OPTICAL FILTERS FOR THE AUGER FLUORESCENCE DETECTOR

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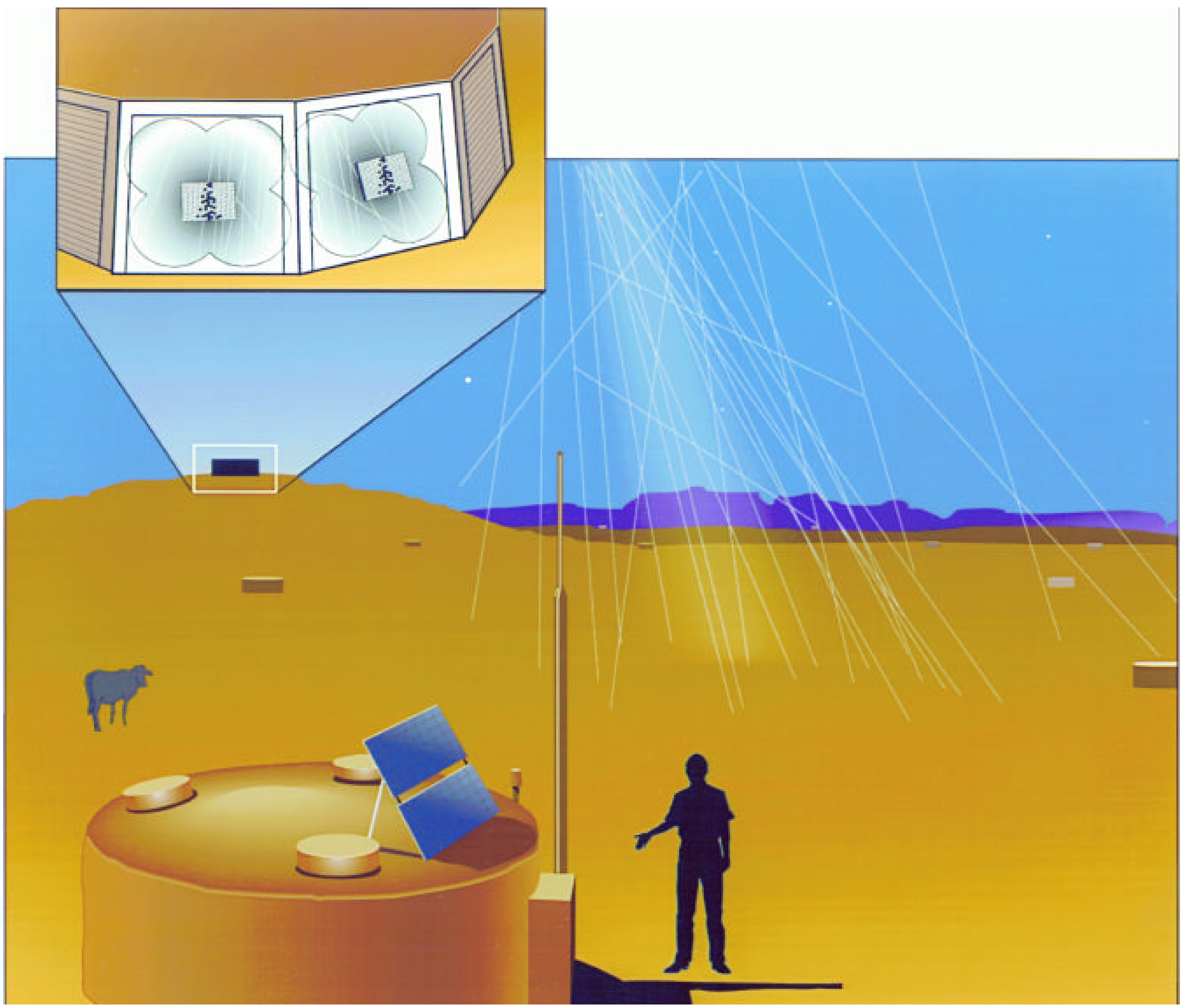
OUTLINE

- The detector array of AUGER
- The use of the optical filters
- Filter performance evaluation
- Background radiation studies
- Conclusions

THE DETECTOR ARRAY OF AUGER

- In the AUGER Project the hybrid detection is used: 1600 ground detectors (water cherenkov tanks) and three Fluorescence detectors (eyes), will record the cosmic ray air showers. An artist view of this technique is seen below.



The Fluorescence Detector (FD)

- For the Extensive Air Shower (EAS) reconstruction, the hybrid detector technique is used in the AUGER Project. The Fluorecsence Detector (FD) is the type of the detector which can record air fluorescence (mainly of nitrogen fluorescence radiation) of a shower event.
- The FD consists from 12 telescopes which have an angular range from 2 to 30 deg in elevation and 0 to 30 deg. In azimuthal angle.
- The telescopes use spherical mirrors and a pixel array of about 20x20 PMT's in their focal plane.
- A "corrector plate" is used in order to correct the optical defects of the mirror. The technique is known as Schmidt camera optics.

THE USE OF THE OPTICAL FILTERS

The motivation for the use of the optical filters comes from the necessity to remove most of the night-sky background radiation (NSBR) and retain at the same time the signal from the air fluorescence caused by an EAS. This requirement gives the specifications of the optical filters to be used, which briefly are the following:

•Transmittance higher than ~75 % is required in the UV signal region (300-400 nm) in order to select the UV radiation of the nitrogen fluorescence.

•Transmittance of the order of 1 % (or less) is needed in order to reject the NSBR in the visible region (~400-650 nm).

•Two filter types could be used : the absorption and the intrference filters.

•Because the available commercial filters do not meet the above requirements, there has been some multilayer optical filter design and small scale production in order to improve the performance. The results of this investigation and the comparison with other absorption or hybrid filters are described below, and this is the main topic of this presentation.

The performance parameters of the PMT/filter

- The **“Detection Efficiency (E_s)”** is the ratio of the integral acceptances with and without the filter, in detecting the signal from the nitrogen fluorescence radiation (E_s=S’/S).
- The **“Detection Efficiency (E_b)”** is the ratio of the integral acceptance, with and without the filter, in detecting the background signal from the night-sky radiation (E_b=B’/B).
- The **“Influence Factor f(?)”** on the E_s due to the incidence angle on the filter dependence.
- The above parameters can be determined using a simulation software which we developed in the MATLAB framework.
- The above parameters can be also measured experimentally.

The role of the filter

- Using the filters, an improvement of the signal-to-noise ratio (S/N) by a factor **R**, which is called **"Improvement Factor"**, is expected.
- The factor R, depends on the signal-to-background ratio, S/B according to the formula given below :

$$R = \frac{E_s}{\sqrt{\dfrac{(S/2B)E_s + E_b}{(S/2B) + 1}}}$$

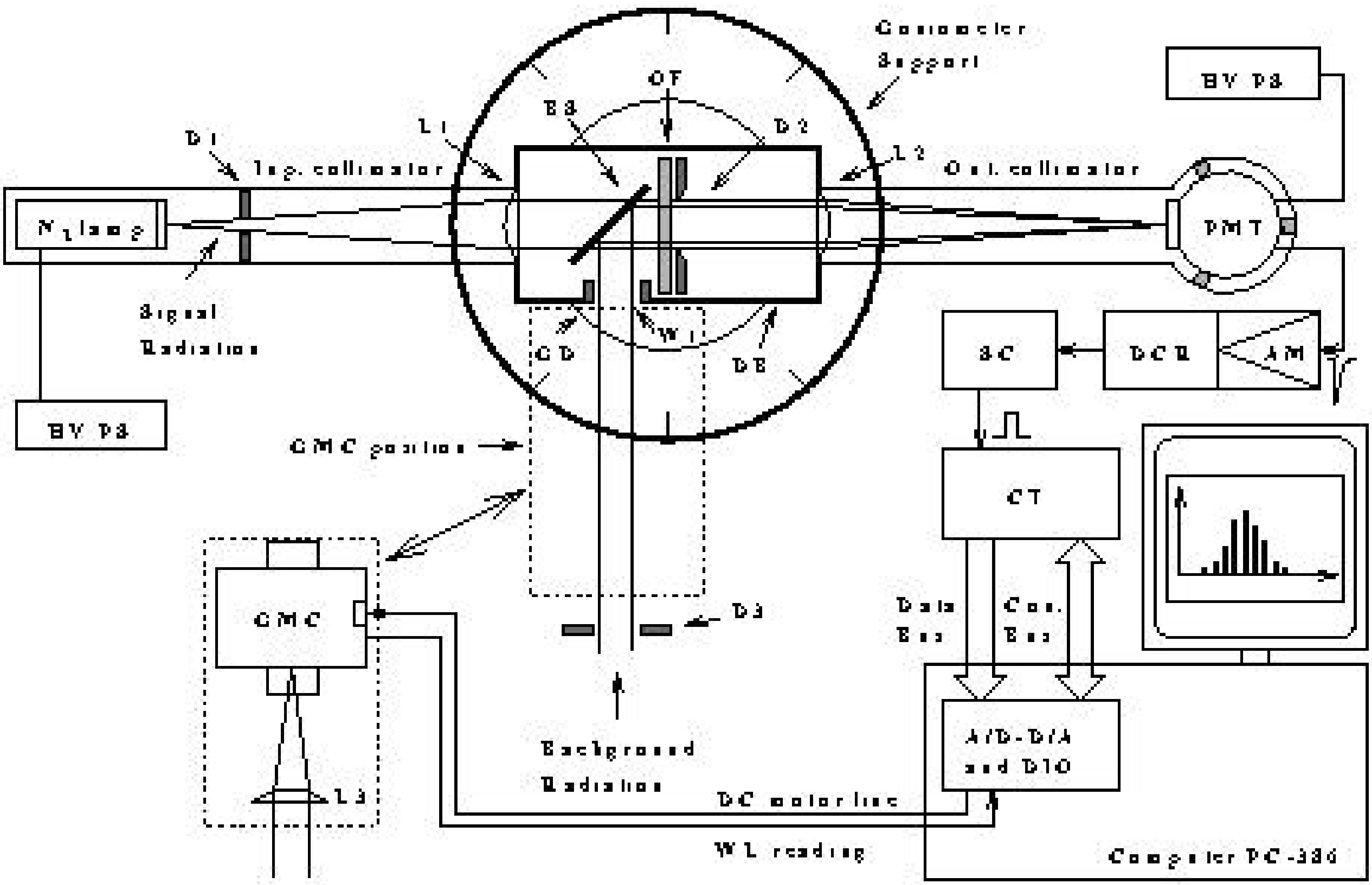
- In the limits where the ratio S/B tends to 0, the factor R takes its maximum value R_b :

$$R_b = \frac{E_s}{\sqrt{E_b}}$$

FILTER PERFORMANCE EVALUATION

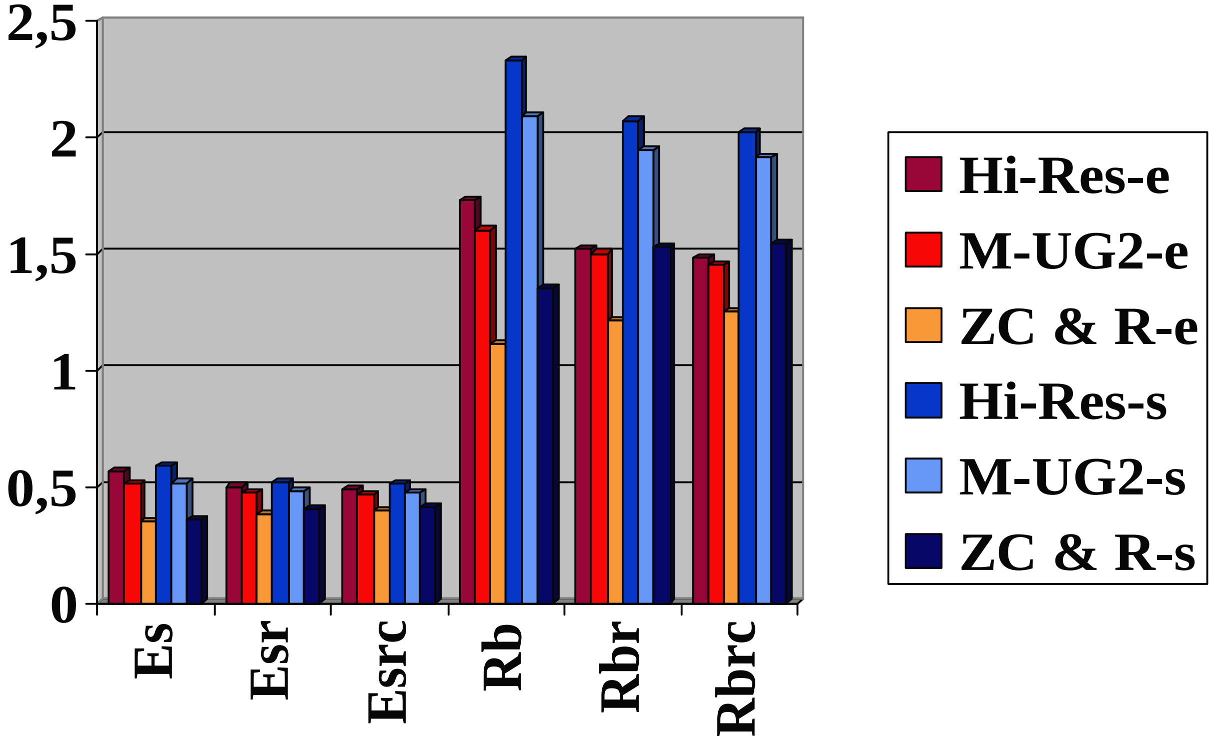
- A specific experimental setup we has been developed in order to study the filter performance under variable background conditions.
- This is based on a fast **“Photon Counting”** system which also can operate in a wide dynamic range of photon flux (from 15cps to 5 Mcps).
- Further studies of the **“Trigger Efficiency”** of the pixel detector, have been made using the same simulation software.

Experimental setup

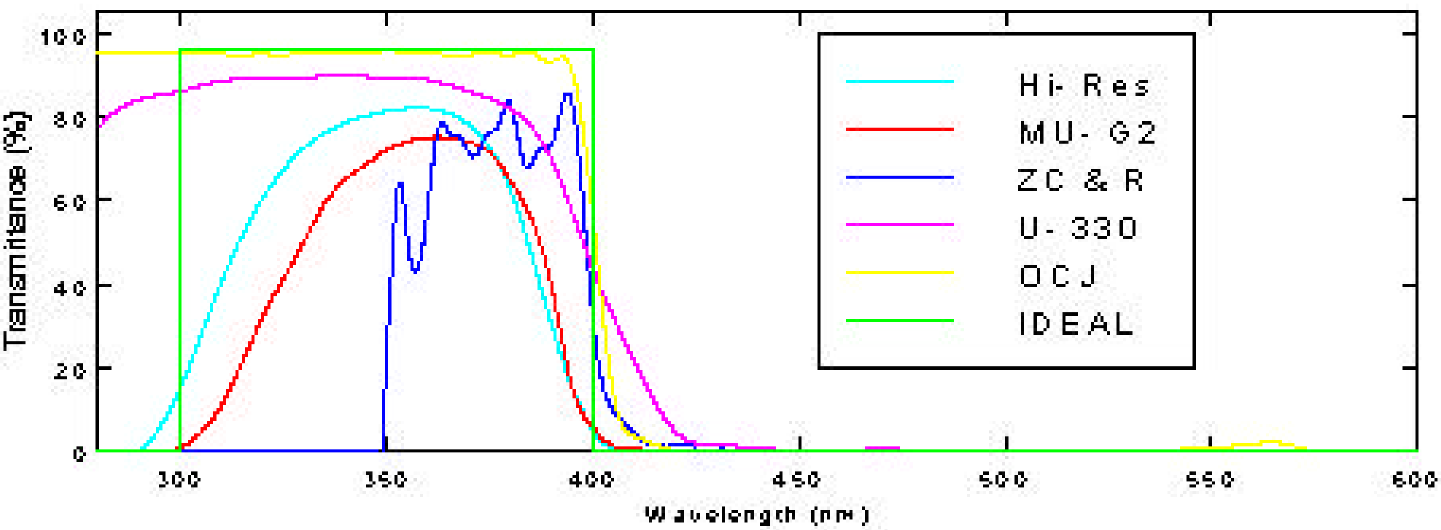


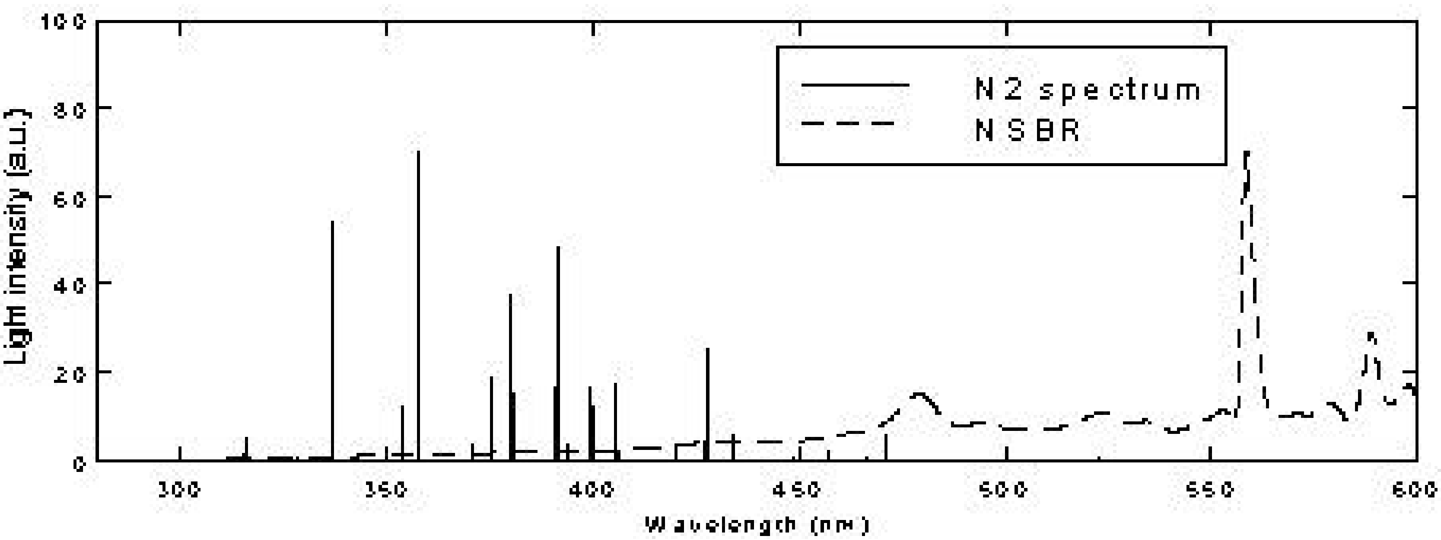
The obtained results

- Several optical filter candidates are examined in this graph using experimental and simulation results (the index “e” means experimental and “e” means simulation. The Hi-Res is an absorption filter with 1 mm thickness of “Hi-Res” type and not necessarily a sample of the Hi-Res experiment filter. We observe an excellent agreement between experimental and simulation results.

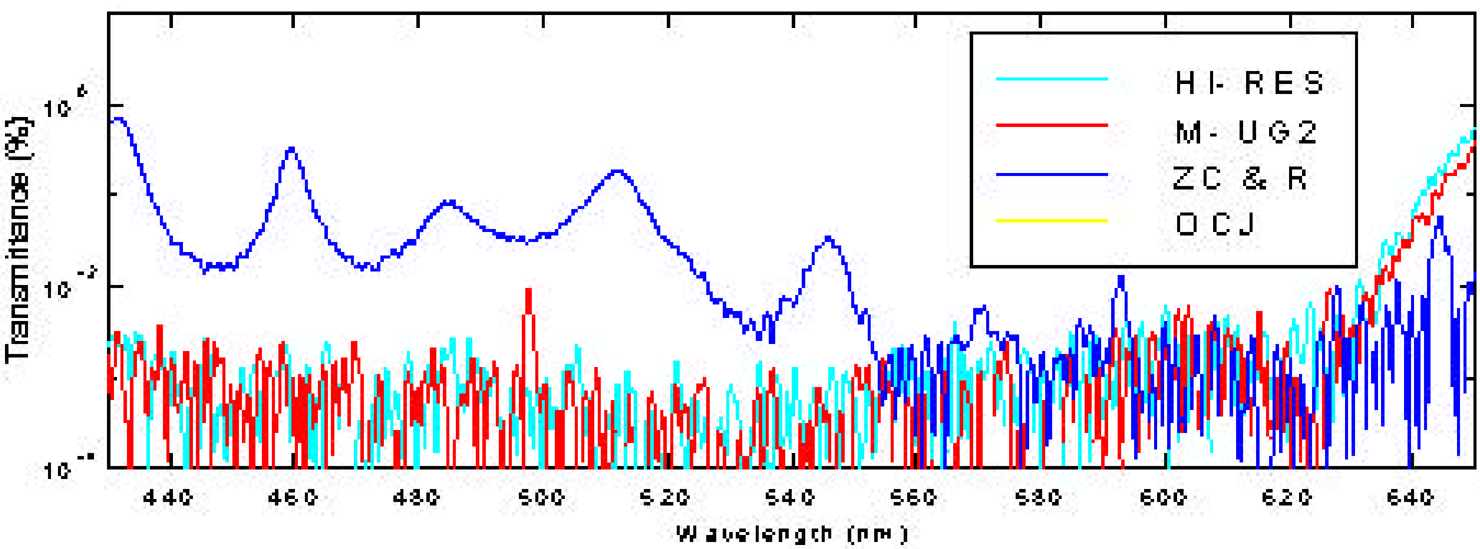


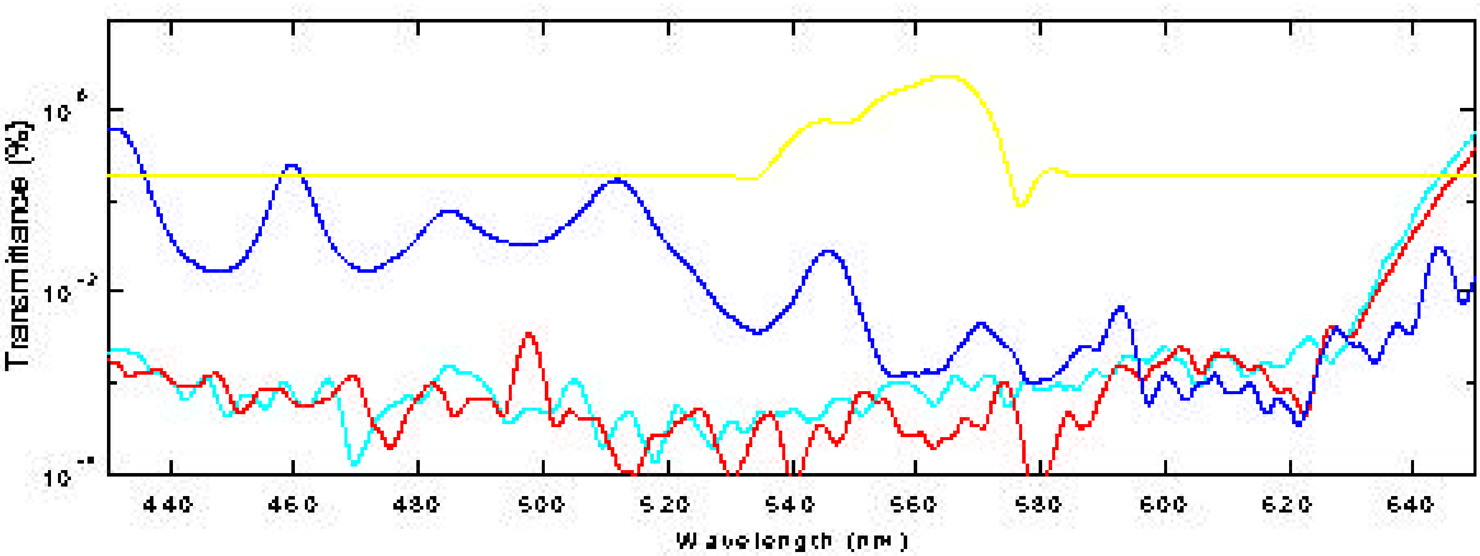
Transmittance measurements in the band-pass region



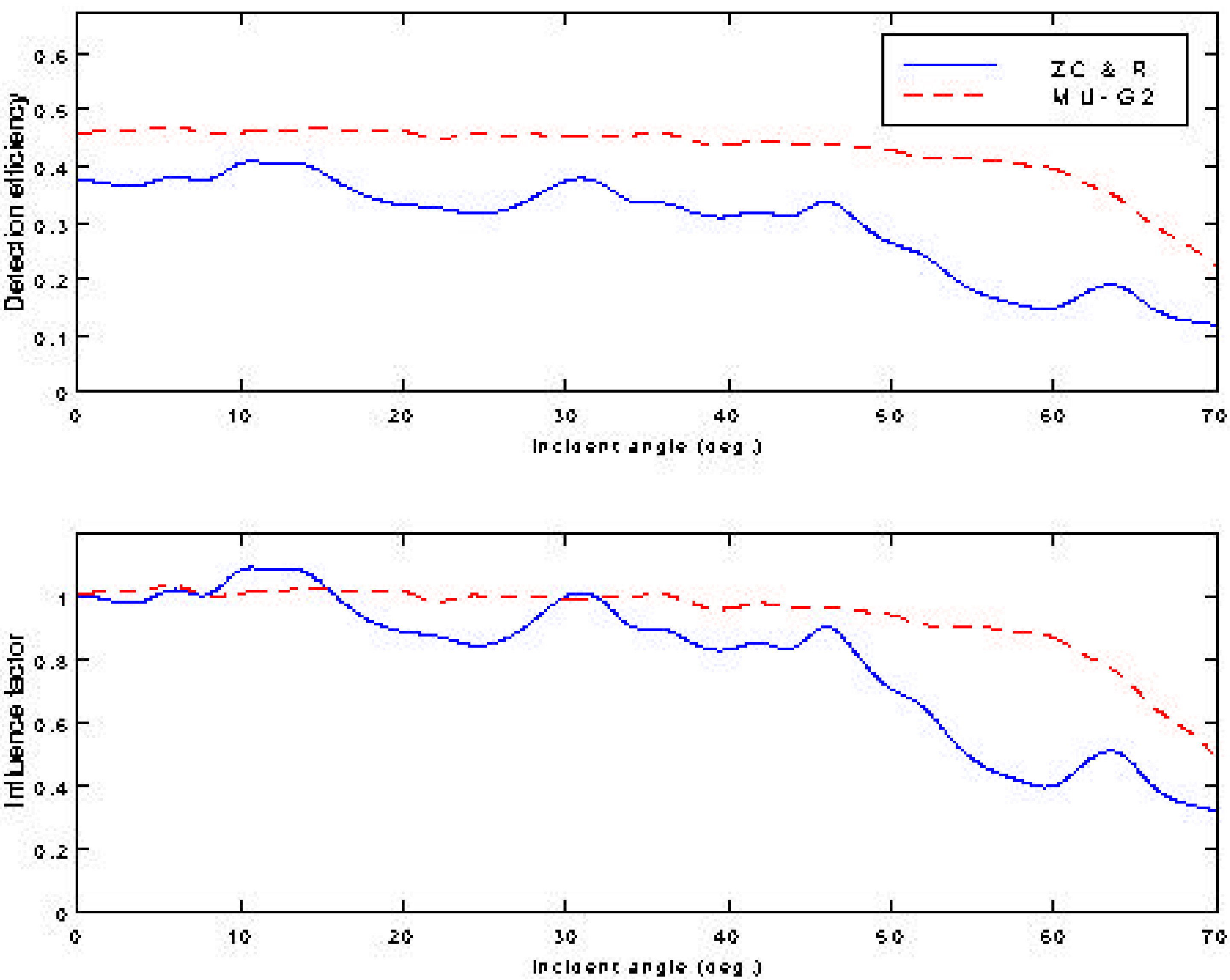


Transmittance measurements in the band-stop region





Measurements of the influence of the incidence angle



Trigger efficiency of the FD

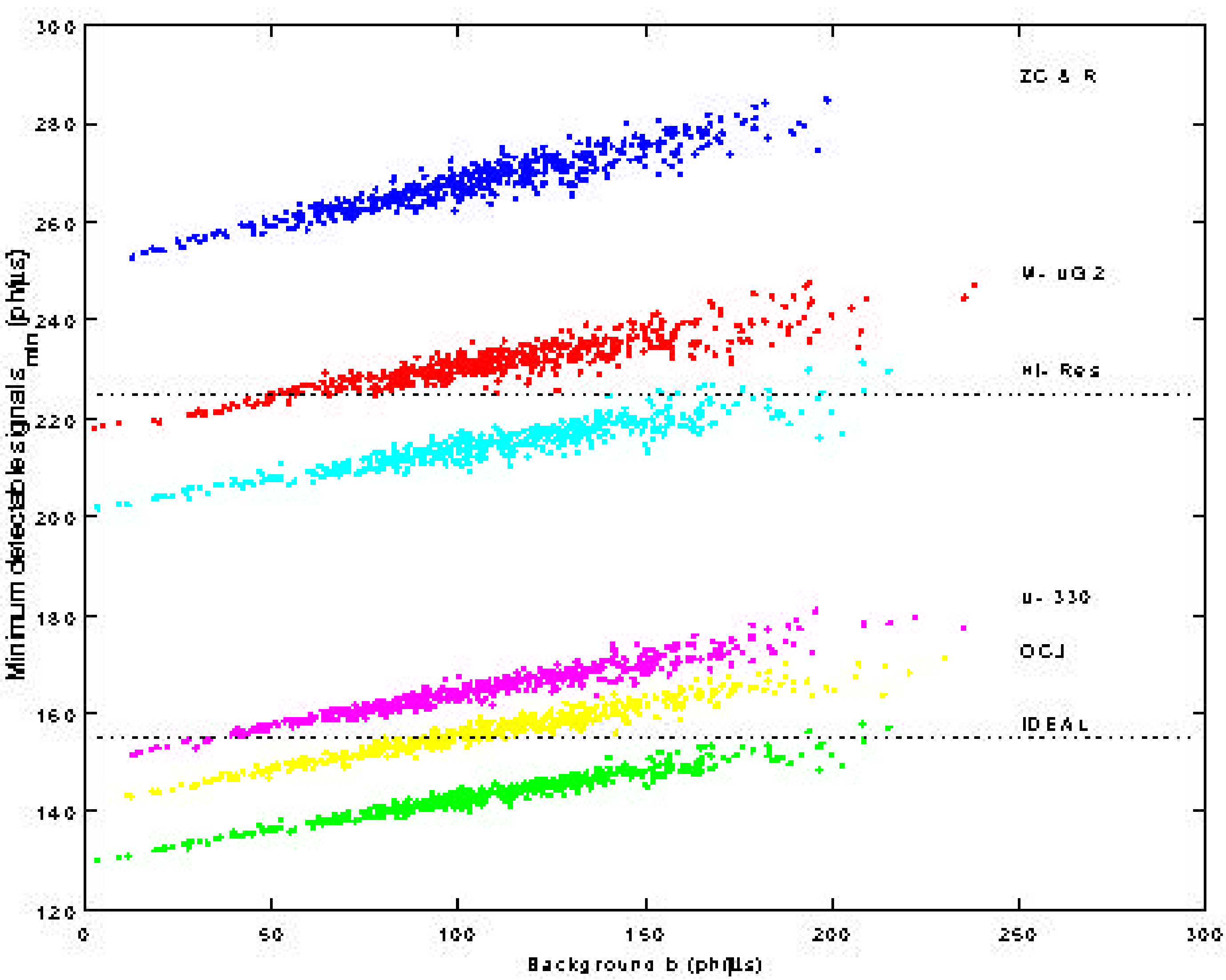
- Even though the description of the filter performance in terms of the parameter R is a useful one, we consider another quantity which describes more explicitly the filter performance in the presence of variable night-sky noise. This is called **“Minimum detectable Signal (s_{min})”.**

- The $\mathbf{s_{min}}$ is the signal which can cause a trigger for a valid cosmic ray event (S/N>n). This condition leads to the expression given below :

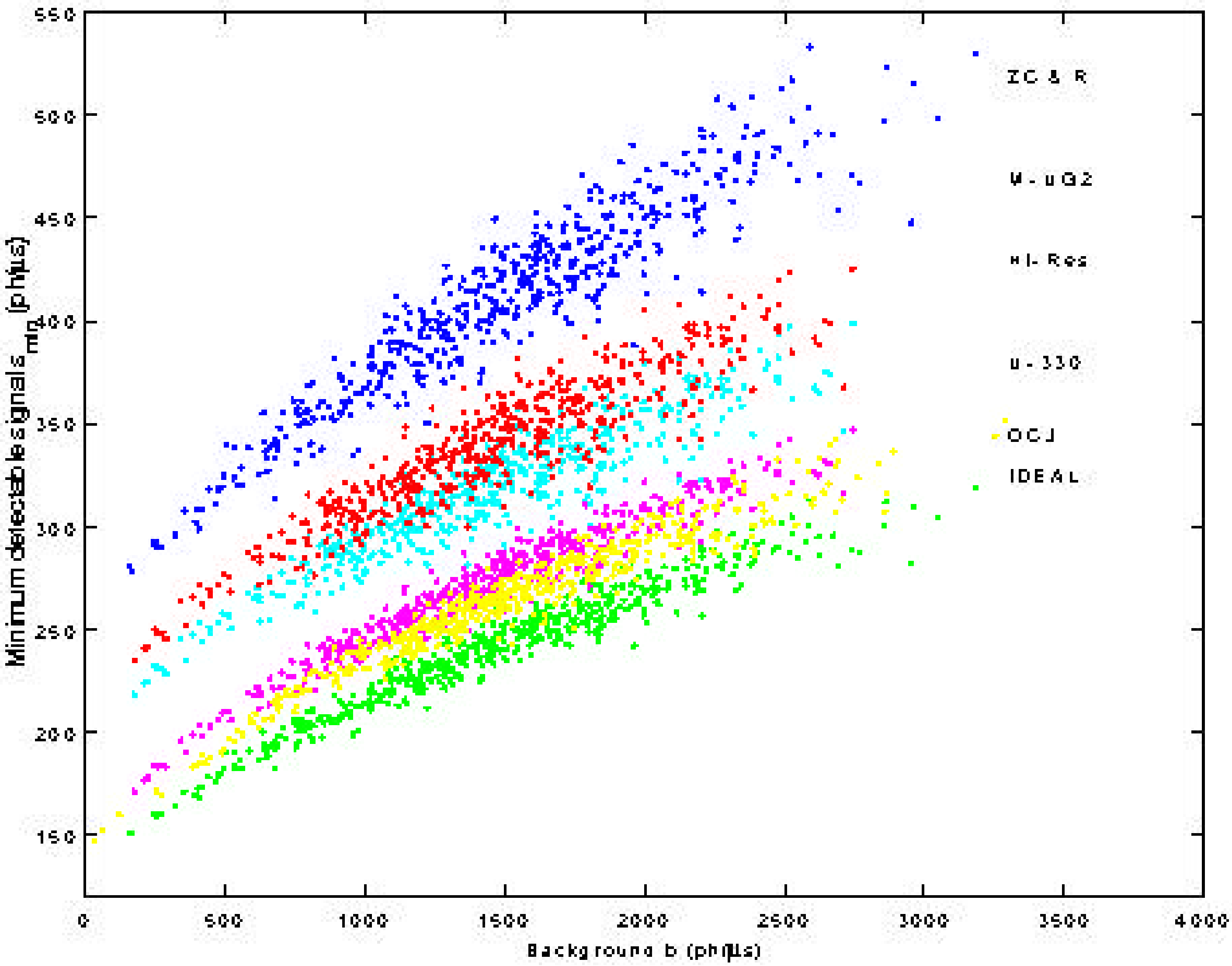
$$s_{\mathrm{min}} = \frac{n^2}{2S_nE_s}\left(1+\sqrt{1+\frac{8bB_nE_b}{n^2}}\right)$$

- We assumed statistical variations of the background intensity level ($s_b/b=0.7$) and the background integral acceptance (due to structure change), expressed with the quantity $s_{Eb}/E_{b\sim}=0.2$. The probability to cause a trigger to the FD, using various filters,.

Trigger capability under moonless night-sky (for S/N=n=5)

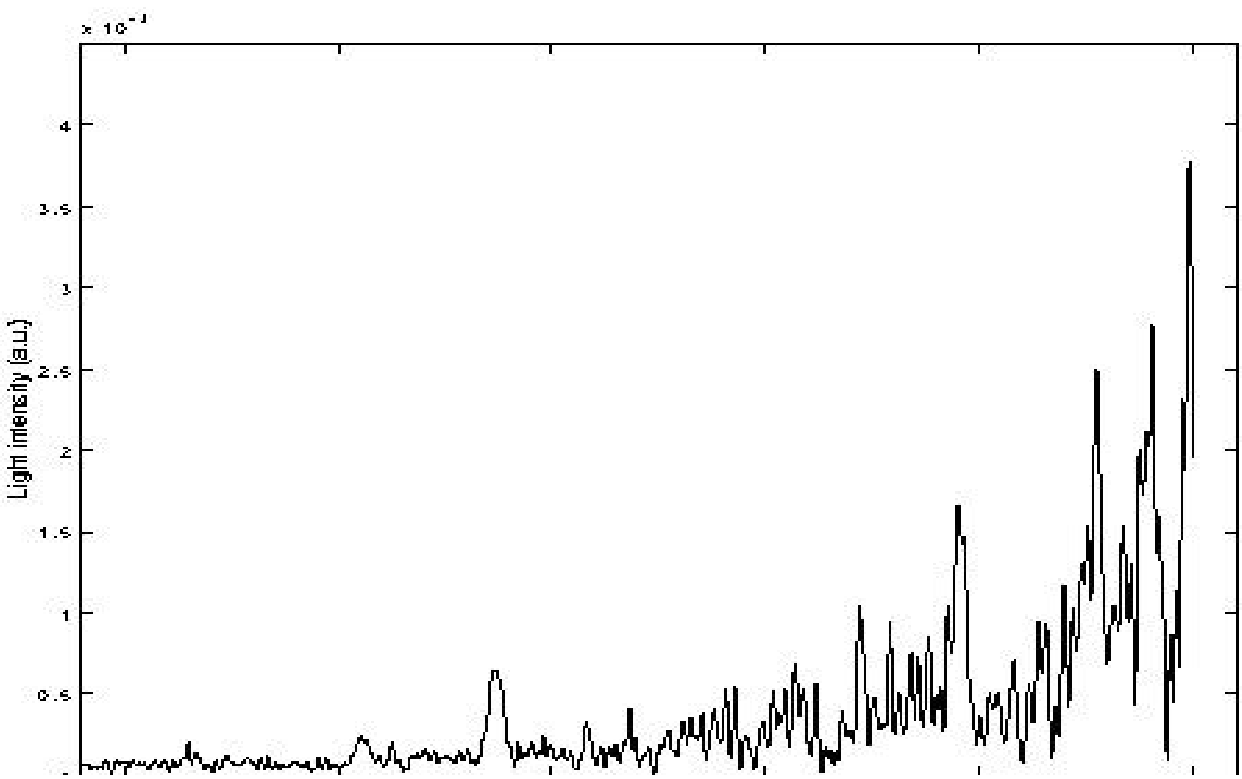


Trigger capability under full moon (for n=5)



BACKGROUND RADIATION STUDIES

- Differential and integral spectroscopic measurements of the background radiation, have been performed in Athens, in our Laboratory, and outside (in Eretria of Evia).
- The spectral lines from the artificial lights cause a variation of the improvement factor R due to the modified structure of the spectrum.



CONCLUSIONS

- **A specific experimental setup has been developed to measure the performance parameters of the pixel detector using a particular filter.**
- **Transmittance measurements have been performed in UoA and NTUA for the available optical filters in various incidence angles.**
- **Studies of the night-sky background radiation spectra have been made concerning their structure and its variation.**
- **Very encouraging results of a simulated interference filter (from OCJ), have been found. Thus, a proposal to use this filter in the FD prototype is under study.**