Simulation of the performance of a Multi-Grid High-Pressure Gas Proportional Scintillation Counter for gamma rays

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Introduction

Recently a new prototype of a high pressure gas detector of the Gas Proportional Scintillation Counter (GPSC) type [1], the Multi-Grid High-Pressure Gas Proportional Scintillation Counter (MGHP-GPSC), was built and tested with α-particles [2]. This detector has a cylindrical geometry, and recent studies have proved that the detector concept works and that the new geometry exhibits better overall performance than the previous planar one [2, 3].

Working principle

The detection of ionizing radiation on a HPXe GPSC relies in the production of light as an amplification stage (electroluminescence) followed by the production of photoelectrons in a photosensitive material. The cylindrical geometry has four main regions defined by an anode and two cylindrical grids, but also by the different reduced electric field (E/p) intensity values:

1. Absorption/drift region
2. Secondary scintillation region
3. Photoelectron collecting region
4. Electric field barrier region

The reduced electric field at the surface of the anode is kept below the Xe ionisation threshold to avoid charge multiplication. The generated photoelectrons will be collected in a collection grid placed above the photocathode.

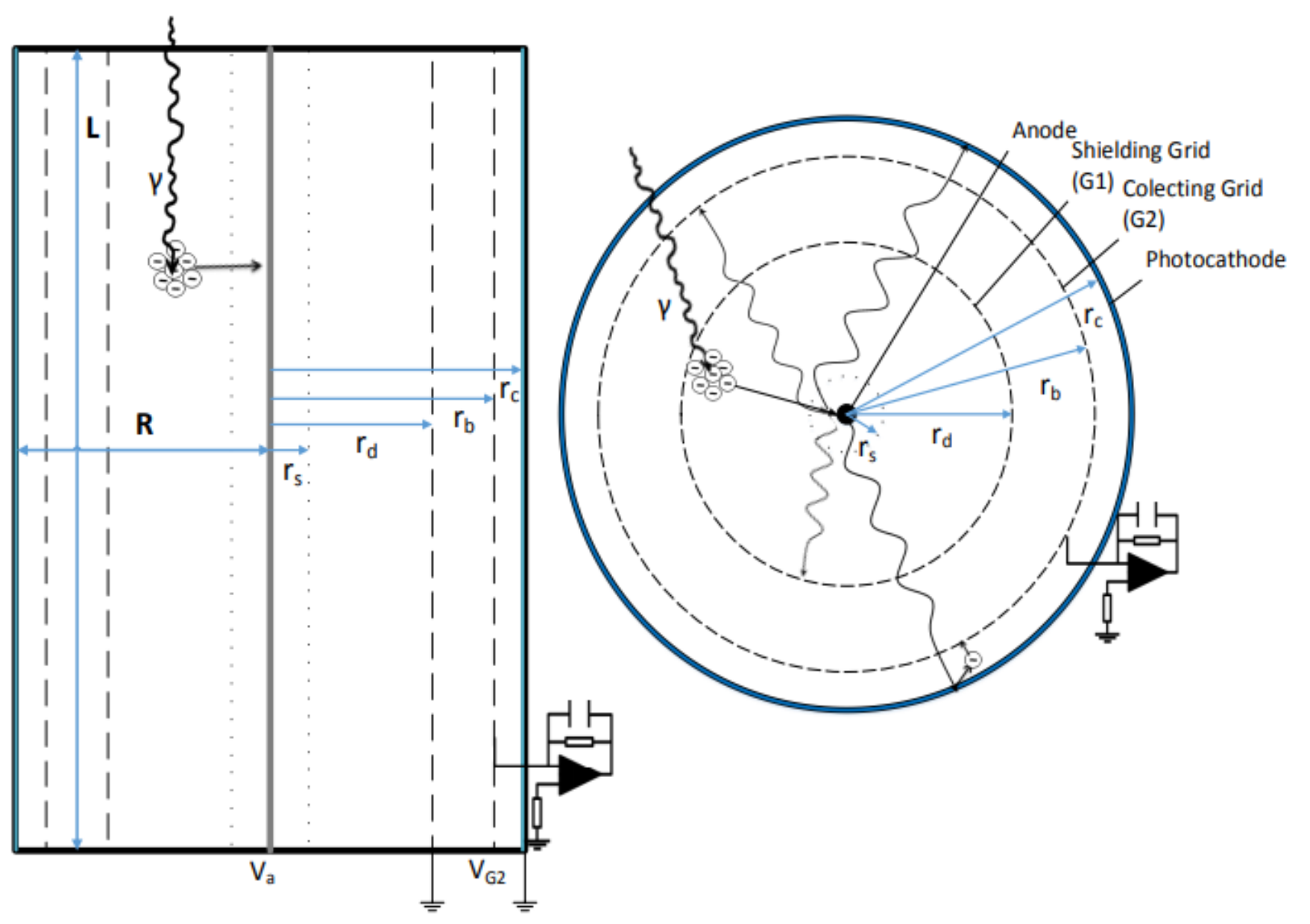

Figure 1: Schematics of the Cylindrical MGHP-GPSC [4]

Results

The cylindrical MGHP-GPSC was tested for α-particles (^{241}Am source) and the results obtained concerning the energy resolution and gain are presented in figure 2:

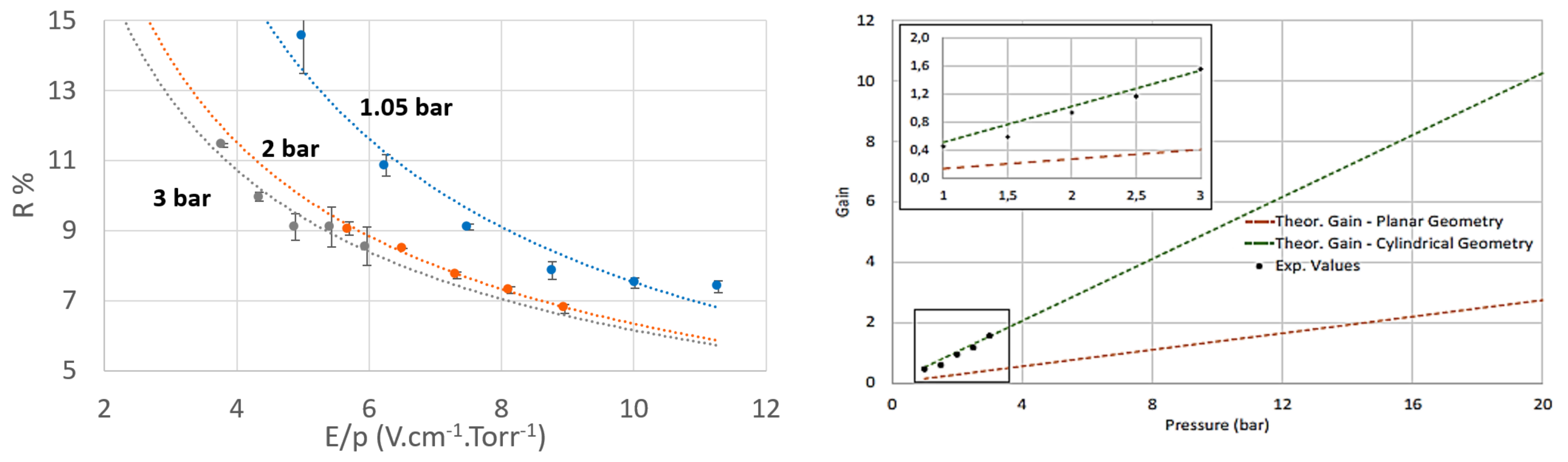

Figure 2: Energy resolution of the GPSC for different pressures as a function of the reduced electric field (left); Gain as a function of the pressure maintaining a constant E/p at the surface of the anode (right) [4]

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The table 1 resumes the main characteristics of the cylindrical HPXe GPSC [4]:

Characteristics	
Pressure range	5 - 20 bar
Det. Efficiency (662 keV 15 atm)	∼ 20 %
Solid Angle	0.48 - 0.87
Detector Active Volume	3369 cm^3
Grids Combined Optical Transmission	∼ 0.54
Detector Gain	1.7 - 6.7 phe-/e-
Energy resolution (^{241}Am source)	6.8 %

Table 1: Resume of the characteristics of the cylindrical geometry

The energy resolution and the theoretical and experimental gain of the GPSC are given by the following formulas [4]:

$$R = 2.355\sqrt{\underbrace{\frac{F}{\overline{n}}}_{e^-} + \underbrace{\frac{1}{\overline{n}} \times \frac{J}{N_s}}_{\text{ampl.}} + \underbrace{\frac{1}{N_e}\left(1+\left(\frac{\sigma_q}{G_q}\right)^2\right)}_{\text{photosensor}} + \underbrace{\frac{ENC}{e\overline{n}G}}_{\text{electronics}} + \underbrace{\left(\frac{\sigma_n}{\overline{n}}\right)^2}_{\substack{\text{energy disp.}\\ \text{from source}}}} \tag{1}$$

$$G_{theo} = N_s \cdot T_{g1} \cdot T_{g2} \cdot QE \cdot \eta_{ext} \tag{2}$$

$$G_{exp} = \frac{\overline{n}_{photoe^-}}{\overline{n}_{primary\,e^-}} \tag{3}$$

Future Work

Although the prototype was tested with α-particles with promising results, its performance for γ-rays may need some improvements, due to the larger range of interaction of these particles in the gas:

- Solid angle correction for events taking place at different positions along the detector axis
- Different grid biasing or spacing
- Compensation at the detector ends due to electric field distortion, that may be related to the electrical discharges observed for higher pressures and that limited the applied voltages

The aim of this work is to study these issues using the GEANT4 code to simulate the interaction of gamma-rays in the detector. From the results obtained, the changes needed in the detector will be inferred and eventually implemented, prior to the tests with γ-rays.

References

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