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Introduction

Dr. De Geronimo develops state-of-the-art low-noise integrated circuits (Application-Specific Integrated Circuits, ASICs) for radiation detectors for medical, safety, security, space, defense, industrial, and physics applications.

Advantages of low-noise ASICs include optimized analog electronics to achieve the highest possible resolution (both charge and timing measurements), very low power dissipation, very high functionality, capability of integrating a very large number of electronic channels in a very small physical size, and a very low production cost.

Dr. De Geronimo collaborates with various research institutions and industries worldwide, and his circuits frequently implement innovative solutions, have generated numerous scientific publications and patents, and have frequently achieved record performance. Some of his developments are designed to operate in extreme environments.

Along with actively designing ASICs, Dr. De Geronimo teaches an advanced graduate course on low-noise design and mentors engineers and students.

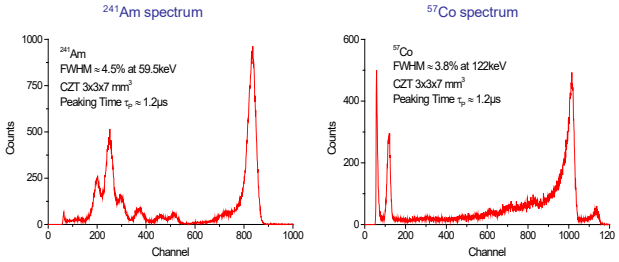
This document contains a list of Dr. De Geronimo's relevant front-end ASIC designs developed while employee of Brookhaven National Laboratory (1997-2016), and currently being used in a variety of research and commercial instruments.

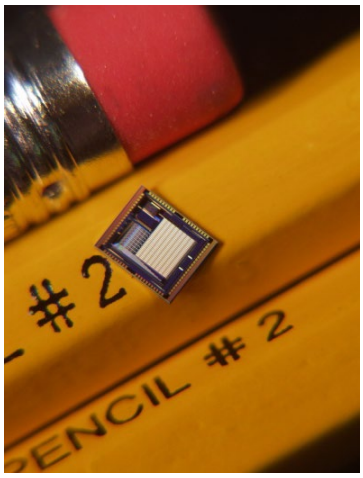
For his ASIC developments after 2016, please see https://www.dgcircuits.com/latest.

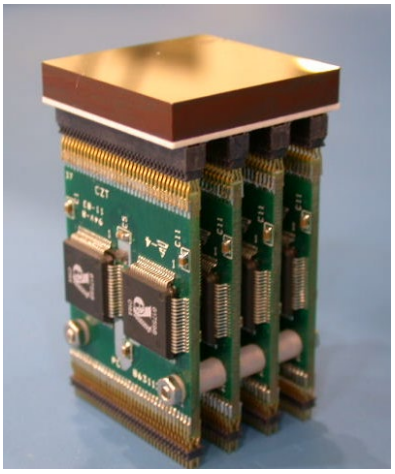
Analog ASICs for EZ-Scope from NucleMed Gamma Camera and Lunar Bone Densitometer from GE

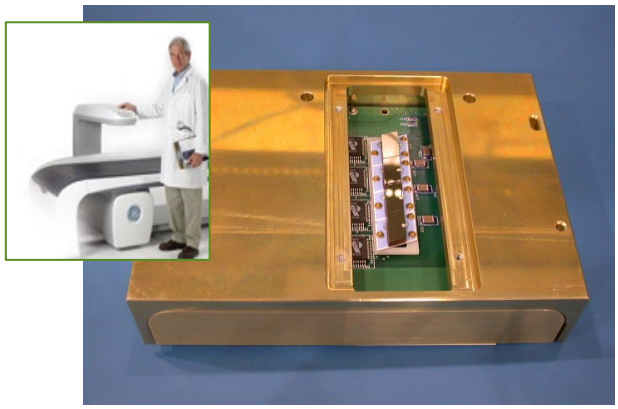
This generation of ASICs has been developed in collaboration with eV Products (now Kromek), an industry leader in the fabrication of CdZnTe detectors. Each channel is equipped with a low-noise charge amplifier with programmable gain, shaper with programmable peaking time, and driver [1].

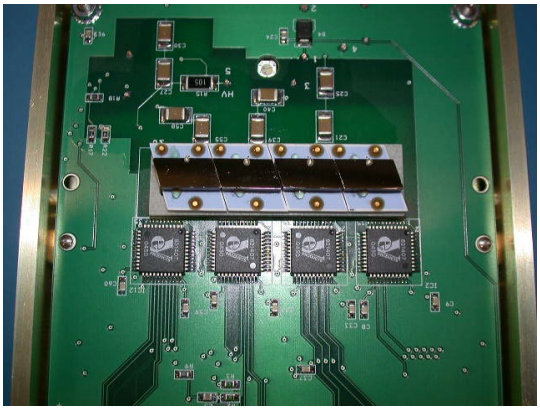
ASIC	Pixel capacitance [pF]	Channel count	Peaking time [µs]	Gain [mV/fC]	Power / channel [mW]	ENC [rms. e⁻]	Applications
General purpose	3	16	0.6, 1.2, 2.0, 4.0	30, 50, 100, 200	18	30+20/pF	*LFOV Gamma Camera SFOV Gamma Camera Nuclear Safeguards*
Medium speed	3	4	0.4	200	18	29+27/pF	*Down Hole Well Logging X-Ray Diffraction Gauges*
High speed bipolar	3	8	0.2	240	18	42+44/pF	*Bone Densitometry Pulse Mode CT Industrial X-Ray*
High capacitance	12	8	0.6, 1.2, 2.0, 4.0	30, 50, 100, 200	35	57+10/pF	*Industrial Strip Detectors Backscatter Gauges Large Area Detector*









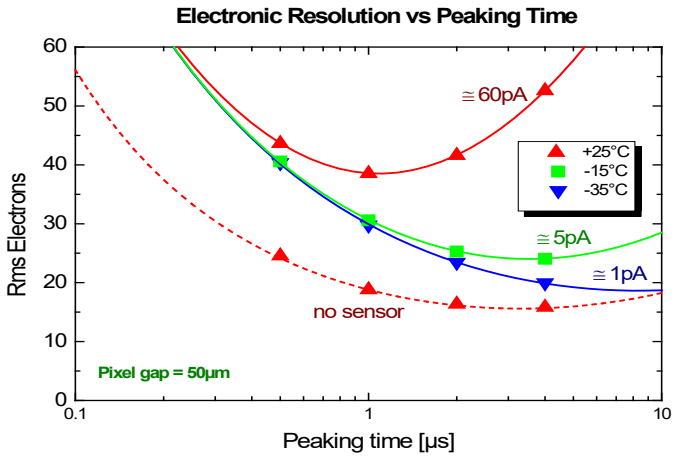


The 16-channel version has been integrated in the commercial gamma camera EZ-Scope from NuclemMed, composed of 128 CdZnTe pixels.

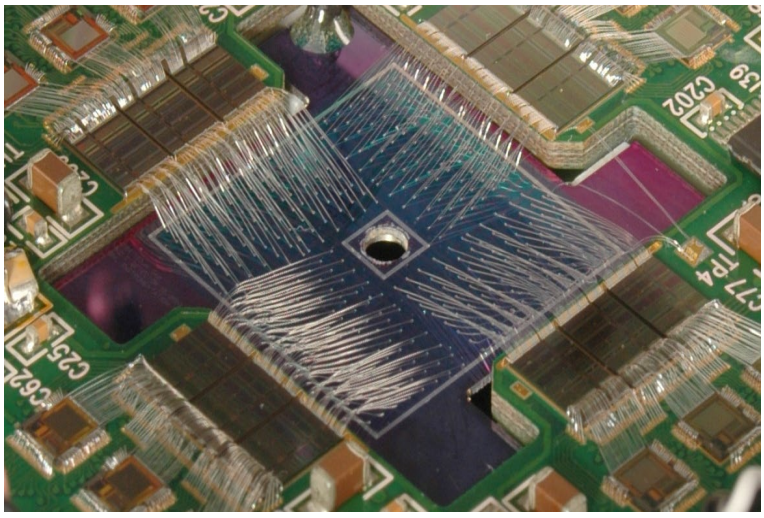
The 8-channel version, which integrates a fast bipolar shaper, is used in the commercial Lunar Bone Densitometer from GE.

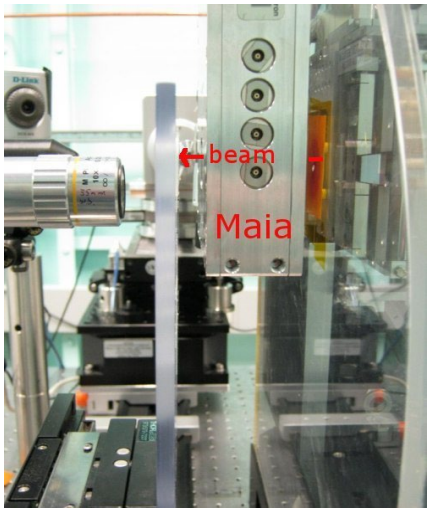
ASIC for Very-High-Resolution Silicon Pixels for Industrial Applications and Physics Research

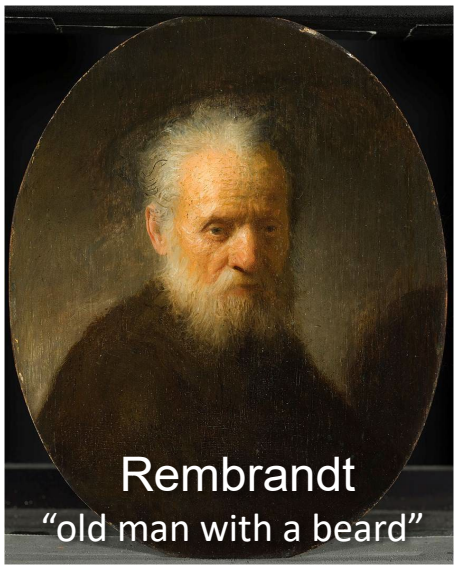
Originally developed for the National Synchrotron Light Source (NSLS), this mixed-signal ASIC integrates 32 low-noise channels and it is capable of performing photon counting and spectral measurements [2].

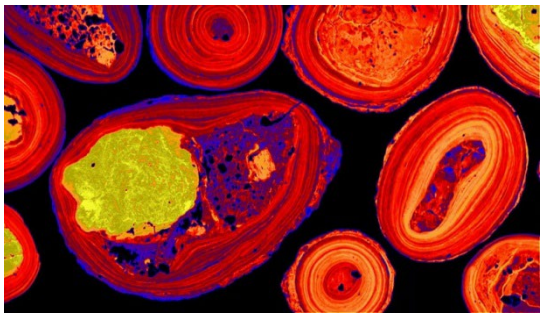


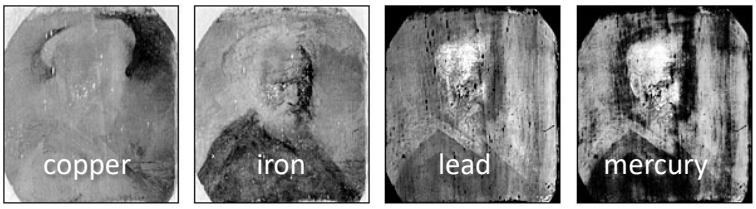
Each channel implements very low-noise preamplification stage with self-adaptive continuous reset, high-order shaper with programmable gain and peaking time, leakage current monitor, bandgap referenced baseline stabilizer, threshold comparator feeding a 24-bit counter, and direct analog output. It is frequently used with the Peak Detector and Derandomizer ASIC described later in this document.

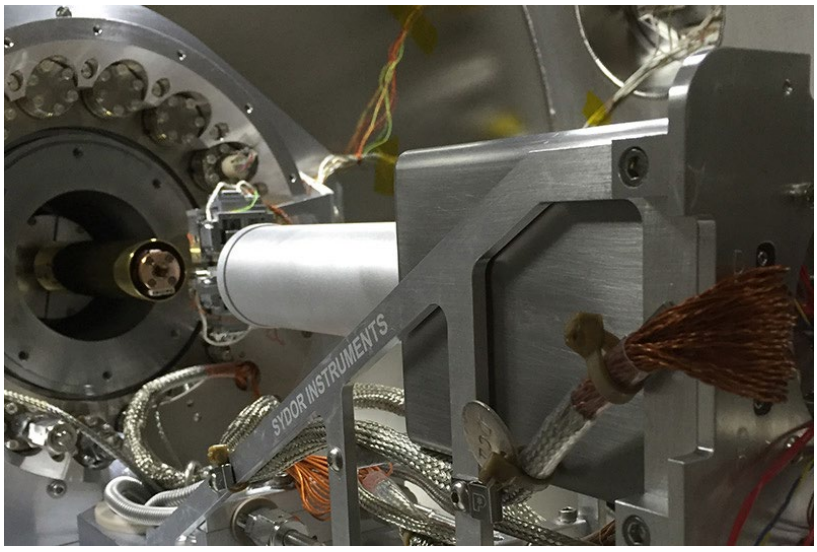








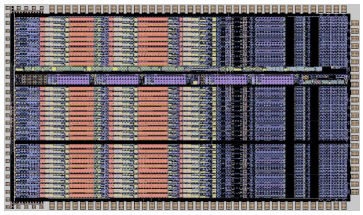




The ASIC has been integrated in various detectors among which the R&D 100 award winning MAIA x-ray imaging microprobe [3], used for material analysis (examples in picture above). It has also been also integrated in commercial instruments from Sydor Technologies and FCT International.

ASIC for Gamma-Ray Medical Imagers

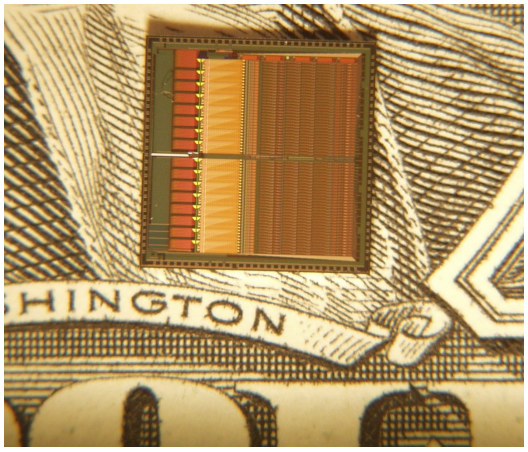
This ASIC is an evolution of the previous one, with front-end, gain, and peaking time optimized for indirect conversion Gamma-ray pixels based on scintillators and Silicon sensors.

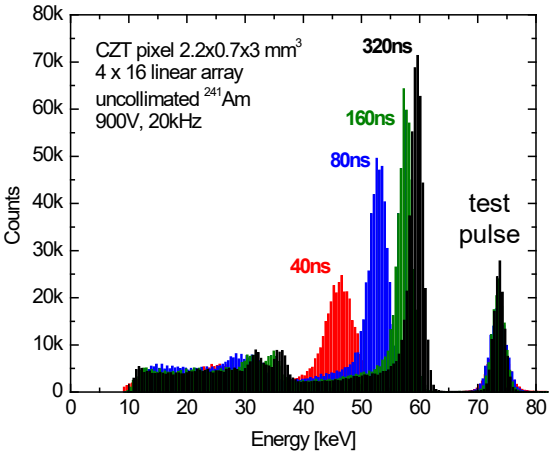


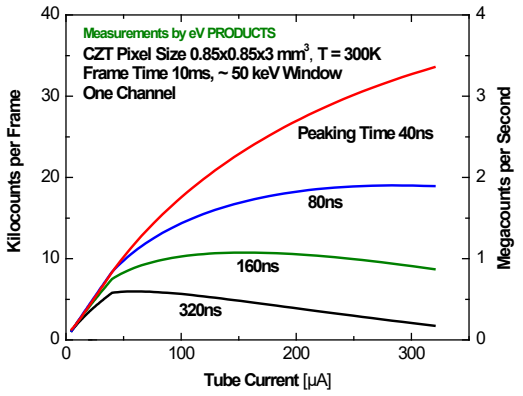
It is integrated in the Gamma-ray SPECT medical imagers commercialized by Digirad Corporation.

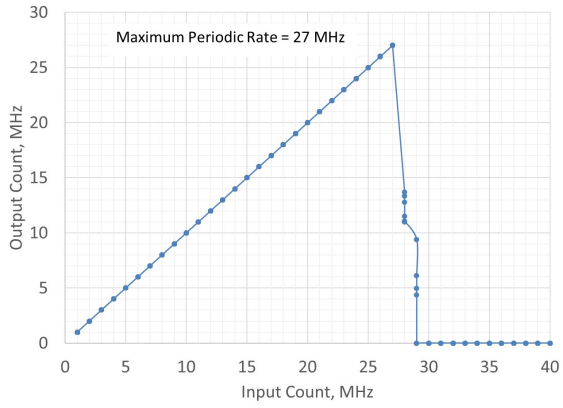
ASIC for Very High Rate Photon Counting Detectors For Medical, Security and Research Applications

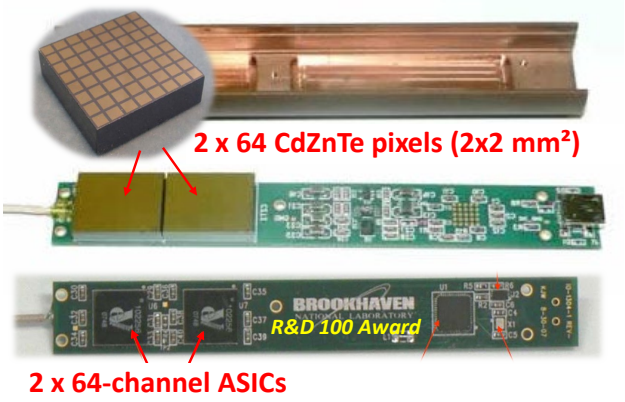
Developed in collaboration with eV Products (now Kromek) for operation with CdZnTe strips and pixels, this ASIC is composed of 64 channels with low-noise charge preamplification, fast high-order shaper (40 ns minimum peaking time), and five window-discriminators with associated 16-bit counters. An efficient readout scheme allows simultaneous measurement and readout through a 60 MHz 16-bit fully differential output bus [4].



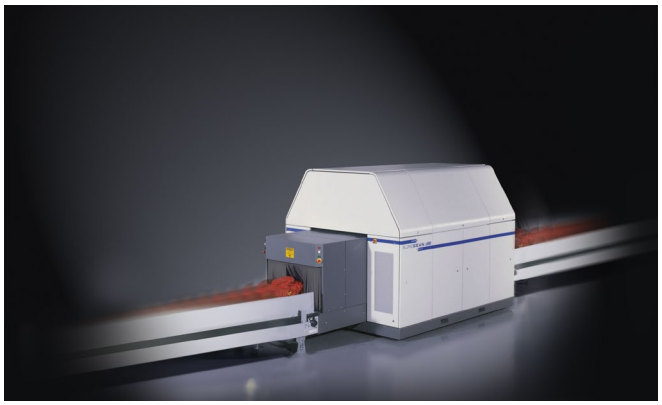


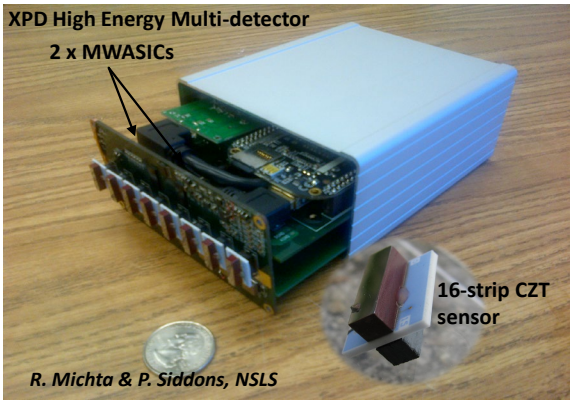






The ASIC has been adopted for the development of the ProxiScan compact gamma camera suited for high-resolution imaging of prostate cancer.

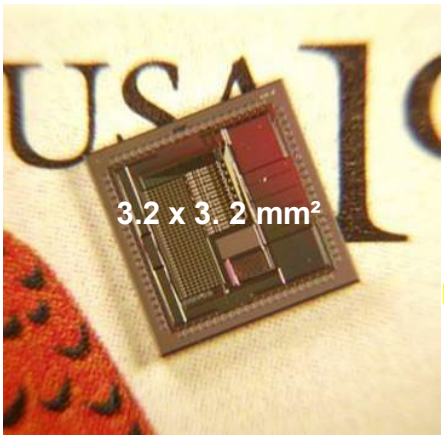


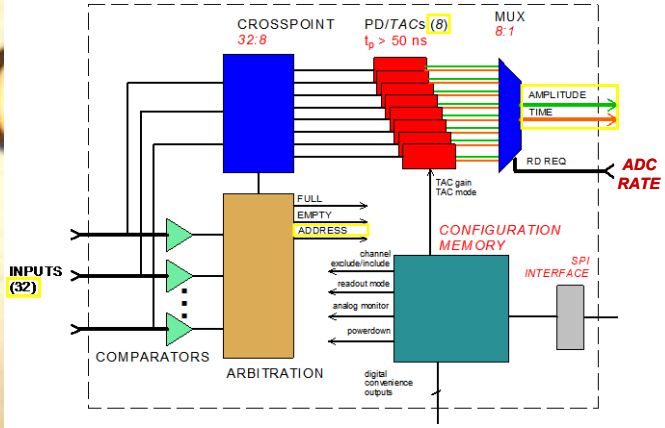


It is also used in airport security instrument such as commercial baggage scanners from SureScan and in research instruments for light source applications. A versions modified for higher rate capability has been adopted by General Electric Global Research.

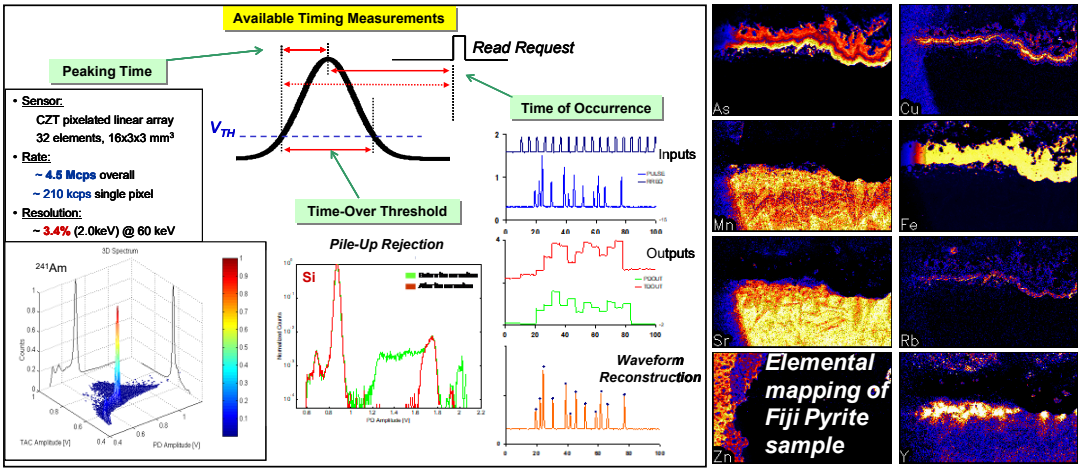
General Purpose Signal Processing ASIC for Silicon and CdZnTe Detectors

This versatile ASIC provides 32 channels of accurate high-rate pulse processing, offering a dramatic reduction in data volume through the use of analog techniques (precision peak detectors and time-to-amplitude converters) together with fast arbitration and sequencing logic to concentrate the data before digitization. In operation the circuit functions like a data-driven analog first-in, first-out (FIFO) memory between the preamplifiers and the ADC. Peak amplitudes of pulses arriving at any one of the 32 inputs are sampled, stored, and queued for readout and digitization through a single output port. Hit timing, pulse risetime, and channel address are also available at the output [5,6].





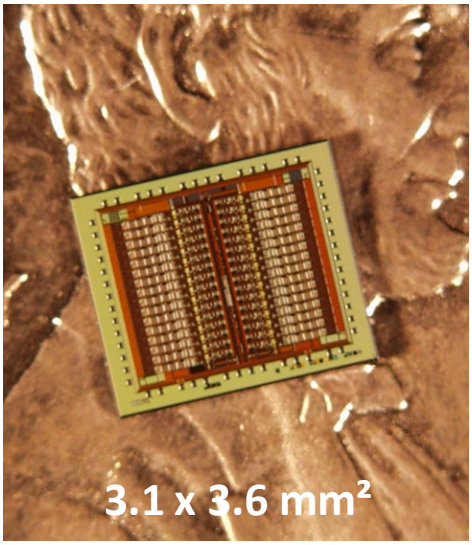
It is based on an analog CMOS peak detect and hold circuit, which combines high speed and accuracy, rail-to-rail sensing and driving, low power, and buffering. The configuration cancels the major error sources of the classical CMOS peak detectors, including offset and common mode gain, by re-using the same amplifier for tracking, peak sensing, and output buffering.

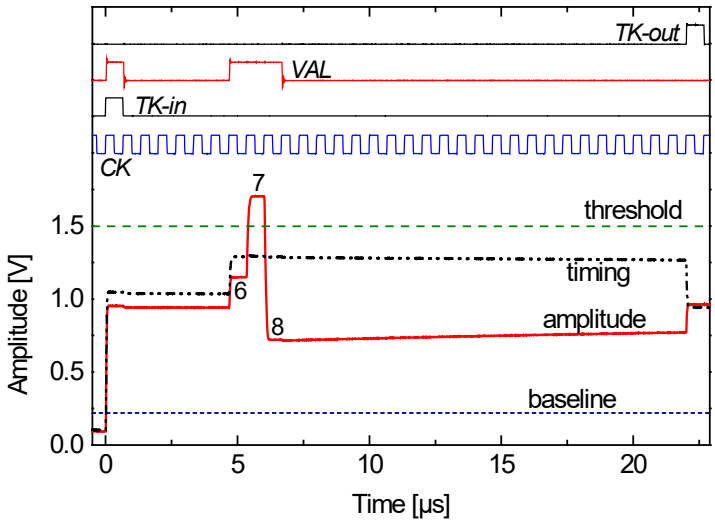


Frequently used as companion of analog front-end ASICs, it has also been developed as a self-consistent instrument with embedded MCA capabilities, replacing the equivalent of 32 MCA channels.

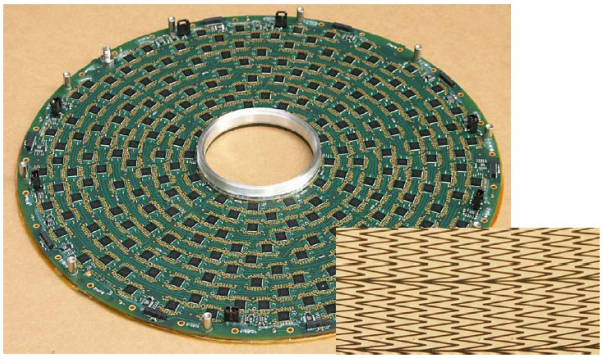
ASIC for Time-Projection Chambers

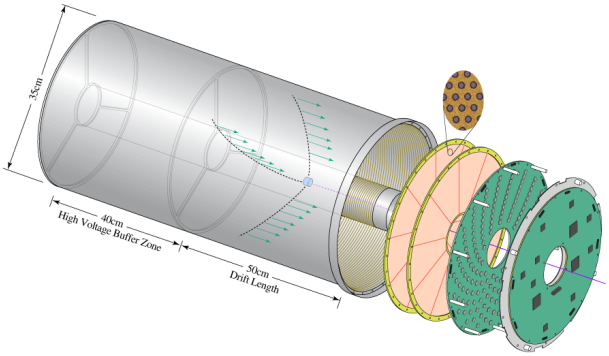
This ASIC integrates 32 channels. Each channel implements a low noise charge preamplifier with continuous reset of new concept, shaping amplifier with bandgap referenced baseline stabilizer, single threshold discriminator, dual-phase peak detector, timing detector, and logic for neighbor enabling including inter-chip communication. The readout process is based on token passing and flag [7].





It has been developed for use in a time projection chamber composed of a can and a single-ended, dual-stage gas electron multiplier, with associated anode plane pixellated into about 8000 pads.

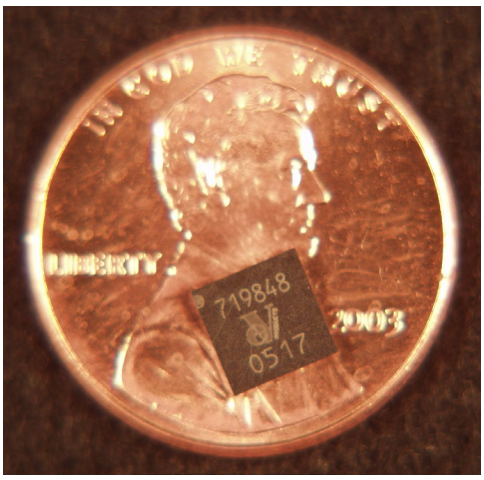


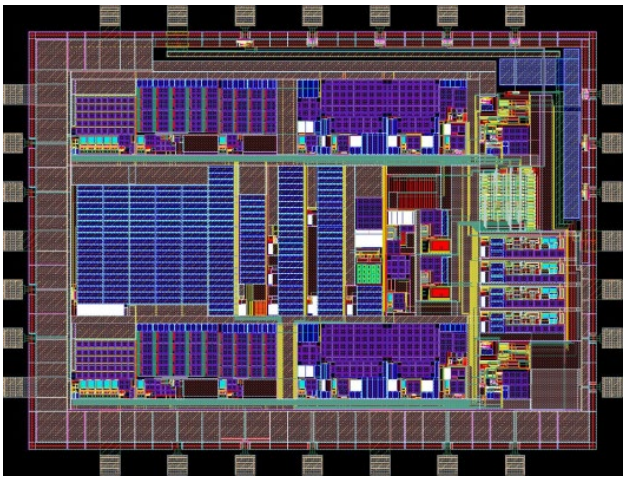


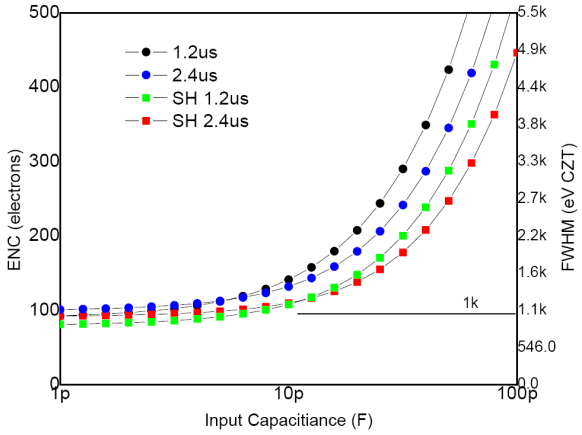
The front-end electronics provides energy, timing, and address information from those pads involved in measuring each track. For center of gravity determination this information must be sampled from the above-threshold pad and from the two adjacent ones.

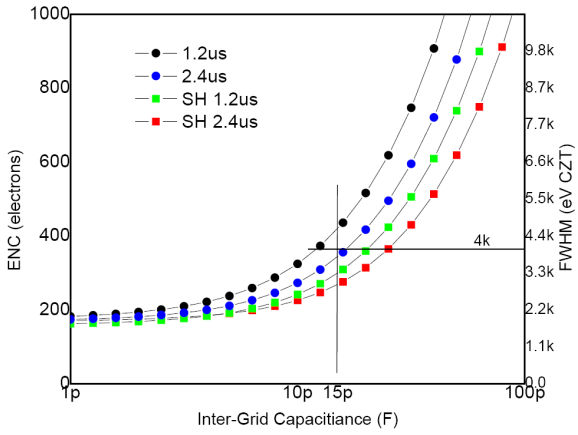
ASICs for Co-Planar Grid Detectors for Security Applications

By using a calibrated difference of two inter-digitized grids, the coplanar-grid (CPG) approach allows to achieve a relatively high resolution in large solid-state crystals (e.g. CdZnTe). I developed a generation of 2- and 3-channels front-end ASICs optimized for CPG sensor [8,9].

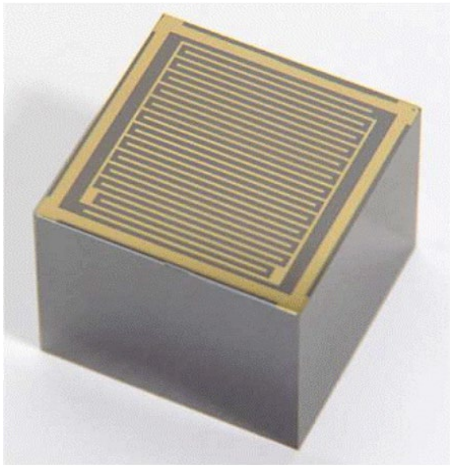


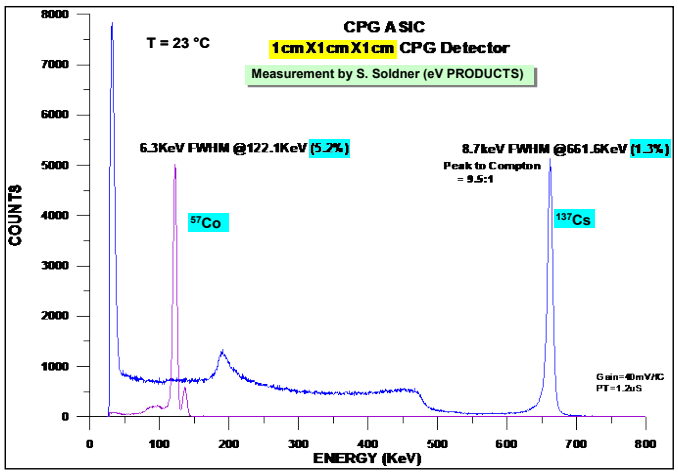


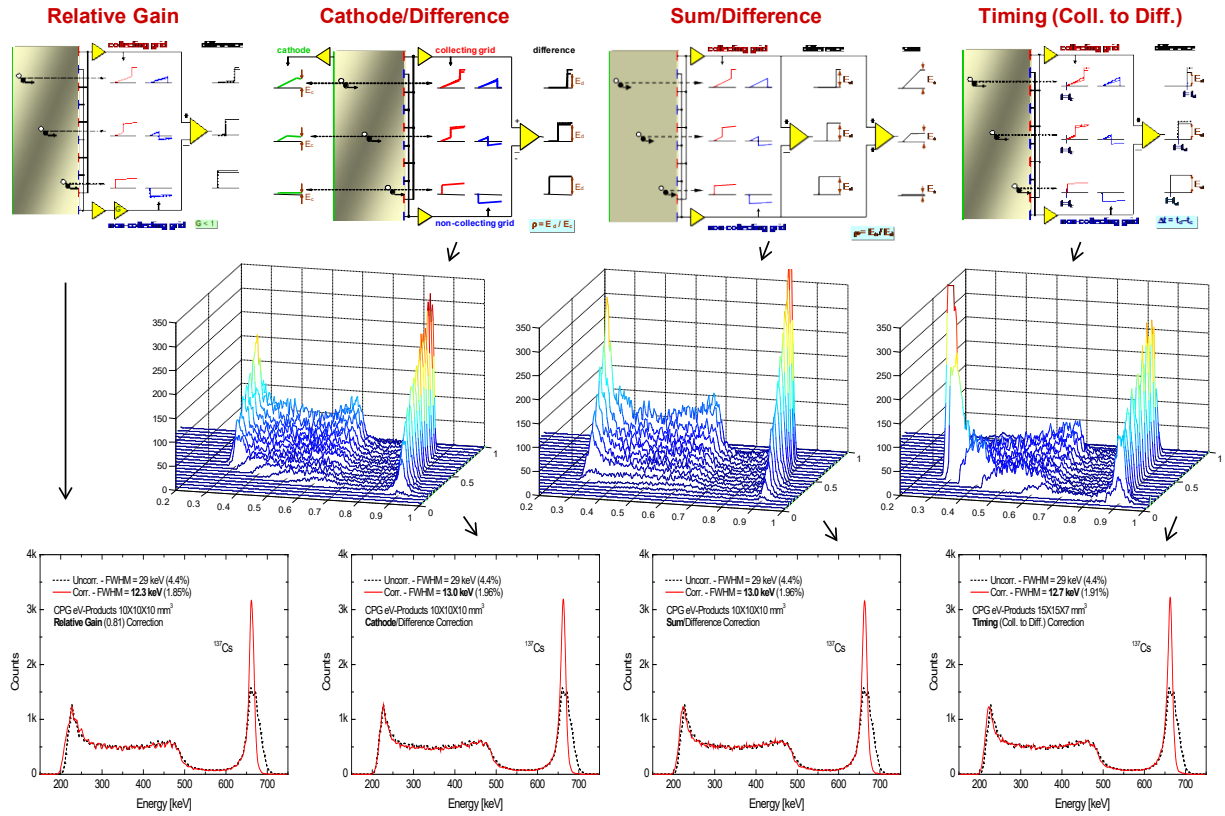




The ASICs read out signals from the two grids (with programmable relative gain) and, depending on the version, also from the cathode signal. They can also measure the relative timing and the sums. One version integrates peak detectors thus minimizing the processing requirements on the downstream electronics. The ASICs are fully programmable and can also operate in dual-independent channel mode.

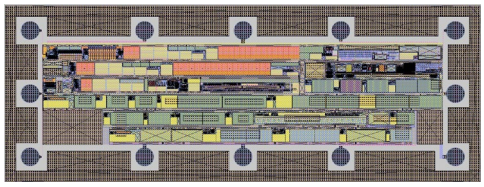






With these ASICs the CPGs can be read out using different approaches. The classical consists of using the relative gain. The cathode/difference allows for digital correction by using the cathode amplitude for depth correction. The sum/difference also allows digital correction with the remarkable advantage of not requiring the high-voltage cathode connection. The timing approach for digital correction, alternative to amplitude, can be applied to either the cathode or the sum signal.

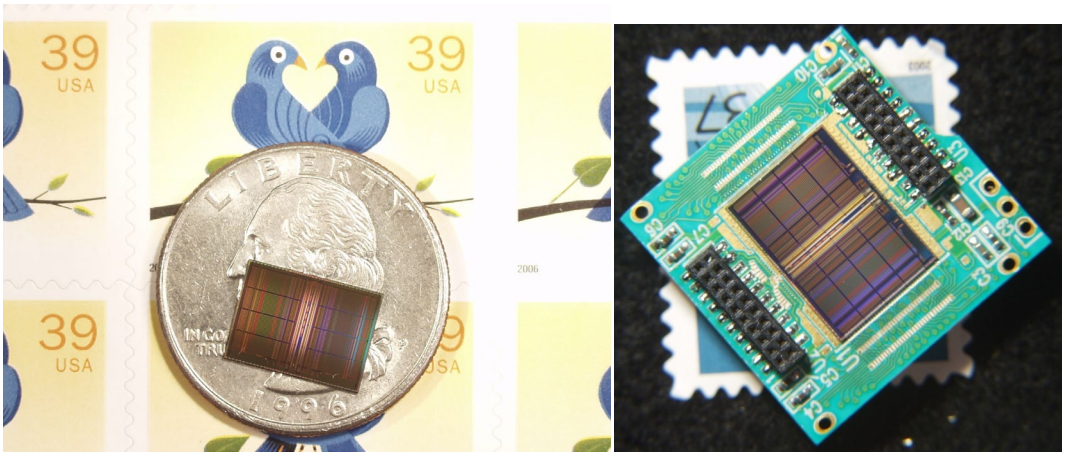
ASIC for Disposable Medical Gamma Probe

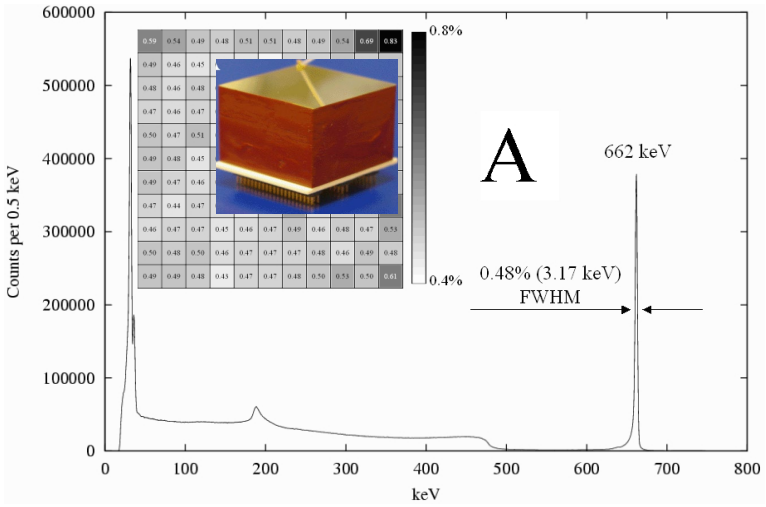


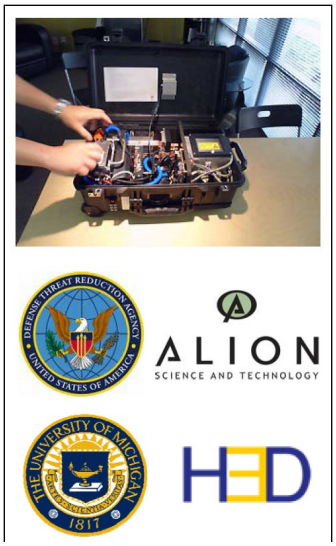
With a very small size of 3 x 1.1 mm², wire- and bump-bondable, this single channel ASIC provides low-noise charge amplification, shaping, discrimination, peak detection and leakage monitoring. It is extensively programmable and implements a smart single-pin interface. It is used in the TruNode disposable medical gamma probe commercialized by Faxitron.

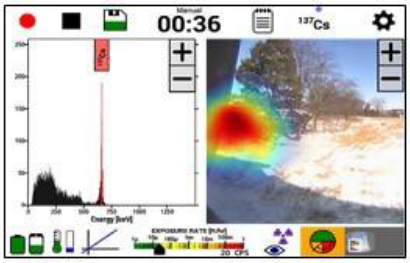
ASIC for High-Resolution 3D Position Sensitive Gamma Ray Imagers for Security Applications

Developed in collaboration with Dr. He of the University of Michigan for his position-sensitive detectors, this ASIC is designed to operate with pixelated wide bandgap sensors like CdZnTe, CdTe, HgI2, and TlBr. It measures the amplitudes and timings associated with an ionizing event on 128 anodes, the anode grid, and the cathode. Each channel provides low noise charge amplification, high-order shaping with peaking time adjustable from 250 ns to 12 µs, gain adjustable to 20 mV/fC or 120 mV/fC (for a dynamic range of 3.2 MeV and 530 keV in CZT), amplitude discrimination with 5-bit trimming, and positive and negative peak and timing detections. The readout can be full or sparse, based on a flag and single- or multi-cycle token passing. All channels, triggered channels only, or triggered with neighbors can be read out thus increasing the rate capability of the system to more than 10 kcps. The ASIC dissipates 330 mW which corresponds to about 2.5 mW per channel [10,11].





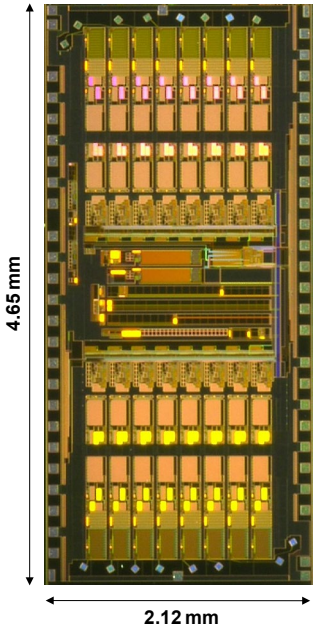


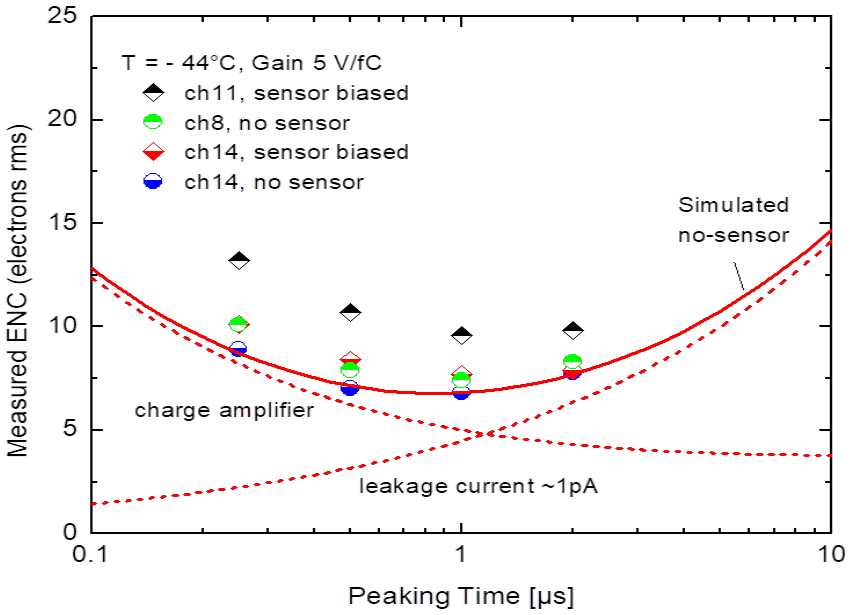


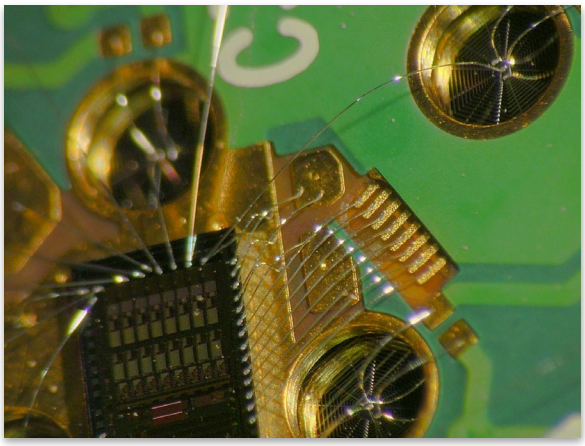
The ASIC exists in different version and for both wire- and bump-bond assembly. It has been adopted by the US Department of Defense and it is used in numerous instruments commercialized by H3D Inc. and eV Products (Kromek).

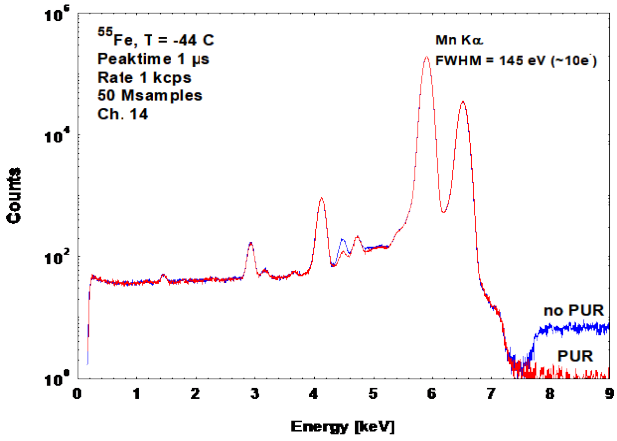
ASIC for Very-High-Resolution X-Ray Imagers for Space Applications

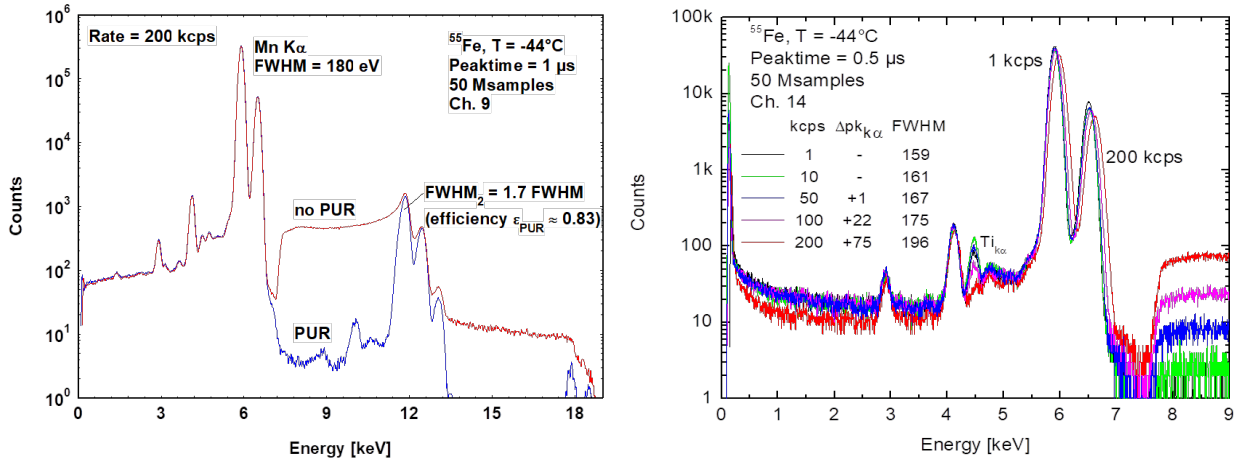
Developed in collaboration with NASA for use in space missions, this ASIC has operates with pixelated silicon drift detectors. The fully programmable ASIC provides 16 channels of low-noise charge amplification, high-order shaping with baseline stabilization, discrimination, peak detection with analog memory, and pile-up rejection. The readout is sparse and based on low voltage differential signaling. The channel dissipates 1.6 mW [12,13].







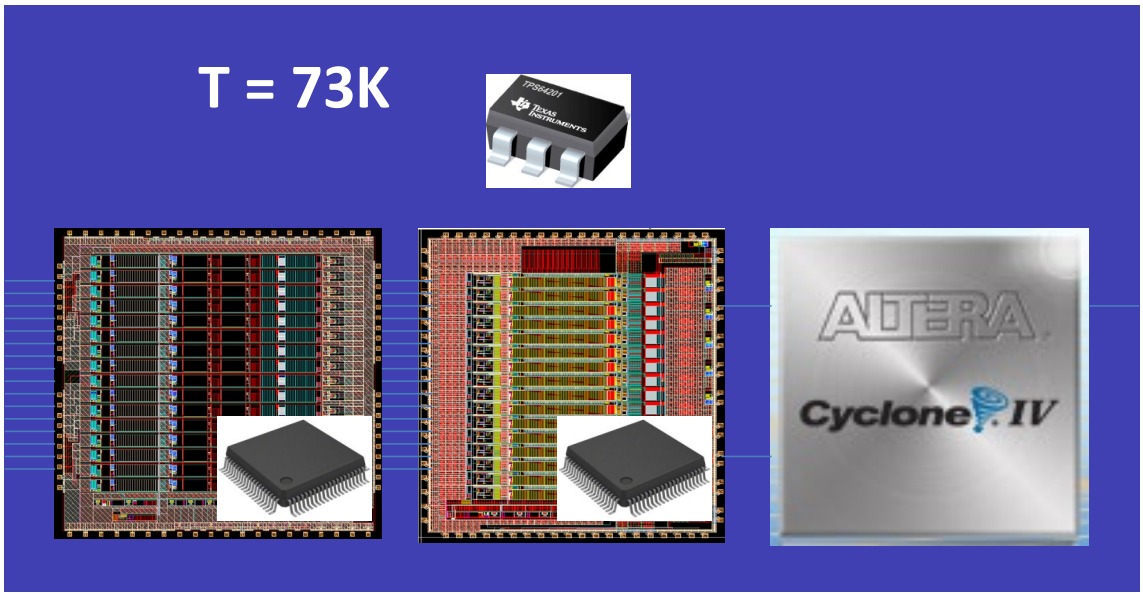


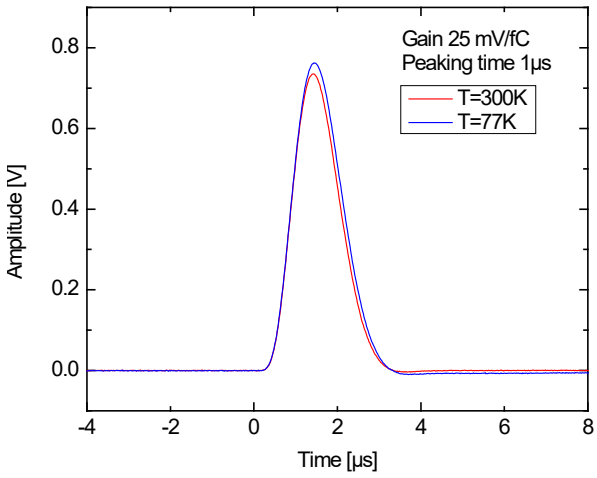


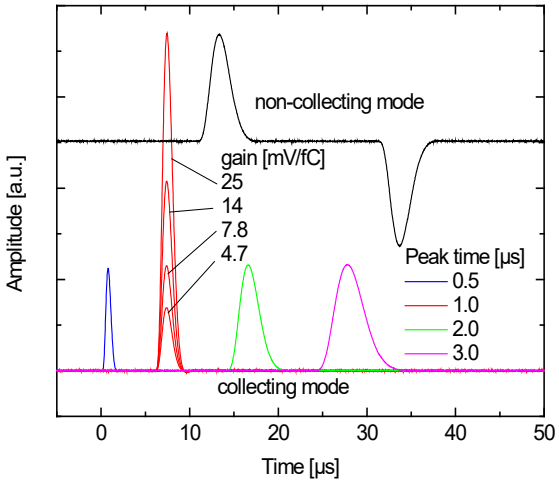
A unit of 64 SDD pixels has been built, read out by four ASICs, covers an area of 12.8 mm² and dissipates with the sensor biased about 15 mW/cm². With a resolution better than 10 rms electrons, can measure show a FWHM of 145 eV at the 5.9 keV peak of a 55^{Fe} source, and less than 80 eV on a test-pulse line at 200 eV.

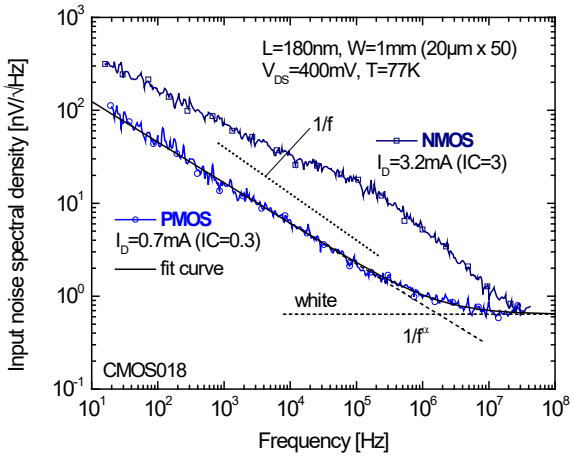
ASICs and Electronics for Cryogenic Detectors

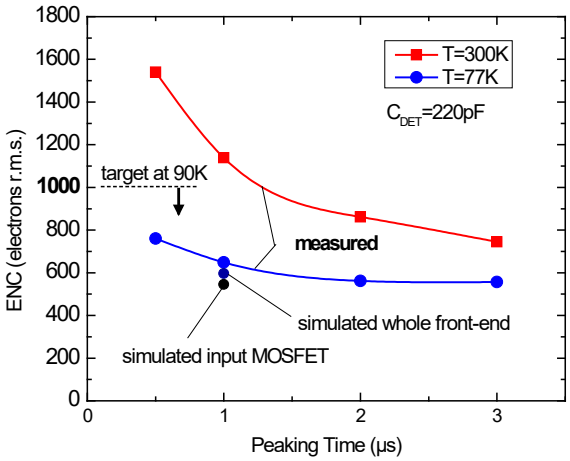
This family of ASICs is capable of operating over a very wide temperature range, from room down to 70K (-200C) with a lifetime in excess of 30 years. It has been developed for use with liquid Argon time-projection chambers in physics experiments. One ASIC provides programmable analog low-noise amplification and filtering, another companion ASIC provides sampling, analog-to-digital conversion (2MS/s, 12-bit) and multiplexing [14].







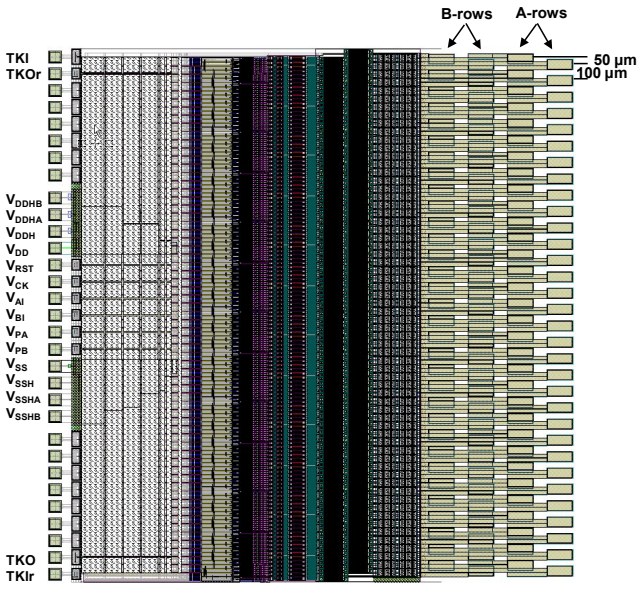


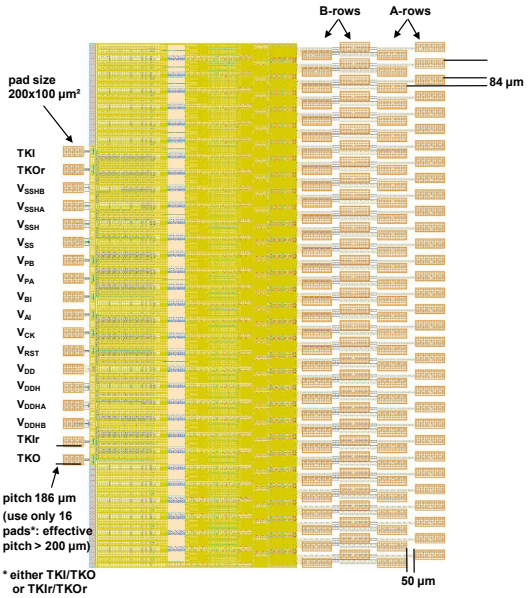


The developments have been accompanied by extensive noise and lifetime studies and modeling, and it has included commercial active and passive components and FPGAs.

High-Voltage Matrix Switching ASIC

Developed for the NSLS, this family of ASICs is designed to sequentially activate rows for the readout of pseudo-pixel detectors. The fast differential outputs can provide fast switching of lines with up to +/- 40V.

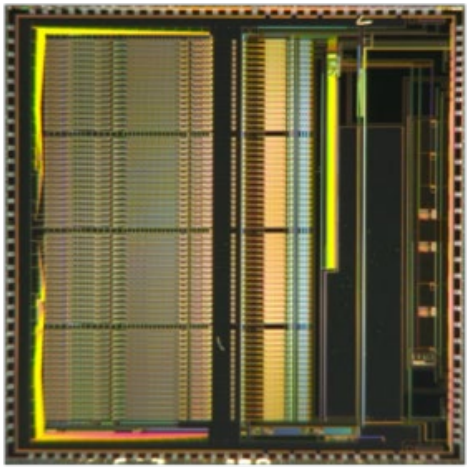


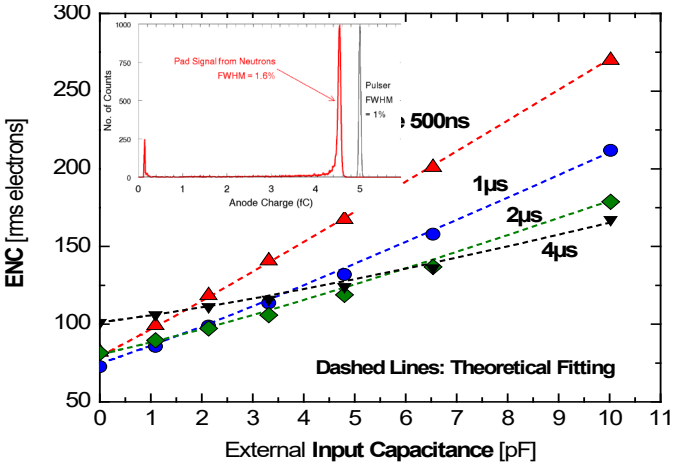


The ASICs can be cascaded in sequence using a token-passing scheme. Exist in versions with different pitch and channel number.

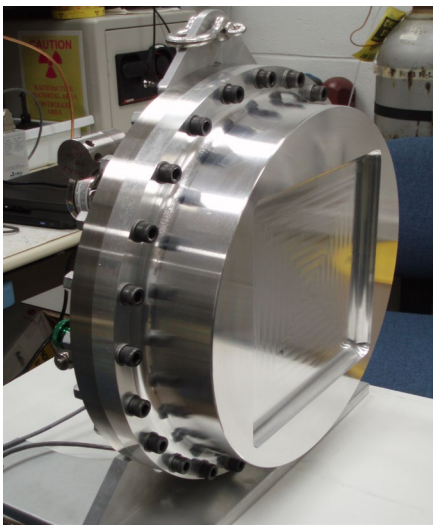
ASIC for Neutron Detectors for Security and Research Applications

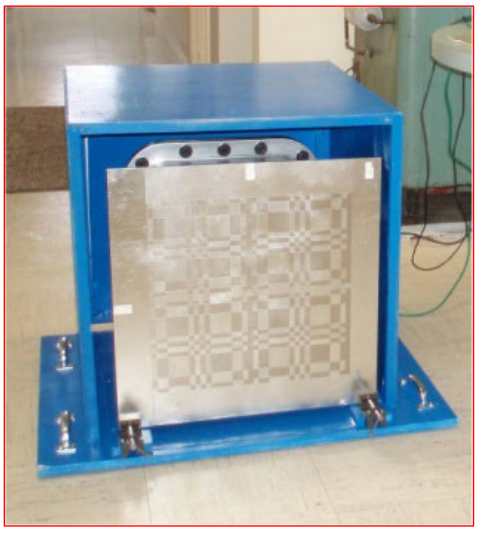
This ASIC has been developed for use in a neutron detector based on 3He gas. It is composed of 64 channels with low noise charge amplification, filtering, timing and amplitude measurement circuits, where an innovative current-mode peak-detector and digitizer (PDAD) is adopted.





The PDAD provides at the same time peak detection and A/D conversion in real time, at low power, and without requiring a clock signal. The channels share an efficient data sparsification and derandomization scheme, a 30-bit 256 deep FIFO, and low voltage differential signaling. can be cascaded in sequence using a token-passing scheme. Exist in versions with different pitch and channel number [15].

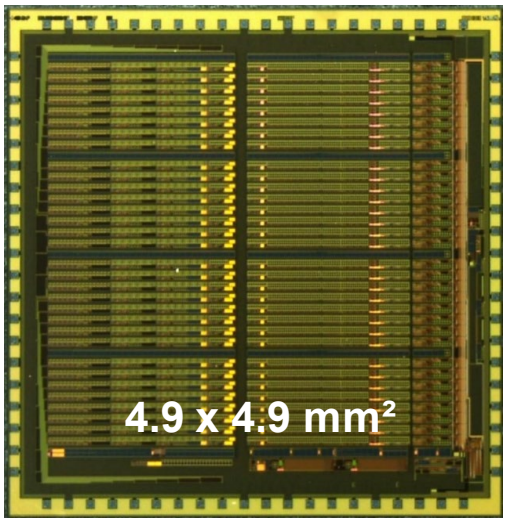


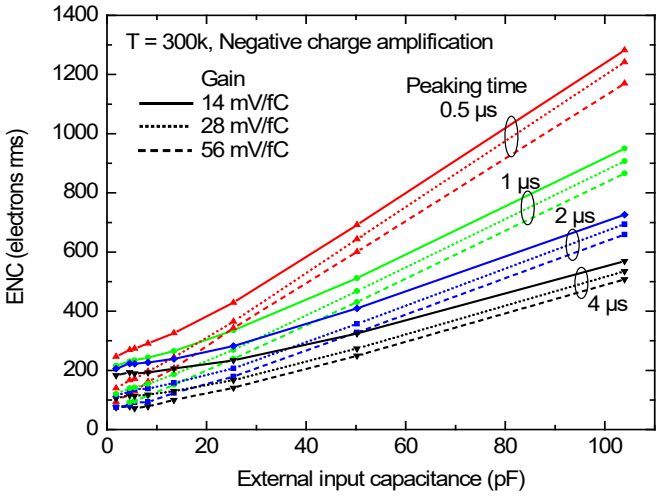


The detector is used in small-angle neutron scattering physics experiments and, with the addition of coded aperture masks, in instruments for national security.

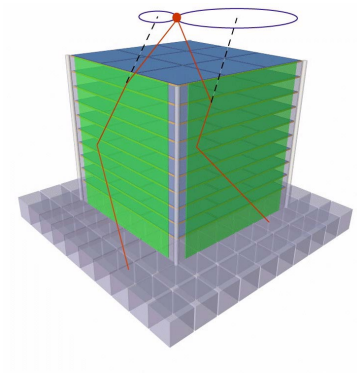
General Purpose Front-End ASIC for Silicon and CdZnTe Detectors for Security and Space Applications

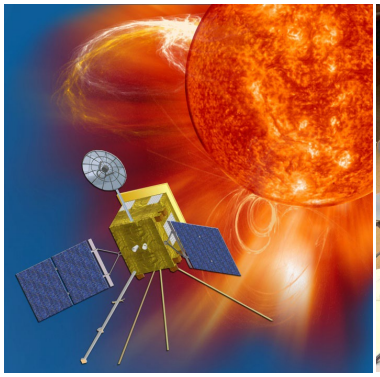
Originally developed for a Silicon Compton telescope, this ASIC has been also used for various other detectors and applications. Composed of 32 channels, it reads out signals in both polarities from each side of a Silicon strip sensor, 2 mm thick 27 cm long, characterized by a strip capacitance of 30 pF. Each front-end channel provides low-noise charge amplification, shaping with a stabilized baseline, discrimination, and peak detection with an analog memory. The channels can process events simultaneously, and the read out is sparsified [16,17].

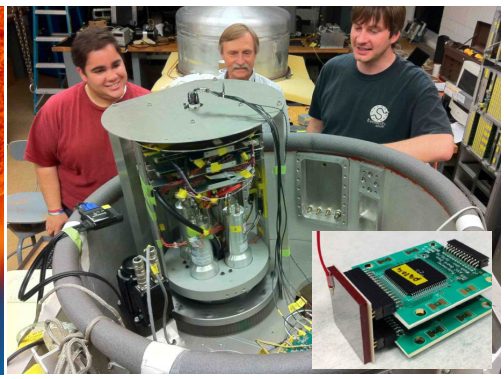




Besides silicon, this ASIC has been adopted read out signals from CdZnTe and Germanium sensors. It has been integrated by South West Research Institute in a space instrument for NASA, and by Washington University in St. Louis in a balloon borne hard X-ray polarimeter.



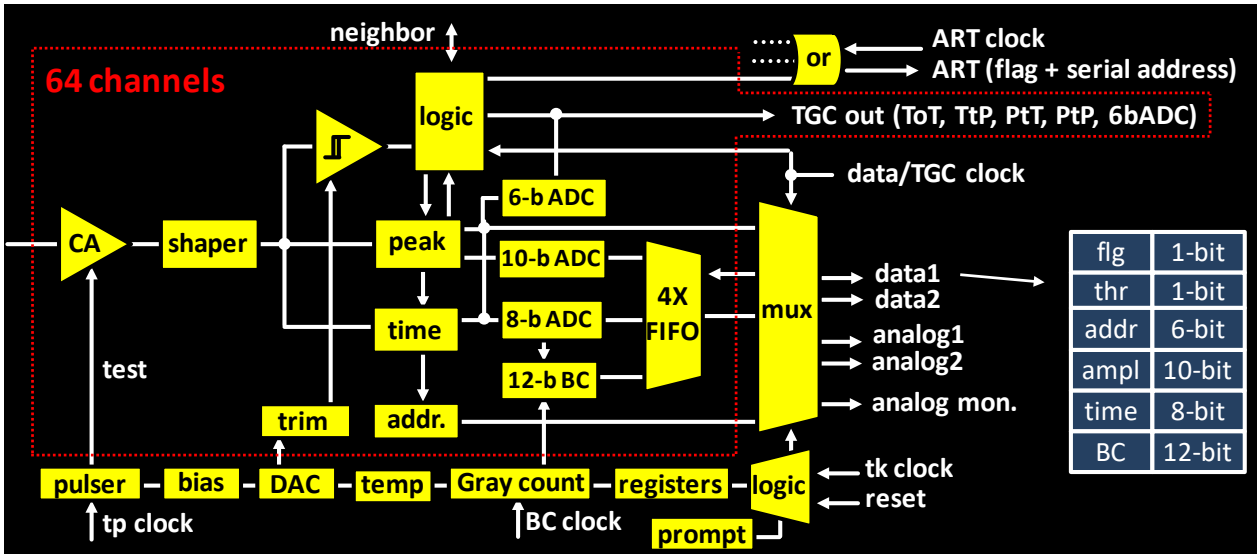




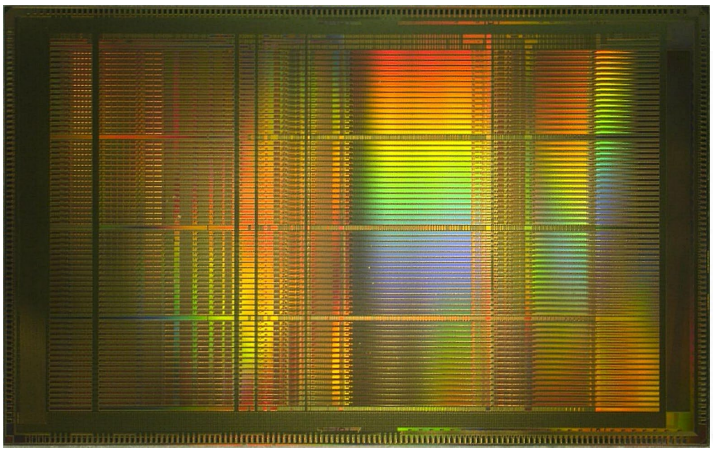
An evolution of this ASIC with improved dynamic range and timing measurement capability has been developed in collaboration with Naval Research Laboratory for a NASA instrument.

Very High Functionality Front-End ASIC for Strip Detectors

Called by CERN the "Swiss-knife of ASICs" for its very high versatility and functionality, this ASIC has been developed for use in the ATLAS Muon detector. It serves different detector technologies with capacitance ranging from few pF to some nF [18].



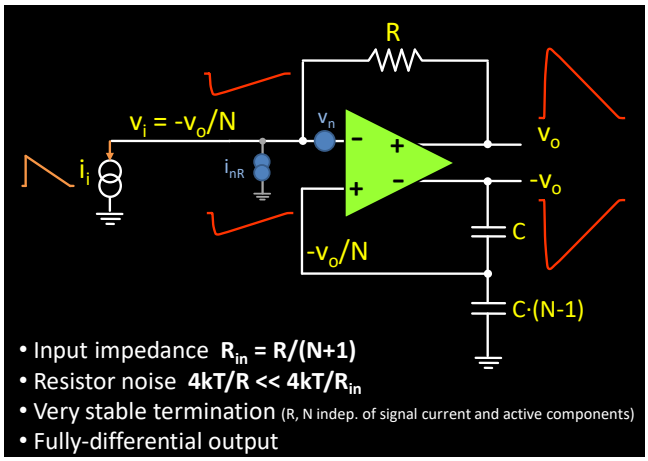
Each of the 64 channels has a low-noise front-end, a fast shaper, trimmable discrimination, peak and timing detection, coarse timestamp from Gray-code counter, three analog to digital converters (6-bit coarse amplitude, 10-bit fine amplitude, 8-bit fine timing), a deep FIFO, direct and multiplexed outputs, various timing measurements (including time-over-threshold), a shared programmable logic core for event rejection, SLVS interfaces, various readout modes, temperature sensor.

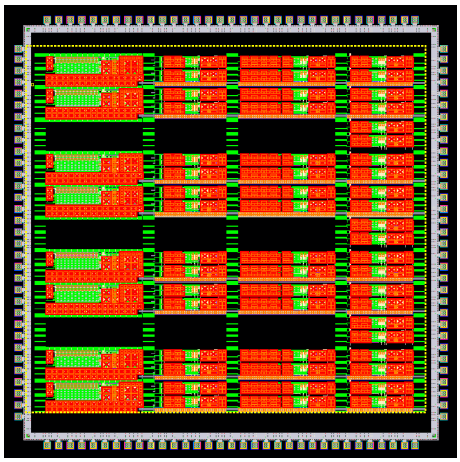


With a transistor count per channel in excess of 100,000 (over 10 million total) it is one of the most complex front-end ASICs in the field. Its extremely high programmability make it suitable for use in a wide range of detectors and applications. It is available in die and 400-BGA packaged form, and it will be offered as off-the-shelf item by CERN.

Low-Noise Line-Terminating ASIC With Fully-Differential Outputs

This ASIC incorporates a preamplifier of new concept based on a fully differential amplifier, and it provides at the same time a very low noise programmable termination and single-ended to fully-differential con-version. The preamplifier feeds two fully-differential anti-aliasing bipolar shapers with different gains, designed to achieve an overall dynamic range of 16-bit and characterized by very high drive capability [19].





The ASIC is composed of eight front-end channels, three programmable summing channels relevant for trigger primitives, and a flexible signal generator. Designed and fabricated in a 65nm CMOS technology it is a candidate for the Phase 2 upgrade of the ATLAS LAr Calorimeter detector, but it may be suitable for applications that require a very low noise termination.

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