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

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1 Introduction

This Letter of Intent (LoI) summarizes the plan for a *large stereoscopic system of medium-size Imaging Atmospheric Cherenkov Telescopes* (IACTs) for Very High Energy (VHE) Gamma-Ray Astronomy from the ground. The acronym HESS stands for *H*igh *E*nergy *S*tereoscopic *S*ystem, emphasizing two main features of the proposed installation, namely

- the simultaneous observation of air showers with several telescopes, under widely different viewing angles, and
- the combination of multiple telescopes to a large system to increase the effective detection area for γ-rays.

The proposed system provides an energy threshold E_{th} of about 100 GeV and, ultimately, a flux sensitivity $F_{\mathrm{min}}(E > 100\ \mathrm{GeV})$ of better than 10^{-12} photons/cm^{2}s. It aims at an order-of-magnitude improvement over the existing IACT array of the HEGRA collaboration [1] that operates on the Canary Island of La Palma. Single IACTs of the HEGRA type provide a threshold of 1 TeV or slightly below, and are sensitive to sources with intensities down to 20% of the Crab Nebula, which is frequently used as a standard candle. In stereoscopic mode, when all telescopes of the HEGRA IACT system are observing the same object, sources at a level of a few percent of the Crab are visible. The HESS system will allow to explore the range of "milli-Crab" γ-ray sources, and will extend the observational range out to redshifts $z \approx 1$.

The scientific goal of the proposed instrument is - in broad terms - the investigation of nonthermal processes in the Universe, using VHE γ-ray emission as a diagnostic tool and a sensitive probe for the collective processes which accelerate particles to energies many orders of magnitude beyond thermal energies. The fact that a significant part of the energy density of the Universe is contained in this nonthermal component illustrates the astonishing efficiency of such cosmic particle accelerators, as well as the importance of this component in the evolution of the Cosmos.

[1] HEGRA = *H*igh *E*nergy *G*amma *R*ay *A*stronomy, a collaboration involving the University of Hamburg, the Max-Planck-Institut für Kernphysik in Heidelberg, the University of Kiel, the Universidad Complutense, Madrid, the Max-Planck-Institut für Physik in Munich, the BUGH Wuppertal, and the Yerevan Physics Institute.

The analysis of source models of VHE γ-ray emission and the study of nonthermal processes in general is the center of the work of the theoretical astrophysics group at the Max-Planck-Institut für Kernphysik in Heidelberg. An outgrowth from this work was the international "Workshop on TeV Gamma-Ray Astrophysics", held in Heidelberg in October 1994. It resulted in a special volume of *Space Science Reviews* (Vol. 75, Nos. 1-2, 1996) which in broad terms contains much of the physics motivation for the present proposal; a brief summary is given later in this Letter of Intent, and a more detailed discussion is contained in Appendix A.

The stereoscopic observation of air showers with arrays of IACTs has been theoretically studied by us in great detail (see Appendix C), and is being experimentally pioneered using the HEGRA system. Compared to single telescopes, the stereoscopic technique allows superior rejection of backgrounds, the unambiguous determination of the shower direction, and the precise measurement of the energy of γ-ray showers. Since the individual telescopes of the HESS observatory represent only a modest step beyond existing devices such as the Whipple IACT, and since first data from the HEGRA IACT array fully confirm our expectations, we are convinced that the performance of the proposed IACT array can be estimated with great reliability. As a result, we are convinced that stereoscopic systems of telescopes constitute the most promising line for the future development of ground-based VHE γ-ray astronomy. We note that a similar project (VERITAS) of a system of 9 IACTs has recently been proposed in the United States.

Characteristics of the HESS telescopes (see also Appendix B) are a mirror area of about 80 m^2, and imaging cameras with a large field of view of about 4° and PMT pixels of size 0.25° or less. The design in particular of the camera builds upon the experience with the HEGRA IACT system; the cameras for these telescopes and their readout systems were developed and built at the Max-Planck-Institut für Kernphysik. In the HESS project, the divisions of experimental particle physics and astrophysics of the institute join, combining a wide range of expertise in theoretical astrophysics, simulation studies, and experimental technologies, and providing a strong and balanced core group for this new endeavor.

2 Physics Motivation

High-energy γ-ray astronomy investigates the *Nonthermal Universe*, as distinct from the thermal world probed by astronomy in most other wavelength ranges up to the X-ray domain. Matter and radiation of this nonthermal universe exhibit energy distributions that have no characteristic scale attributive to a temperature. This implies that the dynamics of this component is determined by nonthermal, collective processes rather than by two-body interactions.

The best-known example for a nonthermal component are the Cosmic Rays, with their energy distribution governed by power-law distributions up to energies of 10^{20} eV. Nonthermal matter and radiation contribute substantially to the energy balance of the medium they pervade. In our Galaxy, the energy density in the Cosmic Rays is comparable to the energy density of the interstellar gas. Similar relations are expected to hold for the extragalactic space.

Yet, despite its significance, sources and accelation mechanisms of nonthermal matter and radiation in general, and of Cosmic Rays in particular, are by no means established. Random interstellar magnetic fields cause a diffusive propagation of charged Cosmics Rays, leaving only the energy spectrum, the composition, and global anisotropies as measureable parameters, but hiding localized sources from direct observation. Interactions along their path and diffusion out of the Galaxy furthermore modify both the spectrum and the composition of Cosmic Rays, and the distributions measured in the vicinity of Earth differ significantly from those at the acceleration site.

Acceleration of charged particles is, however, almost always accompanied by the generation of high-energy γ-rays, e.g. by means of Bremsstrahlung and Inverse Compton collisions with ambient photons in the case of electron accelerators, and by means of interactions with ambient matter in case of hadron accelerators, resulting in π^0 production and their subsequent decay into two photons. The energy spectrum of those γ-rays reflects the energy spectrum of their parent particles. In the energy range considered here, around 100 GeV, the Galaxy is essentially transparent to photon radiation, as is the intergalactic space up to redshifts around $z \approx 1$, at which point $\gamma\gamma$ collisions with diffuse infrared/optical background photon fields introduce a cutoff. Not too distant Cosmic Ray acceleration sites can hence be imaged in the light of high-energy γ-rays.

Over the last decade in particular, a large amount of data concerning high-energy γ-

ray emission has been collected. In the energy range from 100 MeV up to some 10 GeV, the EGRET detector aboard Compton GRO was very successful both in its study of γ-ray point sources as well as in the investigation of the diffuse γ-ray flux, following up on the earlier SAS-2 and COS-B satellites. The modest effective area of the detectors, combined with the low flux of γ-rays, limits the energy range of such space missions. Results at higher energies, in the VHE range, come from ground-based detectors, which suffer from larger backgrounds due to their limited ability to separate γ-ray-induced and hadron-induced air showers, but offer vastly superior effective detection areas and detection rates. Results on γ-ray point sources have so far come mainly from imaging Cherenkov telescopes; well-established sources of VHE γ-rays are the Crab Nebula, the Pulsar Nebula PSR B1706-44, and the AGNs Mrk 421 and Mrk 501.

Despite these unquestionable successes, the issue of the origin of Cosmic Rays remains unsolved, and closer inspection shows that the existing data are unfortunately by no means conclusive, and possibly only of limited relevance. The observed GeV γ-ray sources are most likely *electron* accelerators, interesting in themselves, but dwarfed by the sources of the *nucleonic component*, as far as the energy balance is concerned. The same is true for the two galactic sources of VHE γ-rays; concerning the AGNs, the nature of the parent particles is subject of much debate. With a large degree of certainty, none of the sources discovered so far represents the type of sources responsible for the bulk of Cosmic Rays in the energy region up to the knee. One could summarize the situation in the following theses:

- Nucleonic Cosmic Rays represent one of the key components of the Nonthermal Universe, and contribute significantly to the energy balance of the Universe

- Up to now, *none* of the acceleration sites of this nucleonic component of Cosmic Rays has been identified with any degree of certainty

- In HE and VHE γ-rays, the *only* evidence for a nucleonic origin of part of the observed HE γ-rays is based on the observation of the π° bump in the spectrum of the diffuse γ-rays; even there, open questions in the interpretation of the observed spectrum remain.

On the basis of theoretical models and flux estimates, we believe that a γ-ray detection system concentrating on the energy range from about 100 GeV to a few

TeV, and a flux sensitivity in the "milli-Crab" range is likely to provide decisive data concerning the nature of the sources of the nucleonic Cosmic Rays, and concerning the study of nonthermal processes in the Universe in general. The chosen energy range utilizes the advantages of a lower threshold compared to existing IACTs, resulting in higher detection rates and a larger range in the redshift z. On the other hand, the energy threshold is high enough to provide a reasonable signal-to-noise for γ-ray sources based on nucleon acceleration, with their presumed flat energy spectrum, as compared to diffuse charged Cosmic Rays. Also, sources of nonthermal electrons are generally expected to cut off at lower energies than nucleon acceleration sites, resulting in a cleaner signature of nucleon accelerators at higher energies. Finally, the 100 GeV threshold can be reached with dishes of the Whipple-Class, does not require significant extrapolation beyond proven concepts and technologies, and minimizes technical risks.

While the search for the origin of nucleonic Cosmic Rays is a key issue, the physics scope of the HESS project is not limited to this aspect. More general, the motivations for the proposed telescope system can be summarized in the following points:

- A higher sensitivity should allow the observation of a *statistically significant* number of objects from astronomical object classes, of which single individuals have been detected for the first time by the HEGRA system or presently operating single telescopes. The system aspect will allow good angular and energy resolution so that *morphological* comparisons with observations in other wavelength ranges become possible. In addition, *spectroscopic analysis* of such objects can be done in relatively short times. Examples of such object classes are Pulsar Nebulae, as well as stellar Black Holes (BHs) - all in our Galactic neighbourhood - and Active Galactic Nuclei (AGNs) at distances of the order of 1 Gpc.

- Other *predicted* sources like Supernova Remnants or Molecular Clouds in our Galaxy have not yet been detected, either because they are too extended spatially, or because they are yet too faint. The new large stereoscopic system will be able to perform a decisive experiment regarding the origin of the Galactic Cosmic Rays from these objects.

  Other types of objects have been *predicted* to emit high-energy γ-ray sources, but are too distant and therefore expected to be *presently undetectable* by the

HEGRA IACTs. Examples of such sources are nearby starburst galaxies, nearby clusters of galaxies, and, possibly, compact binary stars in our Galaxy. Such objects might indeed be observable with a large system.

Other sources will in all probability be discovered with the new system.

- At the lower threshold energies *Observational Cosmology* in the sense of a determination of cosmological background radiation fields and of the absolute distance scale becomes possible. One example are the *spectral cutoffs* in the emission from AGNs due to *intergalactic absorption* of VHE γ-rays on the diffuse Infrared/Optical (IR/O) background photon fields generated by stars and dust in galaxies. These cutoffs presently prevent distant extragalactic sources to be seen in VHE γ-rays. The lower threshold of the proposed system will extend the γ-ray horizon out to redshifts $z \approx 1$ (Fig. 1), and will allow to map the cutoff region in redshift and energy space. Another interesting feature are the *γ-ray Halos* that have been suggested to exist around strong AGNs due to the same intergalactic absorption. In particular, if the above-mentioned halos of AGNs can be resolved spatially and spectroscopically, they could be used to determine both the IR/O background, as well as the absolute source distance, with basic implications for cosmology. Again, the angular and spectral resolution provided by the stereoscopic approach with a telescope system are essential.

- In addition to the conventional mechanisms for the production of high-energy γ-rays, cosmological and particle physics scenarios allow the existence of cosmic γ-radiation of *non-accelerator origin.* The collapse of topological defects formed in the very Early Universe has e.g. been proposed as a source for the highest-energy Cosmic Rays. Annihilating supersymmetric dark matter particles (WIMPS) could give rise to monoenergetic γ-ray lines in the 100 GeV range. The HESS system provides sensitivity to discover the predicted flux in this energy range, and/or to put meaningful limits on the dark matter parameter space.

A more detailed discussion of the observation objects is given in Appendix A.

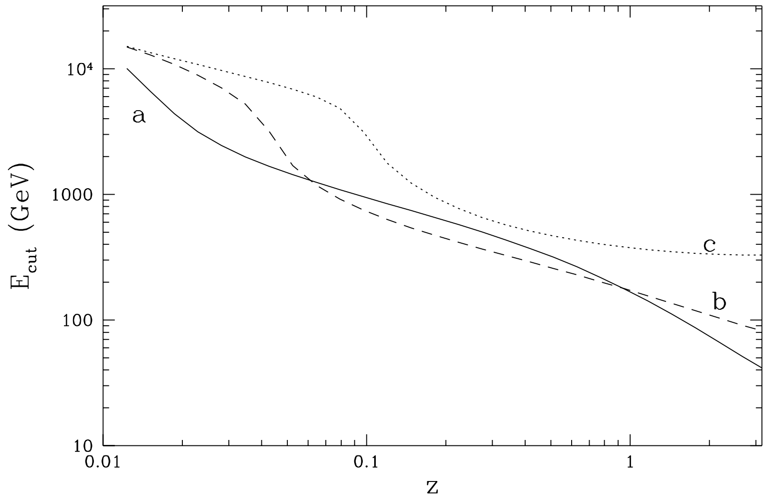

Figure 1: *Energy cutoff in γ-ray spectra due to absorption on the diffuse Infrared/Optical (IR/O) background, as a function of the redshift z of the source, for different models of the IR/O background, see Appendix A for details. The reach of a 100 GeV telescope extends beyond $z \approx 1$.*

3 The HESS Telescope Array

The energy range between 100 GeV and a few TeV is clearly the domain of imaging atmospheric Cherenkov telescopes; we see at present no other competitive technique. By combining telescopes into an array allowing the simultaneous observation of showers with three or four telescopes, the capabilities of the devices are increased even further.

In the proposed IACT array, the required *decrease in threshold* is achieved by increasing the mirror area compared to the present HEGRA telescopes; the *increase in flux sensitivity* results both from the higher rate associated with the lower threshold, and from an increase in the effective detection area by - ultimately - installing a larger number of telescopes. Since the cost of telescopes rises rapidly with increasing mirror area, and since we believe that most of the physics goals listed above are attacked most effectively in the 100 GeV to 1 TeV energy range, we use the minimal dish size consistent with this threshold - about 10 m diameter. We envision an array of telescopes arranged on a square grid with about 100 m spacing, with trigger decisions arranged locally within each *cell* of the array; a cell is formed by the four telescopes at the corners of a 100 by 100 m square. For large arrays, the effective detection area scales

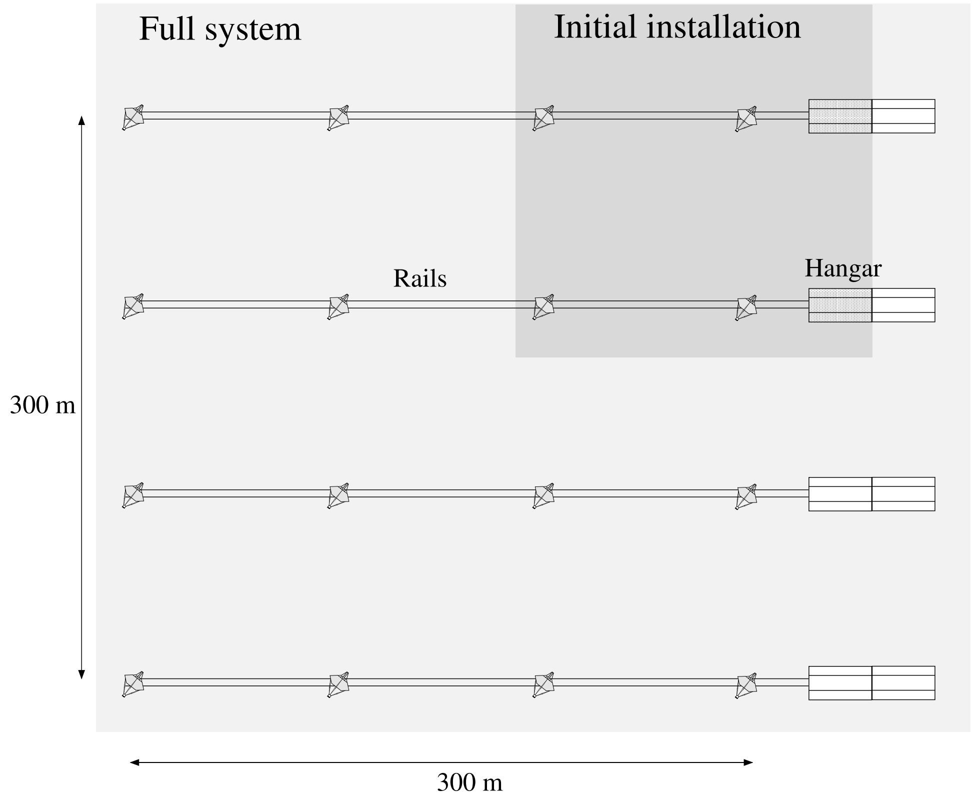

Figure 2: *System of imaging Cherenkov telescopes, starting with an initial array of four telescopes, with the definite aim for a later expansion. Also indicated is one scenario for telescope protection, where the telescopes are moved into storage hangars during moon nights or bad weather. Initially, two rails and two hangars are required; for a larger system, these existing rails and hangars are to be extended, and more to be added.*

simply with the number of cells. We propose to initially install a single 4-telescope cell, and in a second step to enlarge the system to a multi-cell array (Fig. 2). This initial cell will already provide a significant improvement over existing systems such as the HEGRA array, and will allow to probe significant parts of the physics programm discussed above. The site should be chosen to accomodate the maximum practically conceivable size of the array, 16 telescopes distributed over 0.1 km^2.

The proposed *system telescopes* use a modified alt-azimuth mount, a segmented mirror with a total area of 82 m^2 based on Davies-Cotton optics with 12 to 15 m focal length, and a high-resolution camera with conventional photomultiplier tubes and a pulseform recording readout. For details, the reader is referred to Appendix B.

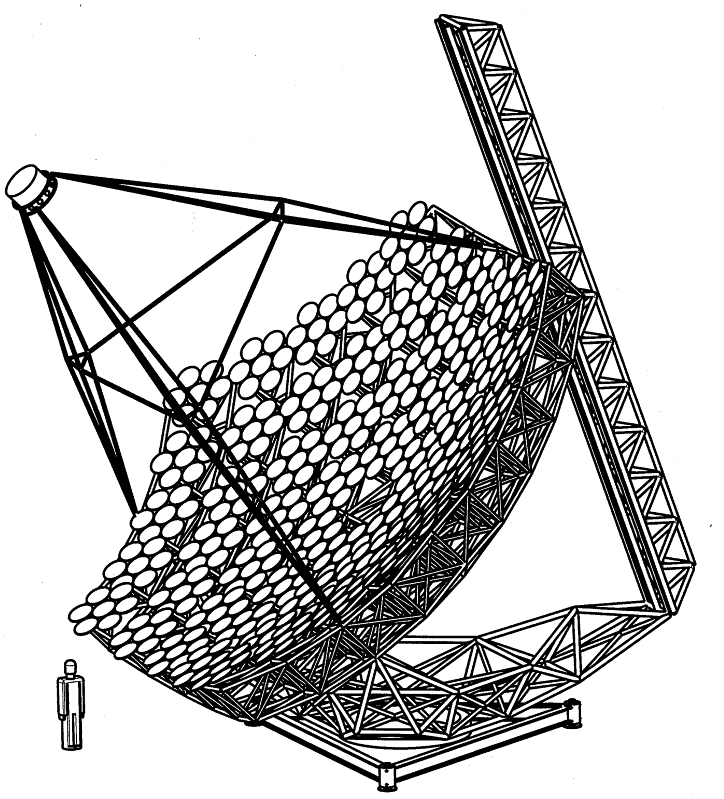

Figure 3: *One design option for an array telescope with its tiled mirror and alt-azimuth mount.*

At this stage, various designs for the *mount and mirror dish* are being considered and evaluated. Fig. 3 shows one design option for a system telescope. Contrary to a conventional alt-azimuth mount, the mirror dish is supported at three points arranged symmetrically; for altitude adjustment it rotates around the axis formed by two of the support points, while the third support point is moved by a linear drive. For positioning in azimuth, the whole assembly can be rotated around the azimuth axis. This modified mount offers advantages concerning the stability of the mirror dish. Another more conventional design study follows the concepts used in the construction of medium-size radio telescopes.

The *mechanical construction* of the telescope mounts and dishes should not present a major technical difficulty, since such structures have been built many times before, for radio telescope arrays and telecommunication antennas. It should be noted that a positional accuracy of about one arcmin will be sufficient, since the angular resolution of the array is of the order of 0.1 degree. This reduces the mechanical requirements in comparison to radio telescopes of a similar size. The question here is economics more than anything else.

The *telescope mirrors* are composed of 420 individual aluminum mirrors of 50 cm diameter. In order to limit the assembly time and the amount of on-site adjustments, groups of seven mirrors are preassembled into 60 mirror "clusters". These clusters have a focal length of 12 to 15 m and are arranged in a Davies-Cotton fashion, following a sphere with the focal point in its center. The optical quality of the individual mirror tiles should be characterized by a 1 mrad spot size, and a reflectivity of 85% or more over the relevant wavelength range. Their surfaces need to be protected, e.g. by Silicon dioxide coating or anodization. The mirror dish provides a spot size of less than 0.05° rms over most (for f = 12 m) or all (for f = 15 m) of the field of view, and allows to use camera pixels as small as 0.15°. The dish introduces a timing spread of about 1.5 ns rms.

The *focal plane instrumentation* could be similar to that developed by us for the HEGRA system in the form of cameras with 271 pixels, consisting at least initially of conventional fast photomultiplier tubes (PMTs) with a Flash-ADC electronic signal processing system. The field of view of the camera should cover 4°, governed by the expected extent of potential sources. The pixel size should be uniform throughout the field of view. In particular for the study of extended sources, camera homogeneity is important. Advances in readout electronics may allow to reduce the cost per readout channel and allow to use a finer granularity of photon detectors, with improved performance both concerning the rejection of Cosmic-Ray backgrounds and the angular resolution for γ rays.

The *multi-level trigger system* requires a coincidence of local triggers from several telescopes of one cell to generate a cell trigger. An individual telescope is triggered by a coincidence of 2 to 4 pixels of a camera, depending on the pixel size, with the additional hardware requirement that the trigger pixels be neighbored, to suppress noise triggers. Pixel trigger thresholds as low as 10 photoelectrons should be achievable; the simulations use a very conservative threshold of 25 photoelectrons. A telescope cell (four telescopes at the corners of a square) is triggered if a minimal number of cell telescopes trigger; normally, the system will be operated with a 3-telescope or 4-telescope coincidence, but for special runs, such as short term observations and scans, a two-telescope trigger may be more effective. In either mode, background from local muons - a major source of background-induced triggers for large single telescopes - is eliminated. Typical trigger rates for the initial four-telescope system will be in the 30 Hz to 100 Hz range, depending on the exact trigger condition.

The *data acquisition system* will follow the concepts used presently for the HEGRA telescopes, and will be based on the VME standard, with some custom-designed modules. Many of the modules originally developed at MPIK for HEGRA can be used. Telescopes will be controlled and read out by local VME CPUs, which transfer their data to a central station via Fast Ethernet. A small farm of workstations or PCs, connected via a fast switch, will be used for event building, online data processing and data reduction.

The telescopes must be operated in open air since any form of conventional telescope dome would be prohibitively expensive. However, it appears equally problematic to leave them unprotected from rain, ice, snow, and strong winds. The site should hence allow the construction of *hangars* which serve for weather protection.

4 Performance of the HESS IACT Array

Here we briefly summarize the *performance of the array*; details are given in Appendix C. We note that these performance figures refer to very conservative choices concerning hardware parameters: telescopes with a product of mirror area times photon detection efficiency of 10 m^2, and with 271-pixel PMT cameras with pixel trigger thresholds of 25 photoelectrons and an integration time of 30 ns. We expect that the telescopes could actually be operated with lower thresholds, and with shorter integration times and hence reduced noise. A reduction in pixel size would further boost the performance.

The key characteristics of the full IACT array are:

- *Threshold:* At 100 GeV energy, 50% of the γ rays incident on the area of the array will be detected, and their energy and direction reconstructed. Above 200 GeV, detection efficiency is nearly 100%.

- *Angular resolution:* The IACT array has the best angular resolution in γ-ray astronomy from MeV energies to ultra-high energies, namely $\delta\theta < 0.1^\circ$ on an event-to-event basis. In combination with its high γ-ray detection rate and its effective CR background suppression capability, this permits the analysis of the angular distribution of moderately extended sources that have an angular size up to $\sim 1^\circ$. The location of point sources can be determined with a precision of an arc minute or less.

- *Energy resolution:* the determination of the energy of *individual* γ-ray primaries with an accuracy of $\Delta E/E \leq 25\%$ permits good spectroscopic measurements, in particular the search for features like sharp cutoffs in the spectra of γ-ray sources.

- *Background suppression:* IACT images in high-resolution cameras allow to effectively distinguish γ-ray-induced and hadron-induced showers. Already at the trigger level, hadronic cascades are suppressed because of their lower light yield and different intensity distribution. Compared to a single telescope, background suppression in an IACT system is further enhanced both at the trigger level and in the image analysis. The combined rejection of nucleonic Cosmic Rays is as large as 10^3. For point sources, the directional information provides an additional rejection factor of around 10^2.

- *Flux sensitivity:* the IACT array in its final stage will be able - typically during several weeks of continuous observations - to measure $\geq 100\,\mathrm{GeV}$ γ-ray signals from VHE emitters at an energy flux level down to $f_\mathrm{E} = EdF/d\log E = E^2 dF/dE \sim 10^{-13}\,\mathrm{erg/cm^2 s}$, which is 2-3 orders of magnitude lower than the fluxes detectable at MeV and GeV energies by the COMPTEL and EGRET instruments aboard the Compton GRO. Fig. 4 illustrates the sensitivity of the array in relation to the Crab γ-ray flux.

- *Detection rate:* the high detection rate of this array will allow the study of highly sporadic nonthermal phenomena from different classes of astrophysical objects well below the detectability by satellite-borne instruments at MeV and GeV energies. For strong sources, such as Mrk 421, variability could be studied at sub-minute time scales.

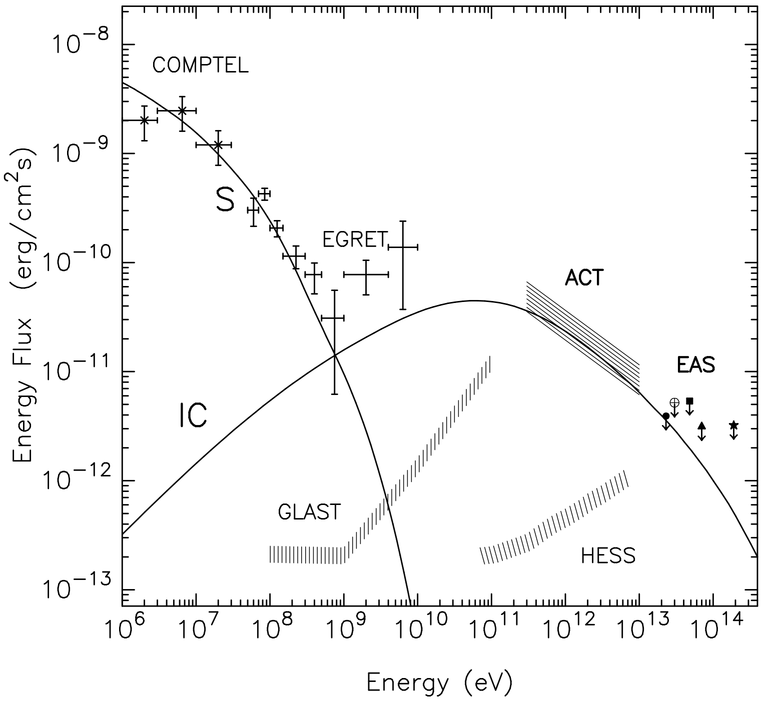

Figure 4: *Sensitivity of the IACT array in its final stage, in relation to the Crab flux as measured by the COMPTEL and EGRET instruments, by existing single IACTs, and by air shower arrays. Indicated are the inverse Compton (IC) and synchrotron (S) contribution to the Crab spectrum. The HESS flux limits refer to 100 h observation time, the included GLAST limits to the sensitivity reached in a 1-year all-sky survey.*

Performance characteristics concerning energy threshold, angular resolution and energy resolution apply equally to the initial 4-telescope cell, as to a final larger array of IACTs. The main difference is a factor of about 5 in the detection rates, and a corresponding change in sensitivity and in the number of detectable sources. Even the 4-telescope cell is far superior to existing IACT installations, and at least equivalent to most next-generation systems presently under discussion.

With the capabilities discussed here, the scope of the proposed array is by no means limited to the in-depth investigation of sources whose selection is based on data in other wavelength regions; rather, it can serve as an efficient survey instrument by itself. The high flux sensitivity of the IACT array and the relatively large field of view of the telescopes, of about $4°$, would allow an effective all-sky survey of point-like sources (namely sources with an angular size less than a few arcminutes) at a level of $f_{\rm E}$ well below 10^{-11} erg/cm^{2}s. This flux is almost 2 orders of magnitude lower than the energy fluxes of typical GeV γ-ray sources detected by EGRET. A sky survey with 16 IACTs, with the telescope axes shifted relative to each other by $1-2^\circ$, would permit a search for such weak sources within an ≈ 100 square degree area of the sky during only one night of observations. This implies that it would be possible to cover in one year more than ten thousand square degrees on the sky.

We emphasize that the superior properties of stereoscopic IACT arrays are no longer only a prediction on the basis of - albeit very detailed - Monte Carlo simulations; first results obtained with the HEGRA IACT system in observations of the Crab Nebula fully confirm the Monte-Carlo based expectations.

5 Site

A key issue is the possible *site* for the proposed array. The Observatorio de los Muchachos (ORM) at La Palma, where the HEGRA array is operated, would again be a good possibility. However it is not clear whether the necessary large, flat area, together with the telescope hangars can be obtained in this national park area.

A promising site is the Calar Alto Observatory on the Sierra de los Filabres in Spain, which is operated jointly by the Max-Planck-Institut für Astronomie (MPIA) in Heidelberg, Germany, and the Spanish Instituto Geografico Nacional (IGN). It could provide the required area. The technical infrastructure of the observatory is excellent. The prospect of scientific and instrumental cooperation with the optical astronomers of MPIA and the availability of optical telescopes for simultaneous observations, in particular of time varying sources, gives this observatory an outstanding attraction for earth-bound γ-ray astronomy.

A third possibility, although certainly more difficult to organize, would be the Gamsberg (in Namibia, Africa), an area owned by the MPIA. This place is without doubt one of the best sites for optical astronomy worldwide and the climatic conditions at this Southern Hemisphere location would be ideal for the proposed system of IACTs. The difficulty associated with this site lies perhaps less in its relative remoteness from Europe, but in the lack of infrastructure and suitable road access. Without other partners and associated projects this appears a difficult proposition at this moment, despite of its basic attractiveness.

6 Time Frame and Schedule

The *time frame* for the proposed project is given both by considerations of a budgetary nature and scientific aspects.

The Max-Planck-Institut für Kernphysik is at present occupied with the final build-up of the focal plane instrumentation of the HEGRA IACT system on La Palma. We consider this as the paramount scientific priority of our institute in the field of γ-ray astronomy.

The HEGRA collaboration has agreed with the Instituto de Astronomia de Canarias (IAC) in Teneriffa, responsible for the ORM at La Palma, to exploit the HEGRA IACT system for at least three years, starting with January 1997. The development of the large IACT system proposed in the present LoI will start when the hardware phase in the HEGRA IACT system is terminated, i.e. during 1997. We expect the initial parts of the new system of IACTs to become operational by the year 2000, at a time when the operation of the HEGRA IACT system is a routine activity.

At the present time, we are investigating various options for the site, the organization - scientifically and technically - and the hardware components. Major decisions concerning the hardware implementation should be taken in early 1998. In the following two years, components should be manufactured, tested, and assembled. Mounts and dishes for the first four telescopes should be manufactured in parallel. We would aim at installing the first telescope in the fall of 1999, and the other three in the spring and early summer of 2000. The winter 1999/2000 could be used for last modifications, based on the experience from the first telescope. To our present knowledge, a critical path item is the mass production of the mirrors. The industrial design and production of the mounts and dishes appears relatively uncritical.

7 Cost Estimates and Funding Profile

Since major choices concerning implementation details are still open at this time, it does not seem appropriate to discuss a detailed cost breakdown. To provide a guideline, we have however costed in some detail one design variant, with major components of the telescope either covered by offers from potential manufactures (mount and mirror dish, mirrors, PMTs), or extrapolated based on the well-known costs of the HEGRA IACT cameras (readout electronics, trigger system, data acquisition system). On this basis, we estimate the production cost per telescope in the 1.5 MDM range, plus total R&D costs of about 300 to 400 TDM. We do not include infrastructure costs such as site access and site preparation; at least in case of the installation on the Calar Alto these costs should be relatively modest. Costs for an (optional) telescope shelter are also not included, but could amount to as much as 1/3 of the system cost. In order to have an initial four-telescope system operational in the year 2000, funding would have to be distributed roughly evenly over the years 1998, 1999, and 2000. Funds of the Max-Planck-Institut für Kernphysik are available to cover most of the R&D work and part of the initial system, but at least during the years 1999 and 2000 contributions from other sources are mandatory.

8 Outlook

We intend to *invite other groups* to either contribute directly to this project, or to join us on the site with their complementary γ-ray instruments, like lower-threshold, large-dish single IACTs. The resulting synergy effects would benefit all parties, may avoid unnecessary parallel technical developments and could lead to cost savings for the different projects. From September 28 to October 3, 1997, we plan a *workshop at the Ringberg* meeting place of the Max-Planck-Gesellschaft near Munich, in order to discuss these questions with interested colleagues.

Three appendices to this document serve to provide details, which go beyond the scope of this brief summary, as well as the relevant references: Appendix A gives the Physics Motivation. Appendix B covers current thoughts concerning the design of the telescopes, their cost, and schedules. As Appendix C, two papers [2] are reproduced, which summarize the studies concerning the performance of the IACT system.

[2] Astroparticle Physics, in press