First experimental results with TOFPET 2 ASIC

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- Time Of Flight PET application ASIC;
- 64 channels 110 nm CMOS, low power (<5.5 mW/channel);
- Specialized in SiPM readout;
- Front-End based on Current Conveyor;
- First version received on February 2016;
- New MPW submitted on September 2016.
• Sharing some common backgrounds and features:
  – ToA based on single threshold detection;
  – Delay line for dark counts suppression, plus suppression from digital control up to 2 MHz in TOFPET 2;
  – Quad-buffered ADC/TDC for digitization of ToA & Energy;
  – High event rate capability, 600 kHz/ch. in TOFPET 2;
  – Low power consumption, 5.5 mW/channel in TOFPET 2.
Energy Measurement Scheme in TOFPET 1 & TOFPET 2

- **TOFPET 2**
  - Energy measurement based on internal charge integration.

- **TOFPET 1**
  - Energy measurement based on ToT, using two TDCs.

**Diagram**:
- **PREAMP. (Current Conveyour)**
  - Postamp. + Disc. (threshold < 3 p.e.)
  - Postamp. + Disc. (threshold < 10 p.e.)
  - Integrator (Quad-Buffered.)
- **Digital Control & Dual Ramp TDC**
- **Delay**
- **Wilk. ADC**
In TOFPET 2, the clock rate of Channel control and Global control were increased to cope with 600 kHz event rate per channel;

The ADC was achieved from the second stage of the second dual-ramp TDC of TOFPET 1. ToT scheme is still available in TOFPET 2, in replacement of integration.
TOFPET 2 Tests

- The tests of TOFPET 2 started end of March 2016;
- The Digital interface, upgraded from TOFPET 1, was tested successfully;
- The data transfer through the LVDS links was tested up to 400 Mbit/s (800 Mbit/s still to be tested).

Tested with 8x8 array MPPC S12642-0404PB (3x3 mm² pixels):
- 1 p.e. = 200 fC;
- 1 p.e. jitter = 100 ps
The performance of the TDCs was first evaluated with test pulses:
- Precise timing external pulses are measured by the 64 channels.

The figure shows the distribution of the 64 channels measurement;

The average of the measure is 26 ps.
First test with SiPMs

- The first evaluation of the ASIC performance with SiPM input signals was done with the MPPC 8x8 pixel array;
- Time measurements of laser pulses with wavelength 420 nm synchronous to the system clock;
- Scanning the time interval of the 200 MHz TDC clock period at 10 different phases.

![Graph showing data distribution](image)
Multi-photon Time Resolution

- The time resolution obtained from a Gaussian is ~40 ps;
- Jitter of laser pulses not de-convoluted;
- No time walk correction was applied;
- Confirms good time performances

![Graph showing time resolution with Sigma = 38 ps]
Threshold Setting and Dark Counts Spectrum

- Threshold level can be set with a resolution as good as $0.125 \text{p.e.}$ per LSB, with range $>4 \text{p.e.}$
- Baseline level can be adjusted with same resolution.
SPTR and CTR

- 2mV RMS noise in agreement with simulations;
- 30mV, 1 p.e. signal amplitude, slew rate 5mV/ns, 3-4 times slower than expected;
- SPTR ~270 ps RMS;
- CTR ~480 ps FWHM.
• Source of low resolution identified in a parasitic capacitance inside the discriminator, increased by metal dummy fillers (not considered in post-layout simulations);
• Discriminator modified to cope with higher stray capacitances;
• Channel metal filling done “in-house”.
The preamplifier of TOFPET 2 is designed to be linear up to 3k p.e for SiPM gain of \(\approx 2.5 \times 10^6\).
The quad-buffered integrator consist of:

- Two current mirrors from the preamp. output, with configurable current attenuation;
- Four capacitors written by current sources;
- A readout buffer with cap. selection switches.

Plus an offset to compensate offset current.
Energy Measurements

- Response of the integrator tested with MPPC S13361-3050AE-04 (new device with low cross-talk);
- Three sources:
  - $^{22}$Na (511 keV, 1274 keV),
  - $^{137}$Cs (32 keV, 662 keV),
  - $^{133}$Ba (31 keV, 81 keV, 356 keV).
- 3x3x5 mm$^3$ LYSO:Ce
- Baseline noise 1.7 LSB, 11.5 keV;
Linearity

- Response of the integrator tested with MPPC S13361-3050AE-04
- After correction of SiPM saturation, $^{22}\text{Na}$ 511 keV peak has 14.4% resolution FWHM (preliminary);
- All the peaks are in the expected position, up to the 1274 keV peak.
Next steps

• New MPW submitted 5\textsuperscript{th} of September, expected by January 2017;
• Timing resolution problems expected to be solved;
• Integrator range expected to be extended.
• Programmability of the integrator allows us to use the ASIC in several configurations (1:1 coupling, light sharing, monolithic crystals), still to be tested.
Thank You!

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