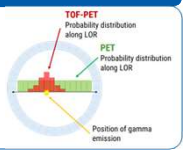
Timing performance characterization of FBK SiPM NUV-HD-MT technology

Michele Penna (mpenna@fbk.eu – michele_penna@polito.it)
F. Acerbi, J. Dalmasson, A. Ficorella, S. Merzi, L. Monreal-Parellada, E. Moretti, G. Paternoster, M. Ruzzarin, O. A. M. Villarreal, N.Zorzi and A. Gola

Research context

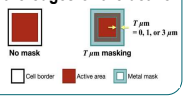
The improvement of the **timing performance** in photon detection is one of the main goal for several research fields ranging from big physics experiments to biomedical applications such as **Time of Flight Positron Emission Tomography (ToF-PET),** where the figure of merit is the **Coincidence Time Resolution (CTR)** that strongly affects reconstruction of the emission point of the two 511 keV gammas.
Among the improvements needed to enhance the CTR: (1) the scintillator crystal materials, (2) the electronics readout, (3) **the detector development.** The latter plays a crucial role in the timing performance evaluation. One of the key parameter that assesses the detector timing performance is the **Single Photon Time Resolution (SPTR)** defined by the time jitter when a single photon is detected (i.e. the precision in time-tagging the single-photon arrival time).



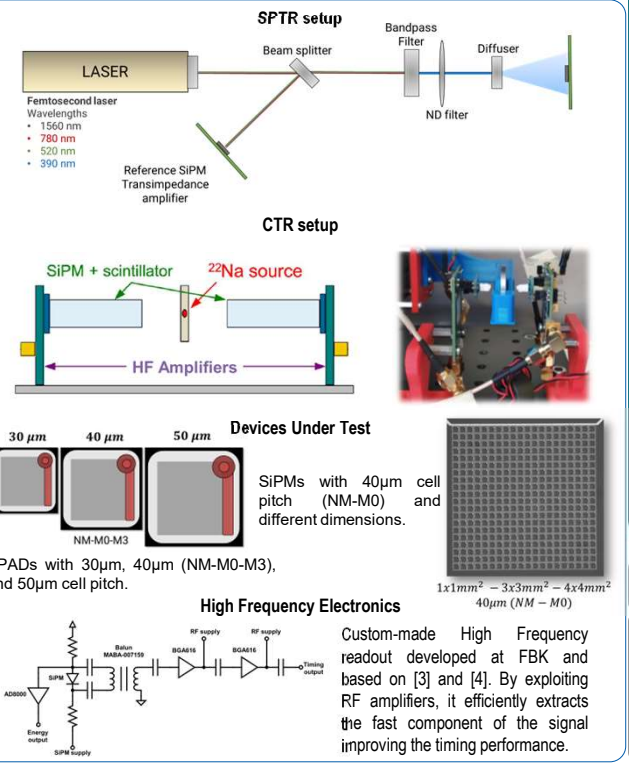
Masked version of FBK NUV-HD-MT SiPMs

NUV-HD Metal-in-Trench SiPM exploits narrow metal-filled trenches placed in the area around the SPADs that allow an almost complete suppression of the internal optical crosstalk [1]. Thanks to this feature the device can be biased at higher overvoltage, improving both the PDE and SPTR. Additionally, a new layout with **metal masking of the edges of the active area of the SPADs** can be implemented on the micro-cell [2] that:

- Removes the outer areas of the SPAD which show worse SPTR.
- Creates higher capacitive coupling between anode and readout leading to a fast peak of the single cell response.

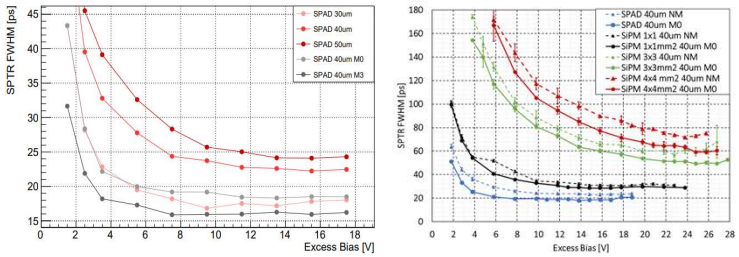


Experimental setups and materials



Results

SPTR measurements



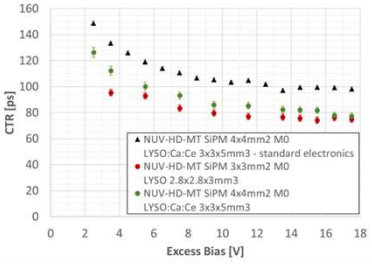
Events were selected (~75% of the total) in a 2σ interval of the amplitude distribution.
SPTR gets better with:

- The increasing excess bias: higher amplitude and steeper leading edge slope.
- The decreasing of the microcell size: jitter due to the avalanche injection position (further studies ongoing).
- The mask thickness: it increases capacitive coupling and covers the outer region of the cell with worse SPTR.

SPAD and $1x1mm^2$ SiPM have similar SPTR: segmentation

- Metal masking effects on bigger devices: better signal extraction

CTR measurements



$4x4\ mm^2$ $40\mu m$ M0 SiPMs achieves **CTR of ~80ps FHWM with the HF readout** compared to the ~95ps using a standard readout electronics. The crsystal used was a co-doped LYSO:CaCe with $3mm\ x\ 3mm\ x\ 5mm$ dimensions.

References

[1] Stefano Merzi *et al*, "NUV-HD SiPMs with metal-filled trenches", JINST, 2023.
[2] S Gundacker *et al*, "On timing-optimized SiPMs for Cherenkov detection to boost low cost time-of-flight PET", Phys. Med. Biol., 2023
[3] J. W. Cates *et al*, "Improved single photon time resolution for analog SiPMs with front end readout that reduces the influence of electronic noise, Phys. Med. Biol., 2018.
[4] S Gundacker *et al*, 'High-frequency SiPM readout advances measured coincidence time resolution limits in TOF-PET ", Phys. Med. Biol., 2019.

Conclusions and next steps

- FBK NUV-HD MT SiPMs show **excellent SPTR and CTR results that are consistent with the state-of-the-art results in literature.** This technology will be exploited in next generation **ToF-PET systems** but also in low cost ToF-PETs that use prompt Cherenkov photons detection.
- **Further studies** ongoing:
  - Characterization of the influence of the avalanche injection point on the timing performance by measuring the SPTR in different position of the microcell with a collimated-light setup.
  - Experimental evaluation of Transit Time Spread on SiPMs with different dimensions to deeply study the effects of the metal mask and its influence on the signal extraction.