Project submitted for the base funding of Artem Alikhanyan National Laboratory (ANL)

TITLE: VERY HIGH ENERGY GAMMA RAY ASTROPHYSICS WITH IMAGING ATMOSPHERIC CHERENKOV TECHNIQUE

Division, group: Experimental Physics Division, Gamma Ray Astrophysics Group, member of H.E.S.S. (High Energy Stereoscopic System) and CTA (Cherenkov Telescope Array) collaborations

DURATION: 3 YEARS

Estimated Project Costs (± 20%)

Estimated total cost of the project (US $) 84510
Including:

Payments to Individual Participants	2x350x36=25200 2x240x36=17280 1x180x36=6480 1x350x15=5250
Equipment	2400
Materials	0
Other Direct Costs	23100
Travel	4800

PROBLEM:

The aim of the project is to continue the research in the filed of Very High Energy (VHE) gamma-ray astrophysics, namely to participate in the realization of scientific program of High Energy Stereoscopic System (H.E.S.S.) and to investigate the peculiarities of gamma-rays detection and useful signal extraction for the low threshold (sub 10-20 GeV) Imaging Atmospheric Cherenkov Telescopes (IACTs).

The basic physics goal of atmospheric Cherenkov experiments is to explore the production and propagation of high-energy particles in the Universe, i.e. the so-called non-thermal Universe. Significant part of the radiation incident on the Earth, is thermal radiation generated in hot objects such as stars (the thermal radiation can reach into the keV energy range and beyond). However, the certain particle populations in the Cosmos cannot result from thermal processes, and must be produced by collective mechanisms, focusing the energy outflow from a source onto a relatively small number of particles. The best-known examples of a non-thermal particle population are the cosmic rays. Their power-law spectrum shows no indication of a characteristic (temperature) scale, and their energies - up to 10^{20} eV and above - are well beyond the capabilities of any conceivable thermal emission mechanism. The non-thermal Universe is of significant importance for our understanding of the Universe, its objects, and their evolution.

Among the atmospheric Cherenkov technique the most powerful detectors are the IACTs. The resent achievements of IACT technique are dominated by so-called third generation IACTs, namely by “Big Four”, H.E.S.S., MAGIC, VERITAS and CANGAROO III. Due to IACT technique the large numbers of astrophysical sources of VHE gamma rays were detected: as of March 2011 the total number of TeV sources is 88 and the H.E.S.S. source catalog consists of 58 objects. In the framework of proposed project it is planed to continue the participation of H.E.S.S. program, i.e. to participate in the observations in Namibia and in data analysis.

The second part of proposed project is to continue the investigations in the field of sub-100 GeV atmospheric Cherenkov technique. In this energy region the contribution of second component of background (cosmic-rays electron-induced air showers) becomes important and mathematical methods of data analysis using in higher energy region are inefficient (Cherenkov images induced by γ-, proton- and electron- showers become similar). It is planned to determine the basic characteristics (effective collection area, detection rates, energy resolution, etc) of a system of large diameter IACTs installed at high altitude (5 km asl.) as well as to investigate the mathematical methods for data processing and primary energy reconstruction algorithms for sub-100 GeV energy region.

And the third part will be concerned to the researches which will be carried out in the framework of Cherenkov Telescope Array (CTA) collaboration.

OBJECTIVES:

As a member of the H.E.S.S. collaboration we plan to continue the participation in the realization of collaboration’s scientific program which covers a diverse range of “hot topics” in modern astrophysics. In particular these objectives are: the origin of galactic and extragalactic cosmic rays, the acceleration and radiation mechanisms in astrophysical sources and in extreme astrophysical conditions, the nature of gamma-ray bursts, the cosmological problems connected with the diffuse background radiation, the search of dark matter (indirect search) in the form of weakly interacting massive particles, etc. In the framework of proposed project one plain to participate in the observations which will carry out by H.E.S.S. collaboration and simulate the gamma-rays production processes in astrophysical sources. H.E.S.S. consists of four telescopes each with a diameter of 13 m, operating since 2004. A fifth telescope with a diameter of 28 m (H.E.S.S. II) is under construction and will lower the energy threshold of H.E.S.S from 100 GeV to 30 GeV.

The second objective is to determine the performance and to investigate the gamma-images selection methods for the large diameter low threshold (sub 10-20 GeV) IACT system taking into account the influence of cosmic ray electrons and the real optical response of telescopes. In particular the effective collection area, detection rates, energy resolution, sensitivity, useful signal separation methods, primary particle energy reconstruction algorithms, etc will be determined for the system of 20 m diameter telescopes installed at 5 km asl. For this aim the MOCCA packages for the development of air showers will be used with the detailed Monte-Carlo program for the calculations of optical response of an IACT. The ray-tracing program takes into account the real geometry, optical properties and arrangement of the reflector composing mirrors. These numerical calculations were performed for the single stand alone 20 m diameter telescope installed at 5 km asl. and the simulation will be enlarged for the system of 5 telescopes.

The third objective is to determine the basic characteristics of CTA telescopes using the MOCCA package with the detailed ray-tracing program describing the real construction and mirror geometry of telescopes.

TASK 1: Participation in the observations carried out within the H.E.S.S. collaboration in Namibia, determination of primary energy reconstruction algorithm for low threshold single stand alone 20 m diameter telescope installed at 5 km asl.

Task description and main milestones	Participating Institutions, expected results, deadlines
Task 1.1 Participation in the H.E.S.S. observations in Namibia.	Within H.E.S.S. collaboration, collection of experimental data, 2011.
Task 1.2 Investigation of primary particle energy reconstruction algorithms for 20 m diameter single stand alone telescope.	ANL group, determination of energy reconstruction algorithm, 2011.
Task 1.3 Determination of optical response functions for CTA IACTs.	ANL group, determination of optical response function, 2011.

TASK 2: Participation in the observations carried out within the H.E.S.S. collaboration in Namibia, simulation of performance of 5&5 taking into account the optical response of IACTs, modeling of gamma-rays production mechanisms in the sources.

Task description and main milestones	Participating Institutions, expected results, deadlines
Task 2.1 Participation in the H.E.S.S. observations in Namibia.	Within H.E.S.S. collaboration, collection of experimental data, 2012.
Task 2.2 Simulation of the performance 5&5.	ANL group, 5&5 system performance determination, 2012.
Task 2.3 Simulation of performance of CTA IACTs.	ANL group, determination of performance for CTA IACTs, 2012.
Task 2.4 Modeling of the gamma-rays production processes in the sources.	ANL group, investigation of gamma-rays emission mechanisms in the sources, 2012.

TASK 3: Participation in the observations carried out within the H.E.S.S. collaboration in Namibia, determination of performance of CTA IACTs, modeling of gamma-rays production mechanisms in the sources.

Task description and main milestones	Participating Institutions, expected results, deadlines
Task 3.1 Participation in the H.E.S.S. observations in Namibia.	Within H.E.S.S. collaboration, collection of experimental data, 2013.
Task 3.2 Simulation of performance of CTA IACTs	ANL group, determination of performance for CTA IACTs, 2013.
Task 3.3 Modeling of the gamma-rays production processes in the sources	ANL group, investigation of gamma-rays emissions mechanisms in the sources, 2013.

IMPACT:

Proposed project concerns to different aspects of VHE gamma ray astronomy including the participation of experimental observation (data collection) within the H.E.S.S. collaboration, the simulations of IACTs performances for CTA consortium and sub 10-20 GeV threshold IACTs, as well as the simulation of gamma rays emission mechanisms in the astrophysical sources. The scientific importance and impact of results is conditioned by the participation in the realization of scientific programs of leading international collaborations in the field of modern VHE astronomy: H.E.S.S. and CTA. VHE gamma-rays reveal direct information about the location of particle acceleration/interaction and gamma-ray emission sites. The flux and energy spectrum of the gamma-rays reflects the flux and spectrum of the high energy particles and hence they can be used to investigate the production and acceleration mechanisms of particles producing these gamma-rays. The present generation of IACTs (H.E.S.S., MAGIC, VERITAS and CANGARO III) has opened the area of ground-based gamma ray astronomy for energies above a few tens of GeV and proposed research will be carried out in this directions.

Brief survey of the worldwide researches made on the project topic, the competitiveness of the project, and achievements of the group (not more than 2 pages):

Nowadays, atmospheric Cherenkov technique is a well-established ground-based technique for the VHE γ-ray emission from astrophysical sources (see e.g. [1, 2]). Among the atmospheric Cherenkov instruments the most powerful detectors are the Imaging Atmospheric Cherenkov Telescopes. The current generation of IACTs are the High Energy Stereoscopic System (H.E.S.S., 23^{o}S latitude 1800 m asl); Major Atmospheric Gamma-ray Imaging Cherenkov Telescope (MAGIC, 29^{o}N latitude, 2200 m asl), Very Energetic Radiation Imaging Telescope Array System (VERITAS, 32^{o}N latitude, 1300 m asl) and Collaboration of Australia and Nippon for a GAmma Ray Observatory in the Outback (CANGAROO-III telescope system, 31^{o}S latitude, 1600 m asl) (see Table 1, [3]).

Instruments	Lat (º)	Long (º)	Alt (m asl)	Tels	Tel. area (m^2)	Pixels	FoV (º)	Thresh.(TeV)
H.E.S.S.	-23	16	1800	4	107	960	5	0.1
VERITAS	32	-111	1275	4	106	499	3.5	0.1
MAGIC I* + II	29	18	2225	2	234	574/1039	3.5*	0.3
CANGAROO-III	-31	137	160	3	57.3	427	4	0.3

Table 1: Properties of selected Imaging Atmospheric Cherenkov Telescopes [3].*) With pixels of two sizes.

Due to IACT technique the large numbers of astrophysical sources of VHE γ-rays were detected. As of November 2010 the total number of TeV sources is 86 (with 26 unidentified sources) according to "Default" catalog of TeVCat [4] which does not include newly announced sources (see Table 2, [5]).

Source class	TeV sources
AGN: BL Lac blazers	23
AGN: Flat-spectrum radio quasar blazers	1
AGN: non-blazar	2
Shell-type supernova remnants	10
Pulsar Wind Nebulae (PWN)	18
X-ray binaries	3
Starburst galaxies	2
Wolf-Rayet stars	1
Unidentified	26
Total	**86**

Table 2: Number of known TeV γ-ray sources by type, as of November 2010 [4].

As of March 2011 the total number of TeV sources (including newly discovered) is 121, 88 from "Default" catalog and 33 from "Newly Announced" catalog of TeVCat. The VHE gamma-ray Sky Map consists of 61 Galactic and 46 Extragalactic sources (see Fig. 1, [6]). It should be noted that the contribution of H.E.S.S. collaboration in the formation of gamma-ray sources catalog is significant: as of March 2011 the H.E.S.S. source catalog consists of 58 objects.

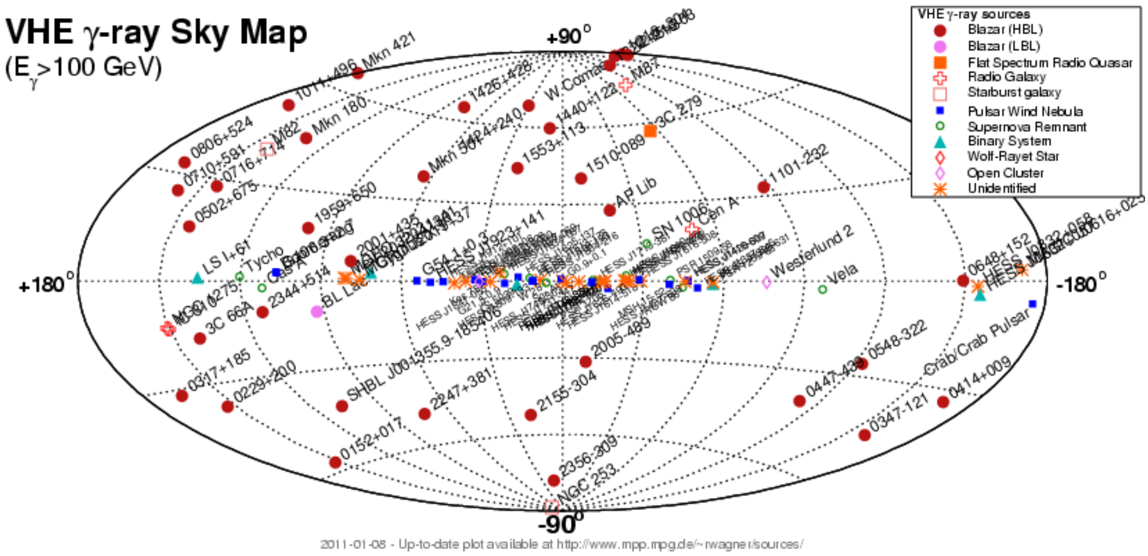

Figure 1. VHE gamma-ray Sky Map (>100 GeV)

The CTA is a large array of Cherenkov telescopes of different sizes, based on proven technology and deployed on an unprecedented scale. CTA will consist of two arrays of Cherenkov telescopes, which aim to: (i) increase sensitivity by another order of magnitude, (ii) increase the angular resolution, (iii) provide uniform energy coverage from some tens of GeV to beyond 100 TeV.

As to achievements of ANL group then the activities of last years were concentrated in the following directions:

1. participation of H.E.S.S. construction (with the "Galaktika" CJSC were fabricated forwarded to collaboration 200 Cherenkov mirrors);
2. investigation of mathematical methods for experimental data analysis [7];
3. investigation of peculiarities of atmospheric Cherenkov technique at the detection of gamma-rays in sub 100 GeV energy region [8,9].

References

1. T. C. Weekes, arXiV:0811.1197v1, 2008
2. J.A. Hinton and W. Hofmann, arXiv:1006.5210v2, 2010.
3. J. Hinton, New Journal of Physics 11 (2009) 055005.
4. http://tevcat.uchicago.edu.
5. J. Vandenbroucke, for the Fermi LAT collaboration, arXiv:1012.0849v2, 2010.
6. http://www.mppmu.mpg.de/~rwagner/sources.
7. A. Atoyan, J. Patera, V. Sahakian, A. Akpherjanian Astropart. Phys 23. (2005) 79-95.
8. V. Sahakian, F. Aharonian, A. Akhperjanian Astropart. Phys. 25 (2006) 233-241.
9. V. Sahakian, A. Akhperjanian Astropart. Phys. 26 (2006) 257-268.

References:

Personnel Commitments (chart, total number of project participants, responsibilities of each).

Total number of participants is 5 for 2011 and 6 from 2012. For the first step (2011) the group consists of V. Sahakian, A.Akhperjanian, G.Papyan, L. Davtyan and 1 master degree student from Yerevan state university. In 2012 the young researcher will join the group after finishing the PhD program.

In the observations within the H.E.S.S. collaboration will participate A. Akhperjanian and G. Papyan. In the data processing, as well as in the investigation of different aspects of the sub-100 GeV atmospheric Chernkov technique and in Monte-Carlo simulations- V. Sahakian, A. Akhperjanian and master degree student. Modeling of gamma-rays production mechanisms in the astrophysical sources- young researcher. In the development of Cherenkov mirror protective coating technology - G. Papyan and L. Davtyan.

As of March 2011 the mean age of the group member is 50,2 with one participant under 35.

Equipment

Equipment description	Cost (US $)
PC	1200 (for 2012) 1200 (for 2013)
Total (for 3 years)	2400

Materials

Materials description	Cost (US $)
-	-

Other Direct Costs

Direct costs description	Cost (US $)
H.E.S.S. collaboration Fee	4200 (for each year)
Participation in the observations within the H.E.S.S. collaboration	3500 (for each year)
Total (for 3 years)	23100

Travel costs (US $)

CIS travel	International travel	Total
	Participation in the CTA meetings	1600 (for each year)
	Total (for 3 years)	4800

Technical Approach and Methodology

H.E.S.S. is an array of four imaging atmospheric Cherenkov telescopes located in the Khomas Highlands of Namibia at an altitude of 1800 m above sea level. Each telescope consists of an optical reflector of about 107 m^2 effective area composed of 382 round mirrors arranged on a Davis-Cotton mount [1]. The cameras consist of 960 fast photomultipliers of individual field of view of 0.16° diameter. The total field of view of the H.E.S.S. instrument is 5° in diameter. The energy threshold of H.E.S.S. at zenith before selection cuts moved from 100 GeV at the commissioning of the experiment in 2003 to 160 GeV due to the degradation of the optical performance in 2006. The point source sensitivity is better than $2 \times 10^{-13} cm^{-2} s^{-1}$ above 1 TeV for a 5 sigma detection in 25 hours [2]. For the H.E.S.S. system the time for the 5 sigma detection is ~30 sec for Crab, ~1 hr for 0.05 Crab, and 25 hrs for 0.01 Crab. As of March 2011 the H.E.S.S. source catalog consists of 58 objects. About the results obtained by H.E.S.S. collaboration see [3]. Here we would like to present only the several selected examples among the important results obtained by H.E.S.S.

In Fig. 1 the morphological image and energy spectrum of supernova remnant RX J1713.7-3946 are presented [4].

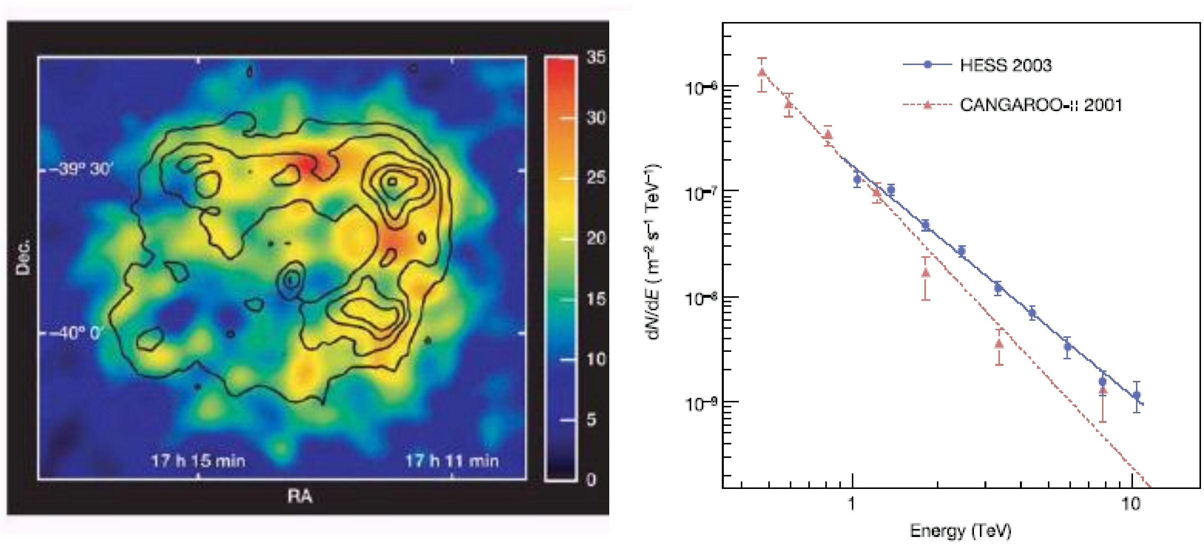

Figure 1. Gamma-ray image and energy spectrum of SNR RX J1713.7-3946. The gamma-like events above 800 GeV are reconstructed.

These data can be described by power law, $dN/dE \sim E^{-\Gamma}$ with $\Gamma = 2.19 \pm 0.09_{stat} \pm 0.15_{sys}$. The integral flux above 1 TeV is founded to be $(1.46 \pm 0.17_{stat} \pm 0.37_{sys}) x 10^{-7}$ photons $m^{-2} s^{-}1$. These data show that the spatially resolved remnant has a shell morphology similar to that seen in X-rays, which demonstrates that very-high-energy particles are accelerated there. The energy spectrum indicates efficient acceleration of charged particles to energy beyond 100 TeV, consisting with current ideas of particle acceleration in young shocks.

The new population of eight previously unknown very high energy gamma-ray sources in the Milky May were detected by the H.E.S.S experiment [5] (see Table 1).

Name	Size, σ (arc min)	Significance	Flux (above 200 GeV) x $10^{-12}cm^{-2}s^{-1}$
HESS J1614-518	12	5.2	9
HESS J1616-508	11	7.4	17
HESS J1640-465	2	11.7	19
HESS J1804-216	13	8.2	16
HESS J1813-178	3	10.2	12
HESS J1825-137	10	4.4	9
HESS J1834-087	12	6.7	13
HESS J1837-069	4	6.0	9

Table 1. Characteristics of the new gamma-ray sources. Size: estimated source extension σ for brightness distribution of the form $\rho \propto \exp(-r^2/2\sigma^2)$. Significance: determined for a point source cut $\theta^2=(0.14)^2$. Flux: estimated flux above 200 GeV (x $10^{-12}cm^{-2}s^{-1}$).

The six sources from these eights there are counterparts at other wavelengths. However, for the two sources, HESS J1813-178 and HESS J1614-518, no counterparts have been found at other wavelengths. HESS J1813-178 resembles the unidentified TeV source discovered by HEGRA, TeV J2032+4130, and the first HESS unidentified gamma-ray source, HESS J1303-63. HESS J1614-518 has no plausible SNR or pulsar counterpart. This source is in the field of view of HESS J1616-508. The fact that for these two sources no counterparts suggests the possibility of a new class of particle accelerators in the Galaxy.

H.E.S.S. observation of Galactic Centre region led to detection of very high energy gamma-rays from the region extending along the Galactic plane for roughly 2^o[6]. The reconstructed gamma-ray spectrum for the region $|l|\leq 0.8^o$, $|b|\leq 0.3^o$ is well described by a power law with photon index $\Gamma=2.29\pm0.07_{stat}\pm0.20_{sys}$.The region of emission correlated spatially with a complex of giant molecular clouds in the central 200 parsecs of the Milky Way. The hardness of the spectrum and the conditions in those molecular clouds indicate that the cosmic rays giving rise to the gamma-rays are likely to be protons and nuclei rather than electrons.

A novel technique for the detection of cosmic rays with arrays of Imaging Atmospheric Cherenkov Telescopes is applied to data from the H.E.S.S. system [7]. Using H.E.S.S. data, an energy spectrum for cosmic-ray iron nuclei in the energy range 13–200 TeV is derived. The reconstructed spectrum is consistent with previous direct measurements and is one of the most precise so far in this energy range. The data set amounts to 357 hours of observation time, and in total, 35364 events in the energy region from 13 to 200 TeV were selected to further analysis. From these data 1899 events were selected with $N_{tel} \geq 2$ (in order to minimize systematic uncertainties due to background estimation). The resolution of the shower parameter reconstruction for these events is ≈0.1° for the shower direction, ≈20 m on the shower core position and ≈15% on the primary energy. The differential iron energy spectrum measured with

H.E.S.S. telescopes and the comparison with direct measurement results are presented in Fig. 2.

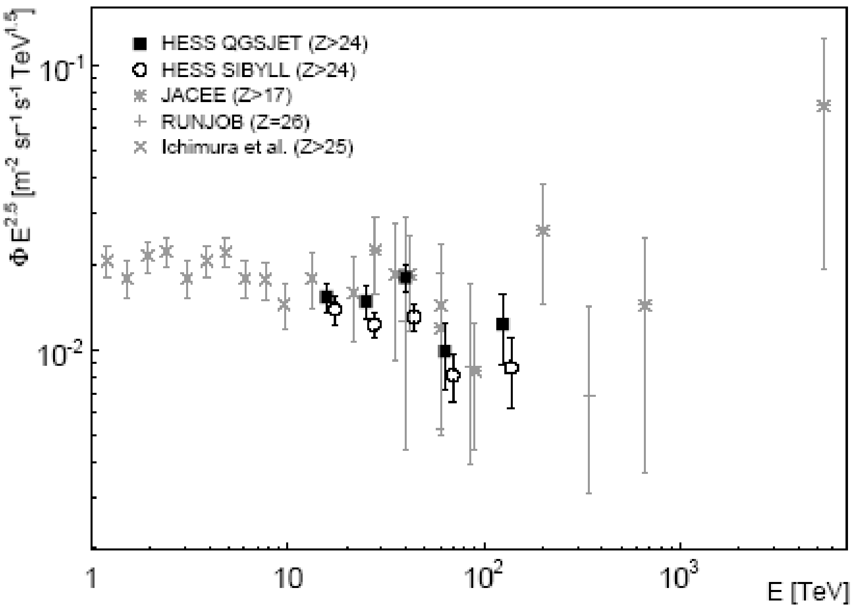

Figure 2. Differential iron energy spectrum measured with H.E.S.S. telescopes multiplied by $E^{2.5}$ for better visibility of structures.

Using H.E.S.S. data an energy spectrum for cosmic-ray electrons at TeV energies were derived (see Fig. 3, [8]).

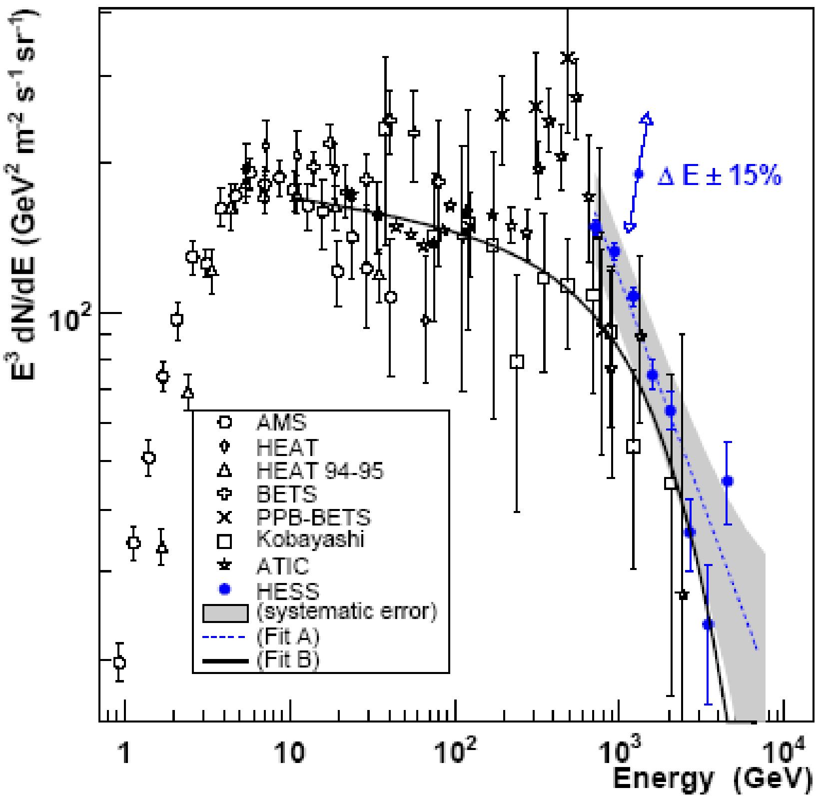

Figure 3. The energy spectrum E^3dN/dE of cosmic ray electrons as measured by H.E.S.S. in comparison with previous measurements. The shaded band indicates the approximate systematic error arising from uncertainties in the modeling of hadronic interactions and in the atmospheric model.

The H.E.S.S. data are well described by a power-law: $dN/dE=k(E/1TeV)^{-\Gamma}$ with $k=(1.17\pm0.02)\times10^{-4}TeV^{-1}m^{-2}sr^{-1}s^{-1}$ and $\Gamma=3.9\pm0.1_{stat}$ and indicate substantial steepening in the energy spectrum above 600 GeV compared to lower energies.

The very high energy gamma-ray emission from the radio galaxy Cantaurus A was discovered [9]. The observations were performed fore more than 120 hrs between April 2004 and July 2008. A signal with a statistical significance of 5σ (330 excess events, N_{ON}=4199 and N_{OFF}=4253) is detected from the region including the radio core (see Fig. 4, left panel).

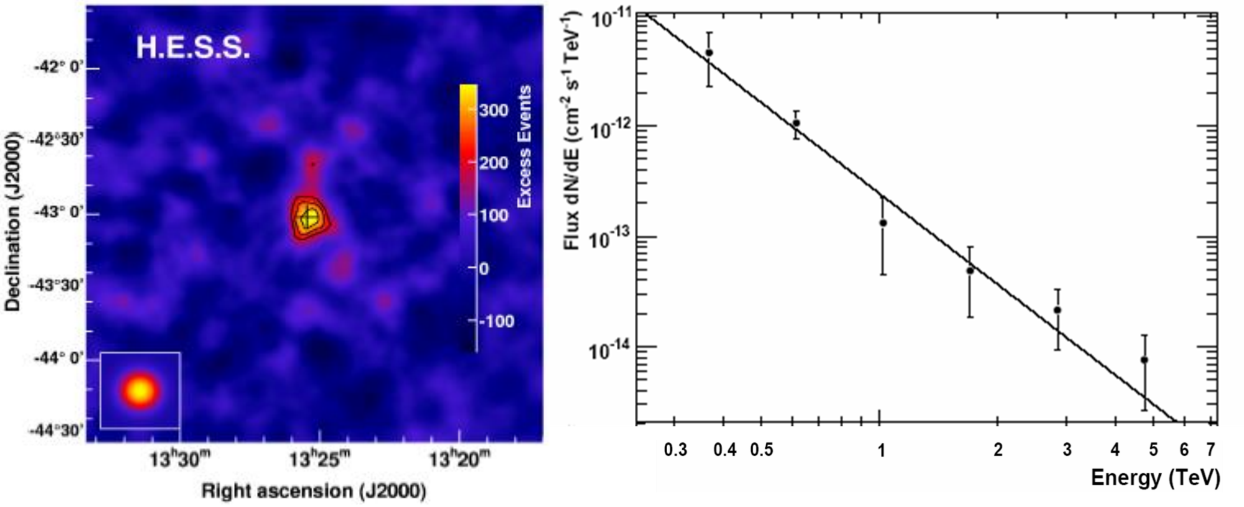

Figure 4. Smoothed excess sky map centered on the Cen A radio core (left panel) and differential energy spectrum (right panel). The cross in left panel indicates the core and overlaid contours correspond to statistical significances of 3, 4, and 5σ, respectively. In right panel the line is best fit.

Differential photon spectrum is well described by power-law (Fig. 4, right panel): $dN/dE=\Phi_0(E/1TeV)^{-\Gamma}$ with normalization factor $\Phi_0=(2.45\pm0.52_{stat}\pm0.49_{sys})\times10^{-13}cm^{-2}s^{-}1TeV^{-1}$ and photon index $\Gamma=2.73\pm0.45_{stat}\pm0.2_{sys}$. The integral flux above 250 GeV is $\Phi(E>250GeV)=(1.56\pm0.67_{stat})\times10^{-12}cm^{-2}s^{-1}$, which corresponds to ~0.8% of the flux of Crab Nebula above the same threshold.

A strong very high energy signal with a statistical significance of 17σ was detected during the four year of H.E.S.S. observations (from 2004 through 2007) of BL Lac object PKS2005-489 (90.3 hrs live time) [10]. The integral flux above 400 GeV is ~3% of the flux from Crab Nebula. The average spectrum from ~300 GeV to ~5 TeV is characterized by power-law with a photon index $\Gamma=3.20\pm0.16_{stat}\pm0.10_{sys}$.

The activities of ANL group over the last years were concentrated in the construction of H.E.S.S. telescopes, in the determination of instrument's performance, in the investigation of mathematical methods for data analysis as well as the peculiarities of the detection of low energy atmospheric showers (sub 100 GeV) with Cherenkov technique also were investigated. In particularly with the participation of ANL group members the Cherenkov mirror coating technology was developed in the "Galaktika" CJSC and 400 mirrors were fabricated for the

H.E.S.S. four telescopes (600 mm diameter) and 900 mirrors for H.E.S.S. II telescope (900 mm diameter). In addition with “Galaktika” CJSC were fabricated and forwarded to the collaboration 200 Cherenkov mirrors with 600 mm diameter. The technical characteristics of these mirrors are presented in Table 2.

Technical Characteristics of H.E.S.S. mirrors manufactured by “Galaktika” CJSC with participation of ANL group	
Geometrical shape	spherical 600 mm diameter
Area	0.28 m^2
Thickness	15 mm
Weight	9.9 kg
Substrate material	glass
Substrate manufacturing technique	ground, polished
Reflective coating	Al
Protective coating	SiO_2
Focal length	(15.00 ± 0.25) m
Point spread function	80% of light in 1 mrad diameter
Reflectivity	>80% between 300 and 600 nm

Table 2. Technical characteristics of H.E.S.S. mirrors manufactured by “Galaktika” CJSC.

The performance of H.E.S.S. telescope was determined using detailed Monte-Carlo program for the calculations of optical response of an IACT. The ray-tracing program takes into account the real geometry, optical properties and arrangement of the reflector composing mirrors. In addition the influence of the reflector design of a large multi-mirror imaging atmospheric Cherenkov telescope on the pulse shape of the light collected by the photo-receiver also was investigated [11, 12]. It was shown that for the large diameter IACTs (larger than 15 m) the spherical (Davies-Cotton) design substantially widens the pulse of collected Cherenkov photons, while the design-induced additional widening is negligibly small for the parabolic design (parabolic reflector with spherical mirror facets). The case of 20 m diameter telescope is presented in Fig. 5.

New mathematical method was developed for the analysis of data obtained by IACTs. Namely the Fourier transform (FT) method for processing images of extensive air showers detected by an IACTs is investigated [13, 14]. The FT-method was applied to the Monte-Carlo simulated bank of TeV proton and gamma-ray air shower images for a stand-alone imaging telescope. Comparison between the FT-method and the currently used standard method shows that the FT technique allows a better and systematic enhancement of the gamma-ray signal (see Fig. 6).

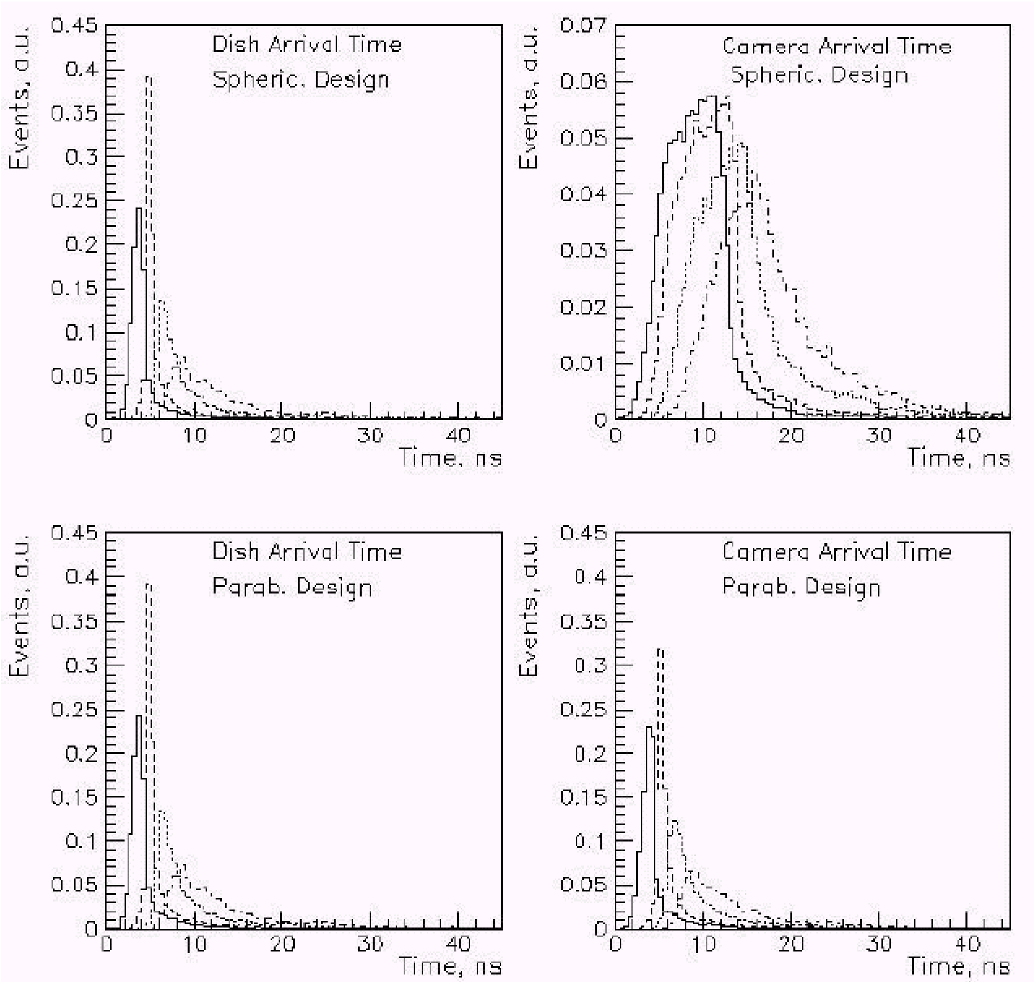

Figure 5. The dish arrival time and camera arrival time distributions of photoelectrons initiated by the photons from 10 GeV gamma-showers. Upper histograms correspond to the spherical reflector, lower histograms – the parabolic reflector. The telescope diameter is 20 m, observation height is 5 km asl., and the showers impact distances are: 50 m (solid), 100 m (dashed), 150 m (dotted) and 200 m (dash-dotted).

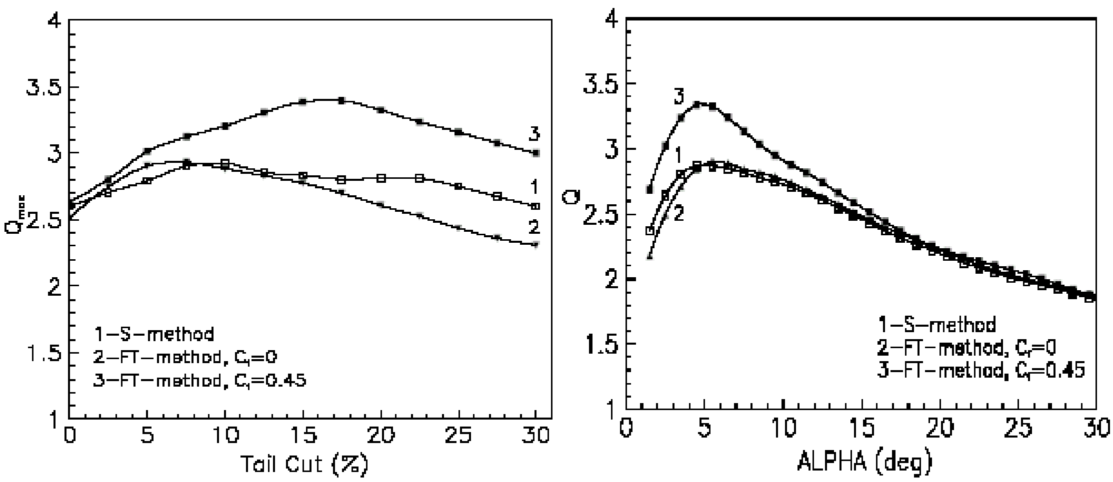

Figure 6. a (left panel): The maximal Q-factors attained at different tail-cuts in the standard approach (curve 1, open squares), and by the Fourier transform method without filtering (curve 2, triangles), and in case of low-pass filter with the parameter C_f=0.45 (curve 3, full squares); b (right panel): The dependences of the Q-factors on alpha parameter for the same 3 cases, but when the tail-cuts are fixed at the respective values corresponding to the absolute maxima of Q_{max} of the curves on the left panel.

The properties of Cherenkov light produced in electromagnetic air showers induced by primary electrons were investigated [15]. The lateral distribution functions of the Cherenkov light produced by electromagnetic air showers initiated by primary gamma-rays and electrons are different. This fact is explained by the difference in the development of cascades from gamma-rays and electrons; electron-showers start to develop and produce light earlier than gamma-showers, but they attenuate rapidly. By propagating much farther into the atmosphere, the gamma-initiated shower carries a Cherenkov component much closer to the ground level than electron initiated showers do; this results in a more intense pool of light close to the shower axis (see Fig. 7).

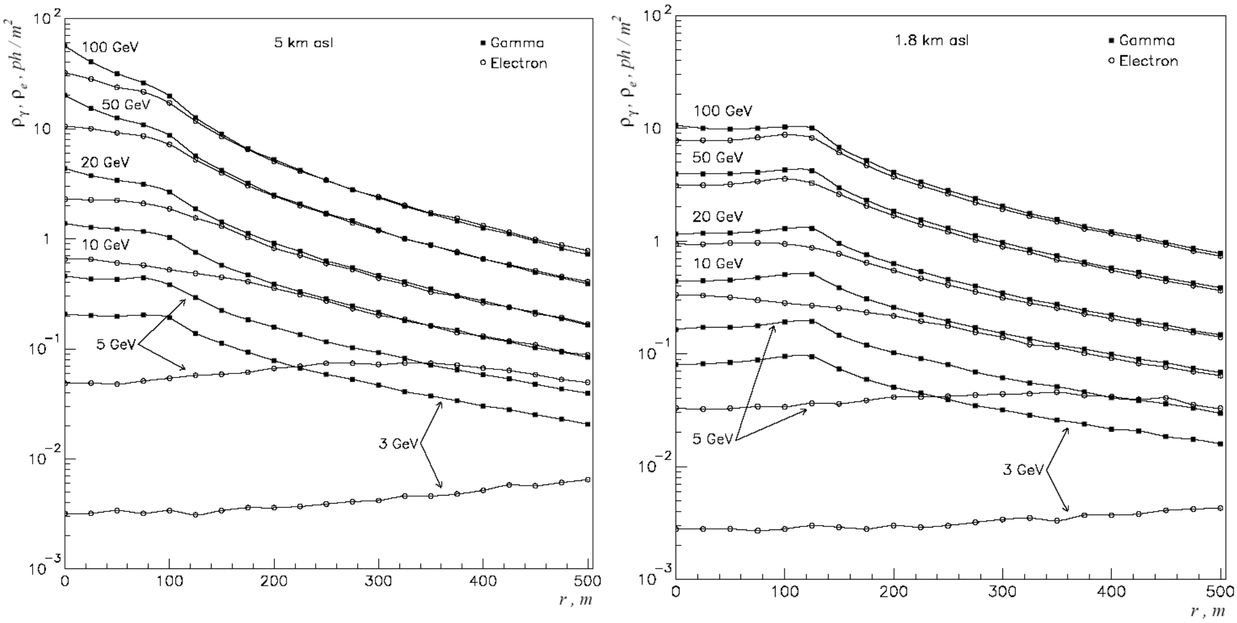

Figure 7. Lateral distribution of the Cherenkov light from gamma- and electron-induced air showers at an altitude of 5 and 1.8 km a.s.l. The energies of primary particles are shown at the curves.

In Fig. 7 the lateral distributions of Cherenkov photons produced by electromagnetic air showers are presented for the observation level of 5 km asl. (the altitude proposed for the project 5&5) and 1.8 km asl. (the altitude of H.E.S.S. telescopes system). It is seen that for both altitudes and for the distances up to 200 m the density of Cherenkov photons in gamma-air showers is higher than in electron-air showers.

The differences in the lateral distributions of Cherenkov photons produced by gamma and electron induced air showers result to the different responses of atmospheric Cherenkov telescopes [16]. In particular the different effective collection areas and detection rates. As a result the detection energy threshold of cosmic ray electron induced showers is higher than that for primary gamma showers due to the differences in the development of electromagnetic air showers initiated by these primaries (see Fig. 8). This can provide a background free detection region for primary gamma rays with energy E ≤5-10 GeV, provided that the misclassified events induced by primary hadrons of significantly higher energies are effectively suppressed.

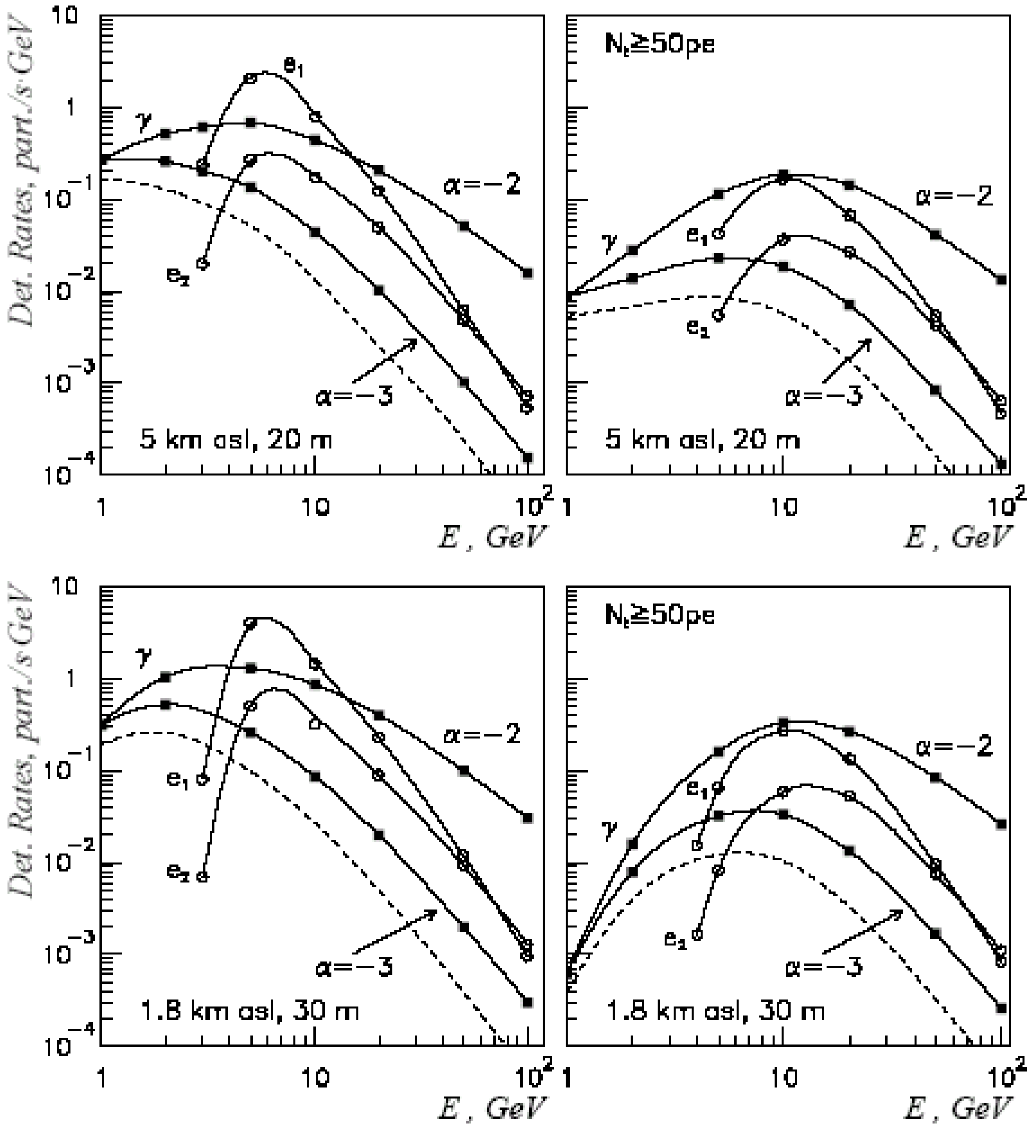

Figure 8. Differential detection rates of showers produced by γ-rays and cosmic ray electrons. The telescope diameters and installation altitudes are 20m at 5 km asl. (upper panels) and 30m at 1.8 km asl. (lower panels). The trigger condition is 2nn/721 ≥ 5pe with photon collection time of 8 ns. For γ-rays the differential flux is normalized to 10^{-3}phm^{-2}s^{-1}GeV^{-1} at 1GeV. Two values for the telescopes angular resolutions is presented: $\theta(E)=0.42(E/5\ \mathrm{GeV}\ )^{-0.4}$ degree (curves are denoted by symbol e_1), and θ is constant and is equal to 0.15^o (symbol e_2 at curves).The dashed lines correspond to the detection rate of diffuse galactic gamma radiation from the direction of the galactic center with the flux of $3\cdot10^{-2}$(E/5 GeV)$^{-2.5}$ ph m^{-2} s^{-1}str^{-1}GeV^{-1} for the case when the telescope angular resolution is dependant on energy.

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