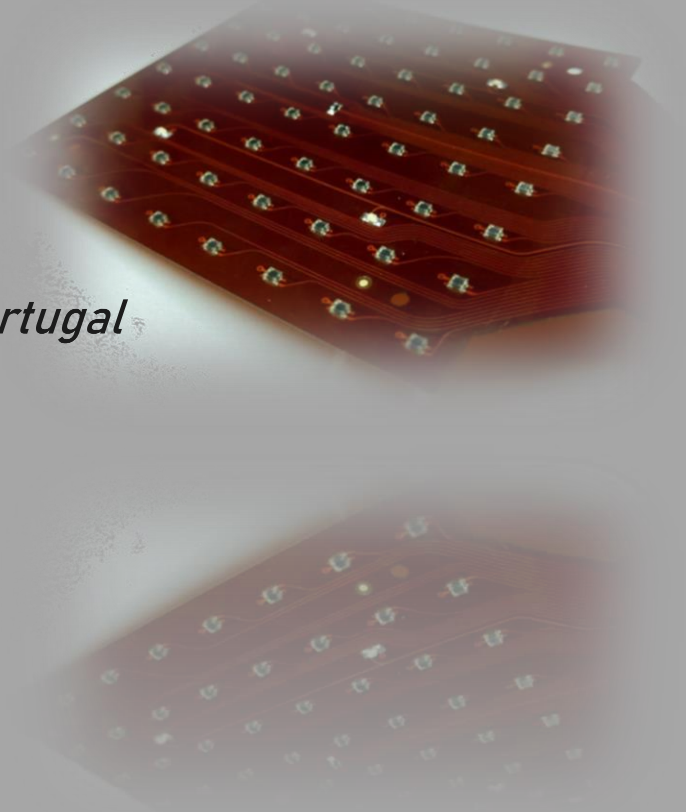
The PISA concept: Photon Induced Scintillation Amplifier, an innovative high-gain photosensor for rare event detection



Cristina M.B. Monteiro[1,*]

R.D.P. Mano[1], R.J.C. Roque[1]

[1]*LIBPhys, Physics Department, University of Coimbra, Portugal*

*cristinam@uc.pt

1290 UNIVERSIDADE D COIMBRA

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Outlook

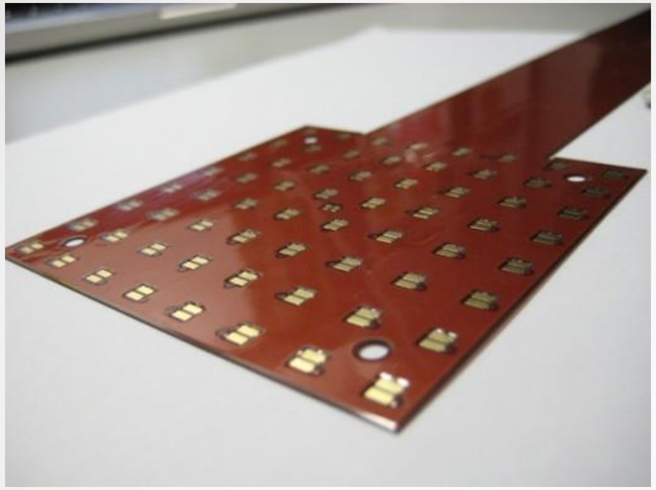
- State-of-the-art
- SiPM readout plane for scintillation readout
- GPMs as alternative to PMT
- Our proposal: the PISA concept
- Stage 1: The 1st prototype with LAAPD readout
- 1st Results: Ne-CF_4 and Ne-CF_4-CH_4 mixtures
- Conclusions & Prospects

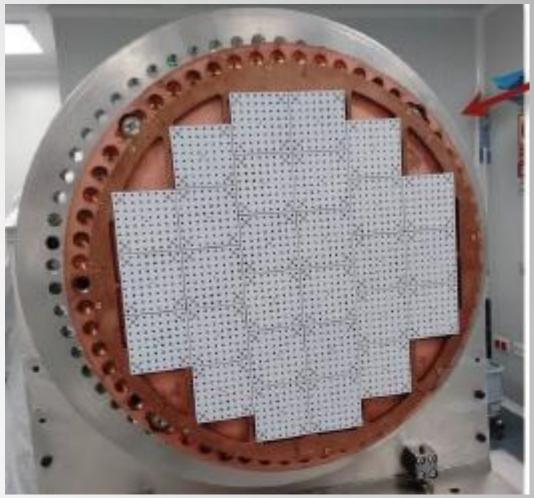
SiPM readout plane for scintillation readout
(e.g. The NEXT Experiment – HPXe TPC)

Dice-Boards

8x8 SiPMs, 1mm^2

1-cm pitch.



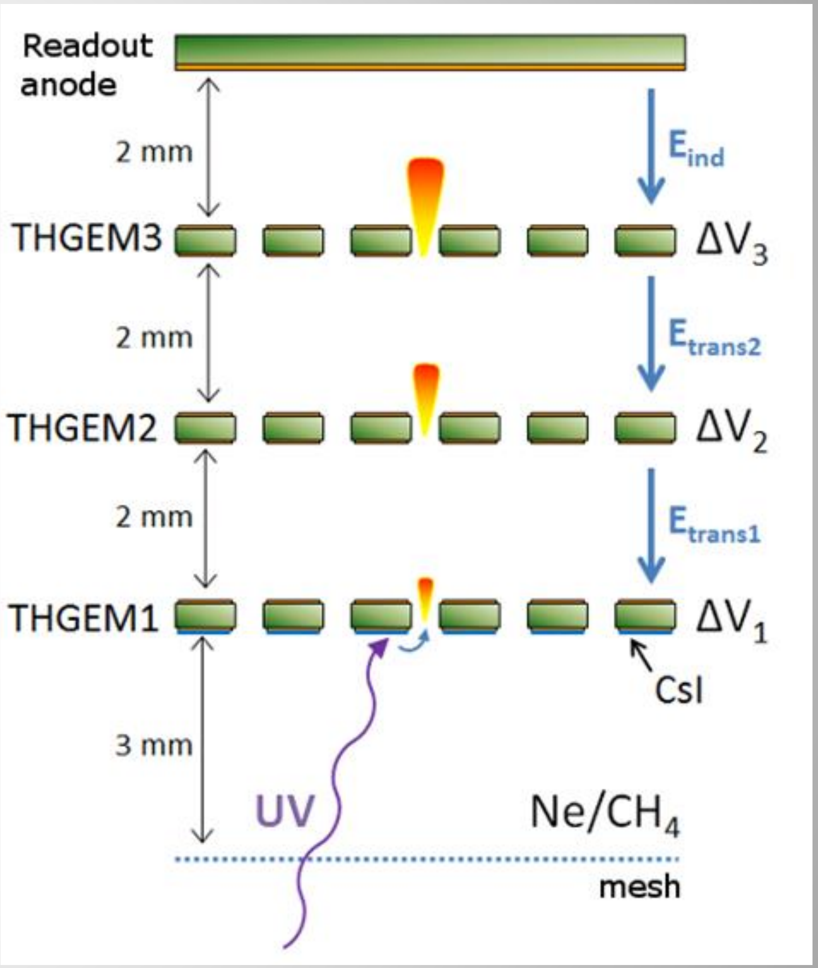


J Renner et al., JINST 13 (2018) P10020

- It can be used “per se” for Xe scintillation readout
- BUT: Compromise between area coverage and energy resolution

GPM alternative to PMT
(state-of-art developed at WIS)

- high single-photon detection efficiency;
- time resolution of 1.2 ns (RMS) for S1 signals;
- σ/E ~9% for S2 of 5.5 MeV αs;
- Fill factor > 80%   (LUX, Xe1t ~50%).
- PDE ~10%   (LUX, Xe1t ~13%)
- Pixelated GPM – improved position resolution (pixel-size dependent)



L Arazi et al., JINST 10 (2015) P10020

GPM necessary improvements

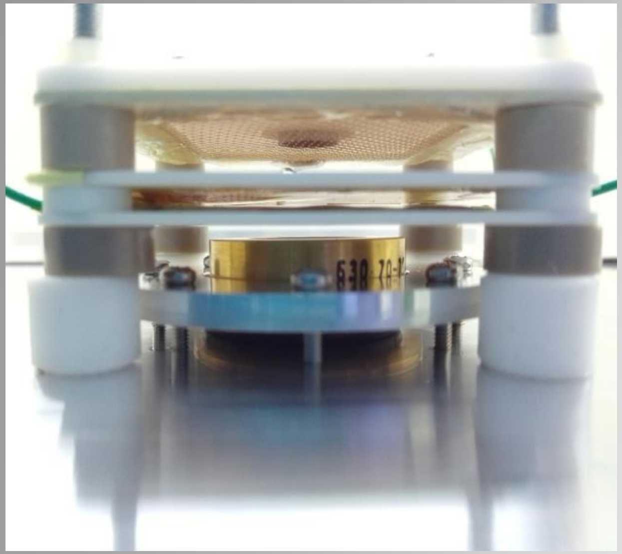
Radiopurity materials – THGEMs made of FR-4

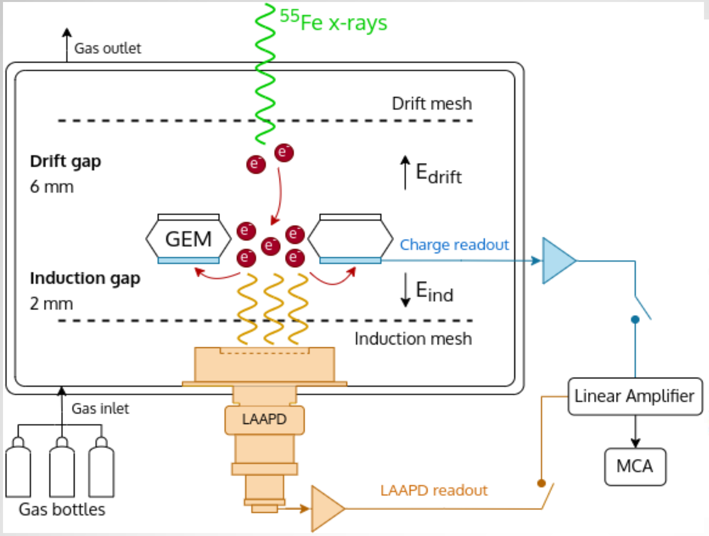
Readout electronics – radiopure & cryogenic operation

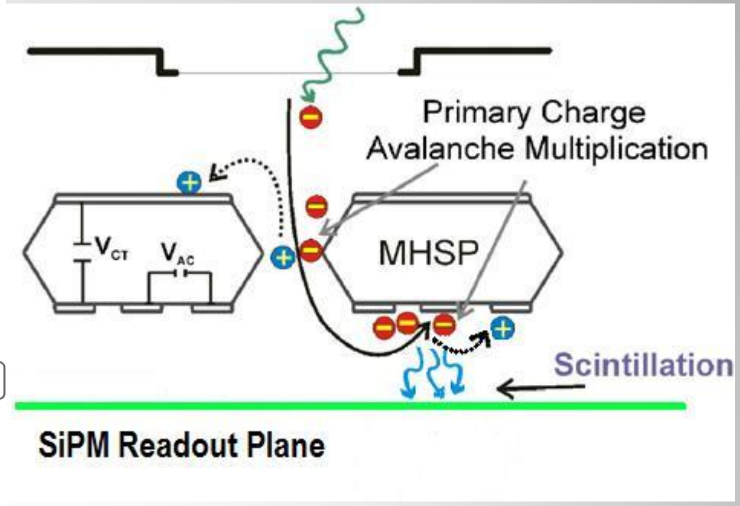
Gain – ~ 10^5

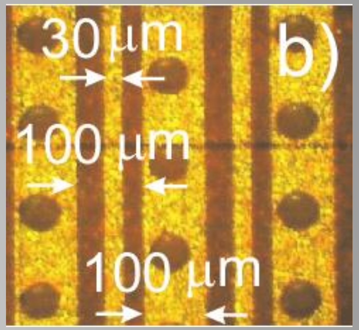
Noise Level – < 6.000 e^-

The PISA concept



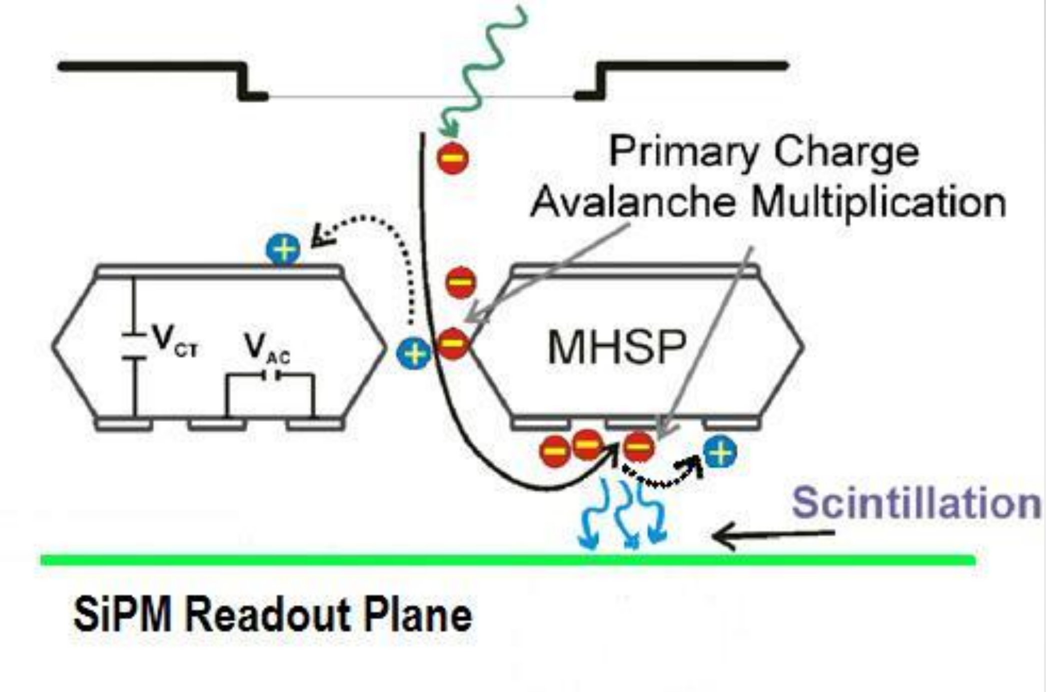






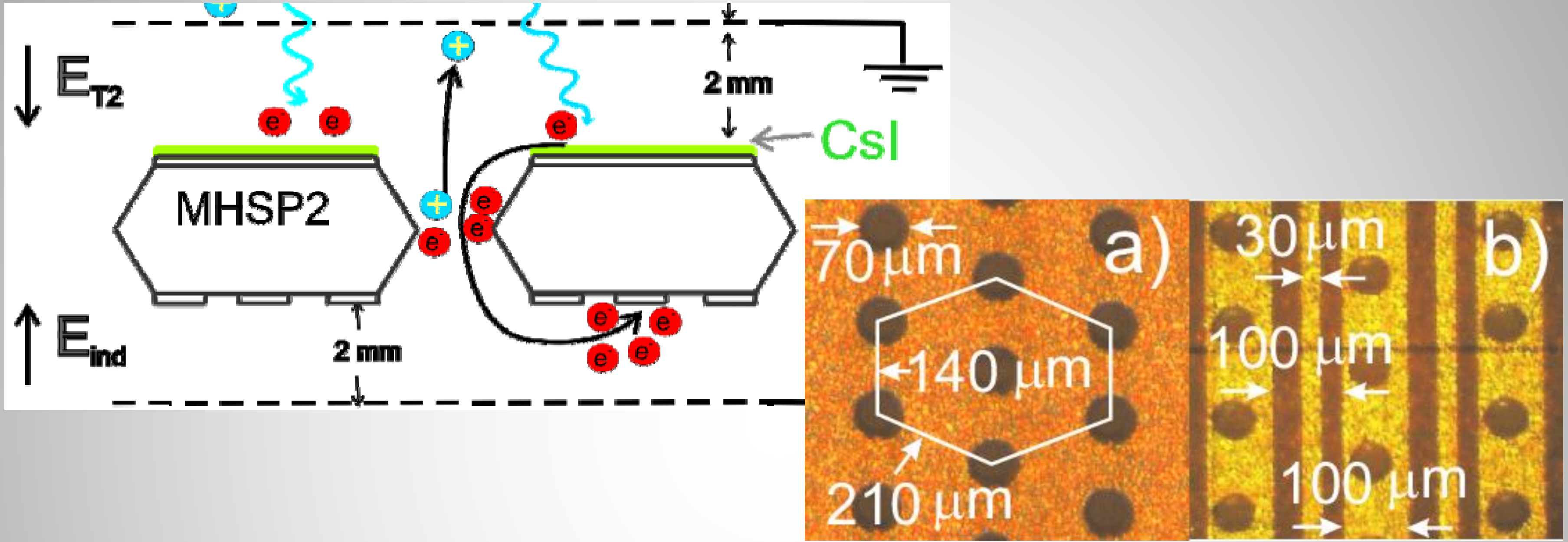
- Ionisation signal readout via reading out the scintillation produced in the electron avalanches instead of the charge. (Using SiPM for scintillation readout ⟹ possibility to achieve large signal output with higher SNR and placing the electronic readout away from the microstructure plane).
- Using MHSP/COBRA microstructure (GEM hole type micropattern foil having strips etched on the bottom surface of the foil for a second charge amplification stage ⟹ achieving larger scintillation output and lower ion backflow).
- **Applications**: VUV Gas Photomultiplier (with a CsI film coating the upper surface of the micropattern foil); ionization signal readout in TPCs (Optical TPCs);
- **1st stage**: using LAAPD for obtaining absolute values of photon output in GEM and MHSP/COBRA;

PISA : GPM with SiPM readout



- Reading out the scintillation produced in the electron avalanches and NOT the charge.
- Merging GPM and SiPM readout plane

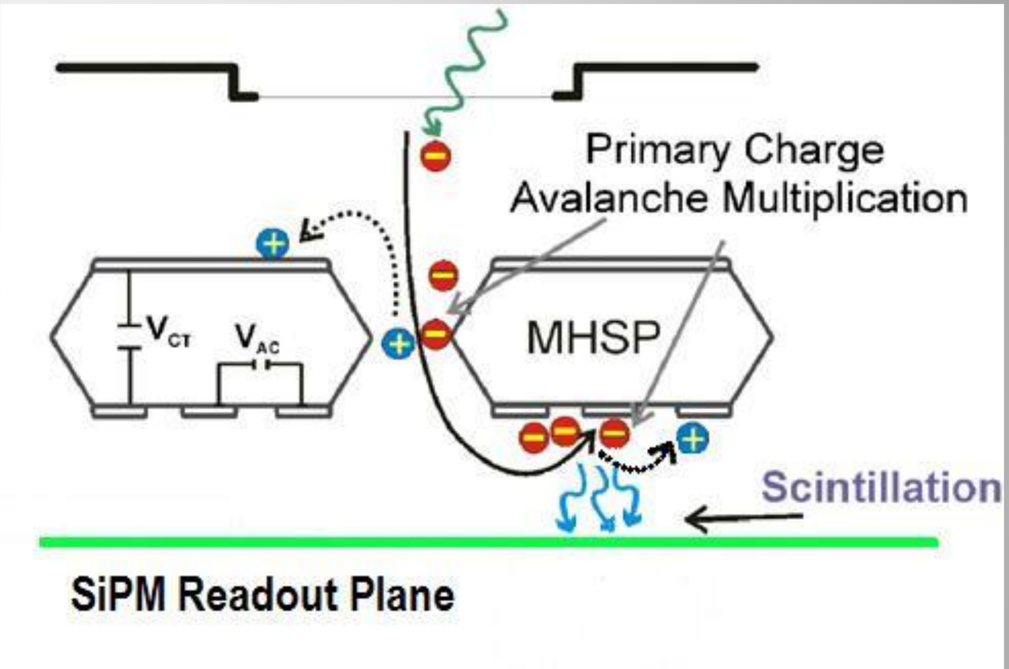
PISA: The MHSP e^--multiplier



- Element made of Kapton 125 μm thick (robust, radiopure)
- 2 e^--avalanche stages in one-single element
- Higher scintillation yield than THGEM

PISA: Advantages

- Compact: only 1 element
- Extra-high gain from SiPMs
- Improved S/N ratio



- Clean Materials: Kapton + Silicon
- Electronics placed far away from the SiPM plane
- Reduced SiPM coverage area.

PISA: R&D

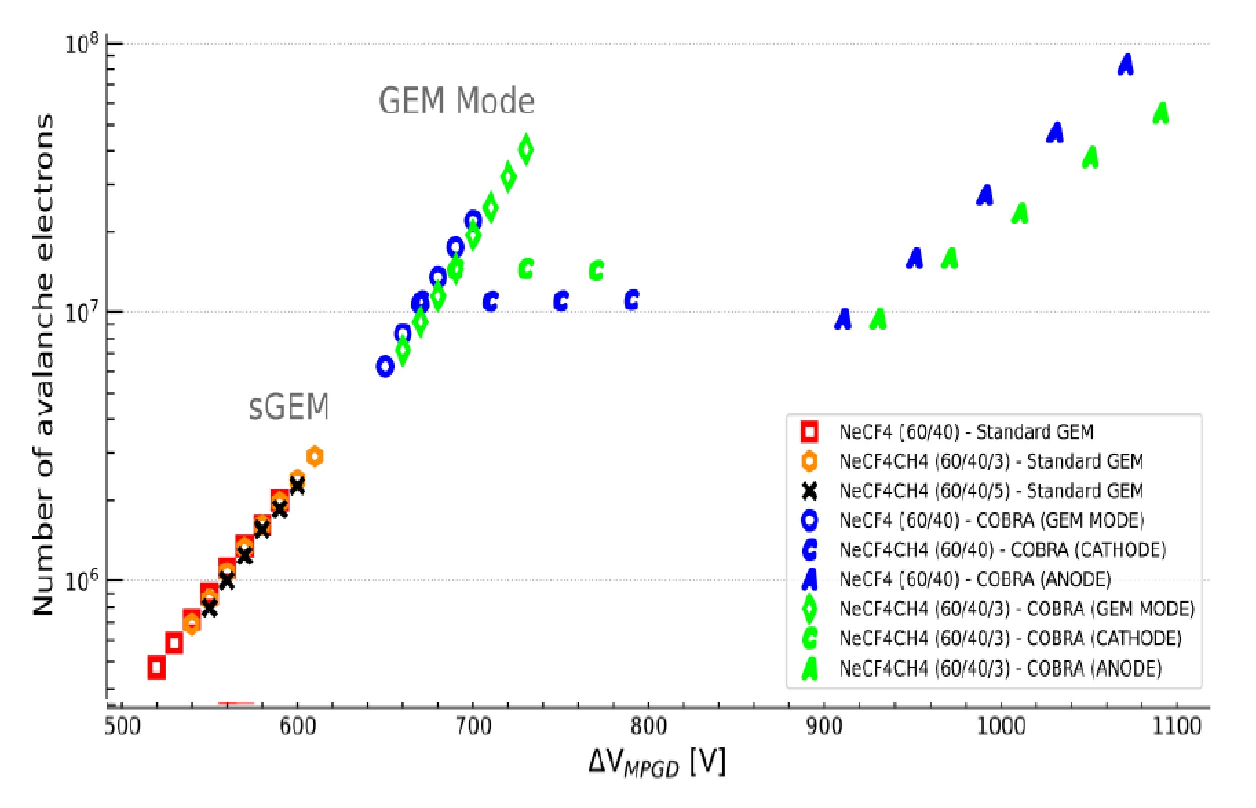
- Proof of principle:

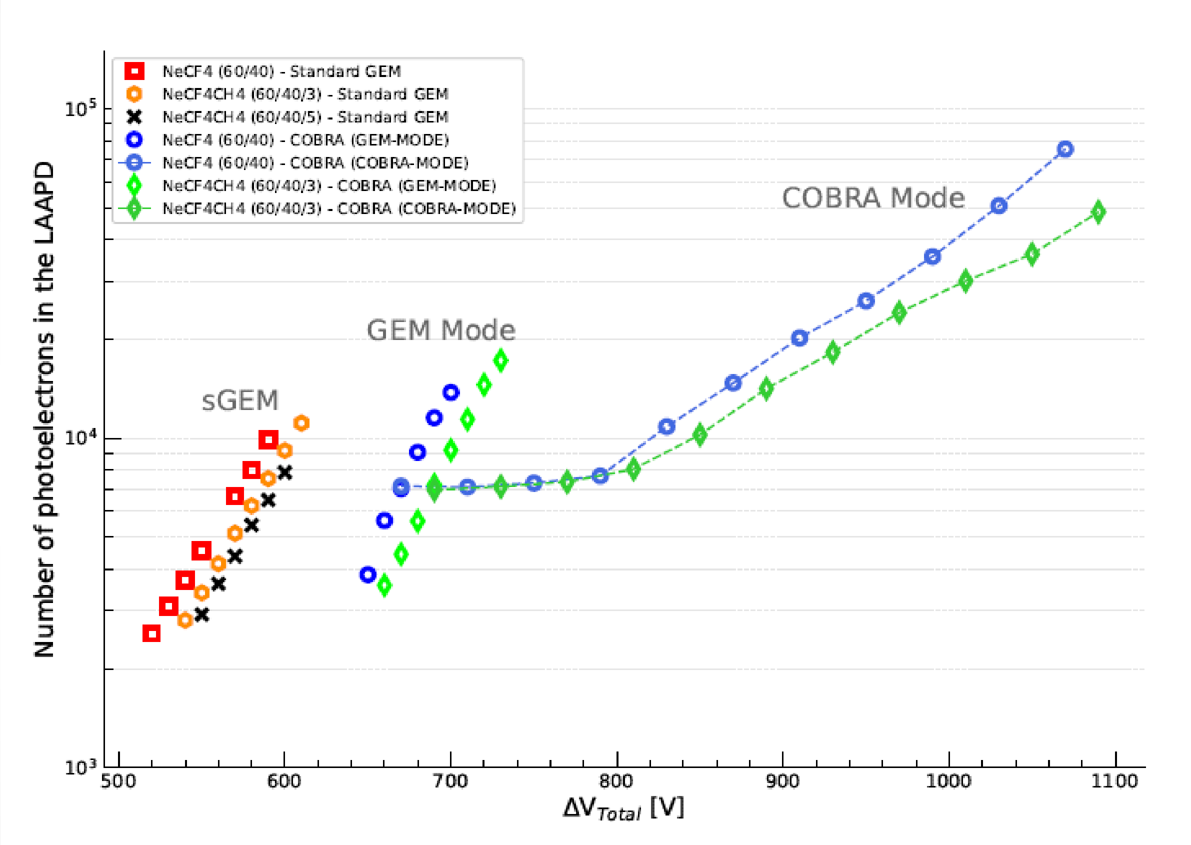
  3x3 cm^2 MHSP + 16-mm diameter LAAPD;

- Filling gas: Ne-based mixtures
  Higher scintillation yield
  Higher photoelectron extraction efficiency, e.g. Ne-CF_4

1st results: Ne-CF_4 and Ne-CF_4-CH_4 mixtures

Standard GEM – 50 μm thick MHSP – 125 μm thick Irradiation with 5.9-keV x-rays





Assuming a conservative w-value ~ 40 eV, for the mixtures of Ne-CF4 (60/40)

- **Charge readout** (left) – gain **~ 10^5** for a single MHSP_125
- **Scintillation readout** (right) – in the LAAPD **~500** photoelectrons per primary electron produced in the gas (to determine the number of electrons at the LAAPD output, one has to consider the additional photosensor gain)

Conclusions & Prospects

The PISA photosensor:

- The gas mixture with CF4 is promising;
- We could achieve optical gains as high as 500 in the present setup (1st stage prototype);
- With SiPM gains of ~10^6, large amplitude signals with good SNR are expected.
- Other gas mixtures will be explored (e.g. with N_2, CO_2, …)

• SiPM coverage (size and pitch): How much?
• (Energy & Position Resolution);

Thank you!

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