Large area scintillation hodoscope for muon diagnostics of heliosphere and Earth's magnetosphere

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Introduction

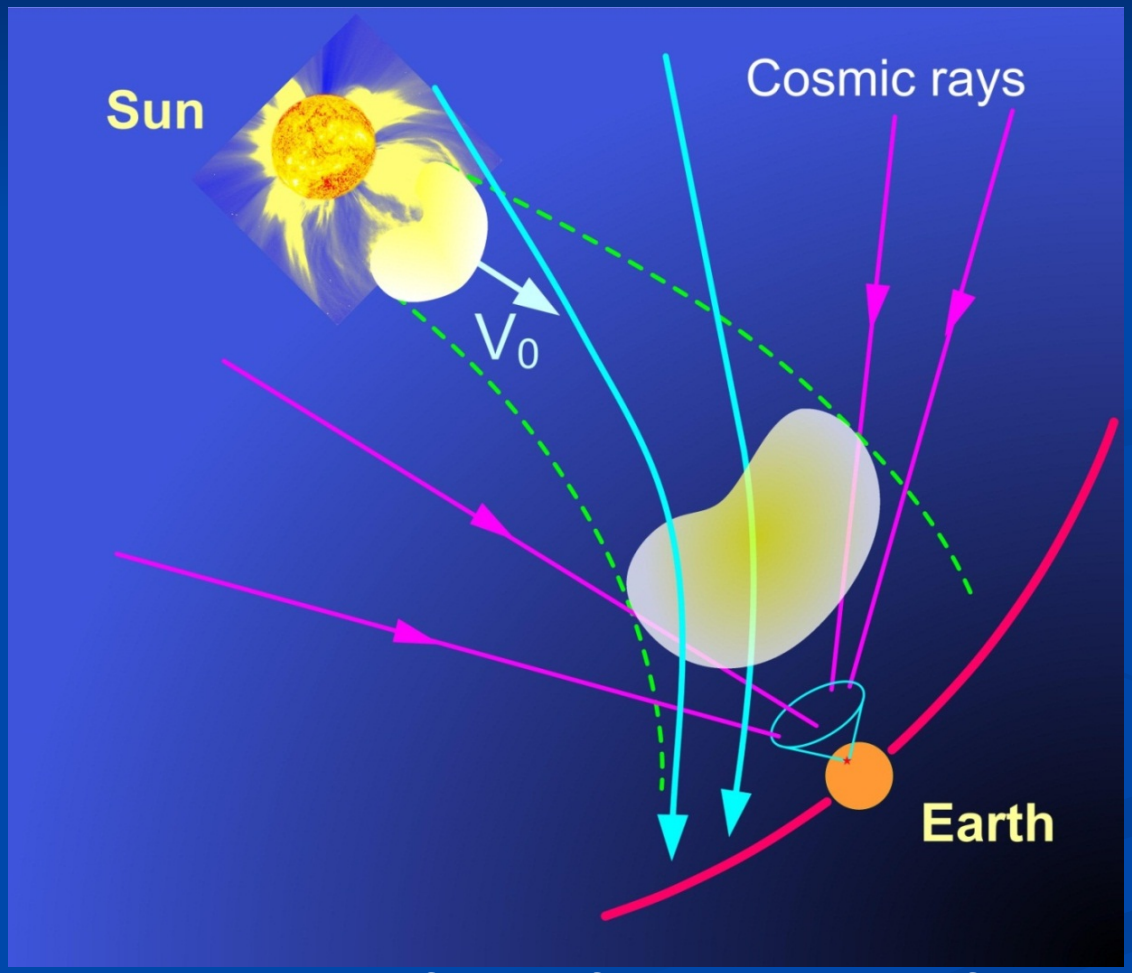
- Despite of enormous amount of information from ground-based and space-born apparatus (ACE, Hinode, RHESSI, SOHO, SDO, STEREO) related to our space environment observations vital problem of space weather forecasting has not been solved yet.
- The main reason: information about the space between the Mercury's and the Earth's orbits is yet very scarce.
- CR variations – the way to study heliospheric disturbances.

Introduction

- Muons are the secondary component of cosmic rays generated by primary cosmic rays in the atmosphere.
- Therefore variations of muon flux depend on primary flux changes and conditions in the atmosphere.
- **The objective of the muon diagnostics** is the solution of the inverse task – study of dynamic processes in the atmosphere and in the near-terrestrial space using cosmic ray muon variation data.

Muon diagnostics of the heliosphere

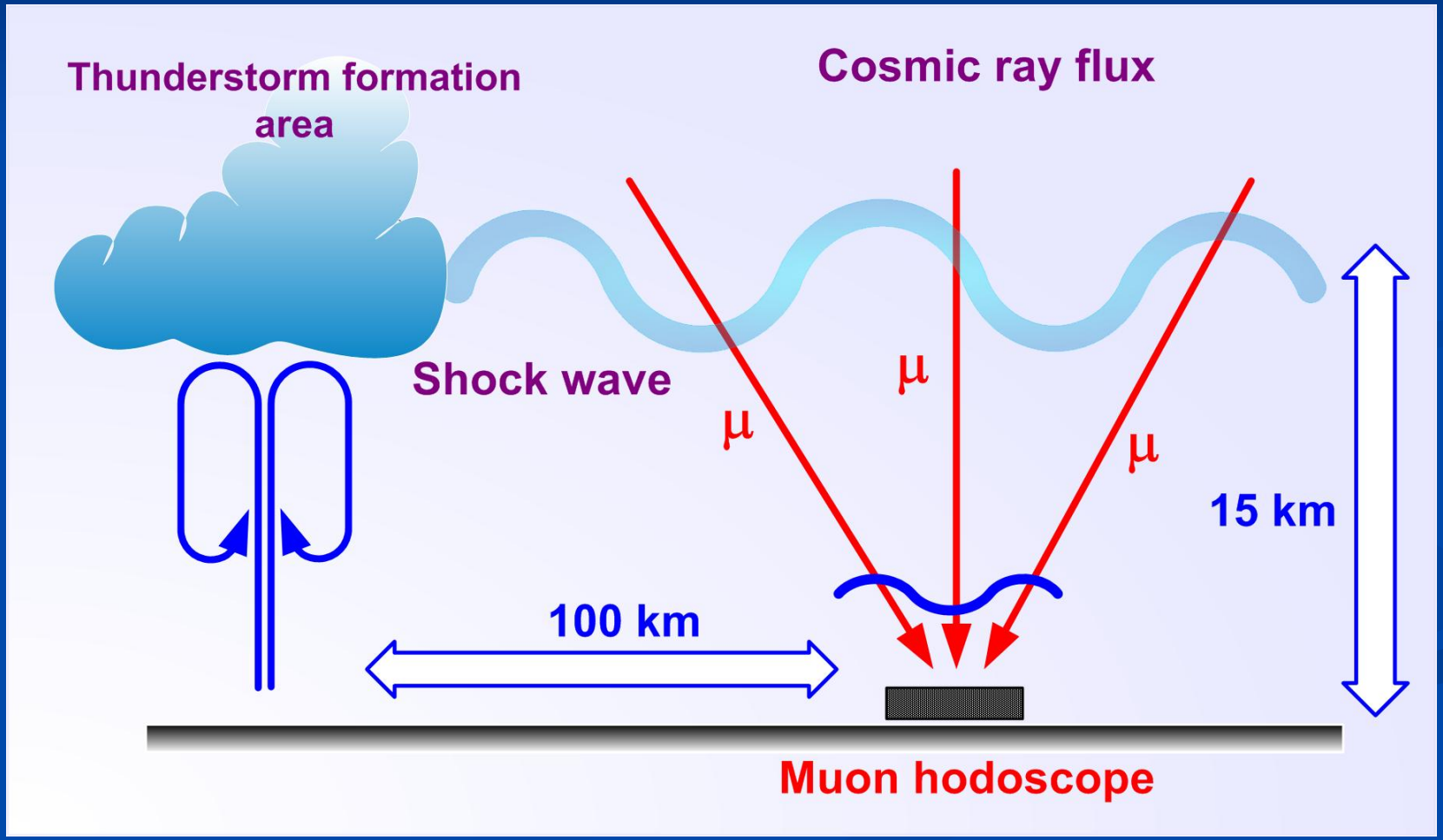
Magnetized plasma clouds formed as a result of CME deflect PCR and hence modulate the flux of generated muons and directed from the plasma clouds



Thus, spatial-angular variations of muon flux can be used for localization of heliosphere disturbances and as a precursor of perturbation of the Earth's magnetosphere.

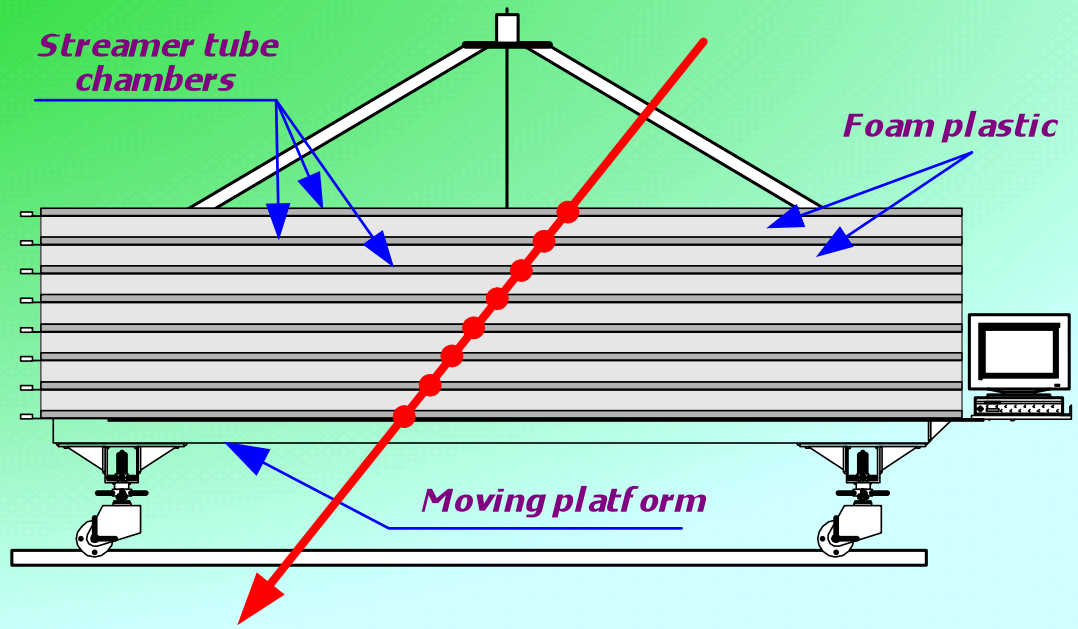
Muon diagnostics of the atmosphere

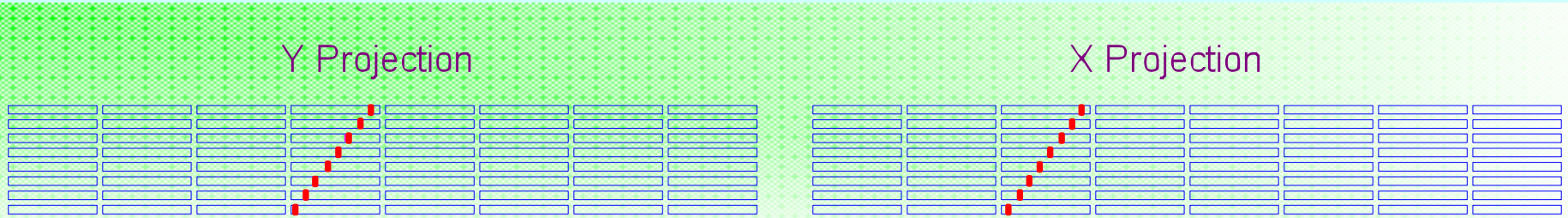
Muon flux at the ground level is strongly related with different thermodynamic processes in the Earth's atmosphere at generation level (barometric, temperature effects) and with more complex wave processes in the upper troposphere.



What is muon hodoscope ?

Setup which can simultaneously detect cosmic ray muons from any direction of upper hemisphere in real time mode with sufficient efficiency and angular resolution.





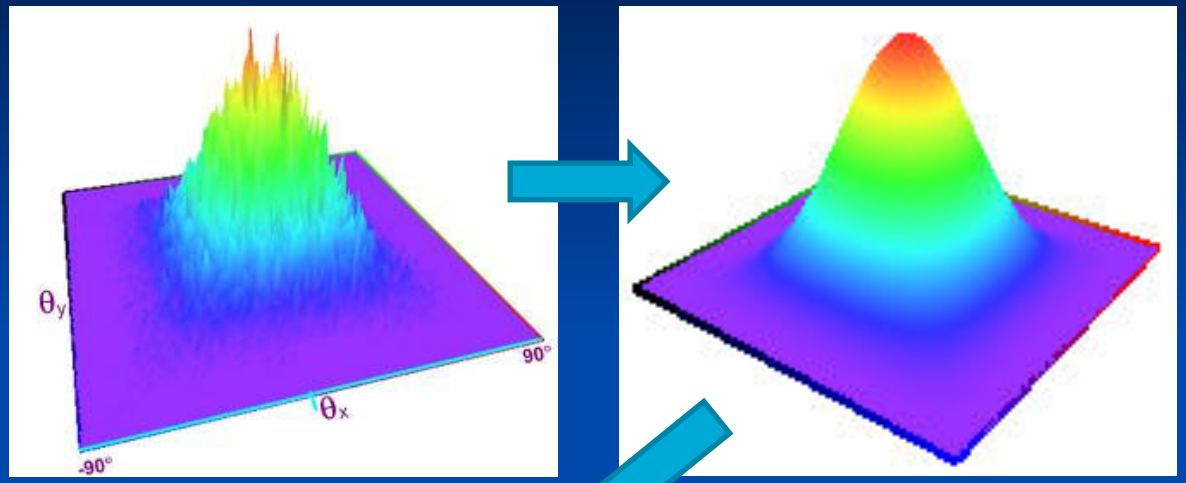
Muon hodoscope URAGAN

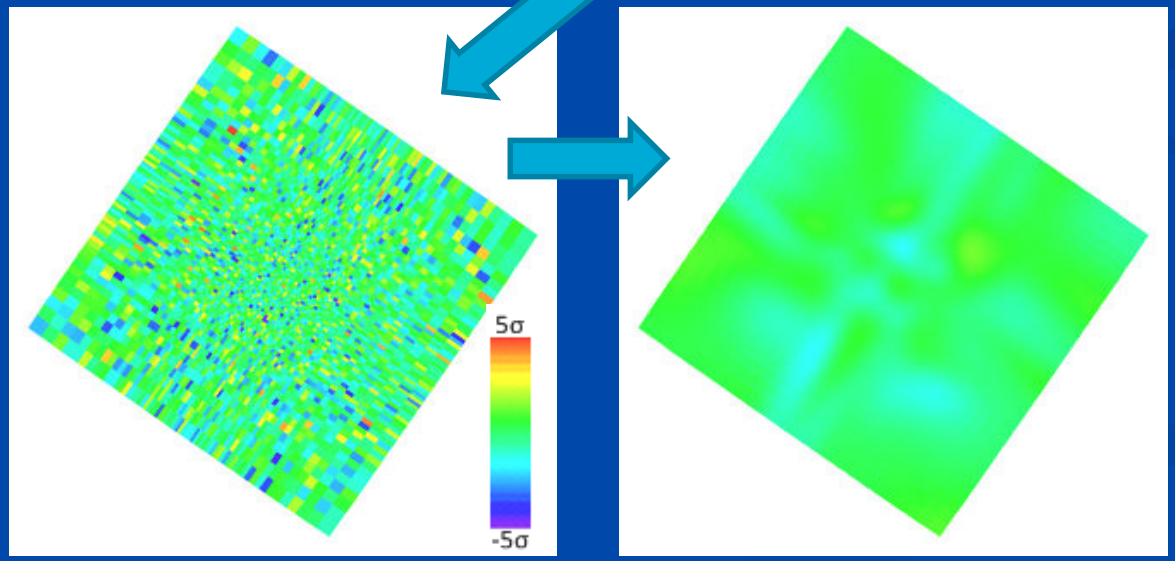
Large area muon hodoscope URAGAN created in the frame Russian-Italian collaboration DECOR is under operation since 2005

~ 4×10^{11} muons since 2006

Total area – 45 m^2 . Counting rate ~ 6000 μ / s.
Resolution: spatial – 1 cm, angular – 1º.
Muon data in real time – http://nevod.mephi.ru.

Transformation of 2D matrix



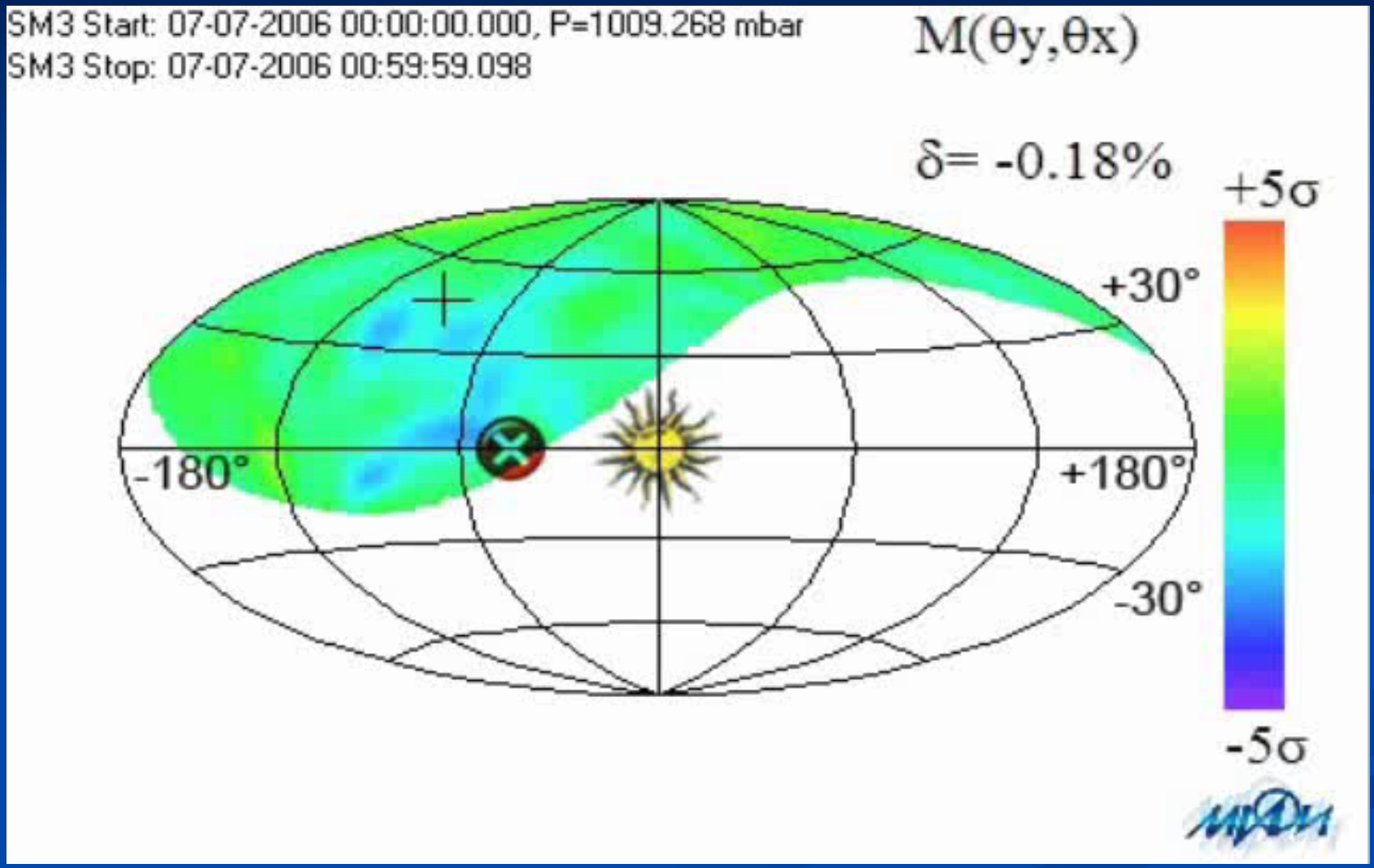


2D-muon intensity matrix:
- 1-minute exposure
- angular matrix 90x90 cells
- statistical errors ~0.1 %

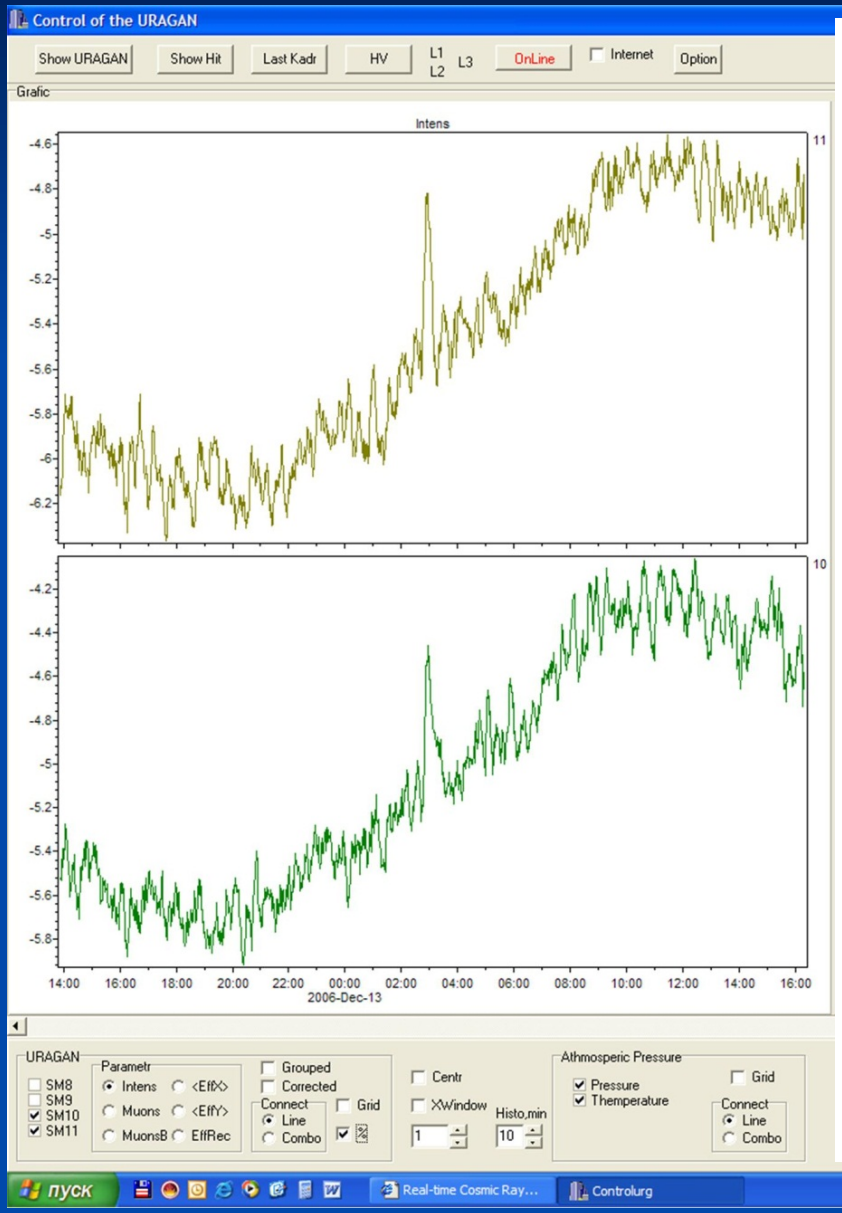
(for 10-minute bin)

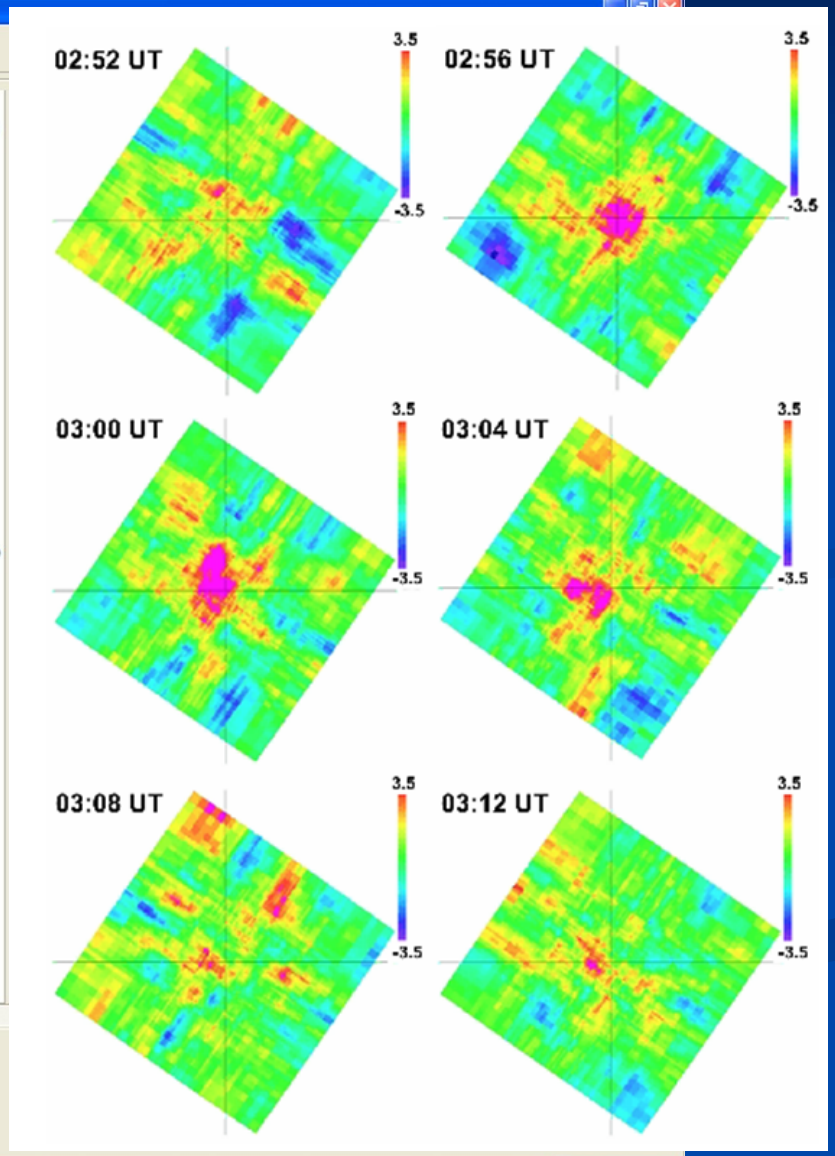
Data processing:
- averaging
- normalizing
- Gaussian filtering of noise (suppression of high frequencies)

Monitoring of heliospheric disturbances by muon hodoscope data in GSE system

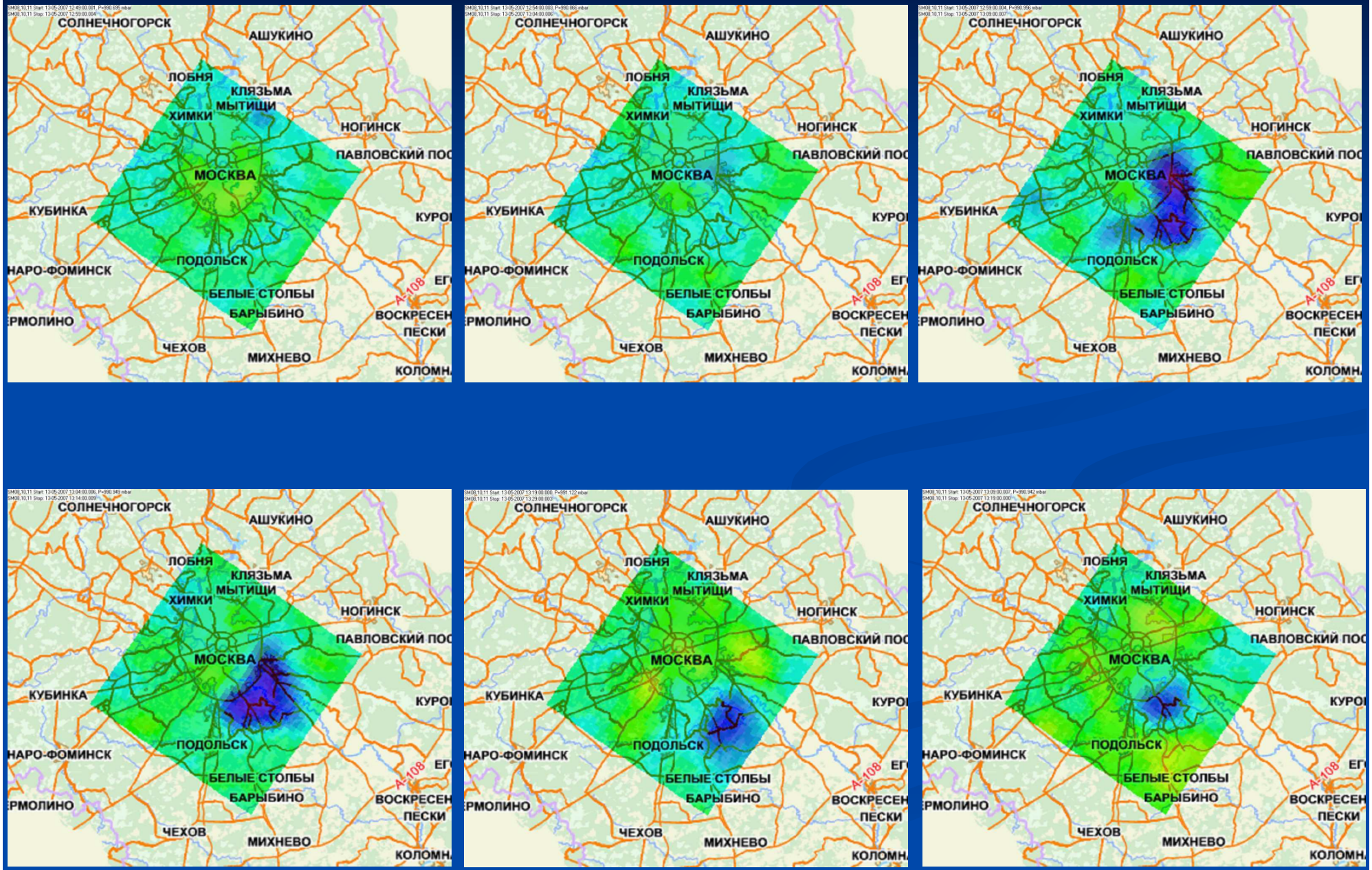


GLE #70 December 13, 2006

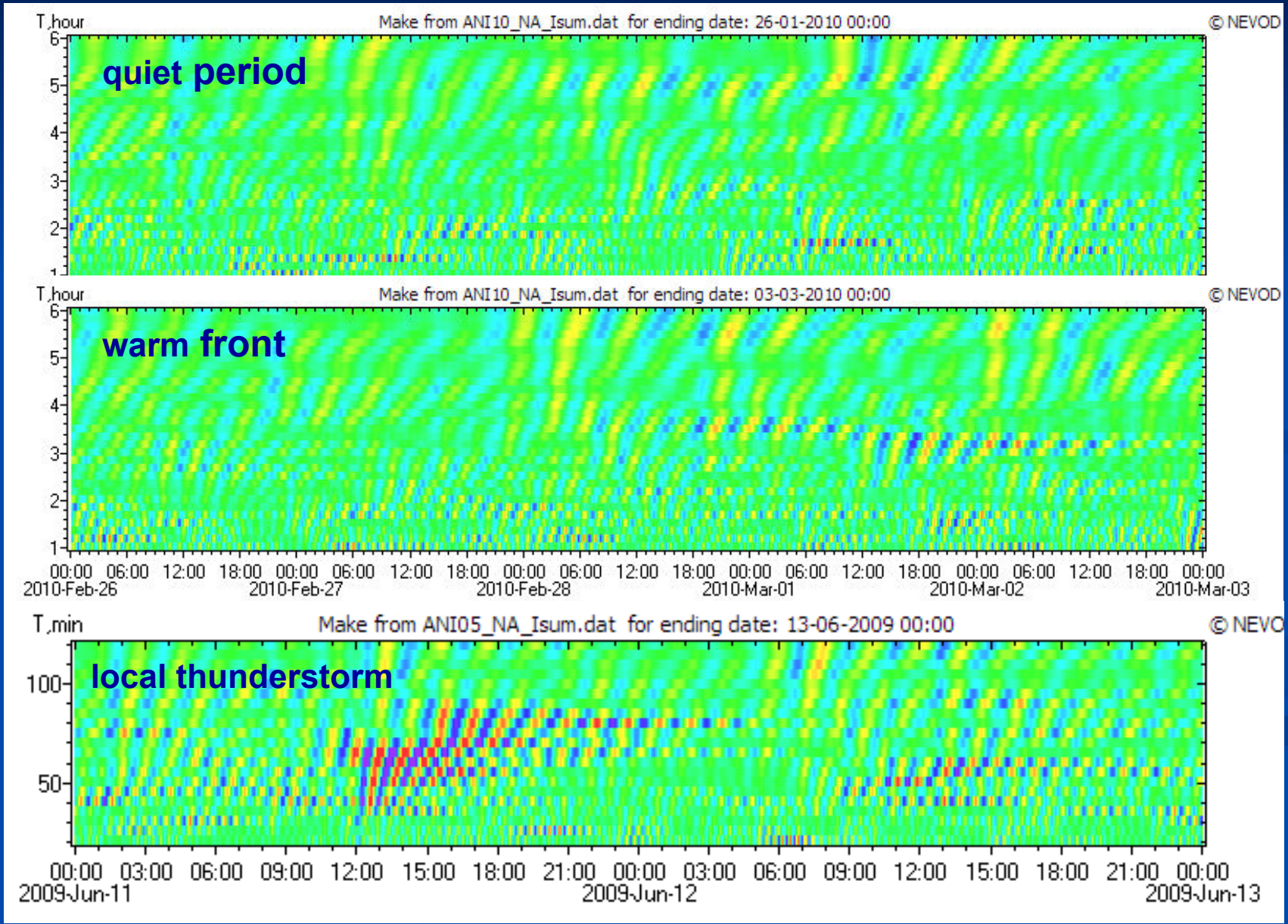




Monitoring of the thunderstorm over Moscow



Wavelet-analysis of atmospheric events



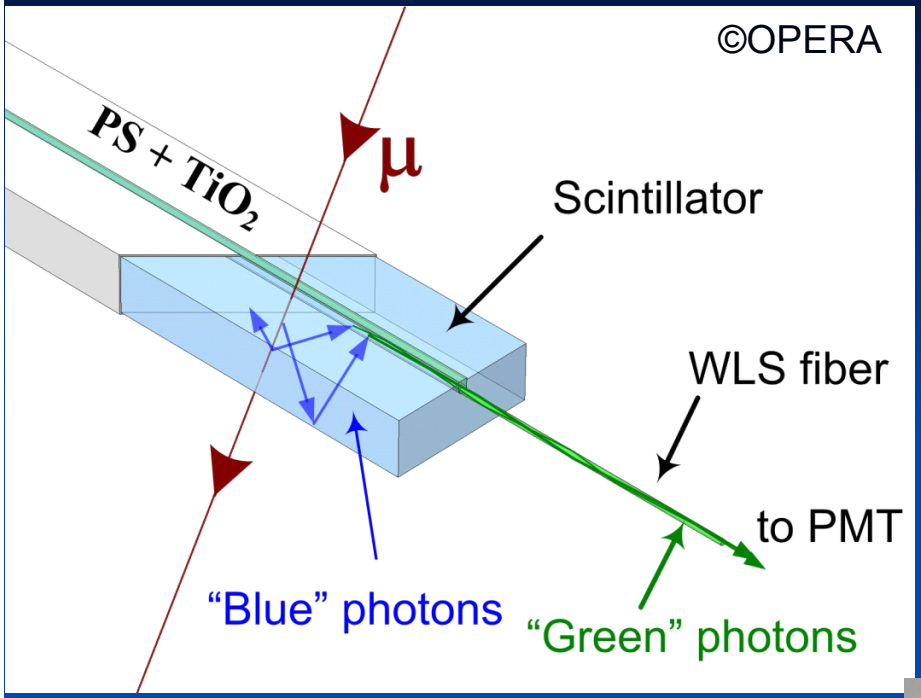
Requirements to new generation of muon hodoscopes

- sensitive area > 40 м^2;
- angular resolution ~ 2º;
- efficiency of muon track registration by the detection unit > 98 %;
- modular approach to construction;
- manufacturability;
- easy handling and transportation;
- simple and low cost operation.

The optimal design of detecting system -

Narrow angle multichannel scintillation detector with the fiber optic light collection

Detection channel



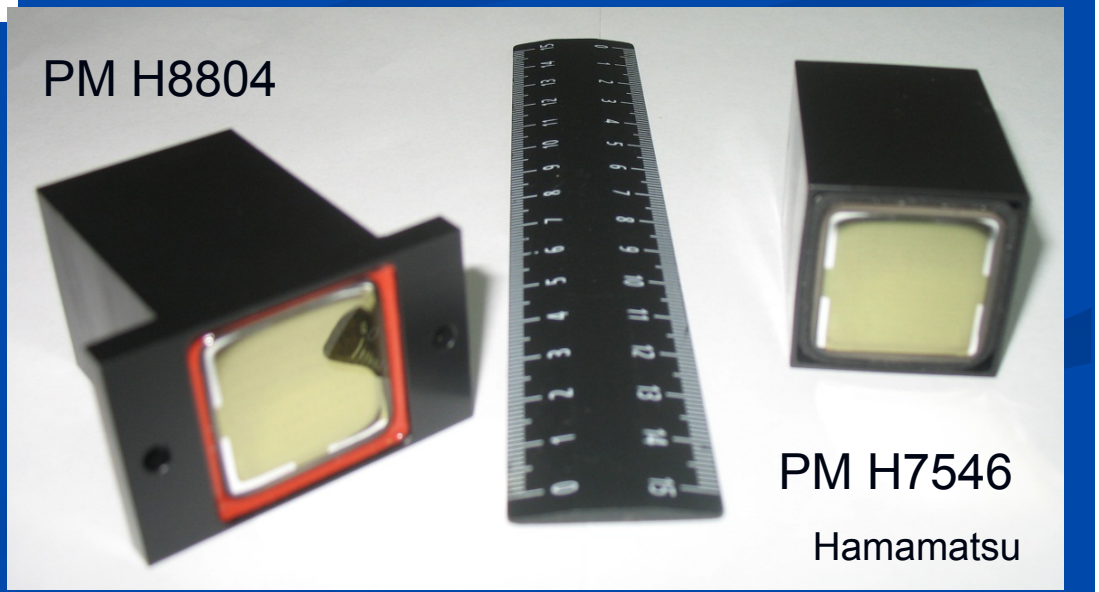
Detection channel

Scintillation strip
10.6 × 26.3 × 3460 mm^3

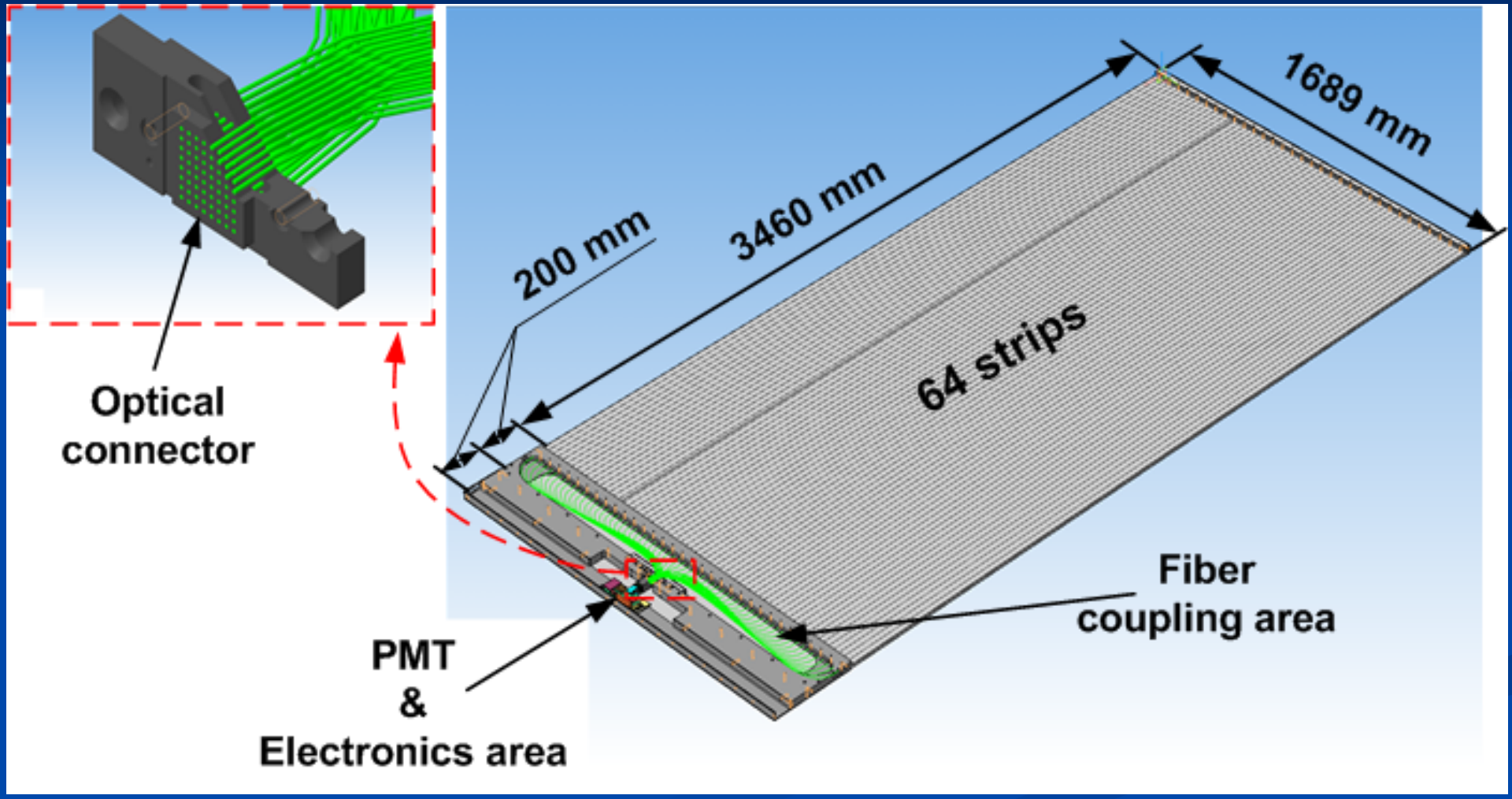
Polystyrene with 2 % p-terphenyl and 0.02 % POPOP) with wavelength shifter (WLS) fiber optic light collection.

Diffuse reflective compound of polystyrene and TiO_2 coextruded with the scintillator surface

64-anode H7546 PMT

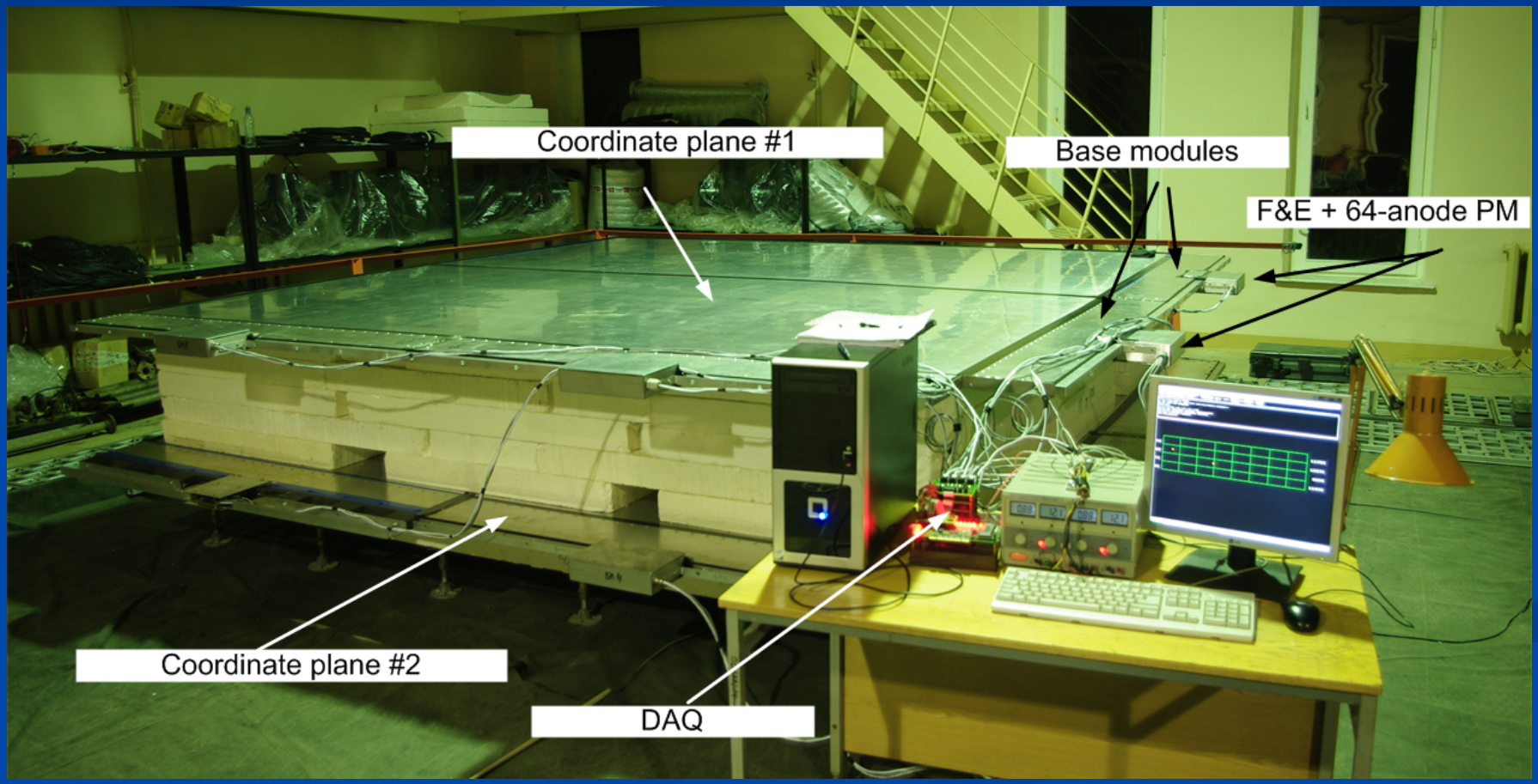


Basic module



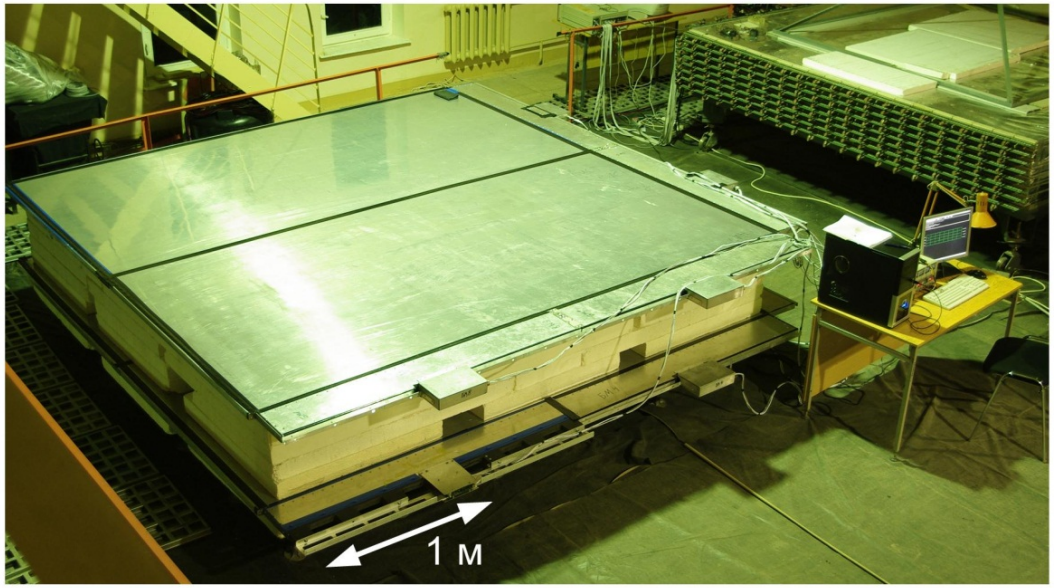
Assembling of basic module

Assembling of first supermodule of ScMH

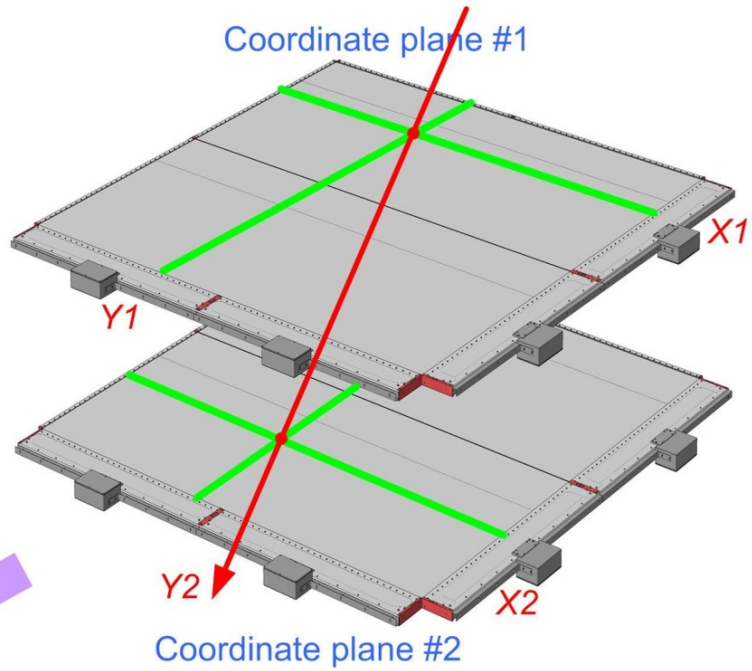


Supermodule of ScMH (2 planes)

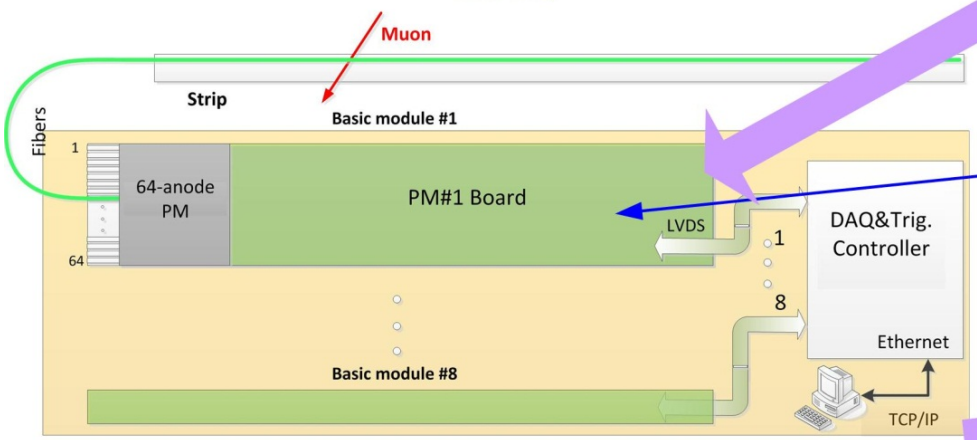
Supermodule of ScMH (2 plane)



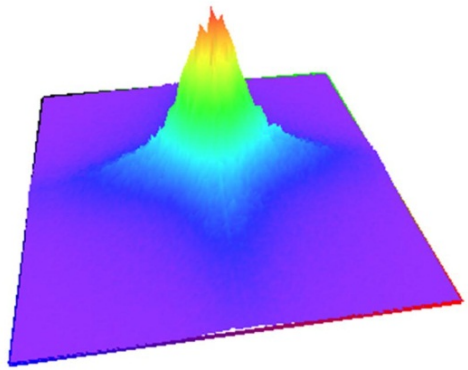
Muon detection



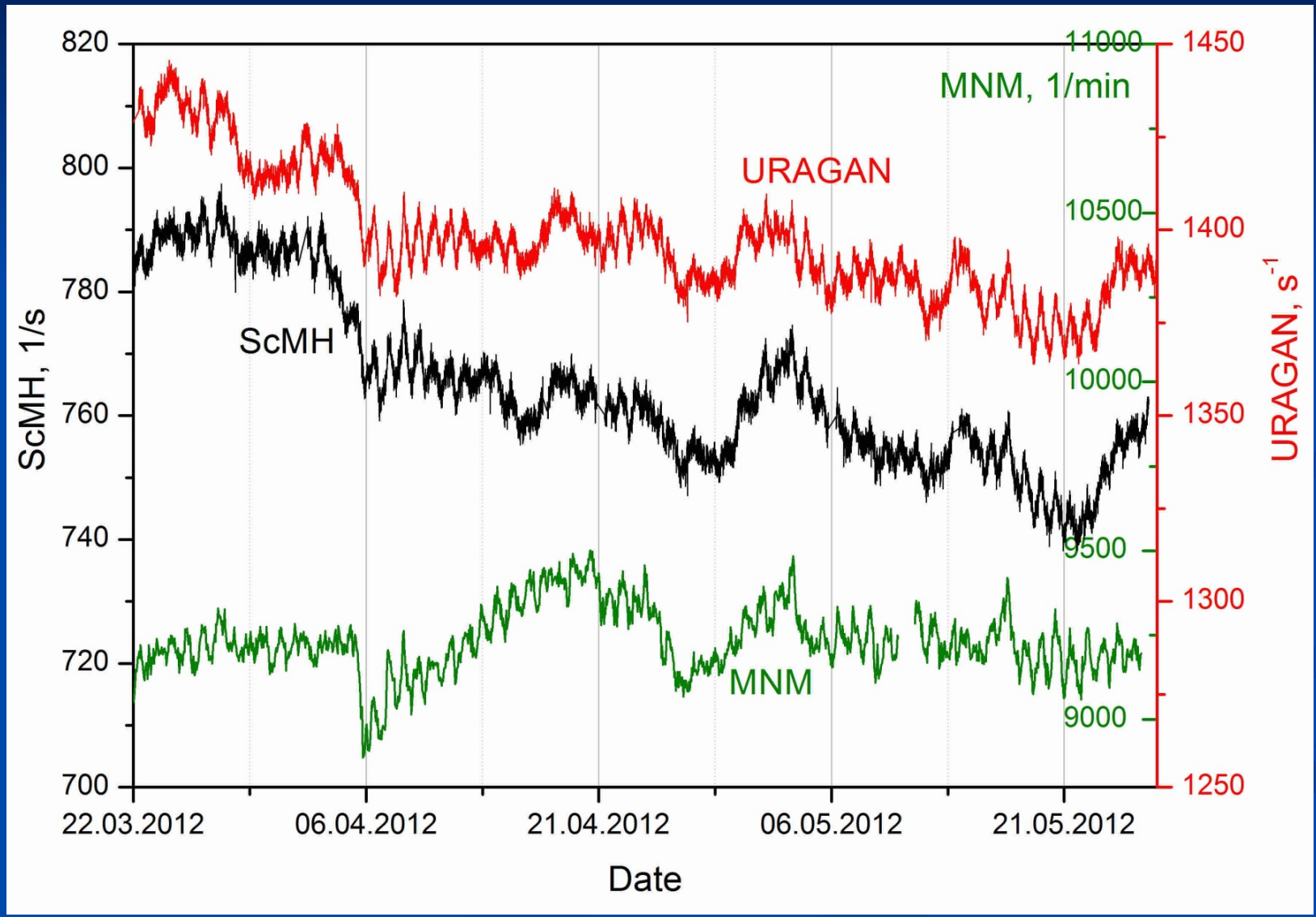
DAQ

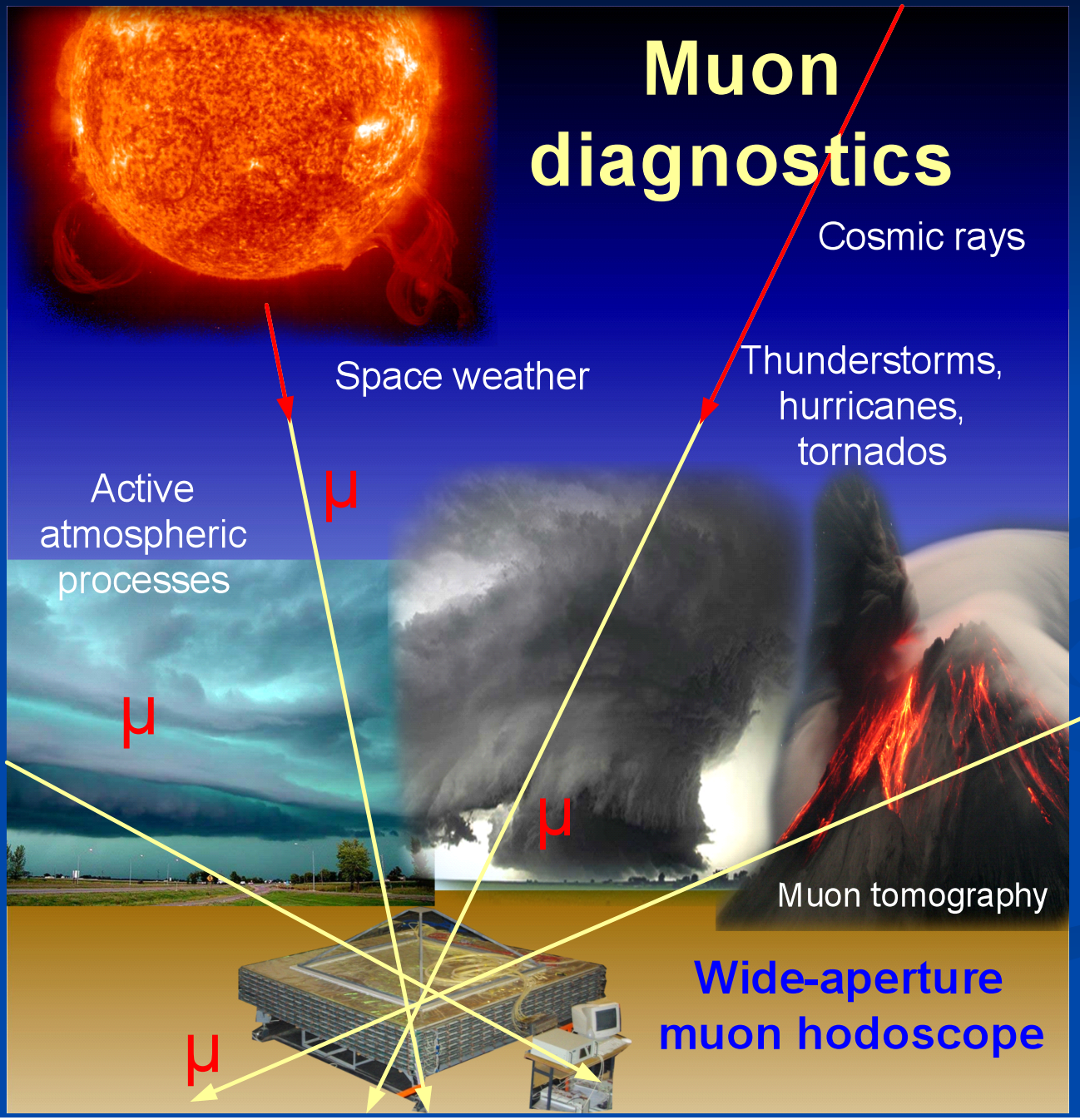


Data matrix



Forbush decrease of April 6, 2012




Muon diagnostics
Cosmic rays
Space weather
Thunderstorms, hurricanes, tornados
Active atmospheric processes
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Muon tomography
Wide-aperture muon hodoscope


Vulcano 2008, 26th-31st May
Thank you for your attention!
http://www.spaceweather.eu/ru/node/99