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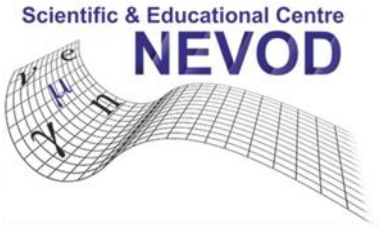

Status of the Russian-Italian experiment NEVOD-EAS

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Università degli Studi di Torino &

National Research Nuclear University, MEPhI

On behalf of the NEVOD-EAS collaboration

IV International Conference on Particle Physics and Astrophysics
Moscow, October 22 – 26, 2018

Experimental complex NEVOD @ MEPhI

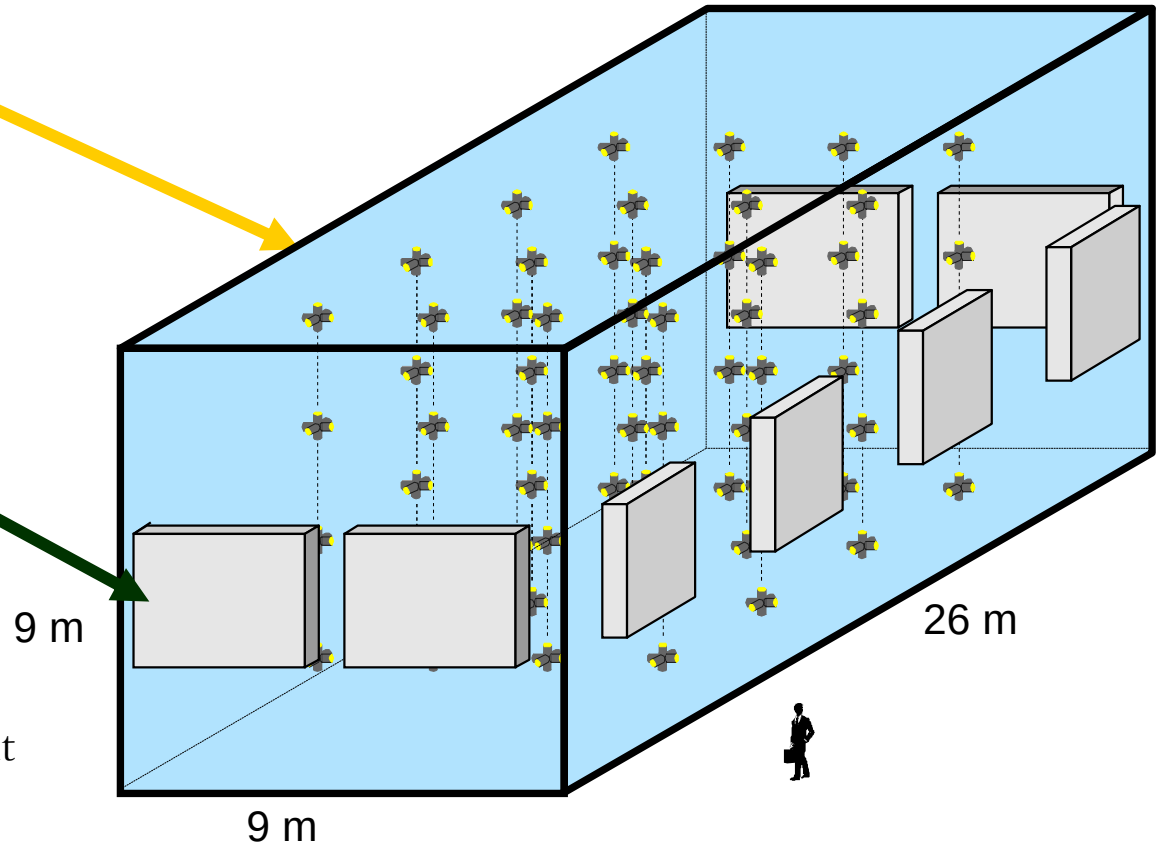
Coordinate-tracking detector DECOR (total area 70 m^2)

8 supermodules (SMs) of streamer tube chambers

Chambers previously used in the NUSEX experiment

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

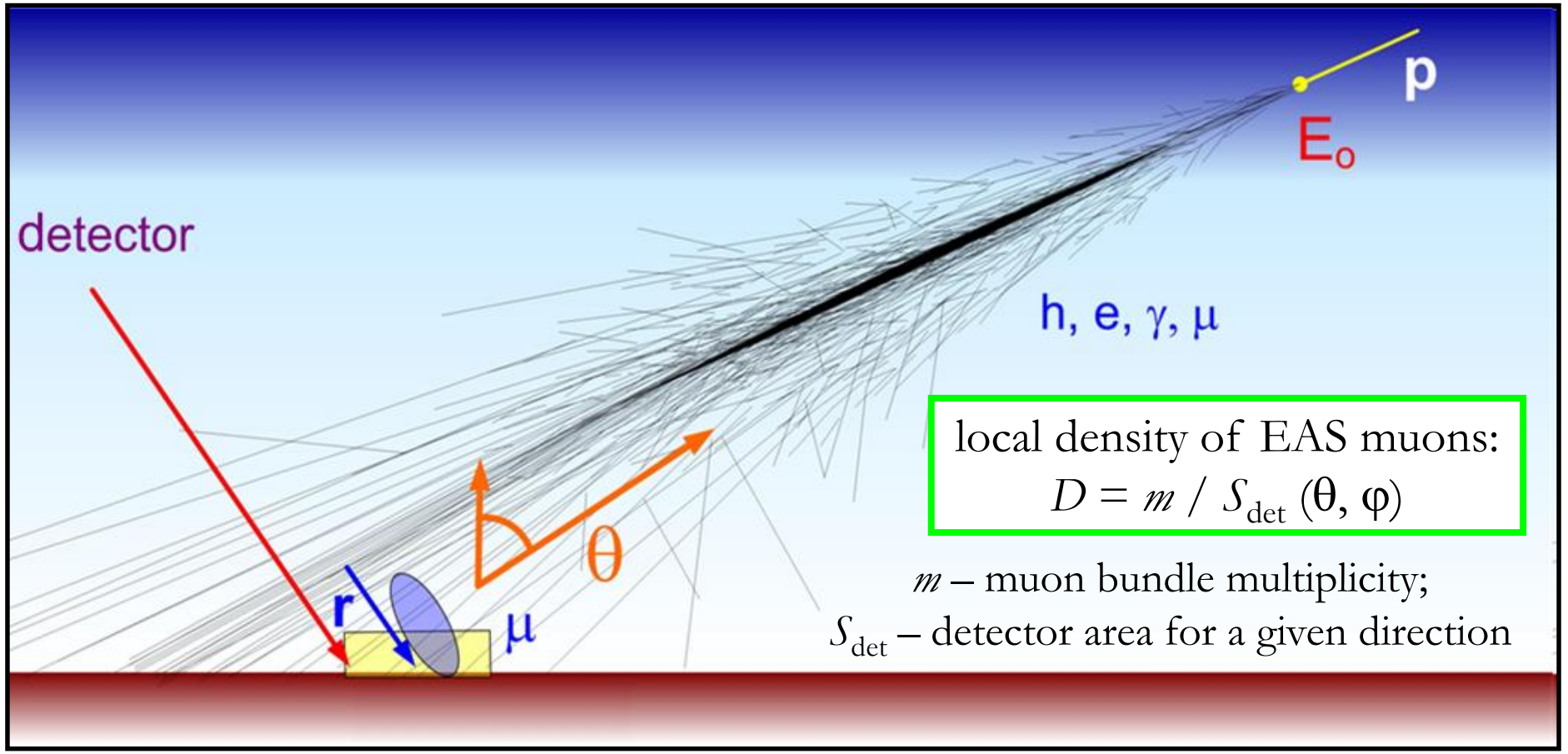
Cherenkov water detector NEVOD (volume 2000 m^3)



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.

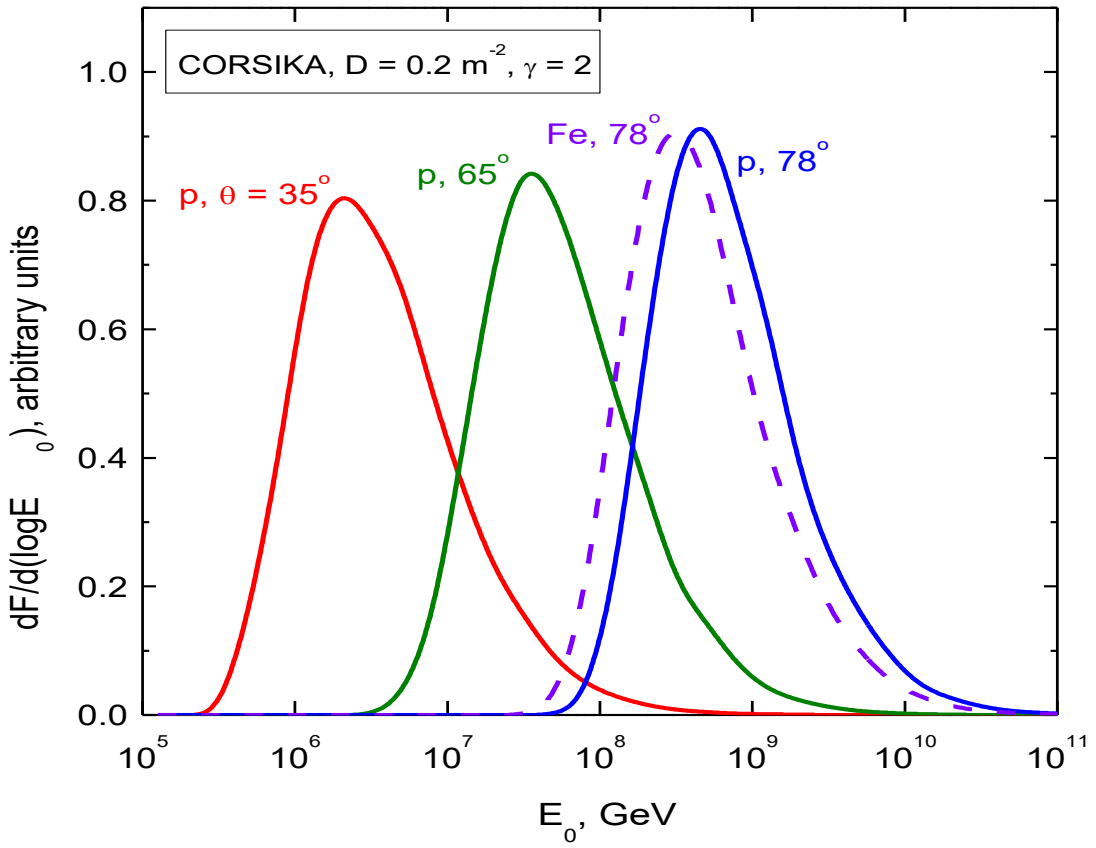
Novel approach to the analysis of data on muon bundles: method of Local Muon Density Spectra (LMDS)

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. Event collection area is determined by transverse dimensions of the showers in muon component. An EAS array helps in locating the shower core position and the Shower Size

Distribution of primary cosmic ray particle energies contributing to events with a fixed muon density at different zenith angles



CORSIKA (QGSJET01)

$D(\theta) \sim E_0$!

$\sigma_{lgE} \sim 0.4$

Contribution to events with a certain muon density give showers with different primary energies, detected at random distances from the axis. However, due to a fast decrease of primary cosmic ray intensity with the increase of energy, the effective primary energy band appears relatively narrow ($\sigma_{lgE} \sim 0.4$). At different zenith angles, the events with a fixed muon density are formed by primary particles with substantially different energies.

NEVOD-EAS

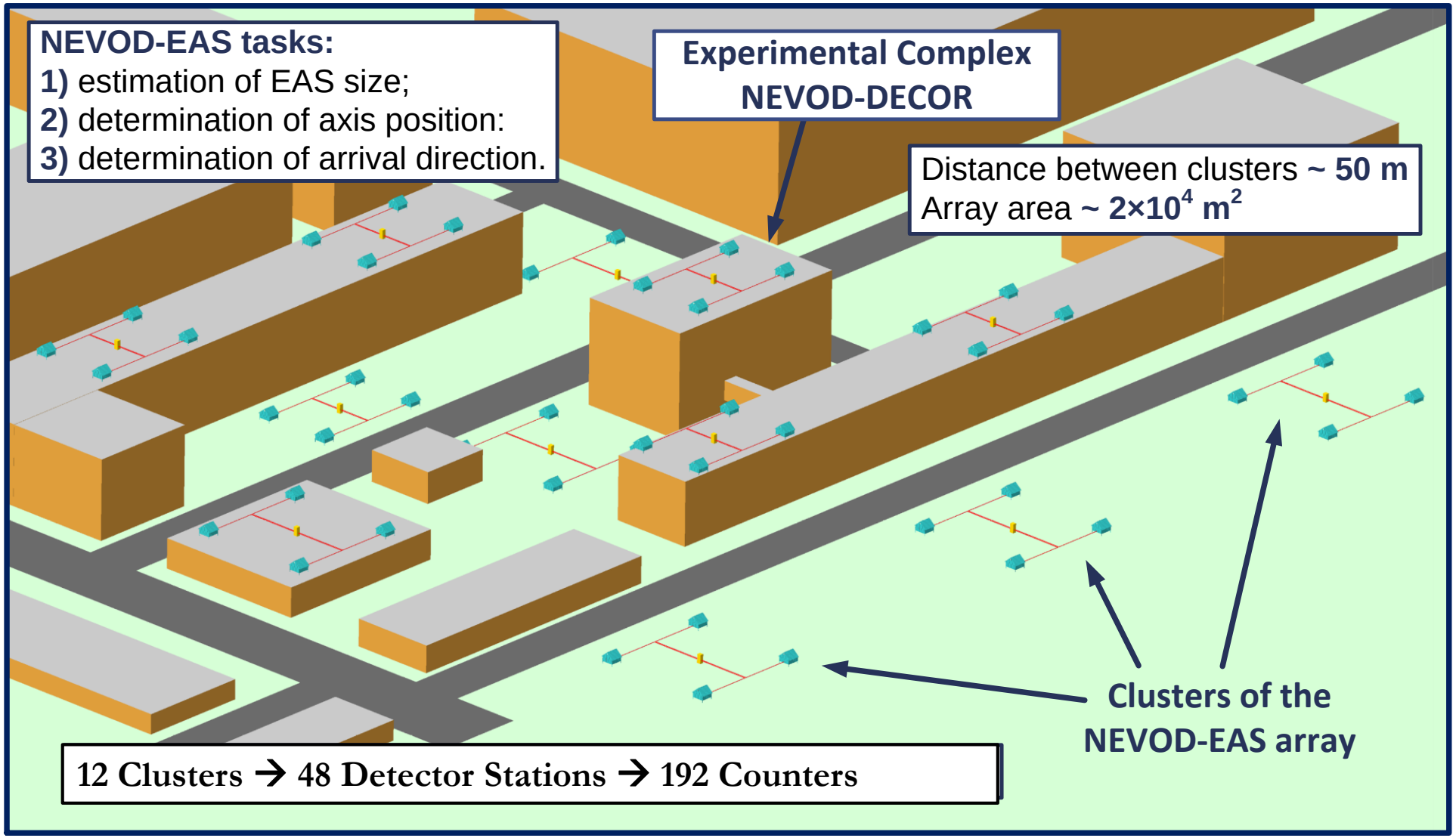
- Joint effort of the Russian-Italian collaboration.

- EAS array aimed to determine:
  - Arrival direction
  - Core location
  - Shower size (Ne)

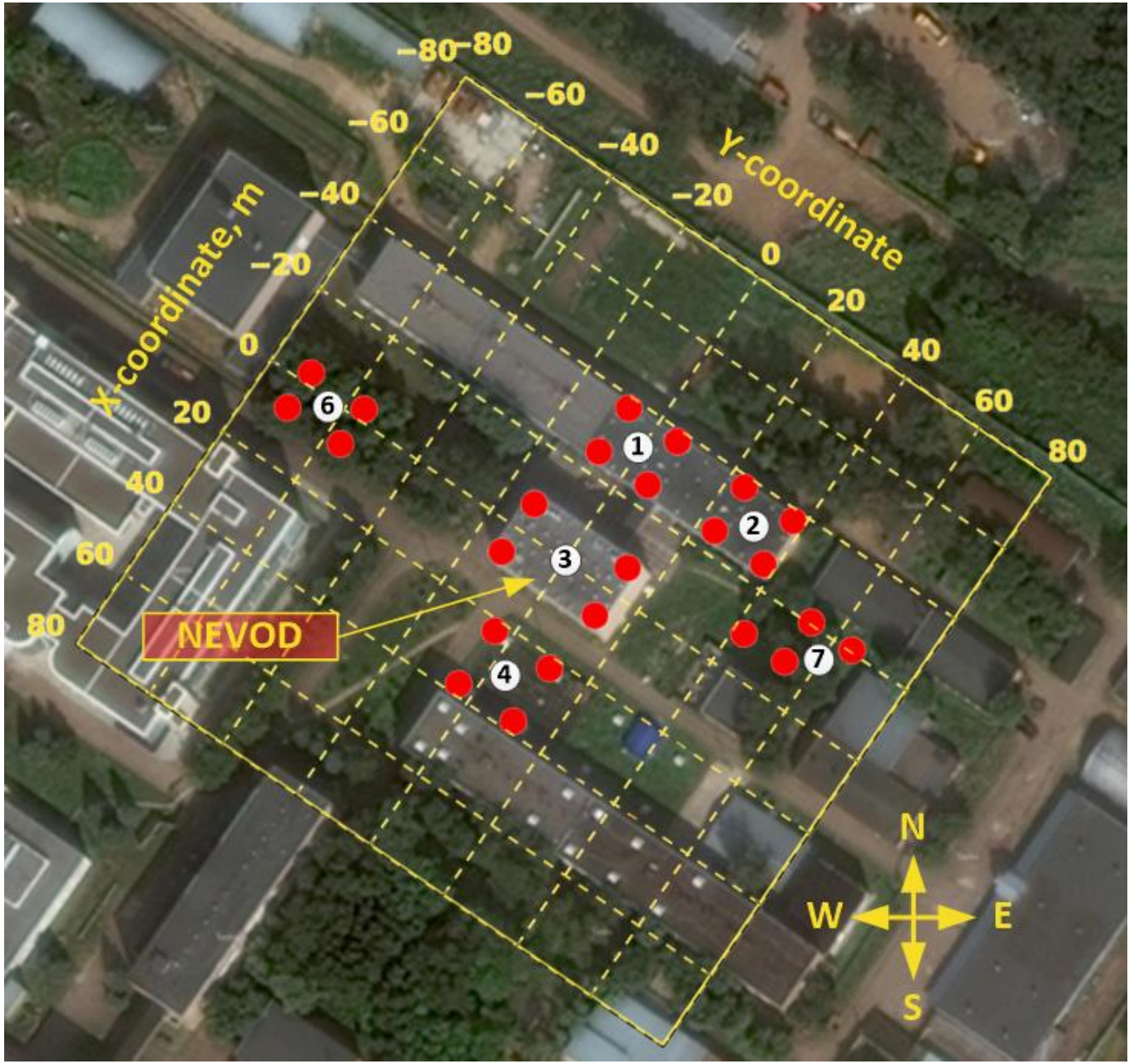
- Calibration of the technique to measure local muon density spectra by the NEVOD-DECOR complex

- Extend the opportunities of the Experimental Complex NEVOD in carrying out multicomponent studies of extensive air showers

NEVOD-EAS array



Current state of the NEVOD-EAS array



6 clusters

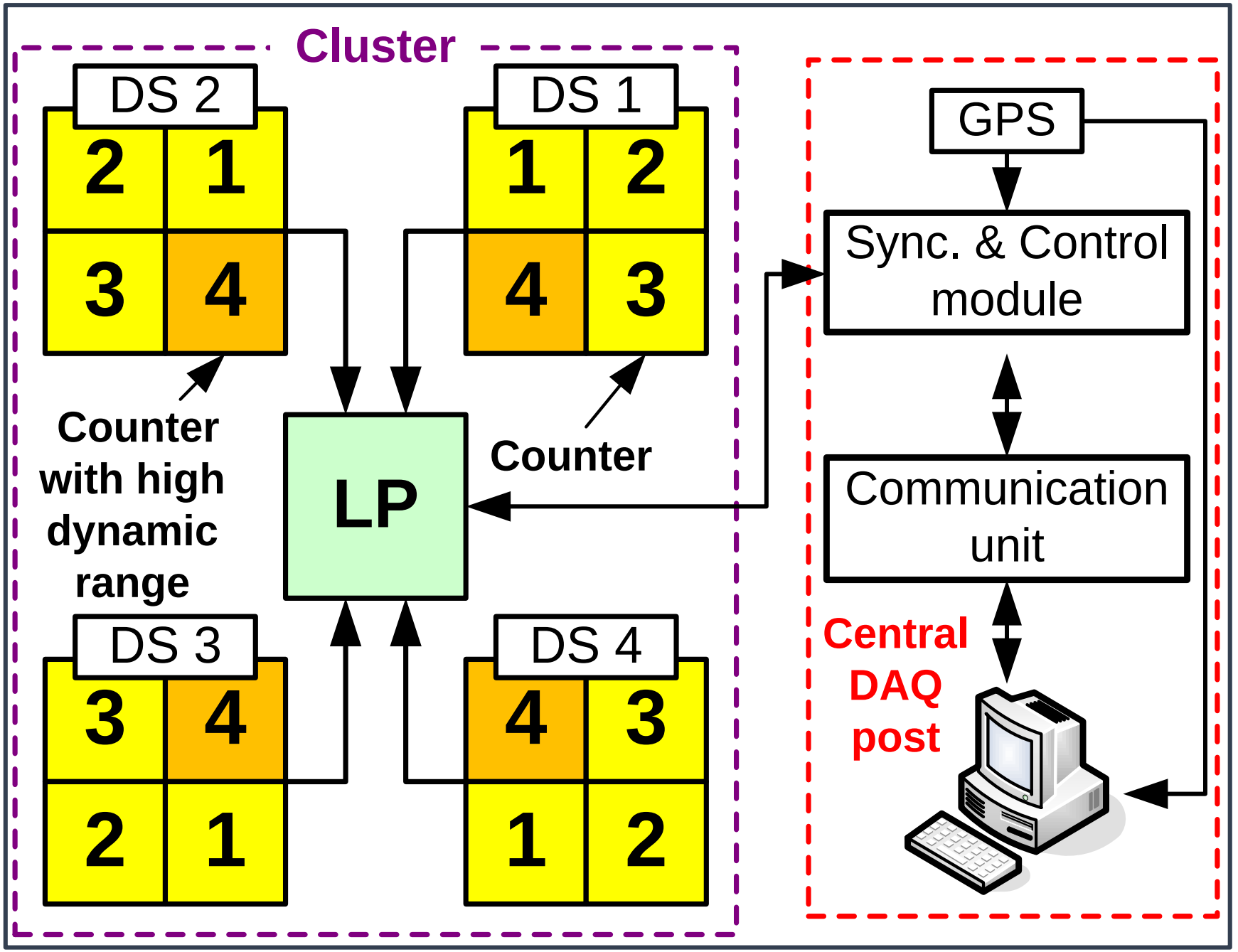
24 detector stations

96 counters

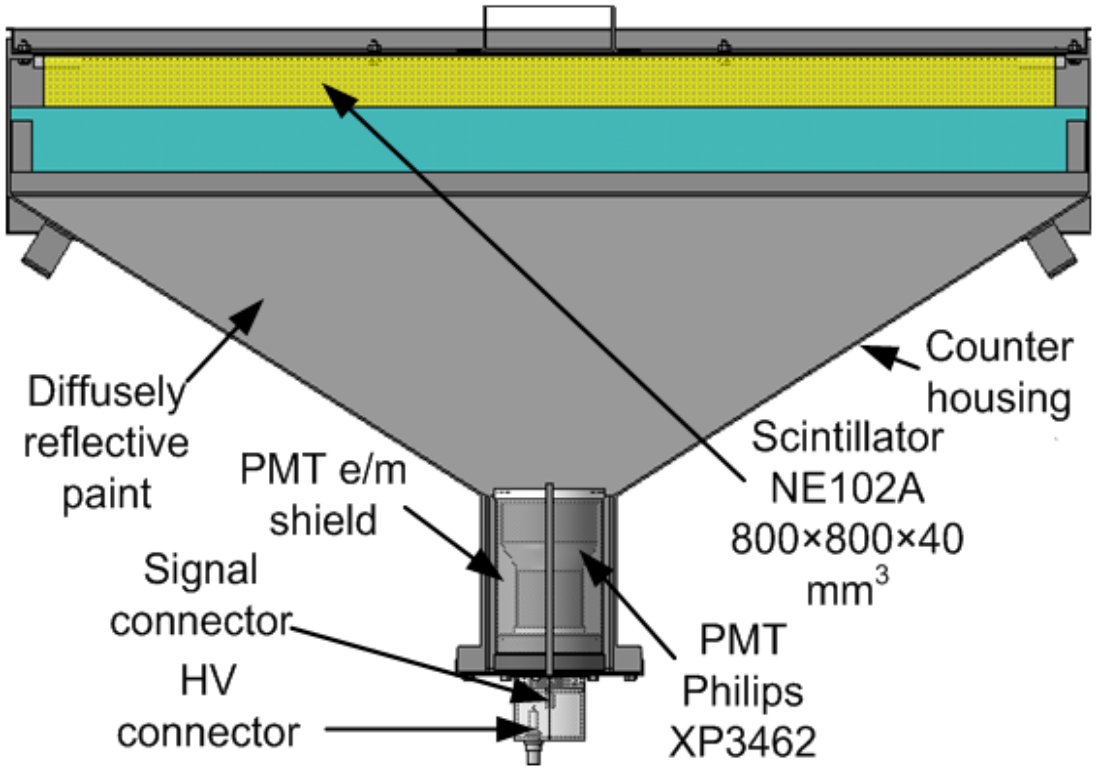
typical cluster size:
15 × 15 m^2

array area:
10^4 m^2

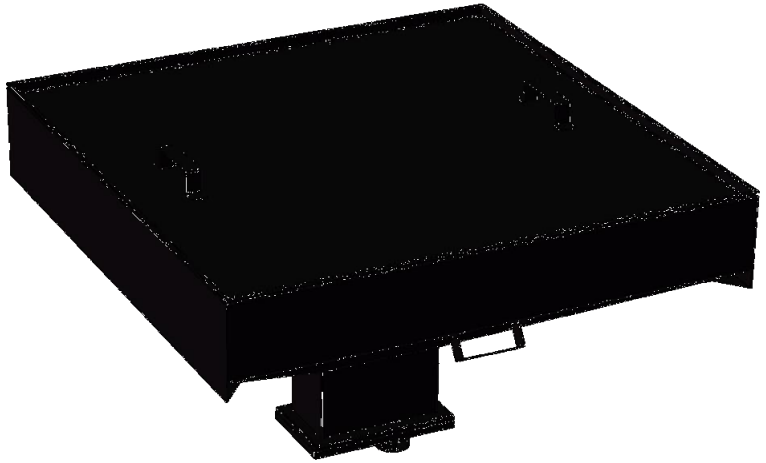
energy range:
from 10^{15} to 10^{17} eV


Cluster
DS 2
2
1
3
4
DS 1
1
2
4
3
DS 3
3
4
2
1
DS 4
4
3
1
2
LP
Counter with high dynamic range
Counter
GPS
Sync. & Control module
Communication unit
Central DAQ post

Scintillation counter



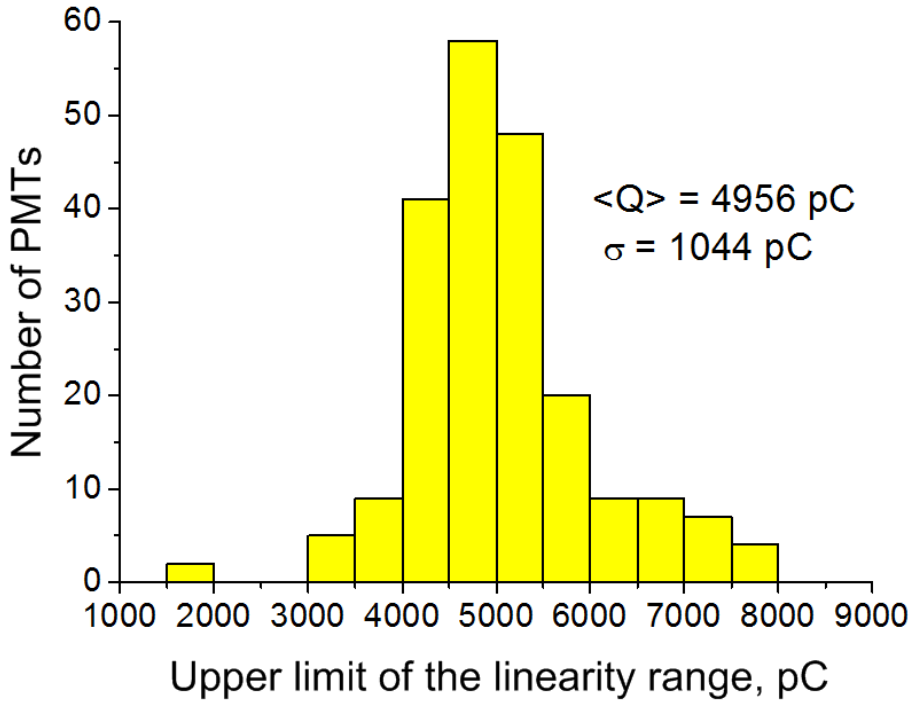
Scintillator:
NE102A 80 × 80 × 4 cm³
Photomultiplier:
Philips XP3462

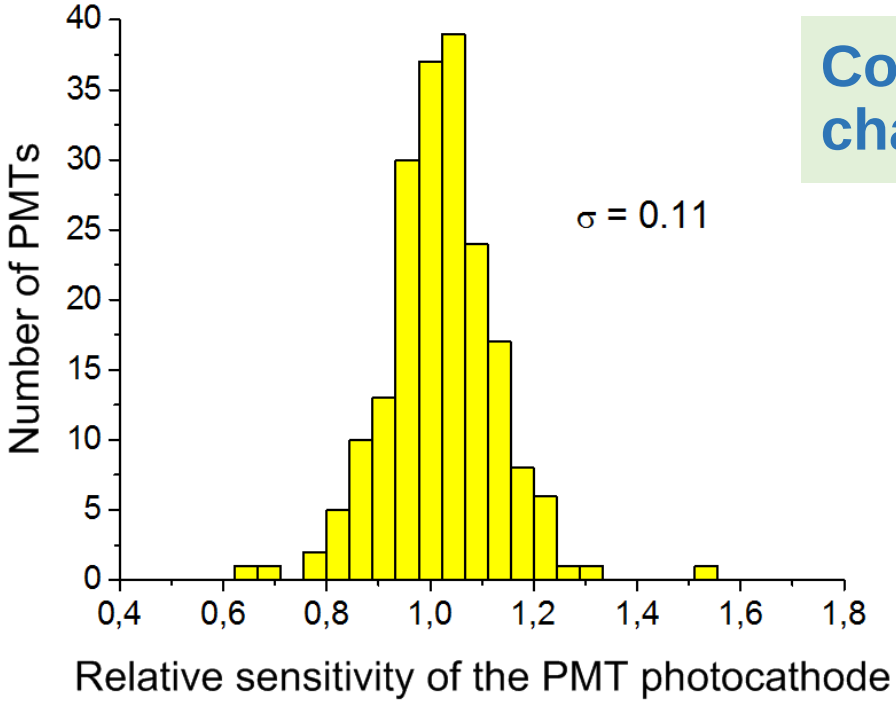


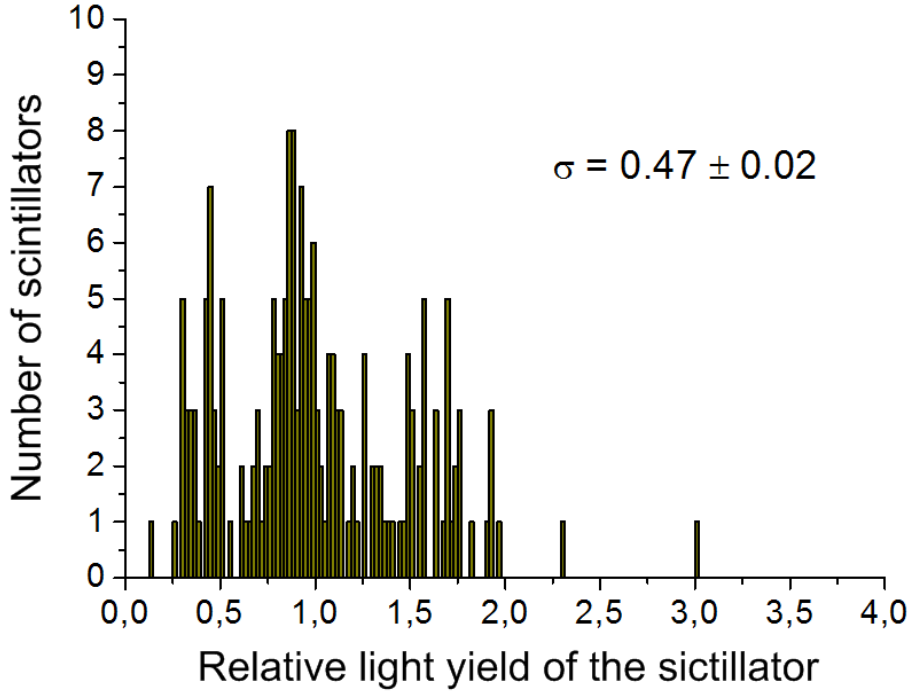
Most probable response to 1 particle (VEM): **~ 13 pC**
Upper limit of dynamic range (with standard PMT): **100 particles (VEM)**
Upper limit of dynamic range (with additional PMT): **10^4 particles/m²**

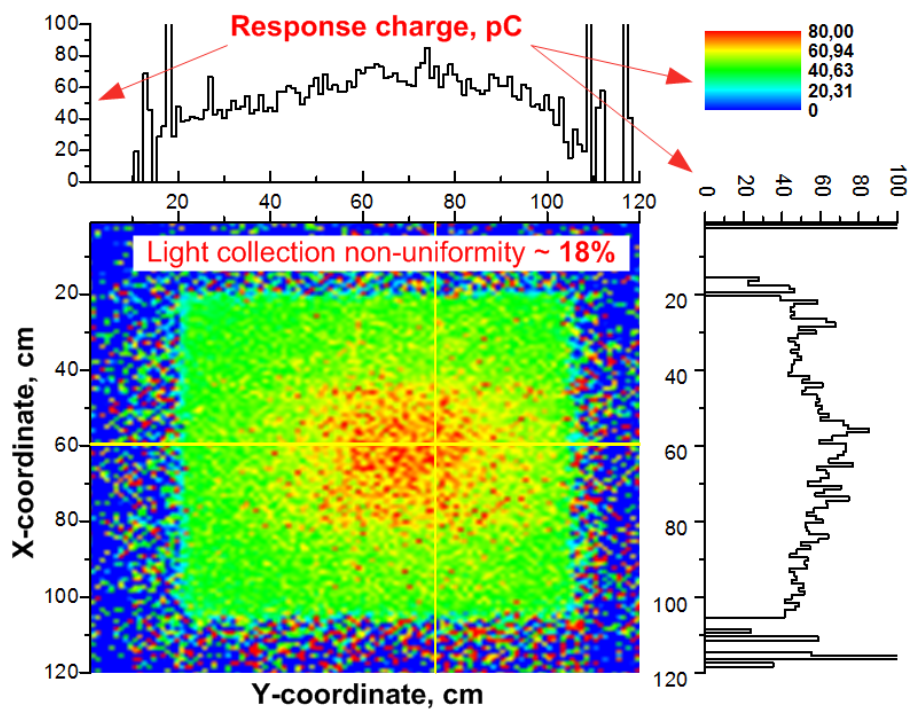
1987 – 2000	**EAS-Top** experiment (Italy)
2003 – 2012	**KASCADE-Grande** experiment (Germany)
Since 2013	**NEVOD-EAS** and **Tunka-Grande** experiments (Russia)

Counter characteristics

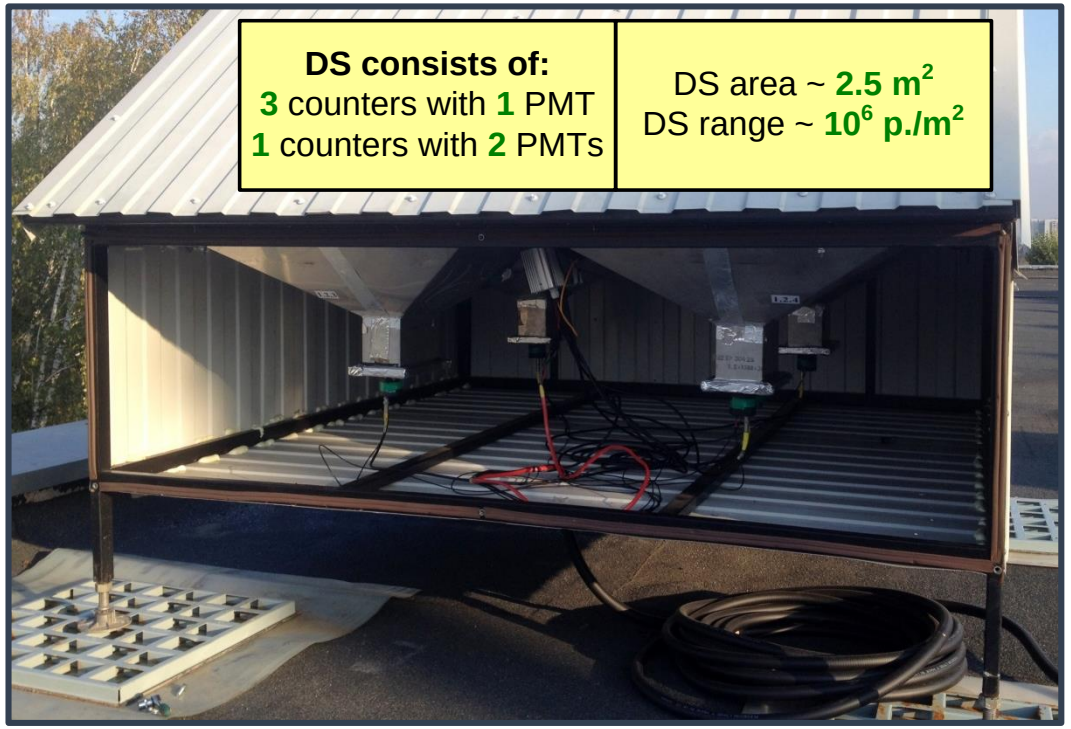






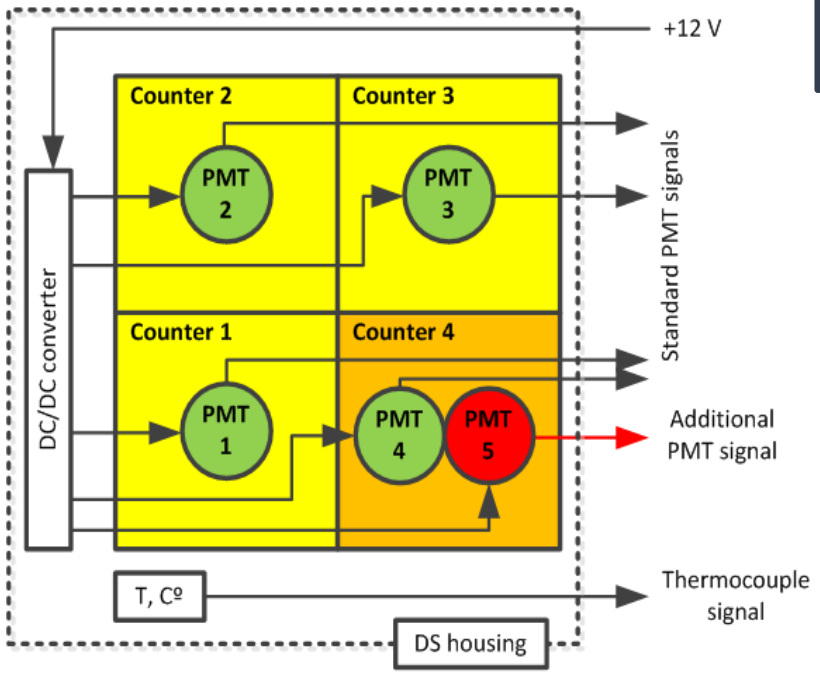


Detector Station (DS)



DS consists of:
3 counters with **1** PMT
1 counters with **2** PMTs

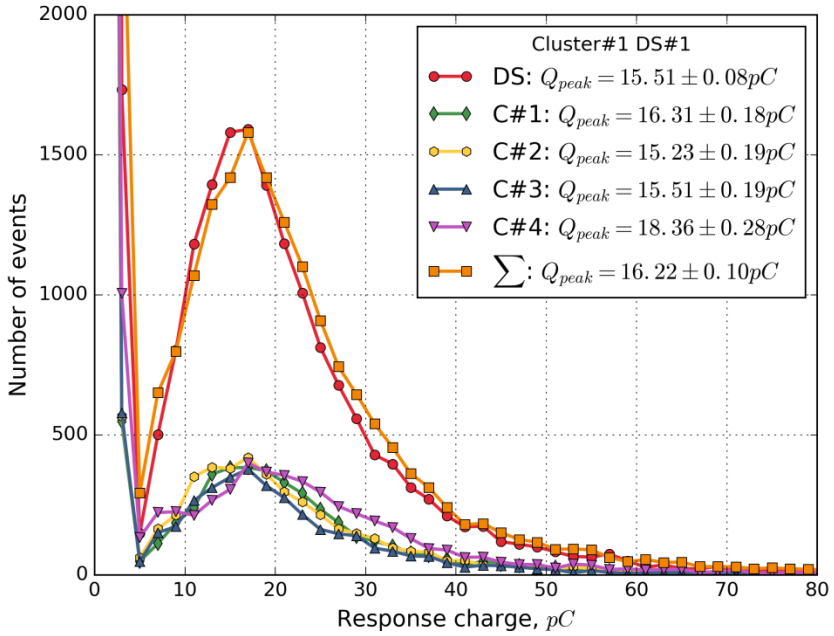
DS area ~ **2.5 m^2**
DS range ~ **10^6 p./m^2**

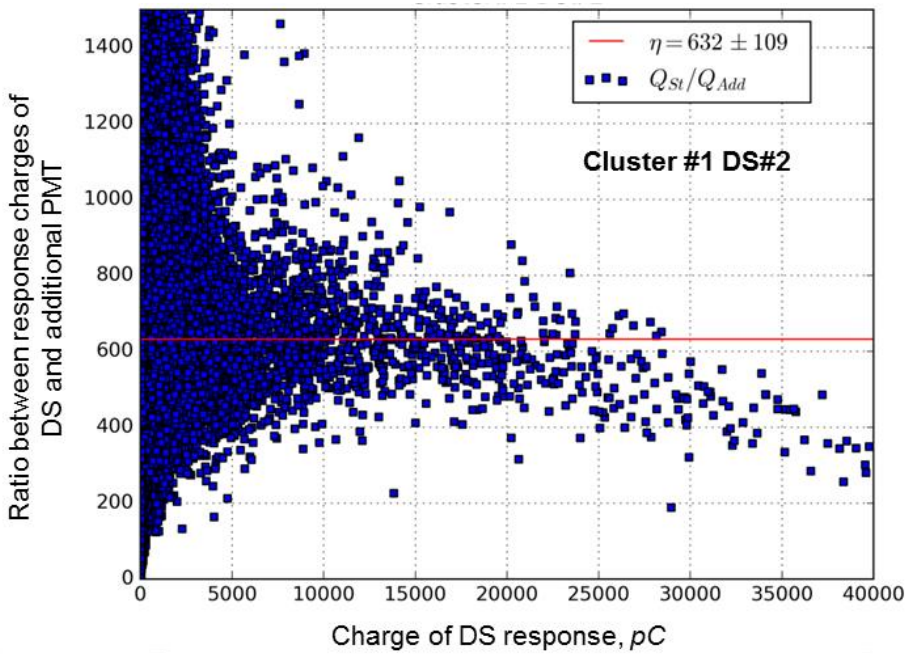


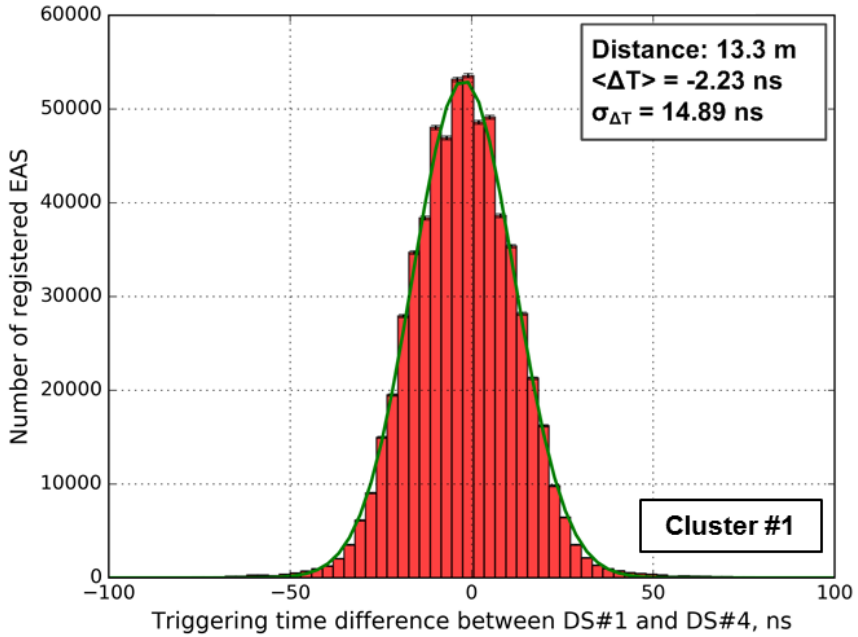
4 PMTs (**standard**): **measuring EAS particle densities and time measurements**.

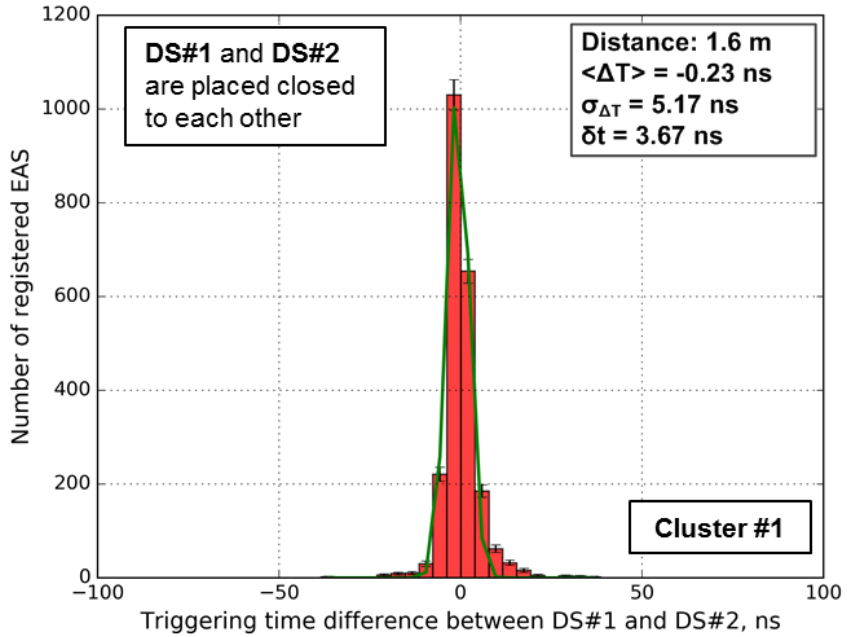
5th PMT **(additional)**: a gain of **≈ 90 times less** than for the standard PMT; **ensures wide linearity range of measured signals at high particle densities**.

Response of DS and counters





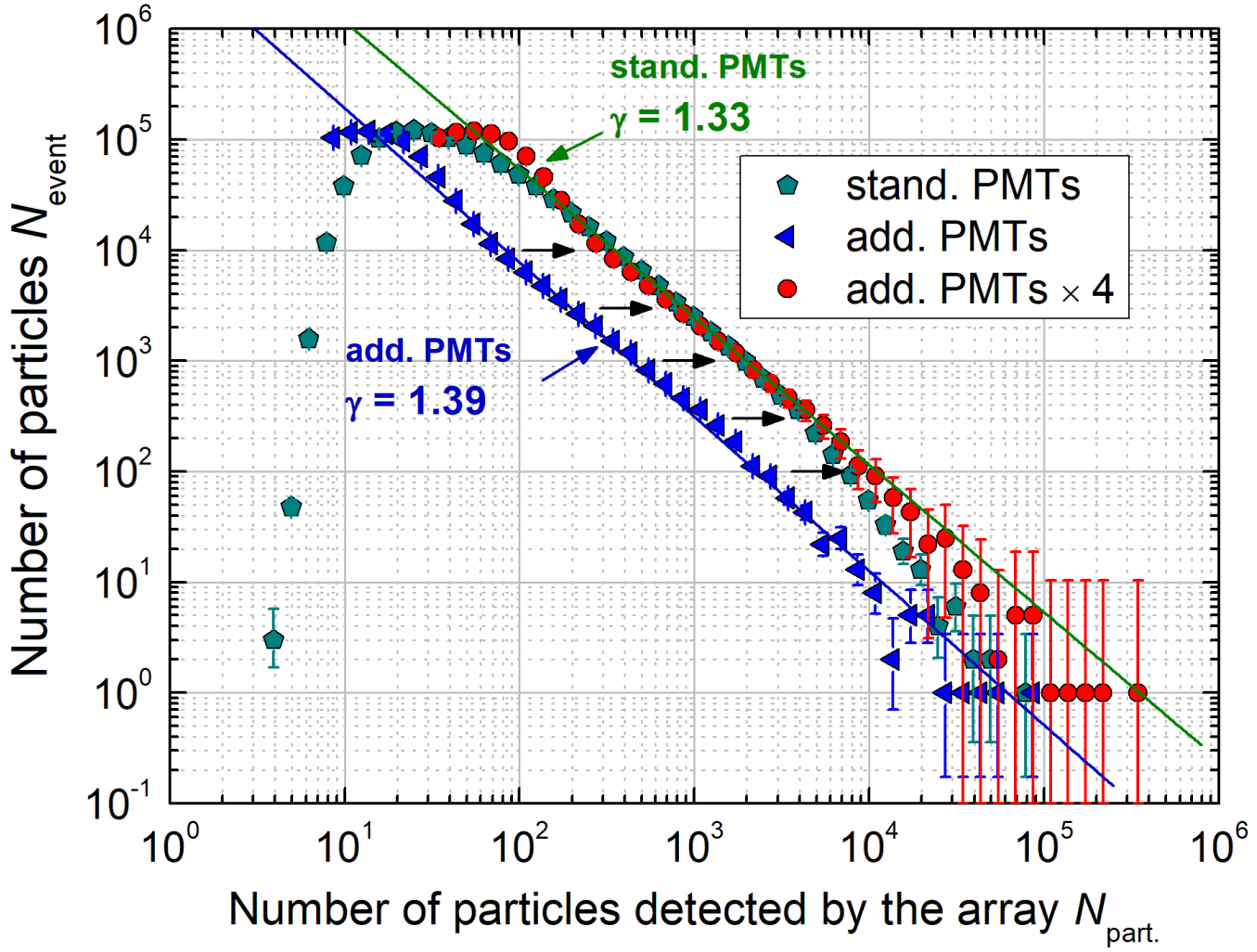




Response of the array during detection of EAS of different energies

Distribution of events on the measured size of extensive air showers
(1136751 events, multiplicity of triggered clusters ≥ 3):

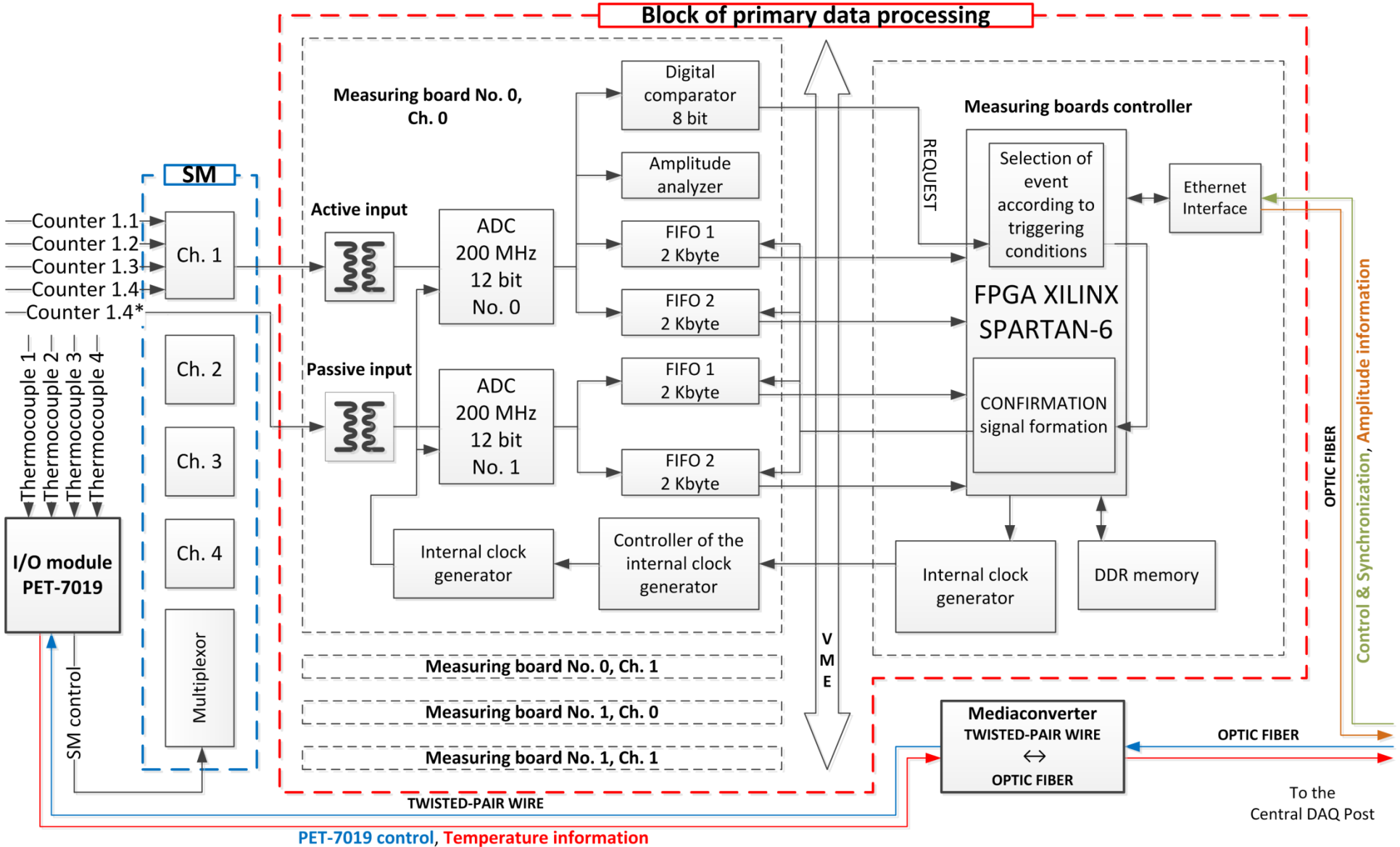
- according to the data of **standard PMTs** of array detector stations (DS);
- according to the data of **additional PMTs** of array DS;
- according to the responses of additional PMTs reduced to the DS area.



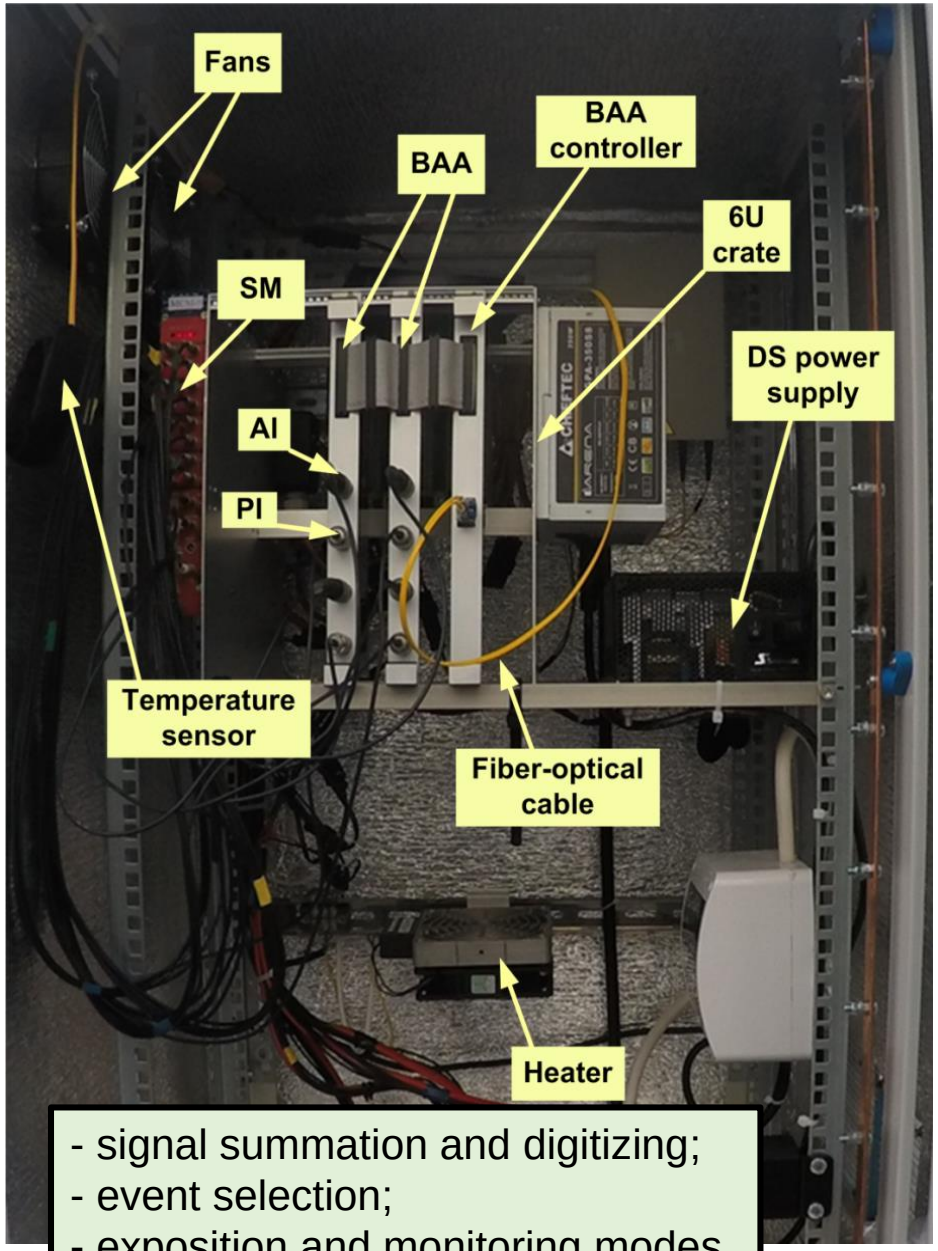
Cluster Local Post (LP)

Main tasks:

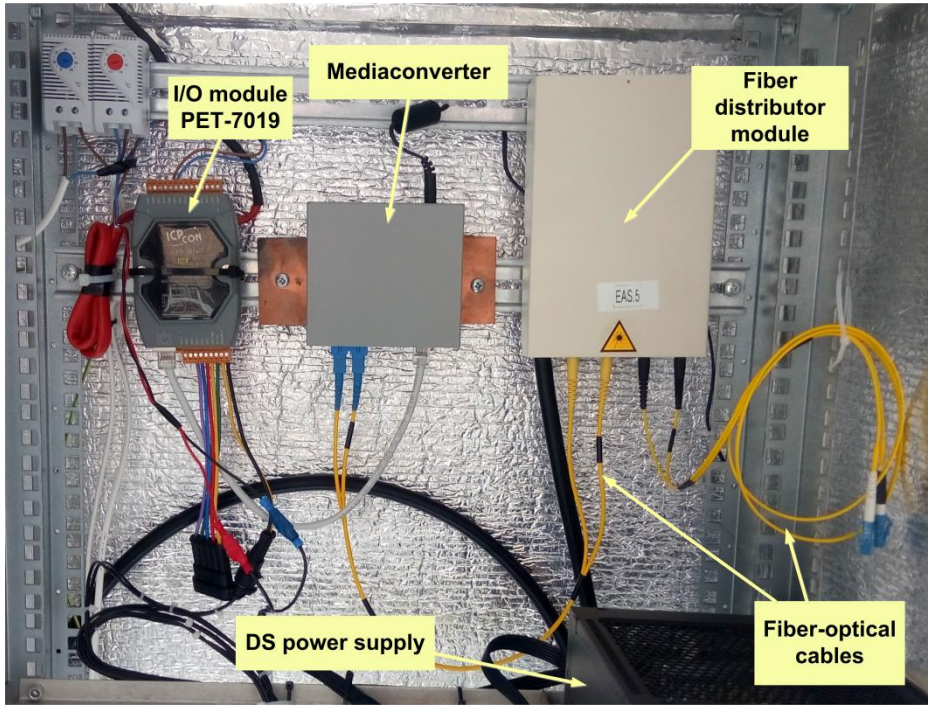
- summation & digitizing of PMTs signals
- event selection
- DS power supply
- operation in exposition and monitoring modes
- control of temperature inside DS and LP

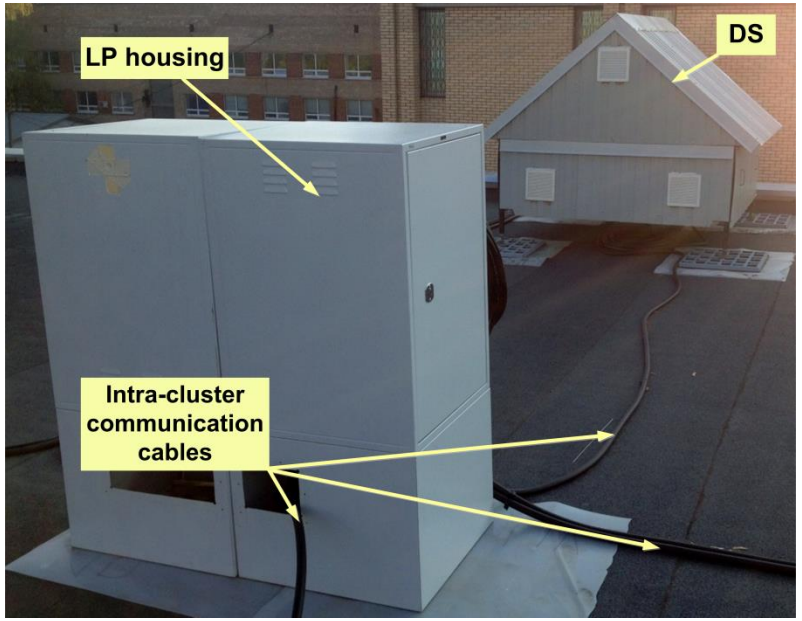


Cluster Local Post (LP)



- signal summation and digitizing;
- event selection;
- exposition and monitoring modes.



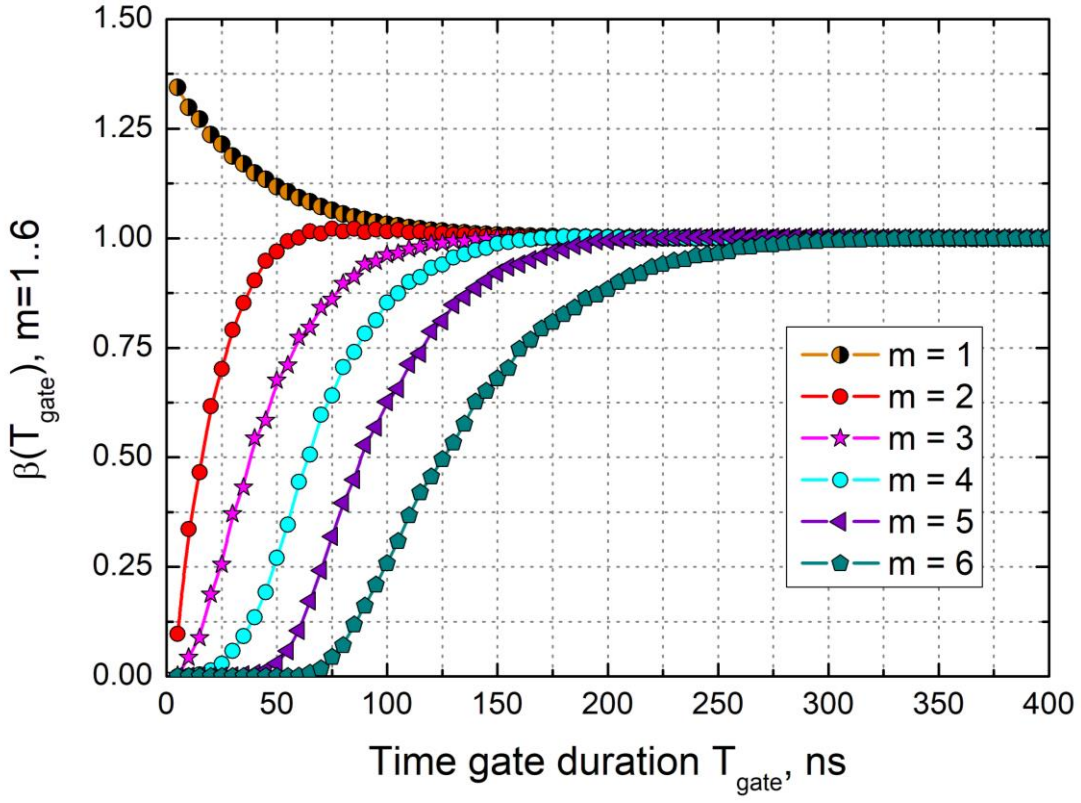


Combining of cluster events into EAS events at the array

Procedure for combination of cluster data:

- Building of a time set of triggers in clusters during the RUN;
- Analysis of time set and search for joint events in cluster;
- Formation of a database of EAS events registered by the NEVOD-EAS array.

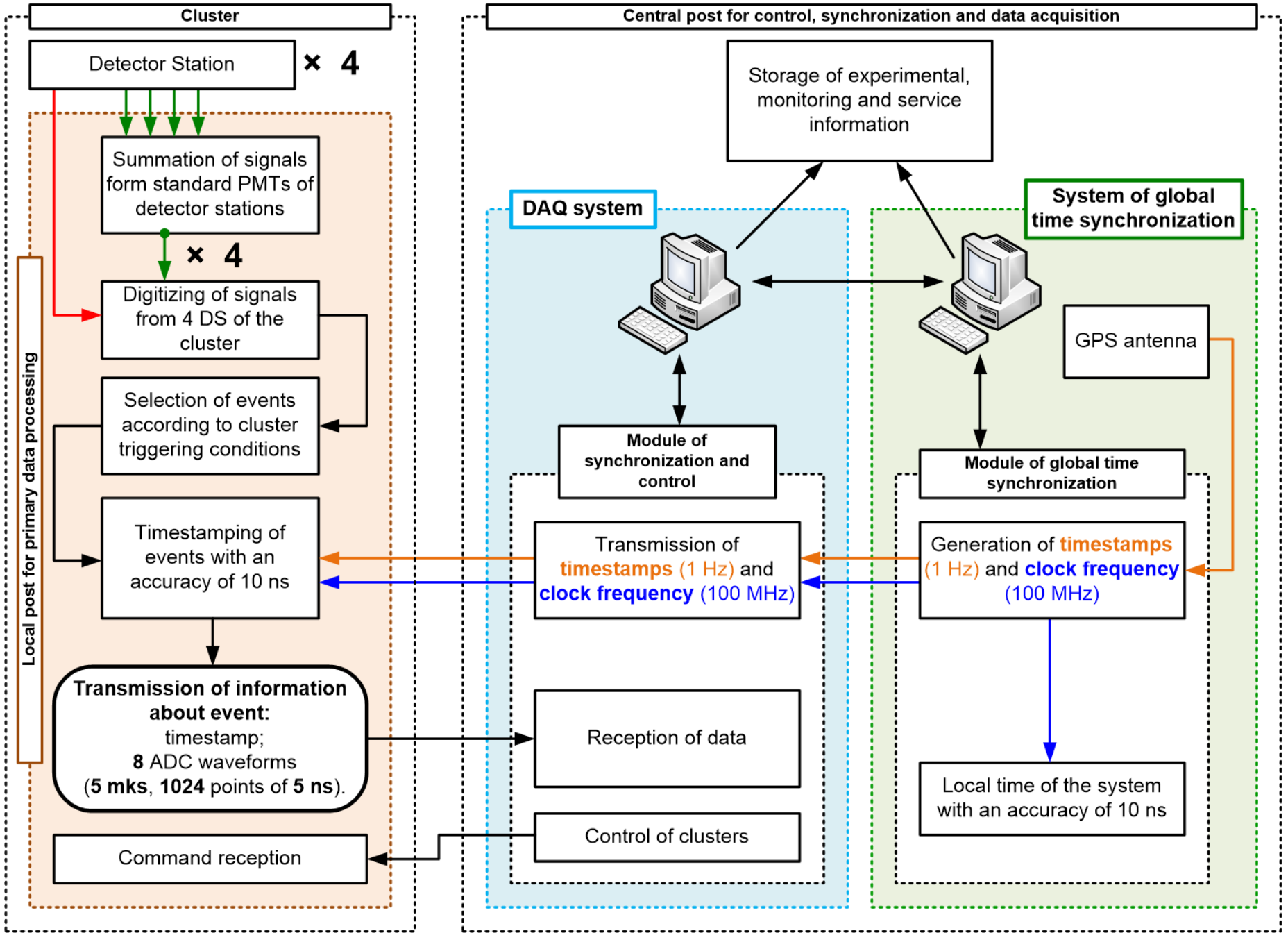
Dependence of the ratio of the number of selected events Nm with cluster triggering multiplicity m to the number of events selected with the Tgate = 400 ns on the duration of the time gate



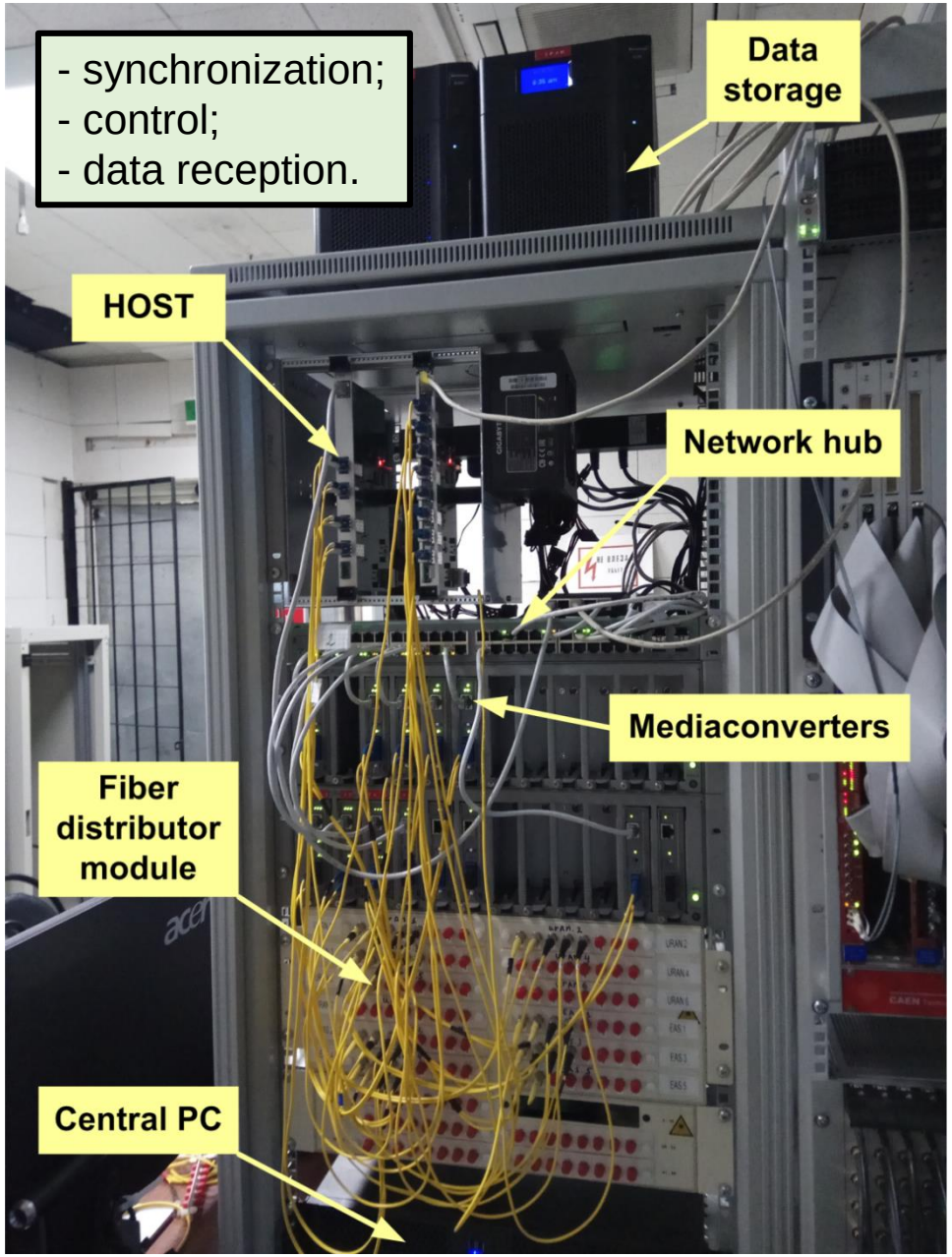
$$\beta_m(T_{\text{gate}}) = \frac{N_m(T_{\text{gate}})}{N_m(T_{\text{gate}} = 400\text{ns})}$$

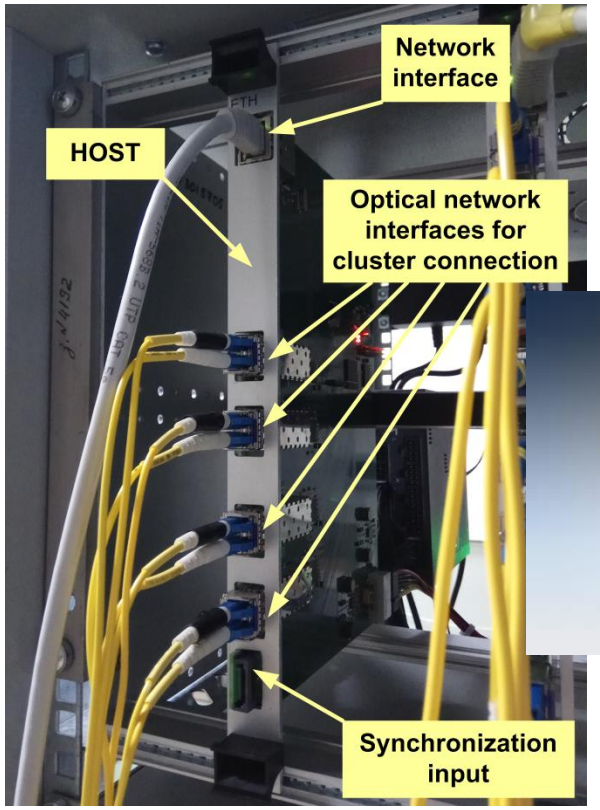
Optimal time gate duration:
350 - 400 ns

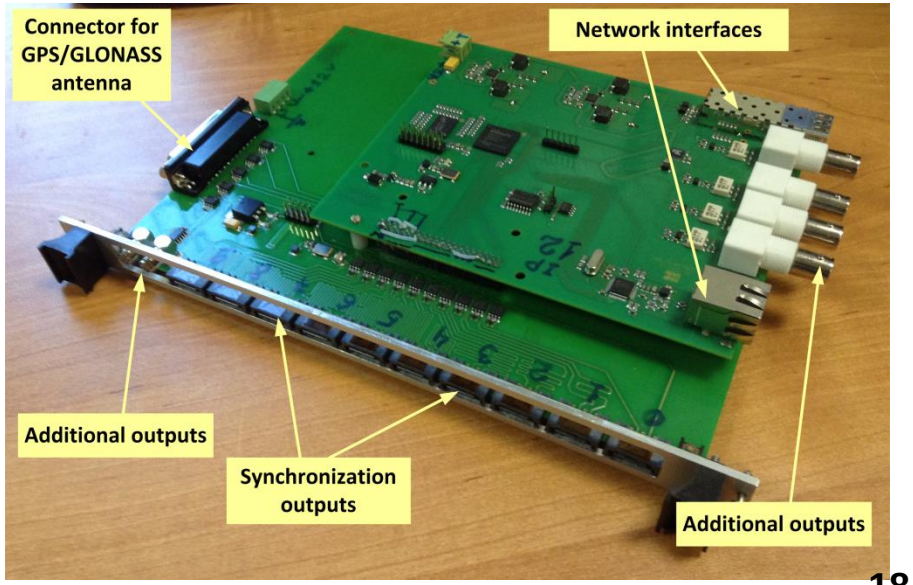
Array DAQ system



Central DAQ Post







NEVOD-EAS data taking

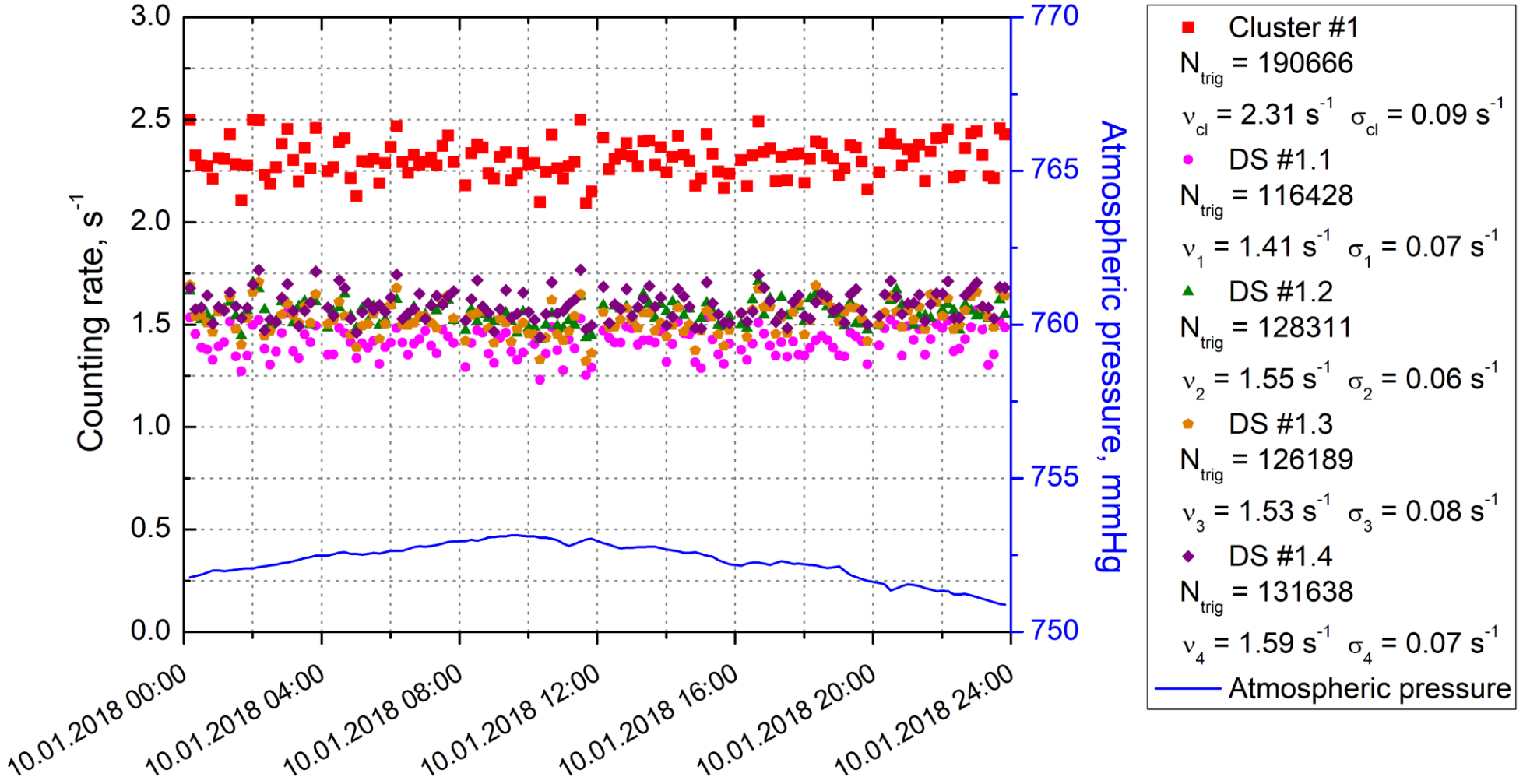
NEVOD-EAS (6 clusters configuration) is in continuous data taking since: 29/12/2017
Experimental series – sequence of **RUNs** with a duration of **24 hours**.
RUN includes **6 intervals** consisting of **"exposition"** and **"monitoring"**.

Exposition:
- **EAS detection.**
- duration **3 hours 50 minutes**.
- DS registration threshold – **0.75 MIP**.
- LP trigger multiplicity DS = **2** (Δt=100ns).
- Clusters operate independently.
- Coincidences between clusters are searched offline.

Monitoring:
- **measurement of DS responses to the passage of 1 muon.**
- duration **10 minutes**.
- registration threshold – **0.5 MIP**.
- multiplicity of triggered DS – **1**.

Using the data of RUN the following parameters are determined for every cluster:
- counting rate of cluster and its DS;
- mean and r.m.s. values of the ADC base lines;
- triggering delays of DS;
- responses of DS to the passage of 1 muon;
- calibration coefficient for the responses of DS additional photomultipliers;
- arrival direction of all detected EAS;
- number of particles registered by DS in every event.

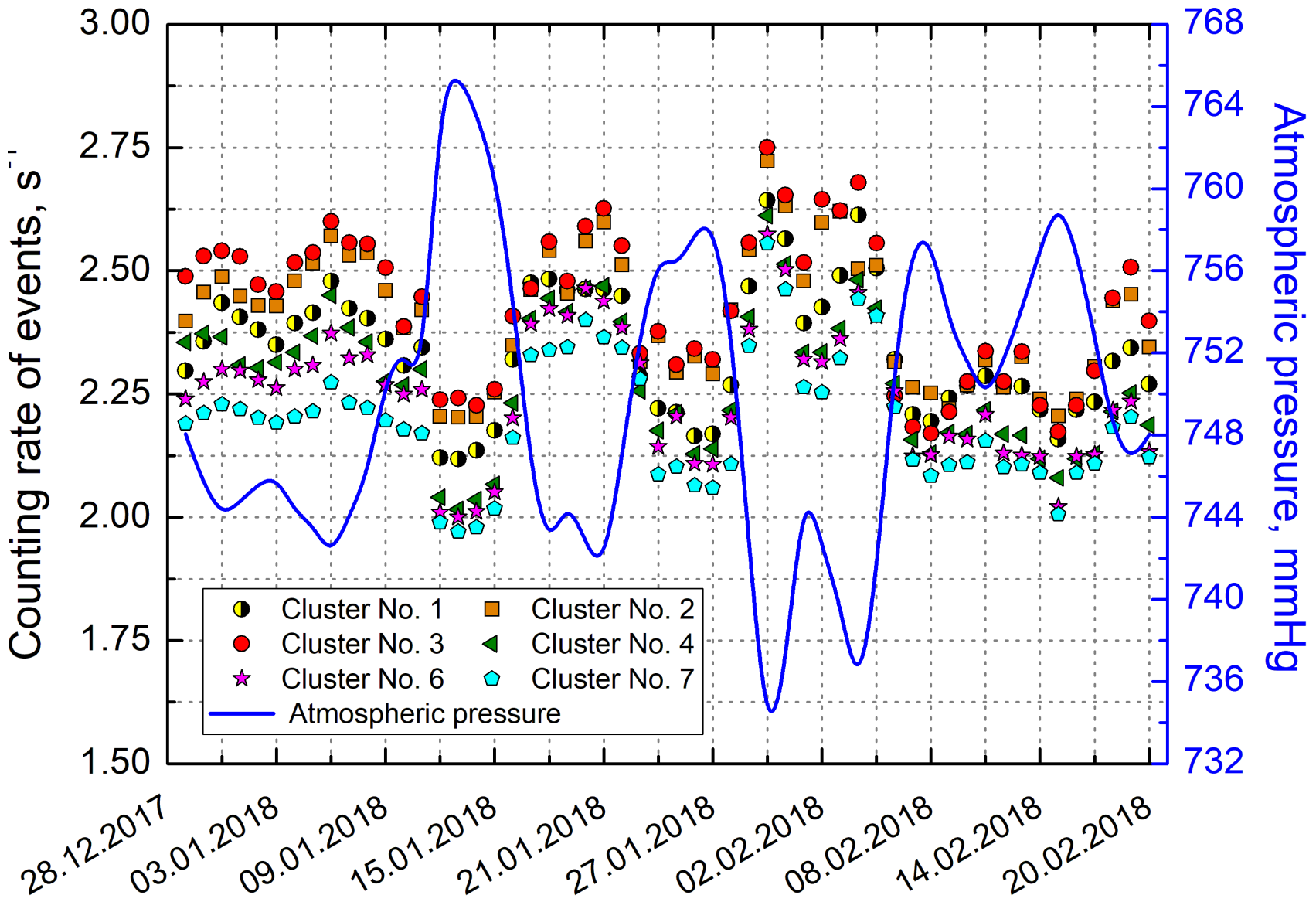
Check of detector stability during each run (i.e. 1 day)



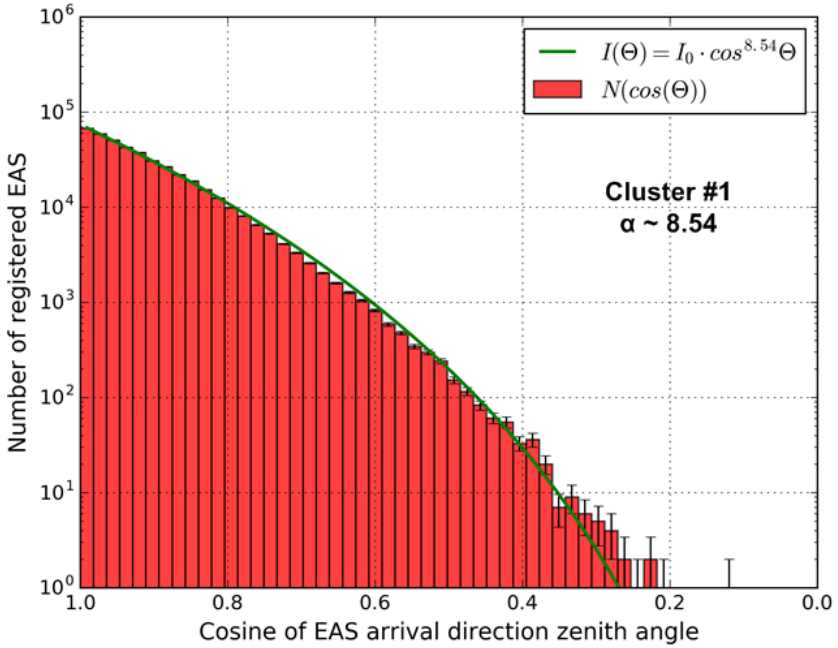
Clusters Counting rate

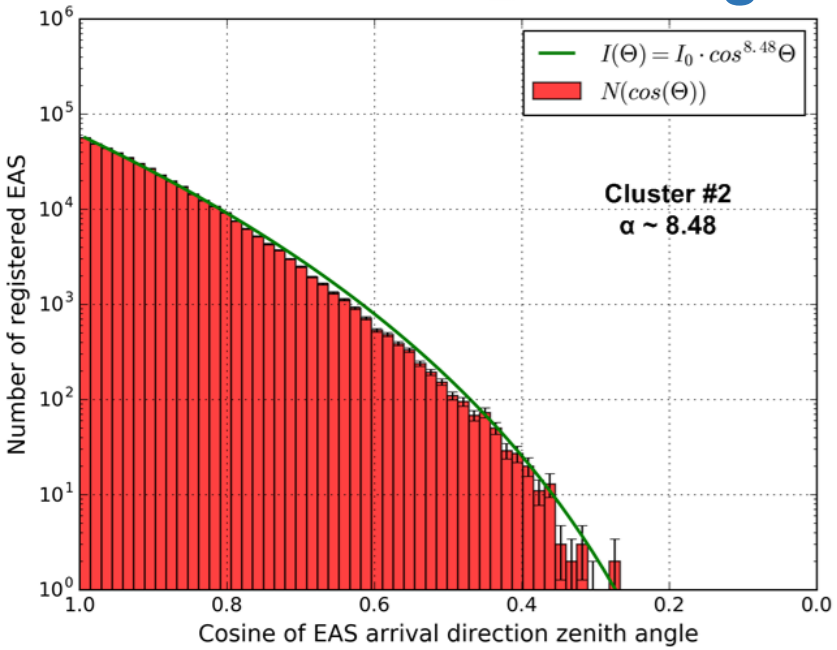
2-fold coincidences

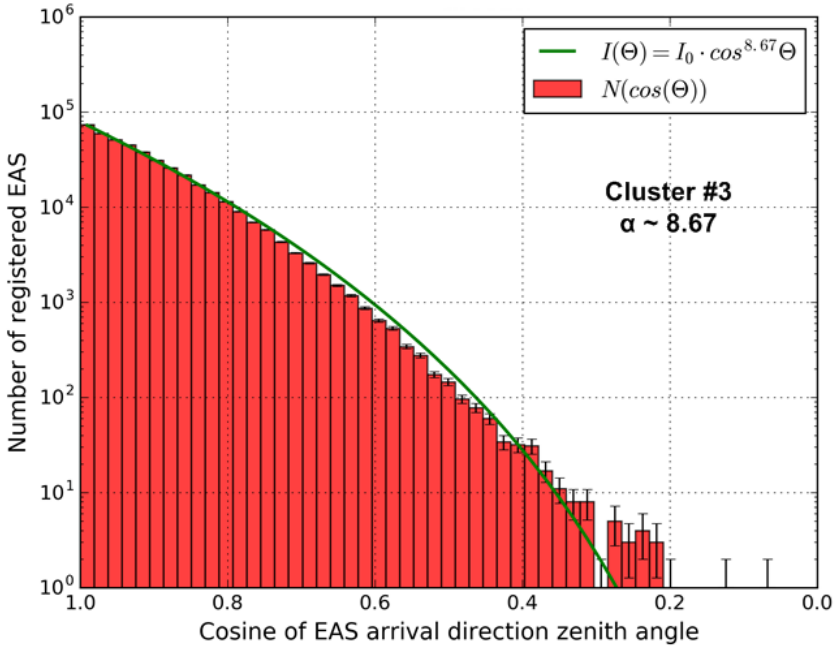
Barometric coefficient: 0.73 %/mmHg

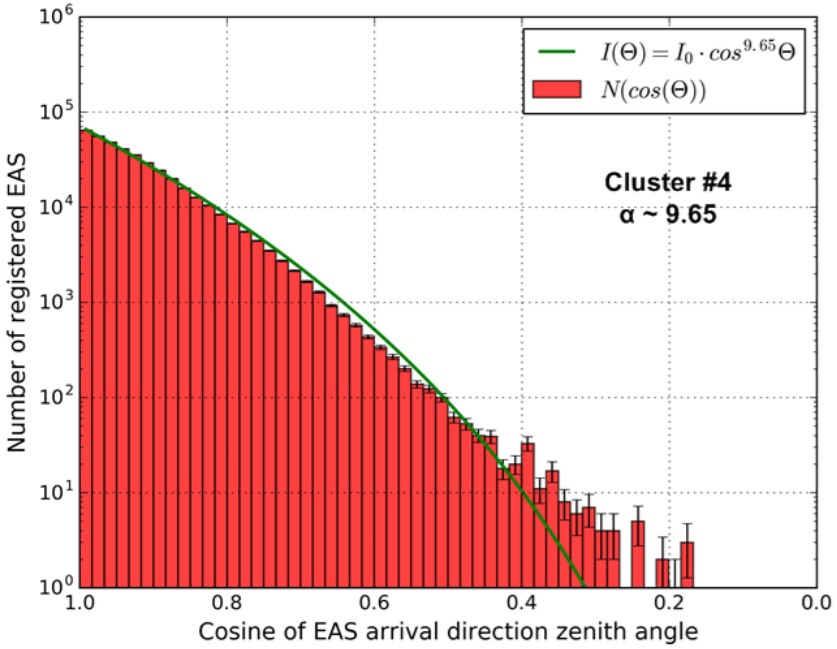


Reconstruction of EAS arrival direction: zenith angles

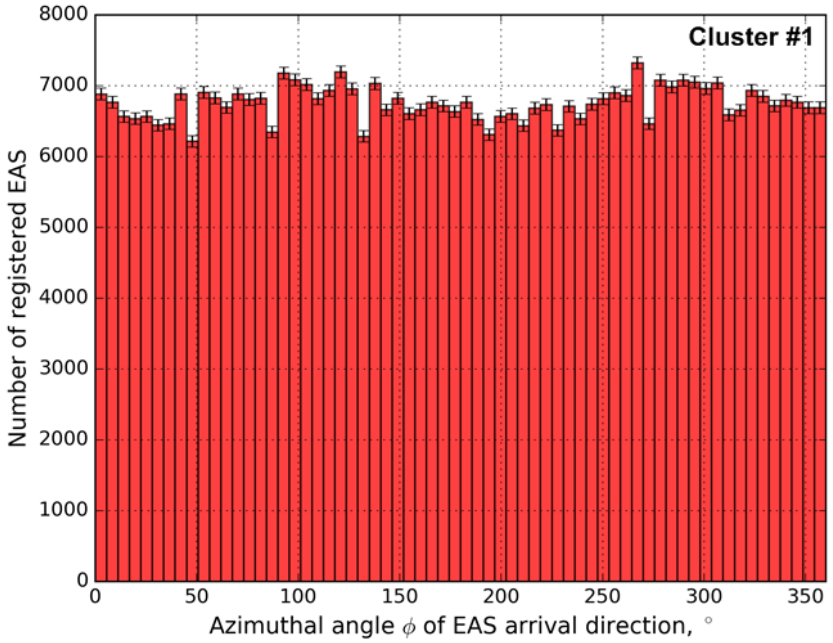


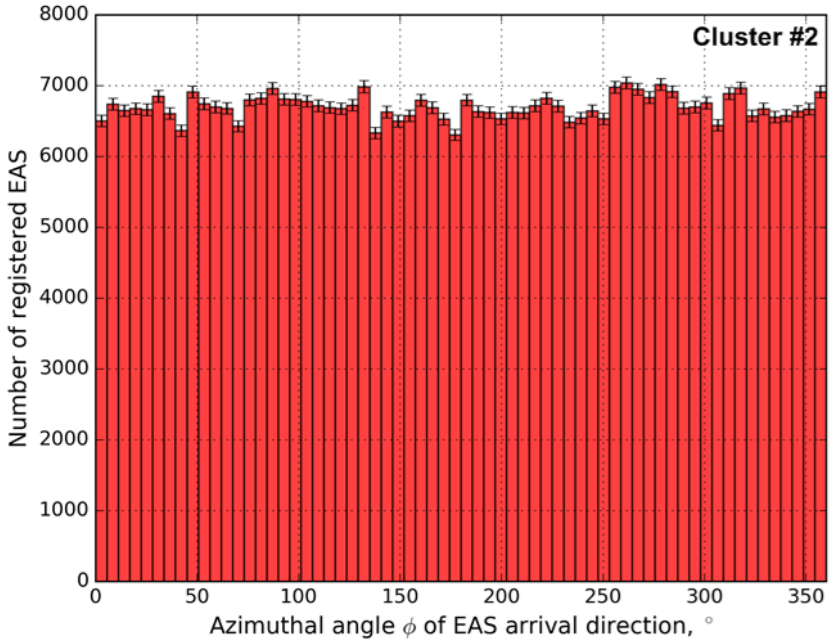


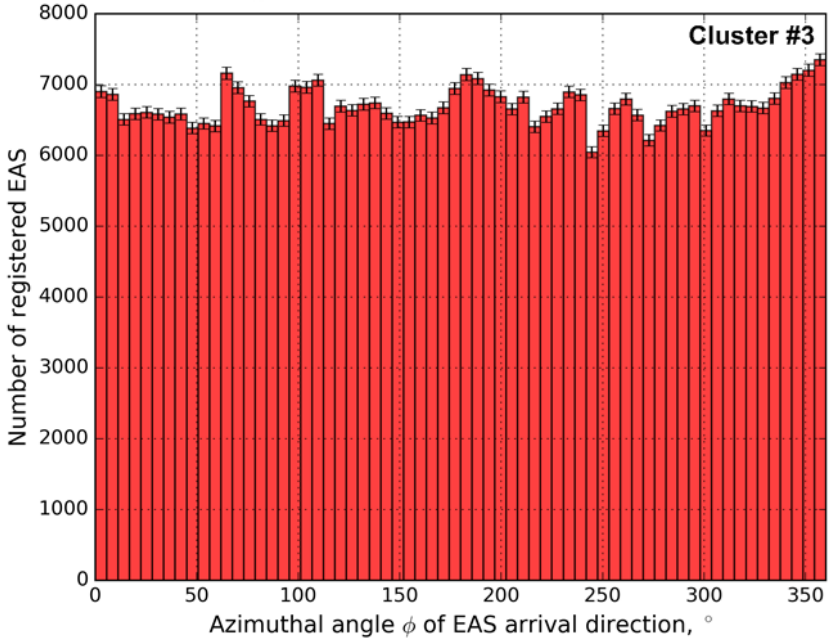


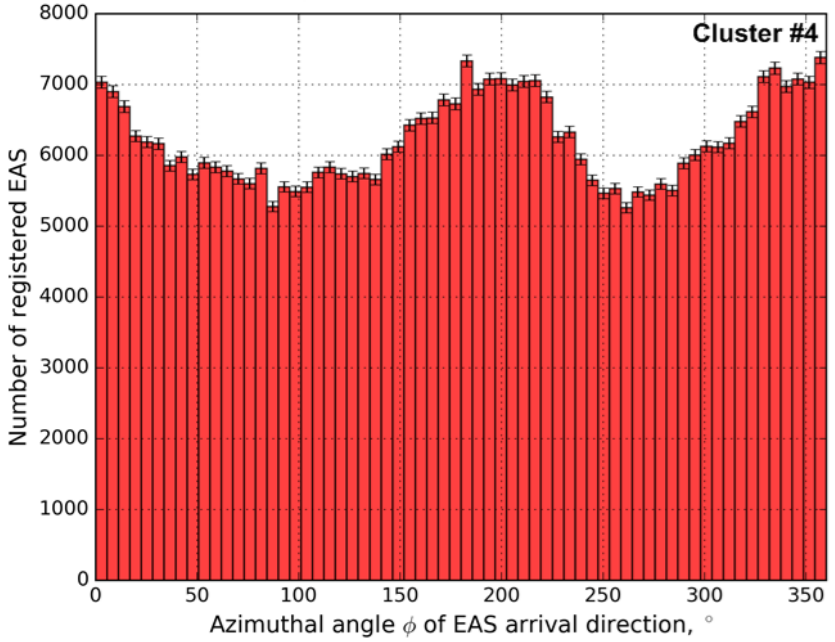


Reconstruction of EAS arrival direction: azimuth angles



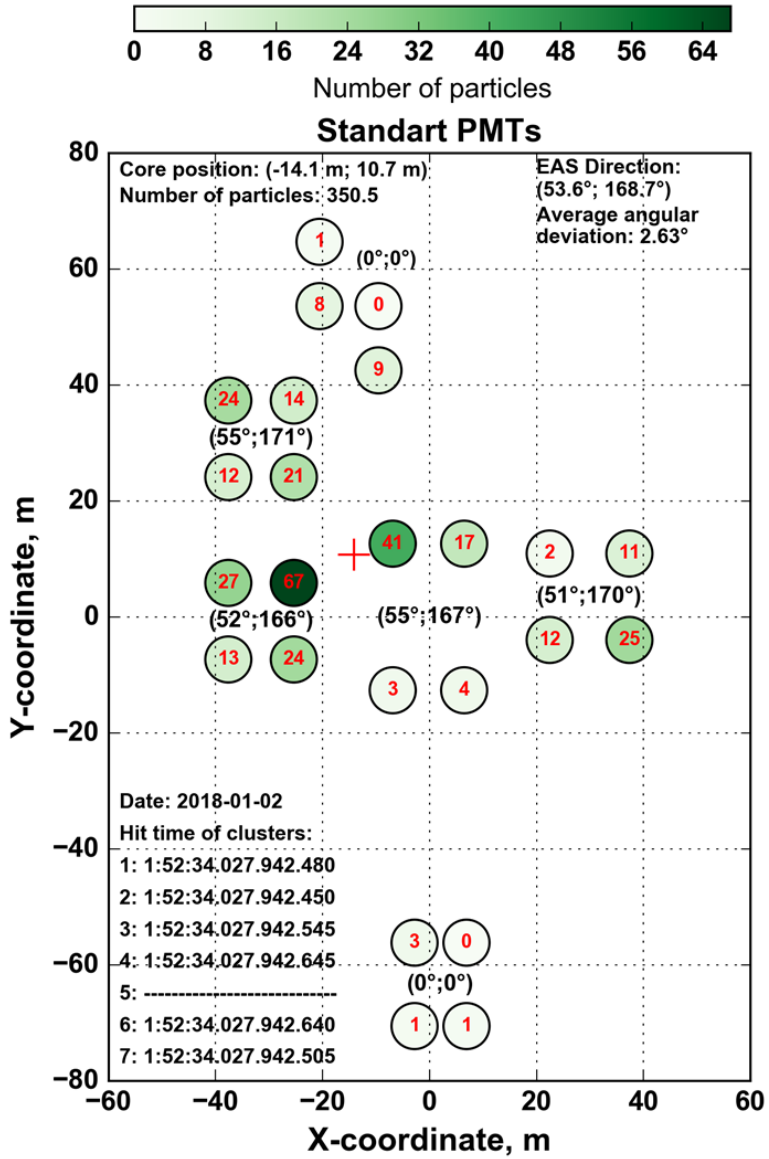


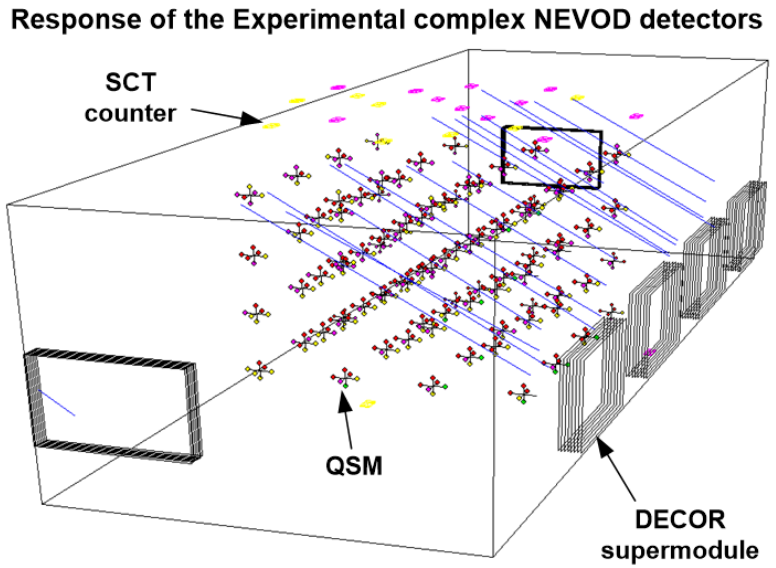


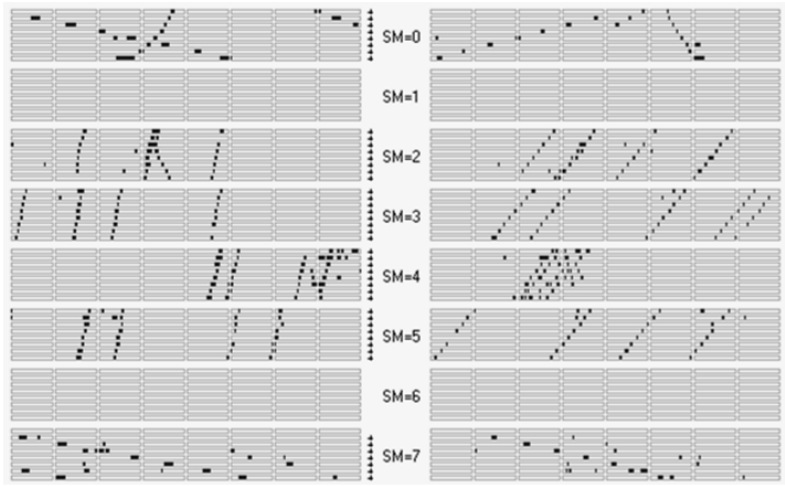


Example of joint event

Event with one of the highest zenith angles







NEVOD-DECOR-SCT: $\theta = 54.9°$, $\phi = 168.0°$, 18 muon tracks

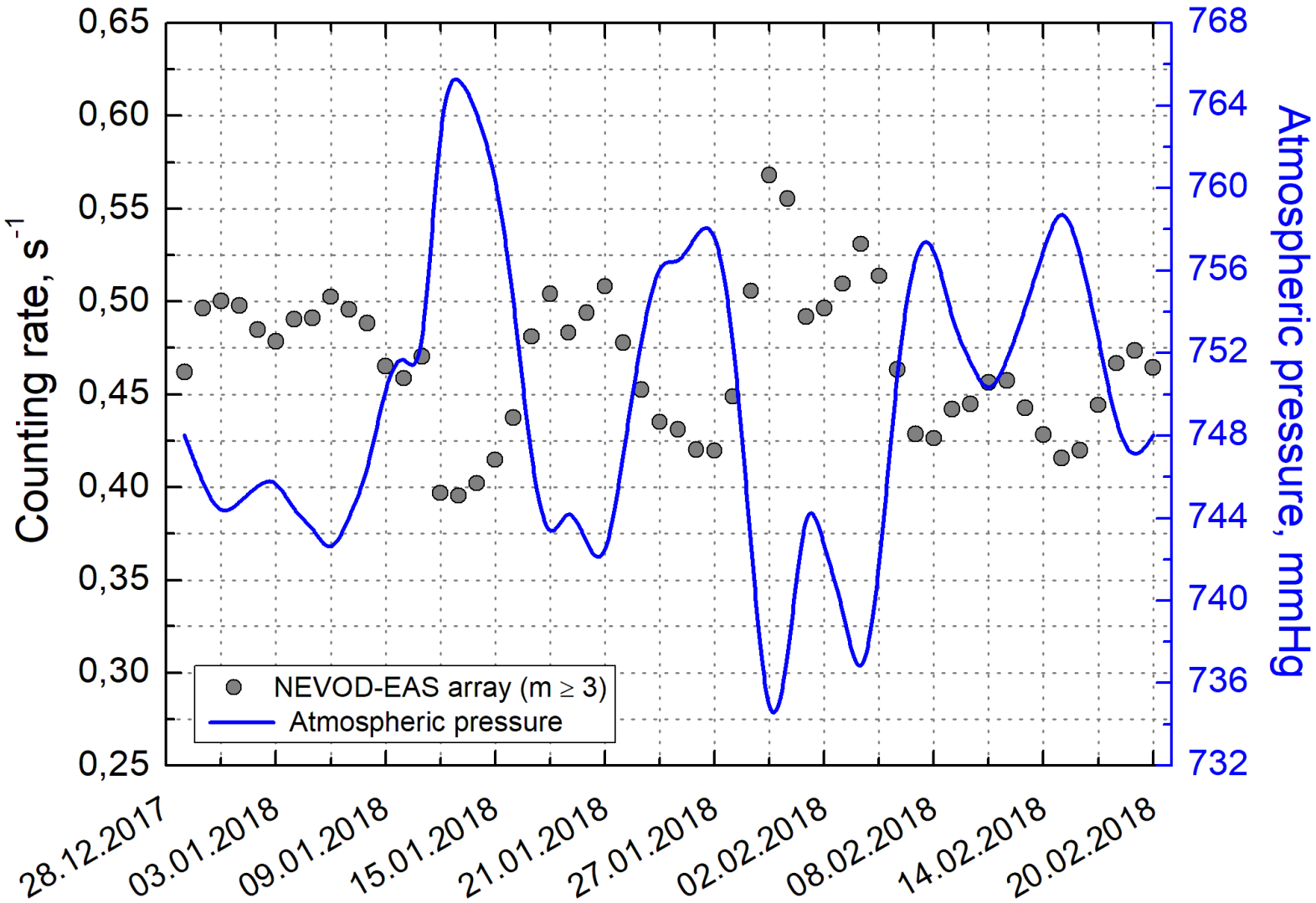
NEVOD-EAS & Cl. #3: $\theta = 53.6°$, $\phi = 168.7°$ and $\theta = 55°$, $\phi = 167°$

Conclusions

- Since end of 2017 6 clusters of the NEVOD-EAS experiment are in continuous data taking with the NEVOD-DECOR.
- Counting rate of the array shows the correct and stable operation of NEVOD-EAS
- EAS zenithal and azimuthal angle distribution as expected
- Coincidences with NEVOD-DECOR events.
- 3 additional clusters will be installed in 2018
- 12 clusters are expected for 2019
- Future programs to extend the EAS array
- Bright future head of the NEVOD scientific complex

Backup Slides

Counting rate of extensive air showers

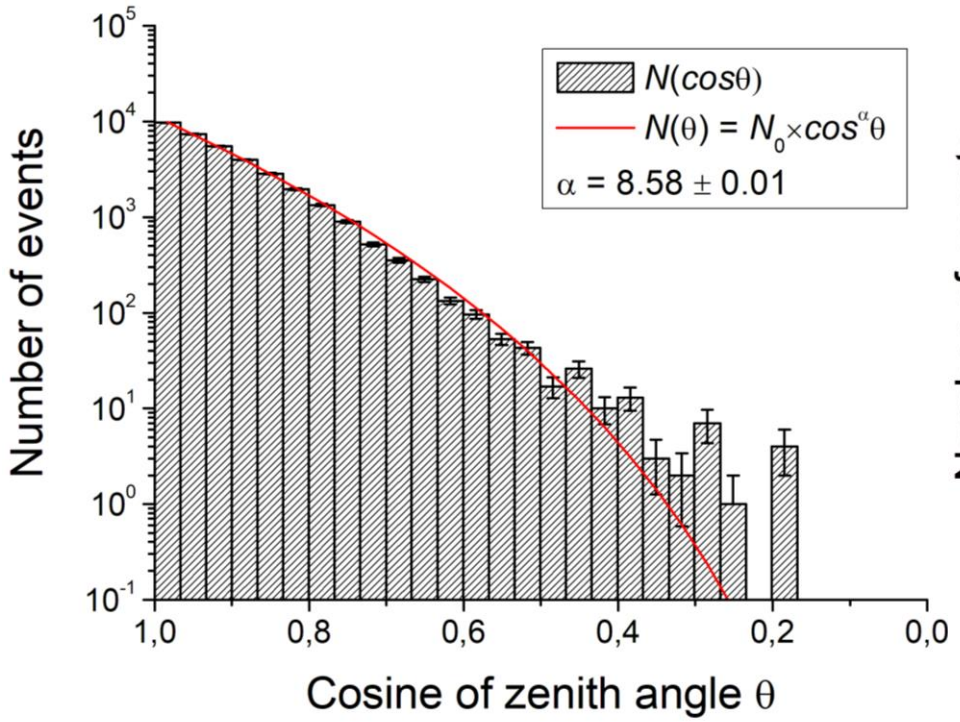


Average counting rate of events with at least **3** triggered clusters is ~ **0.47 s^{-1}**.

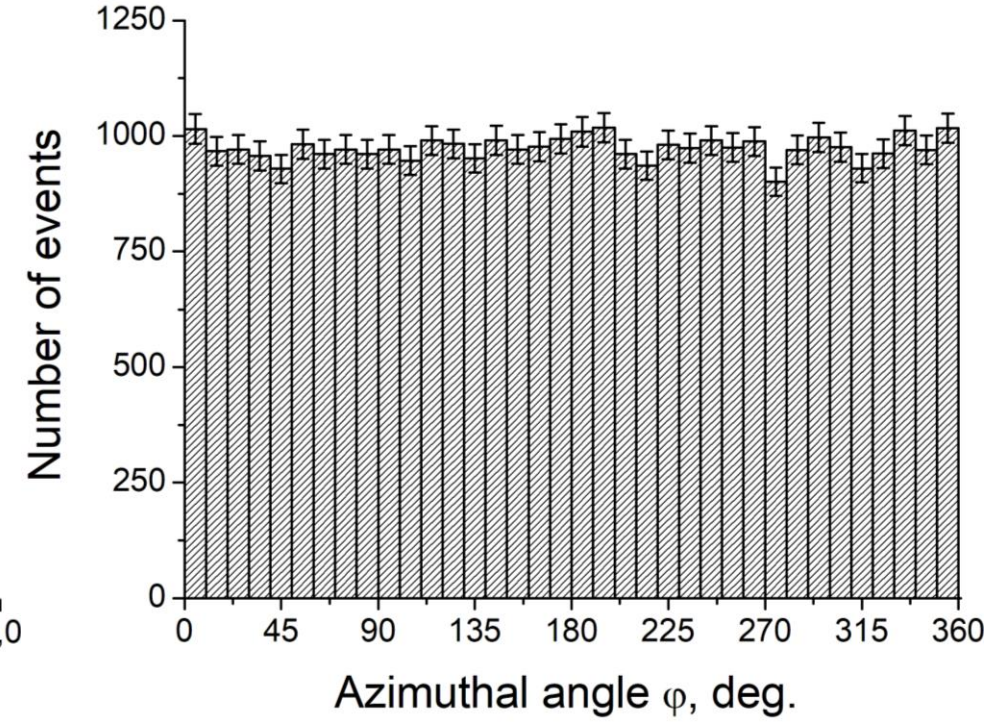
Barometric coefficient : -1.08 %/mmHg

Reconstruction of the arrival direction of extensive air showers

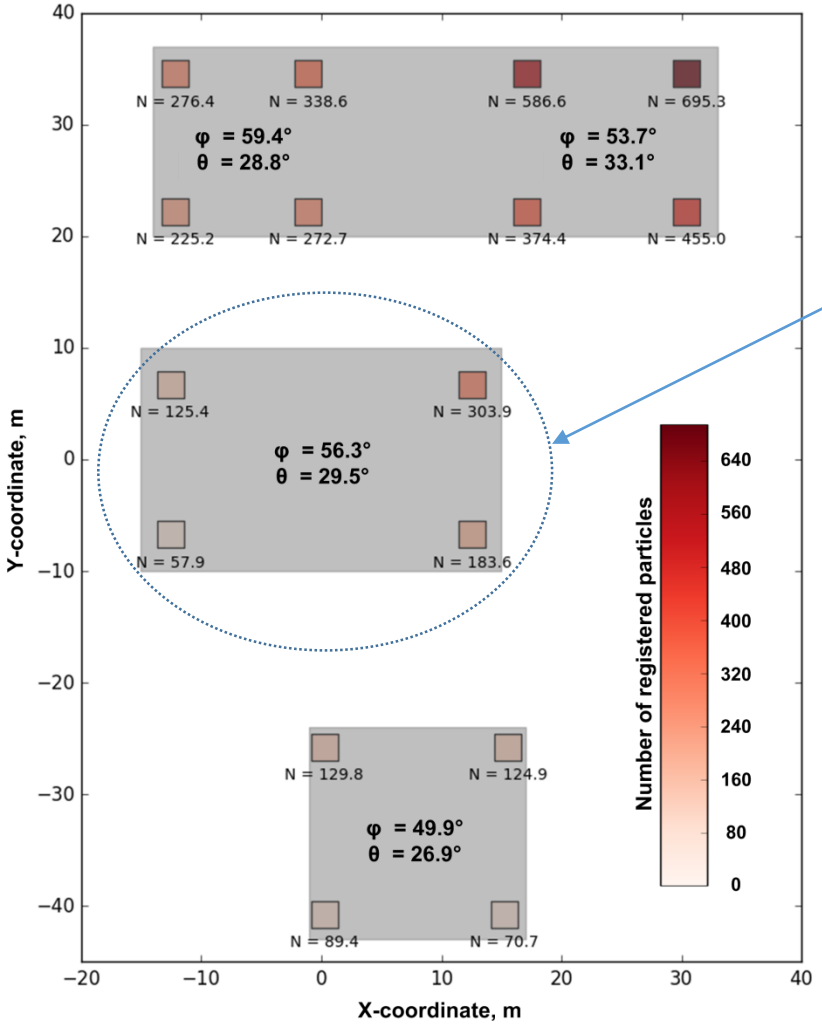
Distribution of events on cosine of zenith angle of EAS arrival direction



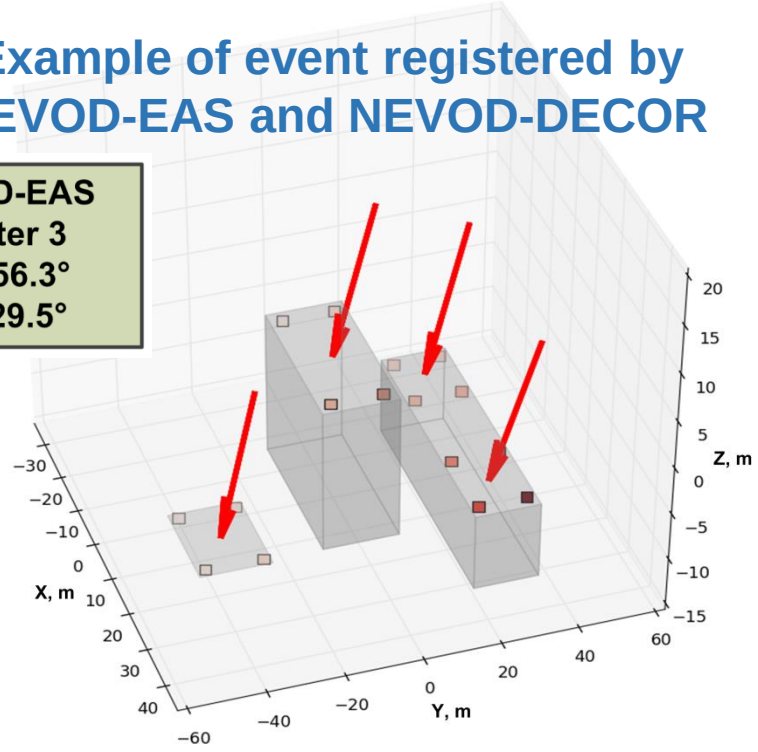
Distribution of events on azimuthal angle of EAS arrival direction

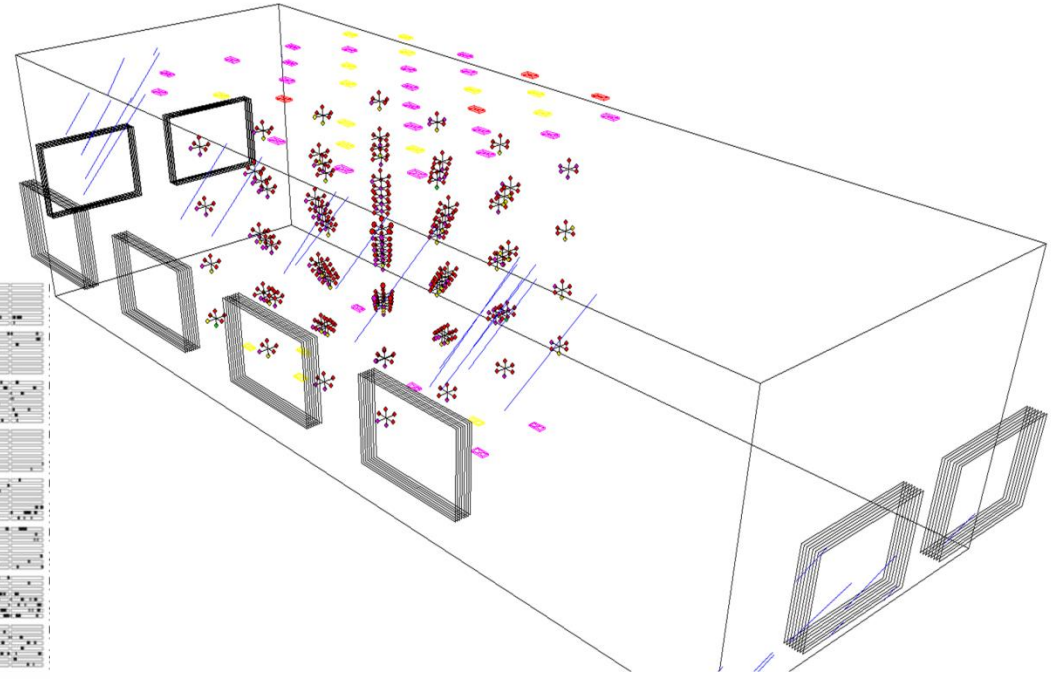


Example of event registered by NEVOD-EAS and NEVOD-DECOR

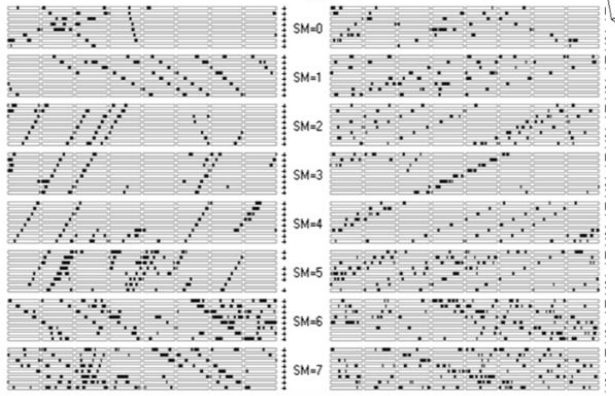


NEVOD-EAS
Cluster 3
φ = 56.3°
θ = 29.5°



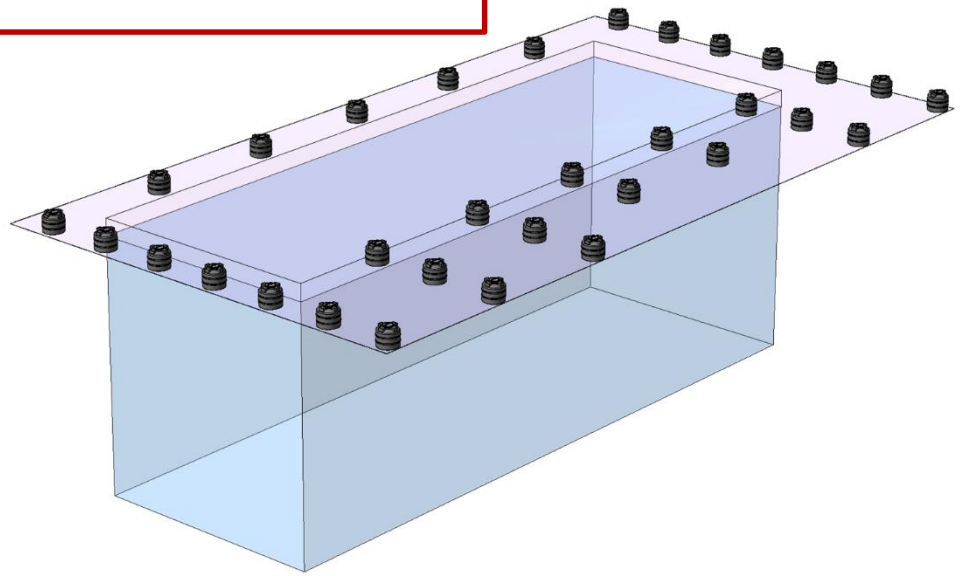


NEVOD-DECOR
φ = 54.4°
θ = 29.5°



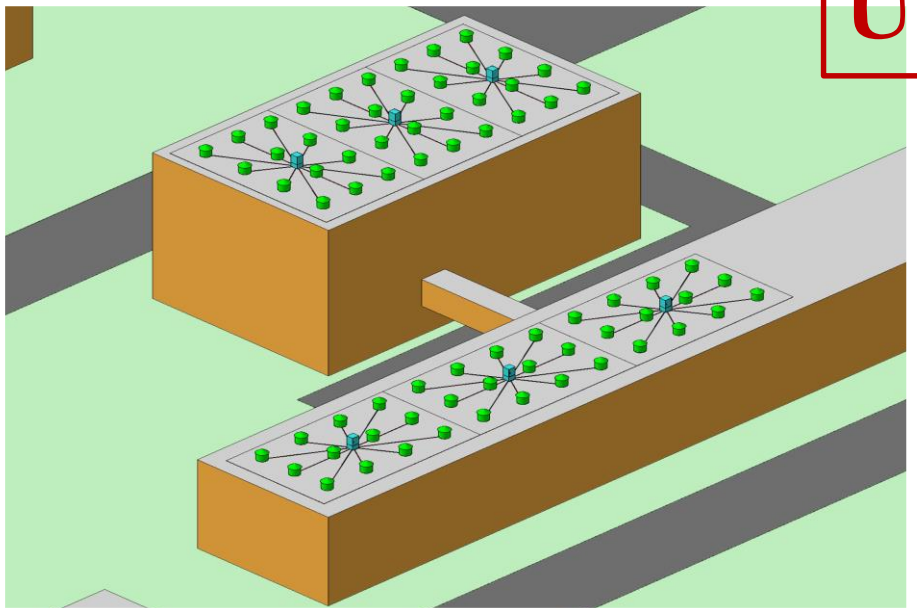
e-n detectors in the NEVOD complex

PRISMA-32



32 en-detectors array (composed of two 16-detector clusters located inside the experimental hall situated on the 4th floor of the NEVOD building around the water pool in MEPhI.
Detection range:
Charged particles; 5-75000/det.
Neutrons: 1-1000/det.

URAN



The URAN setup includes 72 en-detectors
The en-detectors are combined into independent cluster structures of 12 detectors.
Clusters are located on two roofs of the laboratory buildings (3 clusters on each roof).
The characteristic distances between the detectors are 4 - 5 meters.