MAGIC-II

Florian Goebel
for the **MAGIC** group

- MAGIC-I very successful

- Next step: a second telescope: MAGIC-II
  - stereo observations => increased sensitivity
  - advanced technologies => lower energy threshold

- MAGIC-II construction:
  ongoing with strong contributions by MPI group

- CTA: the ultimate VHE gamma-ray observatory?

MAGIC - quo vadis?

MAGIC-I:

- Discovered 9 new sources and >30 publications in refereed journals
- Most discoveries at 4-6 σ significance
  => expect many more sources with improved sensitivity
- Many interesting (particularly high z) sources show hard spectrum
  => reduce energy threshold further

=> MAGIC-II

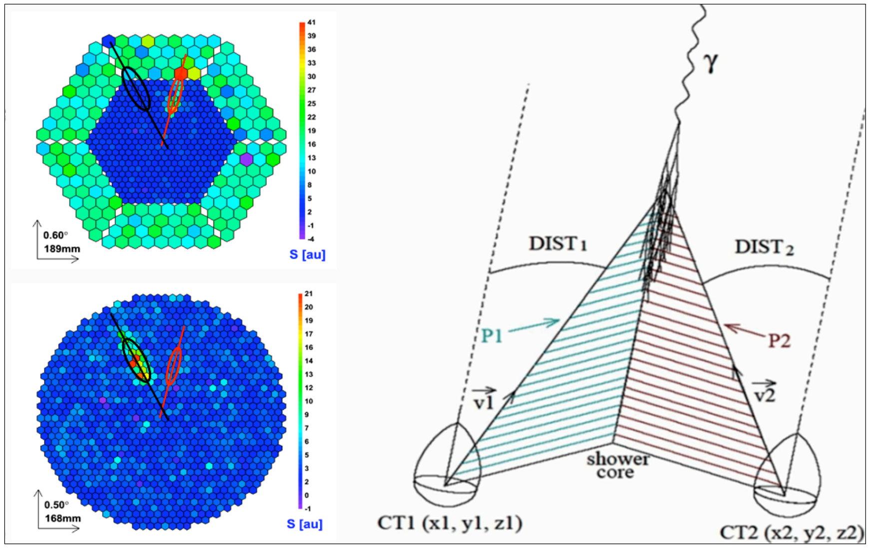
Stereo observation with both telescopes:

- **Increase sensitivity**
  (particularly below 100 GeV)
- **Lower energy threshold** further
  (use improved technology where available)

MAGIC II Monte Carlo Studies

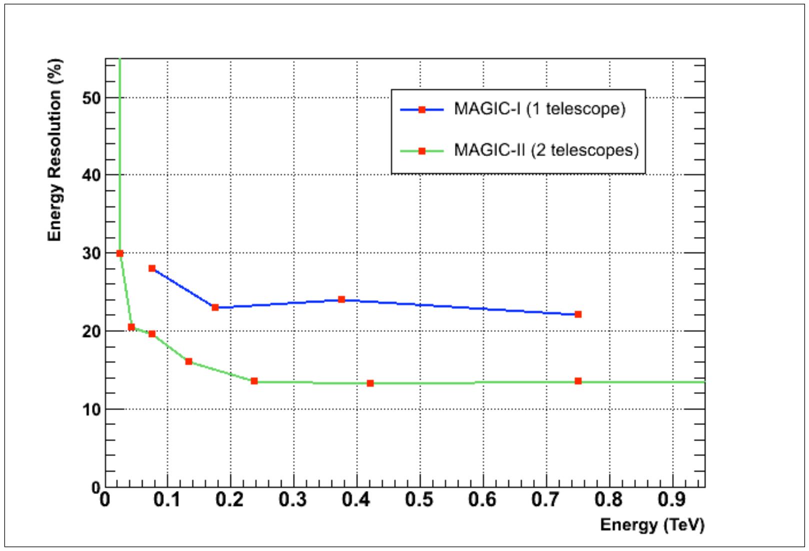
Stereo Analysis:

- observe shower simultaneously with 2 telescopes
- 3D shower reconstruction
- Additional shower parameters:
  - Impact parameter
  - Shower maximum (h_{max})
  - Eliminate ambiguity on arrival direction
- Better reconstruction of energy and arrival direction
- Improved background rejection

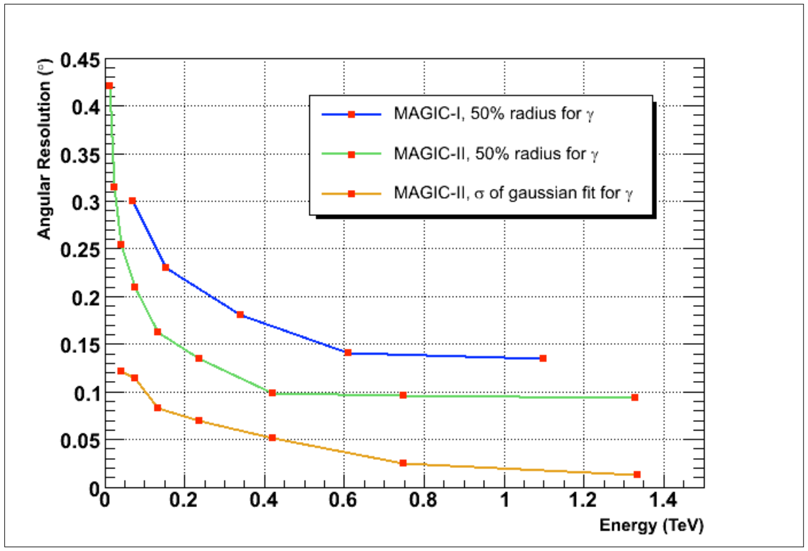


Improved Reconstruction

- Energy resolution
  - MAGIC-I: ~25%
  - MAGIC-II: 14-20% (2 telescopes)



- Angular resolution
  - Substantial (~50%) improvement since source position obtained from intersection point of both showers

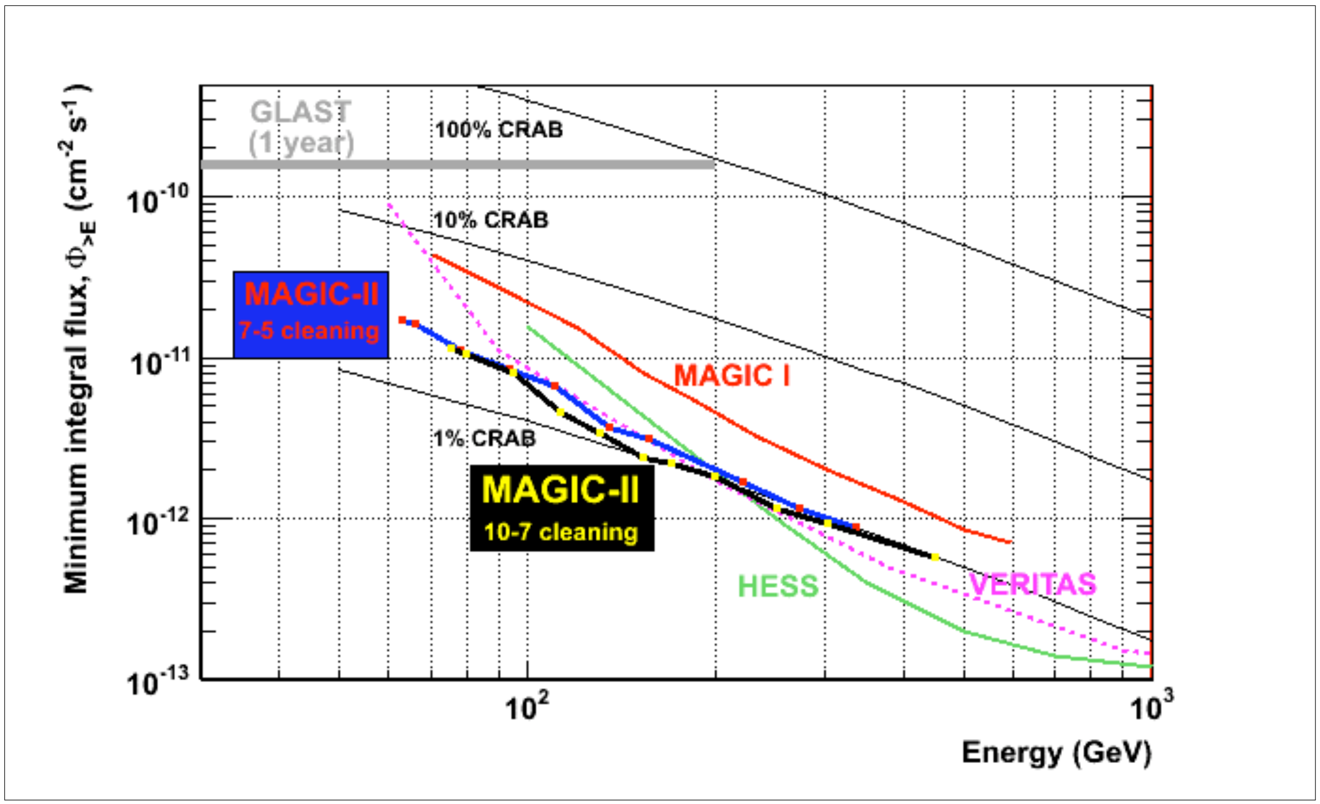


Florian Goebel, MPI project review, December 2007

Improved Sensitivity

using Stereo Analysis

- better **background rejection** down to low energies
- ***increase sensitivity by up to factor 3***
  => reduce observation time by factor 9
- Large gain in sensitivity at low energies (< 100 GeV)



MAGIC-II design
"improved clone"

- Copy MAGIC-I overall design
  => save design efforts, time & money

- Improved technologies & design
  - experience during MAGIC-I construction & operation
  - better components available on the market
    (often enough: old devices not available any more)
  - new cutting edge technologies
    when significant improvements in physics expected

Telescope Structure (MPI responsibility)
(almost) pure clone

- Telescope frame almost identical to MAGIC-II
- Main frame installed December 2005
- remaining installations installed in 2006
  (access tower, fences, safety installations, cabling etc.)

Mirrors (Padova + INAF)

- **1m² mirrors** instead of 4 0.5x0.5 m² mounted on panel
  (=> easier production and installation)

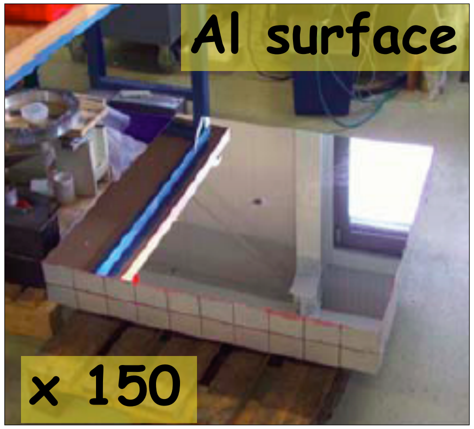
2 technologies:

All aluminum mirrors (Padova)

- MAGiC-I technology:
  Diamond milled Al surface
- Excellent focal spot
  (significantly better than MAGIC-I)

Glass mirrors (INAF)

- New technology:
  2 mm glass plates + Al honeycomb layer
- Faster and cheaper production



+

- Quality tests in Munich

First mirror installation:
23 October 2007

Finish installation of first batch of
42 mirrors on 30 October 2007

.. just in time before getting trapped in clouds

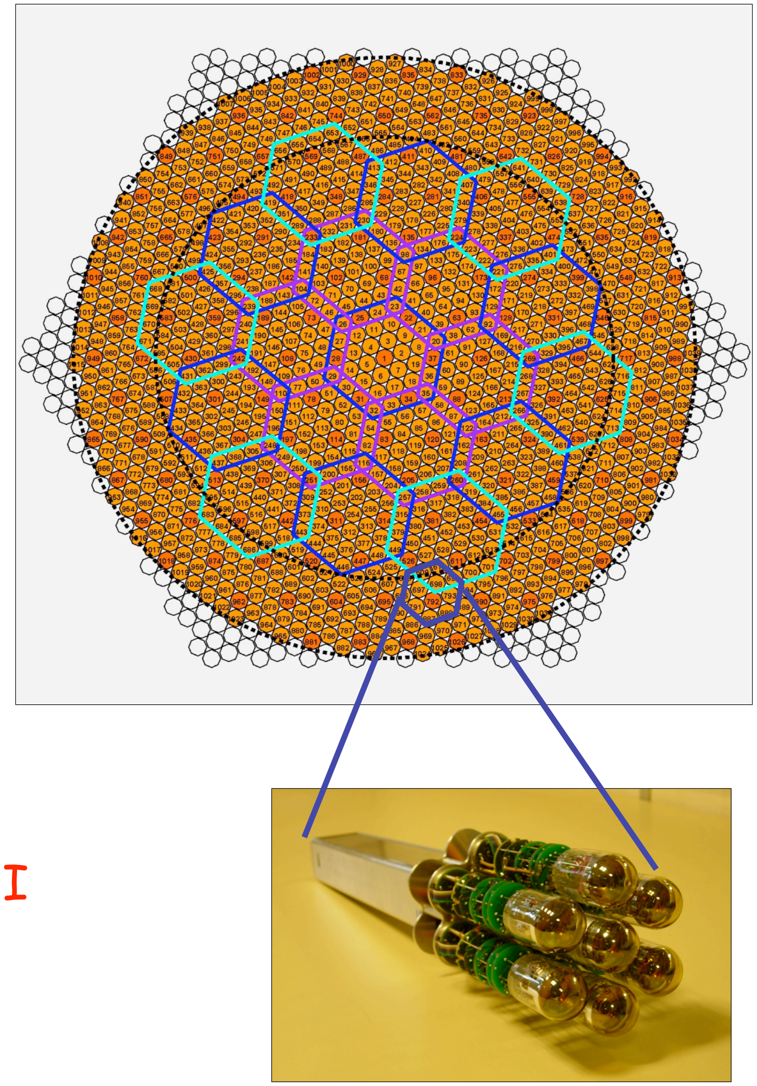
Camera (MPI)

Design criteria:

- High Photon detection efficiency
- High bandwidth of entire signal chain

- Modular design
  Clusters of 7 pixels
  => easy replacement
  => upgrade possibility to higher
  QE photosensors (HPDs)

- Same size (FoV) as MAGIC-I
- Only small 0.1° FoV pixels
  (=> 1039 instead of 577 pixels)
  easier/better analysis
- 1.7 times larger trigger area than MAGIC-I
  => cover larger field of sky
  => sky survey & extended sources



Camera housing

- Housing under construction

- The heart of the camera:
  Water cooled plates
  (finally delivered)

PMT Modules

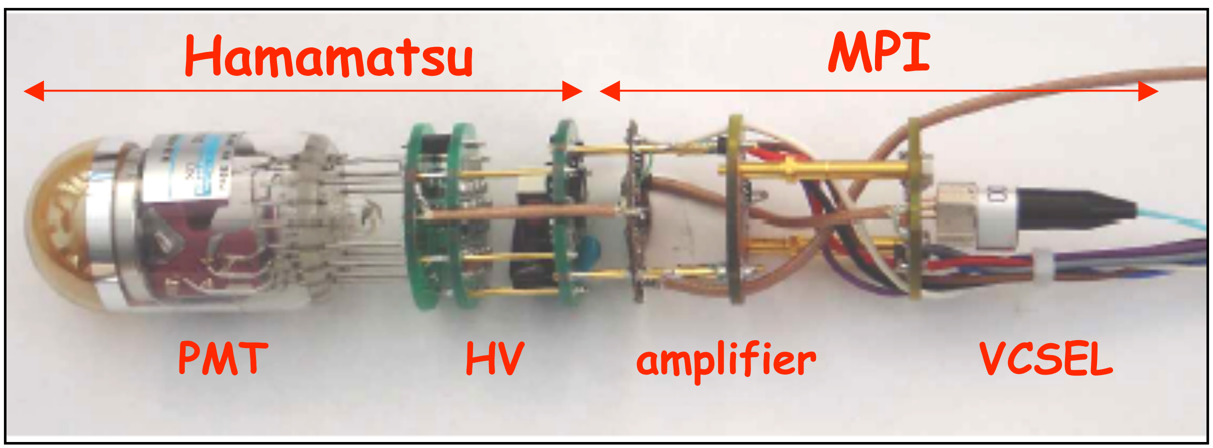
Phase 1:

Hamamatsu R10408 PMTs

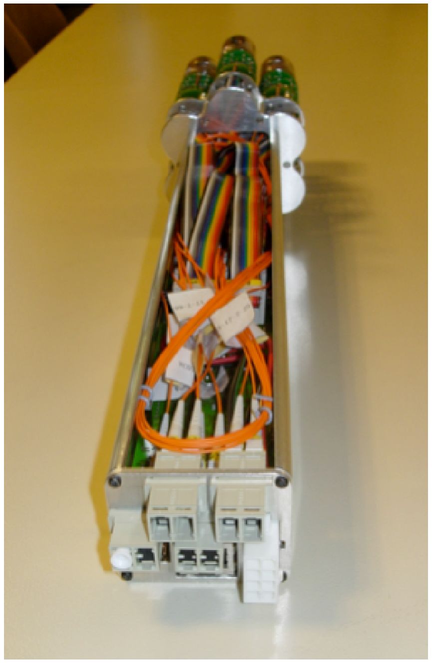
- Peak QE typically 34%   (~15% higher than MAGIC-I)
- ~2 ns signals (fast although not quite as fast as hoped for)
- 0.3-0.4% afterpulse (@ 4 ph.e.)
- Cockroft-Walton HV generator in PMT socket

Frontend electronics (MPI development)

- bandwidth: 700 MHz, dynamic range: 1000



PMT clusters

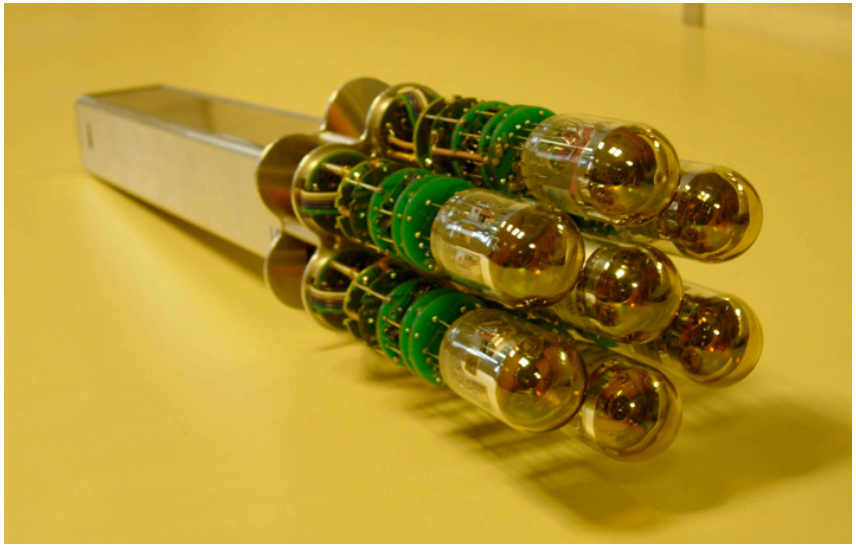


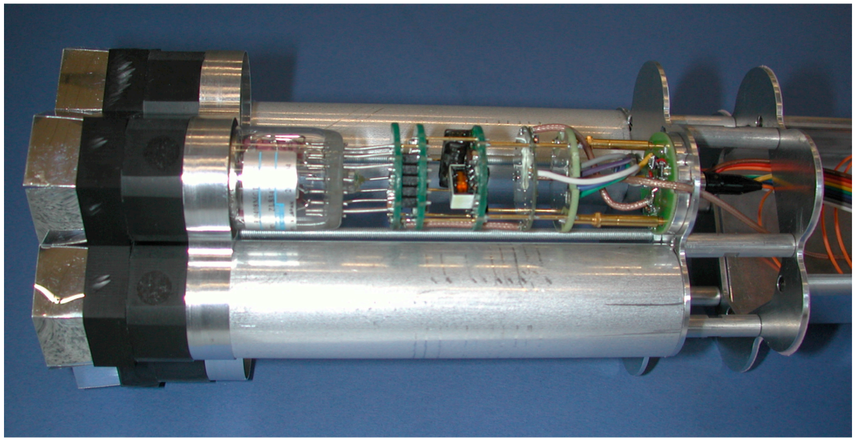
Cluster incorporates:

- 7 PMT modules with
  HV generator & front-end electronics
- Slow control

Production

- started in December
- First 3 (out of 169) clusters ready

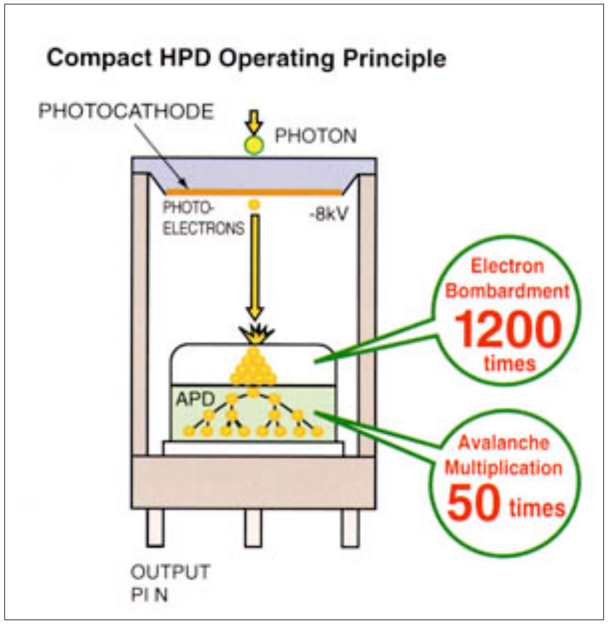




Camera upgrade: HPDs

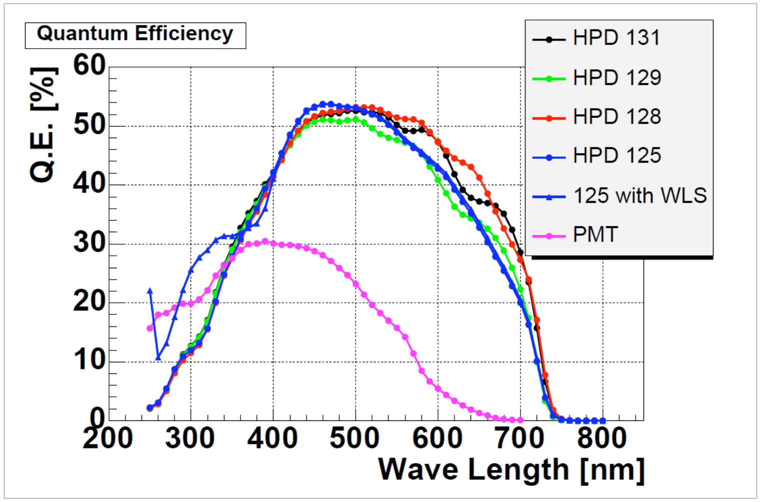
Principle

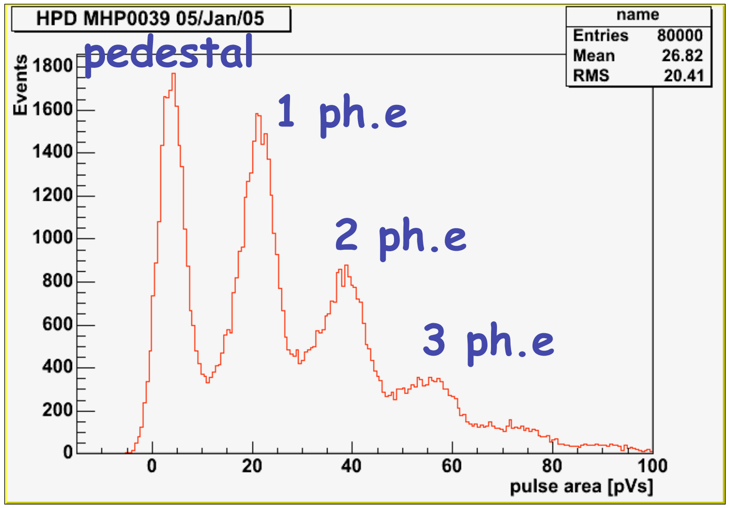
- vacuum tube operated at 6-8 kV
- Avalanche Diode (~300 V)



Advantages

- good single ph.e. resolution
- high QE GaAsP Photocathode (QE>50%)
- Low afterpulse rate (~300 times less than PMTs)





HPD challenges

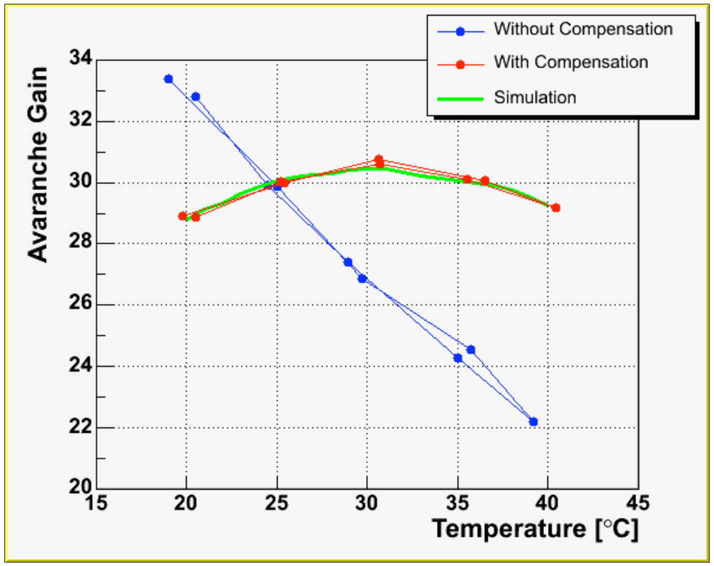
- Temperature dependent APD gain (2%/°C)
  => temperature compensation circuit (regulate V_{APD})

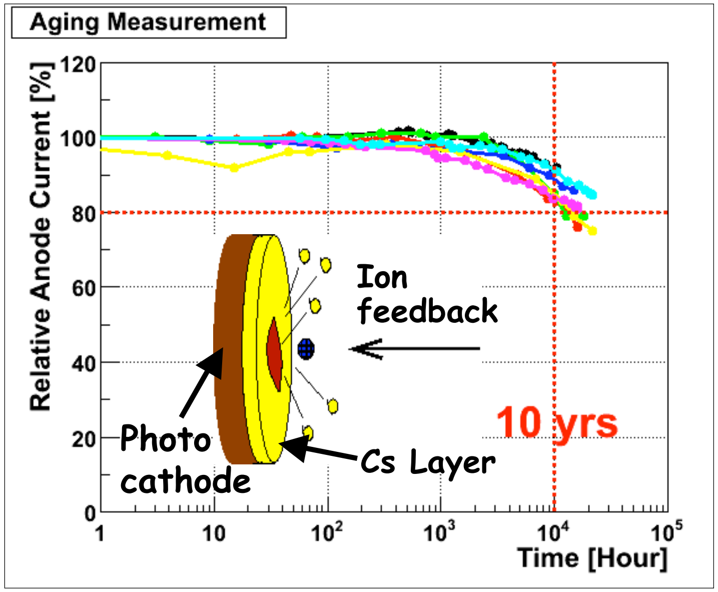
- Life time (photocathode)
  - 10 year under normal observation cond.
  - No moon observations possible anymore

- Protect APD against strong light
  - Current limiting circuitry

Everything under control ?

=> Field test

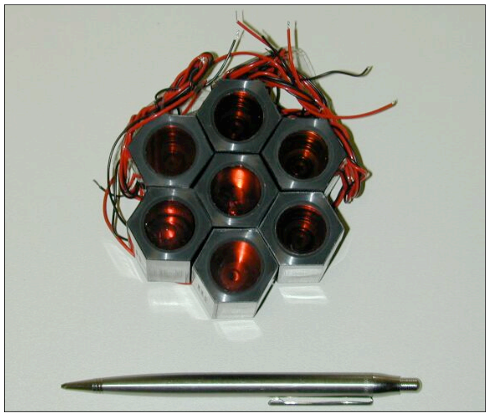


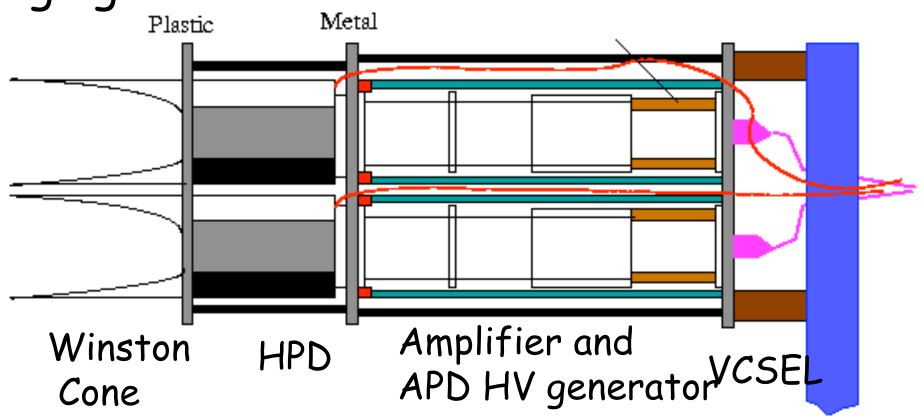


HPD Camera

Incorporate HPD in cluster

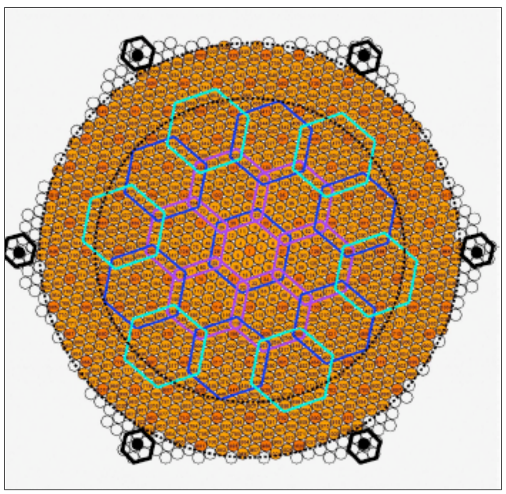
- electronics mainly identical to PMT cluster
- but mechanics challenging





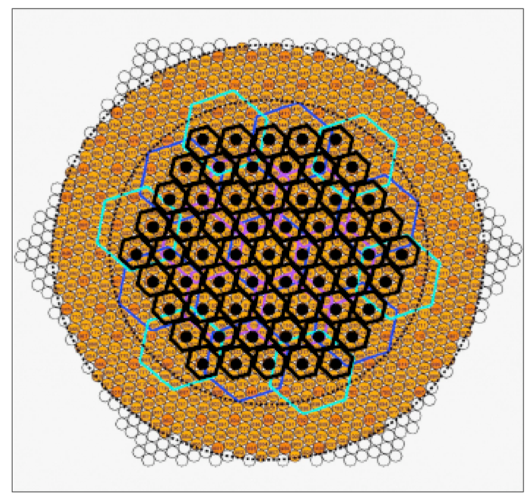
Phase 1
field test

- 6 cluters (42 HPDs) in MAGIC-II camera



Phase 2
physics run

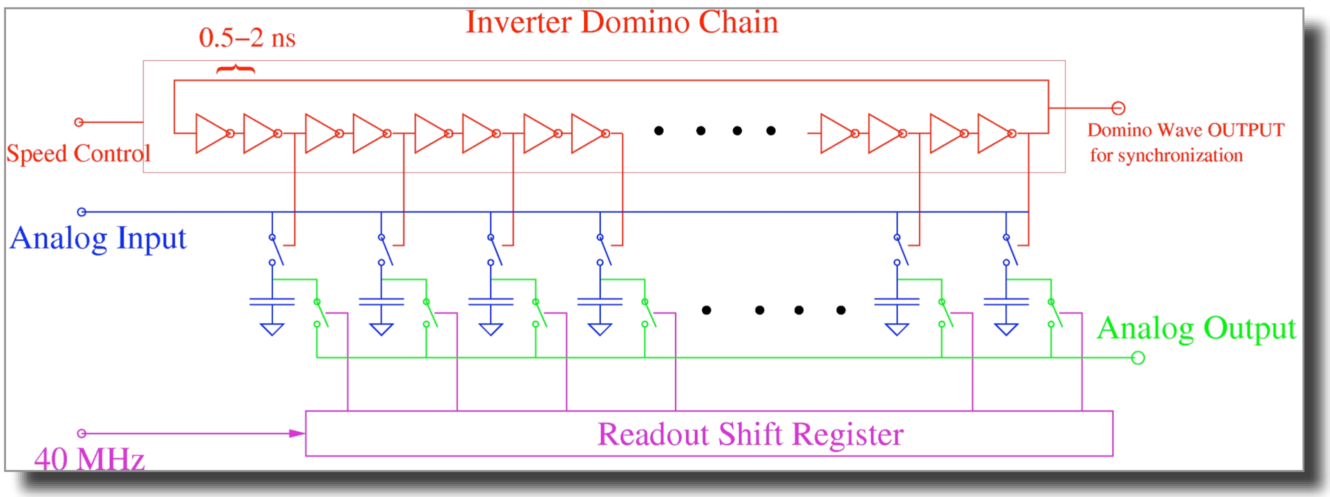
- 427 HPD in MAGIC-II camera

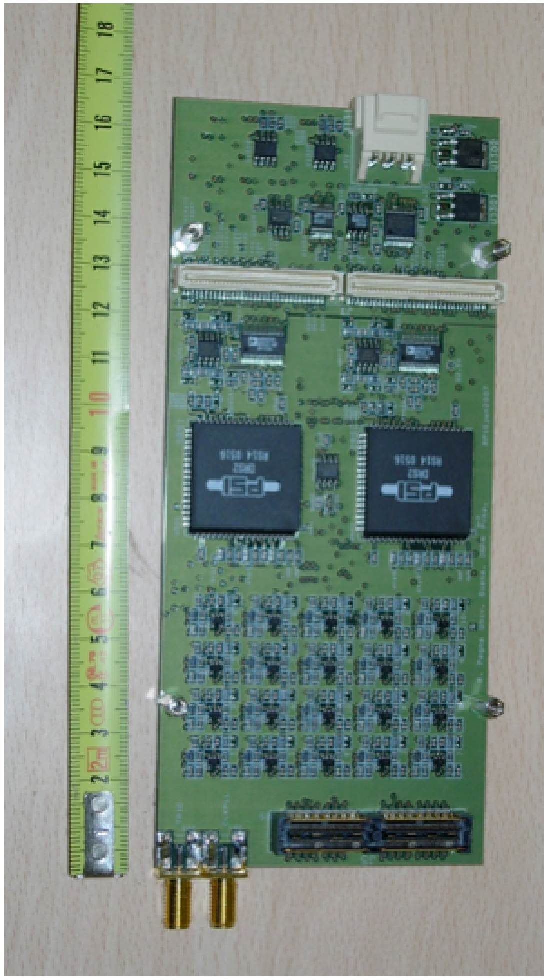


Fast Readout: Domino Ring Sampler
(IFAE, Barcelona & INFN PISA)

Fast sampling allows improvements in sensitivity

- 2 GSamples/s analog sampling
  in series of 1024 capacitors
- slow (40 MHz) readout
  and external 12 bit digitization





- low cost
- low power consumption
- very flexible

MAGIC-II schedule

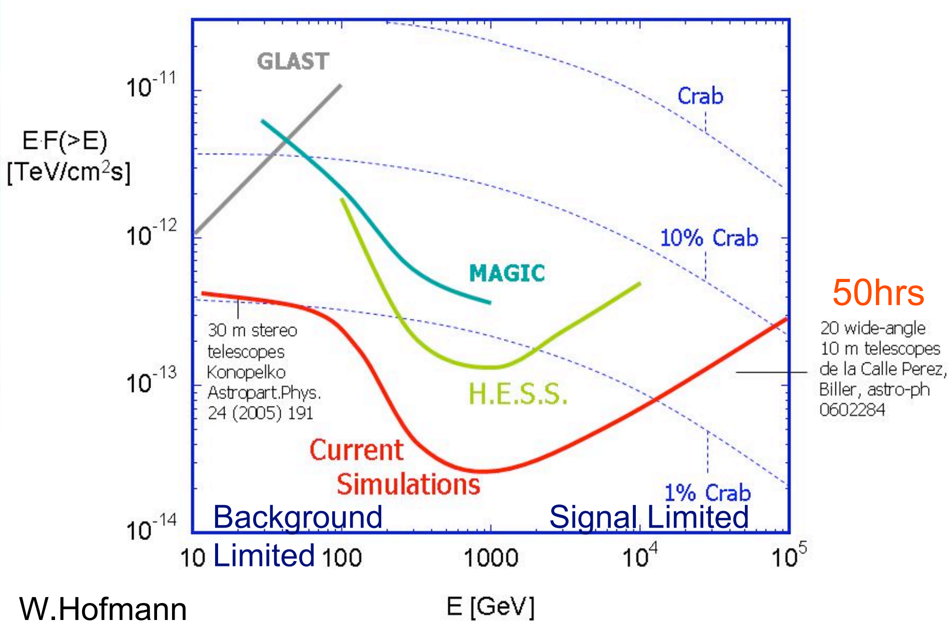
- Not only GLAST and LHC are delayed ....
- All MAGIC-II components in production stage (or already completed)
- Finish production & installation in first half 2008
- MAGIC-II inauguration on 21. September 2008

- HPD cluster to be installed in outer corners of MAGIC-II by mid 2008

- Build second camera to upgrade MAGIC-I telescope in 2009

Future of Gamma ray astronomy
Cherenkov Telescope Array (CTA)
joined European initiative

Fully exploit successful & complementary Cherenkov technique
=> Large array of Cherenkov telescopes



Aim:
- 10 time better sensitivity
- E_{thr} some 10 GeV

Status:
- Applications for design study to European and national funding agencies

Mayor participation of MPI:
- Organization, Camera, MC, telescope structure, physics, site survey

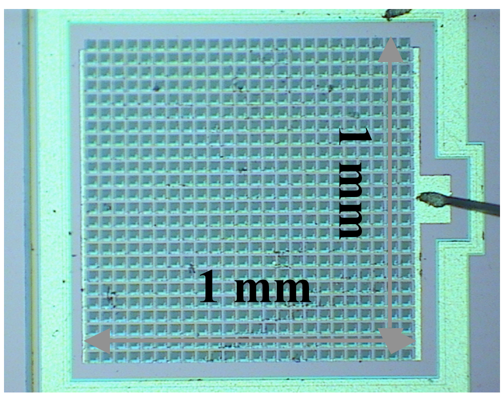
New Technologies

- IACT technique well established but …
- Astroparticle experiments notoriously "light hungry"

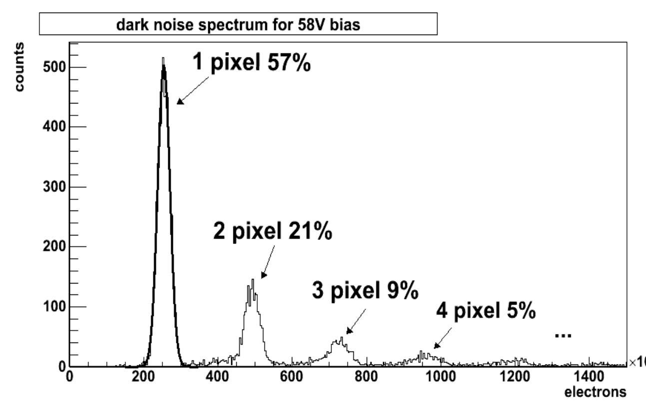
=> Photosensors with higher Photon Detection Efficiency essential

SiPM (MPPC, G-APD, ..)

- Promising new technology
  (high QE, excellent photon resolution, fast signal, robust operation, …)
- Many developments world wide
- Possible technology for advanced CTA (baseline design: PMTs)



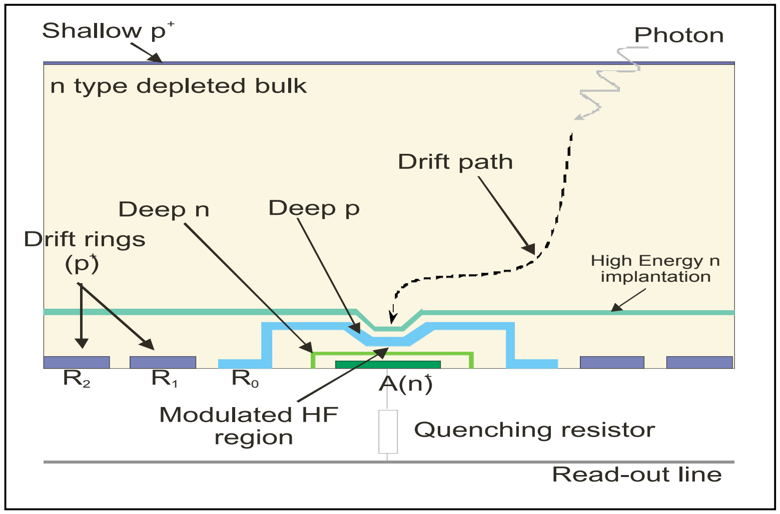
SiPM: matrix of APDs operated in Geiger mode with common readout



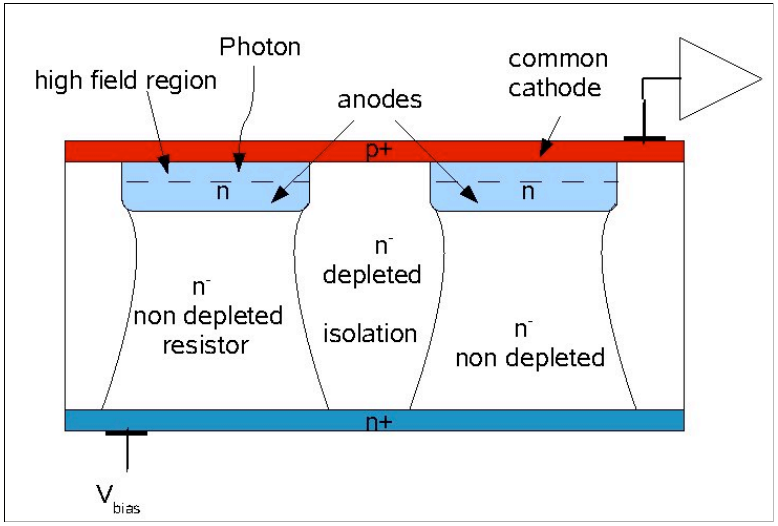
SiPM developments

HLL developments:

Classical SiPMs:
- Effective QE limited by structures on front side => dead areas



1) Back Illuminated SiPMs
   - 100 % active area
     => very high QE possible
   - But: large volume for thermal noise & inernal photon conversion



2) Bulk Resistor SiPMs
   - 75% geometrical fill factor
   - Uniform optical thin entrance window
   - Simple/cheap technology

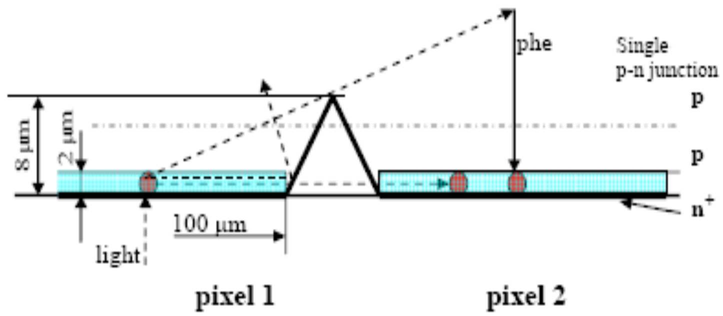
Prototyping for 1) & 2)

Florian Goebel, MPI project review, December 2007

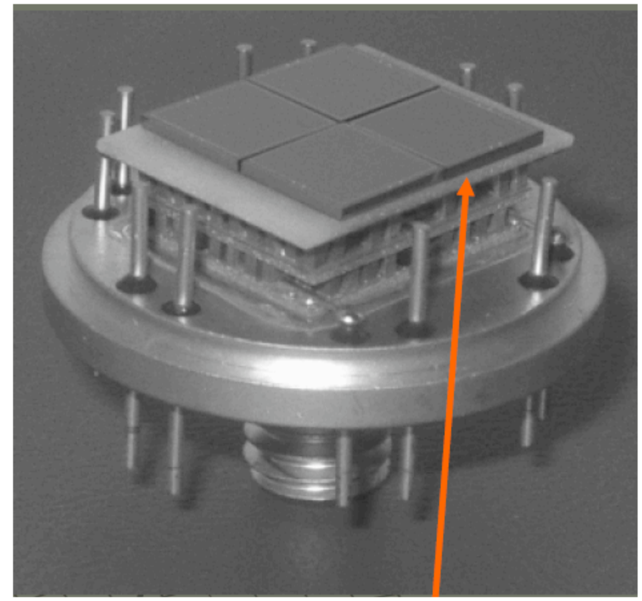
SiPM developments

Collaboration with MEPhI/Dolgoshein

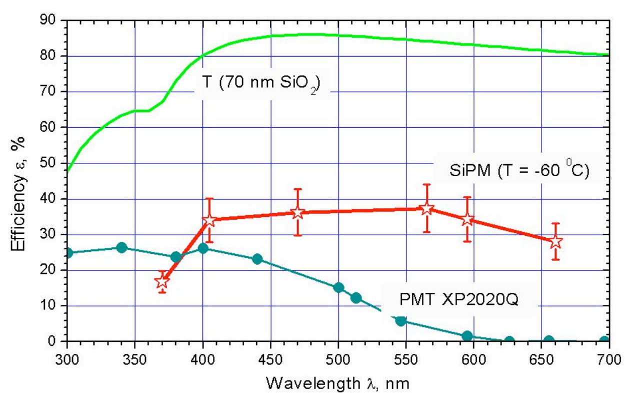
- Cross talk suppression by trenches



Optical crosstalk between two separate pixels



1cm^2 module (4 SiPMs 5x5mm^2) with Peltier cooling



- Increase blue sensitivity with p-on-n technlogy (like Hamamatsu) in collaboration with industry

Summary

- MAGIC is delivering good scientific results

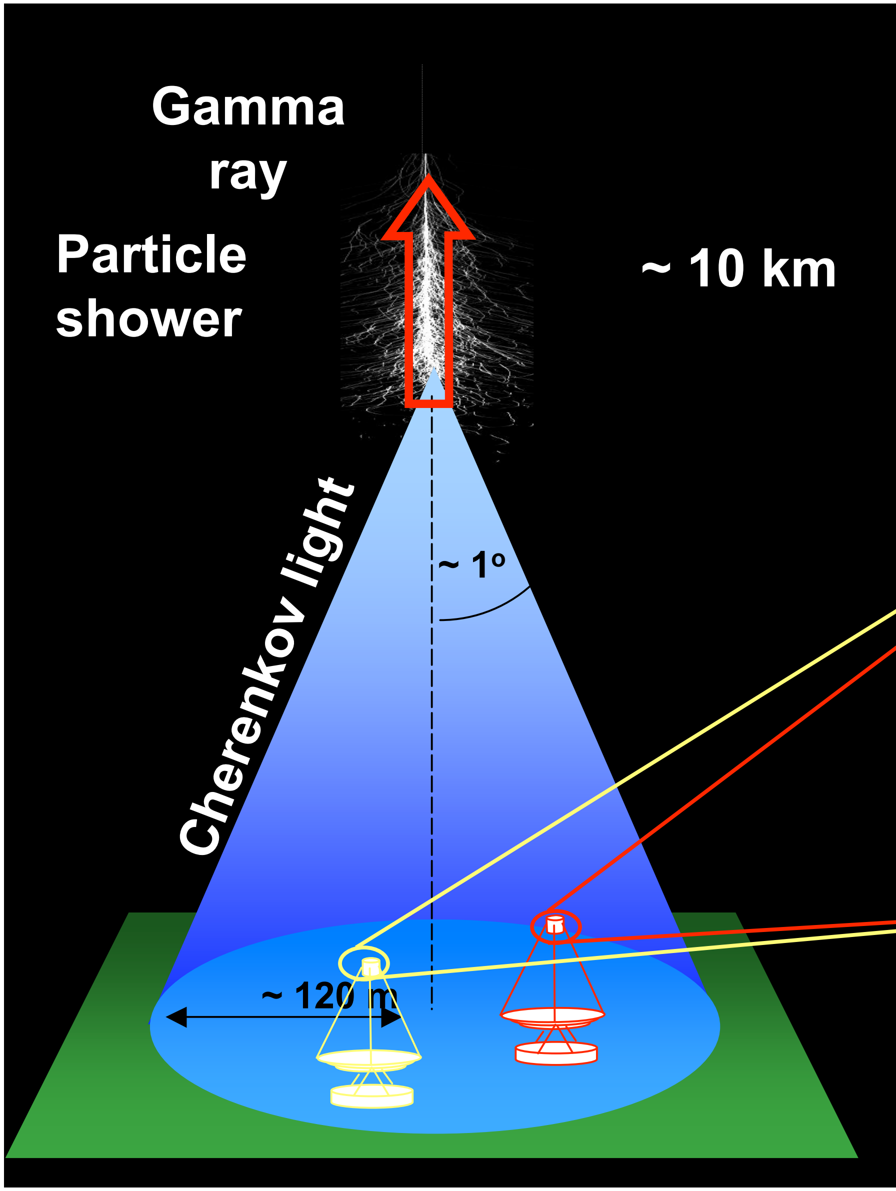
- Mayor improvement expected with MAGIC-II coming operational in 2008 (inauguration 21 Sept 2008)

  => Improve sensitivity by factor ~3

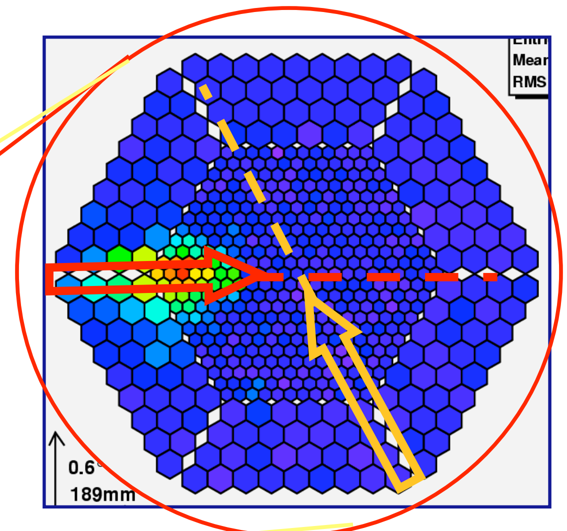
  => Lower analysis threshold

- Design studies for ultimate (?) Cherenkov observatory CTA started

Advantage of stereo observation



Cherenkov light Image of particle shower in telescope camera



reconstruct:
arrival direction, energy
reject hadron background