<u>Production of mirror systems for cosmic rays detectors</u>

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Joint Laboratory of Optics of Palacky University and Institute of Physics of the Academy of Science of the Czech Republic have cooperated and still works on several prestigious international projects of atmospheric optical detectors of cosmic rays. We deal with two French projects with international collaboration placed in French Pyrenees in Themis. These projects are CAT and Celeste. Our last project where we cooperate in the meantime is Pierre Auger Observatory in Argentina.

<u>CAT</u>

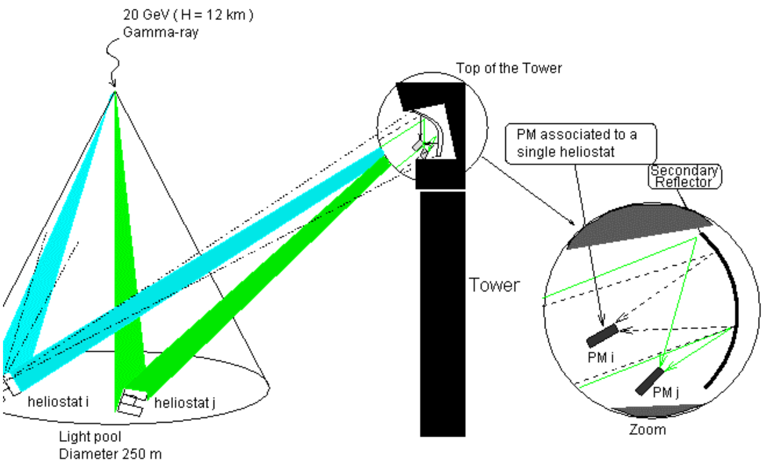
This project was proposed in LPNHE - Ecole Polytechnique and INP2P3. It benefits from experiences form Whipple Observatory at Mount Hopkins in United States. This telescope use imaging technique for observing Cherenkov light from air showers.

Mirror has surface 16 square meters and is composed from 90 segments. One mirror segment has diameter 500 millimeters and radius of curvature 12 meters. Camera in focus is compound from 546 photomultipliers Hamamatsu, one pixel has 13 millimetrs in diameter and resolution is 2,2 mrad. CAT aims on particles with energies 180 – 2000 GeV. We enter the project in 1994 and from 1997 is telescope in full duty.

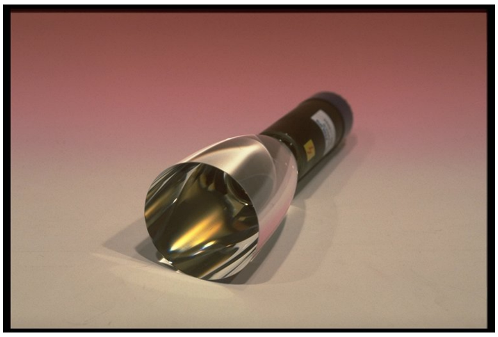
<u>Celeste</u>

Origins of this project comes again from LPNHE in Paris. Inspiration for this project was similar project SOLAR 1 in New Mexico. The basic idea is utilization of former solar energy power station as Cherenkov detector. About 160 heliostats on area approximately 4 hectars served as primary mirror of this huge Cherenkov detector.

But contrary the CAT this project use sampling technique. The face of the wavefront comes thanks to the huge primary mirror in different times at individual heliostats and from these differences in arrival times we are able to reconstruct original wavefront and from its proportions is possible to determine energy and trajectory of initiated cosmic ray particle.



On the top of the solar plant tower is placed secondary mirror. This mirror is composed from three types of mirrors with circumscribed circle 500 millimeters but different radius of curvature (1450, 2240, 3600 millimeters). Besides this secondary mirror system we produce unique ensemble of Winston concentrators. On the backside of this concentrators are glued photomultipliers. This concentrators determine point of view on specific part of primary mirror and this is the only suitable way how decrease high background noise.

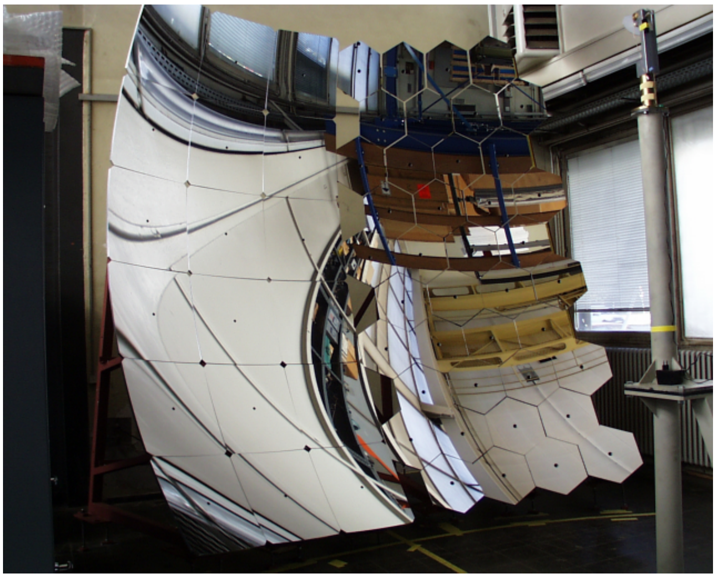


Project Celeste wants to fill gap in energy range and aims on energies between 20 and 300 GeV. Second phase of this project was finished in 1999 and from this year are taken data.

The Pierre Auger Observatory

The basic idea of this project comes from Nobel Prize holder Jim Cronin from University of Chicago and Alan Watson from University of Leeds. This project is dedicated to the study of cosmic rays at the highest energies ever observed. The Pierre Auger observatory is a hybrid detector consisting of a particle detector on the ground and an atmospheric fluorescence detector. We were invited for collaboration on this project on the basis of good results from projects CAT and Celeste. The surface detector system covers an area of 3000 square kilometers with 1600 water Cherenkov detectors of 10 square meters each, distributed on a grid of 1,5 kilometer distance. Four optical detectors are compound from modified Schmidt telescopes with a mirror size of 13 square meters, an aperture of 1,7 meter diameter naturally (2,2 meter diameter with special optical element called correction ring and outgoing from Schmidt correcting plate) and a pixel camera of 440 photomultiplier tubes in the focal plane. Each telescope will have a segmented spherical mirror with radius of curvature of 3,40 meters.

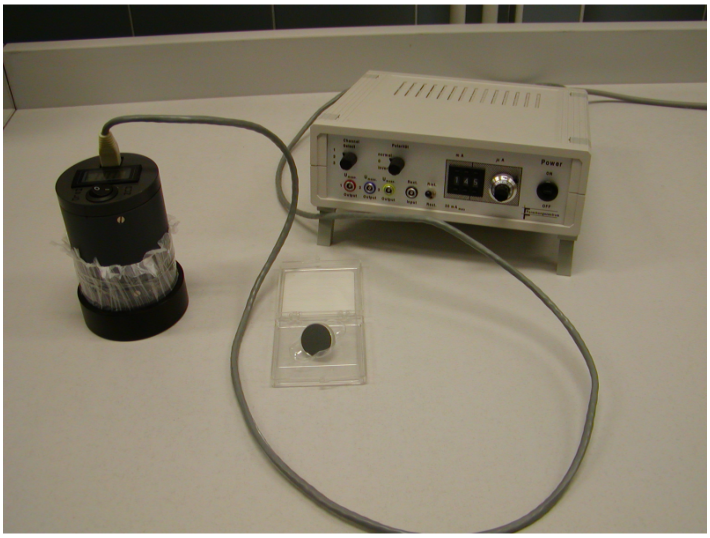
On our optical workshops glass mirrors were made which create one half of the prototype fluorescence detector. The second half of the prototype telescope reflective surface is covered by aluminum mirrors, which was manufactured in the Forschungszentrum in the Karlsruhe, in the Germany. Prototype tests in Argentina were successful and we will make mirrors for the whole project together with our German colleagues from Karlsruhe. 12 detectors will be covered by mirrors manufactured in Joint Laboratory of Optics and the rest of detectors by mirrors manufactured in Germany.



Next aquisition of our laboratories in Auger collaboration is the proposal and computing of the right shape of the correction ring which enlarge the aperture of each fluorescence detector. This project was officially launched in 1999 and is expected to be completed in 2004.

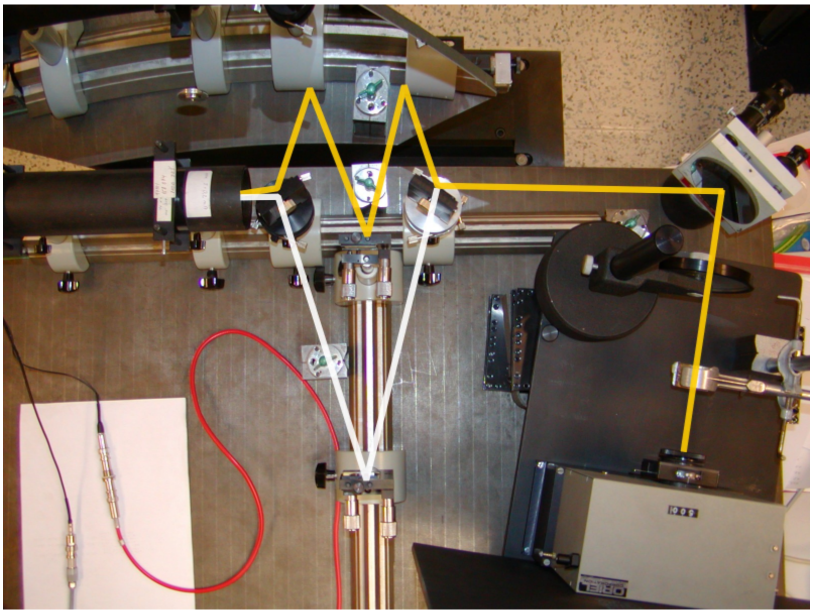
Reflectivity measurement

One from the basic parameters which we have to tested during the production process is reflectivity. We use two principles of measurement at the moment. The first is a classic comparative method. We have a calibrated mirror sample and measure head with UV led source at 375 nanometers and corresponding photodetector.

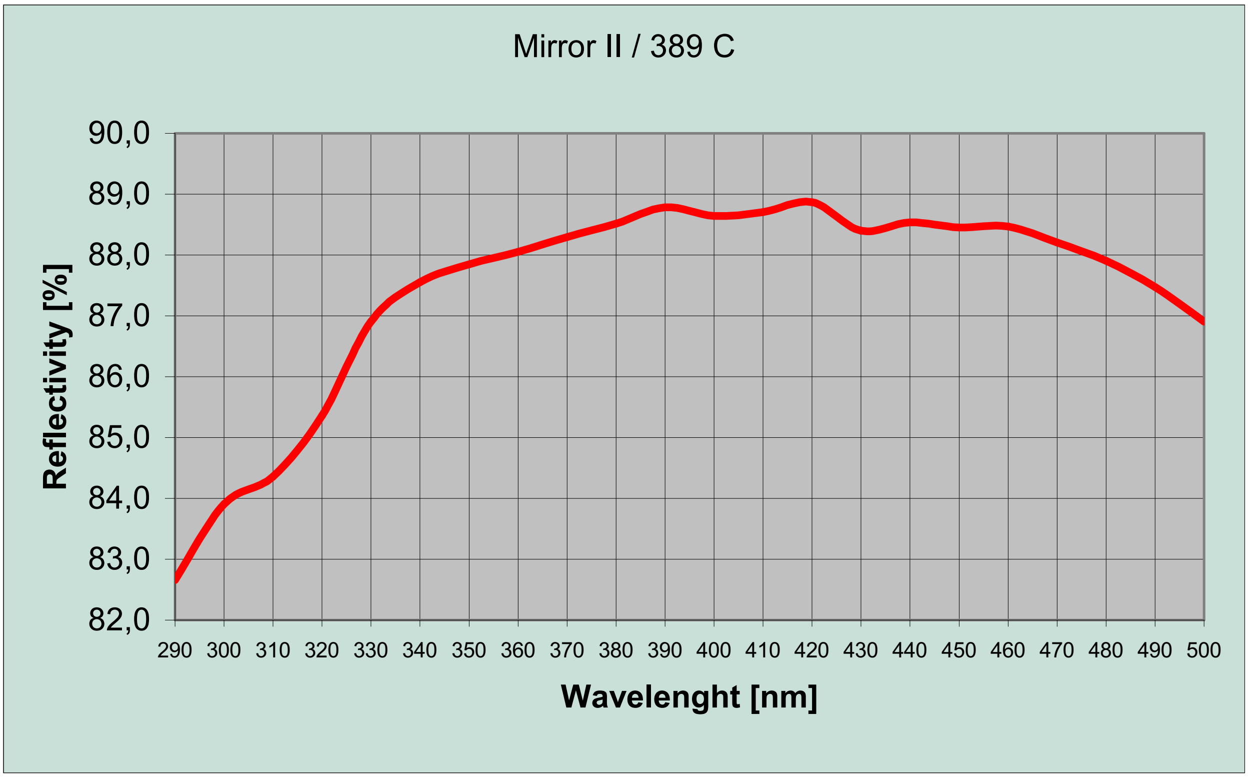


The measurement is based on comparing of voltage on photodetector with calibrated mirror with reflectivity 90,6% on 375 nanometers and measured mirror. This is simple and functional method.
The second one is V-W method. In this method we don't need a mirror with known reflectivity. In this method we compare currents on photomultiplier after two different tracks of beam. In the first stage we measure PM current in branch called "V". In this branch isn't inserted the measured mirror. And in second stage we change the beam trajectory in "W".

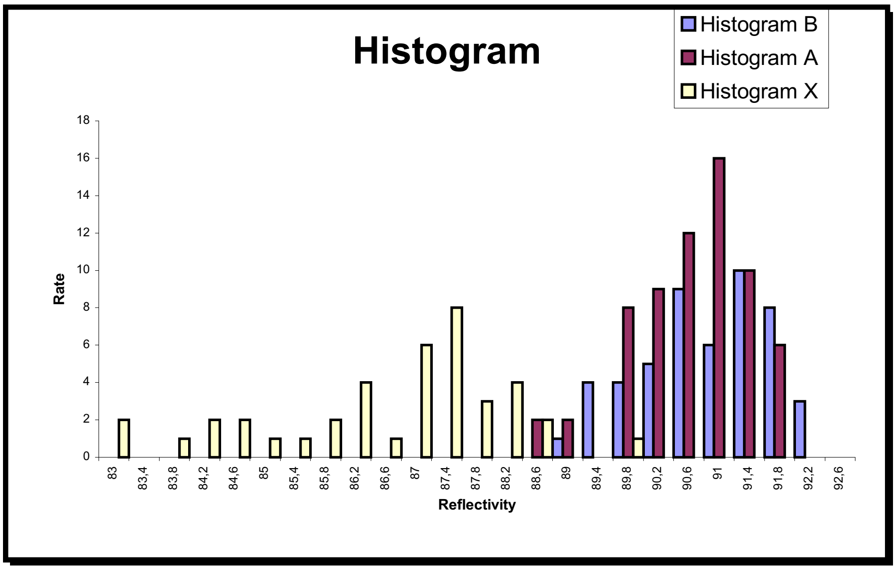
This trajectory is similar as “V”. It has the same length and the same number of reflections on auxiliary mirrors but there are two redundant reflections on measured mirror. And from this two currents we are able to compute decrement corresponding to the two reflections on the measured surface.



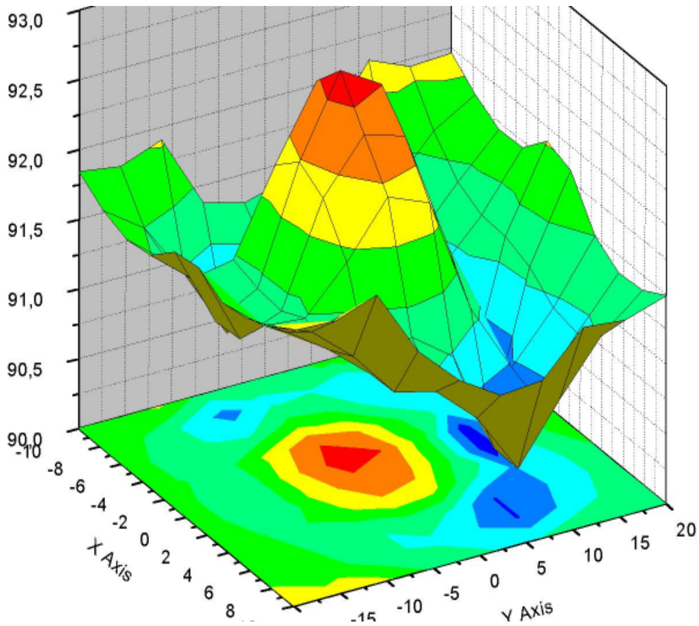
Next advantage is that we are able to change beam wavelength and measure the dependency of reflectivity on wavelength. Some results from our measurements are shown in the next graph.



Average reflectivity of 60 mirrors for one telescope is 90,5% for telescope A, 90,7% for telescope B and 90,8% for telescope C in the UV region (375 nanometers). Next graph shows histogram of reflectivity for prototype and for first two produced telescopes.



Homogeneity of reflectivity over the whole surface lies in 2,5%. This differences are caused by evaporization process, where the mirror is rotating along own axis and the vaporization source of aluminum and silicon dioxide is point.



Conclusion

We present overview of glass mirrors produced in Joint Laboratory of Optics in Olomouc and used in cosmic rays astronomy telescopes and we describe reflectivity measurement of mirrors produced in our laboratory.

Acknowledgement

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