CTA 報告 85:
Schwarzschild-Couder 型望遠鏡用の
焦点面カメラの開発状況

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CTA: A Mixed Array of Different Telescopes

**Large-Sized Telescope (LST)**
- 4 North + 4 South
- \( D = 23 \) m
- \( FOV = 4.5^\circ \)
- \( E = 20 \) GeV – 1 TeV

**Medium-Sized Telescope (MST)**
- \( \sim 24 \) North + \( \sim 15 \) South
- \( D = 12 \) m
- \( FOV = 8^\circ \)
- \( E = 100 \) GeV – 10 TeV

**Schwarzschild-Couder Telescope (SCT)**
- \( \sim 24 \) South
- \( D = 9.6 \) m
- \( FOV = 8^\circ \)
- \( E = 100 \) GeV – 10 TeV

**Small-Sized Telescope (SST)**
- GCT \( \sim 35 \) South
- ASTRI \( \sim 35 \) South
- Davis-Cotton \( \sim 20 \) South
- \( D \sim 4 \) m
- \( FOV \sim 9^\circ \)
- \( E = 1 \) TeV – 300 TeV

Array Layout Examples
Both the primary and secondary mirrors can be segmented to reduce the cost of the optical system. A possible arrangement of mirror facets, as “petals”, is shown in Fig. 7. This scheme has the advantage of requiring a minimal number of different surface shapes. A study of the tolerance of alignment and positioning of mirrors is beyond the scope of this paper. Nevertheless, our experience with the simulations suggests that the requirements are stricter than those applied to the H.E.S.S. and VERITAS optical systems. The use of automated alignment and calibration systems will likely be required, e.g. [29].

- First proposed for IACTs in 2007
- Primary + secondary mirrors
  - Wide field-of-view of ~8°
  - High angular resolution of ~4’
  - Small plate scale of ~0.6’/mm
- Will be used in SCT and SST
- Small angular resolution and wide FOV bring us higher sensitivity
The typical PSF size of SCT is ~6 mm (~4’)

Compact and modular camera front-end electronics with small-pixel photodetectors needed

Silicon photomultipliers (SiPMs or MPPCs) or MAPMTs match the pixel size
TARGET (TeV Array Readout with GSa/s sampling and Event Trigger)

TARGET ASIC (designed by G. Varner @ U. Hawaii)
- 16 channels readout
- 1 GSa/s sampling
- 16-us long buffer
- Trigger circuit

- Application specific integrated circuit (ASIC) for CTA
- Developed TARGET 1 for concept validation (Bechtol et al. 2012)
- TARGET 5 (w/ gain adjustment) for MAPMTs, TARGET 7 for MPPCs
SST-GCT (Gamma Compact Telescope) and CHEC

One of three SST designs, based on SC optical system

Compact High-Energy Camera (CHEC) will be mounted

- CHEC-M: Prototype with MAPMTs
- CHEC-S: Prototype with SiPMs

Shares technologies with SCT

ROBAST Simulation by Cameron Rulten (Obs. Paris)
Development of TARGET ASICs

- TARGET 1 (see Bechtol et al. 2012)
  - The 1st generation of TARGET produced in 2008
  - Limited bandwidth of ~150 MHz at 3 dB
  - High cross talk of ~4%
  - Saturation for high amplitude inputs

- (TARGET 2, 4, and) TARGET 5
  - Produced in 2012 for MAPMTs (CHEC-M)
  - Achieved ~400 MHz bandwidth and low cross talk of ~1%
  - High trigger threshold (~25 mV, ~6 p.e.) due to noise from the sampling circuit
  - Narrow dynamic range and non-linearity of the transfer function

- TARGET 7
  - Produced in 2013 for SiPMs (CHEC-S and SCT)
  - Much better linearity
  - The threshold issue still remains (even worse)
  - New TARGET design will be submitted in 2014
The non-linearity of TARGET 5 transfer functions made our calibration process more difficult, while the noise level was low enough.

Dynamic range of ~1.6 (V) was smaller than our requirement (> 10 bits)
TARGET 7 Transfer Function

- Linearity was much improved from TARGET 5
- Wider dynamic range from ~0.5 to ~2.5 (V) (~0.5 to ~2.1 for TARGET 5)

by J. Vandenbroucke at Wisconsin

Very Preliminary
S-Curve Shape Changes in Sampling Phase (TARGET 5)

**Phase = 0 ns**

- \( \chi^2 / \text{ndf} = 588.7 / 5 \)
- \( p_0 = 78.62 \pm 0.005219 \)
- \( p_1 = 1.224 \pm 0.005034 \)
- \( \sigma = 1.2 \text{ mV} \)

**Phase = 26 ns**

- \( \chi^2 / \text{ndf} = 3.546 \times 10^4 / 20 \)
- \( p_0 = 66.18 \pm 0.01472 \)
- \( p_1 = 3.654 \pm 0.01002 \)
- \( \sigma \approx 4 \text{ mV} \)

- **Sampling arrays of a 64-ns period**
- **Threshold and trigger noise change as the trigger timing shifts in the sampling arrays**
The First Mass Production of Modules for CHEC-M

- Produced by SLAC with TARGET 5 ASICs
- Tested at SLAC in March and April 2014
- Delivered to University of Leicester and tested again in July
  - HV module
  - Trigger functionality
  - Transfer functions
  - Sampling stability
  - Sinusoidal input
CHEC-M with a Prototype of Backplane Board

- Proto-Backplane
- DAQ Boards
- Support Frames in a Huge Dark Box
- LED Flasher for Calibration
- ~40 cm
CHEC-M with a Prototype of Backplane Board
TSV MPPCs of $16 \times 16$ channels (S12642-1616PA-50) will be used for CHEC-S

- Thin-film coating of 20-um thickness, expecting high PDE in UV ($< 350$ nm)
- The first batch has been delivered to the UK in Aug 2014
Plans in 2014

- **TARGET**
  - Finish evaluation and tuning of TARGET 7
  - Submit a new TARGET design that has separated trigger and sampling ASICs
  - Produce TARGET 7 camera modules for proto-SCT and CHEC-S

- **CHEC**
  - Software development of DAQ and slow control
  - Long term test of CHEC-M in a dark box
  - Assemble CHEC-S

- **MPPC**
  - Evaluation of the thin-film coating MPPCs