

Astroparticle Physics & the Atmosphere



Nor Amberd, 23-24 May 2017,
Johannes Knapp, DESY Zeuthen



Astroparticles

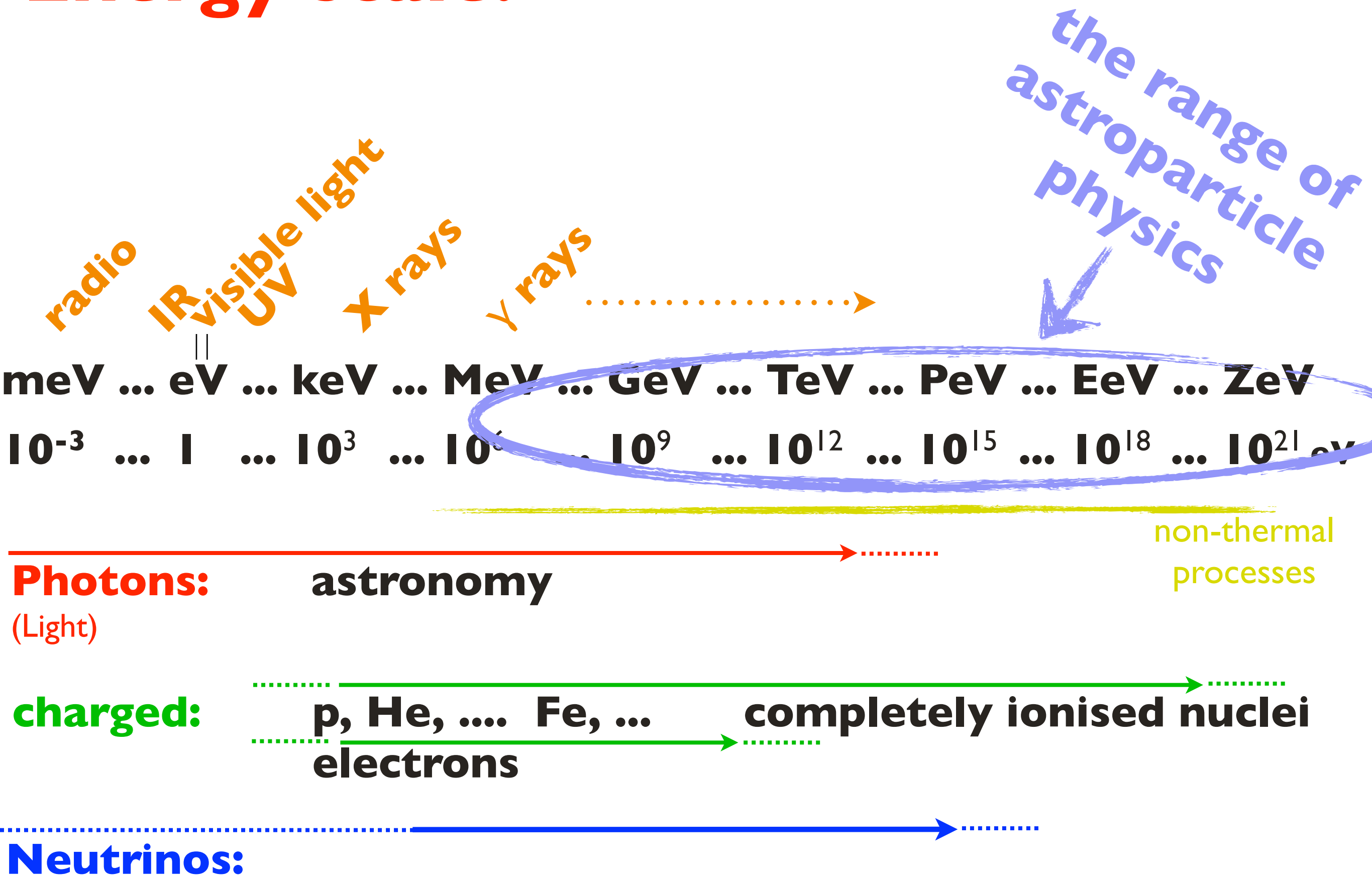
energetic (elementary) **particles**
from space (Sun, Milky Way, distant galaxies)
bombard Earth continuously.

Energies from 10^{-8} eV ... $>10^{20}$ eV

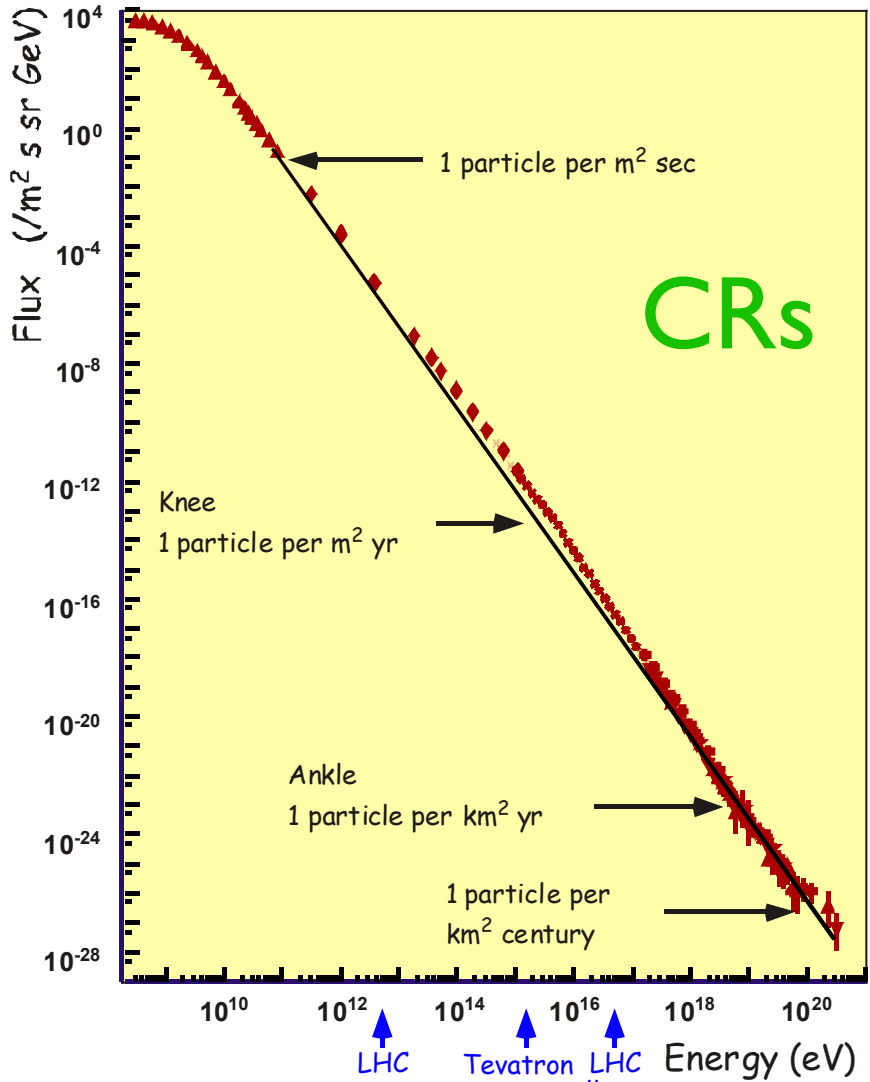
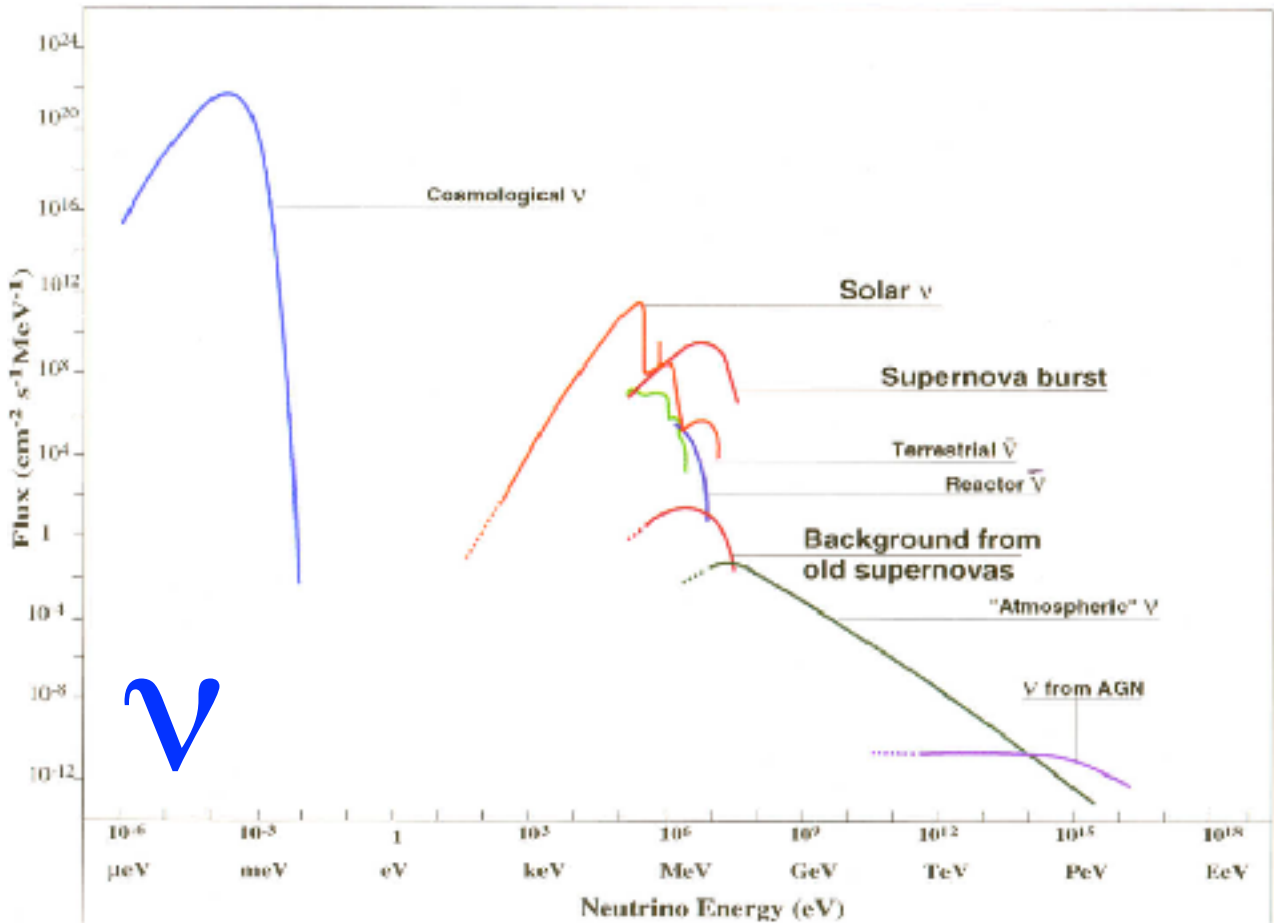
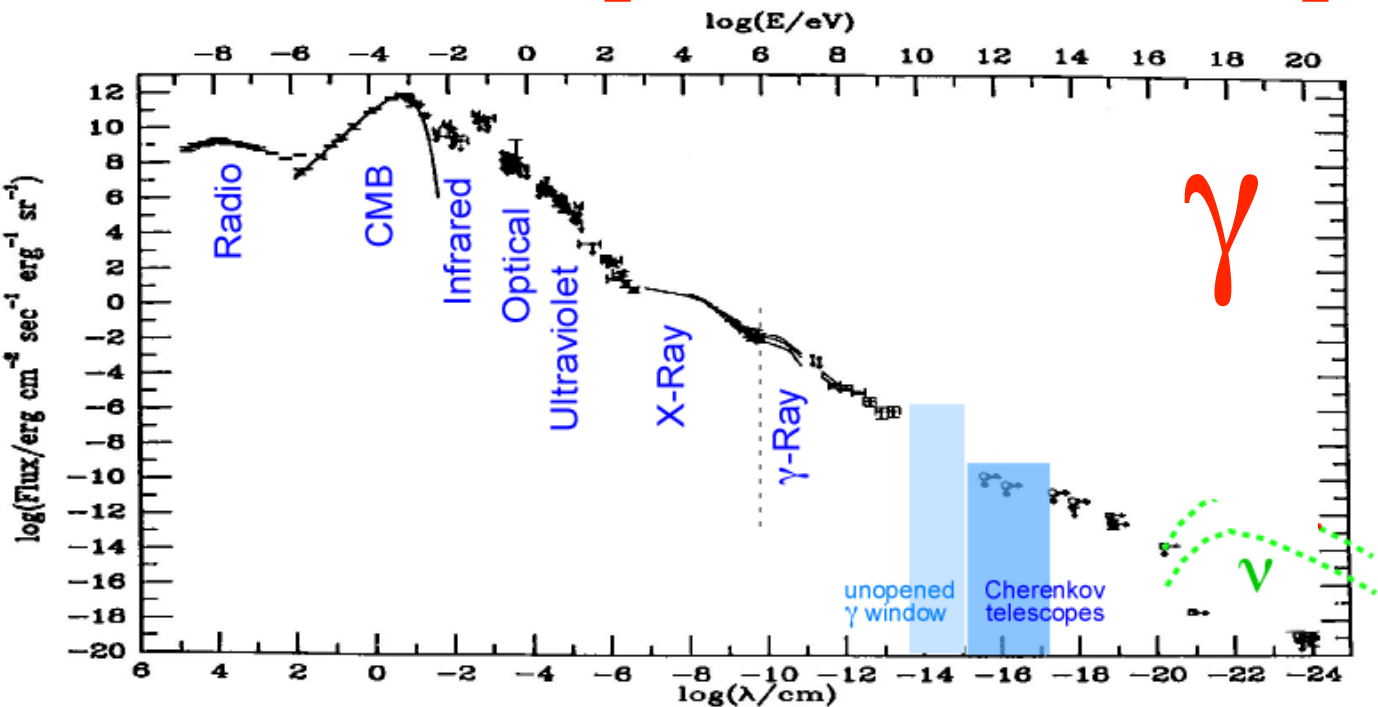


**most energetic particles
in the Universe !**

Energy scale:



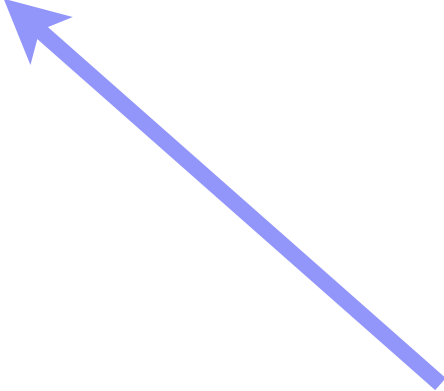
Cosmic particle spectra



steeply falling spectra,
low fluxes at high energies
require huge detectors

**Large, natural volumes
become **part of the detectors:****

atmosphere,
ice shields,
oceans,
...



instrument (sparsely)
to record secondary particles
produced by particle interactions

A shower is a particle multiplier ...

it is easier

to detect a shower

it is more difficult

to measure a shower well
than a single particle

The effective area of an air shower detector
can be much larger $10^5 \dots 10^7 \dots 10^{11} \dots \text{m}^2$

than that of a detector in space $\sim 1 \text{ m}^2$

**Therefore, via air shower technique
much lower particle fluxes at
much higher energies
can be measured.**

... a great blessing

but:
the atmosphere is also a curse.

Atmosphere is part of the detector

can be highly variable
affects the measurement
needs monitoring all the time

Cherenkov Telescopes

most sensitive instruments
for gamma ray astronomy.

~20 GeV ... >300 TeV

air shower

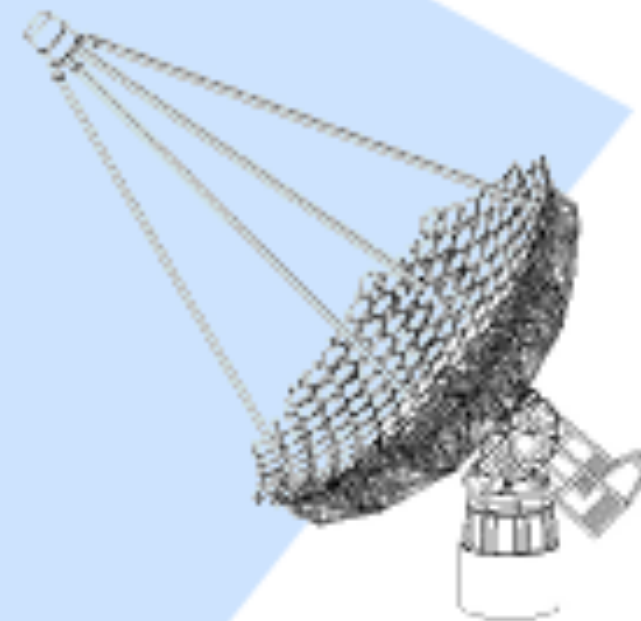
only in dark nights
(10% duty cycle)
need good knowledge
of atmosphere

Fast charged particle in air shower
produce Cherenkov light.
(forward emission)

“Photograph” shower with an
imaging telescope.

Reconstruct identity (γ , p , ...),
energy of primary and
direction to source.

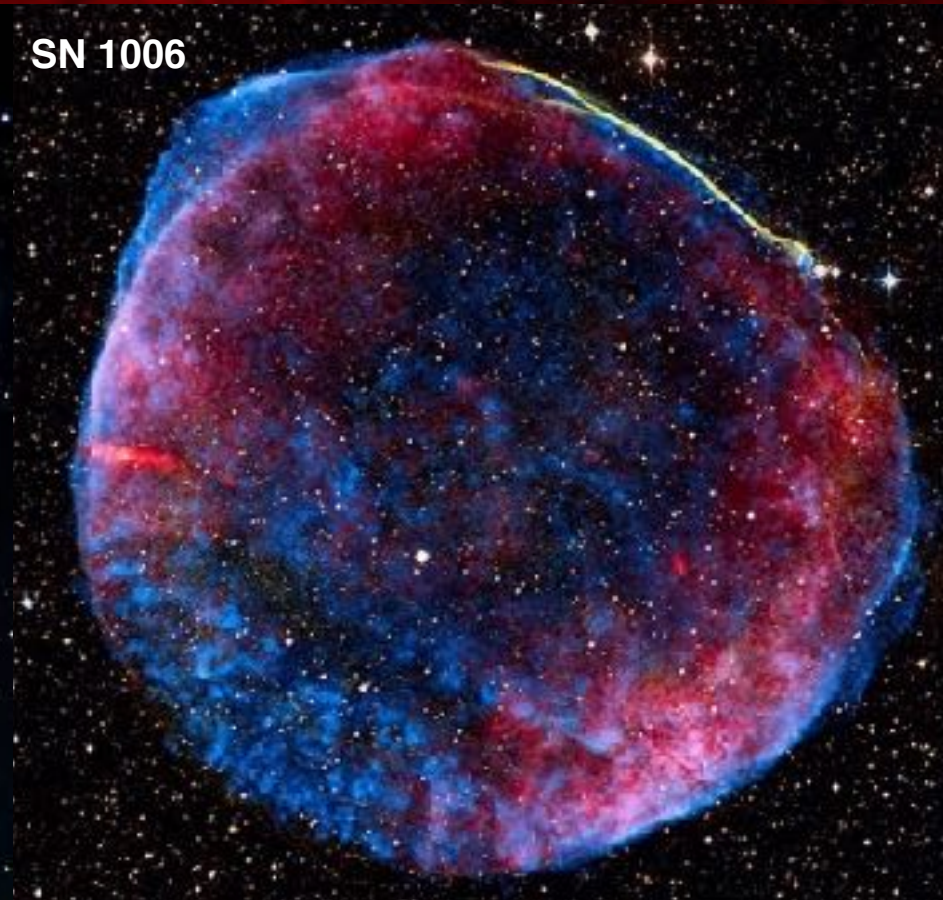
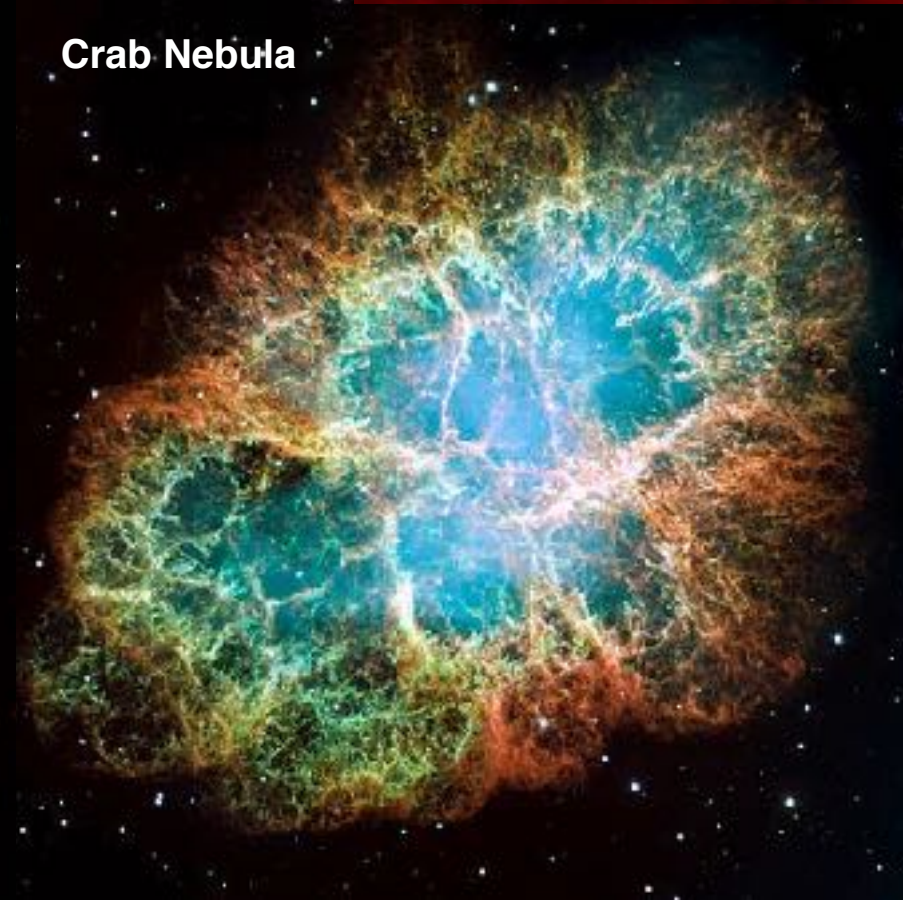
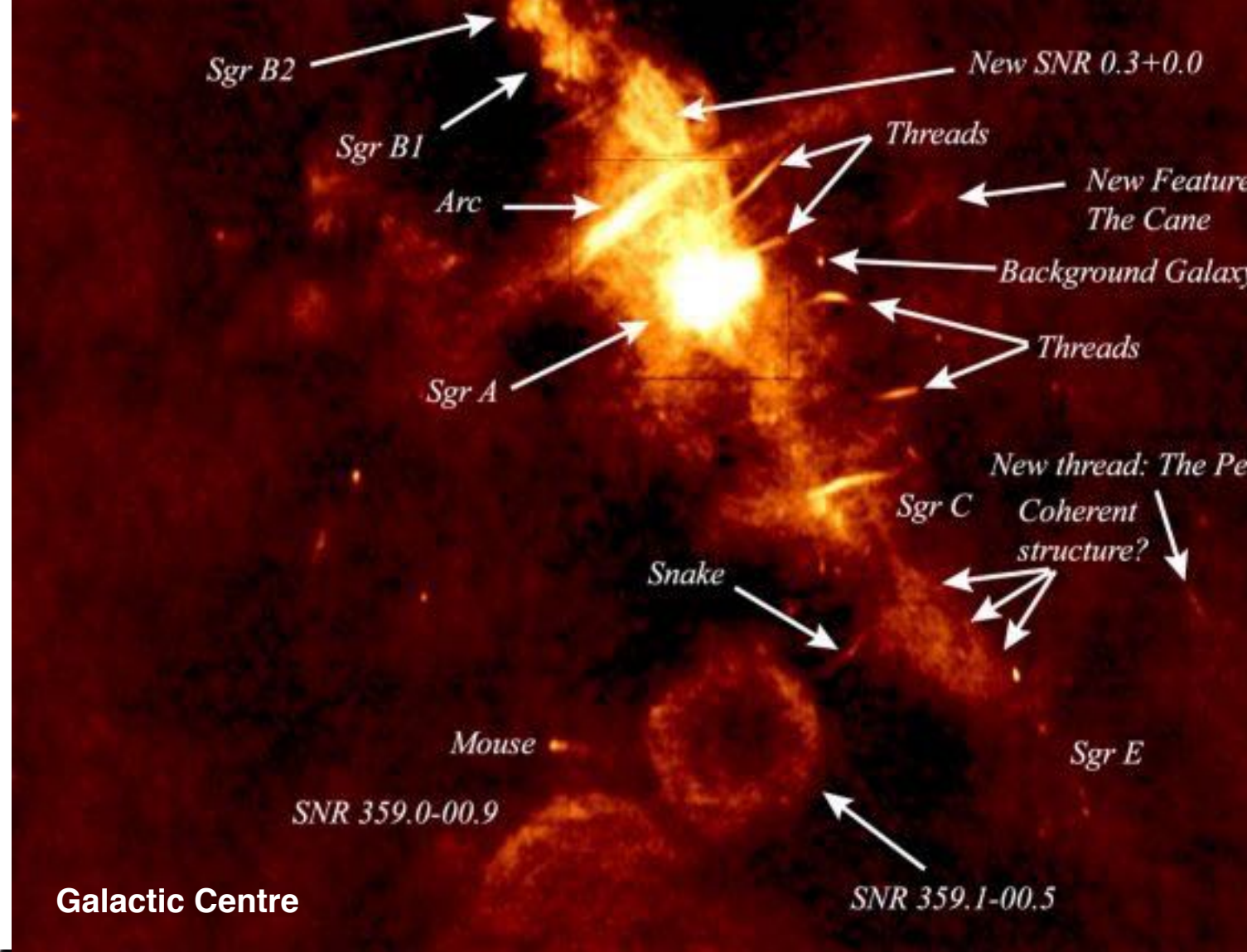
Cherenkov light



Gamma Ray Astronomy

High-energy photons from the most violent objects in the Universe.

high-energy photons are rare, require huge detectors.



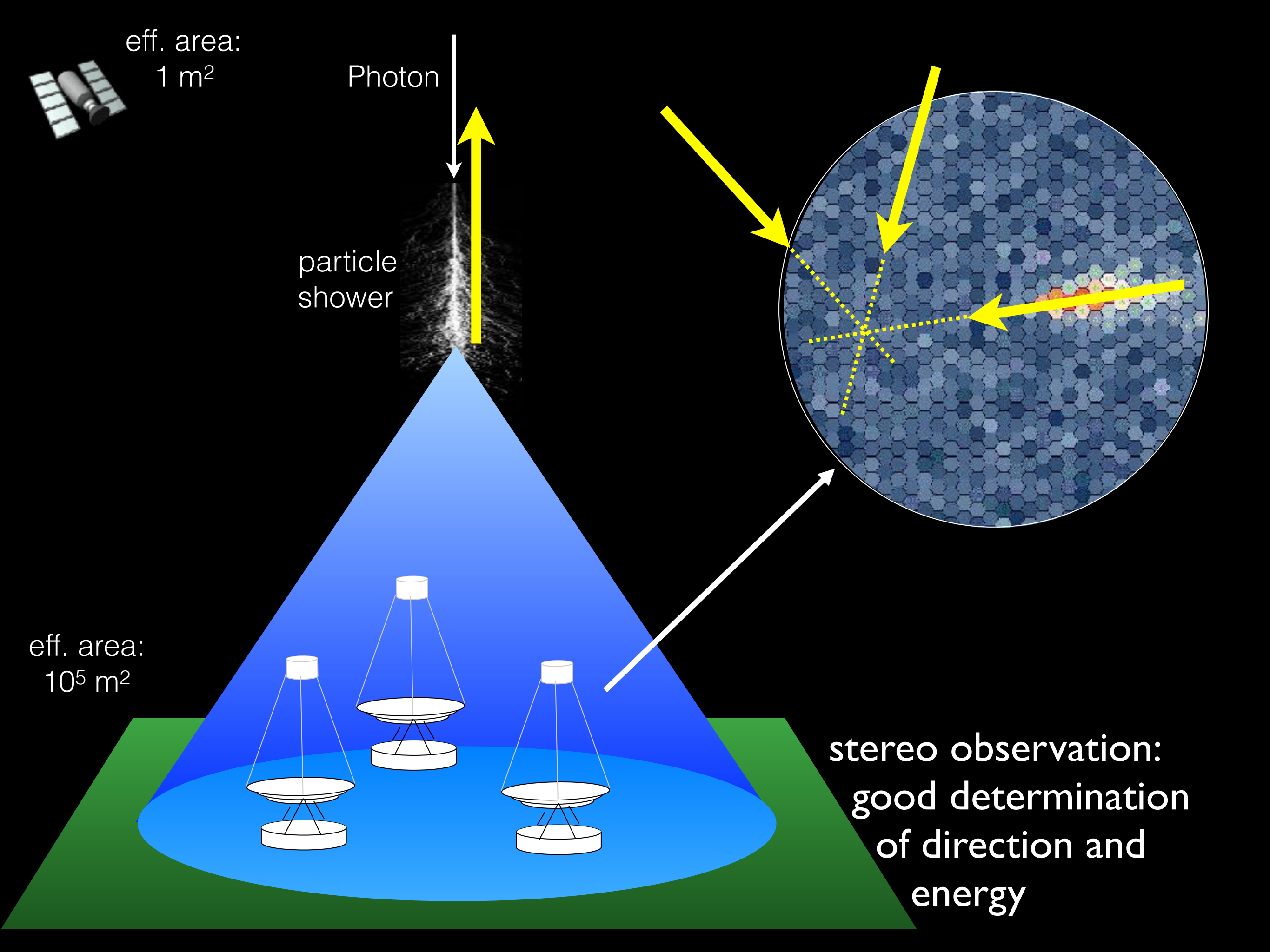
eff. area:
 1 m^2

Photon

particle
shower

eff. area:
 10^5 m^2

stereo observation:
good determination
of direction and
energy



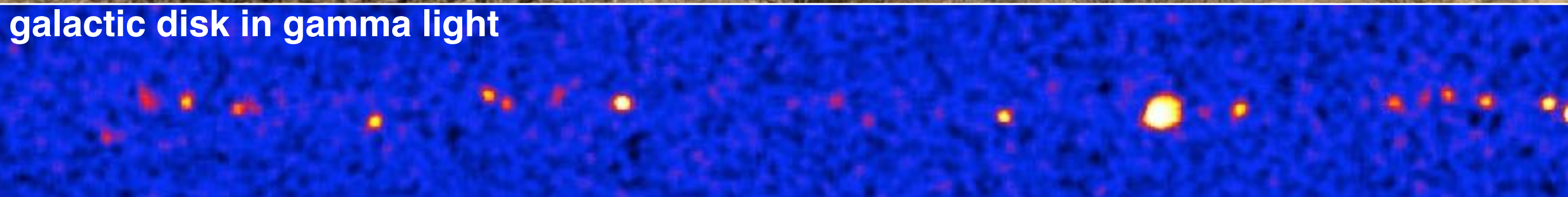
The atmosphere becomes part of the detector:

e.g. HESS Observatory
Namibia: 0.5 km²
5 imaging Cherenkov telescopes

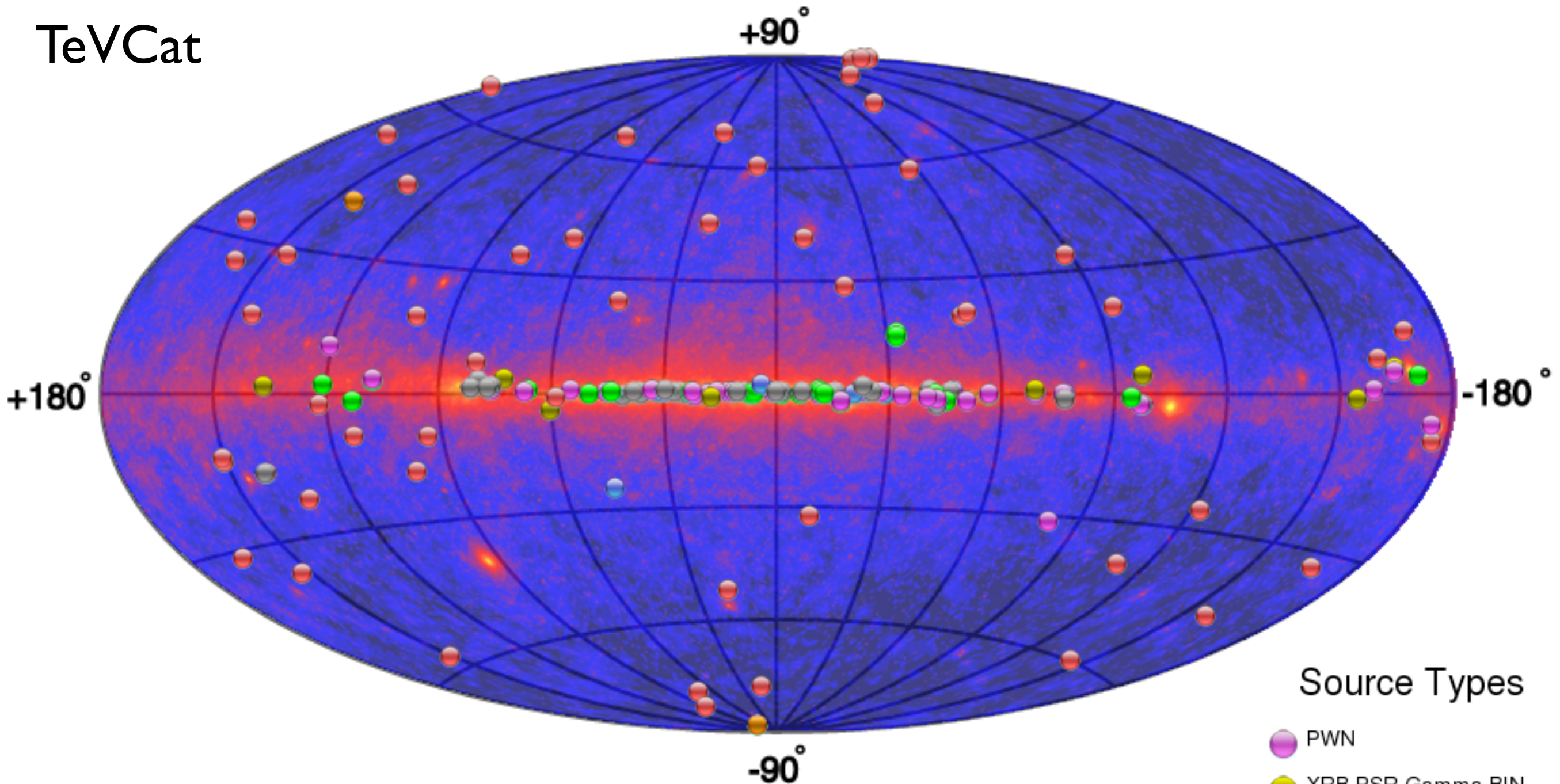
TeV-Gamma rays
($E \approx 10^{11} - 10^{14}$ eV)



galactic disk in gamma light



TeVCat



background image:
Fermi sky map (MeV-GeV)

now: > 180 sources
gal. / extragal. / unid.

gamma emission is present
wherever there are shocks and relativistic flows

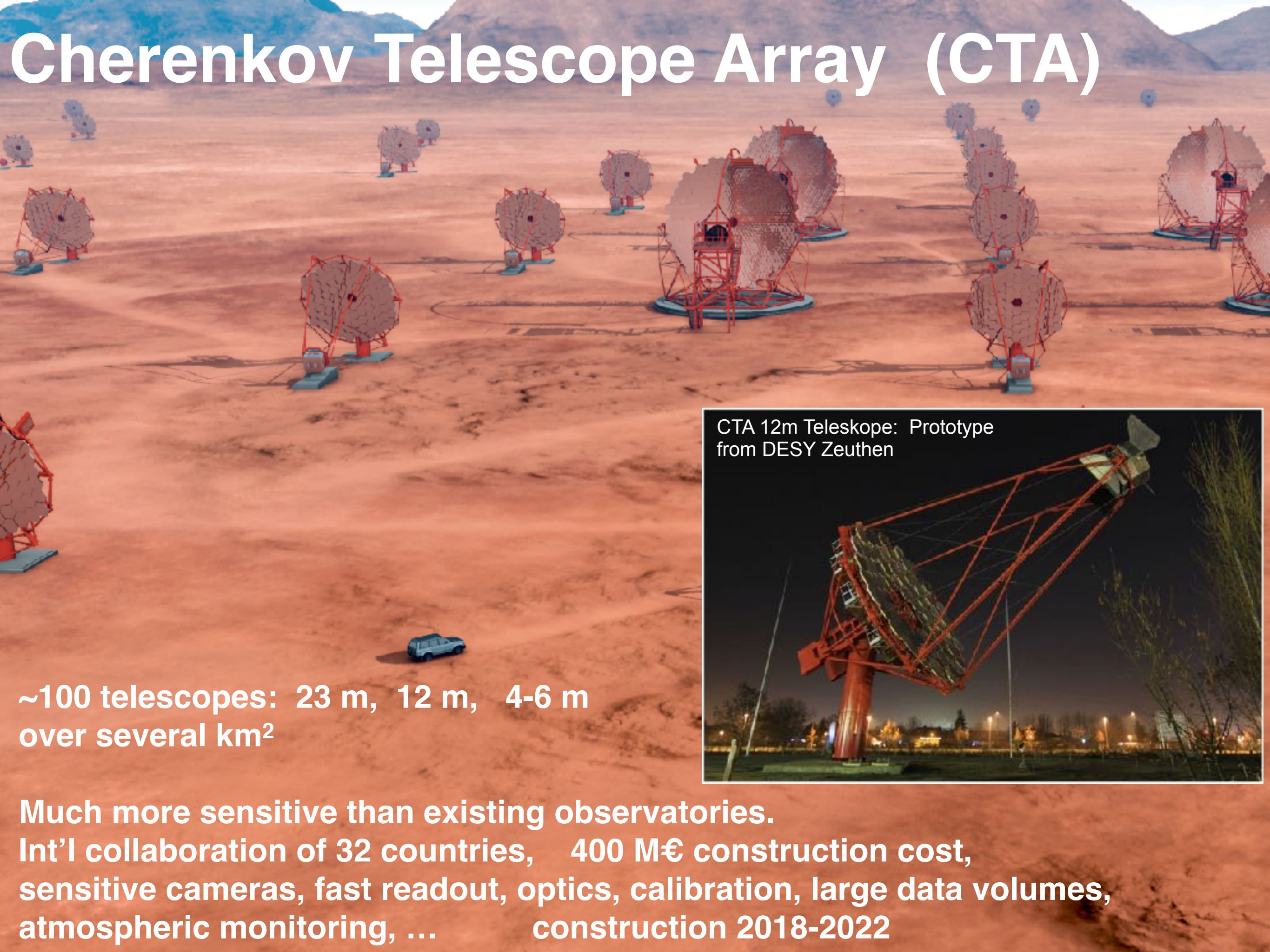
TeV astronomy highlights

from **HESS, MAGIC** and **VERITAS**
Descartes & Rossi Prize for HESS

Supernova remnants:	Nature	432 (2004) 75	
Microquasars:	Science	309 (2005) 746	Science 312 (2006) 1771
Pulsars:	Science	322 (2008) 1221	Science 334 (2011) 69
Galactic Centre:	Nature	439 (2006) 695	Nature 531 (2016) 476
Galactic Survey:	Science	307 (2005) 1839	
LMC:	Science	347 (2015) 406	
Black Holes:	Science	346 (2014) 1080	
Starbursts:	Nature	462 (2009) 770	Science 326 (2009) 1080
Active Galactic Nuclei:	Science	314 (2006) 1424	Science 325 (2009) 444
EBL:	Nature	440 (2006) 1018	Science 320 (2008) 752
Dark Matter:	PRL	96 (2006) 221102	PRL 106 (2011) 161301
	PRL	114 (2015) 081301	PRL 110 (2013) 41301
Lorentz Invariance:	PRL	101 (2008) 170402	
Cosmic Ray Electrons:	PRL	101 (2008) 261104	

+ **many** papers in other journals
... a booming field.

Cherenkov Telescope Array (CTA)



CTA 12m Telescope: Prototype from DESY Zeuthen

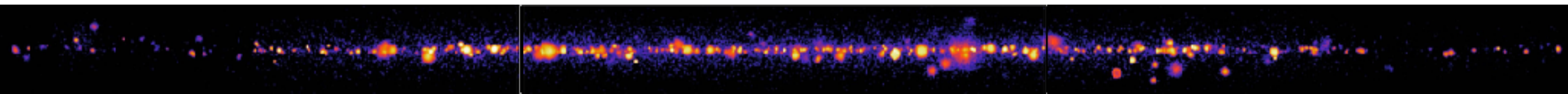


~100 telescopes: 23 m, 12 m, 4-6 m
over several km²

Much more sensitive than existing observatories.
Int'l collaboration of 32 countries, 400 M€ construction cost,
sensitive cameras, fast readout, optics, calibration, large data volumes,
atmospheric monitoring, ... construction 2018-2022

CTA prognosis:

a rich harvest ...



galactic disc:

long. ± 90 deg
lat. ± 5 deg

galactic + extragalactic: ≥ 1000 sources

One observatory with two sites



La Palma

Chile

mid latitude, large, flat area,
~2 km altitude,
good seeing, easy access, ...

La Palma, Spain (near MAGIC site)



Paranal, Chile (ESO site, Atacama desert)



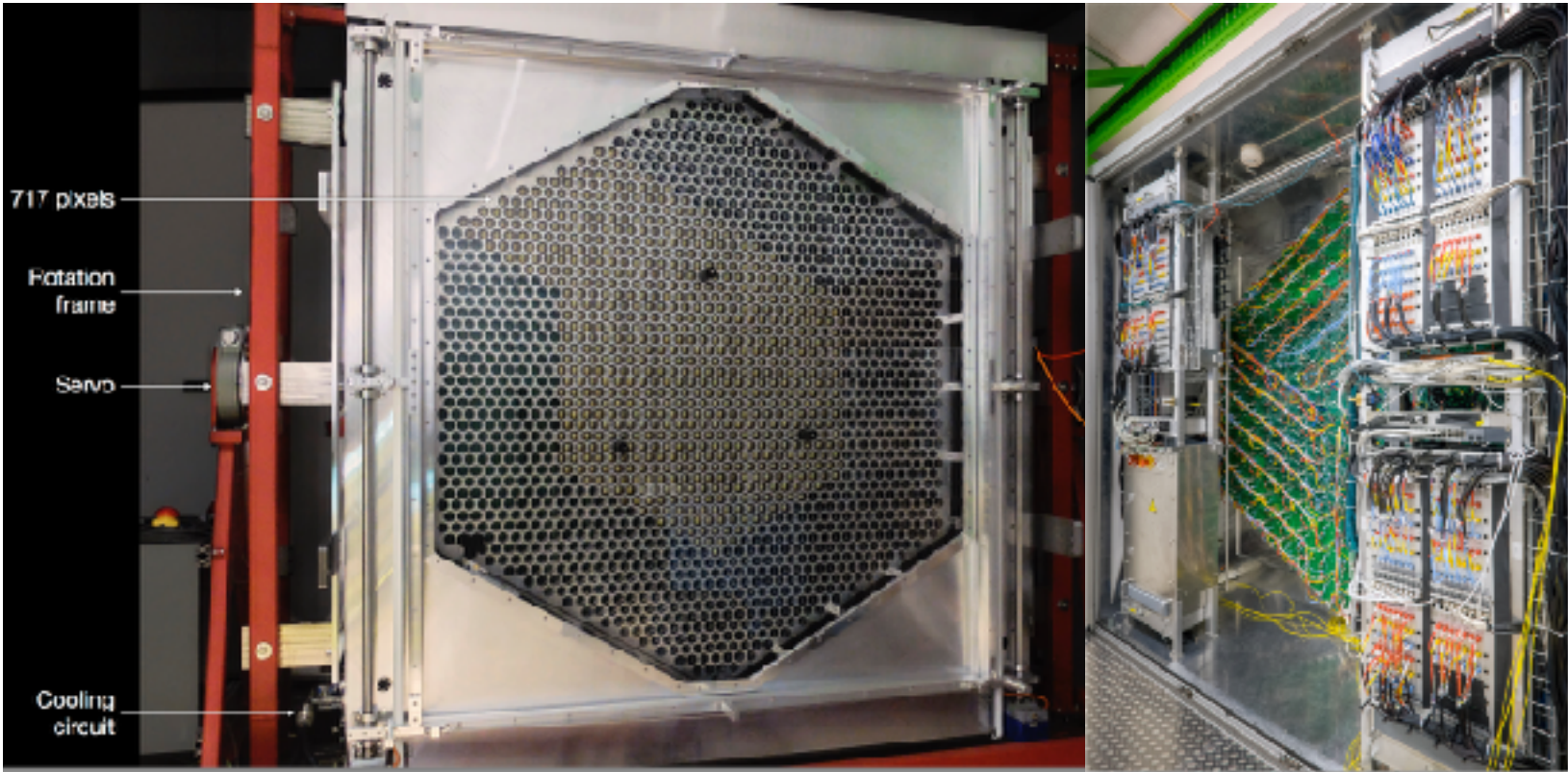
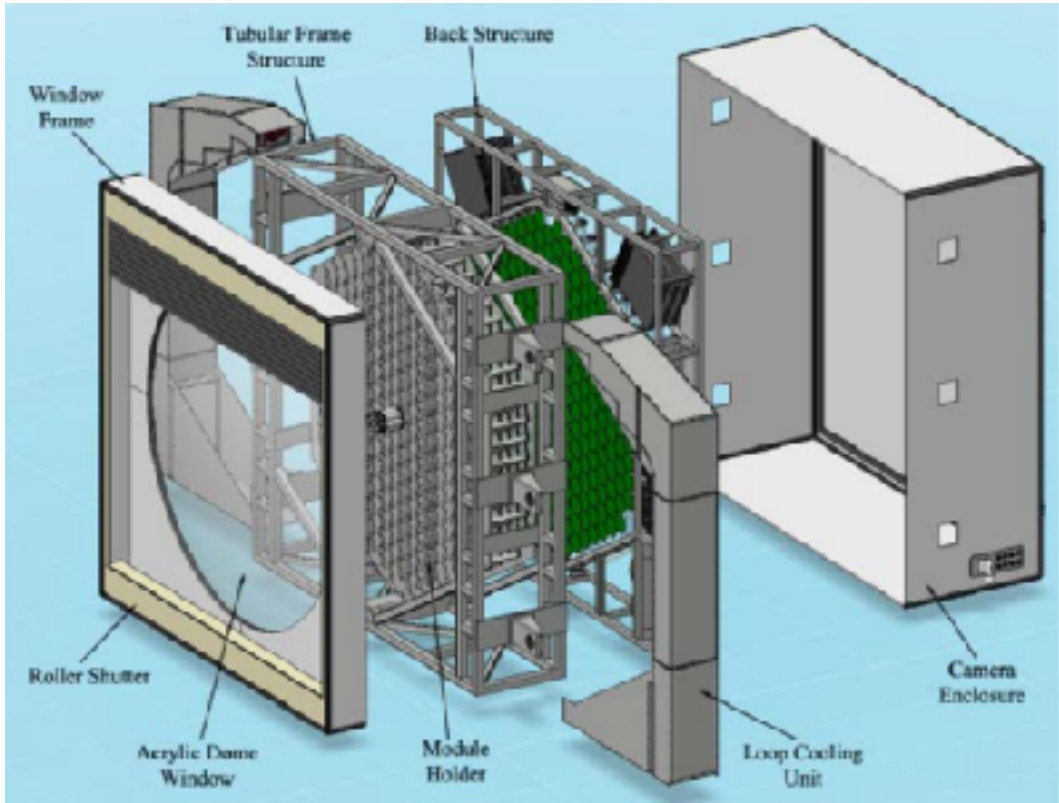
MST Prototype

DESY Zeuthen



France / Spain

MPIK Heidelberg



Large Size Telescope Prototype

Ground breaking on La Palma (2016)



SST Prototypes

dual mirror telescope



at Cracow

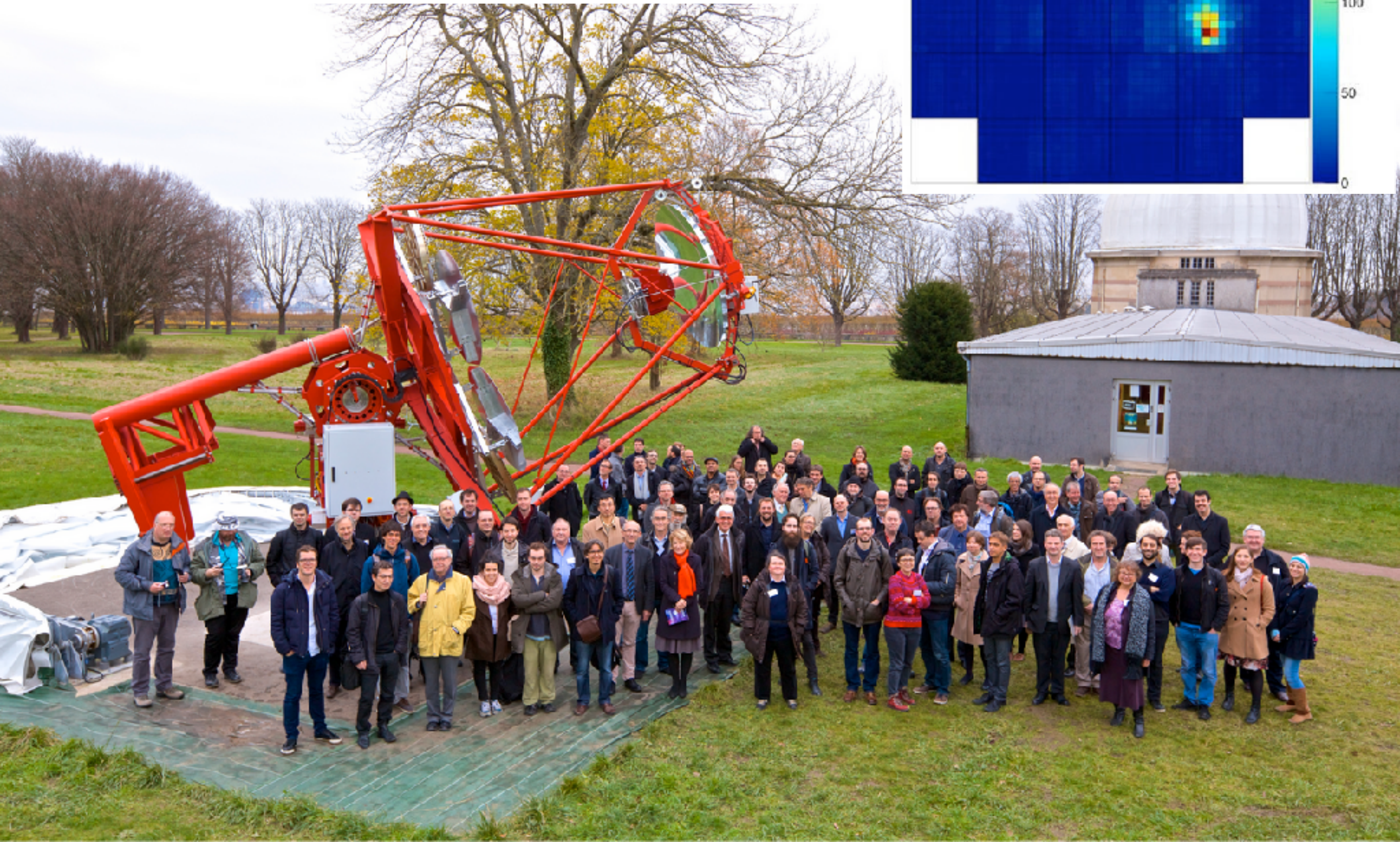
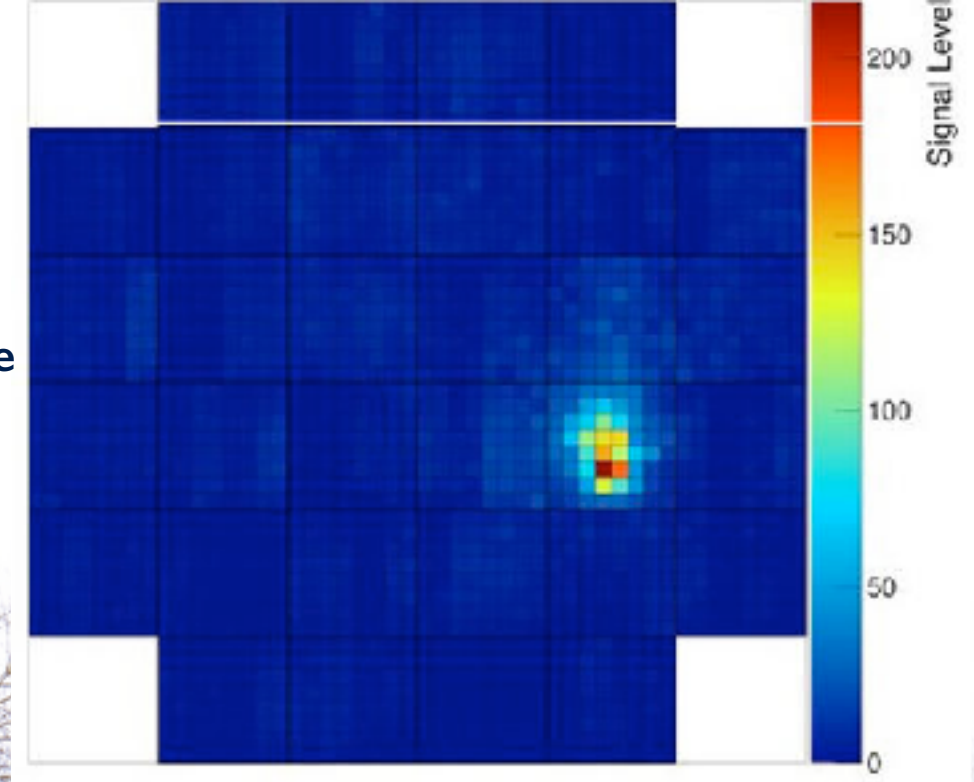


on Sicily

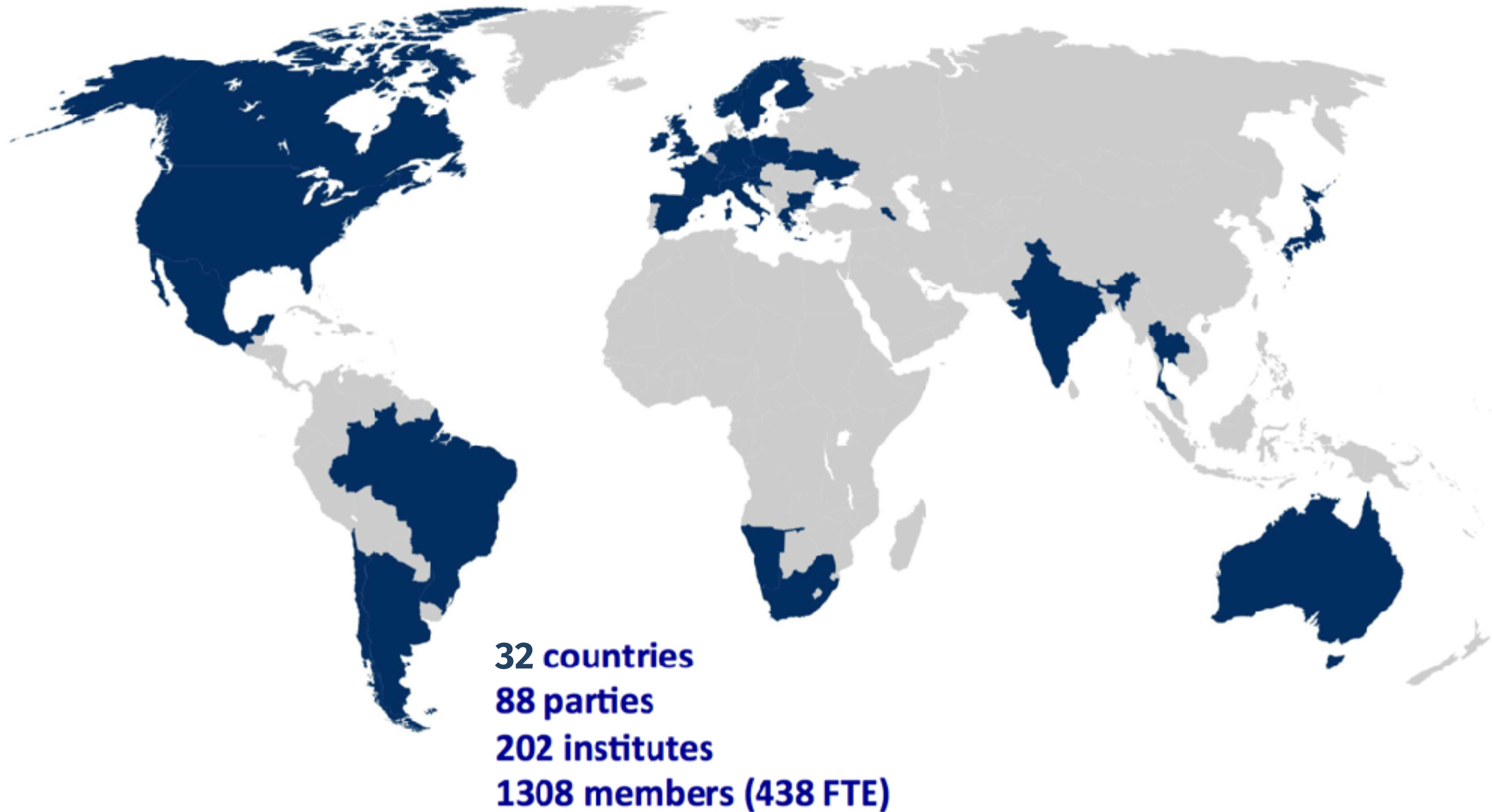
SST Prototype

at Meudon

First images from a
dual mirror telescope



CTA Consortium



Argentina, **Armenia**, Australia, Austria, Brazil, Bulgaria, Canada, Chile, Czech Republic, Croatia, Finland, France, Germany, Greece, India, Italy, Ireland, Japan, Mexico, Namibia, Netherlands, Norway, Poland, Slovenia, Spain, South Africa, Sweden, Switzerland, Thailand, UK, Ukraine, USA

Main Science Themes:

Cosmic Particle Acceleration

- Particle acceleration
- Particle propagation
- Impact of rel. particles on their environment

Probing Extreme Environments

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

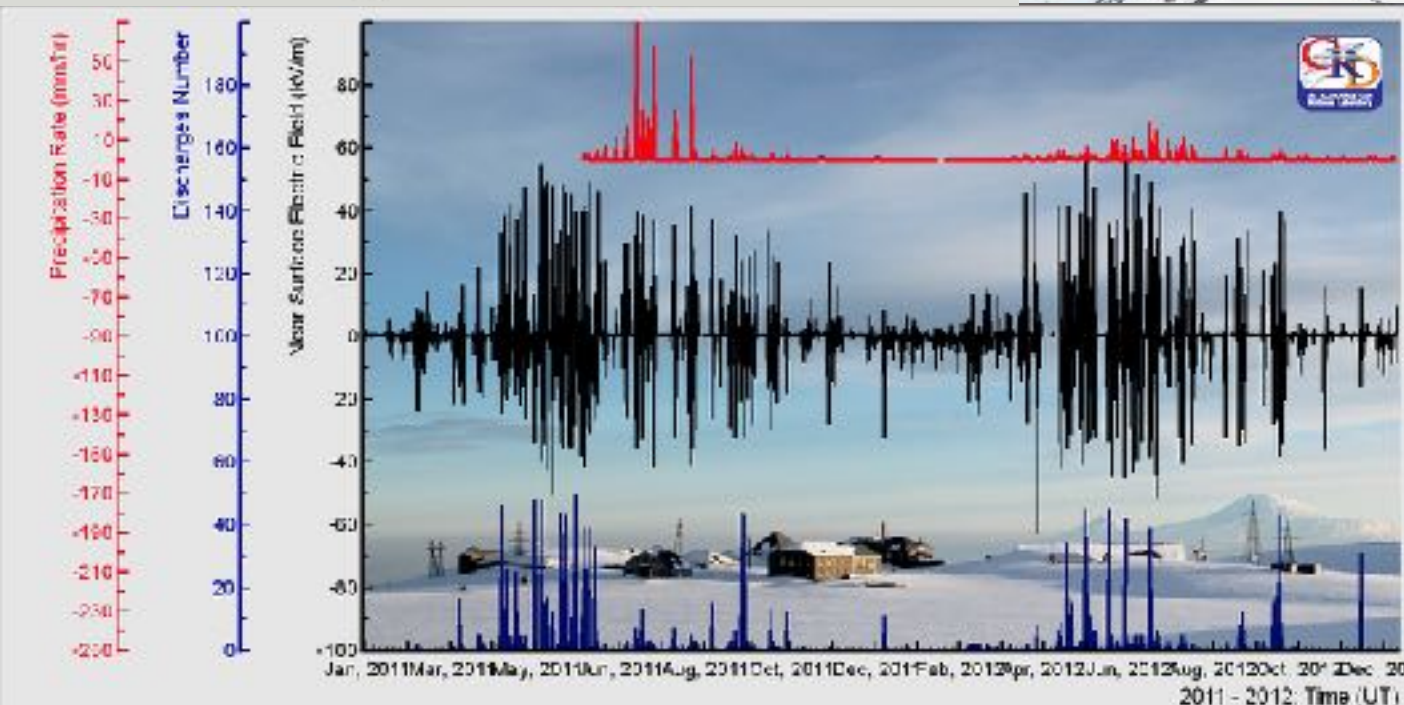
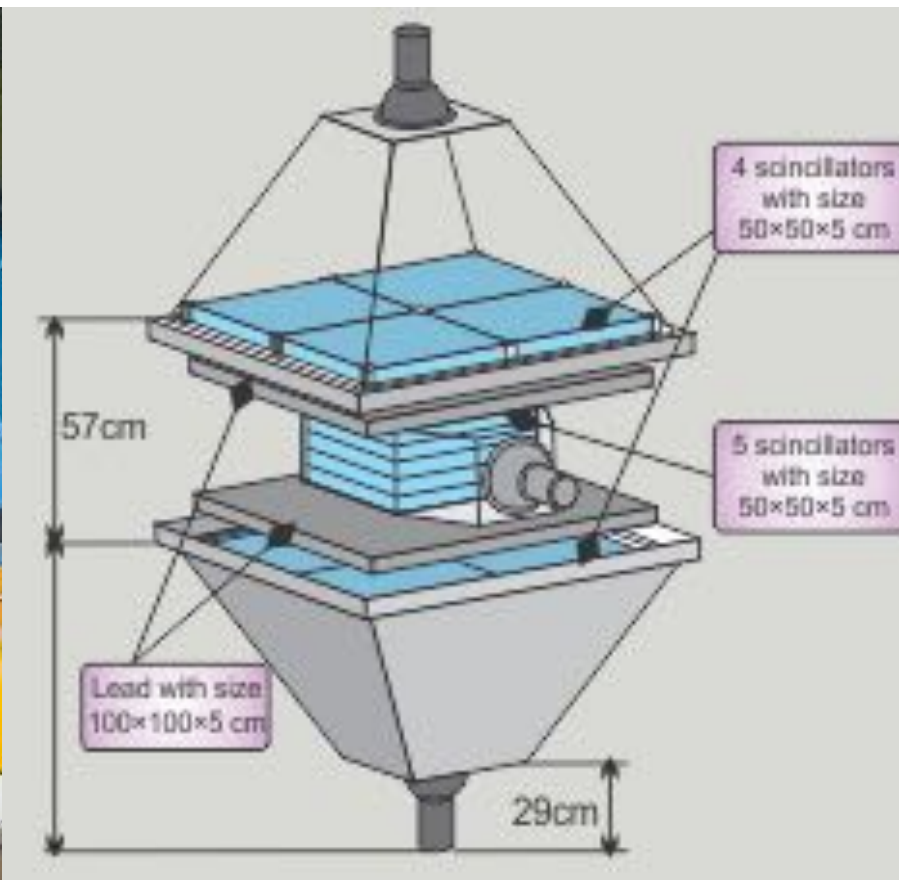
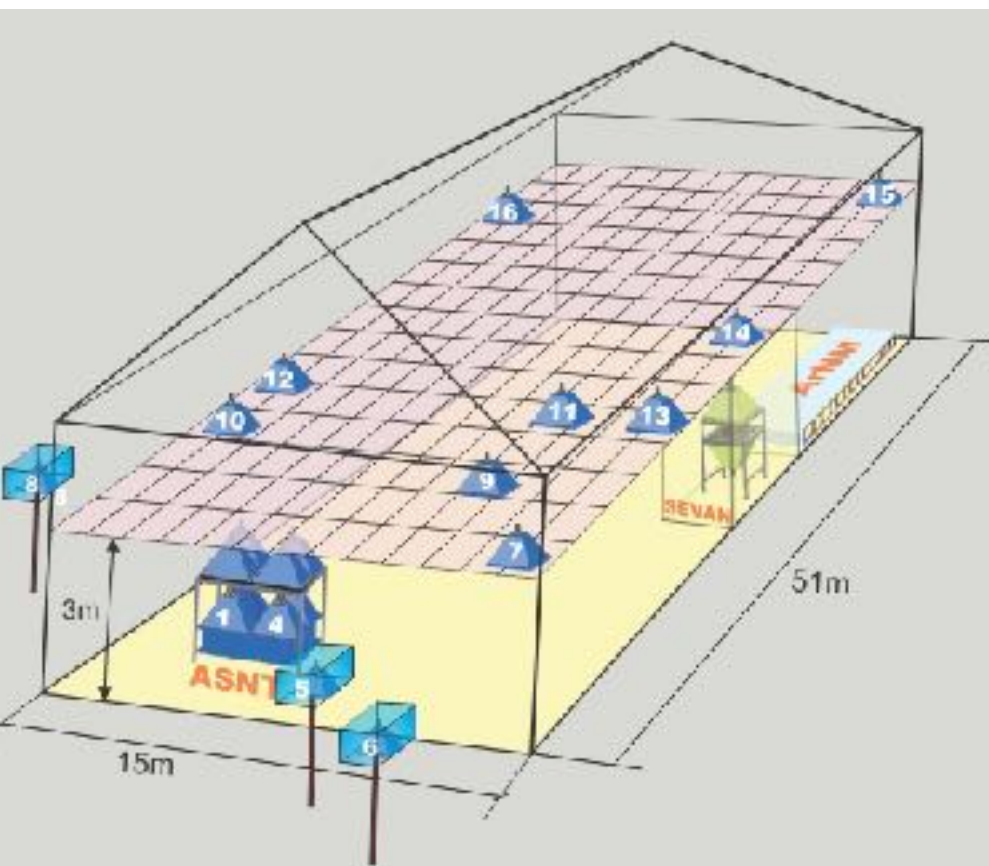
Physics frontiers

- Nature & distribution of Dark Matter
- Lorentz-Invariance at high energies
- Axion-like particles
- Exotics

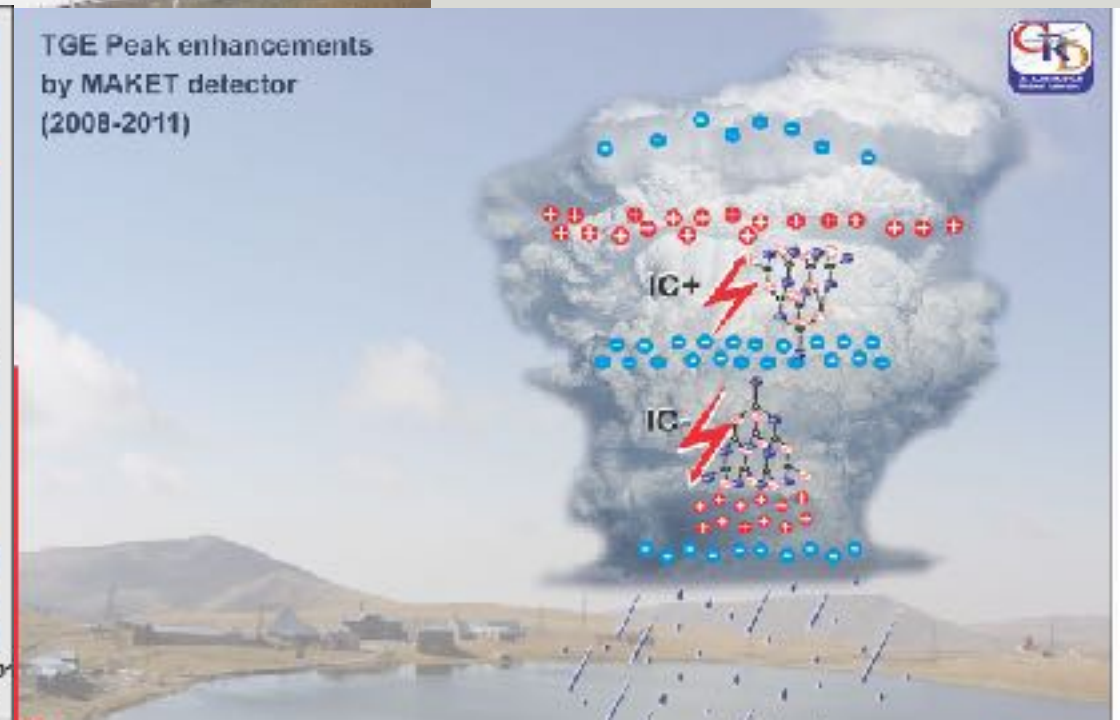


Collaboration with AANL Cosmic Ray Department (Ashot Chilingarian)

cosmic ray physics
gamma ray astronomy (HESS, CTA)
energetic particles from the Sun
particle acceleration in thunderclouds
detectors and control software

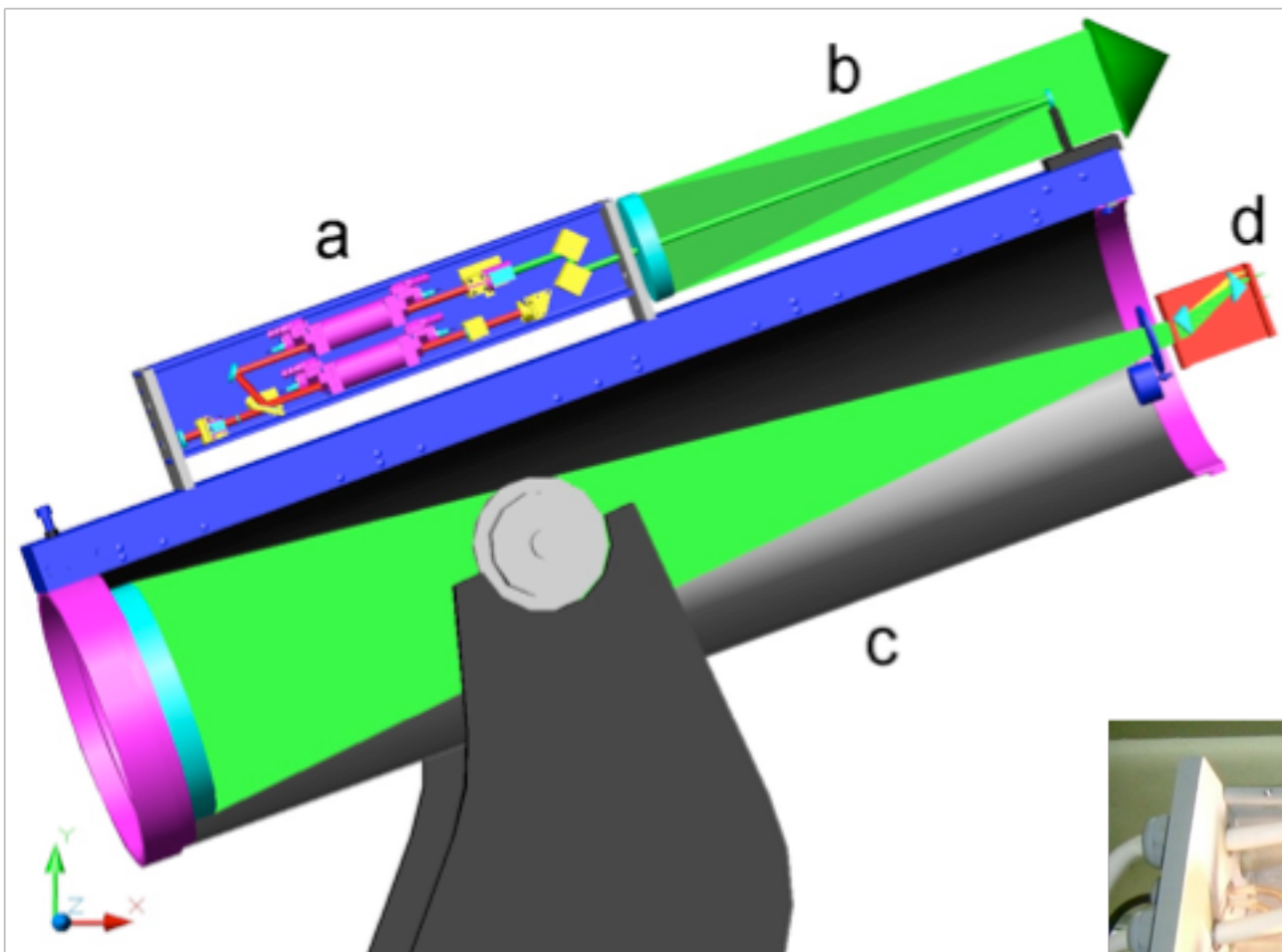


TGE Peak enhancements
by MAKET detector
(2008-2011)

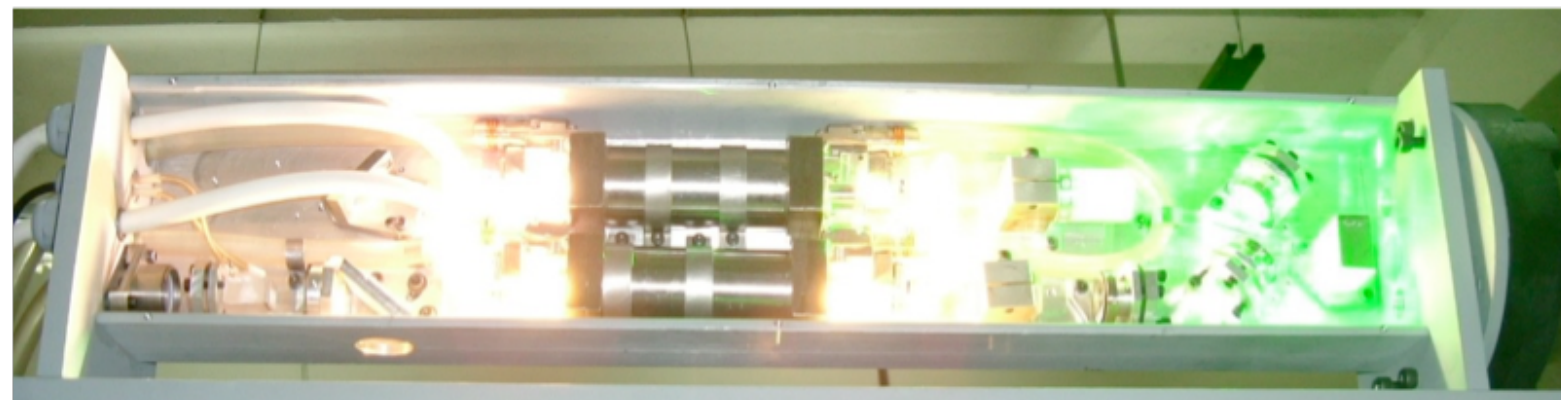


cosmic ray physics
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energetic particles from the Sun
particle acceleration in thunderclouds
detectors and control software

LIDAR: characterising the atmosphere for thunderstorms and CTA
(scattering and absorption of Cherenkov light,
calibration of energy scale)

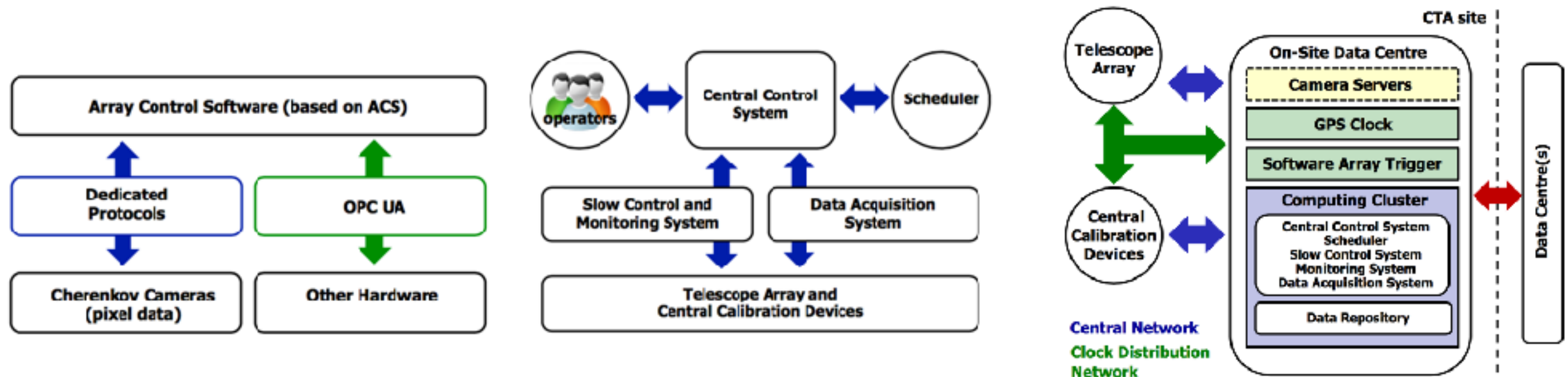


Talks by A Ghalumyan
and M Gaug



cosmic ray physics
gamma ray astronomy (HESS, CTA)
energetic particles from the Sun
particle acceleration in thunderclouds
detectors and control software

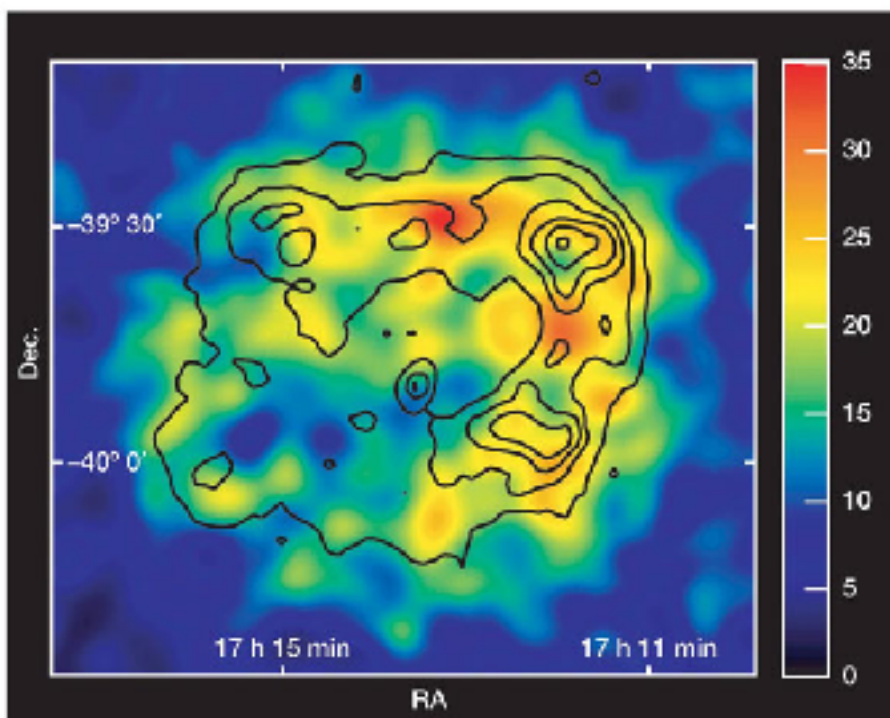
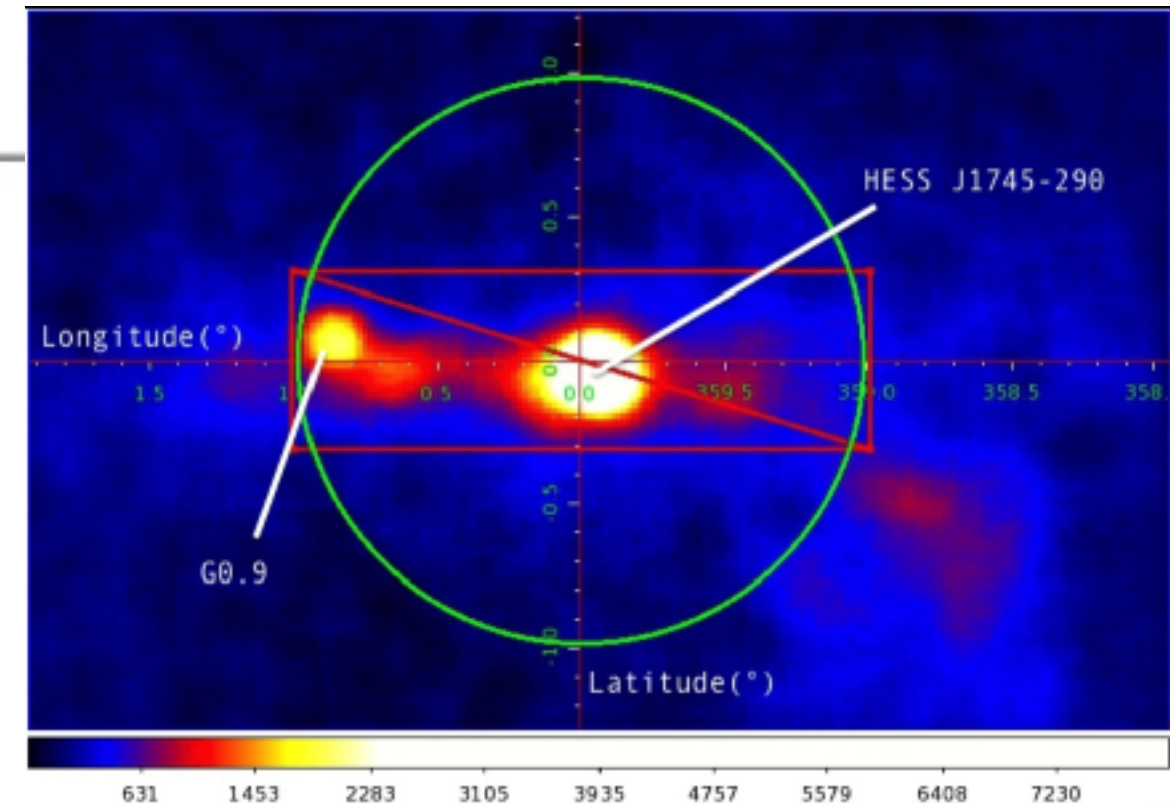
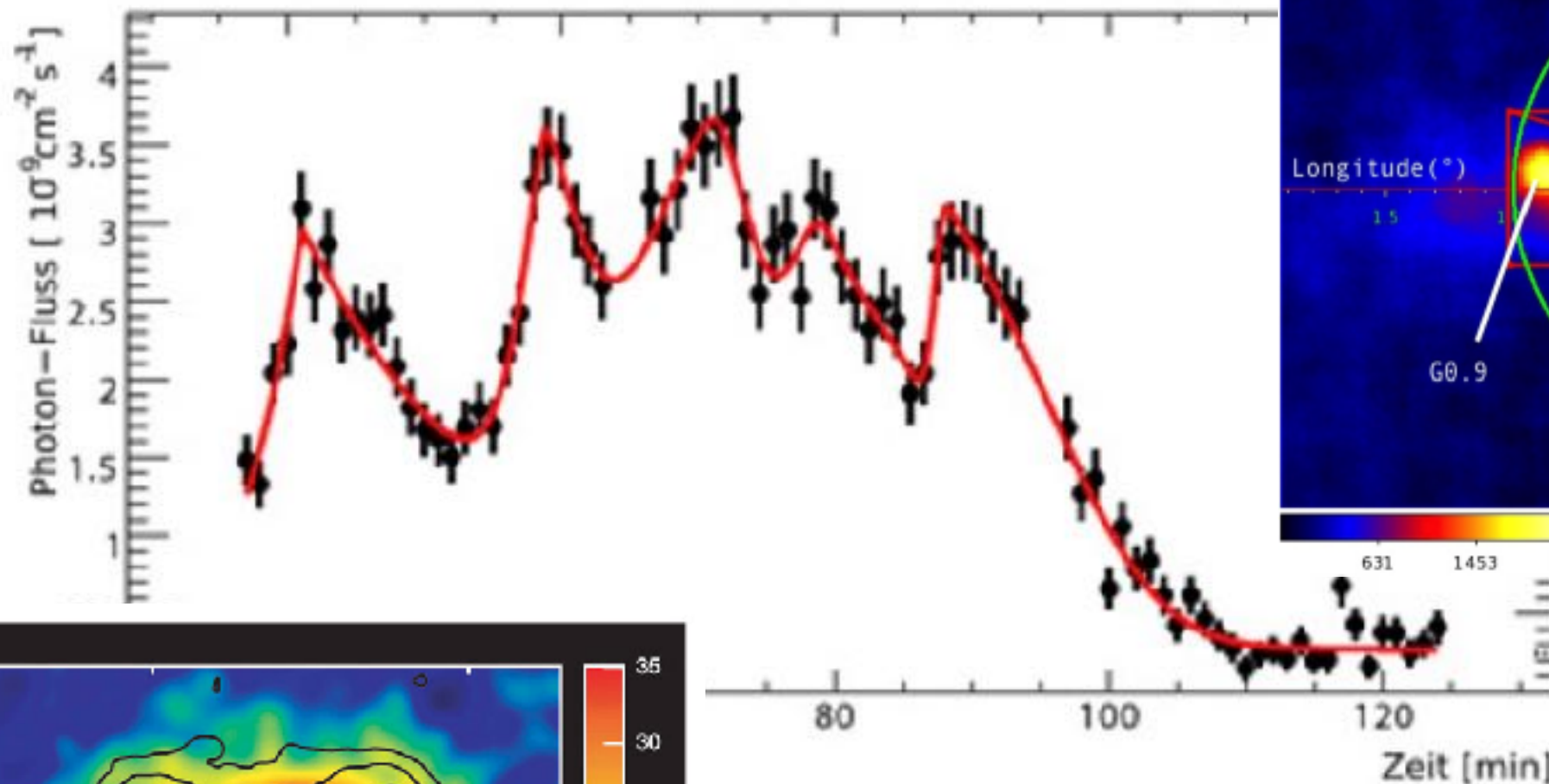
Array Control: steering and reading out the CTA telescopes
and all hardware components
(complex software development)



Talks by I Sadeh, A Khalatyan,
and S Chilingarian

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Gamma Ray Astronomy: Data Analysis



History of Gamma Ray Astronomy

90.

1985: Yerevan Physics Institute
first stereo system of 5 imaging Cherenkov telescopes:

Nor Amberd, 2000 m asl. Mount Aragats, Armenia



was not finished

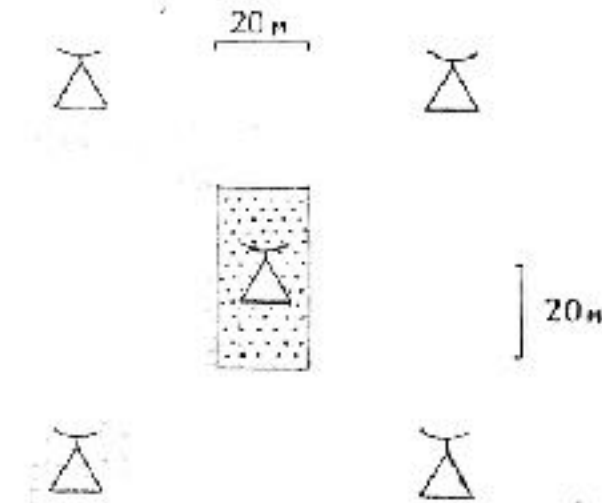


Рис. 38. Установка I.

Δ — телескопы для регистрации ЧС ливней с ПЧД.
■ — детекторы мюонов ШАД.

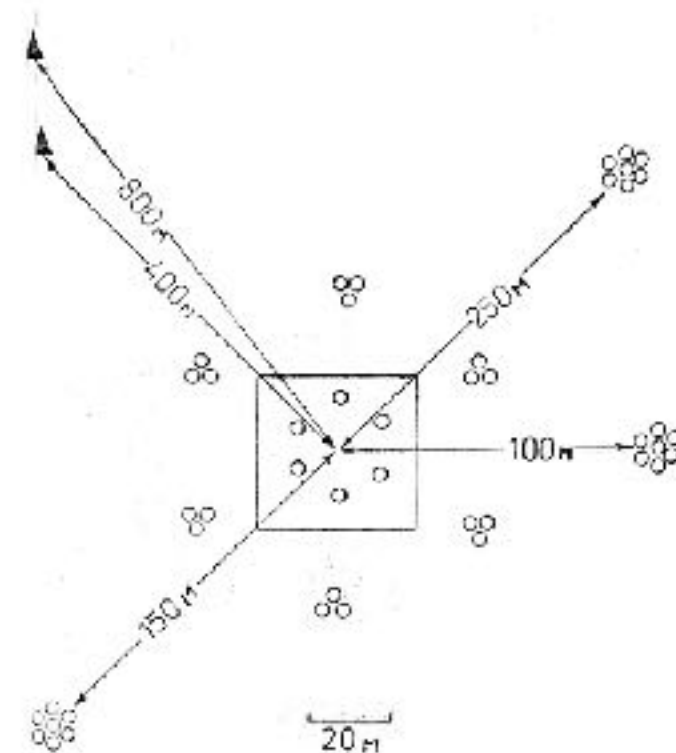


Рис. 39. Установка 2.

□ — центральная часть ШАД для регистрации компонент ШАД.
○, ⊙, ⊗ — детекторы для определения поперечного распределения ЧС ШАД.
▲ — детекторы для определения формы импульсов ЧС ШАД.

HEGRA, La Palma

Proposal for Imaging Air Cherenkov Telescopes in the HEGRA Particle Array

F.A. Aharonian, A.G. Akhperjanian, A.S. Kankanian,
R.G. Mirzoyan, A.A. Stepanian*

Yerevan Physics Institute

* Crimean Astrophysical Observatory

M. Samorski, W. Stamm

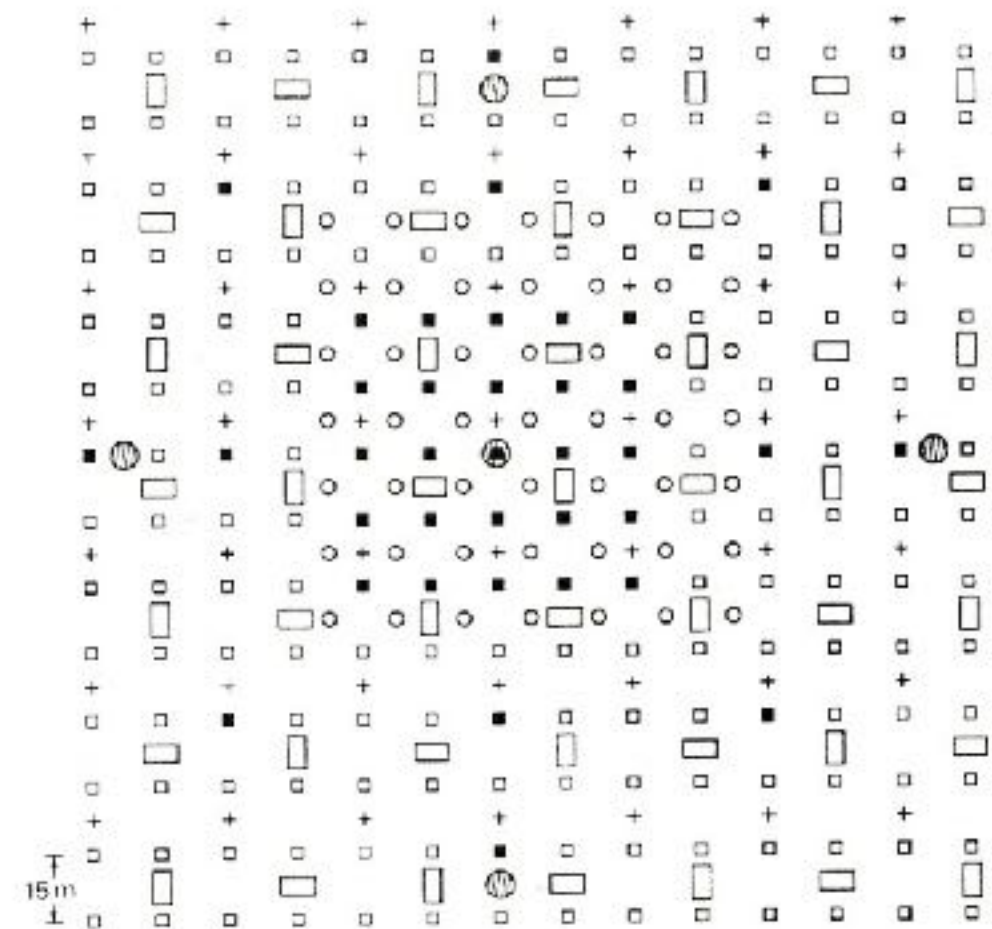
Institut für Kernphysik, University of Kiel

M. Bott-Bodenhausen, E. Lorenz, P. Sawallisch

Max-Planck-Institute for Physics and Astrophysics
Munich

pioneers of
gamma ray
astronomy

+ A Chilingarian
advanced analysis techniques



- ELECTRON DETECTORS:** 1 m² scintillation counters for particle density and fast-timing measurements (2 PM's each), with 5 mm of lead for photon conversion.
- 37 detectors in operation since July 1988 (University of Kiel)
 - 159 additional detectors, 90 of them in operation since July 1989, the rest since December 1990 (MPI Munich together with University of Madrid)
 - 49 further detectors to increase the detector density in the centre of the array, planned for 1991 (University of Hamburg)
 - 49 MUON DETECTORS: 15 m² each, consisting of sandwiches of Geiger tube and absorber layers, planned for 1991/92 (University of Wuppertal together with University of Kiel)
 - + 49 CHERENKOV-LIGHT DETECTORS: each consisting of a 20 cm diameter PM and a light-collecting cone, planned for 1991 (MPI Munich together with University of Madrid)
 - ⊙ 5 CHERENKOV TELESCOPES: 3 m in diameter with 19 mirrors and 37 PM's each, imaging technique, planned for 1991/92 (Yerevan Institute of Physics together with MPI Munich and University of Kiel)

Fig. 1: Status and planned extensions of the HEGRA detector array.



Felix Aharonian

MPIK Heidelberg
& DIAS, Dublin
(HESS, CTA)



Razmik Mirzoyan

MPIP Munich
(MAGIC, CTA)



Ashot Chilingarian

YerPhI/AANL
(MAGIC, CTA)

fruitful links from Germany to YerPhI/AANL
(personal & scientific)

Regular participation of DESY scientists at Schools, workshops and conferences in Armenia.



**The young
generation**

... is the future.



Summary:

Astroparticle Physics is tightly connected to Atmospheric Physics.

CTA is a great experiment in Gamma Ray Astronomy with huge scientific potential, for the next 3 decades.

DESY is a key player in CTA.

**YerPhI is nominal member, but could be more involved
(gamma ray astronomy, atm. monitoring, software, data, ...)**

CTA is suitable for DESY-YerPhI co-operation.

**DESY continues its co-operations
in accelerator, particle and astroparticle physics
and special attention to young scientists.**

Long term support from funding agencies and institutes is needed.

BMBF and State Committee of Science support a pilot study for an institutional partnership DESY – YerPhI.