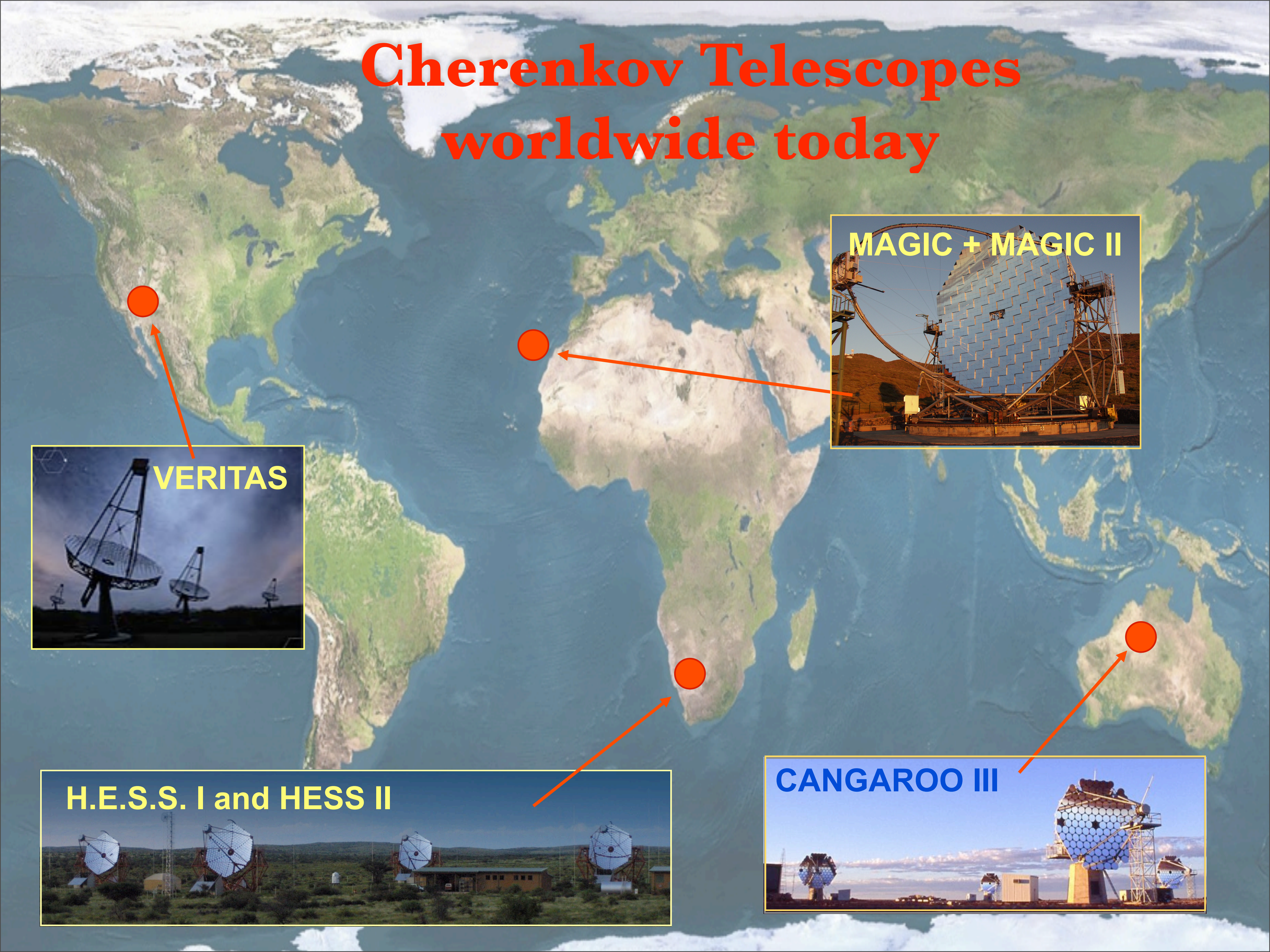
The Cherenkov Telescope Array Project

An advanced facility for ground-based gamma-ray astronomy

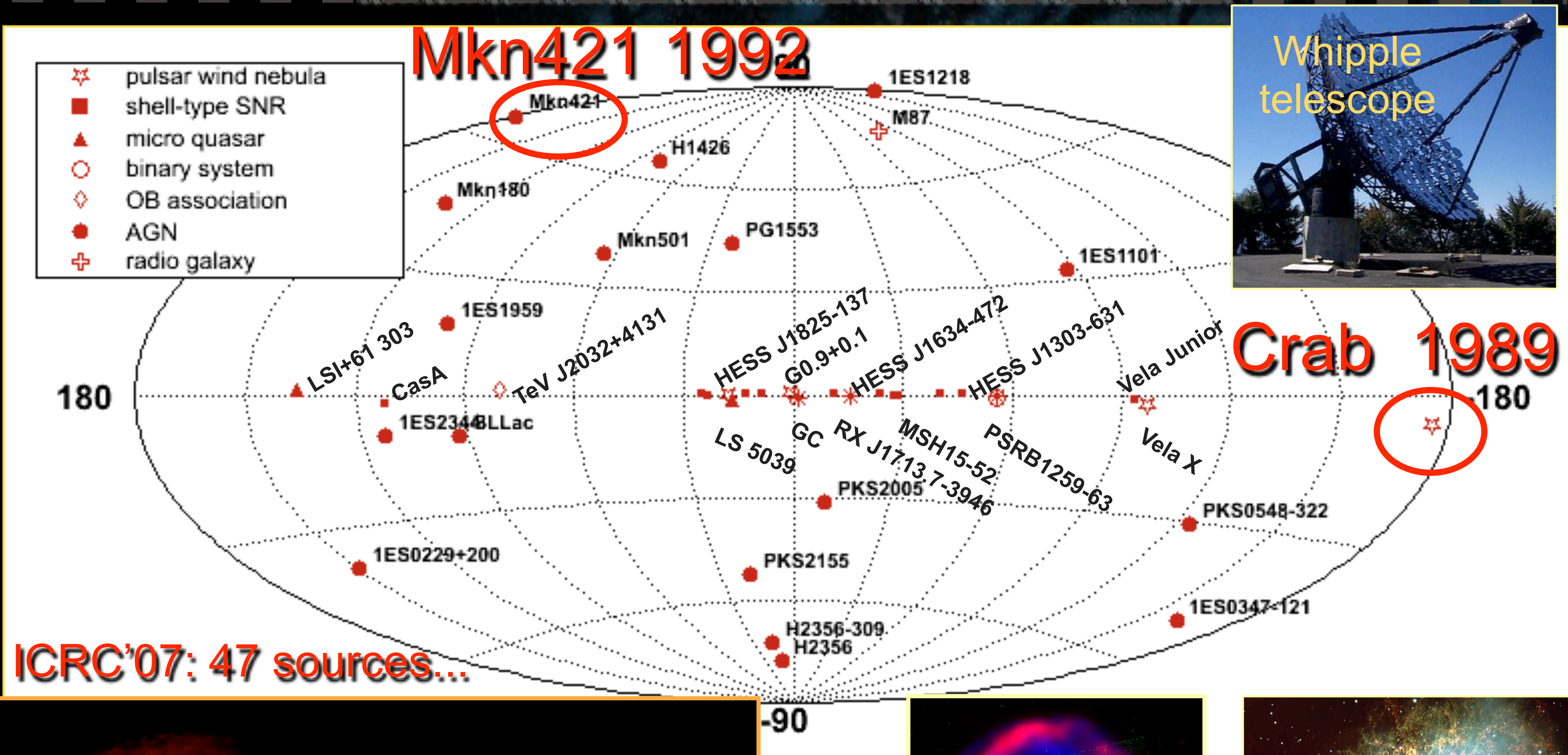
Thomas Schweizer, MPI Munich

Vulcano workshop 2008
Frontier objects in astrophysics and particle physics
May 26-31, Vulcano, Italy

Cherenkov Telescopes worldwide today

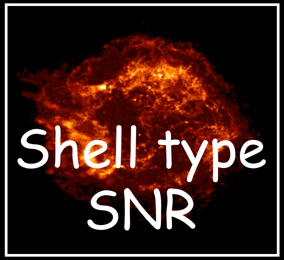


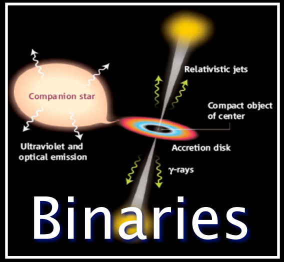
Gamma ray astronomy
today: around 76 sources

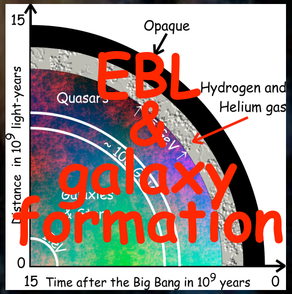


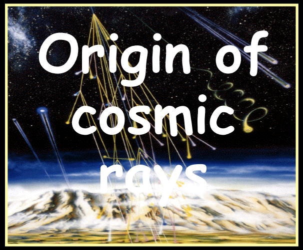
CTA specifications and physics

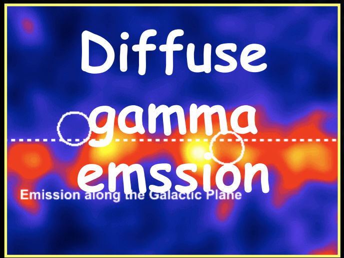
- Boost sensitivity to 1 mCrab
- Expand energy range ~10 GeV to 100 TeV
- Improved angular resolution
- Full sky coverage (two installations)
- Observatory open to external astronomers
- Discovery of new source classes
- Lots of new physics

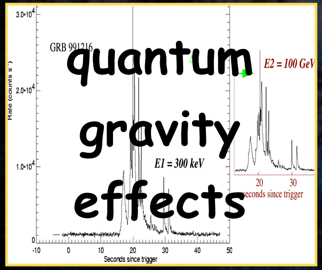


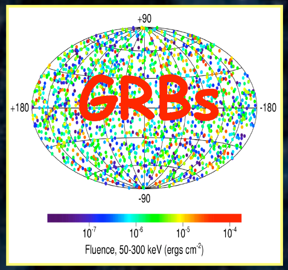




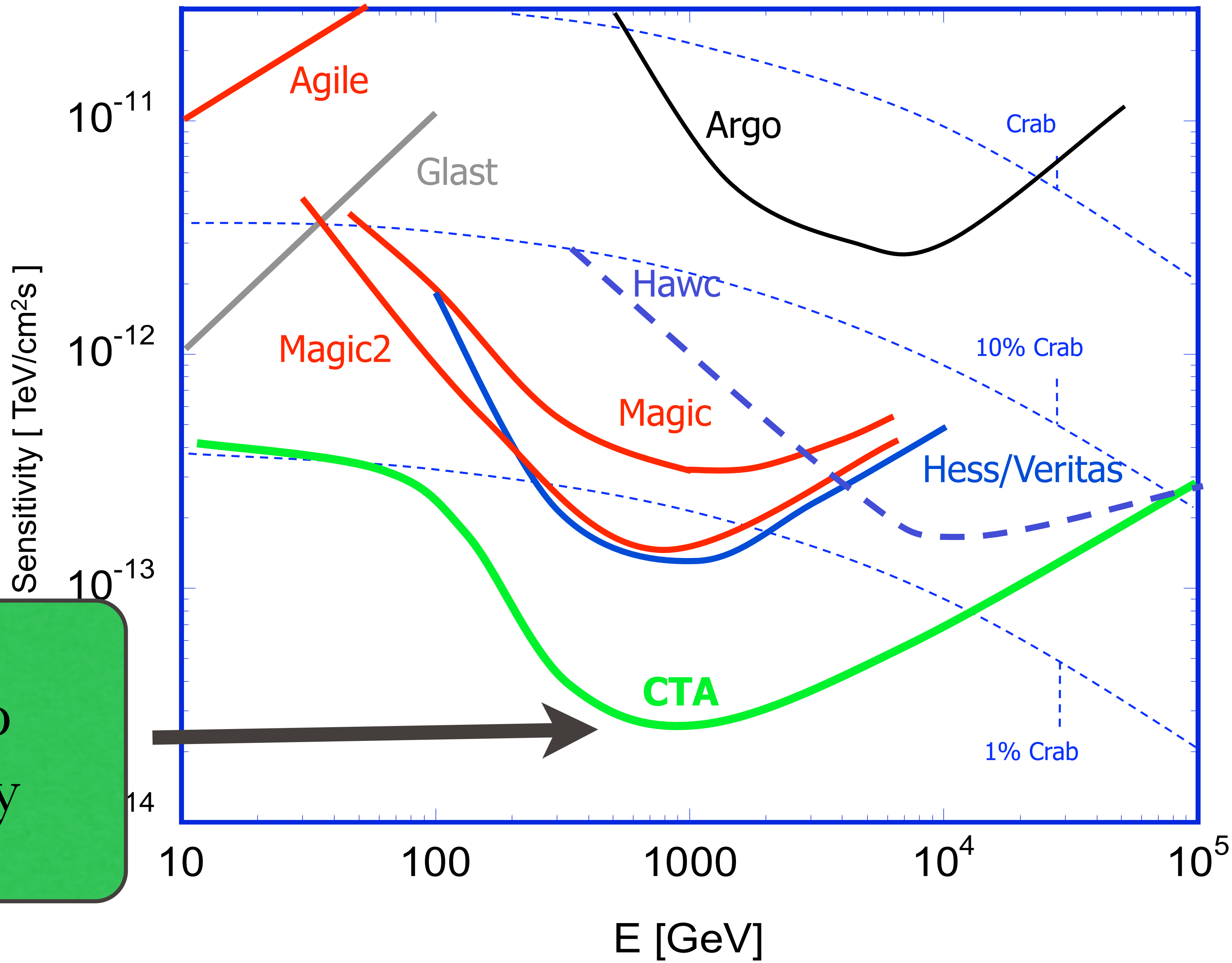








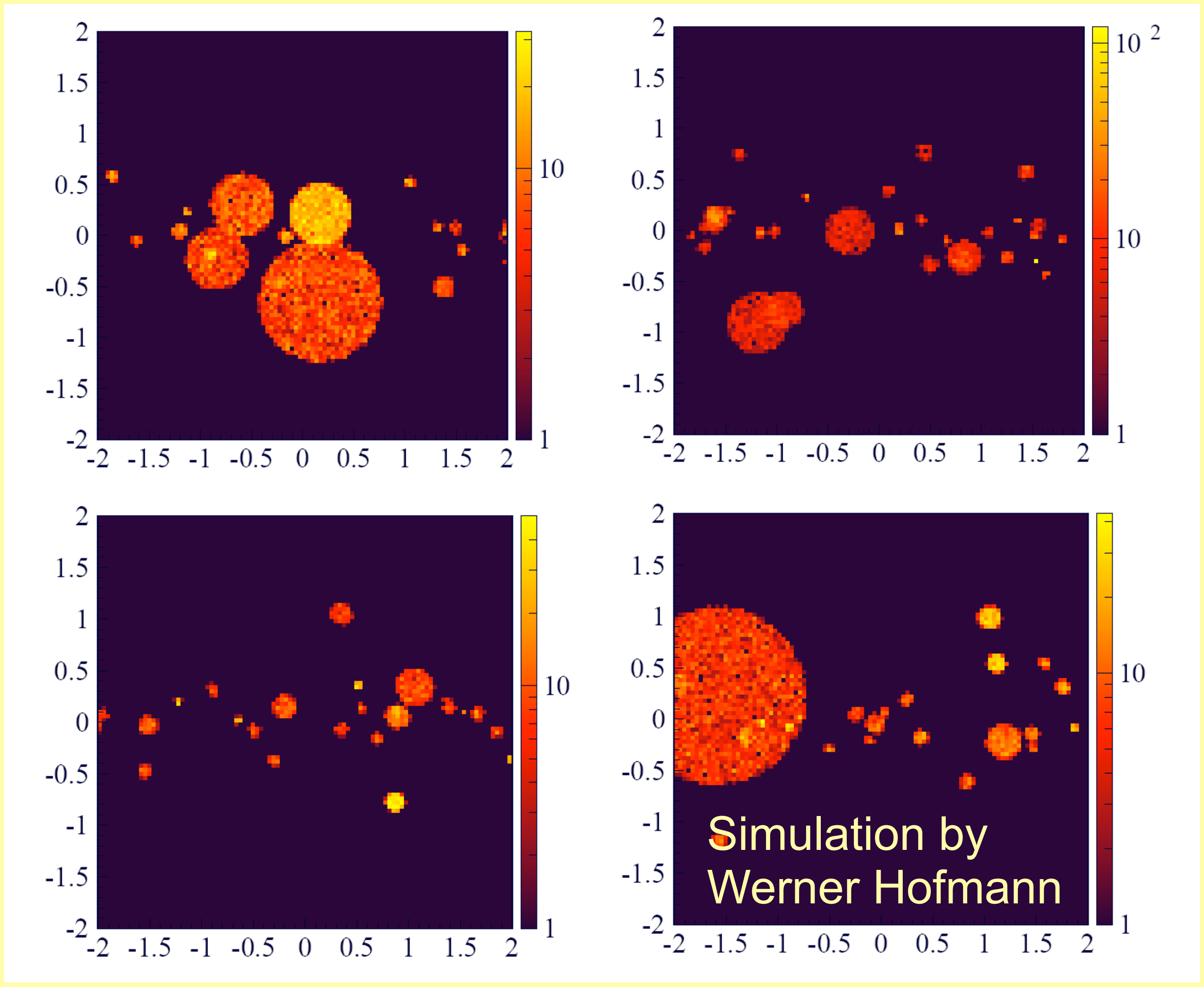
Aimed sensitivity



1 mCrab sensitivity

Galactic physics: CTA deep of view (4°x4°) (Simulation of galactic plane)

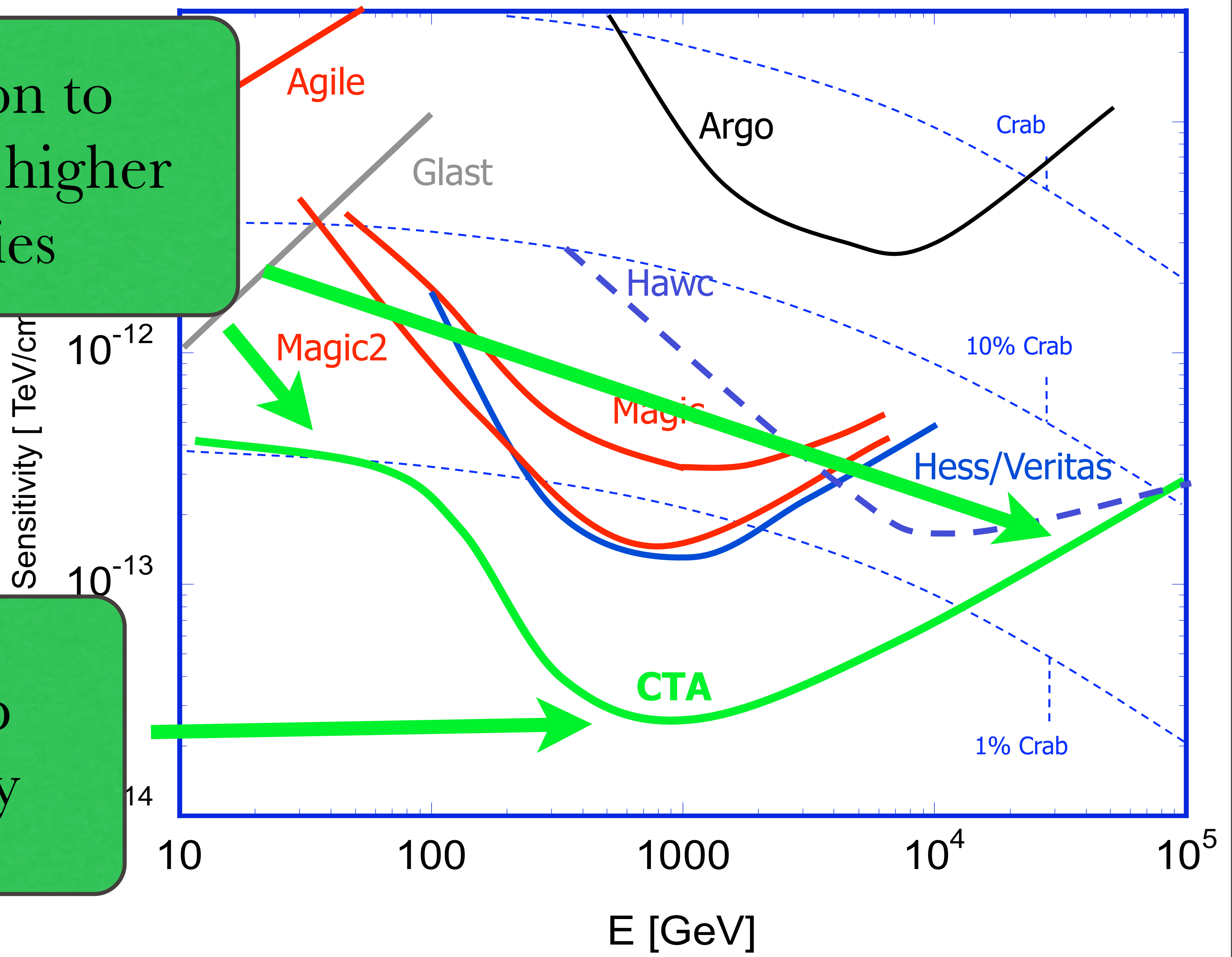
- about 250 SNR + PWN in galactic plane
- CTA sensitivity (1 mCrab)
- CTA angular resolution -> needed for morphology and separation
- FOV 4° x 4°



Aimed sensitivity

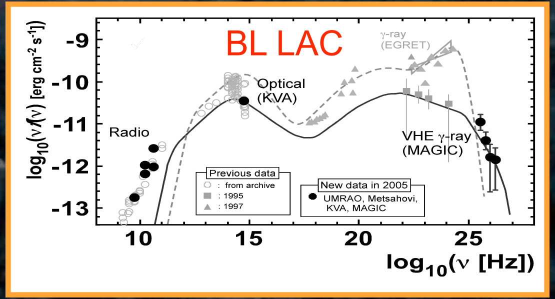
Extension to lower and higher energies

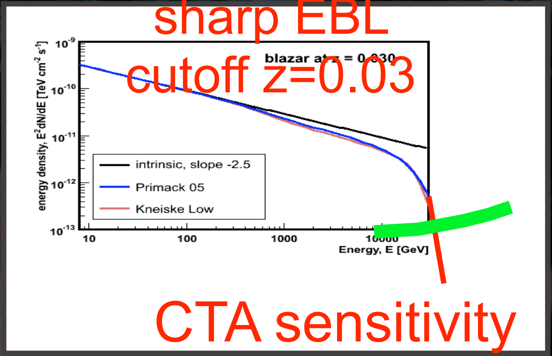
1 mCrab sensitivity

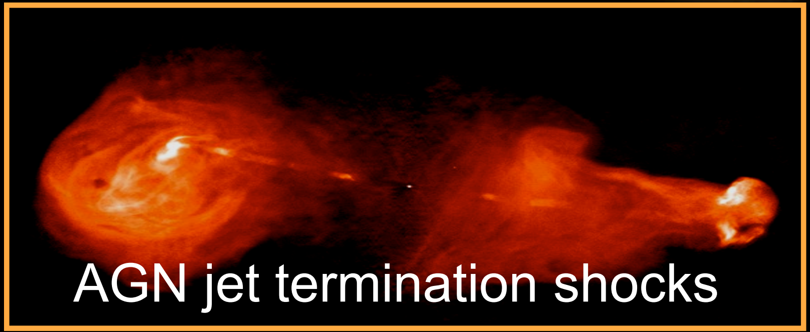


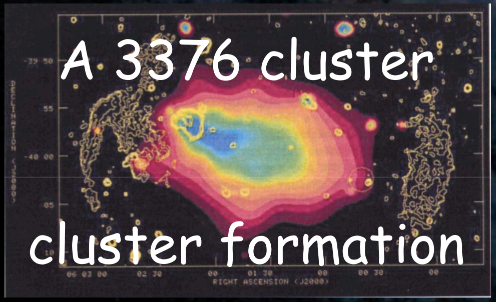
Rich physics in low energy range with high sensitivity: Extragalactic physics

- Many more AGN: many LBL, high redshift HBLs, resolving EBL cutoffs
- Starburst galaxies
- Galaxy clusters
- Galaxy mergers
- Sub galaxy cluster formation
- Hot spots in AGN jet termination shocks

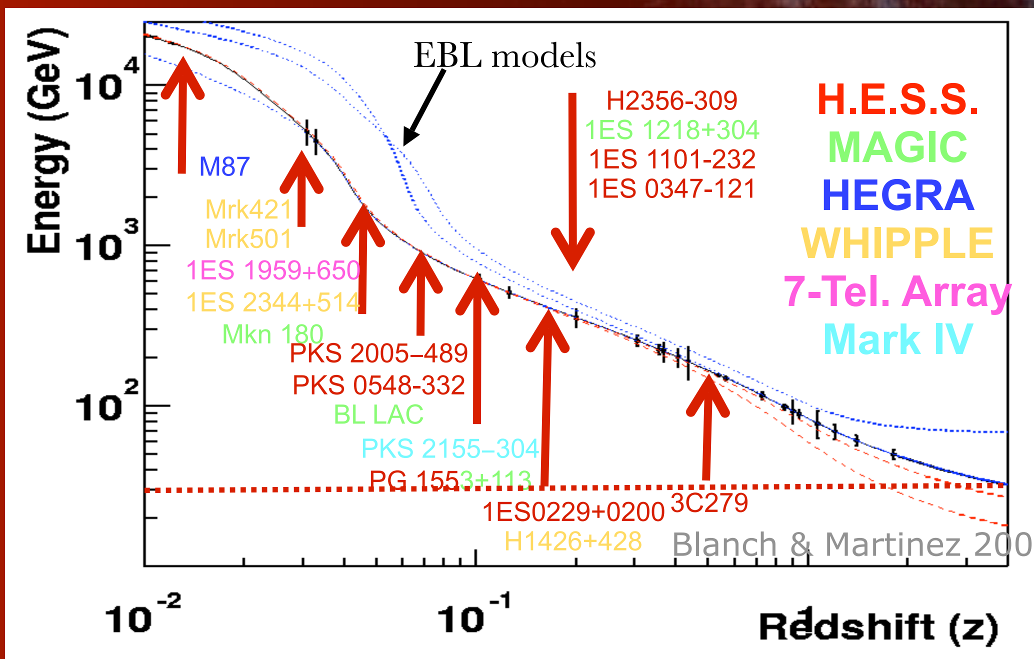


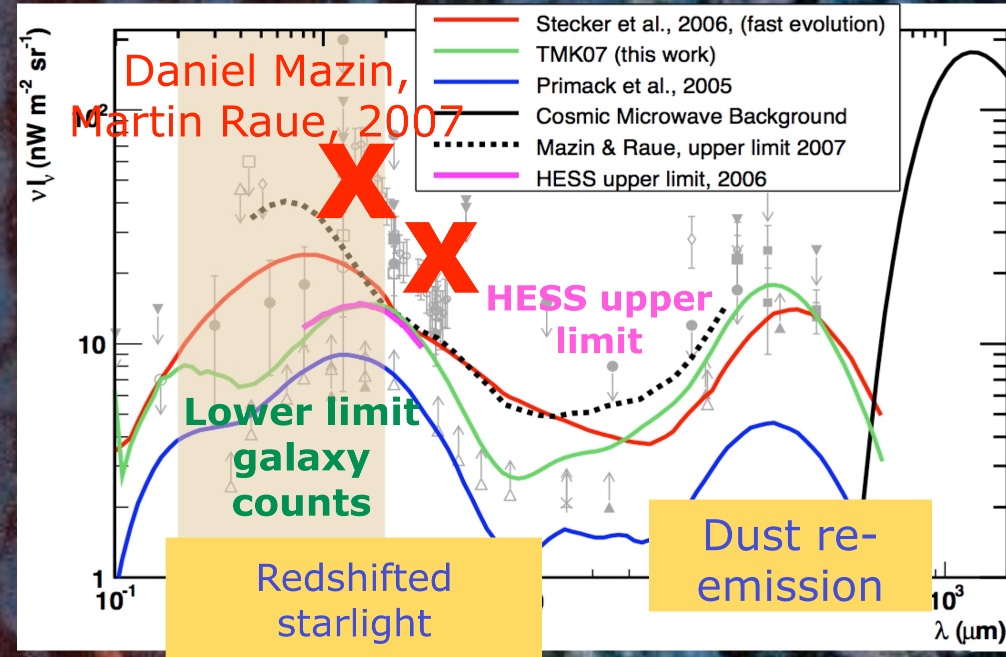


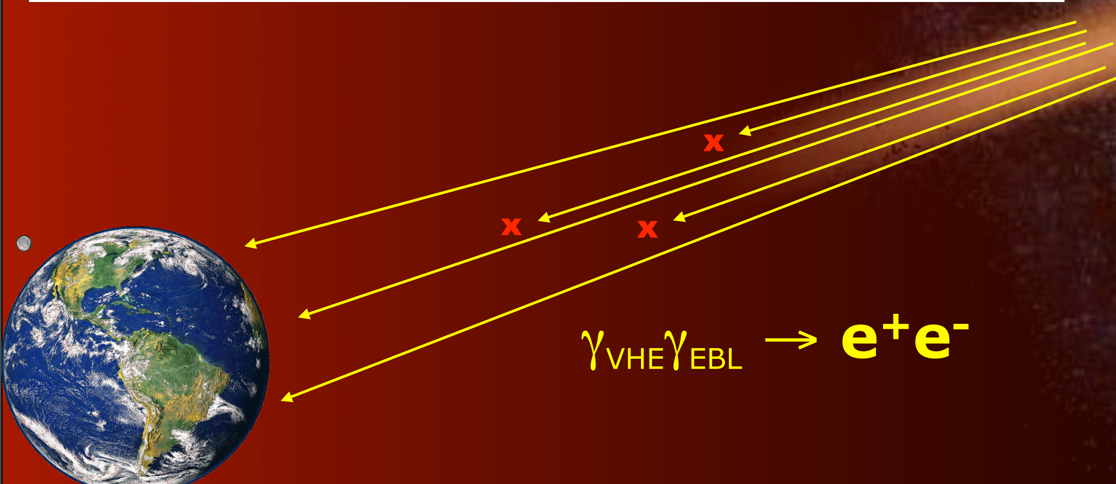


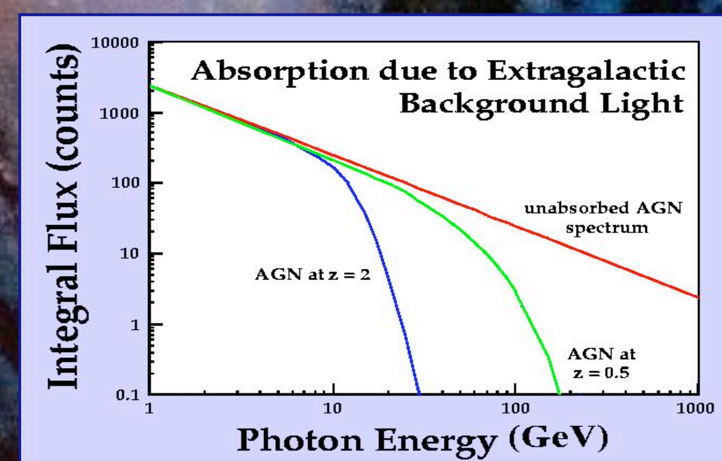


Extension to lower energies: gamma ray horizon at z=2





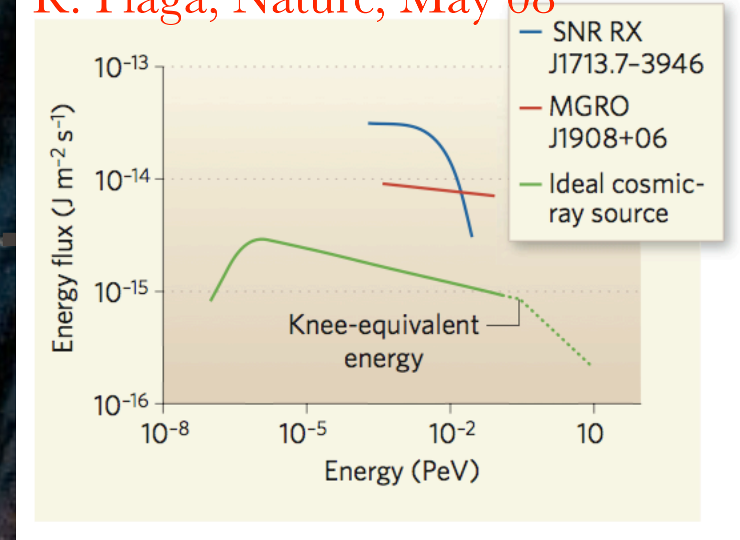


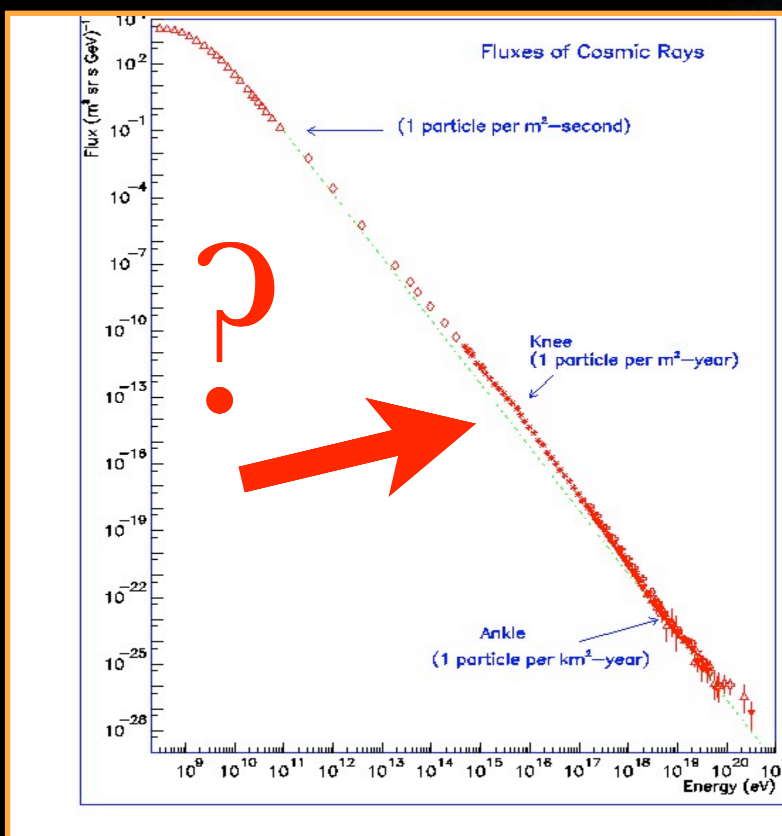


High energies >100 TeV
Long standing question: Origin of the knee

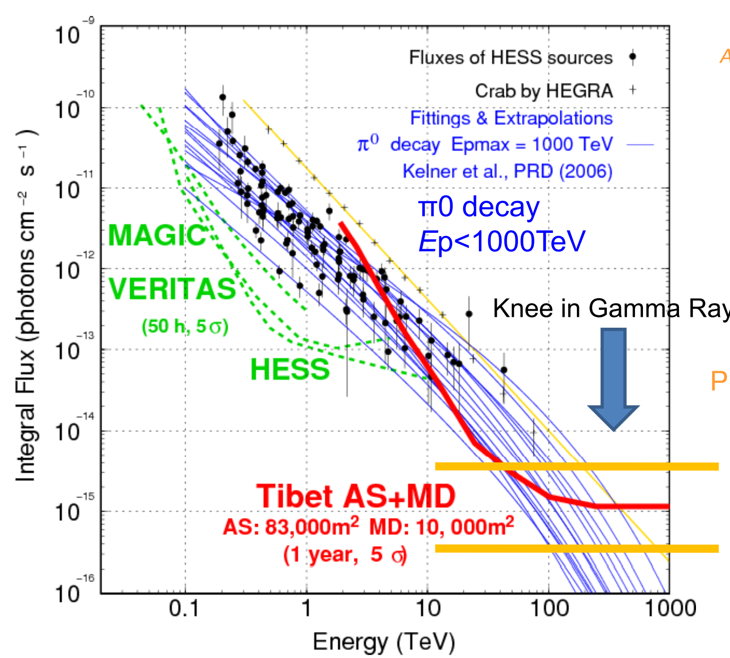
- Probing the knee in gamma rays for individual sources
- Finding the Pevatron source

R. Plaga, Nature, May 08





14th HESS bright galactic sources in Southern Hemisphere



Aharonian et al, ApJ, 636, 777 (2006)

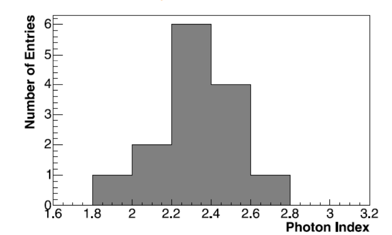
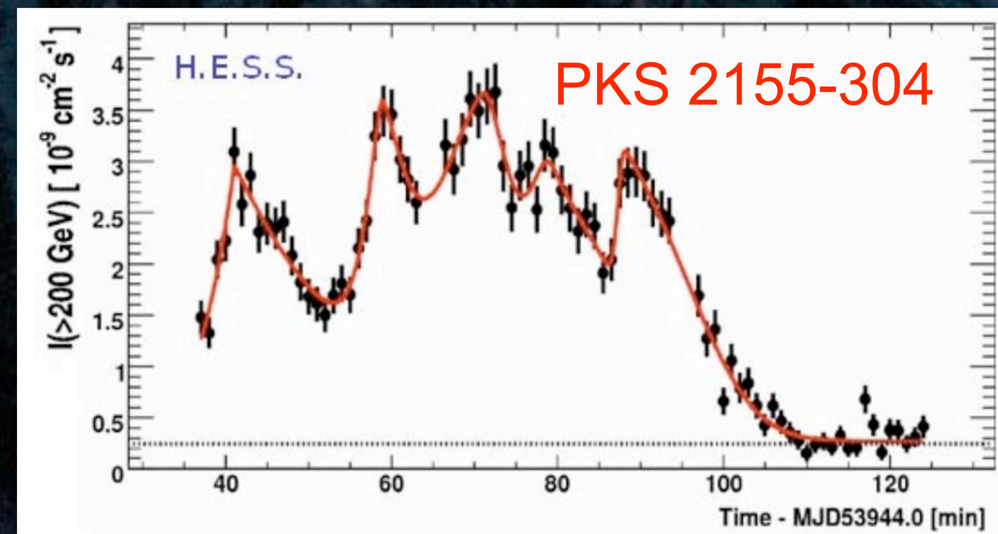


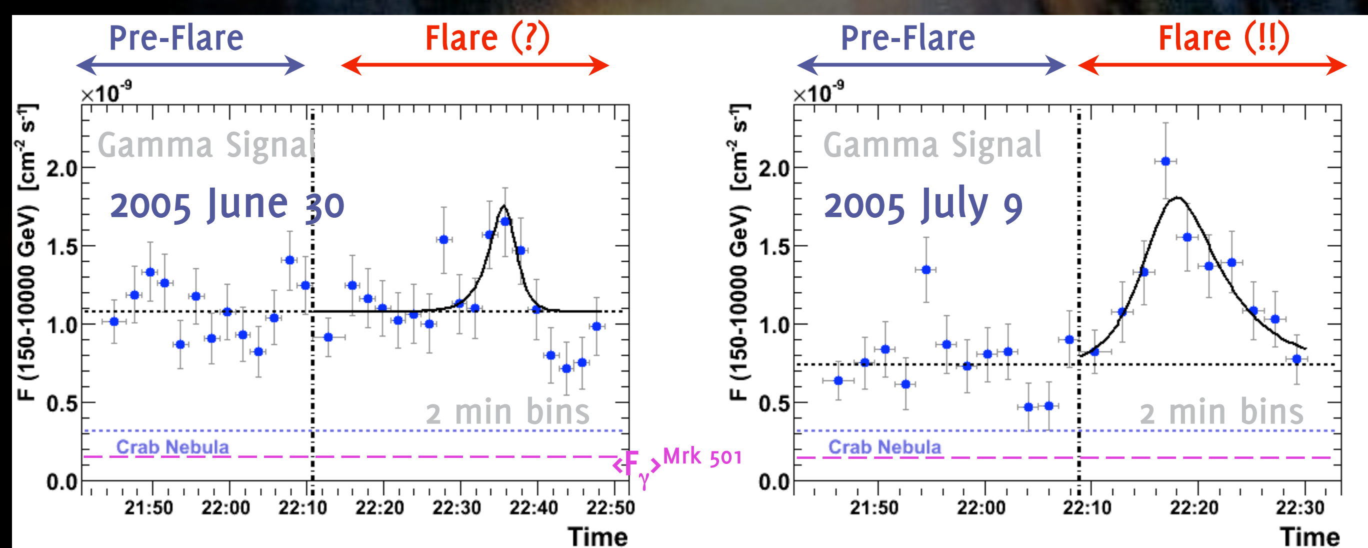
FIG. 8.—Distributions of the photon index of the new sources. The mean photon index is 2.32 with an rms of 0.2.

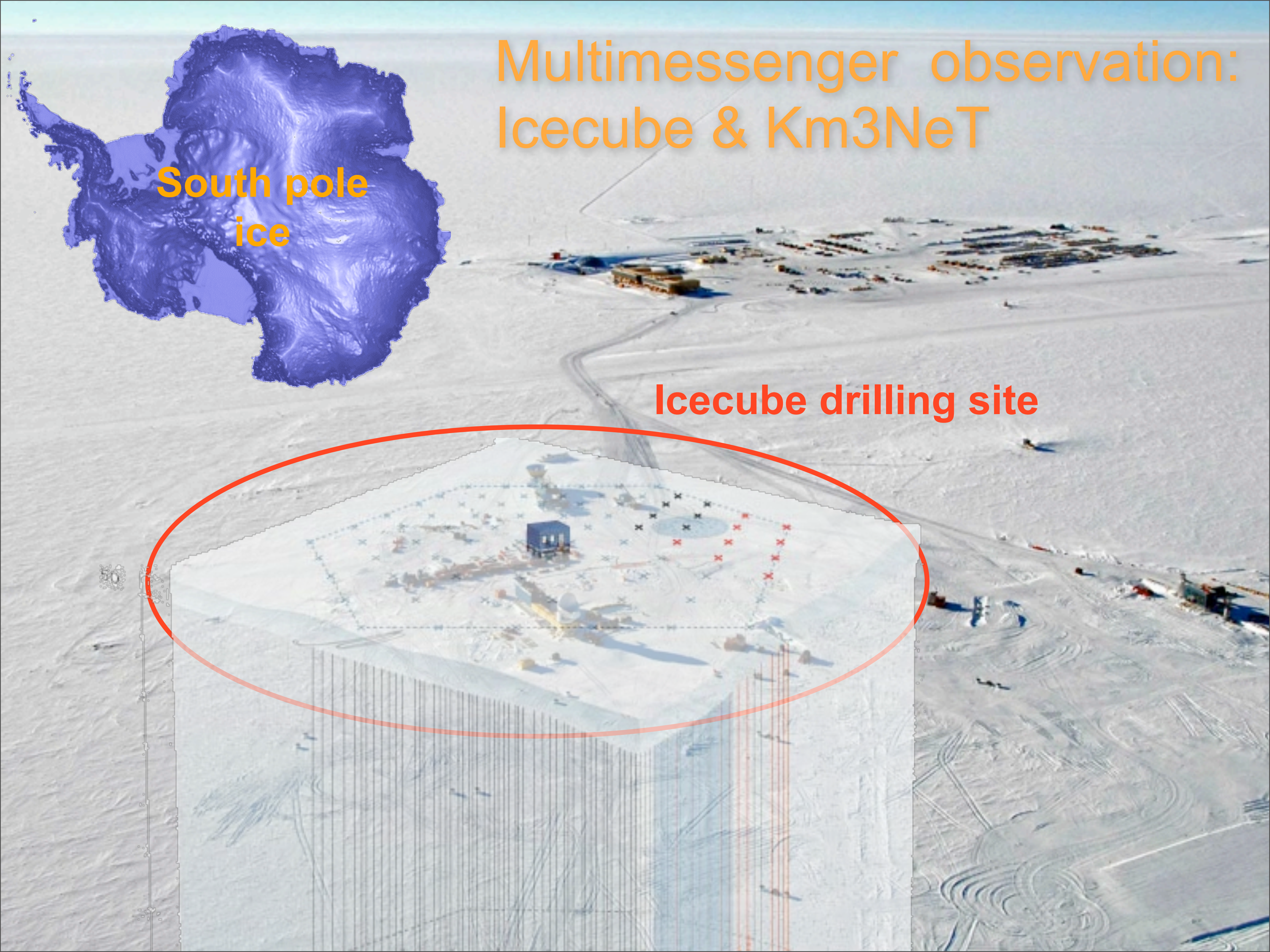
Photon index average −2.3

Advantage of CTA over GLAST: transient sources

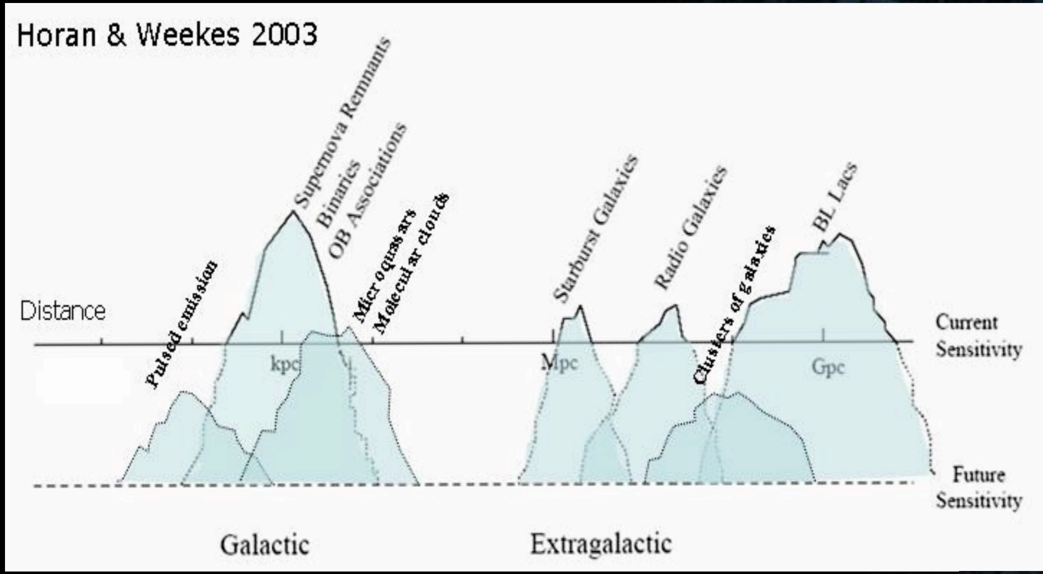
- CTA will resolve finest details and reveal shortest flux variability time scales
- Time resolved multiwavelength studies
- With CTA we will be able to measure accleration and cooling time scales
- Hard limits on quantum gravity scale
  HESS: 0.02 M_p
  MAGIC: 0.04 M_p
  --> CTA: O(0.1 M_p)

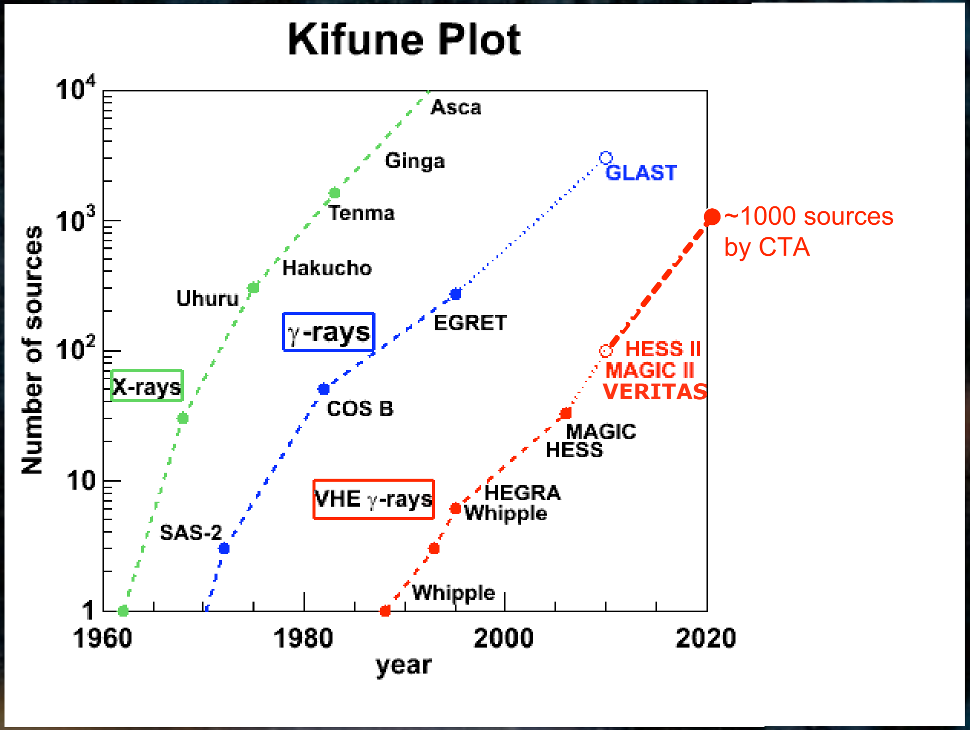





Multimessenger observation:
Icecube & Km3NeT
South pole
ice
Icecube drilling site

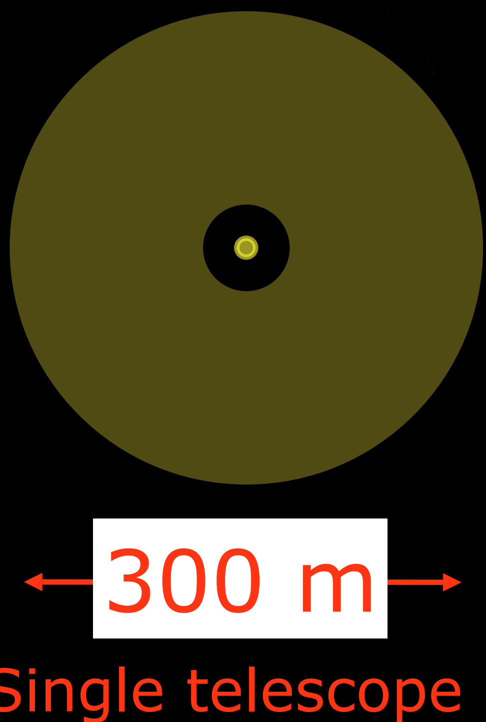
Discovery potential



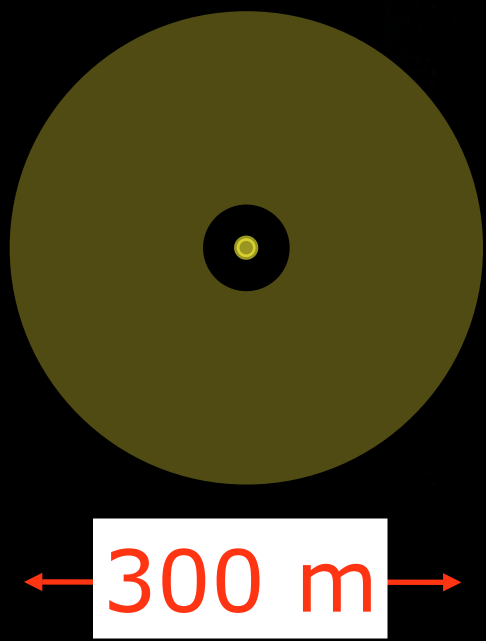


- ✓ At the moment we see only the tip of the iceberg
  -> we expect many new sources and source classes

Design and layout: Telescope Array



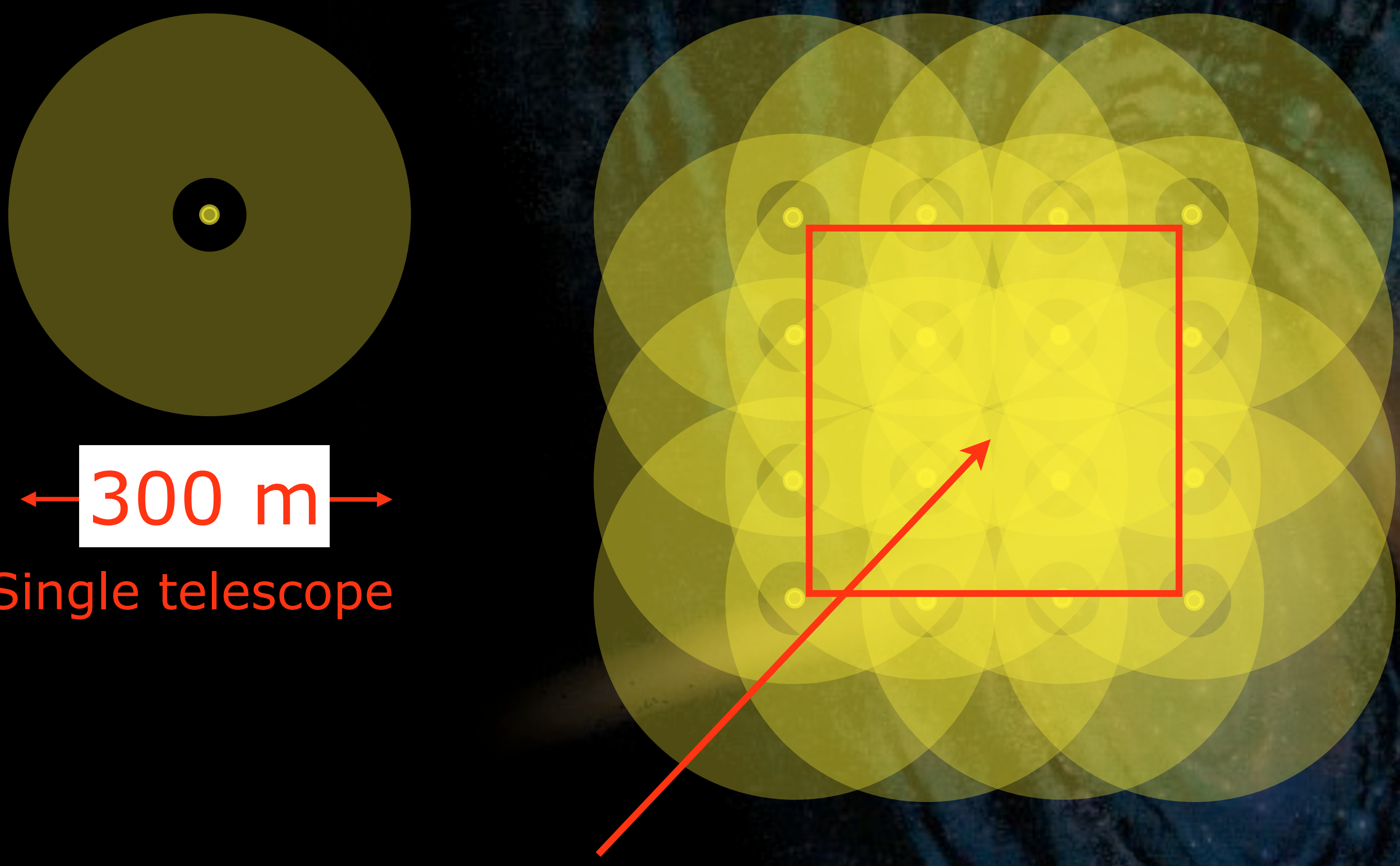
Design and layout: Telescope Array



Single telescope

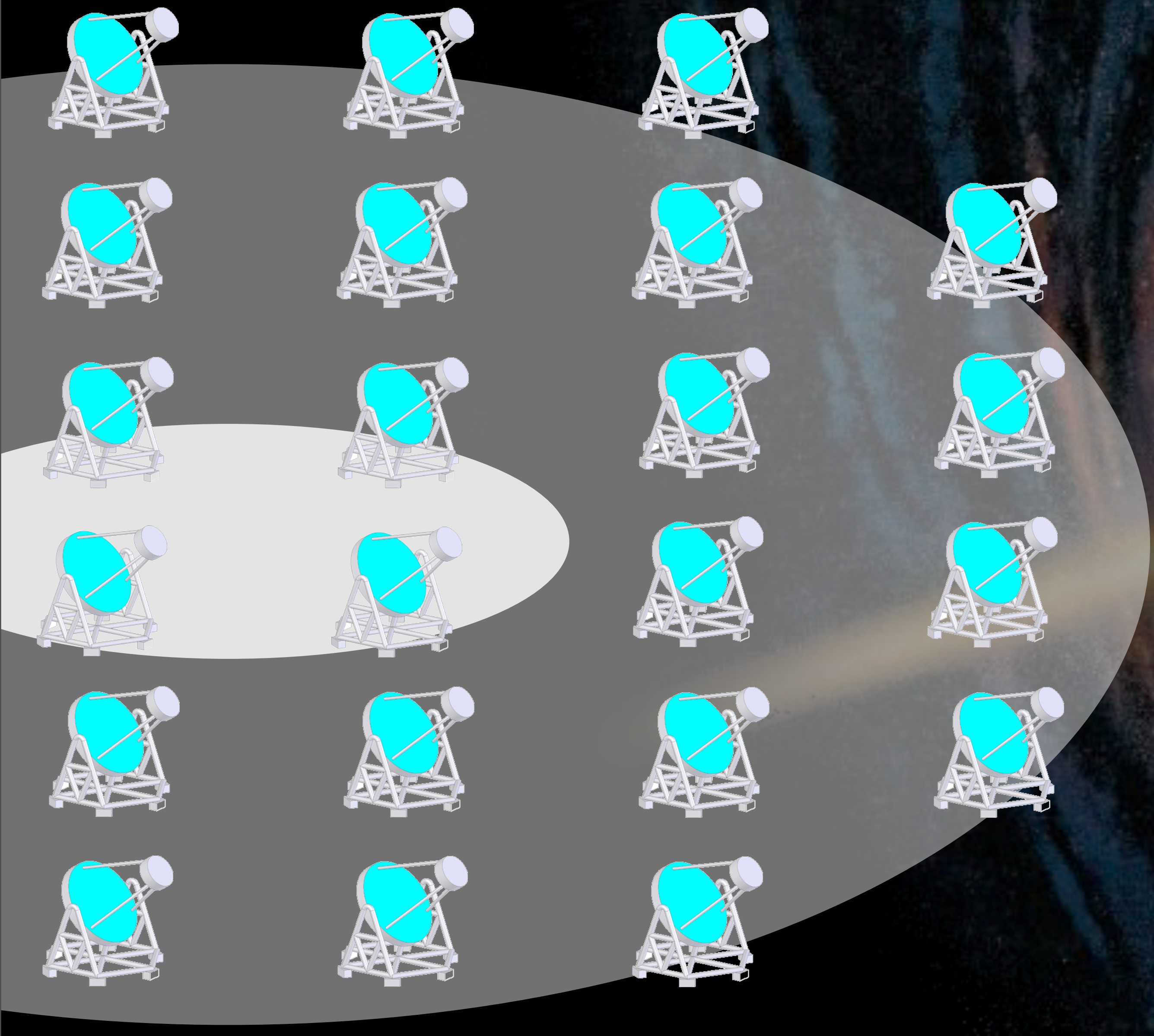
High sensitivity, small region

Design and layout: Telescope Array



High sensitivity, larger region per telescope

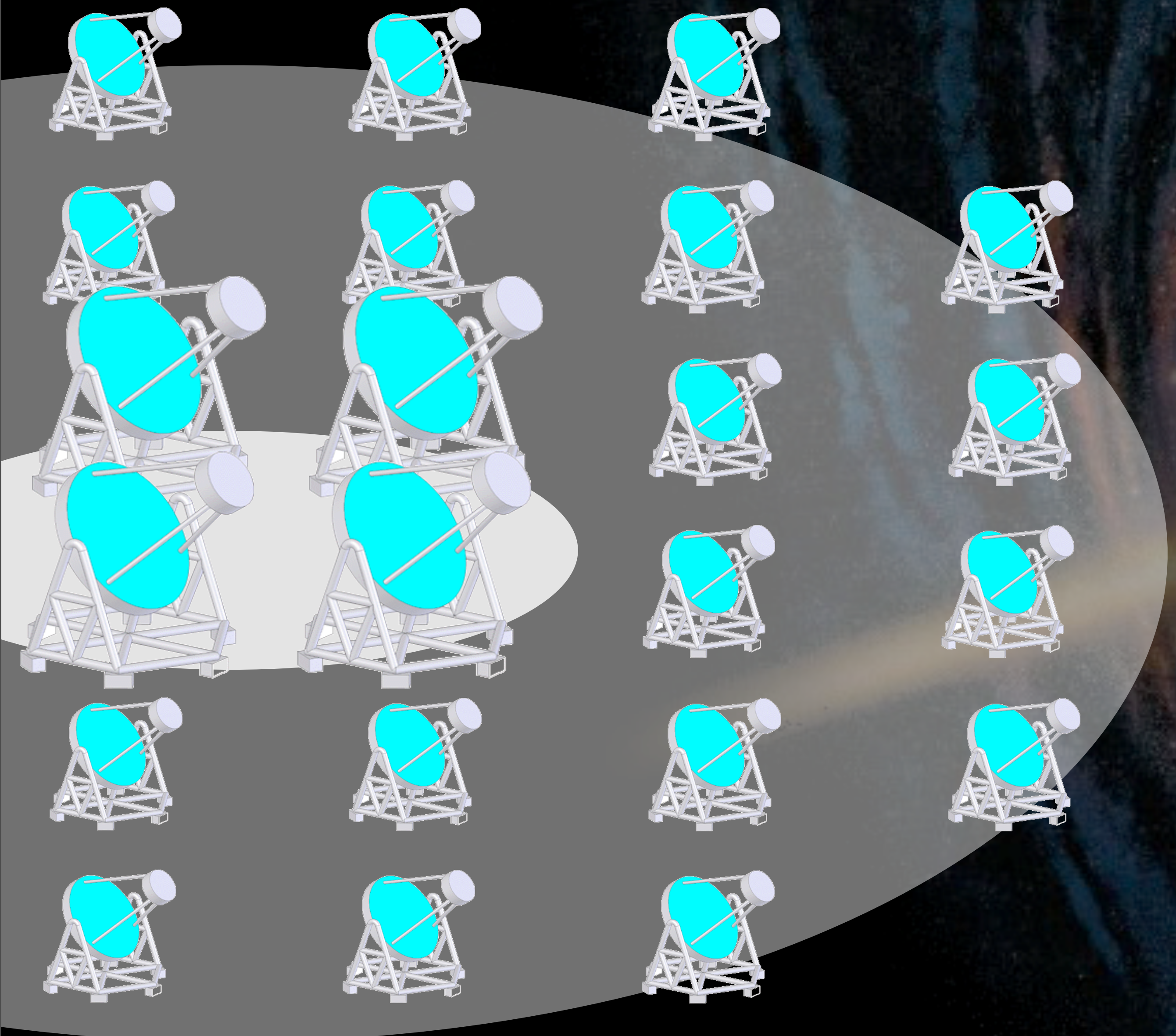
Layout possibilities



Intermediate energy array:

- Many 5-12 m telescopes
- FOV 5-7 deg
- mCrab sensitivity at the 100-300 GeV–10TeV domain
- improved angular resolution

Layout possibilities



Extension to lower energies O(10 GeV):

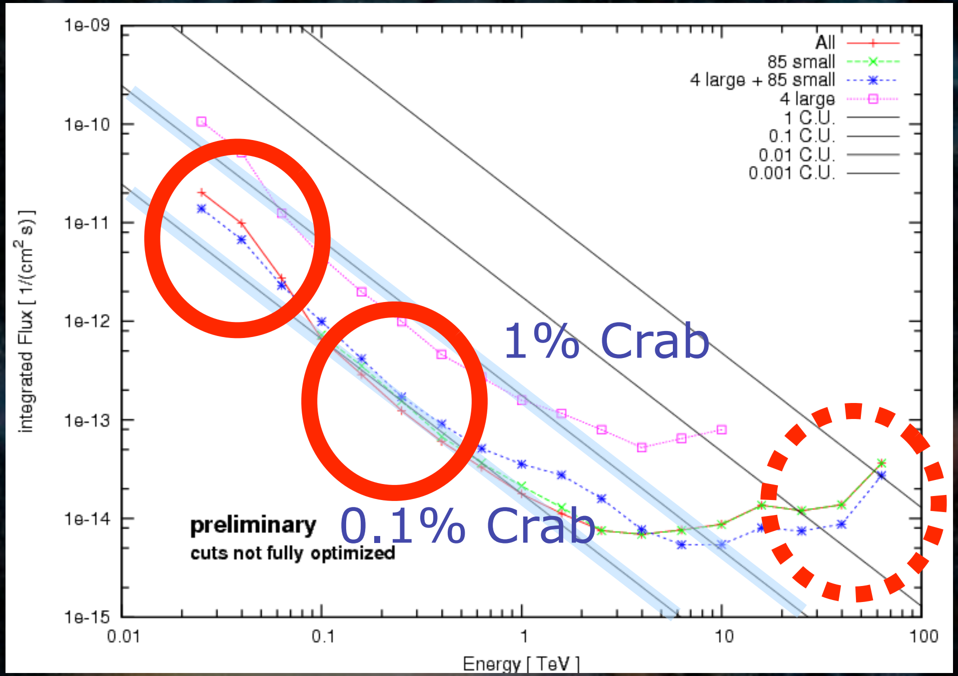
- 21-23m telescopes in the center of the array
- FOV 3 deg for point sources (AGN)
- MC studies show: The core array helps improving sensitivity at lower energies (acts as kind of veto)

Layout possibilities

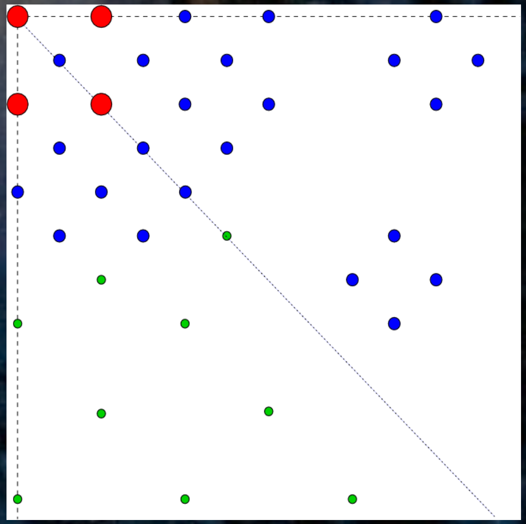
Extension to higher energies O(100TeV):

- Distribute 100 small 5m telescopes over 5 km^2
- Large FOV 5-7 deg
- Very large collection area for 300 TeV fluxes
- Act as Pi-zero small sub-shower veto for larger telescopes

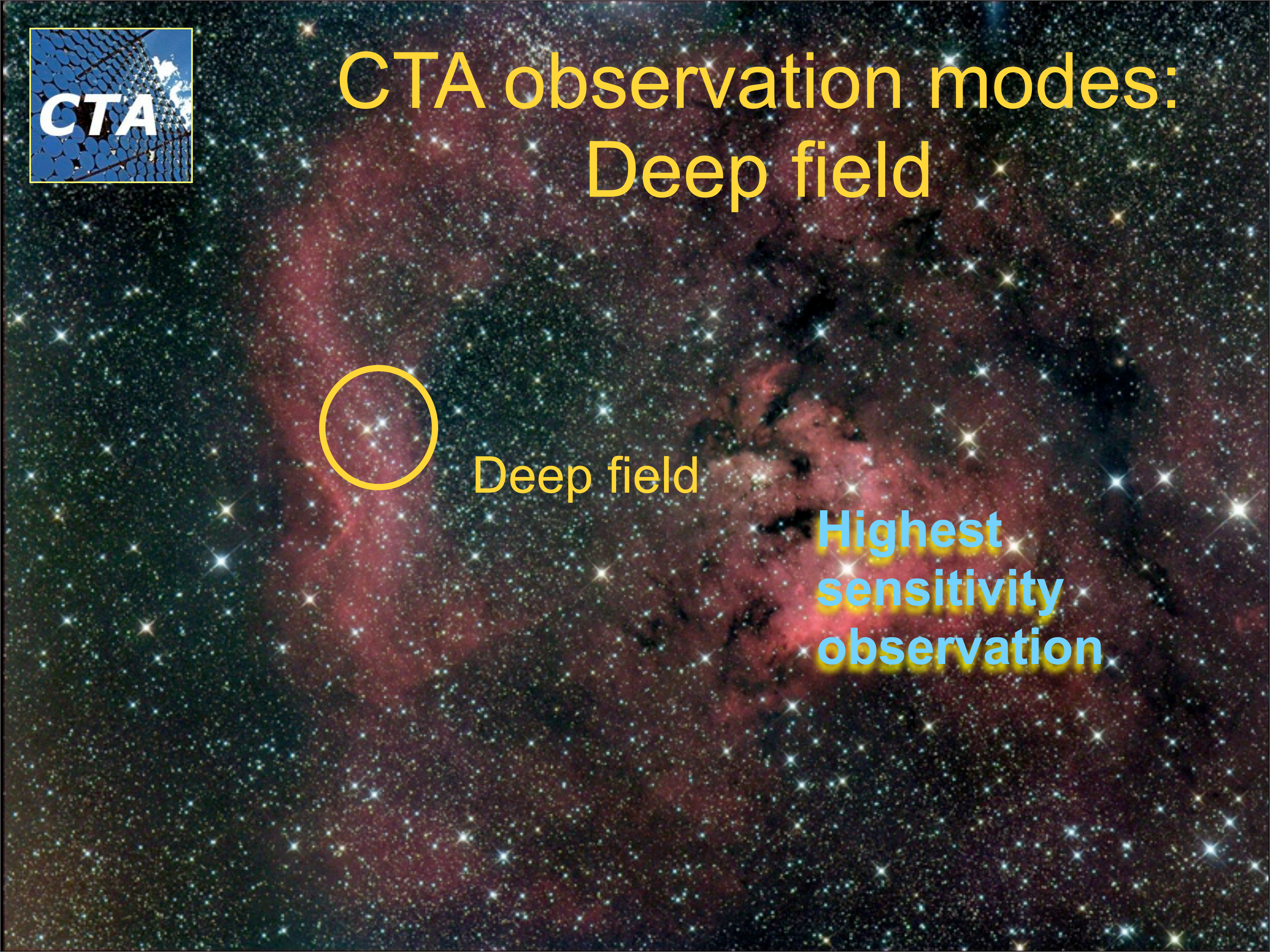
Preliminary MC results: 85 small + 4 big telescopes



- Different telescope sizes for different energy ranges
  - Large telescopes provide for low energy sensitivity
  - Many telescopes provide high sensitivity
  - Large coll. area provides sensitivity at high energies
- MC Simulation:
  - 23m diameter (5° FOV, 0.1° pixel size)
  - 10m diameter (7° FOV, 0.16° pixel size)
- Photodetectors in MC
  - PMTs with 25% QE peak



CTA observation modes: Deep field



CTA observation modes: high flexibility

1/3 array
Deep field

1/3 array
Deep field

1 telescope
Monitor

4 telescopes
Monitor

Permanent monitoring of some AGN

--> ToO-triggers on huge flares

CTA observation modes: survey mode

Wide FOV Scan

Systematic scan of some good part of the sky

4 telescope Monitor

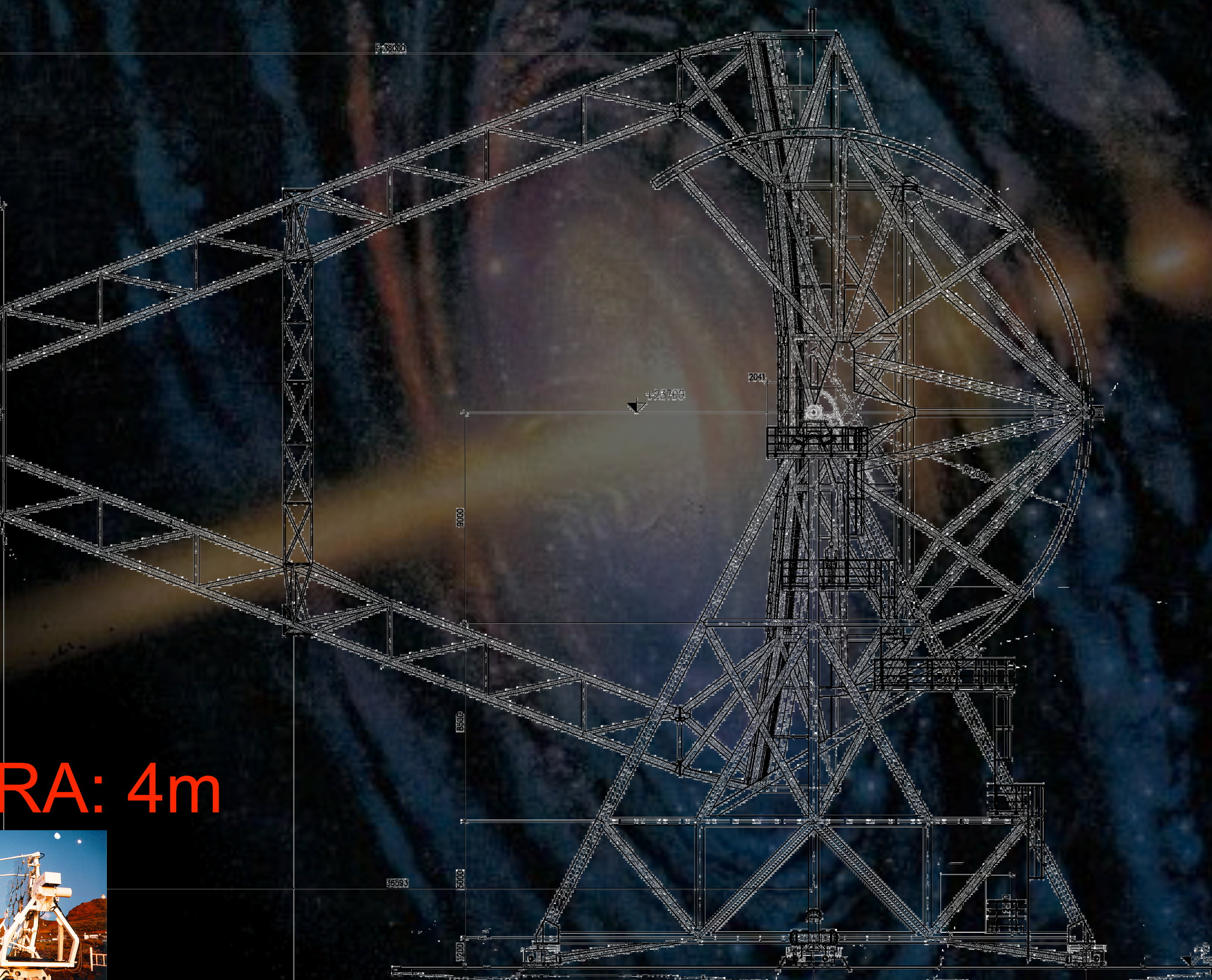
Design study: Telescope structures:

HESS / MAGIC / HEGRA as prototypes

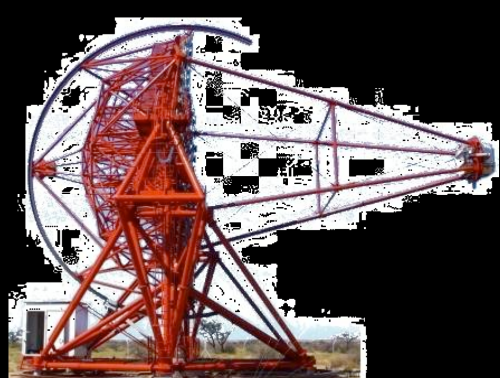
We could start constructing now already!!

MAGIC: 17m

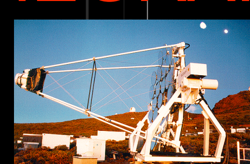
HESS II: 28m



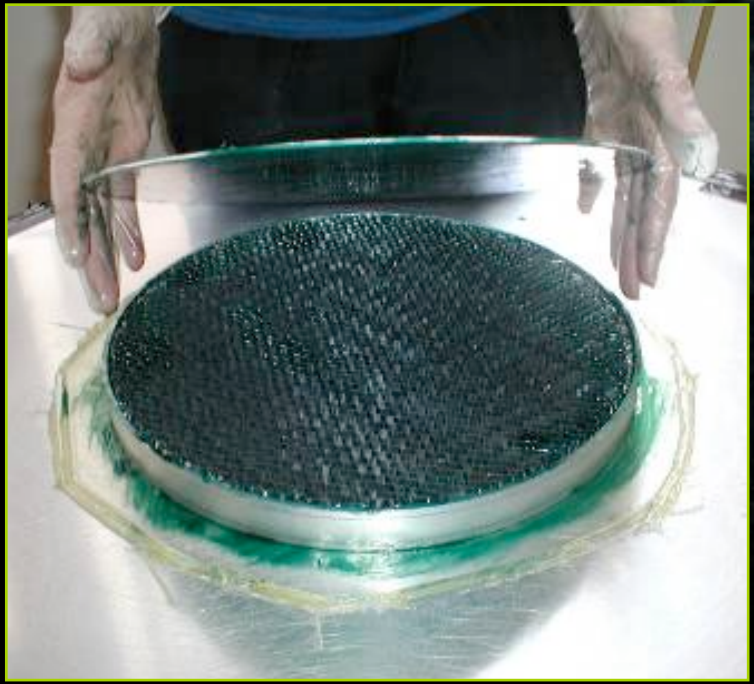
H.E.S.S. 13m



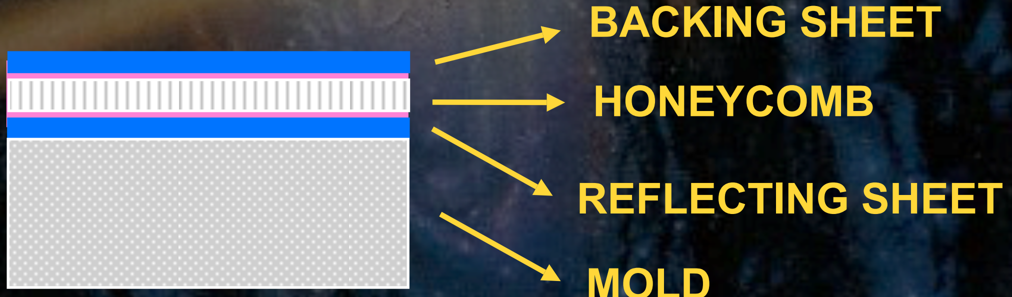
HEGRA: 4m



Mirrors must be cheap and good quality

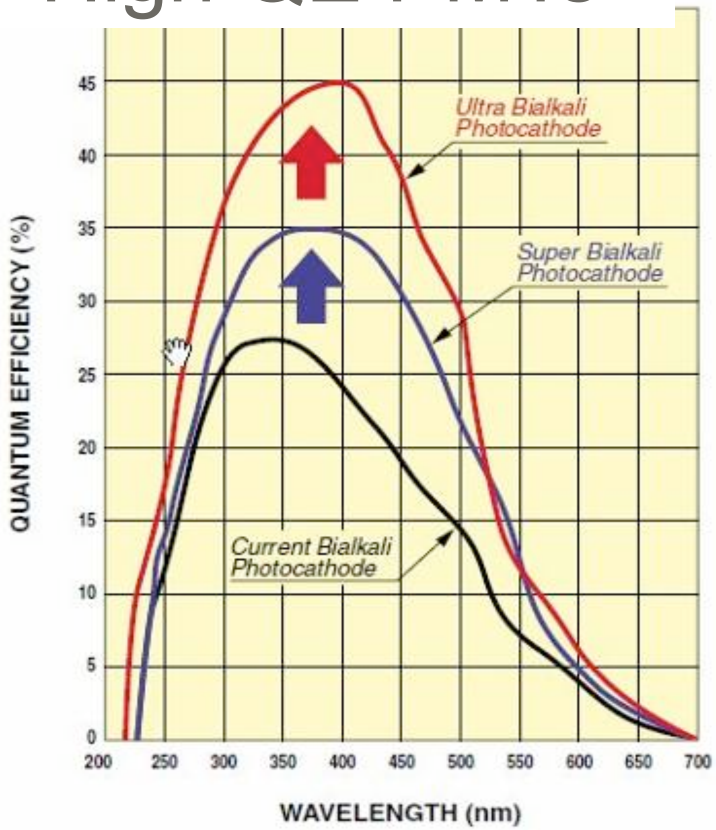


Replication techniques probably more promising for large-scale low-cost production, compared to grinding / milling of mirrors



High QE photosensors

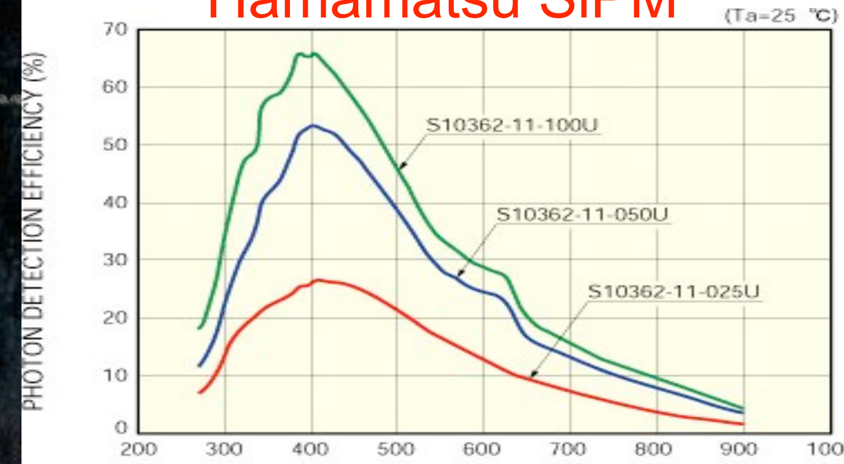
High QE PMTs



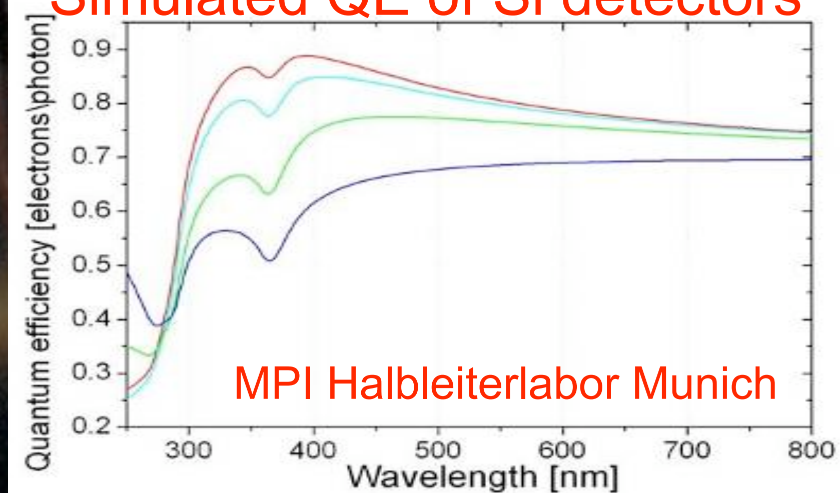
Hamamatsu & Photonis reach 45% QE

SiPM quantum efficiency:

Hamamatsu SiPM



Simulated QE of Si detectors

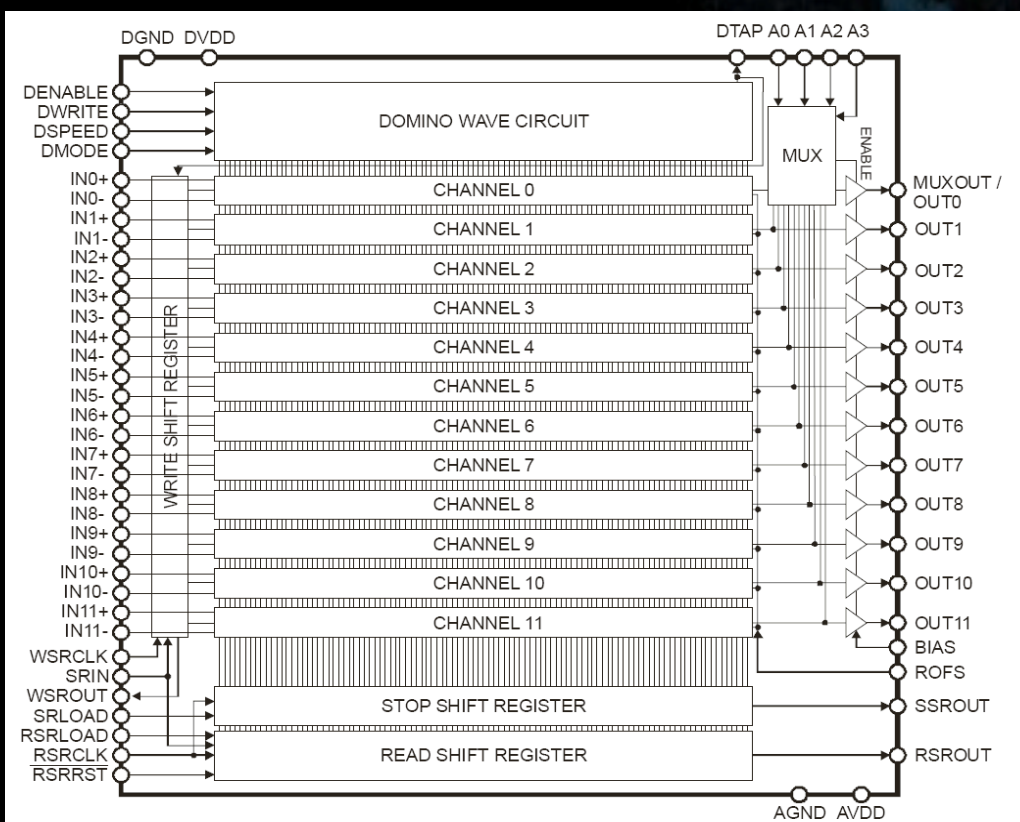


About 60% effective PDE might be realistic in the future

Fast signal digitization vs analog ADC

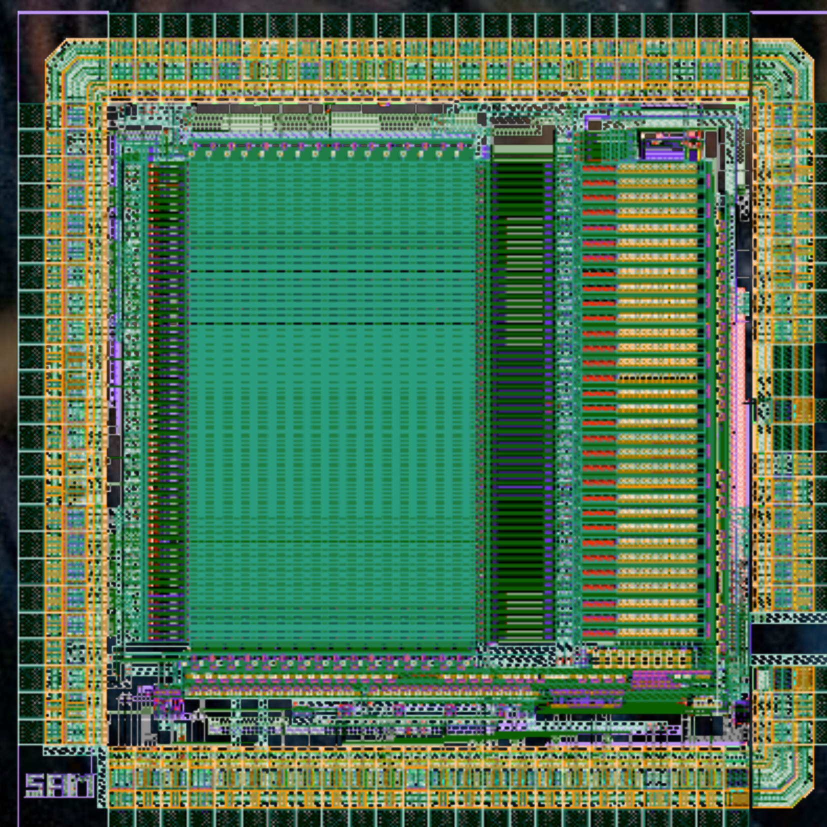
DRS3 (--> DRS4)

12 x 1024 samples
up to 5 Gsamples/s
11.5 bit effective range
450 MHz bandwidth
25 mm^2



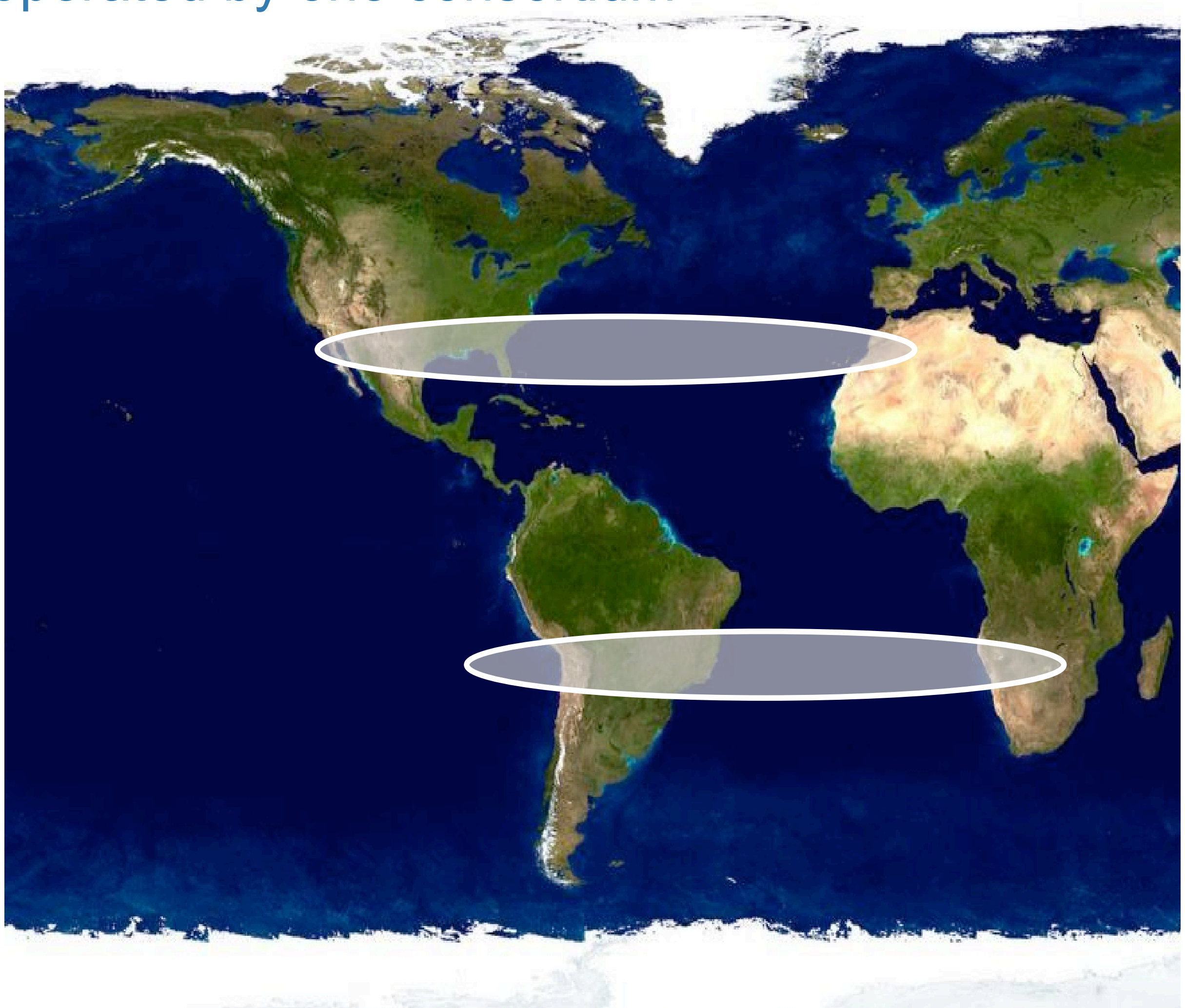
SAM

2 x 256 samples
up to 2 Gsamples/s
12 bit effective range
350 MHz bandwidth
11 mm^2



Two installations: full sky coverage

One observatory with two sites
operated by one consortium



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

CTA Structure now: Workpackages

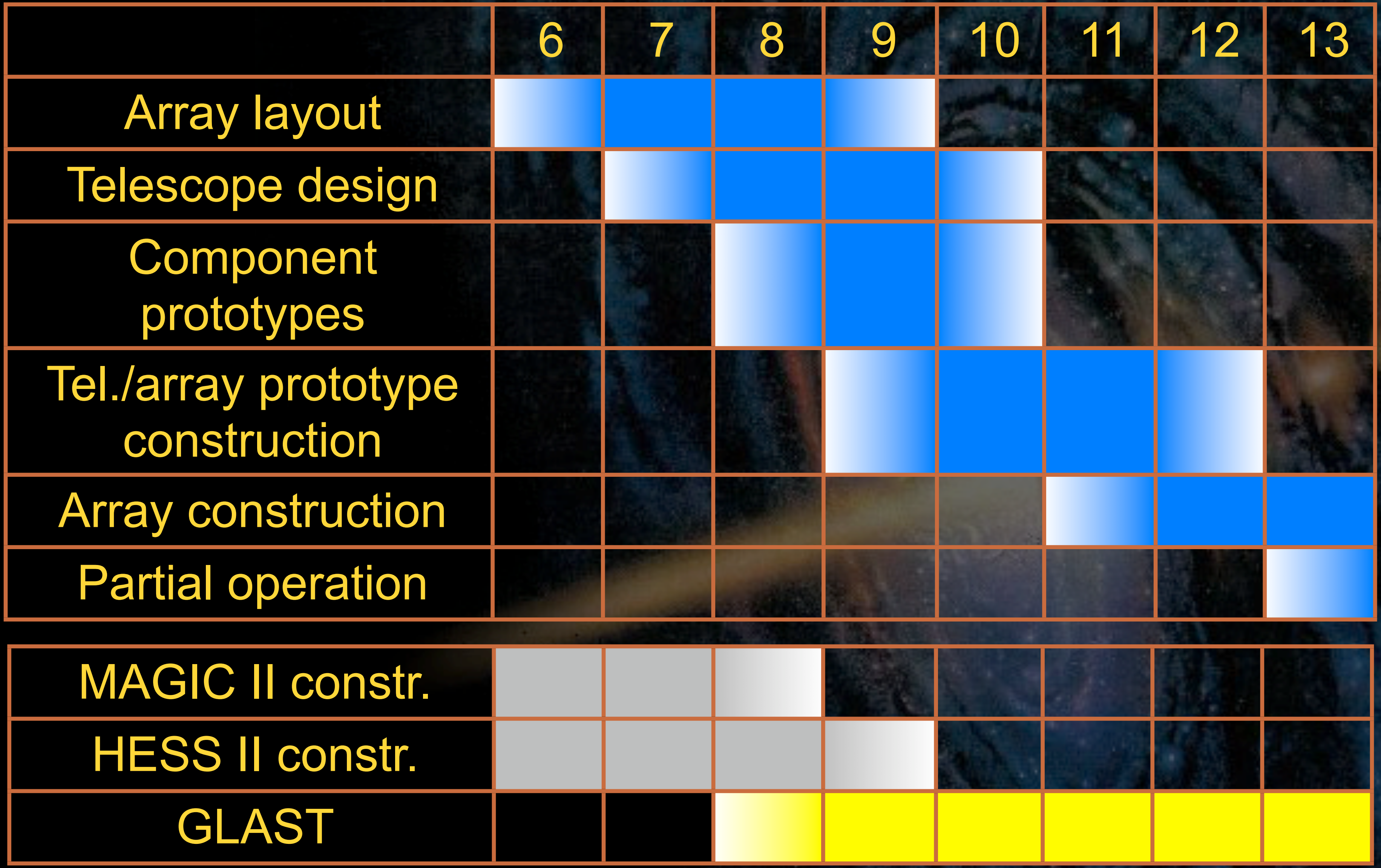
Work Packages:

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 Meetings

May 29-30, 2008, WP MC in Berlin
May 14-16, 2008, WP SITE in Pisa
May 8-9, 2008, WP Datacenter, Zurich
April 14 - 18, 2008, WP Electronics + Focal Plane in Paris, France
April 14 - 18, 2008, WP Telescope + Mirror in Heidelberg
Jan. 24/25, 2008 CTA general meeting Barcelona
Dec. 10, 2007 WP/WG conveners meeting Munich
July 23/24, 2007 WP/WG conveners meeting Heidelberg
March 1/2, 2007 CTA general meeting Paris
Jan. 22, 2007 MC WG group meeting Heidelberg
Nov. 30, 2006 WG conveners meeting Munich
Nov. 17, 2006 Mount & mirror WG meeting Heidelberg
Nov. 15, 2006 MC WG meeting Munich
Nov. 6, 2006 Physics WG meeting Utrecht
Sept. 7, 2006 MC WG meeting Heidelberg
Sept. 6, 2006 IT WG meeting Versoix
July 11, 2006 WG converners meeting Frankfurt
July 5/6, 2006 Camera WG meeting Munich
May 4/5, 2006 CTA kick-off meeting Berlin

Preliminary time line



Conclusions

- CTA is a next generation Cherenkov observatory with one order of magnitude better sensitivity, larger FOV and an improved angular resolution
- There will be one station in the North and one in the South
- European initiative but collaboration with institutions from all over the world such as USA and Japan
- It will be run as an observatory, open to external astronomers
- CTA will be a very large project with around 50 institutions and 500 physicists
- Aiming for a budget of 150 Mio Euros

The end

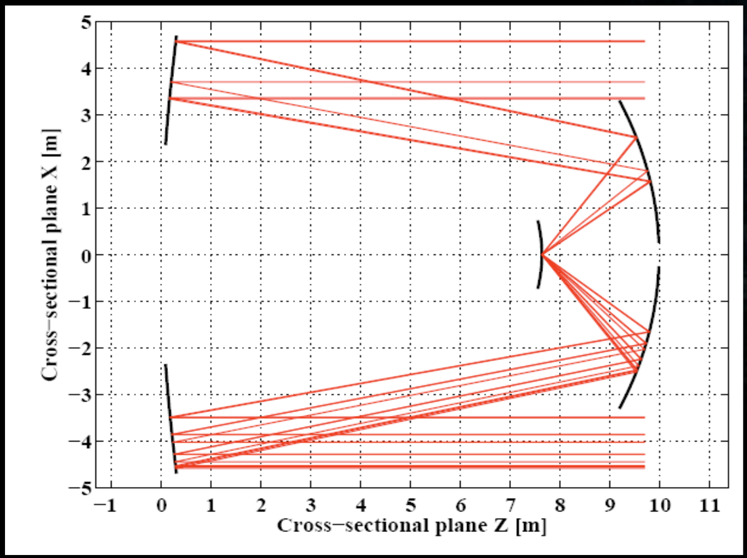
Datacenter and operations center for CTA

- Challenges:
  - ✓ Huge data rates (0.5 PBytes/Year)
  - ✓ Observatory: Automatic calibration and analysis for users

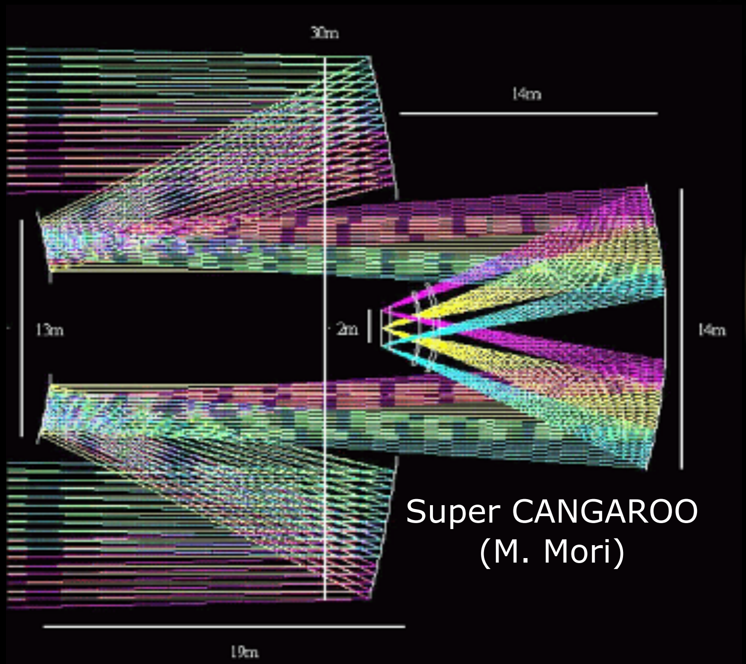

European space operations center

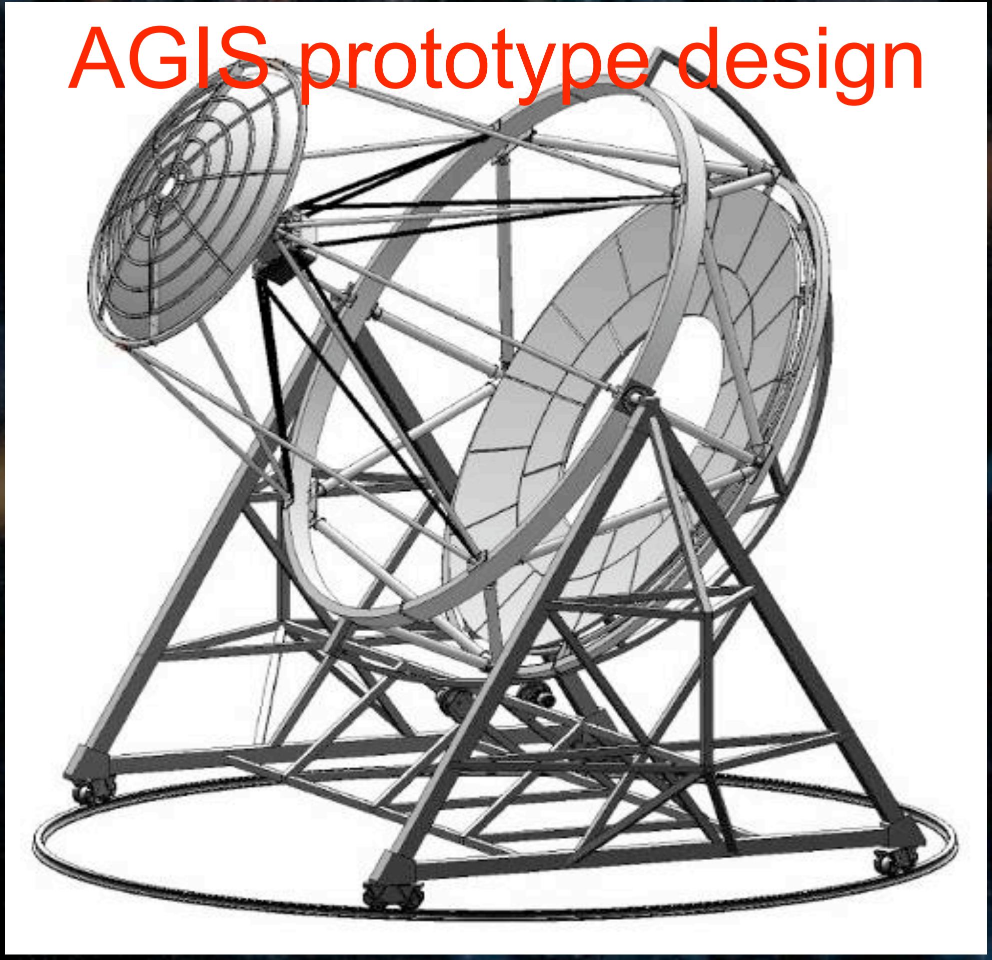
- Organisatorial structure:
  - ✓ Array operation center
  - ✓ Data handling and analysis center
  - ✓ Science operation center
  - ✓ Maybe array control center and data handling in different locations
- Lots of personal (local technicians, operation crew, professional data analyzers for science operation) --> expensive

Telescope optics & wide field of view: 10-20 deg



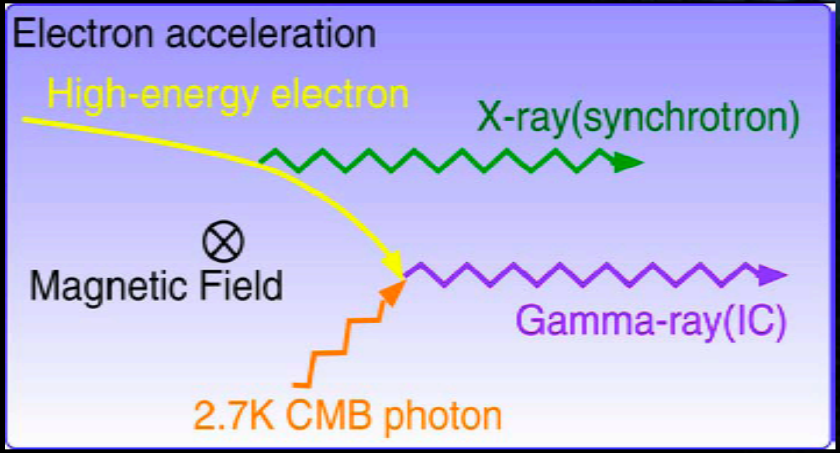
- Very high technical challenge: secondary mirror distance must be controlled by 100um !

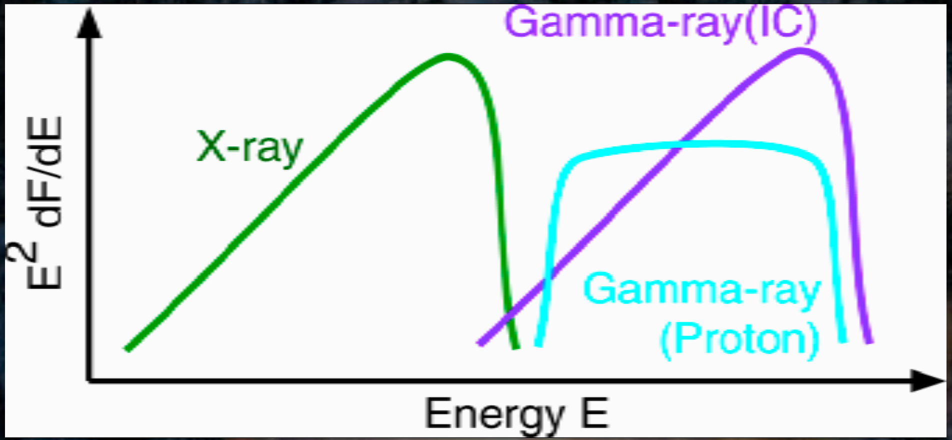


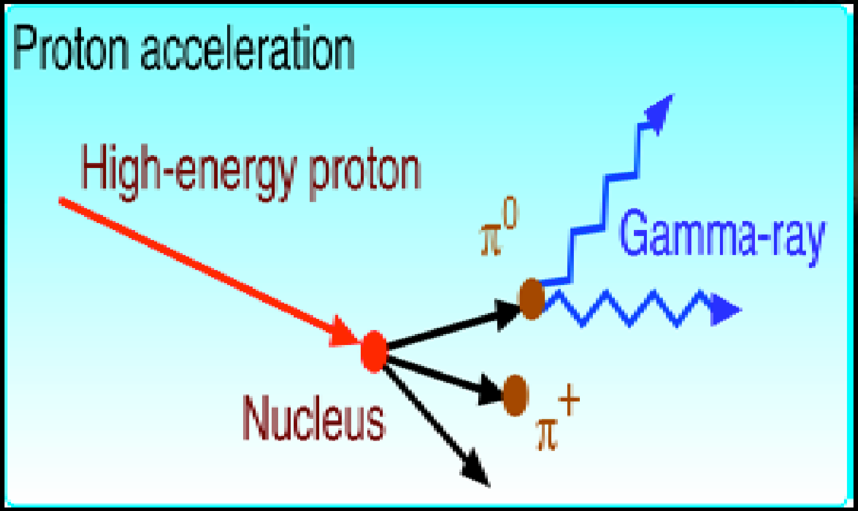


Which objects contribute to hadronic cosmic rays ?

Question: In which objects do we have hadronic acceleration and in which objects leptonic acceleration ?







- SSC model: leptonic acceleration
  - High energy gamma rays
  - Strong synchrotron emission
- π^0-decay: hadronic acceleration
  - High energy gamma rays
  - High energy hadrons --> CR
  - 10 TeV proton -> 1 TeV gamma

Differential flux sensitivity