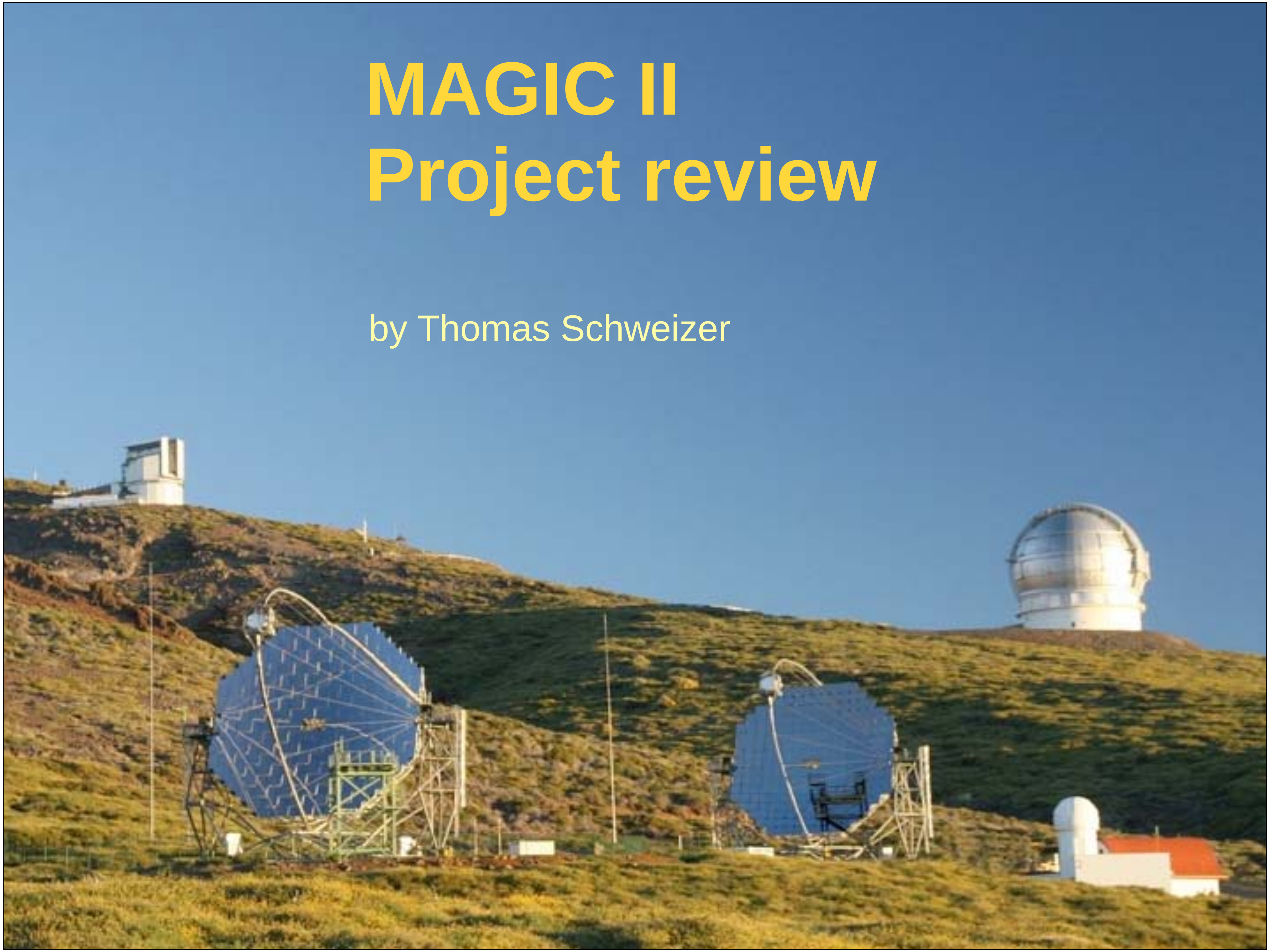
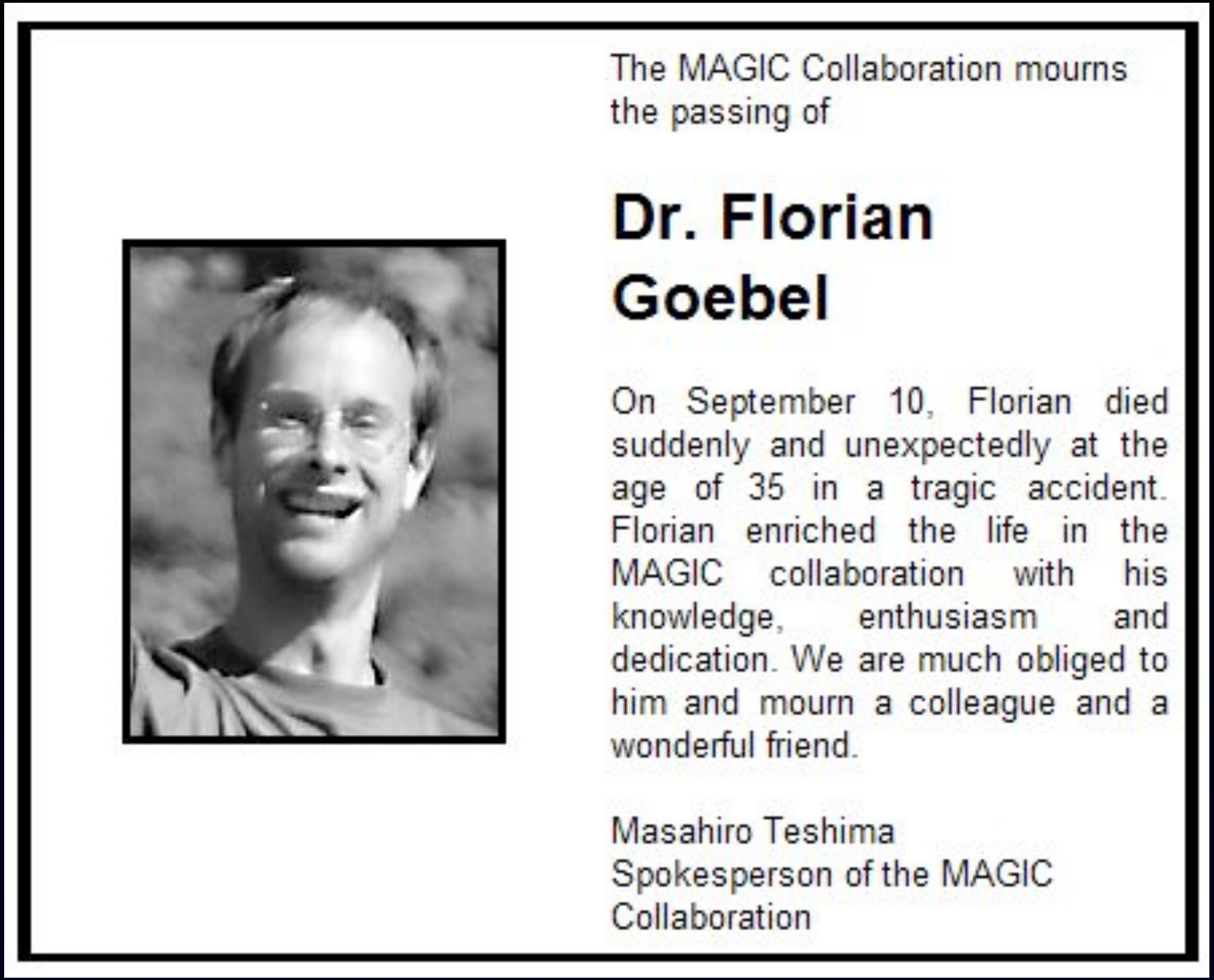


MAGIC II
Project review

by Thomas Schweizer

MAGIC II in memory of Florian



The MAGIC Collaboration mourns the passing of

Dr. Florian Goebel

On September 10, Florian died suddenly and unexpectedly at the age of 35 in a tragic accident. Florian enriched the life in the MAGIC collaboration with his knowledge, enthusiasm and dedication. We are much obliged to him and mourn a colleague and a wonderful friend.

Masahiro Teshima
Spokesperson of the MAGIC Collaboration

The MAGIC Collaboration

Collaboration: ~ 150 Physicists, 23 Institutes, 12 Countries:

Instituto de Astrofisica de Andalucia, IFAE, UABarcelona, UBarcelona,
DESY Zeuthen, Instituto de Astrofisca Canarias, INAF Rome,
Croatian MAGIC consortium, University C. Davis, University Dortmund,
Institut de Ciencies de l'Espai, University Lodz, UCM Madrid, MPI Munich,
INFN/ University Padua, INFN/ University Siena/Pisa, Institute for Nuclear
Research Sofia, Tuorla Observatory,
Yerevan Institute,
INFN/University Udine,
University Würzburg,
ETH Zürich

MAGIC goes stereo

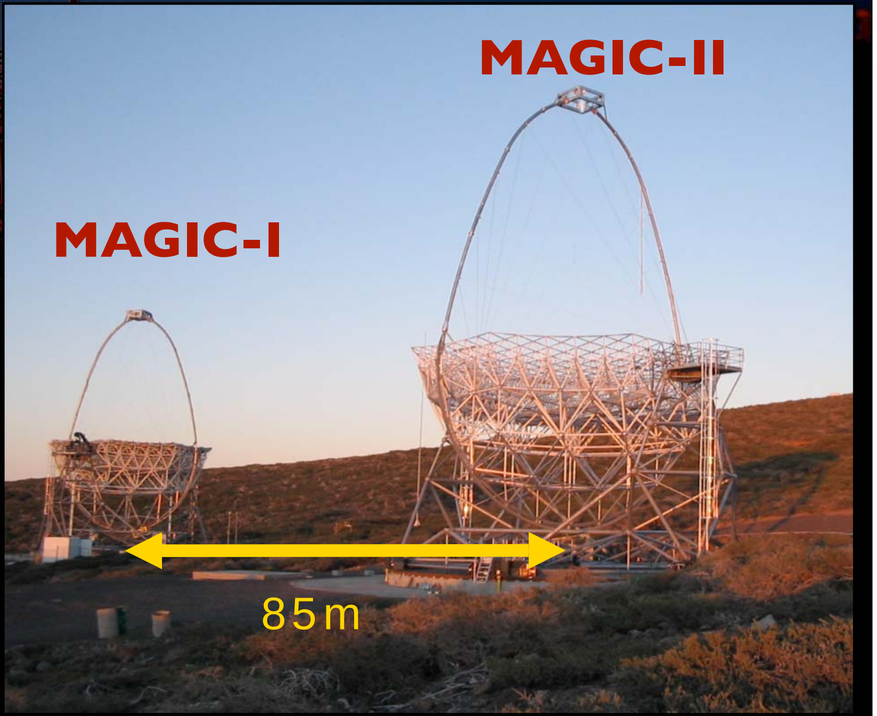
MAGIC-I:

- Discovered many new sources and lots of publications in refereed journals
- Many 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:

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

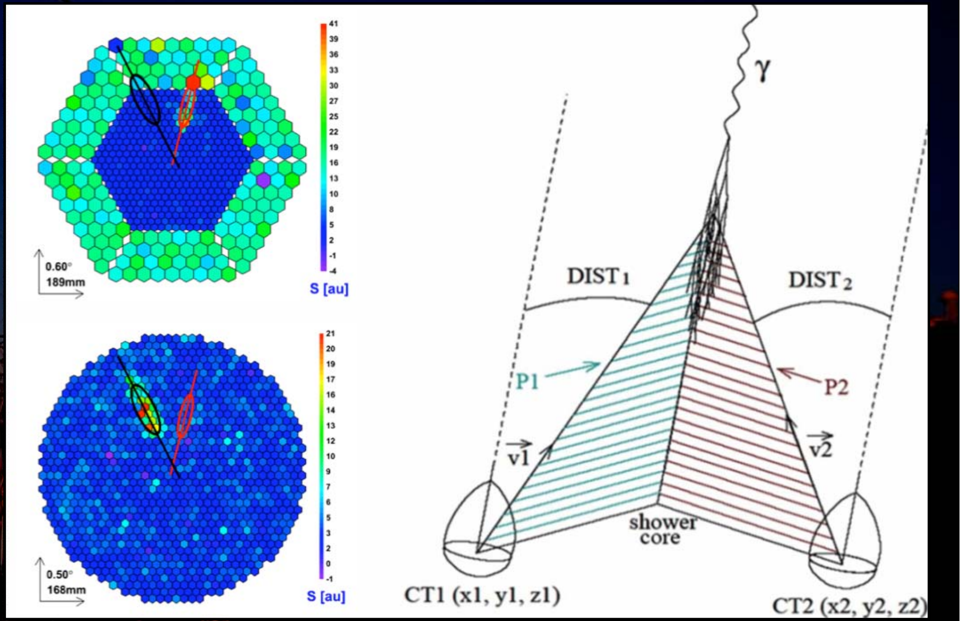


MAGIC II Monte Carlo Studies

Stereo Analysis:

- Observation of showers simultaneously with 2 telescopes

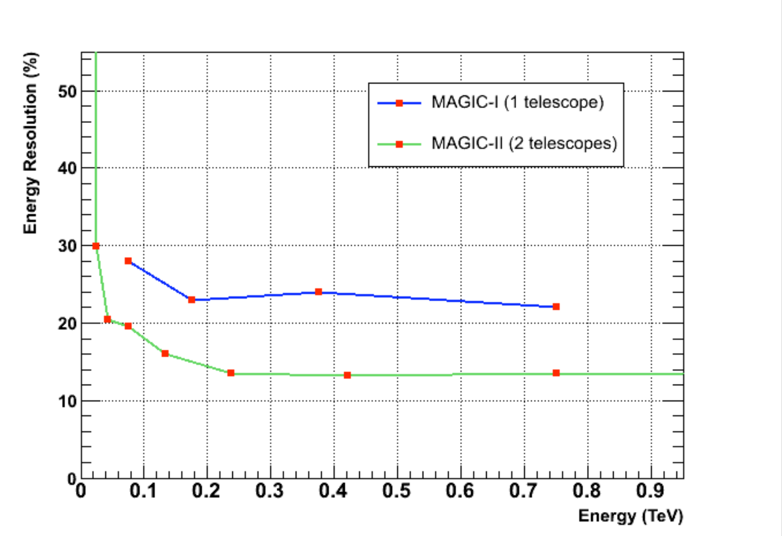
- 3D shower reconstruction
- Additional shower parameters:
  - Impact parameter
  - Shower maximum (h_{max})
  - Eliminate ambiguity on arrival direction

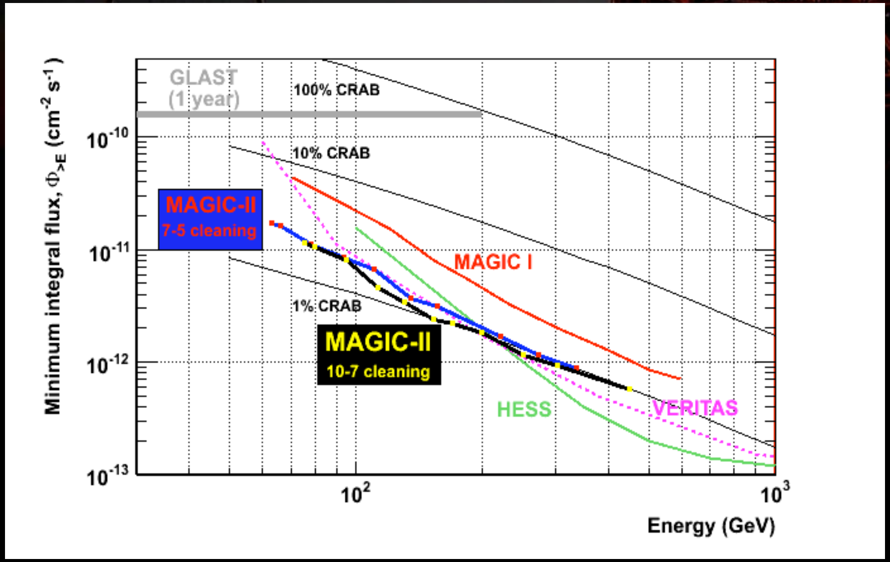


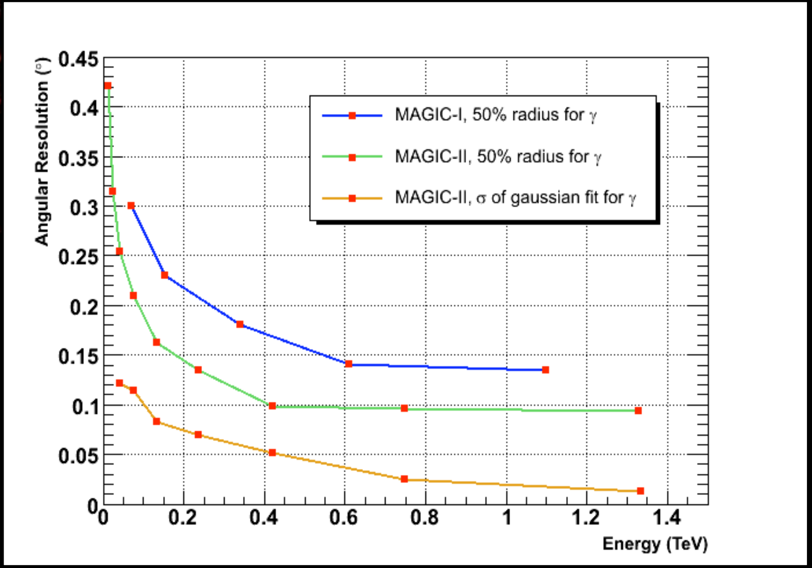
- Better reconstruction of energy and arrival direction
- Improved angular resolution
- Improved background rejection --> Higher sensitivity

Improved shower reconstruction

- Energy resolution
  - MAGIC-I: ~25%
  - MAGIC-II: 14-20% (2 telescopes)
- Angular resolution
  Substantial (~50%) improvement
- Improved sensitivity especially in the lower energy range (2-3)
  (better background rejection)
- MAGIC is unique in it’s low threshold !







Telescope Structure (MPI responsibility)

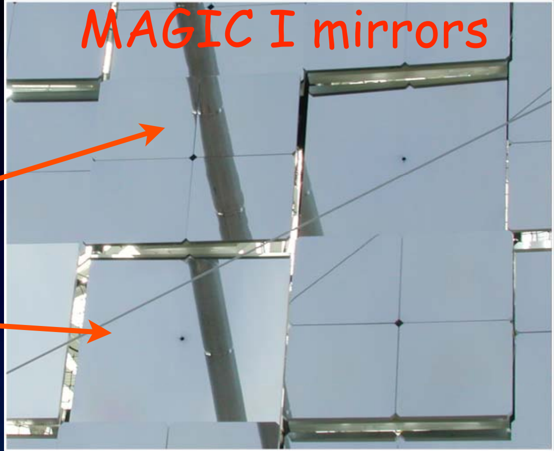
(almost) pure clone

MAGIC-II Telescope frame almost identical to MAGIC-I

- Main frame installed December 2005
- Remaining installations installed in 2006
  (access tower, fences, safety installations, cabling etc.)

Mirrors

- Parabolic tessellated reflector
- 249 spherical **1 m² mirror** elements
- Active mirror control



2 technologies:

- All aluminum mirrors
  - MAGiC-I technology
  - Diamond milled Al surface
  - Excellent focal spot
  - ~87% reflectivity

- Glass mirrors
  - New technology
  - 2 mm glass plates
  - Al honeycomb layer
  - Quality and robustness under investigation

All mirrors on MAGIC II

July 2008

Camera

Design criteria:

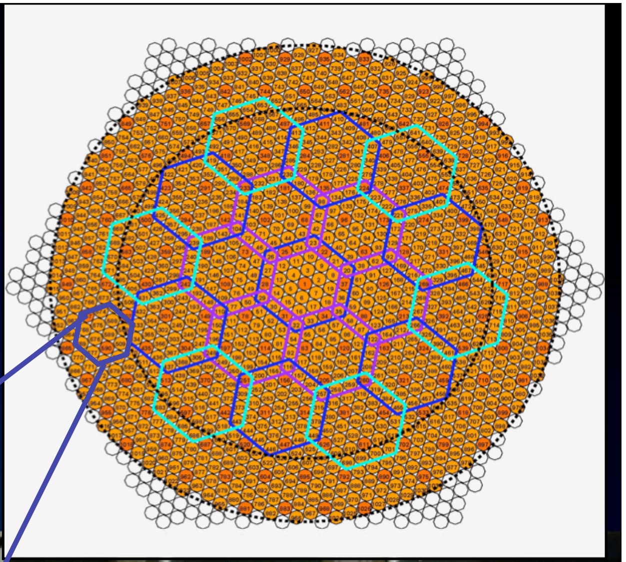
- High Photon detection efficiency
- 500 MHz bandwidth for entire signal chain

Modular design

- Clusters of 7 pixels
  => easy replacement
  => upgrade possibility to higher
  QE photosensors

Field of View (FoV)

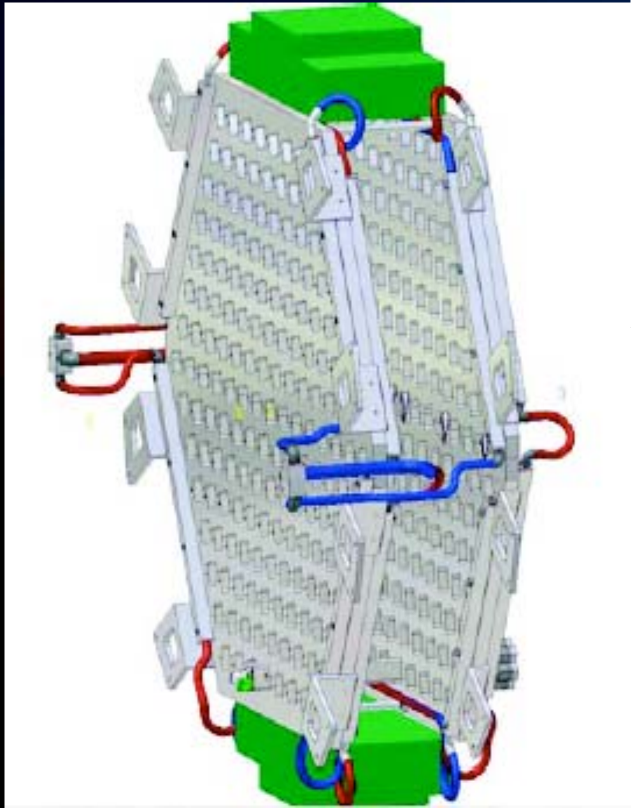
- 1039 identical 0.1º FoV pixels
- Round configuration
- Total FoV: d=3.5º (similar to MAGIC-I)

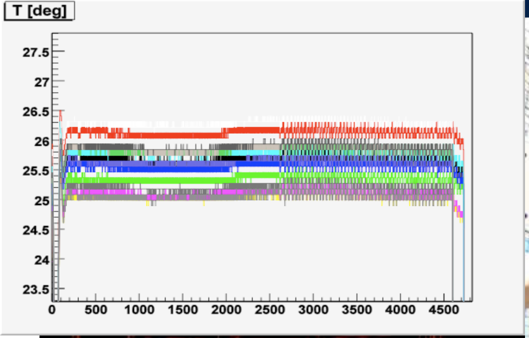


Cooling system

Total heat dissipation in the camera: ~ 1kW
(Clusters, VMEs, Amplifiers, and micro-controllers)

Outdoor temperature: -10°C to +30°C
Maximum power consumption: 8kW
Heating capacity: 6kW
Cooling capacity: 2.9kW
Temperature stability: ±1°C






Water cooled plates

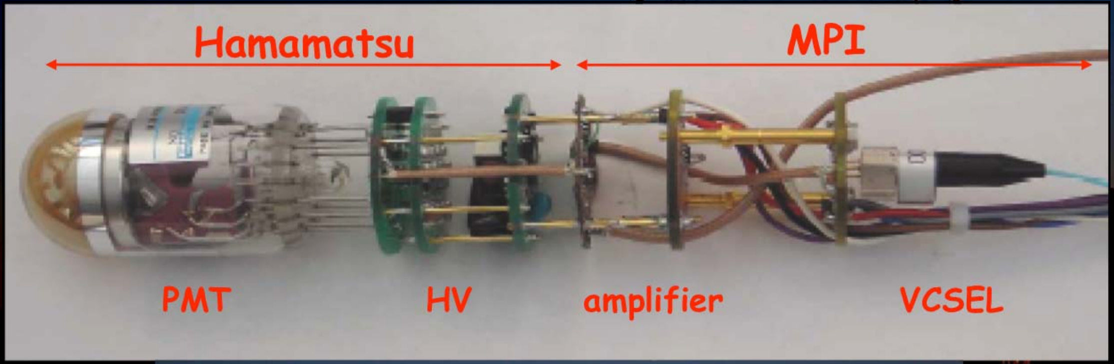
PMT Clusters

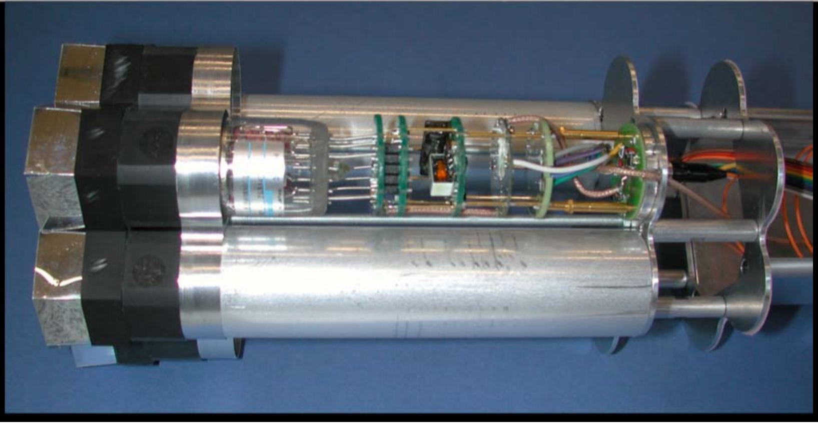
Hamamatsu R10408 PMTs

- Peak QE typically 34%   (~15% higher than MAGIC-I)
- ~2.3 ns signals (fast although not quite as fast as hoped for)
- Cockroft-Walton HV generator in PMT socket

Frontend electronics (MPI development)

- bandwidth: 700 MHz, dynamic range: 1000

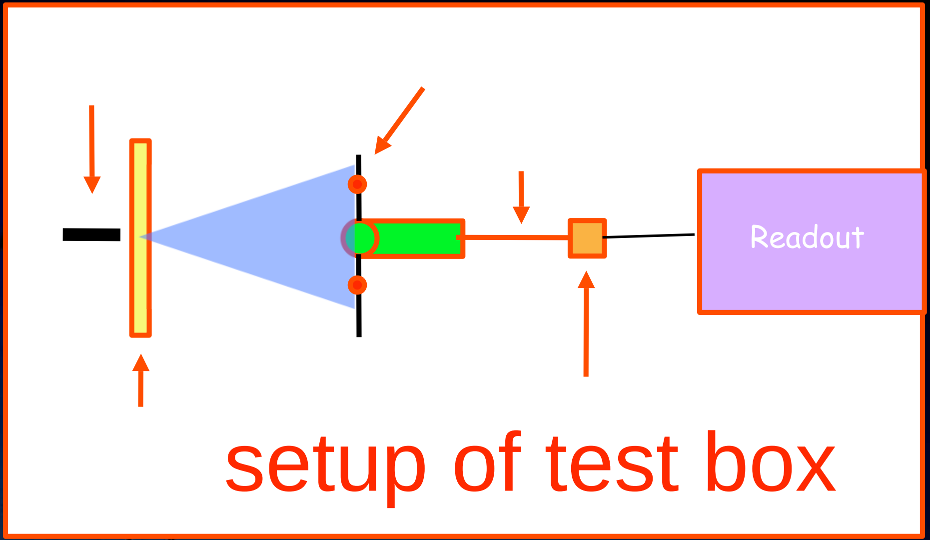




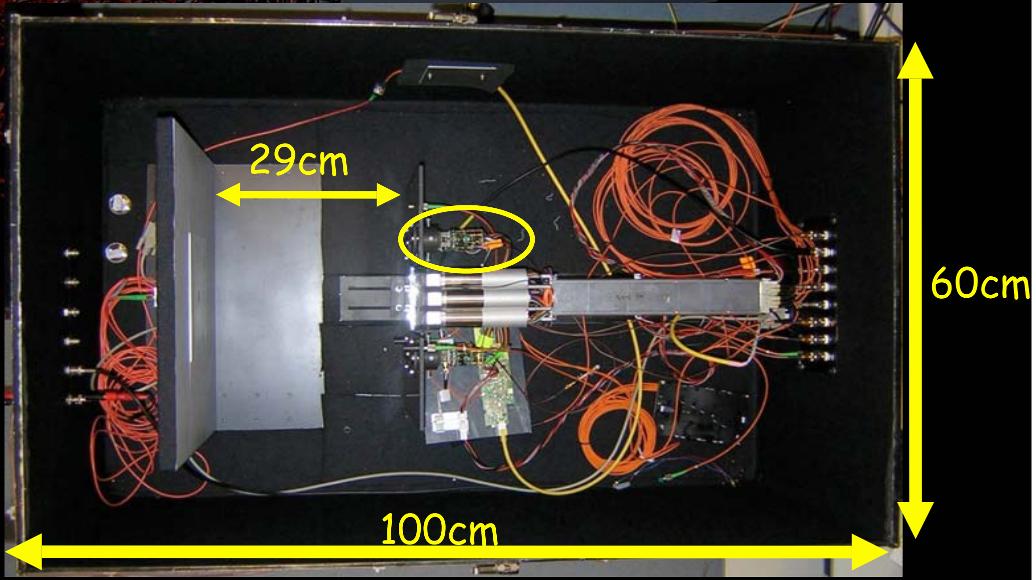
Cluster testing

(Daniela Borla Tridon
+ David Fink
+ Juergen Hose)

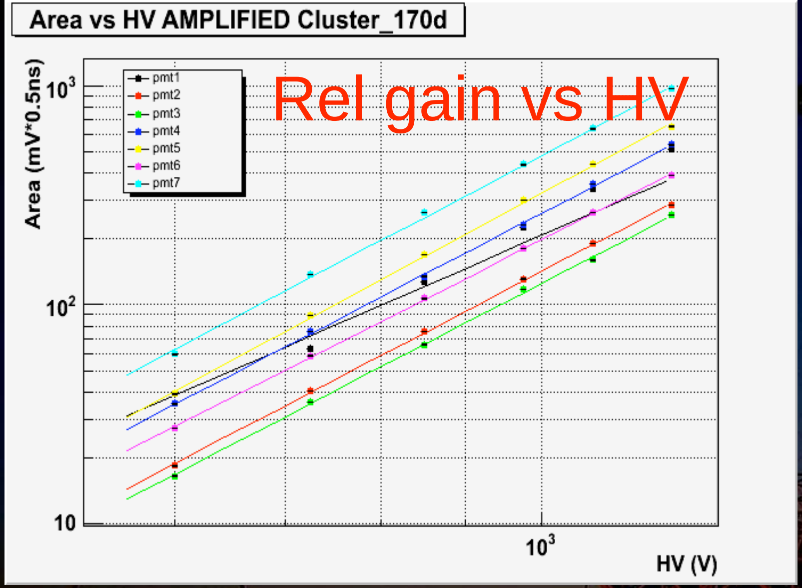
- Pulse shape / width
- Gain (vs. HV)
- Linearity / Dynamic range
- Single Photoelectron resolution
- Photon Detection Efficiency



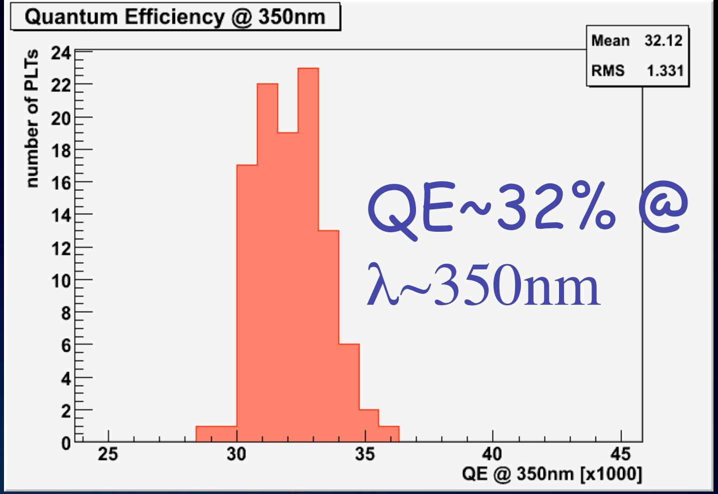
setup of test box



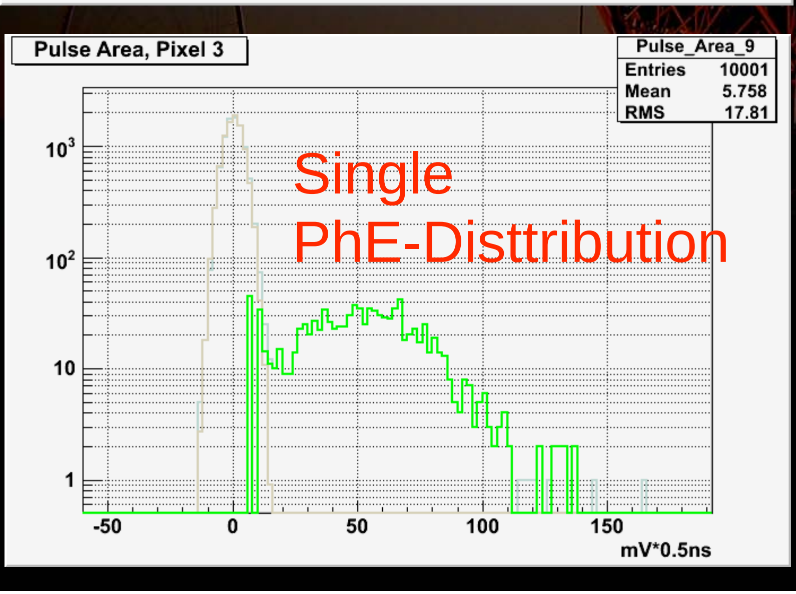
Some test results



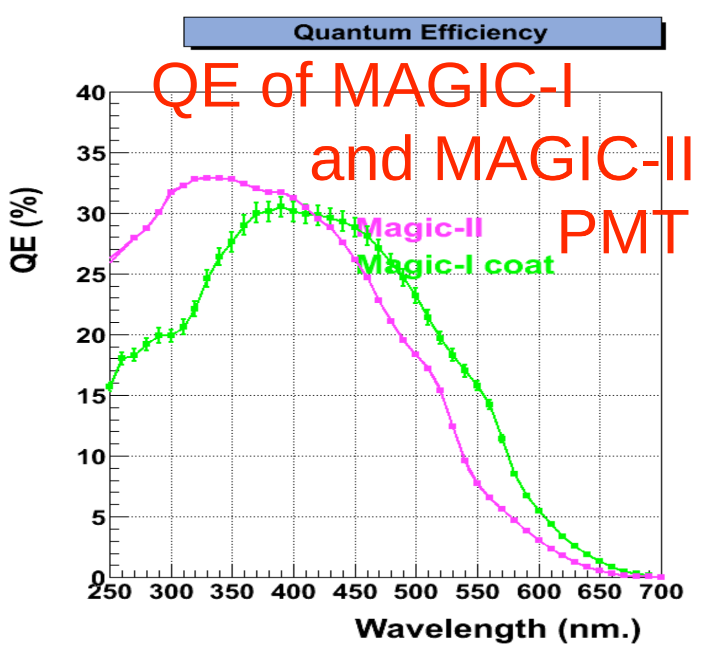
Rel gain vs HV



QE~32% @ λ~350nm

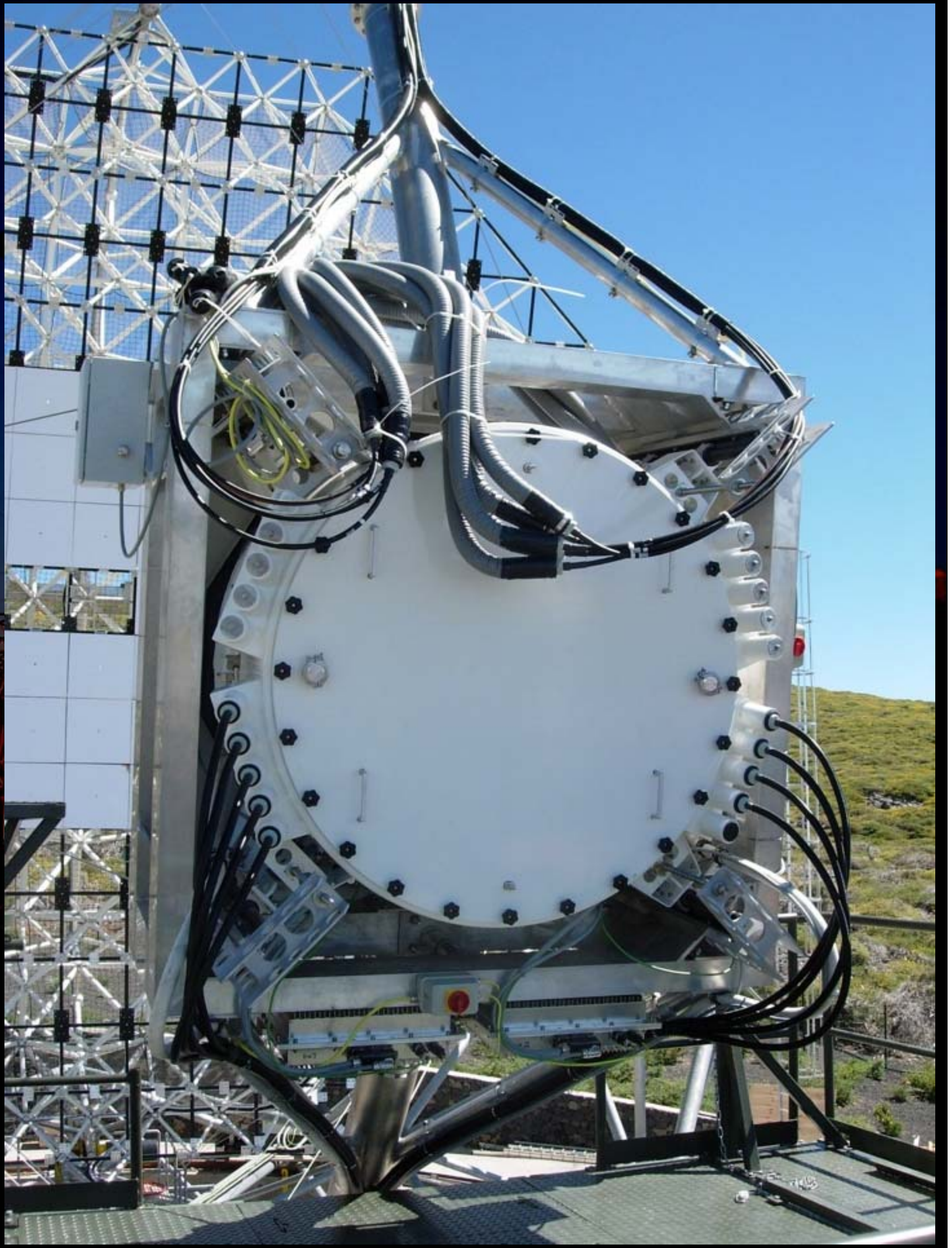


Single PhE-Disttribution



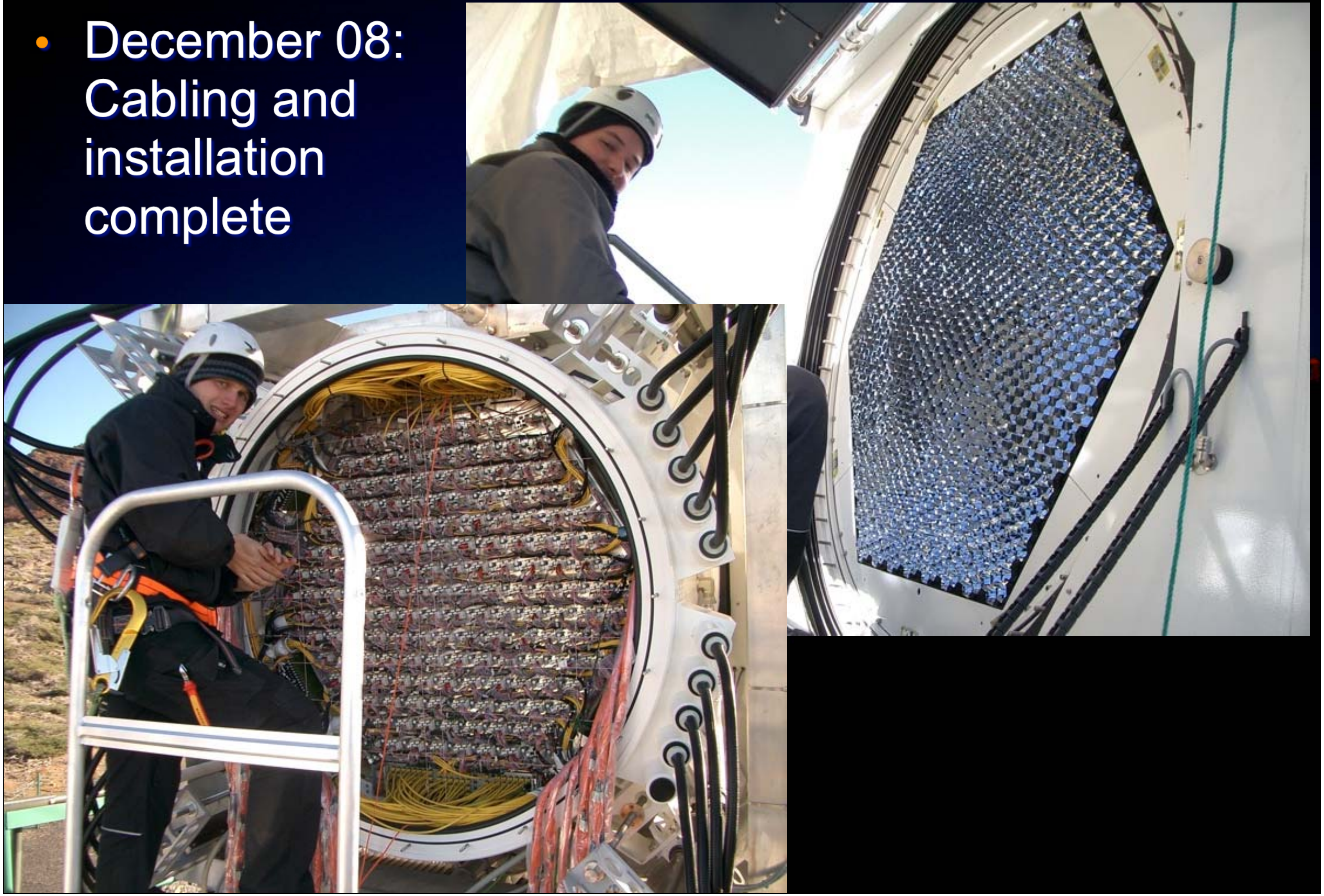
QE of MAGIC-I and MAGIC-II PMT

Camera housing installed Juni 2008



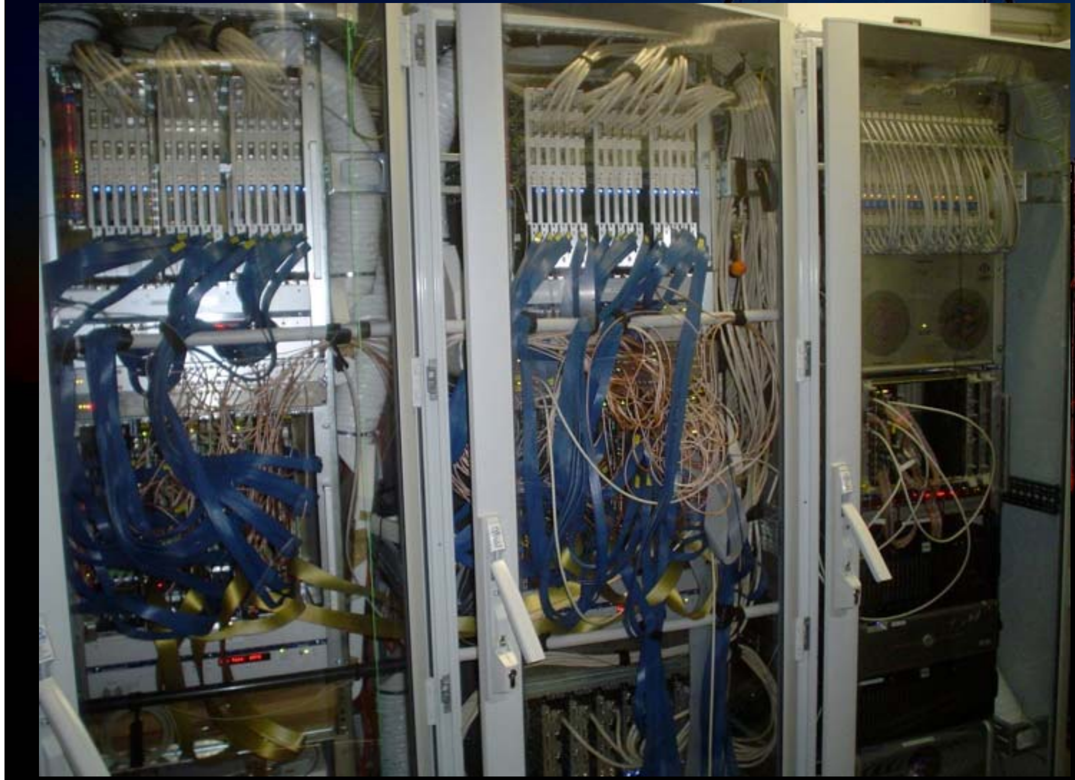
Camera complete !

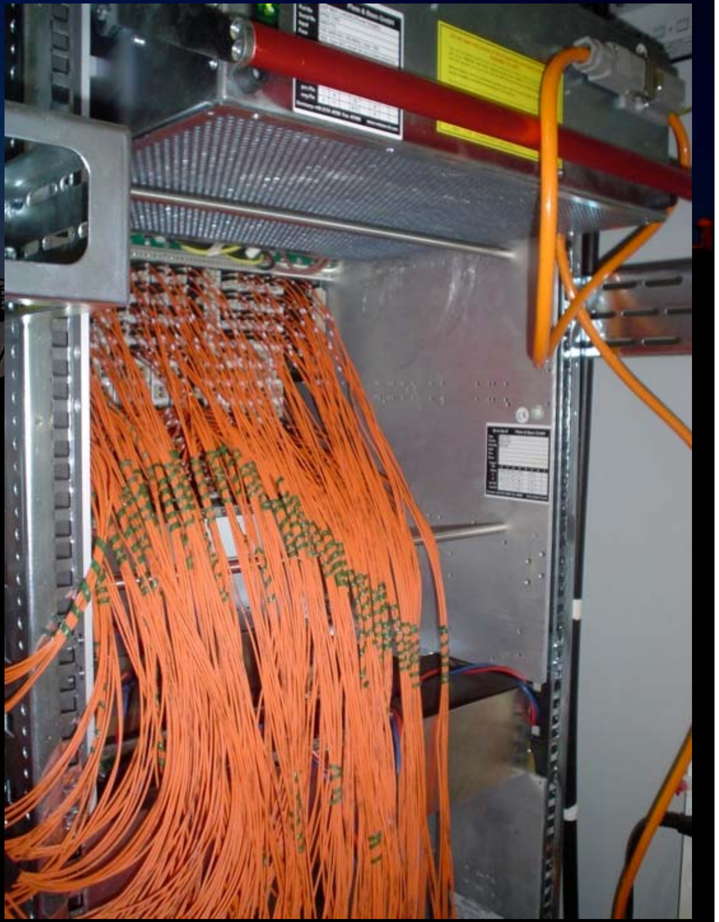
- December 08: Cabling and installation complete



Electronics basically installed

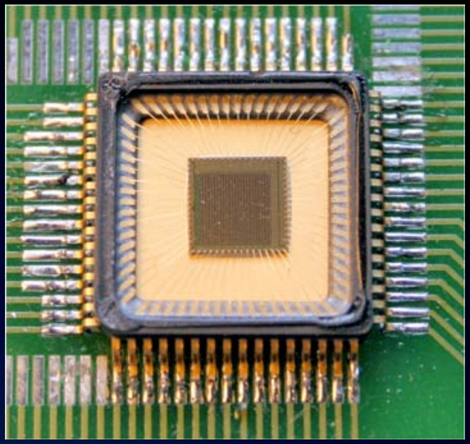
- All cabling done December 2008





Fast Readout installed and cabled Domino Ring Sampler (IFAE, Barcelona & INFN PISA)

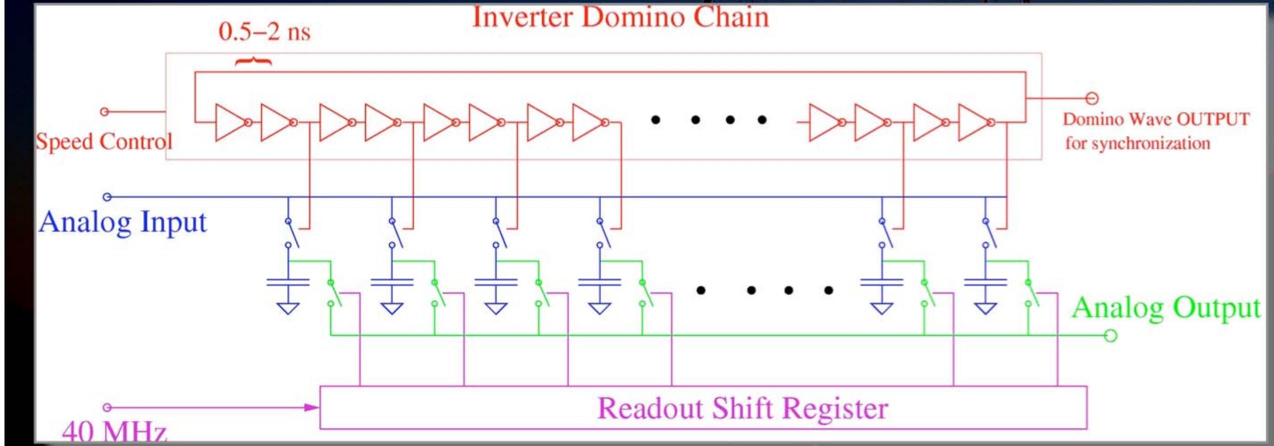
Fast sampling allows improvements in sensitivity

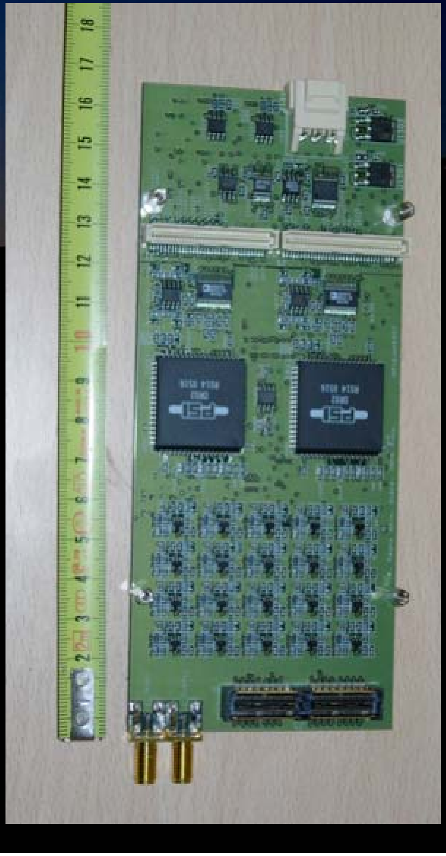


- 2 GSamples/s analog sampling in series of 1024 capacitors
- slow (40 MHz) readout

  and external 12 bit digitization

Chip Design: Stefan Ritt
Paul Scherrer Institute
(Villigen,CH)

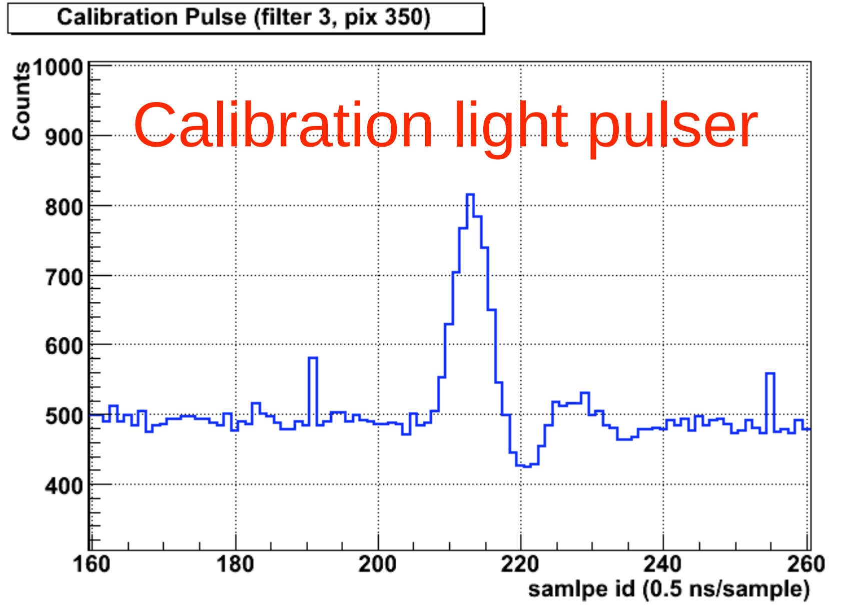


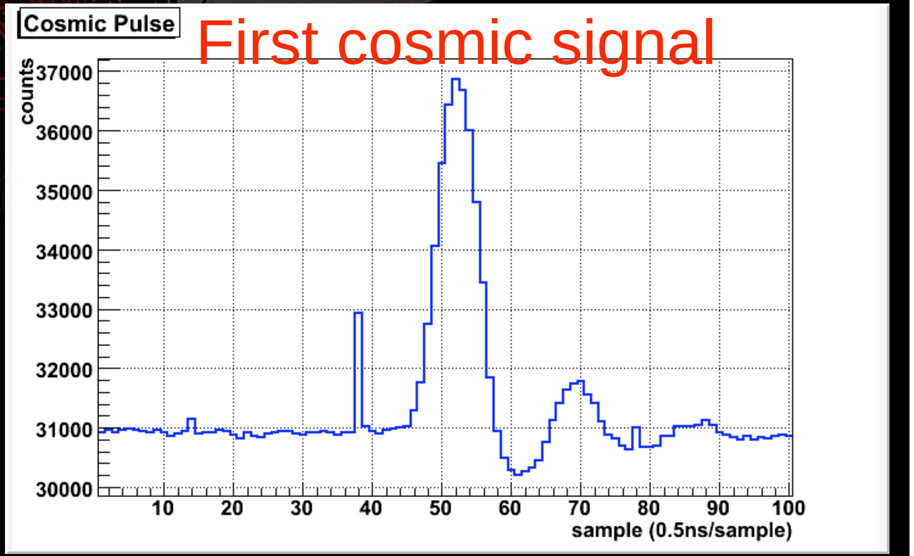


- low cost / small space occupation
- low power consumption
- very flexible

First signals !! December 2008

(still uncalibrated)


Calibration light pulser

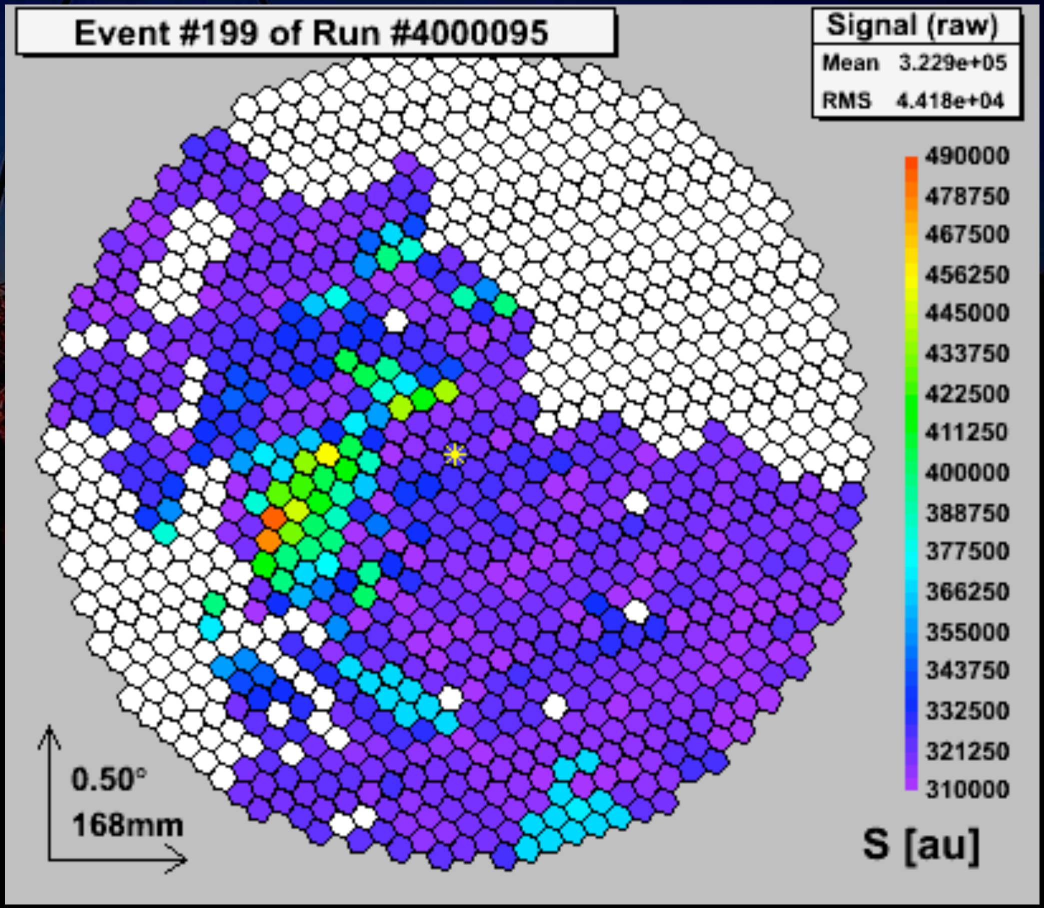

First cosmic signal

First shower image
with partially connected camera
(December 2008)

Uncalibrated
(no gain flatfielding)

and

Without pedestal
subtraction



First shower image
with partially connected camera
(December 2008)

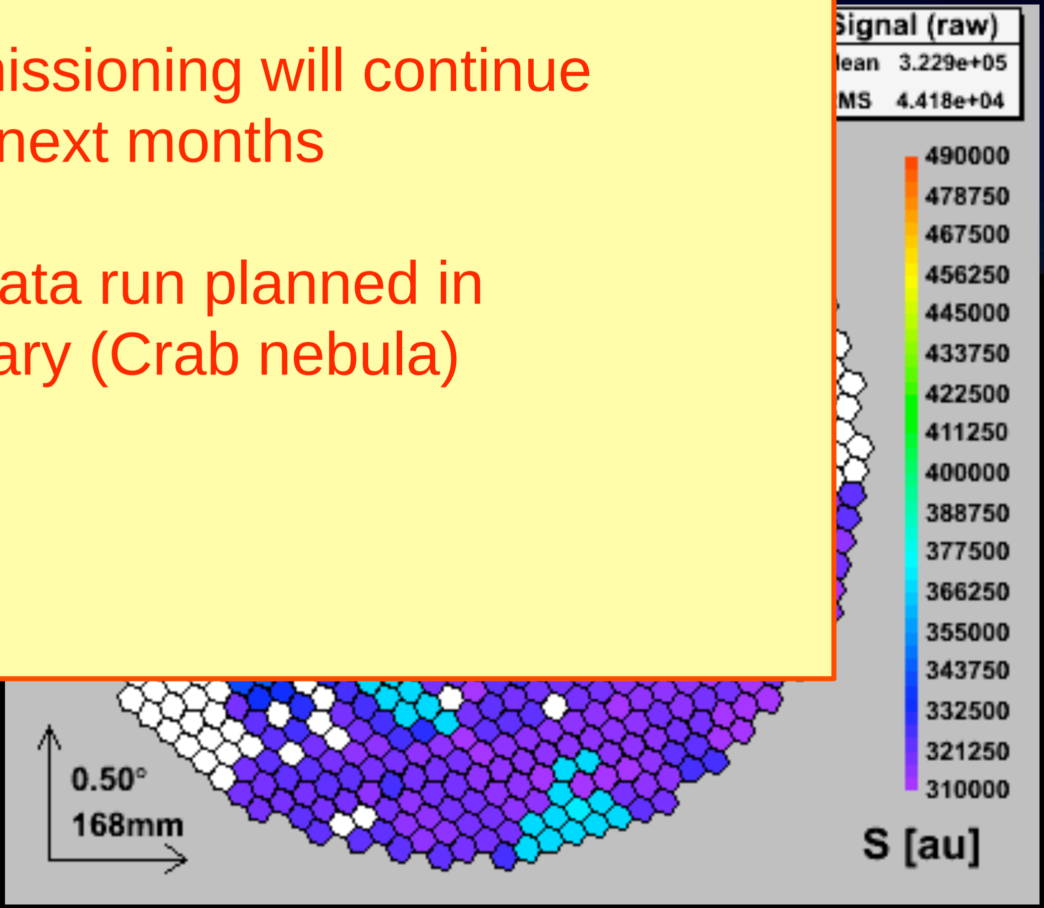
Uncalibrate
(no gain fla

and

Without pe
subtraction

Commissioning will continue
in the next months

First data run planned in
February (Crab nebula)



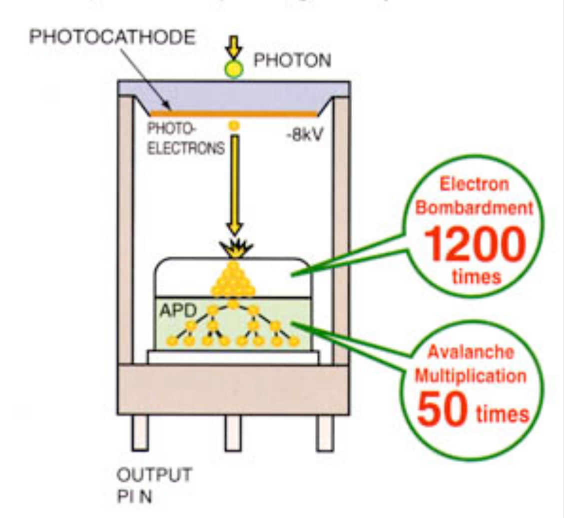
Near future plans: Camera upgrade with 400 hybrid photo detectors (HPD)

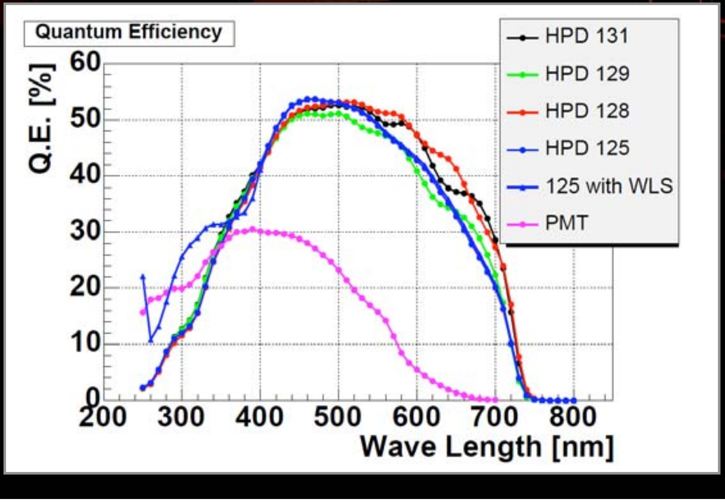
Principle

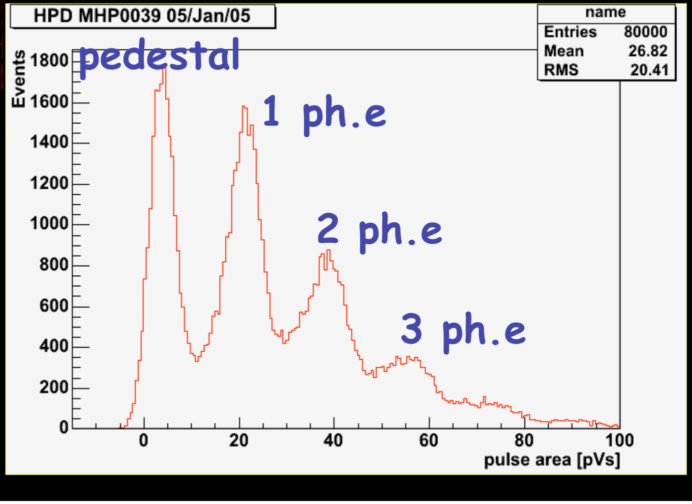
- -Vacuum tube operated at 6-8 kV
- - Avalanche Diode (~300 V)

Advantages

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


Compact HPD Operating Principle


Quantum Efficiency



HPD in Camera

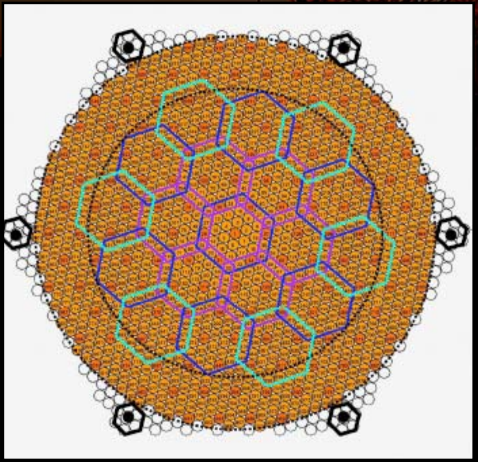
- HPD cluster has same geometrical shape as
- PMT cluster --> easy exchange

Phase 1

Field test

6 clusters (42 HPDs)

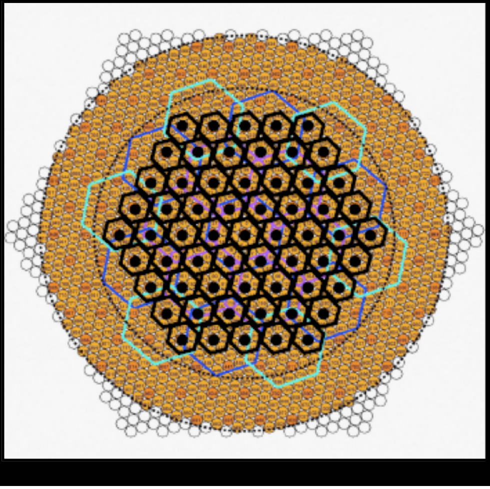
in MAGIC-II camera



Phase 2

427 HPD

in MAGIC-II camera



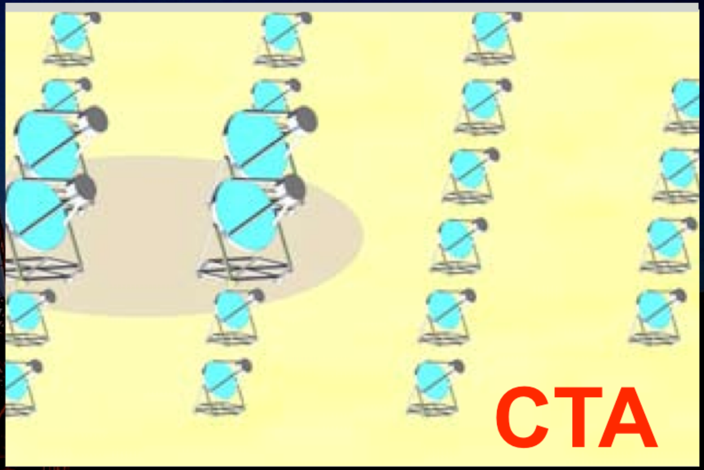
Future outlook: Beyond MAGIC: Cherenkov Telescope Array (CTA)

European Strategy Forum
on Research Infrastructures

ESFRI

EUROPEAN ROADMAP
FOR RESEARCH
INFRASTRUCTURES

Roadmap 2008



- In *gamma-ray astronomy* a similar role will be played by the **Cherenkov Telescope Array (CTA)**. The pioneering Cherenkov telescopes HESS and MAGIC have observed a multitude of gamma ray sources both in our galactic centre and outside our galaxy. The CTA will greatly extend the reach of these two projects and allow for further exciting scientific discoveries. The CTA will be deployed in two locations, one in the southern hemisphere and one in the northern hemisphere (likely sites are in Namibia and in the Canary Islands).

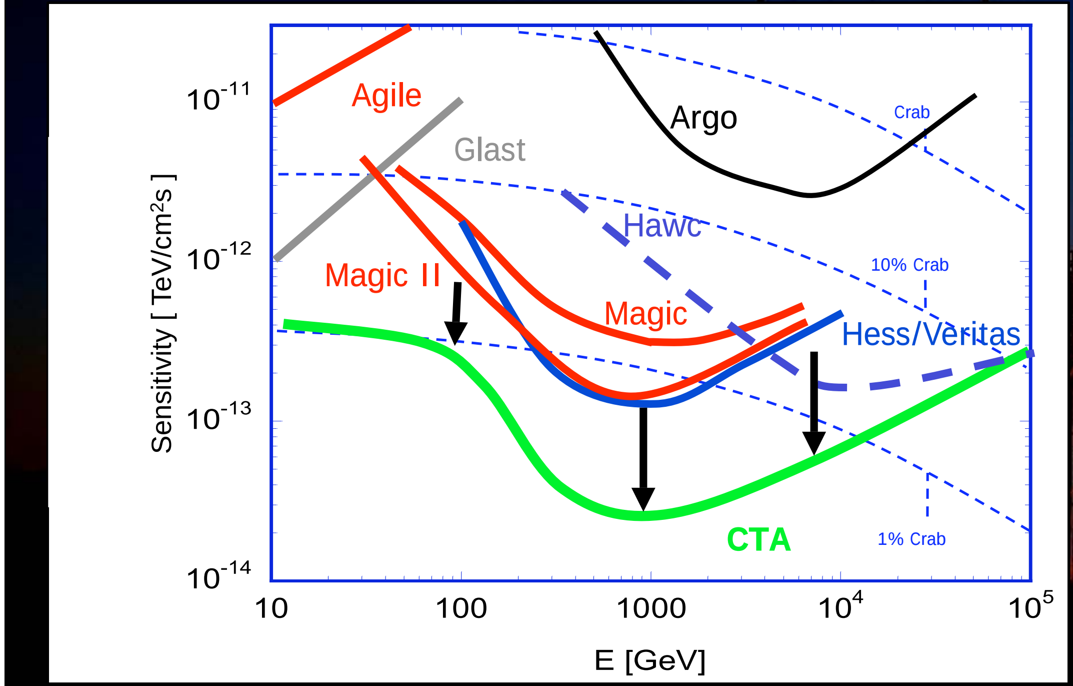
Beyond MAGIC:

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:

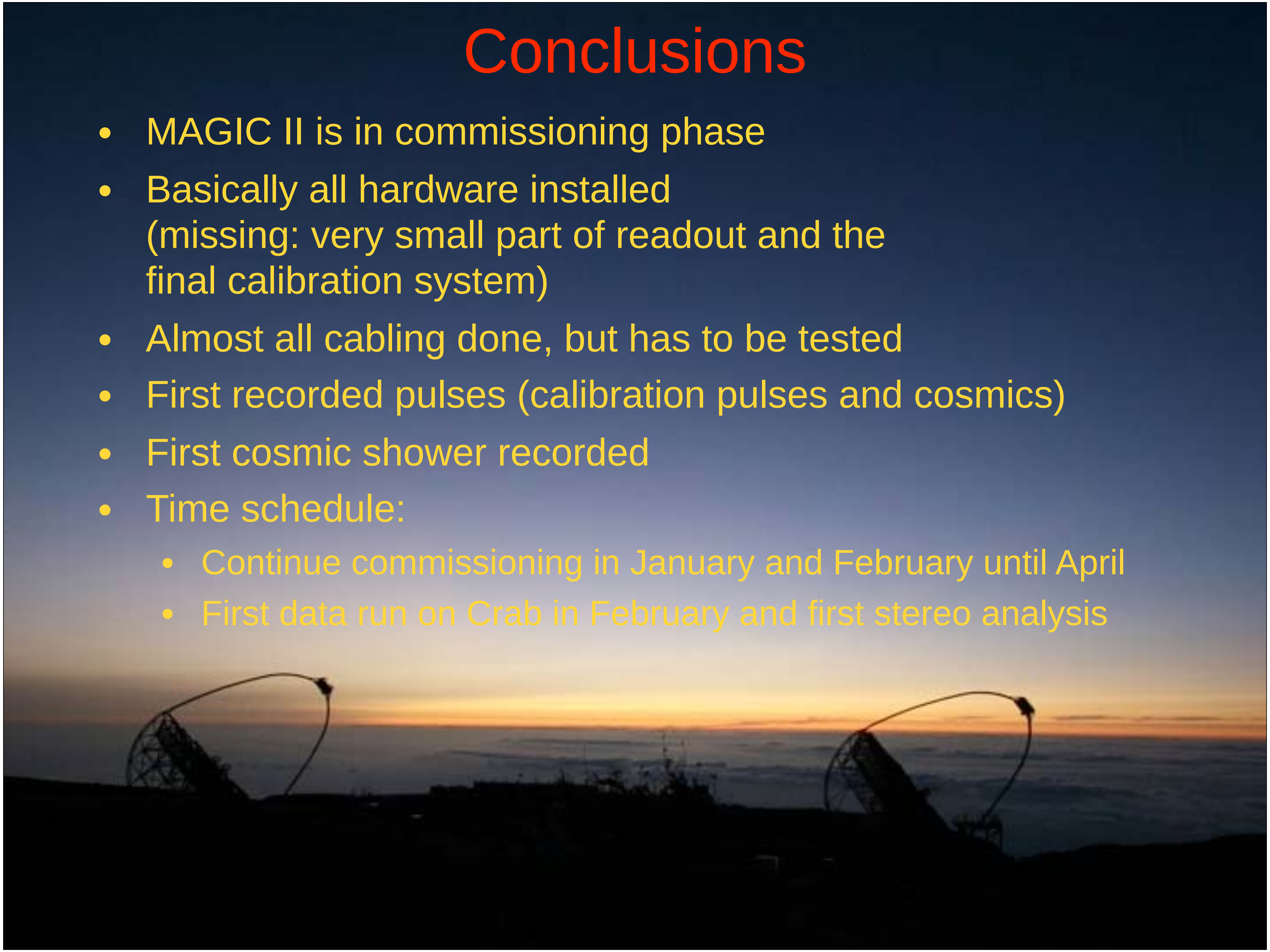
Applications for design study to European and national funding agencies

Mayor participation of MPI:

Organization, Camera, MC, telescope structure, physics, site survey

Conclusions

- MAGIC II is in commissioning phase
- Basically all hardware installed
  (missing: very small part of readout and the
  final calibration system)
- Almost all cabling done, but has to be tested
- First recorded pulses (calibration pulses and cosmics)
- First cosmic shower recorded
- Time schedule:
  - Continue commissioning in January and February until April
  - First data run on Crab in February and first stereo analysis



The end

First mirror installation:

23 October 2007

Trigger installed and cabled December 08

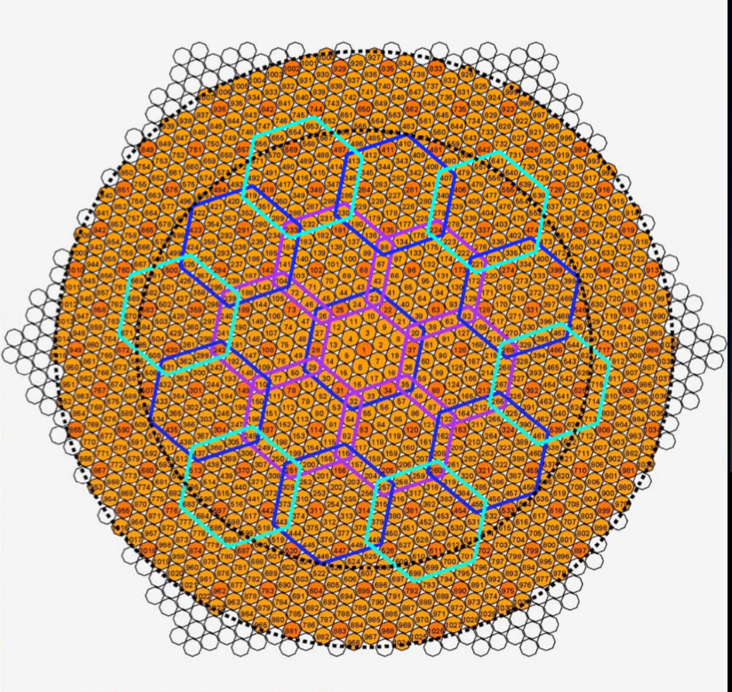
Increase trigger area:

- d=1.9° => d=2.5°

=> Larger effective FOV

=> Improved sensitivity for

- Sky scan
- Extended sources
- Wobble mode observation

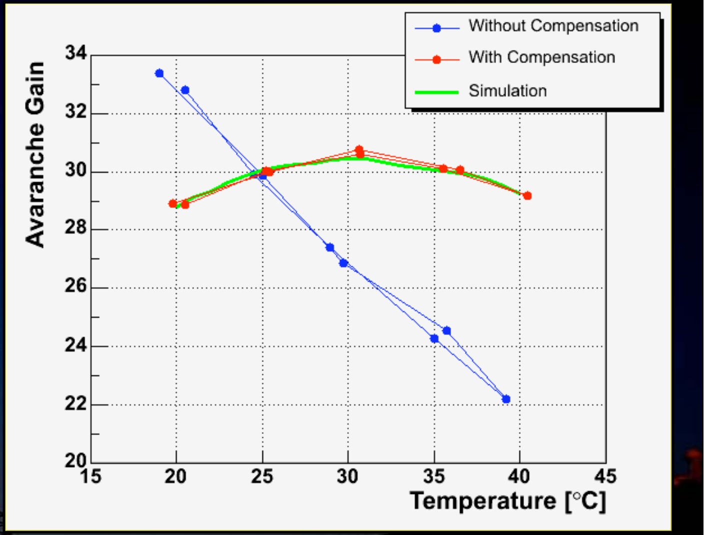


2 telescope coincidence trigger

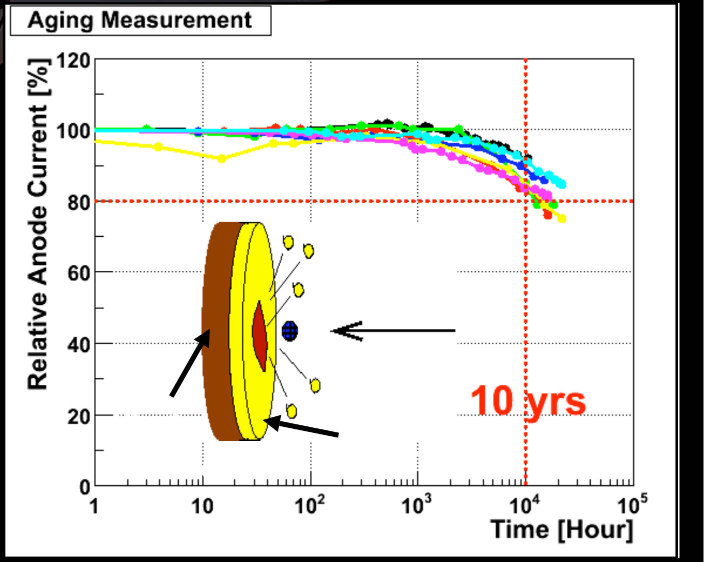
not tested yet (coincidence can be done off-line as well)

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

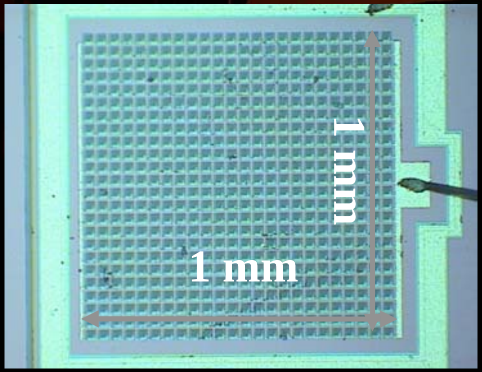
New Technologies

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

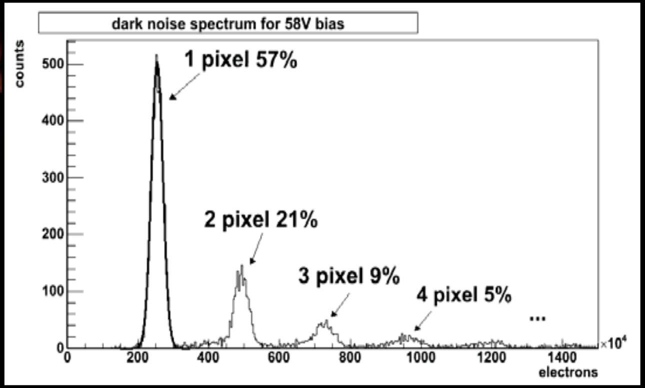
=> Photosensors with higher Photon Detection Efficiency essential

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

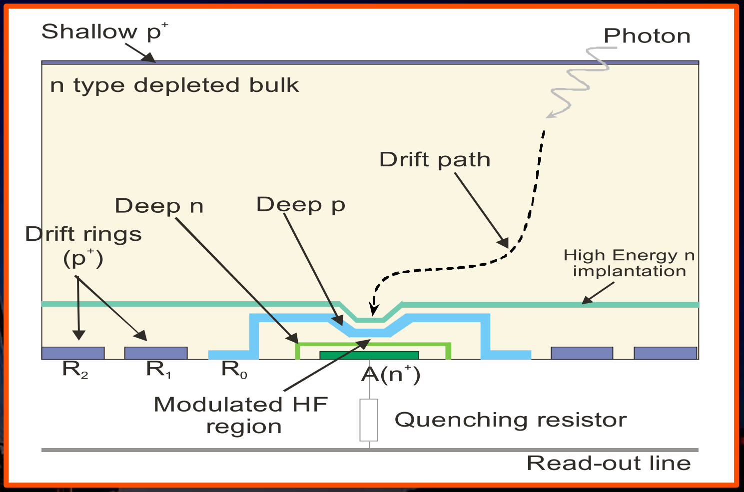


SiPM developments

HLL developments:

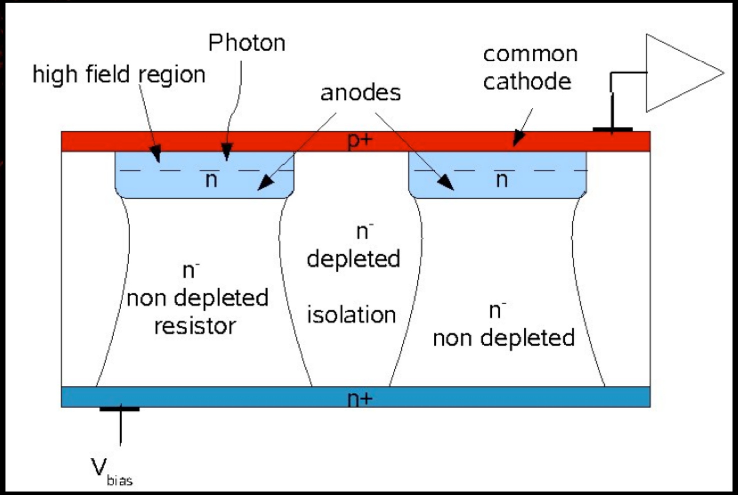
Classical SiPMs:

- 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 & internal photon conversion

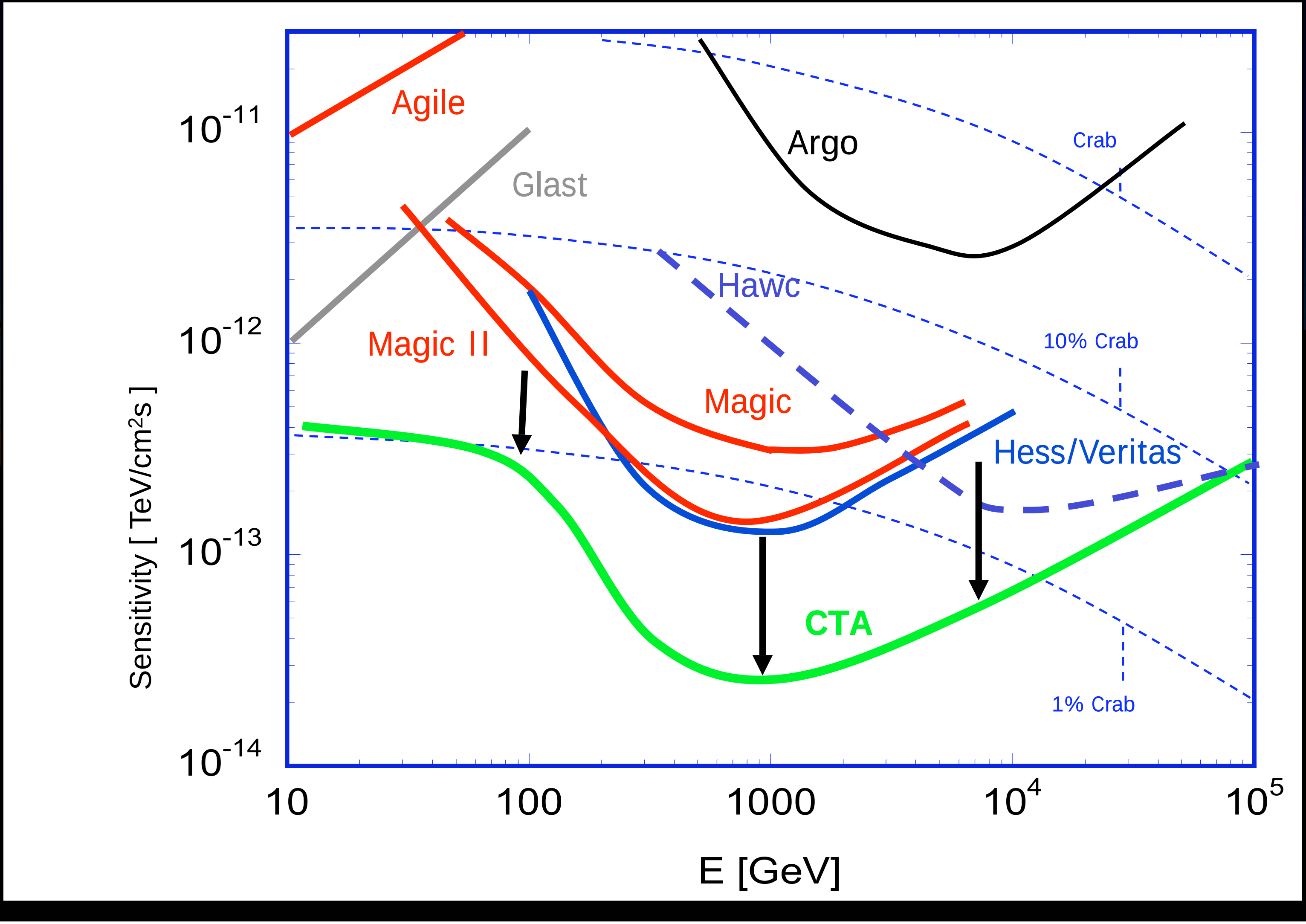


2) Bulk Resistor SiPMs

- 75% geometrical fill factor
- Uniform optical thin entrance window
- Simple/cheap technology

Prototyping for 1) & 2)

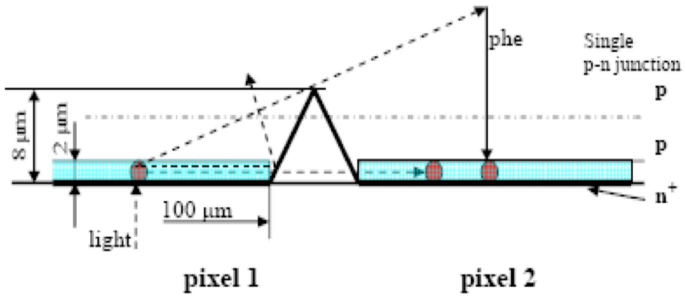
Aimed sensitivity



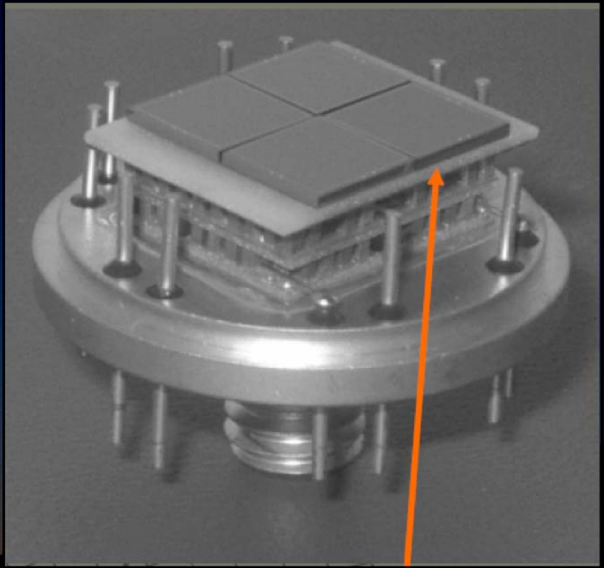
SiPM developments

Collaboration with MEPhI/Dolgoshein

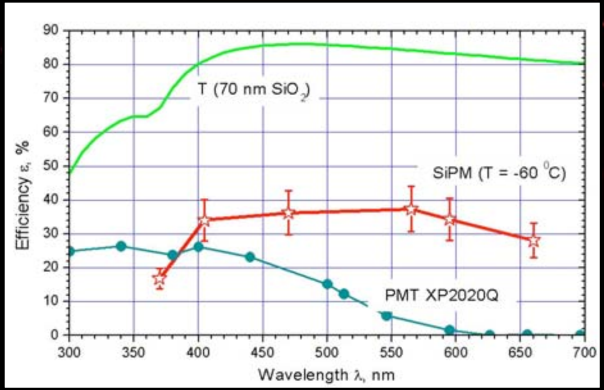
- Cross talk suppression by trenches



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