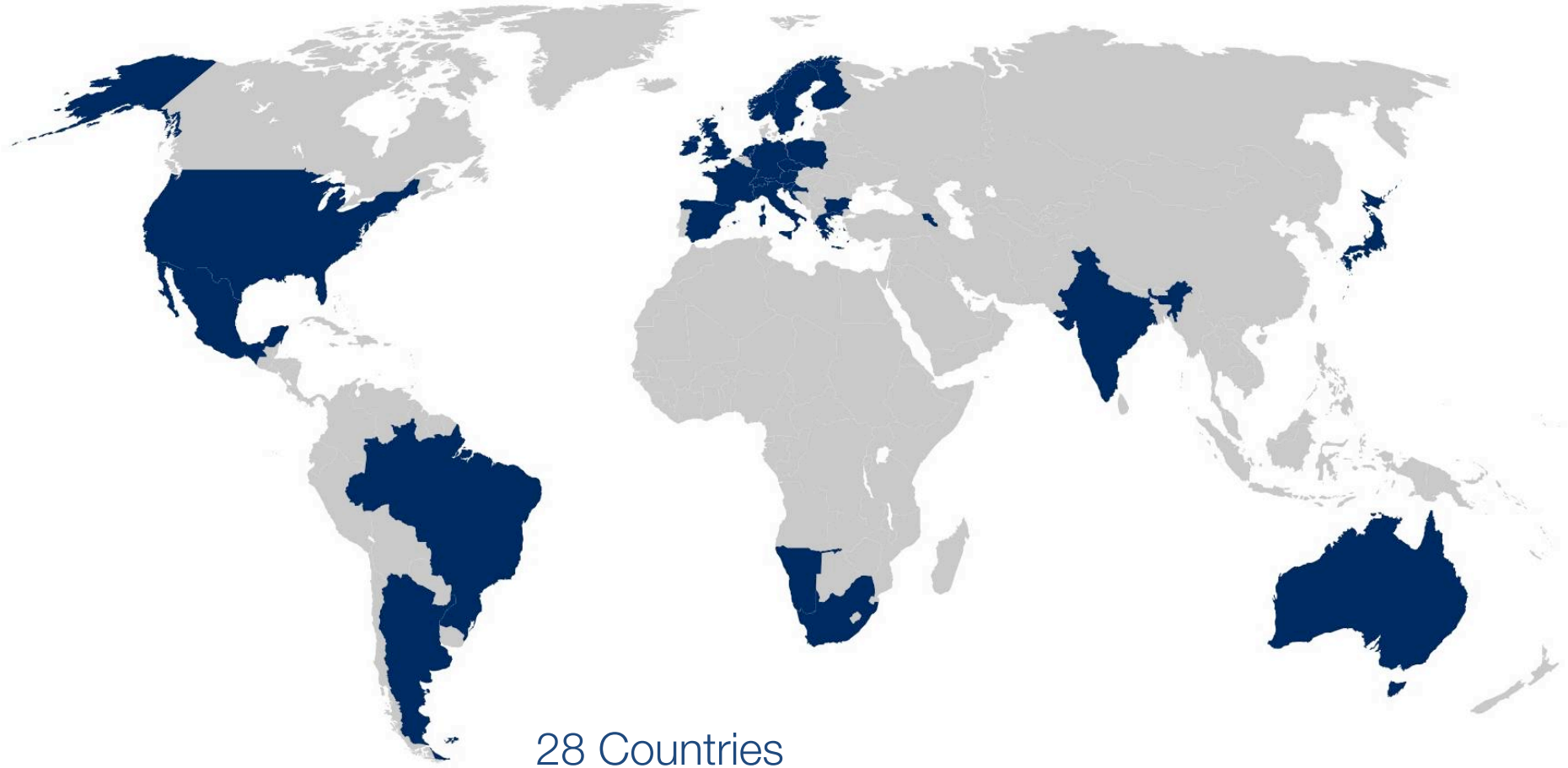
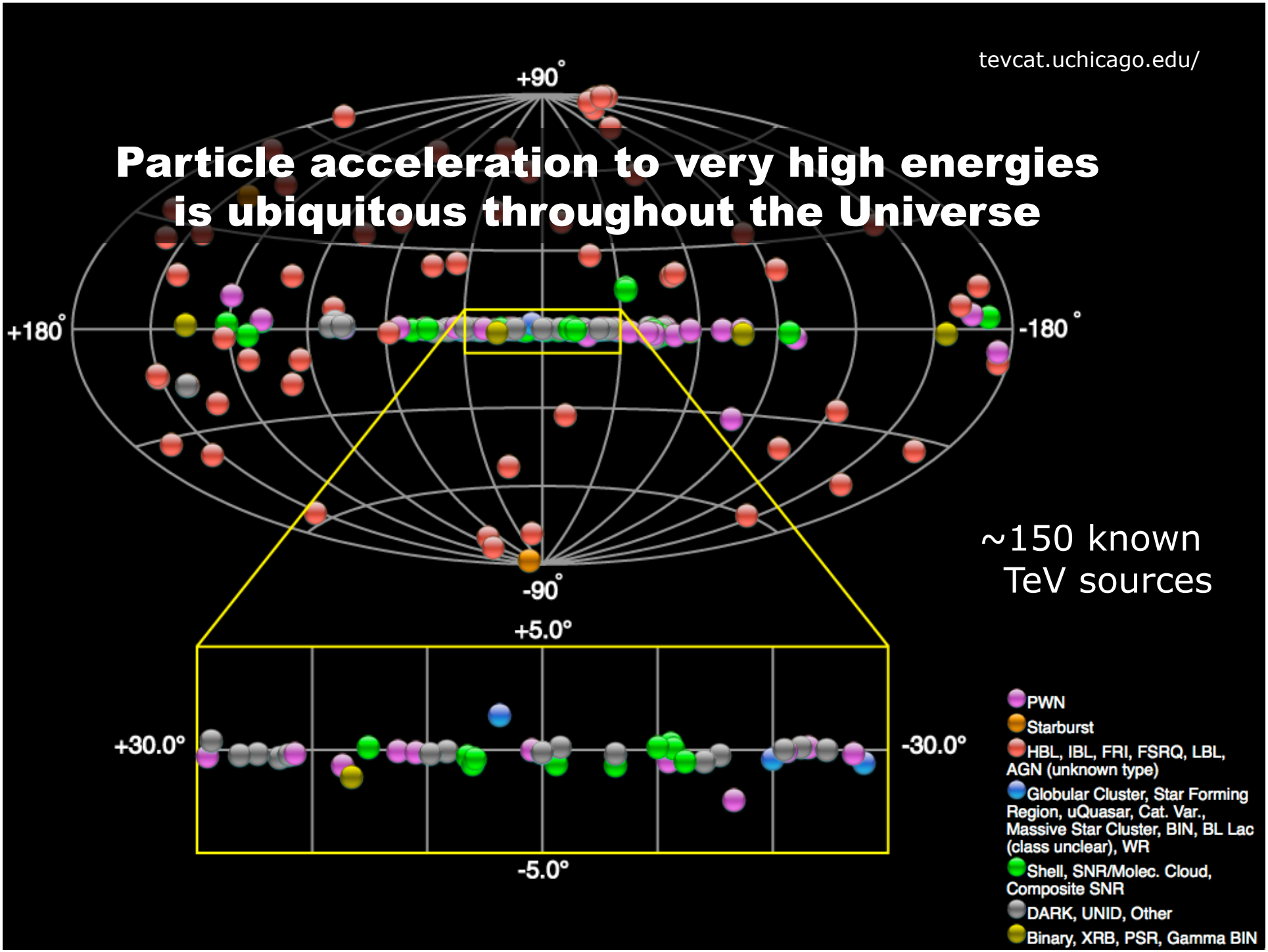
Werner Hofmann May 2014

STATUS OF CTA

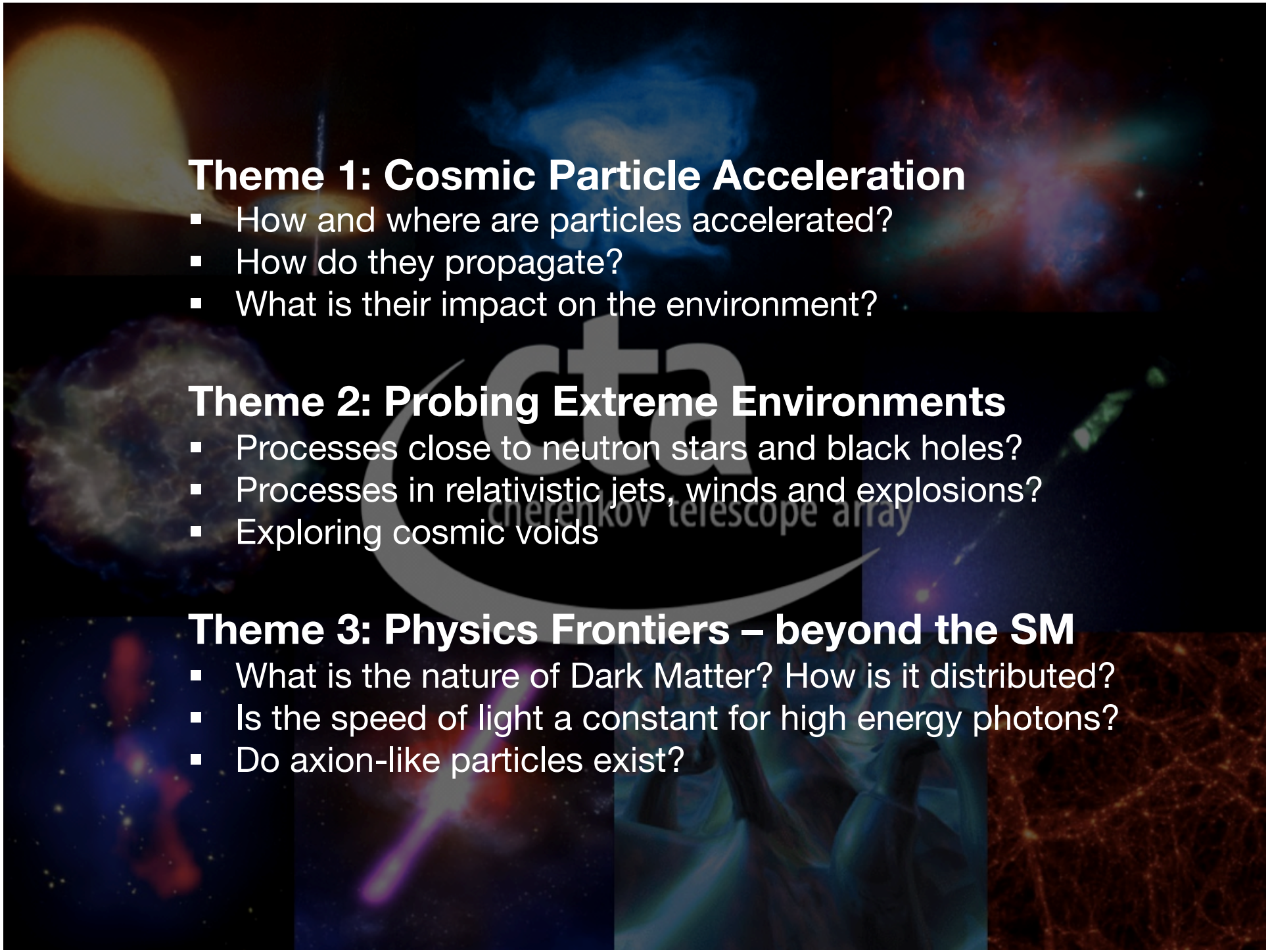
CTA CONSORTIUM



28 Countries
173 Institutes
1178 members


tevcat.uchicago.edu/
Particle acceleration to very high energies is ubiquitous throughout the Universe
+90°
+180°
-180°
-90°
+5.0°
+30.0°
-30.0°
-5.0°
~150 known TeV sources
PWN
Starburst
HBL, IBL, FRI, FSRQ, LBL, AGN (unknown type)
Globular Cluster, Star Forming Region, uQuasar, Cat. Var., Massive Star Cluster, BIN, BL Lac (class unclear), WR
Shell, SNR/Molec. Cloud, Composite SNR
DARK, UNID, Other
Binary, XRB, PSR, Gamma BIN


cta
cherenkov telescope array



Theme 1: Cosmic Particle Acceleration

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

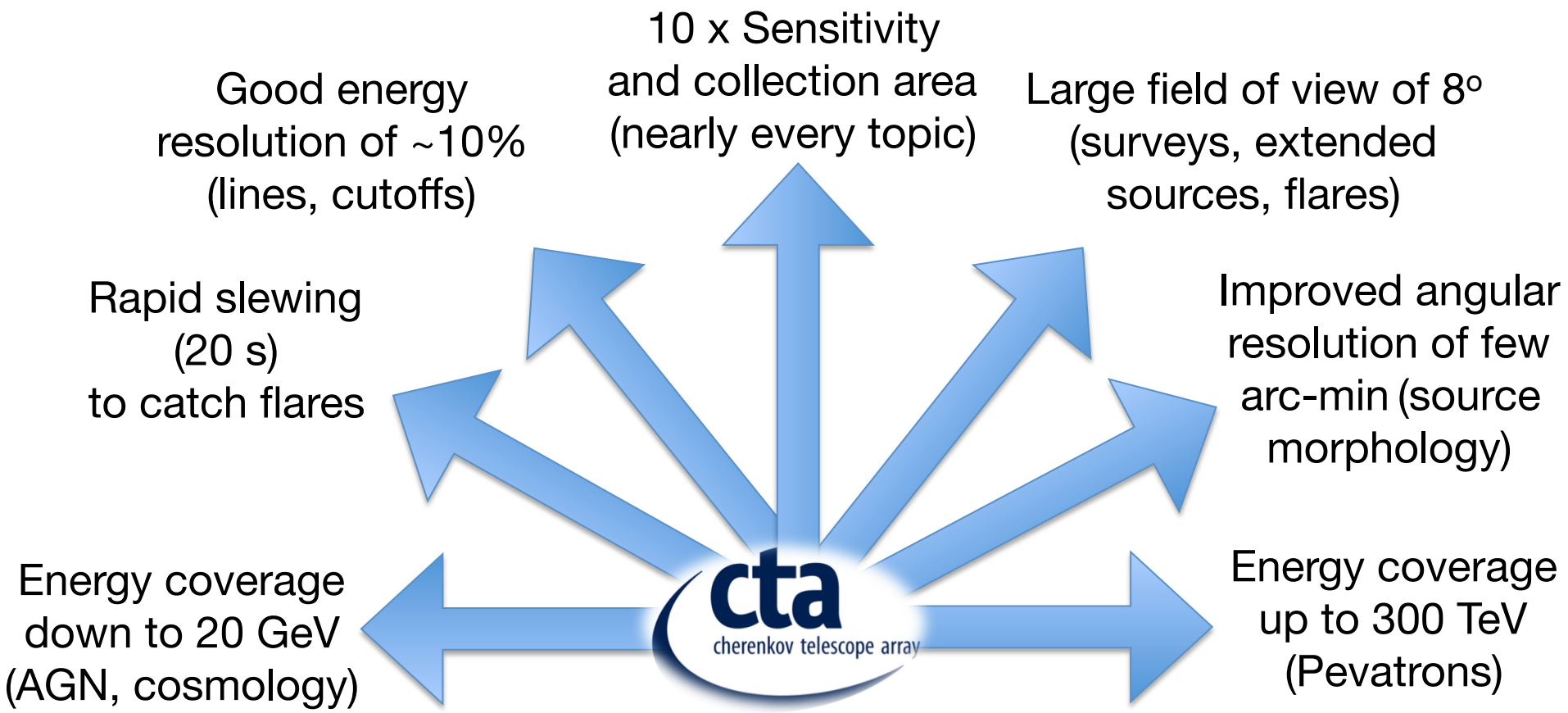
Theme 2: Probing Extreme Environments

- Processes close to neutron stars and black holes?
- Processes in relativistic jets, winds and explosions?
- Exploring cosmic voids

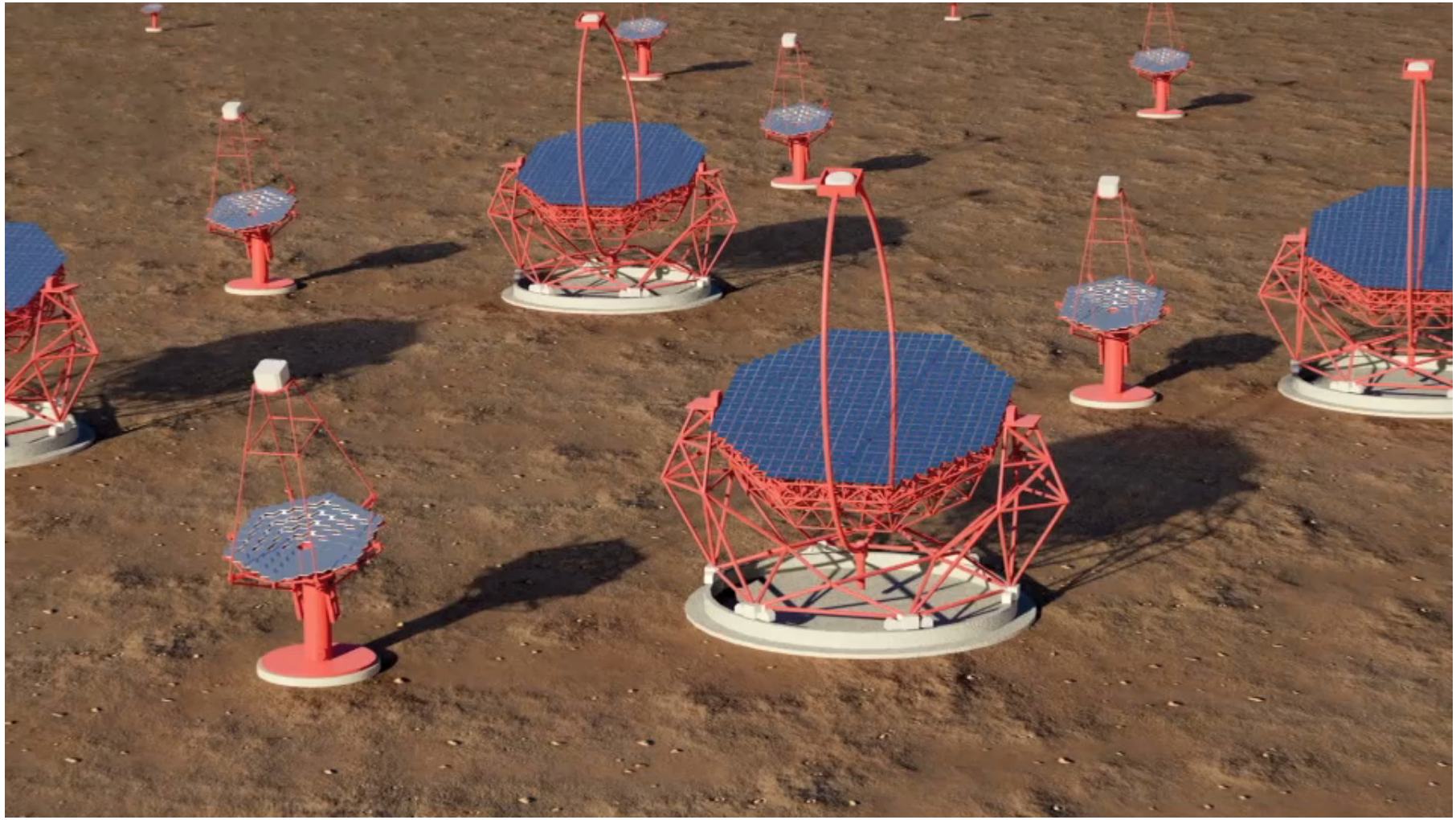
Theme 3: Physics Frontiers – beyond the SM

- What is the nature of Dark Matter? How is it distributed?
- Is the speed of light a constant for high energy photons?
- Do axion-like particles exist?

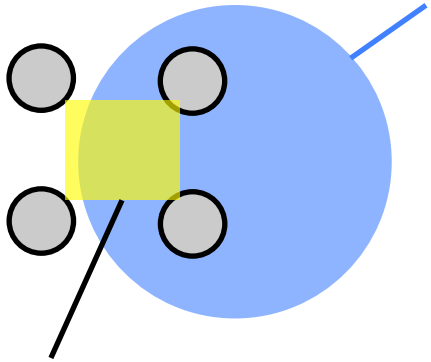
REQUIREMENTS & DRIVERS



Credit:
Multimedia Service,
Institute of Astrophysics of Canary Islands

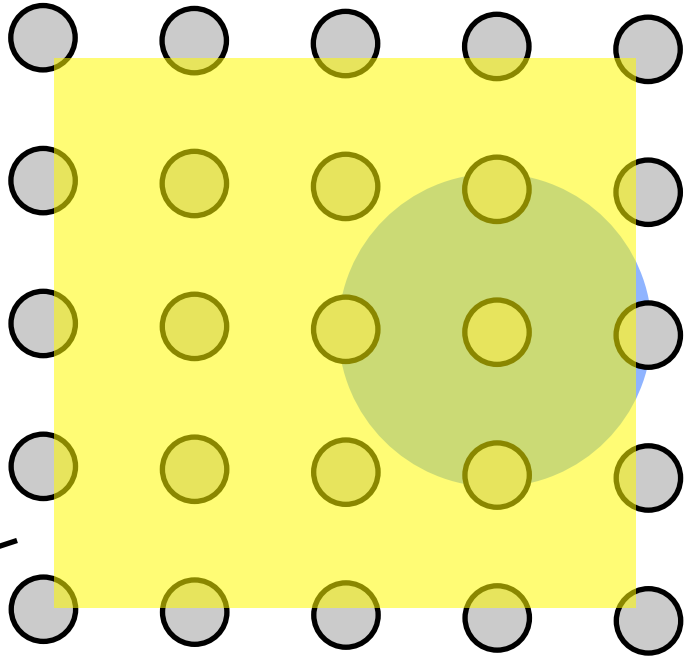


FROM CURRENT ARRAYS TO CTA

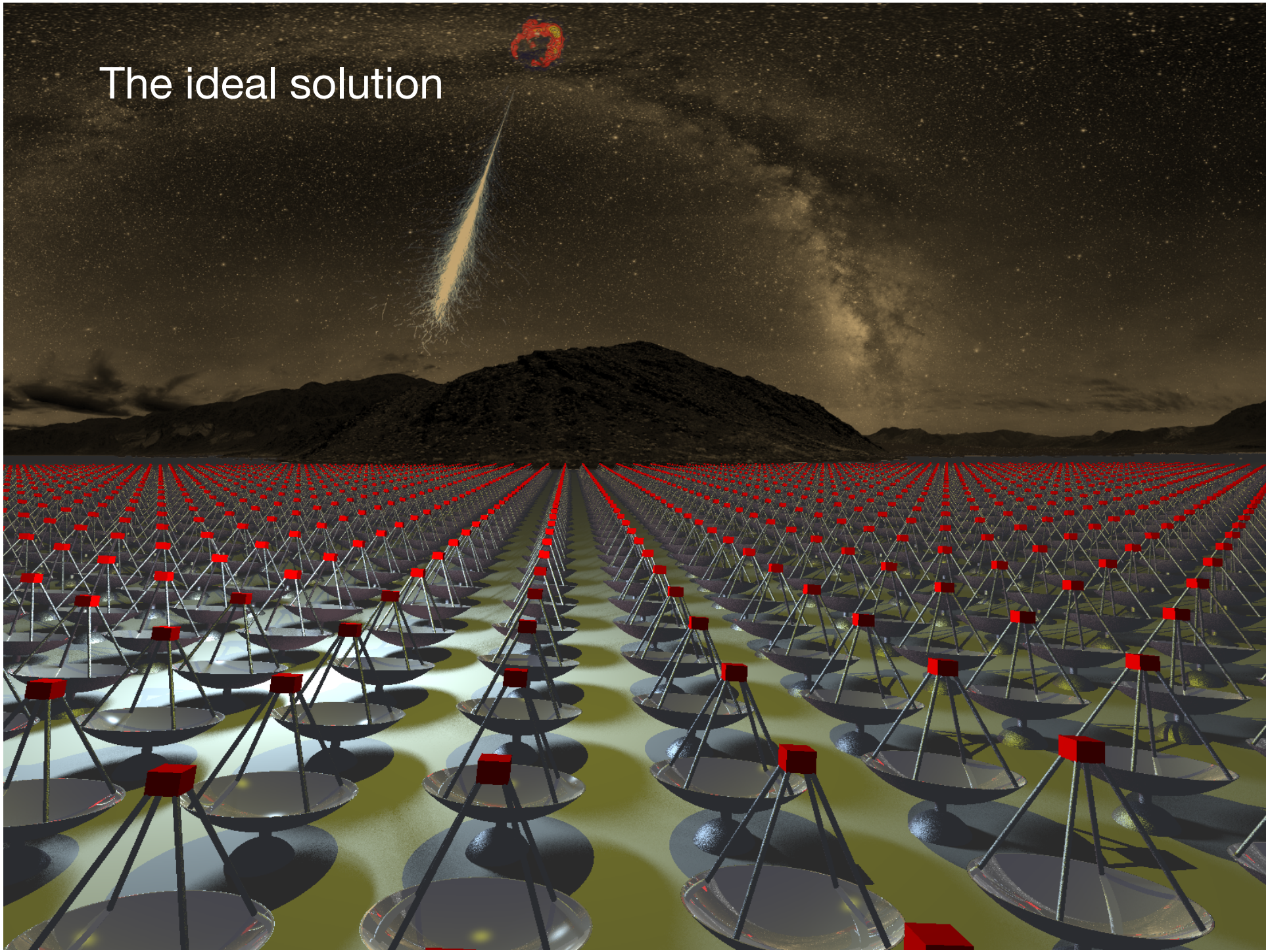


light pool radius
R ≈100-150 m
≈ typical telescope spacing

Sweet spot for
best triggering
and reconstruction:
most showers miss it!

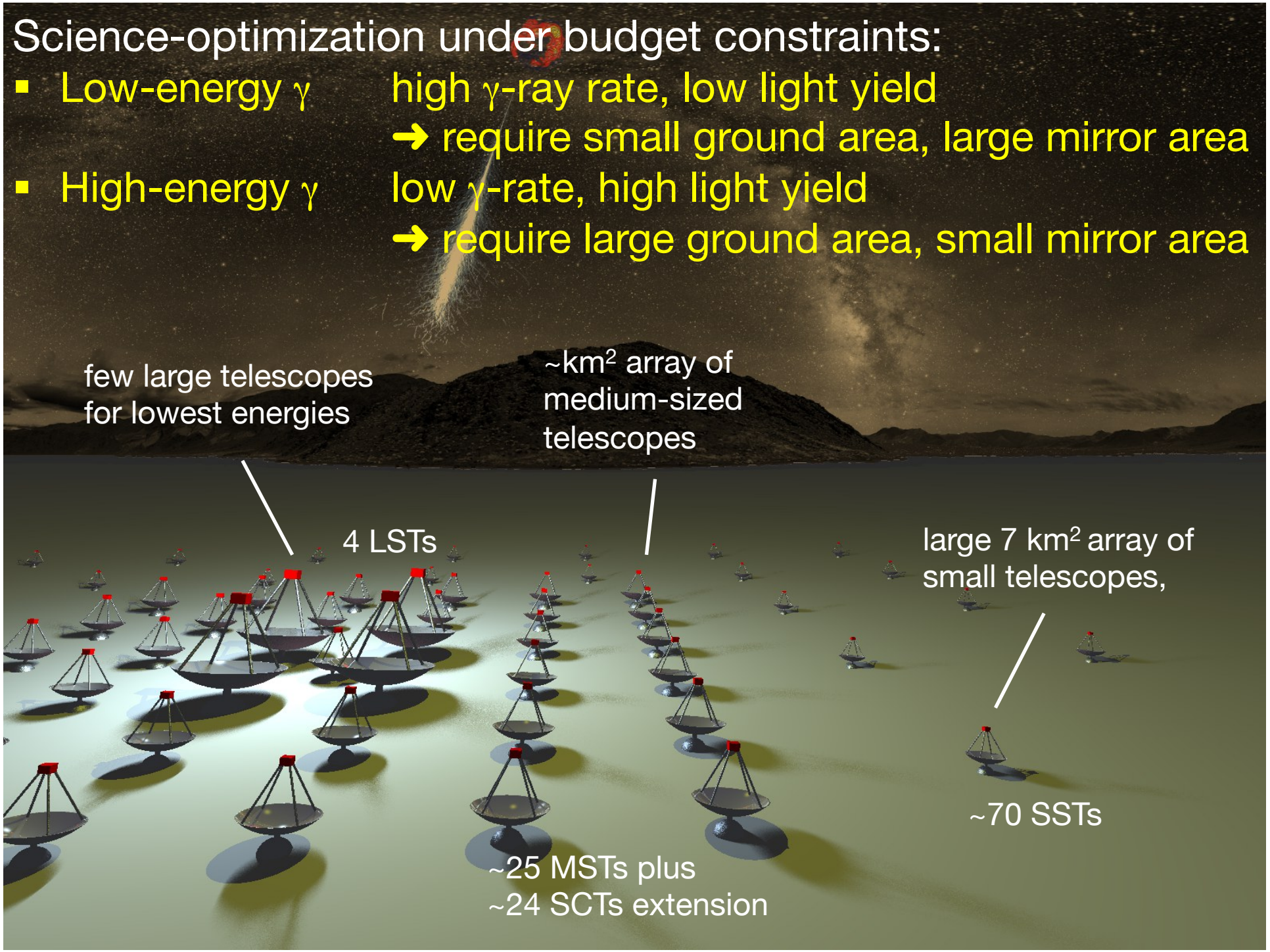


large detection area
more images per shower
lower trigger threshold


The ideal solution

Science-optimization under budget constraints:

- Low-energy γ — high γ-ray rate, low light yield
  ➜ require small ground area, large mirror area
- High-energy γ — low γ-rate, high light yield
  ➜ require large ground area, small mirror area



SOUTHERN AND NORTHERN SITES

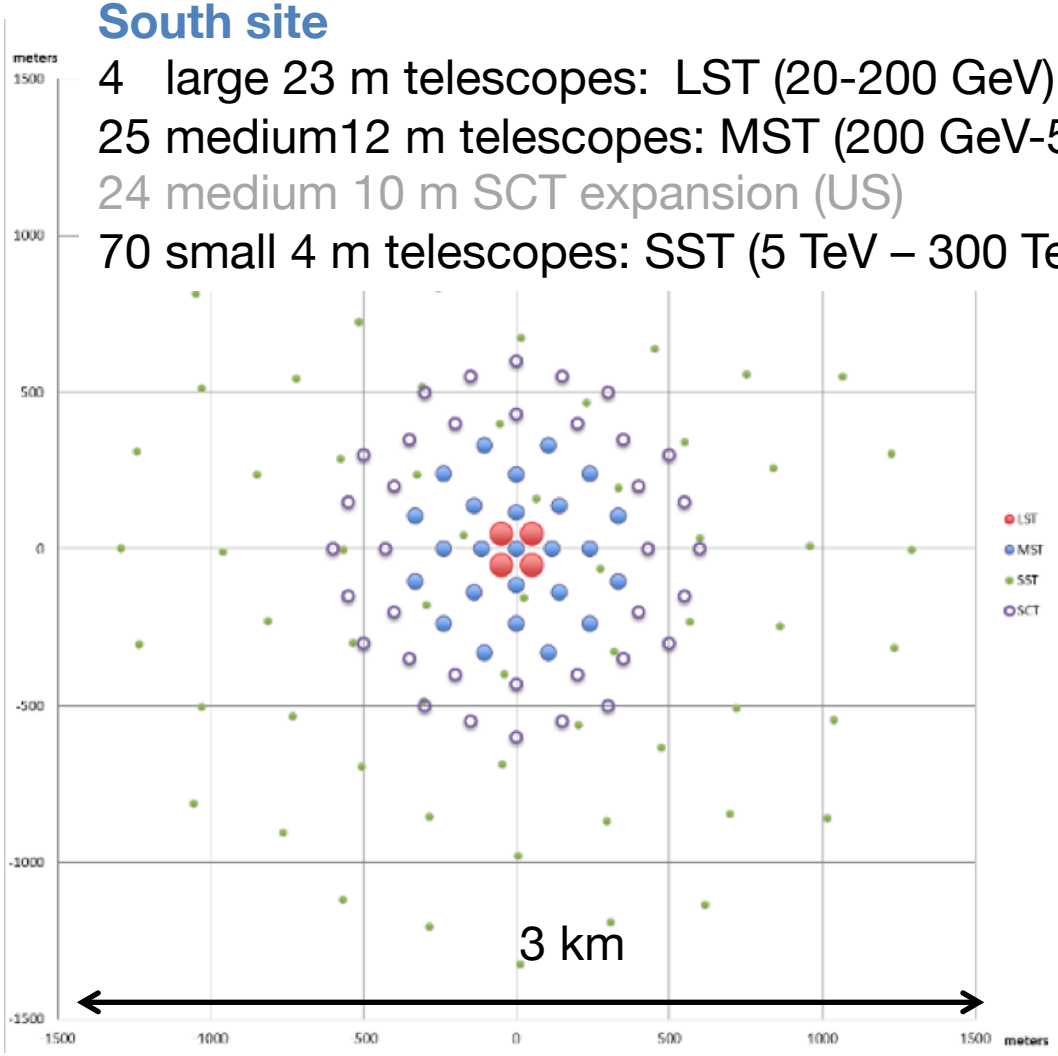
South site

4 large 23 m telescopes: LST (20-200 GeV)

25 medium12 m telescopes: MST (200 GeV-5 TeV)

24 medium 10 m SCT expansion (US)

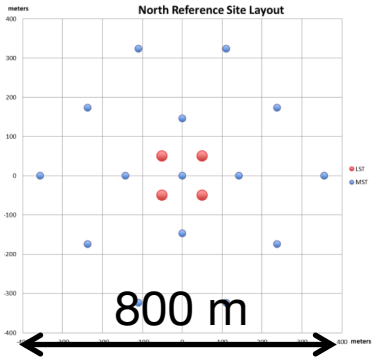
70 small 4 m telescopes: SST (5 TeV – 300 TeV)



North site

4 large LST

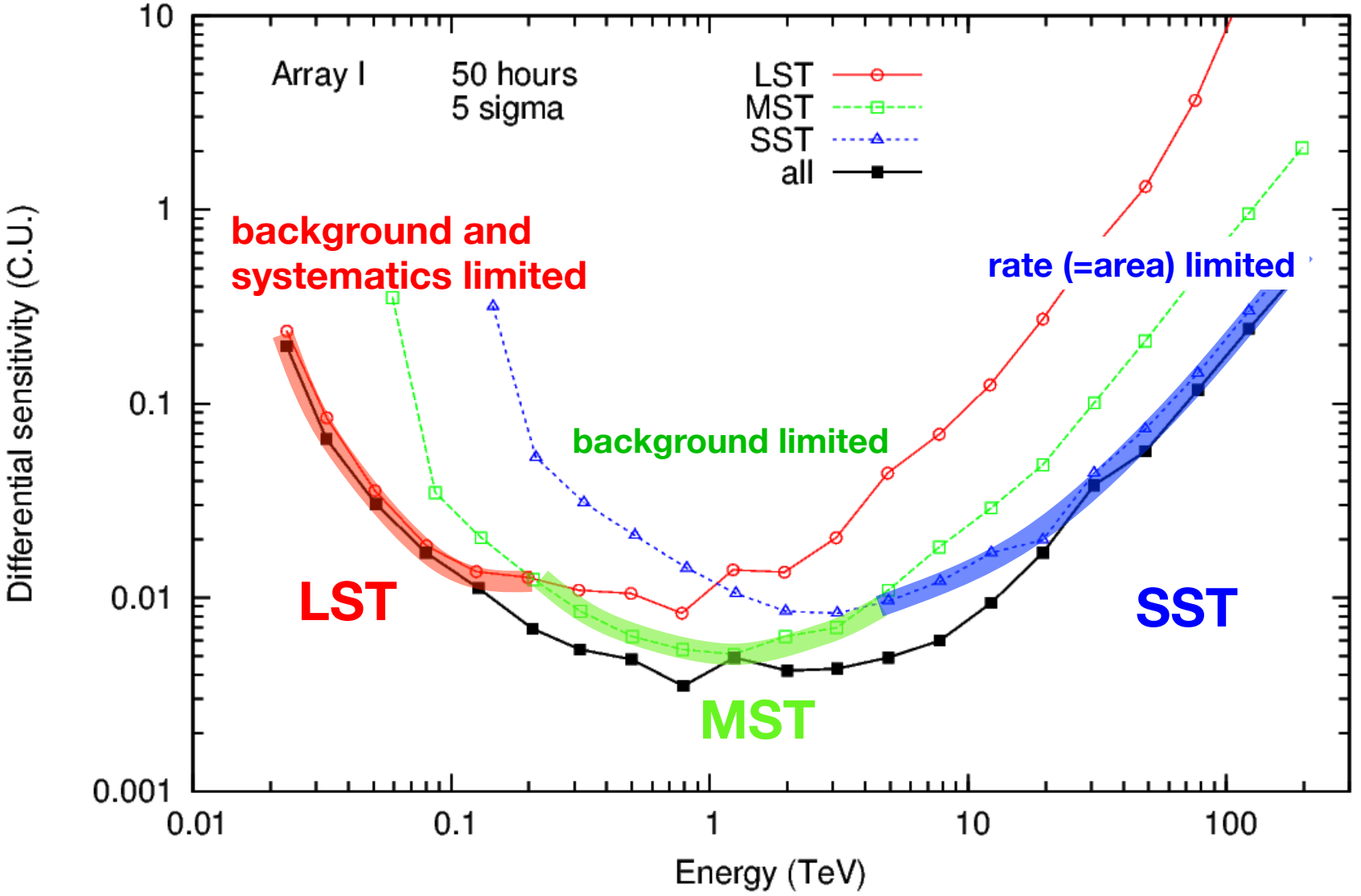
15 medium MST



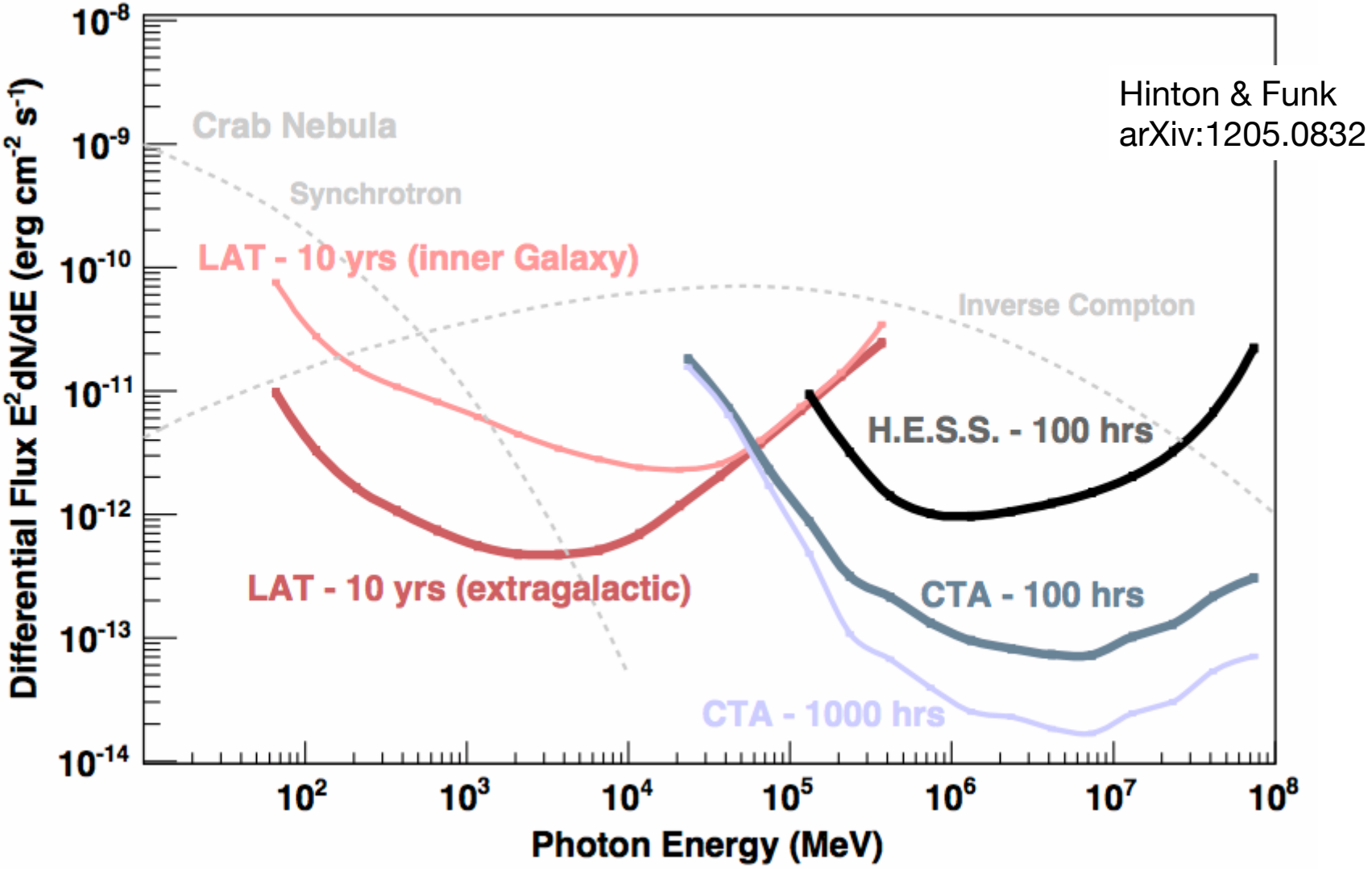
~2/3 of all current sources in Southern sky

SENSITIVITY (IN UNITS OF CRAB FLUX)

FOR DETECTION IN EACH 0.2-DECADE ENERGY BAND

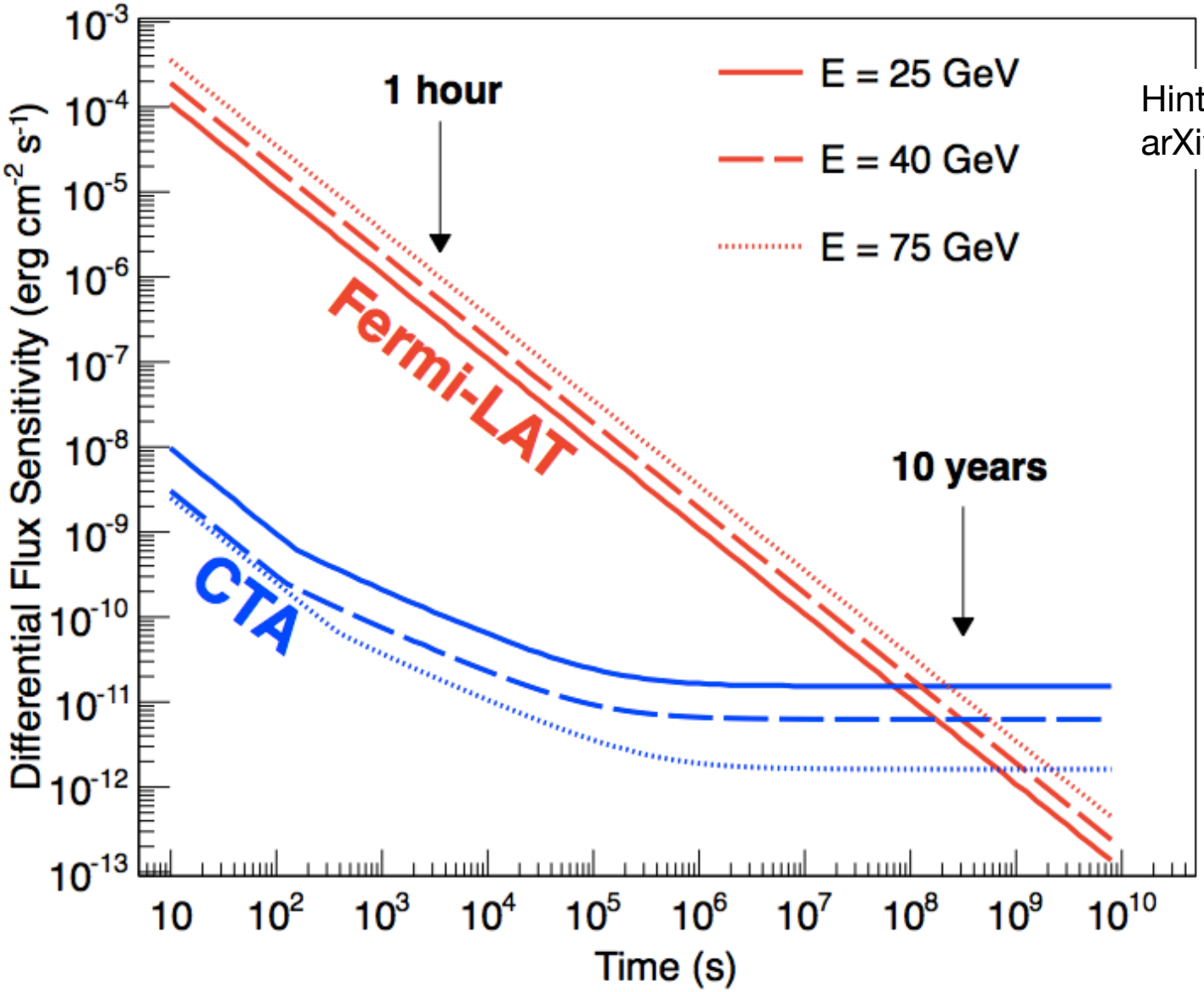


DIFFERENTIAL FLUX SENSITIVITY



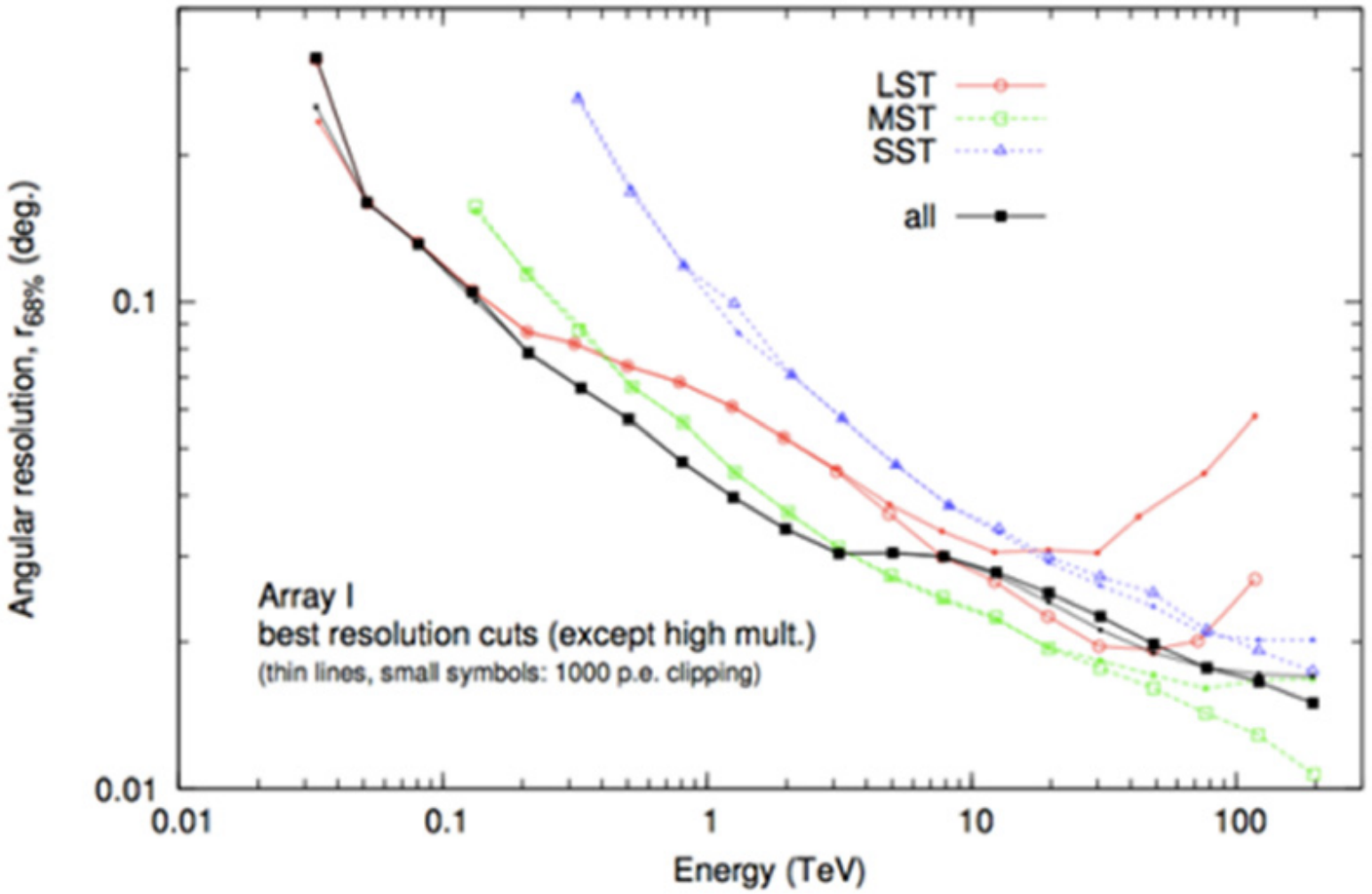
Hinton & Funk
arXiv:1205.0832

SENSITIVITY TO TRANSIENTS



Hinton & Funk
arXiv:1205.0832

ANGULAR RESOLUTION

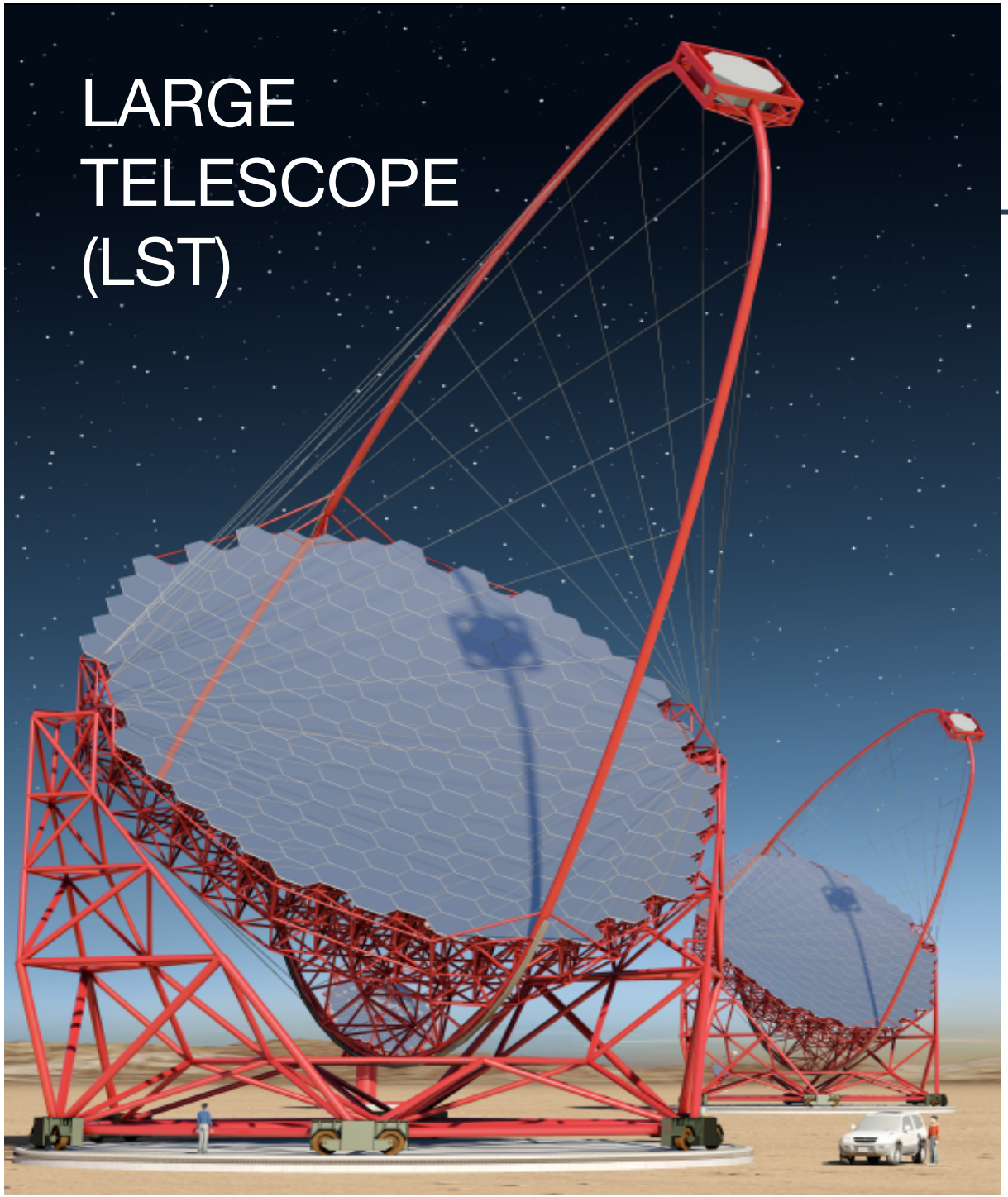


CTA TELESCOPES

TELESCOPE SPECS

	SST "small"	MST "medium"	LST "large"	SCT "medium 2-M"
Number	**70 (S)**	**25 (S)** **15 (N)**	**4 (S)** **4 (N)**	**24 (S)**
Spec'd range	> few TeV	200 GeV to 10 TeV	20 GeV to 1 TeV	200 GeV to 10 TeV
Eff. mirror area	> 5 m^2	> 88 m^2	> 330 m^2	> 40 m^2
Field of view	> 8°	> 7°	> 4.4°	> 7°
Pixel size ~PSF θ_{80}	< 0.25°	< 0.18°	< 0.11°	< 0.075°
Positioning time	90 s, 60 s goal	90 s, 60 s goal	50 s, 20 s goal	90 s, 60 s goal
Availability	> 97% @ 3 h/week	>97% @ 6 h/week	>95% @ 9 h/week	>97% @ 6 h/week
Target capital cost	420 k€	1.6 M€	7.4 M€	2.0 M€

LARGE TELESCOPE (LST)



cta
cherenkov telescope array

23 m diameter
389 m^2 dish area
28 m focal length
1.5 m mirror facets

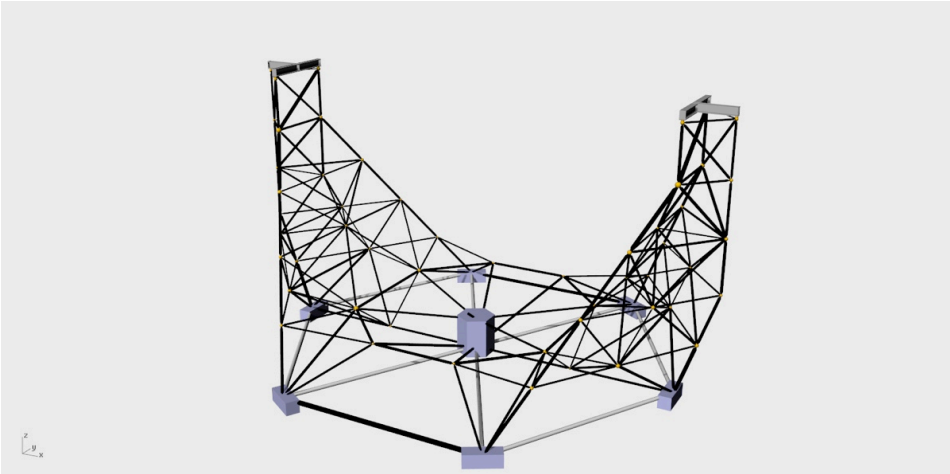
4.5° field of view
0.1° pixels
Camera ∅ over 2 m

Carbon-fibre structure
for 20 s positioning

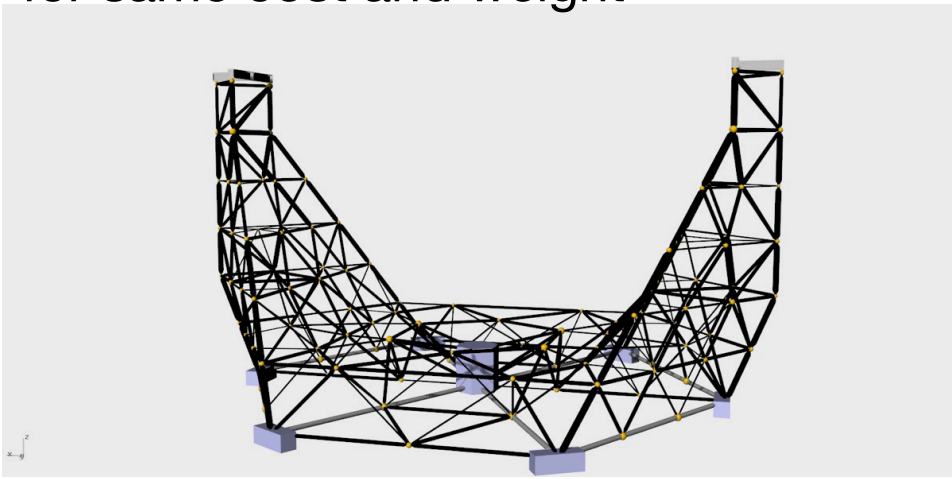
Active mirror control

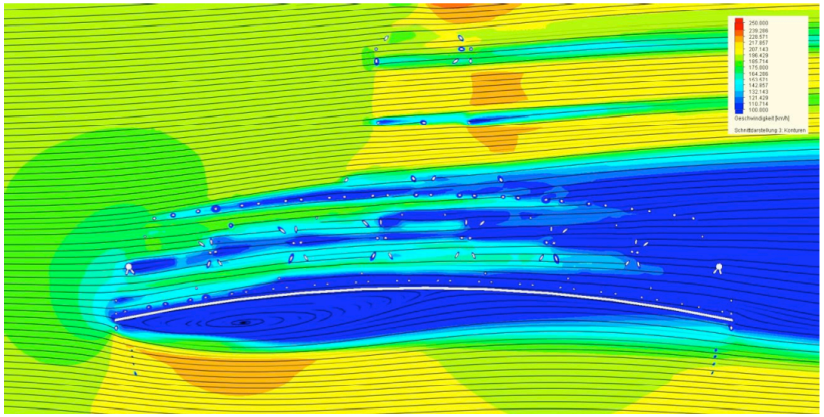
4 LSTs on South site
4 LSTs on North site
Prototype = 1st telescope

REFINEMENTS IN DESIGN (“PHASE 3”)

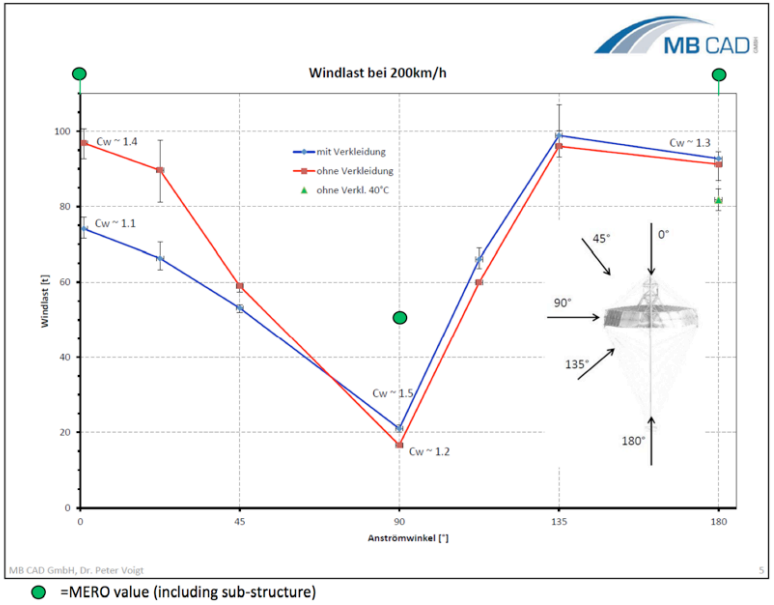


Adding more elements
increases stiffness and redundancy
for same cost and weight





Detailed modeling of wind loads



=MERO value (including sub-structure)

Tests of new
end connectors
for CF tubes

Elevation
drive
prototype

MEDIUM-SIZED 12 M TELESCOPE

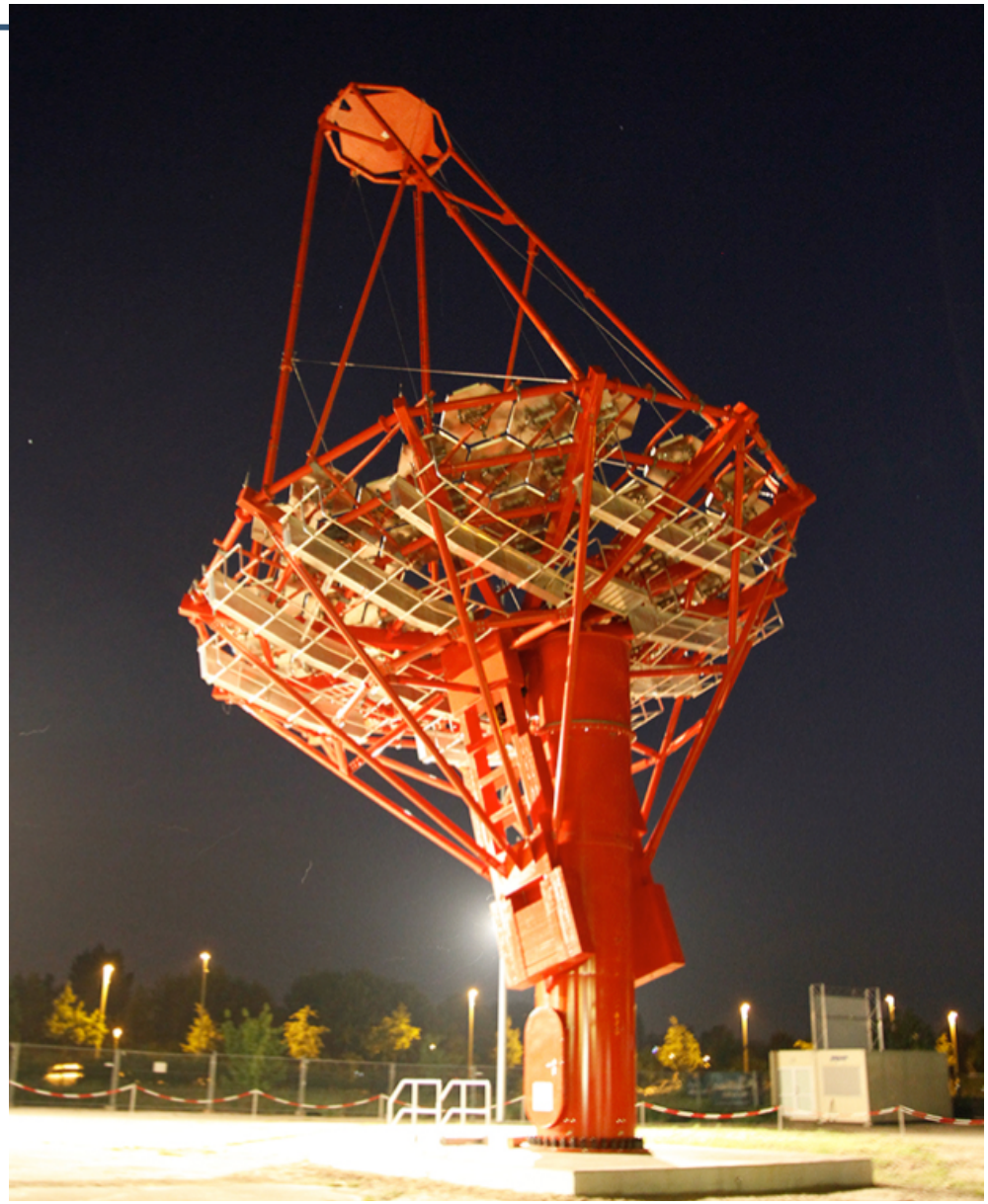
OPTIMIZED FOR THE 100 GEV TO ~10 TEV RANGE

cta
cherenkov telescope array

100 m^2 dish area
16 m focal length
1.2 m mirror facets

8^o field of view
~2000 x 0.18^o pixels

25 MSTs on South site
15 MSTs on North site



Berlin
MST prototype
operational

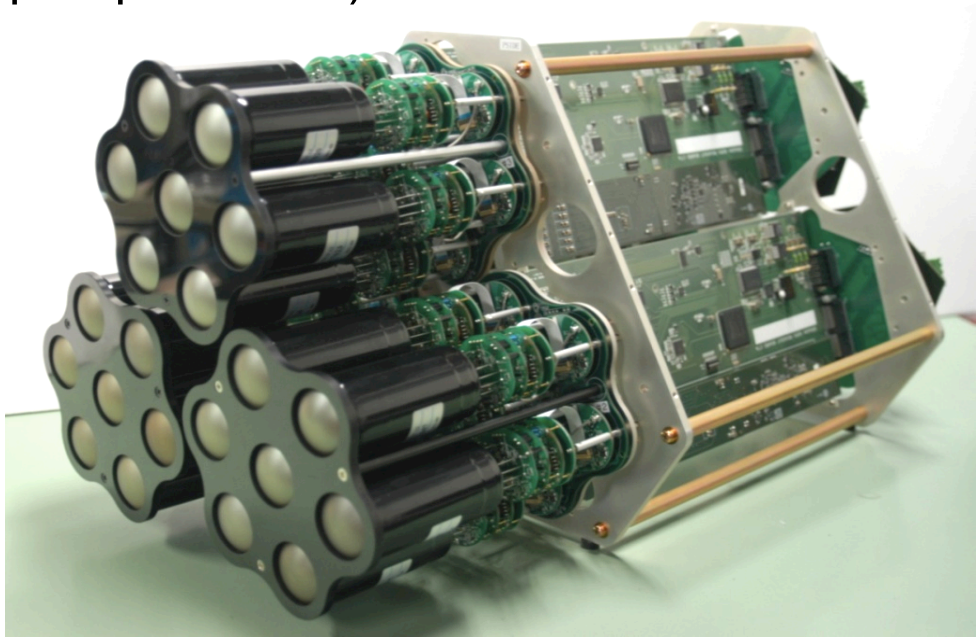
MST PROTOTYPE

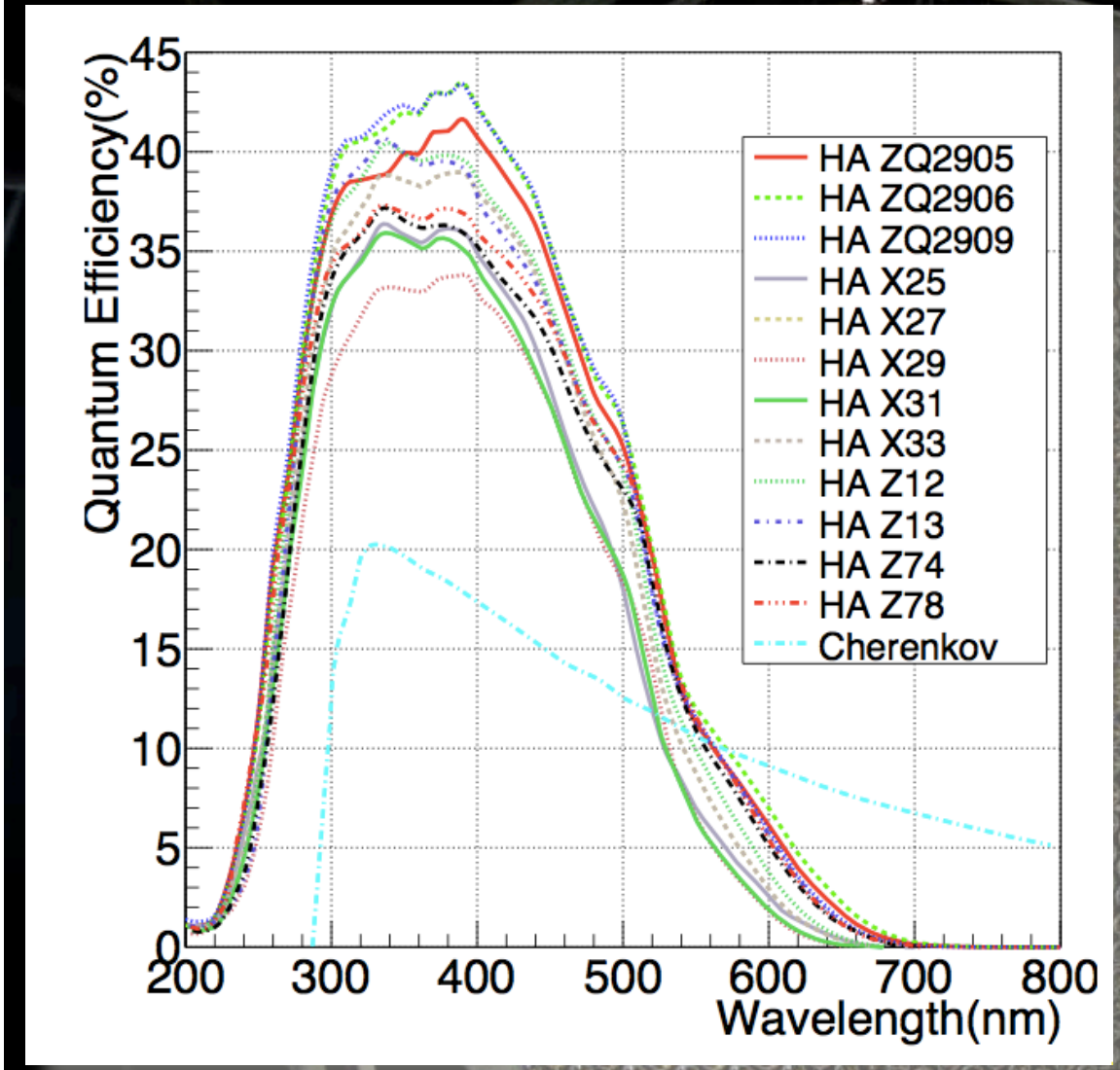
PHOTOMULTIPLIER CAMERAS

Recording signal waveform for “interesting” (triggered) images

Options:

- Capacitor pipeline + analog trigger + (identical) “drawers”
  - NectarCam (Pixel cluster prototypes operational)
  - LSTCam (Pixel cluster prototypes operational)
- Flash-ADC + digital trigger + rack-based electronics
  - Flashcam (144 pixel prototype operational)



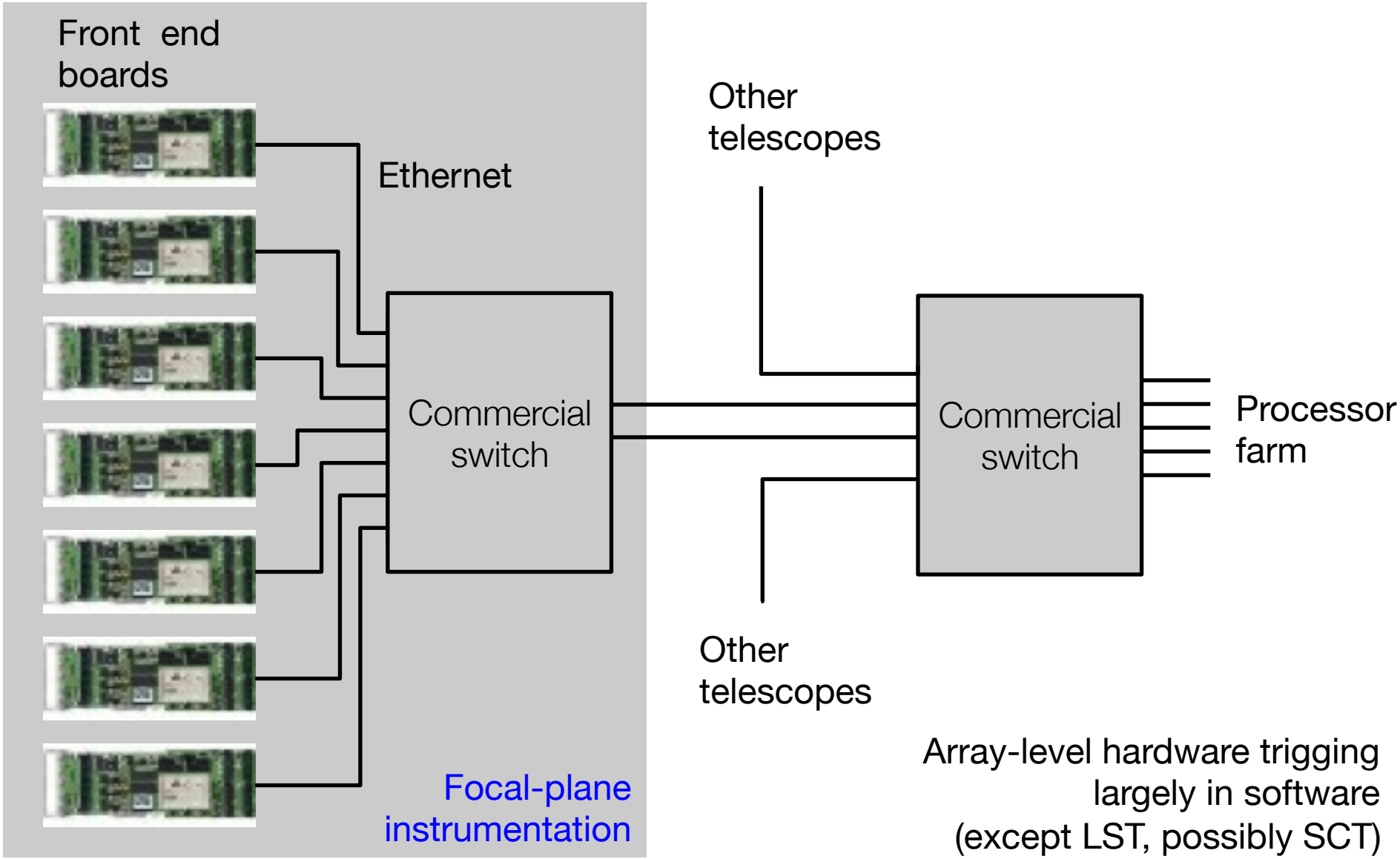


MST & LST cameras:

correspond to
HESS II Camera with its
2048 pixels
On-board electronics
2.5 m ⌀

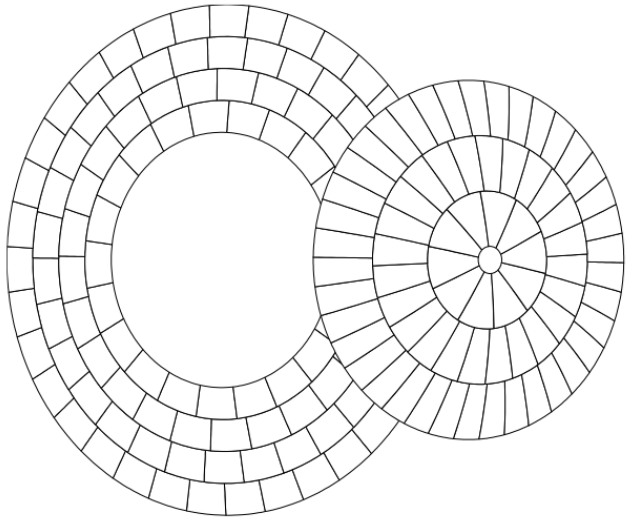
CTA: Improved PMTs
Readout

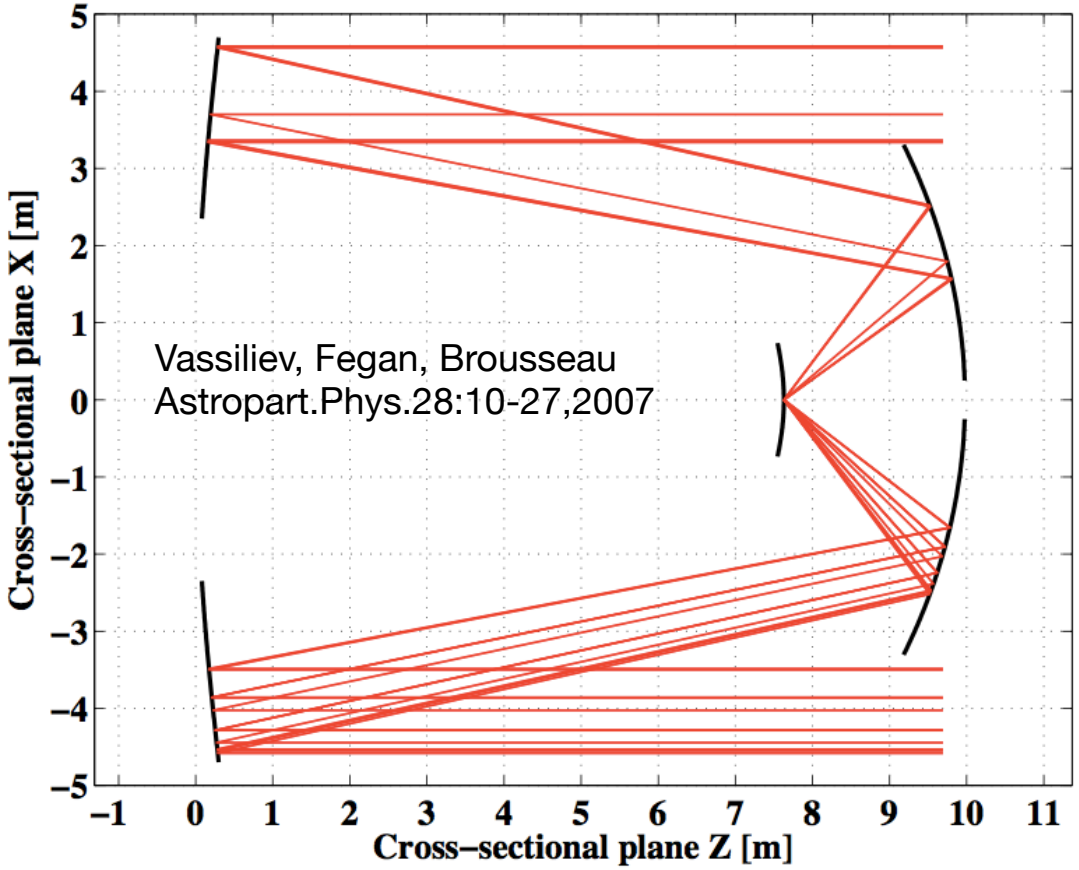
DATA ACQUISITION @ TRIGGER



Array-level hardware trigging largely in software (except LST, possibly SCT)

DUAL-MIRROR TELESCOPES





- Reduced plate scale
- Reduced psf
- Uniform psf across f.o.v.

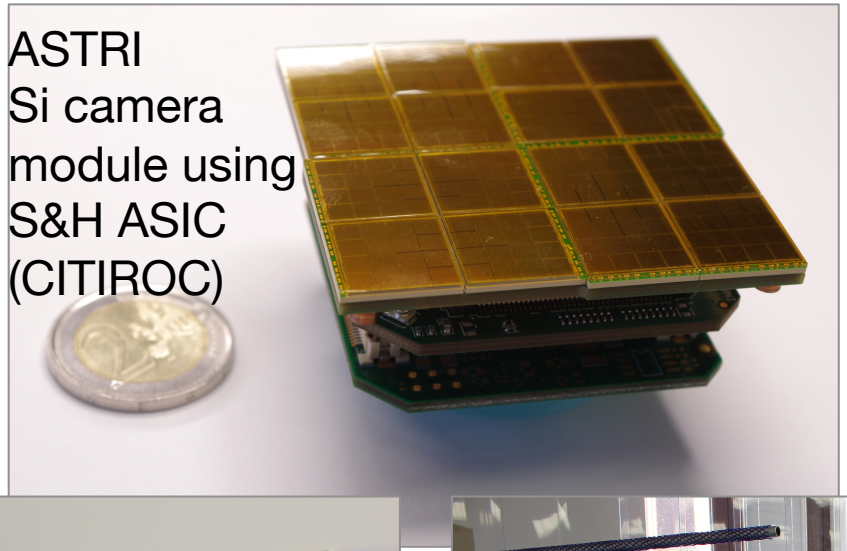
➜ Cost-effective small telescopes with compact sensors (SST-2M)

➜ Higher-performance telescopes with small pixels (SCT)

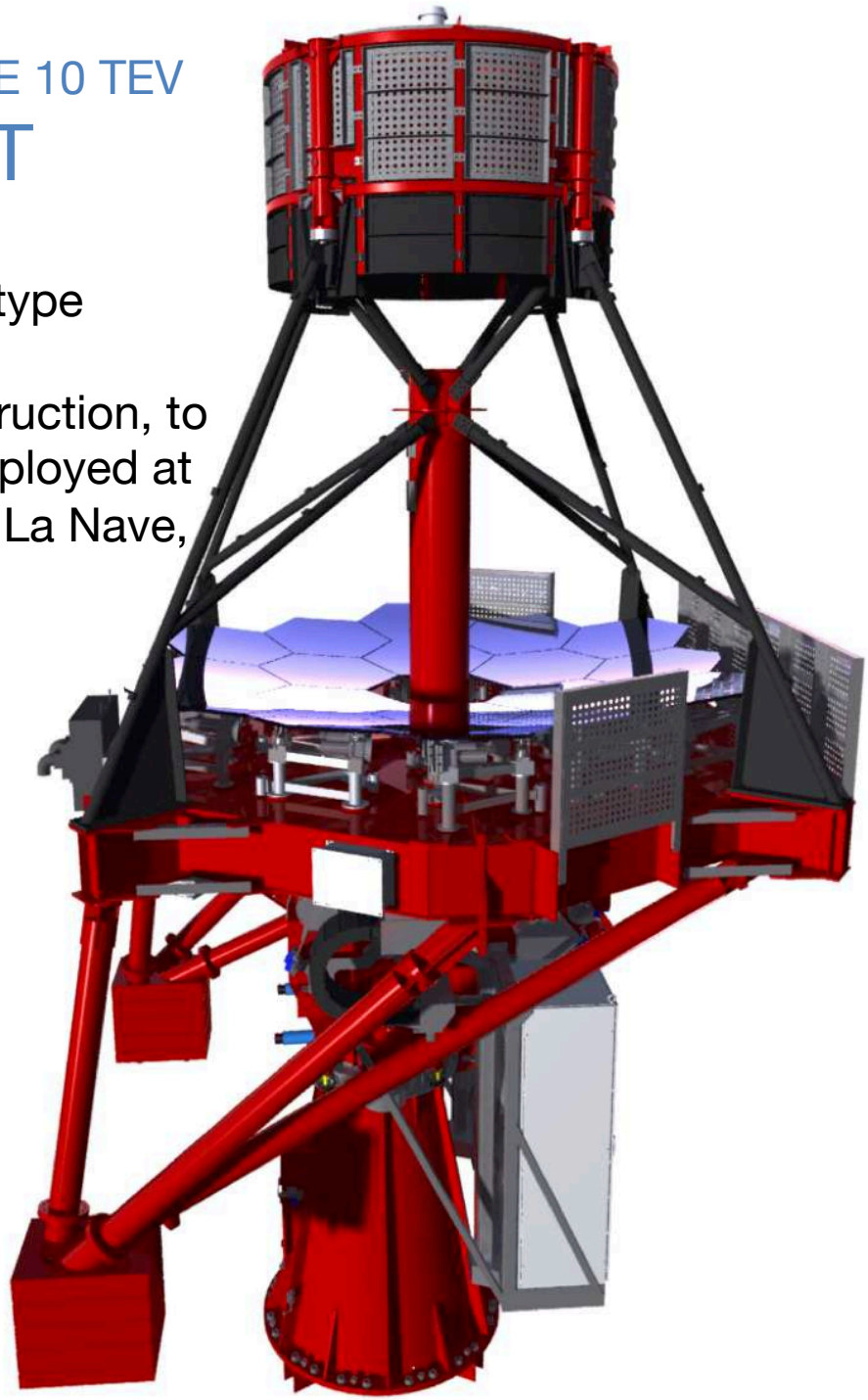
SST - OPTIMIZED FOR THE RANGE ABOVE 10 TEV

ASTRI DUAL MIRROR SST

ASTRI
Si camera
module using
S&H ASIC
(CITIROC)

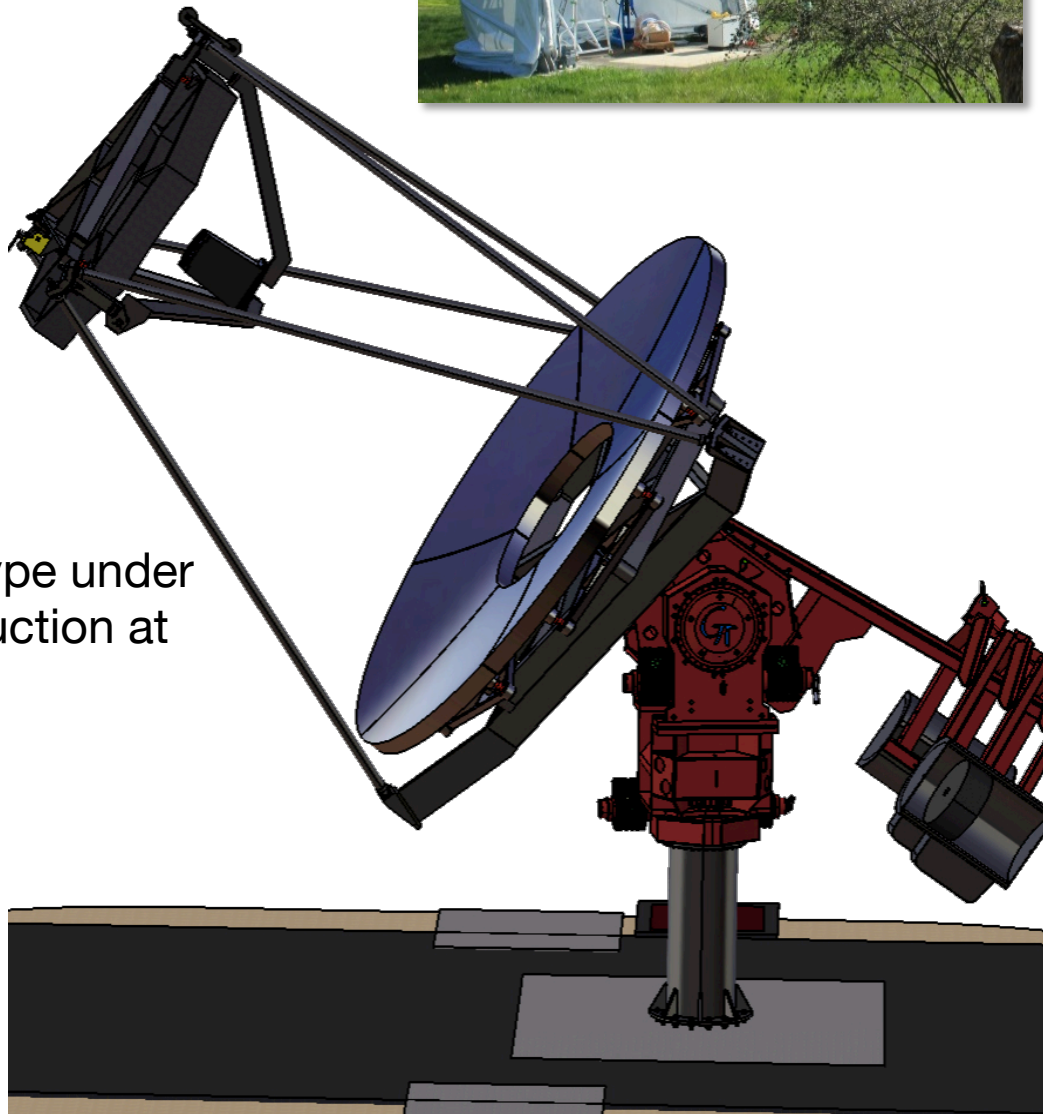


Prototype
under
construction, to
be deployed at
Serra La Nave,
Sicily



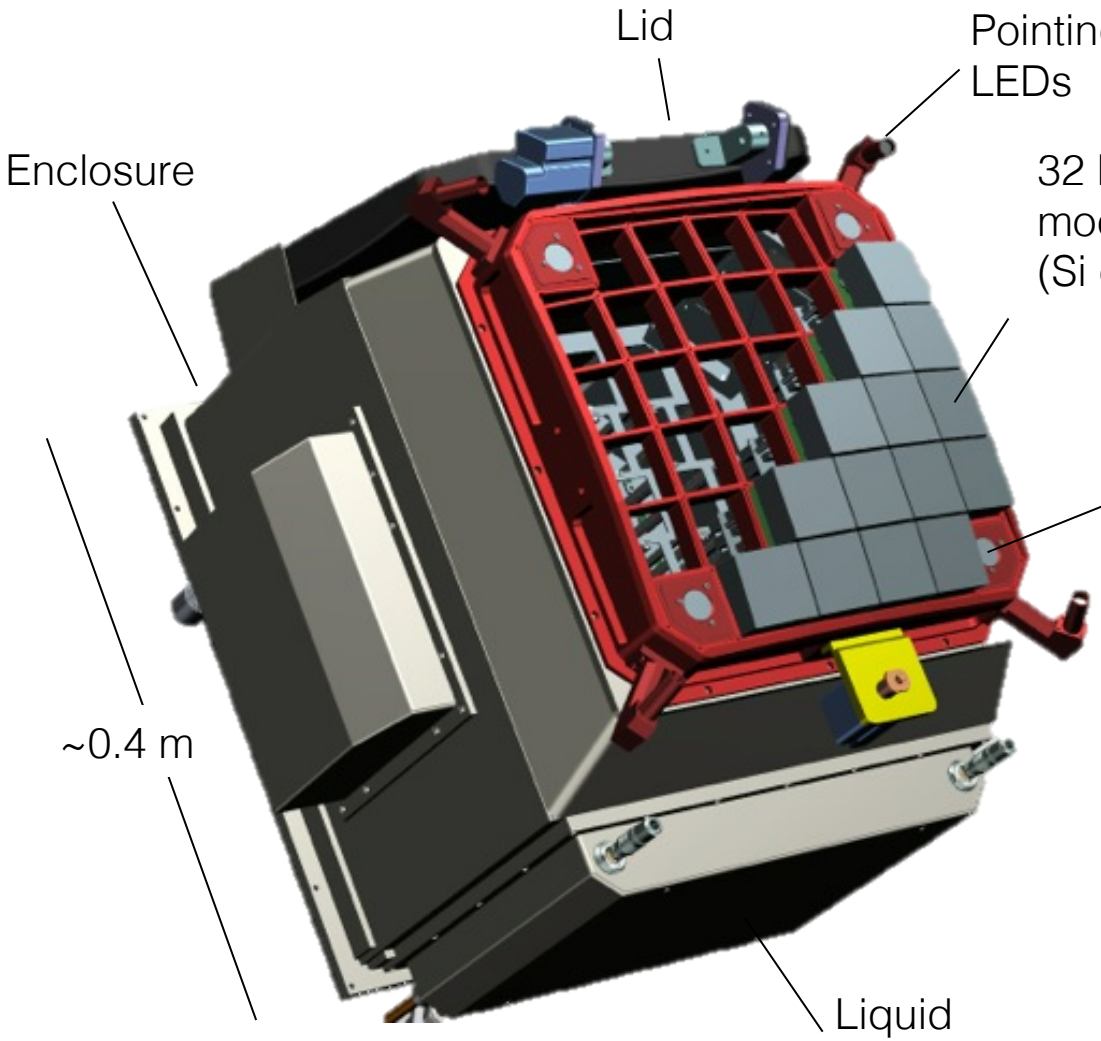
GATE DUAL MIRROR SST

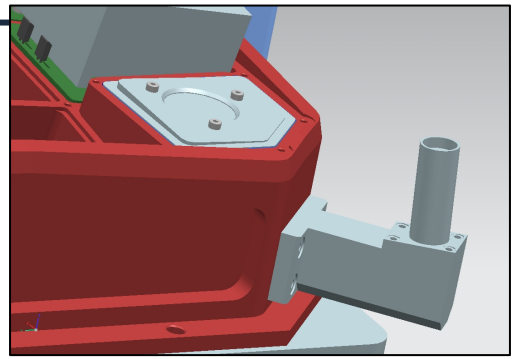
Prototype under construction at Paris

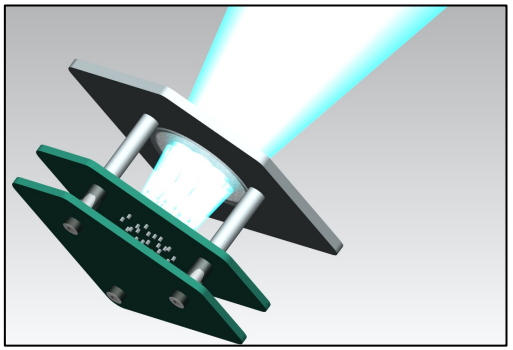


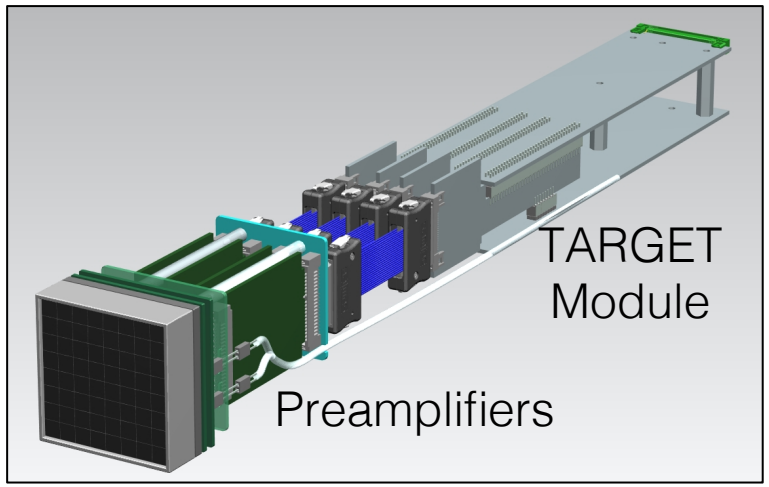
CHEC SST CAMERA

Prototypes ready:
CHEC-M: 10/2014
CHEC-S: Spring 2015

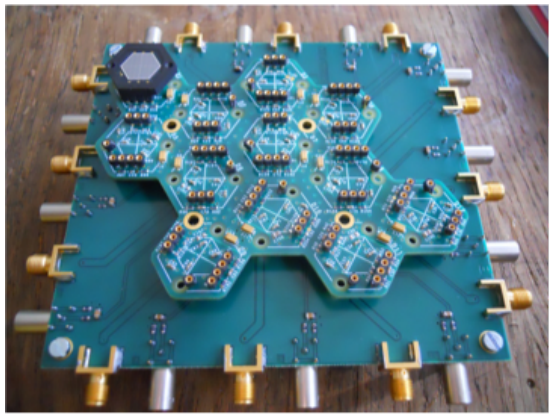


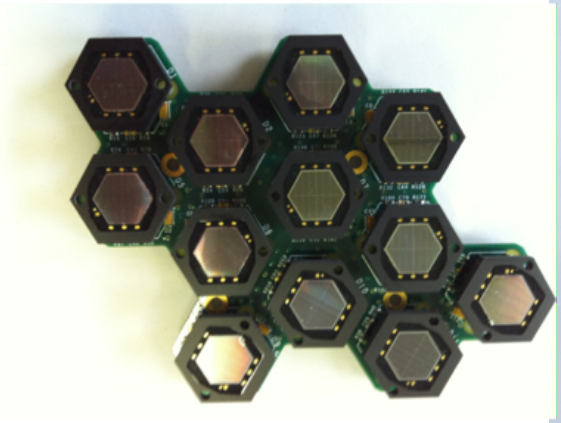


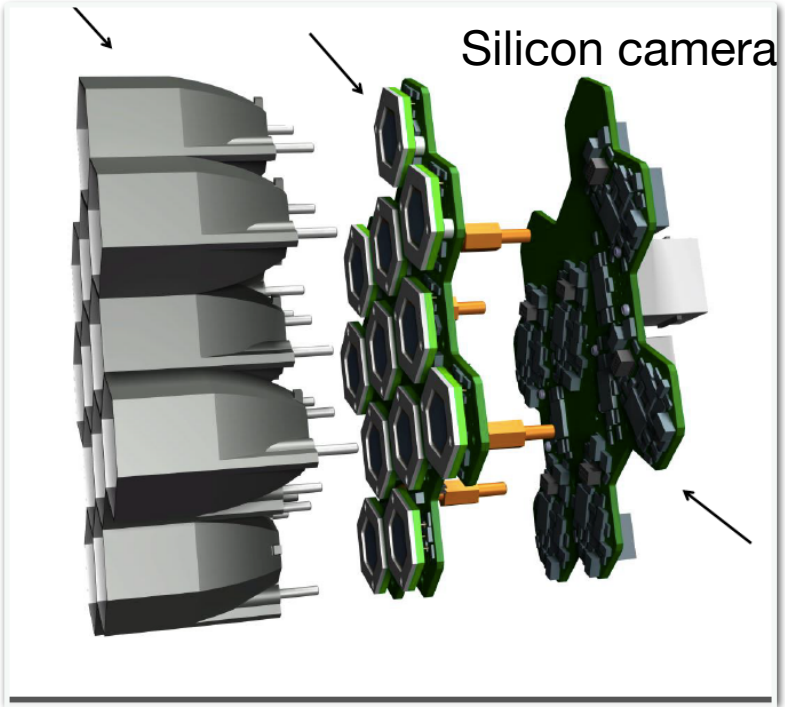




SINGLE-MIRROR SST PROTOTYPE







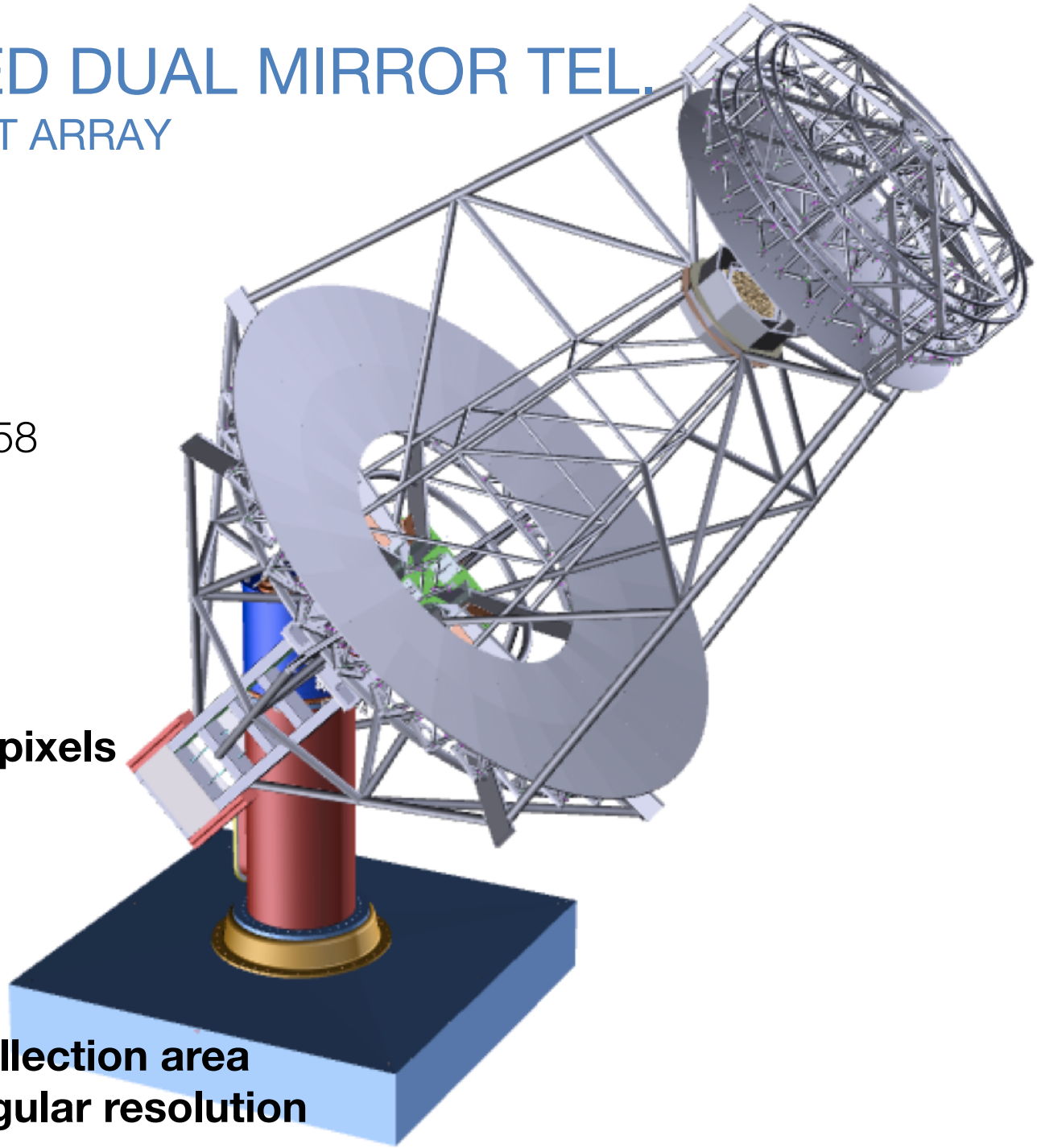
MEDIUM-SIZED DUAL MIRROR TEL.

EXTENDING THE MST ARRAY

9.7 m primary
5.4 m secondary
5.6 m focal length, f/0.58
40 m^2 eff. coll. area
PSF better than 4.5'
across 8^o fov

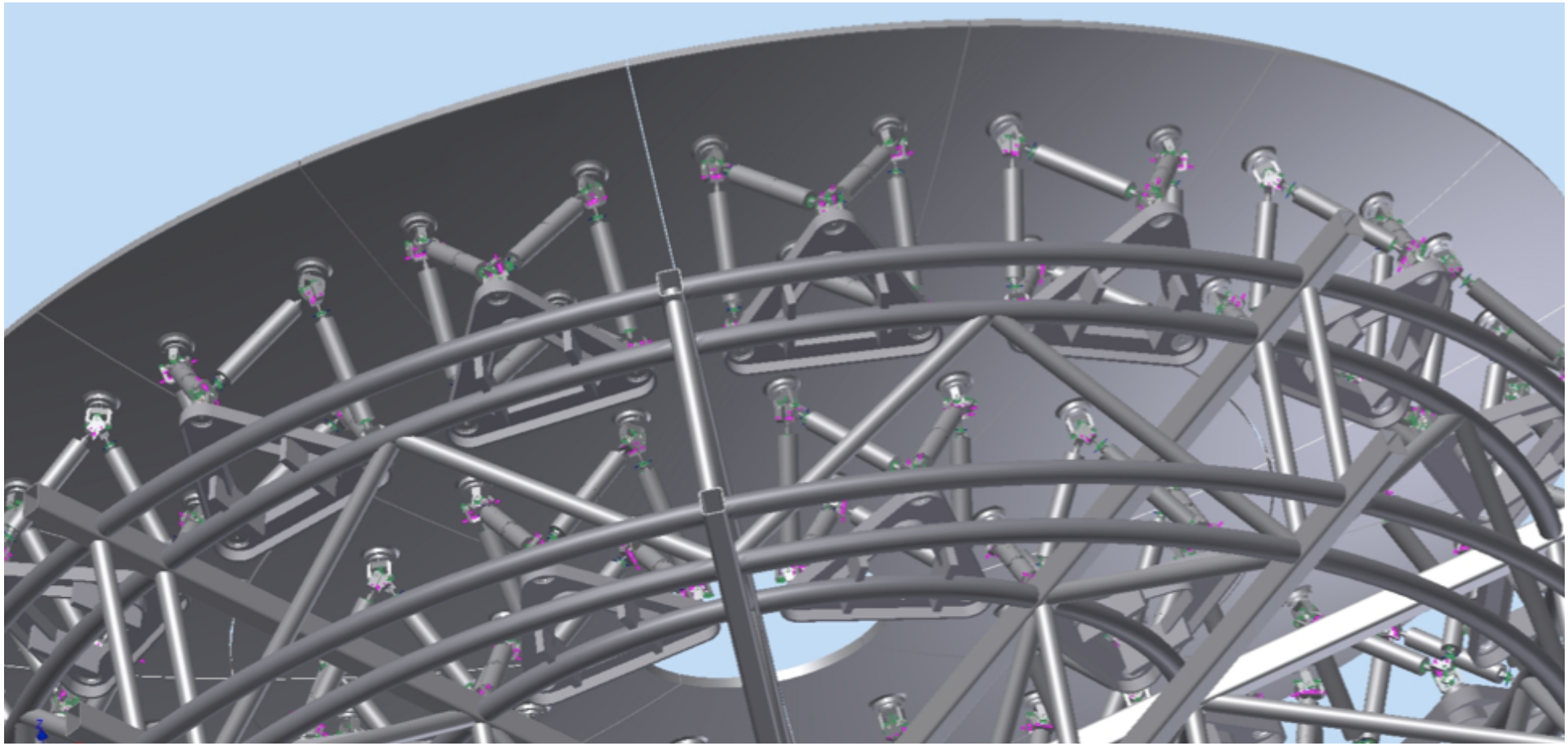
8^o field of view
11328 x 0.07° SiPMT pixels
Target readout ASIC

Extend South array
by adding 24 SCTs



➜ increased γ-ray collection area
➜ improved γ-ray angular resolution

OPTICS & ALIGNMENT CHALLENGING

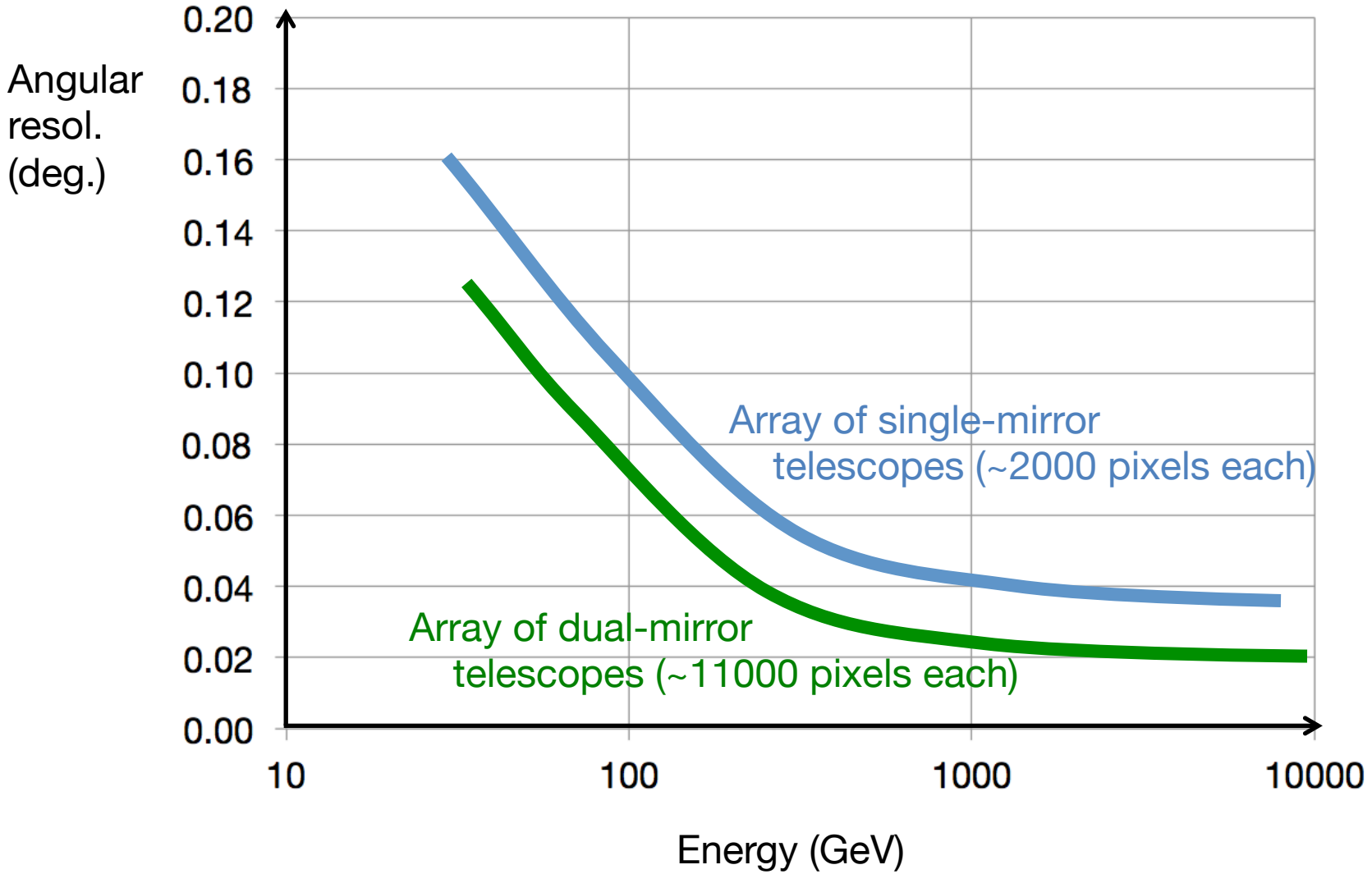


- NSF MRI Project:Prototype (full primary, partial secondary, partial camera) fabricated by 9/2014, commissioned and verified by 9/2015

PROTOTYPING AT VERITAS

Actuators
Edge sensors
Controller

ANGULAR RESOLUTION



PROTOTYPING AND PRE-PRODUCTION

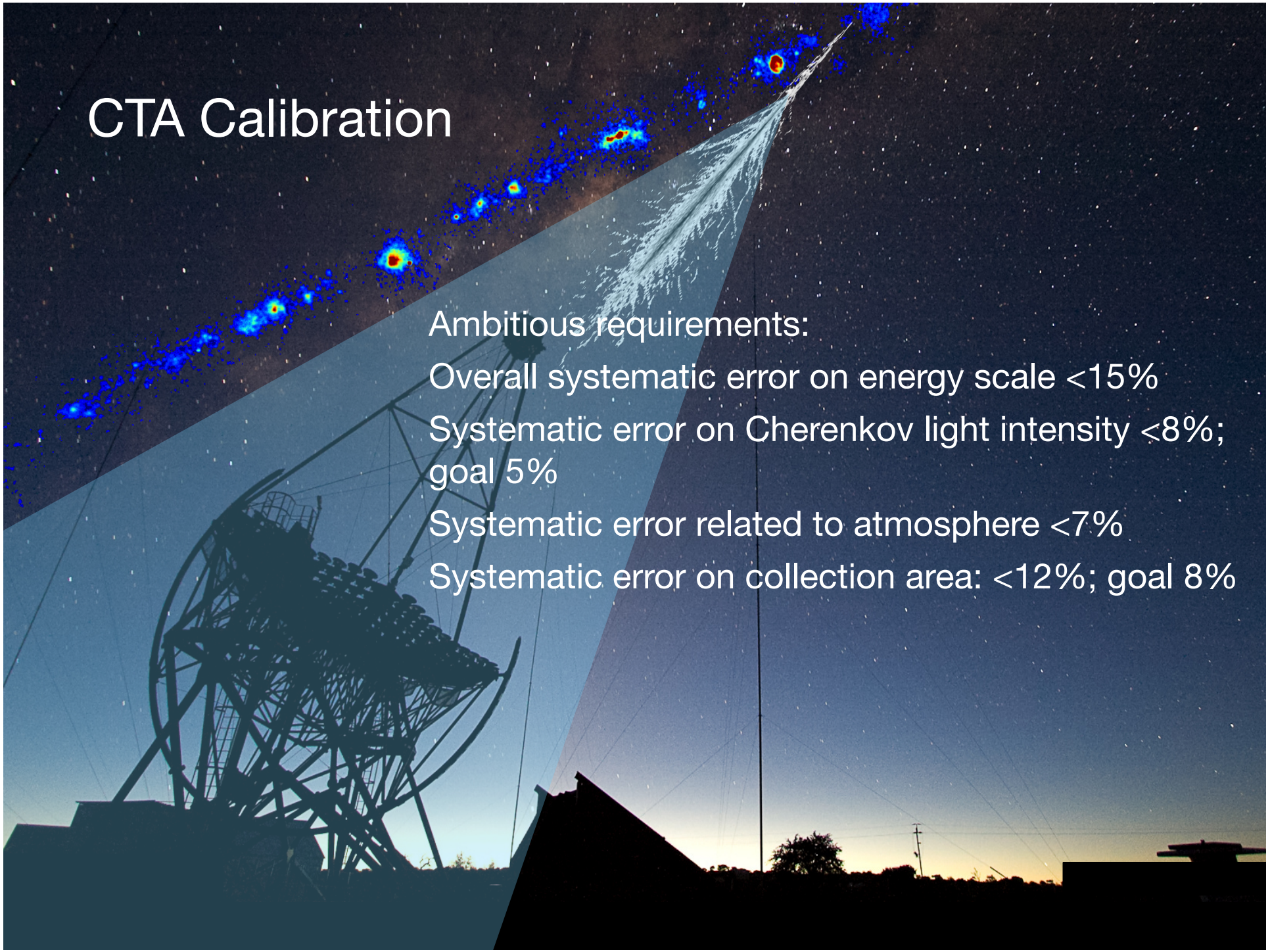
Prototypes

- MST @ Berlin
- SST-1M @ Cracow, SST-2M @ Sicily, Paris
- SCT @ VERITAS

Pre-production telescopes:

- to verify mass production and deployment
- “Mini-arrays” at final sites, used in final arrays
- 1 LST
- O(3) MSTs
- O(5) SST-1M
- O(5) SST-2M

Then mass production and deployment



CTA Calibration

Ambitious requirements:

Overall systematic error on energy scale <15%

Systematic error on Cherenkov light intensity <8%; goal 5%

Systematic error related to atmosphere <7%

Systematic error on collection area: <12%; goal 8%

CALIBRATION

Camera calibration

- Light flashers (simple flashers on each telescope, complex moveable calibration light source)

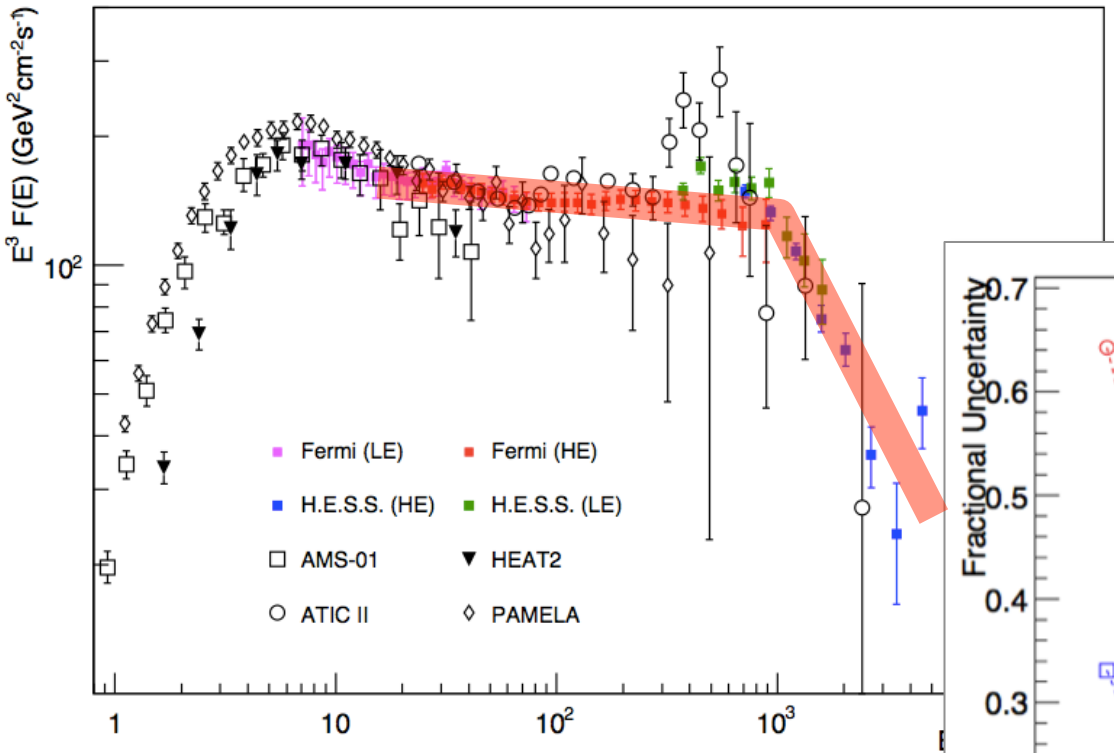
Telescope / array calibration

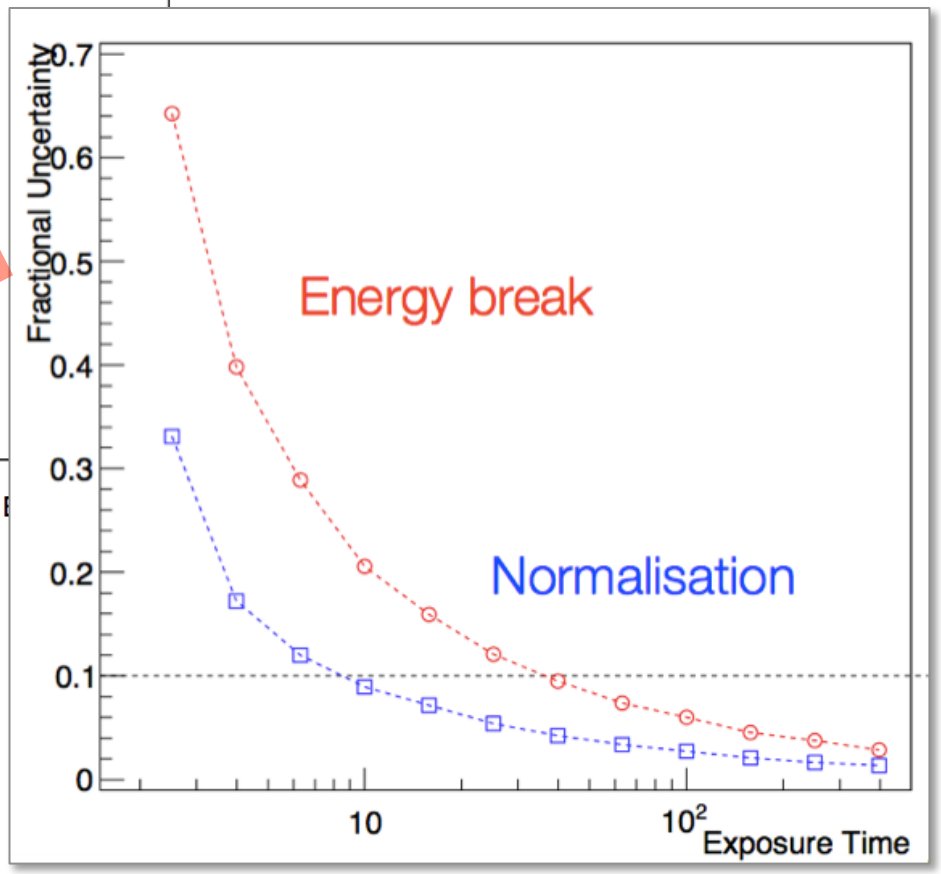
- Telescope cross-calibration with showers (<1%)
- Telescope absolute calibration with muon rings (1-2%)
- Array absolute calibration with CR electron spectrum (<10%)

Atmosphere

- Calibration
  - Extinction from LIDAR, star photometry
  - Atm. profiles from global weather models (& radiosondes)
- Pointing forecast
  - All-sky camera
  - Ceilometer

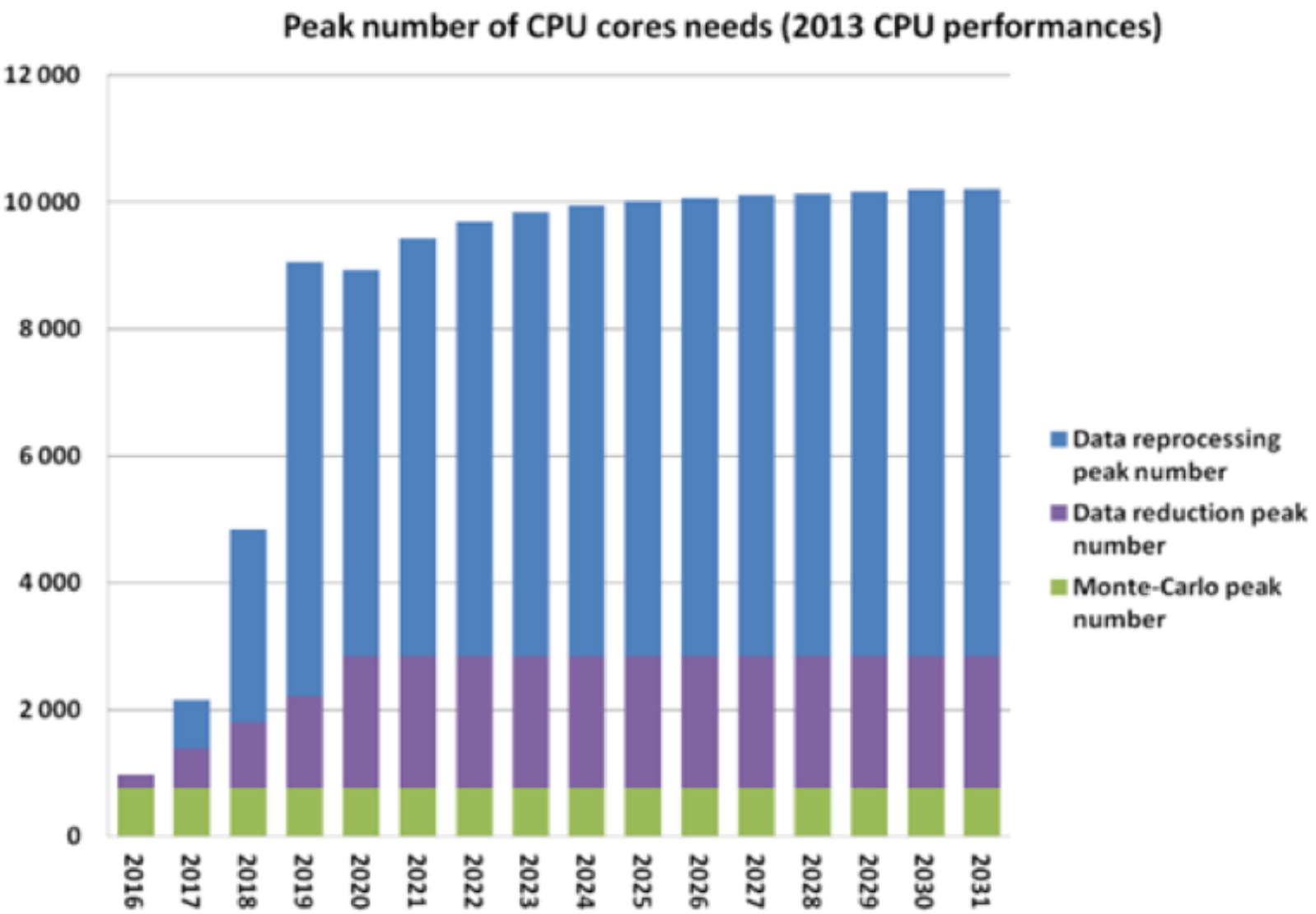
CALIBRATION USING CR ELECTRONS



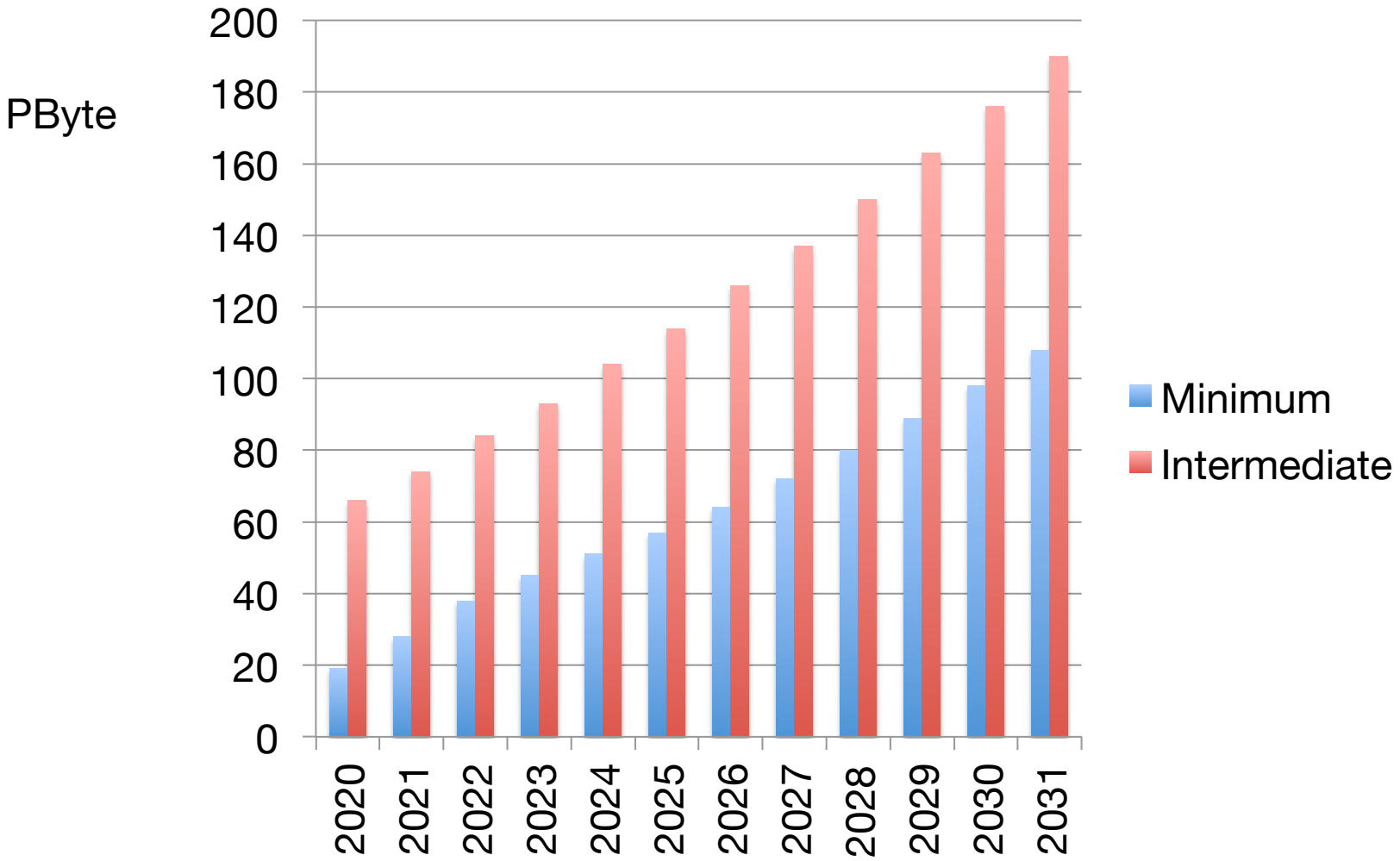


CHALLENGE: HANDLING CTA DATA

PROCESSING NEEDS



STORAGE CAPACITY



SOFTWARE DEV. CENTERS

RECO

VO tools

Sci. Tools

IR
F

MC

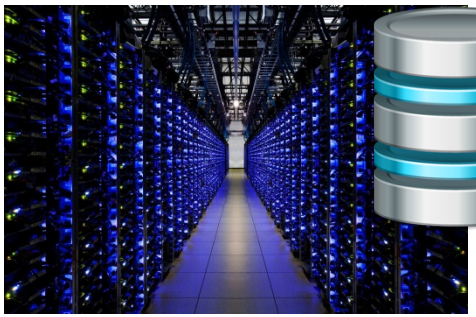
Calib.

...

User Archive ACCESS

Gateway

Archive,
Pipelines,
Helpdesk,
Support,
Observatory
Services.



CENTRAL
DB

Tech DATA

CTA-DATA CENTER (Tier 0)

Archive INGEST

Raw DATA

Tech DATA

CTA-BU-DC

CTA
South

CTA
North

ACTL CENTER

LST

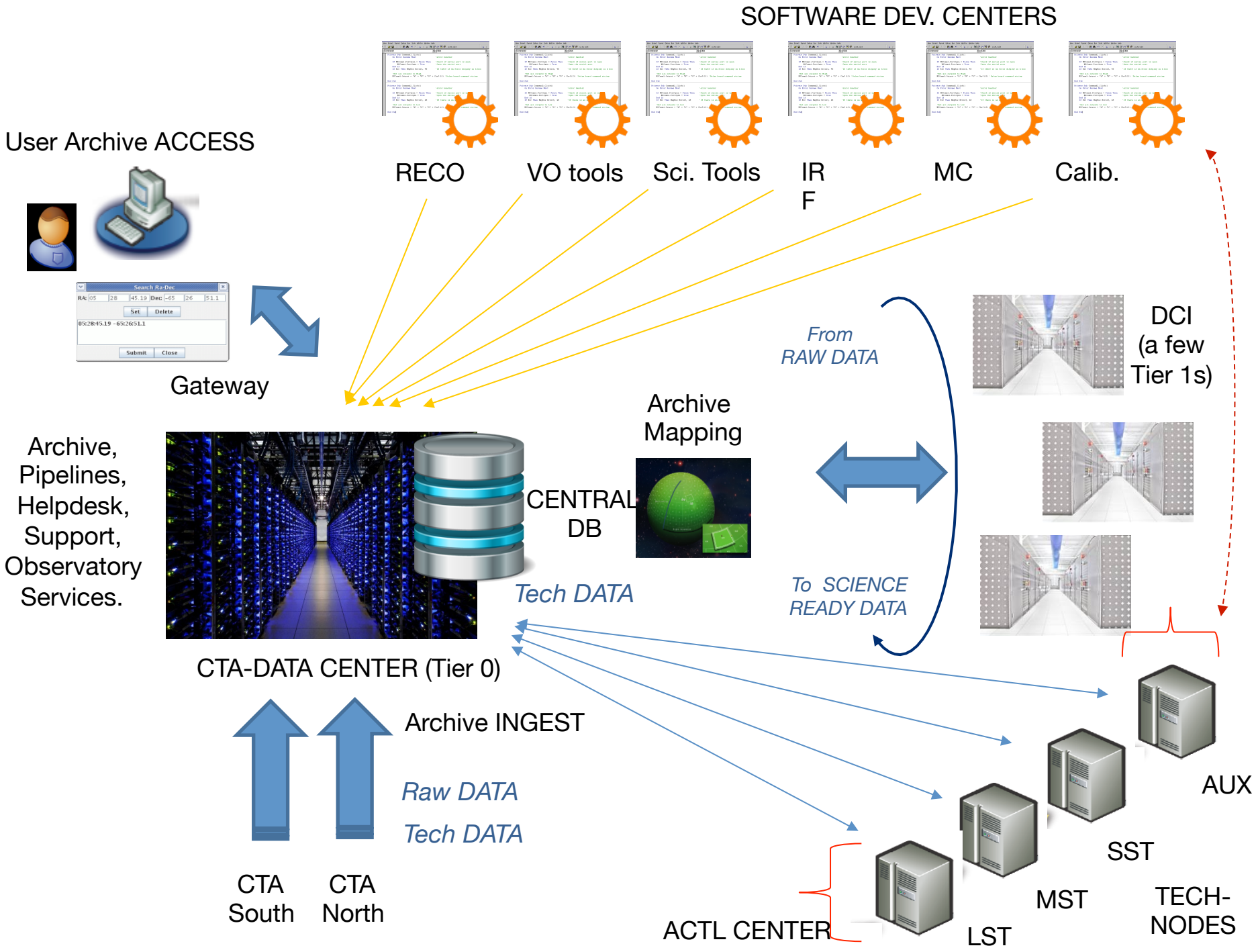
MST

SST

AUX

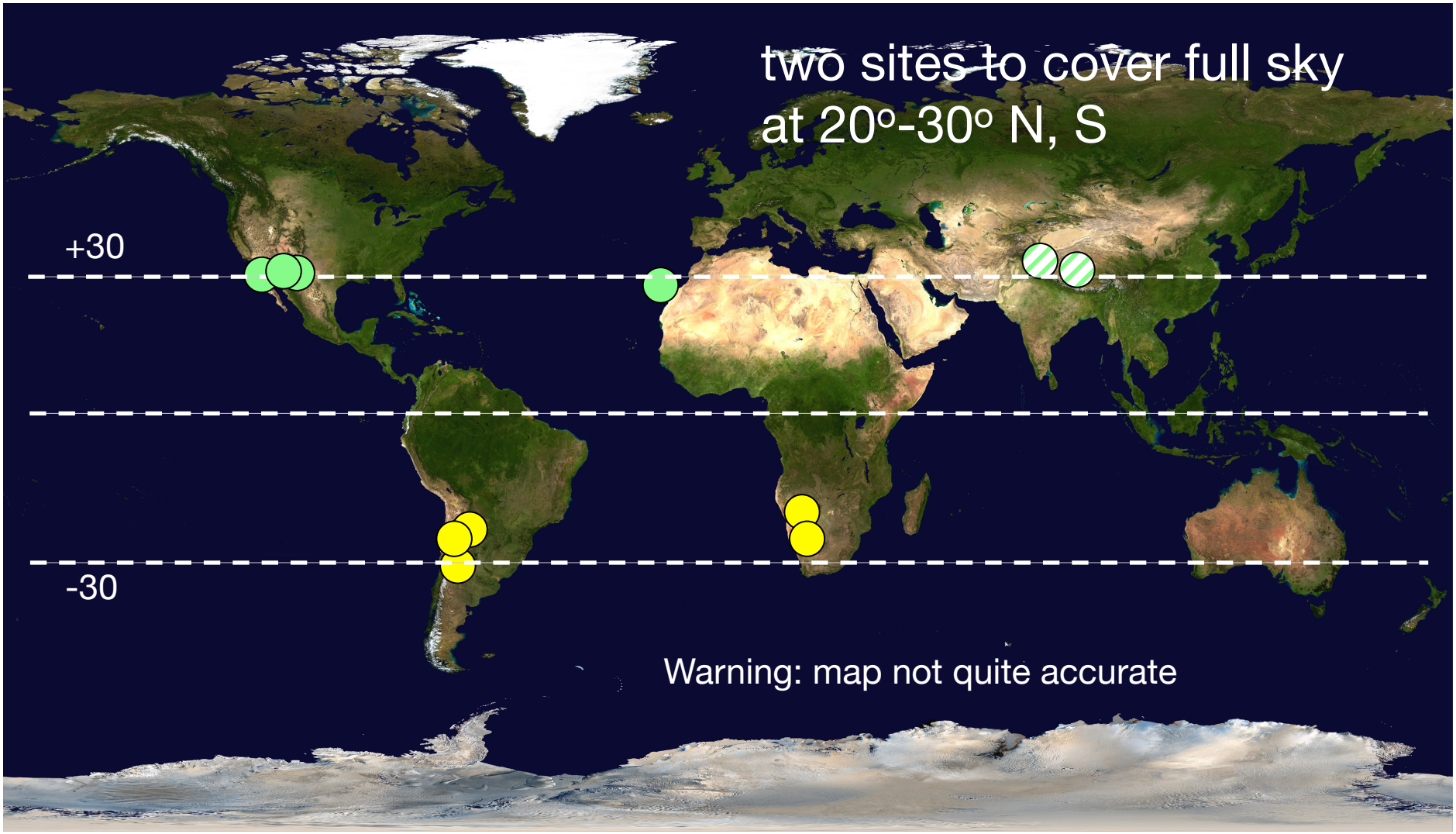
...

TECH-
NODES

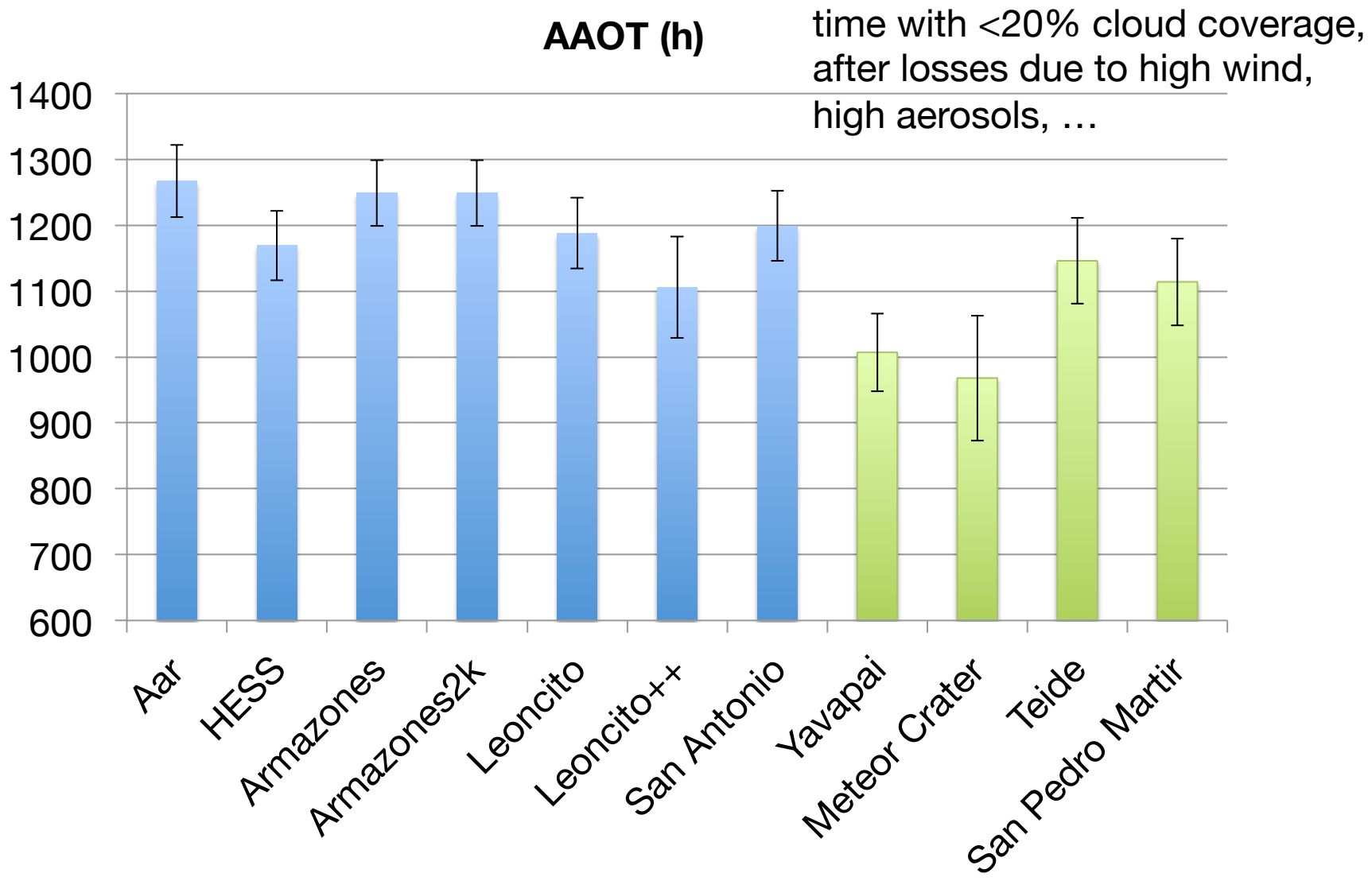

SOFTWARE DEV. CENTERS
RECO
VO tools
Sci. Tools
IR
F
MC
Calib.
User Archive ACCESS
Gateway
From
RAW DATA
DCI
(a few
Tier 1s)
Archive
Mapping
Archive,
Pipelines,
Helpdesk,
Support,
Observatory
Services.
CENTRAL
DB
Tech DATA
To SCIENCE
READY DATA
CTA-DATA CENTER (Tier 0)
Archive INGEST
Raw DATA
Tech DATA
CTA
South
CTA
North
AUX
SST
MST
TECH-
NODES
ACTL CENTER
LST

CTA SITE SELECTION

SITE SELECTION

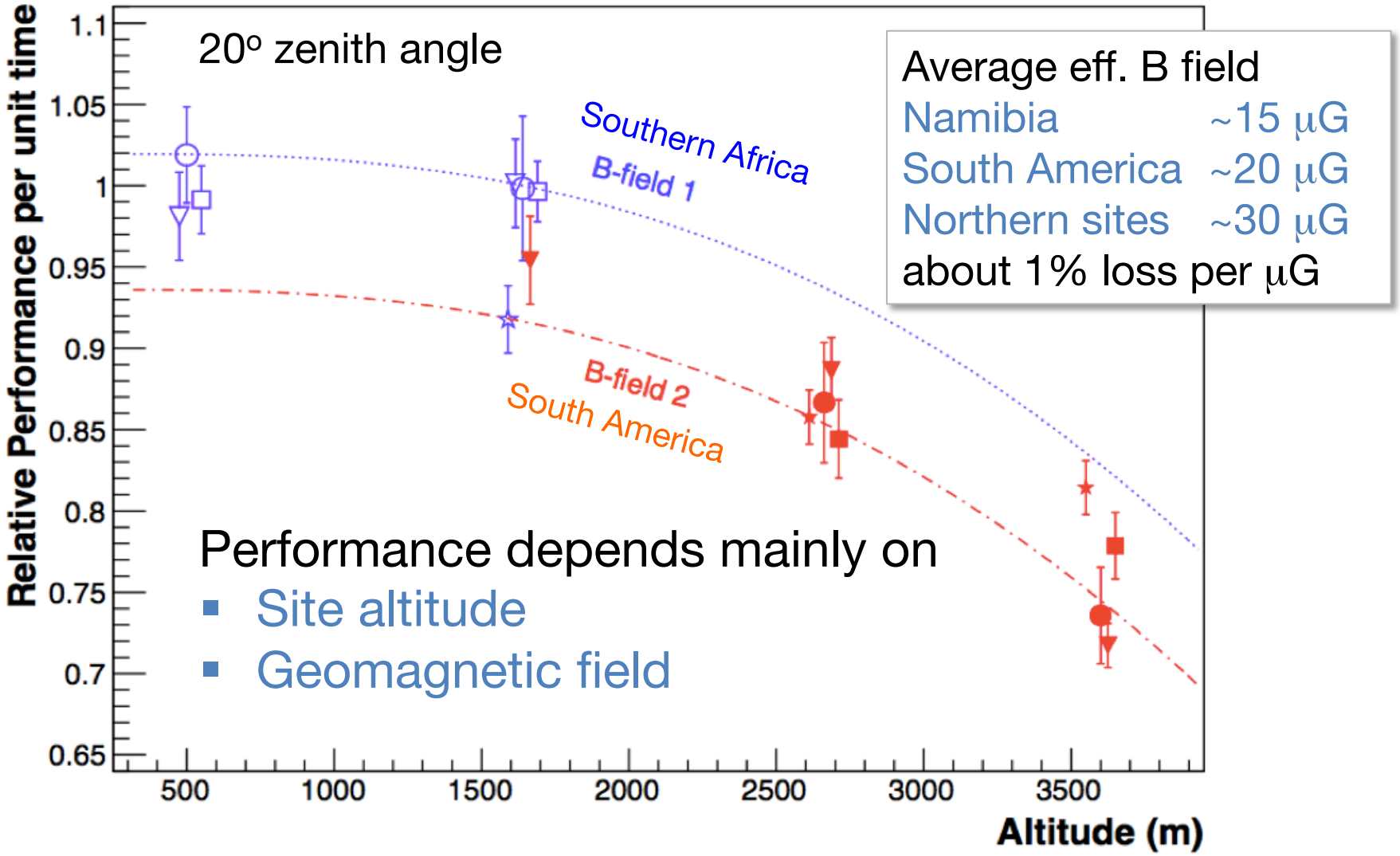


AVERAGE ANNUAL OBSERVATION TIME



SENSITIVITY FOR FIXED OBS. TIME

INTERPLAY OF HEIGHT AND GEOMAGNETIC FIELD



Average eff. B field

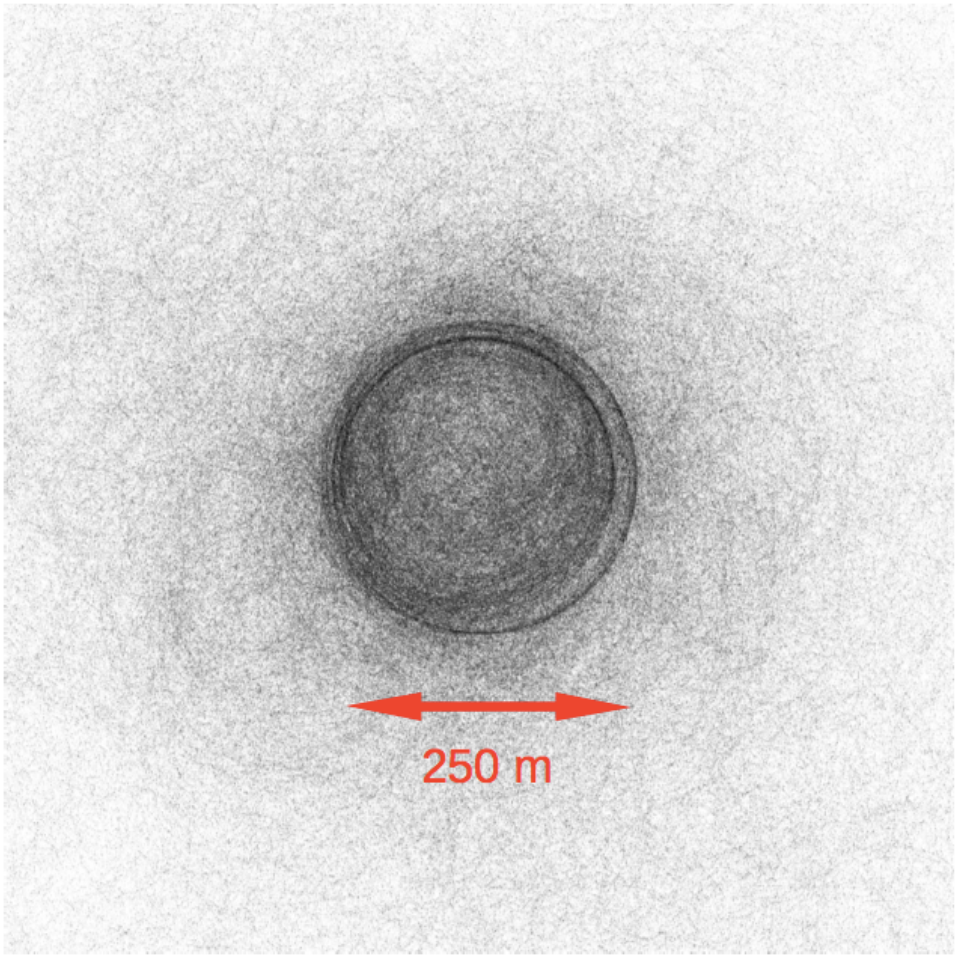
Namibia	~15 μG
South America	~20 μG
Northern sites	~30 μG

about 1% loss per μG

Performance depends mainly on

- Site altitude
- Geomagnetic field

NO GEOMAGNETIC FIELD

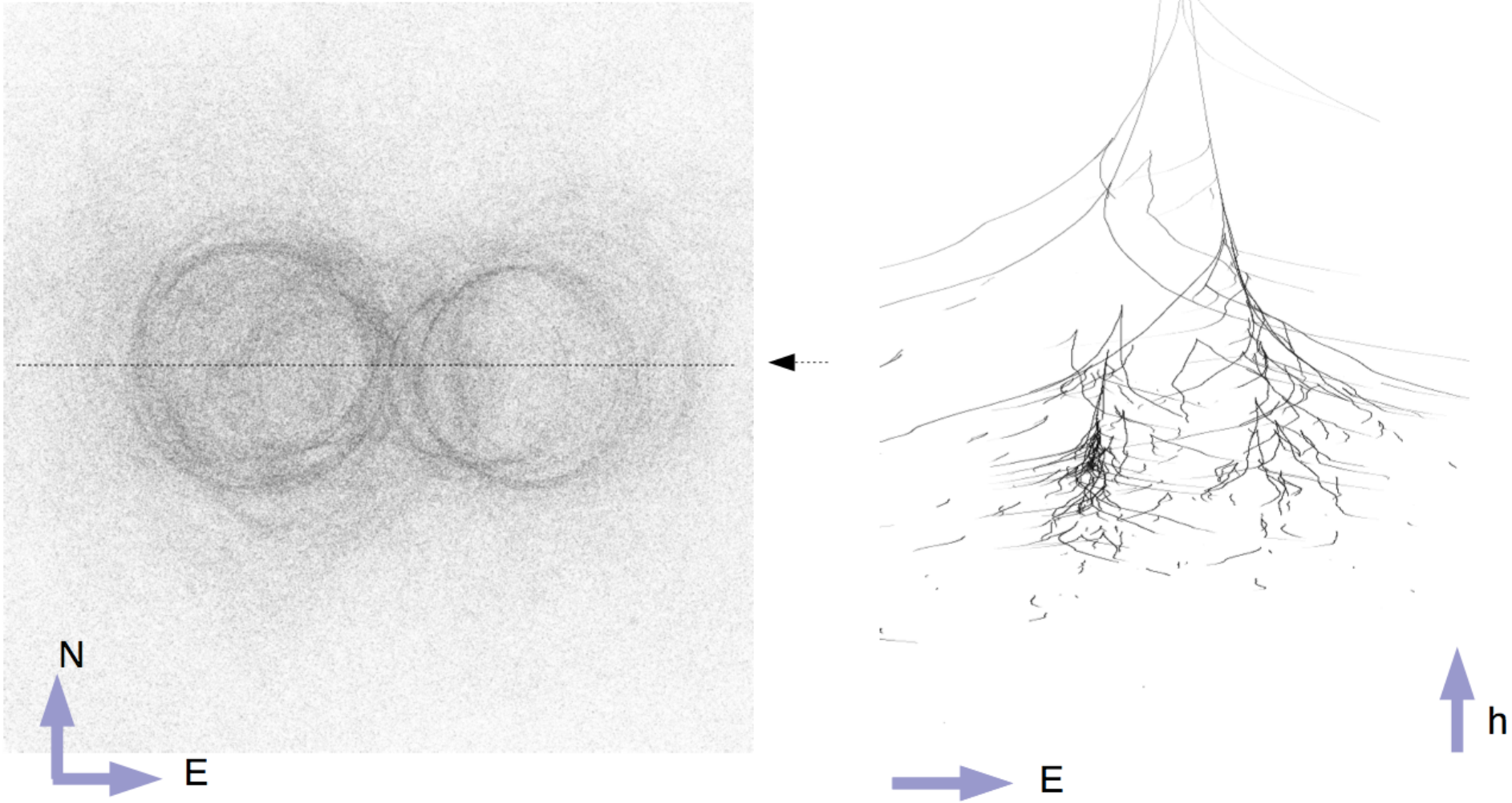


Without geomagnetic field, the gamma-ray showers usually look quite symmetric.

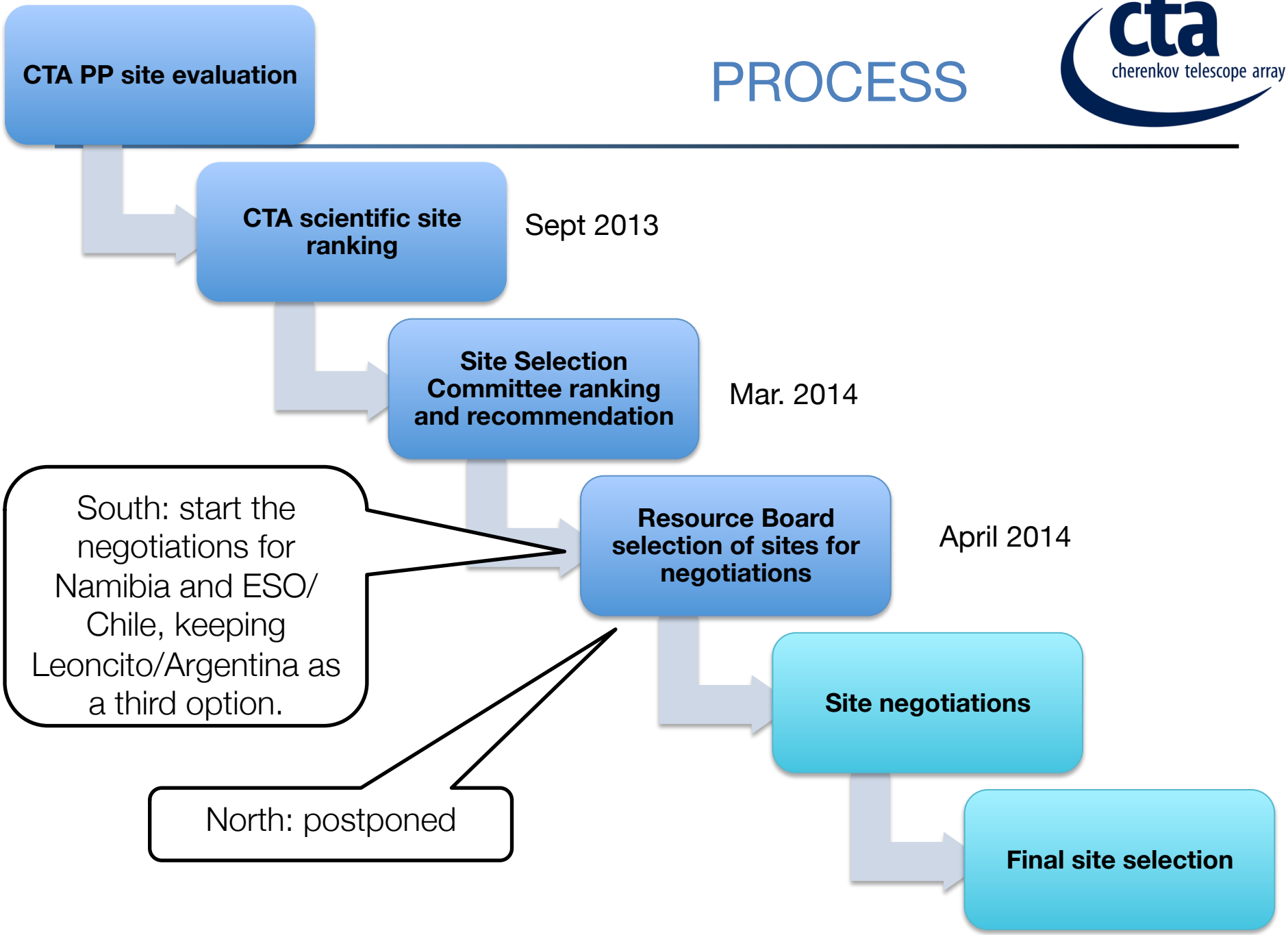
(Picture showing distribution of Cherenkov light arriving on ground).

EFFECT OF GEOMAG. FIELD

With geomagnetic field, the electron-positron pairs split up perpendicular to the B field.

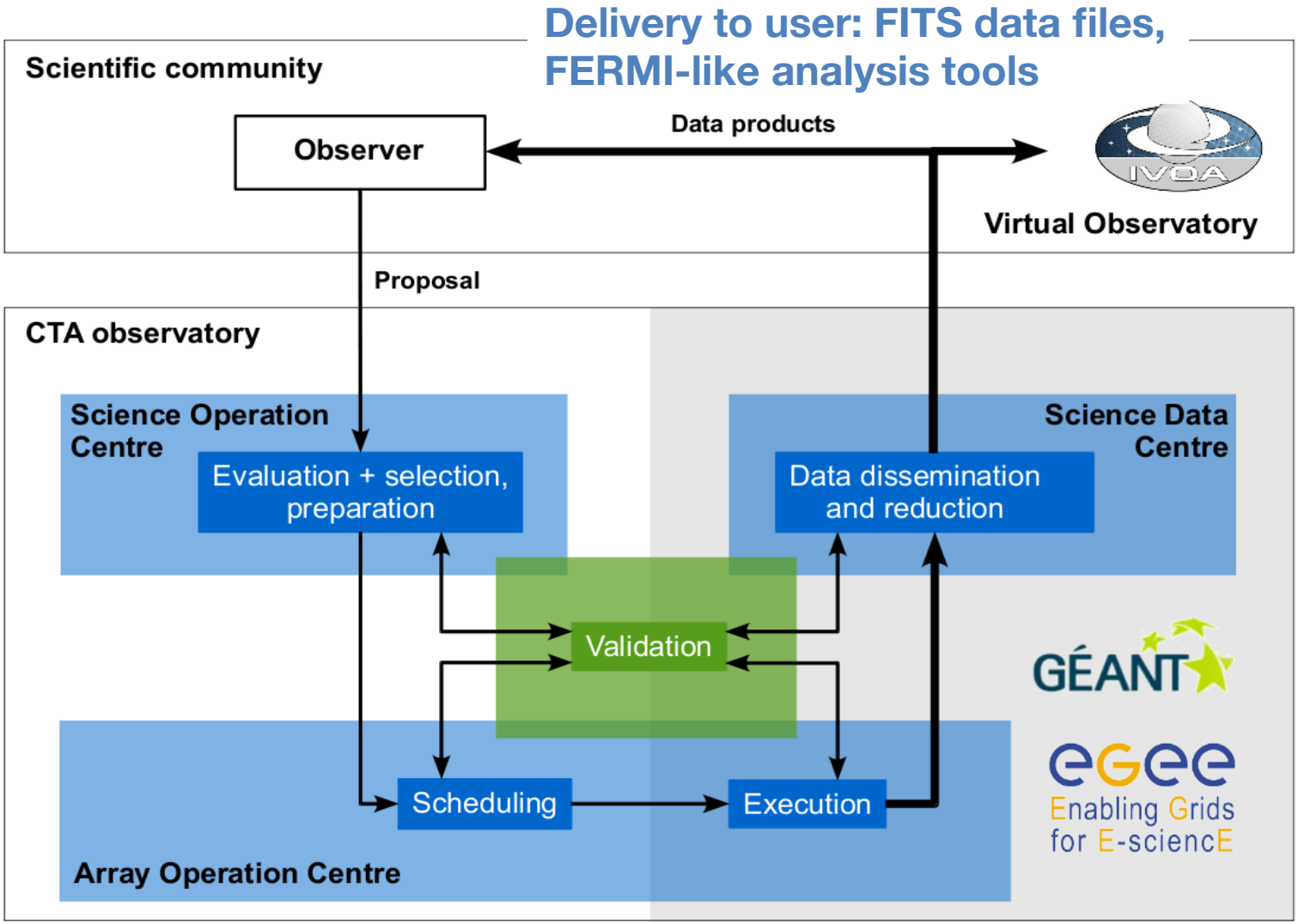


PROCESS


CTA PP site evaluation
CTA scientific site ranking
Sept 2013
Site Selection Committee ranking and recommendation
Mar. 2014
South: start the negotiations for Namibia and ESO/ Chile, keeping Leoncito/Argentina as a third option.
Resource Board selection of sites for negotiations
April 2014
North: postponed
Site negotiations
Final site selection

CTA OBSERVATORY

FOR THE FIRST TIME IN THIS FIELD: OPEN ACCESS



CTA SCHEDULING

Monitoring
4 telescopes

PeV Deep Field
using SSTs

GeV observations
using LSTs

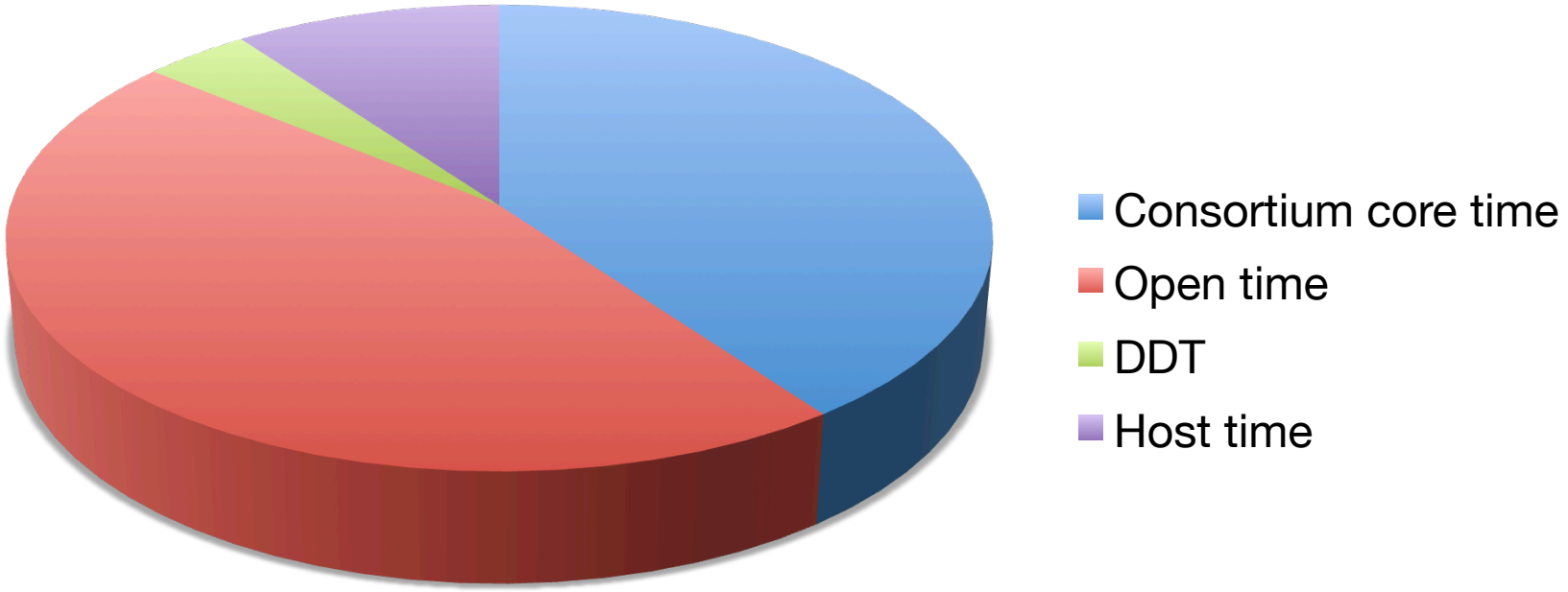
TeV
survey
using
MSTs

Large zenith angle
observations from
other hemisphere

Monitoring
1 telescope

- CTA North and South through single portal, common calls for proposals, identical tools
- Queue mode scheduler taking into account actual sky conditions, sub-arrays & conditions requested in proposal, priorities, TOOs

SHARING OF OBSERVATION TIME:
UNDER DISCUSSION



Example; sharing will be time dependent

- Open time: open to participating countries (?)
- Archival data: fully open, 1yr proprietary time (?)

CORE PROGRAMME

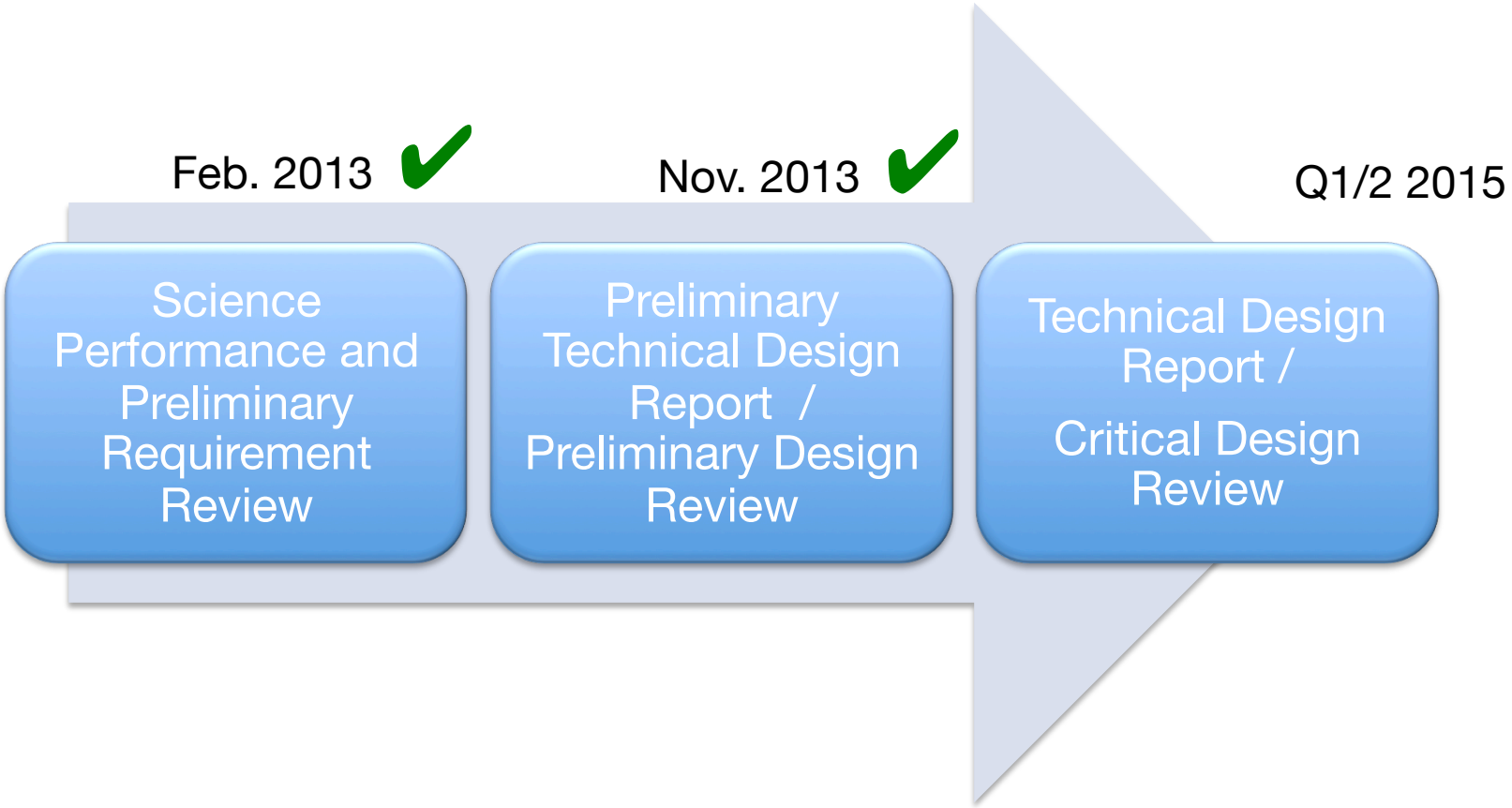
Core Programme using Consortium guaranteed time

- Provides legacy data sets (large sky surveys, surveys of object classes)
- Pre-defined deliverables (catalogs, sky maps, …)
- External review

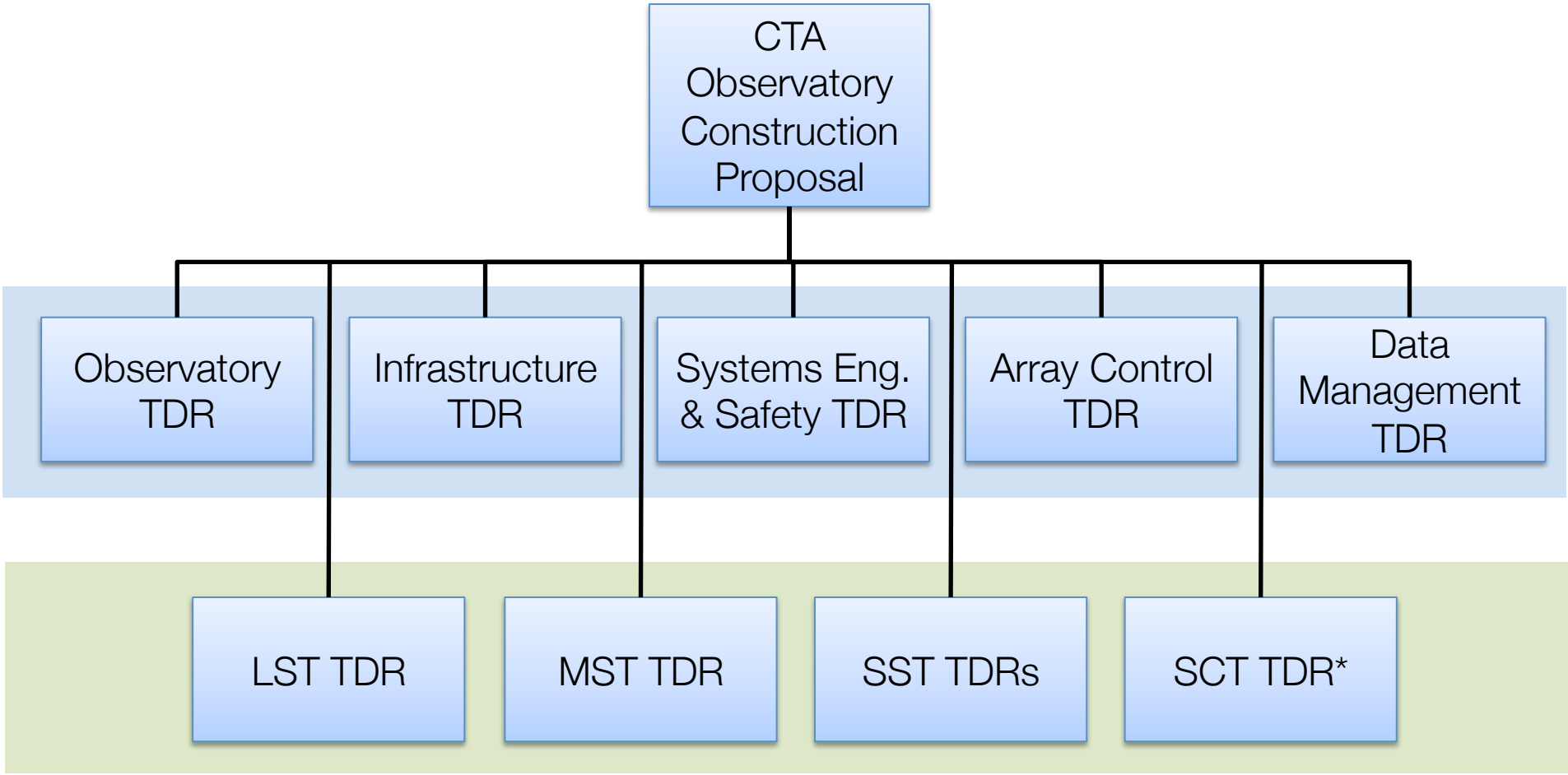
Core Programme fraction time dependent; large in first years, modest later

TOWARDS APPROVAL

FORMAL STEPS TOWARDS APPROVAL



CONCENTRATING ON TDR(S)



1st version this summer to EC as CTA Preparatory Phase deliverable
Final (public) version late Q1, 2015

SUMMARY

CTA STATUS

Design

- Current stage: telescope designs essentially complete; advanced prototyping
- Passed Preliminary Technical Design Review, based on Preliminary Technical Design Report (PTDR)
- Final Technical Design Report (TDR) in Q1 2015, Critical Design Review (CDR) in Q1/2 2015

Organisation

- CTA Consortium of >170 institutes, 28 countries
- Project office (PO) in Heidelberg
- Nature of final legal entity and of location of CTA HQ tbd
- PO supported by FP7 Prep Phase, until mid-2014
- Currently establishing CTA Observatory GmbH interim legal entity, operational mid-2014, to operate PO, serve as legal partner for site agreements etc.

CTA STATUS

Site selection

- Site evaluation and scientific ranking by CTA Consortium
- Site recommendation by agency-appointed Site Selection Committee
- Decision by agency board (Resource Board / LE Council)
- RB Decision April 2014:
  - South: start the negotiations for Aar/Namibia and ESO/Chile, keeping Leoncito/ Argentina as a third option. Aim for final decision before end of 2014.
  - North: decision of negotiations postponed

Approval/construction

- Aim for construction approval in mid-2015
- Estimate 5 year construction period
- Early operation of partial arrays
- Investment cost 150 M€ (2006), escalates to ~200 M€; updated cost estimate in prep.

CTA STATUS

CTA use (working assumptions, tbc)

- Open observatory; regular AOs calling for proposals, bulk of time restricted to proposals from participating countries
- Guaranteed time for CTA Consortium for use for Key Science Projects providing legacy data sets (surveys etc); fraction of guaranteed time large in the first years, modest later
- After (1 y) proprietary period data is made fully open via archive
- Open analysis tools