TenTen 計画 R & D（全体構想）

東大宇宙線研，山梨学大[A]，東海大理[B]，名大 STE 研[C]，
立命大理工[D]，アデレード大[E]

吉越貴紀，大石理子，遠山健，内藤統也[A]，中山幸一，
西嶋恭司[B]，松原豊[C]，森正樹[D]，Roger Clay[E]，
Bruce Dawson[E]，Gavin Rowell[E]

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TenTen Project

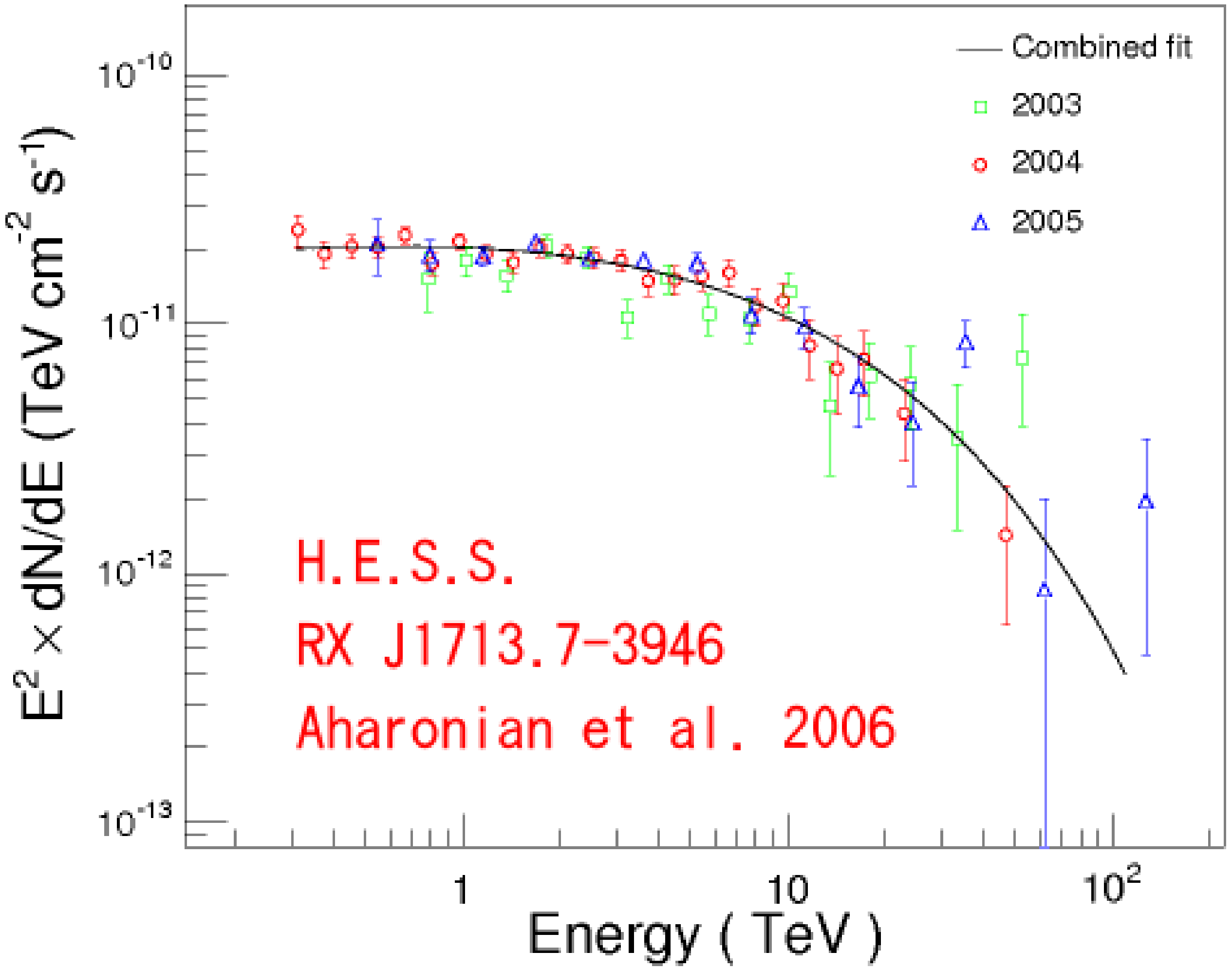
- Effective area of 10 km^2 at energies 10 TeV and above
- Stereoscopic array of 30 ～ 50 telescopes (full scale)
  - Cost-effective design:
    - Inter-telescope spacing exceeding 250 m
    - Mirror area 10 ～ 20 m^2
    - Field of view 5° ～ 10°
  - Roughly one order better sensitivity than that of H.E.S.S.
- Best site in Australia
  - Dry, flat, and low altitude field
- Start with 1 cell (～ 4 telescopes) in Australia
  - Long exposure (several 100 hr) → key science of the full scale

Scientific Motivation

- Highest energy frontier of photon astrophysics

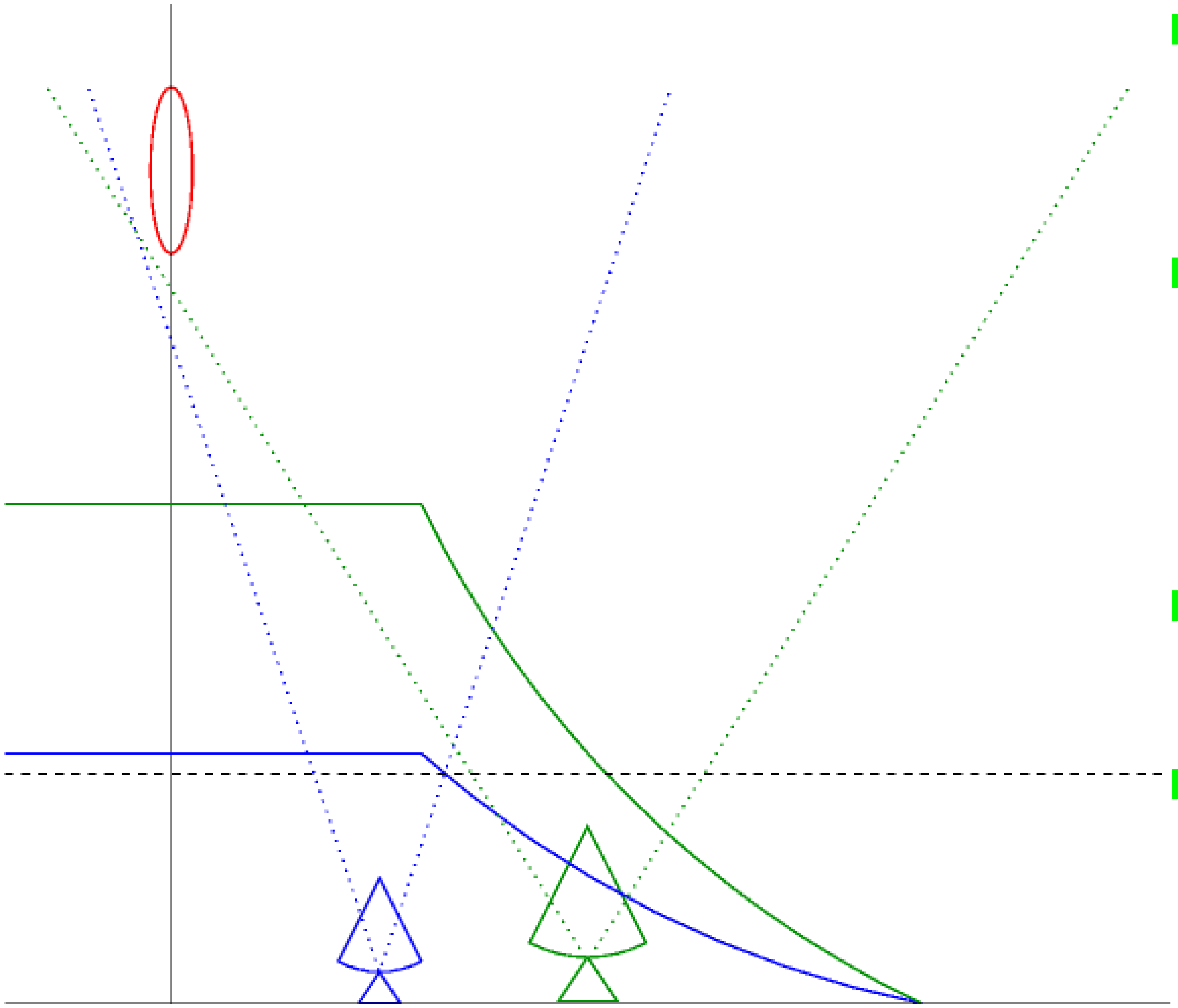
- Origin of Galactic cosmic rays
  - Shell-type SNR is the origin up to the knee?

- RX J1713.7-3946 spectrum measured by H.E.S.S.
  - Cut-off @ 18 TeV
  - Slower cut-off around 10 TeV expected
    - E.g. Kelner et al. 2006
  - No evidence up to the knee



- Deeper observations necessary
  - At higher energies

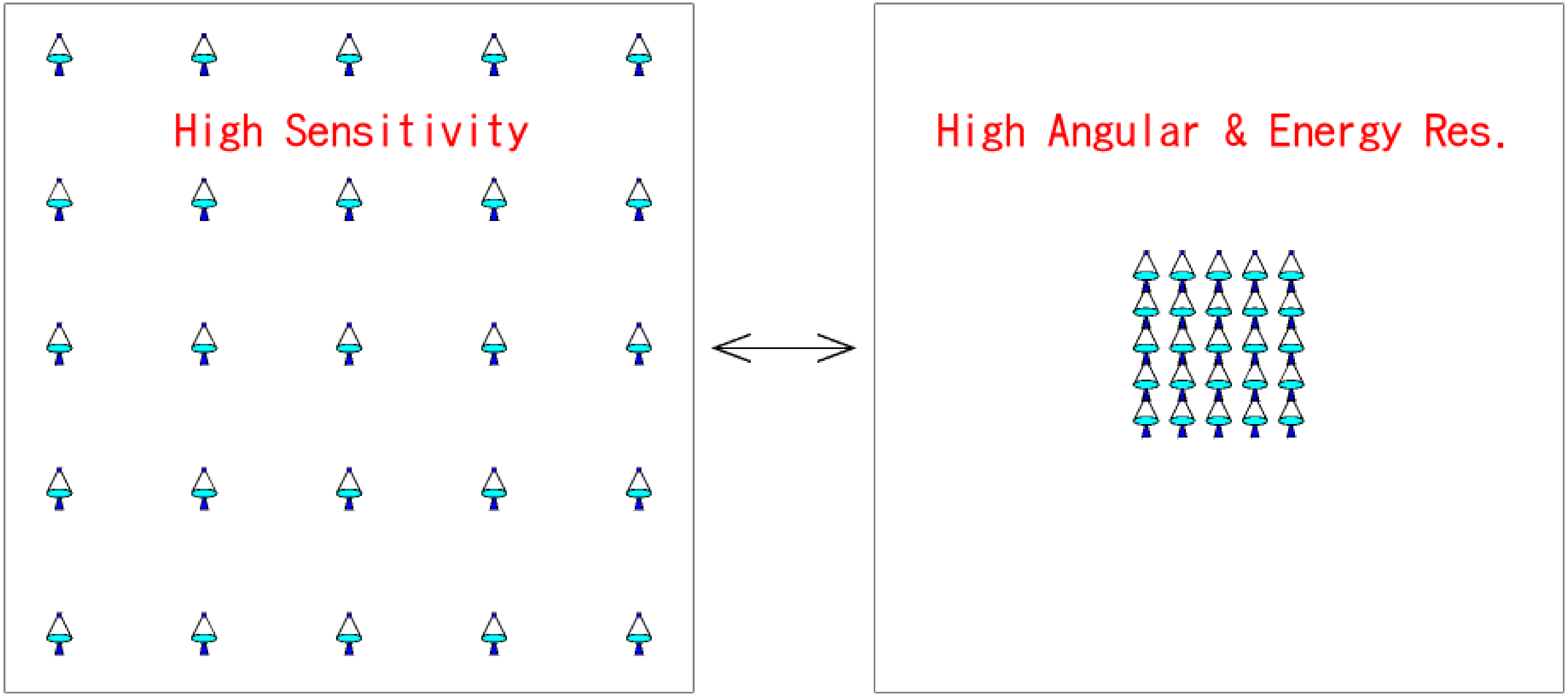
TenTen Concept (Plyasheshnikov et al. 2000)



- **Cherenkov plateau**
  - Radius ～ 150 m
- **Cherenkov tail observable with larger aperture**
  - Expand effective area
- **Wider FOV necessary**
- **Effective area is a function of:**
  - Telescope aperture
  - Telescope span
  - Field of view

An Extension Plan

- "Mobile telescope array"
  - Cream skimming of various arrays
  - Reduce the risk in array optimization

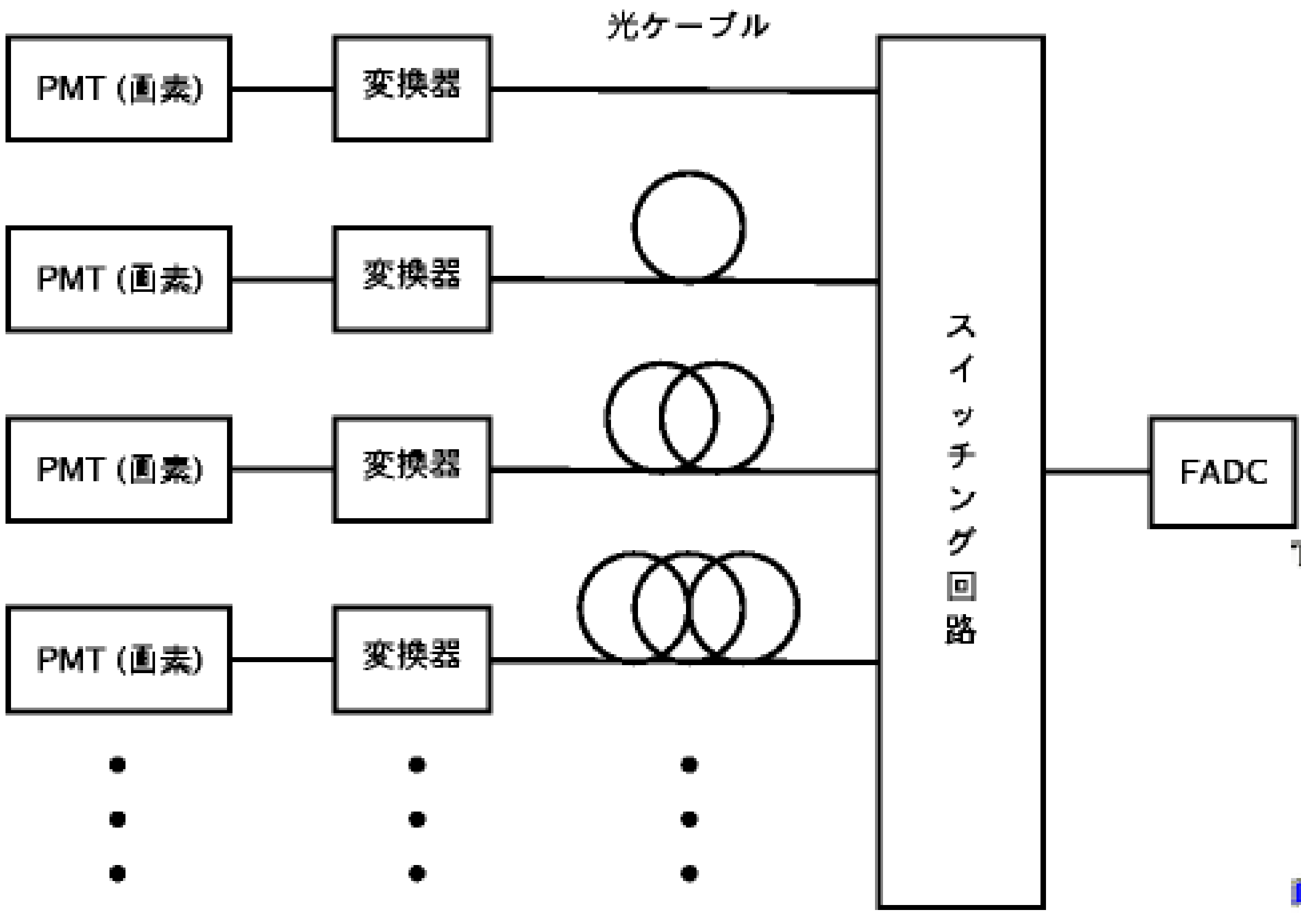


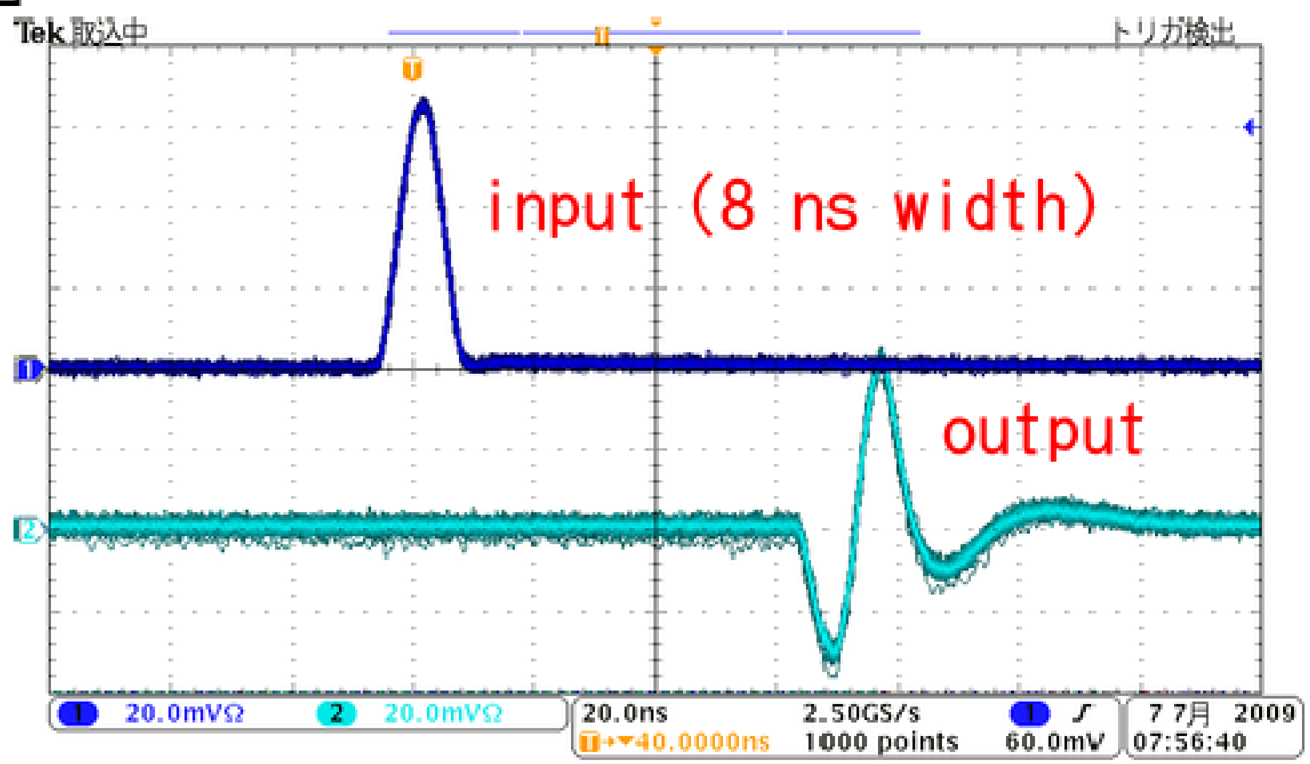
R & D Plan

- Low power consumption system & high capacity battery
  - Make the telescopes independent of the power line
- Automatic calibration of the telescope attitude
  - Many telescopes → reduce the burden of manual measurements
  - More measurements in the mobile telescope array
- Mobile telescope design
  - Carrying vehicle?
- Solar panel

Low Power Consumption System (1)

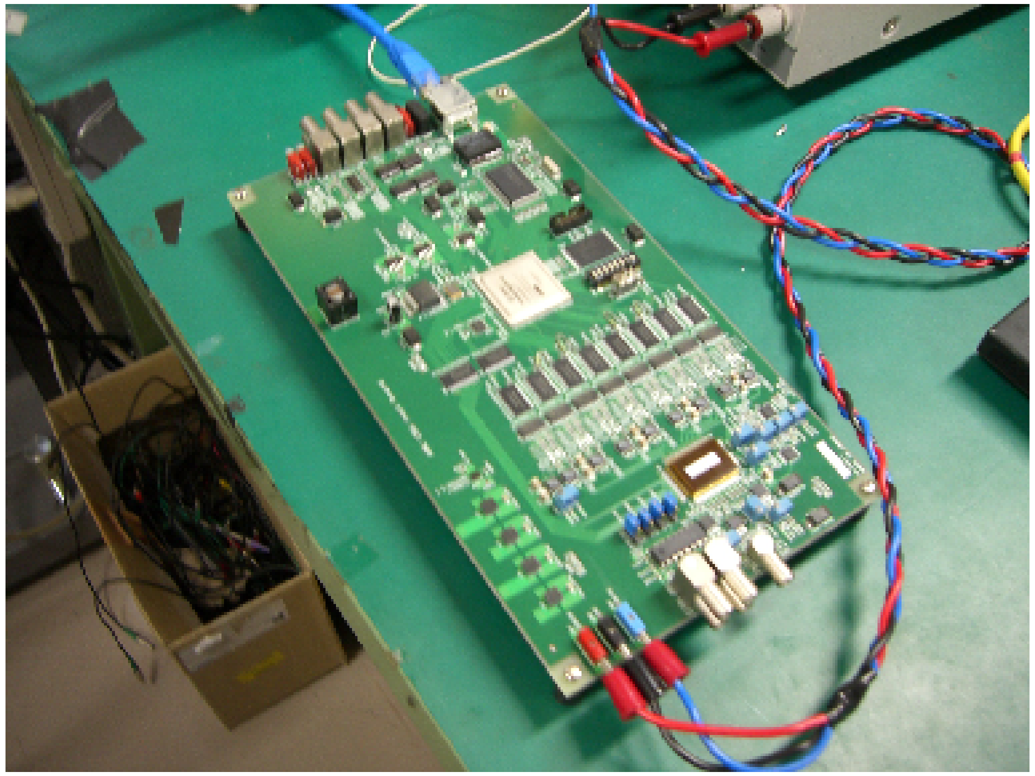
- **Reuse of a flash ADC sampling range with multiple channels**
  - Relative timing offsets with optical delays





Low Power Consumption System (2)

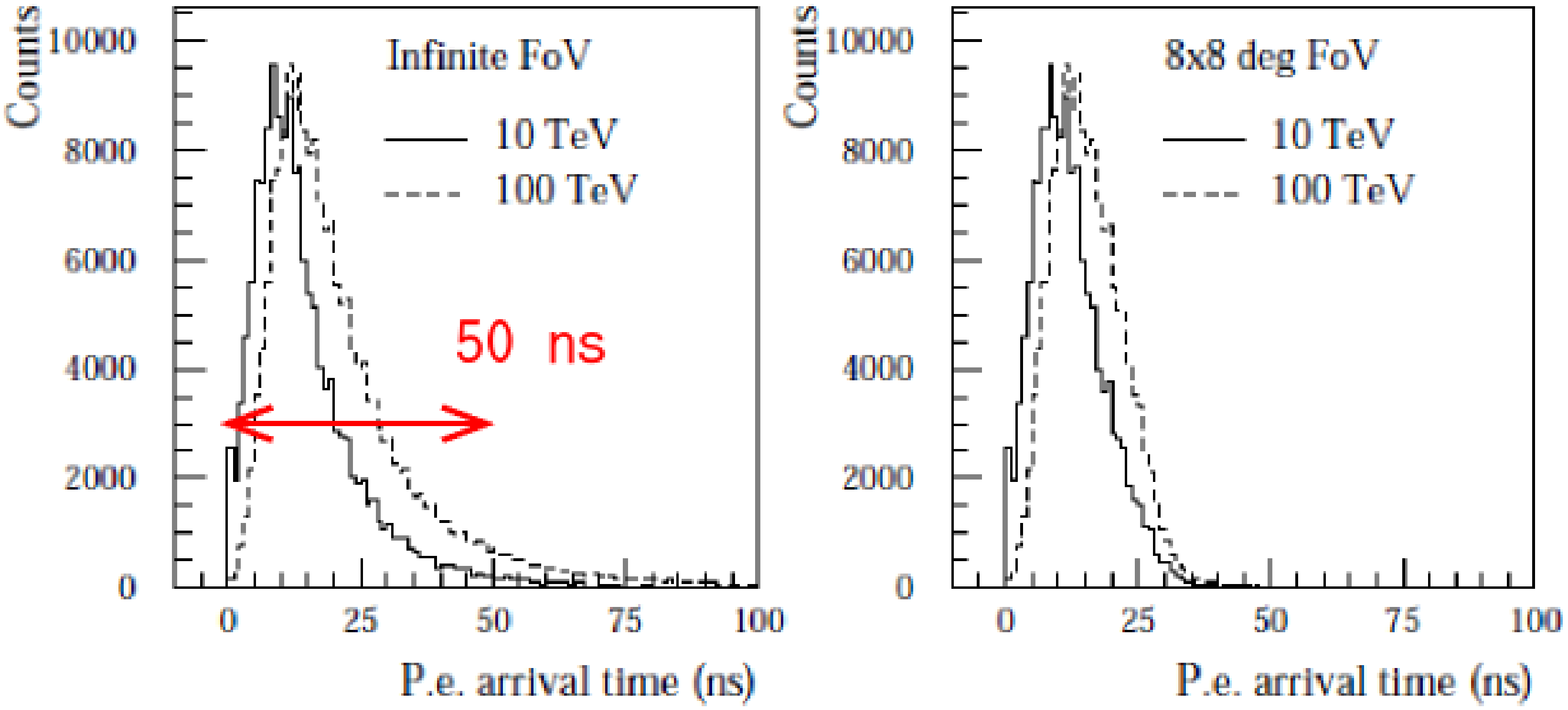
- **Capacitor array**
  - Analog Memory Cell (AMC)
    - KEK, U Tokyo, Kyoto U
  - Power consumption < 10% of FADC



- **Sampling range ～ 50 ns**
  - Longer telescope span
  → wider Cherenkov pulse

- **Prototype in this fiscal year**

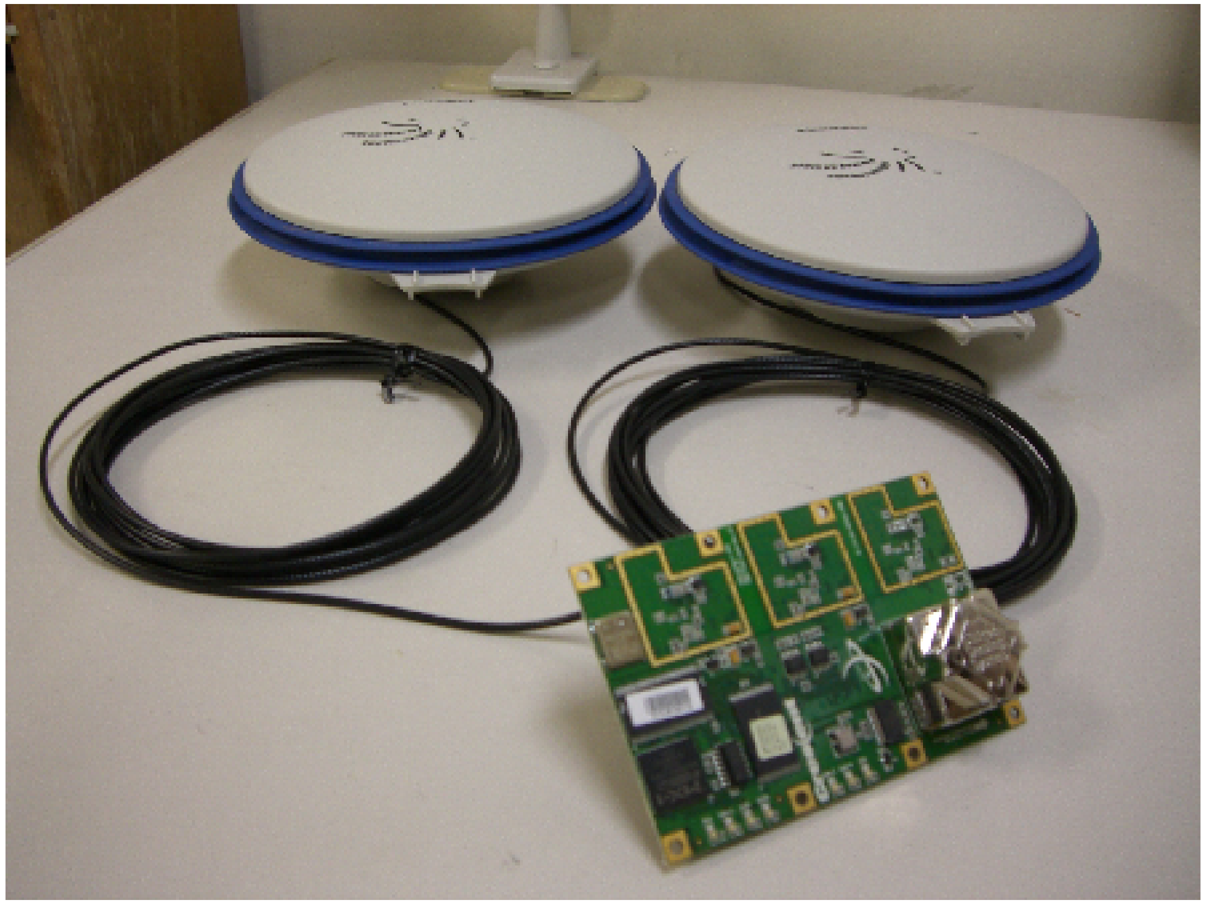
400 m from the core (Stamatescu et al. 2007)

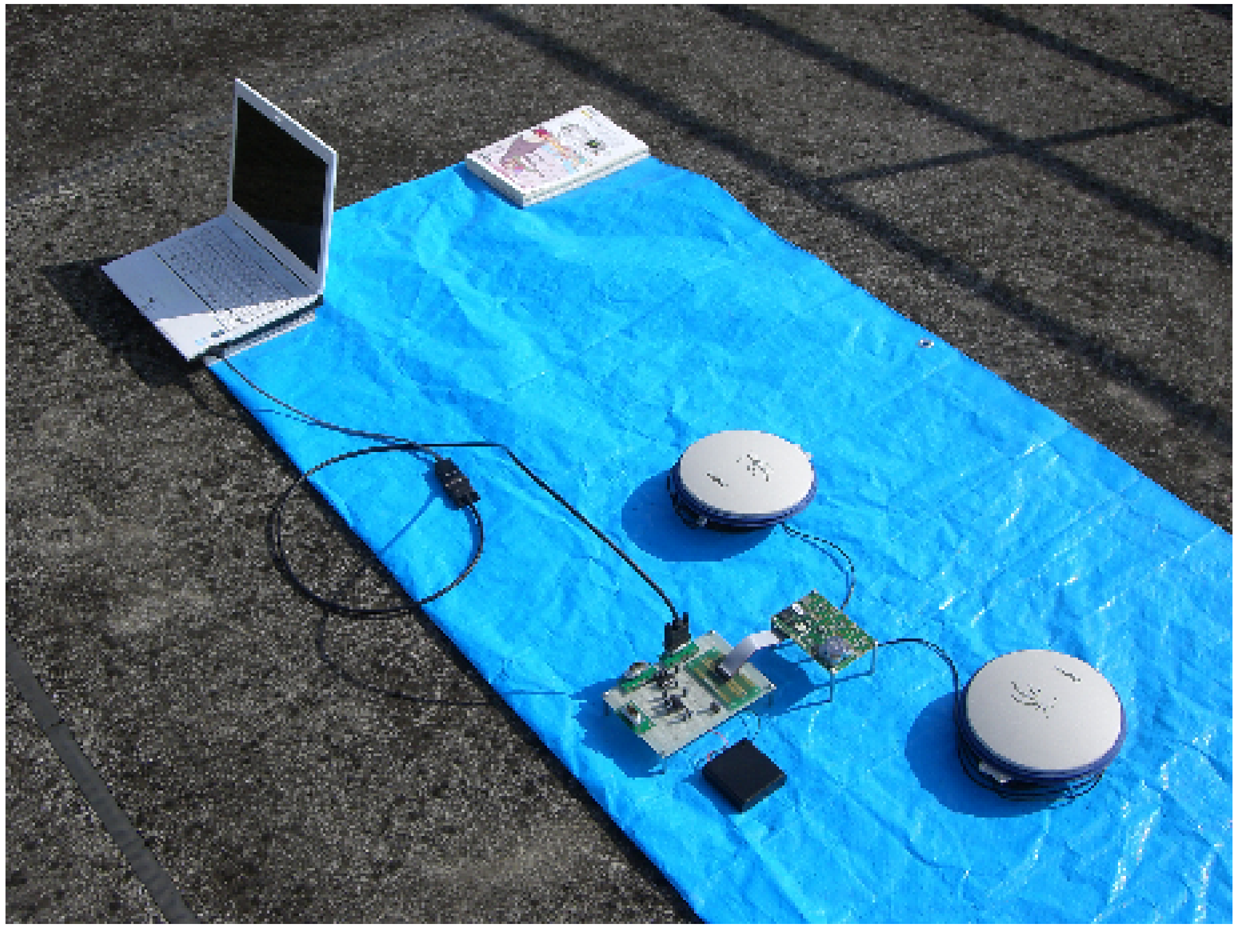


Automatic Calibration of the Telescope Attitude

Absolute calibration with a GPS compass

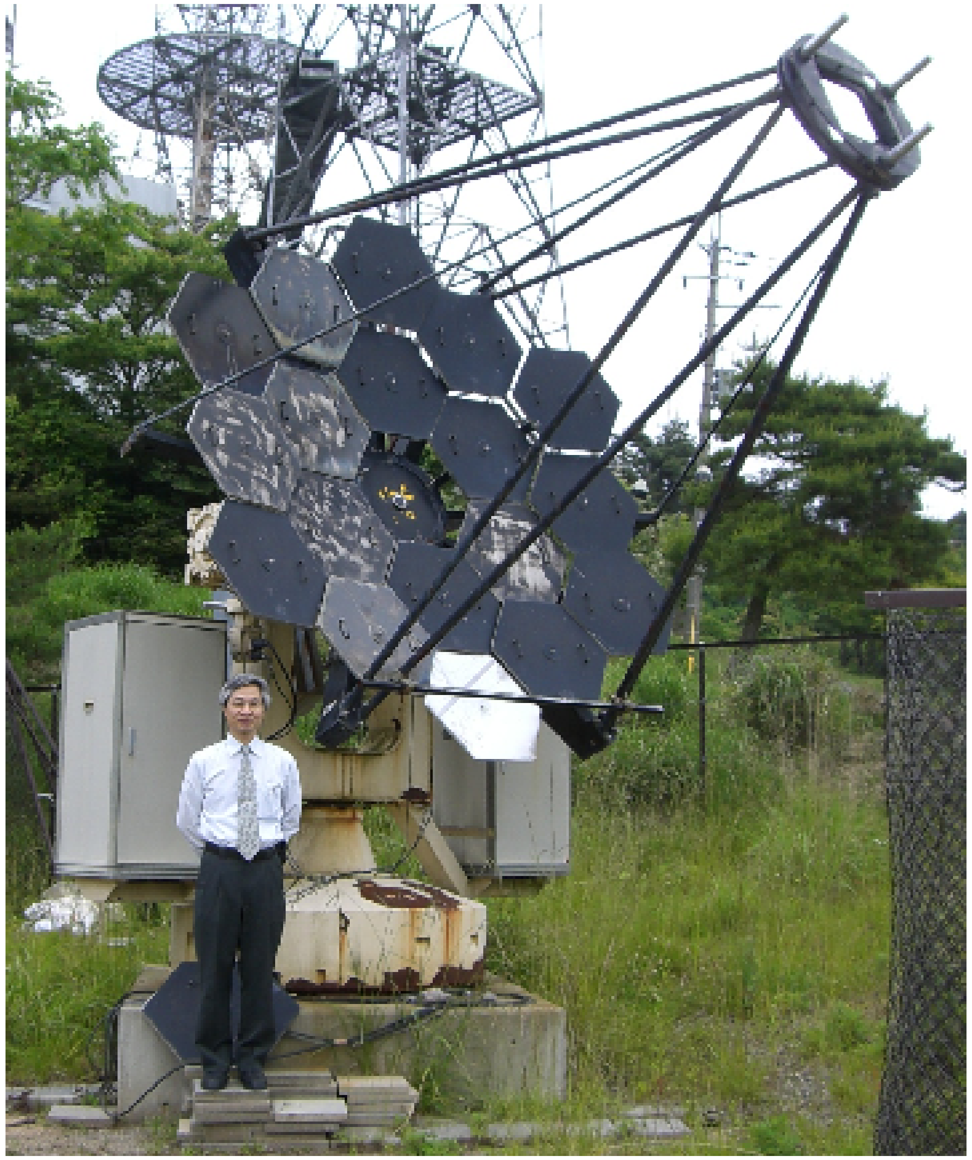
- Real Time Kinematic (RTK)
  - Carrier phase measurements
  - Absolute accuracy < 0.1°
- Next talk by Nakayama (ICRR)





R & D Schedule

- Konan telescope at Mt. Oya → Akeno
  - Repair work necessary
- Developed system will be installed
  - 32 channel camera
- Test observations
  - Shower images
  - Gamma rays from the Crab?



Summary

TenTen project

- Effective area of 10 km^2 at energies 10 TeV and above
- Best site in Australia
- Long exposure with 1 cell → key science

R & D ongoing

- Low power consumption system
  - Reuse of an ADC sampling range with multiple channels
  - AMC circuit for DAQ
- Automatic calibration of the telescope Attitude with GPS
- Test observations scheduled at Akeno

Backup

TenTen Sensitivity

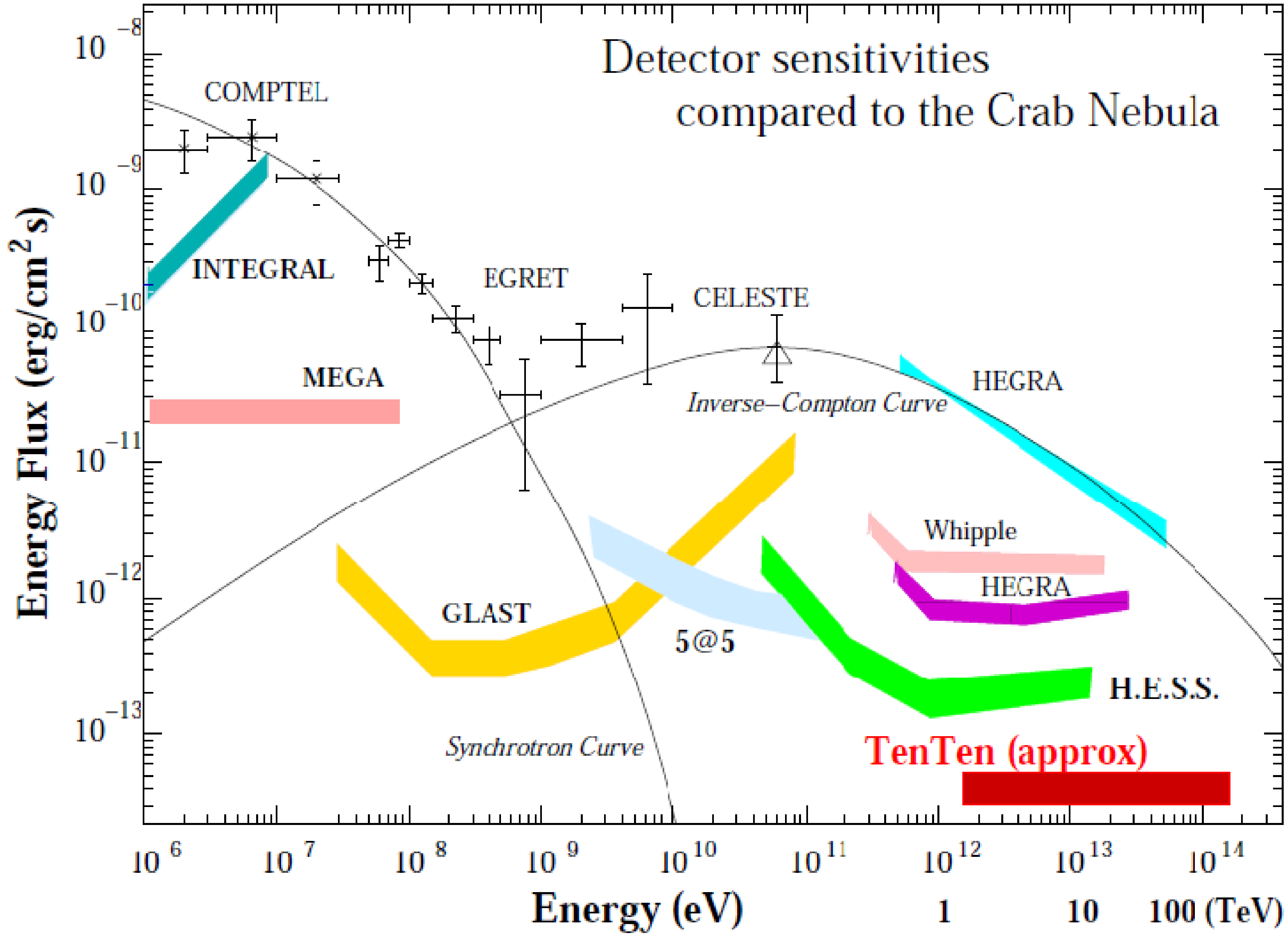
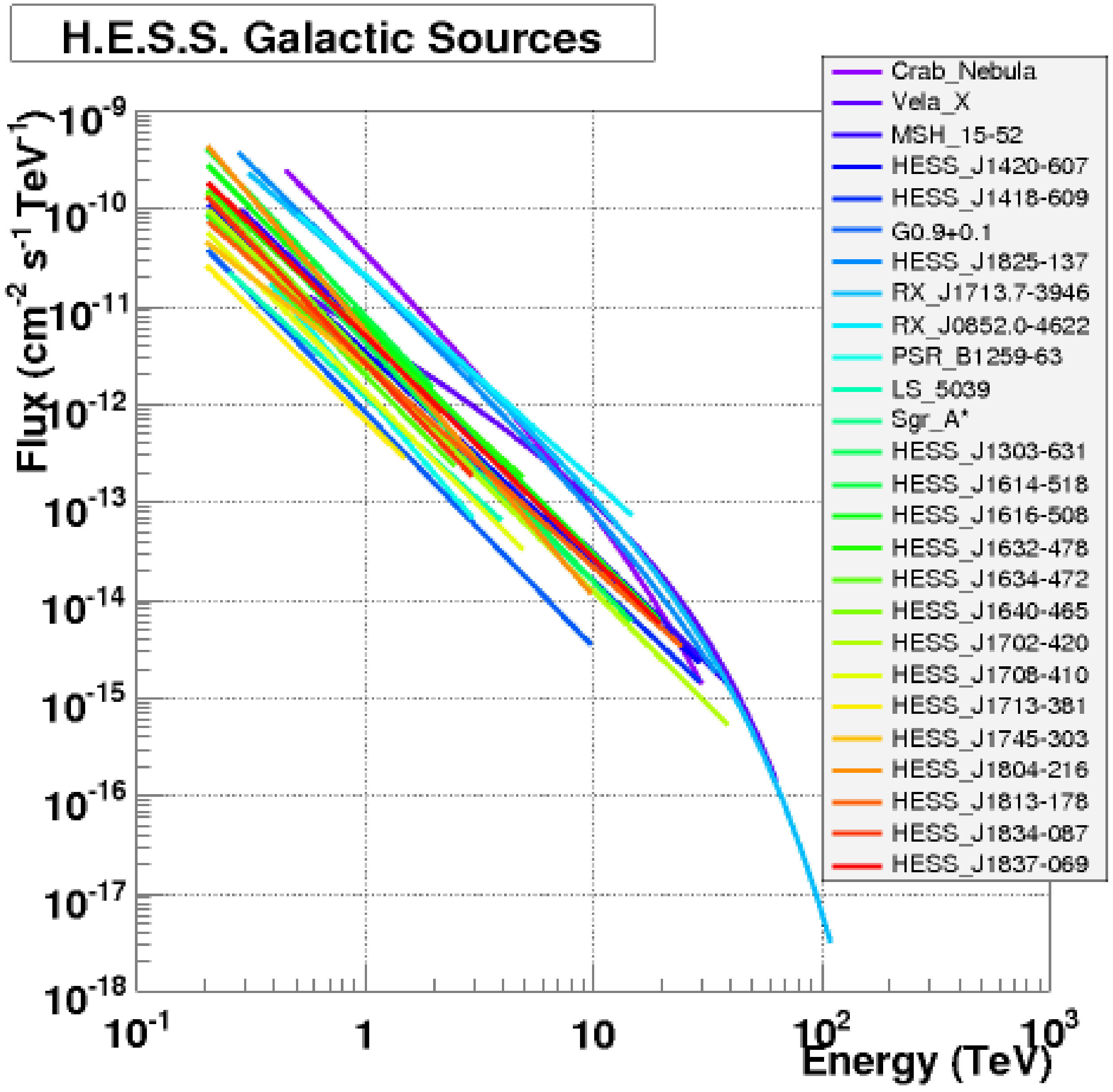
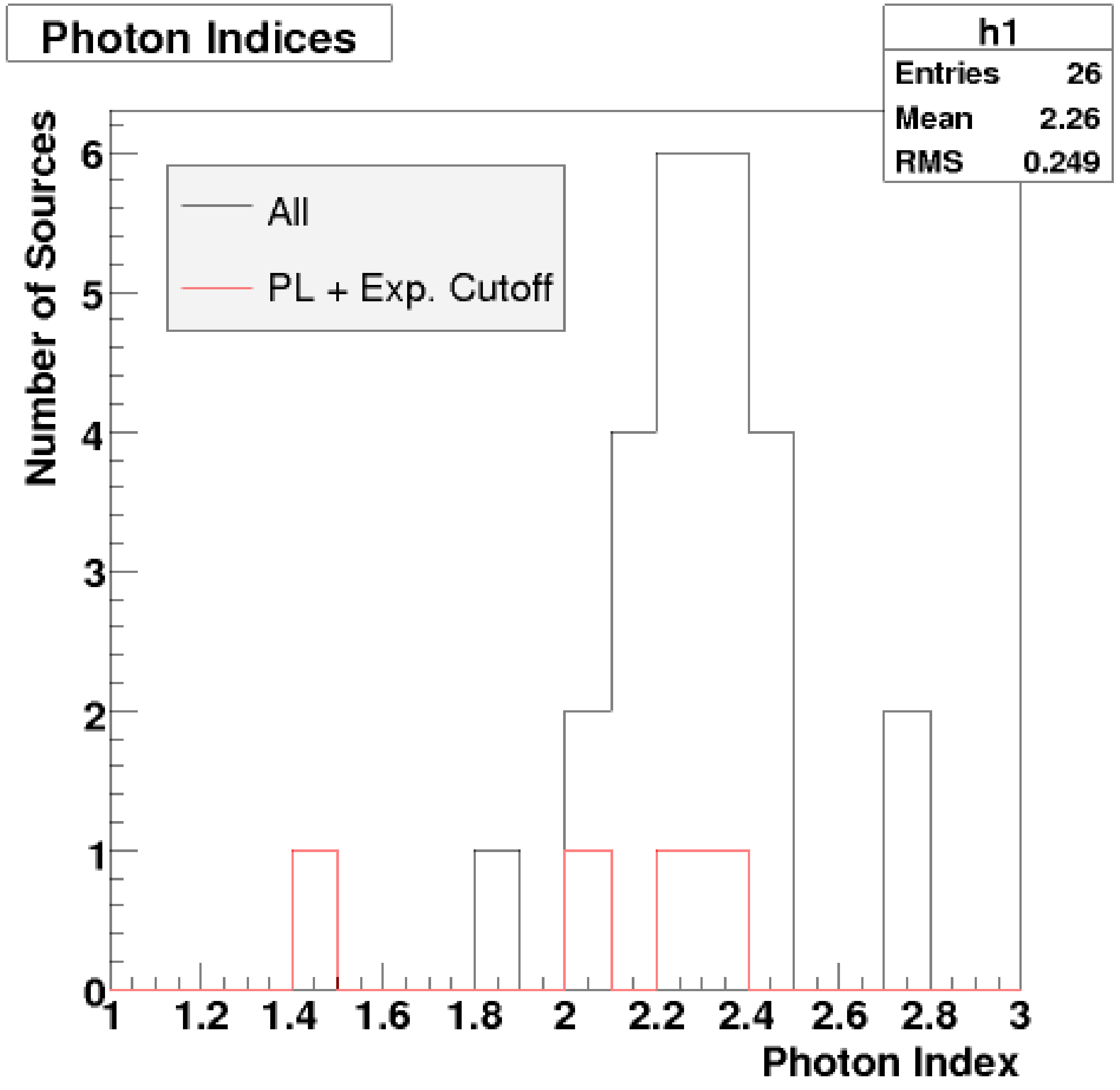


Figure 1: Minimum detectable point source energy flux vs. energy for various space and ground-based γ-ray instruments. The approximate *TenTen* sensitivity is indicated bottom right (A 5σ significance detection above background in 50 hours observation time is demanded). *TenTen* will considerably improve on H.E.S.S. and extend the upper energy coverage to ~100 TeV.

Scientific Motivation (2)

- Hard spectra of Galactic H.E.S.S. Sources
  - Better S/N at high energies





Large Effective Area Is Necessary

- **Sensitivity:**

$$N_\sigma = \frac{N_\gamma}{\sqrt{N_B}} = \frac{F_\gamma A_{\mathrm{eff},\gamma} t \epsilon_\gamma}{\sqrt{F_B \Omega A_{\mathrm{eff},B} t \epsilon_B}} \propto \frac{F_\gamma}{F_B^{1/2} \Omega^{1/2}} A_{\mathrm{eff}}^{1/2} t^{1/2} Q$$

F: flux
Ω: field of view in solid angle
t: observation time
ϵ: efficiency of γ-ray image selections
$A_{\mathrm{eff}} = A_{\mathrm{eff},\gamma} \propto A_{\mathrm{eff},B}$ (assumption)
$Q = \epsilon_\gamma / \epsilon_B^{1/2}$

- Factor $A_{\mathrm{eff}}^{1/2} Q$ controlled relatively easily
- Large effective area is necessary
- Keep high Q → stereoscopic IACT system

→ IACT array

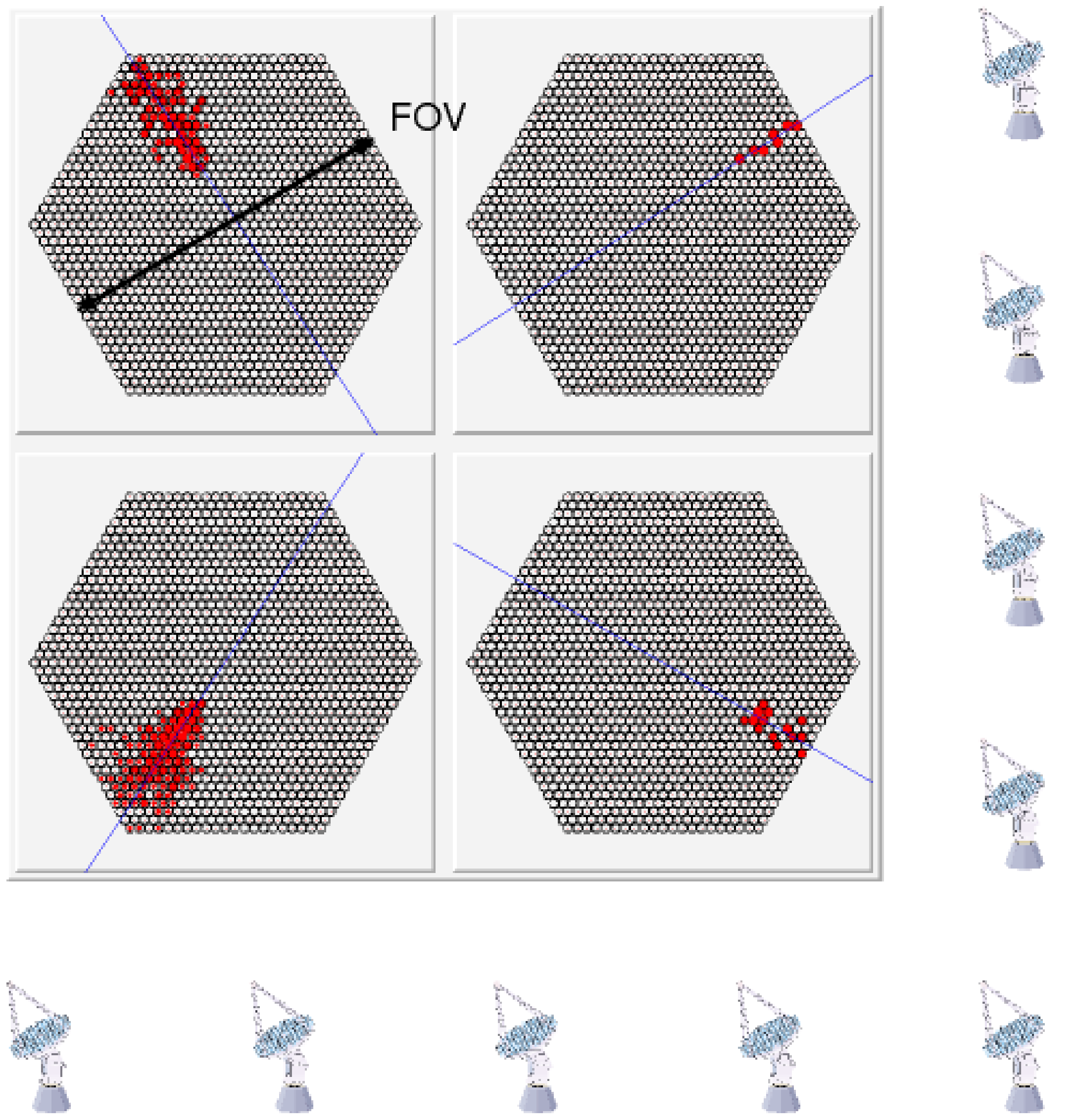
Simulations

Effective area of a cell

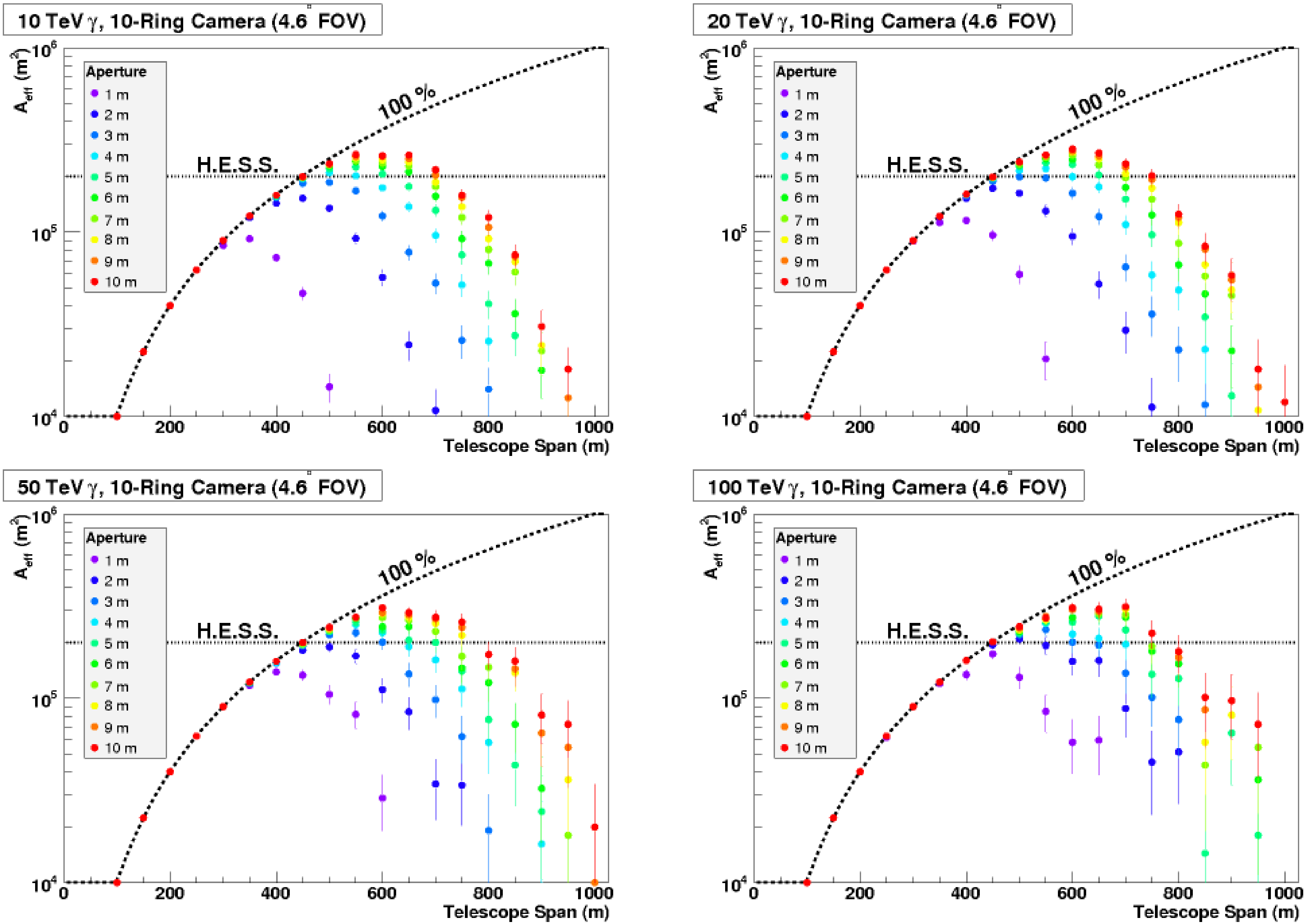
- Net response of one telescope
- $A_{eff}(total) = A_{eff}(cell) \times N$

Conditions:

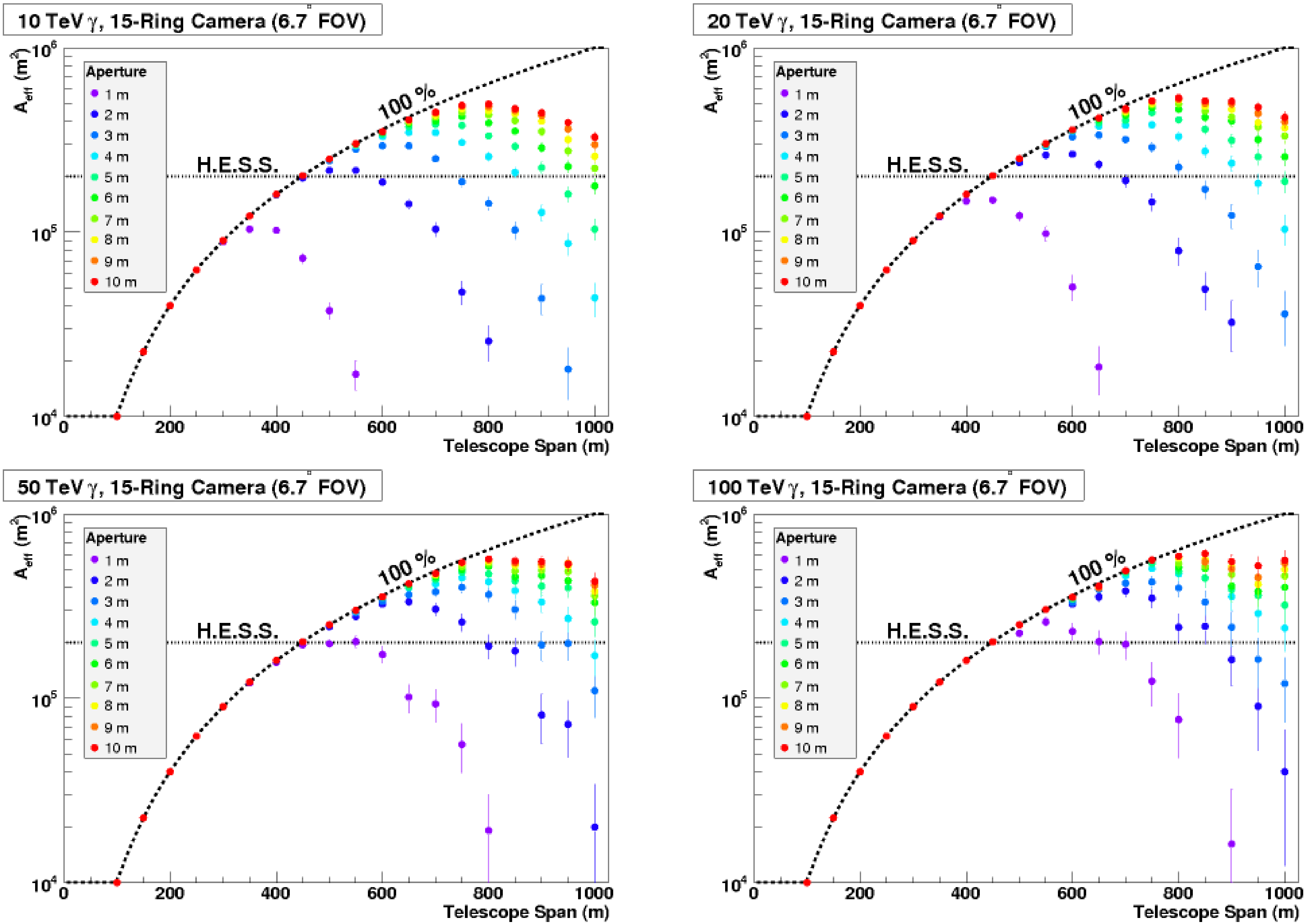
- CORSIKA 6.20
- Gamma rays from a vertical point source
- Geomagnetic field in Woomera
- Altitude: 160 m (Woomera)
- Parabolic reflector (f = 1)
- No blurring
- No NSB
- Hexagonal camera (0.25° pixel)
- Trigger: 5 p.e. × 3 adjacent pixels × any 2 telescopes
- Trigger efficiency only



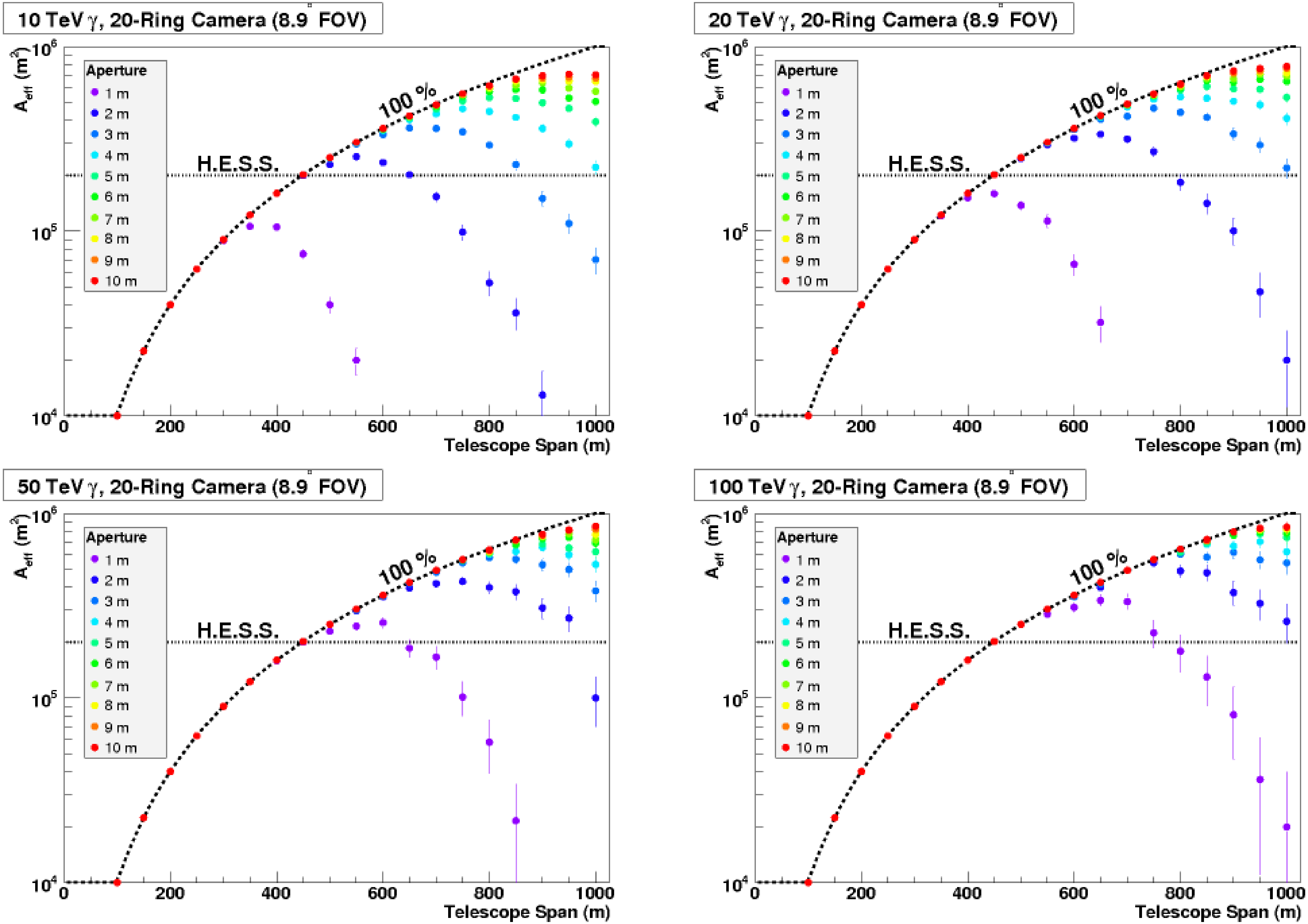
Effective Area of a Cell (4.6° FOV)



Effective Area of a Cell (6.7° FOV)



Effective Area of a Cell (8.9° FOV)



Optimization of the Array Design

Cost curve for one telescope:

- Mount and mirrors: Cost $\propto D^{2.7}$ (D: aperture)
- Camera and electronics: Cost $\propto N_p$ (N_p: number of pixels)
- Total: Cost $\propto D^{2.7} + \alpha N_p$
- Normalization α assumed as:
  - $(5\ \mathrm{m})^{2.7} = \alpha \times 500$ pixels

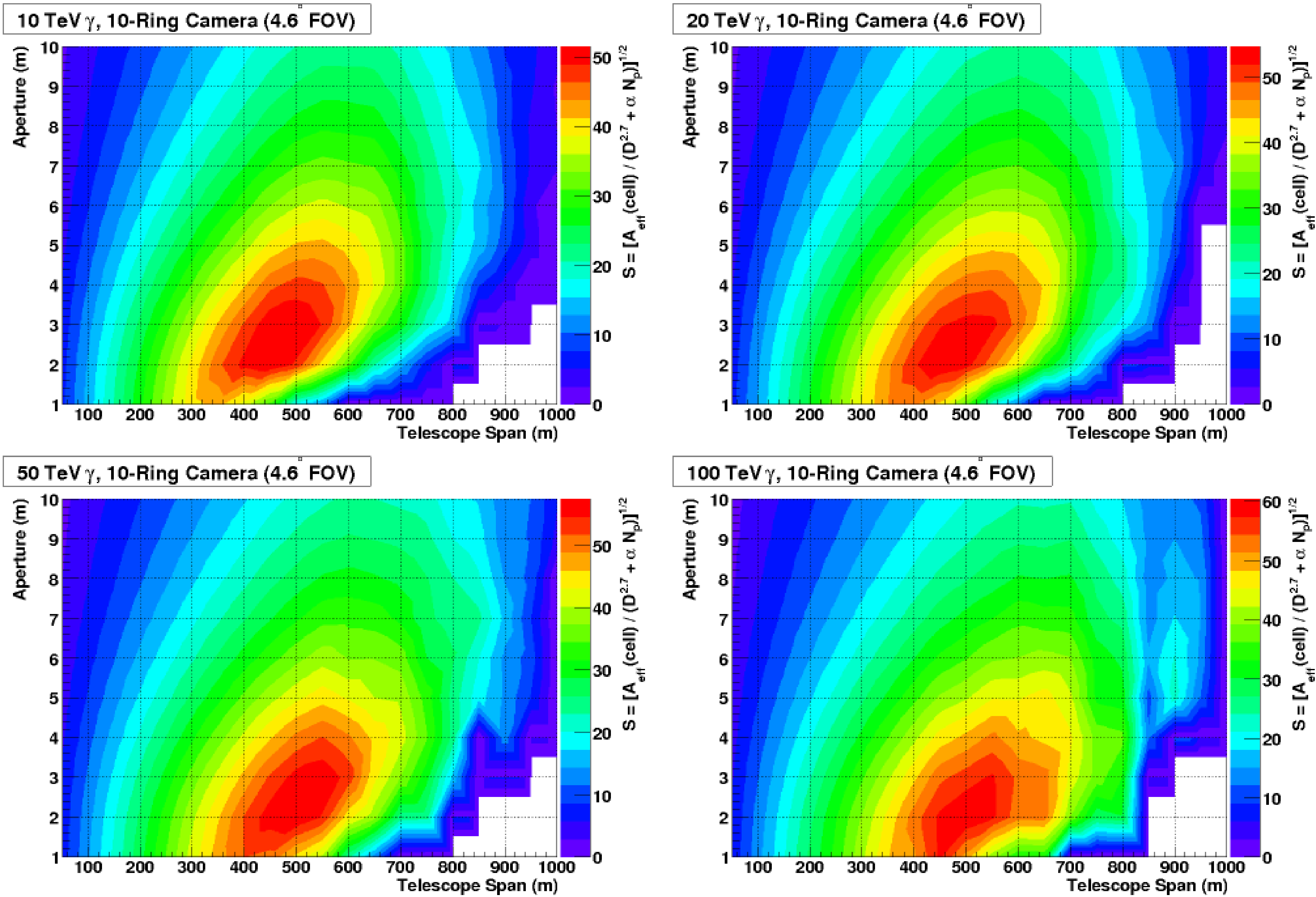
Maximize the effective area with a fixed cost:

- $A_{eff}(\mathrm{total}) = A_{eff}(\mathrm{cell}) \times N$ (N: number of telescopes)
- Cost $\propto (D^{2.7} + \alpha N_p) \times N$
- $A_{eff}(\mathrm{total}) \propto A_{eff}(\mathrm{cell}) \times \mathrm{Cost} / (D^{2.7} + \alpha N_p)$

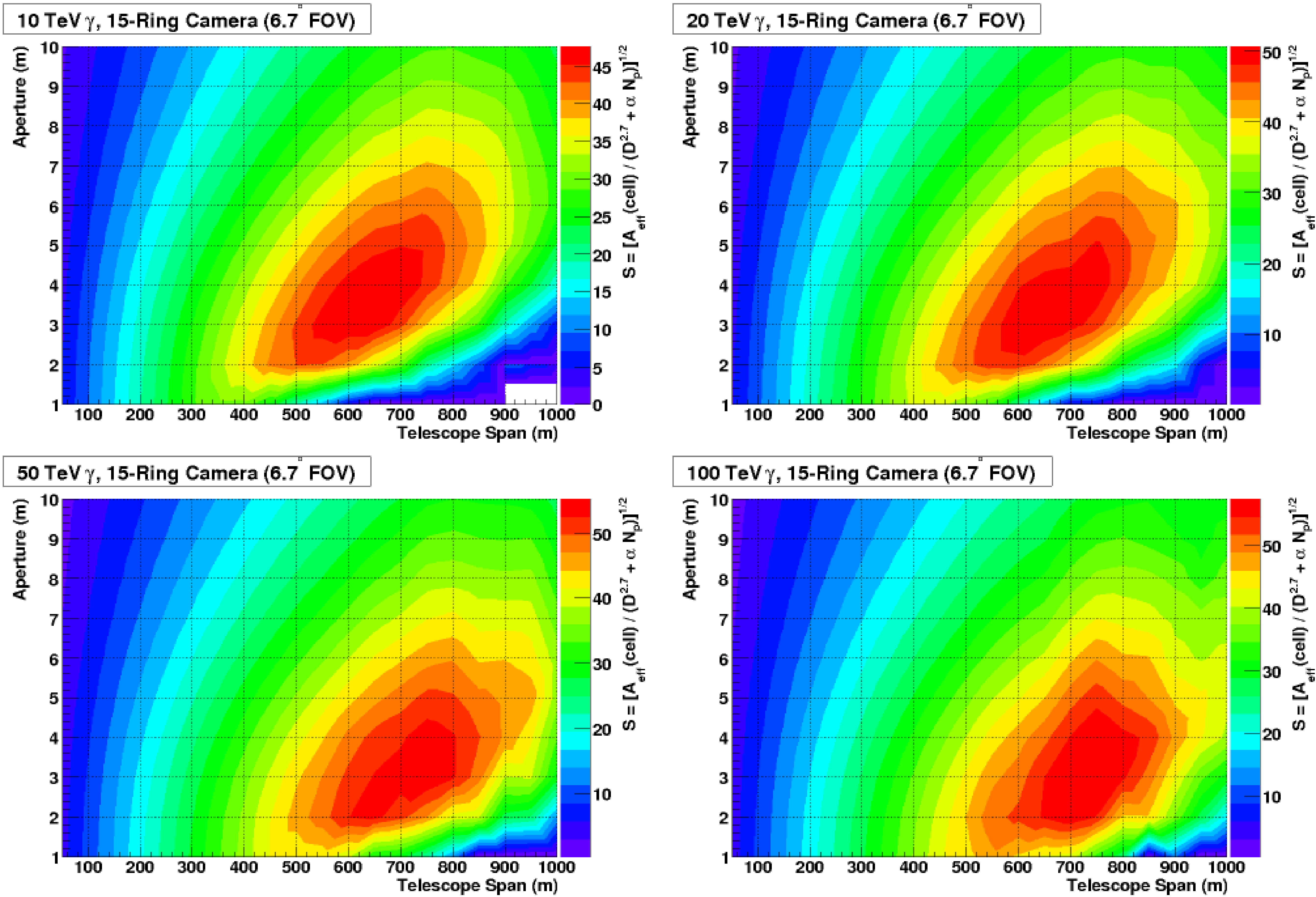
Sensitivity proportional to:

- $S \equiv [A_{eff}(\mathrm{cell}) / (D^{2.7} + \alpha N_p)]^{1/2}$

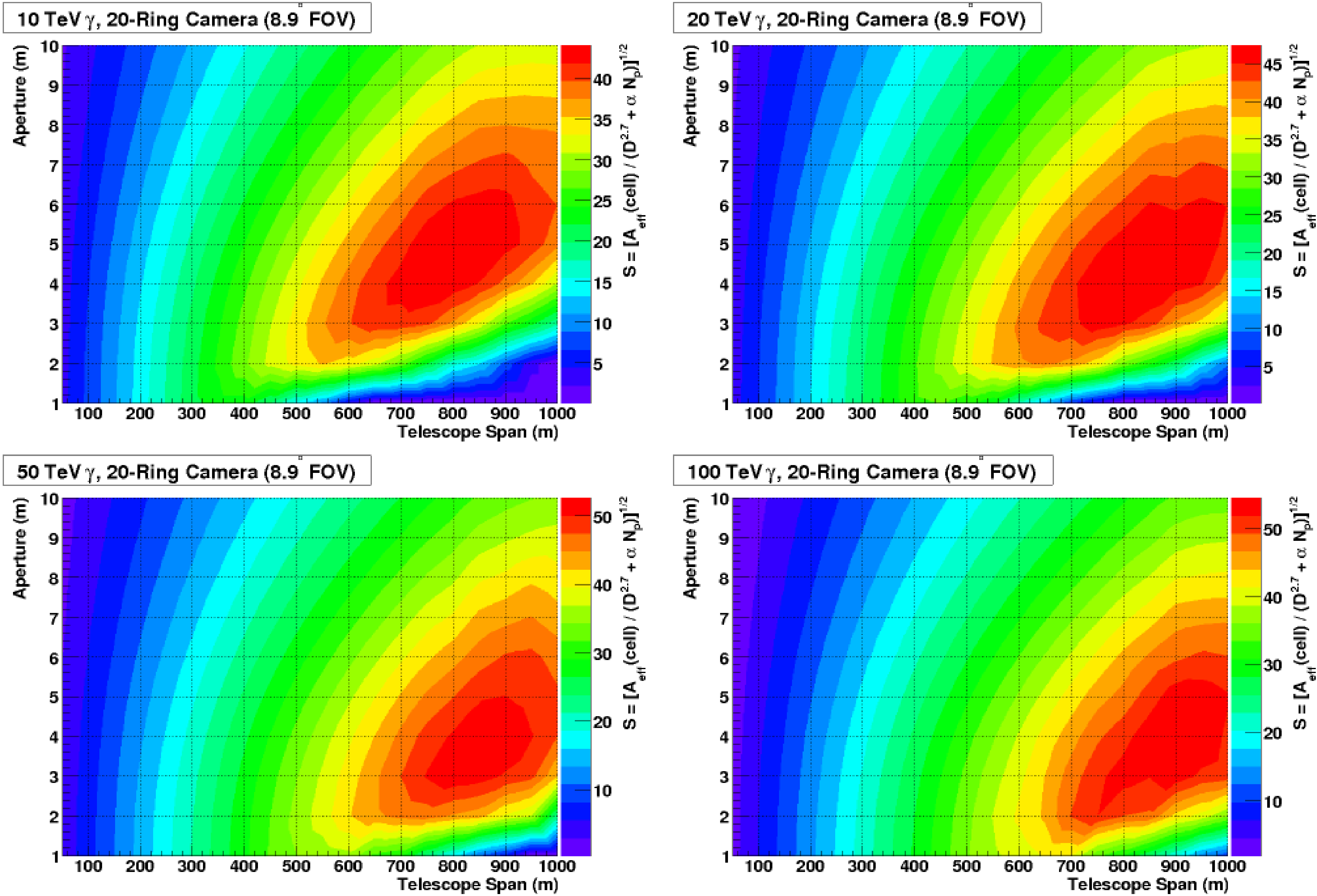
Relative Sensitivity (4.6° FOV)



Relative Sensitivity (6.7° FOV)



Relative Sensitivity (8.9° FOV)



Relative Sensitivity (Combined)