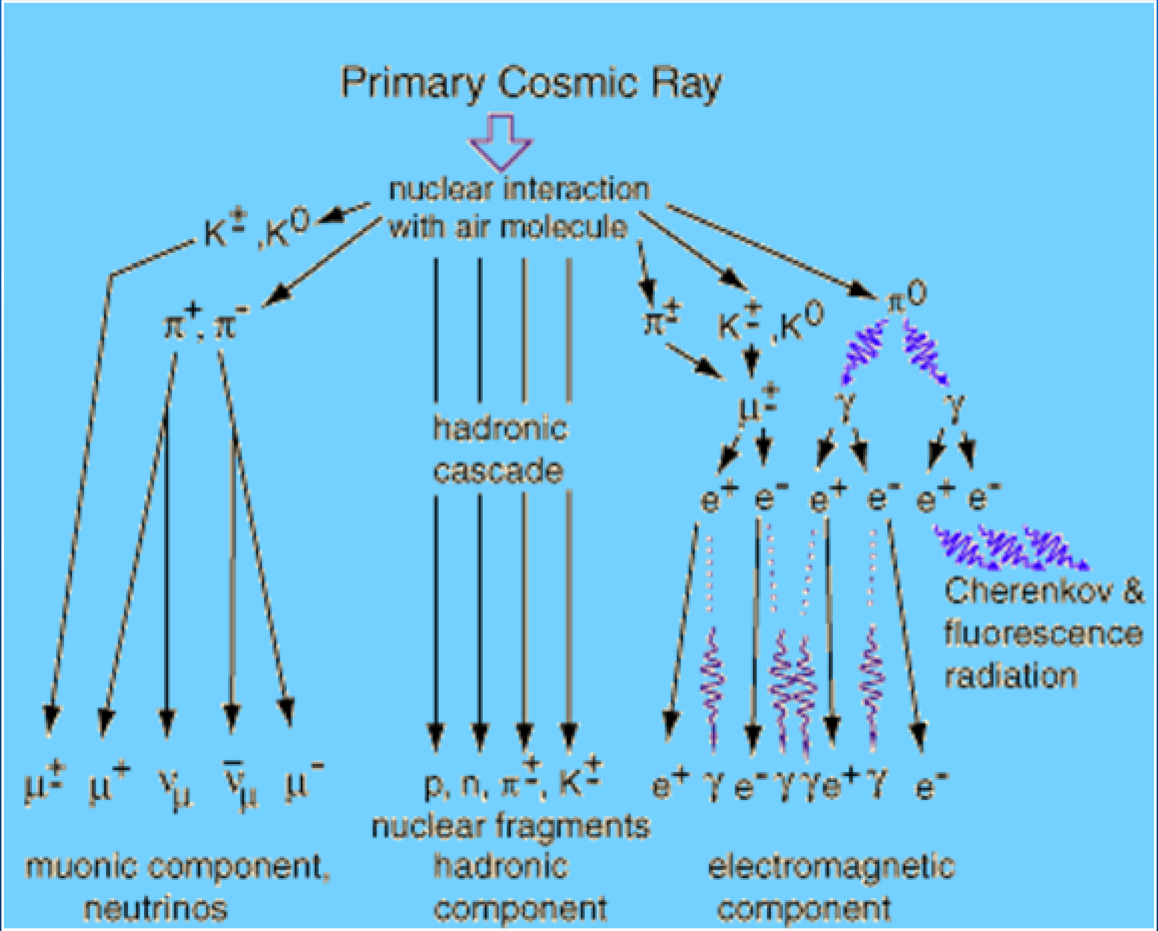
Study of possibility for estimation of atmospheric transparency using cherenkov light telescope

An experiment funded by ALOMAR eARI under the EU Commission's 6th Frame Program

The ground based investigations of cosmic rays use the Air Shower Phenomenon.

Extensive air showers (EAS)



The cascades of secondary particles and nuclei produced by the collision of primary high-energy particles with air molecules.

Primary :

-proton

-nucleus

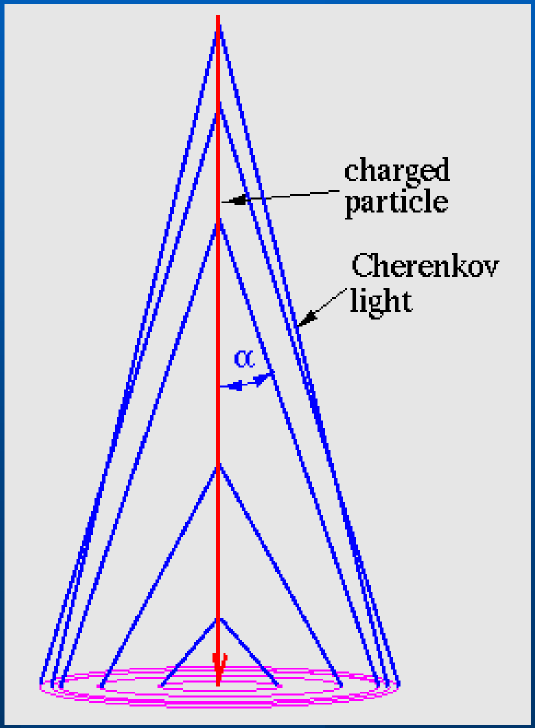
-neutrino

-gamma

Secondary :

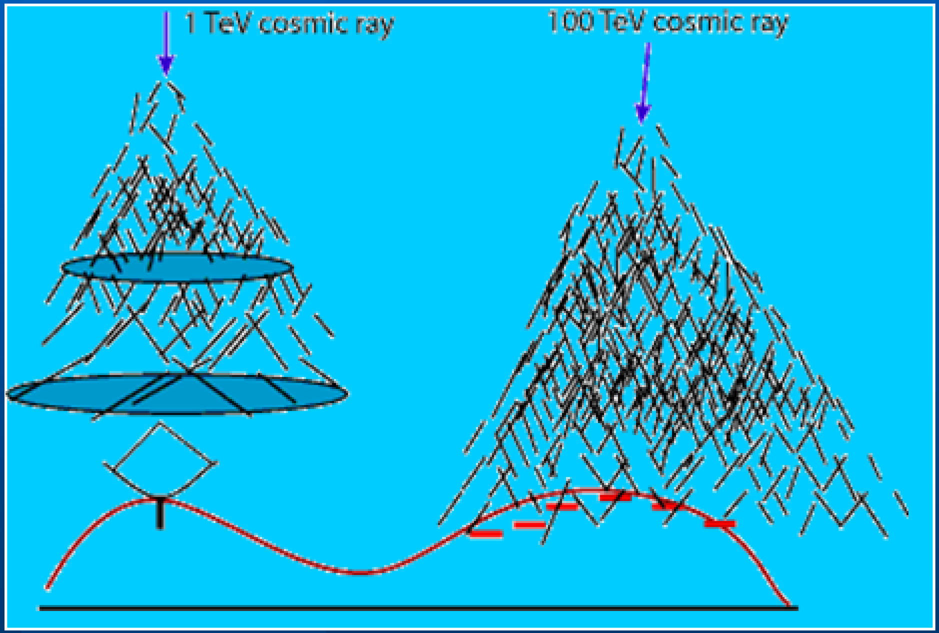
- electromagnetic comp.
- muons
- hadrons
- **Cherenkov light**
- fluorescent light

Cherenkov light emission



- Shower electrons emit Cherenkov light in a narrow cone around the direction of the particle
- Cherenkov angle varies with height since the cherenkov threshold velocity depend on the refractive index *n* of the atmosphere.
- At see level *n*~1.00026, (the maximum Cherenkov angle is ~1.4deg)

Atmospheric Cherenkov technique



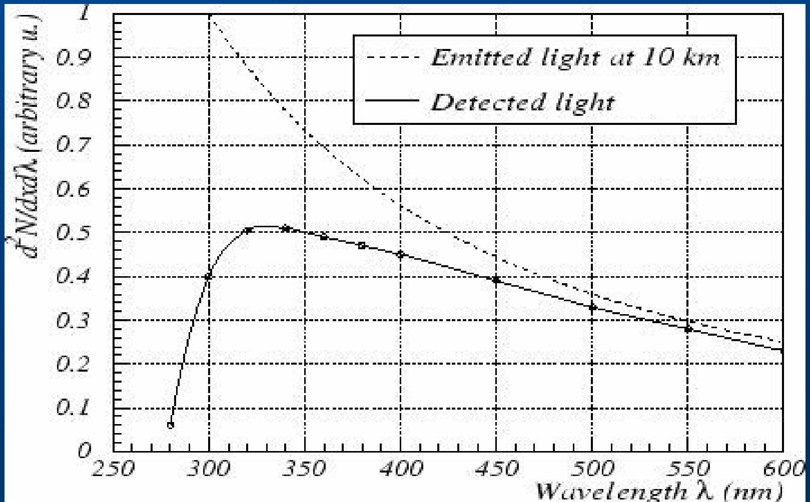
- Atmosphere is target medium for the very high energy cosmic particles and transport medium for the cherenkov photons
- Detectors are sensitive of index of refraction at each altitude

Attenuation of the Cherenkov Light in the Atmosphere

The atmospheric attenuation in the 250nm to 700 nm range depends on molecular absorption, Rayleigh scattering and Mie scattering by aerosols.

And as a function of altitude and wavelength, it determines the probability of the cherenkov photons reaching the atmospheric cherenkov telescope.

Monitoring the properties of the atmosphere is essential for the interpretation of the cherenkov signal in term of the energy spectrum of the cosmic rays and flux variation.



Differential Cherenkov photon spectrum. Continuous line includes absorption by ozone and Rayleigh and Mie scattering. The spectrum has a peak at around 350 nm.

Cherenkov light telescope at ALOMAR Observatory, Norway

Geographical coordinates - 69°16′42 ″ N, 16°00′31″ E, elevation 380m a.s.l.

Atmospheric Cherenkov Light Telescope at ALOMAR observatory consists of :

- Two 1-meter diameter parabolic reflectors.
- Two photomultipliers, type FEU-110 (63mm diameter of the cathode), connected to a coincidence circuit, detect the light spot.
- The pulses are registered by a 2-channel 8 bit logarithmic ADC
- “Master” condition - coincidence of the anode pulses over a certain threshold for the two photomultipliers.

RMR LIDAR at ALOMAR

Rayleigh/Mie/Raman LIDAR measures cloud heights and vertical visibilities by sending out light pulses.

Two powerful Nd-YAG pulsed lasers, each feeding to independent transmitting telescope systems.

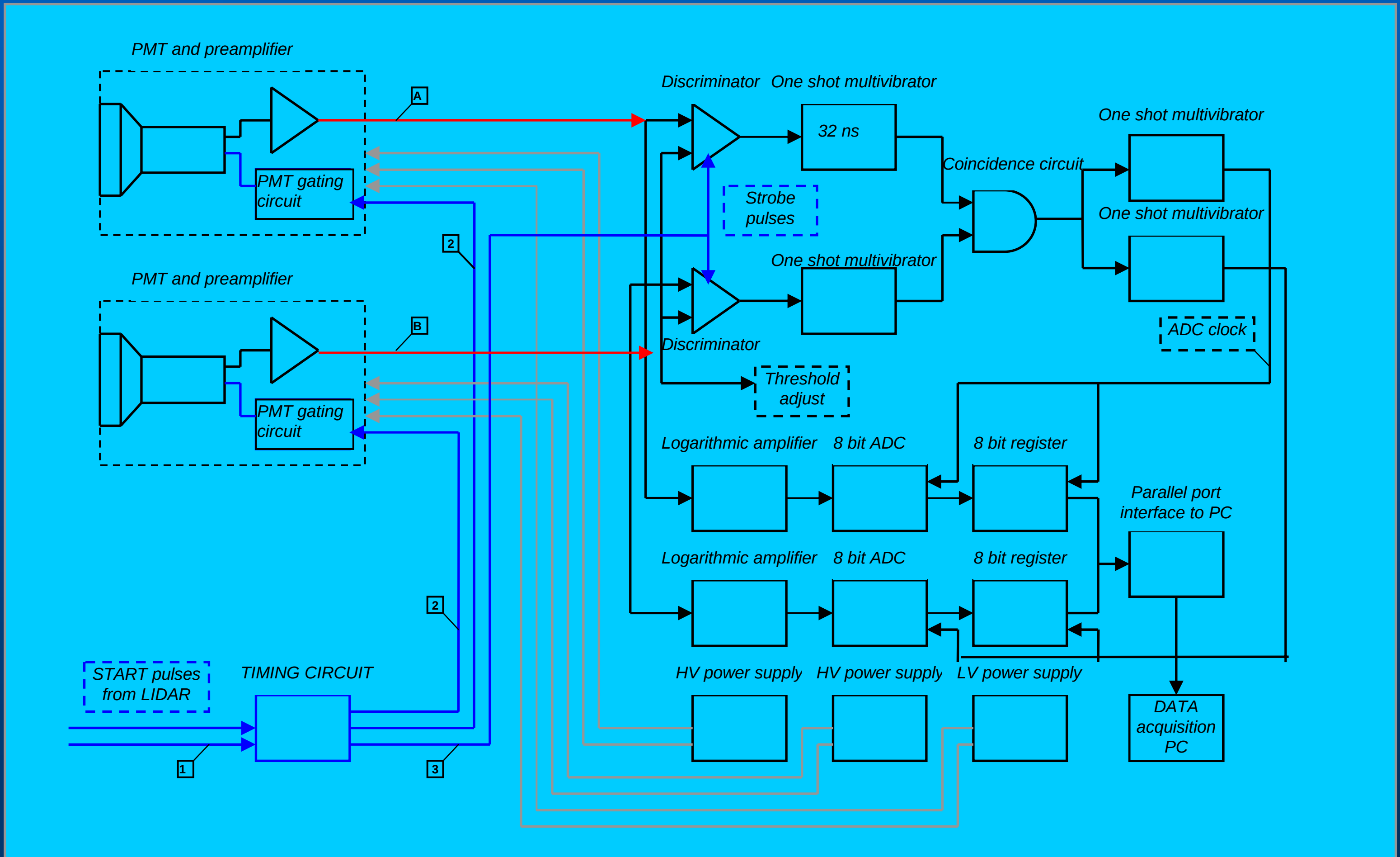
The light back-scattered from the atmosphere is collected by co-axial 1.8 m diameter steerable receiving telescoped.

The RMR LIDAR lasers transmit light at the 1064nm (fundamental) **532 nm** (frequency-doubled) and 355 nm (frequency-tripled) wavelengths.

For more details see www. alomar.rocketrange.no

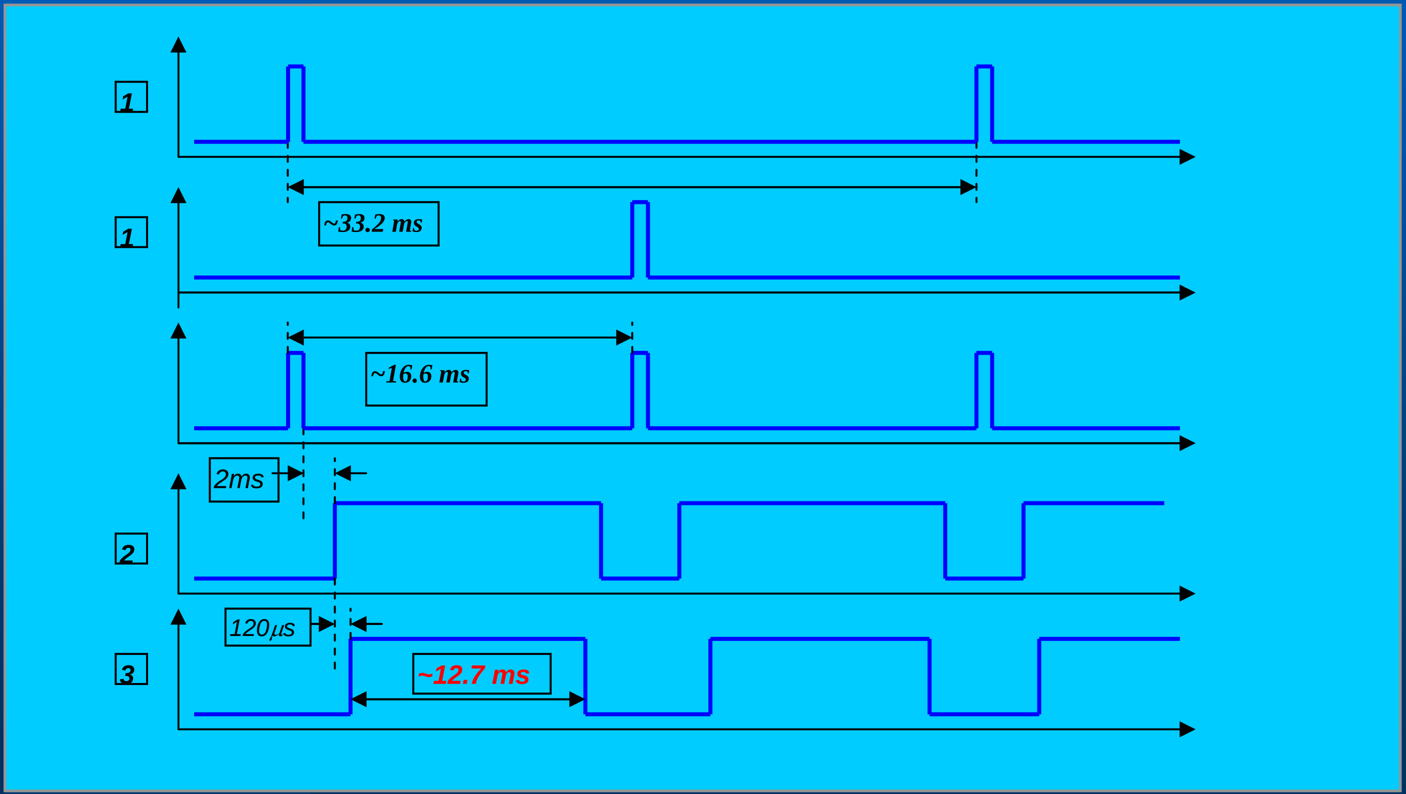
Adjustment the ACT to LIDAR facilities at ALOMAR Observatory

Schematic diagram of the registration part and gating circuit



Adjustment the ACT to LIDAR facilities at ALOMAR Observatory

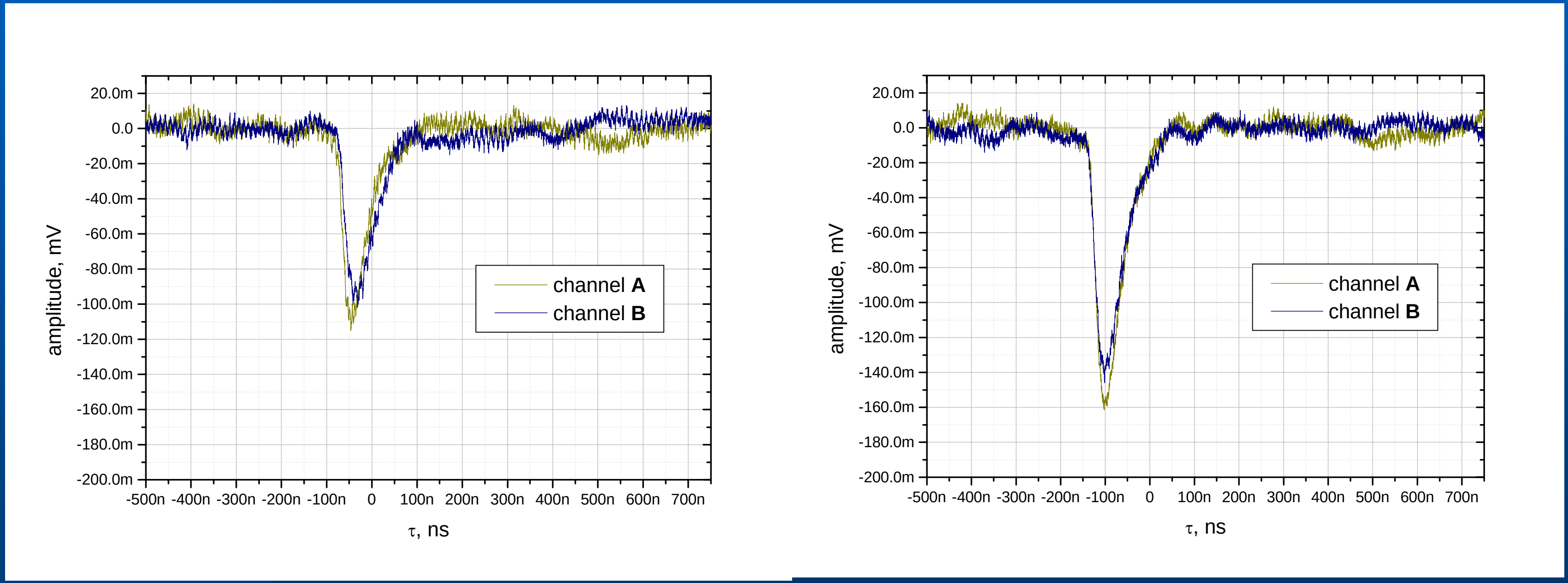
Timing diagram of the gating pulses



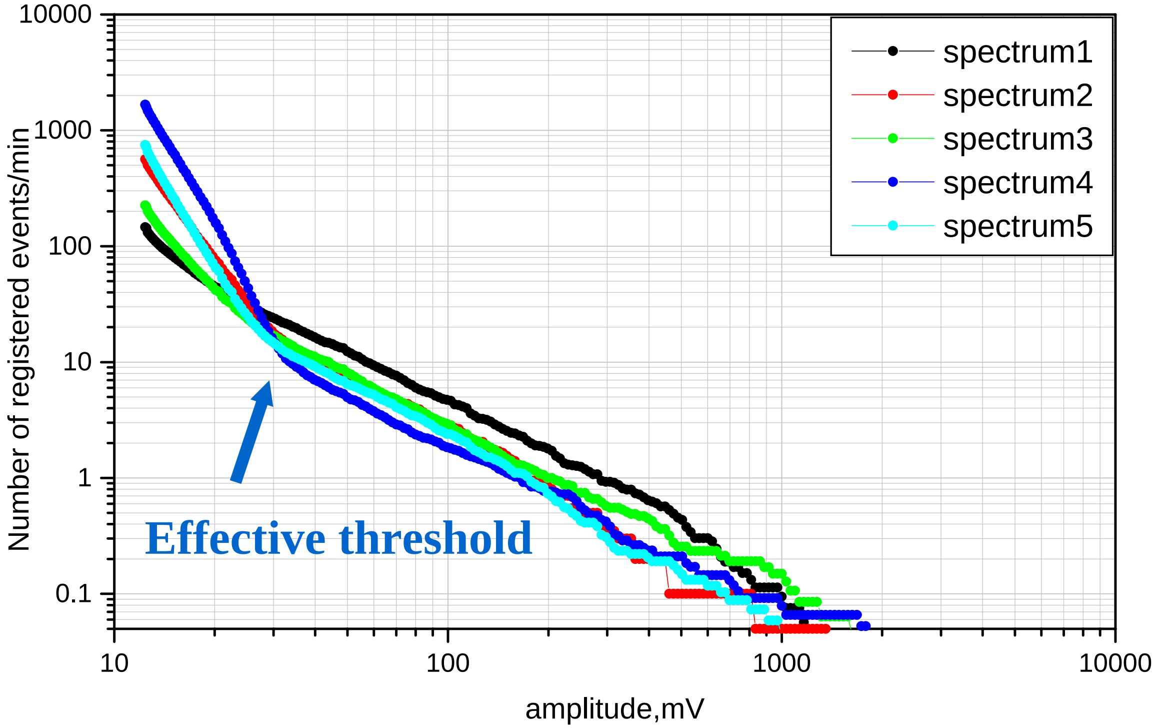
The effective time of observation is *12.7 /* T_{LIDAR} *=76.5 %*

Experimental results

Typical registered pulses

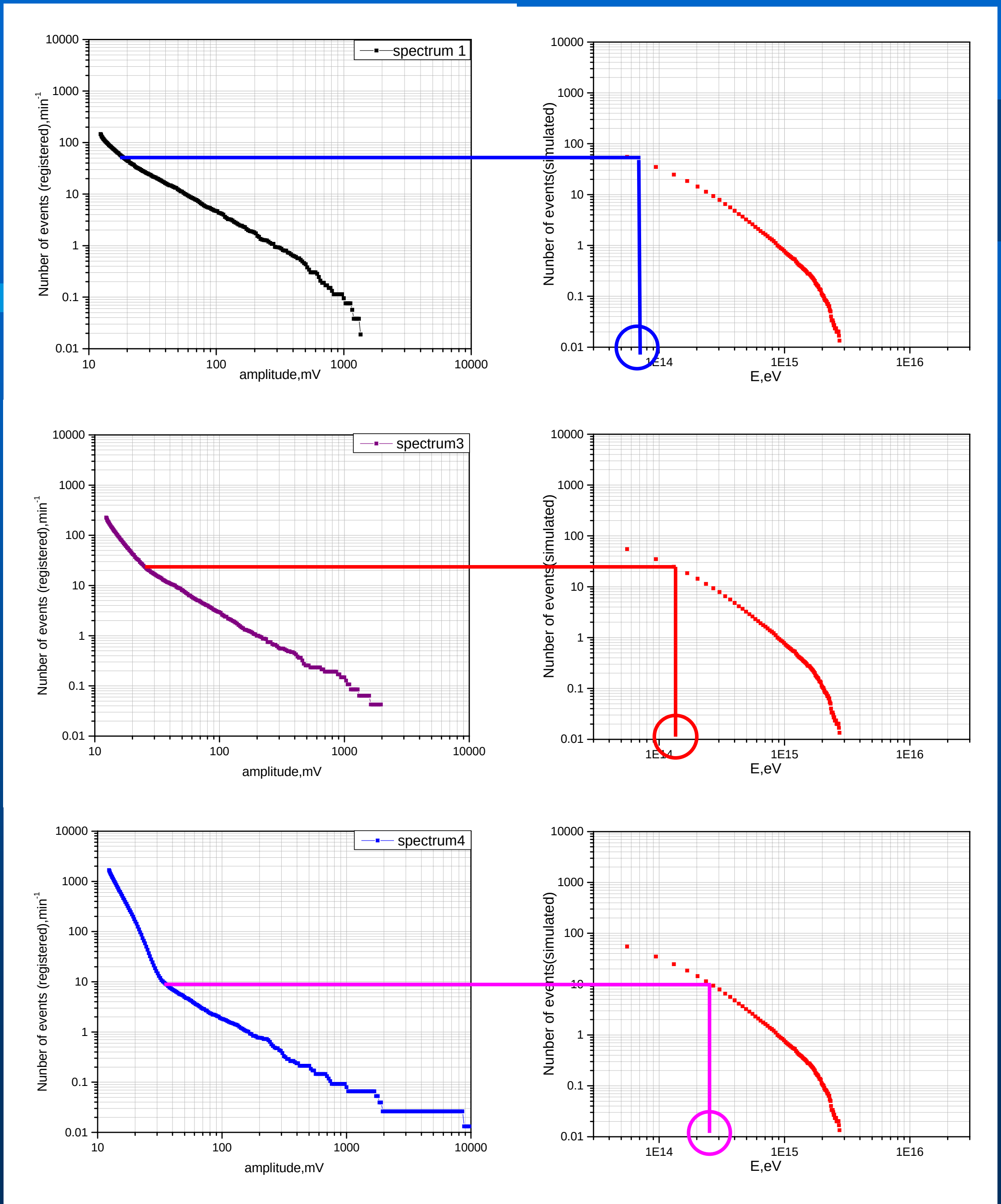


Experimental results



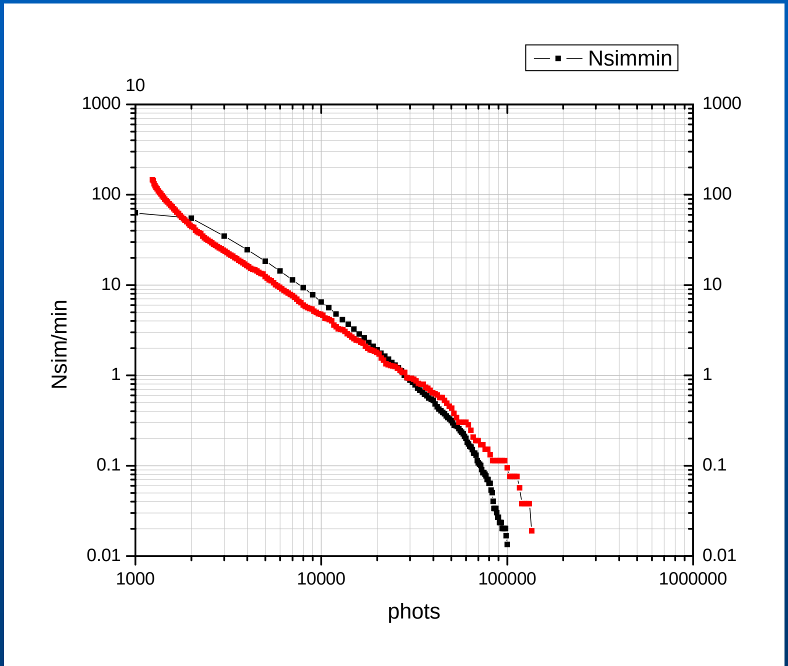
The *spectrum1* (black line) was obtained with simultaneous operation of RMR LIDAR, i.e. in very good atmospheric conditions. The next were obtained during changeable atmospheric conditions above the telescope.

As the atmospheric conditions are getting worse the noise level increases because of scattering of Cherenkov photons and the intensity of Cherenkov light decreases due to absorption



Shifting of the energy threshold of the detector

Monte Carlo simulation were caried out in order to estimate the energy threshold of our cherenkov light telescope



The simulation shows that the energy threshold of the detector is about 5.10^{13} eV

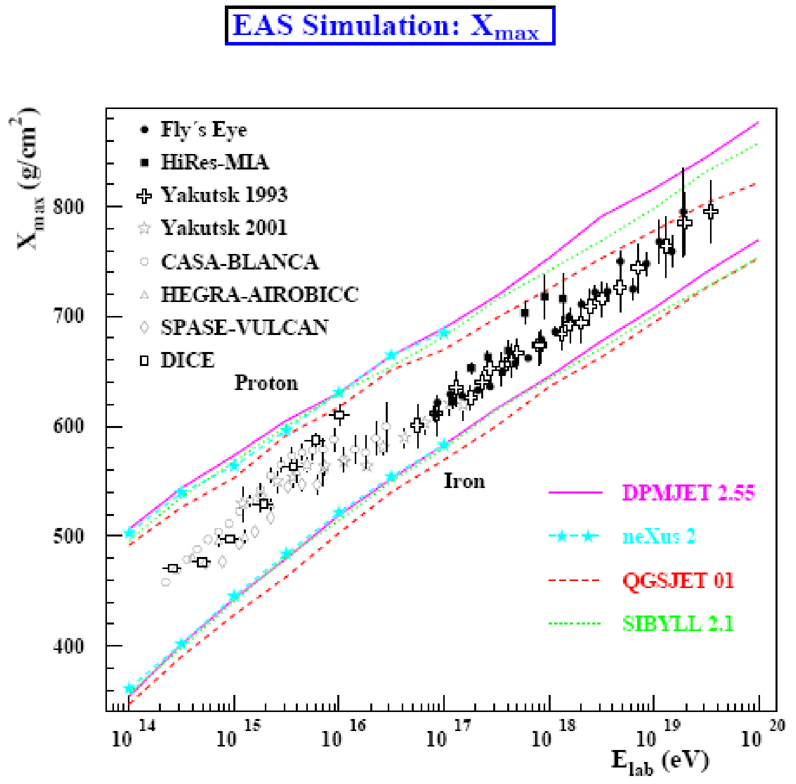
Observed data and the simulation show good agreement

Discussions

The cherenkov light emitted in atmosphere by ultrarelativistic electrons in extensive air shower of cosmic rays carries the important information on the primary energy of the initiated primary particle and the shower development in atmosphere.

Using cherenkov light measurements at ALOMAR Observatory we have the posibility to estimate the primary energy and the position of shower maximum in atmosphere Xmax in quite model independent manner.

The mean depth of shower maximum Xmax as a function of energy



Depth of shower maximum as function of energy and primary particle.

(Vertical incidence, $\varepsilon_{thin} = 10^{-5}$, $E_e > 0.1$ MeV.)

The mean depth of shower maximum Xmax as a function of energy from different experimental data and EAS simulations

Conclusions

- In the present testing experiment has been performed simultaneous operation of the Cherenkov light telescope and the LIDAR system and obtaining data for atmosphere transparency and the cherenkov light amplutide spectrum in different atmospheric conditions.

- It is confirmed that the intensity of the cherenkov light flux above the effective energy threshold of the detectors depends only on the atmospheric conditions, i.e on the transparency of the atmosphere.

Conclusions

- Monitoring the properties of the atmosphere is essential for the interpretation of the cherenkov signal in term of the energy spectrum of the cosmic rays and flux variation.

- The calibration of the dependence of Cherenkov light telscope signal on atmospheric transparency can be done with a LIDAR providing measurements at range ~3-10km

Thank you!