**Abstract**

A new generation of gaseous detectors, named Micro-Pattern Gas Detectors (MPGDs), has been developed thanks to an improved micro-structure technology. A new detector layout, named Fast Timing MPGD (FTM), has been recently proposed. The FTM would combine both the high spatial resolution (100um) and high rate capability (100MHz/cm²) of the MPGDs with a high time resolution of 100ps. This new technology consists of a stack of several coupled layers where drift and multiplication stages alternate in the structure, yielding a significant improvement in timing properties due to competing ionization processes in the different drift regions. This contribution introduces the FTM technology as an innovative PET imaging device concept.

**Time-Of-Flight Positron Emission Tomography**

PET is a non-invasive technique to visualize organs with high metabolic activity

- $^1$P$^-$ sugar (FDG) is administered to a patient and concentrates at high metabolic activity regions (tracer)
- $^1$e$^-$ is released and loses energy during travel (~1mm) before annihilation
- 2$\gamma$ (511 keV) are emitted back to back, their coincident detection determines the Line of Response (LOR)
- w/o TOF equal probability assigned to each point along the LOR
- w/TOF few 100 ps measurement will lead to ~5 cm precision along the LOR
- use of fast timing in PET results in high contrast images

**Ideal TOF-PET detector**

<table>
<thead>
<tr>
<th>LYSO crystal</th>
<th>MRPC</th>
<th>fast MPDG</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

**Photon Conversion**

- GEANT4.10.03 version used
- FTFP_BERT_HP physics list
- Simulation of 511 keV $\gamma$ interaction in different materials and thicknesses:
  - PCB (FR4), kapton, glass (G4_GLASS_LEAD), lead glass (G4_GLASS_PLATE)
- Adapt structure to detect 511 keV $\gamma$ from PET

**Fast Timing Micro Pattern Gaseous Detector (MPDG) for photons**

- Charged particles ionize the gas in the drift region producing e$^-$ multiplied in the gain region
- Improve time resolution by reducing distance of closest e$^-$ pair to the gain region
- Resistive structure→ signal from any layer induced in external pickup strips
- Split drift volume in N layers, each with own amp. structure→ improved time resolution
- Low operational potentials (6/500 V)

**Fast Timing MPGD for photons: from Simulation to Prototypes**

- Photon conversion (GEANT4):
  - estimate the conversion rate in resistive materials and obtain electron energy spectrum
  - trade-off between many detection layers (time res.) vs large drift regions (energy res.)
- Electric field inside the detector (ANSYS, COMSOL)
- Primary ionization (GARFIELD++, GEANT4):
  - number of primaries and first e$^-$ pair distance from amplification layer (time res.)
- Energy resolution with several small detection layers (GEANT4)
- Drift and Avalanche (GARFIELD++):
  - estimate gain of the detector and gain variation (energy res.)
  - simulation of signal formation and shape, spatial and time res. estimation
  - fast gain by integration of Townsend coefficient (COMSOL) corrected for Penning effect (MAGBOLTZ)
- Final prototype performance estimation

**Gain Estimation**

Gas gain estimated as a function of the amplification potential

**Simulation Validation**

- AMPTek X-ray (Ag) passing the FTM drift board simulated using GEANT4
- Cu fluorescence activated
- Final spectra in the drift region available to simulate the final signal
- Comparison with data ongoing

**Contacts**

- Raffaella.Radogna@ba.infn.it
- Piet.Verwilligen@ba.infn.it
- Marcello.Maggi@ba.infn.it