

## Summary

### Cosmic Ray Division of the Yerevan Physics Institute

#### History, status and future plans 2009-2014

In 1942 Alikhanyan brothers initiated first expedition to Aragats. Since then, expeditions on Aragats continued uninterruptedly, in spite of World War II, insufficient funding, and electricity and fuel shortages during the recent history of Armenia. The most important dates and achievements of Cosmic Ray research at Aragats can be itemized as follows:

- 1945-1955 – Experiments at Aragats with Mass-spectrometer of Alikhanyan-Alikhanov: investigations of the composition of secondary CR (energies <100 GeV); exploration of the “third” component in CR; observation of particles with masses between  $\mu$ -meson and proton;
- 1957 – Design and fabrication of the first ionization calorimeter, observation of the rise of hadron non-elastic cross section in the energy range 0.5 - 10 TeV;
- 1970 – Experiments with Wide-gap Spark Chambers; Lenin prize awarded to T.Asatiani and A.Alikhanyan;
- 1975 –Experiment MUON: measuring of the energy spectrum and charge ratio of the horizontal muon flux;
- 1977 – Experiment PION: identification of the pions and protons by TRD; measuring pion and proton energy spectra, inelasticity coefficients inelastic cross sections of hadrons in the energy range 0.5 - 10 TeV;
- 1981-1989 – Start of the ANI Experiment: commencement of the MAKET-ANI and GAMMA surface detector arrays for measuring cosmic ray spectra in the “knee” region ( $10^{14} - 10^{16}$  eV);
- In 1990 an invention was registered by the USSR patent agency authored by Erik Mamaidjanyan and Khachik Babayan with colleges from Moscow State

University on the behavior pion multiple production. Invention consists in the observation that in interactions of high energy pion with light nuclei in 10% of cases few neutral pions (1-3) took more than half of energy of primary particle.

- 1993-1996 – Development of new methodology of multivariate, correlation analysis for signal detection from  $\gamma$ -ray point sources event-by-event analysis of shower data from KASCADE experiment; classification of primary nucleus;
- 1996-1997 – Renewal of Cosmic ray variation studies at Aragats: installation of the Solar Neutron Telescope and resumption of Nor Amberd Neutron Monitor;
- 2000 – Foundation of Aragats Space Environmental Center (ASEC) – for Solar Physics and Space Weather research; measurements of the various secondary fluxes of cosmic rays; inclusion of the large surface arrays in monitoring of the changing fluxes of secondary cosmic rays ;
- 2003 – Simultaneous detection of the intensive solar modulation effects in October – November in the low energy charged particle, neutron and high energy muon fluxes;
- 2004 – Measurement of the spectra of heavy and light components of GCR, observation of very sharp “knee” in light nuclei spectra and absence of “knee” in heavy” nuclei spectra;
- 2005 - Measurements of highest energy protons in Solar Cosmic Rays (GLE 69 at 20 January; detection of Solar protons with  $E > 20 \text{ GeV}$ );
- 2007 - Starting of SEVAN (Space Environmental Viewing and Analysis Network - a new type of world-wide network of particle detectors for monitoring of geophysical parameters

- 2007 – By GAMMA experiment, the energy spectra of primary H, He, O-like and Fe-like nuclei are derived in the  $10^3$ – $10^5$  TeV; the all-particle primary cosmic-ray energy spectrum in the  $3 \cdot 10^3$ – $2 \cdot 10^5$  TeV energy ranges.
- 2008 – Cosmic Ray modulation research; Multivariate analysis and classification of the solar transient events (Ground level enhancements, Geomagnetic effects, Forbush decreases) detected by ASEC monitors during 23<sup>rd</sup> solar activity cycle.

Now the Cosmic Ray Division of Yerevan Physics Institute includes approximately 80 people, who work at the Aragats and Nor-Amberd high altitude stations and at the headquarters in Yerevan where most of the data analysis and computation takes place. Many of the staff members are young graduate students or recent postgraduates. Scientific research on Mt Aragats is constantly searching for new methods and new frontiers as the Armenian physicists do their best in the quest of solving the mysteries of the Universe.

CRD physicists during last 5 years publish 76 papers in referred journals (part of them in collaboration with KASCADE and MAGIC groups) and present 104 reports to international conferences. Detailed information on papers and reports is posted in the CRD WEB pages, [http://aragats.am/CRD\\_Journal\\_Publications\\_2002\\_2008](http://aragats.am/CRD_Journal_Publications_2002_2008) and <http://aragats.am/Conferences/?id=39&other=> .

CRD funding comprises from international scientific foundations; funding of Republic of Armenia and support from US diasporas (NFSAT project). Annual budget rose 3 times during last 10 years and in 2008 approaches K600\$. Broad scientific collaborations, winning of international grants and current achievements of the CRD scientists give hope that this rise will continue in coming years.

CRD is now world leader in the surface monitoring of the secondary cosmic rays. Numerous particle detectors measuring charged and neutral fluxes are operating on 3 levels (1000, 2200 and 3200 above sea level) and provide scientific community with unique data.

Measuring as many as possible of secondary fluxes with various energy thresholds CRD physicists access wide spectrum of primary energies incident on the Earth's atmosphere and can research the solar modulation effects with unprecedented accuracy. Among scientific topics to be addressed in coming years, coinciding with rise of solar activity of the 24<sup>th</sup> cycle are:

1. Detection of the highest energy solar cosmic rays; research of the acceleration mechanisms and propagation in the interplanetary space;
2. Measurements of the geomagnetic effects; research of the interaction of Interplanetary Coronal Mass Ejections with magnetosphere;
3. Multiple correlation analysis of the flare, CME, geo-parameters; identification and explanation of the nontrivial correlations; forming of the model of violent solar event in progress;.

4. Establishing of reliable and timely forewarning services of space storms.
5. Research of atmospheric electricity and mechanisms of the thunderstorms.

Above goals will be reached by 24 hour, all year operation of the ASEC monitors, by actively participating in the international measuring networks, by enlarging SEVAN network to new countries, by establishing on Aragats magnetometric center, by designing and assembling new particle detectors with advanced possibilities to measure neutron flux and by designing and implementing multivariate data analysis methods.

New detectors and new experimental labs for secondary flux monitoring will be established in the campus of Yerevan Physics Institute in Yerevan to measure and compare changing particle fluxes on 3 altitudes.

The research of the Galactic Cosmic Rays after the “knee” will be continued with GAMMA detector to research fine structure of spectra and to distinguish the showers initiated by primary gammas (so called muon poor showers) to measure diffuse flux and search of the point sources of high energy gamma quanta.

If appropriate international funding will be available we'll start preparation for the ANI-new experiment in the energy ranges  $10^{16} - 10^{19}$  eV: perform detailed simulation of the shower propagation in the atmosphere and detector response. The design of detectors will be finalized, orders assigned and prototype array commissioned.

In the Low-background laboratory of YerPhi jointly with Experimental Physics Division we plan to start monitoring the flux of the high energy muons.

CRD will continue international collaboration in measuring radiation dose on the Space station and other spacecrafts using the methodology of controlled emulsion developed in Yerevan Physics Institute.

We plan in 2009 to repair offices and teaching labs; purchase detectors, measuring devices, networking and computer equipment.

The Space Education center will operate for the Yerevan State University undergraduate students; we plan in 2009 the Summer school at Aragats with ~10 participants and international conference in Nor Amberd with ~40 participants.

In 2009 we plan to continue education of 2 PhD students, 3 master student and 3 undergraduate students.