



Leveraging the Open-Source Community in Plasma Physics Modelling:

A Monte Carlo Simulator for Electron Transport

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Electron Transport Parameters Overview

Drift Velocity

Electron average velocity under electric field

Ionization Coefficient

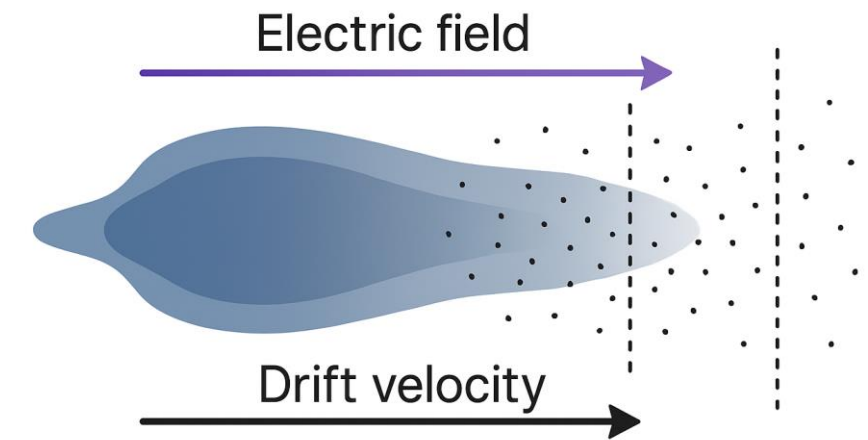
Rate of electron-induced ionization events

Attachment Coefficient

Probability of electrons attaching to molecules

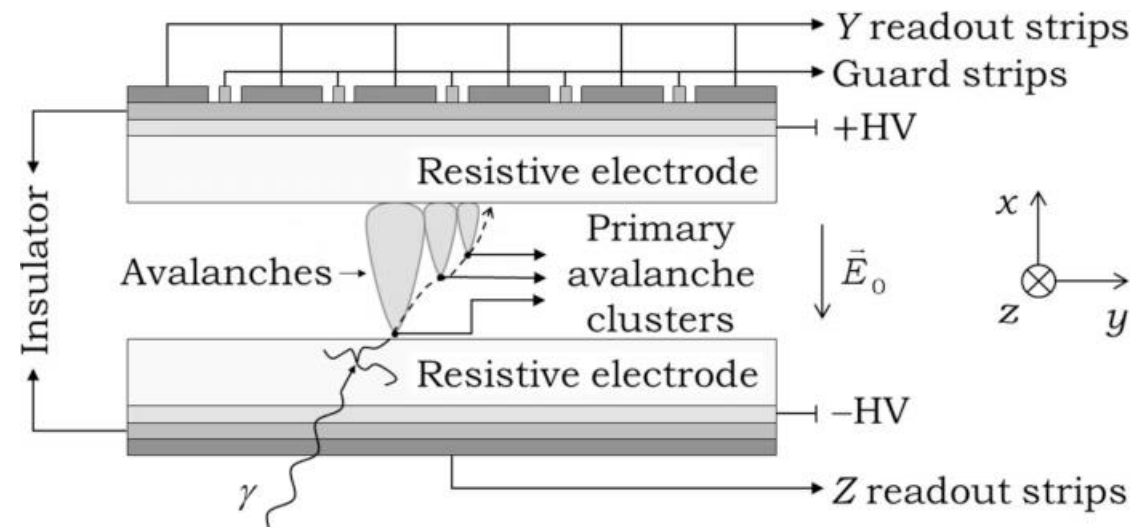
Diffusion

Longitudinal and lateral spread of electrons



Electron cloud drift velocity in electric field with diffusion

Motivation for Electron Transport Simulation



Importance of Parameters

- Critical for plasma and detector performance
- Enable accurate modeling of electron swarms

Applications

- Particle detectors such as RPCs
- Studies of low-temperature plasmas
- Industrial plasma diagnostics and processing



Why a Simulation Tool is Necessary

- Explore New Gas Mixtures
 - Design better accuracy with eco-friendly gas blends
- Cost Efficiency
 - Reduce expensive lab experiments and setups

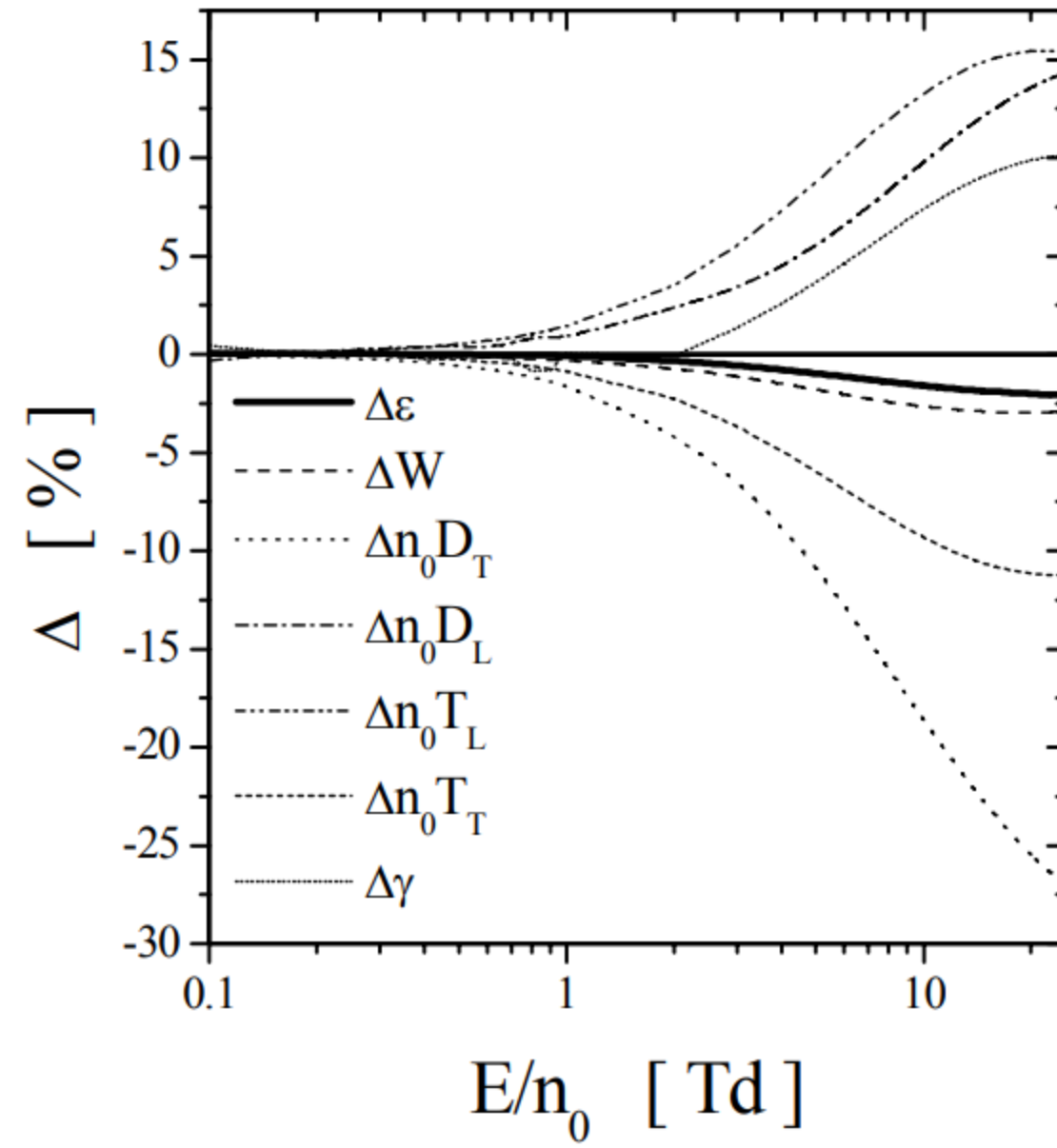
Boltzmann Transport Equation (BTE) & Approximations

BTE for Swarm Parameters

- Electron energy distribution evolution
- Predicts drift velocity, diffusion, Townsend coefficients
- Involves complex integro-differential equations

Two-Term Approximation

- Legendre polynomial expansion simplified to two terms
- Reduces computational complexity



From Kinetic to Particle Model: Collisions Explained

Particle Model Transition

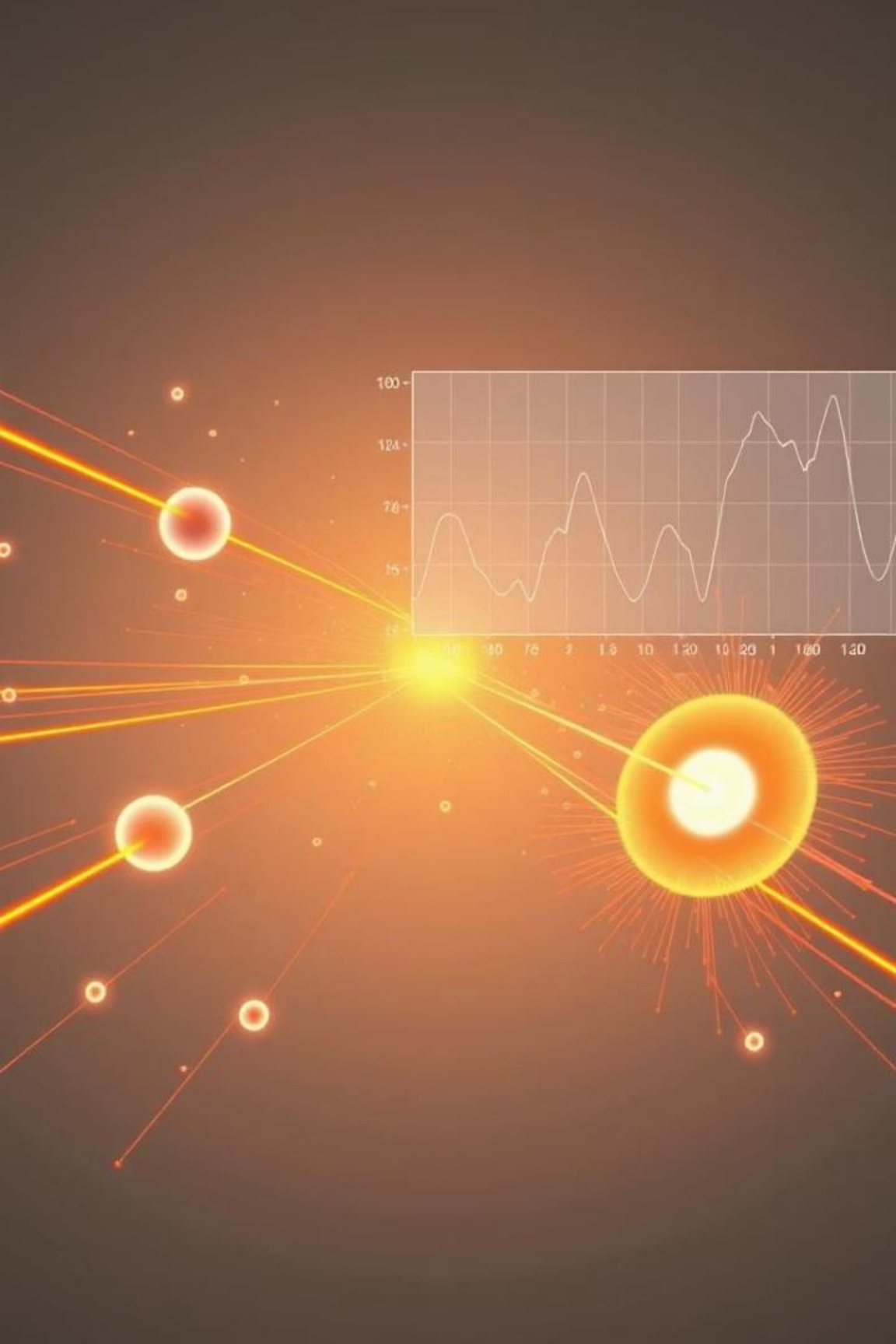
Simulate individual electron collisions probabilistically

Cross Section Data

Quantifies collision probabilities at various energies

Collision Probability

Stochastic approach to electron interaction processes



Types of Electron Collisions in Plasma



Ionization

Creates new charged particles



Attachment

Electrons bind to molecules, reducing free charge



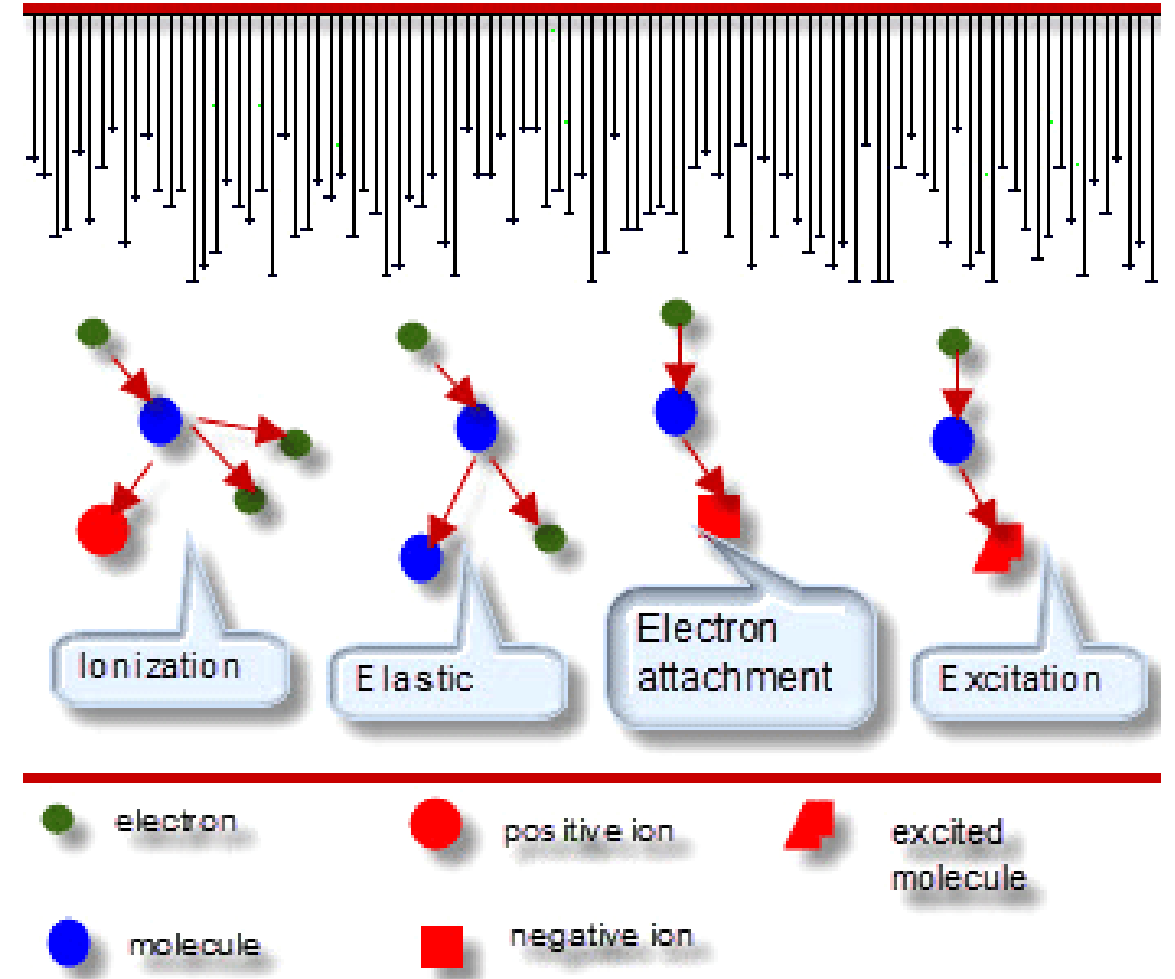
Elastic

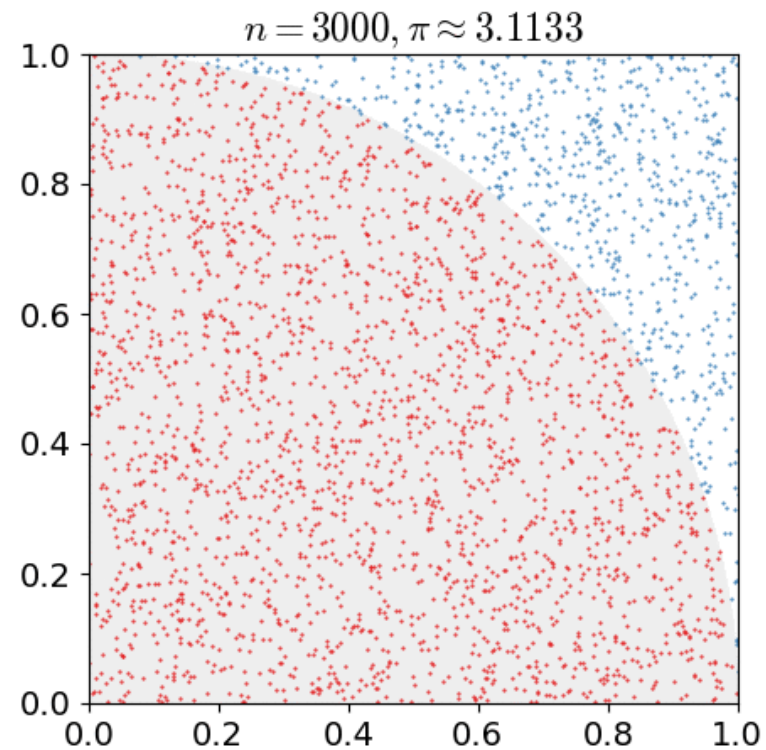
Momentum transfer without energy loss



Excitation

Molecules excited to higher energy states





Monte Carlo Method: Rationale and Overview

1 Why Monte Carlo?

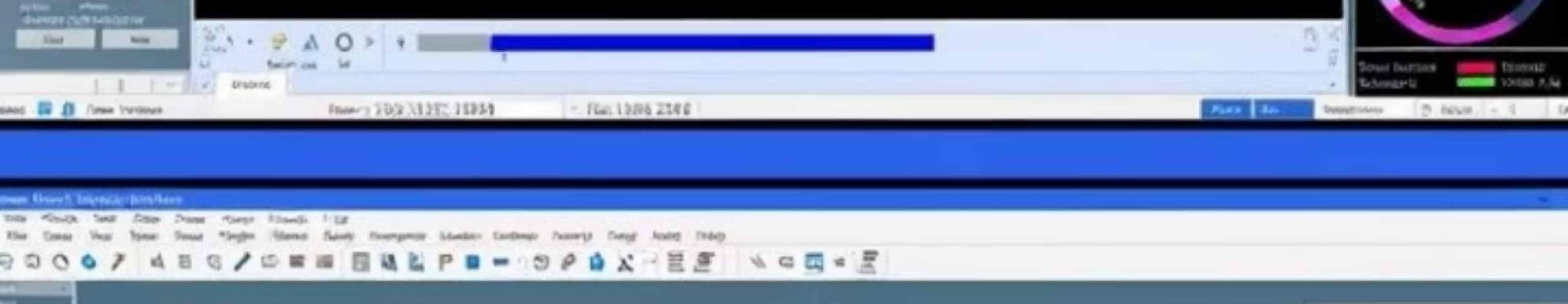
Simulates stochastic electron transport accurately

2 What It Does

Tracks individual electron trajectories and collisions

3 Benefits

Flexibility in complex gas and field configurations



Comparing Existing Electron Transport Tools

Feature	Magboltz	METHES
Gas Library	Closed, limited gases	Open, modifiable
Code Access	Proprietary	Open source
Flexibility	Restricted	Transparent and adaptable

Problem Statement

- The existing open-source code relies on a commercial **MATLAB license**.
- It serves as a **general-purpose Monte Carlo simulator** for electron transport.
- It does **not compute the required transport parameters** specific to our needs.



Requirements for Our Electron Transport Tool

- **Open-source Code**
Ensures transparency and community contribution
- **Integration**
Supports LXCat and existing gas databases seamlessly
- **Accurate Transport Calculations**
Precise computation of key electron parameters
- **Parallel Computing**
Enhances simulation speed and efficiency

Design and Methodology

1 Octave-Based

Open-source language ensures accessibility and modifiability.

2 Monte Carlo Engine

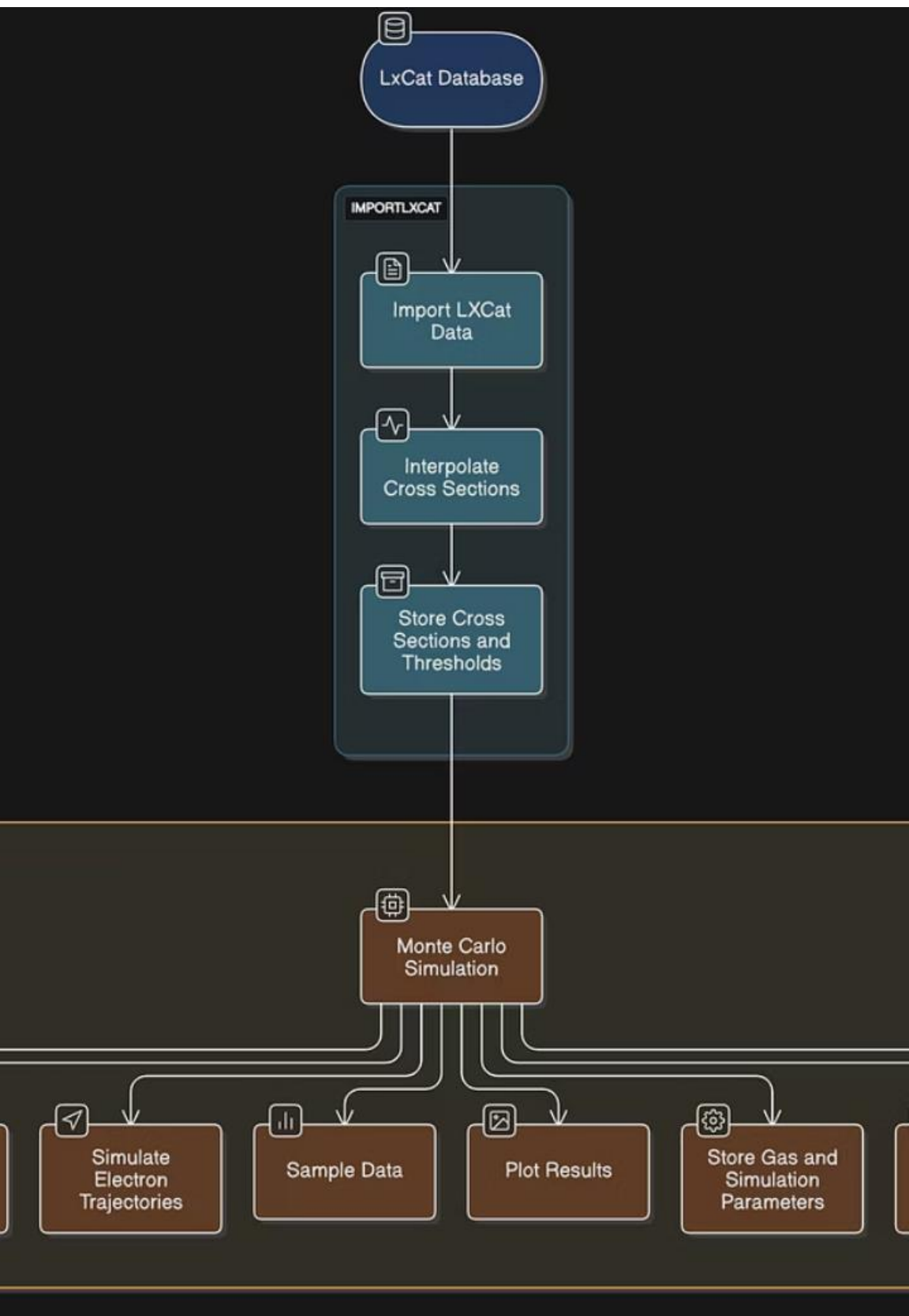
Simulates individual electron transport with random collision events.

3 Workflow

Structured code guides simulation from gas input to output parameters.

4 Parameter Calculation

Computes drift velocity, diffusion, and other key metrics.



Simulation Visualization

Electron Trajectory

The simulation tracks individual electron paths through the gas medium, showing collision events and energy transfers.

Statistical Analysis

Multiple electron trajectories are analyzed to derive macroscopic transport parameters with high accuracy.

Visual Representation

The visualization provides intuitive understanding of complex electron transport phenomena in different gas mixtures.



Test Vest



Ideg Here



Verification

Code Testing

Rigorous unit testing of individual simulation components



Numerical Validation

Verification against analytical solutions for simple cases



Benchmark Comparison

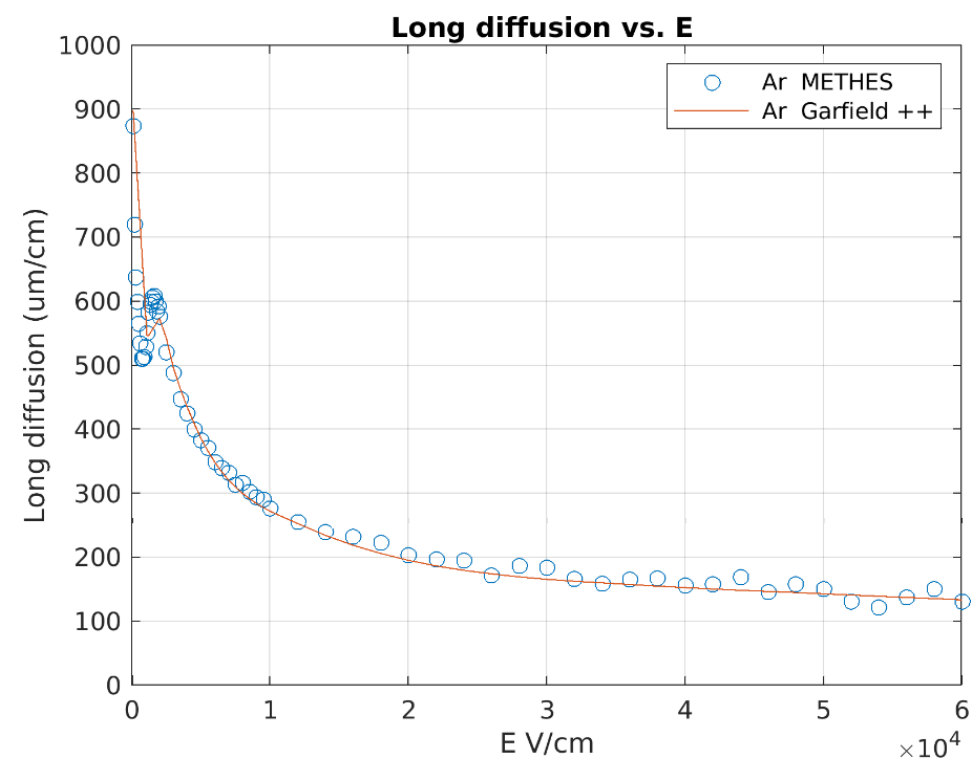
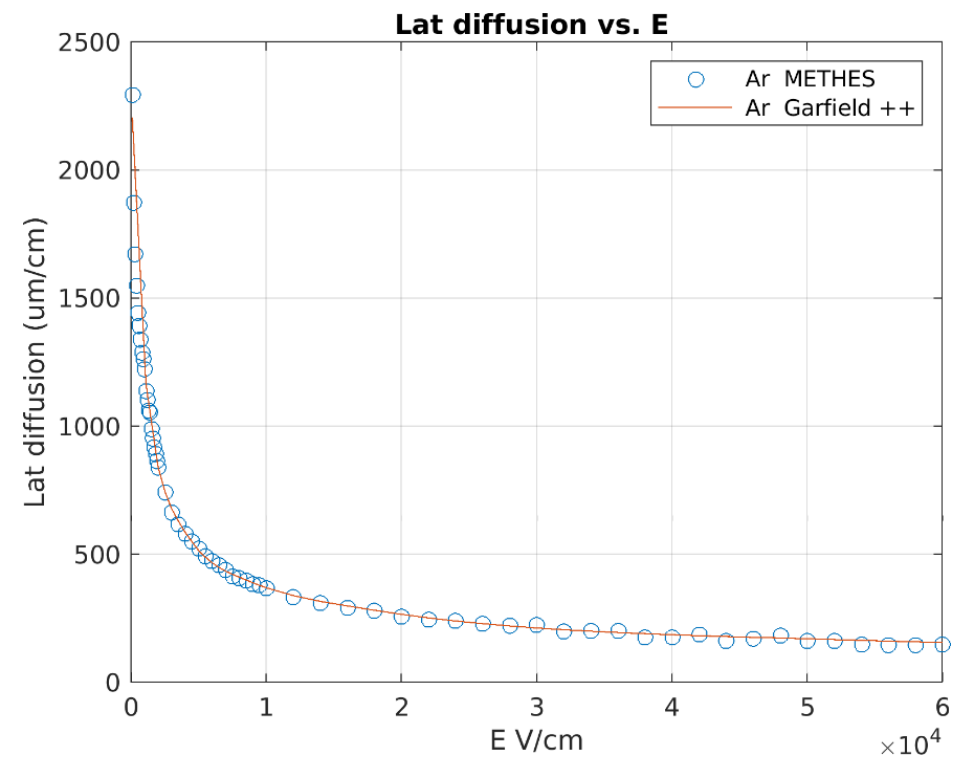
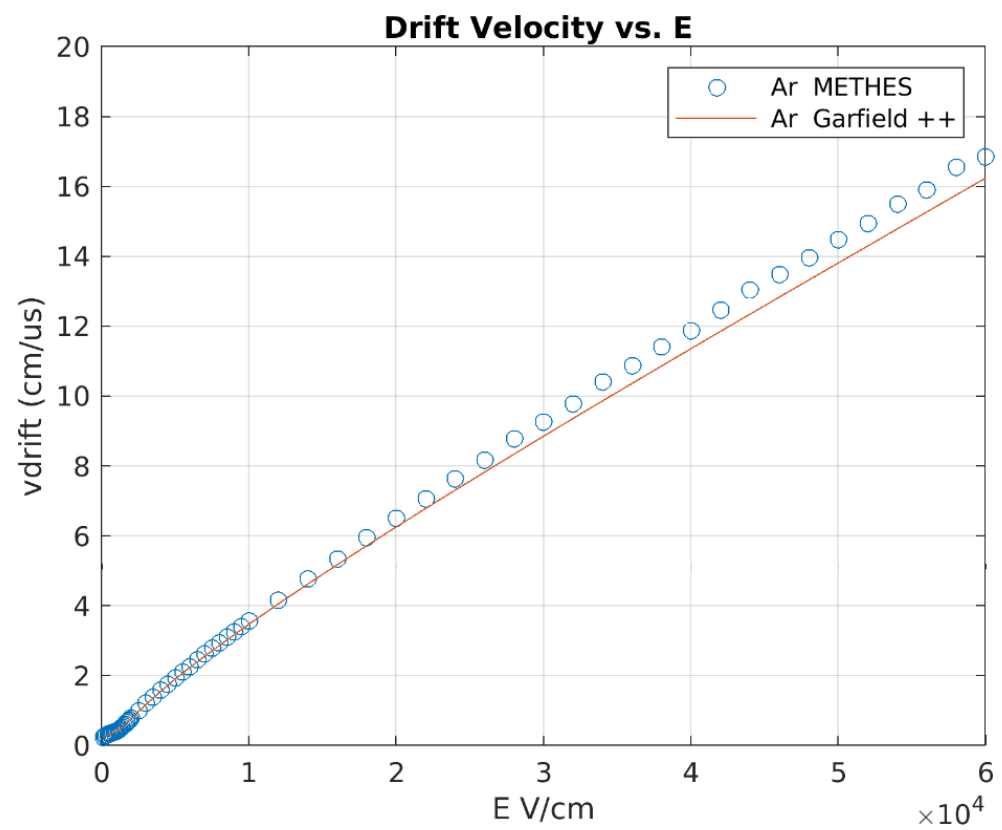
Results compared against established theoretical models

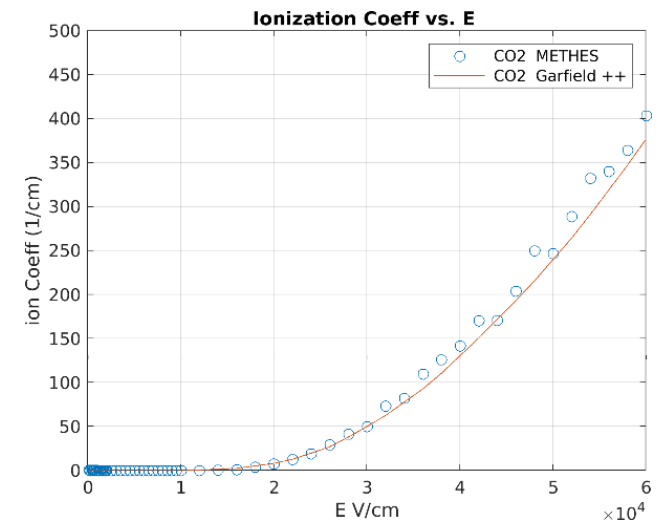
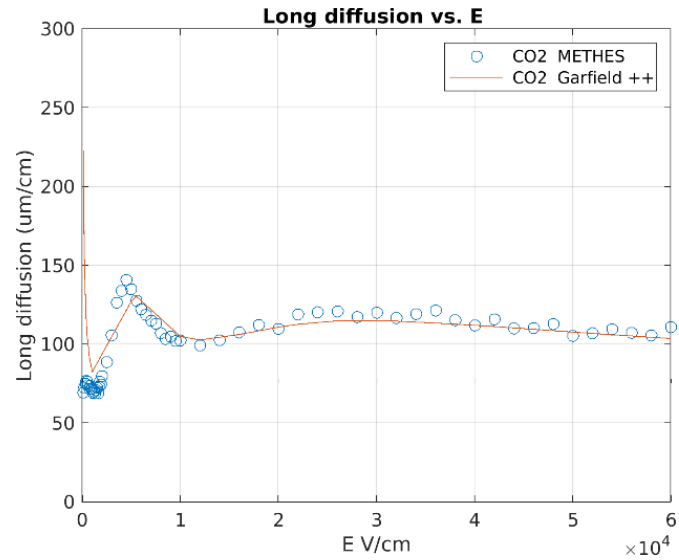
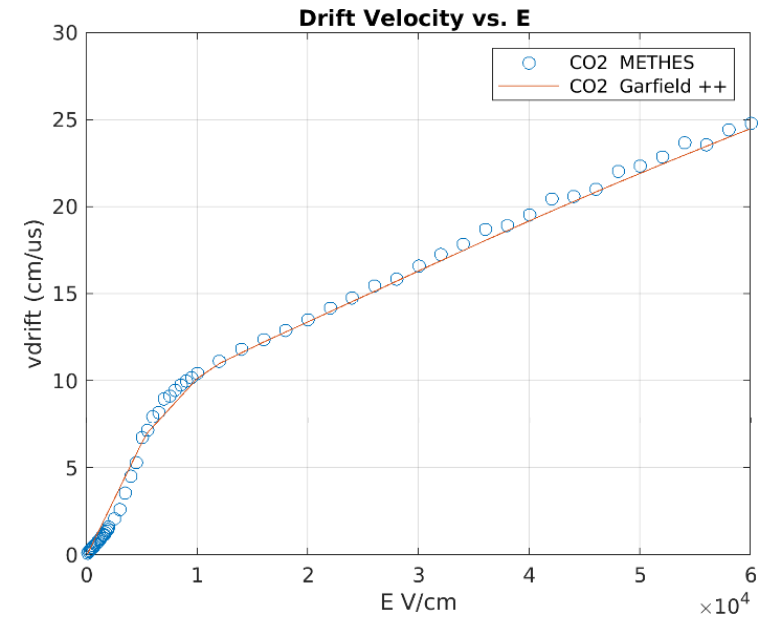
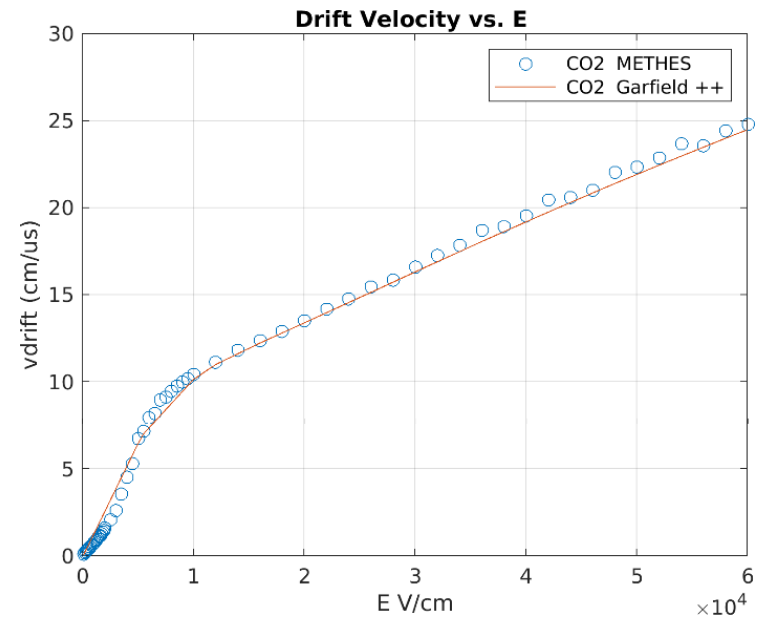
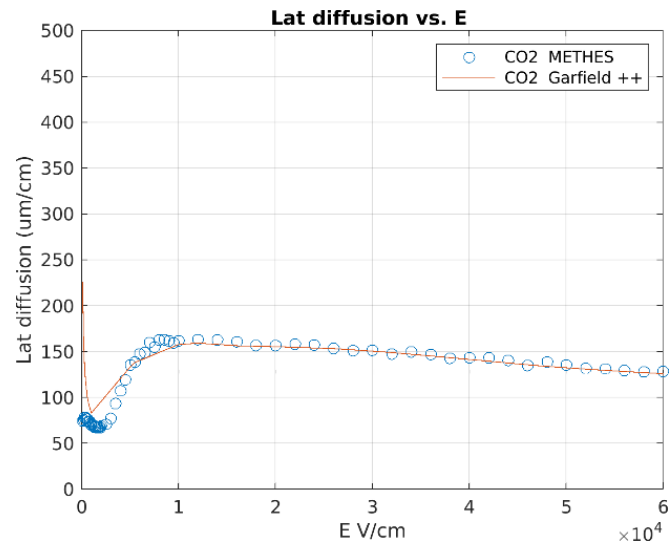


Convergence Testing

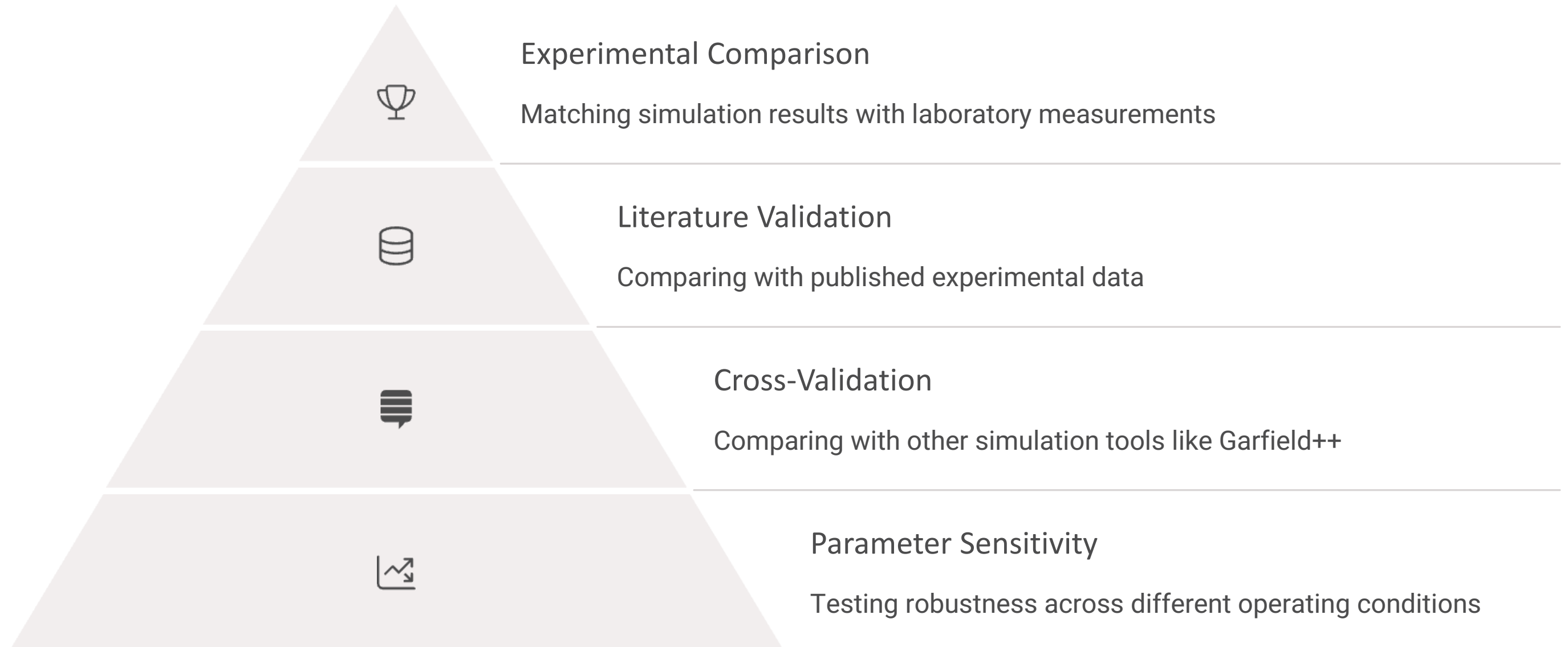
Ensuring stability and accuracy with varying simulation parameters

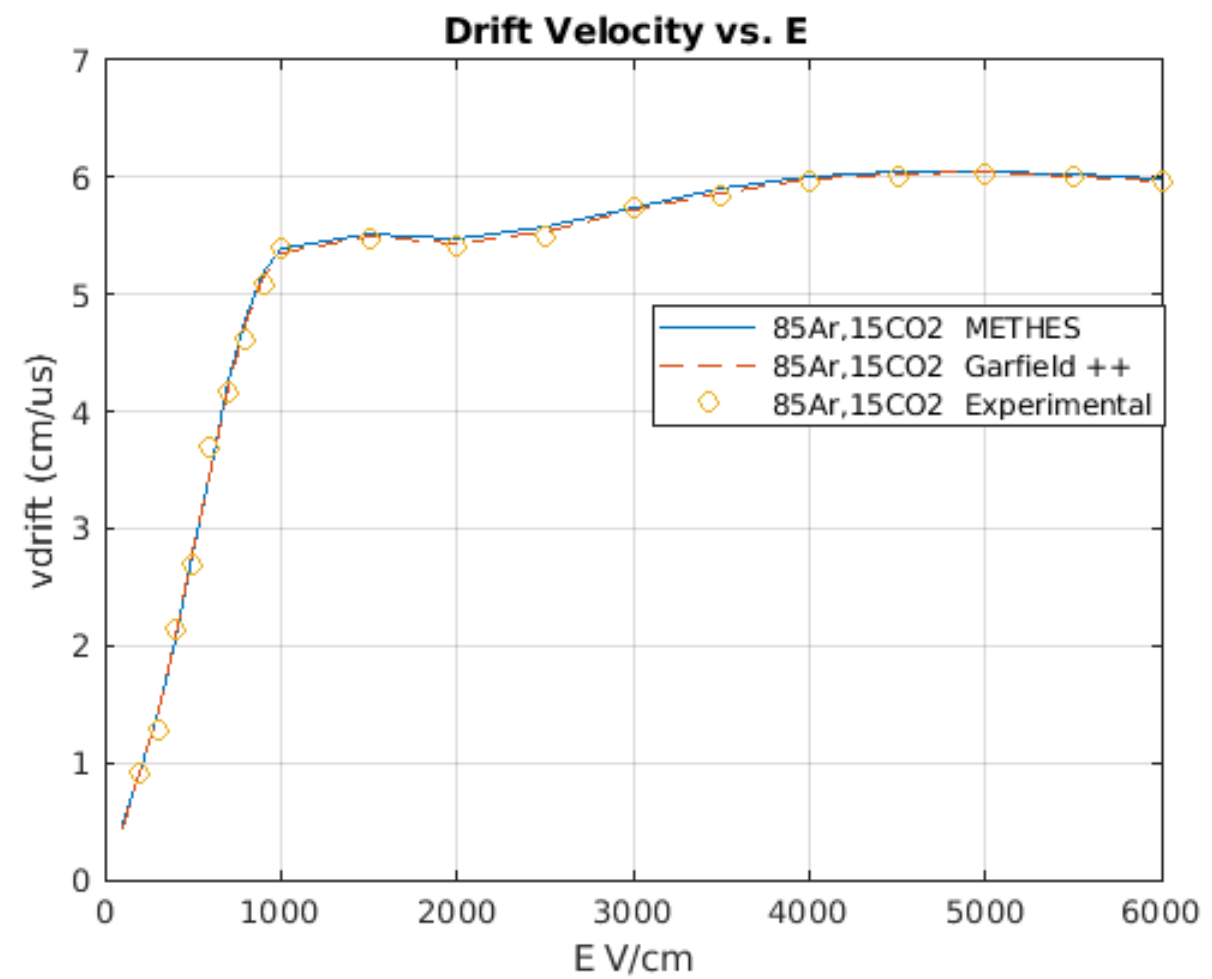
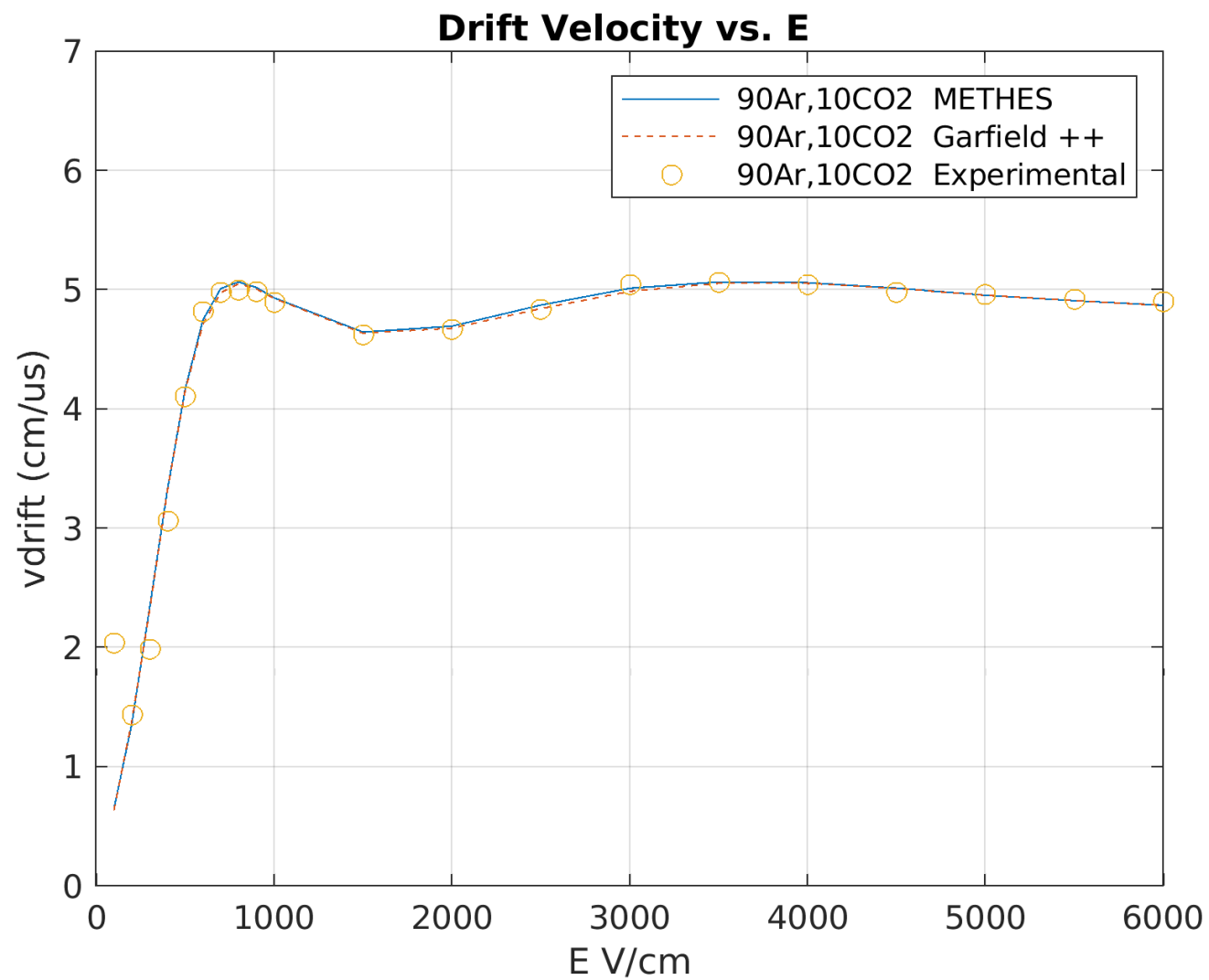






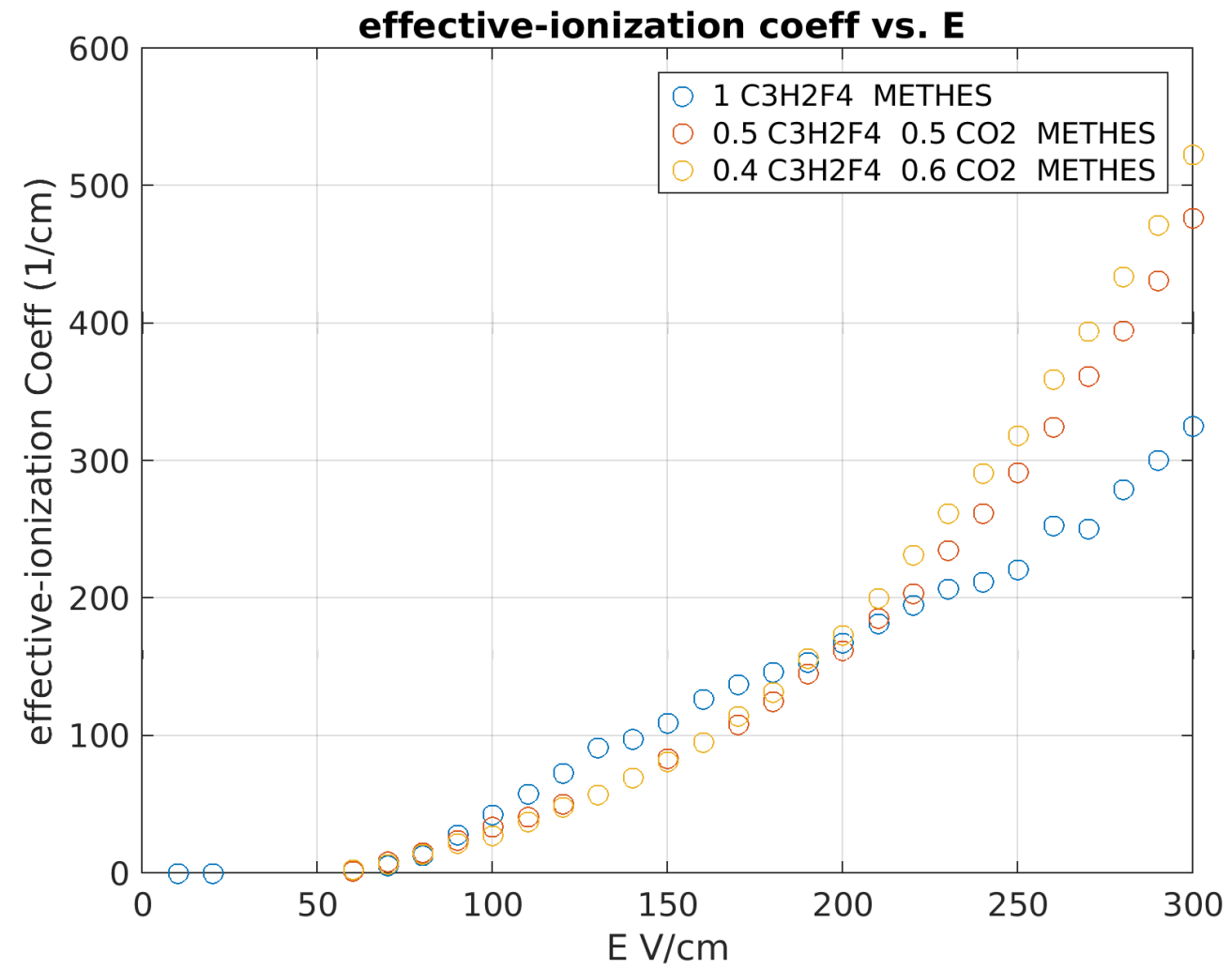
Validation

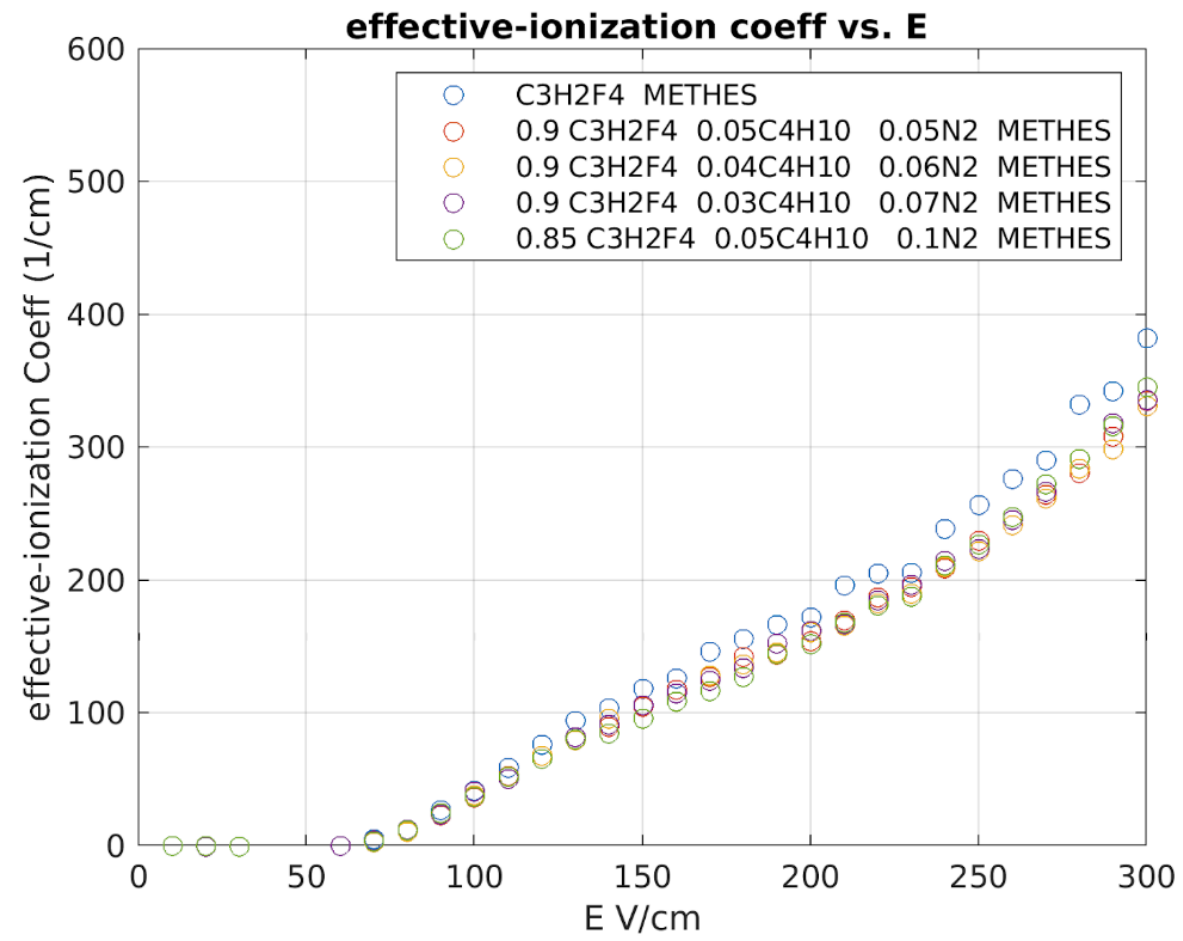


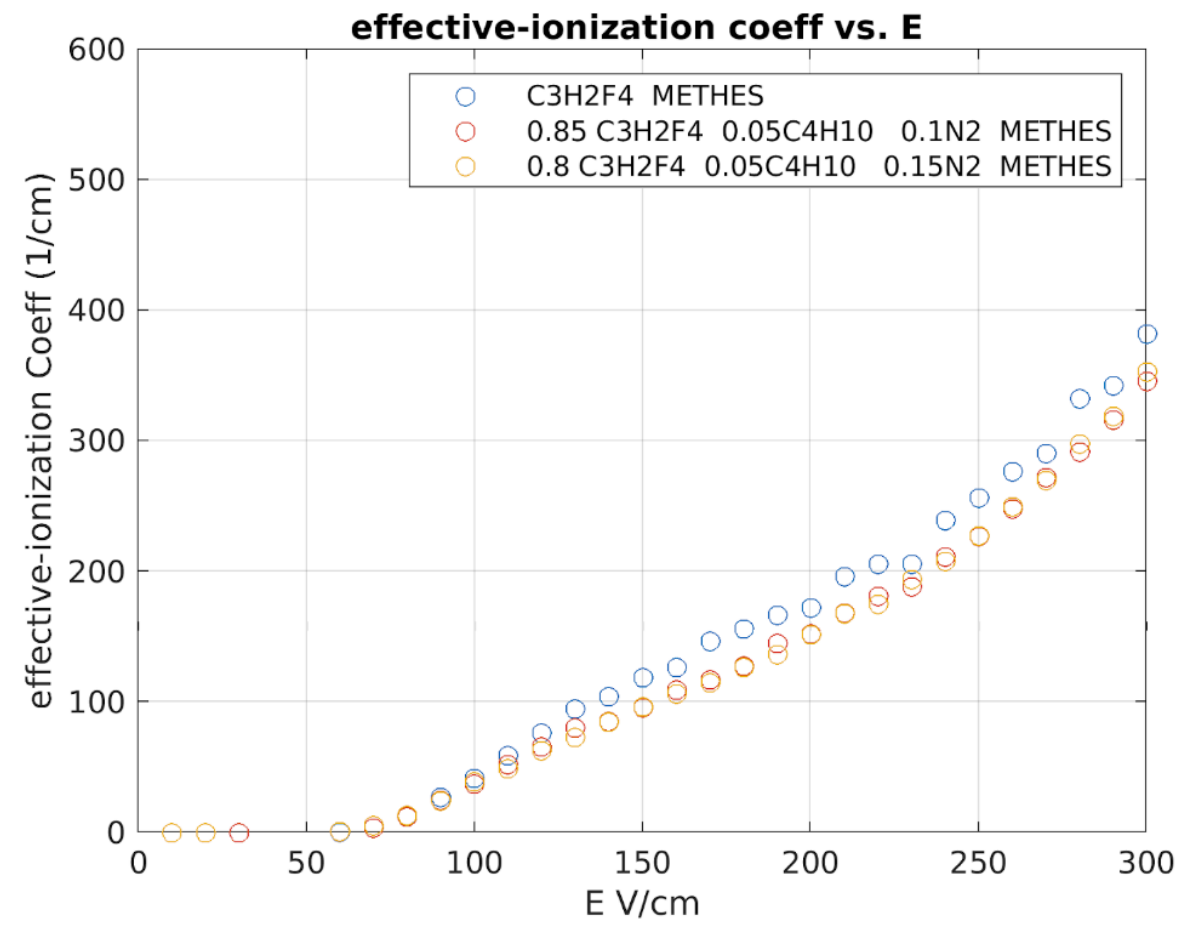


Ratio	E/N (Td)	methes2 Drift Velocity (cm/μs)	Experimental Drift Velocity (cm/μs)	% Deviation
90% Ar / 10% CO ₂	3500	5.0669	5.0650	0.04%
90% Ar / 10% CO ₂	4000	5.0607	5.0474	0.26%
85% Ar / 15% CO ₂	5500	6.0228	6.0155	0.12%
85% Ar / 15% CO ₂	5000	6.0419	6.0253	0.28%
80% Ar / 20% CO ₂	3500	6.4458	6.4624	0.26%

Proposition of new Environmentally green mixtures





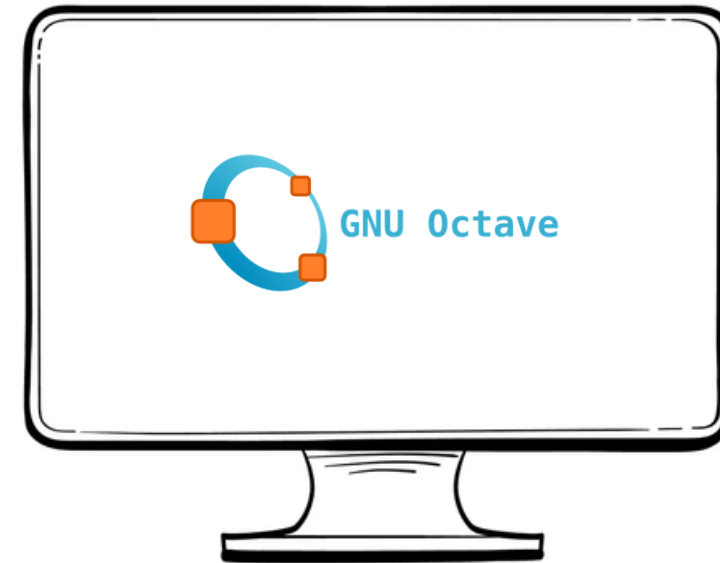


Results Implications

Gas Mixtures lab with dedicated equipment



Class-room Like Exercise





**THANK
YOU**

Any Questions?