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Cluster type EAS array of the NEVOD experimental complex

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Experimental complex NEVOD



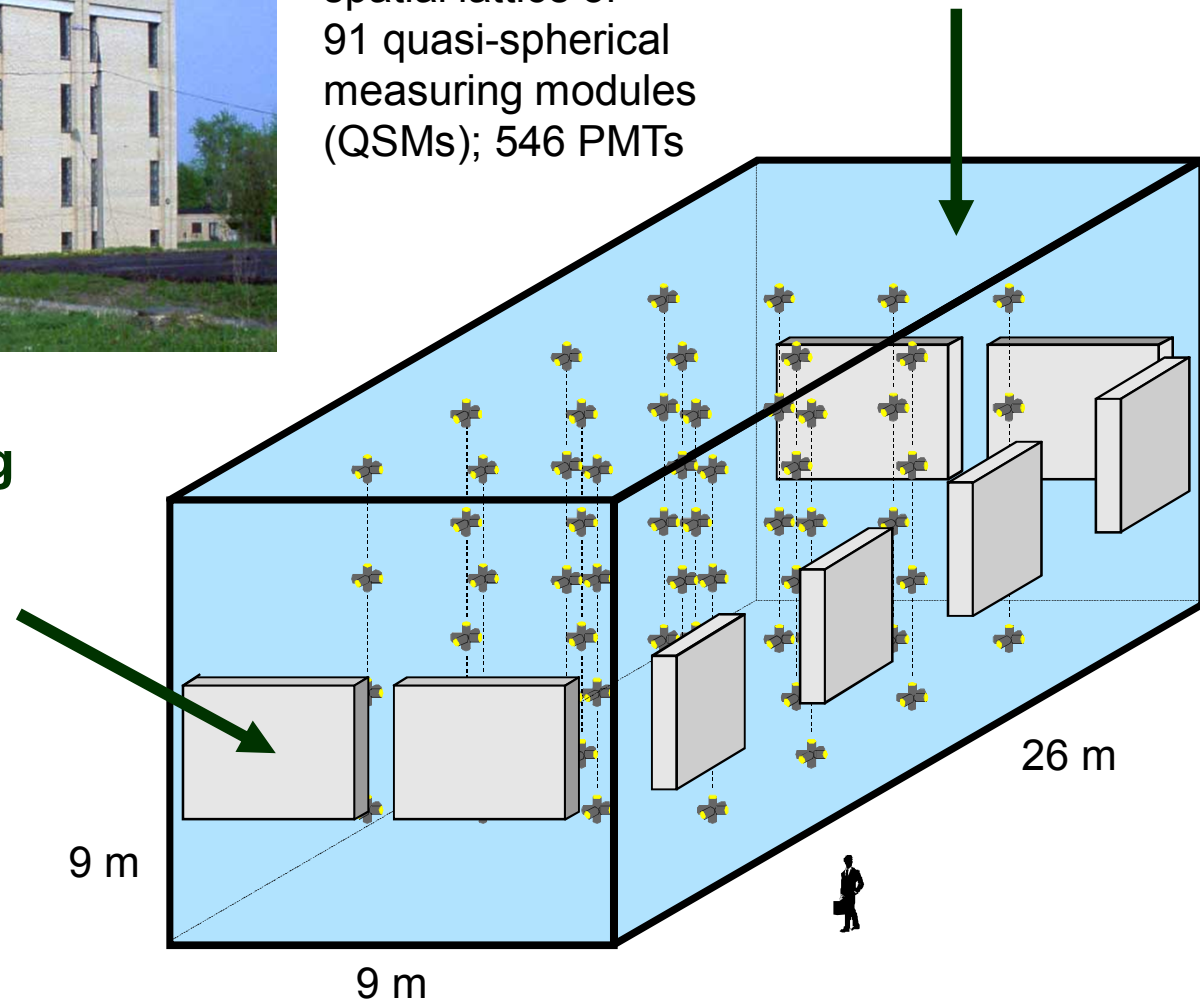
**Cherenkov water
detector NEVOD
(volume 2000 m³)**

spatial lattice of
91 quasi-spherical
measuring modules
(QSMs); 546 PMTs

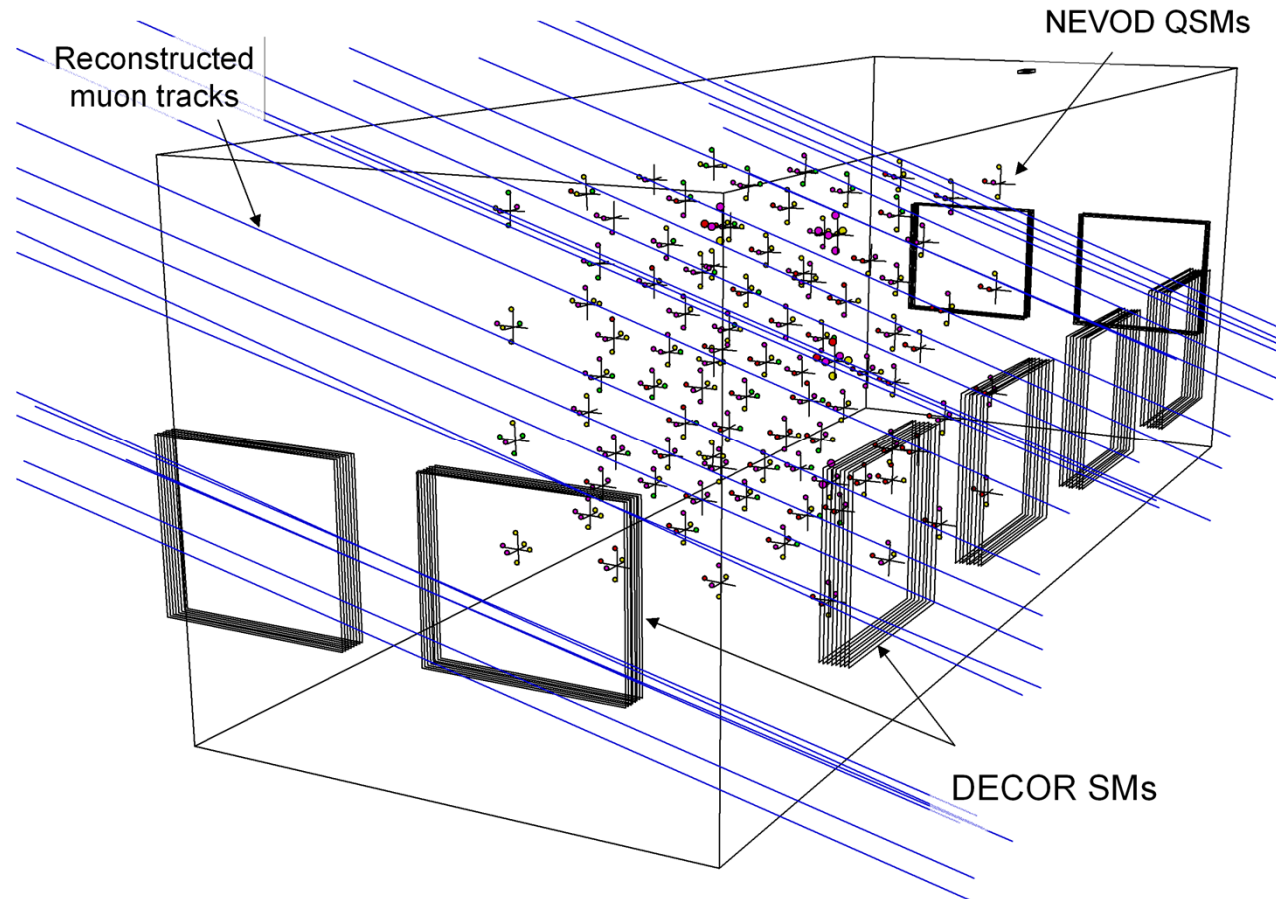
**Coordinate-tracking
detector DECOR
(total area 70 m²)**

8 supermodules (SMs)
of streamer tube chambers

*these chambers
were used earlier
in the NUSEX experiment*



An example of muon bundle event detected in NEVOD-DECOR

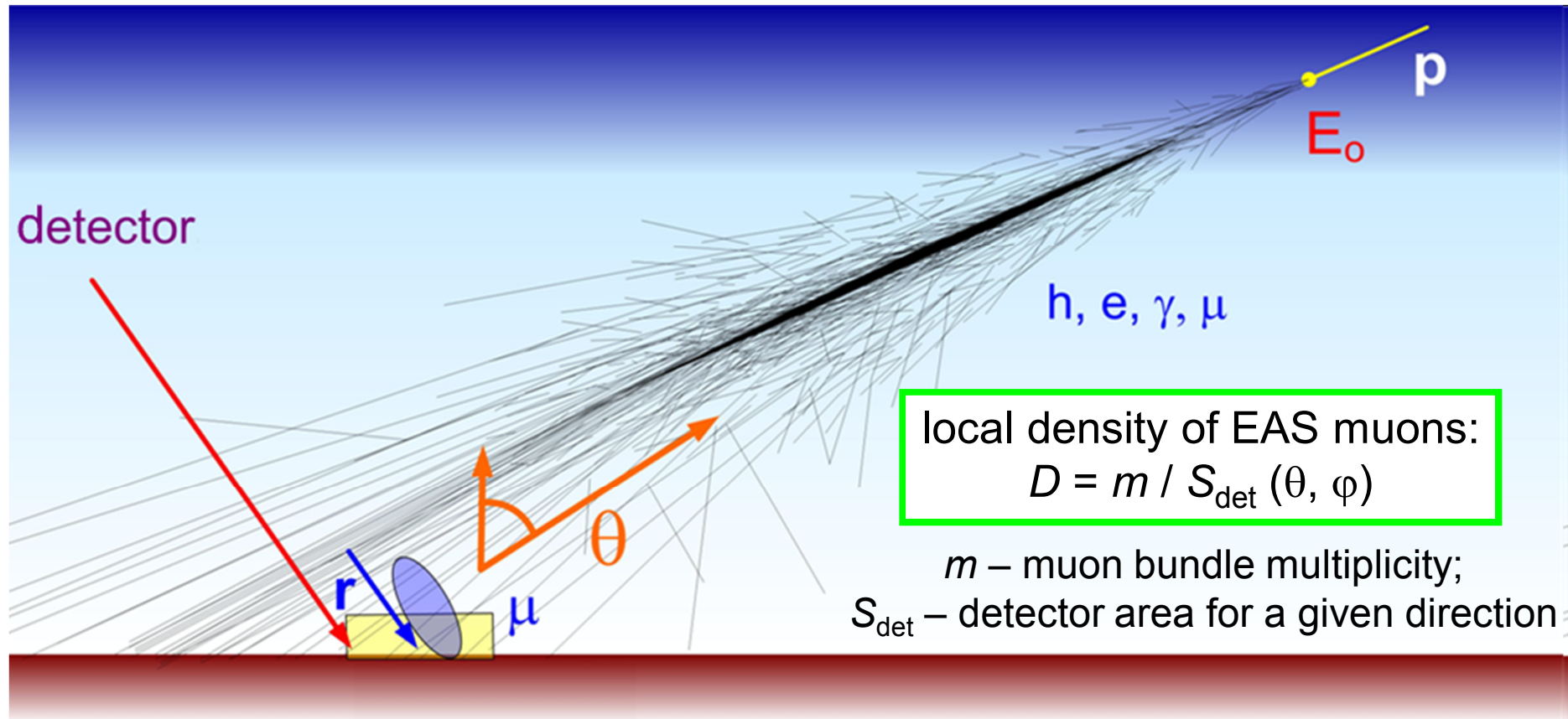


*lines – reconstruction of muon tracks from DECOR data;
circles – hit phototubes in Cherenkov water detector (colors reflect signal amplitudes)*

Local muon density in the event and EAS arrival direction are estimated from DECOR data; the energy deposit is measured in the Cherenkov water calorimeter NEVOD.

Novel approach to the analysis of data on muon bundles: method of Local Muon Density Spectra (LMDS)

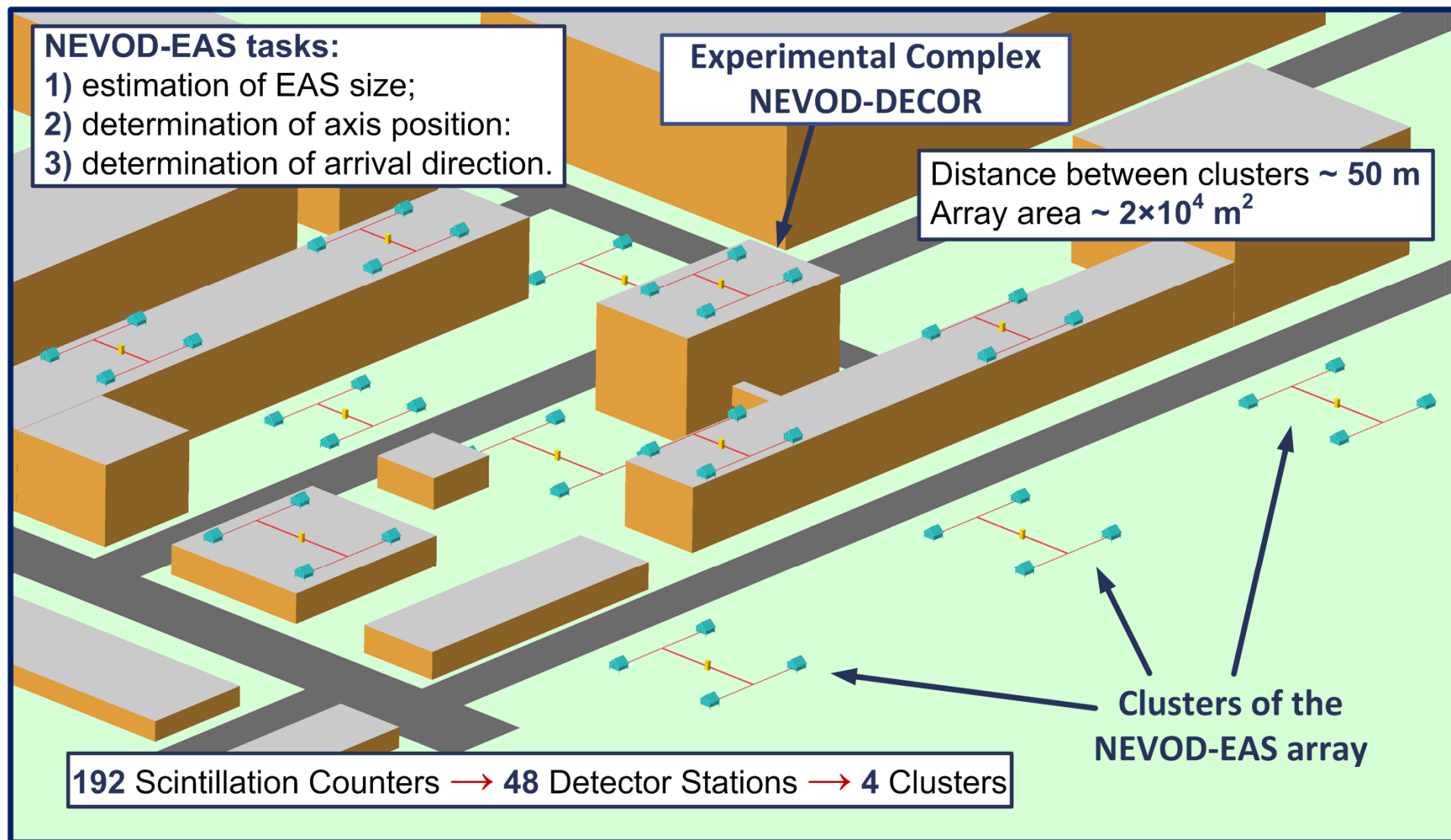
Description of the phenomenology of the LMDS – A.G. Bogdanov et al., Physics of Atomic Nuclei. 2010. V. 73. N 11. P. 1852



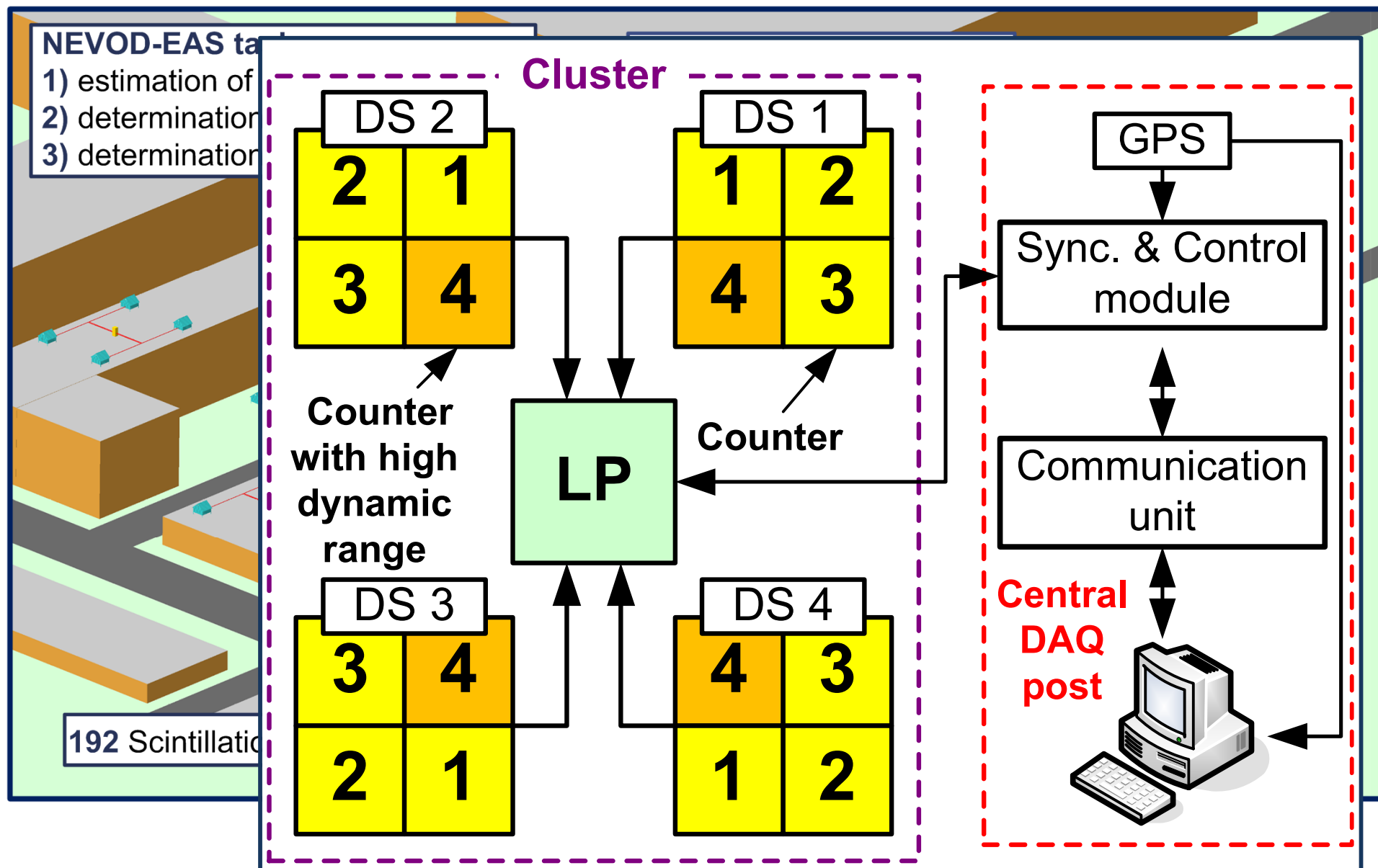
In an individual muon bundle event, local muon density D (at the observation point) is measured. Distribution of events in muon density D forms the LMDS.

Event collection area is determined by transverse dimensions of the showers in muon component (up to several square kilometers at large zenith angles).

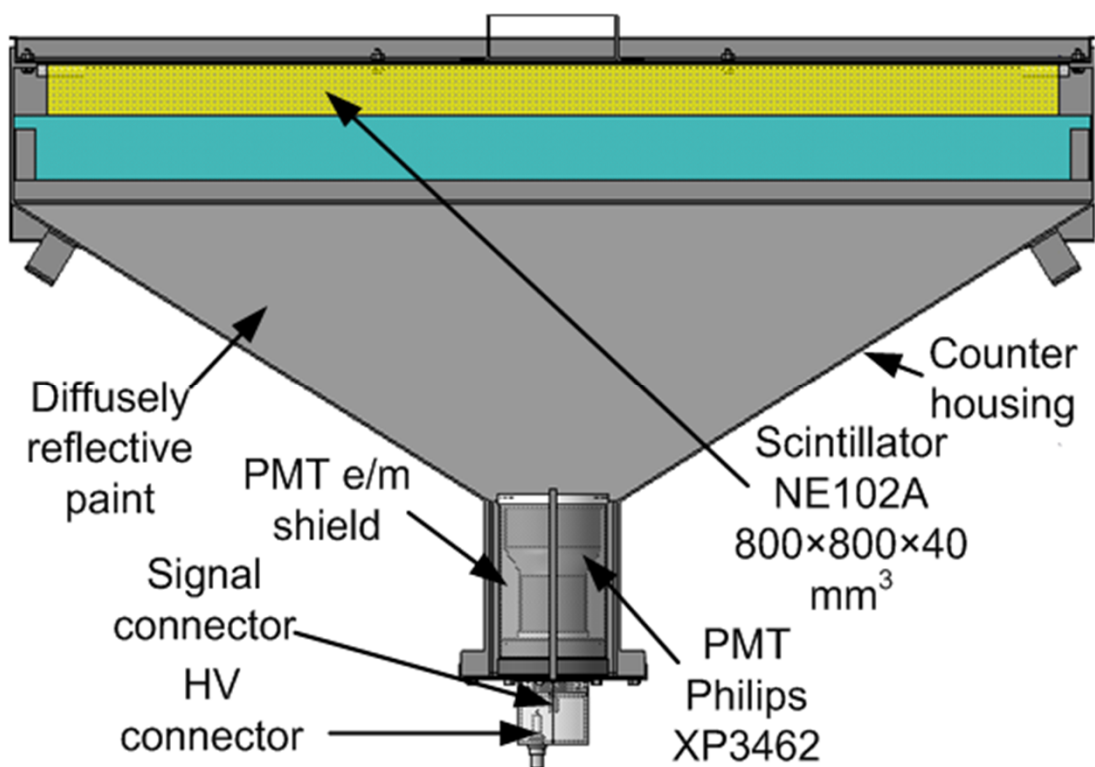
NEVOD-EAS array



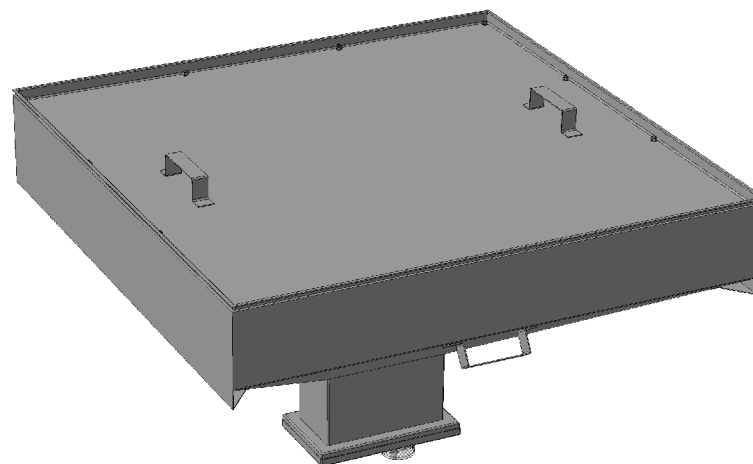
NEVOD-EAS array



Scintillation counter

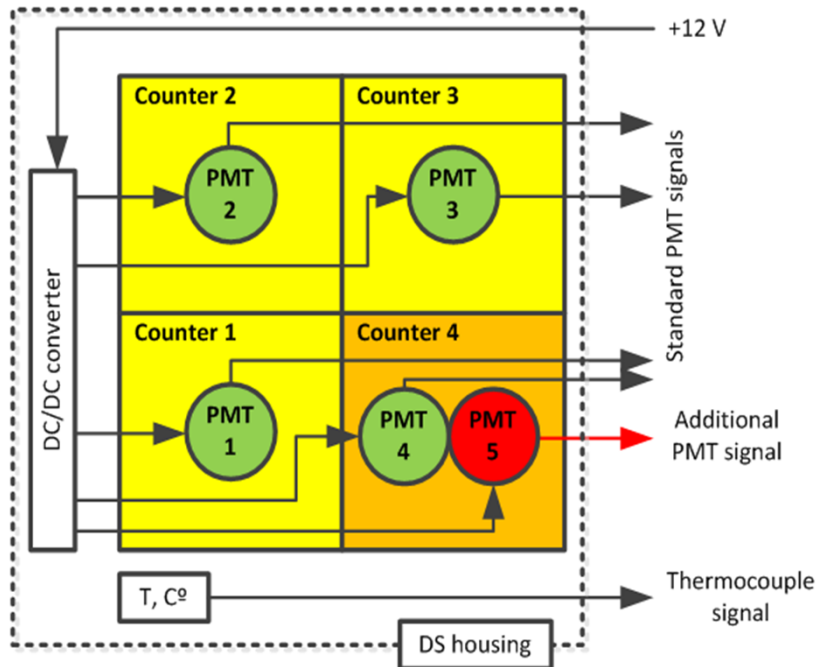
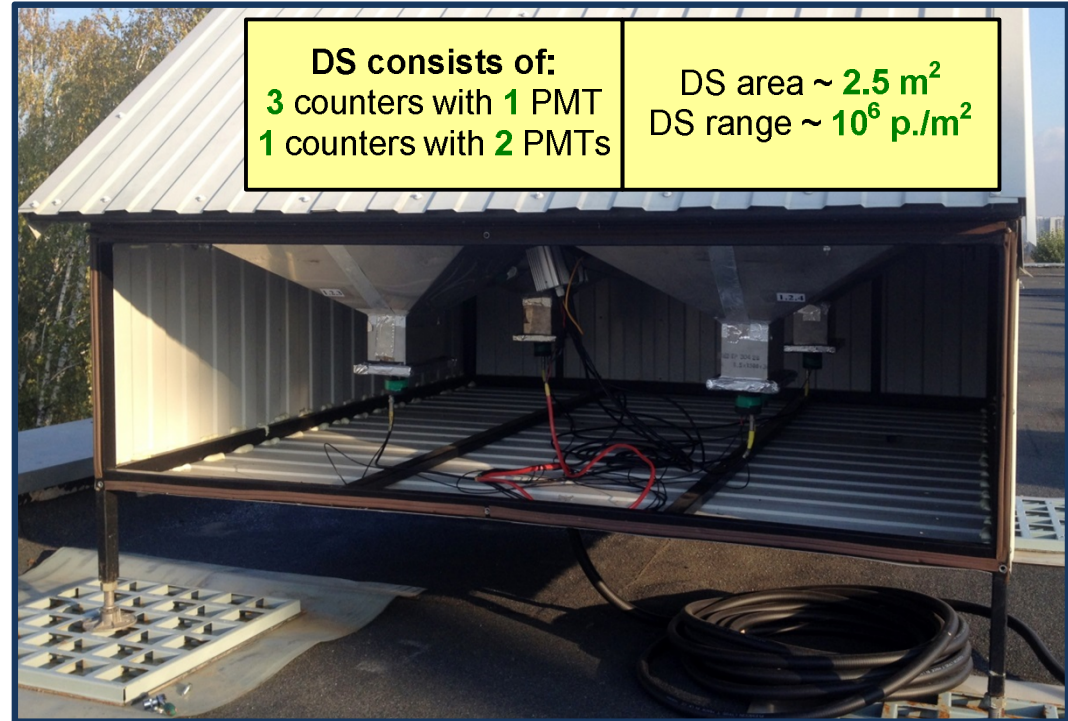


Scintillator:
NE102A $80 \times 80 \times 4 \text{ cm}^3$
Photomultiplier:
Philips XP3462



Most probable response to 1 particle (VEM):	~ 13 pC
Upper limit of dynamic range (with standard PMT):	100 particles (VEM)
Upper limit of dynamic range (with additional PMT):	10^4 particles/m²

Detector Station (DS)



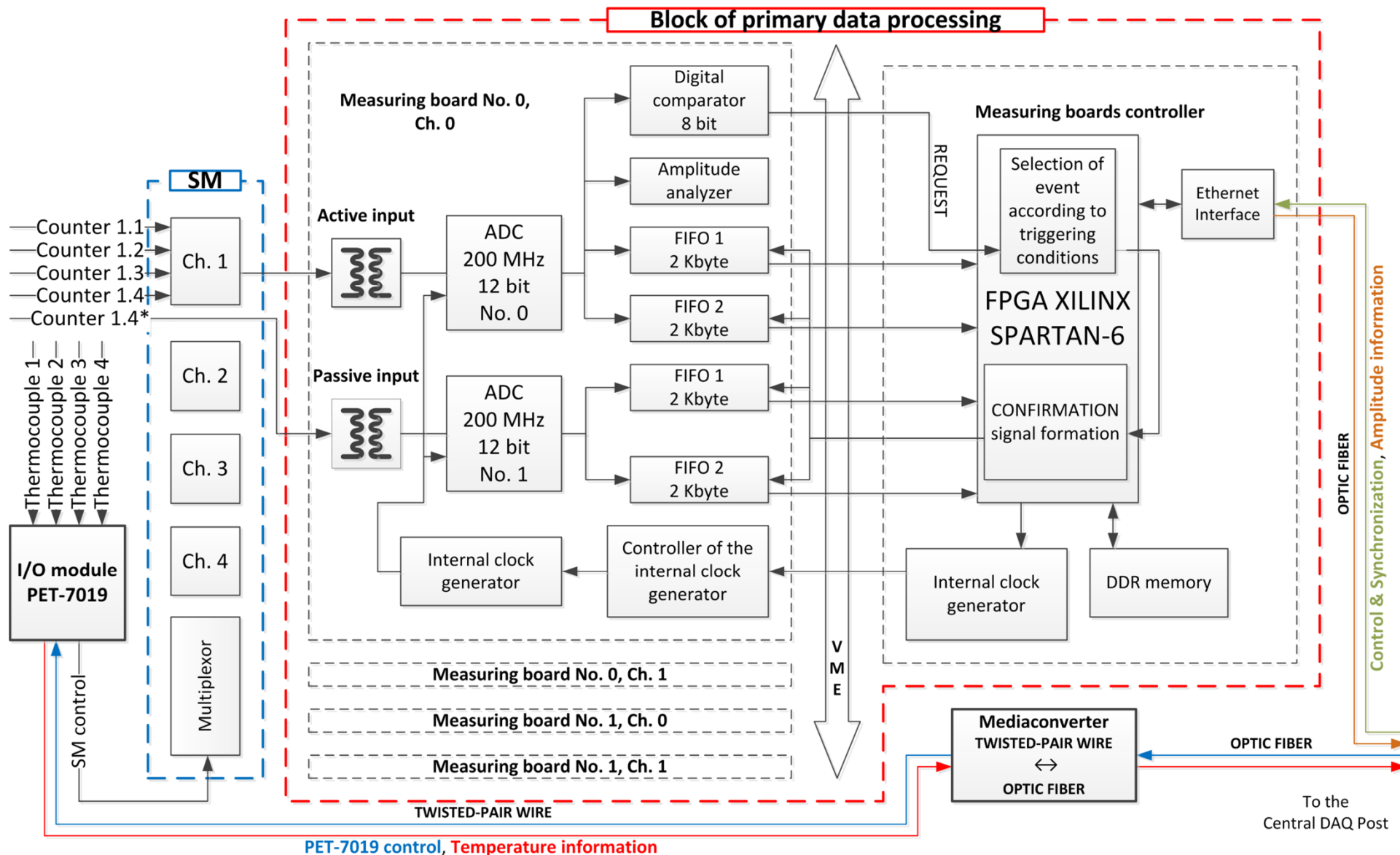
4 PMTs (standard): measuring EAS particle densities and time measurements.

5th PMT (additional): a gain of ≈ 90 times less than for the standard PMT; ensures wide linearity range of measured signals at high particle densities.

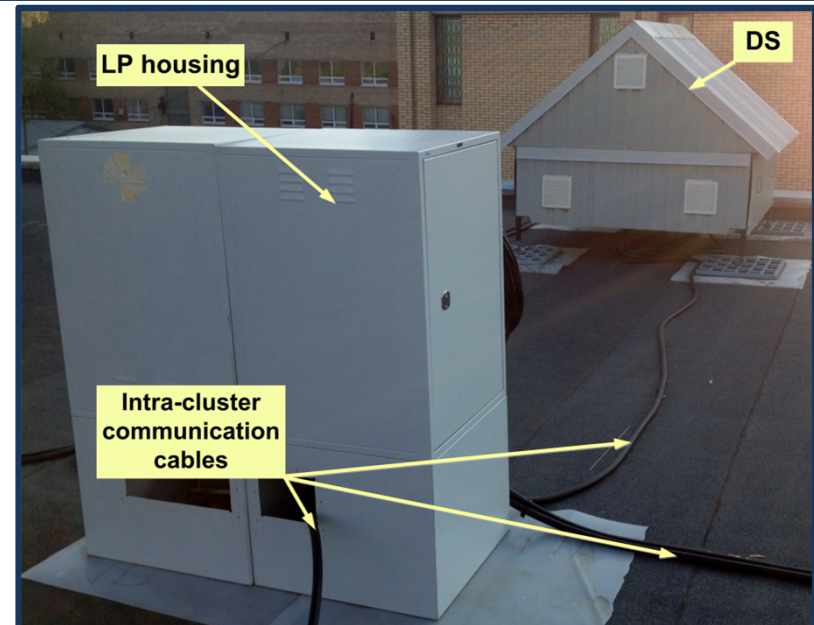
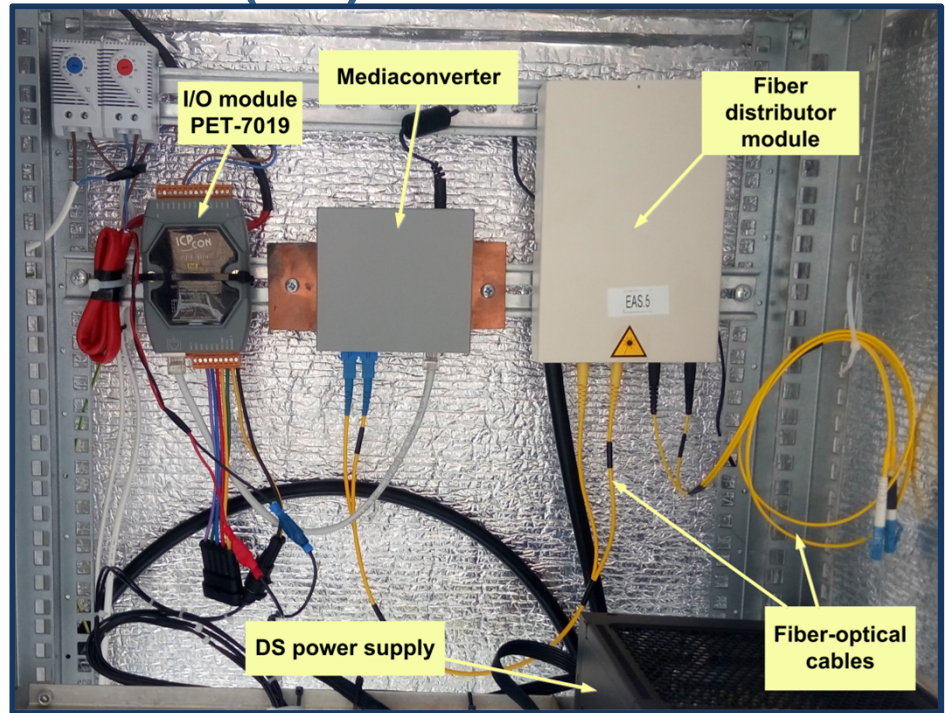
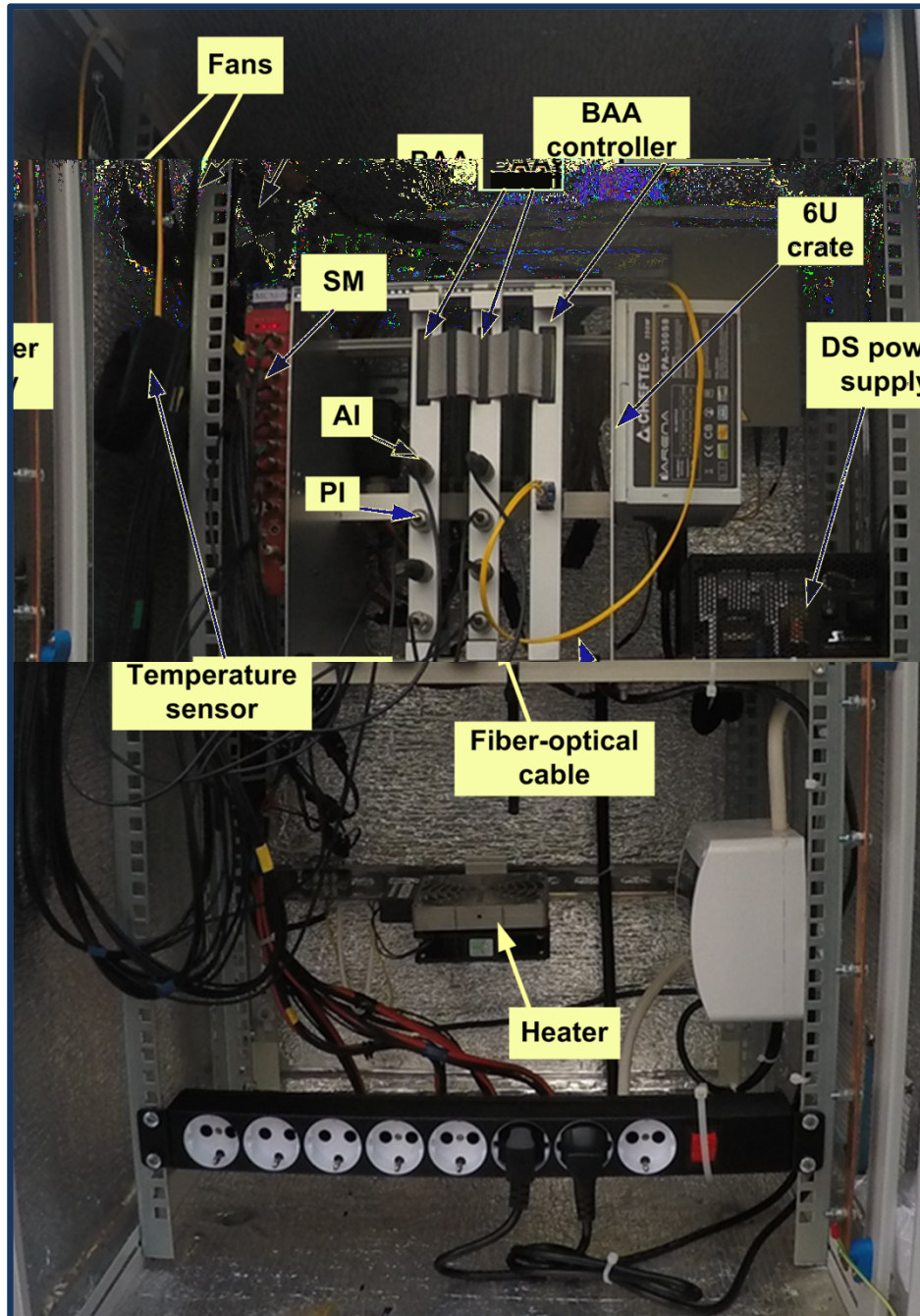
Cluster Local Post (LP)

Main tasks:

- summation & digitizing of PMTs signals
- event selection
- DS power supply
- operation in exposition and monitoring modes
- control of temperature inside DS and LP



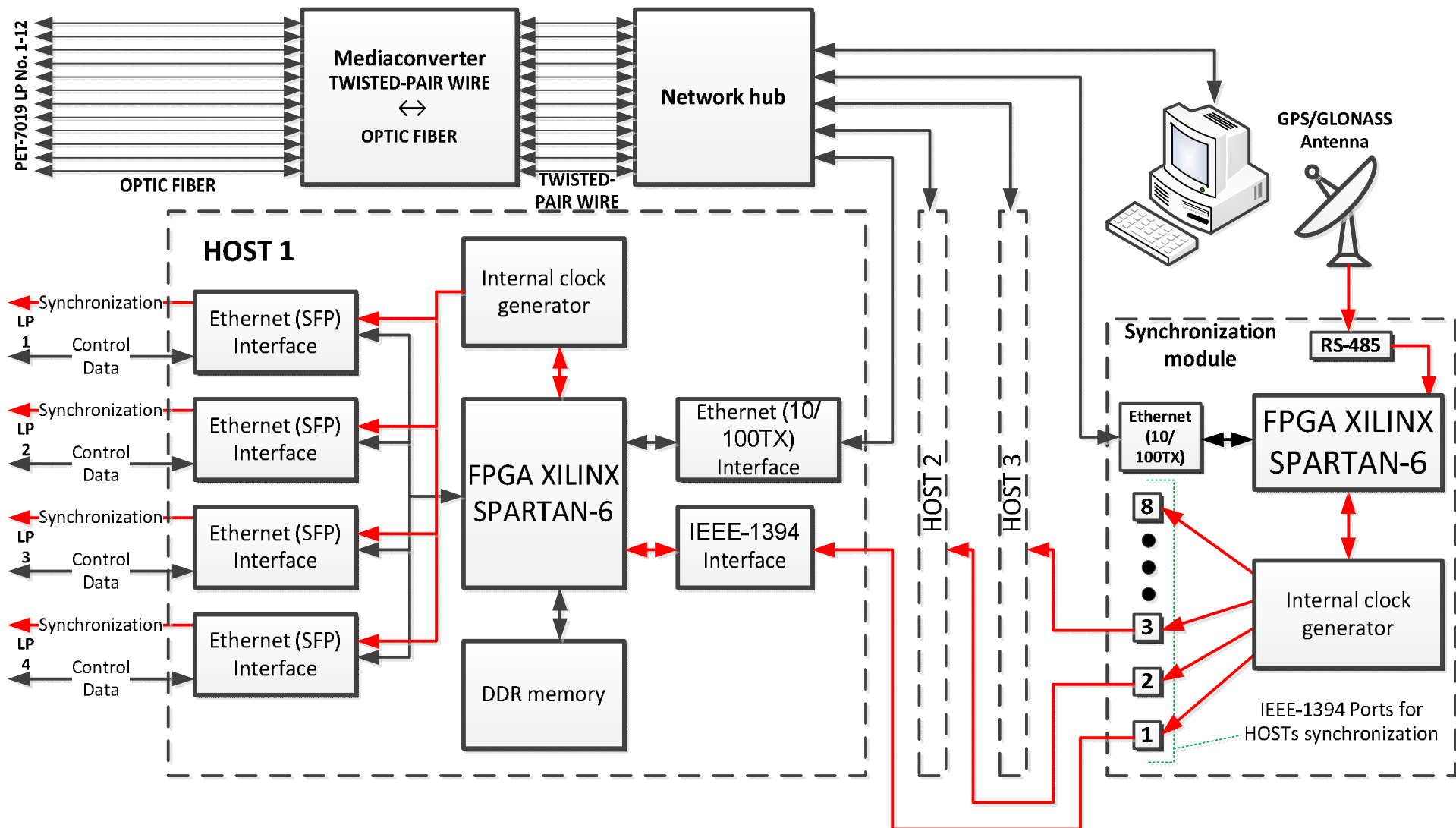
Cluster Local Post (LP)



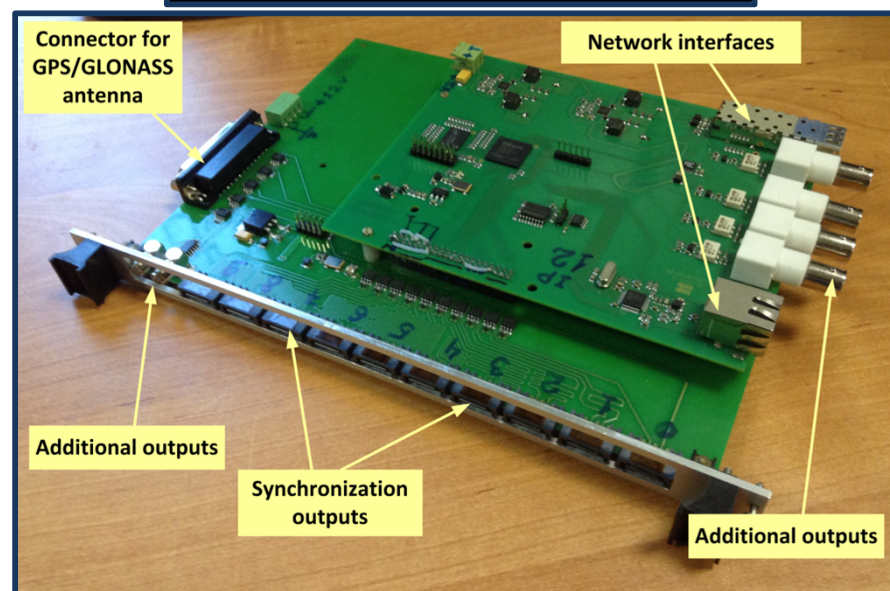
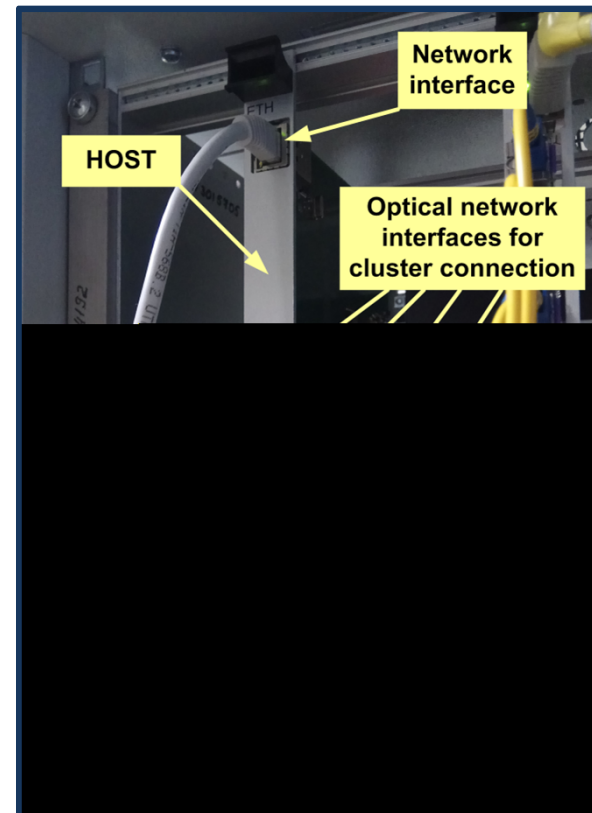
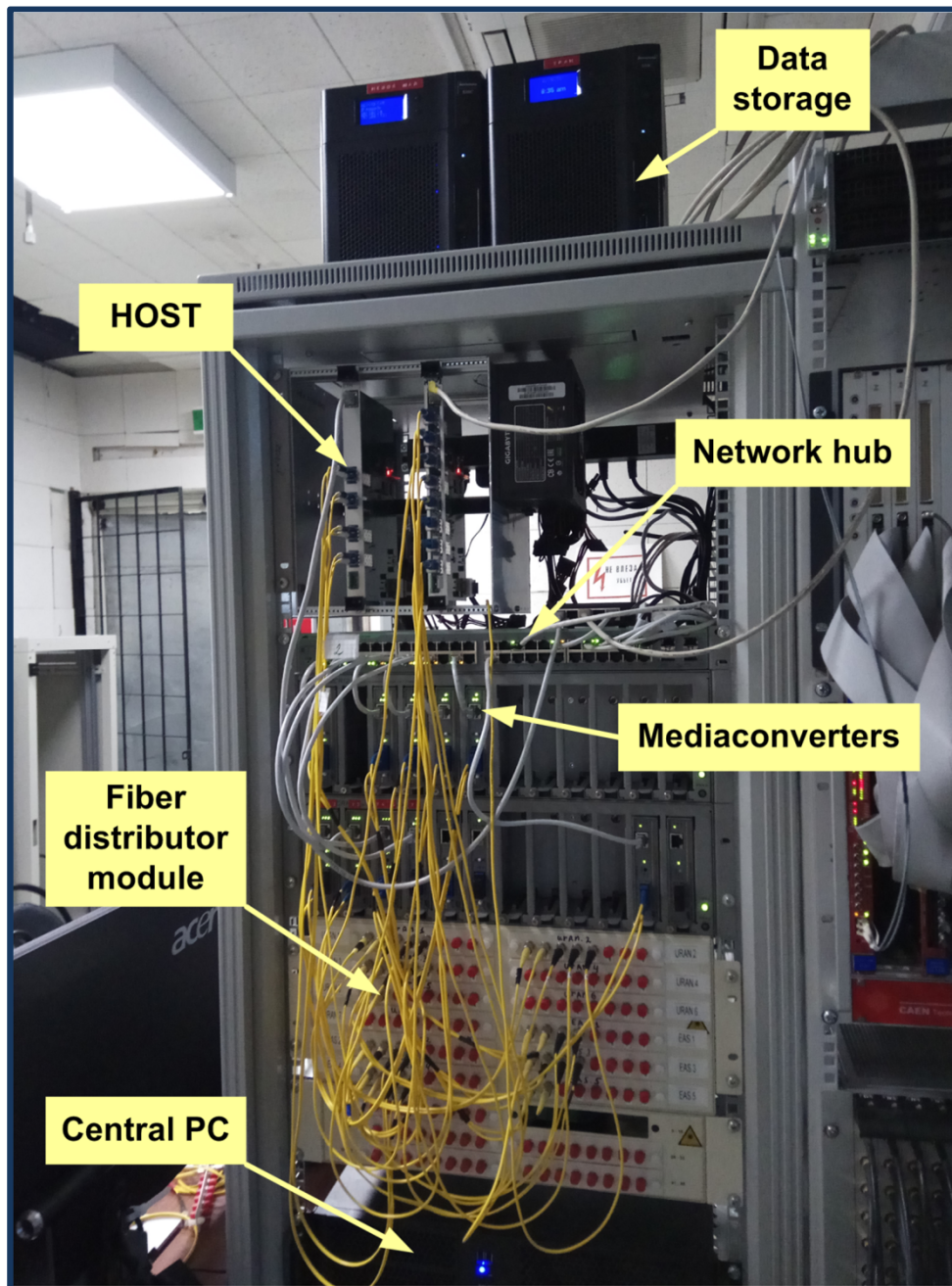
Central DAQ Post

Main tasks:

- cluster synchronization
- cluster control
- reception and storage of experimental and monitoring data



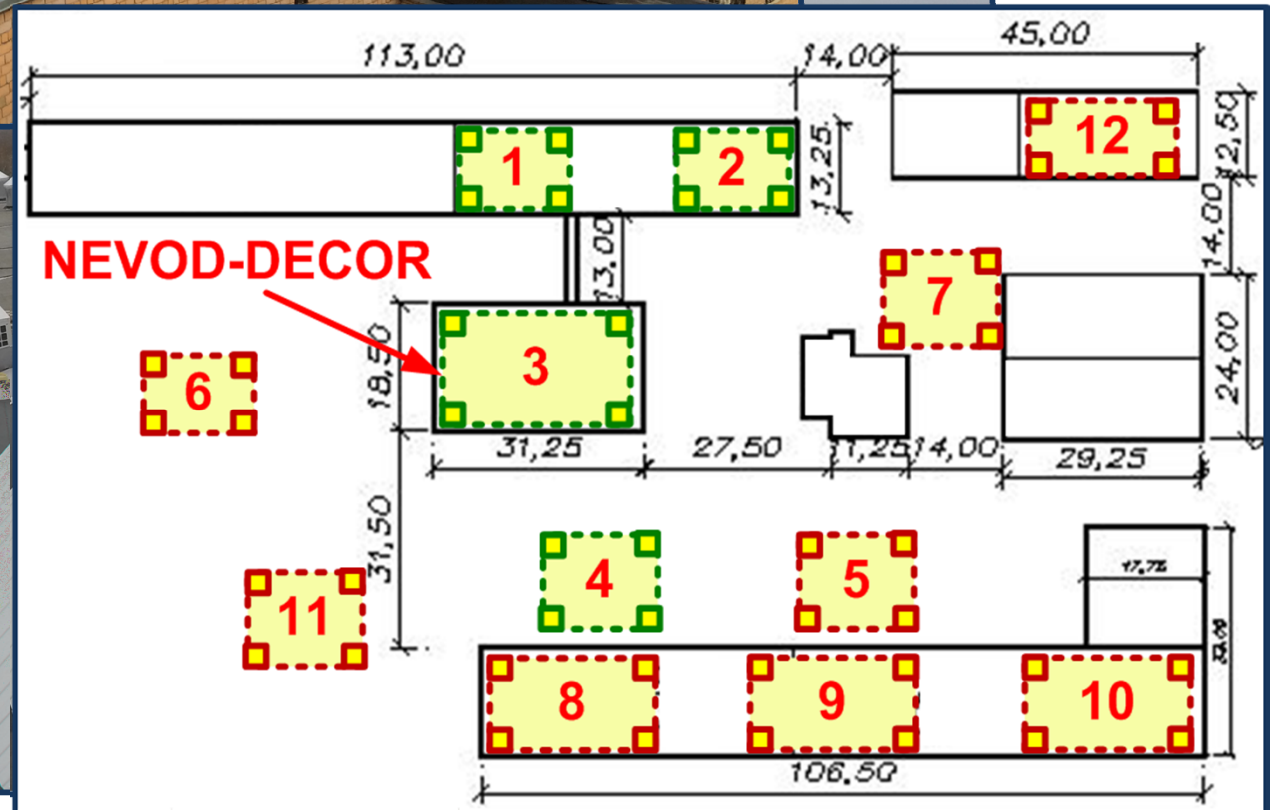
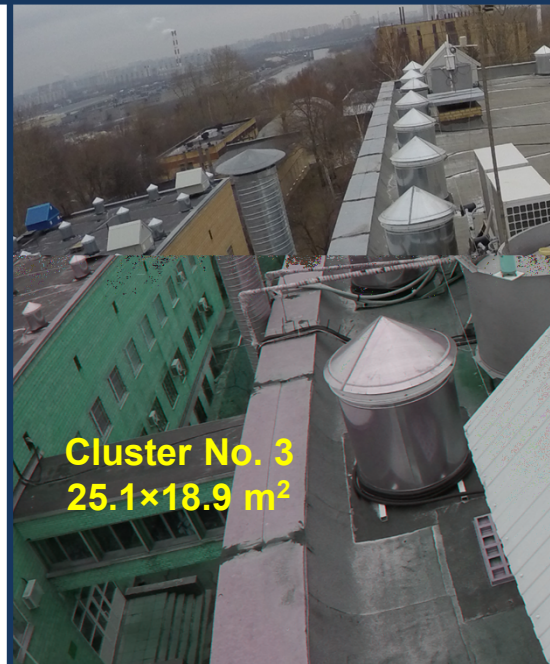
Central DAQ Post



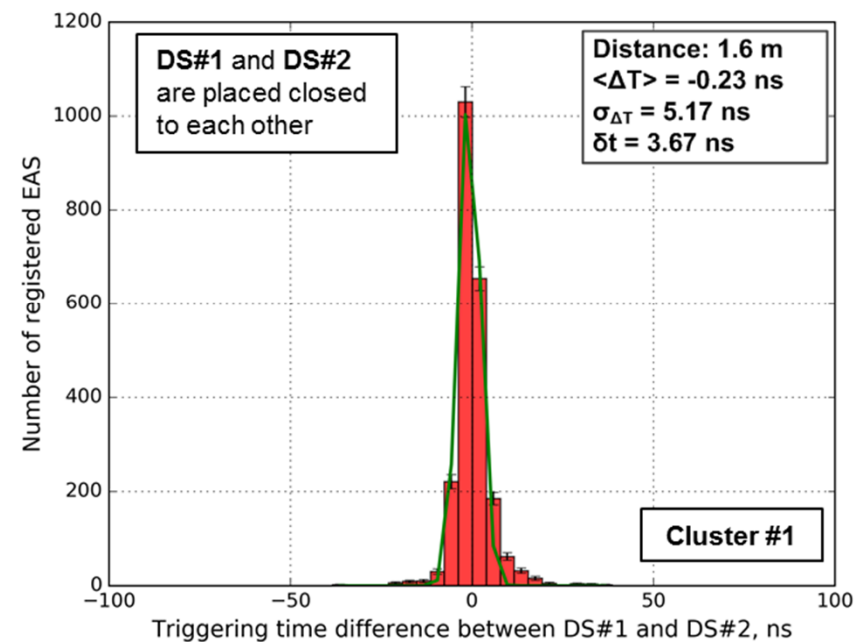
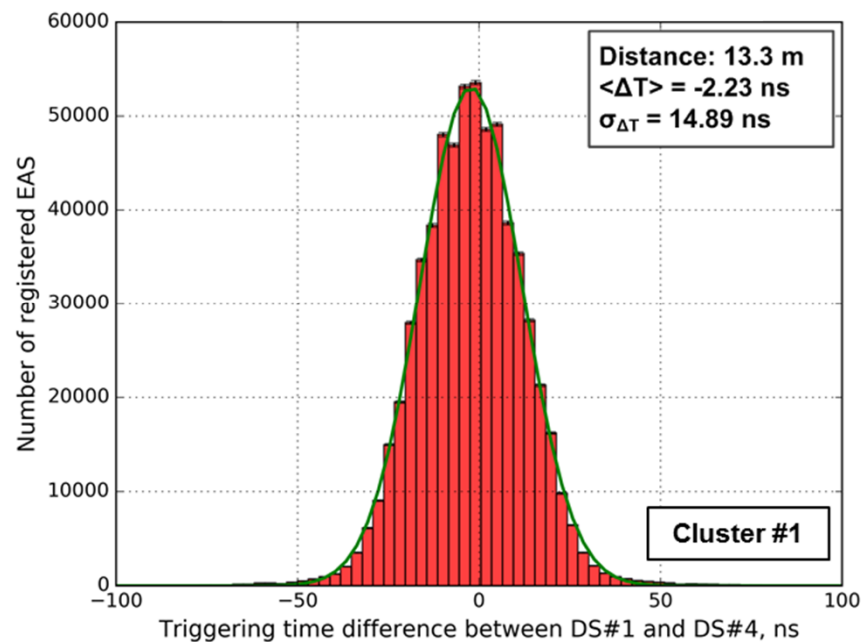
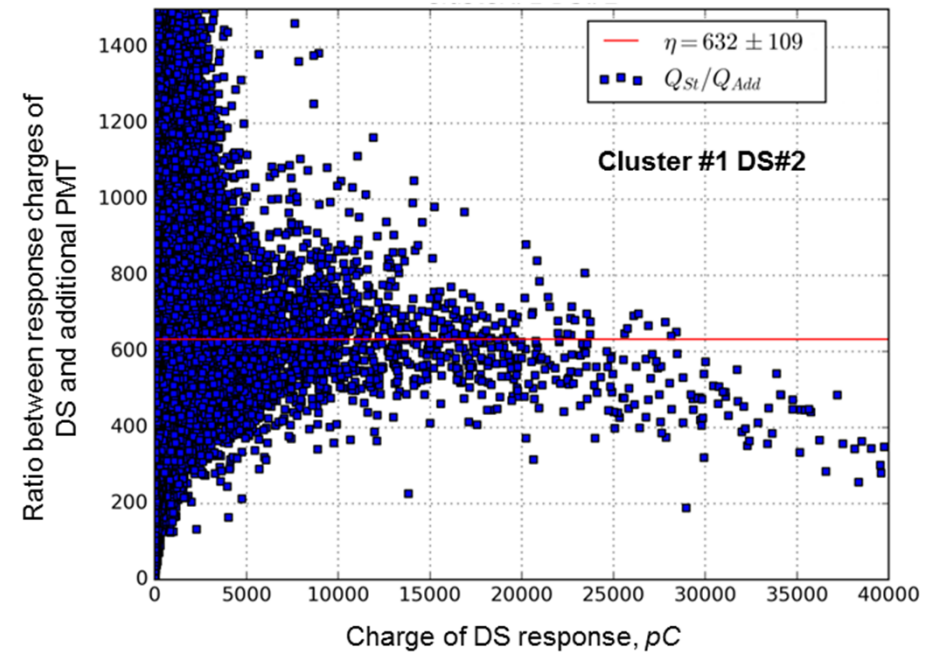
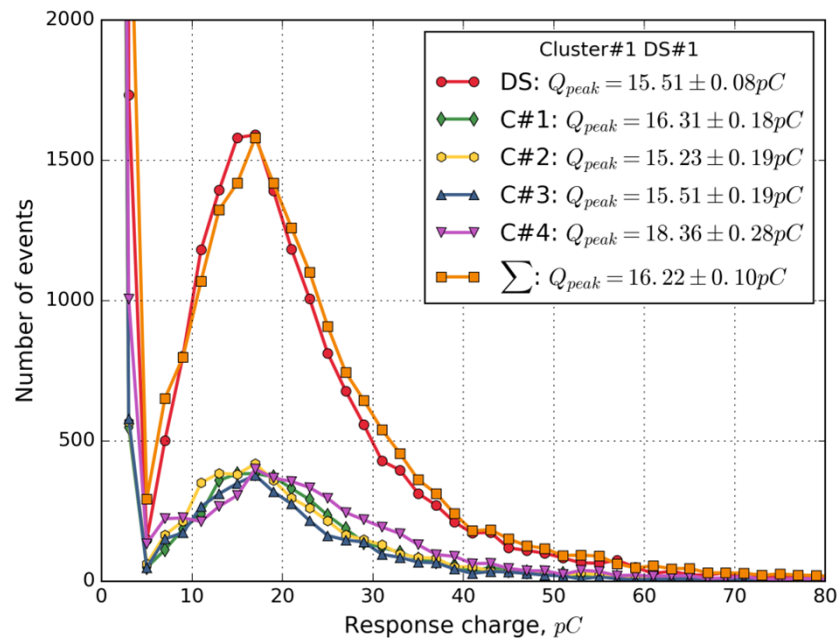
Clusters of the NEVOD-EAS array



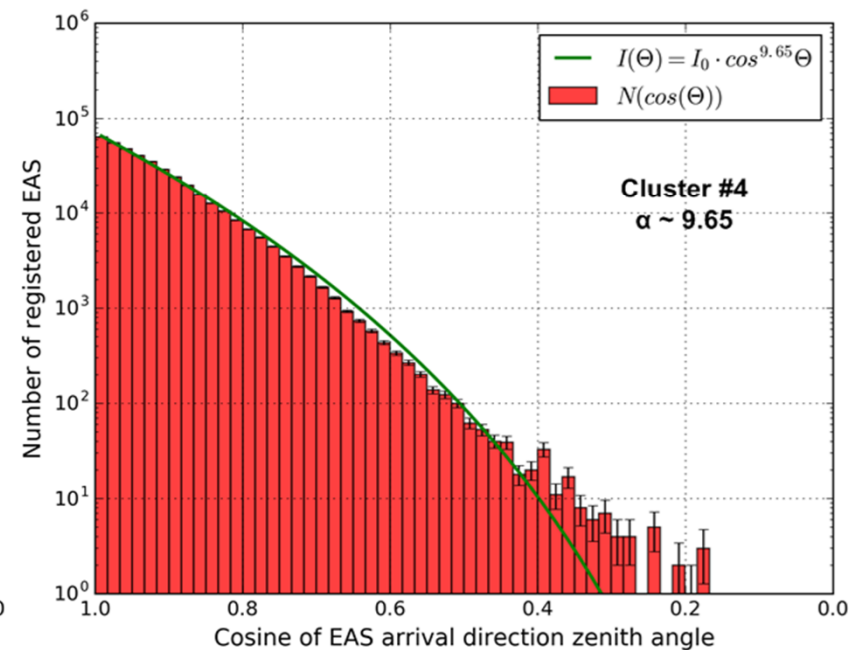
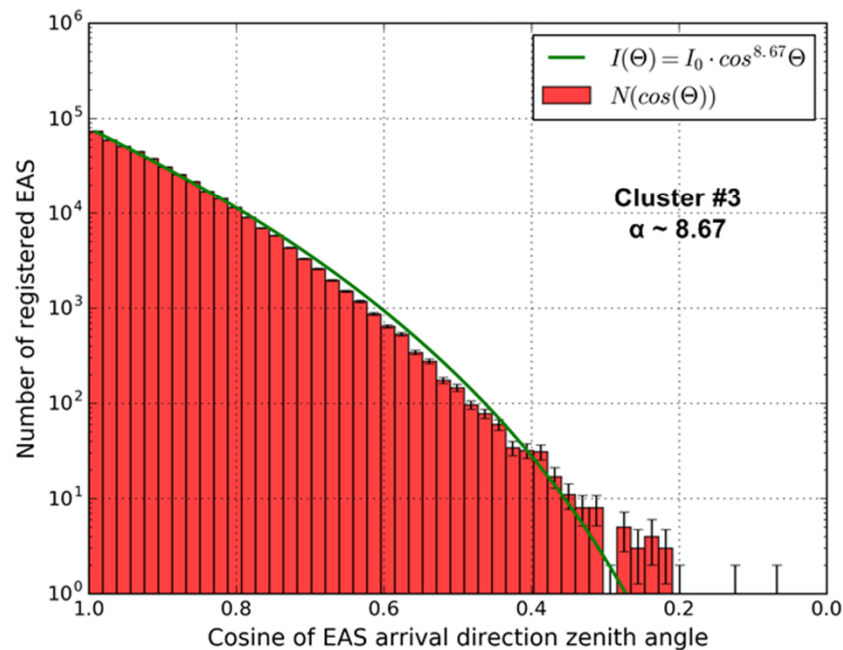
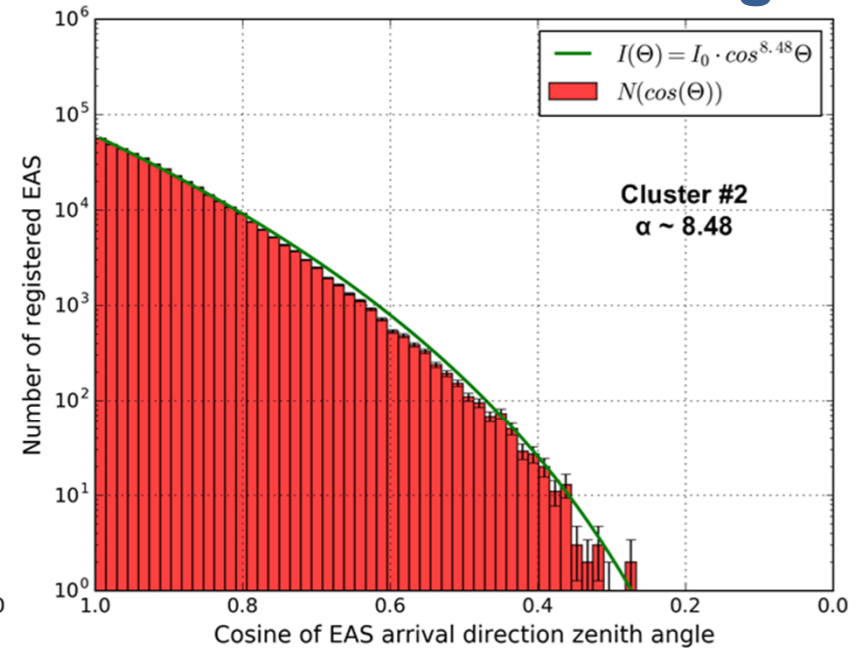
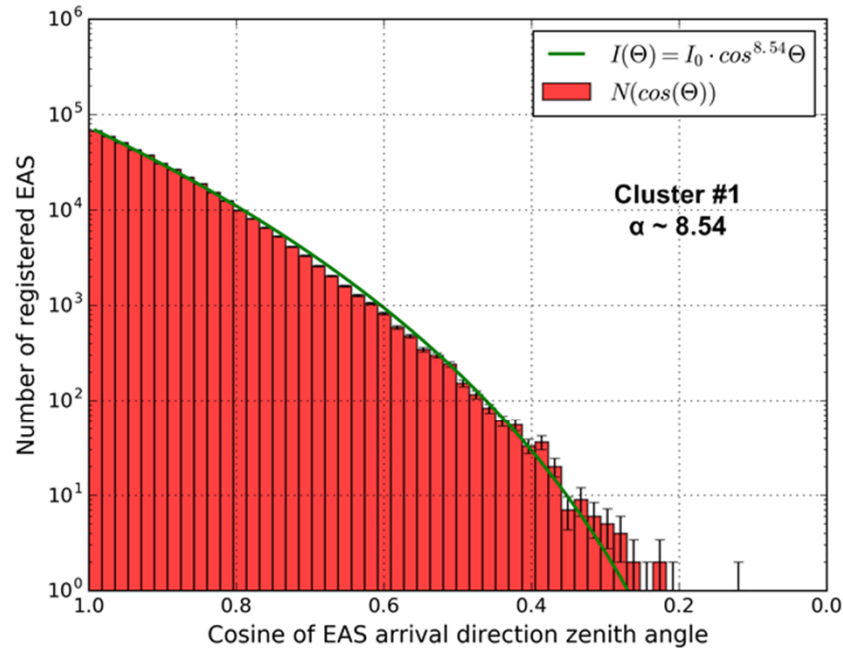
Clusters of the NEVOD-EAS array



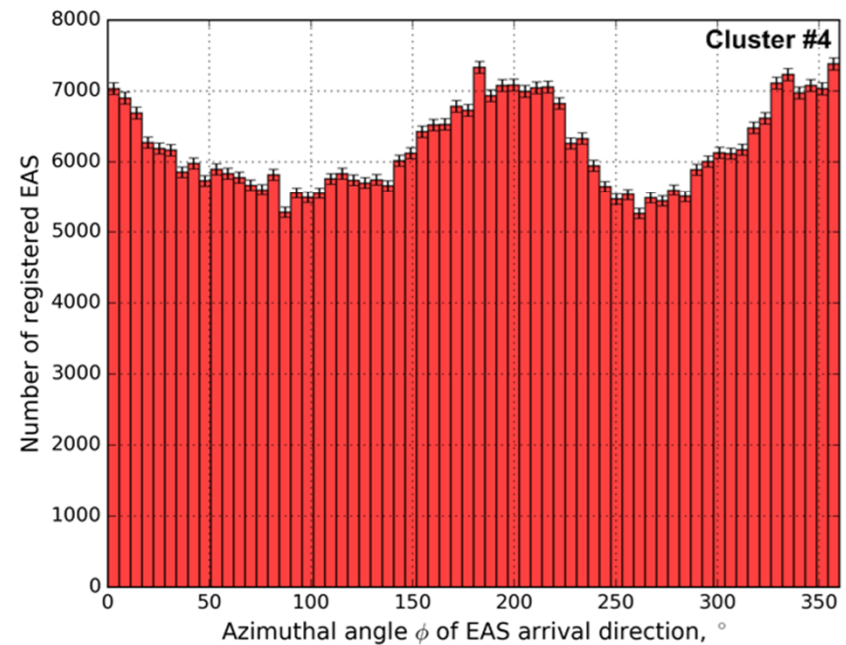
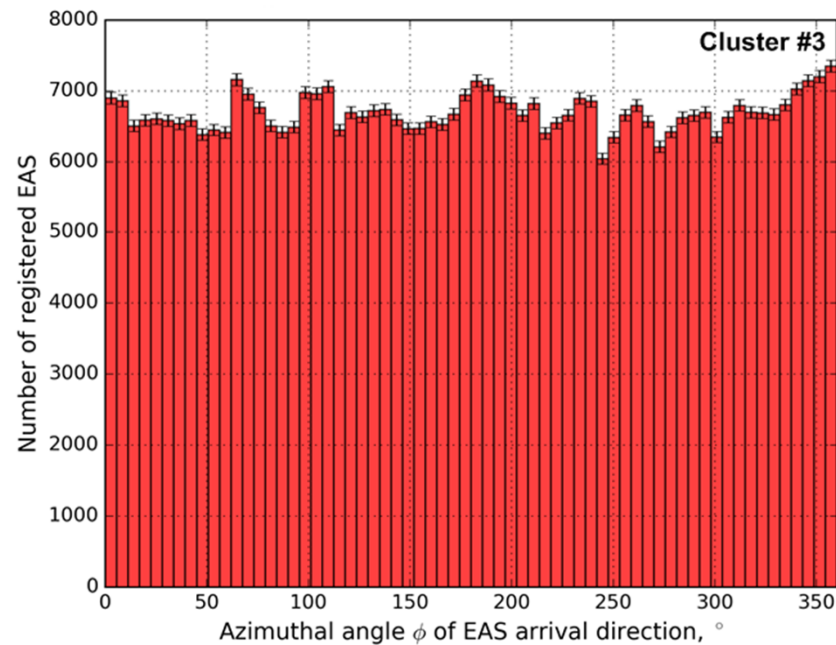
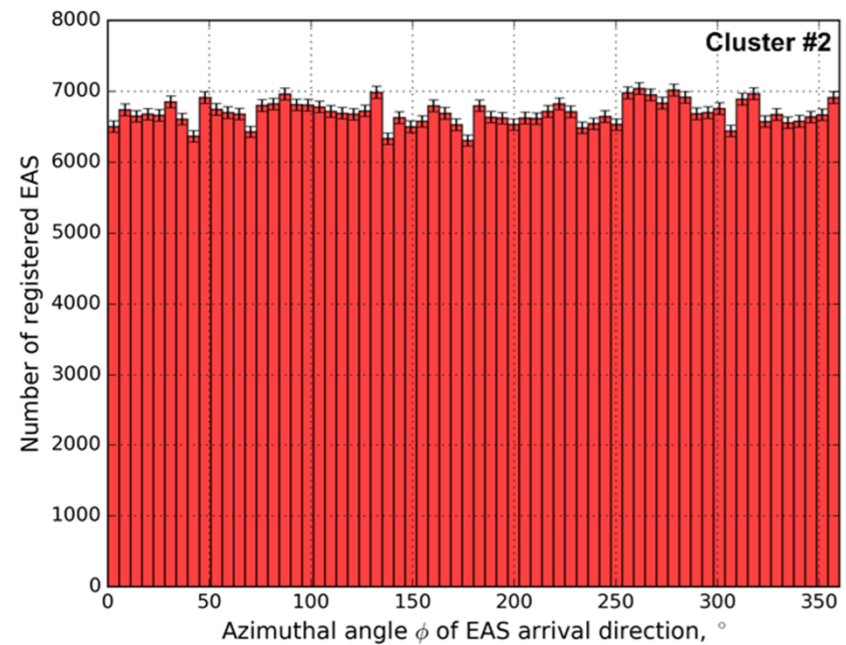
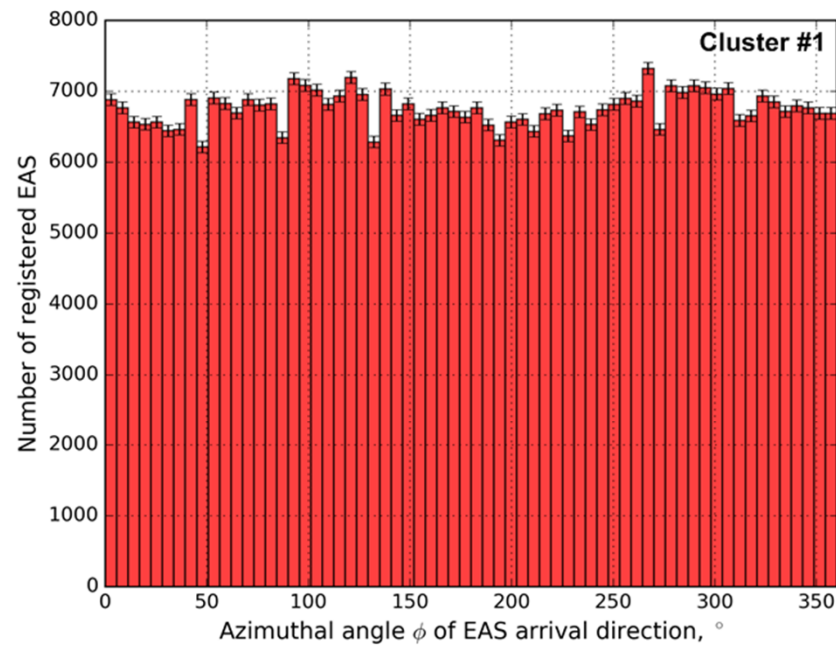
Response of the NEVOD EAS DS and counters



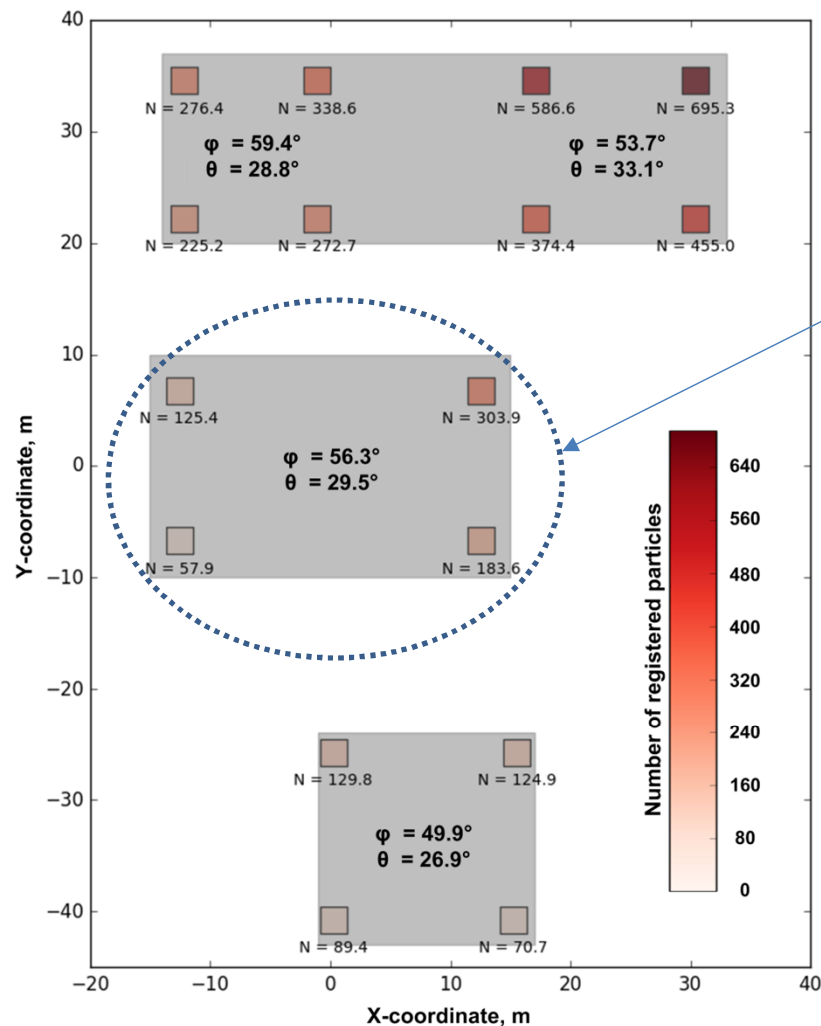
Reconstruction of EAS arrival direction: zenith angles



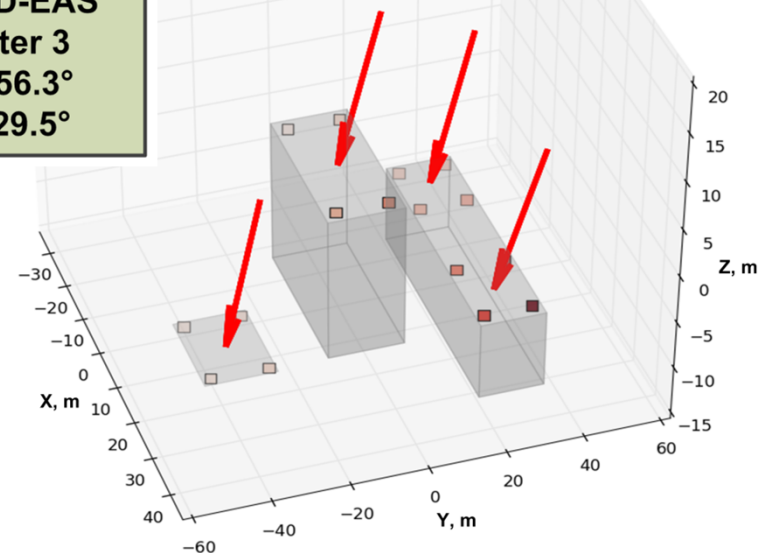
Reconstruction of EAS arrival direction: azimuth angles



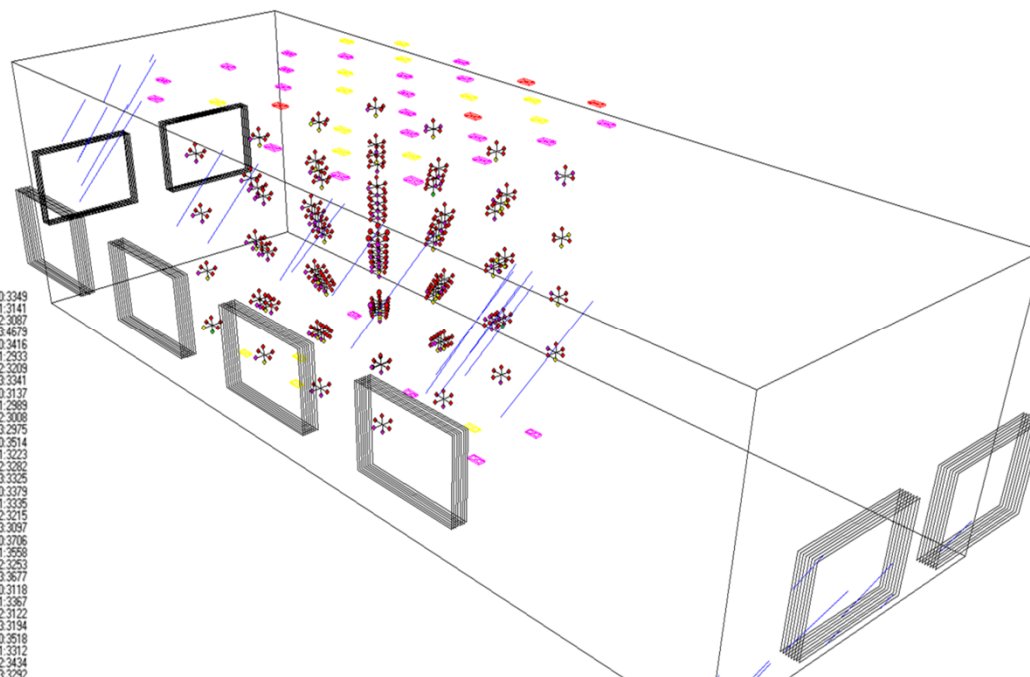
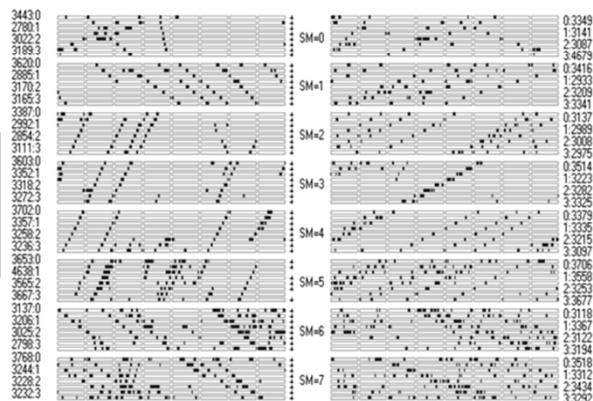
Example of event registered by NEVOD-EAS and NEVOD-DECOR



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



NEVOD-DECOR
 $\varphi = 54.4^\circ$
 $\theta = 29.5^\circ$



Conclusion

In **2015–2016**, 4 first clusters (in total, **64** scintillation counters) of the NEVOD-EAS cluster type shower array located around the Experimental Complex of the CWD NEVOD and coordinate detector DECOR at the area of about **10^4 m^2** have been created and started.

The distributed structure of the NEVOD-EAS array DAQ system allows to deploy registering elements of the setup even at different altitudes and provides implementation of a newly developed cluster approach to the reconstruction of EAS parameters.

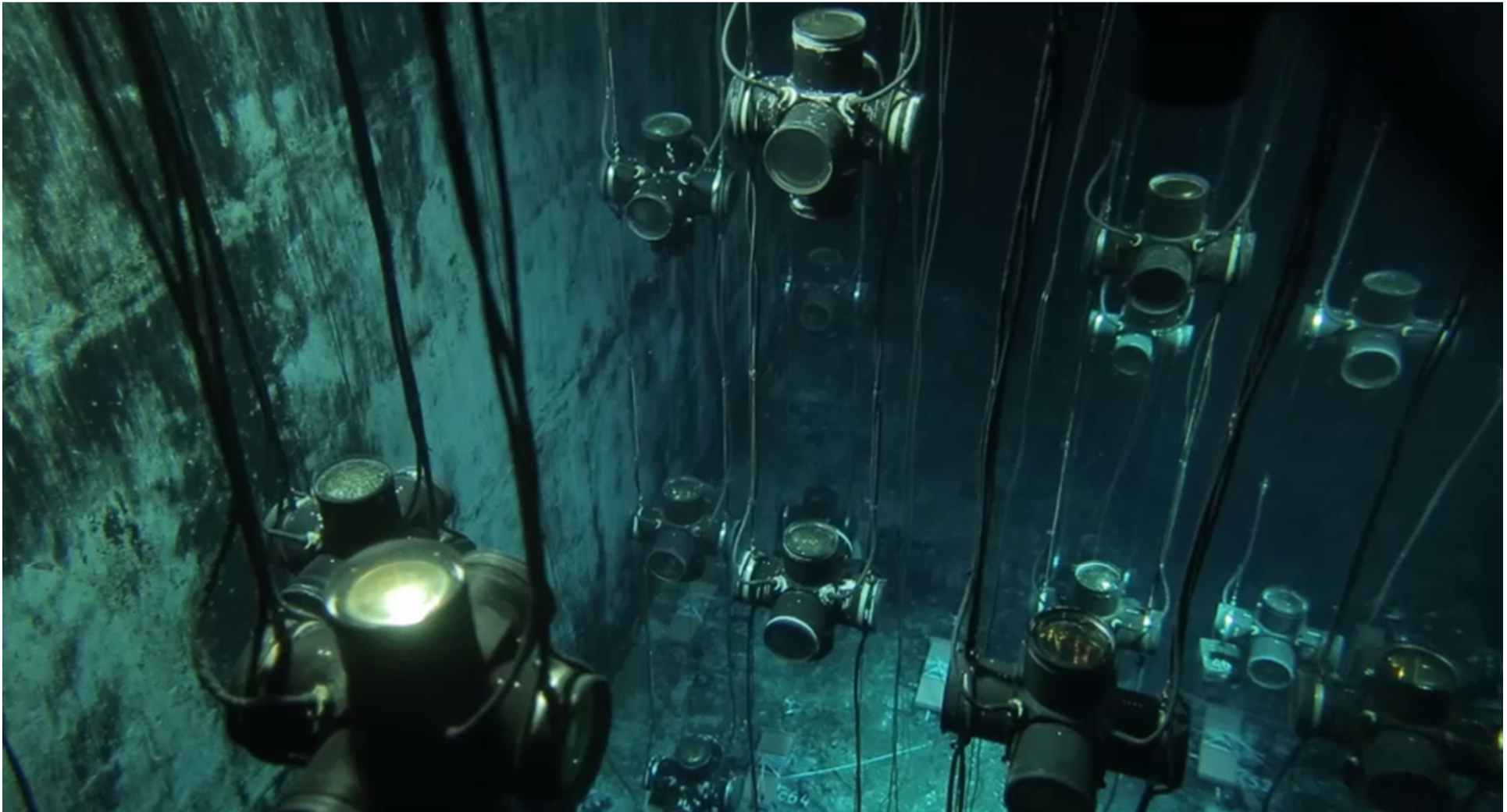
First test and experimental runs showed that the amplitude and temporal characteristics of responses of 4 clusters are quite similar and the detector station time resolution is about **3.7 ns**. The possibility of using of cluster approach to the reconstruction of EAS parameters has been proved.

In the nearest future, the NEVOD-EAS array is planned to be extended up to the area of about **$2 \times 10^5 \text{ m}^2$** .

Thank you for attention!



BACKUP: Detecting system of the CWD NEVOD



91 QSMs are arranged in 25 vertical strings (9 strings \times 3 QSM, 16 strings \times 4 QSM). Each QSM consists of 6 low-noise 12-dynode photomultipliers FEU-200 with flat 15 cm diameter photocathodes directed along rectangular coordinate axes. A wide dynamic range ($1 - 10^5$ photoelectrons) is provided by 2-dynode signal readout and allows to measure both high-energy cascades and energy deposit of muon bundles in the calorimeter.

BACKUP: DECOR supermodules (SMs) in the galleries around the NEVOD water tank



Each SM has an effective area 8.4 m^2 and consists of 8 planes of streamer tube chambers. The length of the chambers is 3.5 m, inner tube cross section is $9 \times 9 \text{ mm}^2$. The planes of the chambers are equipped with a two-dimensional system of external readout strips.

BACKUP: Muon bundle event in the DECOR SMs

multiplicity $m = 144$ particles, zenith angle $\theta = 57^\circ$

