Results of testing the optical module for the Cherenkov water detector

S. Khokhlov[1], L. Classen[2], Z. Izhbulyakova[1], A. Kappes[2],
V. Kindin[1], N. Pasyuk[1]

[1]National Research Nuclear University MEPhI
[2]Muenster University, Germany

V ICPPA, Moscow, Russia,
Oct 05-09, 2020

Introduction

Neutrino telescopes are actively developing instruments for astroparticle physics.

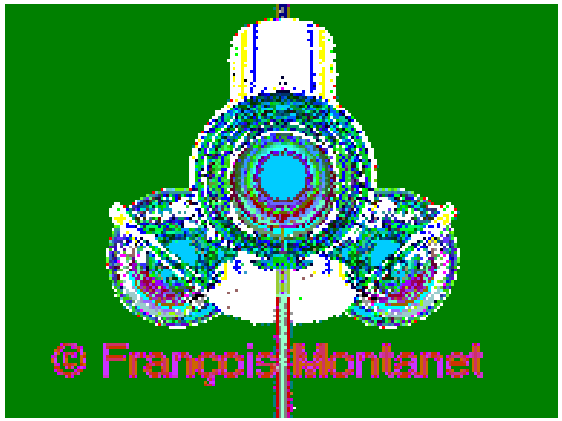
The basic element of Cherenkov water neutrino telescope is a optical module (OM).

One of the most important experimental problems is the calibration of different optical modules under the same conditions.

Tendency of CWD optical module development

Amanda (IceCube) - 1

Baikal (2)



ANTARES (3)

NEVOD (6)

IceCube-Upgrade (24)

KM3NeT (31)

The first quasispherical module (QSM) with 6 PMTs

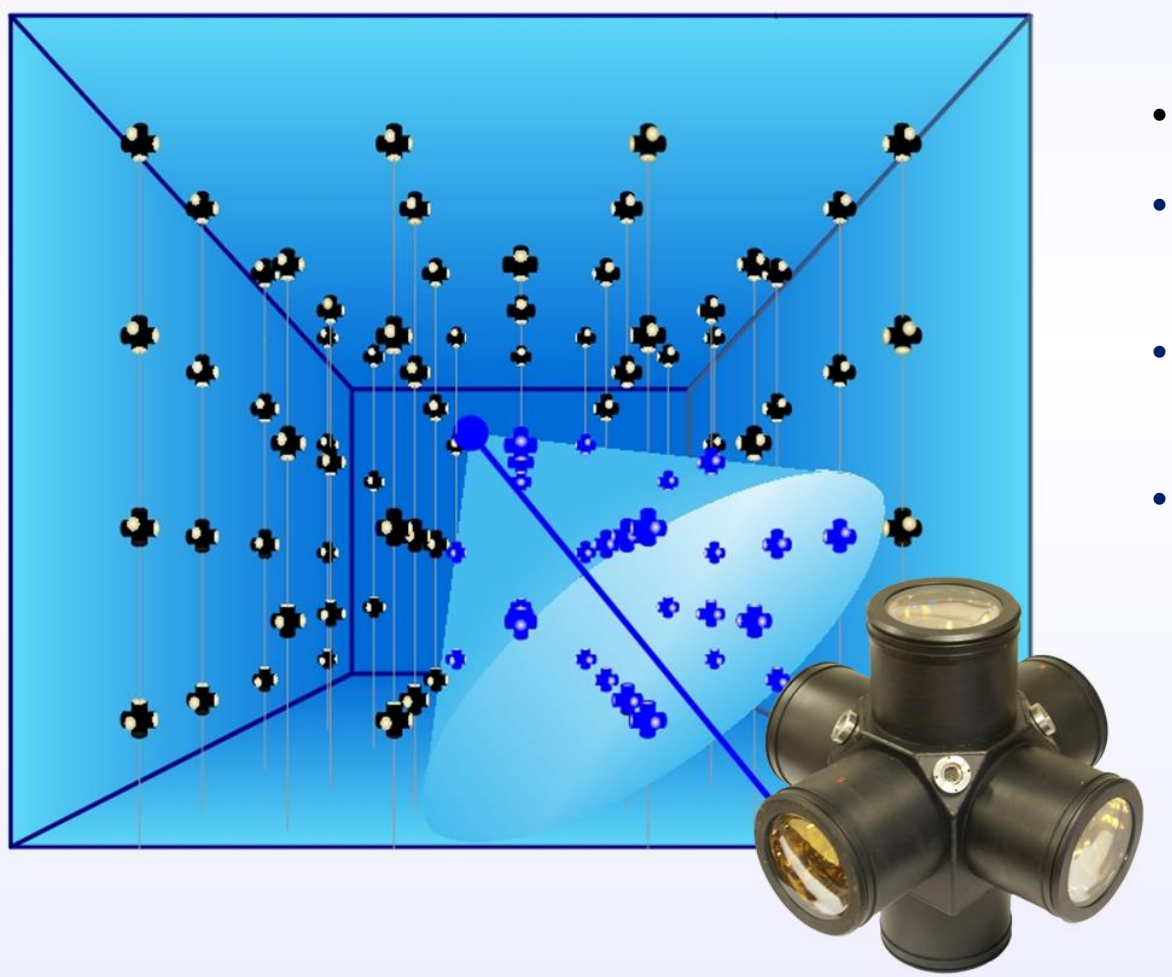
The **idea** of construction of **quasispherical module**s from several PMTs was presented at Cosmic Ray Conference in Kyoto in **1979**

(Borog V.V. et al., Proc. 16th ICRC, 1979 10, 380)

Module with six PMTs oriented along the axes of orthogonal coordinate system is **the simplest configuration** of photomultipliers, the **response** of which does **not depend** on Cherenkov light direction.

Besides independence of response of QSMs on Cherenkov light direction **quasispherical modules** allow to determine this **direction** using the amplitudes of signals from each PMT.

Cherenkov Water Detector NEVOD-91 (1994)

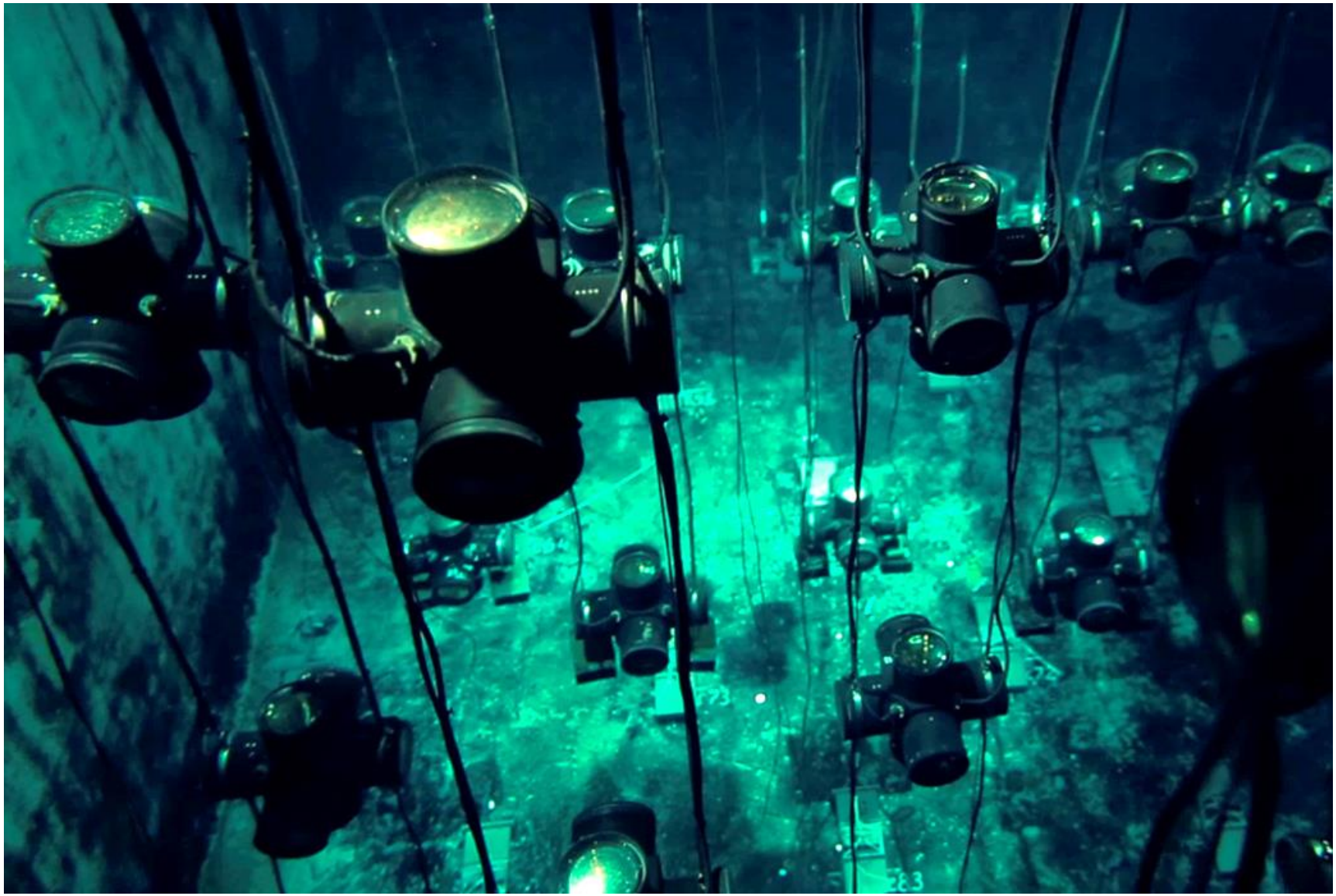


- Sizes 9 x 9 x 26 = 2100 m^3
- Spatial **lattice** from 91 QGM with steps **2 × 2 × 2.5 m^3.**
- Russian PMTs – FEU-49, FEU-125 (now, FEU-200)
- Placement of CWD NEVOD on the ground level allows investigate **all components of cosmic rays** reaching the Earth's surface, **including neutrinos** from the bottom hemisphere.

Registering System allows measure signals in the dynamic range from **1 to 10^5 ph.e**. for each photomultiplier.

Trggering System allows separate events produced by particles coming from the **top**, the **bottom**, and **any side**.

Cherenkov Water Detector NEVOD-91 (1994)



Possibilities of CWD NEVOD for OMs calibration

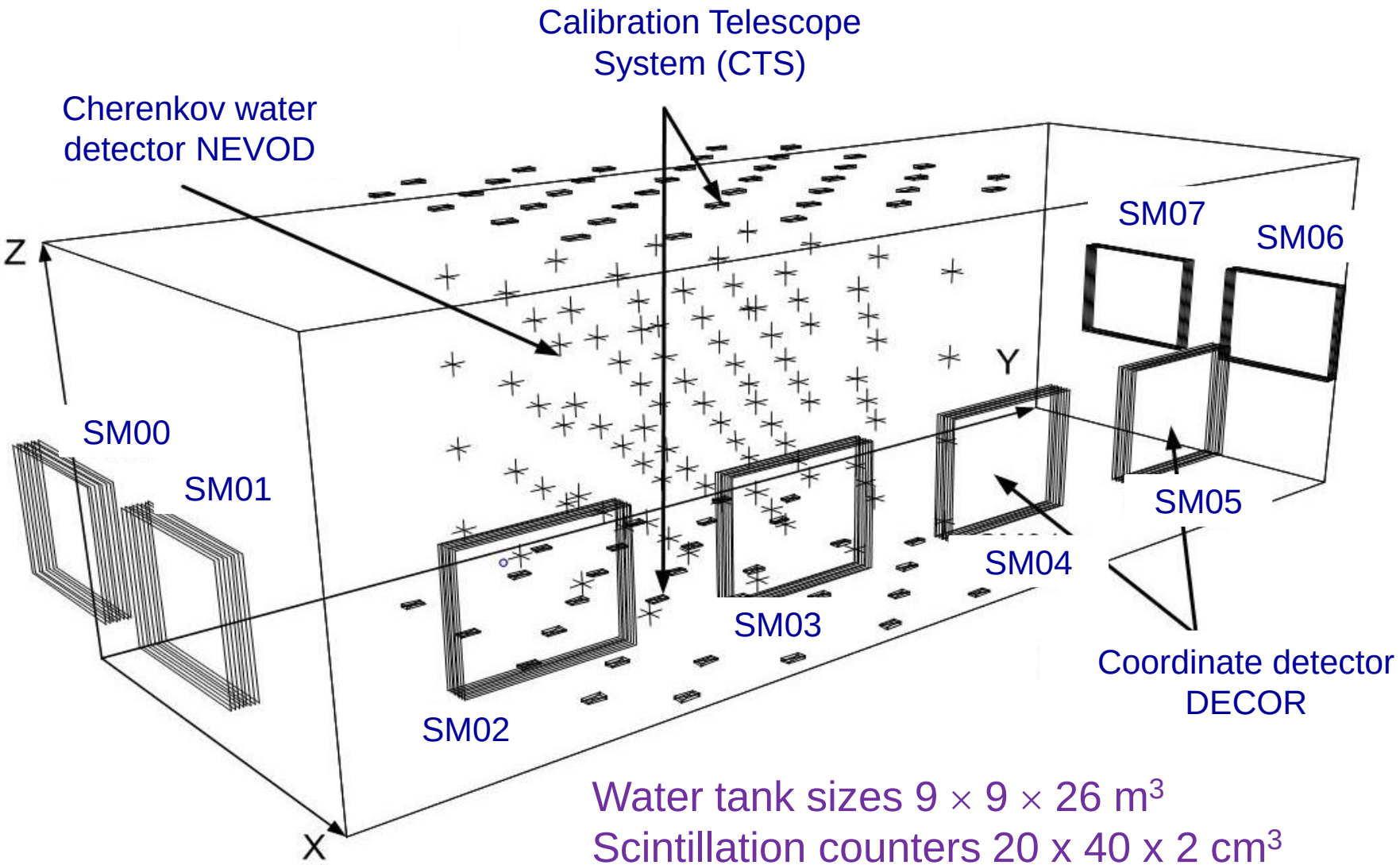
NEVOD facility can be used for calibration of new optical modules for the largest neutrino telescopes: IceCube, KM3NeT and Baikal-GVD.

On July 10 2020, the patent on invention has been registered (RU 2726265 “Complex for measuring the angular dependence of the response of the optical module of the neutrino Cherenkov water telescope”).

To check the calibration technique, we placed in the water tank a test optical module with a PMT Hamamatsu R877.

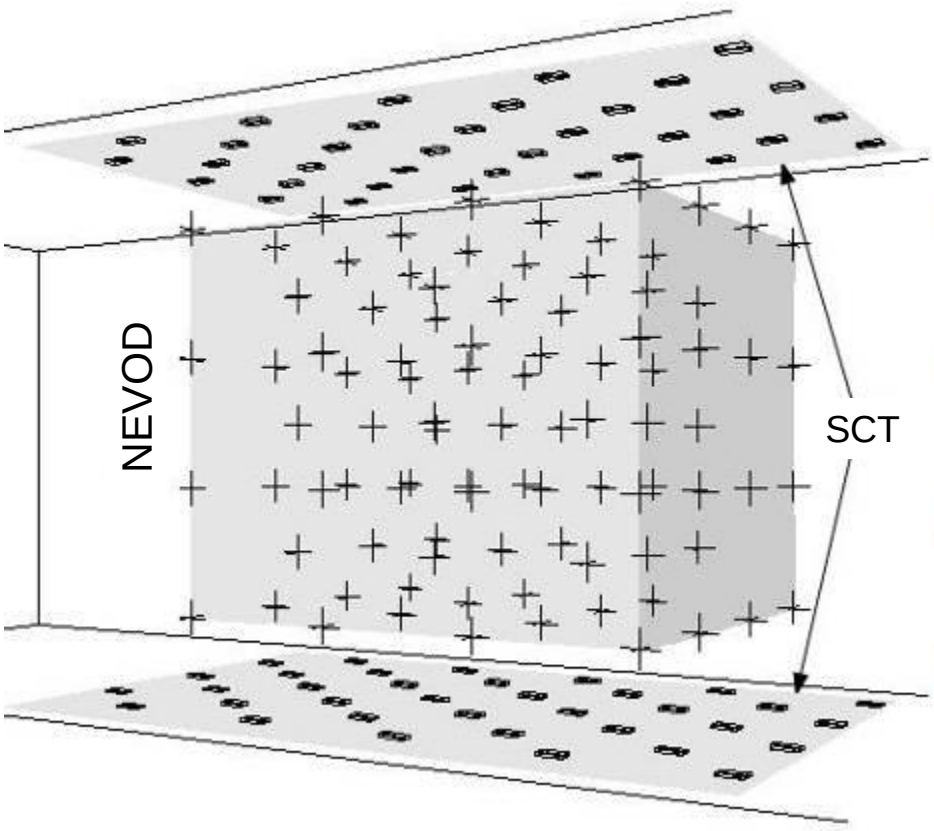
Aug 18 – Sep 23 2020 methodic measuring series have been conducted.

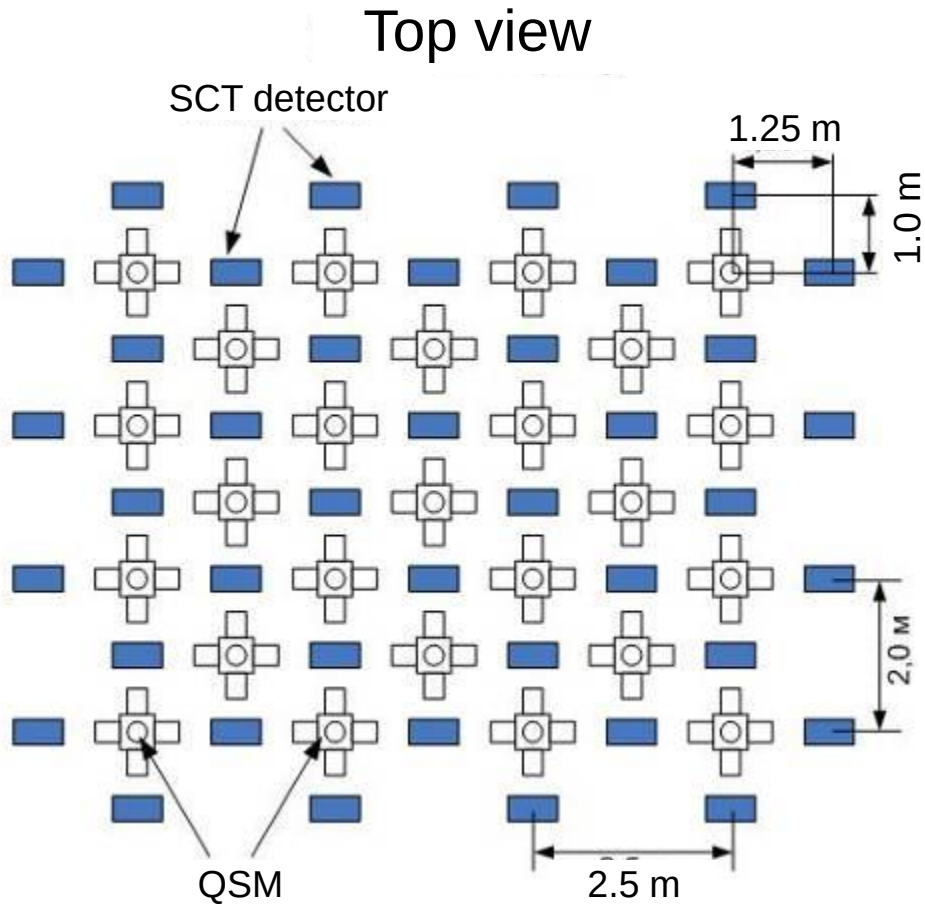
General scheme of NEVOD complex



Water tank sizes $9 \times 9 \times 26$ m^3
Scintillation counters 20 x 40 x 2 cm^3
Size of each supermodule DECOR 8.4 m^2

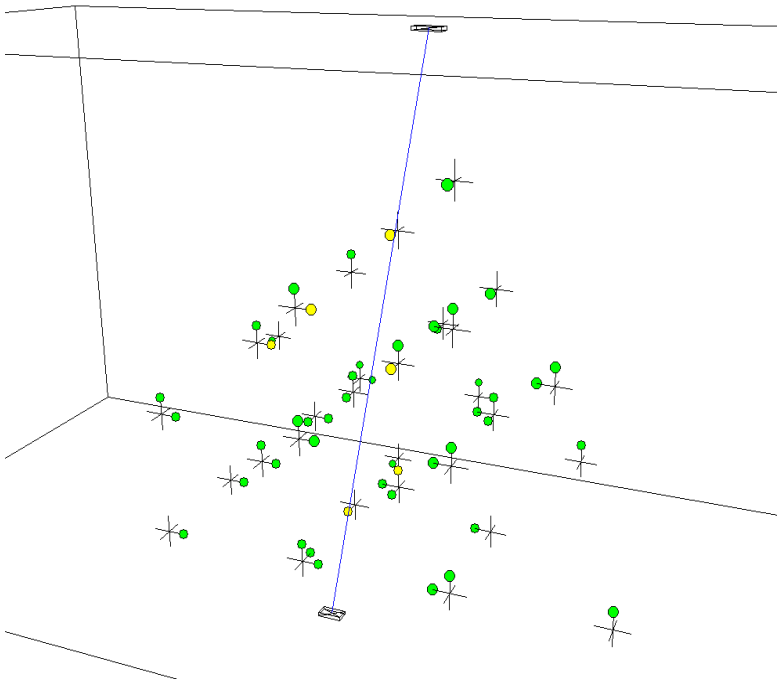
Calibration telescope systrm (CTS)

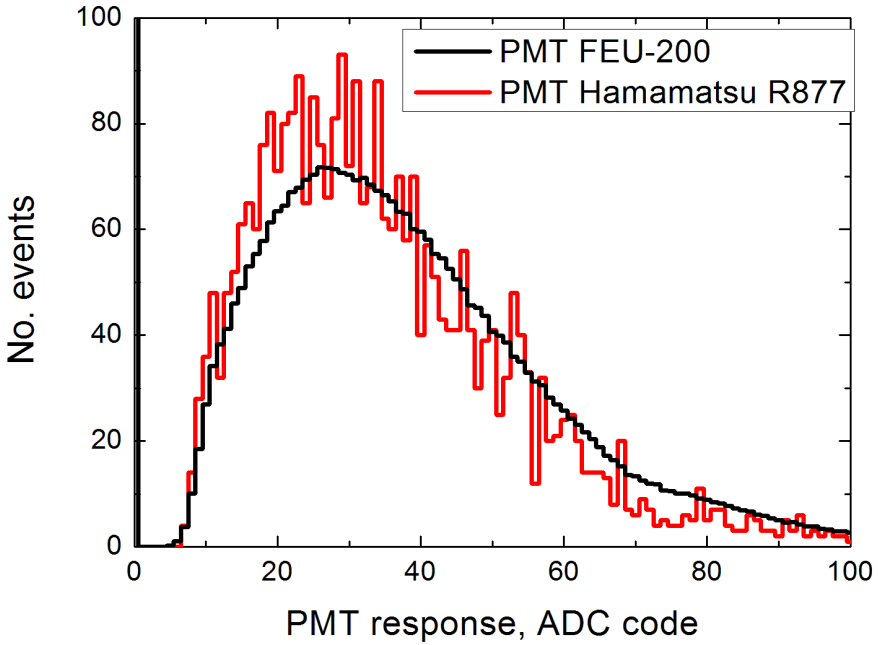




- 2 layers x 40 scintillation detectors.
- Sizes of scintillator $20 \times 40 \times 2$ cm^3.
- Accuracy of track reconstruction is better 2°.

Response of PMTs on near-vertical muons selected by means of calibration telescope system





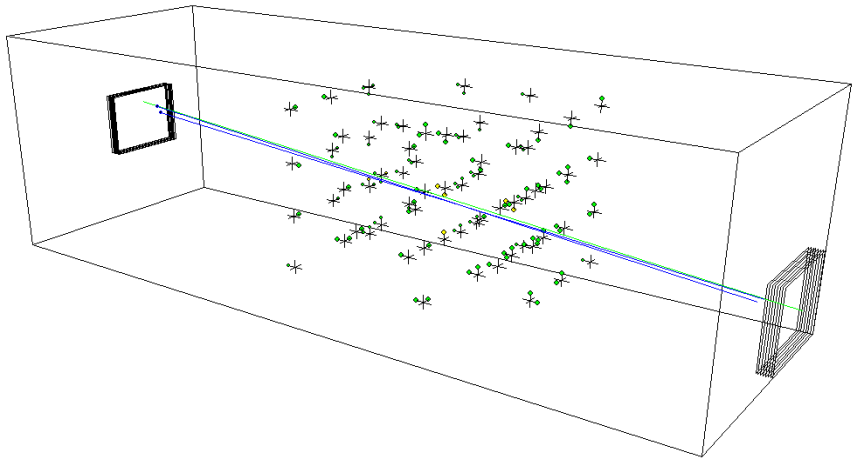
FEU-200: **Eff = 92 %** **<Amp> = 36.9 σ = 25.6**

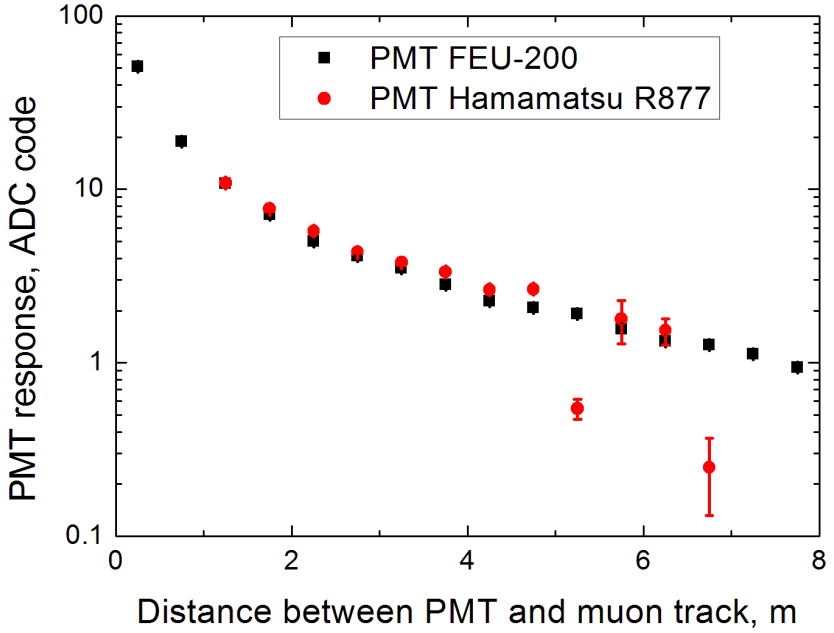
Hamamatsu R877: **Eff = 93 %** **<Amp> = 34.9 σ = 27.3**

Coordinate detector DECOR

8 supermodules x 8 layers of plastic streamer tube chambers.

Response of PMTs on near-horizontal muons selected by means of DECOR



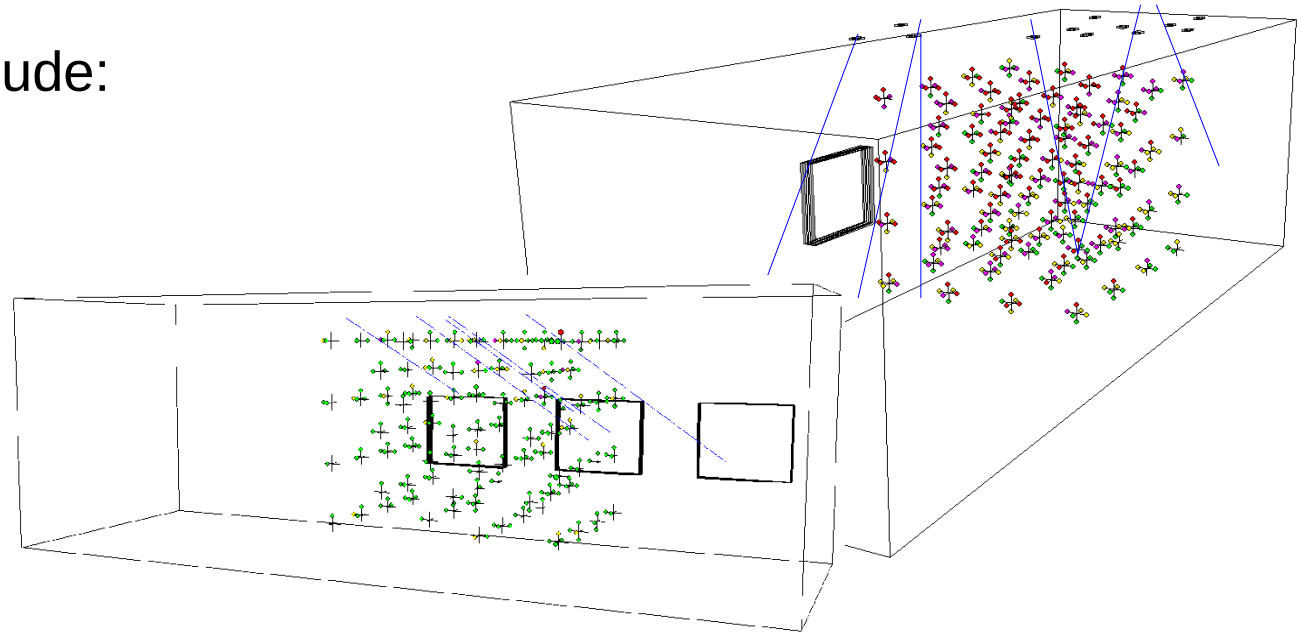


Investigation of cascades with unknown axis

Experimental complex NEVOD-DECOR has a special trigger “60c” (rate ~4 s^{-1}) for detecting of events with big energy deposit.

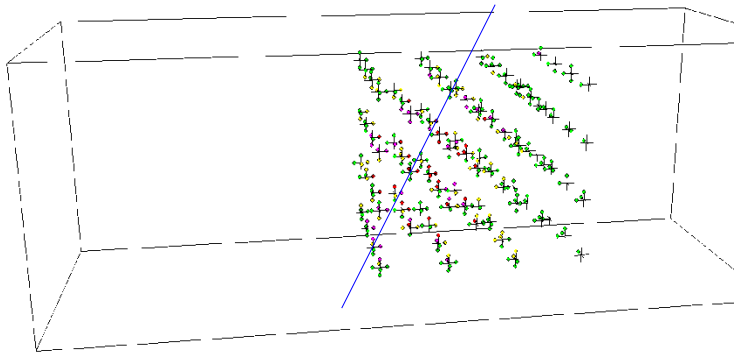
Such events include:

- EAS;
- muon bundles;



- cascades generated by muons and hadrons.

Selection and reconstruction of parameters are based on the compactness of QSM with a powerfull response.
Technique has been tested on the cascades With the known axis.

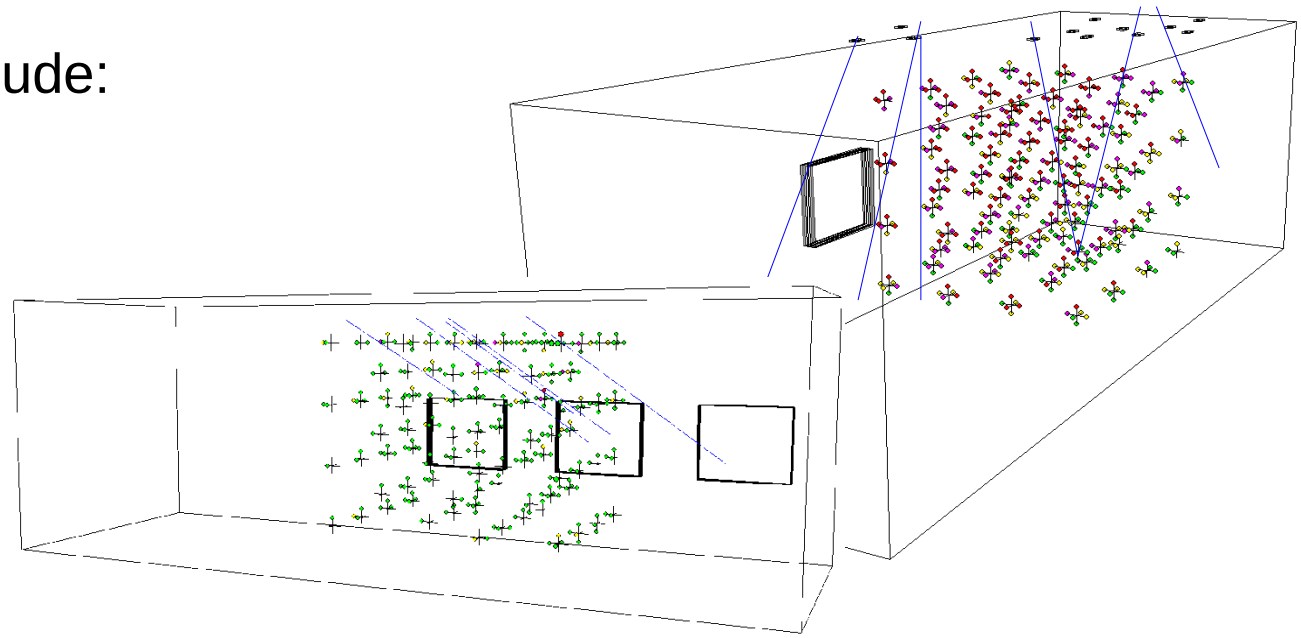


Events with big energy deposit

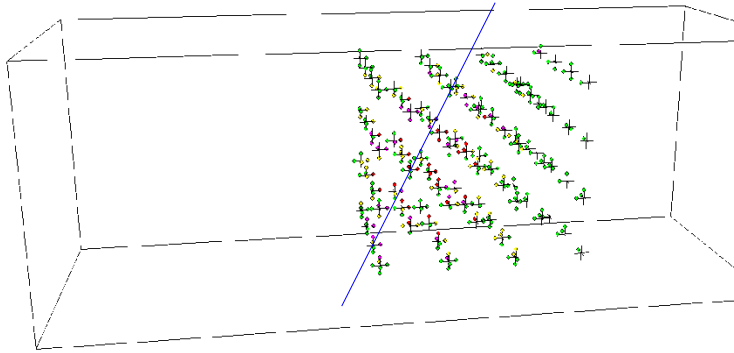
Experimental complex NEVOD has a special trigger “60c” (rate ~4 s^{-1}) for detecting of events with big energy deposit.

Such events include:

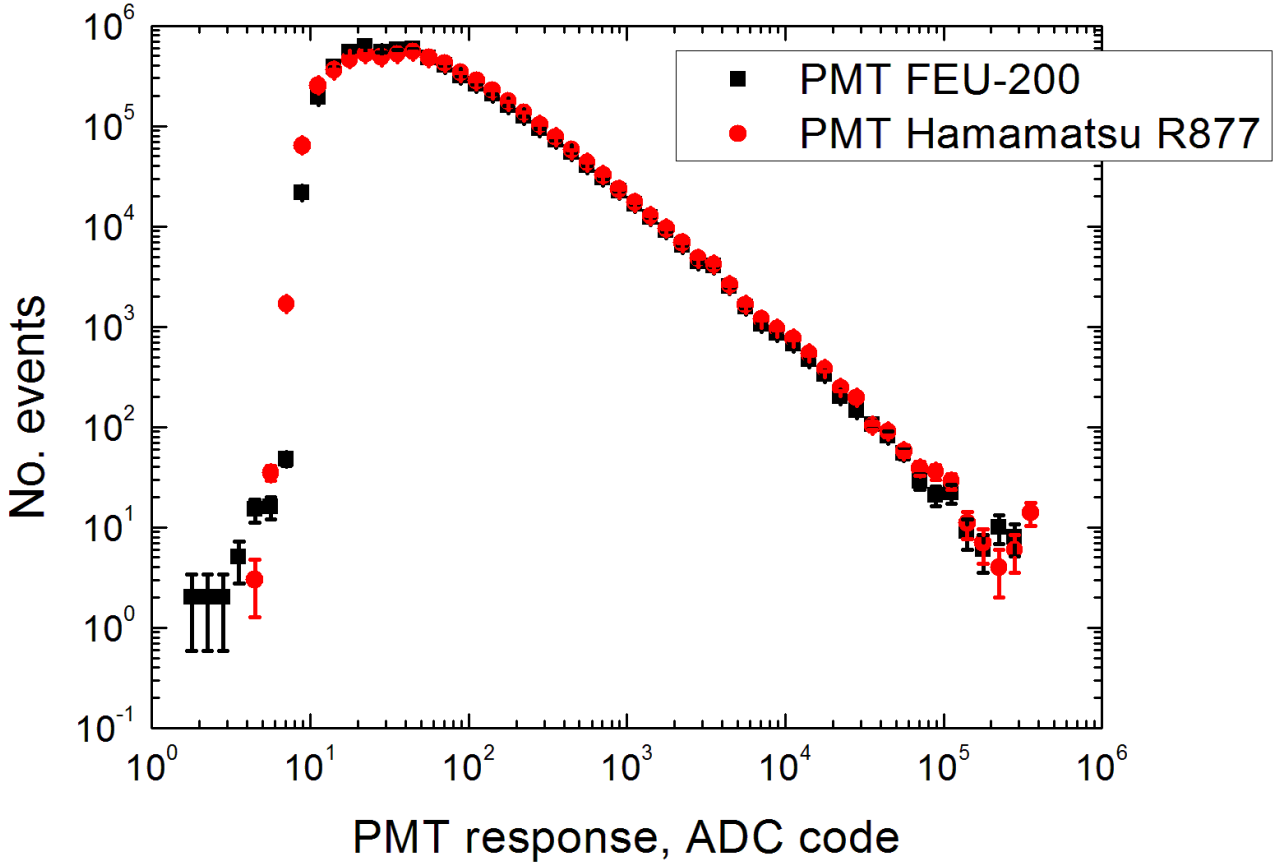
- EAS;
- muon bundles;



cascades generated by muons and hadrons.

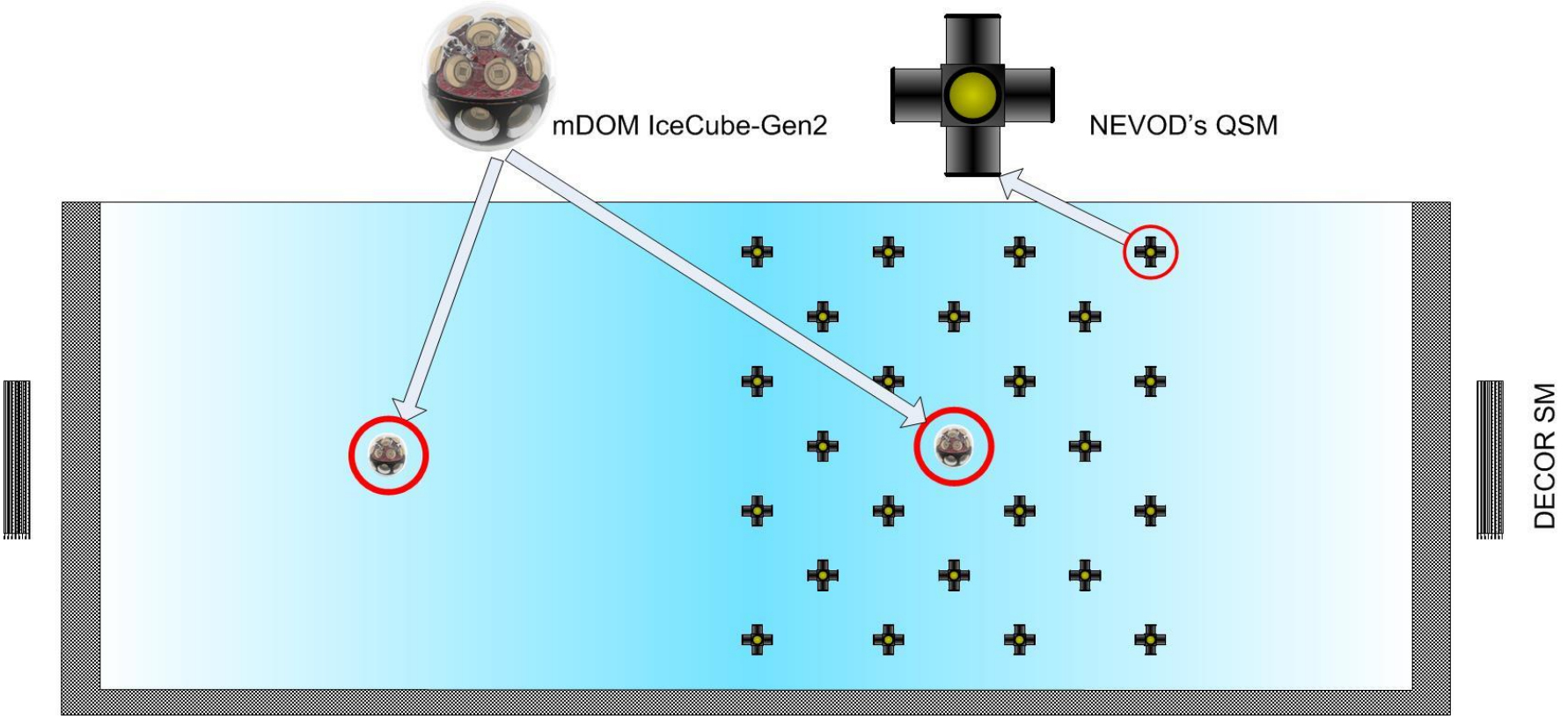


Response of PMTs on events with a big energy deposit



The response of PMT Hamamatsu R877 (D = 13 cm) on the Cherenkov radiation is very close to the response of FEU-200 (D = 17 cm) .

Variants of mDOM calibration in NEVOD



In Muenster University a new optical module mDOM has been developed. mDOM can be used in next generation of IceCube (IceCube-Upgrade).

Calibration of mDOM is planned for 2021.

Conclusion

Experimental complex NEVOD can be used as a test facility for calibration of optical modules of future neutrino telescopes.

- **On July 10 2020, patent on Invention for calibration of optical modules has been registered.**
- **The response of PMT Hamamatsu R877 (D = 13 cm) on the Cherenkov radiation is very close to the response of FEU-200 (D = 17 cm).**
- **Calibration of mDOM (optical module of IceCube-Upgrade) is planned for 2021.**

Thank you for attention!