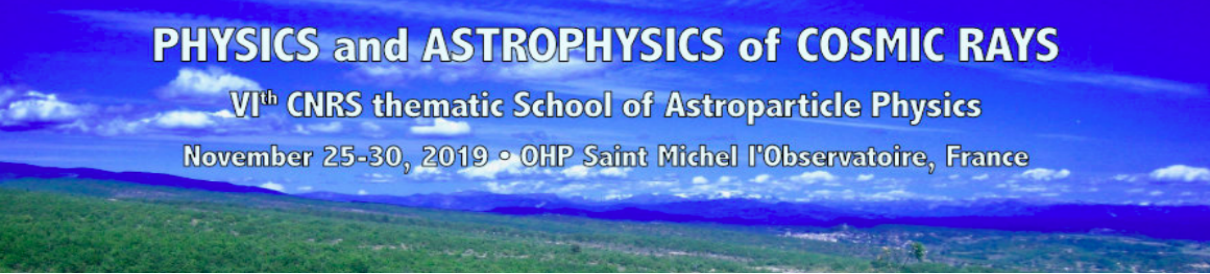


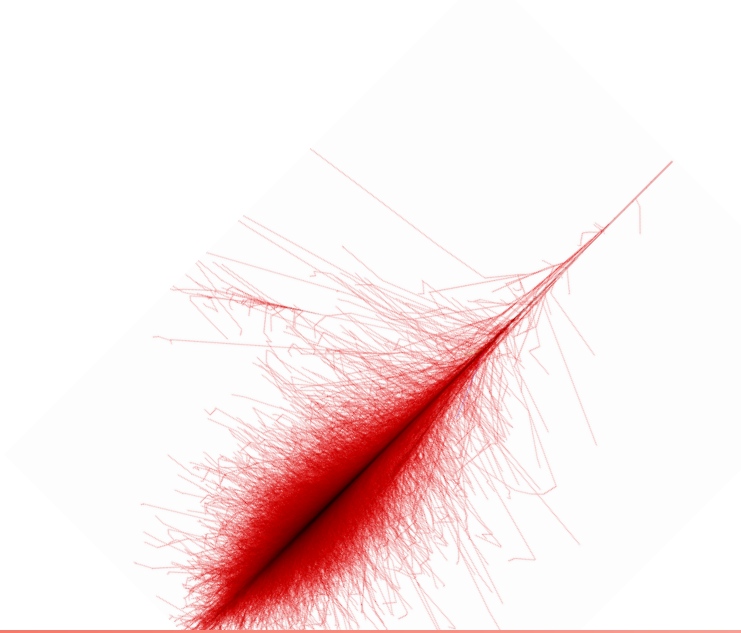

# Baksan EAS array
# Carpet-2 and Carpet-3 experiment

**Romanenko Viktor**

*Baksan Neutrino Observatory*
*of Institute for Nuclear Research of the Russian Academy of Sciences*

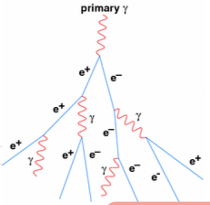
# Outlines



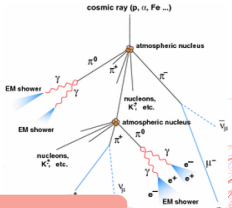


# Introduction

# Ultra-High Energy Gamma-Ray astronomy $\backsim 0.1 - 100$ *PeV*




Detection is done by registering the Extensive Air Shower which was produced by the primary particle




Showers from primary photons are essentially less abundant with hadrons (and, as a result, they are muon-poor) in comparison with showers from primary protons

Therefore large area muon detector is necessary for reliable distinguish of the showers

# Reason #1 - A search of the point sources

**Only three events were recorded**

- The possible burst of the source Cygnus X-3 in energy range $E > 10^{14} eV$ in 1985
- The burst of the Crab Nebula in energy range $E \backsim 10^{14} eV$ in 1989
- The burst of the Crab Nebula in energy range $E \geqslant 10^{14} eV$ on May 29th, 2019[1]
- The burst of the Crab Nebula in energy range $E \geqslant 10^{14} eV$ on June 13th, 2019[2]

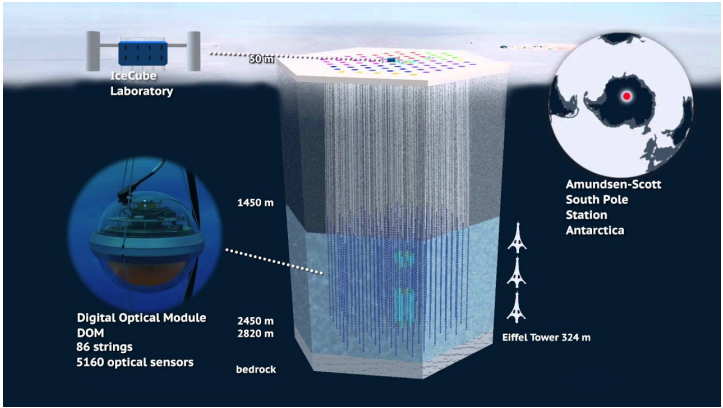
Thus the searches are necessary for describing the generation mechanism of such photons in source

[1] A. U. Abeysekara et al., 2019 ApJ 881 134, arXiv:1905.12518

[2] M. Amenomori et al. (Tibet AS$\gamma$ Collaboration), Phys. Rev. Lett. 123, 051101, arXiv:1906.05521

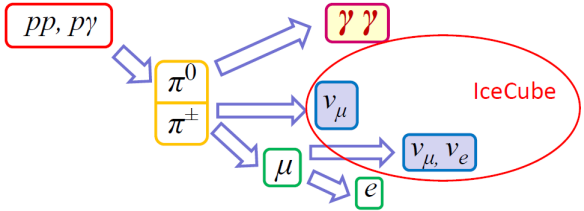
# Reason #2 - Diffuse cosmic gamma-rays search

IceCube results on detection of high-energy astrophysical neutrinos stimulated experiments searching for 100 TeV diffuse gamma rays



# Reason #2 - Diffuse cosmic gamma-rays search

Diffuse gamma rays produced in decays of neutral pions
like as neutrinos in charged

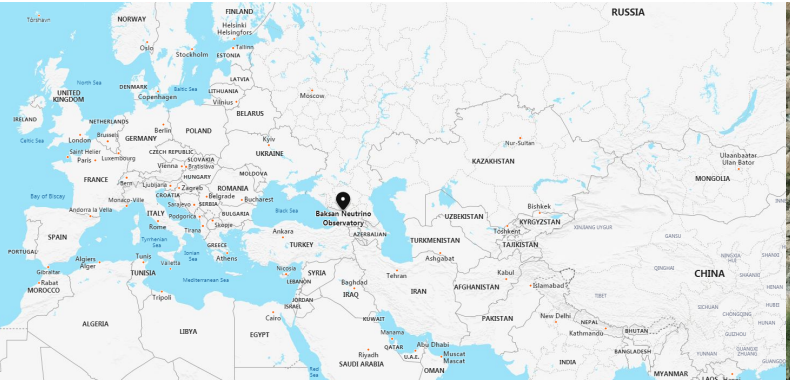


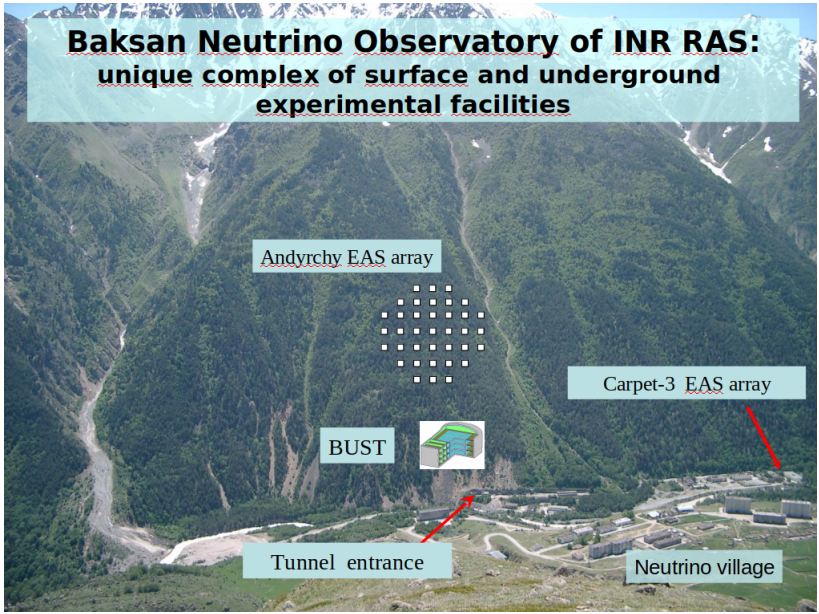

But at the moment there are no reliable data on the registration of such photons

Therefore large-area muon detectors were planned and constructed for a method of muon-poor showers (GRAPES-3, Tibet AS+MD, ALPACA, etc.)

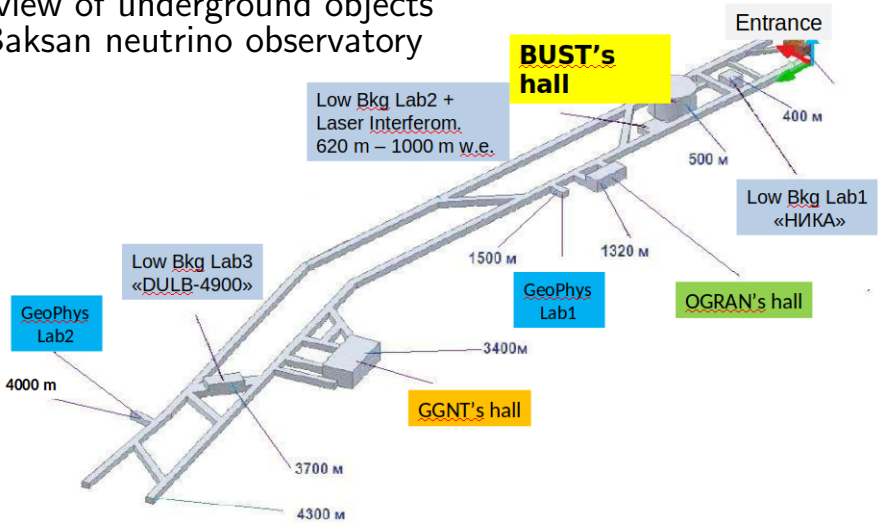
**The Carpet-3 is one of such experiments**

# Baksan Neutrino Observatory





Baksan Neutrino Observatory of INR RAS:
unique complex of surface and underground experimental facilities
Andyrchy EAS array
Carpet-3 EAS array
BUST
Tunnel entrance
Neutrino village

# General view of underground objects of the Baksan neutrino observatory



# Baksan EAS array

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

ON is the real number of events from the Cygnus cell,
OFF is the mean value of the four off-source cells.

[3] Alexeenko, V.V., Chudakov, A.E., Elensky, Y.S. et al. Il Nuovo Cimento C (1987) 10: 151



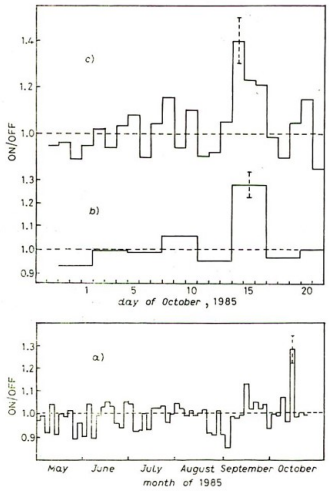
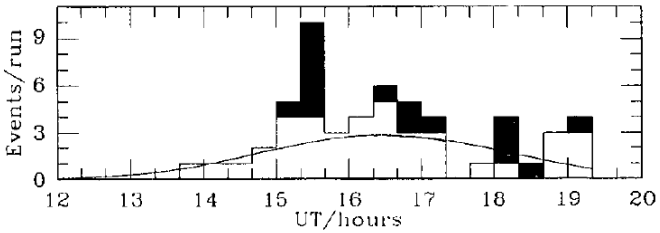



Fig. 5. – ON/OFF ratio for the epoch May-October 1985 (*a*)), and expanded for the duration of the October burst (*b*) 3-day step, *c*) 1-day step).

# The Crab Nebula burst
## on February 23, 1989[4]

With different significance the burst was detected by: KGF (India), Tien Shan (USSR), Baksan (USSR), EAS-TOP (Italy)

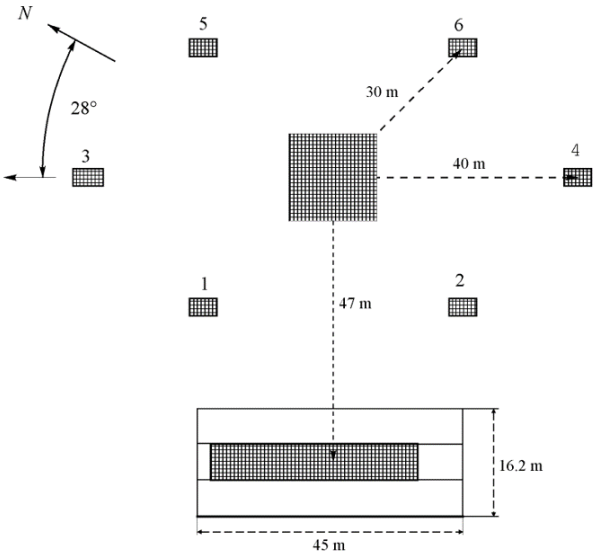


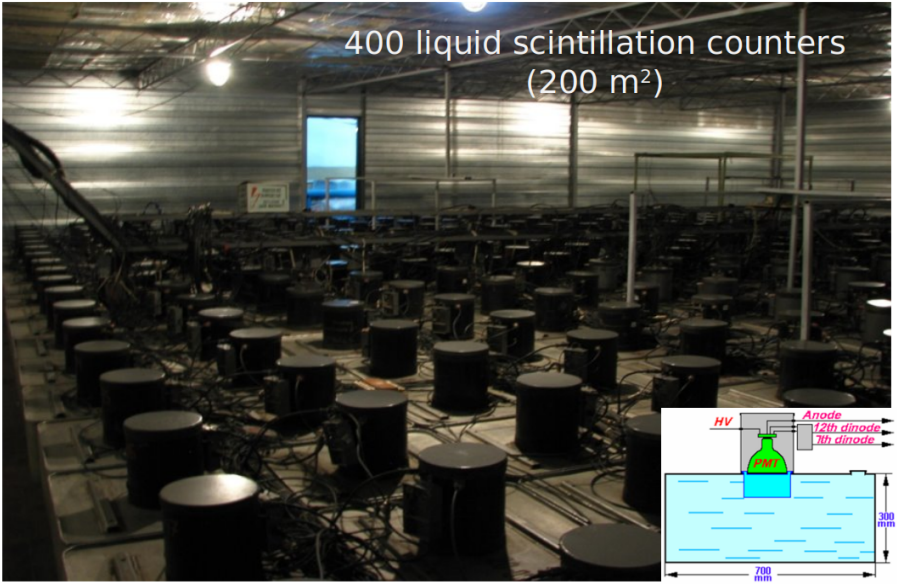

| Array | Observation time (range of UT) | Counts ON | Counts OFF | Excess (SD) |
|---|---|---|---|---|
| KGF | 13–16 | 35 | 17.8 | 3.4 |
| Tien Shan | 13–16 | 6 | 1.6 | 2.6 |
| Baksan | 15–18 | 55 | 34.1 | 3.1 |
| EAS Top (Gran Sasso) | 17–20 | 38<br>403 | 25.5<br>378.3 | 2.1<br>1.2 |

[4] V V Alexeenko et al 1992 J. Phys. G: Nucl. Part. Phys. 18 L83

# Carpet-2 experiment

- "Carpet": 400 liquid scintillation counters ($200m^2$),
- 6 shower detectors: 18 liquid scintillation counters ($9m^2$) each,
- Muon Detector: 175 plastic scintillation counters, $175m^2$, $E_\mu \geqslant 1GeV$.




400 liquid scintillation counters
(200 m²)
HV
Anode
12th dinode
7th dinode
PMT
300 mm
700 mm


126
127
128
122
123
117
118
18
Anode
HV
12 dinodа
730
50
1005

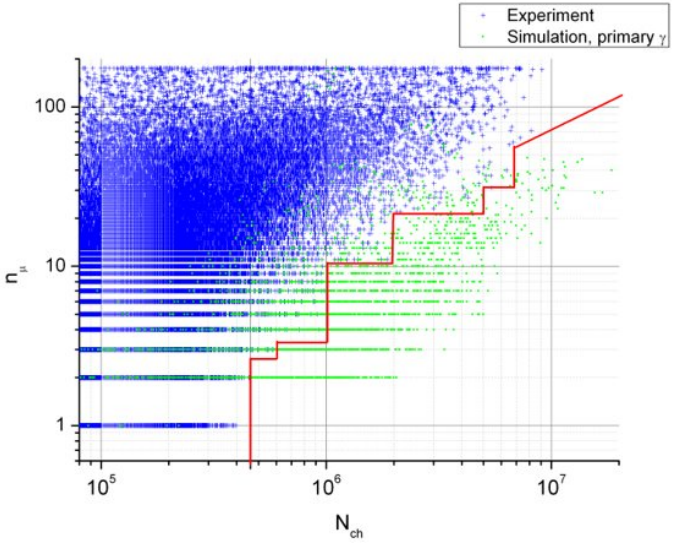
## $N_\mu - N_{ch}$ distribution

$T_{live} = 3390$ *days*

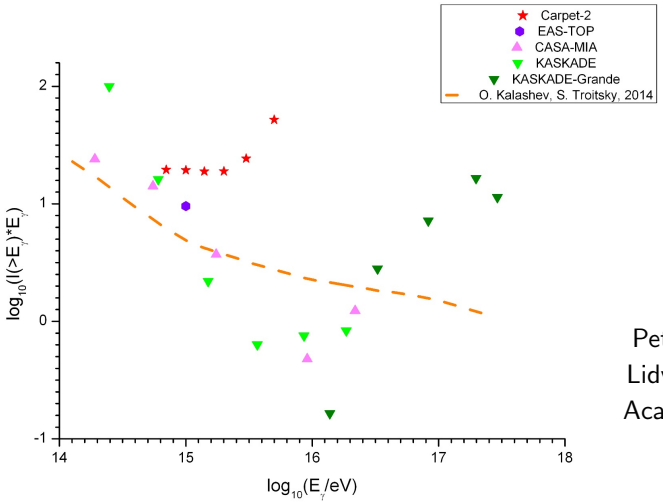
Upper limits on the flux can be estimated using follow formula:

$$I_\gamma(> E_0) = \frac{N_{90}}{S \cdot T \cdot \Omega \cdot \varepsilon_1(> E_0) \cdot \varepsilon_2(> E_0)}$$

where $N_{90} = 2.3$ (from Poisson statistics at a 90% confidence level),
$\varepsilon_1(> E_0)$ is the efficiency of detection of showers and of reconstruction their parameters,
$\varepsilon_2(> E_0)$ is selection efficiency for the gamma showers.



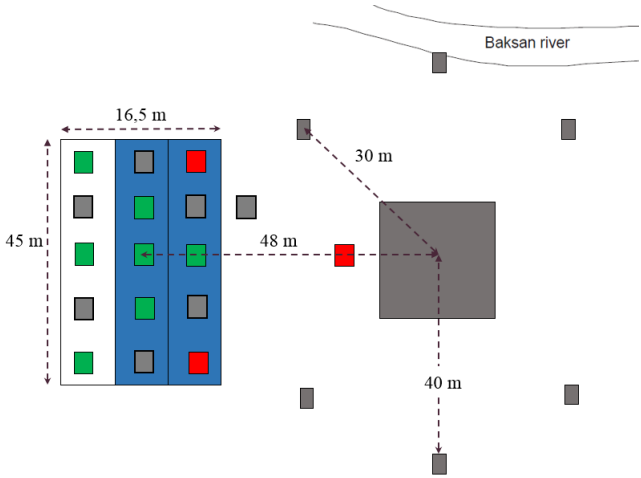
# Upper limits on the flux of diffuse gamma-rays



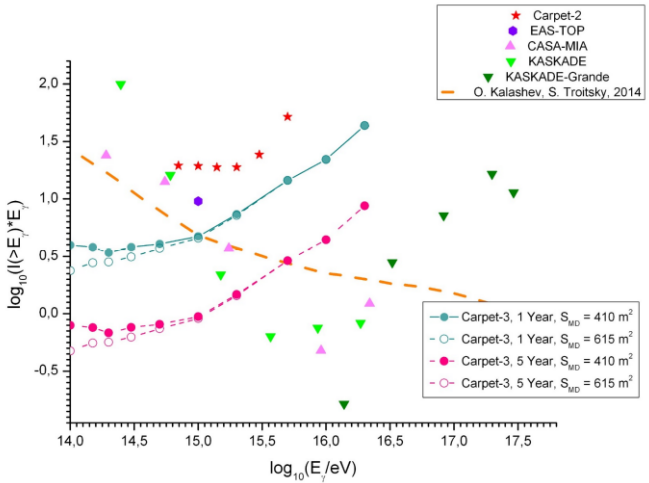

Petkov, V.B., Dzhappuev, D.D., Lidvansky, A.S. et al. Bull. Russ. Acad. Sci. Phys. (2019) 83: 941.

# Carpet-3 experiment

- Muon Detector: 410 plastic scintillation counters, $410m^2, E_\mu \geqslant 1GeV$,
- 7 shower detectors are already installed above MD ($9m^2$) each,
- 20 additional shower detectors are planned in the future ($9m^2$) each,



# Preliminary simulation of Carpet-3




Dzhappuev, D.D., Petkov, V.B., Lidvansky, A.S. et al. Bull. Russ. Acad. Sci. Phys. (2017) 81: 424

# Conclusion

- Large-area muon detectors are necessary to distinguish gamma showers from hadron shower
- The Carpet-3 air shower array is under construction at the Baksan Neutrino Observatory. The aim is to study diffuse gamma-ray background at energy above 100 TeV
- The Carpet-3 project is ready to start operating with 410 $m^2$ MD

After the final accomplishment of this array, it can be competitive in it's class and will have a chance to get the world-best limit on the gamma rays flux of cosmic origin.

This will allow one to solve the problem of the origin of high-energy astrophysical neutrinos detected by IceCube.