Cherenkov Telescope Array

An advanced Facility for ground-based gamma-ray Astronomy

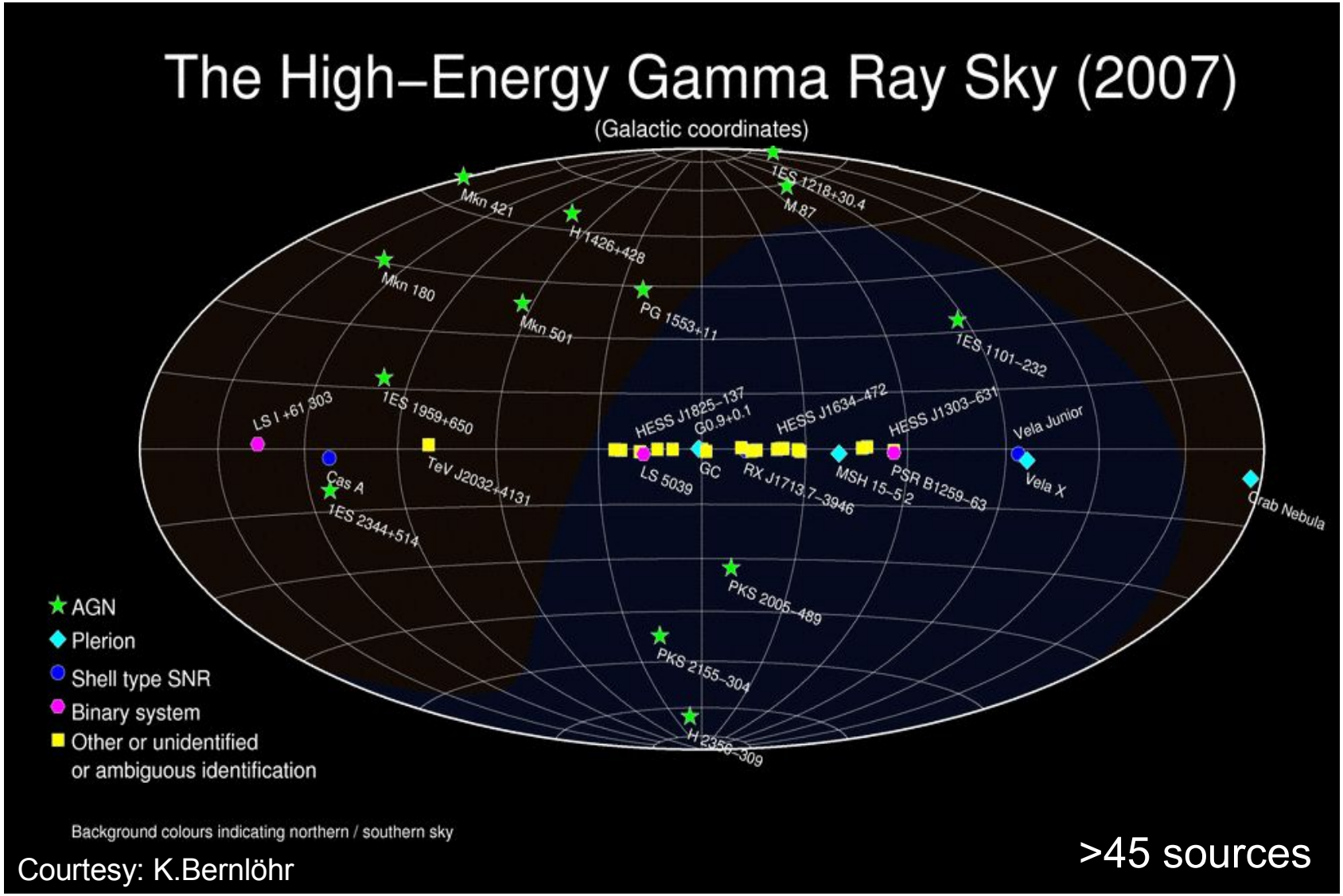
TeV gamma-ray astronomy:

- From ground-based ***experiments*** towards a *TeV gamma-ray* ***observatory***
- CTA within the EU FP7 program

German Hermann, MPI Kernphysik, Heidelberg

Cherenkov Telescope Array

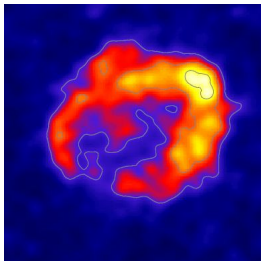
An advanced Facility for ground-based gamma-ray Astronomy



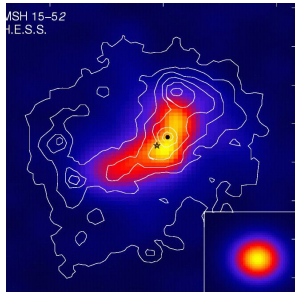
Courtesy: K.Bernlöhr

>45 sources

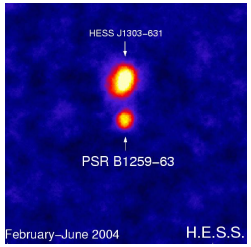
State of the Art TeV Astrophysics …



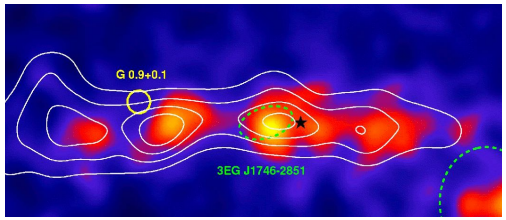
SNR & Sources of Gal. CR



PWN & Pulsars

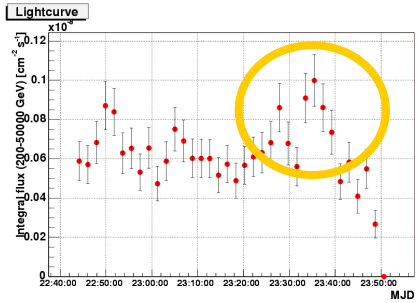


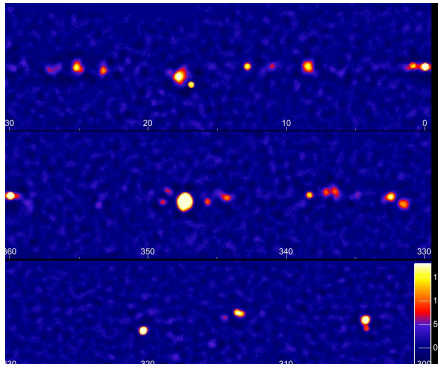
"Dark" Sources



Cosmic Ray Propagation

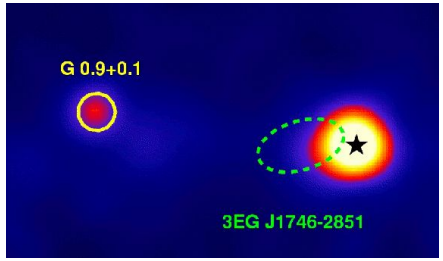
AGNs Relativistic outflows



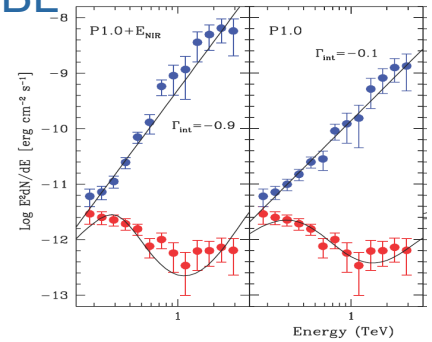


Population Studies

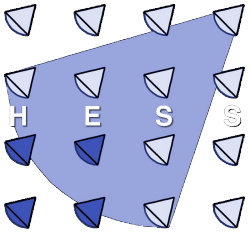
Dark Matter ?

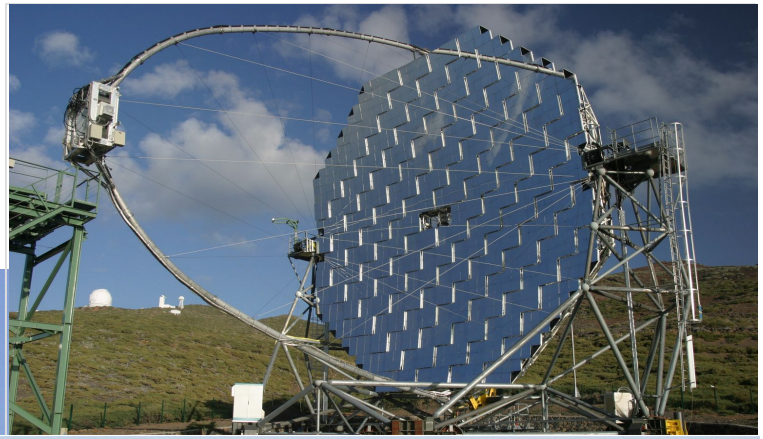


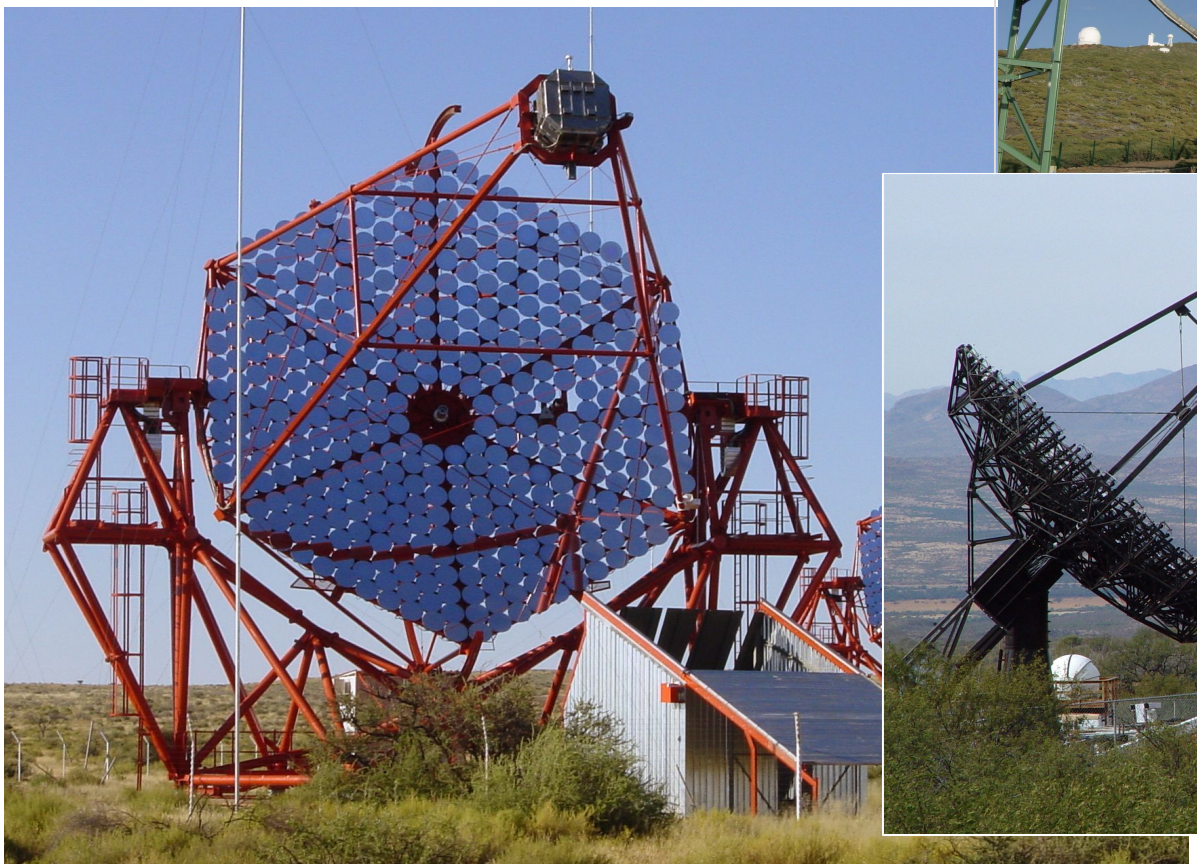
Diffuse EBL



State of the Art TeV Experiments …

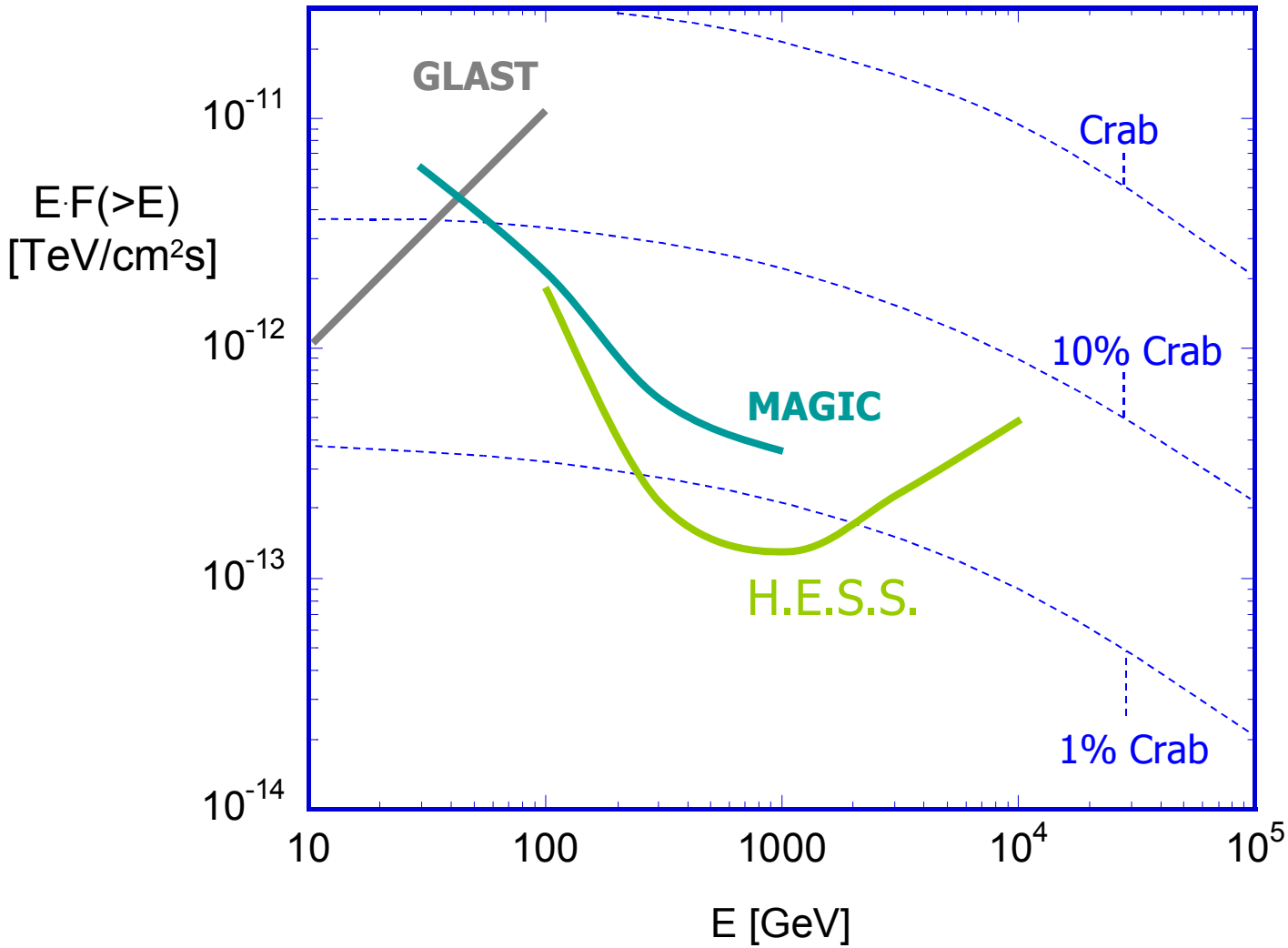






CTA : Sensitivity aimed for

An advanced Facility for ground-based gamma-ray Astronomy



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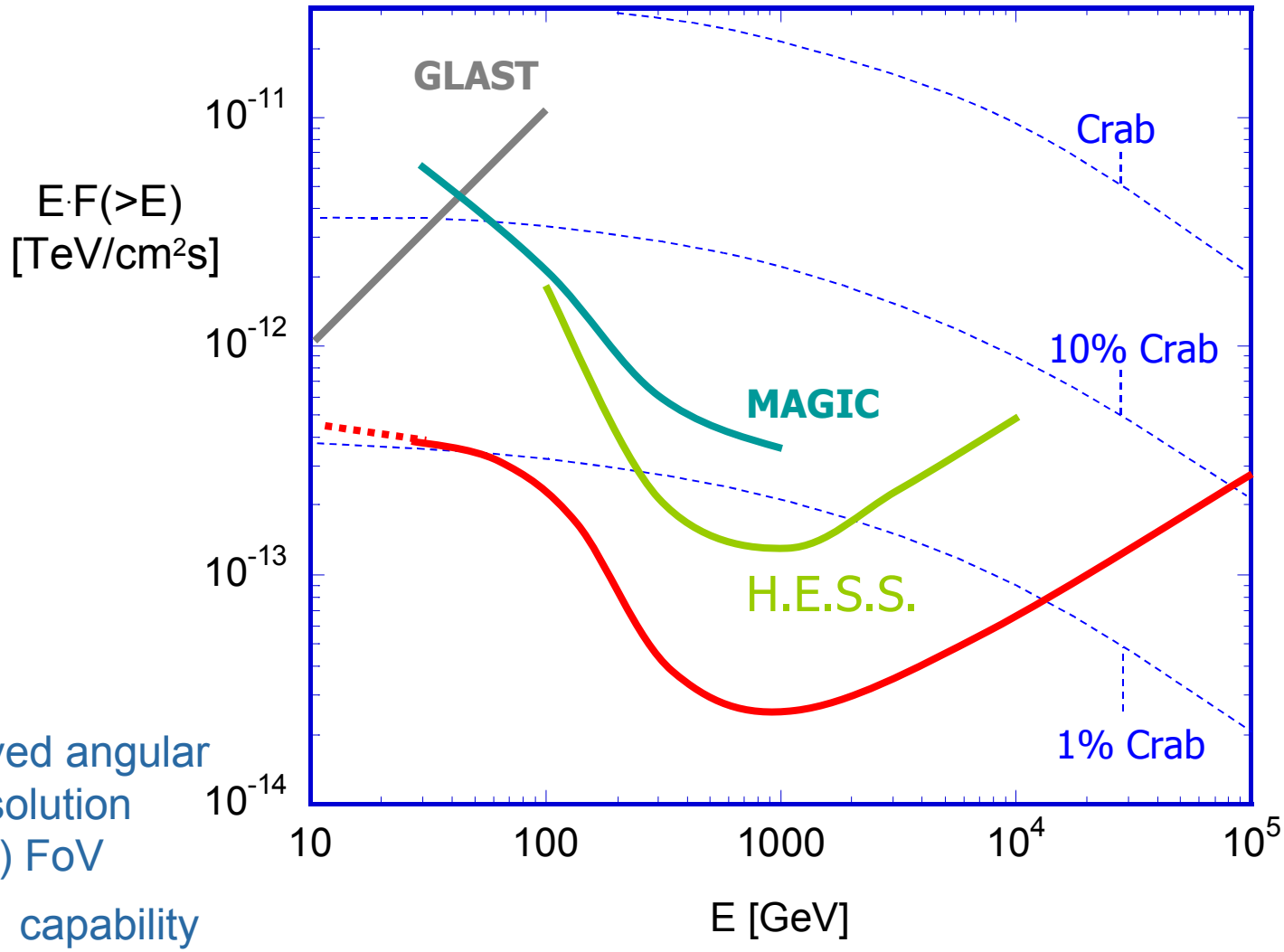

+ Improved angular resolution
+ large(r) FoV
+ all-sky capability

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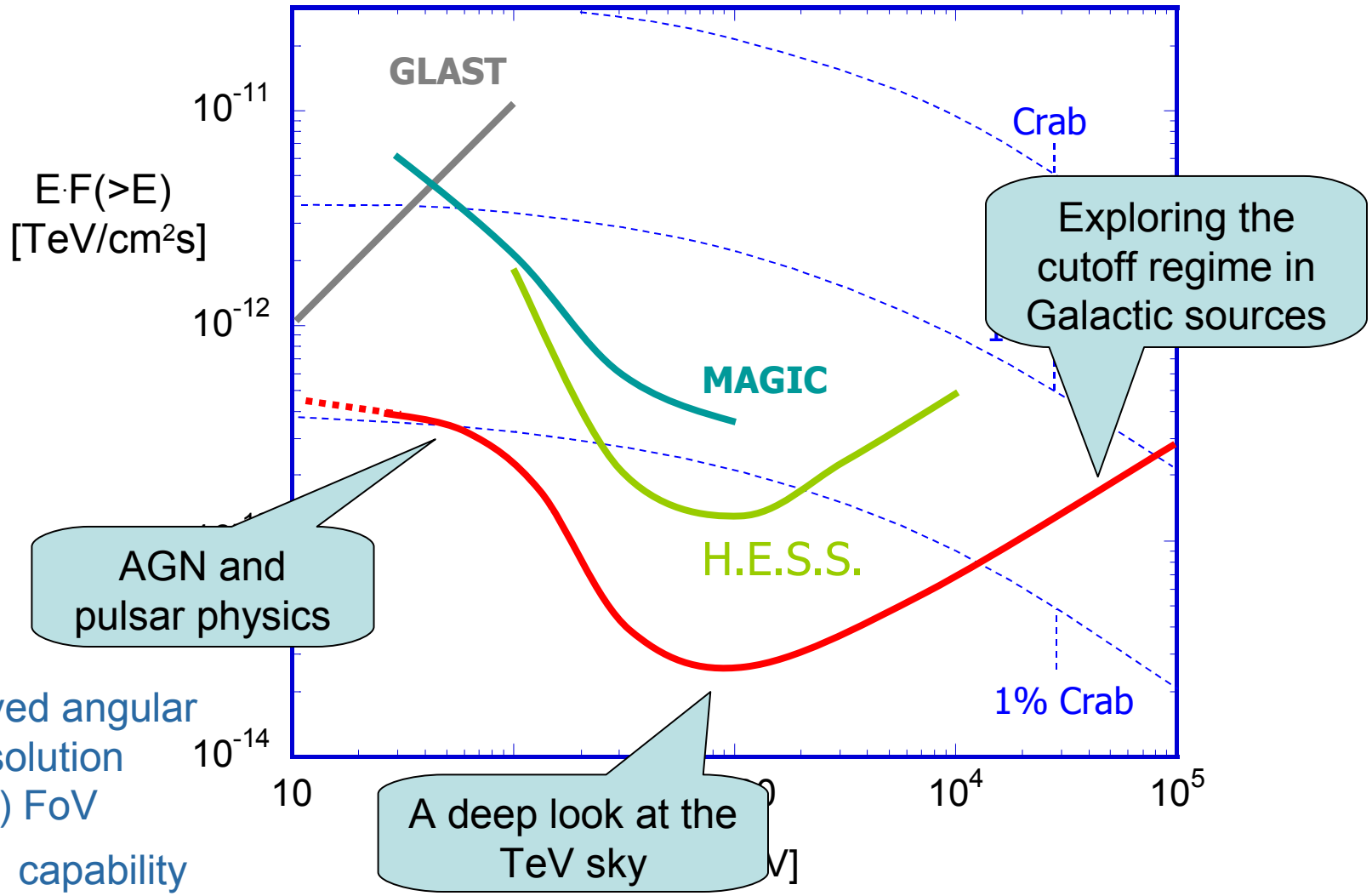
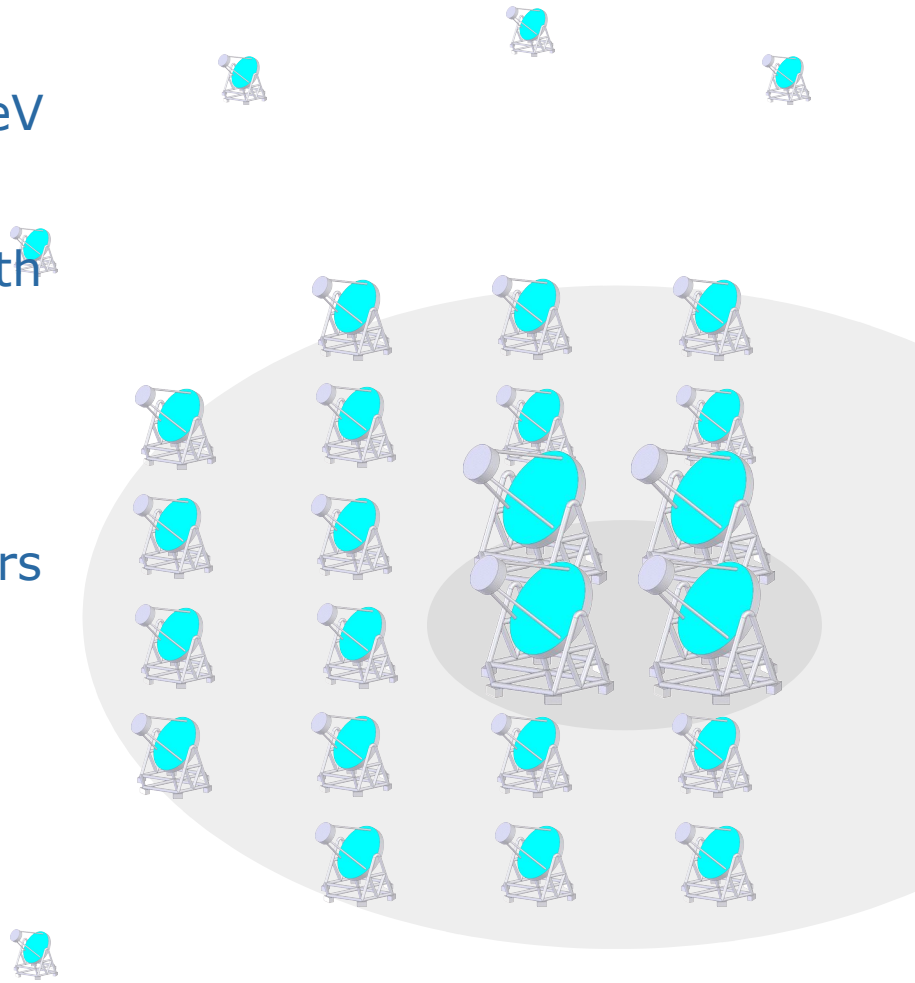


+ Improved angular resolution
+ large(r) FoV
+ all-sky capability

What is CTA ?

An advanced Facility for ground-based gamma-ray Astronomy

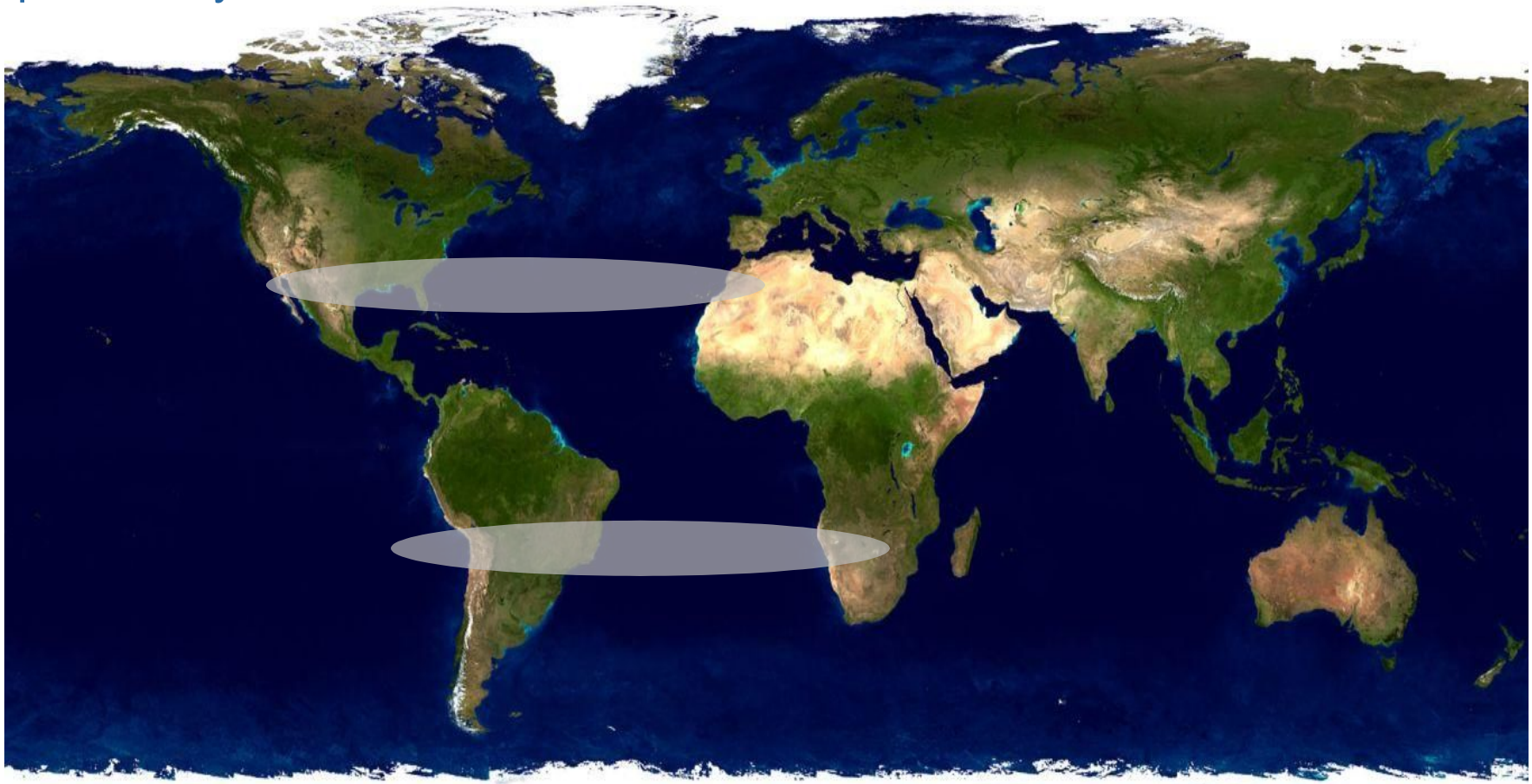
- aims to explore the sky in the some 10 GeV to 100 TeV energy range, with **"core" regime** from ~100 GeV to ~ 10 TeV
- combines **guaranteed science** with significant discovery potential
- builds on **demonstrated** technologies and provides guaranteed performance parameters
- is an **observatory** that provides access and data to a wide community
- provides **full sky** coverage



Cherenkov Telescope Array

An advanced Facility for ground-based gamma-ray Astronomy

One observatory with two sites
operated by one consortium



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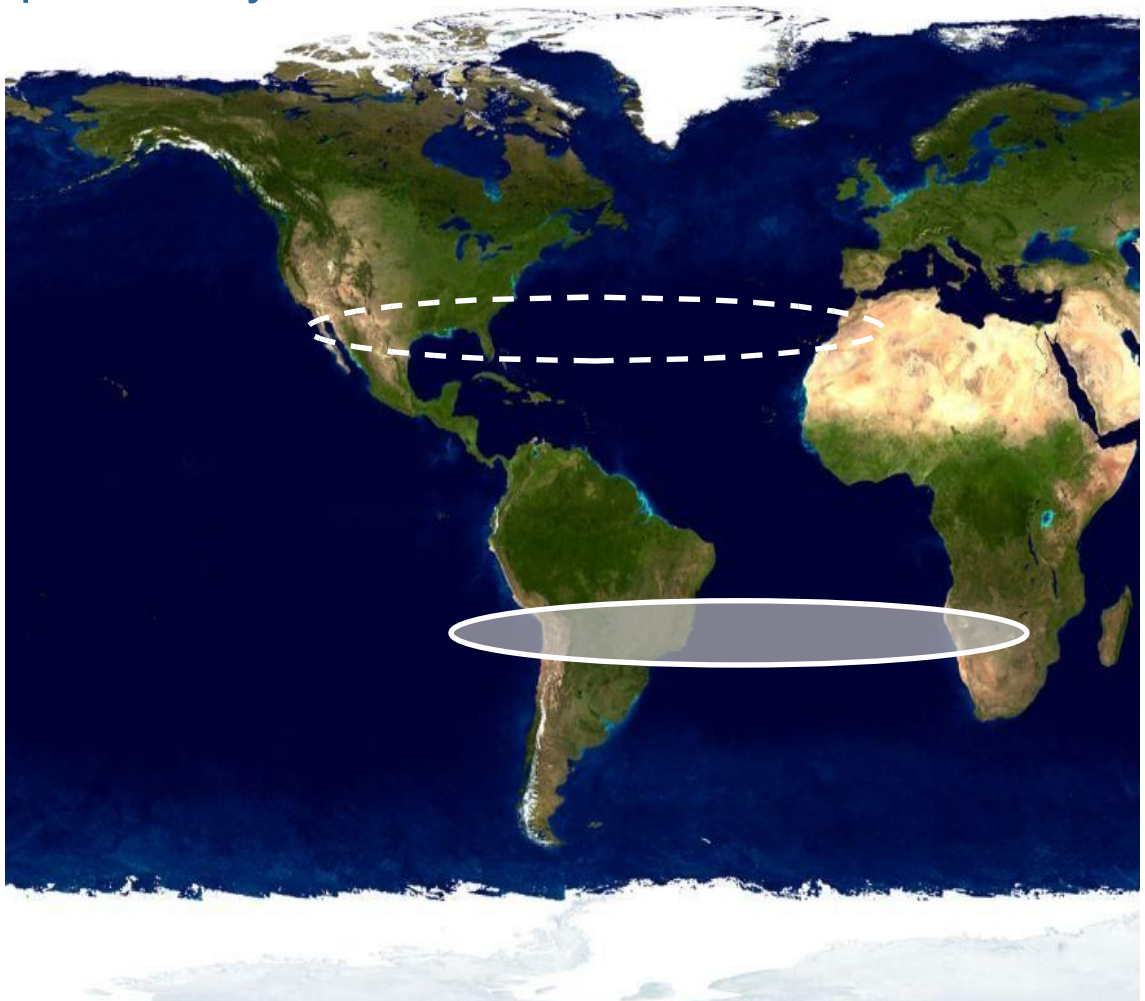

Southern Array (100 ME)

→ Full energy and sensitivity coverage
some 10 GeV …. 100 TeV

→ Angular resolution:
0.02 … 0.2 deg

→ Large field of view
Galactic + Extragal. Sources

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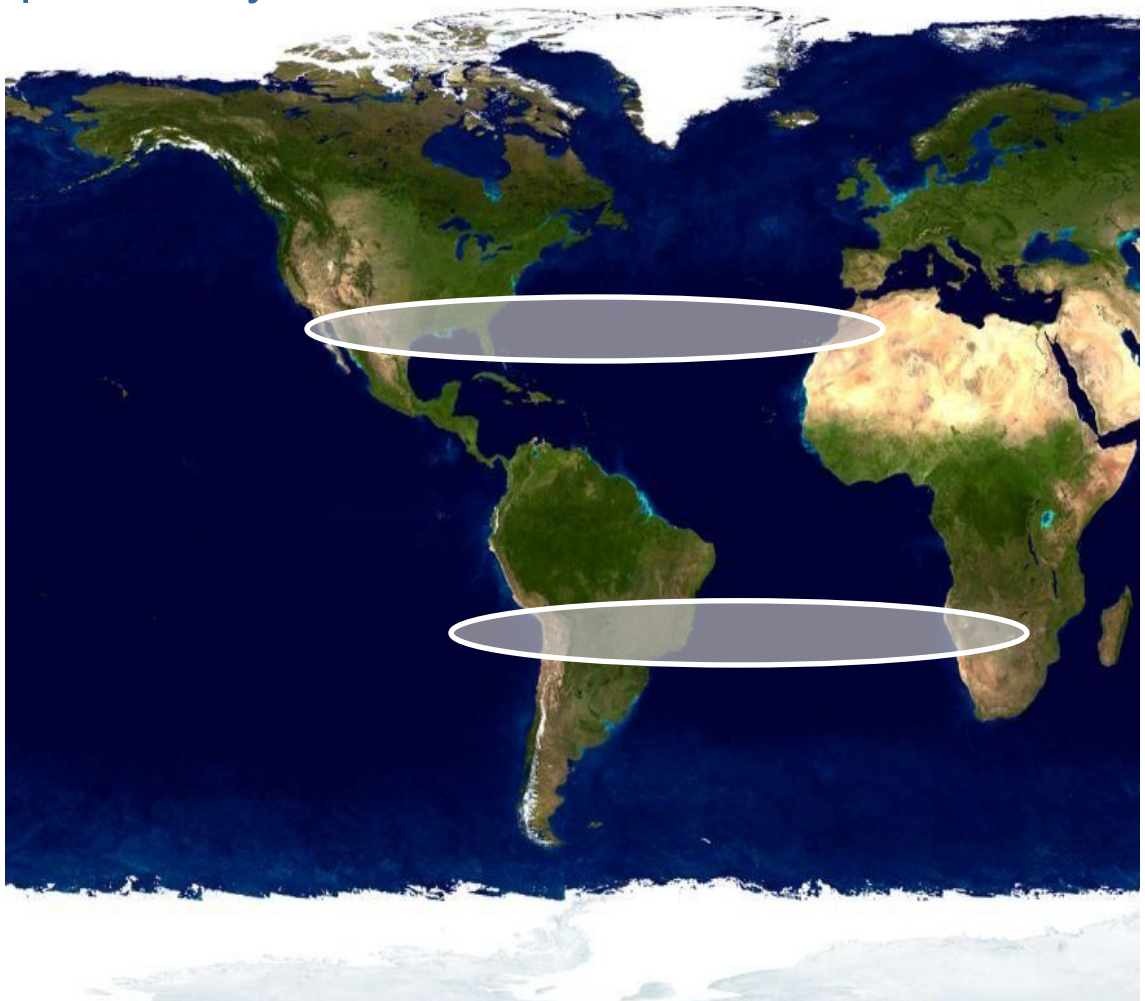


Northern Array (50 ME)

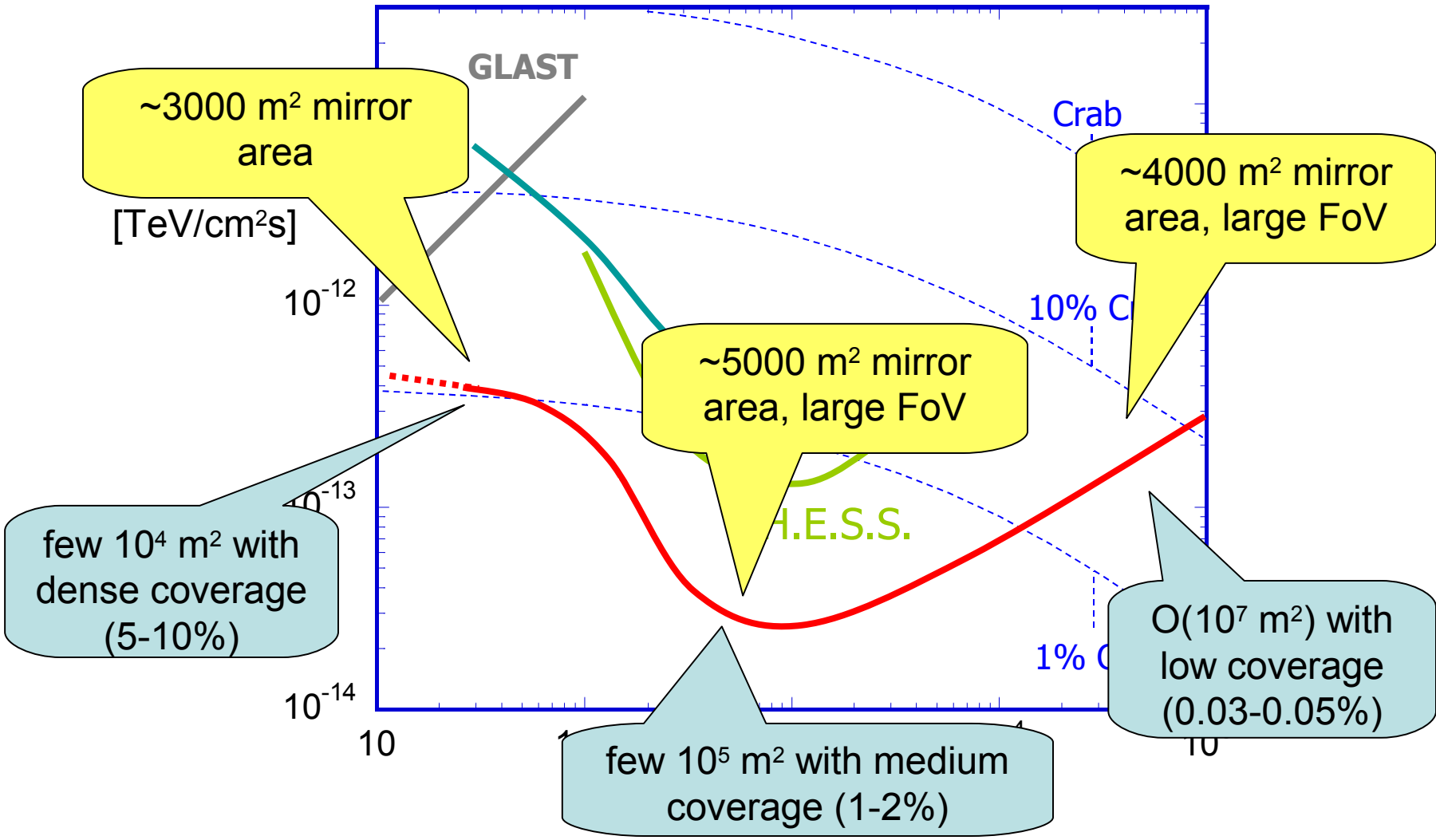
→ complementary to SA for full sky coverage
→ Energy range
some 10 GeV …. ~1 TeV
→ Small field of view
Mainly extragal. Sources

Southern Array (100 ME)

→ Full energy and sensitivity coverage
some 10 GeV …. 100 TeV
→ Angular resolution:
0.02 … 0.2 deg
→ Large field of view
Galactic + Extragal. Sources

Technical Implementation

An advanced Facility for ground-based gamma-ray Astronomy



Technical Implementation

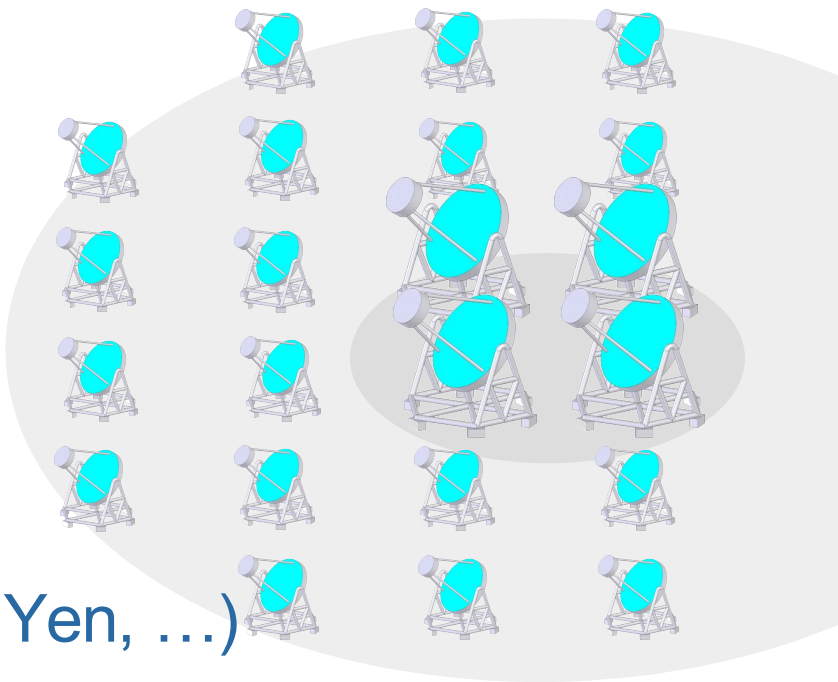
An advanced Facility for ground-based gamma-ray Astronomy

Possibly mix of telescopes:
e.g (5m), 14m, 28m
"Large" FoV (6-8°)

"… detection technique is well understood and very mature …"

"… design based on proven technology …"

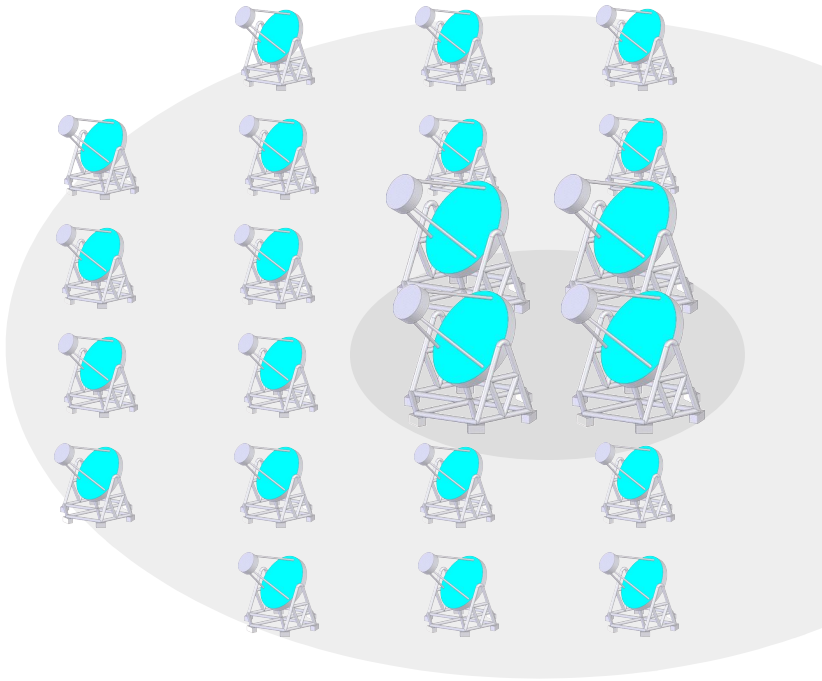
Will need
- O(30-50) telescopes
- O(10000) m^2 mirror area
- O(50) m^2 photo sensitive area
- O(50000-100k) electronics channels



→ Factor of 10 in sensitivity
with only factor of 10 in Euro ($, Yen, …)

CTA : HowTo get there

An advanced Facility for ground-based gamma-ray Astronomy



Community:

- Combine efforts of (all) current groups working in the field
- get other communities interested

Political:

- communicate your case to the funding agencies
- make sure you're on the list

Technical:

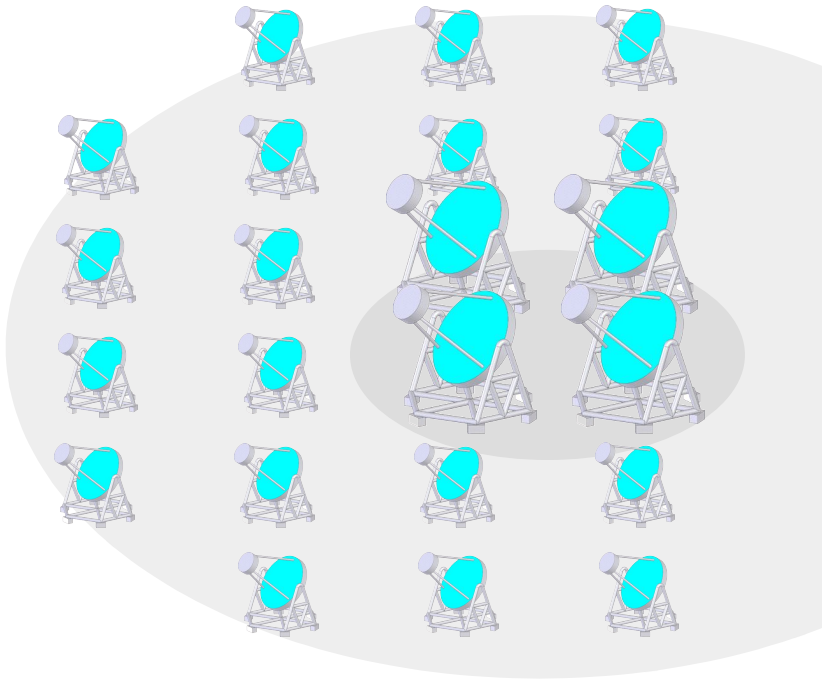
- is it feasible ?
- optimize the design and make it "affordable"

Physics:

- make sure, you've got a good physics case, otherwise …

CTA : HowTo get there

An advanced Facility for ground-based gamma-ray Astronomy



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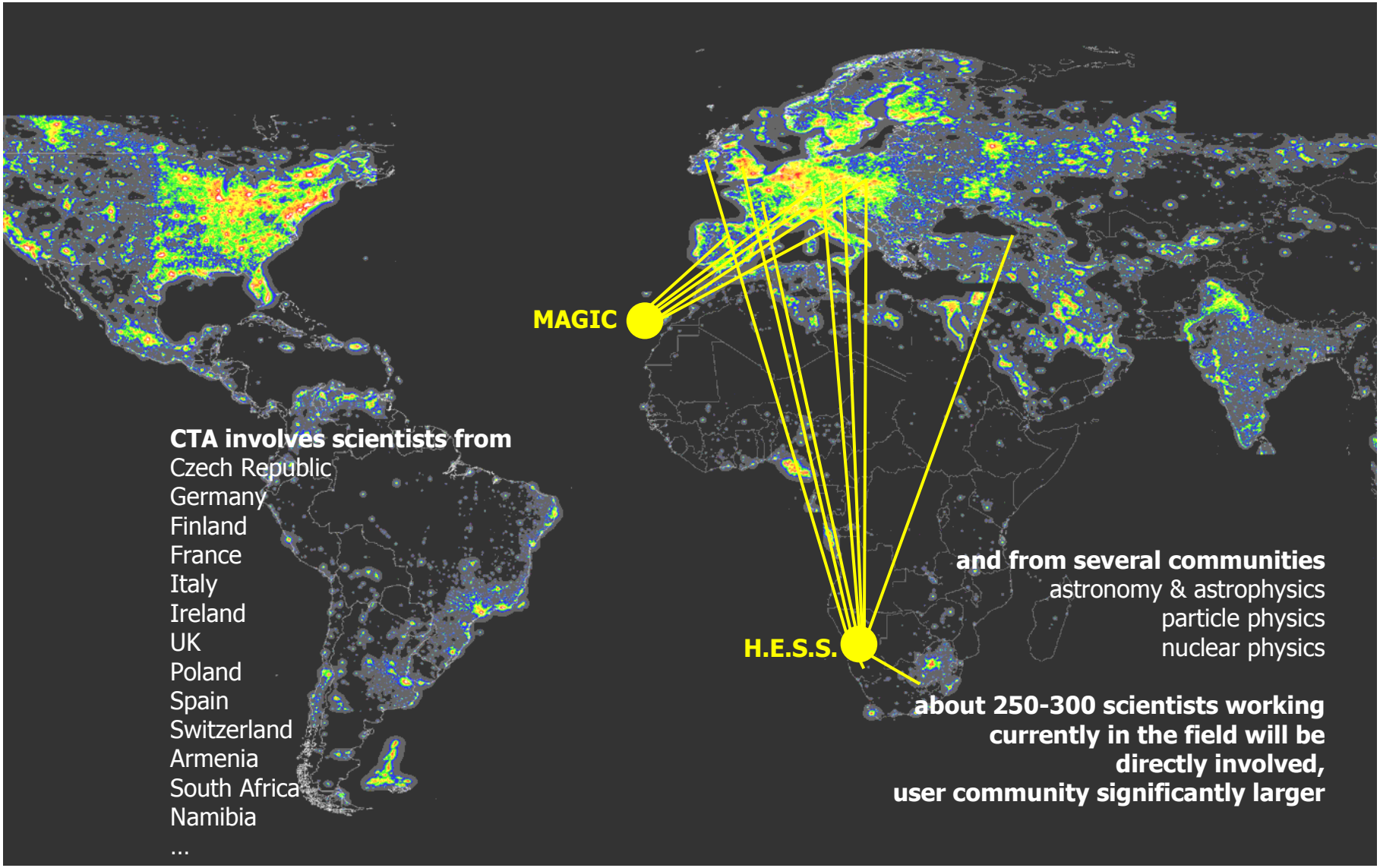
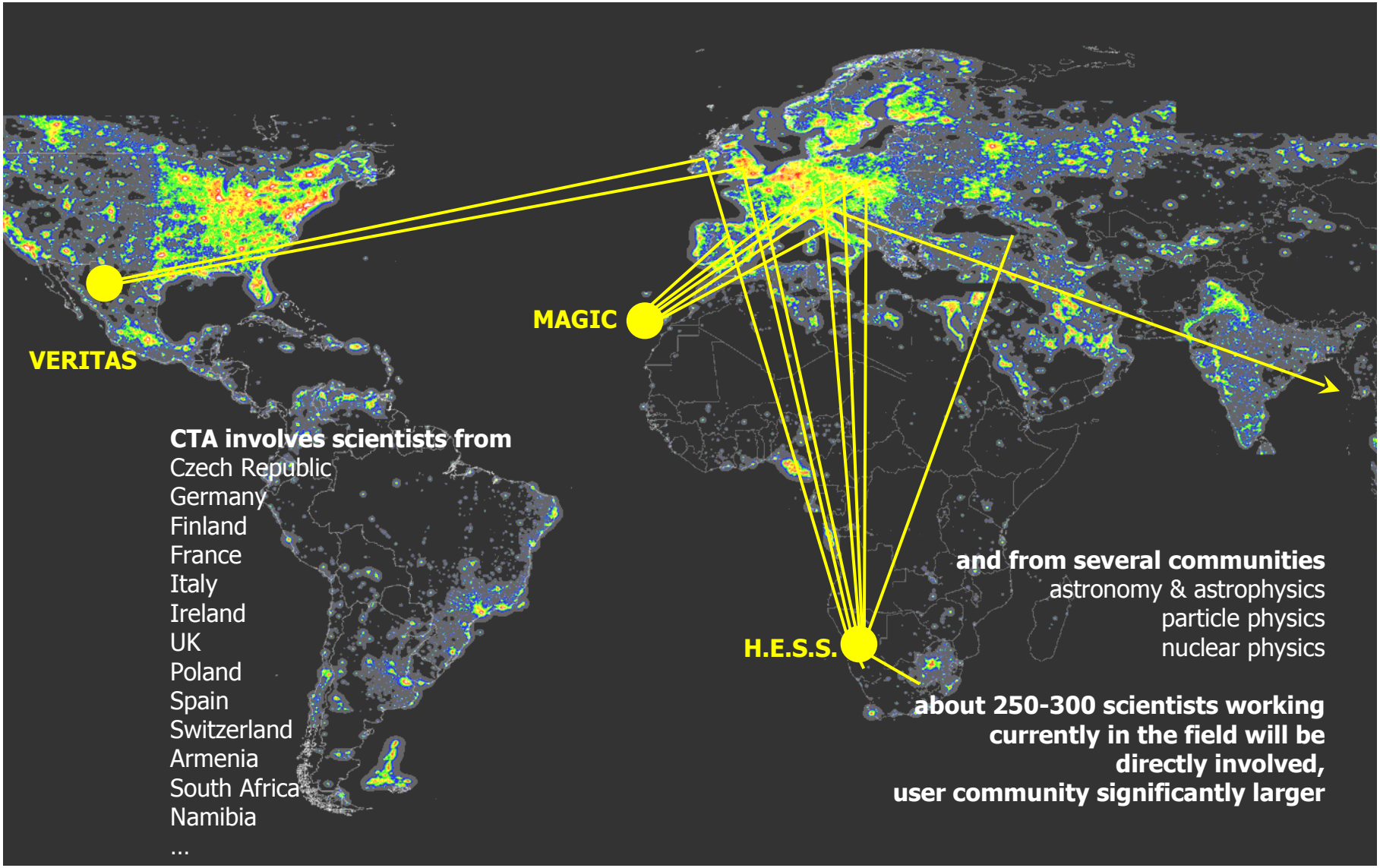
CTA as a European Effort

An advanced Facility for ground-based gamma-ray Astronomy



CTA as an International Effort ?!

An advanced Facility for ground-based gamma-ray Astronomy



CTA : HowTo get there

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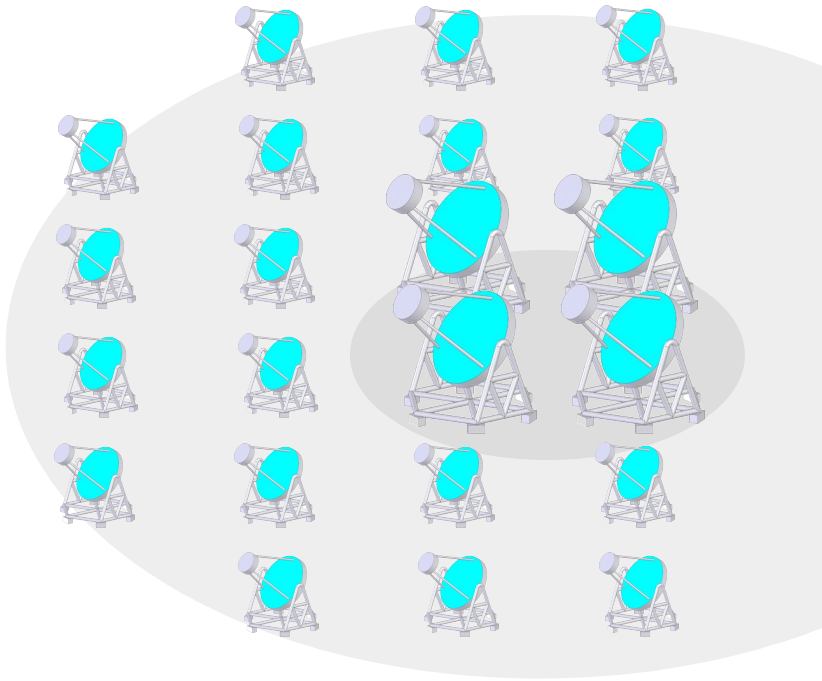

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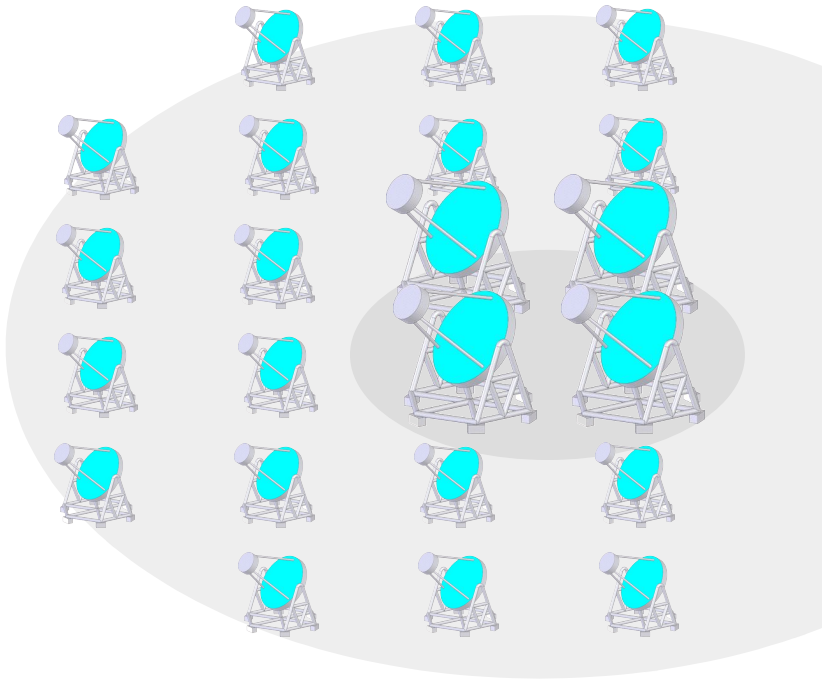

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Cherenkov Telescope Array

An advanced Facility for ground-based gamma-ray Astronomy

First presentation of CTA in November 2005 to the ESFRI committee

1. Project's name and descriptive title
CTA: An advanced facility for ground-based high-energy gamma ray astronomy
2. Short description of project and main characteristics
Imaging atmospheric Cherenkov telescopes have proven an extremely successful approach to gamma ray astronomy in the energy range above a few tens of GeV. The proposed facility will consist of arrays of telescopes, aiming to (a) increase sensitivity by another order of magnitude for deep observations, (b) boost significantly the detection area and hence the detection rates, particularly important for transient phenomena and at the highest energies, (c) increase the angular resolution and hence the ability to resolve the morphology of extended sources, (d) provide wide and uniform energy coverage from some 10 GeV to beyond 100 TeV, and (e) enhance the all sky survey and monitoring capability. These features will allow the exploration of non-thermal processes in the Universe, in close cooperation with and complementing observatories in other wavelength ranges of electromagnetic radiation, and for other messenger types. Given the wealth of sources in the central region of our Galaxy and the richness of their morphological features, a site in the southern hemisphere is attractive. On the other hand, a complementary northern site has to be considered for the study of AGNs and the cosmological evolution of galaxies and star formation. The ensemble would provide full sky coverage and wider energy range coverage as demonstrated by H.E.S.S. - MAGIC large/small zenith angle simultaneous observations.
3. Science case (scientific justification, including new areas to be opened)
Data from Cherenkov telescopes of the latest generation have revealed a sky rich in features at TeV energies; in the last years, the number of sources has quadrupled. First sky maps show the band of

That's how it all began…

ESFRI Proposal
Nov. 2005

European Strategy Forum
on Research Infrastructures

ESFRI

EUROPEAN ROADMAP FOR RESEARCH INFRASTRUCTURES

Report 2006

CTA & the ESFRI Roadmap

An advanced Facility for ground-based gamma-ray Astronomy

European Strategy Forum on Research Infrastructures ESFRI

Report 2006

>Emerging proposals

CTA

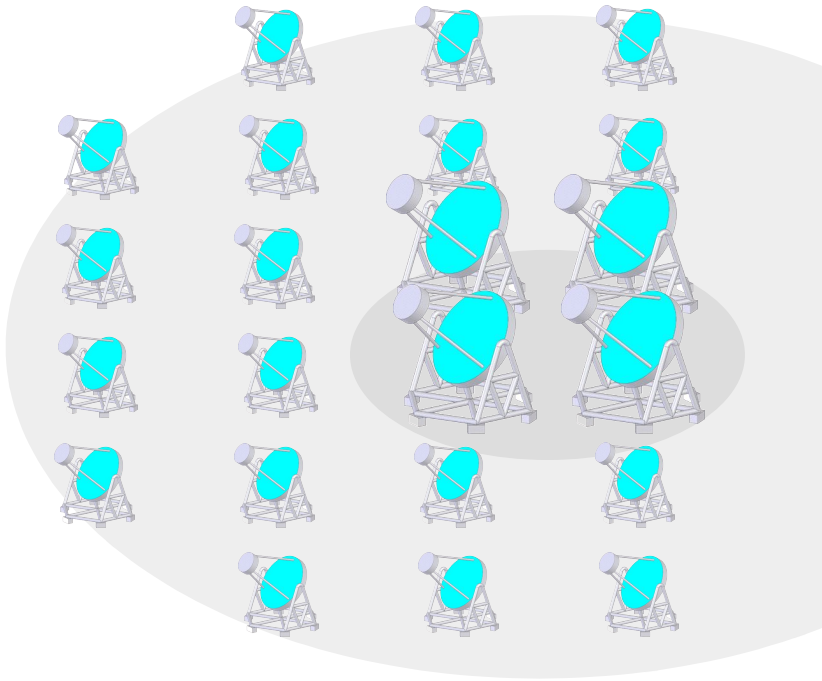
is an advanced facility for ground based high-energy gamma ray astronomy, based on the observation of Cerenkov radiation. This approach has proven to be extremely successful for gamma rays of energies above few tens of GeV. The facility will consist in an array of telescopes enhancing the all sky monitoring capability.

The Expert and Roadmap Working Groups focussed their discussions more on the mature projects, with the Emerging Proposals deserving attention for the future editions of the Roadmap.

→ Update every one to two years (?)

CTA : HowTo get there

An advanced Facility for ground-based gamma-ray Astronomy



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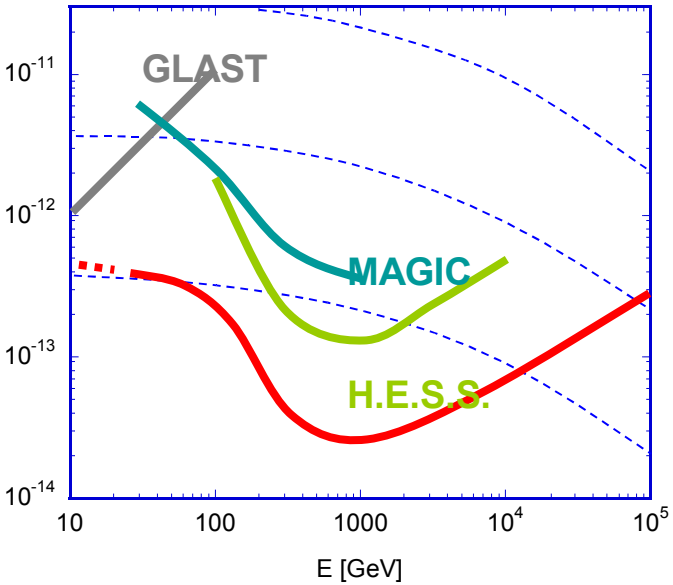
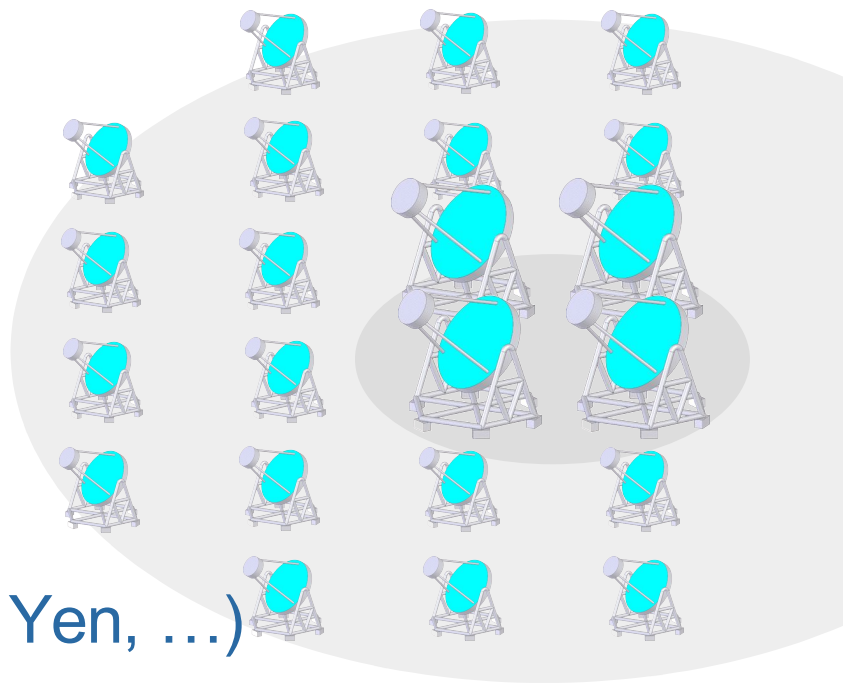
Design Optimization

An advanced Facility for ground-based gamma-ray Astronomy



Possibly mix of telescopes:
e.g (5m), 14m, 28m
Large FoV



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- O(50) m^2 photo sensitive area
- O(50000-100k) electronics channels

→ Factor of 10 in sensitivity
with only factor of 10 in Euro ($, Yen, …)

CTA Design Study: EU application

An advanced Facility for ground-based gamma-ray Astronomy

FP7-INFRASTRUCTURES-2007-1

Design Study (CP) proposal
CTA

COLLABORATIVE PROJECT

Design Study

FP7-INFRASTRUCTURES-2007-1

Cherenkov Telescope Array - an advanced facility for ground-based high-energy gamma ray astronomy

CTA

Date of preparation: May 2, 2007
Version number: 27

Duration: 2008-2010

Requested
EU contribution: 5 MEuro

CTA Design Study: EU application

An advanced Facility for ground-based gamma-ray Astronomy

Participant no.	Participant organisation name	Part. short name	Country
1 (Coordinator)	Max-Planck-Gesellschaft	MPG	Germany
2	Centre Nationale de Recherche Scientifique	CNRS	France
3	Istituto Nazionale di Fisica Nucleare	INFN	Italy
4	Institut de Física d'Altes Energies	IFAE	Spain
5	Institut d'Estudis Espacials de Catalunya (IEEC-CSIC)	IEEC	Spain
6	Friedrich-Alexander Universität Erlangen-Nürnberg	UErlangen	Germany
7	University of Leeds	ULeeds	United Kingdom
8	University of Turku	UTurku	Finland
● ● ●			
29	Universiteit van Amsterdam	UvA	Netherlands
30	Utrecht University	UU	Netherlands
31	North-West University, Potchefstroom Campus	NWU	Republic of South Africa
32	Washington University	WashU	United States
33	Kavli Institute for Astroparticle Physics and Cosmology, Stanford University	StanU	United States
34	The Chancellor, Masters and Scholars of the University of Oxford	UOXF.DL	United Kingdom

34 "participants"
~ 50 institutes
~ O(150) persons involved

Will know by late summer, if successful

Work programme topics addressed

INFRA-2007-2.1.1: Design Studies for research infrastructures in all S&T fields

Name of the coordinating person: Werner Hofmann
e-mail: werner.hofmann@mpi-hd.mpg.de

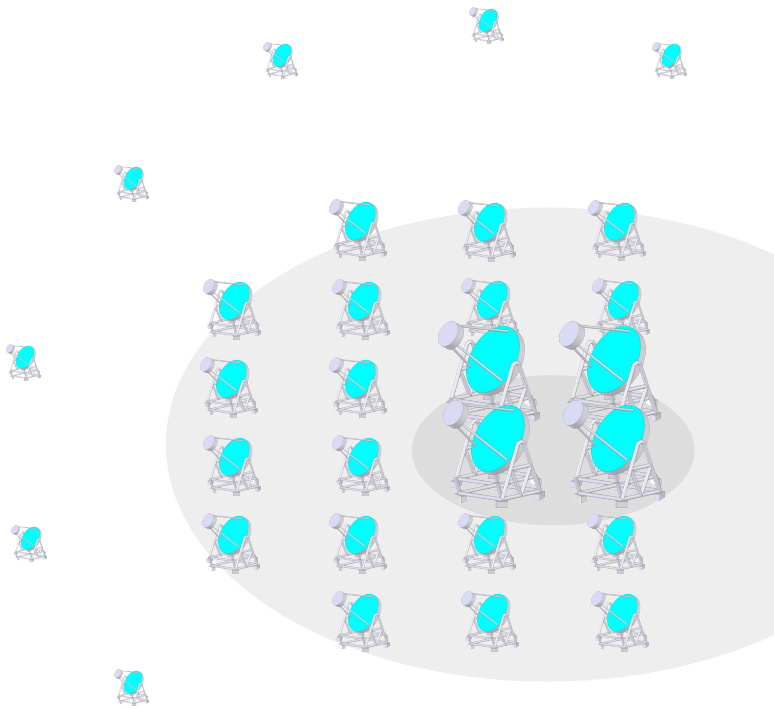
CTA: Design Study

An advanced Facility for ground-based gamma-ray Astronomy

Goal: (Cost) Optimization of Design, Layout and Production

Key Issues:

- Cost efficient production of telescopes and quality control
- Construction, installation and commissioning of the telescopes
- Reliability and maintainability of telescopes, cameras and software
- Operation scheduling an monitoring
- Data access to a wide community; tools for efficient non-expert (physics) data analysis



CTA: Design Study

An advanced Facility for ground-based gamma-ray Astronomy

Work Packages:

WP1	**MNG**	Management of the design study
WP2	**PHYS**	Astrophysics and astroparticle physics
WP3	**MC**	Optimization of array layout, performance studies and analysis algorithms
WP4	**SITE**	Site evaluation and site infrastructure
WP5	**MIR**	Telescope optics and mirror
WP6	**TEL**	Telescope structure, drive, control
WP7	**FPI**	Focal plane instrumentation, mechanics and photo detectors
WP8	**ELEC**	Readout electronics and trigger
WP9	**ATAC**	Atmospheric monitoring, associated science & instrument calib.
WP10	**OBS**	Observatory operation and access
WP11	**DATA**	Data handling, data processing, data management and access
WP12	**QA**	Risk assessment and quality assurance, production planning

CTA: Design Study

An advanced Facility for ground-based gamma-ray Astronomy

WP MC: Optimization of array layout, performance studies and analysis algorithms

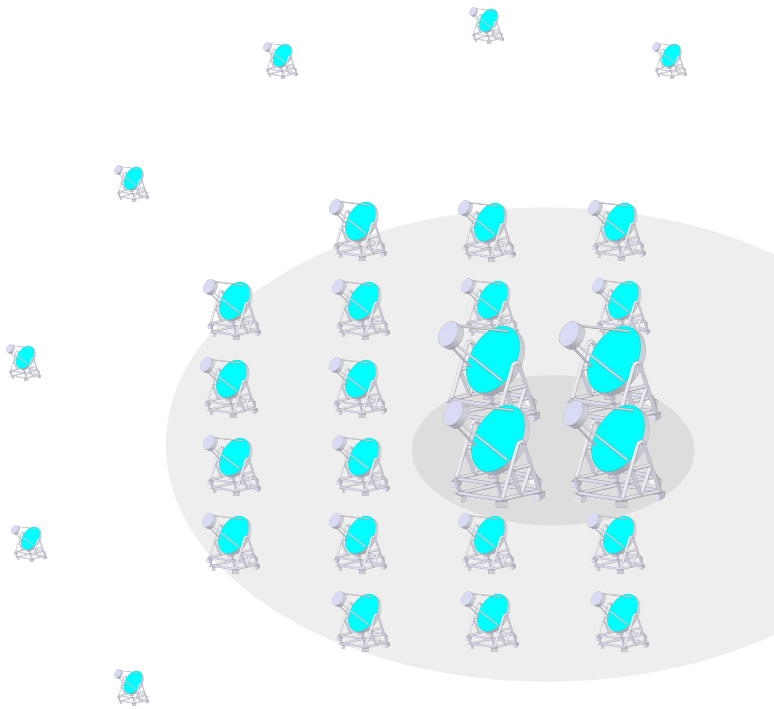
Narrow down multi-parameter space:

Telescope sizes
Camera FoV, pixel size
Camera info (pixel timing, …)

Number of telescopes
Configuration of array

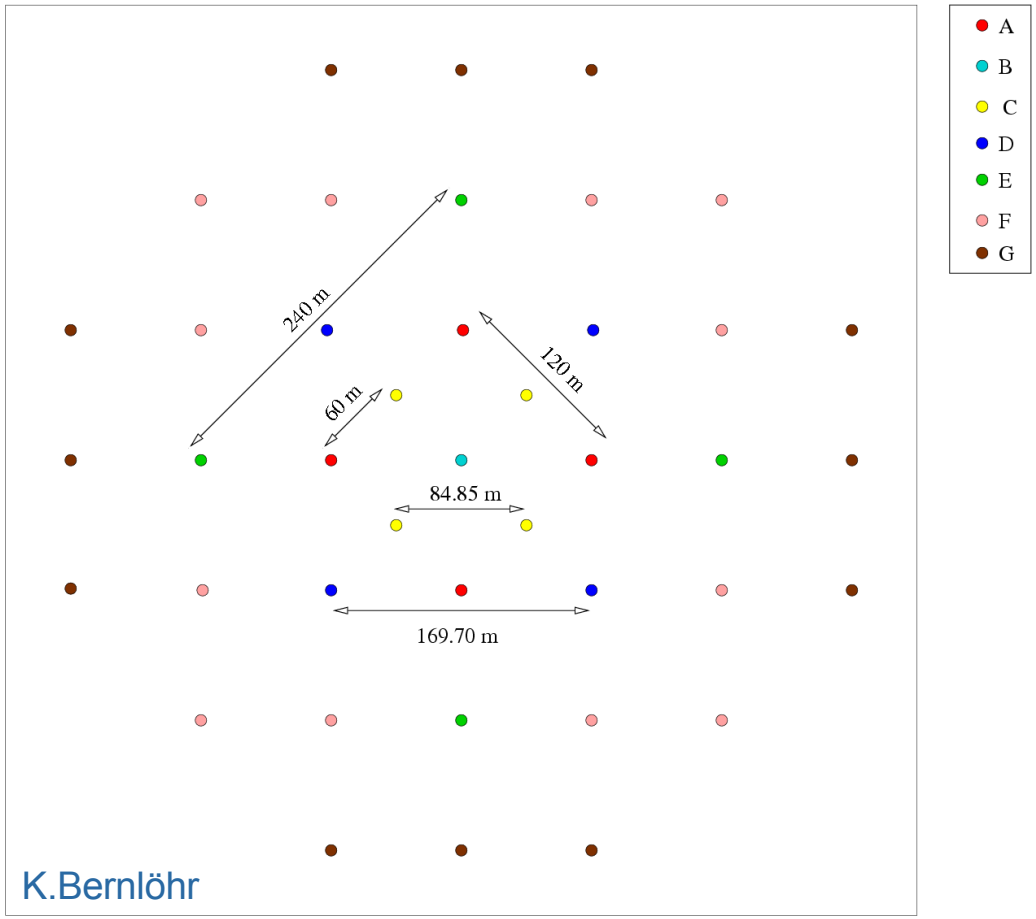
Analysis methods

→ cost over/of performance
(with info from other WPs)



CTA: Simulations of possible layouts

An advanced Facility for ground-based gamma-ray Astronomy



41 telescopes of
100 m² mirror area.
~5 deg cameras
Many different subsets
selectable

See also: http://www.mpi-hd.mpg.de/hfm/CTA/paris_march07

CTA: Simulations of possible layouts

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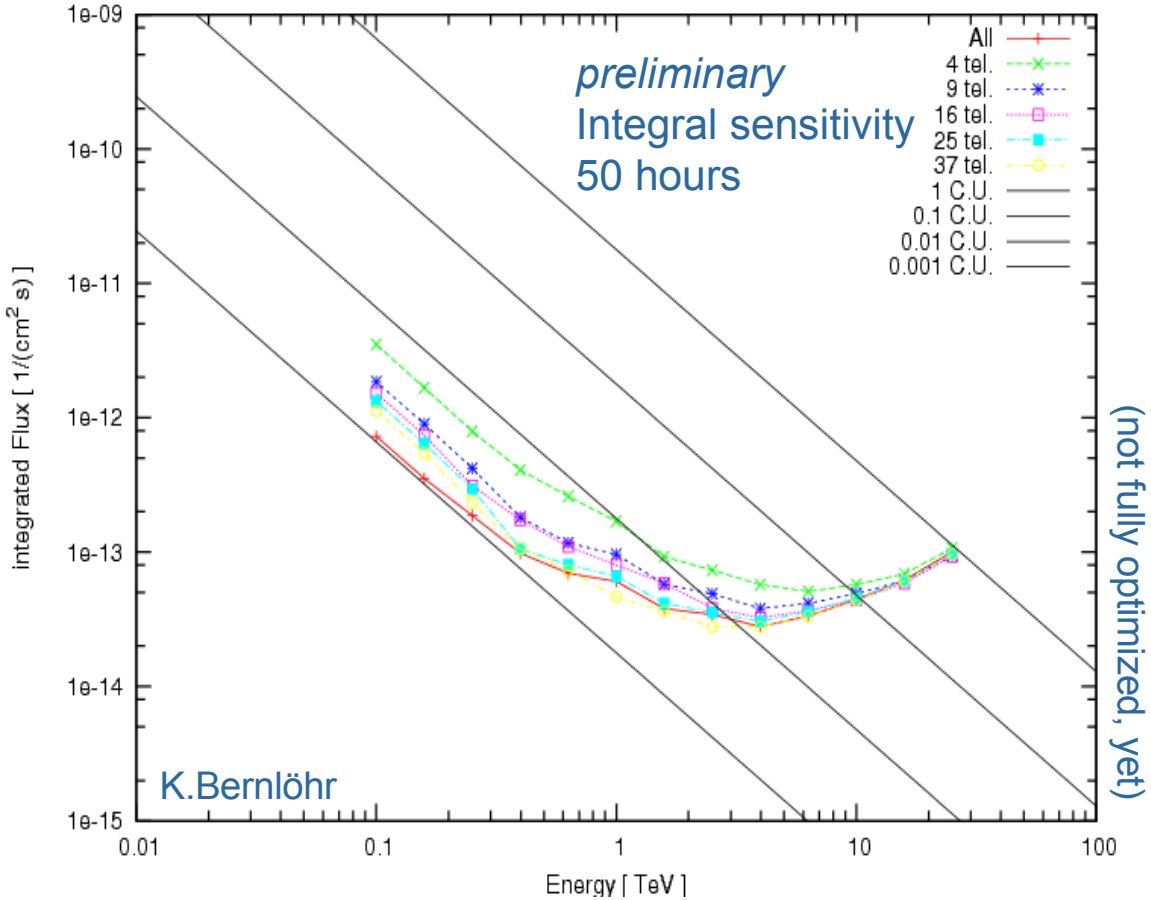


(not fully optimized, yet)

4 CTs → 41 CTs

x 7 improvement in sensitivity (7 mCrab to **1 mCrab** integral)
→ That is faster than √N.

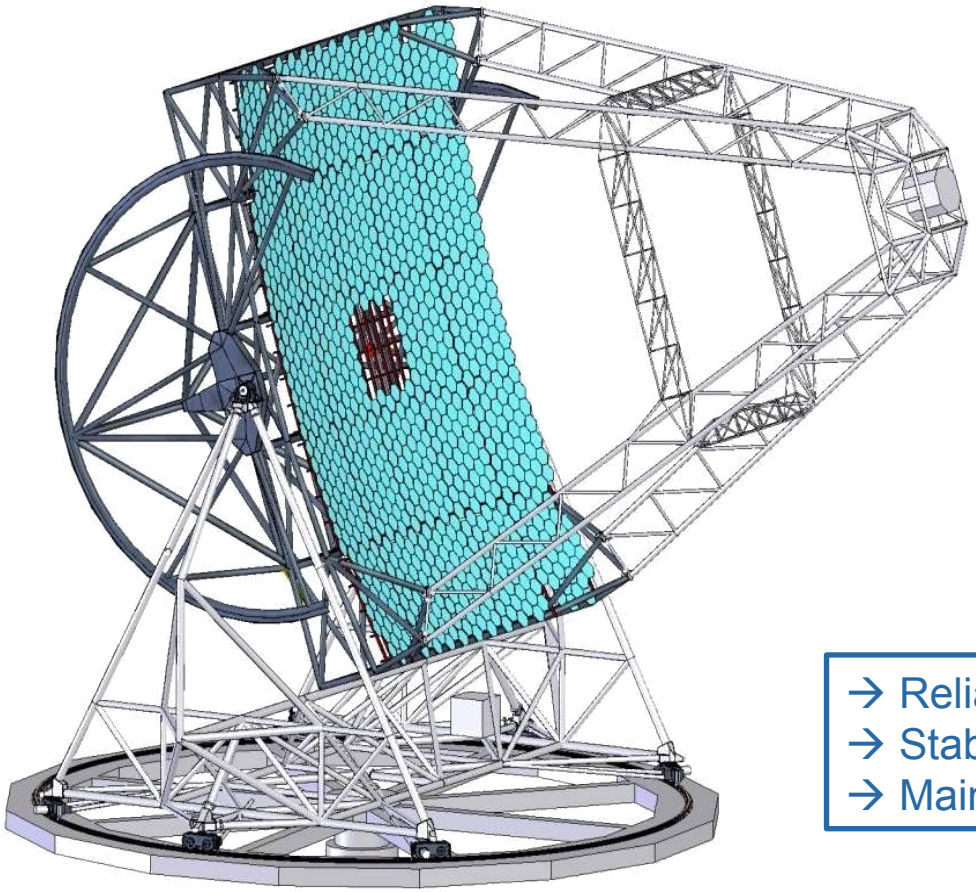
Largest improvement seen below 1 TeV.

See also: http://www.mpi-hd.mpg.de/hfm/CTA/paris_march07

CTA: Design Study

An advanced Facility for ground-based gamma-ray Astronomy

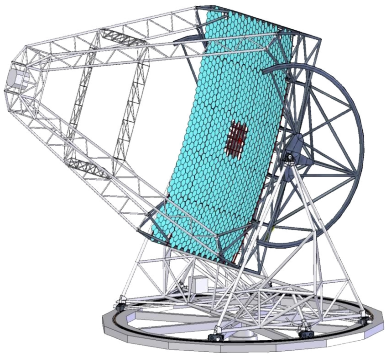
WP TEL: Telescope structure, drive, control



- Evaluation of possible designs
- Identification of industrial components
- Evaluation of dish structures
- Derive "scaling laws"
- Design of cost effective drive emergency and control systems

→ *Conceptual designs* for 2-3 sizes of telescopes

→ Reliability
→ Stability
→ Maintainability

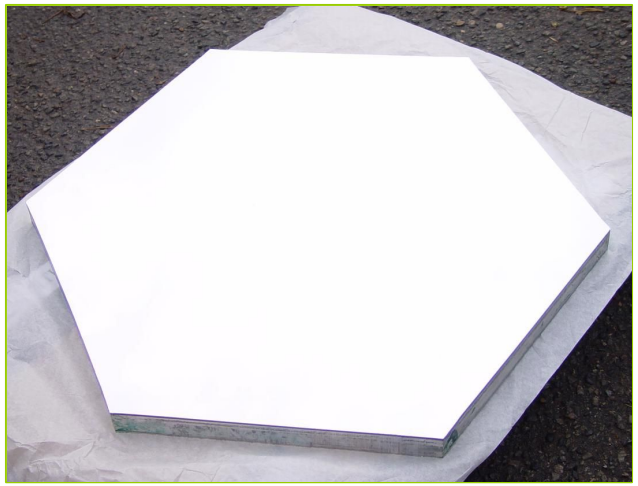


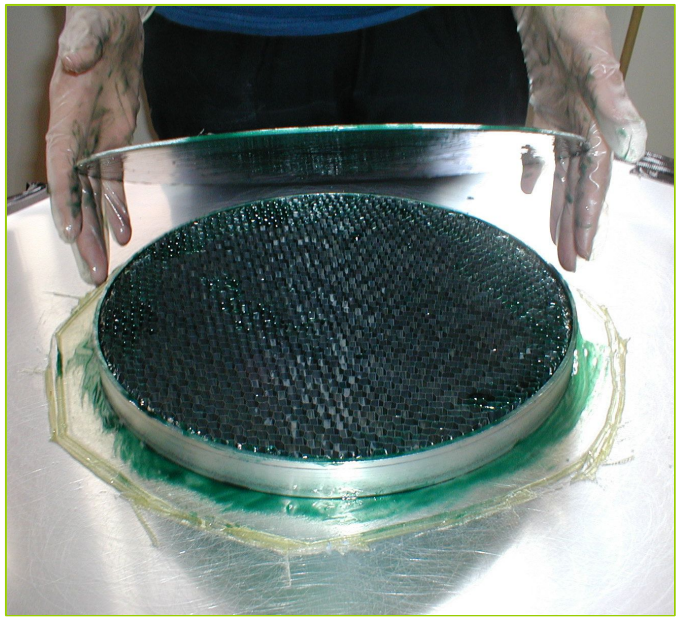
CTA: Design Study

An advanced Facility for ground-based gamma-ray Astronomy

WP MIR: Telescope optics and mirror

- Evaluation of mirror production technologies
- Mirror (mass) production techniques
- Methods of quality control
- Long term (2-3 yrs) field test / ageing

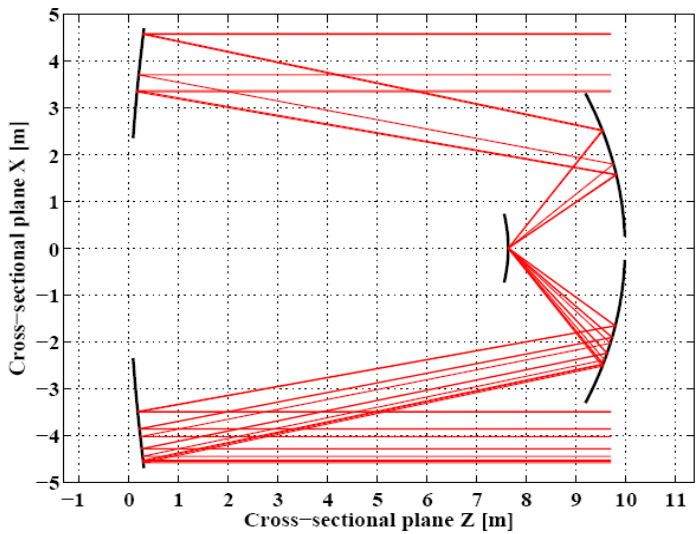




CTA: Design Study

An advanced Facility for ground-based gamma-ray Astronomy

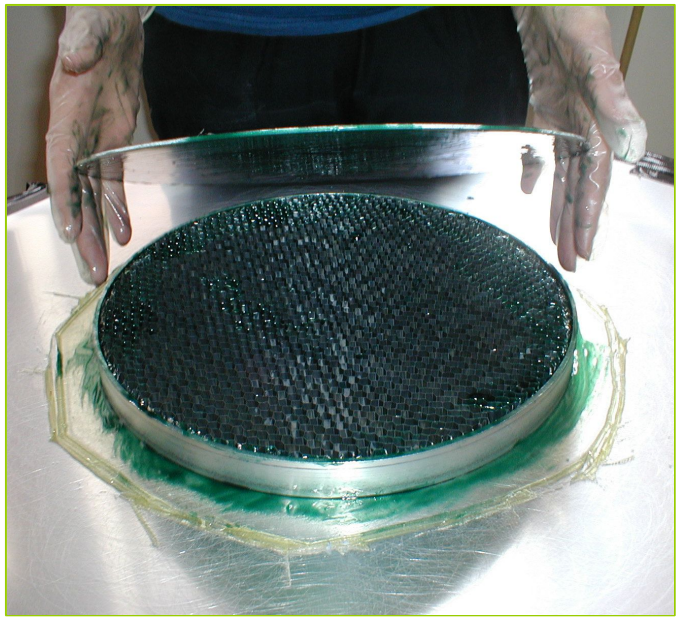
WP MIR: Telescope optics and mirror



V. Vassiliev et al., astro-ph/0612718

- Evaluation of optical design of telescopes
- Wide FoV optics ?

- Evaluation of mirror production technologies
- Mirror (mass) production techniques
- Methods of quality control
- Long term (2-3 yrs) field test / ageing



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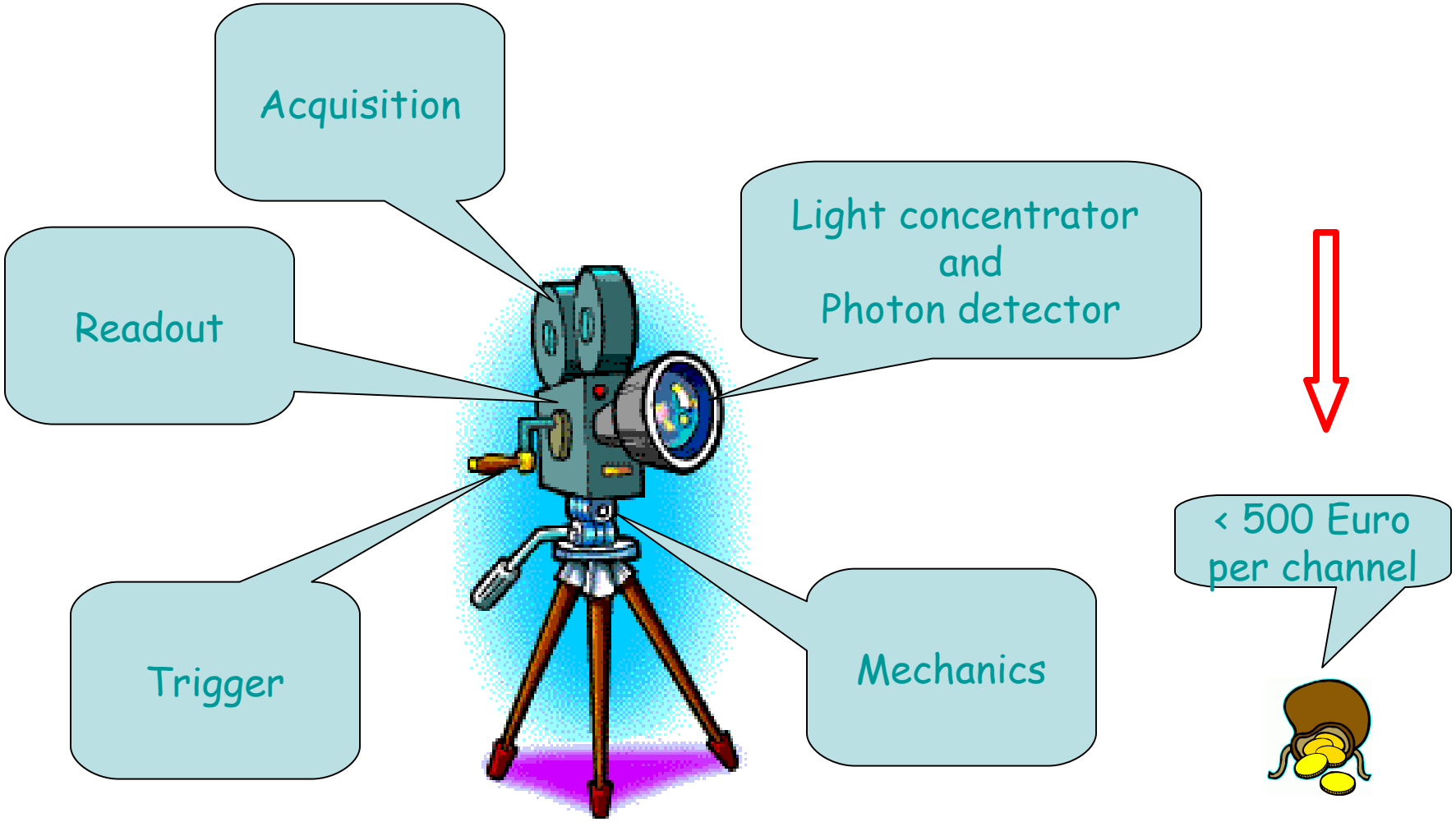

from P.Vincent

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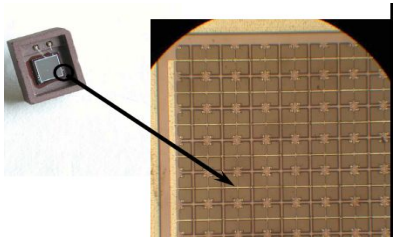
WP ELEC and **FPI**:

O(50) m² photo sensitive area
→ PMT evaluation

Photon Detectors



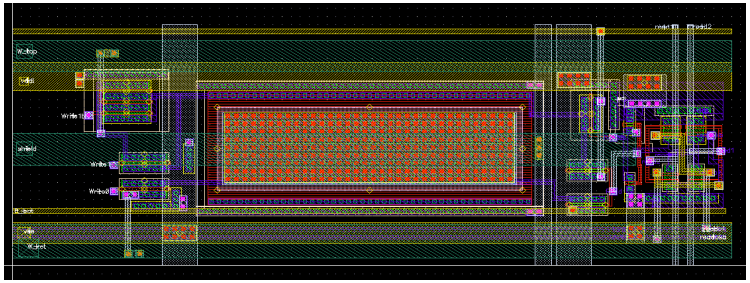
Camera properties

- Signal integration
- Time structure of image/pixel
- Trigger scheme

→ what is the cost of information ?!
→ what do you gain ?! ⟺ **MC**

O(50000) channels
Readout electronics

Highly integrated
(analog) electronics/ASICS
vs fully digital solutions



CTA: Design Study

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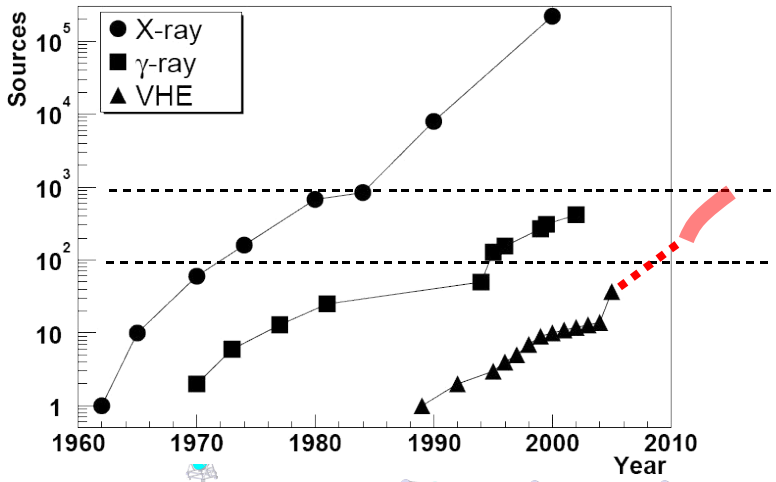
Work Packages:

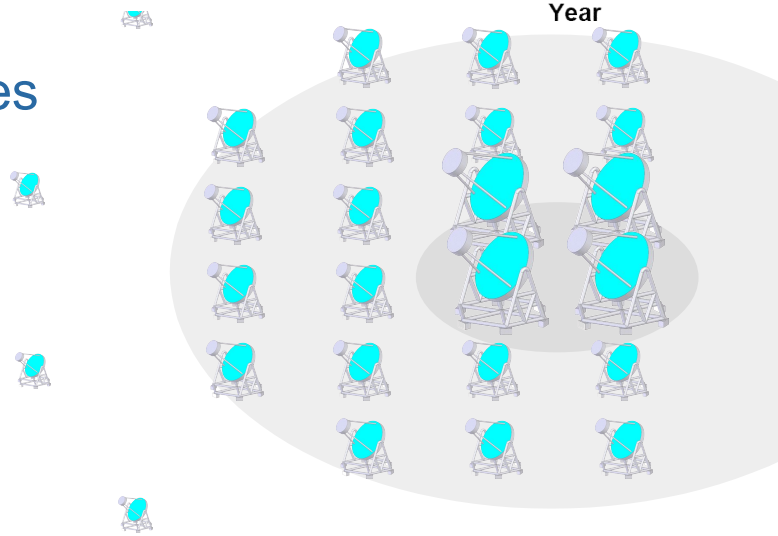
WP1	**MNG**	Management of the design study
WP2	**PHYS**	Astrophysics and astroparticle physics
WP3	**MC**	Optimization of array layout, performance studies and analysis algorithms
WP4	**SITE**	Site evaluation and site infrastructure
WP5	**MIR**	Telescope optics and mirror
WP6	**TEL**	Telescope structure, drive, control
WP7	**FPI**	Focal plane instrumentation, mechanics and photo detectors
WP8	**ELEC**	Readout electronics and trigger
WP9	**ATAC**	Atmospheric monitoring, associated science & instrument calib.
WP10	**OBS**	Observatory operation and access
WP11	**DATA**	Data handling, data processing, data management and access
WP12	**QA**	Risk assessment and quality assurance, production planning

Timeline

An advanced Facility for ground-based gamma-ray Astronomy

May 2nd, 2007	FP7 DS application
Spring 2007	Letter of Intend
2008-2010	Design Study
Mid/End 2008	Proposal (design options)
2009/2010:	Conceptual Design
	w/ implementation choices
2010:	start preparation/installation





From ground-based ***experiments*** towards a *TeV gamma-ray* ***observatory***

See also: http://www.mpi-hd.mpg.de/hfm/CTA