Performance of the Compact High Energy Camera SiPM Prototype Front-End Electronics proposed for the Cherenkov Telescope Array

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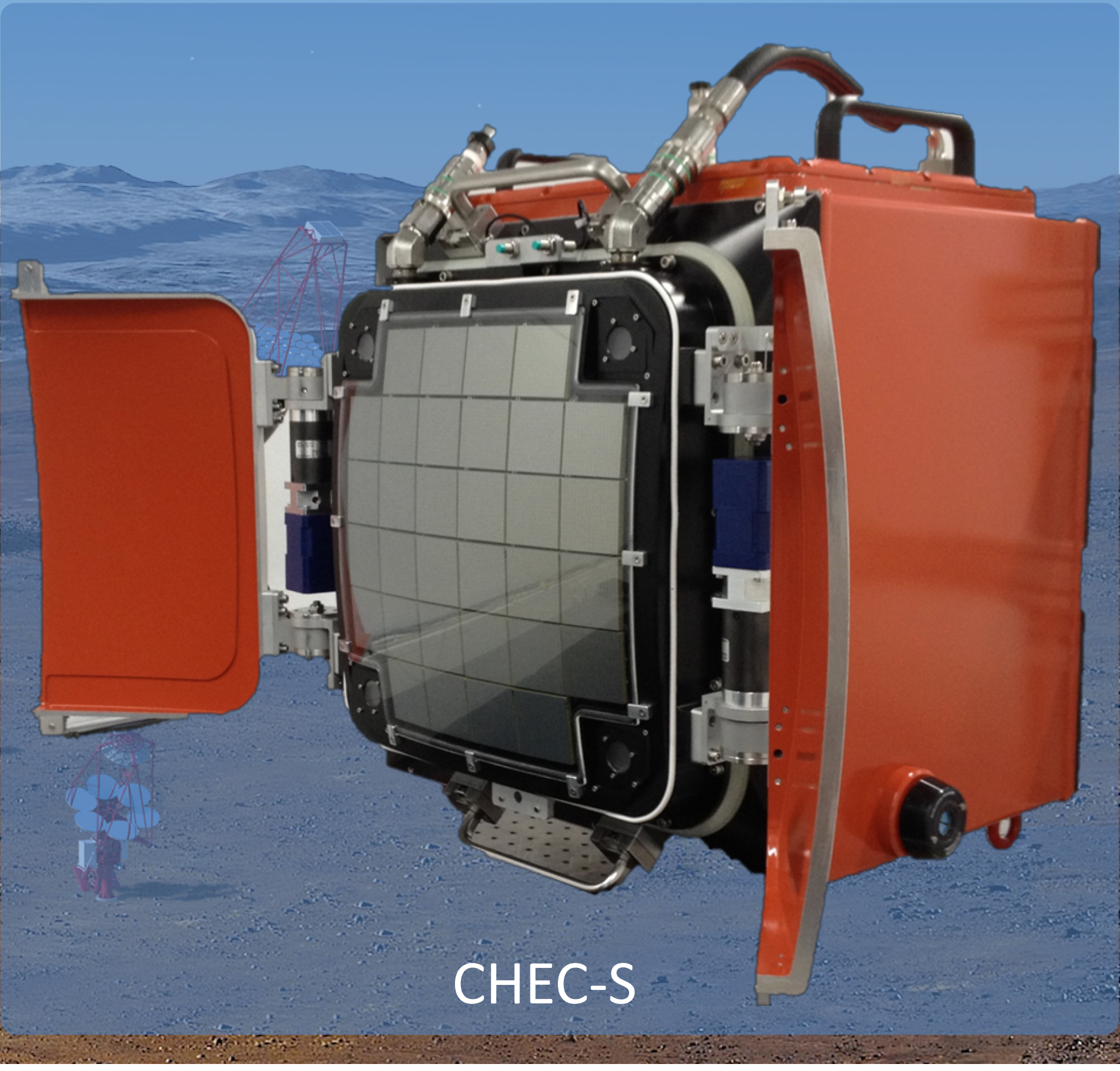
CHEC-S

ABSTRACT

The Compact High Energy Camera (CHEC) is a full-waveform camera, designed and proposed for the dual mirror, Schwarzschild-Couder, small sized telescope of the Cherenkov Telescope Array. CHEC-S is the second prototype and is based upon silicon photomultiplier (SiPM) photodetectors optimised for single photon counting and nanosecond timing. The camera water-cooled focal plane plate comprises a total of 2048 SiPM pixels organised as 32 independent sensor and front-end electronics (FEE) modules providing event detection and signal digitisation of Cherenkov light flashes. Each module comprises an 8 x 8 tile arrangement of SiPM pixels, coupled to a 64-channel preamplifier-buffer followed by a FEE module based around the TARGET chipset, which combines triggering (T5TEA) and waveform capture (TARGET C) functionality.

The CHEC group members

INTRODUCTION

The device under test consists of a single FEE module and SiPM chain. Both are temperature controlled in a similar fashion to CHEC-S using fans and a water-cooled aluminium block thermally coupled to the SiPM (Fig. 1).

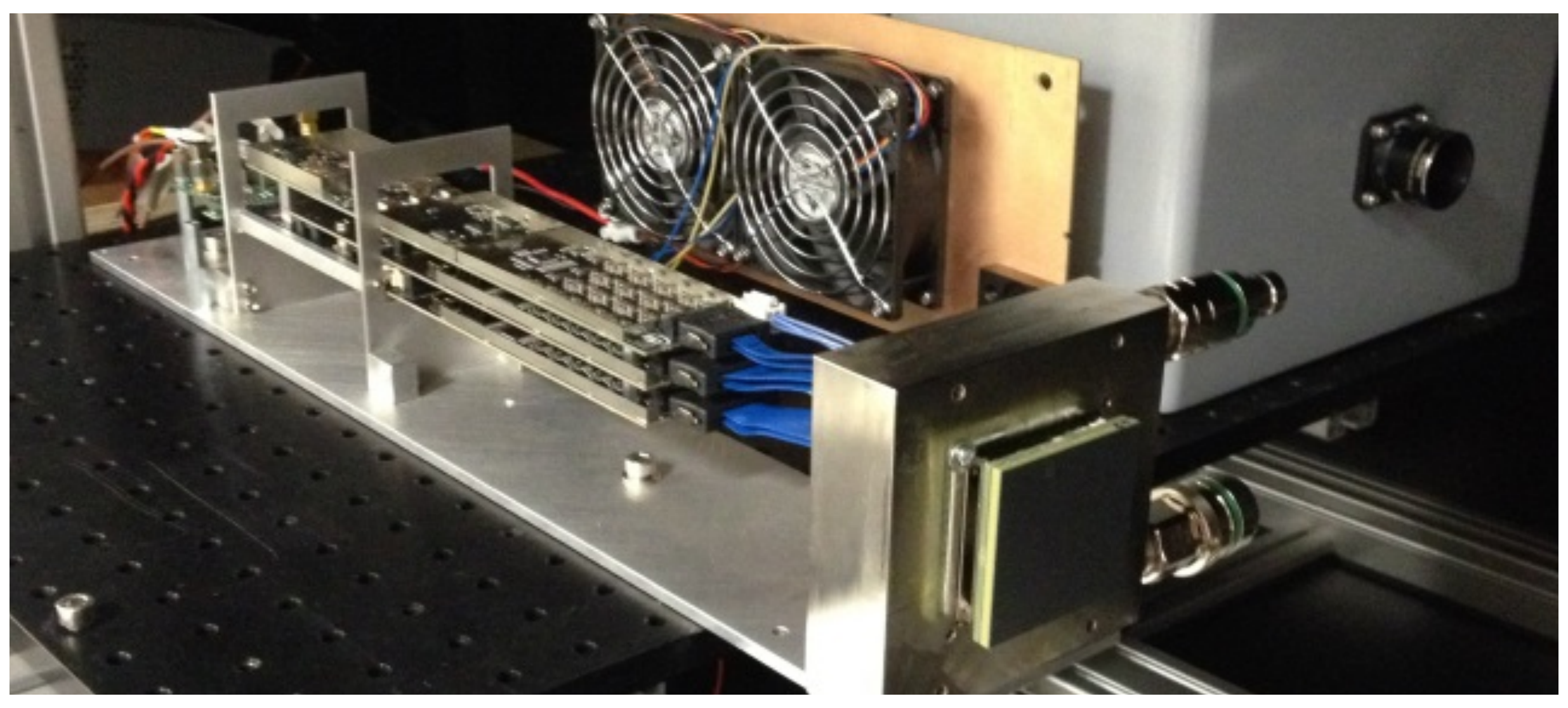

Fig. 1: Single CHEC-S FEE and SiPM chain, at the Space Research Centre, UoL

The SiPM is illuminated with a pulsed diode laser and a diffuse LED for simulated night sky background enabling all aspects of the end-to-end performance to be investigated. Since CHEC-S is capable of full-waveform capture, as opposed to peak amplitude only, further information can be gained, allowing improved energy extraction of a time dispersed signal. Investigations are ongoing at MPIK, ECAP, Nagoya University and University of Leicester, the results shown here are those obtained at the University of Leicester.

SINGLE PHOTOELECTRON DISTRIBUTION

Each FEE module has 16 independent high voltage (HV) bias channels, supplying groups of 4 pixels (Super-Pixel, aka SP). This enables control of the SiPM overvoltage (OV) for each SP HV group via an 8 bit DAC. The OV changes the internal gain of each SiPM affecting the dark count rate, photon detection efficiency and optical crosstalk response. Controlling the OV enables an approximate gain-matching procedure ensuring a uniform output from the entire SiPM (Fig. 2). Fig. 3 shows a typical single photoelectron distribution from a CHEC-S FEE pixel. Illuminating the SiPM at low intensity reveals the characteristic Poisson response and using fitting algorithms allows key characteristics to be obtained including SiPM gain, noise and mean photoelectron (pe) level. Measuring across all 64 pixels when using a gain of 2.9 mV/pe reveals a typical noise of 0.9 mV and average pe of 1.3 per laser pulse.

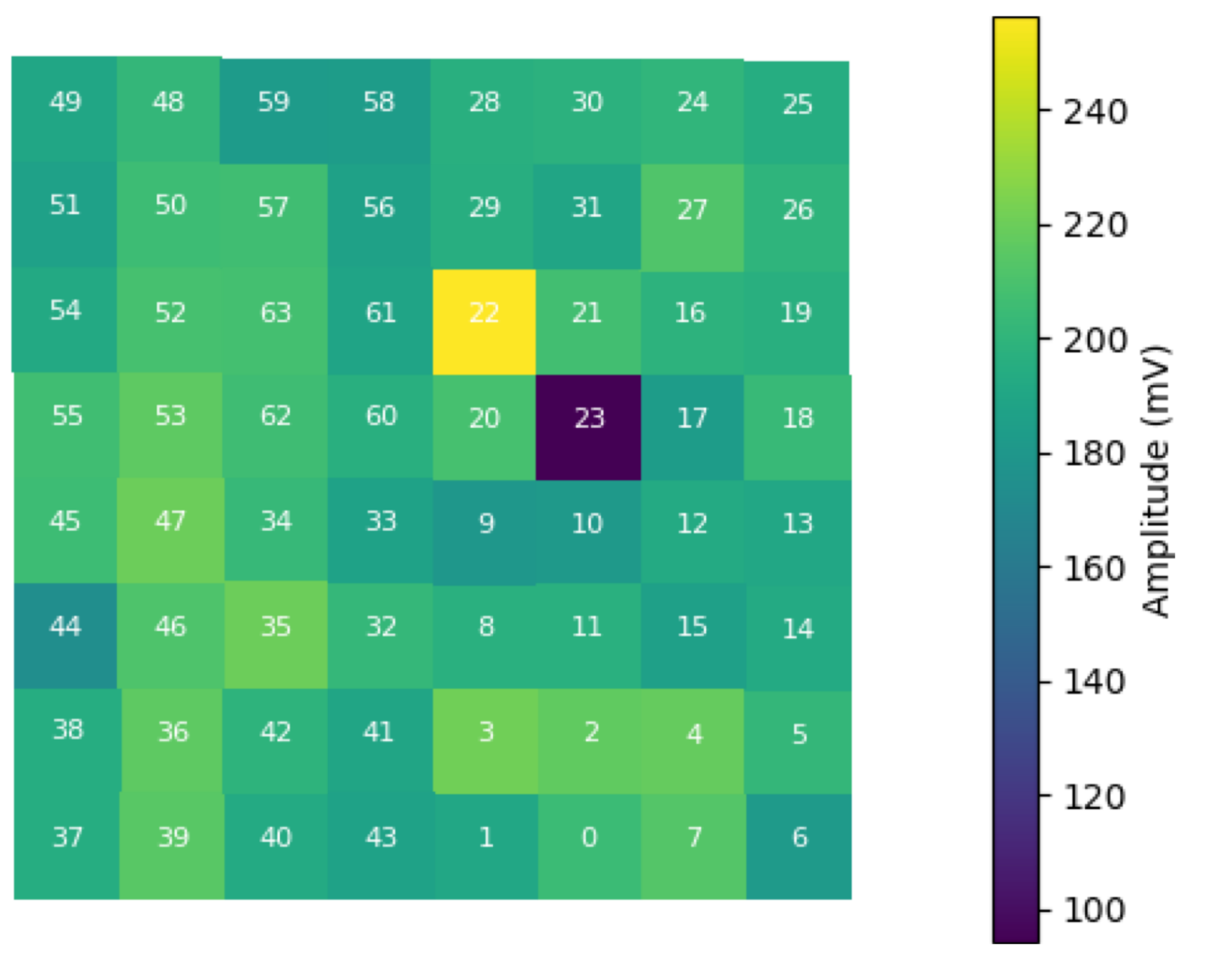

Fig. 2: SiPM response following gain matching procedure, showing broken pixel 23 and compensating pixel 22.

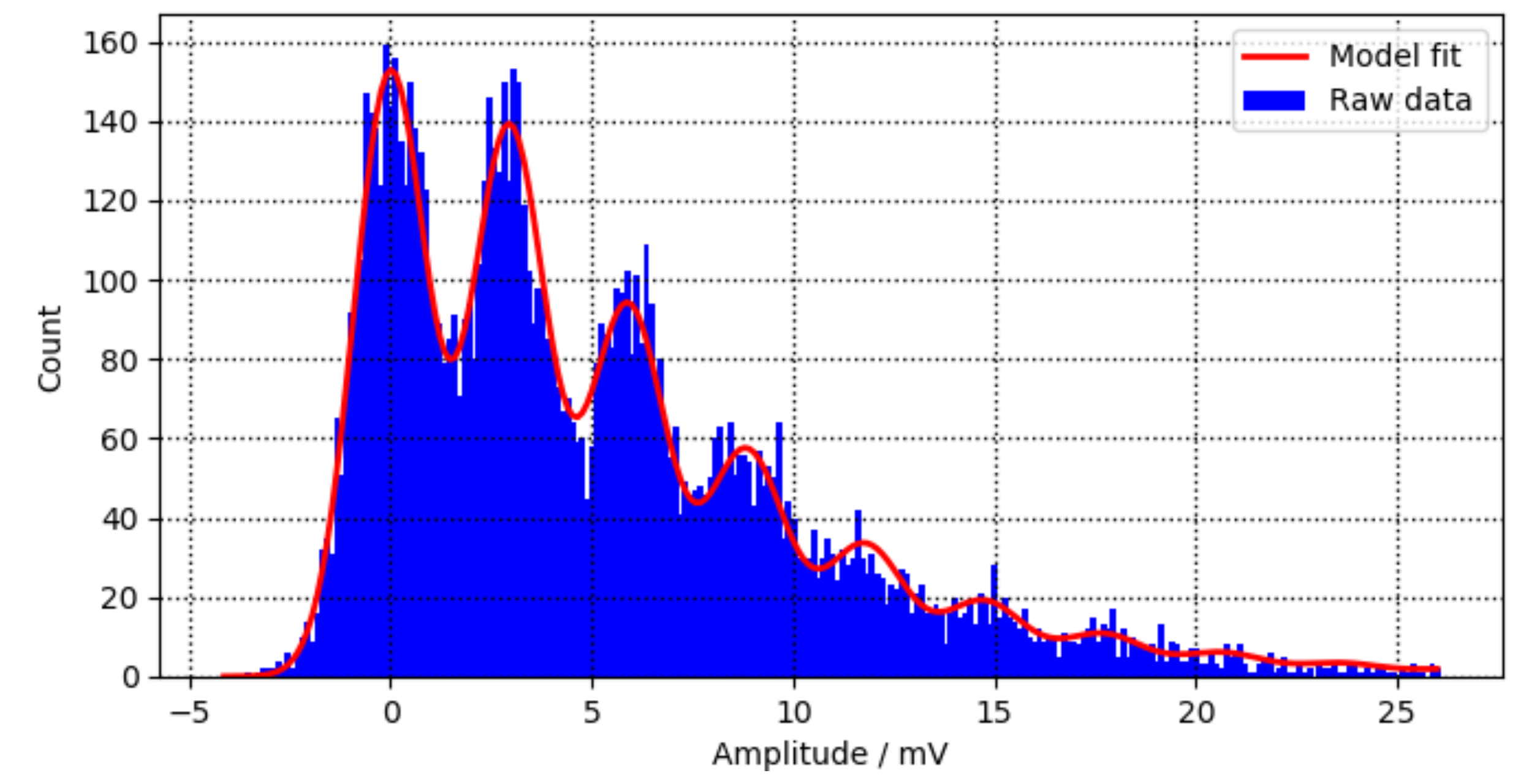

Fig. 3: Low intensity pe distribution showing a characteristic Poisson distribution of pedestal and single pe peaks with an average pe of 1.3 per laser pulse.

DYNAMIC RANGE

TARGET C is able to digitise an input signal waveform within a maximum 1.9 V range, the preamplifier-buffer and FEE shaping circuits are also designed to operate within this range. The internal gain (set by the OV) changes the mV/pe response and consequently changes the dynamic range when measured in pe. Fig. 4 shows the typical channel response at various OVs. Saturated waveform recovery methods (not shown in this image) enable the maximum observable pe to be extended above these levels.

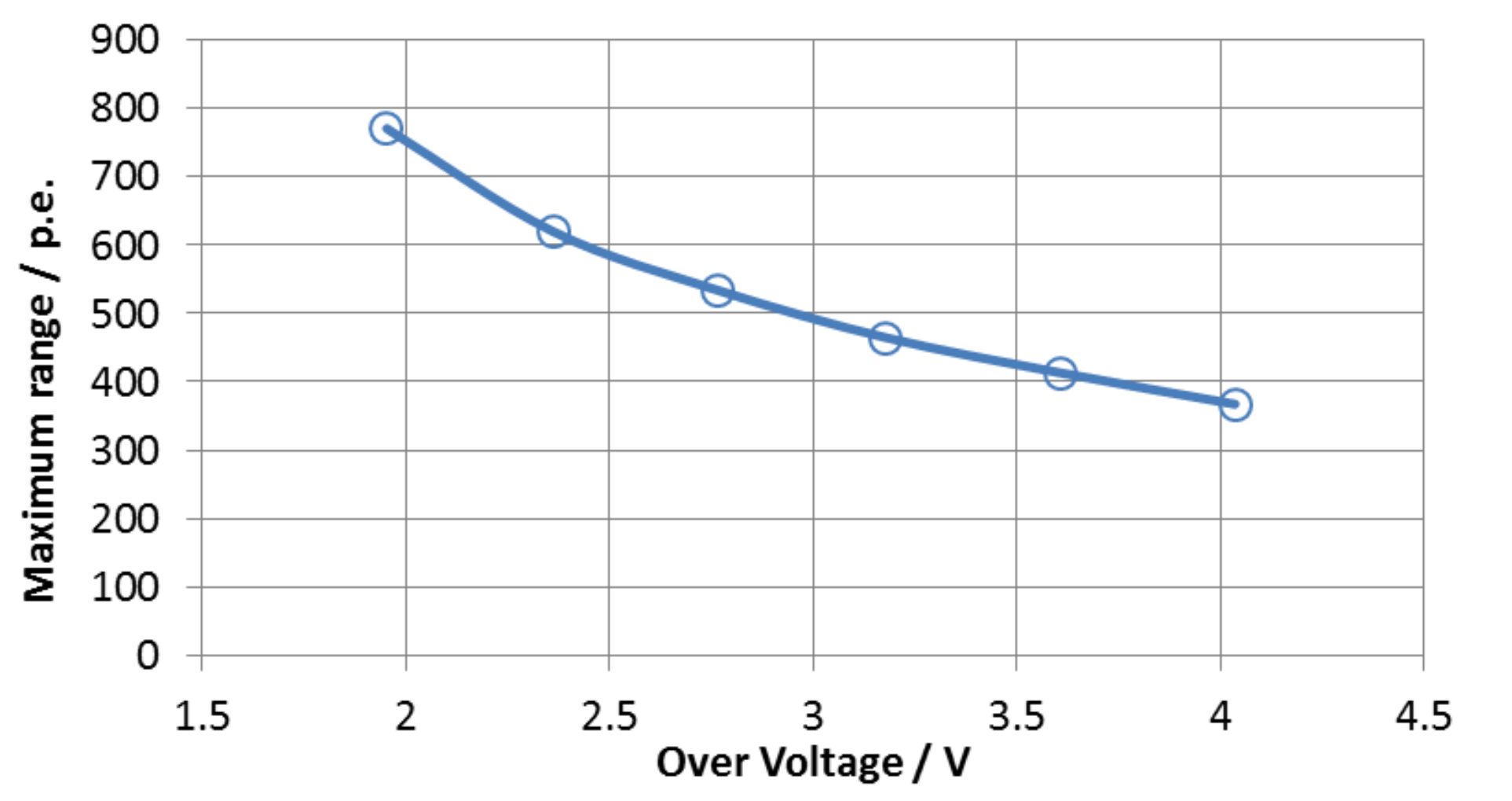

Fig. 4: Full dynamic range of a CHEC-S FEE module prior to saturation recovery.

ANGULAR RESPONSE

The arrival angle of Cherenkov photons from gamma-ray showers incident on the CHEC-S focal plane are in the range 30-60°. The relative photon detection efficiency (PDE) of the SiPM tile was measured to ensure CHEC-S performance at these angles. Fig. 5 shows the waveform peak amplitude at varying incident angles relative to the peak amplitude at the normal to the SiPM tile. The response is flat in the 30-60° range, indicating good performance within this range.

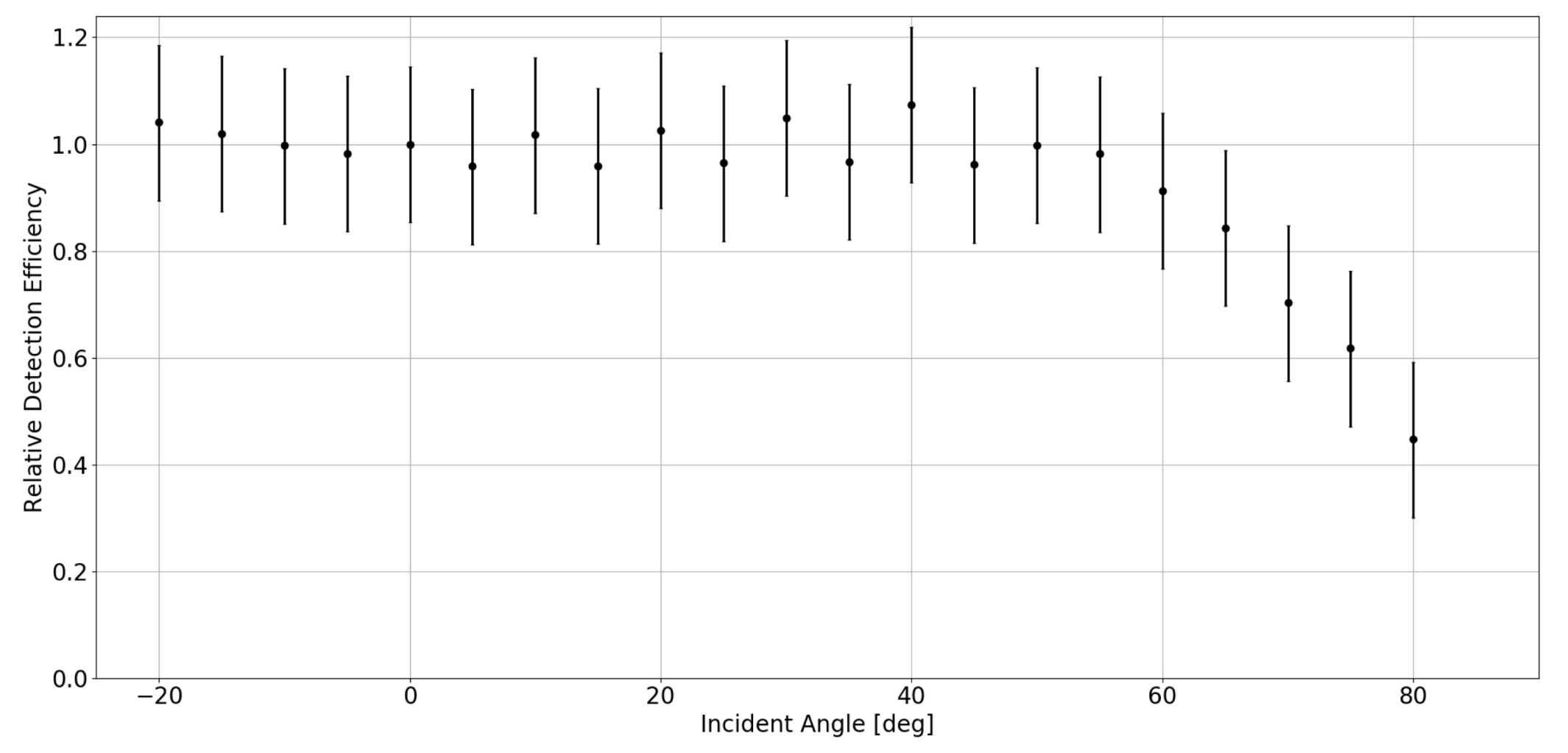

Fig. 5: SiPM performance at varying incident angles. Error bars represent the spread in peak amplitude from 14 central pixels.

ELECTRONIC CROSSTALK

The electronic crosstalk between channels was measured by flat field illumination, individually switching on the HV bias for each SP and comparing the signal level with the crosstalk amplitude of the other channels (without HV). Fig. 6 shows the corresponding crosstalk response in all channels (HV enabled SPs removed). With this method, crosstalk is exaggerated compared to single channel crosstalk. This level of crosstalk is relevant to the trigger ASIC but not the digitising ASIC.

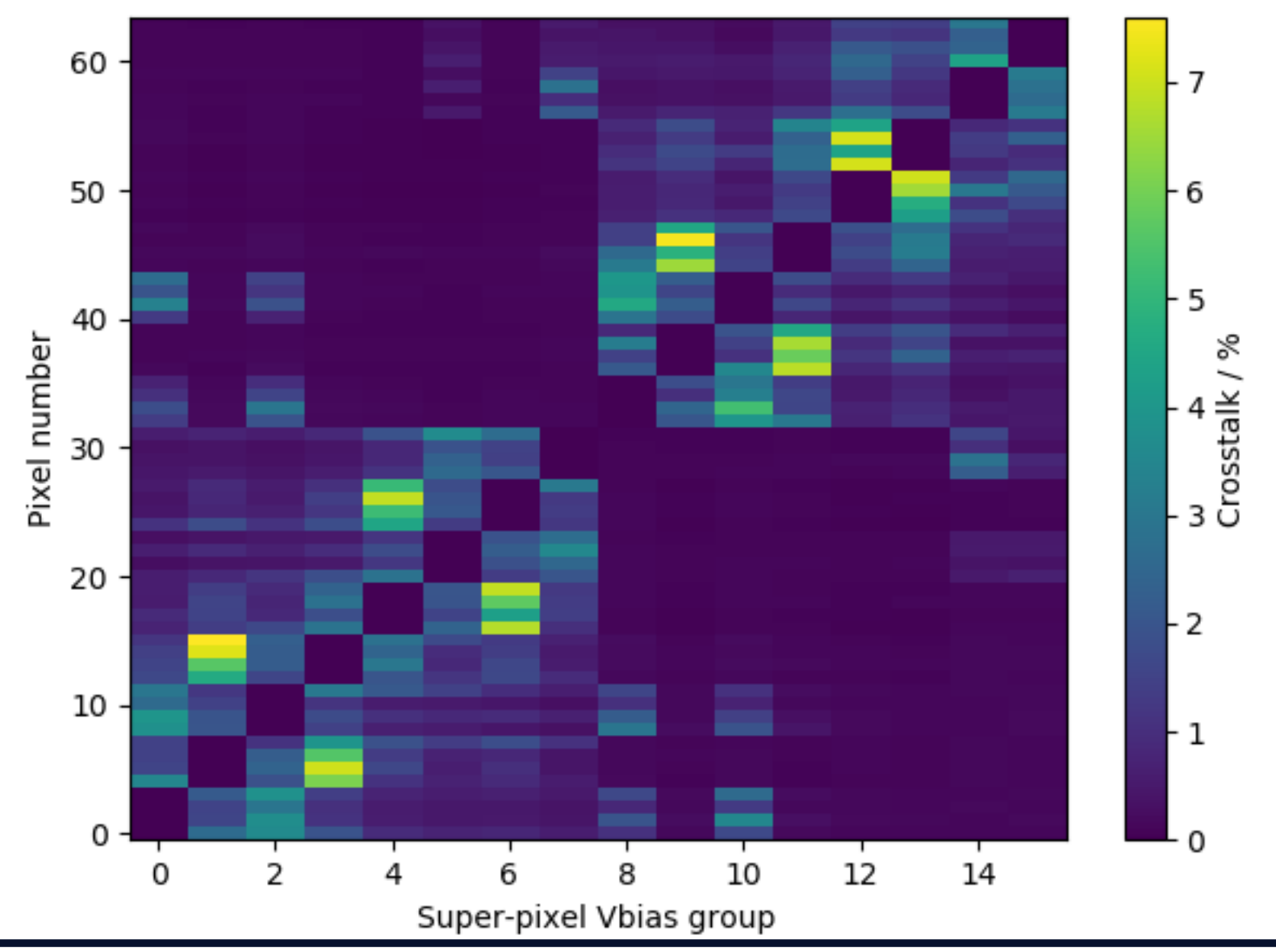

Fig. 6: Measured electronic crosstalk.

ACKNOWLEDGEMENTS

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