Experimental complex for multi-component detection of the EAS in a wide energy range ($10^{15}$ – $10^{19}$ eV)

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Experimental complex NEVOD (MEPhI, Moscow)
General view of the complex

Cherenkov water detector NEVOD:

Muon hodoscope URAGAN
Sensitive area ~ 46 m²

9 x 9 x 26 m³ = 2000 m³;

System of calibration telescopes (SCT)
80 scintillation counters

Coordinate tracking detector DECOR:
Sensitive area ~ 70 m²

Detector PRISMA-32
32 detectors of thermal neutrons
Cherenkov water calorimeter NEVOD

Quasispherical module (QSM)

- Dense spatial lattice of QSM: 91 QSM; 546 PMT
  spacing: 2 m along X and Z; 2.5 m – Y
- PMTs dynamic range – $10^5$ ph.e.

Kokoulin et al. Poster # 146
DECOR – coordinate-tracking detector

Constructed from streamer tube chambers supplied by Istituto di Cosmogeofisica, Torino, Russian-Italian project DECOR

- The vertical arrangement of the detector (!).
- Eight independent supermodules with area of 8.4 m² each.
- High spatial (~ 1 cm) and angular (~1°) measurement accuracy.
- Possibility to separate tracks up to 200 registered particles (3 cm).

The main task of NEVOD-DECOR complex - the study of the muon component in wide ranges of multiplicities and zenith angles (up to the horizon).
Muon bundles in inclined EAS
The method of the Local Muon Density Spectra (LMDS)

\[ D = \frac{\text{(number of muons)}}{\text{(detector area)}}; \quad [D] = \text{particles} / \text{m}^2. \]

- Practically pure muon component
- Collection area rapidly increases with zenith angle (~ 1 km\(^2\) at 80°)
- The arrival direction of the EAS and the local density of muons at the observation point are measured.

At large zenith angles:
New approach: Local density spectra of EAS muons

Tracking detector DECOR: a new approach provides possibility to study PCR in a very wide energy range (from $10^{15}$ to $10^{19}$ eV) by means of a single, not large detector

“Muon puzzle”: the analysis of obtained LMDS reveals an excess of multi-muon events at large zenith angles in comparison with simulations performed within the framework of commonly used hadron interaction models (even under assumption of heavy primaries – iron nuclei).

Kokoulin et al. This conference talk
New detectors:

- Large area tracking detector TREK
- Extensive air shower array NEVOD-EAS
- Detector of atmospheric neutrons URAN
Objectives:
Investigation of muon bundles generated by cosmic rays of ultrahigh energies \((10^{15} - 10^{19} \text{ eV})\) at large zenith angles.

Drift chamber:
- Size - 4000×508×112 mm\(^3\)
- Gas mixture - 94% argon and 6% CO\(_2\)
- Angular resolution \(\sim 30\) mrad
- Coordinate accuracy \(\sim 1\) mm

Tracking detector TREK:
- two vertical planes of 264 drift chambers with X-Y orientation will be mounted on the outer wall of the CWD building.
- Effective area of the detector \(\sim 270\) m\(^2\).

The new detector TREK will surpass currently operating coordinate detector DECOR:
- in the effective area by 3.5 times
- in the separation of close tracks in bundles by 10 times.
The layout of coordinate-tracking detector TREK

TREK detector
MEPhI – IHEP (Protvino) Collaboration

TREK prototype - CTUDC

Bogdanov et al. Poster # 115
Detection of multi-particle events

**DECOR**

Multiplicity: \( m = 46 \)

Projection zenith angle: \( \theta = 64.6^\circ \)

**CTUDC**

Multiplicity: \( m = 32 \)

Projection zenith angle: \( \theta = 65^\circ \)
The problem of LMDS approach – low PCR energy resolution: $\sigma_{\lg E} \approx 0.4$

Contribution to the events with fixed LMDS is provided by EAS with different energies, registered at different (random) distances from the axis.

The idea of improvement - deployment around the NEVOD-DECOR the traditional EAS array.

NEVOD-EAS is located on the roofs of the MEPhI laboratory buildings and between of them.

NEVOD-EAS - array of clusters of KASCADE-Grande scintillation detectors
Central part of NEVOD-EAS detector

Central part of the setup - 12 clusters. The distance between the clusters is $\sim 50$ m. The total area of the setup is $\sim 2 \times 10^4$ m$^2$. 
Detection of EAS

Example of the event registered by NEVOD-EAS and NEVOD-DECOR

NEVOD-EAS
Cluster 3
$\varphi = 56.3^\circ$
$\theta = 29.5^\circ$

NEVOD-DECOR
$\varphi = 54.4^\circ$
$\theta = 29.5^\circ$
URAN - detector for registration of atmospheric neutrons

A study of the neutron component of extensive air showers (EAS).

URAN together with NEVOD facilities allows to conduct investigations of EAS neutron component in the energy range of cosmic rays $10^{14} - 10^{16}$ eV including the “knee” region.

Detector: inorganic scintillation ZnS(Ag) + B$_2$O$_3$

Registration of neutrons:

\[ ^{10}\text{B} + n \rightarrow ^7\text{Li} + \alpha + 2,792 \text{ MeV} \]
\[ ^{10}\text{B} + n \rightarrow ^7\text{Li}^* + \alpha + 2,31 \text{ MeV} \]
\[ ^7\text{Li}^* \rightarrow ^7\text{Li} + \gamma + 482 \text{ keV} \]

The thickness $\sim 50 \text{ mg/cm}^2$; efficiency of neutron detection $\sim 20\%$
URAN - detector for registration of atmospheric neutrons

**URAN:**
- Cluster structure (12 counters in a cluster)
- Distance between counters: 4 - 5 m
- Effective area of the counter: 0.36 m²
- Scintillator: ZnS(Ag)+B₂O₃

**First stage:**
- 72 counters located on the roofs of NEVOD and neighbouring laboratory building near NEVOD
- Total area: $10^3$ m²
Conclusion

Experimental Complex NEVOD

Present:

✓ Continuous measurements and analysis of data obtained with currently operating detectors of experimental complex (CWD NEVOD, DECOR, CTS, URAGAN, PRISMA ...)
✓ Problem of common trigger

2017 – 2018:

• Deployment, start and continuous operation of new facilities: NEVOD-EAS, URAN and TREK
• Careful simulation
• Conducting of a multi-component research of EAS with the complex:

  ➢ **CW calorimeter NEVOD** → cascades, muon bundle and EAS’s core energy deposit
  ➢ **NEVOD-EAS** → EAS parameters
  ➢ **URAN&PRISMA** → e- and n components
  ➢ **DECOR&TREK** → muon bundles (m, θ)
  ➢ **SCT** → muon bundles + e, h+EAS core, energy deposit
Thank you for attention!