The MAGIC Telescope

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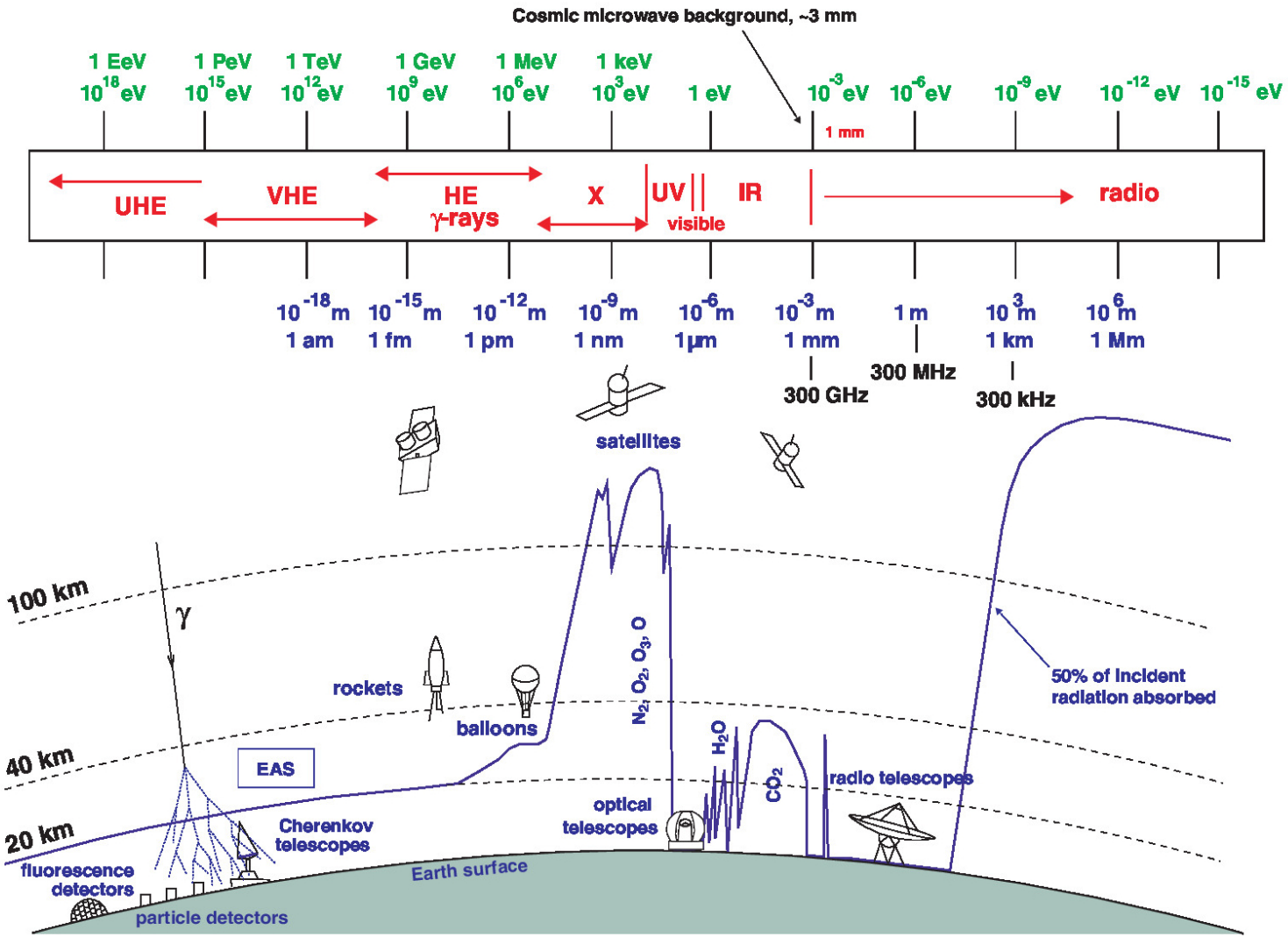
October 29th, 2019, Dubna

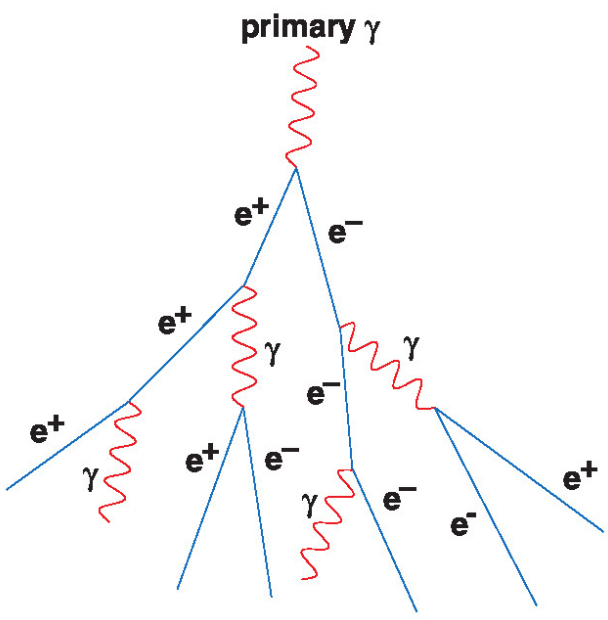
Introduction

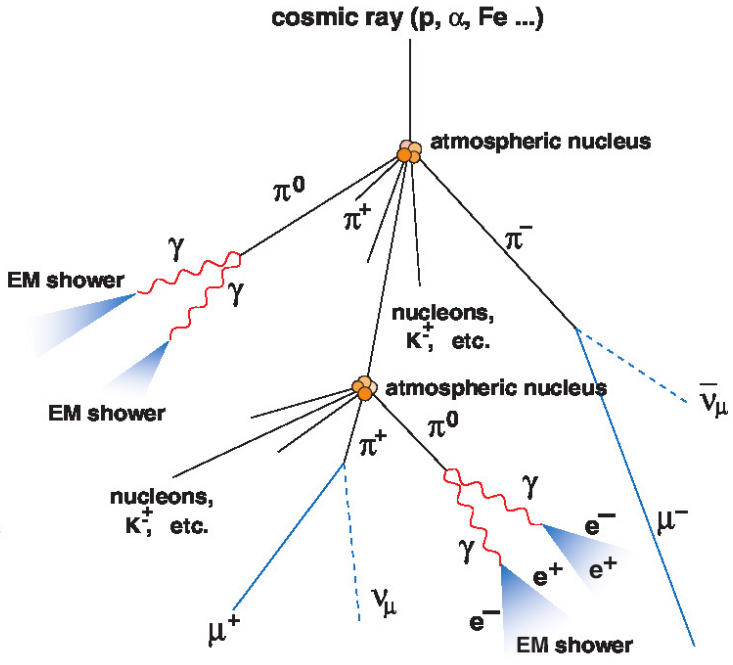
- Electromagnetic spectrum
- Imaging Athmospheric Cherenkov Telescopes (IACT)
- MAGIC Telescopes
- Physics Goals

Electromagnetic Spectrum



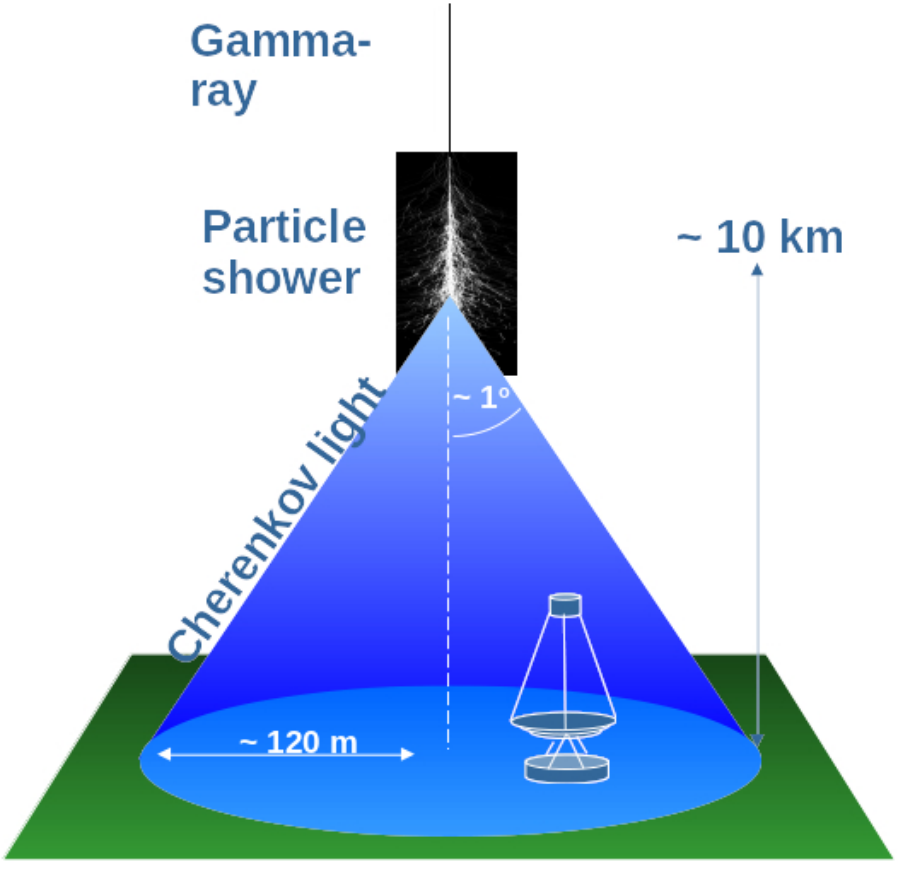
Athmospheric Showers





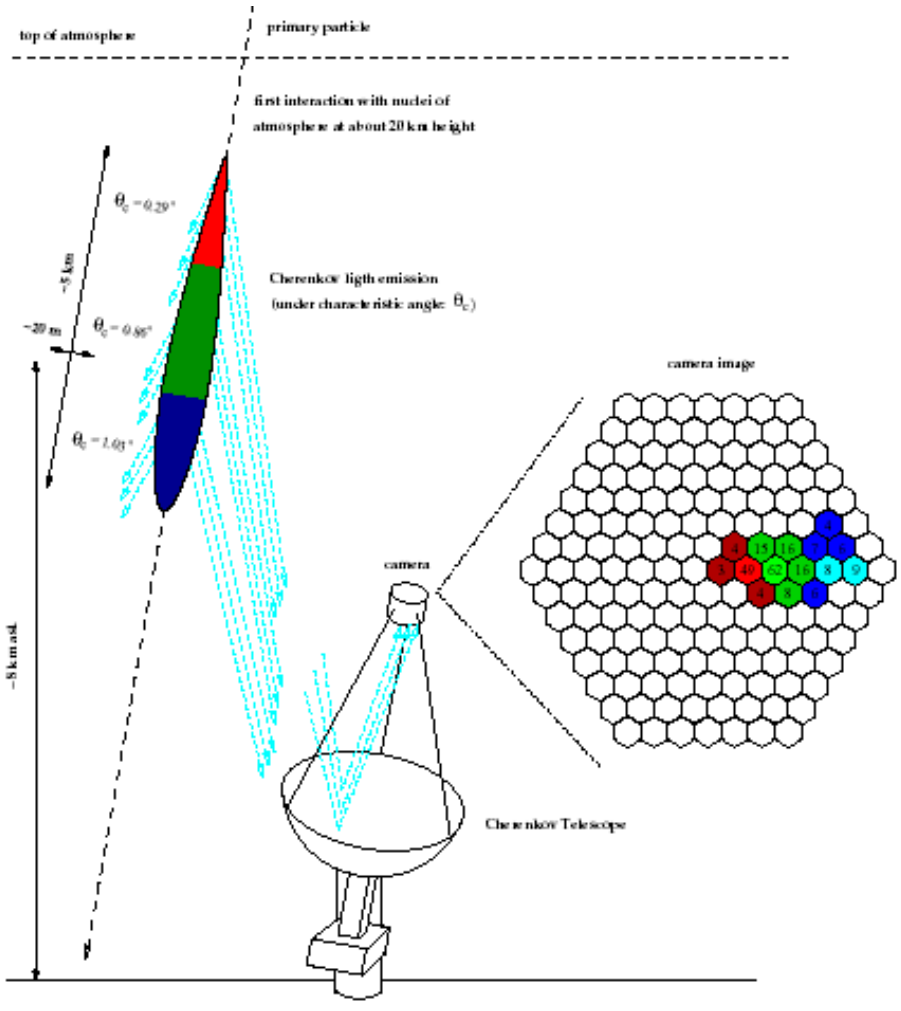
- ES: bremsstrahlung and pair creation
- HS: hadronic interactions. Contains ES
- Ratio of hadron/gamma entering atmosphere is 1000:1
- HS are wider than ES

Cerenkov Radiation



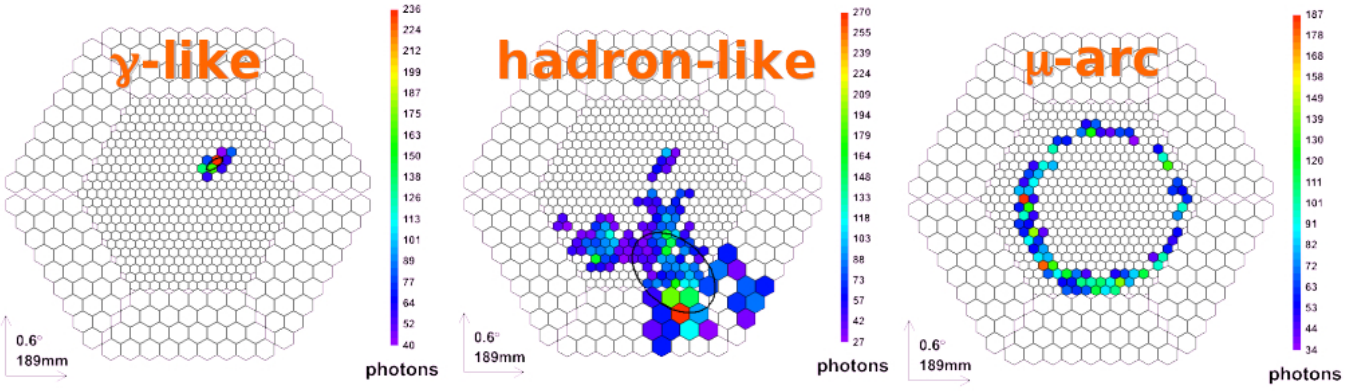
- $\cos(\Theta) = \frac{1}{\beta n}$, $\Theta \leq 1^o$
- Spread of the Cerenkov cone – r $= 120$ m
- $\lambda = 300 - 500$ nm
- Duration is 3 ns

The Imaging Technique



- Imaging Athmospheric Cherenkov Telescopes
- Camera is placed in the focal point of the reflector
- Higher altitudes correspond to smaller angle of the Cerenkov photons

Athmospheric Showers

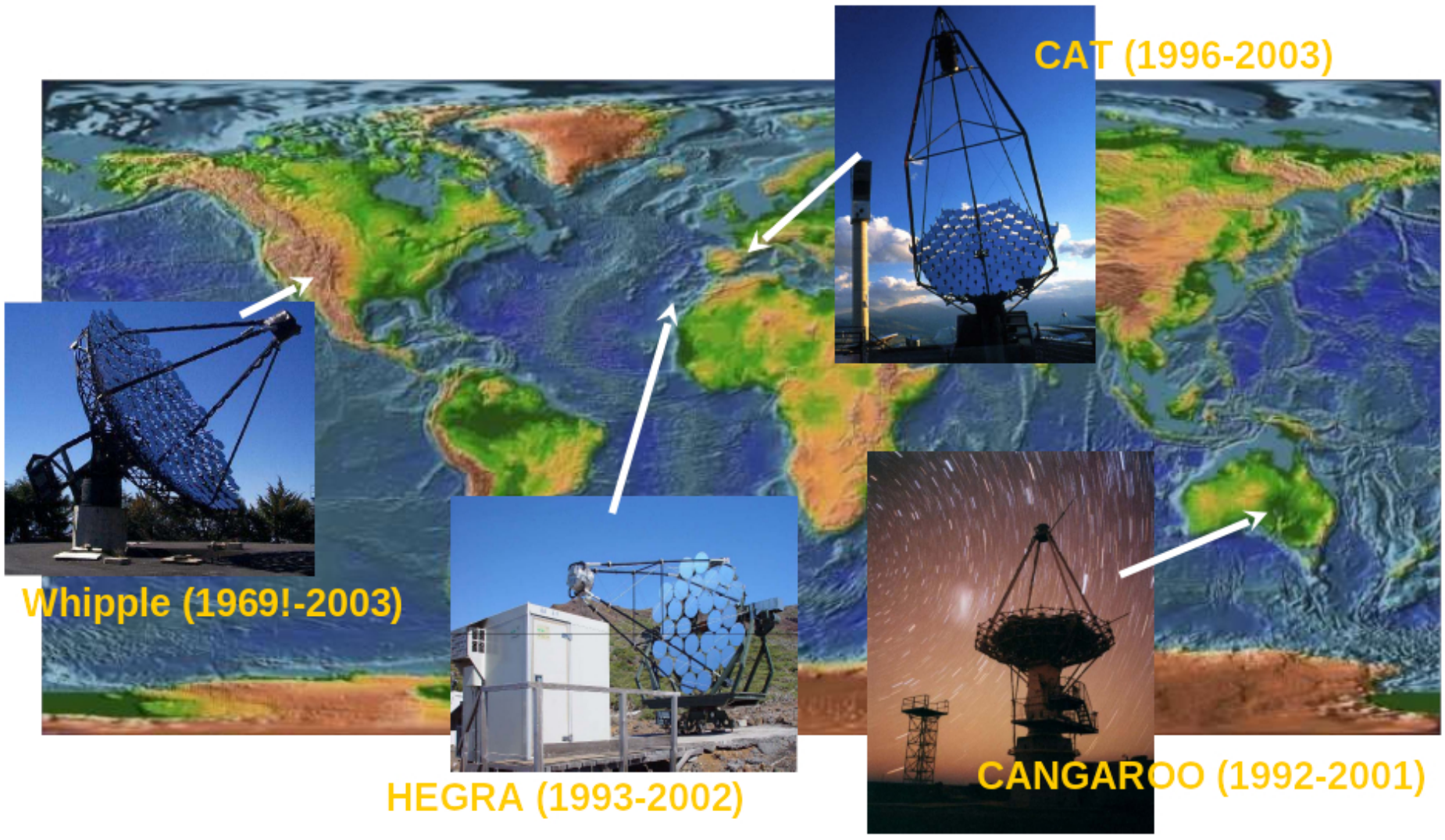


- Gamma image is a ellipse with major axes pointing to source position
- Hadron showers arrival direction is isotopically distributed
- Muon ring

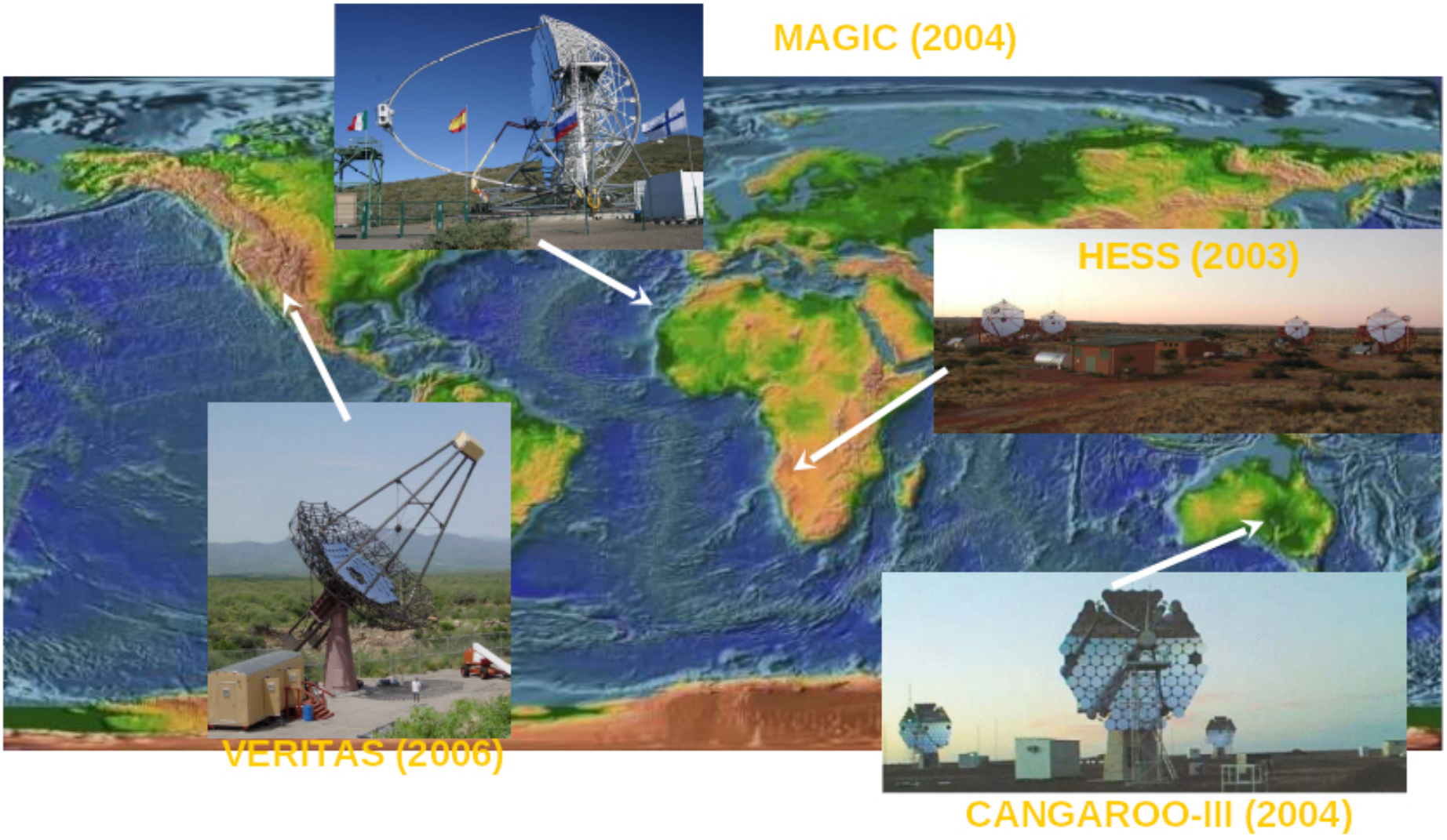
First generation

1. First four telescopes of 1.55 m in 1960 at Crimea
2. Energy threshould was $\sim$ 3.4 GeV
3. No signal was detected over 4 years of observations
4. The limit set for Crab Nebula flux was avout 20 times above the real one

Second generation



Third generation

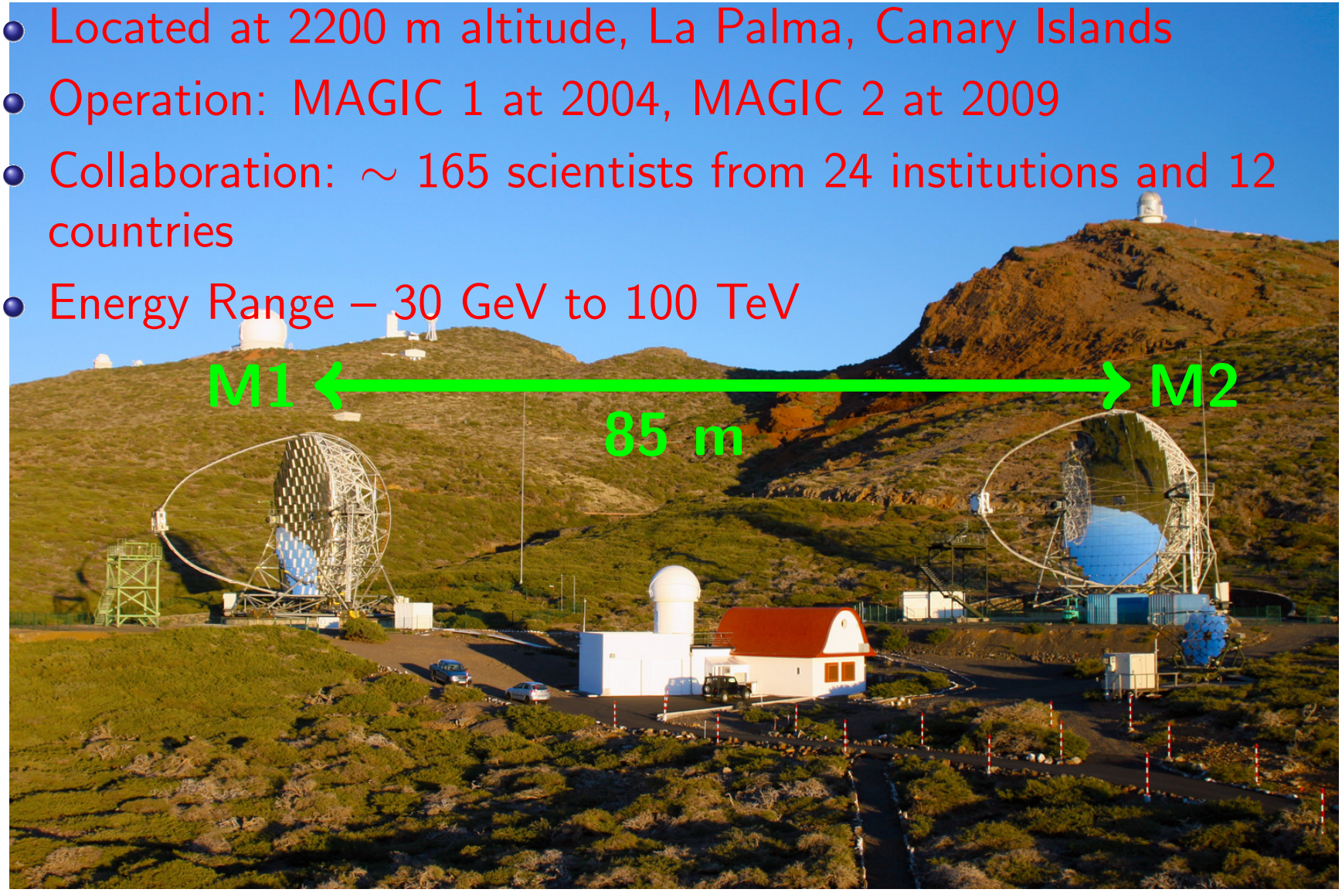


Forth generation

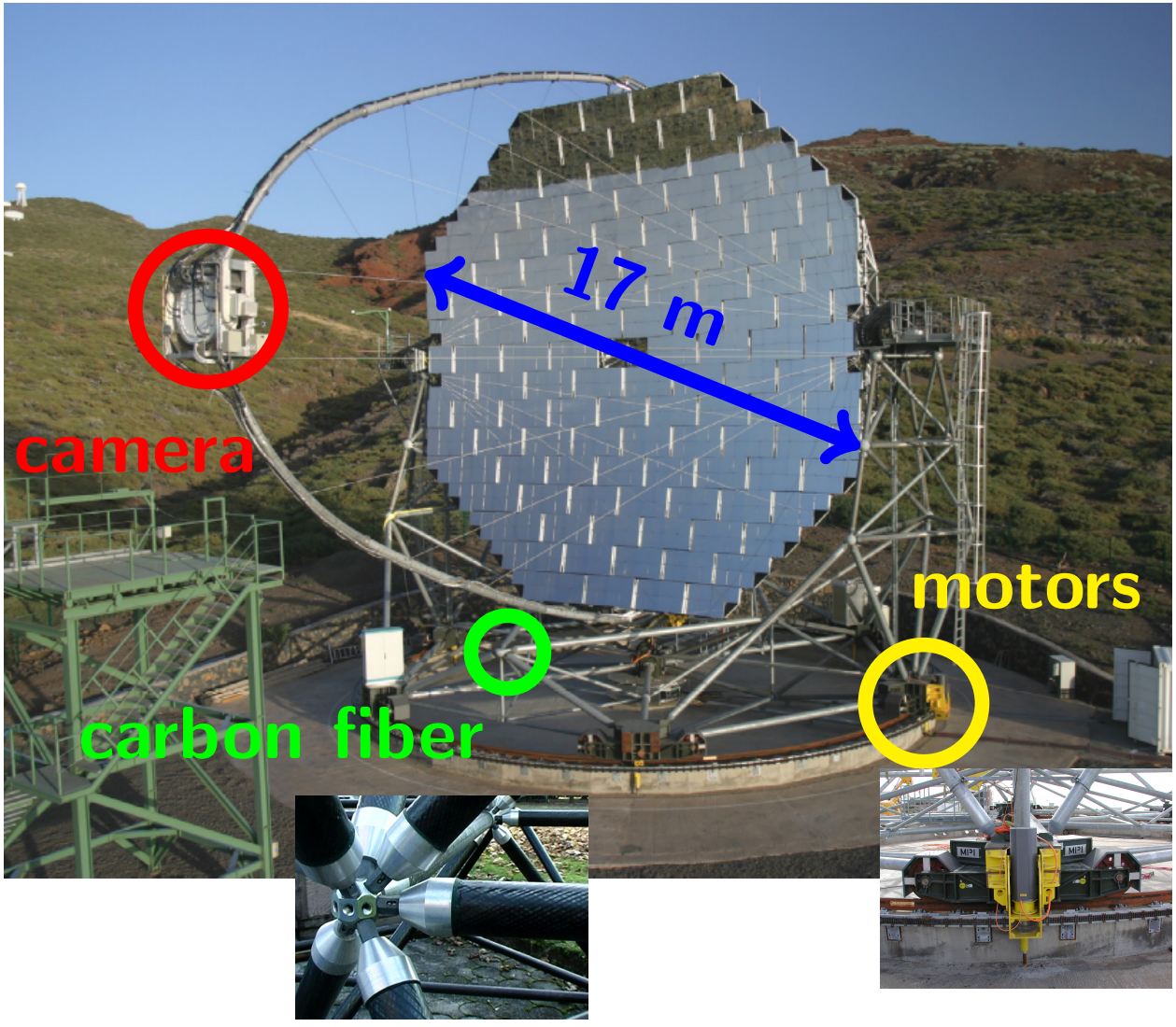
The MAGIC Telescopes

The MAGIC Telescopes

- Located at 2200 m altitude, La Palma, Canary Islands
- Operation: MAGIC 1 at 2004, MAGIC 2 at 2009
- Collaboration: $\sim$ 165 scientists from 24 institutions and 12 countries
- Energy Range – 30 GeV to 100 TeV



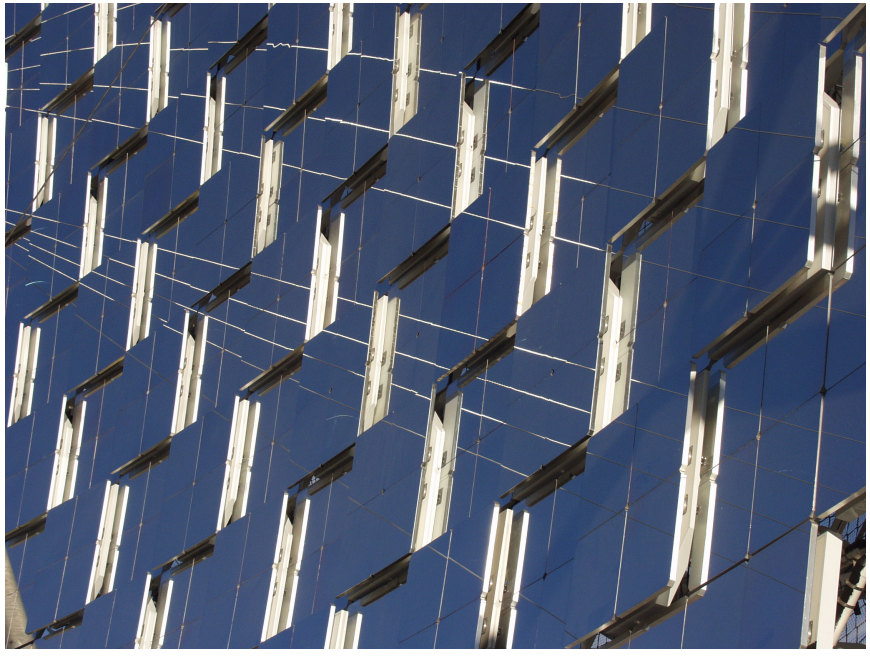
The MAGIC Telescopes



- Mirror diameter 17 m
- Camera FOV 3.5°
- Two 11 kW motors for azimuth movement
- One elevation motor
- Carbon-fiber structure
- Total weight of 66 t
- Repositing time $\sim$ 40 s

Mirrors

M1



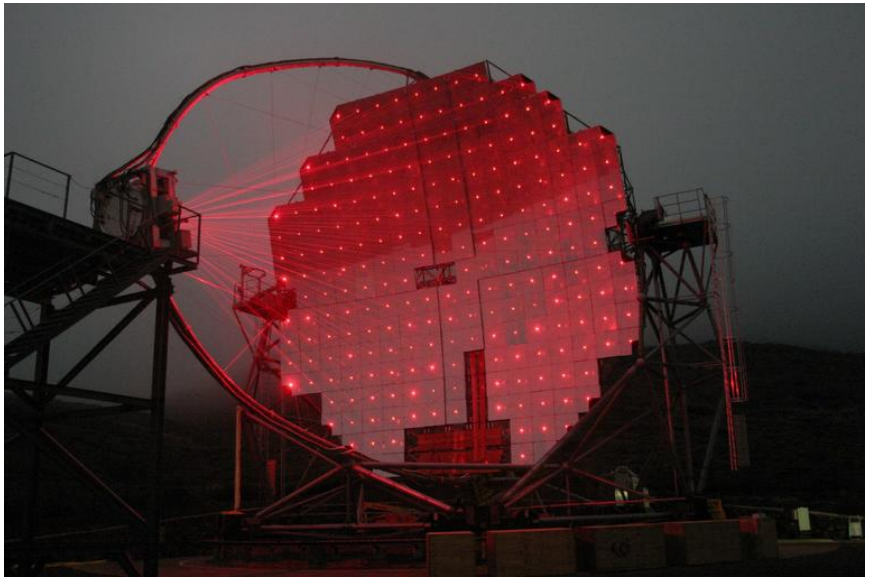
- 247 panels installed in chess-board configuration
- Each panel consist of 3 or 4 segments
- All Al-mirrors
- Total surface of 236 m^2

M2

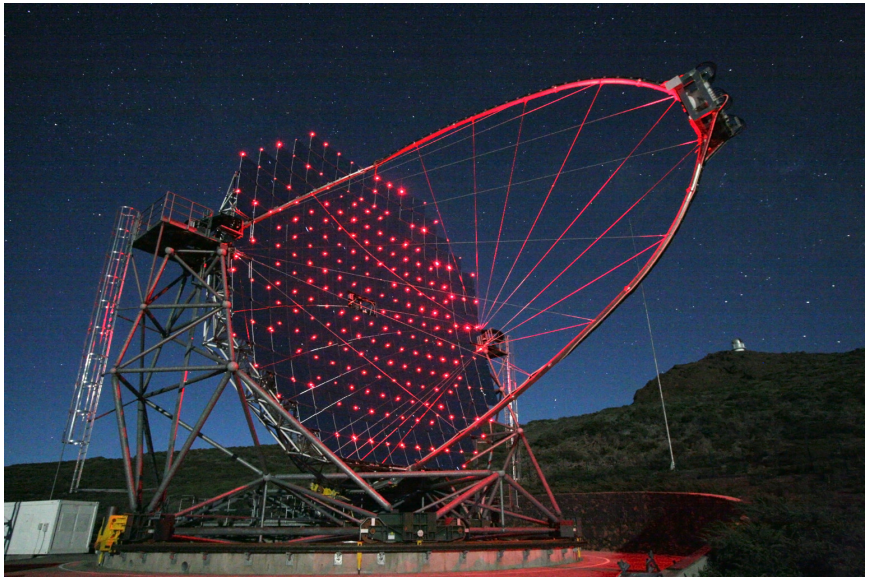
- 247 large mirror segments
- 143 all Al-mirrors, 104 glass mirrors
- Total surface of 241.5 m^2

Active Mirror Control

M1



M2



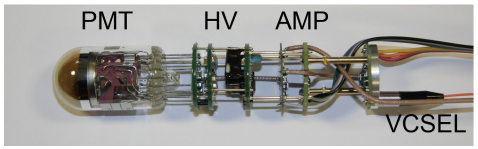
- To correct for distortions of the telescope frame
- The system consists of two actuators per mirror panel and a laser in the center of the mirror
- The predefined tables are used
- Mirror position depends on zenith angle

Camera

M1 pre-upgrade 2011/2012

- FOV 3.5°
- 576 PMT two sizes
- FOV of single PMT 0.1°/0.2°
- QE: $\sim$ 25-30 %

M2 and M1 after upgrade



- FOV 3.5°
- 1039 one inch size
- FOV of single PMT 0.1°
- QE: $\sim$ 35 %

Camera

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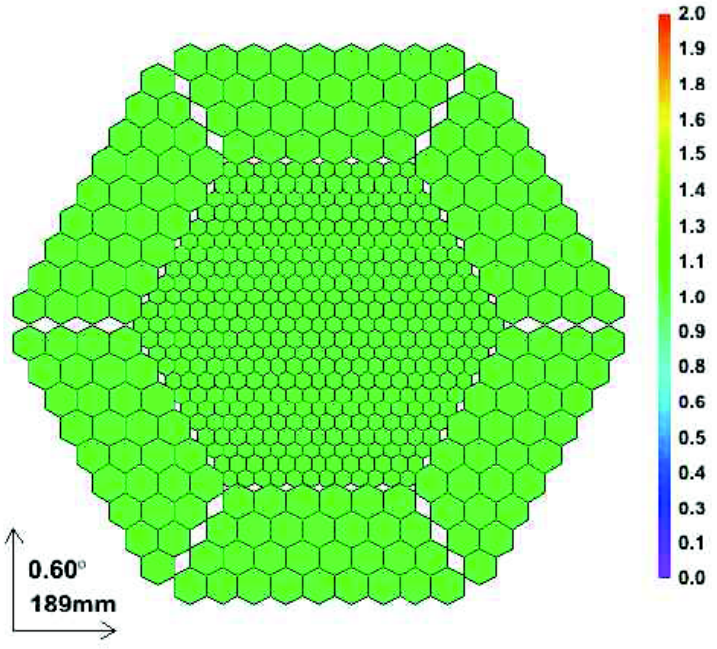

- FOV 3.5^o
- 576 PMT two sizes
- FOV of single PMT 0.1^o/0.2^o
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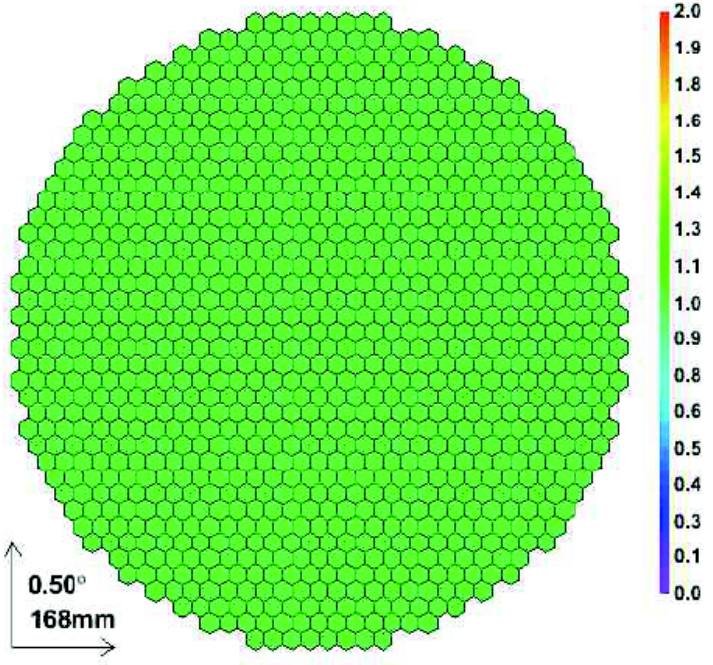
M2 and M1 after upgrade



- FOV 3.5^o
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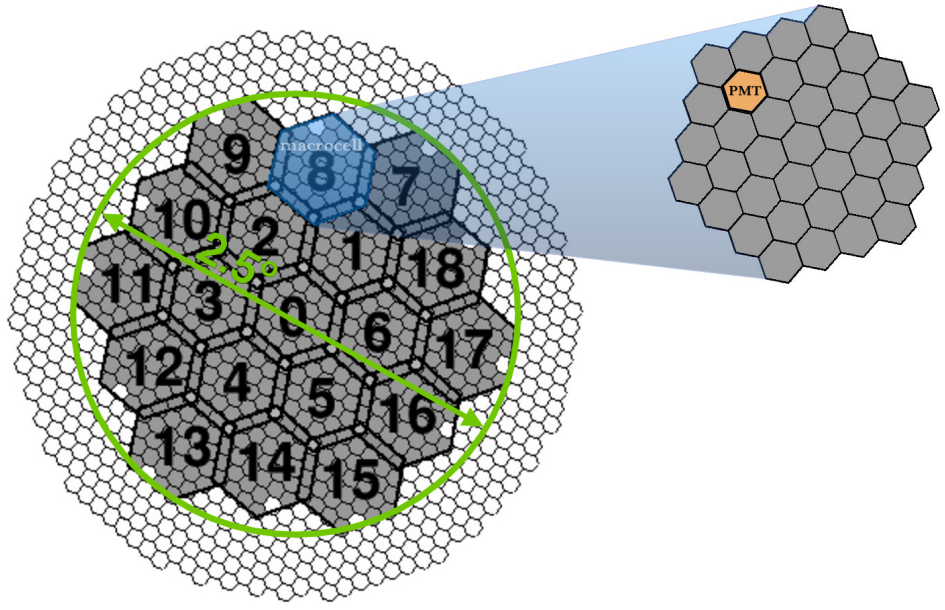
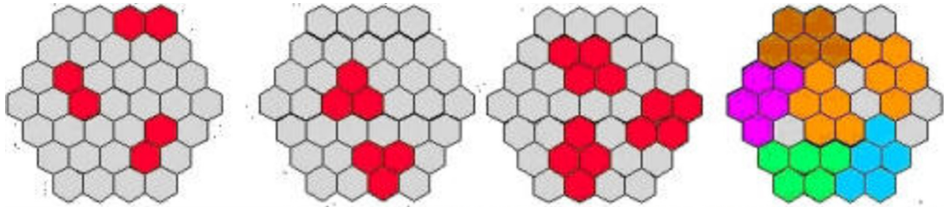
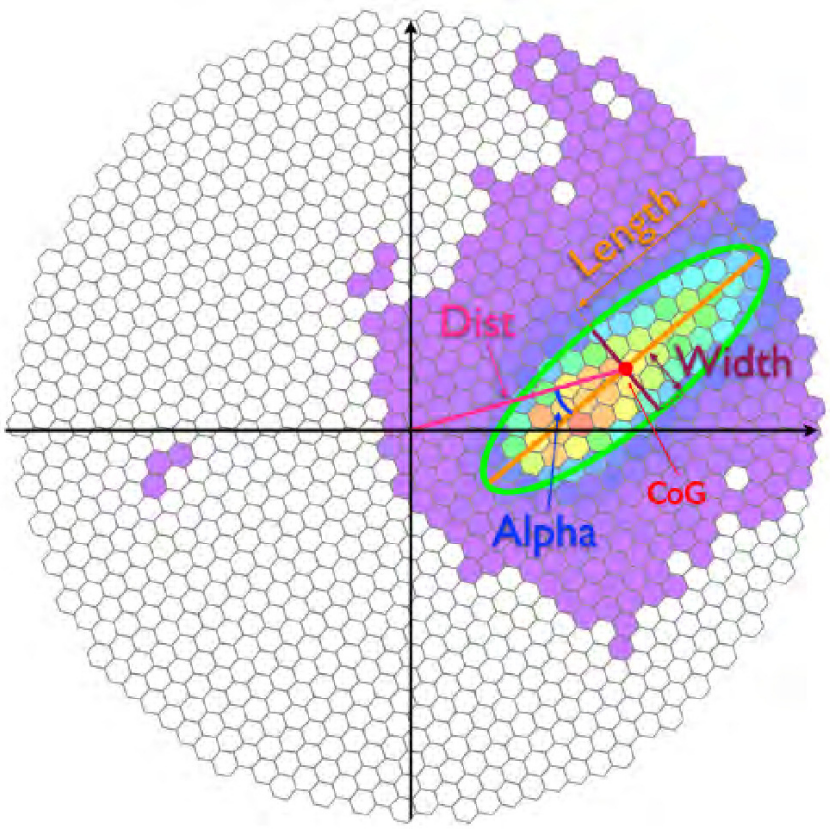
Trigger





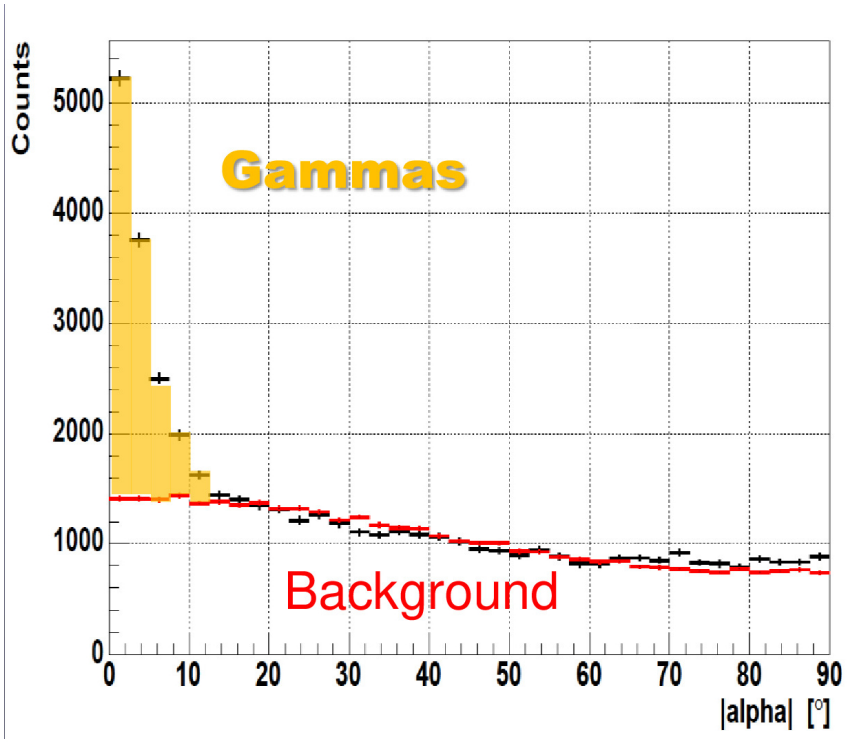
- Level 0: Discriminator threshold
- Level 1:
  - Trigger area is divided into 19 cells of 37 PMTs
  - Next Neighbour (NN) 2,3,4,5
  - 3NN stereo, 4NN mono mode
- Level 3: Stereo Mode
  - Signal is stretched to 100 ns
  - Coincidence within 180 ns

Hillas parameters



- ON/OFF mode
- Ellipse parameters:
  - Length
  - Width
  - Size
  - Alpha
  - Dist
- Hadronness is defined by RF
- RF is trained using MC gamma events and OFF data hadronic events

Hillas parameters



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- Ellipse parameters:
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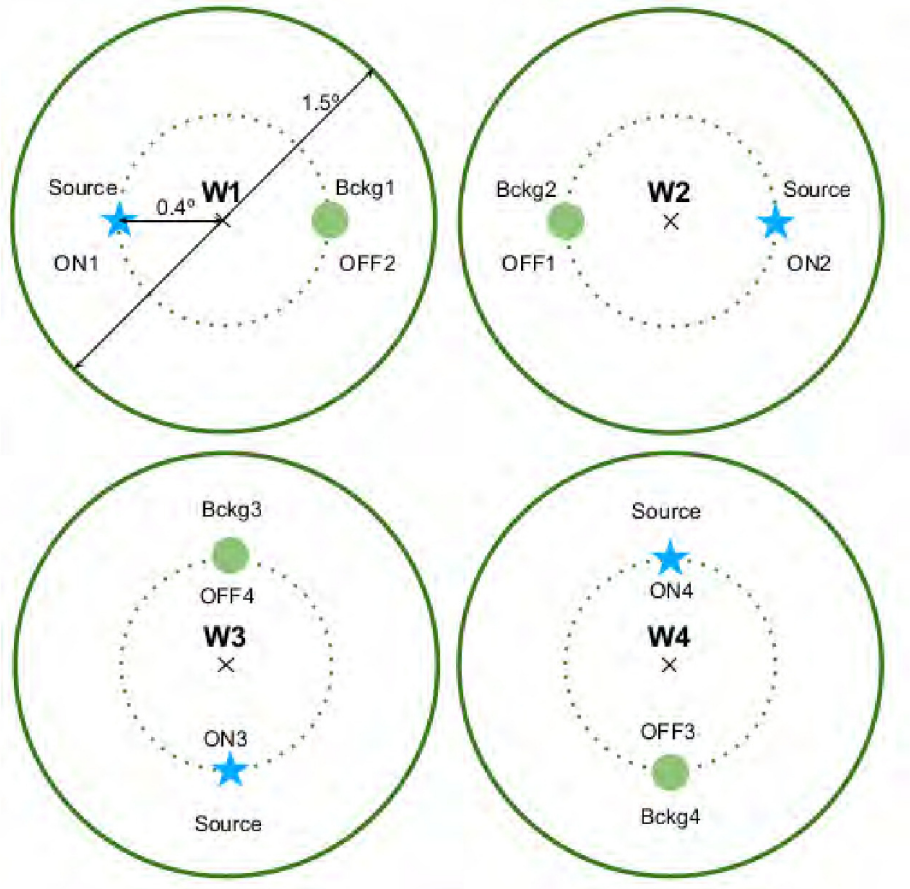
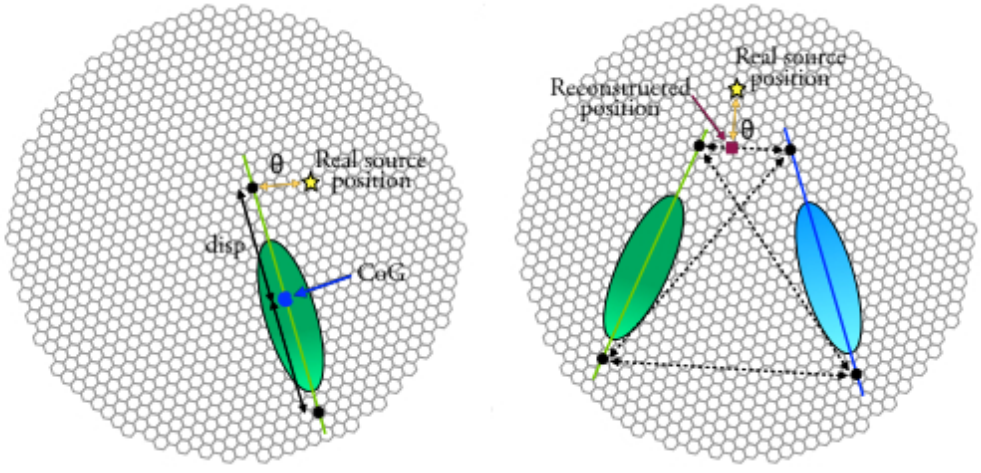
Wobble mode

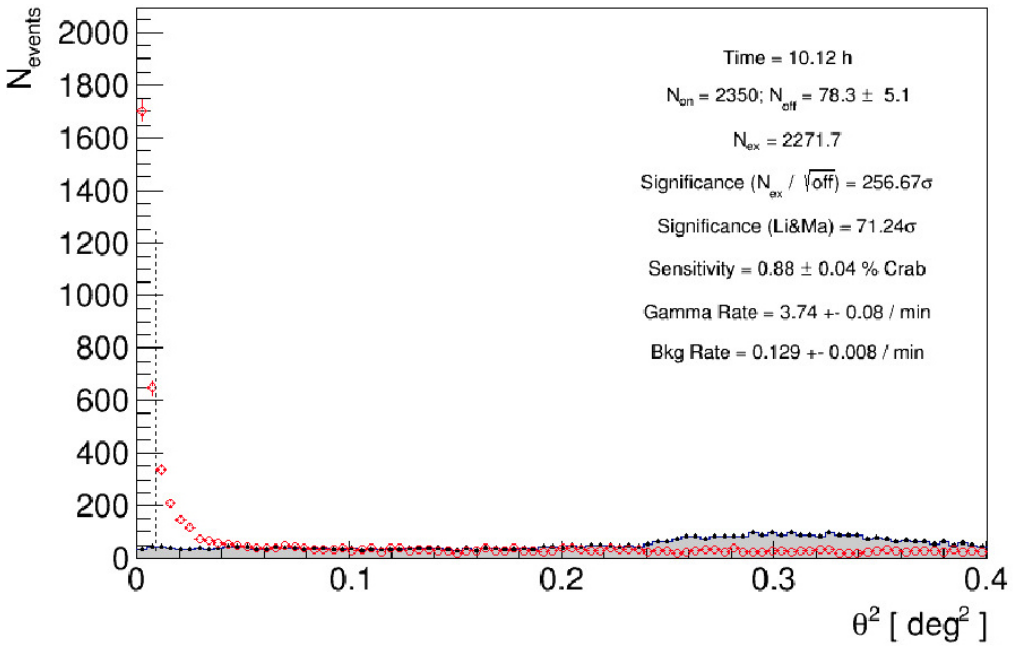


- Advantages:
  - Same conditions for ON/OFF events
  - No extra time for OFF mode
  - Optimal time coverage of the (variable) source
- Disadvantages:
  - Short time wobbling due to camera inhomogeneity
  - Small reduction in trigger region due to the offset

- Telescope pointing 0.4^o away from source
- Four different positions for 15/20 min

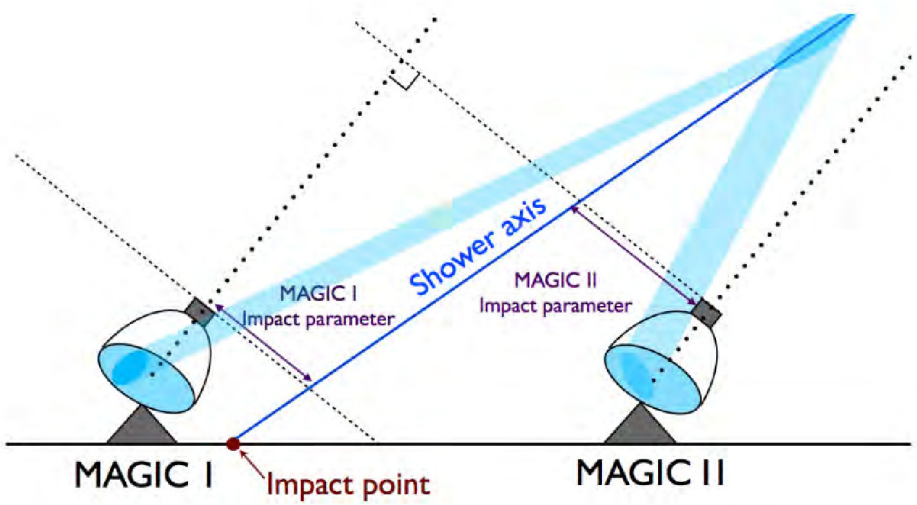
Θ^2 method

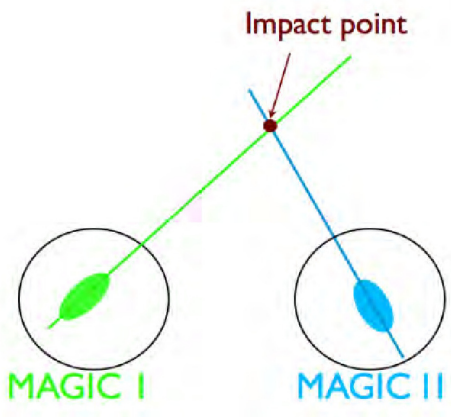




- Used in wobble mode
- Disp is the distance between CoG and source position
- Asymmetry or two telescopes
- Θ is the angular distance between reconstructed position and real position

Signal reconstruction

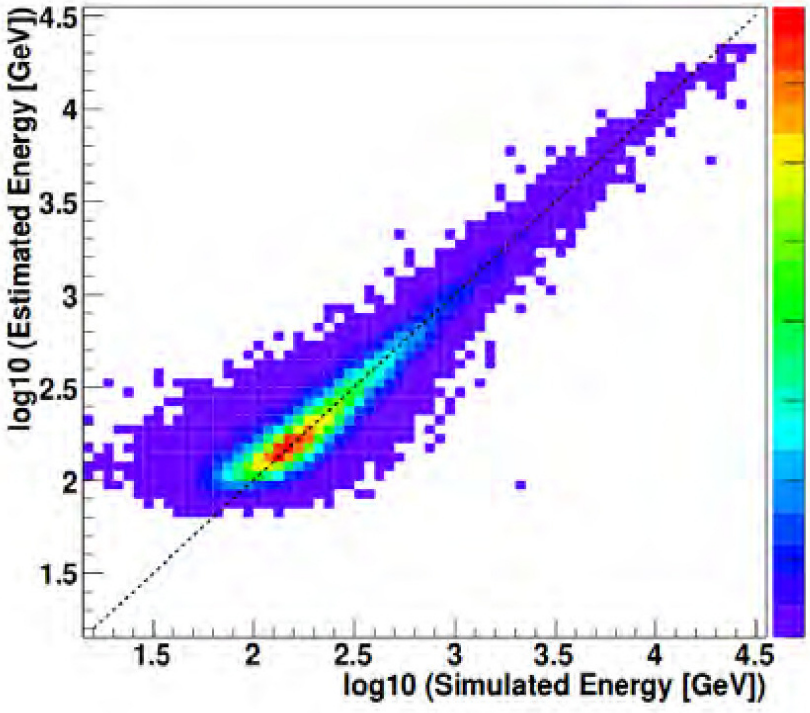


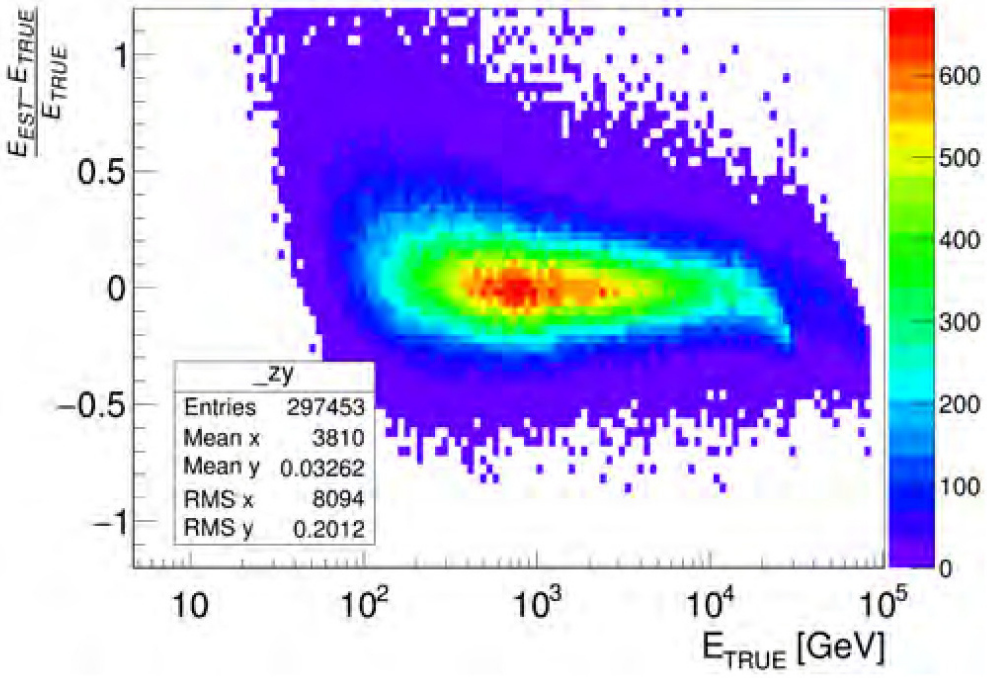


Reconstructed parameters:

- Shower axis
- Impact point
- Impact parameter
- Shower maximum height

Energy Estimation



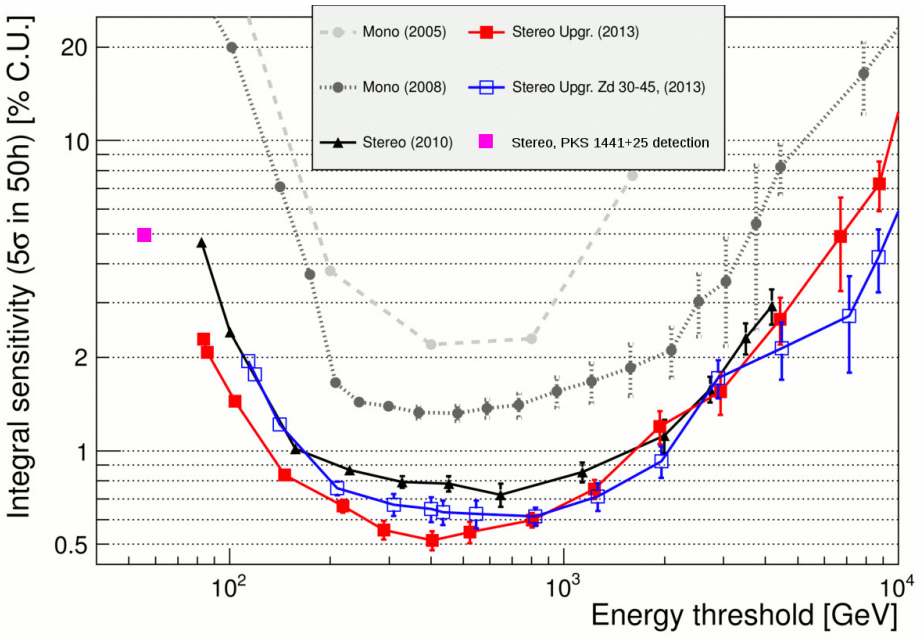


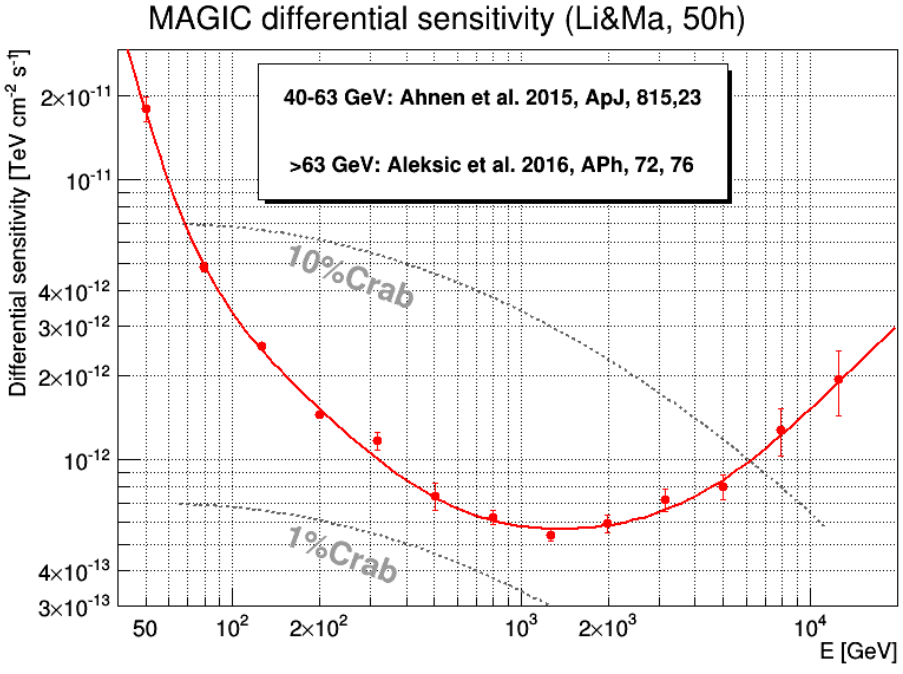
- Monte Carlo with CORSIKA using RF
- Energy resolution is 15 – 25 %

Flux and Sensitivity

$$\frac{d\Phi}{dE} = \frac{dN_\gamma(E)}{dE dA(E) dt}$$

- $dN_\gamma(E)$ is number of gamma events for a given energy E
- t is the effective time of source observation
- $A(E)$ is the effective area where the gammas are collected

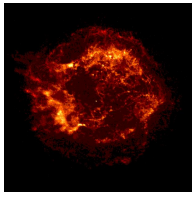




Physics Goals

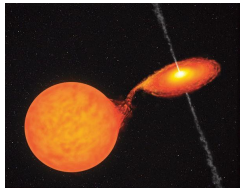
- Galactic

SNR

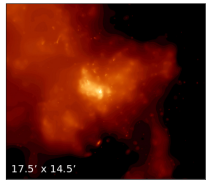


Pulsars

Microquasars



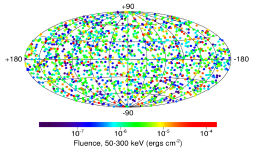
Galactic Center



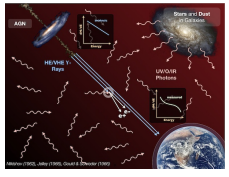
- Extragalactic

AGN

GRB

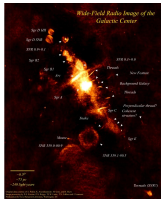


Cosmic Background



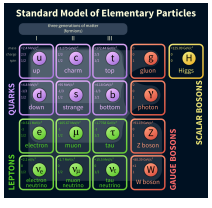
- Fundamental physics

Dark Matter

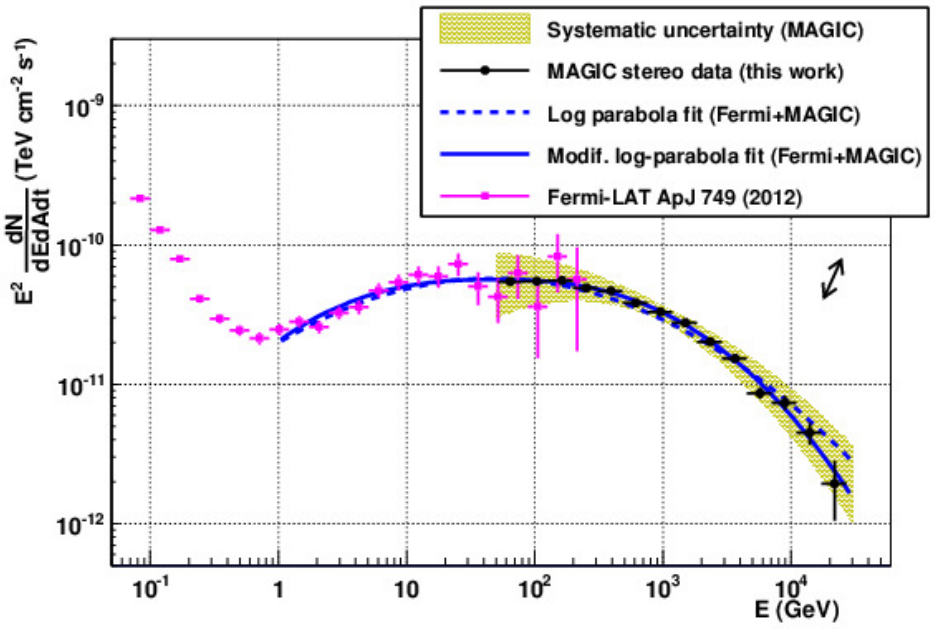


LIV

τ neutrino



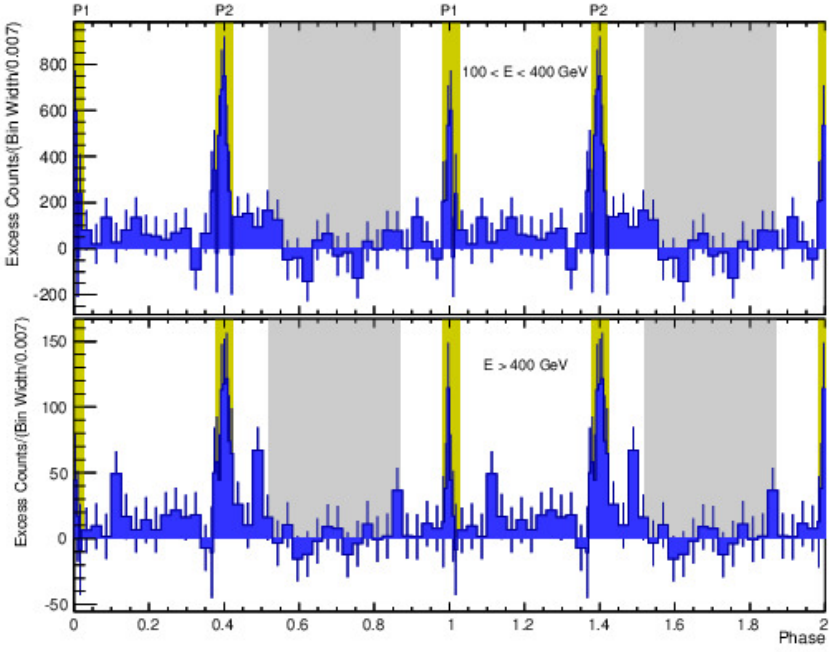
Crab Nebula

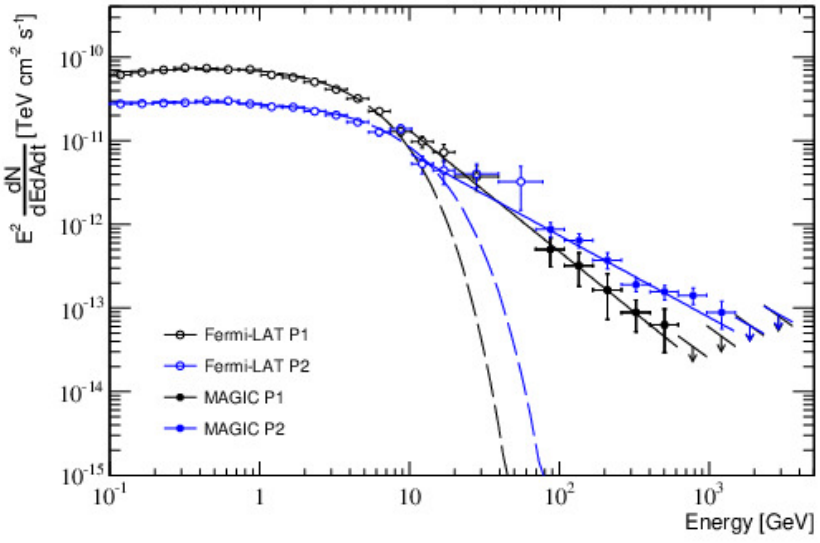


- IC peak at 53 ± 3 GeV

- SNR from 1054
- Adopted as a standard candle due to high luminosity and long-term flux stability.
- MAGIC range from 50 GeV to 30 TeV
- Fermi-LAT data below 300 GeV

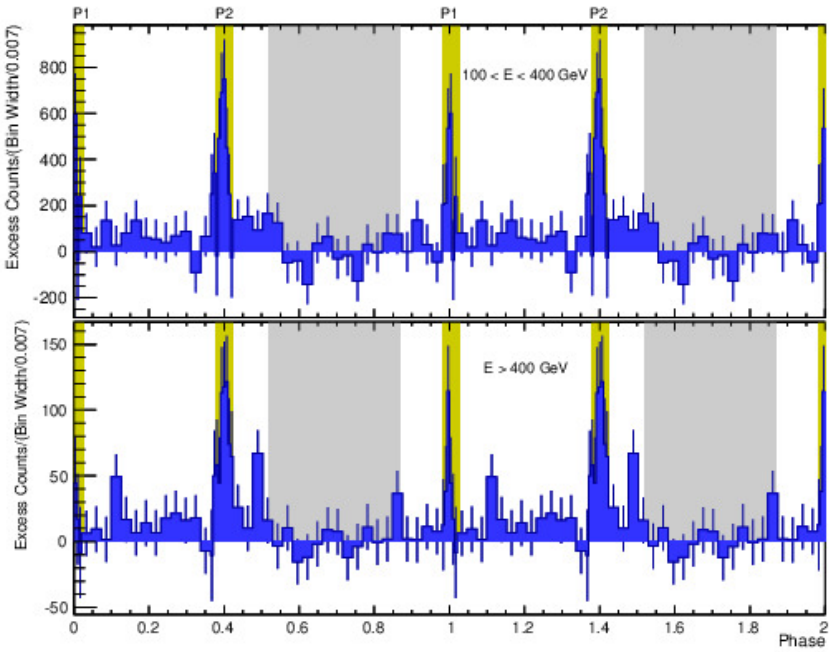
Crab Pulsar

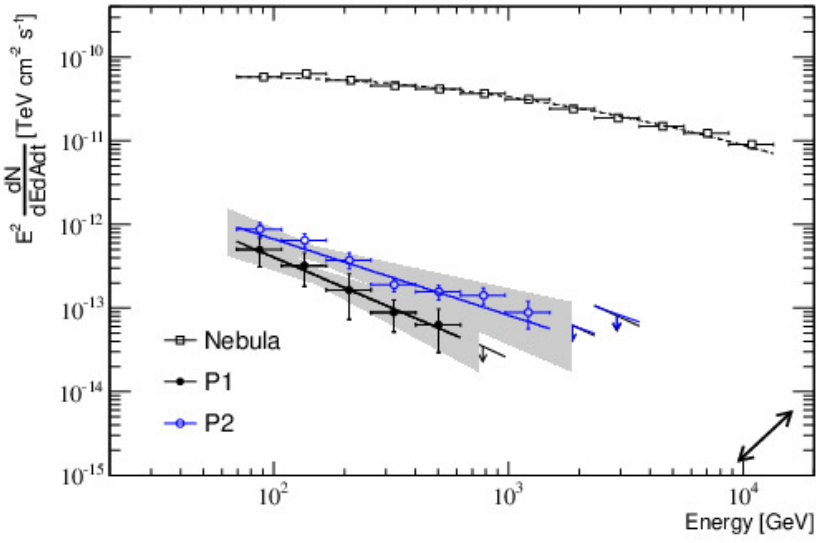




- Rotational period of 33 ms
- Two pulses P1 and P2 separated by $\sim$ 0.4 in phase
- Above 400 GeV significance for P1 2σ and P2 5σ
- Energy spectra up to 1.5 TeV

Crab Pulsar





- Rotational period of 33 ms
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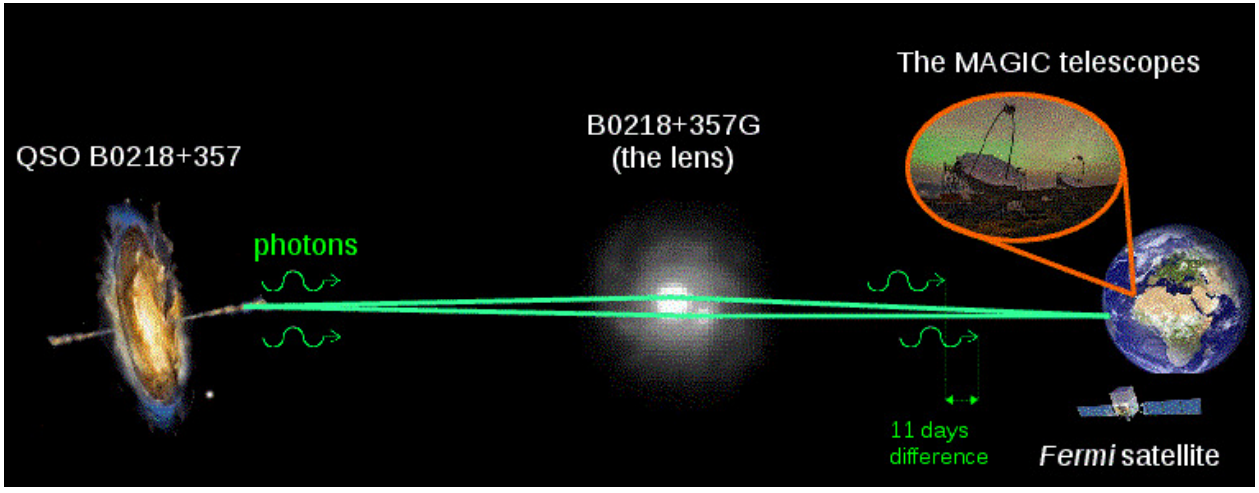
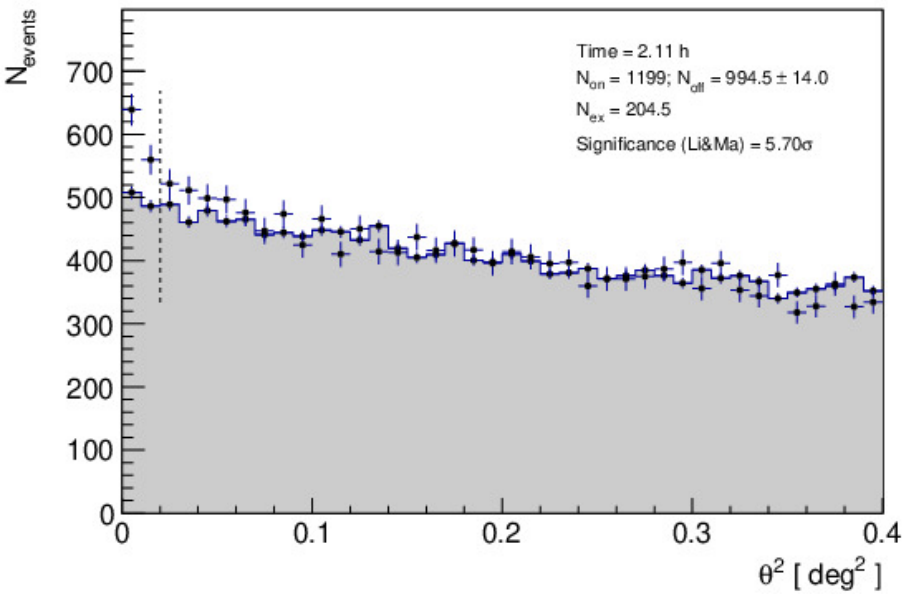
Gravitational lens

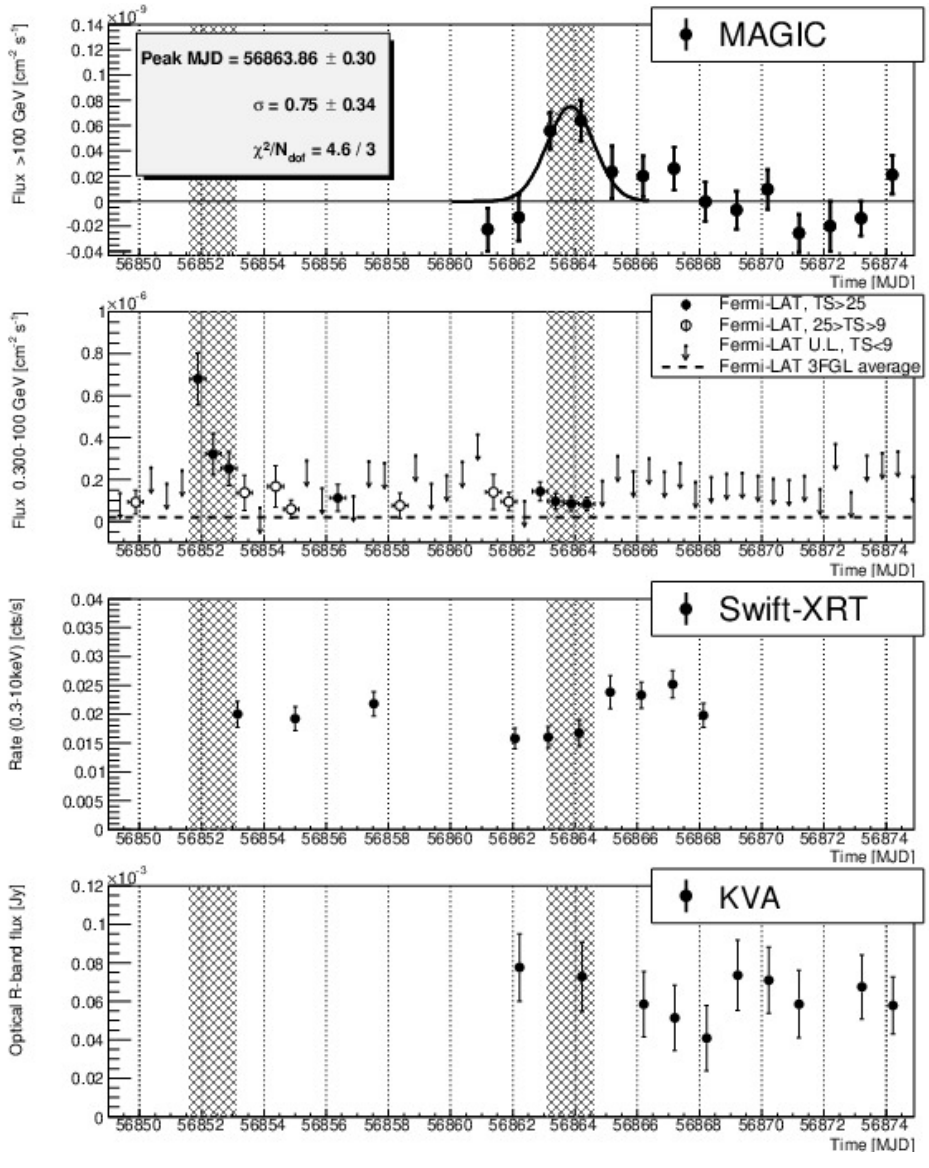


- Distant object QSO B0218+357 with z =0.944
- Photons passing in vicinity of galaxy B012+357G are deflected
- The emission is split in two components which are separated by 10–12 day in time

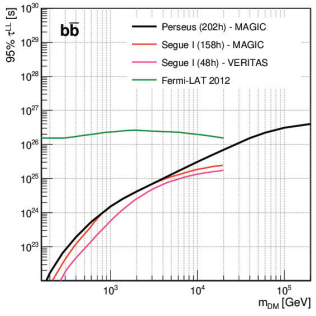
QSO B0218+357

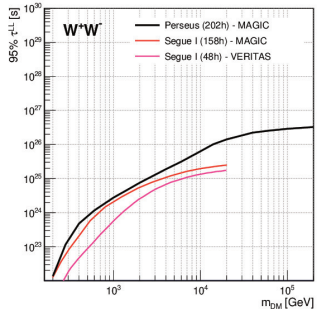


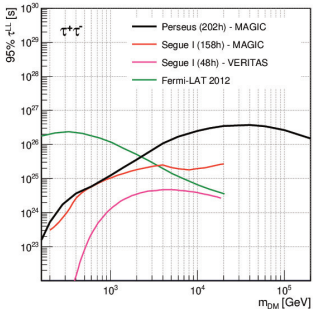
- Outburst in July 2014 detected by Fermi-LAT
- This trigger MWL observation
- MAGIC started observing 10 day later
- Ratio of components measured by Fermi-LAT is 4:1

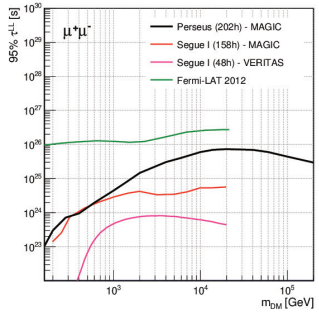


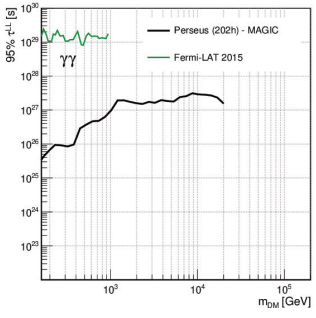
Cold Dark Matter











- Observation through its annihilation or decay products
- Candidates for CDM observation are objects with high ratio mass/luminosity – galactic center, dwarf spheroidal satellite galaxies, intermediate mass black holes and cluster of galaxies
- Observation of Perseus cluster of galaxies for 202 h
- Decay channels studied: $b\bar{b}$, $\tau^+\tau^-$, $\mu^+\mu^-$, W^+W^-, $\gamma\gamma$
- For masses in the range 200 GeV to 200 GeV the mean decay time is less than 10^{26} s

Thank You