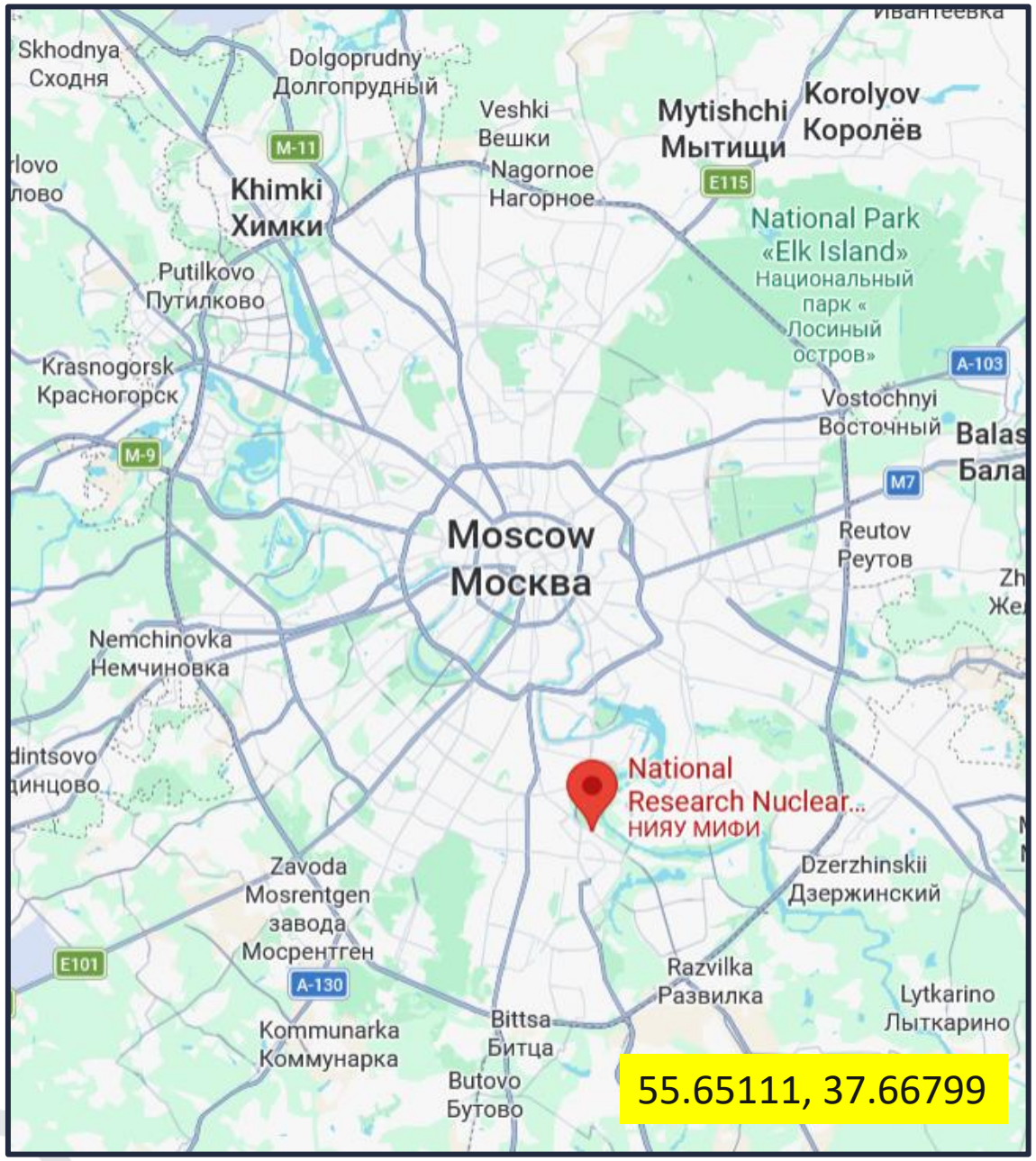
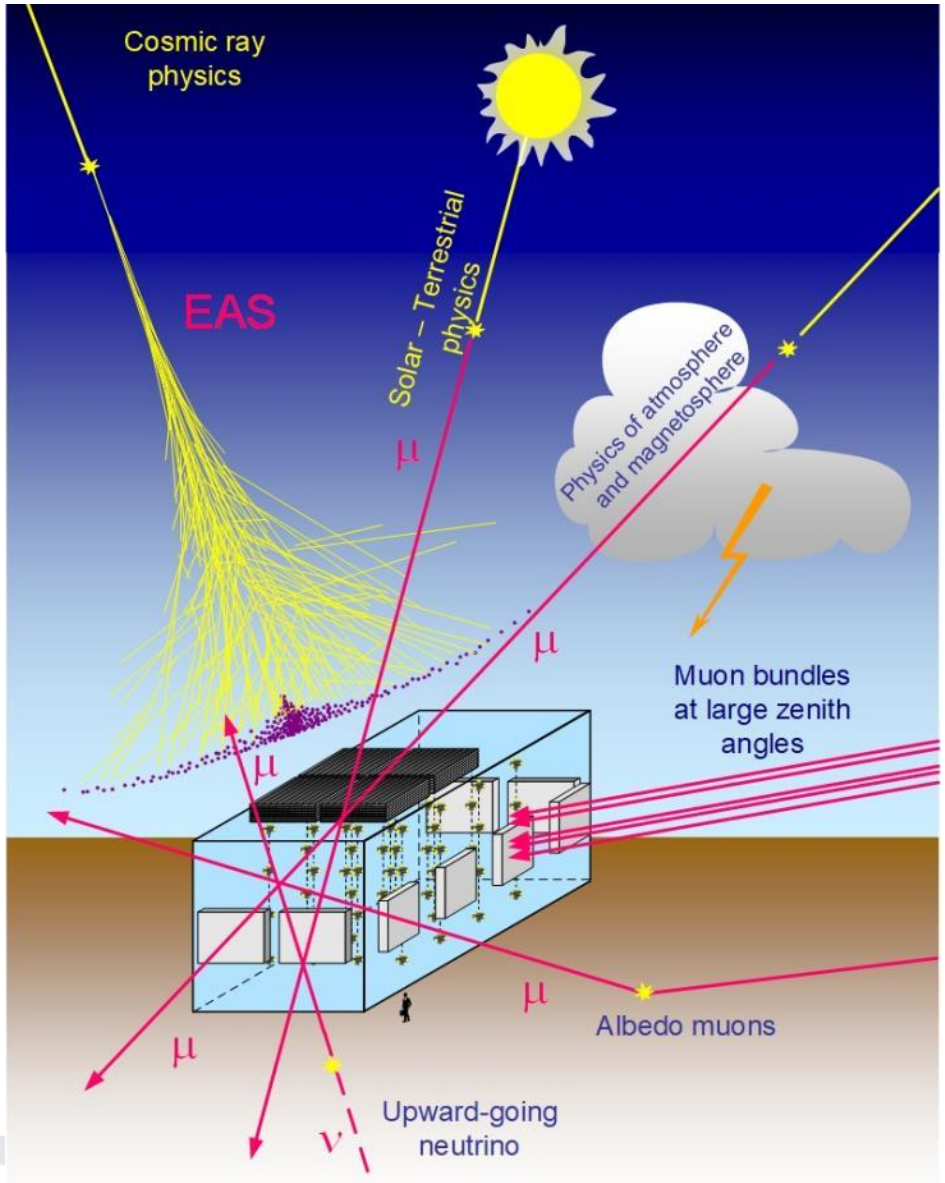
The Unique Scientific Facility “Experimental Complex NEVOD”

Experimental Complex (EC) NEVOD



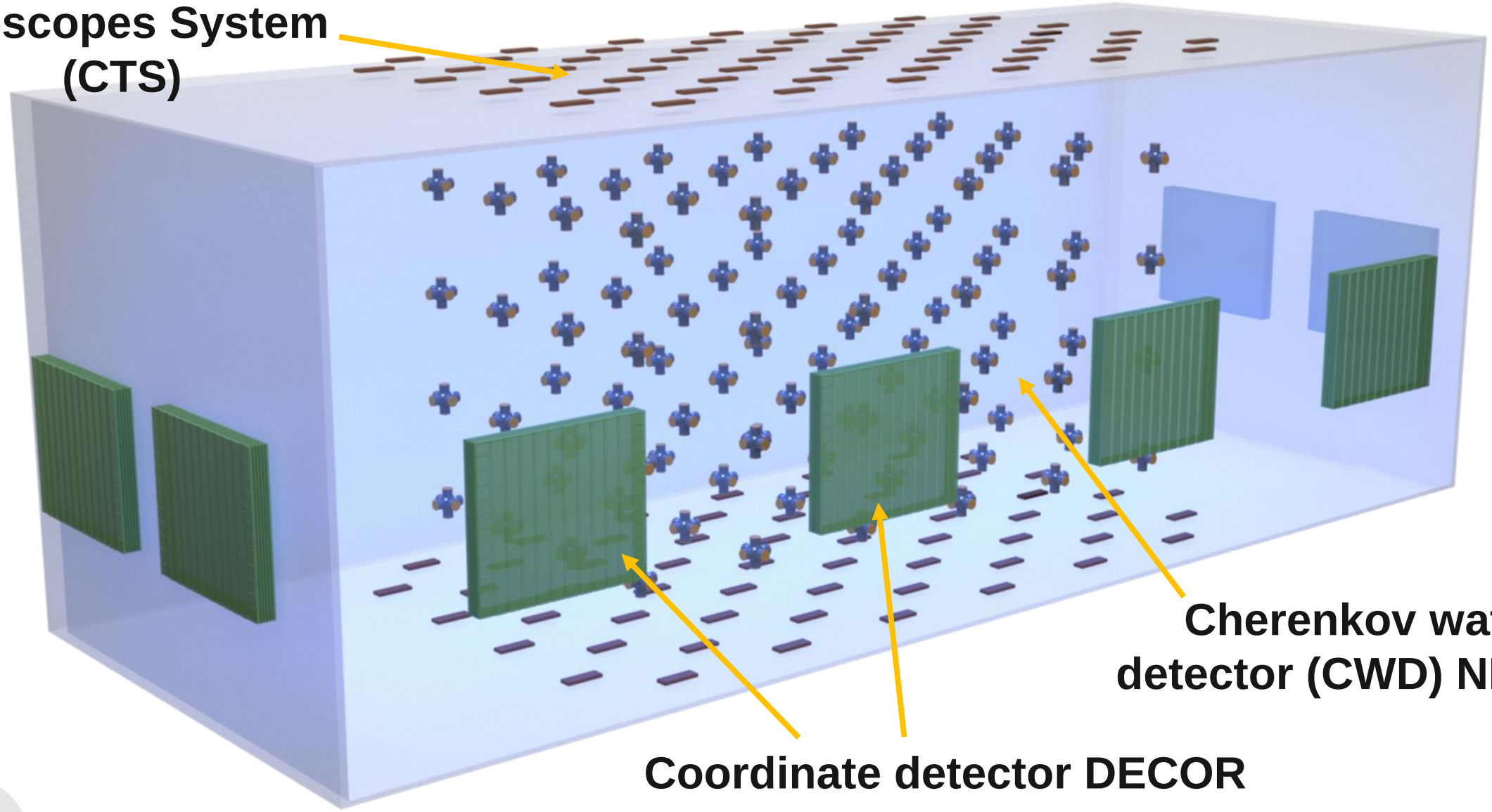
Main research directions of the EC NEVOD



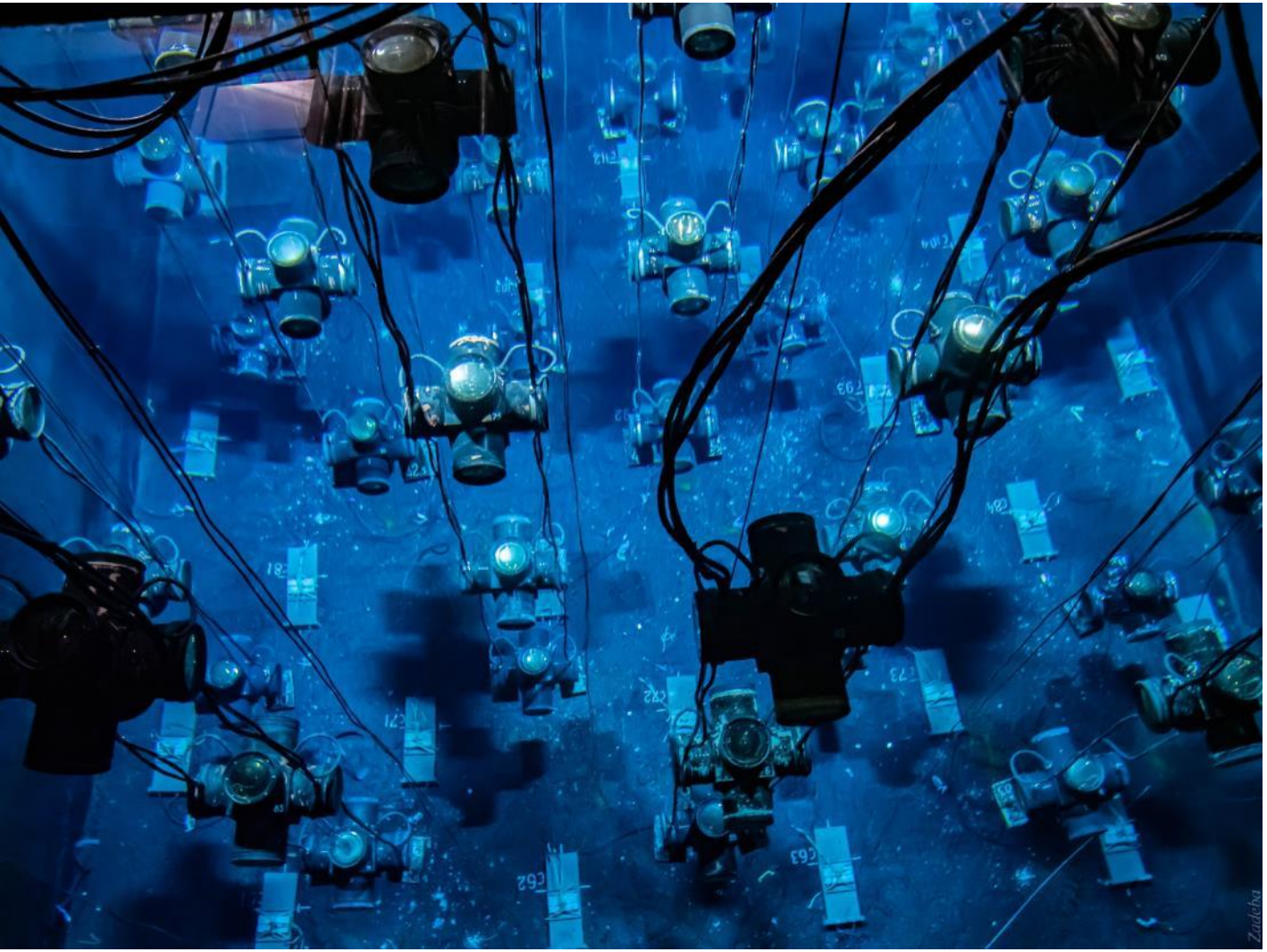
Physics of cosmic rays:

1. Atmospheric neutrinos
2. Atmospheric muons
    a. single and albedo muons
    b. muon bundles
3. Extensive air showers
4. Solar-Terrestrial Physics (muonography, neutron background variations)

Central part of the EC NEVOD



Cherenkov water detector NEVOD

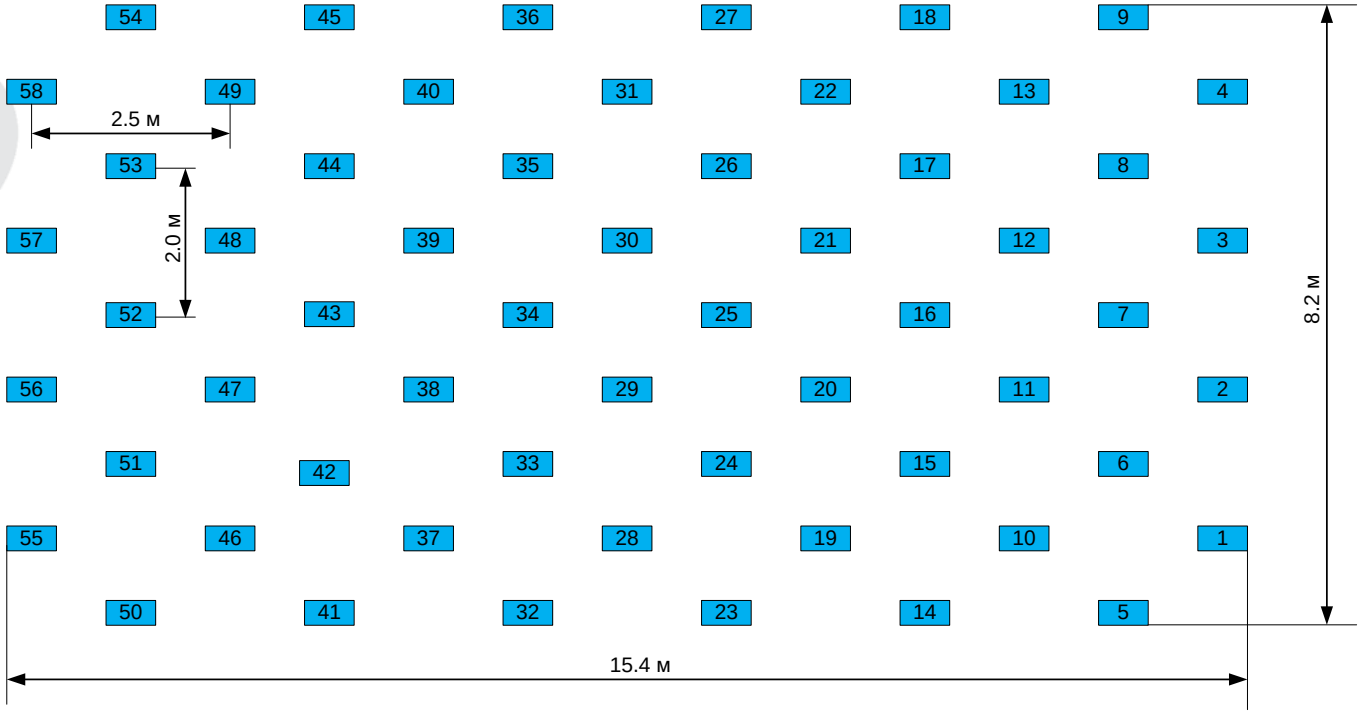


- Volume: **2000** m^3
- The detecting system is formed by a spatial lattice of quasi-spherical modules (QSMs) with six PMTs
- **96** QSMs in **24** strings (step 2×2×2.5 m^3)
- Dynamic range for each PMT **1–10^5** ph.e.
- Energy range: 10^{11} – 10^{19} eV

Small step of spatial lattice and a wide dynamic range allow detector's operation in the **calorimetric mode**.

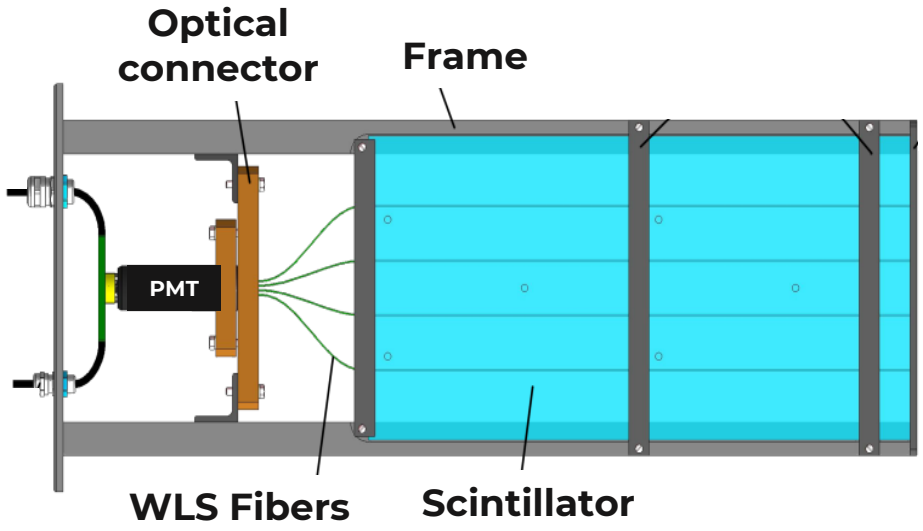
Energy deposit of EAS cores, single muons and muon bundles

Calibration Telescopes System

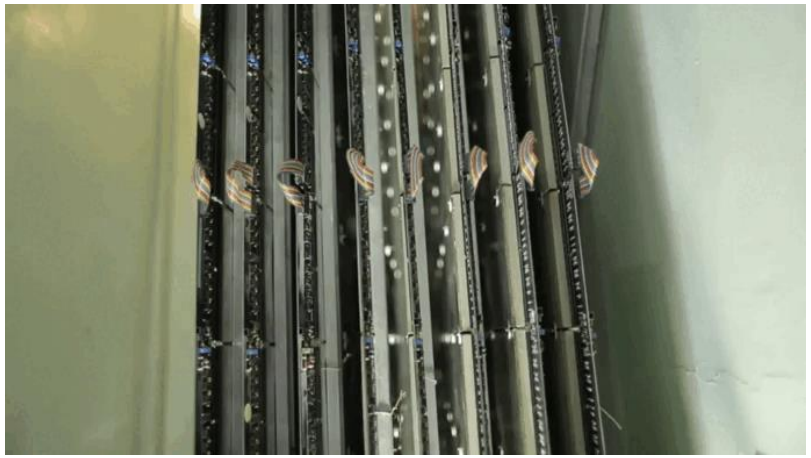


- Area: **120** m^2
- Scintillation counters ($40 \times 20 \times 2$ $см^3$)
- **2** planes of **58** counters each (step 2×2.5 m^2)
- Dynamic range for each counter **1–130** VEM

EAS electron photon (10^{14}-10^{15} eV) and muon (10^{15}-10^{18} eV) components

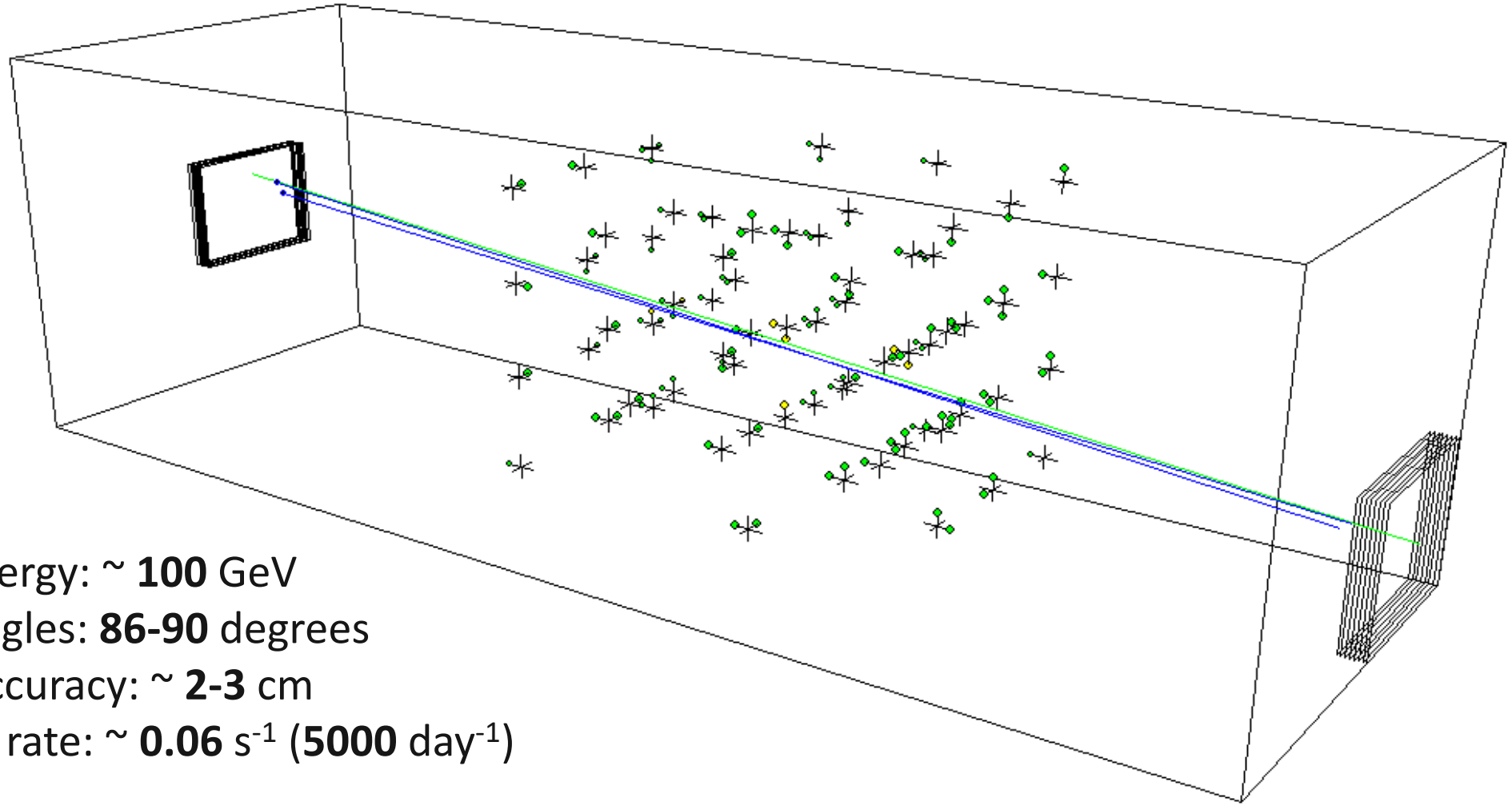


Coordinate detector DECOR (in collaboration with Torino University)



- Area: **70** m^2
- **8** SM of **8** layers of streamer tube chambers
- Good coordinate (< 1 cm) and angular (< 1°) resolution
- Zenith angle range: **20°- 90°**
- Energy range: **10^{13} - 10^{19} eV**

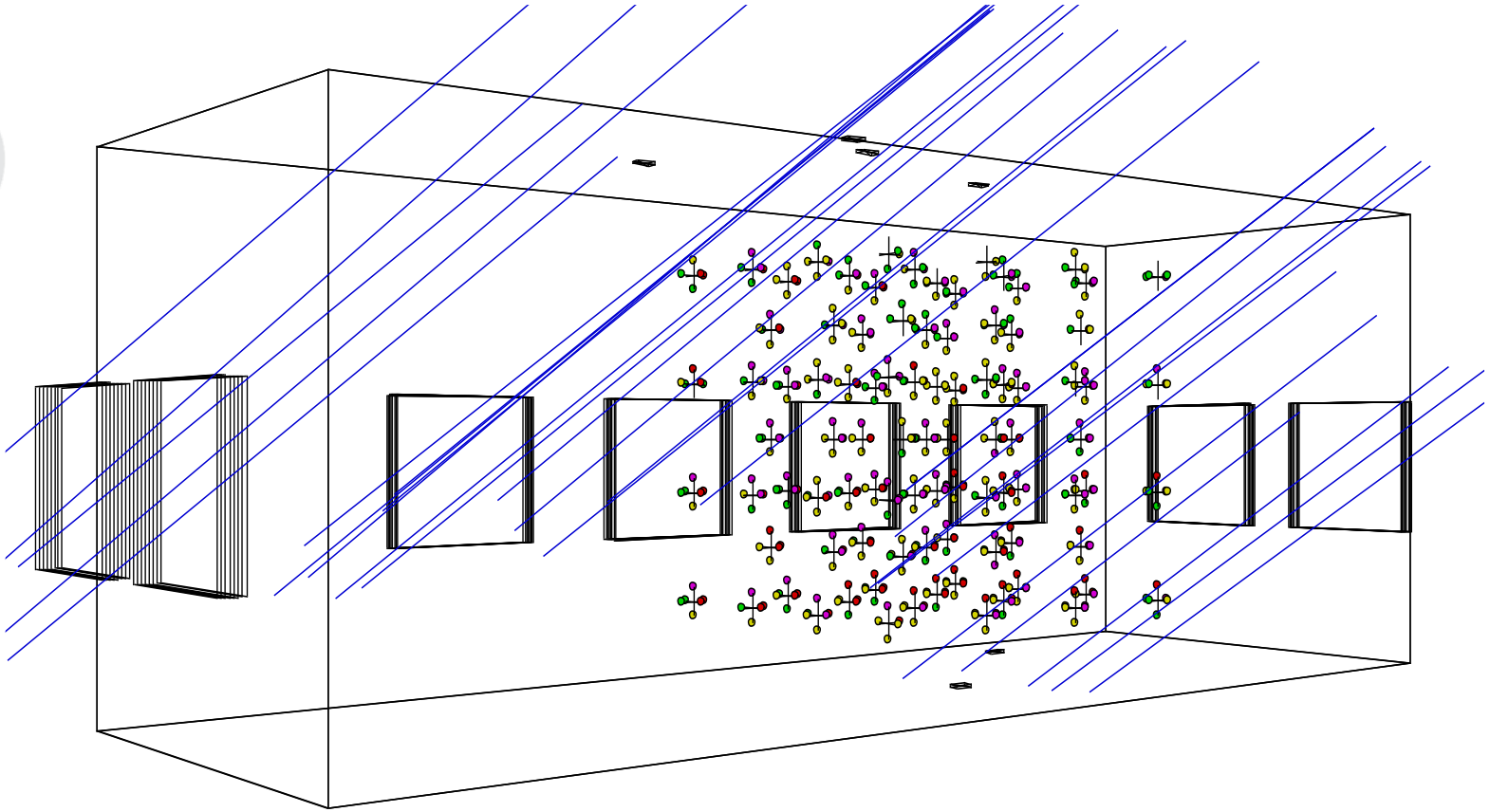
Selection of near-horizontal muons



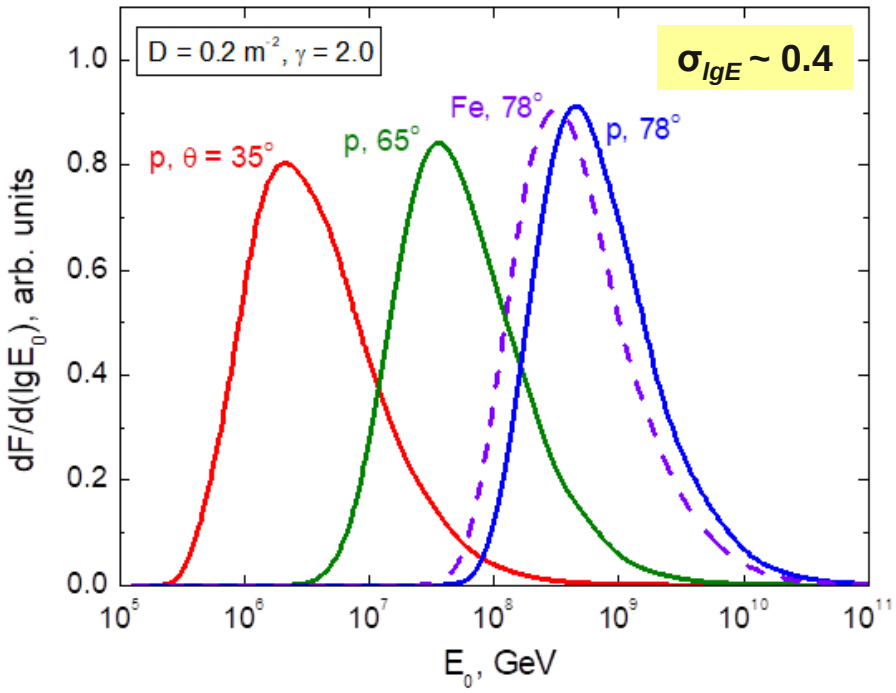
- Muon energy: ~ **100** GeV
- Zenith angles: **86-90** degrees
- Spatial accuracy: ~ **2-3** cm
- Counting rate: ~ **0.06** s^{-1} (**5000** day^{-1})

Calibration of the CWD response by the muon energy deposit

The event with a muon bundle



Distributions of energies of primary particles contributing to events with fixed density of muons

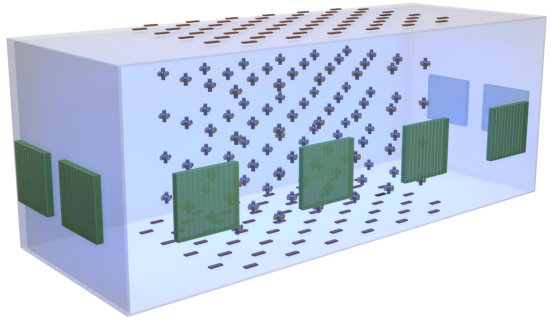


Multiplicity (density), arrival direction, energy deposit of muon bundles from inclined EAS

Muon puzzle

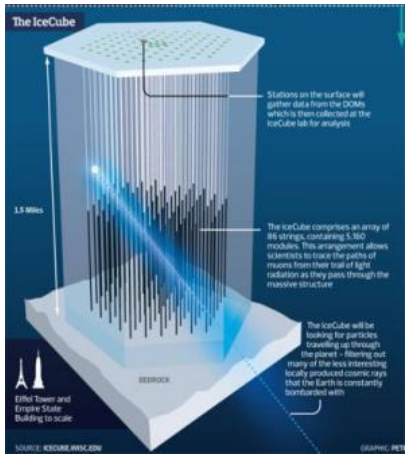
At the National Research Nuclear University MEPhI, the NEVOD-DECOR experiment discovered an **excess of muons** in cosmic rays (the **muon puzzle**), indicating the existence of a new state of matter.

This result has been confirmed at the World's largest facilities **IceCube** and **Pierre Auger Observetory**.



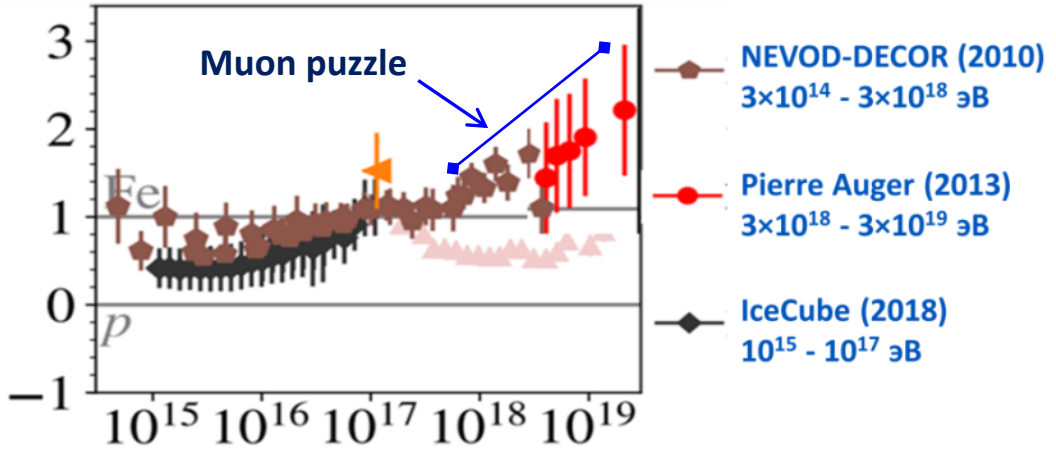
NEVOD-DECOR
S = 100 m^2

Pierre Auger
S = 3000 km^2

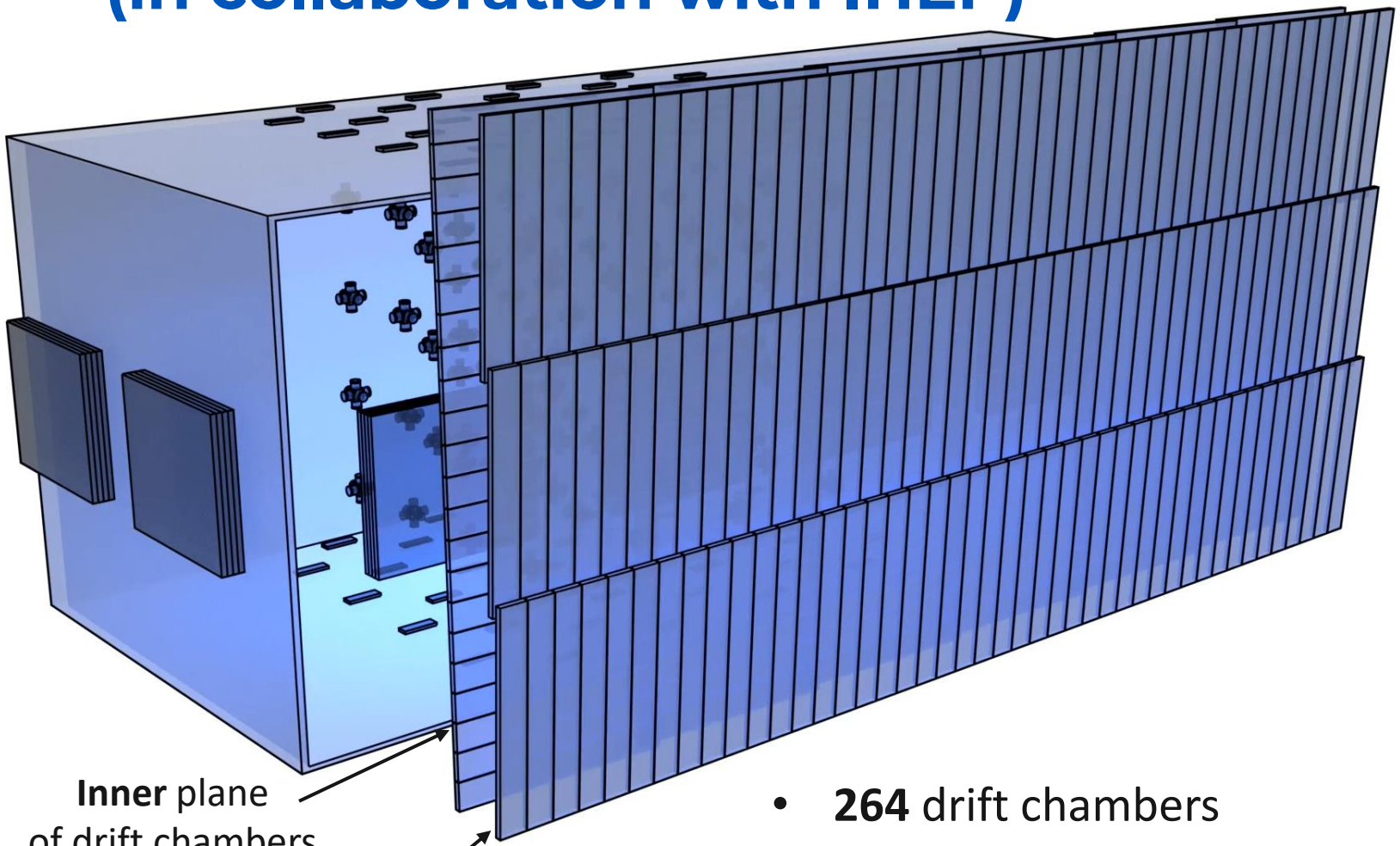


IceCube
S = 1 km^2

H. Dembinski et al. Report on tests and measurements of hadronic interaction properties. EPJ Web Conf. 210, 02004 (2019)



Coordinate detector TREK (in collaboration with IHEP)



Inner plane of drift chambers

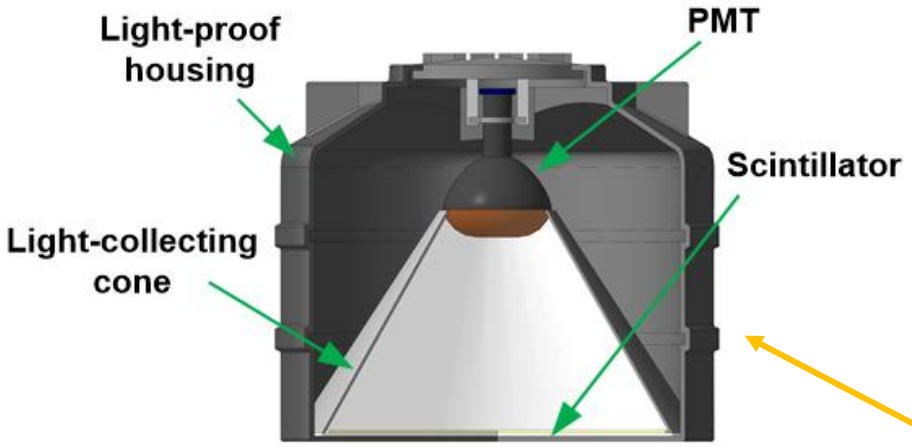
Outer plane of drift chambers

- **264** drift chambers
- Full overlapping of the CWD
- Detector area: **254** m^2

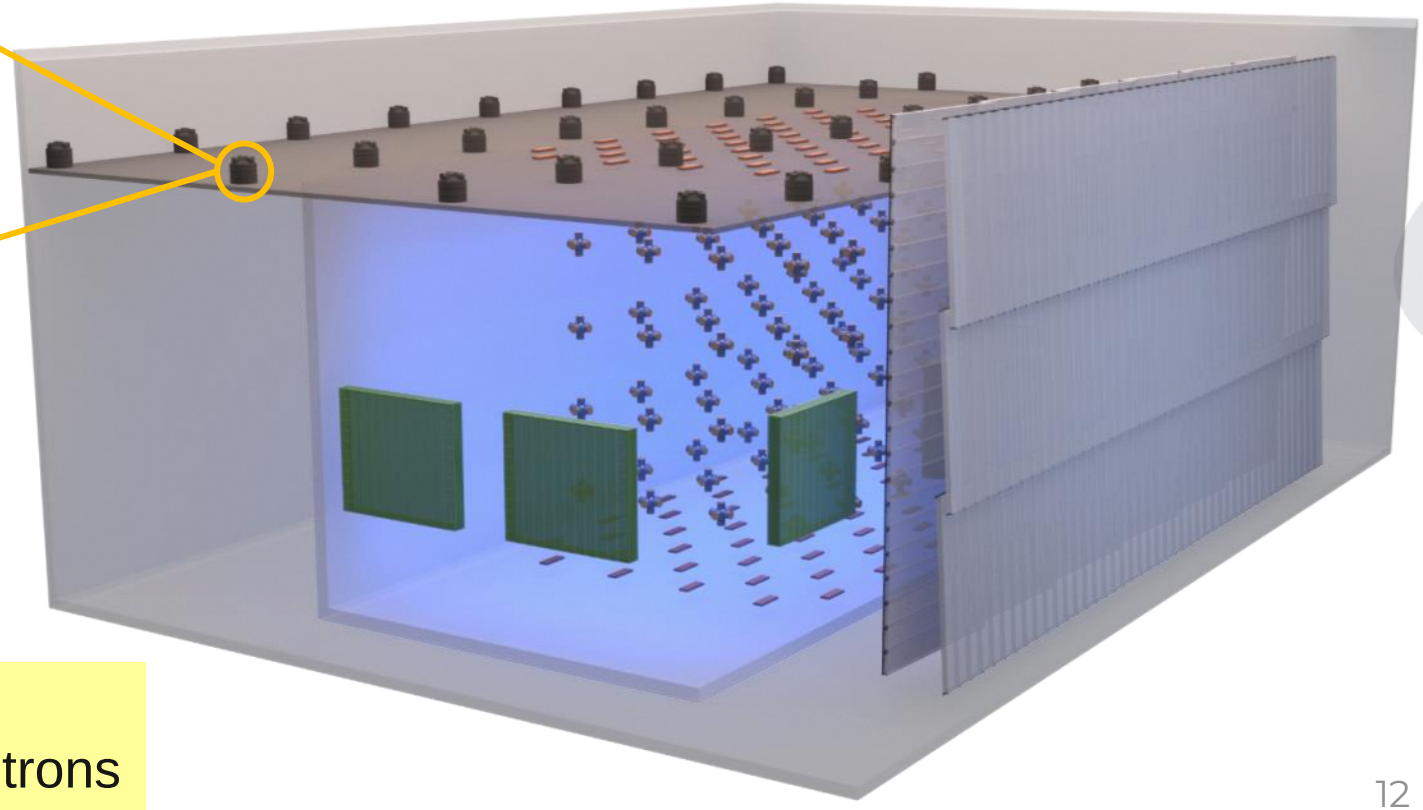
- Spatial accuracy ~ **1** mm
- Angular accuracy ~ **1.7°**
- Two-track resolution: ~ **3** mm

Muon bundles with energies from 10^{14} to 10^{19} eV

PRISMA-36 air-shower array

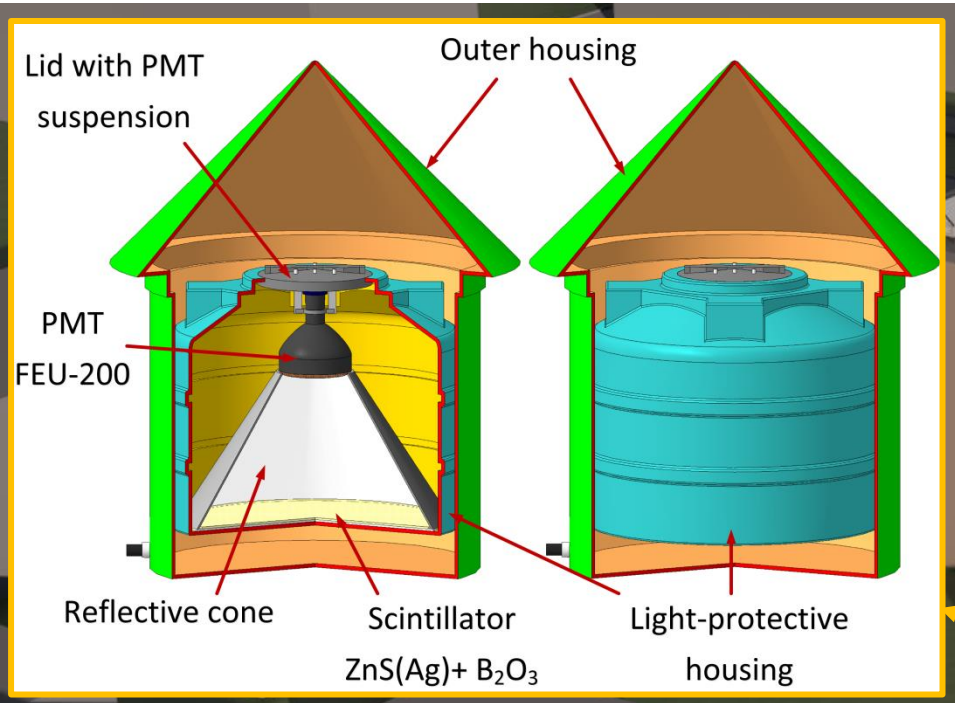


- **32** en-detectors
- The area of the en-detector : **0.36 m²**
- Array area: **~ 500 m²**
- Scintillator: **ZnS(Ag) + LiF**
- Energy range: 10^{14} – 10^{17} eV



- Electron-photon EAS component
- Hadron EAS component by thermal neutrons

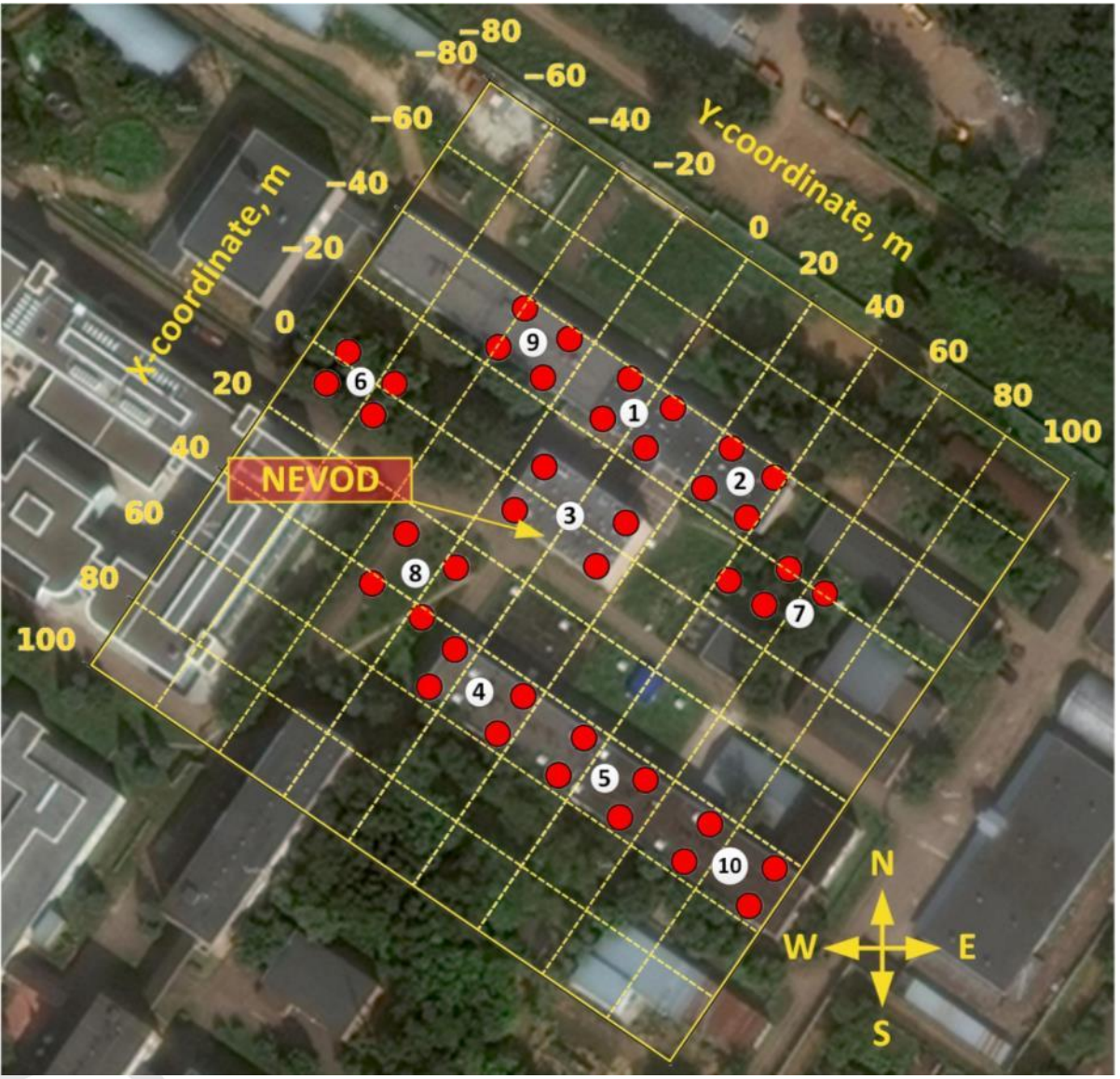
URAN air-shower array

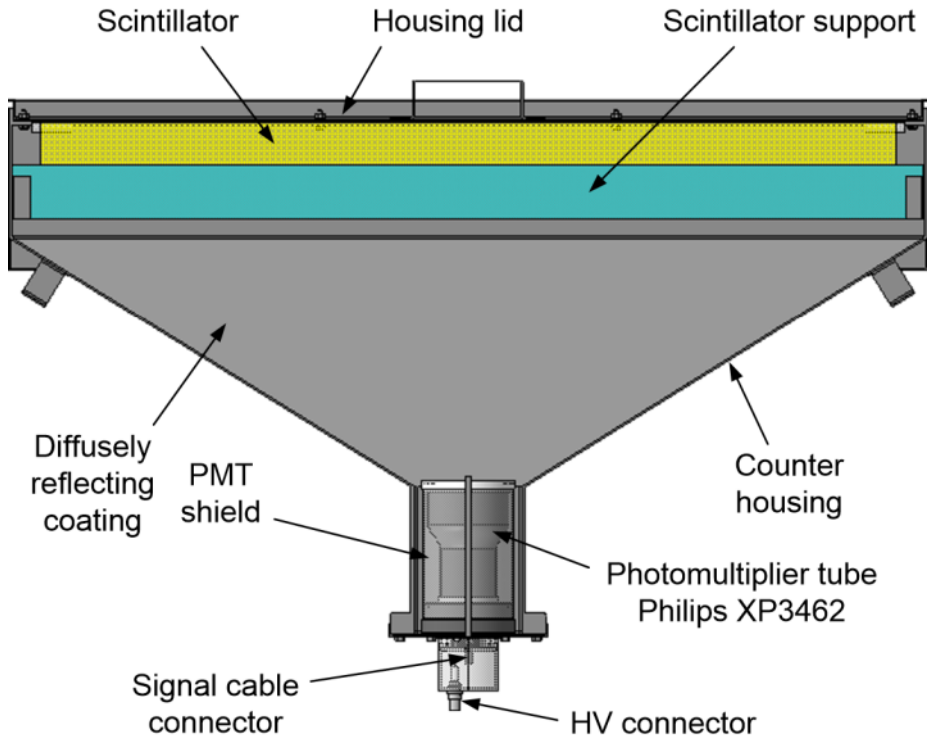


- Area: 10^3 m^2
- 72 en-detectors
- 6 clusters
- Scintillator: ZnS(Ag) + B_2O_3
- Energy range: 10^{15} - 10^{17} eV

- Electron-photon EAS component
- Hadron EAS component by thermal neutrons

NEVOD-EAS air-shower array



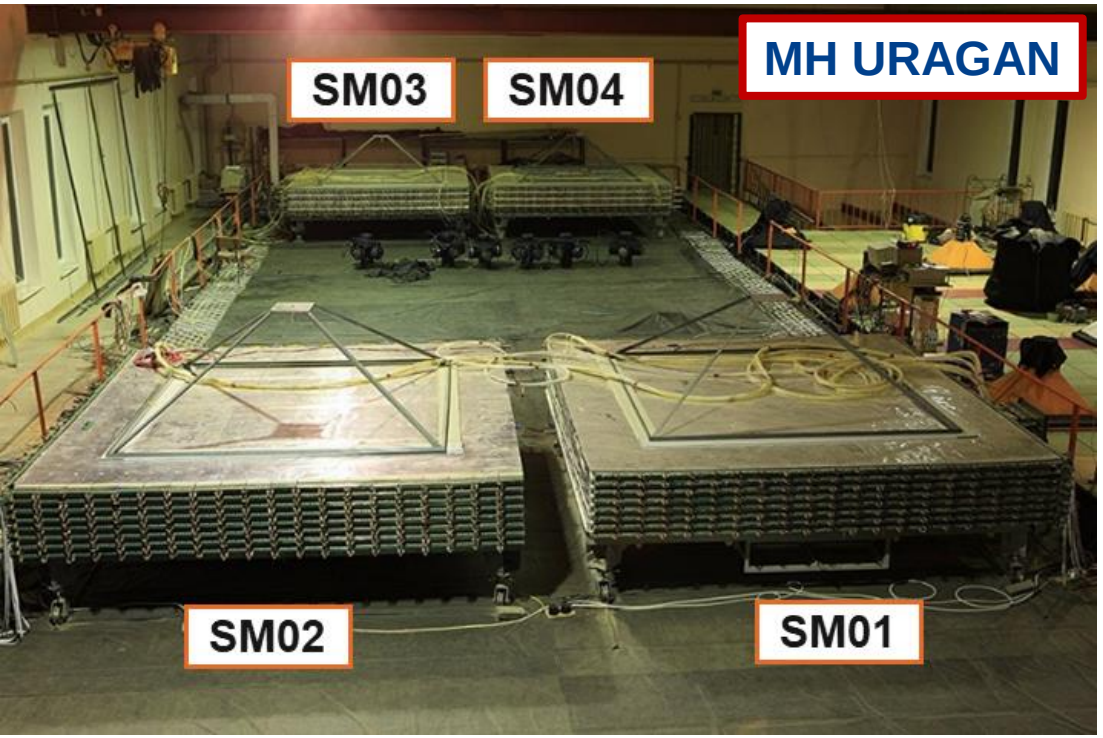


- Area: 10^4 m^2
- 144 detectors, 36 detector stations
- 9 clusters, cluster size: 15 × 15 m^2
- Energy range: 10^{15} - 10^{17} eV
- Accuracy:

  direction - 2.6°, core position - 2.2 m, EAS size - 0.05

- Electron-photon EAS component (size, core position, arrival direction).
- The fastest facility of the EC NEVOD. Serves as a starting point in joint event analysis.

Muon hodoscopes (MH) of the EC NEVOD



Parameter	URAGAN	ScMH
Nos. SMs	4	2
Nos. coordinate planes	8	4
Detecting elements	Streamer tube chambers filled with Ar+CO_2+n-pentane	Scintillation strips with fiber-optical light collection to multi-anode PMTs
SM area	11.5 m^2	11.5 m^2
Total area	46 m^2	23 m^2
Angular accuracy	< 1°	< 2°
Aperture	0° - 80 °	0° - 80 °
Detection efficiency	99%	97%

Control Room