# Design and Performance of the Lead-Concrete Geiger Tower Array within the HEGRA Experiment[1]

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**Abstract**

The HEGRA [1] experiment is characterized by four different types of detectors (scintillator counters, open Čerenkov counters, Čerenkov telescopes and Geiger towers) located within one detector array. The Geiger towers are built with the technical objective to measure the energy deposition and to reconstruct and identify muon tracks. In addition each tower may serve as an independent high resolution muon flux monitor. With these properties the Geiger towers are operating as geometric and energetic calibration instruments in comparison with other detector components and as additional independent measurement instruments with respect to the gamma-hadron separation and the measurement of the chemical composition. In this contribution the design and the performance of the lead-concrete Geiger towers are described.

## 1 Introduction

The primary aims of the HEGRA experiment are detection of directed and diffuse cosmic gamma radiation, measurement of the chemical composition, and the observation of time-variations in one of the cosmic ray components. For this purpose the HEGRA detector is built up on the Canary Island La Palma on the Roque de Los Muchachos at an altitude of 2200 m a.s.l. as a multicomponent detector on an array of $180 \cdot 180$ m$^2$ with a total coverage of 3%. Presently four different types of detectors are involved in continuous data taking. With two Čerenkov telescopes [2] a theory directed search for point sources is performed with a photon energy threshold of about 1 TeV. By a matrix of 219 scintillator counters [3] the direction and lateral particle and energy distribution of air showers is measured with a primary proton energy threshold of 35 TeV. The matrix of 49 open Čerenkov counters (AIROBICC) [4] contributes a measurement of the shower direction and the light distribution with an energy threshold for primary protons of 30 TeV. A matrix of 17 Geiger towers (spacing 30 m) is designed for the measurement of the electron and muon content of the shower, the energy distribution, and the shower direction.

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In contrast to the other components the Geiger towers do not contribute to the trigger. Since by this combination of detectors a great variety of properties of each shower is measured due to independent measurements of identical or closely related quantities also consistency checks of the relevant properties are provided. For the case of the Geiger towers the determination of the shower direction by the reconstruction of muon tracks in comparison to the other components and the measurement of deposited electromagnetic energy in comparison to the scintillator matrix are of special interest.

## 2 Hardware and Readout

Each Geiger tower has an active surface of about 18 $m^2$ and consists of six planes of Geiger tubes, placed in a support structure of gazeous concrete ($\rho = 0.8$ g/cm$^3$). The upper two planes are each followed by a layer of lead measuring 2.5 cm (4.5 radiation lengths). The distance between the planes amounts to about 20 cm. Each plane measures $6.0 \cdot 2.73$ m$^2$ and consists of 160 aluminium Geiger tubes with a length of 6 m and an inner quadratic profile of $1.5 \cdot 1.5$ cm$^2$.

The gas consisting of a mixture of 98.9% Argon, 1.0% Propane and 0.1% Freon is supplied via an open net by a central mixing facility. The system is kept under pressure to avoid air penetration, and the flow rate is 6 l/h per each row of 320 Geiger tubes (two planes). A positive high voltage of about 1150 V is supplied to the wire through the electronic readout board, which receives the Geiger pulse obtained on the wire through a coupling capacitor. This voltage leads to a current of about 1 $\mu$A per Geiger tube. Like the Geiger tubes also the readout boards have been taken from the Fréjus underground detector after its shut down, so that a detailed description of these components can be found in [5]. To adapt the readout system, which was designed for low fluxes of charged particles and respective low trigger rates, the original Geiger pulse level controlled system is supplemented by an edge sensitive secondary readout electronic. The combination of both systems shortens a typical Geiger pulse from 75 $\mu$s to 3 $\mu$s and thus reduces the background due to accidental hits by a factor of 25. The data are read out serially using a FASTBUS system in combination with a DEC-station 5000/200 as controlling and monitoring device. The typical trigger rate from HEGRA of 20 Hz leads to an amount of 600 MByte of data per day. As control facility for each trigger in a run the signal at each single tube is added and the sum is displayed continuously for all towers and finally stored with the data. Malfunctions can thus be instantaneously detected and removed by the operator and inefficient or noisy Geiger tubes can be easily detected in the software data analysis. It should be pointed out that by this readout system per tower only a two dimensional projection of each shower is recorded. As neighbouring Geiger towers are oriented orthogonal to each other, for muon rich showers also a quasi three dimensional reconstruction is possible. In addition by the expansion of the readout electronic a 3 $\mu$s signal is provided each time, when one of the Geiger tubes of a certain plane has fired. If at least three from the four lower planes show this signal at the same time a local trigger pulse is counted per tower. The condition is fulfilled with a rate of about 2.5 kHz mainly due to single muons with an energy above 300 MeV. This rate is sensitive to atmospheric conditions (pressure, negative and positive temperature effect) as well as the working parameters of the Geiger tubes (gas composition, gas flow, high voltage), so that by this signal the quality of each tower is monitored continuously.

## 3 Monte Carlo Simulations

The Geiger towers are described by a detector Monte Carlo based on the GEANT 3.21[6] code. To check the physical reliability of the description the code was slightly changed to the geometry of the iron sampling calorimeter which was calibrated in the electron and hadron beams at DESY and at Bonn as test detector for the Fréjus experiment [5]. It has been confirmed, that the geometrical shape of the detector response agrees with the calibration measurements. The calculations further show that the energy resolution for single electrons above an energy of 5 GeV is $\sigma_{\mathrm{E}}/\mathrm{E} = 20\%$ and that the projected direction of single muon tracks $E_\mu > 10$ GeV can be reconstructed with an accurancy of $0.5^o$. With the air shower Monte Carlo CORSIKA [7] hadron induced air showers above 30 TeV were generated according to the composition and energy dependence given in [8]. The particle output of this program for the case of the HEGRA location was tracked by the detector Monte Carlo. It was found that the total energy deposition inside each Geiger tower can be reconstructed with an accuracy of $\sigma_{\mathrm{E}}/\mathrm{E} = 40\%$. If in (at least) four of the six detector planes Geiger tubes fire in such way that a straight line through these tubes can be fitted, a track through the tower is claimed. This track can either be caused by a showering particle (electron or photon) or by a non-showering particle (hadrons or dominantly muons) or be the result of an overlap of more than one particle. Using the geometrical information of the hits adjacent to such a track as input for a neural net [9] a separation between showering and non-showering tracks has been performed with the result that muons can be identified with an efficiency of 80% if one requires a 80% pure data sample. It should be noted that the investigations of the $\gamma$-hadron and hadron-hadron separation show that the information contained in the showering tracks is close to the muon information.

## 4 Data Analysis and Detector Performance

In the offline standard analysis, using the added signals of all events of a run, the inefficient and noisy Geiger tubes (5%) are marked first. Then the single muon tracks (nonshowering directed hitpattern) are reconstructed to determine the cell efficiency dependent on the (projected) track direction. Corrected for geometrical effects this cell efficiency has been determined to be above 90%, so that single muon tracks can be reconstructed with an efficiency of more than 95%. These efficiencies did not change significantly during the first year of operation. The direction of the reconstructed tracks is continuously compared to the reconstructed direction from the other detector components. By this way the telescope position can be checked with an error of the mean value of $0.05^o$ per night, and the direction of typical showers triggered by the scintillator or Čerenkov array with an standard deviation of $1.0^o$. An analysis based to large degree on the Geiger tower data is presented in [10].

## 5 Conclusions

The HEGRA Geiger tower are an appropriate detector component for a measurement of the energy and the lateral particle distribution in air shower. Track reconstruction of charged particles and the destinction in muons and electrons is possible. By this means they faciliate the $\gamma$-hadron separation and measurement of the chemical composition of primary cosmic rays. Since the absolute direction of the reconstructed tracks depends only on the tower geometry and the deposited energy is measured independently they are a valuable tool for the comparison of the different detector components of HEGRA. Within one year of operation the performance of the detector has been studied with several monitoring tools. Results are compatible with expectations.

## References


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