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Atmospheric Transmission Measurements for the MAGIC Telescope Operation

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Justification: MAGIC will be operated over a wide range of γ-energies up to nearly 80° zenith angle and wide range of background conditions (dark nights, stars in the FOV, moonlight, dusk/dawn). In order to make full use of the detection power of MAGIC a good knowledge of the differential and total atmospheric transmission and background light is needed.

The various possible reasons for losses of Cherenkov-light are

a) Rayleigh scattering

b) Mie/Aerosol scattering and absorption

c) absorption due to Ozone (which can change in concentration and altitude)

d) mirror reflectivity changes (ageing)

e) dew, ice, dust deposit on mirrors and optical elements.

In addition, various variable background conditions can affect the trigger, respectively physics data, such as

a) light from stars

b) NSB from the ionosphere fluorescence

c) scattered moon light

d) scattered sunlight during dusk/dawn (if we want to extend GRB search time)

e) zodiacal light

f) scattered light from man-made light pollution

g) direct starlight from the sky section seen by the camera.

h) Due to the rotation of the earth the airmass between the telescope and the source is constantly changing.

Some of the above effects are changing in a predicable manner such as a) and b) and are taken into account by the MC simulation. Also c)and d) can be added to the MC simulations and applied to the final images, although control measurements are needed.

The possible loss of mirror reflectivity due to dew and icing is normally prevented by mirror heating. Dust deposition needs monitoring and periodic cleaning by a water jet spray (a rotary water jet gun will be mounted in the center of the mirror dish and operated remotely, see the design report). Reflectivity losses due to ageing are expected to occur slowly and periodic measurements with a reflectometer etc. (see the design report) can be used for monitoring.

The most critical loss is Mie/Aerosol scattering. This can be highly variable, even on the basis of hours. Depending on the altitude of the scattering substance the images can be strongly affected. For example, it was sometimes possible to operate the HEGRA AIROBICC detector with high efficiency in the presence of high, dense cloud layers shielding completely the night sky background light. On the other hand rates were very sensitive to water droplet formation in layers just above the detector in case humidity approached or exceeded 80%. Such situations are rather complex due to temperature and water vapour profiles. In principle the site at La Palma is quite favourable as for the prevailing trade wind situation at La Palma the air in higher atmospheric layers is normally very dry. Nevertheless, monitoring the differential and total transmission of the atmosphere is very important. Ideally, it would even require spectral transmission measurements. There are a few tools foreseen for MAGIC to study atmospheric changes.

a) Simple monitoring of high cloud formation by measuring the temperature of the night sky in the 8-12 μ infrared band. Such an instrument has been described by T. Turver et al. (KNP Workshop). The clear night sky has a temperature below $-80°$C while clouds reflect the temperature of the ground. The sensor is a thermopile or a thermistor with a chopper. Reference temperatures can easily generated by Peltier-elements. Filters and optical elements can be found in various catalogues.

b) Measurement of the integral transmission in the visible spectral range. Particularly, low energy showers generate most of their light at high altitudes, say between 1/4 and 1/2 airmass, i.e. in the tropopause where nearly no atmospheric changes occur. At large zenith angles the shower max shifts to even higher altitudes, with even less chance of formation of ice crystals. The light has to pass nearly the same amount of airmass and absorption is a global effect independent of the light being generated at the shower head or tail. Therefore an integral transmission measurement is very likely a good correction parameter. The measurement can be performed using known stars with calibrated emission spectra as light sources. These stars should be in the vicinity of the potential γ source and must be tracked continuously. In principle, only one nearly bright star is sufficient. This star can be observed with a small telescope coupled to a high sensitivity CCD camera. Sets of filters allow one to constantly monitor the spectral distribution as a function of time and zenith angle. Even stars being 10° away from the γ source would be sufficient. It should be possible to build up a sufficient database of possible candidates in a rather short time and to establish the procedure well before the startup of MAGIC. As instrument a small mirror cassegrain telescope, used for amateur observations, with autoguide features should be useful. The object image should be spread over 4-8 pixels in order to avoid strong effects from the dead spacing between pixels. The entire system can be controlled by a PC.

It should be noted that there are second order absorption effects along the shower due to Ozone absorption. At large zenith angles the shower max would be in a layer with high levels of Ozone. The concentration and height of the Ozone layer varies considerably with the time of the year. Mostly affected is the Cherenkov light below 350 nm (see transmission curve in the design report). ON the other hand this light is highly suppressed by Rayleigh scattering. (At large zenith angles only a small fraction of the initial Cherenkov light below 400 nm will reach the ground.)

The light loss of higher energy showers or showers close to the zenith is unevenly suppressed along the shower due to aerosol scattering. This requires a differential measurement of the scattering. Such a measurement can be performed with LIDAR. A frequency doubled diode pumped laser emits short pulses (10 - 30 nsec) of 532 nm photons in the direction of observation. The light beam should have small divergence of ≤ 1 mrad. Photons are scattered back from aerosol, fog droplets or high altitude crystals. The backscattered photons are collected by a large mirror ($\sim \oslash$ 50 cm) and focused on a small Hamamatsu hybrid PM with GaAsP cathode (40% QE at 532 nm) and single electron response. The arrival time of the photons will be measured with about 10-50 nsec precision using a simple scaler based on a 1-bit FIFO (Multihit TDC). A 200 μsec depth is sufficient to both calibrate on background and to measure the time profile of backscattered photons. For the suppression of the night sky background an interference filter of, say, 5-10 nm bandwidth centered at 532 nm would be sufficient. Using a low power (eye safe) laser pulser of, say, 1-10 μJ and 1-3 kHz rep rate would allow one to study the backscatter up to about 40 km distance. Obviously, the highest precision would be obtained only up to 1-5 km where it is mostly needed. Cloud or haze layers would be detected with high precision. It should be noted that it is not necessary to measure the differential absorption close to the telescope. The integral losses of the last 1-2 km above the telescope can be determined by the values measured at larger distance and the integral absorption.

The LIDAR measurements are relative and considerable work is needed to calculate appropriate correction functions. In principle one can carry out studies between 300 and 700 nm provided adequate laser pulsers and filters, respectively optics (Quartz lenses) can be found. Nevertheless, a LIDAR running only at 532 nm would be already a big help. The design of the LIDAR is pursued by the Crimean group.

Monitoring the NSB: Up to now the NSB is treated in a rather simple manner. Only the so-called tailcut is applied for image analysis but no contribution to the error of the individual pixel content is taken into account. In future analyses the contribution of the NSB has to be treated correctly. The first step is a precise measurement. Information on three quantities is provided directly by the camera pixels

a) mean anode current

b) pedestal distribution

c) counting rate above a certain discriminator threshold.

The three quantities are highly correlated but depend all on the PM gain. The most complex and therefore least informative is the scaler rate because it includes effects from afterpulsing and subtle structures of the pulse shape while the anode current measurement should be the most precise one. The pedestal distribution contains also a contribution from electronics noise and pickup. In first order the pedestal width is proportional to the square root of the anode current. For MAGIC it will be mandatory to record the anode currents for each event. This allows one to attach proper weights to each pixel content, particularly if stars are illuminating some pixels. For redundancy an integral measurement of the NSB in the FOV should be added. This can be done with a large area silicon PIN diode looking towards the same section of the sky. A diaphragm at a distance above the photodiode will limit the FOV to that of the camera. The expected photocurrent in the order of a few pA needs to be amplified and will then be digitized. With some filter (BG 12) a proper spectral matching is possible. A second photodiode without diaphragm might serve as a wide angle NSB monitor for the operator. A similar system is presently in use for the HEGRA AIROBICC detector and proved to be very useful as independent safety device.

Monitoring of the global weather parameters: In order to help the operator and to actuate various safety devices the following weather parameters have to be monitored

a) temperature both at ground and at at least 10 m above ground

a') temperature inside the camera at 2-4 points

b) humidity at 1-2 m above ground at the mirror height, at the camera outside and inside the camera

c) wind speed and direction

d) dewpoint

e) rain/snow sensor.

All these infos have to be recorded a few times per hour and trends should be displayed permanently for the operator. From some parameters the safety actions have to be initiated in case values exceed operational limits

a) windspeed exceeding 15 m/sec (attention, the treatment of gusts is difficult)

b) windspeed exceeding 25 m/sec ($\rightarrow$ telescope in safety position)

c) humidity exceeds 98% ($\rightarrow$ close camera and switch off HT of PMs)

d) temperature near dew point ($\rightarrow$ switch on mirror heating, be aware of radiation cooling, i.e. mirror temperature below air temperature in case of no, low windspeed)

e) camera overheating

f) background lights exceed safe values.

Also METEOSAT cloud/weather picture around La Palma should be displayed permanently.