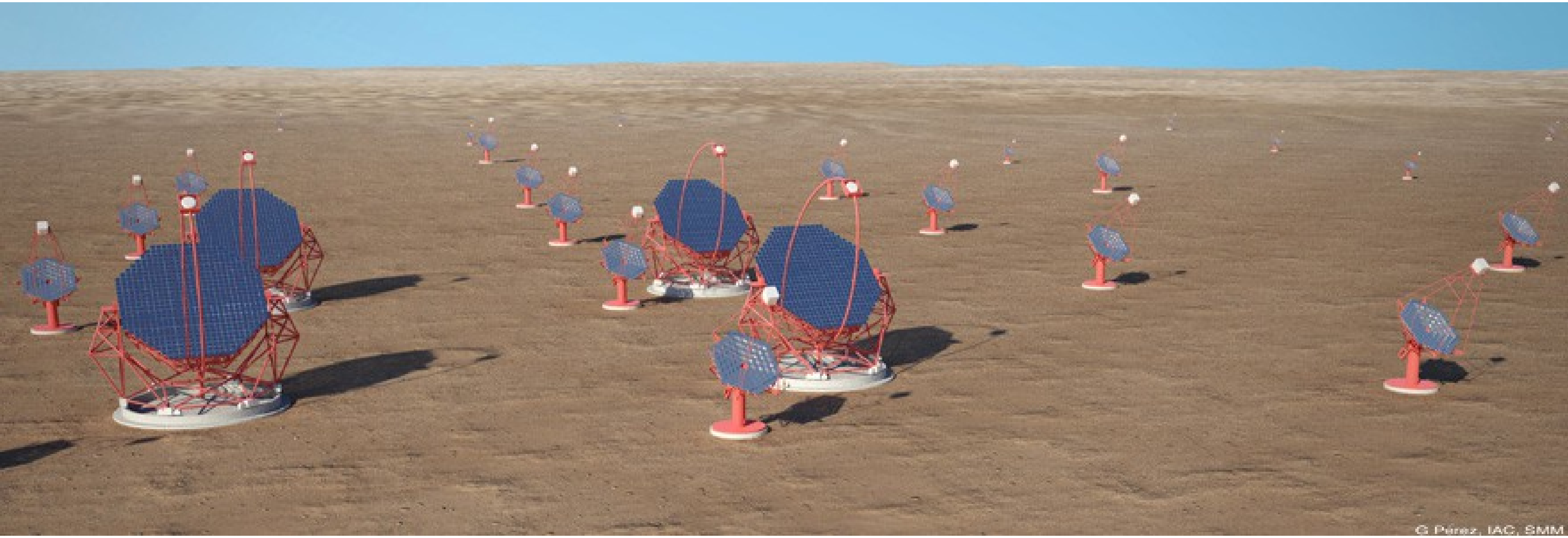
Monte Carlo studies of CTA: an overview

Victor Stamatescu (University of Adelaide)



cherenkov telescope array

CTA Australia Consortium Workshop
Adelaide, 30 September 2013

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Outline

1) The Cherenkov Telescope Array concept

2) Imaging Air Cherenkov Technique & simulation

3) Previous and current large-scale simulation studies

4) On-going dedicated simulation studies

5) Future contributions from the Adelaide group

Please note:
This talk in not given on behalf of the MC working group and only public results have been used

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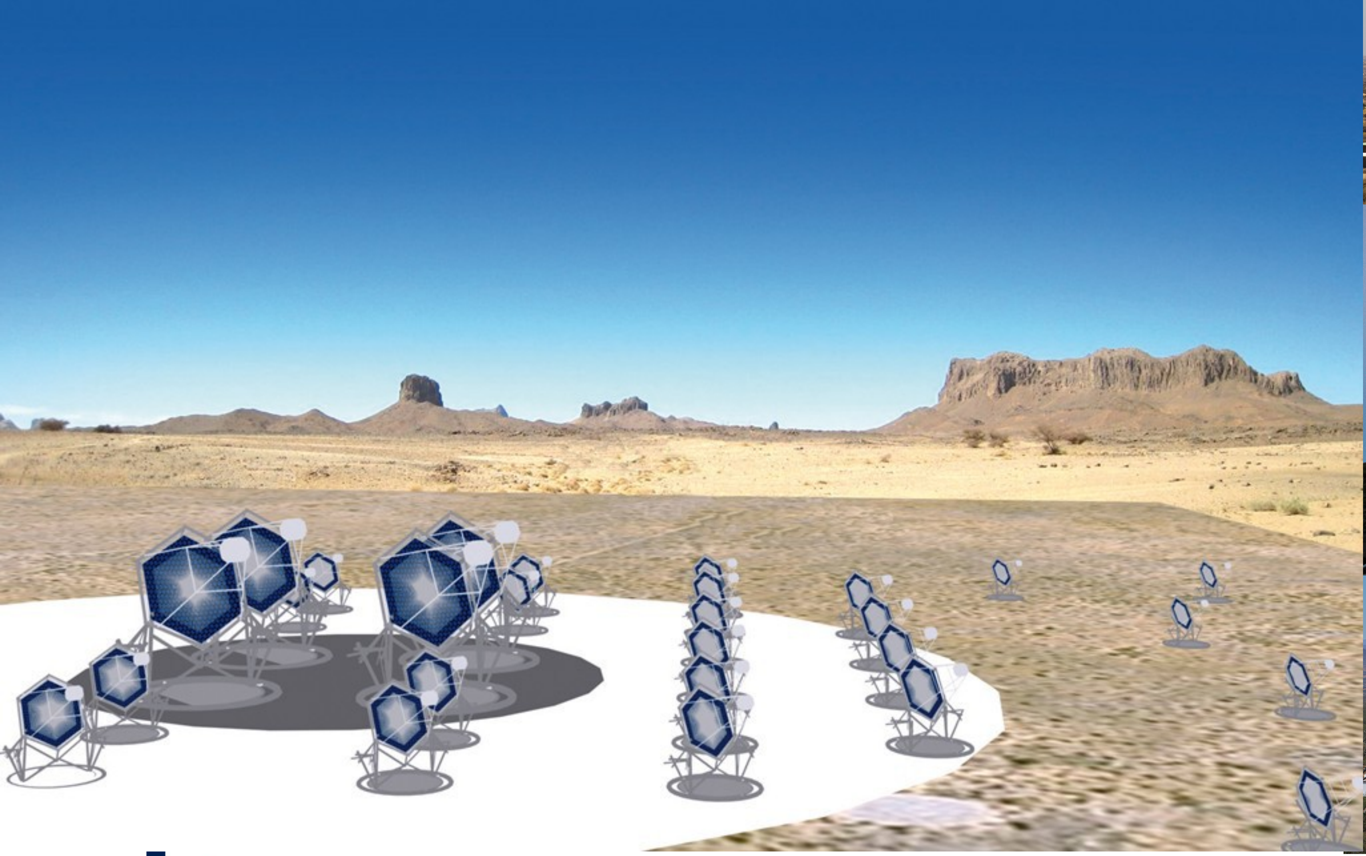
The Cherenkov Telescope Array

CTA aims for
- 10 x better sensitivity than the current-generation instruments
- extended energy coverage above and below to ~4 orders in magnitude



cta
cherenkov telescope array

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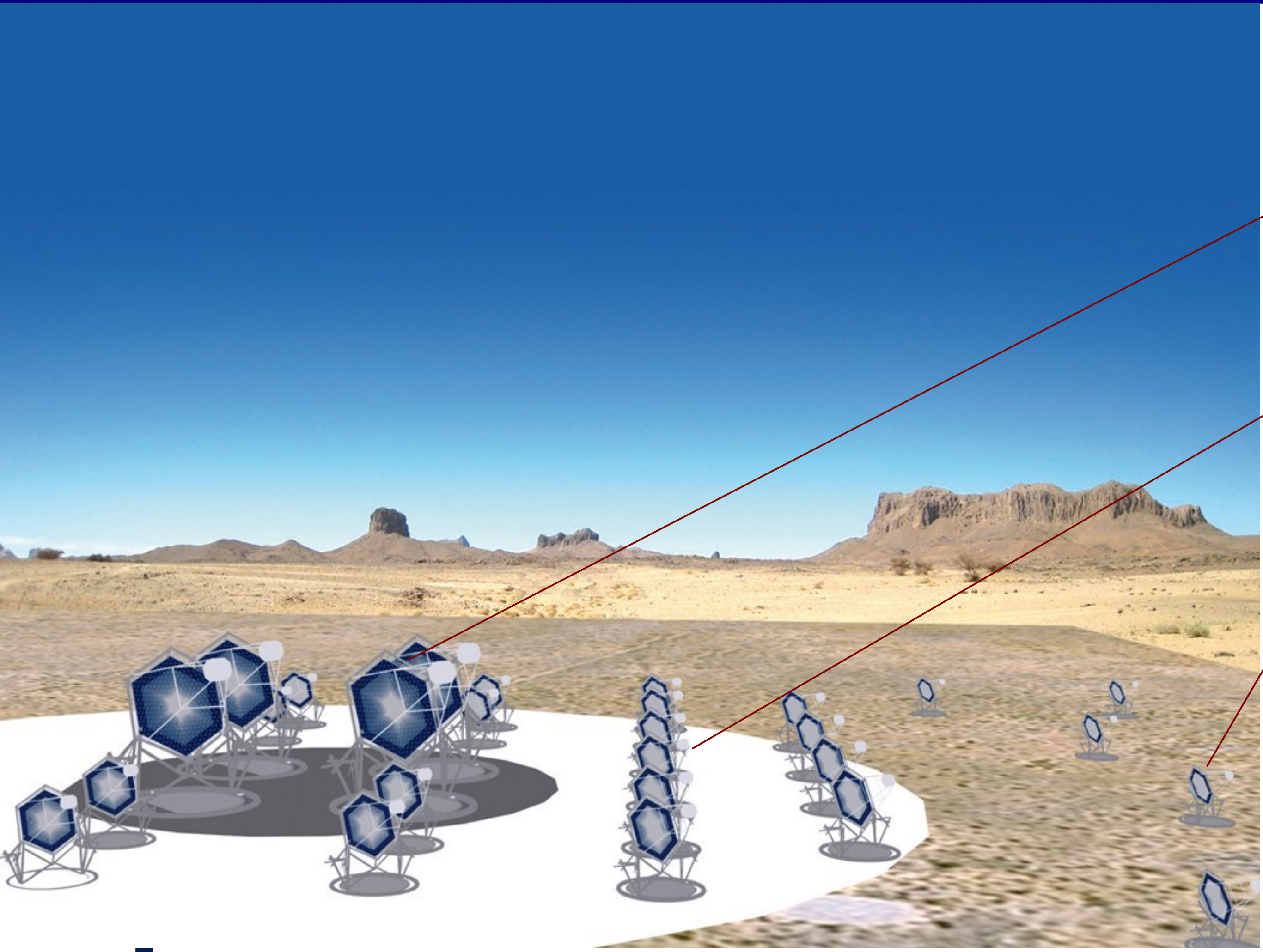
The Cherenkov Telescope Array



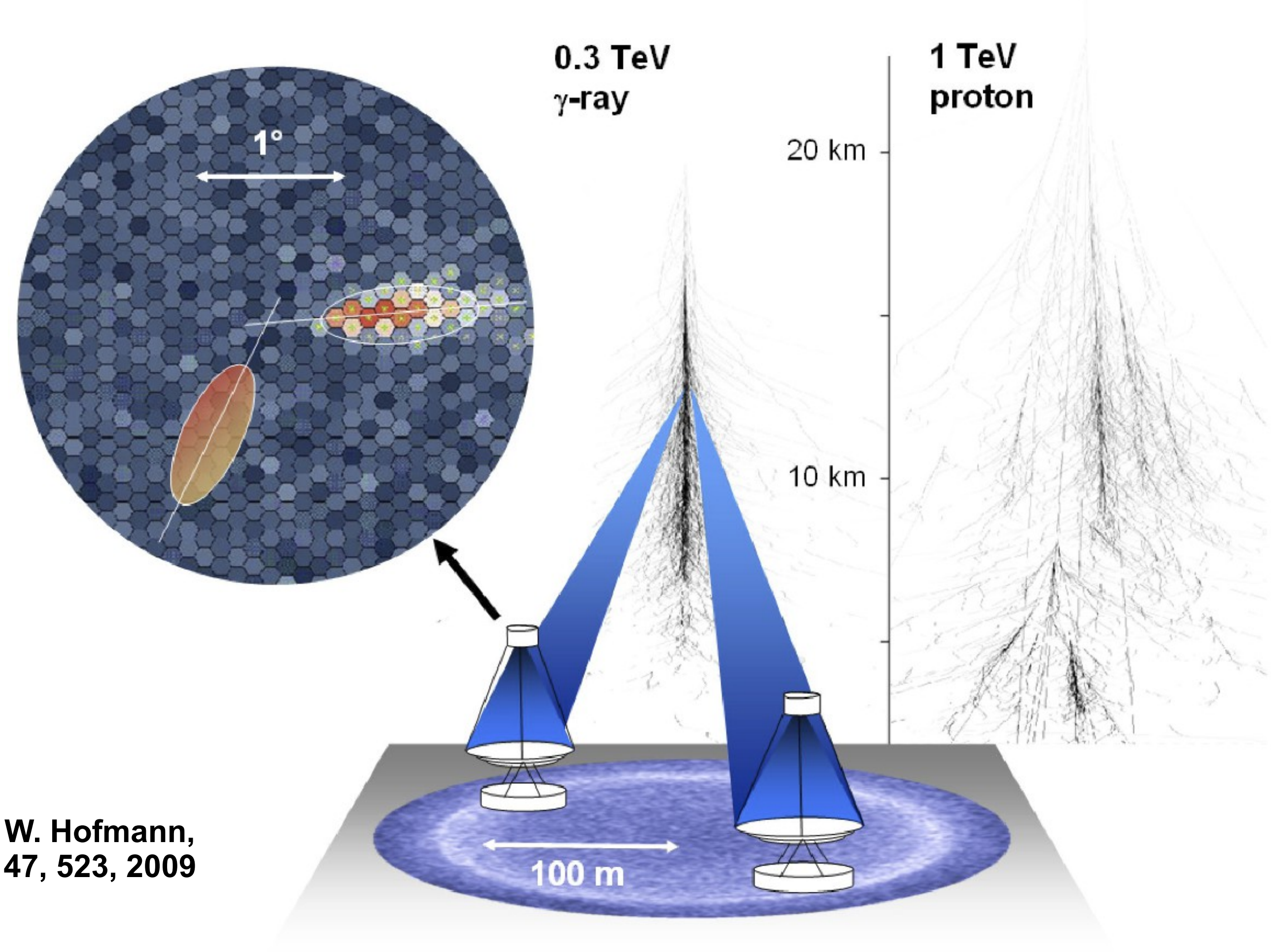
LSTs (~24 m aperture)
operate down to ~20 GeV

MSTs (~12 m aperture)
operate in ~1 TeV range

SSTs (~4-7 m aperture)
operate up > 100 TeV

+ later supplement of
Schwarzschild-Couder (SC) MSTs

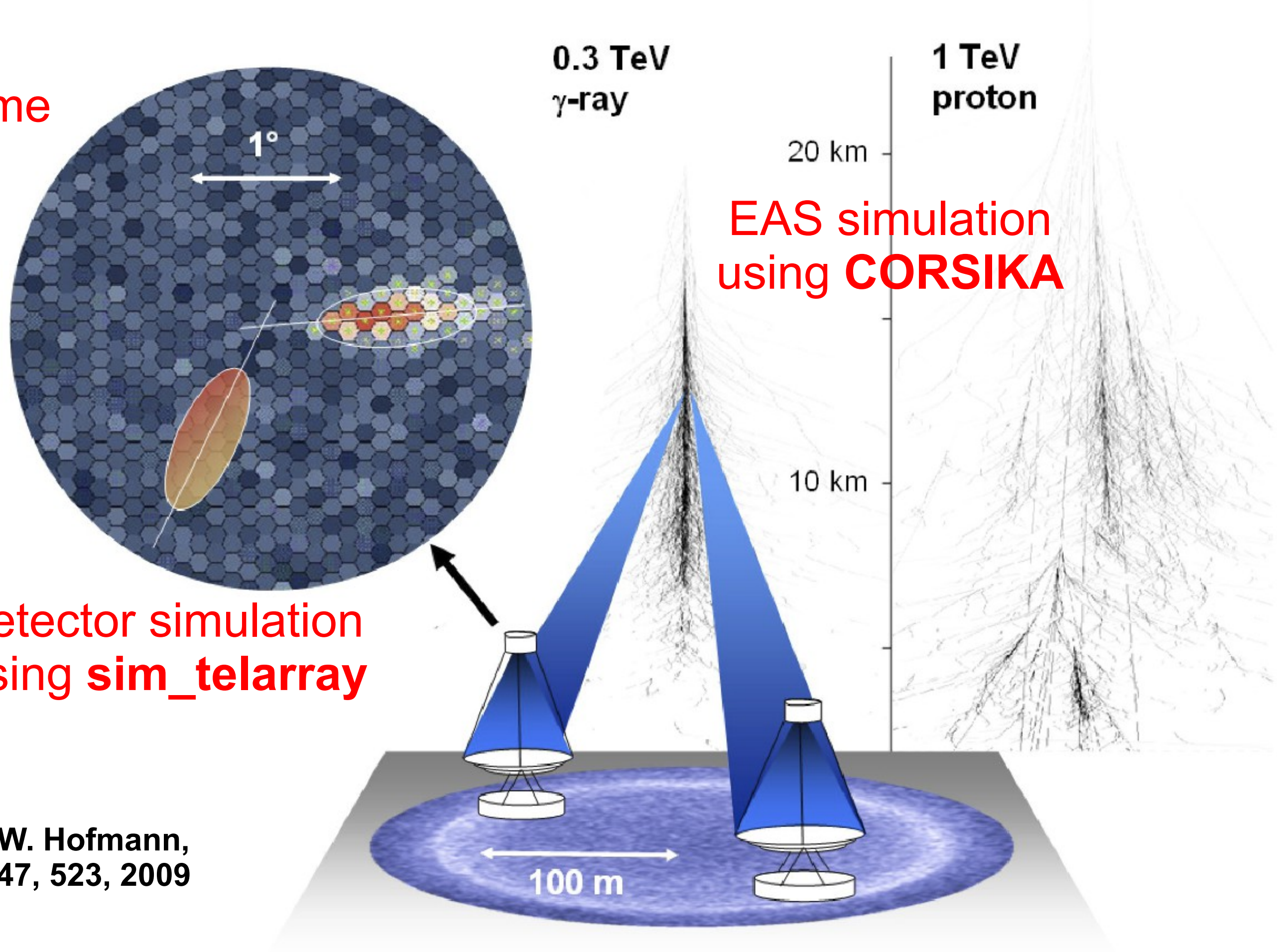
Imaging Air Cherenkov Technique



Credit: J.H. Hinton & W. Hofmann, Ann.Rev.Astrophys., 47, 523, 2009

Imaging Air Cherenkov Technique

Analysis:
use charge and time
in each channel



EAS simulation
using **CORSIKA**

detector simulation
using **sim_telarray**

Credit: J.H. Hinton & W. Hofmann, Ann.Rev.Astrophys., 47, 523, 2009

Large-scale CTA simulations

Monte Carlo working group aims to:

• characterize the expected performance of proposed arrays

• optimize the **telescope design & array layout** for a **fixed total cost** and **at a given site** through an iterative approach (several rounds of simulation with feedback from hardware & physics working groups)

• aim for best performance parameters (sensitivity, angular resolution, ...) that impact on the physics goals

Large-scale CTA simulations

MC simulations performed on the European Grid Infrastructure
and at local sites: MPIK Heidelberg, ISDC Geneva, DESY Zeuthen

Previous (**prod-1**) simulations

- 275 telescopes of 5 different types
- conservative assumptions about telescope parameters
- hypothetical amplitudes of 2000m and 3700m, with zenith angles of 20° and 50°
- results presented in Astroparticle Physics special issue on CTA

Current (**prod-2**) simulations

- 229 telescopes of 7 different types (2 types of MST, 4 types of SST)
- 3 candidate sites with altitudes between 1600m and 3700m
- assumed telescope parameters incorporate current designs (optics, camera, photosensors, trigger, readout)
- multiple telescope trigger schemes simulated in parallel
- save signal traces for each channel – advanced signal extraction vs data transfer rate
- tests with higher rates of NSB, depending on the site

Interface to Physics working group

Physics working group defines **benchmark physics cases** that are used to evaluate the performance of each **candidate array**

MC Input: **CTA performance file** (Aeff, background rate, energy migration matrix, angular resolution) which depend on simulation parameters (zenith angle, site altitude, NSB, ...) + analysis & optimization criteria

Physics User Input: source energy spectrum, spatial morphology and the observation time

Physics Tools Output: possible realizations of energy spectra, light curves, sky maps

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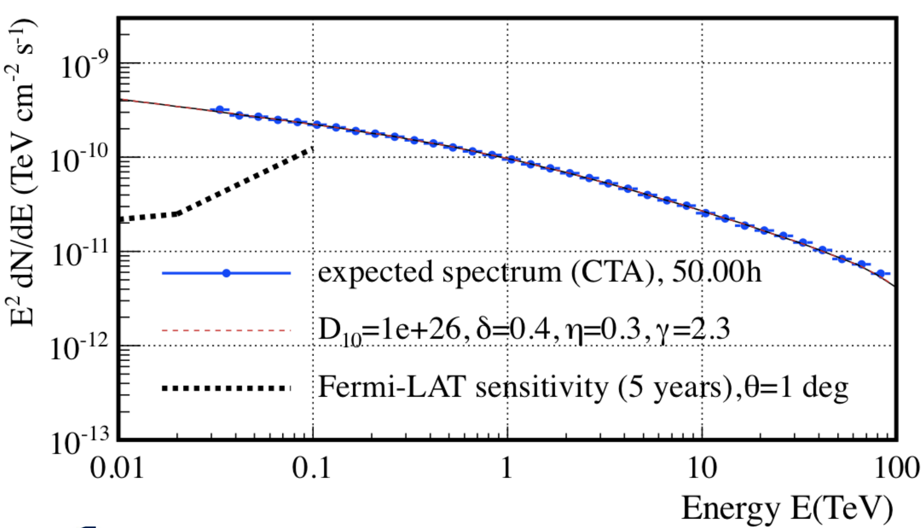

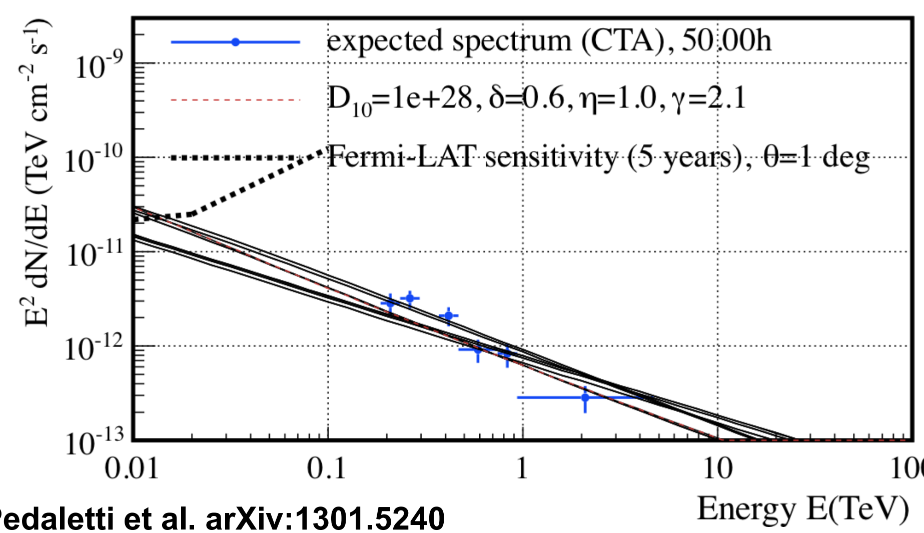

G. Pedaletti et al. arXiv:1301.5240

cta cherenkov telescope array

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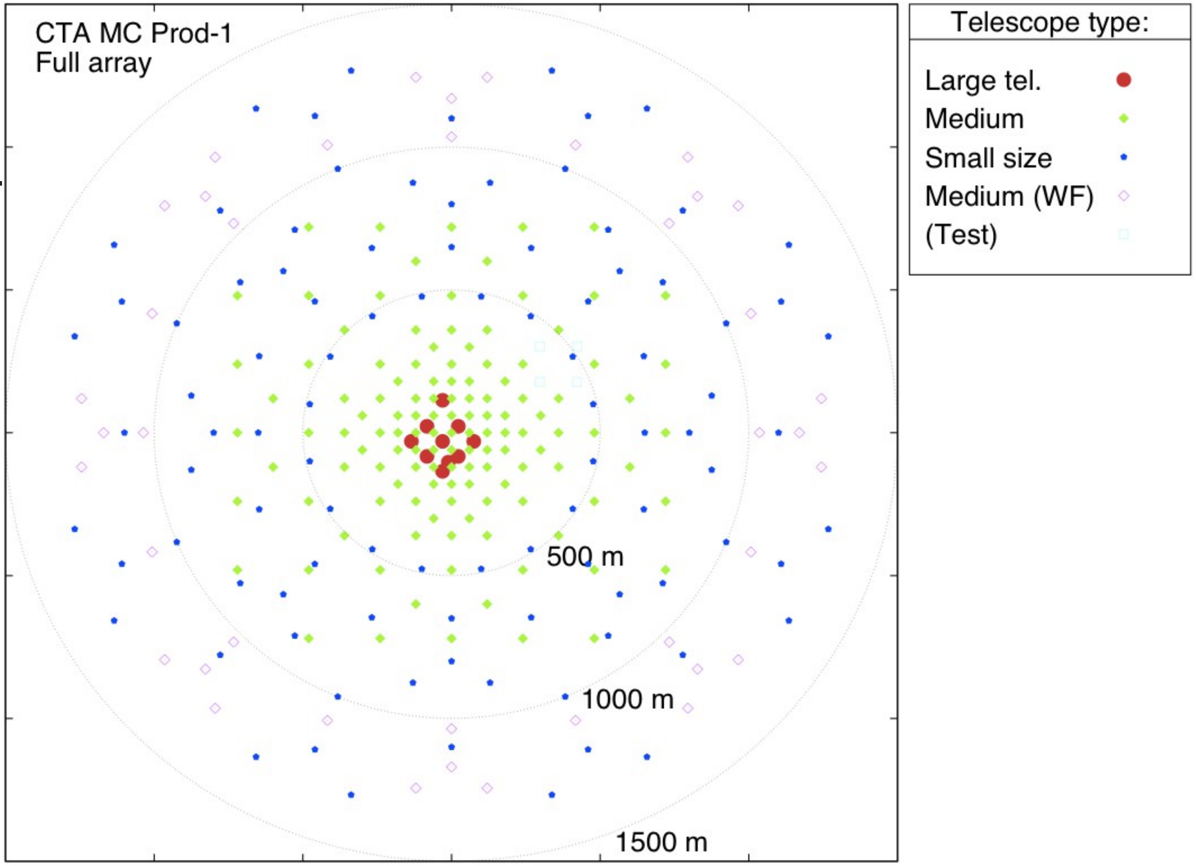
Previous (prod-1) large-scale CTA simulations

	Large (LST)	Medium (MST†)	Small (SST)
Diameter D (m)	24.0	12.3	7.4
Dish shape‡	parab.	DC	DC
Mirror area (m^2)	412	100	37
Mirror tiles	594	144	120
Tile diam. (m)	0.90	0.90	0.60
Focal length f (m)	31.2	15.6	11.2
f/D	1.30	1.27	1.51
f.o.v. diam. (deg.)	5	8	10
Camera diam. (m)	2.8	2.2	2.0
No. of pixels	2841	1765	1417
Pixel diam. (deg.)	0.09	0.18	0.25
Pixel diam. (mm)	49 (50*)	49 (50*)	49 (50*)

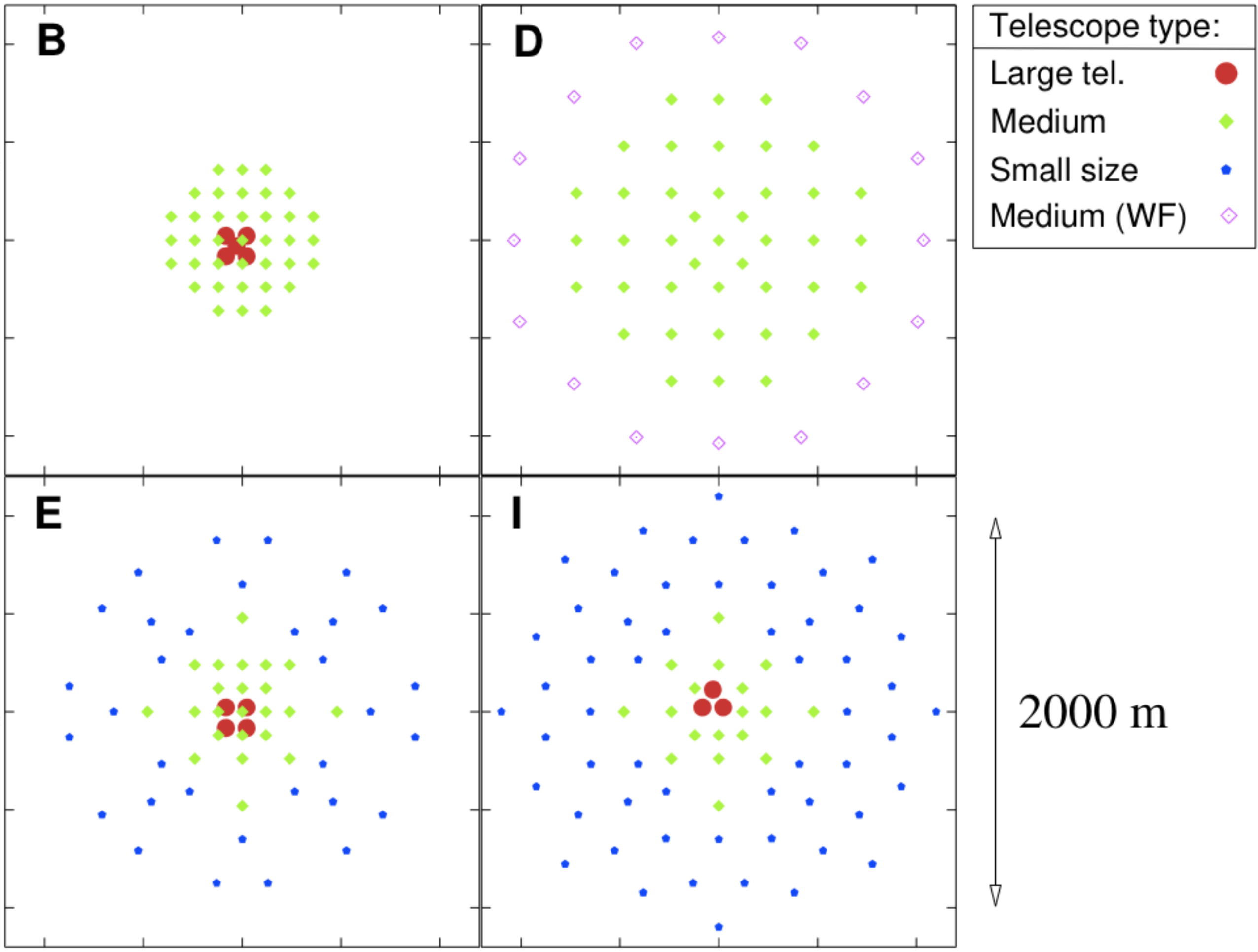


K. Bernlöhr et al. , Astropart.Phys. 43, 171, 2013

Previous (prod-1) large-scale CTA simulations

	LST	MST	SST
A	3 (5°)	41 (8°)	-
B	5 (5°)	37 (8°)	-
C	-	29 (8°)	26 (10°)†
D	-	41 (7.4°)	16 (10°)†
E	4 (4.6°)	23 (8°)	32 (10°)
F	6 (4.8°)	29 (6.3°)	-
G	6 (5°)	9 (8°)	16 (10°)
H	-	25 (7°)	48 (10°)
I	3 (4.9°)	18 (8°)	56 (9°)
J	3 (4.9°)	30 (8°)	16 (9°)†
K	5 (5°)	-	72 (9.5°)
NA	4 (5°)	17 (6°)	-
NB	3 (5°)	17 (6°)	8 (8°)

† With wide-field versions of MSTs instead of actual SSTs.



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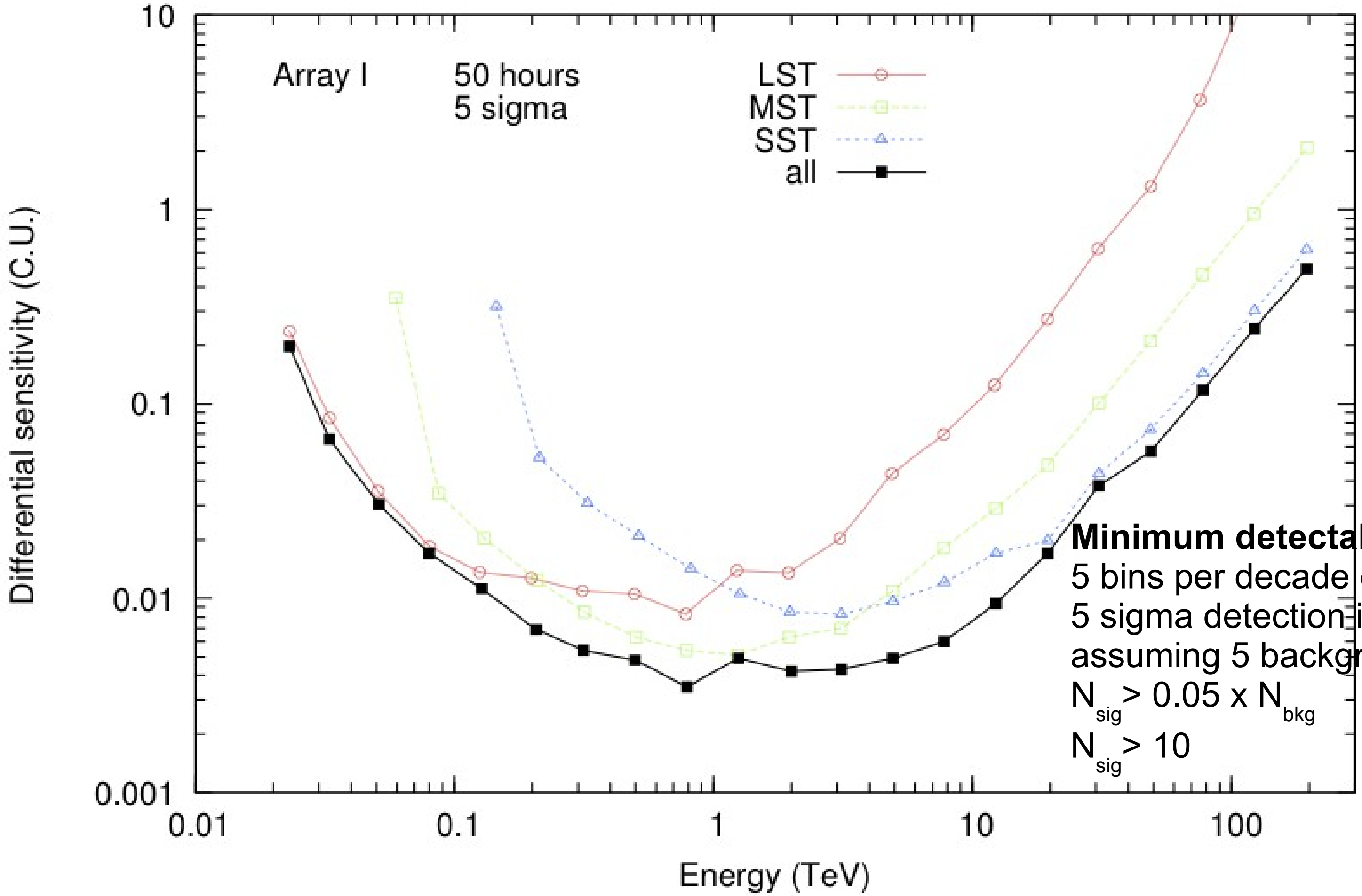
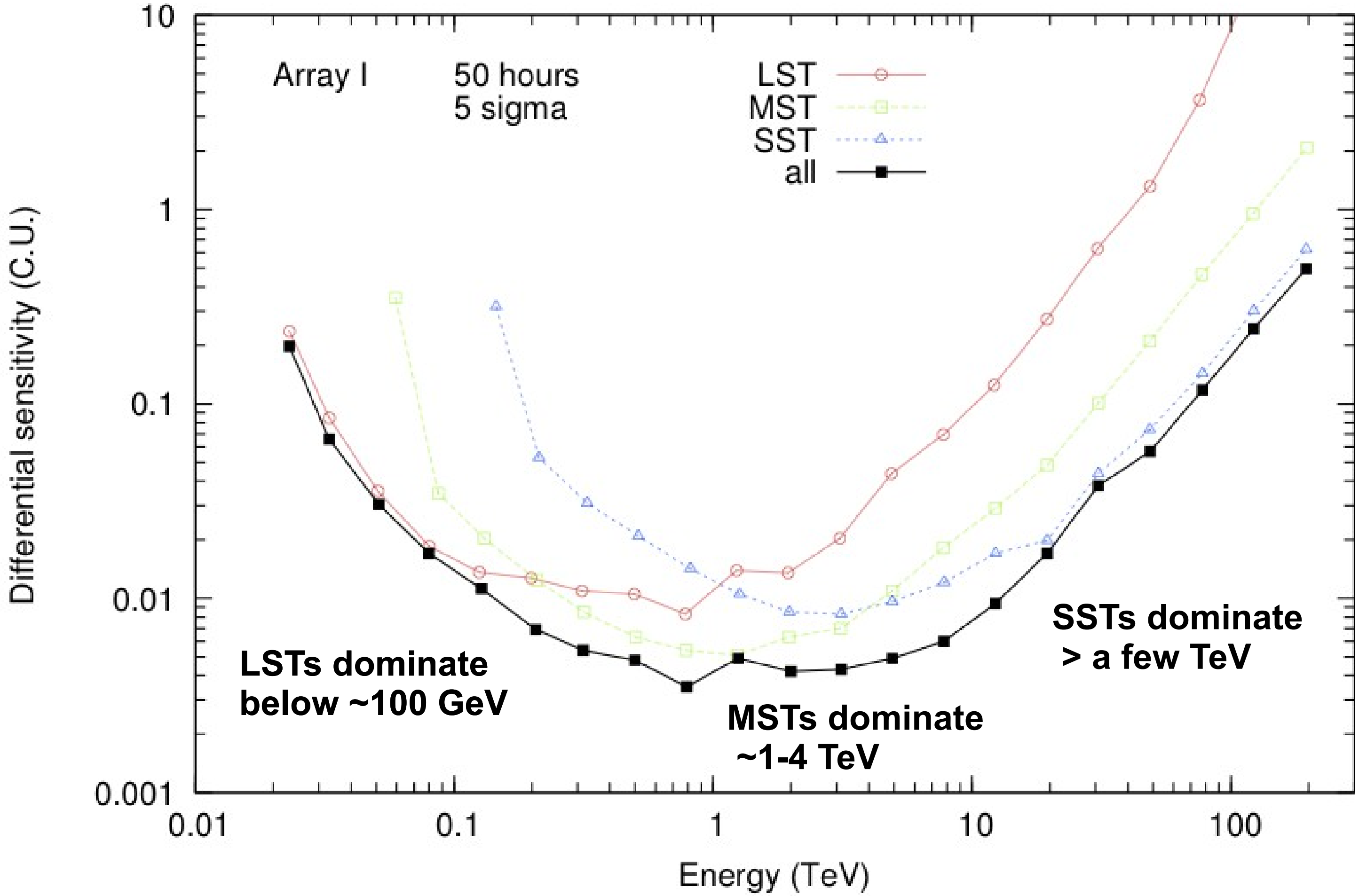
Previous (prod-1) large-scale CTA simulations



Minimum detectable flux in 50h:
5 bins per decade of energy
5 sigma detection in each bin
assuming 5 background control regions
$N_{sig} > 0.05 \times N_{bkg}$
$N_{sig} > 10$

K. Bernlöhr et al. arXiv:1307.2773

Previous (prod-1) large-scale CTA simulations



K. Bernlöhr et al. arXiv:1307.2773

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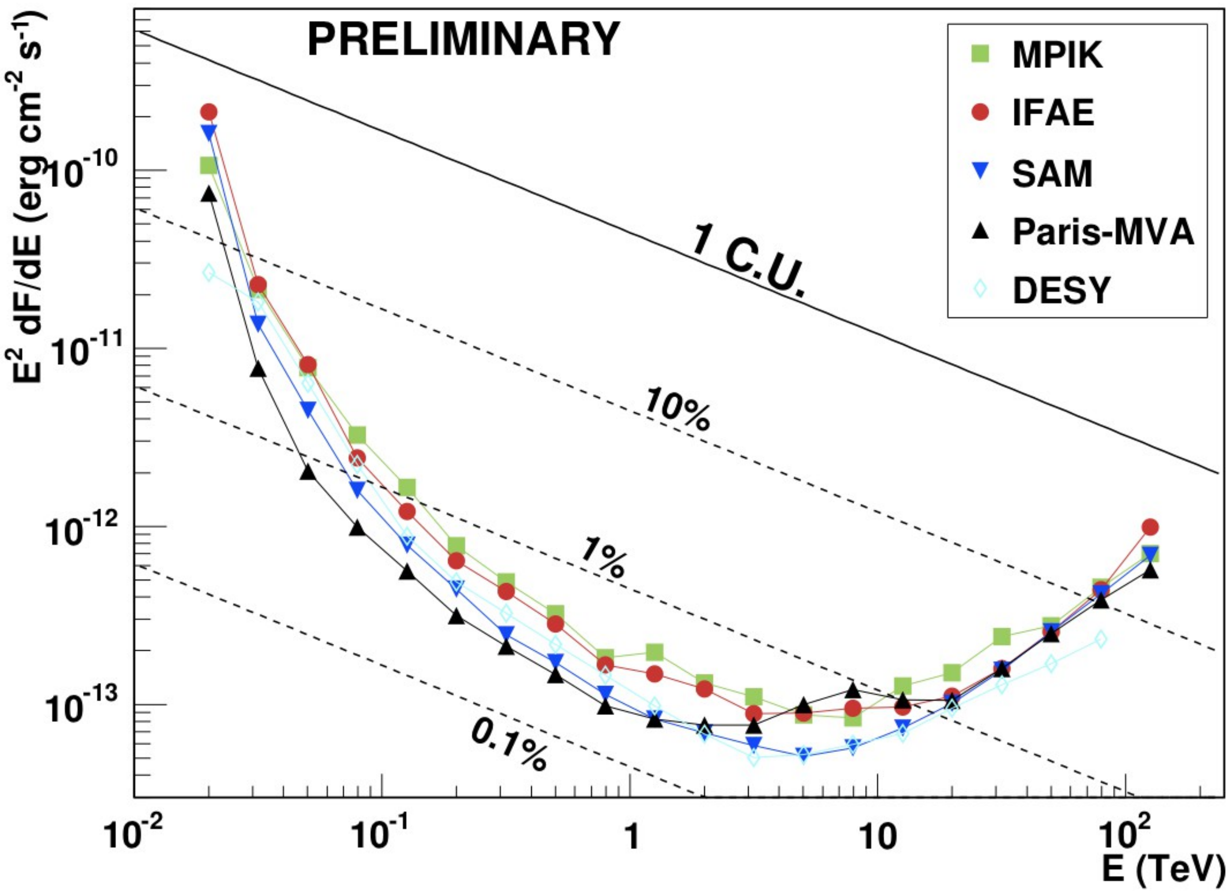

K. Bernlöhr et al. arXiv:1307.2773

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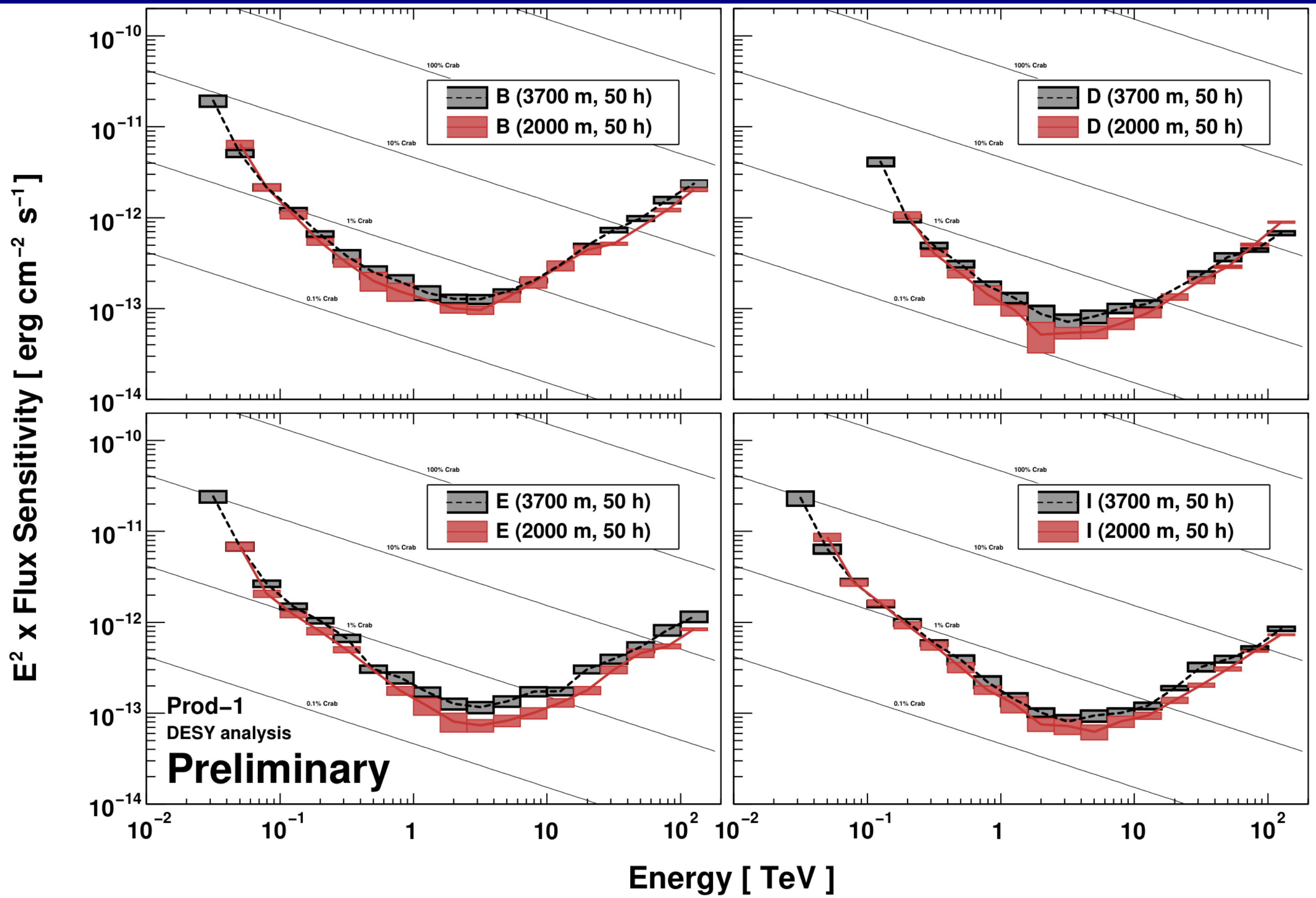
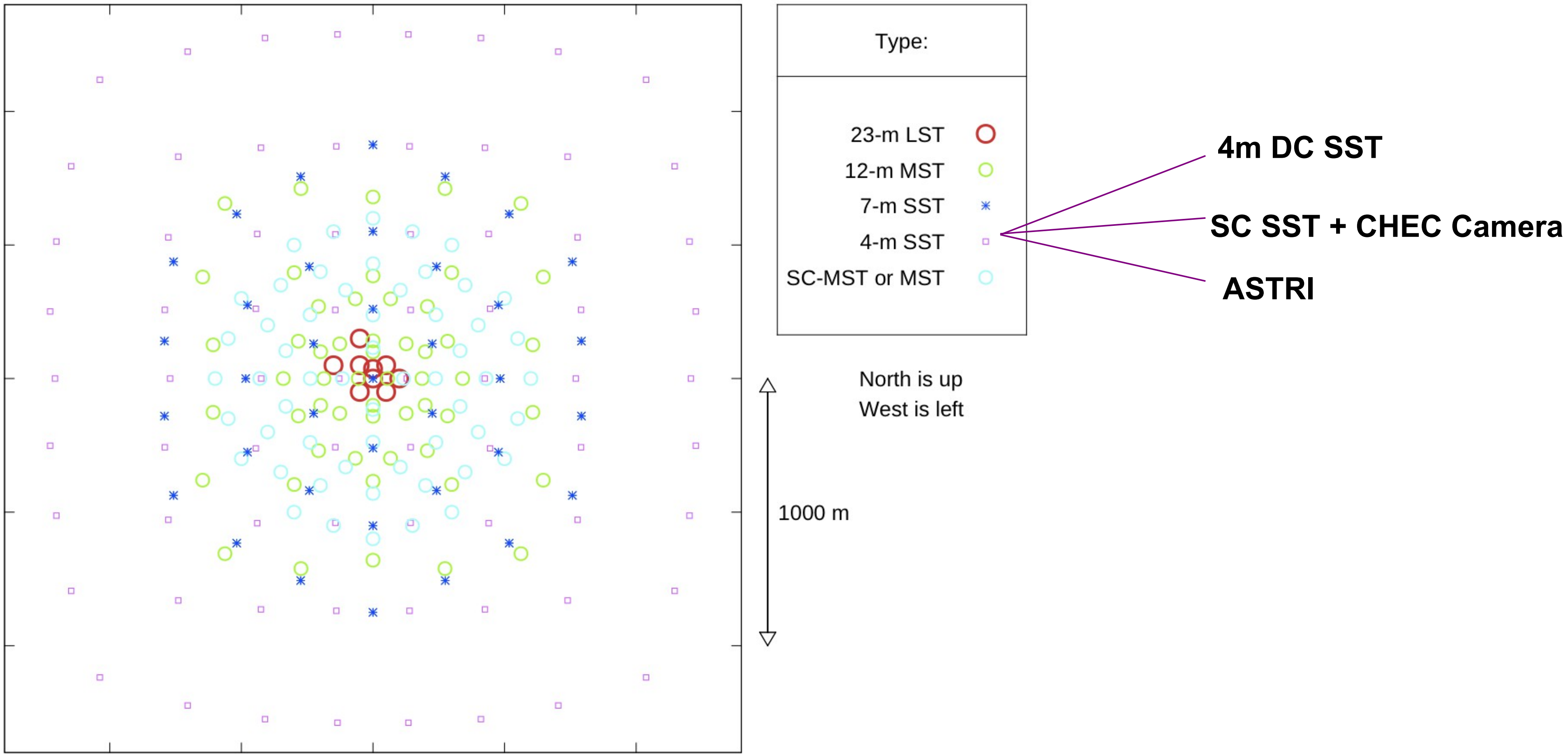


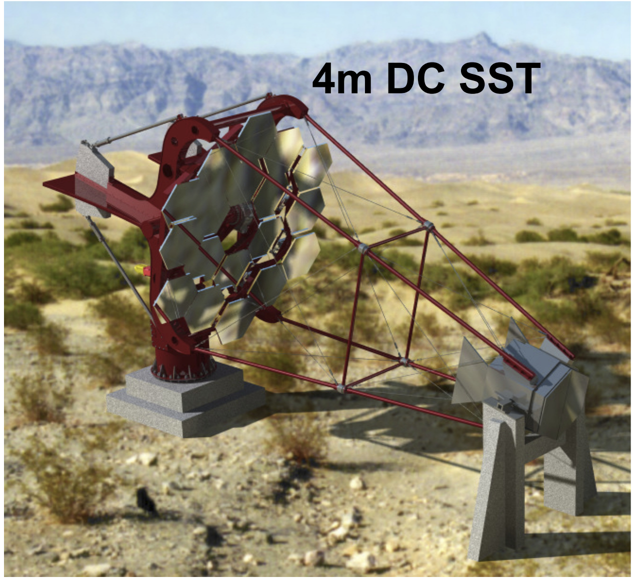
K. Bernlöhr et al. arXiv:1307.2773

Current (prod-2) large-scale CTA simulations

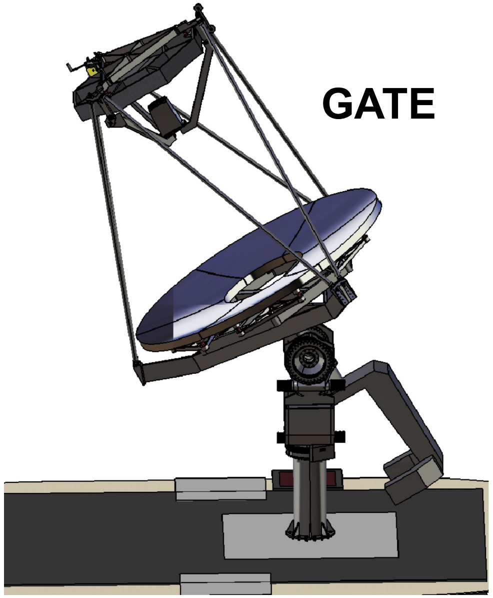


K. Bernlöhr et al. arXiv:1307.2773

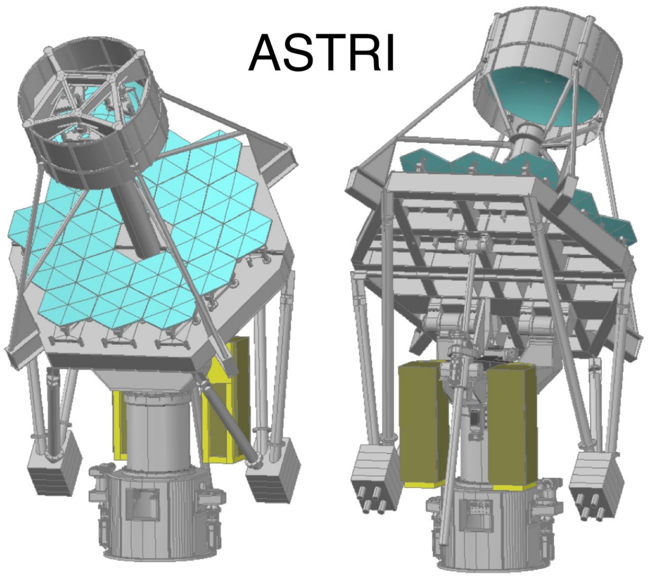
4m-class SST prototypes



R. Moderski et al. arXiv:1307.3137

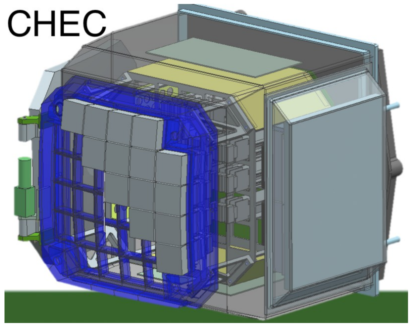


A. Zech et al. arXiv:1307.3035



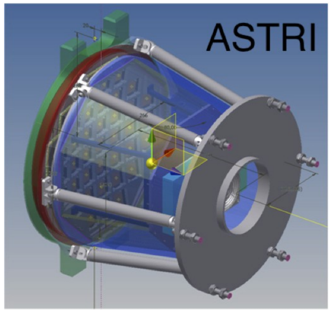
G. Pareschi et al. arXiv:1307.4962

CHEC



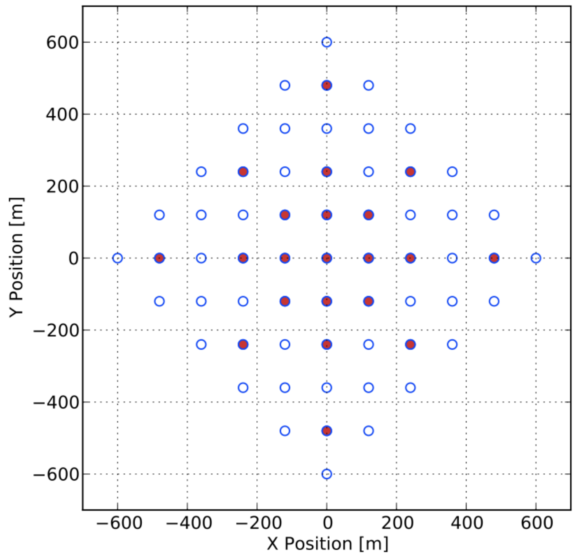
G. Pareschi et al. arXiv:1307.4962

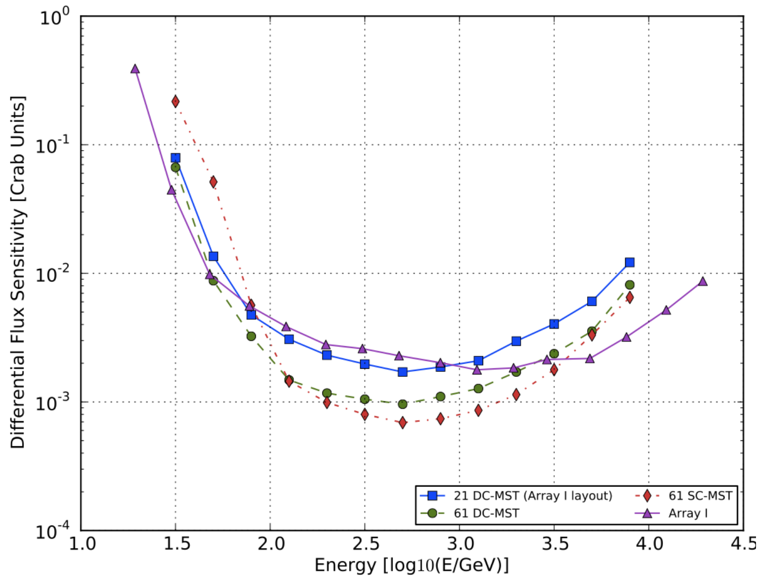
ASTRI

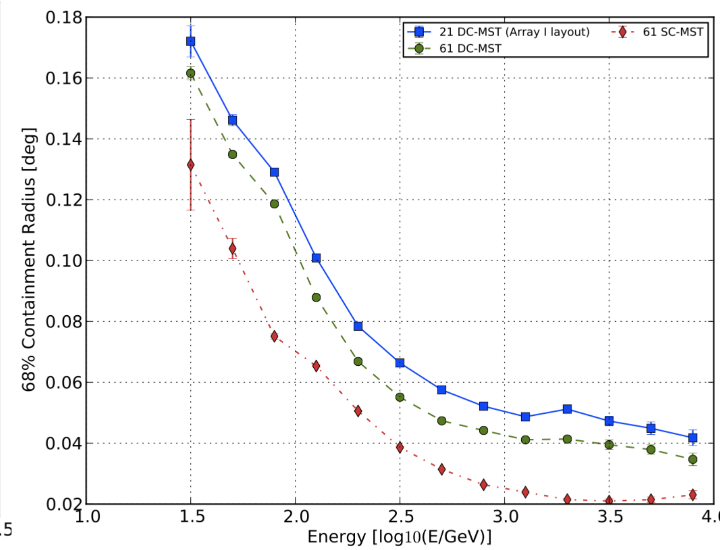


MC comparison of MST designs

Davies Cotton (DC) MSTs vs Schwarzschild-Couder (SC) MSTs
10m aperture
120m inter-telescope spacing



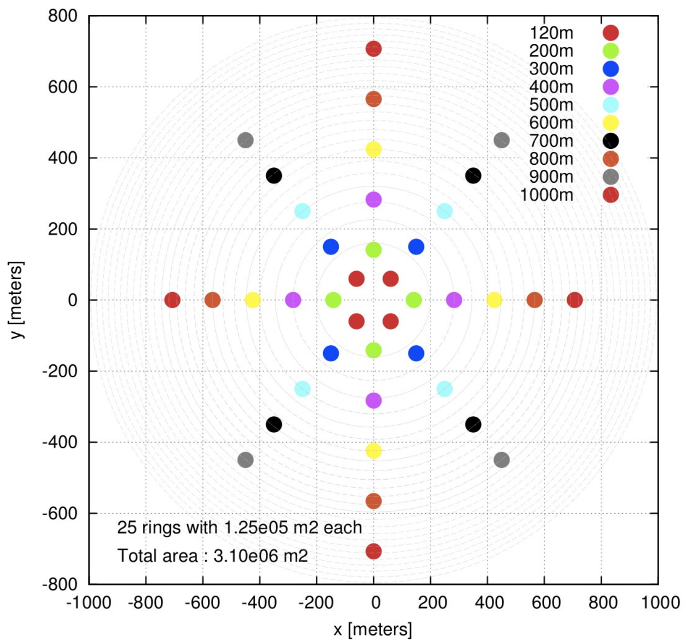


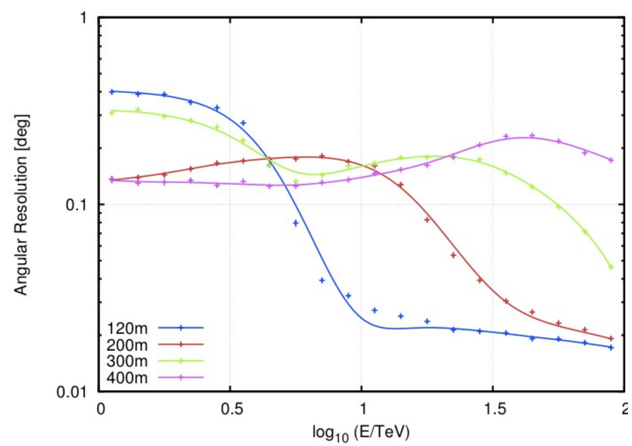


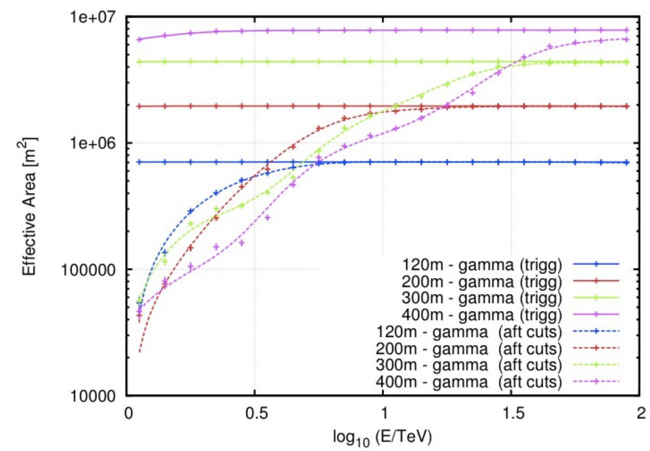
T. Jogler et al. arXiv:1307.5905

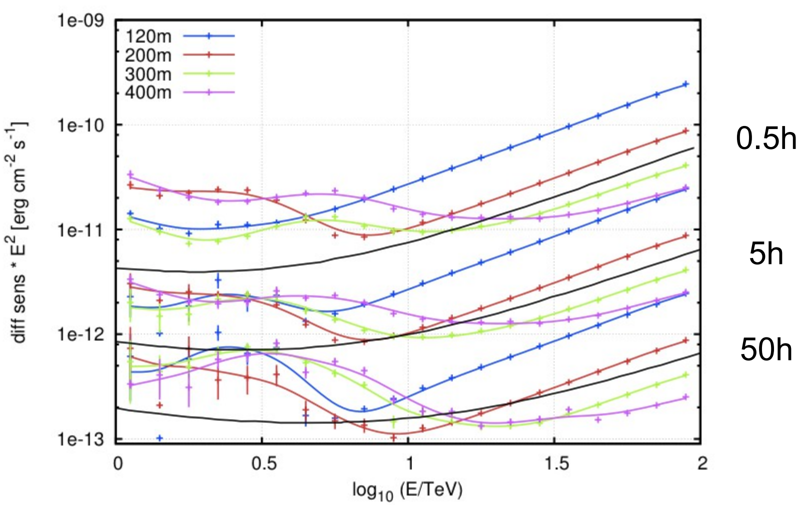
4m DC SST cell spacing

Extrapolated performance of 64 x 4m DC SSTs arranged in 49 cells









A. Barnacka et al. arXiv:1307.3409

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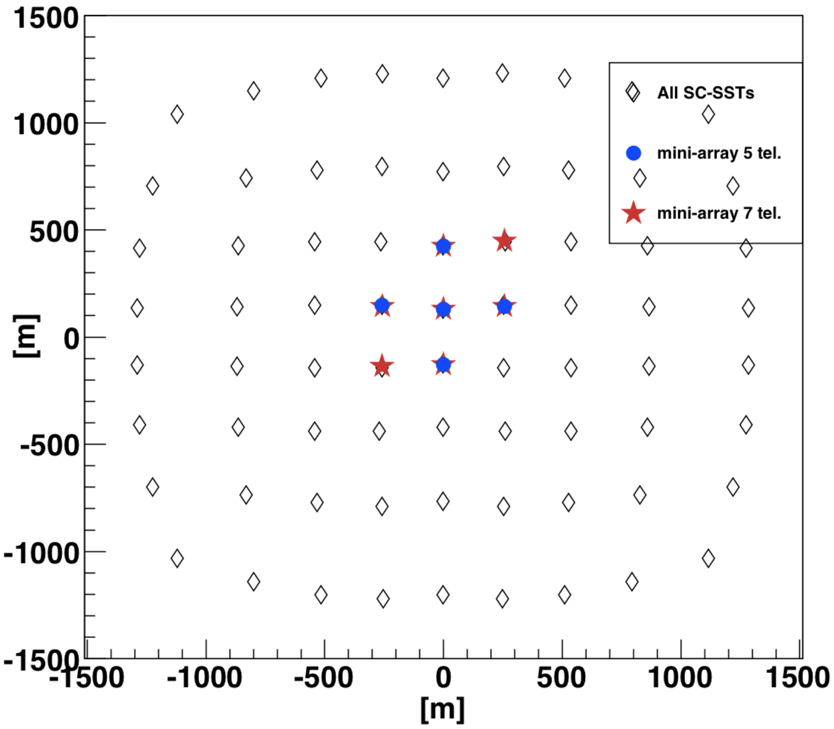
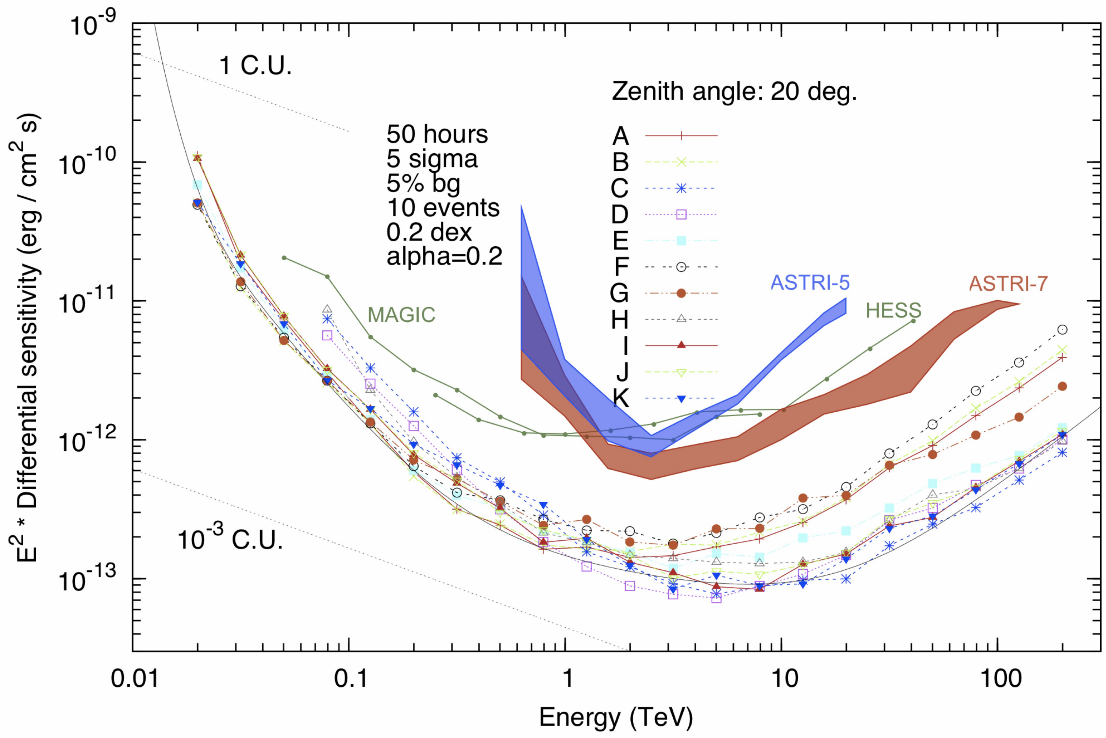
ASTRI mini-array

smallest separation = 260 m





F. Di Pierro et al. arXiv:1307.3992

CTA Monte Carlo at Adelaide

Using computing facilities at ***eResarch SA****, we plan to...*

• analyze prod-2 data with focus on the SST performance at multi-TeV energies:
- run 2 analysis chains in parallel (baseline and advanced)
- compare the different 4m-class SSTs
- study the off-axis performance
- study divergent pointing mode performance
- apply Physics Tools to study relevant science cases

• provide enhancements to existing analysis chains
- improve effective area at the highest energies
- quantify what can be gained by using pixel timing information

• perform dedicated MC productions to answer open questions on SST array design

Current Status: installing CTA simulation and analysis software,
configuring job submission scripts

Summary

- Monte Carlo simulations are used to meet the physics goals of CTA in a cost-effective way

- Subset candidate arrays are drawn from large-scale productions for a fixed total cost and evaluated in terms of physics performance

- Telescope configuration parameters are chosen based on the current technical designs and understanding of the costs involved

- Current focus is on the impact of site altitude with a view to a decision on the Southern and Northern sites for CTA

- Also of interest are comparisons of competing SST designs

- On-going investigations on the effects of higher NSB rates, trigger schemes, and more advanced signal extraction