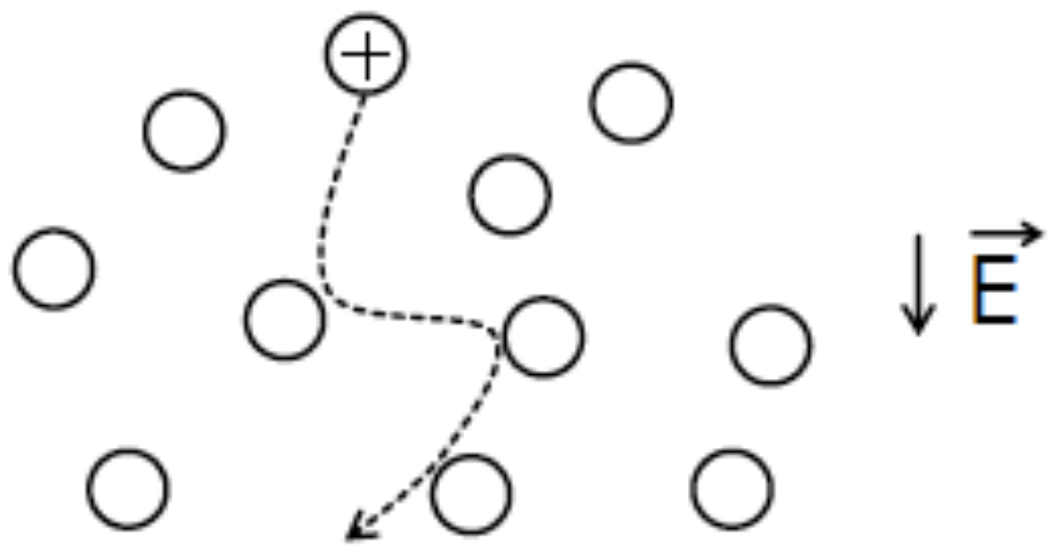
Stony Brook University

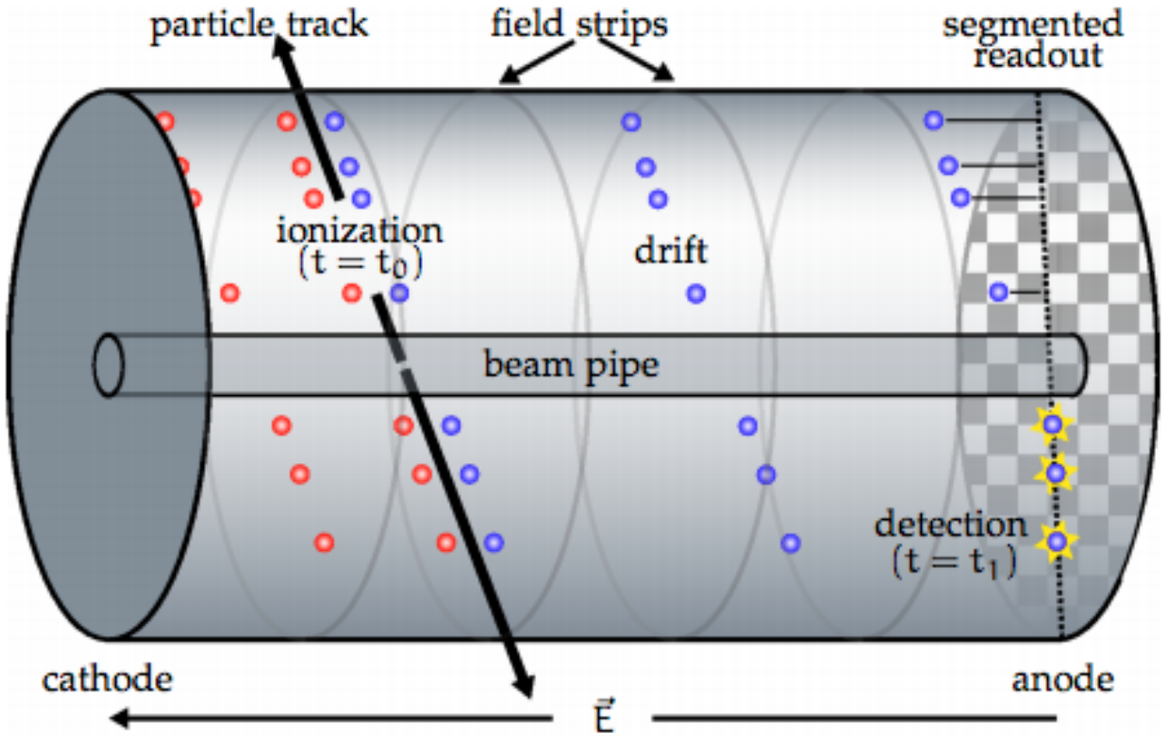
Ion Mobility in Gasses

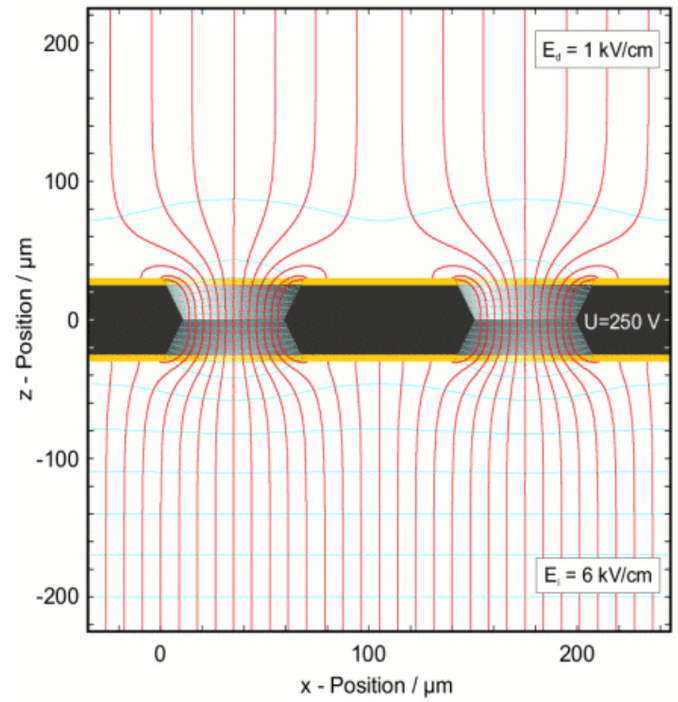


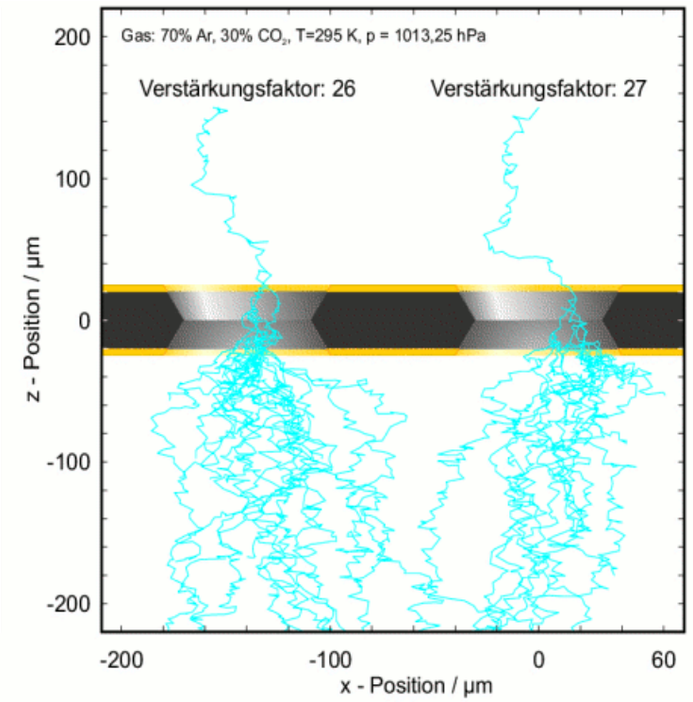
Nils Feege

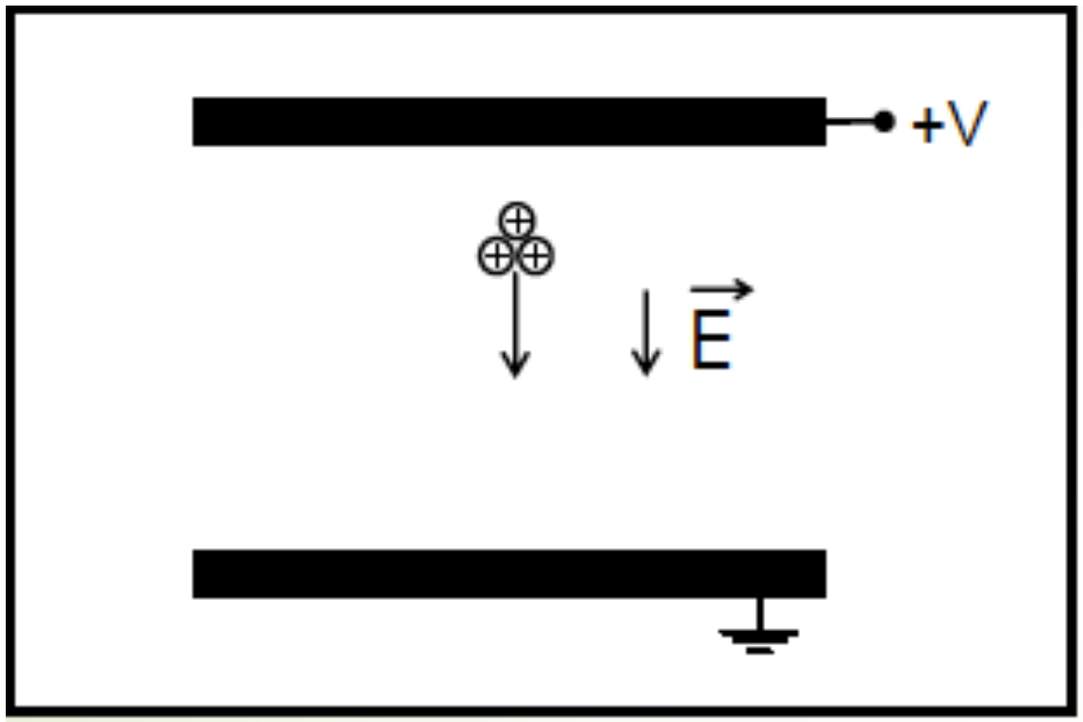
TPC Meeting, Stony Brook University, September 28, 2015

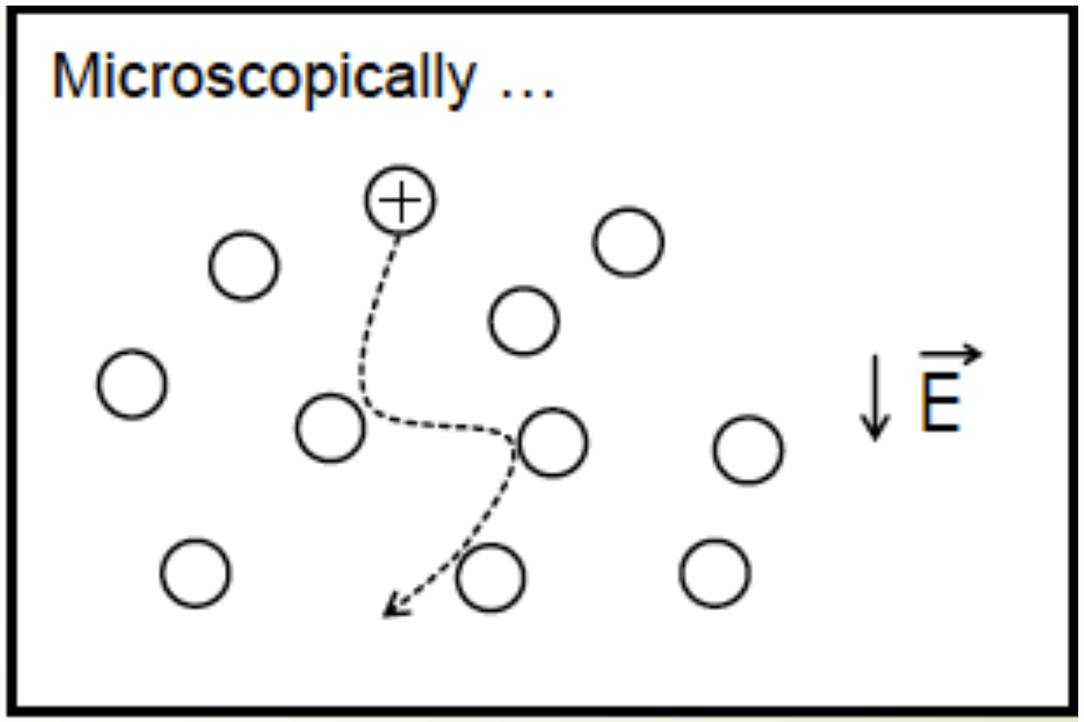
GEMs and Ions



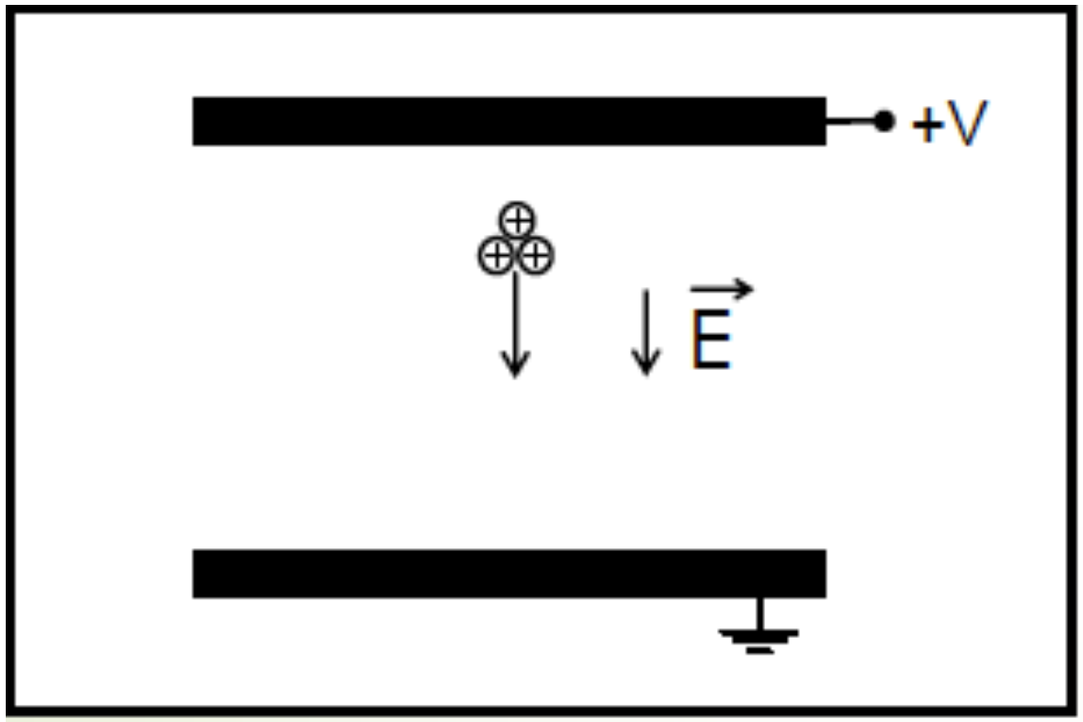


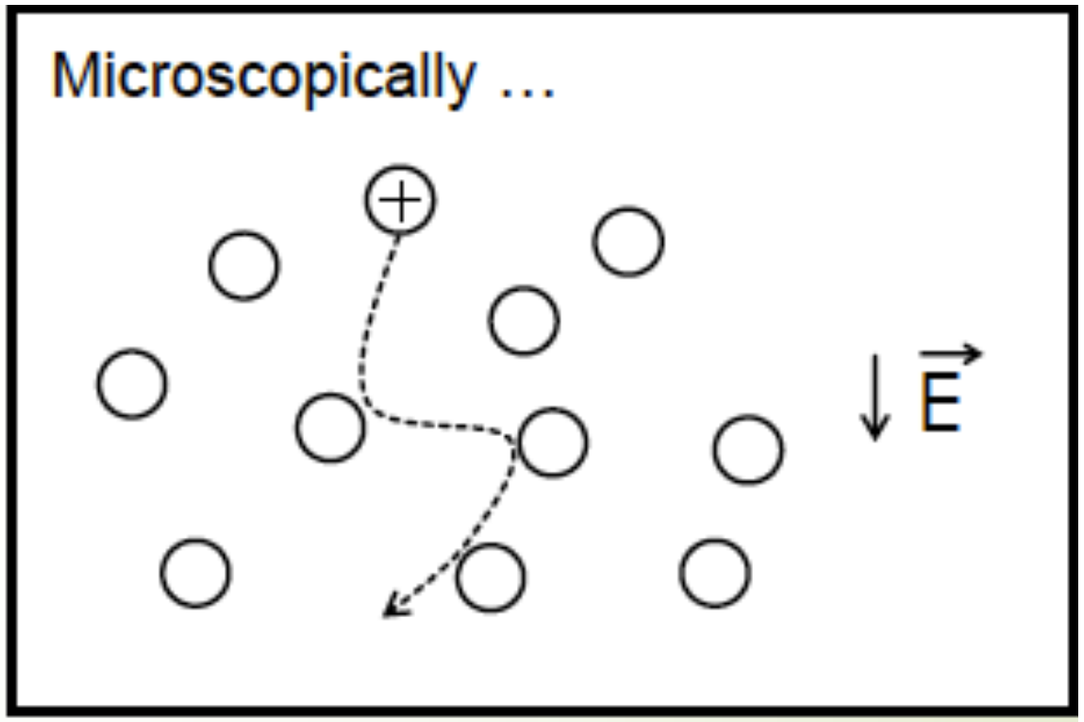






Basic Concepts





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

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

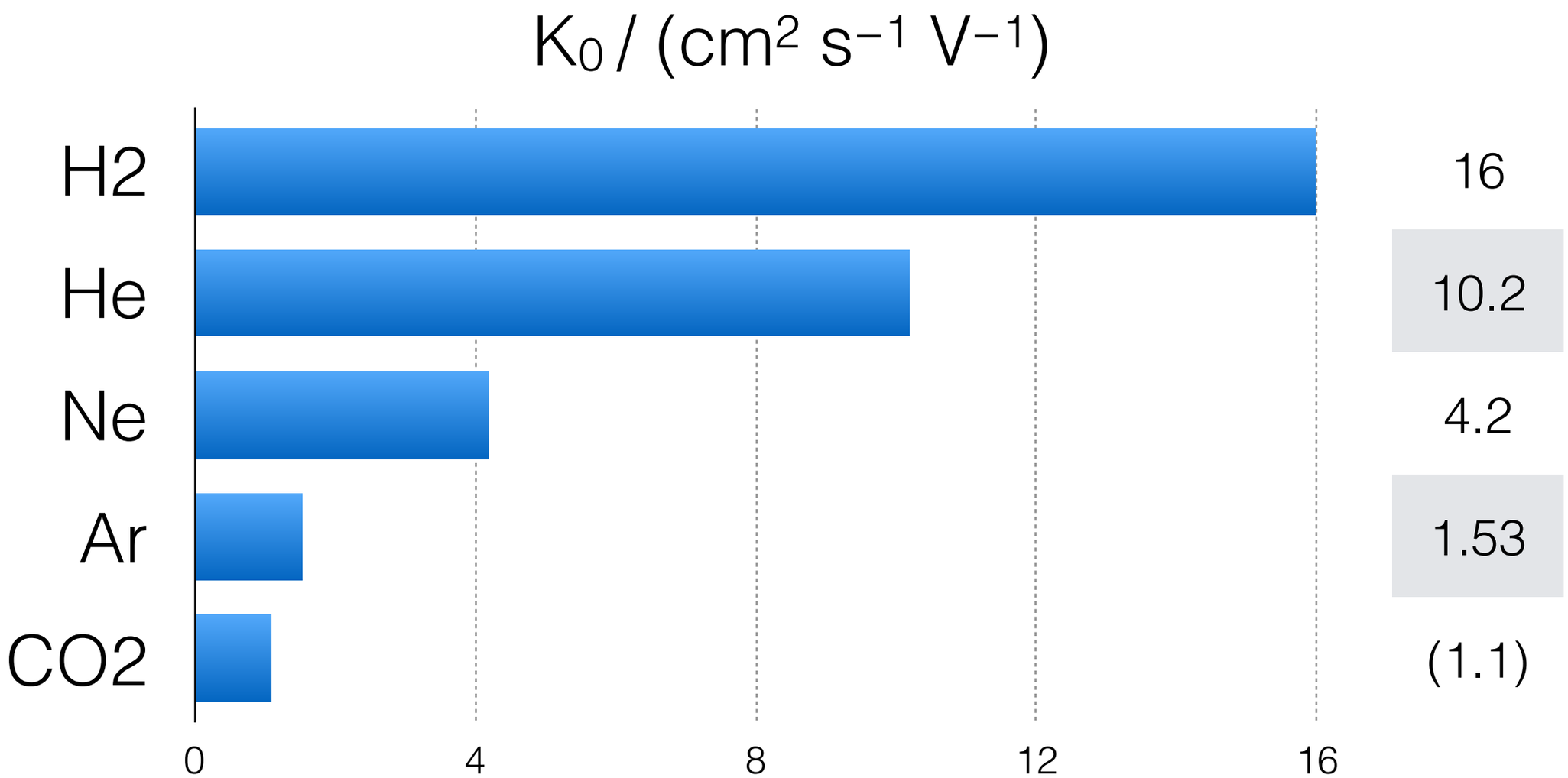
f_1, f_2– molar fraction of gas 1, 2
K_{0g1}, K_{0g2} – ion mobility in the gas 1 and gas 2

'Ohm's law'

$$\mu = \frac{m_1 m_2}{m_1 + m_2}$$

'parallel circuit'

Examples of reduced mobilities for positive ions in their parent gas



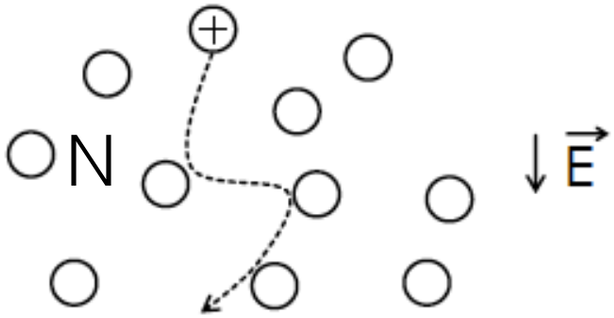
Mobility as function of reduced electric field E/N and E/p

E / N = electric field strength / gas number density

[E / N] = 1 Townsend = 1 Td = 10^{-17} V cm^2

1 atm, 20 °C: N = 2.5 · 10^{19} / cm^3

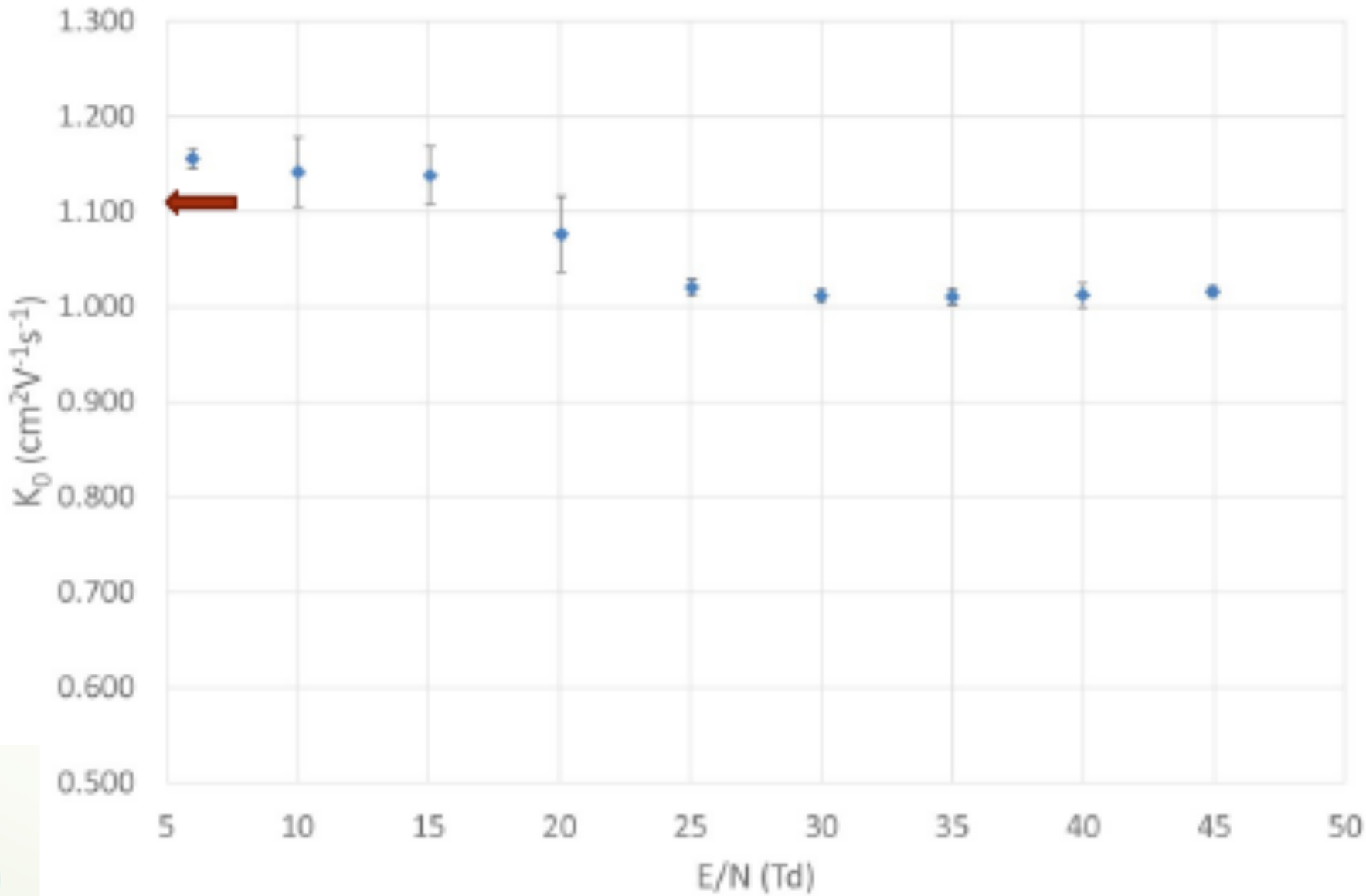
1 atm, 20 °C, 400 V/cm: E / N = 1.6 Td



E / p = electrical field strength / pressure (*historic* unit)

- at temperature T = 96.62 K and pressure p = 1 torr:
  E/N = 1 Td ⇆ E/p = 1 V cm^{-1} torr^{-1}
- at room temperature and pressure:
  E/N Td = (1.0354 · 10^{-2} T) $(E/p)_T$ V cm^{-1} torr^{-1}

CO2 Measurements



Good agreement with earlier reported work..

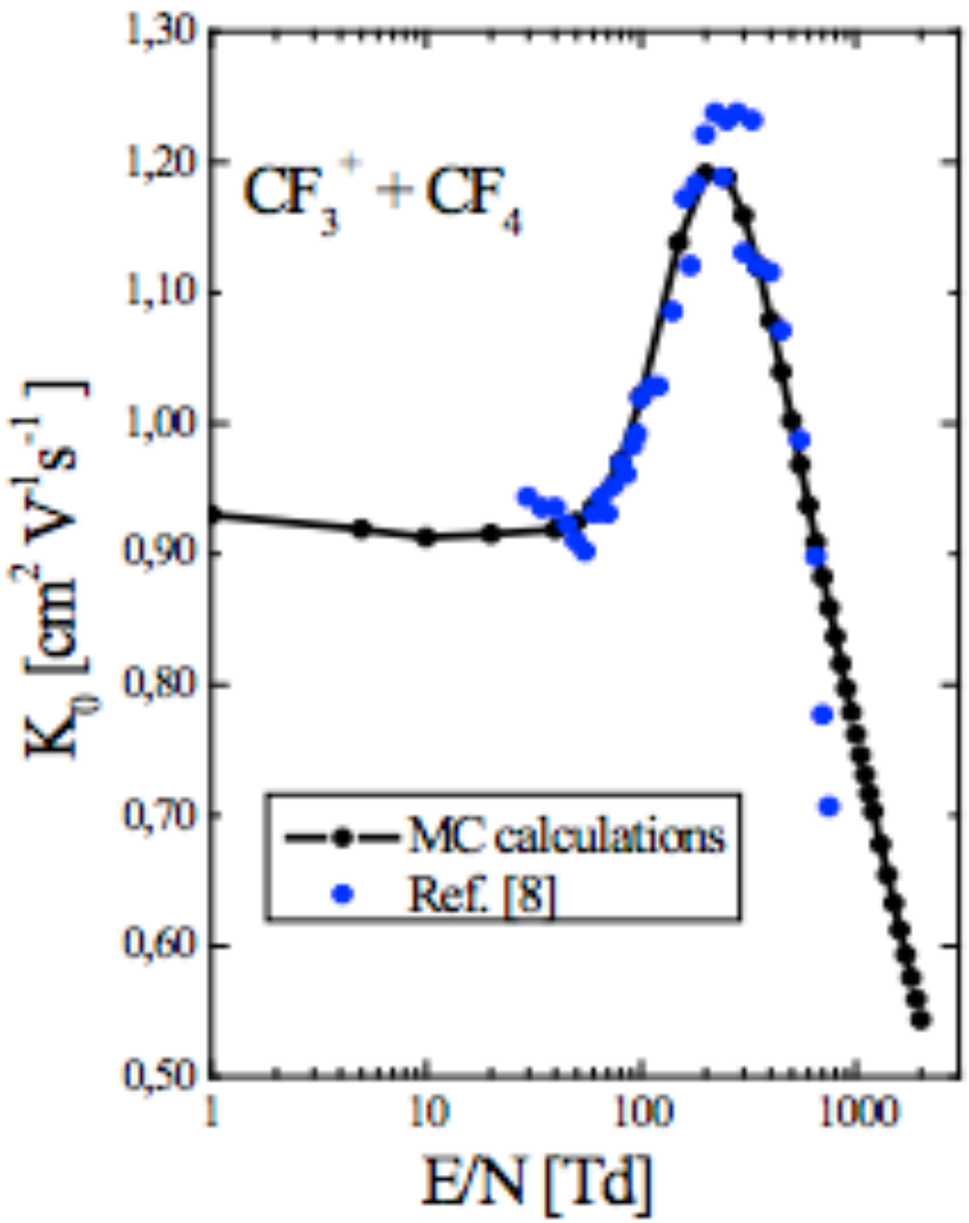
(Schultz, Charpak, Sauli 1977)

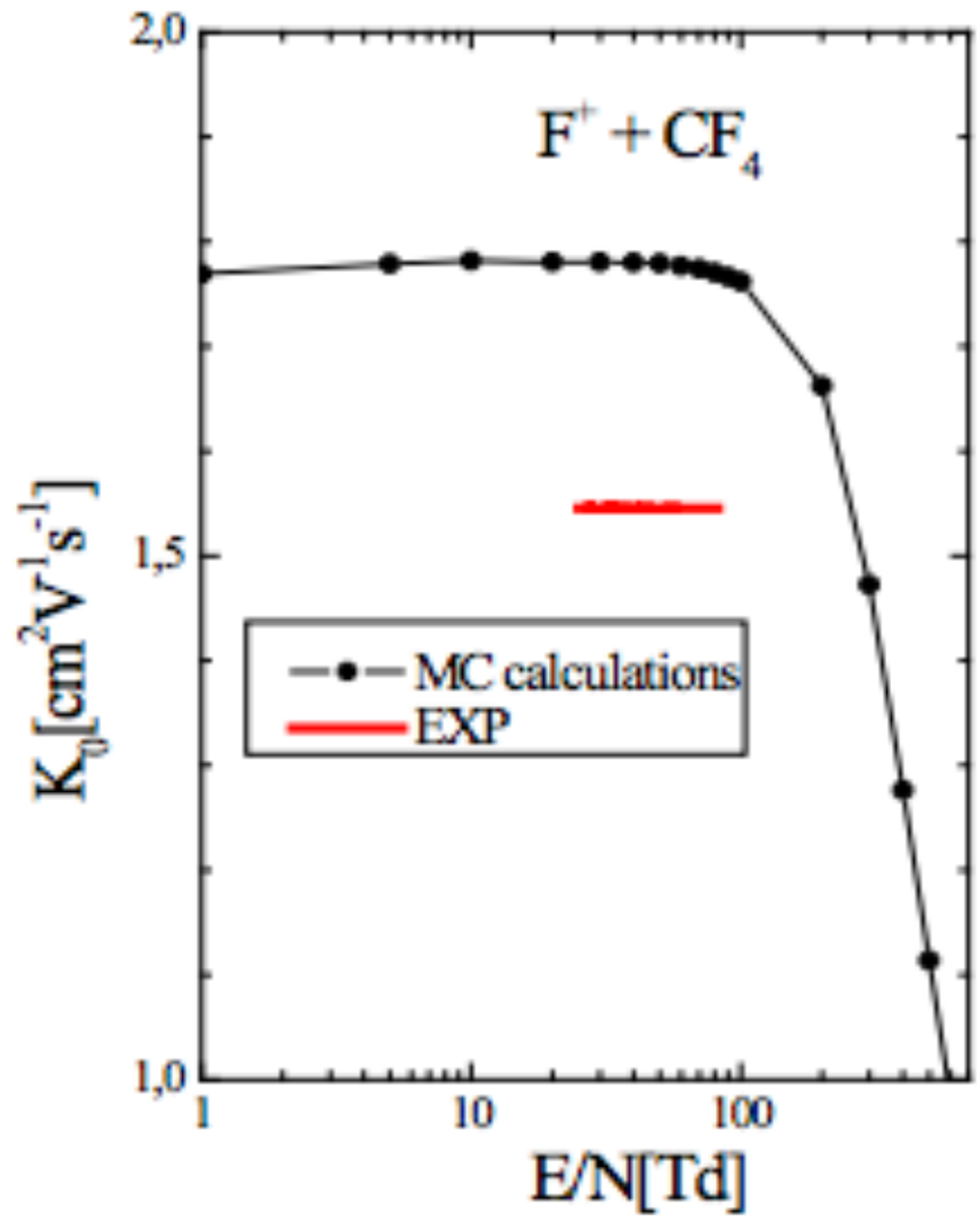
K_{01} ~ 1.09 $cm^2V^{-1}s^{-1}$
(CO_2^+ ?)

$\alpha = 2.63$ Å^3

Calc. Langevin Limit		Experimental value
1.81 $cm^2V^{-1}s^{-1}$	≠	1.16 $cm^2V^{-1}s^{-1}$

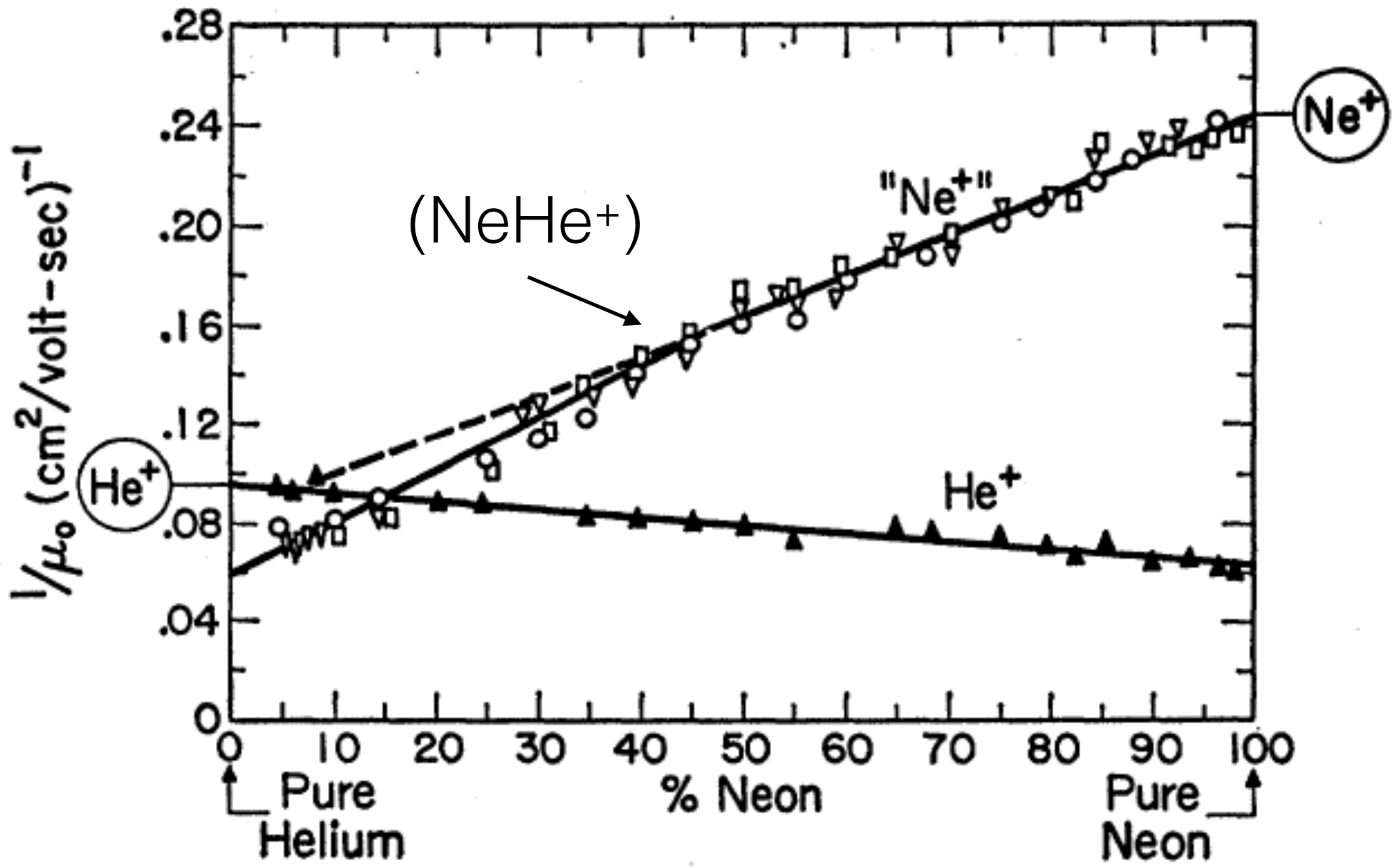
Example: Ions in CF4





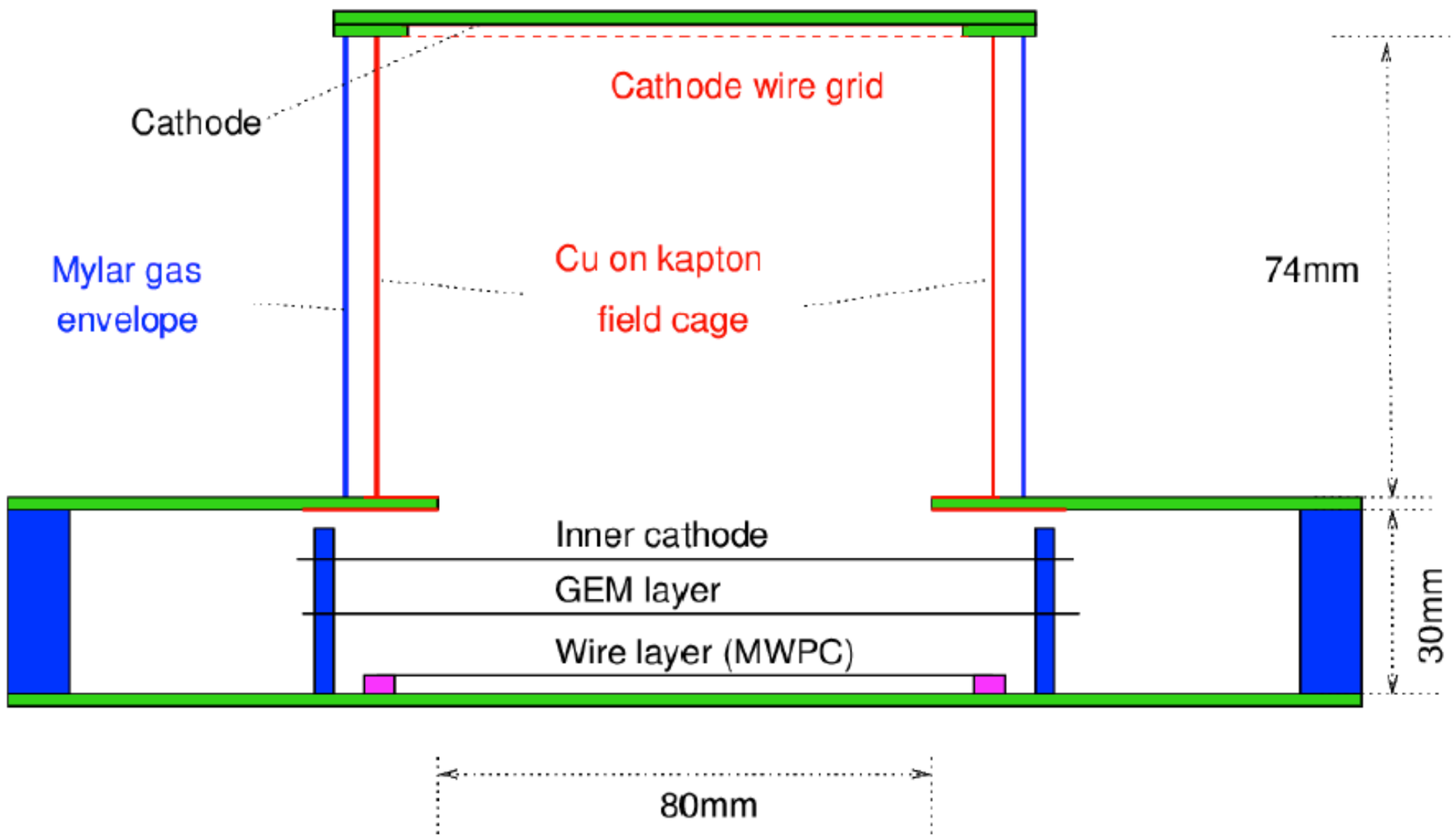
Blanc's Law - Dominant ions affect slope

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



Measuring Ion Mobility

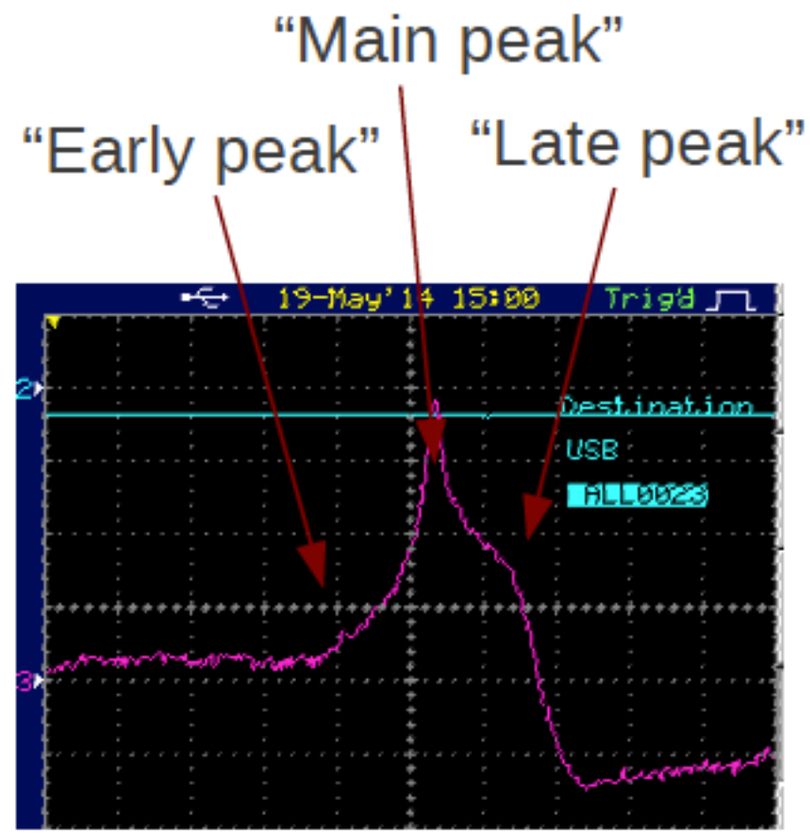
- Drift from GEM to GRID: 87.5mm (+/-0.5mm) at variable field of few 100V/cm
- Higher field (1kV/cm, variable) from MWPC to GEM



Main “peak” mobility values (ambient) for $NeCO_2$ 90:10

- **400V/cm: 2.731 (t=8.1)**
- **300V/cm: 2.764 (t=10.6)**
- **200V/cm: 2.729 (t=16.0)**
- **150V/cm: 2.725 (t=21.3)**

- (Late peak mobility around 2.4)
- (Early peak mobility around 3.1)

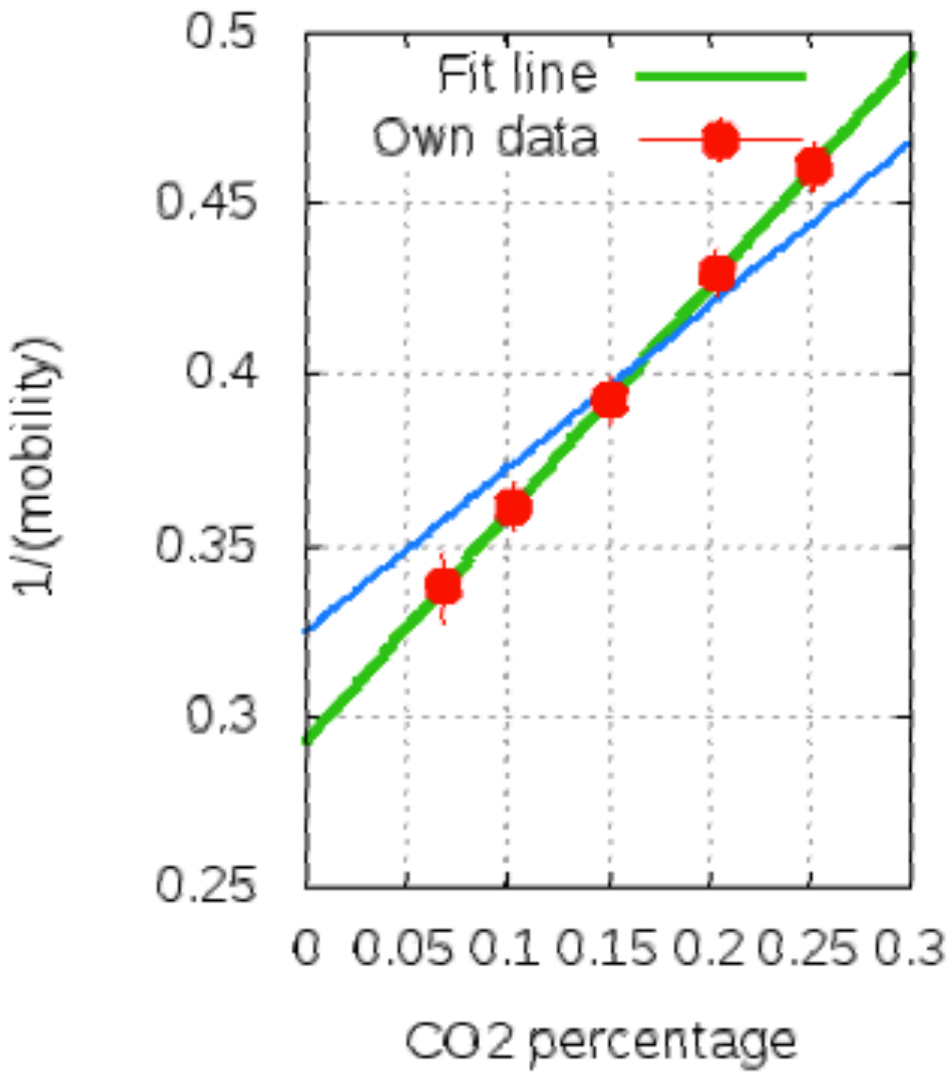


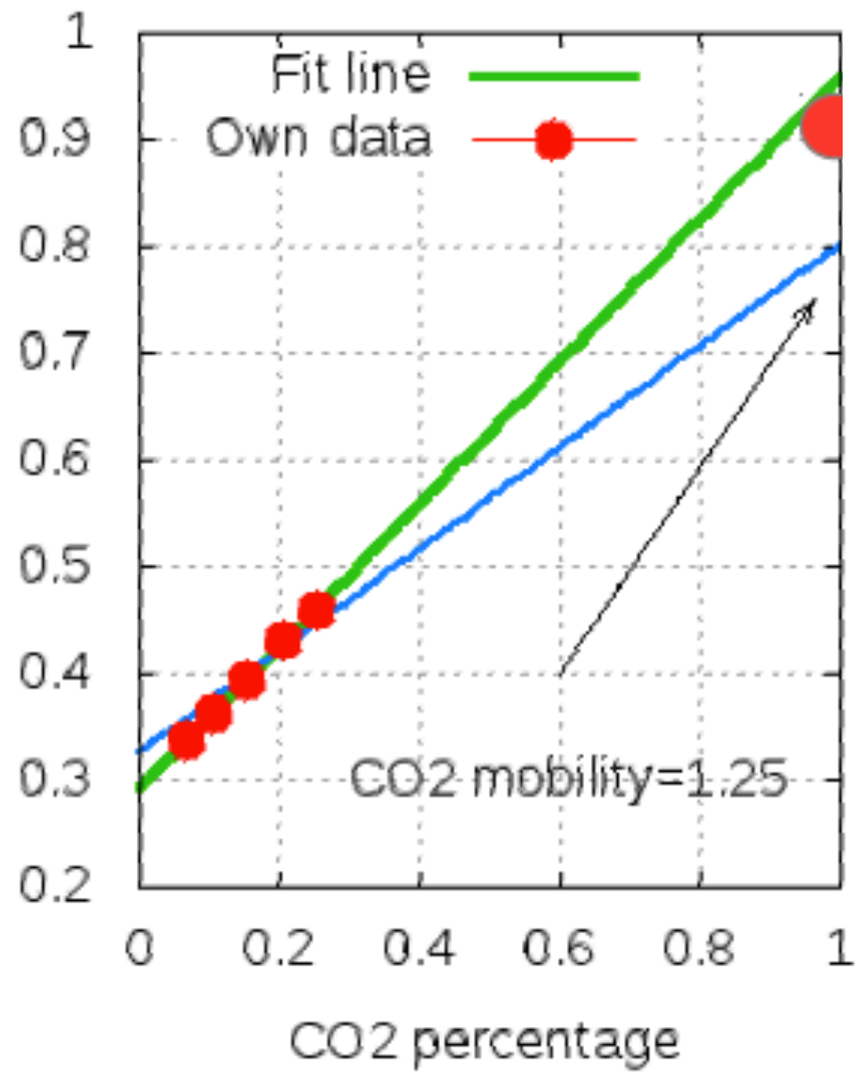
Mobility constant for voltage range relevant to TPC!

Blanc rule for Ne-CO_2 mixtures (main peak)

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

- CO_2 percentage of about 7, 10, 15, 20, 25

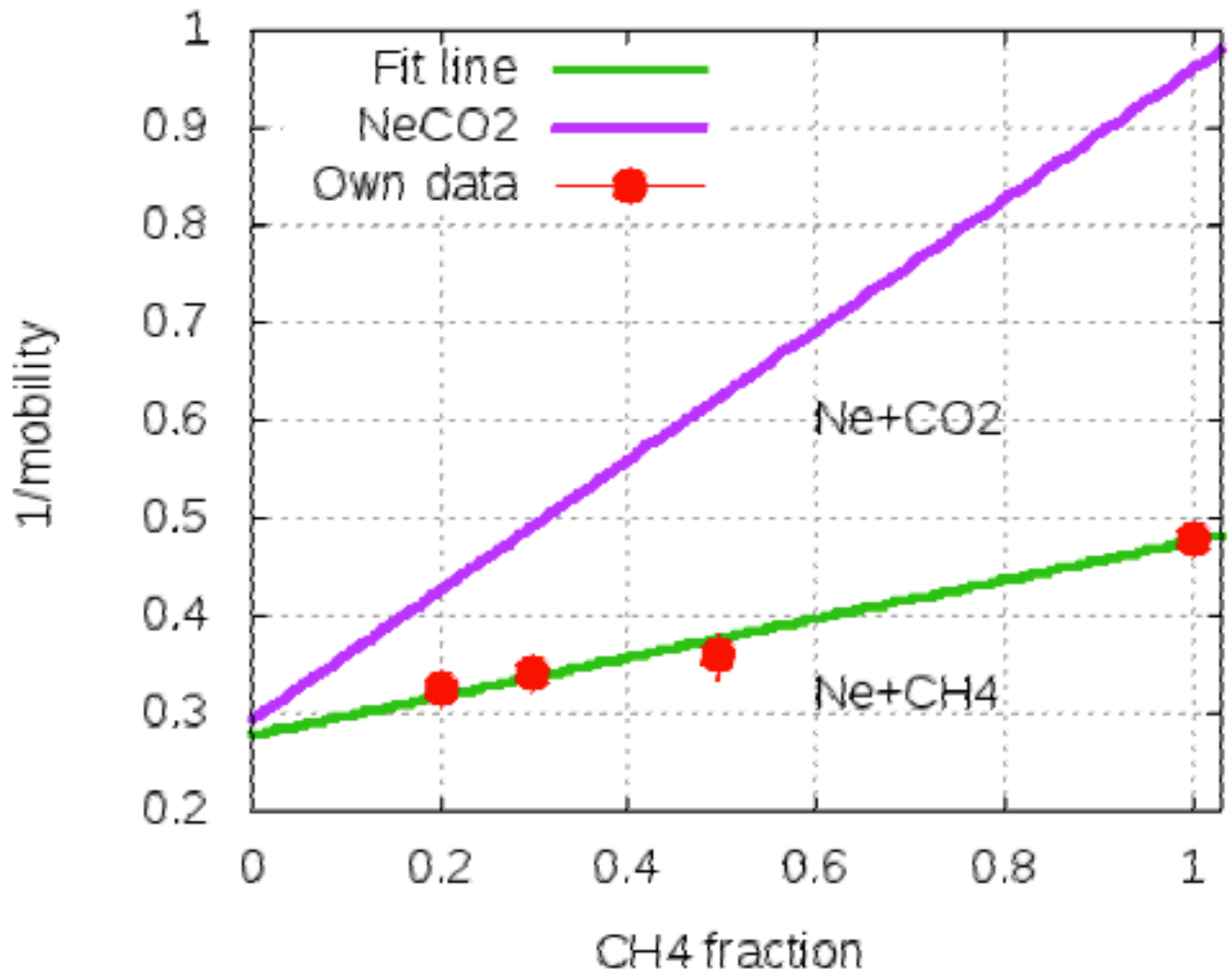




- Charge carriers may be the same in pure CO_2 and $NeCO_2$ mixtures

Blanc rule check for Ne CH_4

- Rather well fulfilled, note agreement again with [3] !



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

References

[1] http://indico.cern.ch/event/323839/session/3/contribution/25/attachments/627120/862951/ACortez_-_RD51_Collaboration_Meeting_CERN_-_Mini-Week_2014.pdf

[2] http://indico.cern.ch/event/323839/session/3/contribution/20/attachments/627122/862953/mobility_ArNe.pdf

[3] V Stojanović et al., “Mobility of positive ions in CF4”, 2014 J. Phys.: Conf. Ser. 514 012059

[4] Biondi, Manfred A. and Chanin, Lorne M., “Blanc's Law - Ion Mobilities in Helium-Neon Mixtures”, PhysRev.122.843

[5] L. G. H. Huxle et al., “Use of the parameter E/N”, 1966 Br. J. Appl. Phys. 17 1237