CTAデュアルミラー光学系用
焦点面検出器の試作器開発

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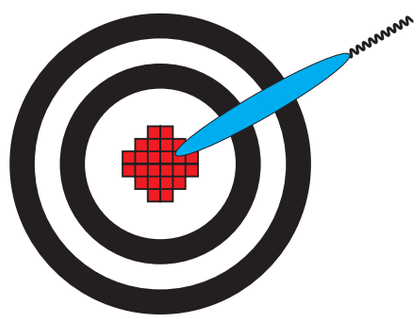
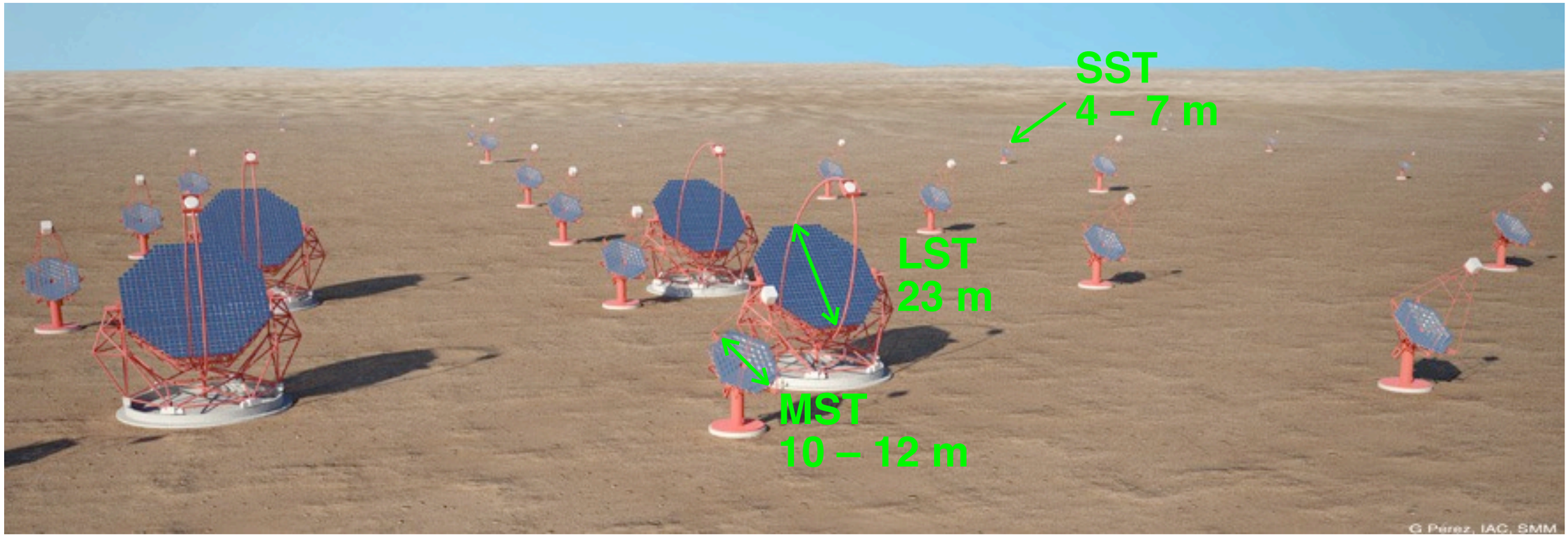


September 20, 2013
JPS meeting
高知

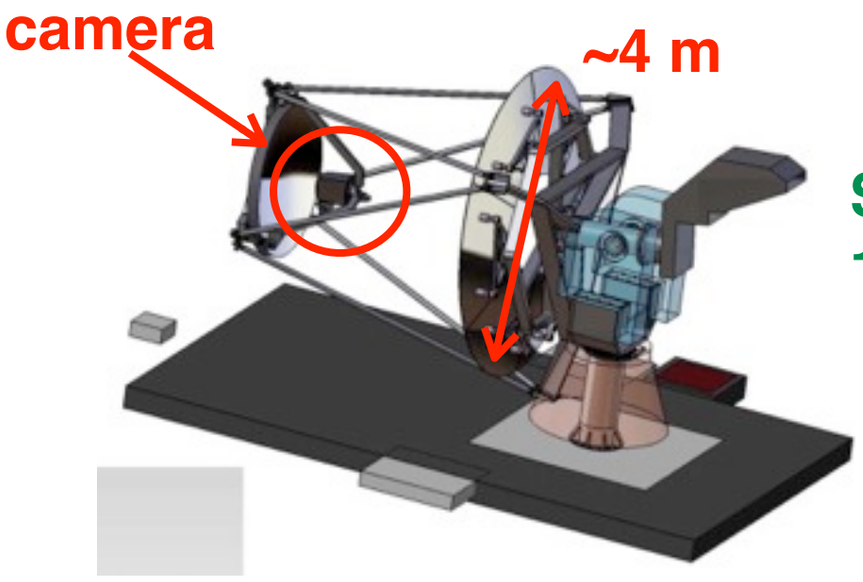
Cherenkov Telescope Array

- **Observations of gamma rays in 20 GeV – 100 TeV band**
  - **Cherenkov light from electromagnetic shower produced by interaction of gamma rays with atmosphere**
- **Large collection area by placing many telescopes**
  - **x10 better sensitivity**
- **Wide energy band coverage by three different size of telescopes**
  - **Large-size telescope (LST): Φ = 23 m, 20 GeV – 1 TeV, 4 telescopes**
  - **Medium-size telescope (MST): Φ = 10 – 12 m, 0.1 – 10 TeV, ~20 telescopes**
  - **Small-size telescope (SST): Φ = 4 – 7 m, 1 – 100 TeV, 30 – 70 telescopes**

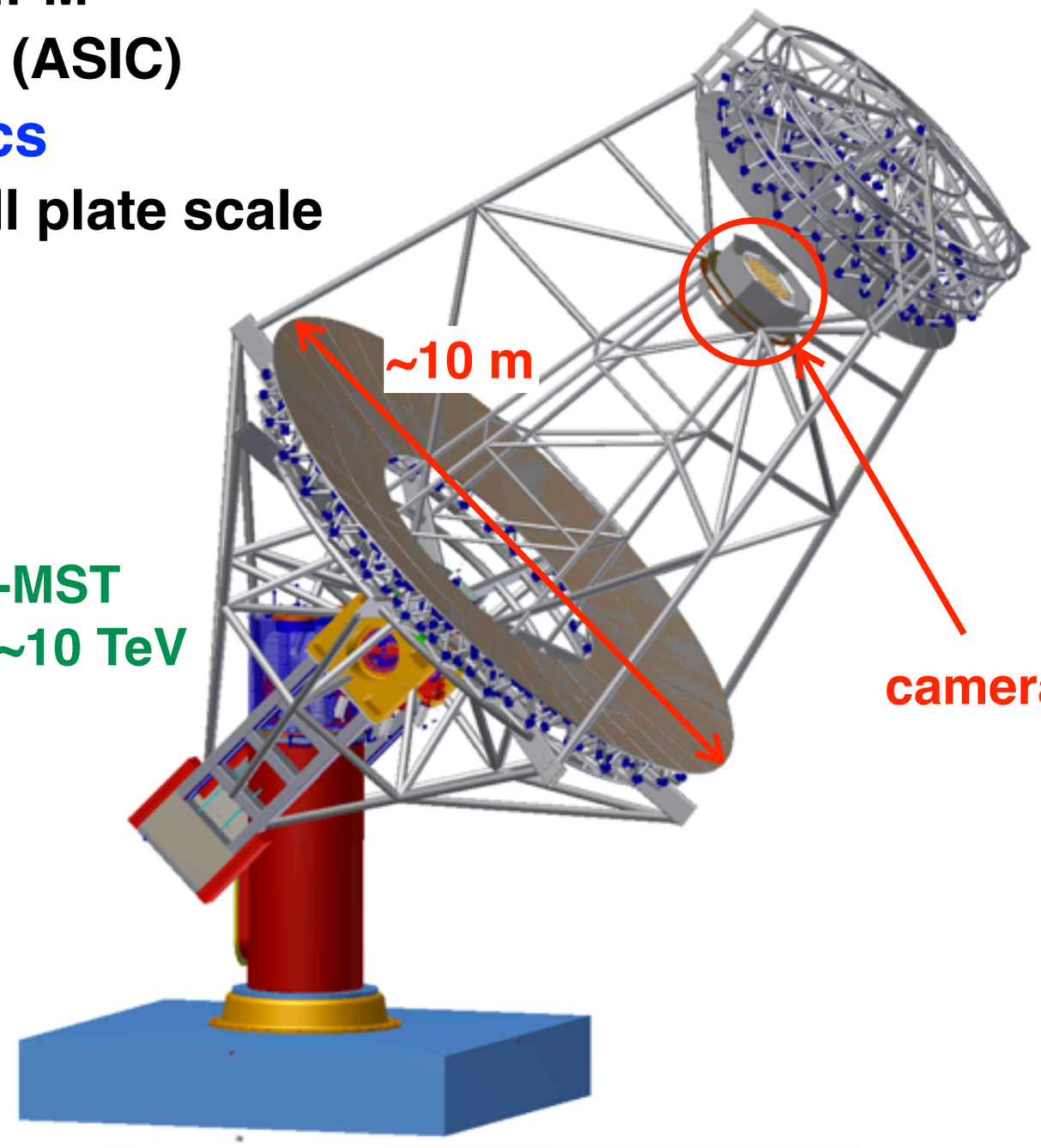


SC-MST/SST Design Concept

- **Dual mirror design with small pixel photon sensor**
  - **Small pixel (~6 mm) photon sensor to reduce camera cost**
    - **Multi-anode photomultiplier or SiPM**
    - **High density readout electronics (ASIC)**
  - **Schwarzschild-Couder (SC) optics**
    - **Short focal length to realize small plate scale**
      - **Technically challenging**
    - **Large field of view**
      - **Longer telescope spacing (larger collection area)**



SC-SST
1~100 TeV



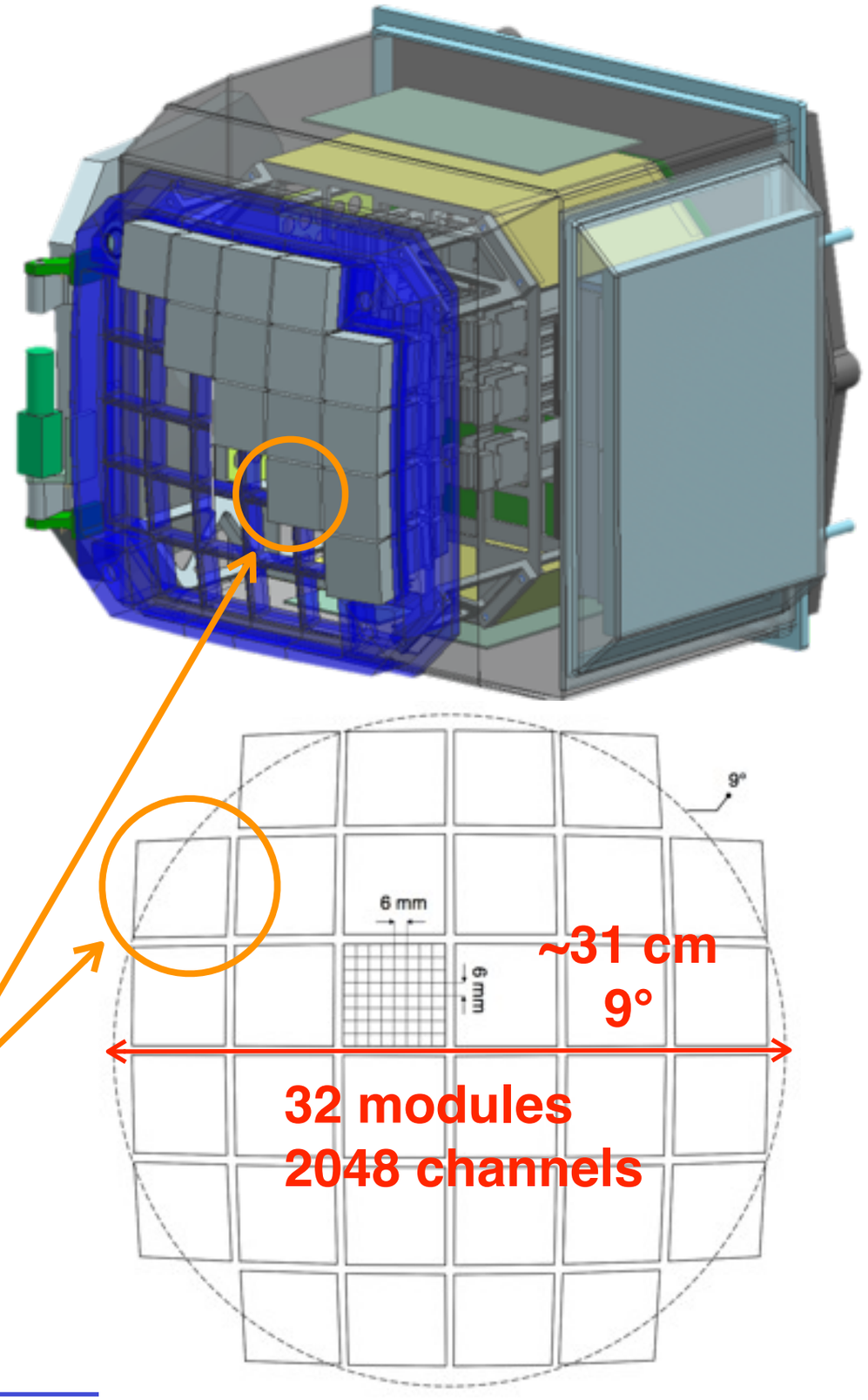
SC-MST
0.1~10 TeV

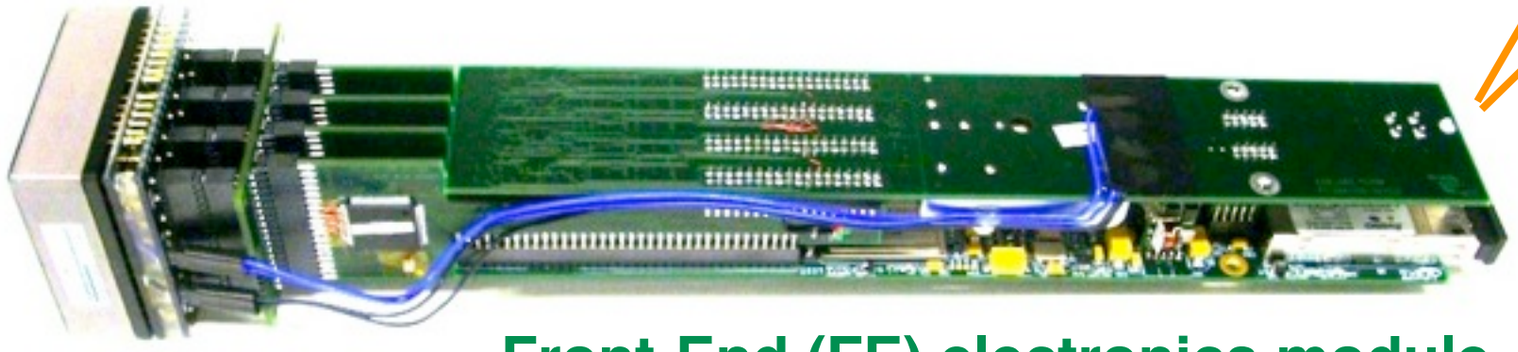
SC-SST Camera Design

❖ SC-SST camera parameters

	32 mod
FOV for 0.18°/pixel (36 mm/°)	8.6°
FOV for 0.28°/pixel (23 mm/°)	13.4°
Angular pixel size for FOV=10°	0.21°
# of pixels per camera	2,048
Power consumption per camera (FE)	350 W
Weight per camera (FE+SiPM)	11 kg
Total cost (FE+SiPM) for 50 CAMs*	$7.2M

*Assuming $20/ch, which does not explicitly include labor for mechanical module assembly and calibrations



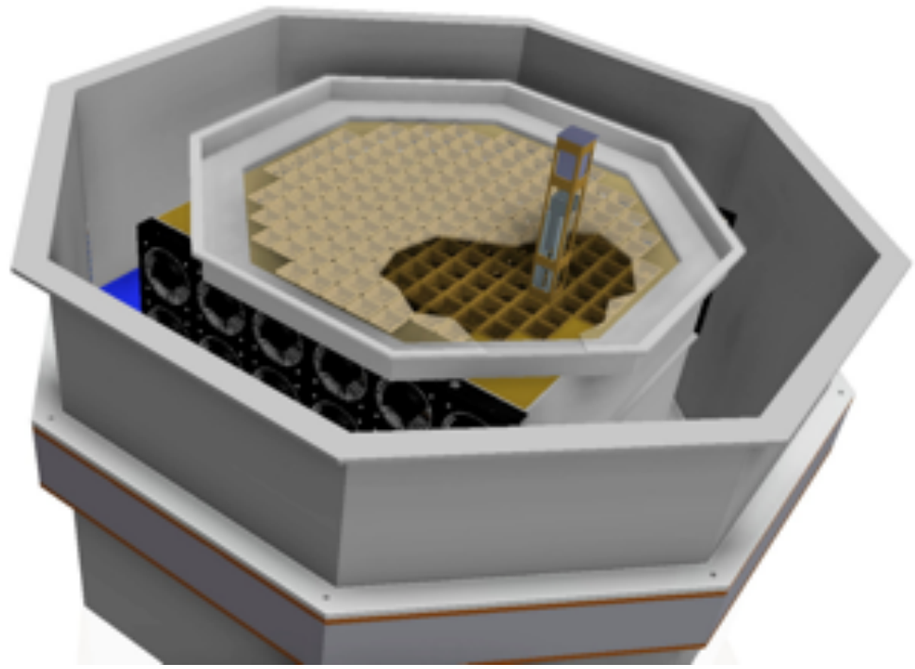


Front-End (FE) electronics module

SC-MST Camera Design

❖ SC-MST camera parameters

FOV	8.0°
Angular pixel size	0.067°
# of pixels per camera	11,328
Power consumption per camera (FE)	2000 W
Weight per camera (FE+SiPM)	61 kg
Total cost (FE+SiPM) for 50 CAMs*	$24M



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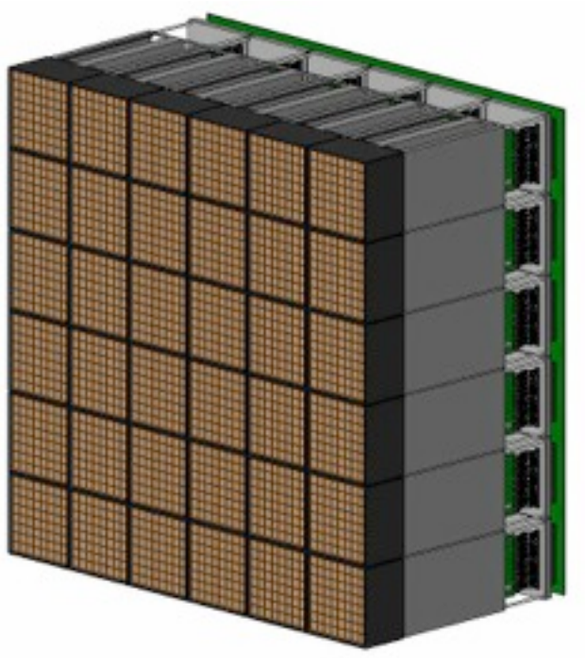
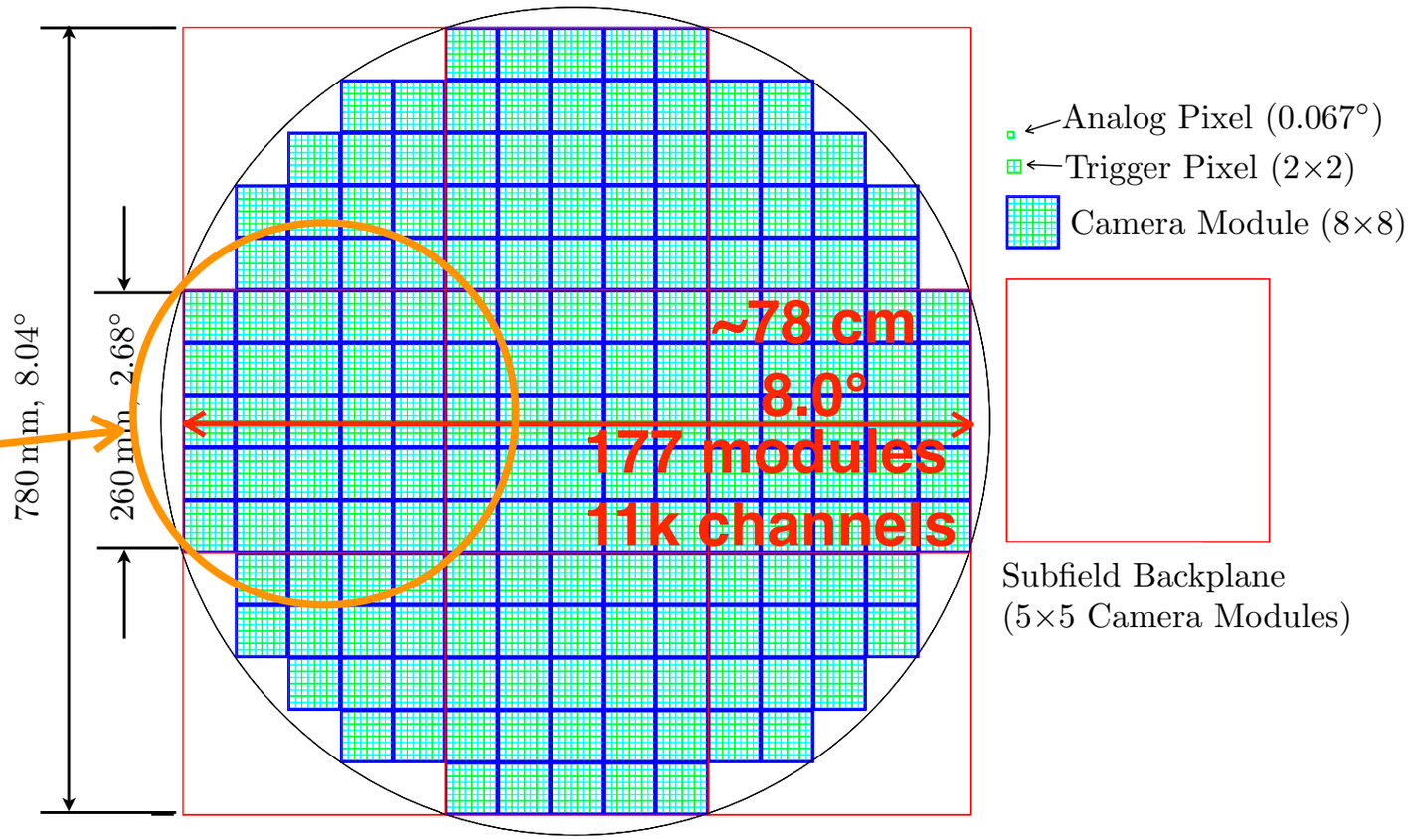
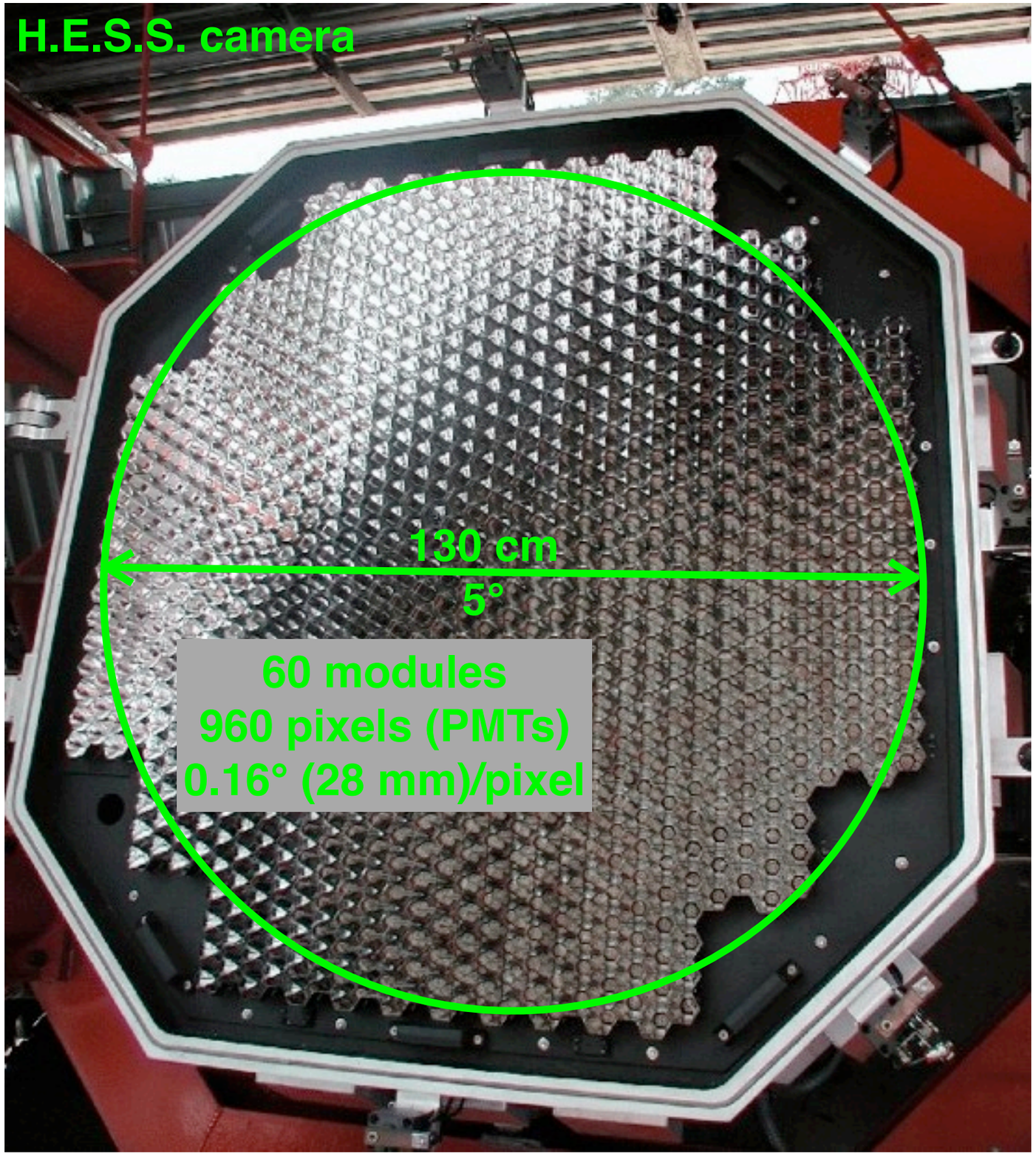
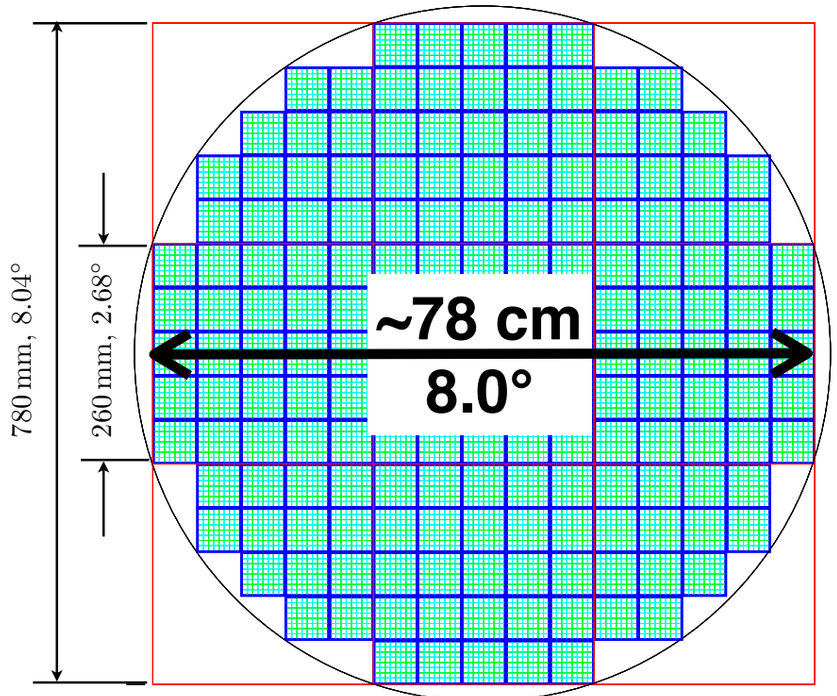




Comparison with Existing Cherenkov Camera



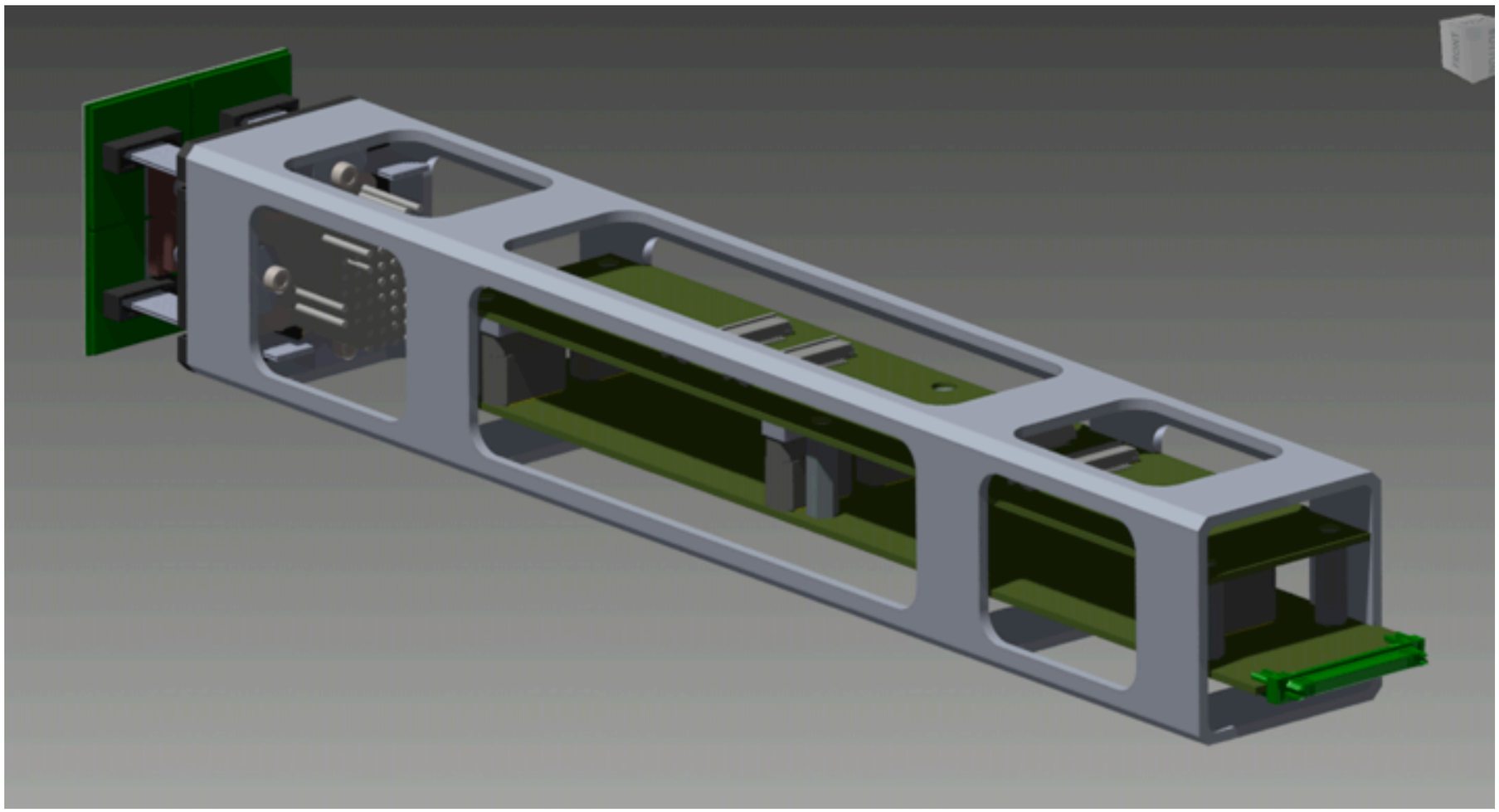
SC-MST camera



177 modules
11k pixels
0.064° (6.2 mm)/pixel

SC Camera Front-End Electronics

- **Board configuration**
  - **Photosensor I/F board: preamp, high voltage (HV), Peltier control**
  - **Signal processing board: TARGET ASIC, FPGA, back-end I/F, power suuply**
- **Minimize # of components for cost reduction and reliability**
  - **Integration of necessary functionalities into an ASIC**



designed by G. Varner (Hawaii)

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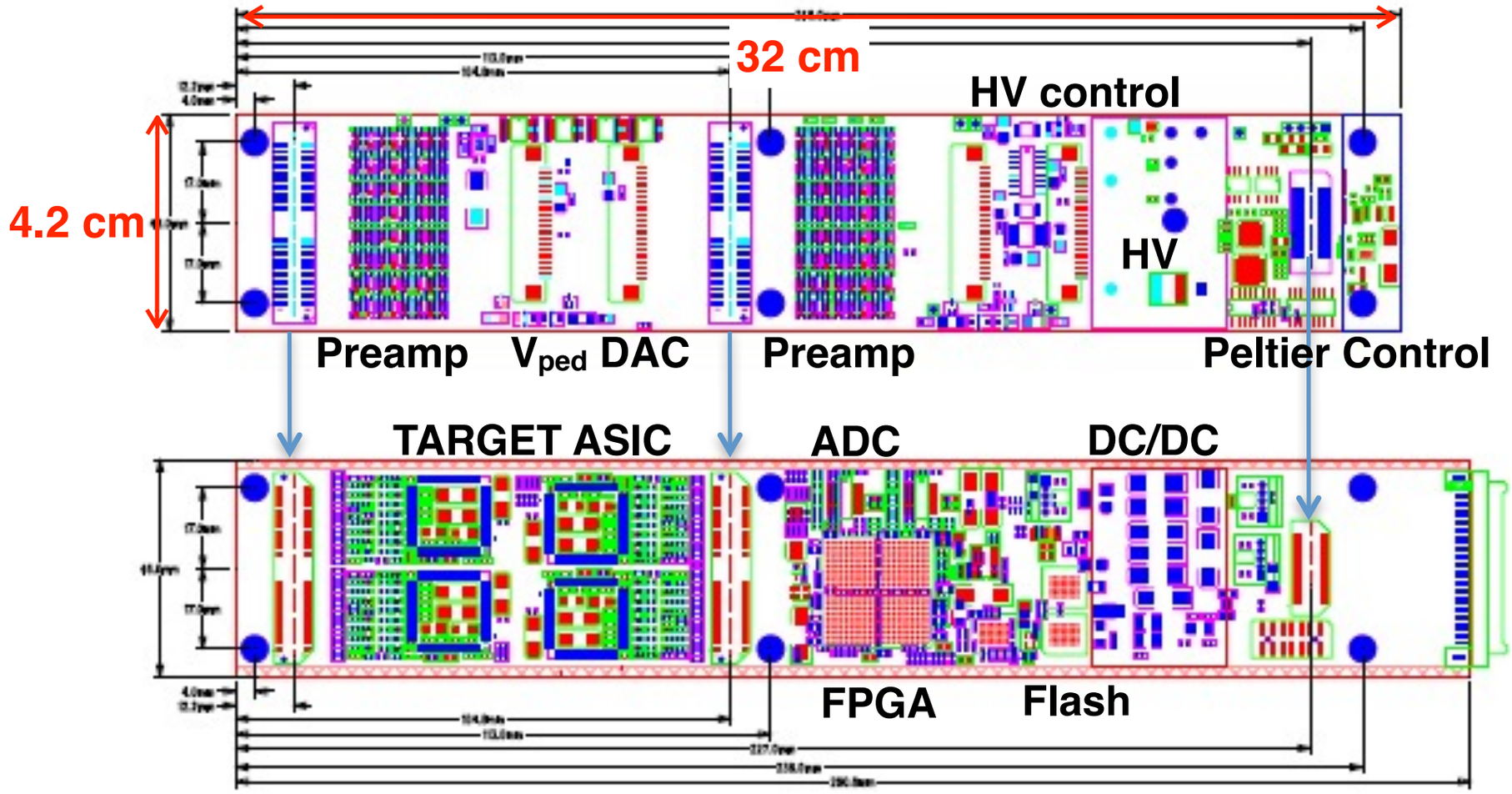

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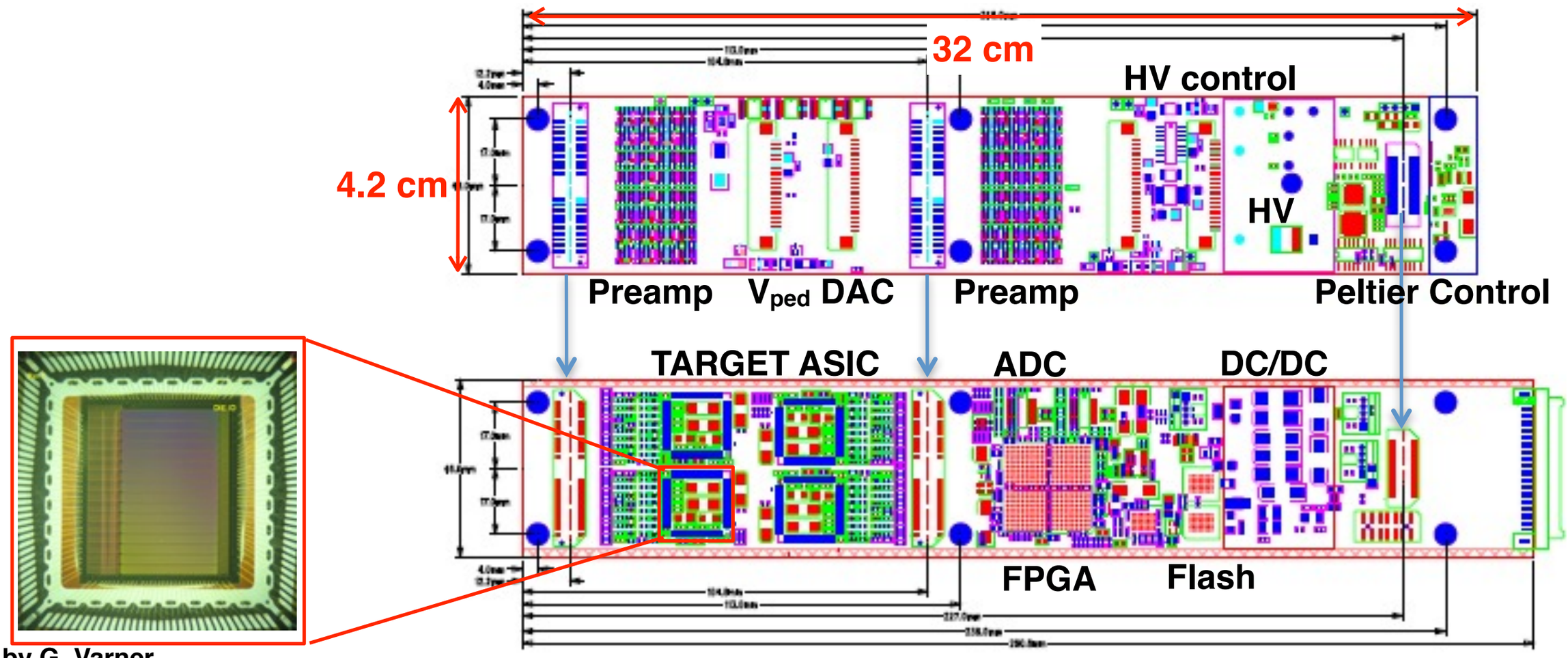

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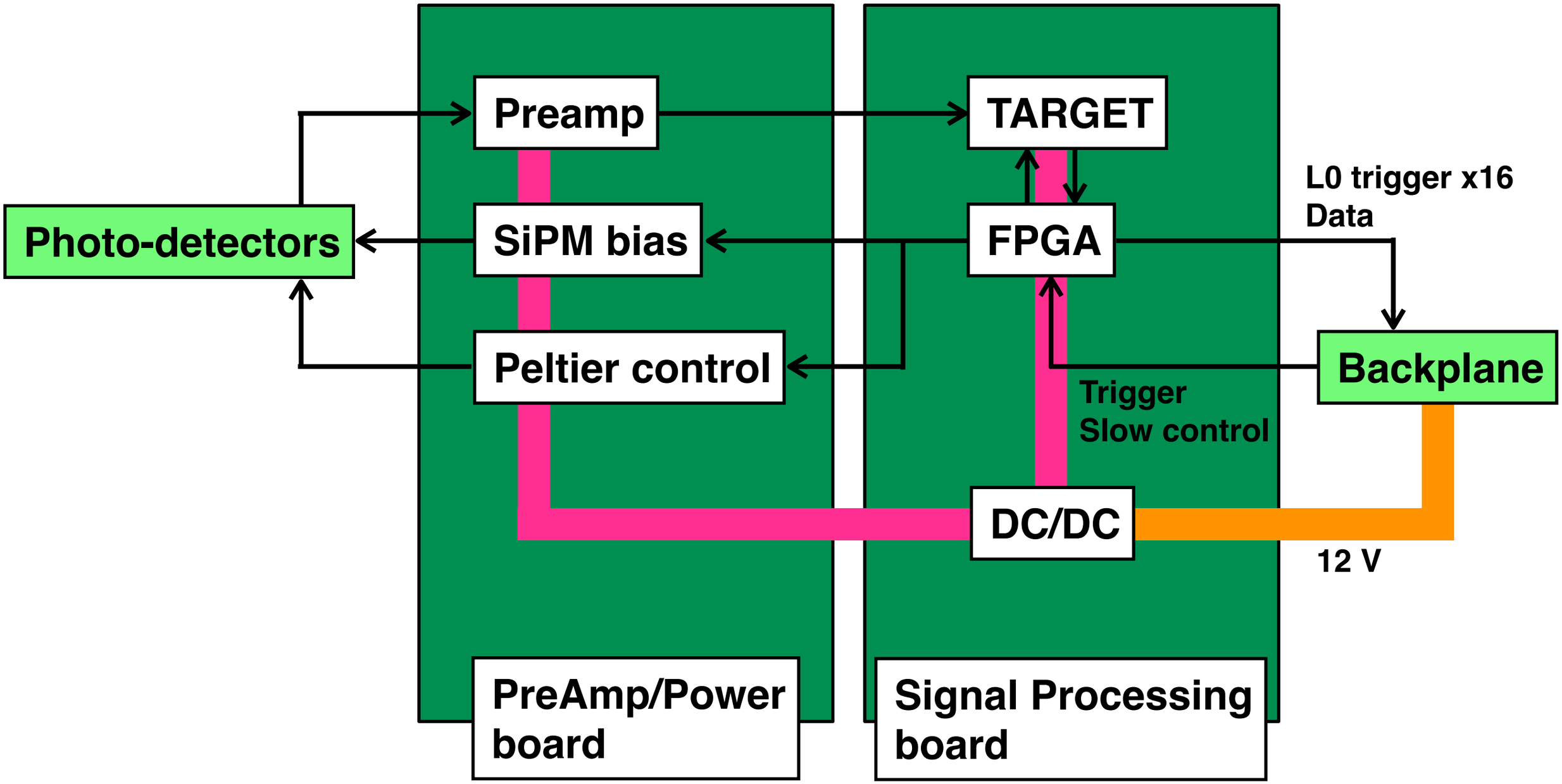
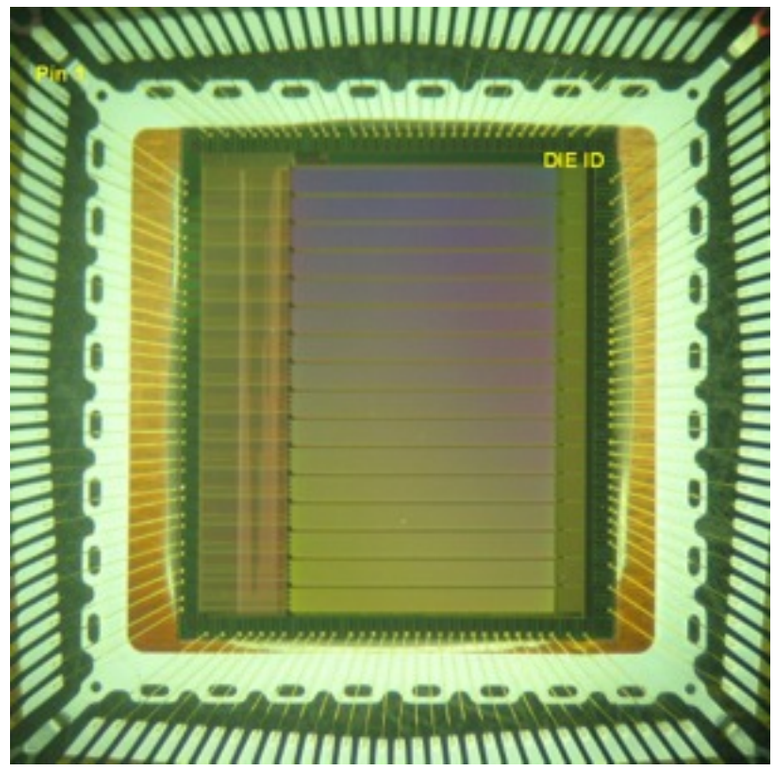
FEE Function Diagram



SC Camera Electronics Design

- **Requirements**
  - Waveform sampling at ~ 1 GSa/s
  - Signal bandwidth > 380 MHz
  - Cross-talk < 1%
  - Look-back time: > 12 μs
  - Dynamic range: > 9 bits
  - Readout (dead) time: < 30 μs
  - Trigger timing: < 4 ns
  - Trigger segment: 0.1° x 0.1° ~ 0.2° x 0.2°
- **TARGET ASIC**
  - Switched capacitor array for high speed waveform sampling
  - Integrated digitization circuits and trigger circuits
    - ✦ Reduction of components and cost, increase reliability
  - Internal bias generator
    - ✦ All digital interface
  - Low power consumption: ~70 mW/channel including FPGA



History of TARGET development

- **TARGET-1**
  - 2008/May delivery
  - BW is limited to ~150 MHz, 8k cells, no analog sum trigger
- **TARGET-2/TARGET-4**
  - 2011/Aug (TARGET-2), 2012/Feb (TARGET-4)
  - Improved BW and cross talk, 16k cells, more (faster) digitization circuits, 4-ch analog sum trigger
  - Problem with serial register loading, DAC voltage routing
- **TARGET-5**
  - 2012/Aug delivery
  - BW is confirmed up to 400 MHz, cross talk < 1%
  - Minimum trigger threshold is too high (~25 mV, ~6 p.e.)
- **TARGET-7**
  - 2013/Sep submission, Dec delivery (expected)
  - Wider dynamic range, better linearity and better temperature stability
  - Lower trigger threshold (<10 mV, 2.5 p.e.)

TARGET-7 Specifications

		TARGET-5	TARGET-7
# of channels		16	16
# of cells/channel		16,384	16,384
Sampling frequency		0.4 – 1.2 GHz	0.5, 1.0 GHz
Bandwidth		> 380 MHz	> 380 MHz
Crosstalk (@ -3dB)		< 1%	< 1%
Dynamic range		0.6–1.0 mV/1.5 V	0.6–1.0 mV/2 V
Wilkinson ADC clock speed		~700 MHz	~500 MHz (external, both edges)
Digitization time		5.9 μs (12 bit)	8.2 μs (12 bit)
# of cells/digitization		32 cells x 16 ch	32 cells x 16 ch
Data transfer speed		~90 Mbps x 16 ch	~90 Mbps x 16 ch
Dead time (48 cells/ch)	10 bit	2.9 + 8 μs	4.1 + 8 μs
	12 bit	11.7 + 8 μs	16.4 + 8 μs
# of trigger output		4 (4 ch analog sum) + 1 (16 ch analog sum)	4 (4 ch analog sum, no gain adjustment)
Trigger threshold at input		25 mV minimum	10 – 80 mV (2.5 – 20 p.e. for MST) 0.2 mV step (nominal, 0.05 p.e. for MST)
Trigger threshold noise		< 4 mV	< 1.6 mV (rms)
Trigger gain adjustment		20%	None

SC-SST/SC-MST Prototype Development

- **SC-MST prototype**
  - **Partially populated mirrors and SiPM camera modules**
    - **Comprehensive study of the structure, mirrors, motorization and control system**
- **SC-SST prototype**
  - **Mini-array: 5 complete telescopes and cameras**
    - **1 MAPM camera + 4 SiPM cameras**
  - **Test array performance, conduct scientific observations**

	2013	2014				2015			
	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
SC-SST	32x MAPM modules	MAPM camera assembly		lab test	field test			Mini-array	
		32x SiPM modules	SiPM camera assembly		lab test	field test			
SC-MST		25x SiPM modules	SiPM camera assembly	lab test	field test				

Summary and Plans

- Waveform sampling capability of TARGET-5 is satisfactory
  - Trigger performance will be fixed by TARGET-7 with better dynamic range and linearity
- Characterization and improvement of SiPM ongoing

22pSD7: 日高直哉

「CTA計画 半導体光検出器MPPCを用いたチェレンコフカメラの開発」

- Plans
  - TARGET-7 will be submitted for fabrication in 2013/Sep
  - Prototype production started
    - SC-SST mini-array
    - SC-MST partial telescope