

CTA 計画に向けた Schwarzschild-Couder 光学系とチェレンコフ撮像カメラの開発

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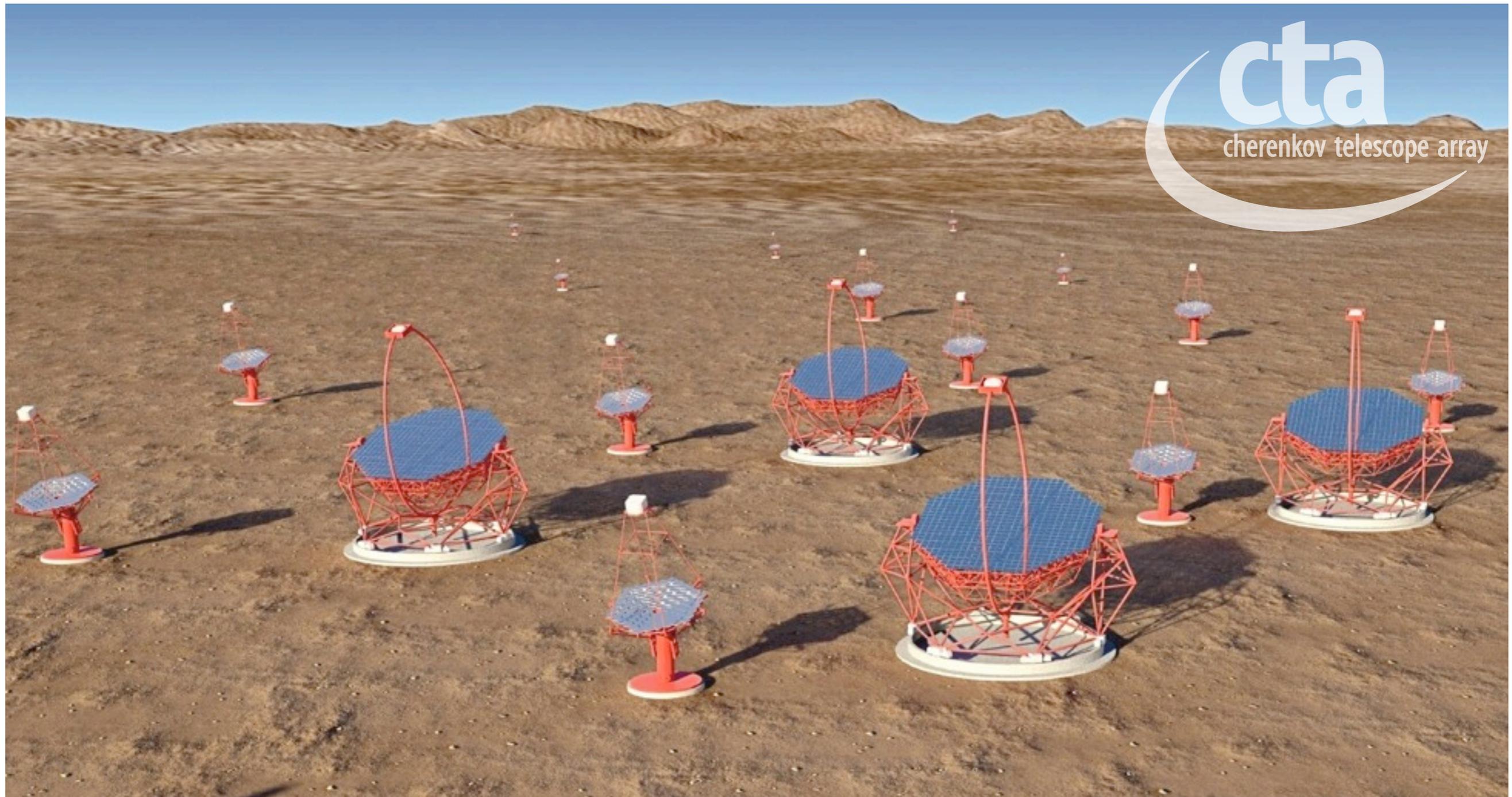
L. L. Ruckman、G. Varner（ハワイ大学）

他 The CTA Consortium

2012 年 9 月 20 日

日本天文学会 2012 年 秋季年会 @ 大分大学

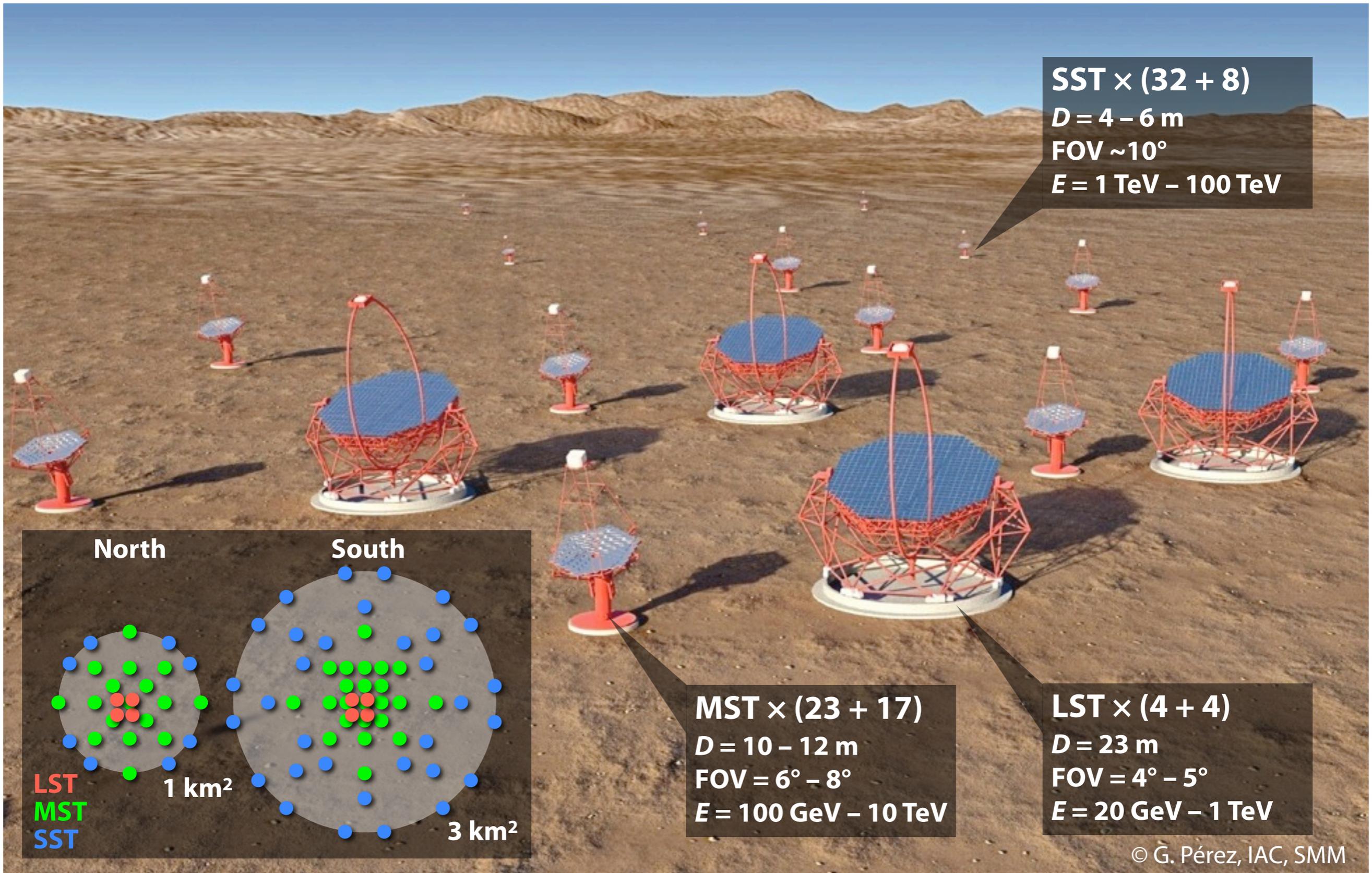
Cherenkov Telescope Array (CTA)



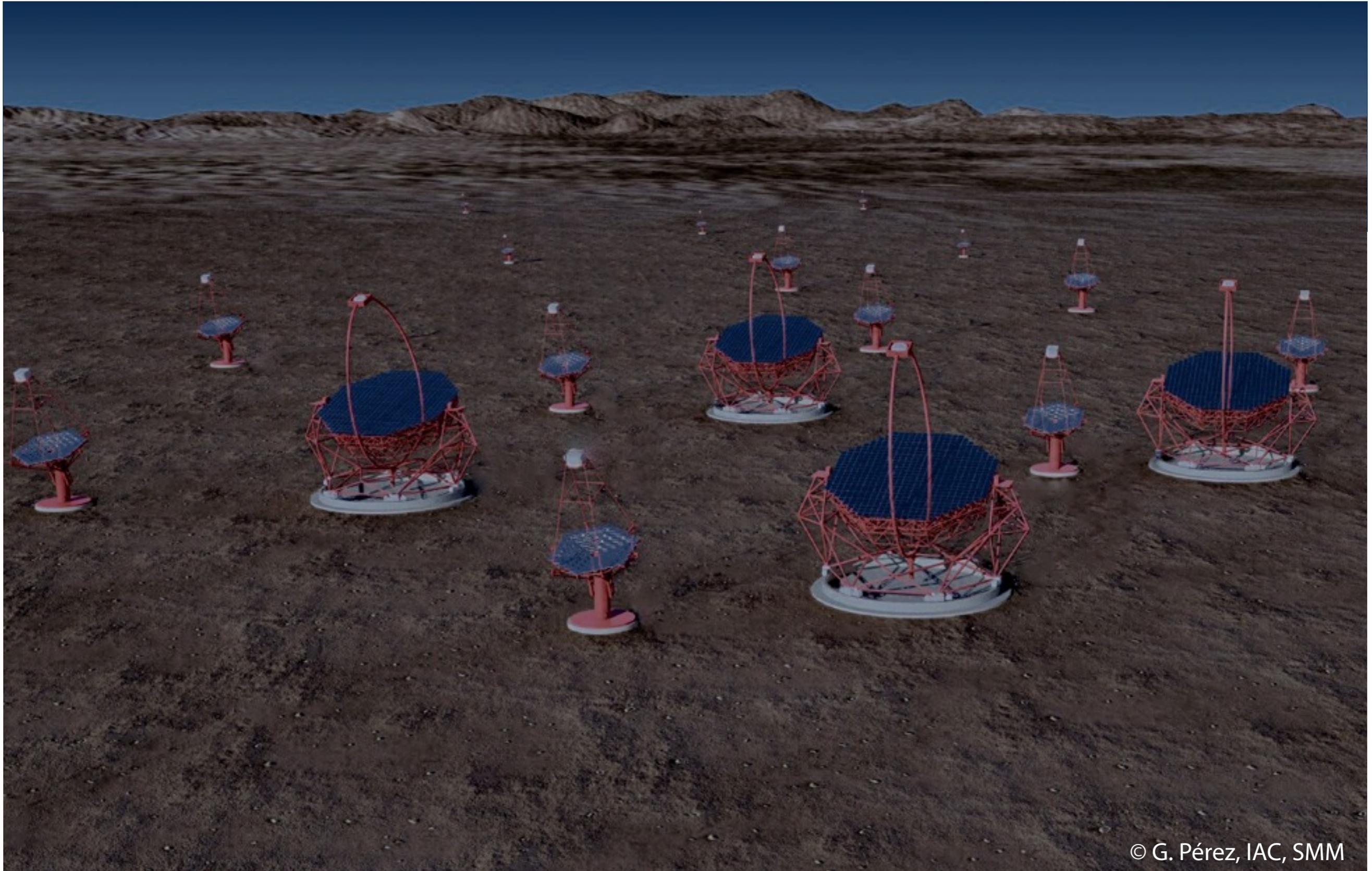
**The Next-generation Very-high-energy
(VHE) Gamma-ray Observatory**



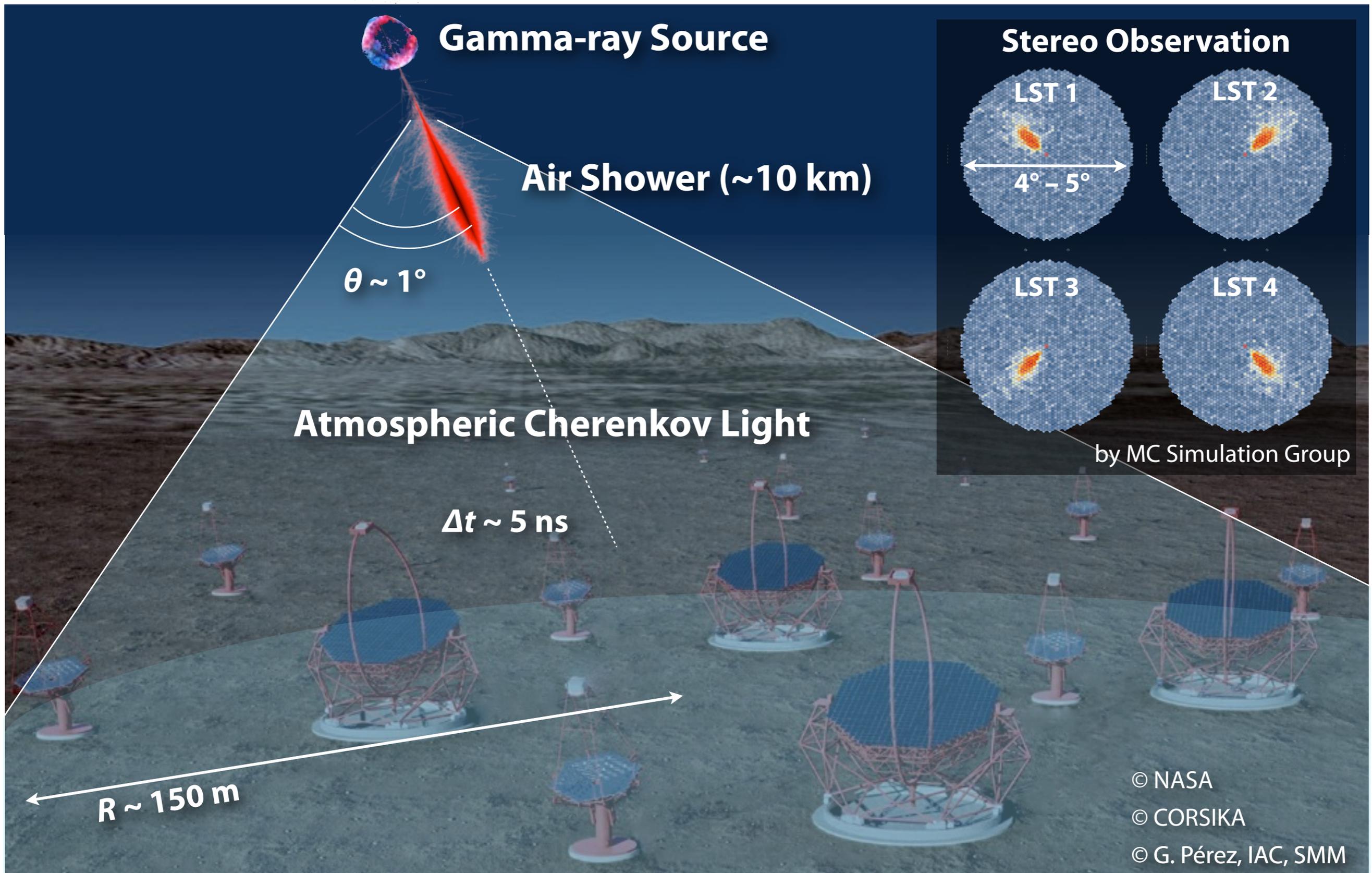
Large/Medium/Small Size Telescopes (LST/MST/SST)



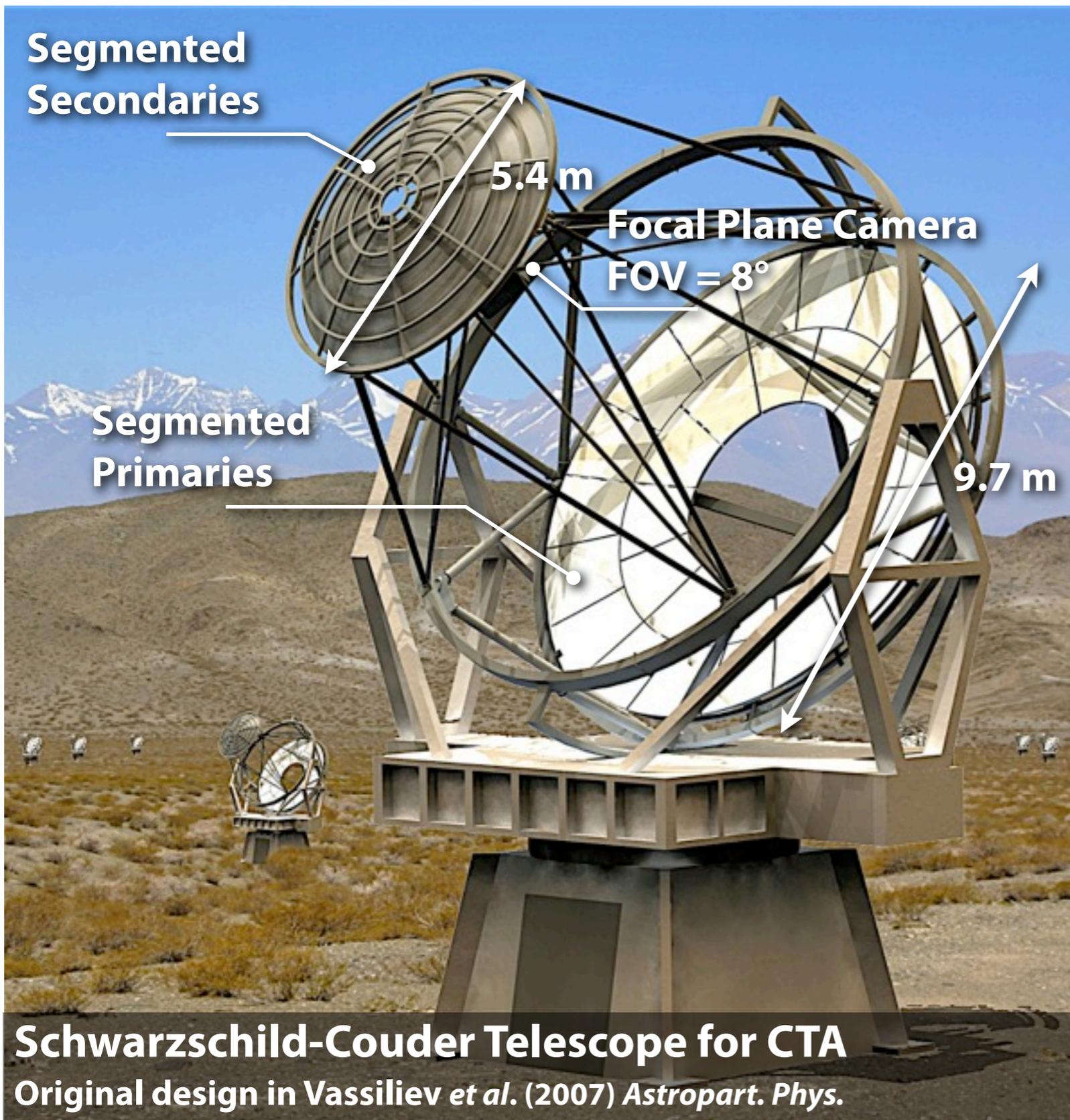
Detection Technique of VHE Gamma Rays



Detection Technique of VHE Gamma Rays



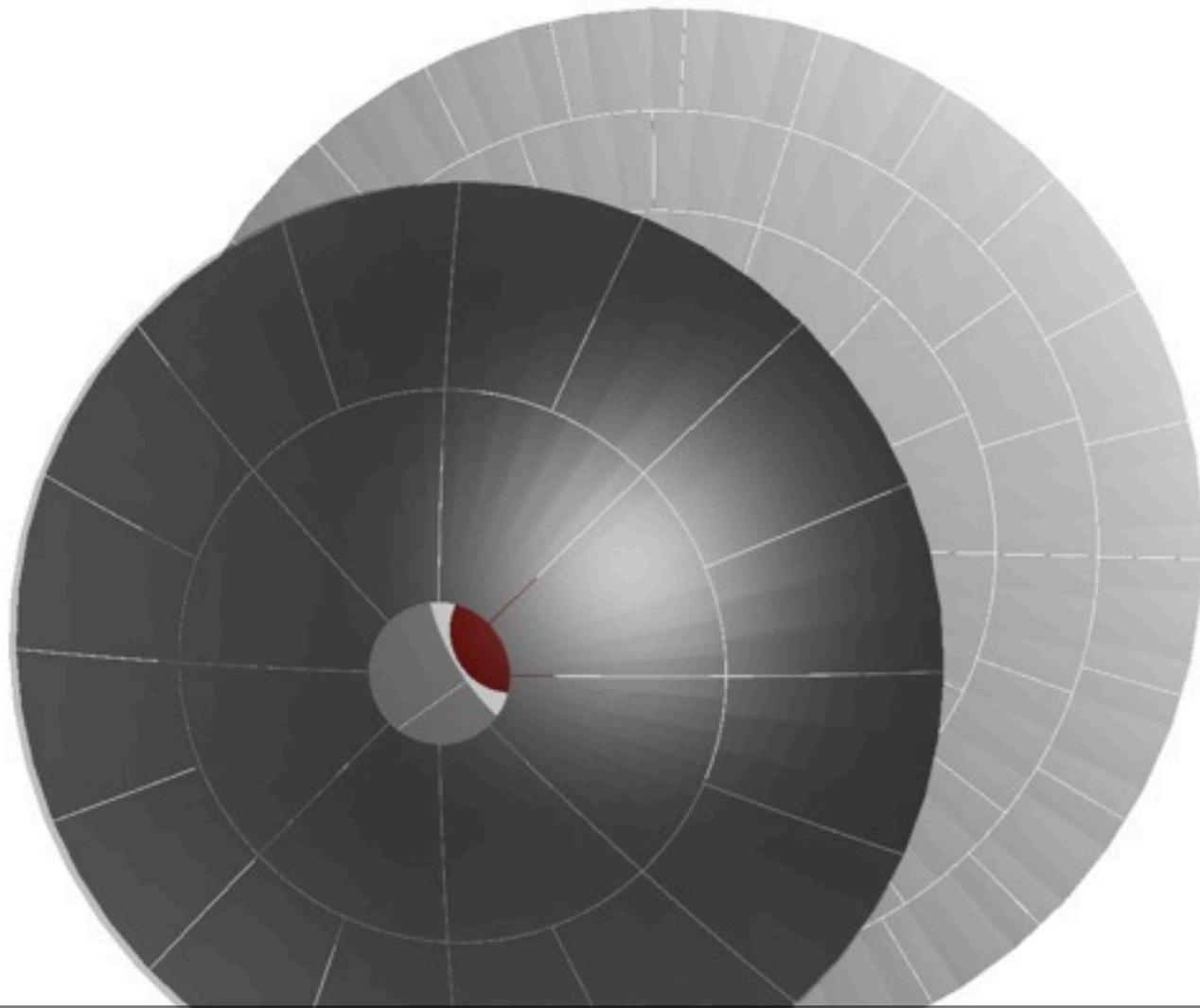
Schwarzschild-Couder (SC) Optical System



- ❖ Candidate for
 - ▶ MSTs by CTA-US
 - ▶ SSTs by Europe-Japan-US
- ❖ The first dual-mirror design for VHE gamma
- ❖ Achieves
 - ▶ Wide FOV of 8°
 - ▶ Fine angular resolution of $4'$
- ❖ Challenges
 - ▶ Segmented aspherical mirrors
 - ▶ Accurate mirror alignment
 - ▶ Compact multi-pixel camera module

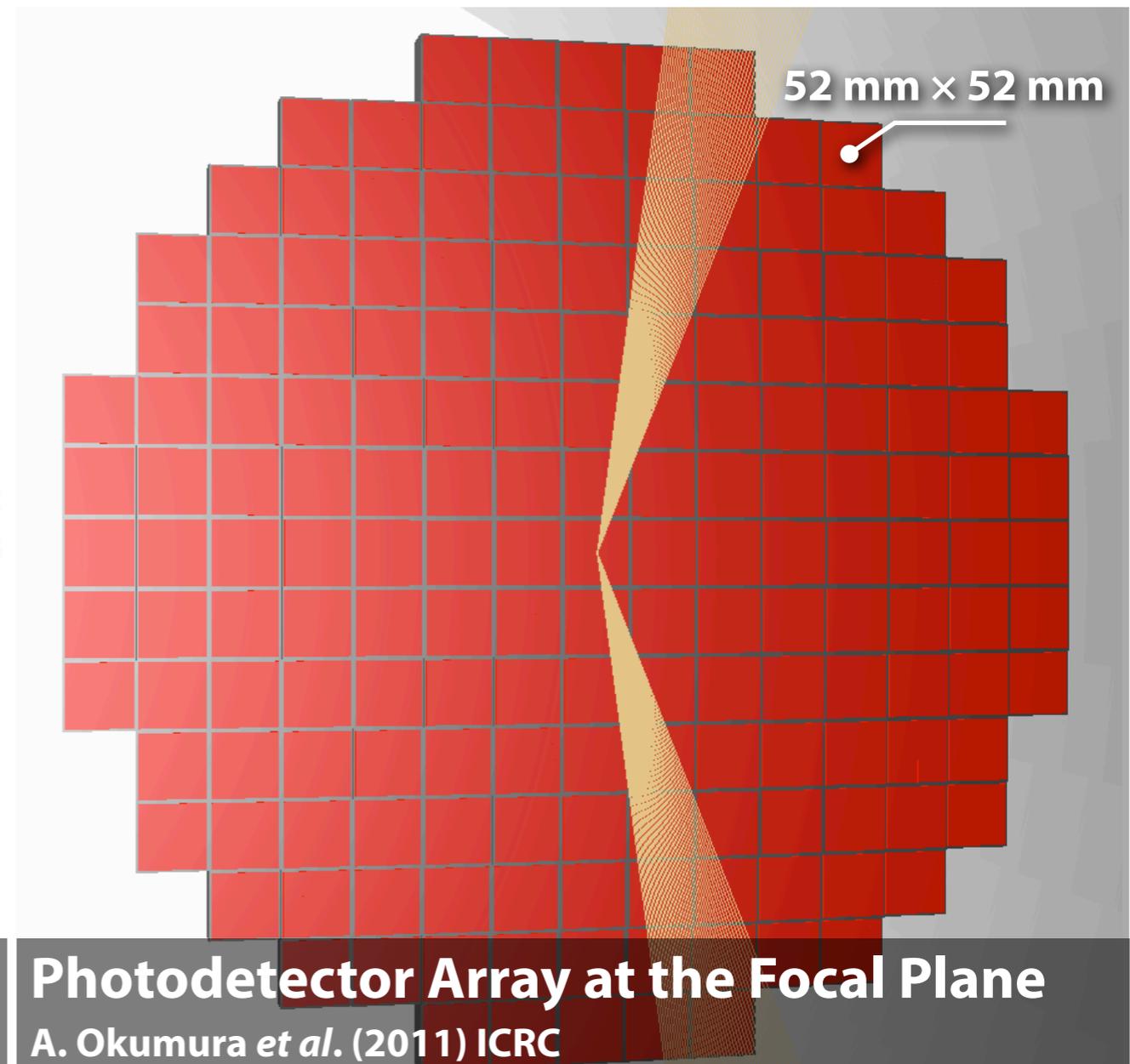
Schwarzschild-Couder Telescope for CTA
Original design in Vassiliev *et al.* (2007) *Astropart. Phys.*

Optical System and Ray-tracing Simulation



SC Telescope with Segmented Mirrors

Original design in Vassiliev *et al.* (2007) *Astropart. Phys.*



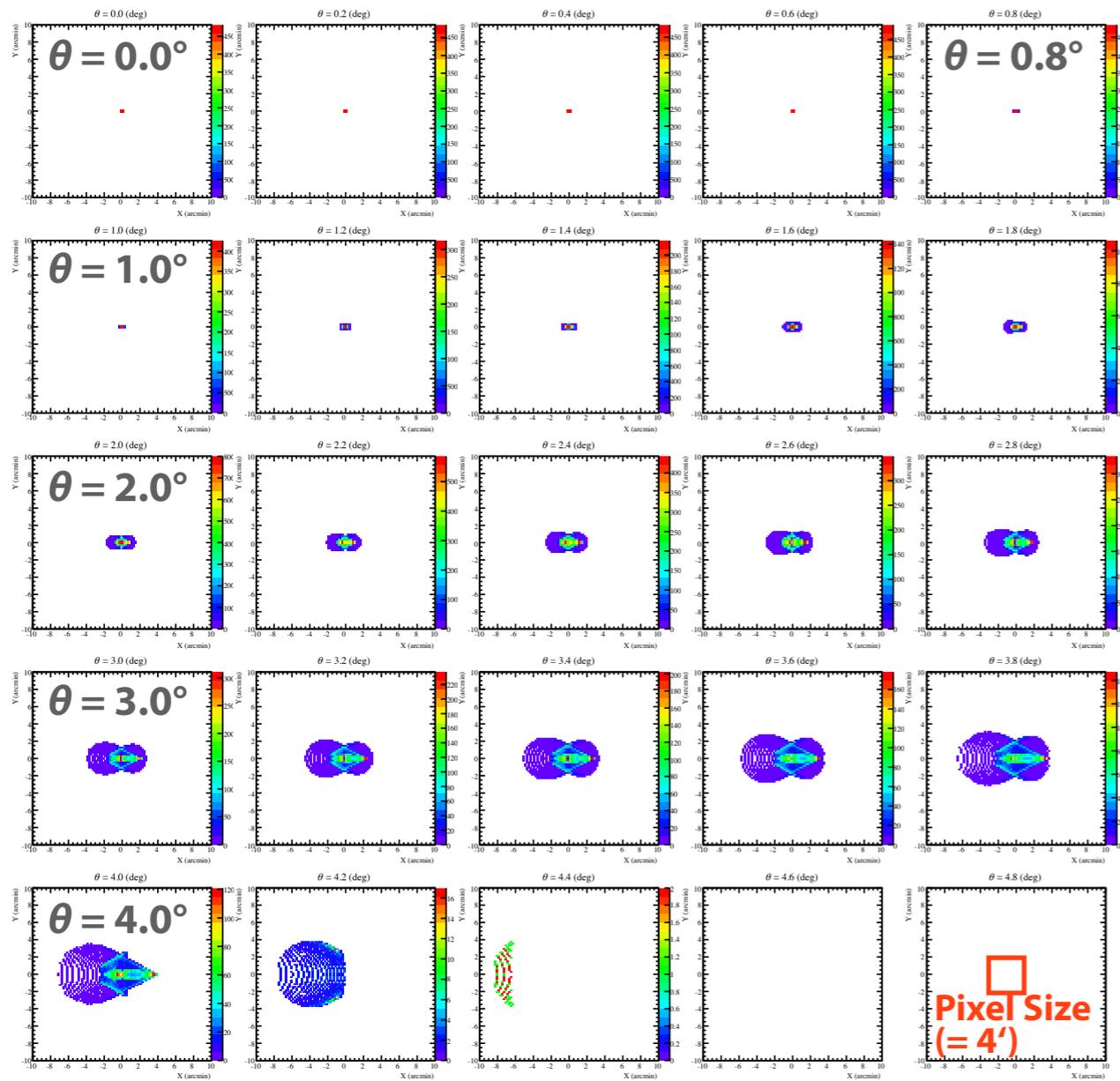
Photodetector Array at the Focal Plane

A. Okumura *et al.* (2011) *ICRC*

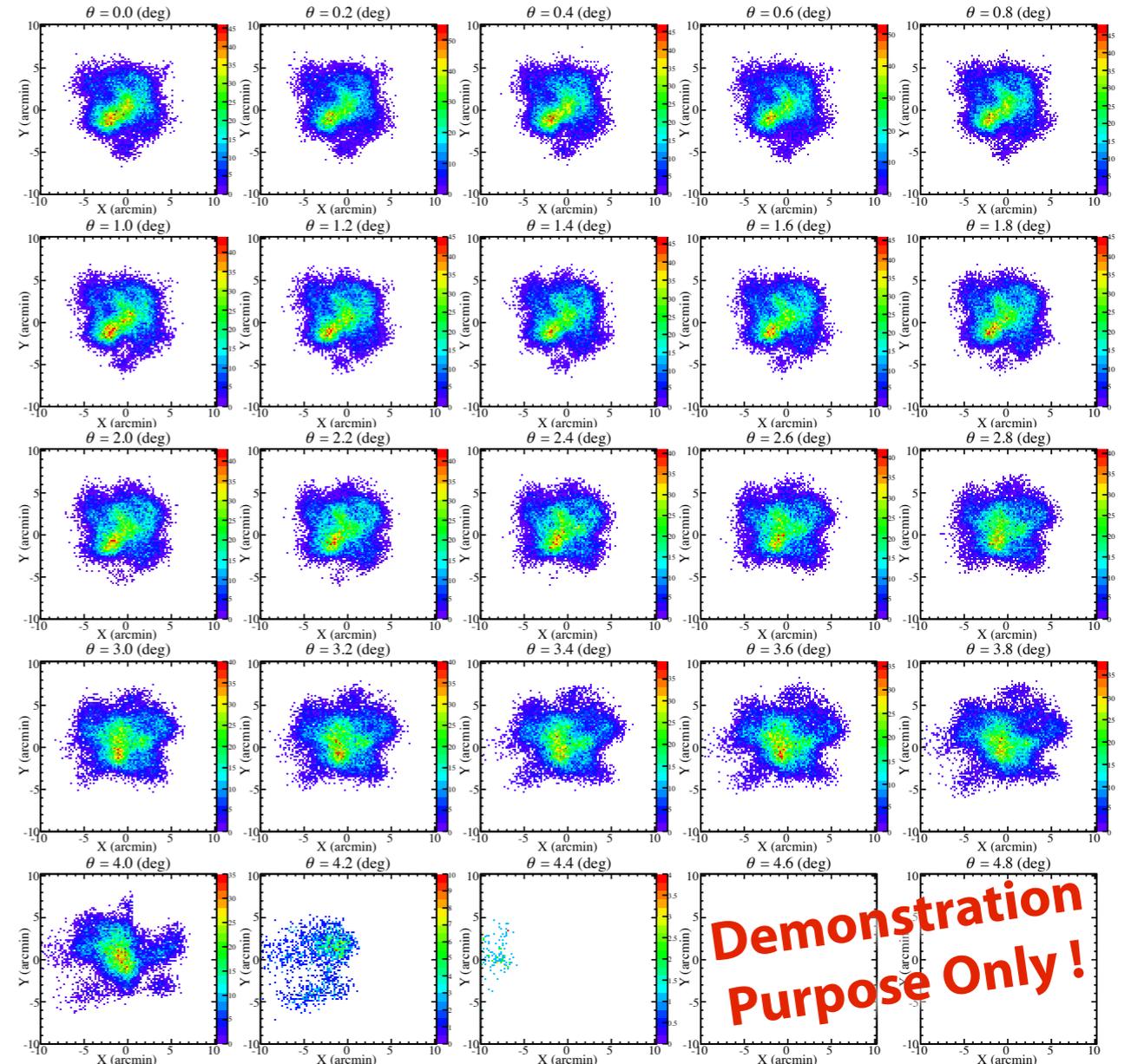
- ❖ Segmented primaries and secondaries with aspherical surfaces
- ❖ Wide FOV of 8° + fine resolution of $4'$ at affordable cost
- ❖ PSF ~ 6 mm, 11,000 pixel photodetector array, pixel size = 6 mm

Point Spread Functions

Ideal Mirrors and Alignments

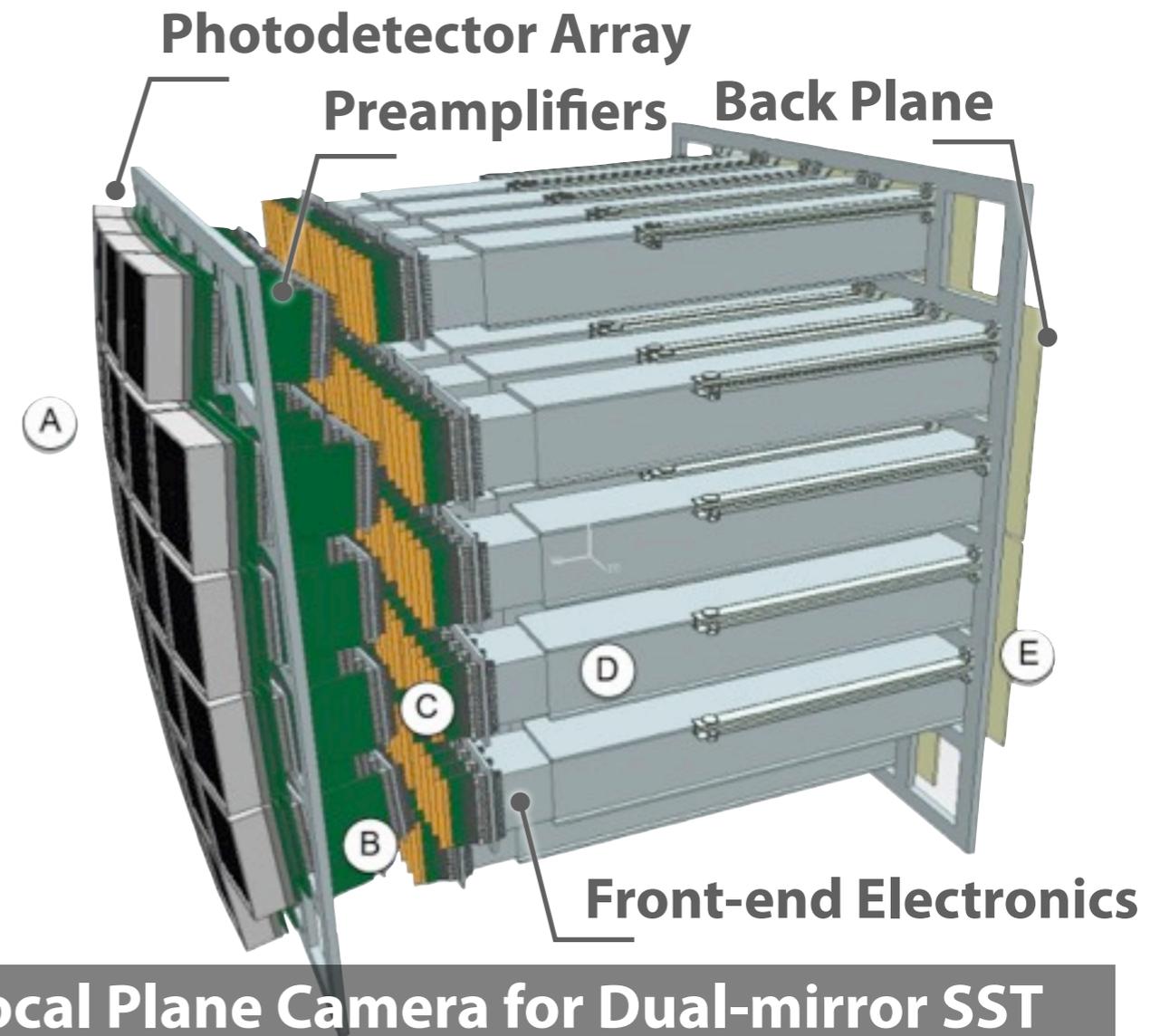
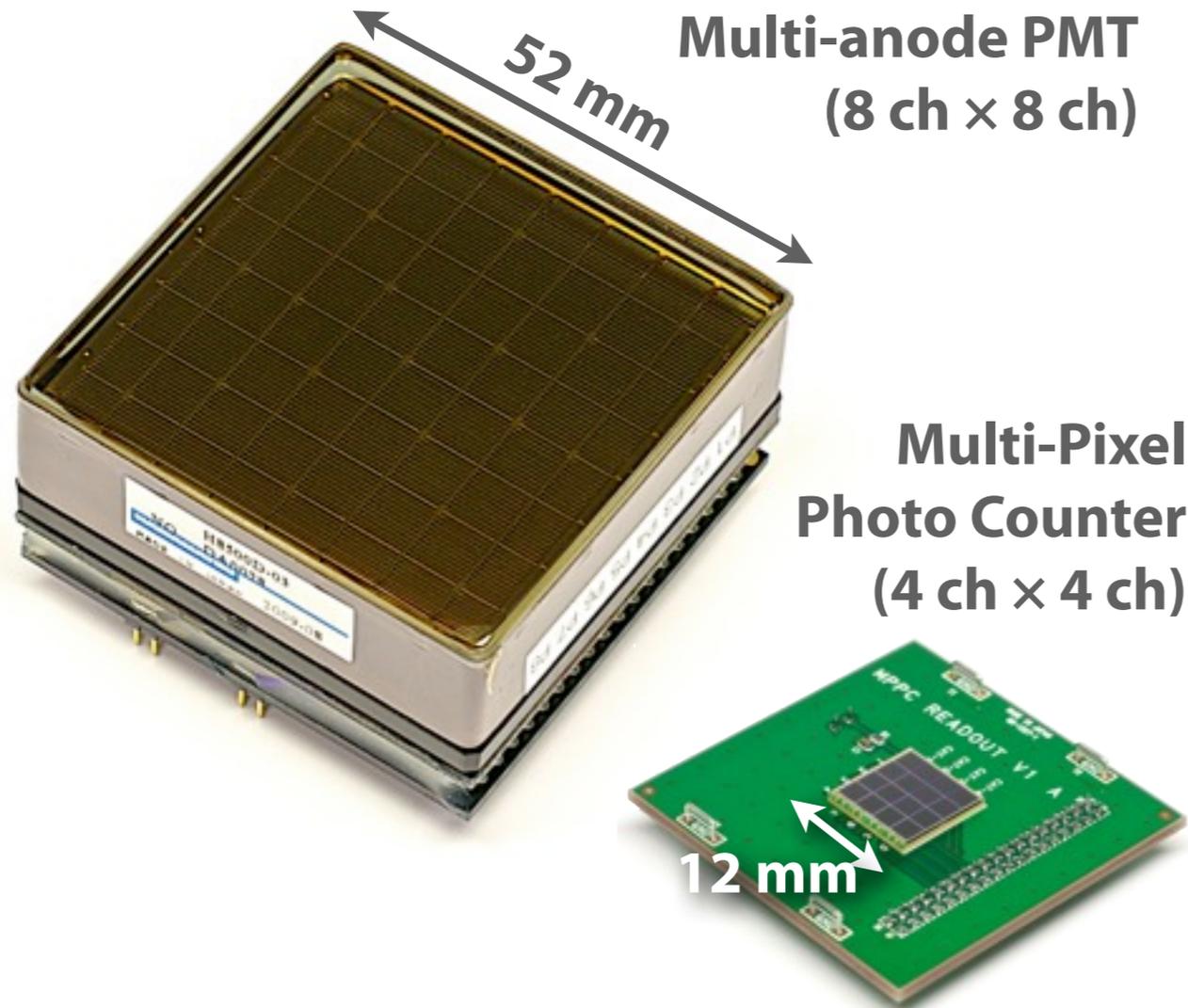


Rough Mirrors + Misalignments



- Studies on tolerance analysis and mirror alignment are ongoing
- Accuracy of $\approx 0.3'$ (rotation) and ≈ 1 mm (translation) for mirror alignments are required

Photodetectors and Camera Electronics



Multi-pixel Photodetectors

From Catalogs of Hamamatsu Photonics

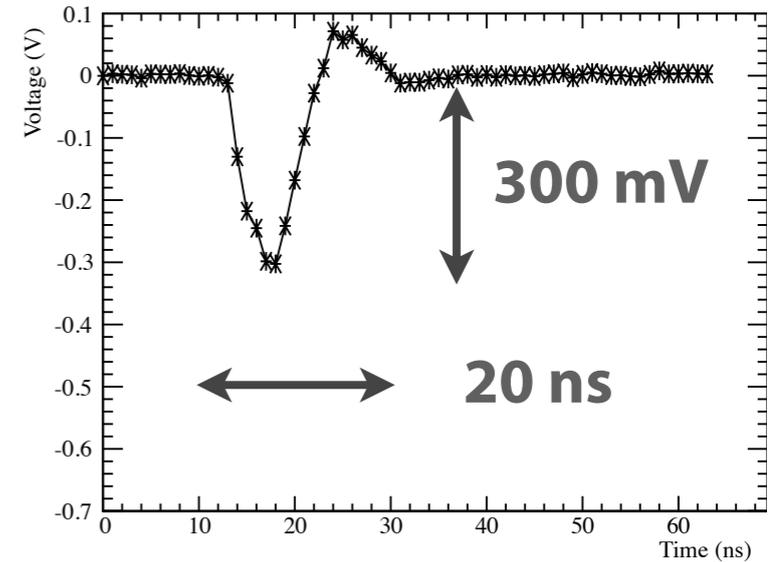
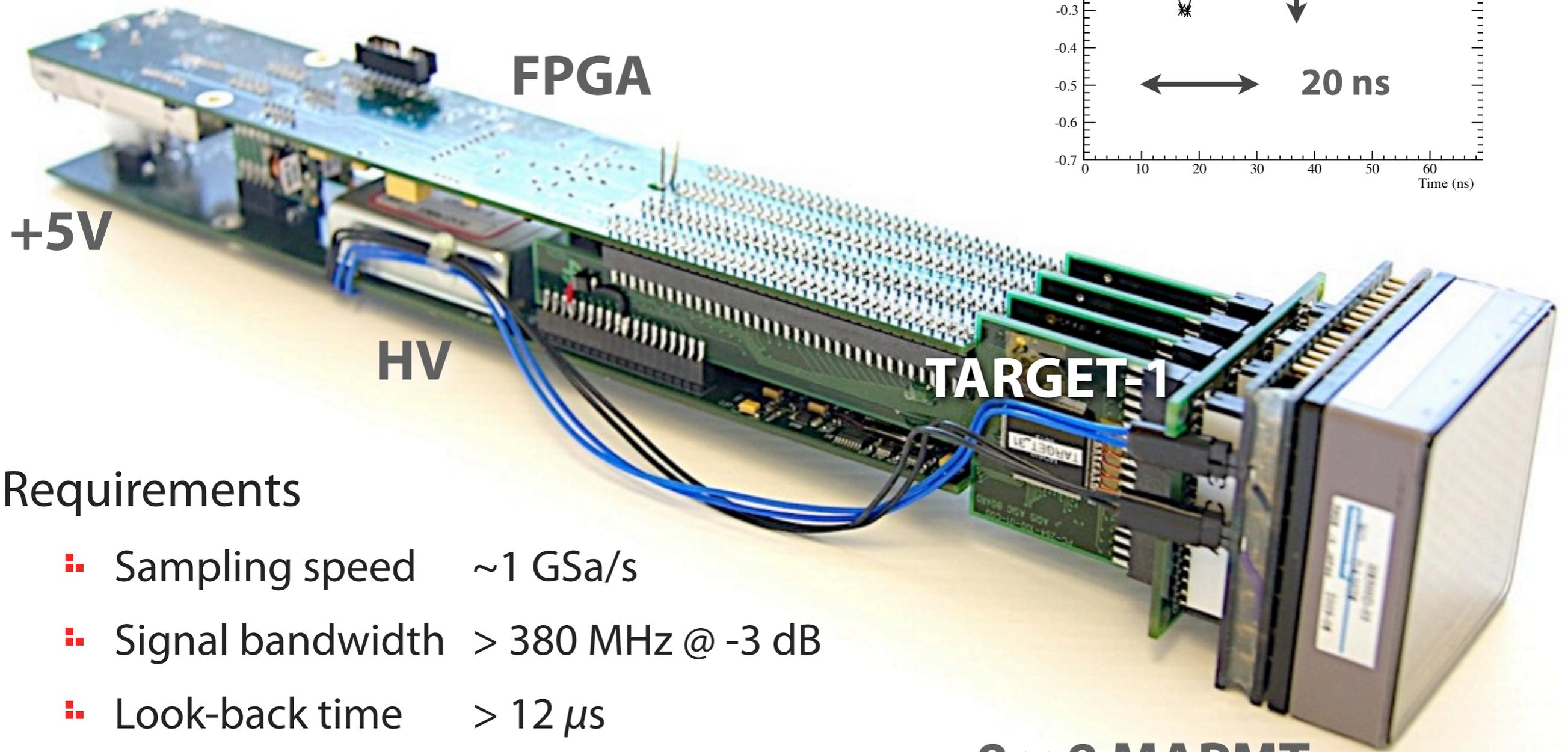
Focal Plane Camera for Dual-mirror SST

by CTA UK Group

- ❖ Allow compact multi-pixel photodetectors to reduce camera cost per pixel
- ❖ 64 ch multi-anode PMTs (H8500) or multi-pixel photo counters (MPPCs)
- ❖ Requires compact multi-channel readout working at low power consumption

The TARGET-1 ASIC + Camera Module

Fiber USB



Requirements

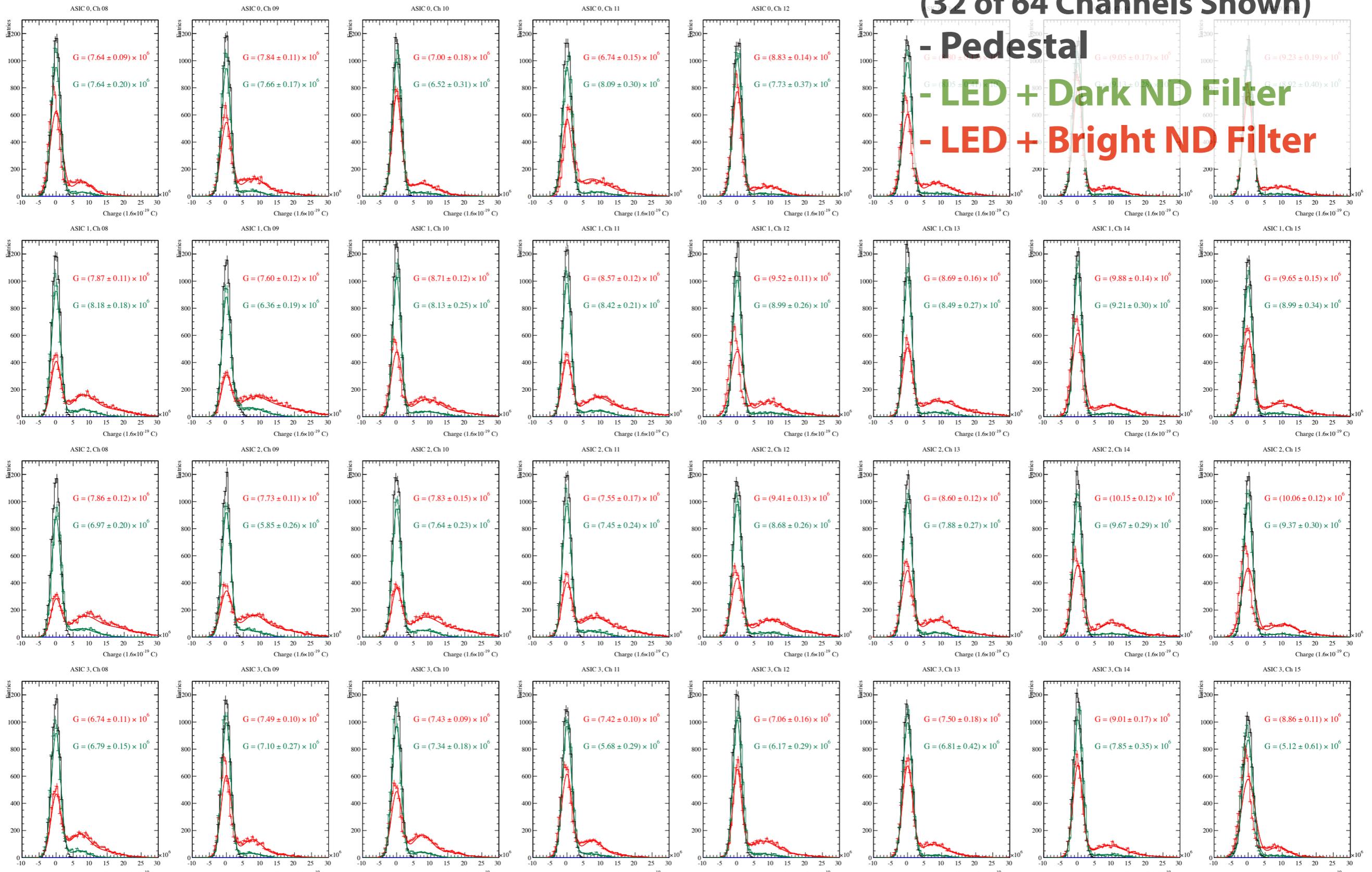
- ❖ Sampling speed ~ 1 GSa/s
- ❖ Signal bandwidth > 380 MHz @ -3 dB
- ❖ Look-back time $> 12 \mu\text{s}$
- ❖ Dynamic range > 9 bits
- ❖ Crosstalk $< 1\%$

**8 × 8 MAPMT
(H8500D-03)**

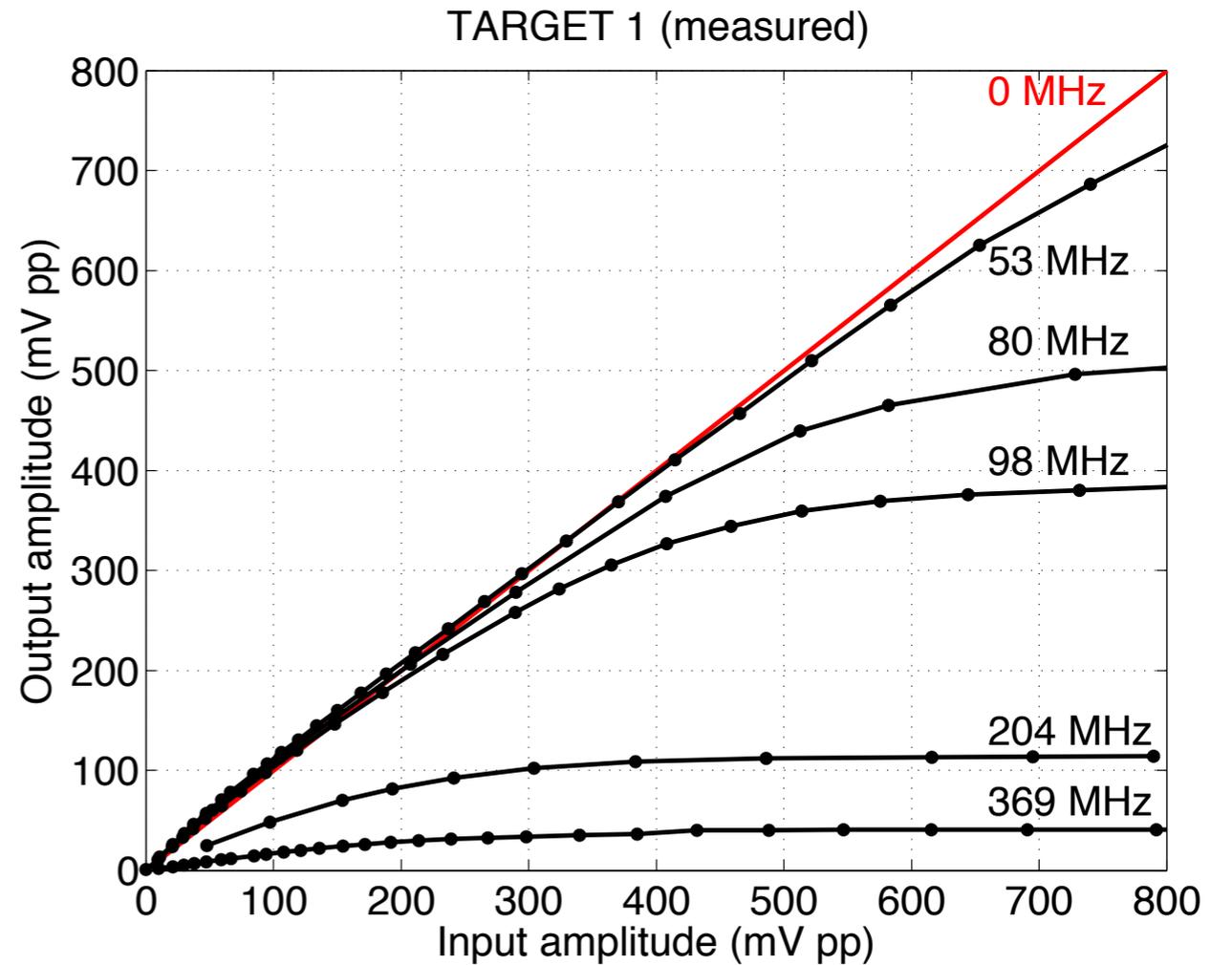
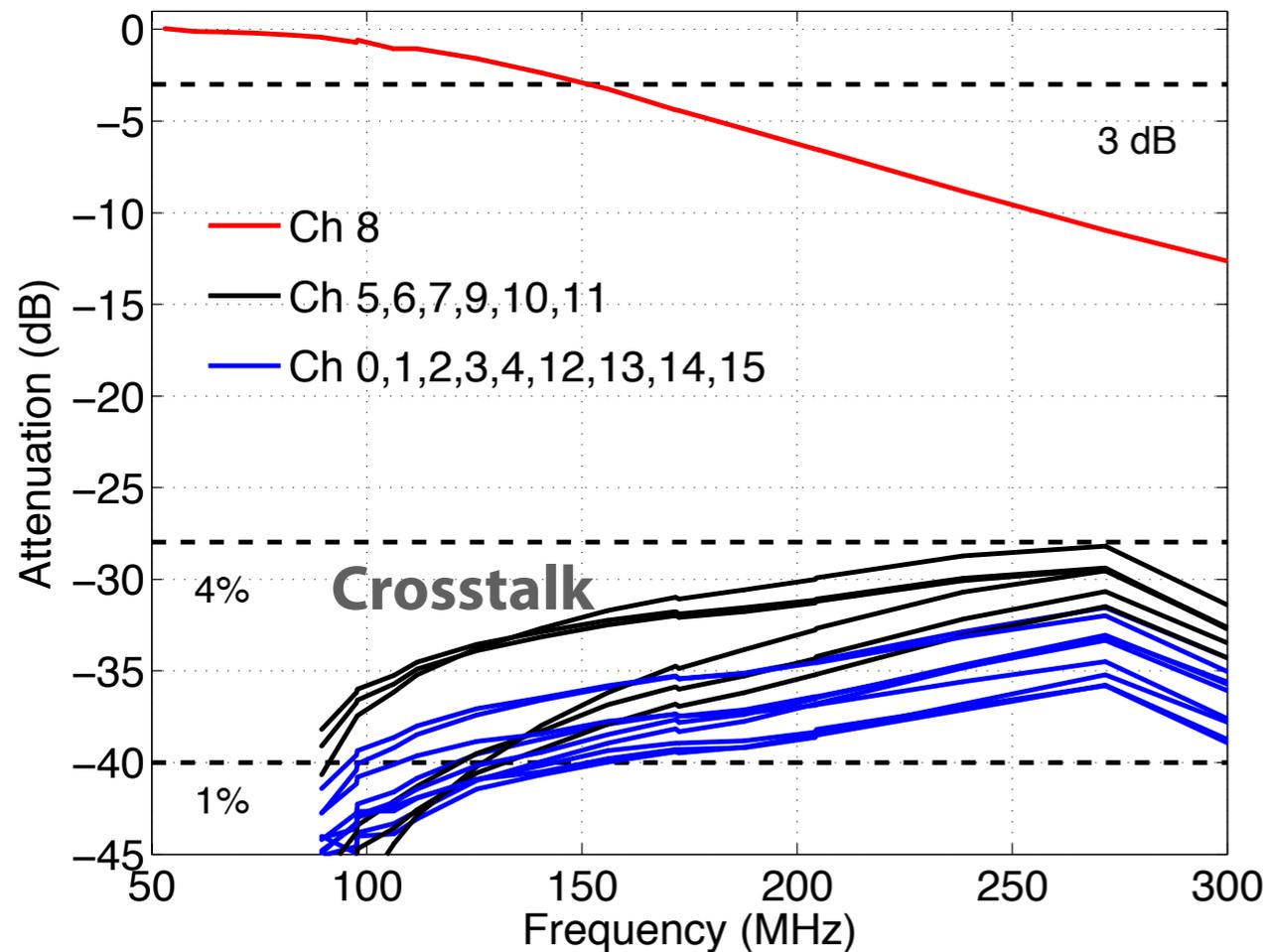
Performance Tests of TARGET 1 (1 p.e. Distribution)

(32 of 64 Channels Shown)

- Pedestal
- LED + Dark ND Filter
- LED + Bright ND Filter



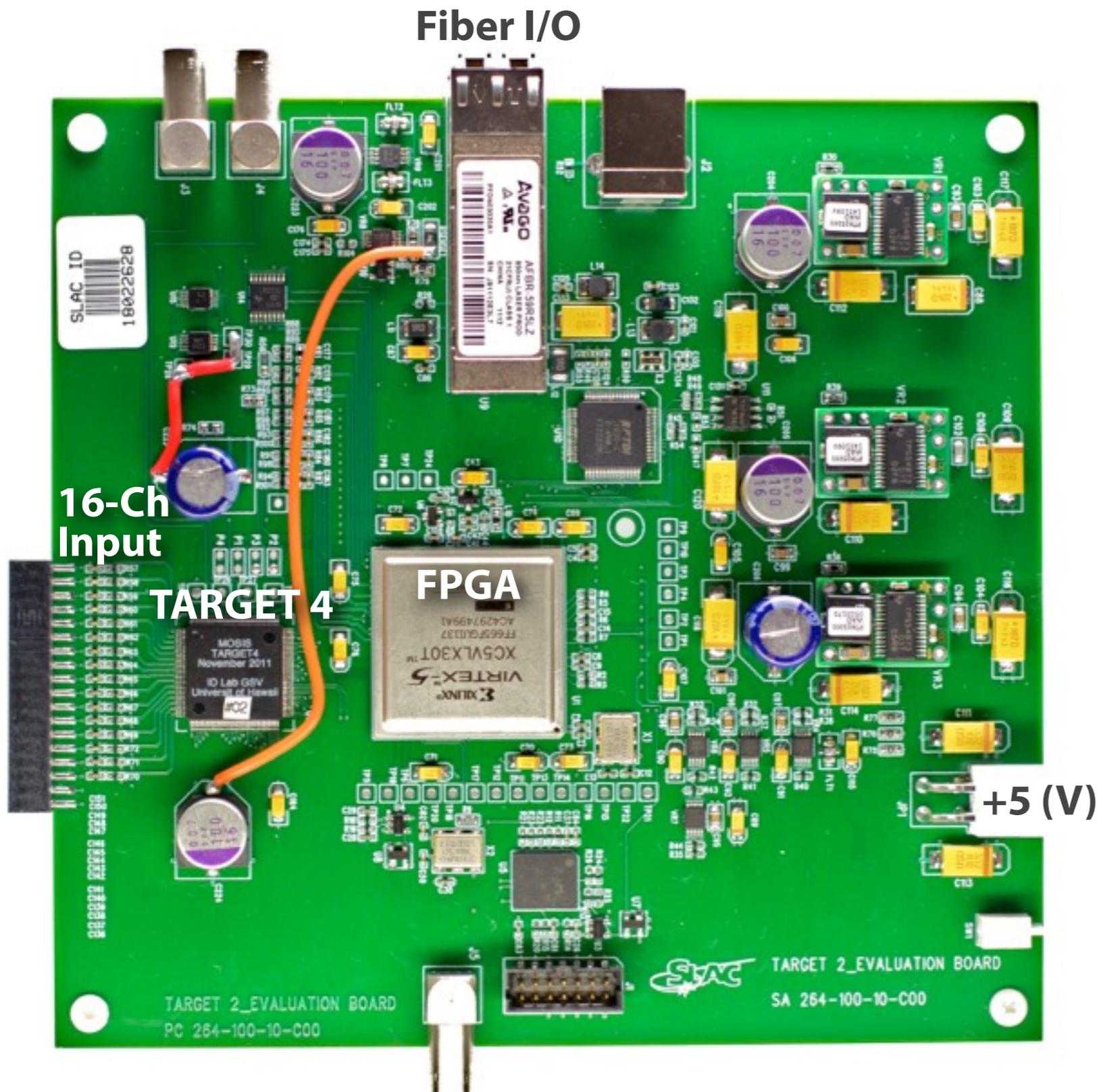
Performance Tests of TARGET 1 (Bandwidth)



Bechtol *et al.* 2012 *Astropart. Phys.*

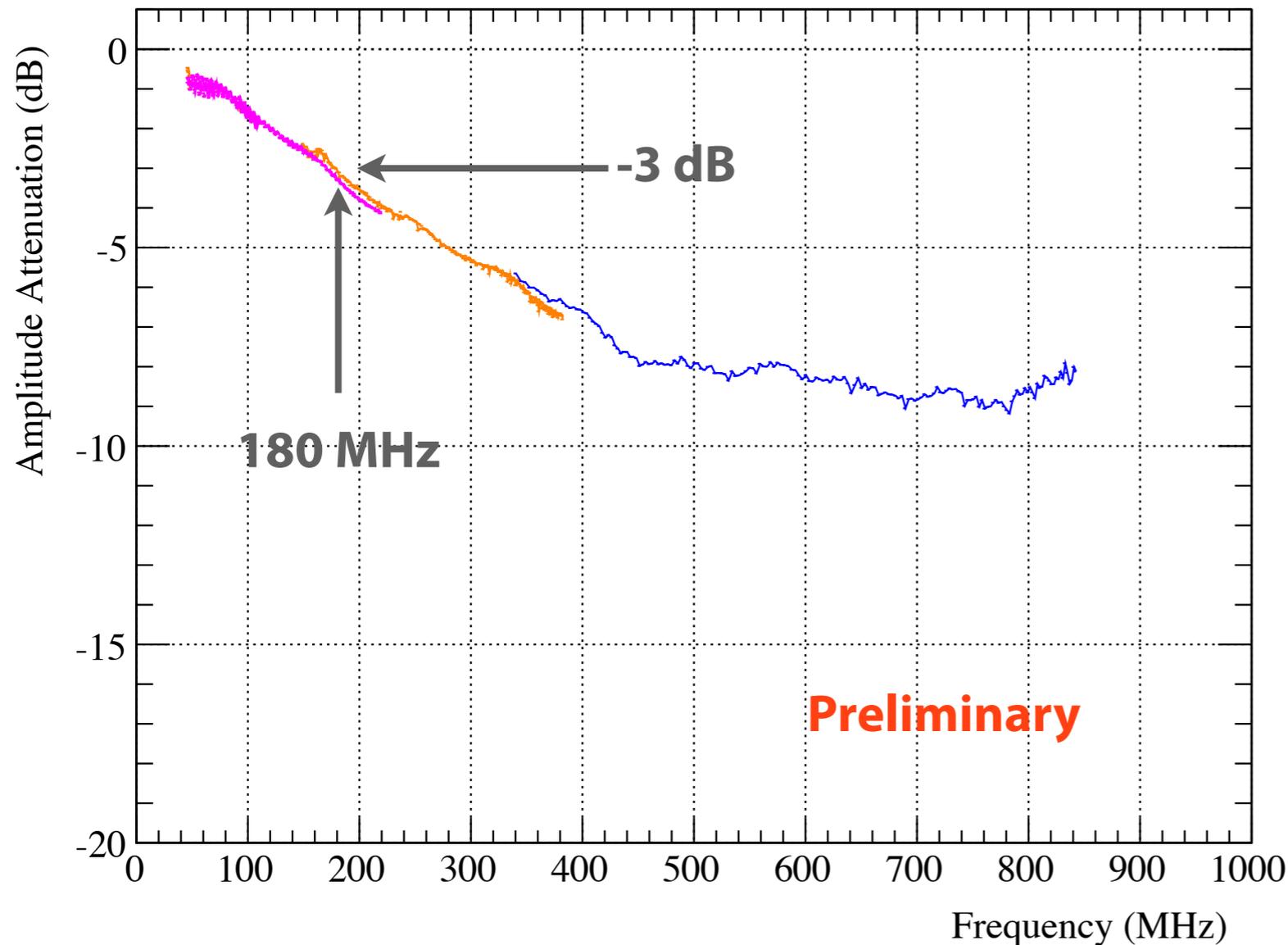
- ❑ Bandwidth is -3 dB at 150 MHz (expect better bandwidth with some optimizations)
- ❑ Low slew rate, saturates at V_{pp} of ~ 300 mV
- ❑ Already improved with newer TARGET variants

The TARGET-2/3/4/5 Evaluation Board



- ❖ New TARGET variants
- ❖ Fixed the non-linearity problem
- ❖ Improved cross-talk $< 1\%$
- ❖ Found new problems
 - ▶ Some control parameters cannot be set properly
 - ▶ A few bias voltages cannot be supplied
 - ▶ Sampling speed is much faster than expected (~ 2.3 GHz)

TARGET 4 Bandwidth



- Measured the bandwidth of TARGET 4 this summer
- -3 dB at 180 MHz
- Was 150 MHz with TARGET 1
- Will test TARGET 5 in Sep 2012

Summary

- ❖ CTA will be the world's largest VHE gamma-ray observatory with 10 times higher sensitivity than those of the current VHE telescopes
- ❖ Dual-mirror telescopes for MSTs and SSTs are under development using the Schwarzschild-Couder optical system
- ❖ Ray trace analyses and feasibility studies of the optical system are on going
- ❖ The TARGET ASIC and camera module were developed and verified the basic functions
- ❖ TARGET 5 will be tested in Sep 2012