Ongoing PhD Thesis

# Study by Simulation and Reconstruction of a Brain-Dedicated Positron Emission Tomograph Based on Resistive Plate Chambers


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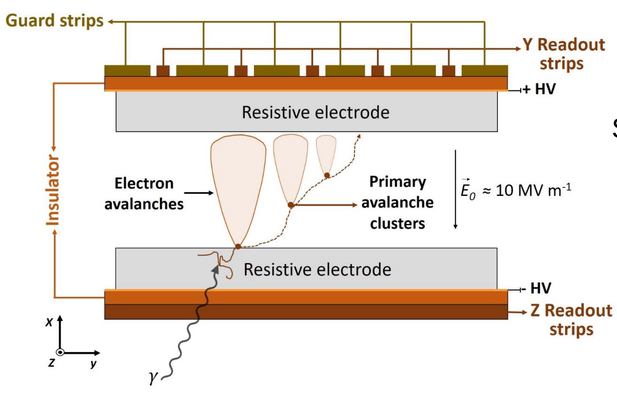
## INTRODUCTION

A new high-resolution brain positron emission tomography (PET) termed HiRezBrainPET is under development. This new PET scanner is based on the Resistive Plate Chamber (RPC) technology, a gaseous particle detector initially developed for high energy physics that match the needs of Nuclear Medicine (Crespo, *et al.*, 2013; Couceiro, *et al.*, 2014). These radiation detectors are simple and inexpensive to construct, present a very good intrinsic position accuracy, and features an excellent time resolution of 300 ps Full Width at Half Maximum (FWHM) for 511 keV photon pairs, allowing the use of Time-of-Flight information. They have also shown to be able to provide Depth-of-Interaction (DOI) information, rendering the corresponding images parallax-free. Given the promising results obtained with the small animal RPC-PET regarding its spatial resolution of 0.4 mm FWHM (Martins, *et al.*, 2014), we are now aiming at the construction of an RPC-PET system dedicated to brain imaging.

## RESISTIVE PLATE CHAMBER DETECTOR

- **Single gap RPC detector**




Sensitive region (gap) filled with:

- **$C_2H_2F_4$,** high primary ionization density
- **$SF_6$,** quencher of fast avalanche growth
- **iso-$C_4H_{10}$,** to slow the aging process

**Figure 1 -** Single gap RPC detector, depicting the processes that lead to signal induction in the electrodes.

- **Multi-gap RPC detector**

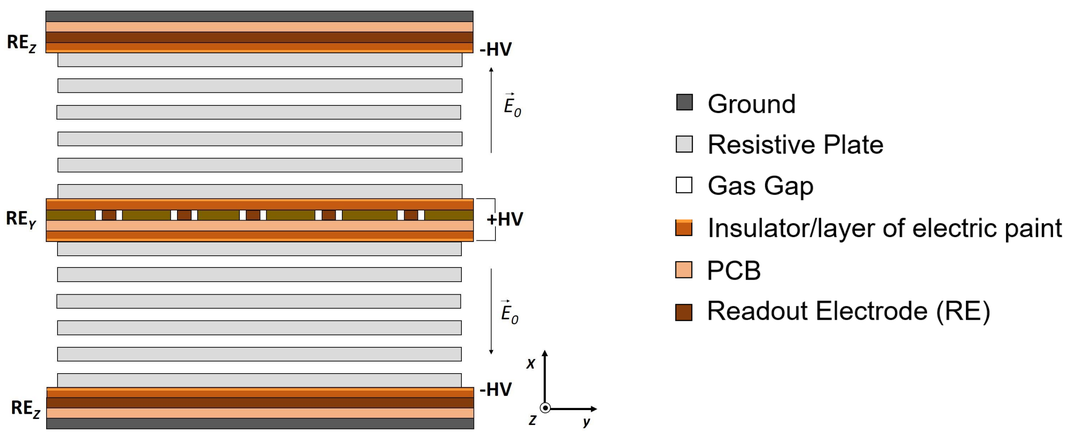



**Figure 2 -** Multi-gap RPC detector consisting of two detection elements with six glass plates and five gas gaps each. Besides the glass and gap layers, the detector to be used in the HiRezBrainPET is composed by insulator layers of kapton with a thin layer of electric paint on the innermost surface, for applying the high voltage, ground layers, and layers of FR4 printed circuit board (PCB) material with copper strips, for the readout electrodes.

## HIREZBRAINPET

- **Motivation**

PET spatial resolution limits brain studies → Decreased resolution due to the parallax error → Solution: DOI information → How? Doubling the number of scintillators and electronics channels → Solution with increased costs

**Given that:**

- RPC-PET detectors have shown experimentally to be able to provide DOI information
- The low production costs associated
- The excellent spatial resolution of 0.4 mm FWHM obtained with the animal RPC-PET

**A brain RPC-PET might provide the very-high spatial resolution required to study and analyze brain images**

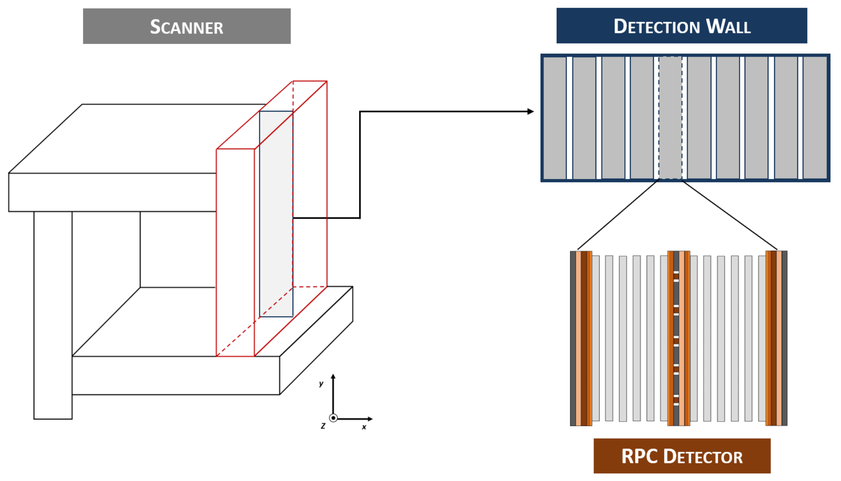



**Figure 3 -** Representation of the starting point geometry for the HiRezBrainPET. A scanner composed of 4 detection walls - one of them delineated in red - each one filled with 10 RPC detectors disposed along the X-direction.

## EFFICIENCY RESULTS

- **Optimization of the RPC detector structure that leads to the highest detection efficiency for 511 keV photons**

**Study A –** Optimization of the glass plate thickness

**Study B –** Influence of the PCB layers and copper strips

### SIMULATED SETUP

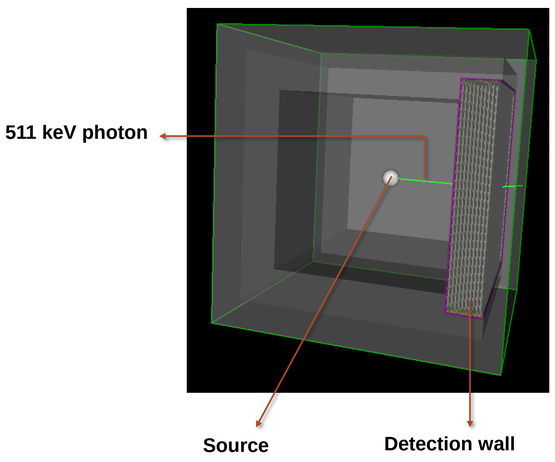



**Figure 4 -** Schematic representation of the setup implemented into GEANT4, version 9.2. p.04, in both studies, to optimize the efficiency of the RPC detector to be applied to the HiRezBrainPET. The studied variables included the thickness of the glass plates, copper strips, and PCB layers.

### RESULTS

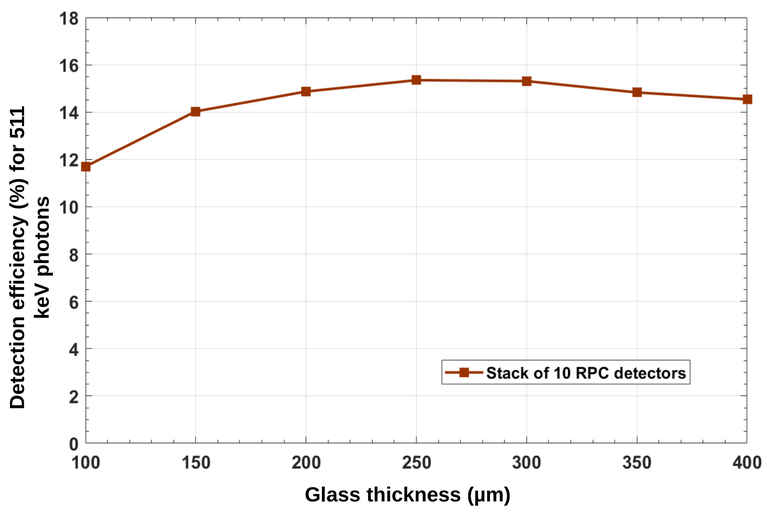



**Figure 5 -** Results from Study A. For a stack of 10 RPC detectors, the results show an efficiency of 15.35% and 15.66% for glass plates of 250 and 280 μm, respectively.

**Table I -** Results from Study B. The detection efficiency obtained when both the FR4 and copper strips materials are replaced by air is 3.83% higher than that obtained with the full detector geometry. Also, replacing the copper strips by air, the detector efficiency improves 0.38% compared to the full geometry. Regarding FR4, when replaced by air in combination with copper strips of 35, 17 and 5 μm thick, it improves the detector efficiency in 2.75%, 3.96% and 1.34%, respectively.

| Scenario | Efficiency (%) | Efficiency Gain (%) |
|---|---|---|
| W FR4<br>W Copper 35 | 15.66 | ---------- |
| Wo FR4<br>W Copper 35 | 16.09 | 2.75 |
| W FR4<br>W Copper 17 | 15.89 | 1.47 |
| Wo FR4<br>W Copper 17 | 16.28 | 3.96 |
| W FR4<br>W Copper 5 | 15.80 | 0.89 |
| Wo FR4<br>W Copper 5 | 15.87 | 1.34 |
| W FR4<br>Wo Copper | 15.71 | 0.38 |
| Wo FR4<br>Wo Copper | 16.26 | 3.83 |

W – With; Wo - Without

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