Comparisons of sets of electron-neutral scattering cross sections and calculated swarm parameters in Helium and Neon

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Introduction

In the context of the recently initiated GEC Plasma Data Exchange project, we compare measured **swarm parameters** with those calculated using sets of cross sections, compiled by different authors, in **helium** and **neon**. These data are on-line at **www.lxcat.laplace.univ-tlse.fr**. The cross section compilations for electron scattering from ground state helium or neon vary mainly in the level of detail provided for inelastic excitation, ranging from one effective excitation level to many individual levels. The swarm parameters were calculated using a **2-term Boltzmann solver** and a **Monte Carlo simulation.** Calculated swarm parameters from the various compilations show good agreement among themselves in both gases, and generally good agreement is obtained between calculated and measured swarm parameters except for ionization coefficients at low E/N where measured ionization coefficients in both gases show strong influences of Penning ionization of impurities.
We conclude that the cross section compilations and their use in a 2-term Boltzmann solver yield results sufficiently accurate for **plasma modeling** purposes

"Complete" sets of cross sections available on LXCat for electron scattering from helium and neon

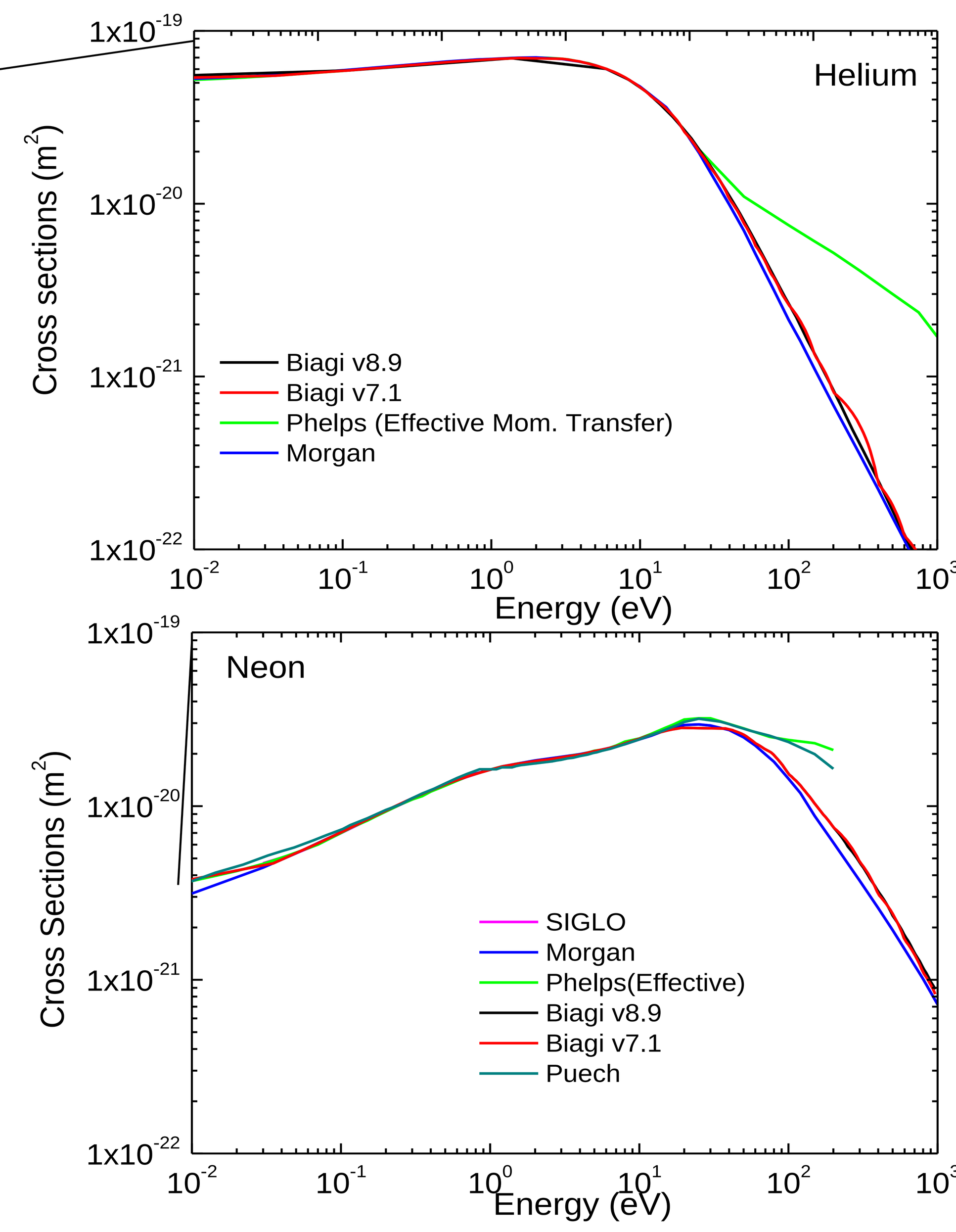
He

Database name	Level of detail for excitation	Comments
Phelps (SIGLO data are from Phelps)	**1 effective excitation level**	For use with a 2-term Boltzmann solver.
Morgan	**2 levels (metastable + resonance)**	For use with a 2-term Boltzmann solver.
Biagi v7.1	**2 excitation levels (triplet and singlet)**	For use with Monte Carlo or multi-term Boltzmann solver.
Biagi v8.9	**49 levels**	For use with Monte Carlo or multi-term Boltzmann solver. Based on quantum calculations of Zatsarinny and Bartschat, with the theoretical results of Yu. Ralechenko (2008) above the resonance region (above 30 eV).

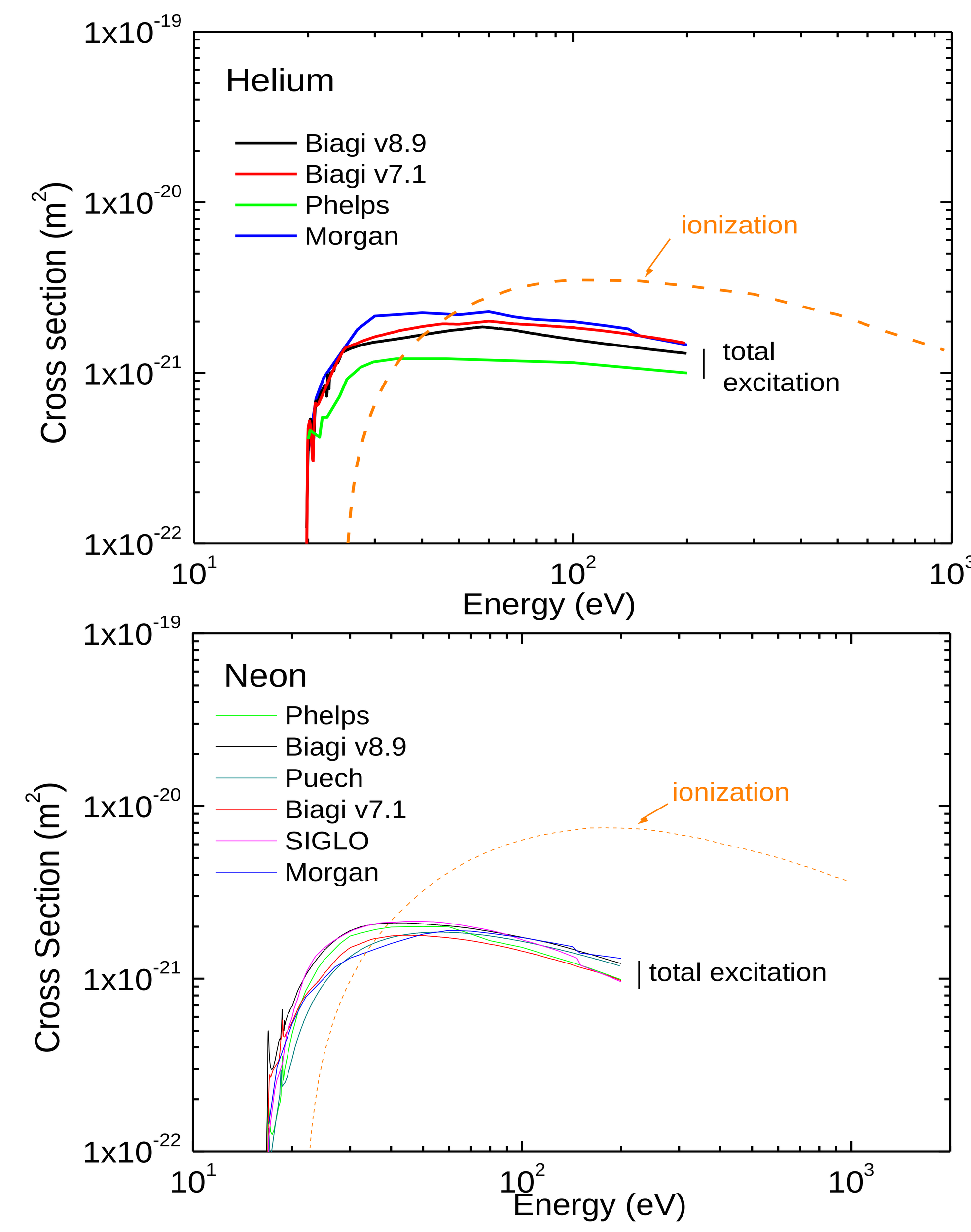
Ne

Database name	Level of detail for excitation	Comments
Phelps	**6 levels**	For use with a 2-term Boltzmann solver. Based on Tachibana, Phys . Rev. A 34, 1007 (1986)
SIGLO	**6 levels**	For use with a multiterm Boltzmann solver. From Meunier et al. J. Appl. Phys. 78, 731 (1995)
Morgan	**2 levels (metastable + resonance)**	For use with a 2-term Boltzmann solver.
Biagi v7.1	**9 excitation levels**	For use with Monte Carlo or multi-term Boltzmann solver.
Biagi v8.9	**45 levels**	For use with Monte Carlo or multi-term Boltzmann solver. Data for the resonance regions are based in part on calculations of Zatsarinny and Bartschat which also agree with the new accurate experimental measurements of Allan. Allan et al. J. Phys. B 42, 42044009 (2009)
Puech	**24 levels**	For use with a 2-term Boltzmann solver. Elastic momentum transfer taken from Biagi v8.9. Puech and Mizzi, J. Phys. D 24, 1974 (1991)

Databases containing cross sections



Elastic momentum transfer cross sections



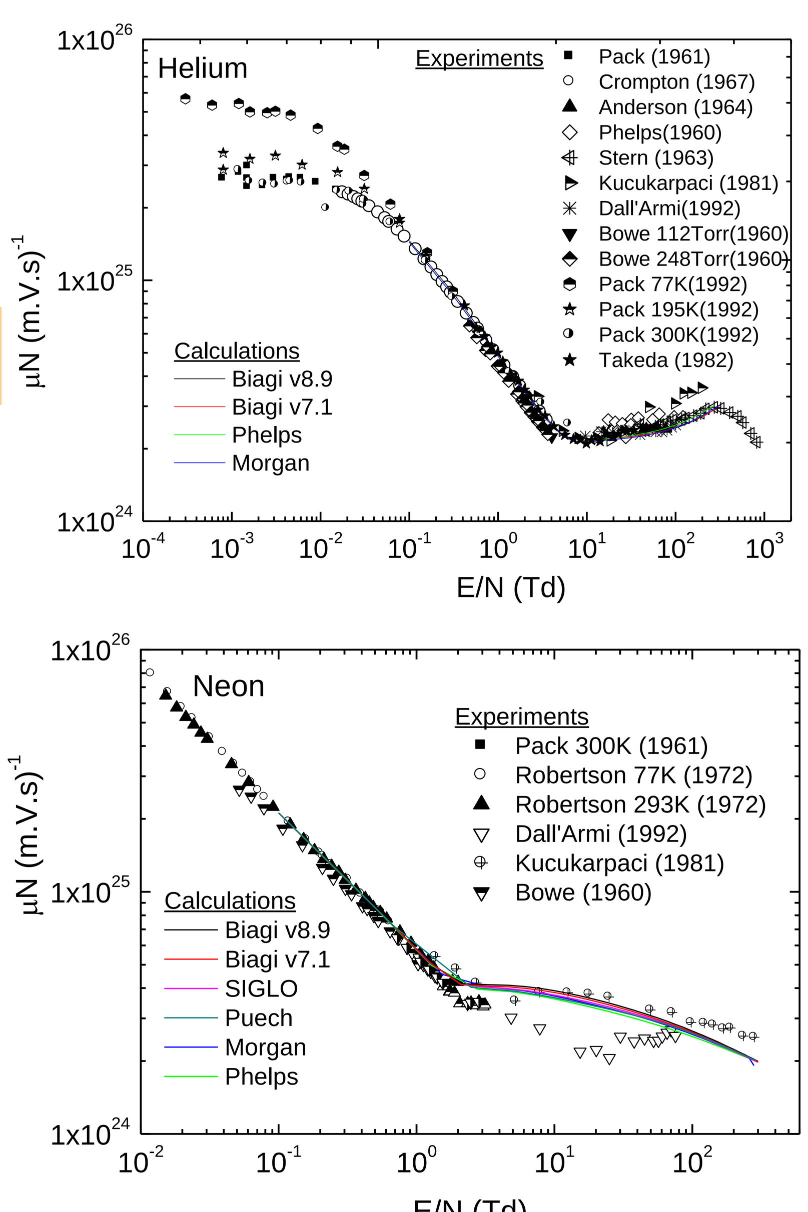
Ionization and sum of inelastic cross sections

Transport and rate coefficients calculated using LXCat input data and comparisons with experiment

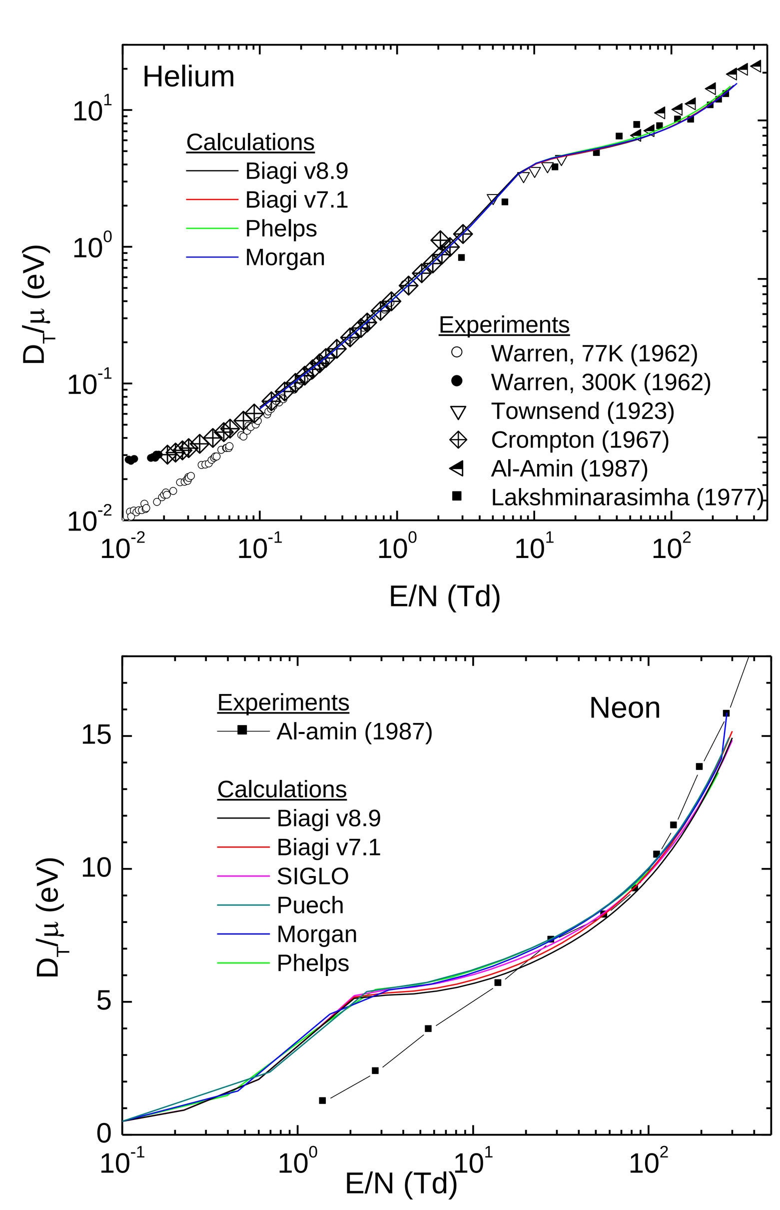
These calculations were performed using BOLSIG+, a 2-term Boltzmann solver

He

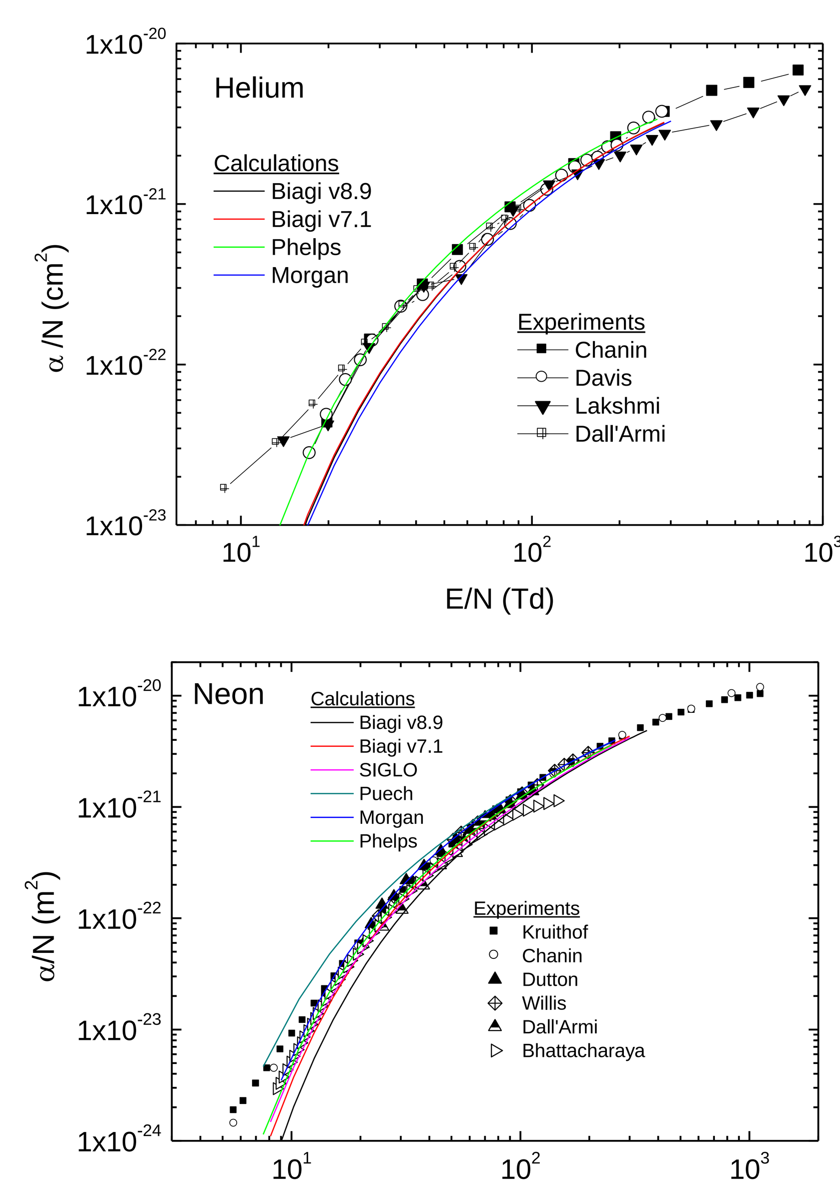
Ne



Mobility x neutral gas density, **μN vs. E/N**
For full range of experimental data, see **LXCat.**

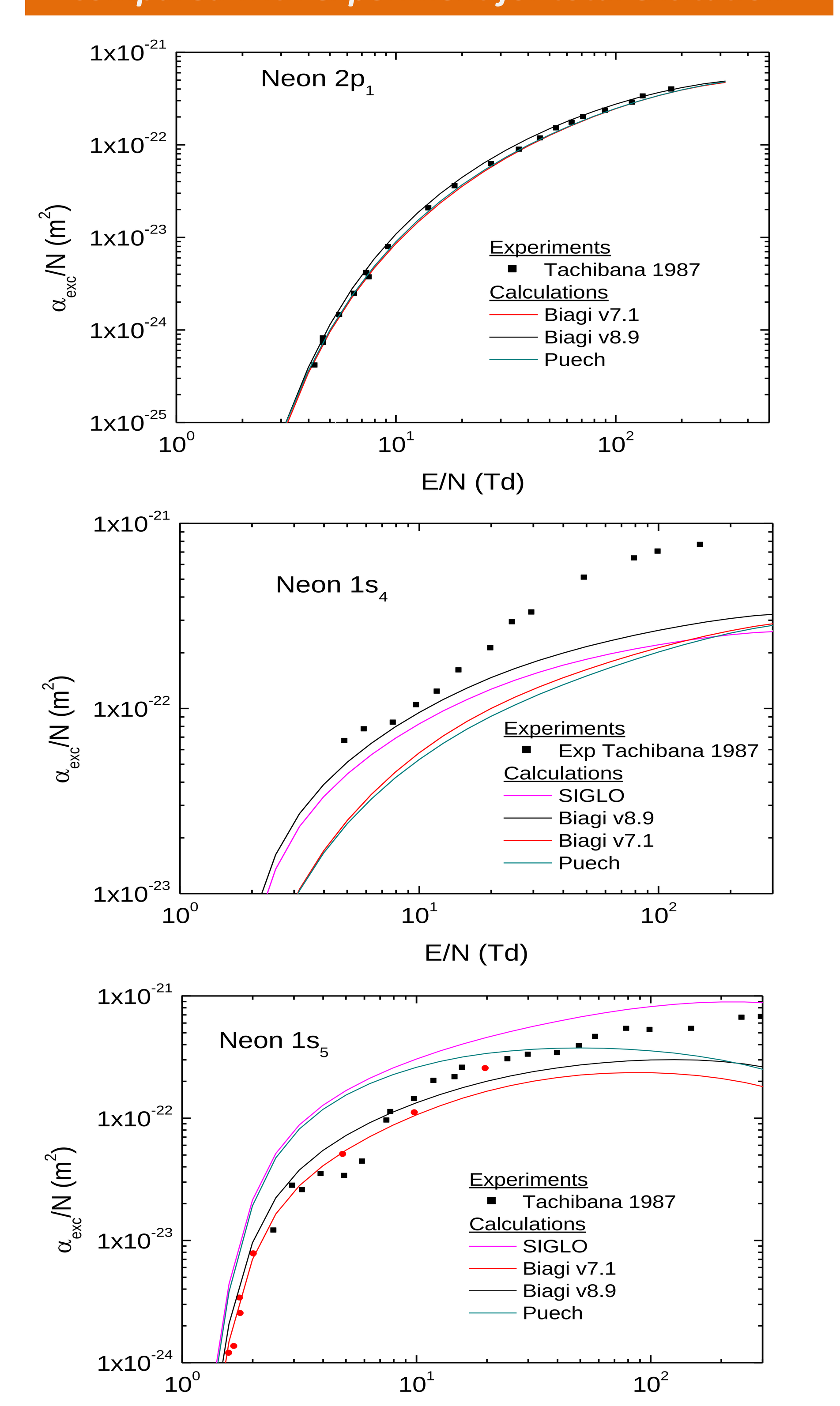


Characteristic energy, **D_T/μ vs. E/N**
For full range of experimental data, see **LXCat.**

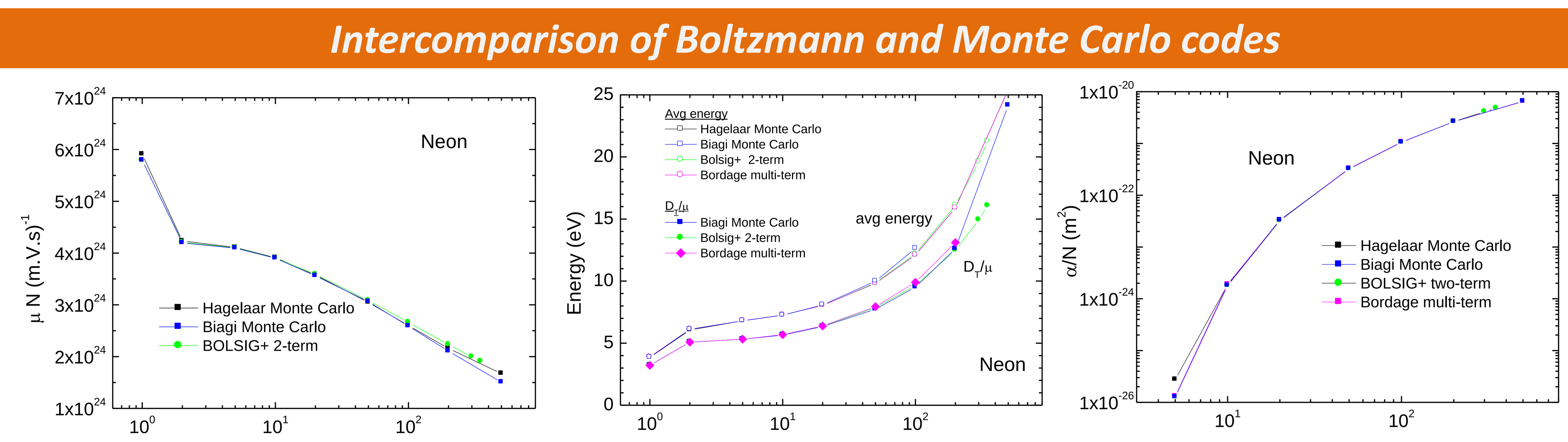


Ionization rate, **α/N vs. E/N**

Rates for direct excitation in neon calculated and compared with experiment for total excitation



Intercomparison of Boltzmann and Monte Carlo codes



The generally good agreement serves to validate the various codes and shows that 2-term Boltzmann solvers are perfectly fine for He and Ne up to some 100's of Td.
Runaway becomes an issue in helium for E/N some 200 Td (PT, higher if SST).

References for codes:

- 2-term Boltzmann : Hagelaar, BOLSIG+ (full version downloadable from LXCat site)
- Multi-term : Segur, Bordage and Yousfi (1985)
- Biagi Monte Carlo : Magboltz (available from the CERN website)
- Hagelaar Monte Carlo : coming soon to the LXCat site

Conclusions

• He : Theoretical cross sections for excitation are now more accurate than experiment. Thus, it is our opinion that theory is more accurate than experiment for swarm data in helium below 100 Td (except maybe for data obtained at ANU).

• Ne : The different sets of cross sections essentially agree in the total excitation cross section and in the predicted transport coefficients, but there are some differences in cross sections for the individual processes.

• The divergence of the calculation (Biagi) of the Townsend coefficient for helium and neon at low electric fields from the measured Townsend coefficients is caused by Penning transfers to impurities in the gases. The impurity concentration required to bring agreement between the experiment and theory is only at the level of 20ppm impurity. It would be beneficial if modern experiments with less than 1 ppm impurities could be carried out to corroborate these conclusions.