LIP Coimbra

RD51 Collaboration

# Ion mobility in Relevant Gas Mixtures
# A Review

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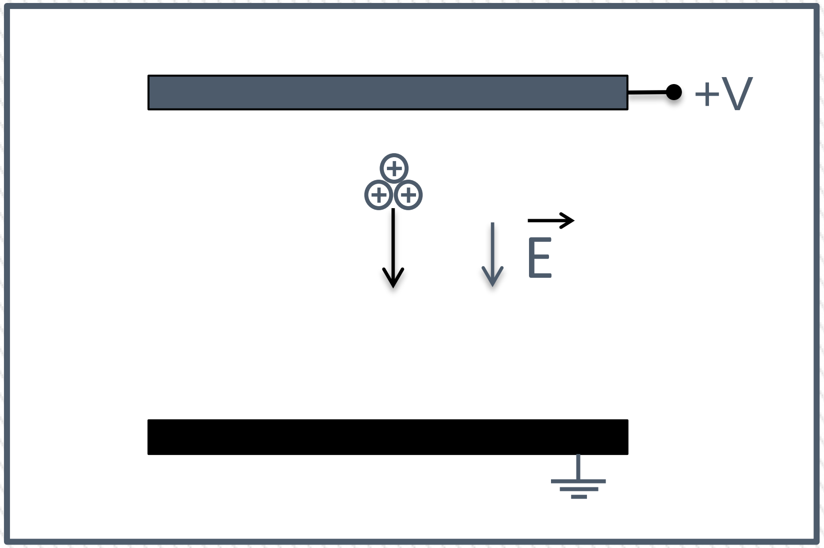
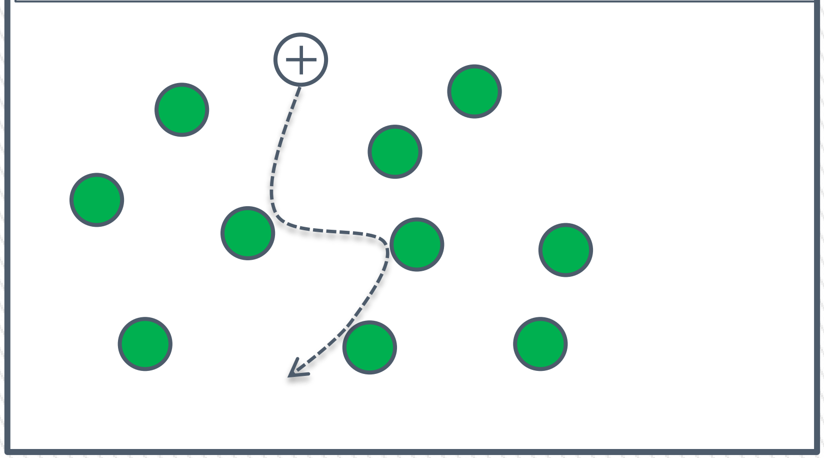
# Basics

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




**Microscopically …**



## 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

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

m – reduced mass

a – neutral polarizability

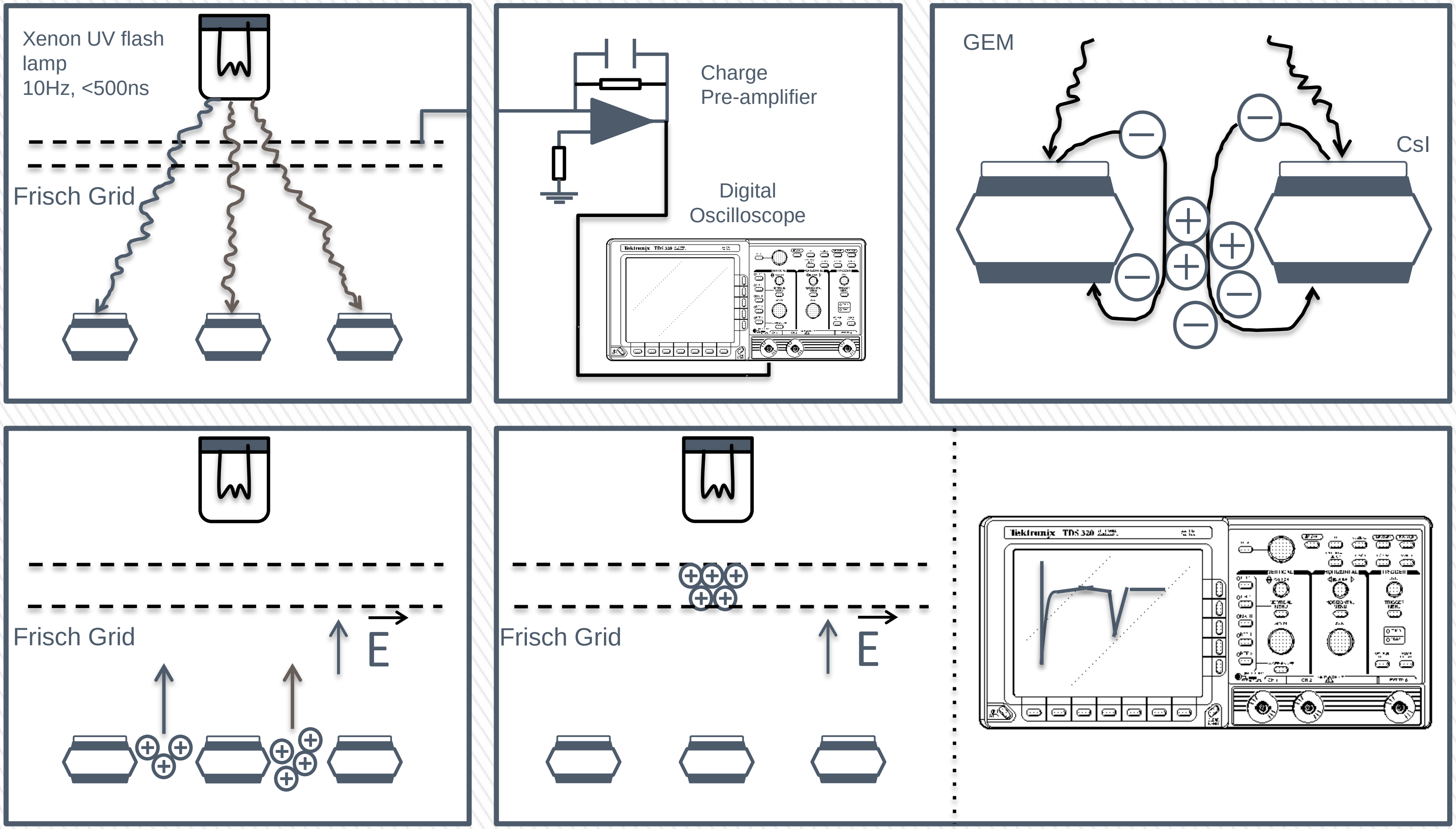
## Blanc's Law

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

$f_1$,$f_2$– molar fraction of gas 1, 2

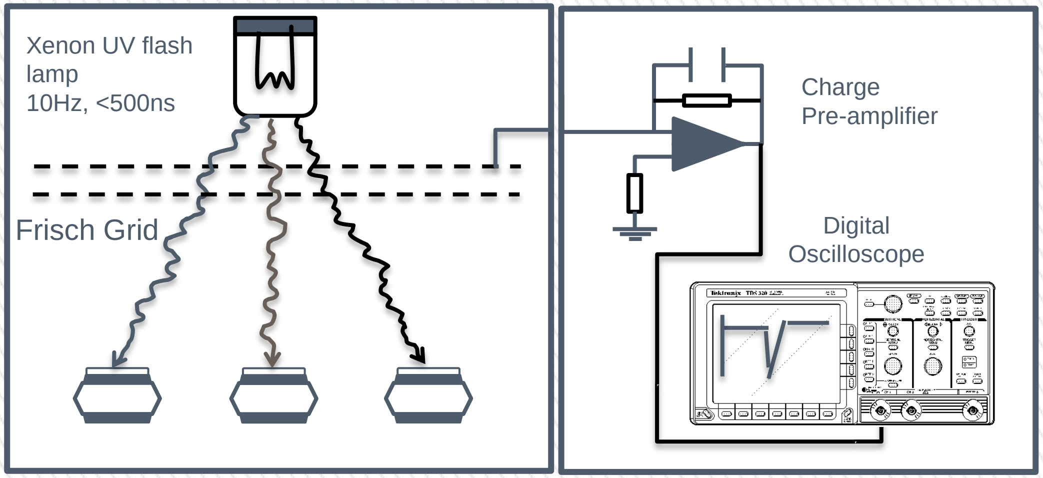
$K_{0g1}$, $K_{0g2}$ – ion mobility in the gas 1 and 2

# Experimental Setup and Working Principle




(Neves, Conde and Távora, 2007)

# Experimental Setup and Working Principle



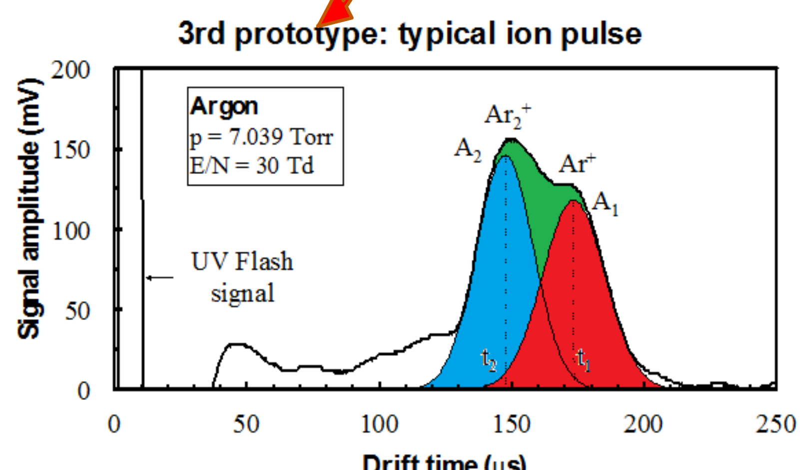

- Subtract the background to the signal
- Identify possible peaks
- Fit Gaussian curves to the spectrum obtained

**Peaks centroids**

⬇

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

$$v_{\mathrm{d}} = \frac{x_{drift}}{t_{drift}} \rightarrow K = \frac{v_{\mathrm{d}}}{E}$$




$K_{01} = 1.57\ cm^2V^{-1}s^{-1}$ ($Ar^+$)
$K_{02} = 1.92\ cm^2V^{-1}s^{-1}$ ($Ar_2^+$)

# Ion Identification Process

**Identification of candidate ions**

- GEM Voltage
- Possible Reactions
    - Cross Section
    - Reaction Rates

**Most Probable Candidates**

**Identification of expected mobility**

- Langevin Limit (formula)
- Blanc's law (mixtures)

**Compare with experimental results**

Theoretical Values = Experimental Values

**Match?**

# Ion Identification Process

Assume that Experimental Results and Theoretical Values are identical

Experimental Values

Theoretical Values

Identification of the ion's mass

- Langevin Limit (formula)
- Blanc's law (mixtures)

Identification of candidate ions based on the mass

**Most Probable Candidates**

**Candidate's Mass**

**=**

**Ion's Expected Mass**

**Match?**

# Experimental Results: Ar

**Ionization**

$Ar + e \rightarrow Ar^{+} + e$

**Above threshold 15.76 eV**

**Appearance Energies**

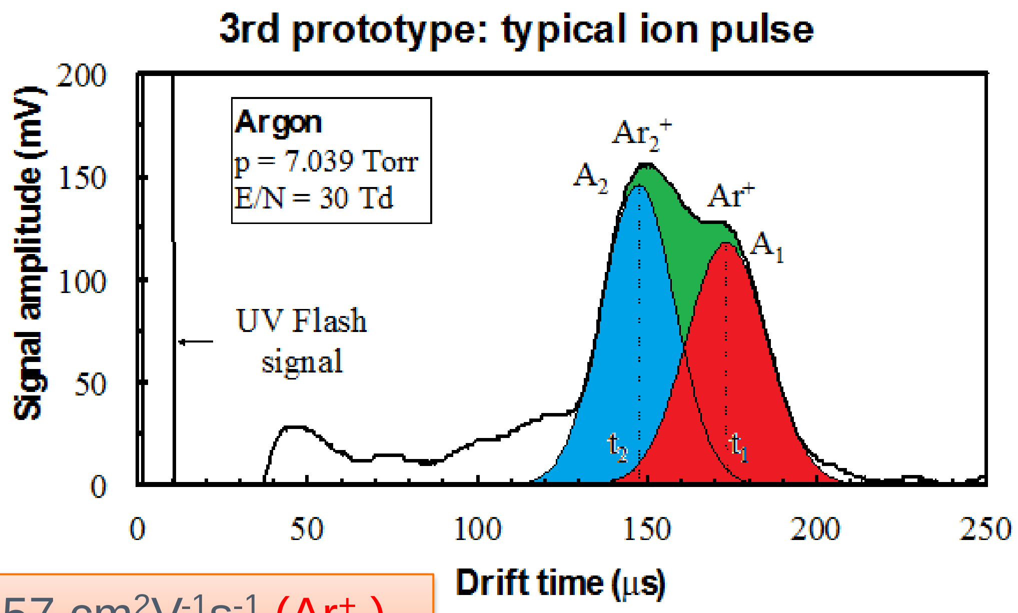
$Ar^{+}$ 15.76 eV

**Secondary Reactions**

$Ar^{+} + 2Ar \rightarrow Ar_2^{+} + Ar$

$Ar^{+} + Ar \rightarrow Ar + Ar^{+}$

For Vgem = 20




$K_{01} = 1.57\ cm^2V^{-1}s^{-1}$ ($Ar^{+}$)
$K_{02} = 1.92\ cm^2V^{-1}s^{-1}$ ($Ar_2^{+}$)

# Experimental Results: $CO_2$

**Ionization**

$CO_2 + e \rightarrow CO_2^+ + e$

Above threshold 13.8 eV

$CO_2 + e \rightarrow CO_2^+ + e$

$\rightarrow CO^+ + 1/2O_2 + e$

$\rightarrow O^+ + CO + e$

above 19.5 eV

**Appearance Energies**

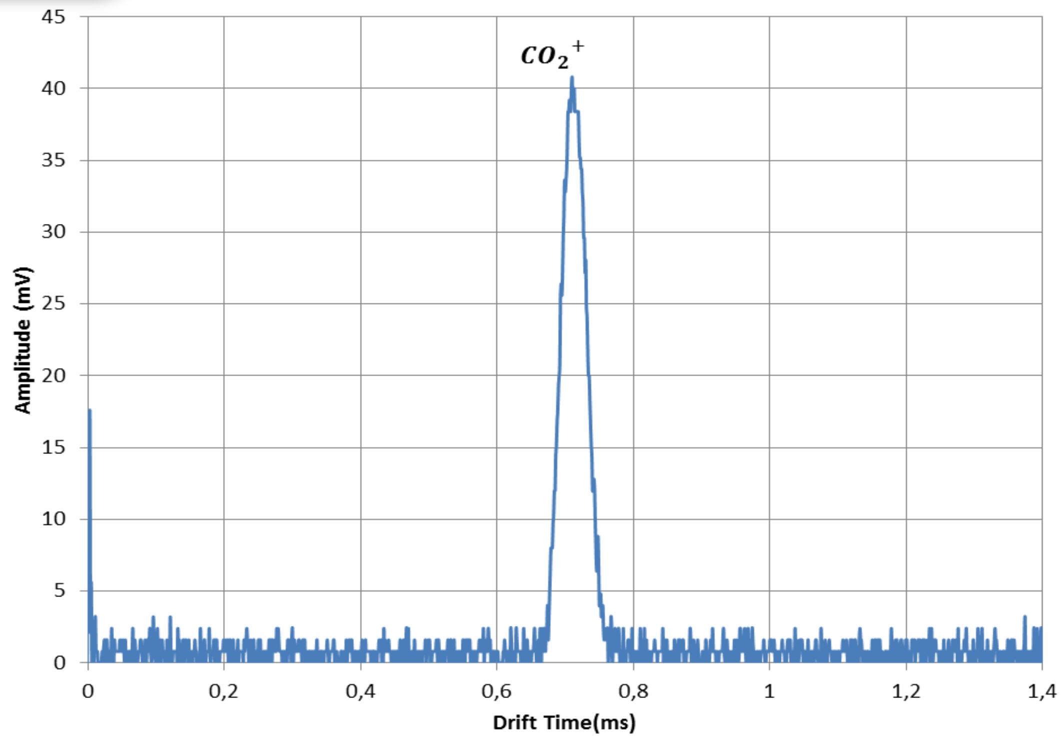
| | |
|---|---|
| $CO_2^+$ | 13.8 eV |
| $CO^+$ | 19.5 eV |
| $O^+$ | 19.1 eV |

**Secondary Reactions**

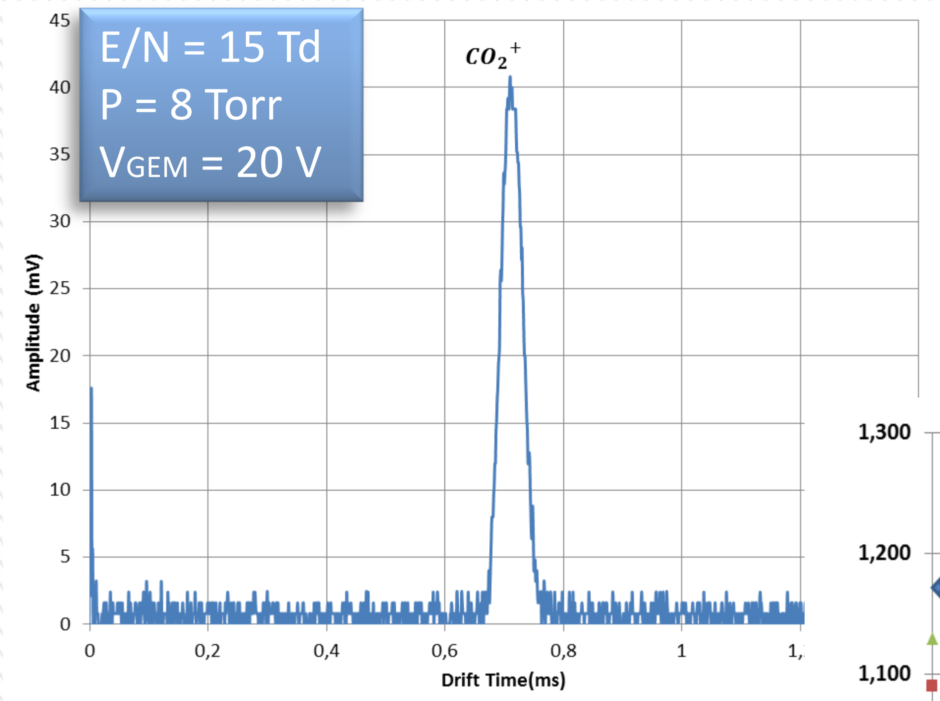
$CO_2^+ + CO_2 \rightarrow CO_2 + CO_2^+$

$CO^+ + CO_2 \rightarrow CO_2^+ + CO$

$O^+ + CO_2 \rightarrow O_2^+ + CO$



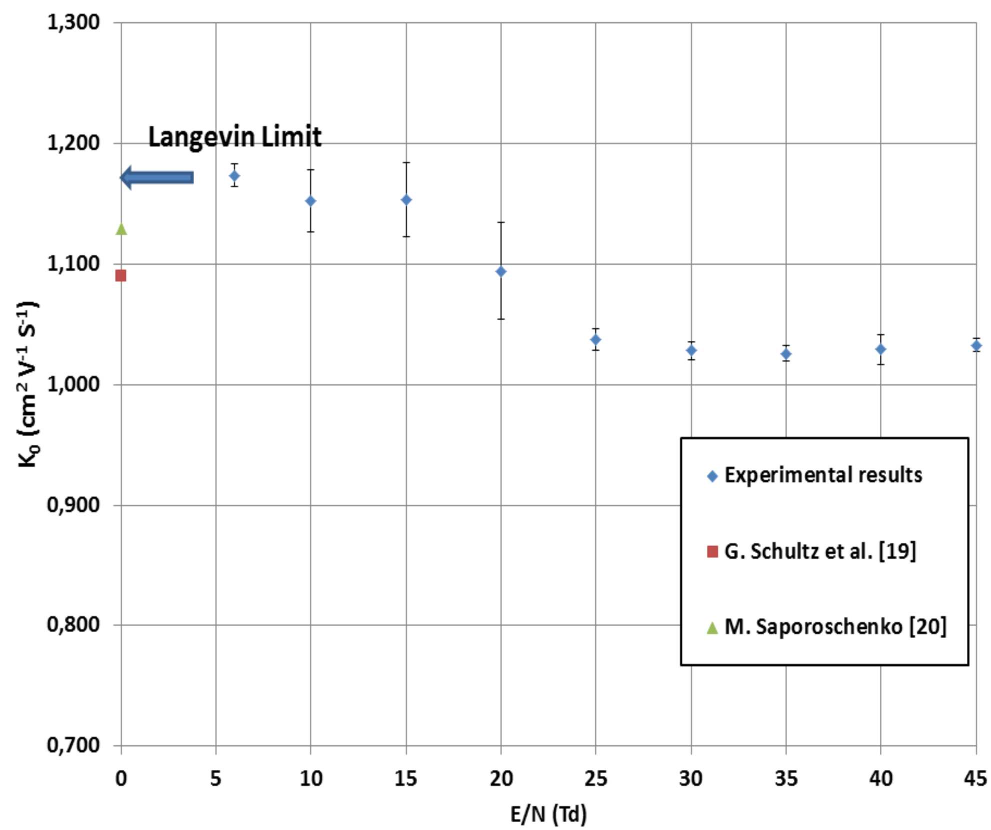
# Experimental Results: $CO_2$




$K_{01} \sim 1.17\ cm^2V^{-1}s^{-1}$ **$CO_2^+$**

Good agreement with earlier reported works:

1. **M. Saporoschenko :** $1.13\ cm^2V^{-1}s^{-1}$
2. **G. Schultz et al. :** $1.09\ cm^2V^{-1}s^{-1}$



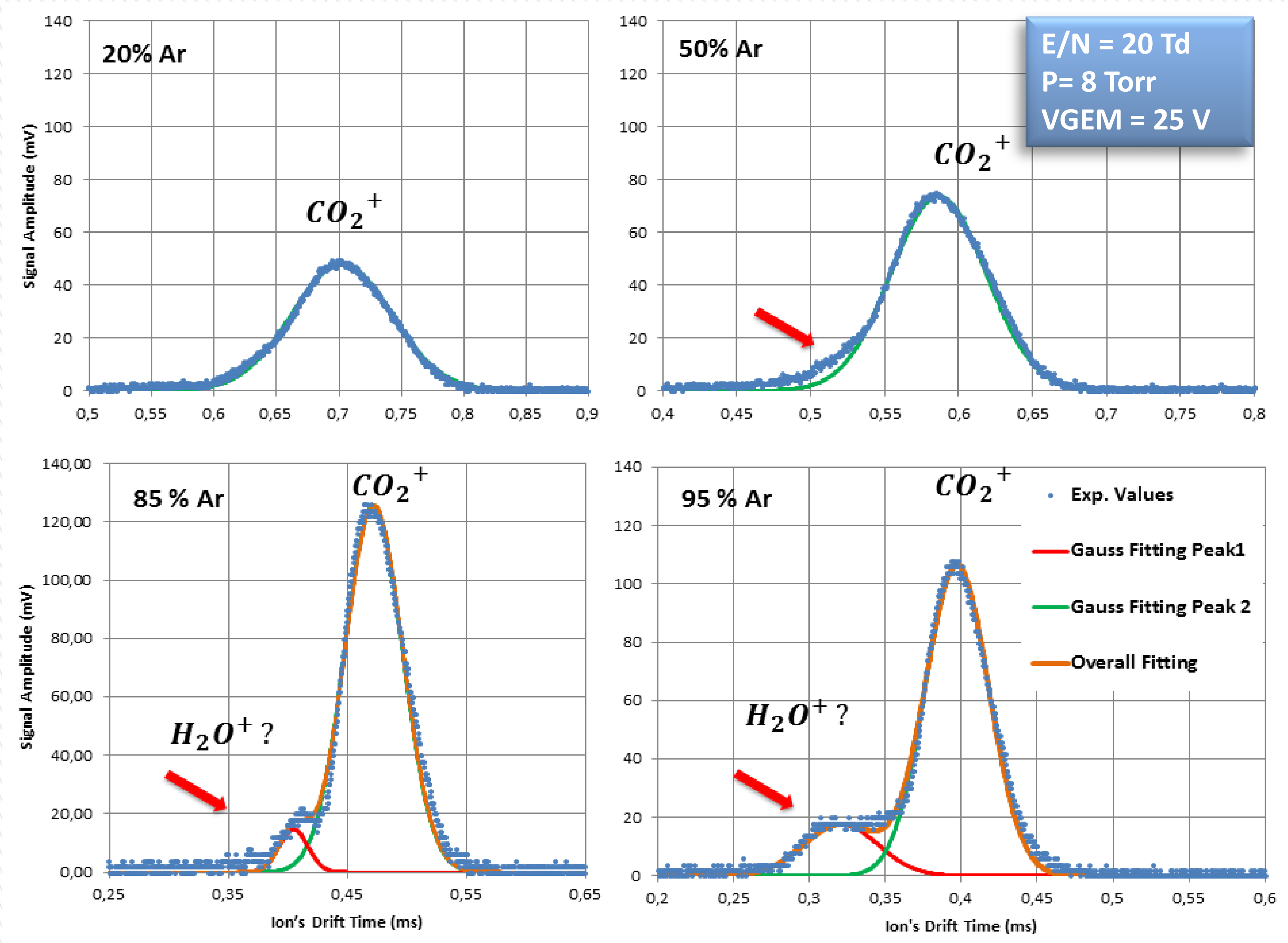

**Calc. Langevin Limit**

$1.82\ cm^2V^{-1}s^{-1} \neq 1.17\ cm^2V^{-1}s^{-1}$

**Charge Transfer Process**

$$CO_2^+ + CO_2 \rightarrow CO_2 + CO_2^+$$

# Experimental Results: Ar-$CO_2$



# Experimental Results: Ar-$CO_2$

- Ions move **faster** with the presence of Ar!

Correction factor

$$\frac{1}{K_{0\,Real}} = \frac{1}{K_{0\,Blanc}} - \Delta\frac{1}{K_{0-CO_2}}\left[\left(\frac{P(Ar\%)}{100}\right)^2 - 1\right]$$

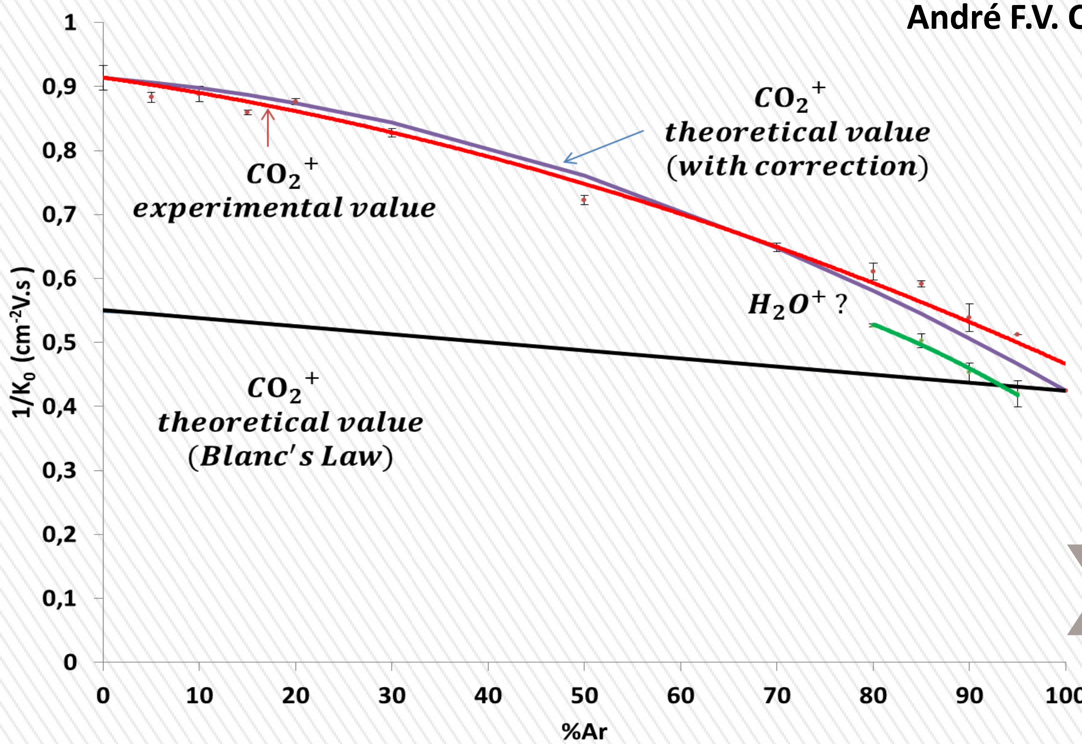
$$\Delta\frac{1}{K_{0-CO_2}} = \frac{1}{K_{0\,(pure\,CO_2 Exp)}} - \frac{1}{K_{0\,(pure\,CO_2 Theoretical)}}$$

Suggested by: André F.V. Cortez

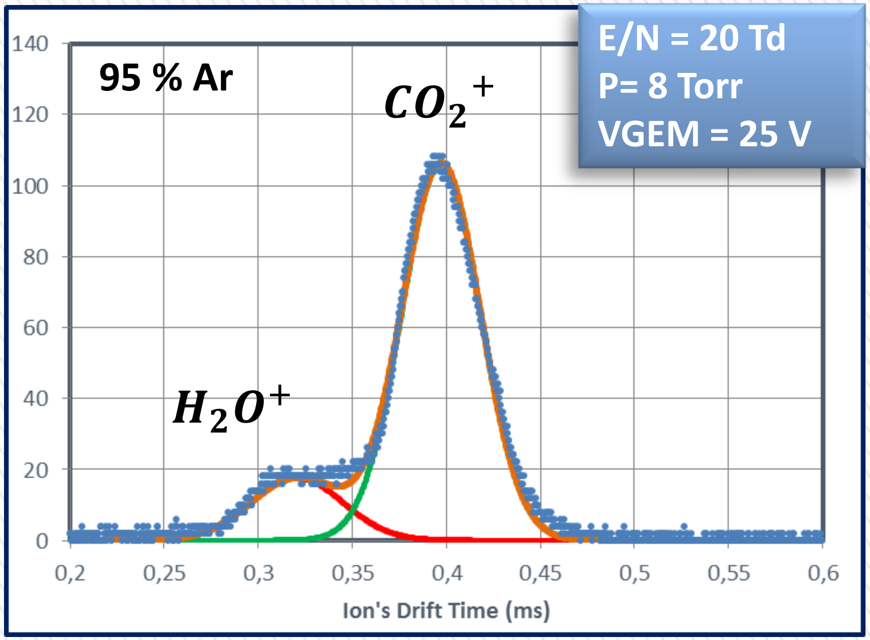
We believe the **2nd** peak is maybe due to:

$H_2O^+$

Appearance of a **2nd** peak for: **Ar > 80%**



# Experimental Results: Ar-$CO_2$




(Charge Transfer Reaction)

$Ar^+ + CO_2 \rightarrow CO_2^+ + Ar$

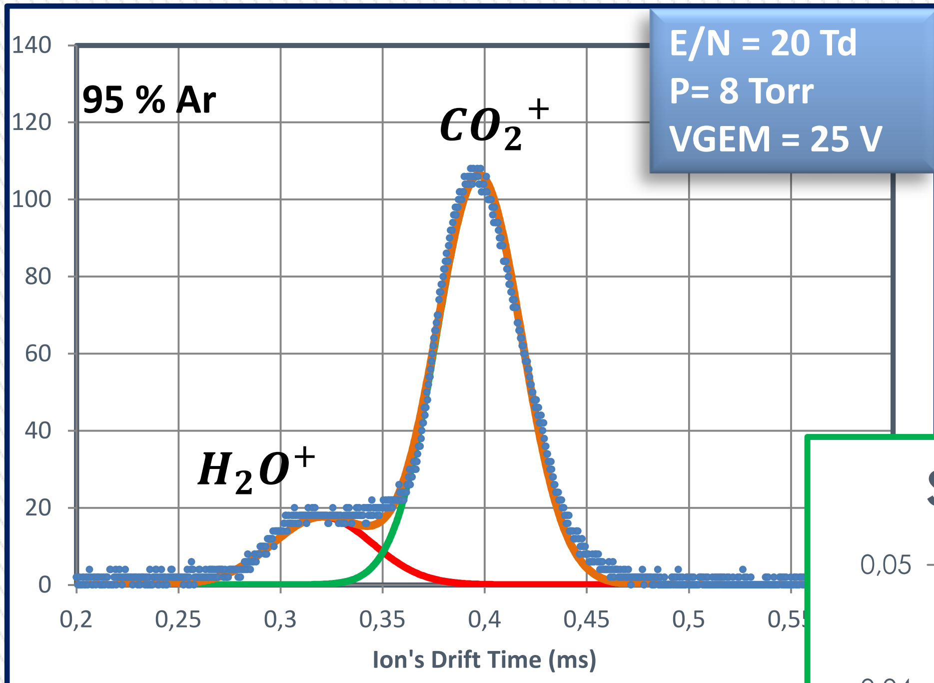
**Prevents the formation of $Ar_2^+$.**

Same Ion Product

$K_{02}$ ~ 1.953 $cm^2V^{-1}s^{-1}$ ($CO_2^+$?)

$K_{01}$ ~ 2.39 $cm^2V^{-1}s^{-1}$ ($O_2^+$ or $H_2O^+$?)

# Experimental Results: Ar-$CO_2$

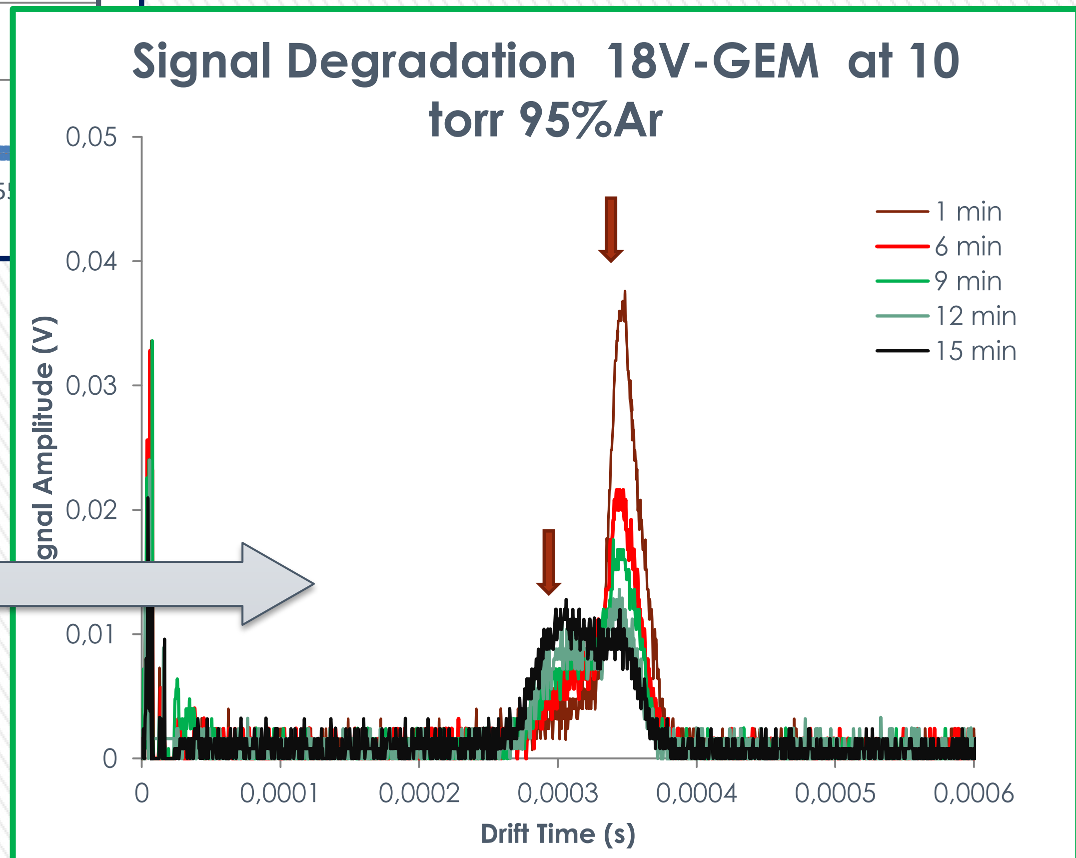



## Why is the first peak not $O_2^+$?

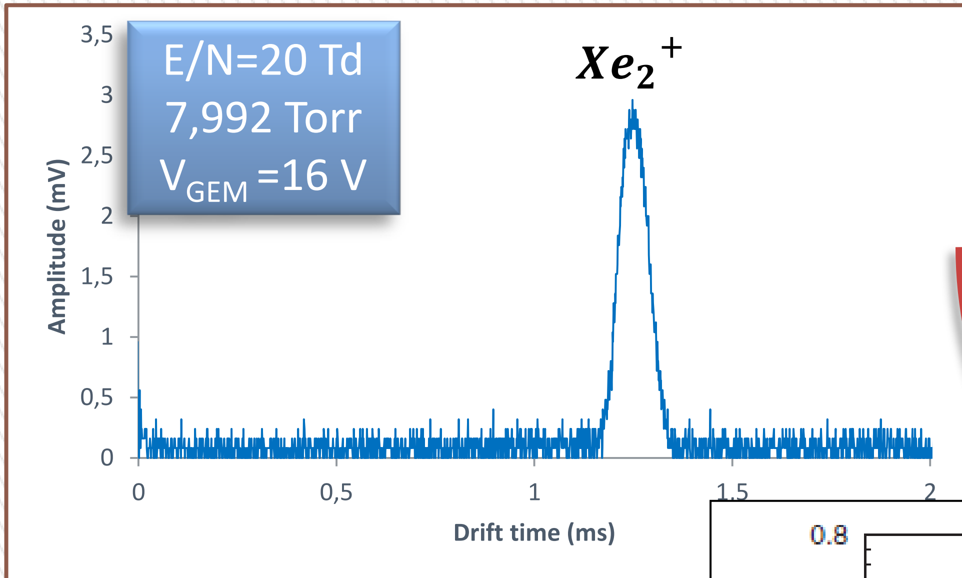
- The small bump appears even for lower energies (18 eV).
- Even for 25 eV, Oxygen has a small probability to be formed

**Causes:**

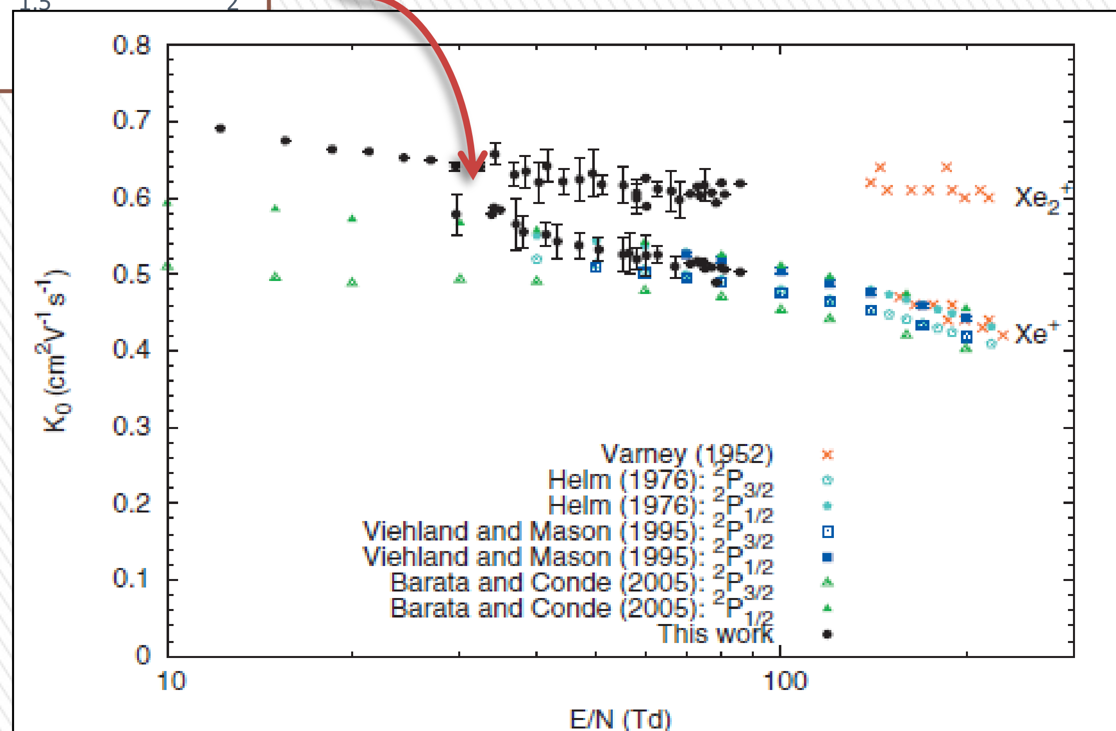
- Gas purity (99,99997%) (HP)
- Outgassing process (LP)



# Experimental Results: Xe

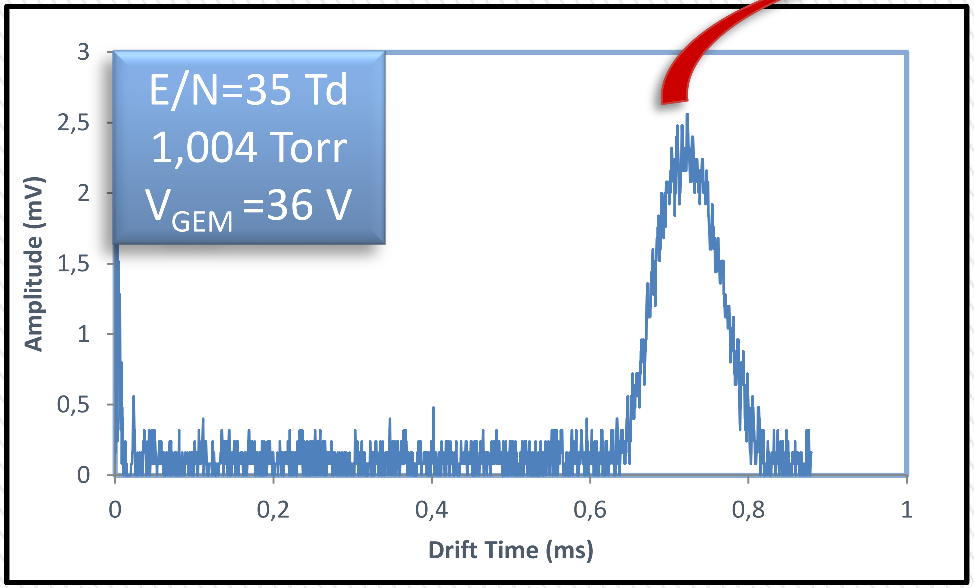



$K_{01}$ ~ 0,637 $cm^2V^{-1}s^{-1}$ **$Xe_2^+$**




P. Neves, C.A. N. Conde and L.M.N Távora

# Experimental Results: TMA



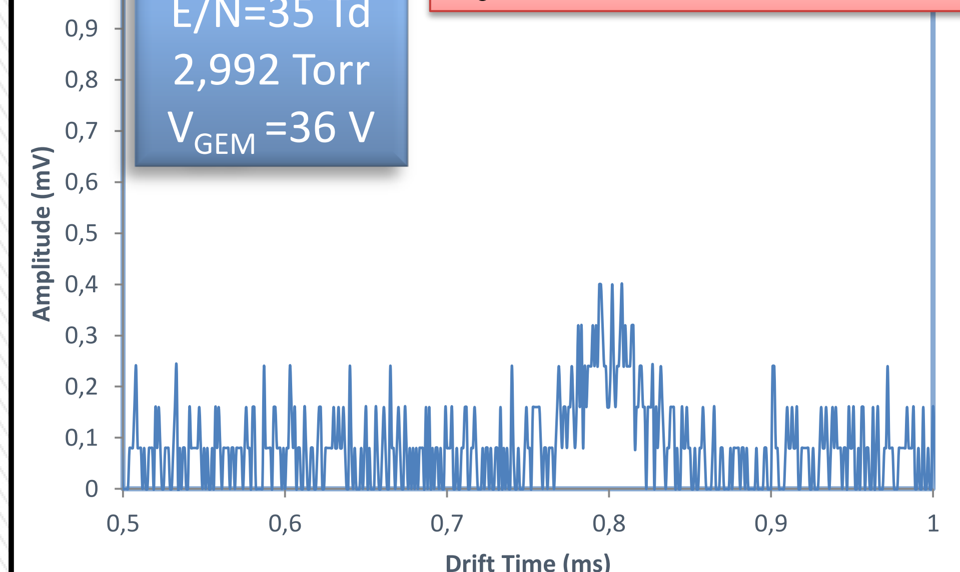

The reduced mobility has a strong dependence of the field for pressures above 3 Torr

Not in Steady State Regime

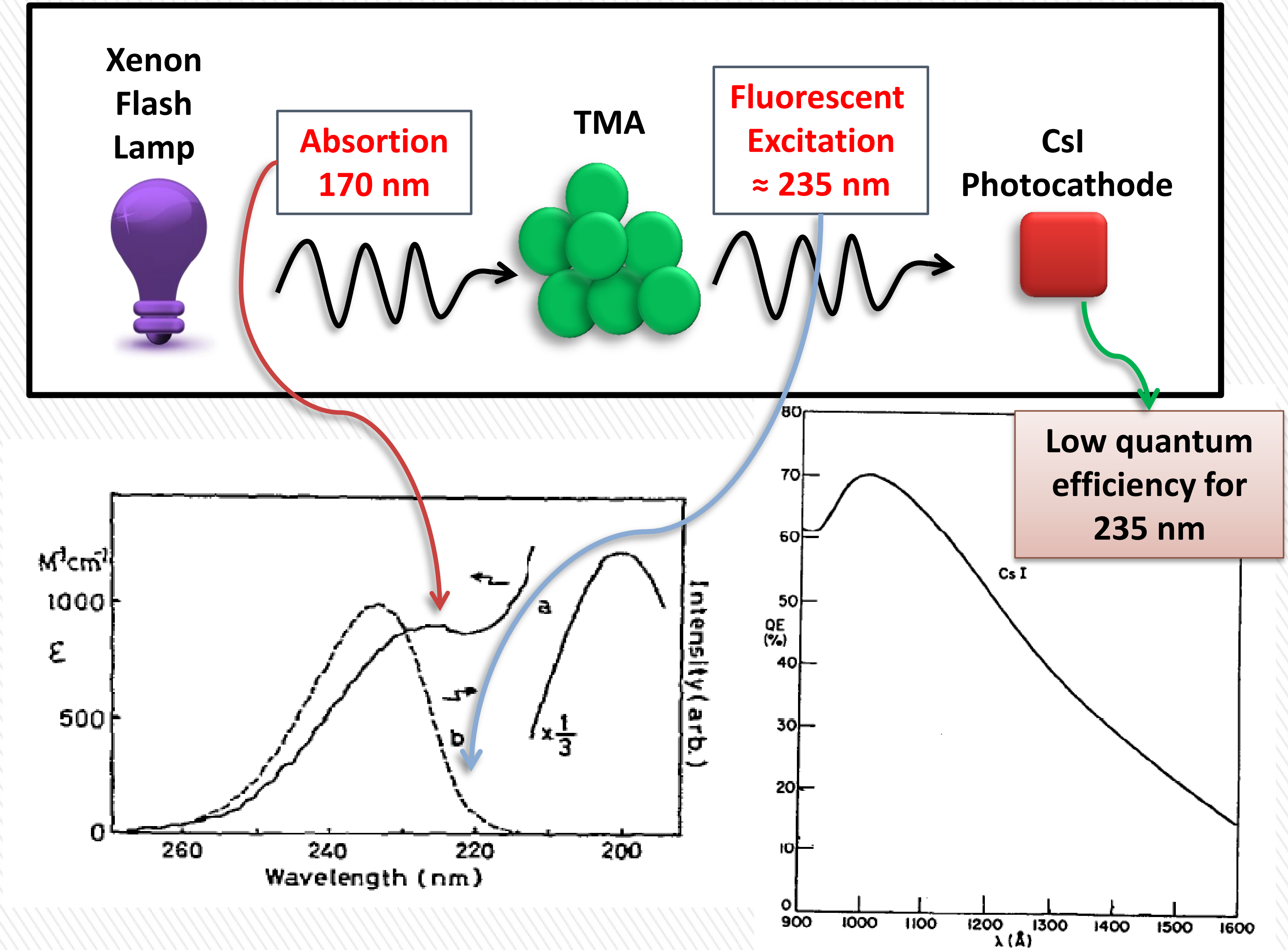
**Ionization Potential**
**7,8 – 9,4 eV**

**It's not possible to observed any peak in pure TMA for pressures above 3 torr or for low voltages in the GEM**

$K_0$=0.567±0,013 $cm^2V^{-1}s^{-1}$



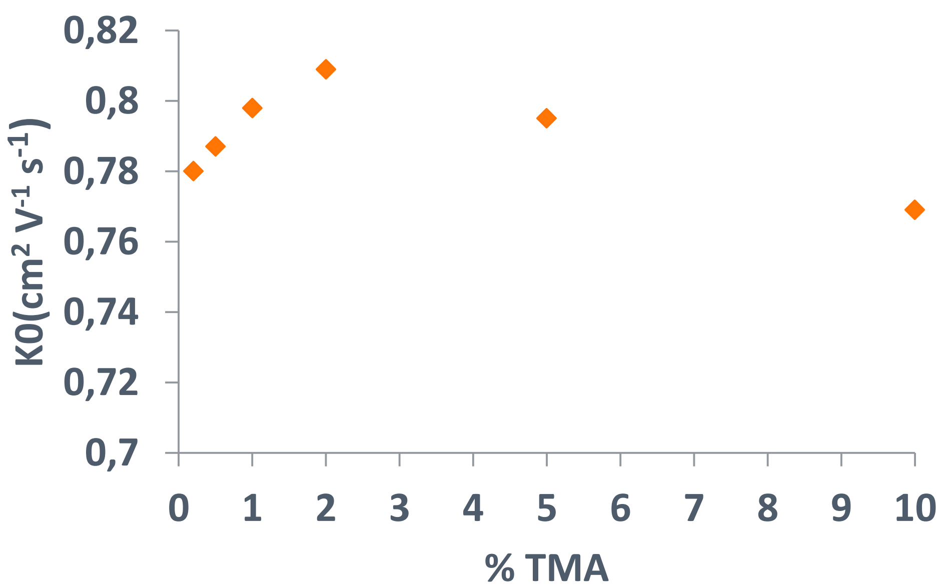
# Experimental Results: TMA



# Experimental Results: Xe-TMA

Interesting results

There is an **increase** in reduced mobility $K_0$
(Preliminary Results)




**Discharges**

- For the same fields does not occur for pure TMA or pure Xe.
- Seems to have a dependence with the relative amounts of TMA in the mixture.

**The results obtained for TMA will be presented in NEXT-Experiment Collaboration Meeting in 6th and 7th of November**

# Future Work

- Pursuit the investigation on the mobility of ions in different gas mixtures of practical use:
  *Ne-CO2*
  *Ne-CO2-N2*
  *Ar-CF4*
  *Ne-CF4*

- Optimization of the detector:
  *Variable Drift Distance*
  *Higher Pressure*
  → 
  - Rate constant influence
  - Study lighter ions (H2)
  - (...)

- Study of improved ion-neutral interaction models

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# Thank you!

**Universidade de Coimbra**

# Mixing Langevin Limit with Blanc's Law

## Langevin Limit

To determine the mobility of an ion within a gas (not the parent).

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

$\mu$ – reduced mass
$\alpha$ – neutral polarizability

### Theoretical Mobility Values

## Experimental Ion Mobility Values

Mobility of an ion within his parent gas (if known).

## Blanc's Law

Used to calculate the mobility of an ion in a gas mixture.

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

$f_1$ , $f_2$ – molar fraction of gas 1 and 2

**Mobility of an ion in a mixture**

# Candidate ions identification

## GEM Voltage

- Maximum energy gained by electrons.
- Primary ions possible to be formed.

Rg (pure)

$Rg + e \rightarrow Rg^{+} + 2e$

## Possible Reactions

Ions formed through reactions of the primary ions with neutral atoms or molecules from the medium.

## Select Most Probable Ions

## Reaction Time

Used to calculate the mobility of an ion in a gas mixture.

$$\tau = \frac{1}{kN}$$

- Identification the possible ions present.

## Universal decay law

Used to calculate the variation of the concentration of a specific ion in a mixture.

$Rg + Rg^{+} \xrightarrow{k} X^{+} + Y$

$$\frac{[Rg^{+}]}{[Rg^{+}]_{0}} = e^{-\frac{t}{\tau}}$$

$$\frac{[X^{+}]}{[X^{+}]_{0}} = 1 - \frac{[Rg^{+}]}{[Rg^{+}]_{0}}$$

- Identification the possible ions present.