Absolute determination of the primary scintillation yield of pure krypton

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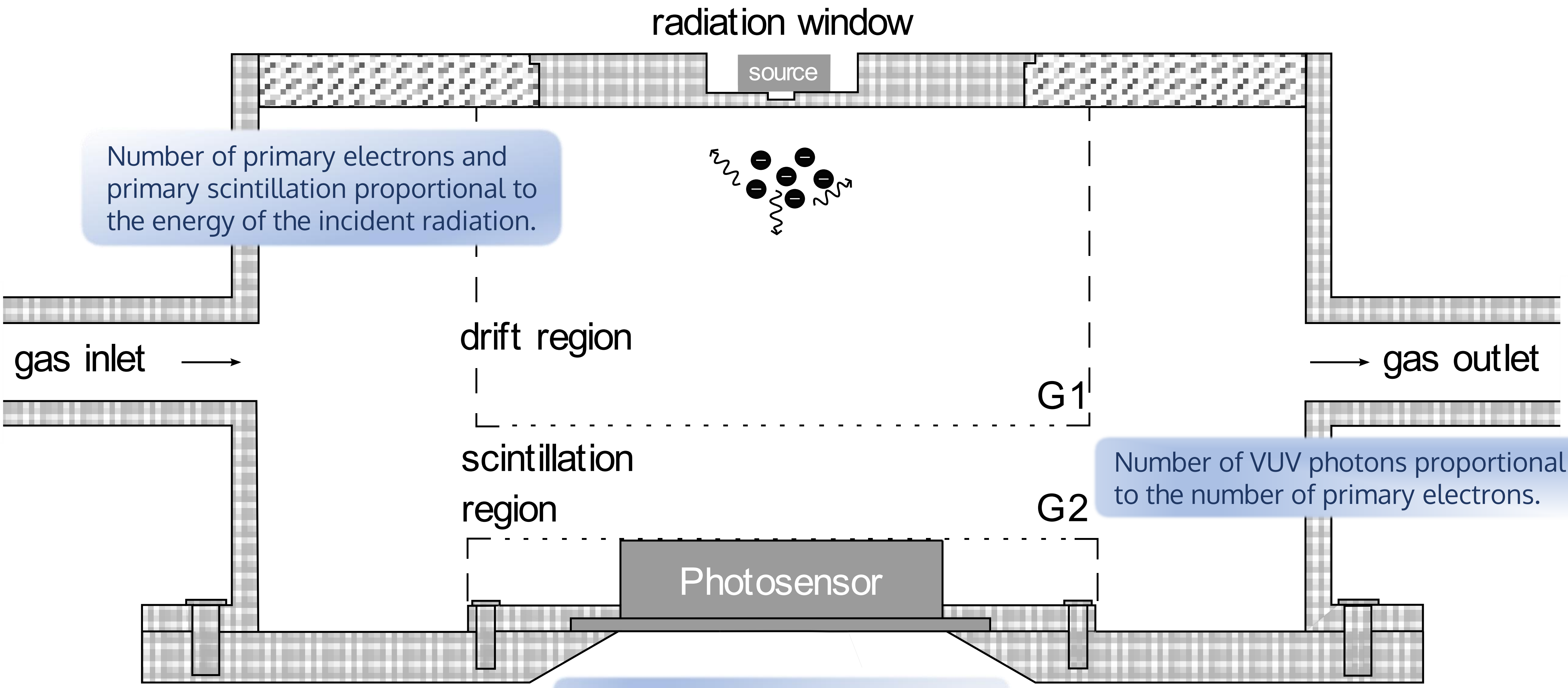
Gas Proportional Scintillation Counter

Number of primary electrons and primary scintillation proportional to the energy of the incident radiation.



Number of VUV photons proportional to the number of primary electrons.

Pulse amplitude proportional to the energy of the incident radiation.

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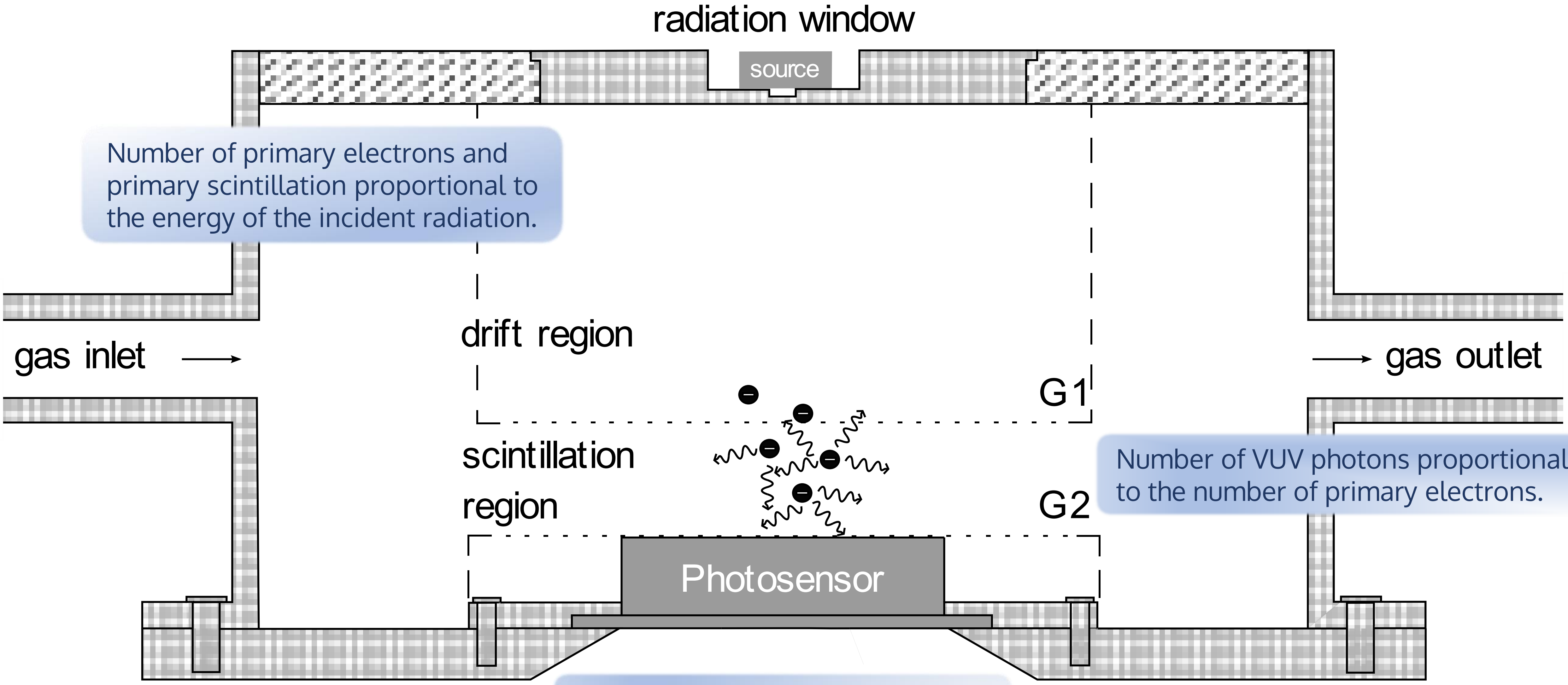

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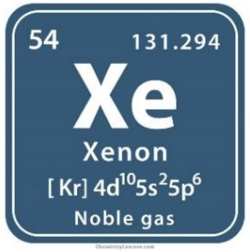
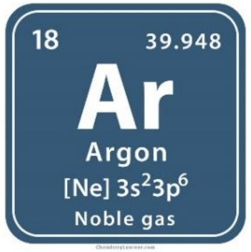


- ❑ Higher density and atomic number
- ❑ Lower ionization and excitation energies



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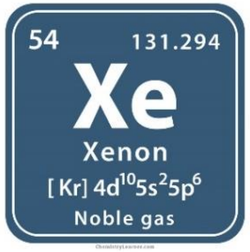

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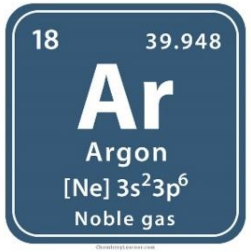

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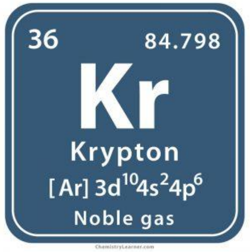

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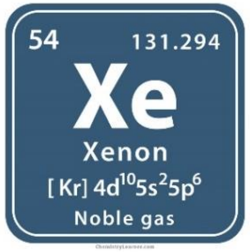

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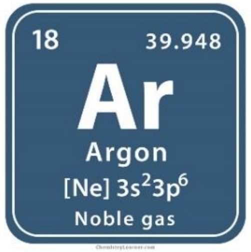

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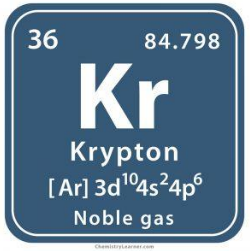

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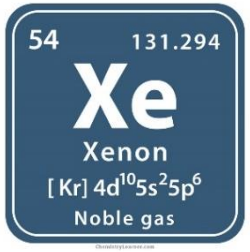

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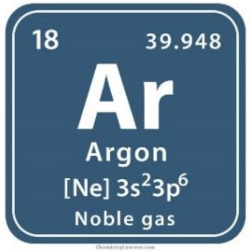

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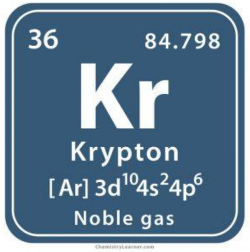

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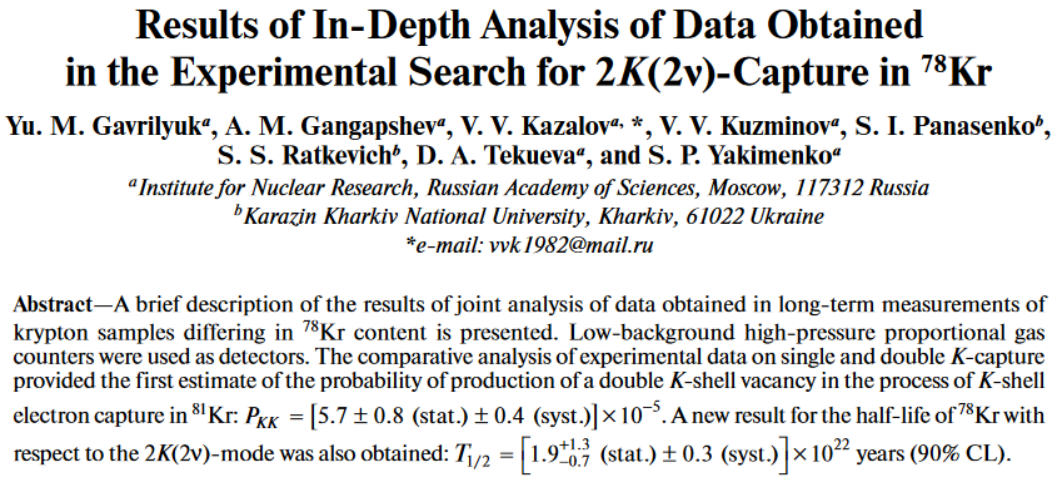
however…



Results of In-Depth Analysis of Data Obtained in the Experimental Search for 2*K*(2ν)-Capture in ^{78}Kr

Yu. M. Gavrilyuk[a], A. M. Gangapshev[a], V. V. Kazalov[a, *], V. V. Kuzminov[a], S. I. Panasenko[b], S. S. Ratkevich[b], D. A. Tekueva[a], and S. P. Yakimenko[a]

[a] *Institute for Nuclear Research, Russian Academy of Sciences, Moscow, 117312 Russia*
[b] *Karazin Kharkiv National University, Kharkiv, 61022 Ukraine*
**e-mail: vvk1982@mail.ru*

Abstract—A brief description of the results of joint analysis of data obtained in long-term measurements of krypton samples differing in ^{78}Kr content is presented. Low-background high-pressure proportional gas counters were used as detectors. The comparative analysis of experimental data on single and double *K*-capture provided the first estimate of the probability of production of a double *K*-shell vacancy in the process of *K*-shell electron capture in ^{81}Kr: $P_{KK} = [5.7 \pm 0.8 \text{ (stat.)} \pm 0.4 \text{ (syst.)}] \times 10^{-5}$. A new result for the half-life of ^{78}Kr with respect to the 2*K*(2ν)-mode was also obtained: $T_{1/2} = [1.9^{+1.3}_{-0.7} \text{ (stat.)} \pm 0.3 \text{ (syst.)}] \times 10^{22}$ years (90% CL).

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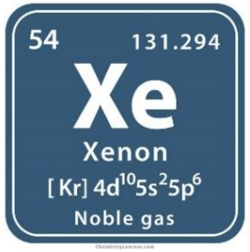

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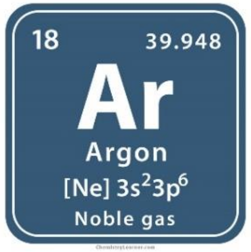

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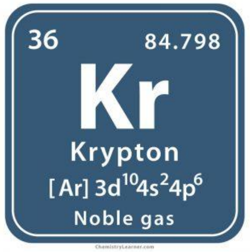

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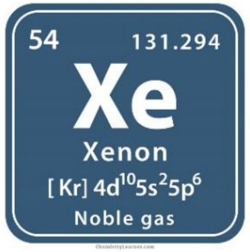

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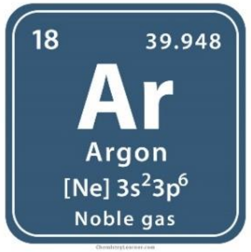

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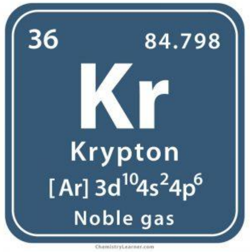

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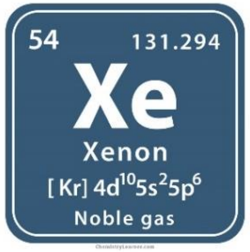

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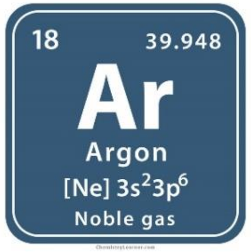

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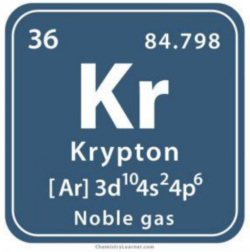

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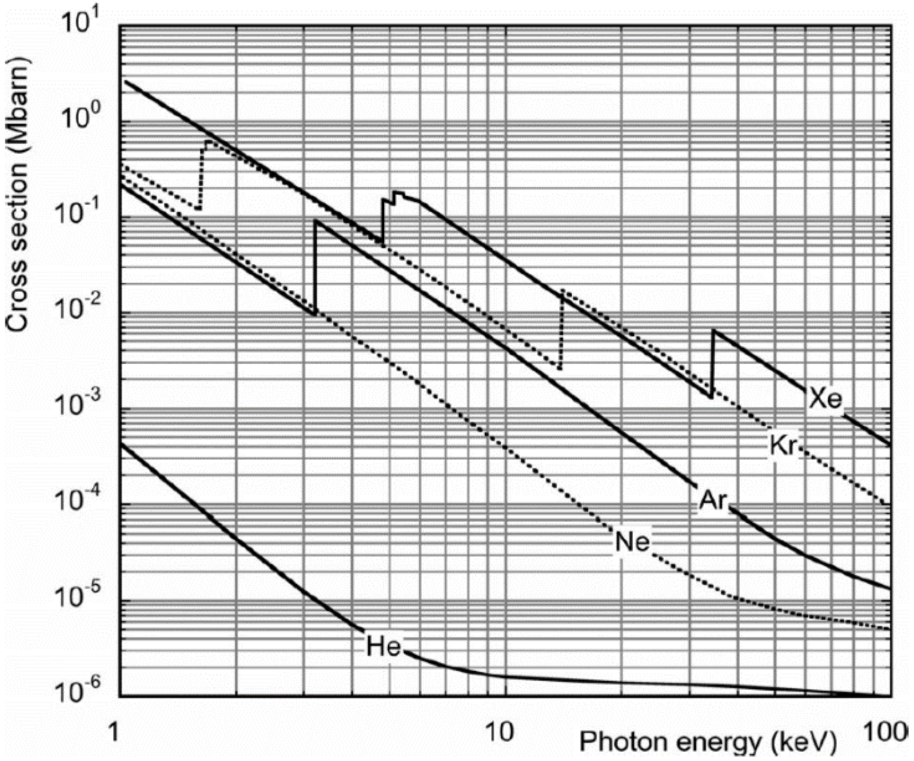

[F. Sauli. Gaseous Radiation Detectors: Fundamentals and Applications. Cambridge: Cambridge University Press, 2014.]

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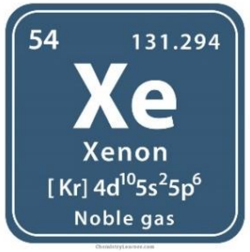

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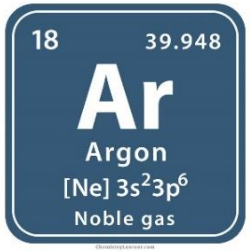

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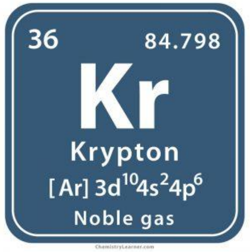

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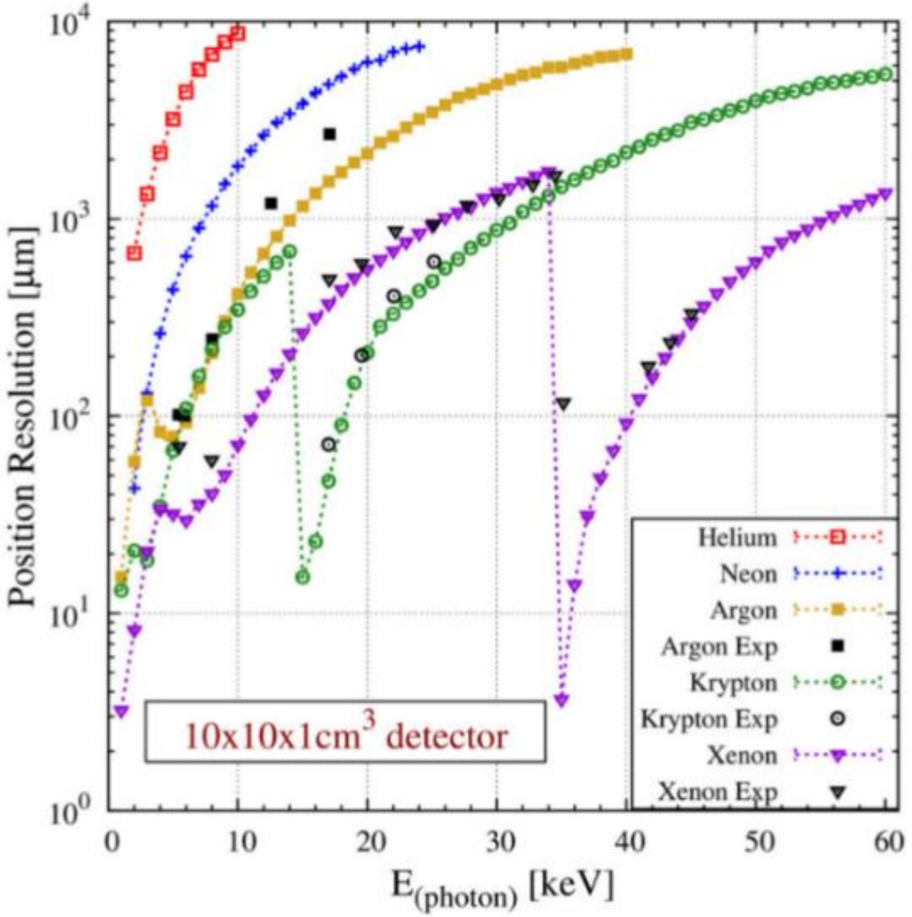
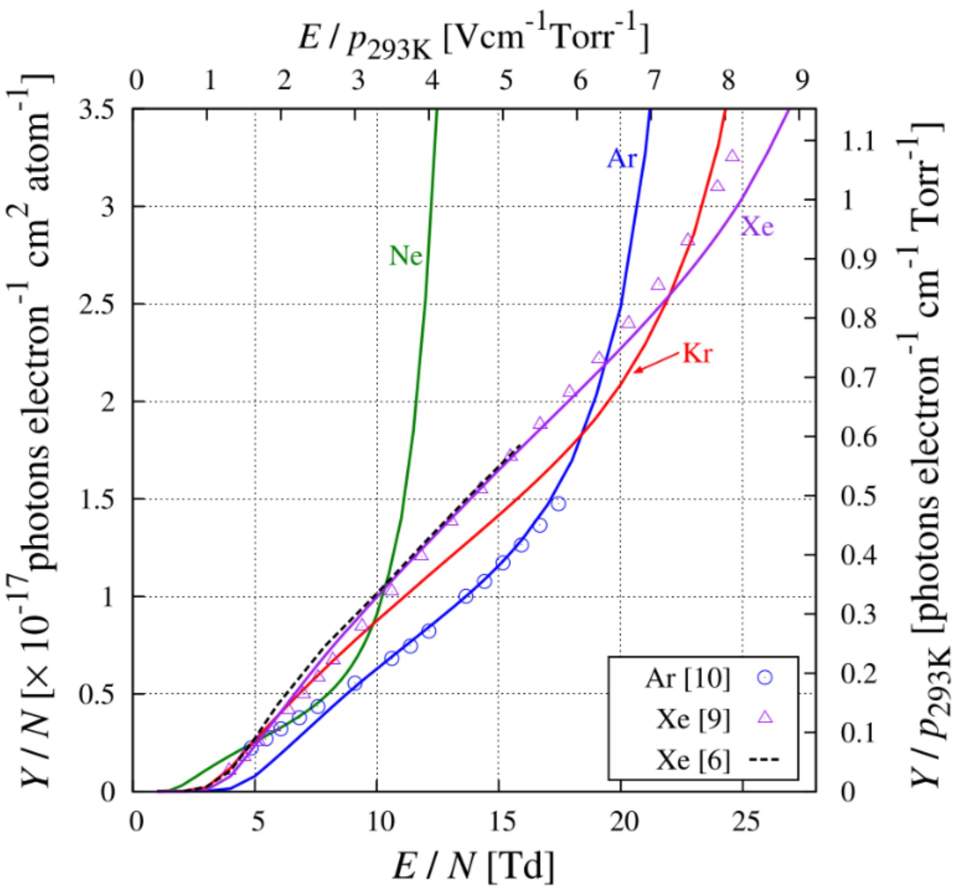


[C. D. R. Azevedo et al., Physics Letters B, 741:272–275, 2015.]

Introduction

‘A simulation toolkit for electroluminescence assessment in rare event experiments’

[C.A.B. Oliveira et al., 2011]



- For Xe and Ar the secondary scintillation yield is already well established;
- Xenon is the gas that has the highest secondary scintillation gains in the linear region, followed by krypton, argon and neon;
- **No experimental data to back up the secondary scintillation yield results obtained for krypton.**

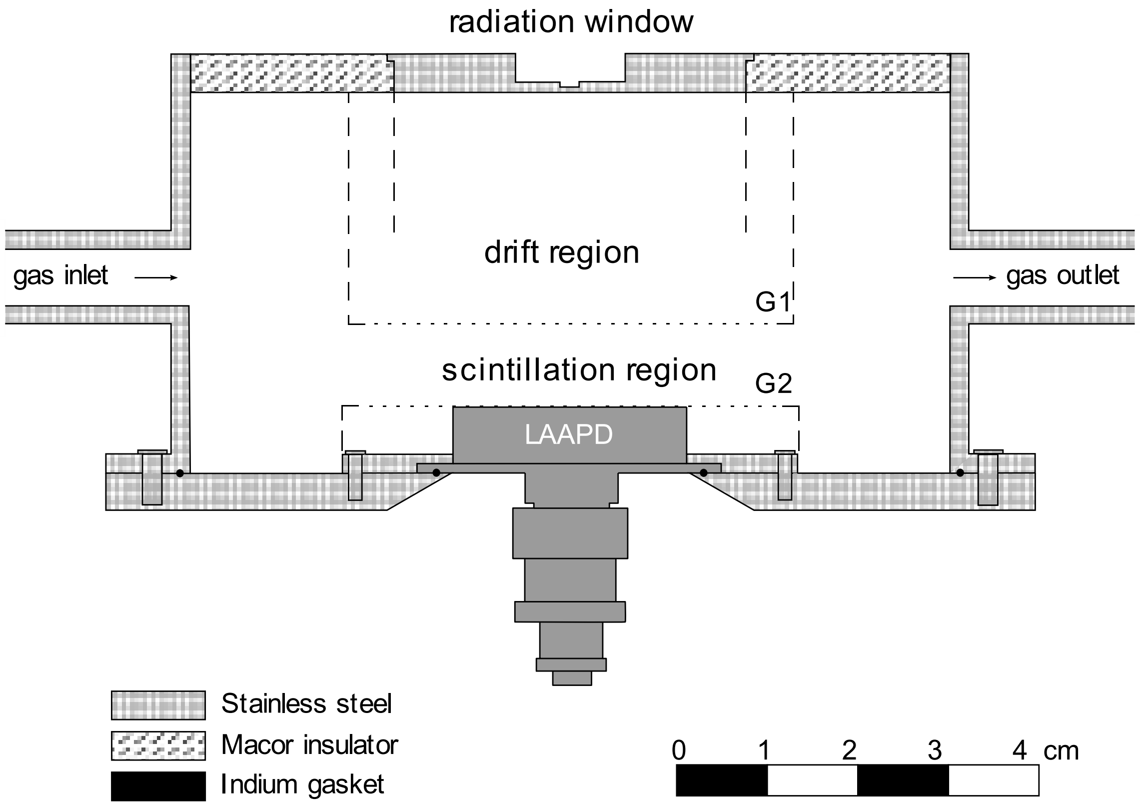
[6] F.P. Santos, et al., J. Phys. D. Appl. Phys. 27 (1994) 42.
[9] C.M.B. Monteiro, et al., J. Instrum. 2 (2007) P05001.
[10] C.M.B. Monteiro, et al., Phys. Lett. B 668 (2008) 167.

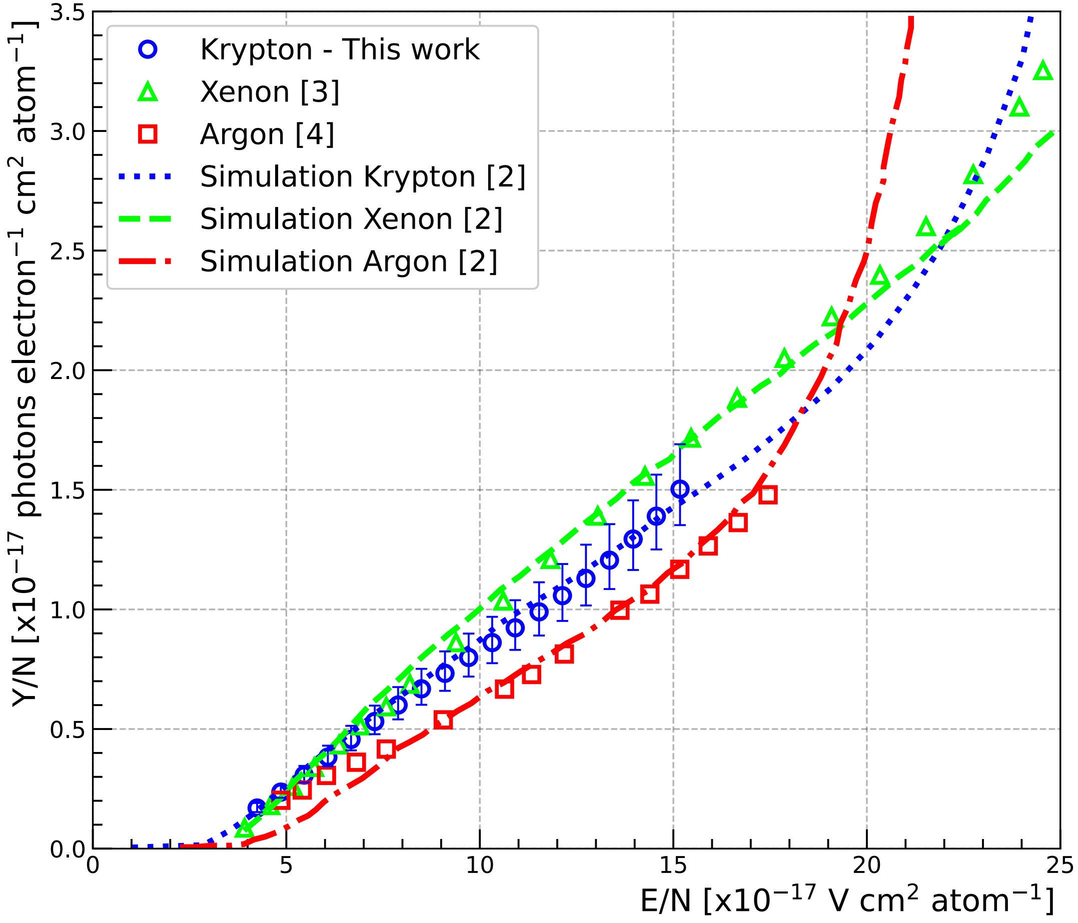
Introduction

R.D.P. Mano, C.A.O. Henriques, F.D. Amaro, C.M.B. Monteiro,

Secondary scintillation yield in pure krypton,

Physics Letters B, Volume 824, 2022





Primary Scintillation

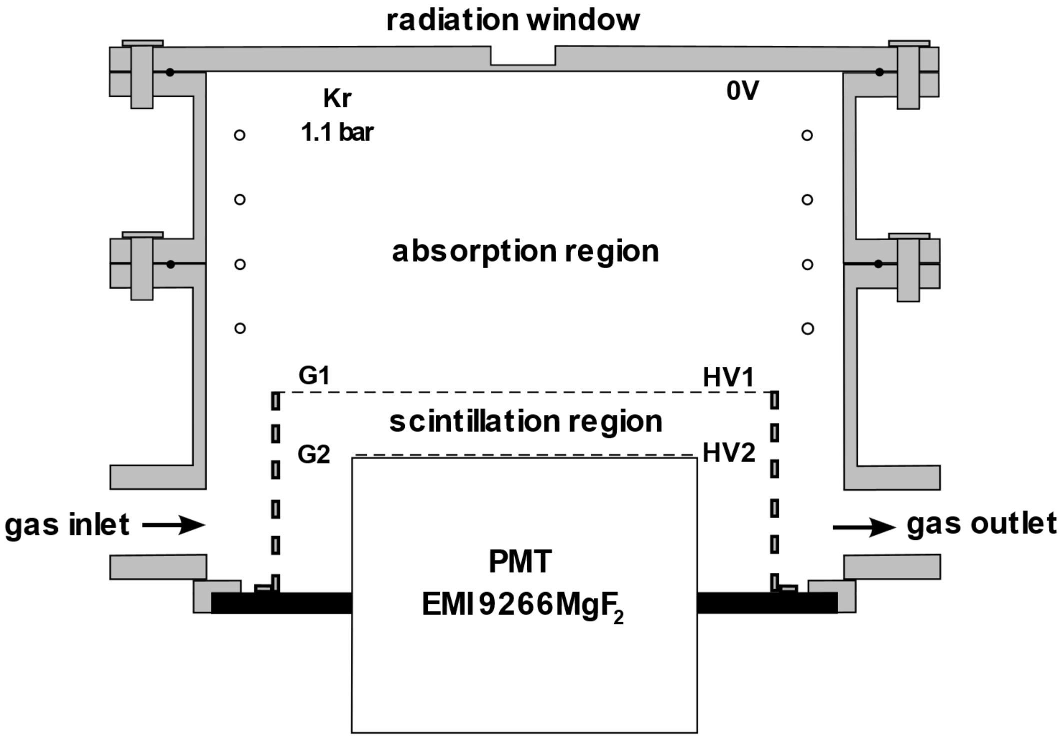
Experimental Setup

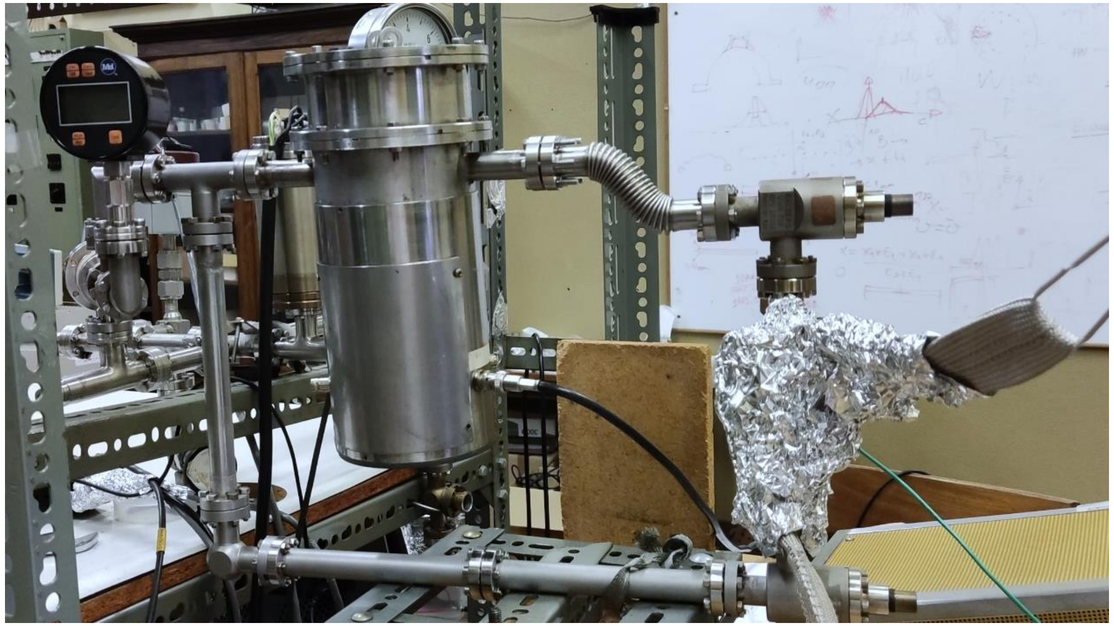
Method

Preliminary Results

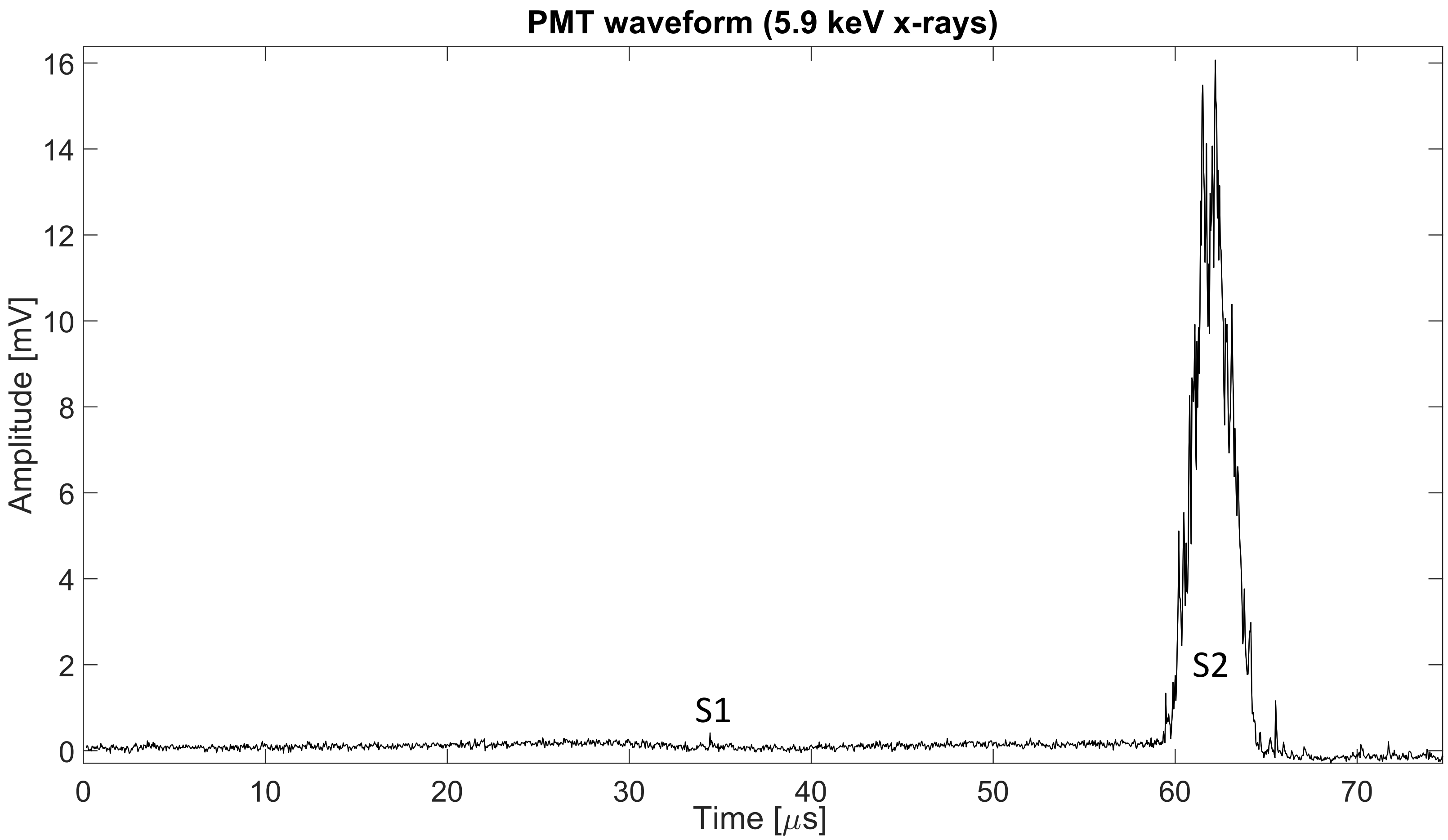
Experimental Setup

- Absorption region: 5.0 cm
- Scintillation region: 0.9 cm
- PMT with a MgF_2 window.
- 1.1 bar of krypton, purified by St707 SAES getters, which were set to a stable temperature of about 150°C.
- Detector irradiated with X-rays from a ^{55}Fe, ^{109}Cd and a ^{244}Cm radioactive sources.
- PMT waveforms were digitized using a high sampling-rate oscilloscope (10GS/s)





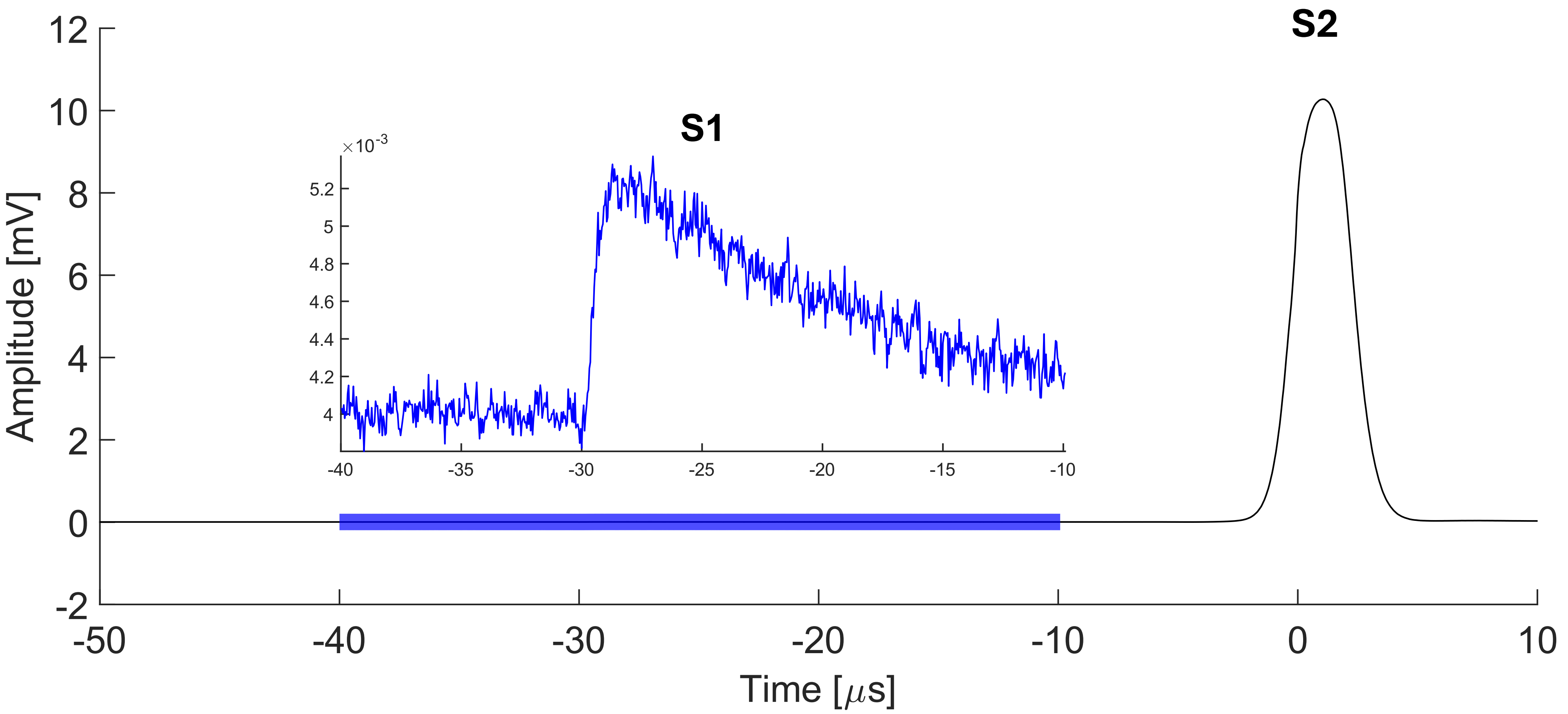
Method – Waveform sampling and averaging



- PMT waveforms are triggered on the rising edge of the **secondary scintillation signal (S2)**
- The **amplitude of the primary scintillation signal (S1) is very low** and may be indistinguishable from the electronic noise
- An **average over several waveforms** is performed to reduce the electronic noise to a low level
- **Background events are discriminated** to avoid additional contamination in the S1 region

Method – Waveform sampling and averaging

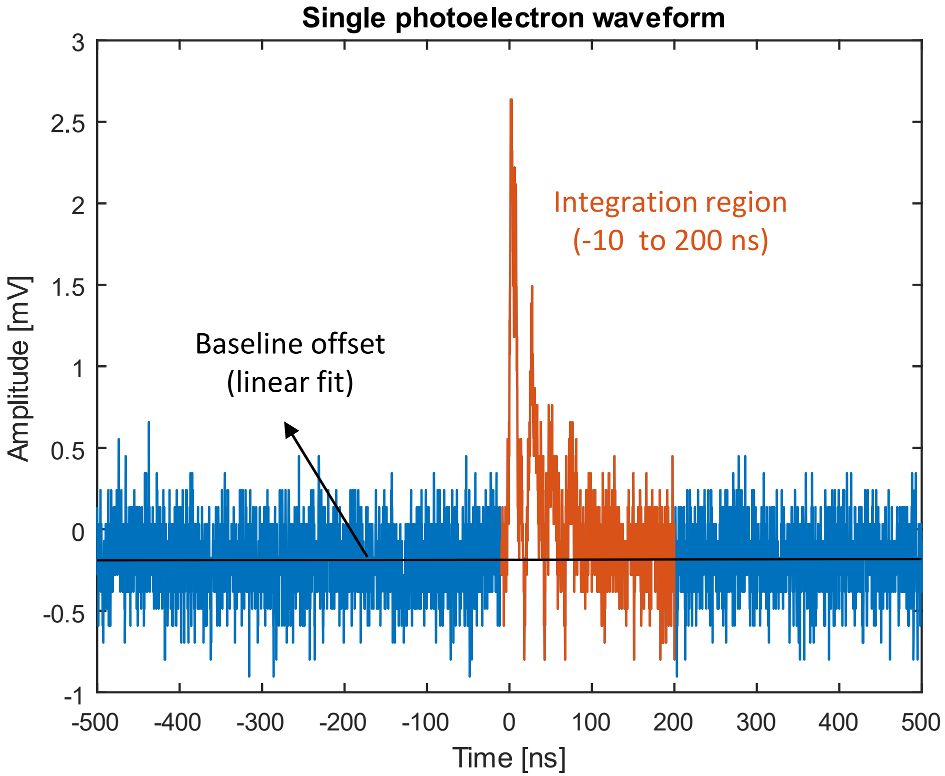
- Typical average waveform obtained for **5.9 keV X-rays** (average of ~ 120k events)

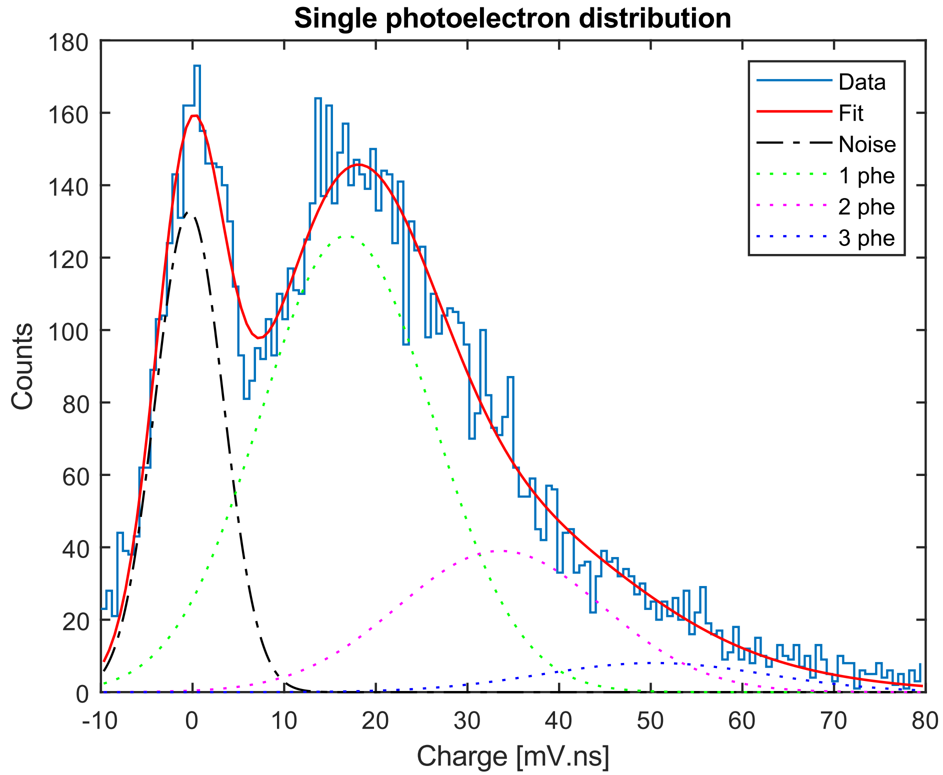


- Primary scintillation signal is now visible
- The tail on the right of S1 results from the interaction of X-rays at different depths in the absorption region

Method – PMT calibration

- A PMT calibration is needed to obtain the absolute values of S1 and S2





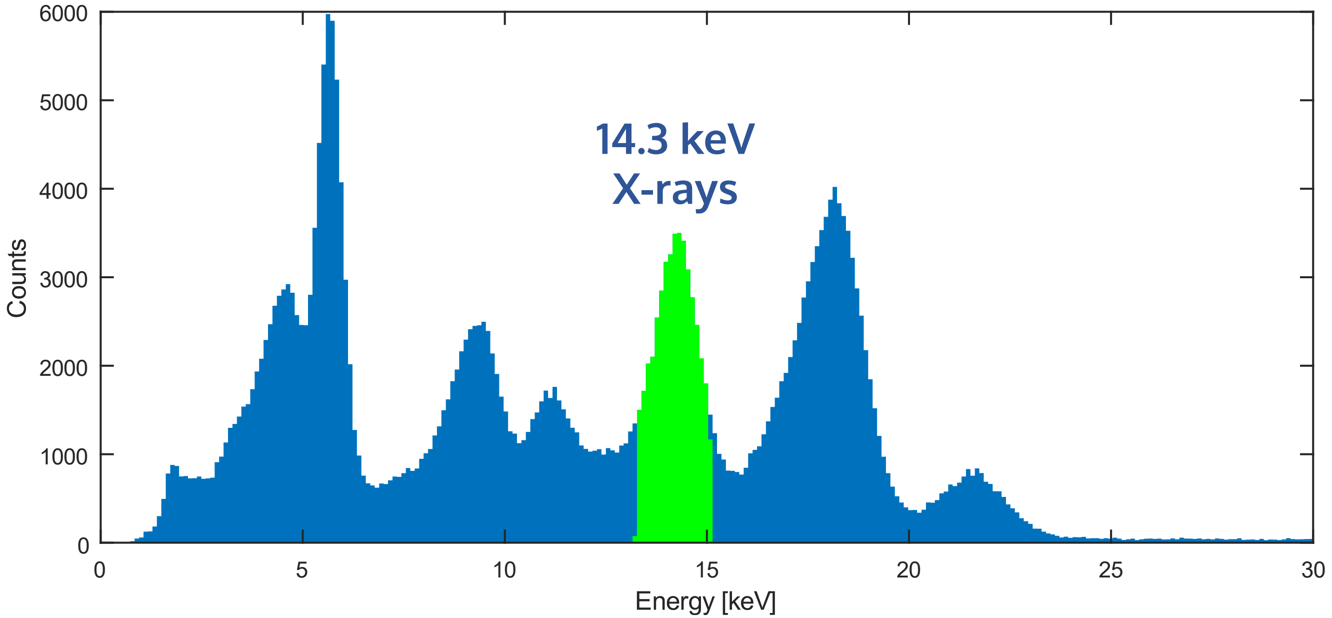
- Single photoelectron waveform obtained using a LED
- Linear fit to correct baseline offset
- Long integration region to include wave reflections

- Sum of 4 Gaussians (electronic noise, 1phe, 2phe and 3phe) to fit the single photoelectron distribution

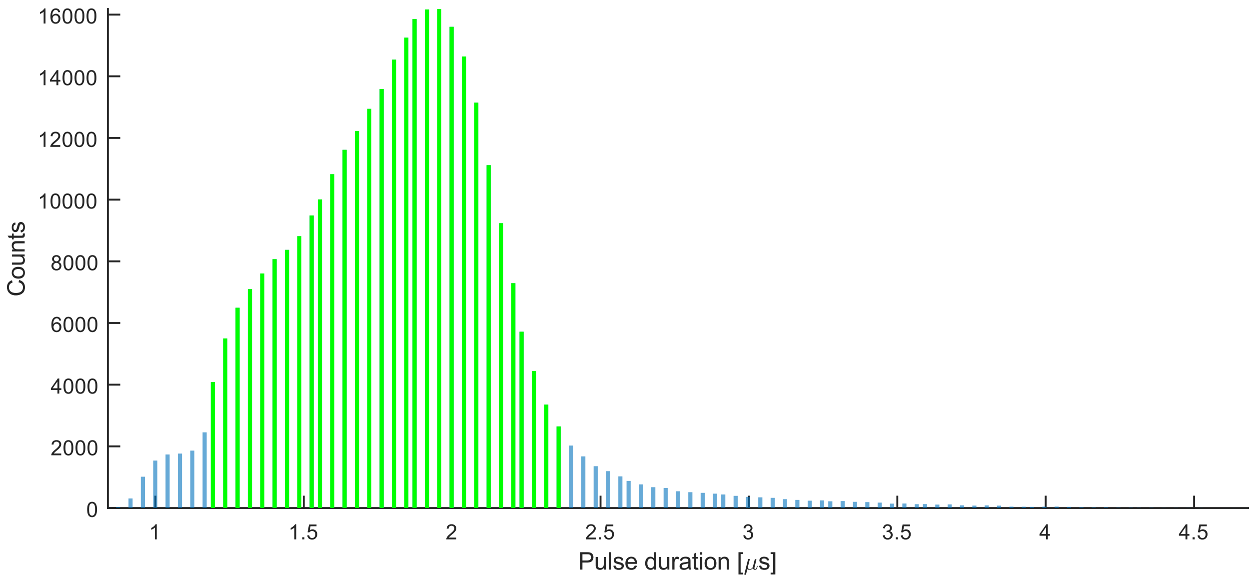
Energy and pulse duration cuts

- Integration of S2 scintillation pulses allows the construction of the energy spectrum of the radioactive sources used
- Waveforms originated for different energies can be selected
- S1 yield can be measured for different energies

^{244}Cm energy spectrum



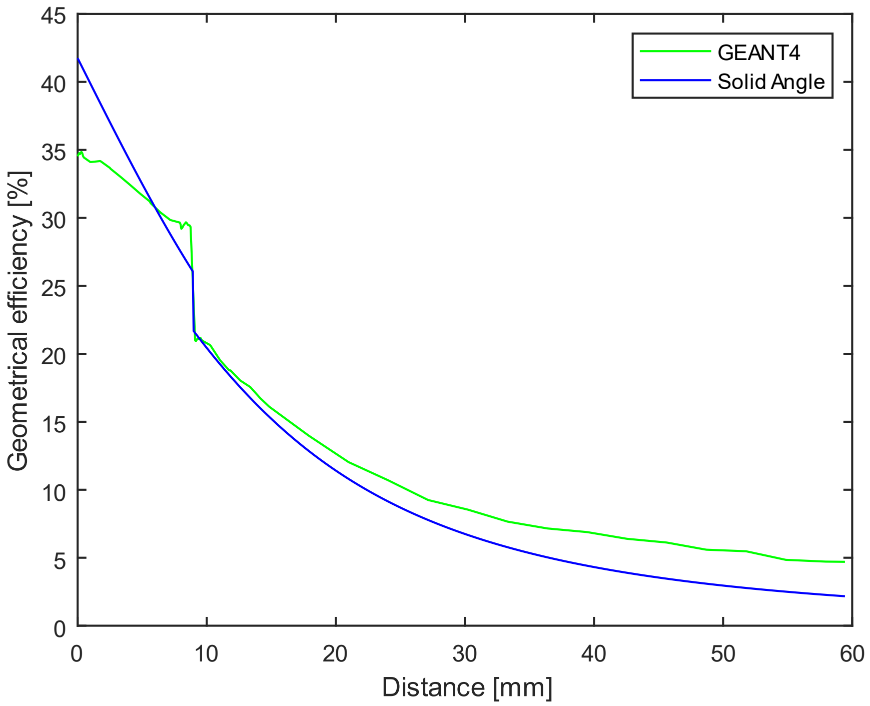
S2 pulse duration



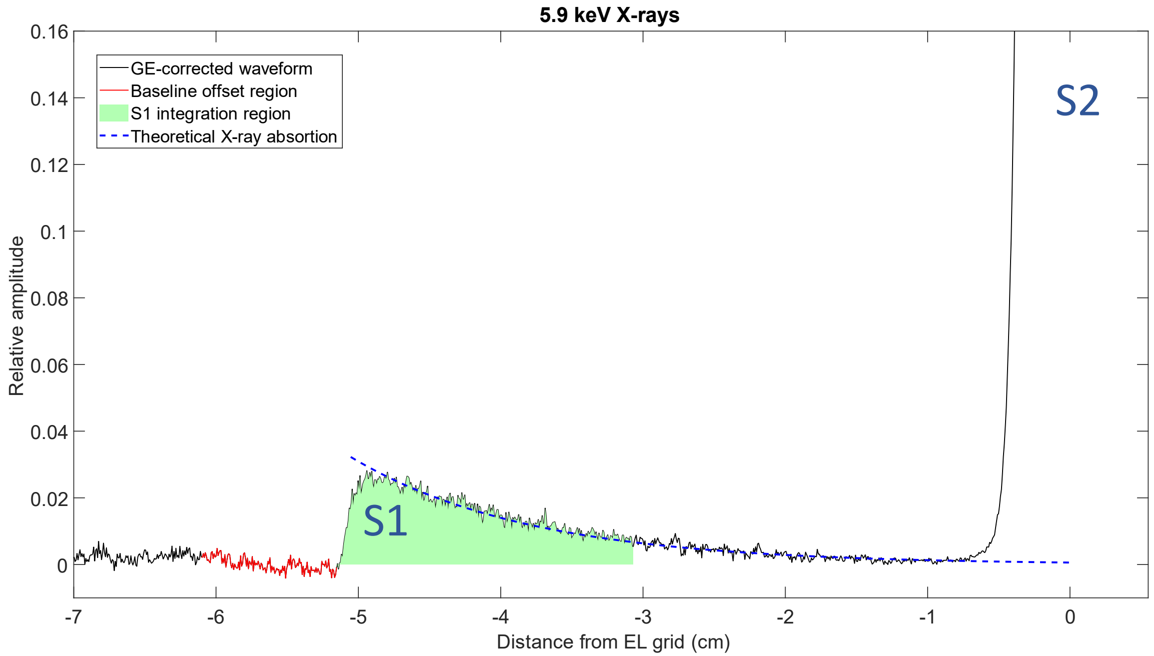
- X-rays interacting inside the EL region must be discriminated, as they do not contribute to S1
- S2 pulse duration is used to cut these events, as well as background events with extremely long durations

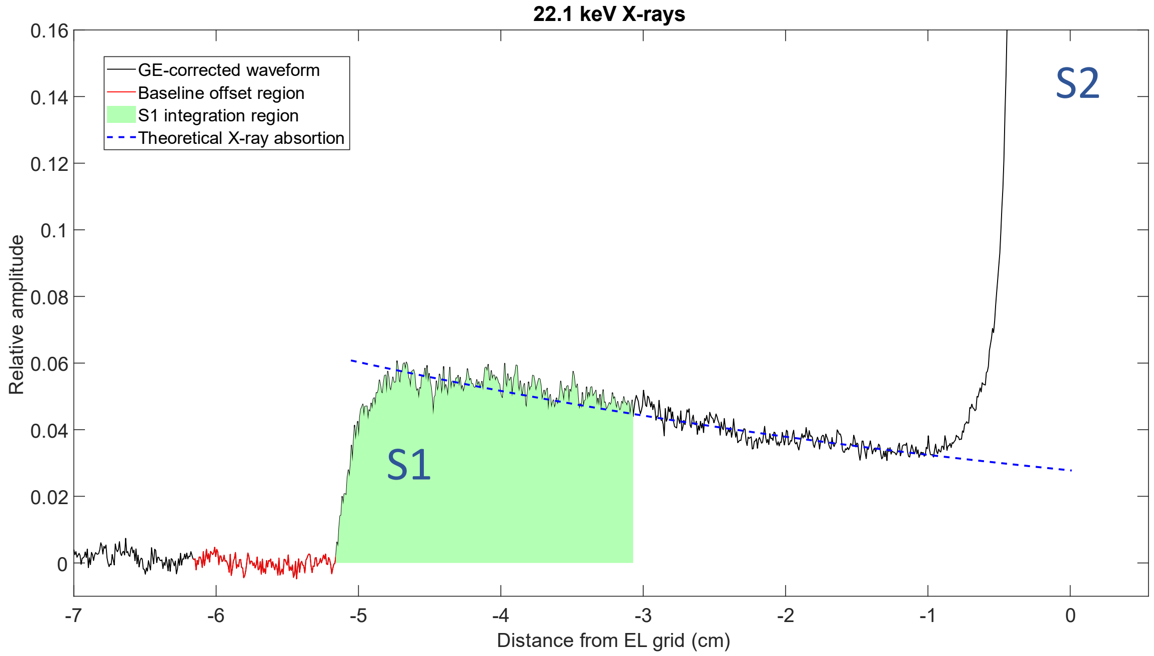
Method – Corrected waveform

- Geometrical efficiency (GE) computed along the detector central axis using GEANT4



- Longitudinal position of X-ray interactions was determined using the electron drift velocity calculated
- Average waveform corrected using the computed GE
- Acceptable agreement between the corrected waveform and the theoretical X-ray absorption





Preliminary Results

X-ray energy [keV]	W_{sc}-value [eV]
5.9	82.9
14.3	82.1
21.6	76.1
22.1	75.3
25.0	77.4

- W_{sc}-values between **75.3 eV and 82.9 eV** were obtained for different X-rays energies.
- Experimental errors in W_{sc}: 10% (stat.) and 15% (sys.)

Conclusions

- Absolute values between 75.3 eV and 82.9 eV were obtained for the w_{sc}-value in Kr gas for different X-rays energies.

- w_{sc}-value will be determined for α-particles and different X-rays energies.

Thank you for your attention

Acknowledgements

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