# RESEARCH AT VATLY

***Nguyen Thi Thao***

for the VATLY team

*Vinh, 11 – 15 October, 2011*

# THE VATLY TEAM


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**VATLY** stands for **V**ietnam **A**uger **T**raining **L**aborator**Y**.

It owes its name to the Pierre Auger Observatory in Argentina with which it is associated. Its aim is to establish in Hanoi a team of researchers of international stature having the ambition to promote in the country teaching and research in fundamental science, and in particular in astrophysics.

This year, the staff includes three Postdocs, two PhD students and two Master students.

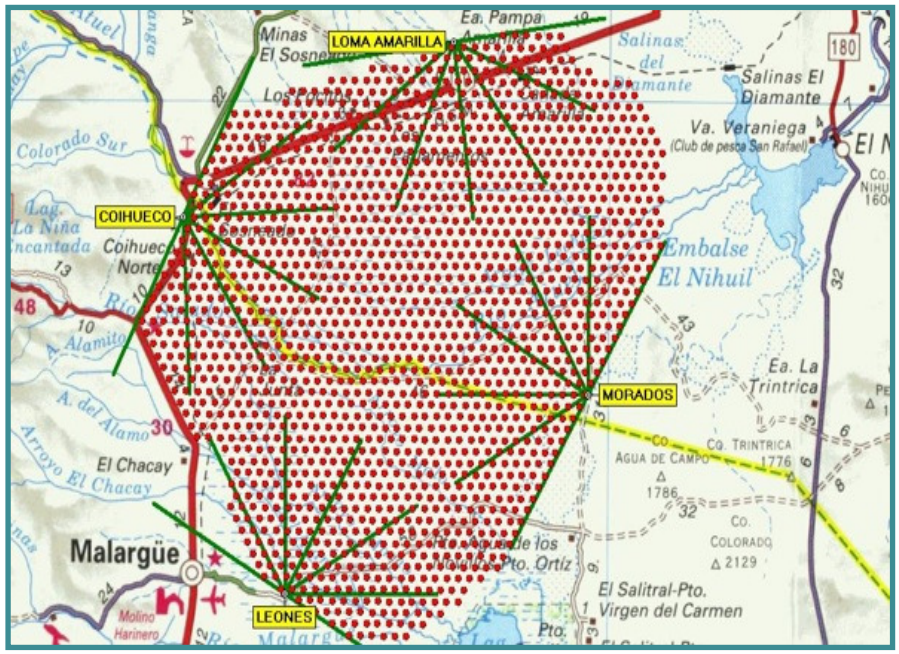
Research interests cover the study of cosmic rays at the extreme end of the energy spectrum and, recently, radio astronomy.
Much of it is made in collaboration with other institutes, using data collected by major research installations abroad. In particular most PhD theses are made under an agreement of joint supervision with foreign universities.

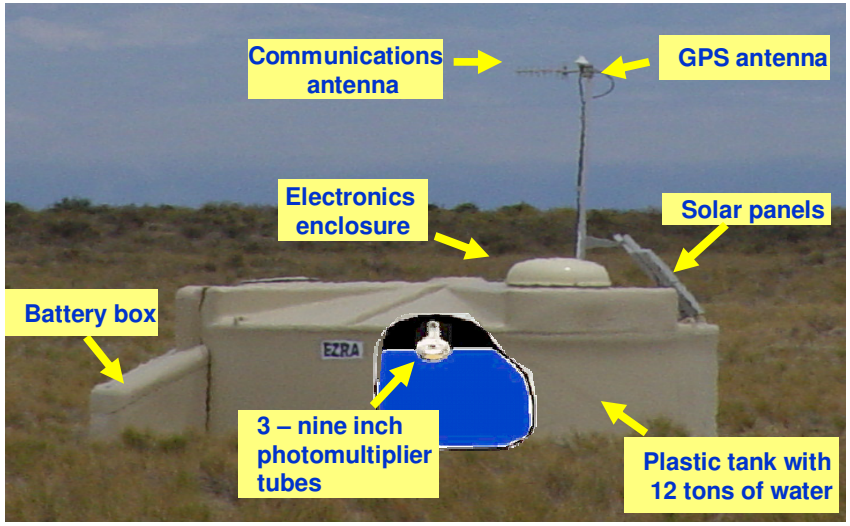
The laboratory is equipped with instruments that are used for training and for domestic research.

We receive support from the Institute for Nuclear Science and Technology (VAEI) that hosts the laboratory (running expenses), from the Ministry of Science and Technology (following a budget request made through Nafosted) and from various organizations in the form of fellowships (Odon Vallet, World Laboratory, etc.) or of occasional support (French CNRS/LIA, host universities/joint supervision PhD theses, etc.)

# The Pierre Auger Observatory (PAO)

The PAO detects Ultra High Energy Cosmic Rays (UHECRs, $E>10^{18}$eV) from the showers they produce when interacting with the earth atmosphere. The aim is to understand what they are (most likely protons or iron nuclei), where they come from and how they are accelerated. It includes an array of 1660 detectors on ground (SD) covering 3000 km$^2$ and 24 fluorescence telescopes (FD).



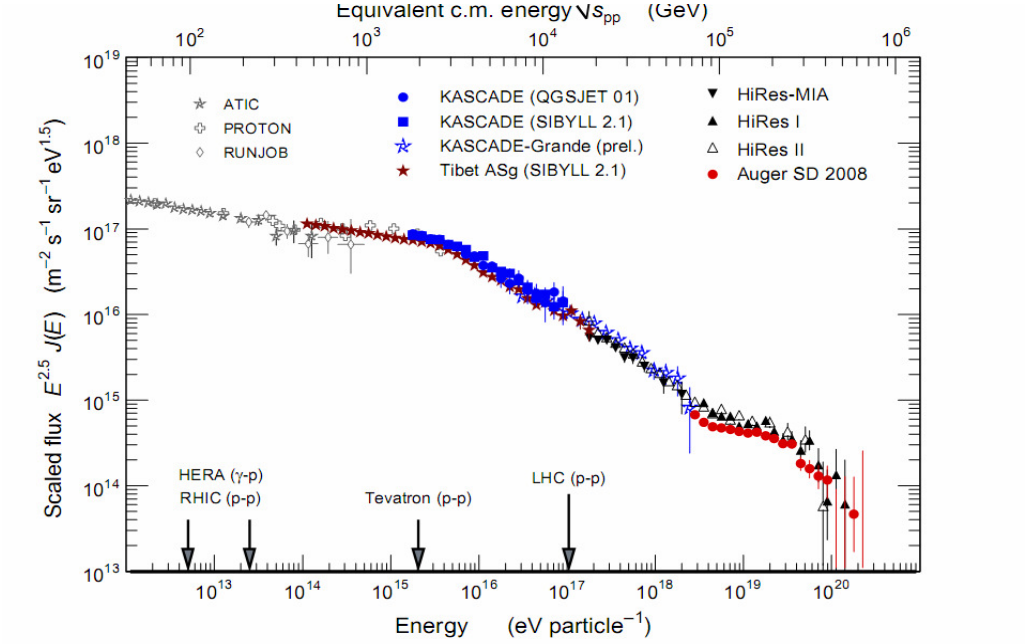



# The Pierre Auger Observatory

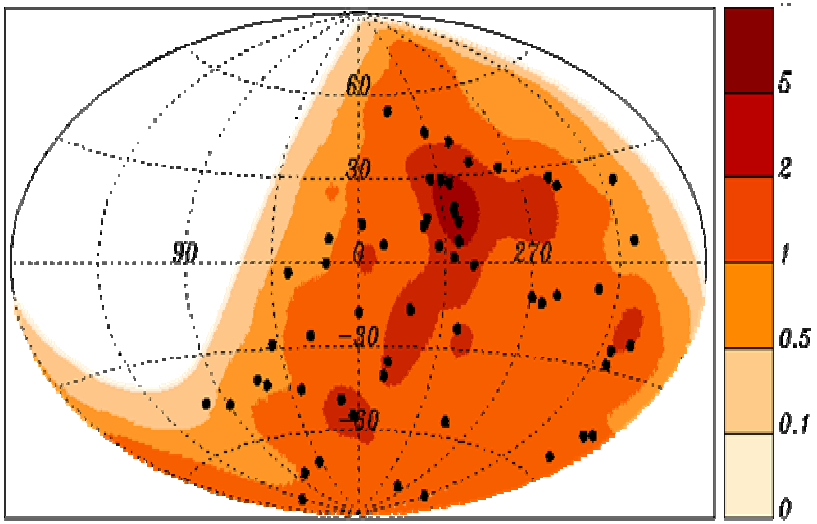


***Two major results have already been obtained:***

- Evidence for interaction with the cosmic microwave background producing an energy cut-off (GZK) at ~$10^{20}$eV;
- Evidence for a correlation with active galaxies in the nearby universe, in particular with Centaurus A.




Energy spectrum x$E^{2.5}$ showing the GZK cutoff




UHECR shower sources (black dots) are compared with galaxy density of nearby universe

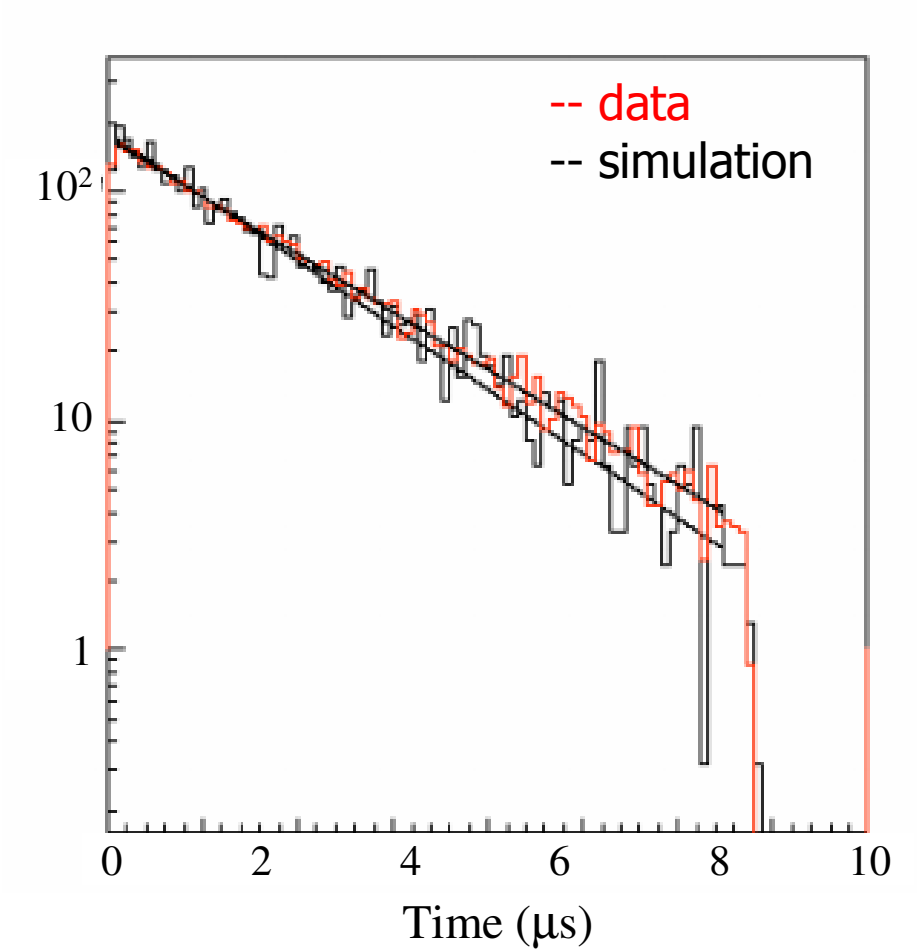
PAO data are dispatched to all collaborating institutions.

Major VATLY contributions include:

- A study of low amplitude signals and the detection of decay electrons from stopping muons;
- A measurement of shower divergences;
- Contributions to the identification of the primaries (iron or protons) from the muon density on ground;
- Detailed studies of showers pointing back to Cen A;
- Detailed studies of the long term stability and ageing of the PAO Cherenkov detectors and of some of their dysfunctions;
- A study of the response of the PAO photomultiplier tubes as a function of photon impact (made in Hanoi).

*A few examples follow:*

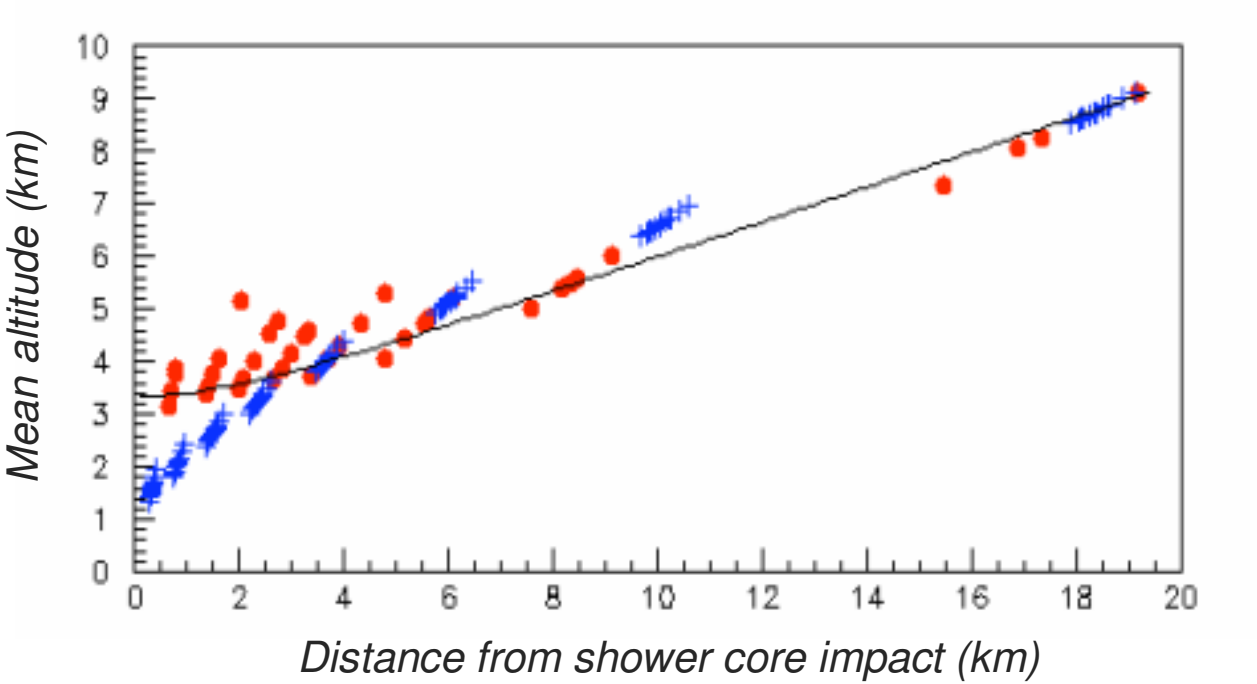
# A study of low amplitude signals and the detection of decay electrons from stopping muons




The time distribution of decays of stopping muons measured in the PAO detectors from the signal produced by the decay electron in the tank is compared with the prediction of the simulation accounting for both decay lifetime and muon capture.

This work represents a sensitive test of the proper response of the detector to low signals close to noise and of the adequacy of the simulation.

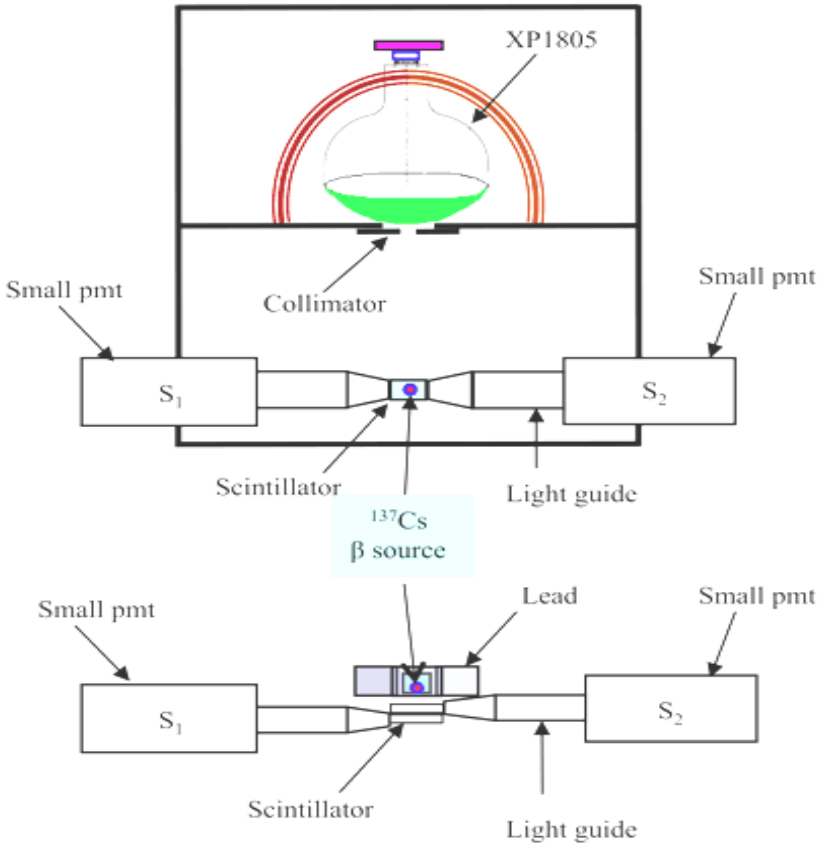
# A measurement of shower divergences

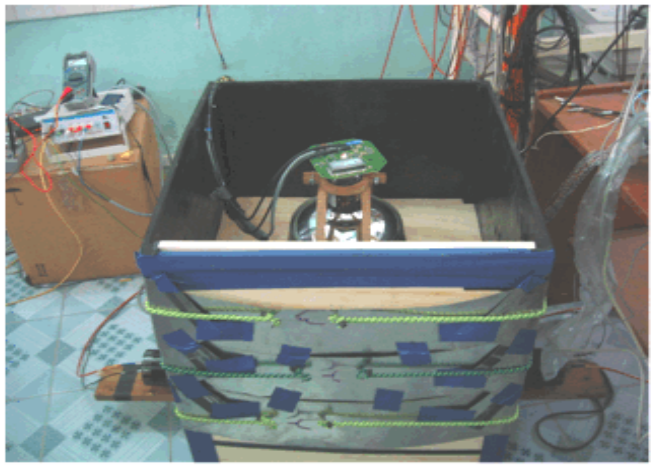


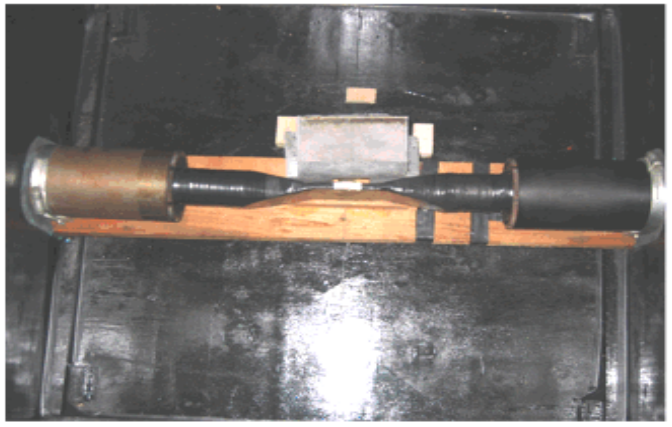

Each ground detector is equipped with three photomultipliers that collect the Cherenkov light emitted by shower particles hitting the tank. An asymmetry between their responses depends on the direction of incidence of the particles, which can therefore be calculated from the asymmetry measurement.

The mean altitude of the shower maximum can be evaluated this way and provides useful information on the shower properties (here shown in red for different energies as a function of distance to the shower axis. Blue crosses show the shower maximum as measured by the longitudinal shower profile).

# Study of the response of the PAO photomultiplier tubes as a function of photon impact

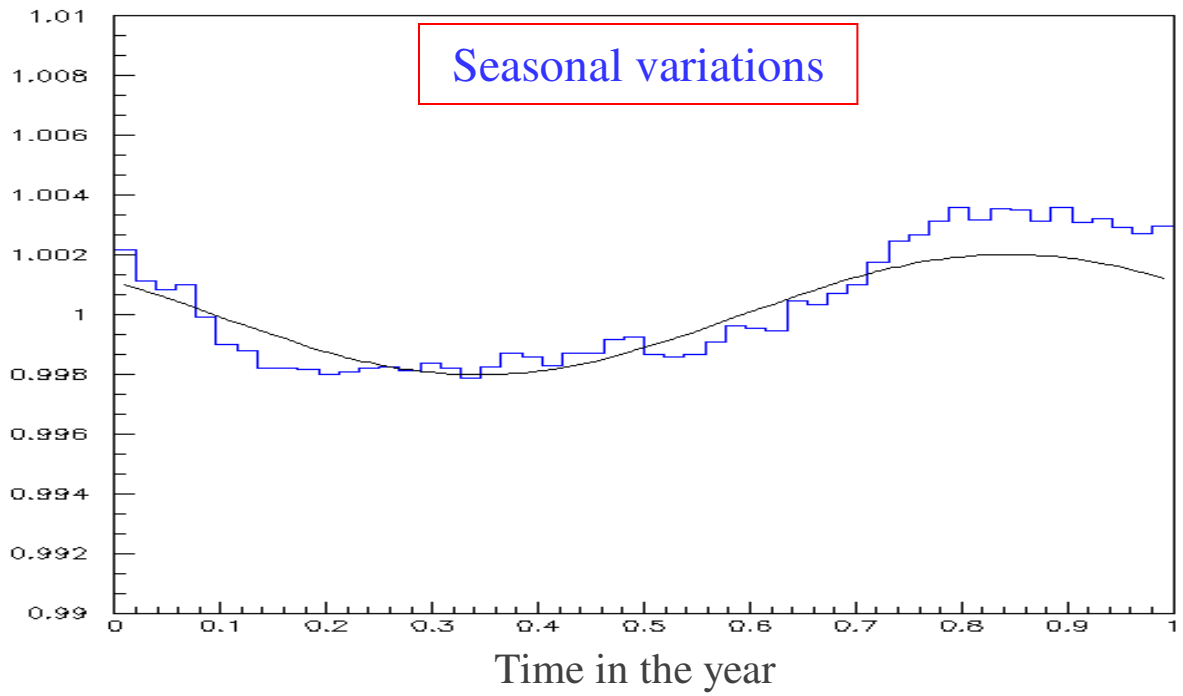




Measurements made in Hanoi have revealed a previously unnoticed dependence that has been explained and described in simple terms. The effect of the geomagnetic field has also been carefully included and studied.

# Detailed studies of the long term stability and ageing of the PAO Cherenkov detectors

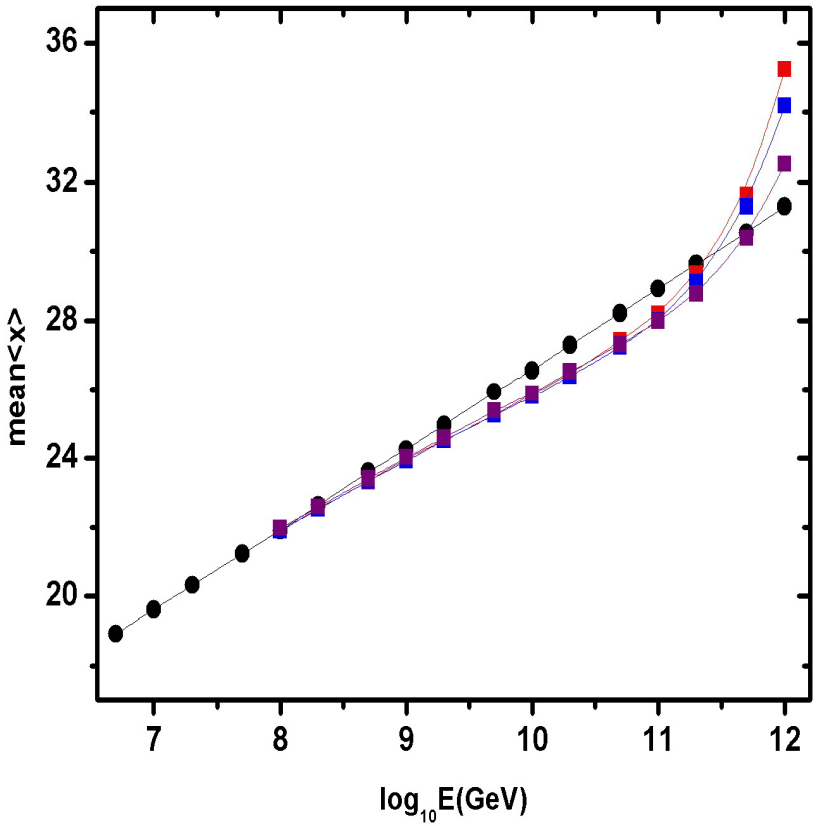



Variations of the pulse shapes of the ground array signals at the per mil level have been identified and explained. They include seasonal variations, day *vs* night oscillations, a very slow long term ageing (~40 years decay time) and a settling down period of a few months following water filling. They are understood in terms of optical and electronic properties of the detectors.

# Shower development studies

In relation with research at the PAO, simulation codes describing the longitudinal and transverse developments of air showers have been conceived and written at VATLY.

They have been used to study the Landau-Pomeranchuk Migdal and Perkins effects. They allow for generating hadronic showers at extreme energies in a short computing time. They are now used to compare proton-induced with iron-induced showers.




*Dependence on energy of the shower parameters calculated for incident electrons (black, LPM excluded) and for three angles of incidence (LPM included): vertical (blue), 30° (red) and 60° (violet).*

The laboratory is equipped with detectors of various types meant to provide training of students and to make the research staff familiar with the tools and techniques used in larger installations.

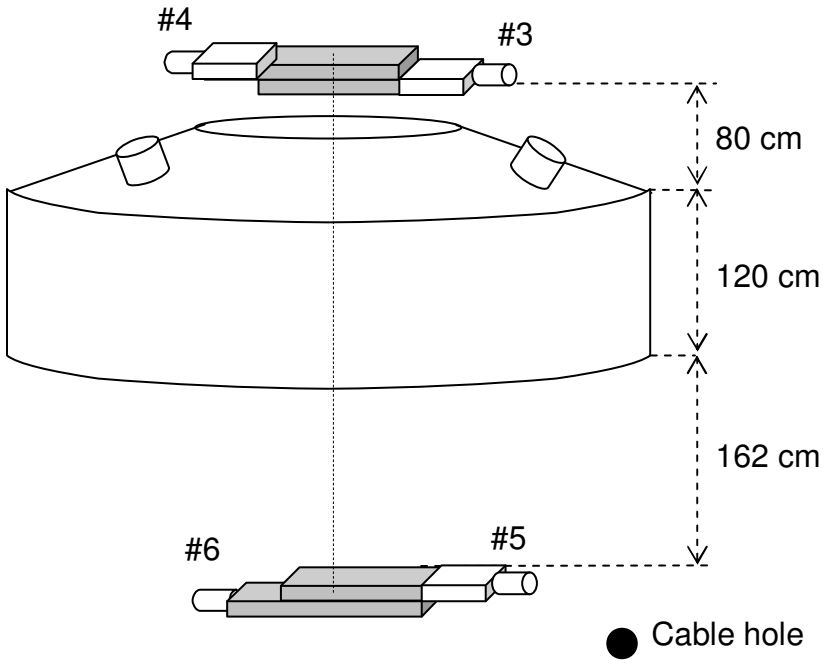
They include scintillator and Cherenkov detectors with their associated electronics and a 2.6 m diameter radio telescope equipped to detect the hydrogen 21 cm line.

*Refurbished the Cherenkov tank*

*Installing the dish of the SRT on the VATLY roof*

A replica of a PAO detector has been constructed on the roof of the Lab. It can be triggered with three smaller Cherenkov detectors surrounding it to study extensive air showers in the TeV range.

A scintillator hodoscope bracketing it from above and below allows for a calibration using relativistic feed-through muons. We are currently performing a study of multi-muon events using decay electrons from stopping muons as a reference.



A radio interferometer including two Yagi antennas has been used to detect the radio emission of the Sun around 600 MHz over a 20m east-west base line.

Beautiful interference fringes have been observed with a signal to noise ratio of ~100 and a signal to background ratio of ~1%.

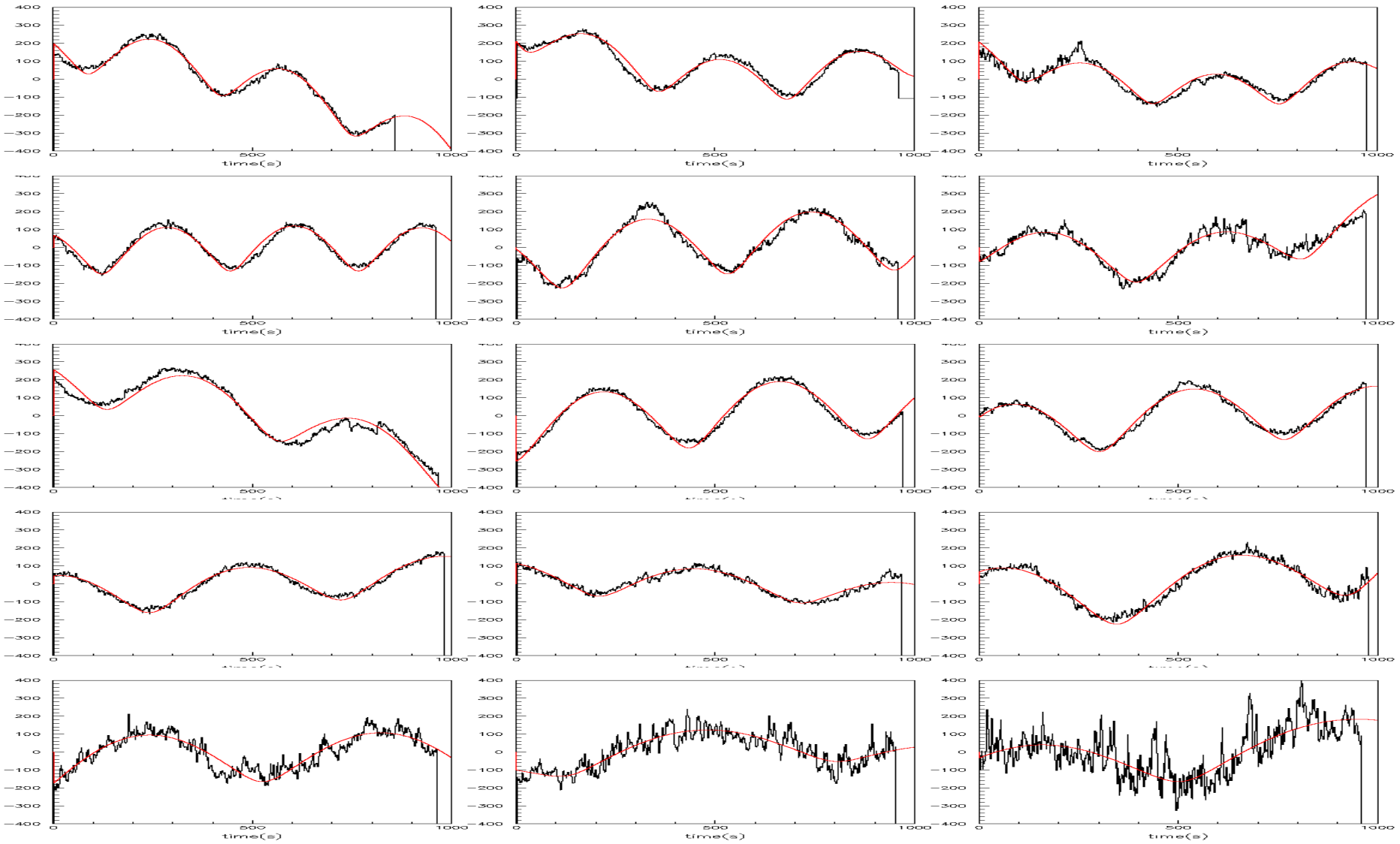
*Tuan Anh in Hoa Binh in front of one antennas of his interferometer*

The power density detected was measured to be 4±4 dB above that expected from the quiet sun.

The interferometer is now used by the Hanoi University of Education to train students.

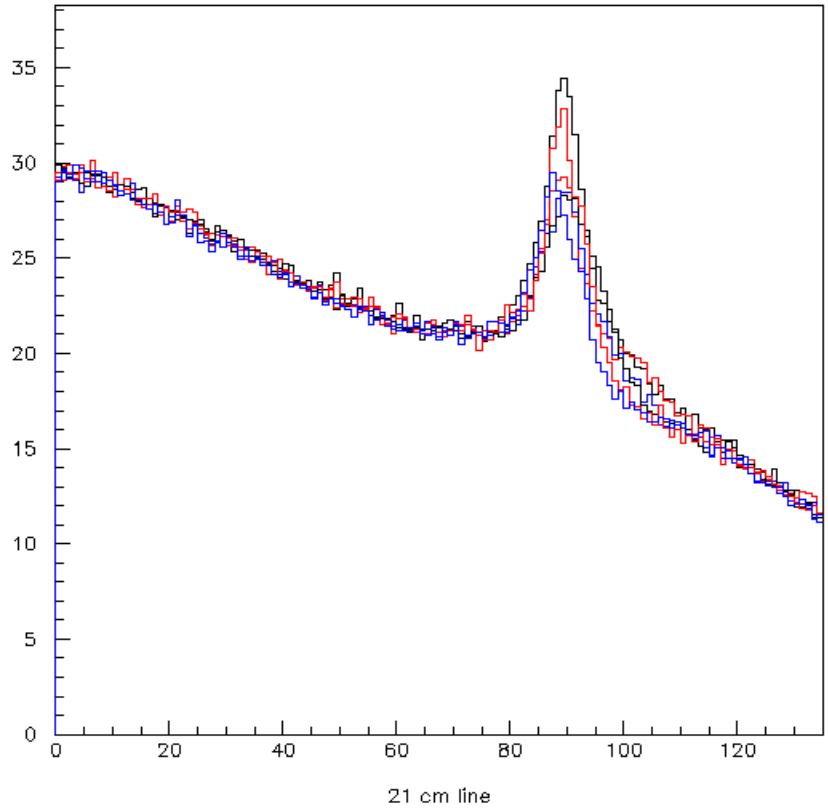
# Solar interferences

One day of measurement, each panel is for 1000 seconds.
The line is the result of a global fit.



A collaboration has been established with the Observatoire Midi-Pyrenees to analyze millimetric data collected at the radio telescope array of Plateau de Bure in the framework of a PhD thesis (joint supervision). In particular, spectroscopic studies (CO line) of a gravitationally lensed galaxy having a red-shift of 2.3 will provide important information on the formation of early galaxies.

We have installed a 2.6 m diameter radio telescope equipped for observation of the 21 cm hydrogen line on the roof of the laboratory.

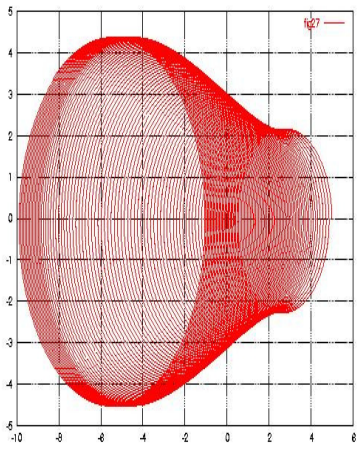


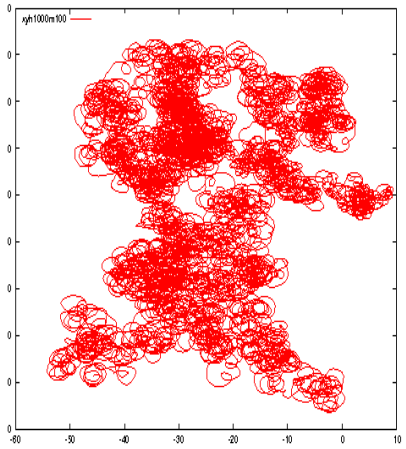

*The research plan includes:*

Detection of the hydrogen in the Milky Way, Doppler measurement of the Galaxy rotation, observation of solar activity over a full rotation cycle and of other strong radio sources (Cen A, Sgr A*).

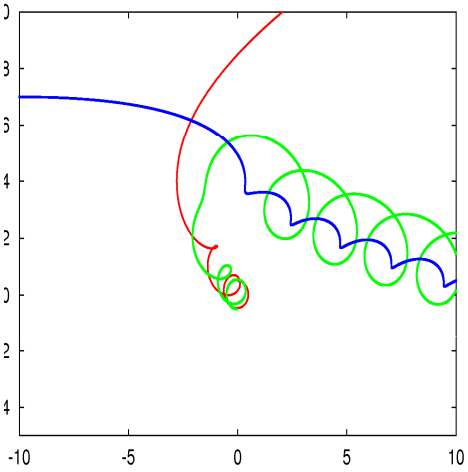
- We train undergraduate students who spend a few months with us to work on their dissertation and occasional master students.

- Most recent works include studies of *Global warming and cosmic rays, Diffusive shock acceleration in young Supernova remnants, The three body problem and X-ray active binaries* and *Gravitational Lensing and Einstein rings.*

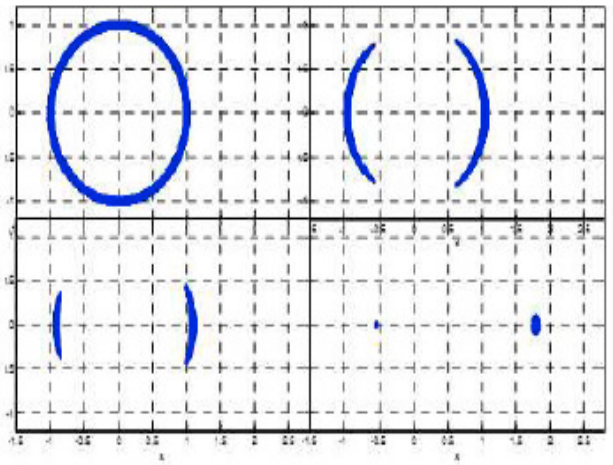




Diffusive shock acceleration: uniform field & random dipoles




Three body capture & X-ray active binaries



Einstein rings fading away as the source-lens-Earth alignment deteriorates.




On 15 June 2011, VATLY celebrated the 10th anniversary of its foundation.

We are members of the Vietnam Astrophysics Group
( http://ftri.fpt.edu.vn/apg/ )
and of the South East Asia Astronomy Network
( http://conference.narit.or.th/seaan/index.htm )

Additional information, including a list of publications and a set of Newsletters is accessible from our website:
http://www.inst.gov.vn/Vatly/Vatly.htm


We express our deepest gratitude to all those who, in Vietnam and abroad, follow our progress and help us improving the quality of our research and overcoming the difficulties that we may meet.
THANK YOU FOR YOUR ATTENTION!