ETH zürich

High Voltage Laboratory

Environmentally-friendly gas mixtures for gaseous tracking and timing detectors

Marnik Metting van Rijn

Kick-off meeting

24 November 2022

Collaboration

ETH zürich

Christian Franck, Marnik Metting van Rijn and N.N. (second doctoral student)

CERN

Piet Verwilligen, Roberto Guida, Rob Veenhof, Beatrice Mandelli and Stephen Biagi

Marnik Metting van Rijn

PhD student	High Voltage Laboratory	August 2022
MSc ETH Physics	ETH Zurich	2020 - 2022
Master's Thesis	*Paul Scherrer Institute, LNS*	2021 - 2022
BSc ETH Physics	ETH Zurich	2017 - 2020

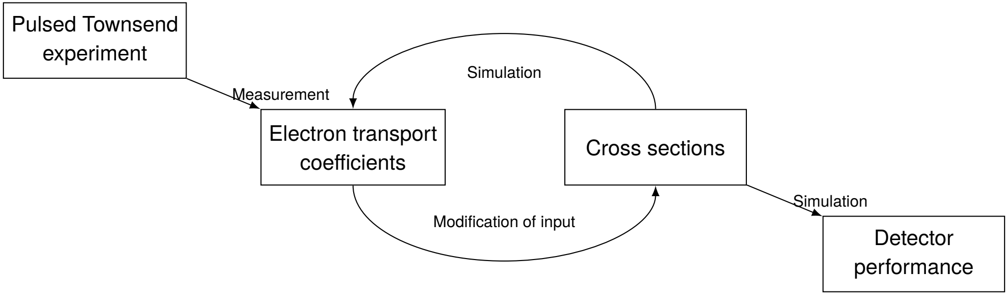
MAGNETIC DYNAMICS OF THE SUPEROXYGENATED STRONGLY CORRELATED ELECTRON SYSTEM $La_2CoO_{4.25}$

Main focus on quantum magnetism, superconductivity and neutron scattering. Personal website

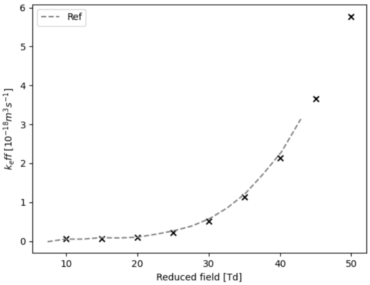
Project objective

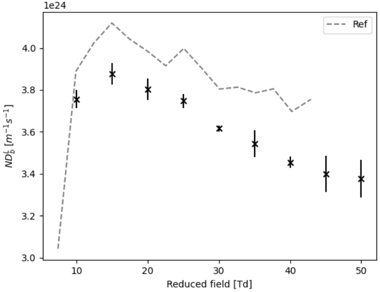
Research goal

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



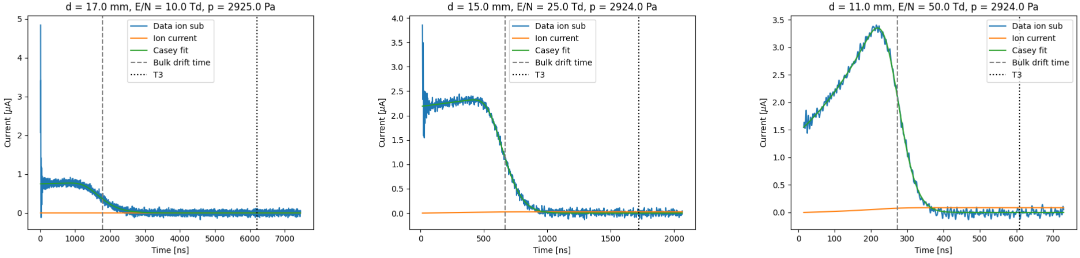
Measuring pure argon at 3 kPa





Haefliger P, Franck C M, 2018, Detailed precision and accuracy analysis of swarm parameters from a Pulsed Townsend experiment, Review of Scientific Instruments 89, 2,023114.

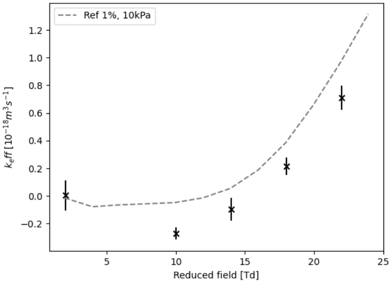
Pure argon data acquisition

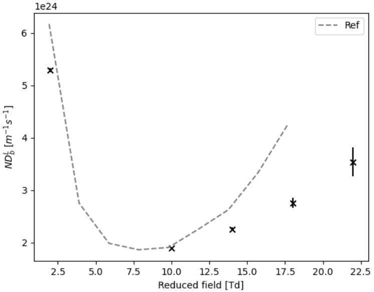


Casey, M. J. E., et al. "Foundations and interpretations of the pulsed-Townsend experiment." Plasma Sources Science and Technology 30.3 (2021): 035017.

Current state of research

Argon/HFO1234ze 0.9 % mixture at 1.7 kPa. Reference measurement was performed at 10 kPa. HFO1234ze has pressure dependence.

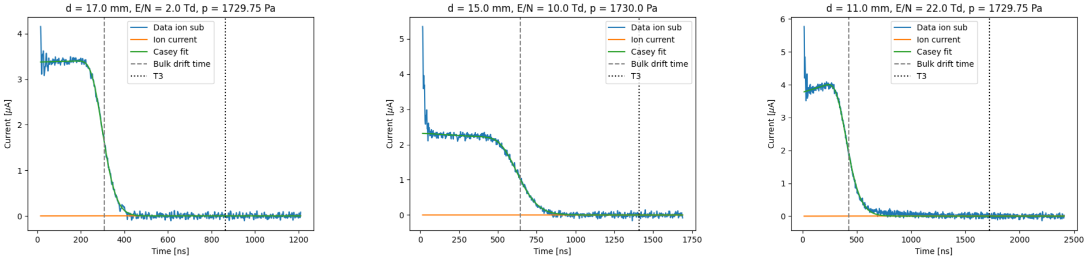




Chachereau, Alise, Mohamed Rabie, and Christian M. Franck. "Electron swarm parameters of the hydrofluoroolefine HFO1234ze." Plasma Sources Science and Technology 25.4 (2016): 045005.

Argon/HFO1234ze data acquisition

Argon/HFO1234ze 0.9 % mixture at 1.7 kPa. Fits based on the theoretical derivations of Casey *et al.* reproduce the data within this range.



Casey, M. J. E., et al. "Foundations and interpretations of the pulsed-Townsend experiment." Plasma Sources Science and Technology 30.3 (2021): 035017.

Limitations of model

Extending the Argon/HFO 0.9 % mixture at 1.7 kPa measurements to higher reduced electric field values

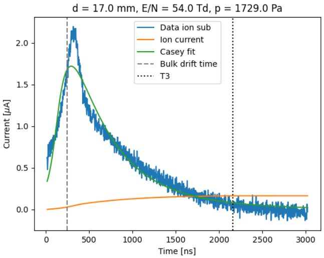
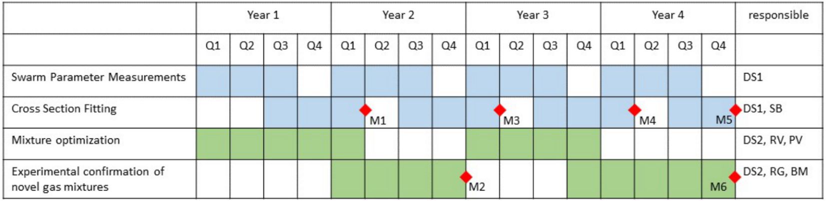


Figure: Poor fit at high E/n values.

- Tail on falling edge needs to be treated with care
- Novel approach required to gather $E/n > 20$ Td data

Research plan - Timeline



Year	Gas
2023	$C_3H_2F_4$ (HFO1234ze)
2024	Gas 2
2025	Gas 3
2026	Gas 4

Table: Estimated project milestones.

- Are modifications to the timeline required?
- Estimate time per gas realistic?

High GWP gases and their substitutes - Gas 2

R134a	SF6	CF_4
$C_3H_2F_4$ (HFO1234ze)	C_4F_7N	$C_3H_2F_4$ (HFO1234ze)
$C_3H_2ClF_3$ (HFO1233zd)	$C_5F_{10}O$	(HFO1336mzz)
		HFE245fa1
		HFE143m

Table: Promising candidate compounds to reduce GHG emission.

- Discuss and select Gas 2
- Which are the most suitable candidates?
- Availability, feasibility, optimal working conditions (E/n, p, ...)
- Mixing with nitrogen through leaks

Introduction to cross section determination

- Evaluate an optimal training structure, collaboration with Stephen
- On-site at CERN, online or hybrid?
- Estimate time duration required for an initial training?

Exchange platform - Agenda

- Where should relevant information (slides, agenda, documentations ...) be stored?
- Is indico an option, external access?
- ETH provides POLYBOX as a sharing platform

EPJ plus journal

The Green Transition of gases employed for radiation detection in Nuclear and High Energy Physics experiments

- Suggested review article to be submitted in $\sim 2 - 3$ months
- Help required, collaboration possible?

Acknowledgement

This project is funded by Schweizerischer Nationalfonds.
Approval for reprinting the CERN logo was confirmed.

References

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https://hvl.ee.ethz.ch

Pulsed Townsend experiment

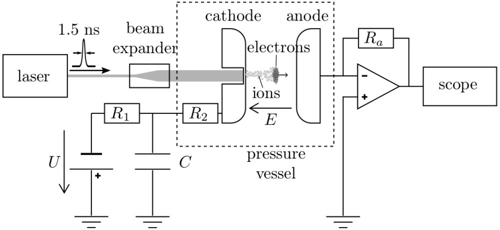

Figure: Pulsed Townsend experiment at the High Voltage Laboratory (ETH Zurich). [?]

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

High-global-warming-potential gases in particle detectors

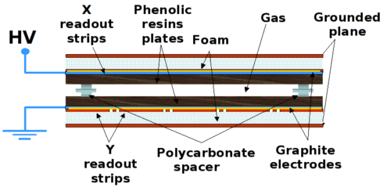

Figure: Schematic of a resistive plate chamber situated at the ATLAS experiment at CERN. [?]

Standard gas mixtures contain R-134a, SF6 and isobutane at atmospheric pressure.

- Passing of high-energy particles ionizes molecules, generating detectable discharges
- Gas mixtures affect detector performance
- At CERN, $\sim 90\%$ GHG emission from detectors
- Similar gases as used in electric-power industry
- Discharge process is identical to GIS
- Requires cross sections to simulate detector performance

Relating the cross sections to transport properties

The integral cross section $\sigma^{(0)}(g)$ reproduces the transport properties via two distinct methods:

Boltzmann equation

- Solves the equation iteratively in the two-term approximation
- BOLSIG+ and MagBoltz
- More approximate, low computing time

Monte Carlo simulation

- Approximates statistical nature by random numbers
- METHES and PymETHes
- Accurate, requires high computational power

Iteratively predicting the transport coefficients and adjusting the initial integral cross section allows finding an inverse relation with the loss of a one-to-one correspondence. Restore uniqueness upon observation of mixtures in the iterative process or reference measurements.

Electron-molecule-scattering cross section

Differential cross section

$$\sigma(\mathbf{g}, \mathbf{g}')d^2\Omega_{\mathbf{g}'} = \frac{\text{Number of particles scattered into solid angle } d\Omega_{\mathbf{g}'}}{\text{Incident particle flux}}$$

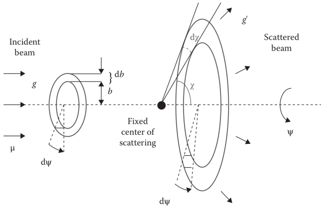

Figure: Scattering process. [?]

- The scattering cross section is a fundamental transport property
- Predicts electron transport coefficients at different mixing concentrations
- $\sigma(g, \chi) = \sum_{l=0}^{\infty} \frac{2l+1}{4\pi}\sigma^{(l)}(g)P_l(\cos\chi)$