The UK contribution to CTA

- Introduction
- The dual mirror SST
  - SST-GATE and ASTRI telescopes
- A camera for the dual mirror SST
  - Overview
  - Sensor, pre-amp, TARGET ASIC and module
  - Enclosure, cooling, DAQ and peripherals
- Summary
SST: science goals and requirements

- SST requirements driven both by CTA’s science goals…
  - E.g. locating and studying PeVatrons requires SST array sensitive from ~1…300 TeV with good energy (~10%) and angular (~0.03°) resolution.
- …and by the limitations imposed by the site, by safety considerations etc.
  - SST must operate in winds with 10 minute average speed, at 10 m height, of up to 36 km/h.
  - In park position, SST must survive 10 minute average wind speed of up to 120 km/h.

Design philosophy

- High energy sensitivity requires SSTs cover large area...but telescope separation cannot be too large (want many images of each shower).
- Need lots of SSTs: low cost essential.
- Could use “small” MST with D = 7 m, F = 11.2 m and PM camera…
The CTA concept, take one

Low energy
Four 23 m telescopes
4…5° FoV
~2000 pixels
~ 0.1°

Medium energy
About twenty-five 12 m telescopes
6…8° FoV
~2000 pixels
~ 0.18°

High energy
About forty 7 m telescopes
8…10° FoV
Camera diameter ~2 m
~2000 pixels
~ 0.23°
Towards a two-mirror SST

- ...but this is expensive, cost dominated by camera: large number of expensive PMs needed.
- Cheaper camera possible?
- UK proposal: switch to using relatively low cost compact sensors.
- Need more sophisticated (two-mirror) optical system to reduce aberrations at large field angles.
- Can then have small pixels across large field of view.
- (Two mirror telescopes first proposed in US for AGIS, will also be used for SCT in CTA.)

- First studies of dual mirror SST optics carried out in UK, e.g. ray tracing for field angles 0°, 2.5°, 5°:
Towards a two-mirror SST

- Results of UK optimisation procedure, is telescope with:
  - Focal length $F = 2.283$ m.
  - Primary diameter $D_P = 4$ m.
  - Secondary diameter $D_S = 2$ m.
  - Camera diameter $D_C = 0.36$ cm.
  - Distance from primary (M1) to secondary mirror (M2) $3.56$ m.
  - Distance from M2 to camera is $0.51$ m.
  - Radius of curvature of camera $\rho_C = 1$ m.

- Resulting point spread functions:

- Image size less than 6 mm diameter (80% of light) across entire $9^\circ$ field of view.
Towards a two-mirror SST

- Range of sensors available:
  - Micro-channel plates.
  - Silicon photo-multipliers (SiPMs).
  - Multi-anode photo-multipliers (MAPMs).

- First UK mechanical design:
  - Demonstrated feasibility of two mirror solution.
The CTA concept, take two

**Low energy**
Four 23 m telescopes
4...5° FoV
~2000 pixels
~ 0.1°

**Medium energy**
About twenty-five 12 m telescopes
6...8° FoV
~2000 pixels
~ 0.18°

**High energy**
About seventy 4 m telescopes
8...10° FoV
1500...2000 pixels
~ 0.17°...0.23°
SST-GATE telescope

- Mechanical design further pursued by French groups…
ASTRI telescope

- ...and by Italian consortium.
- \( F = 2.15 \text{ m}, D_P = 4.3 \text{ m} \).
- Gives \( f = \frac{F}{D_P} = 0.5 \).
- \( D_S = 1.8 \text{ m} \), distance M1 to M2 is 3 m.
- \( D_C = 36 \text{ cm} \), FoV = 9.6°, \( \rho_C = 1 \text{ m} \).
- PSF: \( D_{80} < 6 \text{ mm} \) over entire FoV.
UK project – a camera for the SST-2M

- **Sensors:**
  - Micro-channel plates: predicted lifetime about $10^6$ secs (300 hrs).
  - MAPMs: reasonably priced 64 pixel units available from Hamamatsu.
  - SiPMs: growing range of devices, costs now competitive with PMs.

- Design camera to use either MAPMs (CHEC-M) or SiPMs (CHEC-S) with a pixel size of $\sim 6 \times 6$ mm$^2$…

- …and which can be used on either SST-2M telescope design.

- Collaborate with US groups.

- Use TARGET ASIC and module, designed to readout MAPMs for AGIS, now also being used for SCT SiPM-based camera.
CHEC overview
CHEC overview

TARGET ASIC

16 Preamps

16 x preamp

Amplification and shaping

Trigger

Data

Buffering and serialisation

Digitisation and trigger

Peripherals (calibration, lid…)

Module trigger

6 mm (0.17°) MAPM pixel

0.34° super-pixel

Camera trigger
Any two super-pixel neighbours

Clock

Data serialisation and control

DACQ Boards

64 pixel sensor

x 32

Backplane Board

TARGET Module

FPGA

64 pixel sensor

64 pixel sensor

16 x preamp

Data

Control signals, data
TARGET module with MAPM

Four 16 channel preamp boards

Four ribbon cables

Connection to backplane

HV

TARGET ASIC
Preamp

- MAPM output pulse width ~ 1 ns.
- Less than spread of Cherenkov photon arrival times: stretch pulse to form module trigger.
- Design shaping pre-amplifier, requirements:
  - Dynamic range < 1...~1000 p.e. ↔ 0...~1.2 V.
  - Noise < 0.5 mV.
  - Rise time ~ 4 ns.
  - Pulse width ~ 8 ns.
- Pre-amp output for small...
- ...and large signals.

Saturation (~1000 PE, combination of preamp and MAPM)
Preamp Module

- Focal plane interface
- Amplifier boards
- MAPM or SiPM
- Signal patching board
- 50-Ohm flex-cables (shielded)
- HV Bias
- Target Interface

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TARGET module/pre-amp testing
TARGET module testing
Backplane

- Must allow inter-module triggering.
- Signals from all modules must be provided to FPGA.
- Layout of board now being carried out in US (collaboration with Washington University).
Camera support structure

- Enclosure:

- Internals:
Camera support structure

- **Faceplate:**

- **Lid:**
Cooling

- Water cooled heat exchanger in camera enclosure with fans to circulate air within camera.

- External chiller, placed on ground adjacent to telescope.
Camera calibration

- “Flat fielding” and other calibration operations aided by LED unit in corners of camera.

- Light reflected off M2 onto sensor plane
Peripherals control

- DAQ power-on/reset, 4 fans, 6 temp sensors, 2 motors, 2 micro-switches, position encoder, ambient light sensor, 4 calibration flashers are all controlled by peripherals board.
- E.g. flasher steering curcuitry:

  - Flasher output signal (measured using TARGET module).
  - Pulse width < 4.5 ns.
  - Similar to duration of Cherenkov light flashes camera must measure.
DAQ

- DAQ board routes 32 TARGET module signals to (remote) camera server over optical fibre.
- Generates clock.
- Handles time-stamping of data.
- Steers communication with “house-keeping” FPGA.
- Prototype: Virtex 6 FPGA, Seven Solutions White Rabbit switch.
- Test board for prototype:
SiPMs

- Test range of devices that are currently on the market, including.
  - Excelitas C30742-66.
    - 50 μm cells.
    - 6 × 6 mm² pixels.
  - Hamamatsu S12642-050CN.
    - 50 μm cells.
    - Through Si vias.
    - 3 × 3 mm².
  - SensL MicroFB-SMA-60035.
    - 35 μm cells.
    - Fast output.
    - 6 × 6 mm² pixels.

- For CHEC-S prototype, will use Hamamatsu SiPM.
- New pre-amp and some redesign of mechanical structure of camera required.
Timescale for prototype tests

- CHEC-M prototype ready Autumn 2014.
- Test on SST-GATE telescope in Paris…
- …and on ASTRI telescope on Etna.
- CHEC-S ready for testing mid-2015.
- Design final camera and start production mid-2016.
Summary

- UK groups initiated discussion of two-mirror design for the SST.
- Showed potential for significant cost saving w.r.t. initial CTA concept.
- Produced first optical and mechanical design of two-mirror telescope.
- Prototype telescopes now under construction in France and Italy.
- UK producing camera for these telescopes, in collaboration with Australian, Dutch, Japanese and US groups.
- Ambition is to build 70…80 cameras at cost of ~ £100k each.
- Welcome discussion on possible industry participation in this project.