

Energy deposit of EAS cores detected by the facilities of the Experimental Complex NEVOD

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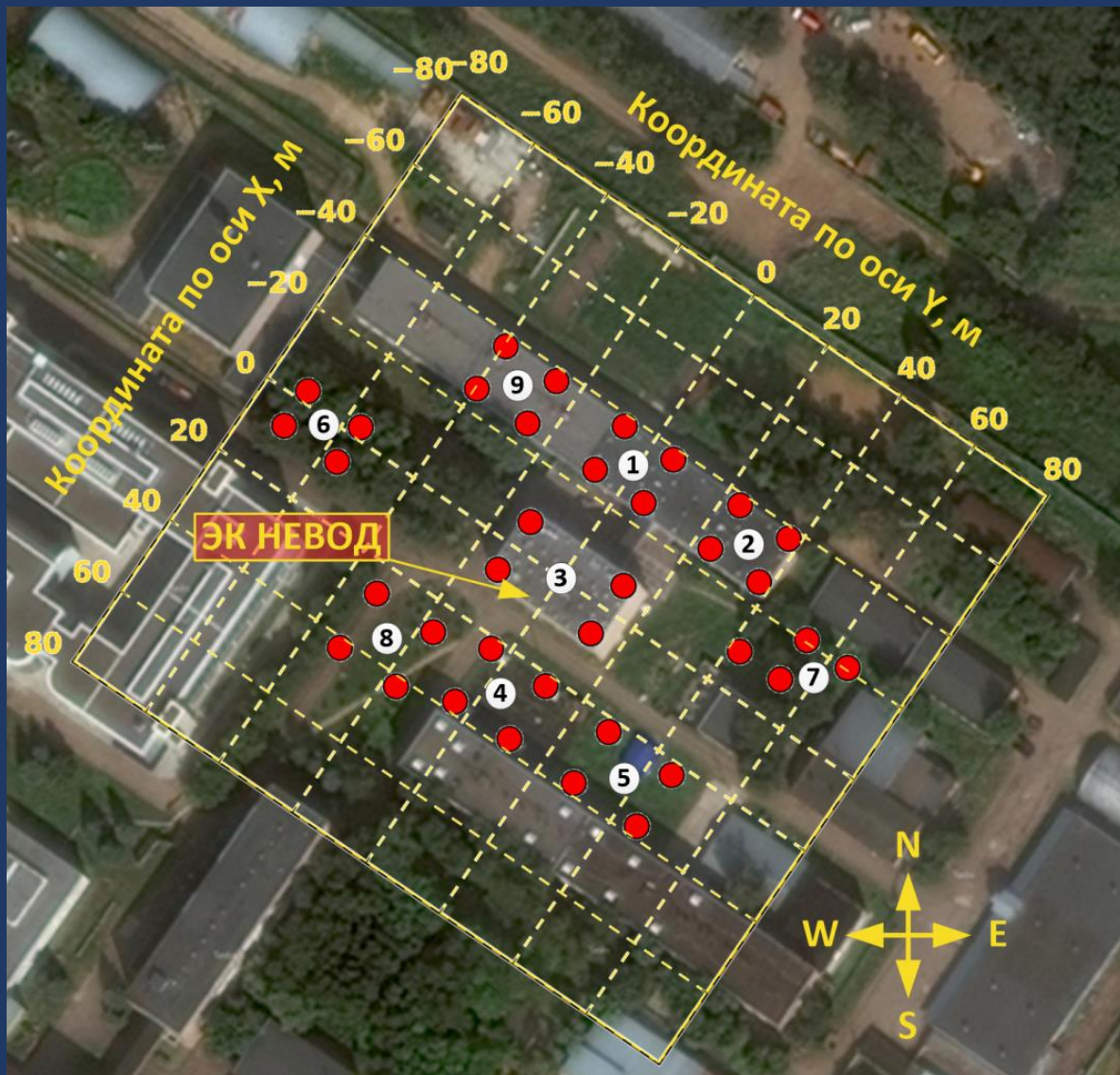
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Introduction

- EAS studies are the only source of information on nucleus-nucleus interactions at very high energies;
- A large number of experimental results have not yet been explained within the frameworks of a unified approach;
- A particular interest are shower cores containing simultaneously electron-photon, muon and hadron EAS components.

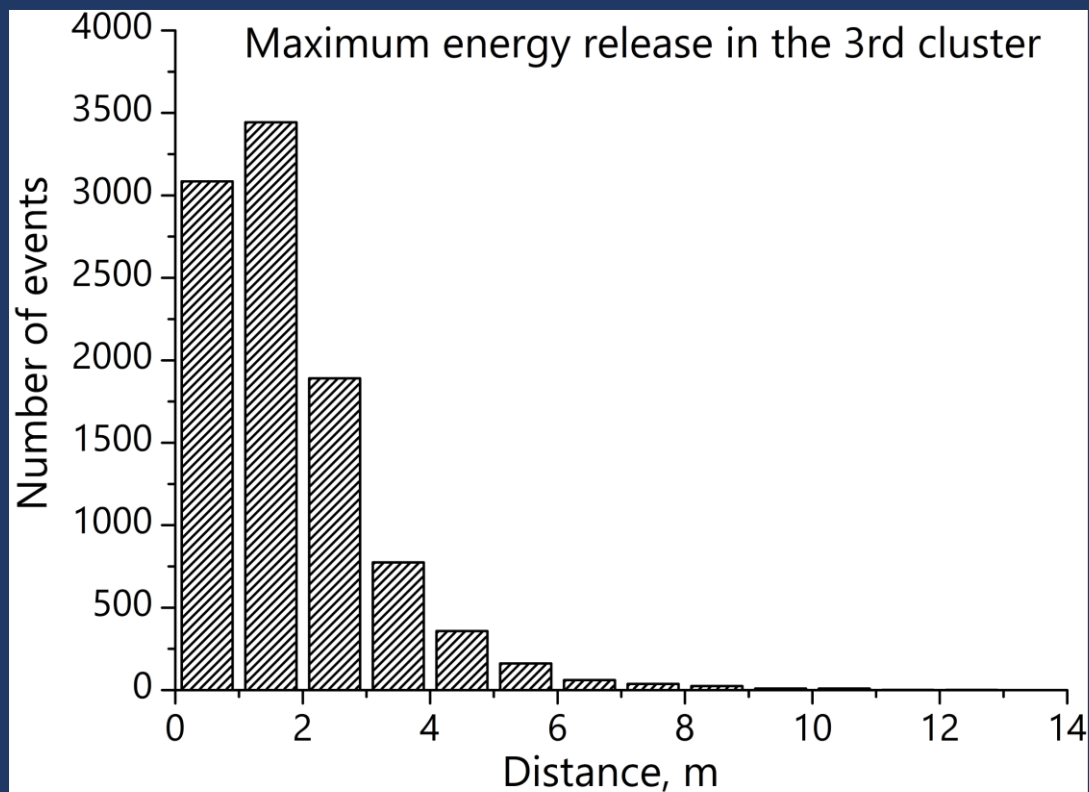
The NEVOD-EAS array



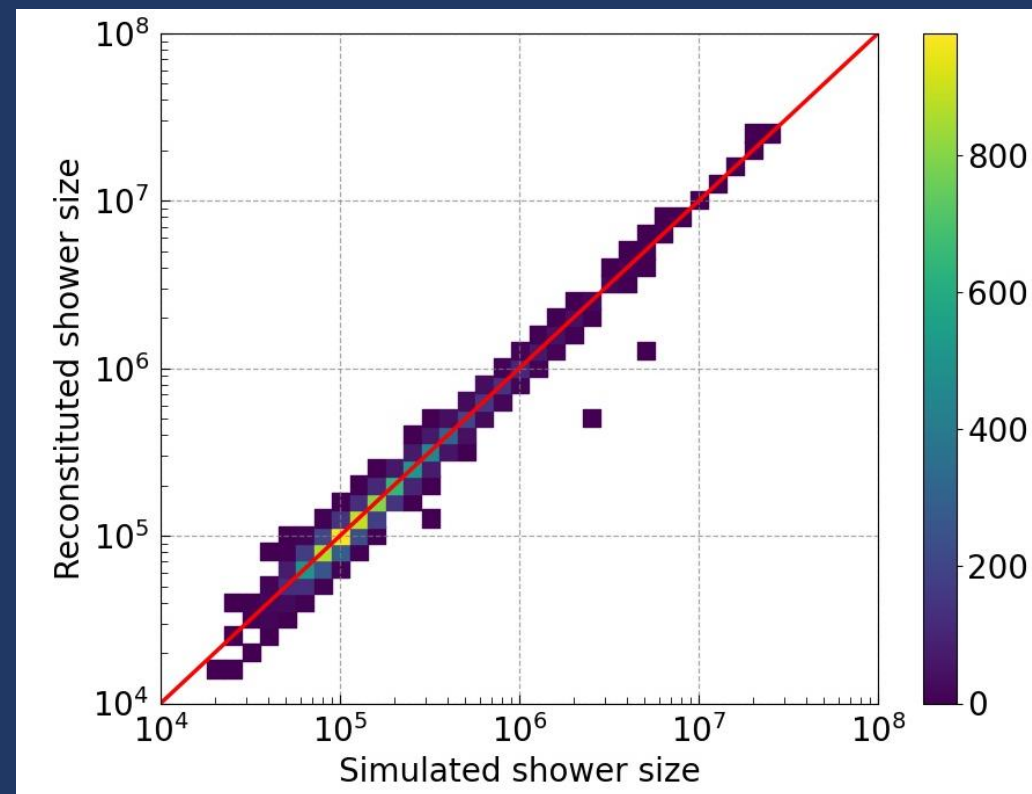
- 144 detectors;
- 36 detector stations;
- 9 clusters;
- Cluster size: $15 \times 15 \text{ m}^2$;
- Array area: 10^4 m^2 ;
- Energy range: $10^{15} - 10^{17} \text{ eV}$.

Reconstruction of coordinates of the axis of the shower and shower size

Simulation in the CORSIKA: QGSJET-II-04 + FLUKA 2020.0.3

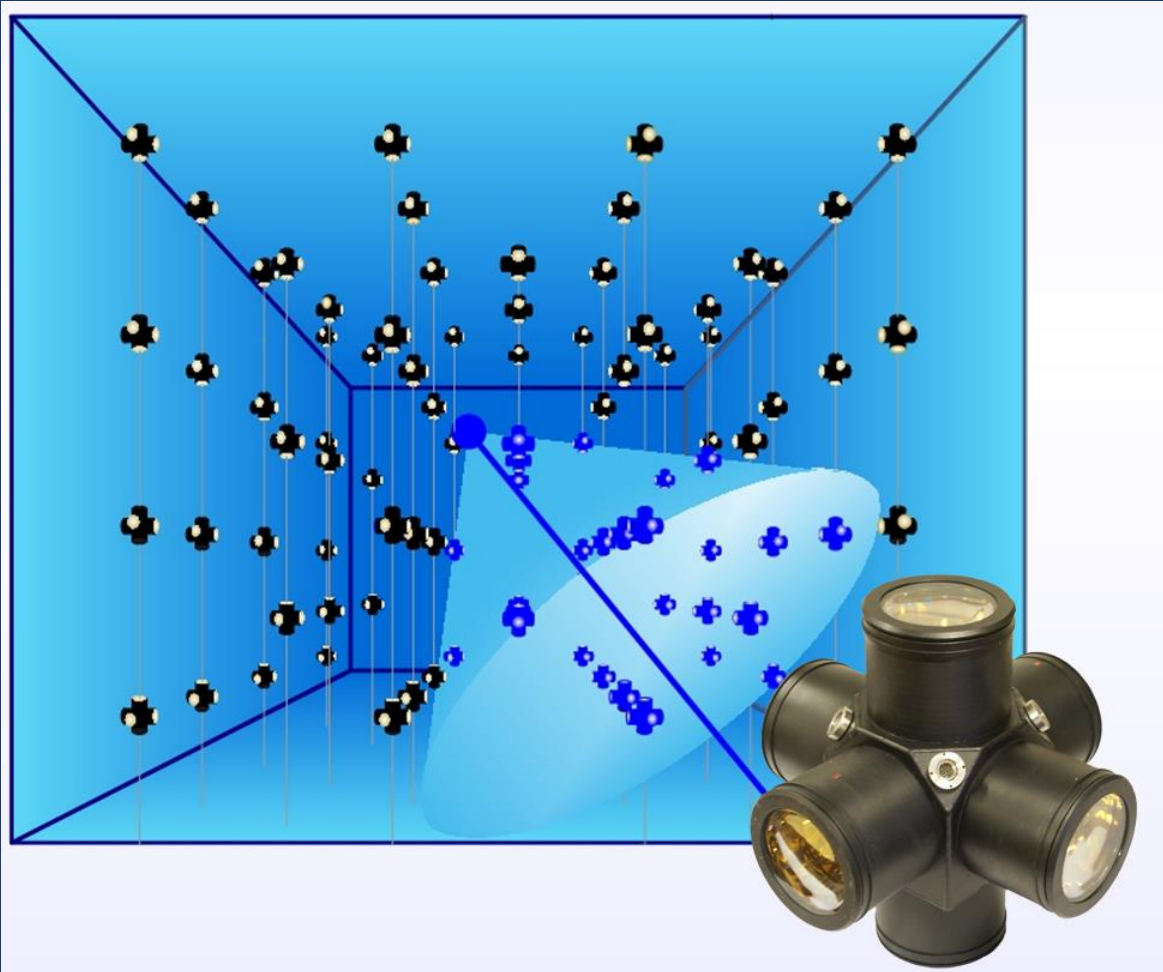


The accuracy of reconstruction of the coordinates of the shower axis is ~ 3.0 m.



The accuracy of the shower size reconstruction is $\sim 12\%$.

Cherenkov water calorimeter NEVOD

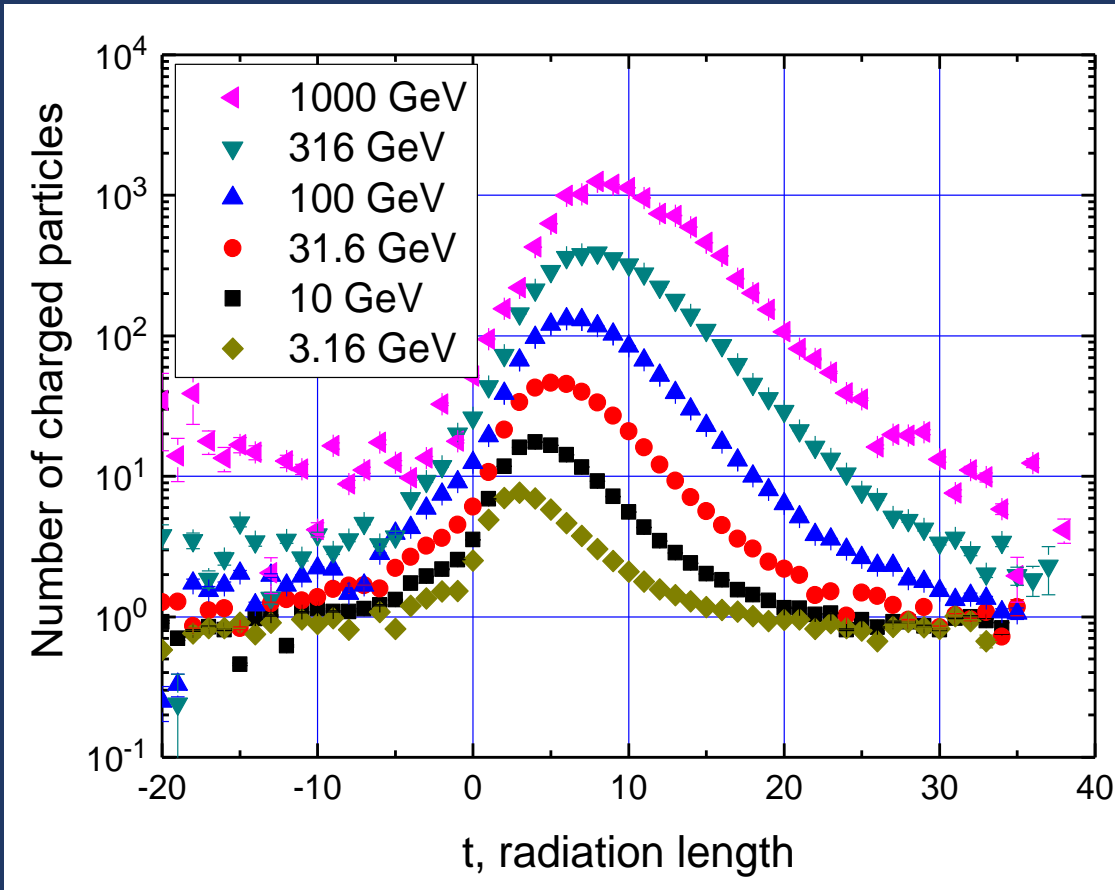


- Volume 2000 m^3 .
- The detecting system is formed by a spatial lattice of quasispherical modules (QSM) which include six PMTs with flat cathodes directed along the coordinate axes.
- 91 QSM in 25 strings (step $1 \times 1 \times 1.25 \text{ m}^3$).
- Dynamic range for each PMT $1 - 10^5 \text{ ph.e.}$

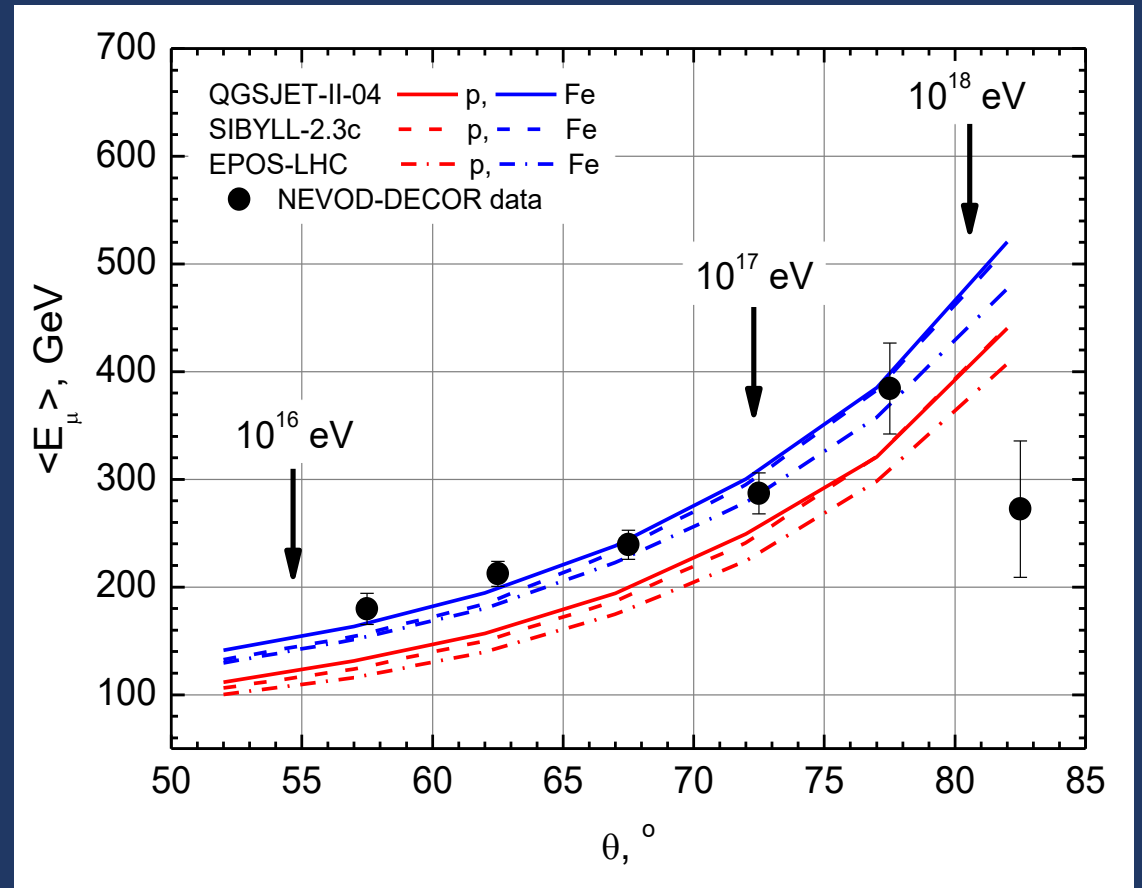
Small step of spatial lattice and a wide dynamic range allow the detector to operate in the calorimetric mode.

Examples of calorimetric studies with Cherenkov water detector

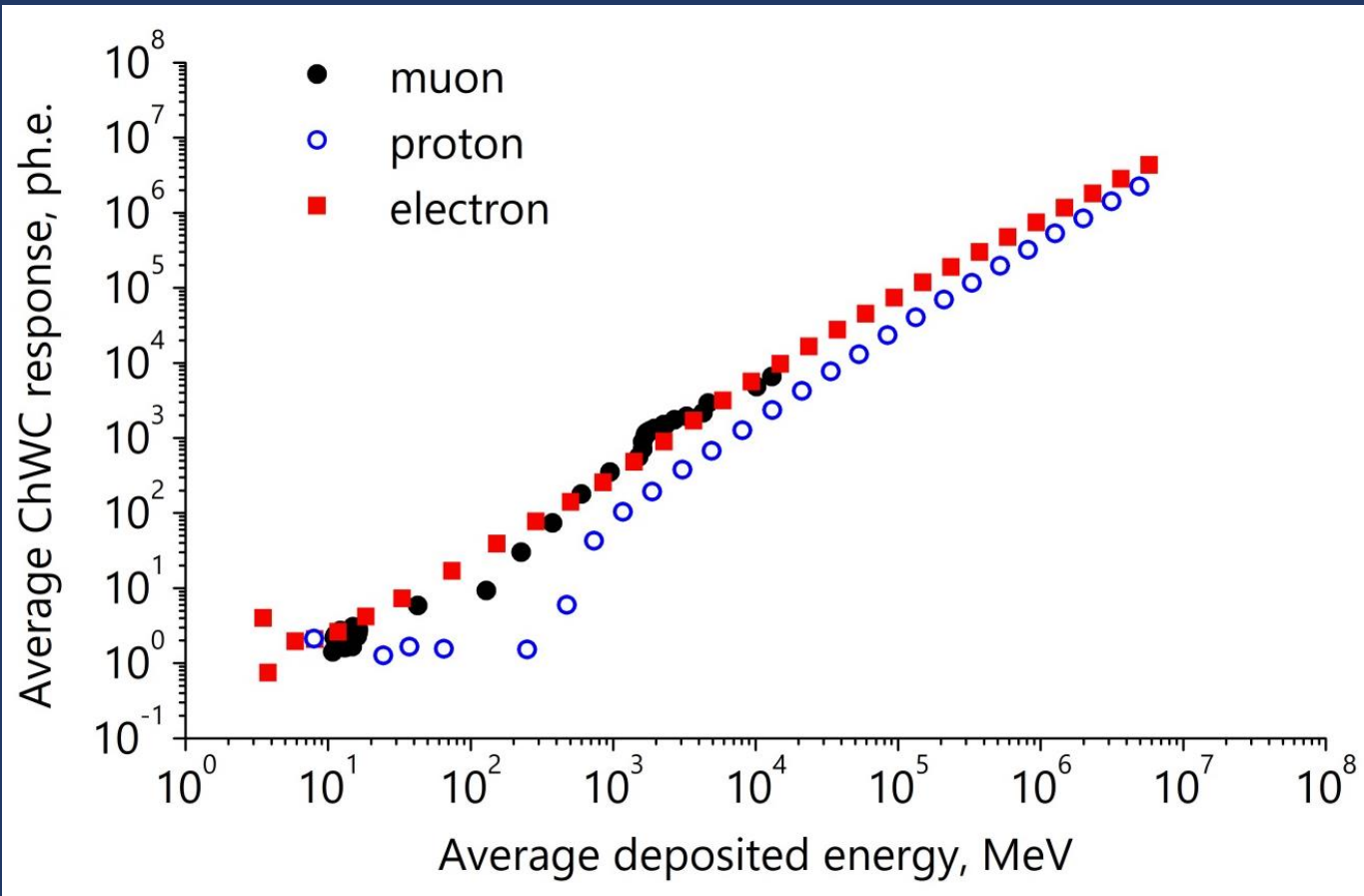
Mean experimental cascade curves.



The average muon energy increases with zenith angle.



Simulation of CWC response on leptons and hadrons



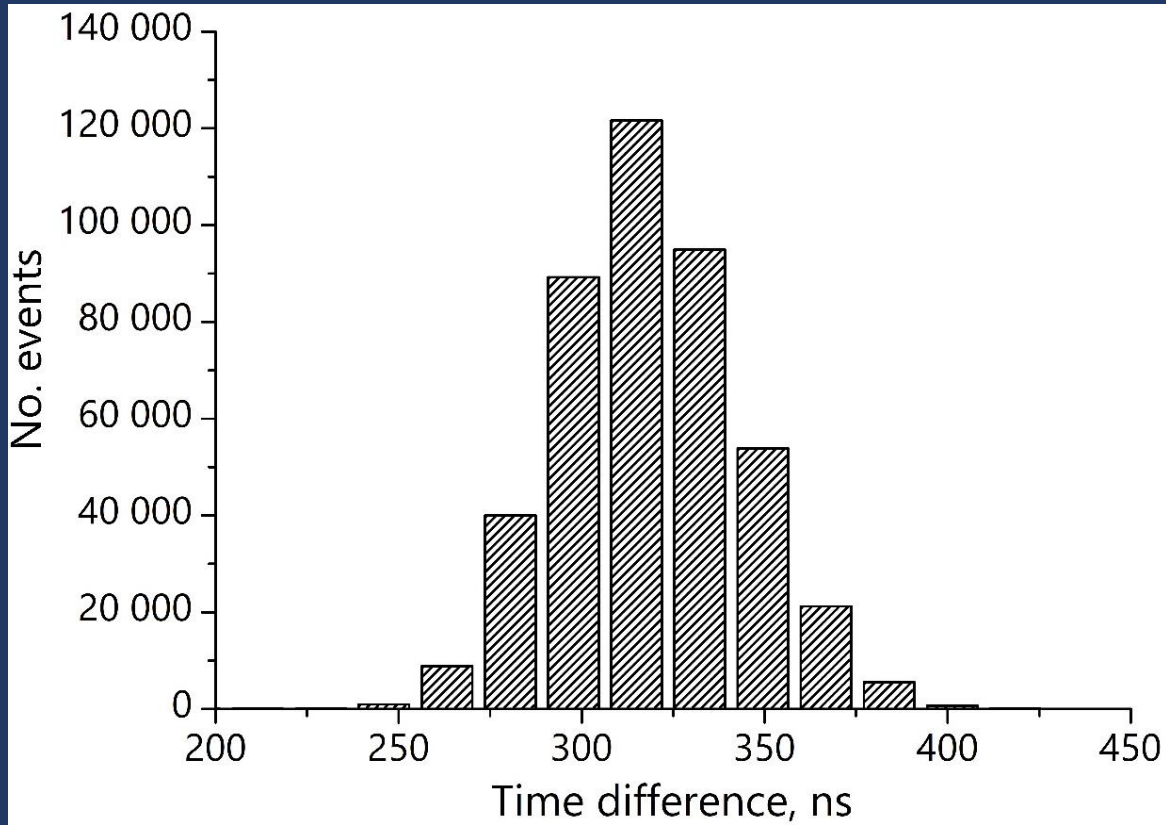
To a first approximation the response of CWC is proportional to deposited energy starting with 1GeV.

The coefficients of proportionality:

- muon: $k_{\mu} = 0.6$ ph.e./MeV;
- electron: $k_e = 0.7$ ph.e./MeV;
- proton: $k_p = 0.3$ ph.e./MeV.

Combining of events

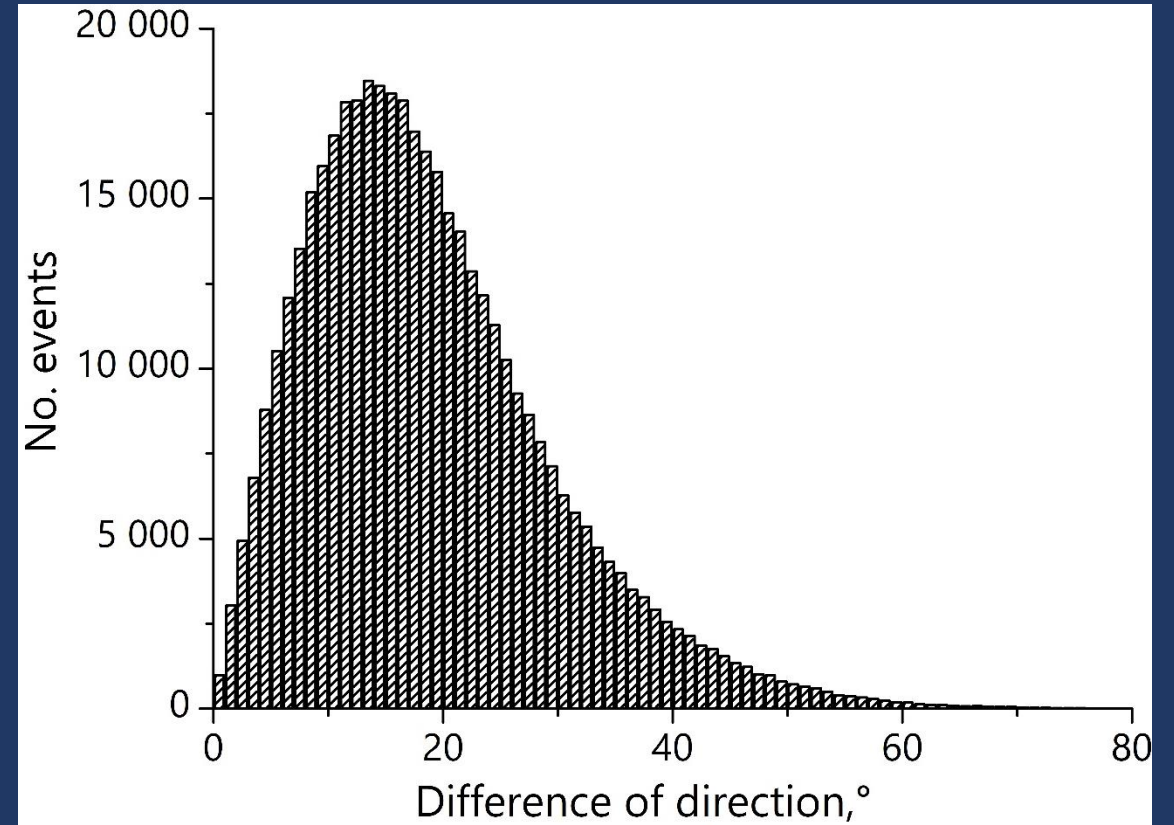
Time difference between
CWC and NEVOD-EAS



$\langle dT \rangle = 326.9 \text{ ns.}$

$\sigma = 28.4 \text{ ns.}$

Difference of directions between
CWC and NEVOD-EAS

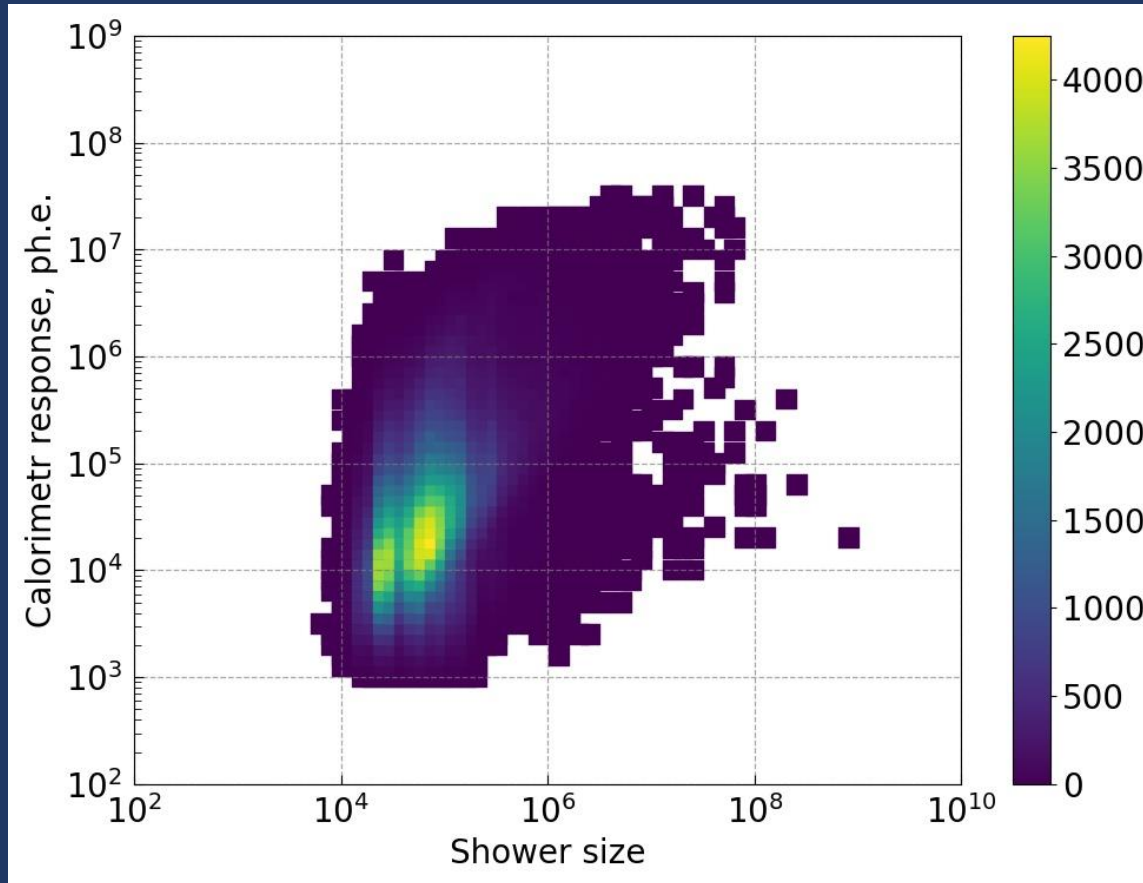


$\langle \alpha \rangle = 18.9^\circ ; \text{FWHM} = 21^\circ.$

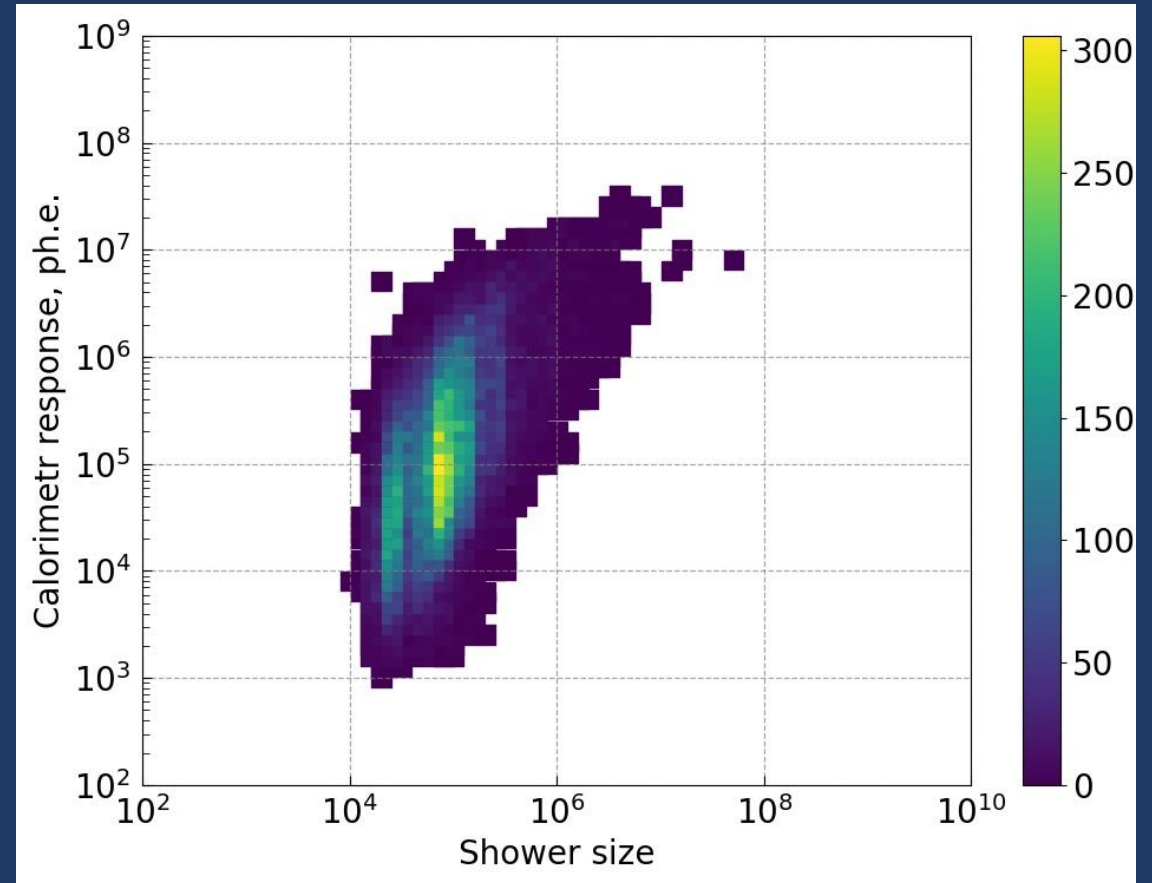
$\langle \cos \alpha \rangle = 0.93.$

Correlation of shower size and energy deposit in the CWC

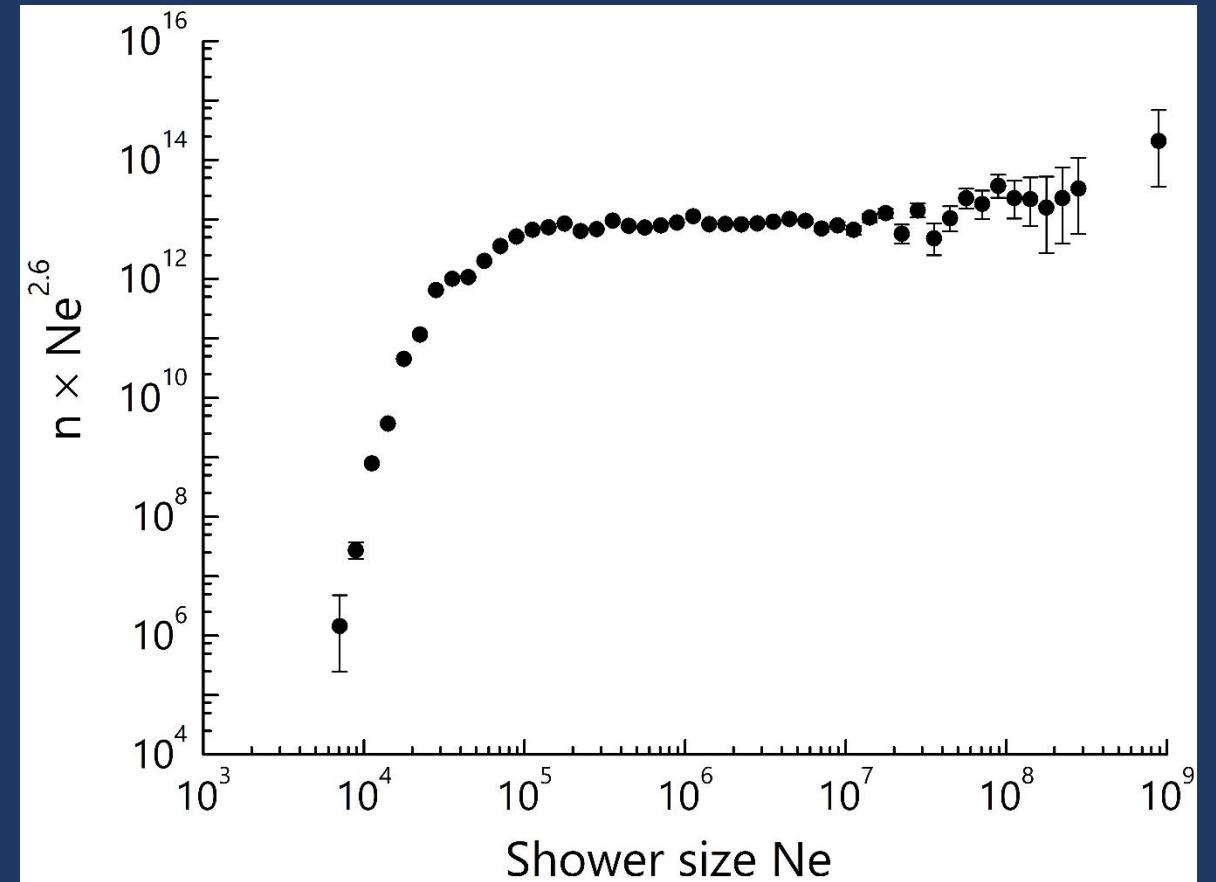
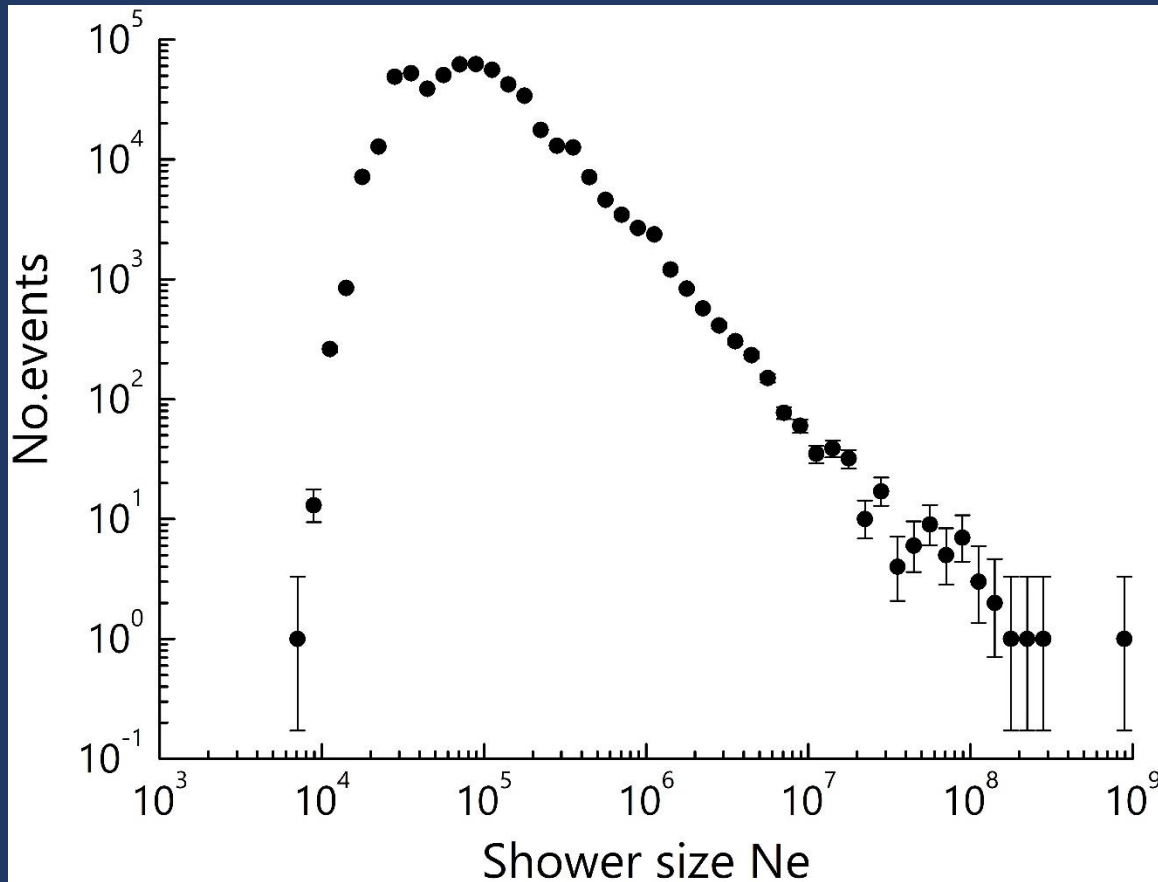
All combined events.



The EAS axis inside the CWC volume
($d < 5$ m).

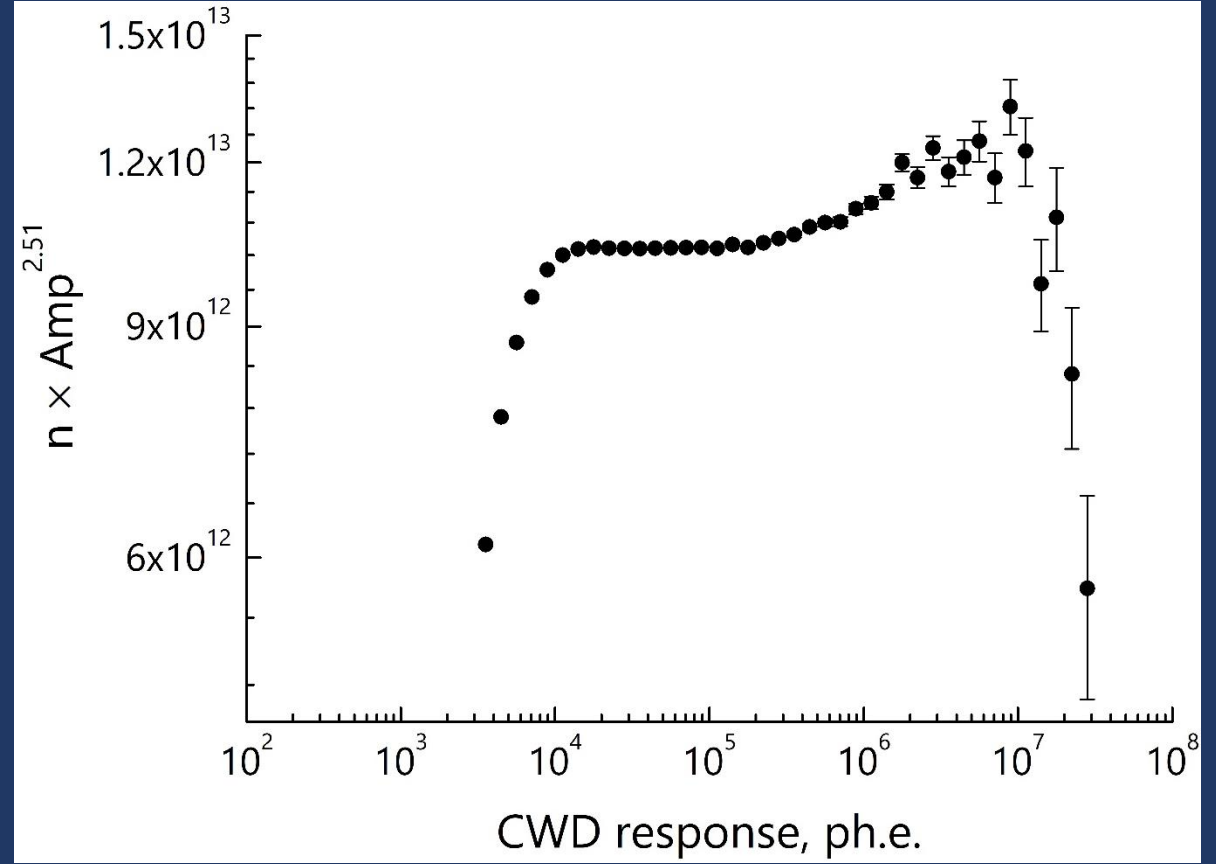
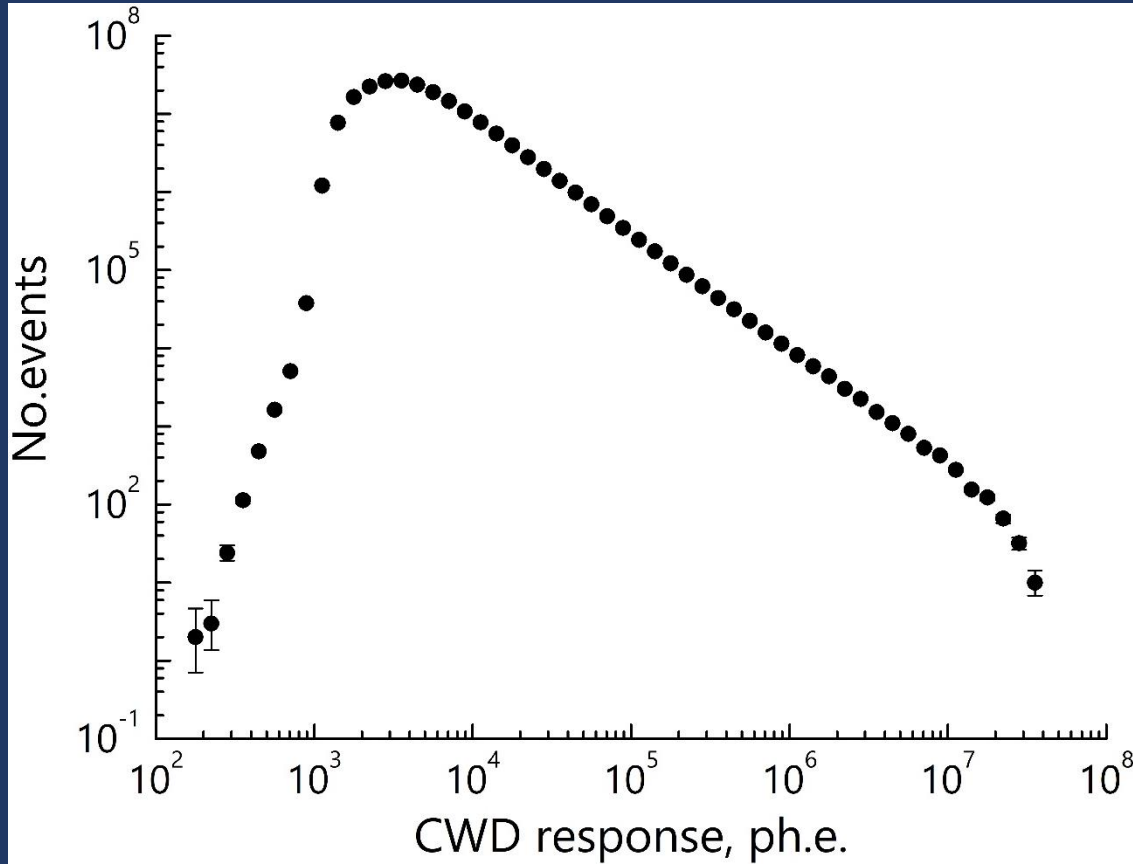


Spectrum of shower size measured with NEVOD-EAS



In the spectrum of shower size a feature above values 10^7 particles is observed.

Spectrum of energy deposit measured with CWD



In the spectrum of CWC response a feature above values $10^{5.5}$ photoelectrons also is observed. The feature in spectrum of CWC response if correspond to specificity of shower size spectrum.

Conclusion

- The Experimental complex NEVOD makes it possible to carry out simultaneous studies of the electron-photon, muon and hadronic components of extensive air showers.
- A comparison of particle directions in air-showers reconstructed with Cherenkov water calorimeter and NEVOD-EAS array gives angle accuracy of 18° .
- In the spectra measured with Cherenkov water detector and the NEVOD-EAS coincident features are observed with shower size above 10^7 particles.



Thank you for your attention!

<http://nevod.mephi.ru/>