Photon feed-back
&
Gain calculations in Micromegas

Özkan ŞAHİN
Uludağ University Physics Department
Bursa -TURKEY

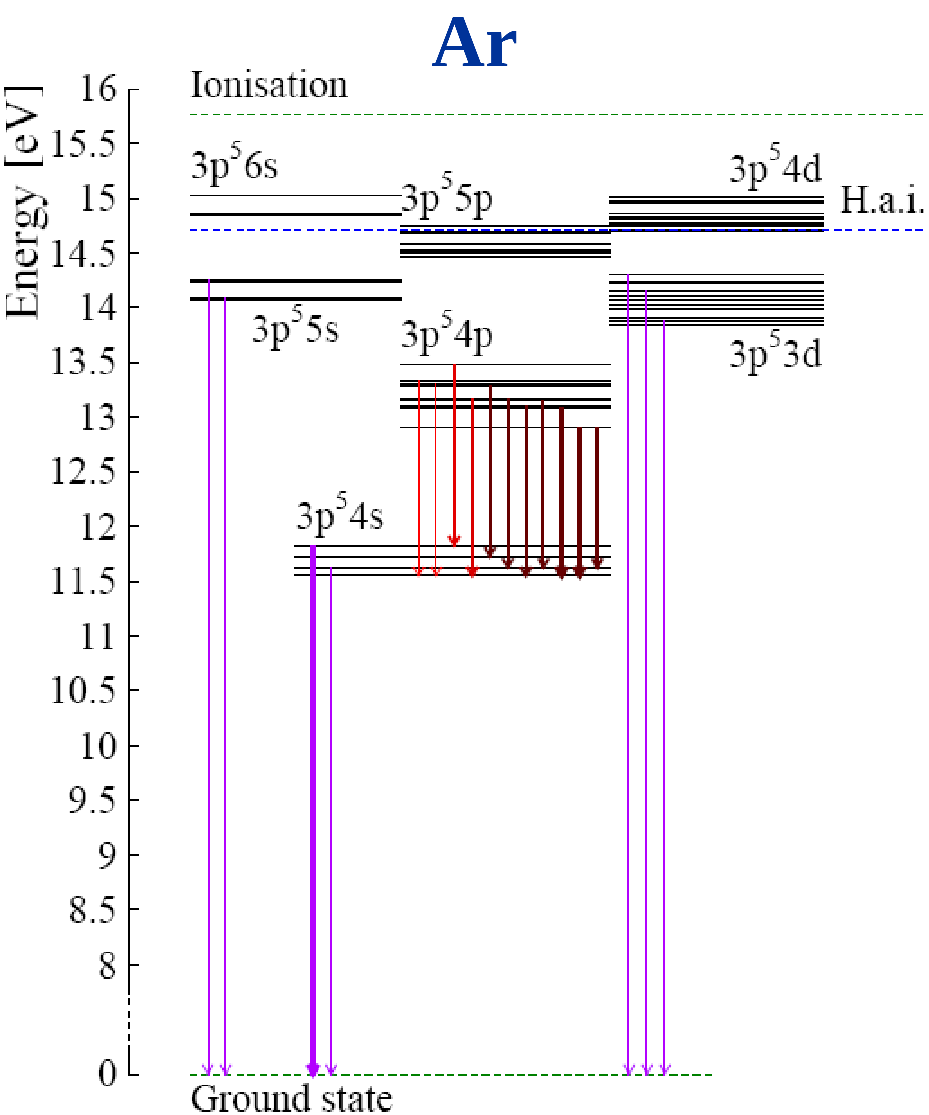
Source of photon feedback

- Excited states (A^*) $\Rightarrow$ radiative decay ($A^* \rightarrow A + \gamma$),
- Photons $\Rightarrow$ photo-electrons (from cathode and in gas itself),
- Secondary, delayed avalanches $\Rightarrow$ over exponential increases at high gains:
  - $G \Rightarrow$ average avalanche size without feedback,
  - $\beta \Rightarrow$ number of secondary avalanches started by one avalanche electron,
    - electrons: 1th step $\Rightarrow \beta G$, 2nd step $\Rightarrow \beta G^2$, 3th step $\Rightarrow \beta G^3$, …
    - Summing over each step:

$$G' = G + \beta G^2 + \beta^2 G^3 + \ldots = G/(1-\beta G)$$

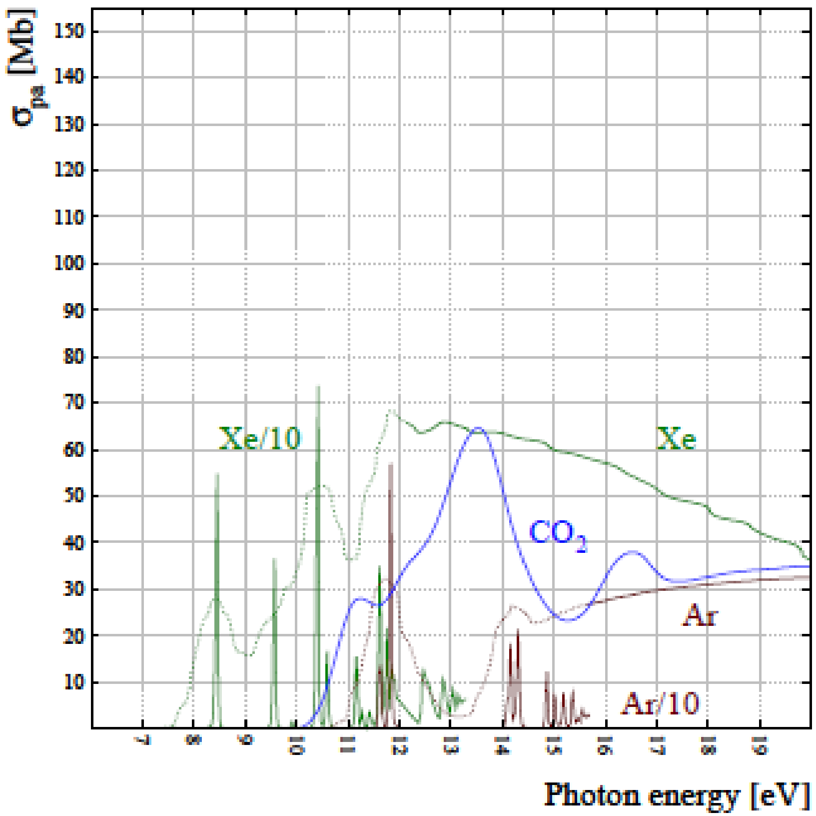
    - G` $\Rightarrow$ average avalanche size with feedback.

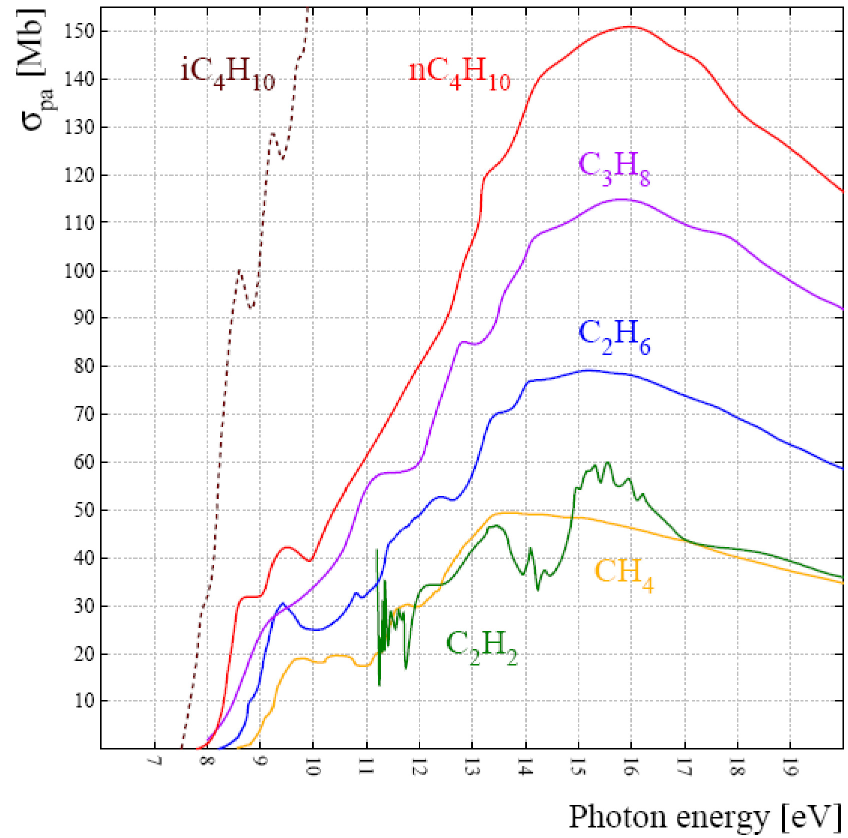
Energy of photons



- **$3p^5 4s$**
  - $Ar^*(^3P_0)$, $Ar^*(^3P_2)$
    11.55 eV, 11.72 eV ⇒ Metastables
    τ ⇒ lifetime of seconds
  - $Ar^*(^3P_1)$, $Ar^*(^3P_3)$
    11.62 eV, 11.83 eV ⇒ UV photons
    $\tau \approx 8.6 \pm 0.4$ ns, $\tau \approx 21 \pm 2$ ns
- **$3p^5 4p$**
  - predominantly decays ⇒ $3p^5 4s$
    red or infrared light (≈ 2 eV)
    τ ⇒ 21.7 – 40.5 ns
- **$3p^5 3d$**
  - threshold energy of 13.85 eV
    $\tau \approx 50$ ns
- **higher levels**
  - less frequently excited in avalanches
    τ ⇒ 100 – 300 ns

Photo-absorption cross sections (σ_{pa})





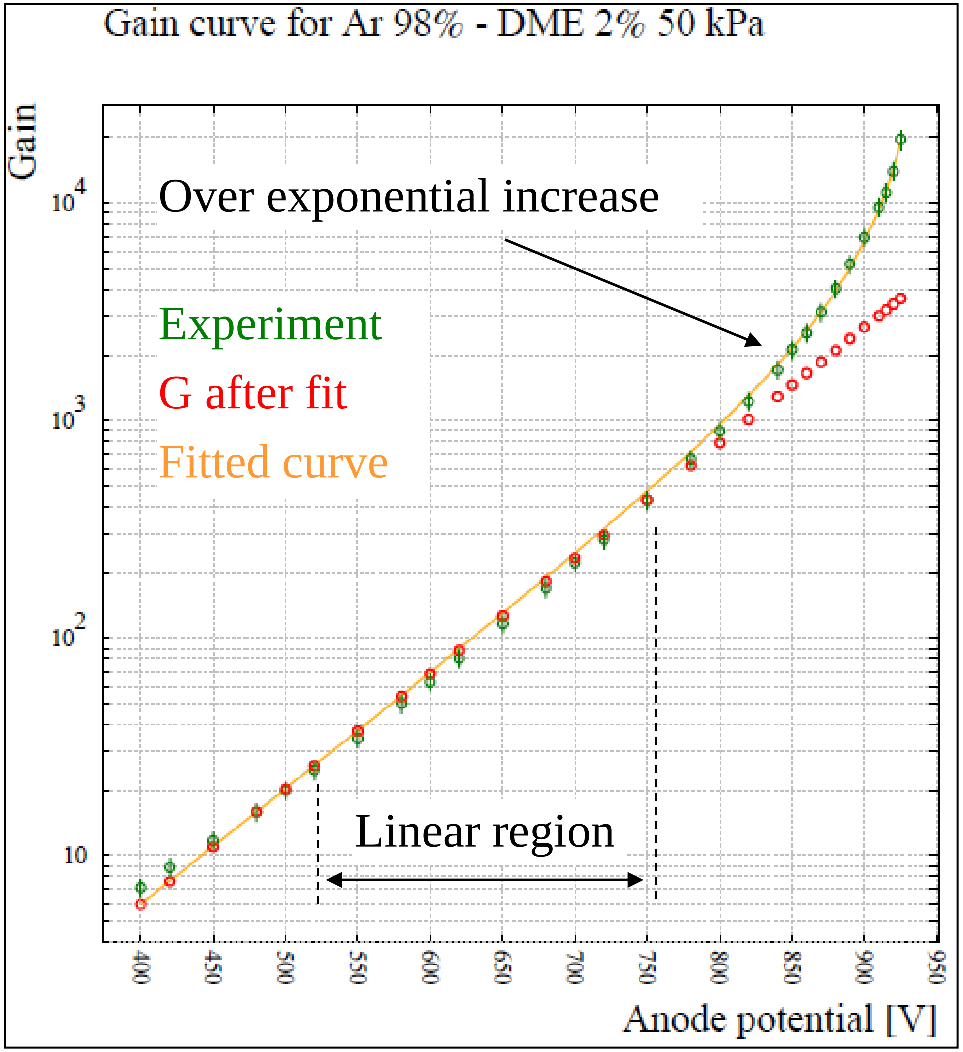
- Large σ_{pa} for Ar below the ionisation,
- Increase on σ_{pa} for bigger molecules,
- σ_{pa} : $C_2H_2 < CH_4 < C_2H_6 < C_3H_8 < nC_4H_{10} < iC_4H_{10}$

Plots: Ö. Şahin, İ. Tapan, E. N. Özmutlu and R. Veenhof, *Penning transfer in argon-based gas mixtures*, 2010 *JINST* **5** P05002.

Calculation method

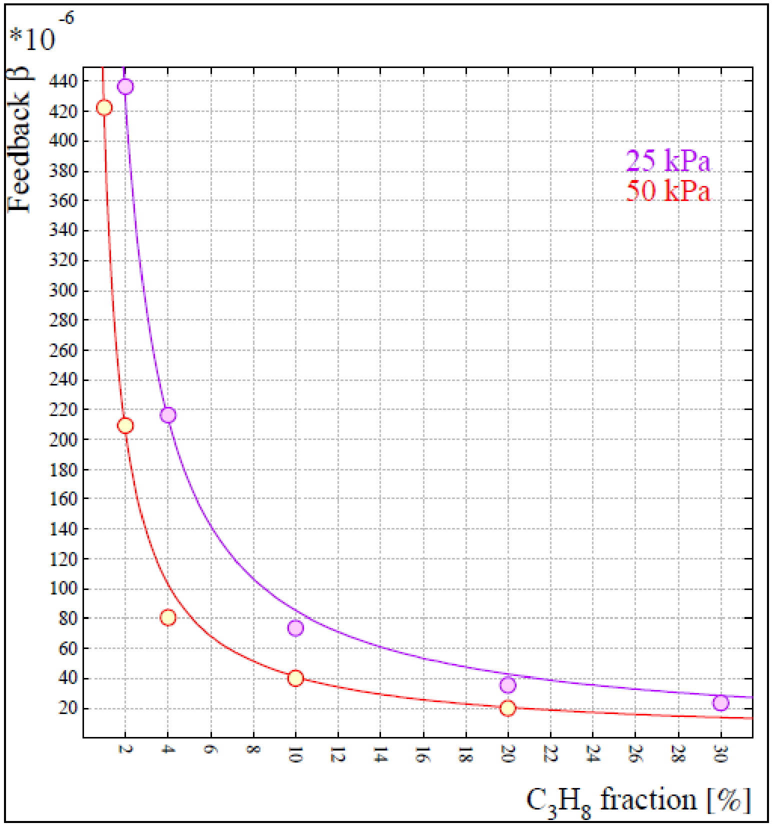
$$G = G' / (1 + \beta G')$$

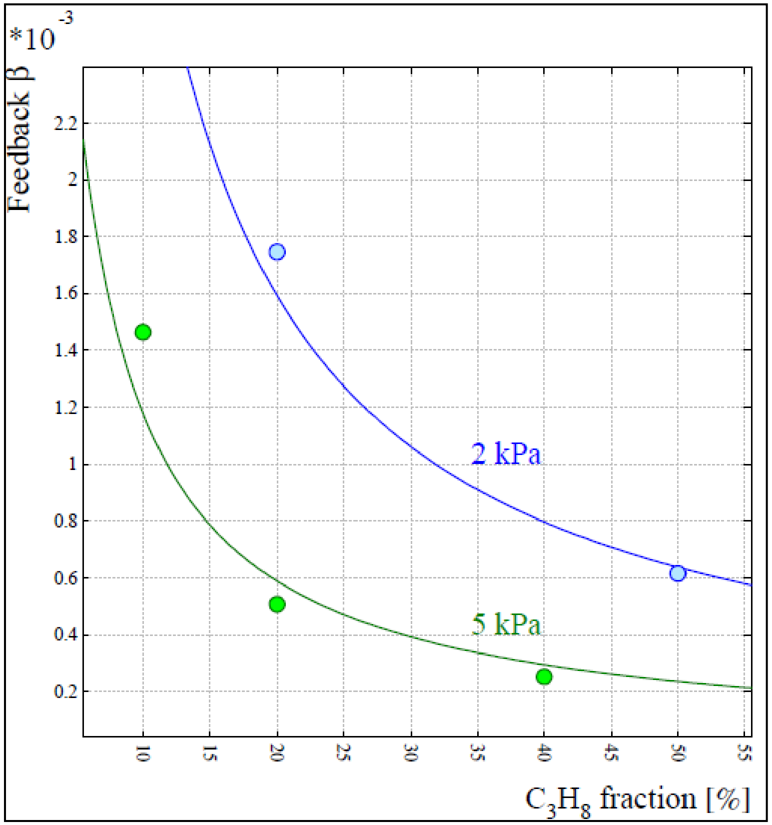
- β fit parameter,
- found by choosing a linear region,
- *G*` experimental gain curves,



Exp. data: I.K. Broni´c and B. Grosswendt., *Comparative study of gas ampli®cation and energy resolution in some argon-based mixtures, Nucl. Instrum. Meth.* **B 168** (2000) 437.

Ar + C_3H_8 mixtures (tube)

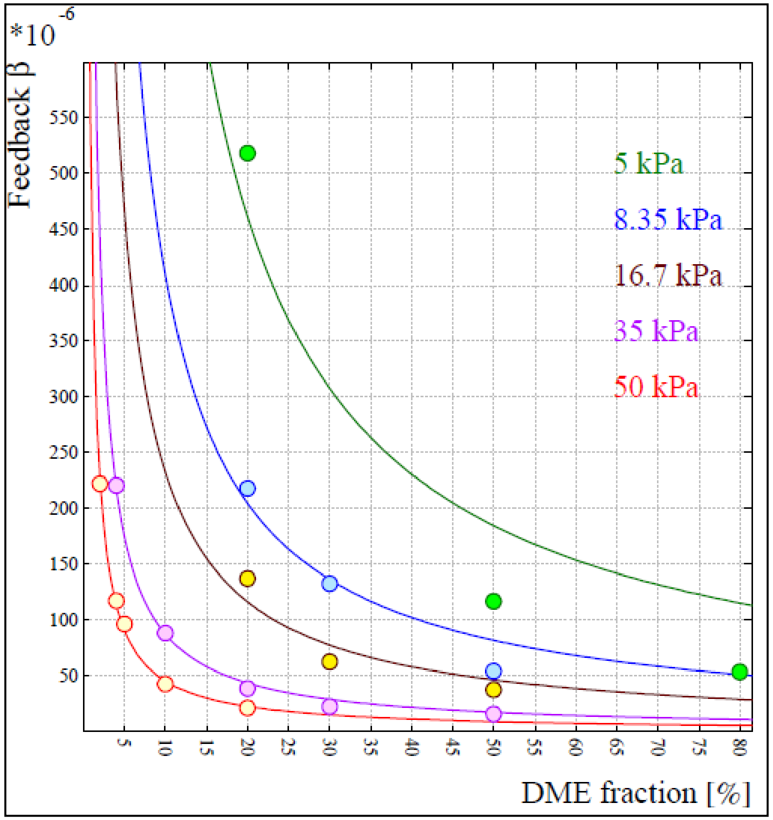




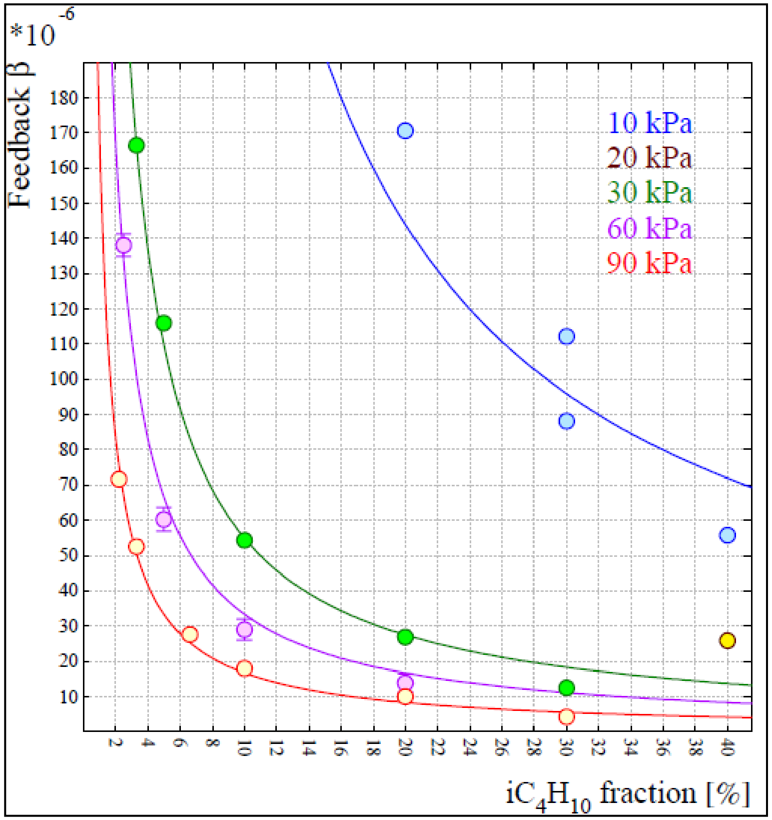
- Fitted by **β/f_q** f_q: concentration of the quencher
- $r_c = 2.5$ cm, $r_a = 15$ µm

Exp. data: I.K. Broni´c and B. Grosswendt., *Comparative study of gas ampli®cation and energy resolution in some argon-based mixtures, Nucl. Instrum. Meth.* **B 168** (2000) 437.

Ar + DME & Ar + iC_4H_{10} mixtures (tube)



r_c = 2.5 cm, r_a = 15 μm



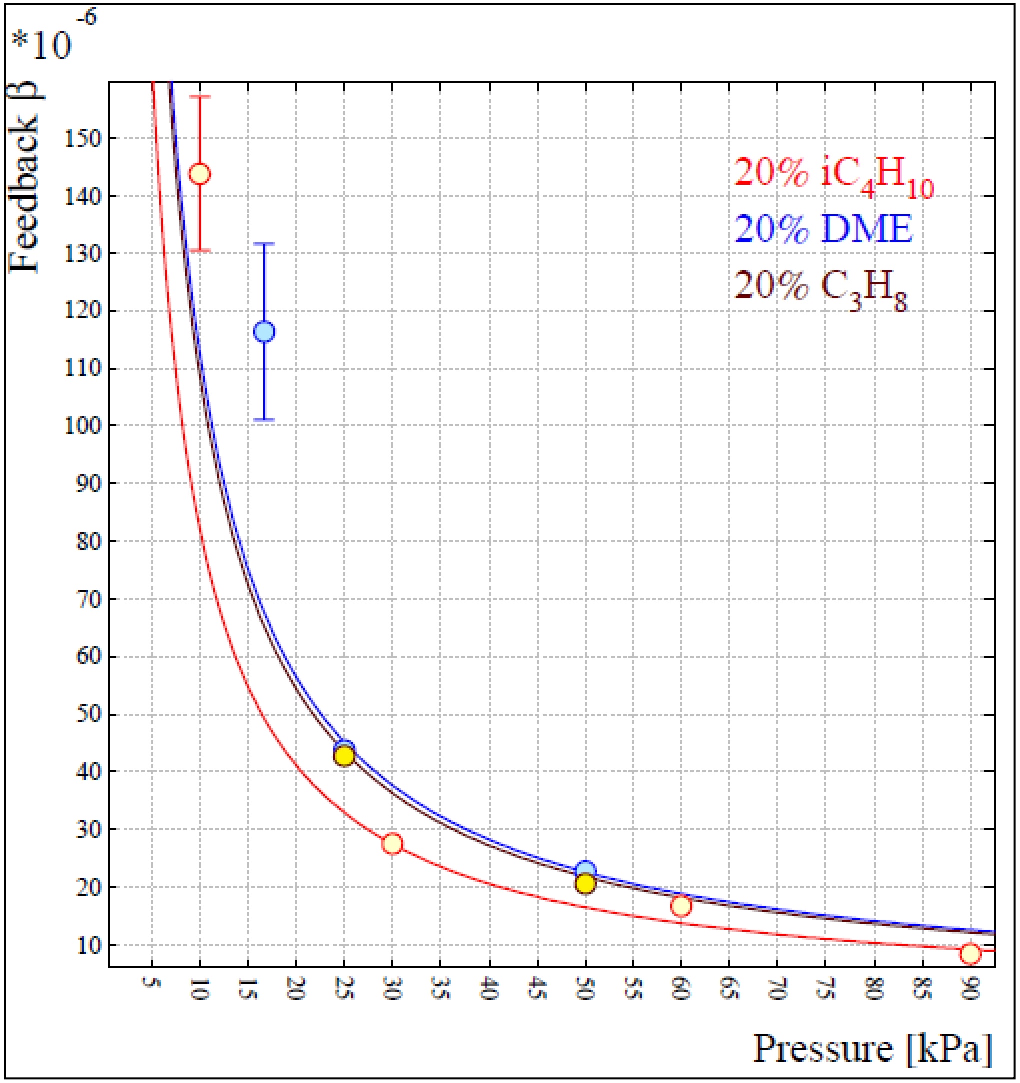
r_c = 2.5 cm, r_a = 12.5 μm

Exp. data: I.K. Broni´c and B. Grosswendt., *Gas amplification and ionization coefficients in isobutane and argon-isobutane mixtures at low gas pressures, Nucl. Instrum. Meth.* **B 142** (1998) 219.

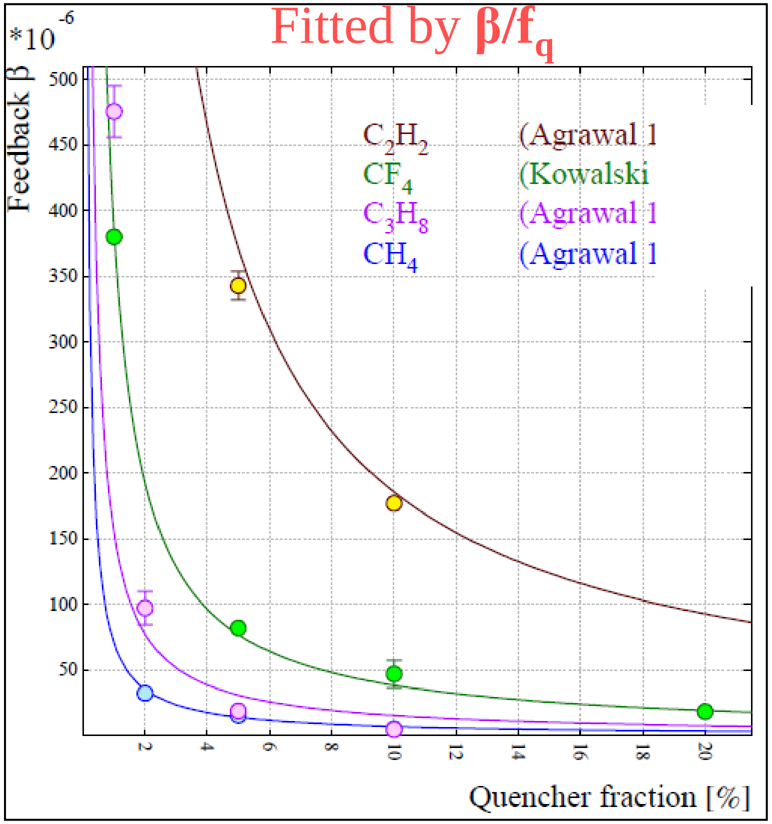
I.K. Broni´c and B. Grosswendt., *Comparative study of gas ampli®cation and energy resolution in some argon-based mixtures, Nucl. Instrum. Meth.* **B 168** (2000) 437.

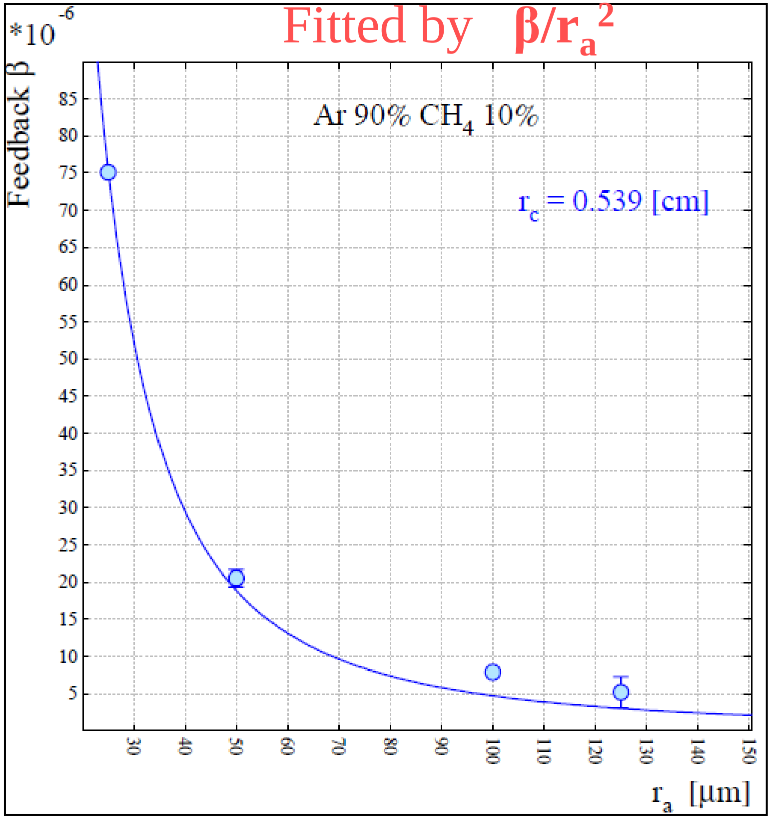
Pressure dependence (tube)

- Fitted by $\boldsymbol{\beta / p_{gas}}$
- big error bars at low pressures
- $\beta_{iC4H10} < \beta_{C3H8} < \beta_{DME}$
- largest σ_{pa} for iC_4H_{10} **!**
- σ_{DME} will be checked **!**



Ar + quenchers & r_a dependence (tube)





❖ σ_{pa} : C_2H_2 < CH_4 < C_3H_8; CF_4 has comparable σ_{pa} with C_2H_2 !

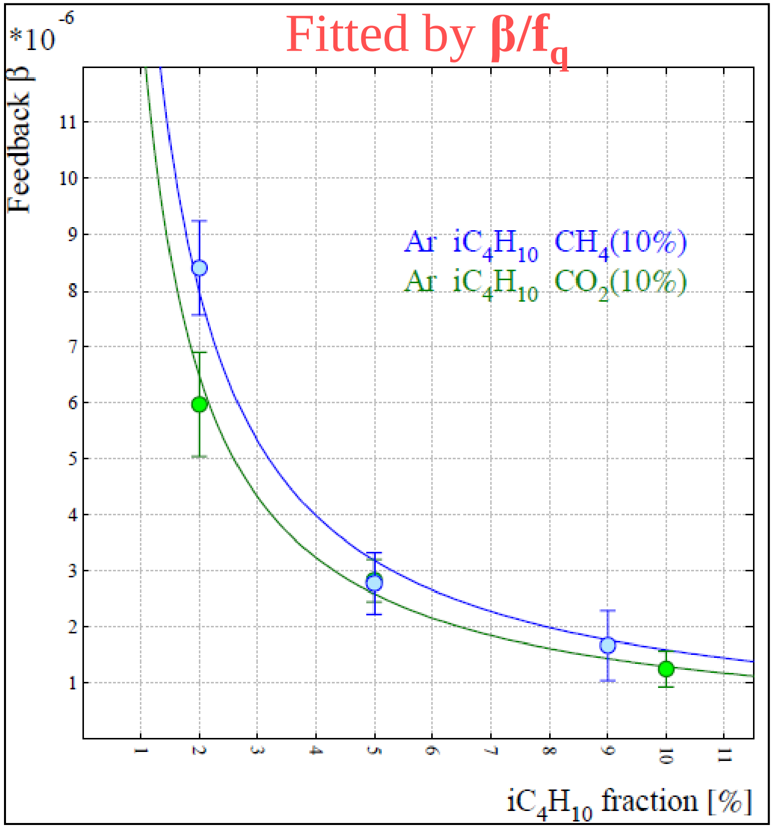
Exp. data: P.C. Agrawal et al., *Study of argon-based Penning gas mixtures for use in proportional counters*, *Nucl. Instrum. Meth.* **A 277** (1989) 557.

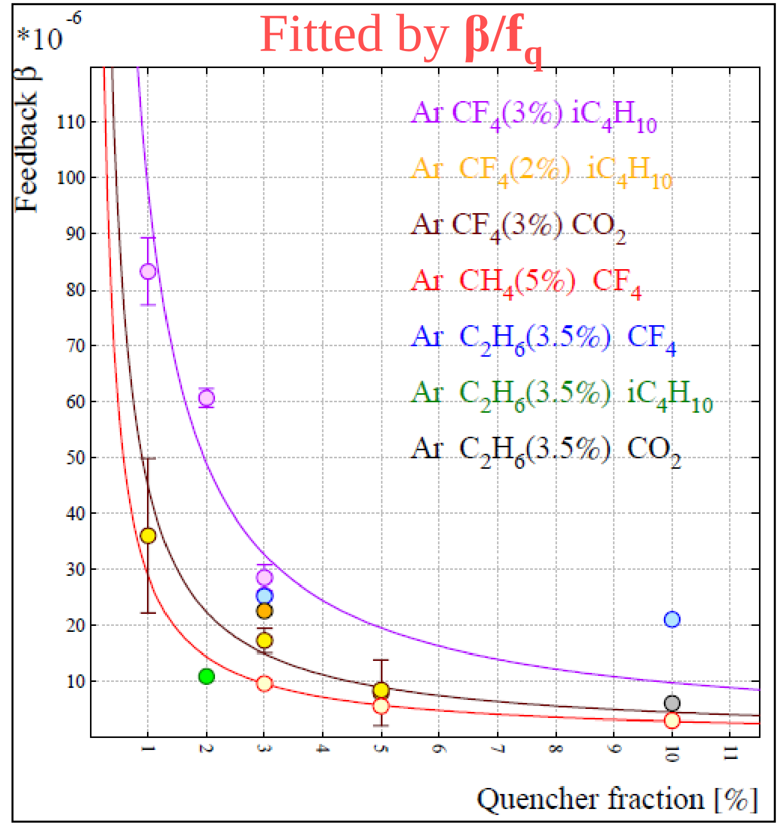
P.C. Agrawal and B.D. Ramsey, *Penning gas mixtures for improving the energy resolution of proportional counters*, IEEE Trans. Nucl. Sci. **36** (1989) 866.

P.C. Agrawal and B.D. Ramsey, *Use of propane as a quench gas in argon-filled proportional counters and comparison with other quench gases, Nucl. Instrum. Meth.* **A 273** (1988) 331.

M. Deptuch, T.Z. Kowalski, *Gas multiplication process in mixtures based on Ar, CO2, CF4 , Nucl. Instrum. Meth.* **A 572** (2007) 184.

Triple mixtures (Micromegas)





- σ_{pa} : $C_2H_2 < CH_4 < C_2H_6 < C_3H_8 < nC_4H_{10} < iC_4H_{10}$
- smallest β in CO_2 **!**
  - abundant vibrational and rotational levels

Exp. data: D. Attie., *TPC review*, *Nucl. Instrum. Meth.* **A 598** (2009) 89.

Private communication, 10 May 2010

Gain calculations in Micromegas

Recent measurements

New developments in Micromegas Microbulk detectors

F.J. Iguaz[1], S. Andriamonje[2], F. Belloni[1], E. Berthoumieux[1], M. Calviani[2], T. Dafni[3], R. De Oliveira[2], E. Ferrer-Ribas[1], J. Galán[1], J.A. García[3], I. Giomataris[1], C. Guerrero[2], F. Gunsing[1], D.C. Herrera[3], I.G. Irastorza[3], T. Papaevangelou[1], A. Rodríguez[3]andA. Tomás[3]

[1]IRFU, Centre d'Études Nucléaires de Saclay (CEA-Saclay), Gif-sur-Yvette, France
[2]European Organization for Nuclear Research (2), Genève, Switzerland
[3]Laboratorio de Física Nuclear y Astropartículas, Universidad de Zaragoza, Spain

October 13, 2011

http://arxiv.org/pdf/1110.2641.pdf

Characterization of microbulk detectors in argon- and neon-based mixtures

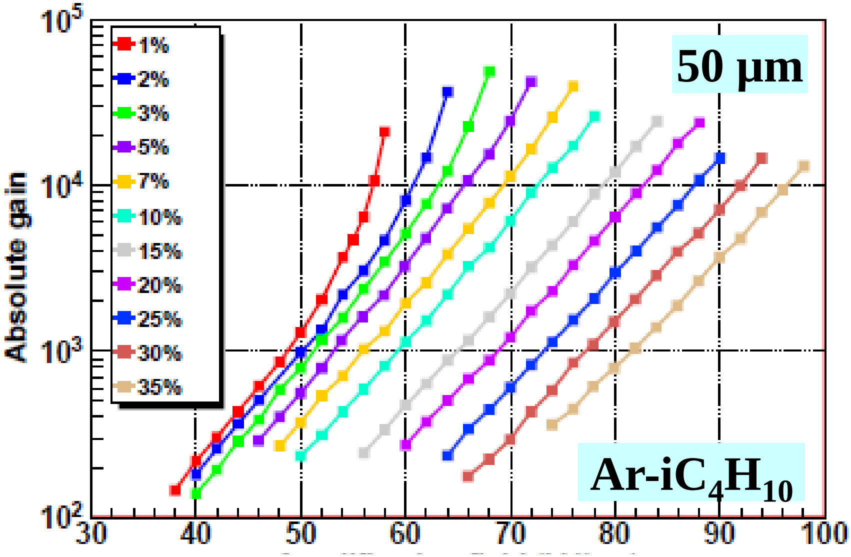
F.J. Iguaz[1], E. Ferrer-Ribas[1], A. Giganon[1], and I. Giomataris[1]

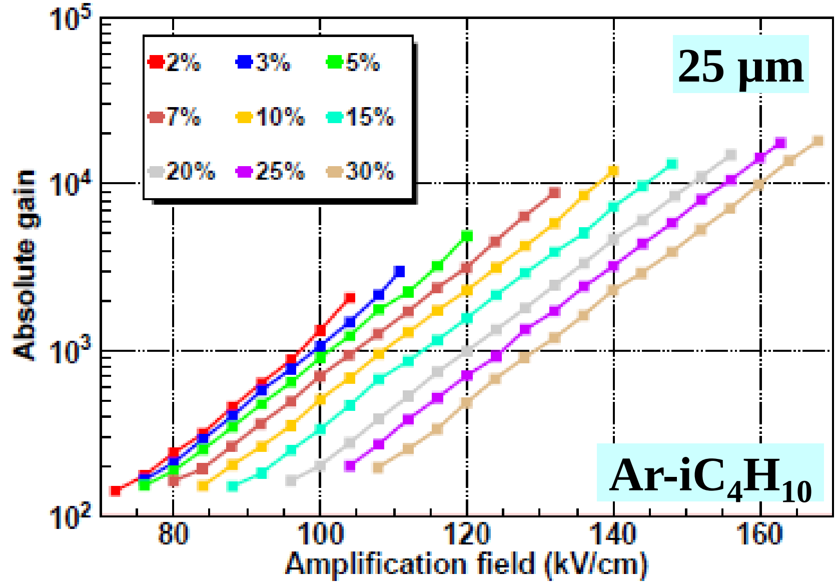
[1]IRFU, Centre d'Études Nucléaires de Saclay (CEA-Saclay), Gif-sur-Yvette, France

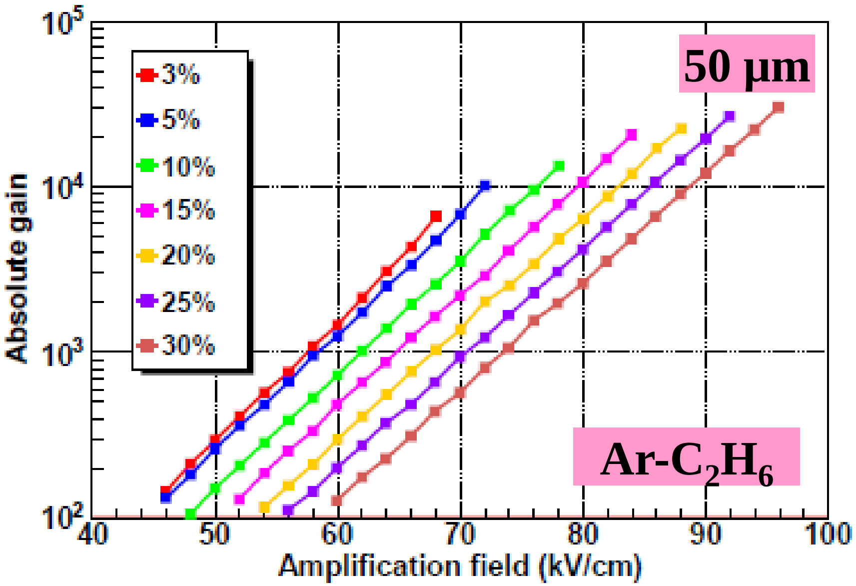
January 17, 2012

http://arxiv.org/abs/1201.3012v1

Exprimental data



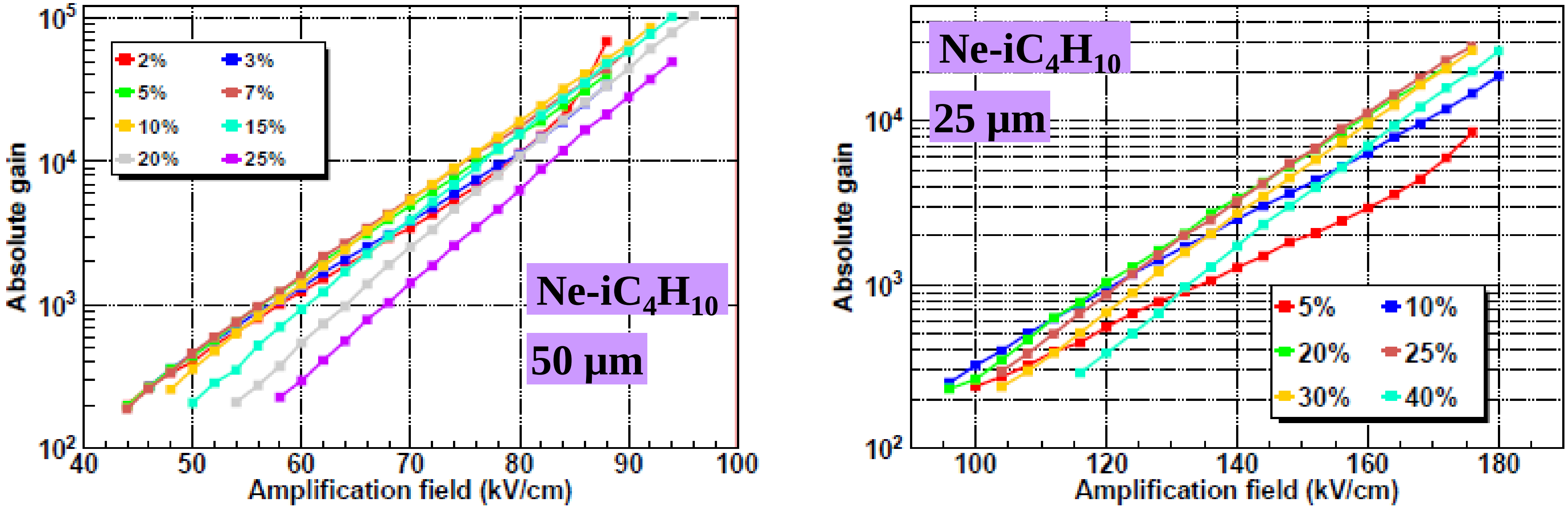




Plots: Fig. 4 and Fig. 7,

F. J. Iguaz et al., Characterization of microbulk detectors in argon- and neon-based mixtures (2012). http://arxiv.org/abs/1201.3012v1

Experimental data



Plots: Fig. 10,

F. J. Iguaz et al., Characterization of microbulk detectors in argon- and neon-based mixtures (2012). http://arxiv.org/abs/1201.3012v1

* Also private communication with F. J. Iguaz for unpublished data, 12 Feb 2012

Measuring the transfer probabilities

- Townsend coefficient adjustment

$$G = \exp(\alpha_{Penning}\, d)$$

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

- d gap distance
- r_i transfer probabilities: assuming α proportional to the sum of ν_{ion},
- α, ν_i : gas properties (pressure, temperature …)
- calculated by Magboltz [S.F. Biagi, *NIM A* **421** (1999) 234–240.]

Gain calibration

- uncertainty on the absolute gain,
- work function,
- calibration of the equipment.

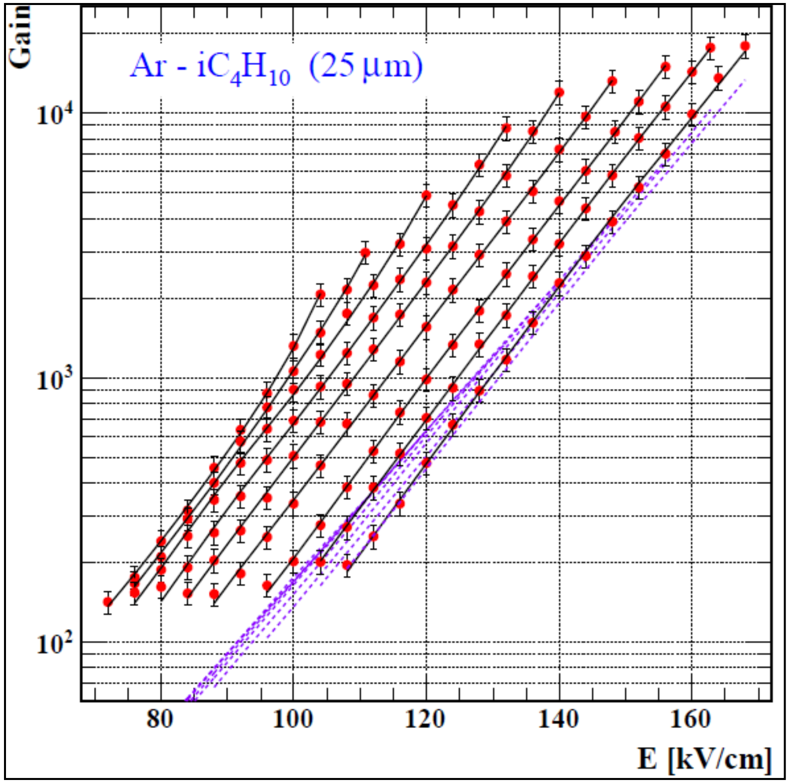
$$G := g\, G$$

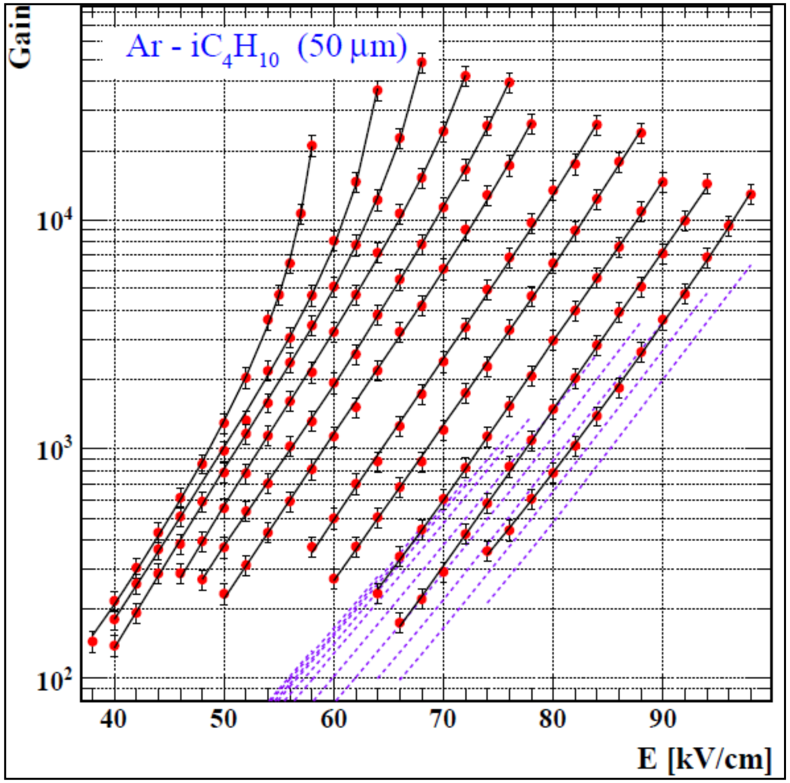
Photon feedback

- secondary avalanches,
- at high gain,
- almost uncorrelated, free parameter.

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

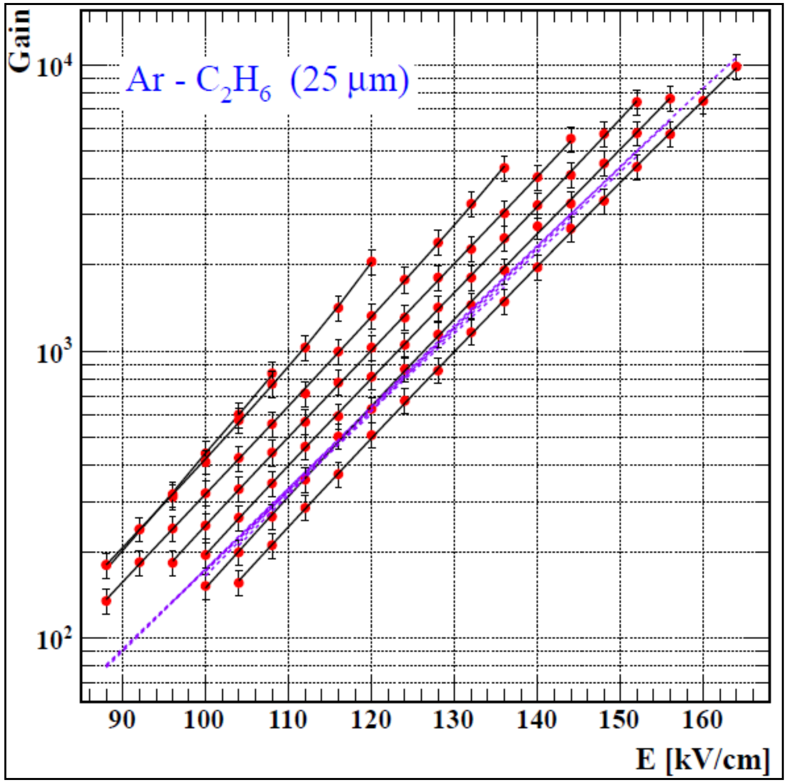
Argon mixtures

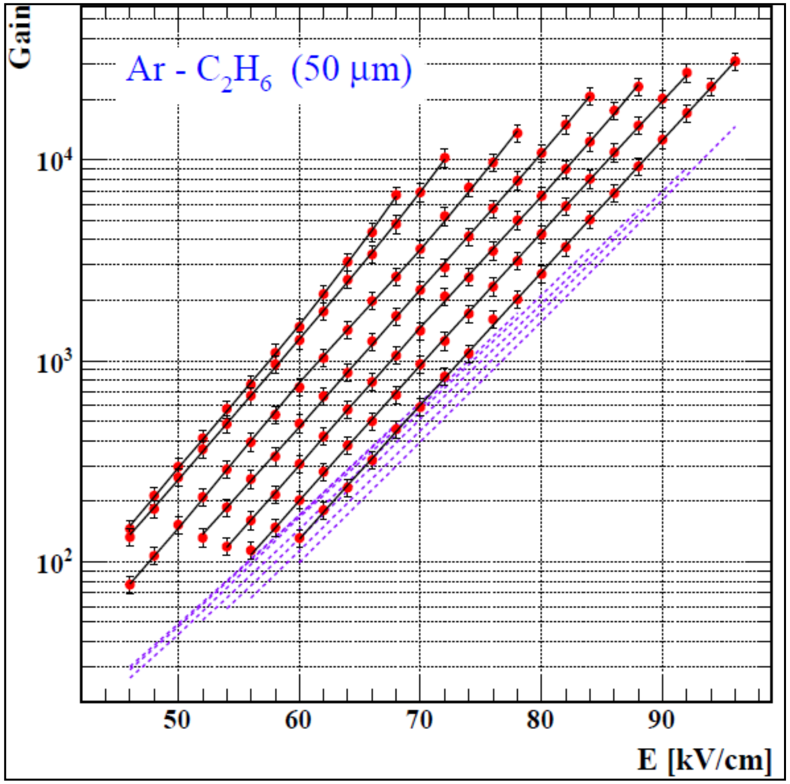




- Ar* **3*p*^{5}4*s*** 11.55 eV ❾ iC_4H_{10} I_p: 10.67 eV
- Visible feedbacks at low concentrations of iC_4H_{10}
- Higher gains in 50 µm MM

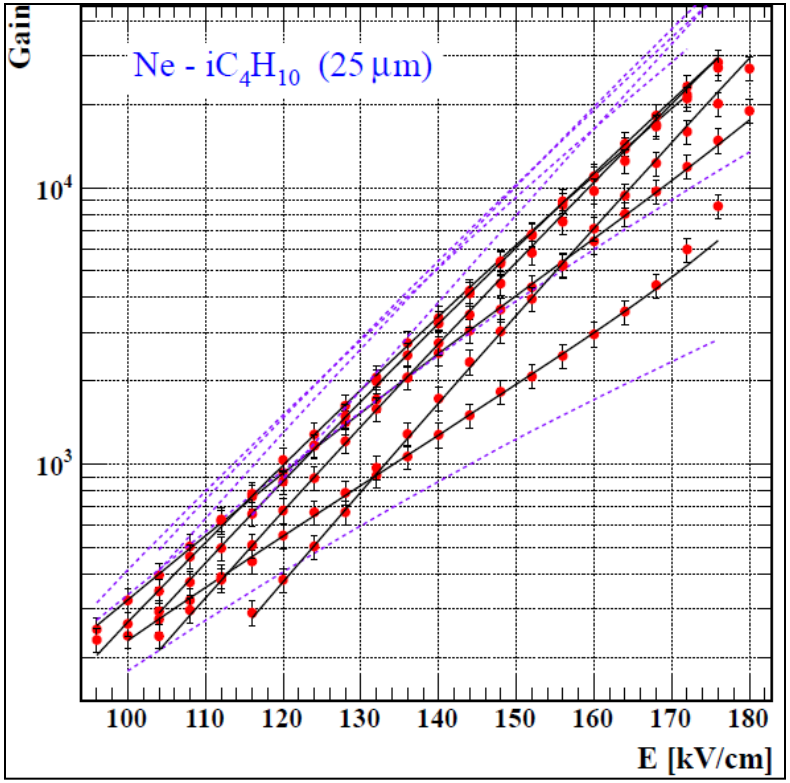
Argon mixtures

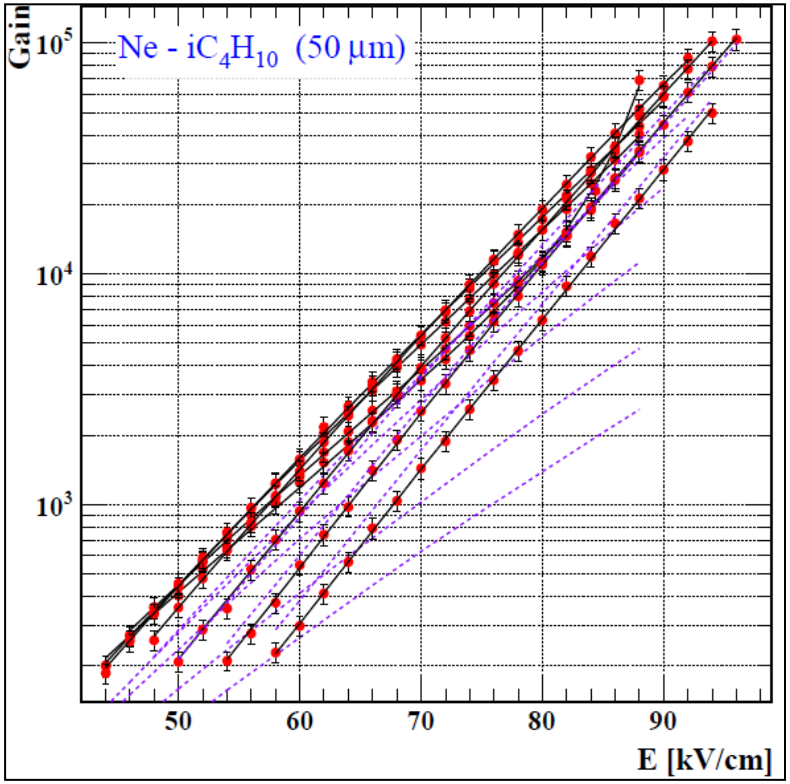




- Ar* **3*p*^{5}4*s*** 11.55 eV ❾ C_2H_6 I_p: 11.52 eV
- Feedbacks at low concentrations of C_2H_6
- Lower achievable gains compared to Ar-iC_4H_{10} mixtures

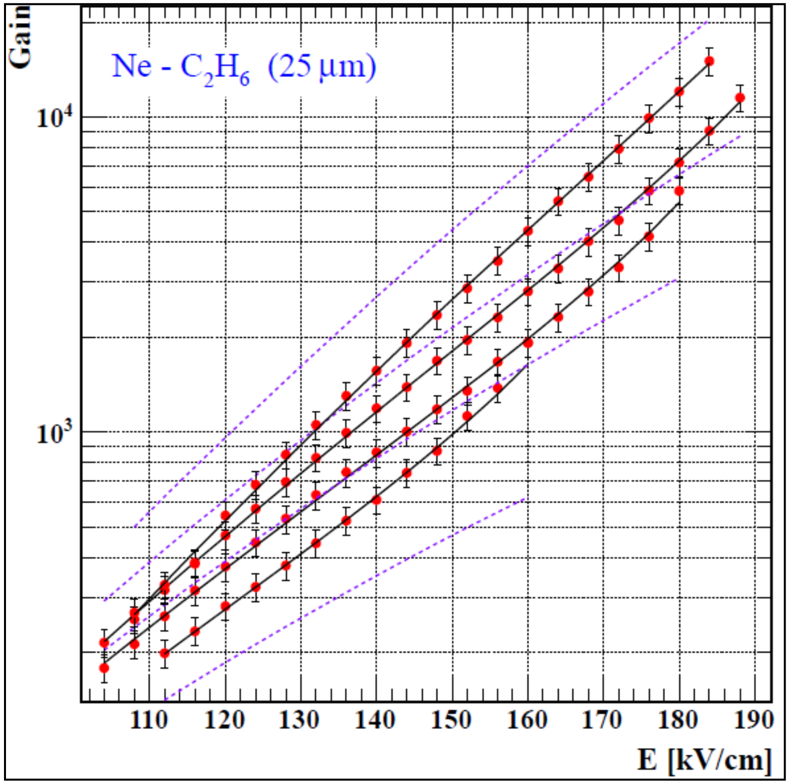
Neon mixtures

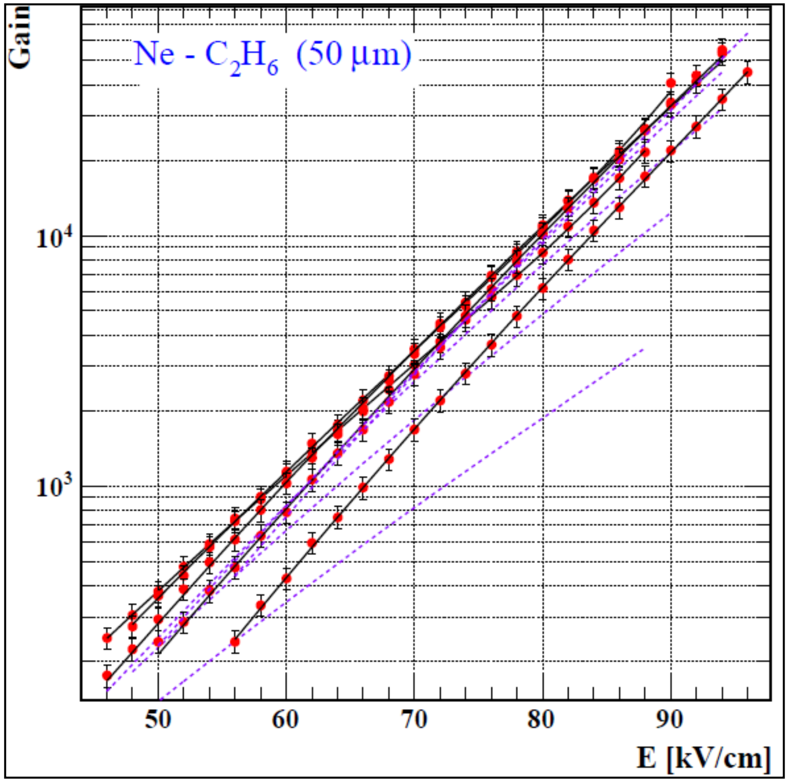




- Lowest state of Ne* 16.62 eV ❾ iC_4H_{10} I_p: 10.67 eV
- **Little feedback**! σ_{pa} of iC_4H_{10} has a maximum around 16 eV
- Highest gains in Ne- iC_4H_{10} mixtures before spark

Neon mixtures

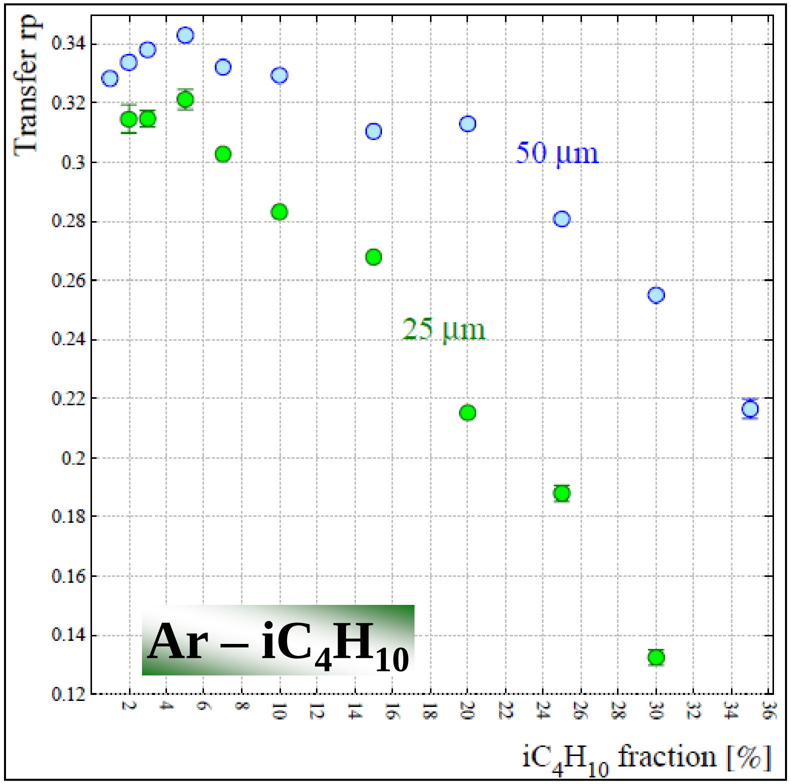


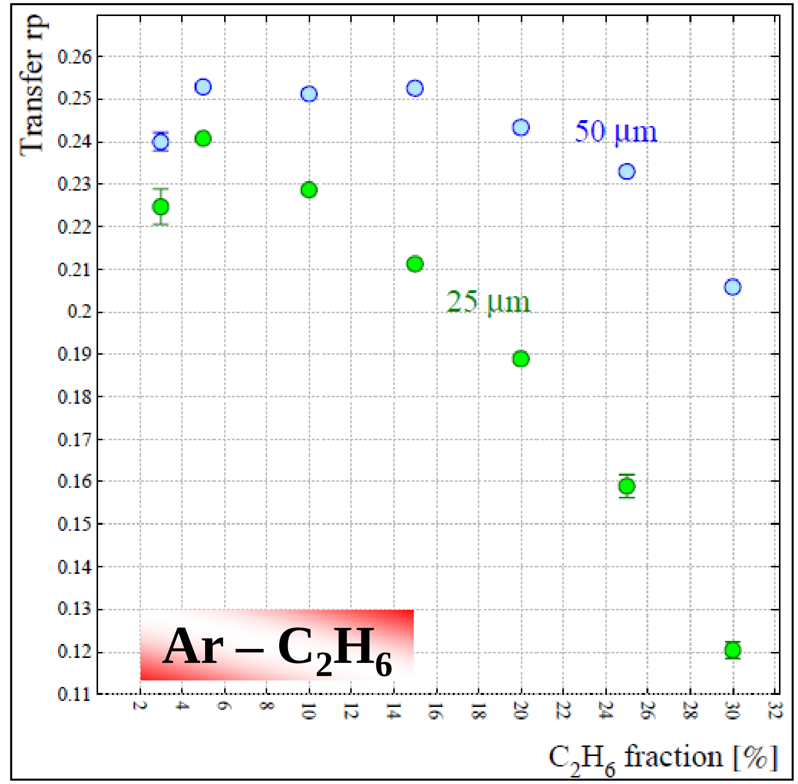


- 5%, 10%, 15%, 25% C_2H_6
- 5%, 10%, 15%, 20%, 25% C_2H_6

- **More feedback**! compared to Ne- iC_4H_{10} mixtures
  - σ_{pa} of C_2H_6 has a maximum around 15 eV

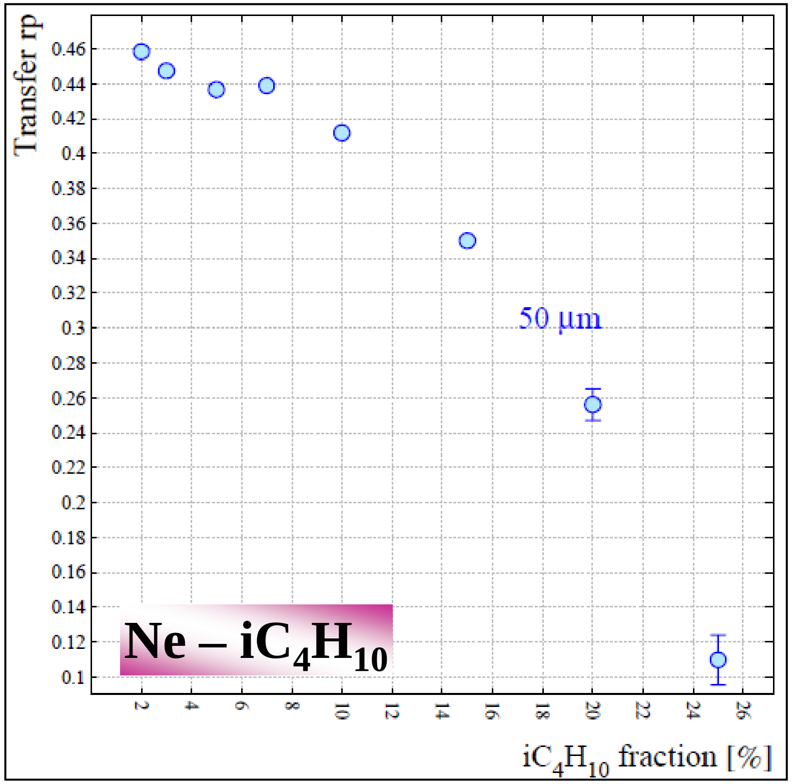
Transfer rates

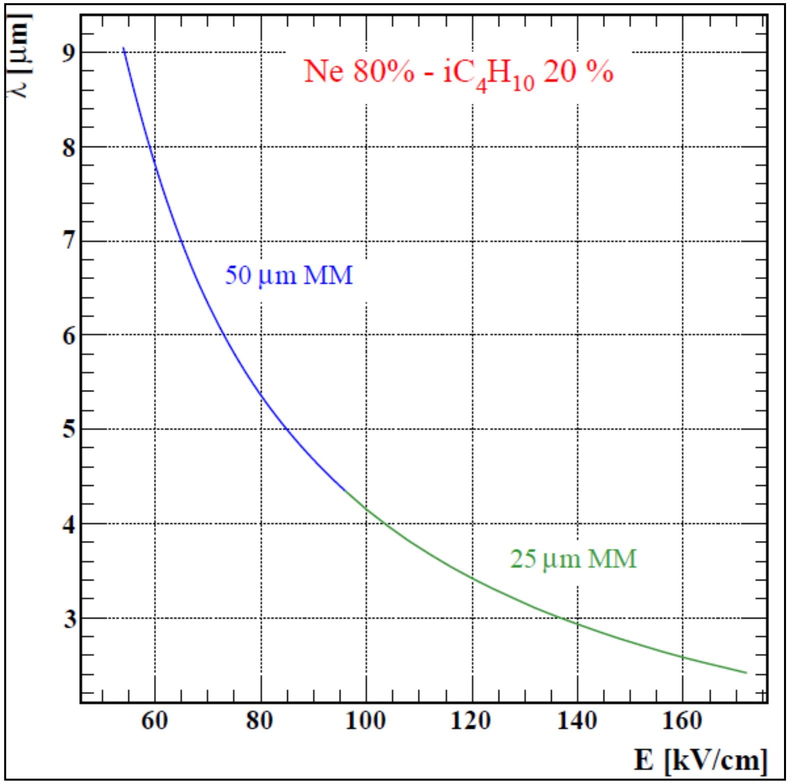




- Decrease on transfer rates at high fraction of quenchers
- r_p : $C_2H_6 < iC_4H_{10}$; iC_4H_{10} bigger molecule than C_2H_6 (shorten collision time)
- Higher transfer transfer rates in 50 µm MM
  - Mean free path of excited atoms !?!

Transfer rates & free path of ionisations



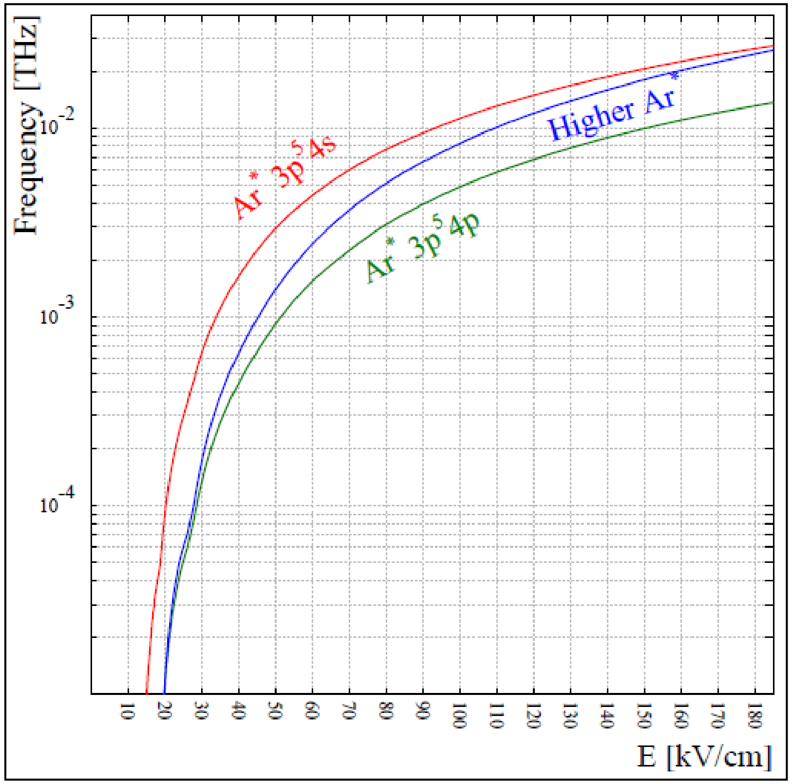


- ❖ Highest transfer rate in Ne-iC_4H_{10}
- ❖ r_p : Ar-C_2H_6 < Ar- iC_4H_{10} < Ne- iC_4H_{10}
  - ❖ Life time of excited Ne* atoms !?!

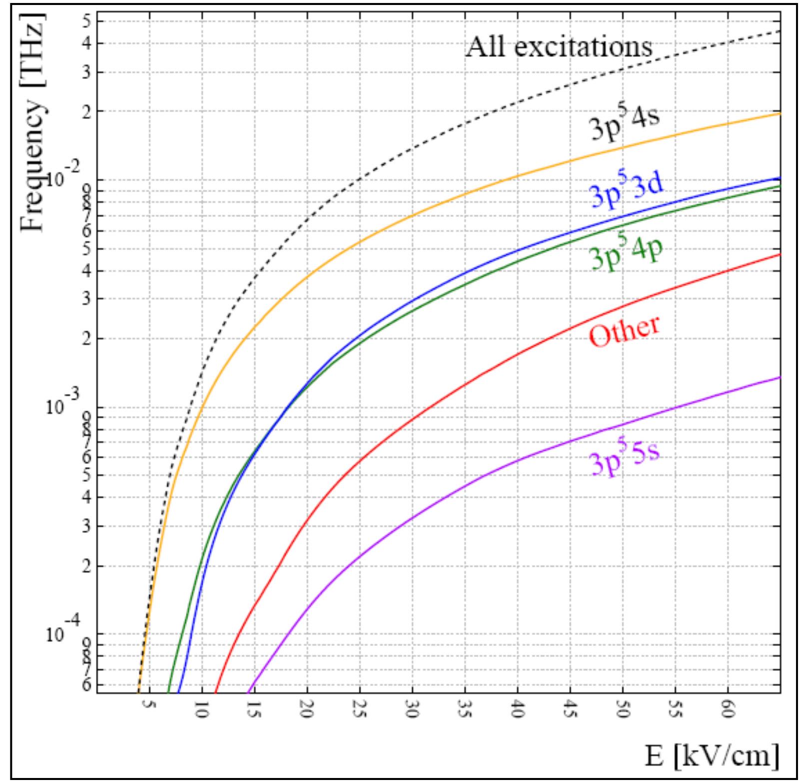
- ❖ Large distances of electrons
  - ❖ Little avalanche sizes at low E
    - ❖ Decrease on gas gain

Production rates of excited states

Ar 70 % - iC_4H_{10} 30% mixture, at 1 atm



Ar 99 % - C_2H_2 1% mixture, at 1 atm



The same transfer probability (r_p) for all of the fits **!!!**

- ❖ Dominant excitations ➒ **3p⁵4s** and **3p⁵4p**
- ❖ Sharper increase of 4s
- ❖ Similar shape of 4p and 3d levels
- ❖ Least produce of the higher states

Summary

- β calculations:
  - quencher fraction, $1/f_q$
  - gas pressure, $1/p_{gas}$
  - radius of the anode , $1/r_a^2$
- Next: quantitative analysis with a theoretical model **!**
- Micromegas:
  - decrease on transfer rates
  - large ionisation free paths
    - microscopic calculations needed
- Next: separation of transfer rates **!**

Thank you …

and

???