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°
E = 20 GeV – 1 TeV

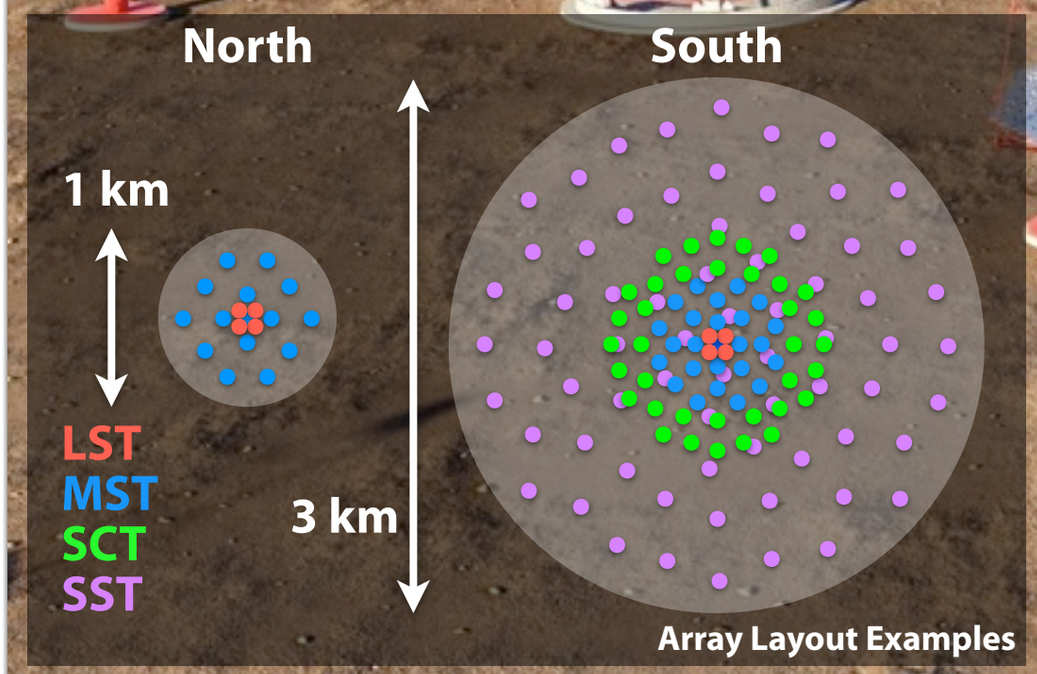
Medium-Sized Telescope (MST)
~24@N + ~15@S
D = 12 m
FOV = 8°
E = 100 GeV – 10 TeV

Schwarzschild-Couder Telescope (SCT)
~24@S
D = 9.6 m
FOV = 8°
E = 100 GeV – 10 TeV

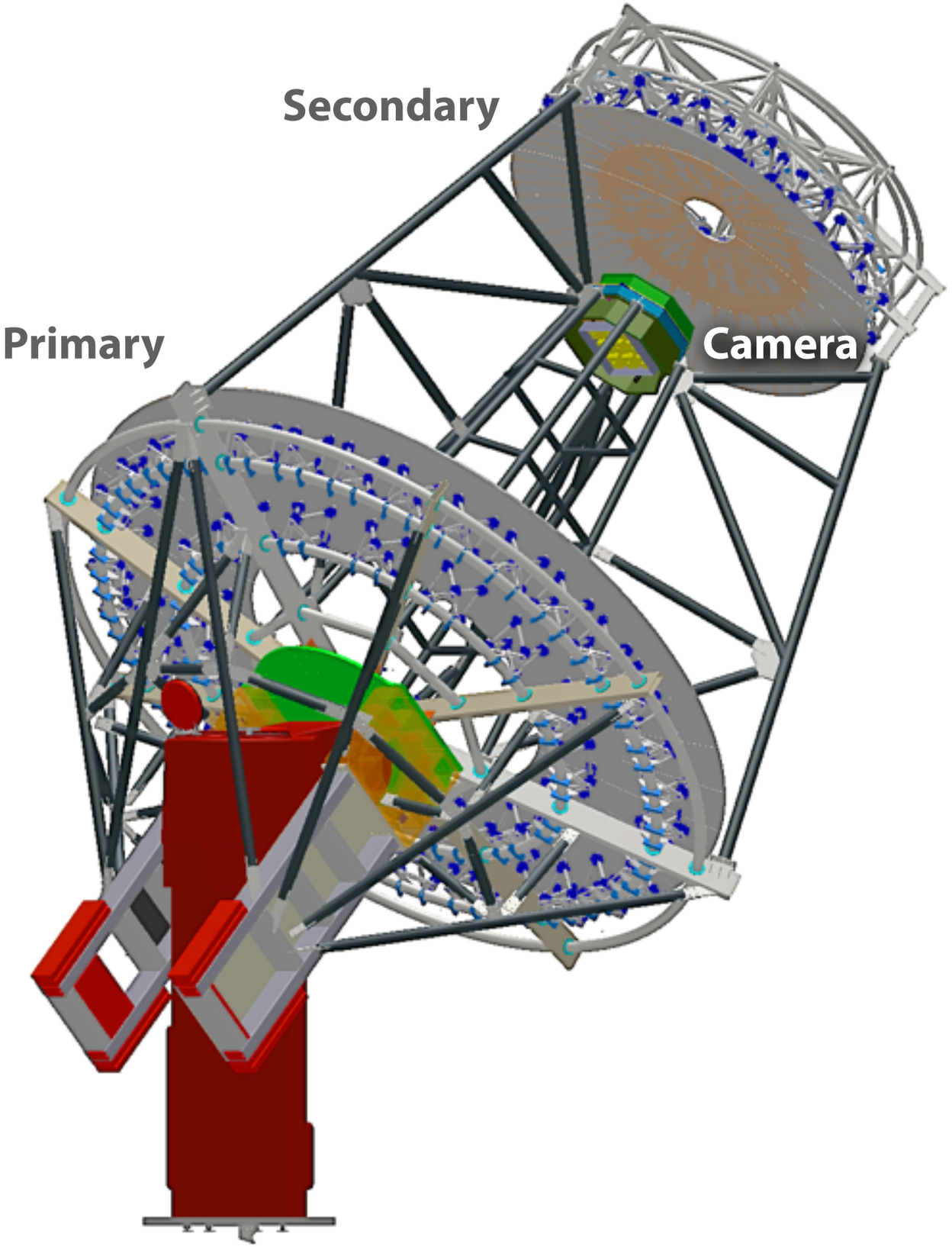
Small-Sized Telescope (SST)

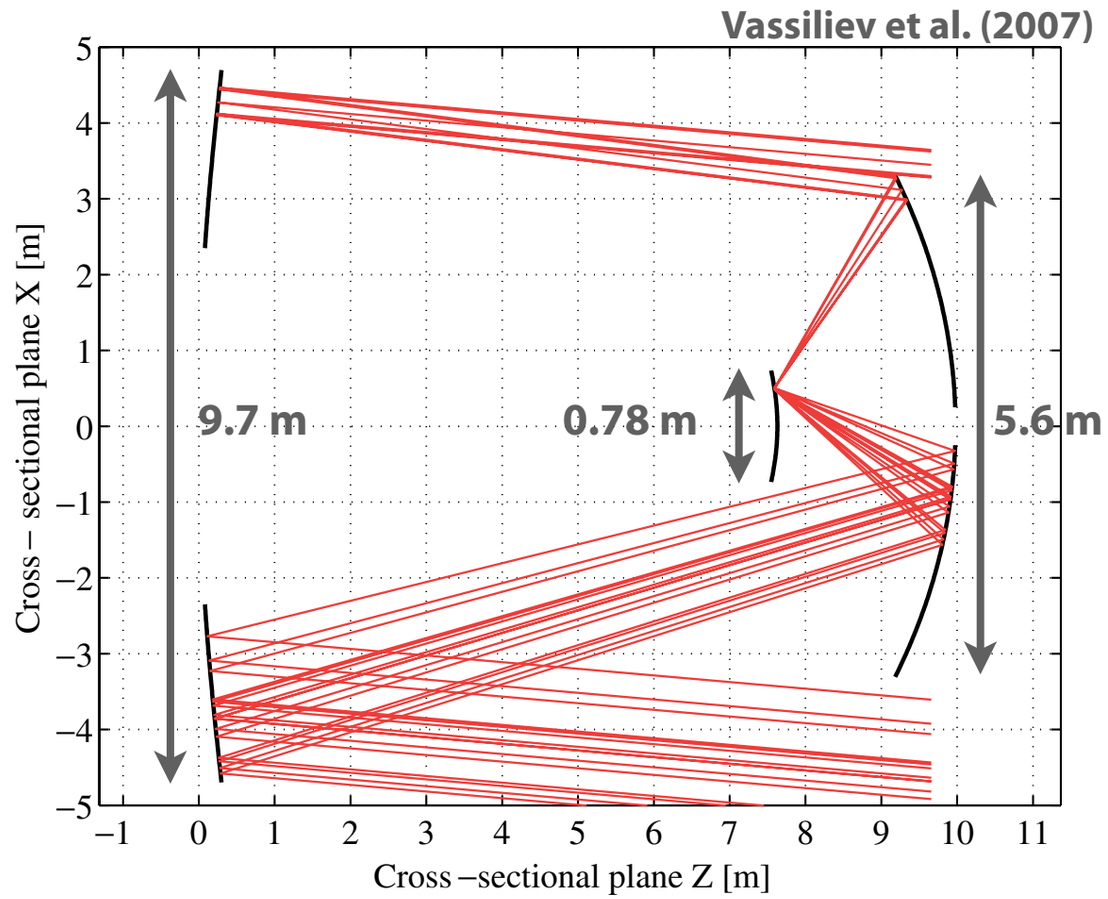
GCT	~35@S
ASTRI	~35@S
Davis-Cotton	~20@S

D ~4 m
FOV ~9°
E = 1 TeV – 300 TeV



Schwarzschild-Couder (SC) Optical System

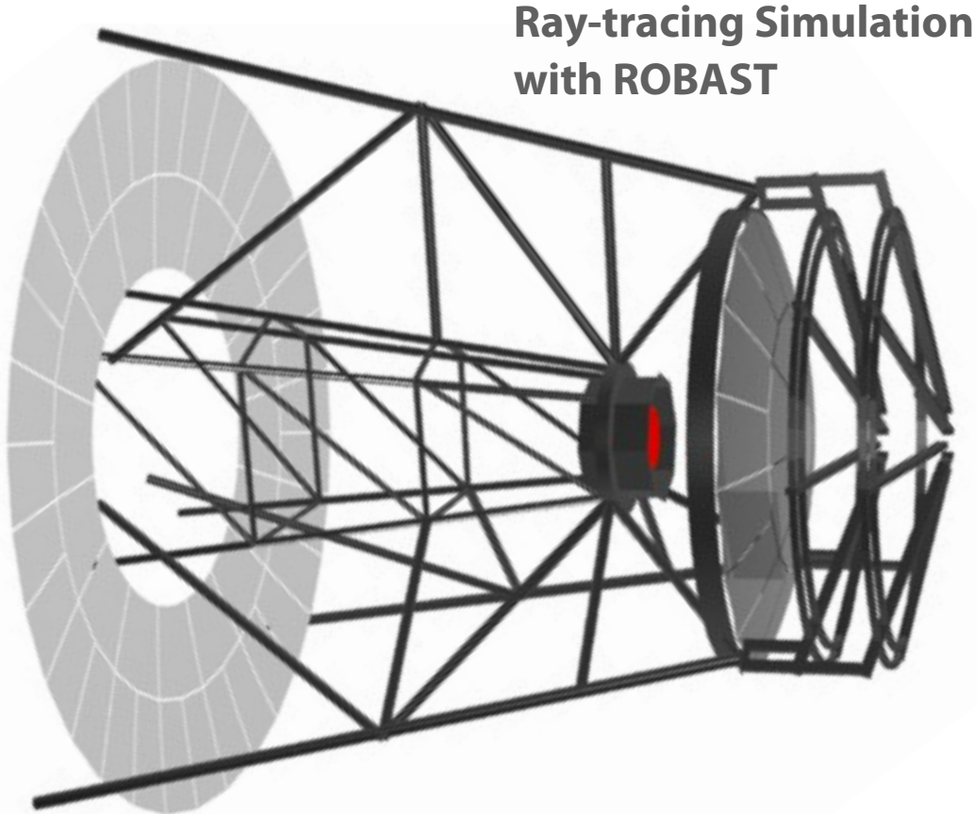




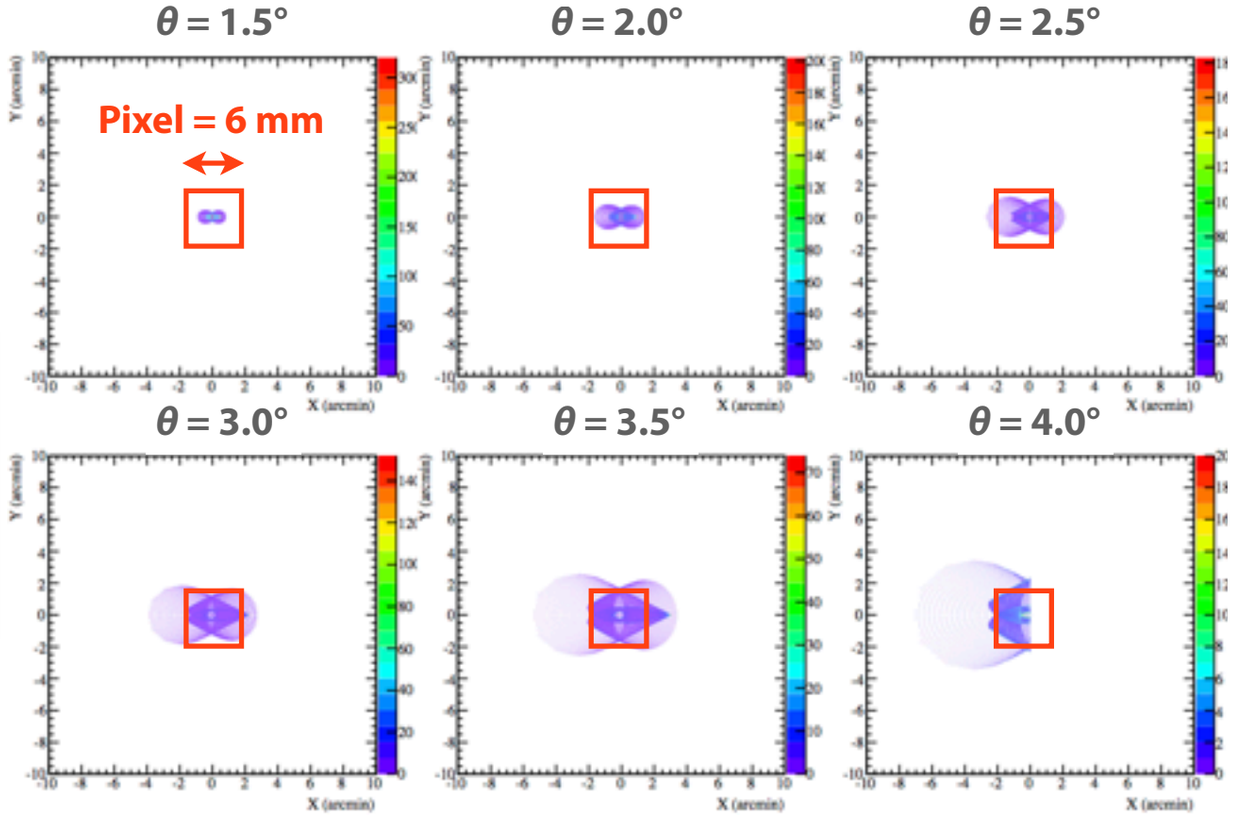
- First proposed for IACTs in 2007
- Primary + secondary mirrors
  - Wide field-of-view of ~8°
  - High angular resolution of ~4′
  - Small plate scale of ~0.6′/mm
- Will be used in SCT and SST
- Small angular resolution and wide FOV bring us higher sensitivity

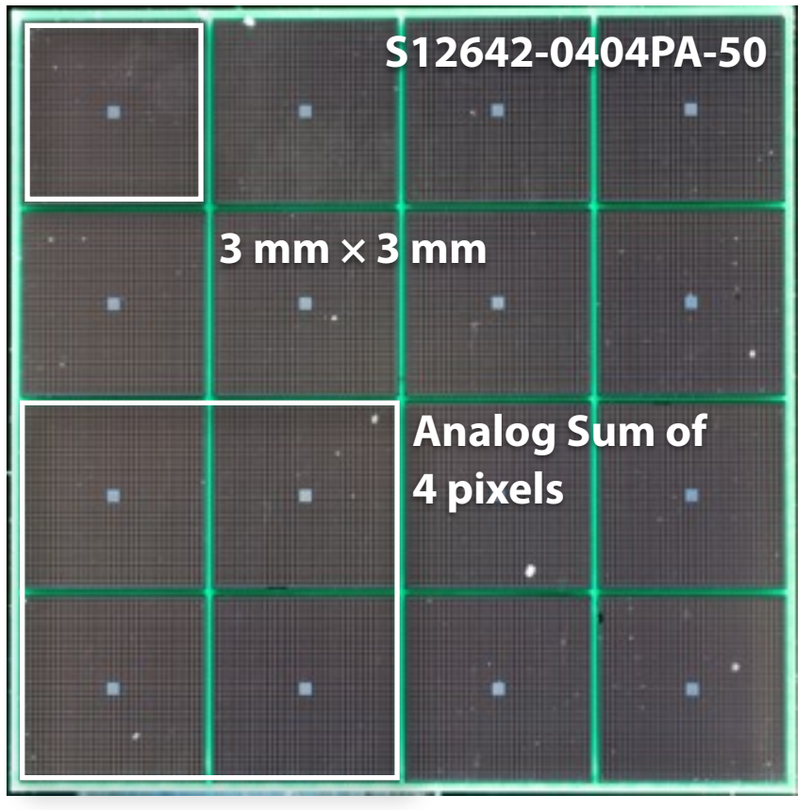
The SCT Optical System and Photodetectors

Ray-tracing Simulation with ROBAST



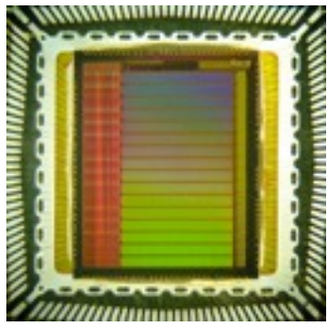
Mirrors' quality and misalignment are not included



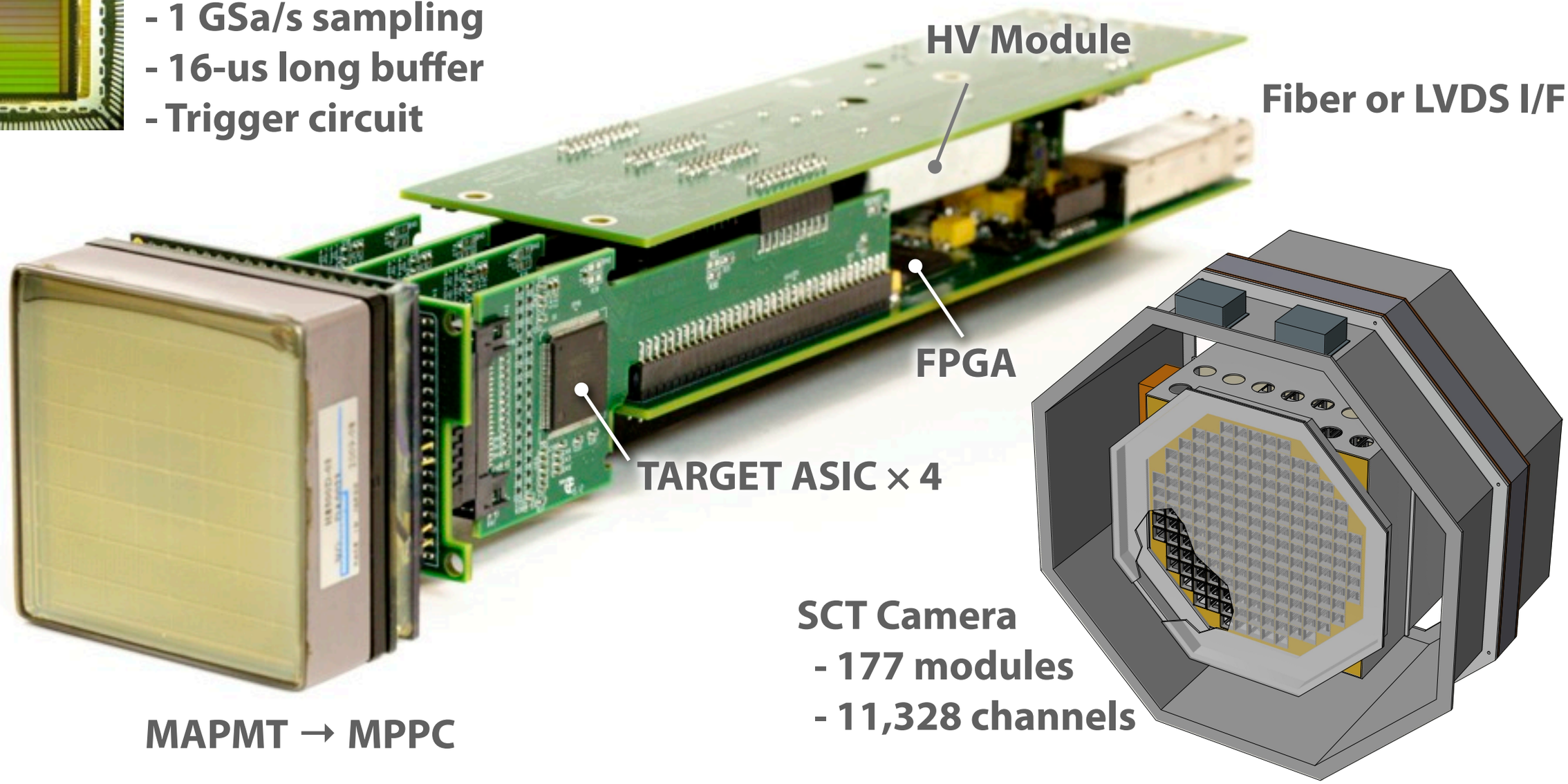


- The typical PSF size of SCT is ~6 mm (~4′)
- Compact and modular camera front-end electronics with small-pixel photodetectors needed
- Silicon photomultipliers (SiPMs or MPPCs) or MAPMTs match the pixel size

TARGET (TeV Array Readout with GSa/s sampling and Event Trigger)

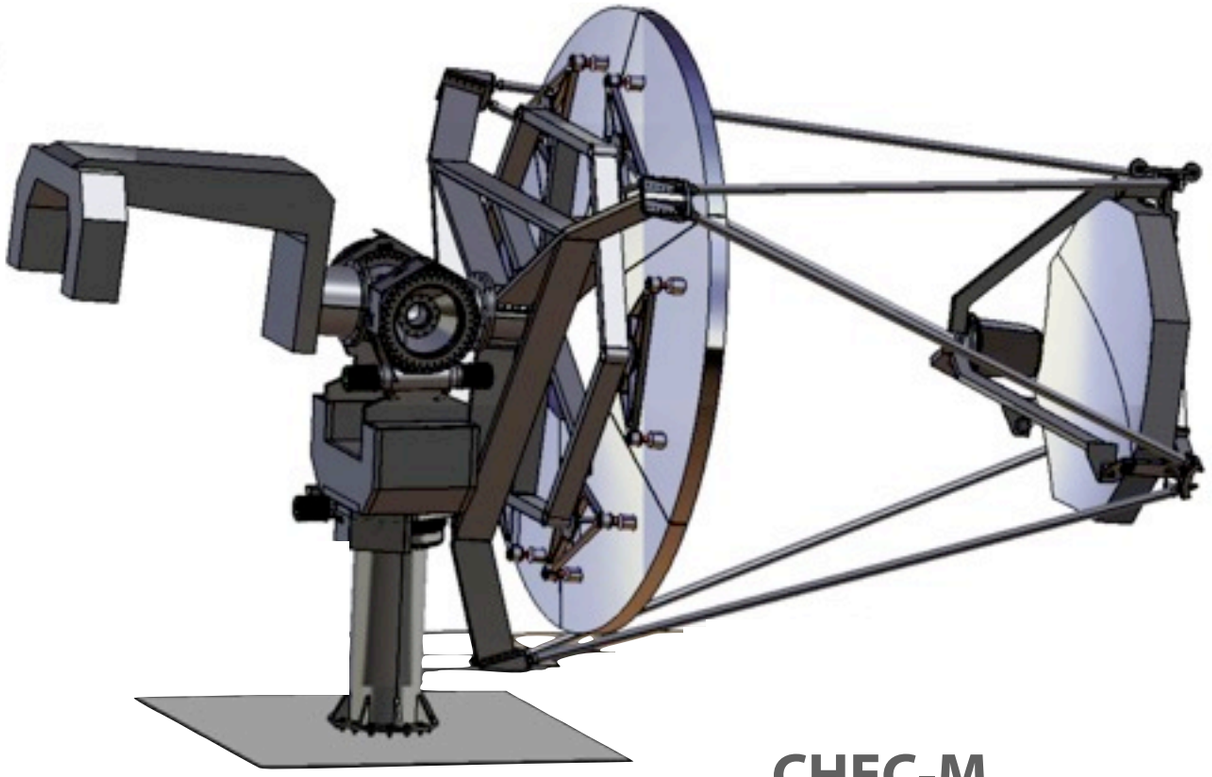


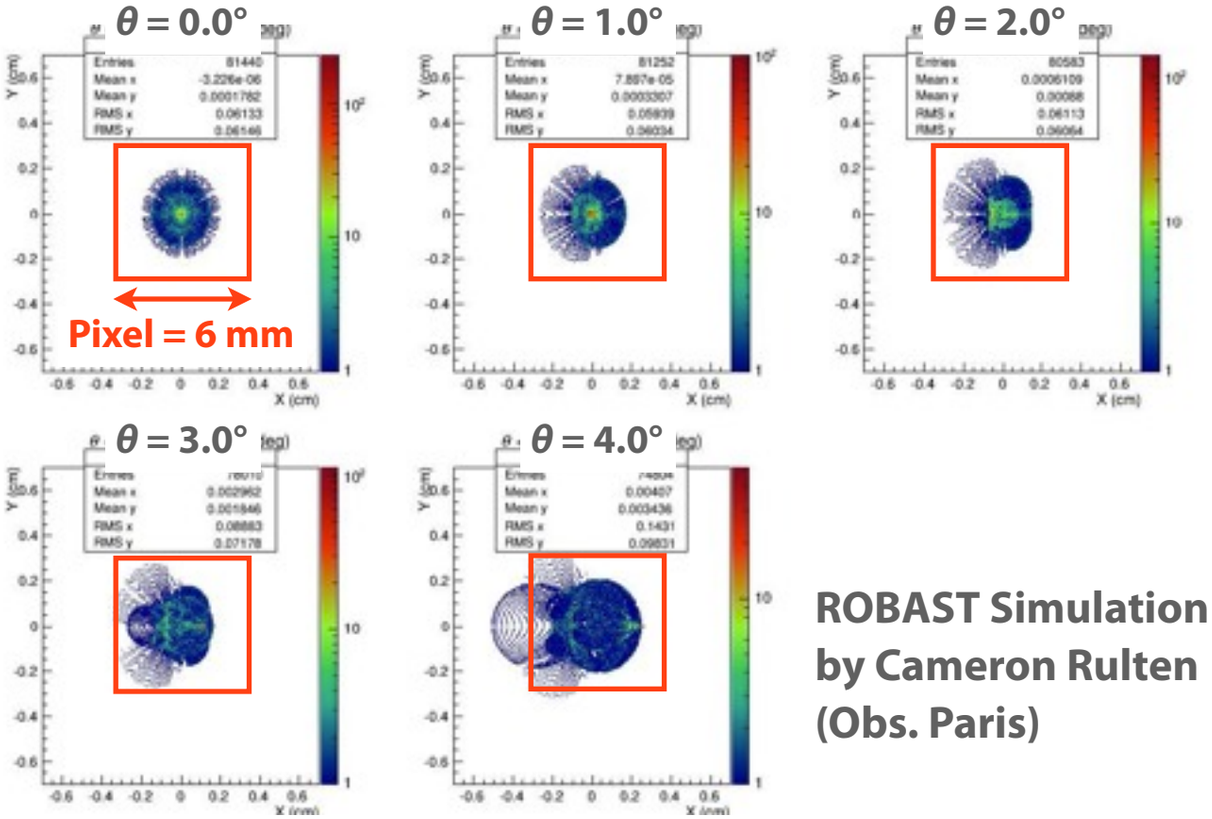
TARGET ASIC (designed by G. Varner @ U. Hawaii)
- 16 channels readout
- 1 GSa/s sampling
- 16-us long buffer
- Trigger circuit



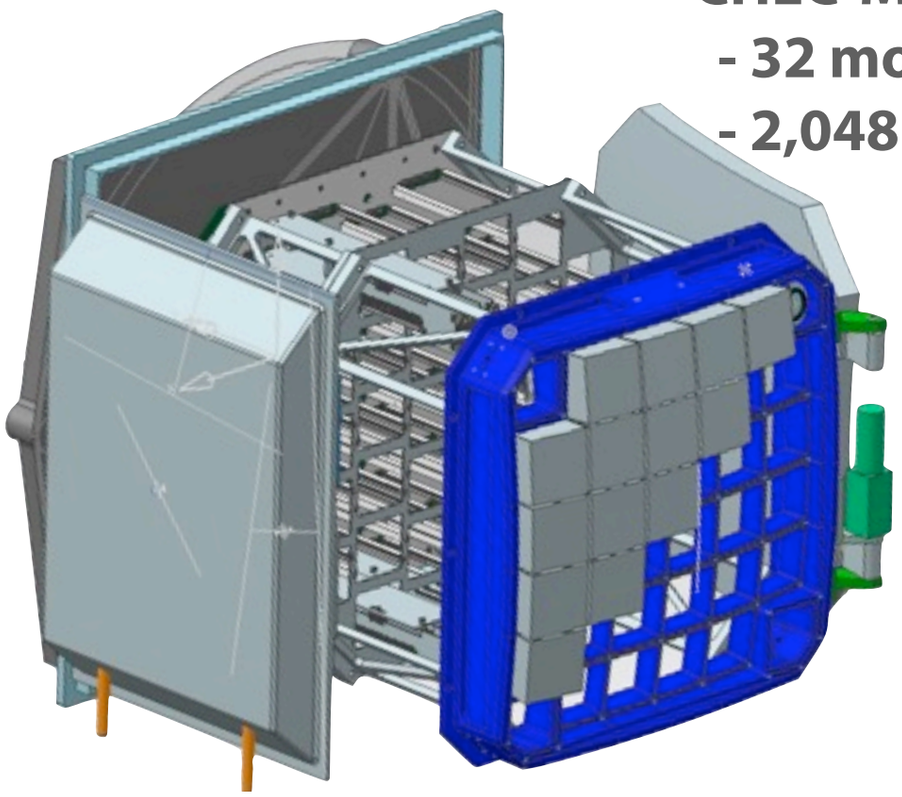
- Application specific integrated circuit (ASIC) for CTA
- Developed TARGET 1 for concept validation (Bechtol et al. 2012)
- TARGET 5 (w/ gain adjustment) for MAPMTs, TARGET 7 for MPPCs

SST-GCT (Gamma Compact Telescope) and CHEC





ROBAST Simulation by Cameron Rulten (Obs. Paris)



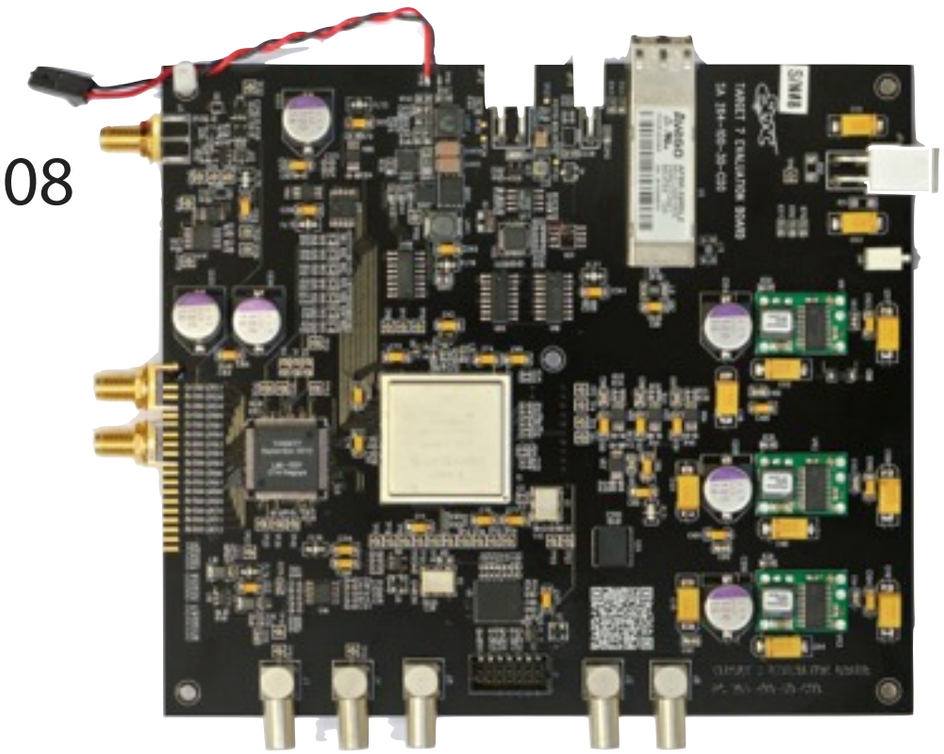
CHEC-M
- **32 modules**
- **2,048 channels**

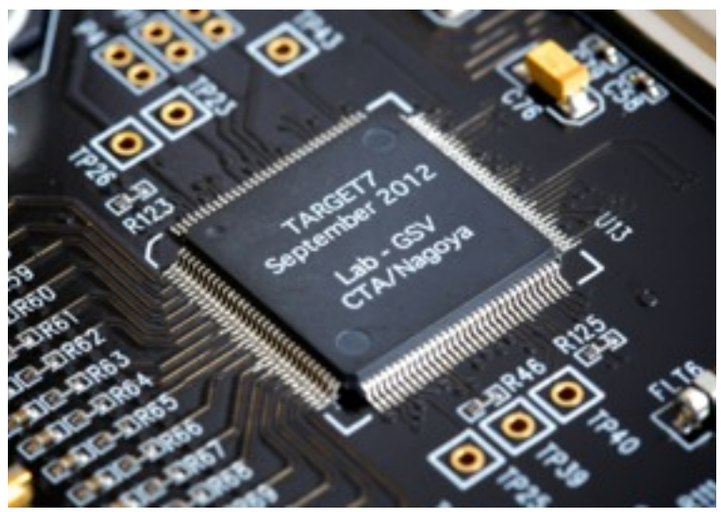
- One of three SST designs, based on SC optical system
- Compact High-Energy Camera (CHEC) will be mounted
  - CHEC-M: Prototype with MAPMTs
  - CHEC-S: Prototype with SiPMs
- Shares technologies with SCT

Development of TARGET ASICs

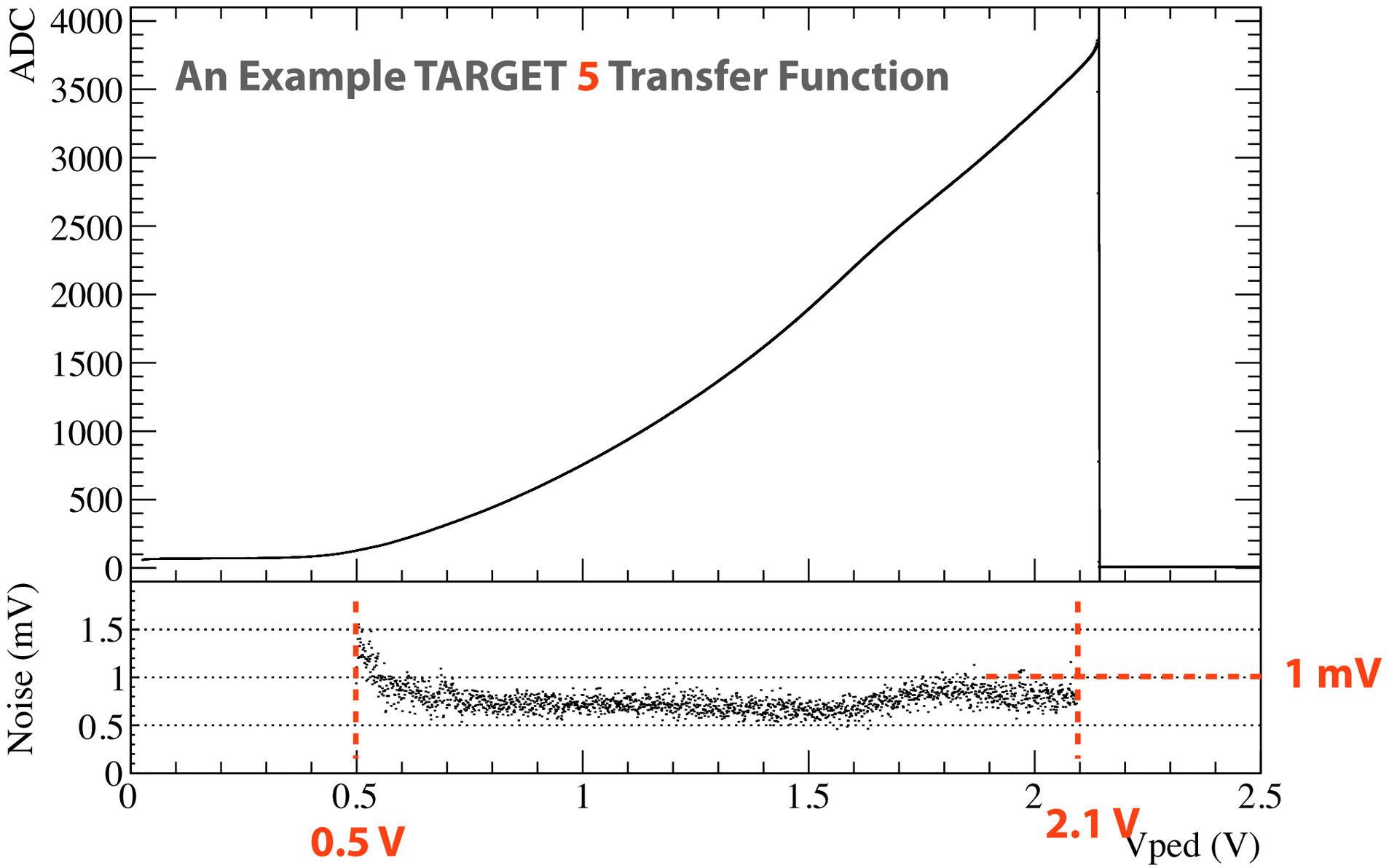
詳細は河島講演 21pSG-5

- 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





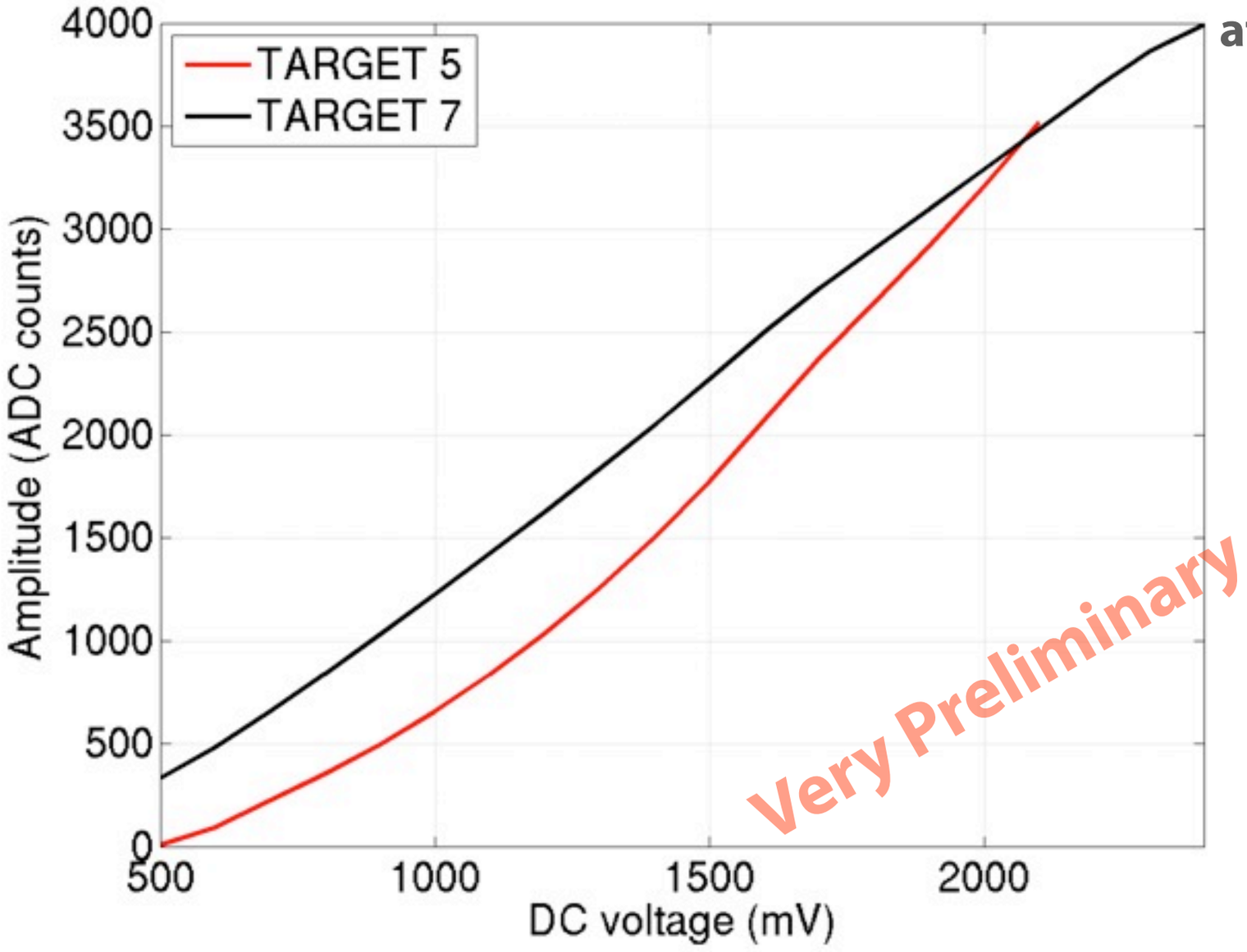
TARGET-5 Transfer Function



- 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

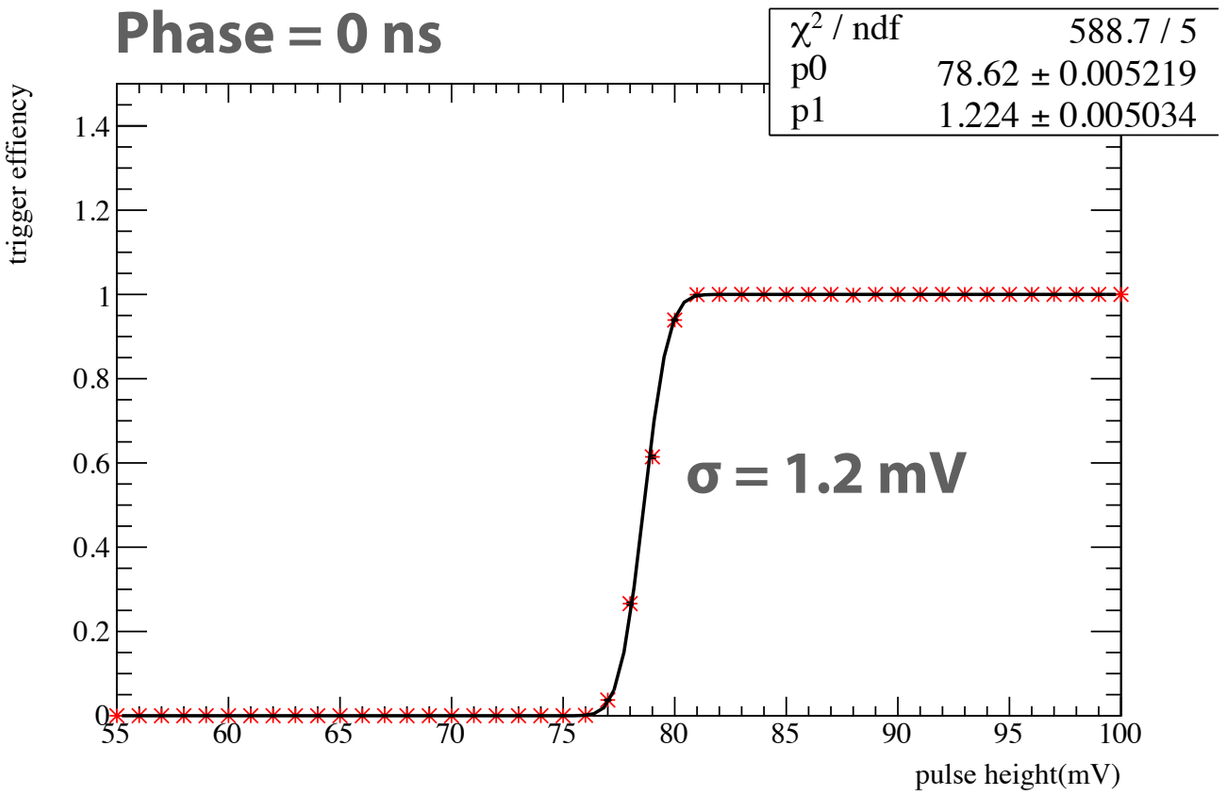
by J. Vandenbroucke at Wisconsin

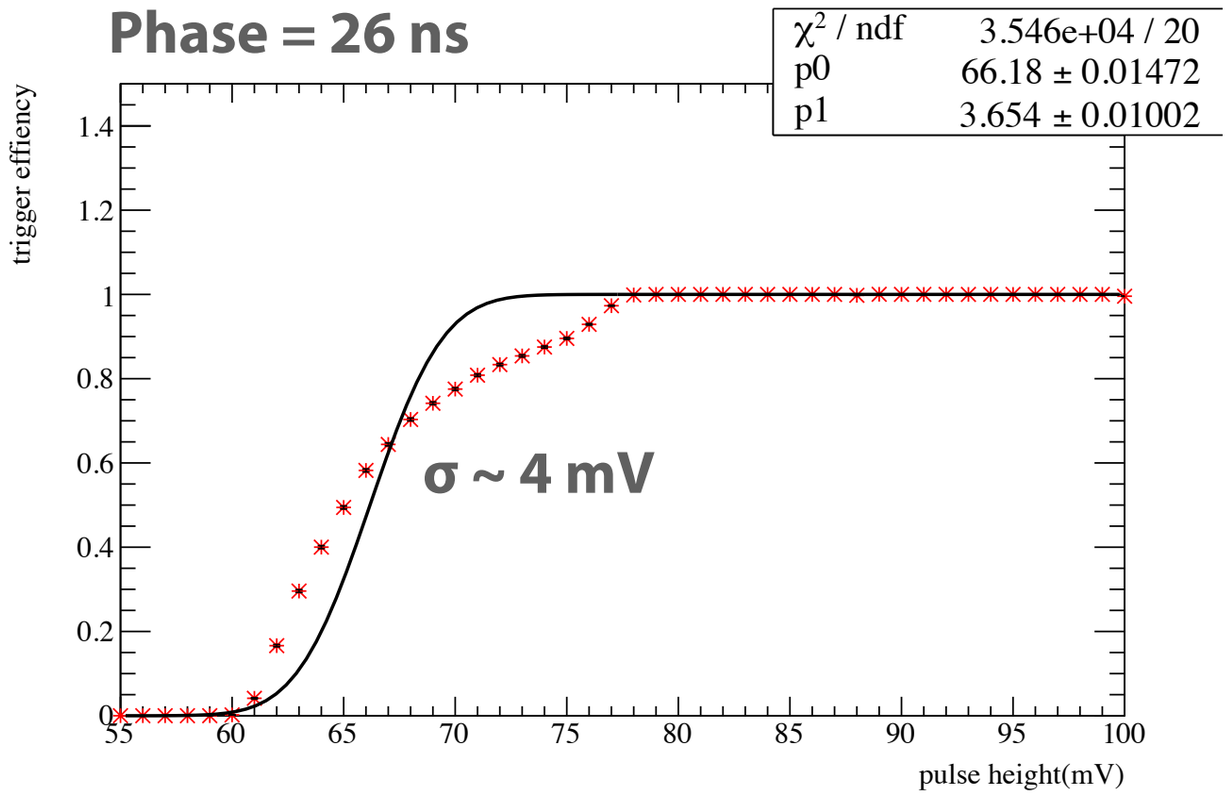


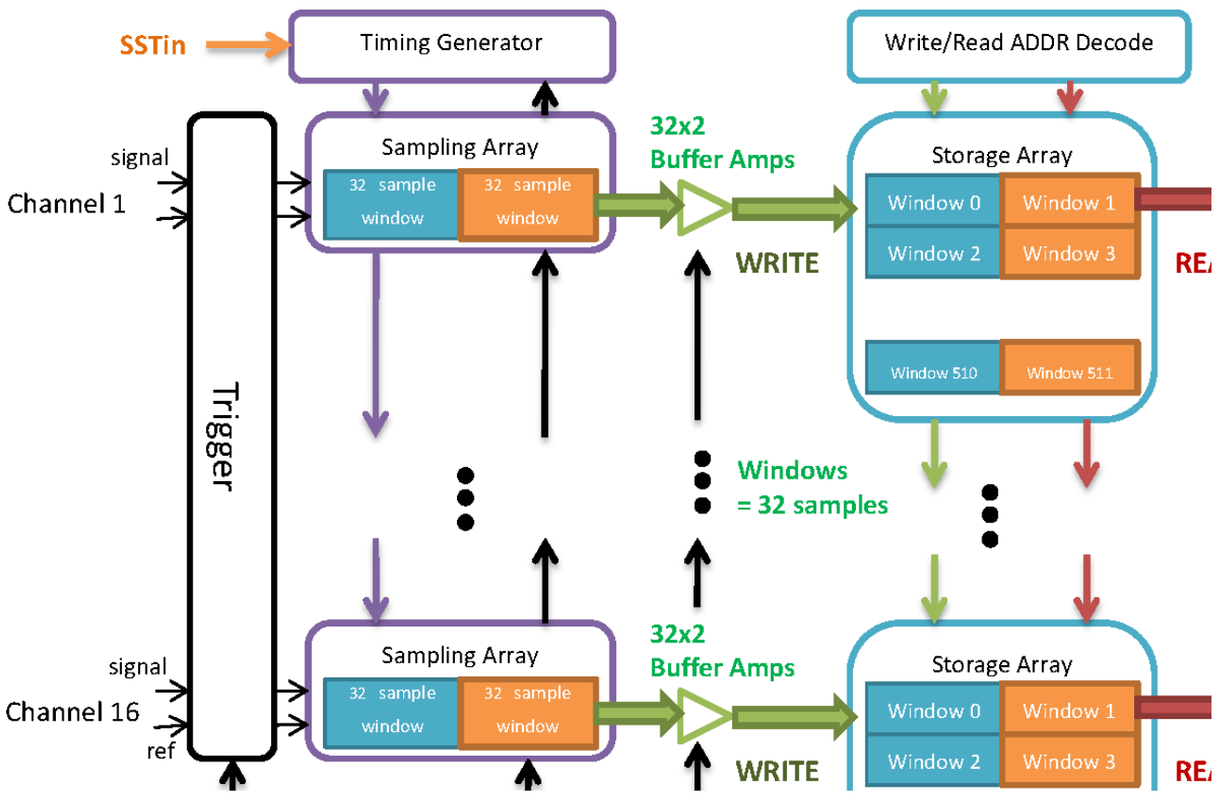
- Linearity was much improved from TARGET 5
- Wider dynamic range from ~0.5 to ~2.5 (V) (~0.5 to ~2.1 for TARGET 5)

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

by Taka Kawashima & Luigi Tibaldo

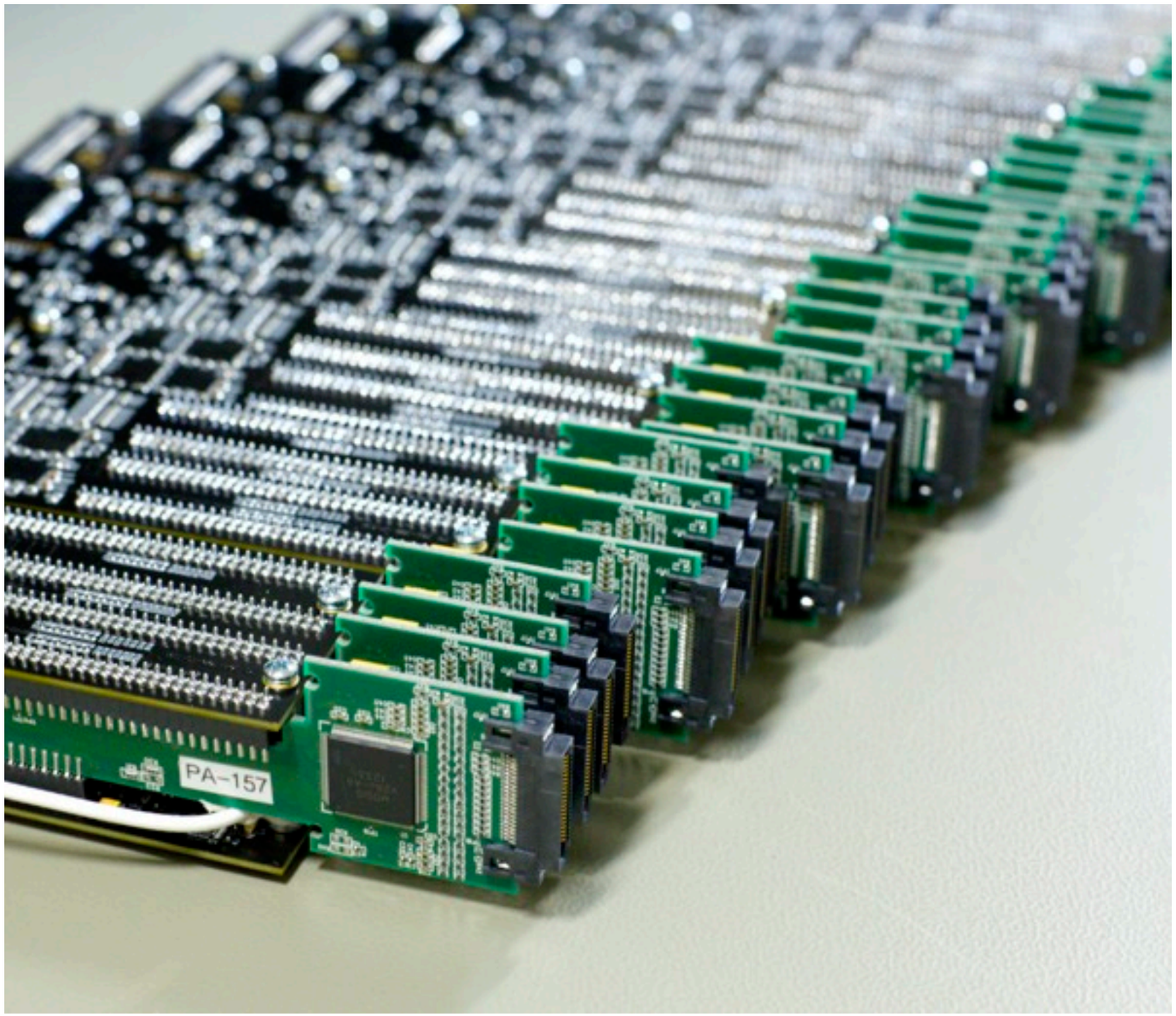






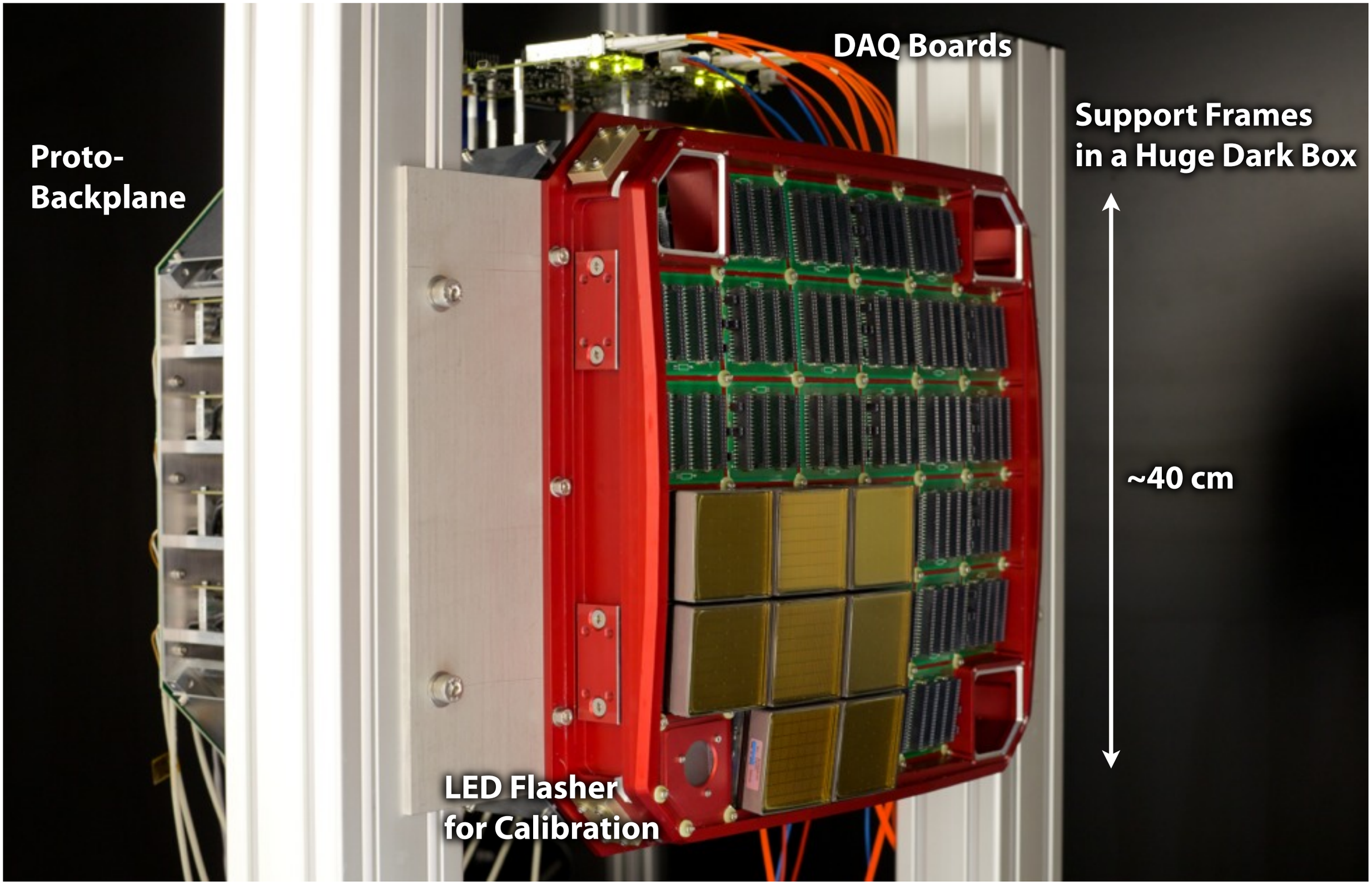
- Sampling arrays of a 64-ns period
- Threshold and trigger noise change as the trigger timing shifts in the sampling arrays

The First Mass Production of Modules for CHEC-M

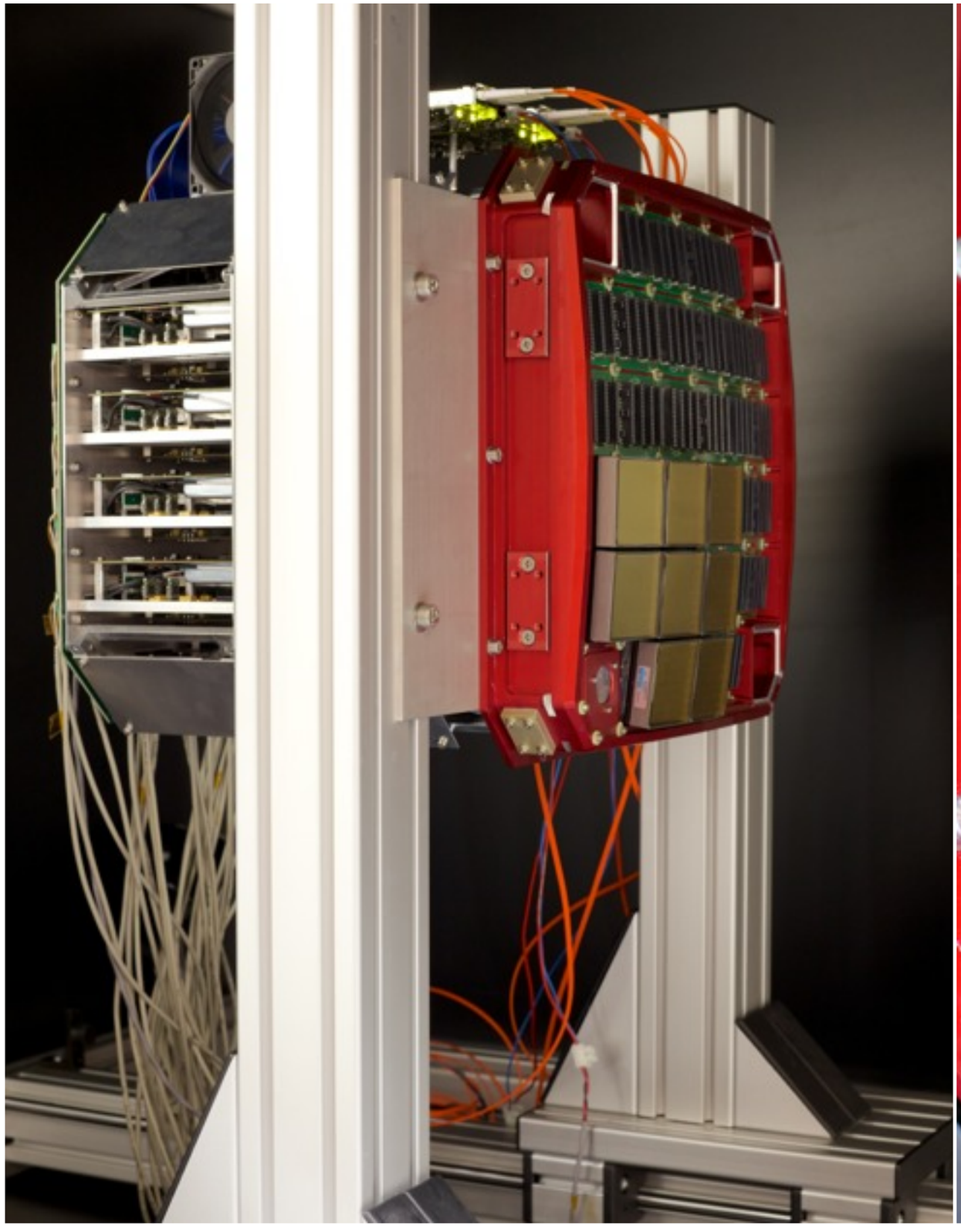


- Produced by SLAC with TARGET 5 ASICs
- Tested at SLAC in March and April 2014
- Delivered to University of Leicester and tested again in July
  - HV module
  - Trigger functionality
  - Transfer functions
  - Sampling stability
  - Sinusoidal input

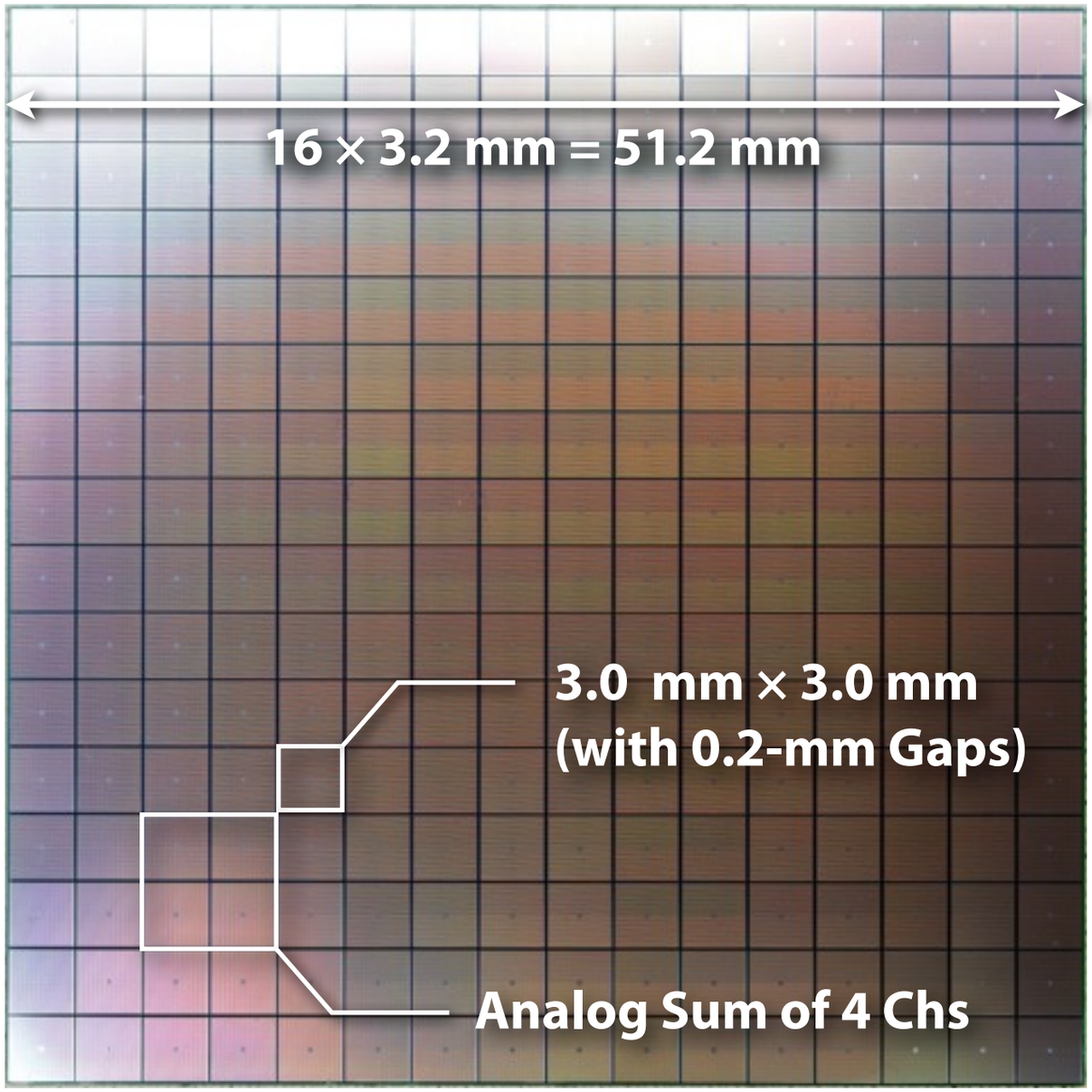
CHEC-M with a Prototype of Backplane Board

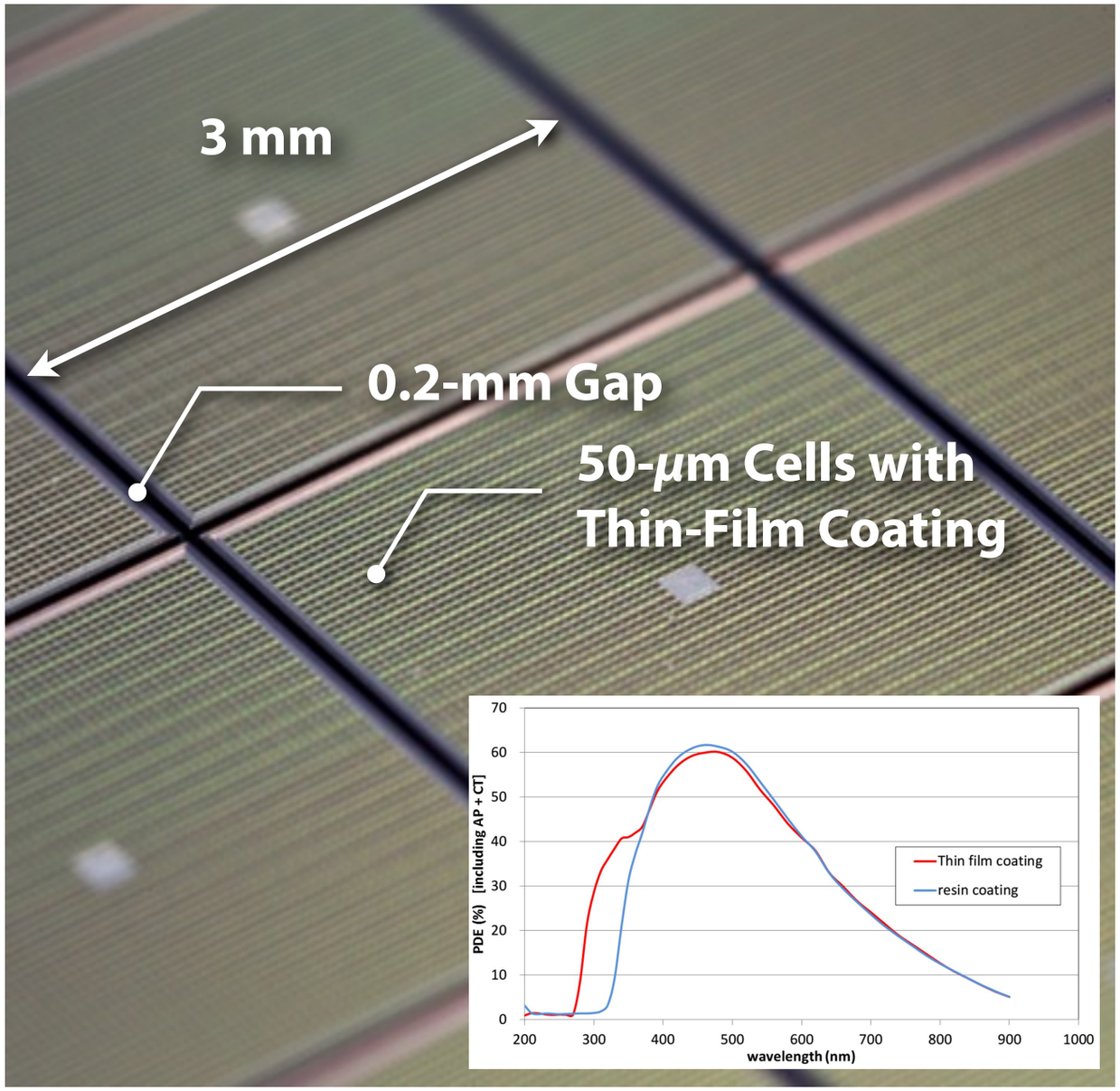


CHEC-M with a Prototype of Backplane Board



16 × 16 MPPC with Thin-Film Coating





- TSV MPPCs of 16 × 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