The Beginning and Construction of the MAGIC Telescopes

Razmik Mirzoyan

Max-Planck-Institute for Physics

Munich, Germany

The very beginning of MAGIC

- In September 1992, after ~2 months of commissioning, we put into operation the 1st IACT of the HEGRA array
- ~2 months later we have got the 1st signal from Crab Nebula, 1st time confirming the pioneering result of the 10m Whipple T. team
- In 1993 we built and put into operation the 2nd HEGRA telescope, started preparing the so-called "stereo" observations
- From the first observations we understood that the imaging camera should have larger field of view, on the order of ≥ 4°
- Also, from image analysis we understood that it is not only the Light of Nigh Sky (LoNS) which is limiting the threshold of an IACT, but the fact that one needs ~100 signal photo electrons in order to talk about a meaningful image, which one can analyze

The first (prototype) IACT of HEGRA in La Palma

- This telescope produced results in a record-short time
- After 2-months of operation we were the first to confirm the gamma-ray emission from Crab Nebula, measured by the team led by Trevor Weekes in Arizona, USA

The very beginning of MAGIC

- Soon it became clear that IACT operation is in contrast with the non-imaging technique, which is working on the verge of the LoNS fluctuations
- This made it clear that the usual consideration that the threshold energy E of an IACT is proportional to $1/\sqrt{A_{mirror}}$ is simply wrong and the correct dependence is $E \sim 1/A_{mirror}$
- I understood that if HEGRA 1st tel. with a 10 m^2 mirror area had a threshold of ~1 TeV, then a telescope with 20 times larger mirror area (~ 200 m^2) should have a threshold of ~20 times less, i.e. 1 TeV/20 ~ 50 GeV

The very beginning of MAGIC

- In 1994 I started looking for a large size telescope and by a chance found on a cover of a solar energy journal the picture of the 17m diameter solar telescope of DLR @Lampoldhausen
- But the optics was very poor
- We understood that we could build our own IACT but with a better optics
- 1995 we made three presentations @ conferences on the future telescope, which sometimes later on we dubbed as MAGIC (Major Atmospheric Gamma Imaging Cherenkov)
- One shall keep in mind that this happened at a very “hot time” for HEGRA IACT array, i.e. the IACTs # 3, #4 were under construction, #5 and #6 under planning

The 1st meeting of the MAGIC collaboration, Hinterriß, Austria,

Photo taken on 20th January, 1996

E-mail from Trevor Weekes to Eckart dated March 1996

Trevor Weekes,13.03.1996 12:01 Uhr,visit to FLWO?

Date: Wed, 13 Mar 96 13:01:43 -0700
From: weekes@egret.sao.arizona.edu (Trevor Weekes)
To: ecl@iws132a.MPPMU.MPG.DE
Subject: visit to FLWO?

Dear Eckart,

I note that you will be attending the HEAD meeting in San Diego (as will many members of our group); I wondered if you would be interested in making a detour to pay a short visit to the Whipple Observatory either before or after the meeting. Failing that I hope that we can find some time during the meeting to discuss our future programs and possible areas of cooperation.

I have been interested to hear of your progress with MAGIC. I was initially puzzled when I heard that you intended to convert an existing solar reflector (I remember your comment at Calgary about the necessity of starting with "a clean sheet of paper"..as we struggled with our own ex-solar reflector I came to agree with you very strongly!) but was relieved when I heard that you were going to build your own 17m reflector.

We have recently received some optimistic feedback on our own plan to upgrade our existing (non-solar!) reflector and we hope to start work on this in this calendar year. We still have an active proposal in to the Smithsonian for an array of telescopes but that is in the longterm. Given our current "good" funding picture and what I will assume will be a similar one for your MAGIC proposal, there may be areas in our future programs that will overlap. In particular if you have not fixed on a site you might consider Arizona; also I understand you are interested in a southern site and we have some experience with the operation of small gamma-ray telescopes in Argentina and have had two Ph.D. students (now doctored and back in Argentina). Dick Lamb conveyed to me your kind offer of sharing your advanced PMT technology and I would be very interested to discuss this further with you.

Tadashi Kifune is planning to visit the Whipple Observatory on the Monday following the HEAD meeting but please come anytime that suits you.

Regards,

Trevor

- German Ministry for Education and Science (BMBF) document about the review of HEGRA by a representative international review committee

Date: February 1-2, 1996

- Reviewers:
- J. Cronin
- D. Fegan
- G. Schatz
- J. Trumper
- A. Watson

Report on the Review of the HEGRA Experiment
held at the
Bundesministerium für Bildung,
Wissenschaft, Forschung und Technologie (BMBF)

Bonn, February 1 - 2, 1996

Members of the Review Committee (henceforth called the Committee) were J. W. Cronin (Chicago), D. J. Fegan (Dublin), G. Schatz (Karlsruhe; Chairman), J. Trümper (Garching), A. A. Watson (Leeds). The HEGRA Collaboration (henceforth the Collaboration) was represented by G. Heinzelmann (Hamburg), W. Hofmann (Heidelberg), E. Lorenz (Munich), H. Meyer (Wuppertal), M. Samorski (Kiel), W. Stamm (Kiel), and H. Völk (Heidelberg). In addition H. Blask (BMBF), K. S. de Boer and G. Morfill (present and former chairman of the funding committee, respectively) attended.

Members of the Committee had received written material on the results and future plans of the Collaboration shortly before the meeting and heard reports by G. Heinzelmann, W. Hofmann, E. Lorenz, H. Meyer, and H. Völk. The Committee outlined its conclusions to H. Blask and K. de Boer during the afternoon of February 2.

The HEGRA experiment in its present form consists of two major parts which are only loosely coupled and could operate separately: the arrays of scintillation counters, wide angle integrating Cherenkov detectors and the muon towers on the one hand (called the Hybrid Array by the Collaboration) and the system of Cherenkov telescopes the other hand. This report therefore considers these parts consecutively and then discusses the proposed MAGIC telescope as a possible future development.

The Hybrid Array

The Hybrid Array consists of 243 scintillation counters for registering the electromagnetic component of extensive air showers (EAS), 77 wide angle integrating detectors for the Cherenkov light emitted by the relativistic particles of the EAS in the atmosphere, and 17 towers which measure mainly the muon component.

Different components of HEGRA were critically reviewed

Hybrid Array beyond 1997 should therefore be rediscussed in late 1996 or early 1997 on the basis of the results then available.

To conclude the Committee gives highest priority to obtaining a larger and homogeneous data set for studying the problem of primary cosmic ray composition. This goal could be achieved by continuous operation of HEGRA during the next two years. These data would also allow a better founded assessment of the prospects of investigating the topics mentioned in the preceding paragraph. The Committe does not see a convincing reasons for enlarging the present AIROBICC array. Although the proposed expansion appears reasonable and would improve the quality of the installation, it was not thought to be decisively so. Instead, the resources, both human and financial, should be concentrated on potentially more promising future developments.

The Cherenkov Telescopes

Construction of the system of Cherenkov telescopes is pursued with a high degree of expertise. The Collaboration was among the very first groups to observe cosmic ray events with two Cherenkov reflectors operating in stereoscopic mode, using the first pair of telescopes. The system, when completed, will not reach the sensitivity of the best Cherenkov telescopes now existing (Whipple) or soon coming into operation (CAT). Its potential to discover new gamma ray sources will therefore be limited. However it will have strong astrophysical potential as it permits the detailed investigation of known sources of gamma rays in the TeV region with much higher spatial and energy resolution than single Cherenkov telescopes. In this respect the arrangement will be unique at least in the northern hemisphere and for the next three to five years. These features are especially important because the production mechanisms of high energy gamma rays in astrophysical objects are frequently unclear or controversial and spatially and spectrally resolved observations constrain theoretical models much more effectively. The close cooperation of the experimental group with theoretical astrophysicists is especially promising in this respect.

The Committee recommends to proceed with the construction of the telescopes as planned.

Conclusions and recommendations of the committee:

Future Plans

The Committee heard two reports about possible future expansions of the HEGRA experiment by E. Lorenz on the MAGIC telescope and by W. Hofmann on an improved more sensitive system of Cherenkov telescopes in the TeV region. The latter plans appear to be in a very early stage of consideration, not surprisingly in view of the present status of the Cherenkov telescopes. This report will therefore discuss only the first project.

The planned MAGIC telescope consists of a single Cherenkov dish of 17 m diameter. It would have considerably higher sensitivity and lower threshold than existing arrangements. The scientific objective of the MAGIC telescope would be quite different from that presently under construction at La Palma. It would offer a unique opportunity to push the operating threshold of the Cherenkov technique down below 50 GeV, a threshold which is not currently attainable by existing or planned installations. MAGIC would be therefore constitute the largest area Cherenkov reflector in either hemisphere, offering unique survey opportunities at low threshold energies.

The project takes advantage of technology developed for solar energy applications and proposes a number of innovatory and challenging approaches, especially with respect to

- the mechanical structure of the mounting
- mirror fabrication
- mirror alignment procedures
- the use of novel light detectors.

Successful realization of any of these objectives would represent a considerable improvement of technology in the field of Cherenkov telescopes and therefore be beneficial for a much wider community. The Committee therefore recommends pursuit of these developments and subsequent construction of the telescope without delay, the latter also in view of plans for new gamma ray satellites with much improved angular resolution and sensitivity which will become available in the long run and whose energy range will probably overlap with that of MAGIC.

This report was approved by all members of the Committee.

Gerd Schatz

G.Schatz, Chairman

Expression of Interest, of VERITAS, from September 1996,

was followed by the

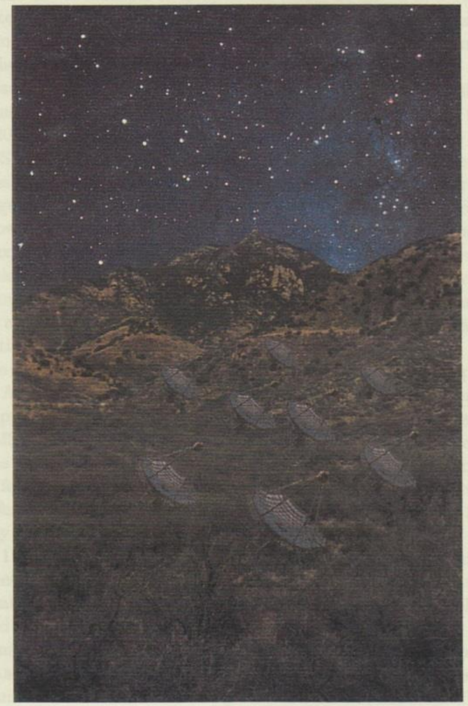
Letter of Intent , VERITAS March 1998

E. Lorenz
do not take away

VERITAS

(Very Energetic Radiation Imaging Telescope Array System)

Letter of Intent



Submitted by Prof. J. A. Gaidos on behalf of the VERITAS Executive Committee:
S. Ahlen (Boston University), D. Carter-Lewis (Iowa State University), D. Fegan (National University of Ireland), G. Fishman (Marshall SFC), J. Gaidos (Purdue University) [Chairman], D. Kieda (University of Utah), J. Rose (University of Leeds), S. Swordy (University of Chicago), M. Ulmer (Northwestern University), T. Weekes (Smithsonian Astrophysical Observatory)

March, 1998

Plans of VERITAS;
a 7 telescope array

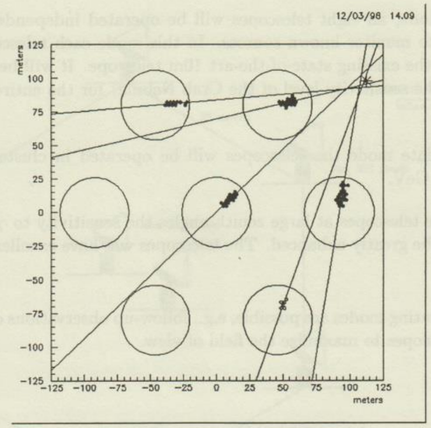


Figure 15: The focal plane distribution of pixels registering a signal from a γ-ray shower of 300 GeV falling at the position shown by the asterisk; the cameras here are of diameter 3.5°. The images have been cleaned and a major axis fitted to each elliptical image (indicated by the lines). The accuracy with which the impact parameter can be determined (from the intersection of the axes) is apparent.

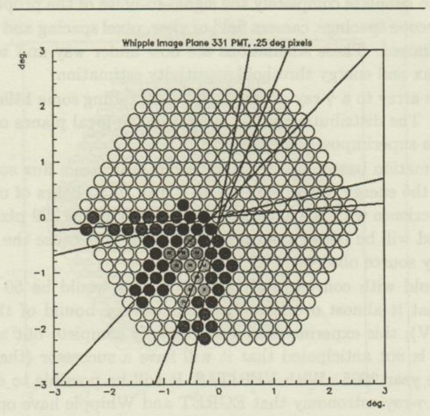
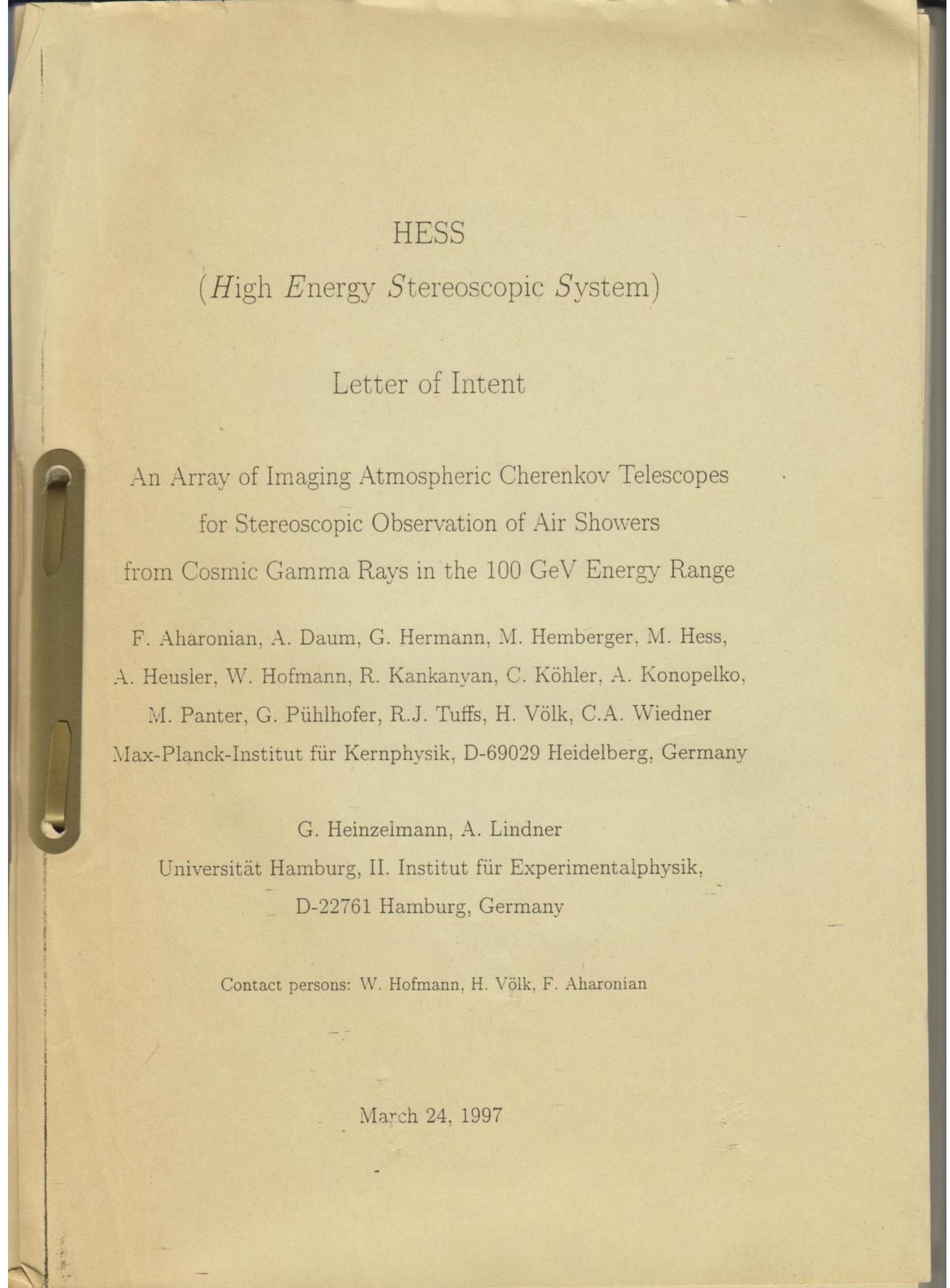


Figure 16: Superposition of the images seen by the seven telescopes for the shower in Fig. 15 showing the accuracy with which the arrival direction can be inferred.

Letter of Intent, HESS



HESS

(*H*igh *E*nergy *S*tereoscopic *S*ystem)

Letter of Intent

An Array of Imaging Atmospheric Cherenkov Telescopes
for Stereoscopic Observation of Air Showers
from Cosmic Gamma Rays in the 100 GeV Energy Range

F. Aharonian, A. Daum, G. Hermann, M. Hemberger, M. Hess,
A. Heusler, W. Hofmann, R. Kankanyan, C. Köhler, A. Konopelko,
M. Panter, G. Pühlhofer, R.J. Tuffs, H. Völk, C.A. Wiedner
Max-Planck-Institut für Kernphysik, D-69029 Heidelberg, Germany

G. Heinzelmann, A. Lindner
Universität Hamburg, II. Institut für Experimentalphysik,
D-22761 Hamburg, Germany

Contact persons: W. Hofmann, H. Völk, F. Aharonian

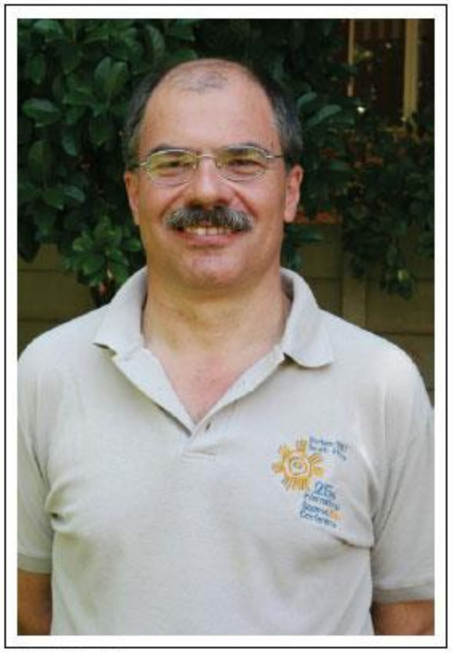
March 24, 1997

A very good, very memorable workshop, 5th in the series

the main organizer:
Okkie de Jager

Okkie de Jager

1961 - 2010


Prof. Okkie de Jager

- Okkie was one of the most enthusiastic astro-physicists I have ever met
- He has top-cited publications in astrophysics
- But he was very actively developing experimental ideas and even patenting and trying to commercialize them (like the low-cost ozone generator or a special low-noise amplifier for radio-telescopes)
- It was Okkie who suggested the principle of Sum-Trigger (though his initial idea needed to be further improved and optimized)
- The tough illness took his life

Constraints in Reducing the Threshold of an IACT

Constraints In Reducing The Threshold Of Imaging Cherenkov Telescopes

Razmick Mirzoyan*

Max-Planck-Institut für Physik, Föhringer Ring 6, D-80805 München, Germany

Abstract

Currently existing gamma ray imaging telescopes measure above the energy threshold of about 300 GeV. In the nearest future some of the existing telescopes will be modified and new telescopes will be operating providing probably an energy threshold of about 100 GeV. It is very interesting to measure also in the energy range between 10–100 GeV, which is not yet explored due to the lack of detectors for this energy range. Here we show that a single large (15–20 m ø class) ground-based imaging telescope can provide measurements of gamma sources above the threshold of 10–30 GeV. Probably the systems of ≥ 3 such telescopes will found the future gamma ray observatories, allowing one to find, measure and classify sources in the whole 10 GeV – 100 TeV energy range.

1. Introduction

The 25th ICRC in Durban and this workshop have very convincingly demonstrated the succes of VHE gamma ray astronomy and once more again underlined the fact that a new branch of astronomy has firmly established itself. The Whipple, the CAT, the HEGRA, the Telescope Array and the TACTIC collaborations (also the Durham group) have reported their measurements on highly variable Active Galactic Nuclei (AGN) Markarian-501 within several months of the source activity and demonstrated good agreement among their data measured on the same days by their rather different telescopes scattered on different continents on the Earth (Protheroe, 1997; Bradbury, these proceedings).

It is already the 5th workshop of the series devoted to the major atmospheric Cherenkov detector. At the 2nd workshop in Calgary T.C. Weekes has discussed the possible developments which might lead to the goal (Weekes, 1993). Since then there have been a lot of new developments in the field, but still, while we know what do we want (a Major Atmospheric Cherenkov Detector), it is not yet very clear how would it finally look like.

The Compton GRO satellite measures up to 10–20 GeV, the planned future missions can measure even somewhat higher energies, but the low flux sensitivity of satellite experiments, which is due to the limited detector area of $\sim 1\ m^2$, can not be dramatically increased. It seems that the wide field of view of satellite detectors and the very high flux sensitivity of very low energy threshold (VeLET) Cherenkov telescopes, which will be operating in the sub-100 GeV domain, are complementary to each other. The combination of both techniques can allow one to perform deep exploration of the Universe in the sub-100 GeV energy range.

In this report I will try to set forth *my subjective vision* concerning the future gamma-ray observatories. There are different views about it. While two of the proposed future arrays of gamma telescopes (the VERITAS and the HESS projects) are oriented to study sources

*On leave from Yerevan Physics Institute, Yerevan, Armenia

I believe that the construction of VeLET telescopes is rather a financial than a technical problem. Taking into account the modest costs for the construction of such telescopes (the estimated cost for a single telescope is ~ 3 Mln USD) and the big scientific expectations, one may conclude that they are inexpensive. A system of ≥ 3 VeLET telescopes, situated on some optimised distance from each other, can be a very powerful instrument for source measurements and can cover the whole energy range from 10 GeV till 50–100 TeV. Such systems meet the requirements for a Major Atmospheric Gamma Imaging Cherenkov detector and will probably found the future gamma ray observatories. Once the telescopes with reliable mounts are built, they will be used for tens of years in future. The progress in the field of light sensors will always push one to use better detectors in the focal plane, one can see it on the example of optical telescopes. 3 telescopes can be arranged, for example, as a triangle with a side length of ~ 130–180 m (of course, it is necessary to perform Monte Carlo studies for optimisation of the distance).

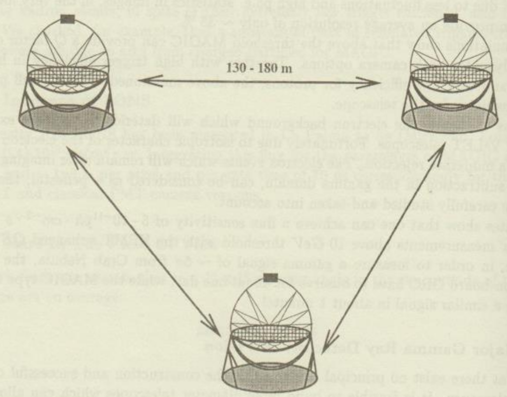


Fig. 5: A minimal configuration with 3 VeLET telescopes of 15-20 m ø class as a future gamma ray observatory.

Such a configuration can provide the necessary flexibility for the system. Due to the relatively large distance between the telescopes they are quasi-independent on one hand (one can observe different sources) and still one can use them in coincidence mode for observation of a single source with higher precision. In the latter case the effective collection area will be limited to the central region inside the triangle. On the one hand the closer are the telescopes to each other, the lower is the trigger threshold of the system. On the other hand already a

Excerpt from the Proc. Towards the Major Atmospheric Cherenkov Detector V, Kruger National Park, South Africa

The trigger threshold of a non-imaging telescope is usually set at the level, which is exceeding the fluctuations of noise due to the afterpulsing in PMTs (Mirzoyan, Lorenz, et al., 1997a) and/or light of the night sky ($LONS$) by a factor of 3–4. The threshold of a non-imaging telescope $E(non-imaging)_{threshold}$, which can be defined as the shower energy which provides the minimum given signal/noise ratio during the given measuring (gate) time, scales with the mirror surface area A_{mirror} as:

$$E(non-imaging)_{threshold} \sim \frac{1}{\sqrt{A_{mirror}}} \quad (2)$$

This is due to the fact that the signal charge (which is proportional to the number of measured Cherenkov photons from a shower) is almost linearly proportional to the mirror area, while the noise fluctuations (r.m.s. value of the charge measured from $LONS$) are proportional only to the square root of it.

Together with the trigger threshold the imaging telescope has also another, a more decisive threshold, namely the imaging one (one needs at least ~ 100 ph.e. per image), which is usually few times higher than the trigger one (see the paragraph 2.1.1 above).

As the measured from a shower charge is almost linearly proportional to its energy, the energy threshold of an imaging telescope relates inversely to the mirror area:

$$E(imaging)_{threshold} \sim \frac{1}{A_{mirror}} \quad (3)$$

(Mirzoyan, 1996b; Mirzoyan, 1997b).

Thoughts of Patrick Fleury in Proc. of the Kruger Nat. Park, 1997

For a programme of multi-imager arrays in the Northern and Southern hemispheres

Patrick Fleury

Ecole Polytechnique - Palaiseau (France)

When in 1992 we called for the Palaiseau workshop which has become the first of the present series, there was only one source firmly established. I had suggested as the workshop title "Towards a Major Atmospheric Cerenkov Detector" which Trevor, who sponsoring the meeting, accepted with reluctance. He said that a single source does not found a new domain in Astrophysics. Certainly I had jumped too early to the conclusion that a new field was born. I did not know that the Crab was quite an atypical object, the brightest in the sky at many different wave lengths.
Still, at the opening of the workshop, Trevor came with a second source and, to makes thing even nicer, this was an extragalactic one, Markarian-421. During the workshop, an array of 10m telescopes was suggested as a "Major project" pretty similar to VERITAS. But clearly enough this was not timely and, in his conclusive remarks, Trevor insisted on the necessity to keep on with a diversity of approaches.

In the mean time, indeed, a lot of progress has been made, in terms of techniques with lower energy thresholds, development in finer imaging by Cangaroo and CAT, breakthroughs in stereoscopy by Hegra. New devices are constructed such as Mark-6, and new groups are coming in, Shalon, Tactic and, not the least, the multi-telescope of Teshima.
Also the problem of bridging the gap at low energies with EGRET is being tackled with two different proposed approaches, a big dish associated with fancy photo-detection with MAGIC, and the solar plants with STACCE and CELESTE.
Another main problem, the one of broad angle survey is also being tackled with the MILAGRO water pool.
But, on top of that, the main progress can be measured in terms of the number of new sources from Northern and Southern skies: about 5 Galactic sources, 3 extra galactic, and possibly the question of the origin of cosmic rays at last answered, and the intergalactic diffuse infrared light severely constrained.

The situation has matured to the point that it is now timely to think in terms of a large scale exploitation of this new field. This requires a Major ACT Detector such as the one proposed too early before, something which is now designated as VERITAS. This is now a funded project and we heard this morning that HESS is pretty much on the way.
VERITAS (and HESS) can be characterised as deployment of this existing state of the art, with a moderate extension to a lower threshold, affording with its 9 telescopes a versatility in

its operating modes, either for the observation of several sources simultaneously, or using all in parallel to reach a better flux sensitivity. VERITAS would be the first ACT Observatory. The simple fact that the risk is kept under strict limits was essential no, no doubt, to convince the funding institution. This will be the same anywhere else.

This brings me to my question:
several groups in the US and also in Europe will participate in VERITAS, but not all groups represented here. Should all of us not work out a world-wide strategy consisting of covering both the Northern and Southern skies, with the construction of an array of similar performance in the South, either in Australia or in Chile or why not in South Africa.
This action would leave enough forces to pursue Research and Developments preparing future generations of detectors. These activities fit better with national or regional collaborations. Concerning the attempts to reach the 10-20 GeV, it is unlikely that neither the big dish nor the solar plants would be mature for a large deployment before several years. These programs cannot justify that so many groups would keep away from the astrophysics exploitation that the present state of the art will permit.

To conclude, I would suggest that discussions be initiated between the interested groups on the implementation of an ACT observatory in the South. A first occasion for a serious debate could be the HESS project meeting in Ringberg next autumn.

Note added in proof: The Ringberg meeting which has now taken place has been the occasion of a constructive debate on this topics.

C. L. Bhat from BARC in Mumbai, India, asking for replicating some technological developments led by MAGIC, for their own 17m MACE project, 1999

Dr C.L.Bhat Head NRL ,23.06.1999 10:49 Uhr,MACE telescope

Date: Wed, 23 Jun 1999 15:19:06 +0530 (IST)
From: "Dr C.L.Bhat Head NRL " <clbhat@magnum.barc.ernet.in>
To: ecl@hegra1.mppmu.mpg.de
Subject: MACE telescope
MIME-Version: 1.0

To,

Dr. Eckart Lorenz,
Max-Planck Institute of Physik,
Postfach 40 12 12,
Fohringer Ring 6,
D-8000, Munchen 60,
Germany.

Dear Prof. Lorenz,

I am pleased to inform you that we have been approved some substantial funding for the development of the MACE telescope. We are expected to complete the fabrication and installation phases of the telescope in next 3-4 years. As you would recall, it is planned to be set up at Mt. Abu (altitude: 1500-1600m), close to where the TACTIC imaging gamma-ray telescope has been installed.

I hope that the MAGIC project has in the meanwhile made a substantial progress. We have benefitted a lot from the quite exhaustive Report you have made on this project. After detailed deliberations here, we have come to the conclusion that it would be both time-efficient and cost-effective for us if we closely follow the MAGIC mechanical design and specifications for the MACE telescope. Besides, having 2 similar systems, operating at two far-off Northen hemisphere locations, would be useful for gamma-ray astronomy as well. As such, we have also decided to have a 17m mirrof for the MACE telescope. The focal-plane instrumentation (photomultiplier-based in our cae) will also be similar with the same pixel resolution of 0.1 degree. We are in touch with M/s ELTEC for supply of mirrors for the MACE telescope. We would prefer to get from them similar mirror facets as used by you for the MAGIC. Our discussions with them are still at a preliminary stage, but, we hope, to finalize our requirement in the next few weeks.

I am keen that we continue to get guidance from your considerable experience for the implementation of the MACE project. In fact, it would help to save considerable time and developmental expenditure if we can replicate some of the major systems that you have developed and tested for the MAGIC. We can also share the responsibility for the development of some new subsystems which can be used both by the MAGIC and MACE telescopes. I look forward to your favourable response in this connection.

With best regards.

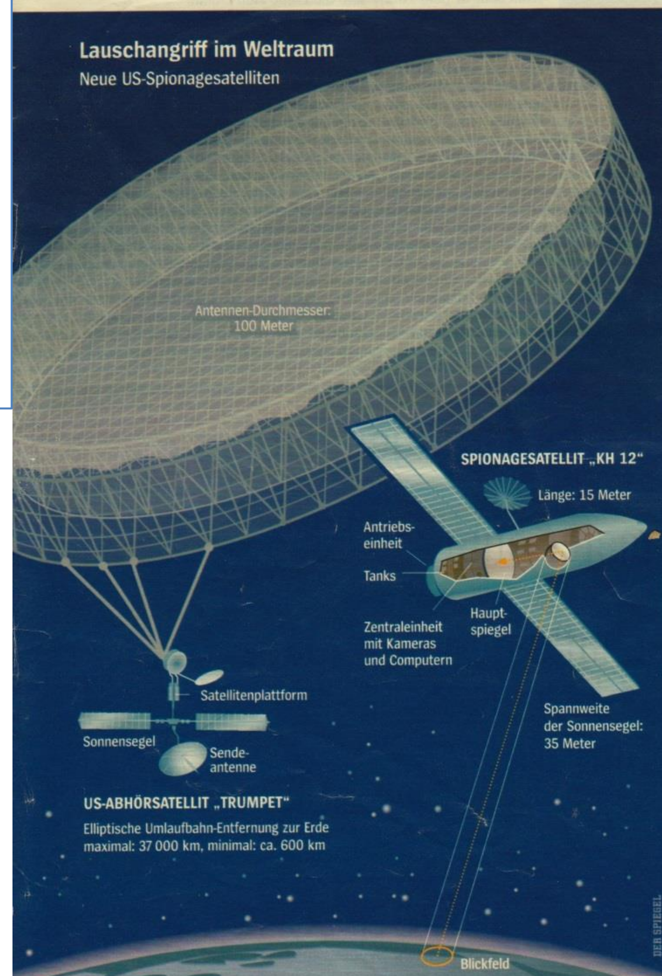
Sincerely yours,
(CC.L. Bhat)

- The shape of this US spy-satellite dish of 100 m diameter reminded us that of MAGIC
- This has independently supported our endeavors that we were on a right track

RÜSTUNG

Tandem der Himmelsspäher

US-Militärs bauen ihre Spionageflotten aus. Fußballfeldgroße Satellitenantennen belauschen den Funk- und Fernsprechverkehr. Radaraugen erspähen selbst gut versteckte Panzerkolonnen. Weltraumgestützte Teleobjektive erfassen zehn Zentimeter große Objekte auf der Erde.



Zwei Titan-4A-Raketen, die schubstärksten im US-Arsenal, werden derzeit startklar gemacht, die eine am Cape Canaveral (Florida), die andere im kalifornischen Vandenberg. In ihrer Spitze verpackt sind die bislang größten, teuersten und leistungsstärksten Radar- und Lauschsatelliten, die Amerikas Militärtechniker je ersonnen haben.

Jeweils rund eine Milliarde Dollar kosteten Entwicklung und Bau der [illegible]n Horch- und Guckposten, die den Ve[illegible]gten Staaten, acht Jahre nach dem Ende des Kalten Krieges, ihre Rolle als weltbeherrschende Supermacht der Himmelsspionage sichern sollen.

Zigtausende von Funksprüchen, verschlüsselten Signaldaten und Handy-Gesprächen gleichzeitig kann beispielsweise die Horchplattform mit dem Codenamen „Trumpet“ (Hörrohr) belauschen, deren Start in Florida vorbereitet wird. Ihr auffälligstes Merkmal entfaltet sie nach Erreichen ihrer Umlaufbahn: Ein System von minimotorbetriebenen Flaschenzügen wird eine tortenförmige Riesenantenne entfalten. Durchmesser: rund 100 Meter (siehe Grafik).

Trumpet ist ein Geschöpf der für elektronische und visuelle Spionage aus dem Weltraum zuständigen US-Behörde, des National Reconnaissance Office (NRO). Auf seiner extrem flach elliptischen [illegible]laufbahn wird sich der Satellit bis zu [illegible] Kilometer von der Erde entfernen. Wenn er sich beim Rückschwung auf wenige hundert Kilometer nähert, wird die Antenne auf die nördlichsten Gebiete der Erde ausgerichtet sein – ein günstiger Standort, um beispielsweise den Funkverkehr zwischen den Kommandanten der russischen Atom-U-Boot-Flotte und der Einsatzzentrale in Moskau zu überwachen.

Dreimal soviel wie der Lauschposten Trumpet wiegt der Spionagesatellit „Lacrosse“, der von der Startbasis Vandenberg auf einen kreisförmigen Orbit in knapp 700 Kilometer Höhe über der Erde gebracht werden soll.

Die Radarsysteme an Bord des knapp 15 Tonnen wiegenden Trumms (Länge: 12 Meter, Durchmesser: 4,4 Meter) liefern nicht nur bei jedem Wetter und zu jeder Tageszeit Bilder von bislang unerreichter Schärfe und Auflösung; sie können auch Objekte wie Panzer oder Raketen aufspüren, die

Eckart, doing the things by himself

- During my 1st visit in MPI lab in June 1990 I saw Eckart „cooking“ a big piece of scintillator for the HEGRA array
- The scintillators turned out to have bubbles everywhere, or vice-versa: numerous bubbles were surrounded by some scintillating material; his only aid was Ina, the long-time colleague, technical help, friend and secretary
- That was the typical Eckart: no problem to solve any problem, possibly by the most cost-efficient way
- Eckart with his PhD students Martin Merck and Albrecht Karle, they put HEGRA scintillator array (252 huts) + AIROBICC (100 huts, Eckart‘s baby) into operation, with Frank Krennrich and myself, plus some people from Kiel, 1st HEGRA IACT

Eckart Lorenz, one of the last Mohicanes in experimental science

a view of someone who worked next to him for 24 years

- Everybody around him knew that there is a reference person who one can go to and ask arbitrary questions about the technology, cosmic rays, gamma rays, neutrino detectors and astrophysics, drak matter experiments, accelerator expeiments, nuclear medicine,…
- Of course that was a luxury for us, which we are missing badly

Eckart Lorenz, the scientist and the inventor

a view of someone who worked next to him for 24 years

- Eckart was absolutely enthusiastic about MAGIC, which he gave shape from the very first days
- The initial criticism about MAGIC, which I can remember, was from a representative committee evaluating MAGIC, about too many new technologies Eckart was simultaneously introducing
  - carbon-fibre frame of the telescopes,
  - all-Al diamond mirrors,
  - sytem of Active Mirror Control,
  - 20s fast rotation of the telescope,
  - fast analog signal transmission via optical fibres by using VCSELs,
  - hemispherical fast PMTs from EMI,...
- The history showed that indeed, we needed relatively long time for „polishing“ the novel technologies, but then, once it became operational, it paid off

Eckart Lorenz, the scientist and the inventor:

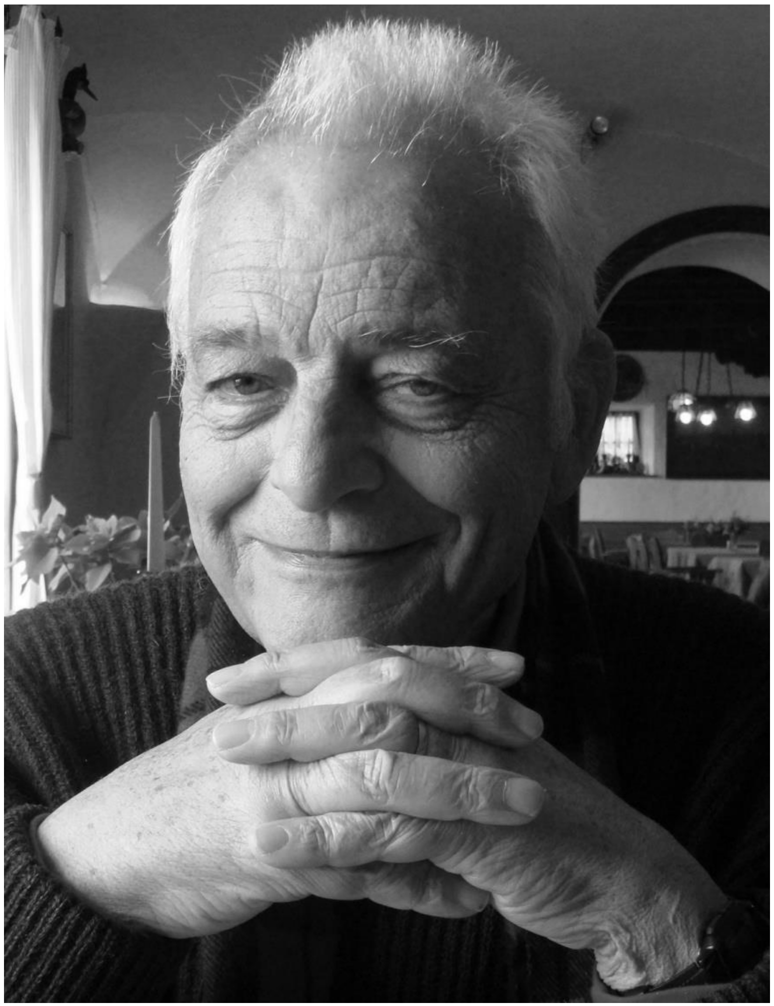
Obtaining membership of Polish Academy of Sciences in Berlin
Unfortunately he enjoyed this moment only ver short; within a minute he fainted, fall down and never get back to consciousness

Eckart, the scientist and the innovator:
a view of someone who worked next to him for 24 years

- When the CTA endeavor started, Eckart became one of its most enthusiastic members
- He started giving shape to the Large Size Telescope (LST) of 23m diameter
- He took onto his shoulders the responsiility for the giant mechanical mount, trying to make it light-weight, optimising performances, asking for fine studies of multi-mode vibrations and oscillations of the telescope, …
- Now we are almost ready with the 23m; Eckart‘s contribution was decisive (you will see that telescope during the trip to ORM on Thursday)!

Eckart, the great scientist and the innovator

a view of someone who worked next to him for 24 years



- Most people sitting in this auditorium and many hundreds who are not present, know that we had a brilliant colleague who gave a shape to current Astroparticle Physics, to physics of cosmic rays and to astrophysics by means of γ-rays

- Our great respect and admiration to him!

Rudy Bock

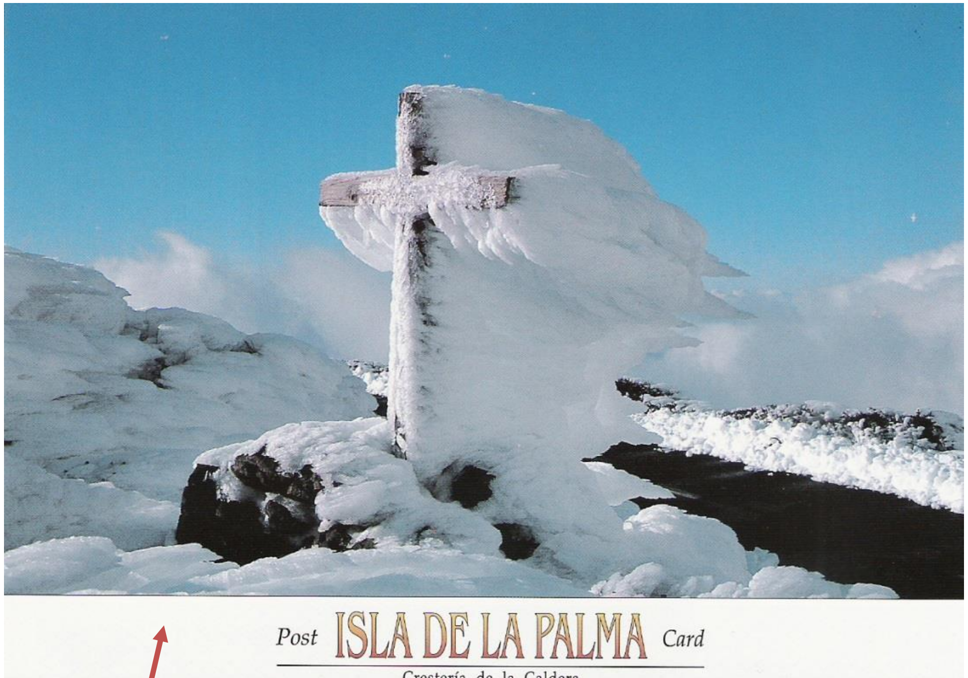
1935 - 2015

- Rudy worked lifelong at CERN and was a real expert in statistics, software and analysis methods, physics in general
- He was a great leader and guided the young generation of Magicians to develop the software and analysis codes for MAGIC
- He taught us that the best method to learn a language is to have girl-friend; after we learnt that, we stopped wondering as to why he was fluent in 10 languages
- His excellent English was a real rescue for us in writing articles; loved people, good food and wine and was enjoying life

Daniel Kranich

1966-2014

- I used to share an office with him and closely learnt his gentle character
- He was one of the best PhDs in our group and in MAGIC
- The quasi-periodicity of Mrk-421 in 1997 (we observed the source for 400h) was his result
- Already in 1997 we published a paper on observations at moon-light
- He took so many responsibilities in MAGIC (scheduler, lead analyser,…)
- Tragically passed away in mountains

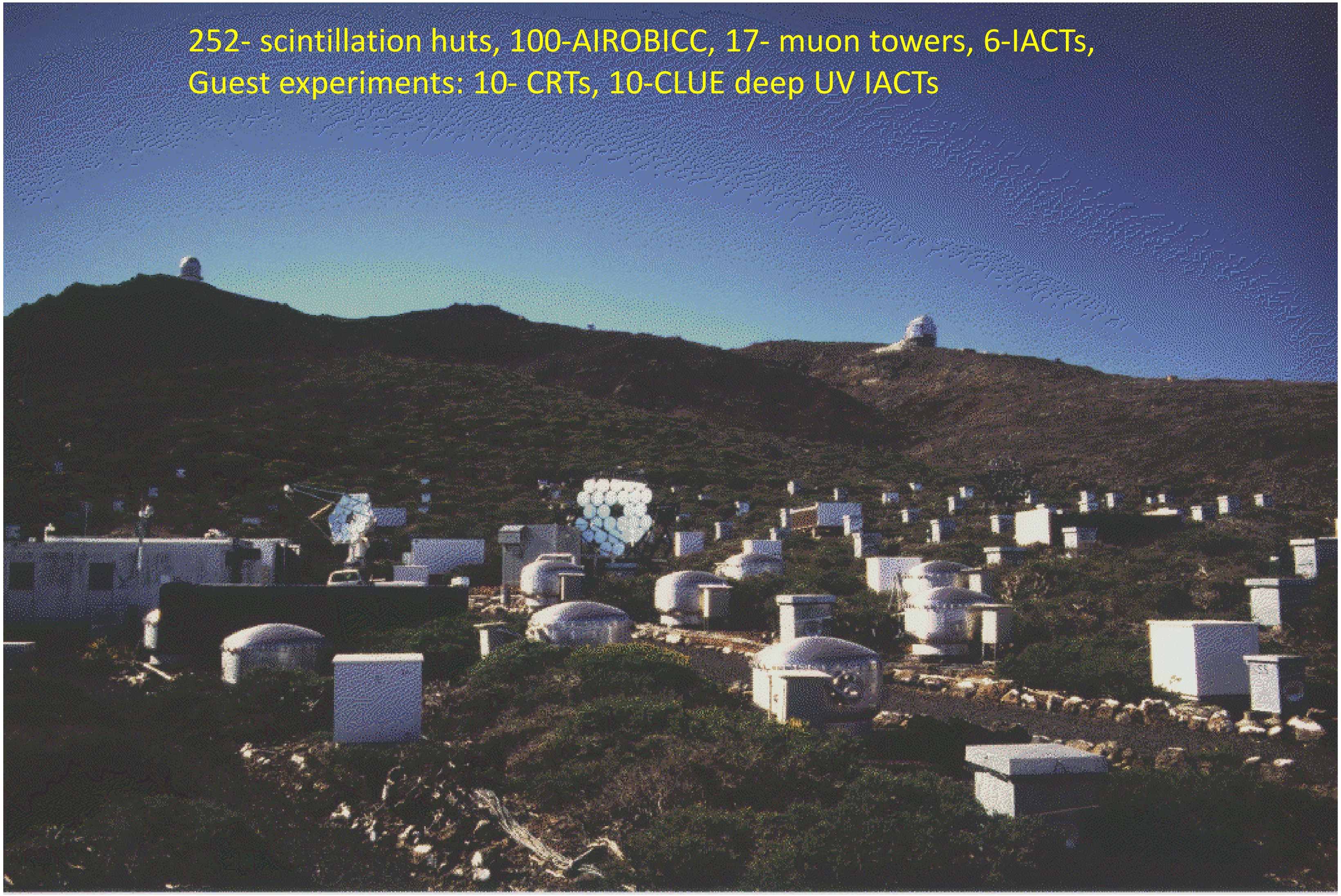


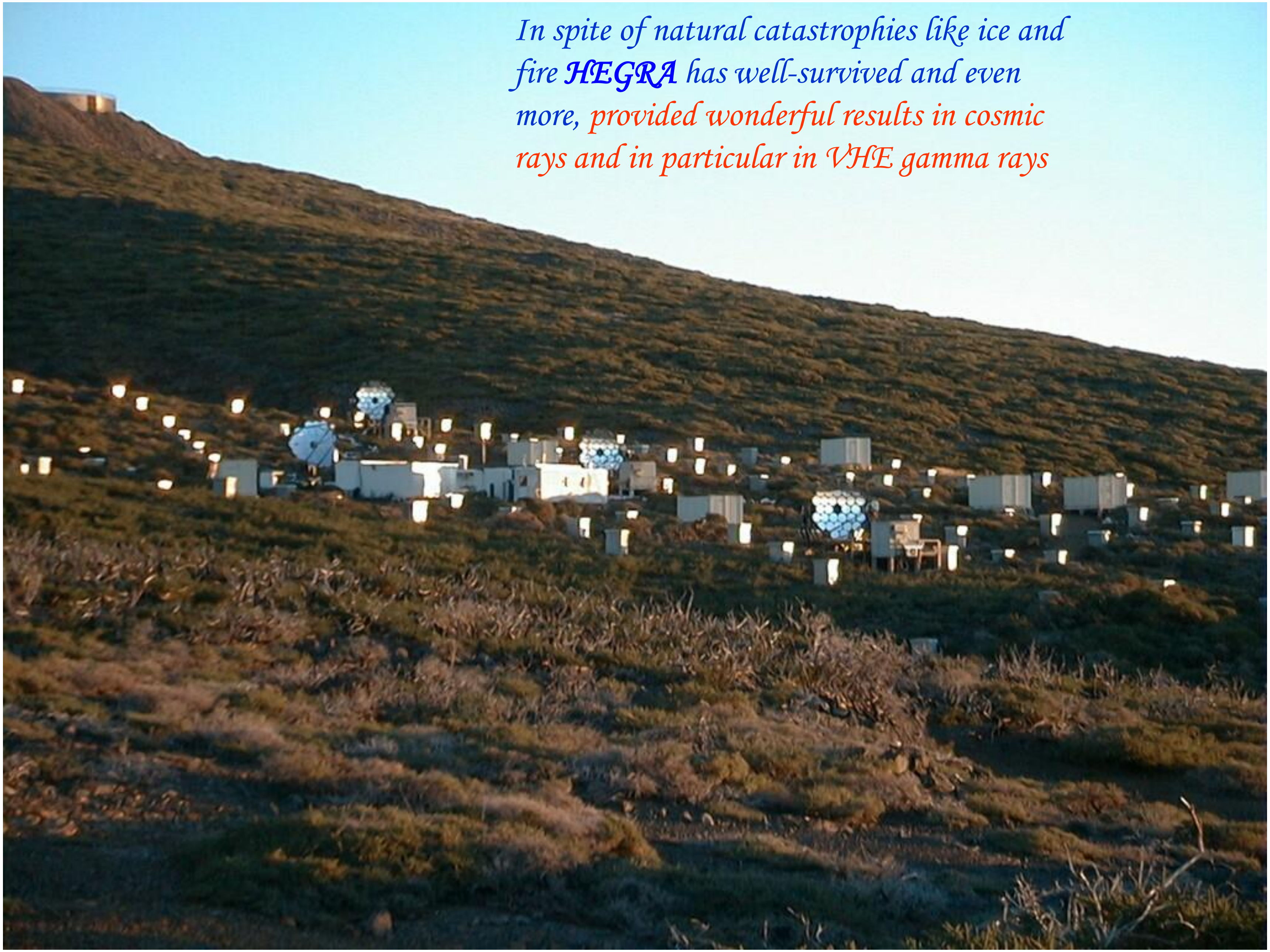
Ice started on Jan. 14 in 1994
hold on for 2 weeks

- Fire on Oct. 17 in 1997 destroyed in less than 45 min. about 1/3 of the HEGRA array

- MPI got reimbursed from the „Allianz“ insurance company 1.7.-Mln DM; that served as the seed money for MAGIC

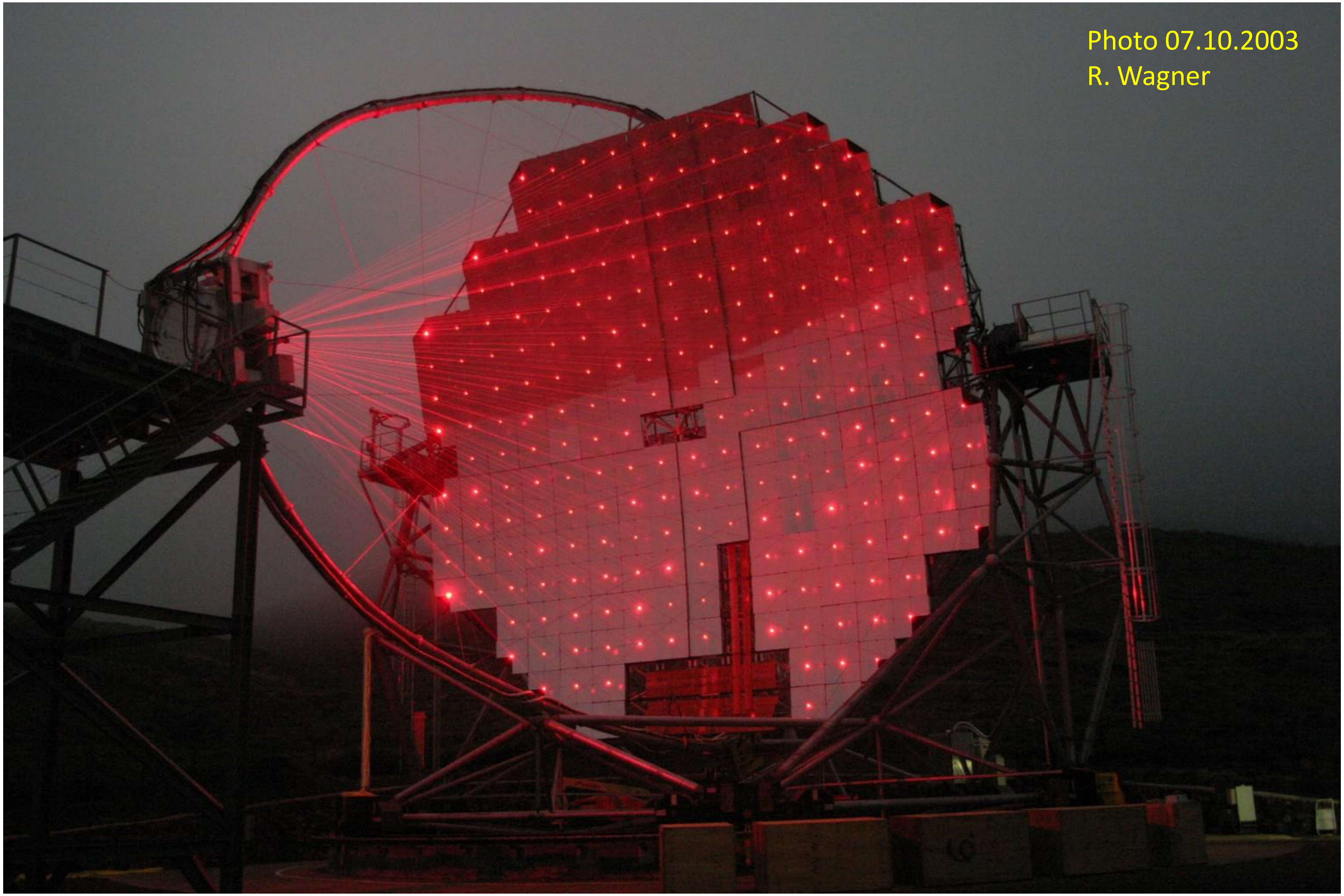
The Multi-component HEGRA detector




In spite of natural catastrophies like ice and fire ***HEGRA*** *has well-survived and even more, provided wonderful results in cosmic rays and in particular in VHE gamma rays*

Installation of the 1st MAGIC reflector frame

MAGIC-I laser show: the system of Active Mirror Control is On



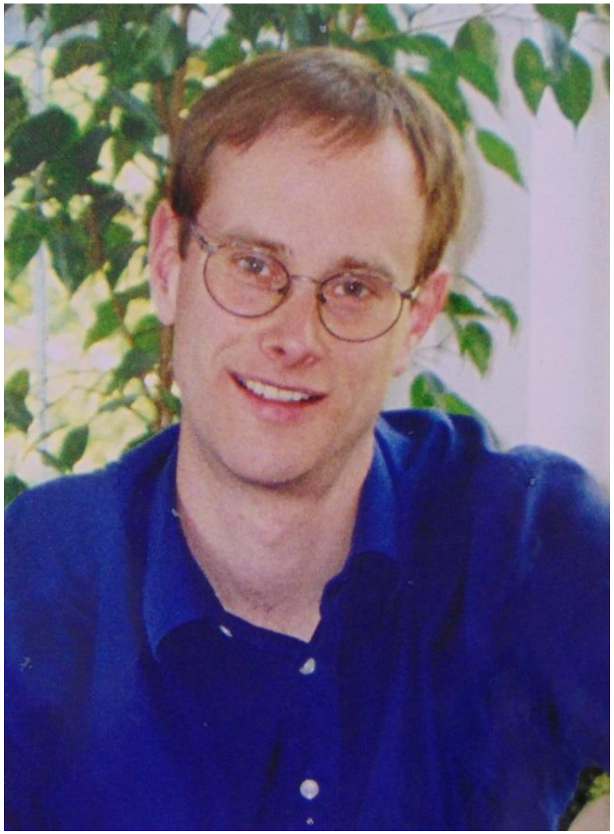

H 10 TABURIENTE PLAYA
MAGIC TELESCOPE
INAUGURATION
SEMINAR ROOM – BREÑA BAJA SALON
COFFEE BREAK – LOUNGE AREA
9 OCTOBER 2003

Science with MAGIC-I stand-alone

- First science results obtained I 2004, but the publication flow stabilized in 2005-2006
- In 2006 VHE gammas from LSI+ 61 303 (Science)
- Crab pulsar at $E \geq 25$ GeV (Science)
- VHE gammas from 3C279, z=0.536 (Science)
- Improved performance of MAGIC through signal timing, ApP
- IC 443, 3C66 A/B
- Probing Quantum Gravity with outburst of Mkn-501, Phys. Lett.
- …..Was a good source hunt
- In 2008 the 2nd MAGIC was built, commissioned and since 2009 operated

Florian Goebel, the manager of M-II

1972 - 2008



- Florian was one of the brightest young astrophysicists in MAGIC, all were convinced he was on the track to make great career
- Florian was there to help whoever and wherever he could, was “universal” in both hardware and software tasks
- With enormous enthusiasm he was involved in almost every task of MAGIC
- He tragically passed away just 2 days before the planned inauguration of M-II on 13th of Sept. 2008


July 20

M-II inauguration, April 25th 2009

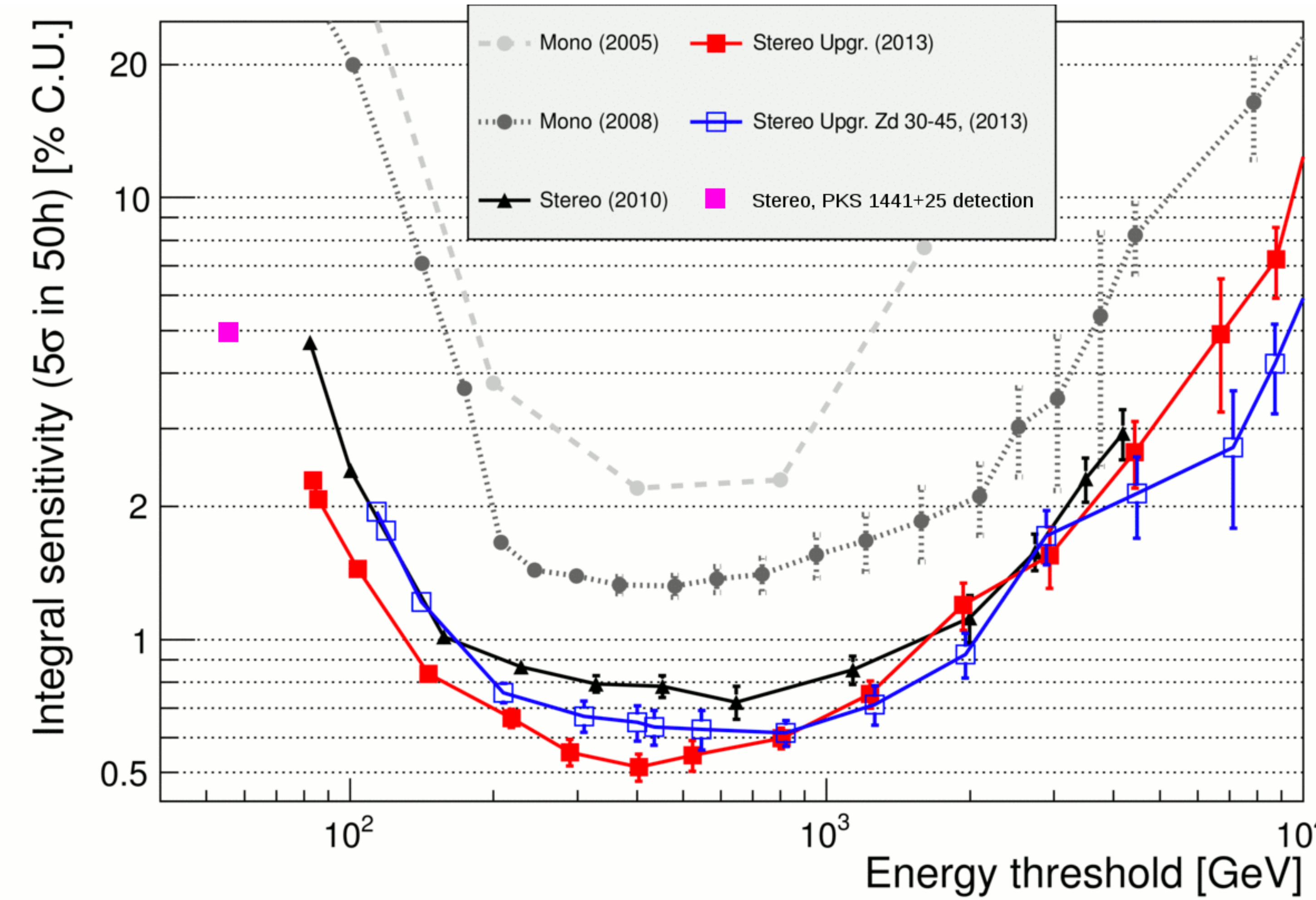
Eckart at the inauguration of the M-II

•MAGIC has opened a new window in the electromagnetic spectrum, into the sub-200 GeV

• With MAGIC discovery of 25 GeV pulsed γ emission from Crab pulsar it became possible making gamma astrophysics @ few tens of GeVs


M-I and M-II telescopes, 2009

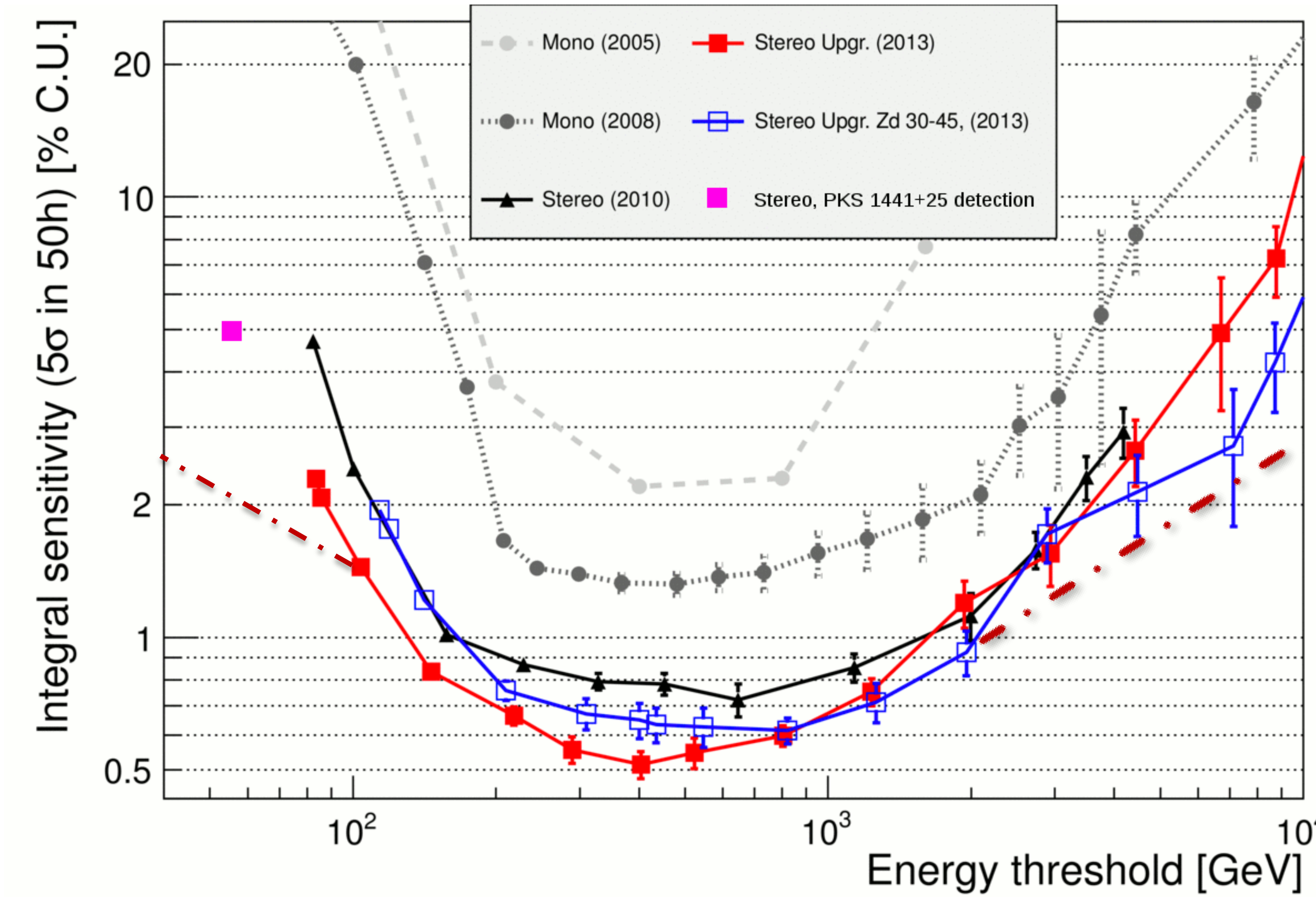
MAGIC sensitivity development during time



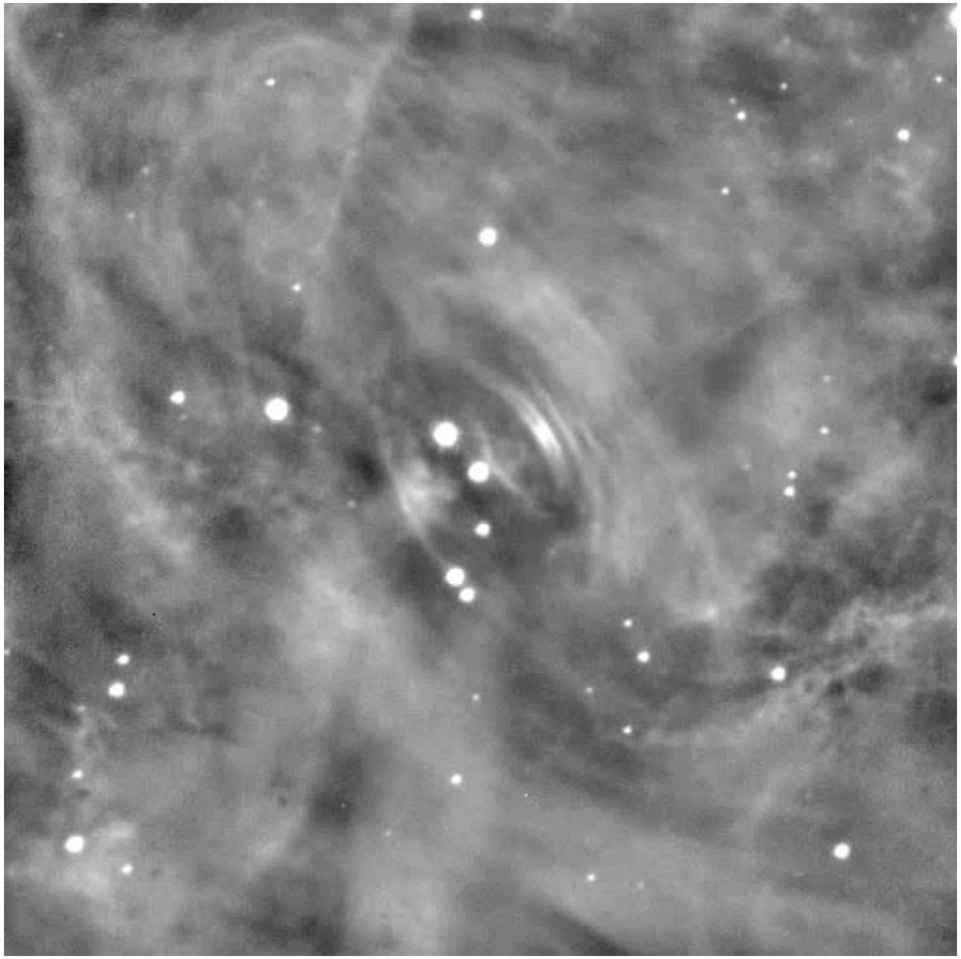
MAGIC upgrade in 2012

- The M-I and M-II were operating with cameras of somewhat different designs, light sensors and readout electronics
- In 2011 - 2012 we decided to make them more similar and built a new imaging camera for the M-I, similar to that of M-II
- Since 2013 MAGICs are in stable operation

Significant Improvements of Sensitivity at Lowest and Highest Energies due to SumT-II & VLZA Observations



The Crab pulsar & MAGIC



Aliu et al. (MAGIC collab.)
Science 322 (2008) 1221
First detection of emission above 25GeV for a pulsar

Aleksic et al (MAGIC collab.), ApJ, 742 (2011) 43,
First spectrum 25-100GeV

Aleksic et al (MAGIC collab.), A&A, 540 (2012) A69
First spectrum 50-400GeV

Aleksic et al (MAGIC collab.), A&A 565, L12 (2014)
Discovery of Bridge Emission

Aleksic et al (MAGIC collab.), A&A, 585 (2016)
Tera-electronvolts pulsed gammas

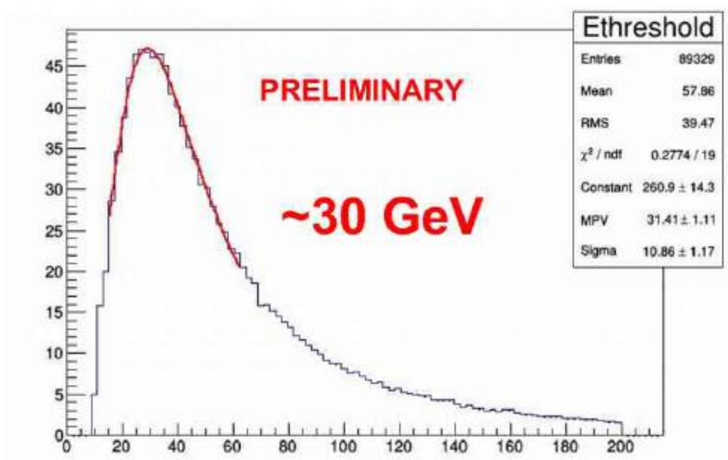
Sum-T2 performance slide from the MAGIC meeting

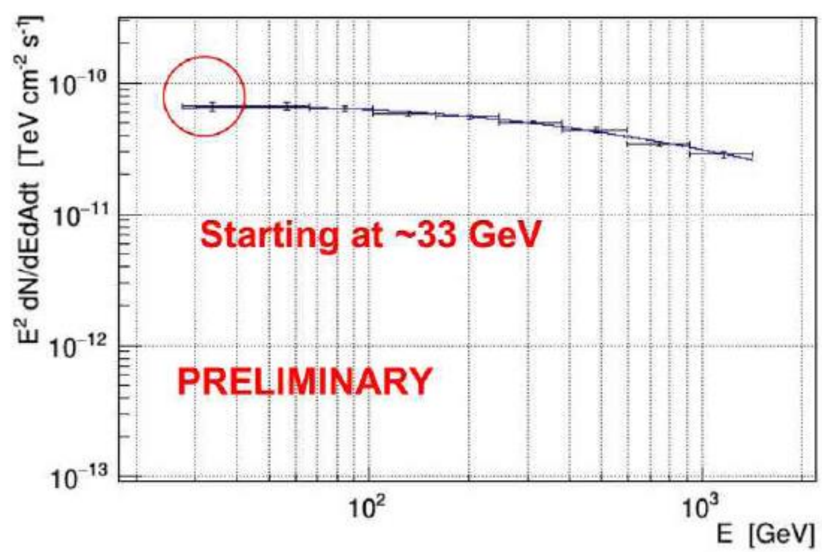
Sum Trigger performance

- Energy threshold now ~30 GeV
- Crab Nebula SED starting at 33 GeV

15y anniversary meeting

J. R. Garcia,
G. Ceribella,
M. Lopez,
T. Saito,
T. Schweizer





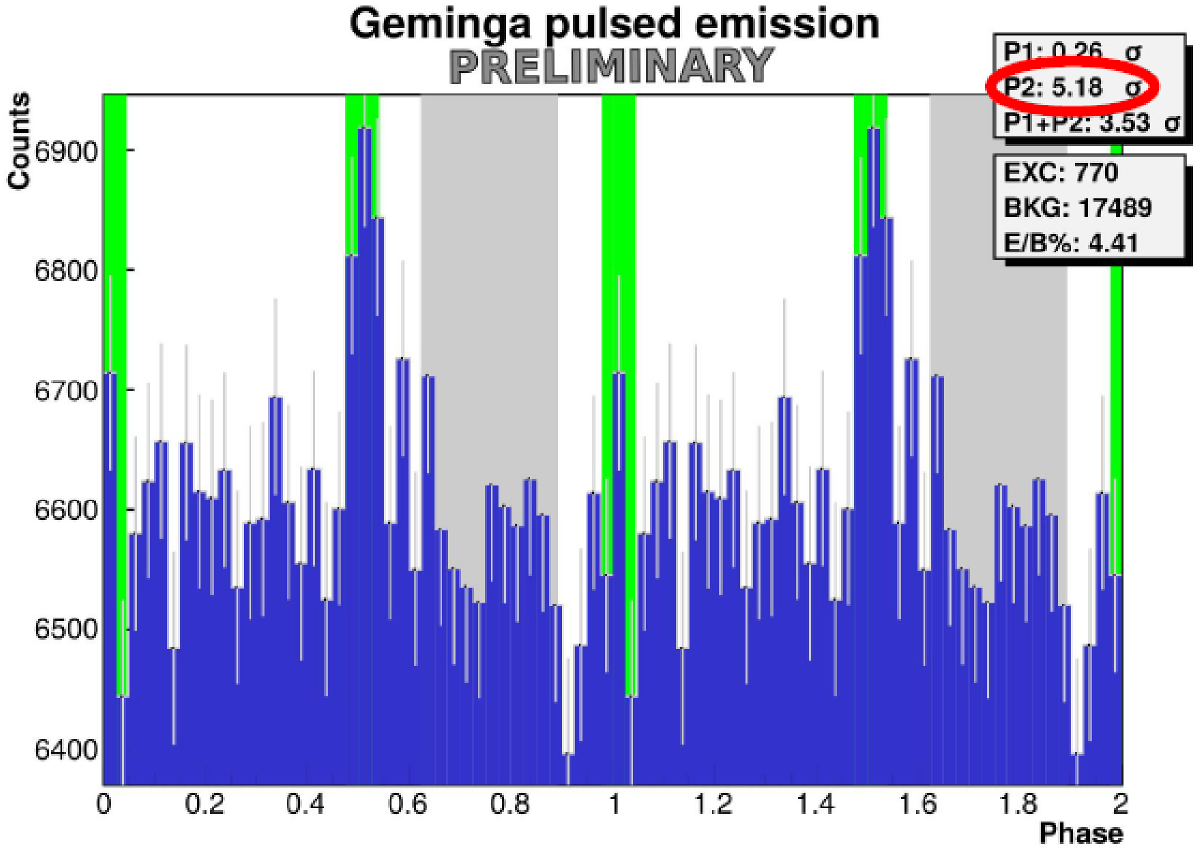
One of the Sum-T2 Results: Discovery of Geminga pulsar @ VHE

Geminga phaseogram
(~30h)

January 2017
February 2017

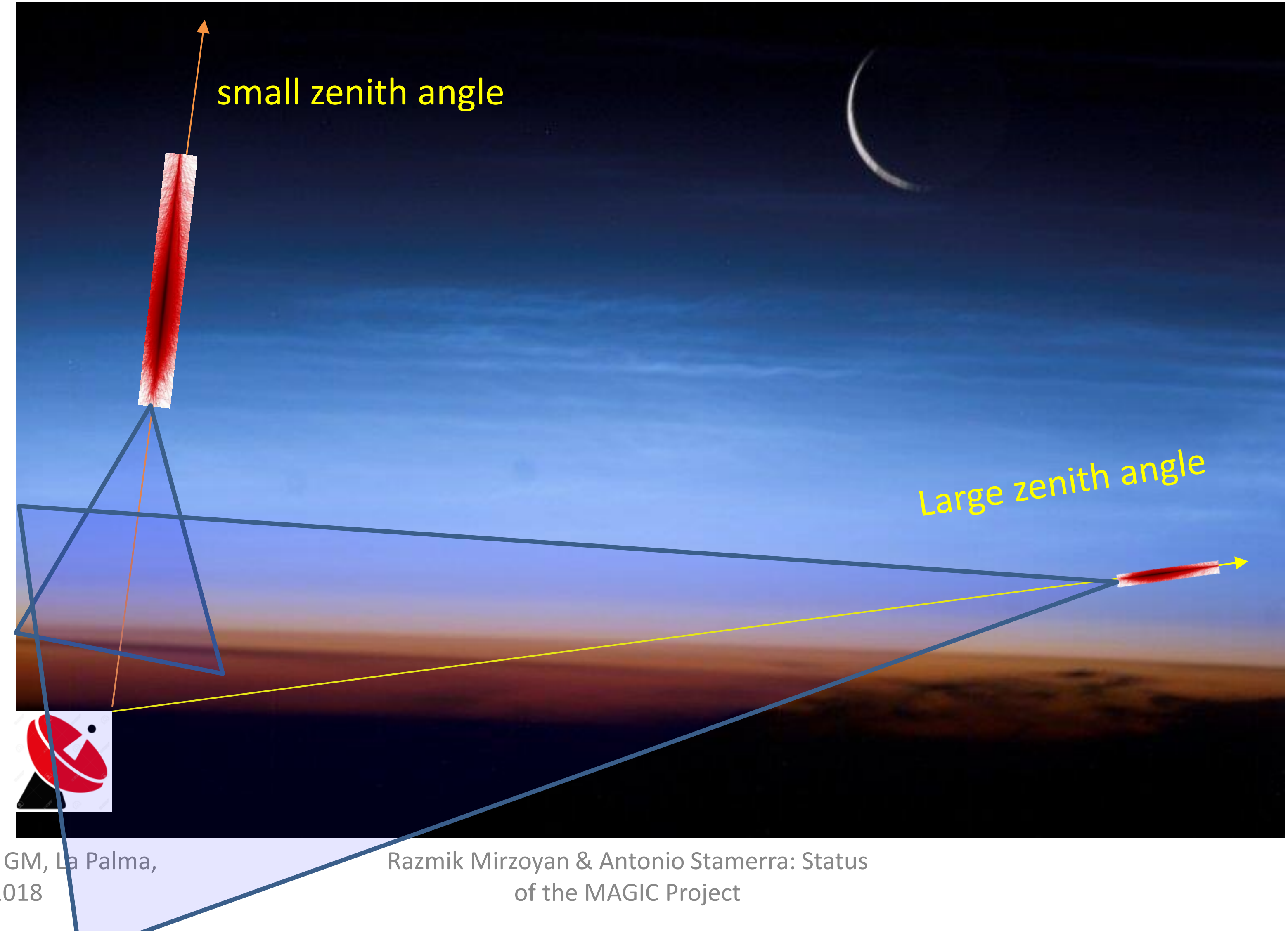
Ephemeris derived from Fermi/LAT data with robust procedure

Cuts from MC efficiency (flute-style)

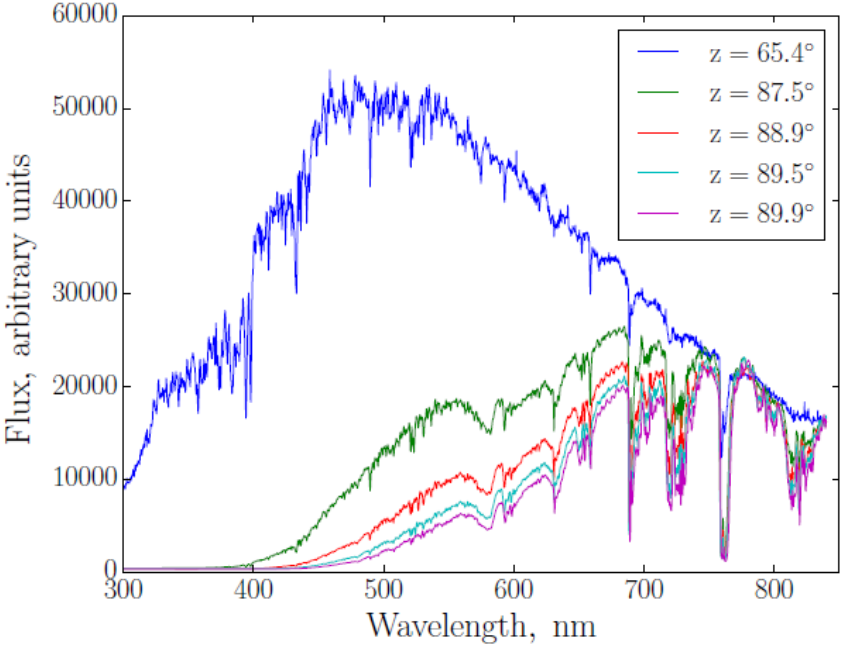


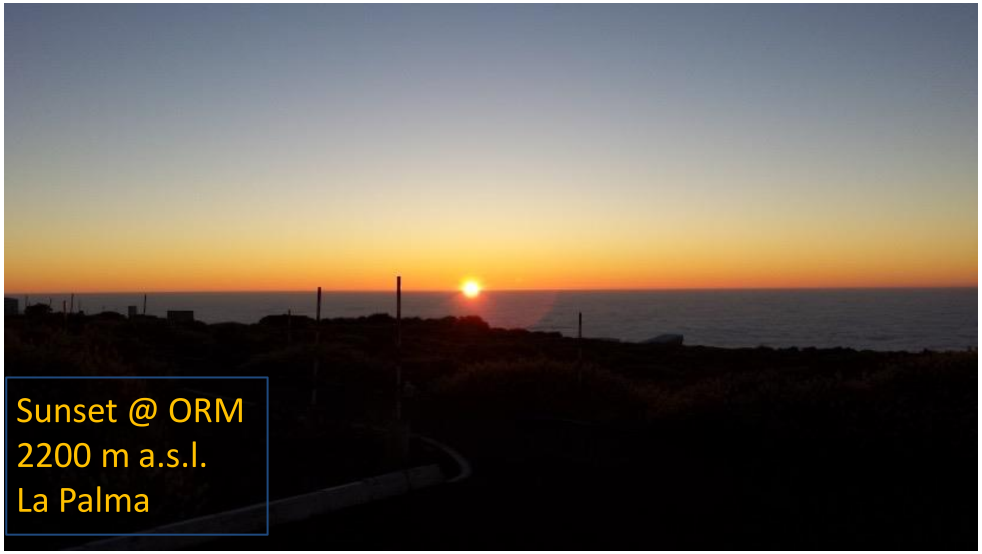
25/06/2018 G. Ceribella

Cartoon on longer path length in atmosphere for an EAS @ large zenith angle observations



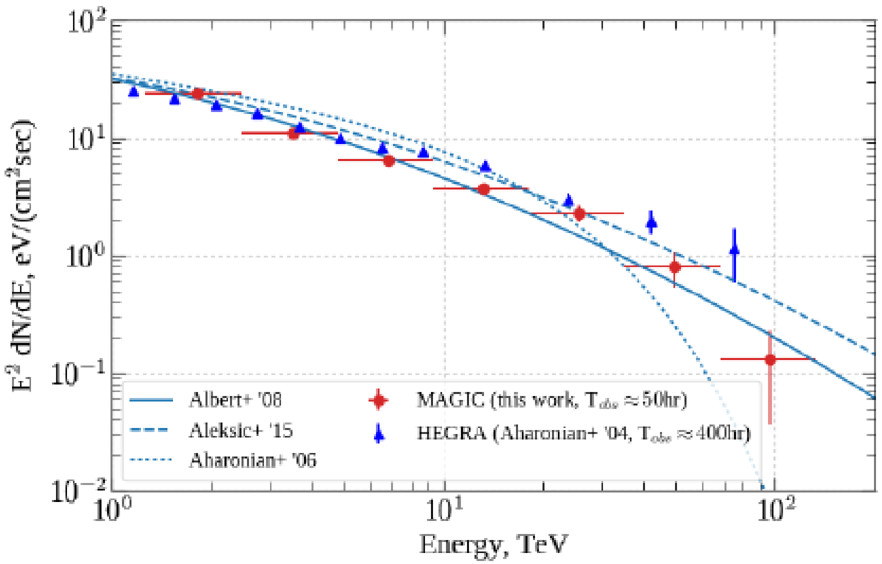
MAGIC Getting a Second Wind at ≥ 100 TeV With Very Large Zenith Angle (VLZA) Observations





Now we are working with a novel for IACTs calibration method of the atmospheric absorption as well developing a very precise, advanced calibration, based on a small optical telescope with a spectrograph

Comparison with HEGRA Crab spectrum: collected similar statistics in ~ 8-times shorter observations with MAGIC



@ r = 4 TeV

Older MAGIC spectrum suggests:
alpha = 2.47 + 0.24*log10(4/1) ~ 2.61
beta = 0.24

CombUnfold:
f_0 = (6.88 +/- 0.45) x 10-13 1/(cm*sec*TeV)
alpha = -2.78 +/- 0.11
beta = -0.20 +/- 0.17

Fold:
f_0 ~ 7.0 x 10-13 1/(cm*sec*TeV)
alpha ~ 2.59
beta ~ 0.30

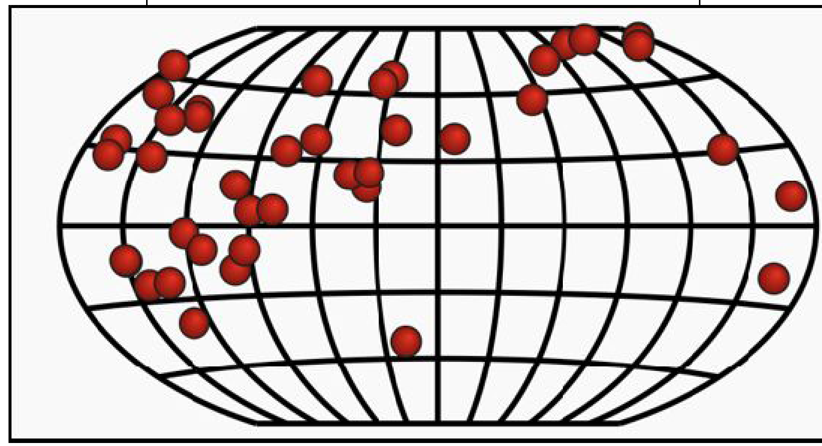
The measured spectrum is consistent with older results within uncertainties.

MAGIC extragalactic sky

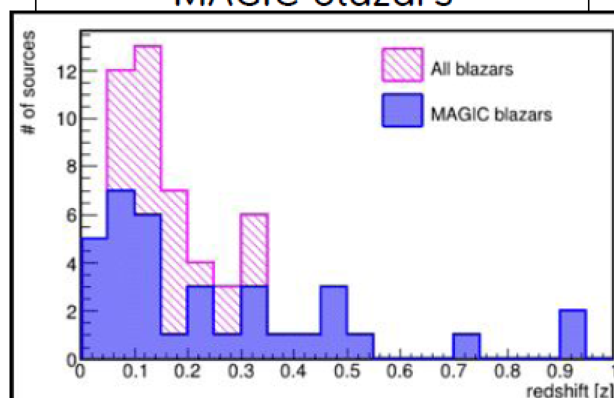
Our science case

- **Characterization of extragalactic TeV emitters**
  - *Blazars*: BL Lac objects and Flat Spectrum Radio Quasars
  - *Radio galaxies*
  - *Seyfert galaxies*
- **Cosmology and fundamental physics**
  - EBL
  - IGMF
  - LIV

41 MAGIC-detected AGNs



redshift distribution of MAGIC blazars



MAGIC is leading the high-z, TeV blazar science case

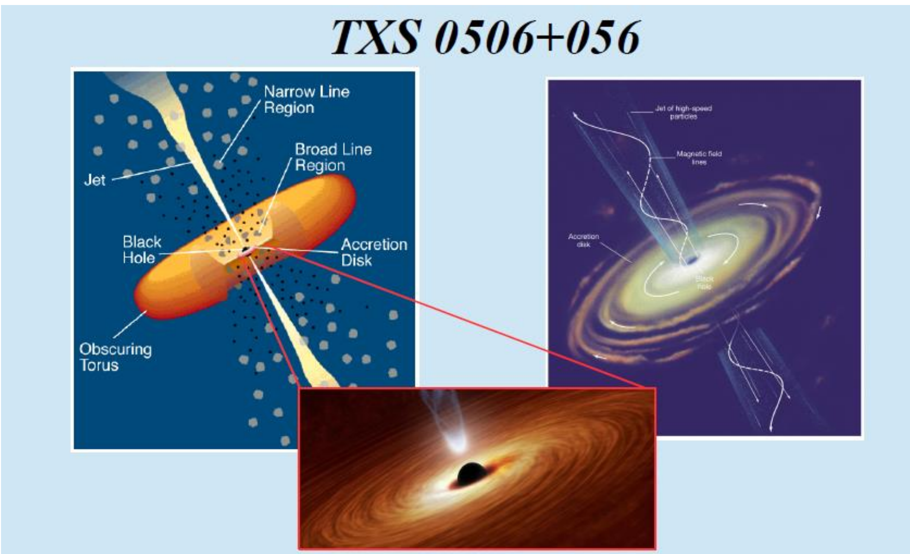
Flat Spectrum Radio Quasars

- The most luminous sources: γ-ray emitting AGN class
  - -the VLBA jets with high Doppler factors, “knots” in the jet
  - -optical spectrum shows broad emission lines
  - -SED: low synchrotron peak frequencies (infrared)

In VHE (>100GeV) γ-rays 8(?) known, 7-MAGIC:

- 3C279 (MAGIC in Feb 2006 and Jan 2007, single night detections, MAGIC in Feb 2014 detection of weak signal
- PKS1510-089 (H.E.S.S. in March-Apr 2009, MAGIC in Feb-Apr 2012, March-June 2013 no VHE variability)
- PKS1222+216 (MAGIC single night in June 2010, VERITAS and MAGIC several nights in Feb 2014)
- PKS1441+25 and B0218+357 the newbies
- S4 0954+65 and BL Lac disputed classifications

Icecube event 170922A



First-time detection of VHE gamma rays by MAGIC from a direction consistent with the recent EHE neutrino event IceCube-170922A

ATel #10817; ***Razmik Mirzoyan for the MAGIC Collaboration***
*on **4 Oct 2017; 17:17 UT***
Credential Certification: Razmik Mirzoyan (Razmik.Mirzoyan@mpp.mpg.de)

Subjects: Optical, Gamma Ray, >GeV, TeV, VHE, UHE, Neutrinos, AGN, Blazar

Referred to by ATel #: 10830, 10833, 10838, 10840, 10844, 10845, 10942

Tweet Recommend 448

After the IceCube neutrino event EHE 170922A detected on 22/09/2017 (GCN circular #21916), Fermi-LAT measured enhanced gamma-ray emission from the blazar TXS 0506+056 (05 09 25.96370, +05 41 35.3279 (J2000), [Lani et al., Astron. J., 139, 1695-1712 (2010)]), located 6 arcmin from the EHE 170922A estimated direction (ATel #10791). MAGIC observed this source under good weather conditions and a 5 sigma detection above 100 GeV was achieved after 12 h of observations from September 28th till October 3rd. This is the first time that VHE gamma rays are measured from a direction consistent with a detected neutrino event. Several follow up observations from other observatories have been reported in ATels: #10773, #10787, #10791, #10792, #10794, #10799, #10801, GCN: #21941, #21930, #21924, #21923, #21917, #21916. The MAGIC contact persons for these observations are R. Mirzoyan (Razmik.Mirzoyan@mpp.mpg.de) E. Bernardini (elisa.bernardini@desy.de), K.Satalecka (konstancja.satalecka@desy.de). MAGIC is a system of two 17m-diameter Imaging Atmospheric Cherenkov Telescopes located at the Observatory Roque de los Muchachos on the Canary island La Palma, Spain, and designed to perform gamma-ray astronomy in the energy range from 50 GeV to greater than 50 TeV.

List of 41 discovered by MAGIC sources:

Name	RA	Dec	Type	Dist	Comments	# source
1ES 033 +595						1
S2 0109 +22						2
RGB J0136 +391						3
3C58				2 kpc		4
S3 0218 +35			Xgal	0.944		5
MAGIC J0223 +403			unid			6
LSI +61 303			Gal, binary	2 kpc		7
IC310			Xgal	0.0189		8
S50716 +714			Xgal	0.31		9
RBS 0723			Xgal	0.198		10
S4 0954 +65			Xgal			11
Mrk 180			Xgal	0.045		12
1ES 1011 +496			Xgal	0.212		13
RXJ 1136.5 +6737			Xgal	0.1342		14
MS 1221.8 +2452			Xgal	0.218		15
3C 279			Xgal	0.536		16
PG1553 +113			Xgal	~0.5	Co-disc. HESS	17
H1722 +119			Xgal			18
OT 081			Xgal			19
MAGIC J2001 +435						20
1ES 2037 +521				0.053		21
B3 2247 +381				0.1187		22
BL Lacertae				0.069	Vague hint from Crimea	23
MAGIC J1857.6 +0297				unid	Part of 2 source	24
MAGIC J1857.2				Gal, PWN	Part of 2	25

List of 41 discovered by MAGIC sources:

+0263					Part 2 of source	
Galactic center ARC			8.5 kpc	unid	Co-disc. HESS, VERITAS	26
1ES 1741 +196			0.083	Xgal		27
1ES 1727 +502			0.055	Xgal		28
PKS 1441 +25			0.939	Xgal		29
4C 21.35			0.432	Xgal		30
1ES 1218 +304			0.182	Xgal		31
1ES 1215 +303			0.130	Xgal		32
1ES 1011 +496			0.212	Xgal		33
1ES 0647 +250			0.45	Xgal		34
IC 443			1.5 kpc	Gal		35
Crab pulsar			2 kpc	Gal		36
NGC 1275			0.017559	Xgal		37
MAGIC J1746.4-2853			UD			38
TXS 0506+056			0.3365			39
TON 0599			0.7247			40
PGC 2402248			0.065			41

Summary

- The MAGIC experiment is in its historical best condition and with MoU of 2017 the CB decided to operate MAGICs for further 5 years
- We have published some 190 articles in peer-reviewed journals
- We are in the best, most productive phase of our science productivity
- At very low energies (~ 20-30 GeV) and at very high energies (≥ 100 TeV) we got a serious boost in sensitivity
- I wish us a successful conference and I am sure that in the next days we will learn a lot about the interesting science pursued with MAGIC

10-minutes presentation of the spokesperson

- My colleague from MPI, an engineer-physicist Juergen Gebauer went to La Palma with Eckart for installing work of detectors. Back from LP he complained emotionally (but not very loud), that Eckart used to work 16 hours a day and unfortunately he and the rest of the crew had to do the same
- He told me he will refuse to do the same in future

Eckart Lorenz, the scientist:

a private view of someone who worked next to him for 24 years

- Eckart was born on June 7 in 1938
- Not-surprisingly his early memories were linked to the end-phase of the WW2, to hunger, family Escape (mother + 4 small kids) from regions of active military actions, loss of father
- Bitter events which impregnated his life
- Despite all these he was always in high-spirits
- He used to tell really funny stories from his childhood, with a fine humor