The NECTAr GHz Digitizer ASIC for the Cherenkov Telescope Arrays

The future international very high energy gamma ray observatory, the Cherenkov Telescope Array (CTA), will consist of an array of 50-100 dishes of various sizes. Each telescope will have a camera with photo-detectors installed in its focal plane and the associated front-end electronics to capture the Cherenkov light associated with the particle showers produced by gammas photons in the atmosphere. The total number of electronic channels will be larger than 100,000.

Electronics for future Atmospheric Cherenkov Telescope Arrays

- The electronics has to be:
  - modular (easy replacement of components)
  - low cost: goal 300 Euros/channel
  - reliable
  - easy to calibrate

Main Requirements for the FE Electronics

- short signal ~ 5 ns. Night sky background rate ~ 100 MHz
- short read-out window (5-10 ns) to optimize S/N
- bandwidth in the 200-400 MHz range
- sampling rate 8 >> 2 Hz to allow proper signal reconstruction
- pixel time resolution < 1 ns
- dynamic range > 14 bits (with single PE measurement)
- dead time < 5% (< 5 µs for a 10 kHz trigger rate)

The NECTAr input buffers

- From SAM (RI) to NECTAr: capability driven by the input buffers ensuring a high signal impedance is multiplied by a transimpedance amplifier driving the slow rise (1/V) for a moderate skin effect in the design (Unix Barcelona IFPU)

Electronics based on ultrafast analogue memories allow a full solution for these requirements (on HESS, HESS-2, R1 & MAGIC)

NECTAr0: prototype of the digitizer ASIC

NECTAr0, designed in AMS CMOS 0.35um technology, integrates:

- 2 fully differential channels of switch capacitor array analogue memory (SCA)
- Sampling DLL Matrix structure: Extended Version of SAM (HESS2) [1]
- Programmable sampling frequency (500-4,000 MHz)
- Circular LL (programmable) latency buffer
- 1024-cell depth = up to 500ns latency @ 2 G5/s, 2us @ 0.5G/s
- Region of Interest (ROI) readout with programmable length (typically Nf=16 cells)
- Pedestalspread corrected on chip by trim DACs calibrated once for all

- Digitized data directly usable for calculations.
- Robustness to power pulsing capability: readout start + ADC are off during sampling phase
- Oscilloscope and spectrum analyzer

Tests on the NECTAr ASIC prototype have been performed on a prototype of this board

NECTAr0: measured performances on the prototype Front End Board

- Power consumption: 210mW (10% of the total power dissipation for a camera channel). Can be reduced further with on-chip calibration schemes
- Charge (Q) calculated only by the SCA as the sum of PE samples
- Electrical PE = PE signal delivered by a PMT with 2.1G(p.e)/ns and
  - 8-bit configuration (1.15V) - 20% peak fluctuation on HG
  - >11.2mV amplitude on HG

- Photodetection Spectrum with filtered LED source. Vertical: 400mV/div, Horizontal: 10ns/div
- High resolution measurements for the NECTAr prototype
- Power pulsing capability for reduced power consumption
- Deadtime < 200ns for an event (2 pixels 16 cells)
- Digital output with the classical triggers:

- End Board trigger (EBT): 30 pixels with 500ns latency @ 2G5/s
- Trigger algorithms (majority, analogue sum..) [1]
- With on-board digitizer (ADC), digital output with the classical triggers

- Digital output with the classical triggers
- With on-board digitizer (ADC), digital output with the classical triggers
- With on-board digitizer (ADC), digital output with the classical triggers

- Characteristic of the PE signal at the input buffer of the SCA

- Gain and bandwidth of the SCA buffer

- Linear range: 300V/div, 10 mV/div, 10ns/div
- Flat response with expected 1% PE resolution

- Readout of a single PE pulse with 500ns latency

- Linear range: 4000 PE with resolution of 20% for 1 PE
- Signal to noise ratio >10

- Q-resolution far better than expectations of Poisson statistics (and requirements)
- Similar results > 5PS

- Spectrum with a signal of 400ps width (10,000 PE)

- Single PE peak located at 100 ADC count as expected
- No pedestal peak

- Digital output with the classical triggers

- NECTAr already fulfills the requirements of the CTA Camera and is

- Next Steps:
  - Full module characterization
  - Study of a new chip prototype (more channels, longer integration time, programmable gain input amplifiers)

Topical Workshop on Electronic Devices for Particle Physics – Vienna – 26-30 September 2011

(R1) Delagrange E., et al., NIMA 567 (2006), 21-26
(R2) Rabii F. et al., IEEE ICICDT Proceedings, Grenoble (2006), 135-138
(R3) Gascon D., Sanuy A., talk given at this conference (TWEPP 2011)