Electron Swarm Parameters and Electron Collision Cross Sections

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1. Introduction

- Reliable data on electron collision cross sections and electron swarm parameters: the key to quantitative modeling of low-temperature plasmas
- Collection and evaluation for reliable sets of cross sections are needed.
- Electron swarm data and their analysis can evaluate and even provide cross section data.
- Electron swarm study, known to be complementary to beam experiment

2. Electron swarm parameters

- Every possible scattering process of electrons is reflected in their collective behaviors.

  - Elastic momentum transfer and vibrational excitation
- A trace amount of molecular impurities in a Ramsauer gas (Ar, for example) can alter swarm parameters drastically.

  - Manifestation of vibrational excitation processes in the mixture

  - Diminished elastic momentum transfer to the molecule because of its low density

⇒Chance to separate determination of elastic momentum and vibrational cross sections

For example,

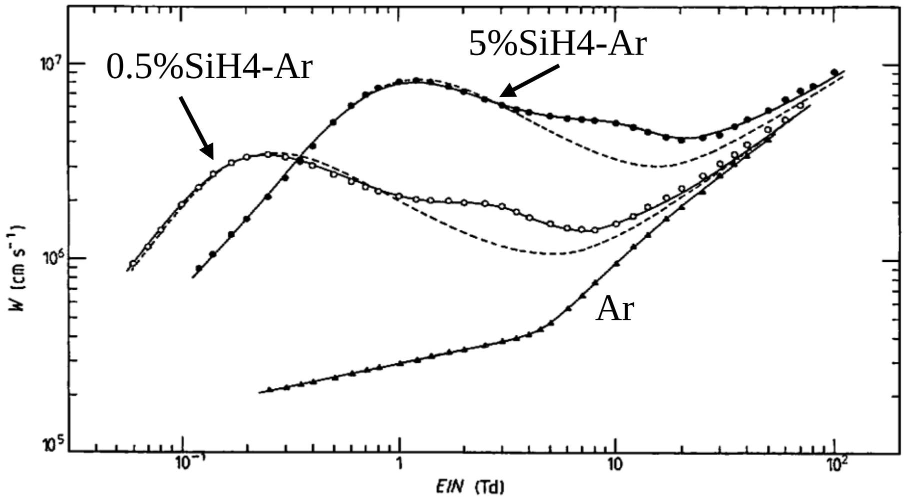


Figure 5. The drift velocity, *W*, in SiH_4–Ar mixtures. Measured values: ○, 0.501% SiH_4–Ar; ●, 5.04% SiH_4–Ar; ▲, Ar (Nakamura and Kurachi 1988). Calculated values: ———, using the present cross sections; – – – –, using the cross sections of Hayashi (1987).

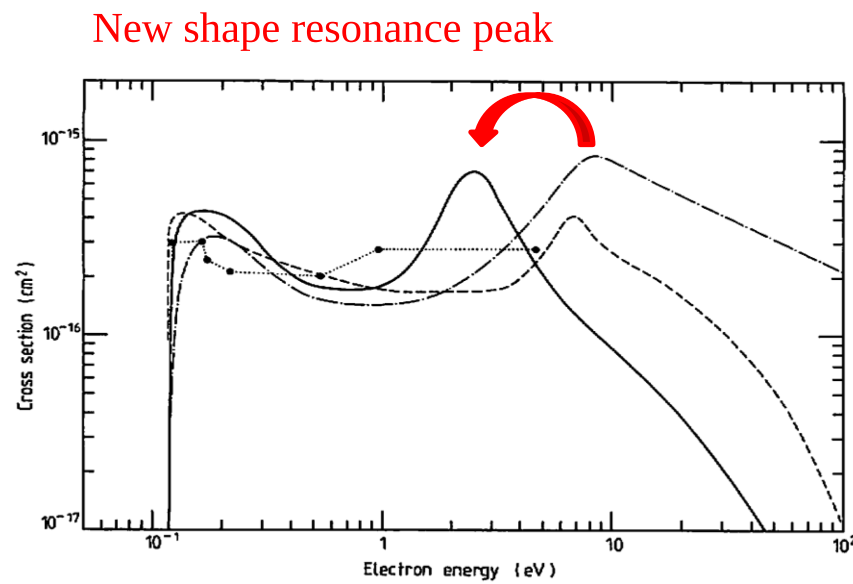


Figure 2. The vibrational excitation cross section q_{v24} for the monosilane molecule: ———, present results; – – – –, Hayashi (1987); —·—·—, Ohmori *et al* (1986); ····●····, Mathieson *et al* (1987).

M. Kurachi and Y. Nakamura, *J. Phys. D* **22**, 107-112 (1989)

This swarm-derived resonance peak was confirmed by electron beam experiment. (H. Tanaka e al., 1990).

Then we established a procedure;

- **Step 1: Swarm parameters in mixtures**

  Vibrational excitation cross sections

- **Step 2: Swarm parameters in pure gas**

  Elastic momentum transfer cross section

These two steps are repeated alternately until the set of cross sections of the molecule converges and is consistent with all known experimental swarm parameters in pure gas and also in the mixtures.

Tool: Visually-interactive Boltzmann equation analysis

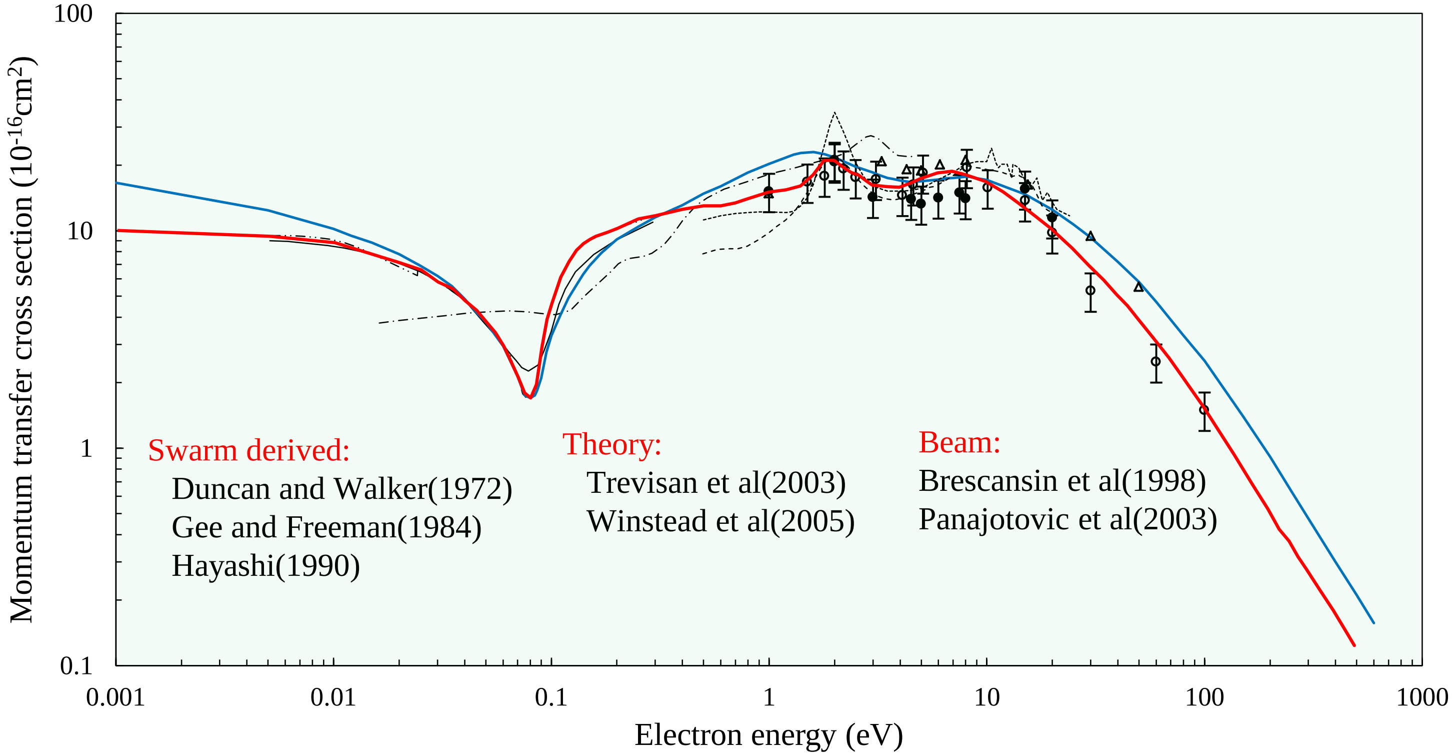
3. An example: C_2H_4

Ethylene(C_2H_4) is one of the simple hydrocarbon molecules with two double-bonded carbon atoms. Experimental swarm data in ethene, however, are rather scarce.

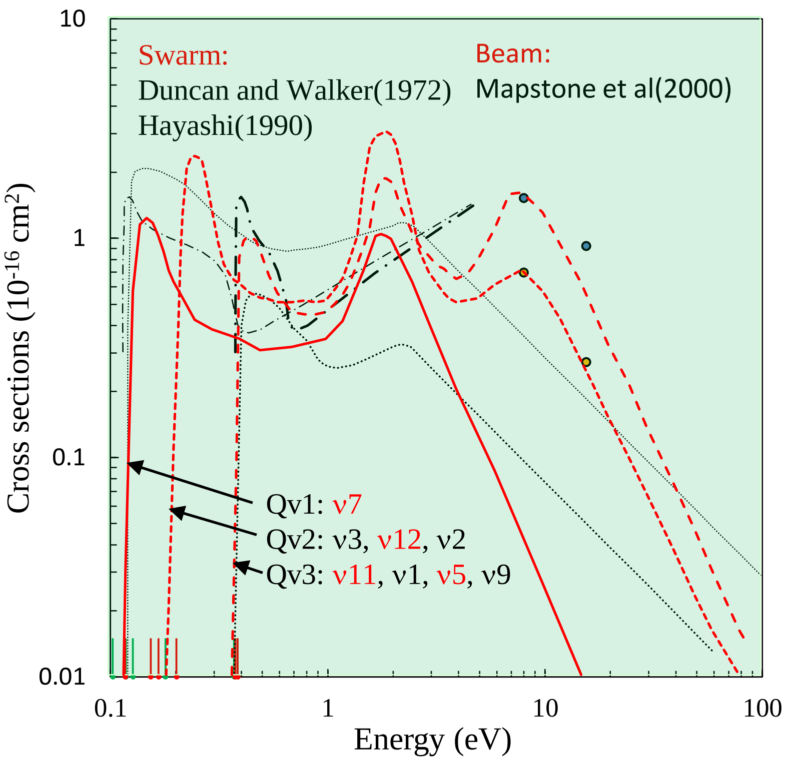
We have already studied ethane (single-bonded) and acetylene (triple-bonded), and the present study will complete a systematic investigation on the molecular bond.

Preparation of an initial cross section set

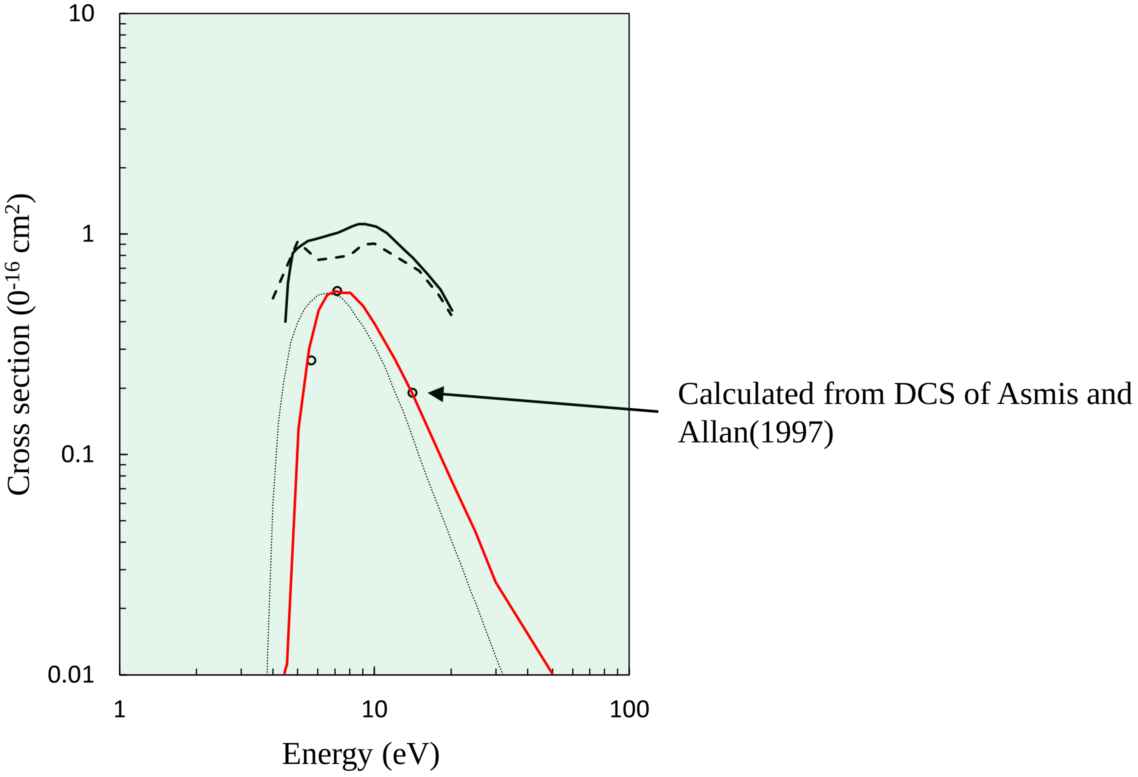
(1) Elastic momentum transfer, Q_m



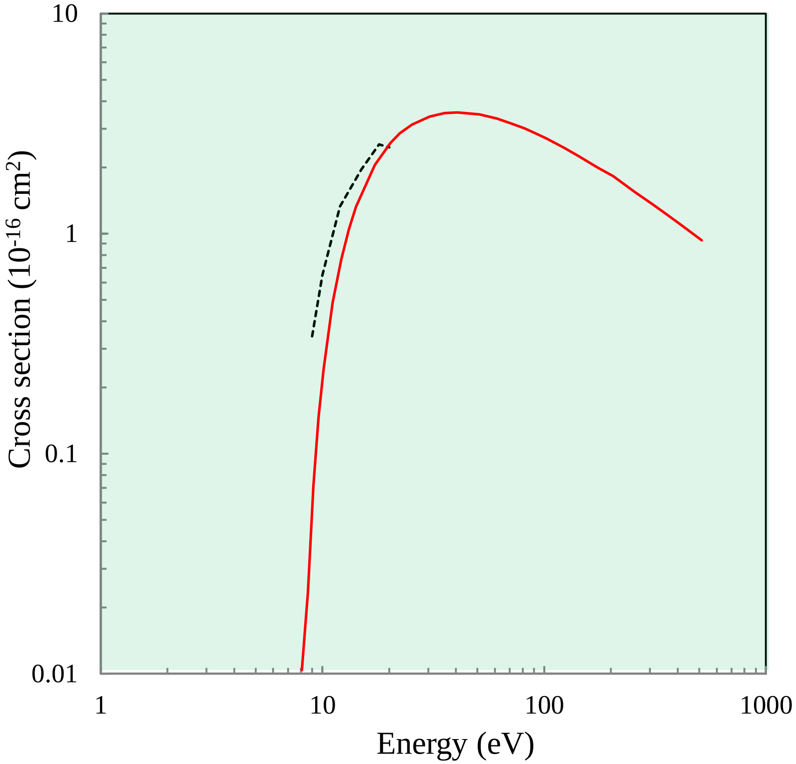
(2) Vibrational excitation, Q_v



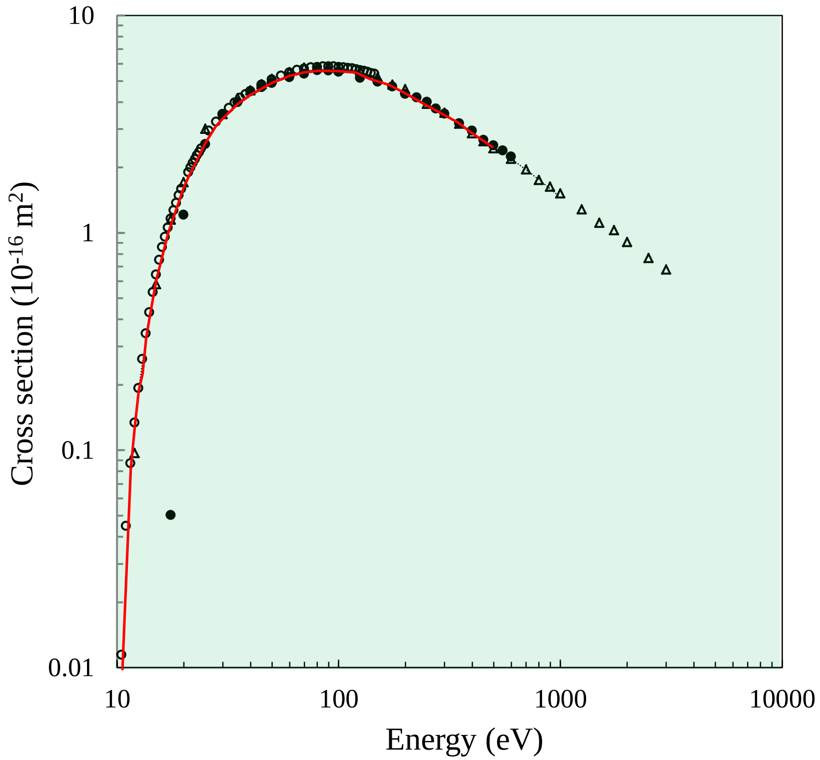
(3) Electronic excitation, Q_{ex1}



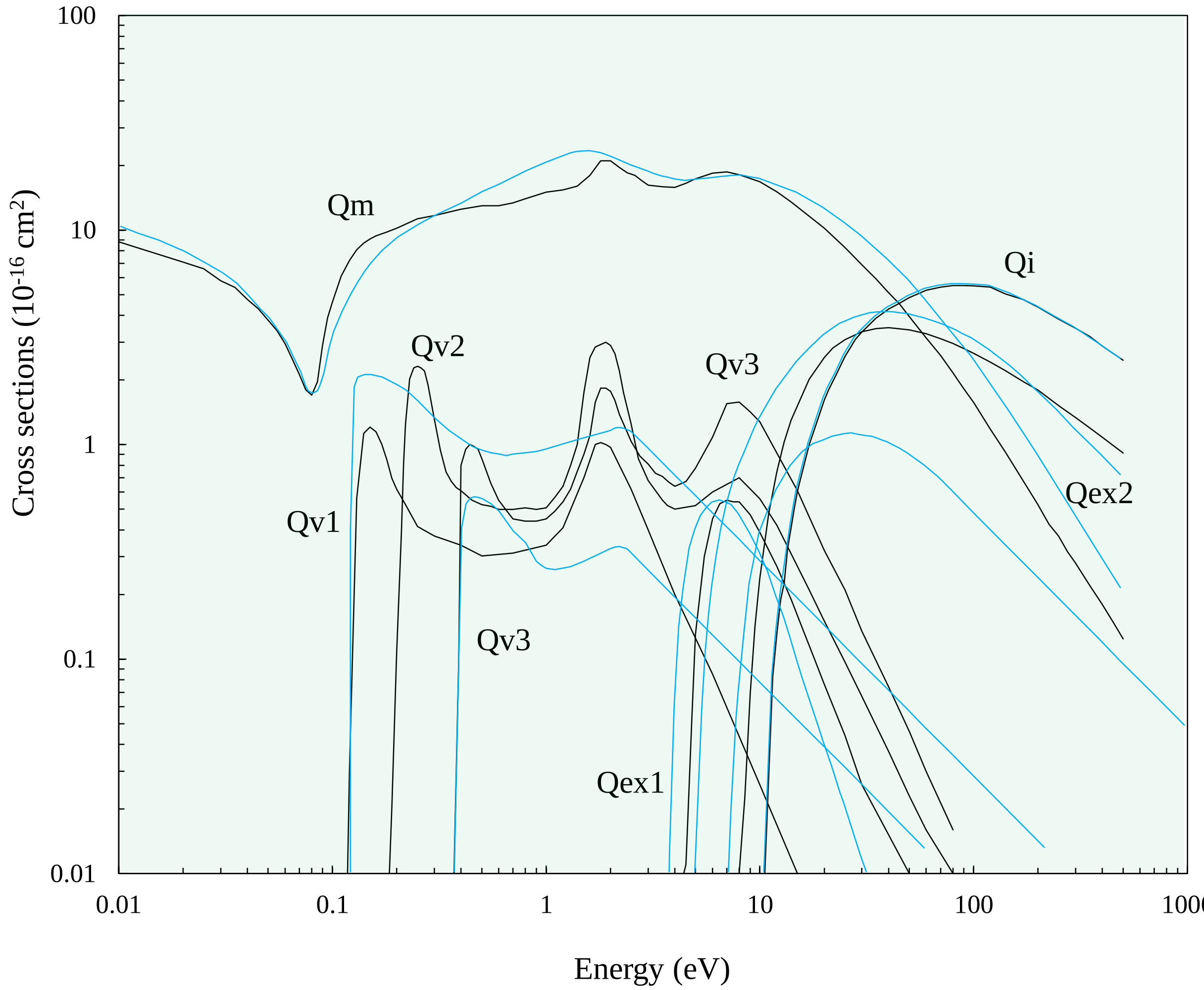
(4) Electronic excitation, Q_{ex2}



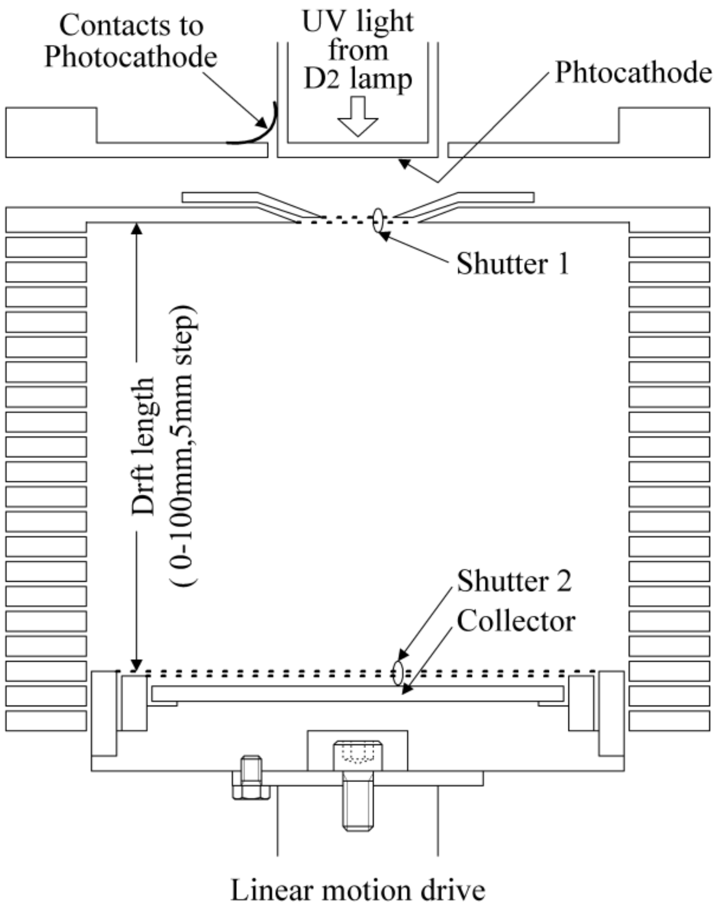
(5) Total ionization, Q_i

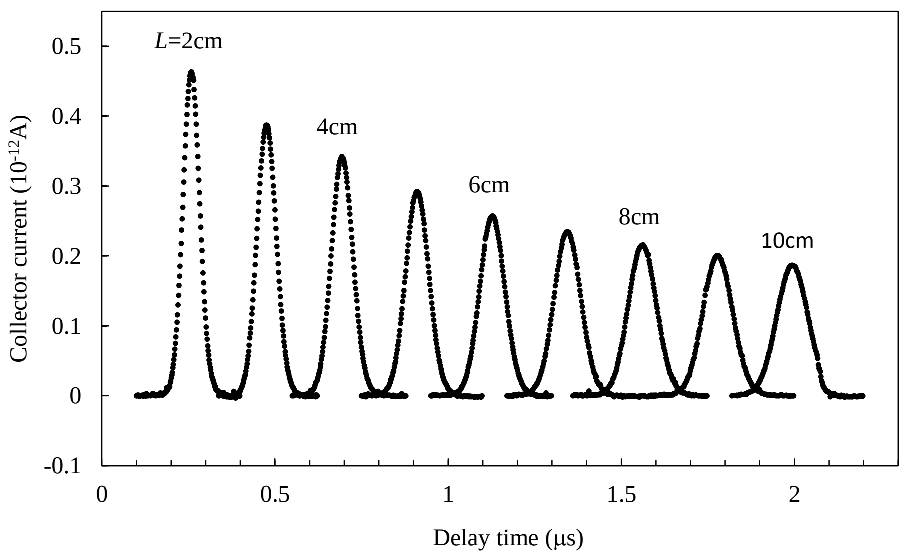


Initial Set of Cross Sections for C_2H_4



Measurement of swarm parameters

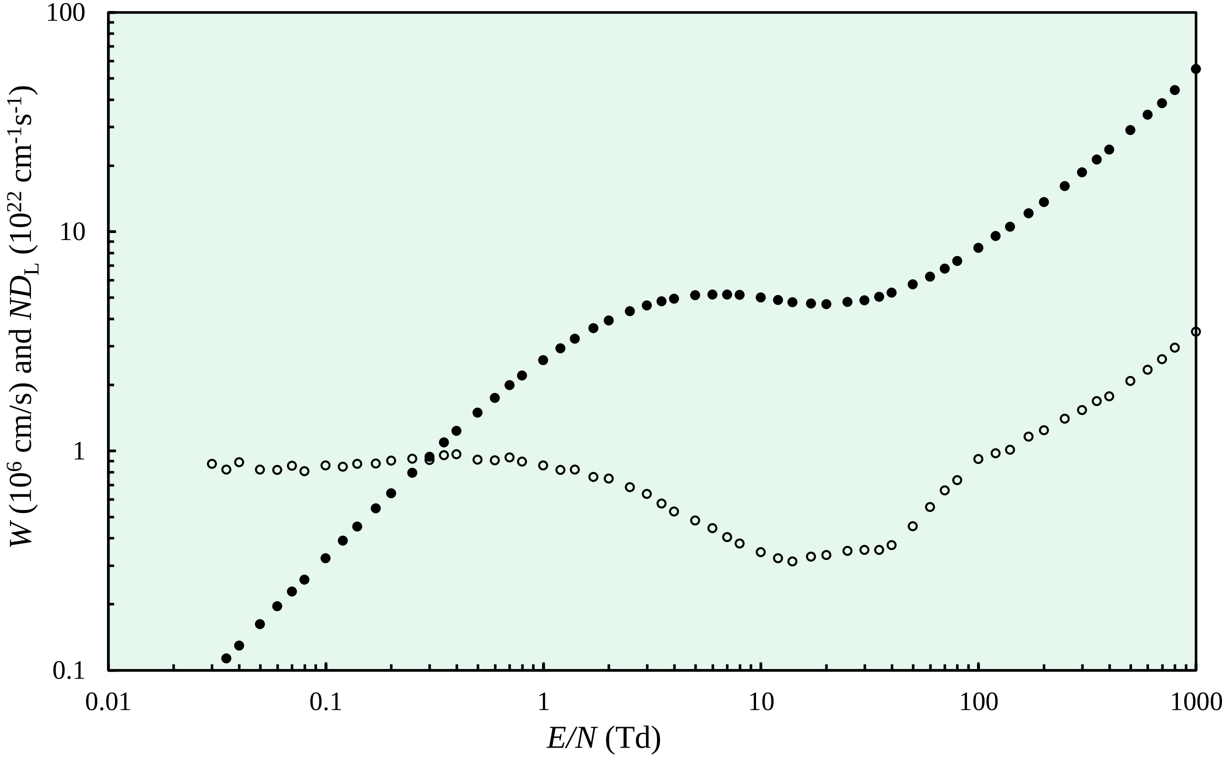




(1) Pure C_2H_4

Estimated uncertainty of swarm parameters

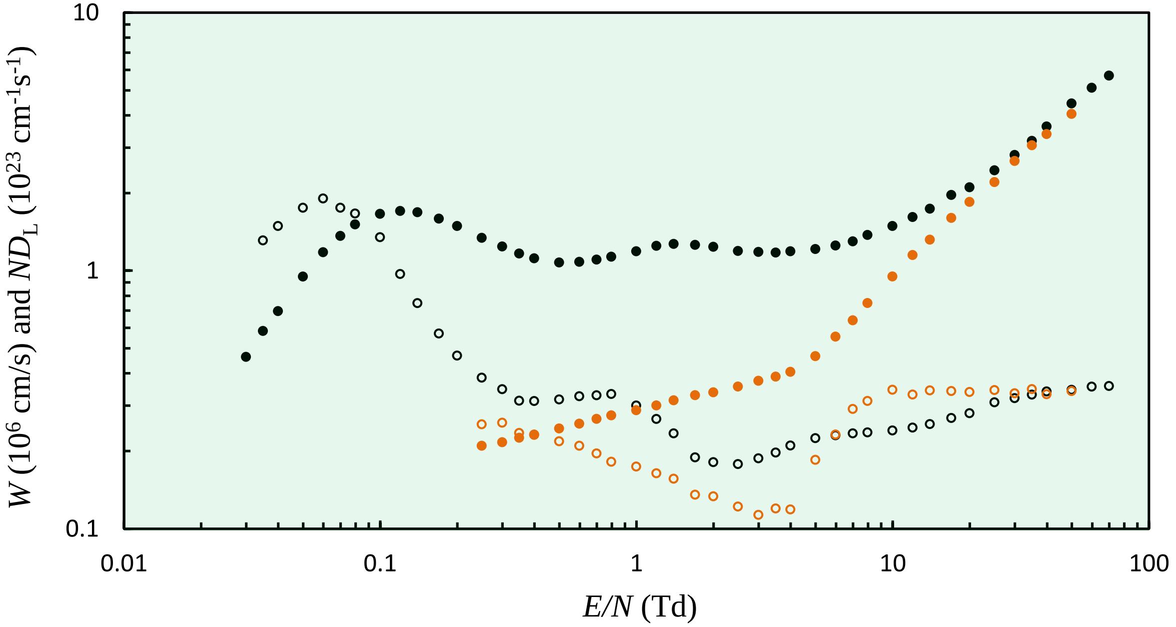
drift velocity: ±0.5%, ND_L: ±3%



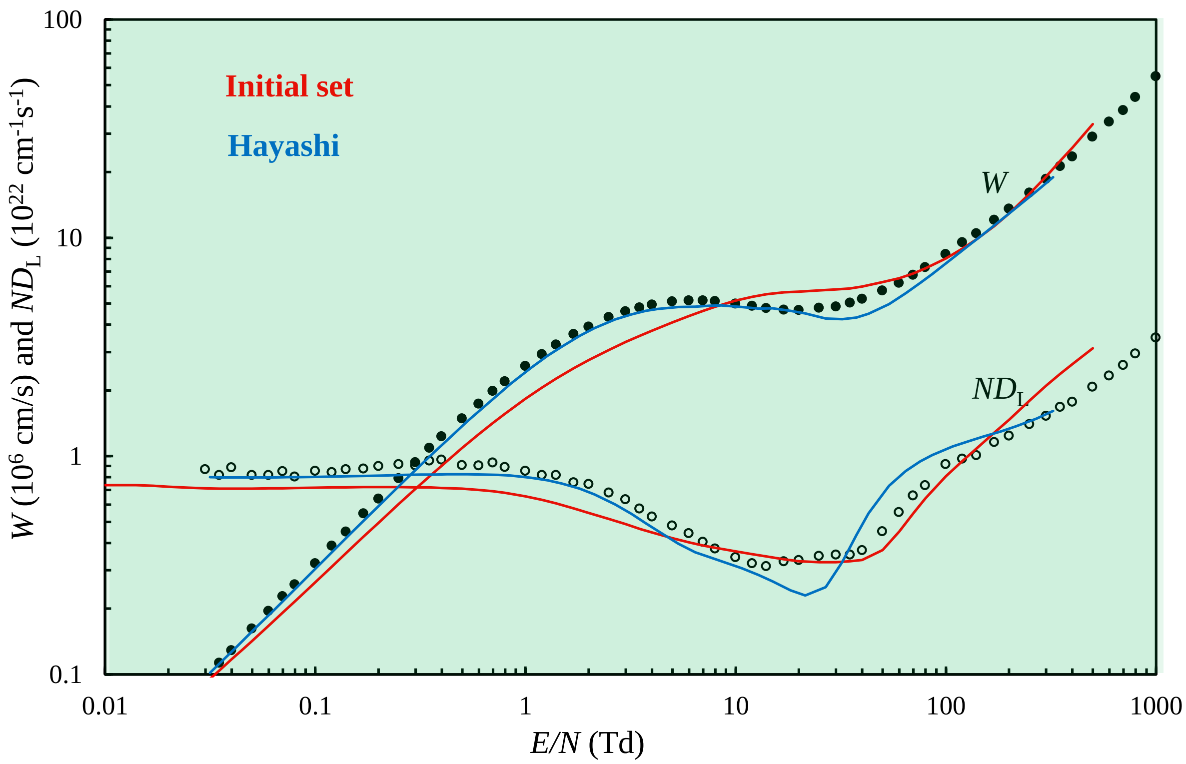
(2) 0.5% C_2H_4-Ar mixture

Estimated uncertainty of swarm parameters

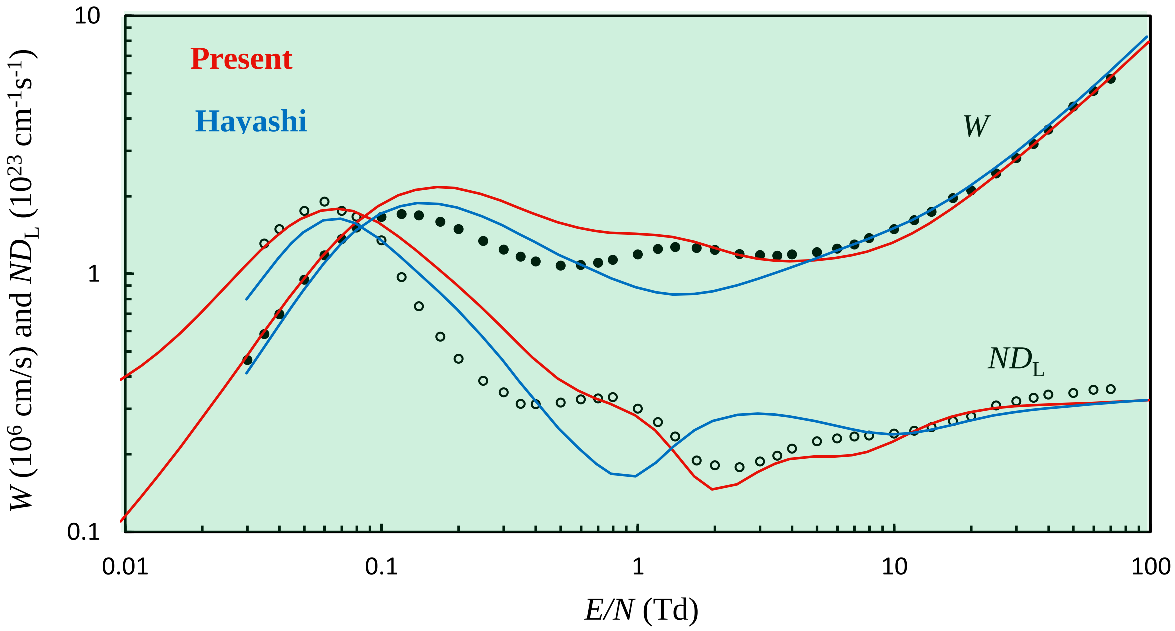
drift velocity: ±2%, ND_L: ±6%



Amendment begins with Q_m using swarms in pure C_2H_4.

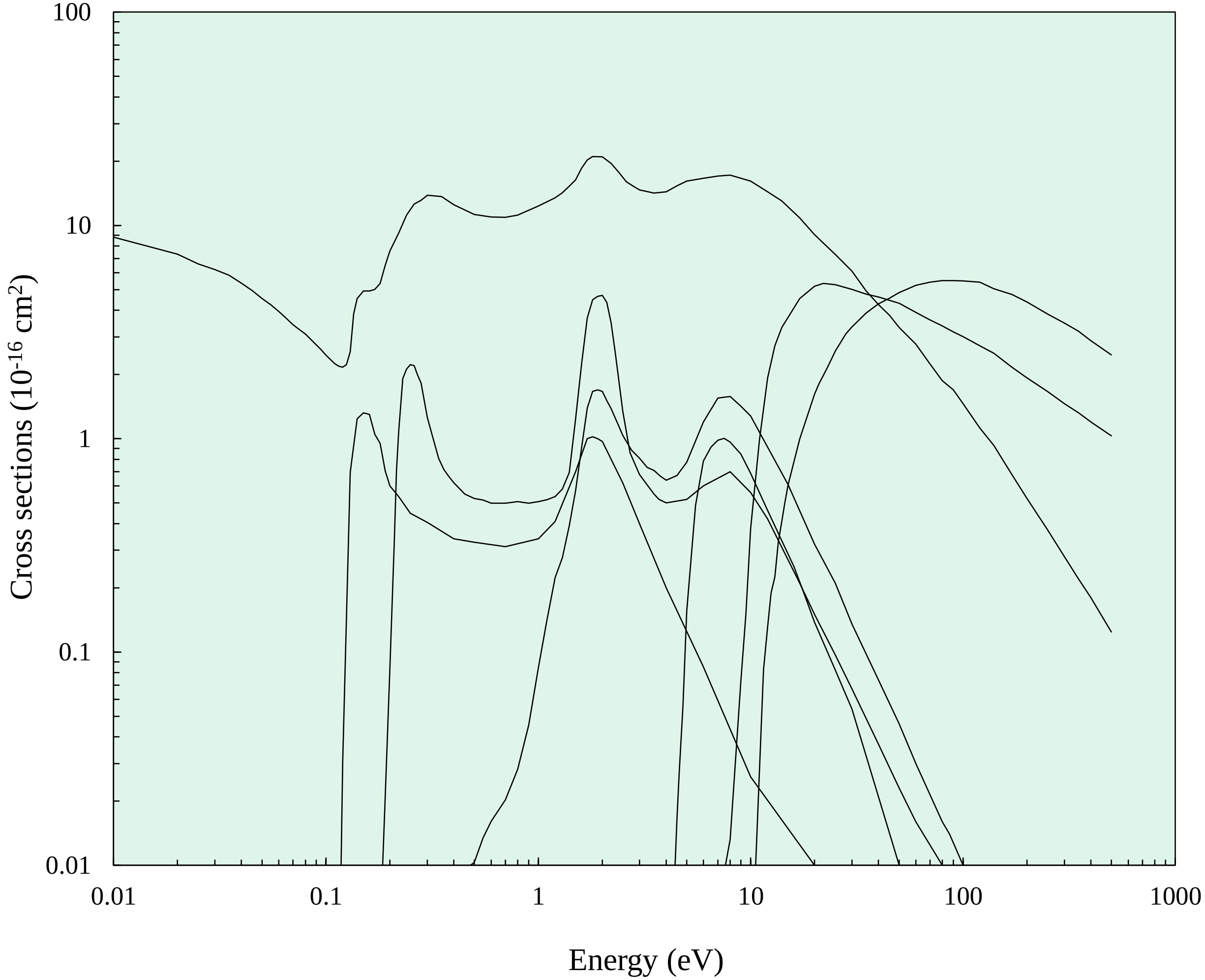


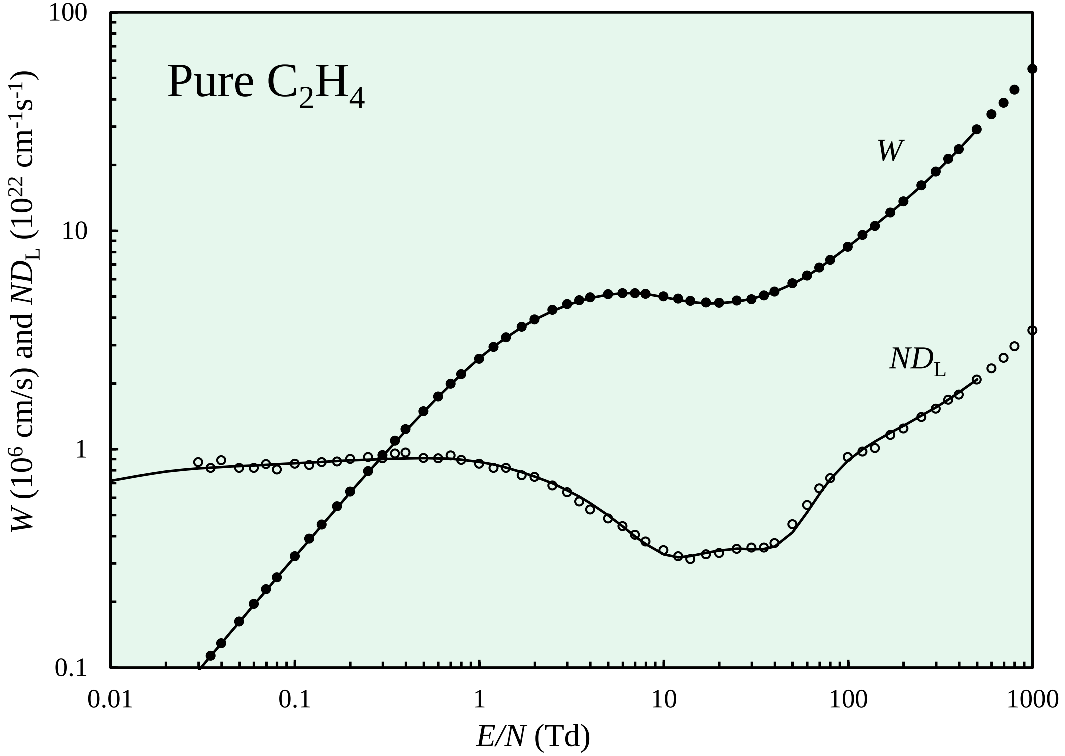
Then move to vibrational cross sections using swarms in C_2H_4-Ar mixtures.



These two steps are repeated alternately until the set converges.

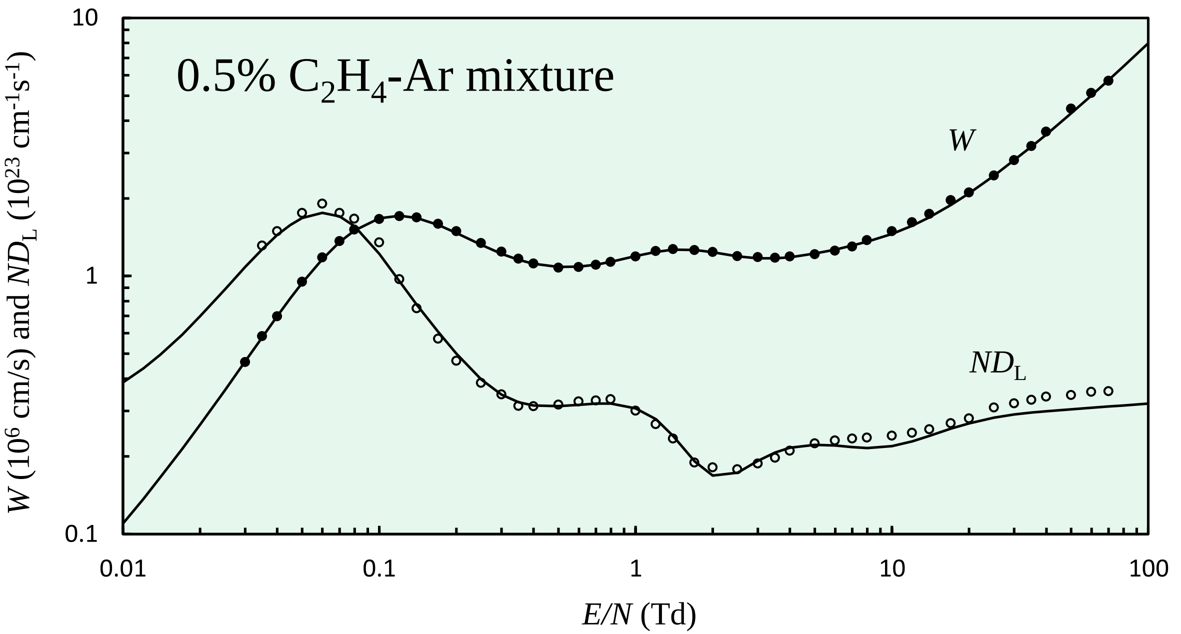
Final set of cross sections



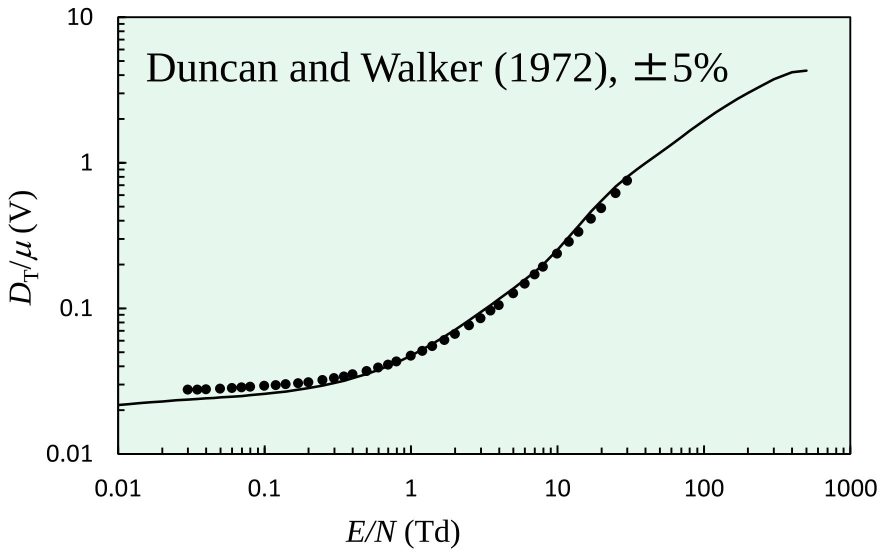


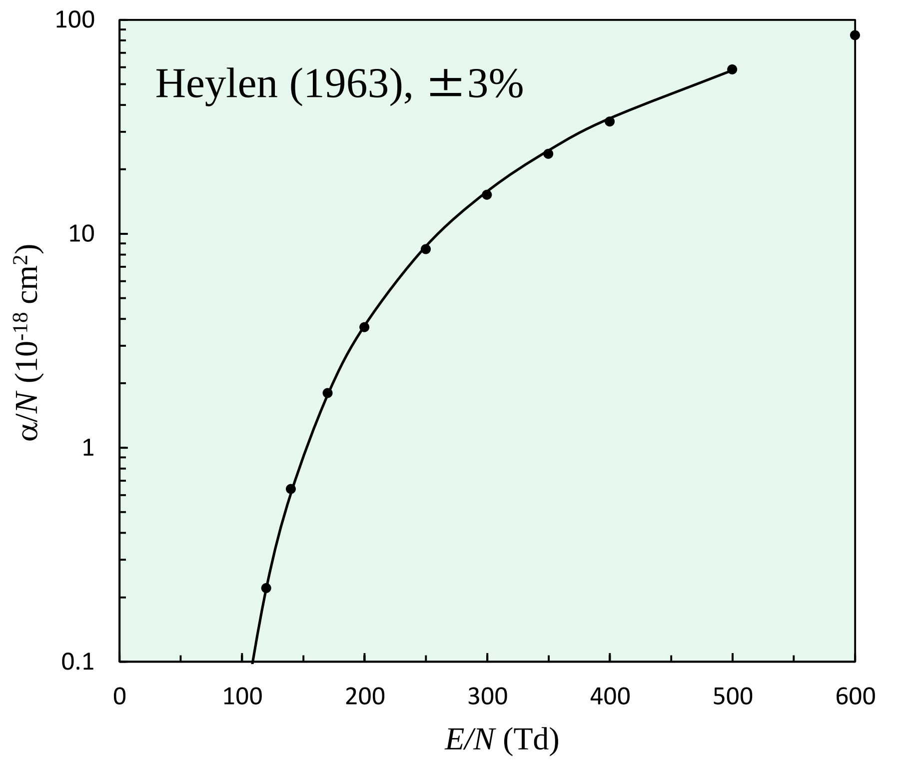
Our final cross section set was compiled so that it was consistent with …

… swarm parameters in pure C_2H_4 (above) and also in C_2H_4-Ar mixture (right).

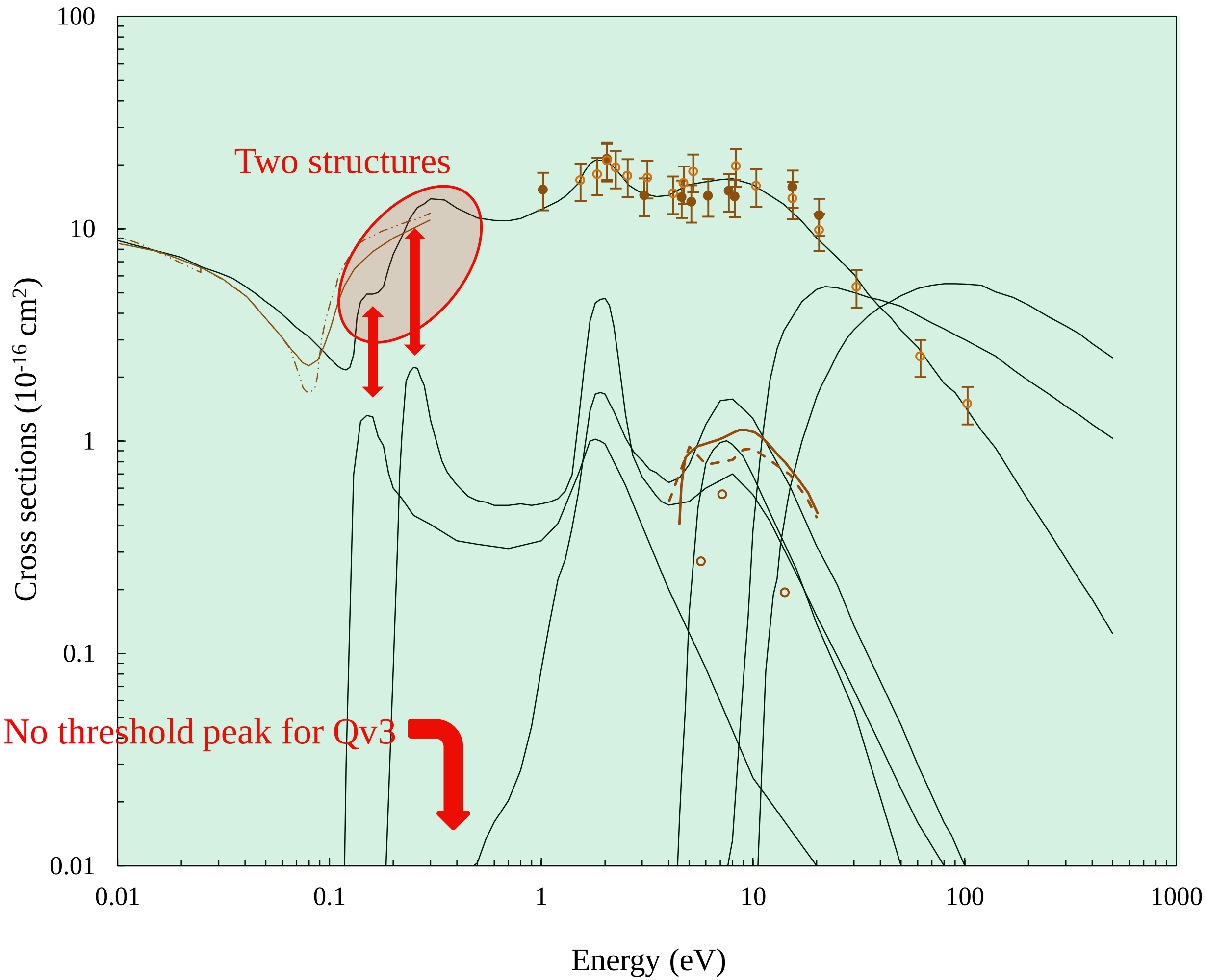


Our final set is consistent also with…





Features of the final cross section set



Conclusions

- In order to evaluate cross section data for a molecule electron swarm parameters in dilute mixtures of the molecule and argon can be very useful.
- Alternate use of experimental swarm data in the mixture and in pure molecular gas can give a more reliable set of cross sections for the molecule.