Fast Timing MPGD for ToF-PET

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Abstract

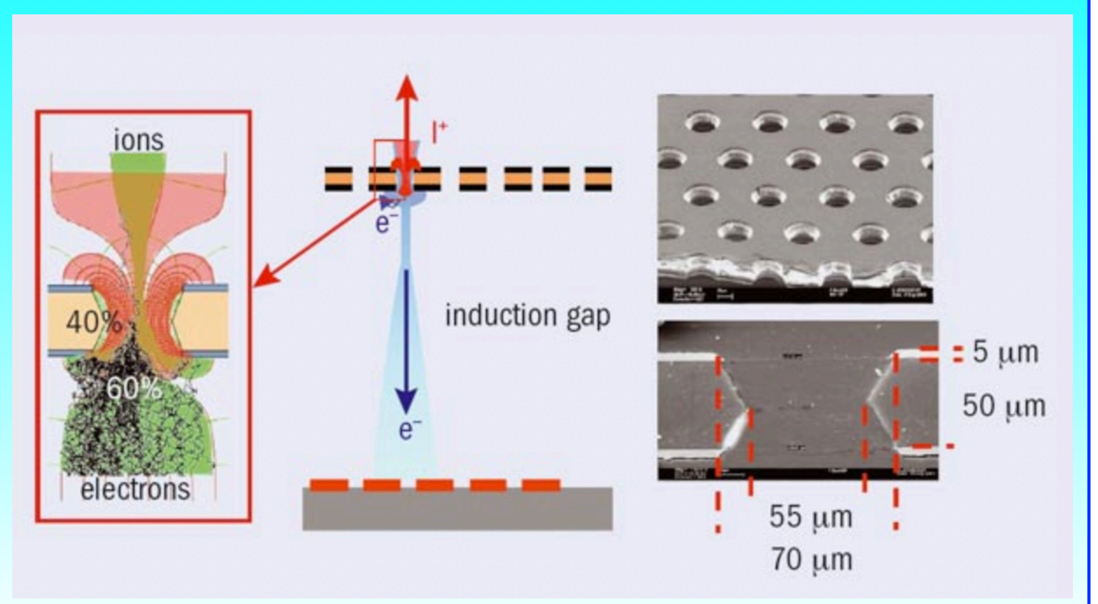
The positron emission tomography (PET) is an effective functional imaging technique especially for cancer diagnosis. Its performance is strictly connected to the ability to detect and reconstruct photons emitted by the positron - electron annihilation. Its sensitivity is enhanced when time information are included (time-of-flight (ToF) PET). The measure of the detection time difference between the two photons leads to a higher contrast image and more accurate diagnoses. We describe the studies for a possible development of a ToF-PET based on Micro Pattern Gas Detector (MPGD). This kind of detector has a very good spatial and time resolution (order of 100 μm and few ns, respectively) and very low price, making it suitable for a full-body scanner. Further improvement in the time precision (suitable goal is to achieve values of the order of 100 ps) could be reached thanks to the Fast Timing MPGD (FTM) design, where multiple layers of MPGD compete in better measuring time information.

Positron Emission Tomography (PET)

The Positron Emission Tomography (PET) is an imaging technique used in medical application. It is based on the detection of photons emitted after electron-positron annihilation. A positron-emitting radio nuclide (tracer) inside a biologically active molecule concentrates in tissues under investigations. The tracer undergoes β^+ decay, producing a positron that will annihilate in ~1mm with an electron. This e^+e^- annihilation produces two back-to-back photons with energy of 511 keV. The detection of these photons allows to reconstruct a straight line, called "line of response" (LOR), along which the annihilation took place. The measurement of several hundreds of thousands of LORs allows to reconstruct the position of the tracer. This reconstruction can be improved when time-of-flight (ToF -PET) information is used, reducing the background. ToF information allows to reduce the window for the two photons to be detected, reducing the misidentified pairs.

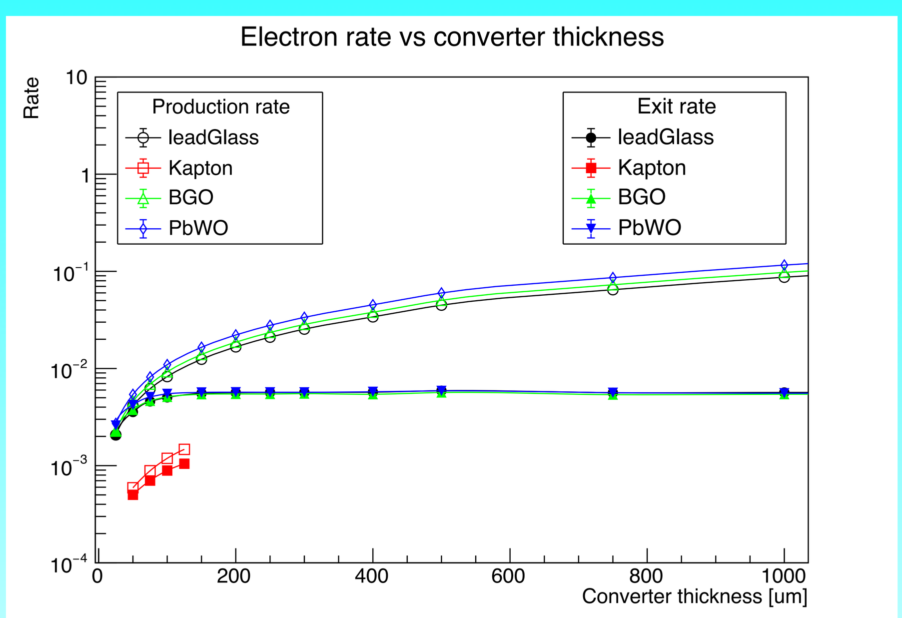
MicroPattern Gas Detector (MPGD)

A Micro Pattern Gas Detector (MPGD) is a gas detector with small amplification region (<100 µm), separated from drift region and with a pitch size of a few hundred µm. These detectors offer an intrinsic high rate capability (~ MHz/mm²), excellent spatial resolution (~100 µm), and good time resolution (order of ns) [1]



Photon interaction

Interactions between 511 keV photon with a converter (needed to produce Compton-electron for signal generation) have been studied profit of Geant4 package [v10.07] [2], in different configurations.



Single layer design:

- converter [different thickness and different materials]
- top electrode [75 μm kapton]
- MPGD [50 μm kapton]
- resistive ring [100 nm DLC = G4_C]
- drift region [300 μm Ar-Co2 70:30]
- bottom electrode [75 μm kapton]

Production rate: number of electrons (per incident photon) produced in the converter
Exit rate: number of electrons (per incident photon) exiting the converter layer

- **Kapton:** tested thickness compatible with current MPGD amplification region (and with no converter —> see "scheme B" next box)
- **Lead glass**, **BGO** and **PbWO:** tested several configurations (see "scheme A" next box)

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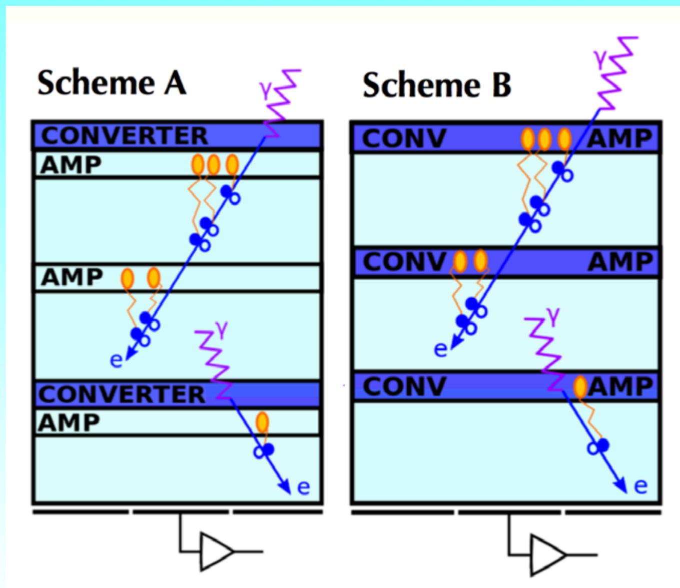
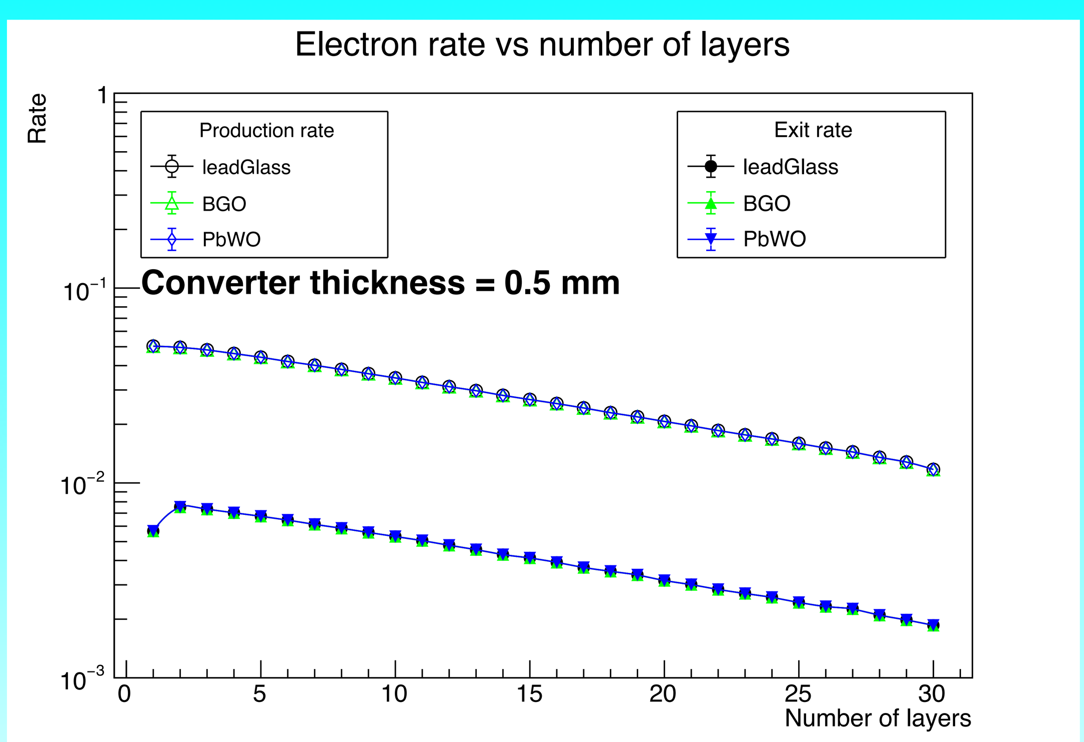
Better time resolution could be obtained using several drift regions each one coupled to its multiplication stage. The expected gain is proportional to the number of layers used.

Two different schemes investigated [3]:

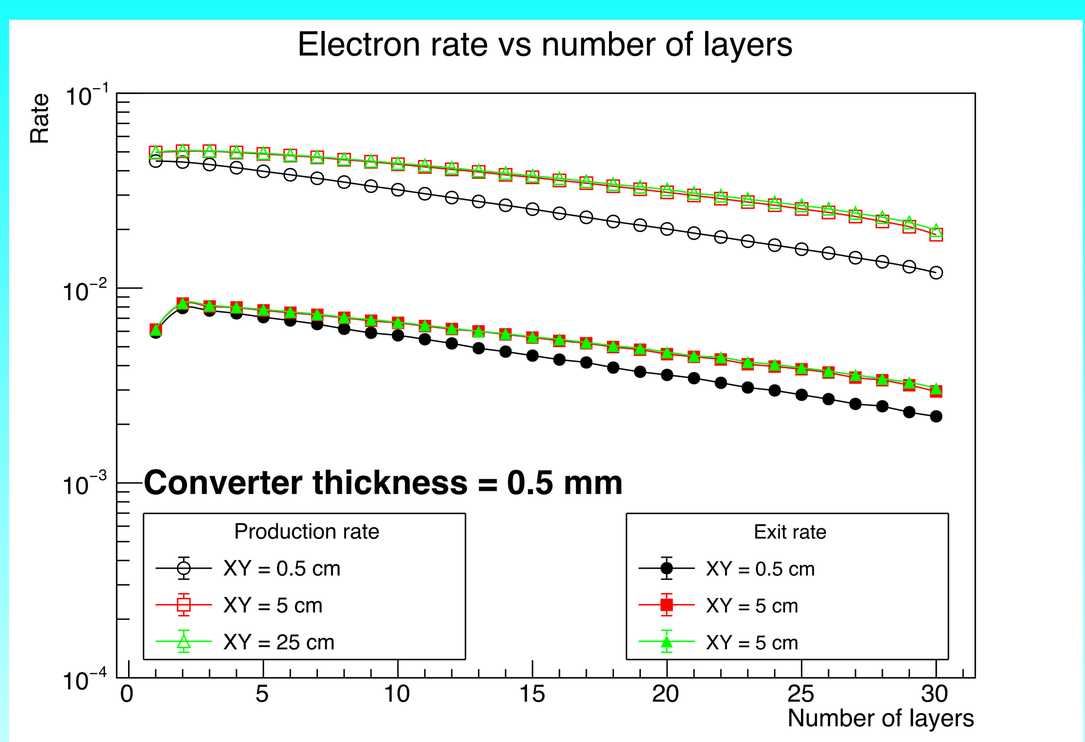
A) Photon-converter separated from amplification layer
B) Amplification layer used also as photon-converter [too low production electron rate —> see "kapton" previous box]



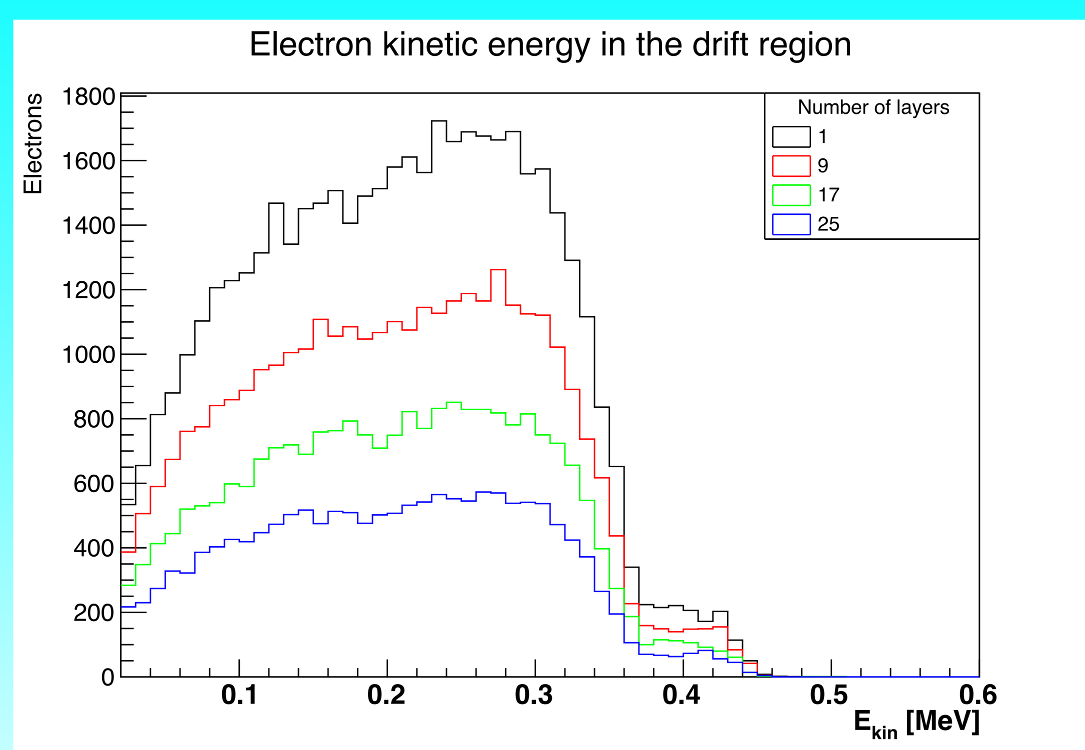
Impact of multiple layers



Production and exit rate, for three converter materials, simulating different number of layers



Production and exit rate, changing transverse dimension of the converter, simulating different number of layers
Converter: **lead glass of 0.5 mm**



Energy spectrum of the electrons reaching the drift region
Converter: **lead glass of 0.5 mm**

Conclusion

Geant4 studies have been performed simulating a new fast timing detector based on MPGD technology targeting ToF-PET application. Time performance could be improved using different independent drift-amplification regions. Electron rates and energy spectrum have been investigated for different material and simulating different number of layers.

References & contacts

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[1]. https://cerncourier.com/a/the-continuing-rise-of-micropattern-detectors/]
[2] https://geant4.web.cern.ch
[3] https://doi.org/10.1051/epjconf/201921402033