High Performance Readout Electronics for Silicon Photomultipliers

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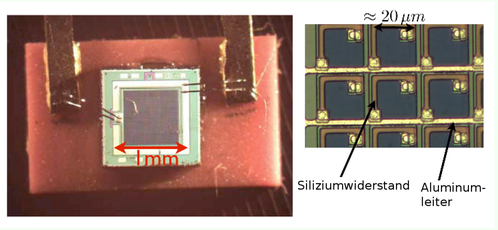
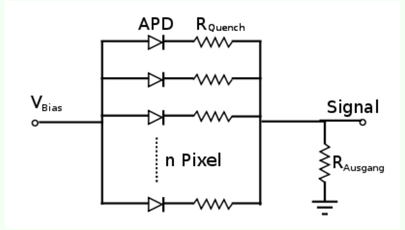
Silicon Photomultiplier (SiPM)

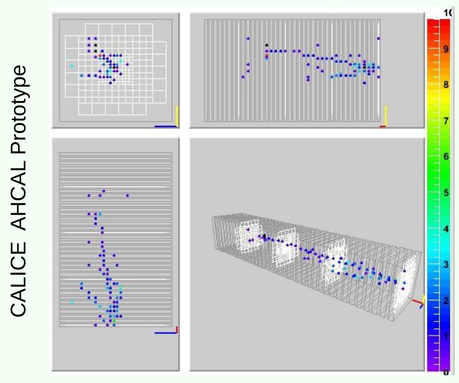




Novel photo detectors:

- High gain ≈ 10^5 to 10^6
- Compact design possible
- Low operating voltage (< 100 V)
- Insensitive to magnetic fields
- Optical crosstalk
- Large temperature dependence
- High dark rate ≈ 10^5 to 10^6 Hz

Silicon Photomultiplier in Detector Applications



Hadronic Calorimetry:

Very high granularity can be achieved

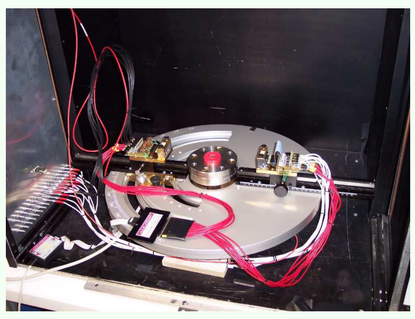
⟶ Improved energy resolution through particle flow algorithms possible

Direct coupling of the SiPM to the scintillator possible

Positron Emission Tomography:

Combination with MRI possible

Time-of-Flight measurements increase the sensitivity

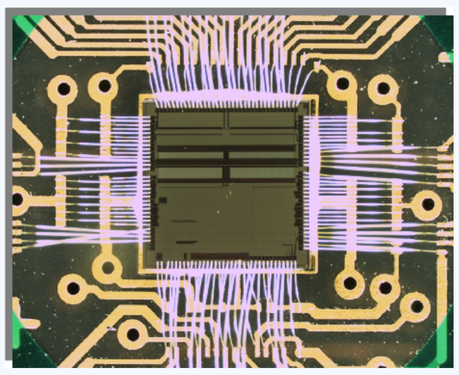


Front-End Electronics requirements for ToF PET:

Precise signal timing ⟶ Timing resolution < 200 ps
Coincidence trigger ⟶ Energy resolution ~ 15 %
SiPM variations ⟶ Tuneable bias voltage

⟶ Dedicated readout electronics required

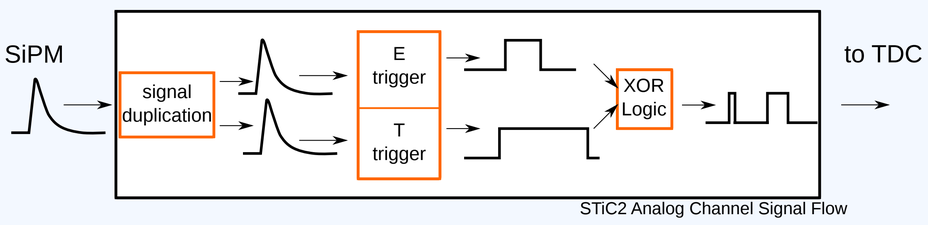
STiC2 - SiPM Readout ASIC for ToF Applications Overview



STiC2 bonded to a test PCB

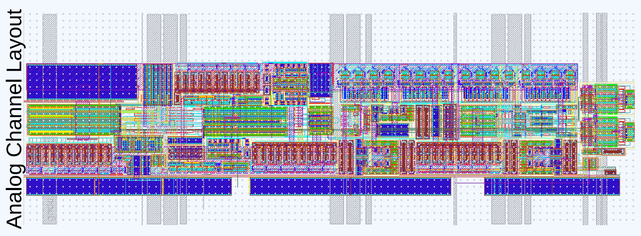
- Readout ASIC with very high time resolution developed in the EndoTOF-PET US project
- Provides high precision input stage and high resolution Time-to-Digital converter
- DAC allows to control input terminal voltage for bias tuning and temperature compensation
- Time-to-Digital Converter measures arrival time and width of the SiPM signal for energy measurements
- Digital part builds events with time and energy information from TDC measurements
- Events are transmitted over a 160 MBit/s LVDS serial link
- 16 channel testchip developed in UMC 0.18µm technology, submitted in April 2012
- Chip has returned in July 2012 and is currently being tested

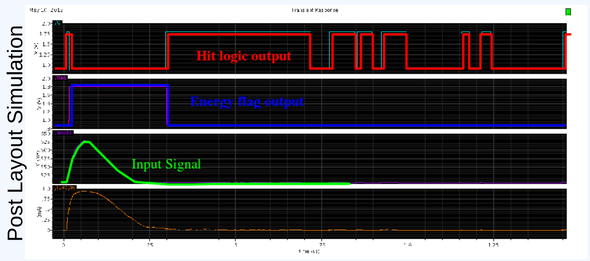
Analog Signal Processing



STiC2 Analog Channel Signal Flow

- Low impedance input stage duplicates signal current
- Low threshold discriminator generates a precise timing trigger
- Discriminator with higher threshold for Time-over-Threshold energy measurements
- Combined signal retains time and energy information of the event



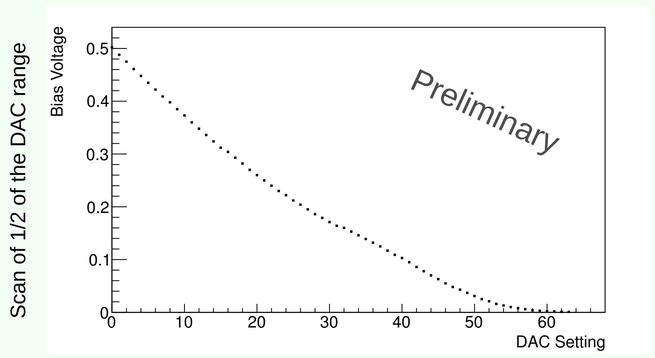


SiPM Bias Voltage DAC

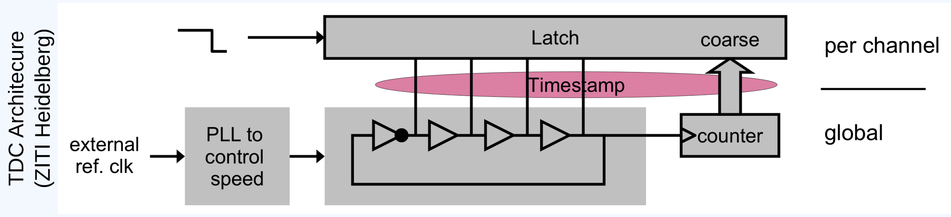
Bias tuning allows for compensation of breakdown voltage variations due to temperature or production fluctuations

Full scale range: > 0.8V
Linear range: > 0.5V

Temperature variations of ~10°C can be compensated



Time-to-Digital Conversion

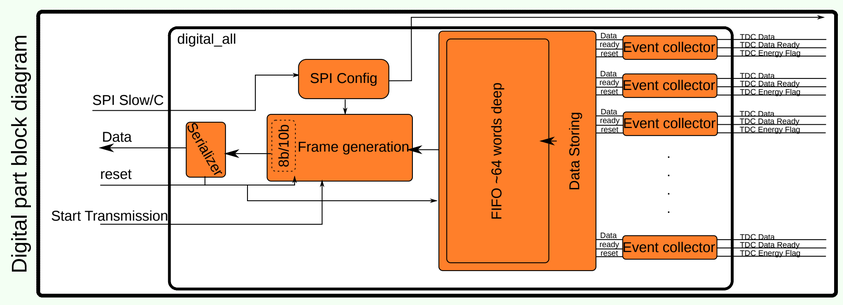


A PLL creates timestamps with a coarse and fine counter value:

- 625 MHz coarse counter measures time in bins of 1.6 ns
- Ring oscillator for the fine time consists of 16 elements and subdivides the coarse counter period in 32 bins of 50 ps

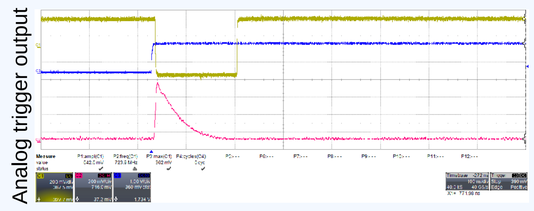
Upon hits, the TDC channels store the current timestamp

Data Storing and Transmission



- Digital part records only events with enough energy
- Events are stored with time and energy information in a buffer and transmitted in frames over a serial link to the DAQ

First Functionality Tests



- Configuration and frame transmission working
- Analog channel outputs are functional
- Detailed characterisation started

Contact

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