Baksan Air Shower Array: Review of Results and Prospects for the Future

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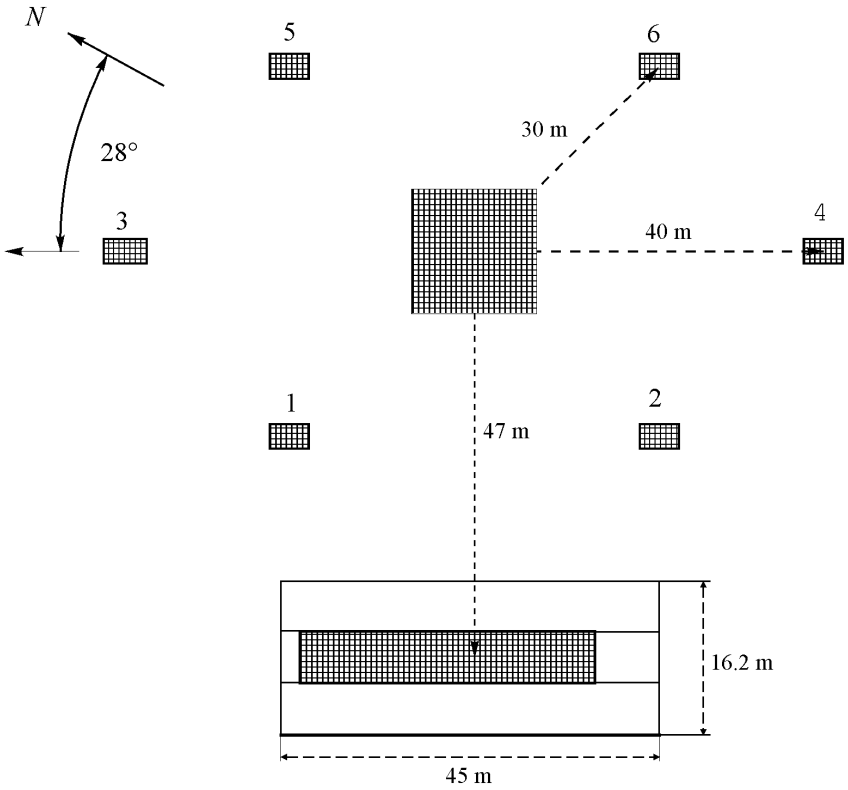
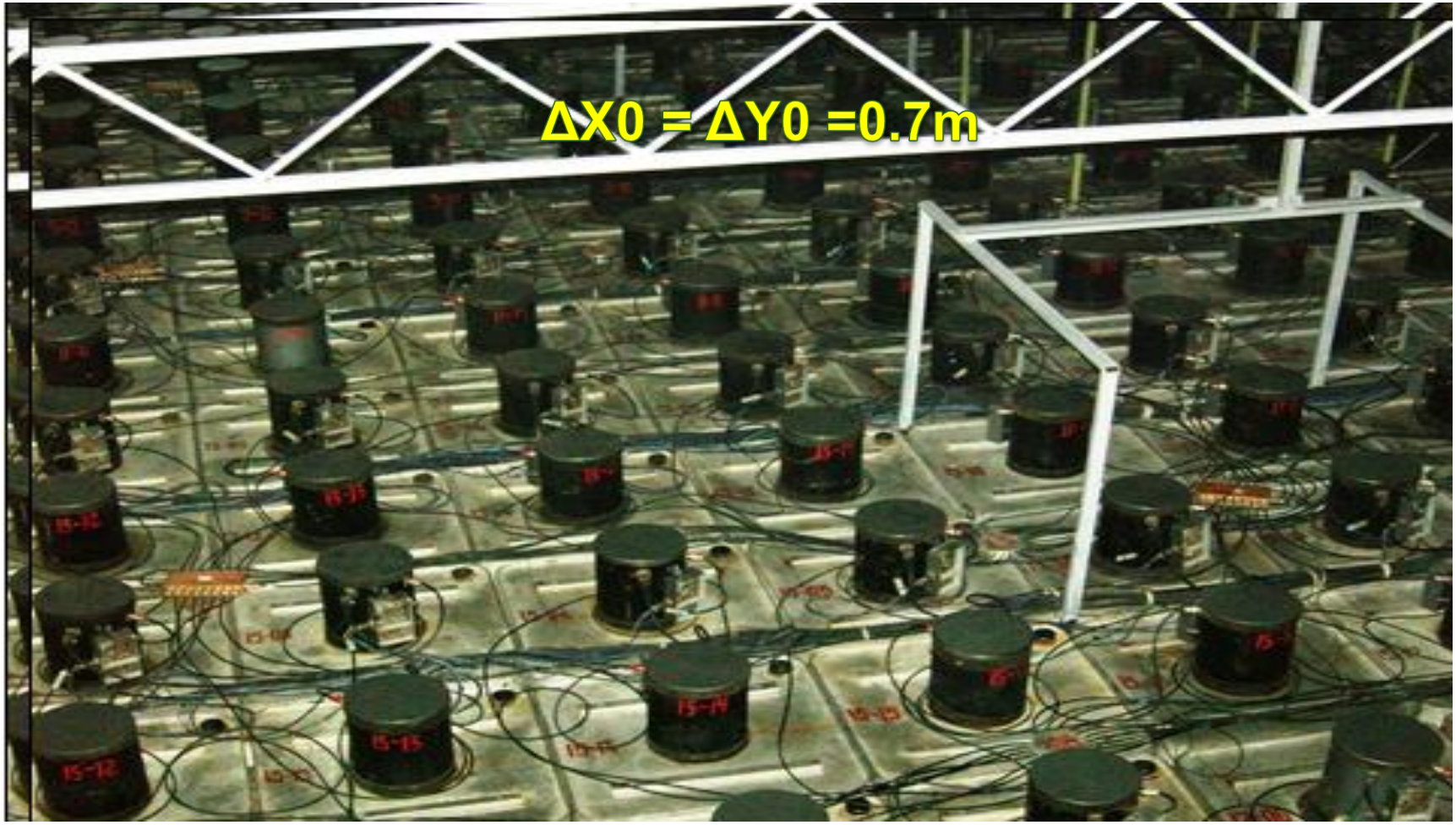
The BASA: Scheme and view



The Carpet array (400 detectors)



1st tunnel of MD(205 detectors)

EAS studies with the Carpet array

- High-precision measurements of LDF and its fluctuations; EAS with irregular structure were found
- Study of EAS structure near its axis and estimation of the flattening region near the core

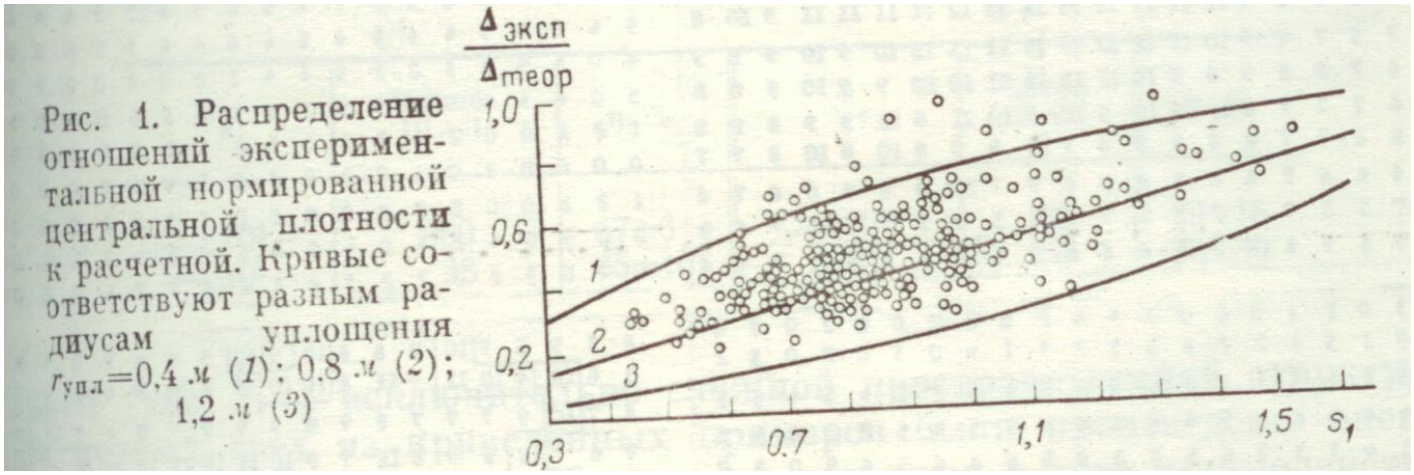


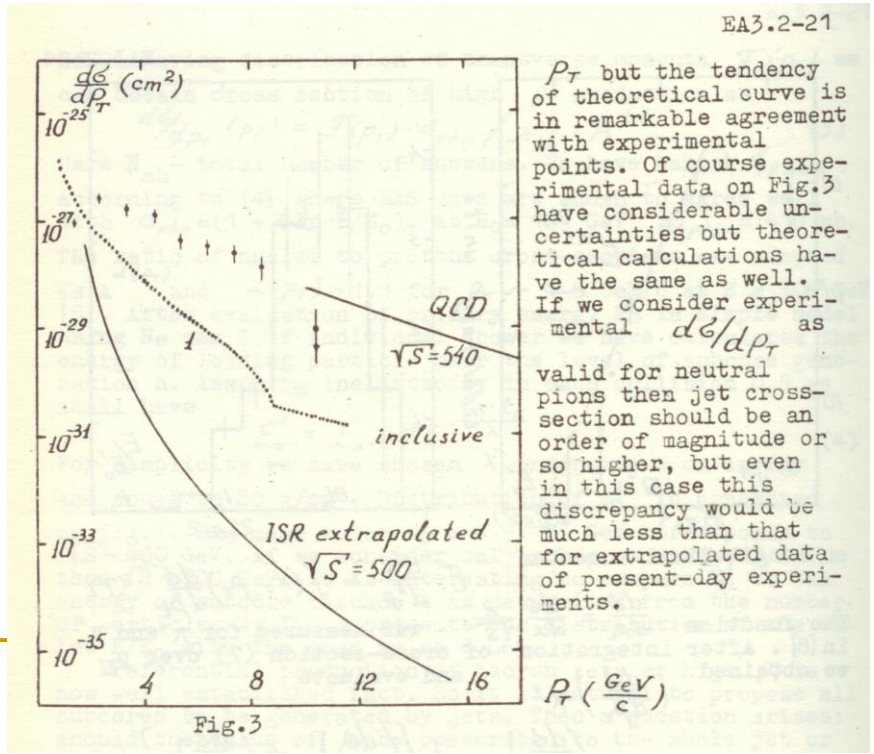
Рис. 1. Распределение отношений экспериментальной нормированной центральной плотности к расчетной. Кривые соответствуют разным радиусам уплощения $r_{упл}$=0,4 м (1); 0,8 м (2); 1,2 м (3)

Multi-core EAS and high transverse momenta in hadron-hadron interactions

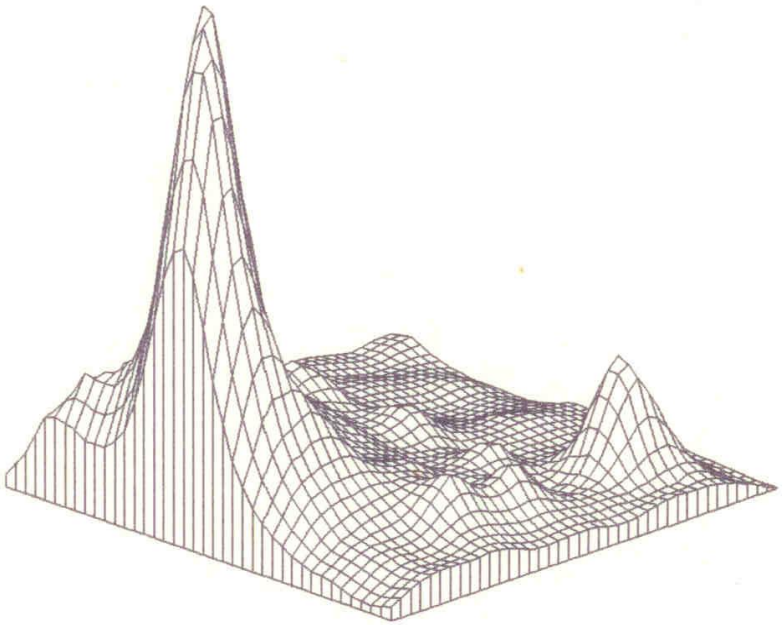
- From the analysis of multicore showers (Carpet) the cross section of generation of high Pt jets at √S ~ 500 GeV is estimated and demonstrated to be in agreement with QCD predictions (1981, at least one year before the similar results of UA1 and UA2 collaborations at the CERN SPS-collider).
- (The plot from this report was reprinted in CERN Courier immediately)

A.E. Chudakov, D.D. Dzhappuyev, A.S. Lidvansky, V.A. Tizengauzen, V.P. Sulakov, G. Navarra, Investigation of EAS with multicore structure,
16th ICRC, Kyoto, Japan, v. 8, p. 222 (1979).

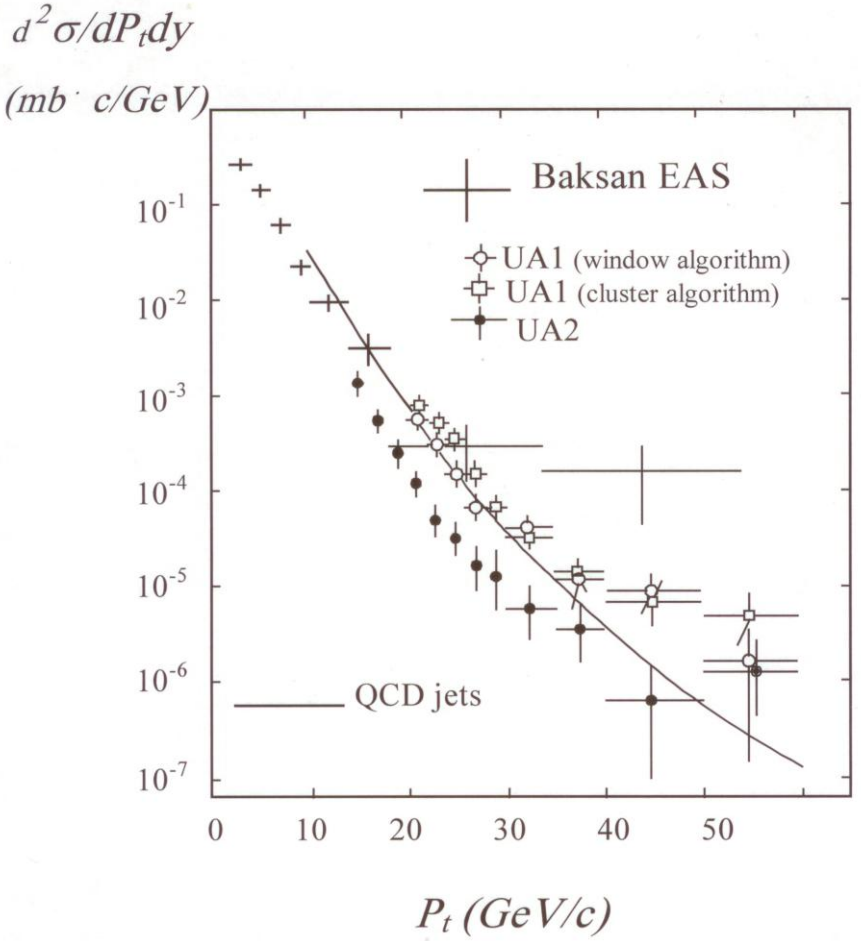
A.E. Chudakov, K. Dobrzynski, E. Krys,
A.S. Lidvansky, G. Navarra, V.A. Tizengauzen,
J. Wdowczyk. The data on multicore air showers and cross-section of high-Pt jet production at √S ~ 500 GeV,
Proc. of 17th ICRC, Paris, 1981, v.6, p. 183-186.



First confirmation of QCD
in high-Pt physics

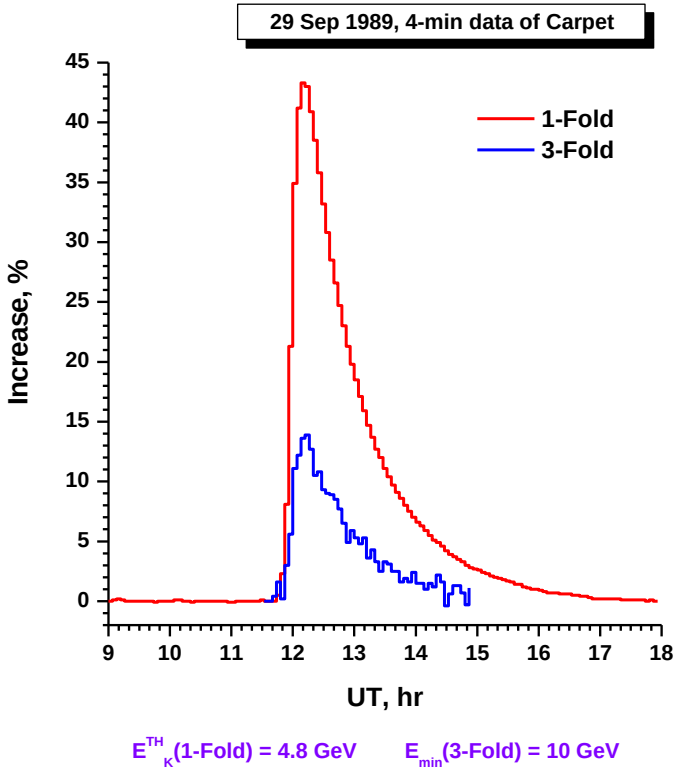


An example of multicore event
(smoothed particle density)

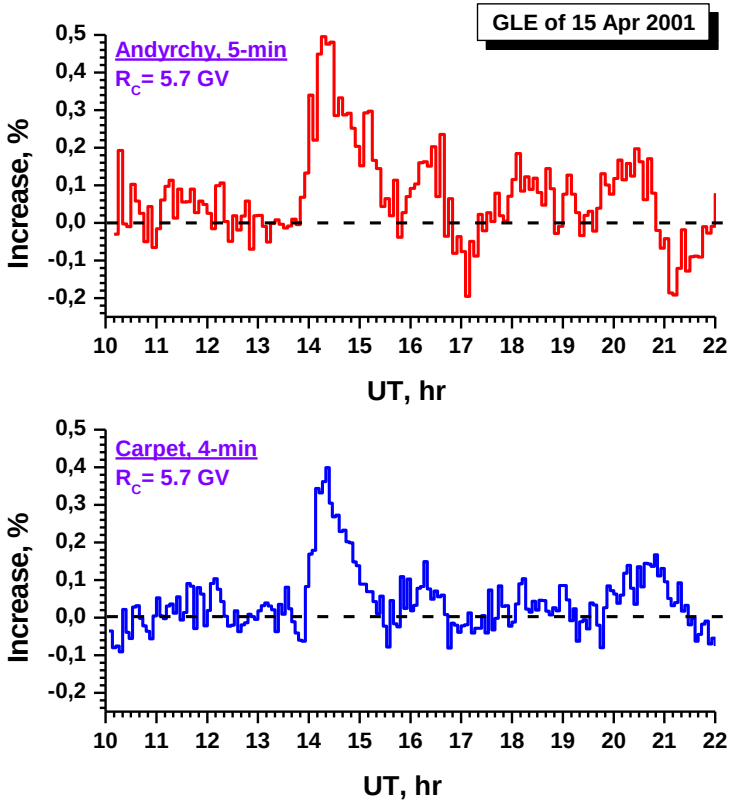


Cross-section of high P_t events in an air shower experiment compared to a calculation for QCD jets and first experiments at CERN SPS collider.

Detection of GLE from solar flares



E^{TH}_{K}(1-Fold) = 4.8 GeV E_{min}(3-Fold) = 10 GeV



Anisotropy of cosmic rays

10 TeV Carpet 1981
2.5 TeV BUST 1987
100 TeV Andyrchi 2004

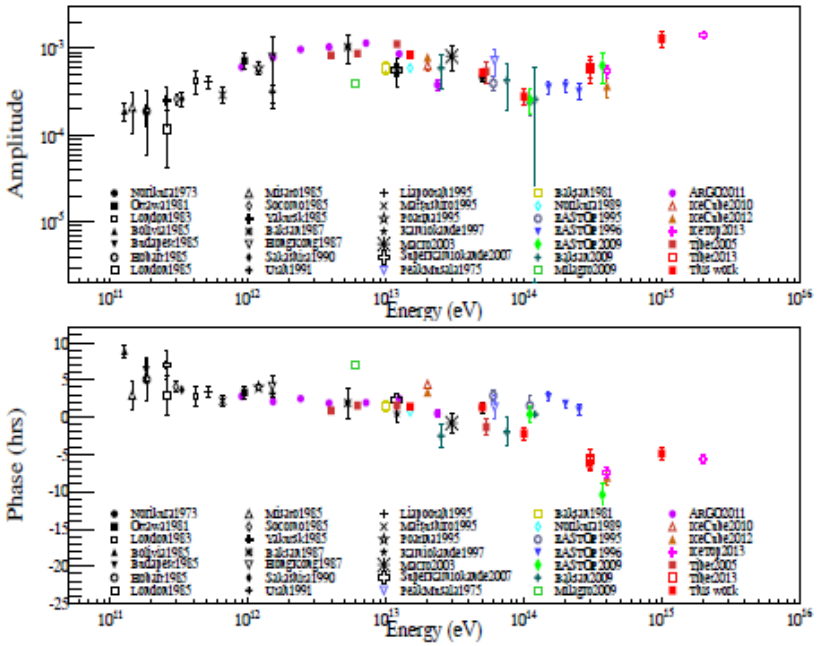
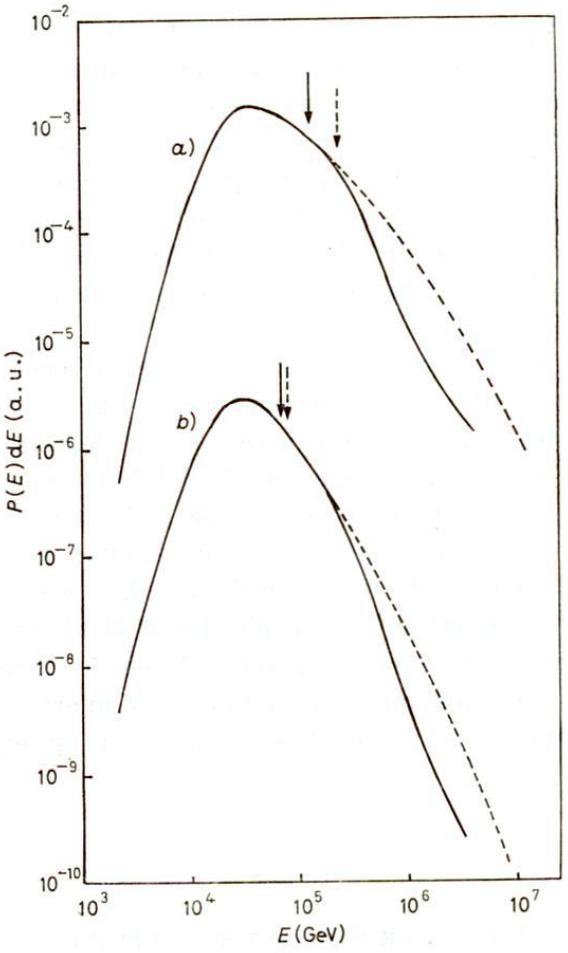


FIG. 5.— The energy dependences of amplitude (top) and phase (bottom), of the first harmonics of the CRs anisotropy obtained in this work, and reported from previous measurements. They are underground muon observations: Norikura(1973) (Sakakibara et al. 1973), Ottawa(1983) (Bercovitch & Agrawal 1981), London(1983) (Thambyahpillai 1983), Bolivia(1985) (Swinson & Nagashima 1985), Budapest(1985) (Swinson & Nagashima 1985), Hobart(1985) (Swinson & Nagashima 1985), London(1985) (Swinson & Nagashima 1985), Misato(1985) (Swinson & Nagashima 1985), Socorro(1985) (Swinson & Nagashima 1985), Yakutsk(1985) (Swinson & Nagashima 1985), Banksan(1987) (Andreyev et al. 1987), HongKong(1987) (Lee & Ng 1987), Sakashita(1990) (Ueno et al. 1990), Utah(1991) (Cutler & Groom 1991), Liapootah(1995) (Munakata et al. 1995), Matsushiro(1995) (Mori et al. 1995), Poatina(1995) (Fenton et al. 1995), Kamiokande(1997) (Munakata et al. 1997), Marco(2003) (Ambrosio et al. 2003), SuperKamiokande(2007) (Guillian et al. 2007), and air shower array experiments: PeakMusala(1975) (Gombosi et al. 1975), Baksan(1981) (Alexeyenko et al. 1981), Norikura(1989) (Nagashima et al. 1989), EASTOP(1995,1996,2009) (Aglietta et al. 1995, 1996, 2009), Baksan(2009) (Alekseenko et al. 2009), Milagro(2009) (Abdo et al. 2009), IceCube(2010,2012) (Abbasi et al. 2010, 2012), IceTop(2013) (Aartsen et al. 2013), ARGO-YBJ(2015) (Bartoli et al. 2015), Tibet(2005,2013) (Amenomori et al. 2005b; Amenomori et al. 2013).

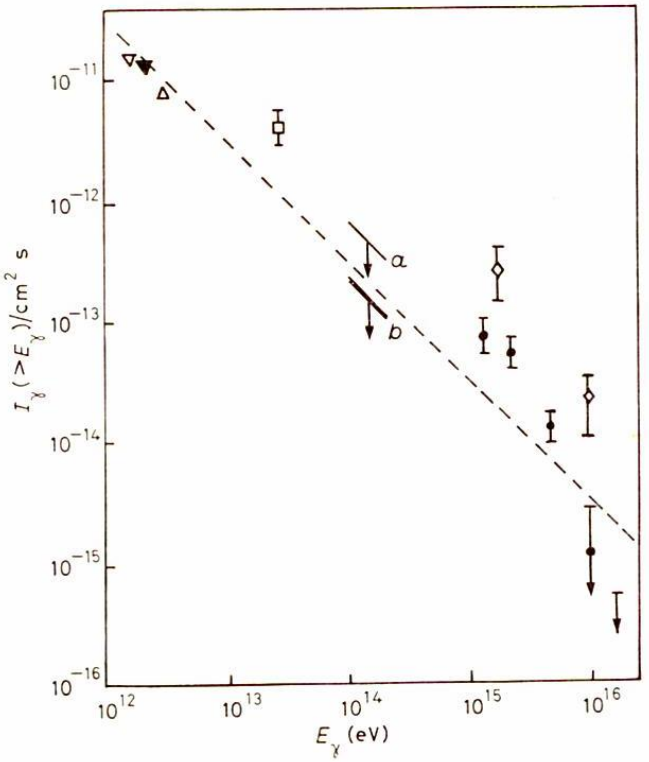
UHE Gamma Ray Astronomy: Cygnus X-3 campaign in 1980s

There were:
One obviously wrong (as it became
clear much later) publication of Kiel University group;
A deluge of experimental and theoretical works;
A specially constructed EAS array called Cygnus;
A hypothetical new elementary particle cygnet;
A hypothesis of violated confinement (free gluons);
And many other experimental efforts and witty hypotheses.

BASA results on DC signal from Cyg X-3



Two spectral indices (2.1 and 2.7) were used and MWB absorption taken into account. Other experimental data: VHE (Cherenkov), Plateau Rosa, Kiel, and Haverah Park.



Burst of Cyg X-3 on October 14-16, 1985

CYGNUS X-3 OBSERVATION IN GAMMA-RAY ENERGY RANGE $> 10^{14}$ eV 159

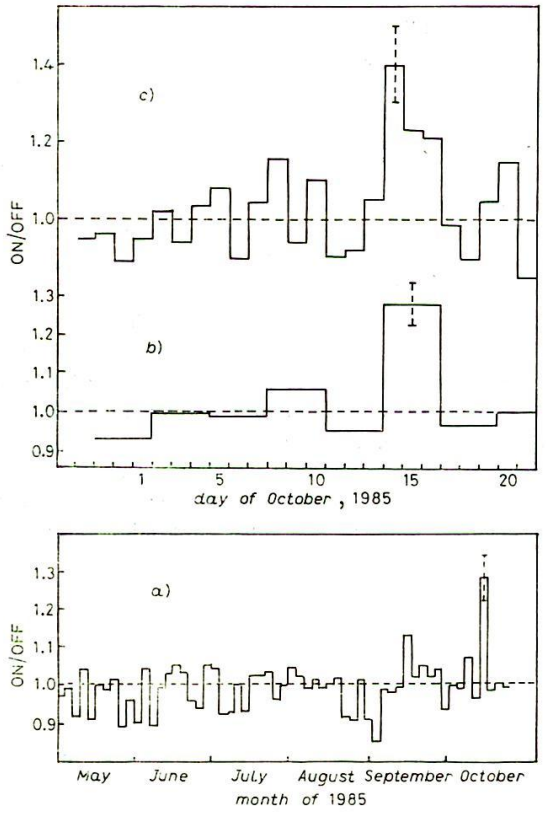
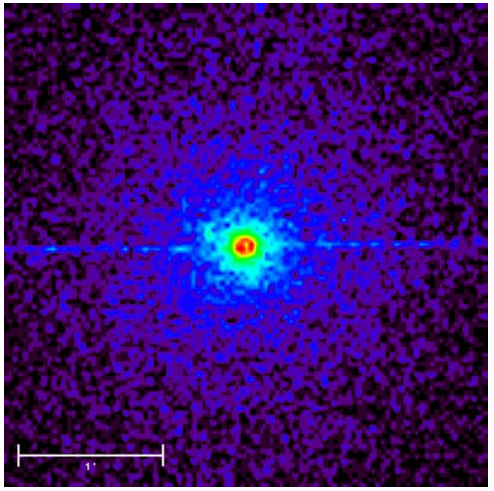


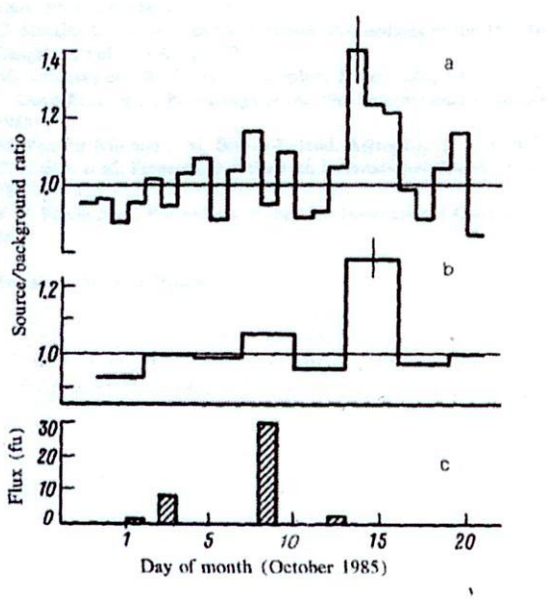
Fig. 5. – ON/OFF ratio for the epoch May-October 1985 (*a*)), and expanded for the duration of the October burst (*b*) 3-day step, *c*) 1-day step).

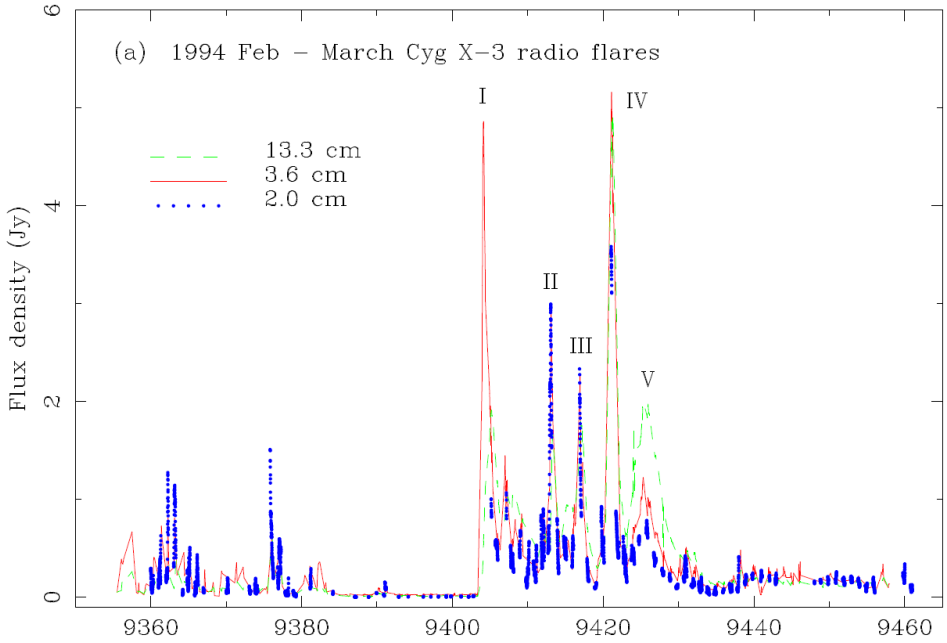


X-ray image (Chandra, 1999)

V.V. Alexeenko, A.E. Chudakov, Ya.S. Elensky, N.S. Khaerdinov, A.S. Lidvansky, N.I. Metlinsky, S.Kh. Ozrokov, V.V. Sklayrov, V.A. Tizengauzen, G. Navarra,
Cygnus X-3 Observation in Gamma-Ray Energy Range 10^{14} eV. Il Nuovo Cimento, 10C, 151-161 (1987).

Burst on October 14-16, 1985





Cygnus X-3 in outburst (Feb-March, 1994)

В.В. Алексеенко, А.С. Лидванский, Н.А. Метлинский, С.Х. Озроков, В.В. Скляров, В.А. Тизенгаузен, Н.С. Хаердинов, А.Е. Чудаков. О возможной вспышке источника Лебедь X-3 в диапазоне энергий $E > 10^{14}$ эВ. Письма в ЖЭТФ, 44, 202-205 (1986).

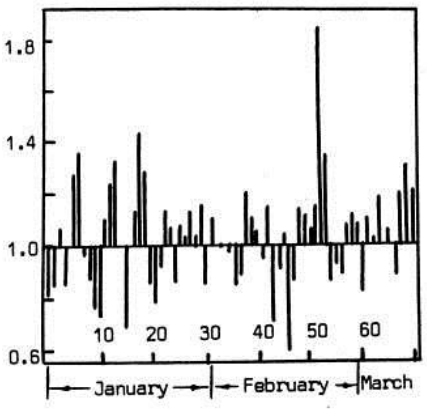
Gamma-ray astronomy

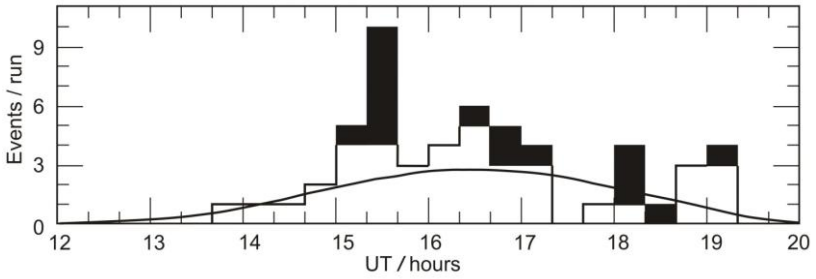
The Crab Nebula burst on Feb 23, 1989 r.
Baksan, KGF, Tien Shan, EAS-TOP

V.V. Alexeenko, A.S. Lidvansky, V.A. Tizengauzen,
A Search for > 10^{14} eV Gamma Rays from Point Sources at Baksan Air Shower Array, Proceed. of Intern. Workshop on Very High Energy Gamma Ray Astronomy, Crimea, 1989, ed. by A.A. Stepanyan, D.J. Fegan, and M.F. Cawley, p. 137

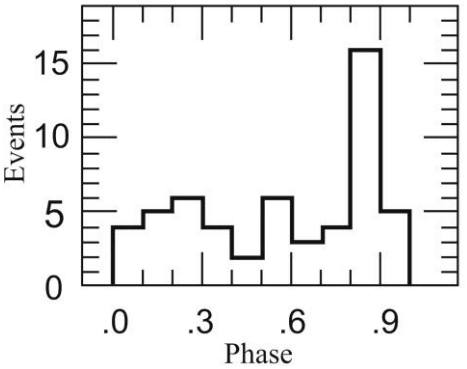
- Acharya B.S., Rao M.V.S., Sivaprasad K., Sreekantan B.V., and Vishwanath P.R., First simultaneous detection of PeV energy burst from the Crab Nebula,
  Nature, **347** (1990)**,** 364-5.

- V.V. Alexeenko, Yu.M. Andreyev, A.E. Chudakov, Ya.S. Elensky, A.S. Lidvansky, S.Kh. Ozrokov, Yu.V. Stenkin, V.A. Tizengauzen, L.J. Graham, J.L. Osborne, A.W. Wolfendale. The ultra-high energy gamma-ray burst from the Crab Nebula observed by the Baksan EAS array. Journ. of Phys. G : Nucl. Part. Phys. 18 (1992) L83-L88.

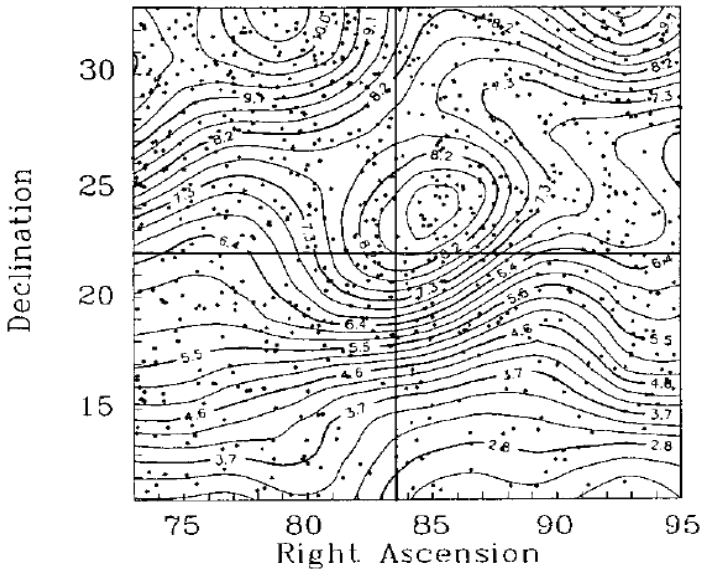


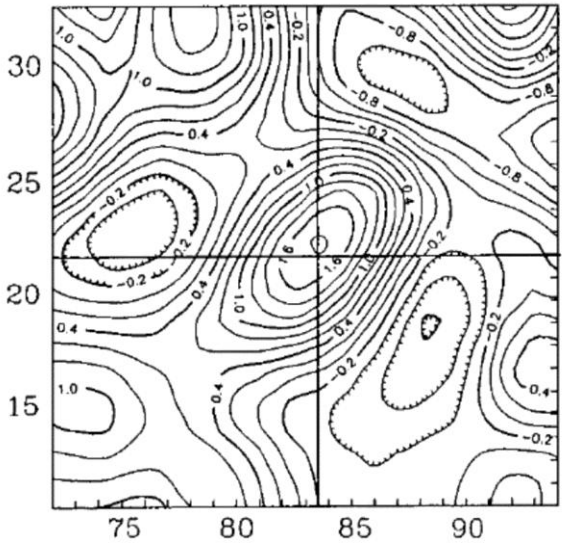


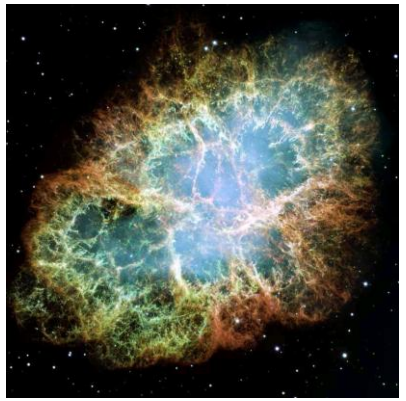
Time dependence of the counting rate in the source cell with a radius of 2.5°



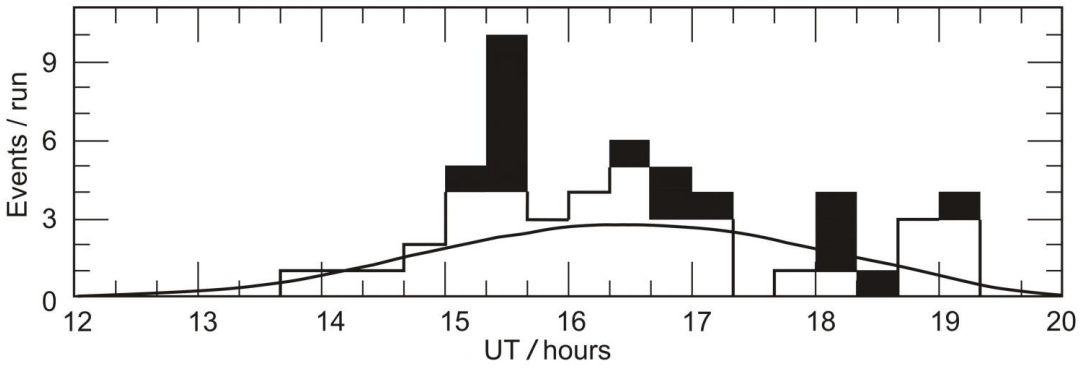
Phase analysis with period of pulsar PSR0531 (without absolute time reference)

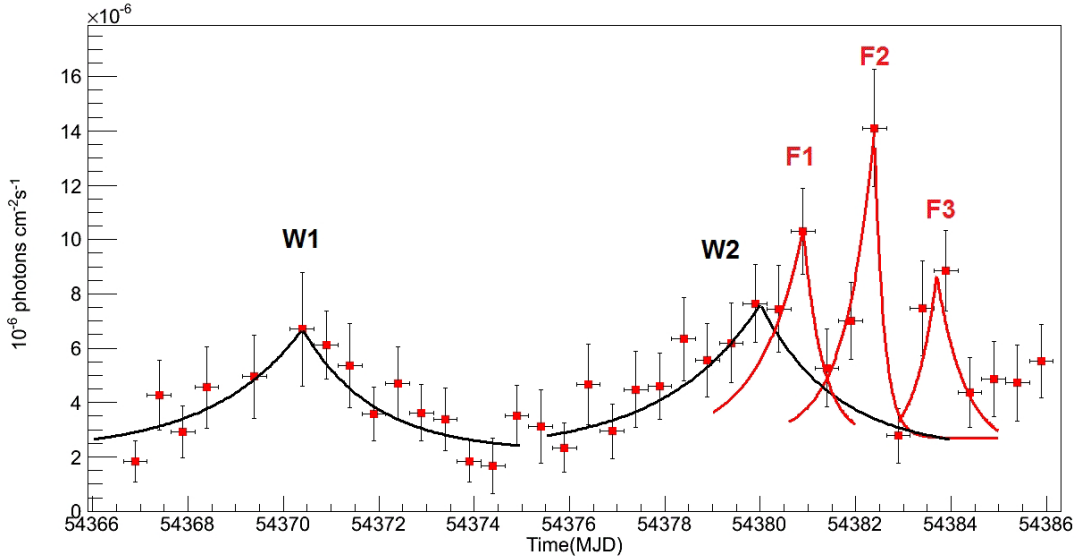


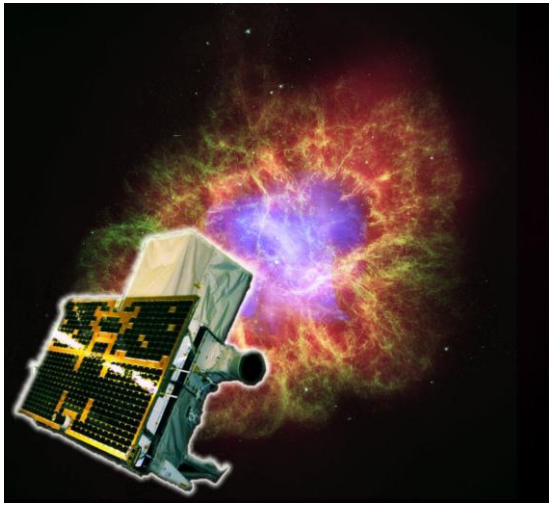




Similar triple time structure of flares for energies differing by a factor of 10^6. Single scale factor (about 20, hours and days, for a period of repetition and duration of pulses).







E. Striani et al., Variable gamma-ray emission from the Crab Nebula: short flares and long “waves”, Astrophys. Journ., 76552, 2013 March 1

Variations of cosmic rays during thunderstorms

Disturbances in secondary cosmic ray intensity during thunderstorms were first discovered in pioneering experiment in 1985 г.

Alexeyenko, V.V., Chudakov, A.E., Sborshikov, V.G., and Tizengauzen, V.A., Short perturbations of cosmic ray intensity and electric field in atmosphere, Proc. 19th ICRC, La Jolla, 1985, vol. 5, pp. 352-355.

The experiment restarted again at a new level in 2000.

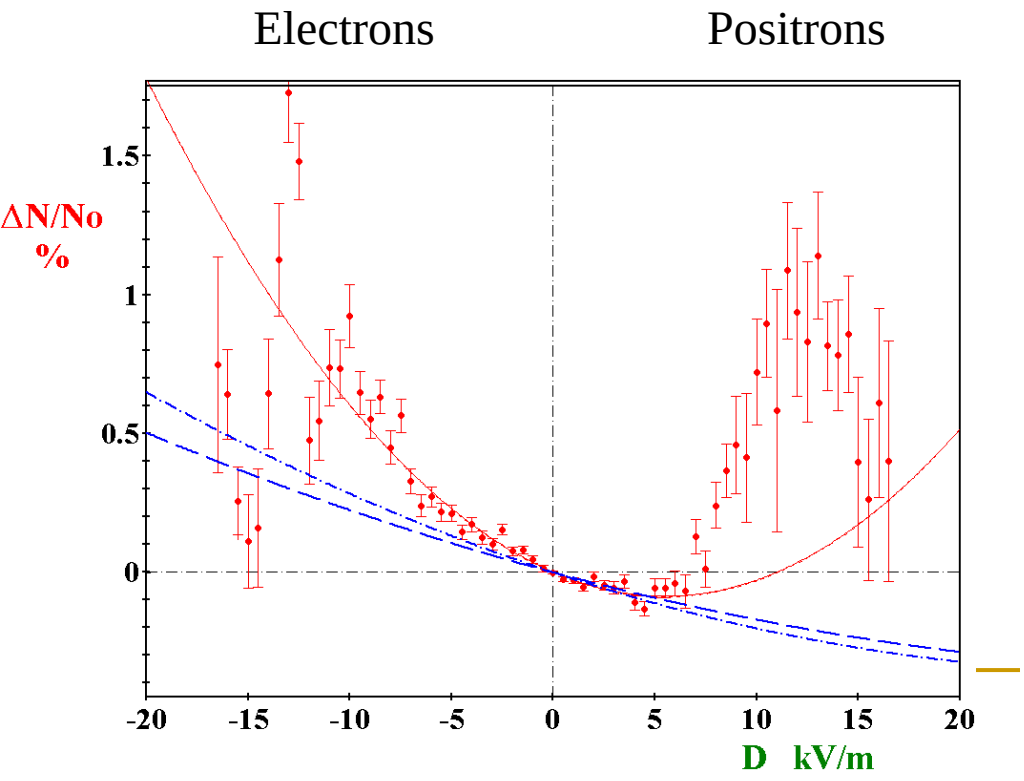
V.V. Alexeenko, N.S. Khaerdinov, A.S. Lidvansky, and V.B. Petkov, Transient Variations of Secondary Cosmic Rays due to Atmospheric Electric Field and Evidence for Pre-Lightning Particle Acceleration, Physics Letters A, 2002, vol. 301, issues 3-4, pp. 299-306.

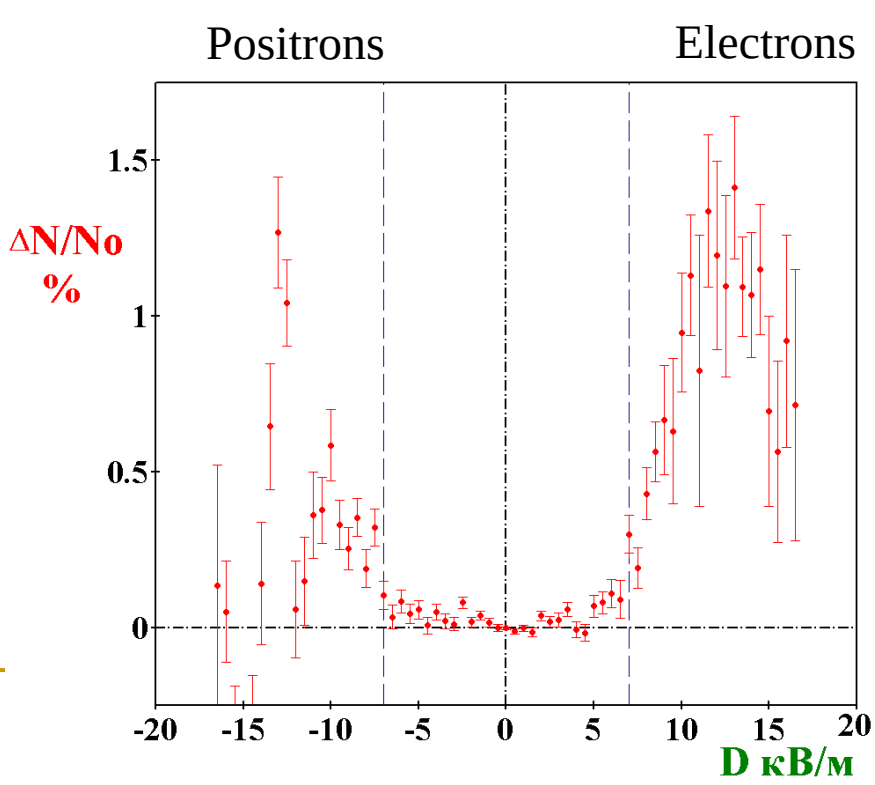
At the moment this line of research represents the separate field of science. The specialized annual TEPA (Thunderstorm Elementary Particle Acceleration) workshops are carried out at Nor-Amberd (Armenia).

Correlation the intensity of soft CR component with near-earth electric field as measured and calculated (on the left panel). The difference (not explained by the spectrum transformation in the field near the ground surface) is shown on the right panel

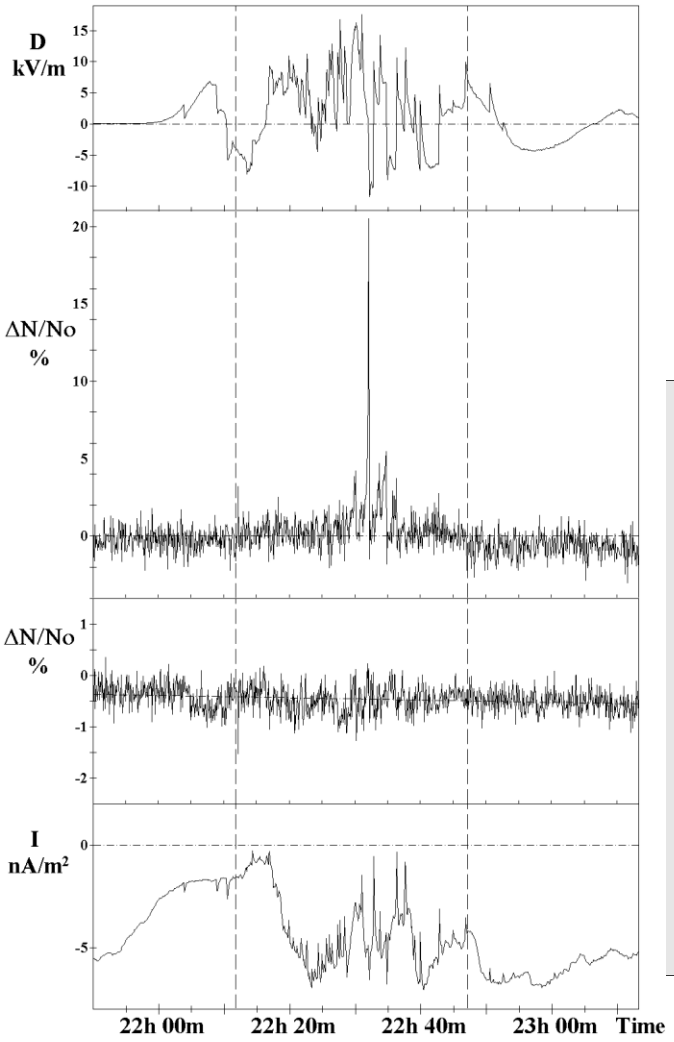
Accelerated near the ground

Accelerated in the clouds

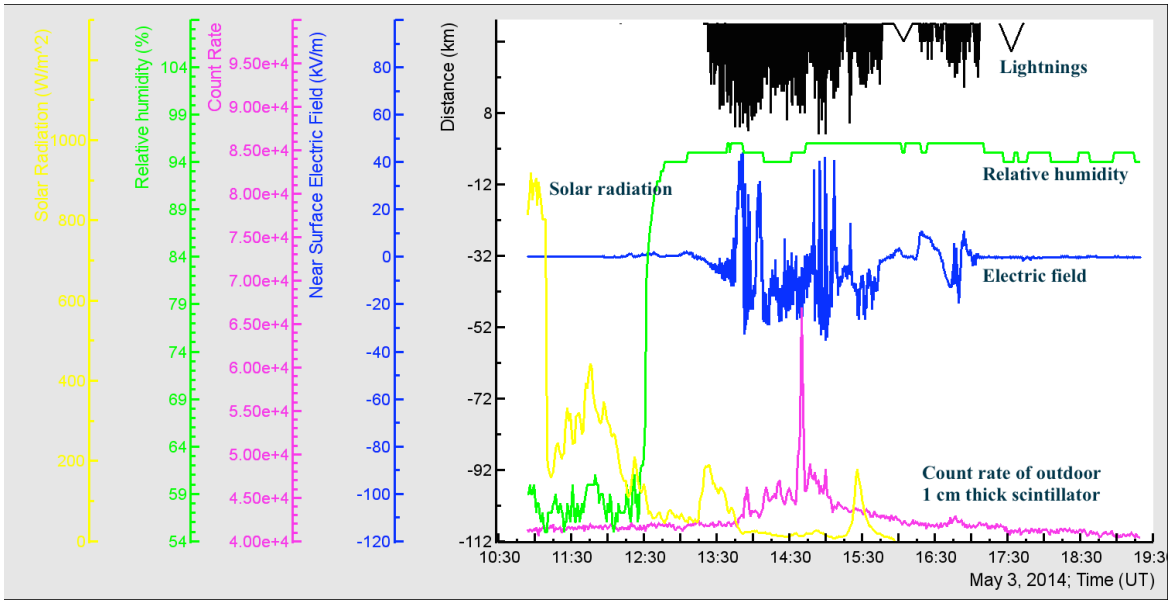




Strong enhancement of the soft component on September 7, 2000, Baksan Valley.

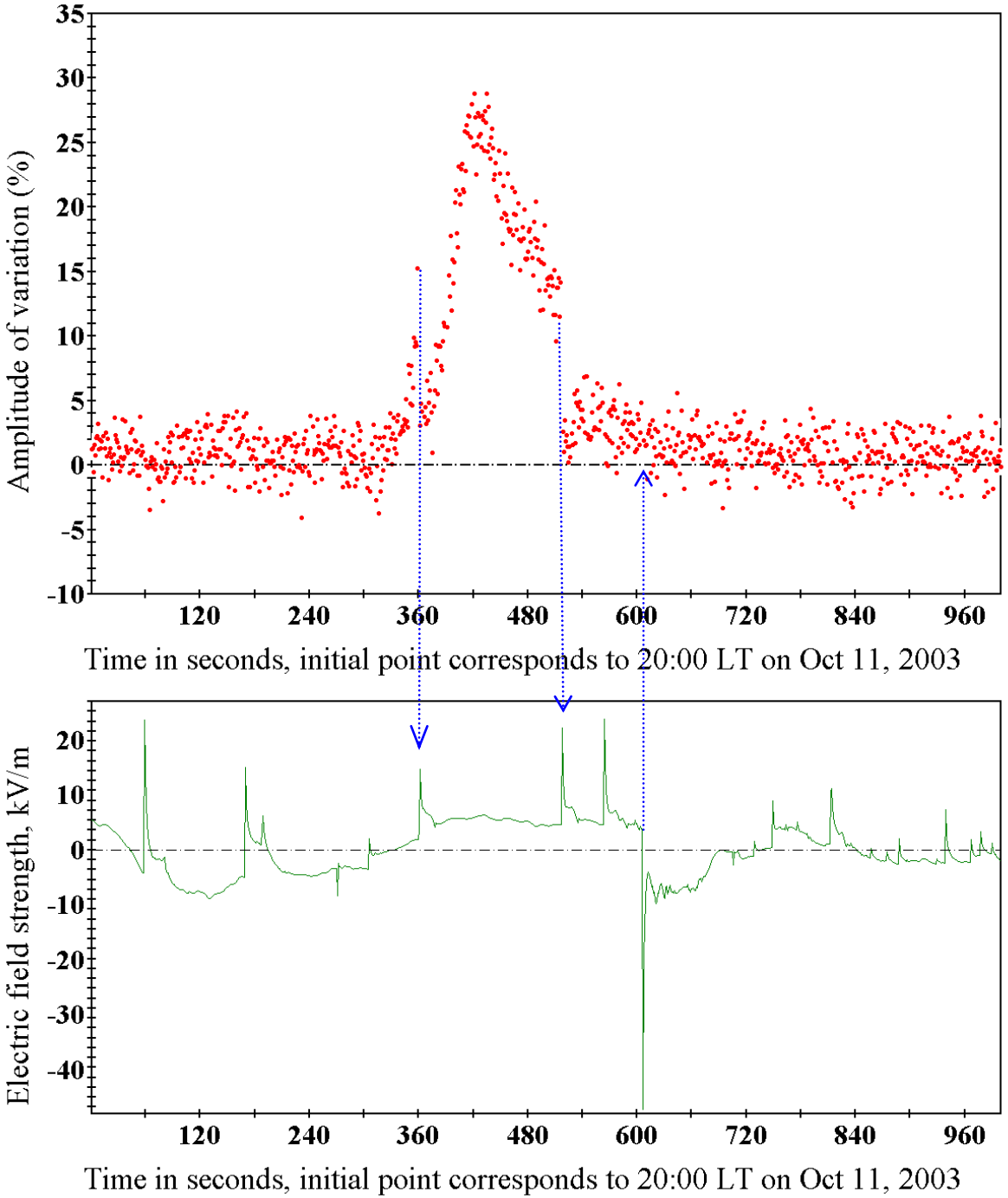


Mt. Aragats experiment in Armenia. Very similar example of TGE.

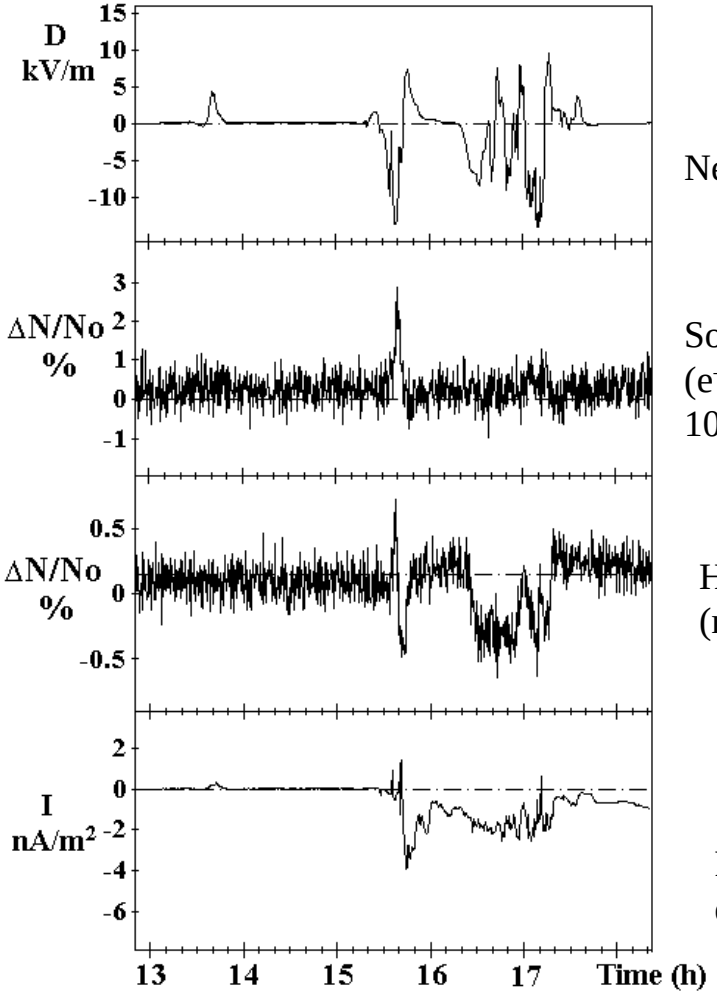


Record enhancement during thunderstorm on October 11, 2003

Estimates of minimal distance to two lightning strokes exerting strong effect on the intensity are 4.4 and 3.1 km. Other lightning discharges, including very near, give no such an effect.



Two strong variations of muons on one day of a year separated by seven years: September 24, 2000 and 2007. In the latter event sharp variations associated with lightning discharges are observed

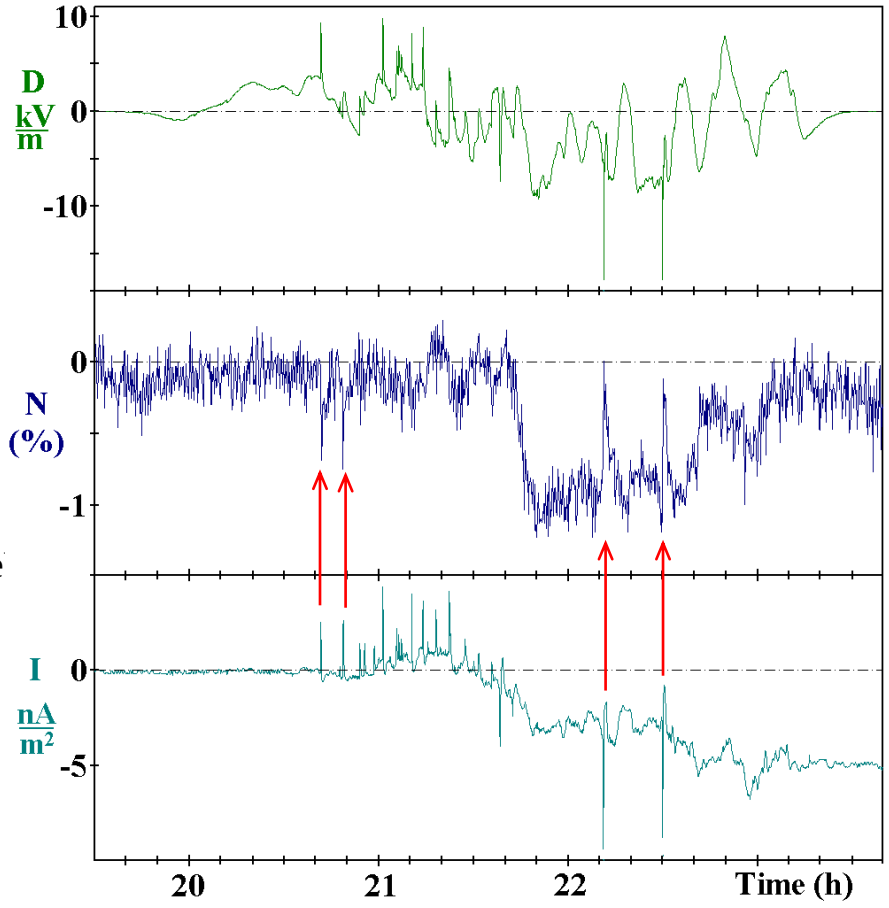


Near ground field

Soft component
(e^-, e^+, γ)
10-30 MeV

Hard component
(muons > 100 Me

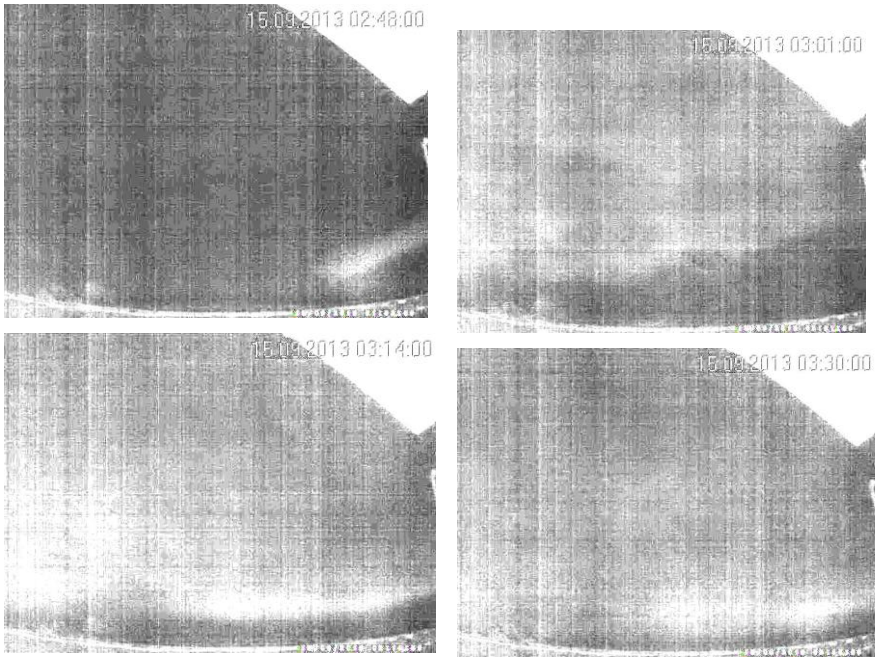
Precipitation
electric current



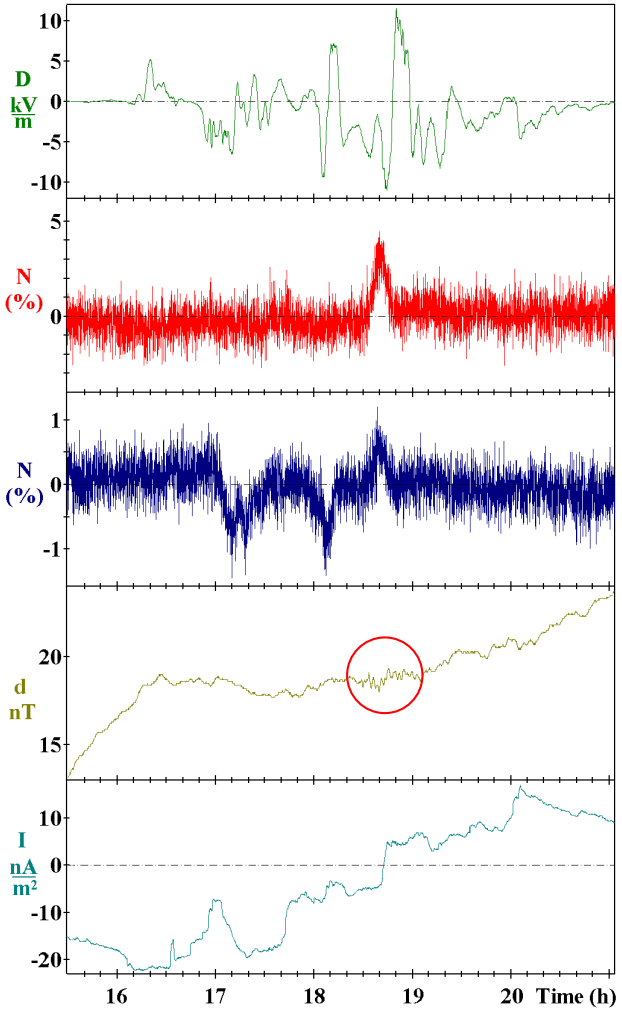
CR Variations during thunderstorms:

geomagnetic pulsations and new type of high-altitude discharge coincident with muon intensity disturbances

Thunderstorm event on September 15, 2013.



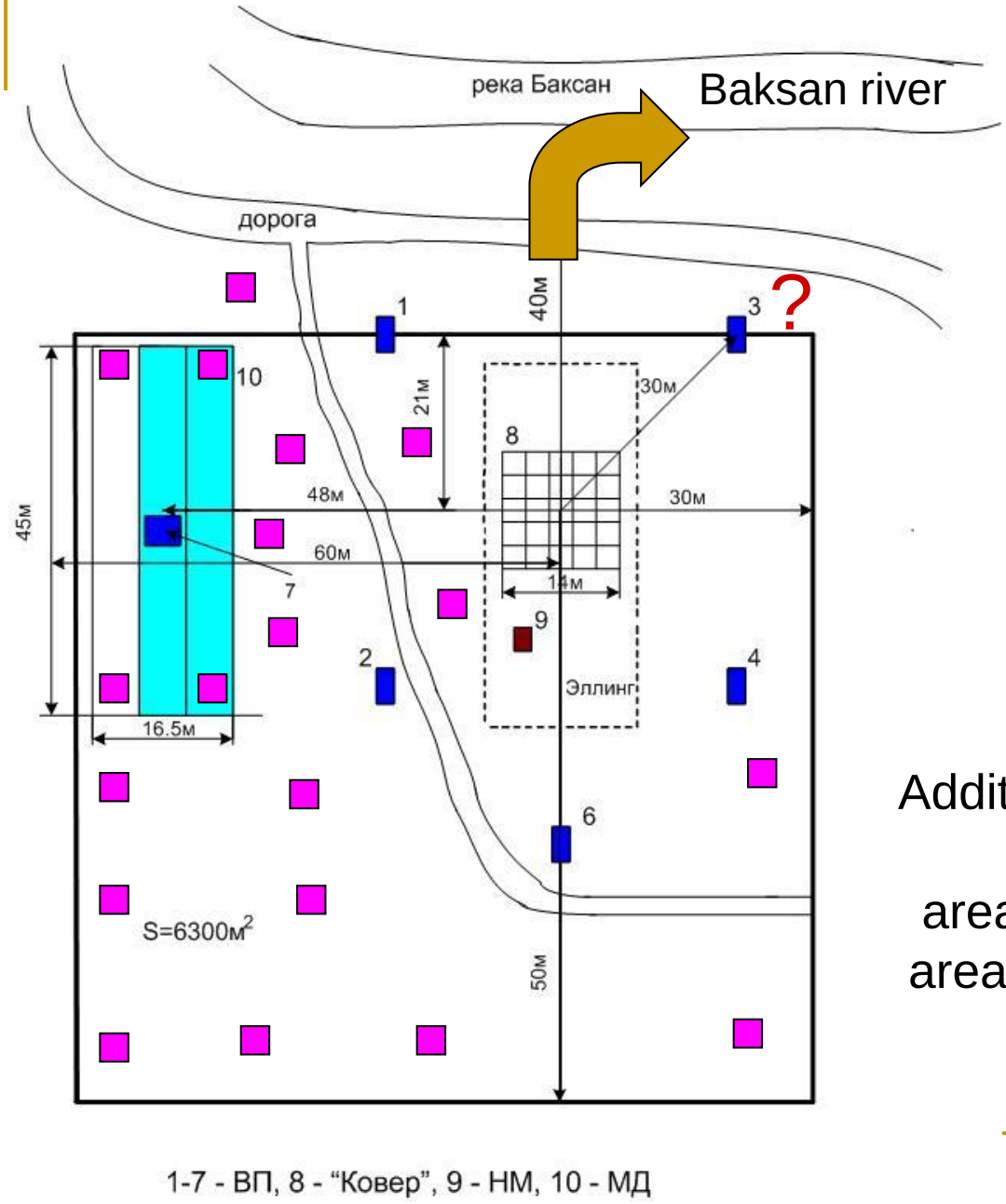
The event on October 15, 2007



Present-day prospects: Back to gamma-ray astronomy. Carpet-3 project

- Motivation: Ice Cube high-energy neutrino events
- Prediction of associated gamma rays
- Method: to search for diffuse gamma rays by selecting muon-poor showers
- Task and plans: to increase the area of the Muon Detector

Third tunnel of MD



1-7 - ВП, 8 - “Ковер”, 9 - НМ, 10 - МД

Carpet-3:
planned to operate since 2018

Muon Detector 410 m^2

Additional 20 modules of surface detectors of 8.3 m^2 area (9 scintillation counters of area of 0.92 m^2 in each module) December 2017

Conclusions

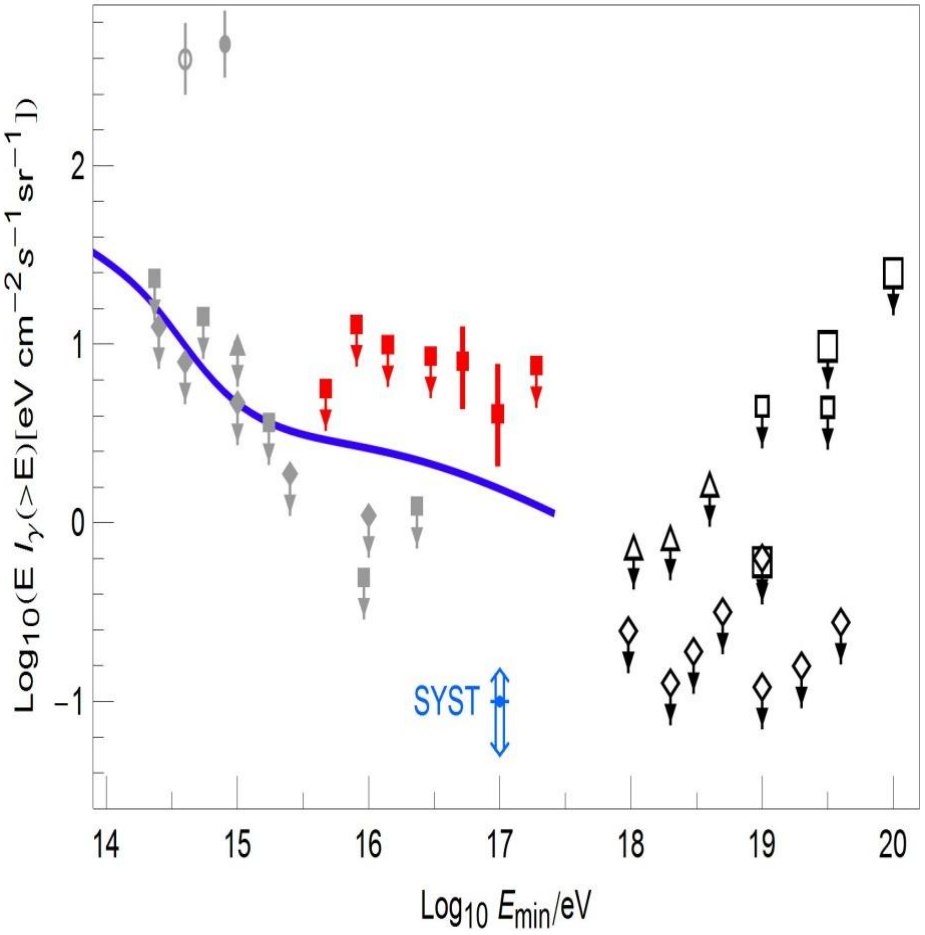
1. The Carpet air shower array was very efficient and useful instrument for cosmic ray studies

2. Carpet-3 project could be quite competitive in estimating the diffuse flux of high energy gamma rays

2. To perform this task better, it is highly desirable to increase the area of the Muon Detector as much as possible

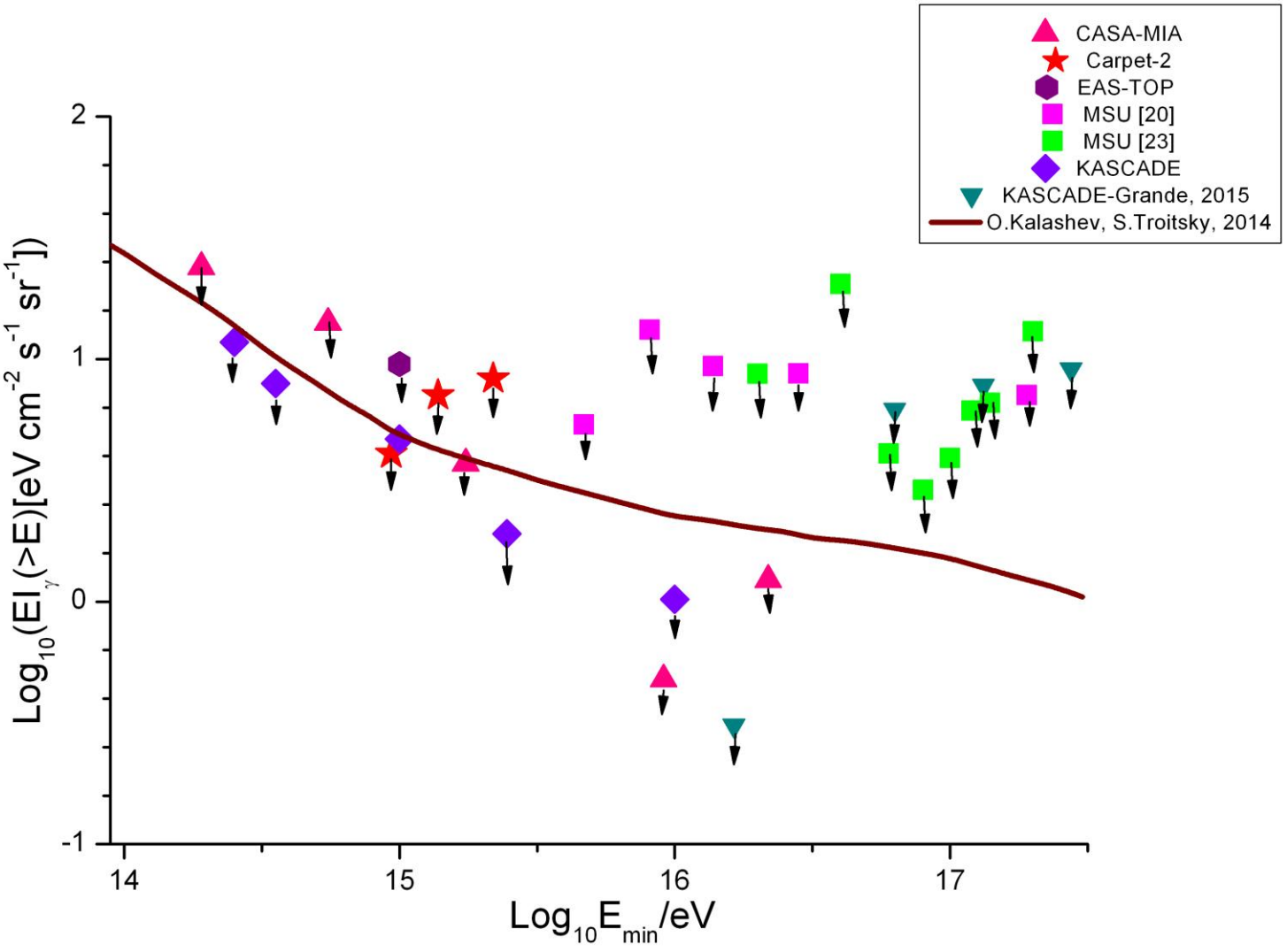
3. In spite of heavy damage due to a natural disaster, project is going on. 400 square meters MD is already in operation and work to reach 600 in the future is now in progress

The diffuse cosmic photon integral flux versus the photon minimal energy [data of experiments]



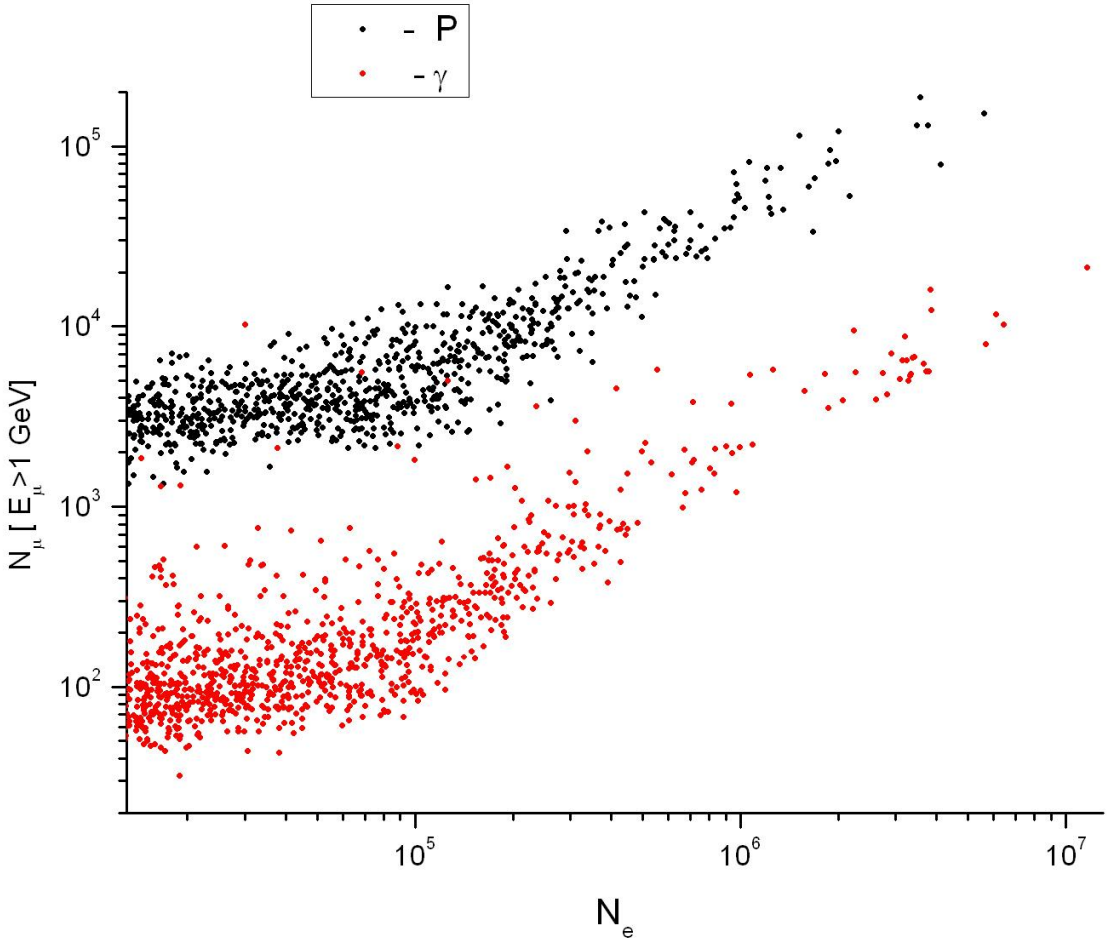
Estimates of the integral gamma-ray flux: Detection claims by Tien Shan (gray open circle) and Lodz (gray solid circle) and EAS-MSU (dark red squares and error bars).
Gray triangles, squares and diamonds are for EAS-TOP, CASA-MIA, and KASCADE, respectively.
Black open symbols: triangles (Yakutsk), diamonds (Pierre Auger), small squares (AGASA, large squares (Telescope Array).
The curve represents a theoretical prediction for the model in which photons and neutrinos are produced in cosmic-ray collisions with the hot gas surrounding our Galaxy, assuming the
best IceCube observed neutrino spectrum.

Upper limits on the flux of diffuse cosmic gamma rays

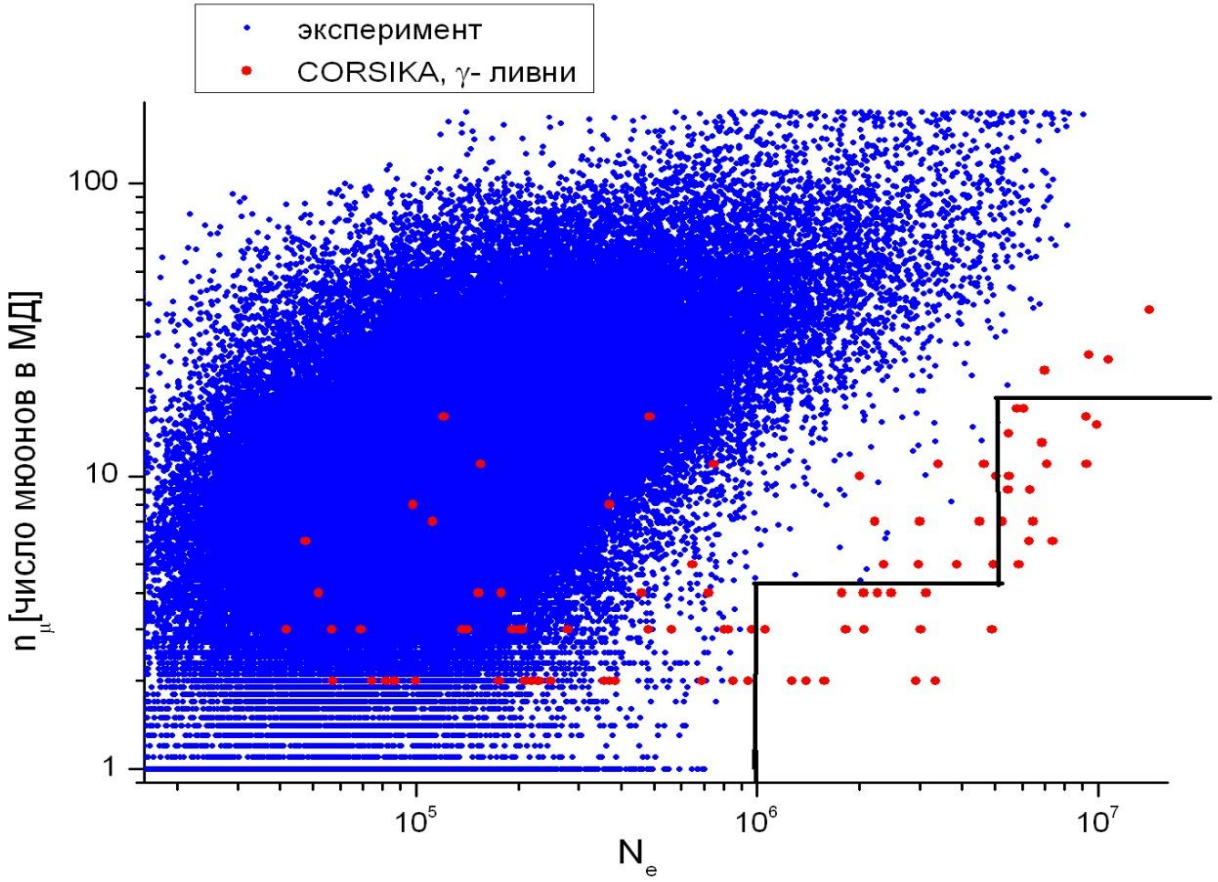


Method: To record muon-poor showers using a large-area muon detector

Nμ - Ne distribution for EAS with axes well inside the Carpet at an infinite MD area [calculation]



n_μ – N_e distribution: experiment and CORSIKA gammas



Carpet-3 sensitivity to the flux of diffuse cosmic gamma rays