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Model Consideration for Modeling Electron Drift in Argon and Helium

October 15, 2019

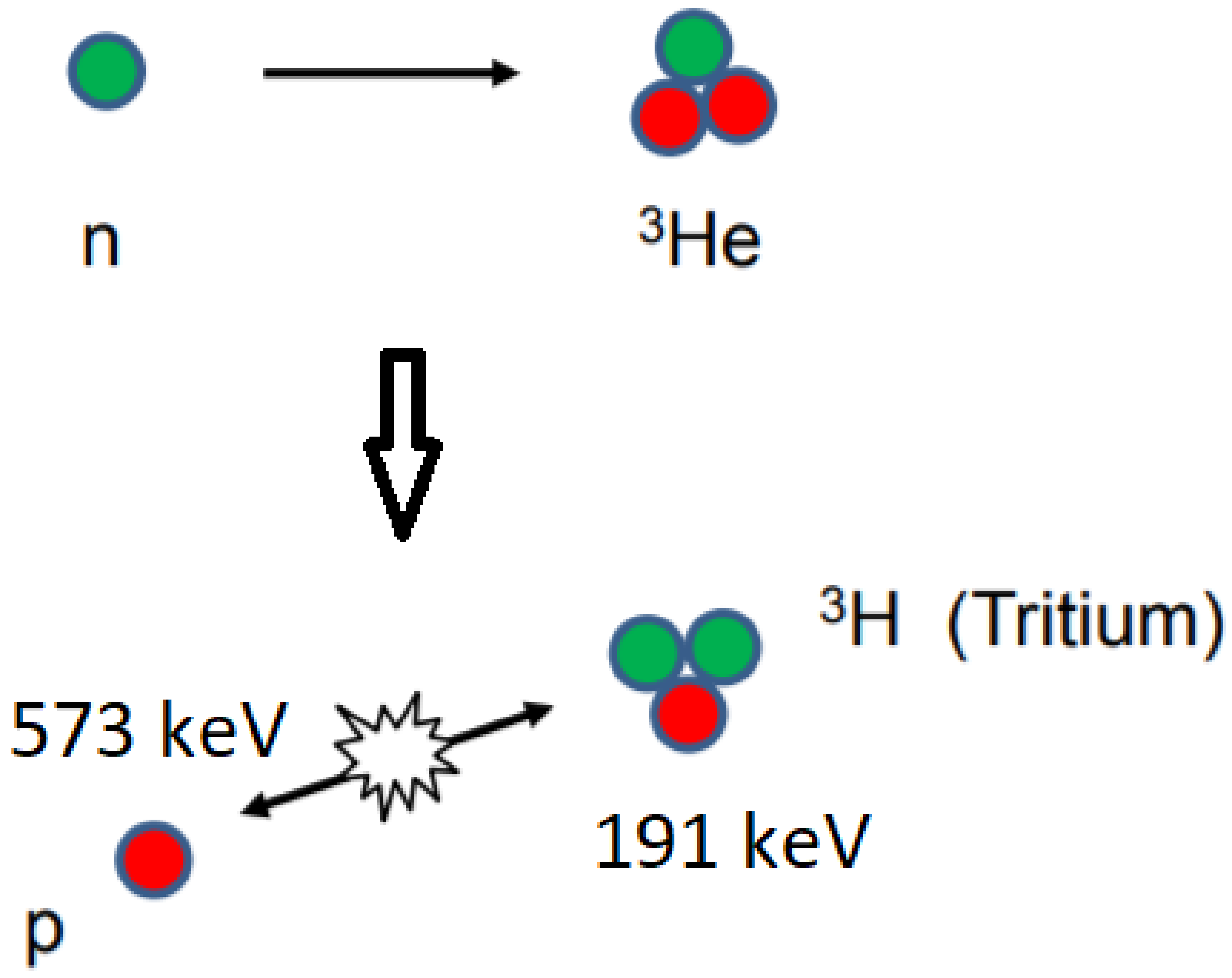
BAKER HUGHES a GE company

Model the Behavior of Electrons Generated by the Detection of Radiation

- Measured radiation is typically gamma or neutrons.
- Typical detector is cylindrical with a thin anode wire at its center.
- Through direct or indirect means the radiation generates electrons in the gas.
- These electrons will accelerate in the electric field and generate secondary electrons in order to amplify the generated signal.
- The final charge pulse is routed to an amplifier for analysis.

^{3}He Neutron Reaction

- Used in the detection of neutrons in gas filled detectors.
- ^{3}He consists of 2 protons and 1 neutron. Common ^{4}He has 2 protons and 2 neutrons.
- Helium-3 is one of the few elements that has a high cross-section for neutron capture.
- Natural abundance is very rare, only 0.000137% of Helium on Earth
- Gas must be generated from the decay of tritium
- Neutron capture generates a proton and a triton which then generate electrons in the gas which can then be measured.



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Modeling Objectives

Determine electron transport characteristics

- Drift Velocity
- Townsend Coefficient

Model these for different conditions

- Gas Mix and Pressure
- Properties will be determined as a function of electric fields

Chose conditions that are verifiable using available data

- To meet this requirement a static electric field was applied
- This geometry represents a parallel plate configuration

Once verified more complex fields and geometries can be tackled

Drift Velocity Modeling

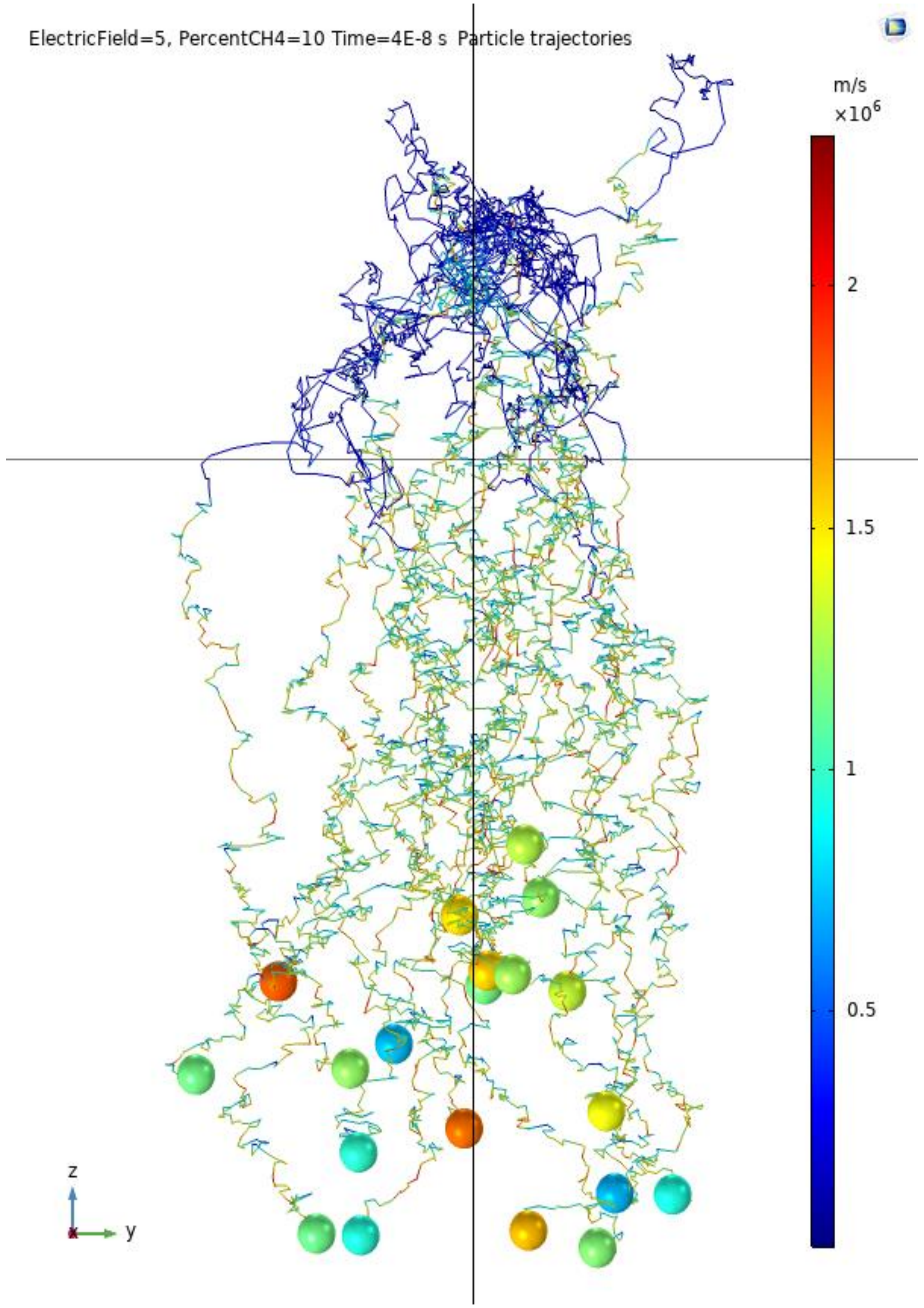
- Electrons released into the gas under a constant electric field.
- Initial study performed to determine the effect of the solver time step on the result.
- Selected the following gases.

  Ar/CH_4 (90%/10%)

  Ar/CH_4 (80%/20%)

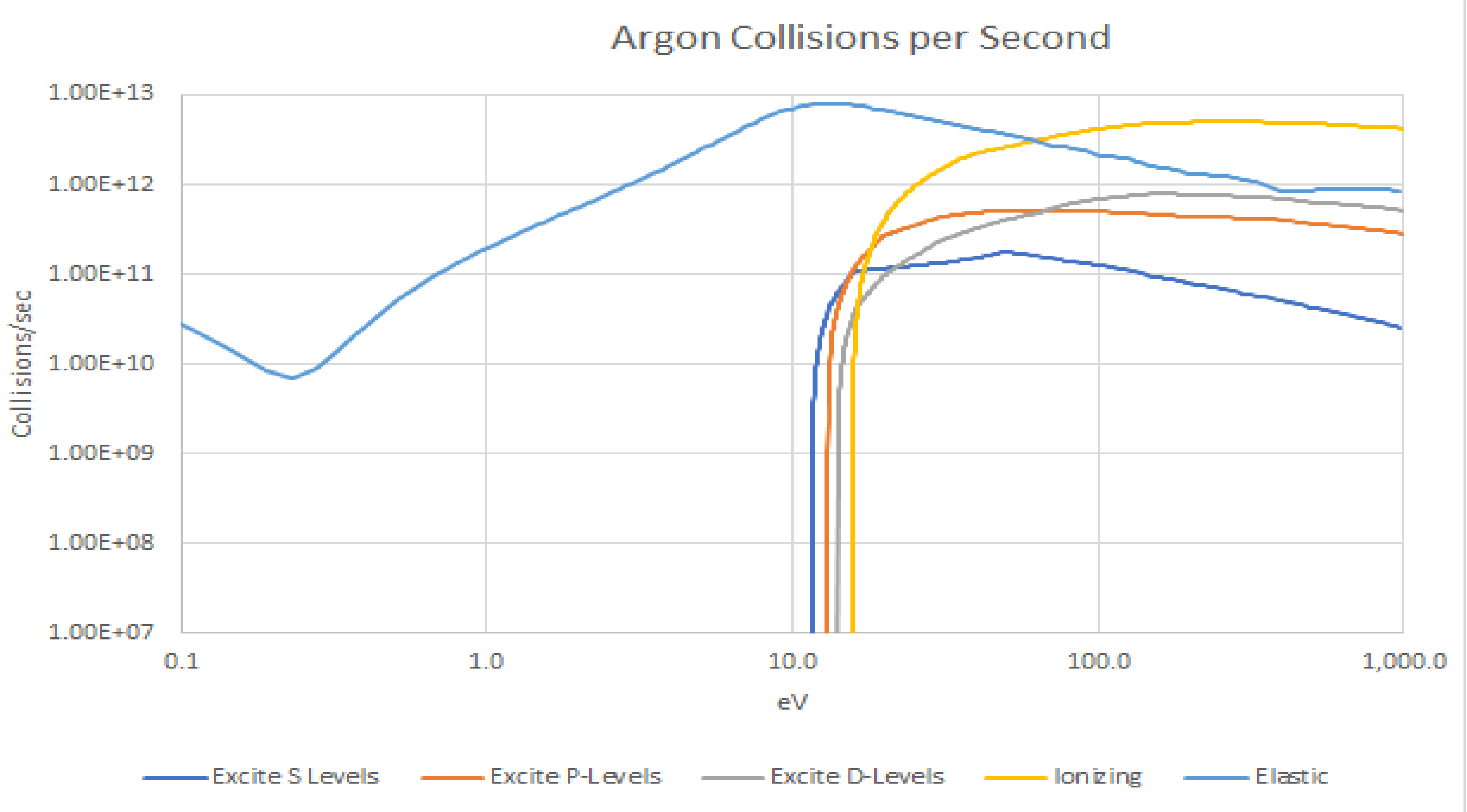
  He/CO_2 (90%/10%)

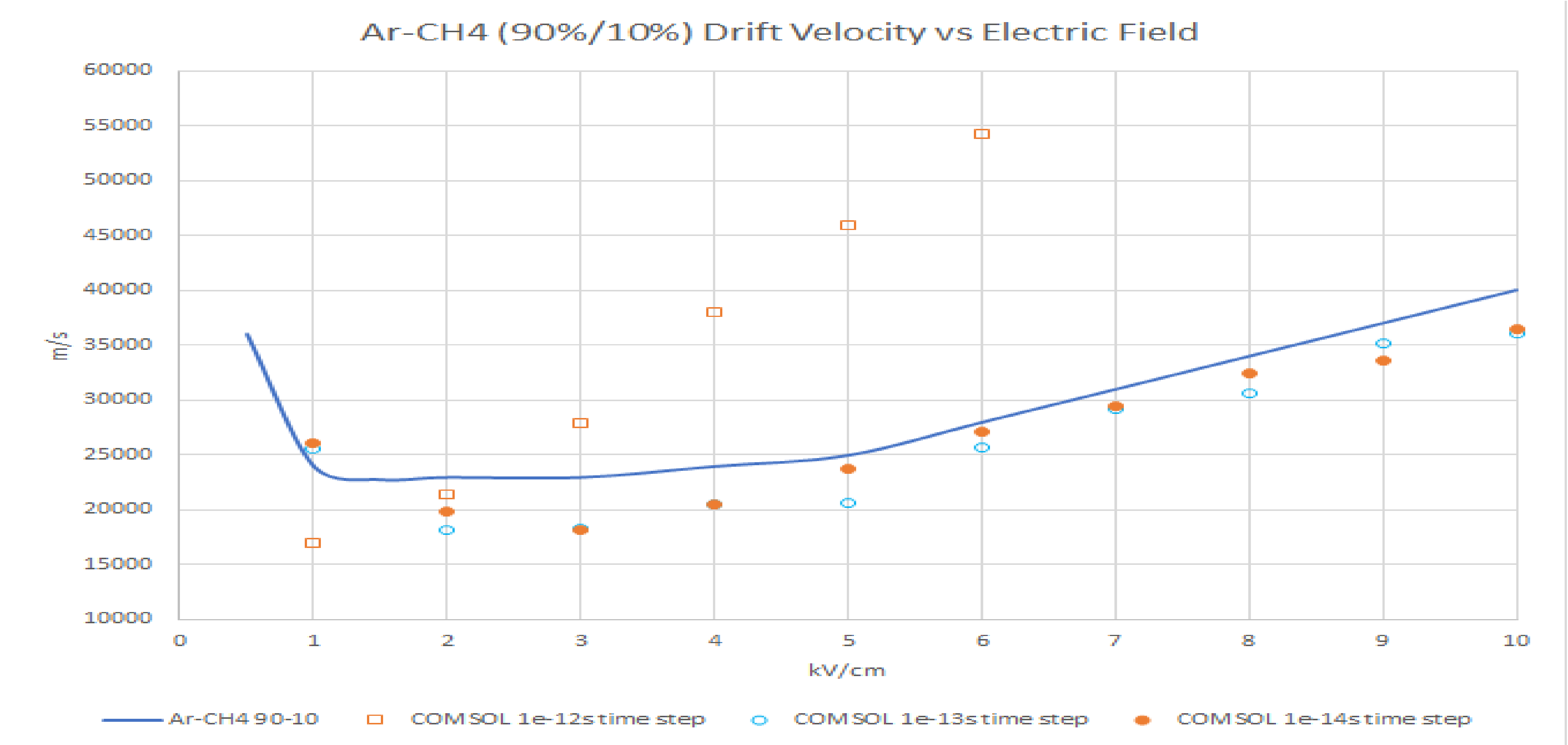
  He/CO_2 (80%/20%)
- Electric fields values from 10^3-10^4 V/cm



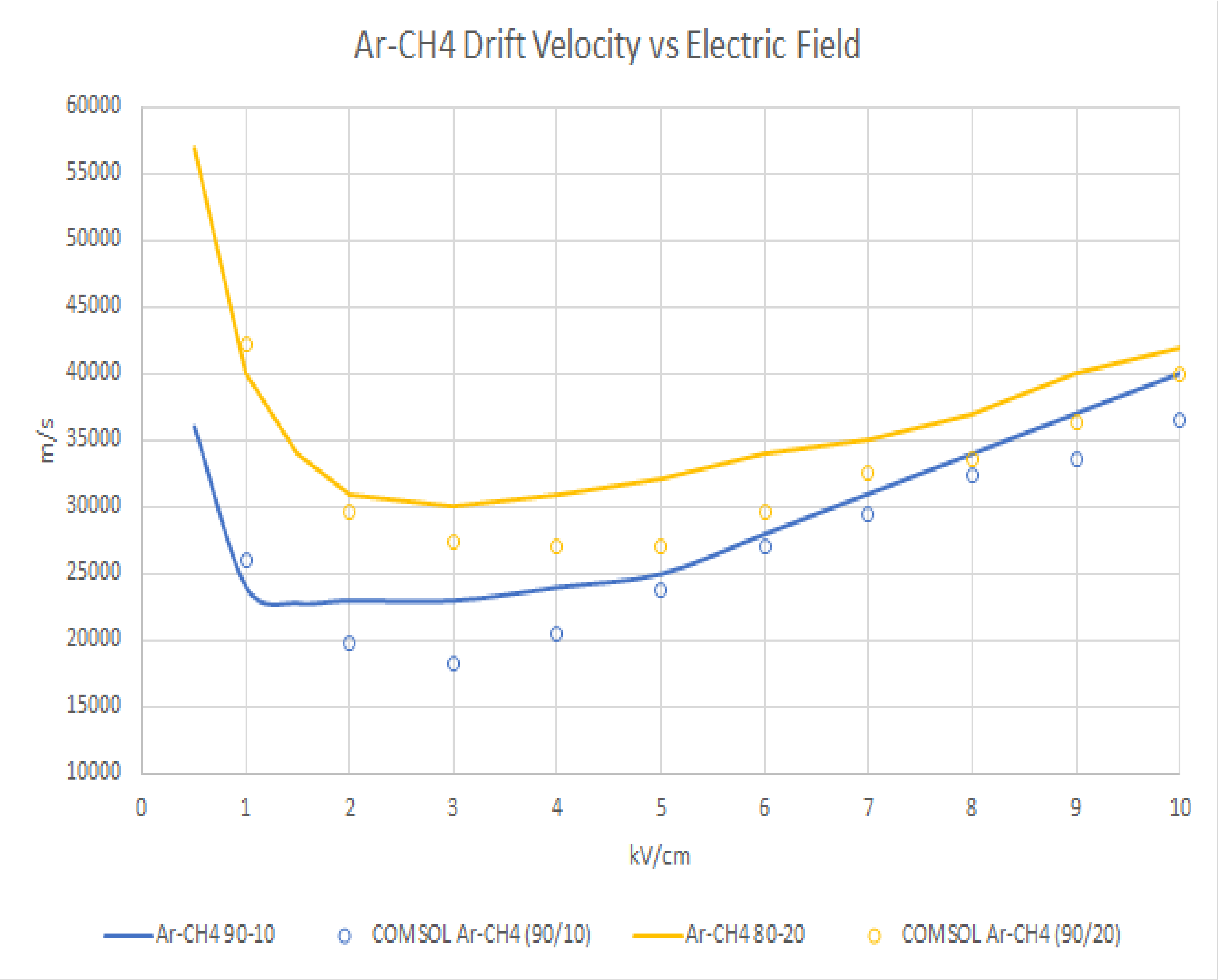
Solver Time Step

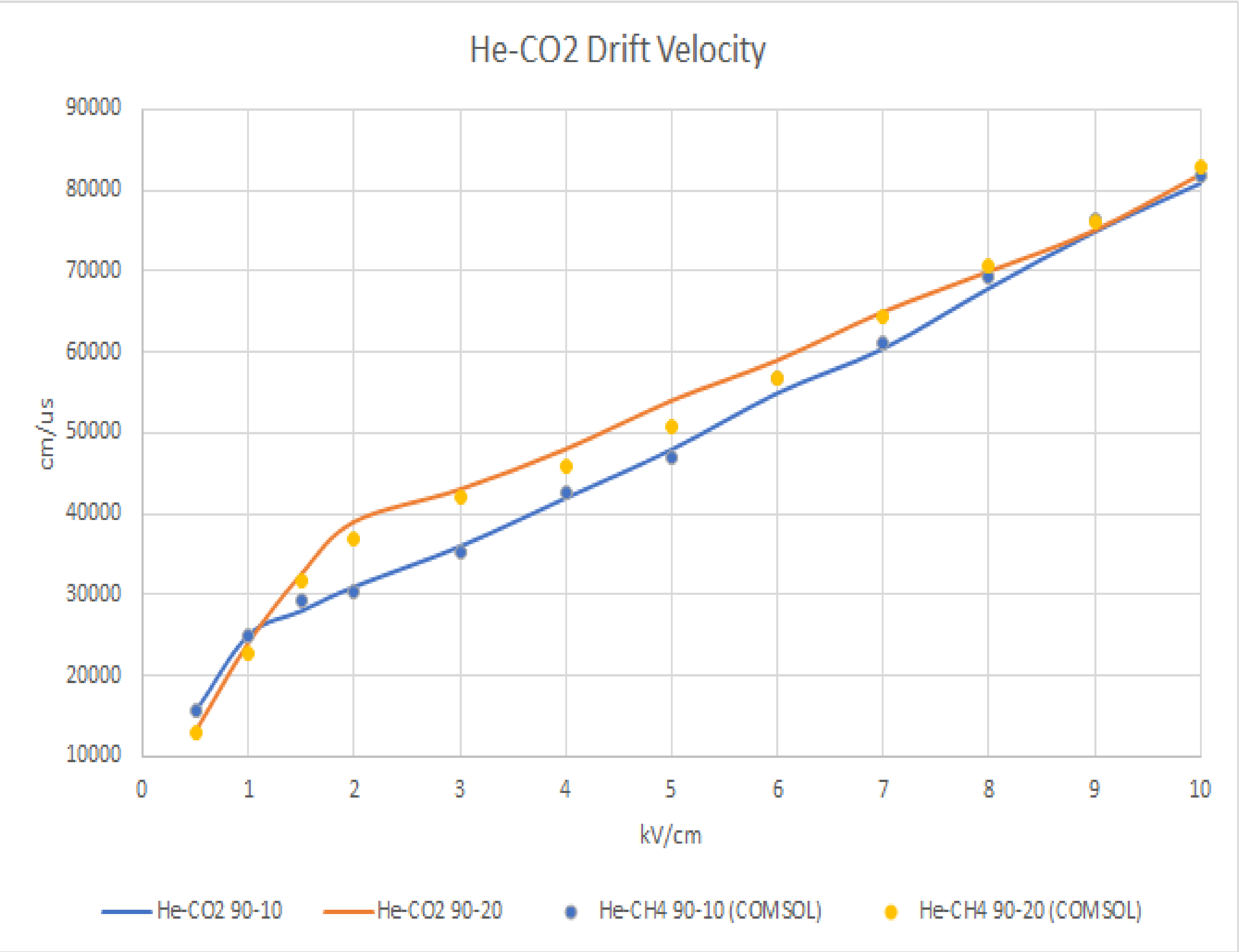
- From the collision cross section the collisions/sec can be determined for a given pressure (1 atm used in these models).
- General guidance is to use a solver time step that is 10x smaller than the time between collisions
- Time steps evaluated were 10^{-12}, 10^{-11}, and 10^{-14} seconds
- Note that time steps in the “Study Settings” are not the same as “Solver Time Steps”.
- Results for these parameters are shown on the graph to the left.





Drift Velocity Results





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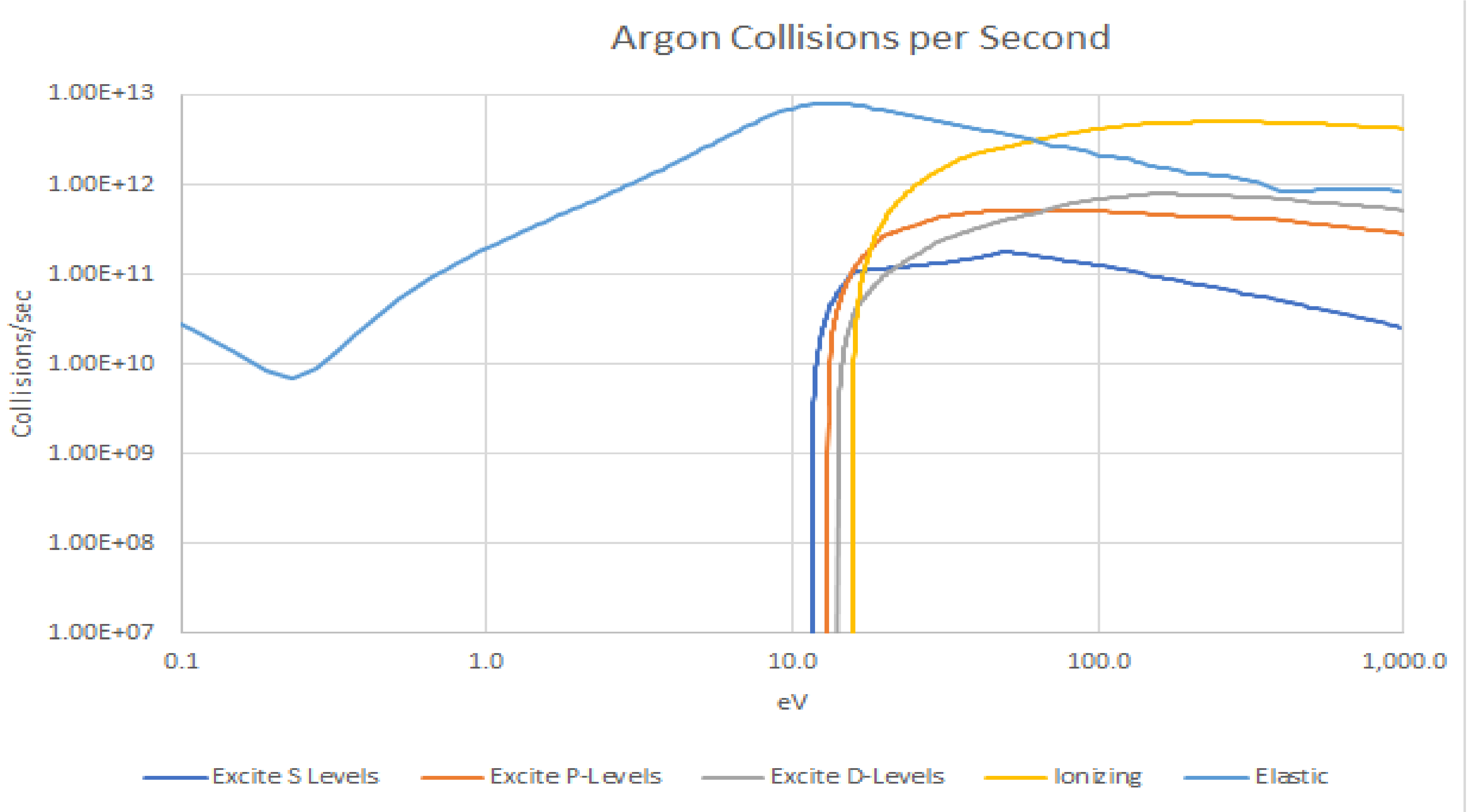
Townsend Coefficient

- Townsend coefficient (α) is the number of collisions per unit distance, typically cm^{-1}.
- Electron multiplication factor or "gas gain" is related to the coefficient as follows, where d is the distance the electrons travel in the direction of the electric field.

$$gain = e^{\alpha d}$$

- The coefficient to gain relationship only applies to the uniform electric field case.
- More complex fields and geometries will require modeling of secondary electrons



Lessons Learned

Drift Velocity

- Electrons released into the gas do not reach their steady state velocity immediately.
- To calculate the study state velocity the initial transient conditions should be ignored

Townsend Coefficient and Gas Gain

- Other non-modeled effects play a role in the eventual gas gain. Most notable is referred to as the *Penning effect*. Atoms in an excited state transfer energy thereby releasing free electrons.
- Simulations require very small time steps limiting the use cases when electron trajectories are relatively long. This is especially an issue when simulating large numbers of secondary electrons.

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