

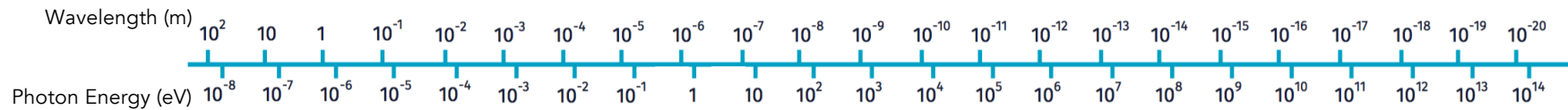


Building CTA

Astroparticle Physics in Germany
Mainz, Sept 17th 2018

Jim Hinton - MPIK





Major Astronomical Facilities

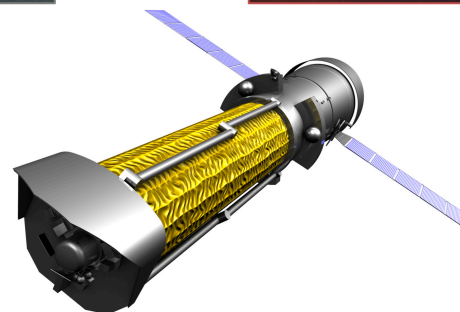
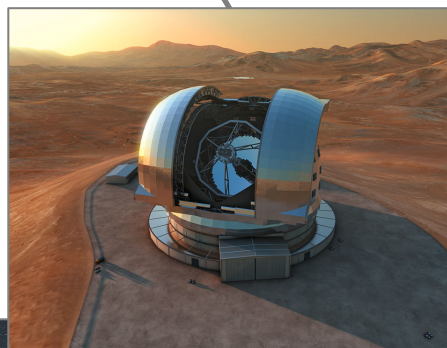
SKA

ALMA

E-ELT

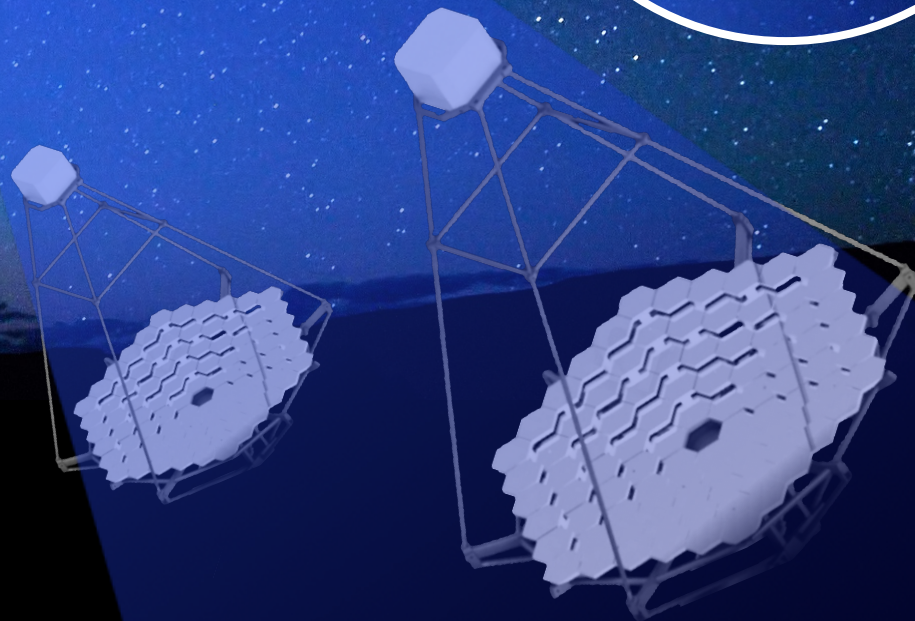
Athena

CTA



γ -ray enters the atmosphere

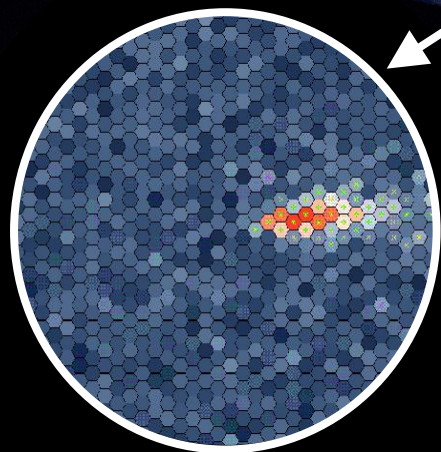
Electromagnetic cascade



0.1 km² "light pool", a few photons per m².

γ -ray enters the atmosphere

Electromagnetic cascade



10 nanosecond snapshot

0.1 km² "light pool", a few photons per m².

Existing Facilities

→ Karl Mannheim + David Berge



HESS
1x28m
4x12m
Namibia

Since
~2004



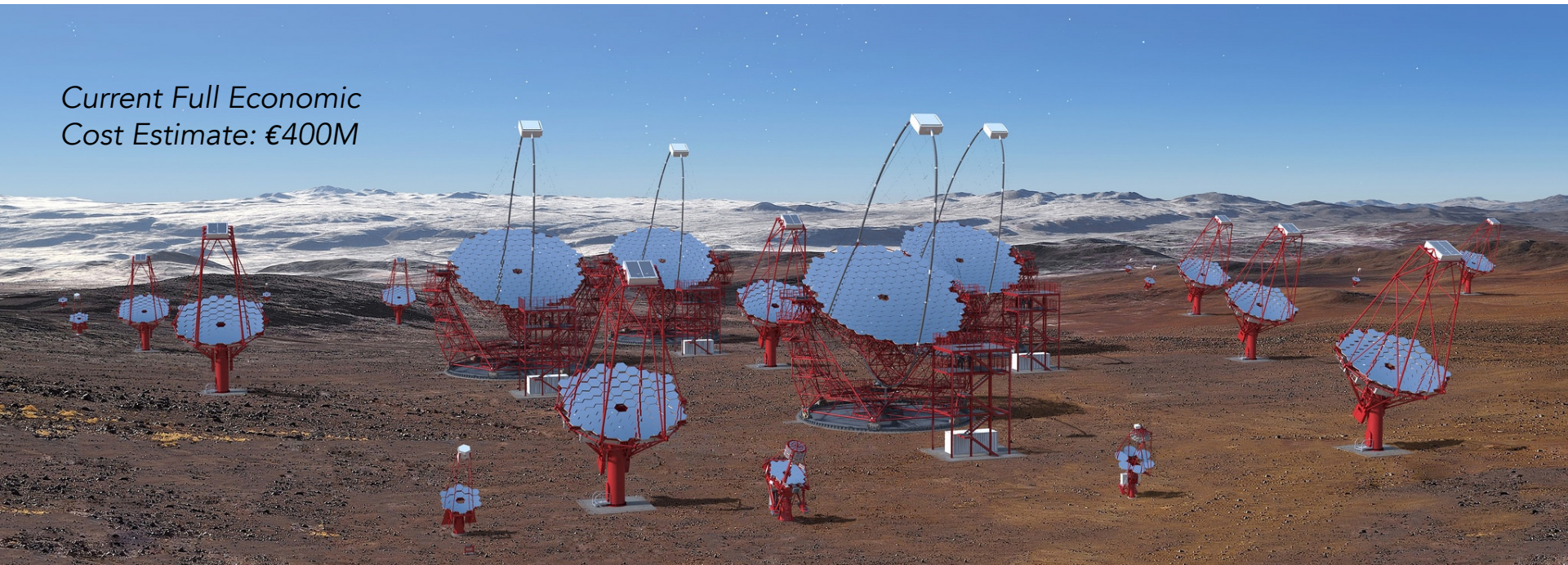
MAGIC
2x 17m
La Palma

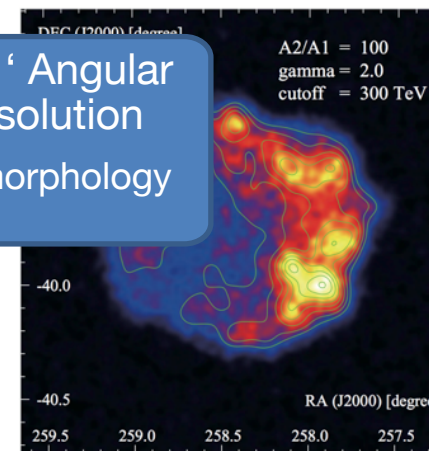
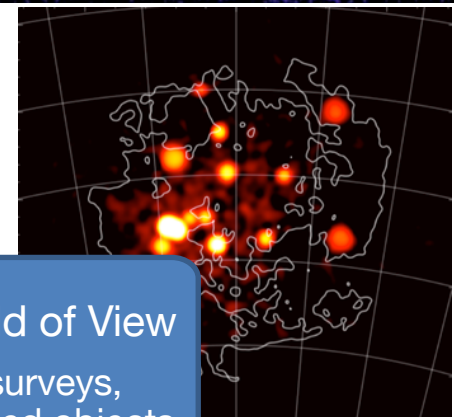
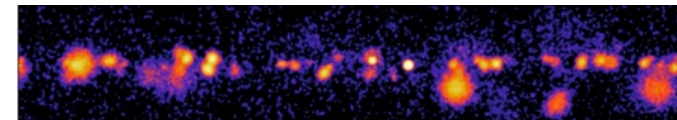
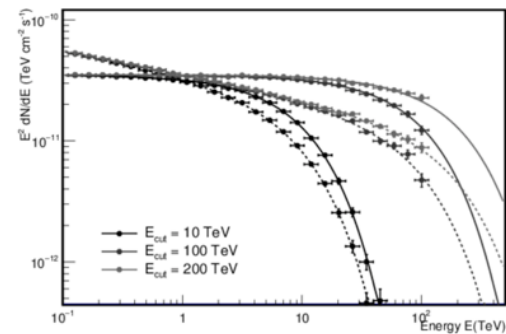
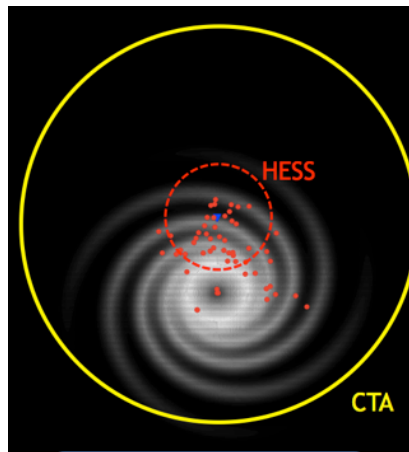
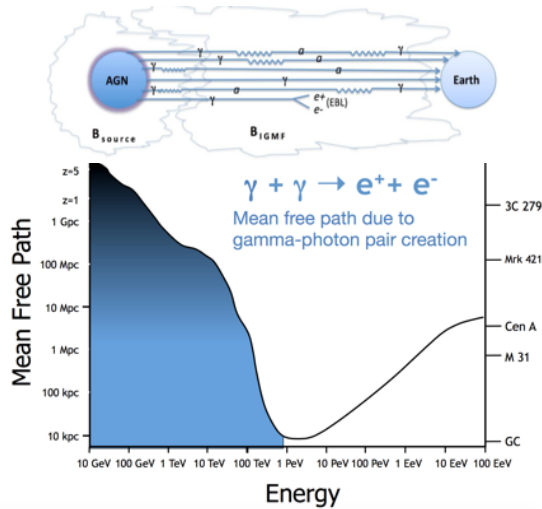
- ⊙ Major Germany role in **HESS** and **MAGIC** projects (MPG+DESY+Universities) + **VERITAS** in Arizona (4x12m telescopes, DESY is partner)

The Cherenkov Telescope Array

- ⊙ A global effort to build the first true VHE observatory
 - + A user facility serving a wide community
 - Data access to all German scientists
- ⊙ A huge improvement in all aspects of performance
 - + ~100 telescopes on two sites for access to the whole sky

Current Full Economic
Cost Estimate: €400M





10 x Sensitivity,
Large Collection
Area
→ all topics

Energies up to
300 TeV
→ Pevatrons

8° Field of View
→ surveys,
extended objects

Few ' Angular
Resolution
→ morphology

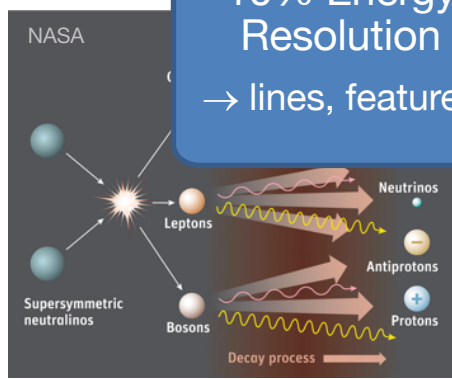
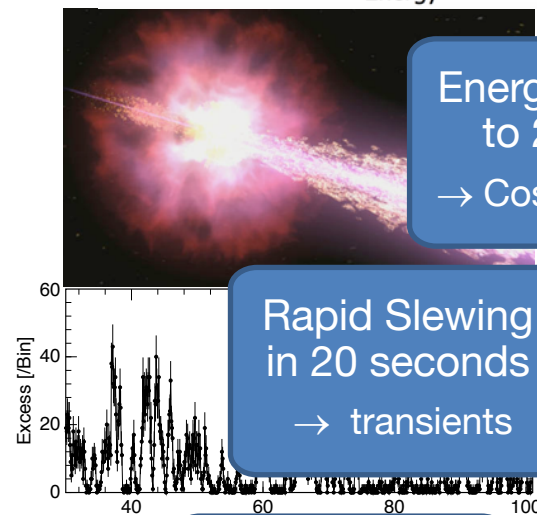
cta

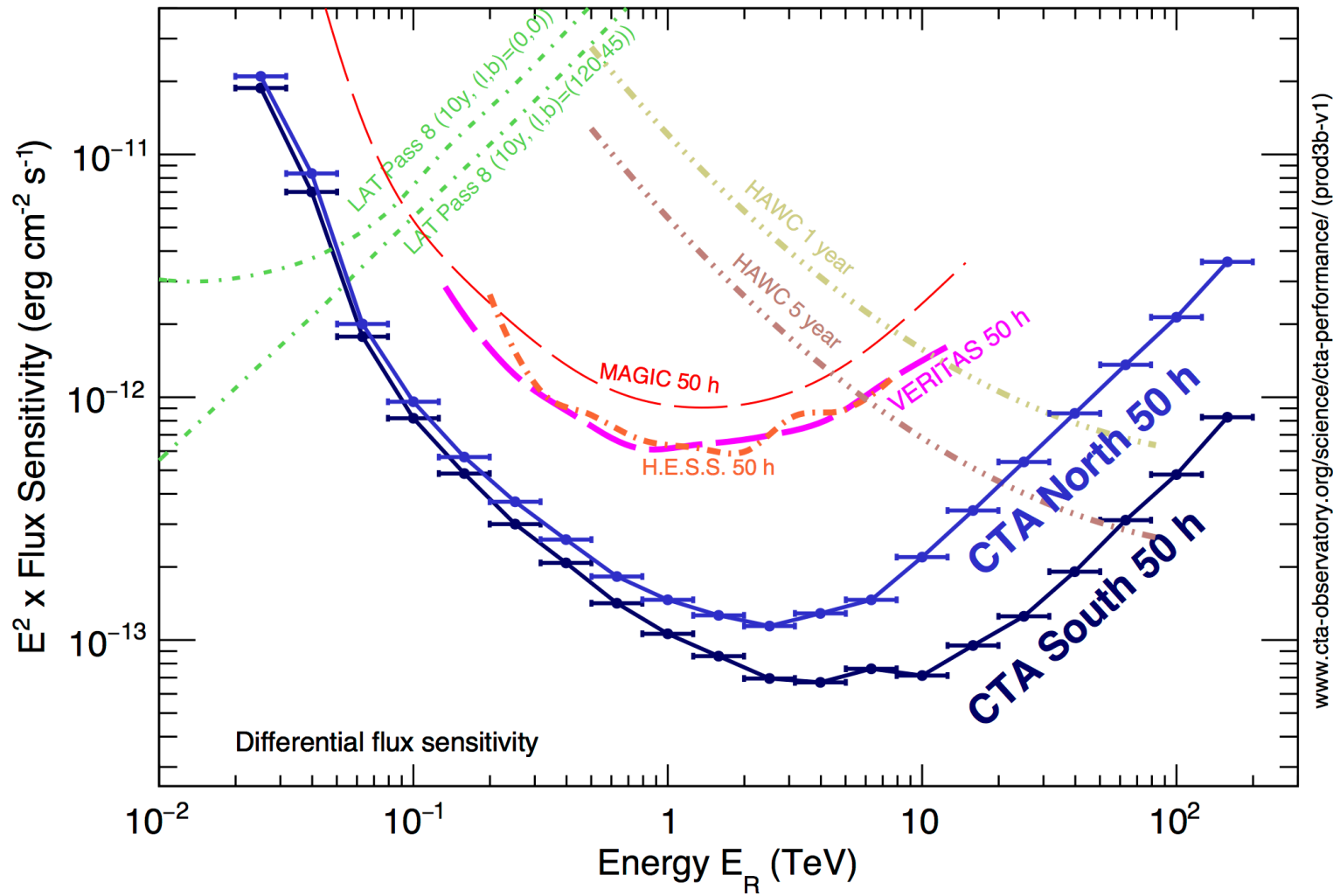
Energies down
to 20 GeV
→ Cosmology++

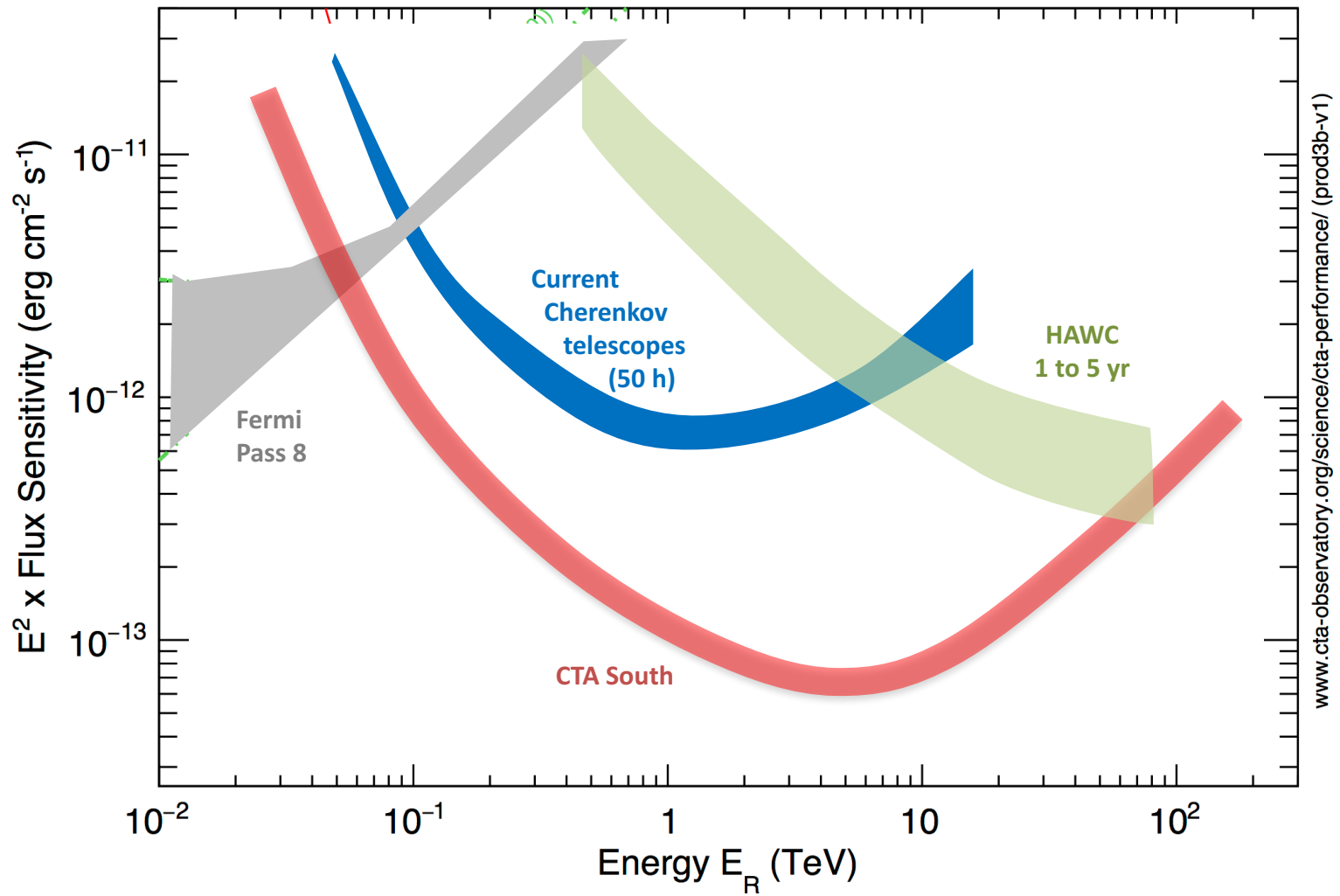
Rapid Slewing
in 20 seconds
→ transients

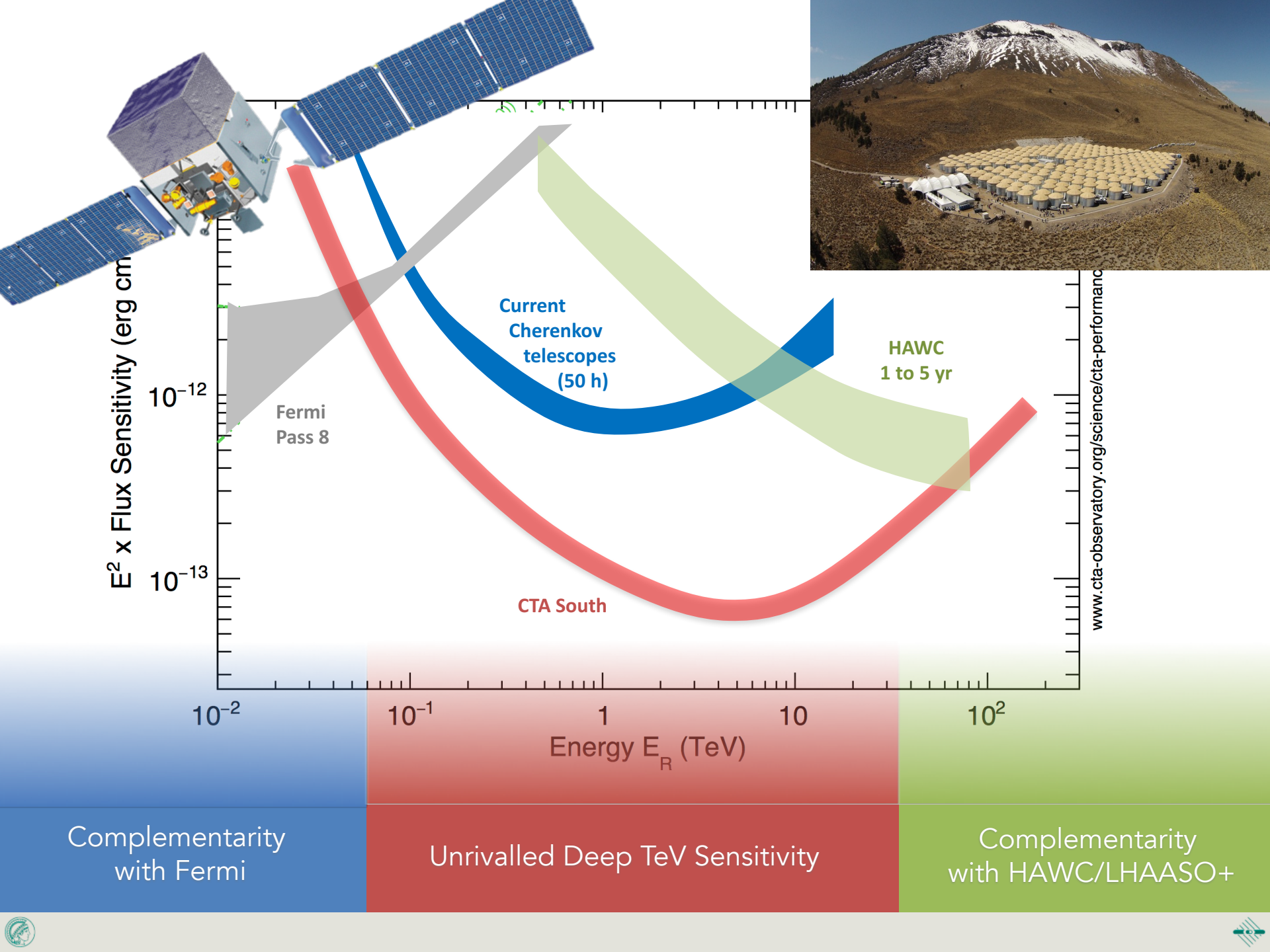
10% Energy
Resolution
→ lines, features

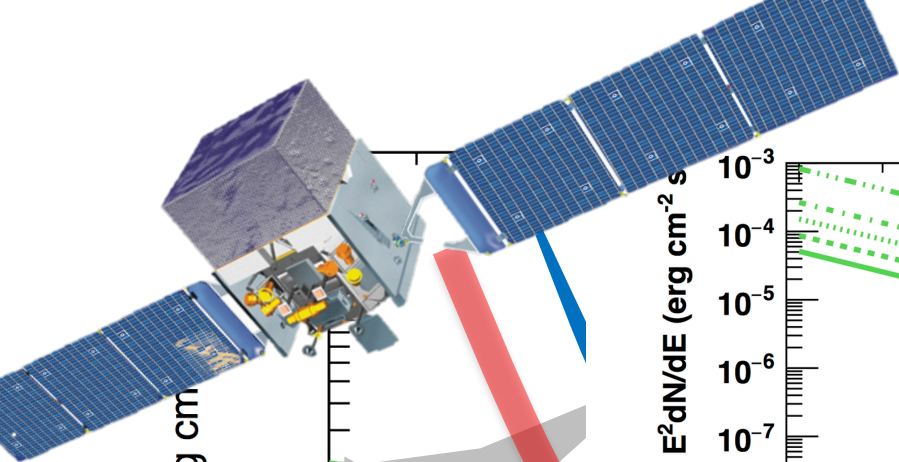
See 'Science with CTA'
<https://arxiv.org/abs/1709.07997>











$E^2 \times \text{Flux Sensitivity (erg cm}^{-2} \text{ s}^{-1})$

10^{-12}

10^{-13}

Fermi
Pass 8

10^{-2}

10^{-1}

Energy E_R (TeV)

Complementarity
with Fermi

Differential Flux Sensitivity $E^2 dN/dE$ (erg cm $^{-2}$ s $^{-1}$)

10^{-3}

10^{-4}

10^{-5}

10^{-6}

10^{-7}

10^{-8}

10^{-9}

10^{-10}

10^{-11}

10^{-12}

10^{-13}

10

10^2

10^3

10^4

Time (s)

1 min

10 min

1 hour

CTA

Fermi LAT

- $E = 25$ GeV
- - - $E = 40$ GeV
- ... $E = 75$ GeV
- . - $E = 100$ GeV
- - - $E = 250$ GeV

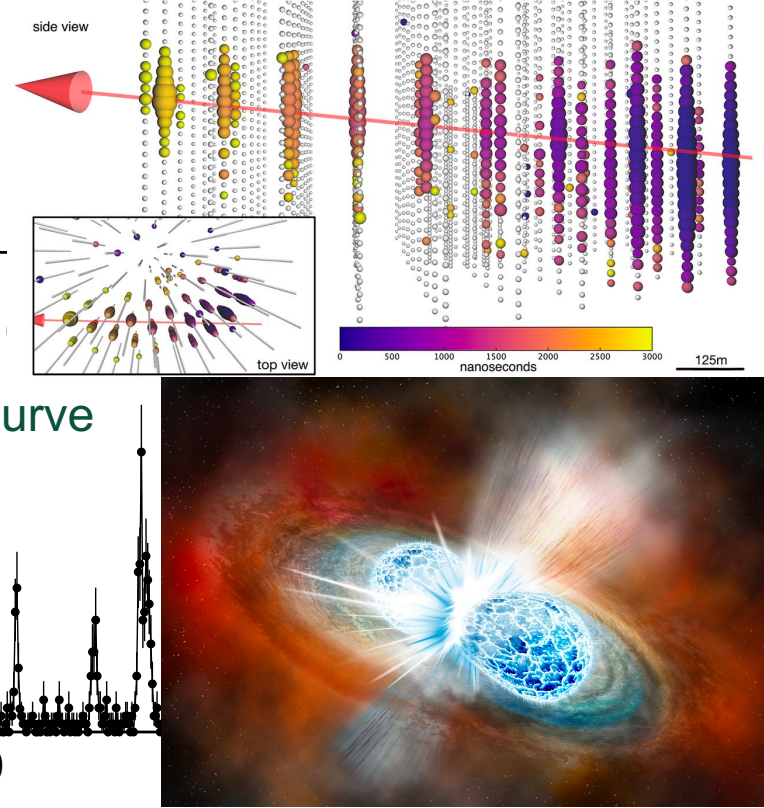
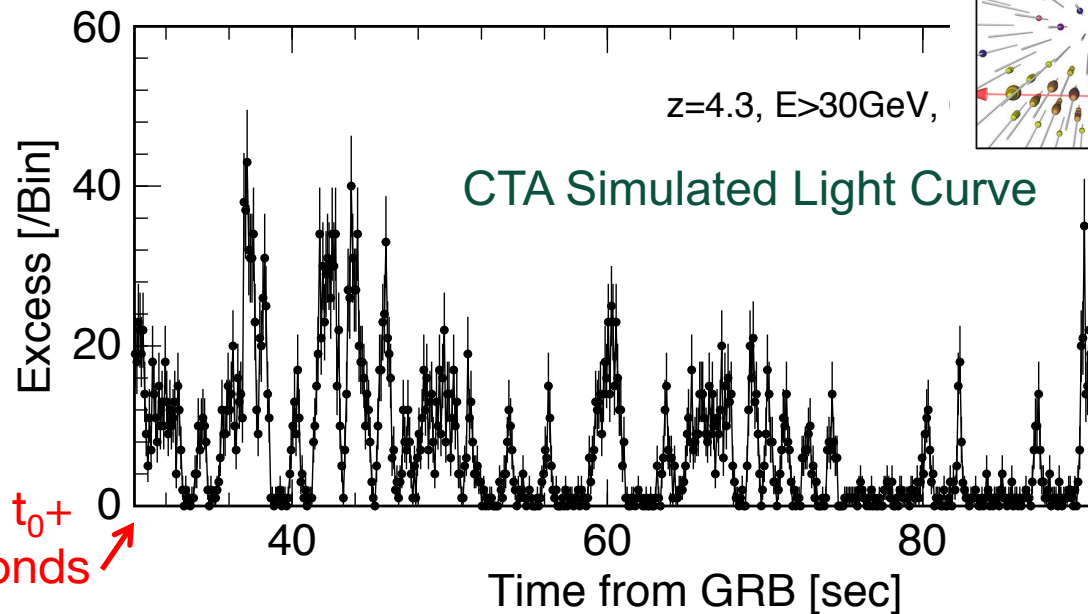
www.cta-observatory.org/science/cta-performance/ (prod3b-v1)

Unrivalled Deep TeV Sensitivity

Complementarity
with HAWC/LHAASO+

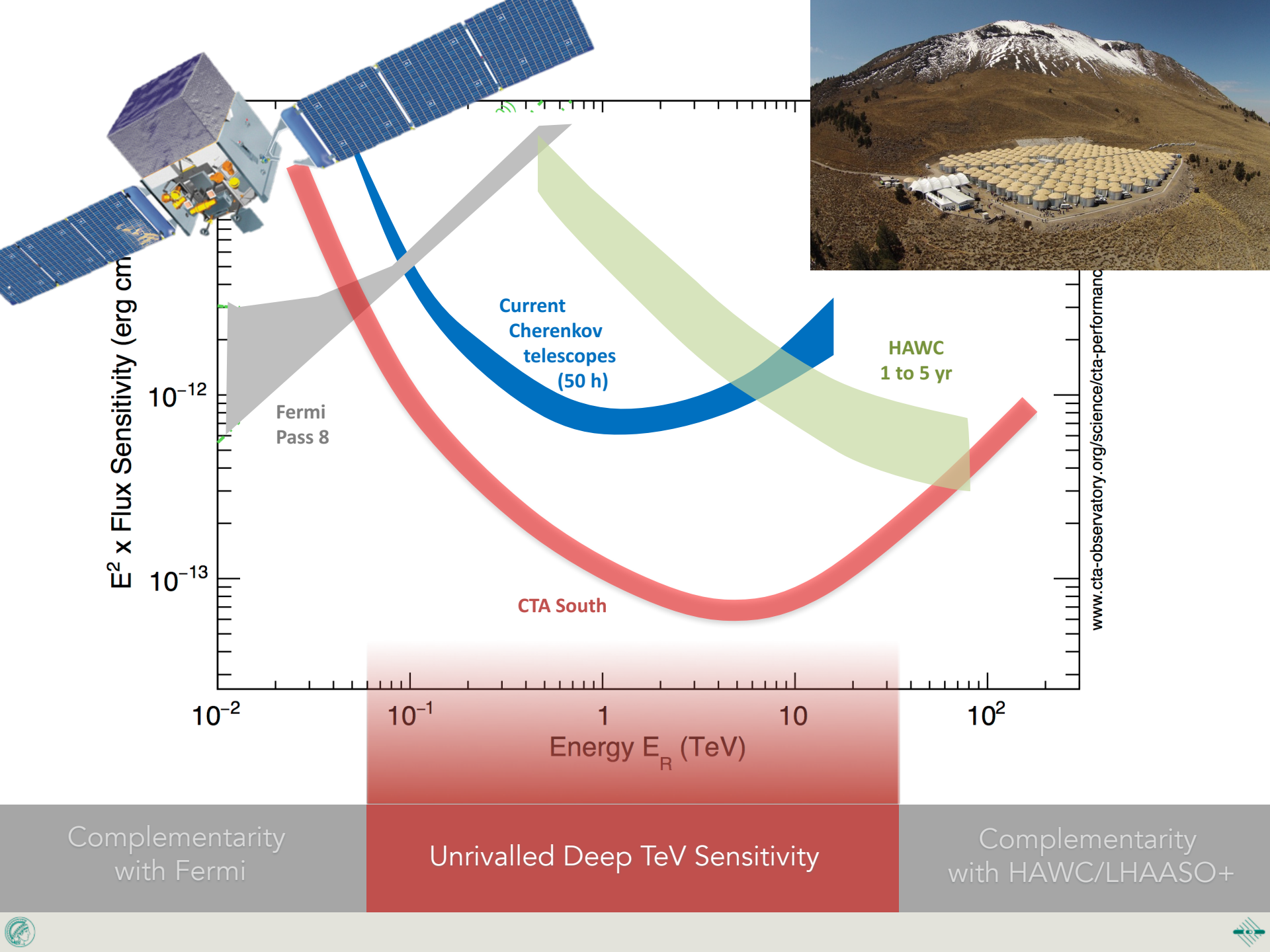


Alerts & Triggers

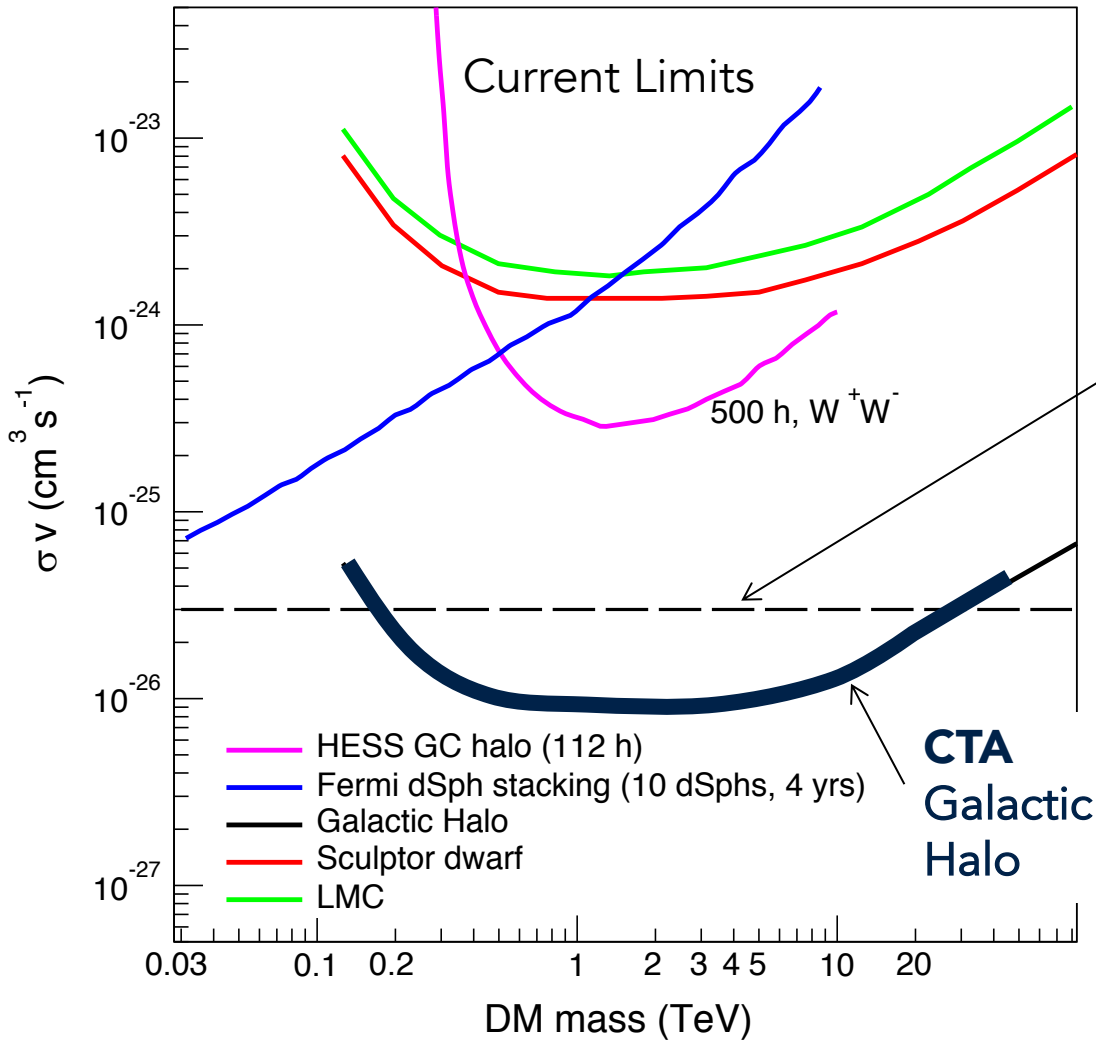


- ⊙ Alerts and triggers to CTA for variable/transient objects
 - + Including gravitational waves, neutrinos, FRBs, optical transients, ...
- ⊙ Triggers from CTA** → whole community
 - + Rate expected to be low – but identified events likely to be extremely important: GW/ ν sub-threshold, redshift measurement, ...

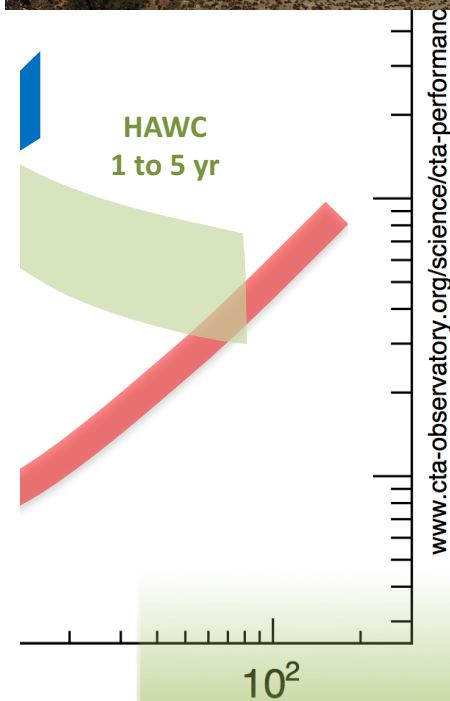
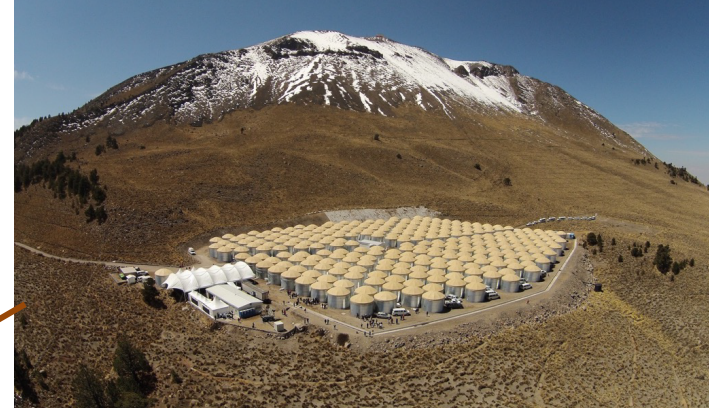
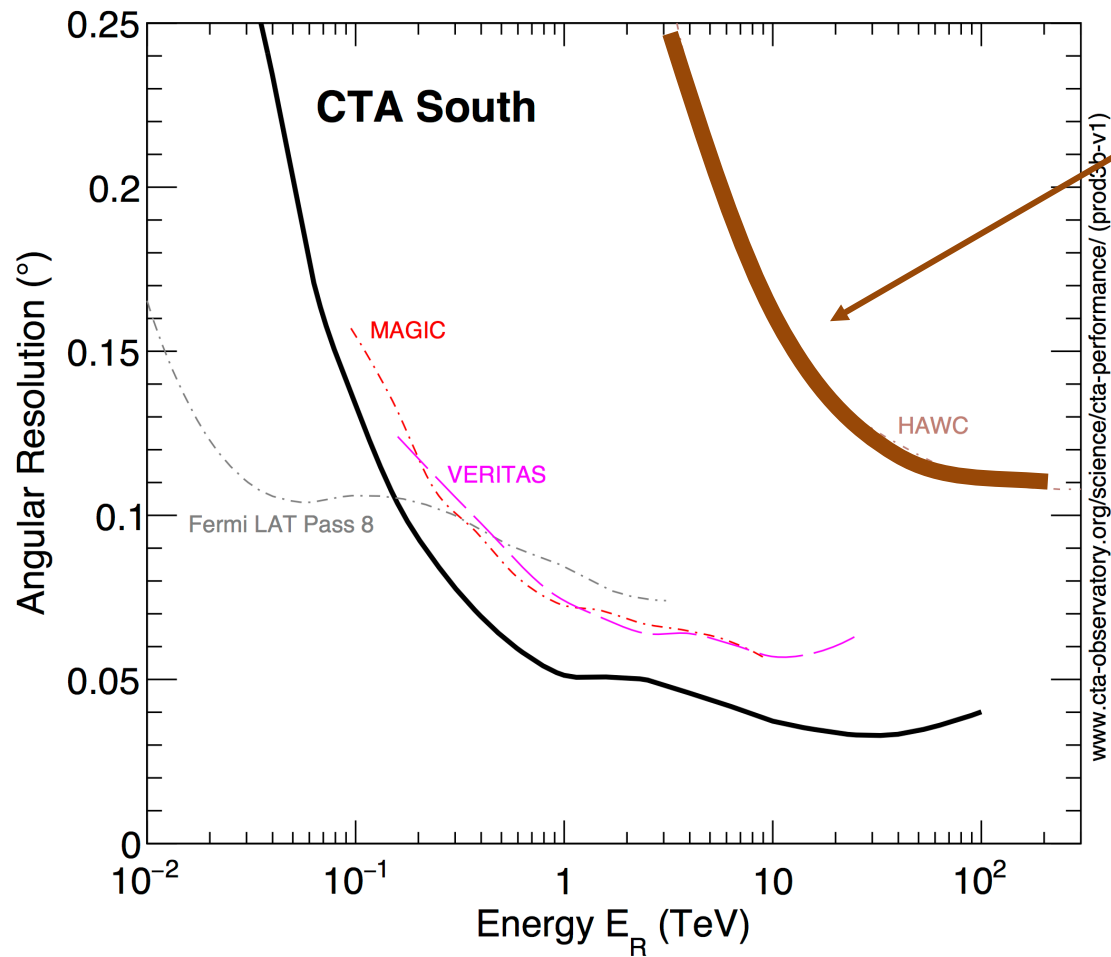
**Alert generation in 1 minute



e.g. Dark Matter Annihilation



- ⊙ Approx. expected self-annihilation cross-section for a thermal relic of the big bang
- ⊙ Very real potential to discover the nature of dark matter with CTA
- ⊙ Highly complementary to other searches

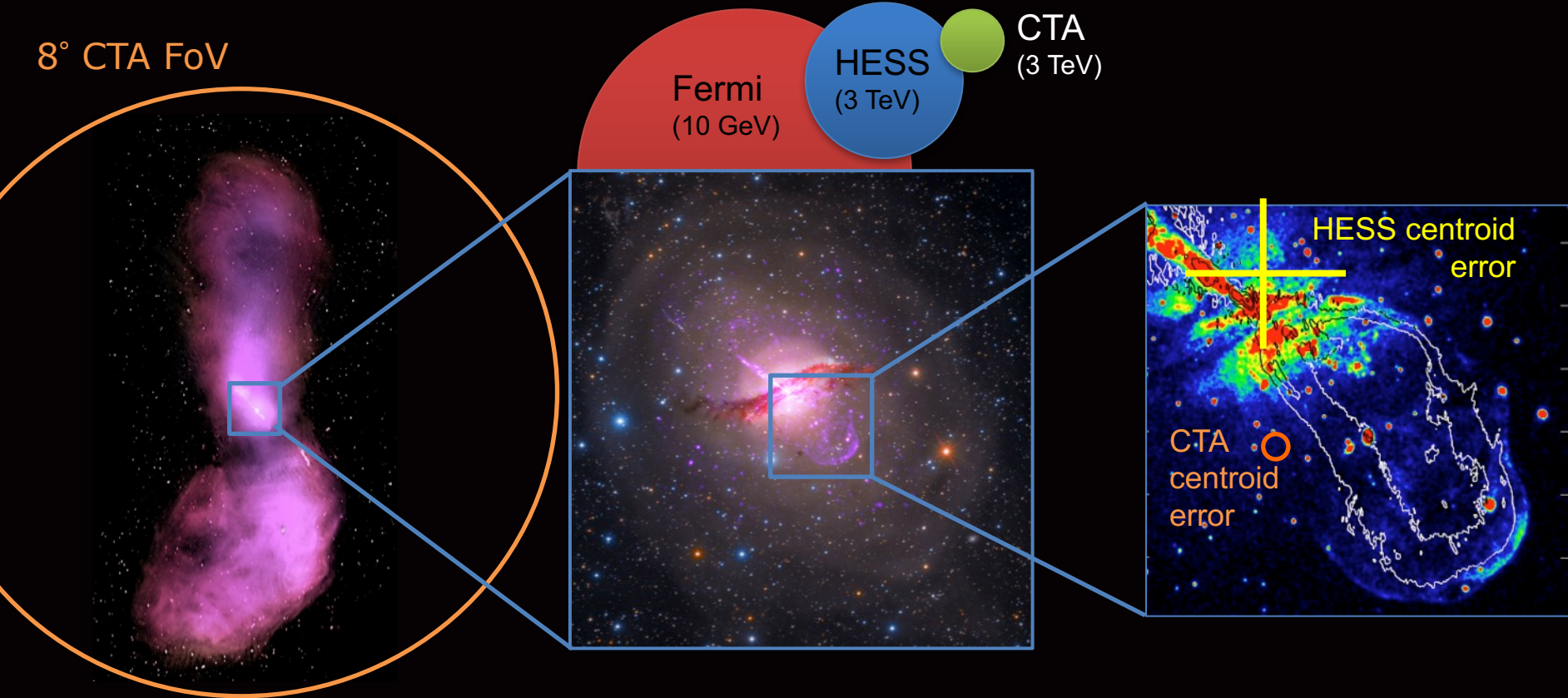


Complementarity
with Fermi

Unrivalled Deep TeV Sensitivity

Complementarity
with HAWC/LHAASO+

Resolving Power



● Example: nearby active galaxy Centaurus A

**Breaking news (TeVPA) -
extension along jet measured
using HESS at $\sim 4\sigma$*

Design Drivers

⊙ All sky coverage

→ Two sites:

- + CTA-South: Paranal Chile
- + CTA-North: La Palma, Canary Islands
(main requirements: minimum clouds, altitude $\sim 2\text{km}$)

⊙ Wide energy coverage

→ Multi km^2 coverage at highest energies, sensitivity to very low Cherenkov densities or lowest energies

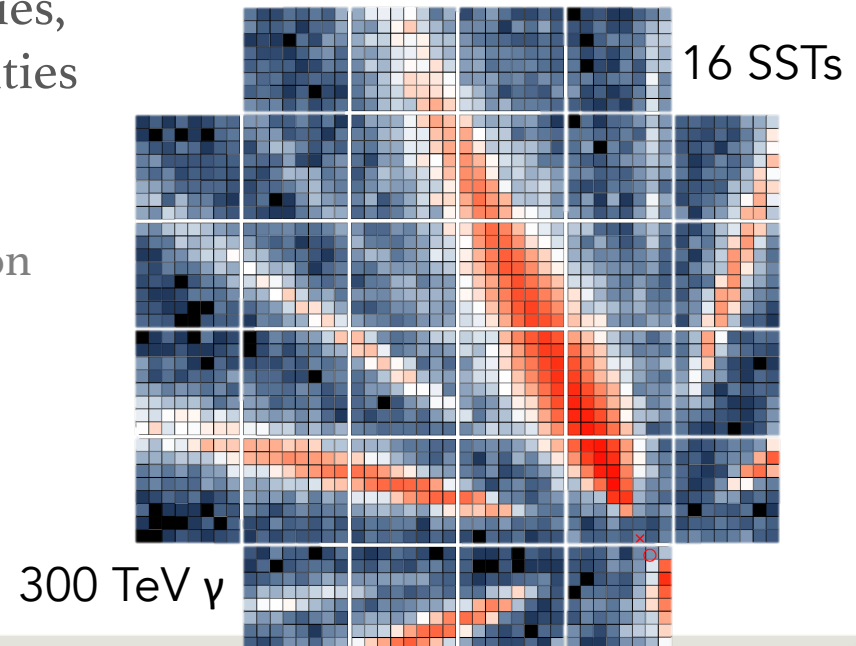
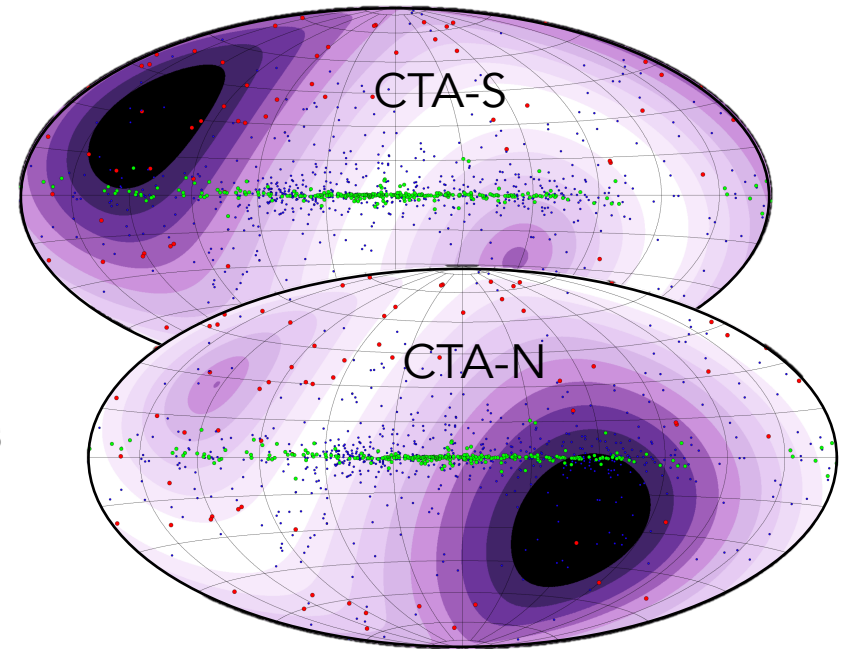
→ Multiple telescope sizes

- + Many small and a few large, core region covered by medium size

⊙ Precision/sensitivity

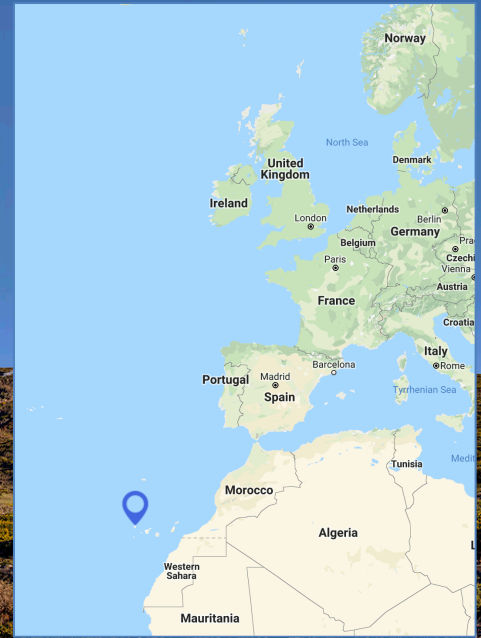
→ High telescope multiplicity events

→ Many telescopes



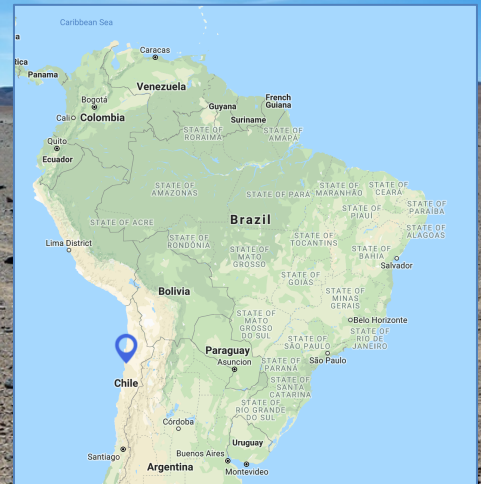
CTA-North

Observatorio del Roque de los Muchachos of the Instituto de Astrofísica de Canarias (IAC) at 2200 m



CTA-South

European Southern Observatory (ESO) site at 2100 m



CTA-North
Observatory
Instituto de

Vulcano Lulllaillaco
6739 m, 190 km east

Cerro Armazones
E-ELT

Cerro Paranal
Very Large Telescope

Proposed Site for the
Cherenkov Telescope Array



© Marc-André Besel

CTA-South
European



Paranal

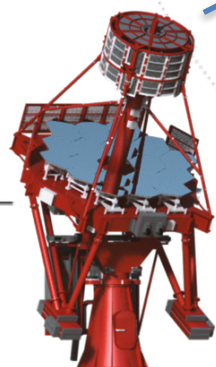
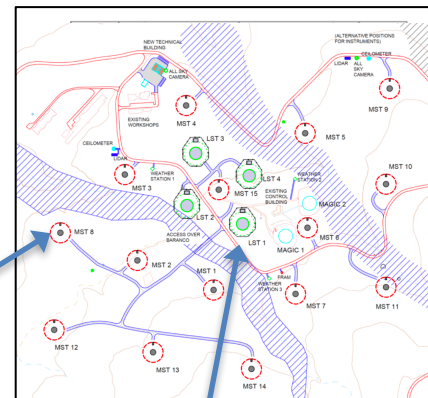
MST

12 m

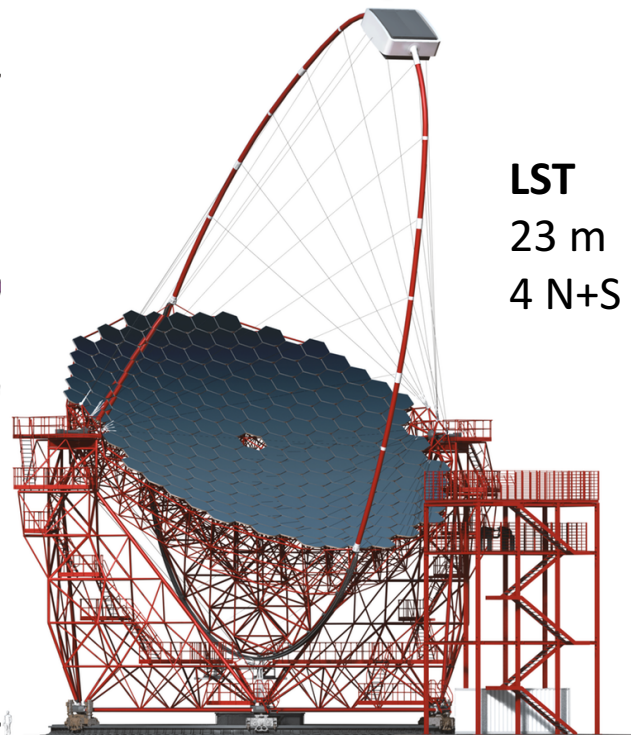
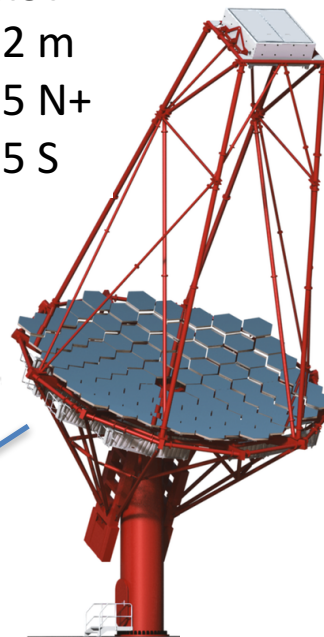
15 N+

25 S

La Palma



SST
4 m
70 S



LST

23 m

4 N+S

4 LSTs, 25 MSTs, 70 SSTs

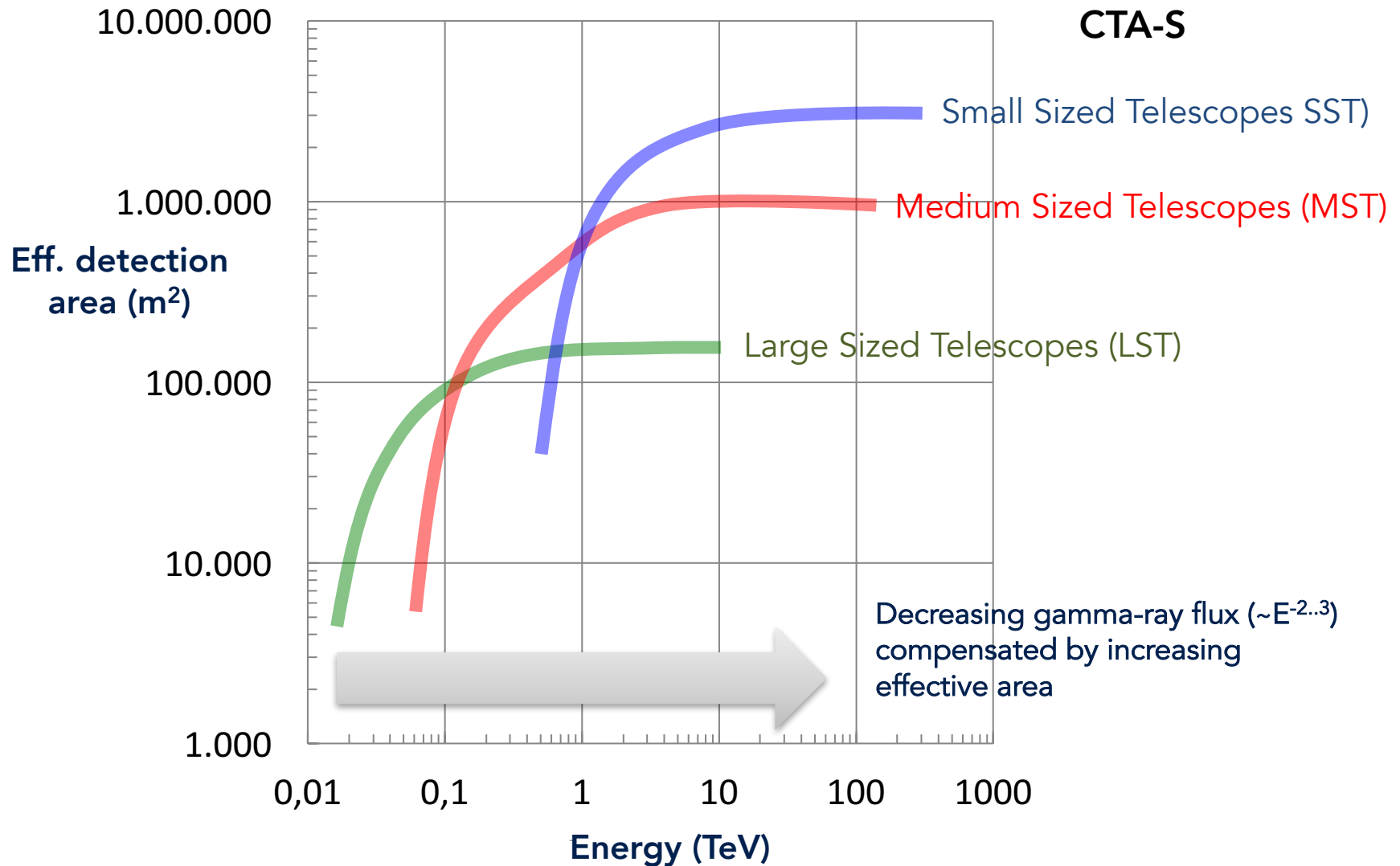
17th September 2018

Astroparticle Physics in Germany - Mainz

20



Telescope Roles



CTA Partners



- CTA Consortium >1400 individuals from 31 nations
- Including the teams of VERITAS, H.E.S.S. & MAGIC



CTAO and CTAC

- CTA is a partnership between a scientific consortium (CTAC) and a legal entity with overall responsibility for construction and operation (CTAO)
 - CTAC Spokespersons: Werner Hofmann & Rene Ong
- CTAO gGmbH founded 2014 as interim legal entity
 - CTAO European Research Infrastructure Consortium (ERIC) as final legal entity - expected early 2020
 - Board of governmental representatives (+CTAO) preparing
- Director Prof Frederico Ferrini (from 1st March 2018)
 - Formally director of the European Gravitational Obs.
- Project Manager Wolfgang Wild (from 1st Sept. 2017)
 - Former proj. man. for European part of the ALMA Obs.
- Project Office established in Bologna
 - Bologna as future ERIC HQ
 - Science Data Management Centre to be hosted on the DESY campus in Zeuthen



+JH: CTAO Project Scientist

CTAO

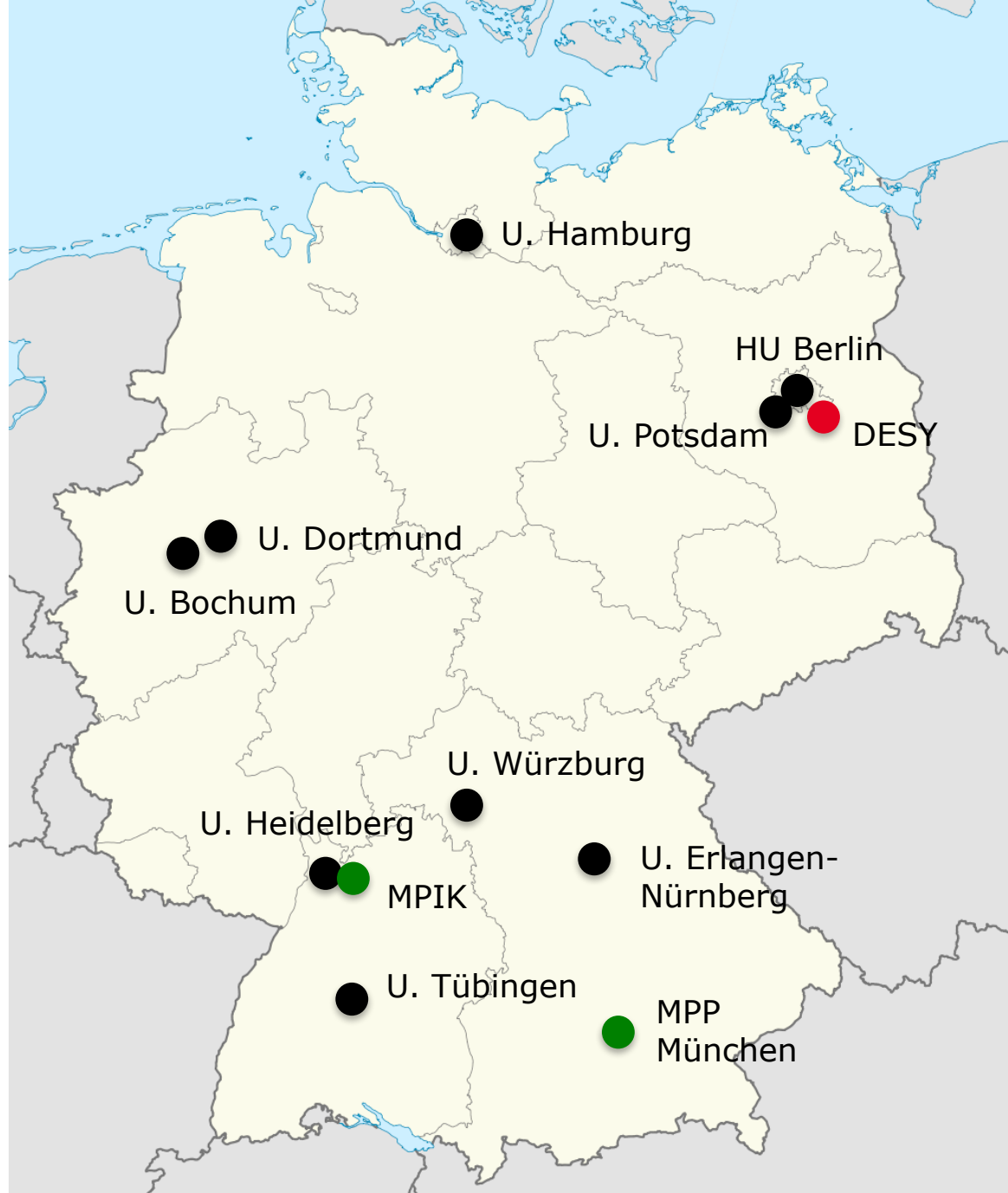
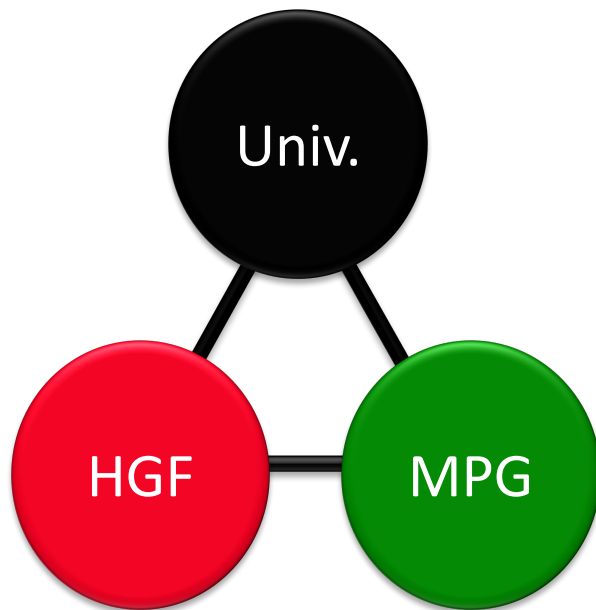
Temporary
accom. for
SDMC
Zeuthen
Since
9/2018



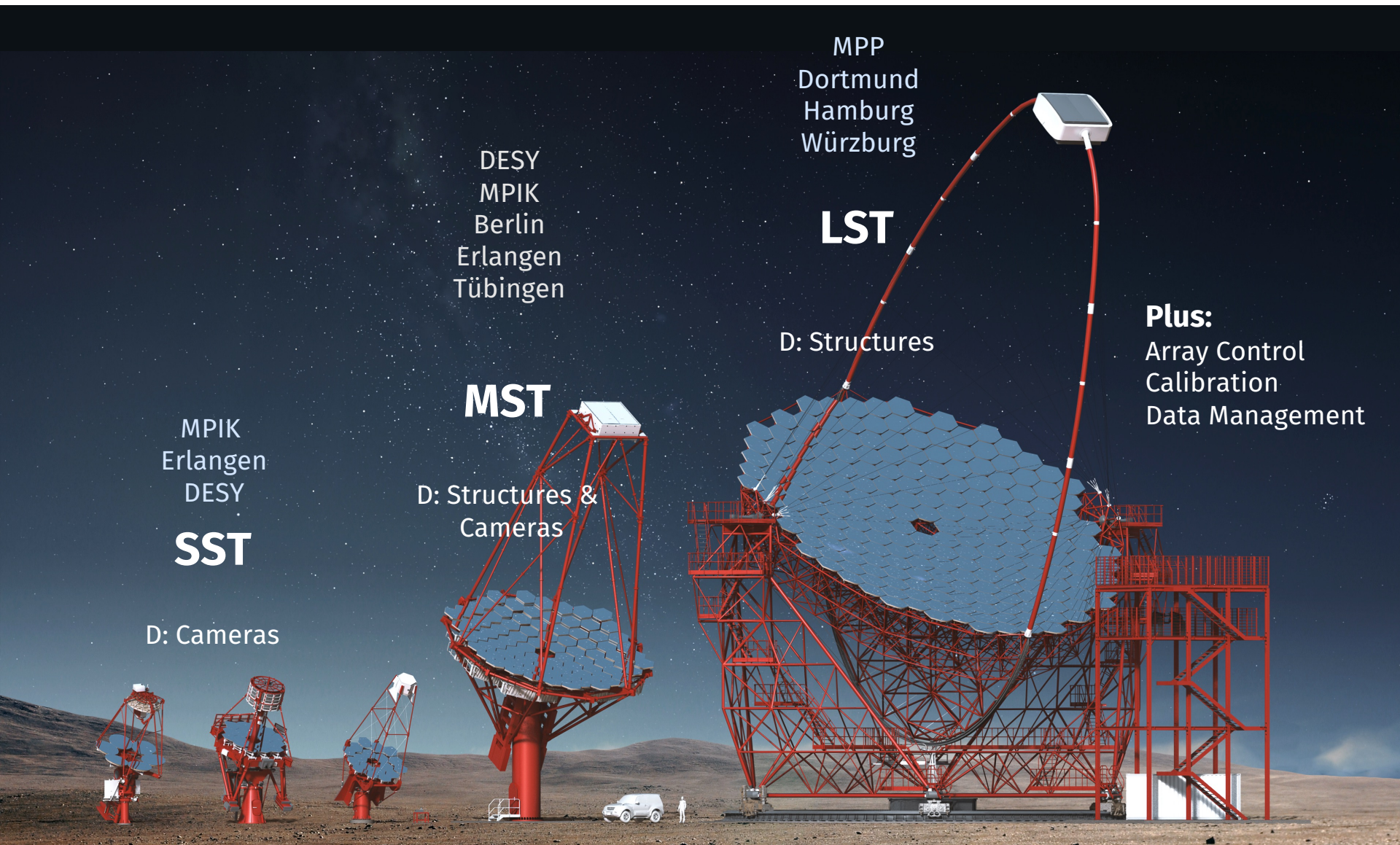
Bologna
Office
since
3/2017



Germany in CTA

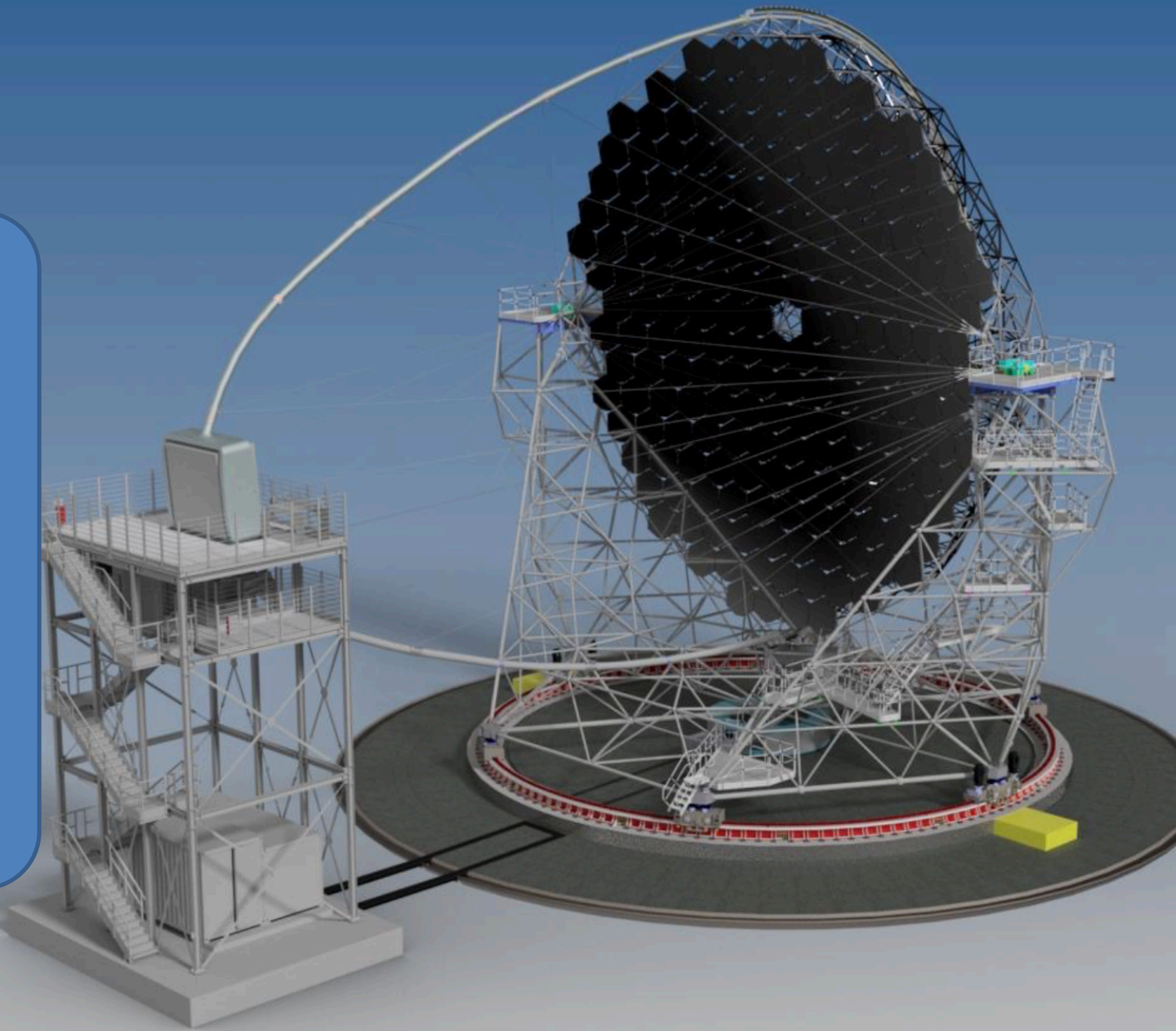


Germany in CTA



LST

- 390m² dish
- 28 m focal length
- 4.5° field of view
- 1855x 0.1° pixels
- Fast slewing
→ 20 s
- 4 LSTs South,
4 LSTs North



LST Project : Big International Effort

BR(Brazil), CH(Switzerland), DE(Germany), ES(Spain), FR(France), IN(India), IT(Italy), HR(Croatia), JP(Japan), SE(Sweden)

LST sub-consortium:
10 countries
195 members
55 FTEs

Focal Plane Instr.
Electronics (JP/IT/ES)
Camera body (ES)

Camera Supporting
Structure (FR/IT)

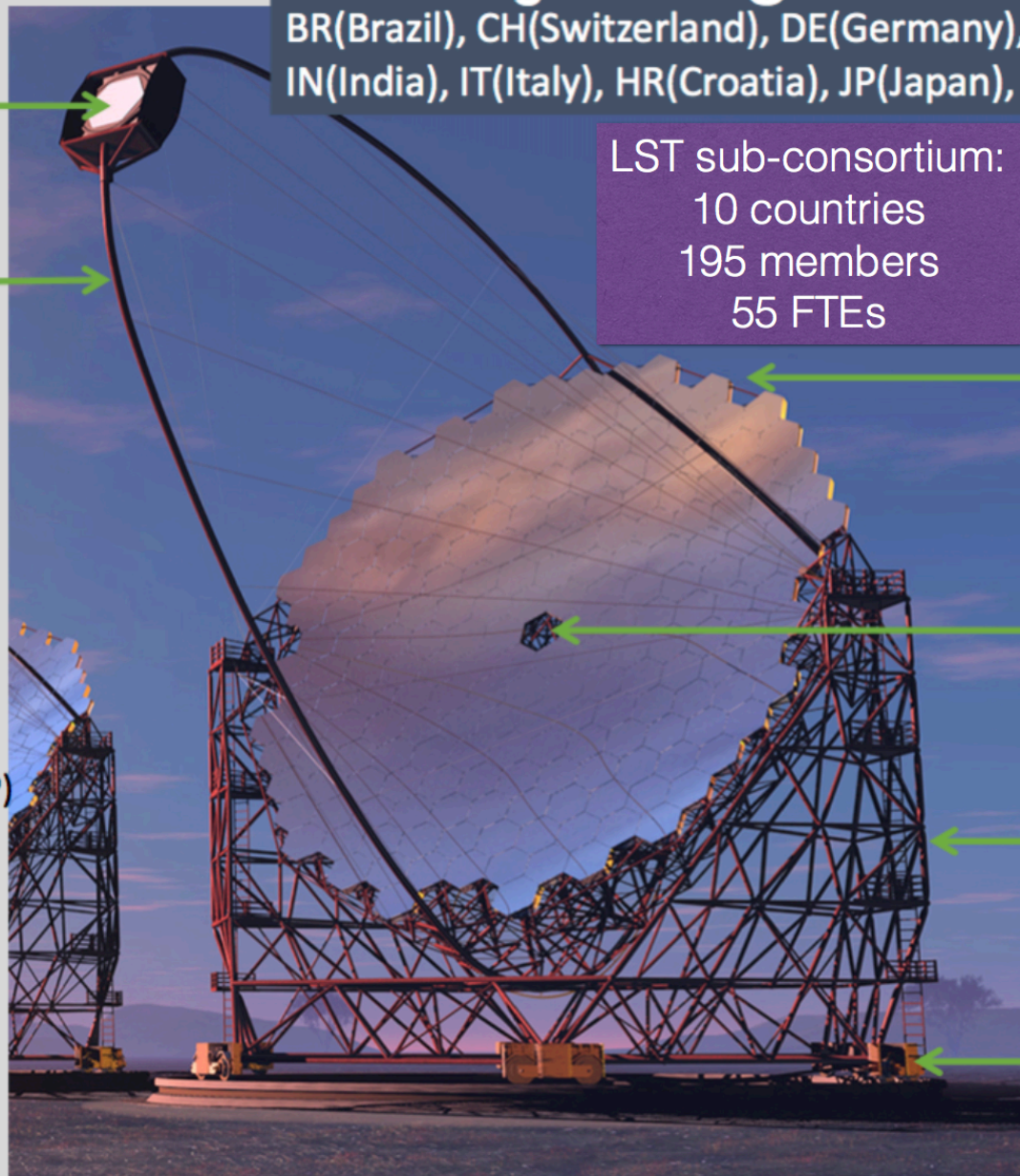
Mirror (JP)
Interface Plate(DE/BR/JP)
Actuator (JP/CH)
CMOS-Cam (JP)

Star Guider (SE)
Calibration Box (IN/IT)

Flywheel, UPS (JP)
Computers, network (JP)

Structure (DE)
Access Tower (DE/ES)

Drive (DE/FR/ES)
Bogie (DE/ES/IT)
Rail (DE/ES)
Foundation (ES)



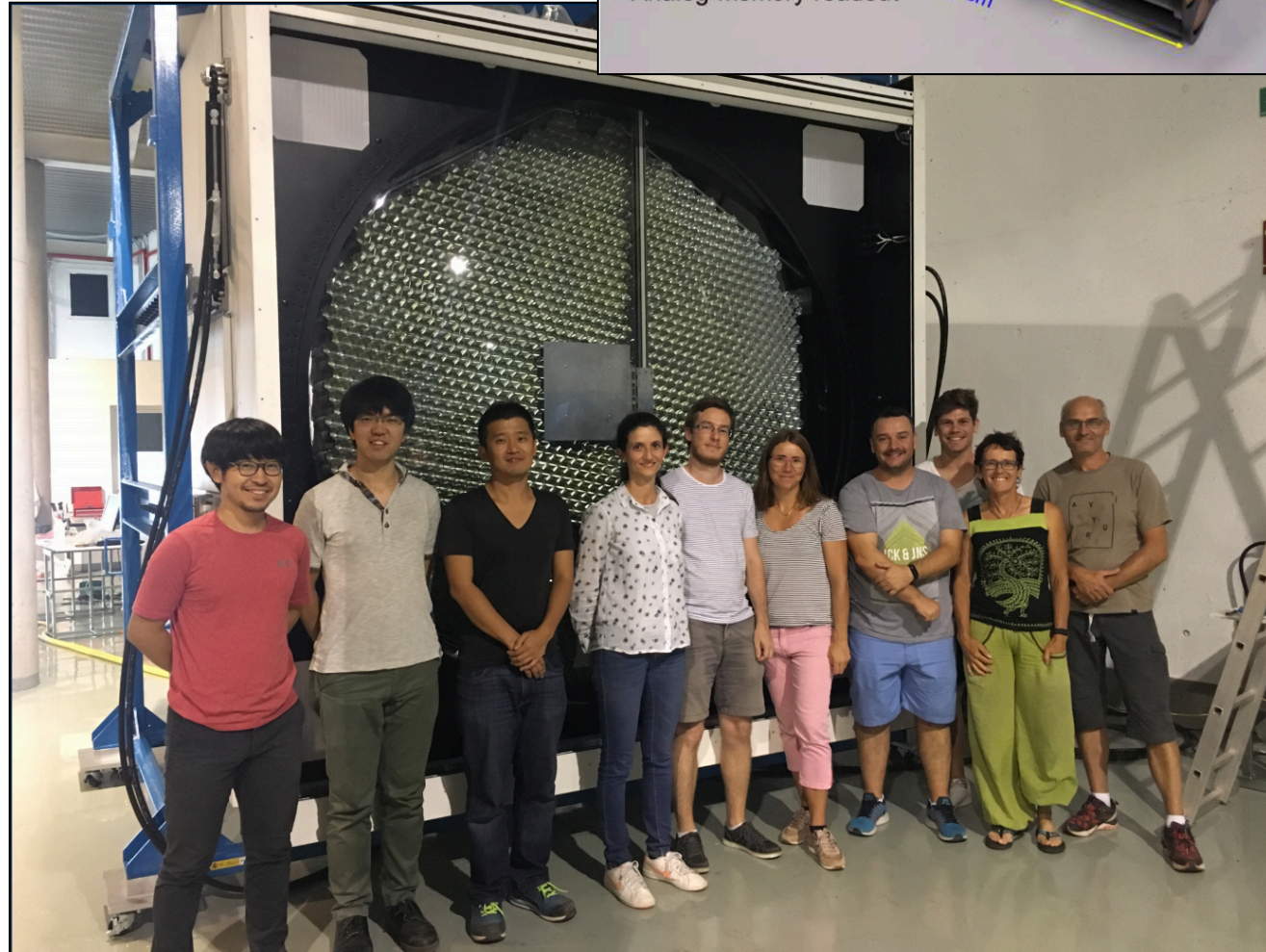
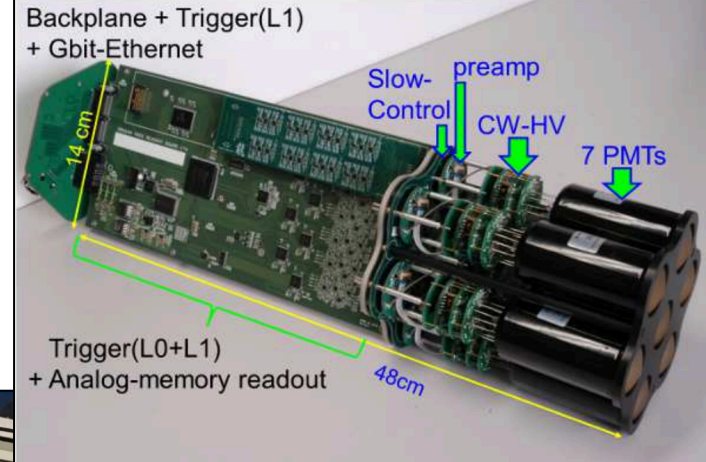
The LST1 today



D. Mazin, Picture taken on Sept 12, 2018

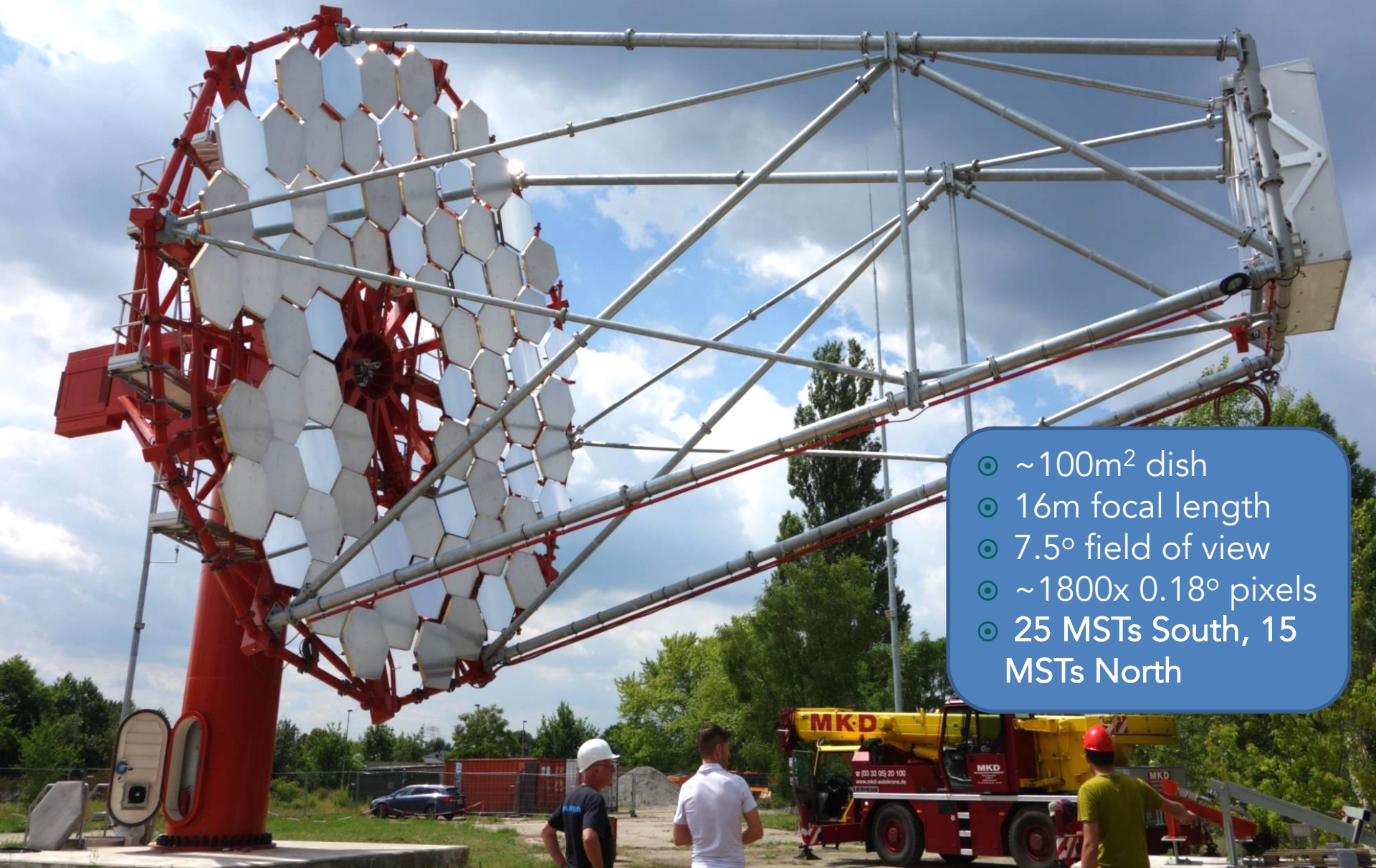
LST Camera

- Prototype camera ready at sea level in La Palma
 - High QE PMTs
 - 1 ns sampling ASIC (DRS4)
- Telescope integration imminent
 - Inauguration 10th October



MST

Prototype @ Adlershof, Berlin



- ~100m² dish
- 16m focal length
- 7.5° field of view
- ~1800x 0.18° pixels
- 25 MSTs South, 15 MSTs North

MST

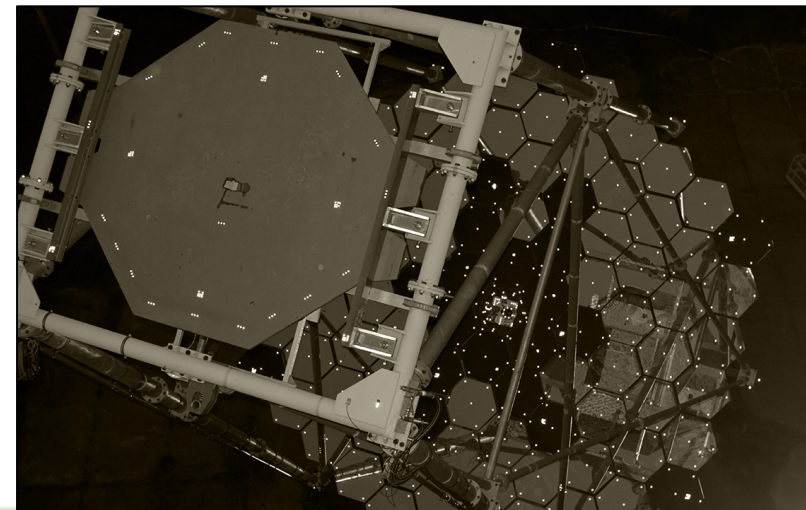
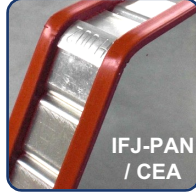
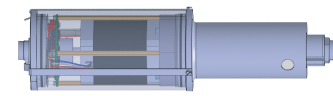
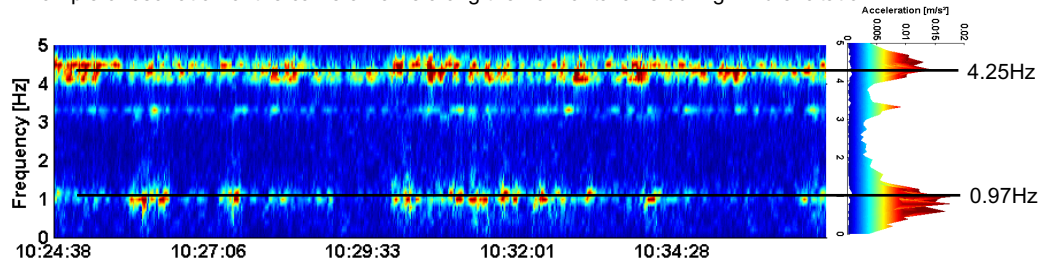
◉ Tel. Structure is a DESY-led international partnership



◉ Adlershof activities

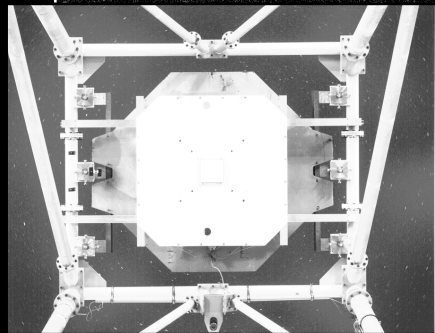
- ✦ Mirror and actuator technology evaluation
 - ✦ Condition monitoring and metrology of structure
- Refinement/finalisation of design

Example of oscillation of the camera frame along the horizontal axis during wind excitation

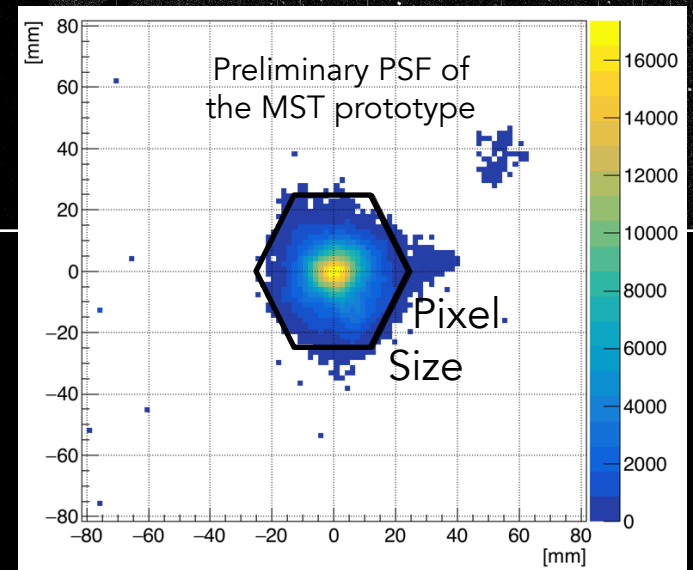


MST

- Guide star camera testing on MAGIC



- PSF measurement Adlershof



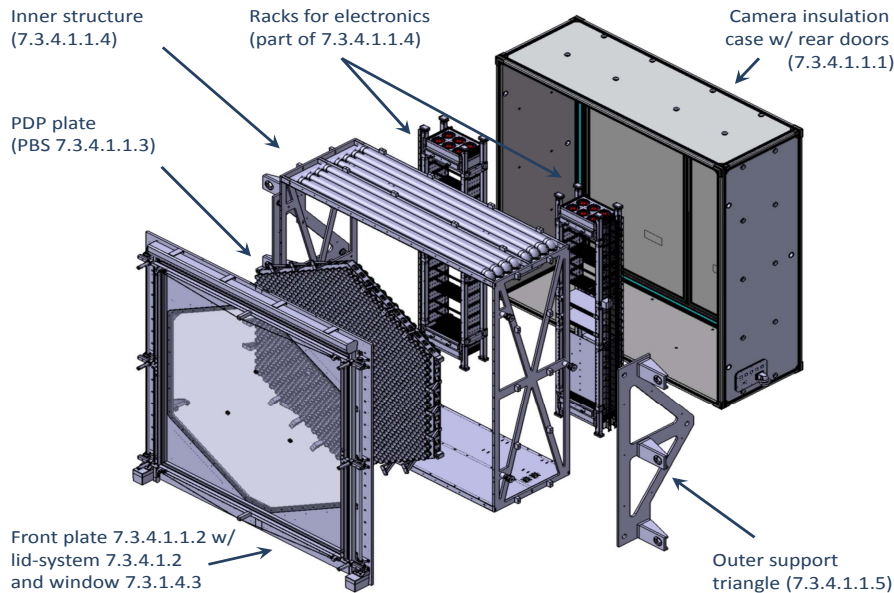
MST Cameras

Common (also LST)
1.5" PMT + light guide
→ 5cm pixel

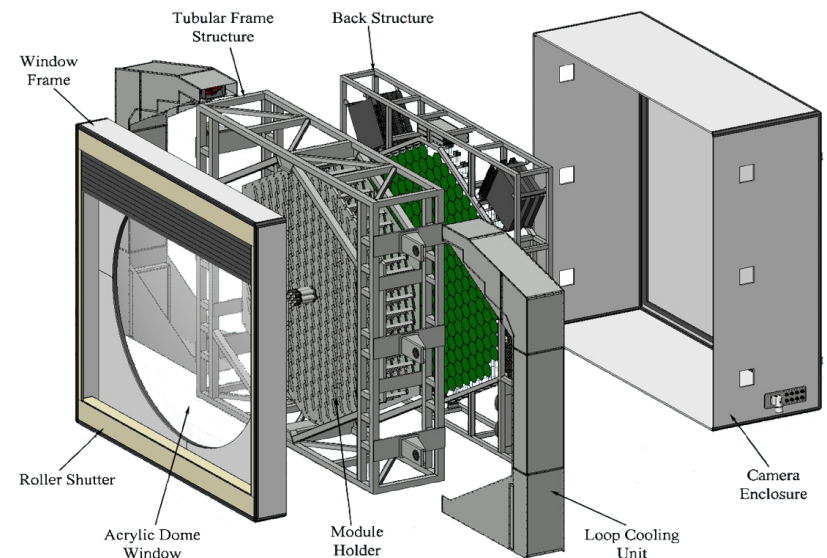


- Two camera designs with different architecture and technology, both fulfilling CTA requirements
 - NectarCam based on Nectar ASIC, FlashCam with commercial FADCs
- Unified interface to telescope structure, cameras exchangeable

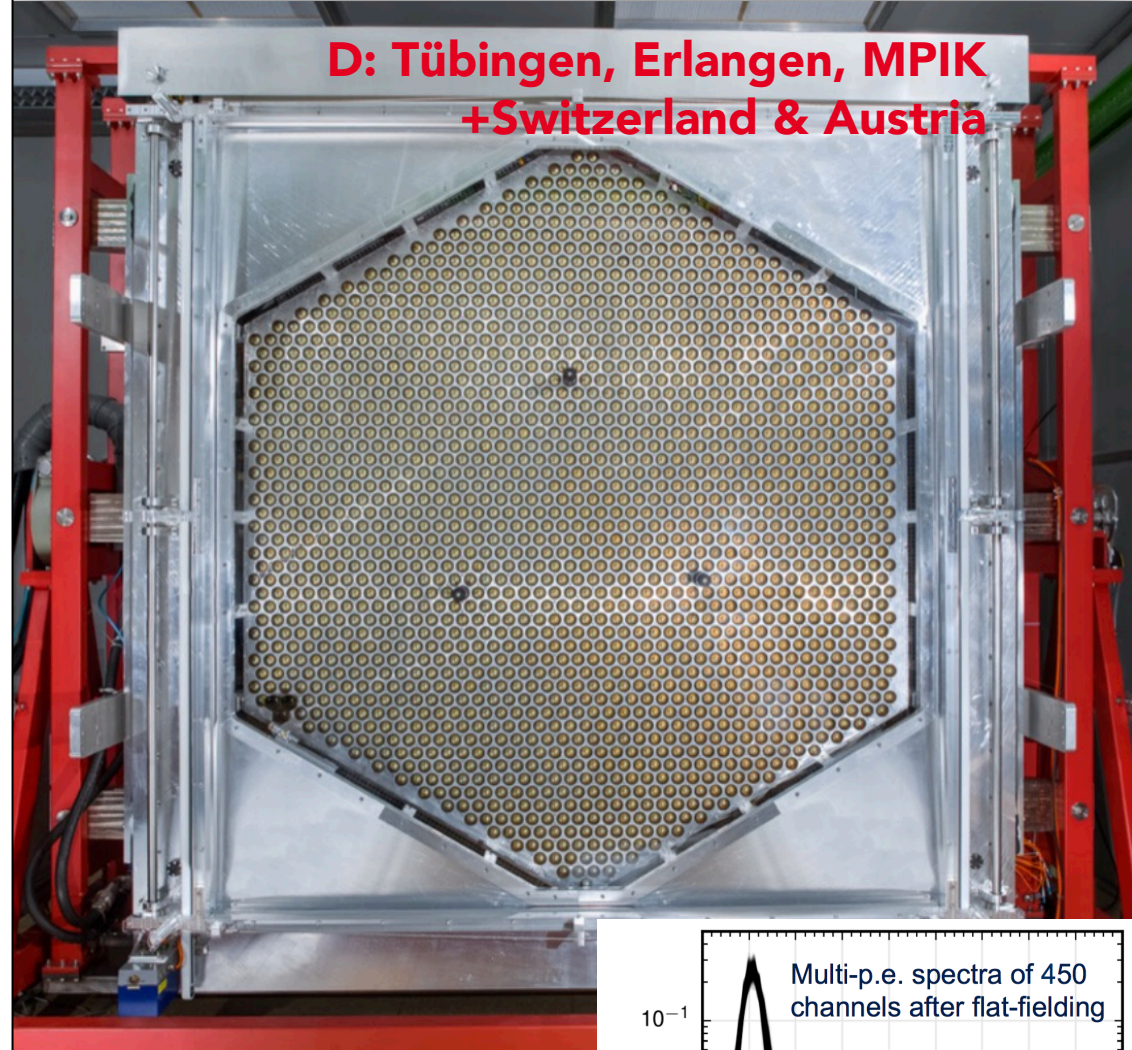
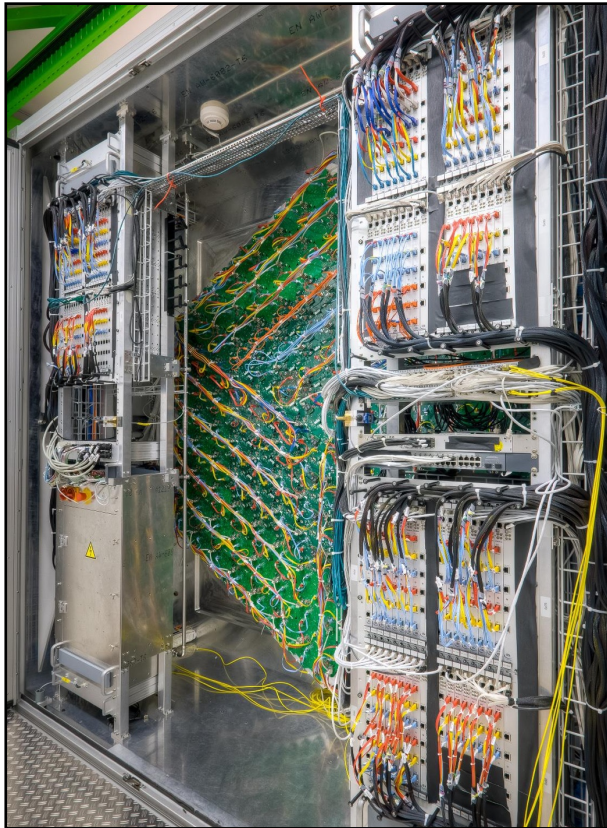
FlashCam



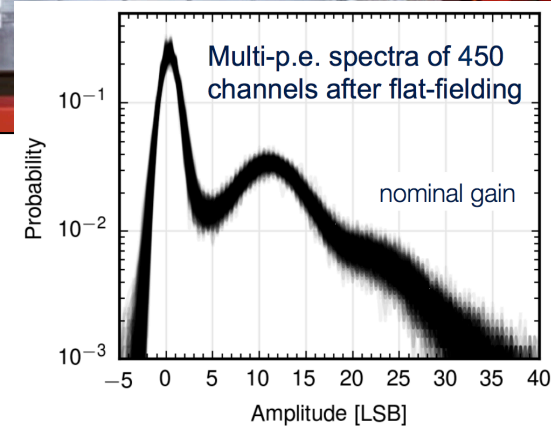
NectarCam



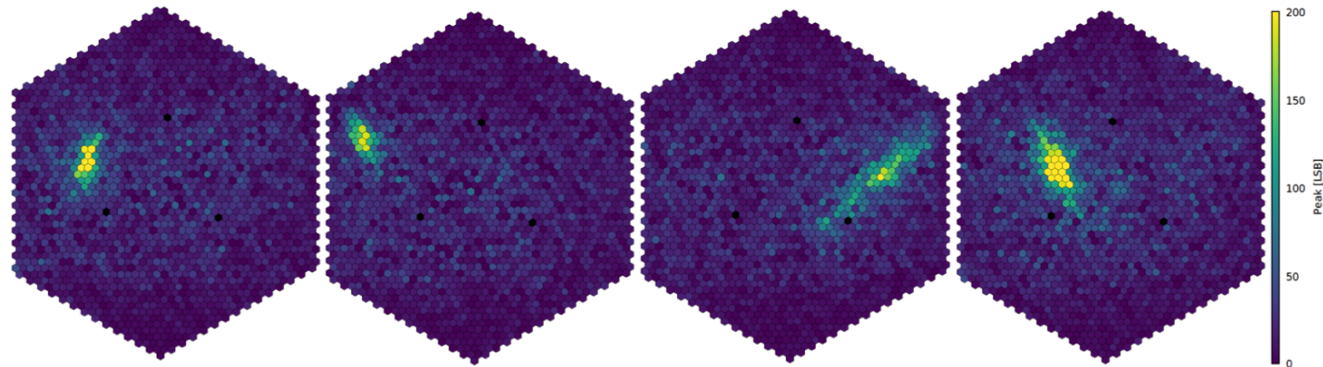
FlashCam



Rack-based digitising electronics, commercial 250 MHz FADCs
25 kHz readout of waveforms for all pixels – deadtime free
Prototype completed early 2017
→ extensive performance + stress testing

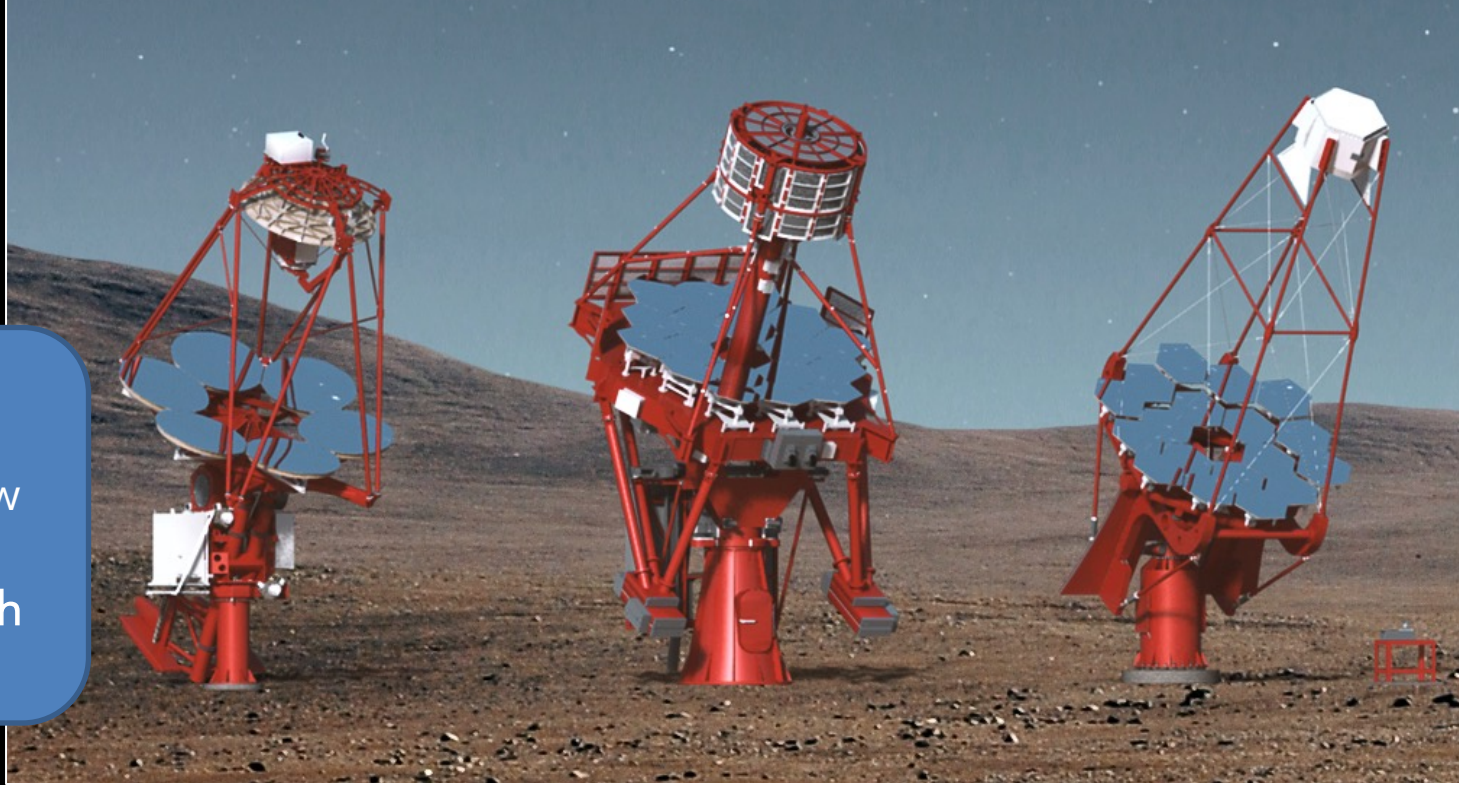


- ⊙ Integration/
Test campaign
FC@Adlershof
Sept. 2017
- ⊙ Despite non-
optimal Berlin
conditions –
Cherenkov
images!

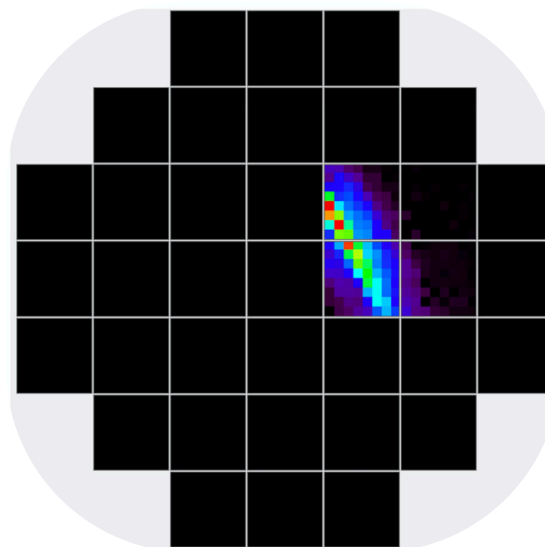
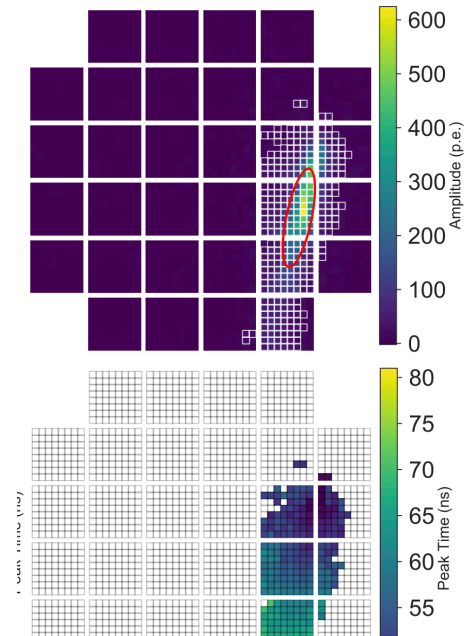


SSTs

- $\sim 8\text{m}^2$ dish
- $\sim 9^\circ$ field of view
- $\sim 0.2^\circ$ pixels
- 70 SSTs in South

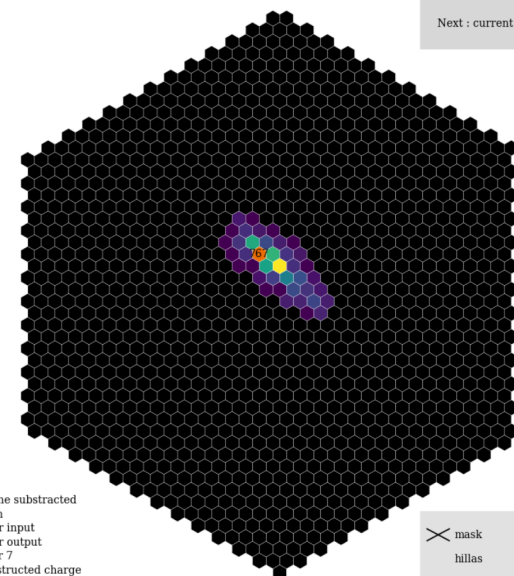


- Smaller size makes different photosensors/optics viable
 - + Silicon photomultipliers and dual reflector option
- Advanced prototyping efforts for three designs
 - + SST-IM in Krakow, dual mirror: ASTRI in Sicily, GCT in Paris
- Consolidation underway
 - + Decision on technologies expected in early 2019



- sum
- std
- mean
- max
- time

- raw
- baseline subtracted
- photon
- trigger input
- trigger output
- cluster 7
- reconstructed charge

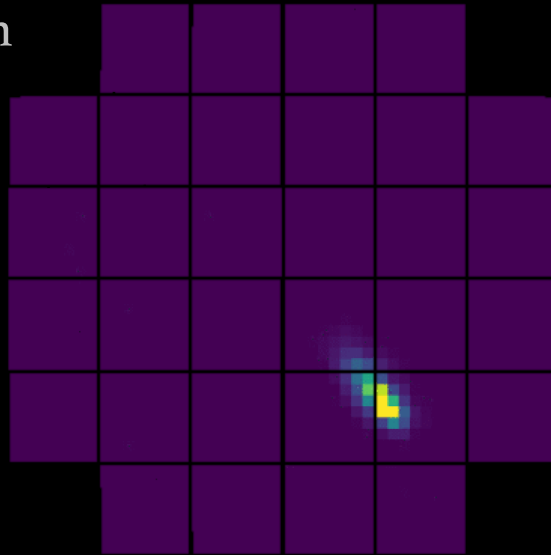


Next : current event #2014



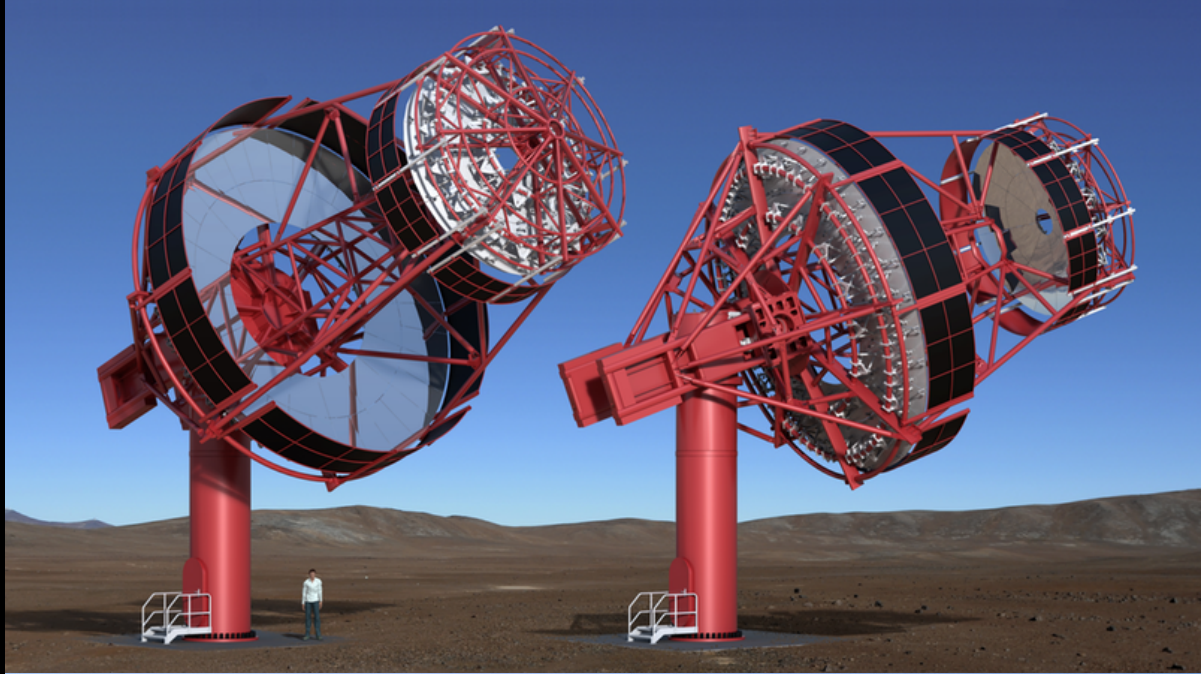
CHEC


- Dual mirror option for SSTs –
 - ✦ CHEC-M (multi-anode PMTs) tested in Paris on GCT
 - ✦ CHEC-S (SiPMs) ready for field tests in Sicily
 - ✦ $2048 \times 6\text{mm}$ pixel, 1 ns sampling (TARGET ASIC)
- International Partnership
 - ✦ Germany, UK, NL, Japan, Australia
- German Groups
 - ✦ Uni. Erlangen
 - ✦ DESY
 - ✦ MPIK



SCT

- ◉ Dual mirror alternative for medium energy coverage
- ◉ Prototype being commissioned now at VERITAS site
 - ✦ US led
 - ✦ DESY, MPIK, Erlangen contributions



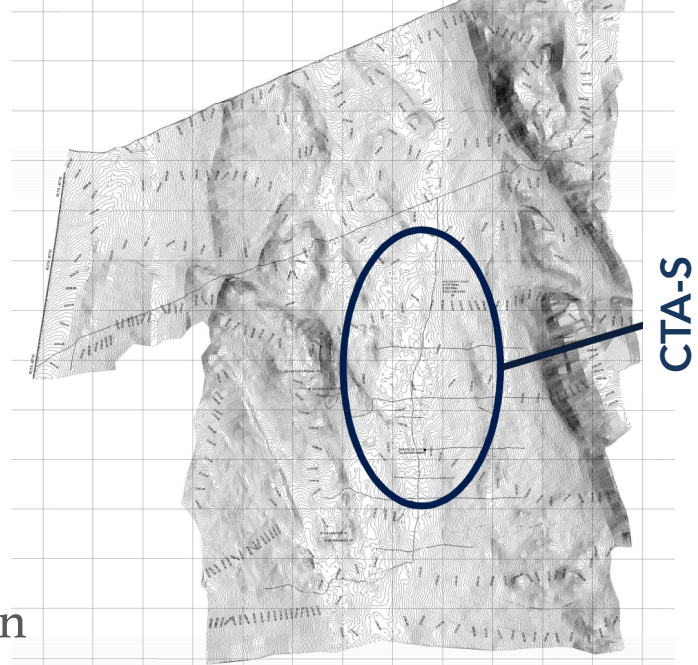
Strategy Report on Research Infrastructures
ESFRI ROADMAP 2018

8 Landmarks & 6 Projects
Delivering Excellence in Research

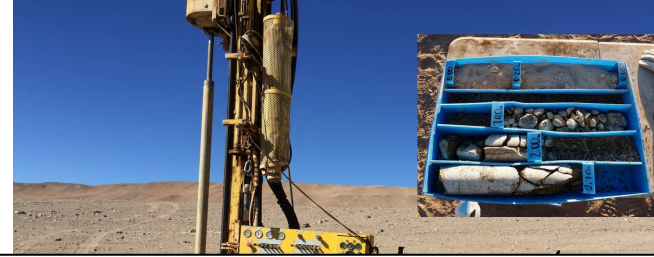


Next Steps

- Final technology choices
 - + SST by early 2019
- Site development
 - + Southern site
 - + Conclude agreements (v. soon!)
 - + Detailed infrastructure – design → build
 - + Northern site
 - + Detailed planning of Phase-I ongoing
 - + Phase-I is infrastructure + LSTs 2-4 + one MST
- Legal/financial
 - + Final MoU signatures exp. 2018
 - + ERIC creation exp. early 2020
 - + IKC agreements → telescope mass production



Next Steps



Project Phases

Pre-Construction

Current Phase

Pre-Production

2019-2021

Production

2021-2025

Current Phase

Pre-Construction



First Pre-Production
Telescopes on Site



CTA Offices Open
in Bologna

Infrastructure Design
& Procurement



ERIC
Established

Q1 2017

Q3 2017

Q1 2018

Q3 2018

Q1 2019

Q3 2019

Q1 2020

LST 1 Prototype
Completed on
North Site



Financial
Threshold
Reached



Home

Programme

Venue

Pre-Registration

Travel

CTA

Contact

Bologna, 6-9 May 2019

cta

1st Science Symposium

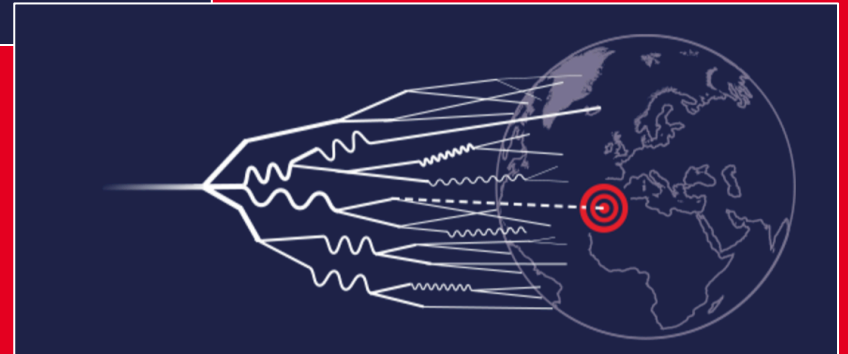
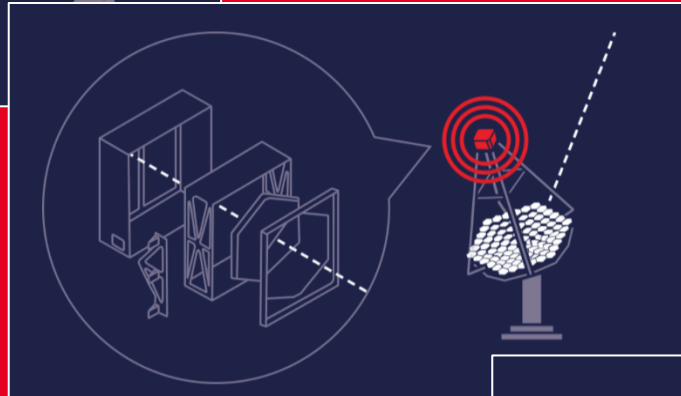
Exploring the High-Energy Universe with CTA

Pre-registration

#ctasymposium2019

www.cta-symposium.com

Questions?





Science with the Cherenkov Telescope Array

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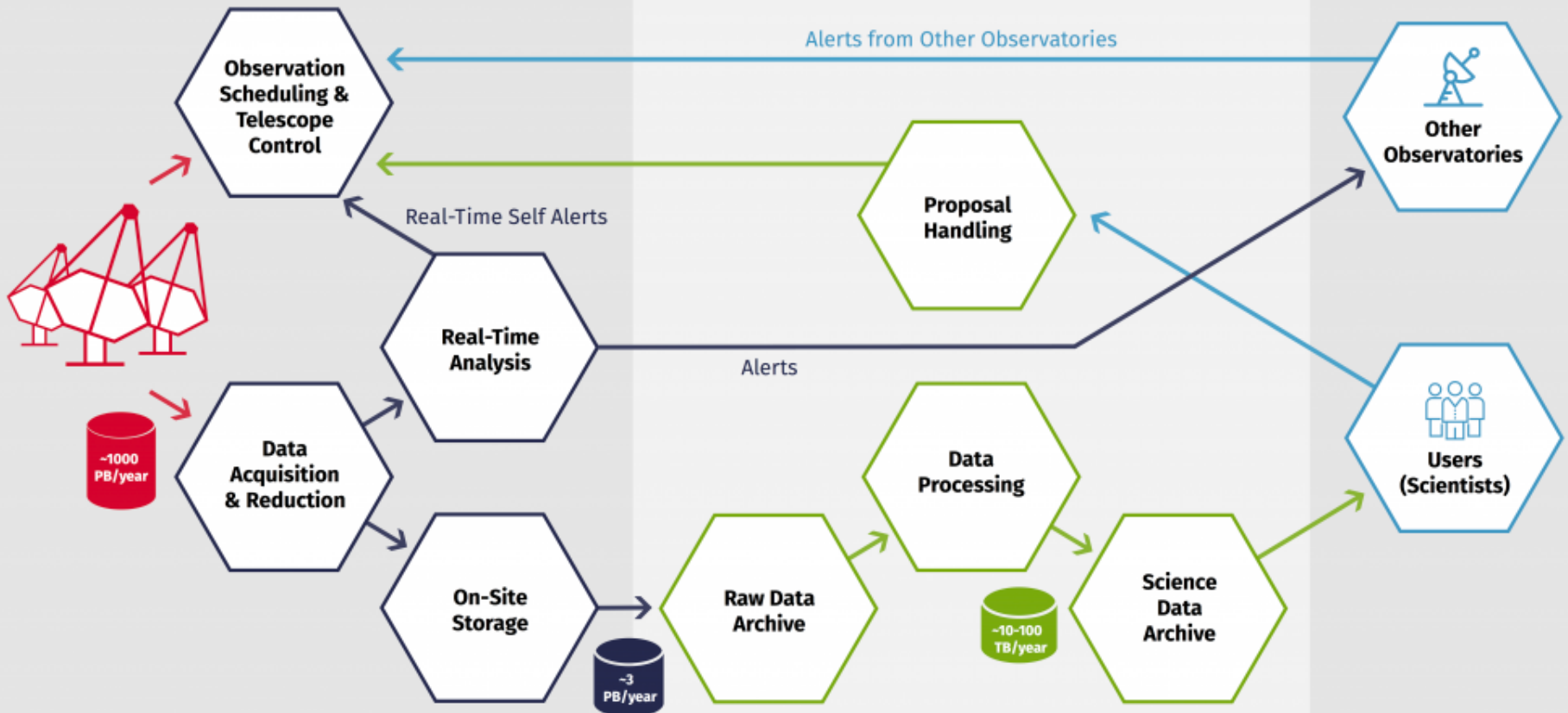
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On Site

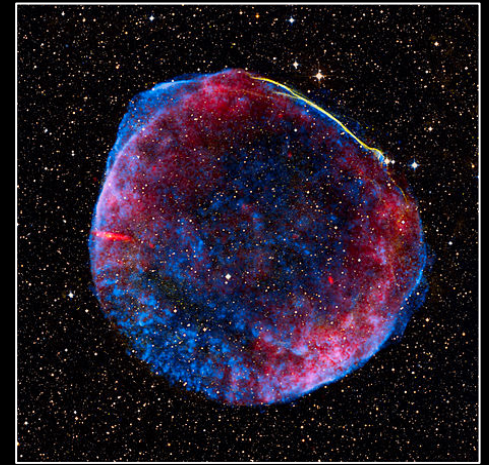
Off Site

Outside World



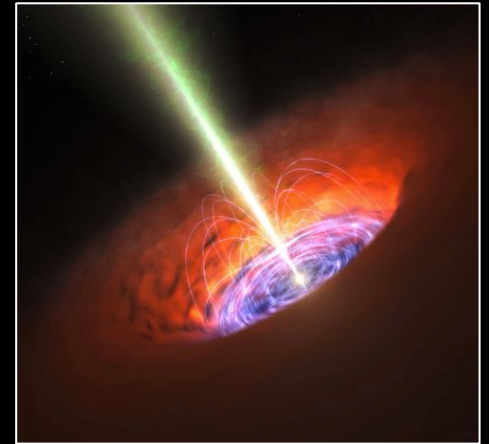
Theme 1: Cosmic Particle Acceleration

- How and where are particles accelerated?
- How do they propagate?
- What is their impact on the environment?



Theme 2: Probing Extreme Environments

- Close to neutron stars and black holes
- Relativistic jets, winds and explosions
- Cosmic voids



Theme 3: Physics Frontiers

- What is the nature of Dark Matter?
- Is the speed of light constant?
- Do axion-like particles exist?

