VMM3a: an ASIC for Tracking Detectors

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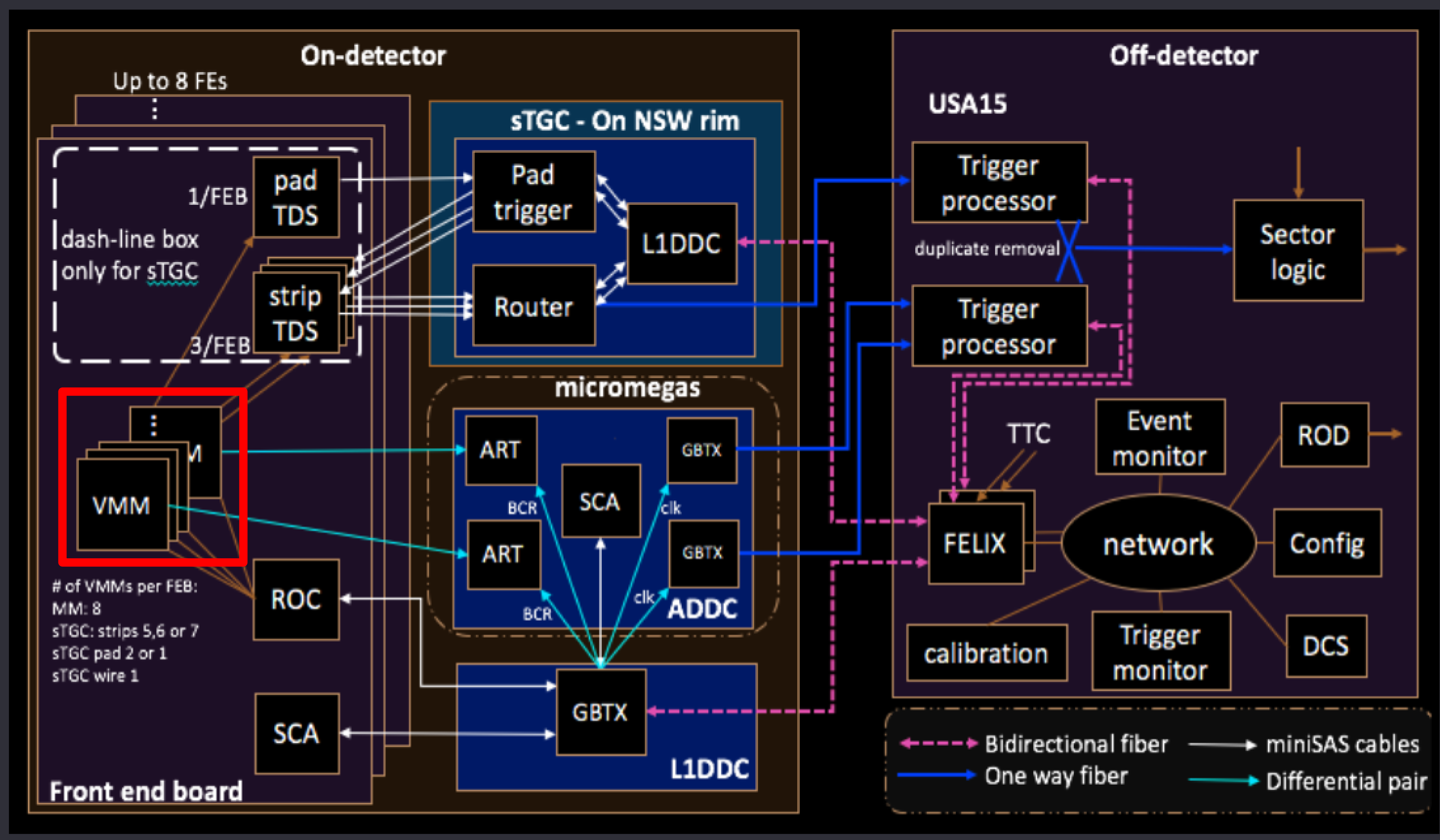
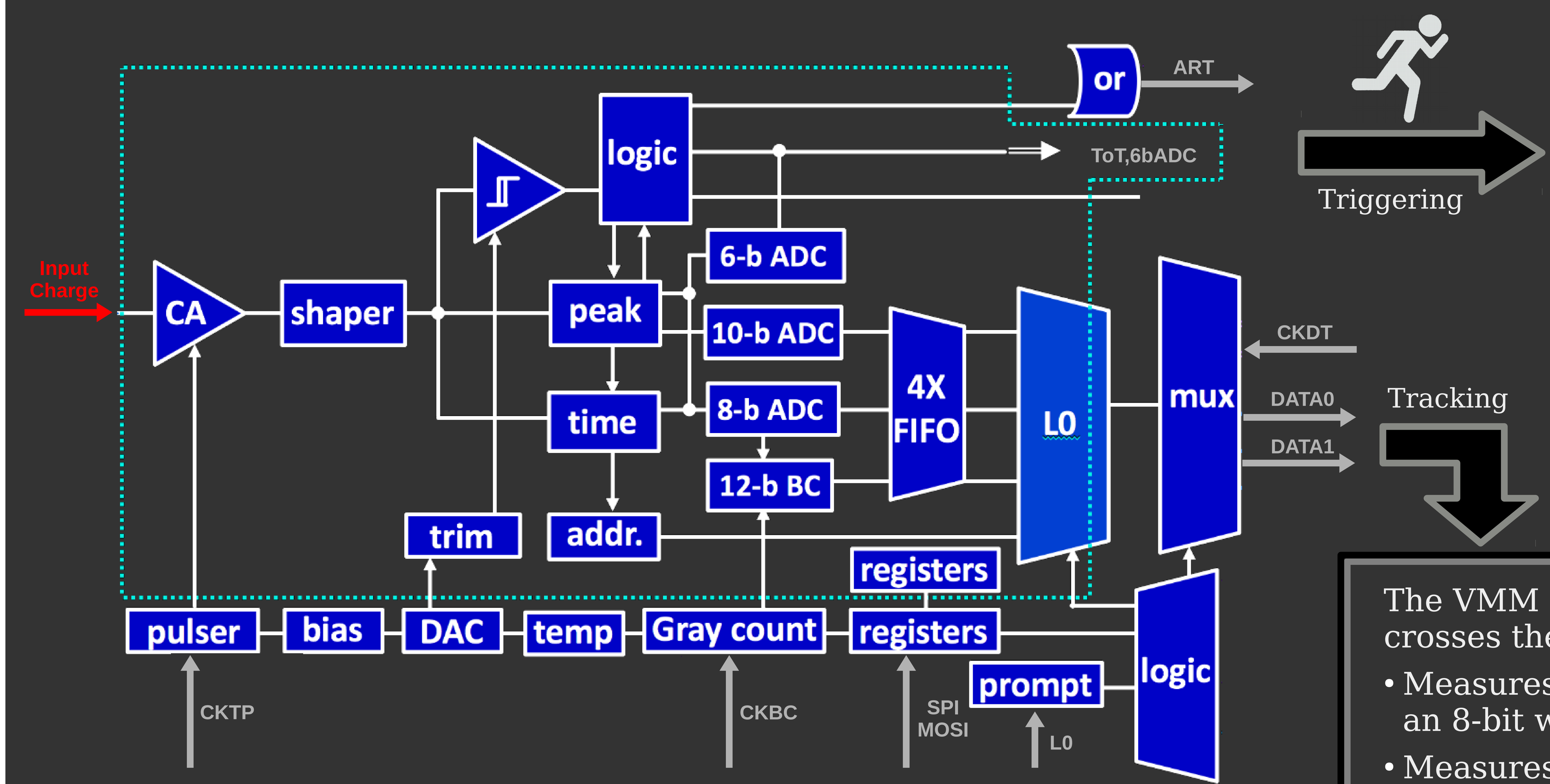
Introduction – The New Small Wheel Electronics

During LS2, each of the so-called "Small Wheels" of the ATLAS muon spectrometer will be replaced by the "New Small Wheel" (NSW), which is designed to cope with the increased particle flux due to the LHC upgrades. Two gaseous detector technologies, the Micromegas (MM), mainly used to reconstruct muon tracks and the small strip Thin Gap Chambers (sTGC), mainly used for triggering, comprise the NSW. The 2.4 million readout channels of those chambers will require a new generation of electronics to read them out. The cornerstone of the NSW's electronics system is the VMM Application-Specific Integrated Circuit (ASIC) [1,2], which connects to the detector readout elements to provide trigger and tracking data to ATLAS



VMM3a – A Tracking & Triggering Solution in a Single Chip



The VMM can be used for **Triggering**. Upon the detection of a peak that crosses the user-defined threshold, the chip:

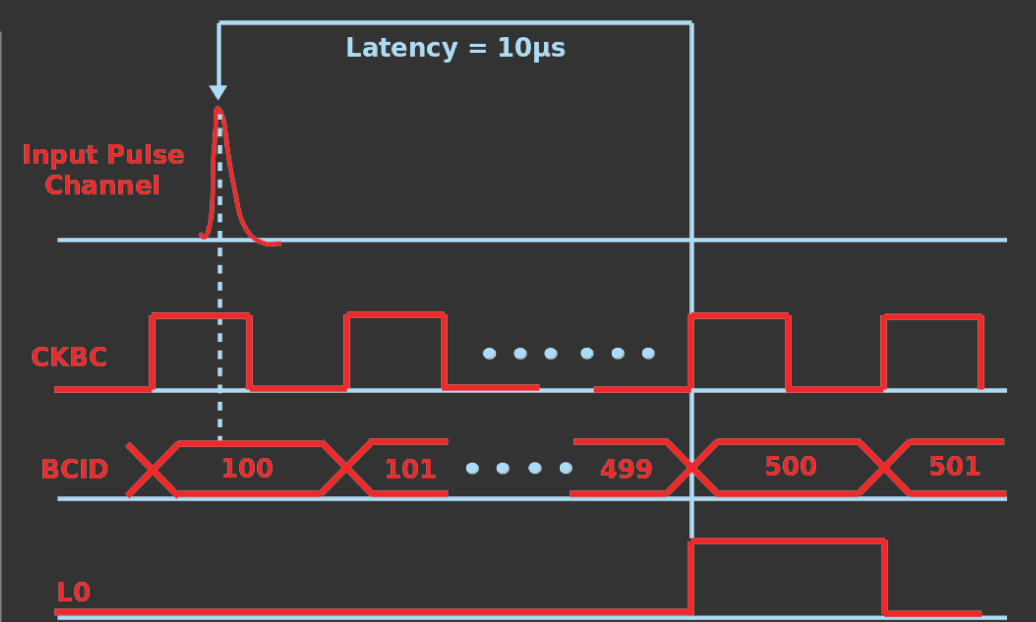
- Sends the address of the channel that the pulse was detected on to the trigger-aggregating electronics (Address-In-Real Time or ART, used by MM)
- Sends a coarse but rapid measurement of the amplitude encoded by its 6-bit ADC to the trigger-aggregating electronics (6bADC, used by sTGC)
- Sends a single-bit Time-over-Threshold signal to the trigger-aggregating electronics (ToT, used by sTGC)

The VMM can be used for **Tracking**. Upon the detection of a peak that crosses the user-defined threshold, the channel:

- Measures the timing of the pulse with <1ns accuracy and encodes it in an 8-bit word through its Time-to-Amplitude Converter (TDO)
- Measures the amplitude of the pulse with <1fC accuracy and encodes it in a 10-bit word through its peak detector (PDO)
- Tags the event with the BC counter value (BCID)
- Is ready to register another event after ~250ns

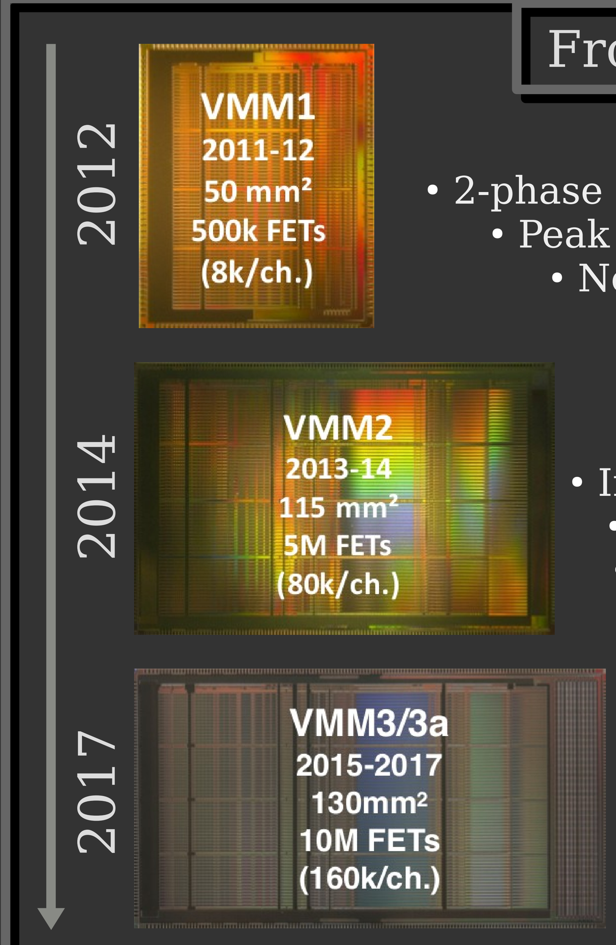
Developed in Brookhaven National Laboratory and designed to serve both NSW detector technologies, the VMM is a radiation-tolerant, mixed-signal ASIC packaged in a Ball Grid Array with outline dimensions of 21x21mm^2. The chip is comprised of 64 discrete channels. Each channel connects to a detector readout element and performs charge amplification, discrimination and precise amplitude and timing measurements through Analog-to-Digital Converters (ADCs). It also provides trigger data with a very low latency. Its fourth prototype, dubbed VMM3a, will soon be deployed in ATLAS. With the ASIC's support, the NSW will provide trigger primitives to ATLAS with a precision of ~2mrad and reconstruct muon tracks with a spatial resolution of ~100μm

The channel data get stored in the VMM's Level-0 (L0) buffers. The L0 selection logic applies a pre-defined latency to the input L0 trigger, that allows for the VMM to "look back in time" and select only muon-related data to forward out. The readout of the tracking data is performed by another device that extracts the data with an effective rate of 512Mbps via two data lines (DATA0/1)



The VMM is compliant with a L0 latency of 10μs and a L0 rate of 1MHz for Phase-II, for a worst case scenario rate of 20 kHz/cm^2

From VMM1 to VMM3a



- Mixed-signal
- 2-phase readout with external ADC
- Peak and timing information
- Neighbouring readout

↓ +

- Continuous readout
- Increased range of CA gains
- Three ADCs per channel
- Digital logic with FIFOs

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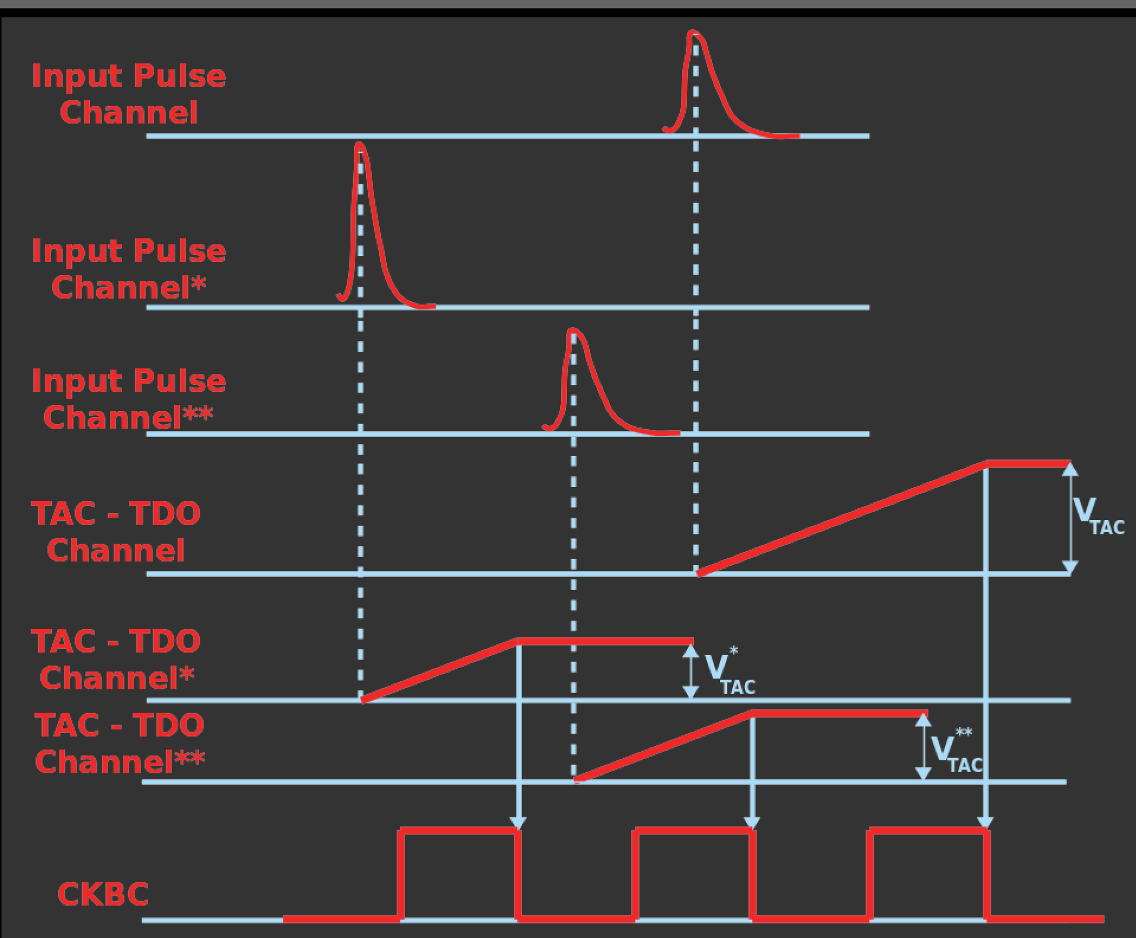
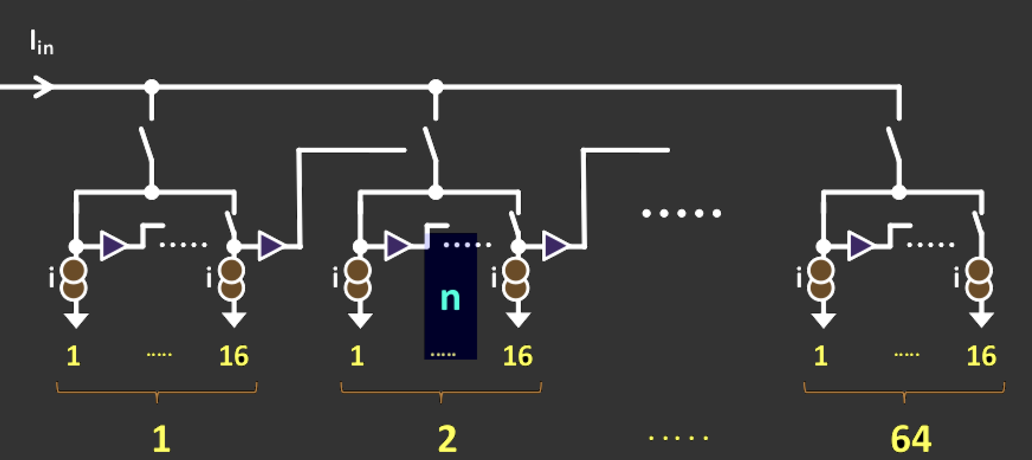
- ATLAS L0 readout
- SEU protection
- ADC optimizations
- Timing ramp optimization



The channel's peak detector measures the pulse's amplitude, while the Time-to-Amplitude Converter (TAC) measures the timing of the pulse by using a voltage ramp that triggers on the pulse's peak (or at the threshold crossing) and halts on the next falling edge of the BC clock (see figure on the left). The two voltages are digitized by a set of innovative low-power ADCs [3]. The ADC data alongside the channel ID and the pulse's BCID tag are then stored in the VMM's L0 buffers



References / Further Reading:
[1] *VMM1 - An ASIC for Micropattern Detectors.* G. De Geronimo et al., IEEE Transactions on Nuclear Science (Vol 60, Issue: 3, June 2013)
[2] *VMM3, An ASIC for Micropattern Detectors.* G. Iakovidis, MPGD 2017, ATL-MUON-PROC-2018-003, 22 March 2018
[3] *ASIC for Small Angle Neutron Scattering Experiments at the SNS.* G. De Geronimo et al., IEEE Transactions on Nuclear Science (Volume: 54, Issue: 3, June 2007)

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