ETH zürich

HVL High Voltage Laboratory

Environmentally-friendly gas mixtures for gaseous tracking and timing detectors

Marnik Metting van Rijn

First Quarter Meeting

31st March 2023

Collaboration

Christian Franck, Dario Stocco and
Marnik Metting van Rijn

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Beatrice Mandelli and Stephen Biagi

Project overview

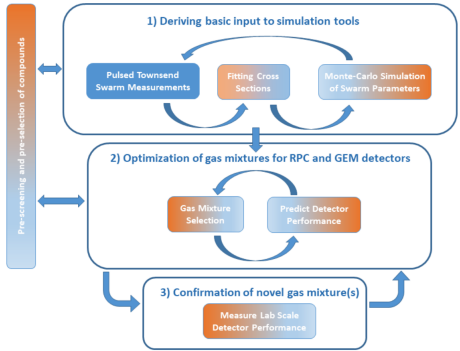


Figure: Work solely performed at ETH Zurich is indicated in blue whilst collaborative work is in blue and orange.

Projected timeline

Figure: Marnik Metting van Rijn

Figure: Dario Stocco

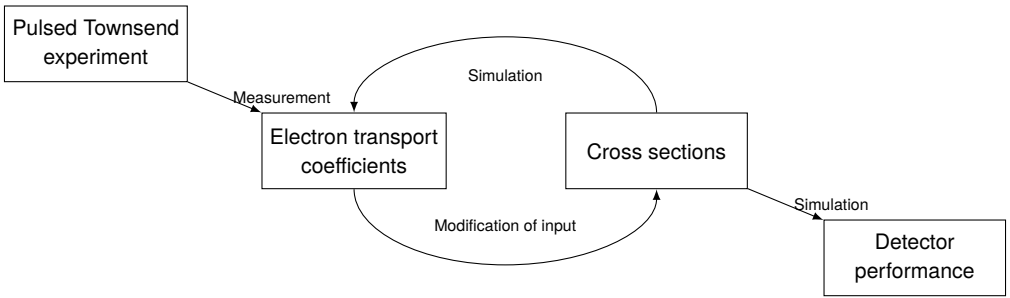
	Year 1				Year 2				Year 3				Year 4				responsible
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	
Swarm Parameter Measurements																	DS1
Cross Section Fitting						M1				M3				M4		M5	DS1, SB
Mixture optimization																	DS2, RV, PV
Experimental confirmation of novel gas mixtures								M2								M6	DS2, RG, BM

Figure: Anticipated timeline of project representing the division in work.

Project objective

Research goal

Determine the vibrational-excitation, momentum-transfer, ionisation, attachment and integral cross sections for several promising candidate gases in gaseous tracking and timing detectors.



Experimental results

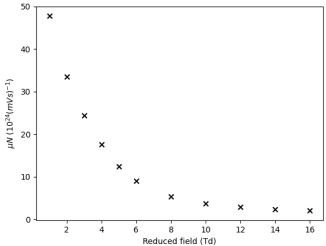


Figure: Normalized mobility as a function of reduced electric field in a 2 % Argon HFO1234ze mixture. Errorbars within marker.

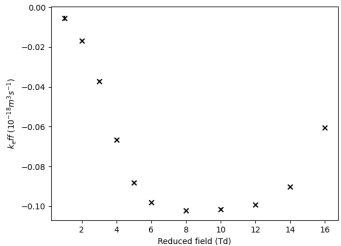


Figure: Rate coefficient as a function of reduced electric field in a 2 % Argon HFO1234ze mixture. Errorbars within marker.

Diluted HFO1234ze argon measurement performed at 0.5 %, 1 %, 2 % and 5 % mixtures.

Available HFO1234ze data

Table: IR-spectra attained vibrational modes [1].

C-C	110 meV
CF_3	137 meV
C-F	144 meV
CF_3	166 meV
C=C	211 meV
C-H	386 meV

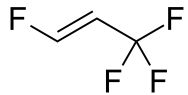


Figure: Chemical structure of tetrafluorpropene.

Table: Dipole moments in HFO1234ze [2] and H_2O [3].

H_2O	1.86 D
HFO1234ze	1.13 D
Ratio	0.61

- Measurements set physical boundaries

Elastic and vibrational modes

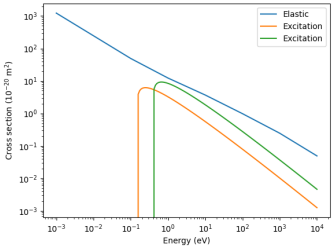
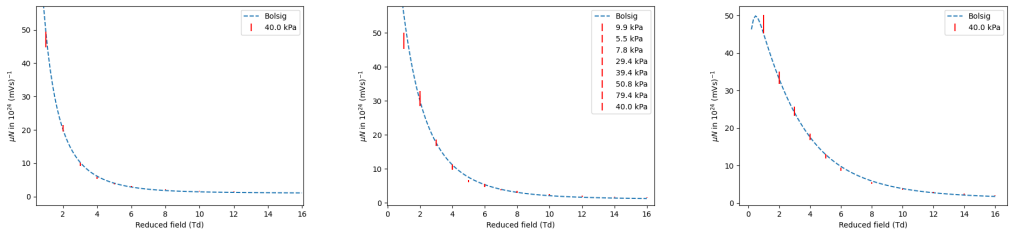


Figure: Excitations motivated by infrared measurements.

Scaled elastic line of water vapour [4] and divided by a factor of three. Vibrational excitation are modelled with

- $0.144\,\text{eV}$ (C-F) and $1 \times 10^{-20}\,\text{m}^2$ and
- $0.386\,\text{eV}$ (C-H) and $4 \times 10^{-20}\,\text{m}^2$.

Simulation



(a) $0.5\ \%$ (b) $1\ \%$ (c) $2\ \%$

Figure: Normalized mobility as function of reduced electric field. Errorbars are fixed to $5\ \%$. Underlying cross section set shown in upper slide and was propagated with Bolsig [5].

Conclusion and Outlook

- Performed diluted HFO1234ze measurements
- Determined preliminary set for elastic and vibrational cross sections

Table: Projected milestones concerning HFO1234ze

April 2023	Pure HFO1234ze swarm measurements
Mai 2023	Vibrational resonance and low energy attachment
June 2023	Electronic excitations
August 2023	Self consistent set of cross section for HFO1234ze

Discussion

- Training structure for Dario
- Intensive course at CERN in cross sections provided by Stephen
- List of promising gases
- Lab tour at ETH/CERN

References

[1] Jan Schwabedissen, Timo Glodde, Yury V. Vishnevskiy, Hans-Georg Stammler, Lukas Flierl, Andreas J. Kornath, and Norbert W. Mitzel.
Structures and properties of trans -1,3,3,3-tetrafluoro- propene (hfo-1234ze) and 2,3,3,3-tetrafluoropropene (hfo-1234yf) refrigerants.
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[3] Shelley L. Shostak, William L. Ebenstein, and J. S. Muenter.
The dipole moment of water. i. dipole moments and hyperfine properties of h ₂ o and hdo in the ground and excited vibrational states.
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[4] Yukikazu Itikawa and Nigel Mason.
Cross sections for electron collisions with water molecules.
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[5] G J M Hagelaar and L C Pitchford.
Solving the boltzmann equation to obtain electron transport coefficients and rate coefficients for fluid models.
Plasma Sources Science and Technology, 14:722–733, 11 2005.

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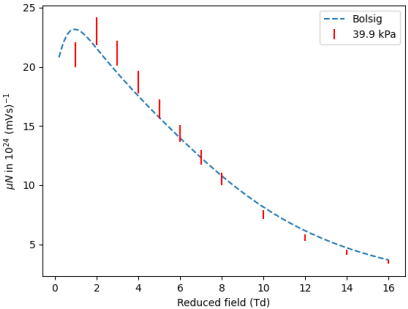
A: 5 % Measurement



(a) 5 %

B: Water Vapour

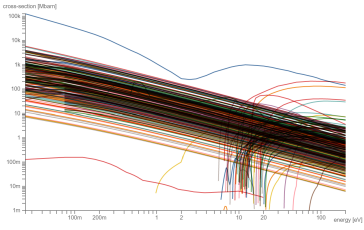


Figure: Cross section of water vapour taken from garfield.

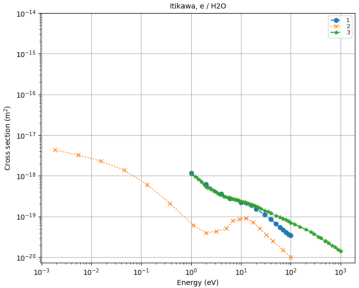


Figure: Total elastic cross section (green) [4].

C: Pulsed Townsend experiment

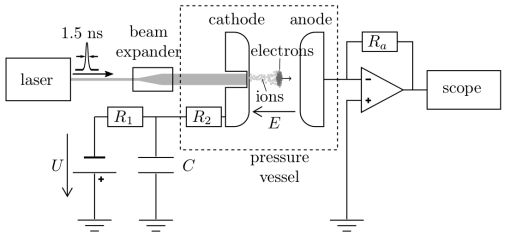


Figure: Pulsed Townsend experiment at the High Voltage Laboratory (ETH Zurich). [**?**]

Rate	Bulk velocity	Bulk diffusion
ν_{eff}	W_b	D_b

Table: Attained electron transport coefficients

- Allows study of arbitrary gas mixtures
- Highly automated experimental set up