Recent gas gain calculations:

Xe-TMA, C_3H_8- and CH_4-based TEG, Ne-CO_2

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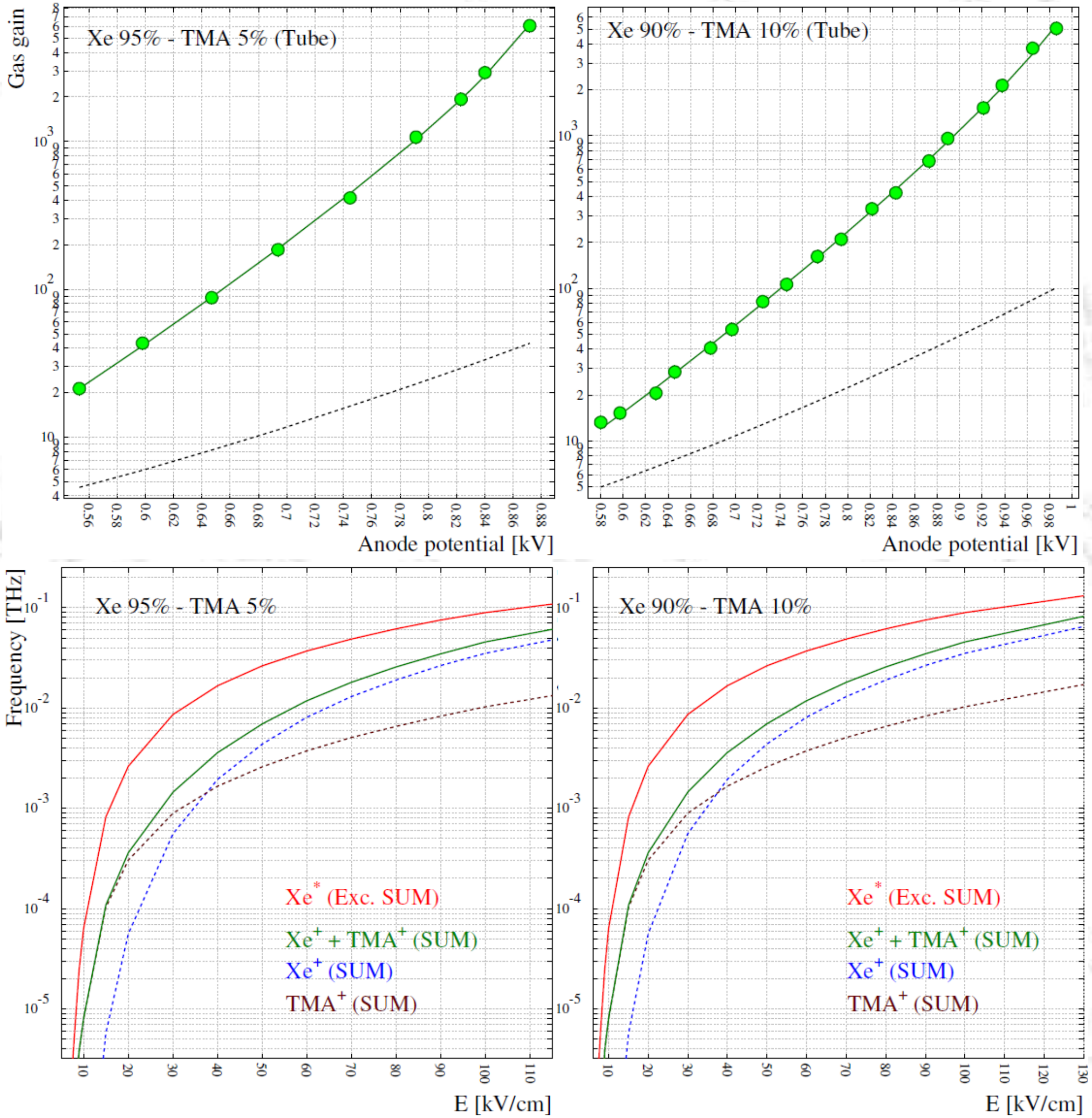
Xe – TMA: Gain fits (Tube)



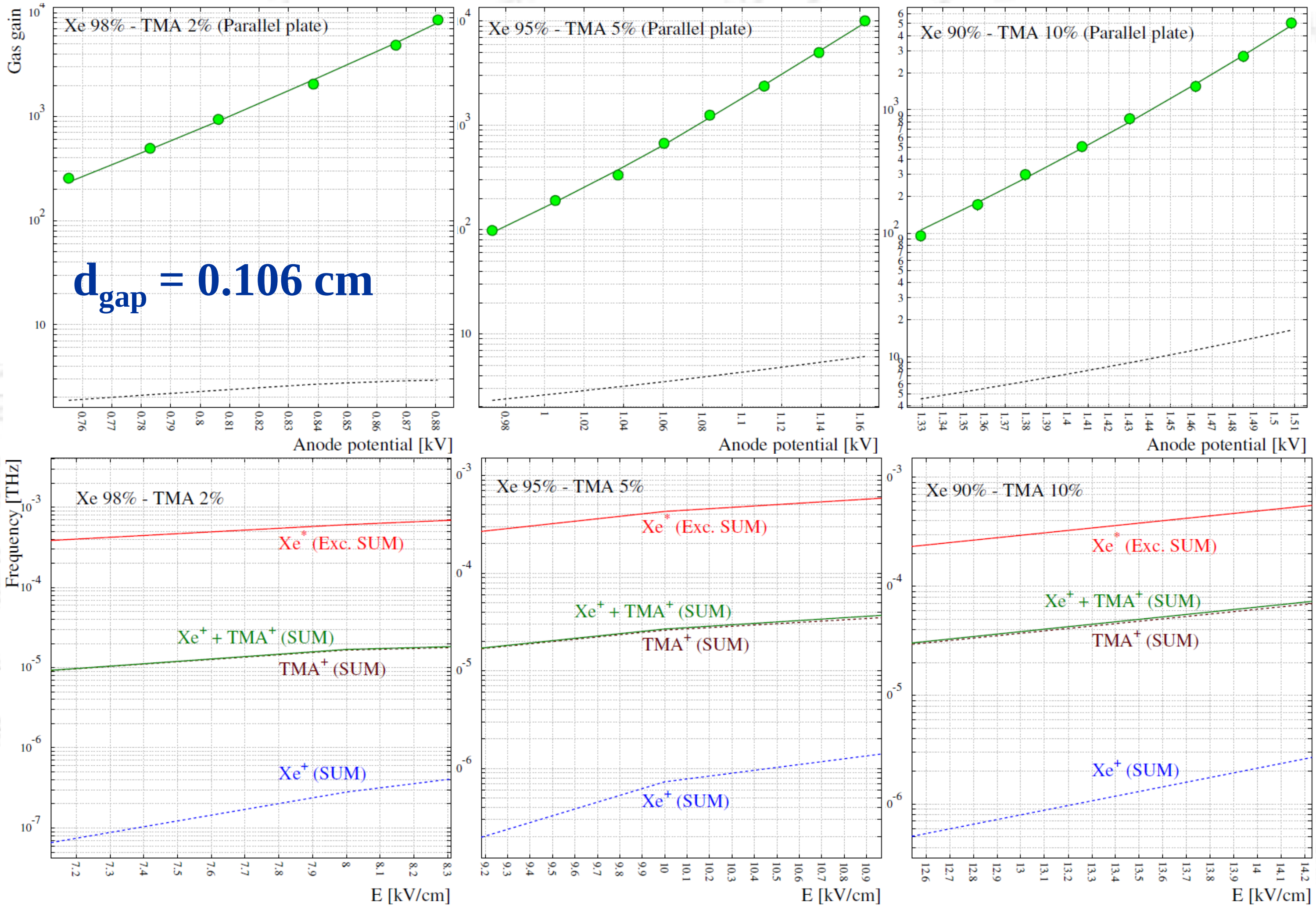
- Gain scaling needed
- Feedback correction

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

- High Penning effect on the gain for 5% TMA
- Contribution from all Xe*
- Xe excitations have the biggest production rate
- Xe ionisations become dominant at high e-fields

Exp. Data: B.D. Ramsey, P.C. Agrawal, Xenon-based Penning mixtures for proportional counters, **NIM A*278* *(1989) 576.***
doi:10.1016/0168-9002(89)90882-6

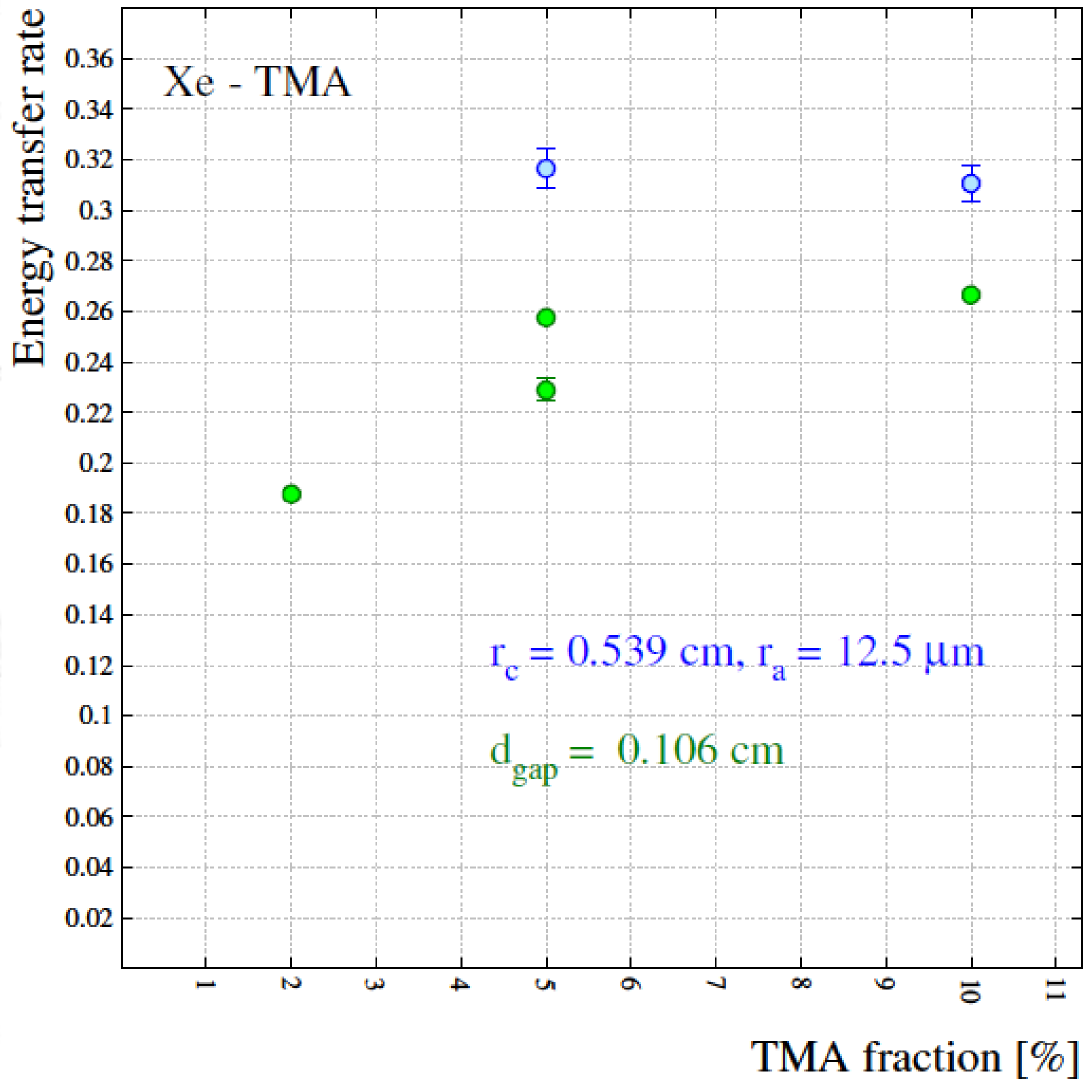
Xe – TMA: Gain fits (Parallel plate)



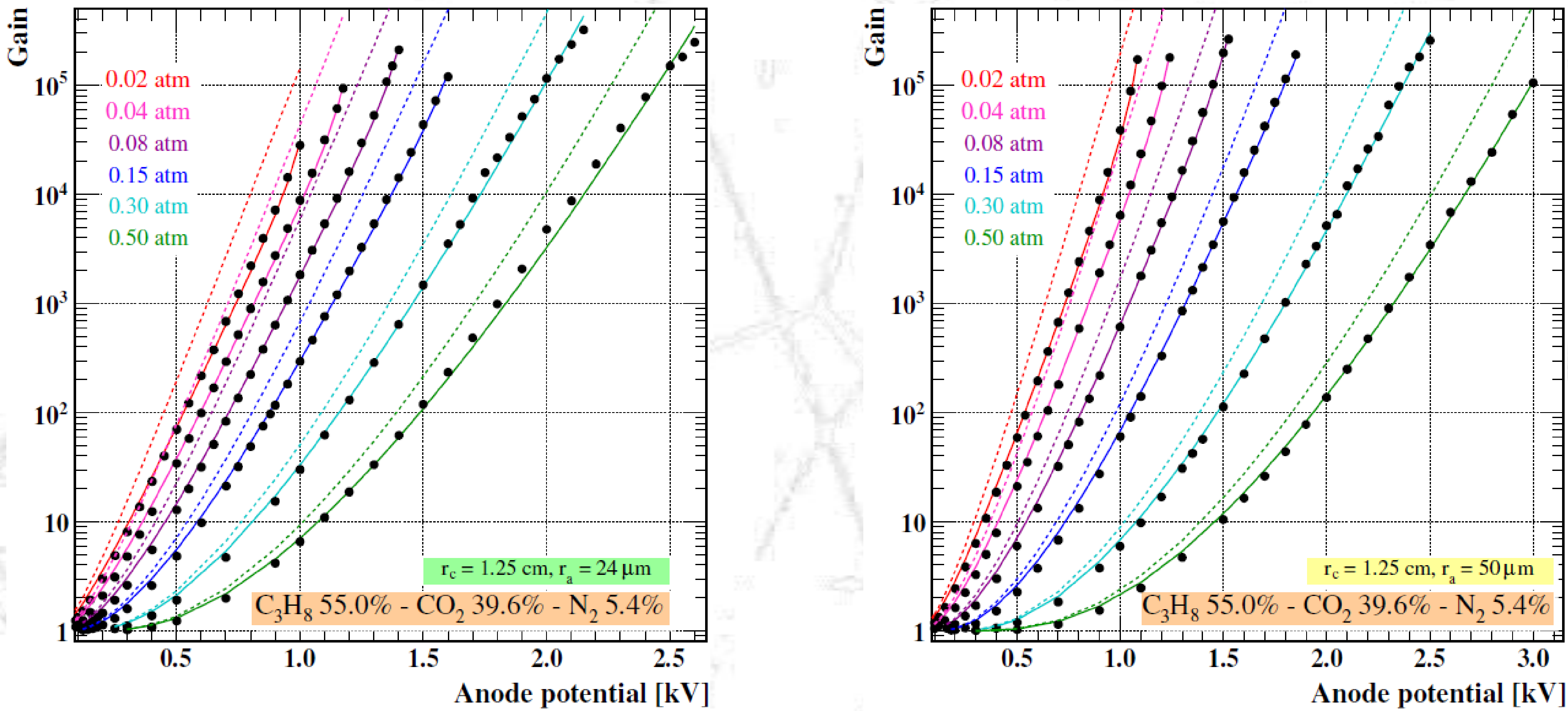
- ❖ **No gain scaling needed !**
- ❖ Very high impact of Penning transfer on the gas gain
- ❖ **Very limited working range (e-field)**
- ❖ Low Xe ionisation rates in the range
- ❖ Very sensitive to Xe*

Xe – TMA: Penning transfer rates

- Higher transfer rates in tube,
- Almost flat rate for the tube ?
- Increasing rate for the **PPC**,
  - Xe see more TMA molecules to transfer,
- PPC rates can give an idea for MMs applications

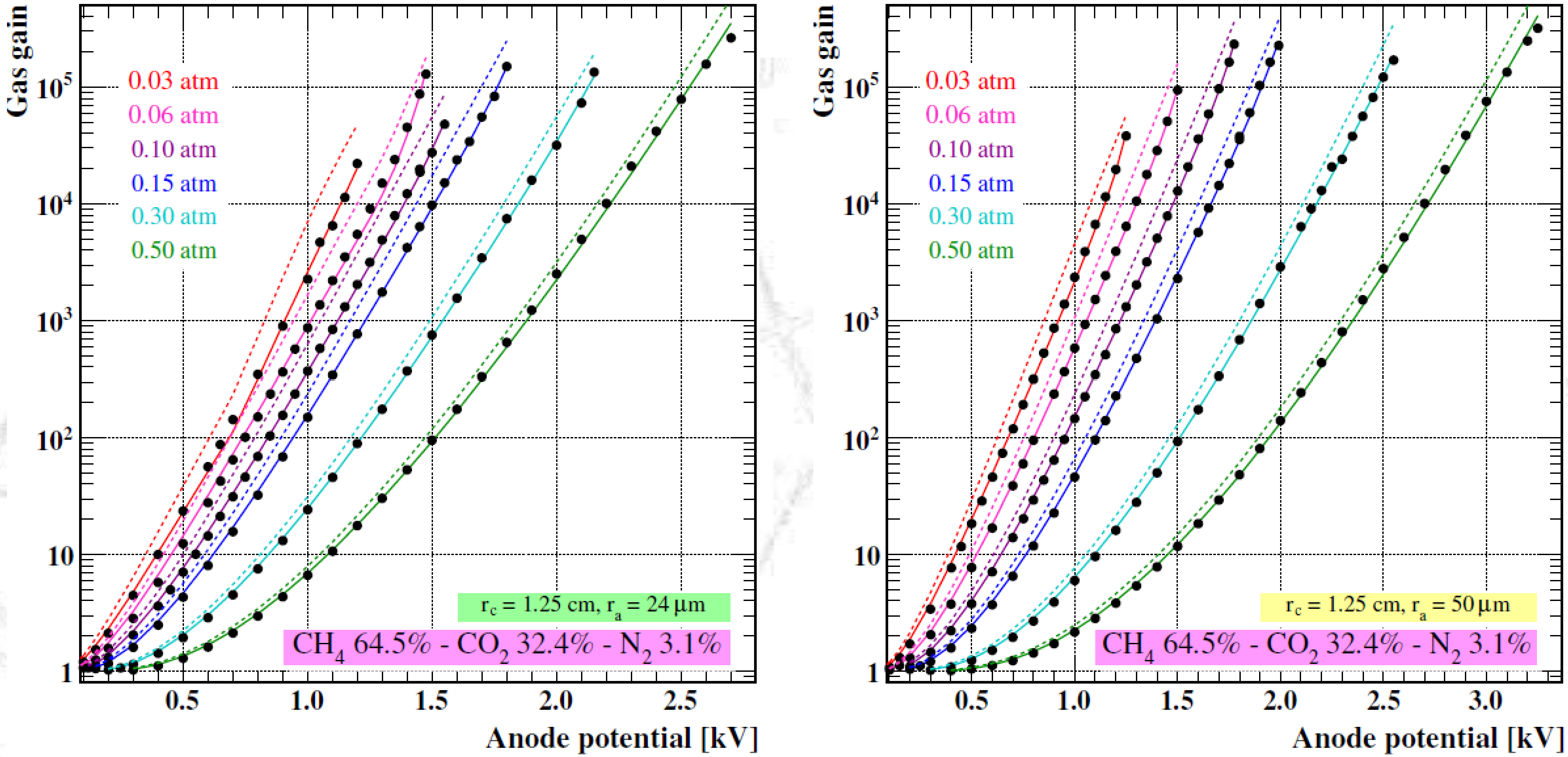


Propane based TEG: Gain measurement & calculation



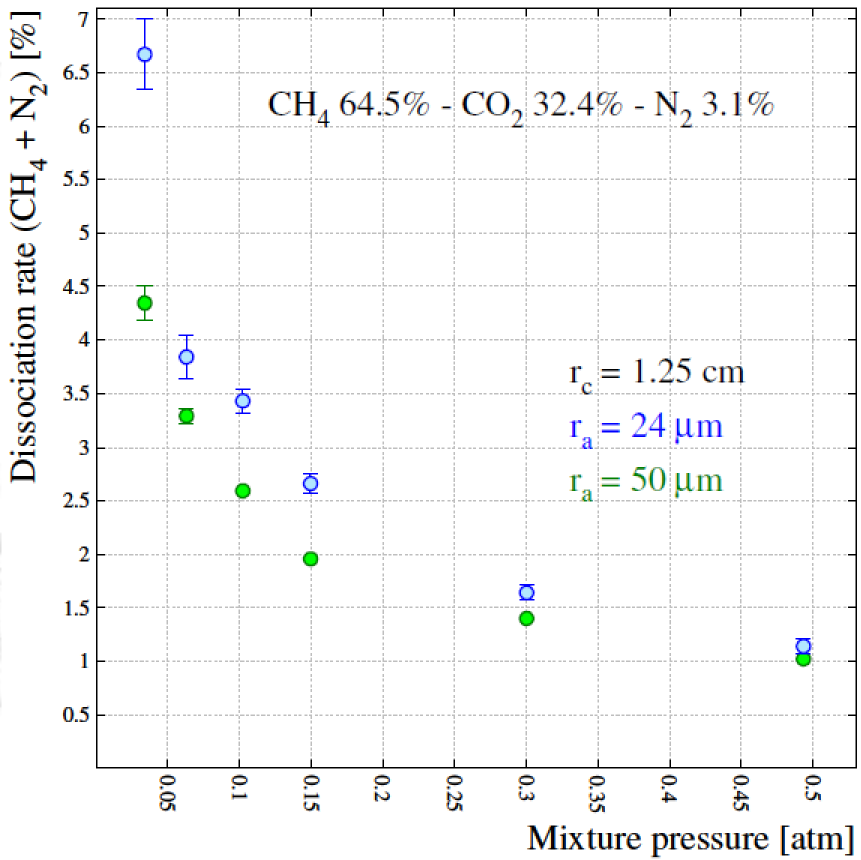
- Disagreement with experimental data (dashed lines),
- Measurements in Krakow by Tadeusz KOWALSKI,
- Gain scaling factor does not explain the problem; perfectly fine calibration,
- Answer: Higher value of calculated gain due to neutral dissociations,
- N_2 already updated but **still update for C_3H_8 is needed**

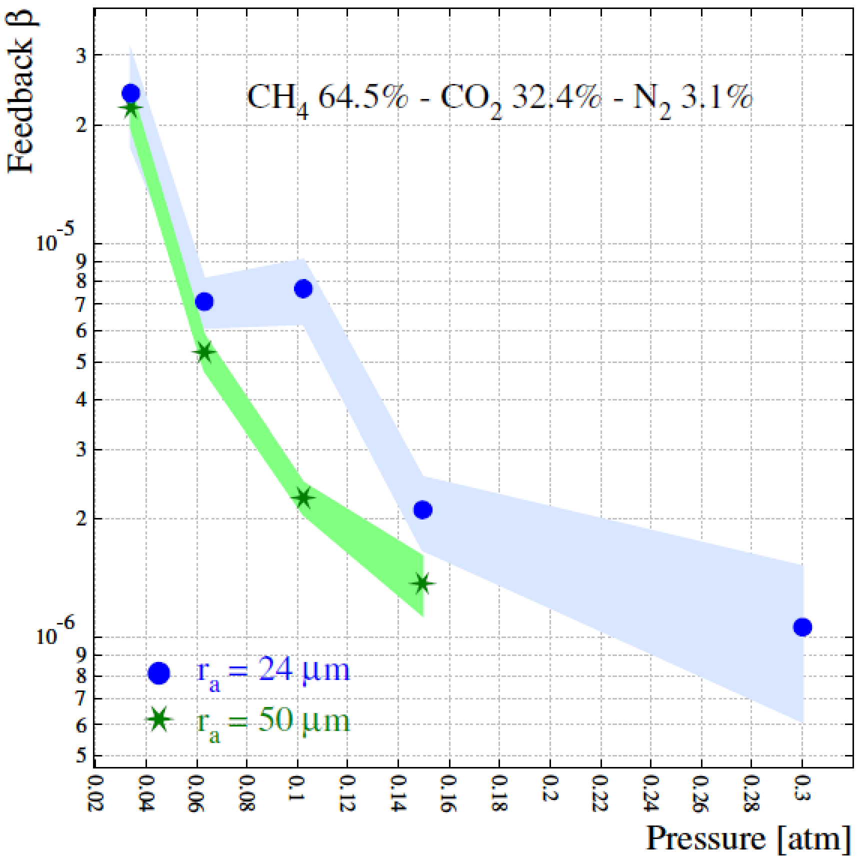
Methane based TEG: Gain Fits



- Magboltz 10.9 gives detailed information about dissociations of CH_4 and N_2
- Do not expect large dissociations for CO_2,
- Straight lines derived by taking into account the dissociative excitations,

Methane based TEG: Dissociation rate and feedback





- Dissociation rates close each other with increasing pressure,
  - Non-equilibrium effects !!

- Nothing strange for decreases with pressure,
- Ions may also contribute to the feedback by arriving cathode

Ne – CO_2 measurements and calculations

CO_2 percentage

1) 1%
2) 2%
3) 4%
4) 5%
5) 7%
6) 10%
7) 5%
8) 20%
9) 30%
10) 50%
11) 74%
12) **Pure CO_2**

Pure Ne (a week ago) !!!

Penning correction

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

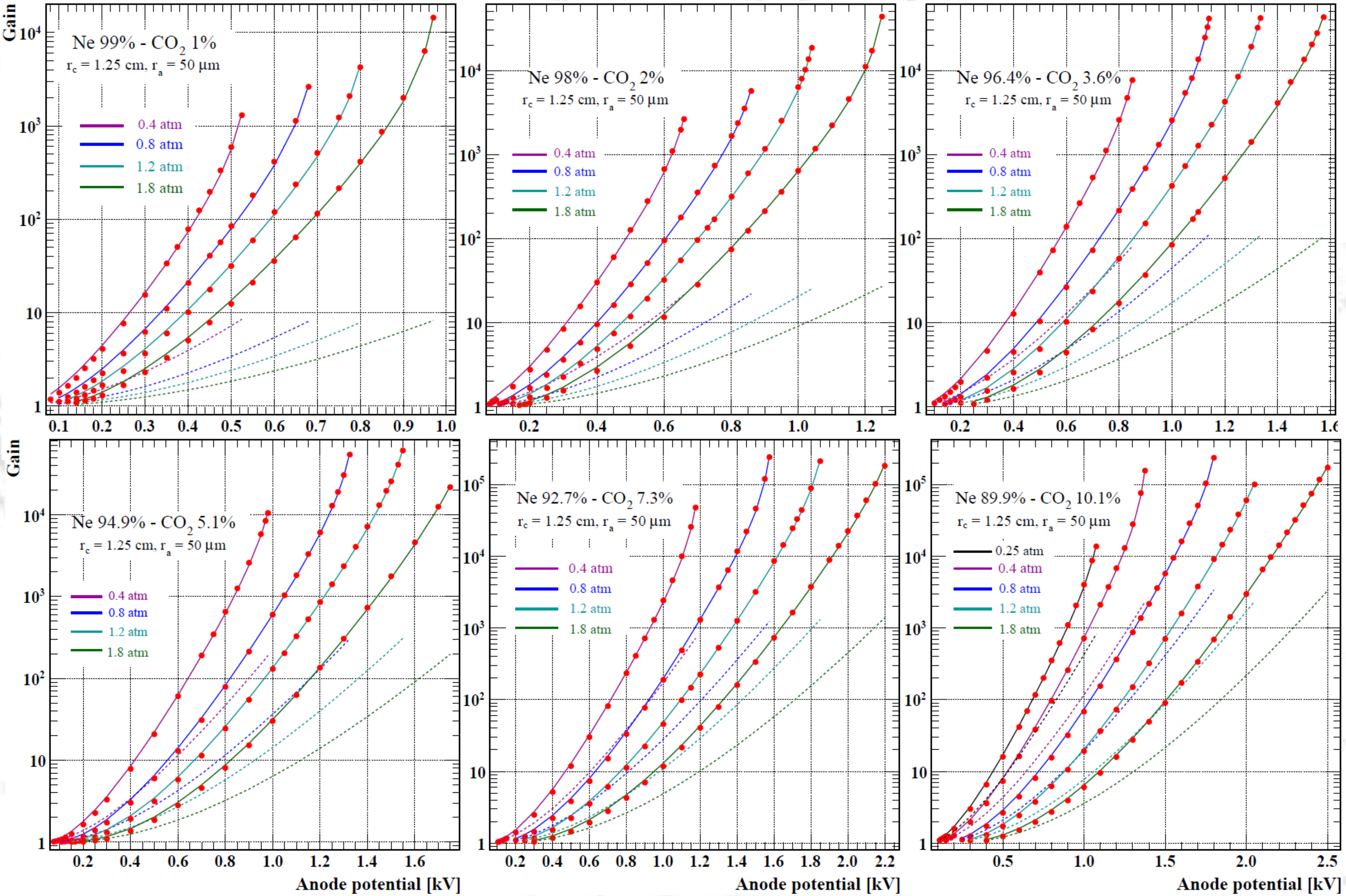
$$\alpha_{Penning} = \alpha \frac{\sum \nu_i^{\text{ion}} + \sum r_i \, \nu_i^{\text{exc}}}{\sum \nu_i^{\text{ion}}}$$

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

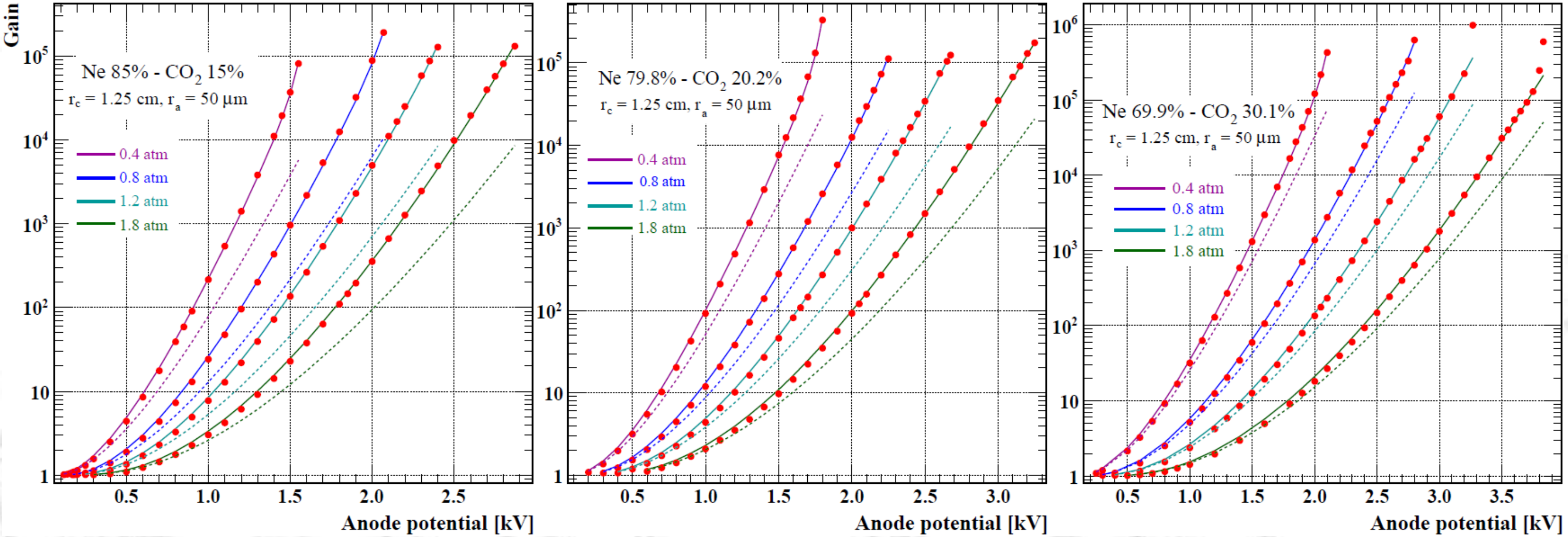
!!! No gain scaling needed in the fits !!!

- 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: Gain fits (r_a = 50 µm)

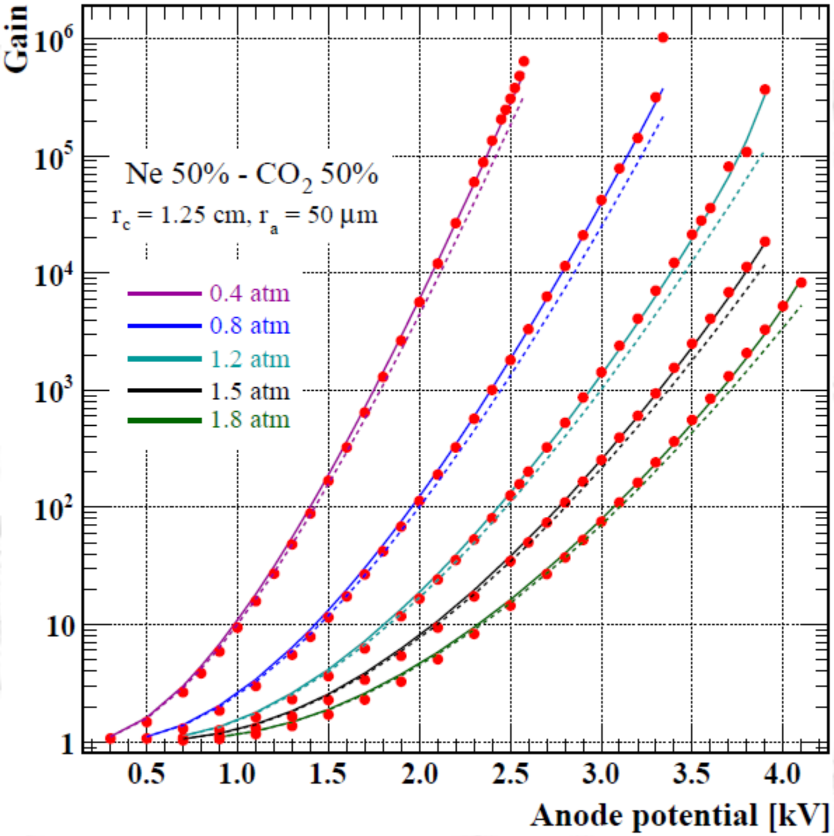


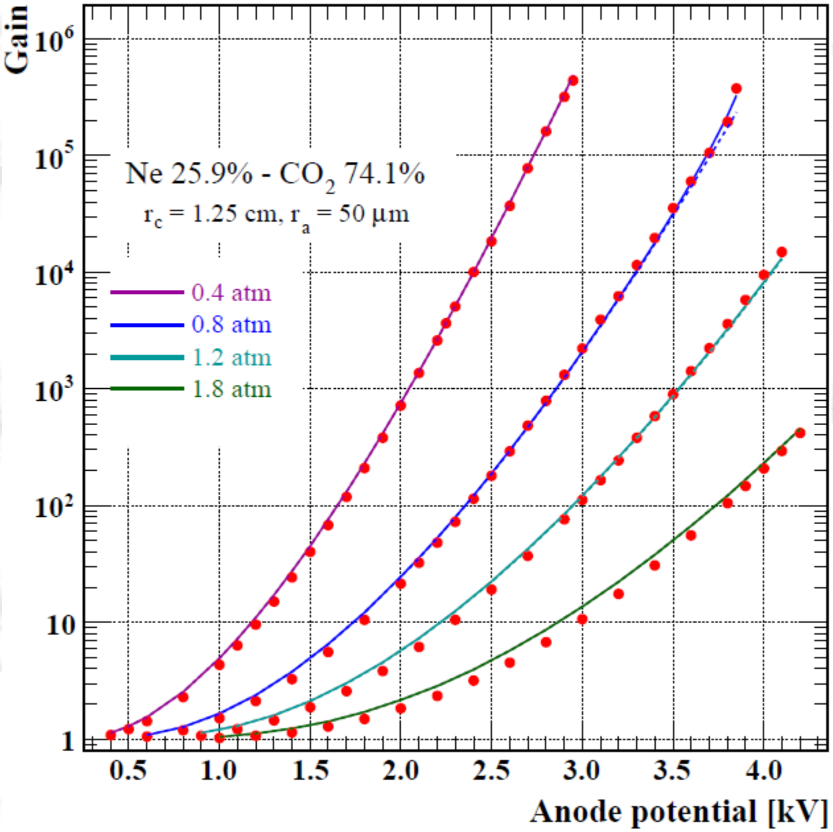
Ne – CO_2: Gain fits (r_a = 50 μm)



- Energy transfers have more impact on gain (Penning effect) with increasing pressure and CO2 concentration,
- 20.2% CO_2: no visible over – exponential increases higher than 0.4 atm but still feedback parameters are needed to get better agreement
- 30.1% CO_2 mixture: no fit of the latest gain data at 1.2 atm and 1.8 atm,
  - Given photon feedback is valid if we still working in proportional region,
  - Proportionality of the gain curves destroys (breakdown points?).

Ne – CO_2: Gain fits (r_a = 50 μm)

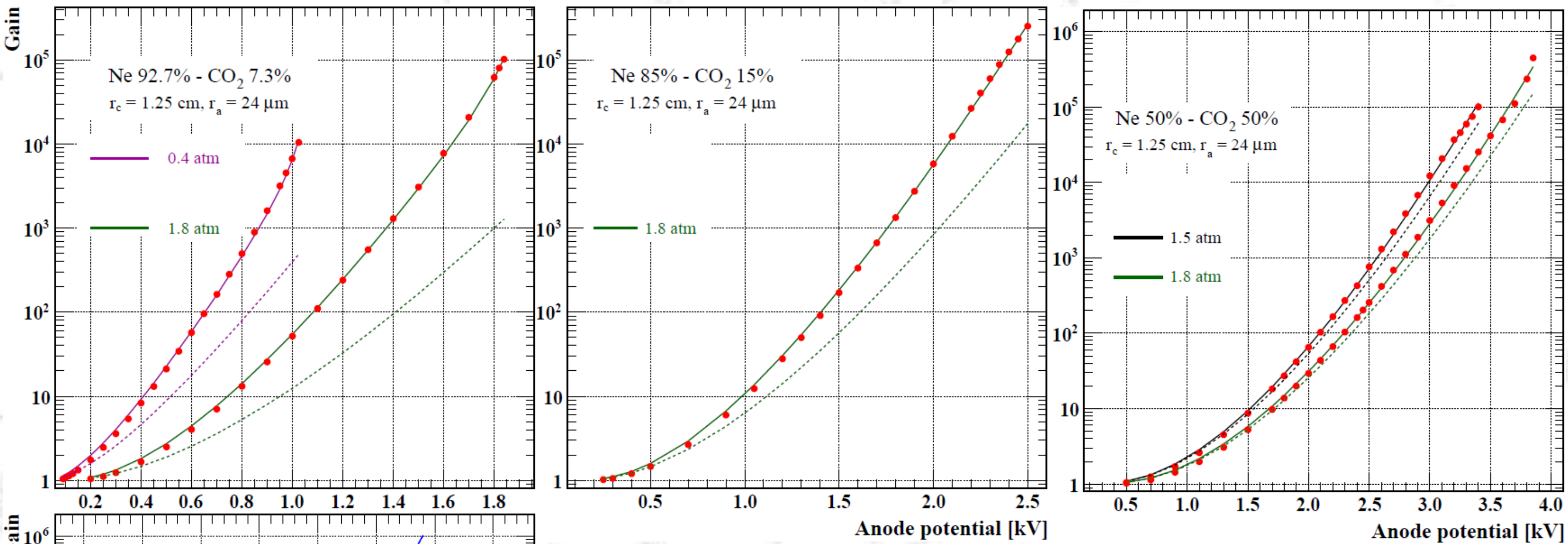


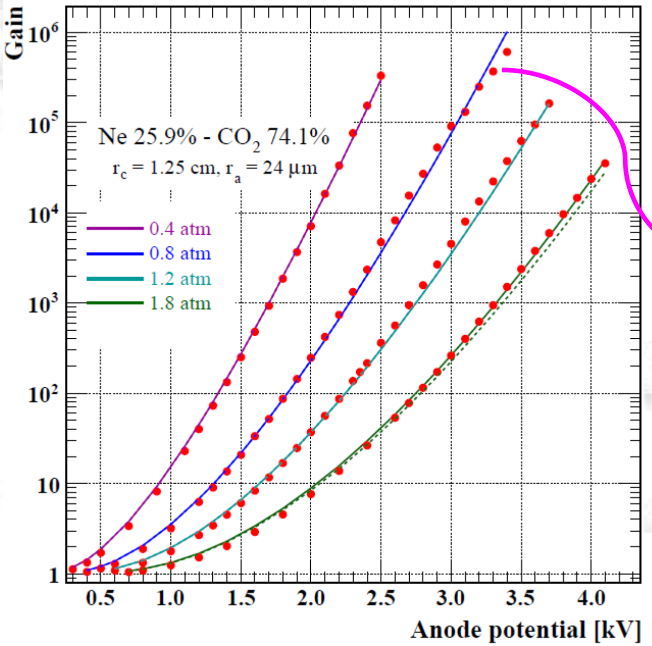


- ❖ the biggest admixture concentration in which Penning effect on gain is clearly seen,
- ❖ Still we have feedback but the uncertainty is large (see later),
- ❖ the fits with feedback parameter at 0.4 and 0.8 atm are not shown on the plot.

- ❖ **0.04** transfer rate at 0.8 atm;
- ❖ 0.4, 1.2 and 1.8 atm data are fitted **without Townsend adjustment,**
- ❖ 1.8 atm: worse agreement 2 – 6 kV,

Ne – CO_2: Gain fits (r_a = 24 μm)



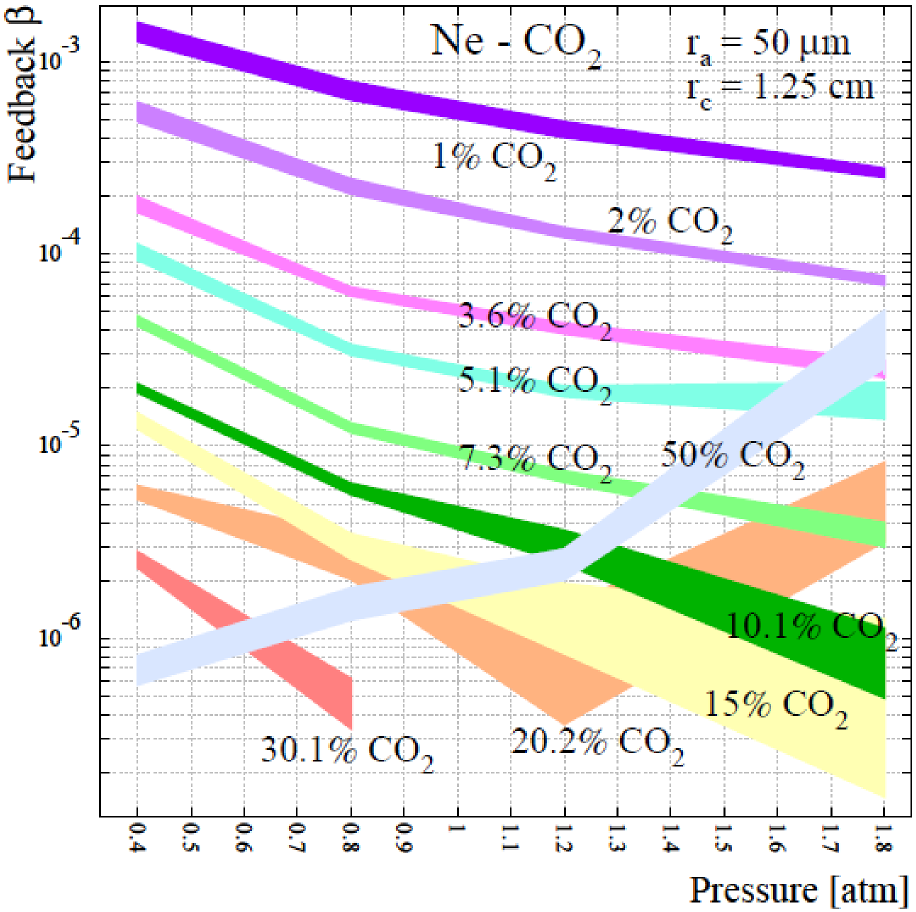


❖ No Penning adjustment needed for 74.1% CO_2, like seen in data measured with r_a = 50 μm

❖ last 2 gain points at 0.8 atm: calculated gains are bigger than the measured ones,

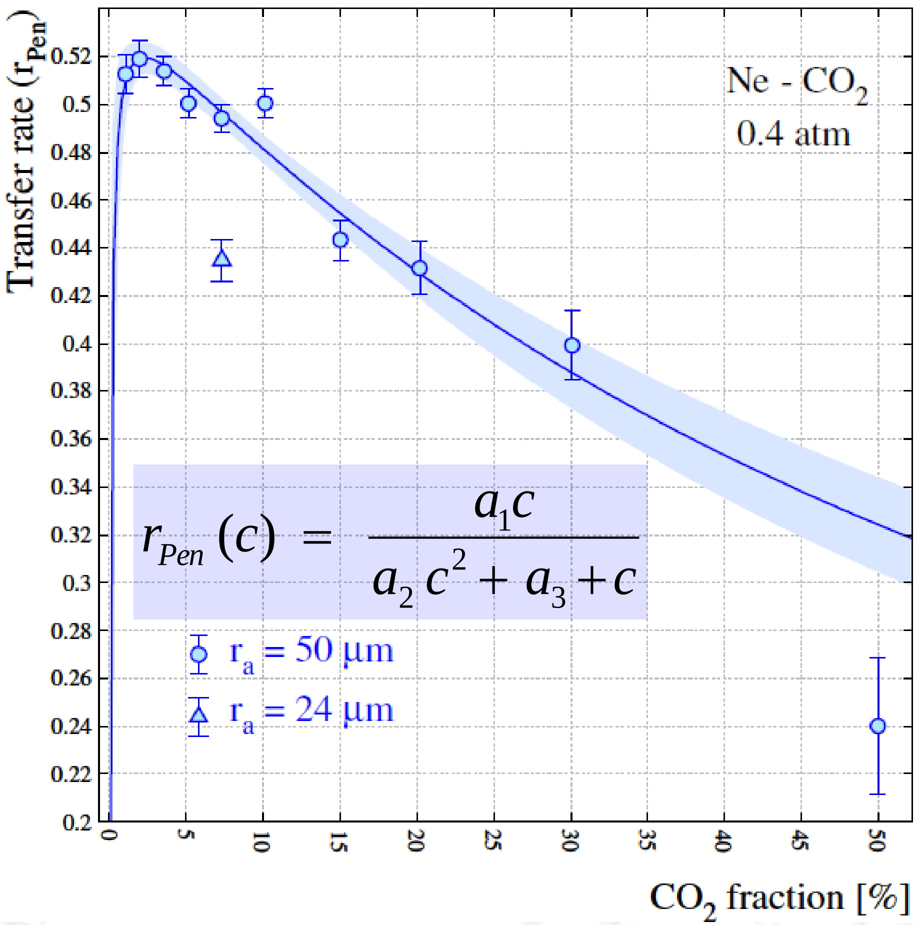
❖ **Space charge ??!!!??**

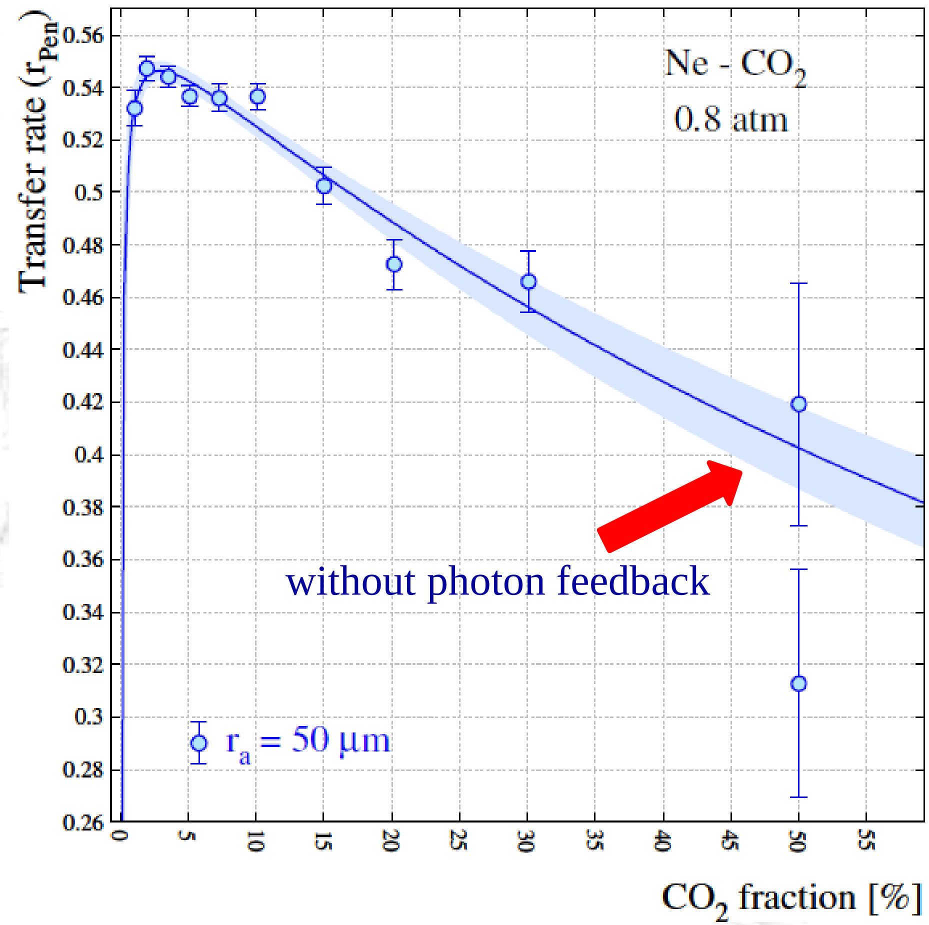
Ne – CO_2: Feedback parameters



- Feedback always decrease with pressure and fraction of CO_2 up to 15%,
  - Mean free path of the photons
- Increases of feedback for 30% and 50% CO_2 due to ions arriving cathode

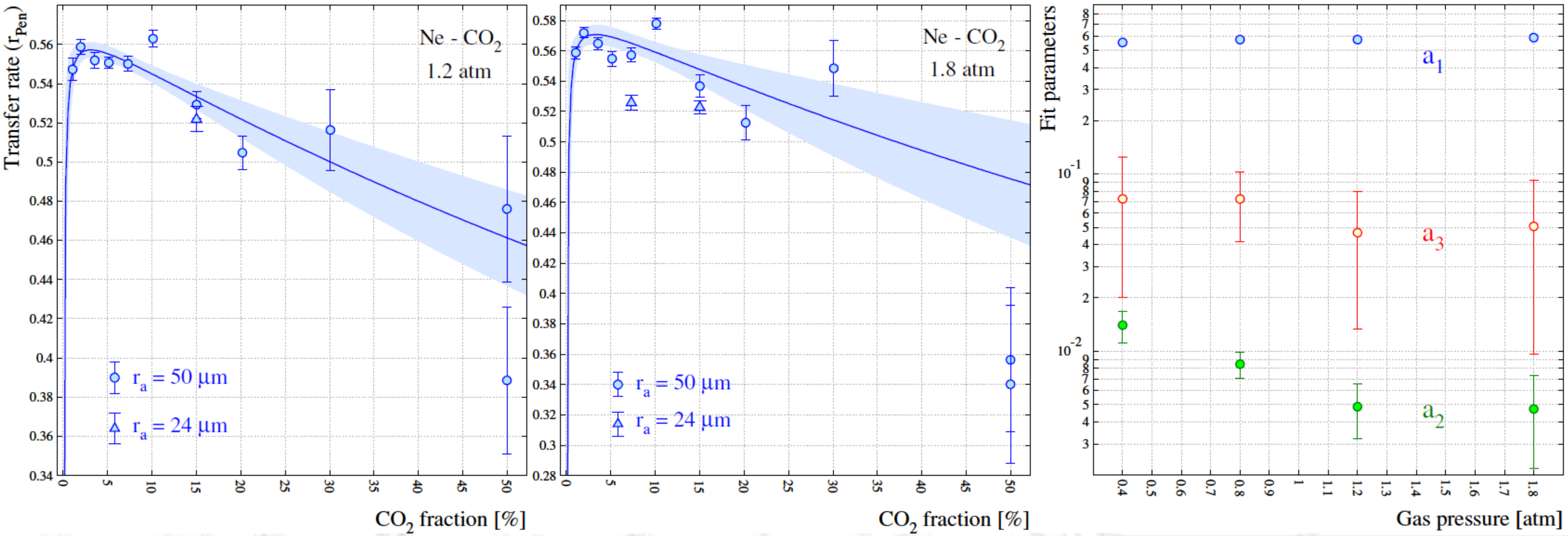
Ne – CO_2: Penning transfer rates





- ❖ Decrease of the transfer rates with increasing admixture fraction,
- ❖ The rates can be described using a 3 parameter fit function,

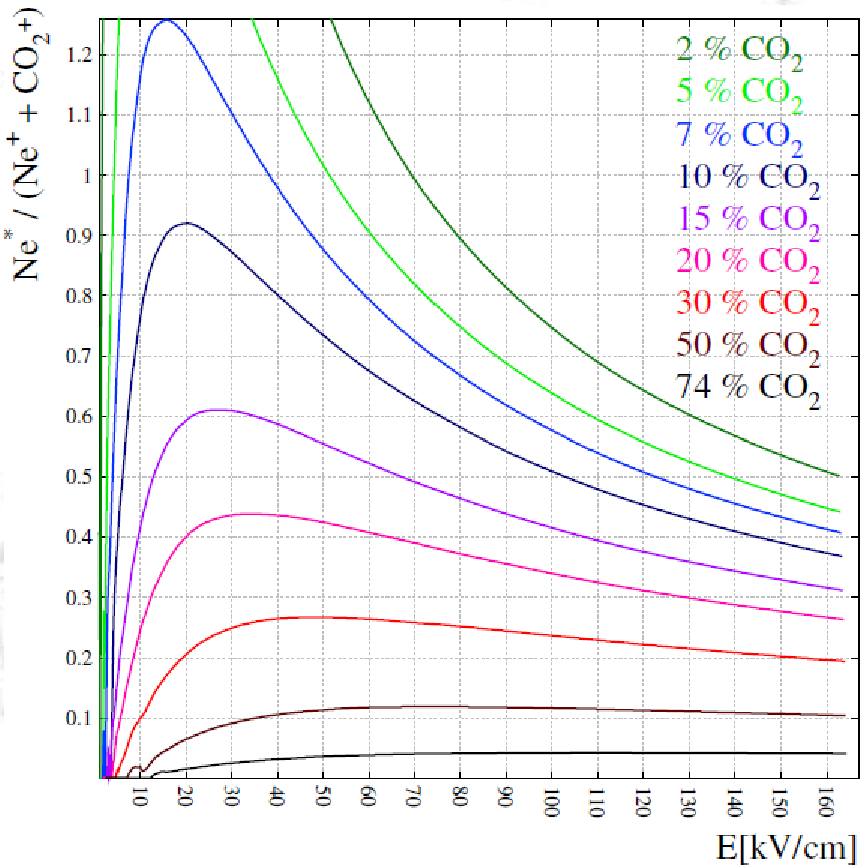
Ne – CO_2: Penning transfer rates and parameters

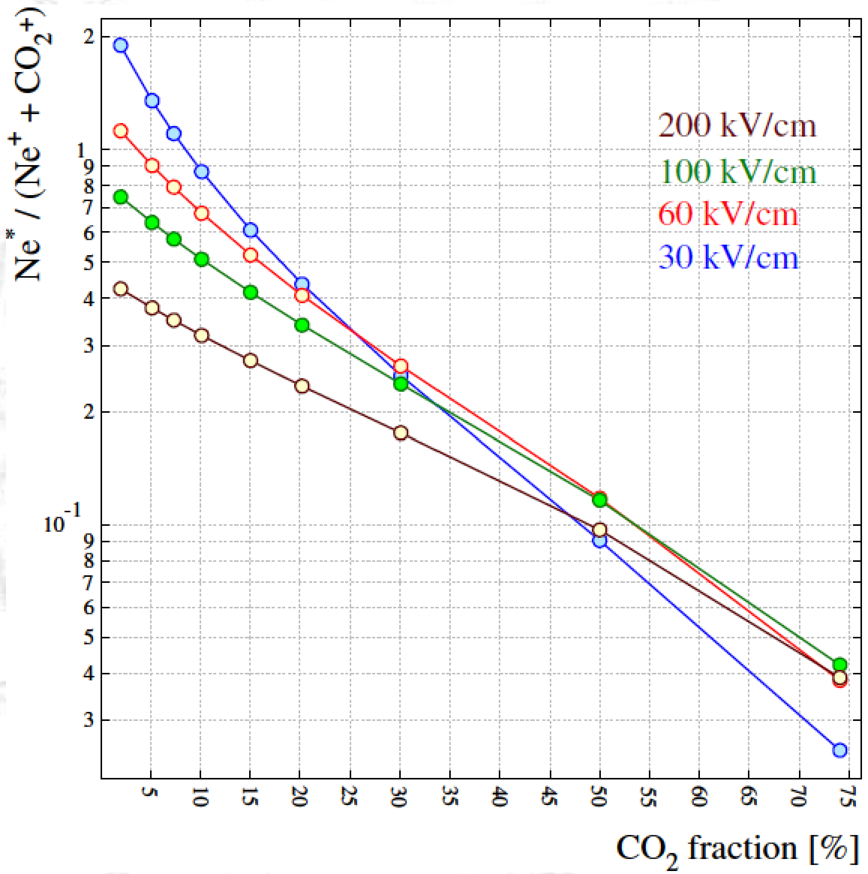


$$r_{Pen}(c) = \frac{a_1 c}{a_2 c^2 + a_3 + c}$$

- Large errors at 50% CO_2,
- Lower energy transfer derived from r_a = 24 μm tube,
- The highest transfer rate at the highest pressure (1.8 atm),
  - collision times shortened by pressure increase ,
- a_1 : asymptotic value of the transfer rate; almost flat,
- a_2 and a_3 both drops with pressure; a2 indicates three-body interaction energy losses may happen, like excimer formation

Ne – CO_2: Fraction of excitations (Ne*)

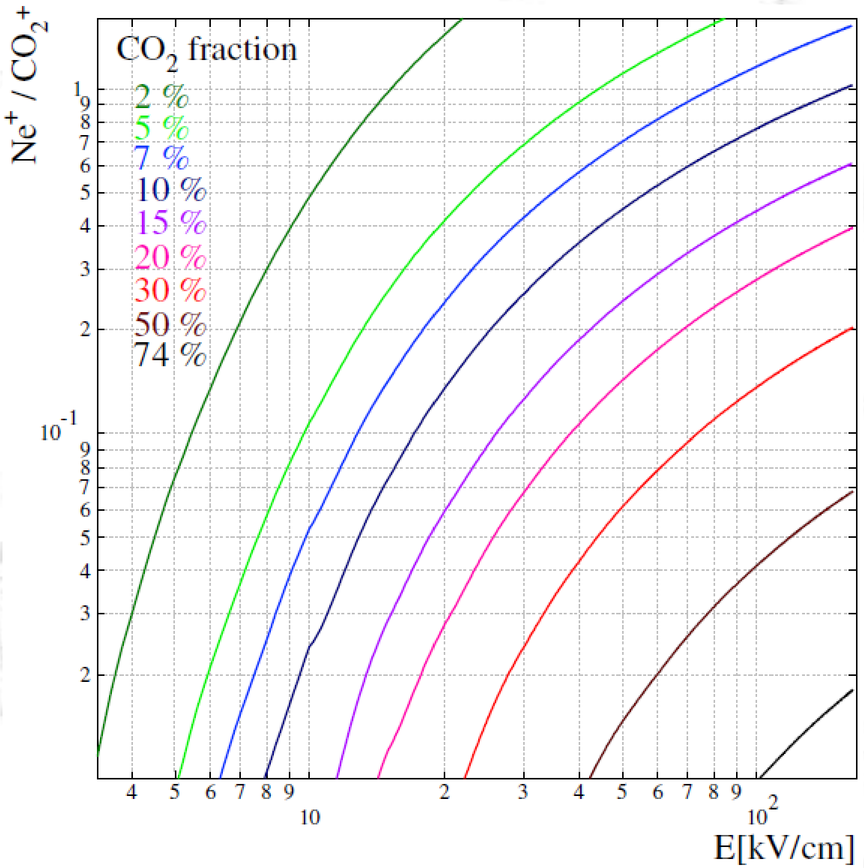


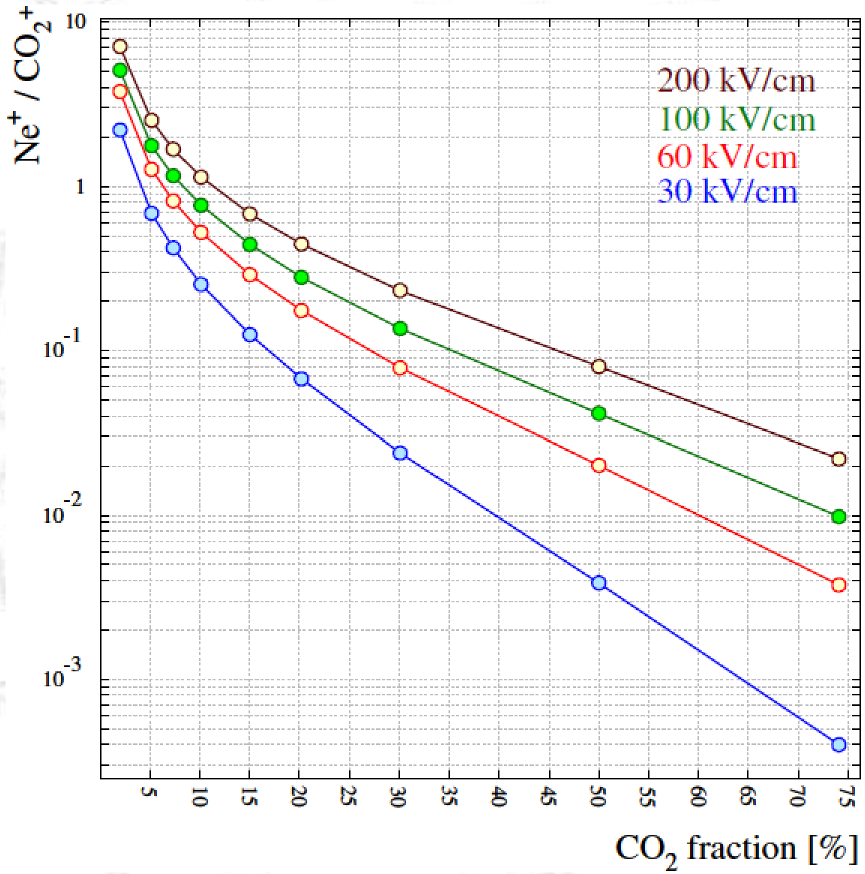


❖ Effect of the excited Ne atoms to the total ionisation becomes significantly small at high CO_2 percentages (left plot) and at high e–fields (right plot):

- ❖ IP CO_2 = 13.8 eV and IP Ne = 21.6 eV
- ❖ Easy to ionise CO_2 rather than excite or ionise Ne atoms

Ne – CO_2: Fraction of ionisations

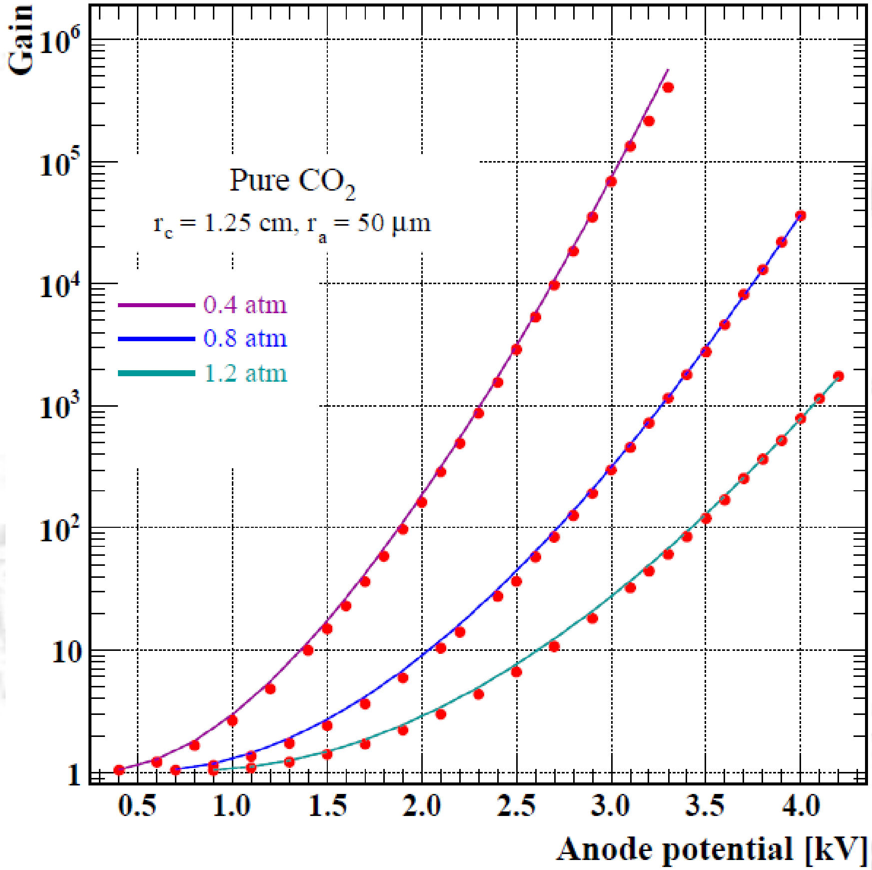


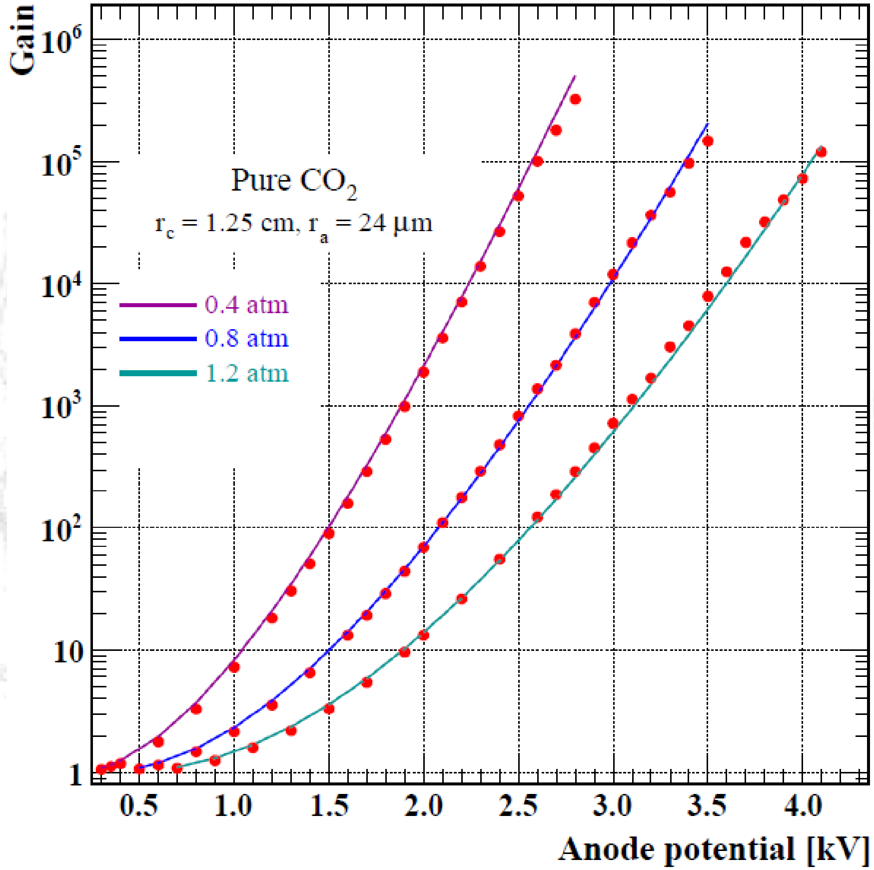


❖ Most of the electron energy is picked up to ionise CO_2 molecules because of the high ionisation cross section for CO_2,

❖ Ne^+ / CO_2^+ fraction changes by factor 700 at 200 kV/cm (plot on the right); even becomes larger for lower e–fields (see the lines for 100, 60, 30 kV/cm)

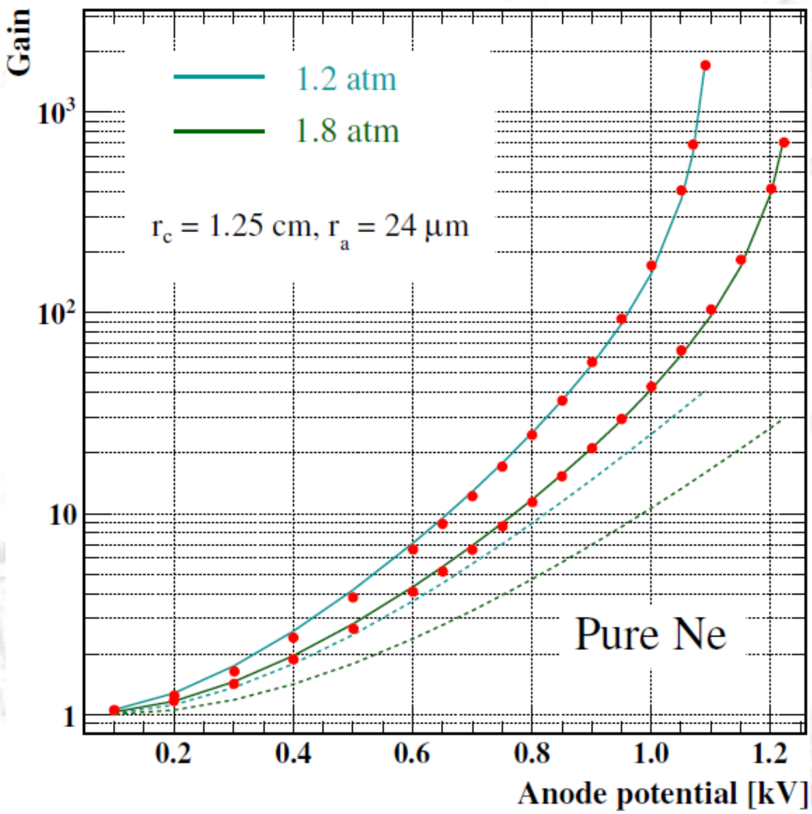
Pure CO_2 measurements and calculations

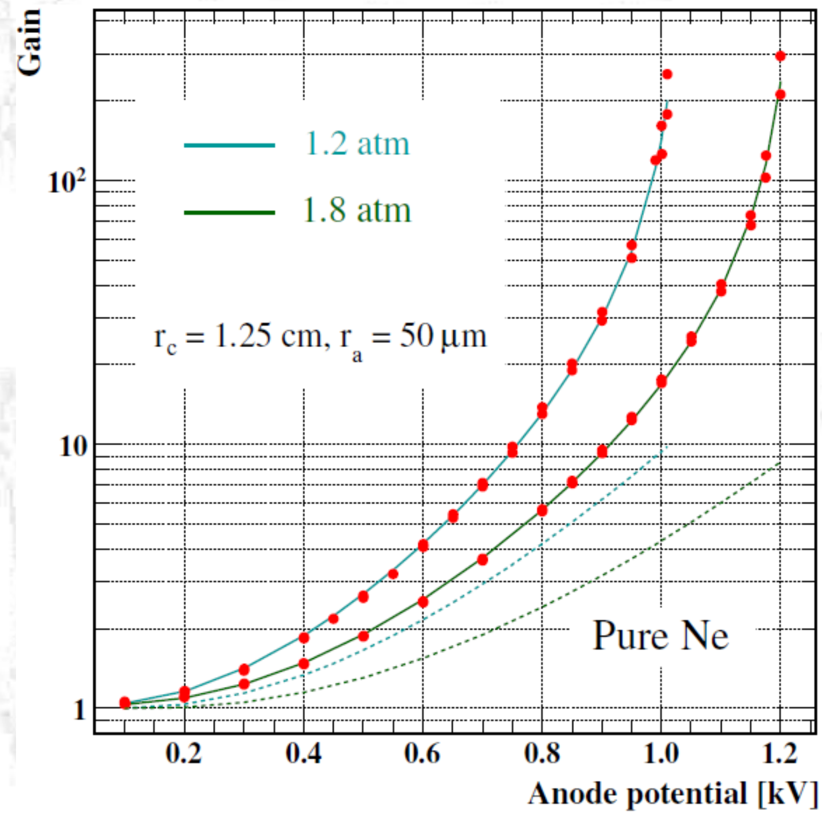




- ❖ Space charge effect in some measurements,
- ❖ Perfectly fine fits with all experimental gain curves; without any scaling or correction factor:
  - ❖ high precision measurements (thanks to Tadeusz),
  - ❖ correct cross sections used in Magboltz (thanks to Steve), .

Pure Ne measurements and calculations





- Very strong photon feed-back on the gain curves:
  - no quenching gas to absorb the photons emitted from excited neon atoms,
  - excimers can increase the multiplications and also produce the feed-back
- Impurities in Ne may also contribute to the gain via Penning transfer mechanisms,
- Straight lines: includes 20 eV and upper excited states of Ne
  - homonuclear associative ionisations : **$Ne^* + Ne \rightarrow Ne_2^+ + e^-$**

Summary

❖ **Xe-TMA:** Penning transfer rates derived from PPC can be used as guide for MMs,

❖ Diego et al. have experimental data measured in MMs to make a comparison by introducing the correct e-field configuration,

❖ **TEG mixtures:** Calculations give higher gain than the measured data,

❖ Dissociative excitations of the molecules should be taken into account,

❖ Perfectly fine fits for CH_4 based TEG mixtures (CH_4 already updated),

❖ Non-equlibrium effects for the different anode wires is visible from the dis. enegy loss rates, calculations with Garfield++ can proof the effect,

❖ Recalculate the C_3H_8 based data after Magboltz C_3H_8 update,

❖ **Ne-CO_2:** Model fits the drops on the transfer rate at high CO_2 fractions,

❖ High ionisation and excitation thresholds of Ne is important factor since the electron energy mostly used by CO_2 molecules having to have lower thresholds,

❖ Calculations for pure CO_2 measurements perfectly fine overlaps,

❖ Excimers, homenuclear associative ionisations and impurities of the gas are very critical points for the fitting the gain curves of pure Ne measurements.

Thanks and ???