Operation of Microchannel Plate PMTs with TOFPET multichannel timing electronics

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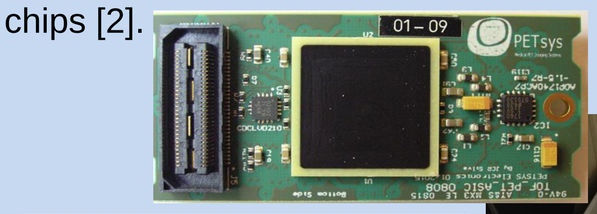
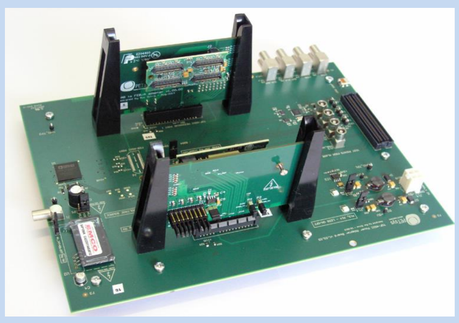
Introduction

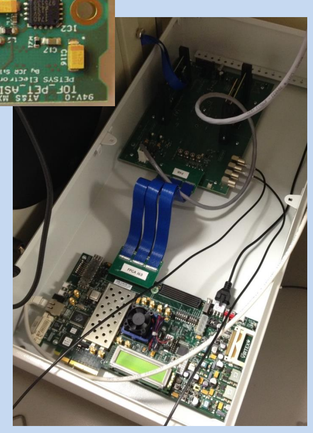
We describe an experimental programme to evaluate TOFPET (Time-of-Flight Positron Emission Tomography) multichannel timing electronics using microchannel plate (MCP) PMTs in single photon counting mode. Time resolution measurements were made using i) the on-board electronic stim signal, ii) a Photek PMT210 high speed single anode MCP photomultiplier detector and, iii) a multi-anode MCP detector using a pixelated multi-layer ceramic readout. Measurements were first made using the original, mk1 256 channel PETsys TOF ASIC evaluation kit and are now underway with the more recent TOFPET2 electronics.

PETsys Evaluation kits

The PETsys TOF ASIC evaluation kits consist of hardware packages designed to control and evaluate the performance of the TOFPET ASIC chips [2].





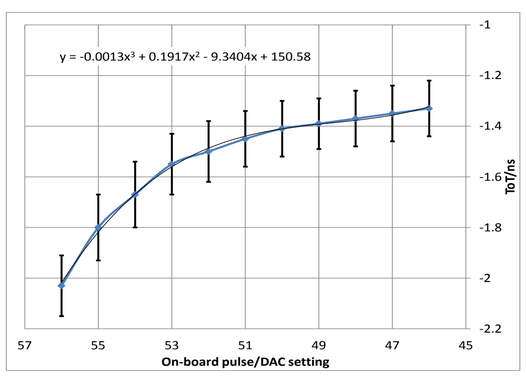


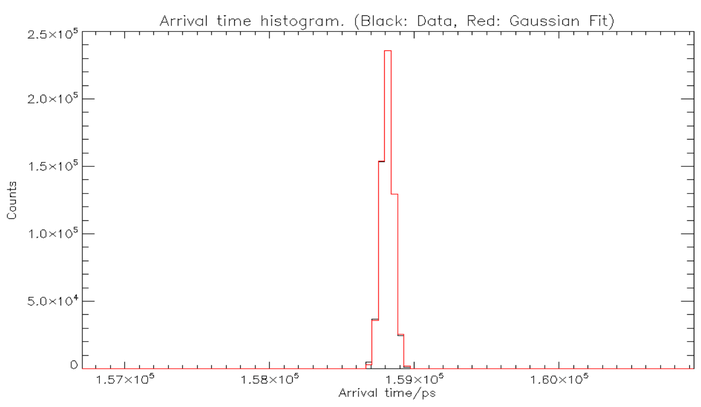
TOFPET is optimised for SiPM array applications but this study investigated operation with microchannel plate photomultipliers.

The evaluation kit v4 shown allows 256 independent channels.

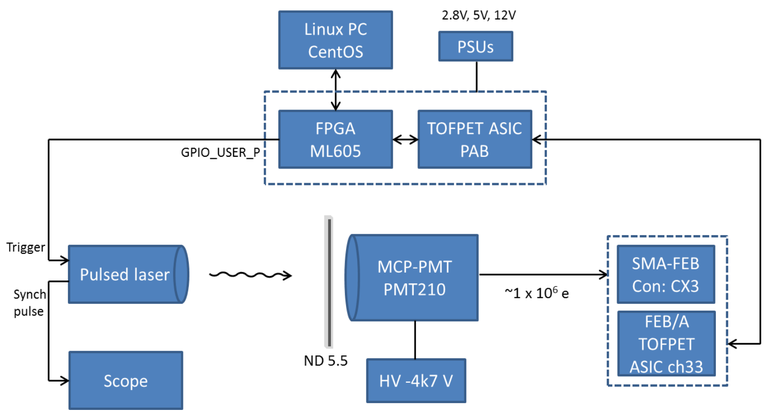
TOFPET Performance with Internal Test Pulse

An internal FPGA-generated test pulse was fed to a charge injection circuit which directly triggered the ASIC front-end for signal calibration (see figures below for time-over-threshold (ToT) calibration and arrival time spread). A time resolution of σ=43 ps was measured after applying amplitude walk correction (AWC) to the ToT data.



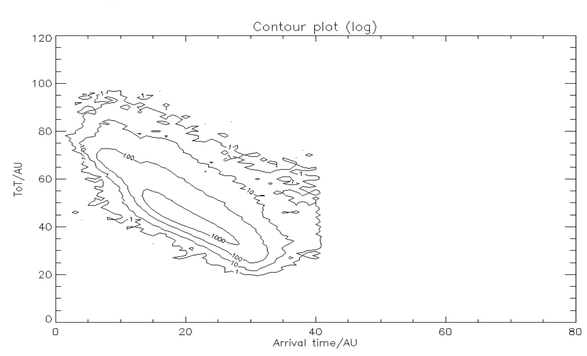


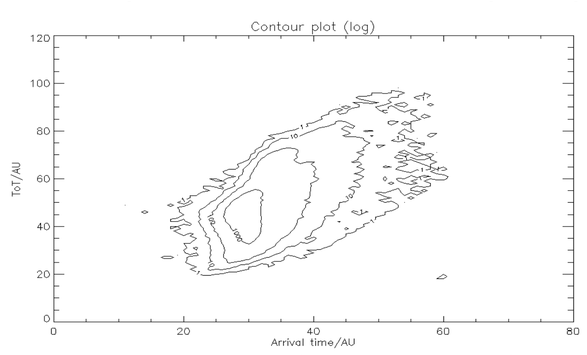
Performance with a MCP-PMT Detector



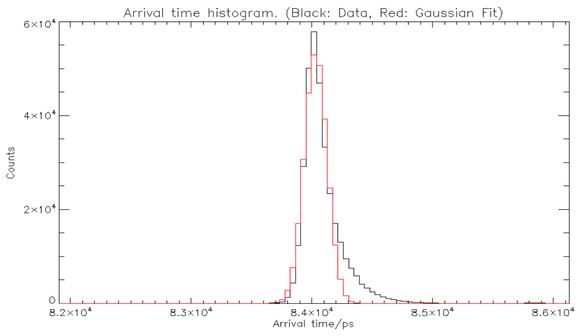
Mounted inside a dark box, the signal output from a PMT210 was connected into an individual ASIC channel. The FPGA on-board test pulse triggered a laser (40 ps width) allowing synchronous photon events to be analysed.

Operating in single photon mode (MCP-PMT est. 8.2 x 10^5 electrons) a logarithmic contour plot of ToT versus arrival time reveals amplitude walk. The figures below illustrate before and after amplitude walk correction (AWC).



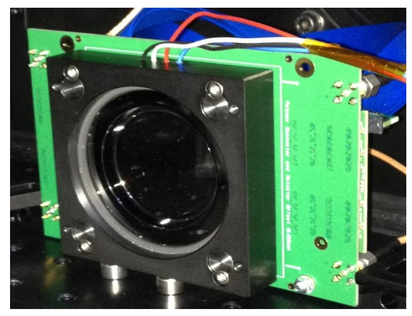


Implementing AWC to the event arrival time the contour plot aligns the peak value with the arrival time and results in an optimised time resolution of σ=96 ps (225 ps before correction). In future analysis software an empirical look up table, to fit non-linear amplitude walk data, will be implemented per channel.



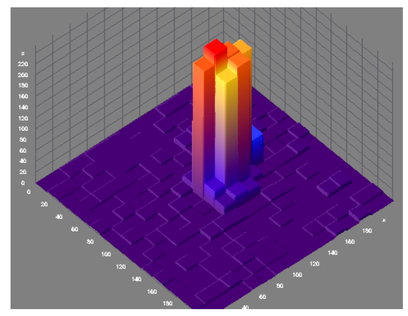
Multi-anode 256 pixel imaging

The focused laser source image (lower right) was produced by a multi-anode pixelated MCP readout, electrically coupled via an anisotropic conductive film to an impedance matched header PCB with 4 TOFPET ASICs (upper right).

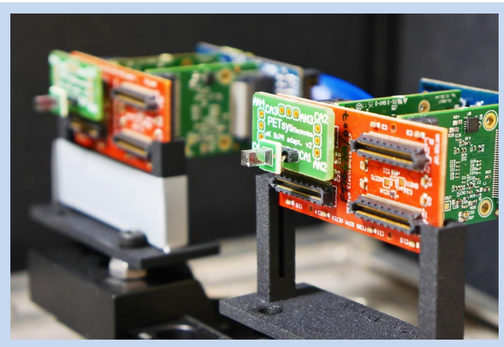


New TOFPET2

TOFPET2 is the new generation ASIC from PETsys. It incorporates significant design advances including charge integration for pulse amplitude measurement and is capable of ~4 times higher event rate [3]. Designs incorporating the new ASIC are in production at Leicester.



TOFPET2 Summary [3]



The TOFPET2 SiPM front end

- 64 independent channels in 5x5 mm^2
- Low-noise and low-power
- Optimised for TOF measurement in PET
- Standard CMOS 110 nm
- Positive or negative signal polarity
- Dynamic range 100 fC - 1500 pC
- Noise 1.5 mV (1 p.e. ~ 30 mV)
- Charge integration ADC 10 bit
- TDC time binning 30 ps
- Low power: <12.5 mW/Channel
- Very high event rate capability up to 30 Mcps per ASIC
- On-chip calibration circuitry
- Maximum event rate is 480kHz per channel
- Up to 2 MHz dark counts rejection

References

[1] Bugalho, R., Rolo, M. D., Zorraquino, C., Silva, R., Silva, J. C., Veckalns, V., ... & Varela, J. (2013, October). Design and performance of an ASIC for TOF applications. In *Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC), 2013 IEEE* (pp. 1-4). IEEE.

[2] PETsys Electronics, Mar 2016. PETsys TOF ASIC Evaluation Kit_v4 - Hardware User Guide. 1.0 edn. PETsys

[3] Di Francesco, A., et al. "TOFPET2: a high-performance ASIC for time and amplitude measurements of SiPM signals in time-of-flight applications." Journal of Instrumentation 11.03 (2016): C03042.

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