デュアルミラー光学系用の
カメラモジュールの開発と性能評価

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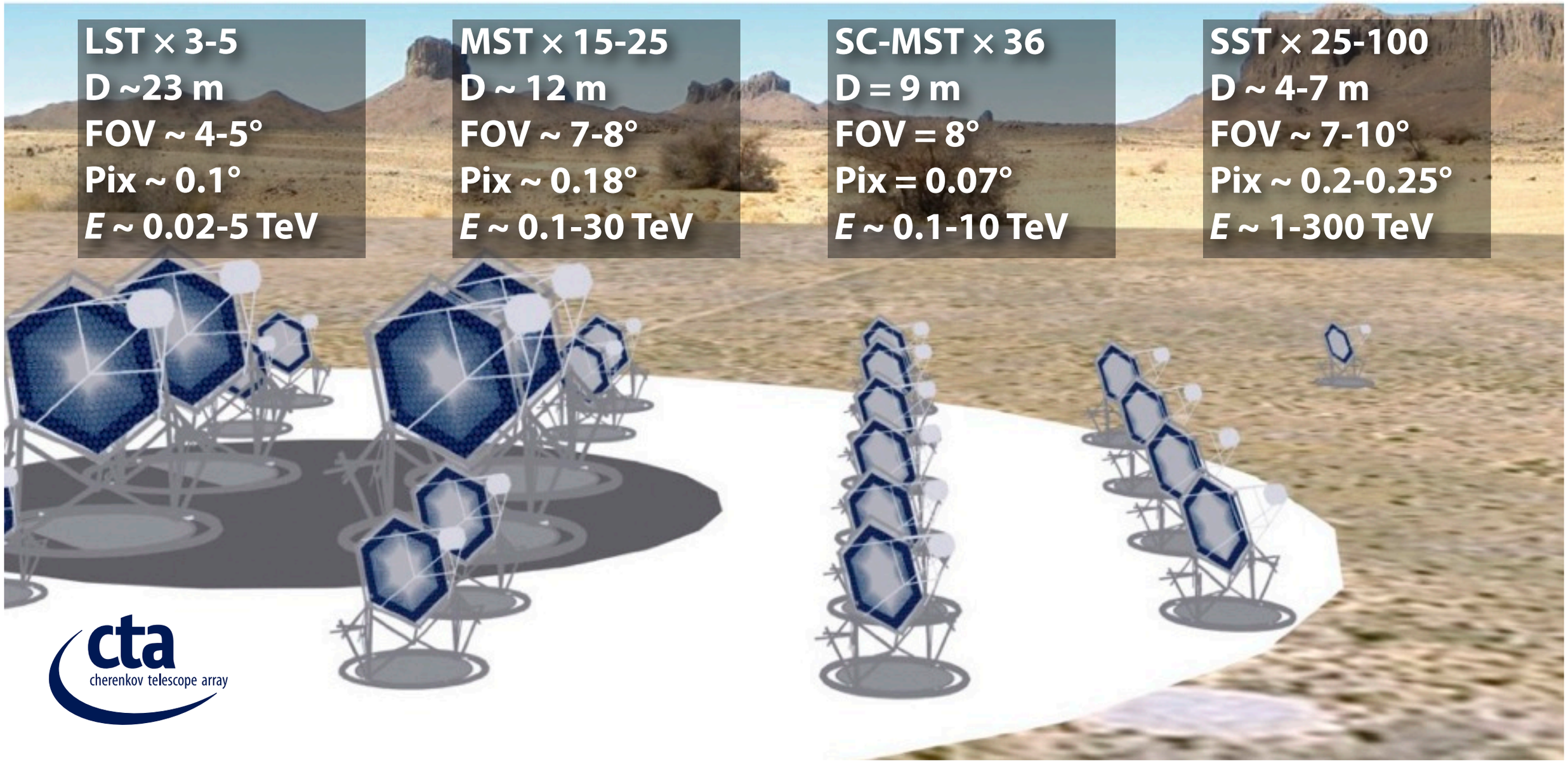
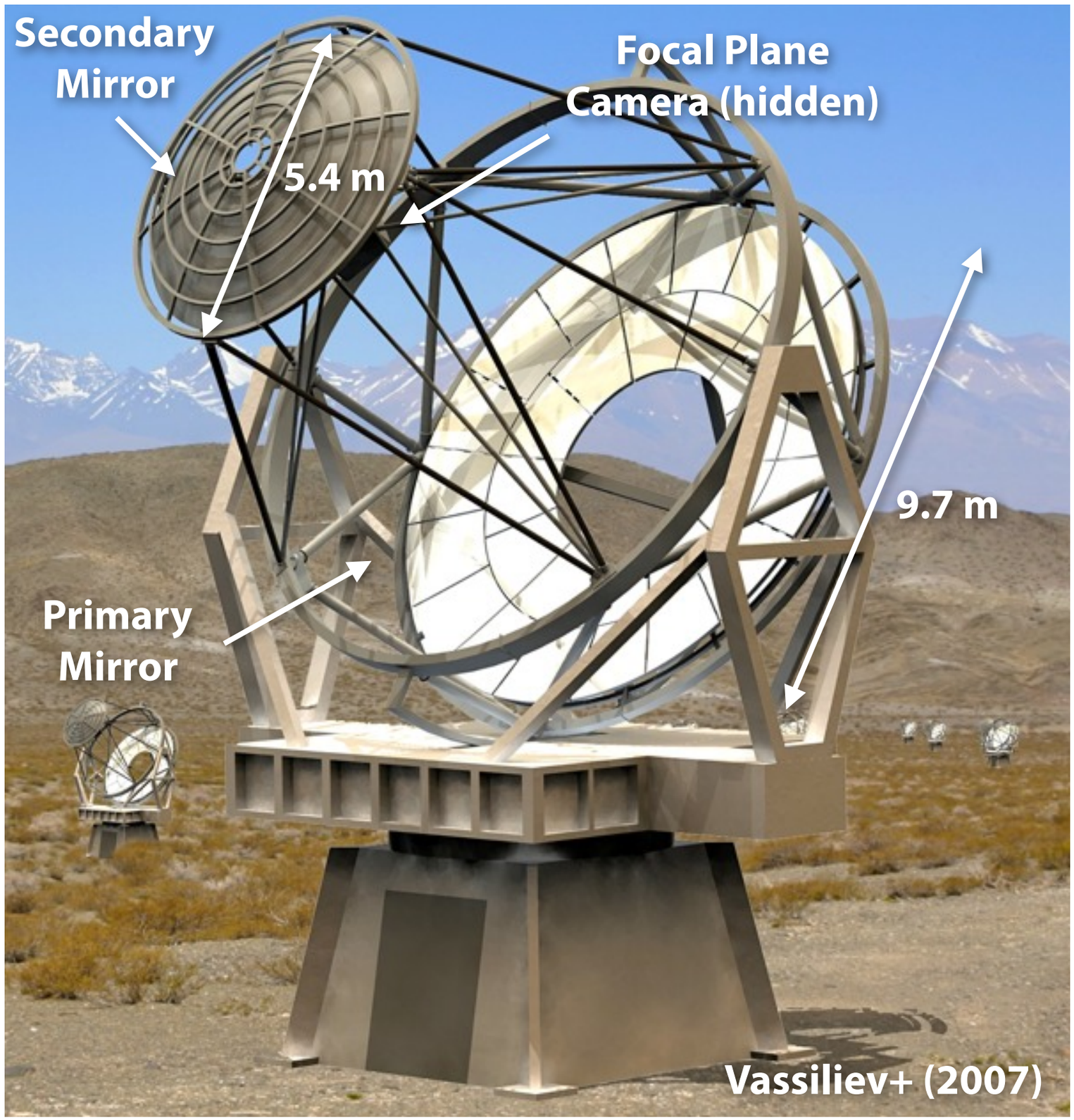
The Cherenkov Telescope Array (CTA) Observatory



- The next-generation imaging atmospheric Cherenkov telescope (IACT)
- Consists of Large/Medium/Small Size Telescopes (LSTs/MSTs/SSTs)
- Expansion with Schwarzschild-Couder MSTs by CTA-US

The Schwarzschild-Couder Optical System



- Originally planned for AGIS (→ CTA-US)
- Fairly large mirror size with diameter of **9.7 m**
- Wide FOV of **8°**
- Small angular resolution of **< 4'**
- MAPMT array consisting of more than **11,000 channels**
- The first challenge of a dual-mirror system in CR experiments

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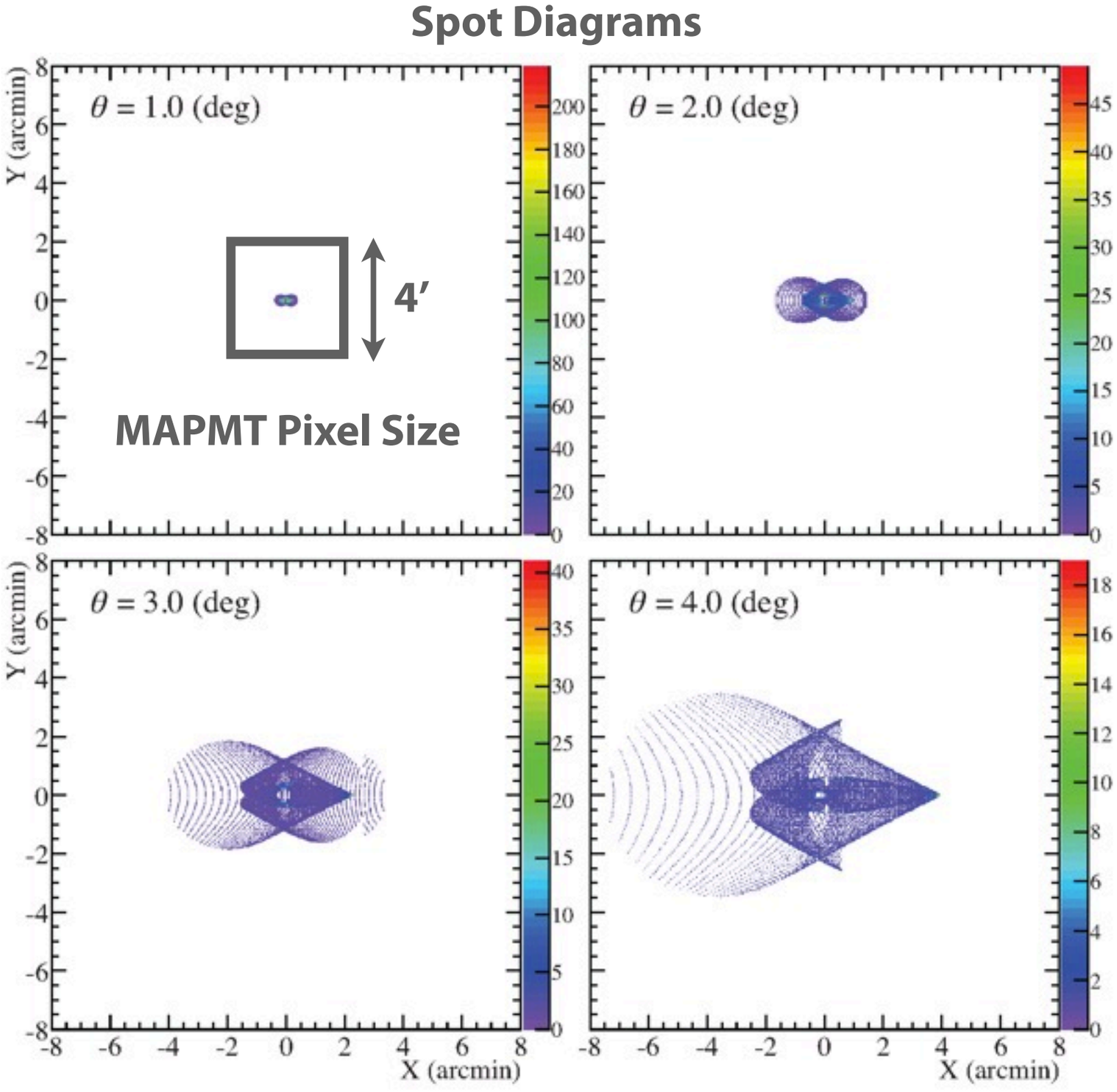

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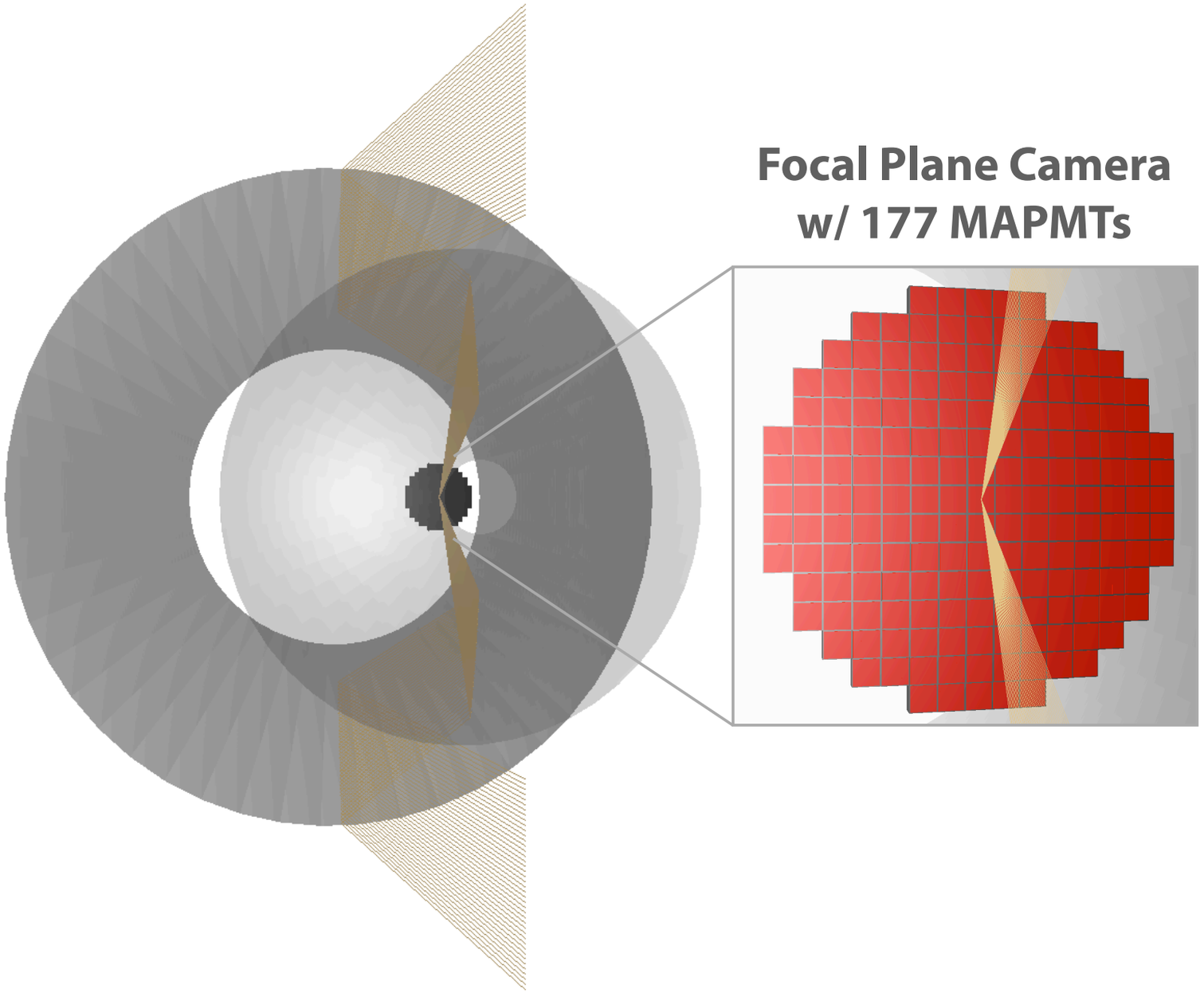

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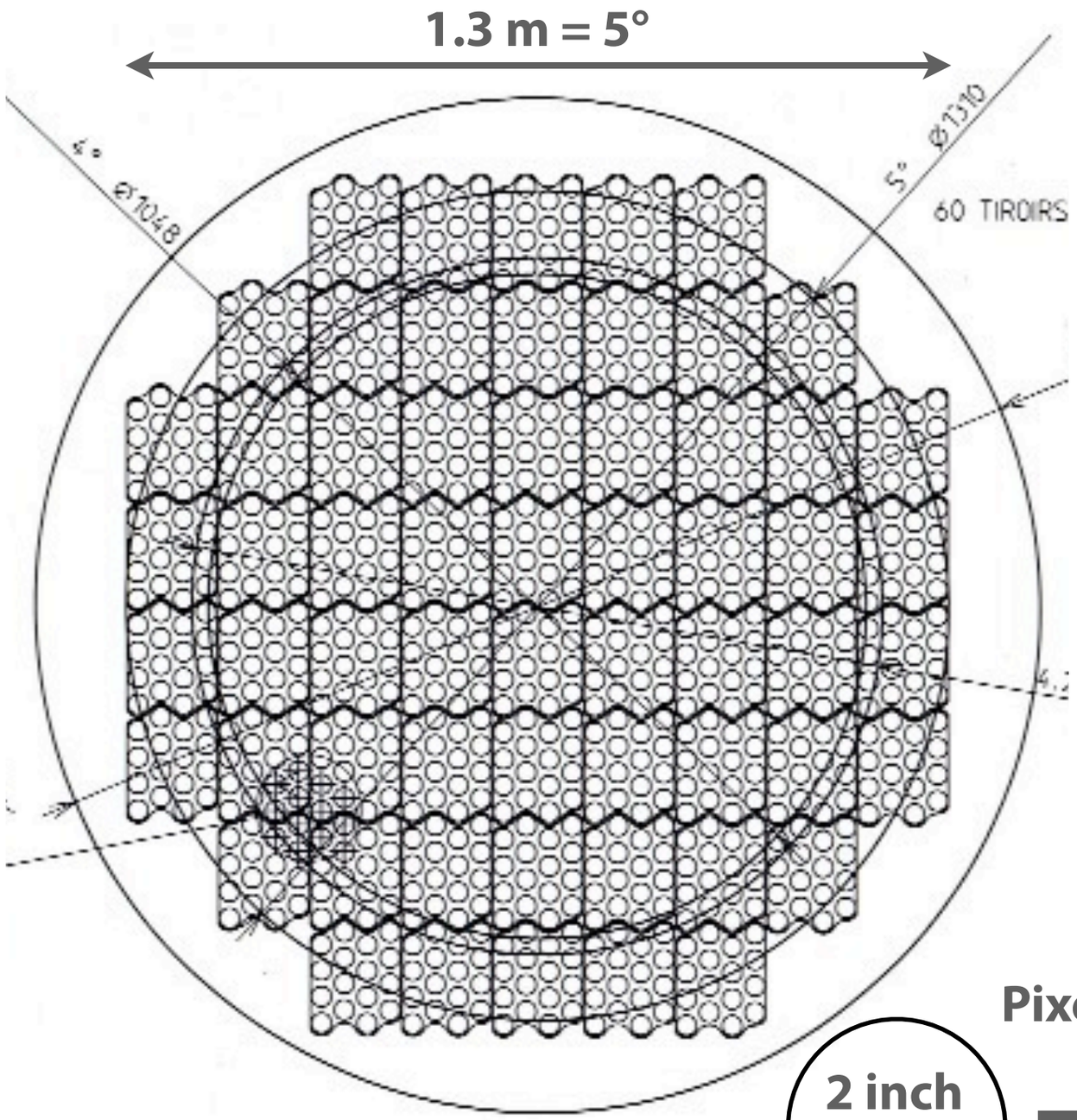
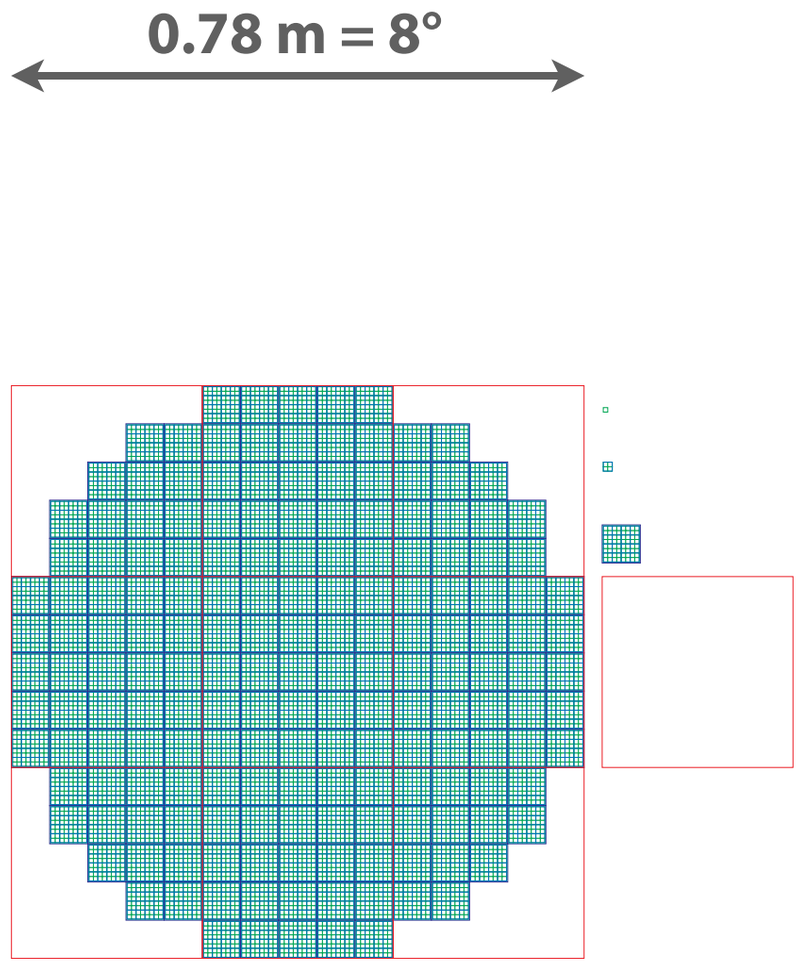
Need a Very Compact Front-end Electronics with Low $/ch





Pixel Size

2 inch
× 1000

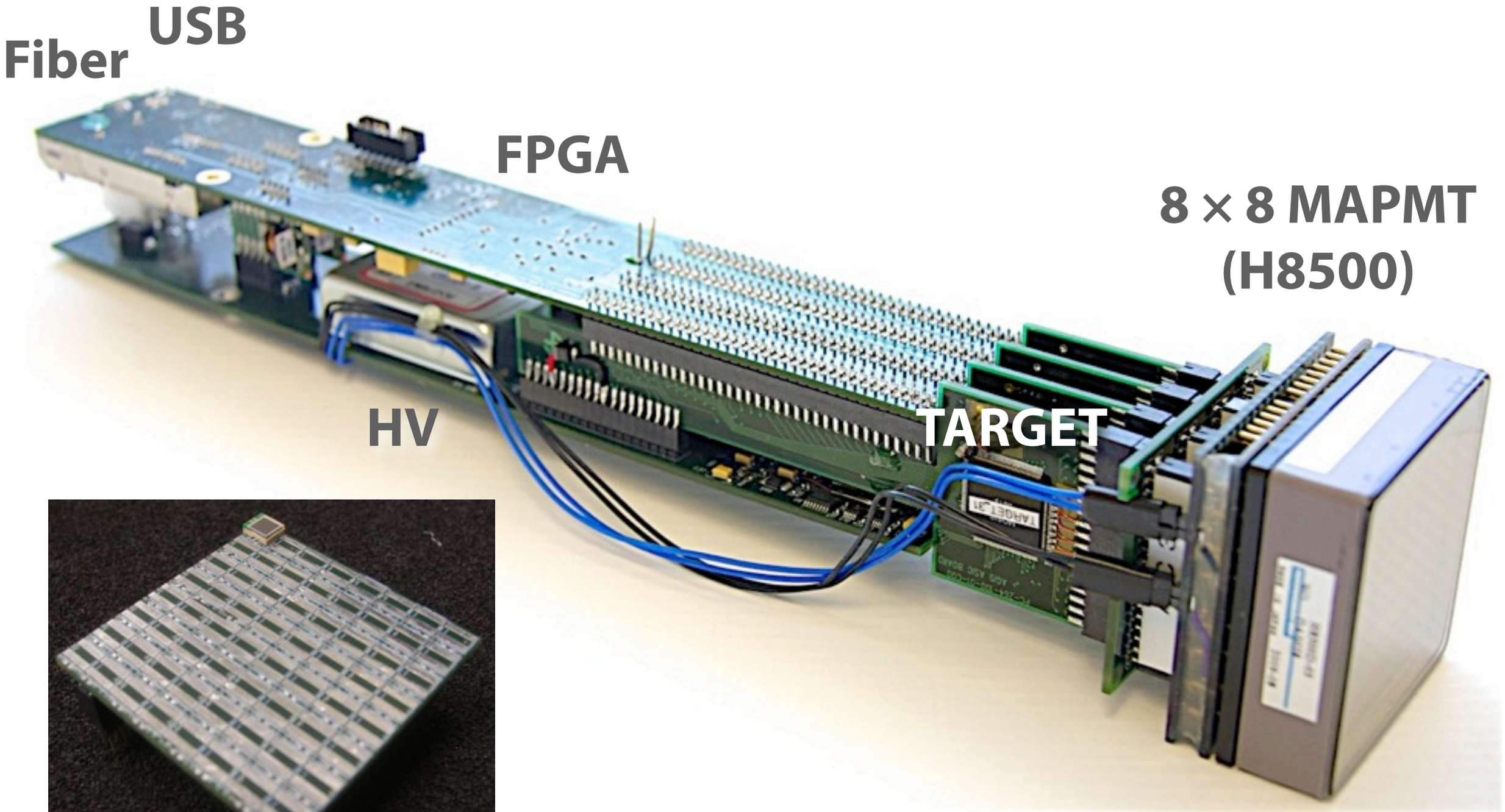
□ 6 mm
× 10000

HESS Camera w/ Regular PMTs

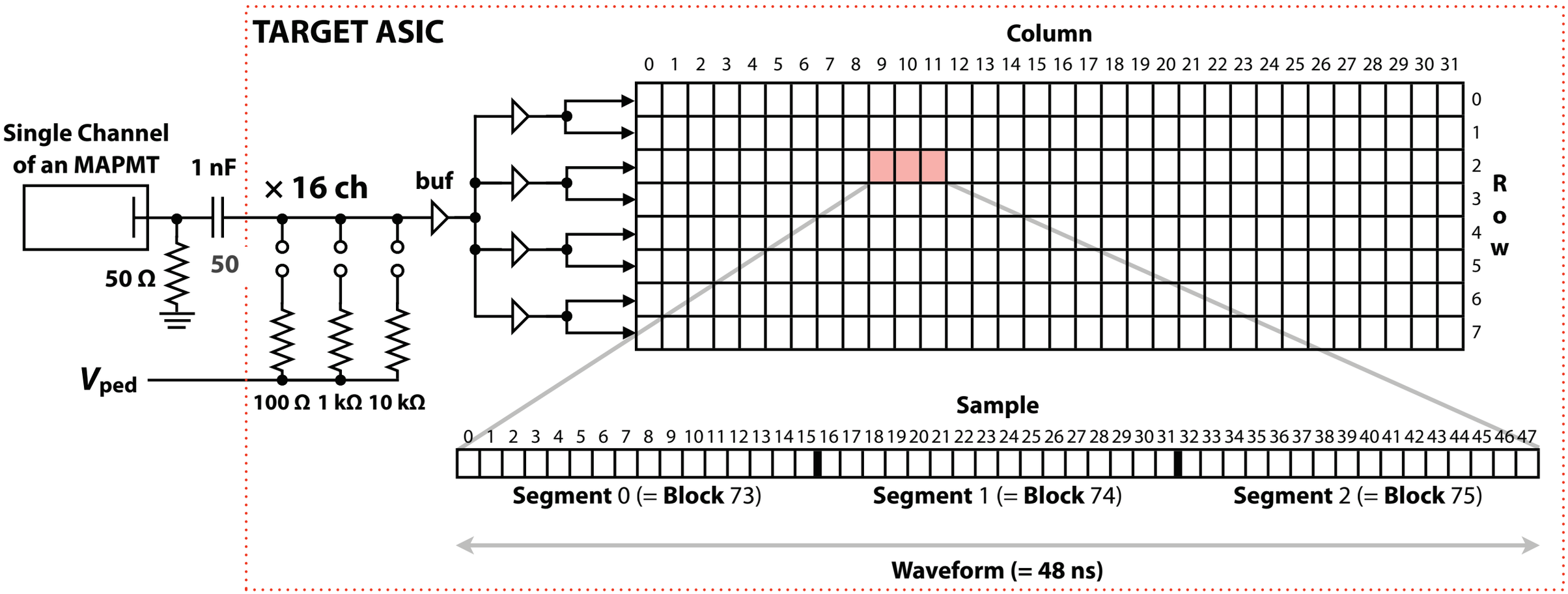
SC Optics Camera w/ MAPMTs

The TARGET Camera Module

TeV Array with Gsa/s sampling and Experimental Trigger

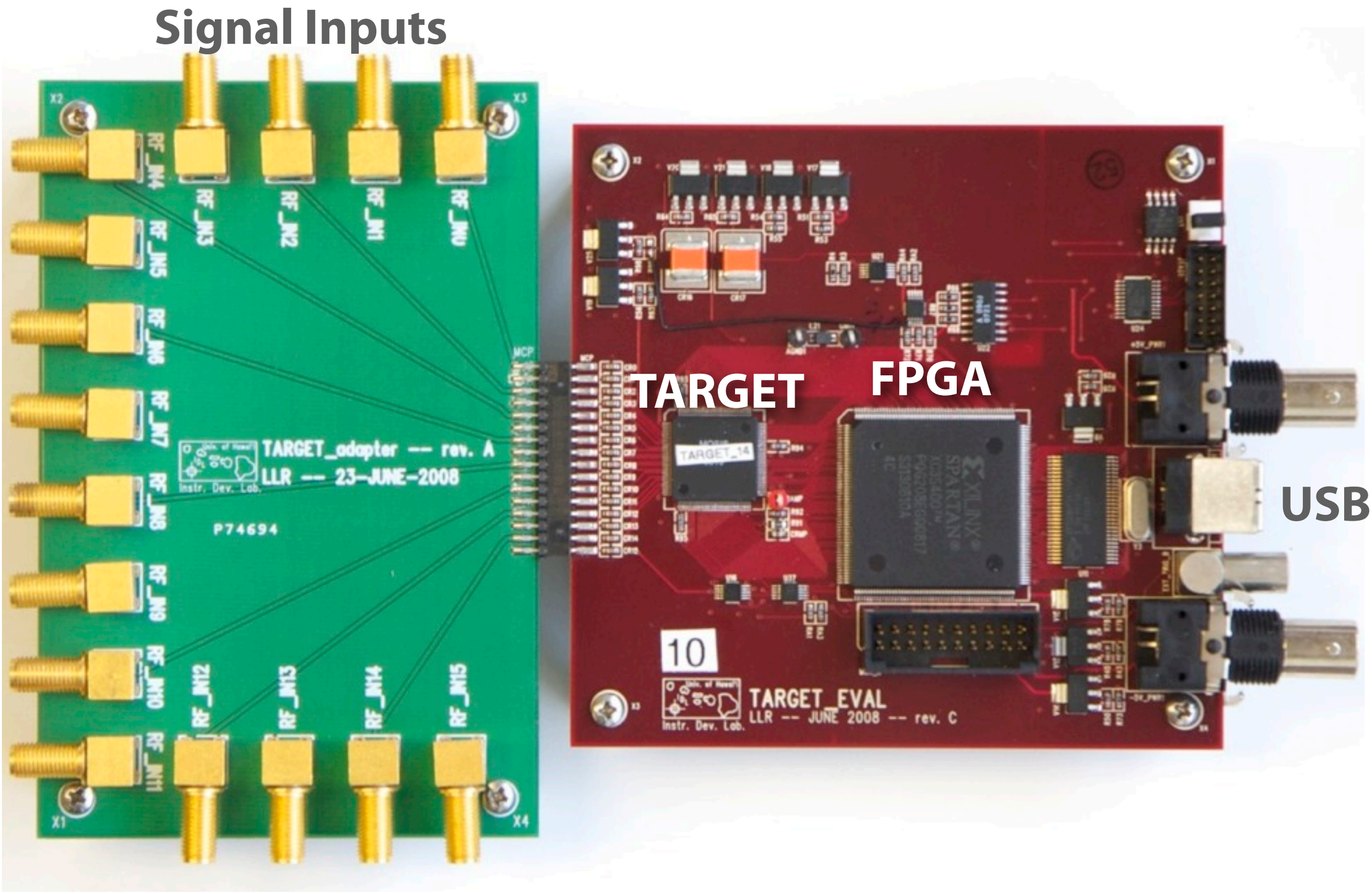


TARGET Concept

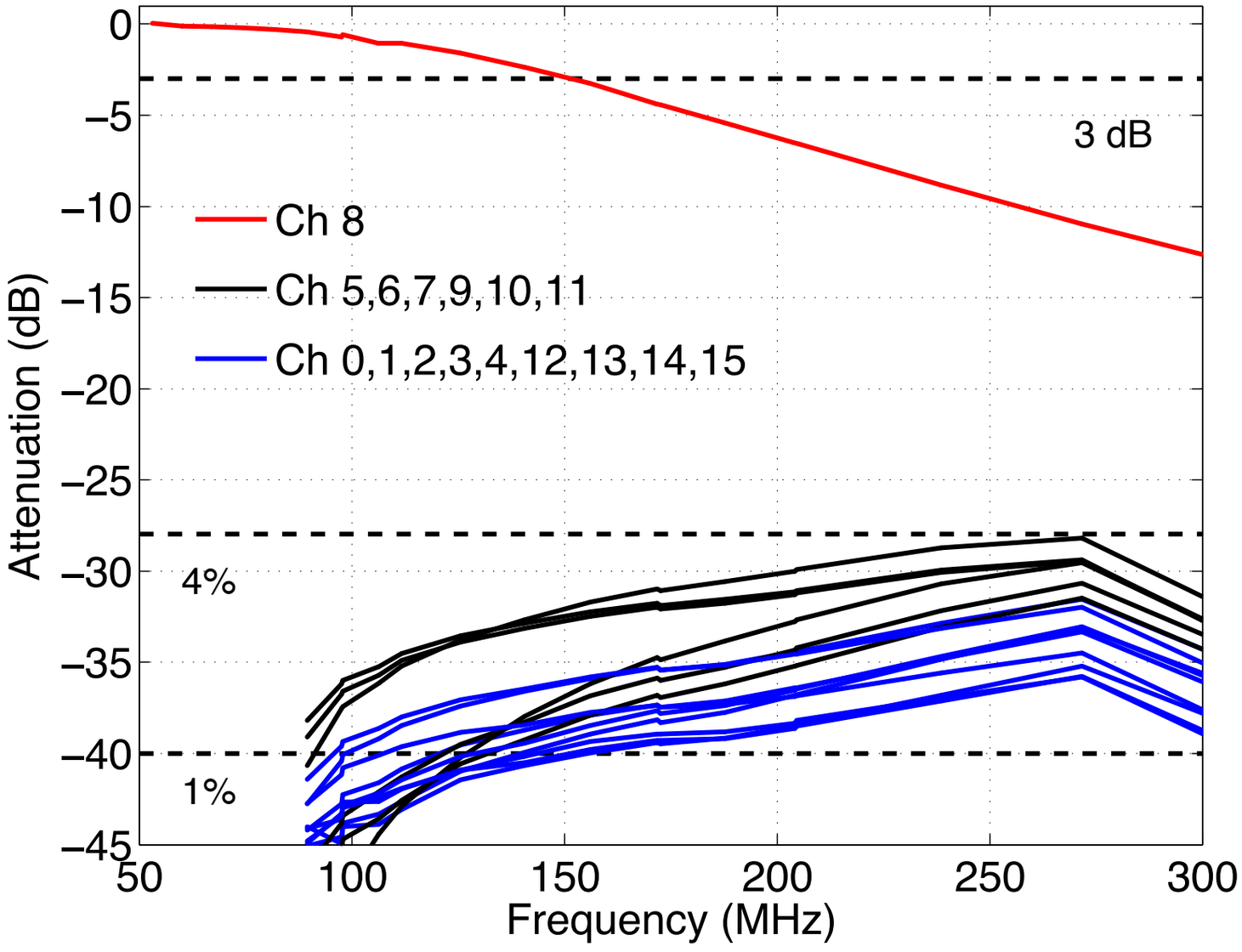


- **16-ch** integrated system × **4096 capacitors** (= 4-*μs* buffer at 1 GHz)
- **Self trigger**, **1 GHz or faster** sampling speed
- **9 or 10-bits** dynamic range
- Low cost (~$20/ch), low power (~5W/64ch)

TARGET 1 Evaluation Board



Bandwidth and Cross Talk

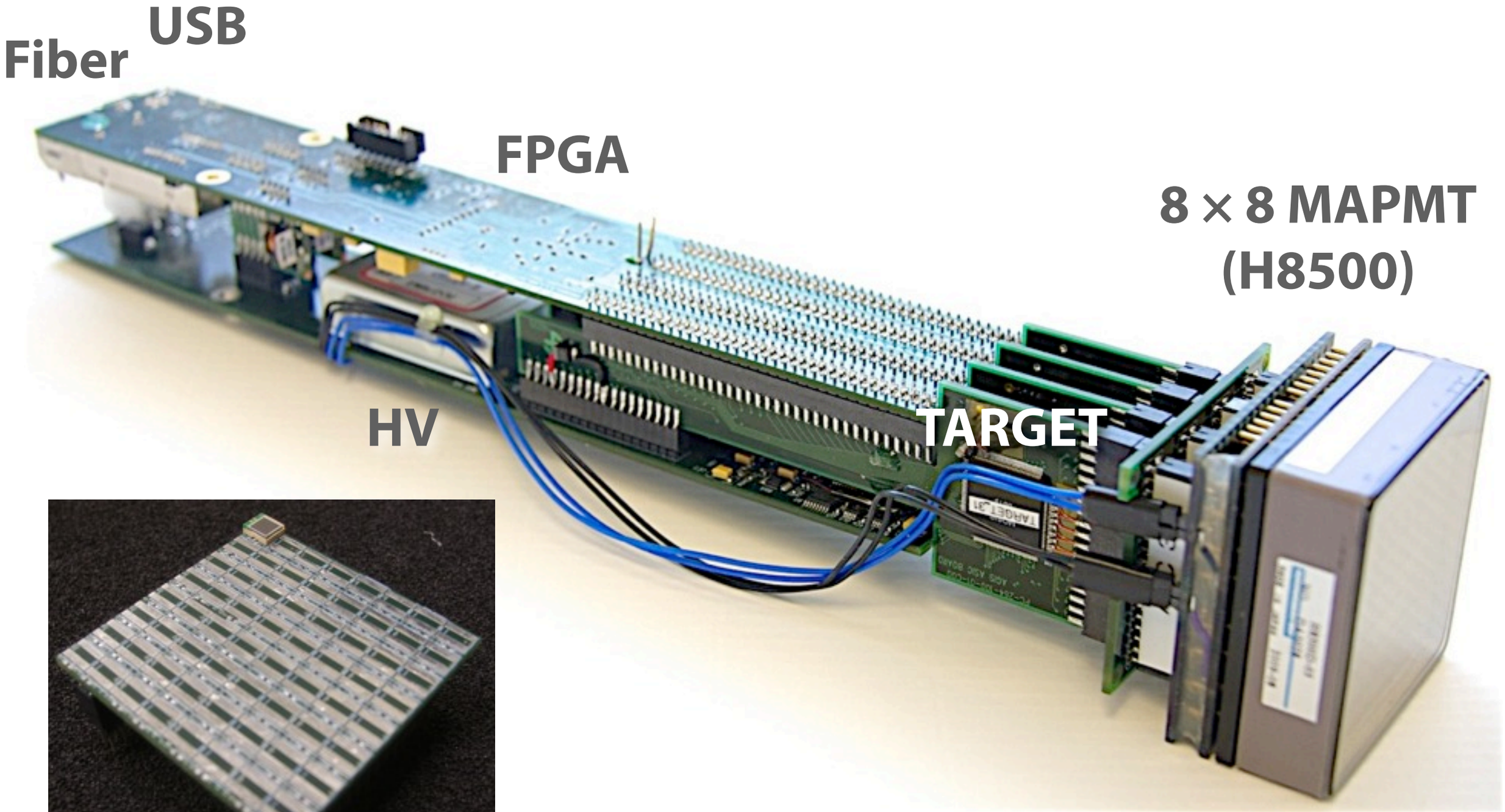


- Bandwidth and cross talk were measured with sinusoid input
- Bandwidth ~150 MHz at 3 dB →
  >380 MHz in TARGET 2
- Cross talk ~4% at 300 MHz →
  < 1% in TARGET 2

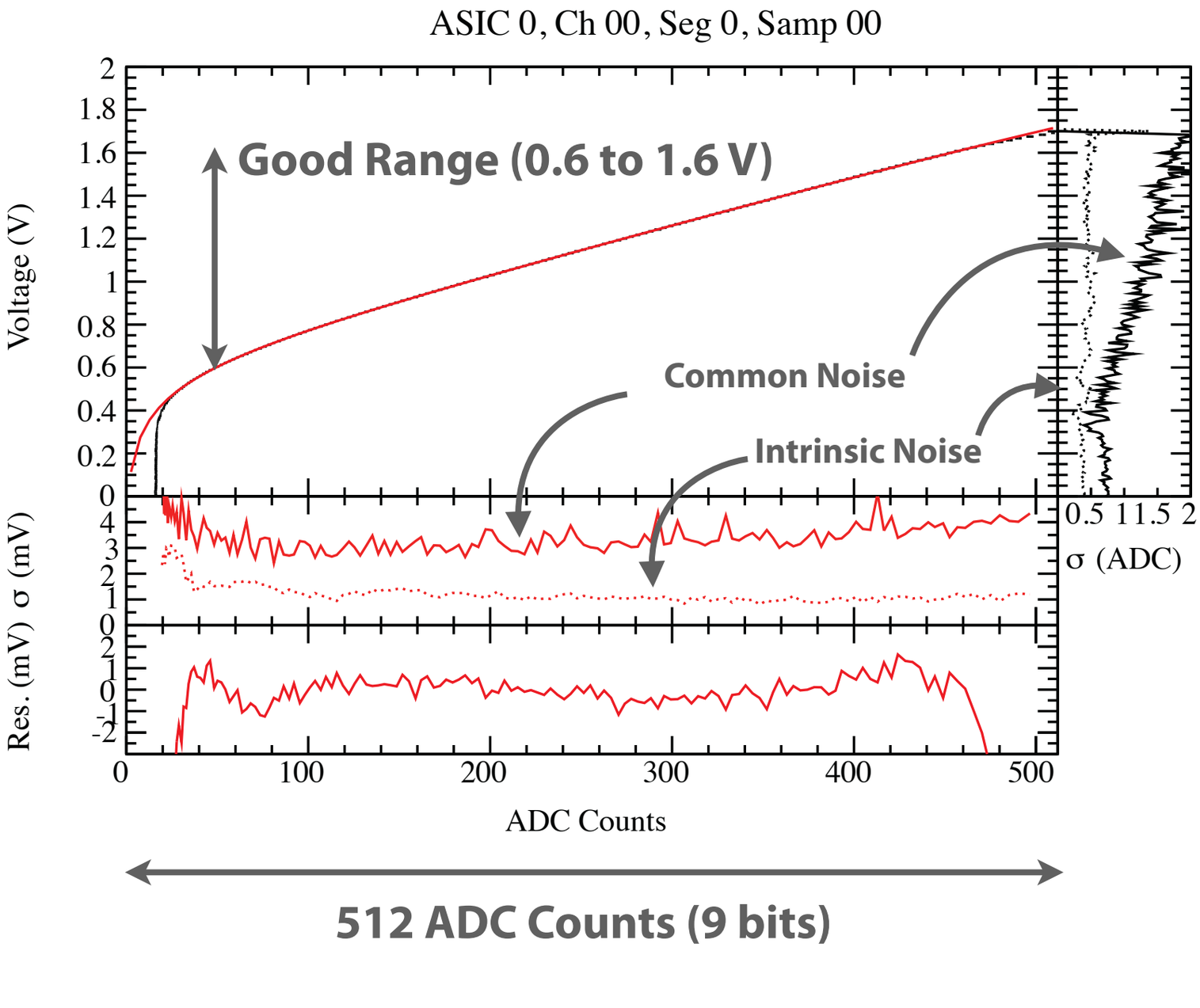
Bechtol+ 2011 (arXiv:1105.1832)

The TARGET Camera Module

TeV Array with Gsa/s sampling and Experimental Trigger



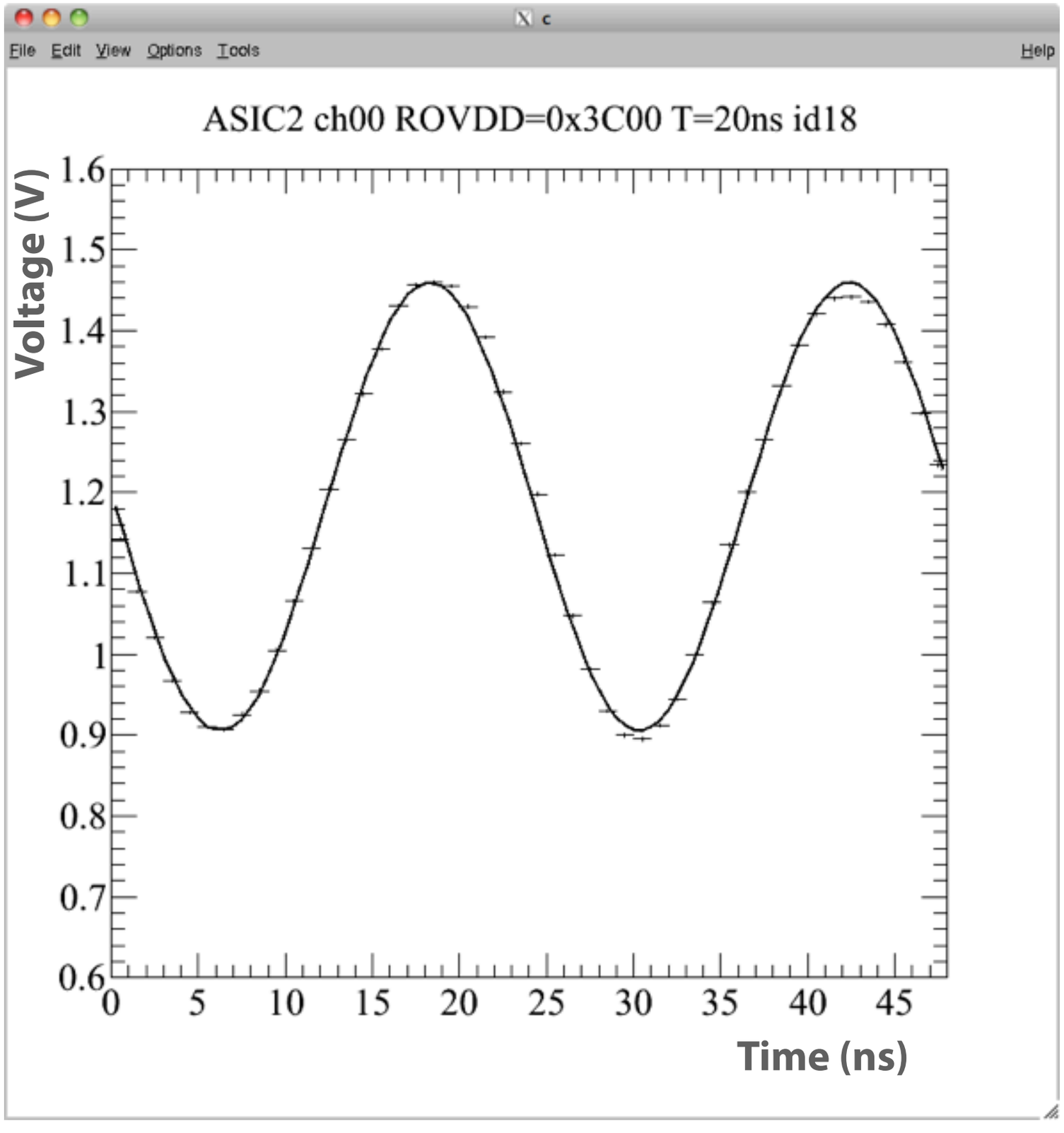
Calibration of the Transfer Function



- Measure the ADC count in ~8 mV step
- Dominant noise is common between Ch *N* and Ch *N* + 8 ~4 (mV) (~2 ADC)
- Intrinsic noise ~1 (mV) (~0.5 ADC)
- Fit *V* v.s. ADC with simple a function
- Fitting residual is ~0.5 (mV) (~0.25 ADC)

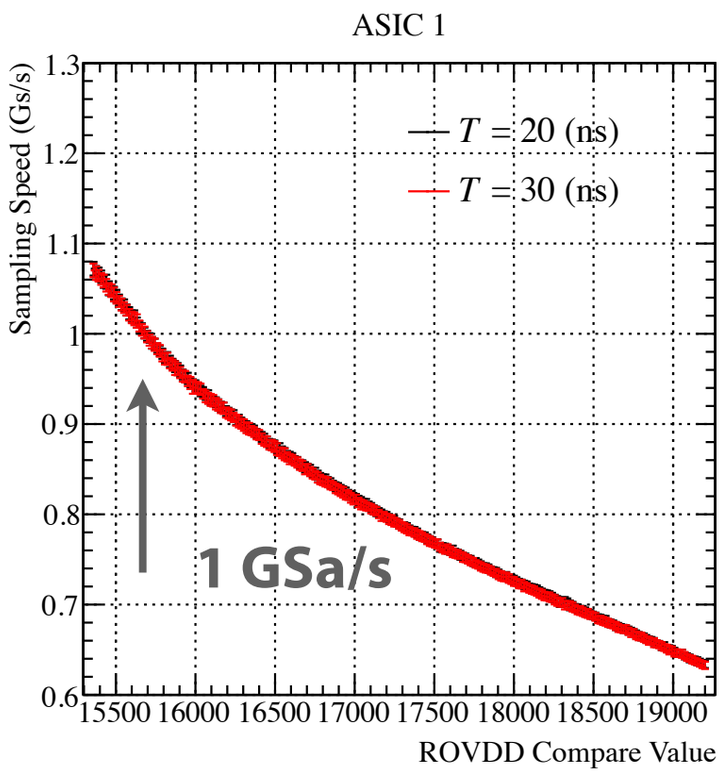
$$V = p_0 + p_1 \mathrm{ADC} + p_2 \mathrm{ADC}^{1/2} + p_3 \mathrm{ADC}^{1/3} + p_4 \mathrm{ADC}^{1/4} + p_5 \mathrm{ADC}^{5}$$

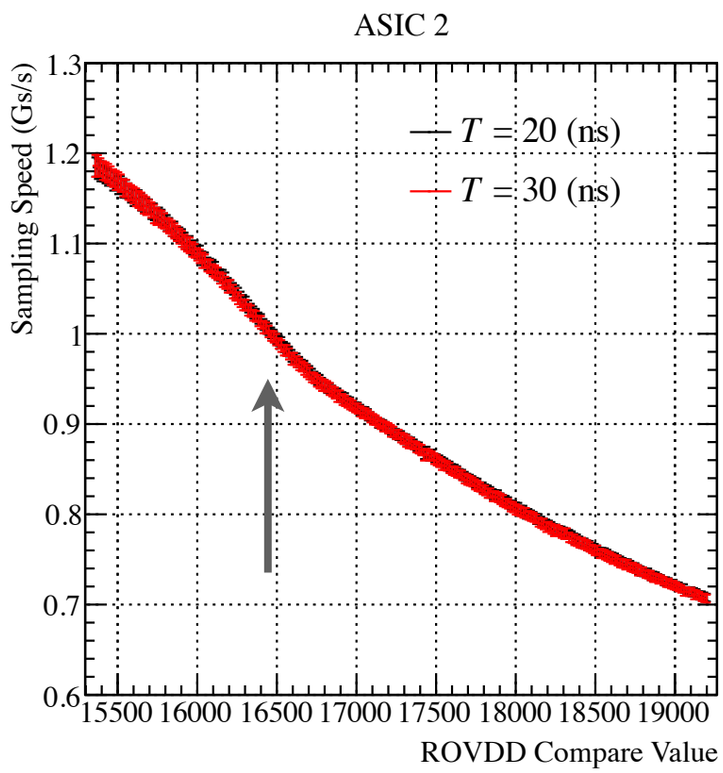
Calibration of the Sampling Speed

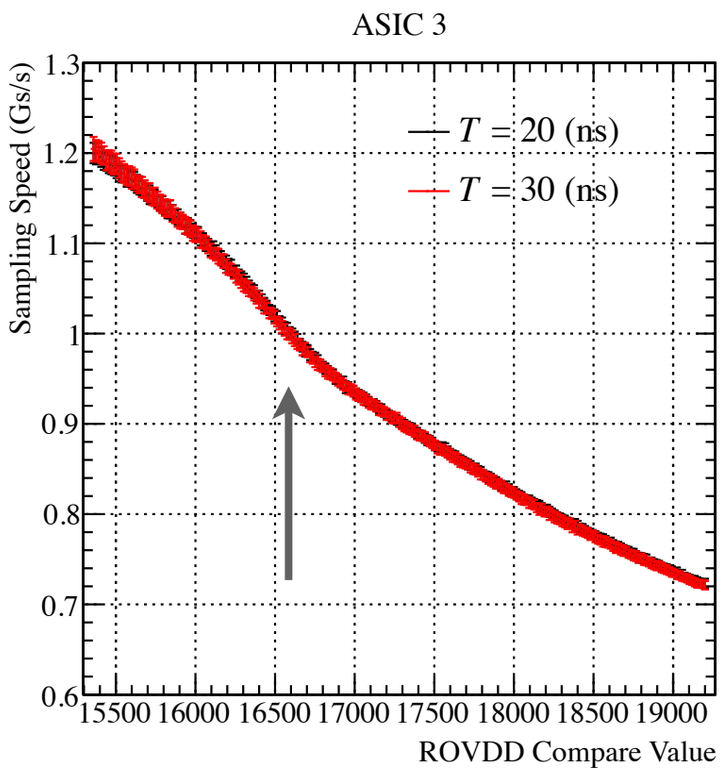


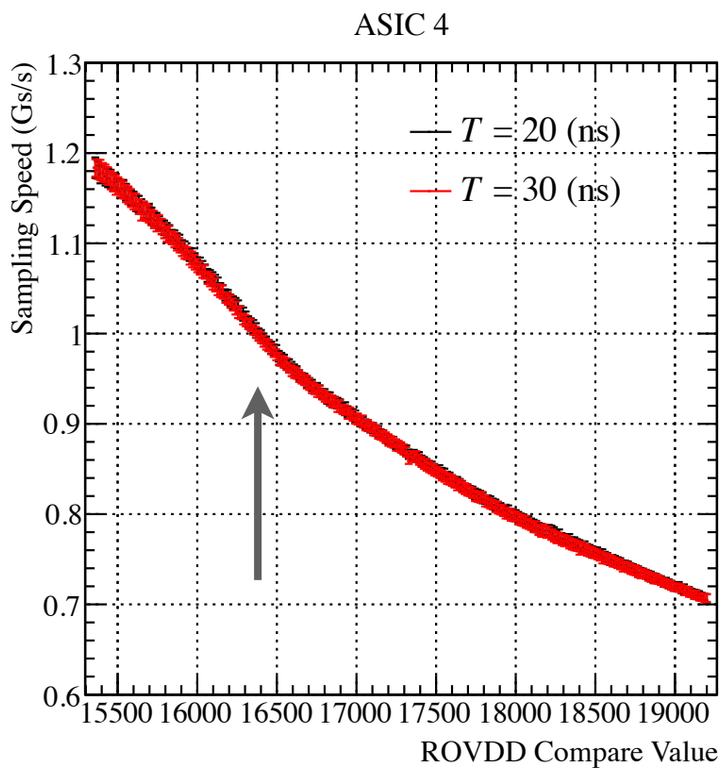
- Sampling speed is adjustable via control DC voltage
- Input 20 (ns) or 30 (ns) cycle sinusoid wave to the module
- Convert ADC counts to voltage using the transfer functions
- Fit the waveform and obtain the sampling speed

Calibration of the Sampling Speed









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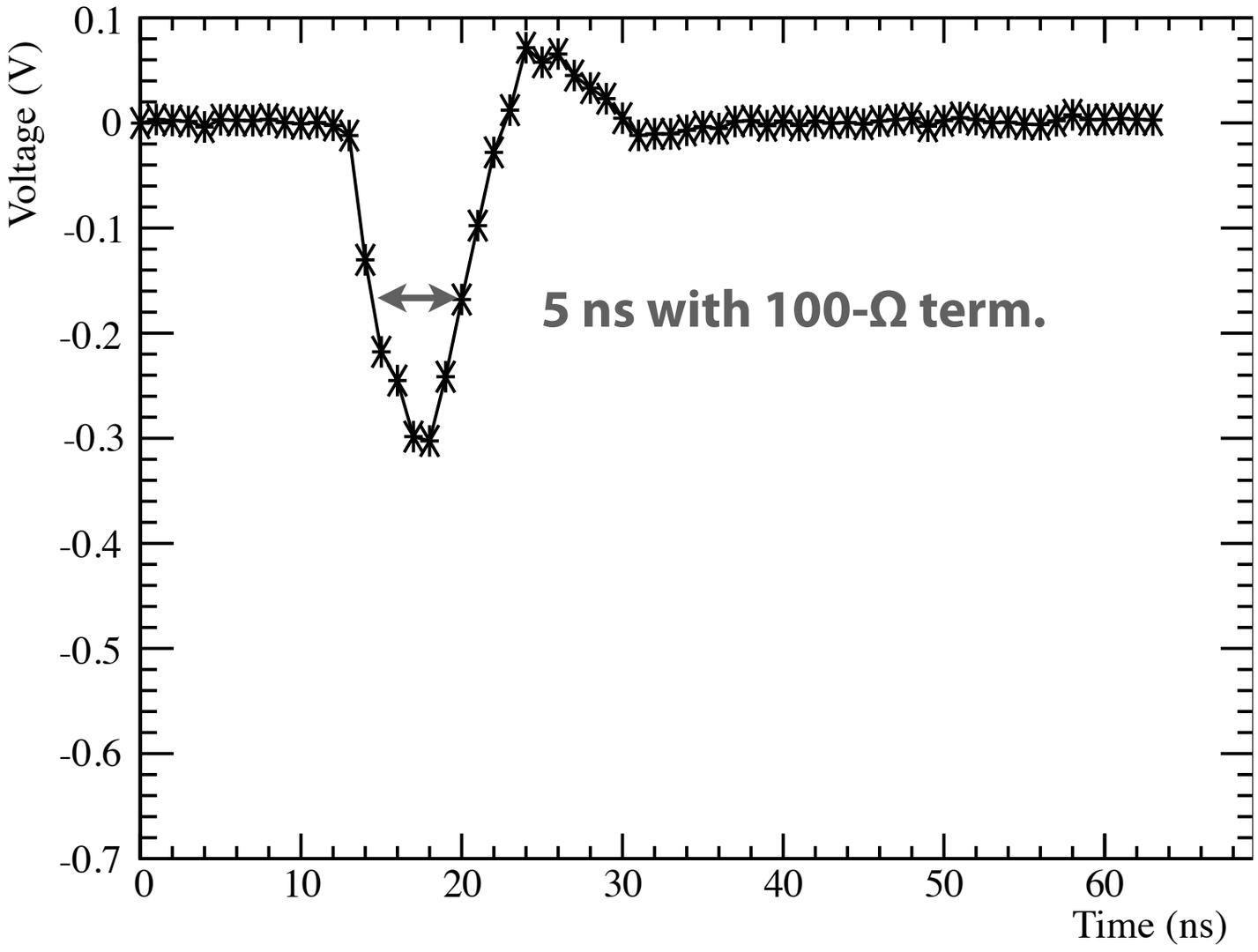
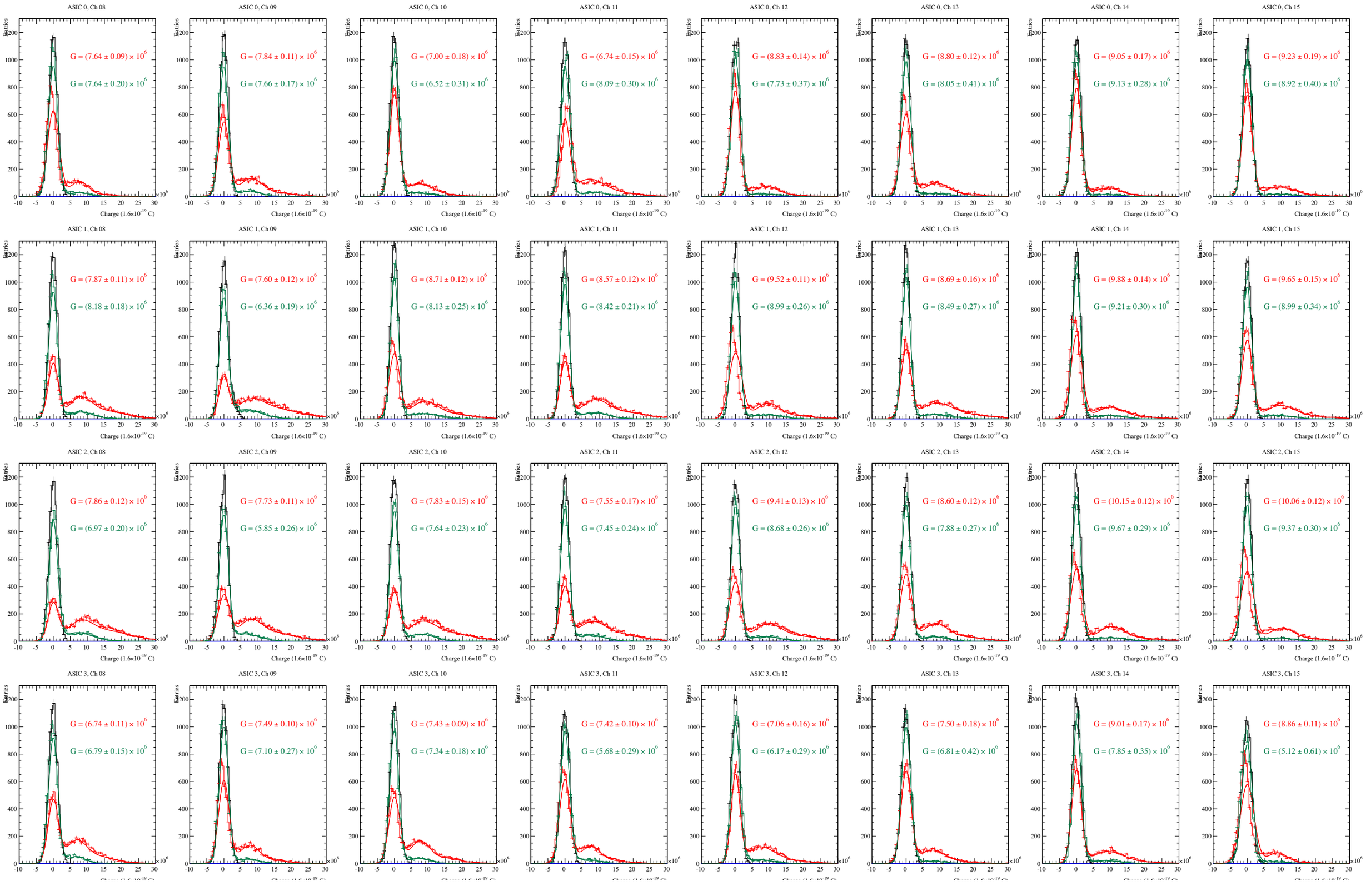
Example of MAPMT Output



- Confirmed
  - Waveform acquisition at 1 GSa/s
  - Self trigger

1 Photoelectron Distribution (32 Channels)



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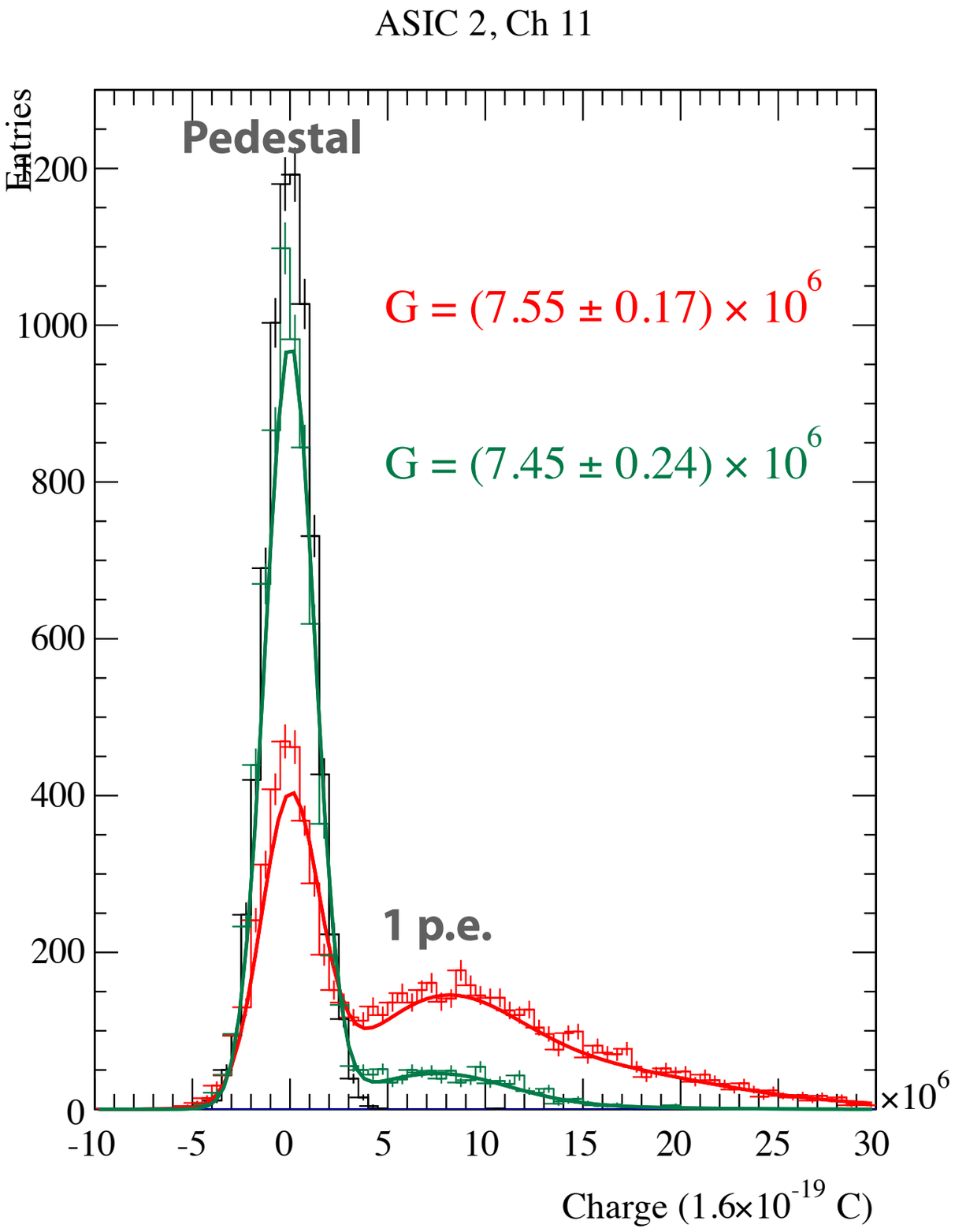
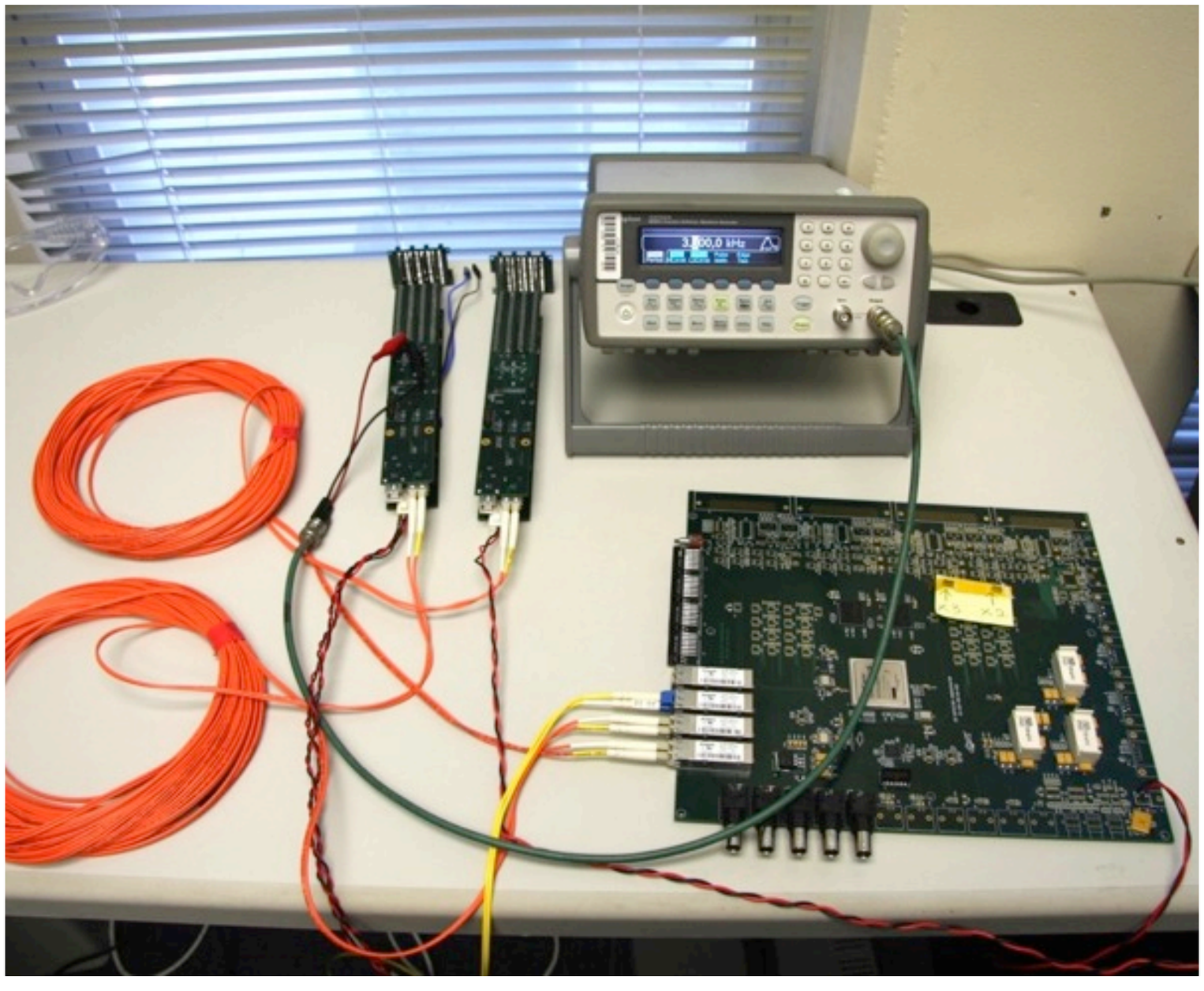


- 1 p.e. measurements using the pulsed LED and two different ND filters
- HV = -1050 (V)
  typical gain ~ 8×10^6
- Results of two different ND filters are shown

Test Bench of Fiber Link

Camera Module × 2

Function Generator



Backend Board

- Prototype of a backplane board
- Receive data from multiple camera modules
- Broadcast commands from the board to modules
  - PC ⇄ Board ⇄ Modules
- > 6.6 kHz DAQ

Summary

- TARGET 1 has been developed for the Schwarzschild-Couder optical system
- Confirmed the basic functionalities of the TARGET camera module
- TARGET 2 has been already fabricated and delivered
- Some improvements are expected in TARGET 2