE OF EXPERIMENTAL AND CALCULATED TRANSPORT COEFICIENTS IN H2O
CALCULATION USES 210 ROTATIONAL TRANSITIONS DATA SET (2004).
USED DTEXP FROM ELFORD (GASEOUS ELECTRONICS AND ITS APPLICATIONS)
WHICH ARE TYPICALLY 1 MILLIVOLT LOWER THAN THE SWANSEA (1987) PLOT..

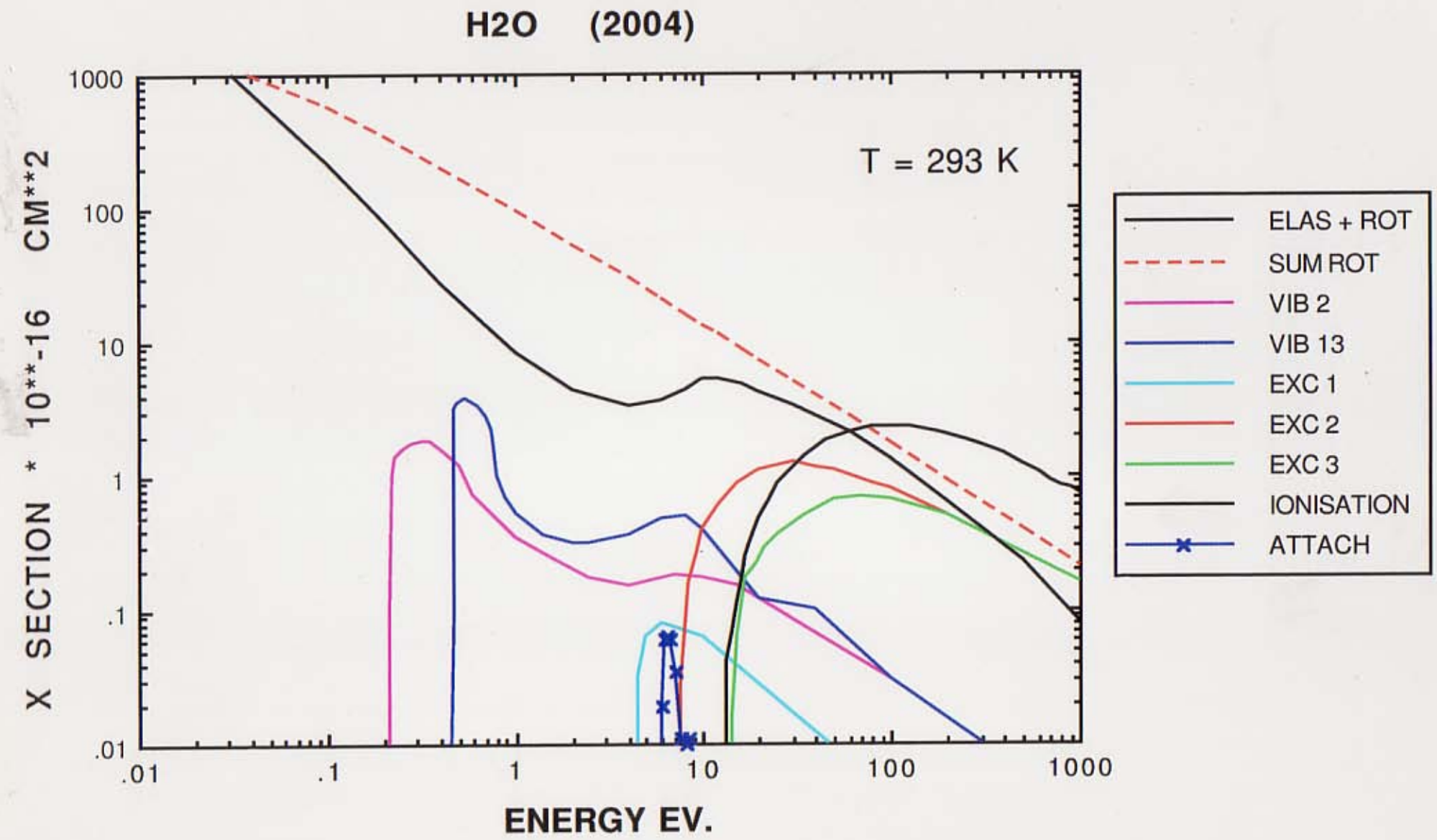
BRACKETS GIVE EXPERIMENTAL AND CALCULATION ERRORS ON THE LAST DIGITS.
CALCULATION ERRORS ARE STATISTICAL ERRORS FROM MONTE CARLO.

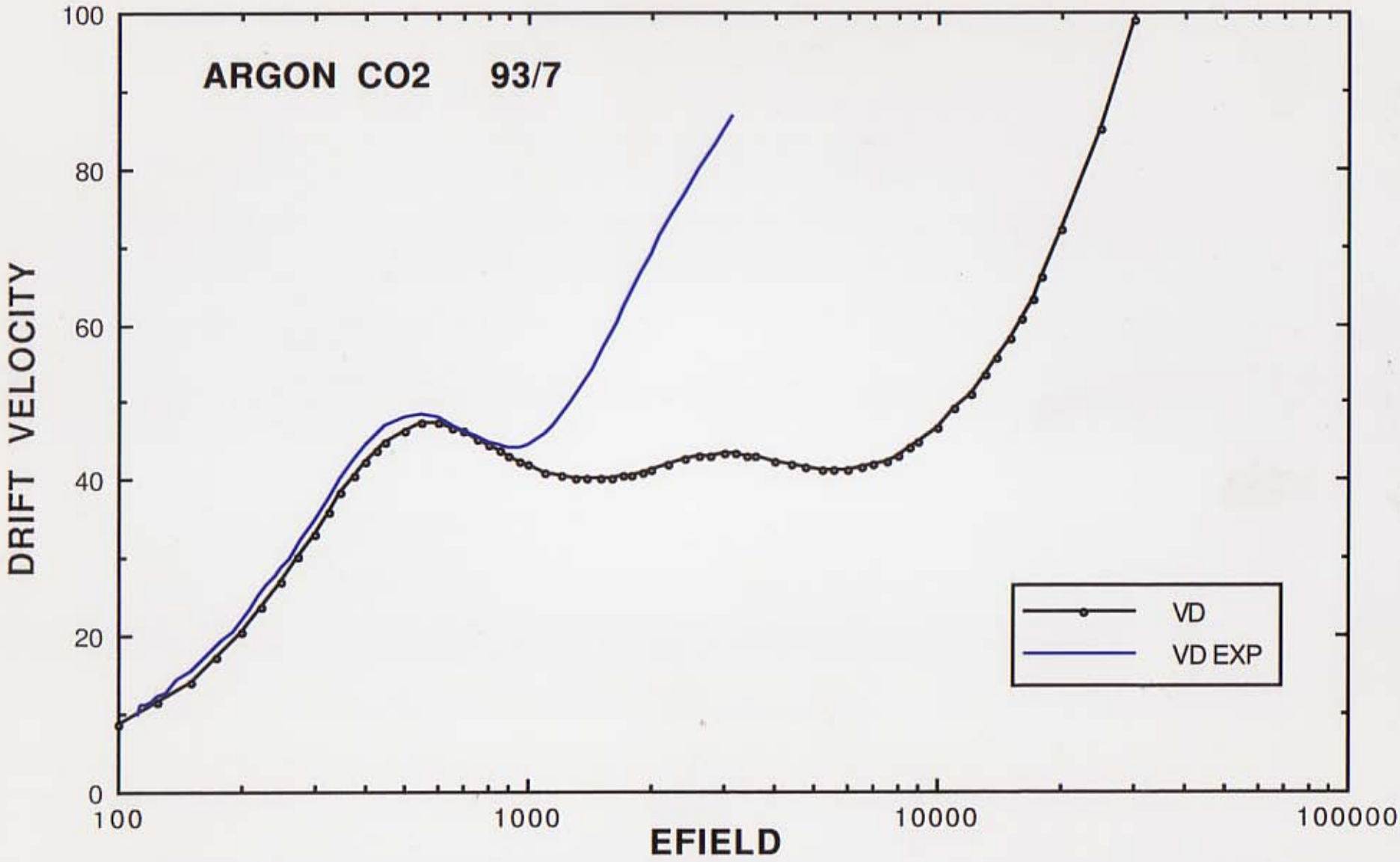
ELECTRIC FIELD IN TOWNSEND T=293 KELVIN

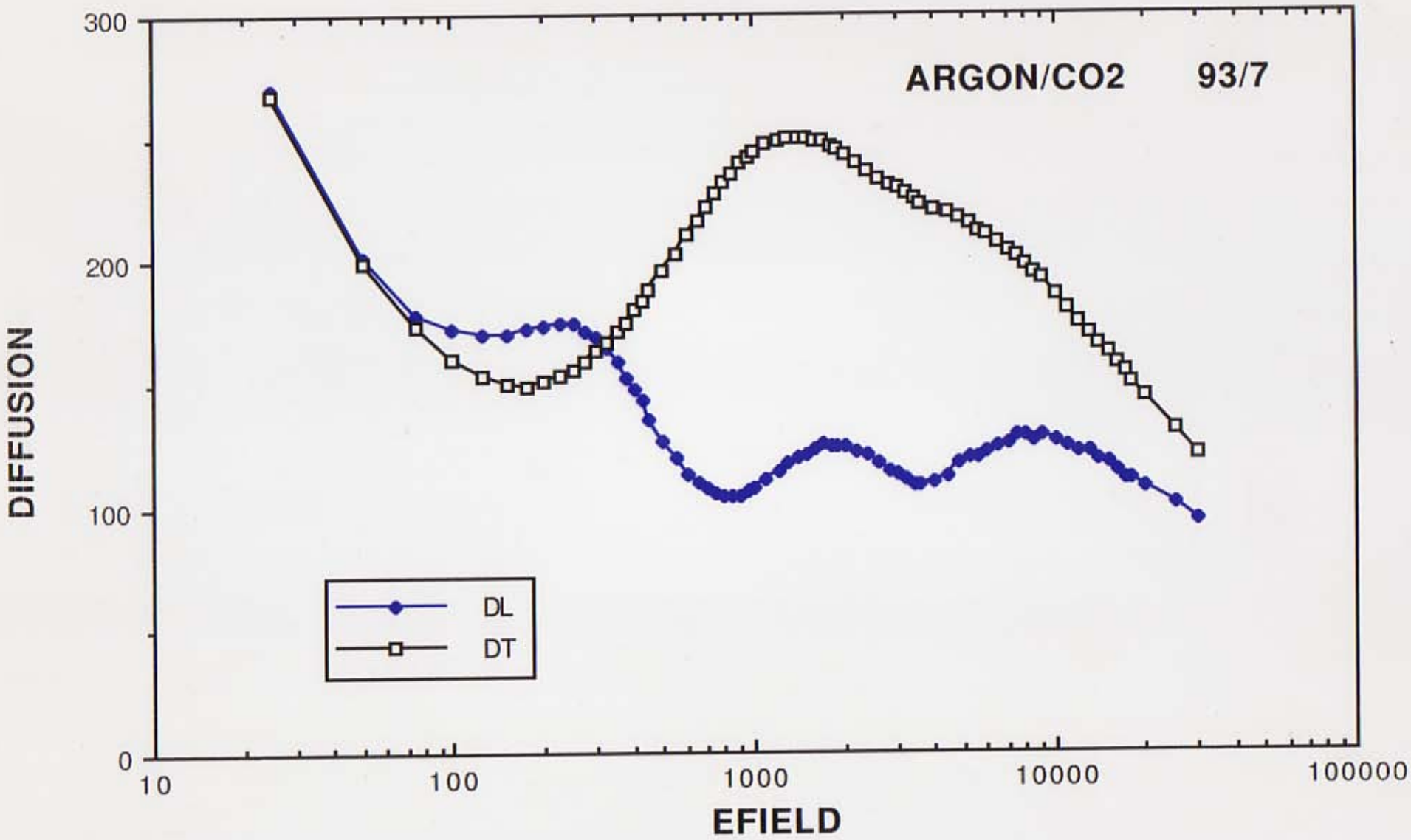
EFLD	VEXP	VCALC	DTEXP	DTCALC	DLEXP	DLCALC
2	0.452(4)	0.456(7)	0.0254	0.0251(5)	0.0254(25)	0.0252(8)
4	0.905(9)	0.909(8)	0.0254	0.0253(6)	0.0254(25)	0.0256(4)
8	1.82(1)	1.821(9)	0.0257	0.0256(5)	0.0264(25)	0.0262(6)
10	2.28(2)	2.283(10)	0.0258	0.0257(5)		0.0263(6)
16	3.69(3)	3.705(10)	0.0267	0.0267(5)	0.0285(28)	0.0282(6)
20	4.67(3)	4.70(1)	0.0273	0.0275(6)	0.0300(30)	0.0307(7)
24	5.72(4)	5.75(1)	0.0285	0.0289(6)	0.0340(34)	0.0340(8)
28	6.82(6)	6.87(1)	0.0315	0.0308(7)	0.0410(41)	0.0402(12)
32	8.10(7)	8.11(1)		0.0355(12)	0.0600(60)	0.0550(25)
40	11.35(9)	11.29(4)		0.078(5)	0.290(60)	0.233(25)
48	17.0(5)	16.8(1)		0.305(16)	1.4(2)	1.12(4)
56	29.0(9)	28.4(2)		0.810(16)	2.8(4)	3.1(1)
64	49.4(15)	48.5(3)	1.8	1.47(4)	4.2(4)	4.4(1)
72	74.0(20)	73.8(5)	2.3	2.0(1)	4.0(4)	4.4(1)
80	98.0(30)	98.0(5)	2.6	2.4(1)		3.7(1)
100	144(5)	143(1)	3.0	3.0(1)		3.1(1)
120	173(6)	173(1)	3.3	3.5(1)		3.0(2)
200	257(8)	260(3)	3.7	4.8(2)		4.1(2)
400		430(4)		6.9(2)		6.3(3)
1000		810(10)		12.0(6)		11.0(8)

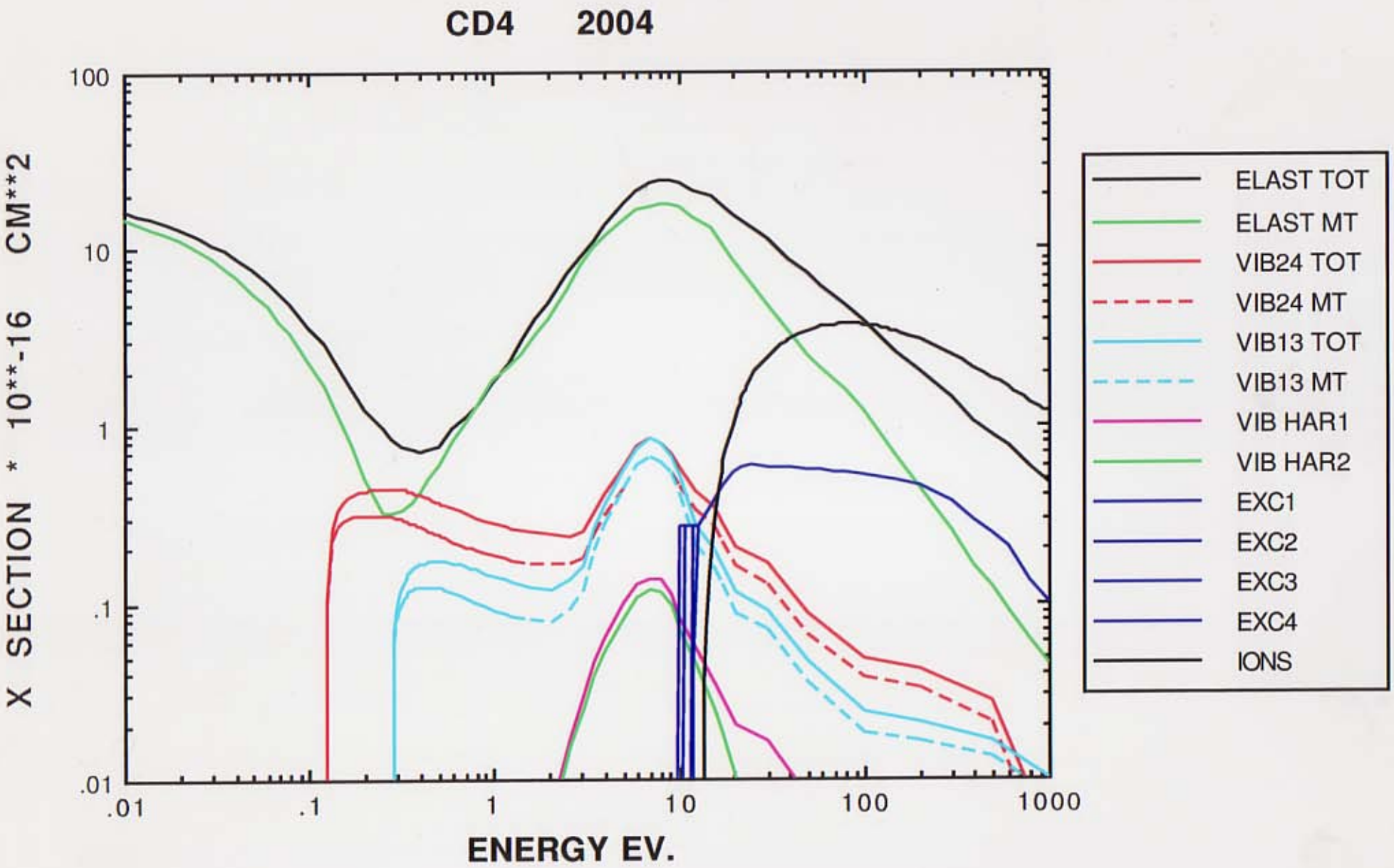
ADDITIONAL TRANSPORT DATA: ALPHA AND ATT IN CM**-1 AT 760 TORR AND 293K
WR IS TOF DRIFT VELOCITY.

EFLD	ALPHA(EXP)	ALPHA(CALC)	ATT(EXP)	ATT(CALC)	WR
40			2(1)	2(1)	
48		0.1(1)	14(3)	15(1)	
56	4(2)	1.3(1)	56(10)	50(1)	
64	7(2)	5.0(3)	95(20)	89(2)	
72	12(2)	12(1)	110(10)	116(3)	
80	20(4)	20(1)	125(10)	130(4)	
100	55(4)	62(2)	130(10)	144(4)	
120	110(10)	107(5)	130(10)	122(6)	
200	485(20)	498(2)	100(10)	100(1)	292(2)
400	1625(50)	1666(3)		48(1)	534(2)
1000	4900(100)	4590(5)		15(2)	1088(8)


H2O (2004)
T = 293 K
X SECTION * 10**-16 CM**2
ENERGY EV.
1000
100
10
1
.1
.01
.01
.1
1
10
100
1000
ELAS + ROT
SUM ROT
VIB 2
VIB 13
EXC 1
EXC 2
EXC 3
IONISATION
ATTACH


ARGON CO2 93/7
DRIFT VELOCITY
EFIELD
100
80
60
40
20
0
100
1000
10000
100000
VD
VD EXP

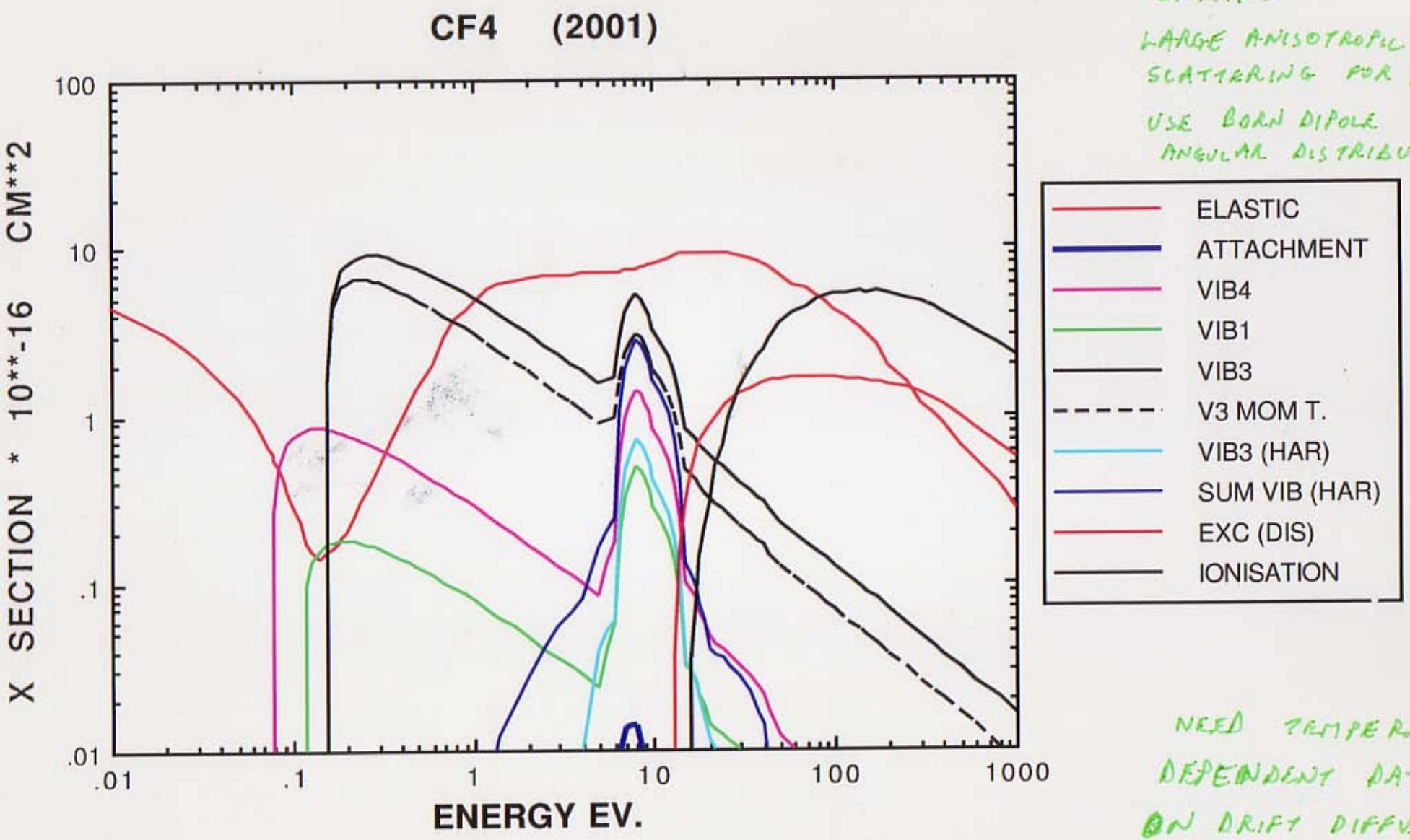

ARGON/CO2 93/7
DIFFUSION
EFIELD
300
200
100
0
10
100
1000
10000
100000
DL
DT


CD4 2004
X SECTION * 10**-16 CM**2
100
10
1
.1
.01
.01
.1
1
10
100
1000
ENERGY EV.
ELAST TOT
ELAST MT
VIB24 TOT
VIB24 MT
VIB13 TOT
VIB13 MT
VIB HAR1
VIB HAR2
EXC1
EXC2
EXC3
EXC4
IONS

UPDATED IONISATION X SECTION SINCE CF4 (1998)

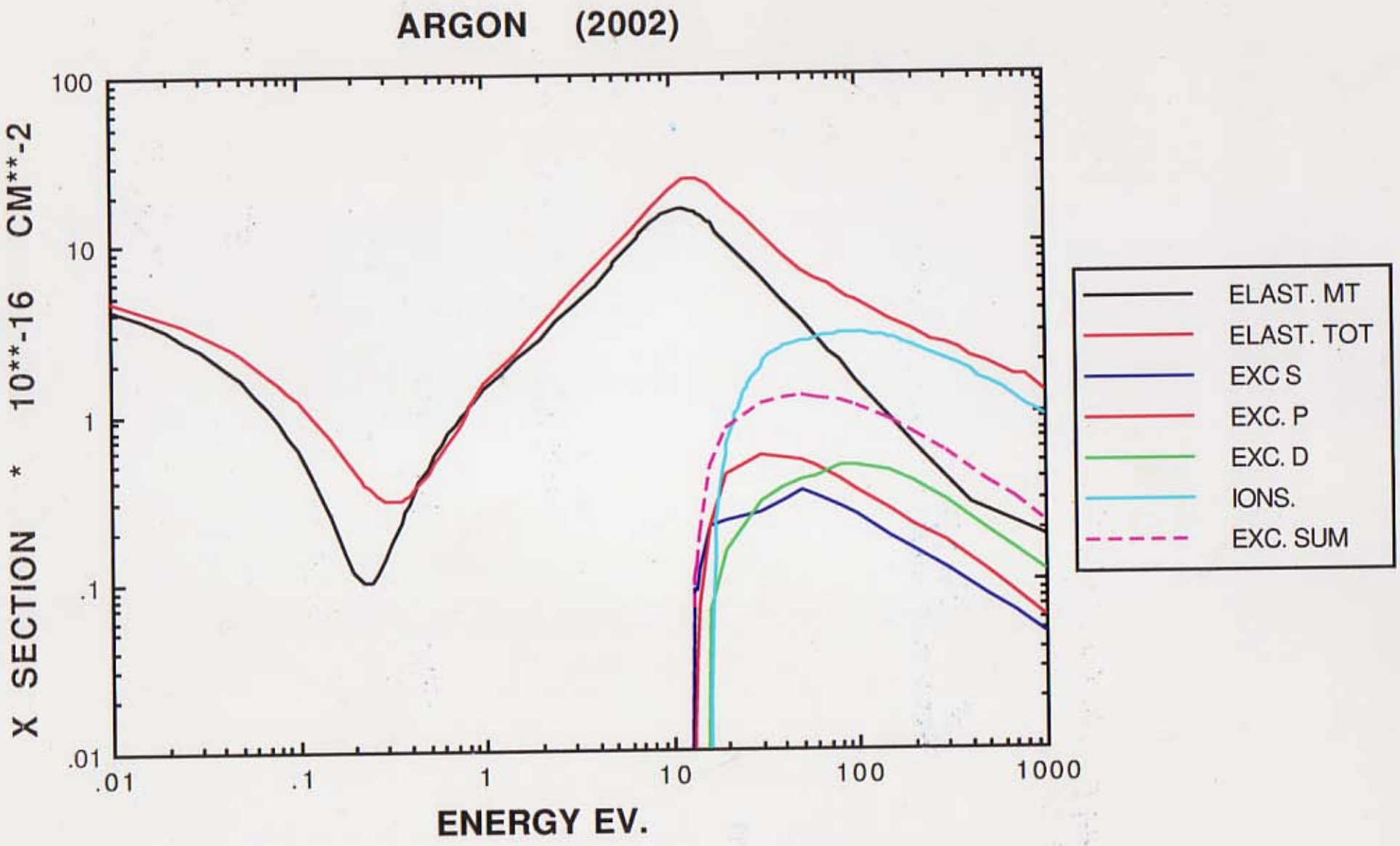
LARGE ANISOTROPIC SCATTERING FOR ν_3

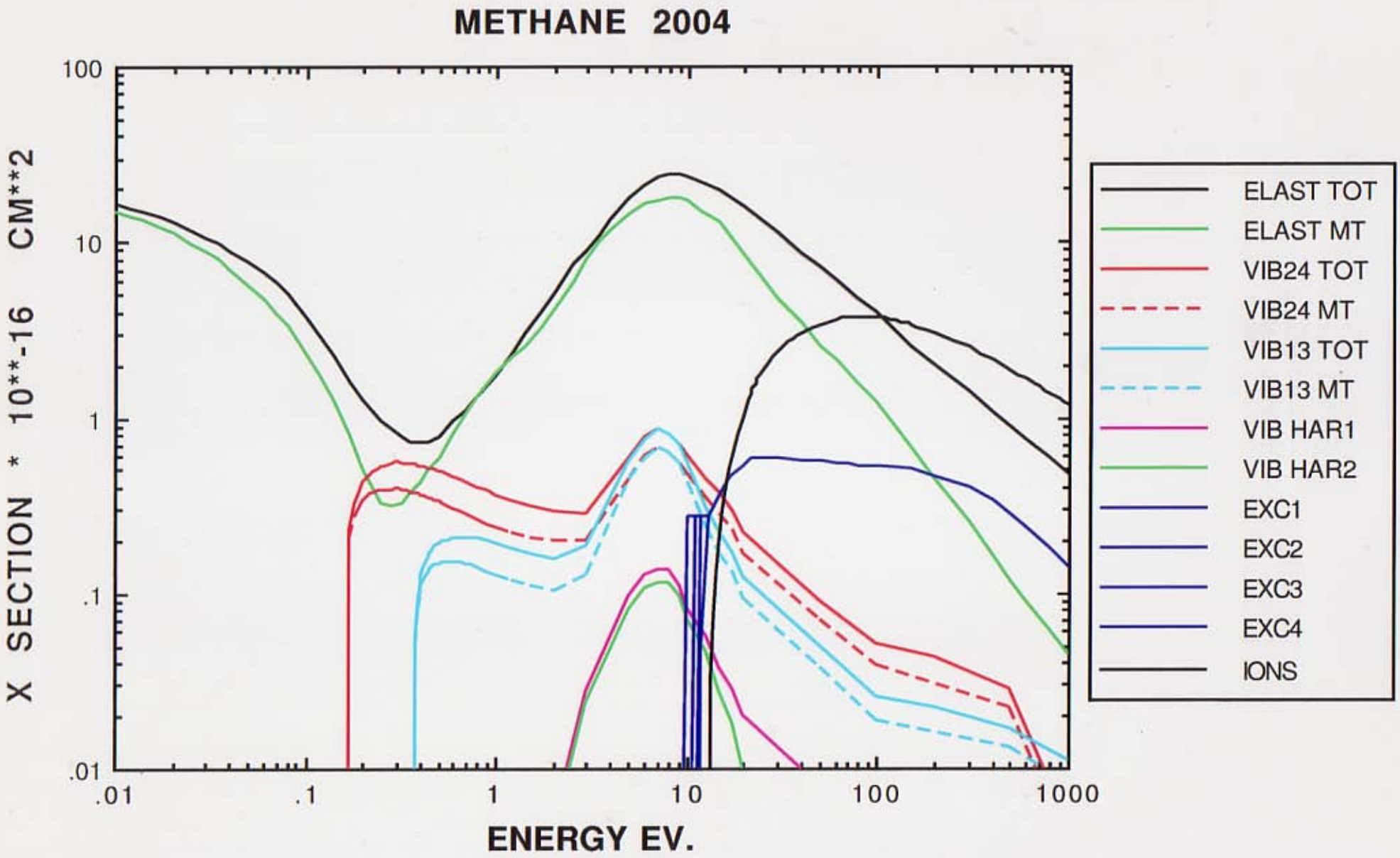
USE BORN DIPOLE ANGULAR DISTRIBUTION.



NEED TEMPERATURE DEPENDENT DATA ON DRIFT DIFFUSION

TO FIX ELASTIC BELOW 0.08 EV.


ARGON (2002)
X SECTION * 10**-16 CM**-2
100
10
1
.1
.01
.01
.1
1
10
100
1000
ENERGY EV.
ELAST. MT
ELAST. TOT
EXC S
EXC. P
EXC. D
IONS.
EXC. SUM


METHANE 2004
X SECTION * 10**-16 CM**2
100
10
1
.1
.01
.01
.1
1
10
100
1000
ENERGY EV.
ELAST TOT
ELAST MT
VIB24 TOT
VIB24 MT
VIB13 TOT
VIB13 MT
VIB HAR1
VIB HAR2
EXC1
EXC2
EXC3
EXC4
IONS

AVALANCHE FLUCTUATIONS

ORIGINALLY ALKHAZOV AND LEGLER

GAVE FOR NON-ATTACHING GASSES:

$$P(Z) = \frac{Z^{(1/F-1)} \, \exp[-Z/F]}{F^2 \, \Gamma(1/F)}$$

WHERE:

$$F = \int_{\text{ANODE}}^{\text{ORIGIN}} \frac{F_0(E') \, \alpha'(E') \, dr}{\exp\left[\int_{r}^{\text{ORIGIN}} \alpha'(E') \, dr'\right]} \qquad (1)$$

AND $F_0(E) = [2B^2 - 1] / [4B - 2B^2 - 1]$

WHERE $B = \exp[-\alpha E_{ION}/E]$

EXTENSION TO ATTACHING GASSES :-

REPLACE α' BY $[\alpha' - \eta']$

WHERE η IS ATTACHMENT COEFFICIENT.

AND REPLACE F BY $F \times P(0)$

WHERE $$P(0) = 1 - \exp\left[\int_{r''}^{\text{ORIGIN}} \eta(E) \, dr.\right] \qquad (2)$$

WHERE r'' IS THE RADIUS AT WHICH

$$|\alpha'| > |\eta'|$$

THE PATH INTEGRAL IN FORMULA (1)

IS NOW TAKEN OVER $\int_{\text{ANODE}}^{r''}$ INSTEAD OF

$\int_{\text{ANODE}}^{\text{ORIGIN}}$

THESE FORMULAE ALLOW THE

CORRECT STATISTICAL BEHAVIOUR OF AVALANCHE

FLUCTUATIONS TO BE MODELLED FOR ANY PATH

LENGTH INTEGRAL IN THE CHAMBER.

RESULTS FROM SIMULATION

1) FOR X-RAYS AND PHOTO ELECTRONS ONLY

INPUT DATA FROM BOLTZMANN SOLUTION

USING DERIVED CROSS SECTIONS FROM ELECTRON

ATOM - MOLECULE SCATTERING.

RESOLUTION FOR CALCULATION $\approx \begin{pmatrix} 5.8 \text{ to} \\ 6.1 \end{pmatrix}$ % AT 6 keV

RESOLUTION FROM MEASUREMENT $= 6.3 - 6.5$ %

DIFFERENCE DUE TO ELECTRONIC NOISE
OF $\sim 2-3$ K ELECTRONS.

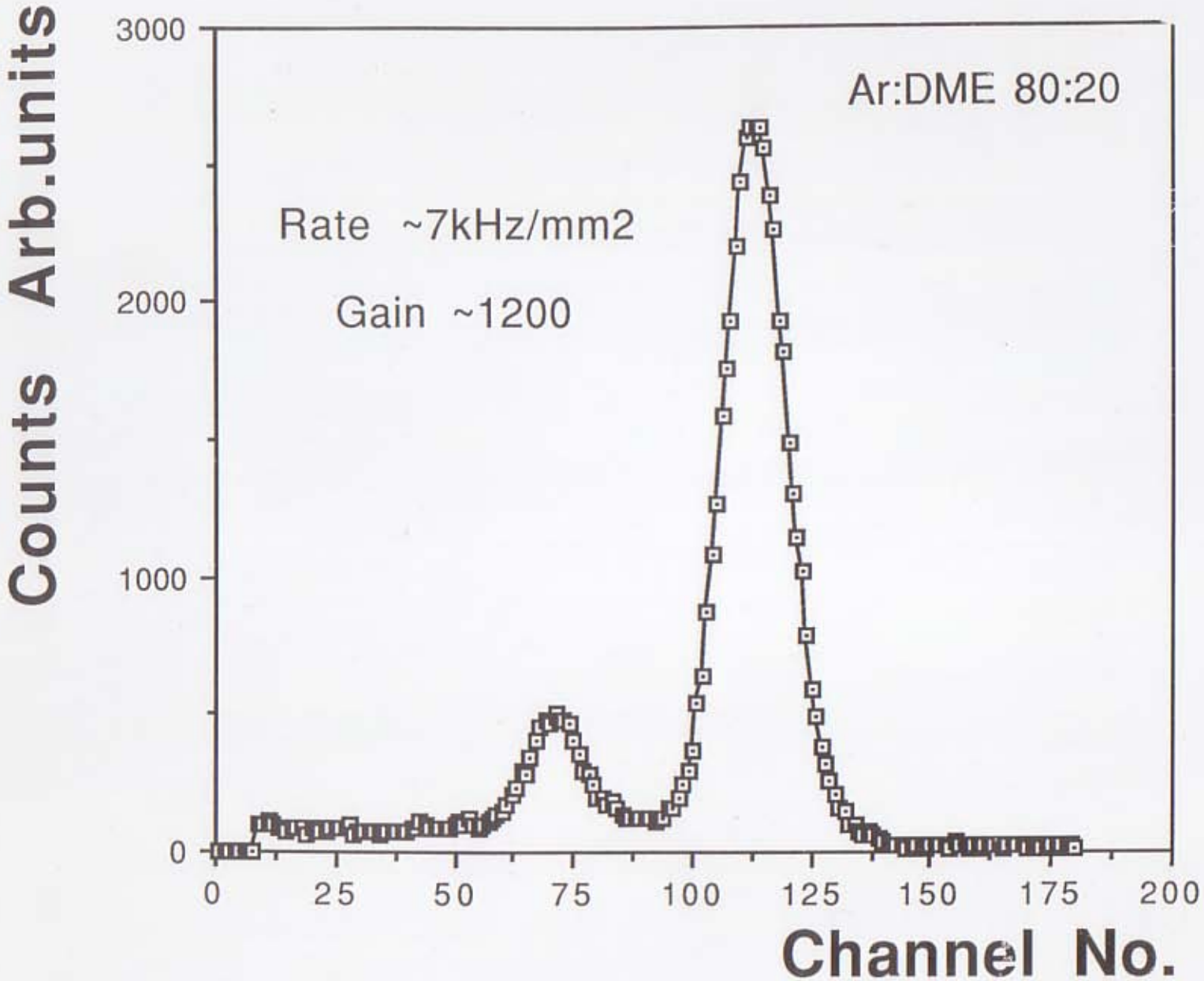
GIVES CONFIDENCE THAT THE SIMULATION IS CORRECT.

NOTE : AVALANCHE FLUCTUATIONS ~ 4.6 %

AVERAGE GAIN WIDTH ~ 5.4 %

DIFFERENCE CAUSED BY PATH LENGTH

VARIATIONS IN $\int \alpha \, dr$ INTEGRAL $\approx 2-3$ %



BATCH 2

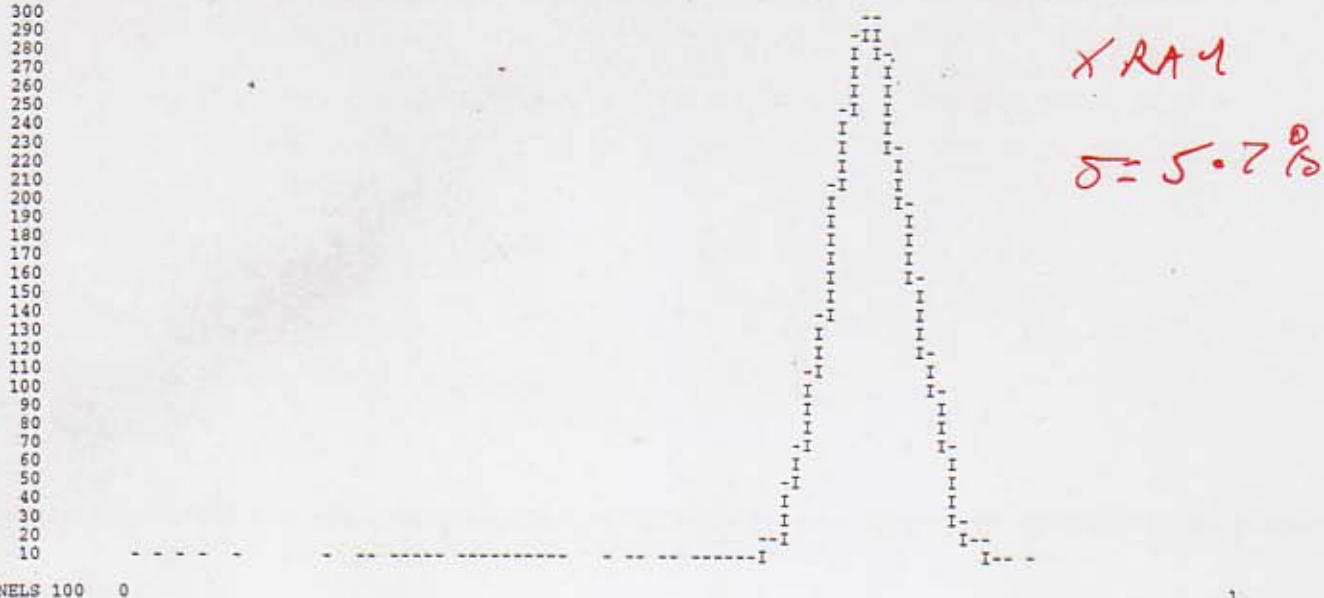
8KeV X-RAYS

$\sigma = 5.9\%$

FWHM = 13.9%

TOTAL AVALANCHE CHARGE PER X-RAY

HBOOK ID = 607 DATE 05/04/94 NO = 12




```
CHANNELS 100   0                                                                                                                   1
         10    0         1         2         3         4         5         6         7         8         9                        0
          1    1234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890

CONTENTS 100                                                                    112222222111
         10                                                                 1146030489973951962 21
          1.   1 1 1 1  2       1  21 21111 3331342112   3 13 42 553692699748391673049223802 66 1

LOW-EDGE1000                                                    1111111111111111111111111111111111111111111111111111111111111111
*10**- 2 100        1111122222333334444455555666667777788888999990000011111222223333344444555556666677777888889999 9
         10    2468024680246802468024680246802468024680246802468024680246802468024680246802468024680246802468024680246802468024680246802468
          1.   0000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000

* ENTRIES =       2997      * ALL CHANNELS = 0.2997E+04      * UNDERFLOW = 0.0000E+00      * OVERFLOW = 0.0000E+00
* BIN WID = 0.2000E+04      * MEAN VALUE   = 0.1330E+06      * R . M . S = 0.1264E+05
```