Neutrino-4 experiment on search for sterile neutrino with multi-section model of detector

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Collaboration Neutrino-4:

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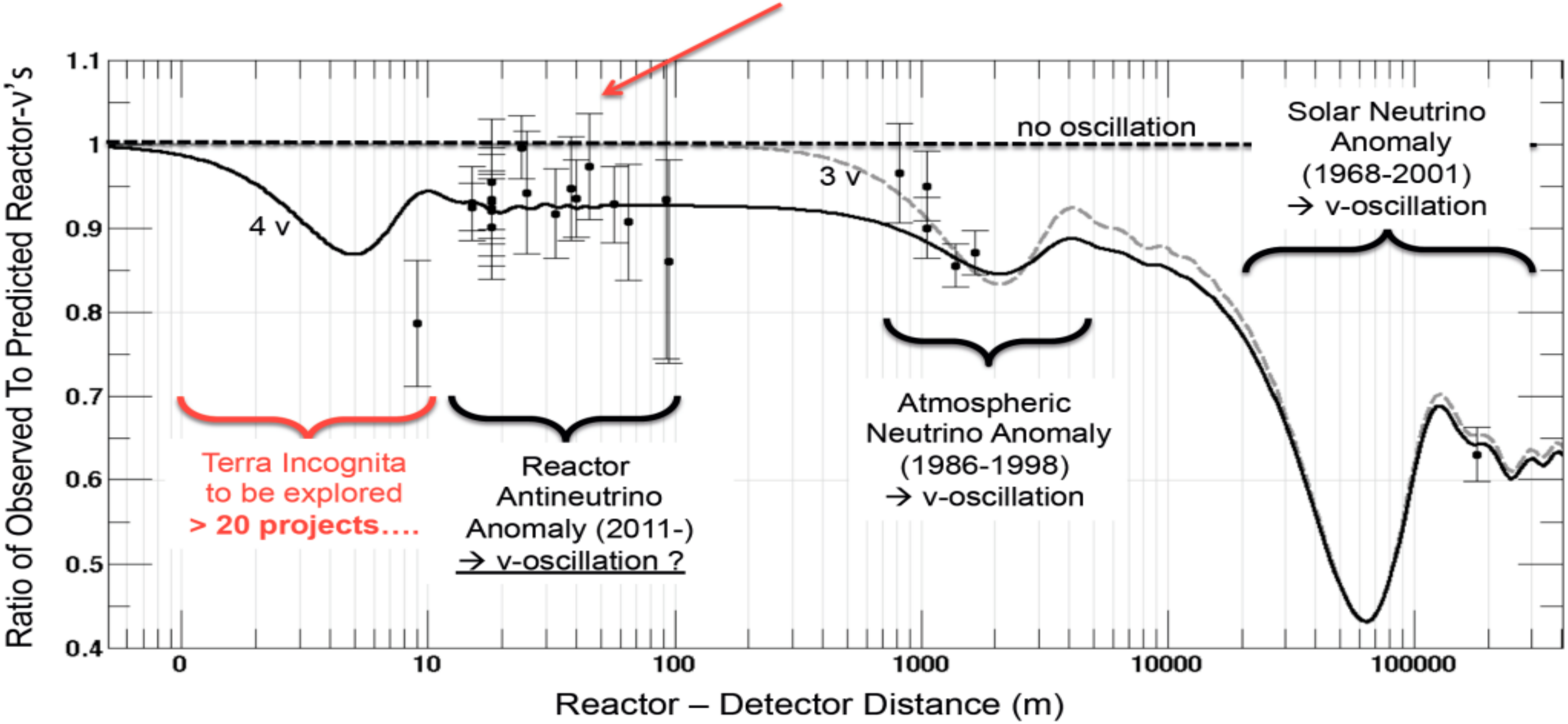
G. Mention et al., Phys. Rev. D83, 073006, 2011

The reactor antineutrino anomaly and sterile neutrino

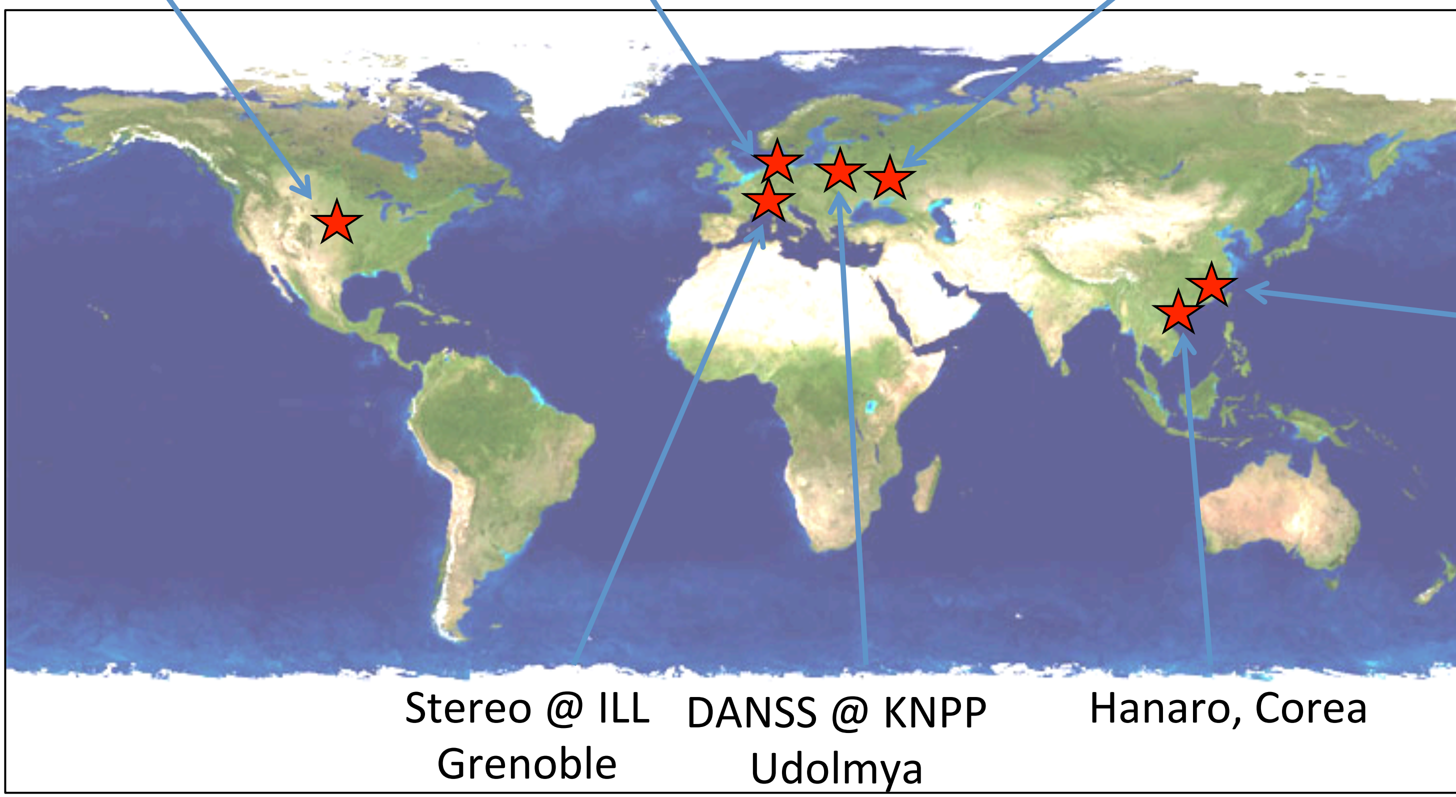
The Reactor Anomaly

- Observed/predicted averaged event ratio: R=0.927±0.023 (3.0 σ)

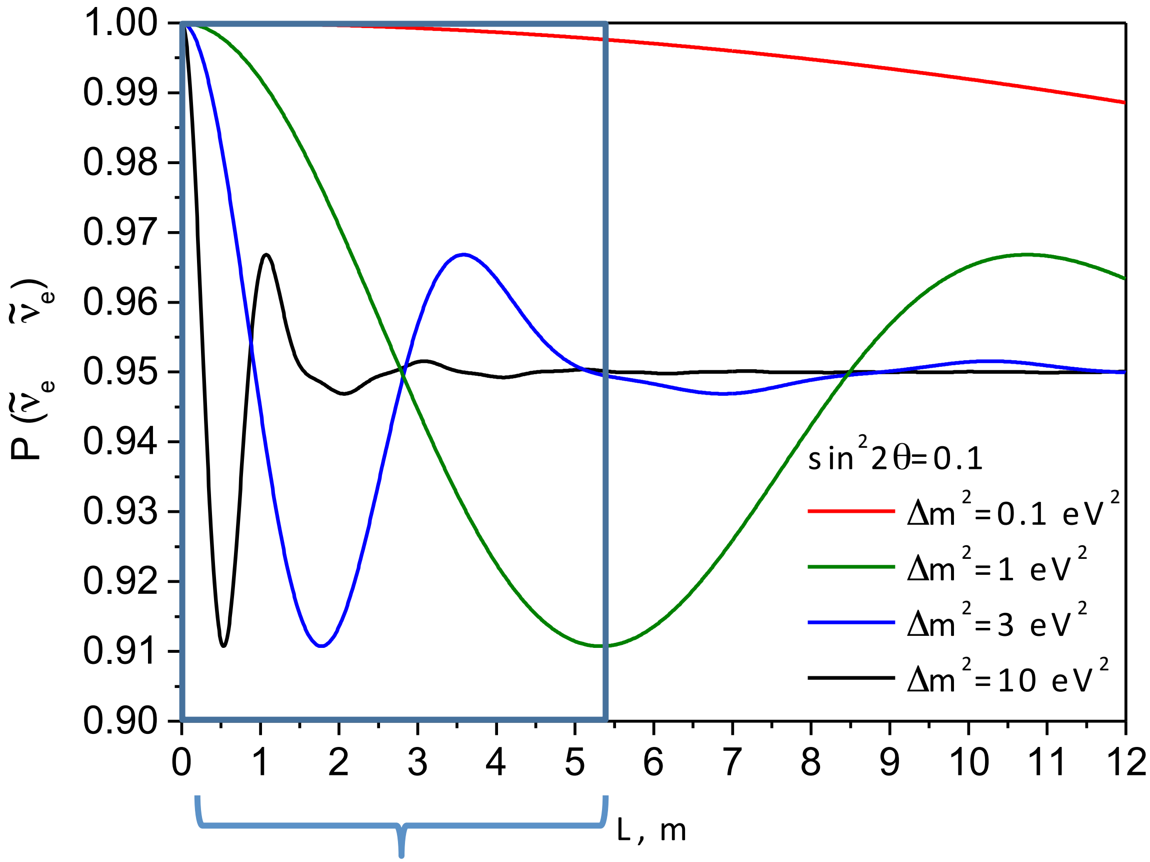


CEA DSM Irfu T. Lasserre

New Short Baseline Reactor Experiments

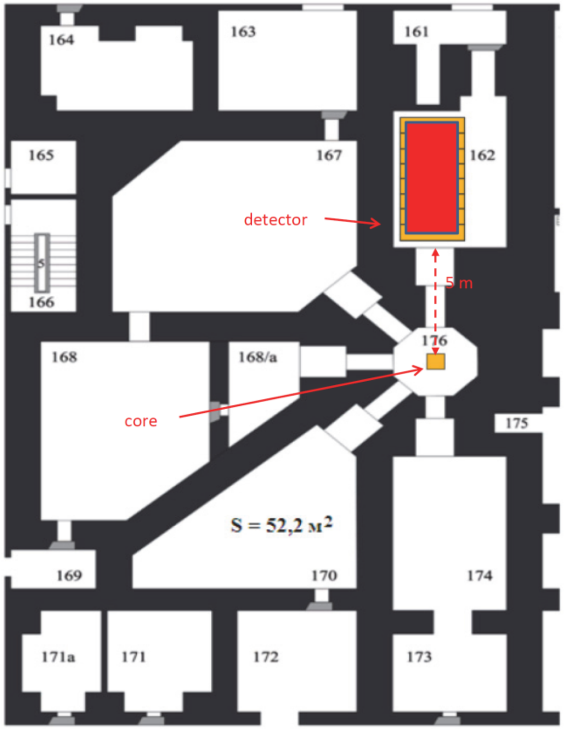


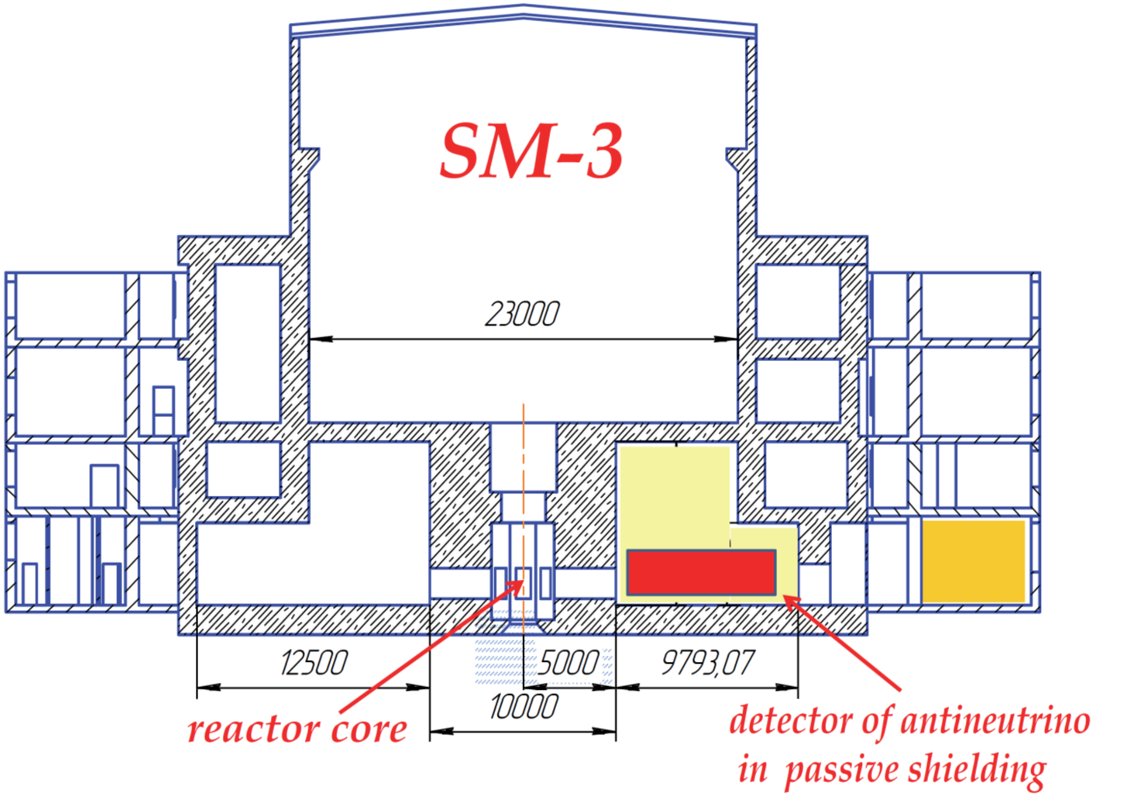
$$P(\tilde{\nu}_e \rightarrow \tilde{\nu}_e) = 1 - \sin^2 2\theta_{14} \;\; \sin^2\left(1.27\,\frac{\Delta m^2_{14}[\mathrm{eV}^2]L[\mathrm{m}]}{E_{\tilde{\nu}}[\mathrm{MeV}]}\right)$$



Biological reactor shielding

Reactor: SM-3 reactor in Dimitrovgrad (Russia): 100 MW compact core 35x42x42 cm^3



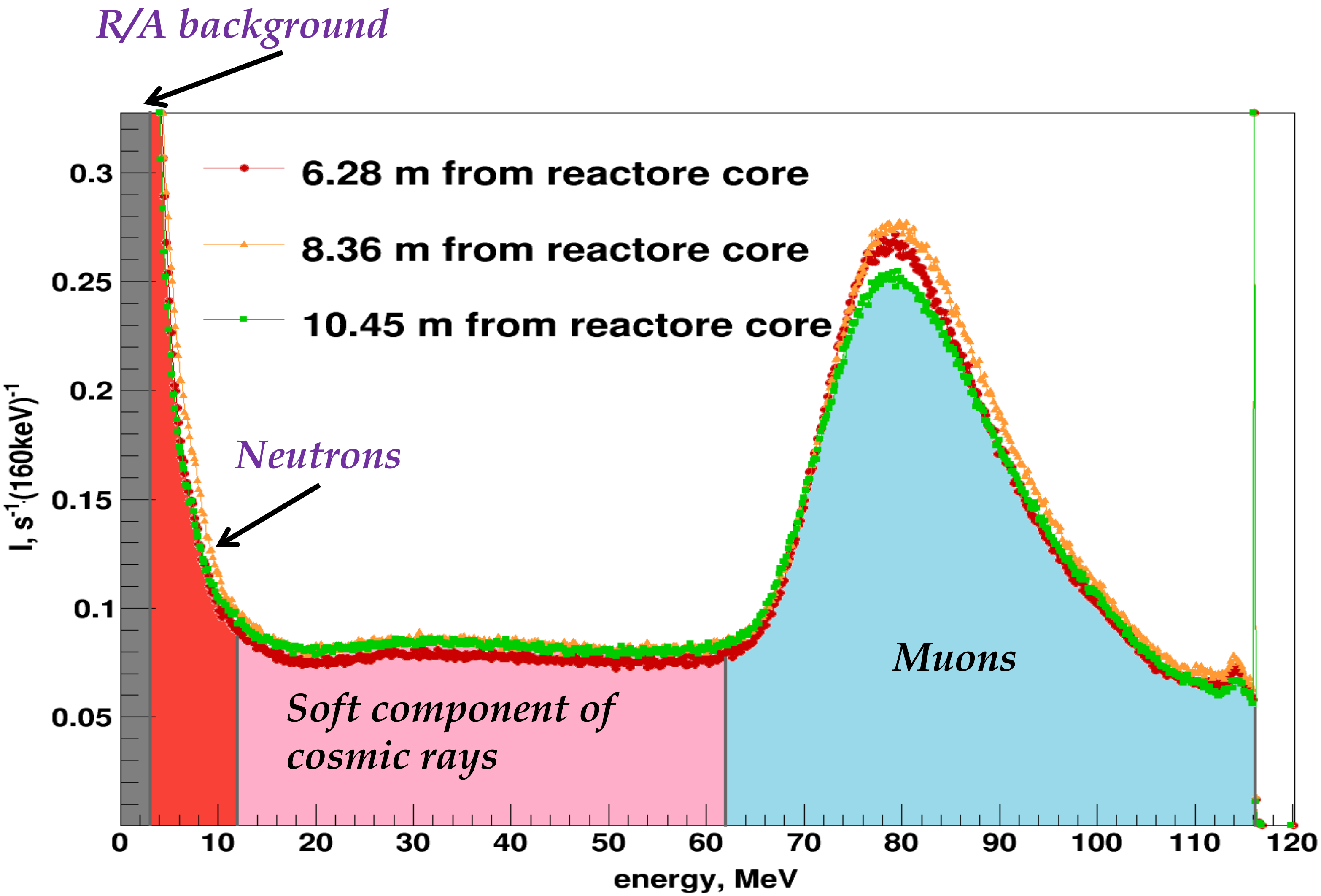


Neutrino channel outside and inside

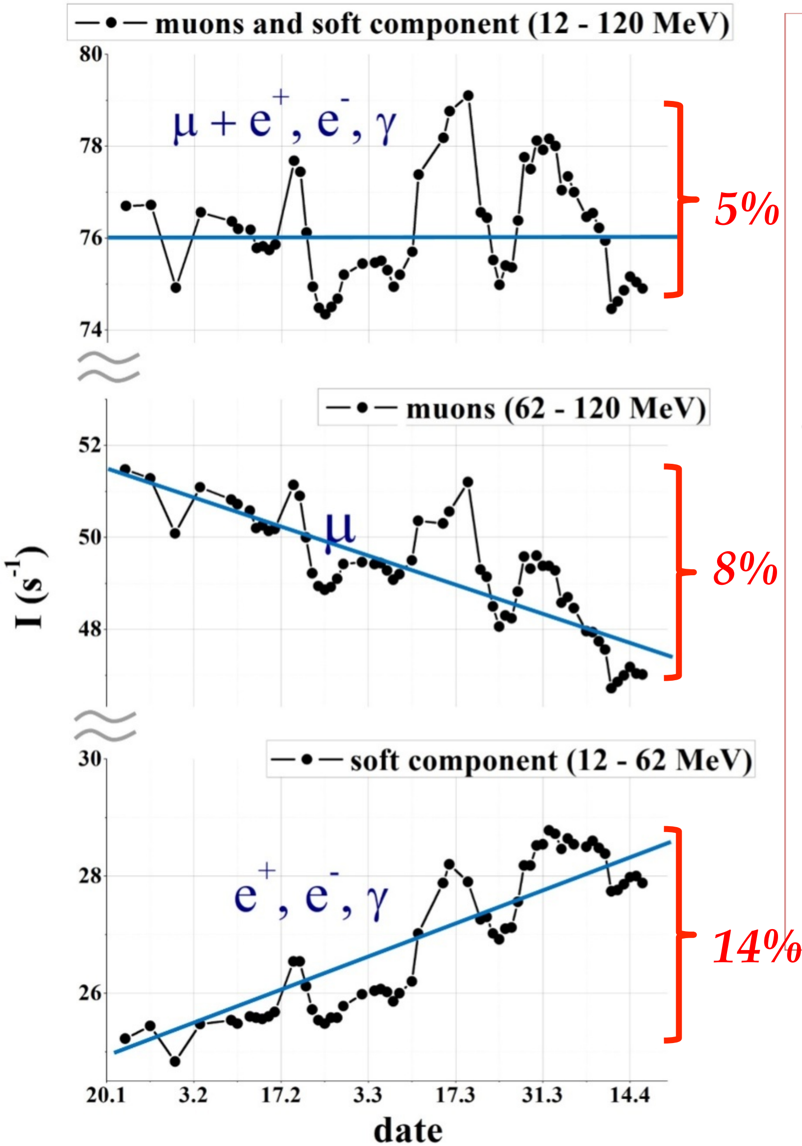
Range of measurements for the reactor antineutrino flux is 6 – 12 meters from the active reactor core

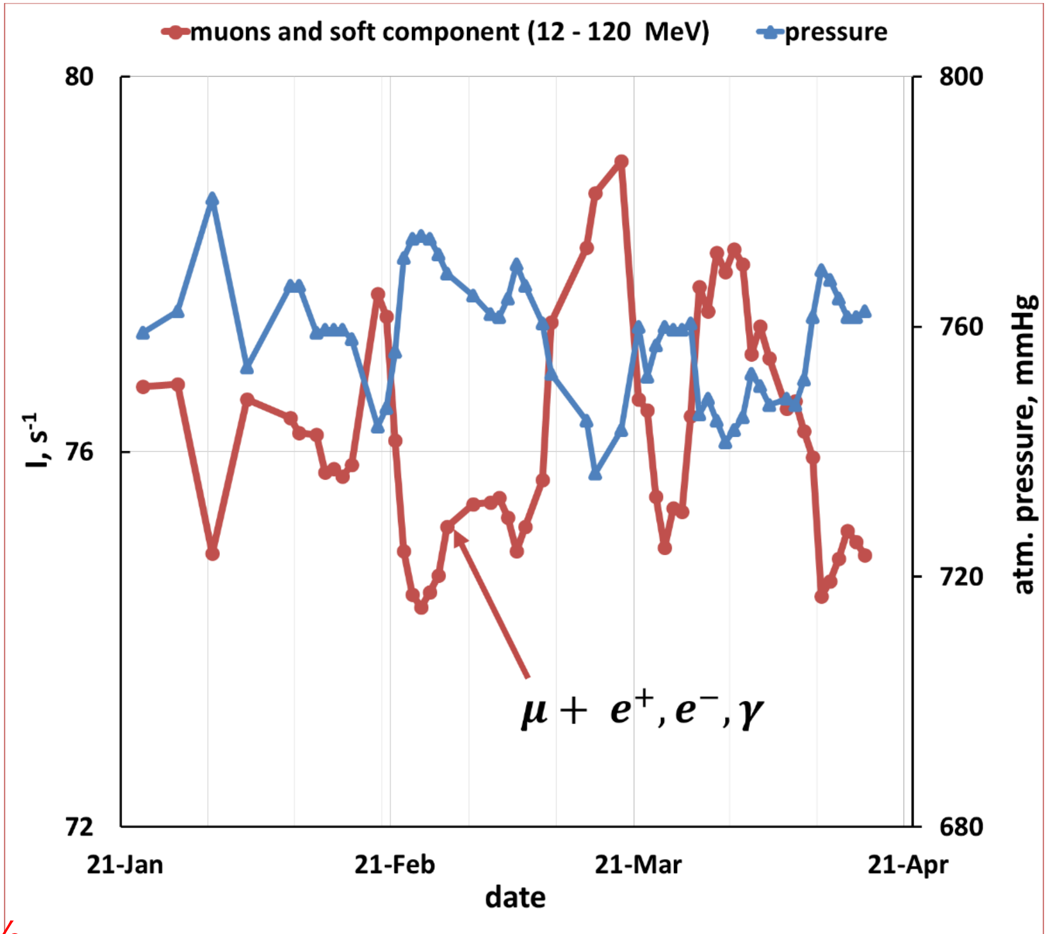
Passive shielding of 60 tons

Different part of spectrum at the different distance

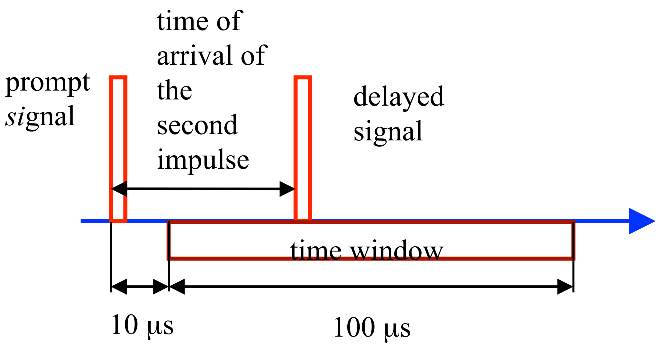


The effects of atmospheric temperature and pressure on cosmic rays

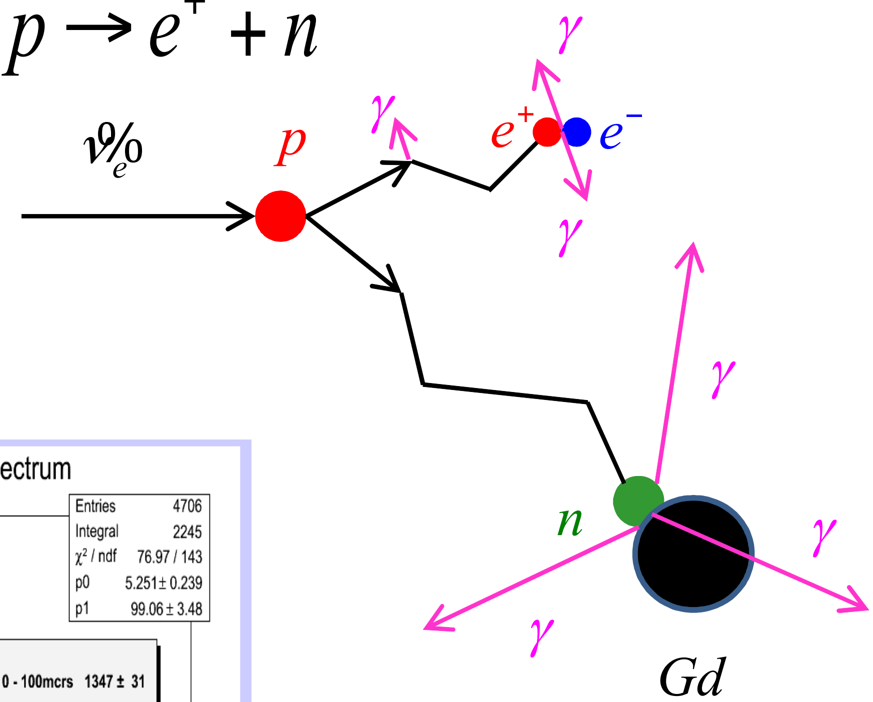


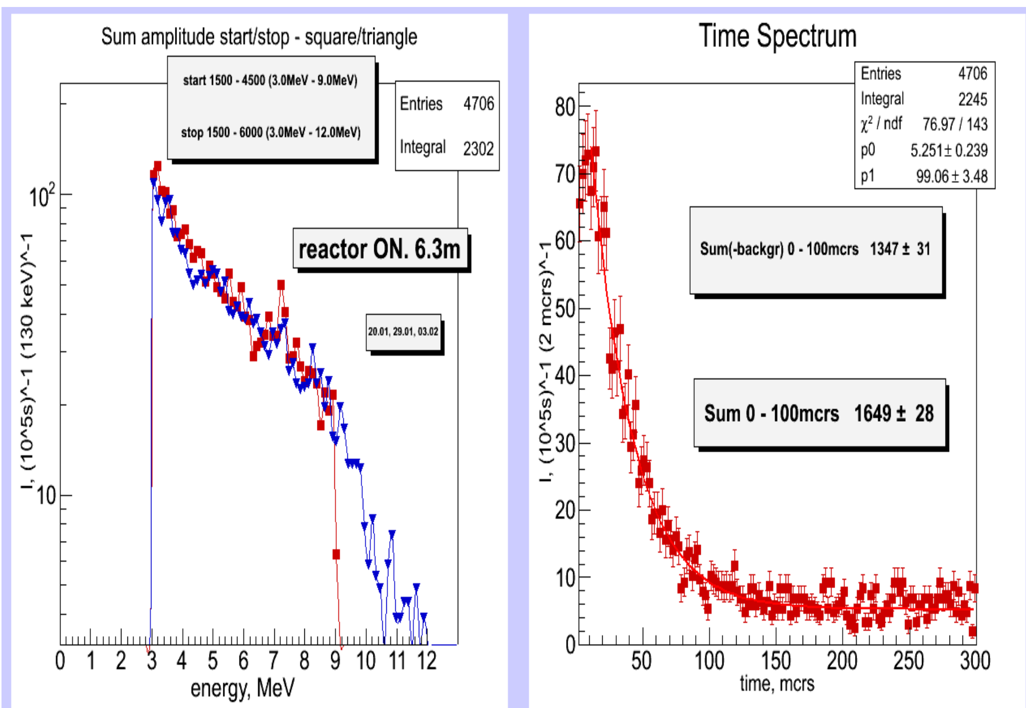


Signal of correlated events



$$\tilde{\nu}_e + p \rightarrow e^+ + n$$





General scheme of experimental setup

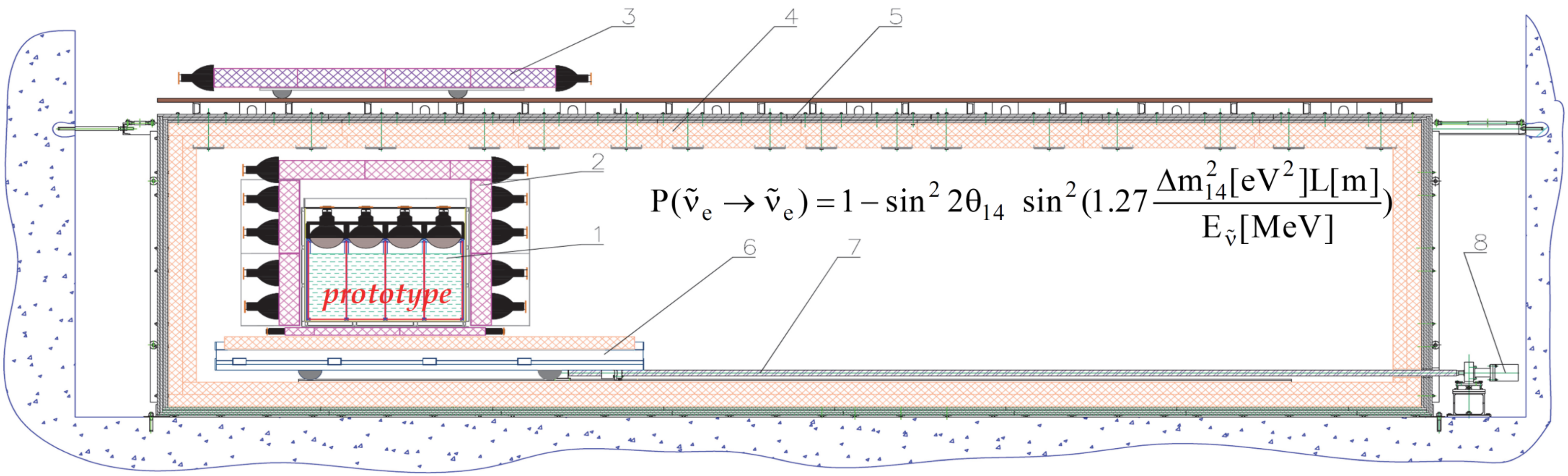
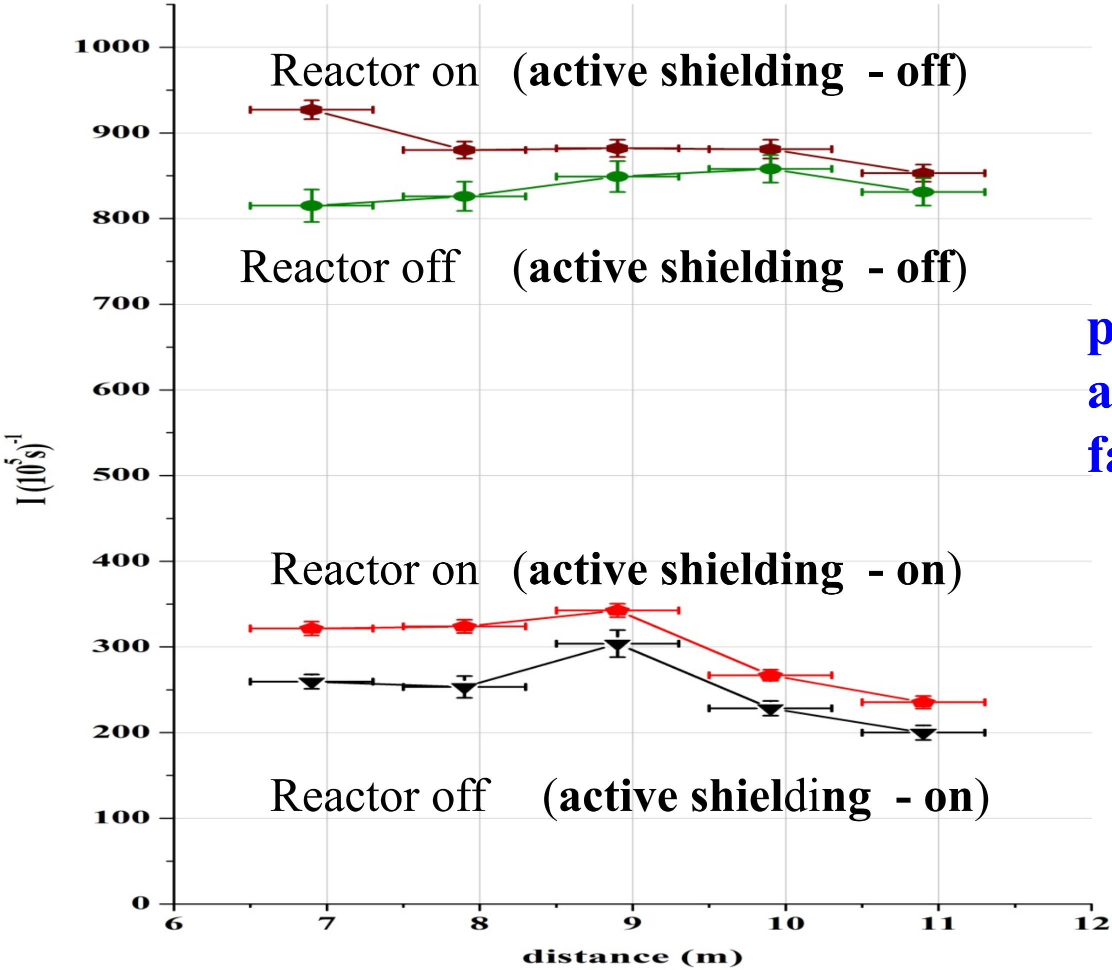


Fig. 1. General scheme of experimental setup. 1 – detector of reactor antineutrino, 2 – internal active shielding, 3 – external active shielding (umbrella), 4 – steel and lead passive shielding, 5 – borated polyethylene passive shielding, 6 – moveable platform, 7 – feed screw, 8 – step motor.

Two level of active shielding

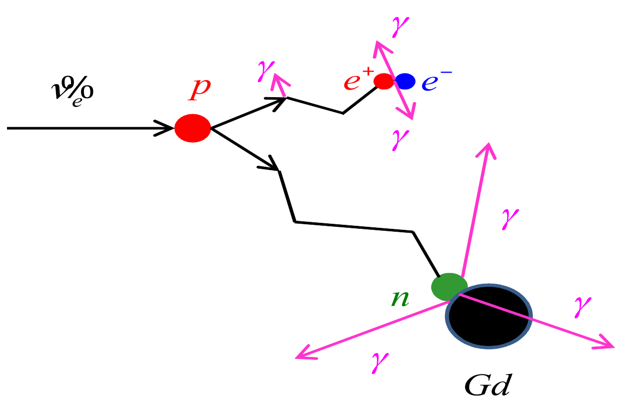


The total suppression provided by two level active shielding is by factor about 4 times.

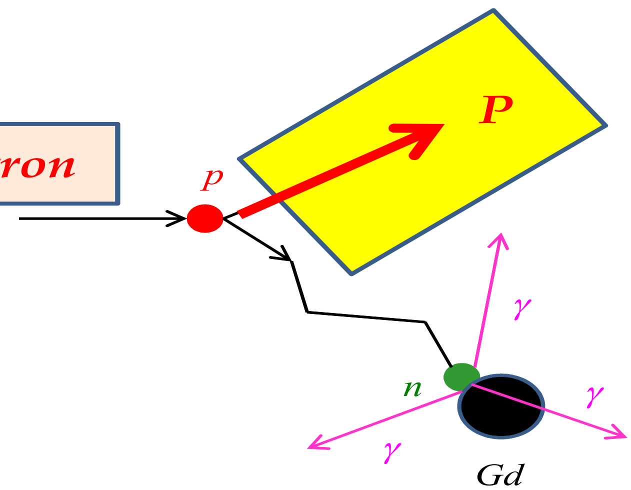
The problem of fast neutrons

False event

Neutrino event



fast neutron



Neutron scattering imitate neutrino reaction

Multi-section model of detector

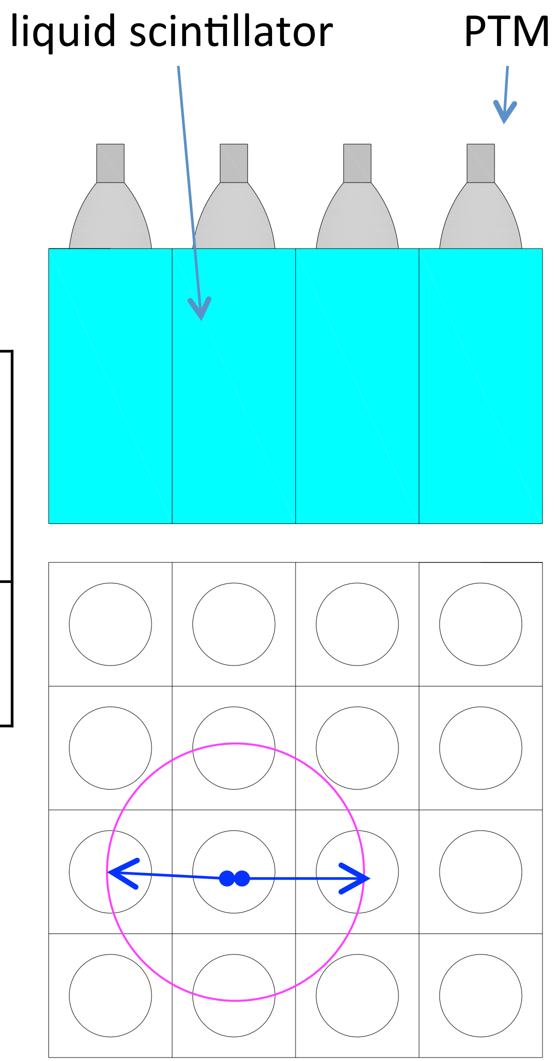
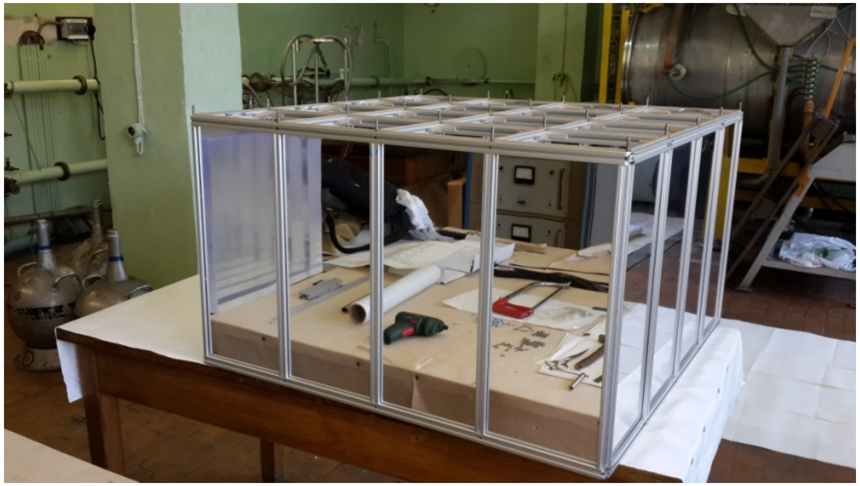


Table 1. The probability of double-start events registration in various sections.

central section	side section	corner section	average
0.42	0.29	0.19	0.30

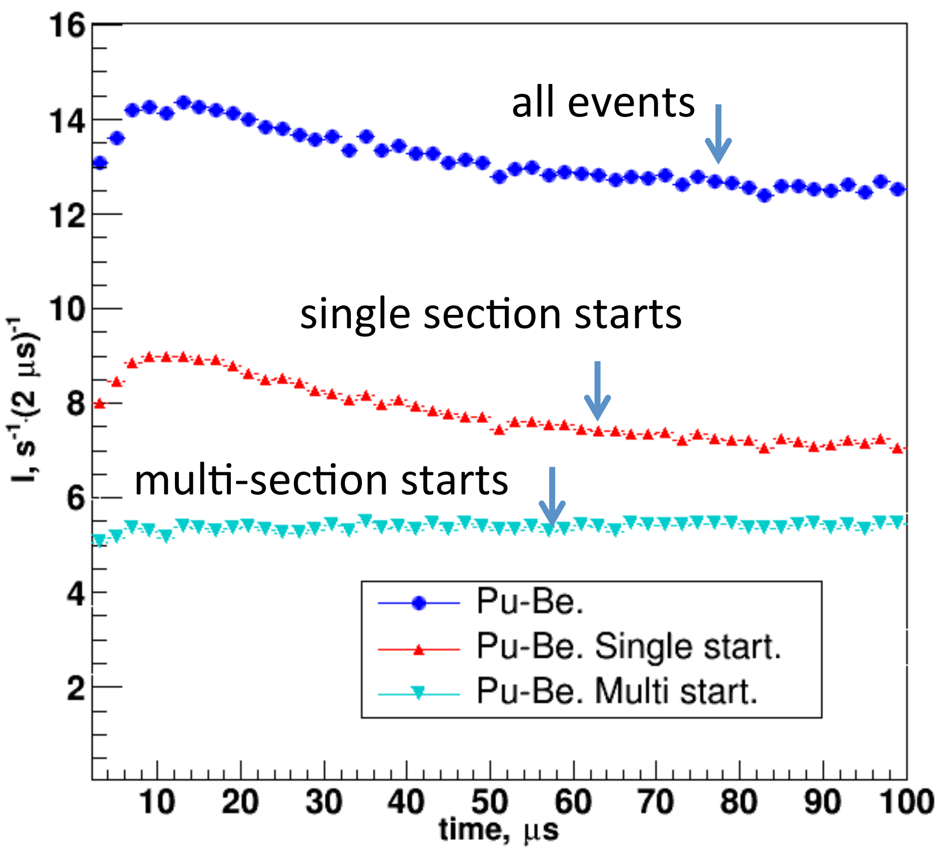
Monte-Carlo calculations

Multi-section antineutrino detector model




The detector consists of 16 sections 22.5 x 22.5 x 50 cm^3 with fixed baffles. The baffles are made of acrylic plastic and have specular surface serve to prevent light from leaving the section. Scintillator material is mineral oil (CH_2) with addition of Gadolinium 1g per litter.

Test measurements with neutron Pu-Be source



Before getting down to the main measurements with a new detector model, measurements with neutron Pu-Be source were made.

This experiment proved that rapid neutrons provide single section starts.

Energy calibration

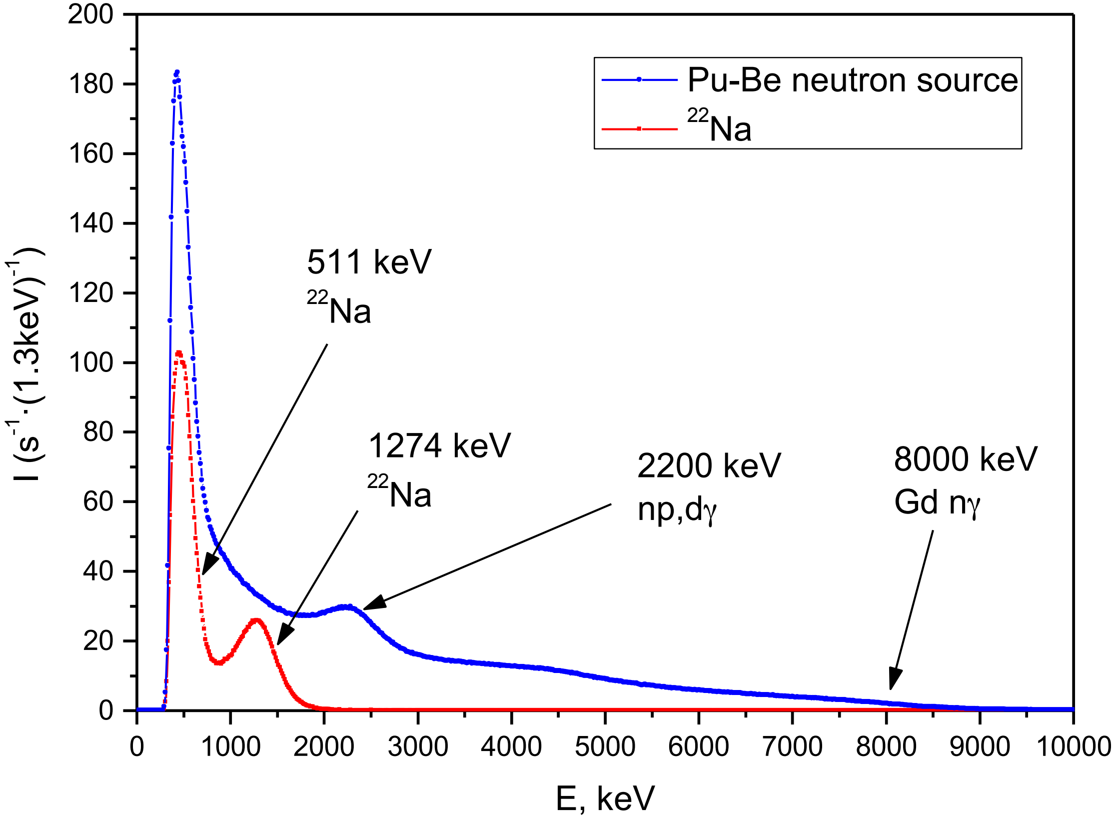
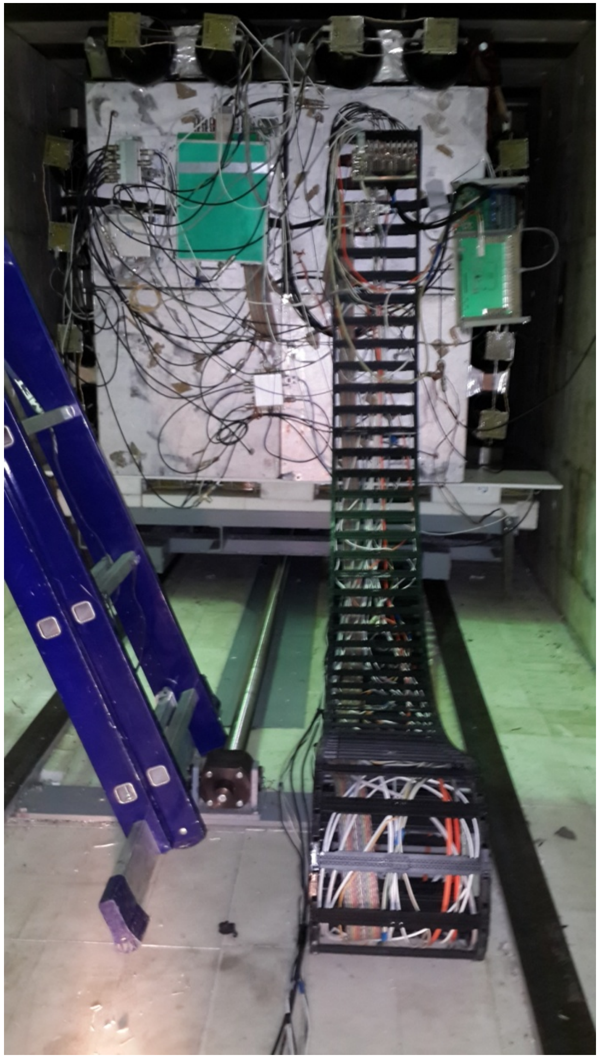
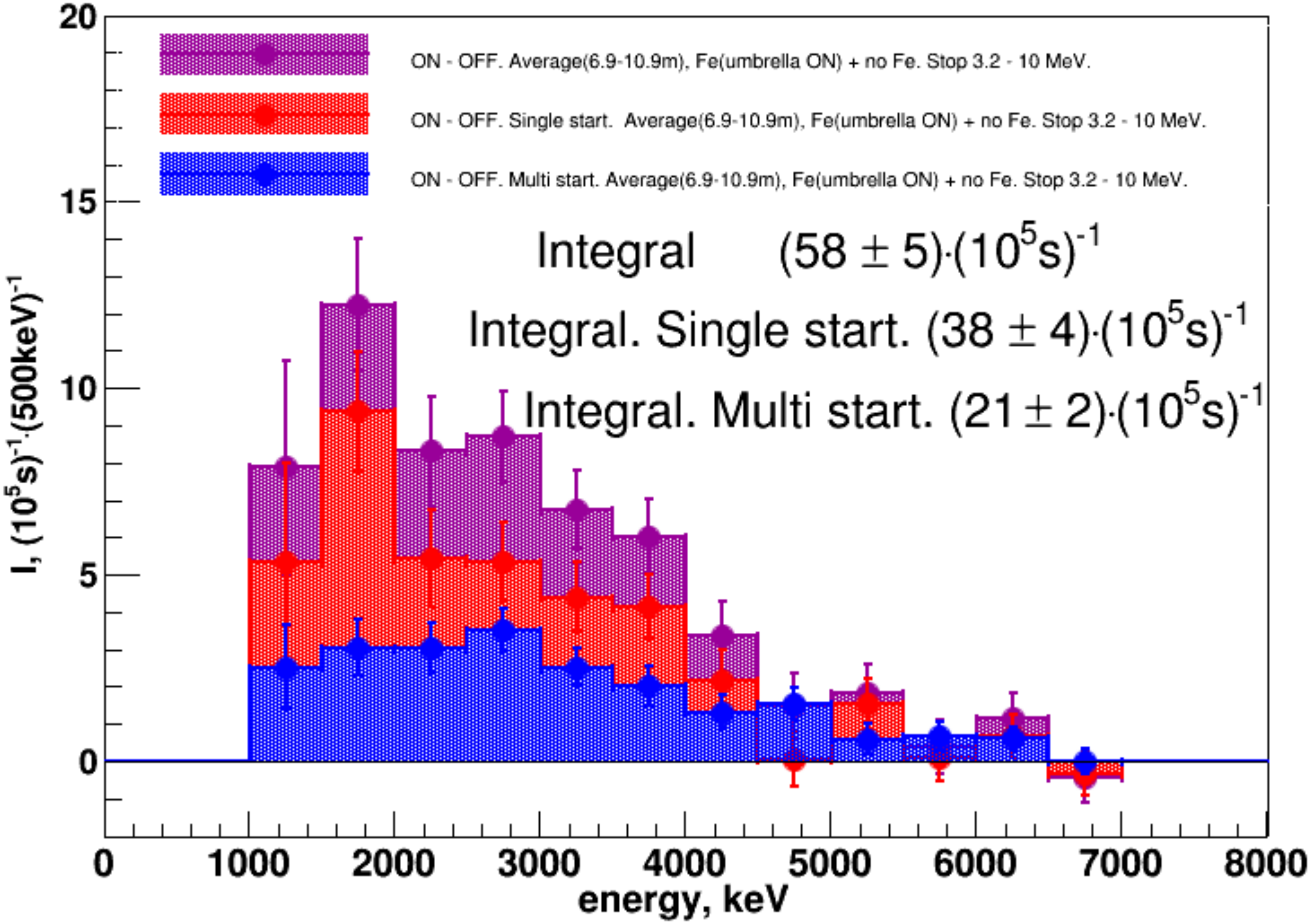


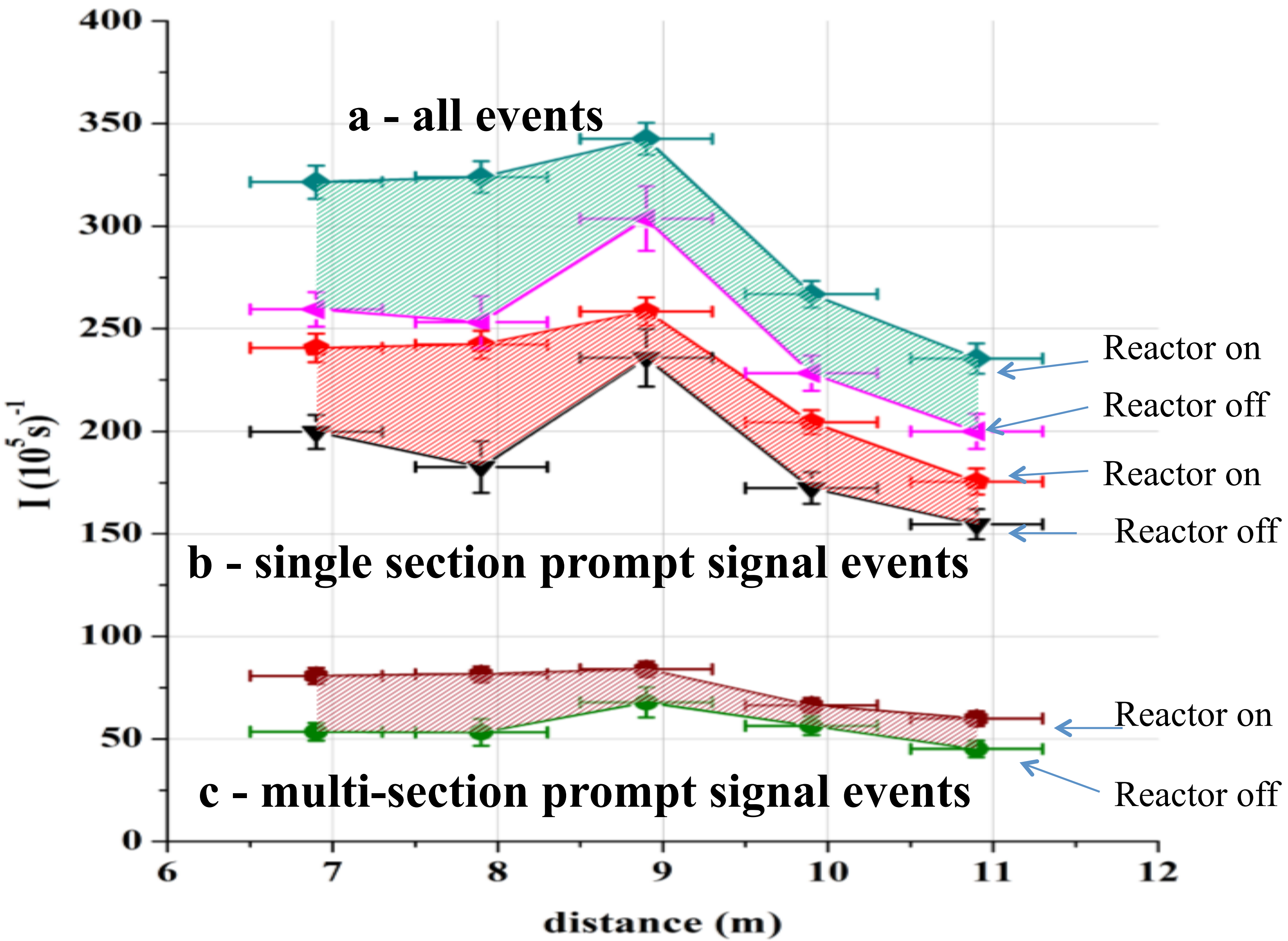
Fig. 5. Results of energy calibration.



The difference spectra (ON-OFF) of prompt signals

Differences in count rates in reactor on and off regimes for double and single starts integrated over all distances are (35±7)% and (65±11)%.





a - all events
b - single section prompt signal events
c - multi-section prompt signal events
Reactor on
Reactor off
Reactor on
Reactor off
Reactor on
Reactor off
I (10^{5}s)$^{-1}$
distance (m)
0
50
100
150
200
250
300
350
400
6
7
8
9
10
11
12

Neutrino flux dependence on the distance from the reactor core

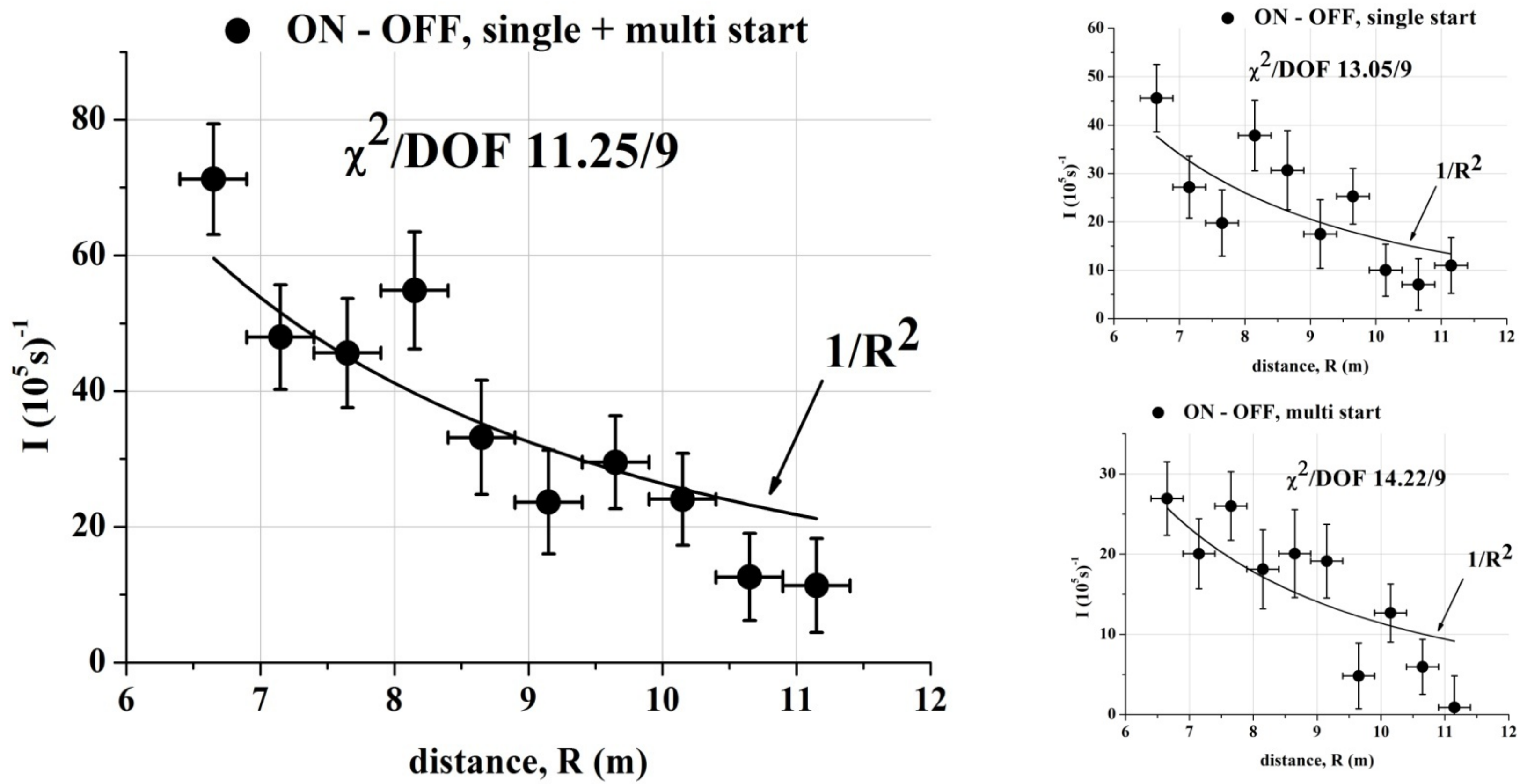
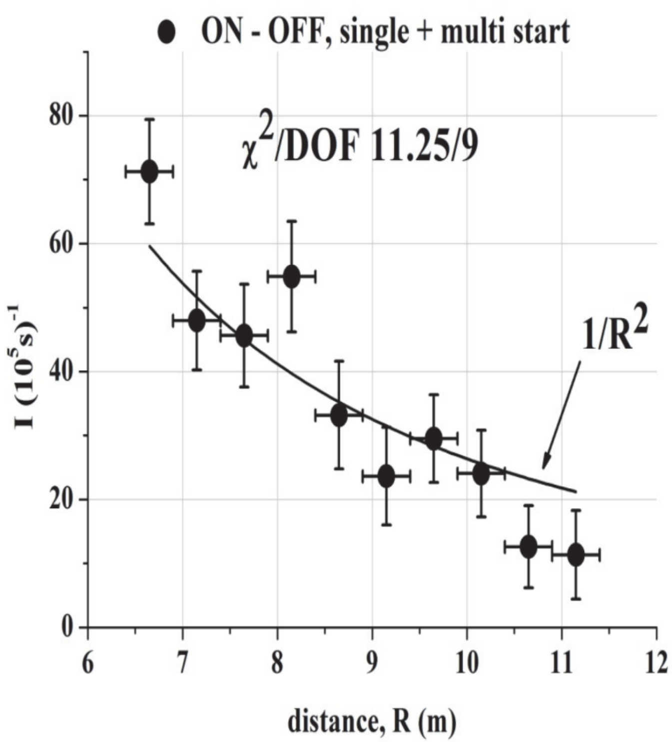


Fig. 2. Neutrino flux dependence on the distance from the reactor core (6-11 meters). Measurements performed with sectioned neutrino detector prototype. Difference in count rates, in reactor on and off regimes, for delayed coincidence in time window 100 μs with cut off random coincidence: a - all events, b - single section prompt signal events, c - multi-section prompt signal events.

Neutrino flux dependence on the distance from the reactor core



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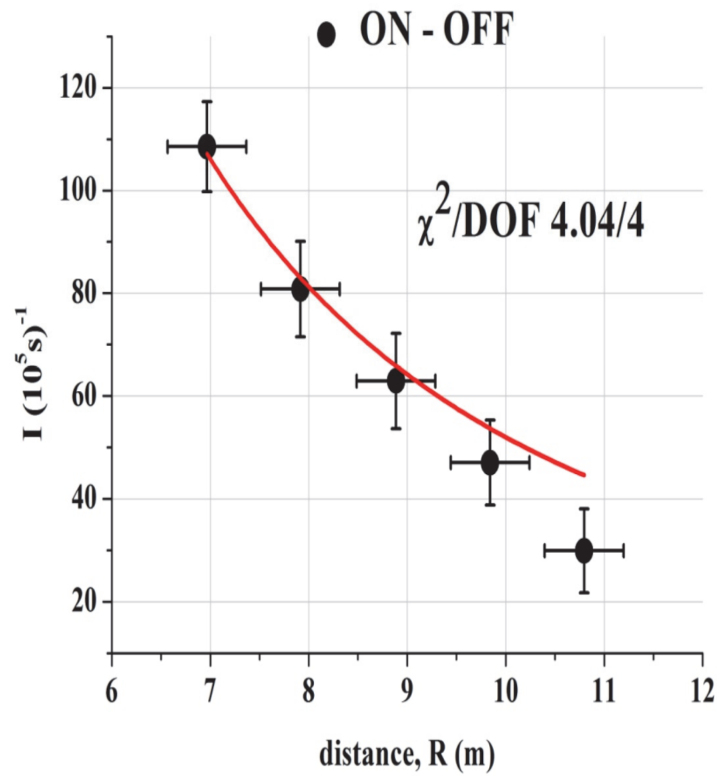
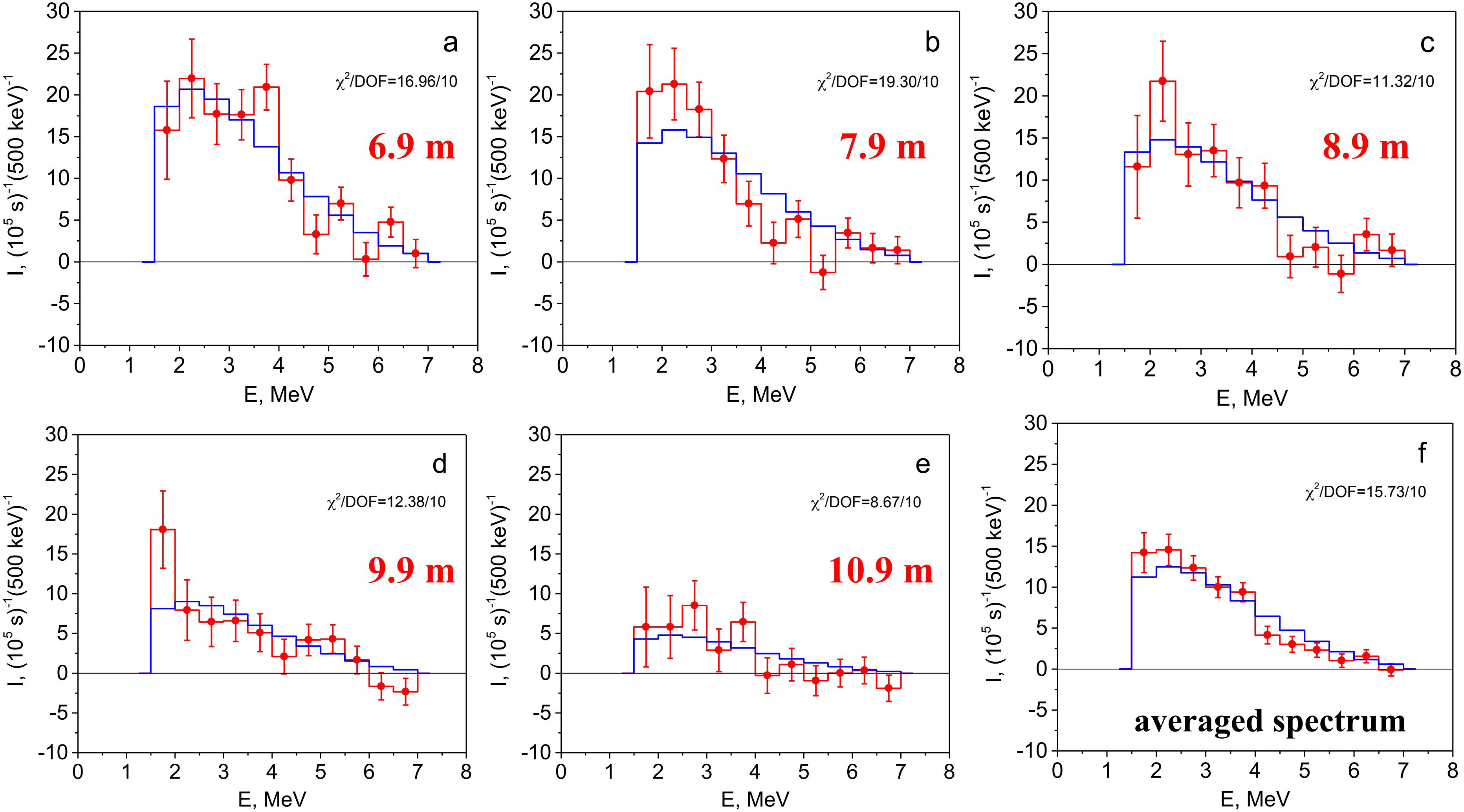


Fig.3. Measurements of antineutrino flux dependence on distance from the reactor core (6 - 11 m) with both prototypes of a neutrino detector.

$$P(\tilde{\nu}_e \rightarrow \tilde{\nu}_e) = 1 - \sin^2 2\theta_{14} \ \sin^2(1.27 \frac{\Delta m_{14}^2[eV^2]L[m]}{E_{\tilde{\nu}}[MeV]})$$

Results of positron (promt) spectrum measuring at various distances and comparison with MC calculations of zero oscillation scenario: a – 6.9 m, b – 7.9 m, c – 8.9 m, d – 9.9 m, e – 10.9 m, f –averaged spectrum.



G. Mention et al., Phys. Rev. D83, 073006, 2011

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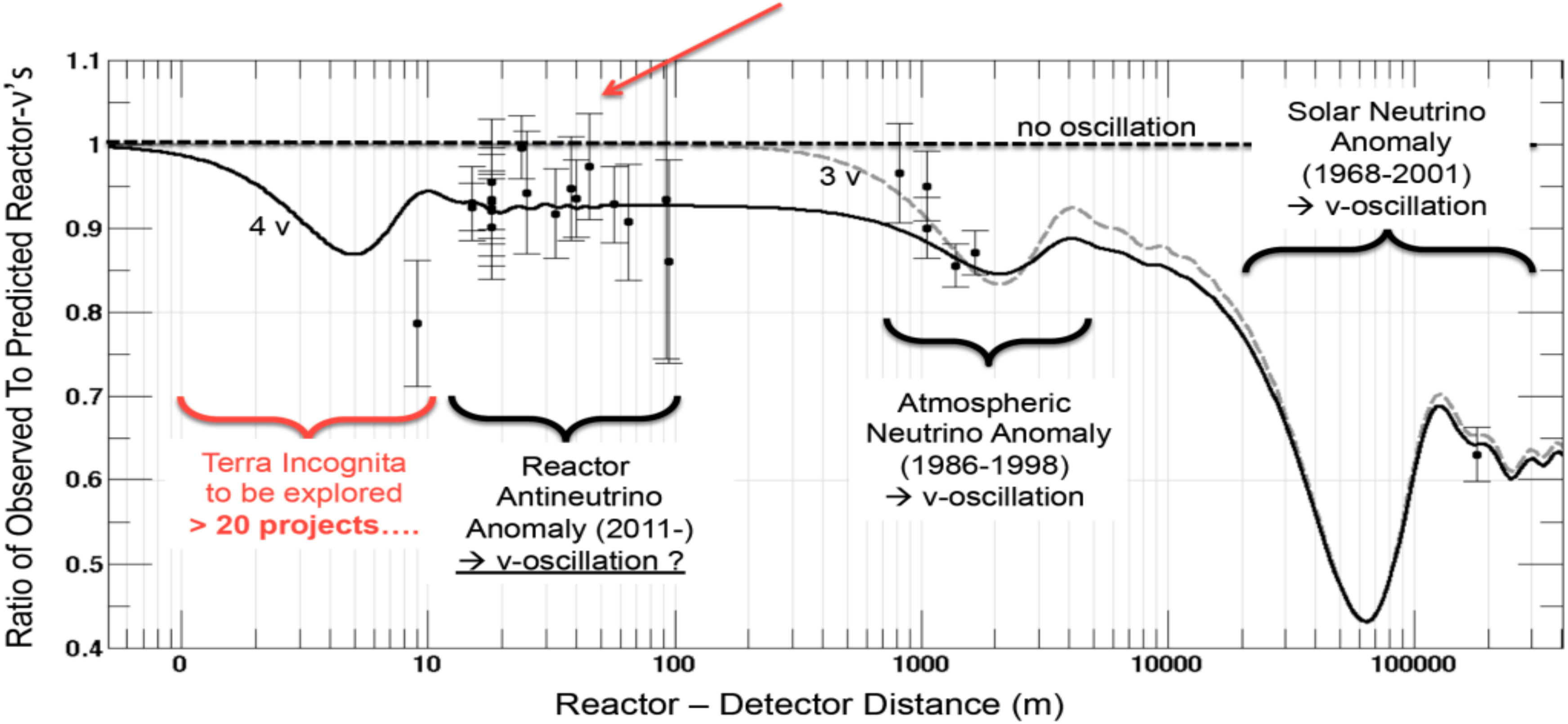
- Observed/predicted averaged event ratio: R=0.927±0.023 (3.0 σ)



The first measurement of antineutrino flux at the short distance from reactor core

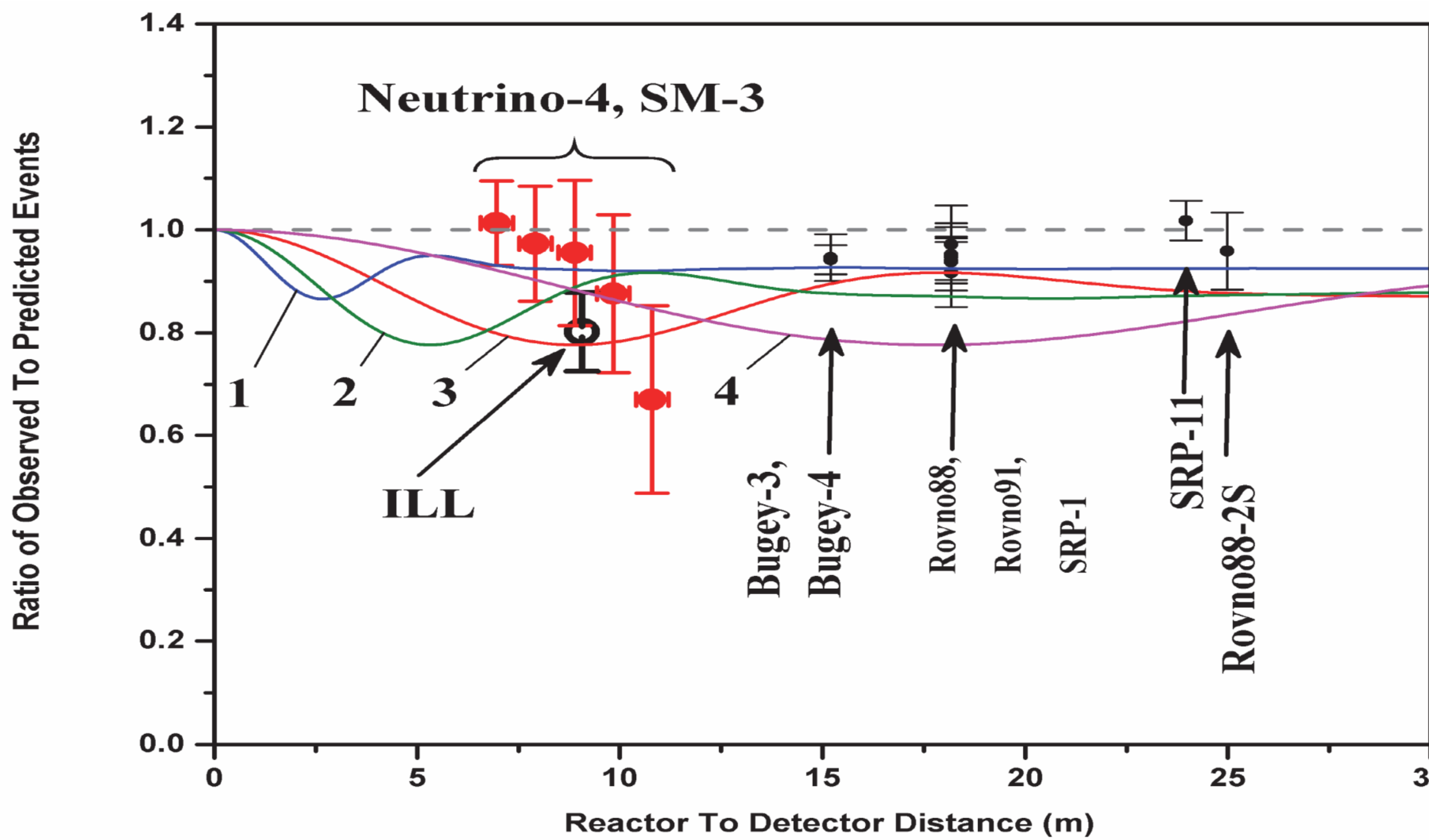


Fig. 4. Measurements of neutrino flux dependence on the distance from the reactor core performed with the prototype of moveable detector in NEUTRINO-4 experiment, and other measurements performed with fixed detectors.

1 -- Δm^2_{14}=2 eV^2 $\sin^2 2\theta_{14}$ =0.15;

2 -- Δm^2_{14}=1 eV^2, $\sin^2 2\theta_{14}$=0.25

3-- Δm^2_{14}=0.6 eV^2, $\sin^2 2\theta_{14}$=0.25

4 -- Δm^2_{14}=0.3 eV^2, $\sin^2 2\theta_{14}$=0.25

FUTURE PROSPECTS

The full-scale detector with liquid scintillator volume of $3\ m^3$ (5x10 sections) is installed already

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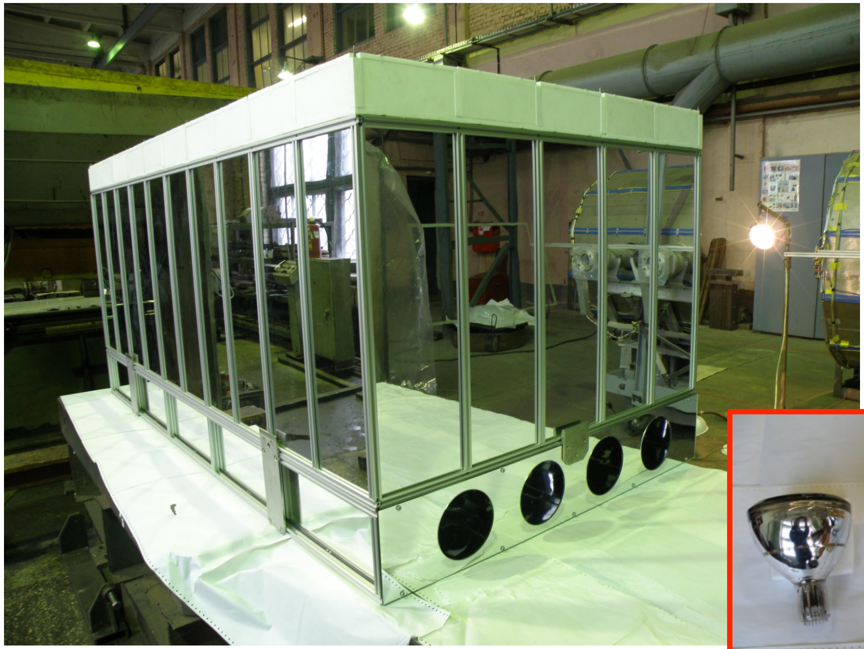

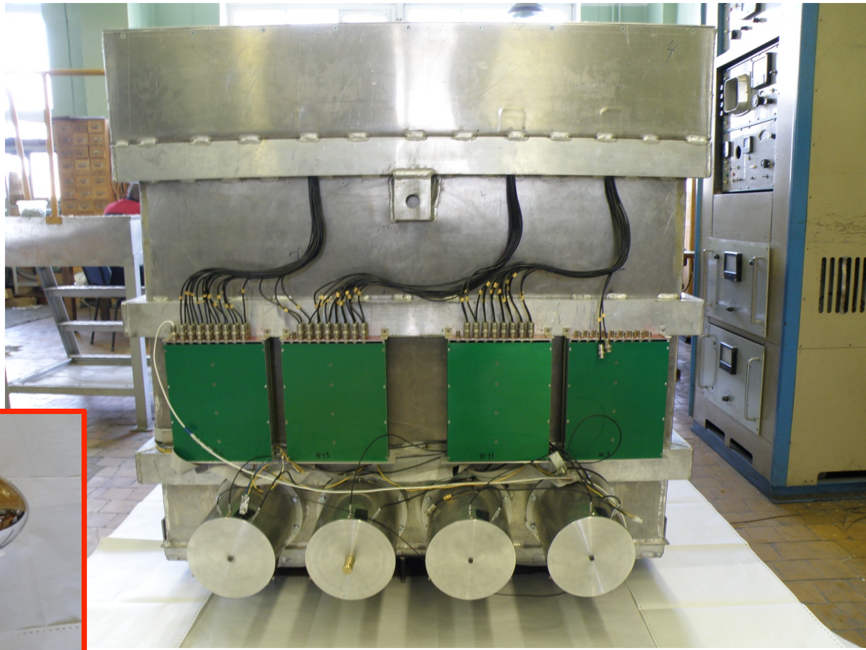

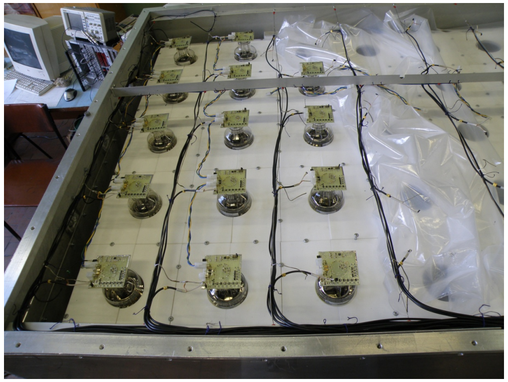

CONCLUSION

Measurements of antineutrino flux at small reactor distances with moveable detector carried out for the first time.

New detector will allow us to obtain up to 1.5-3.0% statistic accuracy of measurements at the distances from 6 to 12 meters after 2 years of measurements.
We hope that would bring light to the problem of neutrino oscillation in the sterile state.

Thank you for attention