

# First experimental results with TOFPET 2 ASIC

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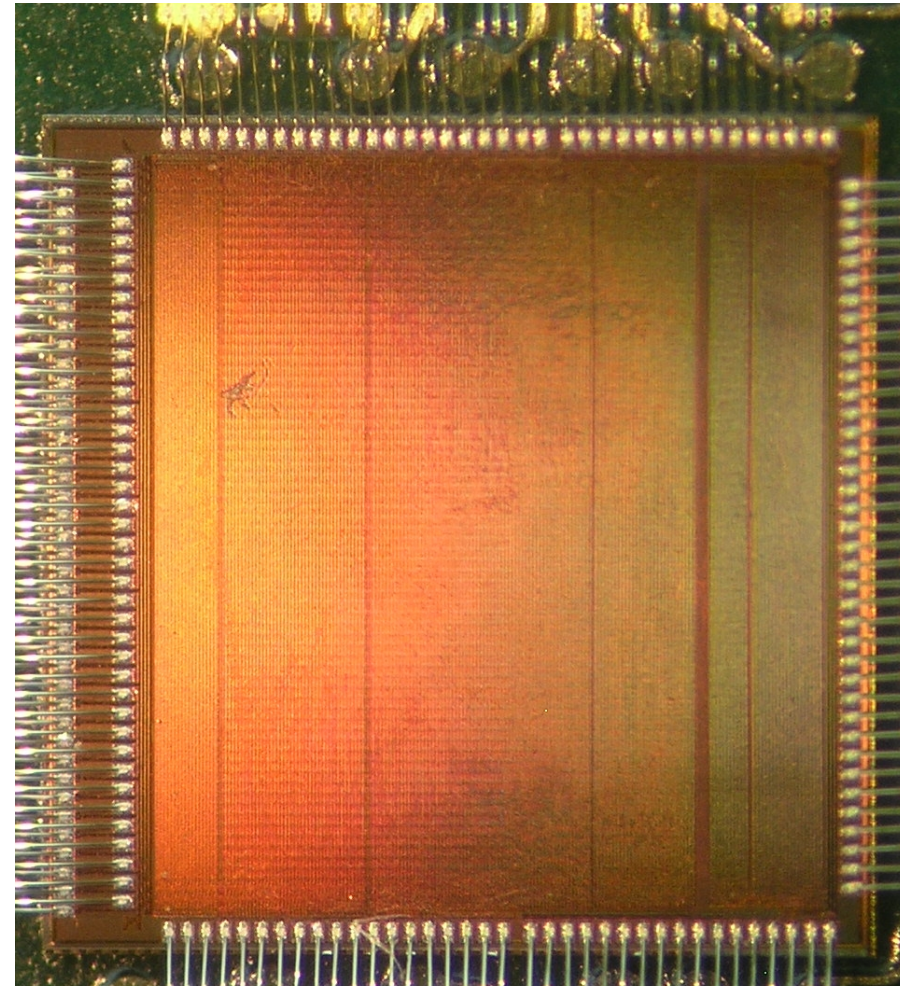
*LIP, Laboratório de Instrumentação e Física  
Experimental de Partículas*

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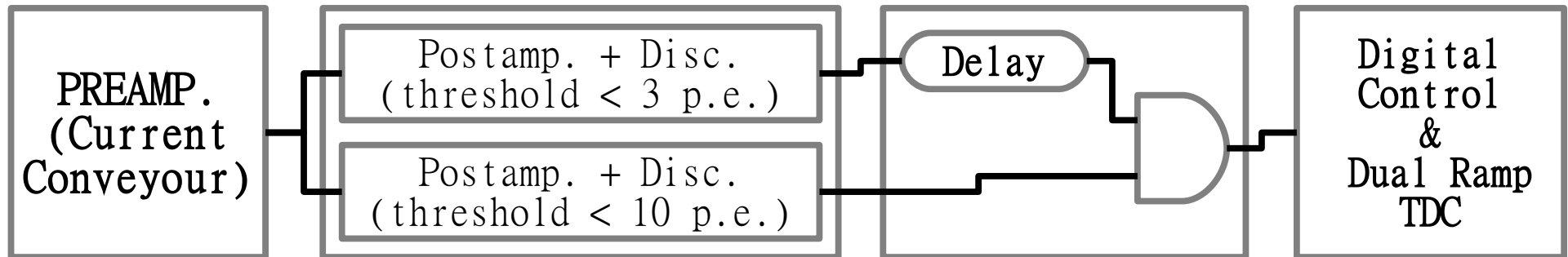
# TOFPET 2

- 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.



# TOFPET family ASICs

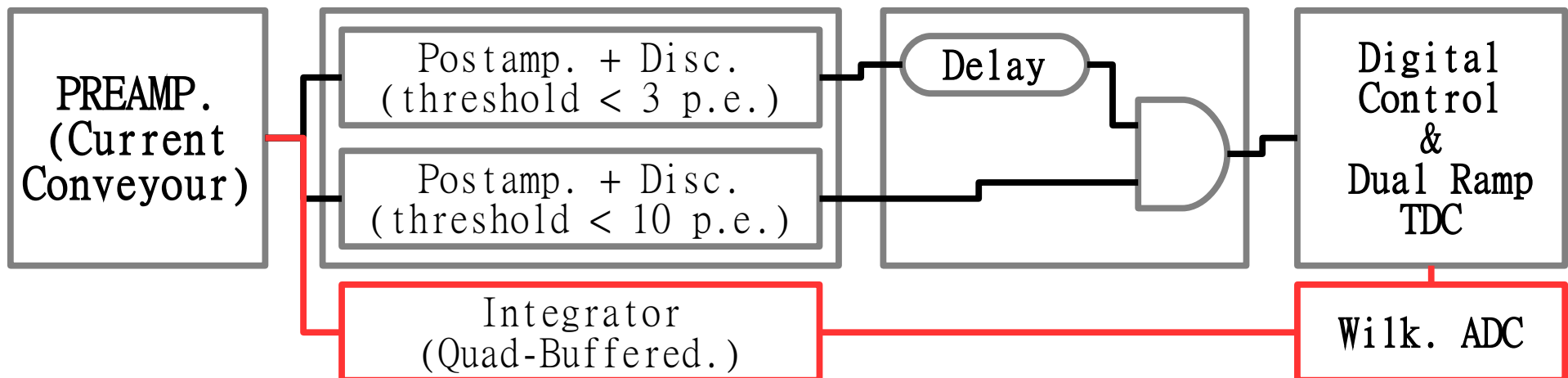
## Signal Processing For Timing in TOFPET 1 & 2 ASICs



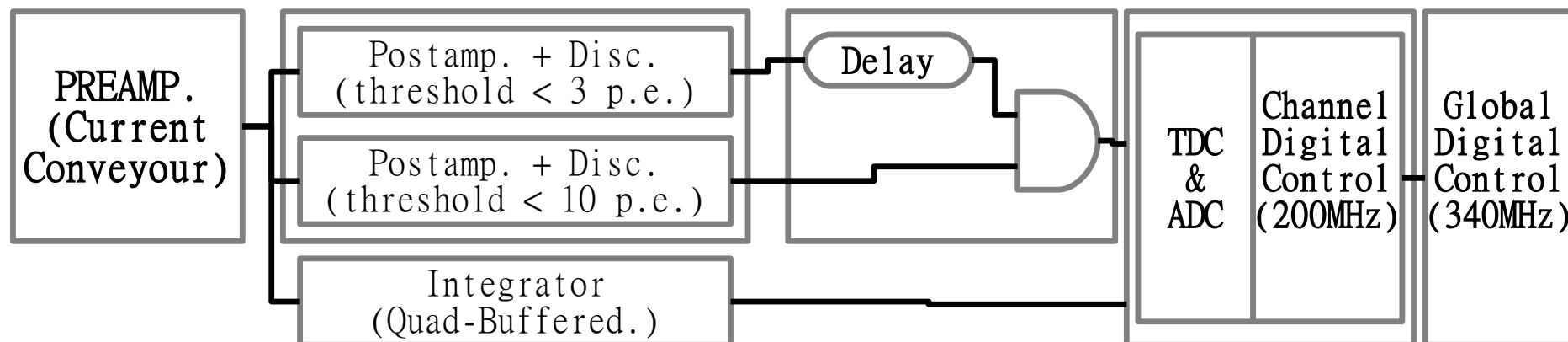
- Sharing some common backgrounds and features:
  - ToA based on single threshold detection;
  - Delay line for dark counts suppression, plus suppression from digital control up to 2MHz in TOFEPT 2;
  - Quad-buffered ADC/TDC for digitization of ToA & Energy;
  - High event rate capability, 600 kHz/ch. 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.



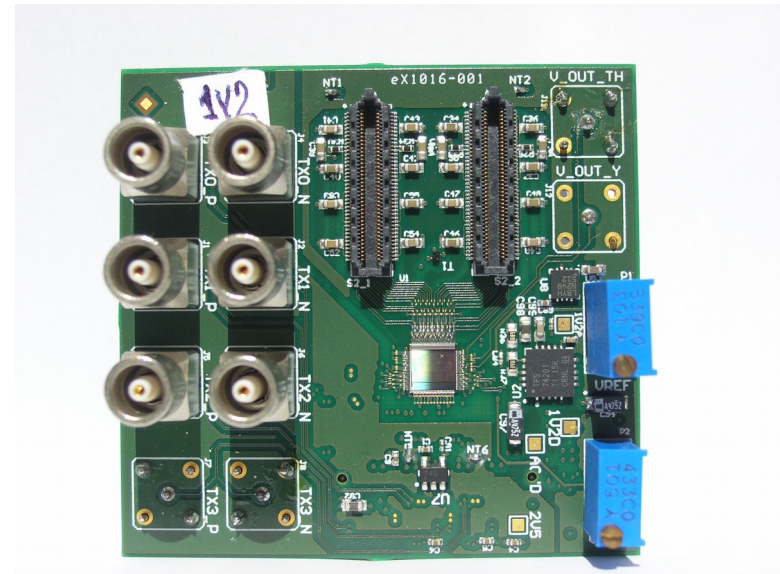
# TOFPET 2 Architecture



- 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).

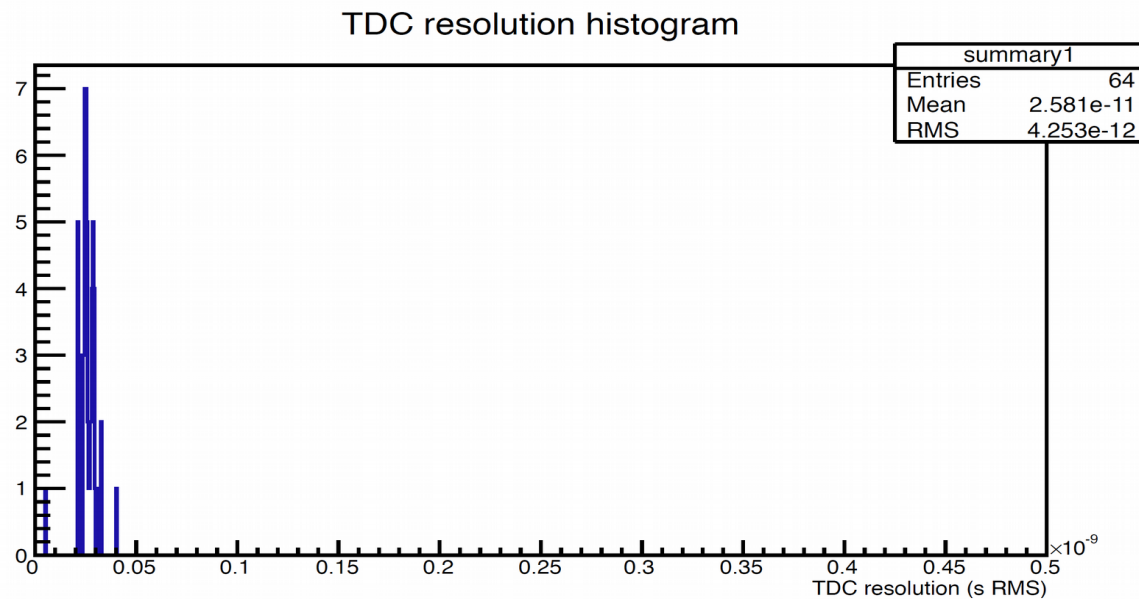


Tested with 8x8 array  
MPPC S12642-0404PB  
(3x3 mm<sup>2</sup> pixels):

- 1 p.e. = 200 fC;
- 1 p.e. jitter = 100 ps

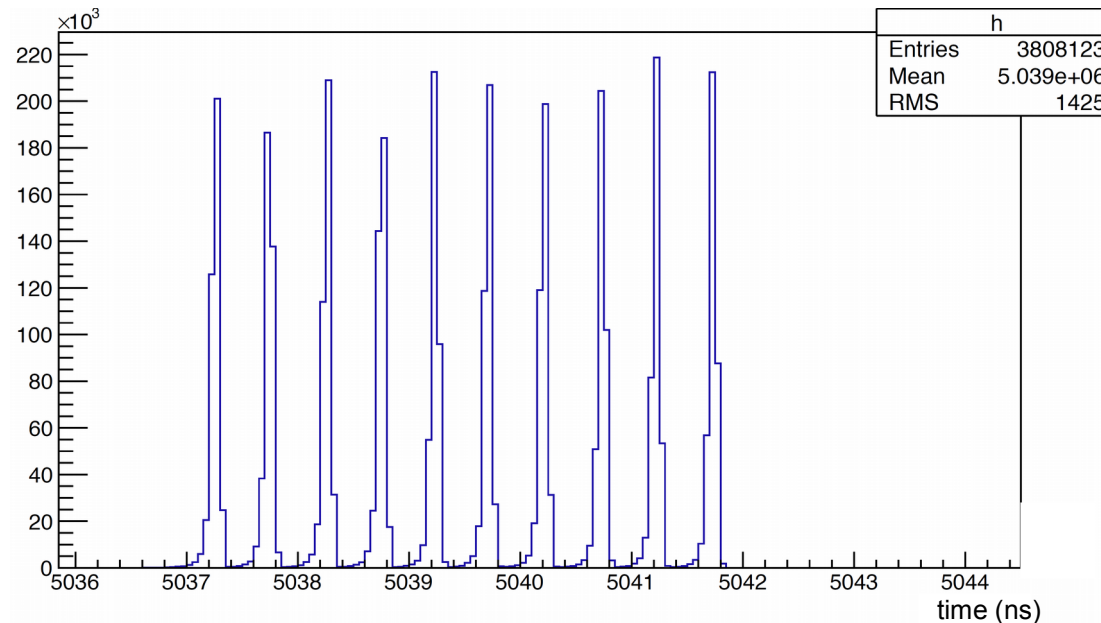
# TDC Resolution

- 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

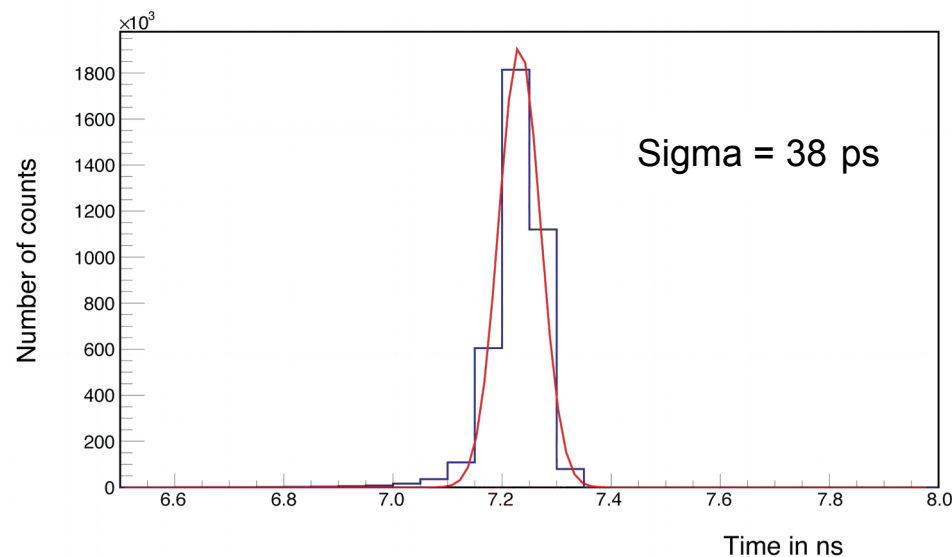
- The first evaluation of the ASIC performance with SiPM input signals was done with the MPPC 8x8 pixel array;
- Time measurements of laser pulses with wavelength 420 nm synchronous to the system clock;
- Scanning the time interval of the 200 MHz TDC clock period at 10 different phases.



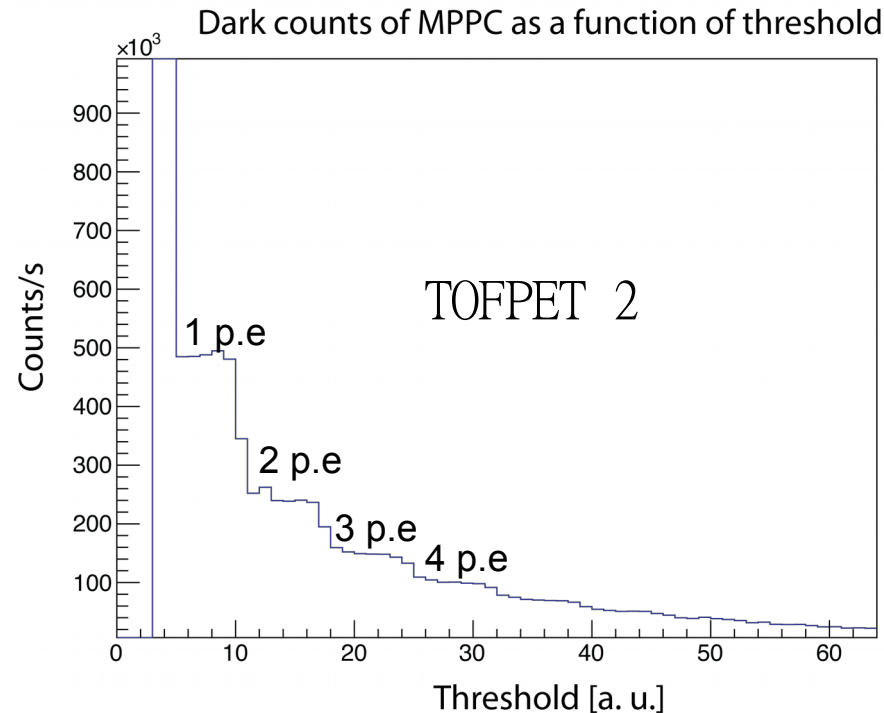


# Multi-photon Time Resolution

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



# Threshold Setting and Dark Counts Spectrum

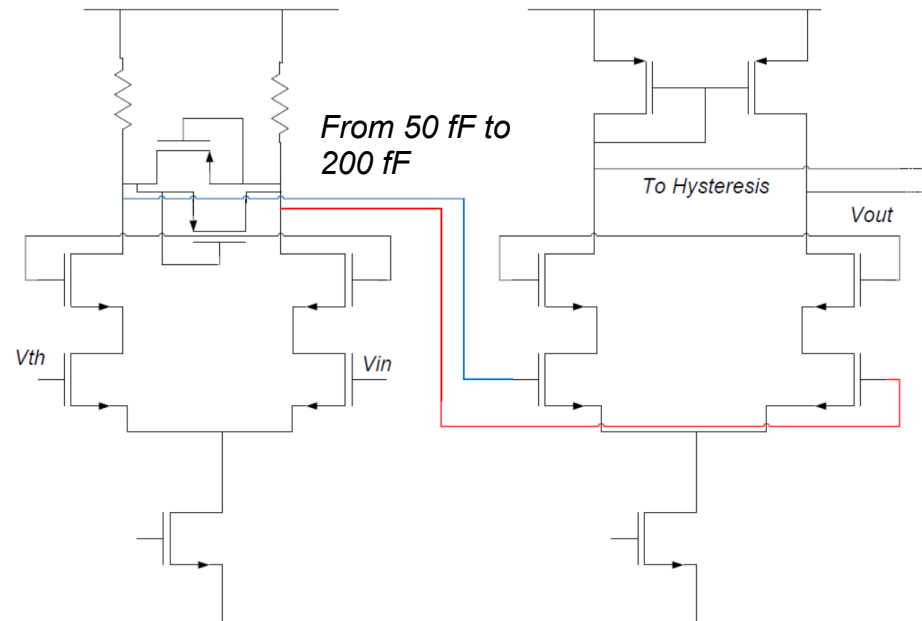


- Threshold level can be set with a resolution as good as 0.125 p.e. per LSB, with range >4 p.e.
- Baseline level can be adjusted with same resolution.

# SPTR and CTR

- 2 mV RMS noise in agreement with simulations;
- 30 mV, 1 p.e. signal amplitude, slew rate 5 mV/ns, 3-4 times slower than expected;
- SPTR  $\sim 270$  ps RMS;
- CTR  $\sim 480$  ps FWHM.

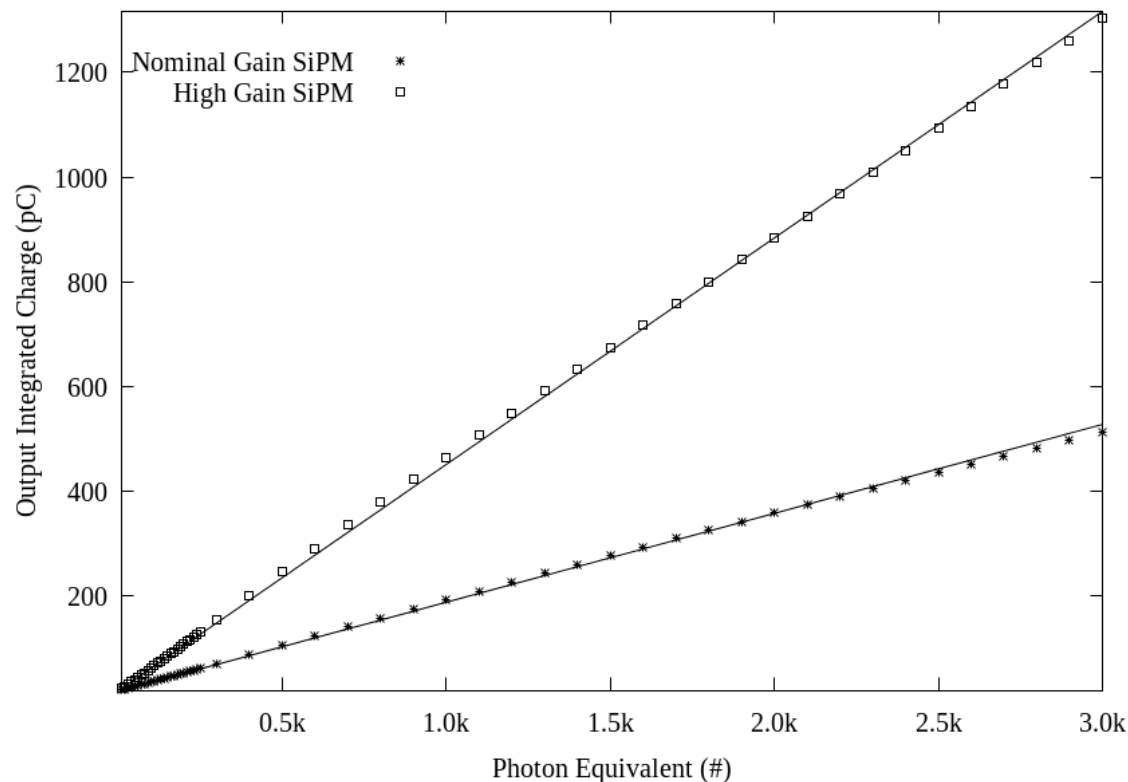
# Discriminator



- 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".

# Preamplifier linearity for signal integration

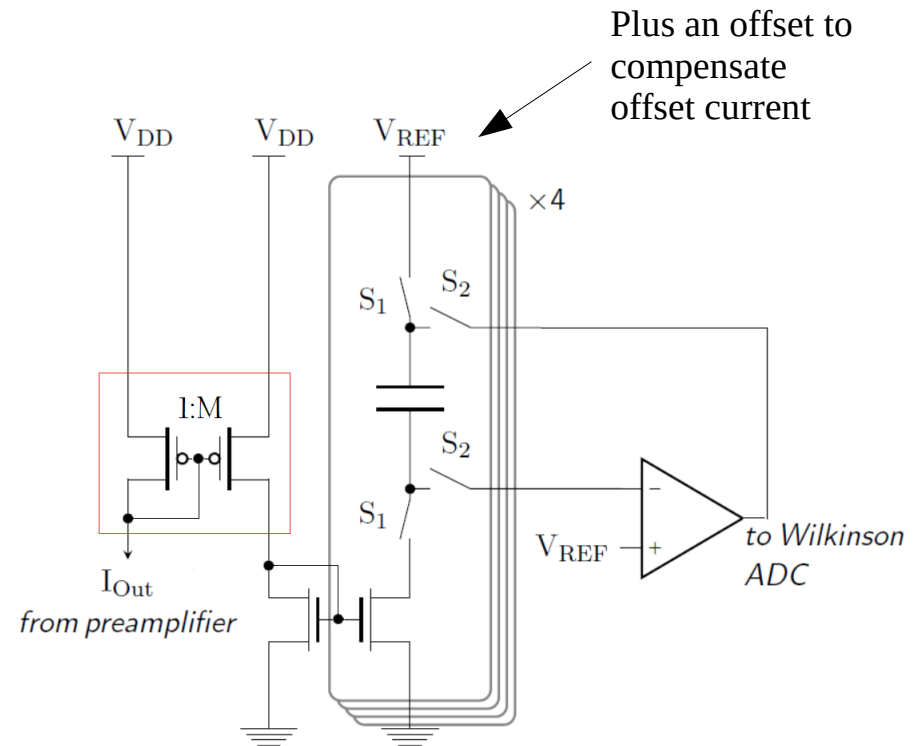
The preamplifier of TOFPET 2 is designed to be linear up to 3k p.e for SiPM gain of  $\sim 2.5 \times 10^6$ .



# Integrator

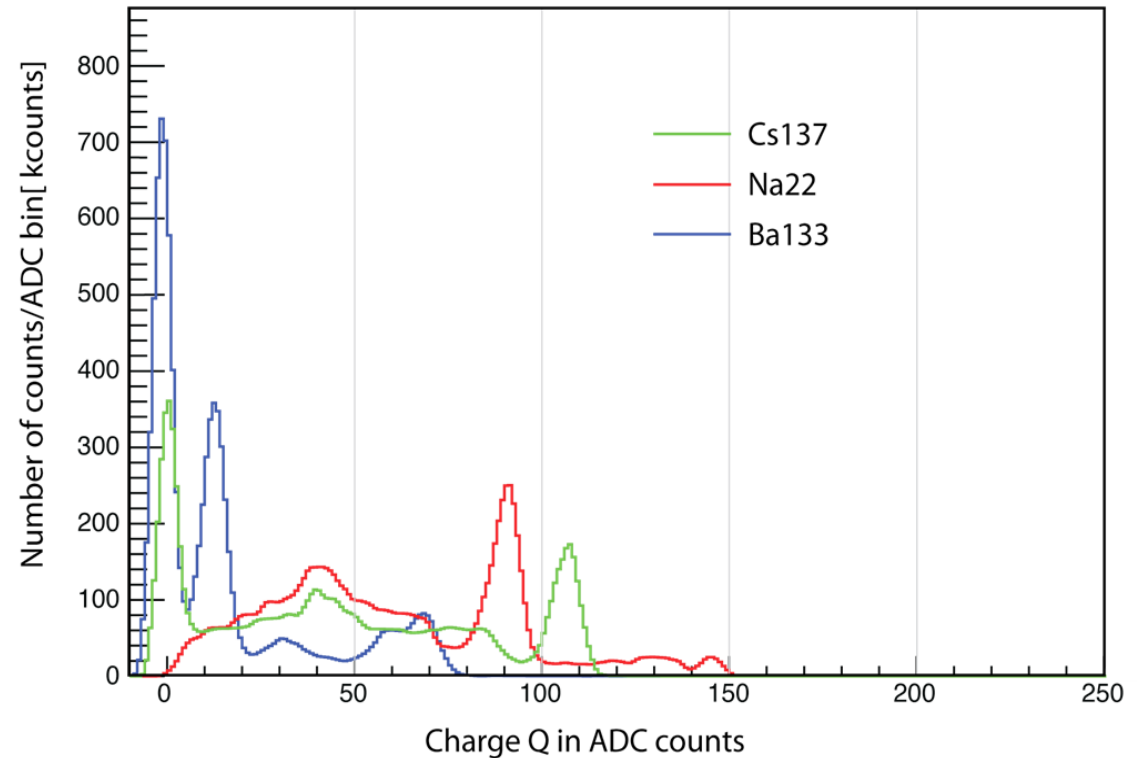
The quad-buffered integrator consist of:

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



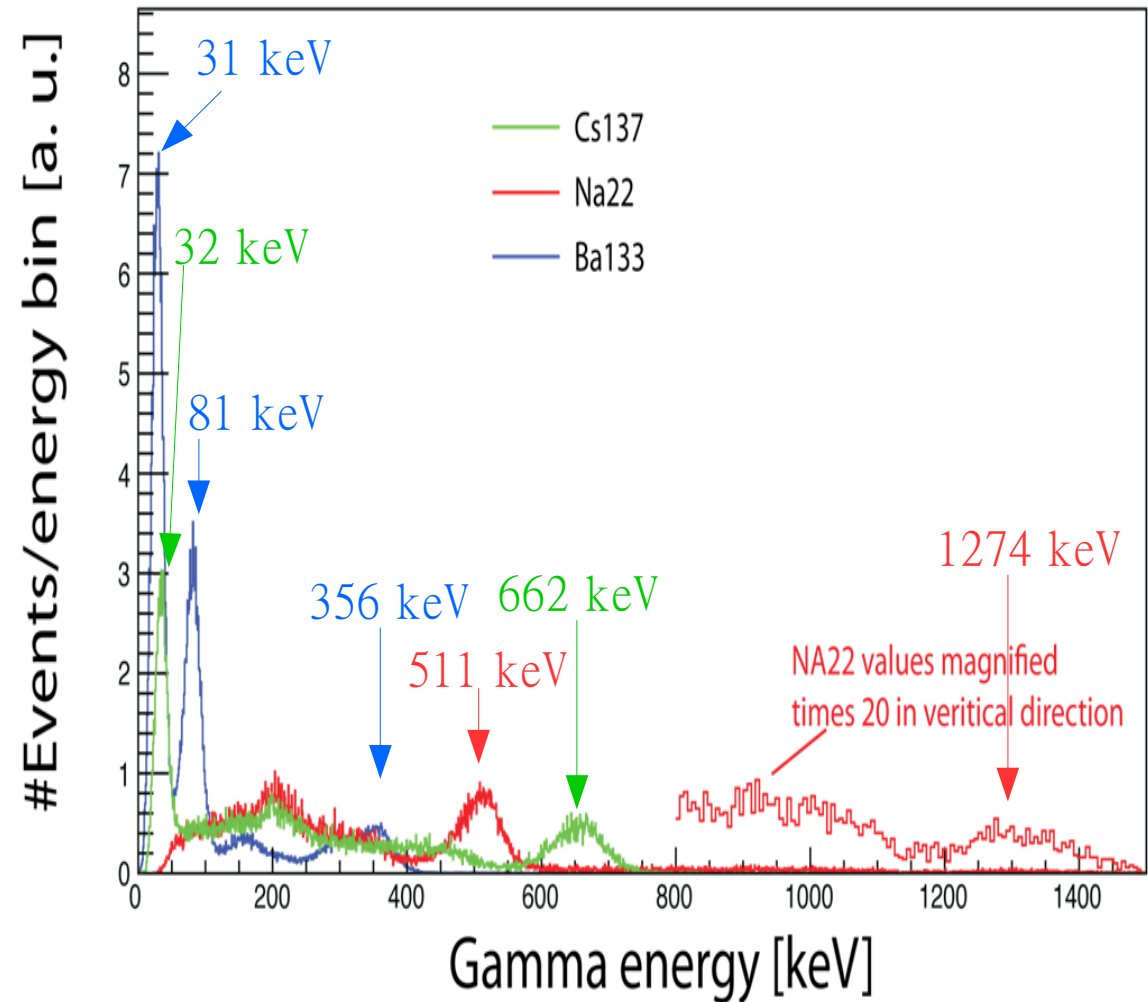
# Energy Measurements

- Respose of the integrtror tested with MPPC S13361-3050AE-04 (new device with low cross-talk);
- Three sources:
  - $^{22}\text{Na}$  (511 keV, 1274 keV),
  - $^{137}\text{Cs}$  (32 keV, 662 keV),
  - $^{133}\text{Ba}$  (31 keV, 81 keV, 356 keV).
- $3 \times 3 \times 5 \text{ mm}^3$  LYSO:Ce
- Baseline noise 1.7 LSB, 11.5 keV;



# Linearity

- Respose of the integrtror 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<sup>th</sup> 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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