Electron transport in water vapour in the presence of electrostatic fields

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INTRODUCTION

- Both

  Electron transport properties in water vapour

and

  Electron – water vapour collision cross sections have been of interest for many years.

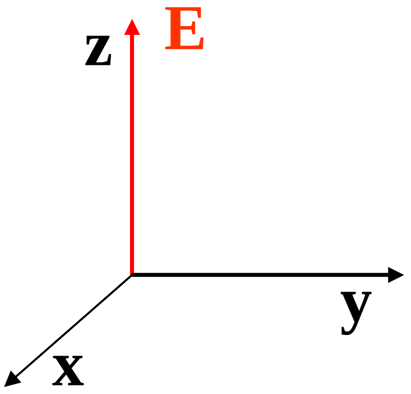
- In the present work we calculate transport coefficients for a range of E/n_0 (0.001 – 1500 Td) using the recent cross sections compiled by Brunger and Thorn and Itikawa and Mason and compare with those calculated from the cross sections used over 20 years ago by Ness and Robson.

- Comparison is also made with the experiments of Elford (1990 & 1995) and Hasegawa, Date and Shimozuma (2007)

Theory & Experiment meet

Assume hydrodynamic conditions – to 2nd order in ∇n

Rate coefficient R



Drift velocity $\mathbf{W} = (0,0,-W)$

Diffusion tensor $\mathbf{D} = \begin{bmatrix} D_T & 0 & 0 \\ 0 & D_T & 0 \\ 0 & 0 & D_L \end{bmatrix}$

KINETIC THEORY

Solve the Boltzmann equation

$$\left[\partial_t + \mathbf{c}\cdot\partial_{\mathbf{r}} + \frac{e}{m}\mathbf{E}\cdot\partial_{\mathbf{c}} + J\right] f = 0,$$

by making the expansion

$$f(\mathbf{r},\mathbf{c},t) = \sum_{l=0}^{\infty}\sum_{m=-l}^{l}\sum_{s=0}^{\infty}\sum_{\lambda=0}^{s}\sum_{\mu=-\lambda}^{\lambda} F(lm\nu| s\lambda\mu) R_{\nu l}(\alpha c) Y_m^{[l]}(\hat{\mathbf{c}}) G_\mu^{(s\lambda)} n(\mathbf{r},t)$$

$R_{\nu l}(\alpha c) \sim$ Sonine polynomial

$Y_m^{[l]}(\hat{\mathbf{c}})$ spherical harmonics

$G_\mu^{(s\lambda)}$ s^{th} application of the gradient operator in irreducible tensor notation.

$F(l,m,\nu|s\lambda\mu) \Rightarrow$ Transport coefficients

Mean Energy

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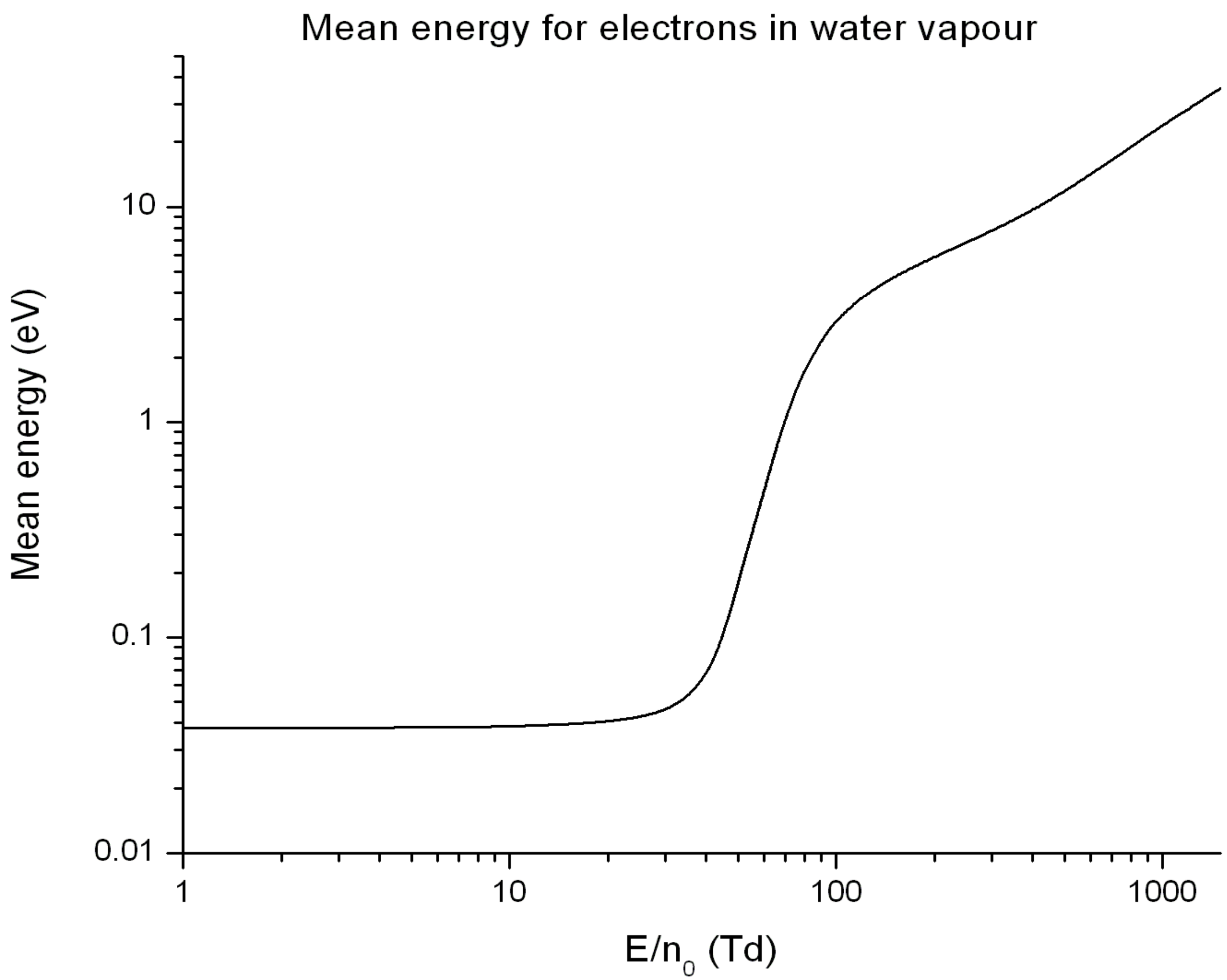
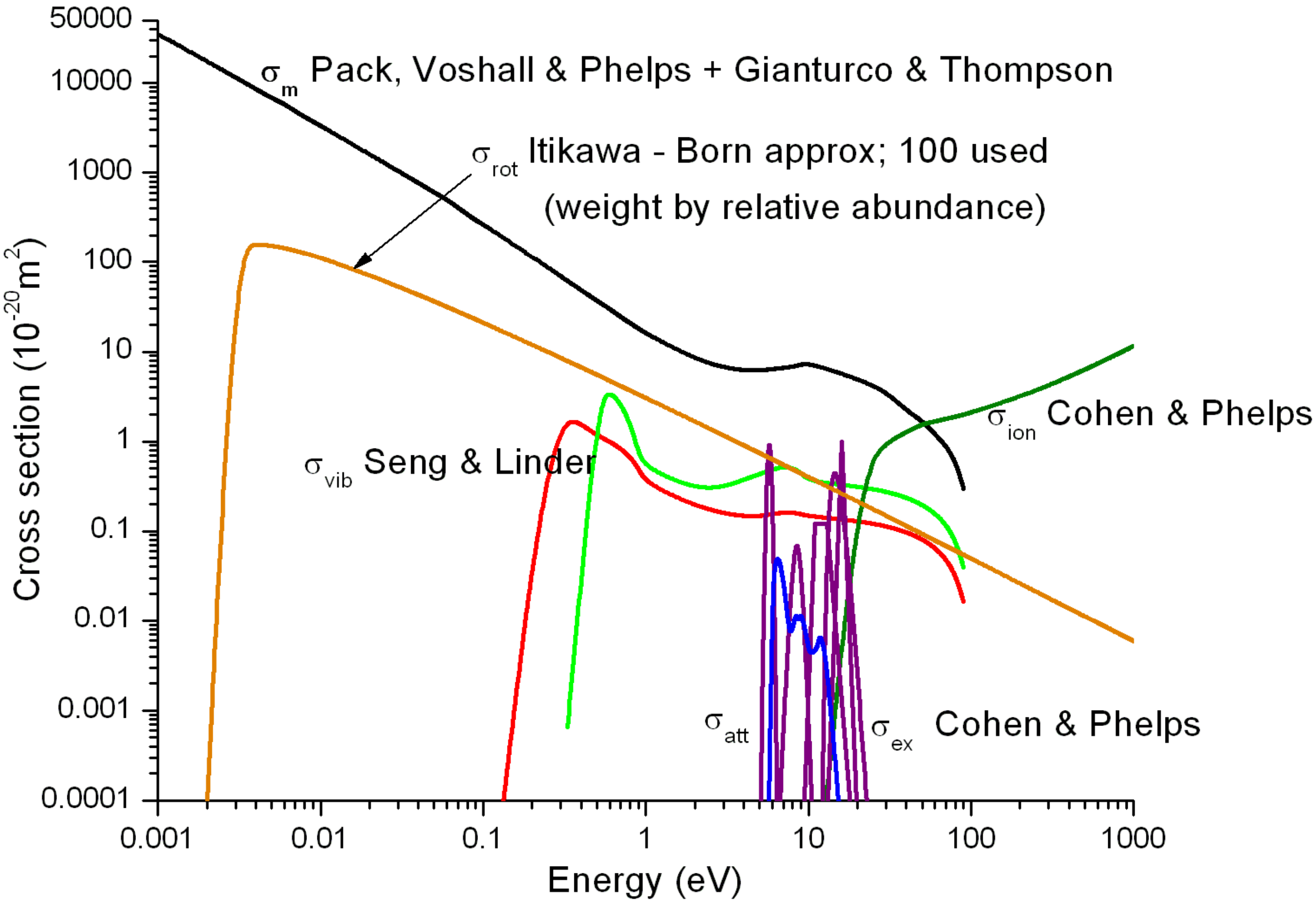


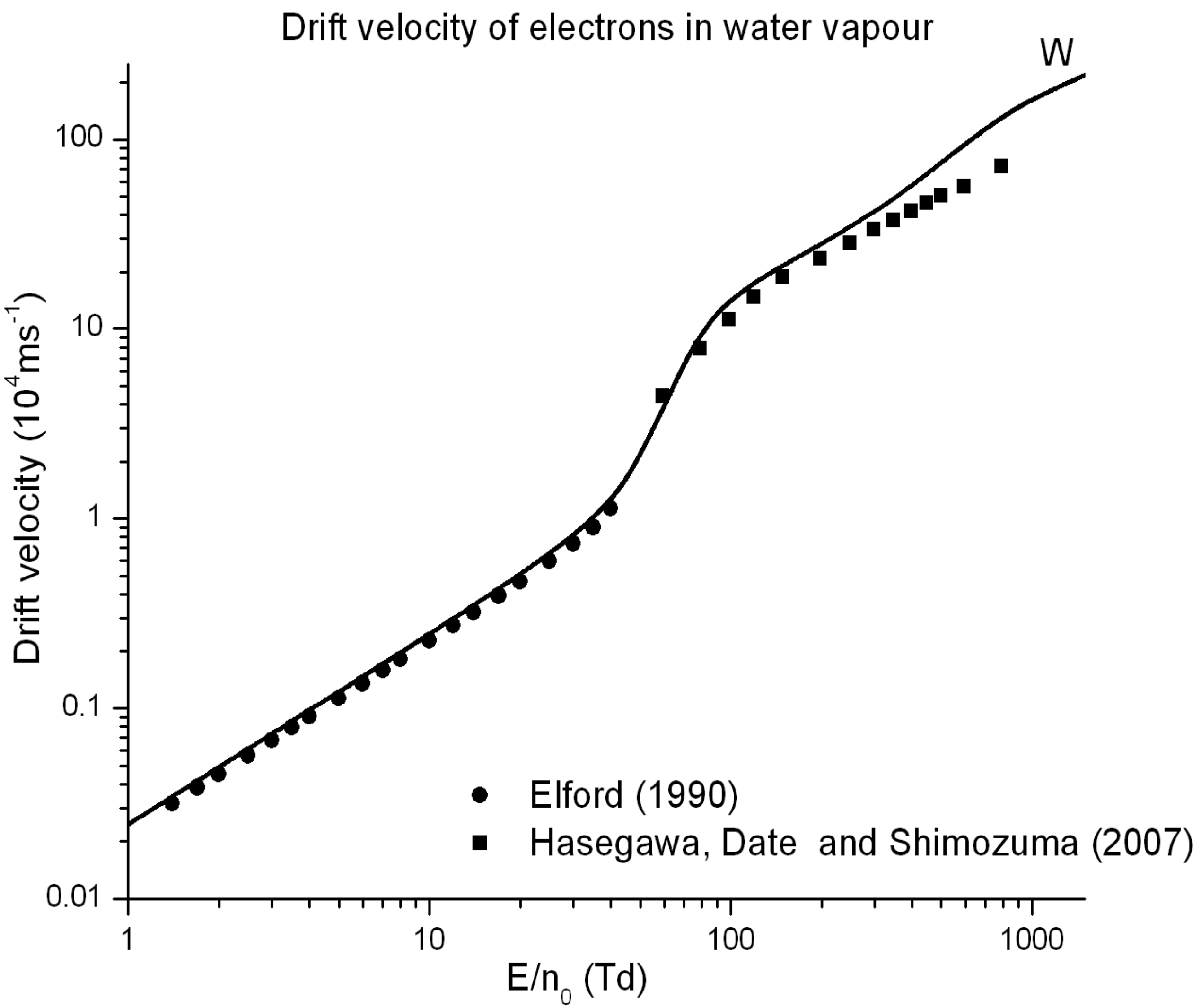
Cross sections

- To date four sets of cross sections have been used

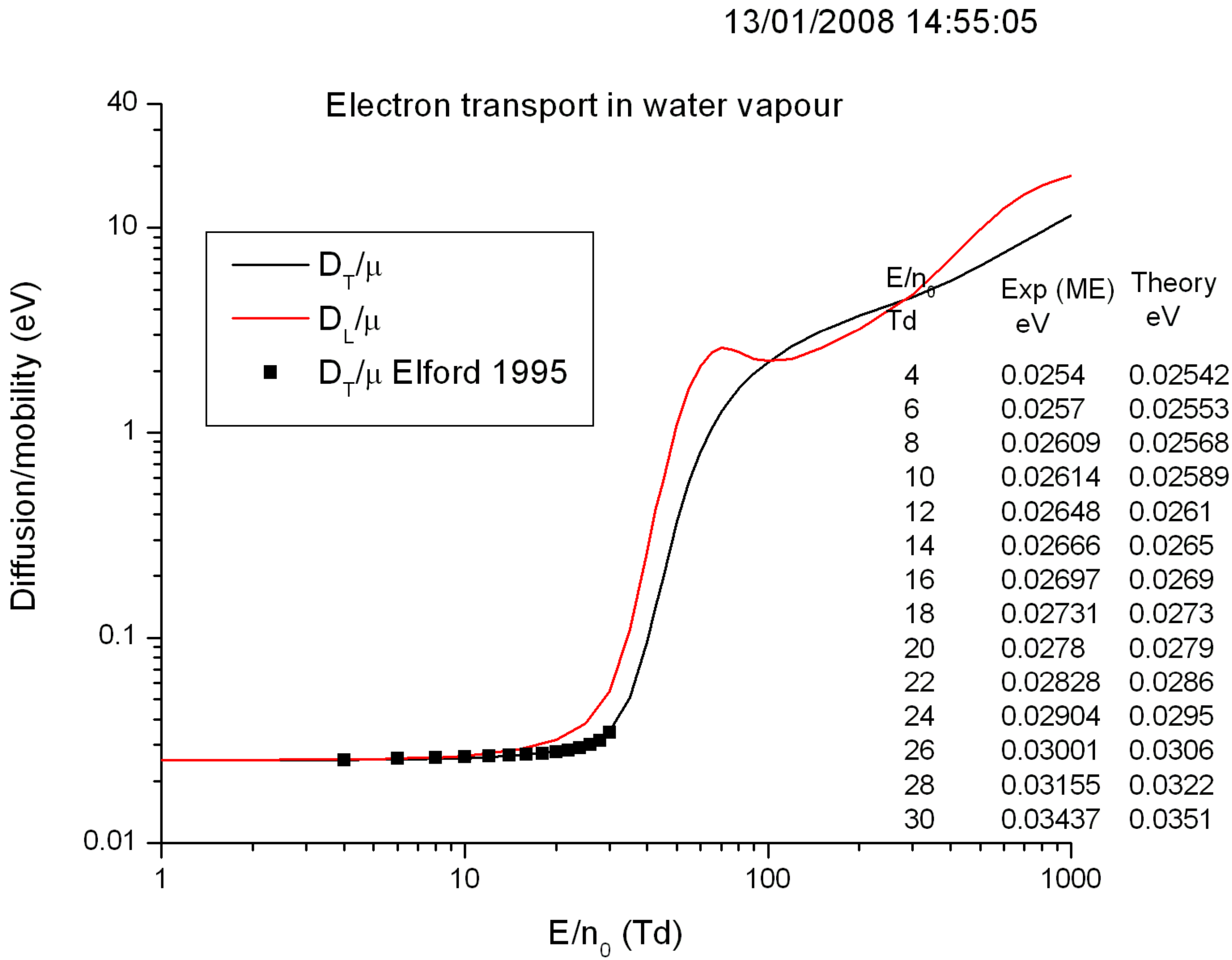
1) The set used by Ness and Robson in 1988
2) A combination of the cross sections from Brunger and Thorn & Itikawa and Mason
3) A different combination of the cross sections from Brunger and Thorn & Itikawa and Mason
4) A combination of the set used by Ness and Robson with that of Brunger and Thorn & Itikawa and Mason


σ m Pack, Voshall & Phelps + Gianturco & Thompson
σ rot Itikawa - Born approx; 100 used
(weight by relative abundance)
σ vib Seng & Linder
σ ion Cohen & Phelps
σ att
σ ex Cohen & Phelps
Cross section (10-20 m2)
Energy (eV)
50000
10000
1000
100
10
1
0.1
0.01
0.001
0.0001
0.001
0.01
0.1
1
10
100
1000

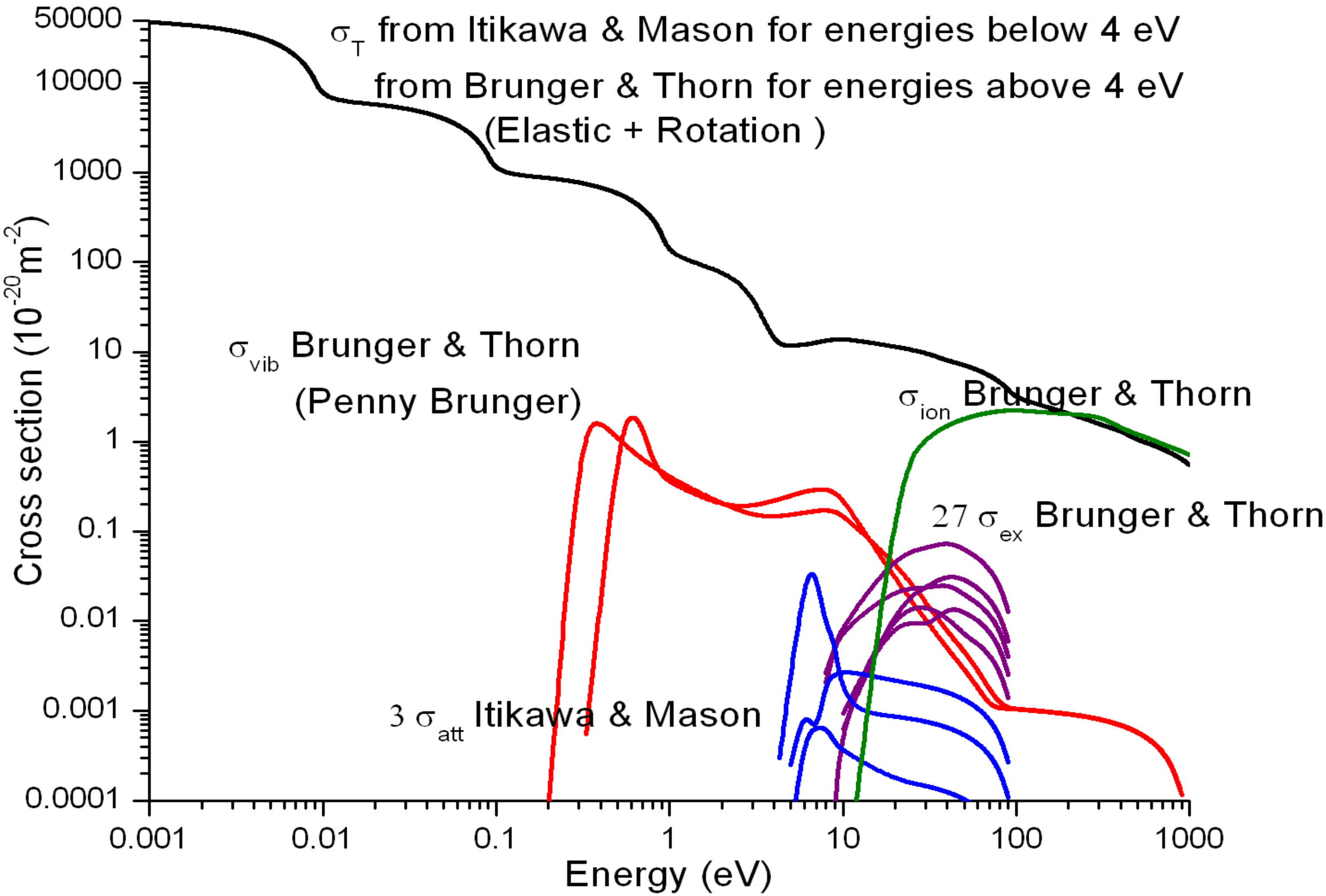
Drift velocity



Diffusion

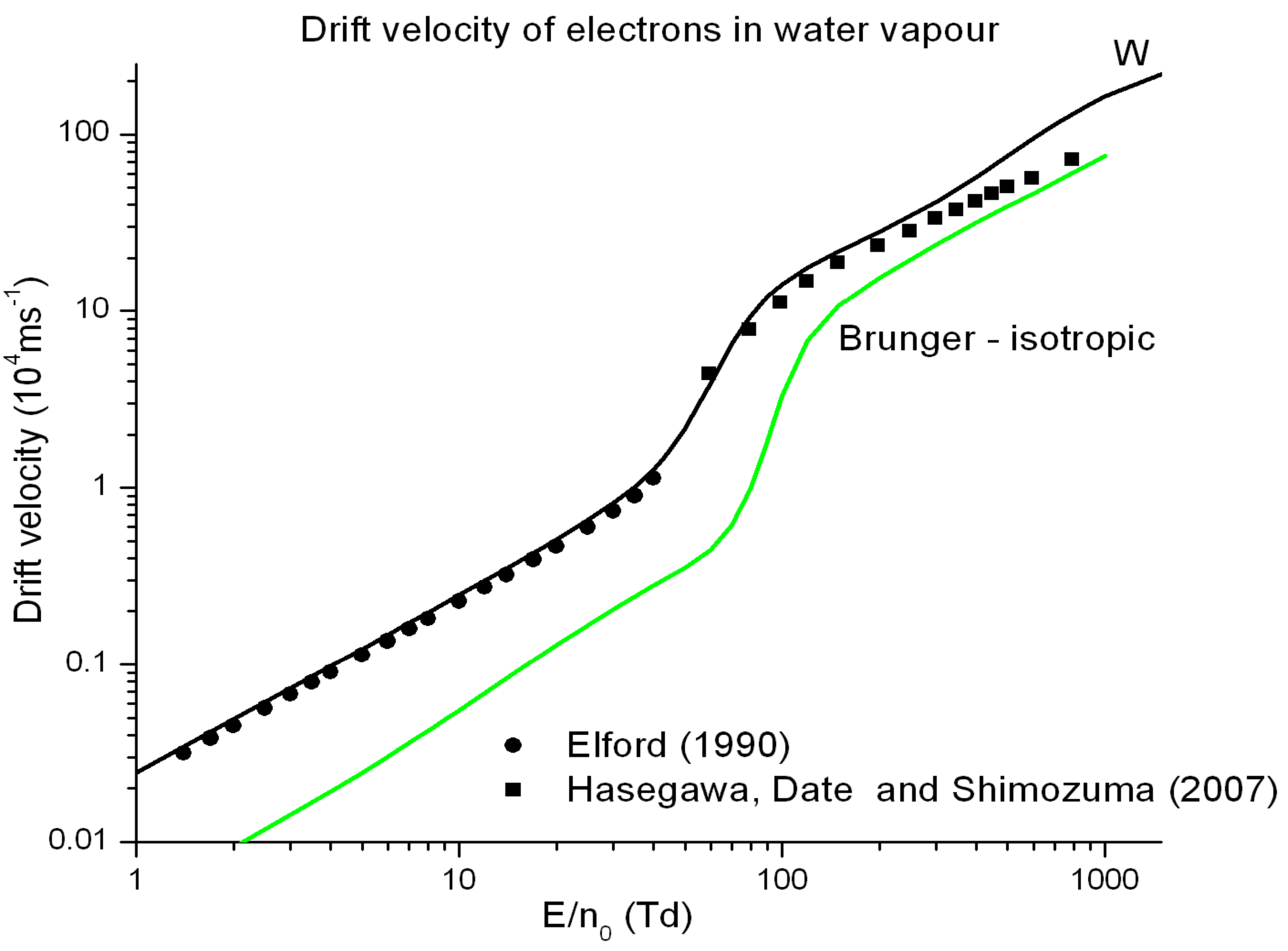


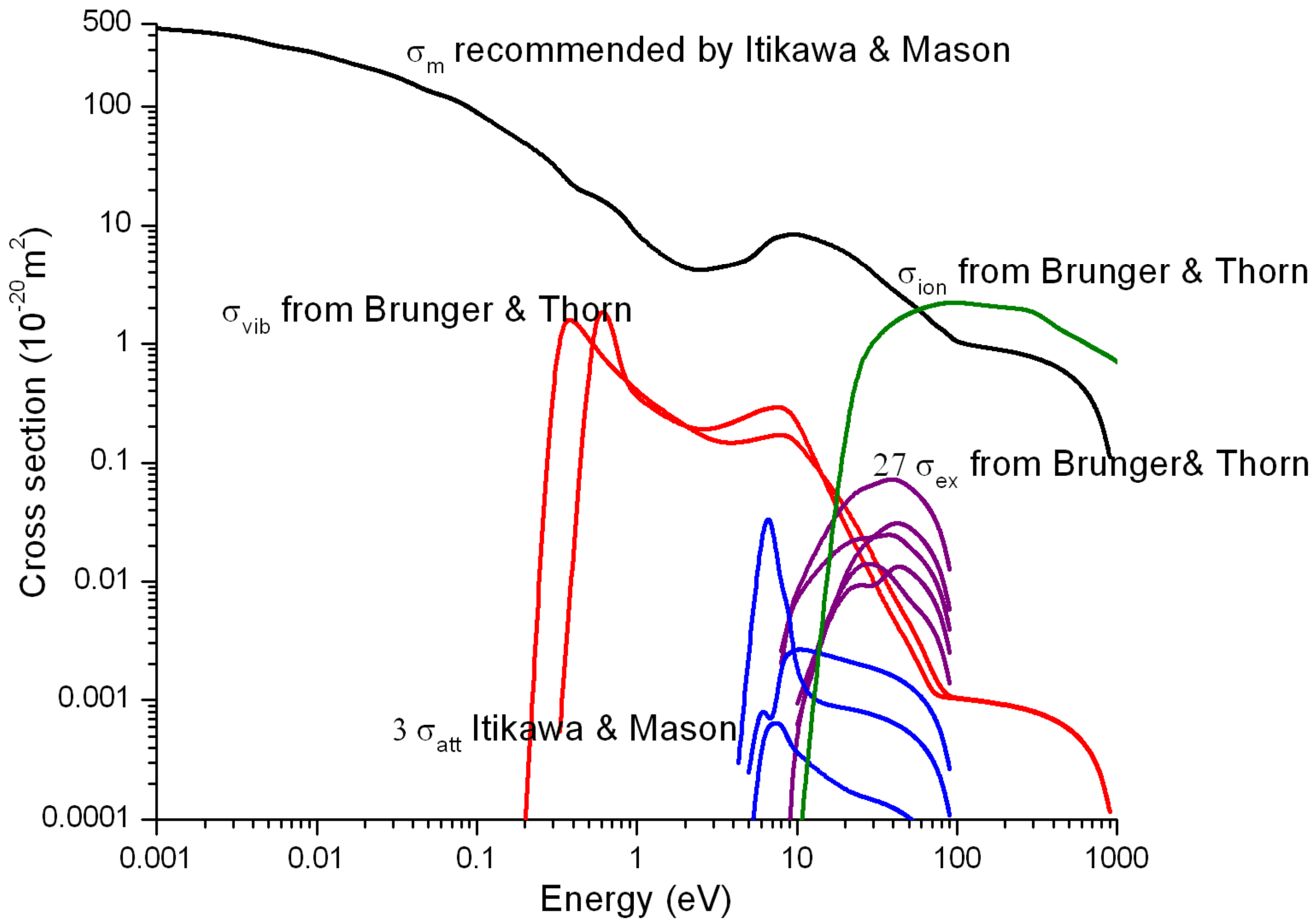
E/n0 Td	Exp (ME) eV	Theory eV
4	0.0254	0.02542
6	0.0257	0.02553
8	0.02609	0.02568
10	0.02614	0.02589
12	0.02648	0.0261
14	0.02666	0.0265
16	0.02697	0.0269
18	0.02731	0.0273
20	0.0278	0.0279
22	0.02828	0.0286
24	0.02904	0.0295
26	0.03001	0.0306
28	0.03155	0.0322
30	0.03437	0.0351



σT from Itikawa & Mason for energies below 4 eV
from Brunger & Thorn for energies above 4 eV
(Elastic + Rotation)
σvib Brunger & Thorn
(Penny Brunger)
σion Brunger & Thorn
27 σex Brunger & Thorn
3 σatt Itikawa & Mason
Cross section (10-20 m-2)
50000
10000
1000
100
10
1
0.1
0.01
0.001
0.0001
0.001
0.01
0.1
1
10
100
1000
Energy (eV)

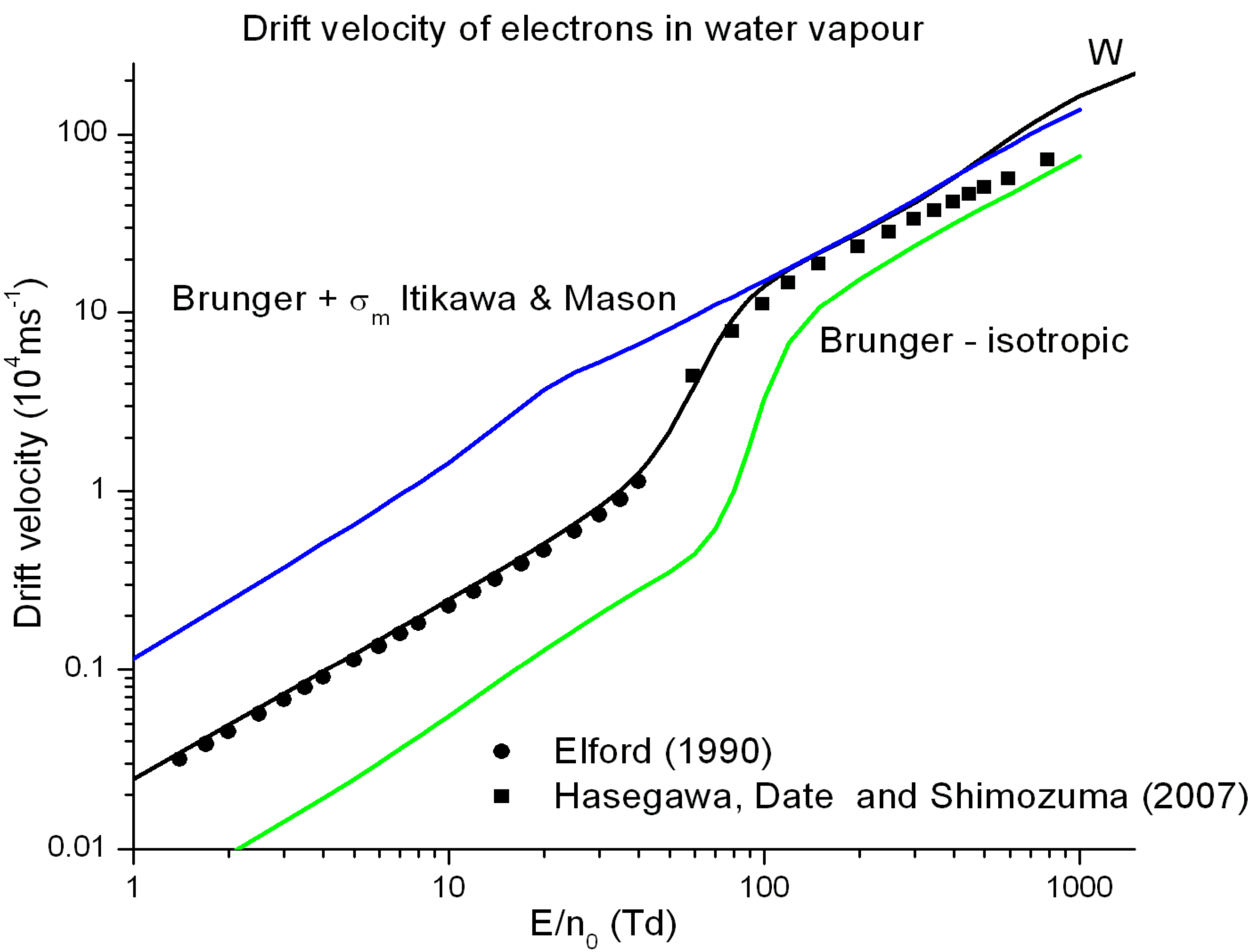
Drift velocity

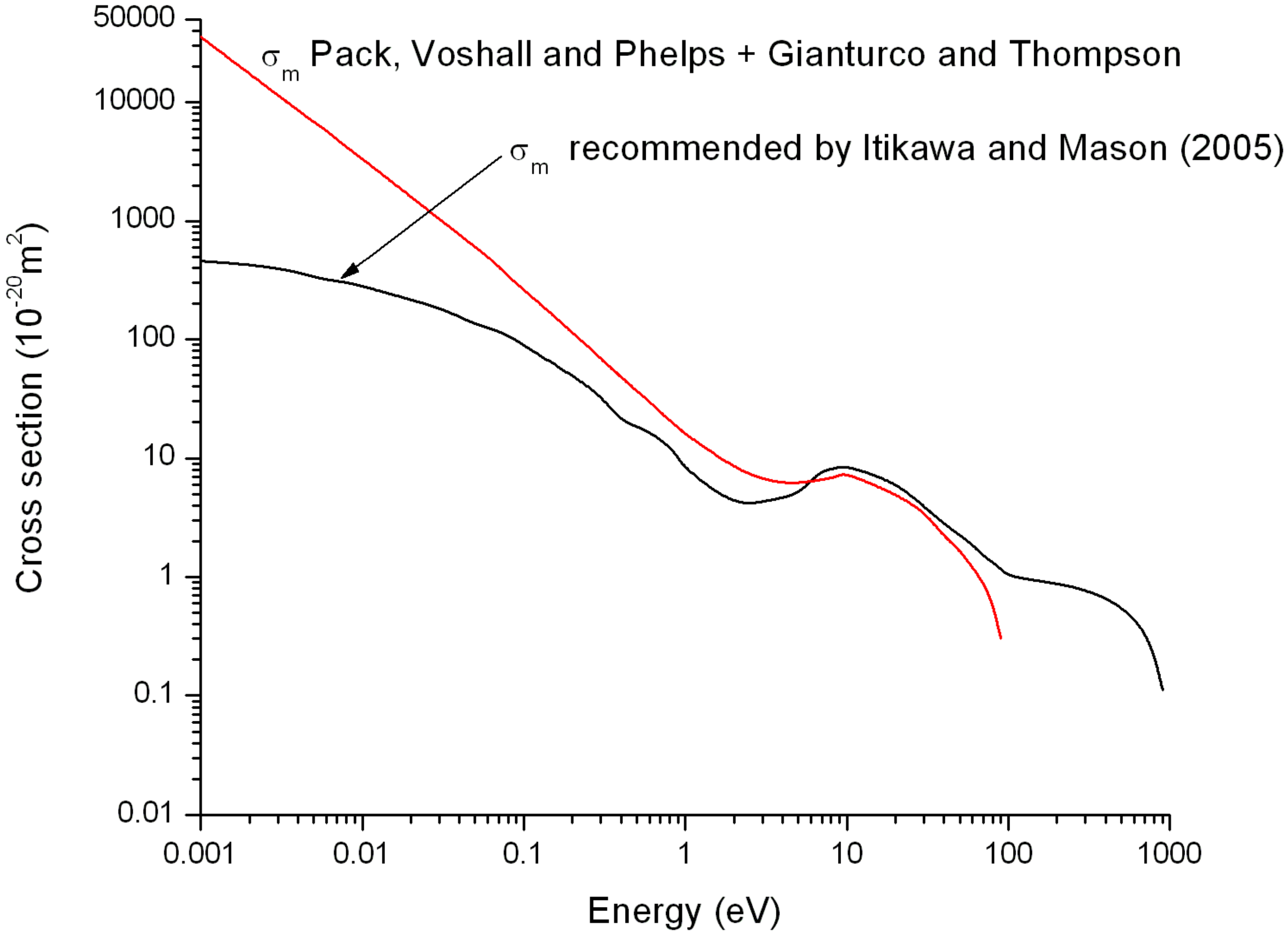


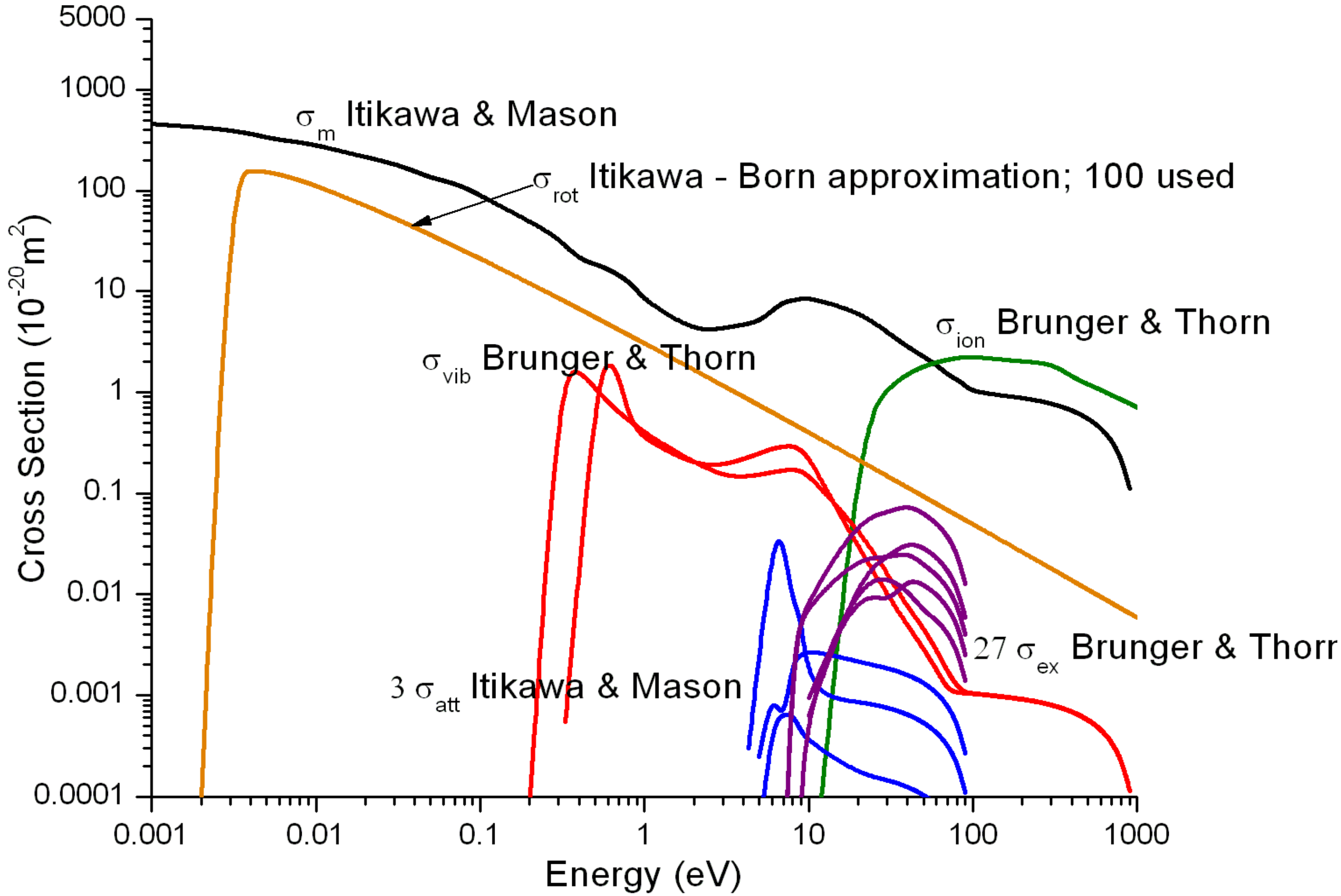


σm recommended by Itikawa & Mason
σion from Brunger & Thorn
σvib from Brunger & Thorn
27 σex from Brunger& Thorn
3 σatt Itikawa & Mason
Cross section (10-20 m2)
Energy (eV)
500
100
10
1
0.1
0.01
0.001
0.0001
0.001
0.01
0.1
1
10
100
1000

Drift velocity

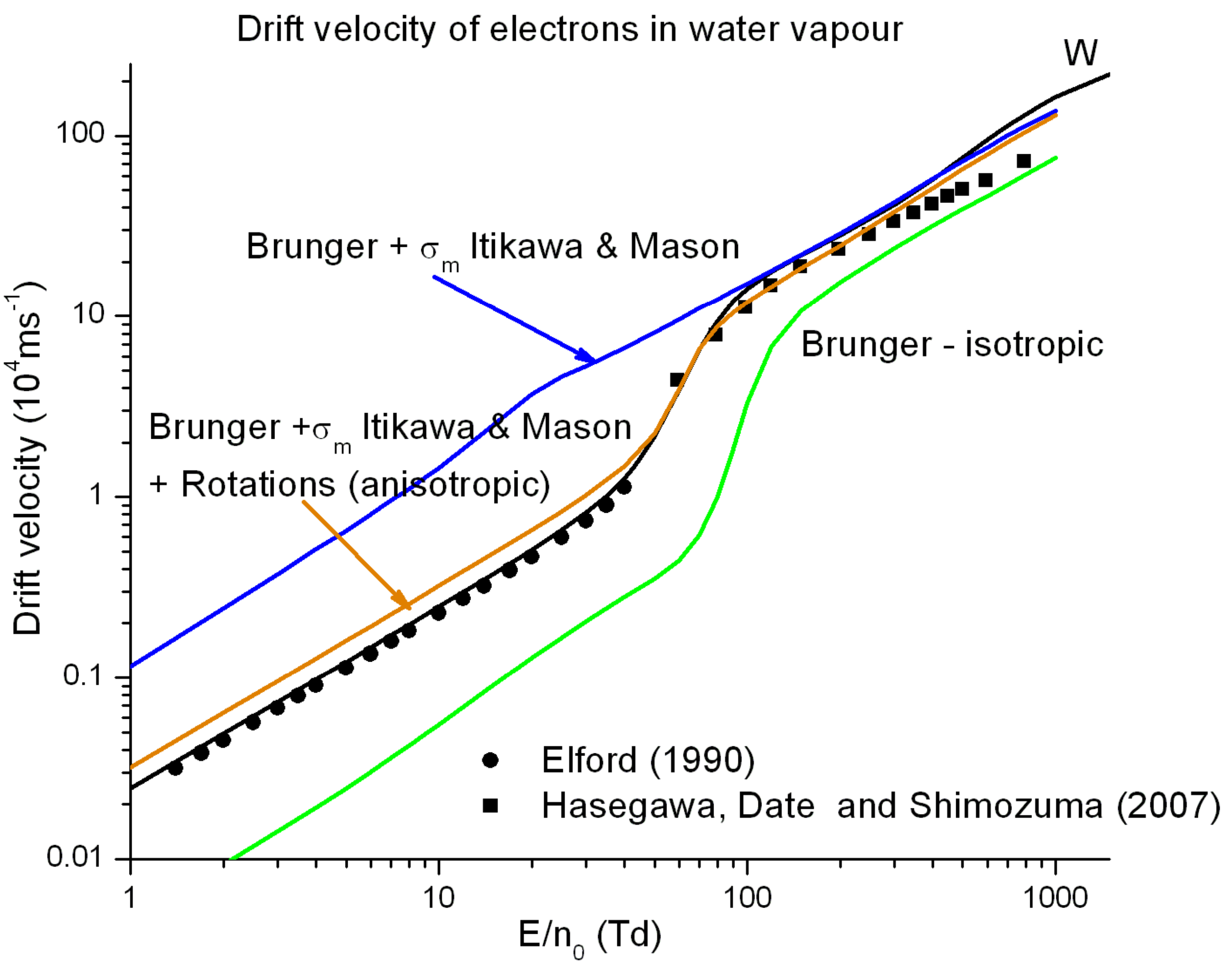



σm Pack, Voshall and Phelps + Gianturco and Thompson
σm recommended by Itikawa and Mason (2005).
Cross section (10^-20 m^2)
Energy (eV)
50000
10000
1000
100
10
1
0.1
0.01
0.001
0.01
0.1
1
10
100
1000



5000
1000
100
10
1
0.1
0.01
0.001
0.0001
Cross Section (10^-20 m^2)
0.001
0.01
0.1
1
10
100
1000
Energy (eV)
σ m Itikawa & Mason
σ rot Itikawa - Born approximation; 100 used
σ ion Brunger & Thorn
σ vib Brunger & Thorn
27 σ ex Brunger & Thorn
3 σ att Itikawa & Mason

Drift velocity



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CONCLUSION

1. A work in progress.
2. Moment method converges over full range of E/n_0.
3. Problems with the low energy (< a few eV) electron-water vapour cross sections. These still effect transport up to 1000 Td (~20 eV).
4. Best option to date? Combine low energy component of the set I used in 1988 with the vibrations and above of Brunger and Thorn.
5. Need for accurate swarm experimental data in the full range 0 – 1000 Td for electrons in water vapour.