Ion back flow reduction in GEM-like cascades operating in HpXe

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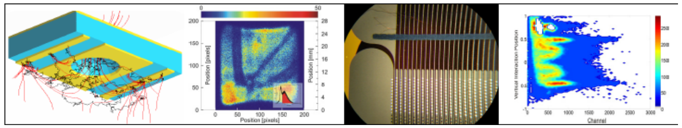


Motivation

HpXe and dual-phase based detectors or TPCs

- gamma-ray imaging
- neutrinoless double-beta decay
- WIMPs
- …

- require readout devices capable of:
  - operating at HpXe
  - reducing ion back flow to the conversion region

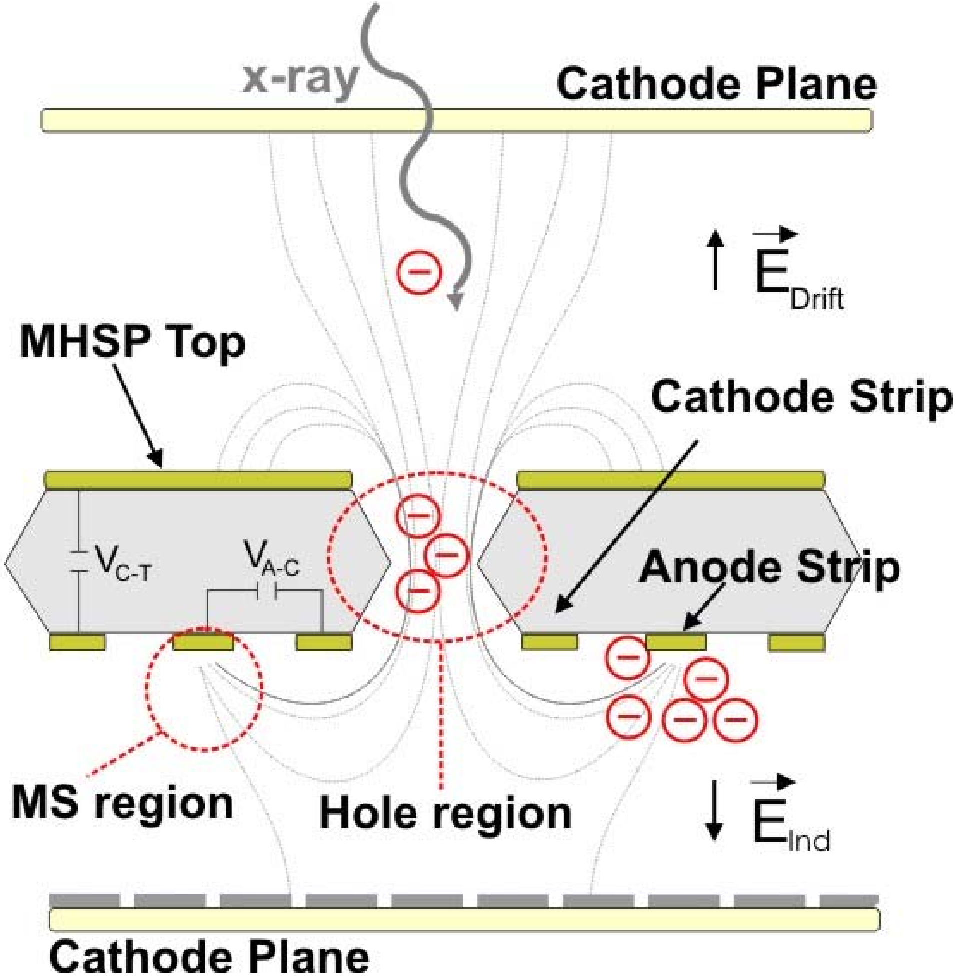
Ion backflow problems and needs

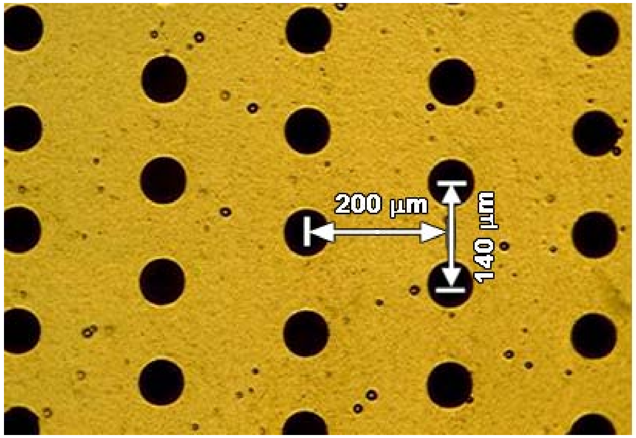
Positive ions produced in avalanches limit the detector performance and the electron multiplication gain:

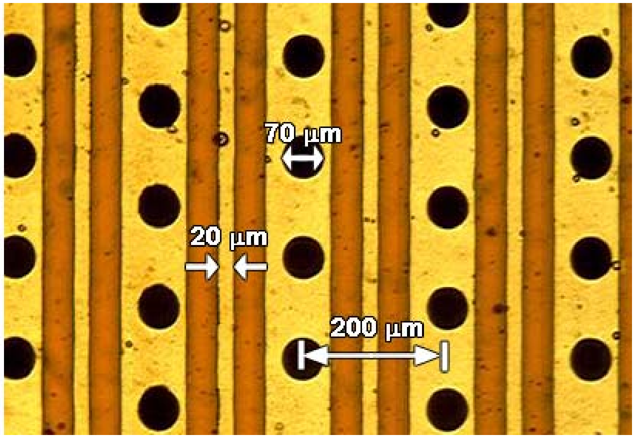
- In GPMs, trigger secondary avalanches, which cause gain limitations and localization deterioration (critical in visible-sensitive GPMs).
- In TPCs, result in dynamic track distortions. This seriously affects the tracking properties of TPCs in high-multiplicity experiments.
- Needs for good performance:
  - GPMs – # ions/primary electron ≤ 10 (10^{-5} IBF @ $G=10^{6}$)
  - TPCs – # ions/primary electron ≤ 1 (10^{-4} IBF @ $G=10^{4}$)
    - Minimum gain for primary electrons ~ 10

MicroHole & Strip Plate (MHSP)

- Operation Principle







JFCA Veloso et al., RSI 71(2000)2371

MicroHole & Strip Plate (MHSP)

- This device provides:
  - High gains – ~ 10^4-10^5
  - Fast charge collection – 10 ns
  - High energy resolution – 13.5% @ 5.9keV x-rays - Xe
  - High rate capability – > 0.5 MHz/mm^2
  - **Low ion back-flow to the conversion region**
  - Low UV photon feedback
  - **High pressure operation capability**
  - 2-D intrinsic capability – σ~125μm (with resistive line)

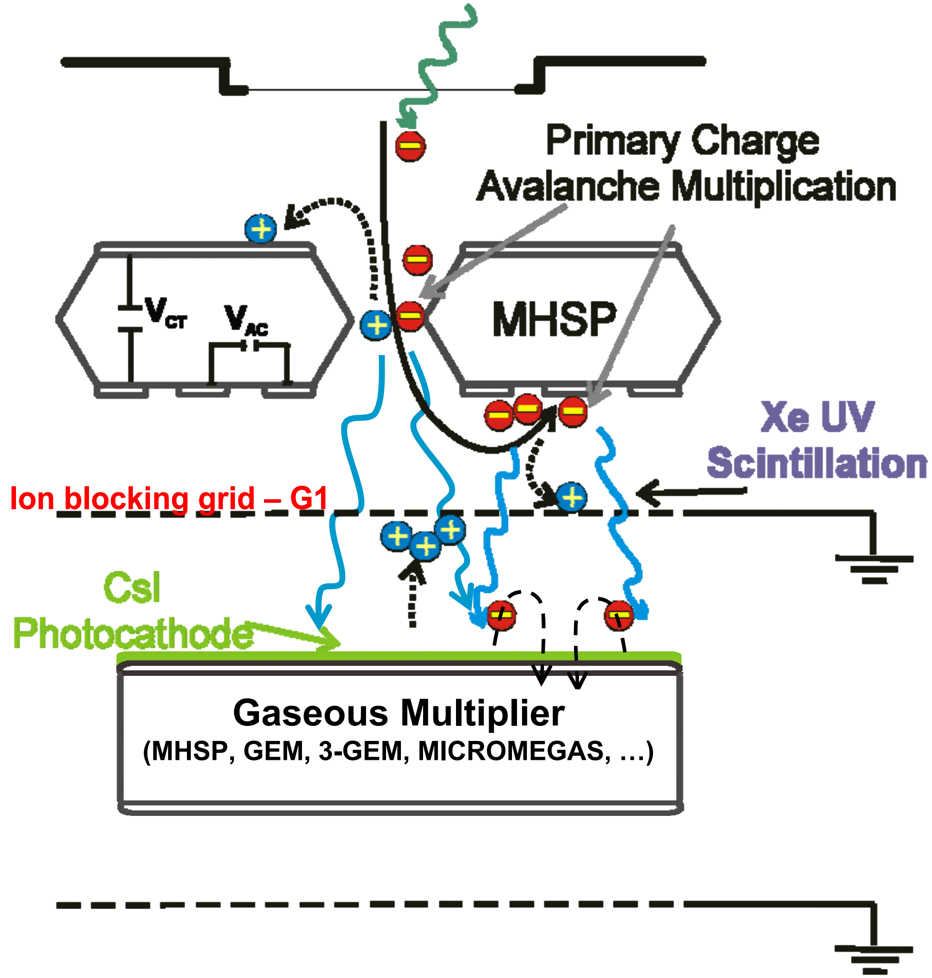
PACEM - a solution for IBF reduction

Photon-Assisted Cascaded Electron Multiplier

uses the light produced in the avalanche in the first element for signal amplification and transmission to the next cascade element, while a mesh is used to block both electrons and ions.

Photon-Assisted Cascaded Electron Multiplier (PACEM)

Operation principle

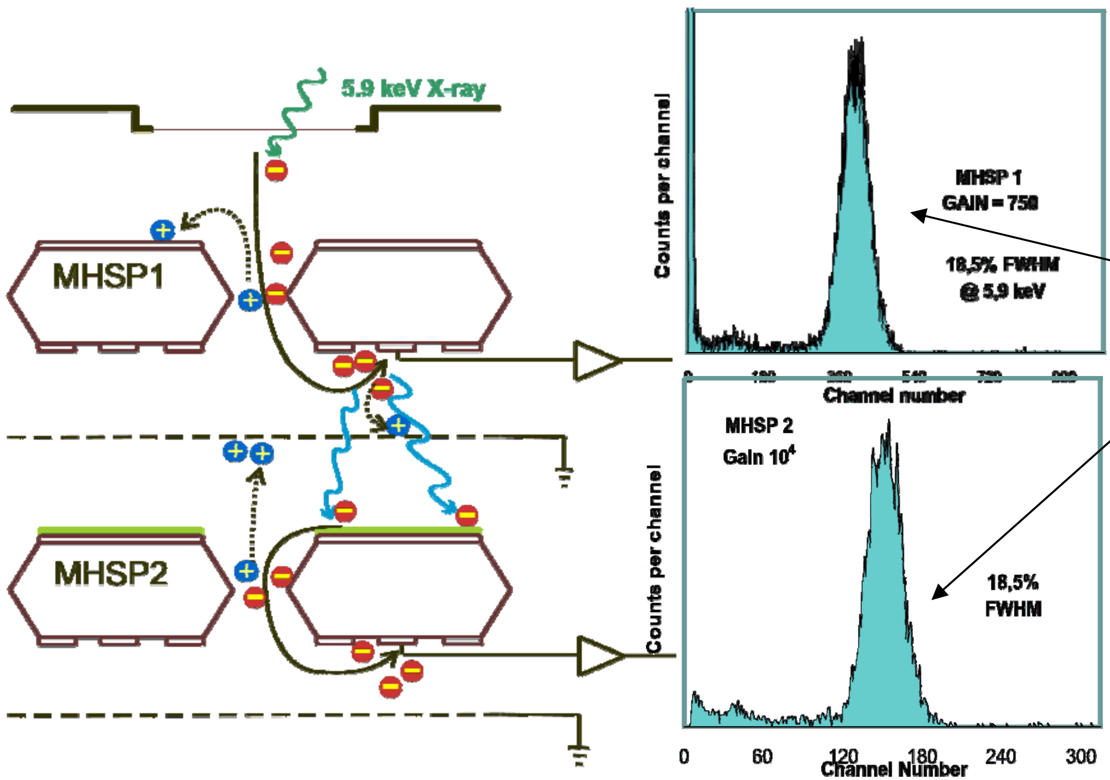


uses scintillation gases (noble, CF_4, …)

JFCA Veloso et al., JINST (2006) 1 P08003

Photon-Assisted Cascaded Electron Multiplier (PACEM)

First validation (pulse mode)



- Pure Xenon
- **Light gain ≈ 10**
  - no change in R_E =>
  preserve statistical information
- G ~ 10^4

PACEM - a solution for IBF reduction

- PACEM (Xe ^ CF_4 @ 1 bar) - demonstrated
  - TPC conditions

    ~1 ion/pe => IBF ≈ **10^{-4}** @ $G=10^4$
  - GPM conditions

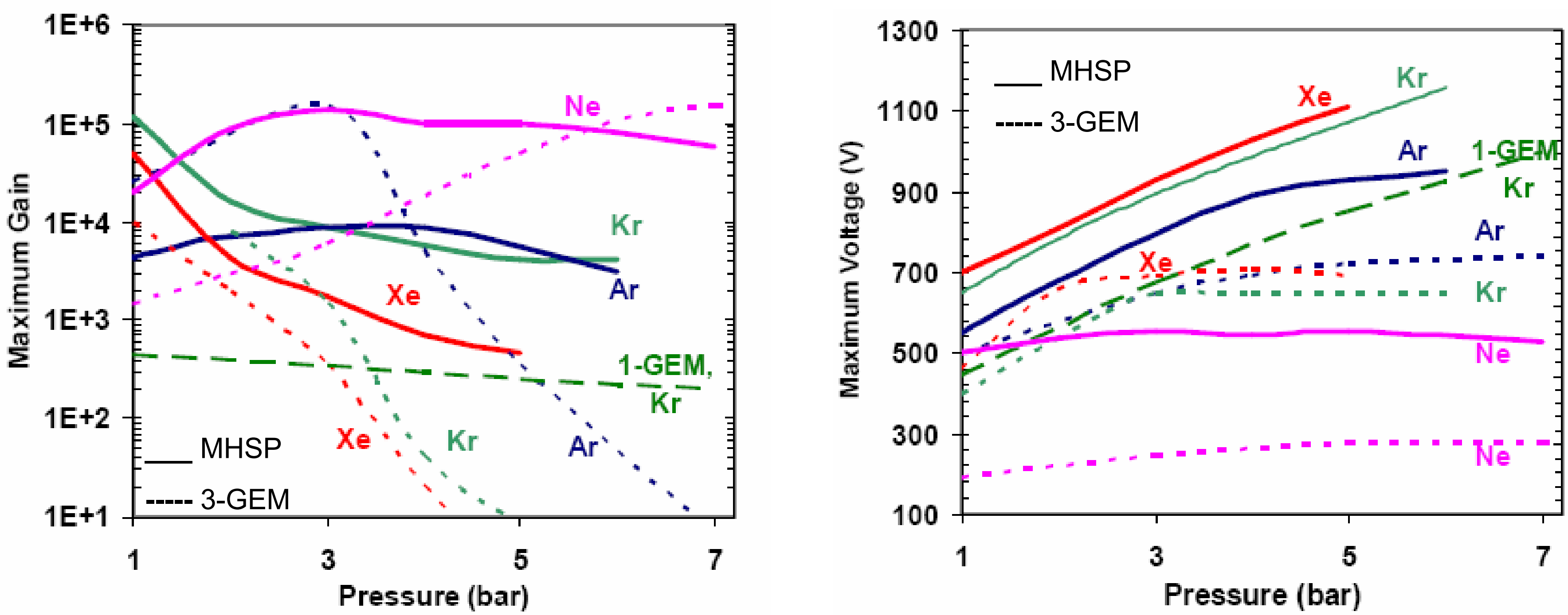
    ~10 ions/pe => IBF ≈ **10^{-5}** @ $G=10^6$

-JFCA Veloso et al., NIMA 581 (2007) 261

-FD Amaro et al. Trans. Nucl. Science (in press)

MicroHole & Strip Plate (MHSP)

Good performance at high pressure:

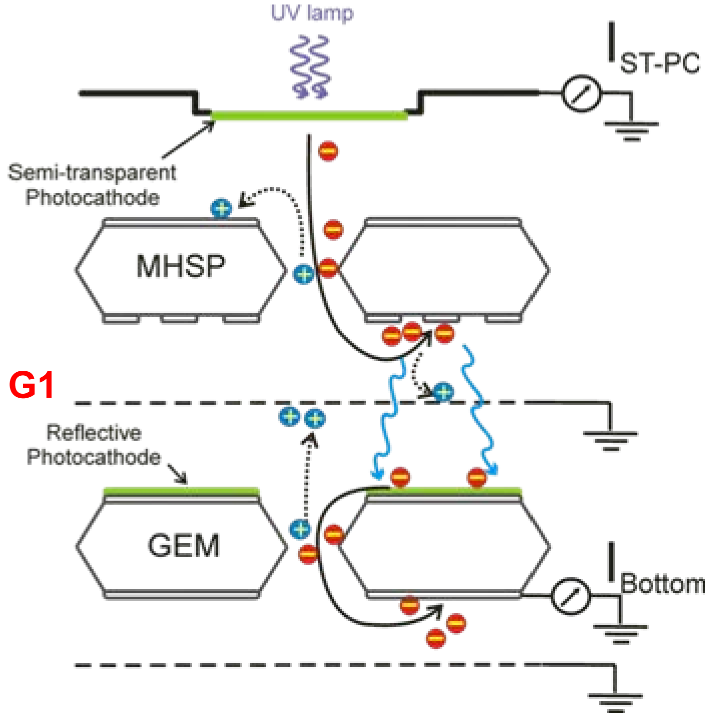


- High gain for pure xenon
  - 1 bar => G = 5×10^4
  - 5 bar => G = 5×10^2

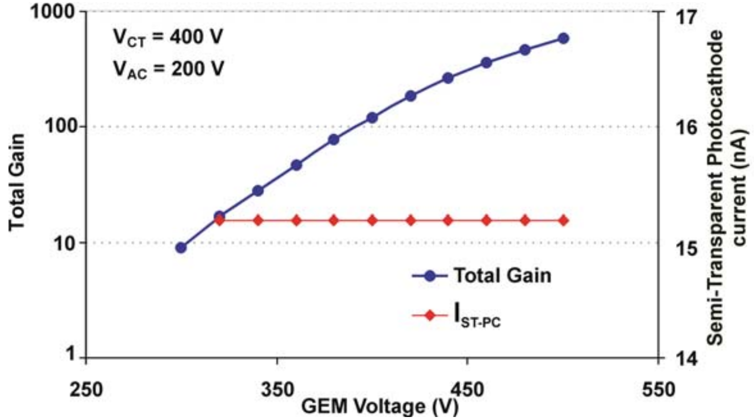
FD Amaro et al., JINST (2006) 1 P04003
A. Buzulutskov, NIMA 494 (2002) 148

Optical gains & grid efficiency – HpXe

Current Mode:

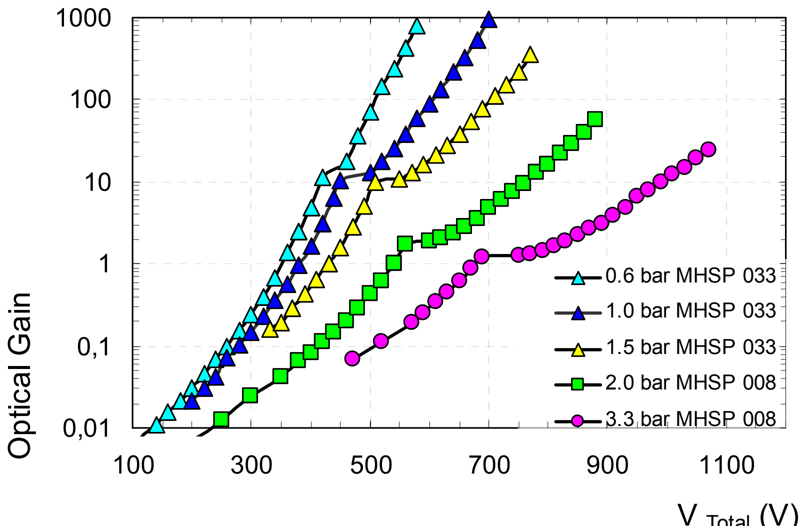


CsI photocathode + gas
~ 4% efficiency



No variation in the ions going to the drift region, with total gain

➡ **Full efficiency of the blocking grid, G1**

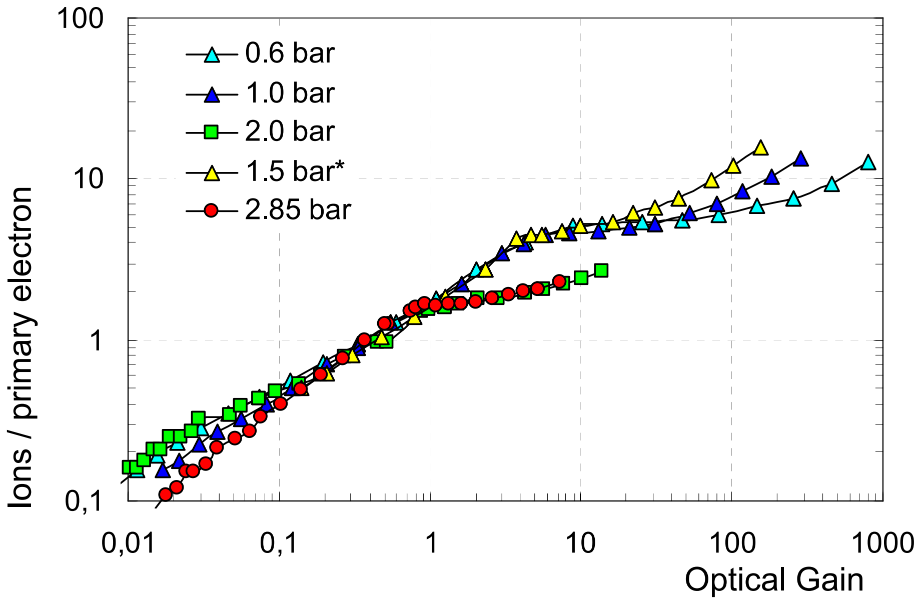


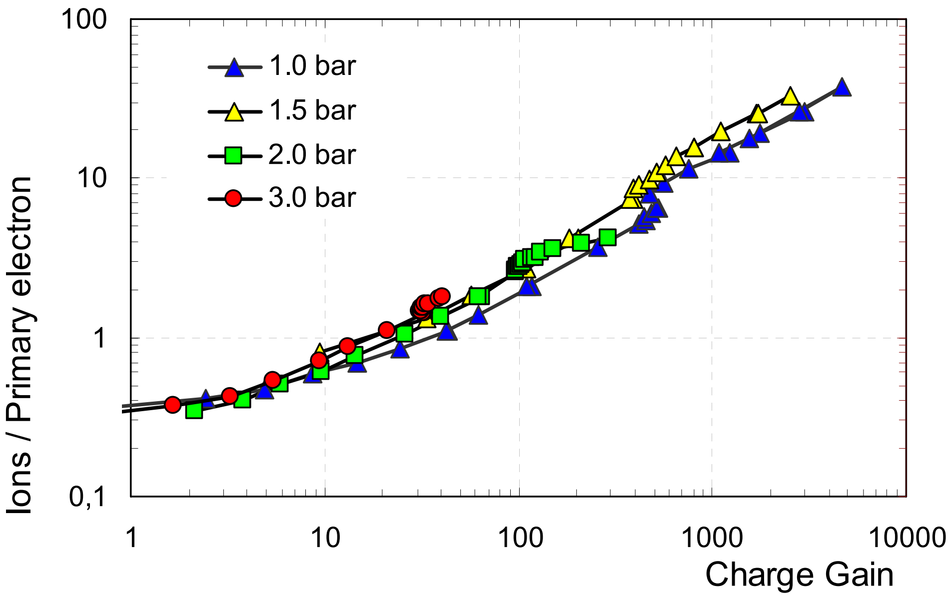
➡ **Optical Gains of ≈ 10^3 @** 1 bar **^ 30 @** 3.3 bar

IBF studies – HpXe

TPC conditions (low drift field **= 0.1kV/cm/bar**)

$$IBF = \frac{\text{Ions / Primary electron}}{\text{Total Gain}}$$





~2 ions/primary electron @ 3 bar

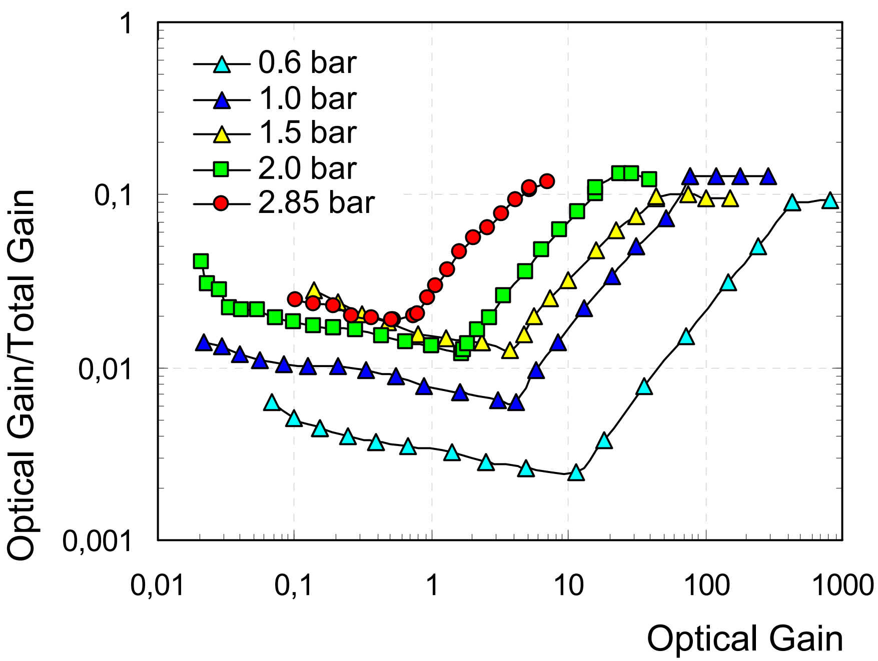
➡ **IBF ≈ 2×10^{-4} @ Gain = 10^4**

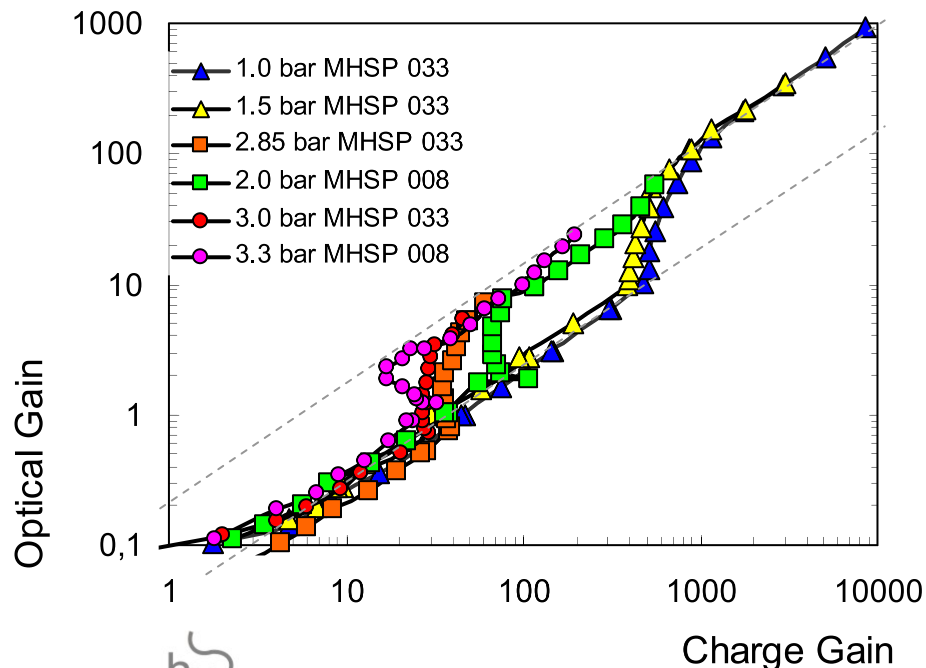
ions/primary electron

➡ **Only depends on charge gain**

Reducing V_{CT} in V_{total}, further improvements are obtained

Optical gain versus V_{CT} and V_{AC}

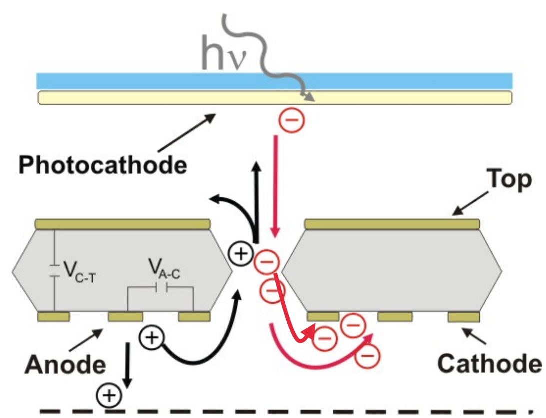




↑ V_{CT} (GEM mode) => OG/TG ↓

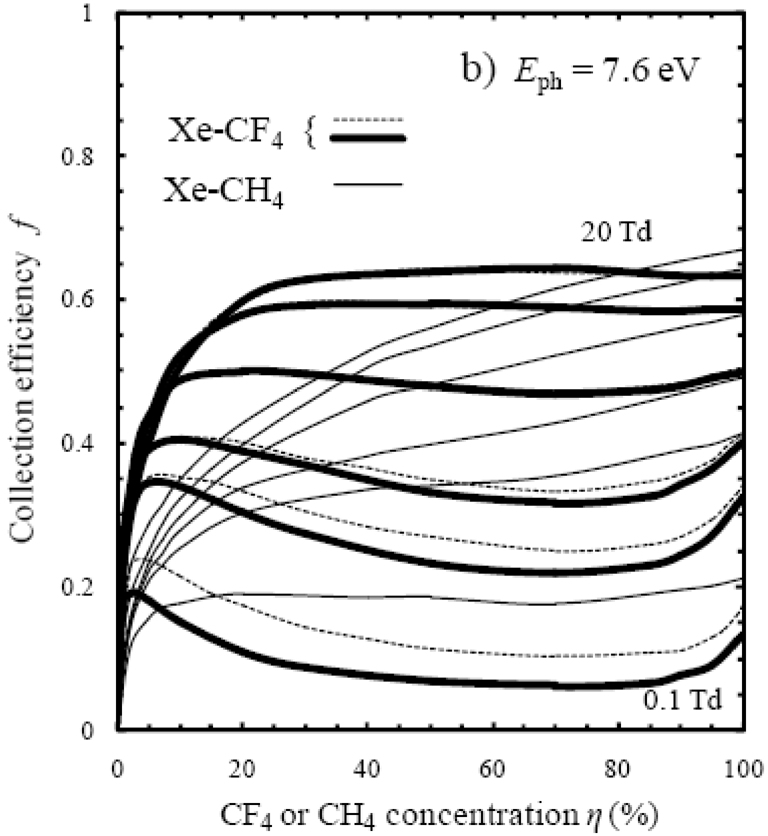
↑ V_{AC} => OG/TG↑ - no charge ↑

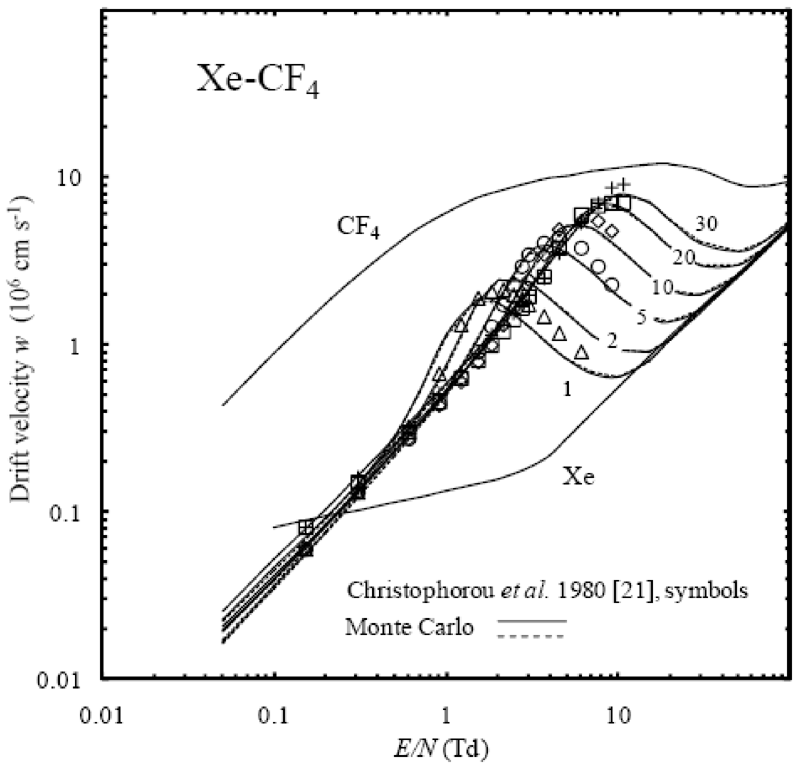
After strip multiplication => OG/TG ~ ct^e.



PE extraction from CsI PCs in Xe-CF_4 mixtures

Simulation results from: J. Escada, PJBM Rachinhas, THVT Dias, et al., Conf. Rec. IEEE Nucl. Sci. Symposium, Honolulu, October 2007.





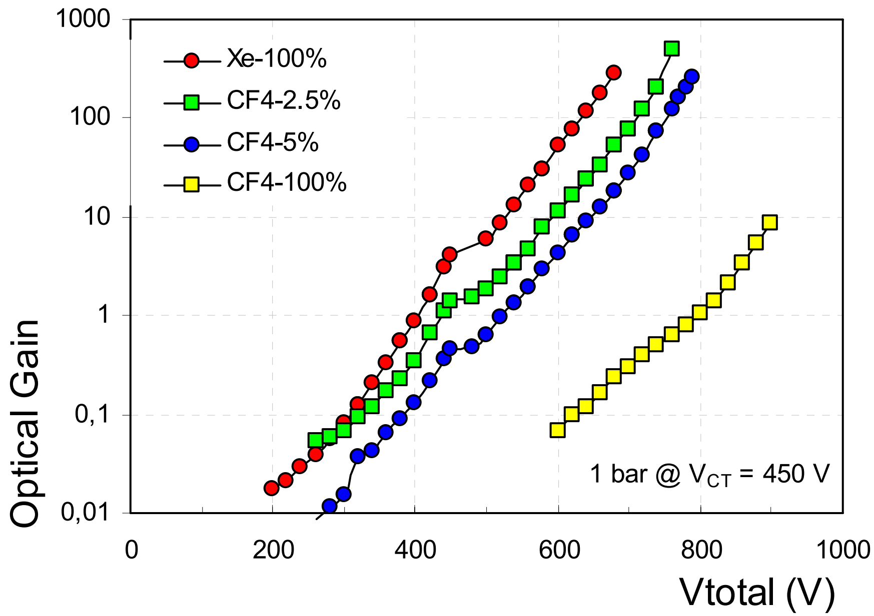
Adding a small %CF_4 to Xe

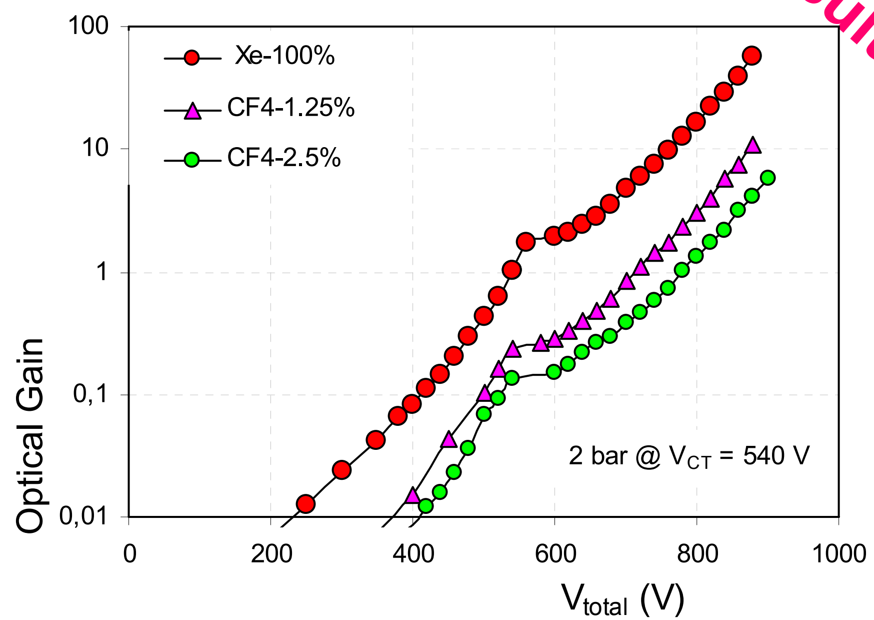
Xe-CF_4 faster than pure Xe

=> high effect on PE extraction → **Important to study in PACEM concept**

Optical gains – $Xe\text{-}CF_4$

preliminary results





- high optical gain achieved

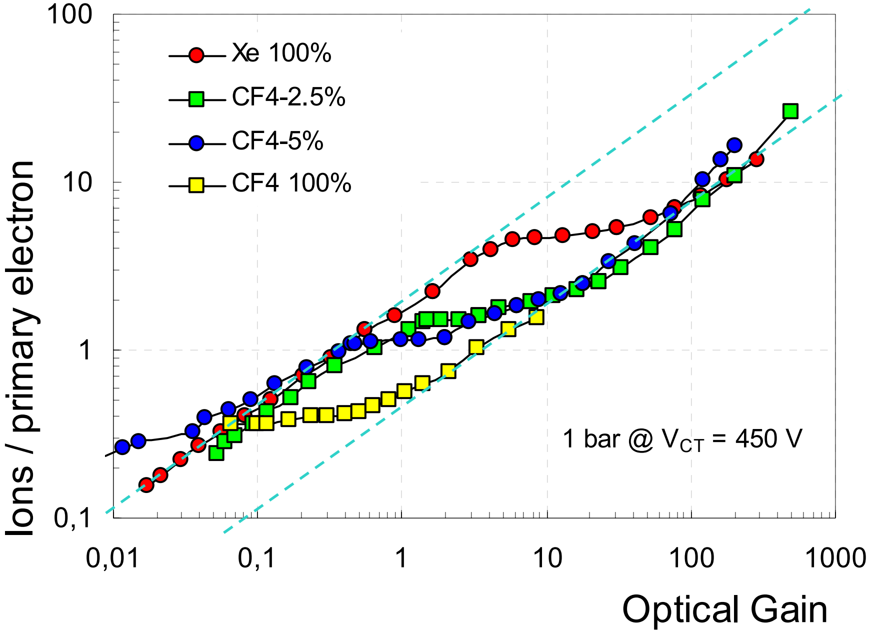
- good indications for $Xe\text{-}CF_4$ mixture operation

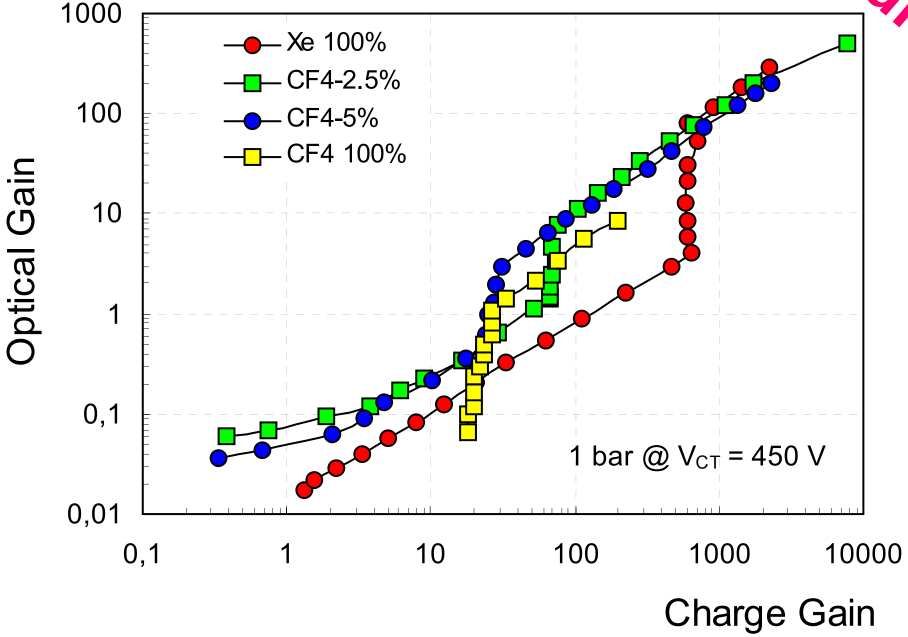
Operation conditions below optimum values

IBF studies – Xe-CF_4

preliminary results

TPC conditions (low drift field, 1kV/cm/bar)





~2 ions/primary electron
for Xe with a small amount of CF_4

IBF ≈ 2×10^{-4} @ Gain = 10^4

optical gain - higher than pure Xe for the same charge gain

Conclusions

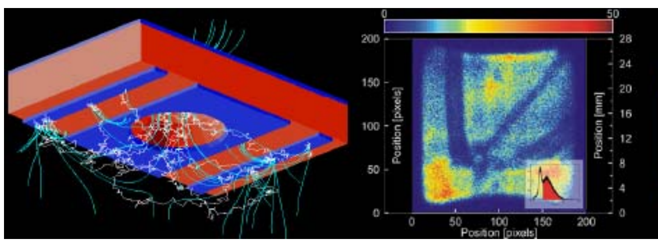
- HpXe operation
  - High optical gain, even @ Hp
    optical gain ~ 10^3 for 1.0 bar
    optical gain ~ 30 for 3.3 bar
  - IBF in TPC conditions
    ~2 ions/pe @ 3.3 bar => IBF ≈ **10^{-4}** @ G=10^4

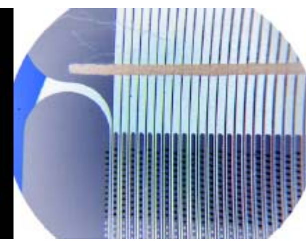
  -Systematic studies are in course for IBF optimization and for higher pressure operation.

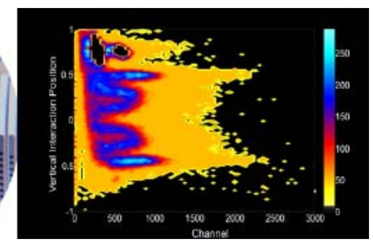
- Xe + CF_4 (not optimized)
  - high optical gain – higher than pure Xe for the same charge gain
  - better IBF than pure Xe
  - good indications for Xe-CF_4 mixture operation
    => important to continue this study

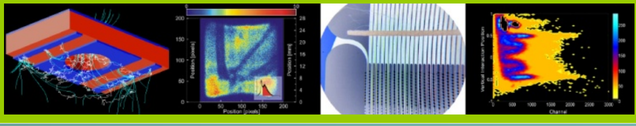
better quality MHSPs will allow us to reach higher gains and IBF performance

Thanks for your attention

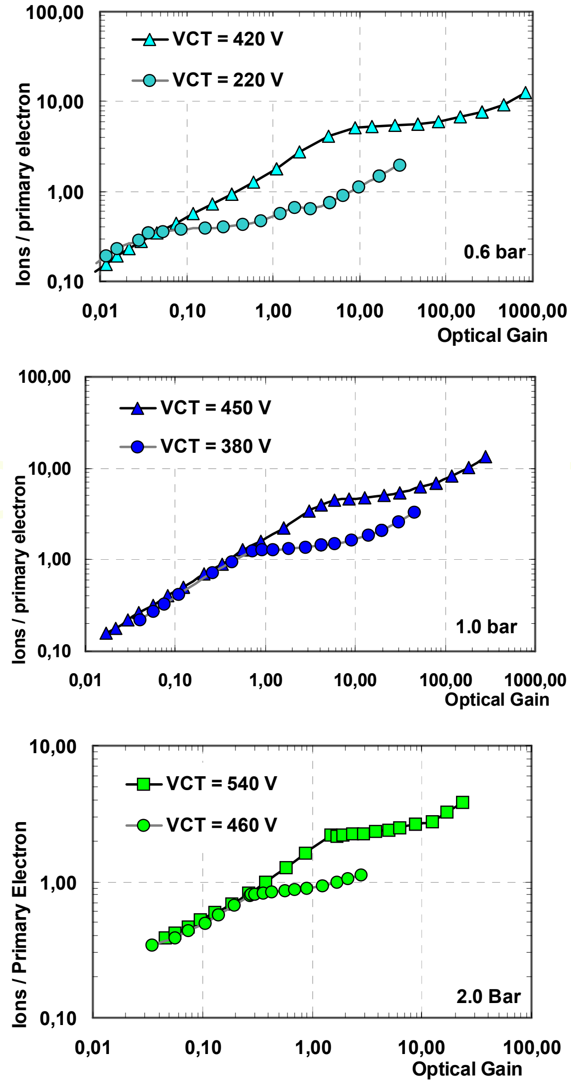






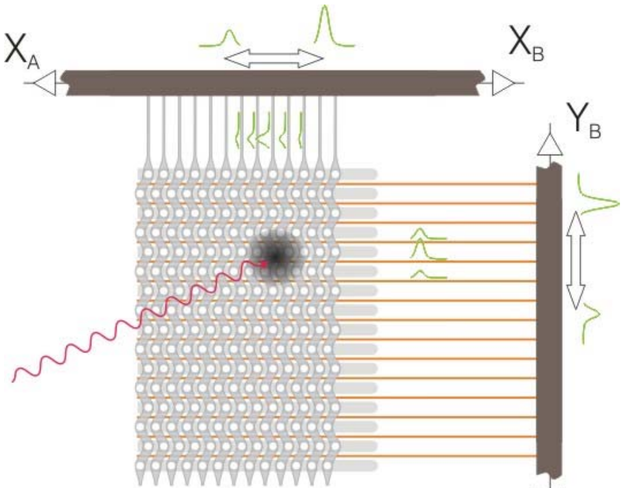


Backup Slides


VCT = 420 V
VCT = 220 V
0.6 bar
Ions / primary electron
Optical Gain
VCT = 450 V
VCT = 380 V
1.0 bar
Ions / primary electron
Optical Gain
VCT = 540 V
VCT = 460 V
2.0 Bar
Ions / Primary Electron
Optical Gain

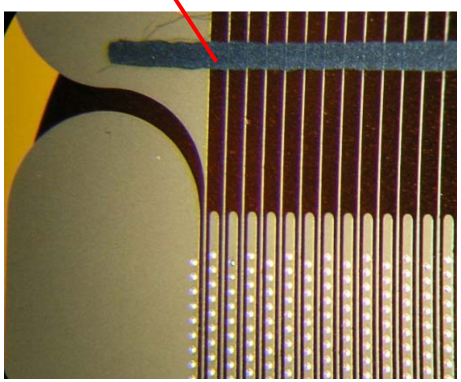
2D-Imaging – single photon counting

preliminary results

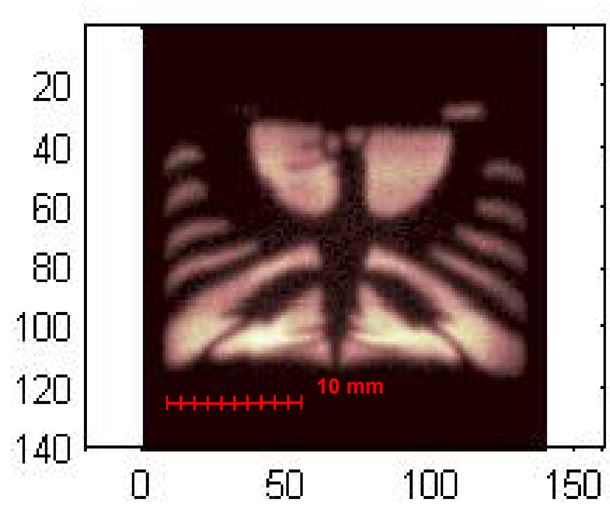


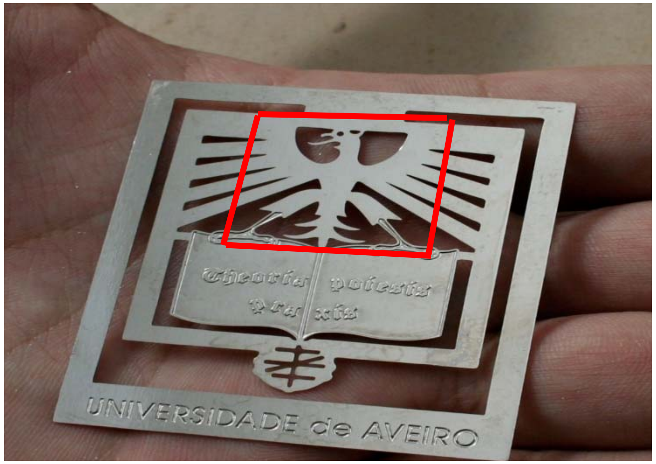
$$X = \frac{X_A}{X_B + X_A}$$

Resistive line ~ 100Ω /strip



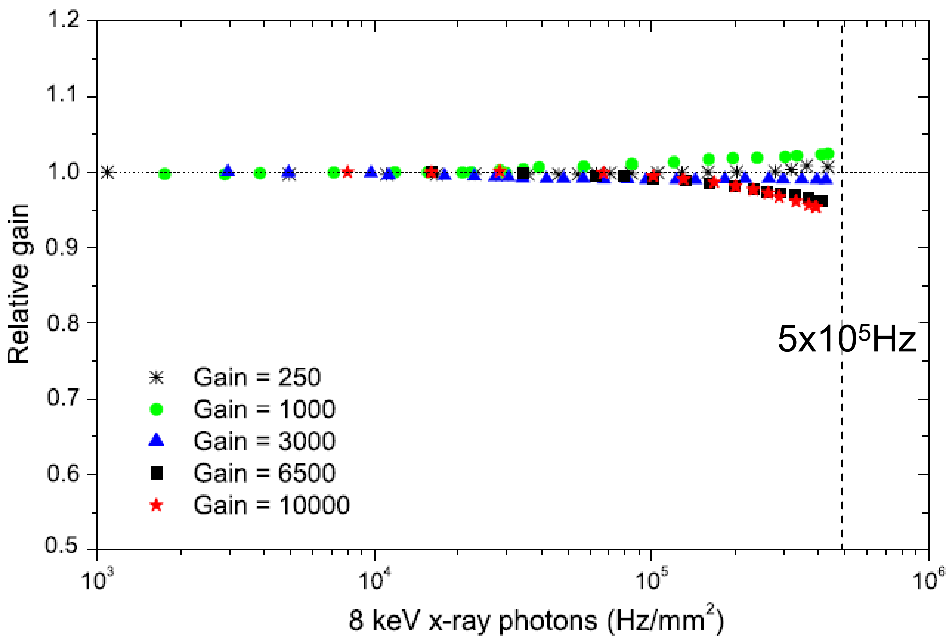
(See NS24-392, H. Natal da Luz et al.)

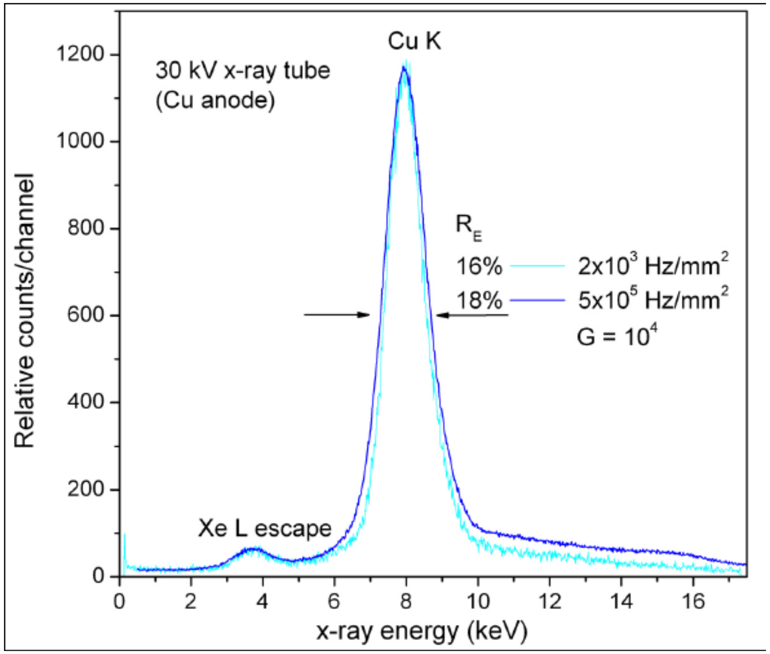




2D-Rp **< 300 µm (FWHM)** – full area

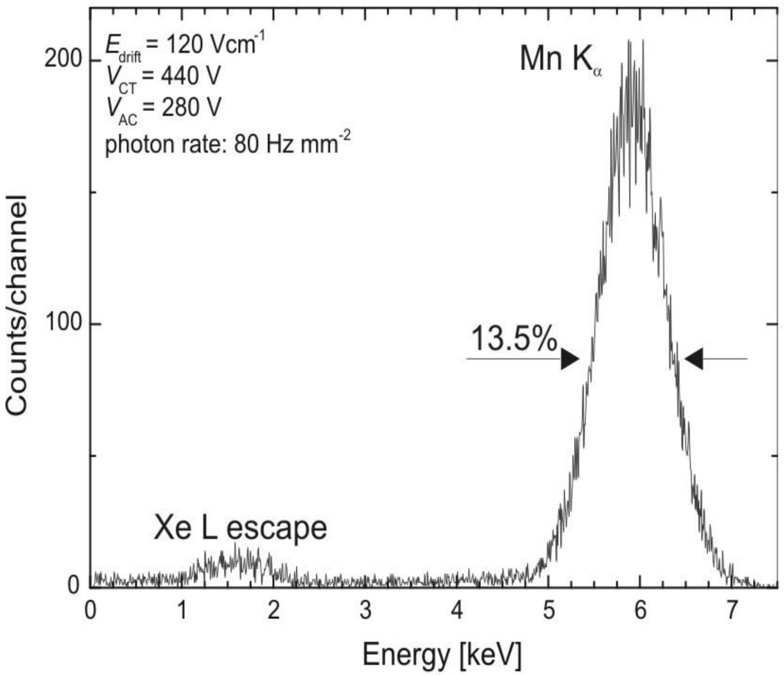
Count rate capability

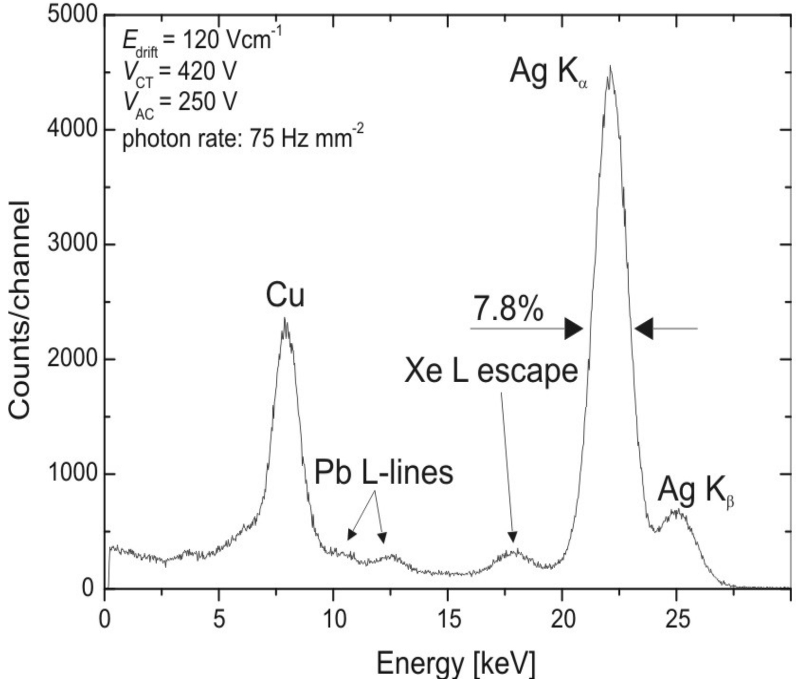




less than 5% variation @ G = 10^4
No visible variation @ G = 3000

Energy Resolution





@ G > 10^4