Recent gain calculations

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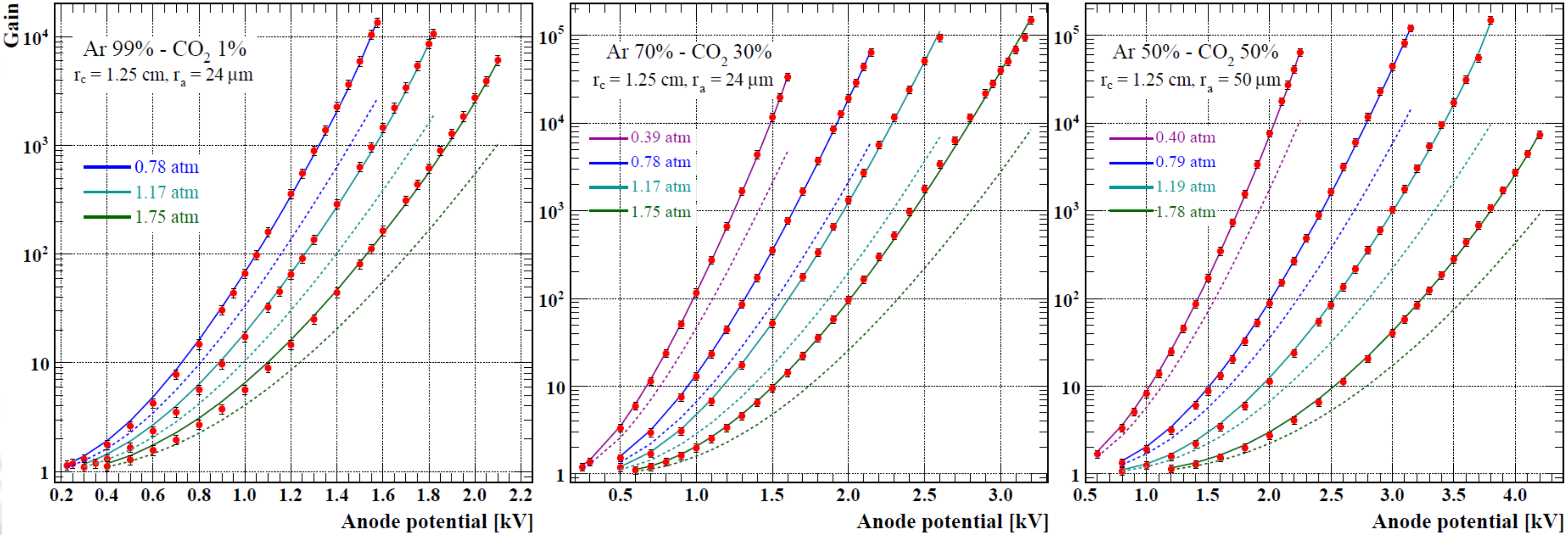
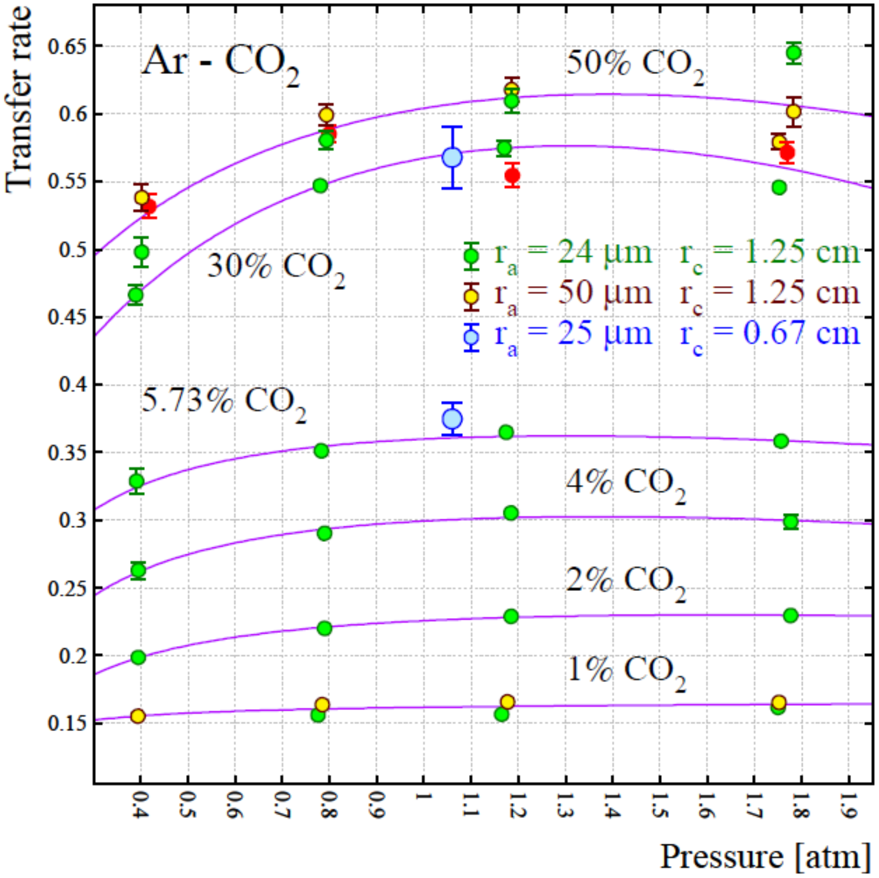
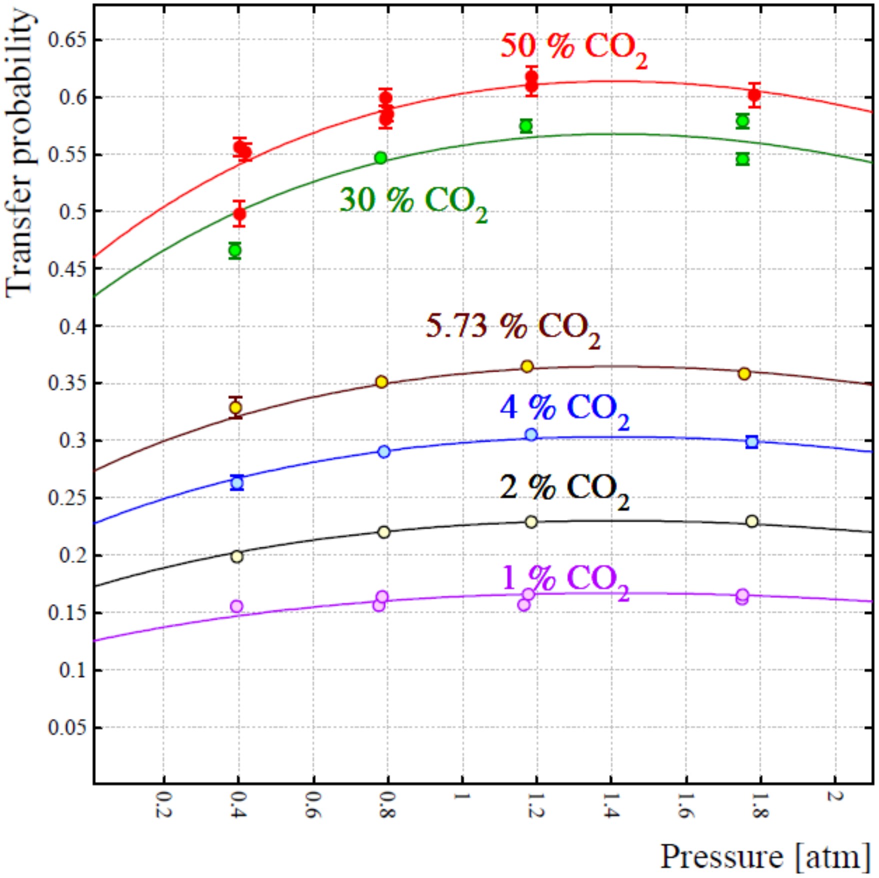
Gain measurements and fits for Ar – CO_2 mixtures



- High precision gain measurements in Krakow (Tadeusz KOWALSKI)
  - special guard for dark current
- **no need to use gain scaling**
- Wide gain regime: ionisation to gain of 10^5; less than 5% error on gas gain
- Pressure range: 0.4 – 1.8 atm
- Admixture concentration: 1 – 50 % CO_2

Extracted transfer rates





- ❖ Fit function for 1%, 2%, 4% CO$_2$

$$r(p) = \frac{a_1 p}{p + a_2} + \boxed{a_3 p^2}$$

- ❖ Fit function for 5.73%, 30%, 50% CO$_2$

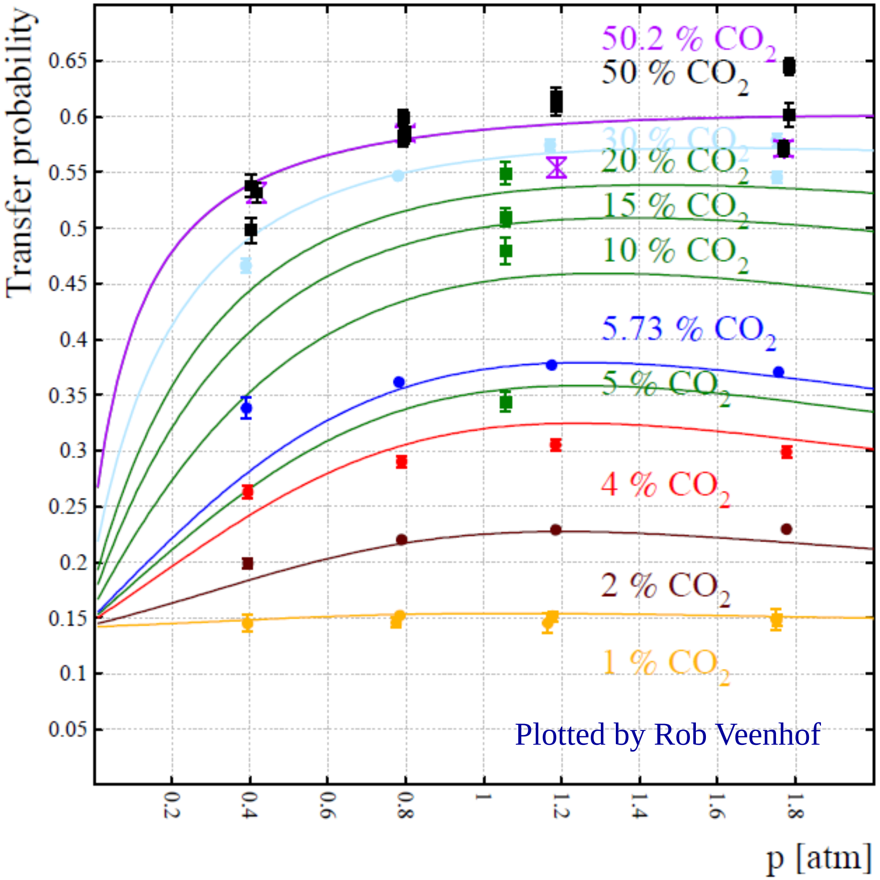
$$r(p) = \frac{a_1 p + a_3}{p + a_2} + \boxed{a_4 p^2}$$

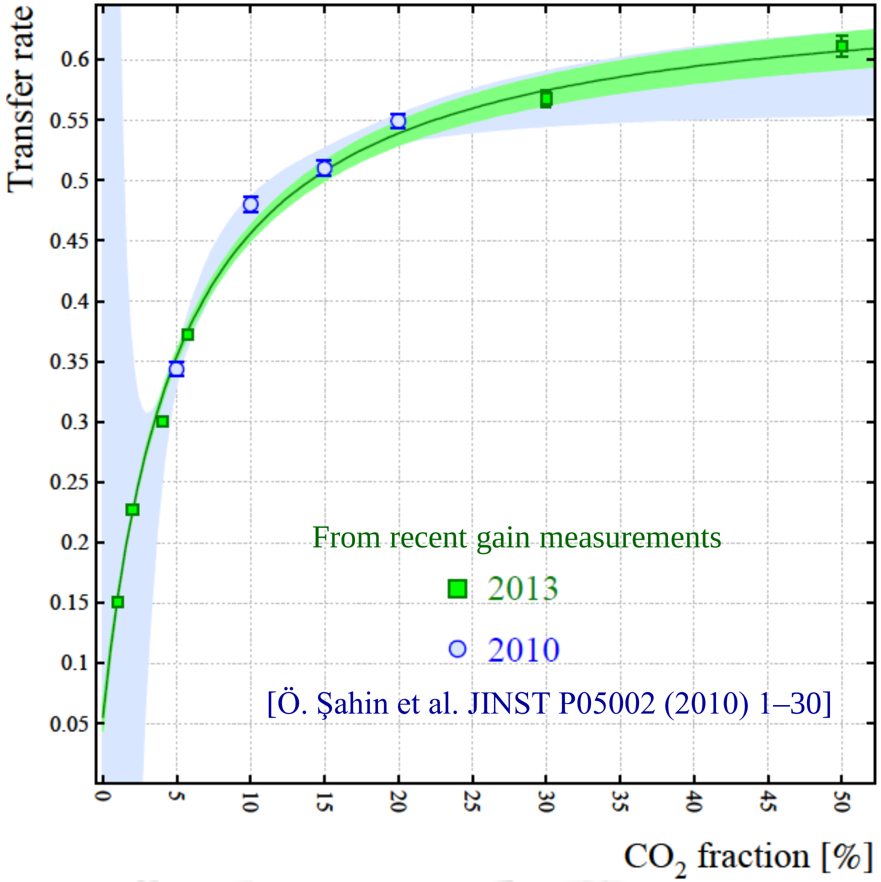
- ❖ Scaled fits: normalised to 50% CO$_2$, using its fit parameters (plot on the left)

- ❖ **p^2** dependence:

  evidence of 3–body interactions

Modelling of the transfer rates

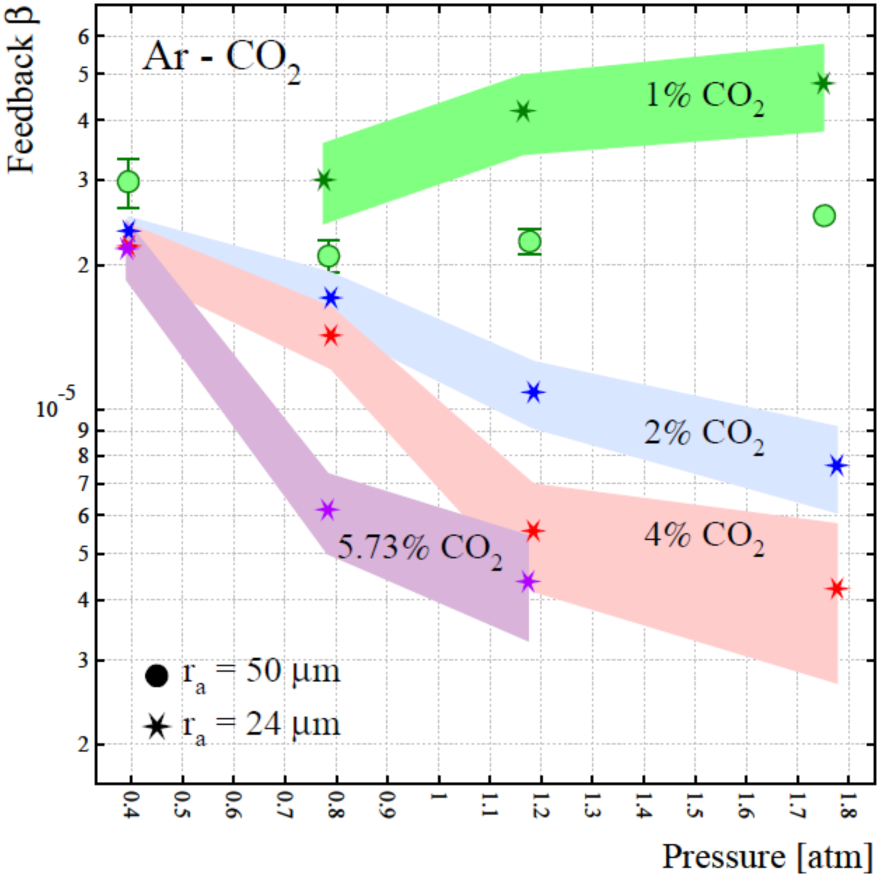


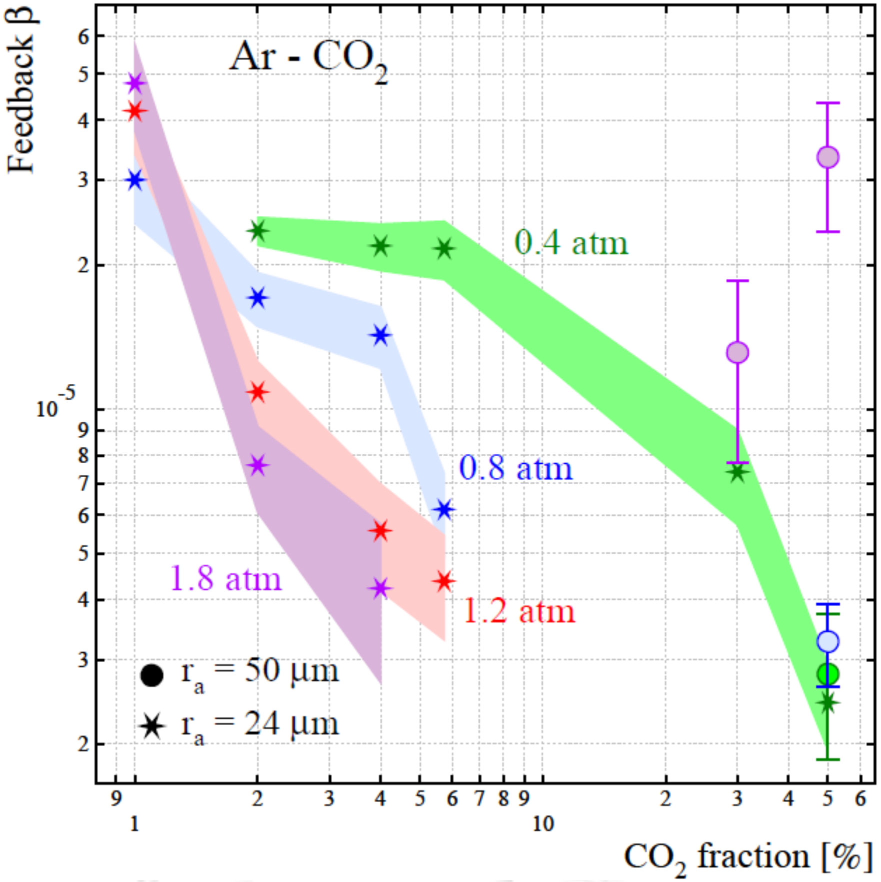


- Combined fit (concentration + pressure)
- All transfer rates included: Green curves extracted from T.Z. Kowalski *et al.* NIM *A* **323** (1992) 289–293

- Confirmation of the transfer curves with earlier data at 1070 hPa
- Lower uncertainty with recent data
- Positive radiative term at low CO2 concentrations

Pressure and concentration depence of feedback

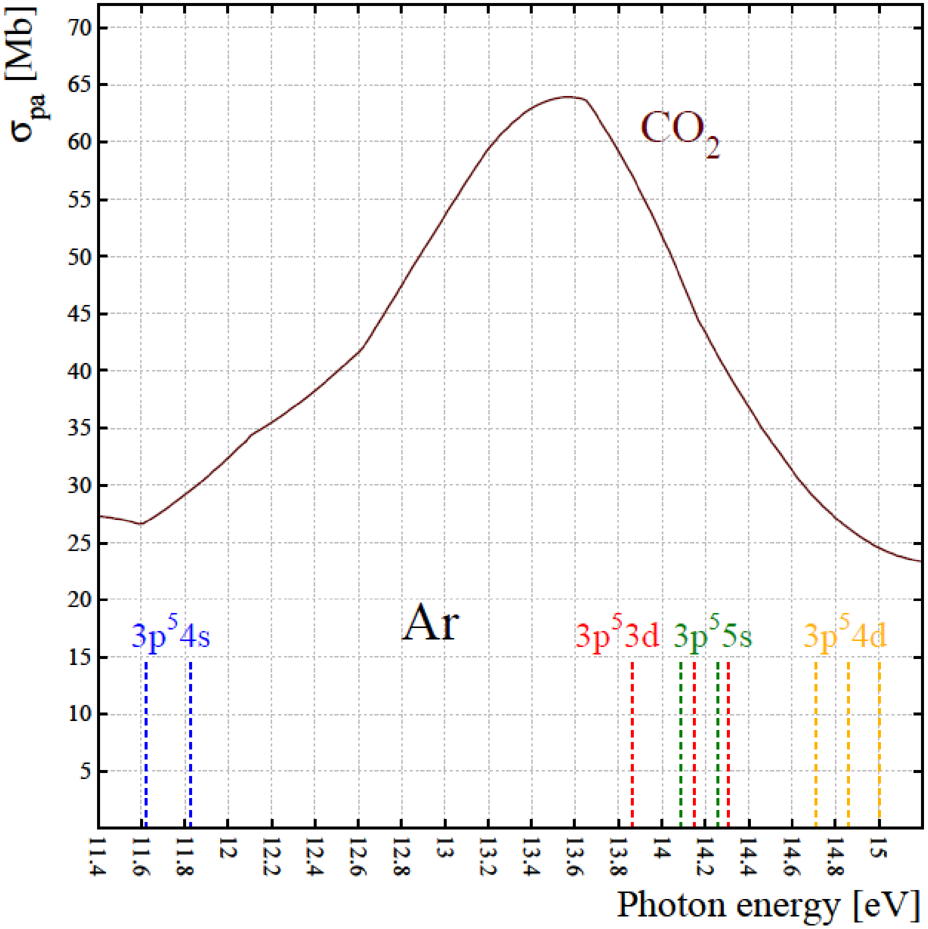




- ❖ 1% CO_2 : increase with gas pressure
  - ❖ higher β for 24 µm anode radius
- ❖ 2%, 4%, 5.73% CO_2 : decrease on β with pressure
- ❖ 0.4 atm: almost flat β for the mixtures with 2%, 4% and 5.73% CO_2
- ❖ 0.8 atm – 1.2 atm: β decrease with CO_2 concentrations

Decreases of β easy to explain in terms of photon mean free path **!!!**

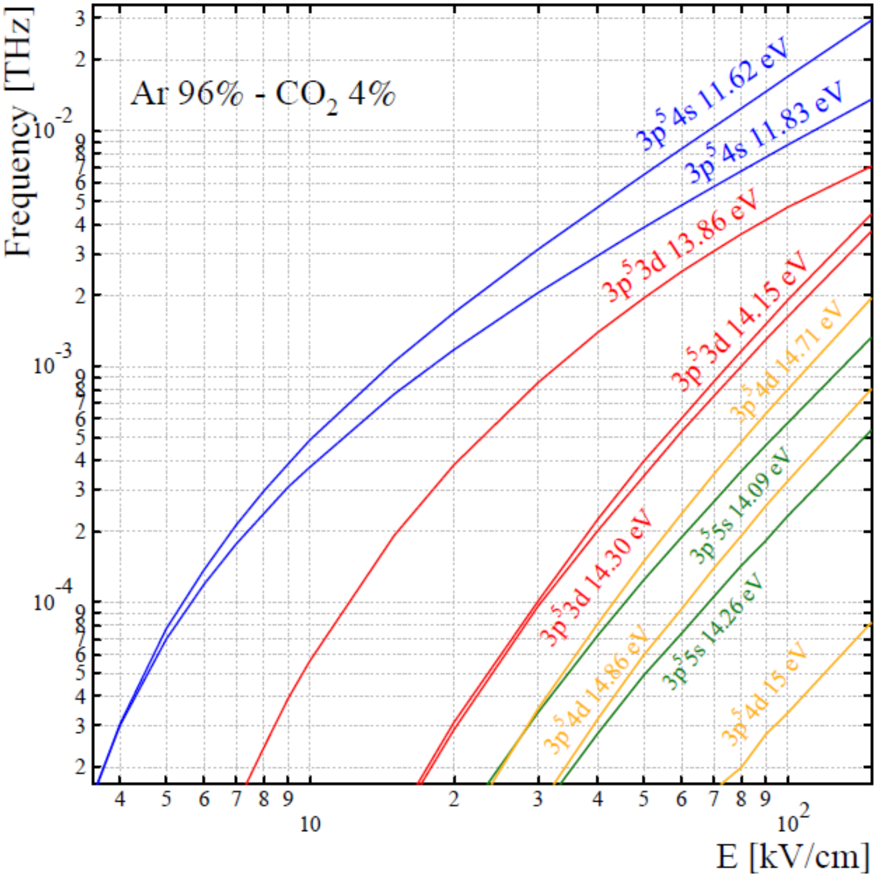
Photo – absorption cross section of CO_2

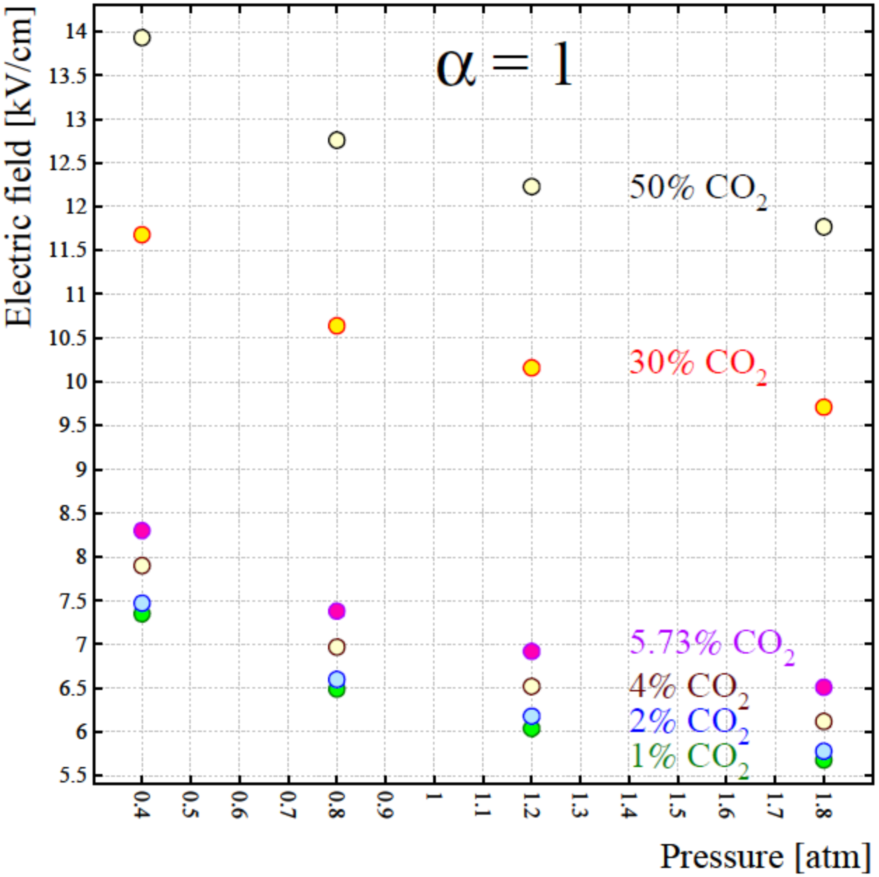


Cross section compiled from J. Berkowitz, *Atomic and Molecular Photoabsorption*, Chapter 5, p. 189–197, Academic Press (2002)

- ❖ photons from 3d and higher radiative levels can ionise CO_2
- ❖ 4s photons produce photo – electron if they arrive the cathode but they can not ionise CO_2
- ❖ non – radiative states decays to intermediate states; they have not enough energy to ionise CO_2 or to extract electron from cathode
- ❖ σ_{pa} : 3d, 5s > 4s > 4d

Production rates and avalanche region



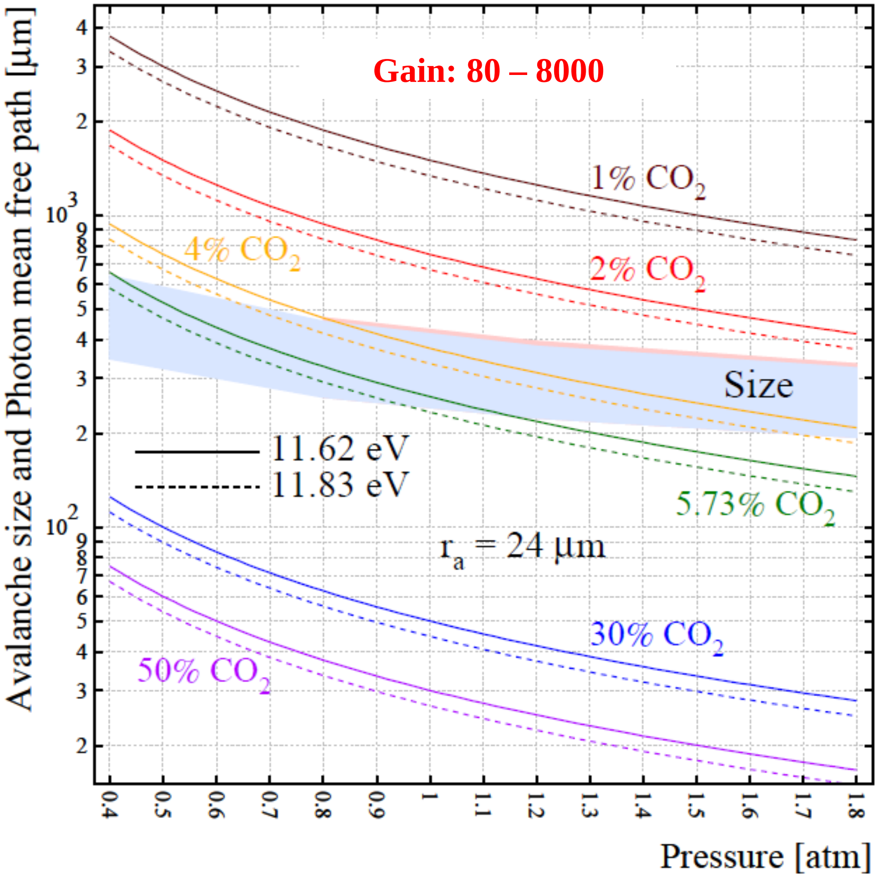


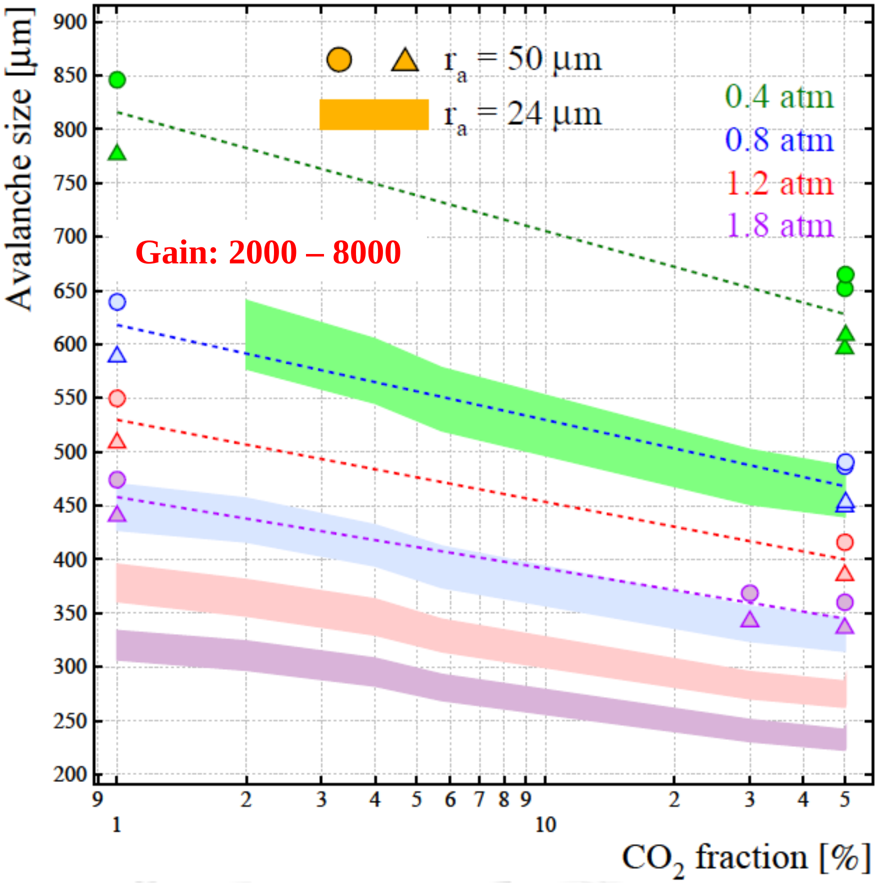
- ❖ 4s levels are the most abudantly produced
  - ❖ they are not lost in Penning transfers
  - ❖ they can contribute to feedback effectively by arriving the cathode **???**

- ❖ α = 1 used to define avalanche sizes

$$r_{size} = \frac{V_{anode}(gain\,curves)}{E(\alpha = 1,\ Magboltz)\ \log(r_{tube}/r_{anode})}$$

Absorption distance of the excited states

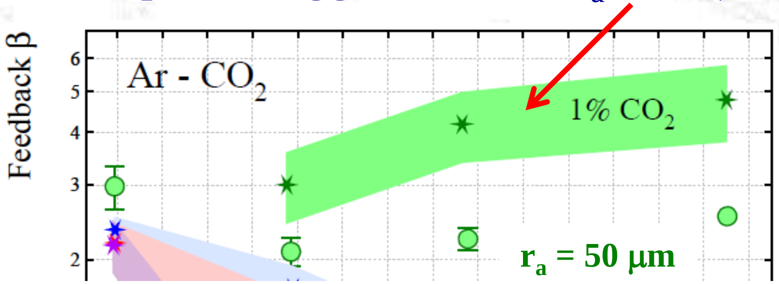




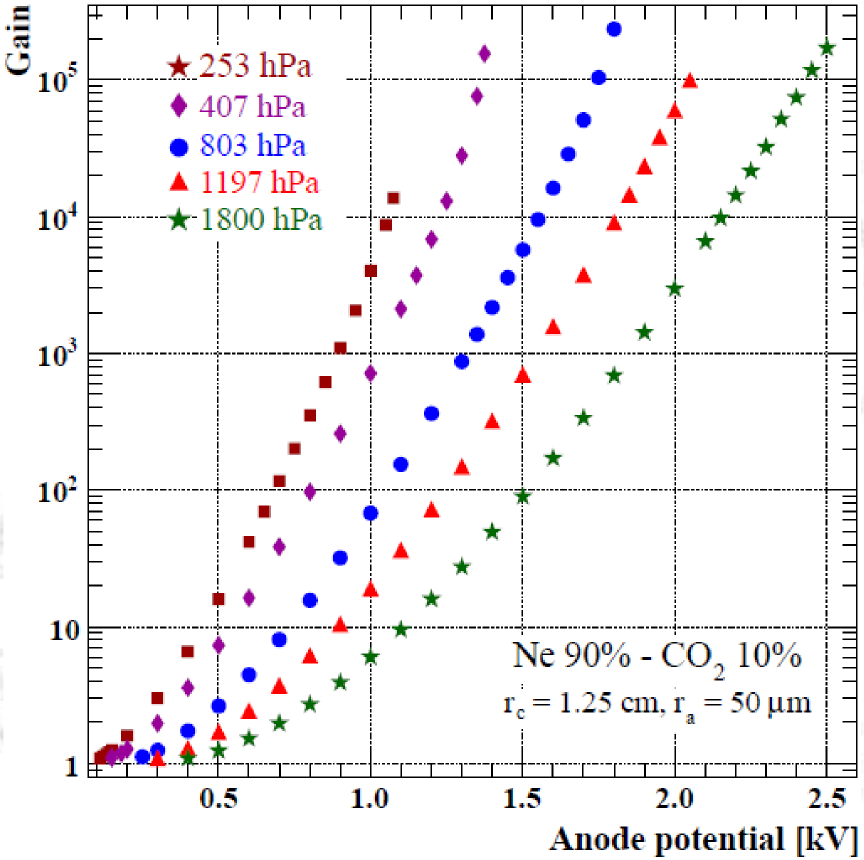
❖ Both avalanche sizes and photon mean free path decreases with pressure and size reduction is smaller than the mean free path

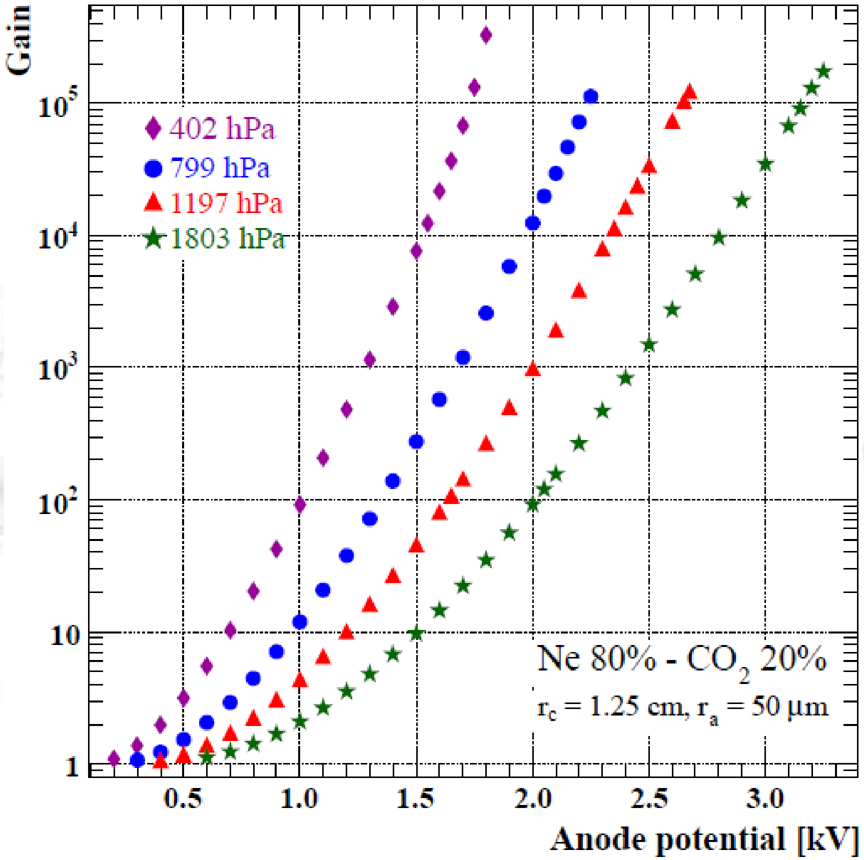
❖ photons in 1% and 2% CO_2 stopped outside the avalanche (still in gas) while the rest are absorbed in the avalanche

❖ Size in the tube with thinner anode wire is smaller: explains bigger beta for r_a = 24 μm



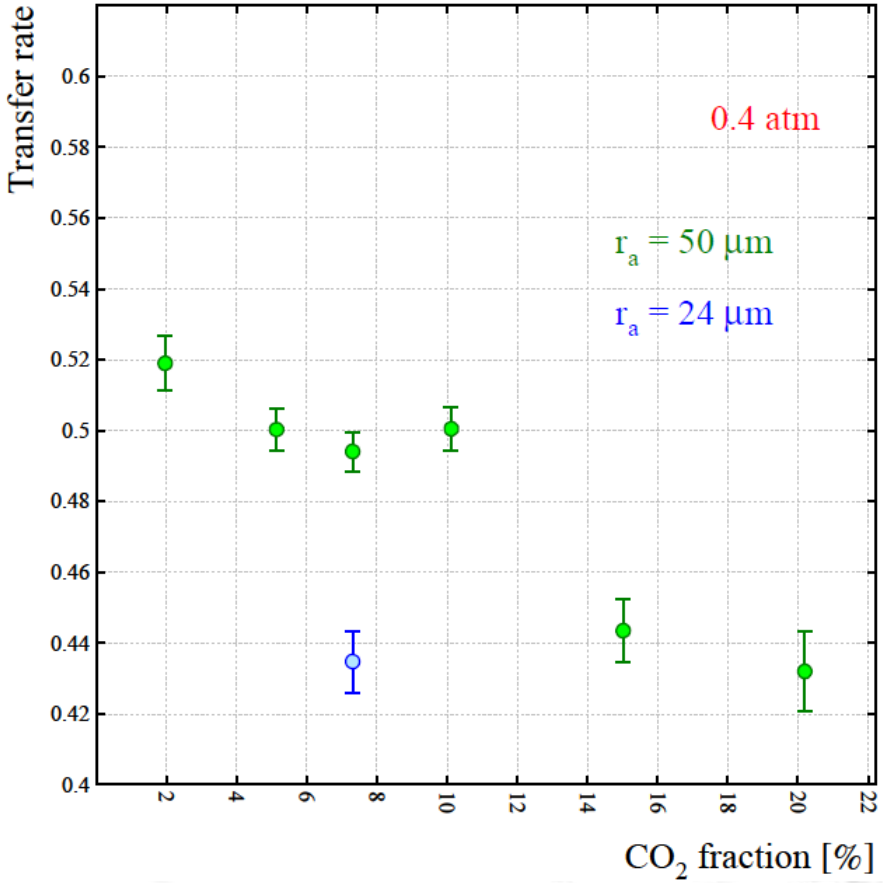
Gain in Ne – CO_2 mixtures

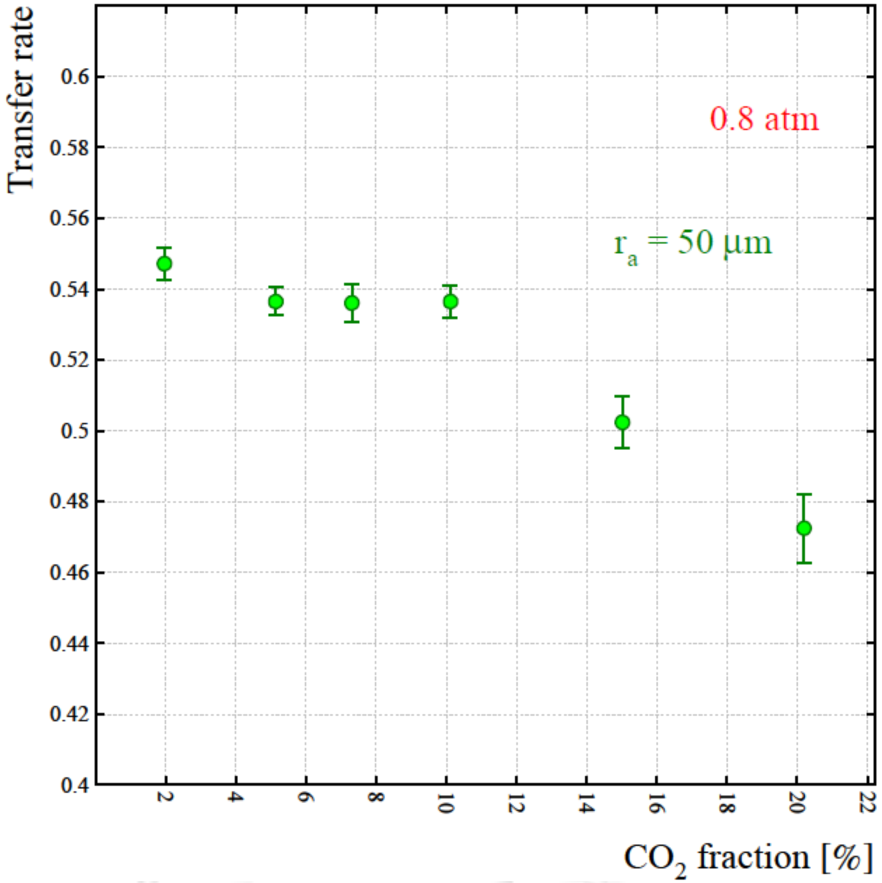




- Measured by Tadeusz KOWALSKI with the same technique and equipment
- Present calculations cover 2% – 20 % CO_2 mixtures
  - All excited states of Ne can ionise CO_2 (3d and higher in Ar – CO_2 mixtures)
  - No gain scaling needed as before

Transfer rates (0.4 and 0.8 atm)





❖ the biggest transfer at the lowest CO_2 concentration

❖ bump in 10% CO2 mixture then sharp decrease for higher fractions

❖ larger rate for the tube with thicker anode wire (r_a = 50 μm)

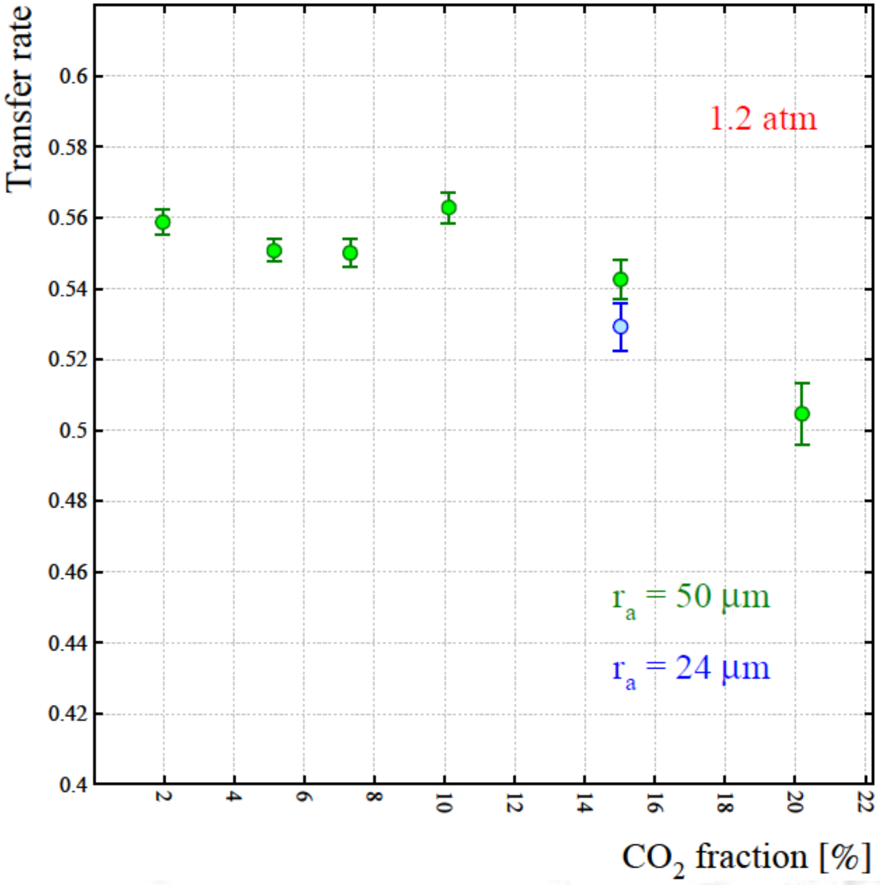
❖ rates are almost flat including 10% CO_2

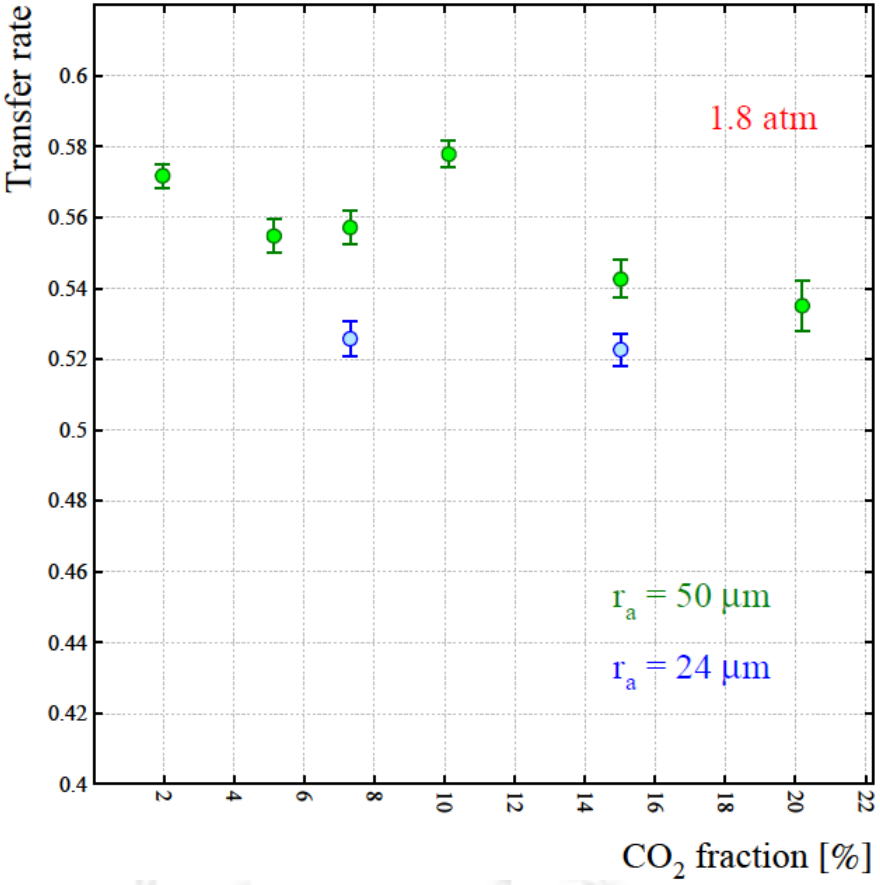
❖ then they decrease in 15% and 20% CO_2

❖ the rates are bigger at 0.8 atm

❖ errors on transfer rates are getting bigger for high concentrations

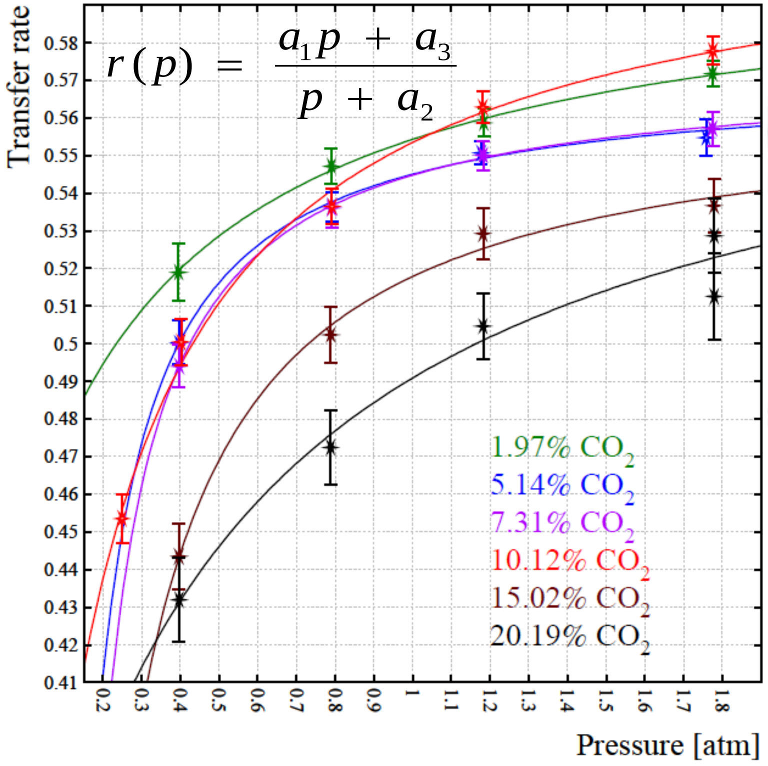
Transfer rates (1.2 and 1.8 atm)

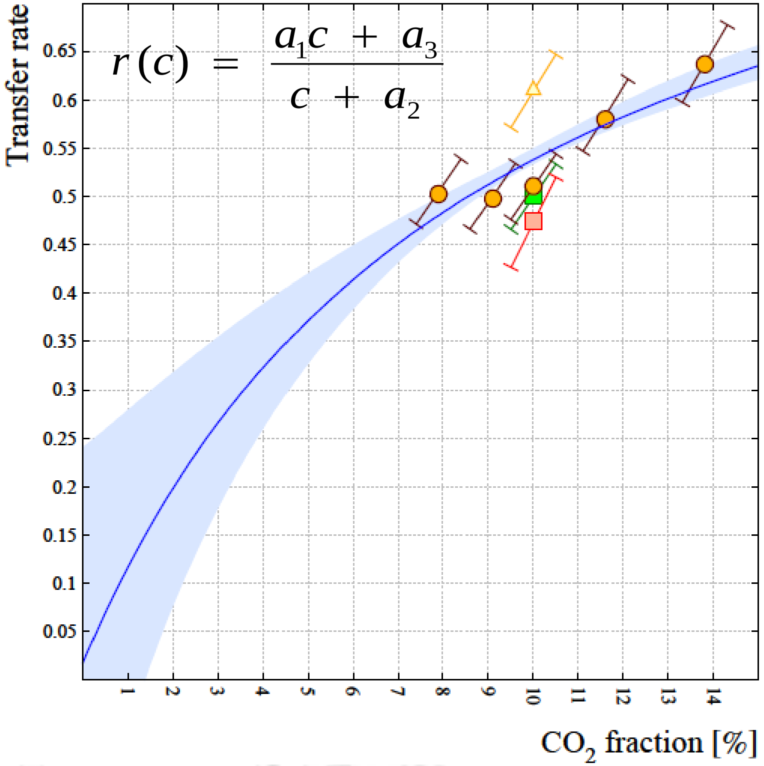




- ❖ the rates reach a maximum for 10% CO_2 mixture (see bumps)
- ❖ maximum and minimum transfer rate gaps over CO_2 concentrations become smaller with increasing pressure
- ❖ we get smaller rate in the tube with thinner anode wire (blue circles on the plots)
- ❖ **the rates interestingly decrease with increase of CO_2 fraction (first time) !!!**

Modelling the transfer rates





- ❖ no drops at the highest pressure
    - ❖ there was in Ar – CO_2 mixtures
- ❖fit parameters for some mixtures are not physically meaningful
    - ❖ measurements below 0.4 atm may help to get more sensible results for radiative terms

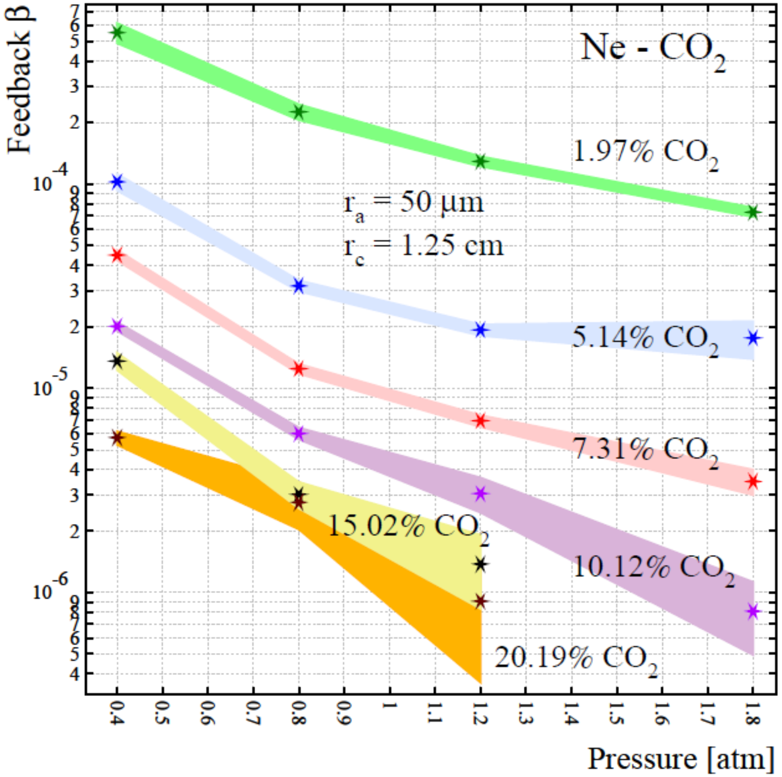
- ❖ ALICE TPC results does not confirm the decrease with CO_2 concentration
    - ❖ 0.5% uncertainty on CO_2 fraction
    - ❖ gain range: 2 10^4 – 5 10^5

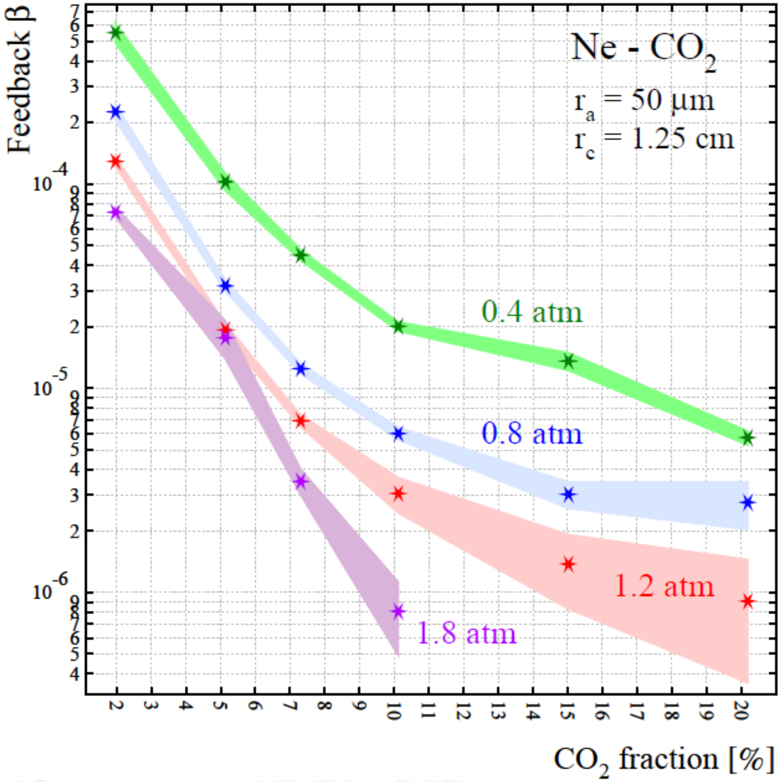
Experimental data:

C. Garabatos, The ALICE TPC, NIM A **535** (2004) 197–200. Proceedings of the 10th International Vienna Conference on Instrumentation.

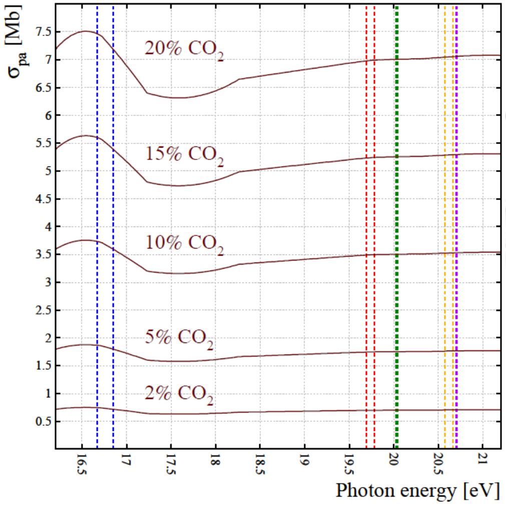
Unpublished data for R. Veenhof, Choosing a gas mixture for the Alice TPC, ALICE-INT-2003-29 version 1.0, CERN,2003.

Feedback parameters in Ne – CO_2 mixtures





- both increase of pressure and CO_2 concentration lead decrease on feedback parameters
- feedback in Ne – CO_2 mixtures is change broader range compared to Ne – CO_2 mixtures
  - Ar – CO_2 : 3 – 20 10^{-6}, Ne – CO_2 : 0.7 – 600 10^{-6}
- calculations on avalanche sizes and photon mean free paths for Ne – CO_2 mixtures are in progress

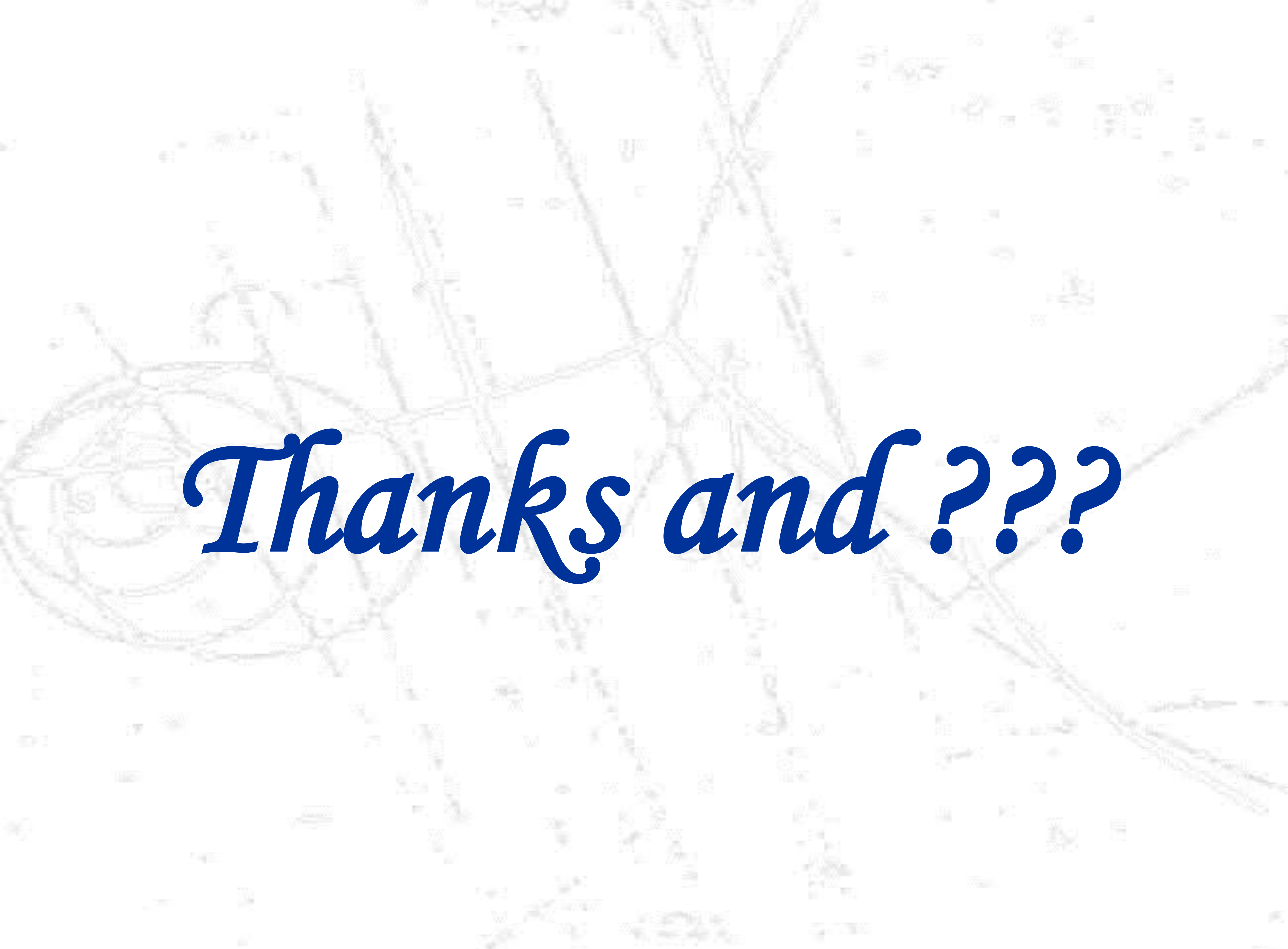


Next

- Hope to publish the results that we have for Ar – CO2 mixtures in very soon

- We have last minute experimental gain data for Ne – CO_2 mixtures only 3 days ago; measured in 30% and 50% CO_2 fractions
  - 3.5% CO_2 data will also be ready in a few days (private communication with Tadeusz KOWALSKI, 13th Oct)
  - very important to fill gaps modelling of the transfer rates
  - calculations are in progress
  - **measurements in 1% CO_2 would also be very useful !!!**

- Physical meaning of drops of the transfer rates at high CO_2 fractions has to be worked closely
  - We will check Magboltz cross sections for Ne by comparing the literature



Thanks and ???