# The Gamma-ray Cherenkov Telescope for CTA



- Progress with GCT structure and design changes for preproduction.
- Status of CHEC-M.
- GCT tests: March in Paris.
- CHEC-S status:
  - Sensors.
  - TARGET ASICs and modules.
  - Focal plane and mechanics.
- Future plans.
- Summary



### Tim Greenshaw, Liverpool University

# Status of GCT





# Status of GCT structure



Slewing studies:



Elevation rotation up to 90.6°
 (specification 91°), limited by:



Azimuth rotation -81° to 442° (range 523°, specification 510°), limited by end switches.



# Status of GCT



- Rotation speeds in azimuth and elevation meet CTA specs.
- Example of position, speed, acceleration and jerk profile:



- Emergency stop tested.
- Example here, stop from maximum azimuth rotation speed:



 Small amplitude oscillations of frequency ~ 1.5 Hz largely due to movement of counterweight.

# Design changes for pre-production



- Telescope movement:
  - Extend elevation range to 91°.
  - Simplify exchange of motors.
  - Simplify mounting of fork.
- Counterweight:
  - Reinforce beams.
  - Modify attachment mechanism (ensure can reach 91° in azimuth).



# Design changes for pre-production



- Telescope control:
  - Investigate using one motor per axis.
  - Reduces costs, simplifies installation and maintenance.
- Emergency stop:
  - Replace transformer on prototype with resistor for dissipation of energy?
  - Smaller, lighter cheaper.



# Design changes for pre-production

Tower:

- Broaden base to match common SST foundation.
- Lightning protection:
  - Add lightning rods to highest points on M1 and M2 and to counterweight.
- Electrics:
  - Increase cooling fan capacity in cabinets.
  - Add preventative maintenance elements.



cherenkov telescope array

# Status of CHEC-M



- Uses multi-anode photomultipliers first Cherenkov light seen on GCT prototype in Paris, November 2015.
- Upgrade to use control electronics foreseen for CHEC-S/preproduction cameras.
- Improve camera control and safety.
- E.g. Power Board:



Assembly of upgraded CHEC-M for second round of tests on telescope:



#### Power Board

 Extensive testing in MPIK before CHEC-M shipped to Paris.

# GCT tests 2017



- Second round of complete telescope tests took place in last two weeks of March.
- Camera mounted on telescope.
- Recall prototype primary consists of two (circular) aluminium mirror segments, remaining four segments are dummies.
- Mechanical actuators installed, but mirror segments not yet aligned.
- Telescope motion checked.
- Tracking also implemented for tests.



## Test overview



Date	ate Onsite			Main Activities	Data	Notes
20	Monday	RW, JB, JZ, JW, SL, PD, JG, SJL	Cloudy	Camera transport (4:30 pm), Unpacking, Setup PC	-	
21	Tuesday	RW, JB, JZ, JW, SL, PD, JG, SJL, MB, JL	Cloudy	Setup chiller, fibres, PSU, seal camera, safety training, analysis training, install camera	-	
22	2 Wednesday RW, JB, JZ, JW, SL, PD, JG, SJL, MB, JL, HS Cloudy / Rain		Cloudy / Rain	Camera turn on, sanity tests, analysis training, first calibration runs	LED runs, first calibration	Shelter closed
23	B Thursday RW, JZ, JW, SL, PD, SJL, Rain HS		Rain	Debugging, trigger threshold curves	LED runs, Bias curves	Shelter mostly closed
24	Friday	RW, JG, SJL, JW	<b>Cloudy with gaps</b>	Tried for CR, trigger problems	-	Needed finer grain control on thrigger threshold
27	Monday		Good	Trigger rate stabalization Control CUIL First CP	CP	Observing
21	wonday	JZ, KW, SL, SJL, JW, JG	9000	Trigger rate stabalisation, control GOI, First CK		Observing:
28	28 Tuesday RW, SL, SJL, JW, JG Good		Good	Trigger rate stabalisation, Control GUI, technical on-sky data	Steady CR at 0.1 Hz, Zenith scan, Ex. NSB triggers	Observing!
29	Wednesday	JZ, RW, JW, JG, SJL, HC	Good	Trigger rate stabalisation, Control GUI, mirror alignment, observing	Bias curves, CR, Jupiter, Mrk421 Mrk501	Observing!
30	Thursday	RW, JW, JG, SJL, HC	Overcast	Trigger rate stabalisation, mirror alignment, observing	Bias curves, CR, Jupiter, Mrk421 Mrk501	Observing after 3 am
31	Friday	RW	Rain	Trigger investigations	-	-

- Twelve members of the camera team involved.
- Analysis training, code debugging and GUI development during the day.
- Still a lot of debugging required in the evenings typically midnight before on-sky observations running 'smoothly'.
- Only 3 nights of nice weather.
- 0.1 Hz steady CR rate with  $\sim 2$  k events on disk.
- Primary mirror segments poorly aligned.

# Documentation



- Problems with communication with camera.
- Tracked to optical fibre.
- Cleaning connection to camera solved problem.
- Safety board reset.
- Small coding bugs found and fixed on the fly.
- Lots of work required to establish acceptable trigger rate.

### Issues/bugs recorded on Redmine

#### Bug #17341

HV Ramp for Valu	es < 350V Breaks		
Added by White Richard	13 days ago. Updated 4 days ago.		
Status:	Assigned	Start date:	
Priority:	Normal	Due date:	
Assigned To:	Zorn Justus	% Done:	
Category:	AIV	Spent time:	
Target version:	-		
When loading a config file with an H	/ value set to less than the initial Ramp voltage of 350	0V, the HV will end up ramping to 950V.	
When loading a config file with an H' Subtasks Related issues	/ value set to less than the initial Ramp voltage of 350	DV, the HV will end up ramping to 950V.	
When loading a config file with an H <sup>1</sup> Subtasks Related issues History	/ value set to less than the initial Ramp voltage of 350	DV, the HV will end up ramping to 950V.	
When loading a config file with an H <sup>1</sup> Subtasks Related issues History Updated by White Richar	/ value set to less than the initial Ramp voltage of 350	DV, the HV will end up ramping to 950V.	
When loading a config file with an H <sup>1</sup> Subtasks Related issues History Updated by White Richar	/ value set to less than the initial Ramp voltage of 350	DV, the HV will end up ramping to 950V.	

## Documentation

A nightly log

summarising

issues

observations and

Links to the run list...



### Run Log on Redmine <u>https://forge.in2p3.fr/projects/gct/wiki/Paris\_March2017\_Log</u>.

### d2017-03-22 (Wednesday)

Start Time	End Time	Cam. Op.	Cam. Mon.	Logger	Analysis	Tel. Op.	Other Participant
20:44	01:30	J. Zom	H. Schoorlemmer	R. White	J. Watson	None	J. Graham J. Lapington

#### **Overview and Objectives**

- First camera power up in the dark DONE
- Ped and TF with and without HV with the lid closed DONE, but not successful
- · Lid open, LED flasher run with external trigger check for pulses DONE
- · LED flasher runs for each of 40 LEDs DONE, but only for 100 events per LED
- NSB runs NO TIME

#### Summary

- Data location: /d1/checM/Paris\_March2017
- Created run-logging scheme
  - Use issues to capture runs
    - Created category: CHEC-M Data Run, move between when we decide to use a run
    - Subject should be "Run12345 TYPE" where "TYPE" is "PED", "TF", "LED", "OBS", "OTHER"
    - Use the issue to capture data analysis for this run, and to associate ped and tf with a run (related issues), and link to more detailed wiki analysis pages
    - Use status to capture
      - New: data being taken
      - Assigned: data to be analysed (good or bad)
      - Rejected: junk data
      - Inprogress then Closed: good data being analysed, then analysis complete with plots attached
      - Resolved: bad data that was assigned and we understand why it's bad / have created bug reports
  - See 

     https://forge.in2p3.fr/projects/gct/wiki/Paris\_March2017\_RunList
- We managed to get a few pedestal runs, but SB coms meant that we lost data, and running at 600 Hz we also seemed to crash, with DACQs restarting etc.

#### Issues

- TM trigger counter in log needs header
- SB coms are flaky #17251
- Running at 600 Hz seems flaky #17251

## Documentation



- Run list on Redmine
  - https://forge.in2p3.fr/projects/gct/wiki/Paris\_March2017\_RunList.
- Each run/set of runs captured as Redmine Issue.
- Runs categorised as:
  - New.
  - Rejected/junk.
  - Assigned for analysis.
  - Closed (analysis complete).
- Runs can be linked to calibration runs.
- Run plots can be attached directly.

		Ass	signe	d for analysis		2		
		•	# -	Subject	Status	Created	Updated	Related issues
			17496	Run05277 OBS Mrk501	Assigned	03/30/2017 05:33 AM	03/30/2017 05:33 AM	
			17483	Run05259 OBS Mrk421	Assigned	03/30/2017 03:21 AM	03/30/2017 04:08 AM	Related to #17475
is.			17482	Run05258 OBS Mrk421	Assigned	03/30/2017 02:57 AM	03/30/2017 03:22 AM	Related to #17475
		-	17490	Bup05256 OBS Mrk424	Assigned	02/20/2017 02-40 AM	02/20/2047 02-59 AM	ated to #17475
History	d by Grai	ham Jar	nie 9 days ago					ated to #17475
File PED Rundb152 prg added     God predestal. Mean and ski dev as expected.								ated to #17478, Related to #17476, Related to #17480, Related to #17482, ated to #17483
File PE     Status	D_Run05							
Good pedestal	. Mean an	nd std dev	as expected.					
Updated by Graham Jamle 9 days ago  • File dotated (PED_Rwn64562png)							ated to #17450	
Updated by White Richard less than a minute ago							ated to #17447	
	toff.	10.	terfstre-it.					

# Compilation of events





# Further tests with CHEC-M



- Carry out mirror alignment.
- Analyse data taken in March.
- Perform further short run when moon and weather permit, hopefully end of April.
- Test remote control of CHEC-M (with telescope steered by team in Paris).
- Aim to present results at CTA meeting in Rio de Janeiro (15<sup>th</sup>...19<sup>th</sup> May).
- Then write paper on CHEC-M.



# Status of CHEC-S: tests of SiPMs

- Large range of silicon photomultipliers tested.
- Cell sizes 35, 50 and
   75 μm.
- Pixel sizes 3 × 3 and 6 × 6 mm<sup>2</sup>, with range of fill factors.
- Technology variants such as (Hamamatsu):
  - Standard
  - LCT5.
  - LVR.
  - Silicone and epoxy protective coatings.

Measure PDE against overvoltage:



- LVR operates at lower overvoltage than other SIPMs.
- LVR 75  $\mu$ m cell higher PDE than 50  $\mu$ m cell.
- Maximum PDE of LVR higher than LCT5.



# Status of CHEC-S: tests of SIPMs

Measure optical cross talk as function of overvoltage:



- Cross talk of 6 mm pixels is higher than that of 3 mm pixels.
- Cross talk of 75 µm cells is higher than that of 50 µm cells.
- Cross talk of epoxy coating is higher than that of silicone.
- Cross talk of LVR devices is higher than that of LCT5 at a given overvoltage.



# Status of CHEC-S: tests of SiPMS



Comparison of PDE versus cross talk:



- LVR technology looks to be best.
- Pick pixel size considering also its effects on field of view of CHEC.

- Adding lenslets to 3 mm pixels to bridge interpixel gaps may give both best performance (PDE, crosstalk) and increased FoV.
- Current recommendation:
  - LVR 50 µm cell,
    3 mm pixel.
- Verification of test results required (discussion of some apparent discrepancies ongoing).
- Projected cost for 39 cameras (1250 modules) in 2019 is €1.1M.

# Status of CHEC-S: TARGET ASICs



- TARGET7 ASICs had improved dynamic range w.r.t. TARGET 5 but...
- ...suffered from trigger noise problems.
  - Sampling off, trigger threshold
     4 mV (approx. one p.e.)
  - Sampling on, trigger threshold 15 mV.
- Separate trigger and sampling functions onto T5TEA and TC chips, respectively.
- TC maintains good sampling performance of T7.



- With expected buffer performance of 3...4 mV/p.e.:
  - Dynamic range from about 1 to above 40 p.e.
  - Trigger noise below 0.5 p.e.

# Status of CHEC-S: front end electronics



### • Test complete front-end chain:





#### Waveform recorded through T5TEA and TARGET C. Channel 8



- Noise introduced by buffer/shaper small.
- Full evaluation of trigger performance and charge resolution underway.

## Front end electronics





# Status of CHEC-S: mechanics



- Many modifications of CHEC-S design w.r.t. original CHEC-M:
  - Add window to protect sensors.
  - Water cool sensor plane as well as camera body.
  - Dual aluminium doors with weather-sealed stepper motors Powe and gearboxes.
  - Separate 12 V (approx. 50 A) and 80 V (approx. 2 A) supplies.
  - Improvements to electronics layout.
  - Camera assembly simplified.
  - Size  $50 \times 52 \times 56$  cm<sup>3</sup>.
  - Mass 44 kg.



## Status of CHEC-S: mechanics





Rack:



 Heat exchanger:



# Status of CHEC: focal plane cooling



## Tests of water-cooled focal plane:



- Good thermal contact between focal plane ribs and SiPM/buffer planes essential.
- Without thermal grease:

With

thermal

grease:



# Status of CHEC-S: doors



- Tested doors in Durham wind tunnel.
- Wind speeds:
  - 9 m/s (operating, CTA req.).
  - ◆ 12.5 m/s (transition, CTA req.).
  - ◆ 15 m/s (operating, CHEC goal).
  - 30 m/s (closed only, survival, CTA req.).
- Wind directions:



• Operation to 15 m/s functioned well.



Door opened slightly at 30 m/s.



 Understood and fixed implemented – retest when CHEC-S assembled.

# CHEC plans



## CHEC-S:

- Complete component development for CHEC-S.
- Field test CHEC-S on both GCT and ASTRI prototypes in 2017.
- Pre-production camera:
  - Expect design very similar to CHEC-S.
  - Build 3 preproduction cameras in total, including upgrade of CHEC-S (sensors, buffers).
  - Funding in place.
  - Perhaps additional (partial) cameras for test purposes.

- Advanced Deployment:
  - Six cameras for use on miniarray (GCT and ASTRI).
  - Construction possible with existing funding and internal MPIK funds.
- Production camera:
  - Exact number of cameras required/possible depends on IKC process and funding situation.
- Camera cost (following recent SiPM quotes) about €150k.

## Summary



- Progress with GCT good.
- Comprehensive prototype telescope and camera test programme underway.
- Design and review preproduction structure by mid-2017.
- Test SiPM camera in 2017.
- Plan to install first telescopes on southern site 2018.

