Status of gas gain measurements and calculations in Ne-CO_2 mixtures

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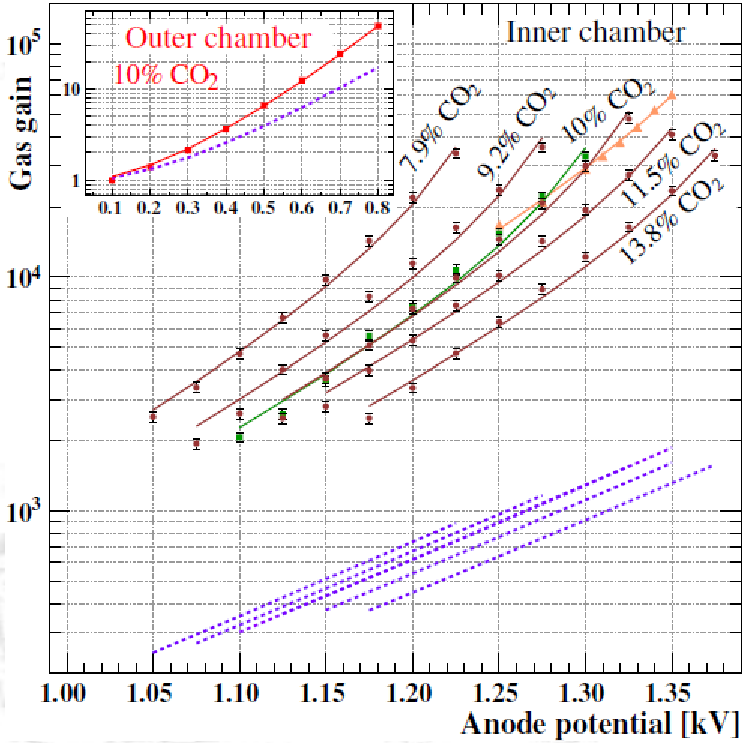
ALICE TPC (earlier measurements and calculations)



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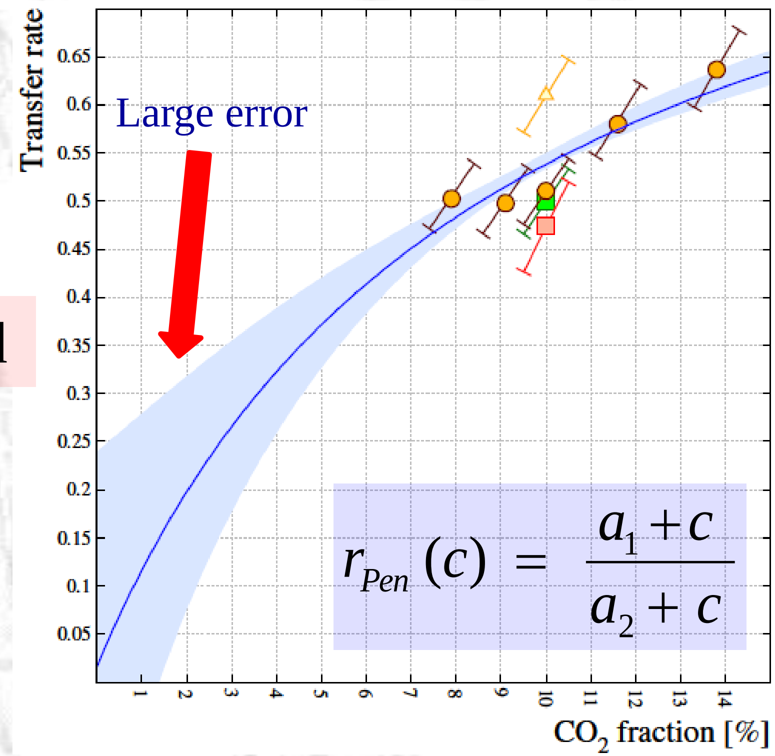


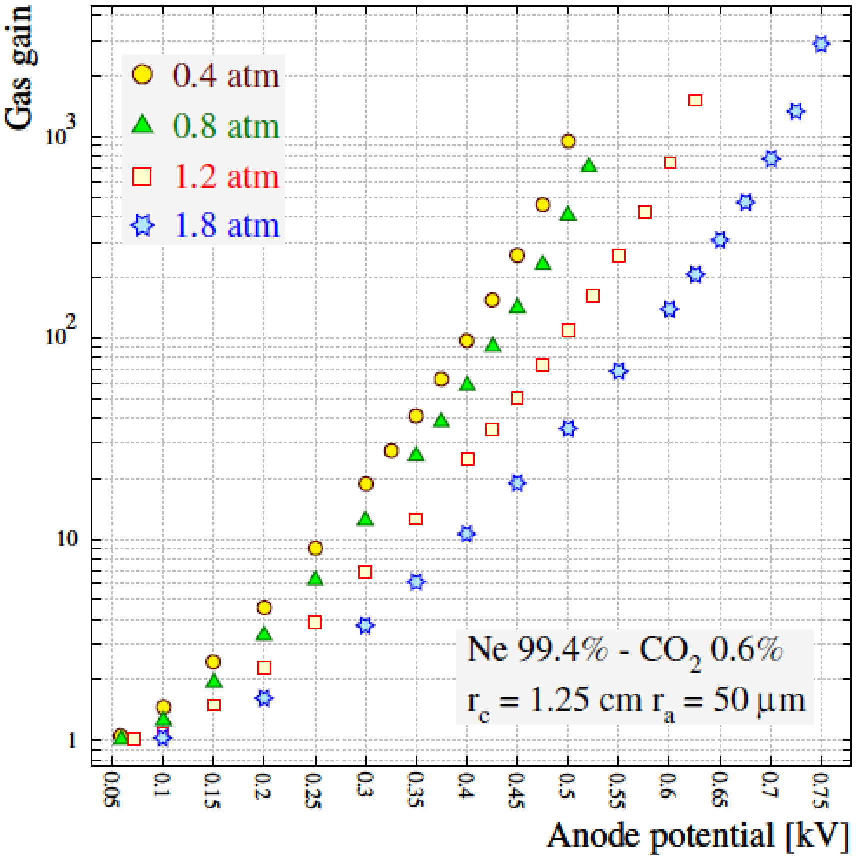
- ❖ Measurements: C. Garabatos and D. Vranic
- ❖ Pressure: 990-1010 mbar
- ❖ Gain: limited range $2\times10^3 - 5\times10^4$
- ❖ CO_2 fraction: 7.9 % - 13.8 %
- ❖ Uncertainty: CO_2 ± 0.5 % (absolute)

- ❖ Difficult to use a comprehensive transfer fit
- ❖ Radiative transfer rate: $a_1 / a_2 = 0.01 \pm 0.22$
  - ❖ no measurements at low CO_2 fractions
- ❖ **Experimental deficiencies prevent to achieve accurate information about the processes involving Penning transfer.**

Ne – CO_2 gas gain measurements at Krakow

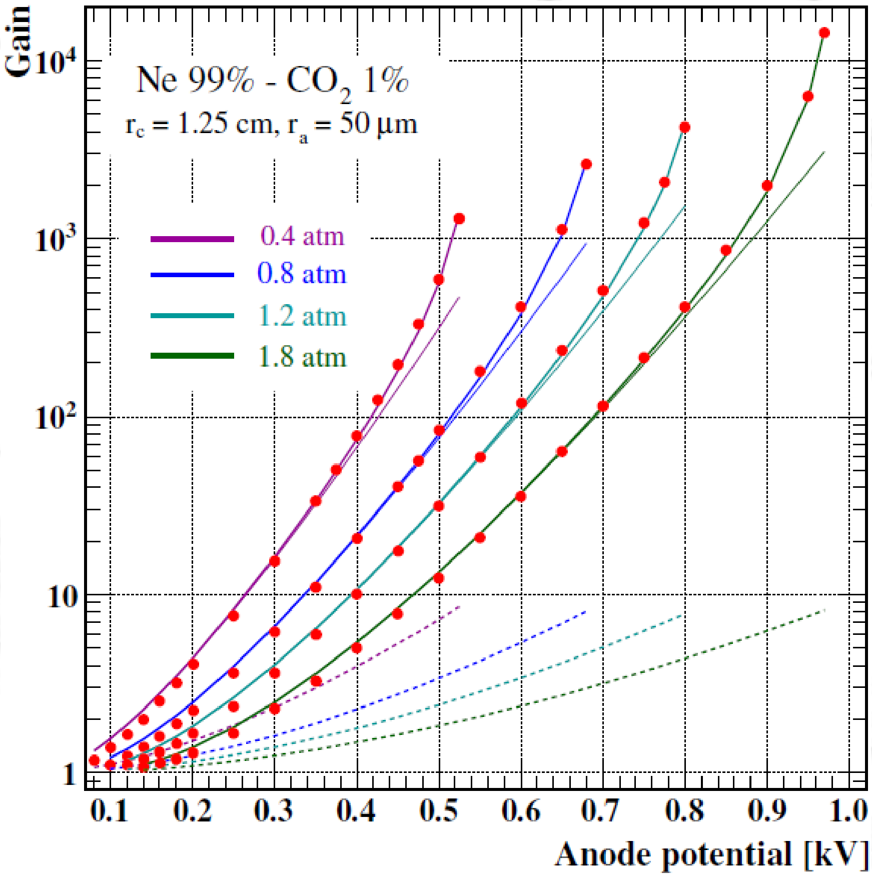
CO_2 percentage

1) **0.6%**
2) 1%
3) 2%
4) 4%
5) 5%
6) 7%
7) 10%
8) 15%
9) 20%
10) 30%
11) **40%**
12) 50%
13) **60%**
14) **Pure CO_2**



- Gas gains: measured by Tadeusz KOWALSKI,
- Single wire proportional counters: $r_c = 1.25$ cm, $r_a = 24$ µm or $r_a = 50$ µm,
- Wide gain regime: ionisation to higher than10^5; less than 5% error on gas gain,
- Pressure range: 0.4 – 1.8 atm; in addition 0.25 atm for a few mixtures.

Ne – CO_2 gas gain calculations



Penning correction

- $Ne^* + CO_2 \rightarrow Ne + CO_2^+ + e^-$
- All of the excited Ne atoms can ionise CO_2

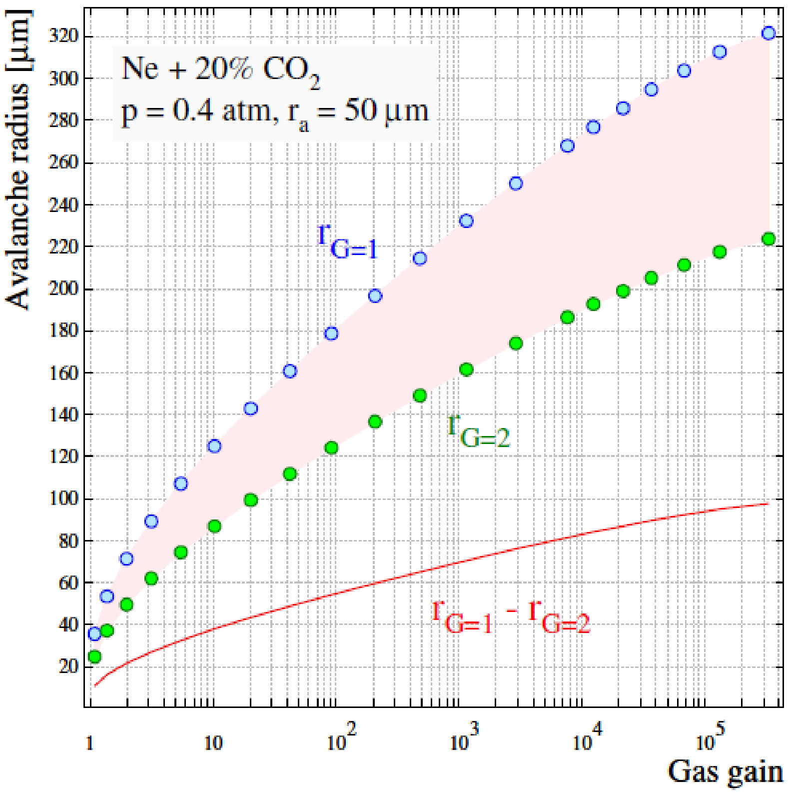
$$\alpha_{Penning} = \alpha \frac{\sum \nu_i^{ion} + \sum r_i \, \nu_i^{exc}}{\sum \nu_i^{ion}}$$

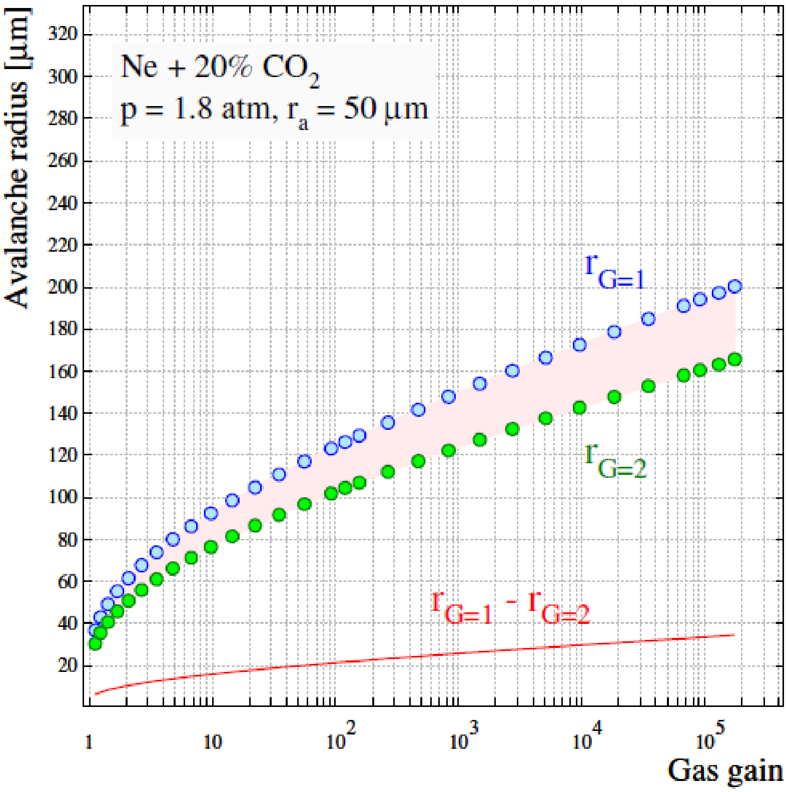
Photon feedback $G' = G/(1-\beta G)$

Production frequencies of the ionisations and excitations with **Magboltz 10.10**

- Dashed lines: **without** corrections (Penning, feedback),
- Thin lines: with Penning, **without** feedback corrections ,
- Thick lines: final fits **with** Penning and feedback corrections.

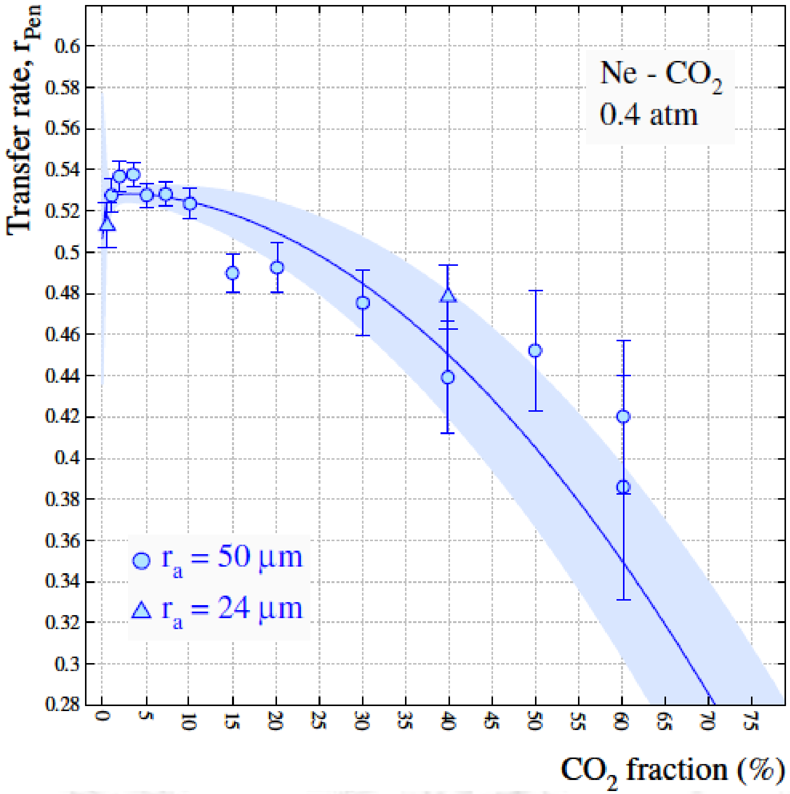
Avalanche sizes

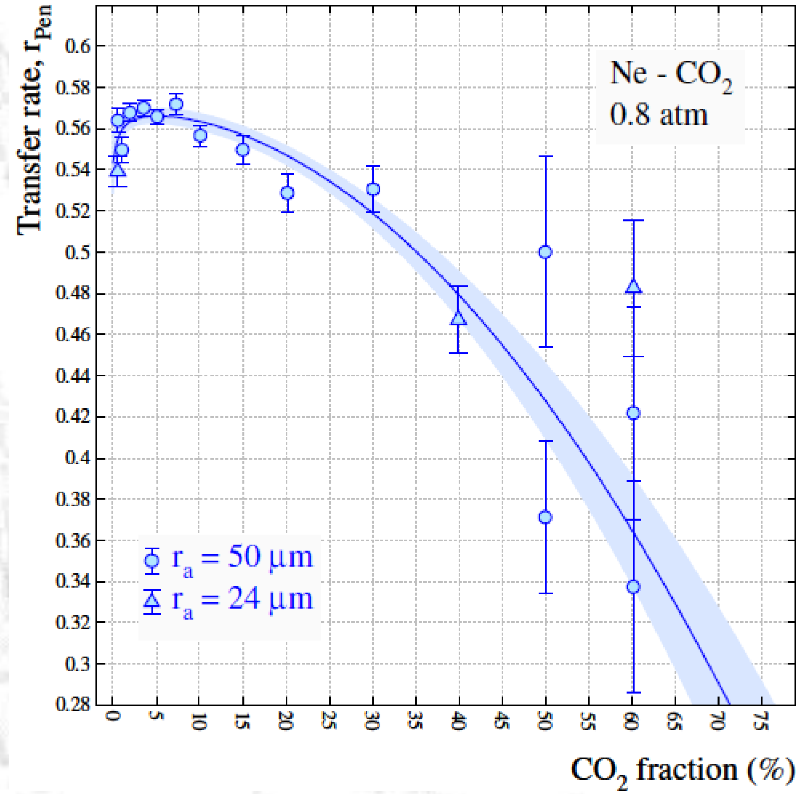




- The circles $r_{G=1}$, $r_{G=2}$: radius from G=1 and G=2 to the highest measured gas gains
- Pink bands: intermediate zone between the multiplication and drift region,
  - electric field strenght become radially smaller with the depth of $\mathbf{r_{G=1} - r_{G=2}}$
  - production of the excitations and ionisations compete each other
- **Less** Penning transfer at **lower pressure** in the same mixture (will see next slides)

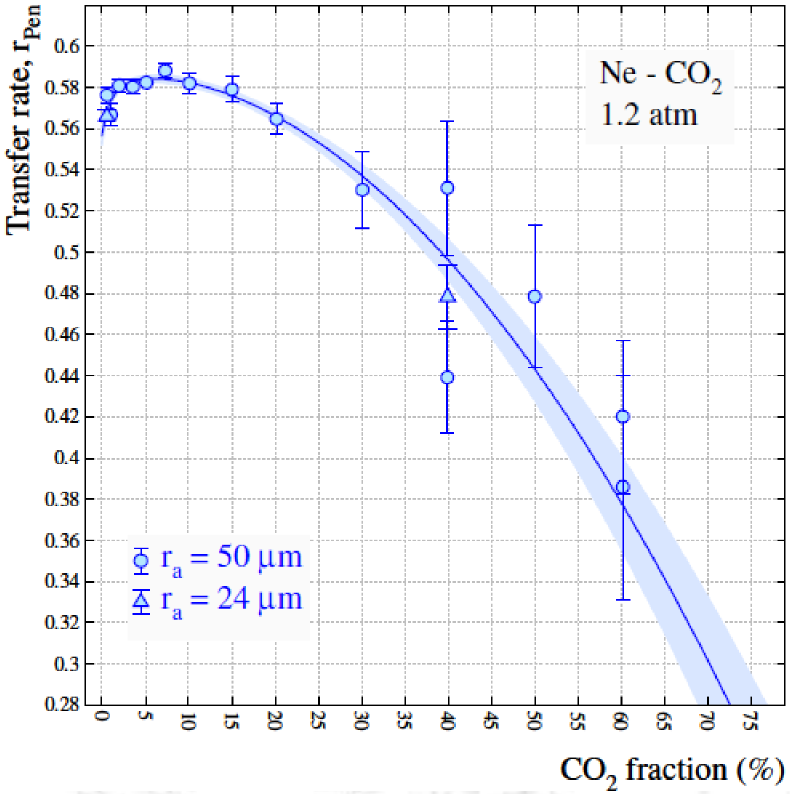
Transfer rates

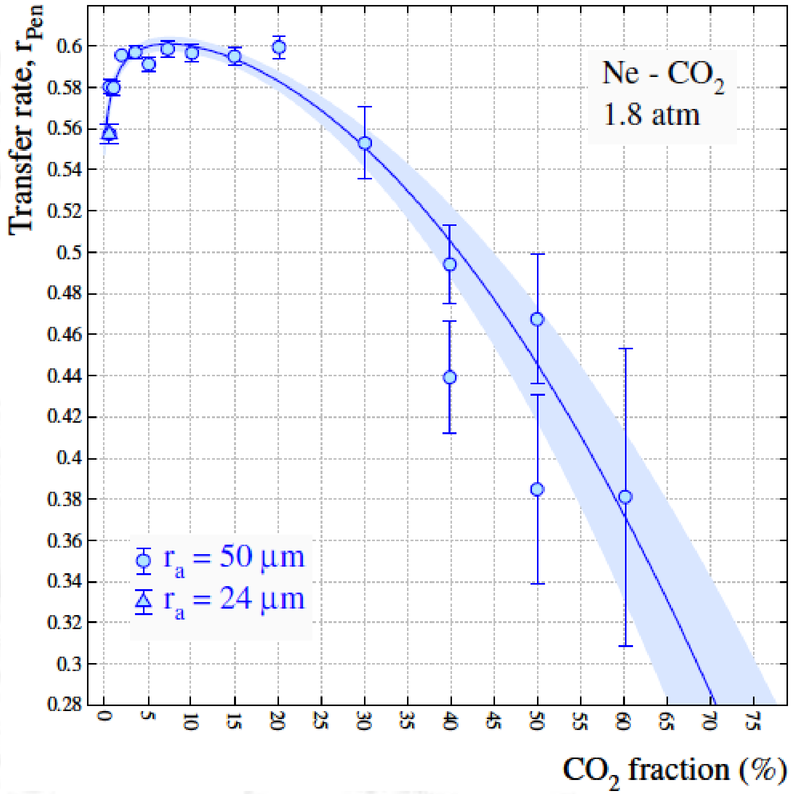




- Transfer rates first increase at low CO_2 concentrations and reach a peak
  - more visible at high pressures
- After peak, continues decrease of the transfer rates with increasing CO_2 fractions
- Large uncertainties at high CO_2 fractions due to lack of data
  - measurements beyond 60% CO_2 on the way

Transfer rates (fit function)





$$r_{Pen}(c) = \frac{a_1 c + a_3}{c + a_2} - a_4 c^2$$

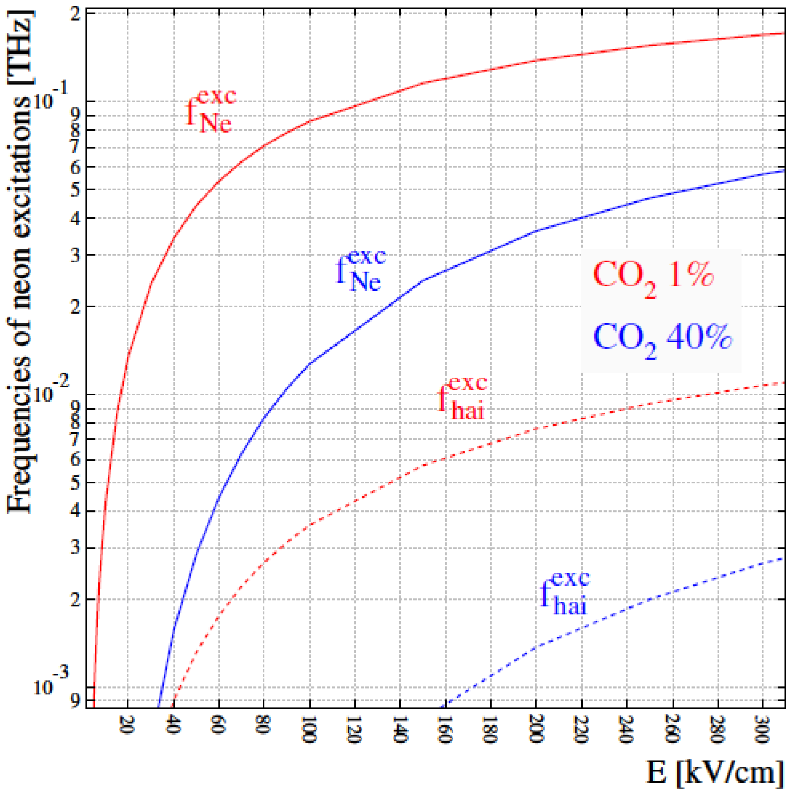
- **a_4** : reduction parameter of the rates
  - **c^2** dependence of the fit function points **three – body interactions**

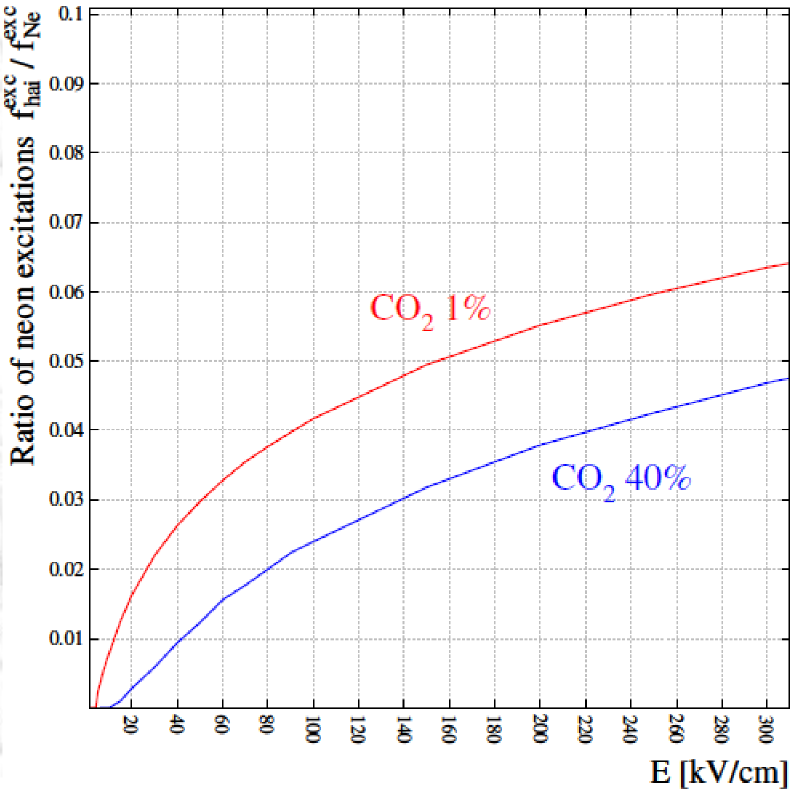
Fitting parameters

Pressure [atm]	a_1	a_2	a_3/a_2	a_4
0.4	0.5298 ± 0.0057	0.0016 ± 0.0002	0.5064 ± 0.0707	0.4981 ± 0.0806
0.8	0.5710 ± 0.0050	0.0074 ± 0.0002	0.5428 ± 0.0147	0.5710 ± 0.0767
1.2	0.5916 ± 0.0026	0.0108 ± 0.0001	0.5564 ± 0.0044	0.5916 ± 0.0646
1.8	0.6133 ± 0.0047	0.0126 ± 0.0002	0.5543 ± 0.0070	0.6133 ± 0.1169

- **a_1** : asymptotic values of the transfer rates,
  - smaller than 1: energy loses with inelastic collisions; the number of rotation, vibration and polyad modes of CO_2 molecules,
  - such losses become unlikely to occur at high pressures since a_1 increase
- **a_2** : collisional energy transfer probability, $Ne^* + CO_2 \rightarrow Ne + CO_2^+ + e^-$
  - the time between collisions shorter at higher pressure
- **a_3/a_2**: radiative transfer and homonuclear associative ionisation of neon (h.a.i.)
  - $\gamma + CO_2 \rightarrow CO_2^+ + e^-$
  - $Ne^* + Ne \rightarrow Ne_2^+ + e^-$

Contribution of the h.a.i processes to the a_3/a_2 parameter





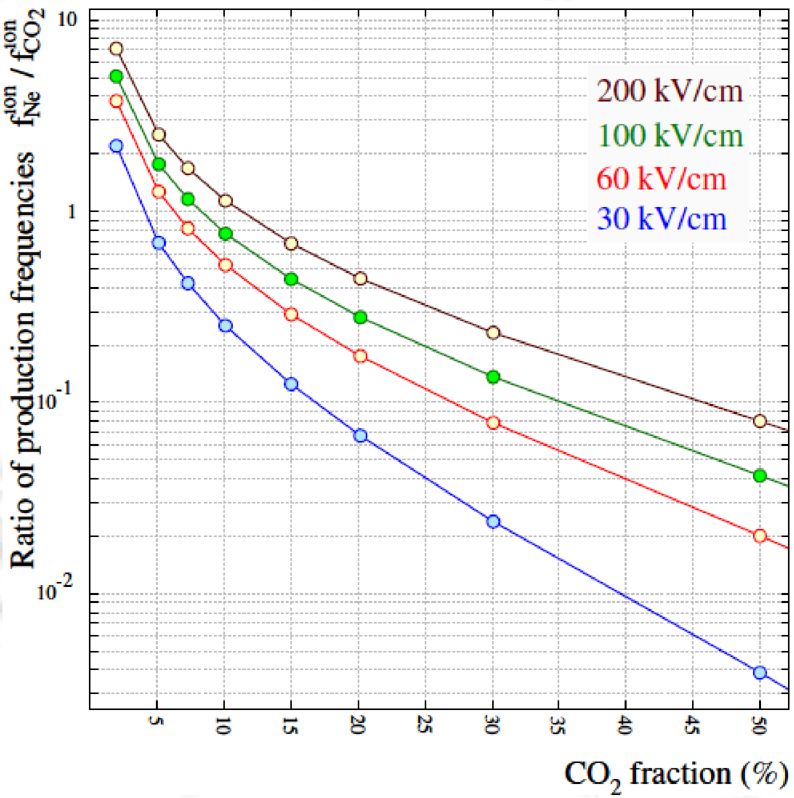
❖ h.a.i. states are less frequently produced (threshold is high 20.86 eV)

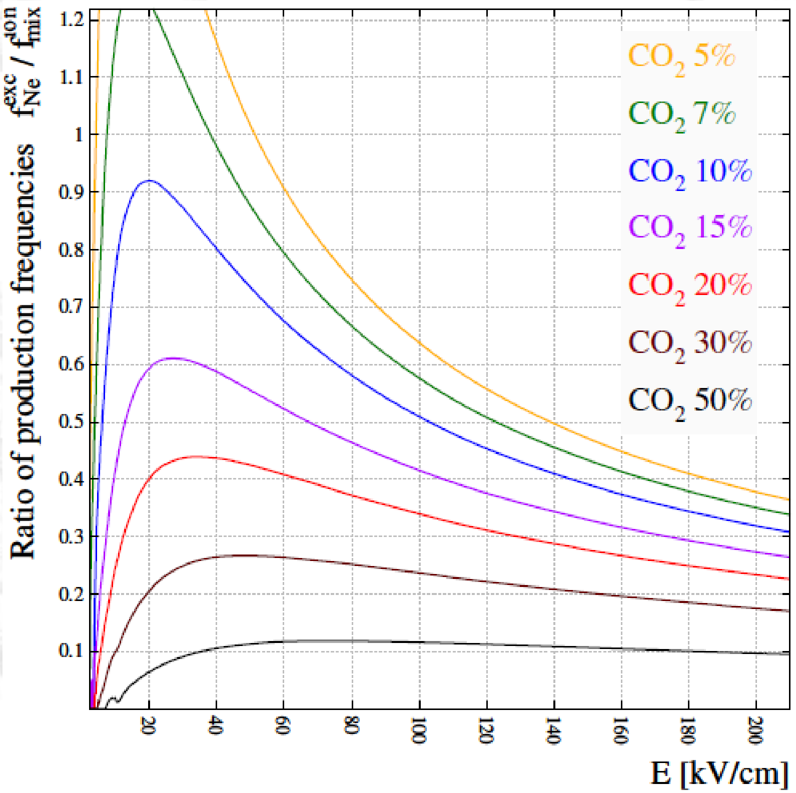
❖ even if all h.a.i states take place in multiplications, their contributions can not excess several percentages,

❖ the contribution will be less at high CO2 concentrations,

❖ **radiative transfer** remains as the **dominant** process in a_3/a_2 paraneter

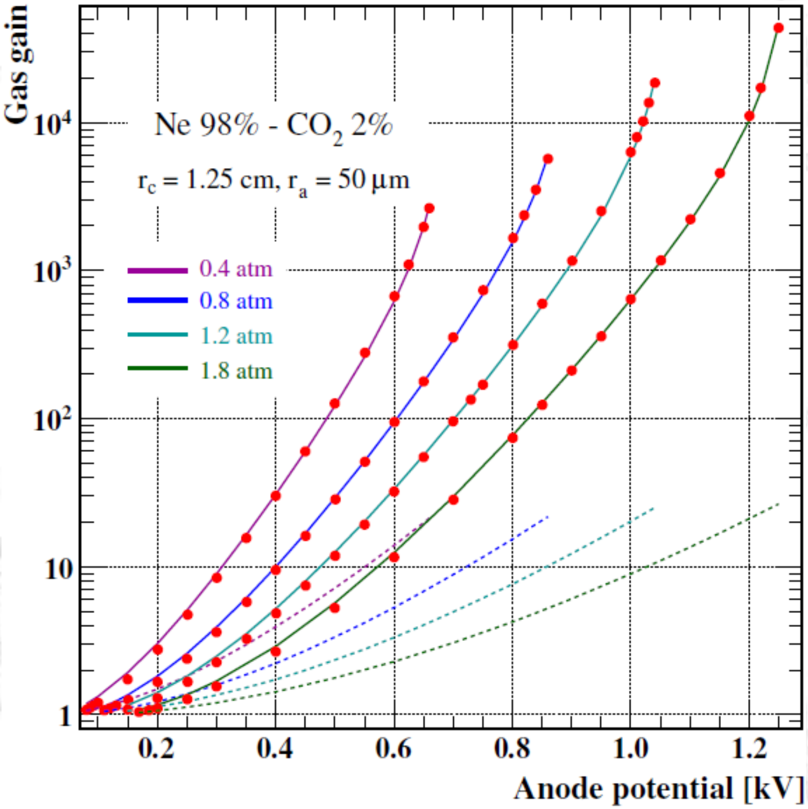
Understanding the transfer drops, parameter a_4 (production frequencies)

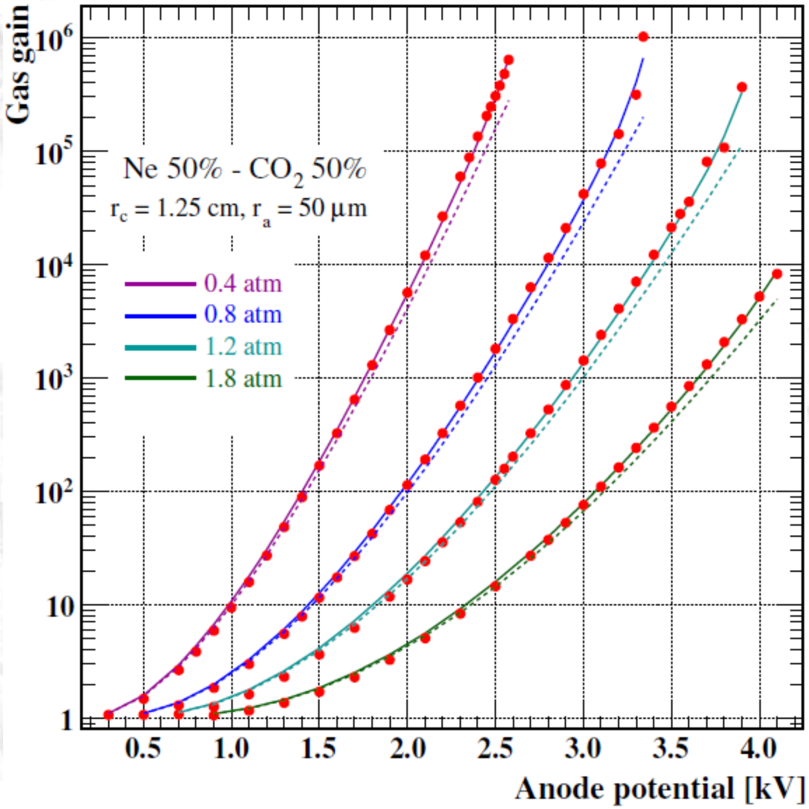




- the largest part of the gain comes from CO_2 ionisations,
  - ionisation potentials: CO_2^+ 13.78 eV, Ne^+ 21.56 eV
- fraction of neon excitations become smaller than unity beyond 10% CO_2,
- Penning impact on gain enhancements will be smaller at high CO_2 percentages.

Effect of the production rates



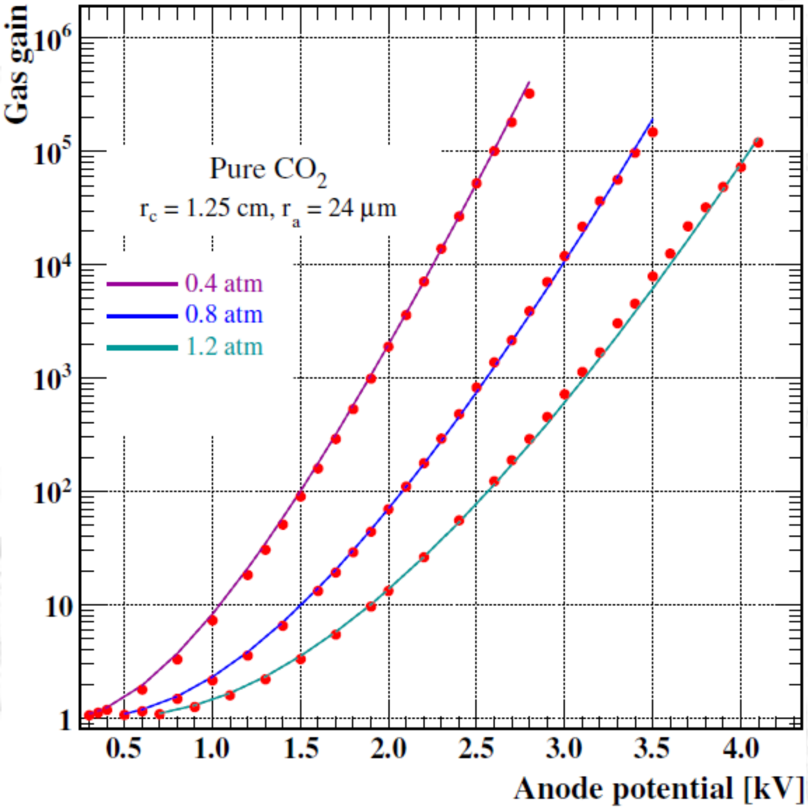


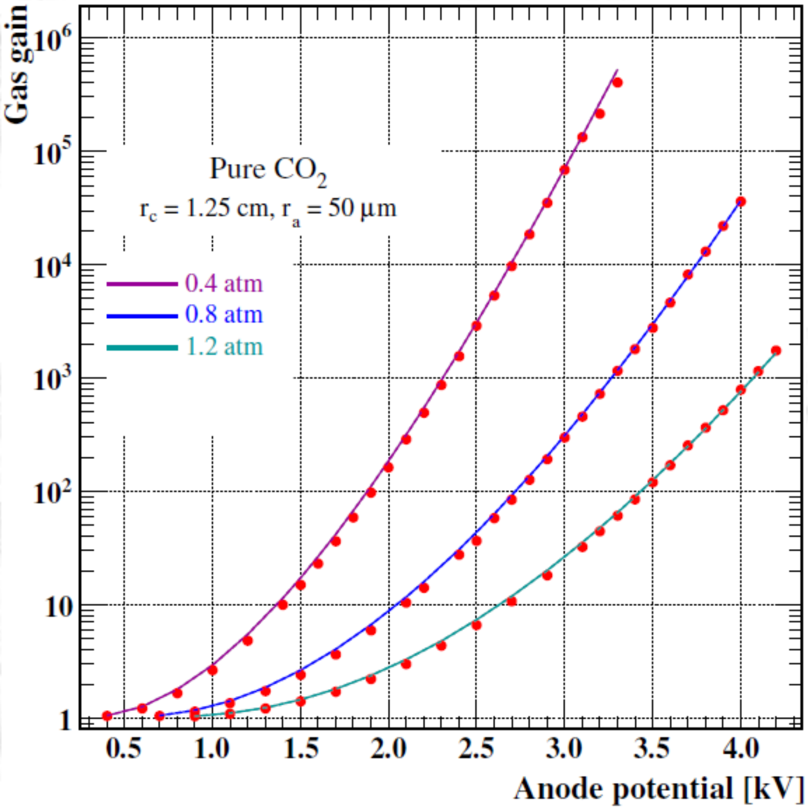
❖ decrease on Penning impact does not mean smaller Penning transfer probability,

❖ even if the population of the excited neon atoms diminish at high CO_2 fractions, they can still efficiently transfer to ionize CO_2 molecules,

❖ transfer drops can not be explained in terms of production rates.

Gain calculations in pure CO_2





❖ **Are the CO_2 ionisation cross sections are wrong in Magboltz ???**

❖ Calculations for the pure CO_2 mixtures confirms that Magboltz use perfectly correct cross sections

❖ **There should really be other physical processes leading the transfer rate drops**

Proposed mechanisms for the transfer drops

❖ **Neon excimers** (three-body reaction):

$Ne^* + Ne + Ne \rightarrow Ne_2^* + Ne$ (1)

$Ne_2^* + CO_2 \rightarrow Ne + Ne + CO_2^*$ (2)

CO2* can dissociate to form neutral fragments like CO, O and C (3)

❖ at the same pressure efficiency of (1) and thereby (2) will decrease with increasing fraction of CO_2 so, neon excimer formation is working inverse way of transfer reductions; not correct answer.

❖ **Other three-body reactions:**

$Ne^* + Ne + CO_2 \rightarrow NeCO_2^* + Ne$ (4)

$Ne^* + CO_2 + CO_2 \rightarrow NeCO_2^* + CO_2$ (5)

❖ (4) and (5) can dissociate through; $NeCO_2^* \rightarrow Ne + C + O_2$ (6)

$\rightarrow Ne + CO + O$ (7)

The mechanisms (4) and (5) are dominated by partial pressure of CO_2; **formation of the $NeCO_2^*$ complex is the approach to explain energy transfer drops !!!**

Thanks and ???