

Penning effects in Xe: voltage and pressure dependence of the maximum gain

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Noble-gas operation of Micro-Hole and Strip Plate electron multipliers at atmospheric-to-high pressures

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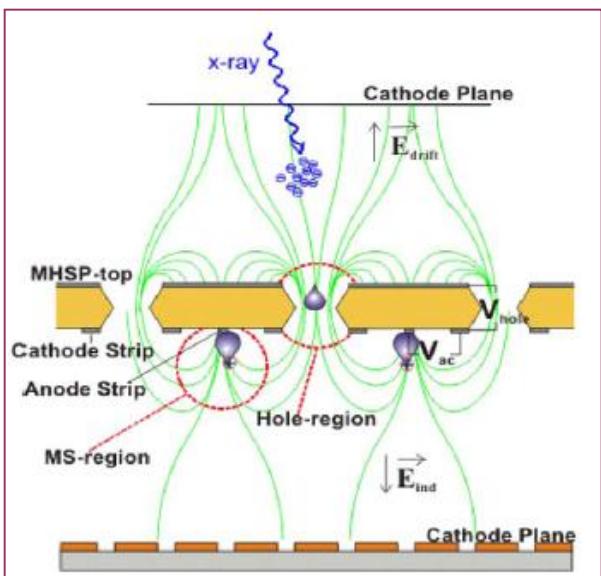
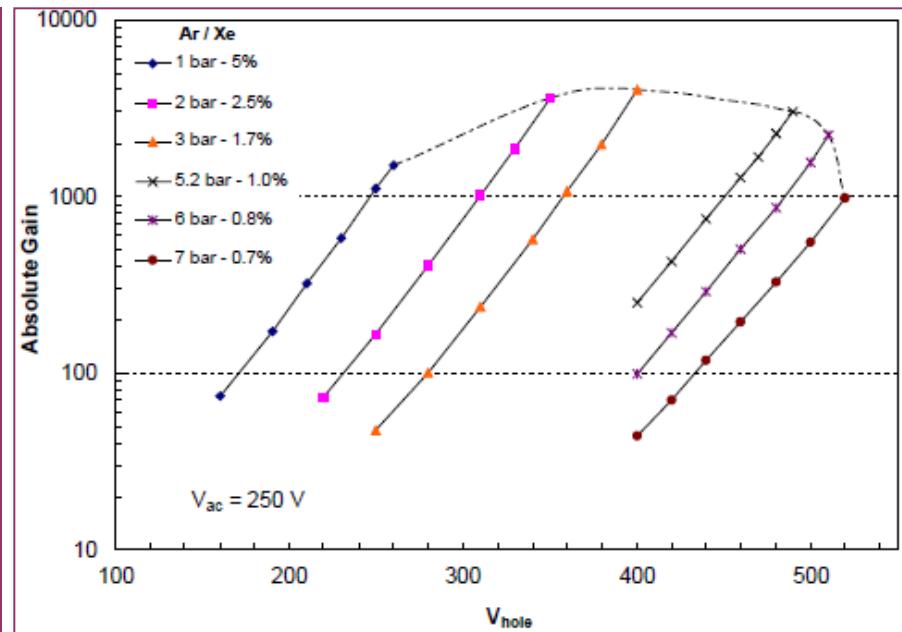
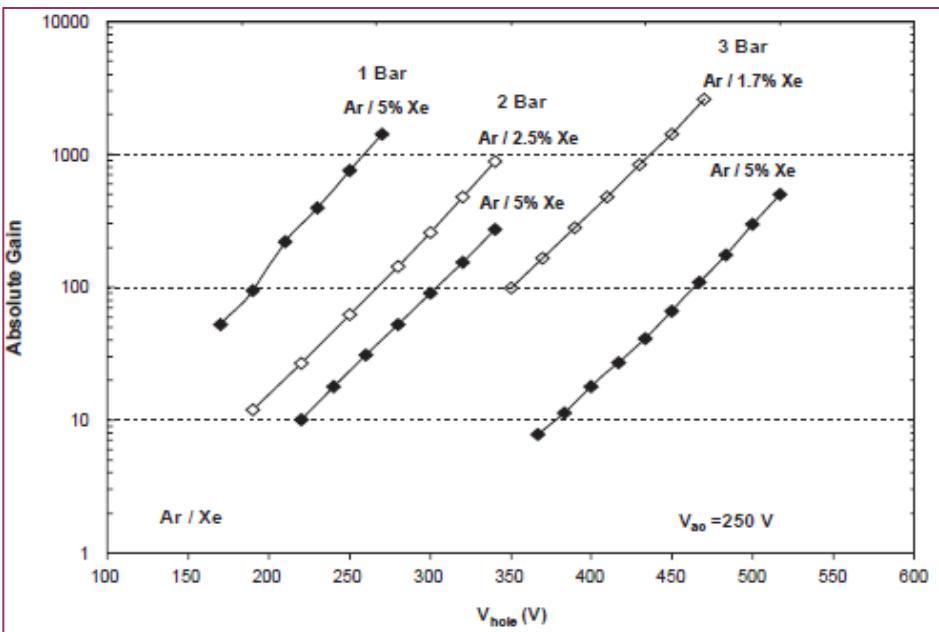
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Abstract

We present the performance of a Micro-Hole and Strip Plate (MHSP) electron multiplier in argon–xenon mixtures, at pressures of 1–7 bar. This microstructure can operate at high pressures without significant reduction of the maximum achievable gain. Absolute gains of $1\text{--}4 \times 10^3$ were reached in Ar/50 mbar Xe over this pressure range; the maximum gain is imposed by the discharge limit, dropping at higher pressures. Energy resolutions between 14% and 16% were reached for 6 keV X-rays; they do not degrade significantly with increasing pressure. Better performances are expected by improved manufacturing of the MHSP.

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❖ Ar – Xe mixtures

❖ Maximum gain for 4 – 5 % Xe at 1 atm !

❖ Maximums shift with pressure !

F. Amaro et al., *Nucl. Instr. And Meth. A* **535** (2004) 341–346.

Measuring the transfer probabilities

❖ Townsend coefficient adjustment

$$G = \exp \int_{\text{tube}}^{\text{anode}} dr \alpha(E(r)) \frac{\sum v_i^{\text{ion}}(E(r)) + \sum r_i v_i^{\text{exc}}(E(r))}{\sum v_i^{\text{ion}}(E(r))}$$

- ❖ r_i transfer probabilities: assuming α proportional to the sum of v_{ion} ,
- ❖ α, v_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.

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

Energy transfer processes



❖ The following can happen for an excited atom (A^*):



$$r = \frac{pc \frac{f_{B^+}}{\tau_{A^*B}} + p(1-c) \frac{f_{A^+}}{\tau_{A^*A}} + \frac{f_{rad}}{\tau_{A^*}}}{pc \frac{f_{B^+} + f_{\bar{B}}}{\tau_{A^*B}} + p(1-c) \frac{f_{A^+} + f_{\bar{A}}}{\tau_{A^*A}} + \frac{1}{\tau_{A^*}}}$$

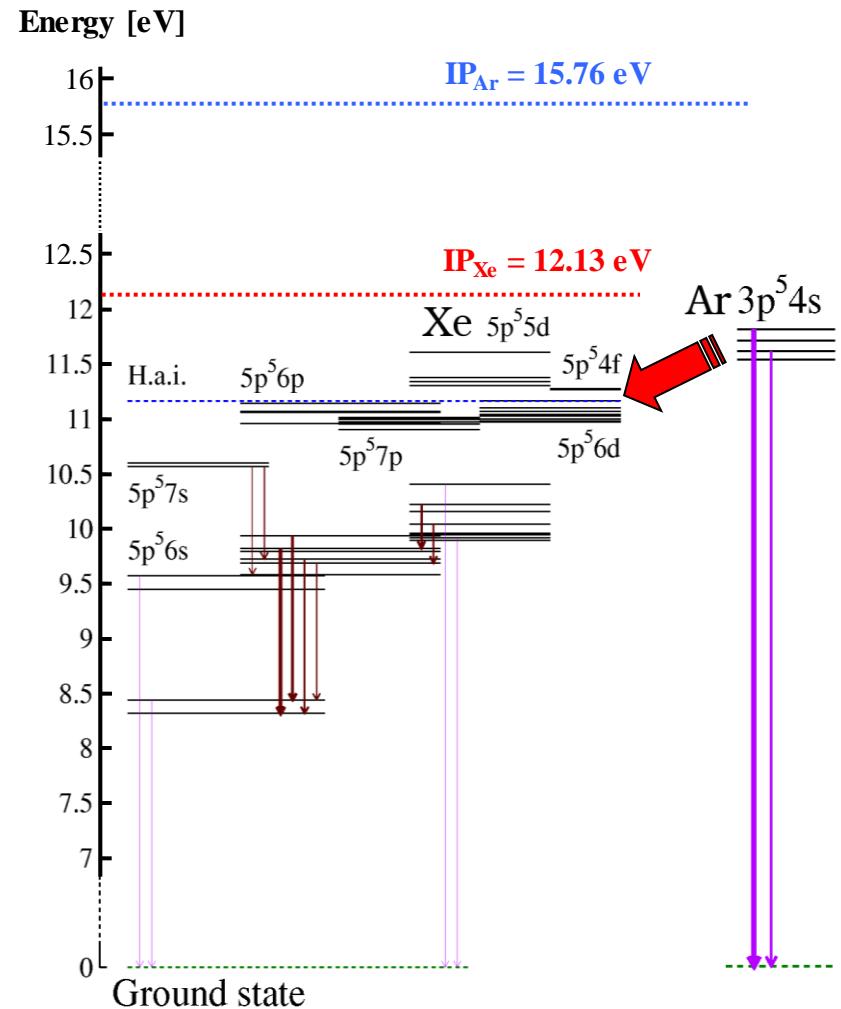


p : dimensionless pressure, $p_{\text{gas}} = p \times 1 \text{ atm}$

c : concentration of the quencher gas

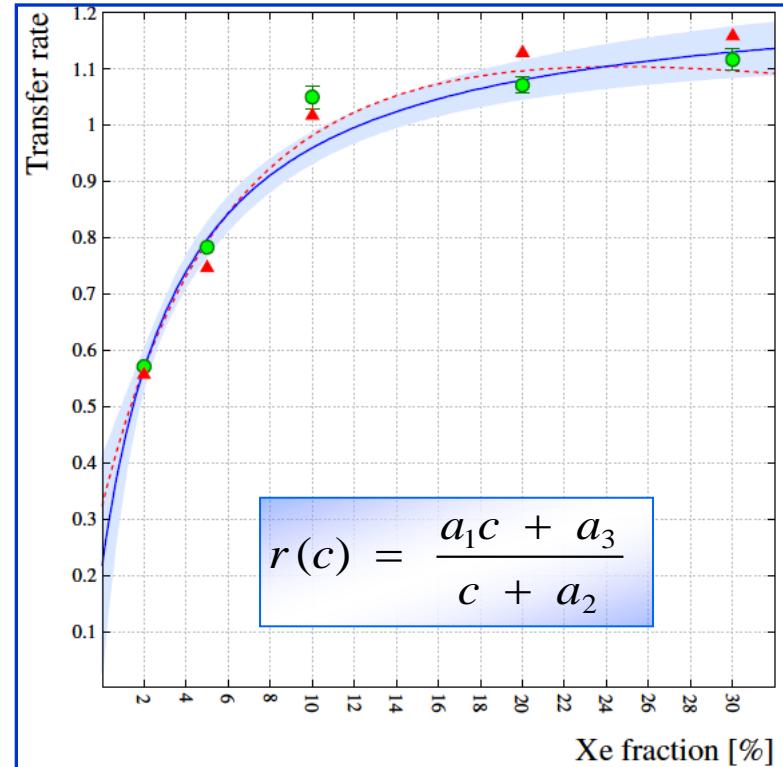
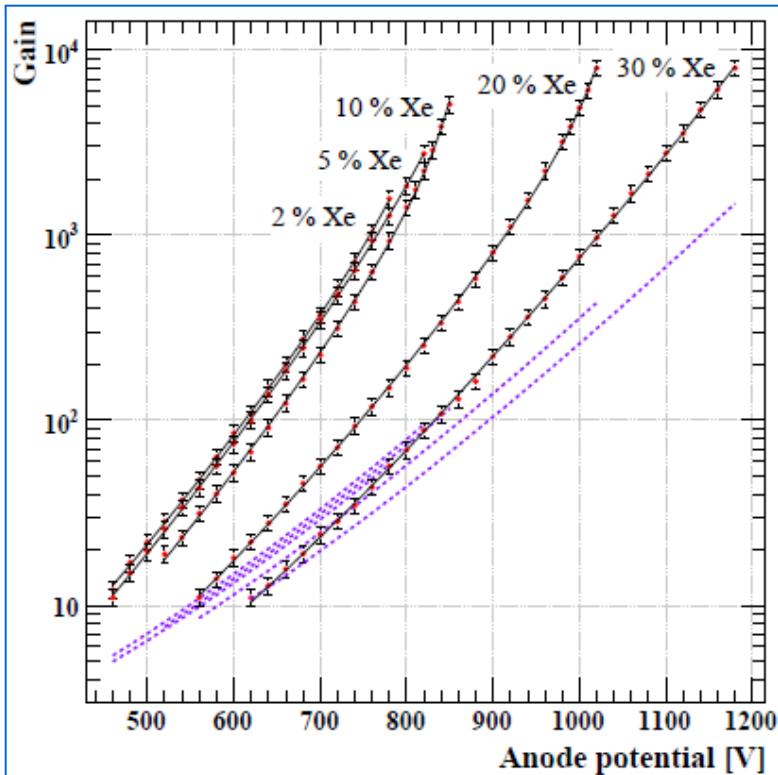
Ionisation processes in Xenon – Argon Mixtures

- ❖ $\text{Ar}^* + \text{Xe} \rightarrow \text{Ar} + \text{Xe}^+ + e^-$
 $\varepsilon > 12.13 \text{ eV}$ Ar* states can transfer
- ❖ $\text{Xe}^* + \text{Xe} \rightarrow \text{Xe}_2^+ + e^-$
 $\varepsilon > 11.162 \text{ eV}$ Xe* states can transfer
- ❖ Also Ar* induced transfers are possible



[Ö. Şahin et al. *JINST P05002* (2010) 1–30.]

Learning from experimental data



- ❖ Feedback, $G > 10^3$
 - ❖ 1 atm
 - ❖ 1 x 1 cm² tube, 25 μm diameter wire
- [P.C. Agrawal et al. *Nucl. Instrum. Meth. A* **277** (1989) 557.]

Fit parameters:

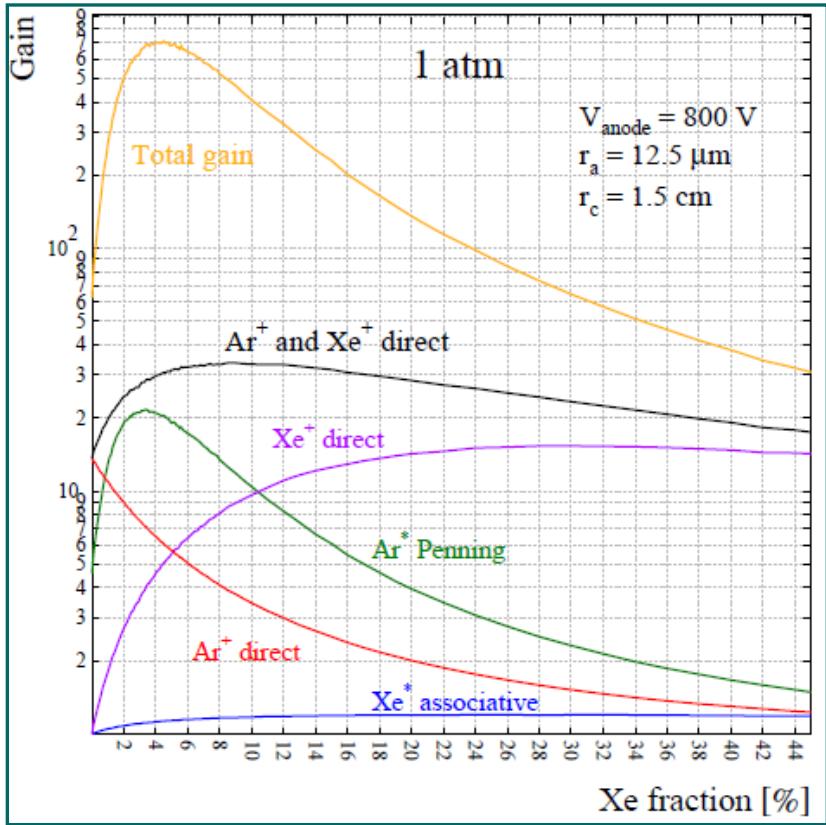
$$a_1 = 1.248 \pm 0.086$$

$$a_2 = 0.039 \pm 0.022$$

$$a_3 = 0.008 \pm 0.012$$

[Ö. Şahin et al. *JINST* **P05002** (2010) 1–30.]

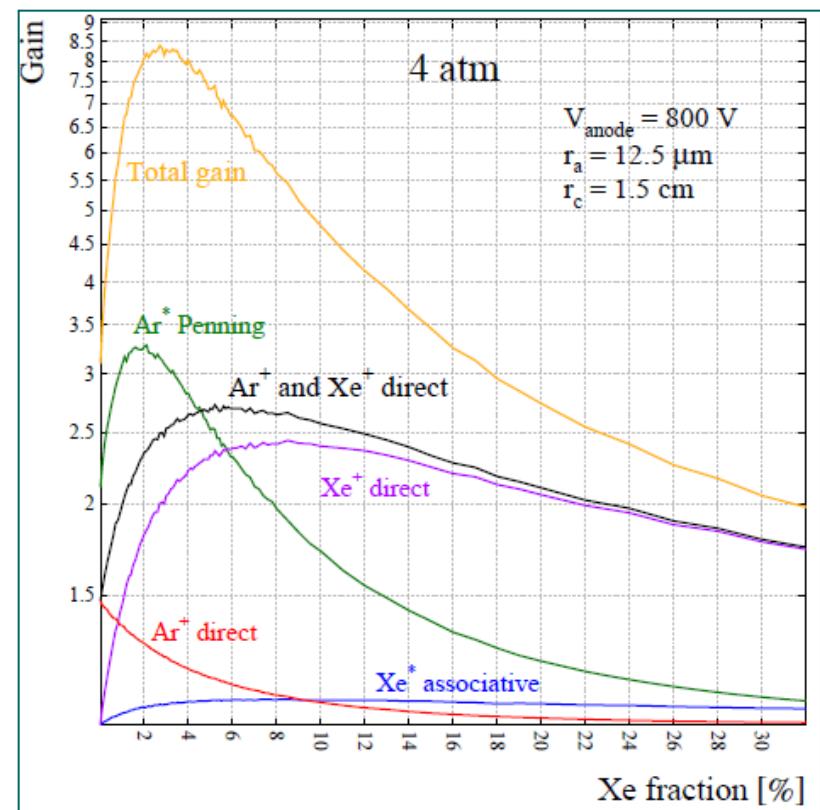
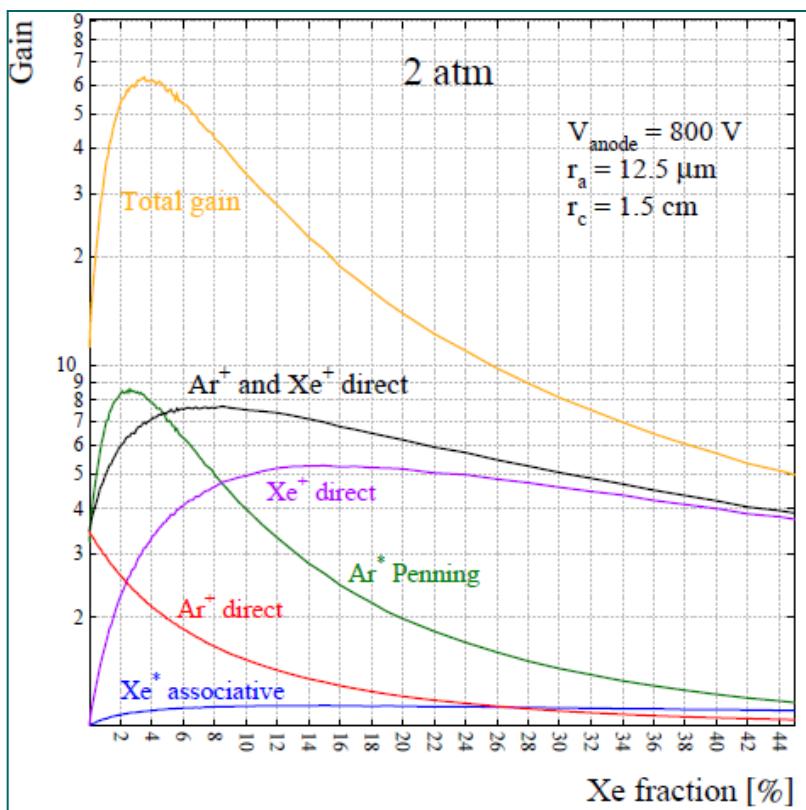
Contributions to the total gain



- ❖ 0 - 50 % Xe, Xe – Ar mixtures
- ❖ 100 output files of Magboltz 8.9.7
- ❖ More steps up to 6 % Xe (0.1 %)
- ❖ Cylindrical tube

- ❖ No feedback term used
- ❖ Xe⁺ dominant after \odot 4.6 %
- ❖ Direct ionisations ($\text{Ar}^+ + \text{Xe}^+$) > Penning ionisations (Ar^*)
- ❖ Total gain peak \odot 4 – 5 % Xe

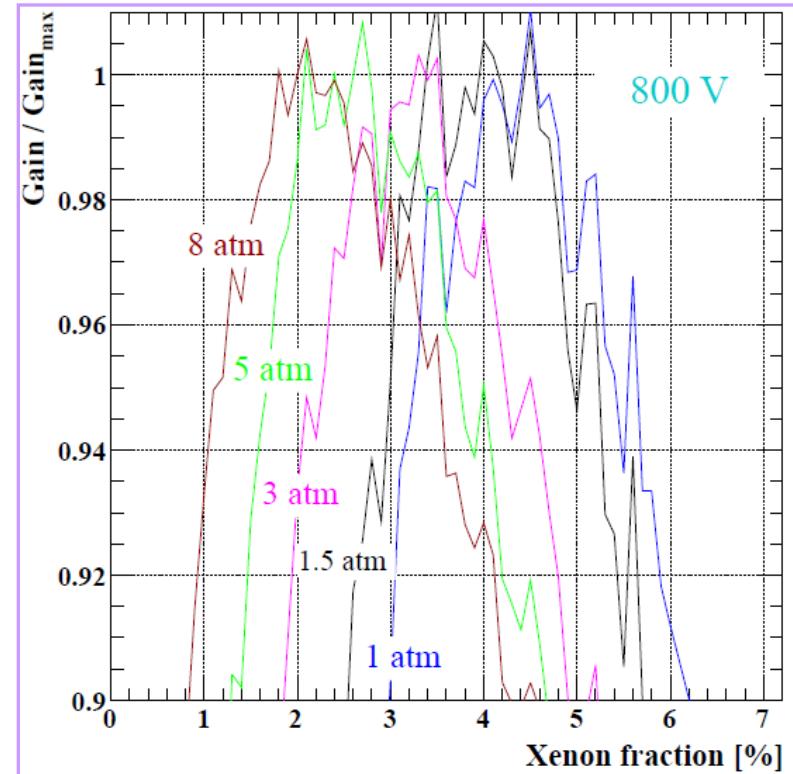
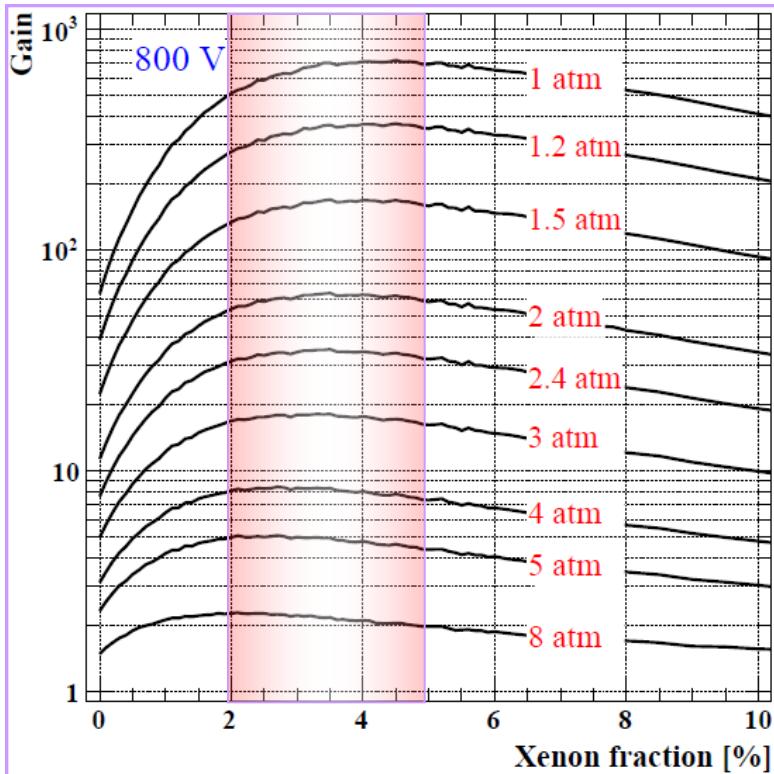
Contributions to the total gain



- ❖ Total gain peak \odot 3 – 4 % Xe
- ❖ Ar* begins dominant at lower Xe
- ❖ Xe⁺ > Ar*, >8.5 % Xe

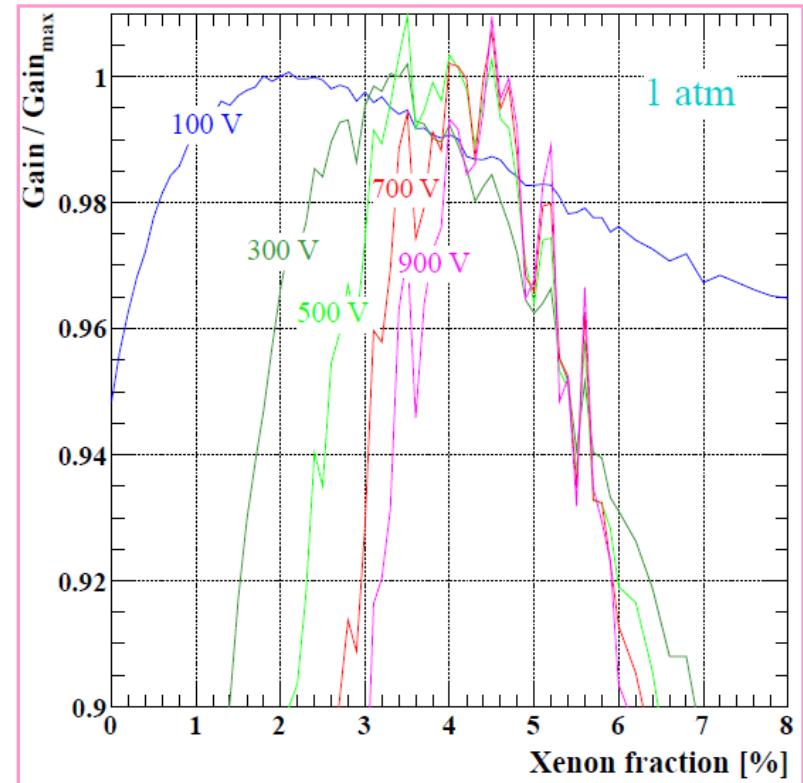
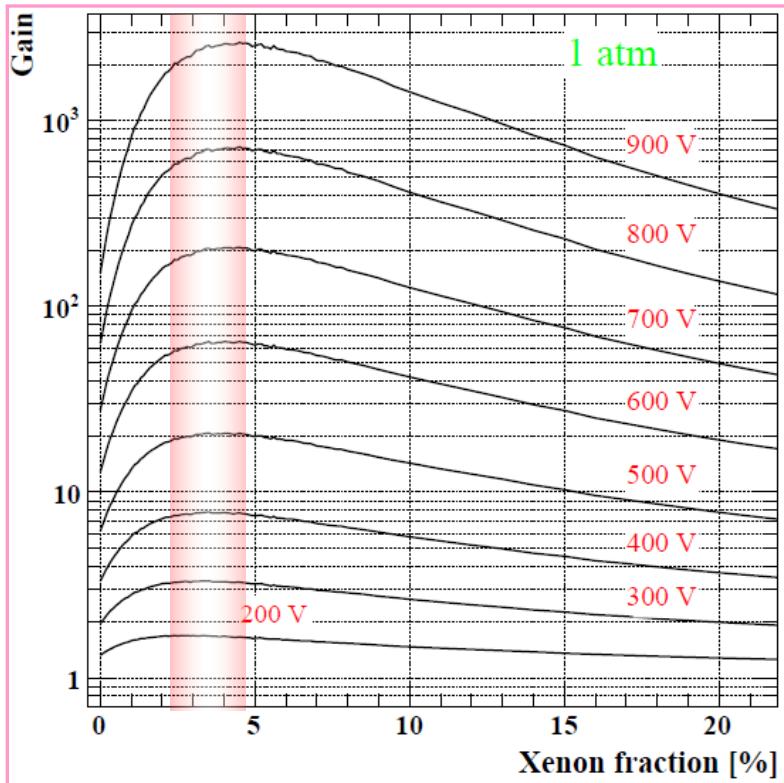
- ❖ Total gain peak \odot 2 – 3.5 % Xe
- ❖ Ar* maximum \odot 2 % Xe
- ❖ Effect of Xe⁺ associative ionisation more visible

Pressure dependence



- ❖ Apparent shifts on maximum gain by increasing pressure
 - ❖ Not linearly
 - ! Maximum gain sits ⏰ 4 – 5 % Xe at 1 atm as indicated earlier !
- F. Amaro et al., *Nucl. Instr. And Meth. A* **535** (2004) 341–346.

Voltage dependence



- ❖ Fraction of Xe increase for the highest gains when increase the voltage
- ❖ Broader maximums at low voltages
- ❖ Maximums getting same Xe fraction at high voltages

Conclusions

- ❖ Pressure and voltage dependence for the maximum gains
 - ❖ Strong pressure effects
 - ❖ Same trend at high voltages
- ❖ Systematic measurements are welcomed
- ❖ Thanks to João Veloso for his ideas
- ❖ Next
 - ❖ increase statistics of calculations (number of collisions Magboltz)
 - ❖ other geometries, fixed gradient of the electric fields ...

Thank you ...