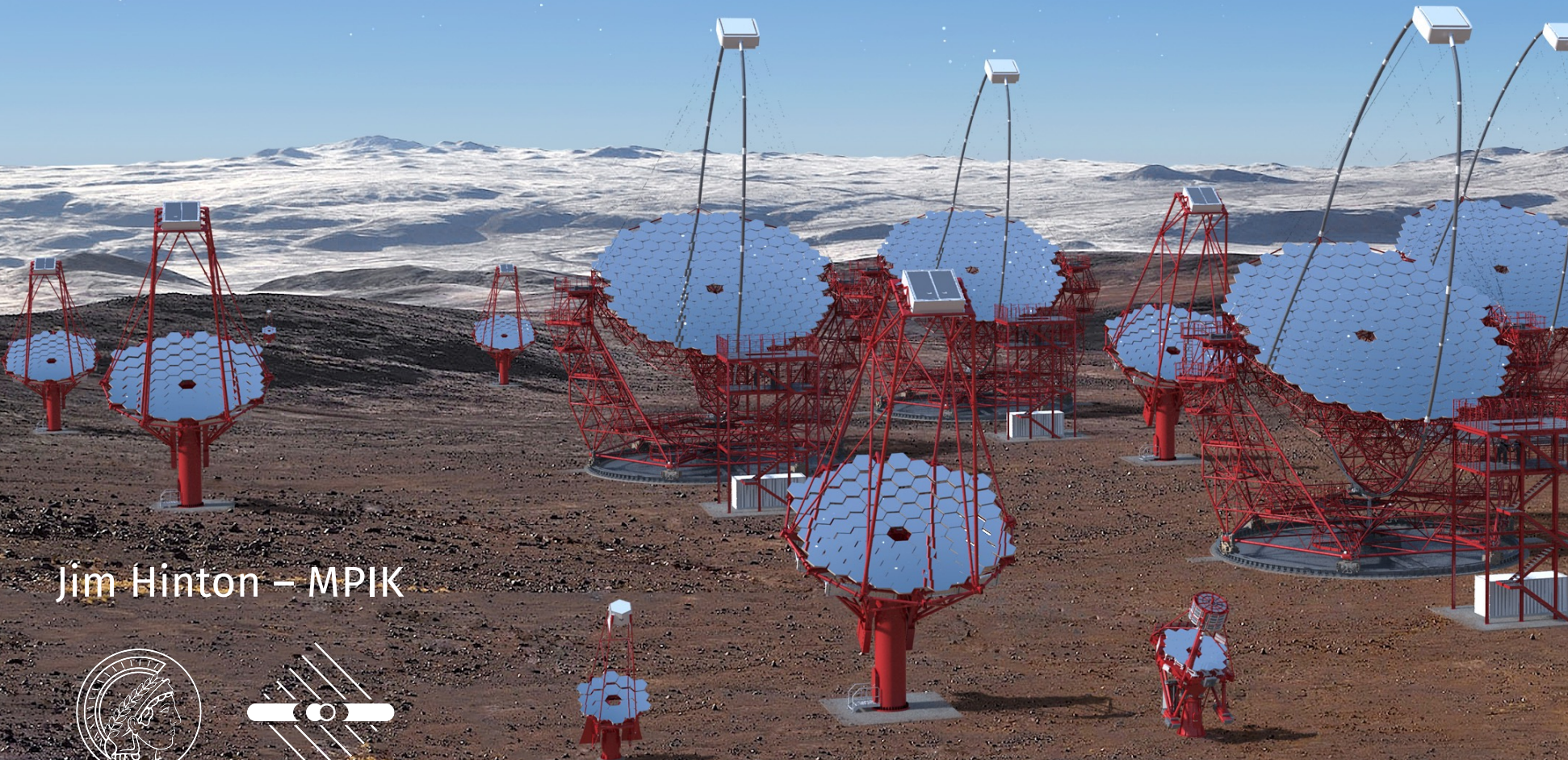




cherenkov
telescope
array

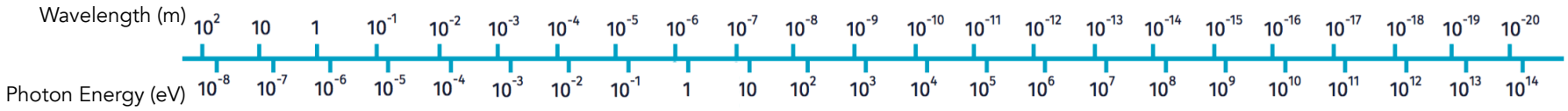
Status & Perspectives



Jim Hinton – MPIK



Helmholtz MU Annual Symposium, Mainz, Dec 12th 2016



Major Astronomical Facilities

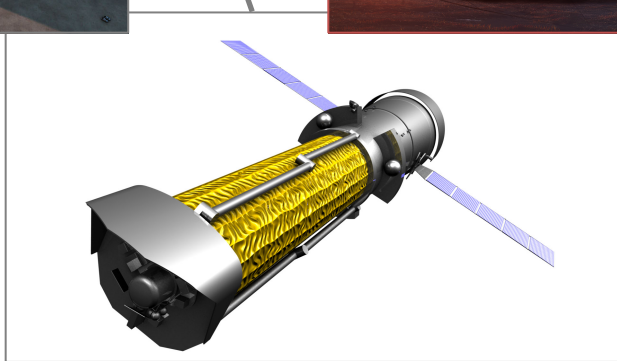
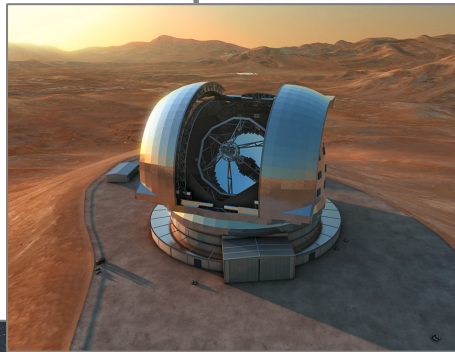
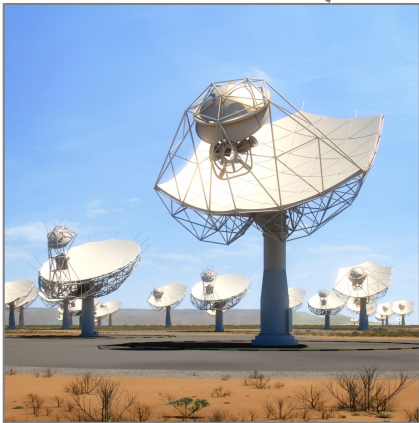
SKA

ALMA

E-ELT

Athena

CTA



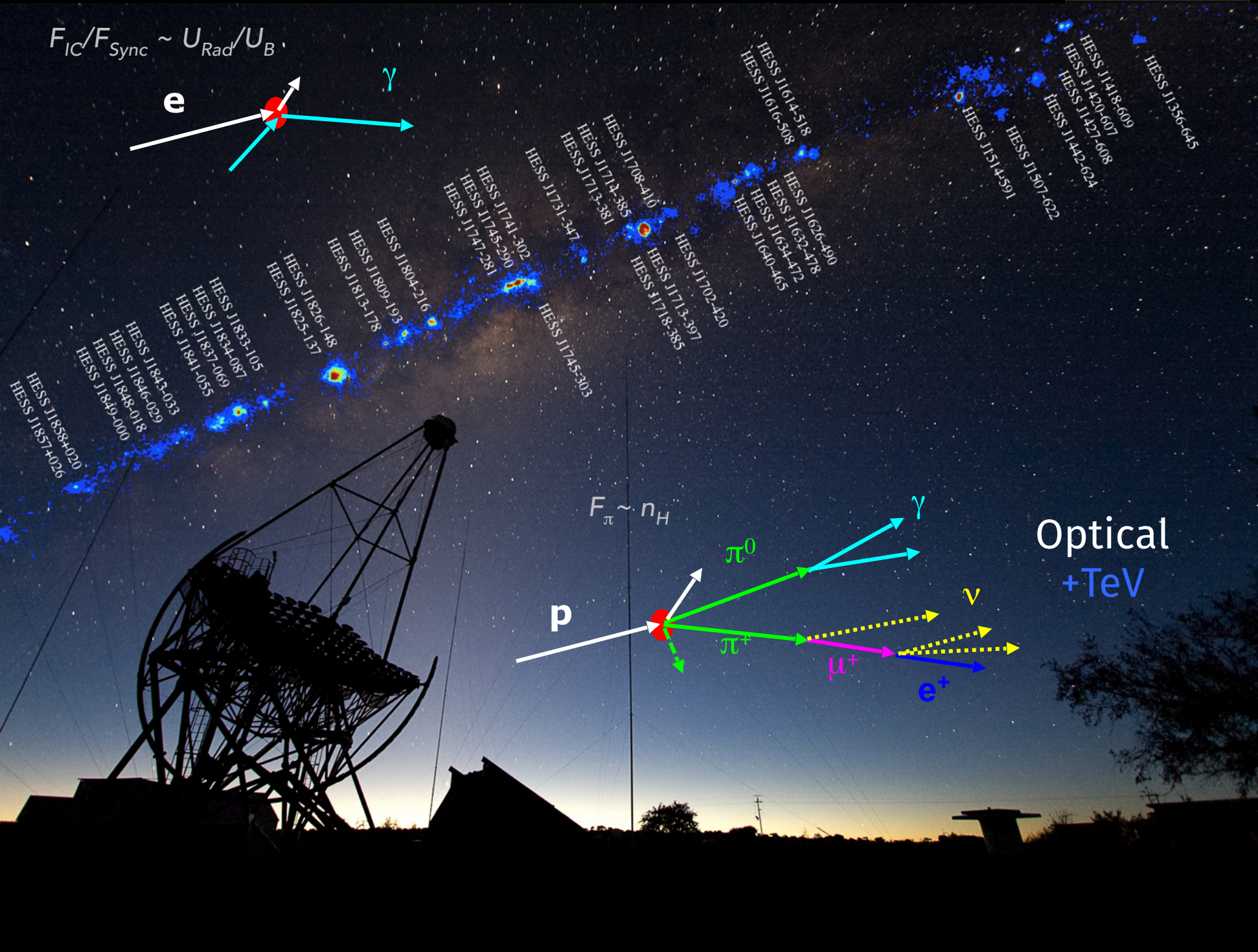
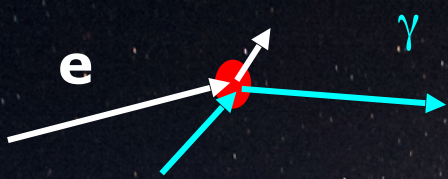


Optical

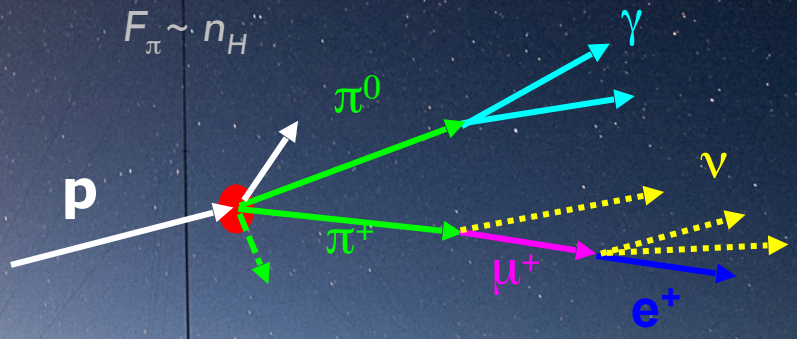


Optical
+TeV

$$F_{IC}/F_{Sync} \sim U_{Rad}/U_B$$



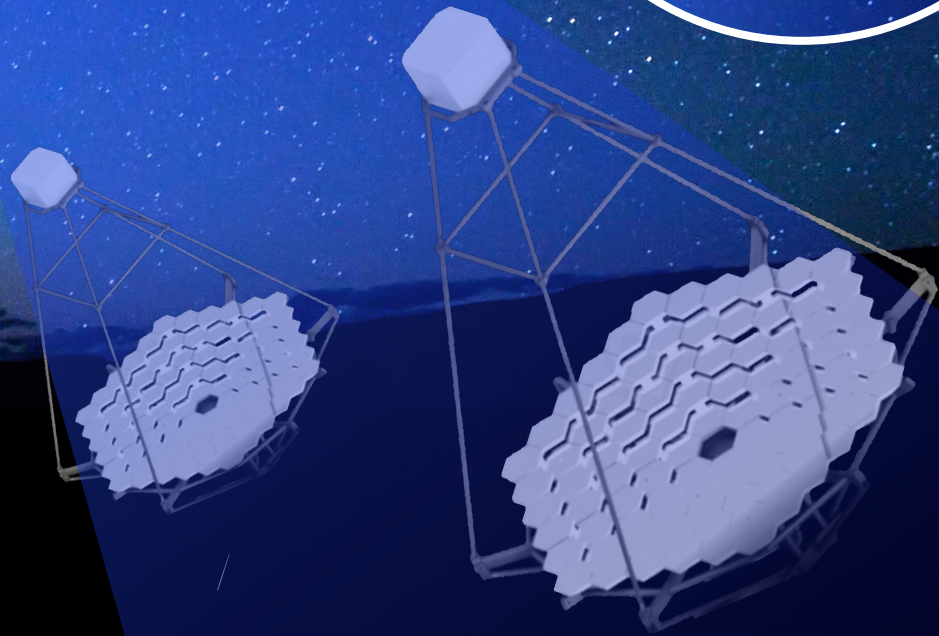
$$F_{\pi} \sim n_H$$



Optical
+TeV

γ -ray enters the atmosphere

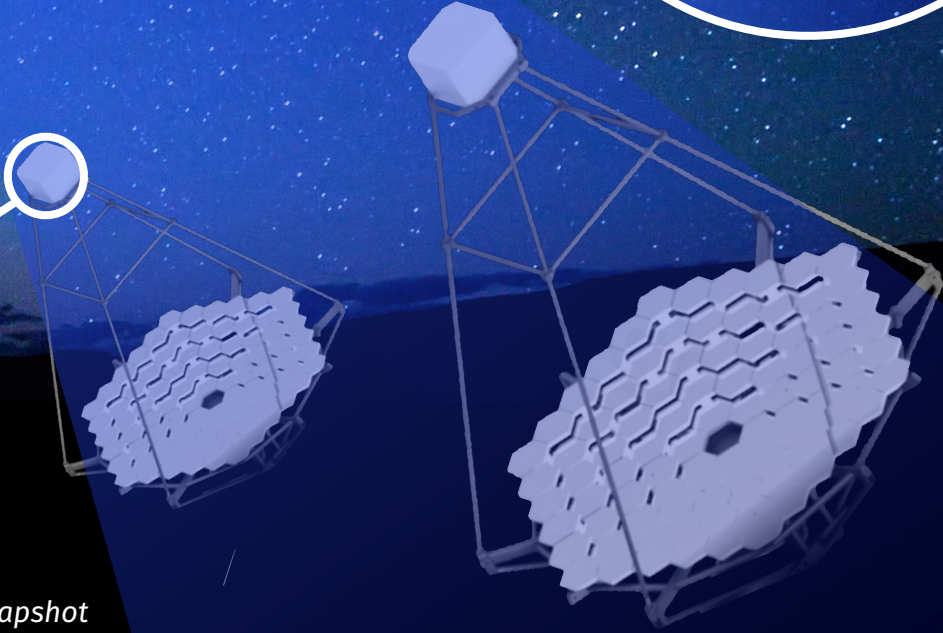
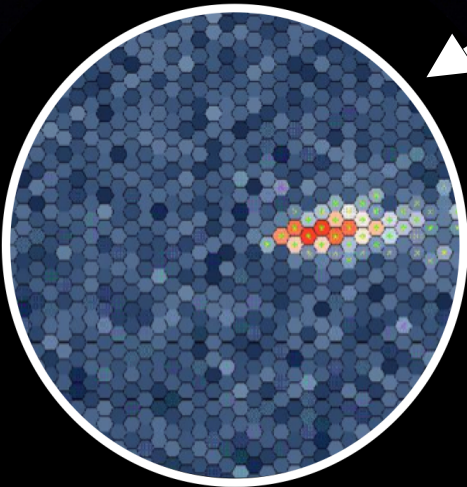
Electromagnetic cascade



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

γ -ray enters the atmosphere

Electromagnetic cascade



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

The Cherenkov Telescope Array



10 GeV 100 GeV 1 TeV 10 TeV 100 TeV

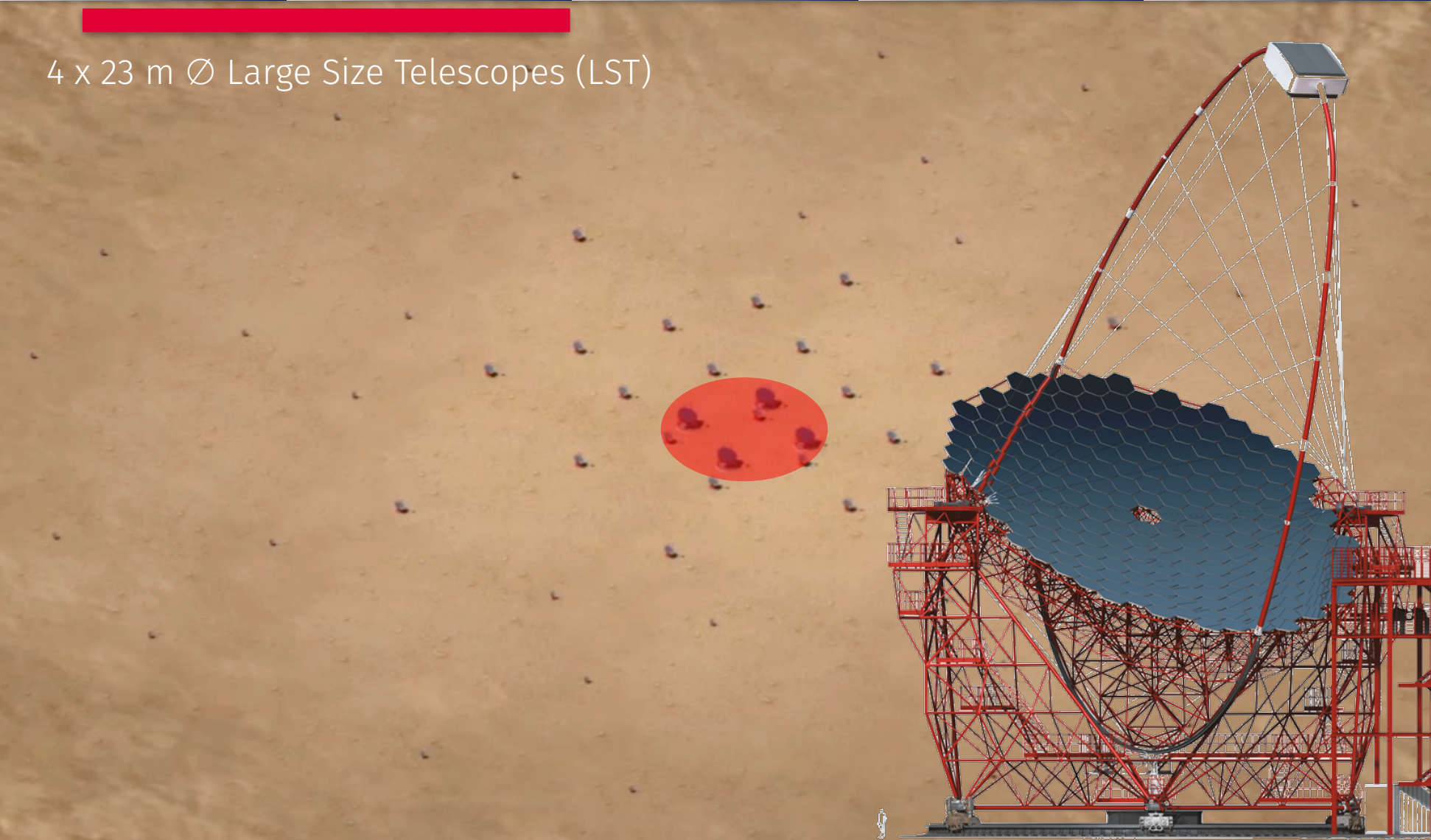


Layout: Multi-phase optimisation process via simulations: DESY, MPIK, +++

The Cherenkov Telescope Array



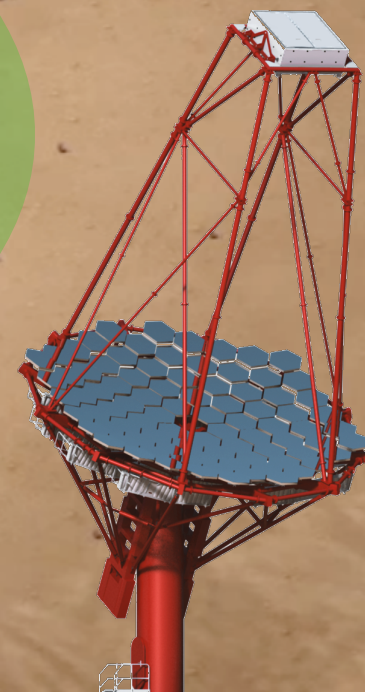
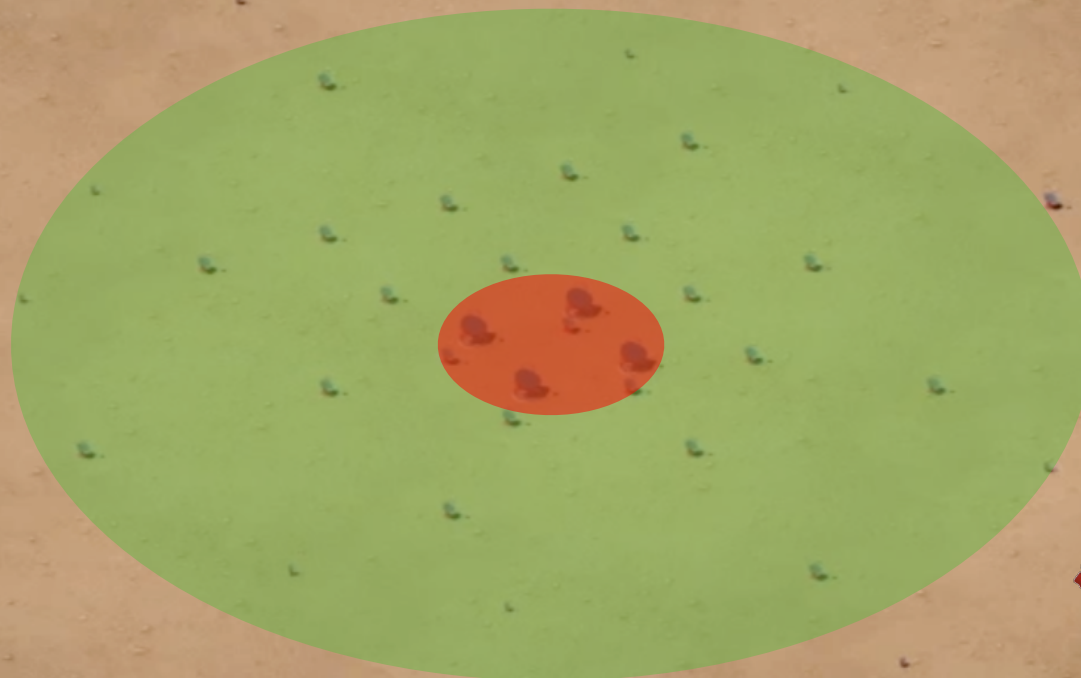
4 x 23 m \varnothing Large Size Telescopes (LST)



The Cherenkov Telescope Array



25 x 12 m \varnothing Medium Size Telescopes (MST) (North: 15)



The Cherenkov Telescope Array



10 GeV 100 GeV 1 TeV 10 TeV 100 TeV

70 x 4 m \varnothing Small Size Telescopes (SST) (South only)



The Cherenkov Telescope Array



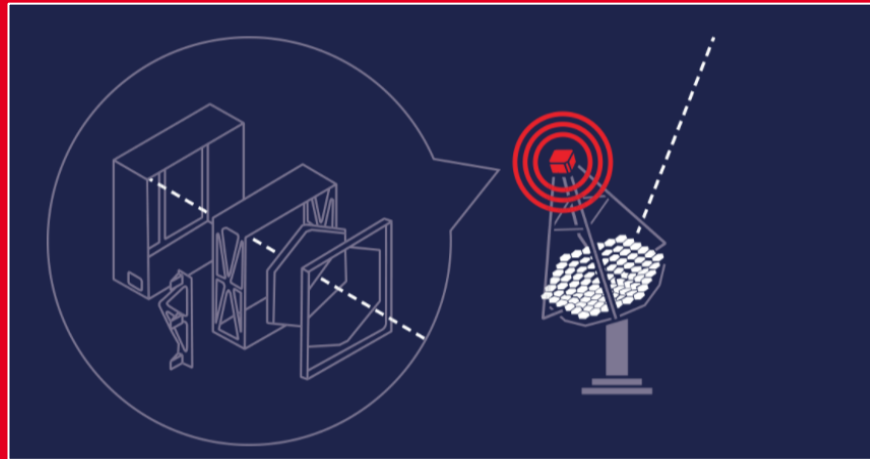
70 x 4 m \varnothing Small Size Telescopes (SST) (South only)

Compared to current instruments:

- up to 10x better sensitivity
- over 4 decades coverage in energy
- much larger field of view
- better angular and energy resolution
- up to 400x increased survey speed



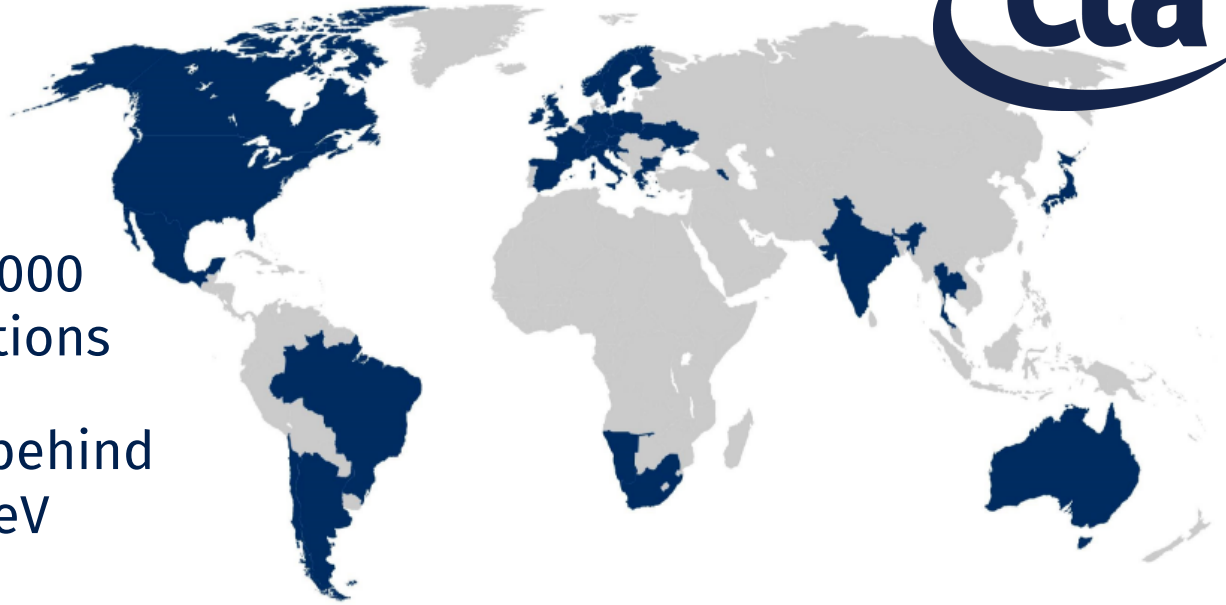
Status



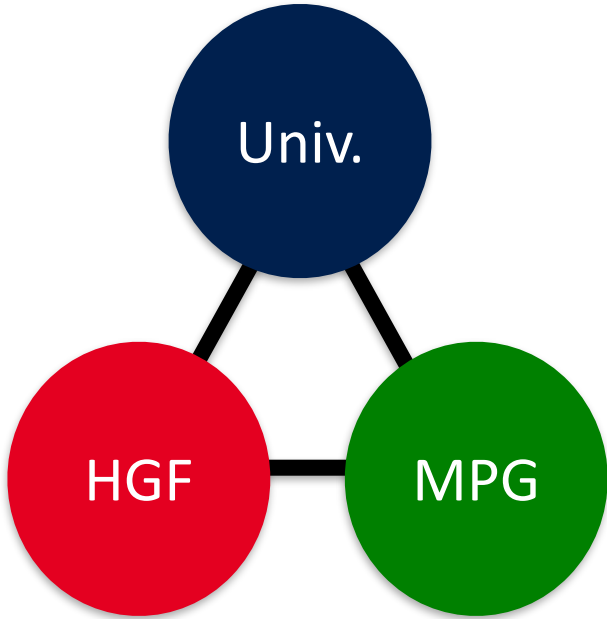
CTA Partners



- CTA Consortium of >1000 scientists from 32 nations
- Including the teams behind all major operating TeV instruments

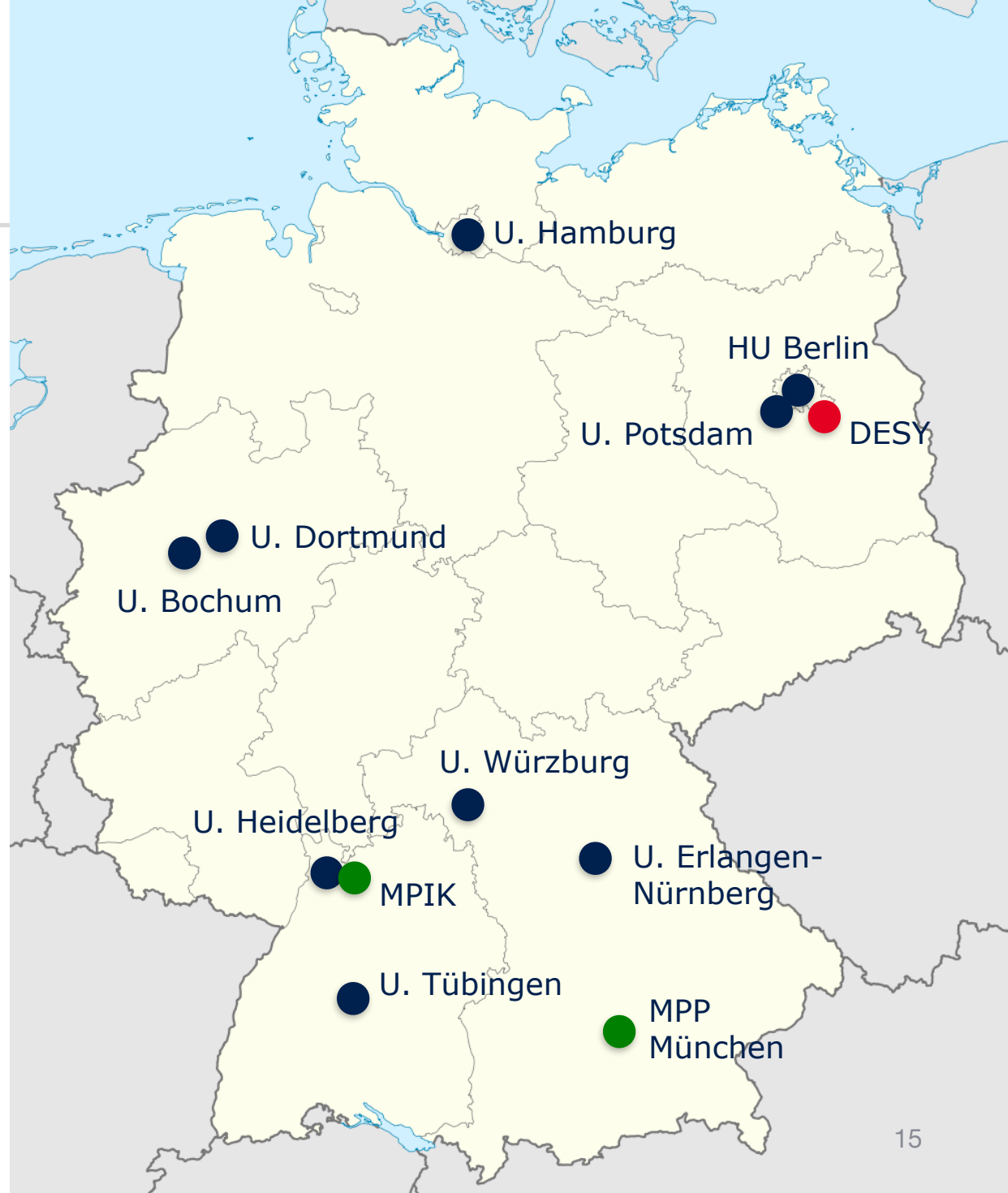


Germany in CTA

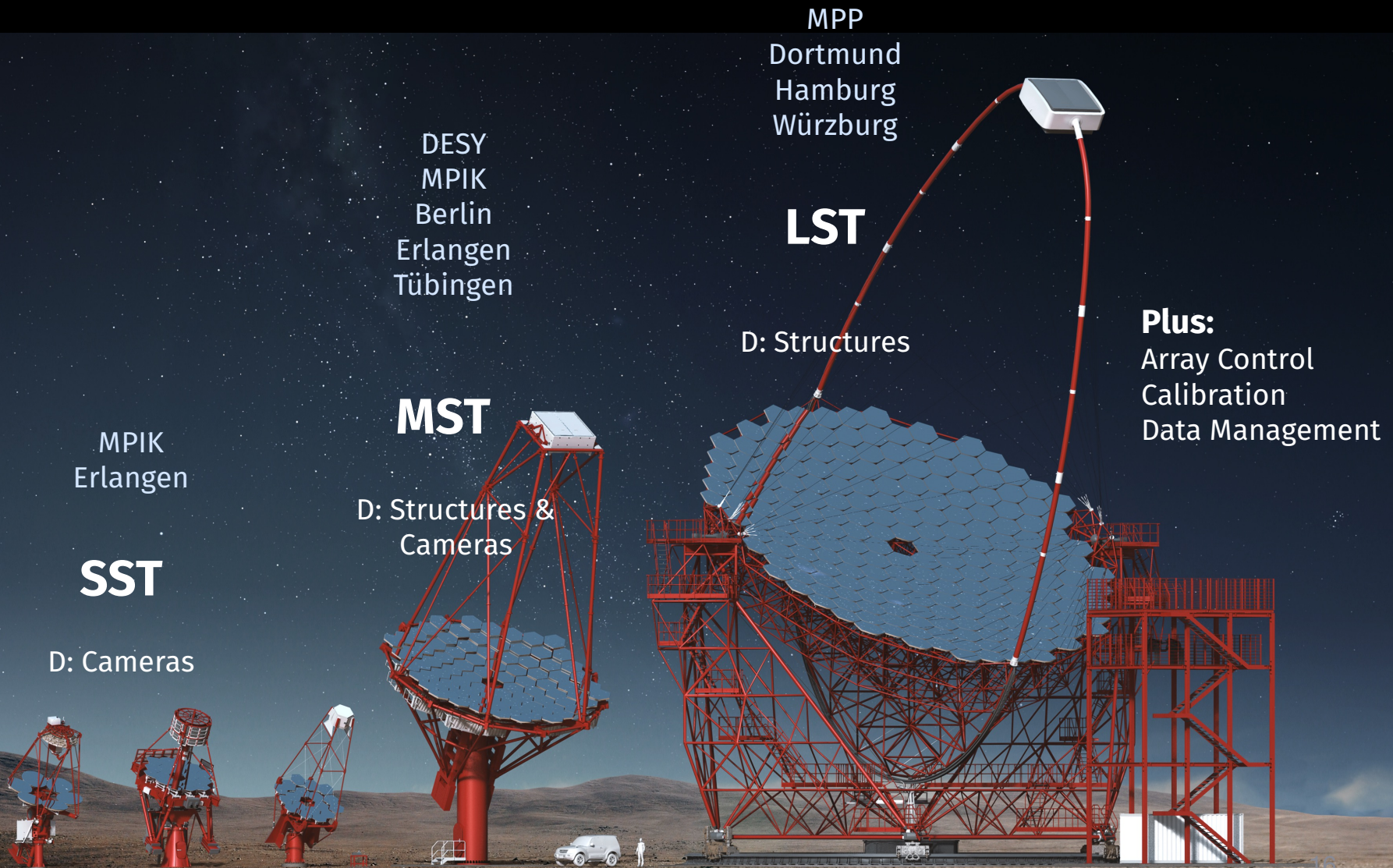


Strong German Role:

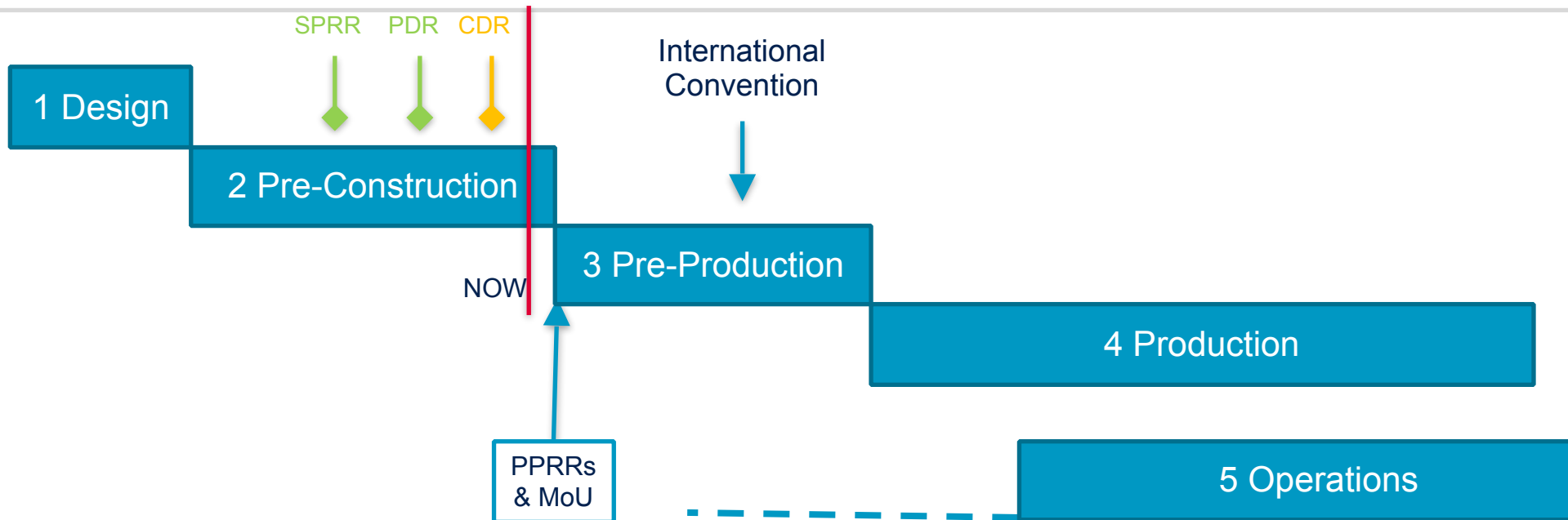
Council Vice Chair,
Spokesperson, WP leads,
science coordinators, +++



Germany in CTA

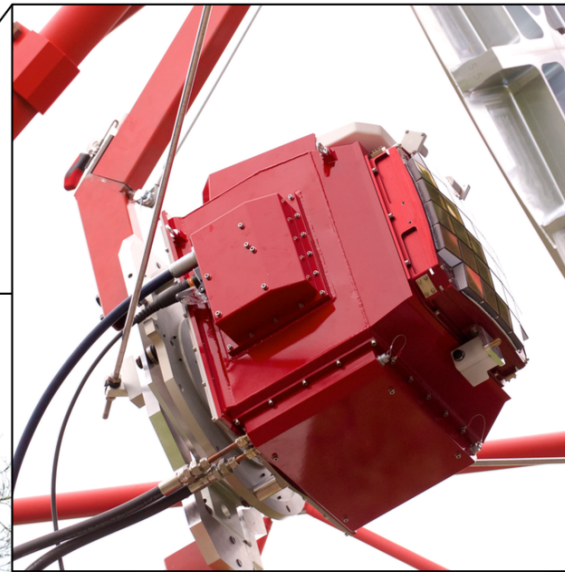


Project Organisation and Phases

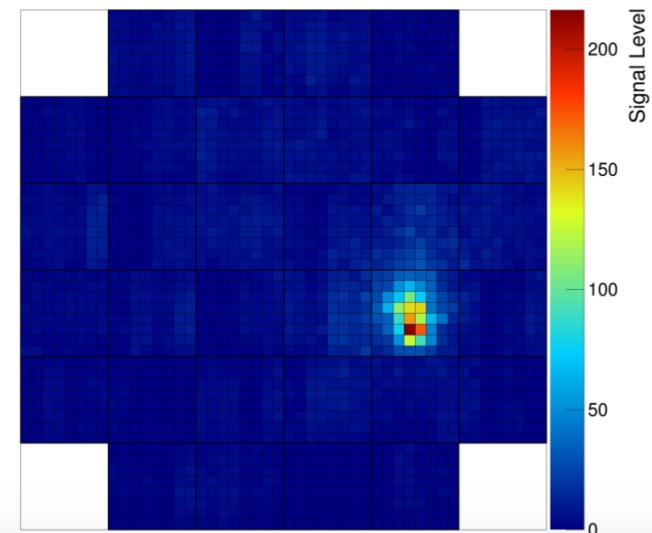


- CTA Observatory gGmbH set up with major partner countries as shareholders
 - approved Business Plan and sites selected incl. HQ and SDMC
 - Signed MoU for construction within next few months
 - International convention for final phase (in preparation)
- Site preparations start in 2017 and pre-production telescopes from 2018
 - *Pre-production is 10% scale preparation for mass production/deployment*
- Science operations with partial arrays possible from 2019

GCT Small-Sized Telescope



Dec. 2015:
first
Cherenkov
images
from a CTA
telescope



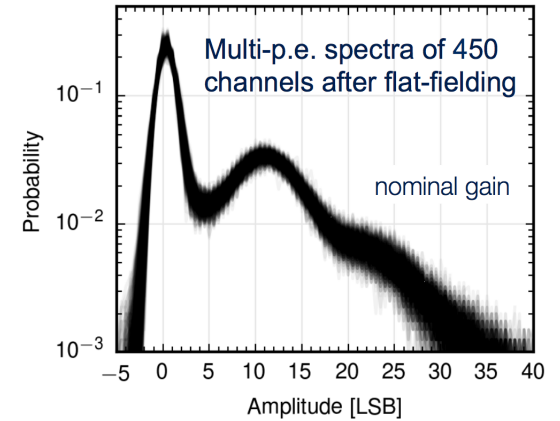
Medium Size Telescope



Adlershof
Berlin



FlashCam MST Camera



Functionality ✓

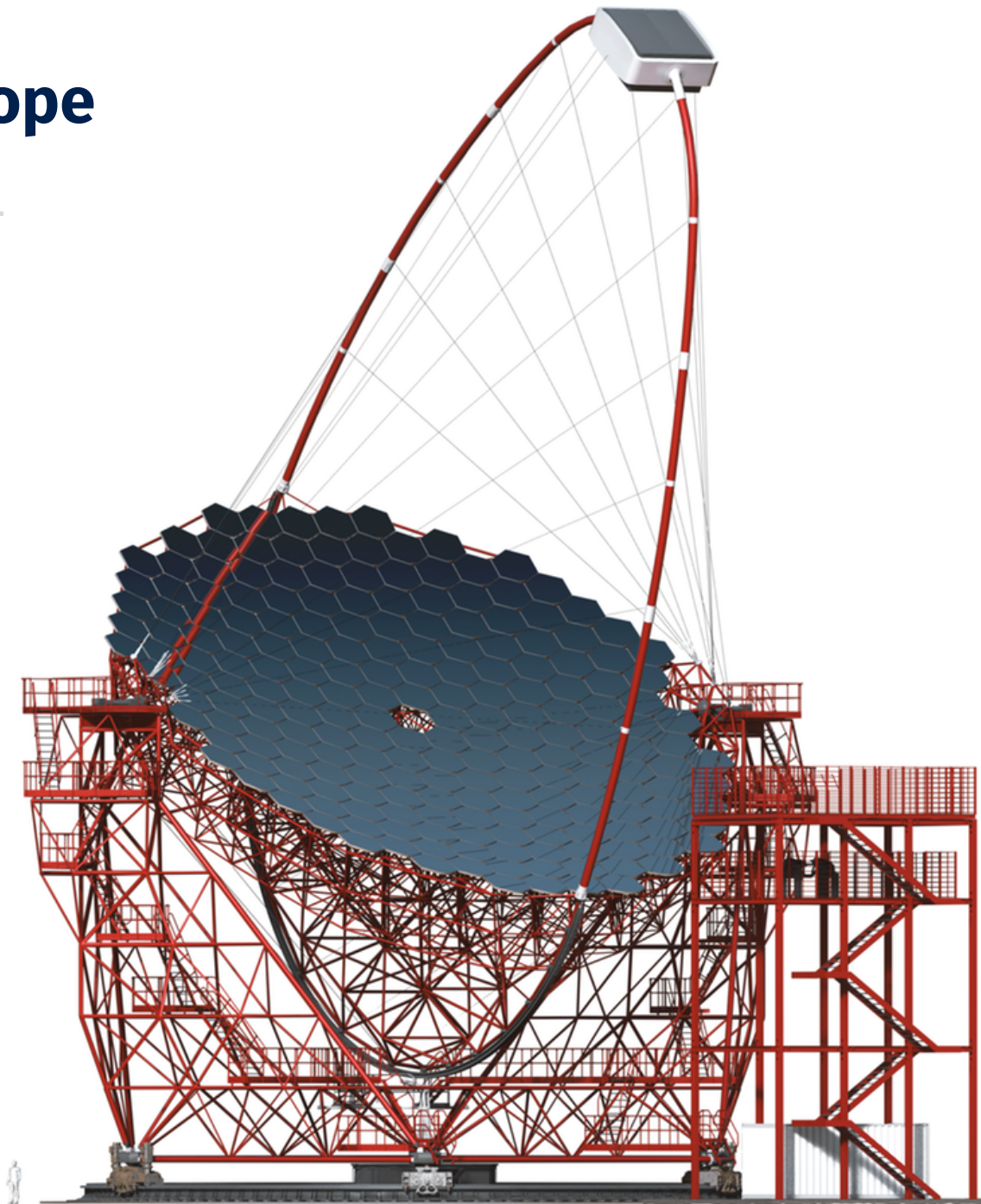
Now undergoing
stress tests
(mechanical,
thermal, electrical)
at MPIK

Large-Sized Telescope

Effort led by MPI Munich



MERO structure
ready to ship



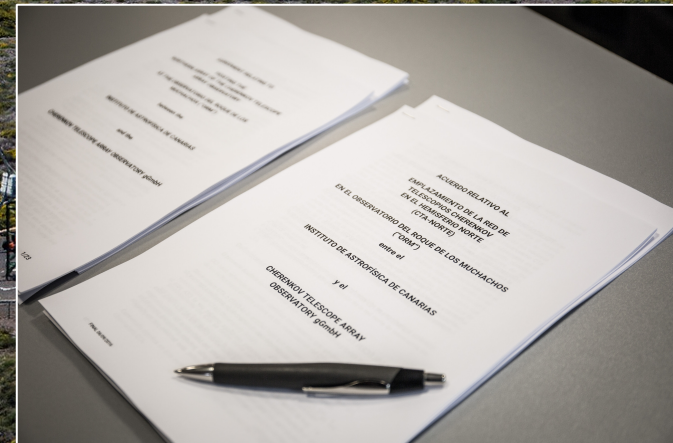
Construction of first LST started



Inauguration of
telescope planned for
November 2017



Northern Site: La Palma



Hosting Agreement with IAC
signed in Sept. 2016

Southern Site: ESO Chile



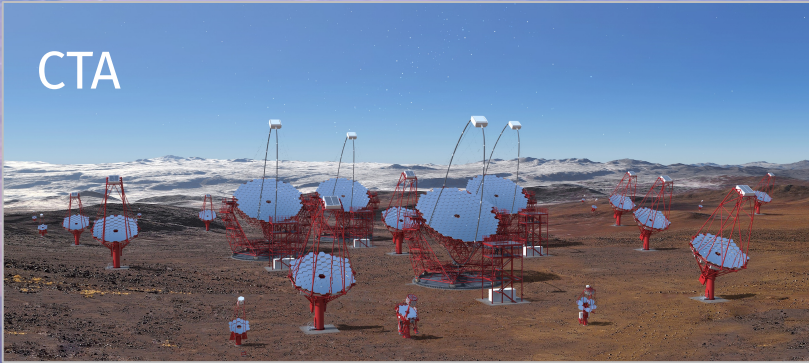
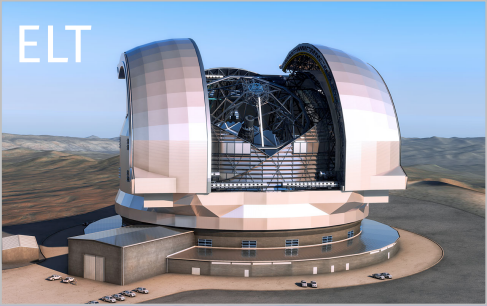
Cerro Armazones
E-ELT

Cerro Paranal
Very Large Telescope

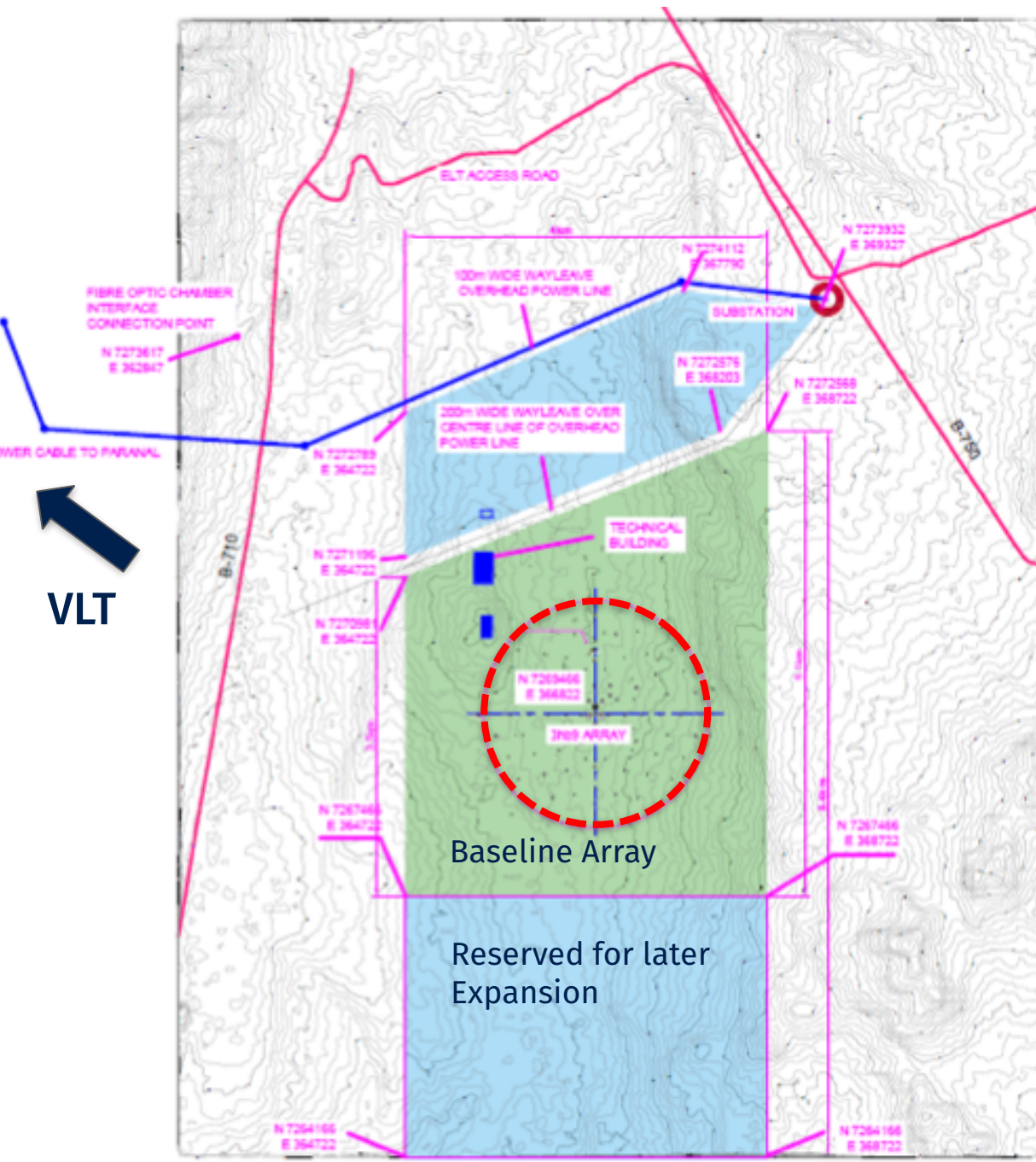
Proposed Site for the
Cherenkov Telescope Array



Southern Site: ESO Chile



E-ELT



Hosting agreement with ESO finalized, expect signature before end of the year

ESO as scientific partner of CTAO; array will be operated by ESO, for CTAO

CTAO Headquarters in Bologna

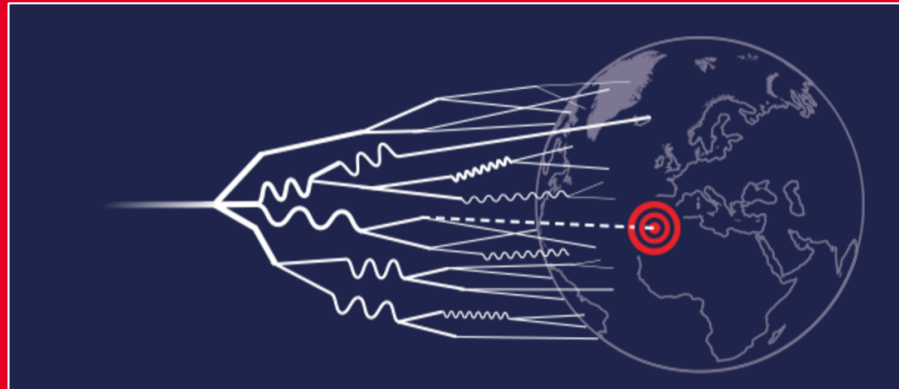


Move of Project Office
to Bologna starting in January 2017

CTAO Science Data Management Centre at DESY/Zeuthen

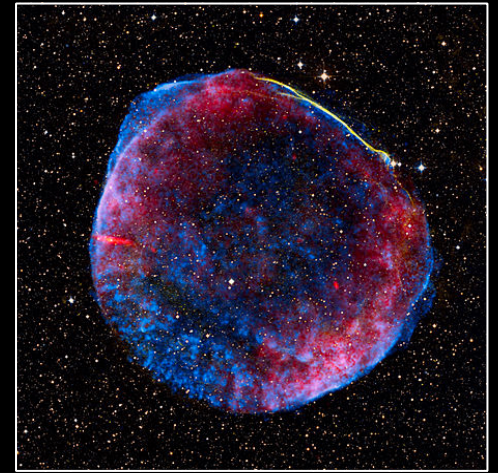


Perspectives



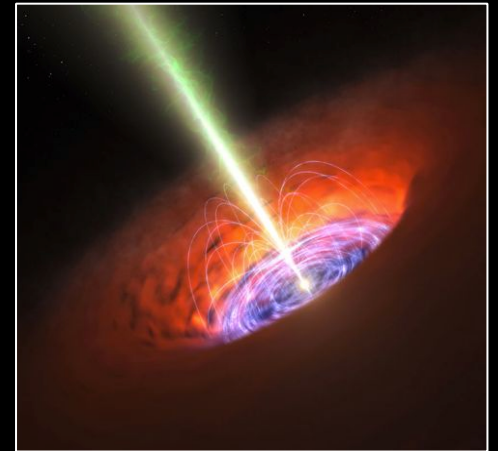
Theme 1: Cosmic Particle Acceleration

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



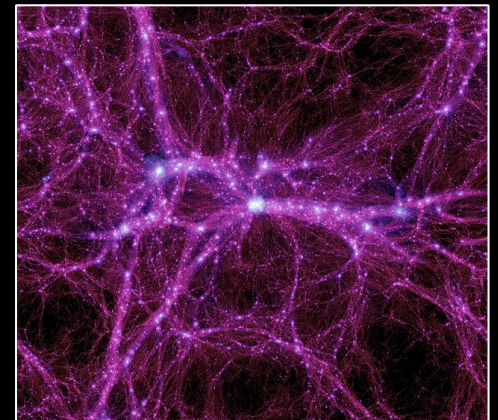
Theme 2: Probing Extreme Environments

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



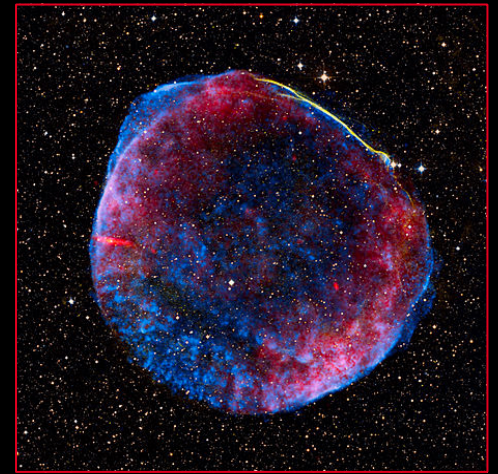
Theme 3: Physics Frontiers

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



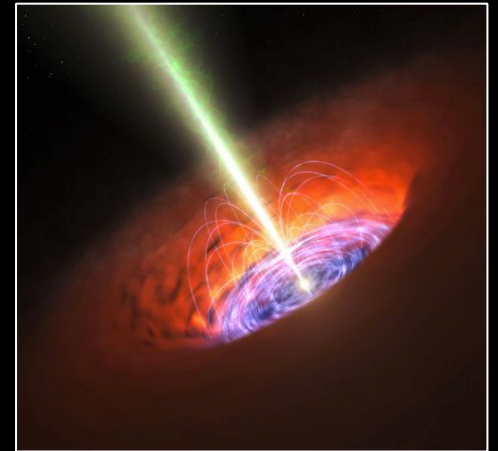
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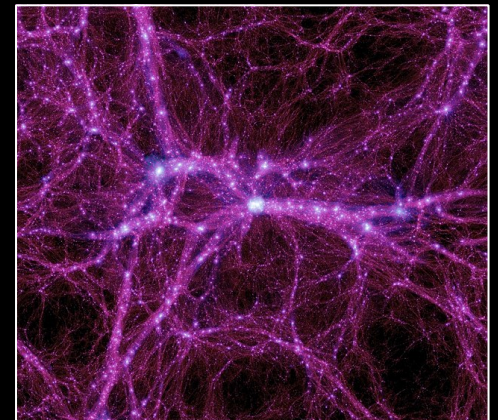
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Theme 3: Physics Frontiers

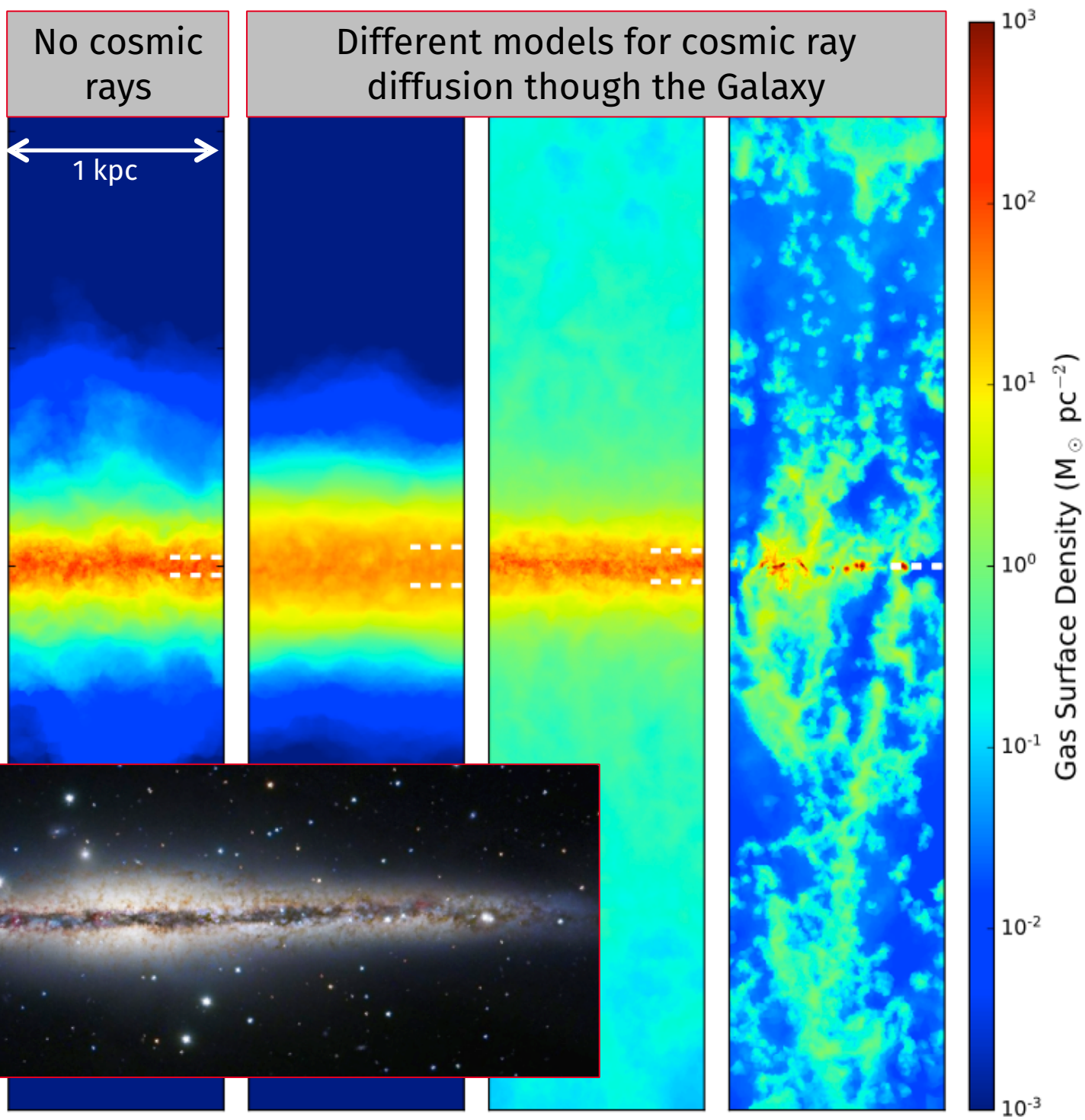
- What is the nature of Dark Matter?
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C.M. Simpson, R. Pakmor,
F. Marinacci, C. Pfrommer,
V. Springel, S.C.O. Glover, P.C.
Clark, R.J. Smith,
arXiv:1606.02324

Simulations of galactic disk

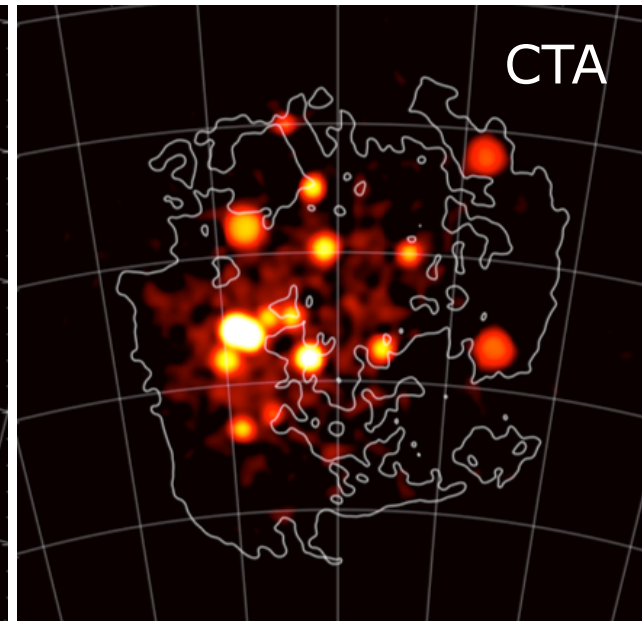
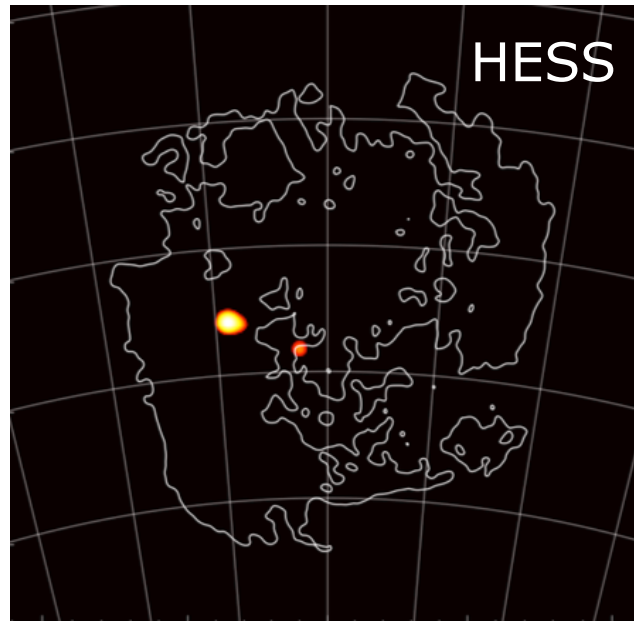
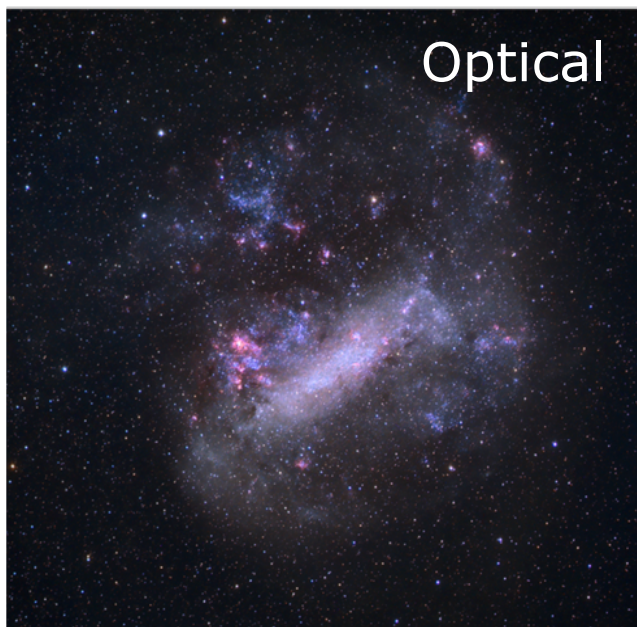
Color scale:
Gas density



Cosmic rays in galaxies



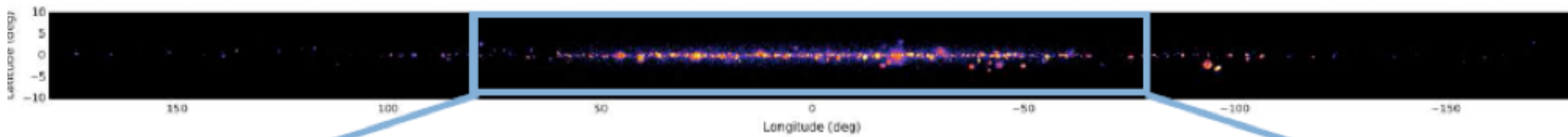
- CTA Impact?
 - Tracing very high energy particle acceleration and propagation
 - Example: **Survey of the the Large Magellenic Cloud** – nearby star-forming galaxy
 - Wide field of view, dramatically improved background rejection power and collection area → **a Survey Machine**



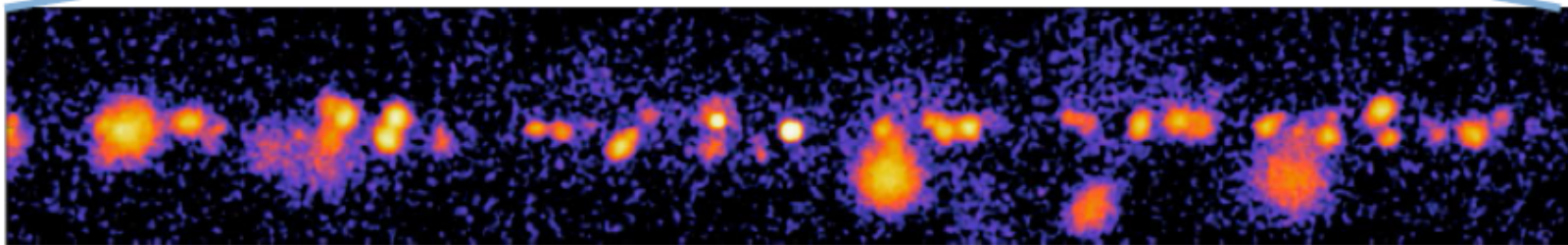
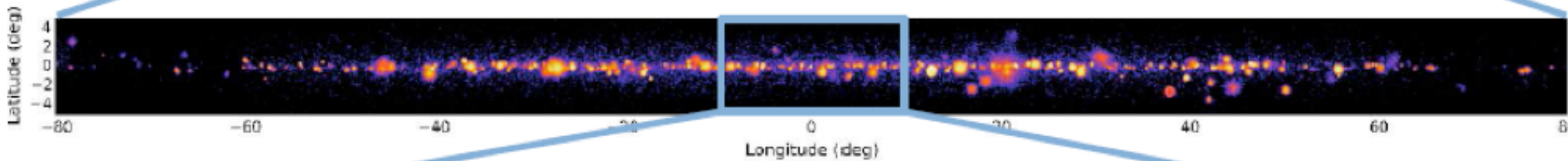
Cosmic rays in galaxies



Full-plane coverage: longitude $\pm 180^\circ$, latitude $b \pm 10^\circ$



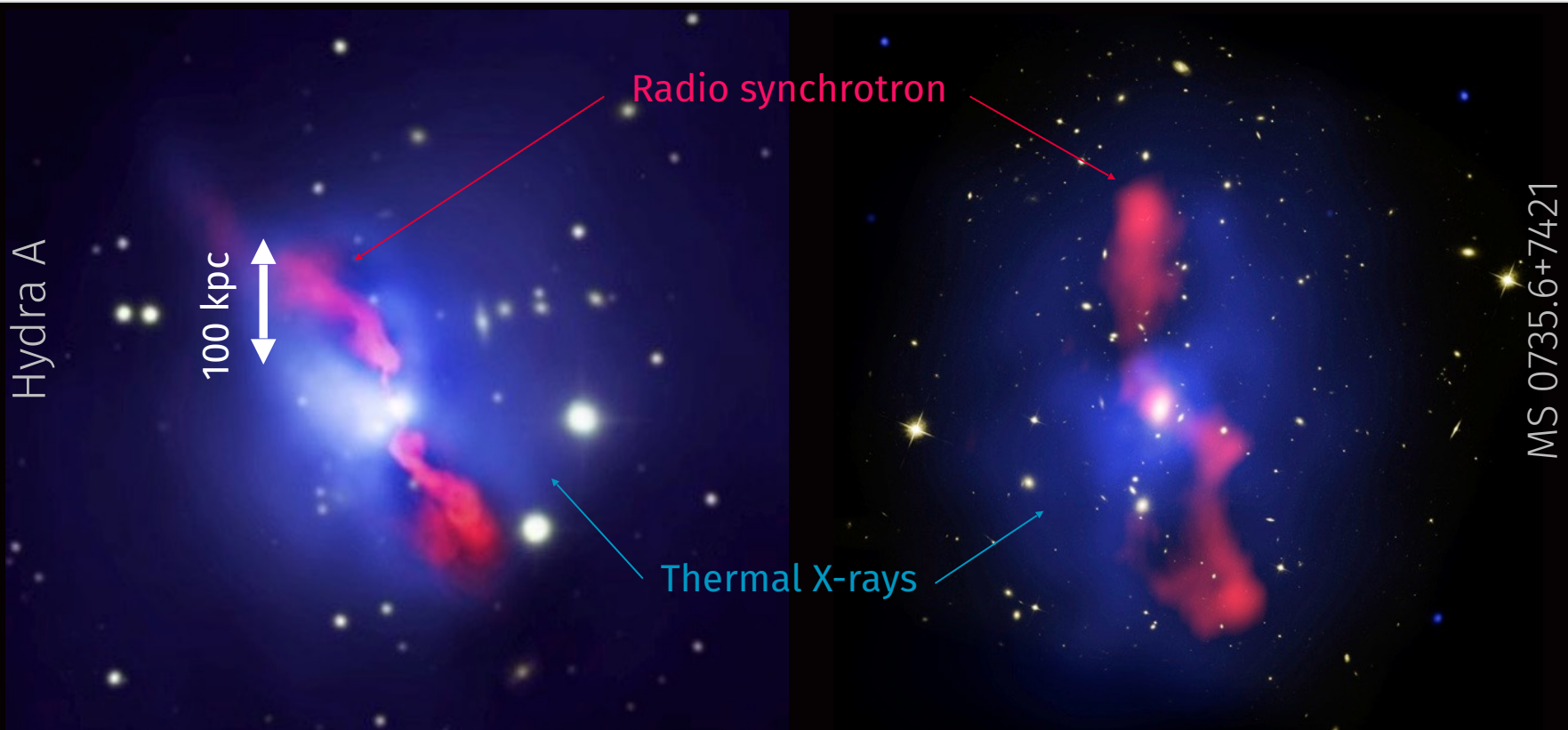
Deeper inner galaxy exposure: $l \pm 80^\circ$



Fine detail revealed with \sim arcmin PSF

- CTA survey of our own galaxy - key science project - 1 year

Cosmic rays beyond galaxies

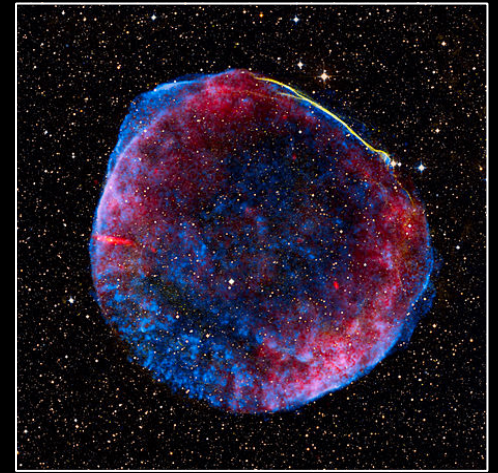


- **The biggest bubbles in the universe**
 - *Cluster-scale AGN outbursts* - vast holes in the ICM: $PV \sim 10^{61}$ erg
 - What provides the internal pressure? –very likely cosmic rays
 - CTA can prove if this is the case

e.g. Hinton, Domainko & Pope MNRAS 2007

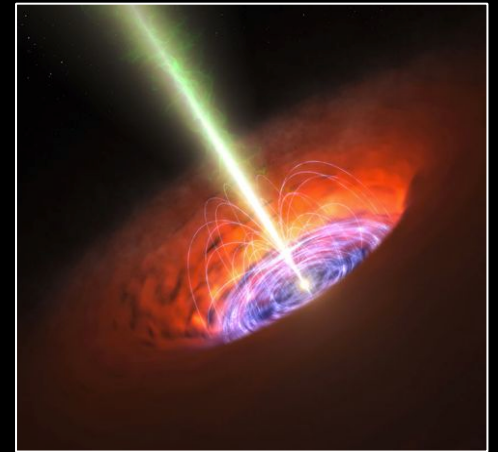
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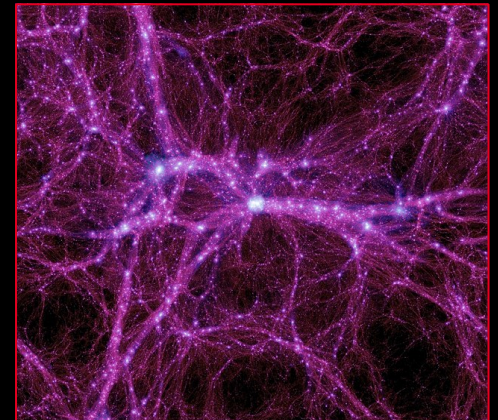
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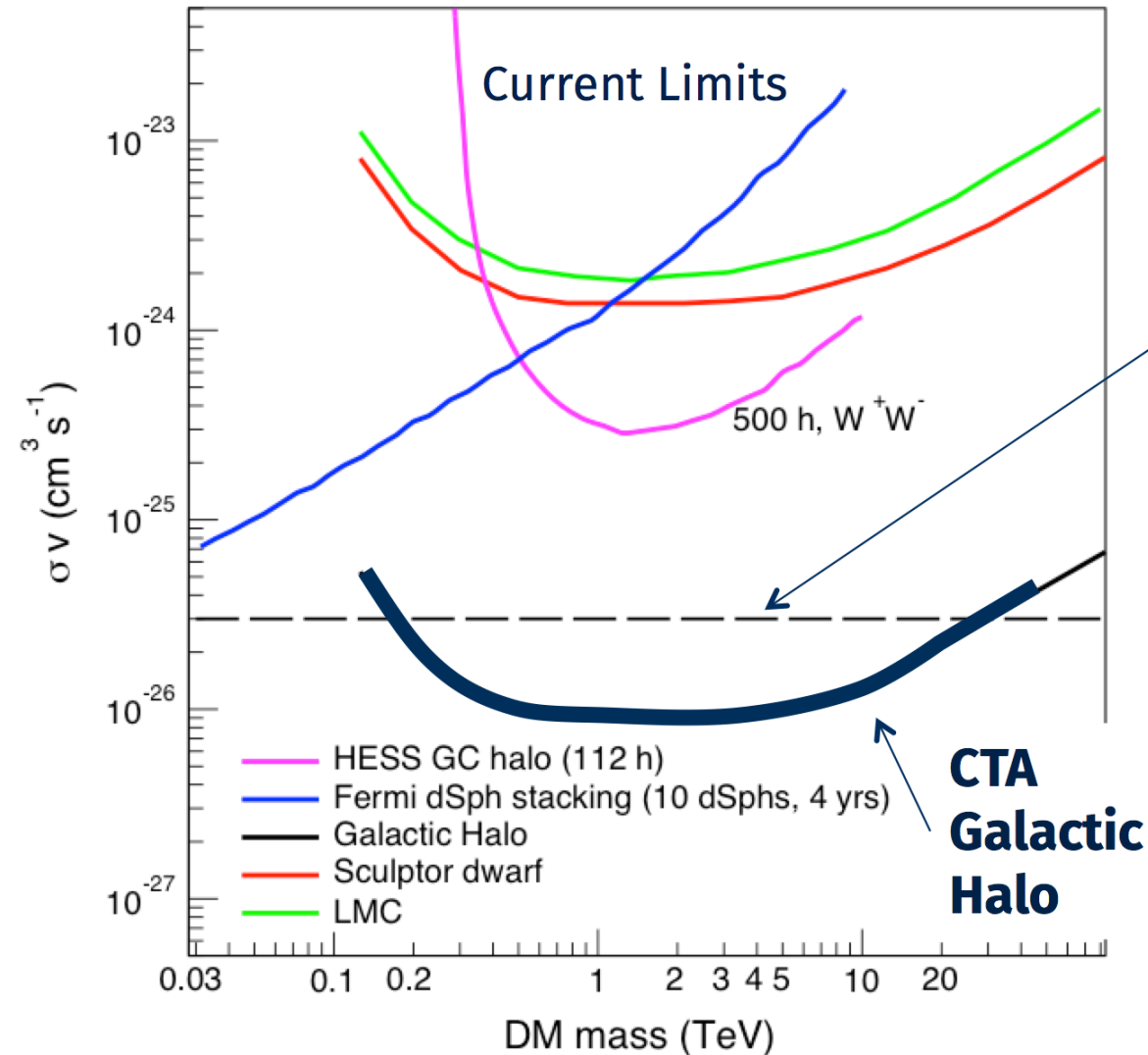


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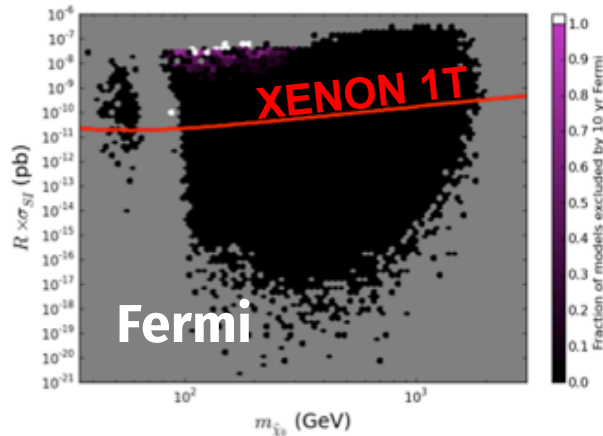
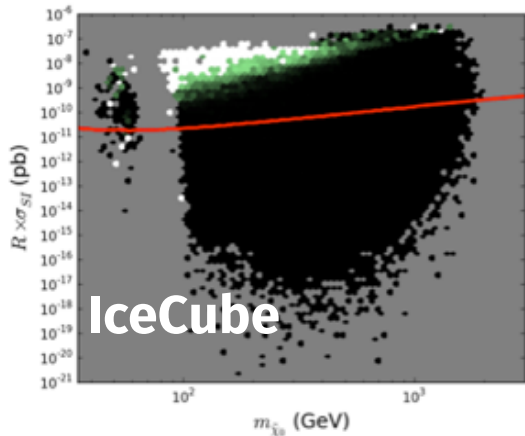
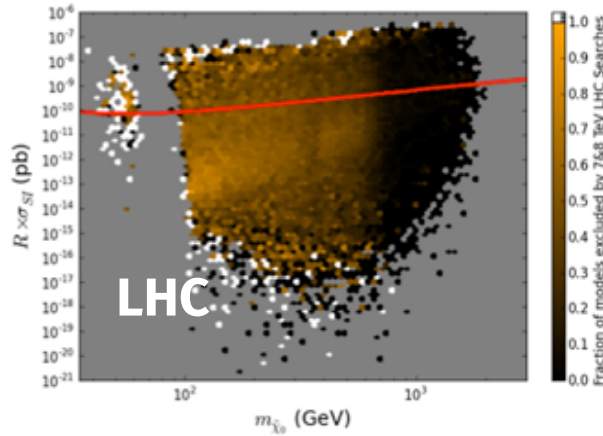
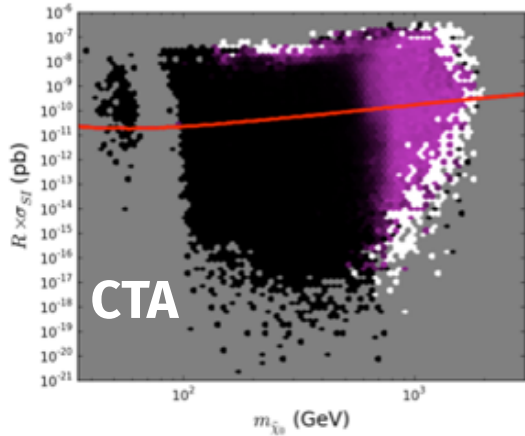


Dark Matter Annihilation



- 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

Dark Matter Annihilation



M. Cahill-Rowley et al.
arXiv:1305.6921

Expected self-annihilation cross-section for a **thermal relic** of the big bang

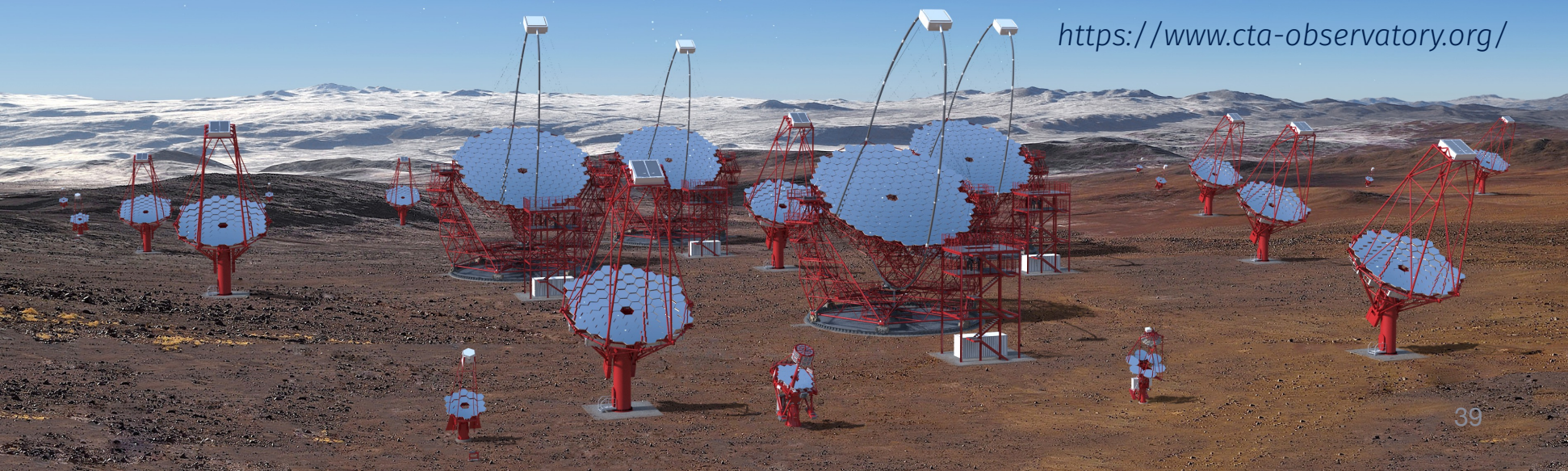
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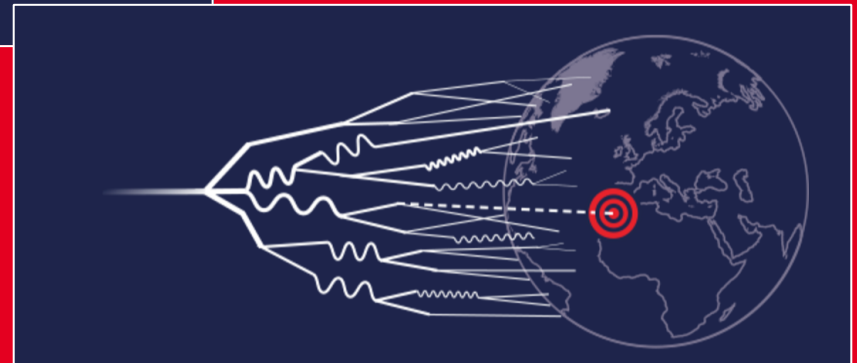
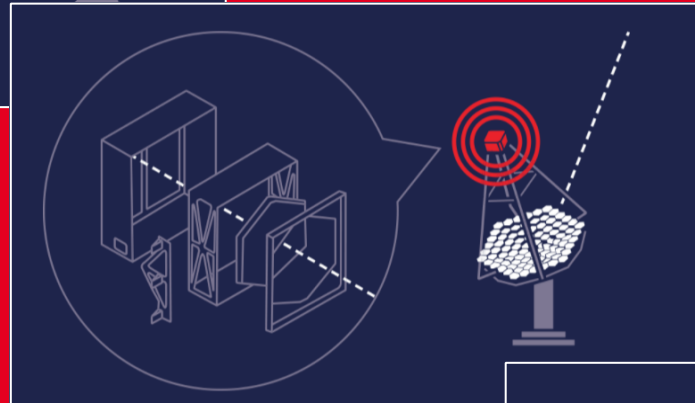
Conclusions

- CTA will transform our understanding of the extreme universe
 - Huge performance improvement relative to current instruments
 - Very broad scientific reach
- An open observatory serving a wide community
 - And working together with MM+MWL observatories, e.g. **VLA**
- Rapidly progressing to Observatory construction
- Very strong Helmholtz and wider German role

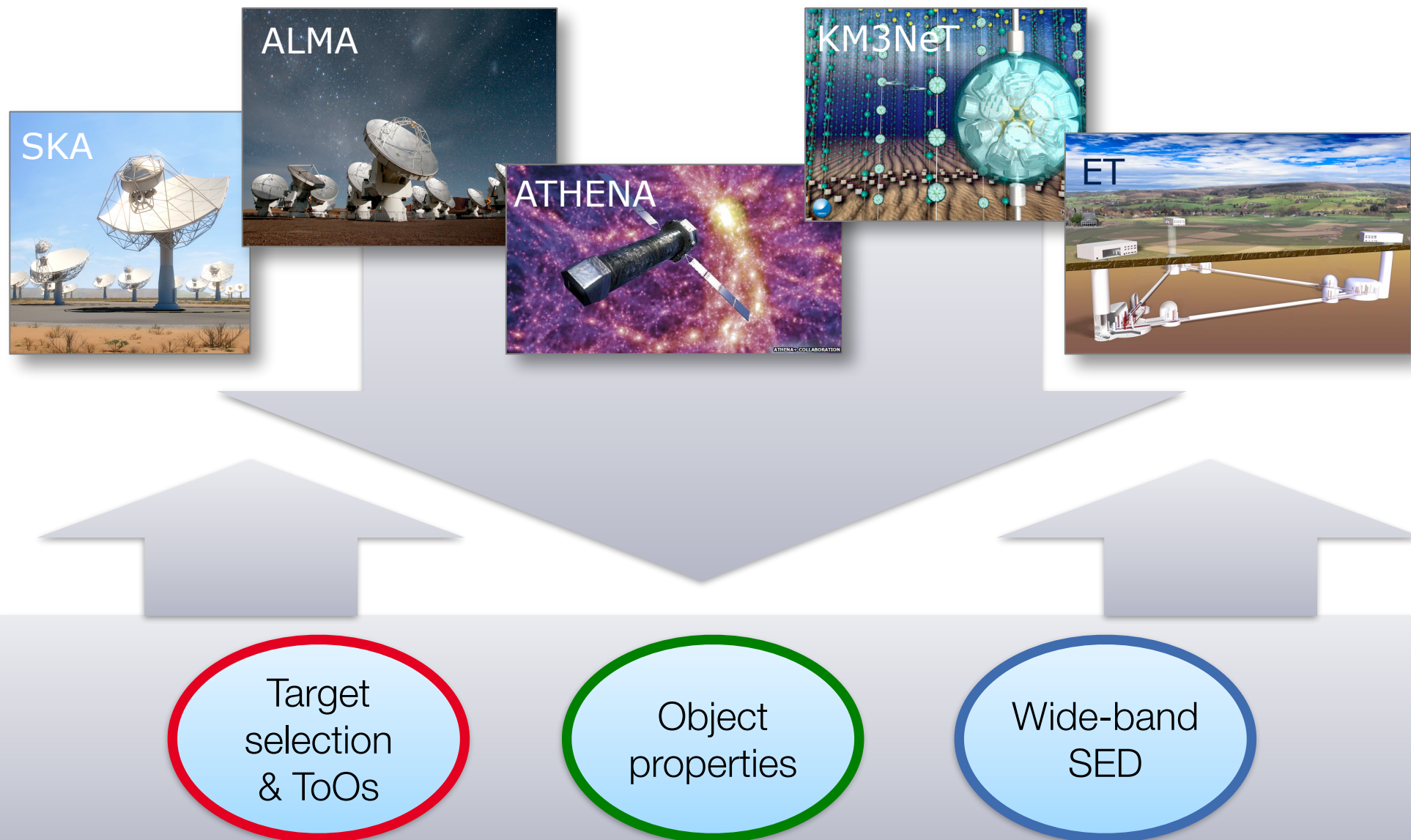
<https://www.cta-observatory.org/>



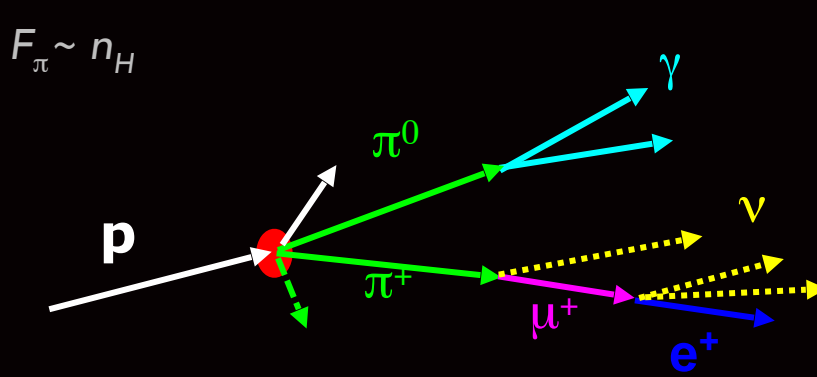
Questions?



Crucial: Multi-wavelength and Multi-messenger Link



Non-thermal Emission



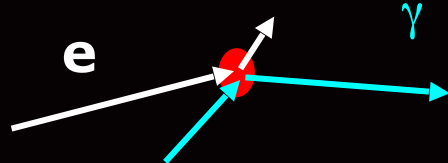
$$F_{\pi} \sim n_H$$

$$E_{\gamma} \sim E_p/10$$

π^0 decay

Log(E_{γ})

$$F_{IC}/F_{Sync} \sim U_{Rad}/U_B$$

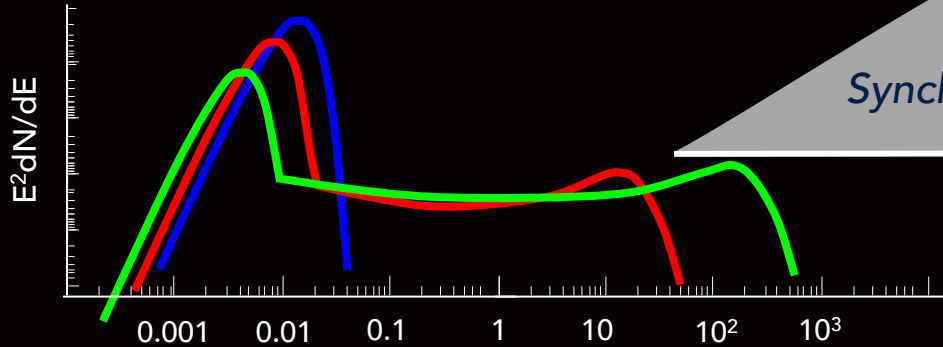


$$E_{\gamma} \sim E_e^2$$

Typical particle distributions

Synchrotron

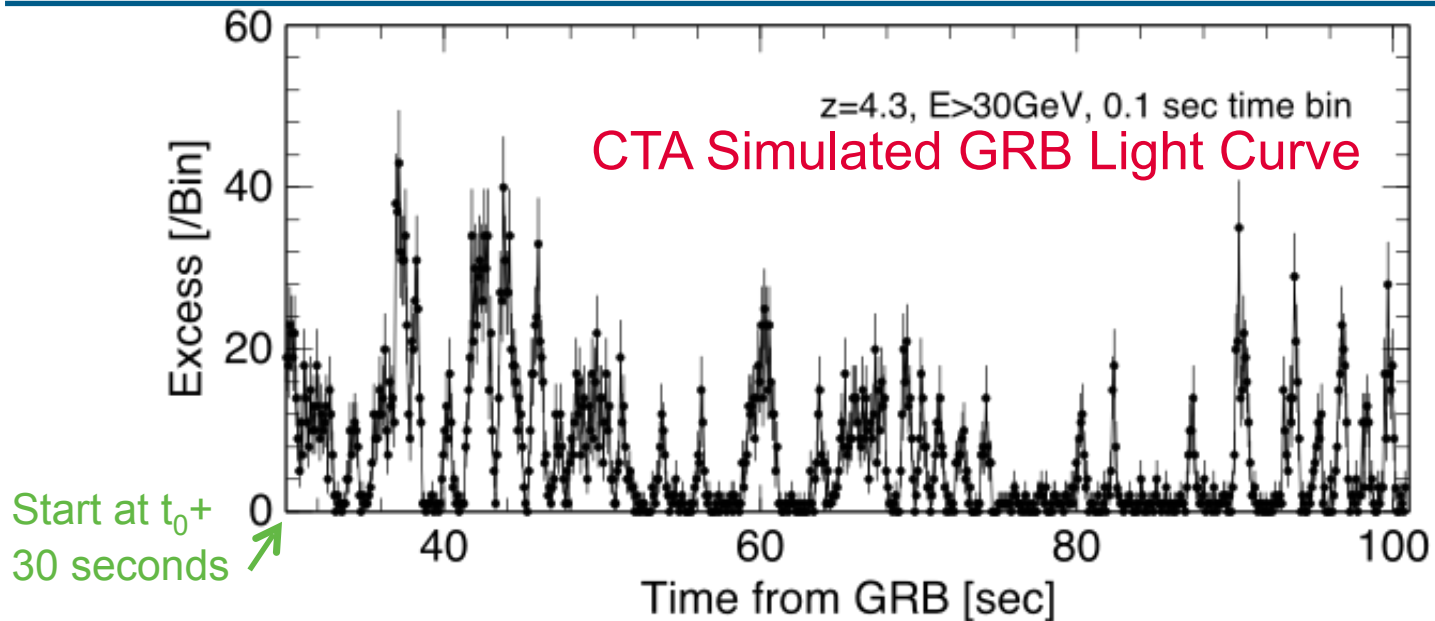
Inverse Compton Scattering



Typical photon spectra

See e.g. Kang, Jones, Gieseler 2002

Alerts and Triggers



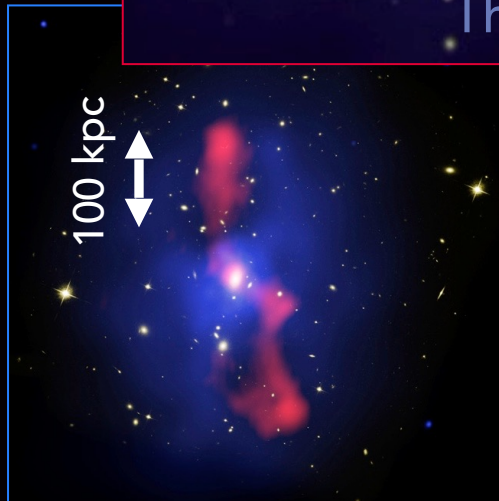
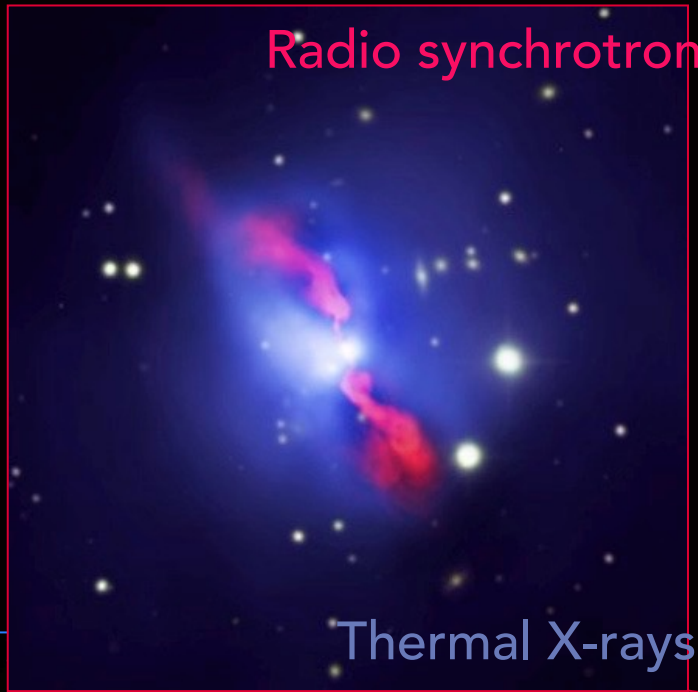
- Alerts and triggers to/from CTA for variable objects
 - Including gravitational waves, neutrinos, optical transient factories, FRBs
 - Three-four orders of magnitude more sensitive than Fermi-LAT for timescales below one hour – huge discovery potential
- Triggers from CTA → broad astronomical community
 - Rate expected to be low – but identified events likely to be extremely important: GW sub-threshold, redshift measurement, ...

Cosmic rays beyond Galaxies

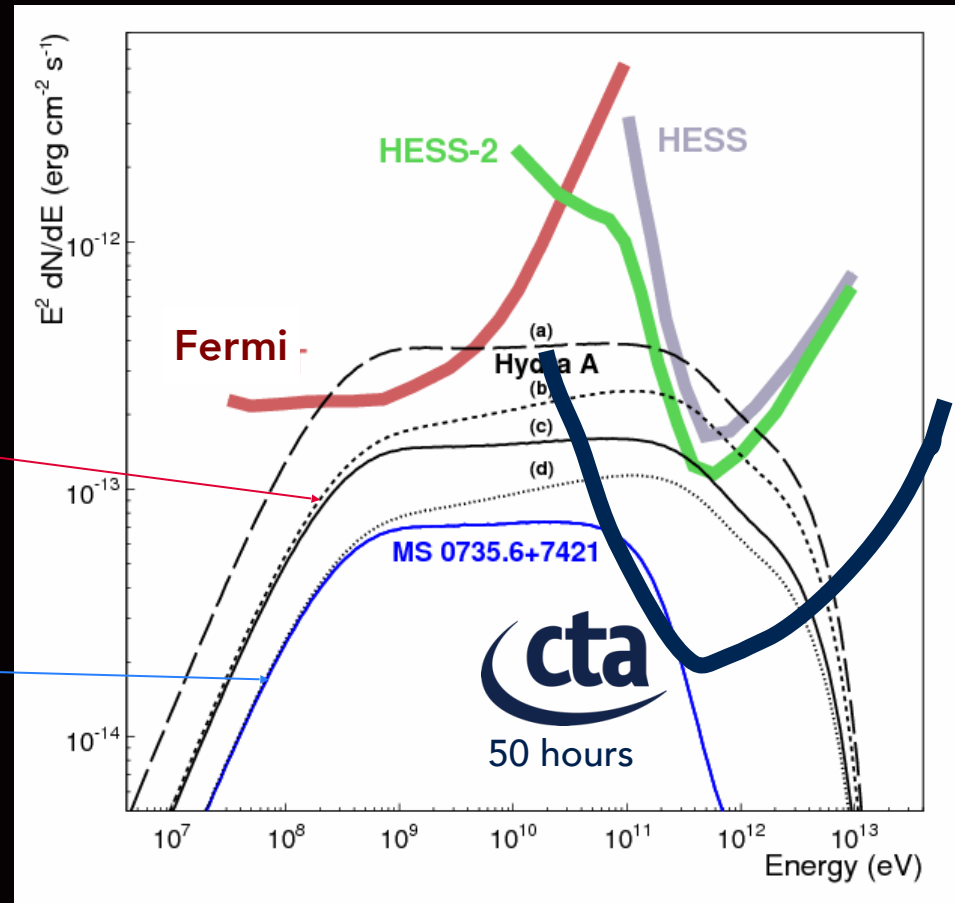


X-ray IC limits and lifetime arguments against just electrons+B-fields in bubbles → hadronic cosmic-rays → CTA

e.g. Hinton, Domainko & Pope MNRAS 2007



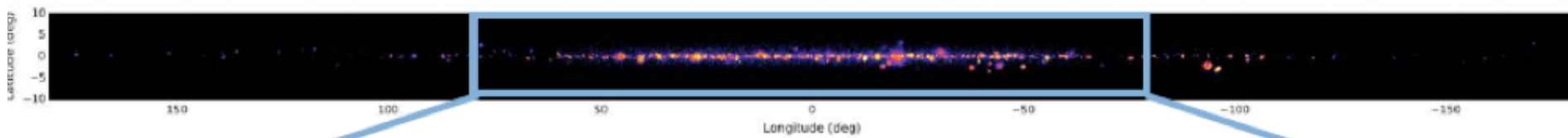
PV $\sim 10^{61}$ erg



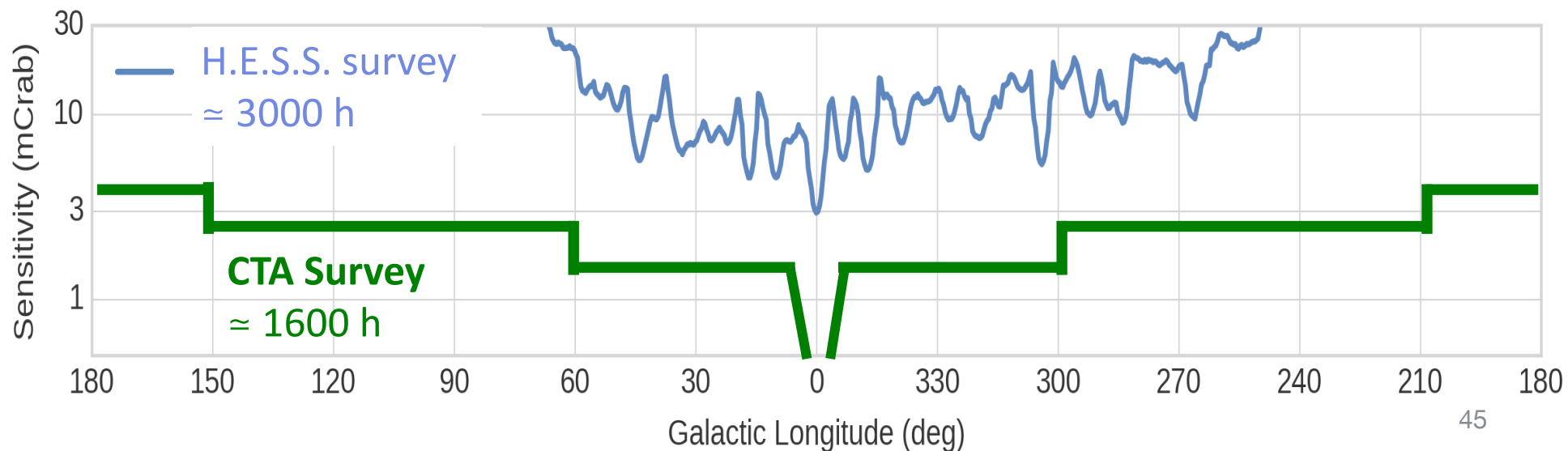
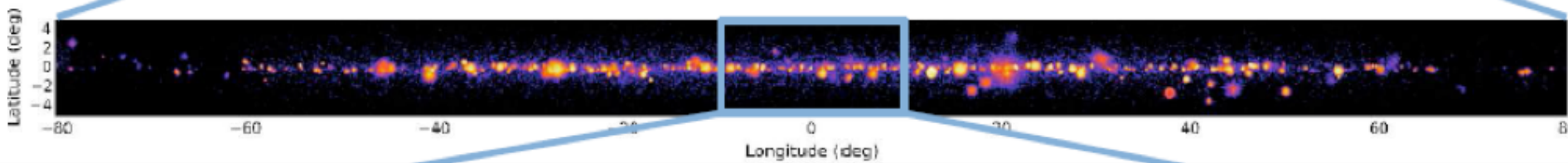
Galactic Plane Survey



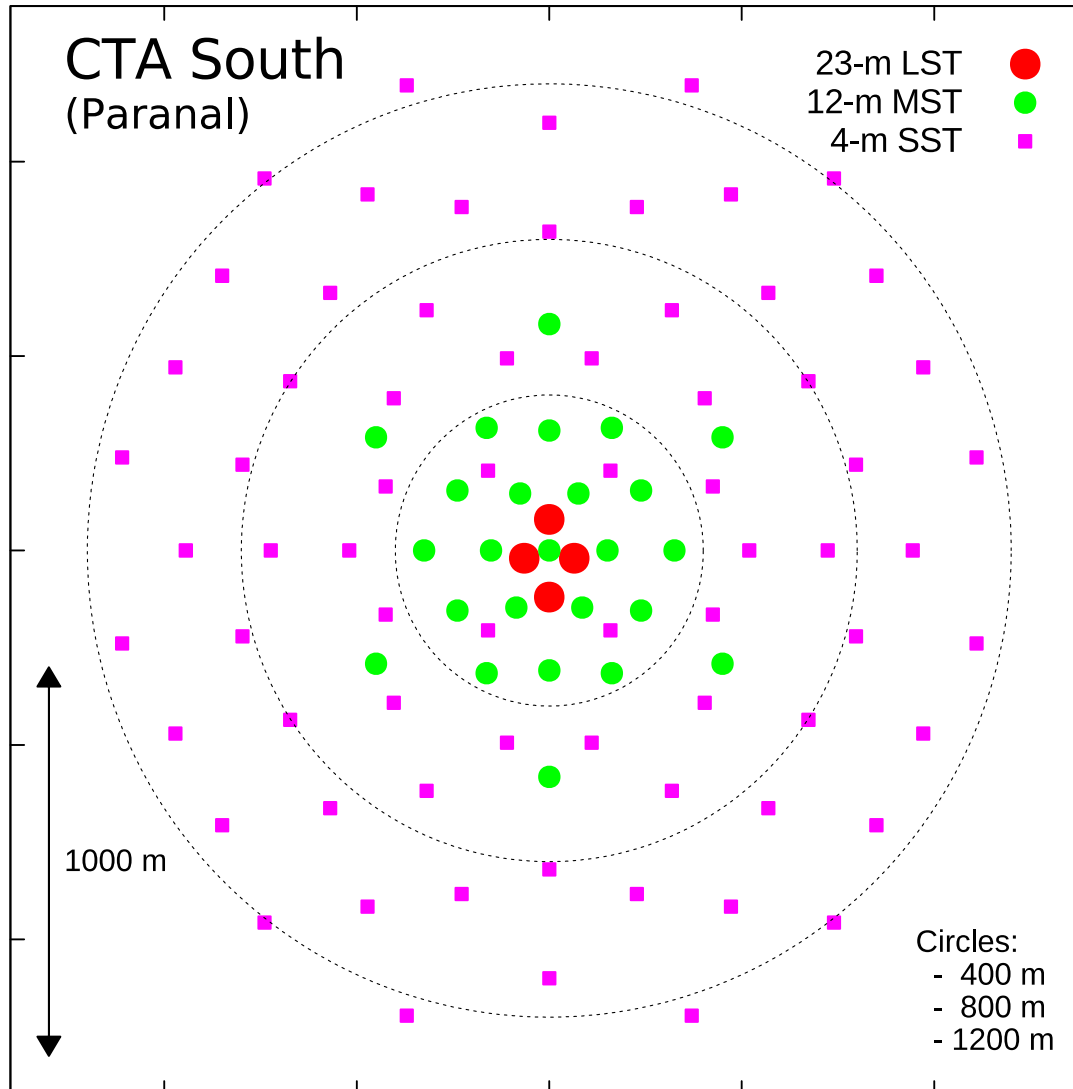
Full-plane coverage: longitude $\pm 180^\circ$, latitude $b \pm 10^\circ$



Deeper inner galaxy exposure: $l \pm 80^\circ$



Array Layout South



Layout optimized
using detailed
simulations –
many million CPU-h

Last steps fine-tuning
at % level

(DESY, MPI Heidelberg)