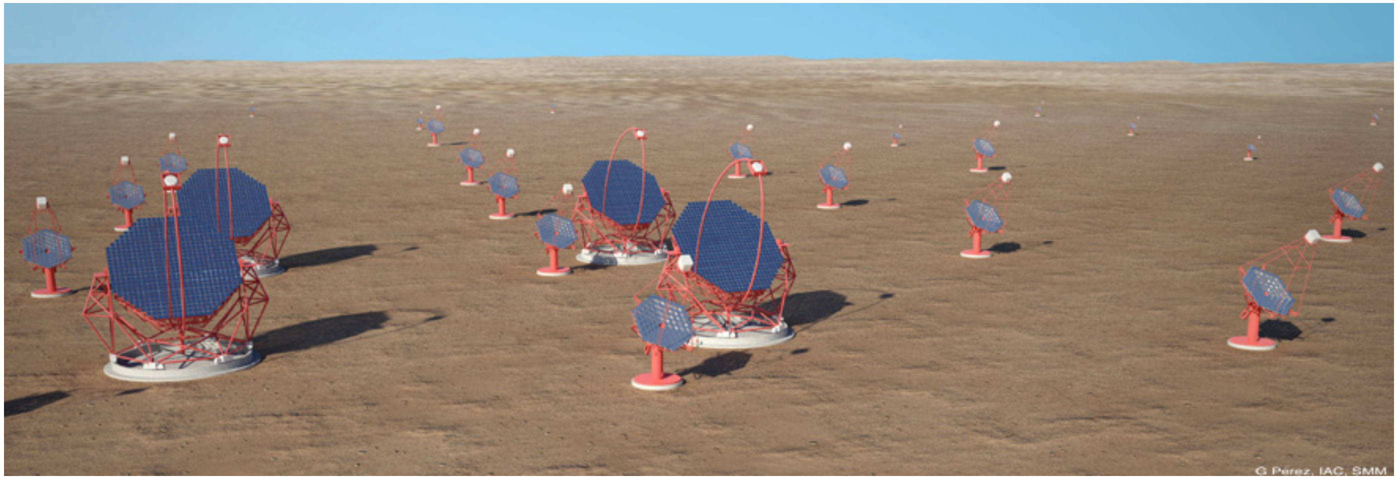
The Cherenkov Telescope Array: Status and Plans



Workshop on a Wide Field-of-View Southern Hemisphere TeV Gamma Ray Observatory

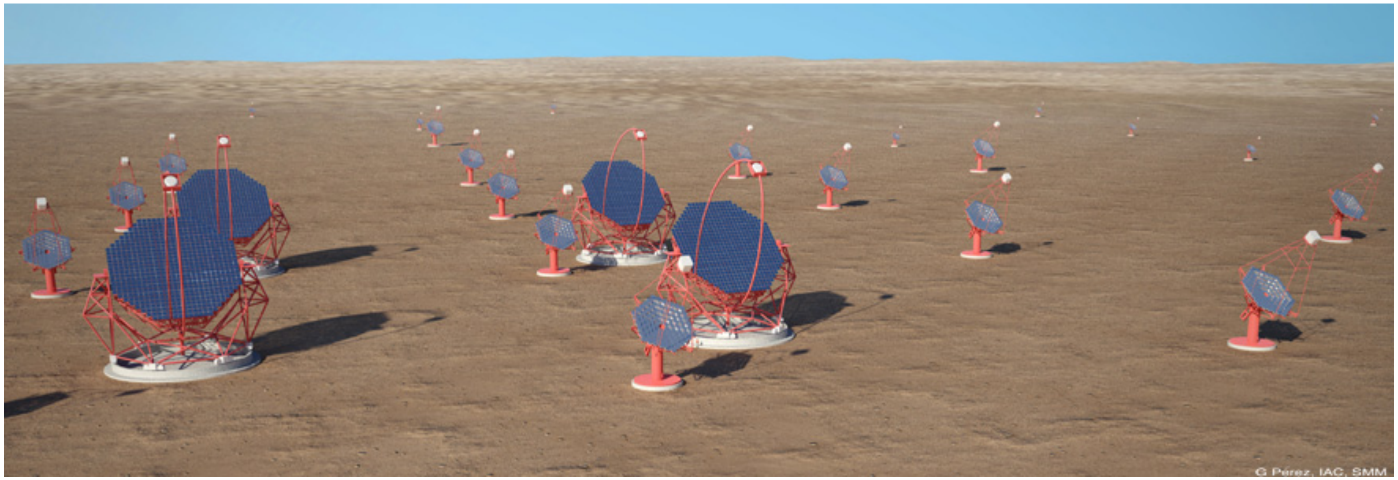
November 10, 2016

David A. Williams, University of California, Santa Cruz,

on behalf of the CTA Consortium

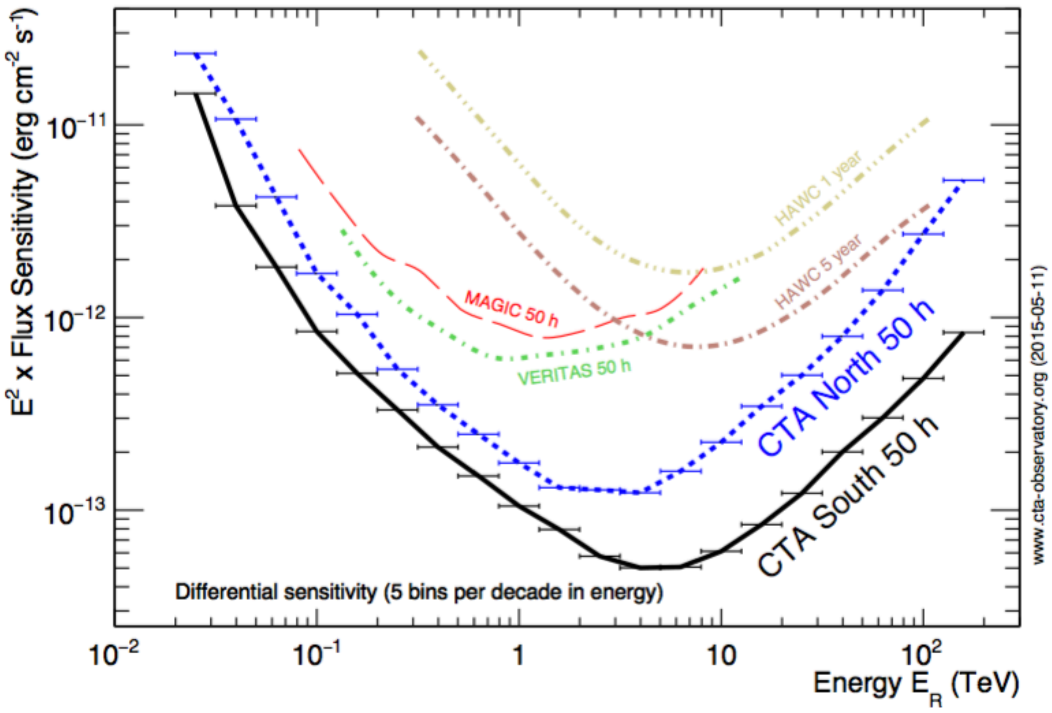
www.cta-observatory.org

The CTA Concept ("Baseline")

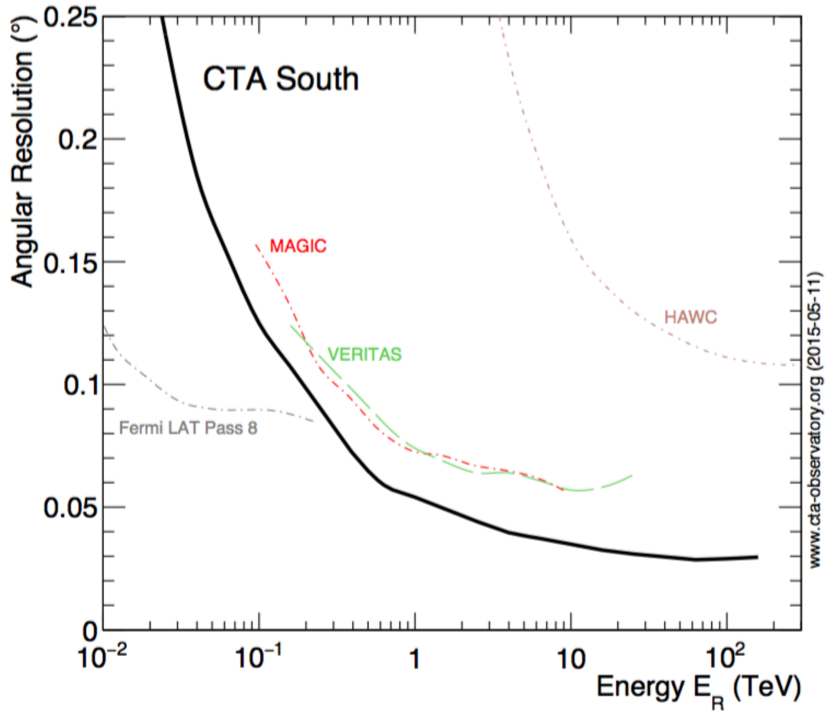


- Arrays in both hemispheres for full sky coverage
  - ESO, Paranal, Chile in the south (negotiations); ORM, La Palma, Spain in the north
- 4 large (23 m) telescopes (LSTs) in the center — threshold of 30 GeV
- Southern array adds:
  - 25 medium (9-12 m) telescopes (MSTs) — 100 GeV – 10 TeV energy coverage
  - 70 small (~4 m) telescopes (SSTs) covering >3 km^2 — expand collection area >10 TeV for Galactic sources
- Northern array adds 15 MSTs (no SSTs)
- Construction to begin in 2017, continue through ~2023

CTA flux sensitivity – steady point sources



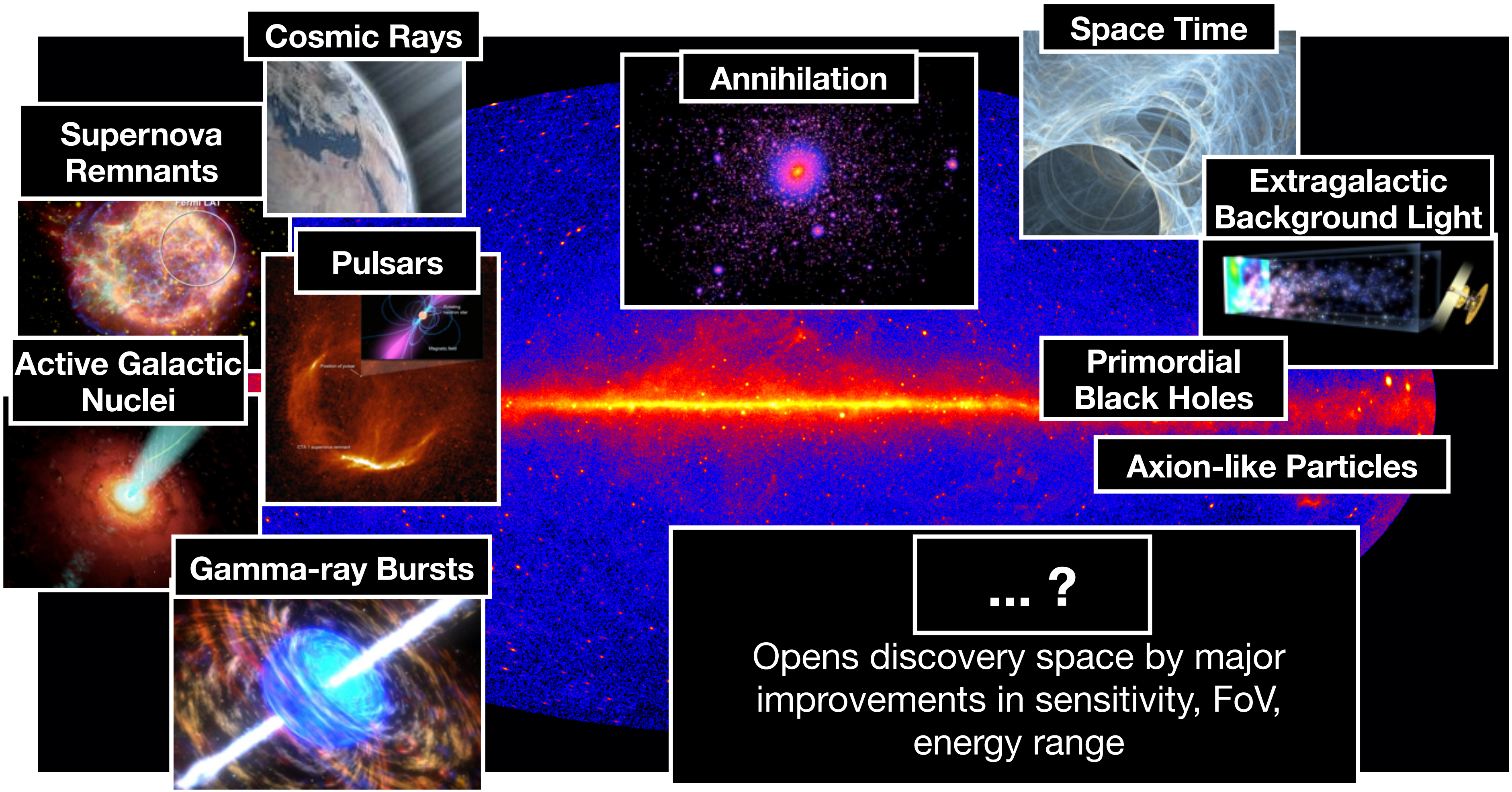
Differential point source sensitivity



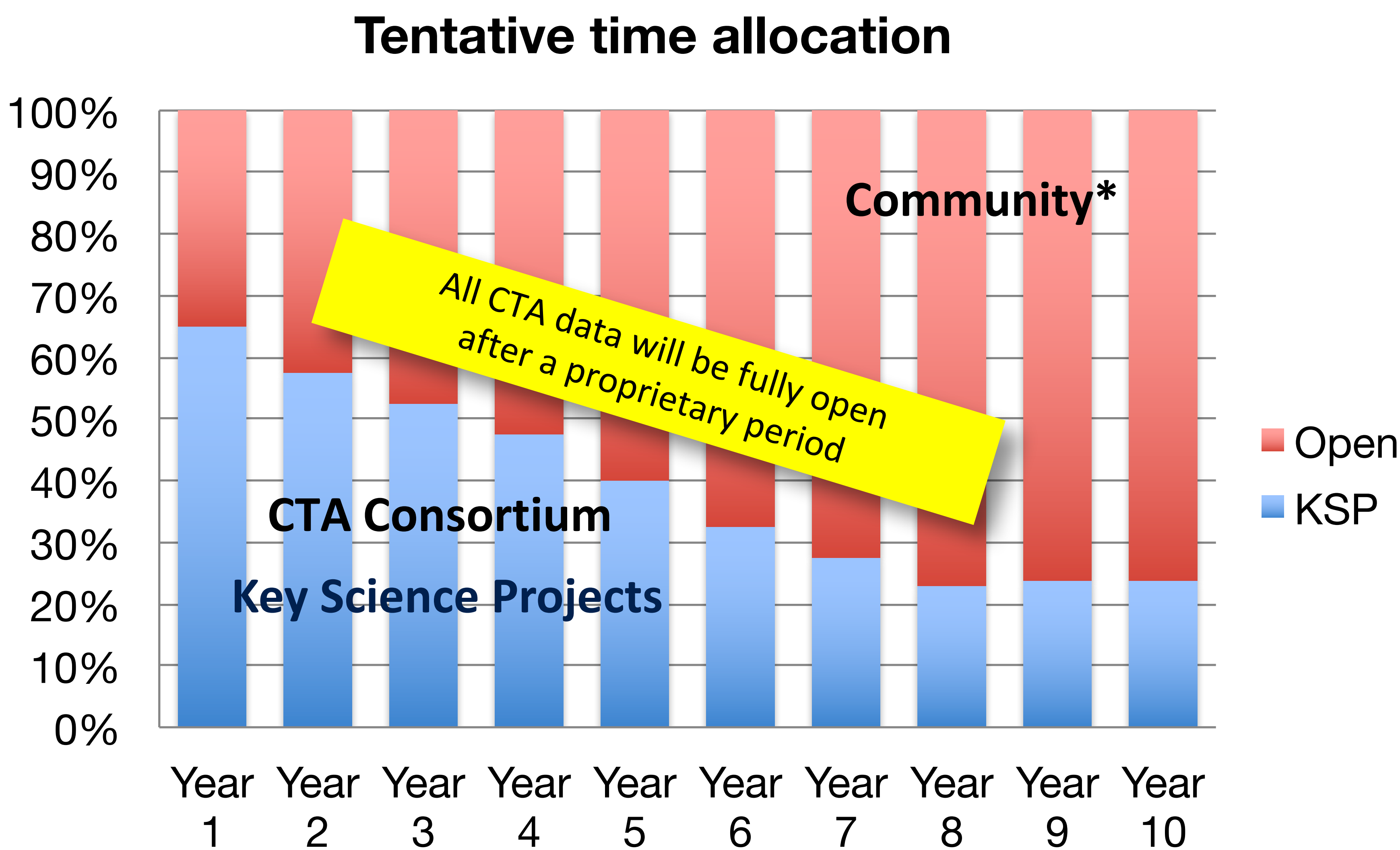
Angular resolution
(80% containment radius)

Broad Spectrum of Science

Particle Acceleration | **Dark Matter** | **Cosmology**

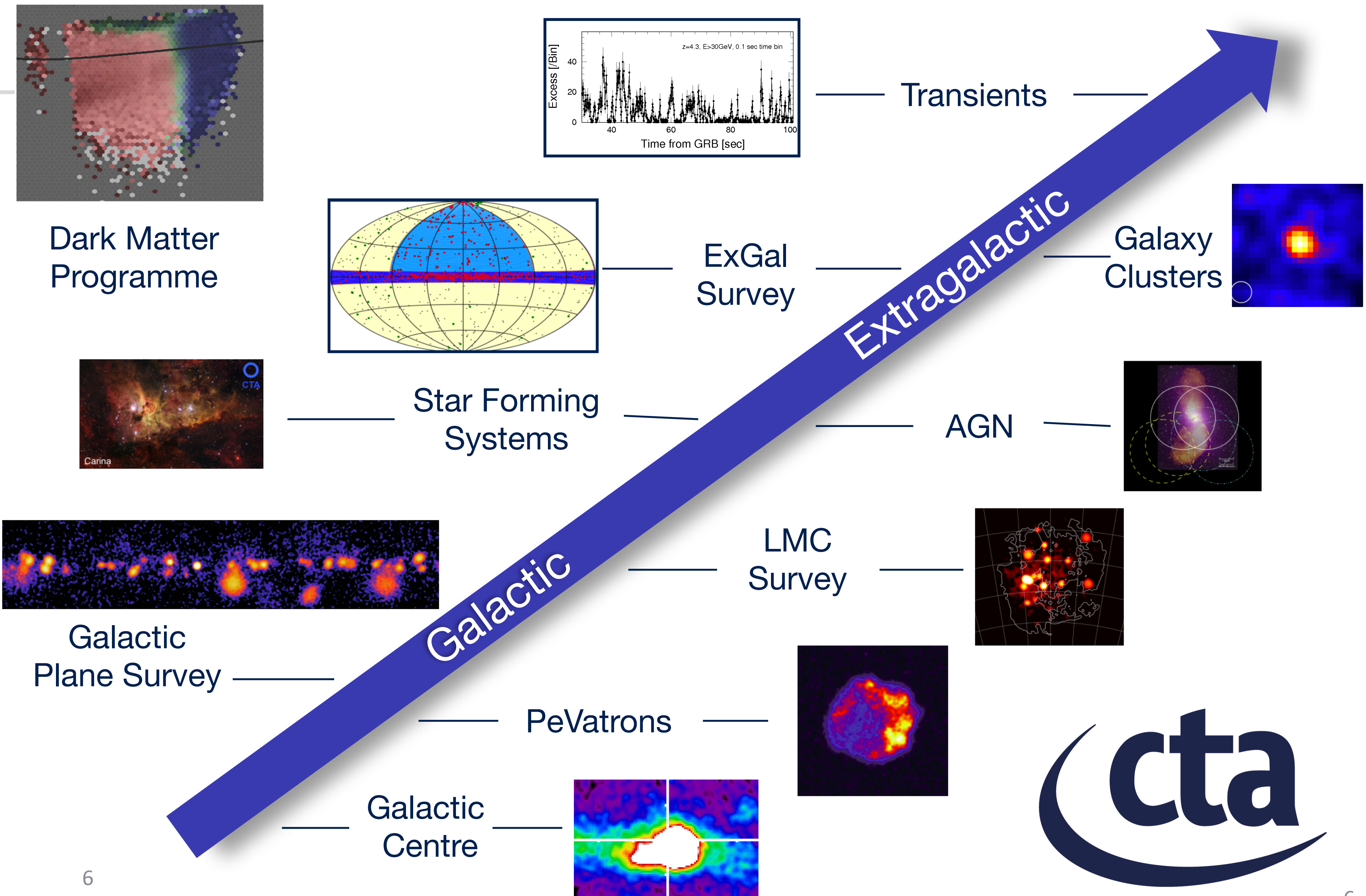


Time Allocation & Community Access

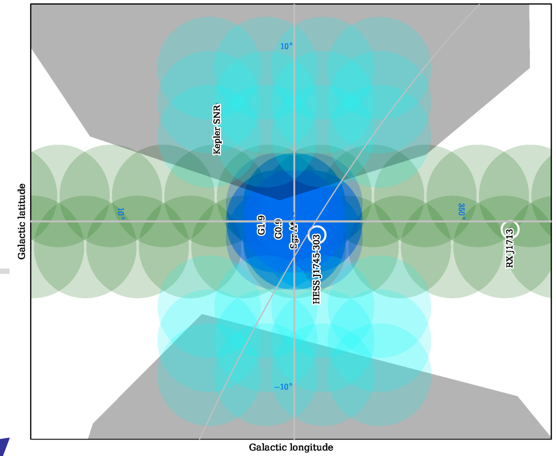


*of scientists from nations contributing to CTA construction and operations and from site host nations

Key Science Projects (KSPs)

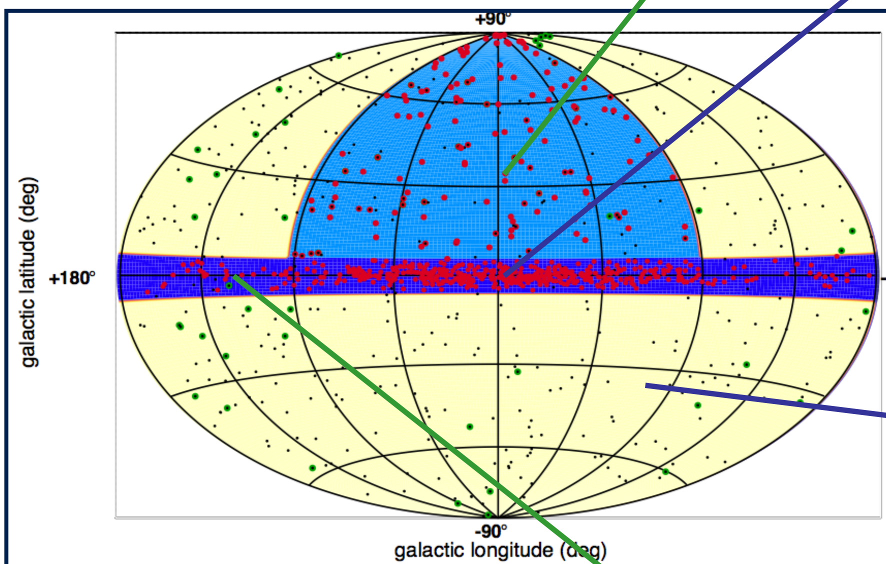


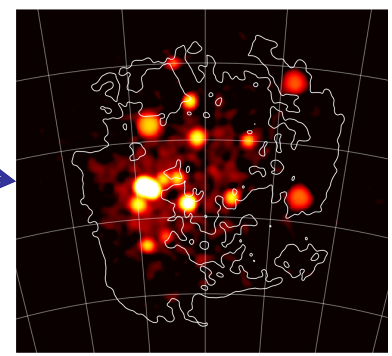
The Survey Key Science Projects



Extragalactic Survey:
Unbiased survey of ¼ sky to ~6 mCrab
VHE population study, duty cycle
New, unknown sources; 1000 h

Galactic Centre Survey:
ID of the central source
Spectrum, morphology of diffuse emission
Deep DM search
Central exposure: 525 h, 10°x10° : 300 h





Galactic Plane Survey:
Survey of entire plane to ~2 mCrab
Galactic source population: SNRs, PWNe, etc.
PeVatron candidates, early view of GC, 1620 h

Large Magellanic Cloud Survey:
Face-on satellite galaxy with high SFR
Extreme Gal. sources, diffuse emission (CRs)
DM search; 340 h in six pointings

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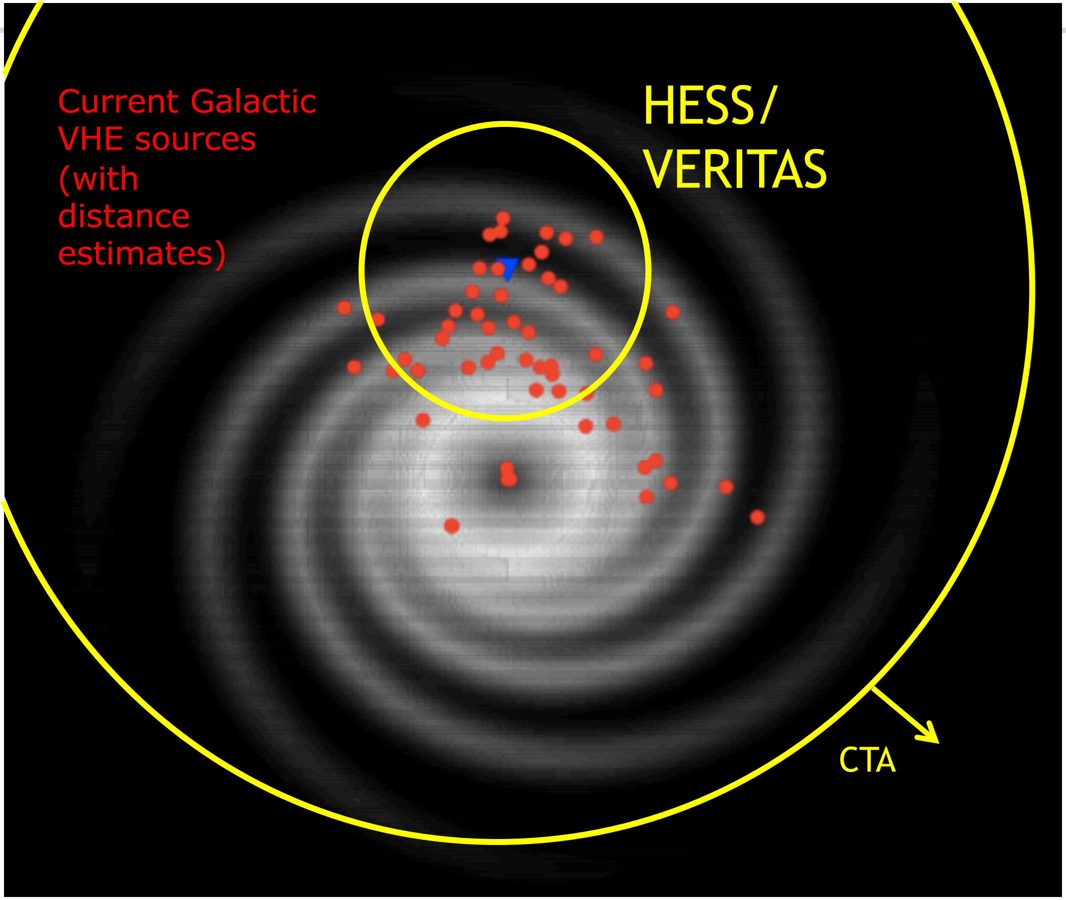
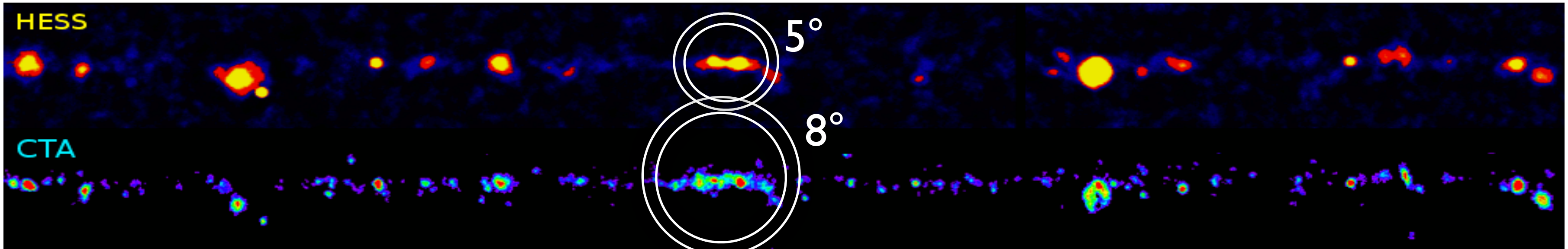
Galactic Particle Accelerators

Surveys of:

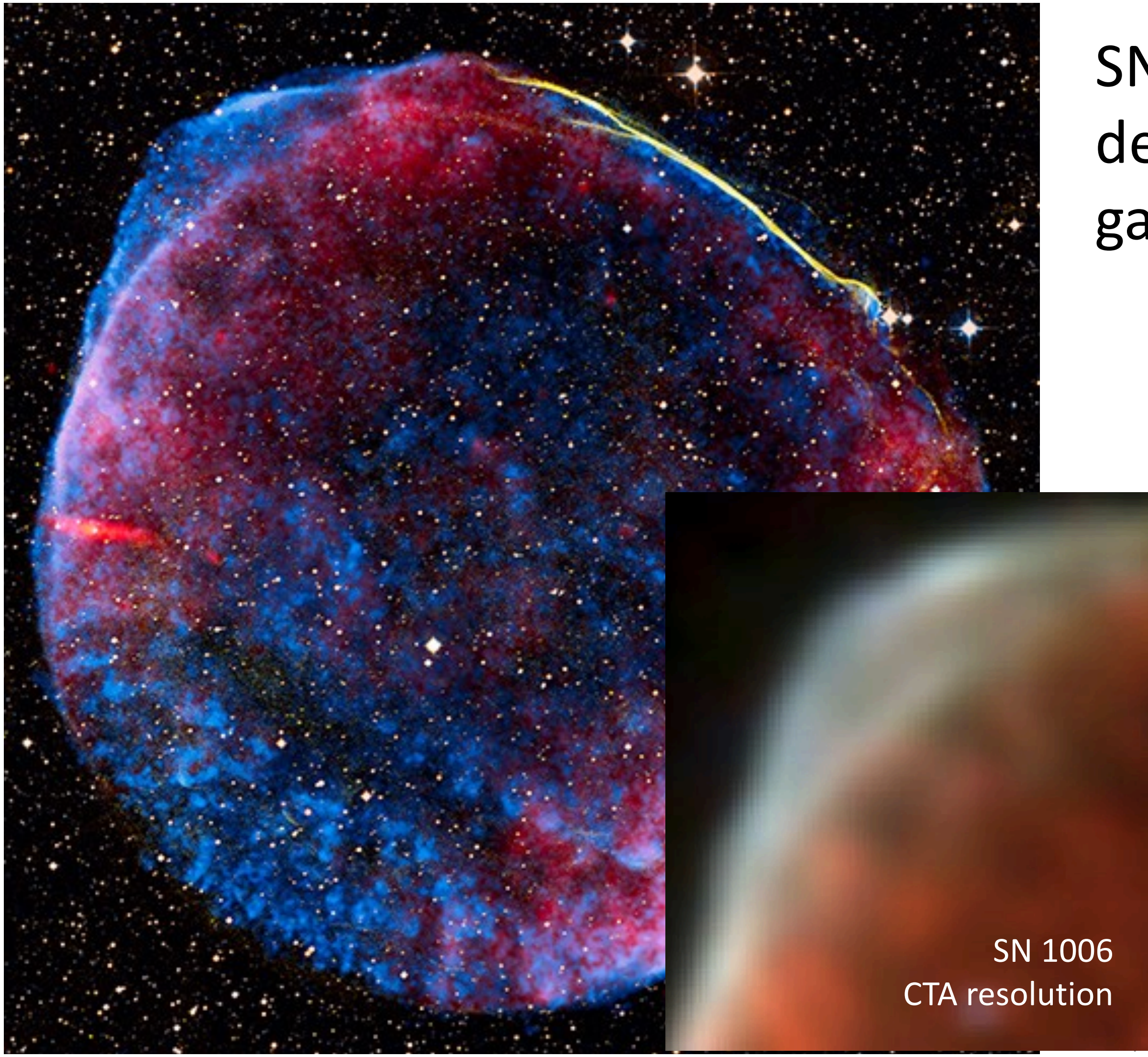
- Galactic center
- Galactic plane
- LMC

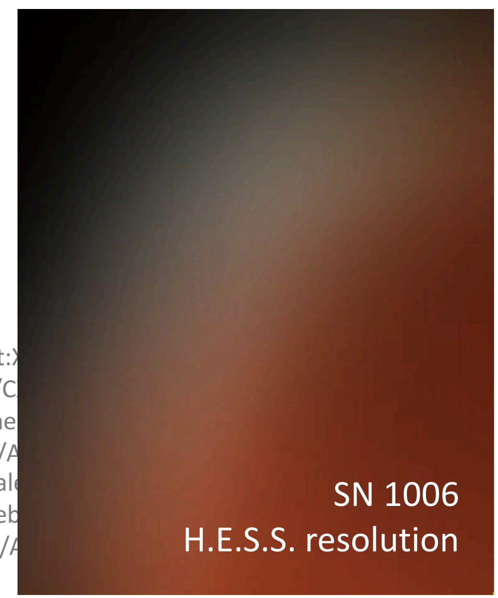


Survey speed:
x300 faster than
current IACTs



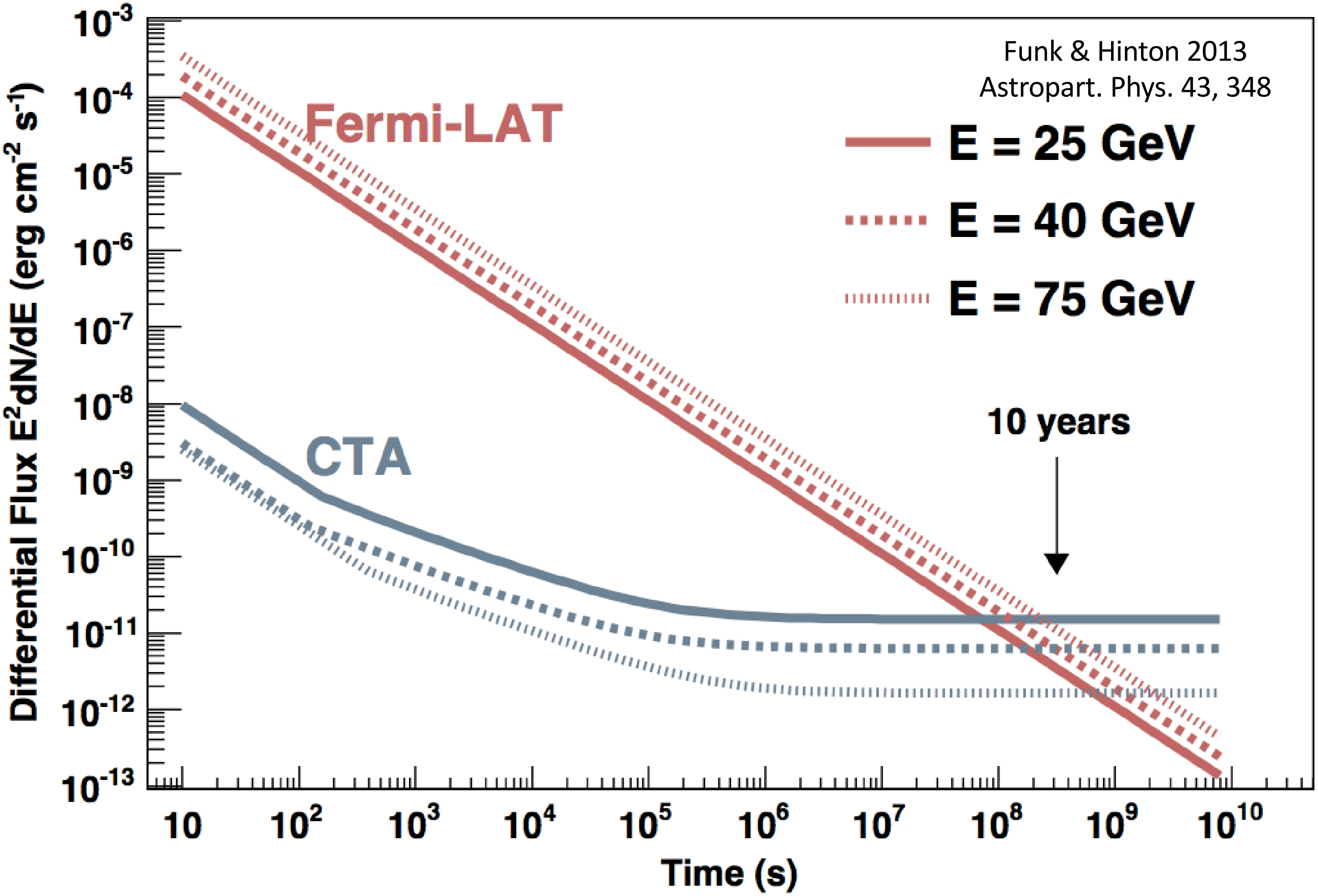
Resolving complex sources





SN 1006 — a detected VHE gamma-ray source

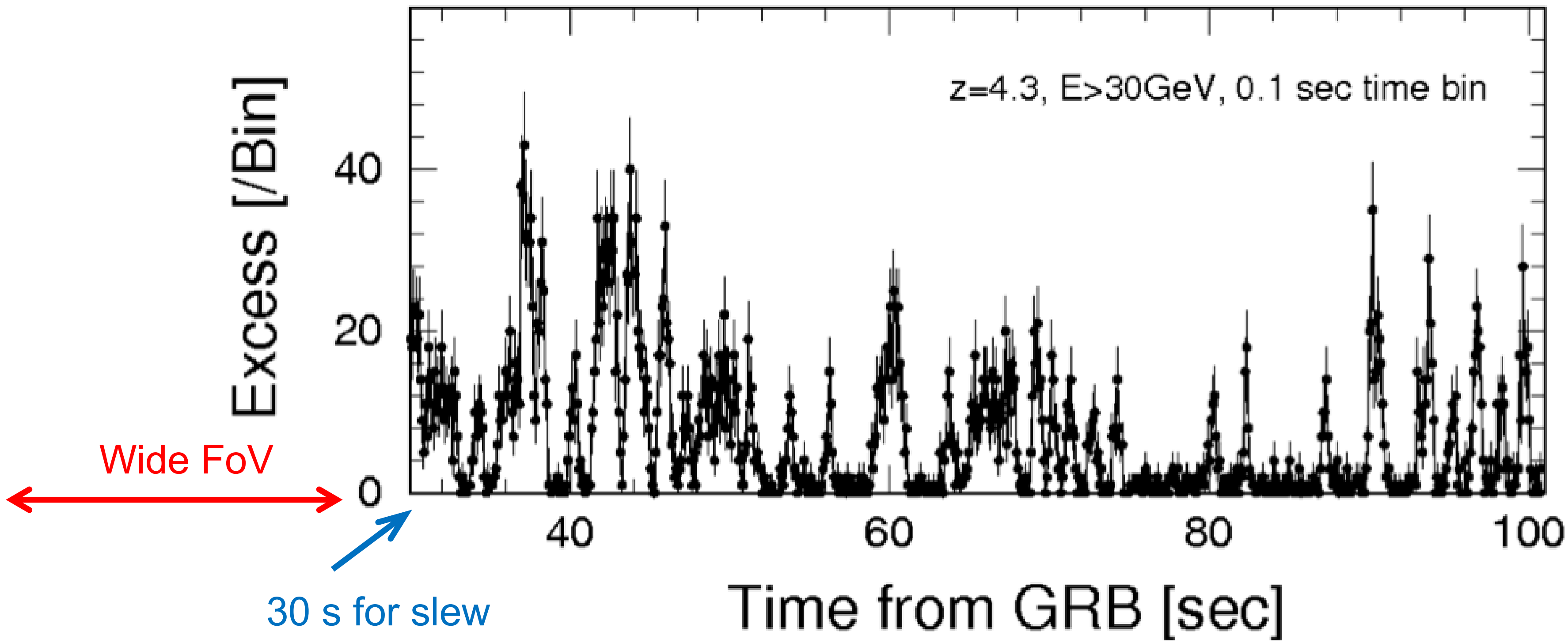
Opening up the Transient Domain



Field of view, duty cycle also matter

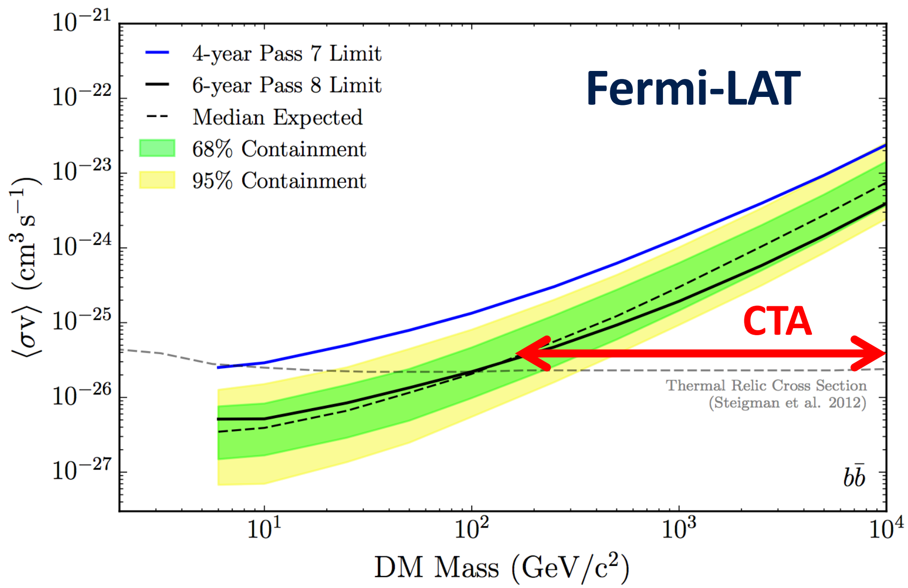
A simulated GRB (E > 30 GeV)

CTA Simulation of GRB 080916C seen by GBM + LAT



from
Gamma-Ray Burst Science in the Era of Cherenkov Telescope Array
(Astroparticle Physics special issue article)
Susumu Inoue et al.

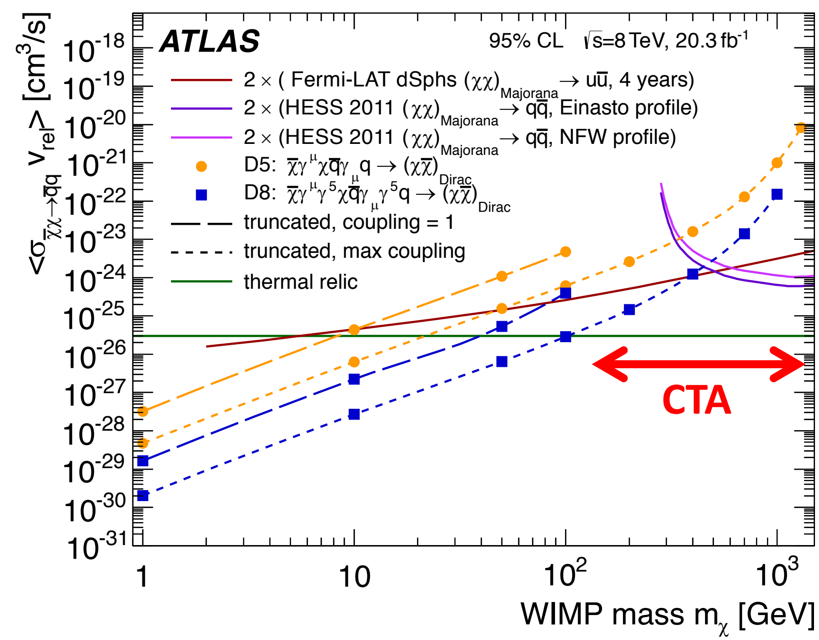
Still Looking for the Nature of Dark Matter



Ackermann et al. 2015, PRL 115, 231301

LHC direct production search and Fermi-LAT indirect search rule out light WIMPS with thermal relic cross section

CTA probes WIMP masses not reached by these experiments



Aad et al. 2015, Eur. Phys. J. C 75, 299

Many intriguing reports of evidence for dark matter particles— none has yet proved convincing

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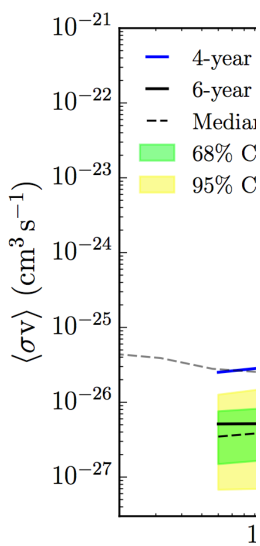
Still Looking for the Nature of Dark Matter



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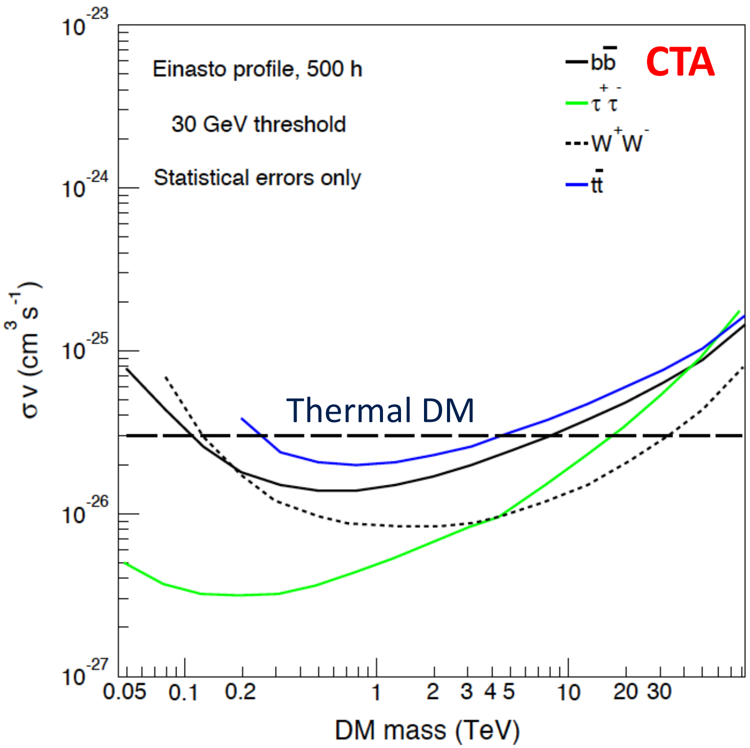

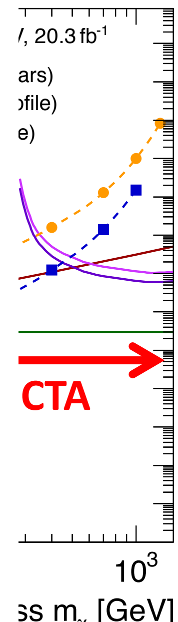

299

Many intr
matter

CTA will probe, *at the level of the thermal relic cross section,* WIMP masses and couplings not accessible to the LHC or direct detection

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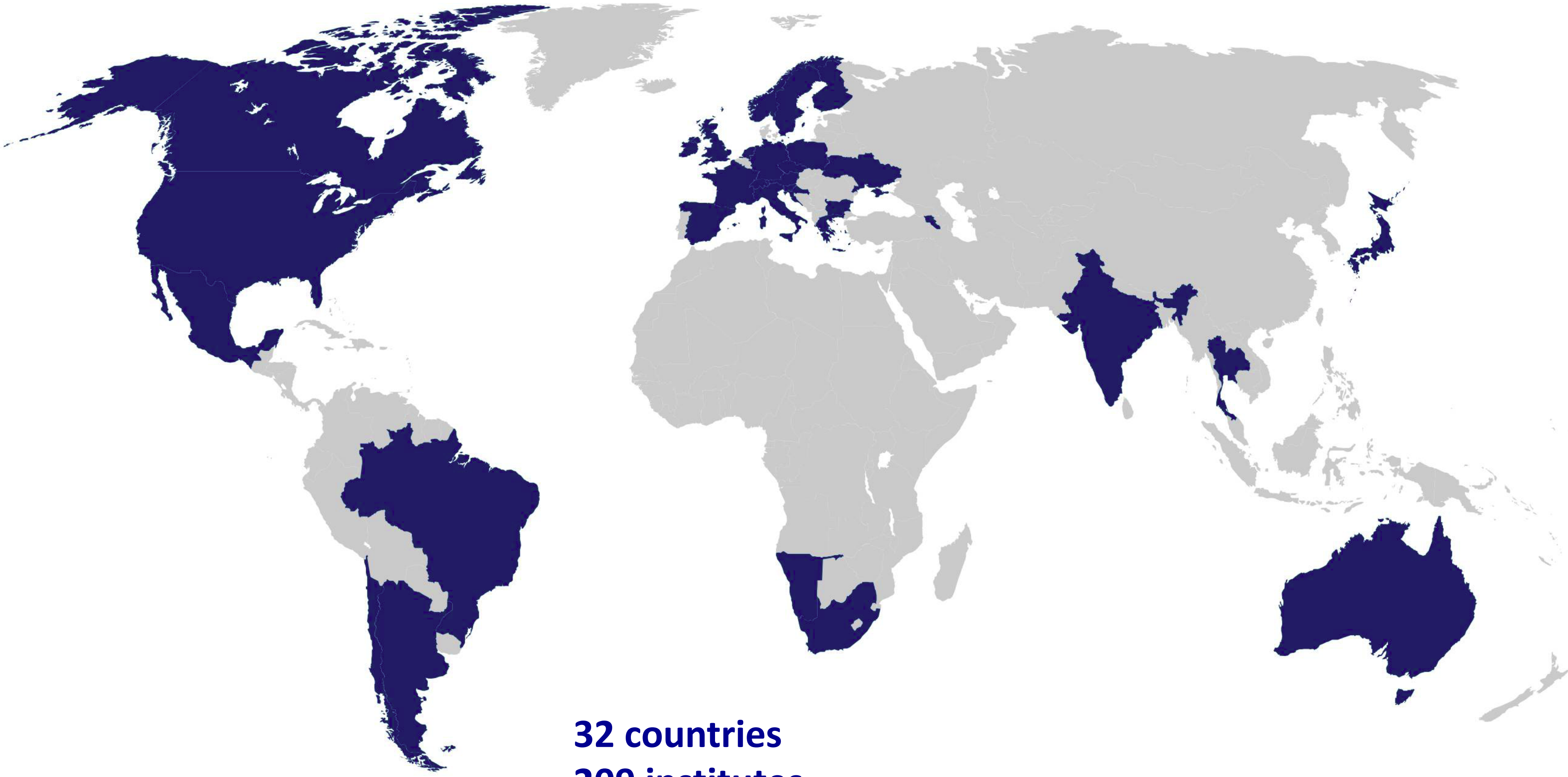
A Southern Wide Field of View Observatory

- Find transients that CTA could follow-up more deeply
  - GRB
  - AGN and XRB flares
  - New objects?
- Find objects dominated by emission above a few TeV
- Find objects with <100% emission duty cycle
- Find extended sources
- Help map diffuse emission
  - Important background, *e.g.*, for Galactic center halo dark matter search

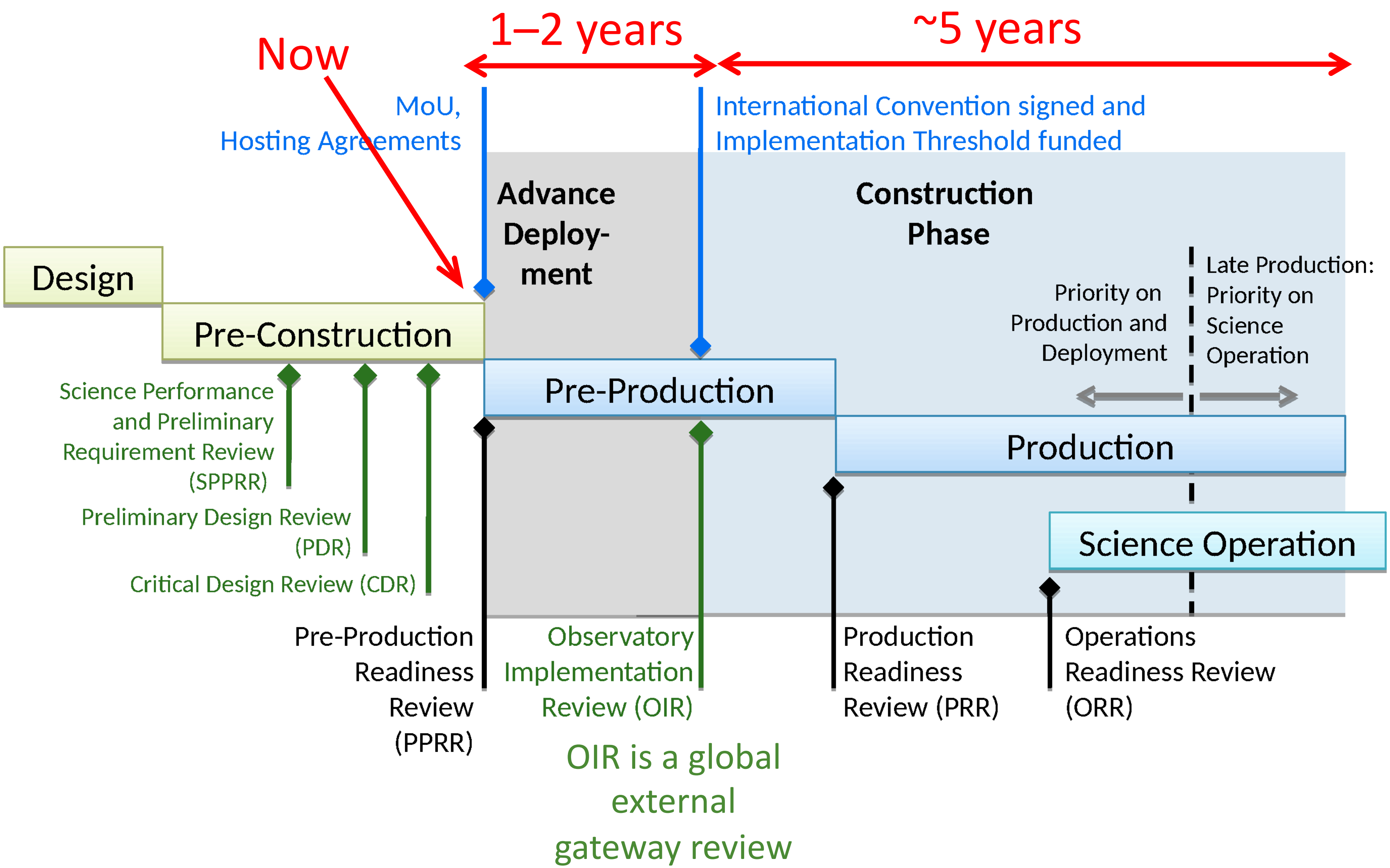
HAWC will teach us a lot about the frequency of these objects

Consortium Membership



32 countries
209 institutes
1346 members (456 FTE)

CTA Timeline



Threshold Implementation: How to Start

Funding situation at threshold should allow to be constructed

Site	Telescopes	Threshold Arrays	Baseline Arrays
North	LST	**4**	4
	MST	**5**	15
South	LST	**0**	4
	MST	**15**	25
	SST	**50**	70

South: additional LSTs highly desirable, but not required for threshold

North: additional MSTs highly desirable, but not required for threshold

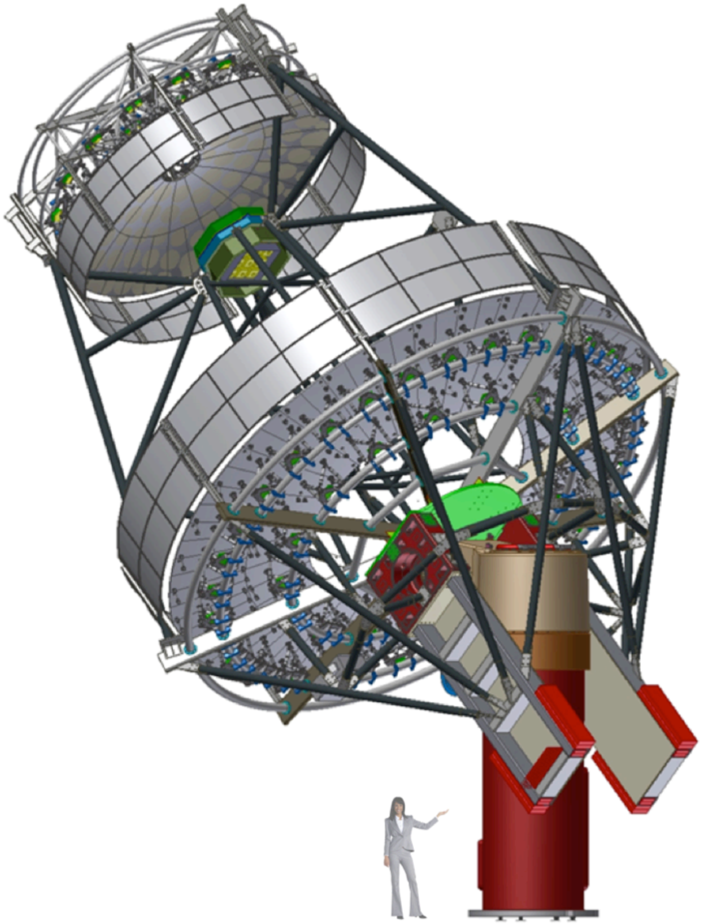
Telescope cost: South ~90 M, North ~60 M

Fitting It All Together

- CTA Observatory GmbH (CTAO) formed to manage construction and operation
- Expected that most of the hardware will be provided as in-kind contributions by members of CTA Consortium (CTAC)
- Work in progress to clarify the roles of multiple designs for medium- and small-sized telescopes (MSTs & SSTs)
- Single, unified design and construction effort for large-sized telescopes (LSTs)
- U.S. groups are developing novel MST design

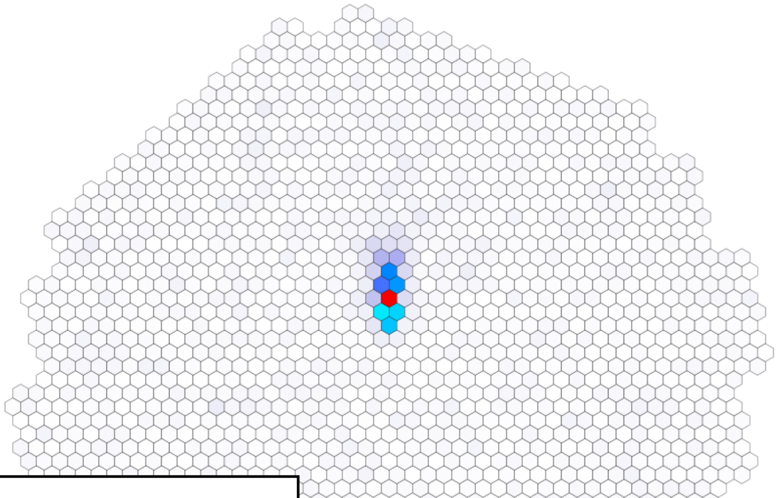
Two-Mirror Atmospheric Cherenkov Telescope: The Schwarzschild-Couder Telescope (SCT)

- Designed to deliver performance close to theoretical limit of Cherekov technique
- Innovative U.S. design key to boosting CTA performance
- Corrects aberrations providing higher resolution, wider field
- Small plate scale enables SiPM camera
- Deep analog memory waveform samplers to minimize dead-time and allow flexible triggering
- High level of integration into ASICs allows dramatic cost savings (<$80 per channel) and high reliability (11,328 channels)
- Overall cost comparable to single-mirror medium-sized telescope
- Adopted now by European groups also for small-sized telescopes

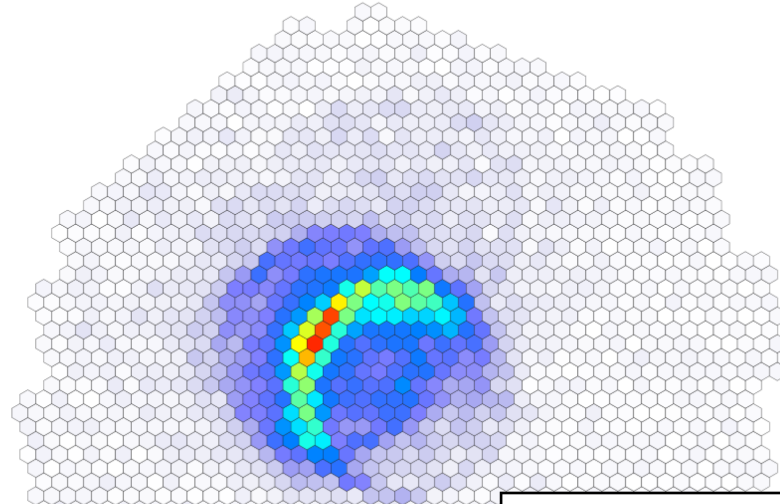


Uses the same positioner and foundation as single-mirror MST

The SCT: Showers Measured Better

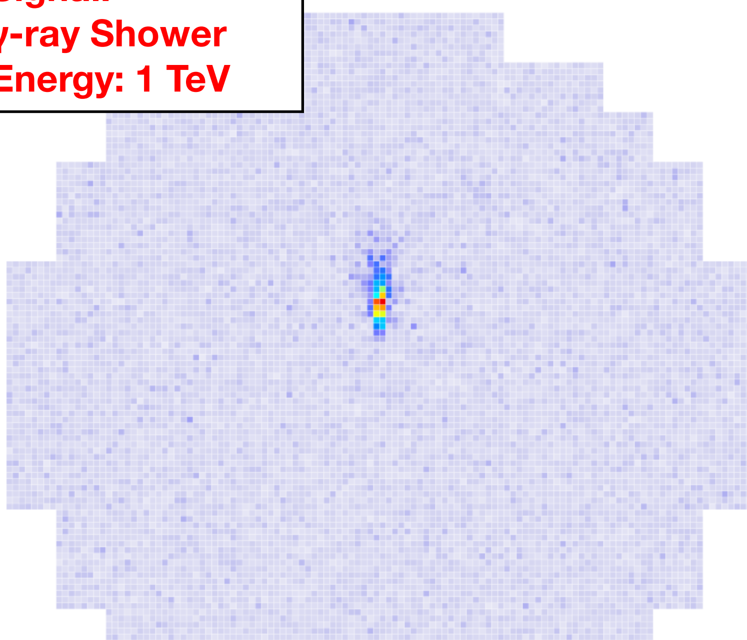


Single-Mirror
MST
Images
8° field of view
0.18° pixels
1,570 channels

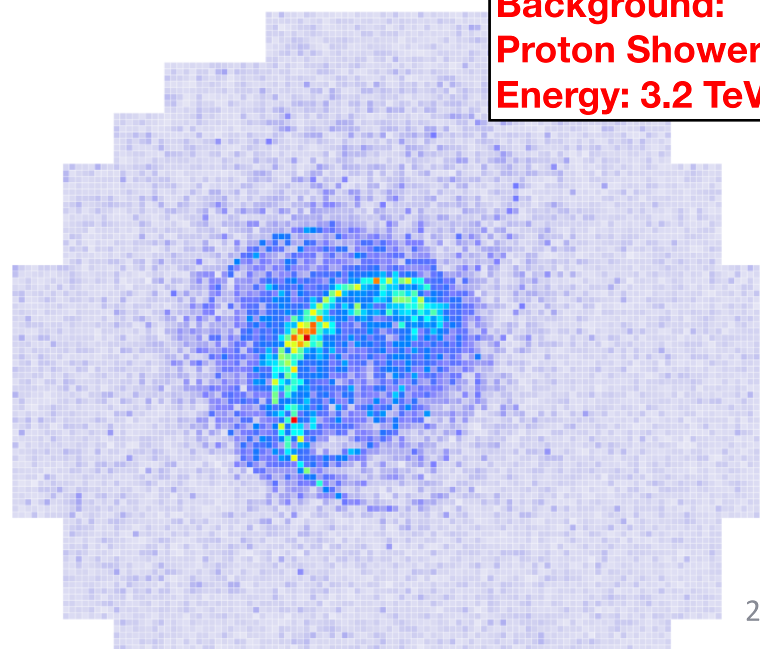


Signal:
γ-ray Shower
Energy: 1 TeV

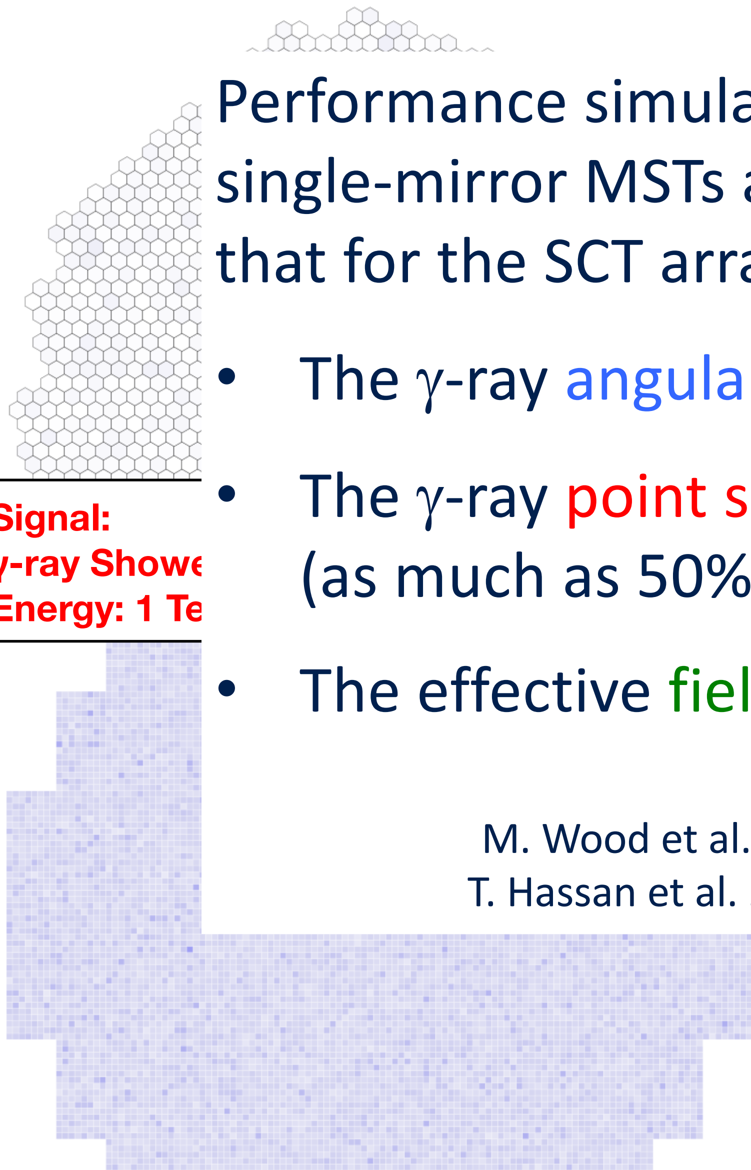
Background:
Proton Shower
Energy: 3.2 TeV

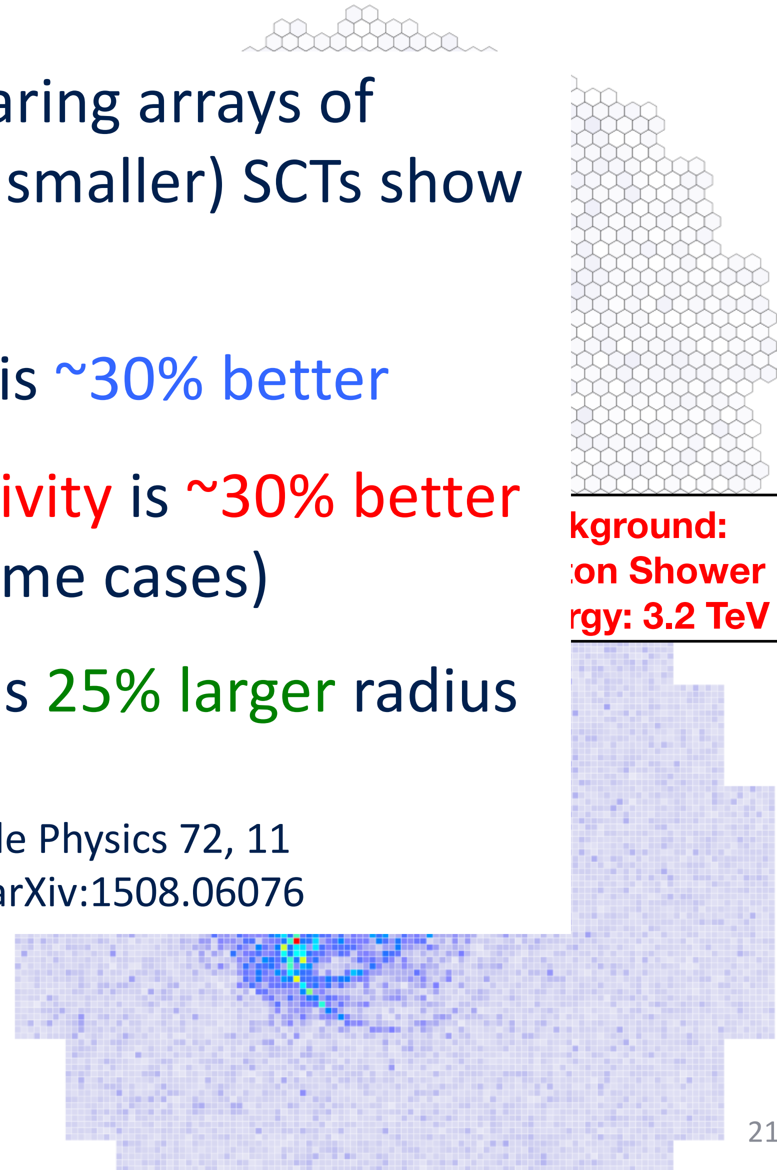


U.S. Design
SCT
Images
8° field of view
0.067° pixels
11,328 channels



The SCT: Showers Measured Better





Performance simulations comparing arrays of single-mirror MSTs and (slightly smaller) SCTs show that for the SCT array:

- The γ-ray angular resolution is ~30% better
- The γ-ray point source sensitivity is ~30% better (as much as 50% better in some cases)
- The effective field of view has 25% larger radius

M. Wood et al. 2016, Astroparticle Physics 72, 11
T. Hassan et al. 2015, Proc. ICRC, arXiv:1508.06076

pSCT – Structure

Webcam — http://cta-psct.physics.ucla.edu/

1. pSCT team of US, German, and Mexican institutions completed the assembly of the telescope structure in August 2016.

1. Structure was balanced, motion system activated and base functionality verified.

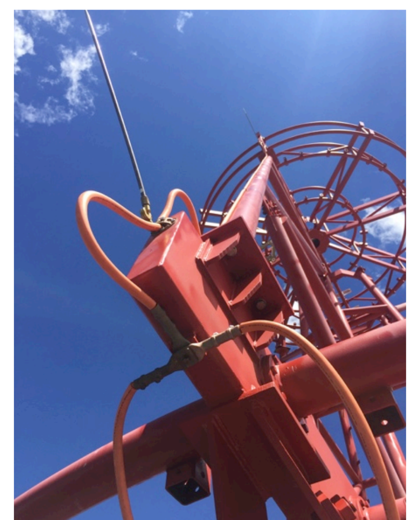
2. pSCT lightning protection system installed.

3. Installation of auxiliary sub-systems: power, cooling, M1&M2 baffles etc. is planned for November.

4. Commissioning activities of the pSCT tracking control system are planned for December.

Structure assembled, August 18, 2016

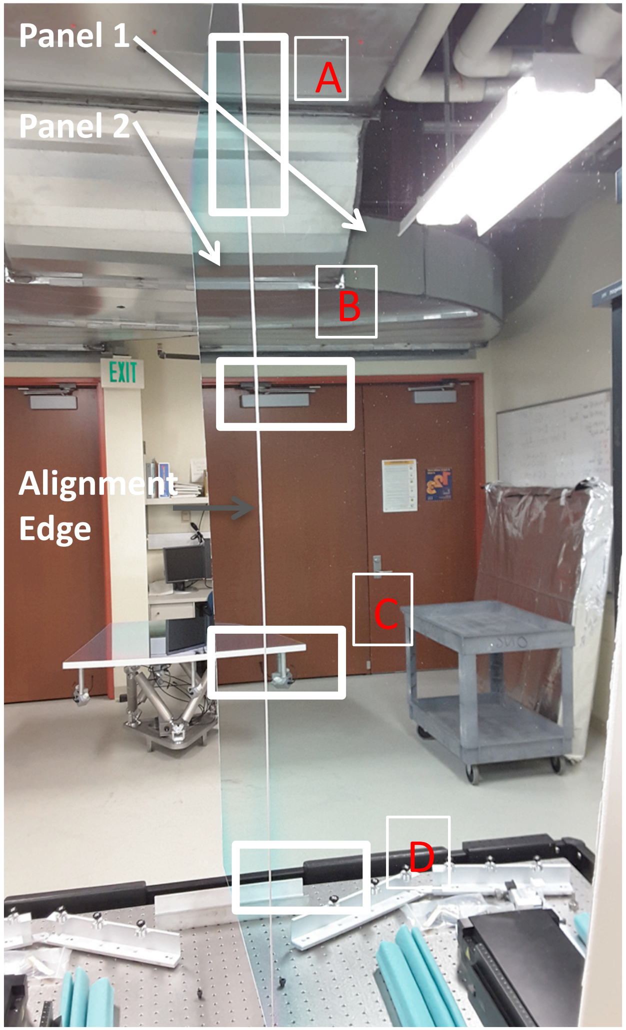
pSCT balanced and motion control activated



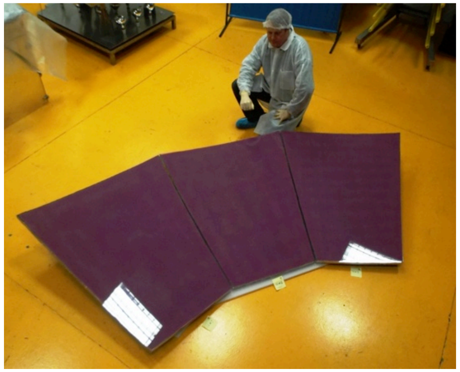
pSCT lightning protection installed

pSCT
&
VERITAS

pSCT – Optics and Camera

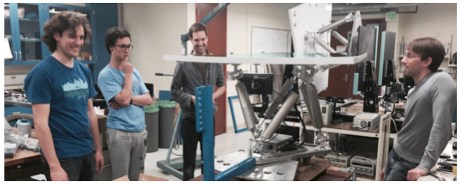


Two primary mirror panels aligned at UCLA

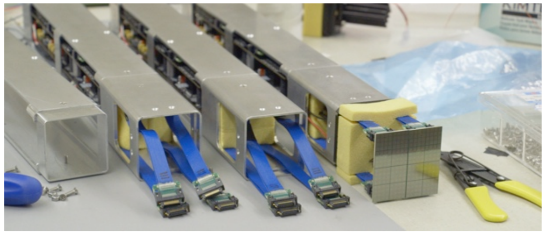


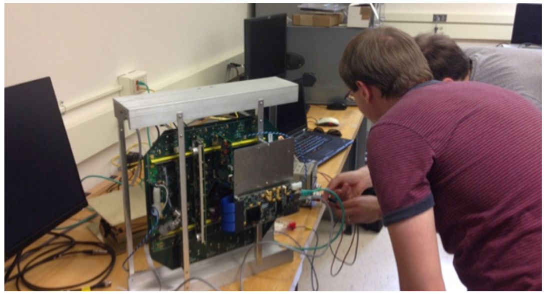
Secondary mirror panels: technology demonstrated, fabrication started

pSCT global alignment system: optical tables fabricated, undergoing calibration

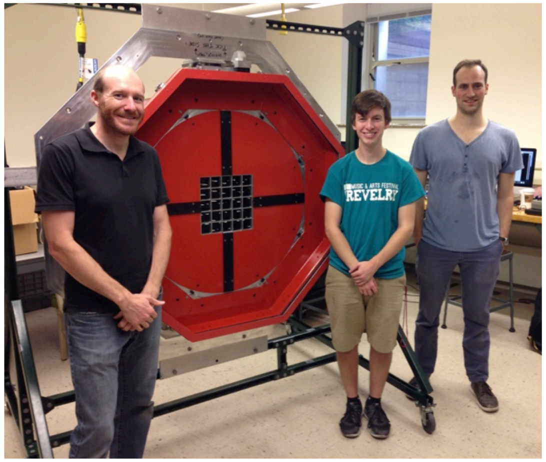


pSCT optical system integration team





Electronics assembly and backplane integration

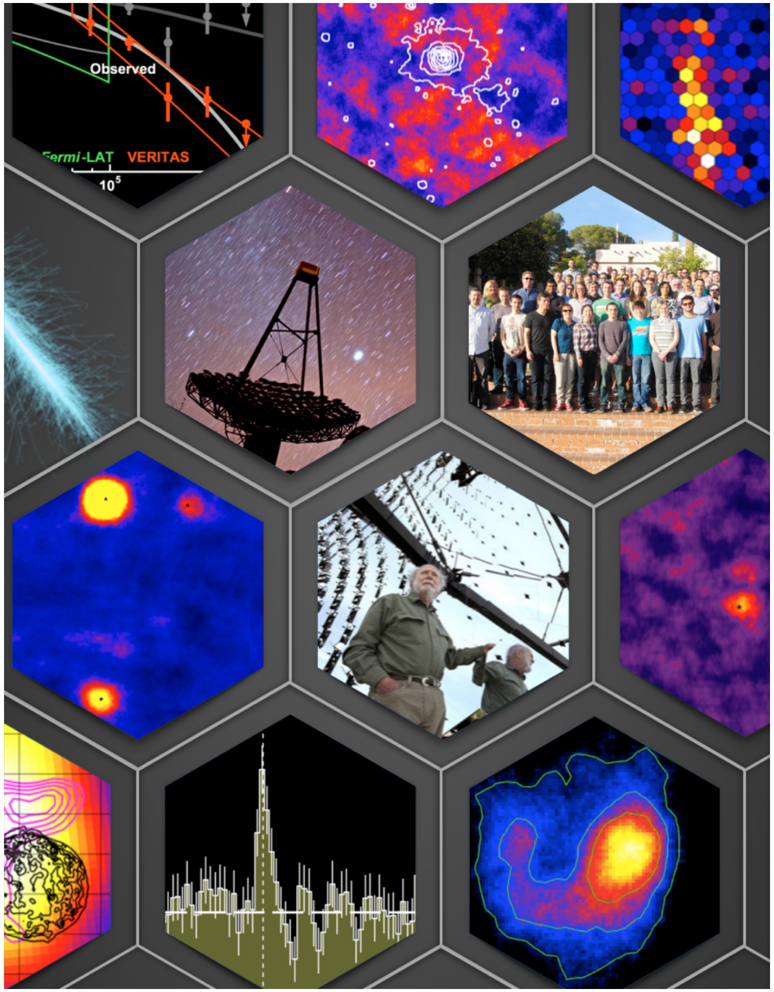


pSCT camera Integration

pSCT Inauguration June 29, 2017

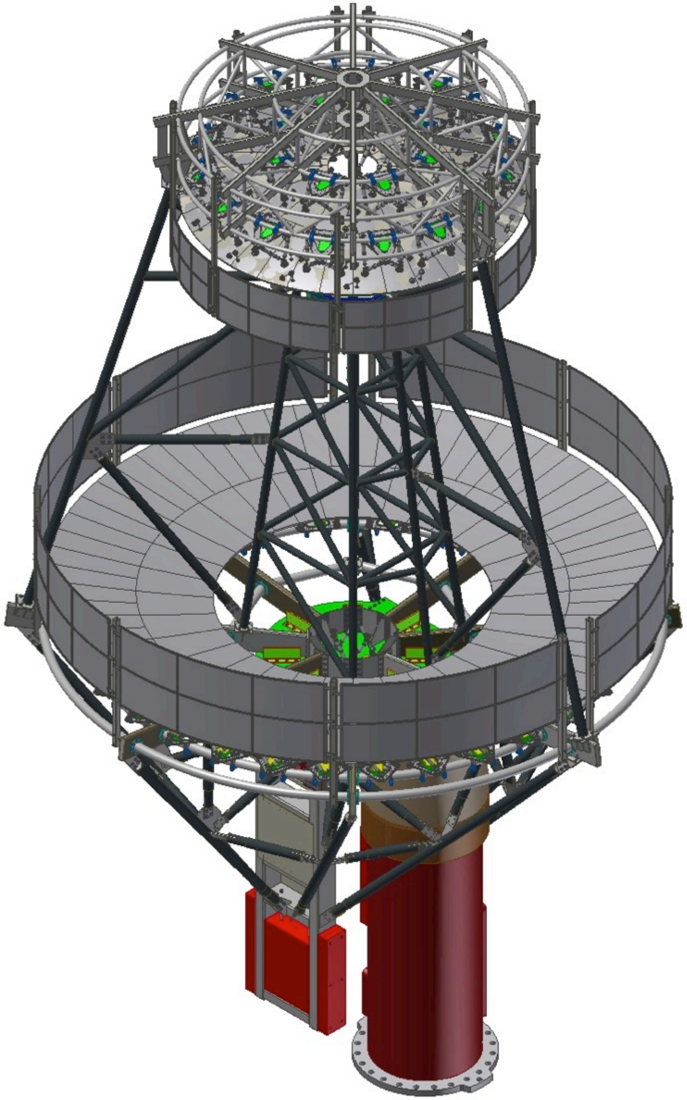
pSCT inauguration planned next year in conjunction with a **Celebration of ten years of VERITAS June 28–29 in Tucson, Arizona**

Inauguration will be at the Whipple Observatory on the second day of the celebration



CTA-US Goals

- **Implementation of the baseline MST arrays**
  - ✓ **Dominate sensitivity in the core 100 GeV – 10 TeV energy range**
- Complete prototype SCT
  - ✓ Verify performance
  - ✓ Vet performance and cost through CTA reviews — one preconstruction review already (September 2013)
- Lead completion of baseline MST array(s) in S or N with SCTs
  - ✓ Assembling consortium
  - ✓ In collaboration with international partners
- Secure $25M in construction funding
  - ✓ NSF Astronomy MSIP (2017 call?)
  - ✓ NSF Physics mid-scale (in parallel)
- Support CTA operations at a commensurate level
  - ✓ ~$1.8M per year for 10 years, starting ~2023
- Participate in full spectrum of CTA science
  - ✓ Key Science Projects
  - ✓ Open time proposals



Summary

- 10-fold improved sensitivity for TeV studies of the cosmos
  - ✓ Analogous to the advance from EGRET to Fermi-LAT
- Angular resolution substantially better
- Detailed studies of Galactic cosmic-ray acceleration
- New sensitivity to the high-energy processes in blazar jets
- Astrophysics foundation and sensitivity for recognizing new fundamental physics — Sensitive searches for dark matter in its cosmic home
- Prototypes well along in development
- Construction soon to begin – details also still being hashed out
- U.S. groups aim to play a significant role with medium-sized telescopes
- Broad access to CTA by scientists in participating countries
- Valuable role for a wide field of view instrument in the south with sensitivity to complement CTA and HAWC