Electroluminescence Yield in Pure Krypton

R.D.P. Mano, C.M.B. Monteiro

LIBPhys, Department of Physics, University of Coimbra, Portugal

Introduction

Gas Proportional Scintillation Counters (GPSC) are gas-filled detectors in which the charge signal produced by an x-ray interaction is amplified by secondary scintillation (electroluminescence) taking place in a rare gas atmosphere. Primary electrons produced by the interacting radiation are driven towards the scintillation region, where the electric field is high enough to excite but not ionize the noble gas atoms, producing a scintillation pulse through atom de-excitation, proportional to the number of primary electrons and, thus, proportional to the incident x-ray energy. Krypton is denser than argon, much less expensive than xenon, presenting even the highest absorption cross section for x-rays in the 14–34 keV energy range. These are advantages in applications where large detection volumes and high pressure are required. The electroluminescence (EL) yield of Xe and Ar have been determined both experimentally and by simulation while for Kr only simulation results were reported in the literature. In this work, we present absolute measurements of the EL yield for Kr, using the same methodology as for Xe and Ar. The obtained experimental results are compared with simulation results.

Method

The **Electroluminescence Yield**, **Y**, is the number of secondary scintillation photons (N_{VUV}) emitted per primary electron per unit of path length, and is given by the following equation:

$$Y = \frac{N_{VUV}}{N_e \times d}$$

where $N_e = E_{XR}/W_{Kr} = 246$ is the average number of electrons produced by the absorption of the 5.9 keV x-rays in the gas (Kr *w*-value = 24) and **d = 0.9 cm** is the GPSC scintillation gap.

The number of secondary scintillation photons (N_{VUV}) emitted is given by:

$$N_{VUV} = \frac{N_{VUV(LAAPD)}}{\Omega_r \times T}$$

$\Omega_r = 0.2$ is the LAAPD relative solid angle, **T = 80%** is the grid transparency and $N_{VUV(LAAPD)}$ is the average number of VUV photons that reach the LAAPD:

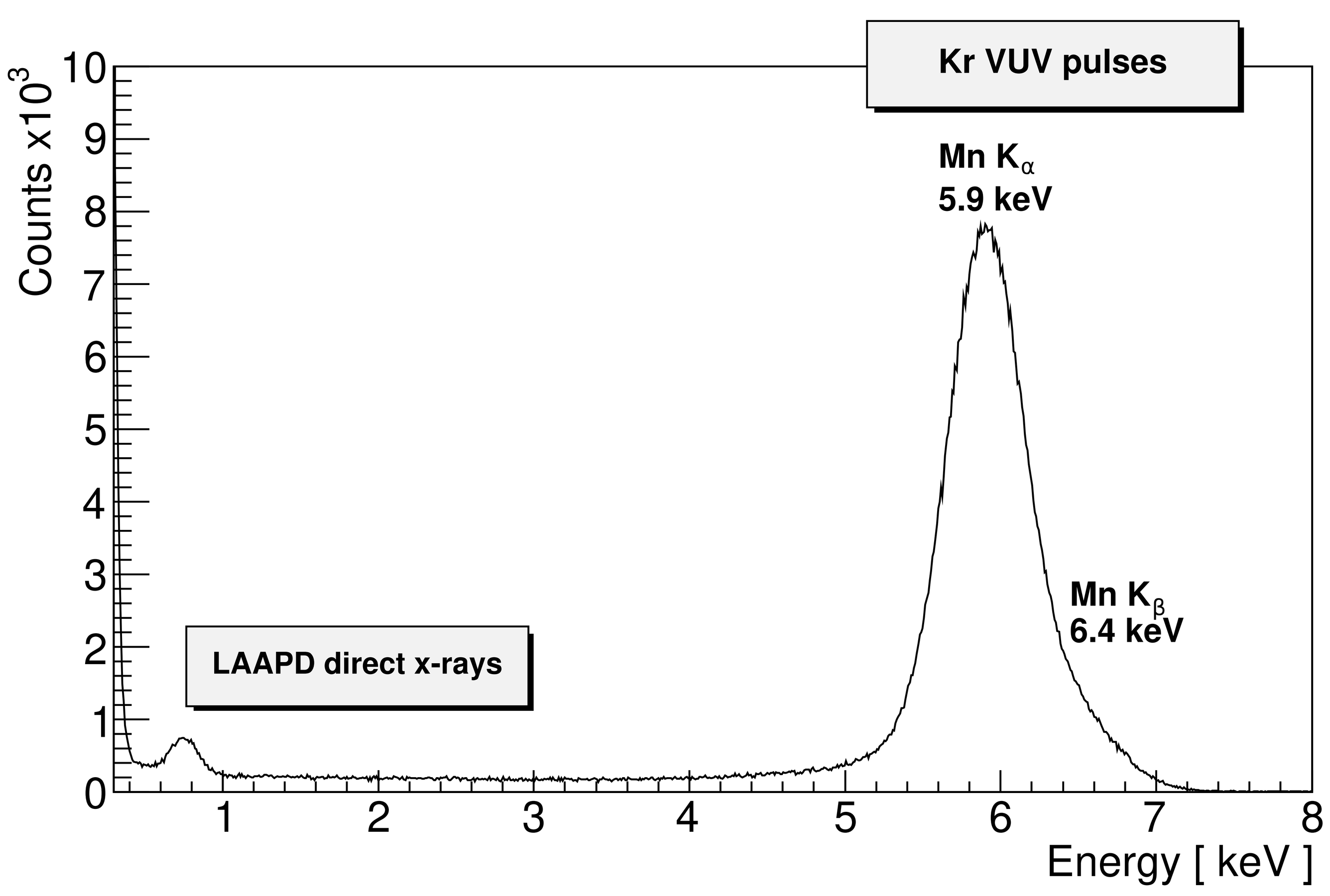
$$N_{VUV(LAAPD)} = \frac{A_{VUV}}{A_{dxr}} \times \frac{N_{e(LAAPD)}}{QE}$$

A_{VUV} is the amplitude of the VUV pulses from Kr electroluminescence induced by x-rays absorbed in the gas;

A_{dxr} is the amplitude of the x-ray pulses directly absorbed in the LAAPD, crossing the gas without interacting;

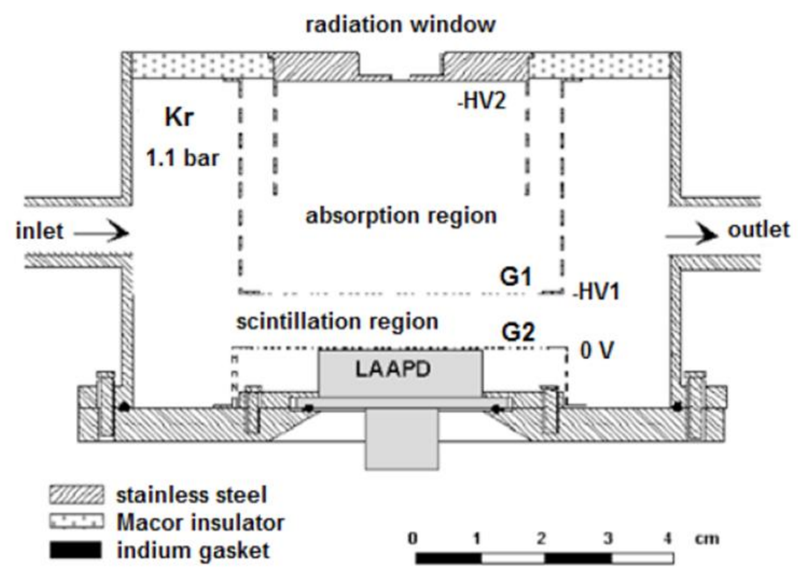
QE = 90% is the LAAPD quantum efficiency for the Kr second continuum wavelength, 148 nm;

$N_{e(LAAPD)} = E_{XR}/W_{Si} = 1628$ is the average number of electron–hole pairs produced through direct absorption of the 5.9-keV x-rays in the LAAPD (silicon W-Value = 3.62



Experimental Setup

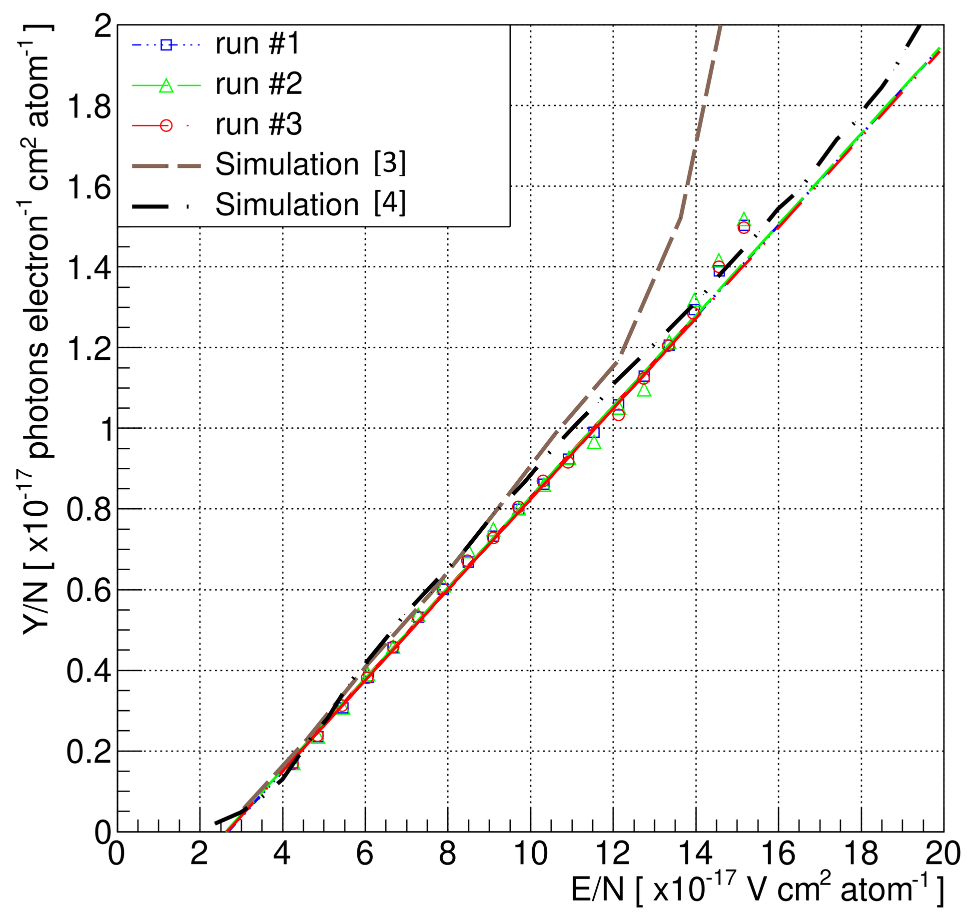
A standard uniform field type GPSC was used with a 2.5 cm thick absorption region and a 0.9 cm thick scintillation region. The detector is depicted schematically in the figure below.

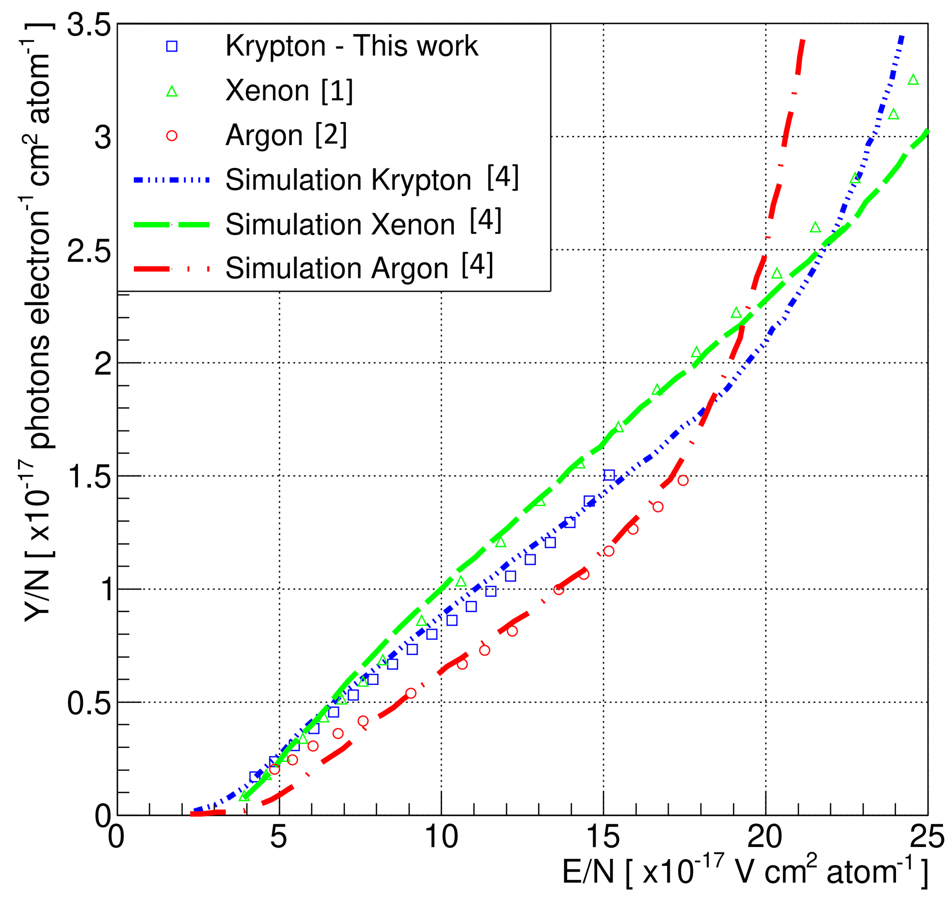


It integrates a large area avalanche photodiode (LAAPD) from Advanced Photonics, Inc. (16 mm in diameter) as the VUV photosensor.

The GPSC enclosure is a stainless steel cylinder with 10 cm in diameter and 5 cm in height.

Krypton EL Yield





Conclusions

- Absolute measurements of the electroluminescence yield obtained in a Kr GPSC are reported for the first time.
- The obtained experimental results are compatible with results from simulation, in particular with 3D simulation results available in the literature.
- The EL yield obtained in Kr is only about 15% lower than the one in Xe, and significantly higher (40%) than the one in Ar.
- The results presented, combined with the energy resolution of 10% for 5.9 keV x-rays obtained with the Kr GPSC (a small degradation against Xe GPSC), show that krypton presents advantages in specific applications where large detection volumes or high pressures are requirements and the Kr natural radioactivity background will not seriously affect its operation or the possibility of efficient background discrimination in rare-event detection. Kr is much more inexpensive than Xe and presents even the highest absorption cross section for x-rays in the 14–34 keV energy range. Kr detectors have been already proposed for double-beta decay and double-electron capture experiments.

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