

RD51 Collaboration Meeting @TUM (Munich), June 2018

Ion Mobility studies in Ar-CF₄-iC₄H₁₀ mixtures for the LCTPC Collaboration

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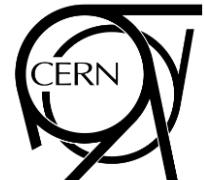
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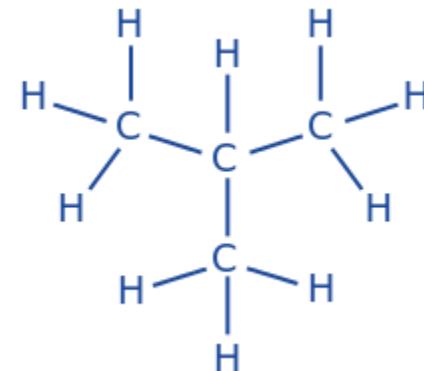




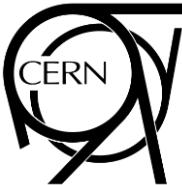
Contents

Ion Mobility Measurement at LIP-Coimbra

- Basic Concepts
- Experimental Setup and Working Principle
- Preliminary Results Ar-CF4-iC4H10:
 - Ar-CF4
 - iC4H10
 - Ar-iC4H10
 - CF4-iC4H10
 - Ar-CF4-iC4H10



Conclusions and Future Work



Present status: ion mobility measurements

Systematically measure ion mobility in gaseous mixtures of interest

Scarce data available on ion mobility of mixtures relevant for the LCTPC (Linear Collider TPC), although measurements for other gases have been performed since long.



Ar-CF₄-iC₄H₁₀

Desired Characteristics

Search for the ions with the highest mobility rapidly flush the TPC.

To stop the ions with a 'gating device' and dimension the gap in the gating device it is important to know the thickness of the ion cloud.

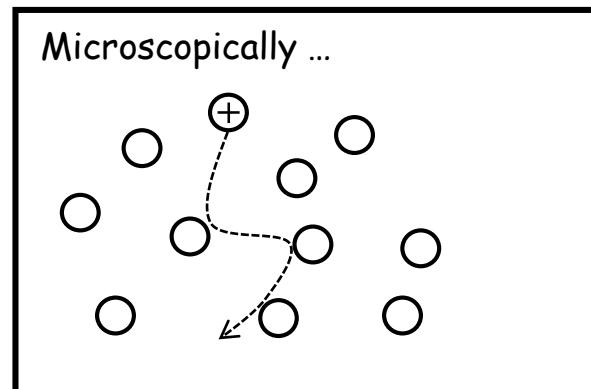
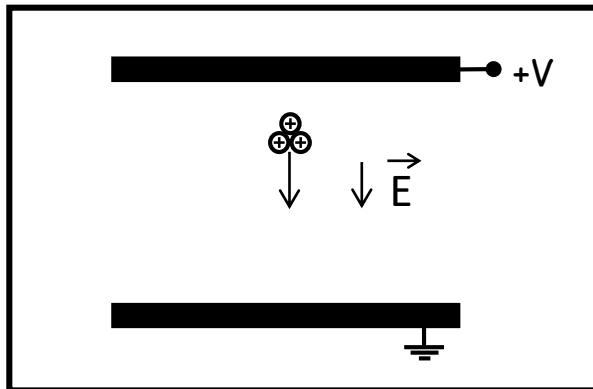
Identify the drifting ions and relevant mechanisms on ion formation.

...Present Status

- Data already collected for:
 - the complementary mixtures CF₄-CH₄, CF₄-C₂H₆ and CF₄-iC₄H₁₀;
 - iC₄H₁₀ ions on their parent gas and Ar-iC₄H₁₀ mixtures.
- Results on Xe-CF₄ and Ar-CF₄ already published (available in the RD51-Notes) !

Basic concepts

Let us consider a group of ions moving in a gaseous medium under the influence of a uniform electric field...



Drift velocity

$$v_d = KE$$

E - Electric Field
K - Ion Mobility

Reduced Mobility

$$K_0 = KN/N_0$$

N - Gas number density
 N_0 - Loschmidt Number

Langevin Limit

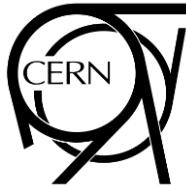
$$K_0 = 13.88 \left(\frac{1}{\alpha \mu} \right)^{\frac{1}{2}}$$

μ - reduced mass
 α - neutral polarizability

Blanc's Law

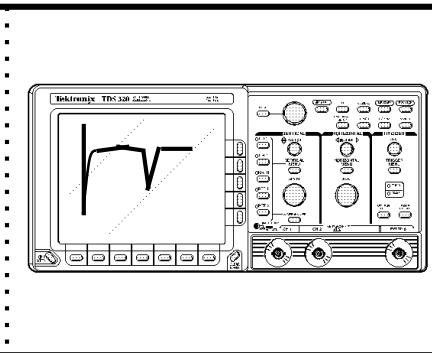
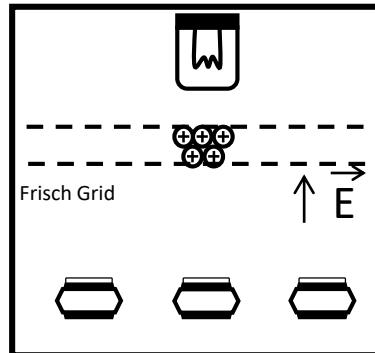
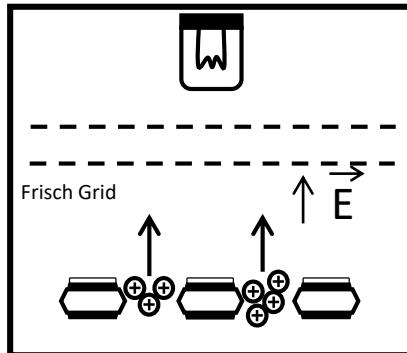
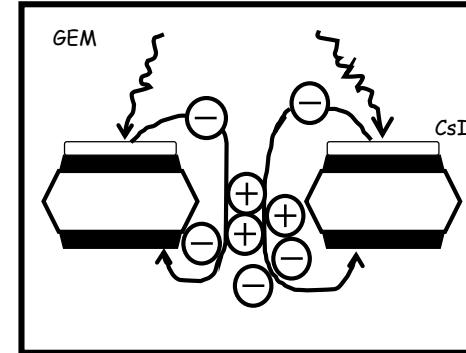
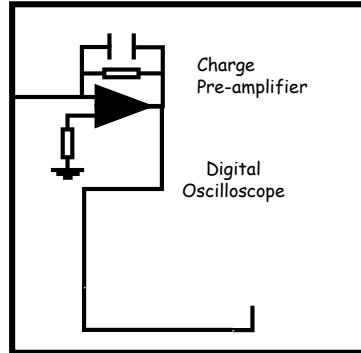
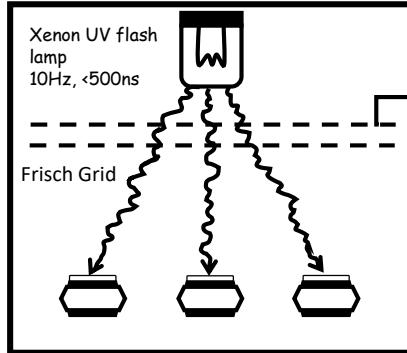
$$\frac{1}{K_{0\text{mix}}} = \frac{f_1}{K_{0g1}} + \frac{f_2}{K_{0g2}}$$

f_1, f_2 - molar fraction of gas 1, 2
 K_{0g1}, K_{0g2} - ion mobility in the gases 1 and 2



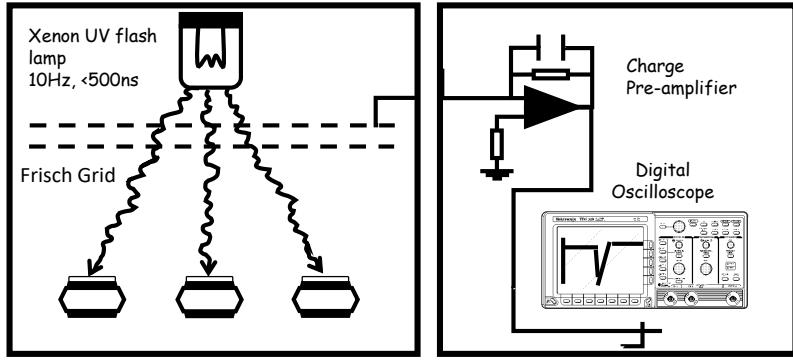
Experimental Setup and Working Principle

(Neves, Conde and Távora, 2007)





Experimental Setup and Working Principle



peaks centroids



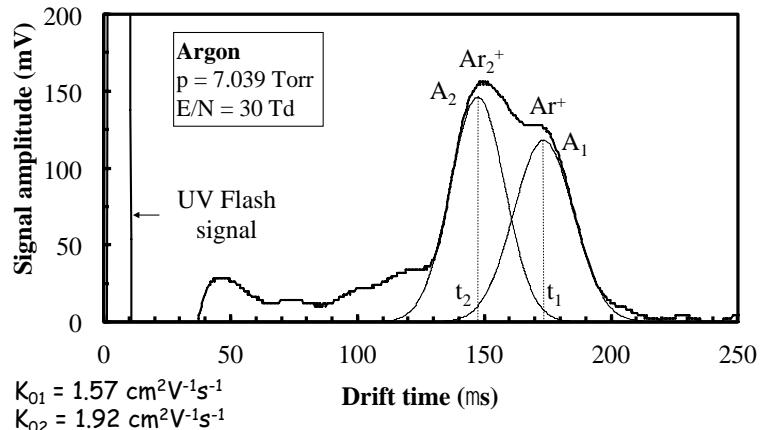
average drift time of the ion's distribution (t_{drift})

$$v_d = \frac{x_{drift}}{t_{drift}} \rightarrow K = \frac{v_d}{E}$$

After the signal and the background were recorded...

- Subtract the background to the signal
- Identify possible peaks
- Fit Gaussian curves to the spectrum obtained

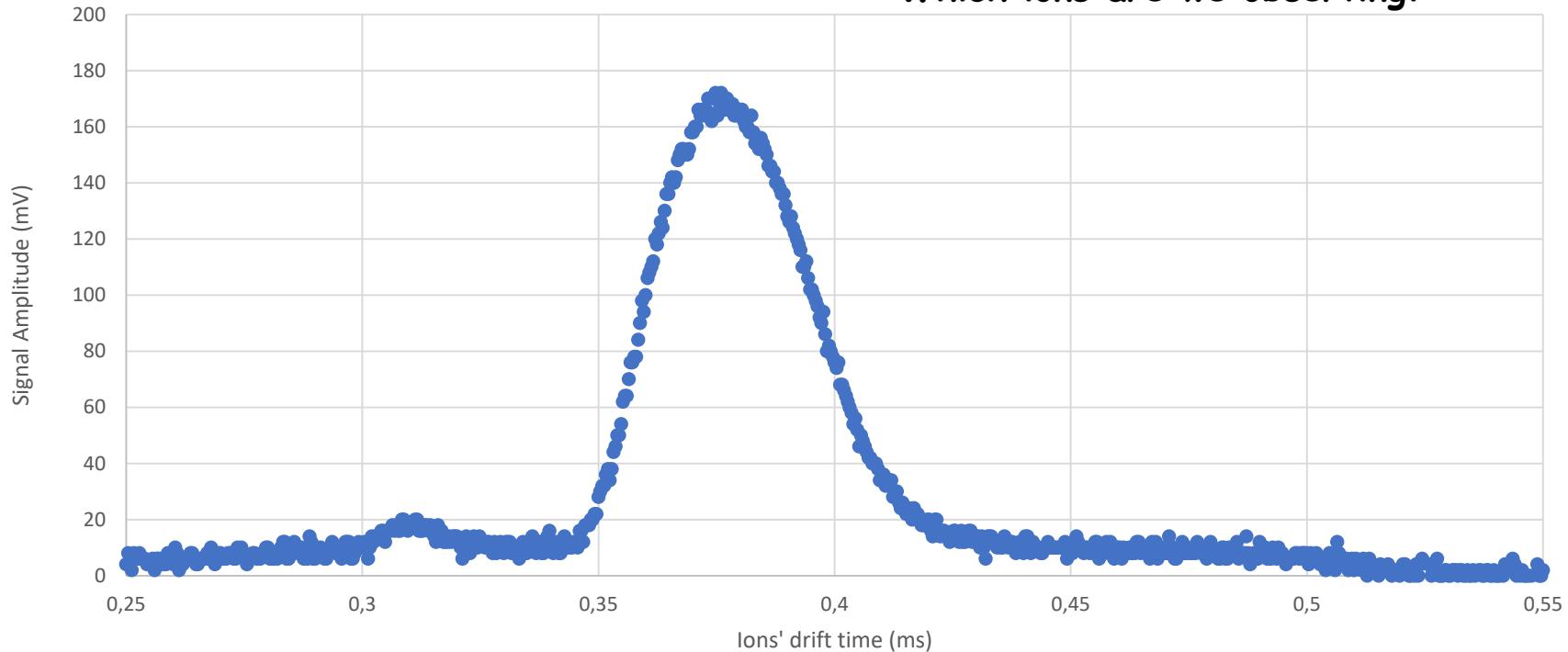
3rd prototype: typical ion pulse





Ion Identification: Ar-CF₄-iC₄H₁₀

Which ions are we observing?

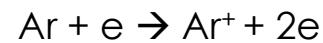




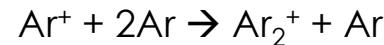
Experimental Results: Ar

REACTIONS

Ar^+ 15.76 eV

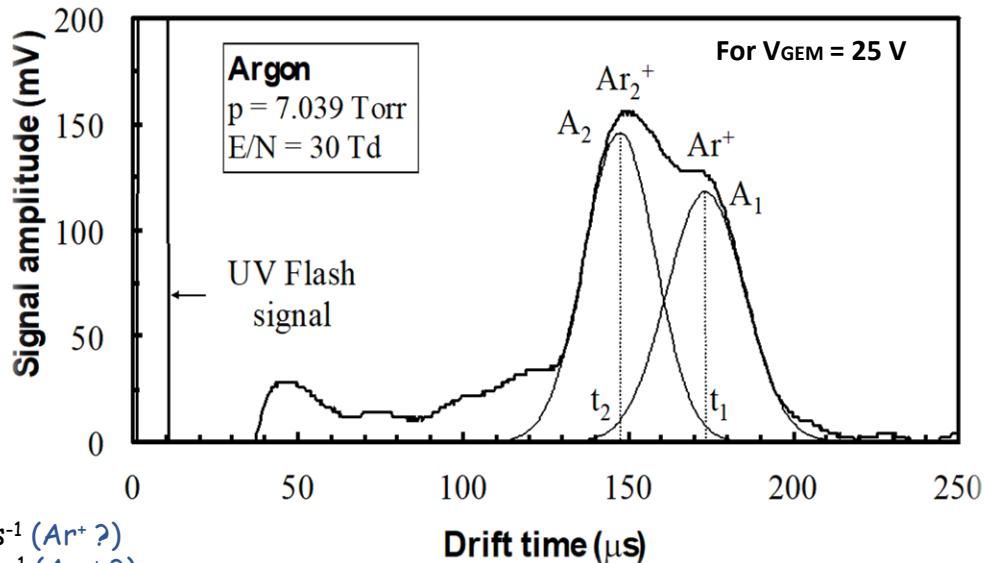


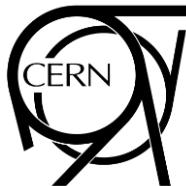
Above threshold
15.76 eV



$$K_{01} \sim 1.57 \text{ cm}^2 \text{V}^{-1} \text{s}^{-1} (\text{Ar}^+ ?)$$

$$K_{02} \sim 1.92 \text{ cm}^2 \text{V}^{-1} \text{s}^{-1} (\text{Ar}_2^+ ?)$$





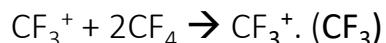
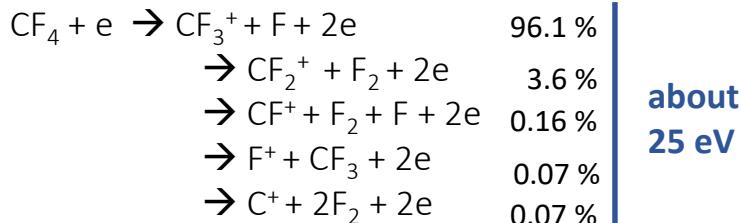
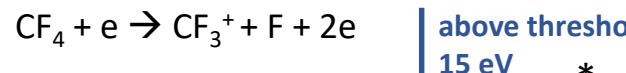
Experimental Results: CF₄

IONIZATION

REACTIONS

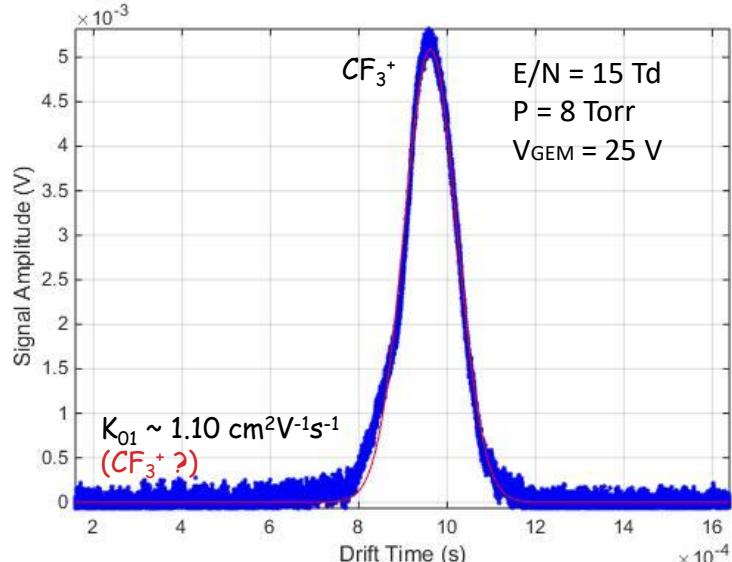
Appearance Energies

CF ₃ ⁺	15.0 eV
CF ₂ ⁺	19.0 eV
CF ⁺	22.3 eV
F ⁺	23.1 eV



Possibility of
Cluster Formation

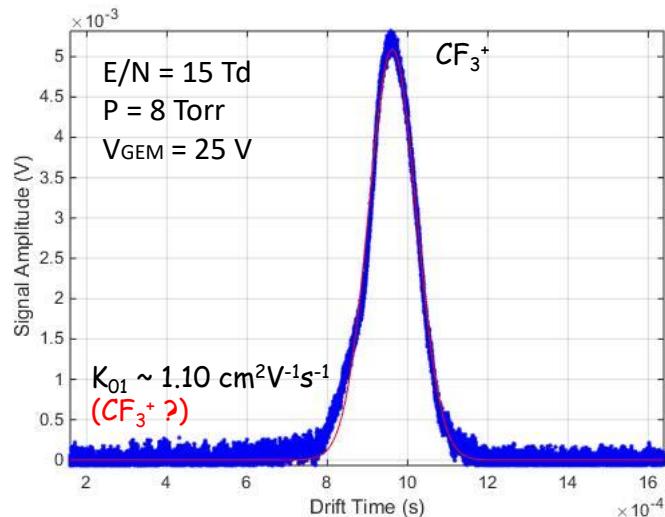
(Pressure dependent)



* values obtained from ionization cross sections for electron impact of 25 eV



Experimental Results: CF₄



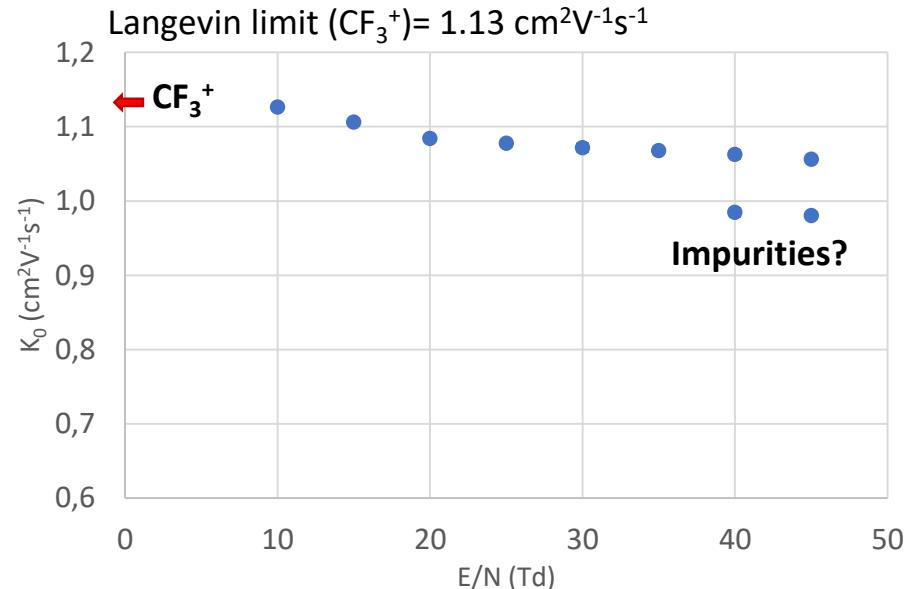
Fair agreement with
earlier reported work...
(Basurto, Urquijo 2002)

Experimental value

$$K_{01} \sim 0.96 \text{ cm}^2\text{V}^{-1}\text{s}^{-1} \quad (\text{CF}_3^+. \text{CF}_4?)$$

Calc. Langevin Limit

$$0.92 \text{ cm}^2\text{V}^{-1}\text{s}^{-1}$$



Calc. Langevin Limit

$$1.13 \text{ cm}^2\text{V}^{-1}\text{s}^{-1} \sim$$

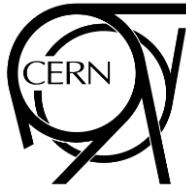
Experimental value

$$1.12 \text{ cm}^2\text{V}^{-1}\text{s}^{-1}$$

0.9% error

Cluster Formation





Experimental Results: iC₄H₁₀

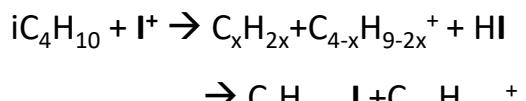
Appearance Energies (eV)

C ₂ H ₄ ⁺	14.07
C ₂ H ₅ ⁺	13.80
C ₃ H ₅ ⁺	14.55
C ₃ H ₆ ⁺	10.88
C ₃ H ₇ ⁺	11.16
t-C ₄ H ₉ ⁺	11.60
iso-C ₄ H ₁₀ ⁺	10.23

Most produced primary ions:

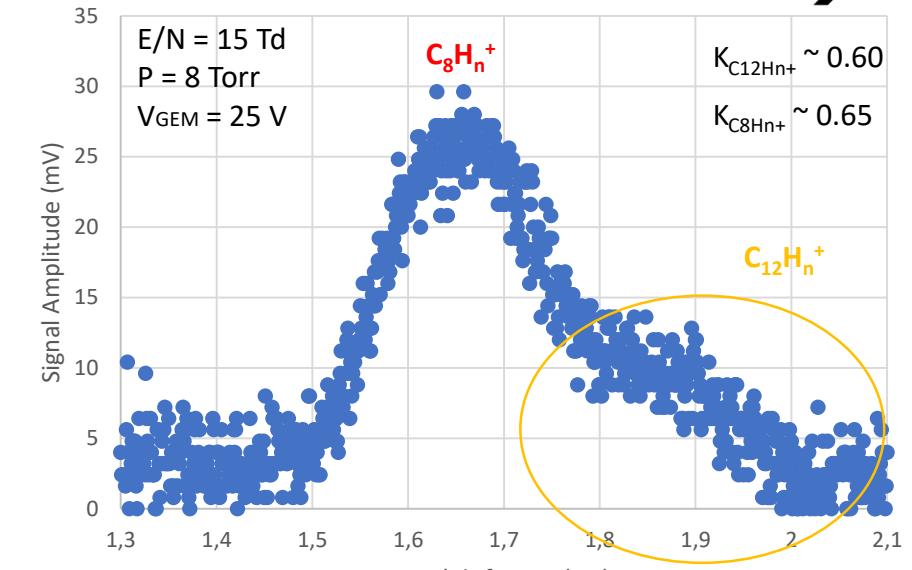
- C₃H₇⁺
- C₃H₅⁺
- C₂H₃⁺
- C₃H₆⁺

Quick reactions ($k \approx 10^{-9}$ cc/s)

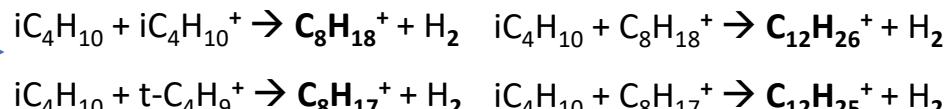


$$x = 0, 1, 2 \text{ or } 3$$

Leading to
t-C₄H₉⁺



Slow reactions ($k \approx 10^{-14}$ cc/s)

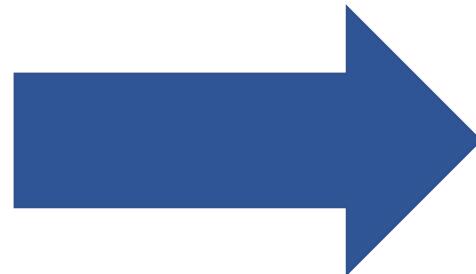


Let's now move to the binary gas mixtures:

Ar-CF₄

CF₄-iC₄H₁₀

Ar-iC₄H₁₀



Ar-CF₄-iC₄H₁₀

Experimental Results: Ar-CF₄

Ions move faster with the presence of Ar.

Behaviour well described by Blanc's law and Langevin theory.

Amplitude rises until 90% of Ar

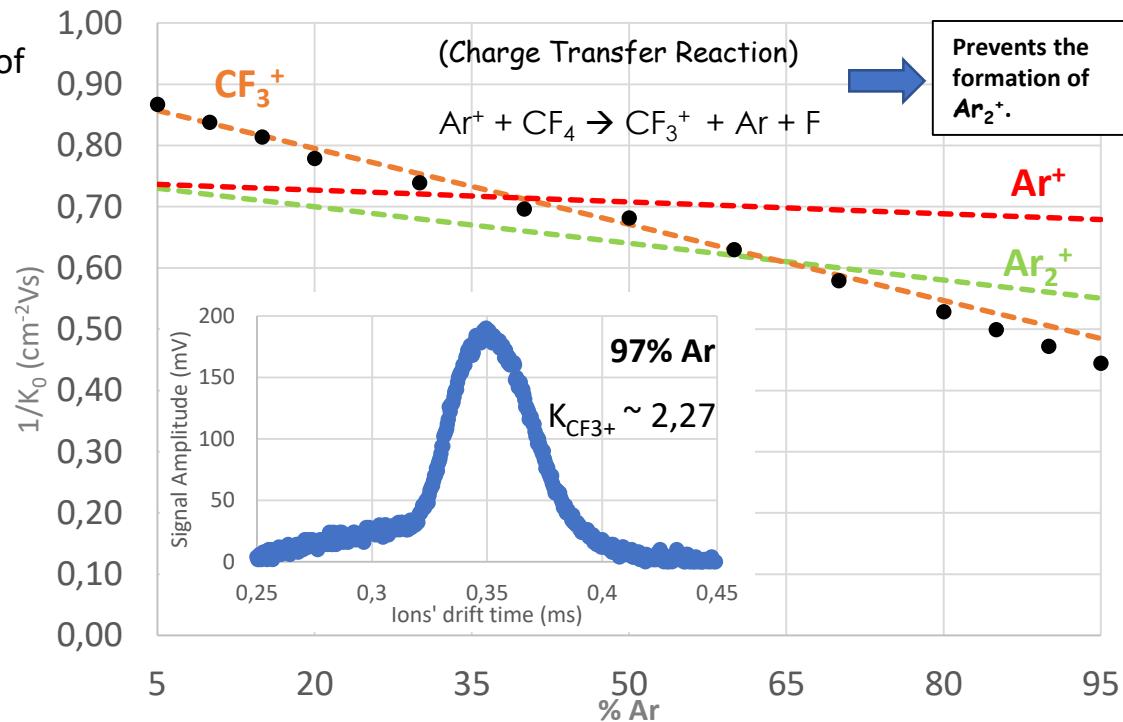


- Cross section.
- Presence of Ar leads to the same ion as in pure CF₄.

Only one peak for 15 Td
a bump appears for Ar > 80%



- Probably due to impurities.

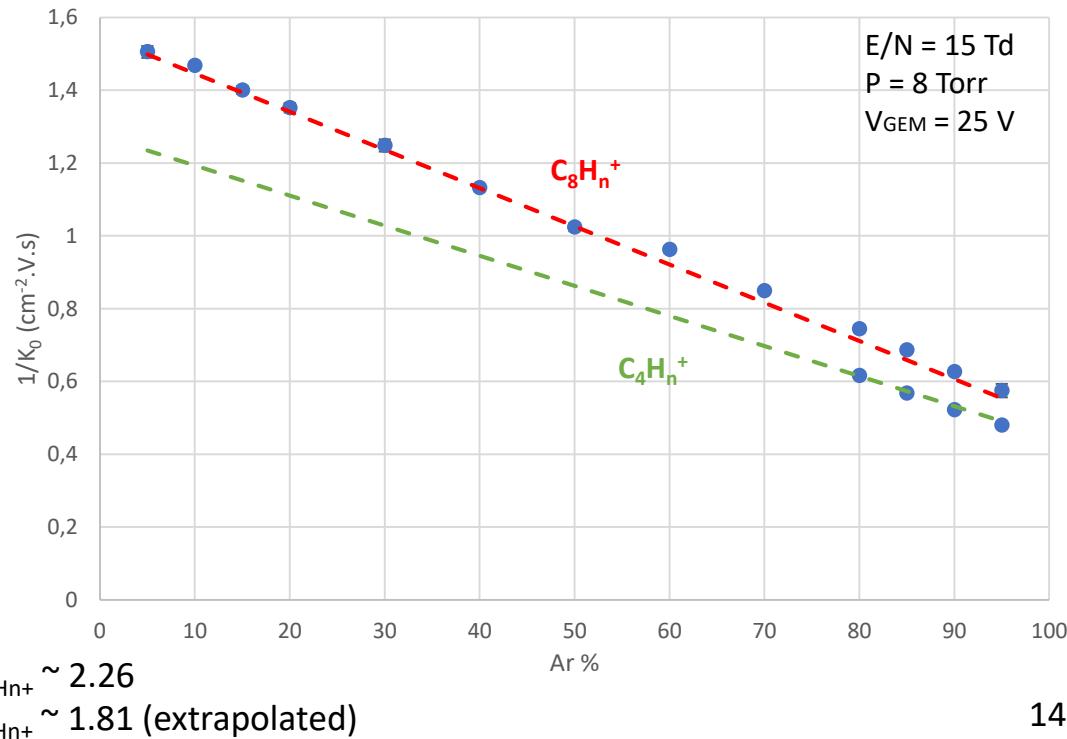
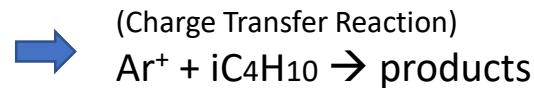
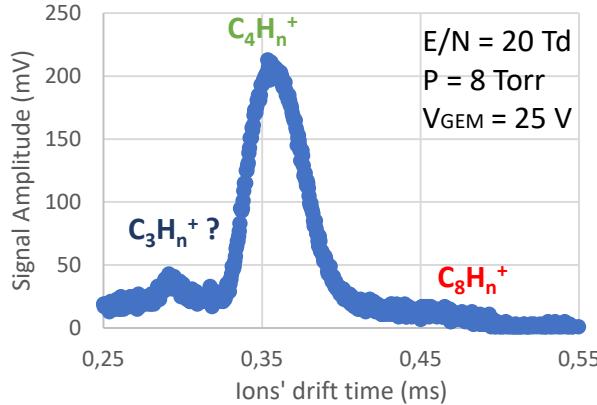


Increasing pressure may lead to the formation of cluster (10% slower than CF₃⁺)

Experimental Results: Ar-iC₄H₁₀

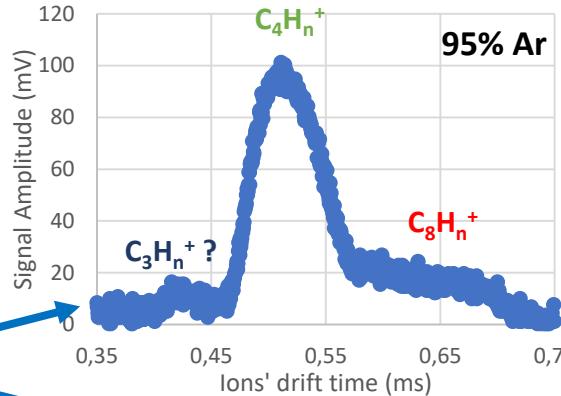
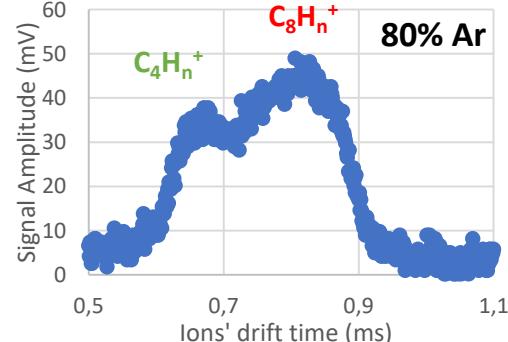
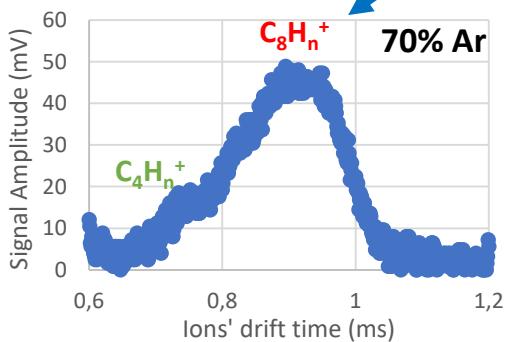
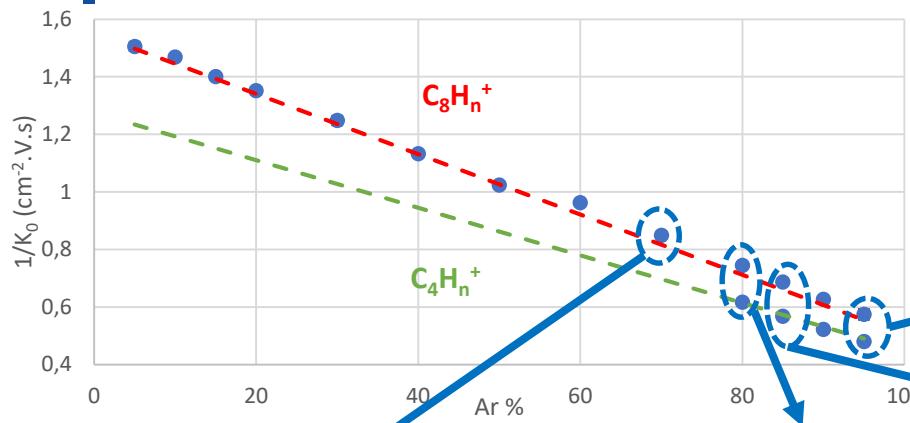
- Ions move faster** and the signal **amplitude increases** with the presence of Ar
- One peak** observed up to 70% Ar and **two peaks** down to 80% Ar
- Behaviour **well described** by Blanc's law and Langevin theory

98% Ar – 2% iC₄H₁₀

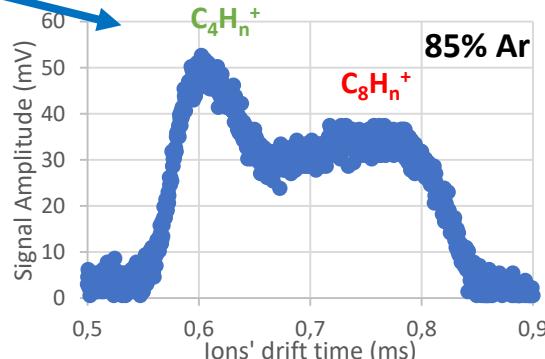




Experimental Results: Ar-iC₄H₁₀

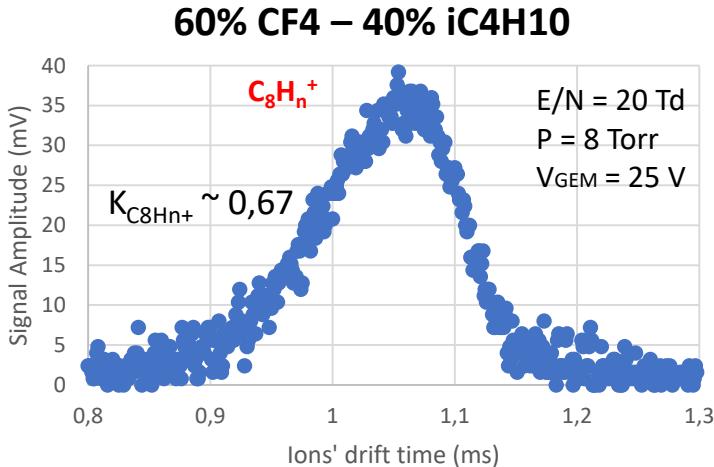


Increasing Ar concentration
Incomplete reactions

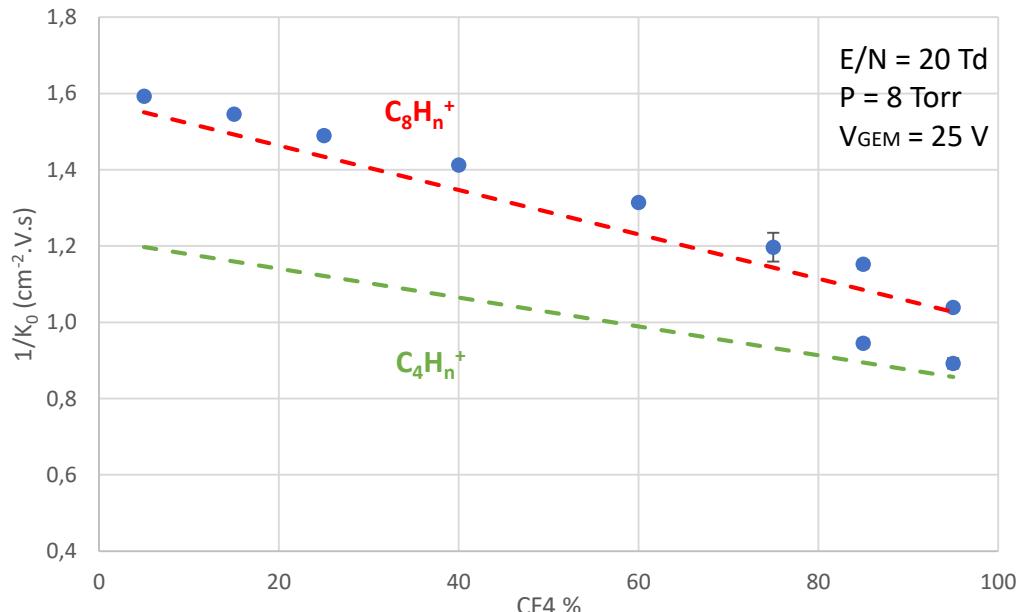


Experimental Results: CF₄-iC₄H₁₀

- Ions move **faster** and the signal amplitude **increases** with the presence of CF₄
- One peak observed up to 75% CF₄ and **two peaks** down to 85% CF₄
- Behaviour **well described** by Blanc's law and Langevin theory

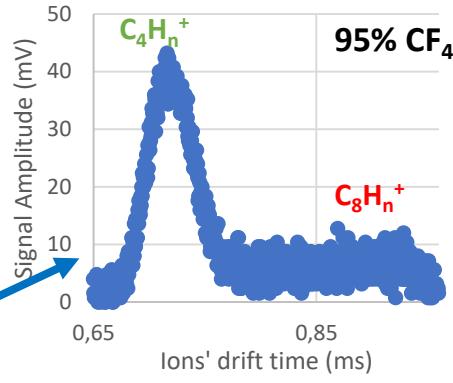
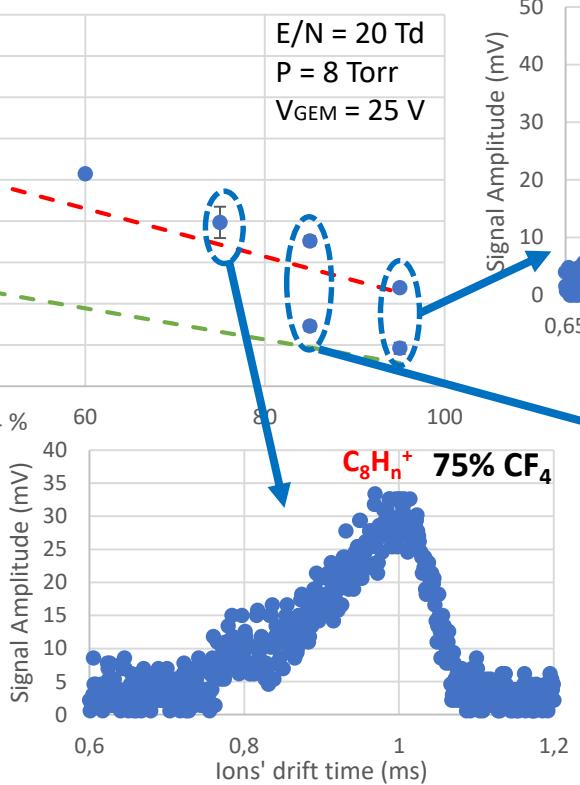
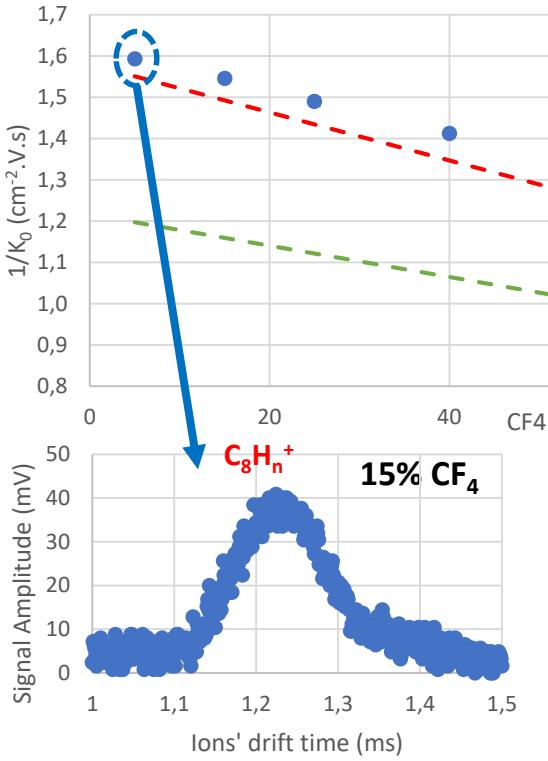


(Charge Transfer Reaction)
 $CF_3^+ + iC_4H_{10} \rightarrow \text{products}$





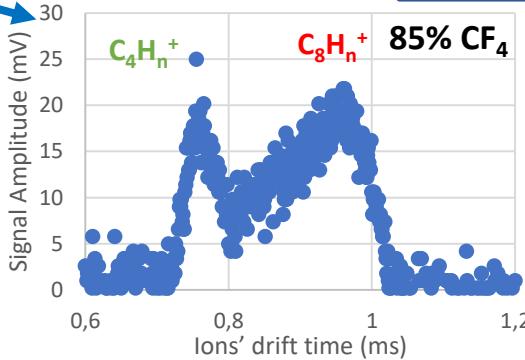
Experimental Results: CF₄-iC₄H₁₀



Increasing CF₄ concentration

Incomplete reactions

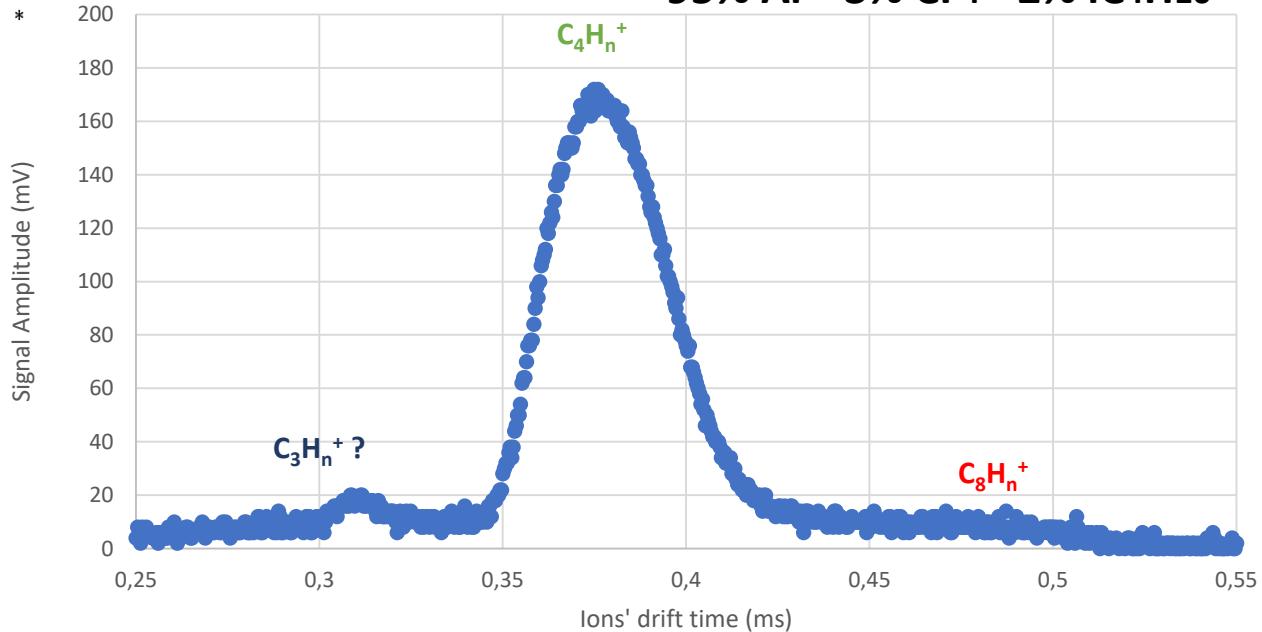
Similar behavior as in Ar-iC₄H₁₀





Experimental Results: Ar-CF₄-iC₄H₁₀

95% Ar - 3% CF₄ - 2% iC₄H₁₀



Same peaks as in 98% Ar – 2% iC₄H₁₀ mixture

Increasing pressure leads to C₁₂H_n⁺ formation!

Theor. Values

(cm² V⁻¹ s⁻¹)

$$K_{C_4H_n^+} \sim 2.15$$



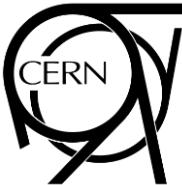
Exp. Values

(cm² V⁻¹ s⁻¹)

$$K_{01} \sim 2.16 \pm 0.02$$

Theor.

0.5 %



Conclusions and Future Work

- Measurements on ion mobility for the LCTPC already performed.
 - Ions drifting were identified.
 - Study alternative gas mixture compositions for the LCTPC.
 - Pursuit the investigation on the mobility of ions in different gas mixtures of practical use (if you have any suggestions feel free to contact us):
 - Ne-CF4
 - Ne-iC4H10
 - Xe-iC4H10
 - New detector for negative ion drift measurements already assembled.
 - ▶ First measurements will follow soon.
 - ▶ *SF6 and mixtures of SF6 with additive gases of interest.*
- With this new detector we expect
to be able to:
- Study the rate constant influence
 - Study the influence of O2 in gas mixtures
 - Study lighter ions (H2)
 - Negative ions (for NITPCs)
 - (...)



Thanks!

Any questions?

You can contact me at
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