CTA デュアルミラー光学系用の
1 GHz 波形記録回路 TARGET の開発と性能評価

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Detection Technique for 10 GeV to 100 TeV Gamma Rays

γ-ray source

Air Shower
e^-, e^+, γ

~1.3°

$n_{air} \simeq 1.00029$

Δt ~5 ns

100 m – 1 km

R ~ 150 m

PMT Array (HESS)

Funk+ (08)

Shower Image

- GHz sampling
- 1 – 10 μs buffer length
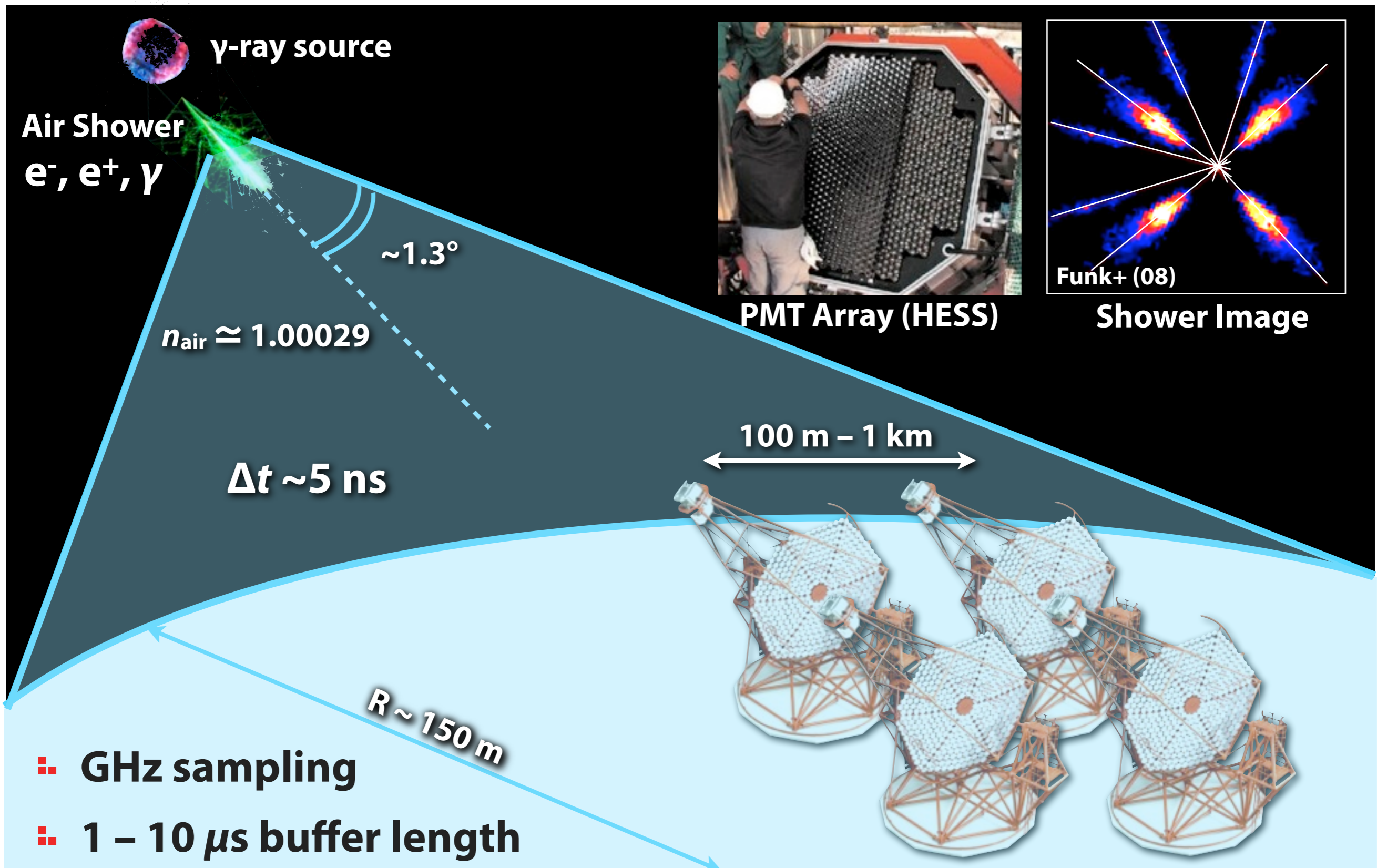
The Cherenkov Telescope Array (CTA) Observatory

LST × 3–5
$D \sim 23$ m
FOV ~ 4–5°
Pix ~ 0.1°
$E \sim 0.02$–5 TeV

MST × 15–25
$D \sim 12$ m
FOV ~ 7–8°
Pix ~ 0.18°
$E \sim 0.1$–30 TeV

SC-MST × 36
$D = 9$ m
FOV = 8°
Pix = 0.07°
$E \sim 0.1$–10 TeV
Dual Mirror

SST × 25–100
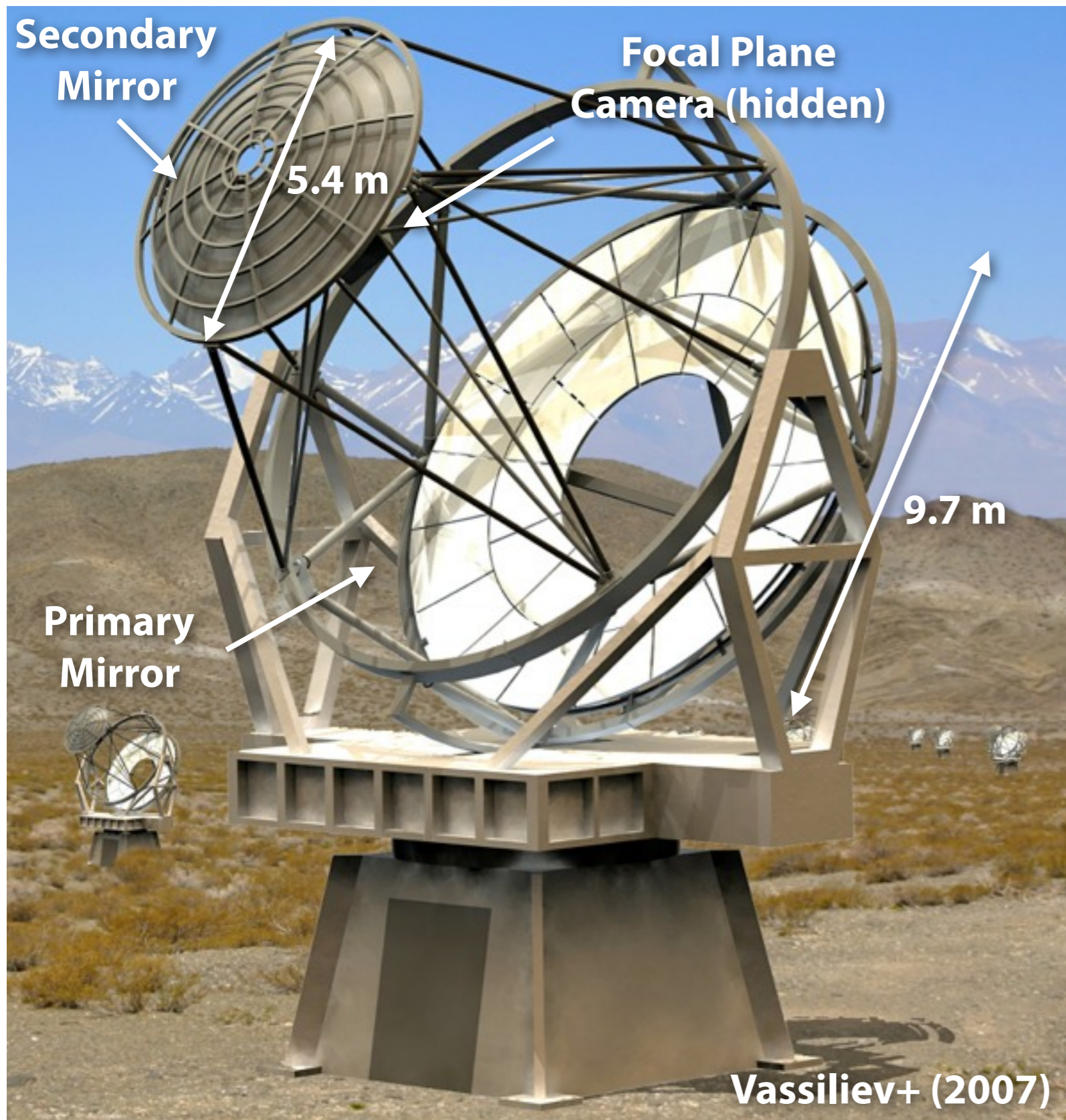$D \sim 4$–7 m
FOV ~ 7–10°
Pix ~ 0.2–0.25°
$E \sim 1$–300 TeV
Dual Mirror ?

- The next-generation gamma-ray Cherenkov telescope

- Consists of Large/Medium/Small Size Telescopes (**LST**s/**MST**s/**SST**s)

- + Extension using **Schwarzschild-Couder MST**s proposed by CTA-US + Nagoya

The Schwarzschild-Couder Optical System

Secondary Mirror · 5.4 m · Focal Plane Camera (hidden) · Primary Mirror · 9.7 m · Vassiliev+ (2007)

- The first challenge of a **dual-mirror system** in CR experiments

- **9.7-m** primary + **5.4-m** secondary

- Wide FOV of **8°**

- Small spot size of **< 6 mm (4 arcmin)**
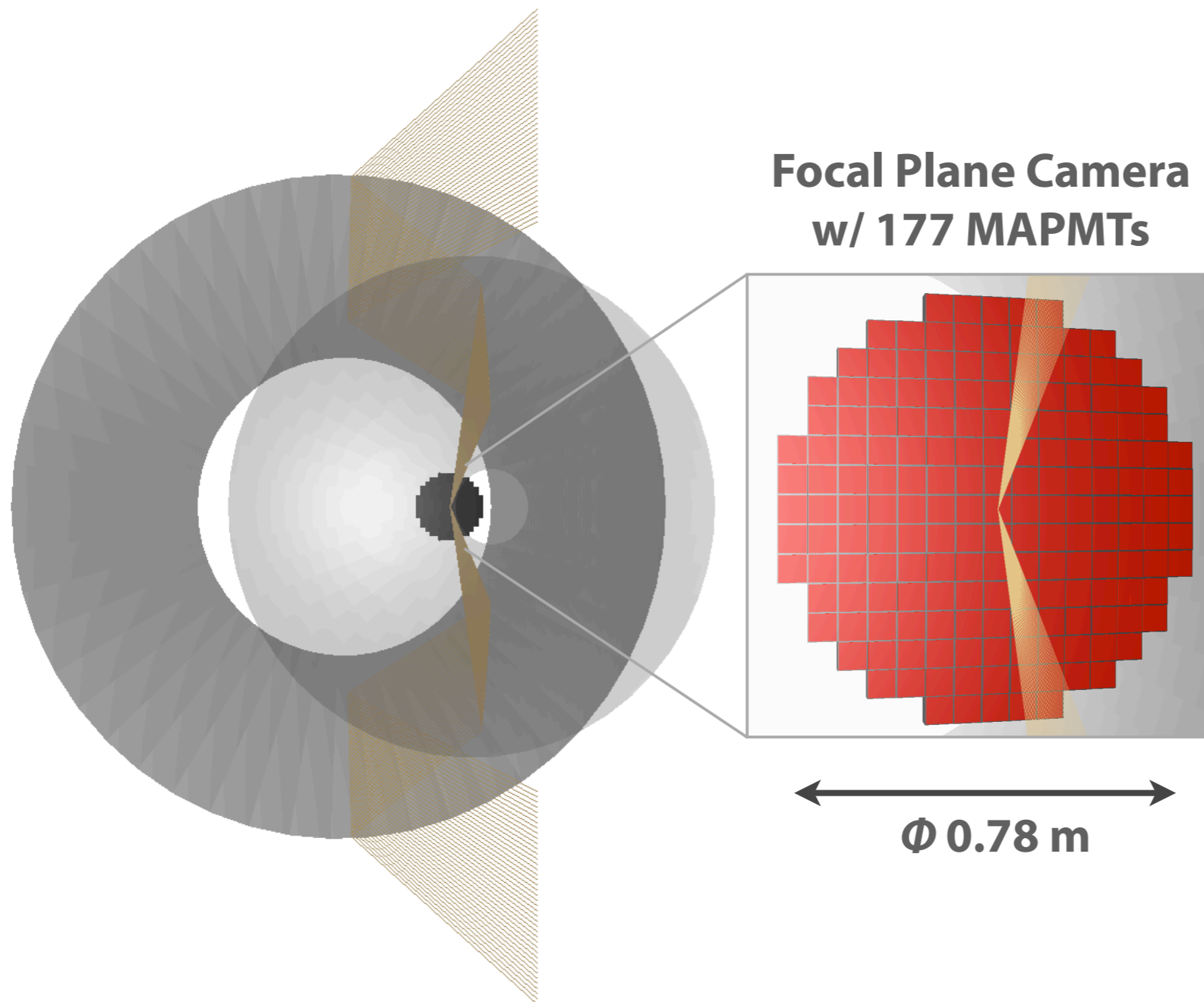
- MAPMT array consisting of more than **11,000 channels**

The Schwarzschild-Coude Optical System

Spot Diagrams
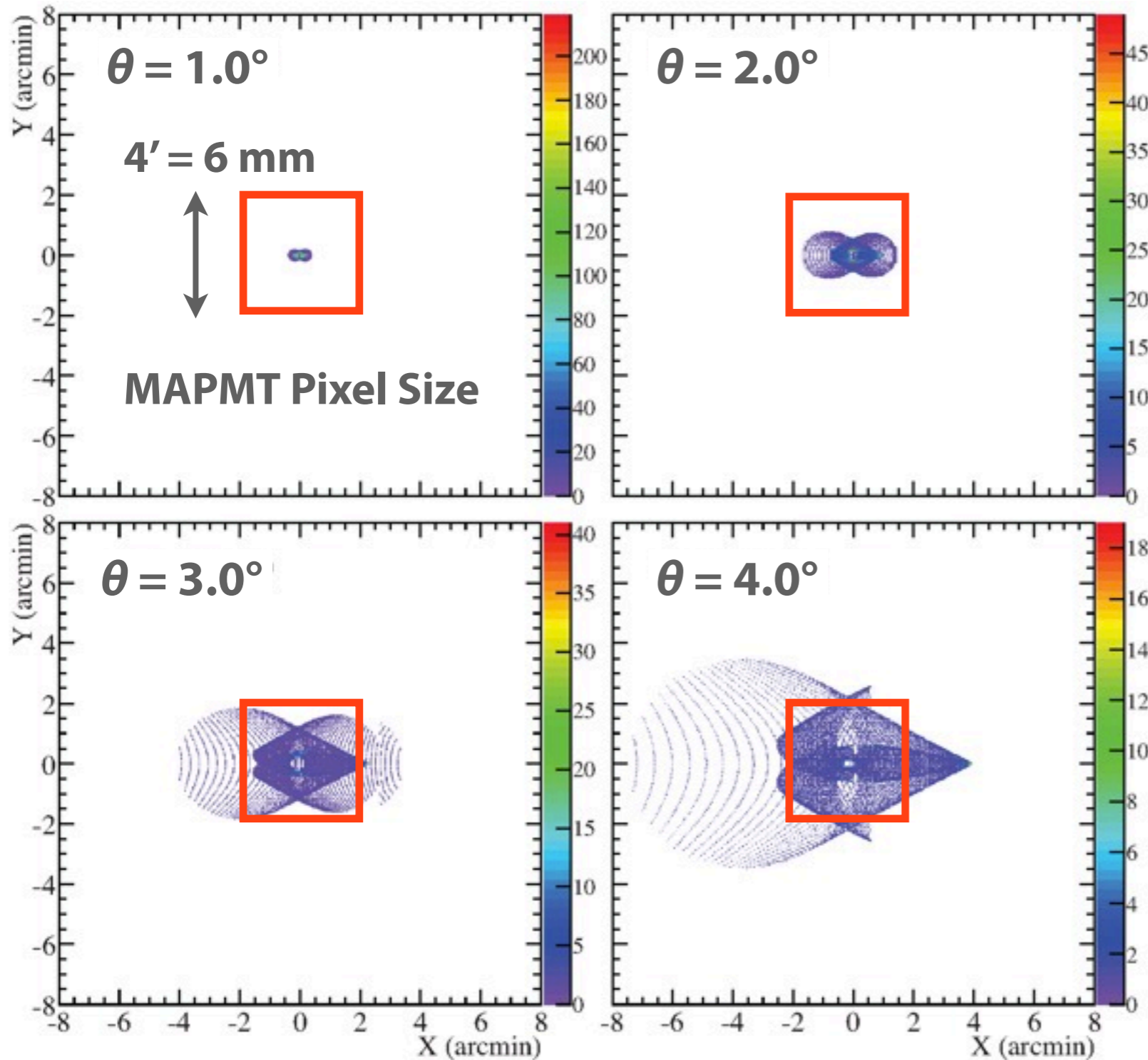
Okumura+ (2011)

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The Schwarzschild-Coude Optical System
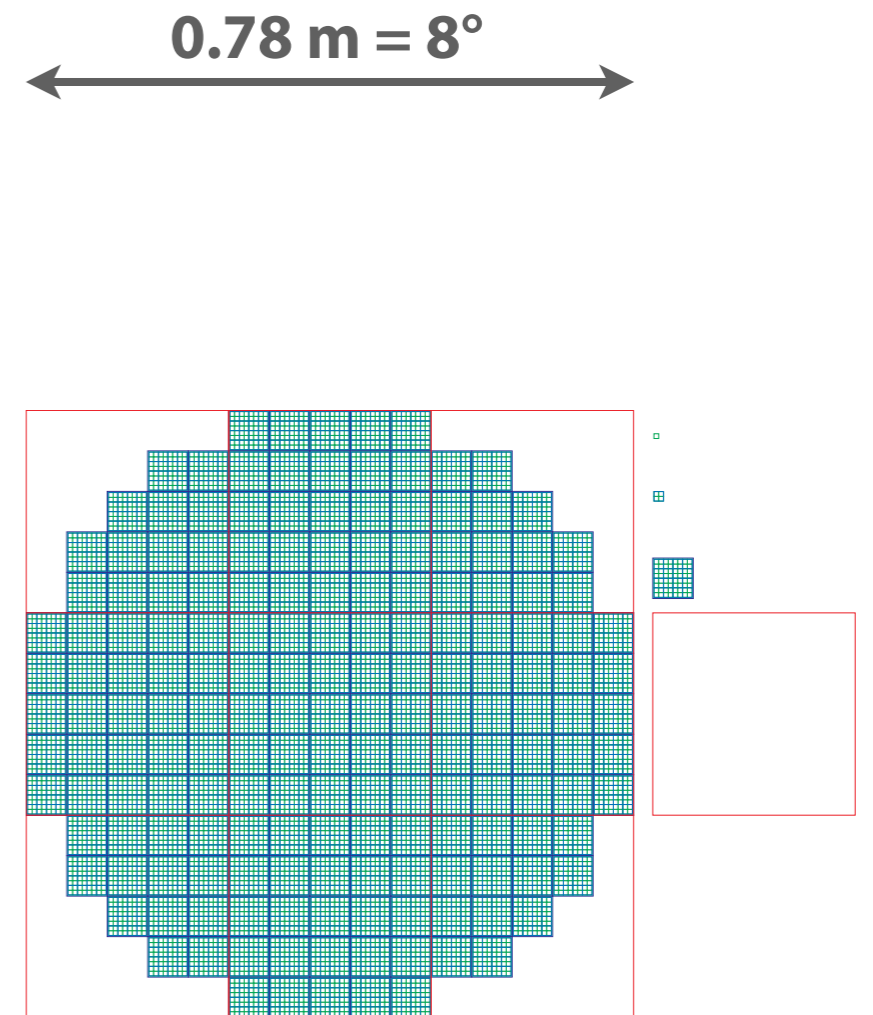
**Focal Plane Camera
w/ 177 MAPMTs**

Φ 0.78 m

- The first challenge of a **dual-mirror system** in CR experiments

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Okumura+ (2011)
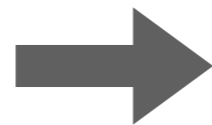
Need a Very Compact Front-end Electronics with Low $/ch

1.3 m = 5°

0.78 m = 8°

Pixel Size

2 inch × 1000 → 6 mm × 10000
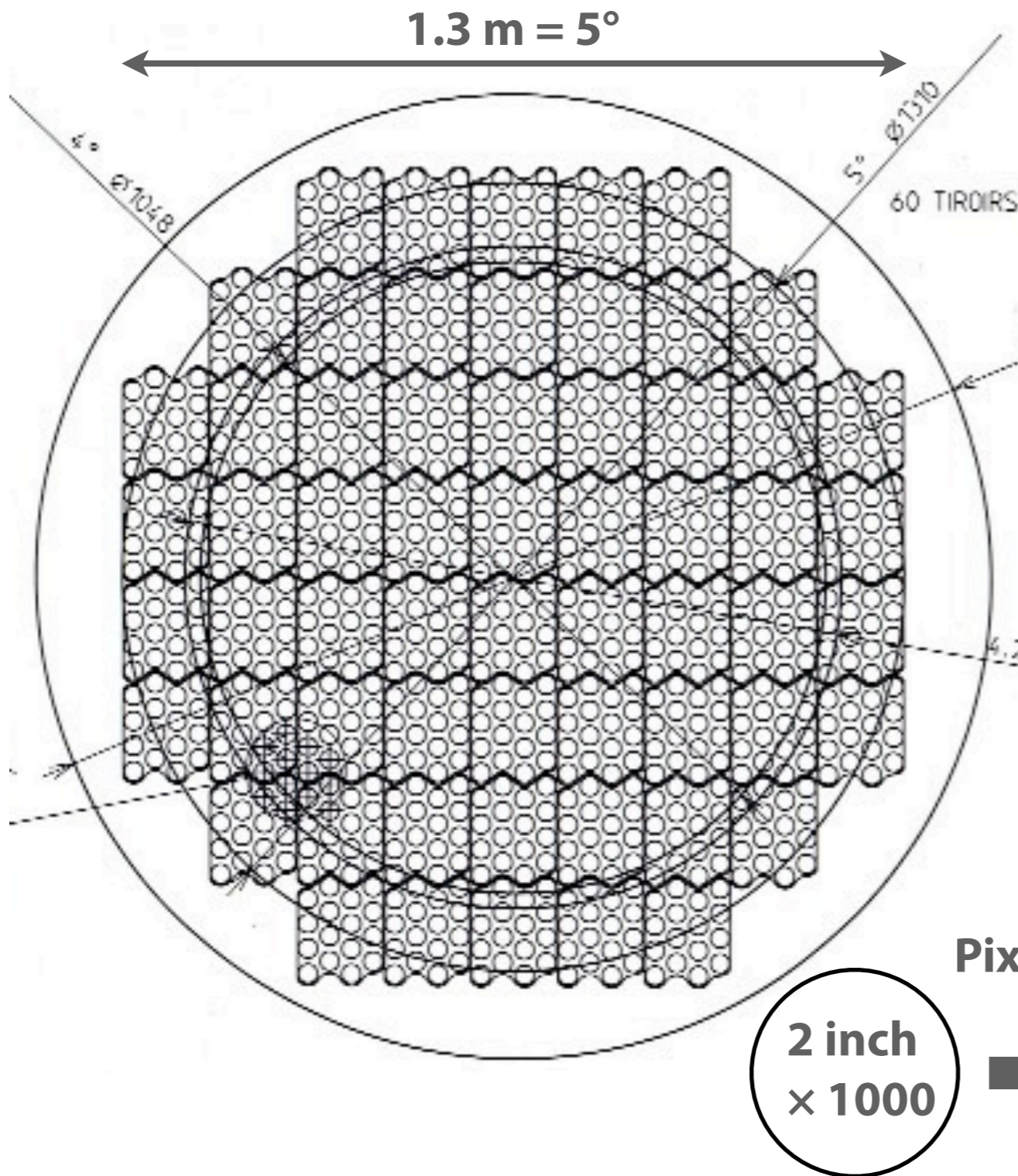
HESS Camera w/ Regular PMTs

SC Optics Camera w/ MAPMTs or MPPCs
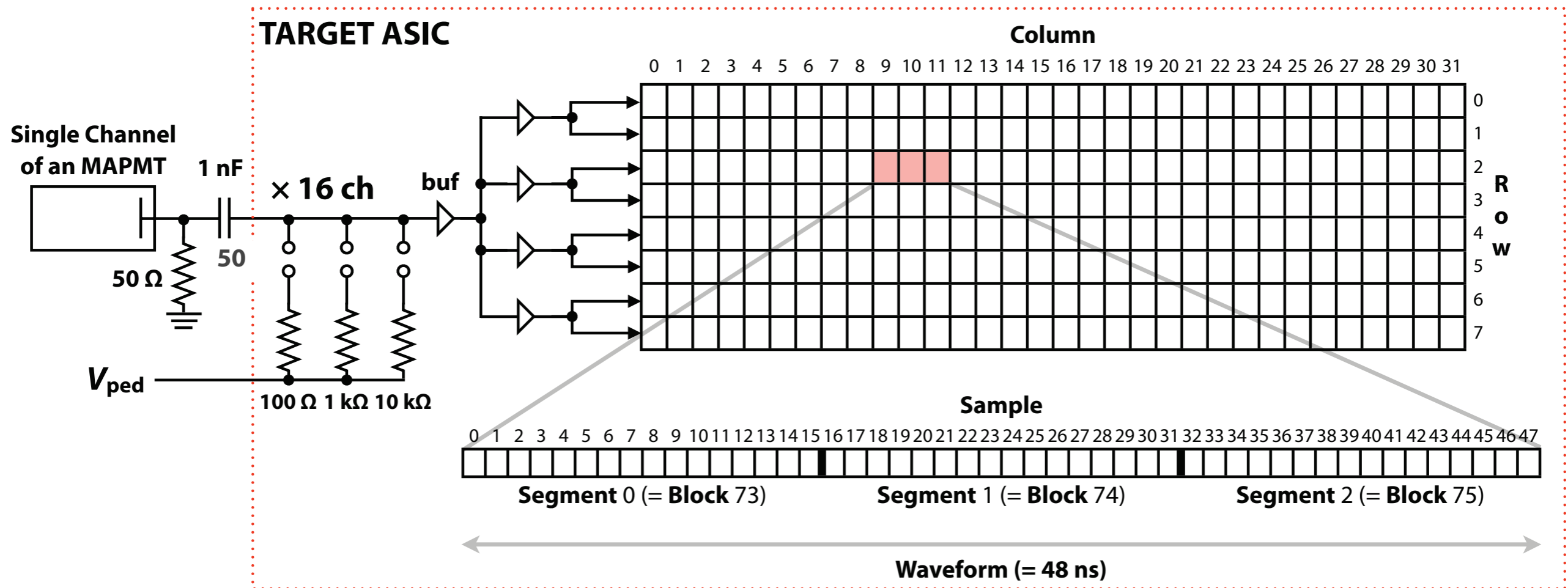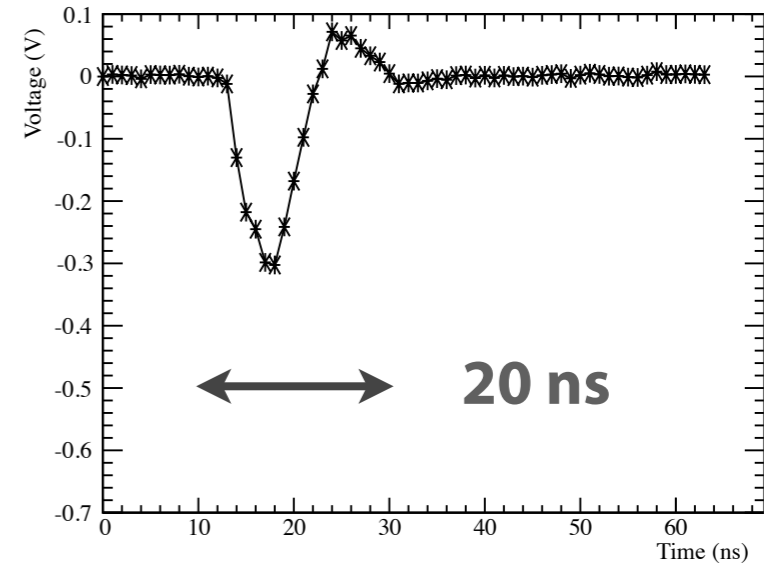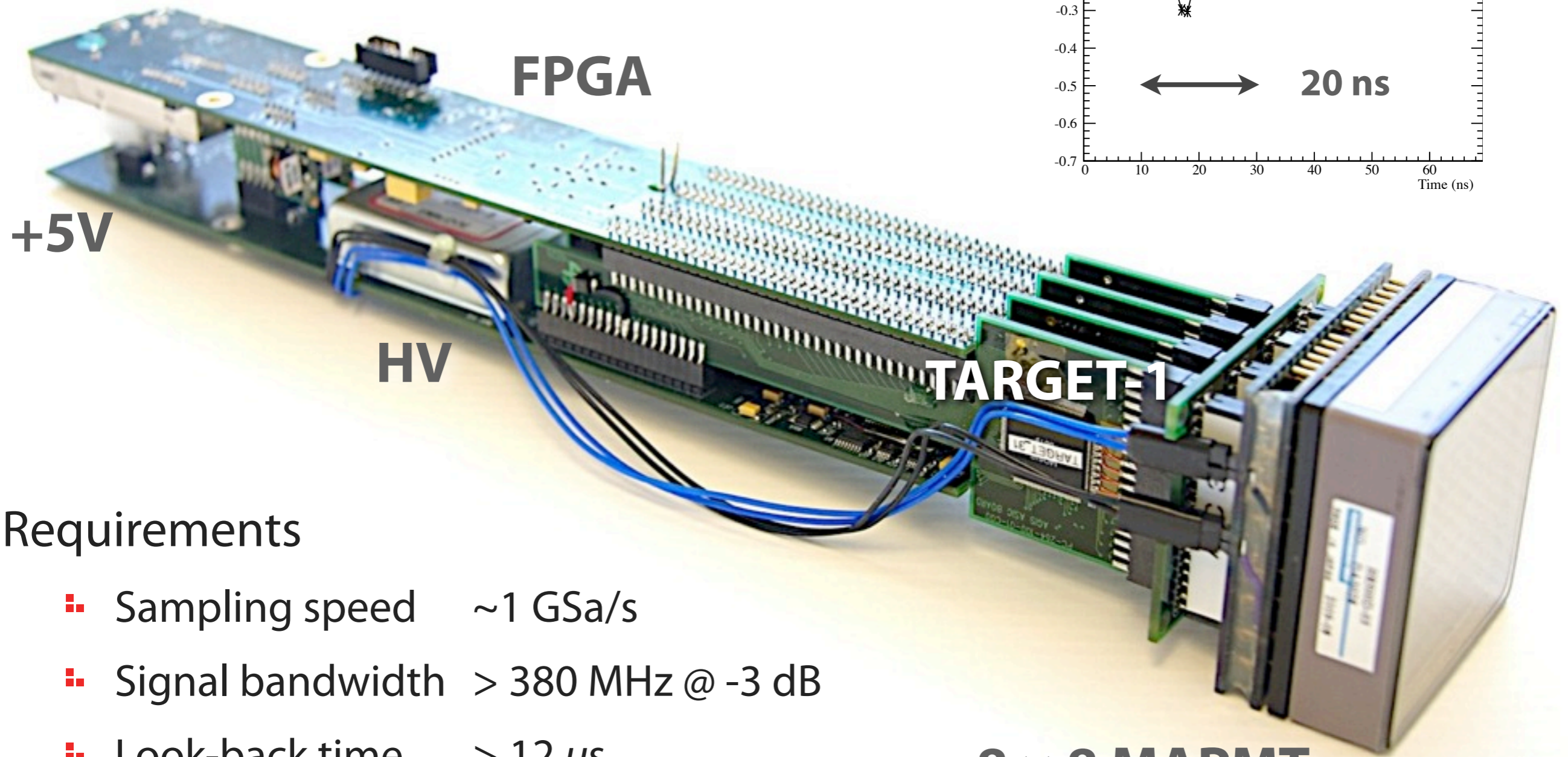
TARGET-1 Concept

TARGET = TeV Array with Gsa/s sampling and Experimental Trigger

- **16-ch** integrated system × **4096 capacitors** (= 4-μs buffer at 1 GHz)
- **1 GHz or faster** sampling speed, **self trigger**
- **9 or 10-bits** dynamic range, digitized by Wilkinson-type ADCs
- Low cost (~**$20/ch**), low power (~**5W/64ch**)

The TARGET-1 ASIC + Camera Module

Fiber

USB

FPGA

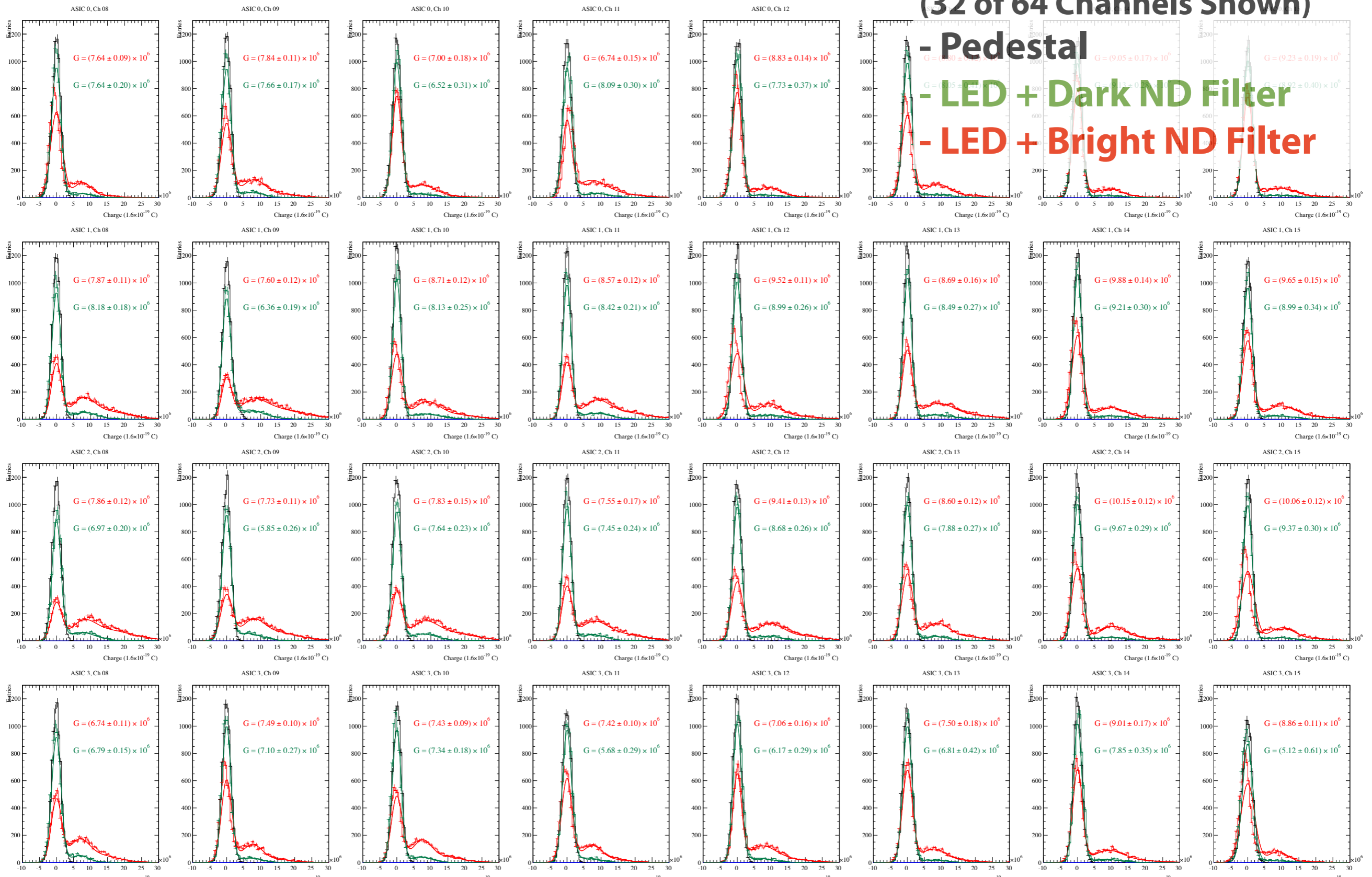+5V

HV

TARGET-1

20 ns

8 × 8 MAPMT
(H8500D-03)

Requirements

- Sampling speed ~1 GSa/s
- Signal bandwidth > 380 MHz @ -3 dB
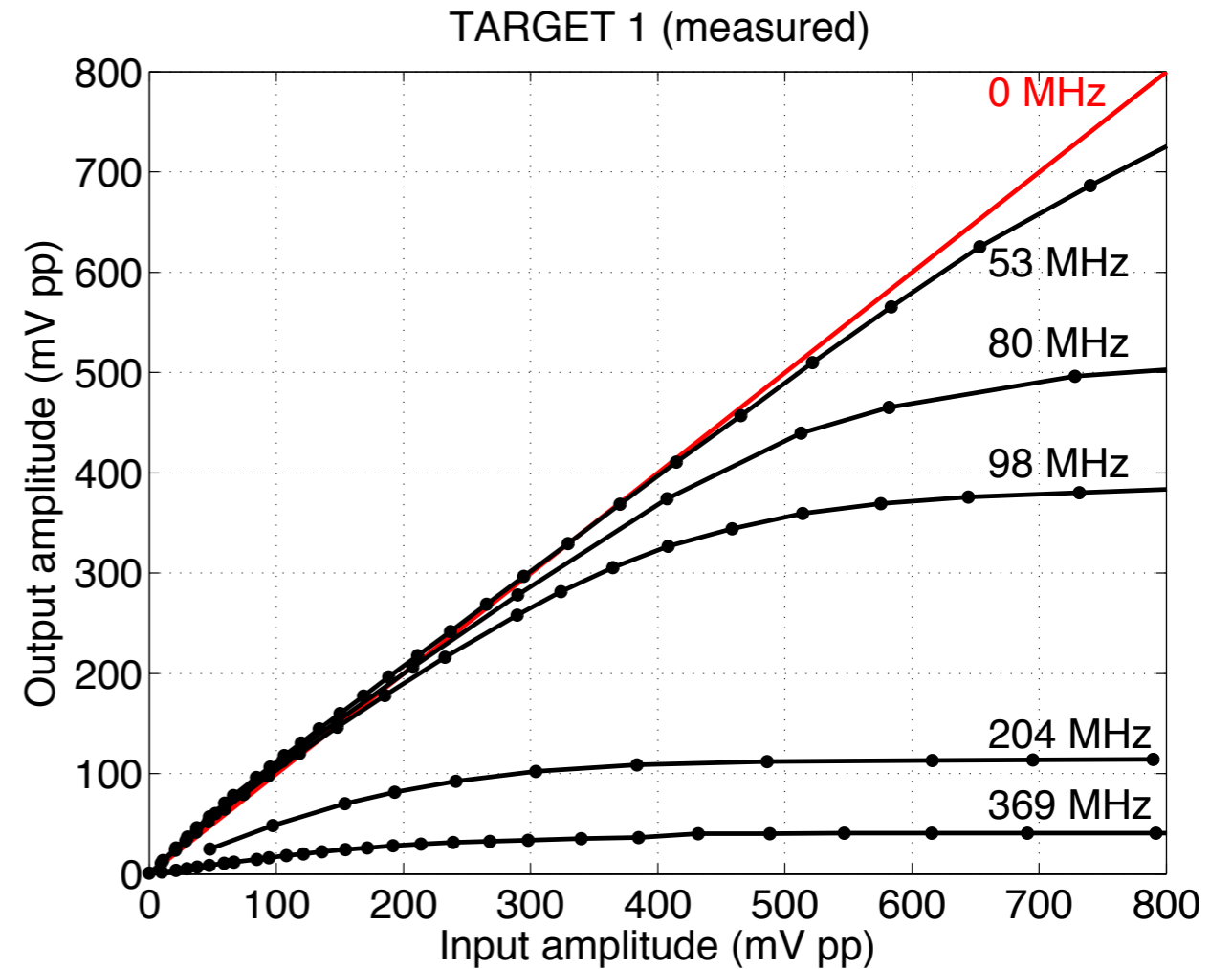- Look-back time > 12 μs
- Dynamic range > 9 bits
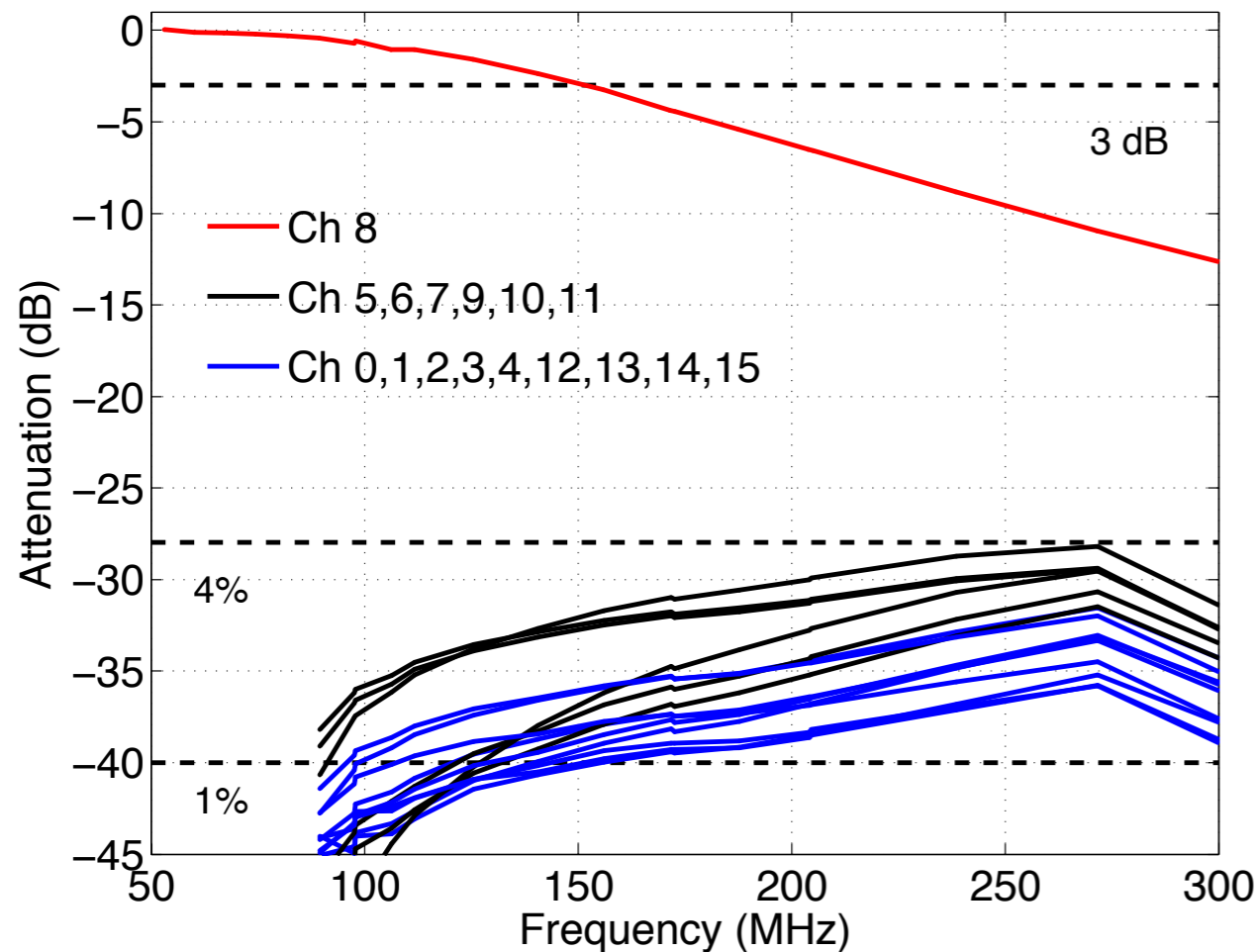
Performance Tests of TARGET 1 (1 p.e. Distribution)

(32 of 64 Channels Shown)
- Pedestal
- LED + Dark ND Filter
- LED + Bright ND Filter

Performance Tests of TARGET 1 (Bandwidth)

TARGET 1 (measured)

Bechtol+ 2011 (arXiv:1105.1832)

- Bandwidth is -3 dB @ 150 MHz, not fast enough yet

- Low slew rate, saturates at Vpp of ~500 mV

- To be improved with new TARGET variants

TARGET Variants and Specifications

|	TARGET 1	TARGET 2	TARGET 3	TARGET 4
Year of Delivery	2010	2011	2011	2012
Number of Channels	16	16	16	16
Storage Cells/Channel	4,096	**16,384**	**16,384**	**16,384**
Sampling Rate (GHz)	0.5 - 2.5	0.5 - 1.5	0.5 - 1.5	0.5 - 1.5
Dynamic Range (Bits)	9	9	**10**	**10**
Gain	60	60	none	none
Wilkinson ADC Clock Speed (MHz)	~100	**~700**	**~700**	**~700**
ADC Conversion at a Time (Blocks)	2 × 16	**16 × 32**	**16 × 32**	**16 × 32**
Readout Time per Sample (ns)	20	20	20	20
Trigger Analog Sum		4	none	none
Trigger Outputs	1 + 1	4	4	4
Trigger Thresholds		4 + 1	4 + 1	4 + 1
Trigger Mask		16	16	16
Ramp Offset Adjustment		0 - 1 (V)	0 - 1 (V)	0 - 1 (V)
Ramp Slope Adjustment		0.5 - 10 (μs)	0.5 - 10 (μs)	0.5 - 10 (μs)
PUbias Fast Reset		1	1	1
Improved RCO Monitor		1	1	1

The TARGET-2/3/4 Evaluation Board
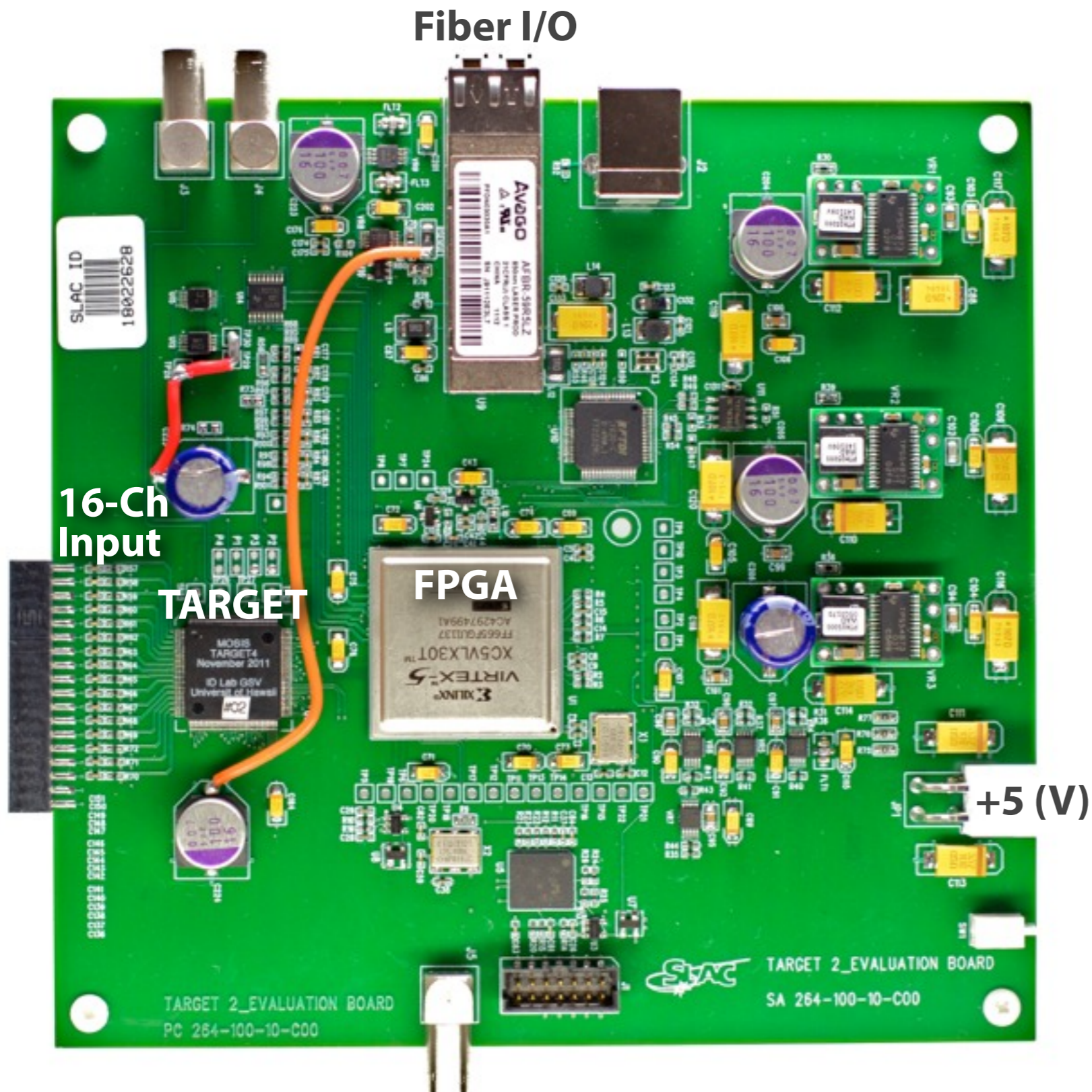
- Started evaluating TARGET 2 and 3
- Struggling with some problems which were not observed with TARGET 1
  - Some control parameters cannot be set properly
  - A few bias voltages cannot be supplied
  - Sampling speed is much faster than expected (~2.7 GHz)
  - "Surgical operation"

Example of "Corrupted" Register Value of TARGET 2

Measured Threshold
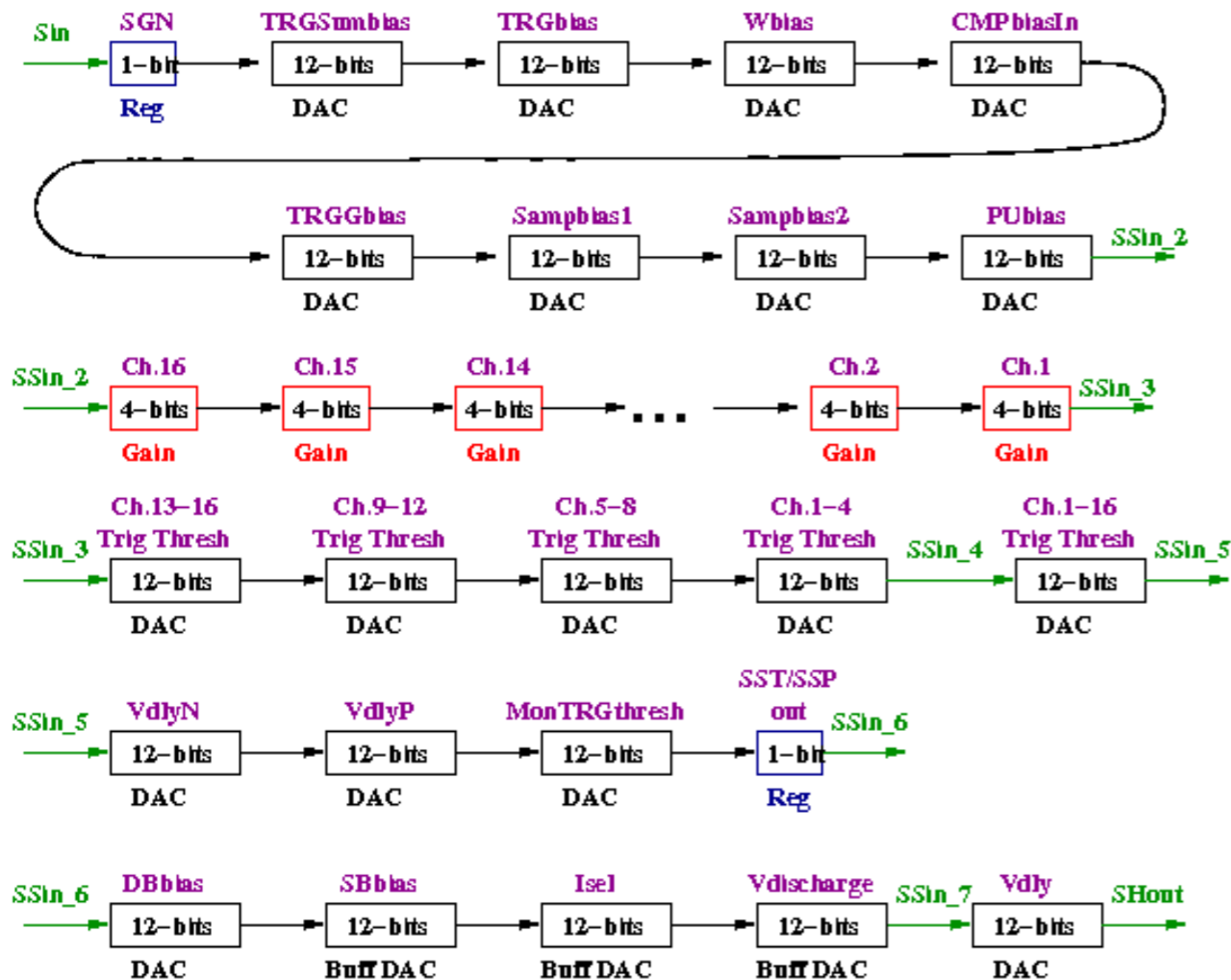
Routing Map of Configuration Register Chain
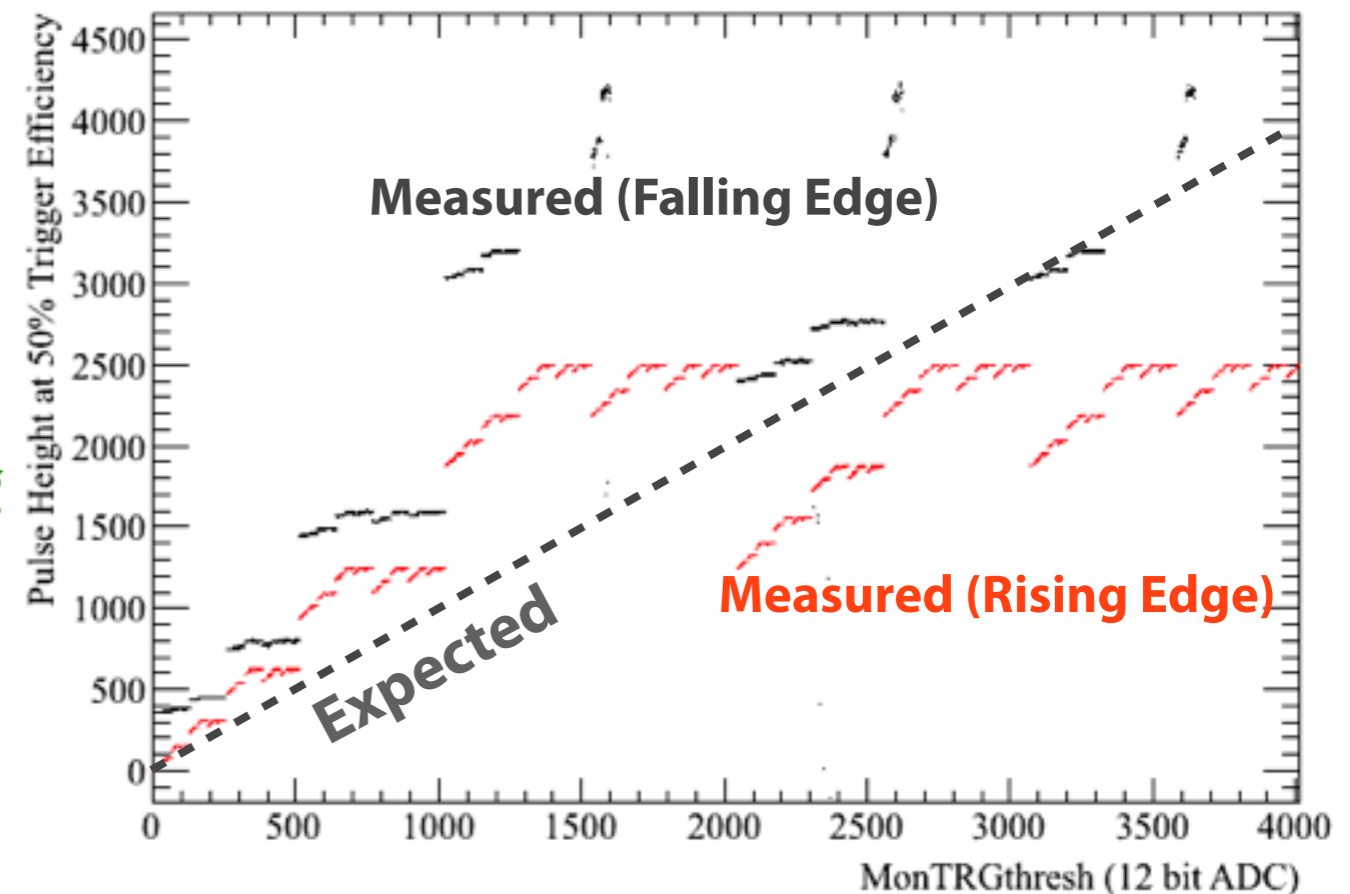
Input Register (Threshold)

- Configuration register chain sent from FPGA is not properly reflected inside TARGET

- But essential measurements can be done with limited configuration values

- Fixed in TARGET 4 (partially)

Summary

- The **Schwarzschild-Couder telescope** is under development by the CTA-US team + Nagoya University

- The **prototype camera module** and the **TARGET** ASICs have been developed and being tested

- New TARGET variants were designed and delivered to improve the TARGET-1 performance

- Some problems have been found, but we are trying to fix them in 2012