Experiment Neutrino-4 search for sterile neutrino at SM-3 reactor

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for collaboration
PNPI NRC KI (Gatchina)
NRC KI (Moscow)
RIAR (Dimitrovgrad)

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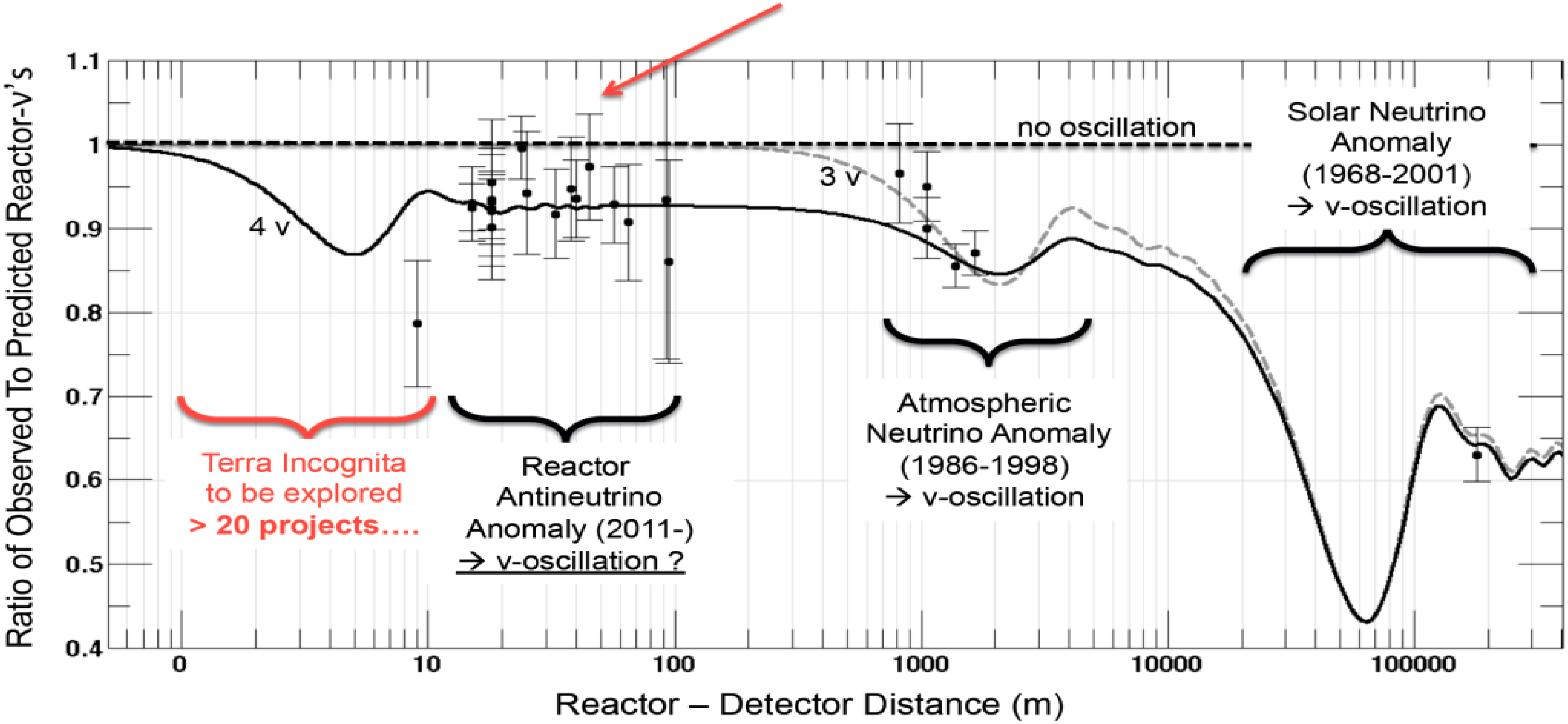
27–31 октября 2014 г.

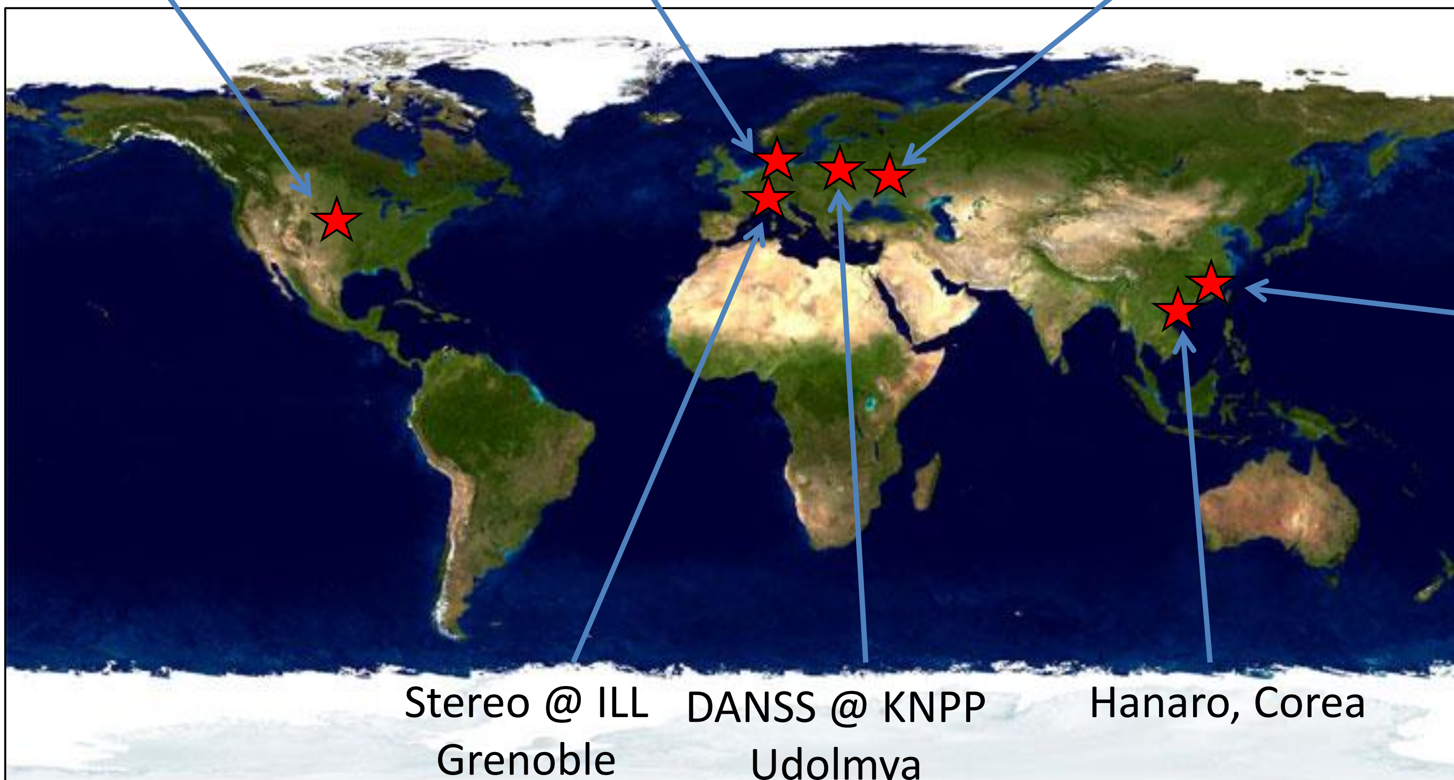
The reactor antineutrino anomaly and sterile neutrino

The Reactor Anomaly

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



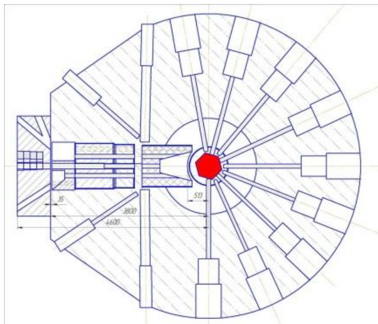
New Short Baseline Reactor Experiments



Preparation of antineutrino detector prototype at PNPI and first test at WWR-M reactor

NEUTRINO-4 experiment

Preparation at WWR-M reactor (18 MW) in PNPI (Gatchina)



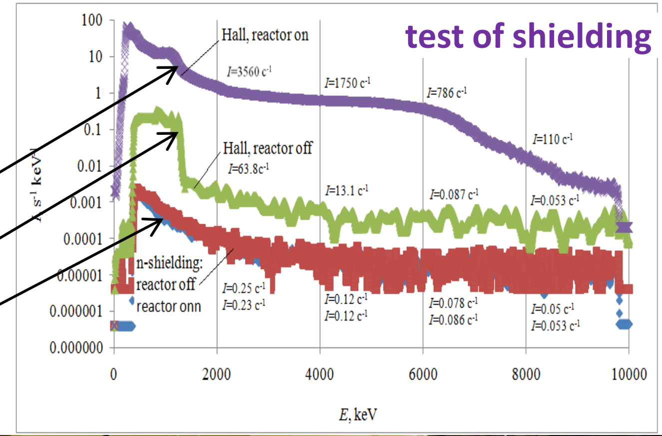
Reactor power - 18 MW

Size of active core – 0.6 m

reactor on without shielding

reactor off without shielding

reactor on/off with shielding



Installation of antineutrino detector prototype with liquid scintillator (total volume 0.4 m^3)

Installation of anticoinsidence shielding from plastic scintillator 0.5x0.5x0.125 m^3 with PMT (32 pieces)

Prototype of antineutrino detector at WWR-M reactor

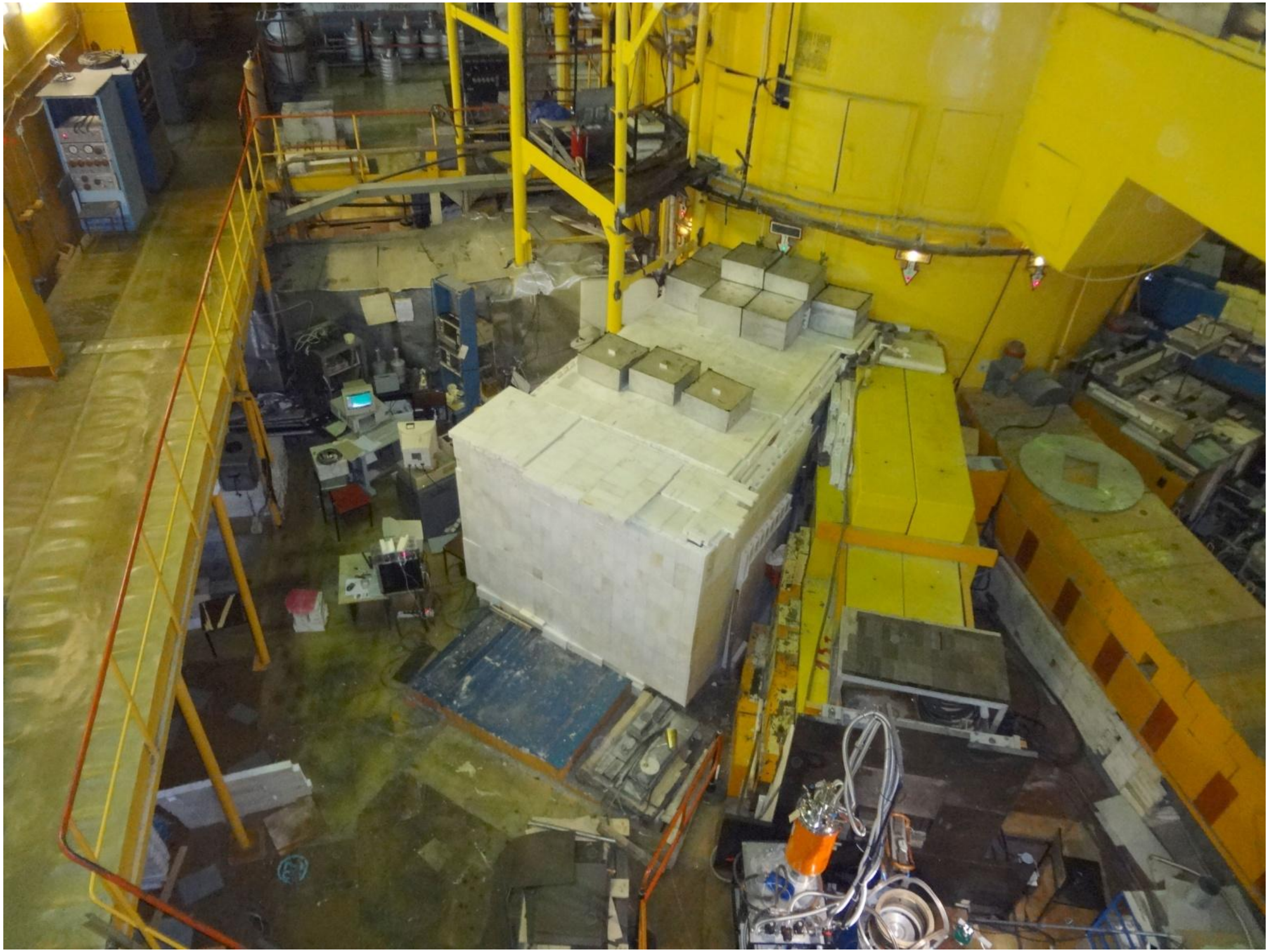
Liquid scintillator BC-525(Gd)

Detector with active shielding 4π

Filling by liquid scitillator
400 liters

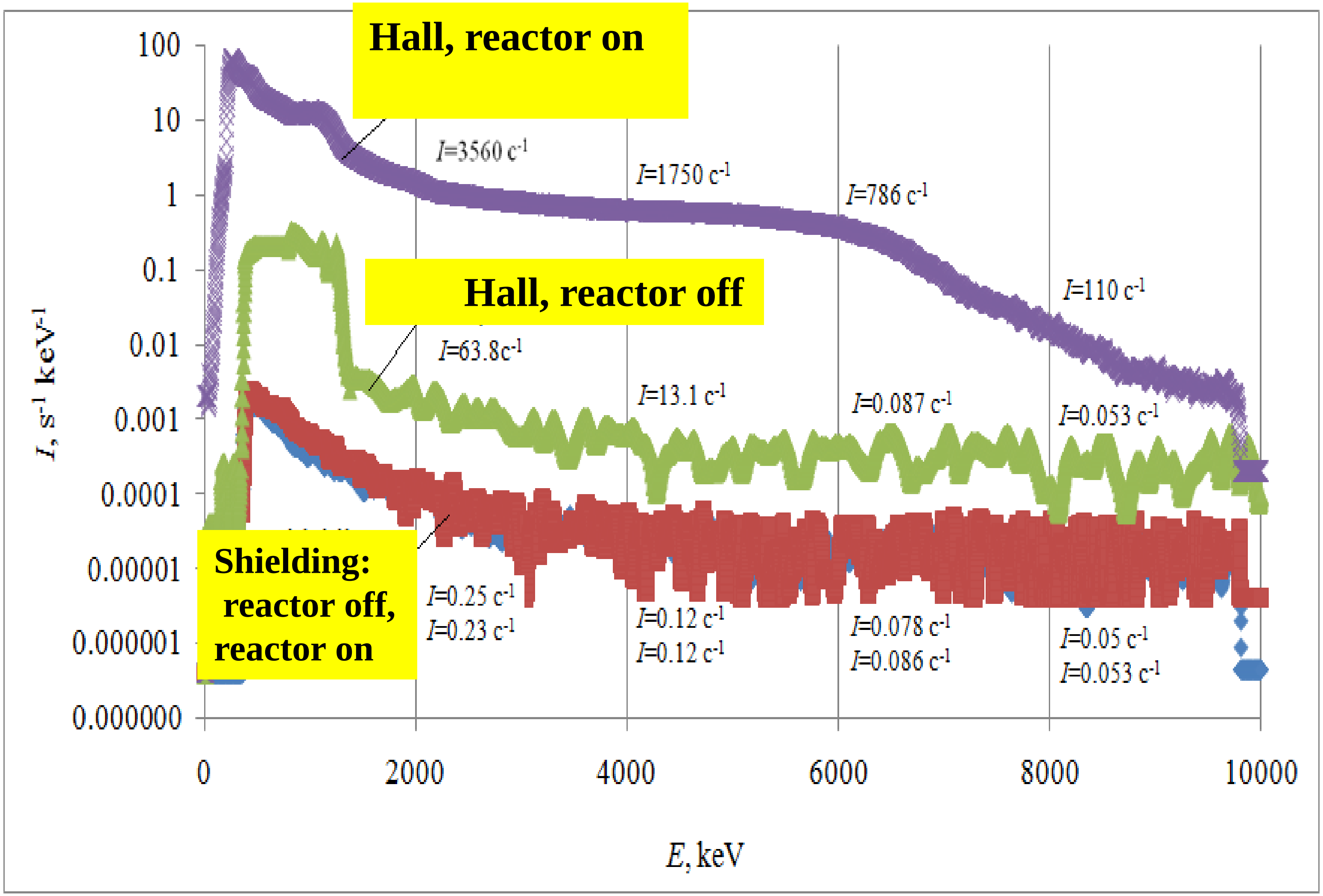
installation of model inside of
passive shielding

Lead shielding + Concrete shielding + (CH_2 + B)



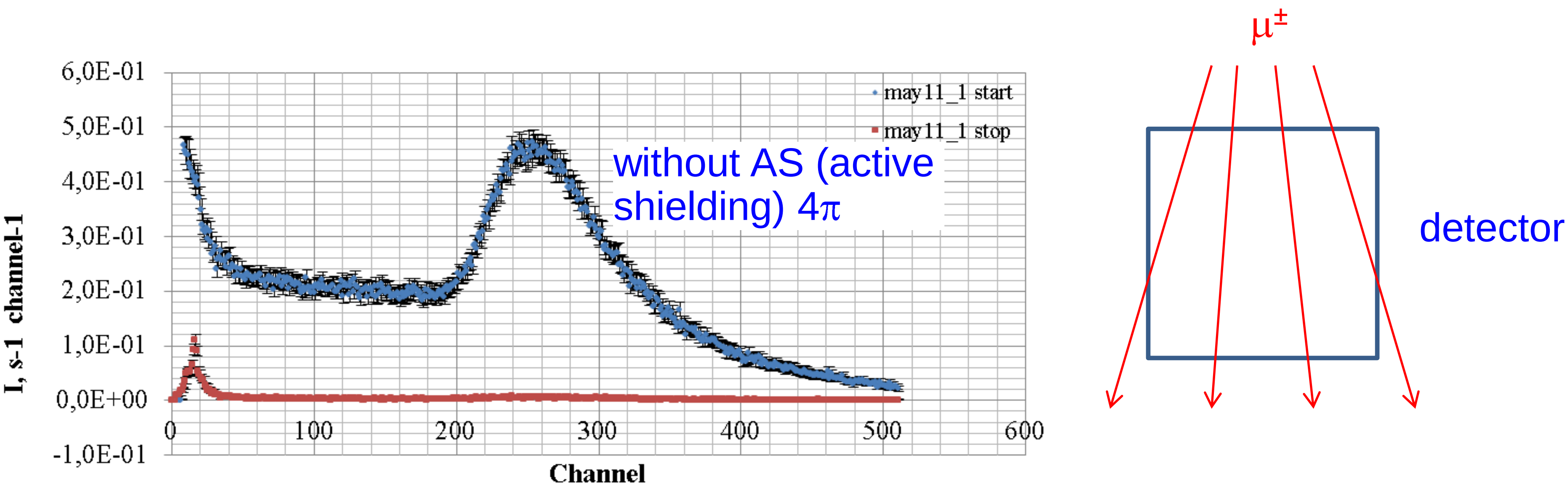
Background of gamma-rays at WWR-M reactor
(with shielding, without shielding and reactor on, reactor off)

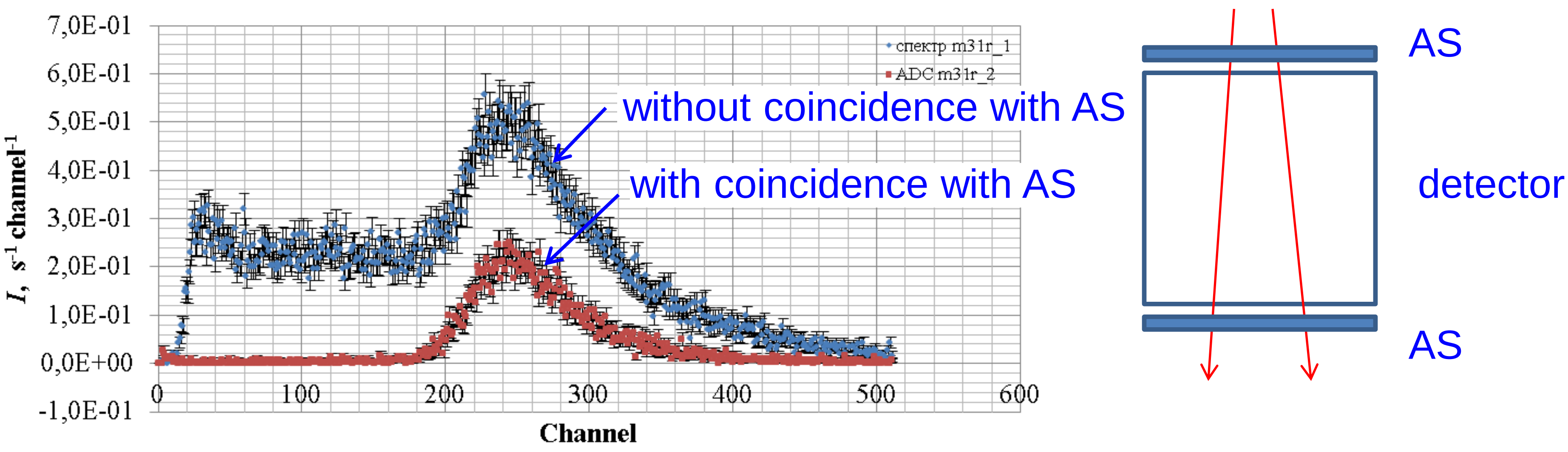
Shielding factor - 10^4 - 10^5



The first results of measurements

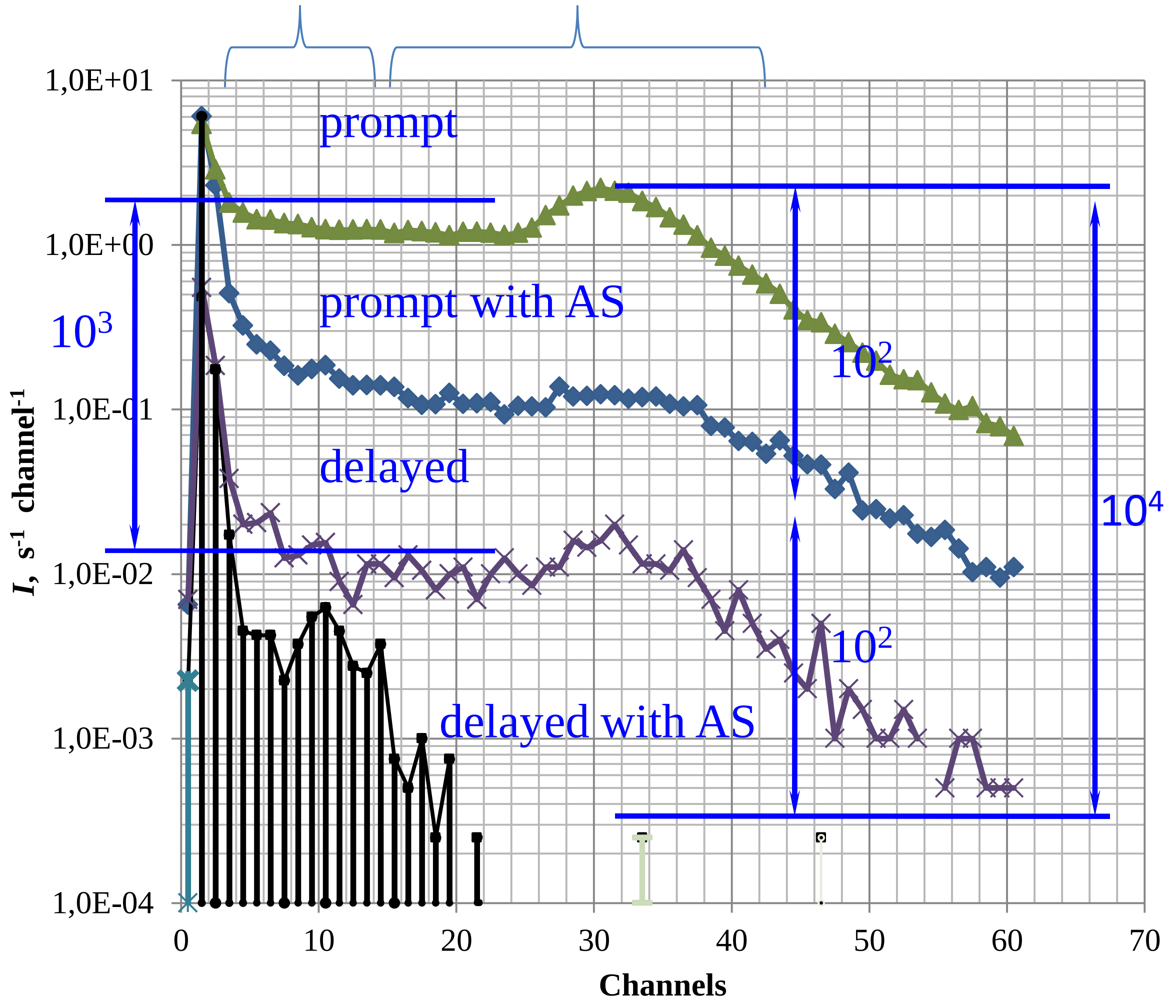
Spectrum of signals from neutrino detector

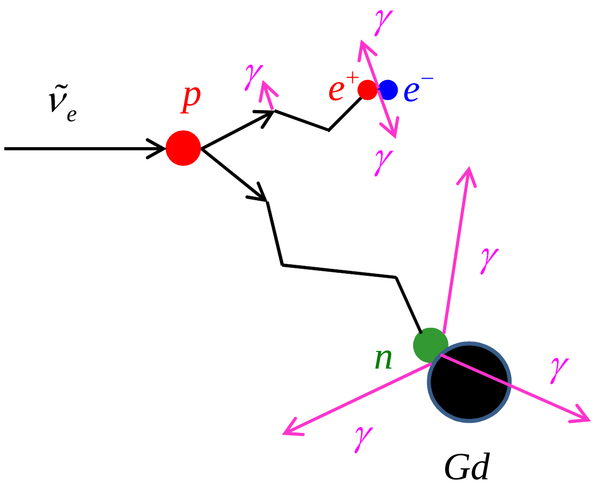


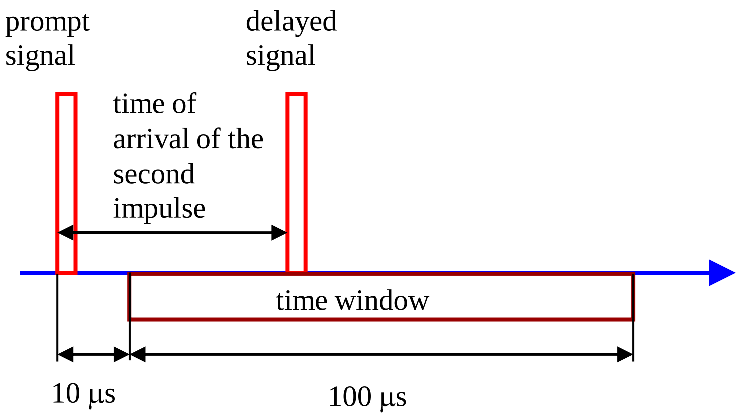


Cosmic background problem.
Correlated events (prompt, delayed)

$20\ s^{-1}/10^3 = 2\cdot10^{-2}\ s^{-1}$ $\quad 10^2\ s^{-1}/10^4 = 10^{-2}\ s^{-1}$

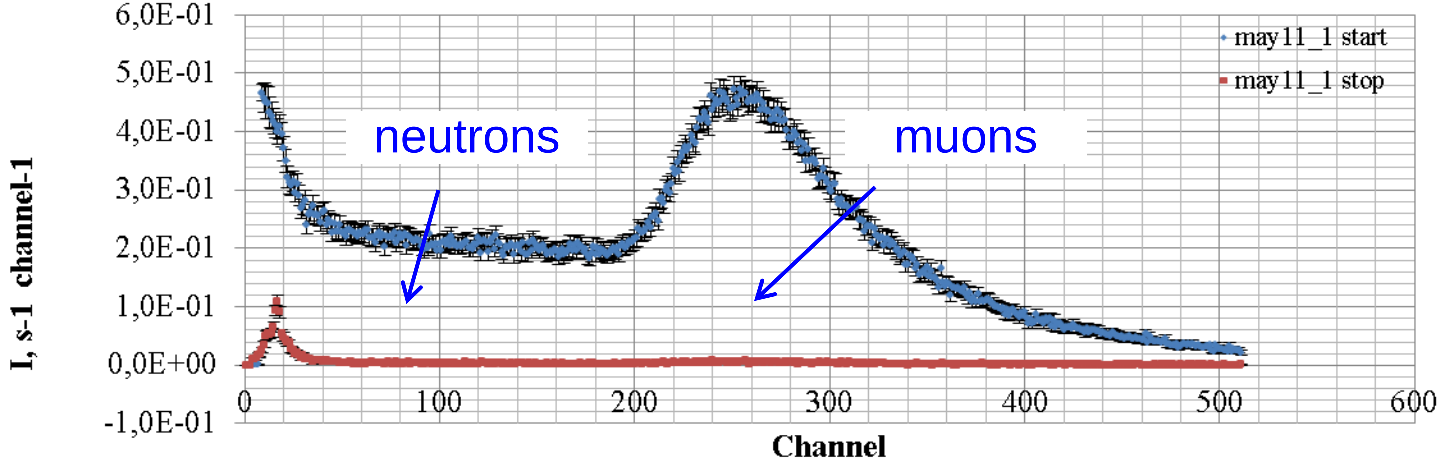


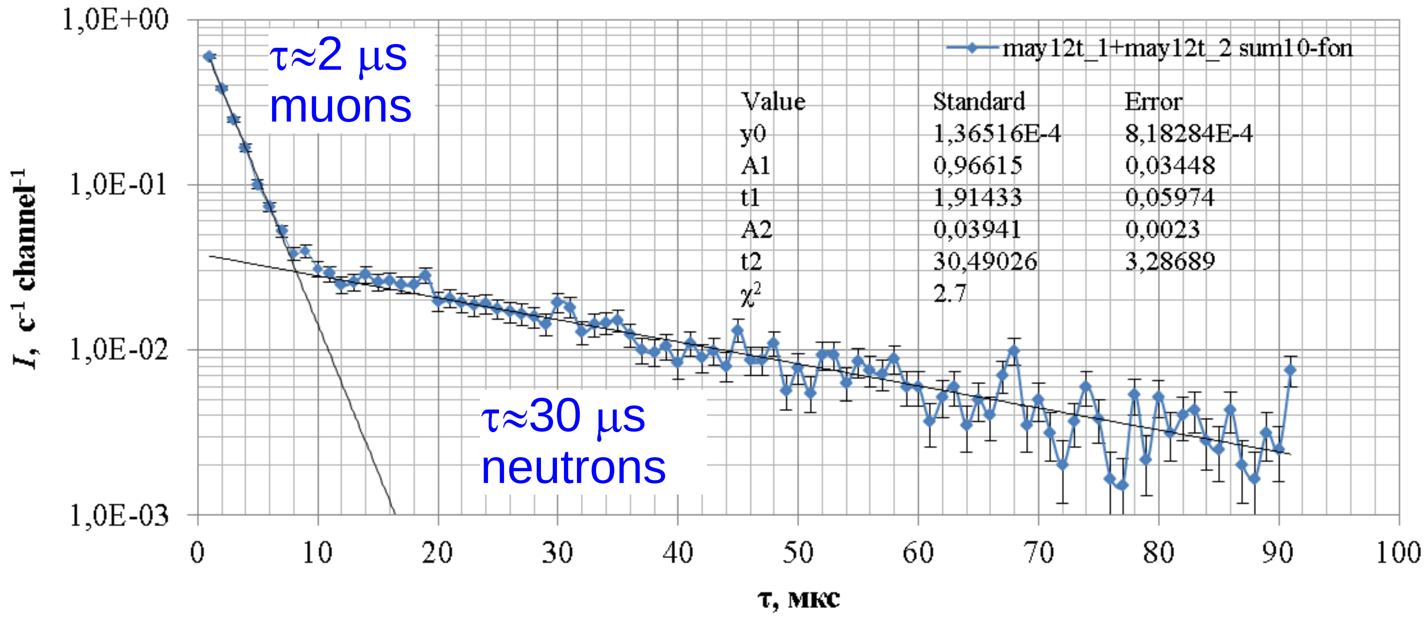




But expected neutrino count $\sim 2\cdot10^{-3}\ s^{-1}$

Spectrum and time dependence of events (delayed after prompt) for all spectrum

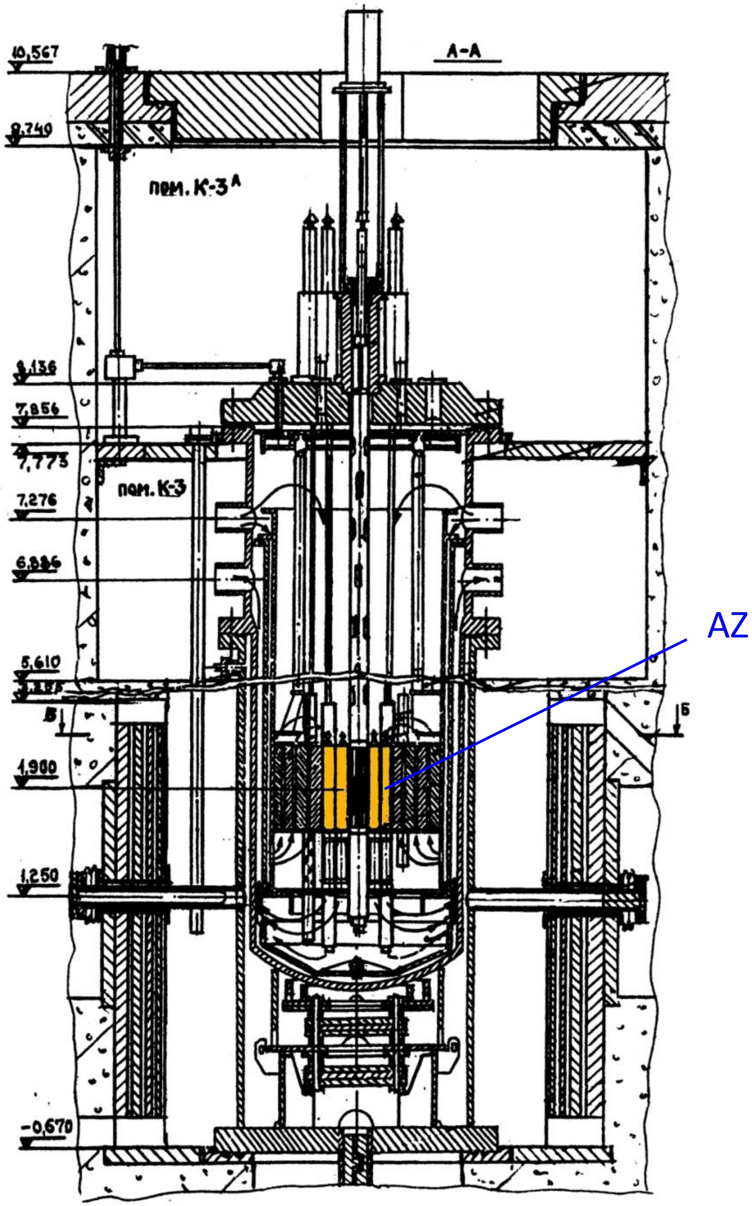


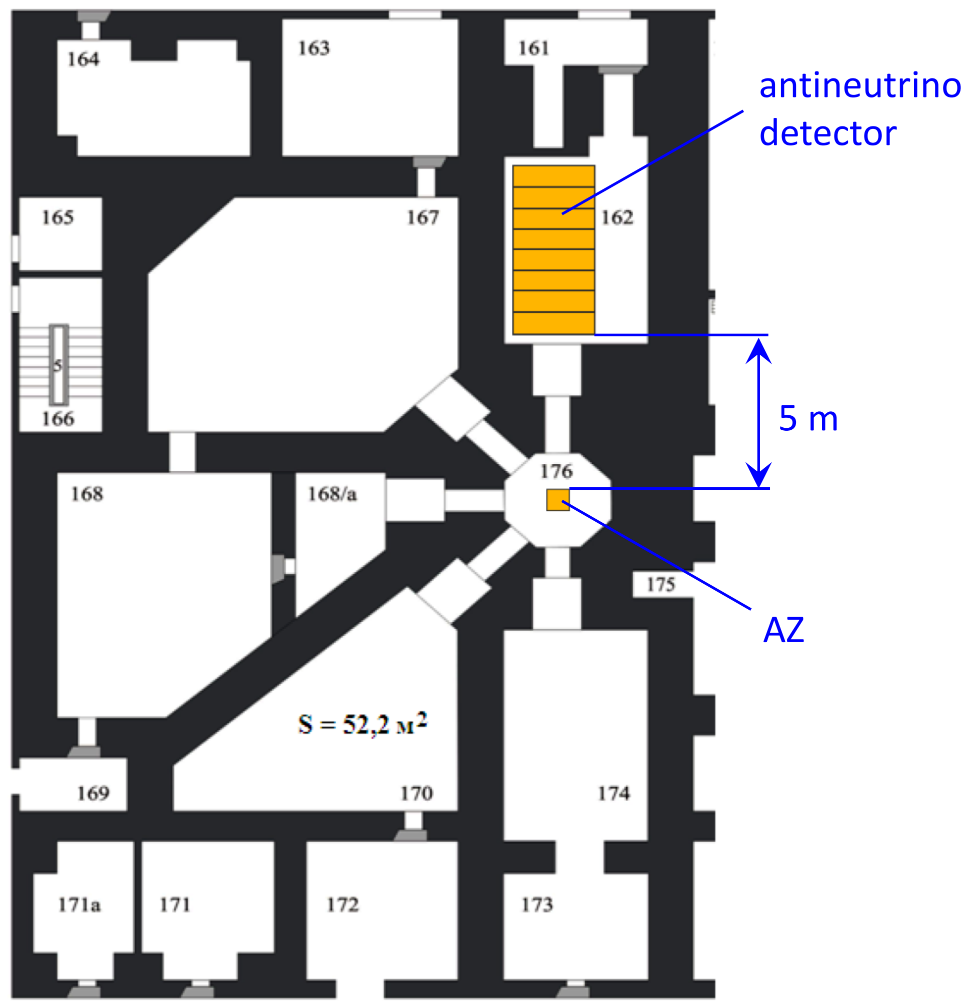


Project for NEUTRINO-4 experiment
at 100 MW SM-3 reactor
Dimitrovgrad (Russia)

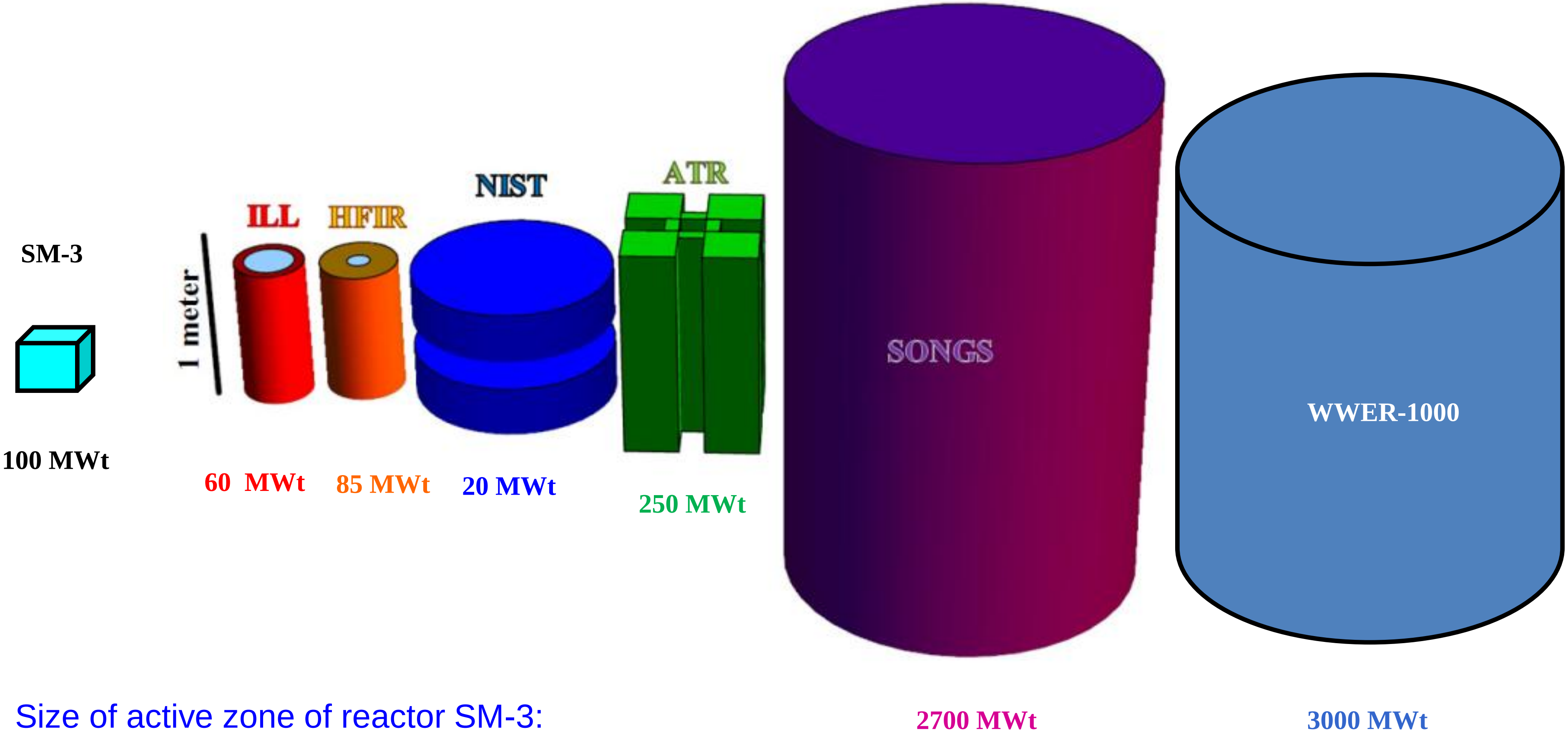
Scheme of the experiment on reactor SM-3

P=90 MWt, core size 35 x 40 x 40 cm^3, minimal distance 5



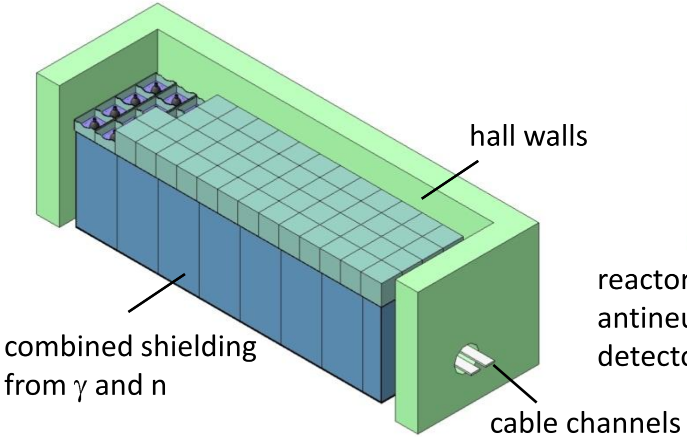


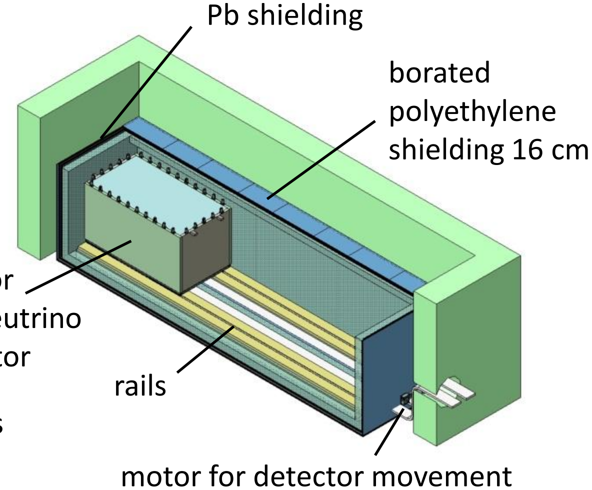
Core size and power of different reactors

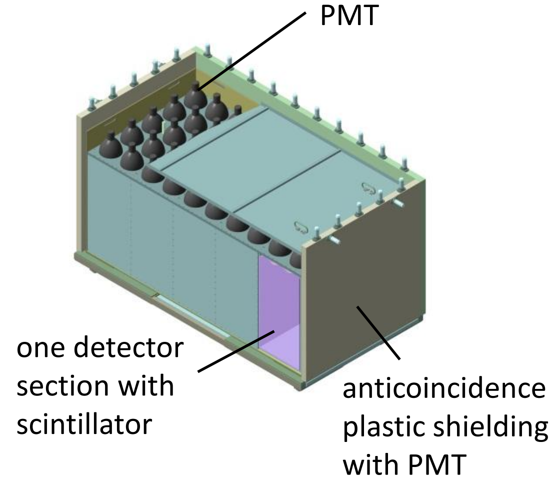


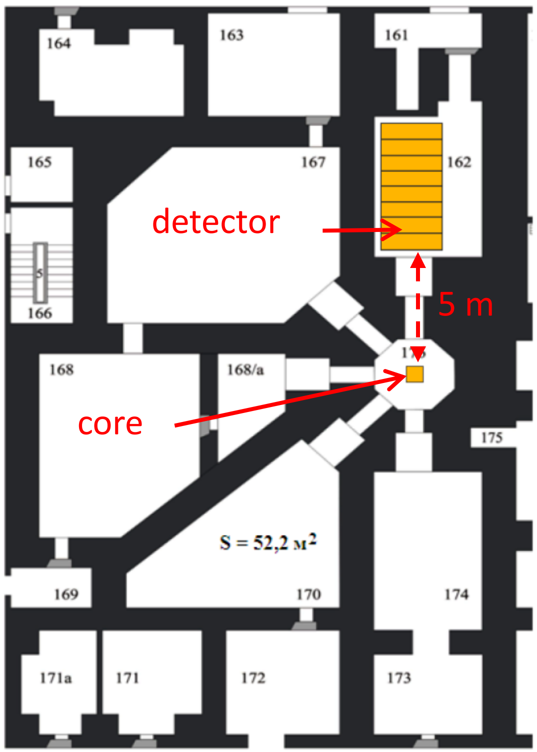
Size of active zone of reactor SM-3:
$42 \times 42 \times 35$ cm^3

Project for NEUTRINO-4 experiment at 100 MW SM-3 reactor Dimitrovgrad (Russia)





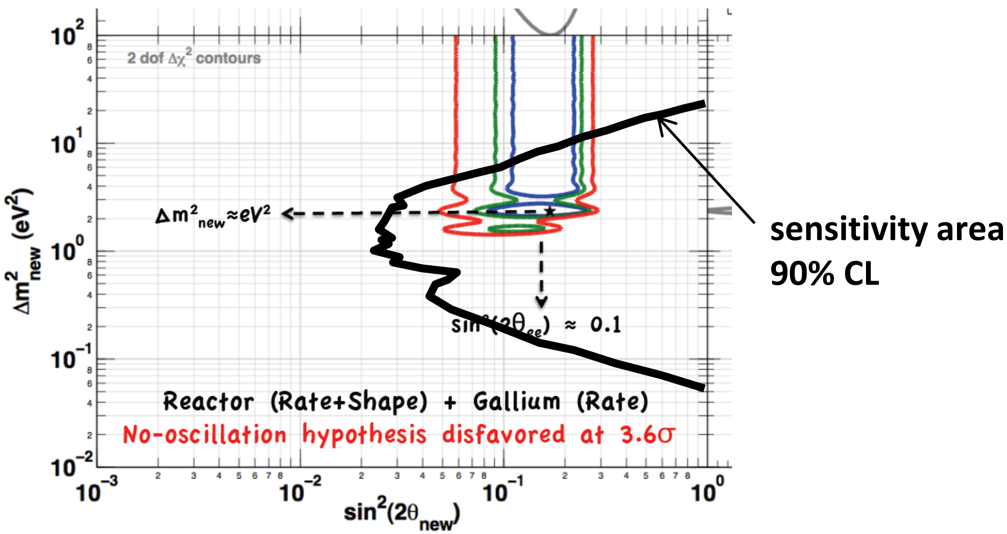




SM-3 reactor

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

1.6 m^3 detector: 2 sections moveable detector at 6-12 m



Structure of passive shielding

Mounting at SM-3 reactor

Lead walls (6 cm thickness) and movable platform are installed

Polyethylene(B) walls, roof and floor (16 cm thickness) - 10 m^3

Installation of step motor to move 2 tons detector

Step motor

Total weight of the passive shielding is 60 ton

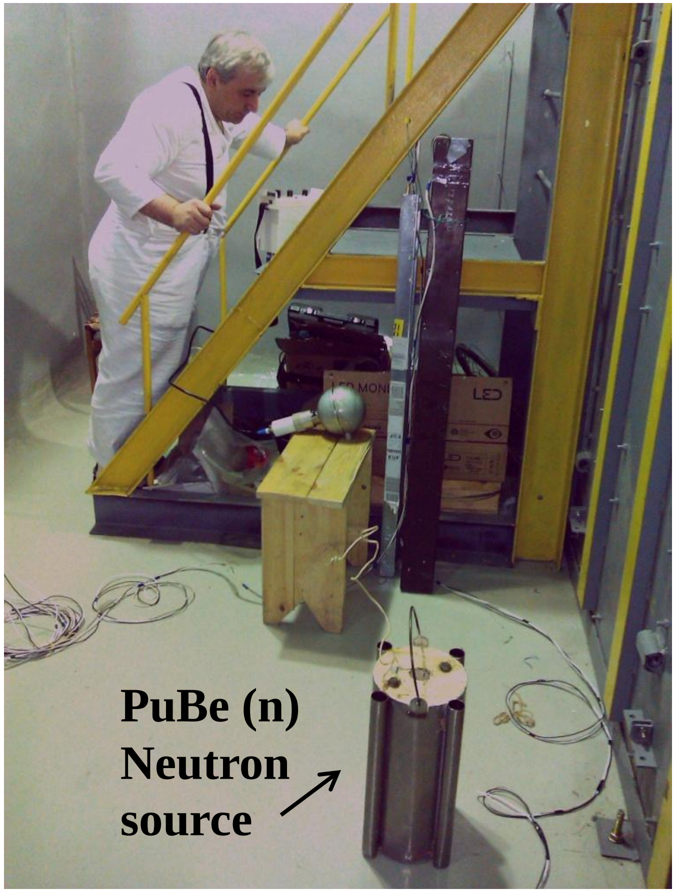
Finish

Neutrino channel outside and inside

Passive shielding of 60 tons

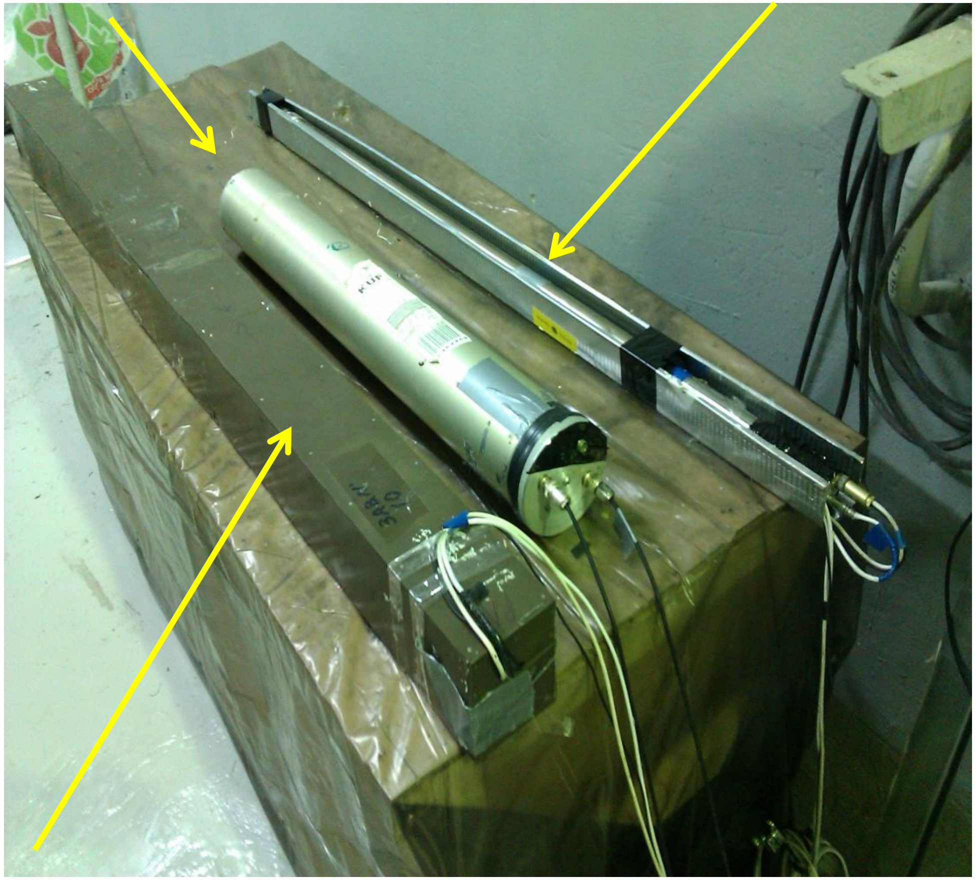
Range of measurements for the reactor antineutrino flux is 6 – 12 meters from the active reactor core

Studies of background condition by means of gamma and neutron detectors



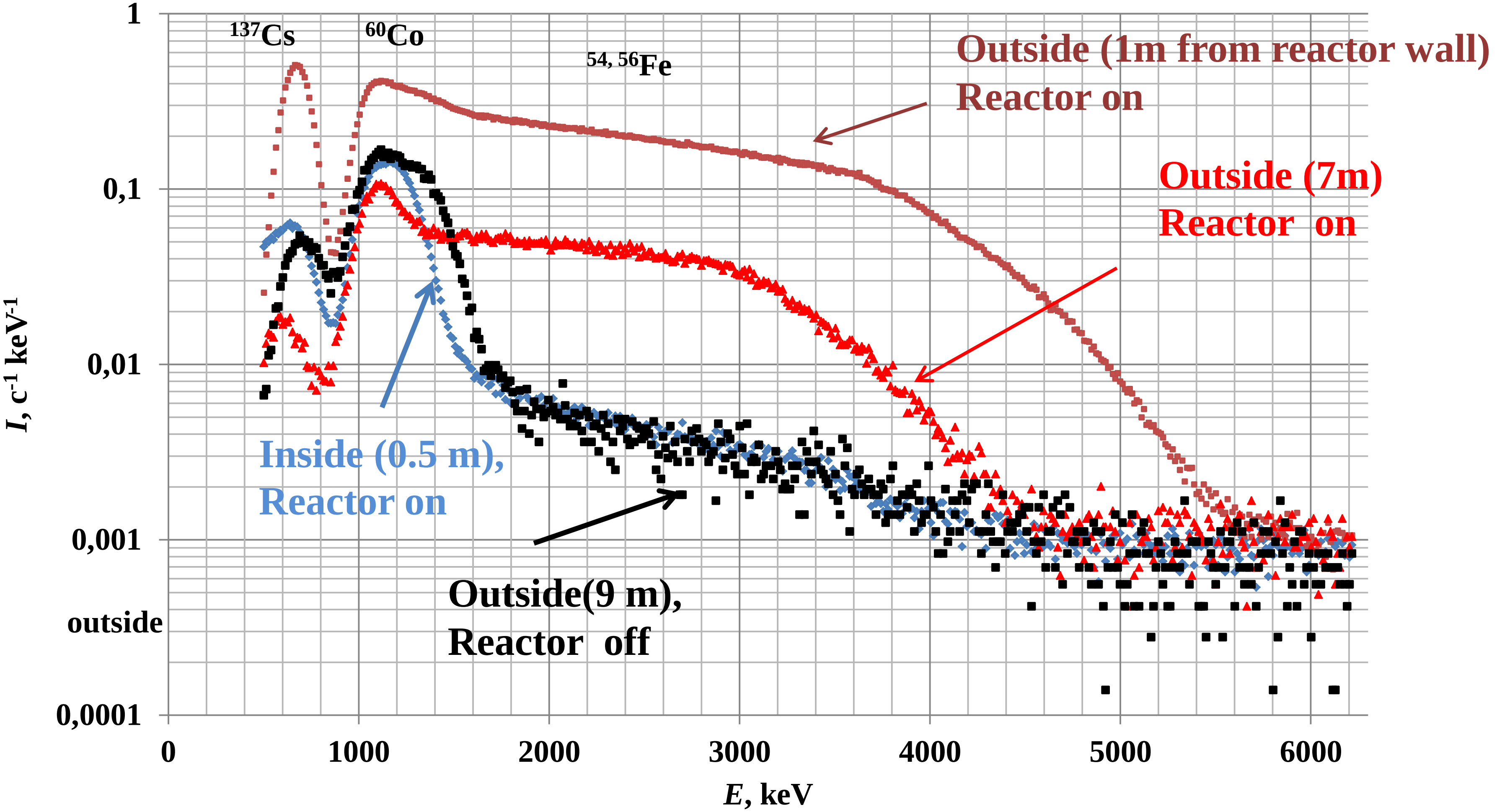
Calibration procedure

Gamma detector NaJ *Thermal neutron detector*

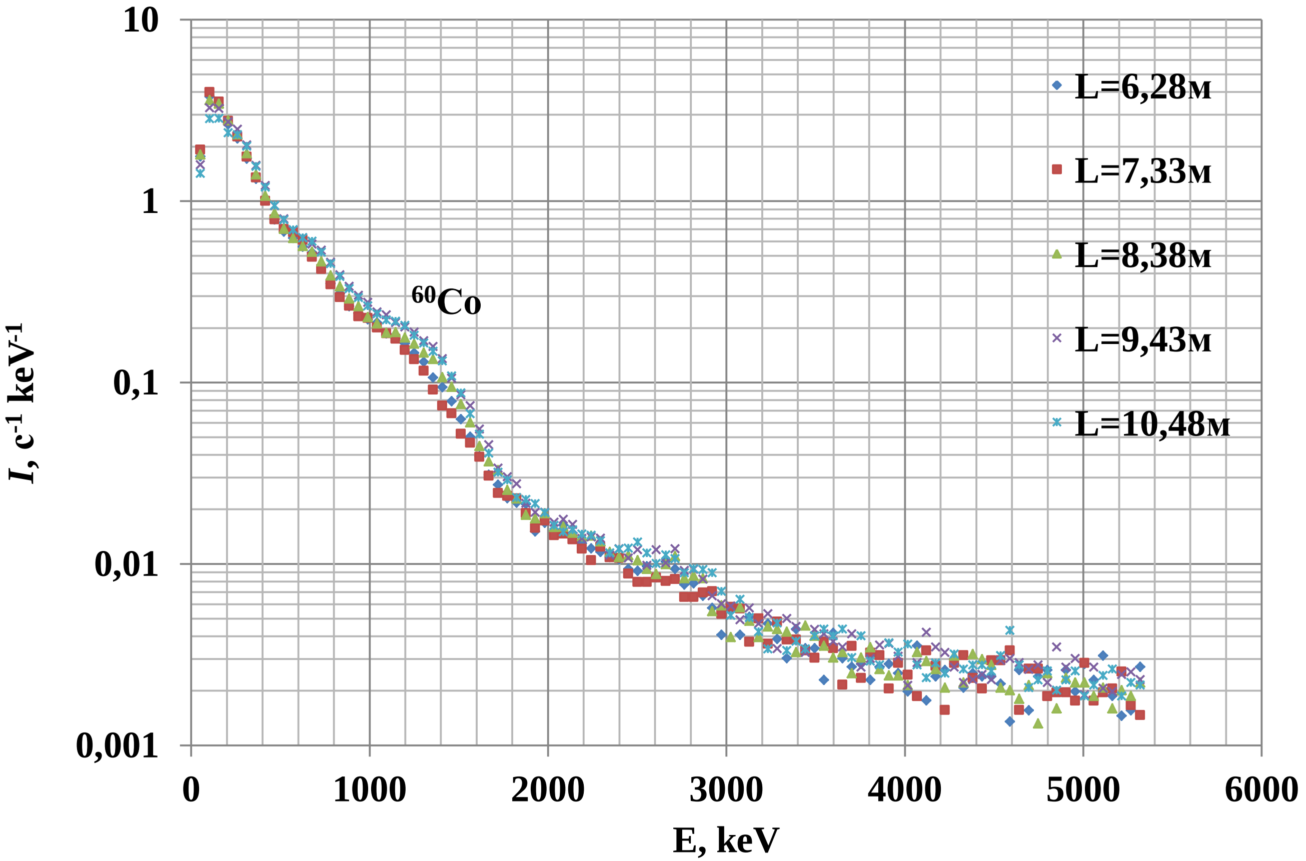


Fast neutron detector

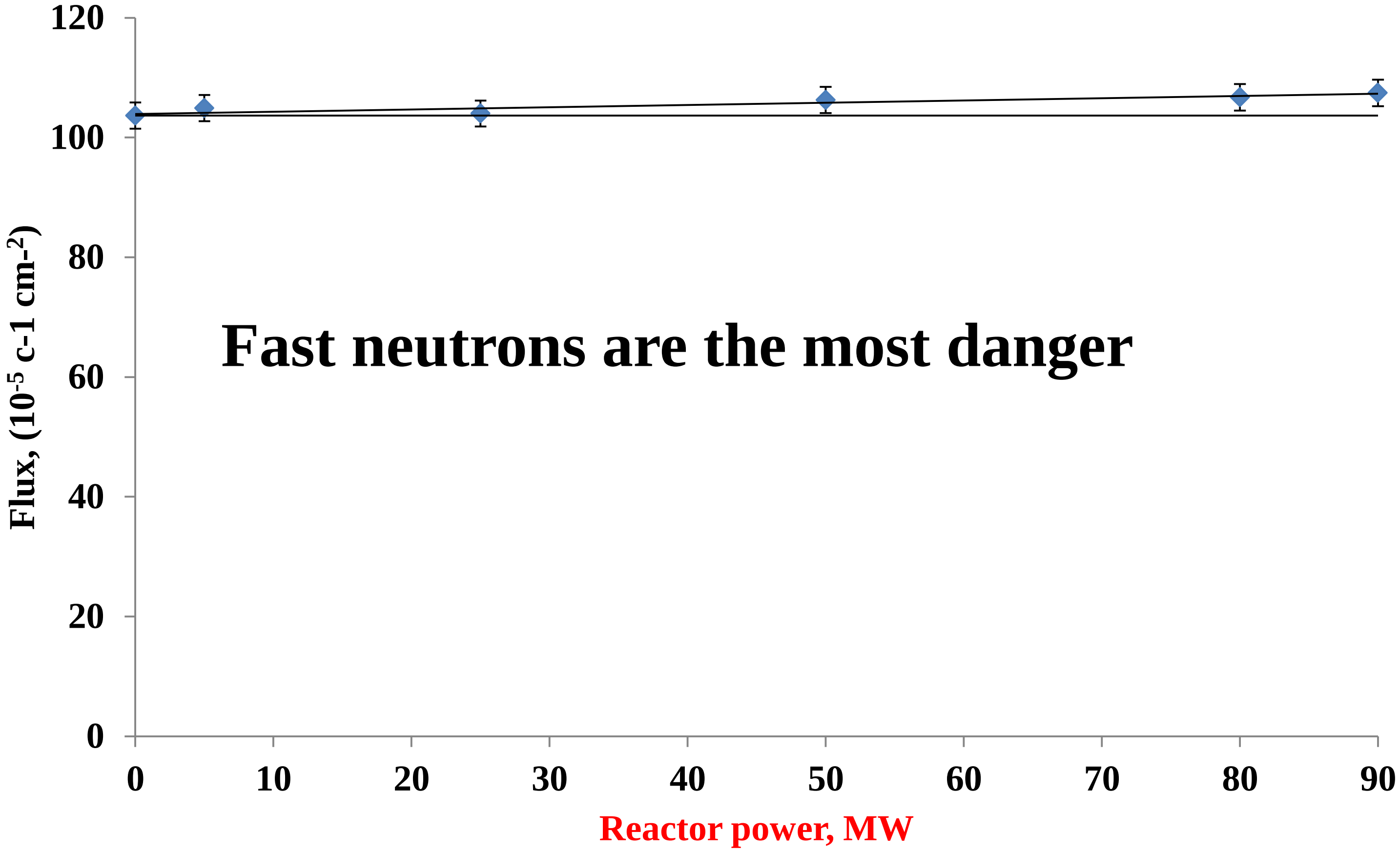
Gamma-rays background outside and inside shielding, Reactor on , reactor off



Gamma-rays background distribution inside shielding, Reactor on

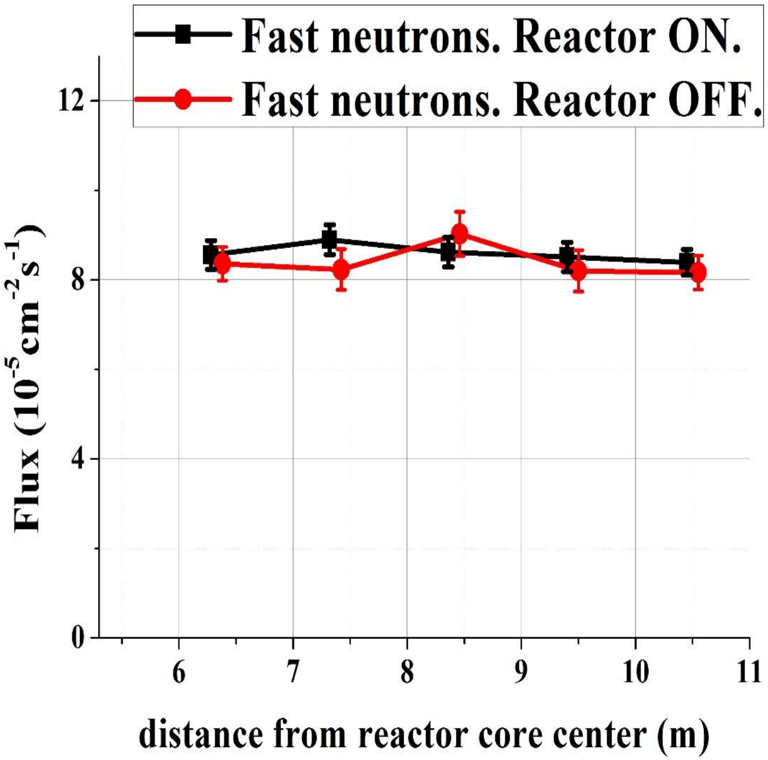


Measurement of fast neutron flux near the reactor wall (outside the shielding) during increase reactor power



Fast neutrons are the most danger

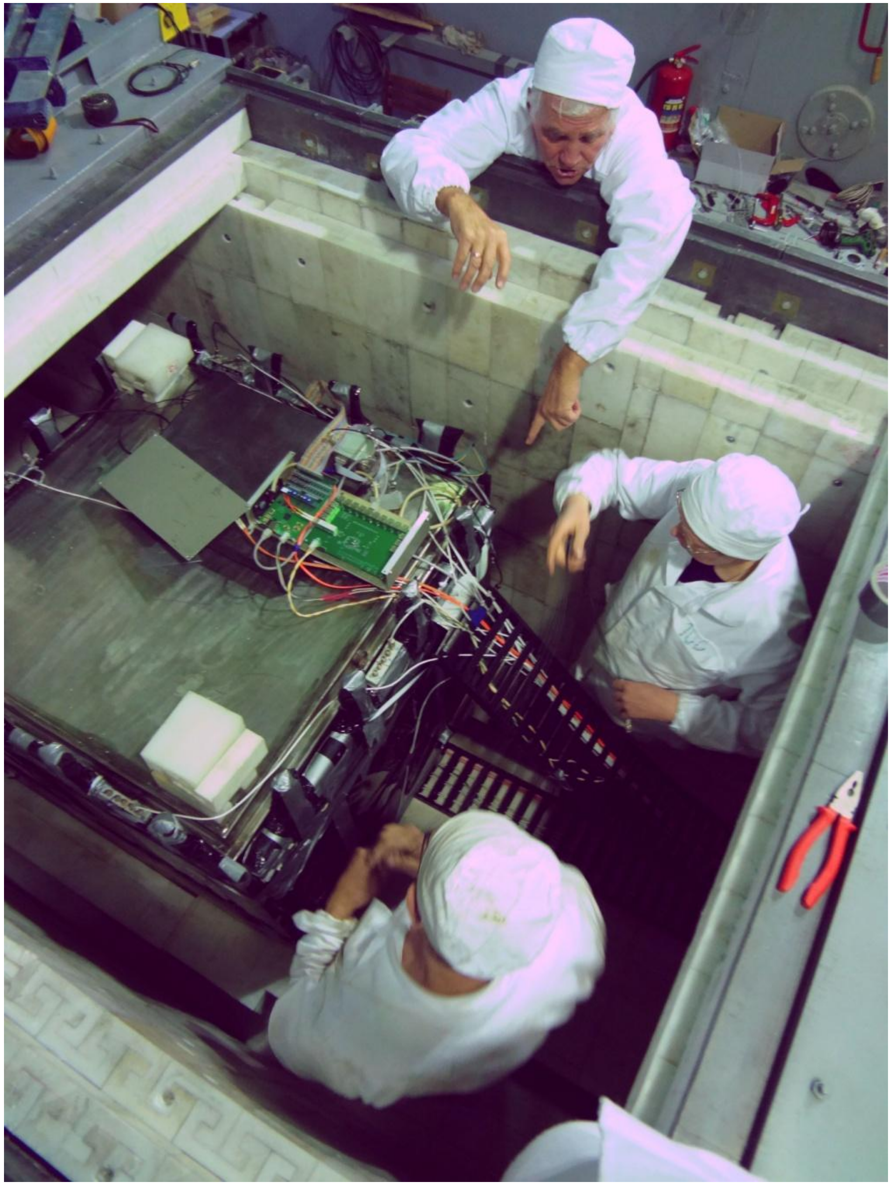
Thermal and fast neutrons fluxes inside shielding and on top of shielding, P=90 MWt.

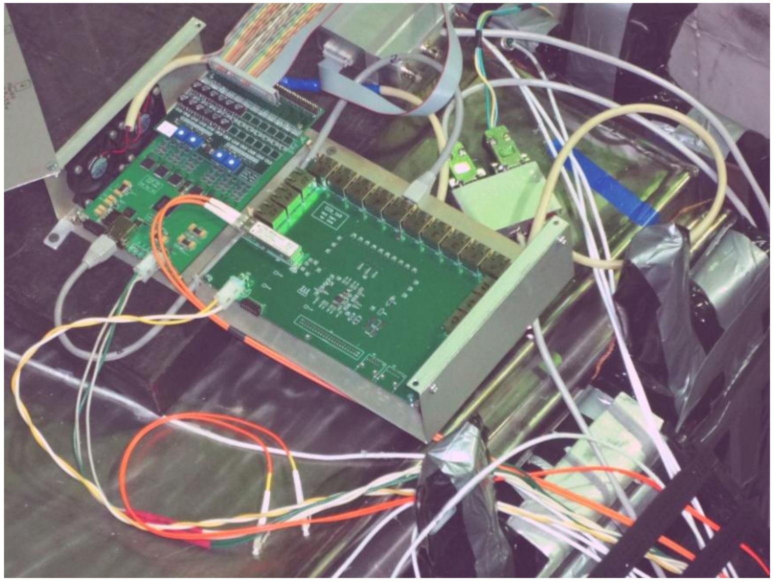


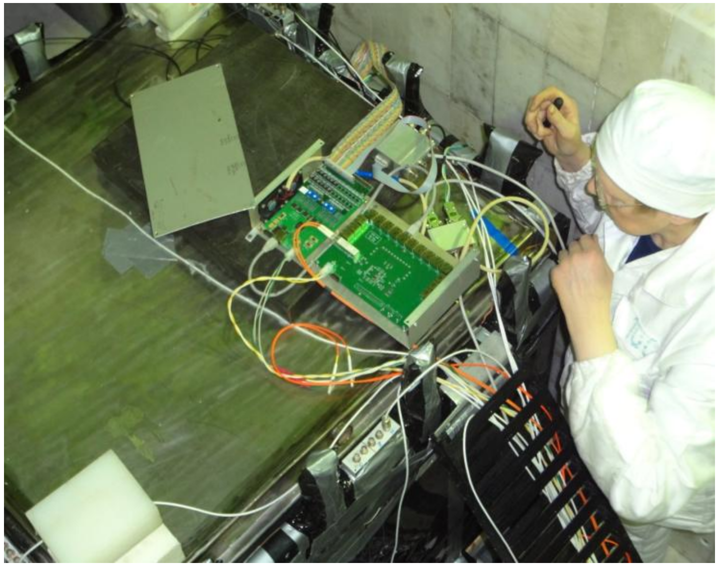
Thermal neutrons flux ($s^{-1}cm^{-2}$)	*Fast neutrons flux* ($s^{-1}cm^{-2}$)	*Place of measurment*
(0.34±0.07) 10^{-5}	**(4.4±0.5) 10^{-5}**	**Inside**
(17.7±1.2) 10^{-5}	**(69±2) 10^{-5}**	**On the top**
Shielding factor K_{th}= 53	**Shielding factor K_{fast} = 16**	

Assembling of NEUTRINO-4 detector prototype with electronics

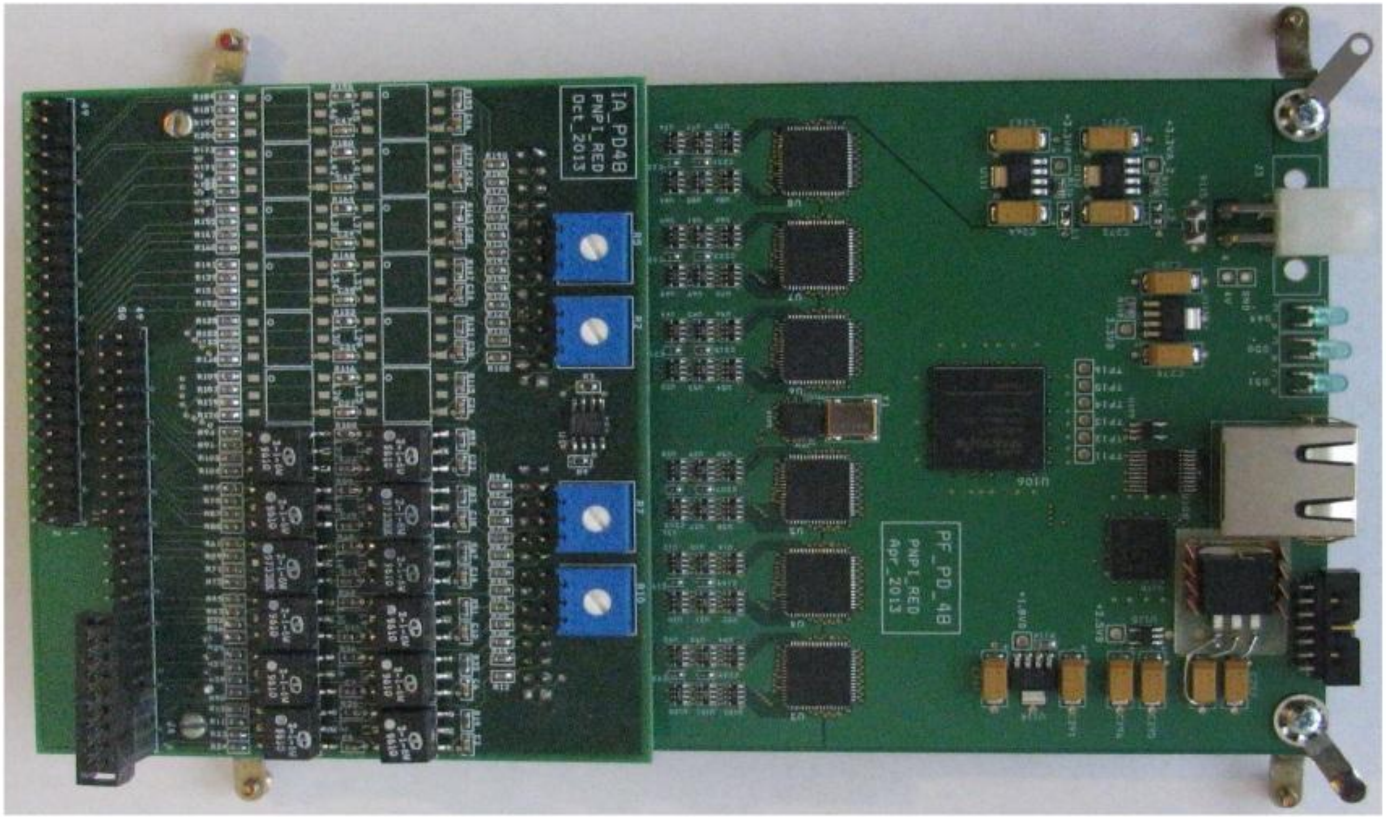
Assembling of electronics for prototype of NEUTRINO-4 detector







FlashADC: ....12-Bit Octal-Channel ADS5282.
Sampling Rate: ....65 MSPS.
Sampling Period: ....15.38 ns.
Number of Channels: 48

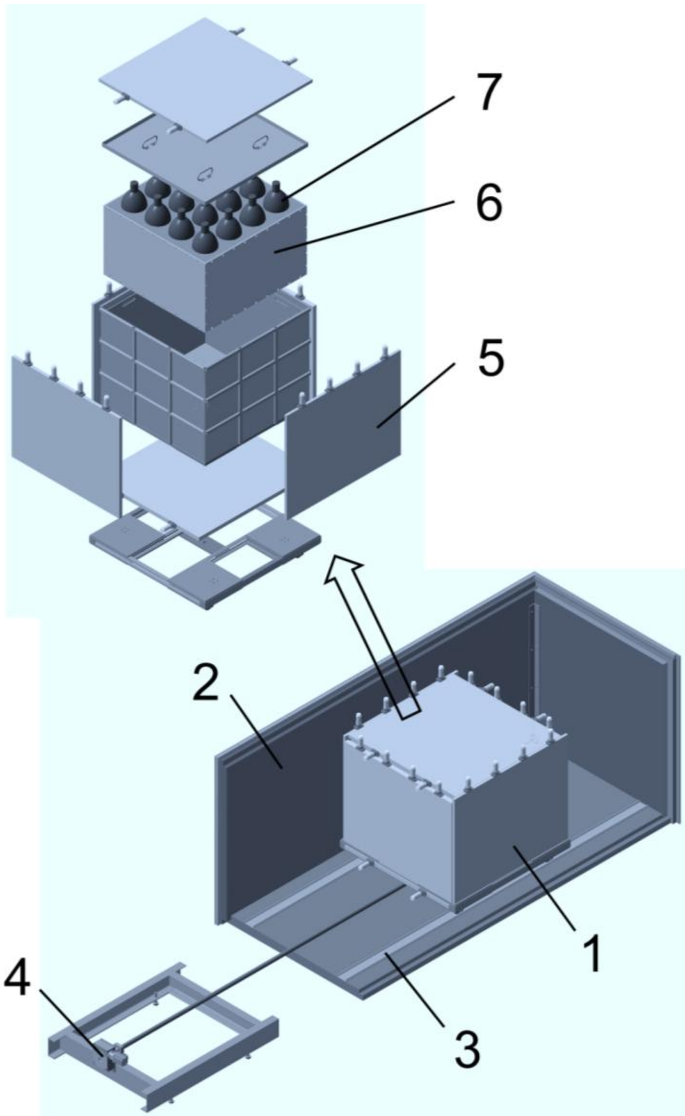


Outlay of the neutrino laboratory (left side - passive shielding of neutrino detector, 60 tons)

Computer room – data processing

We begin the first measurements on model of the neutrino detector

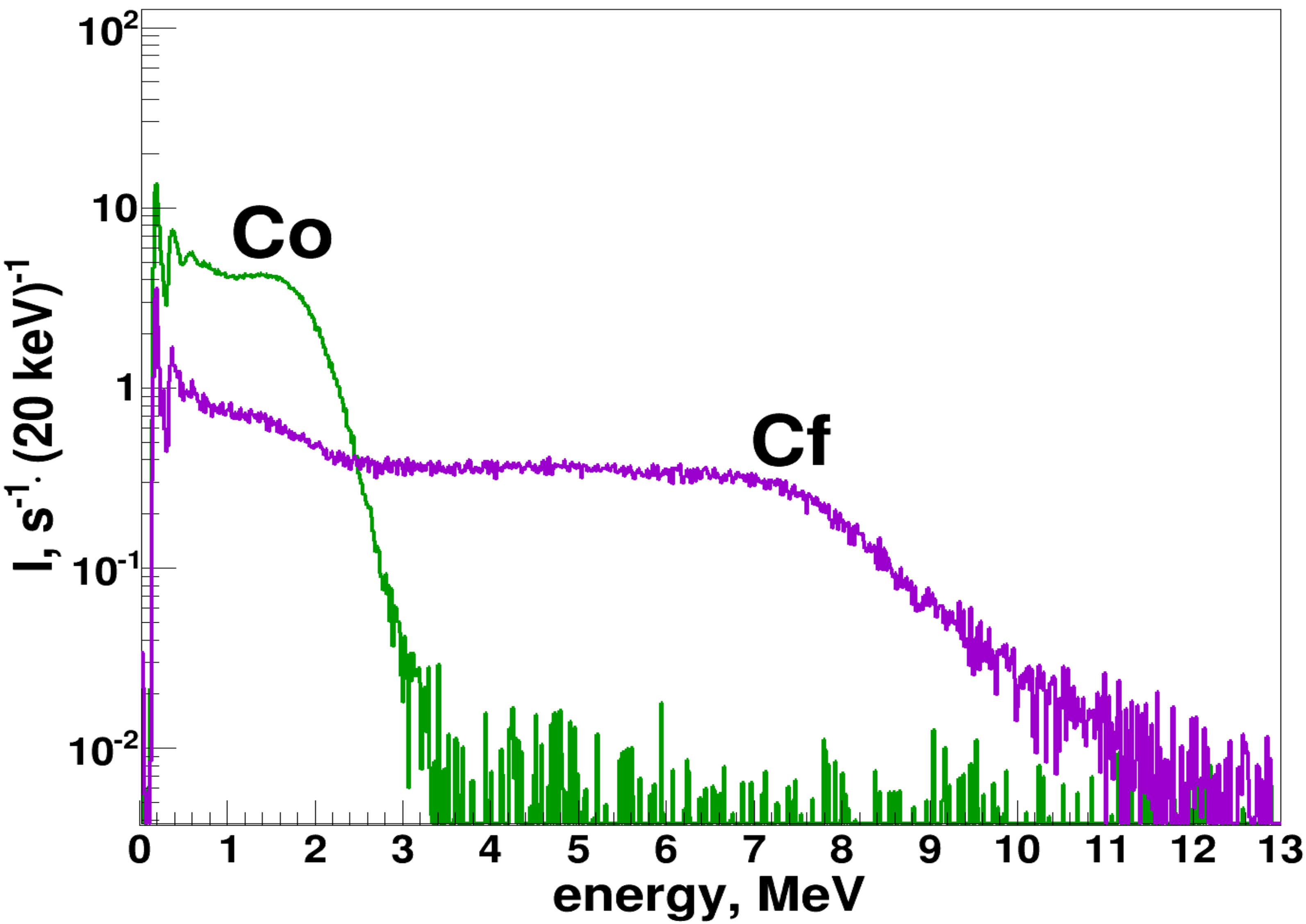
Prototype of NEUTRINO-4 detector, 400 l



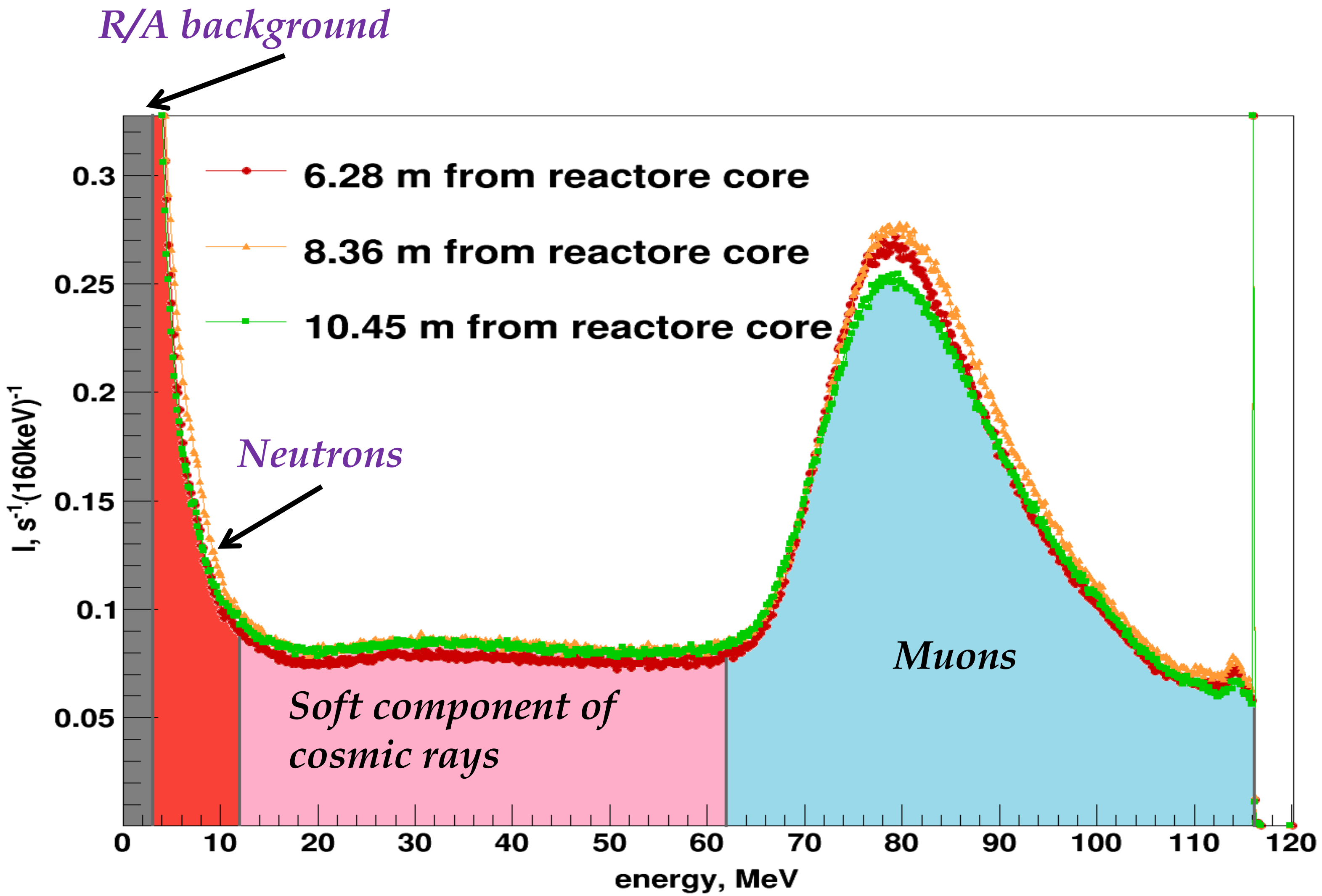
The model of the neutrino detector installed in passive shielding

1 – detector of reactor antineutrino,
2 – passive shielding,
3 – rail,
4 – the engine for detector movement,
5 – active shielding with PMT,
6 – volume with liquid scintillator liquid with Gd (~ 400 l),
7 – Detector PMT.

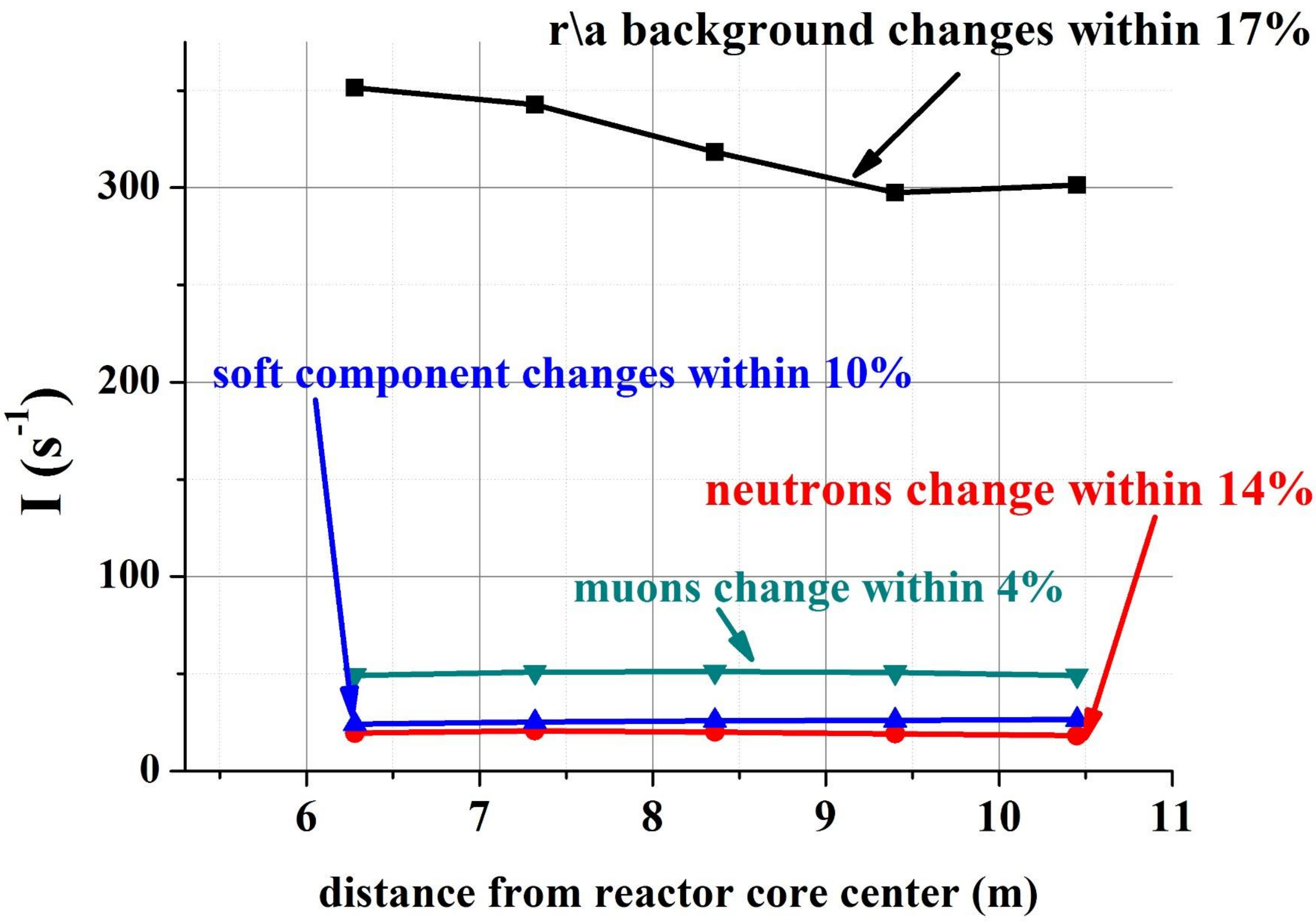
Energy Calibration of Spectrum



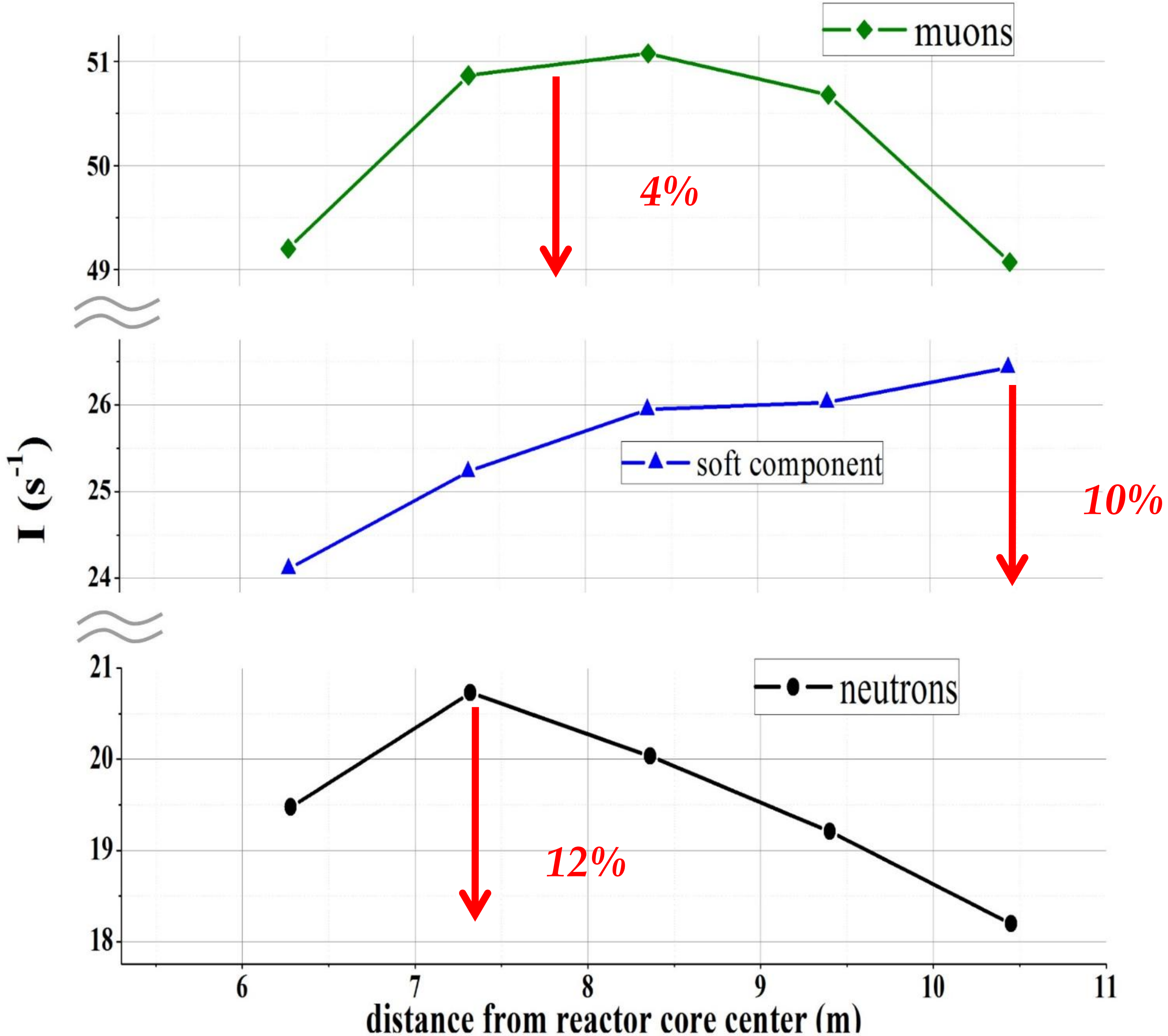
Different part of spectrum at the different distance



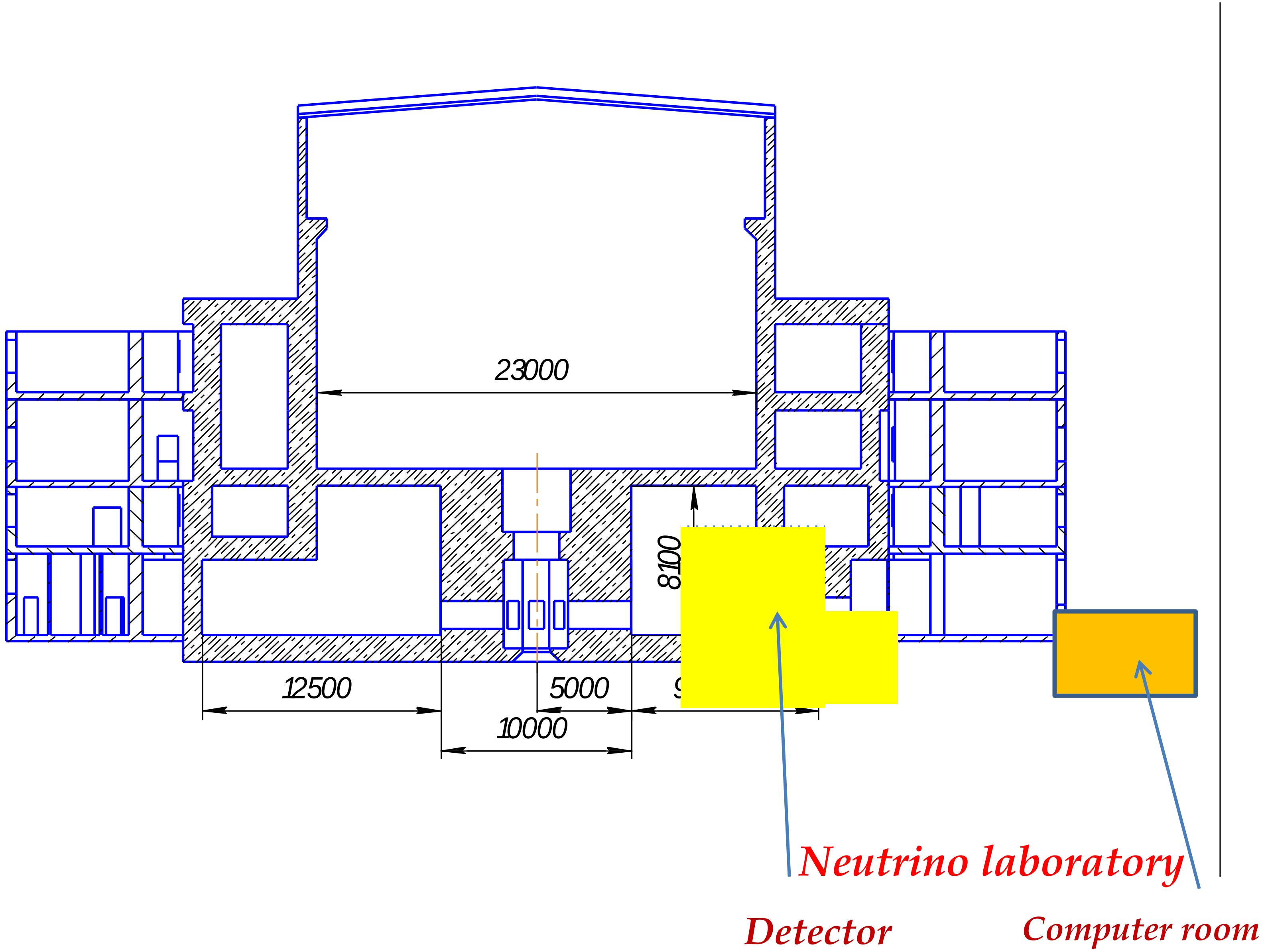
Different parts of spectrum distance dependence



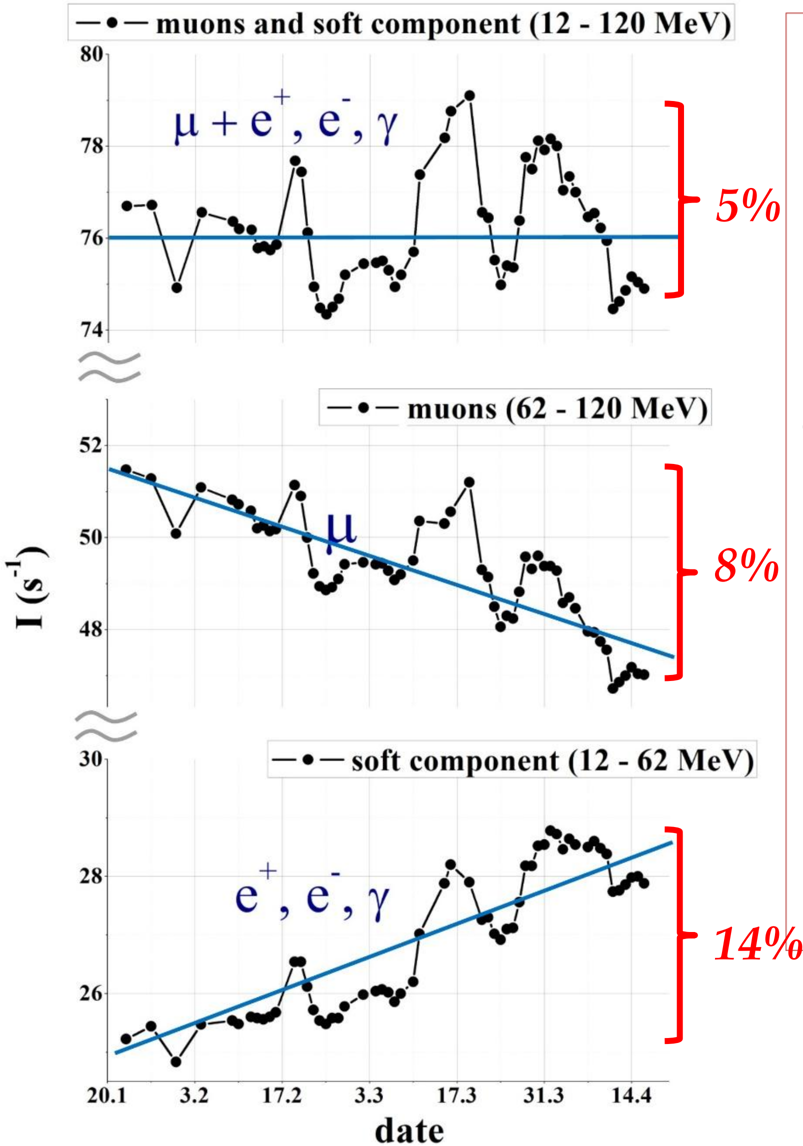
Distance dependence of intensity in the different parts of spectrum (larger scale)

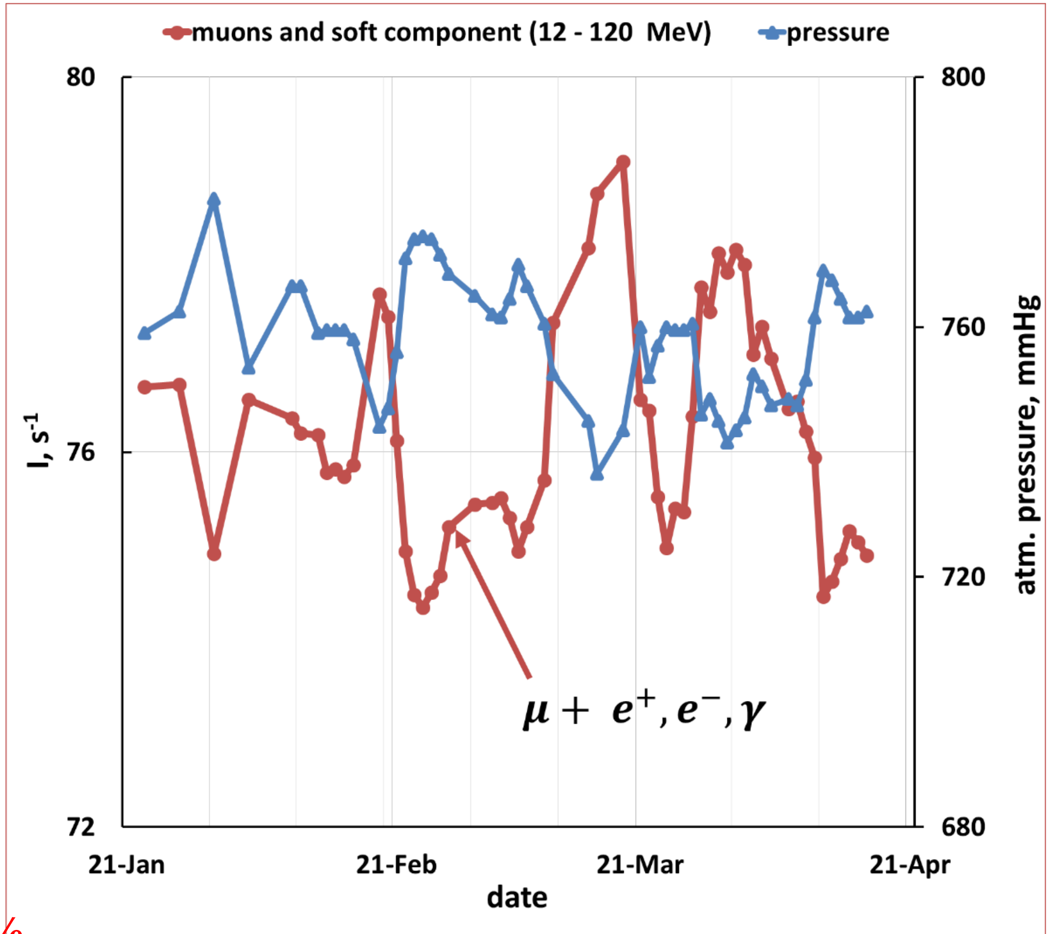


SM-3 reactor building scheme: concrete structures distribution



The effects of atmospheric temperature and pressure on cosmic rays

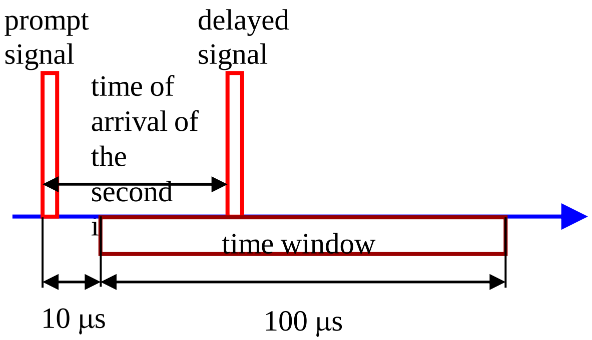


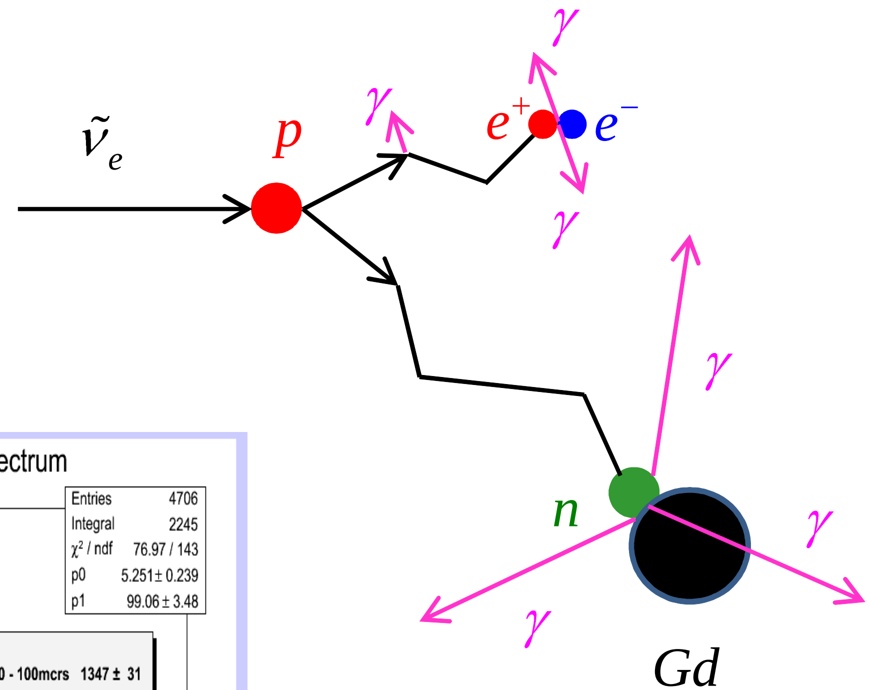


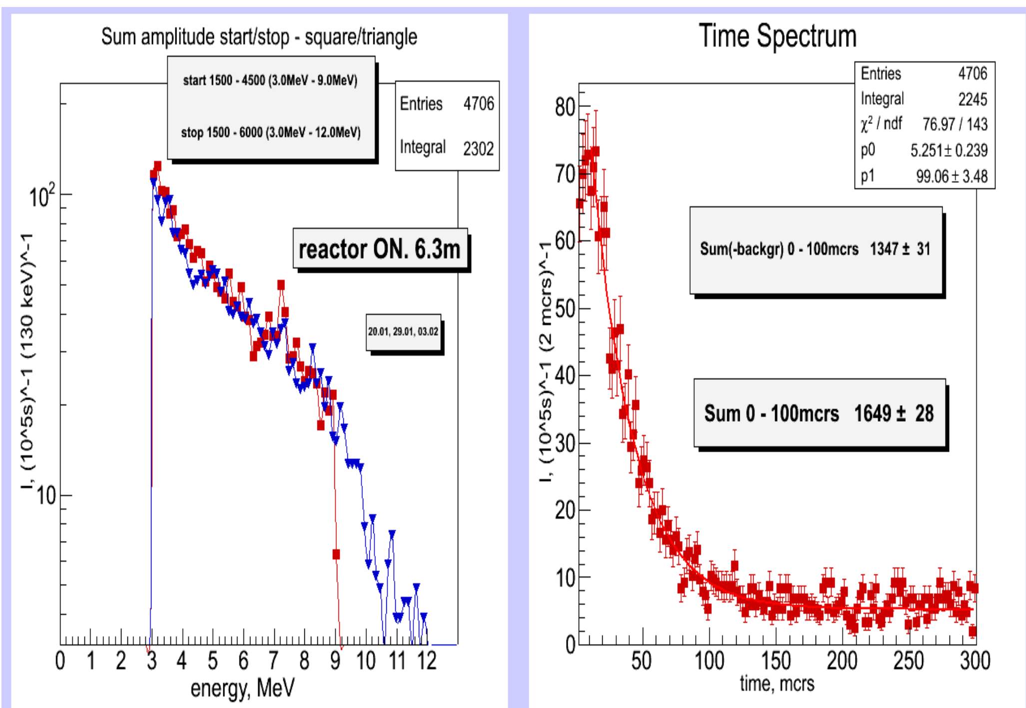
Measurement of correlated events

(search for reactor antineutrino)

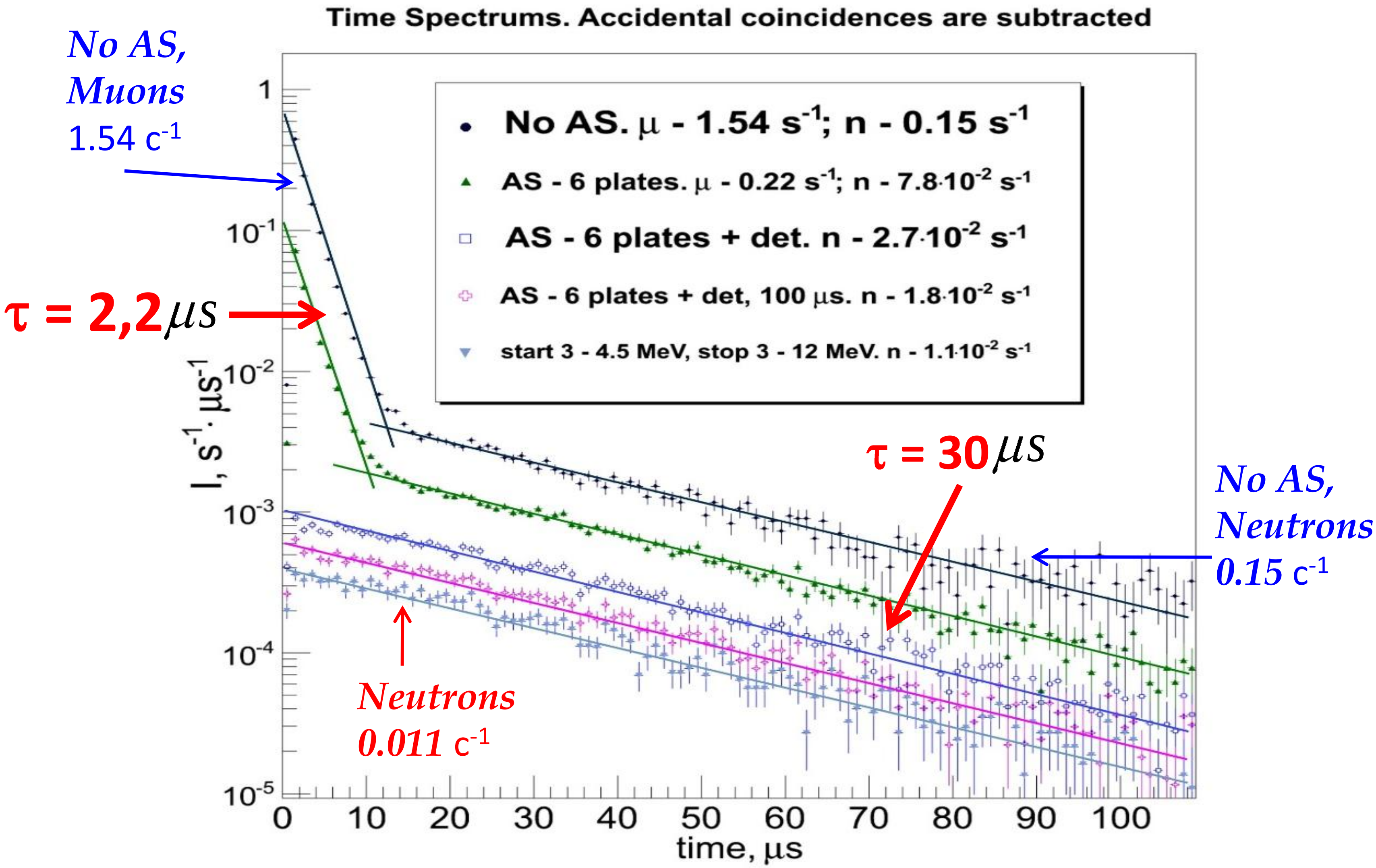
Signal of correlated event



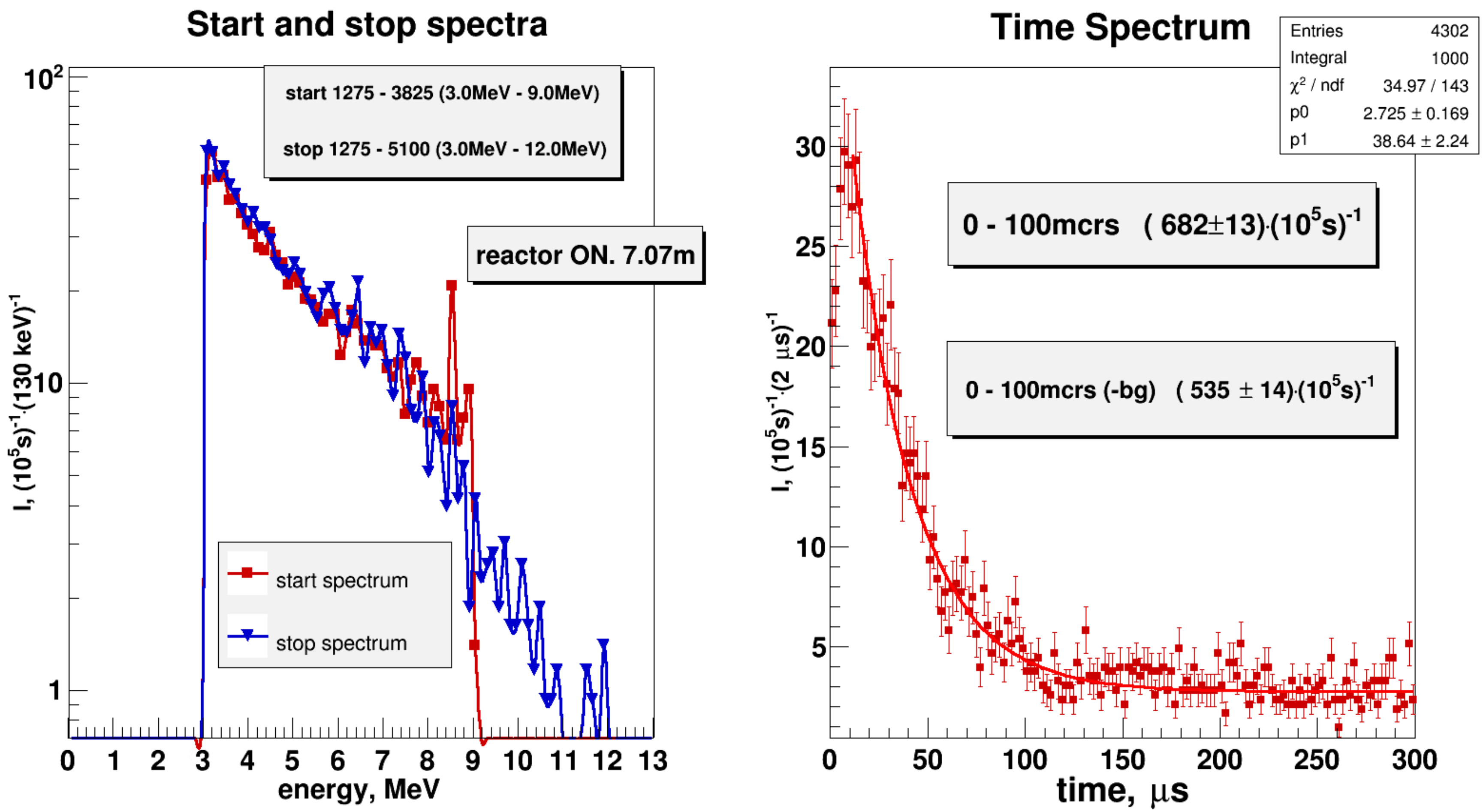




Time spectra for different configurations of active shielding (AS)

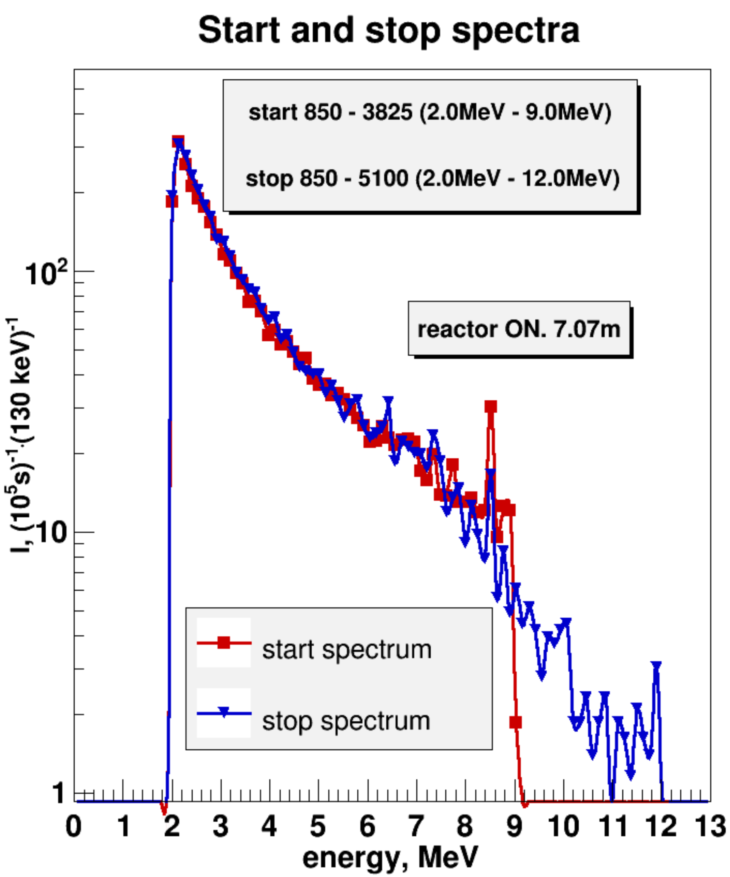


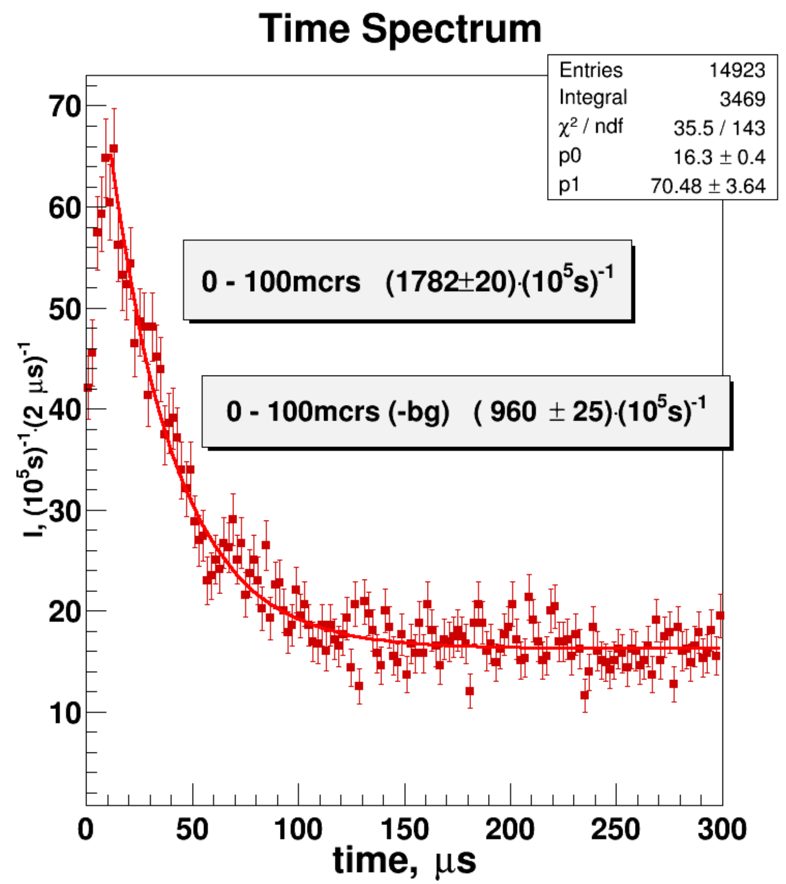
Correlated signals
(energy spectra and time spectrum)



Correlated signals

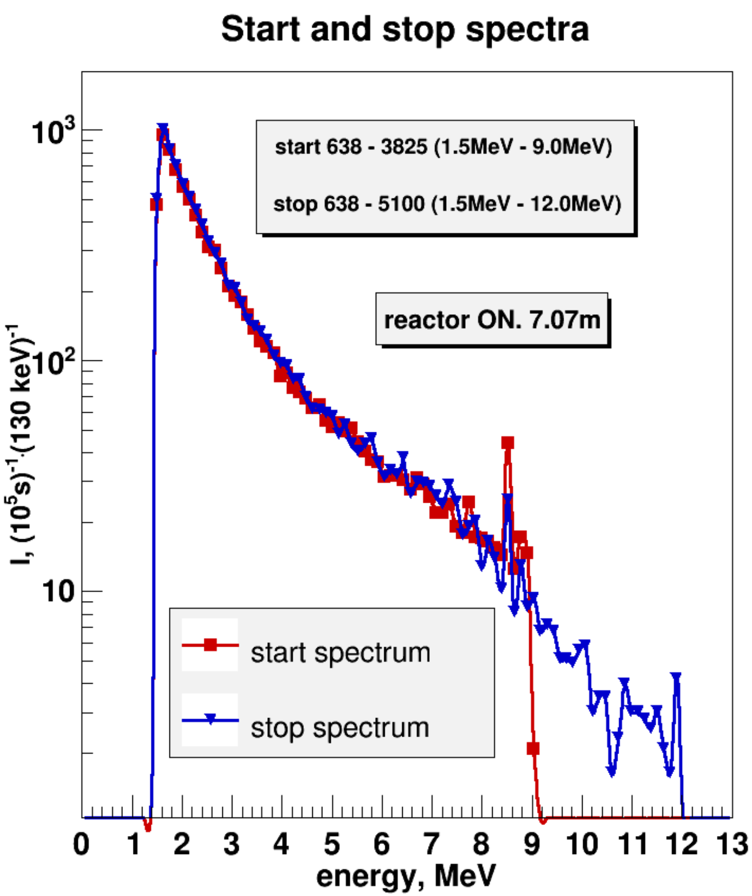
(energy spectra and time spectrum)

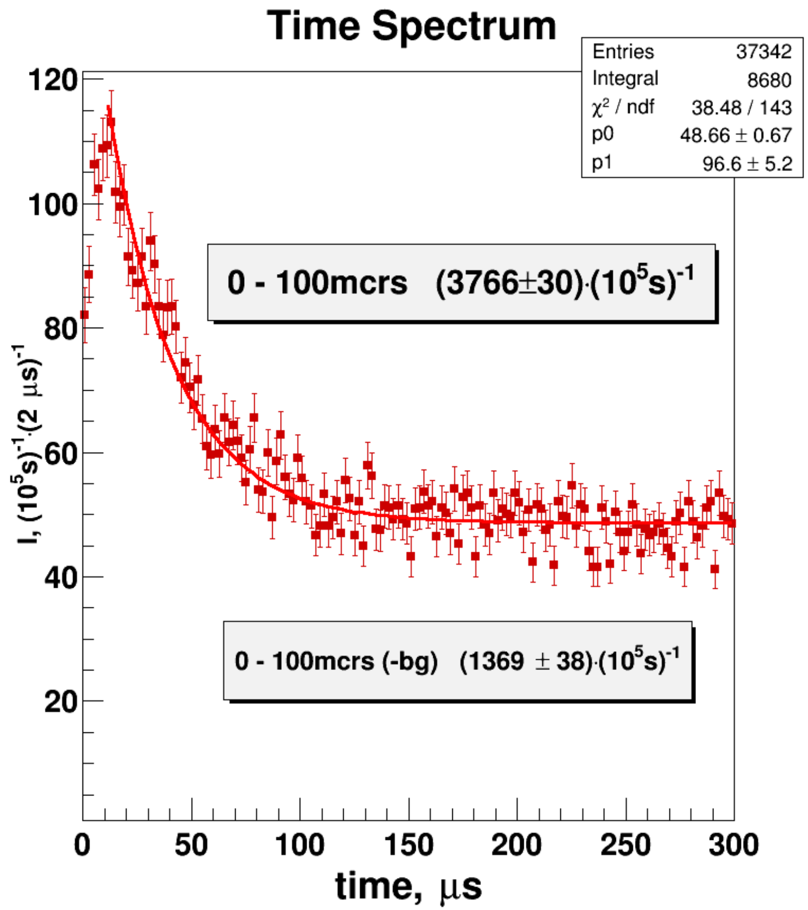




Correlated signals

(energy spectra and time spectrum)



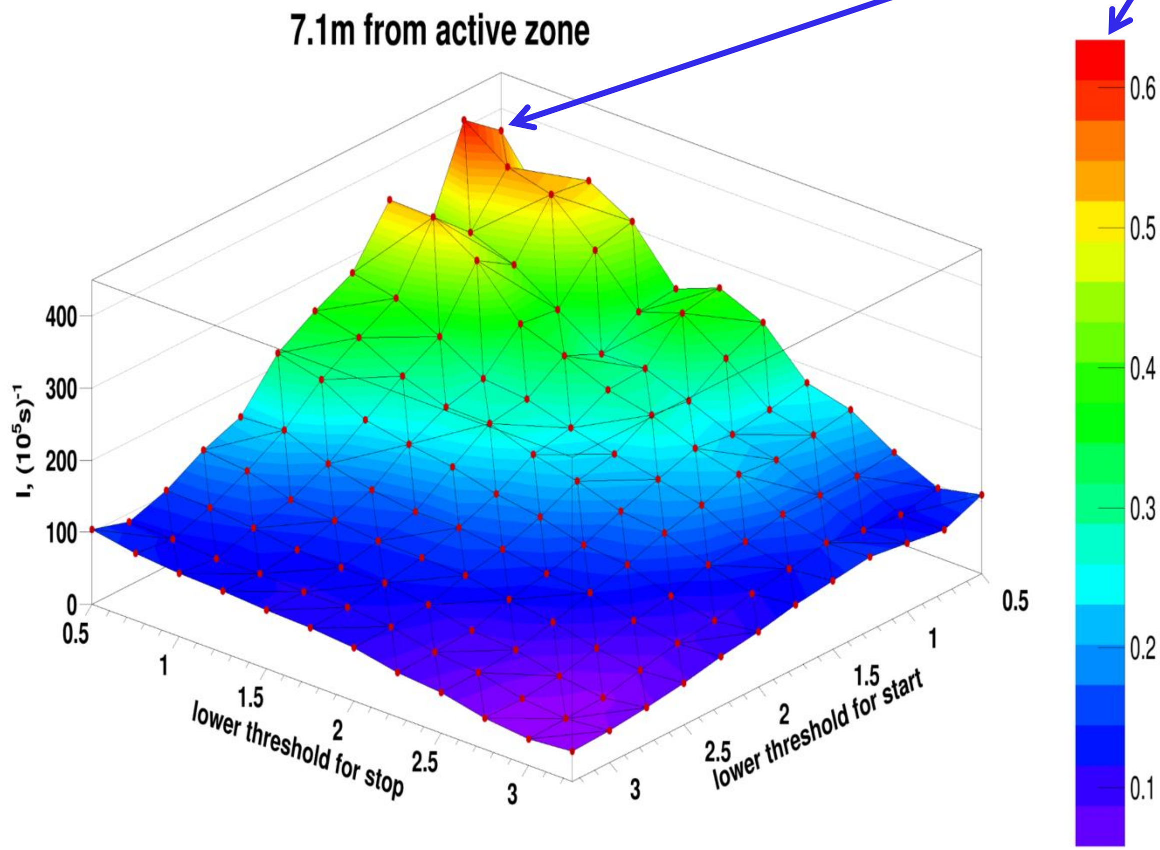


Second version of active shielding

(thickness of plastic scitillator plates 12cm instead of 3cm)

On-Off effect dependence from lower start/stop thresholds

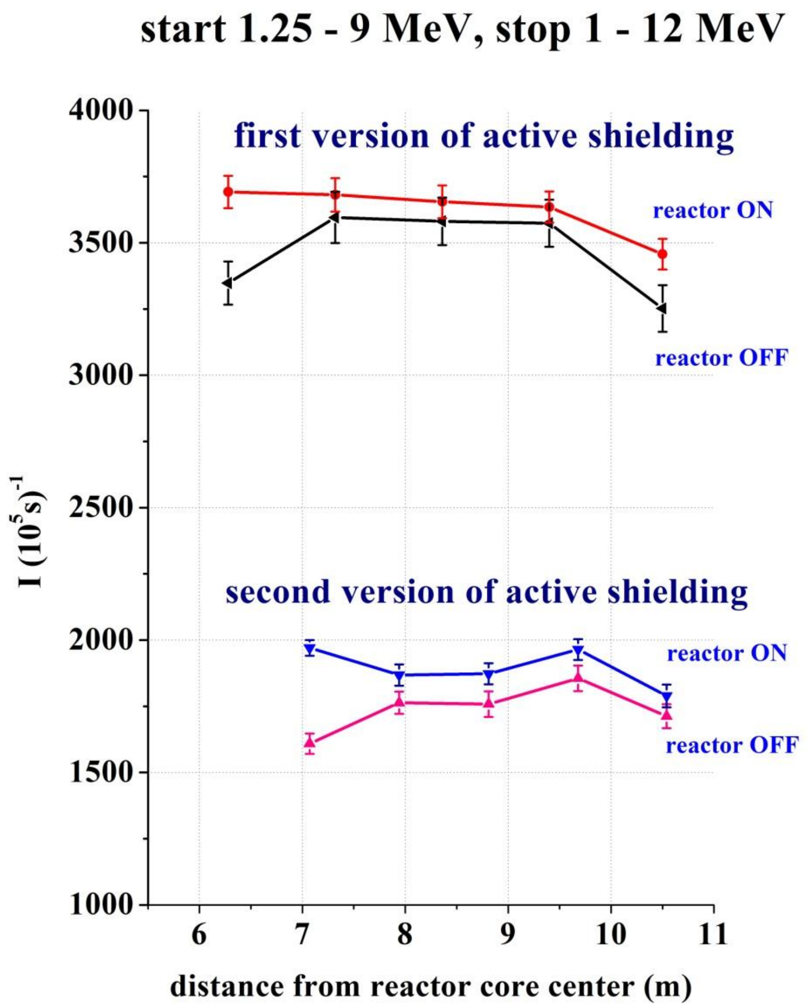
Efficiency of neutrino registration

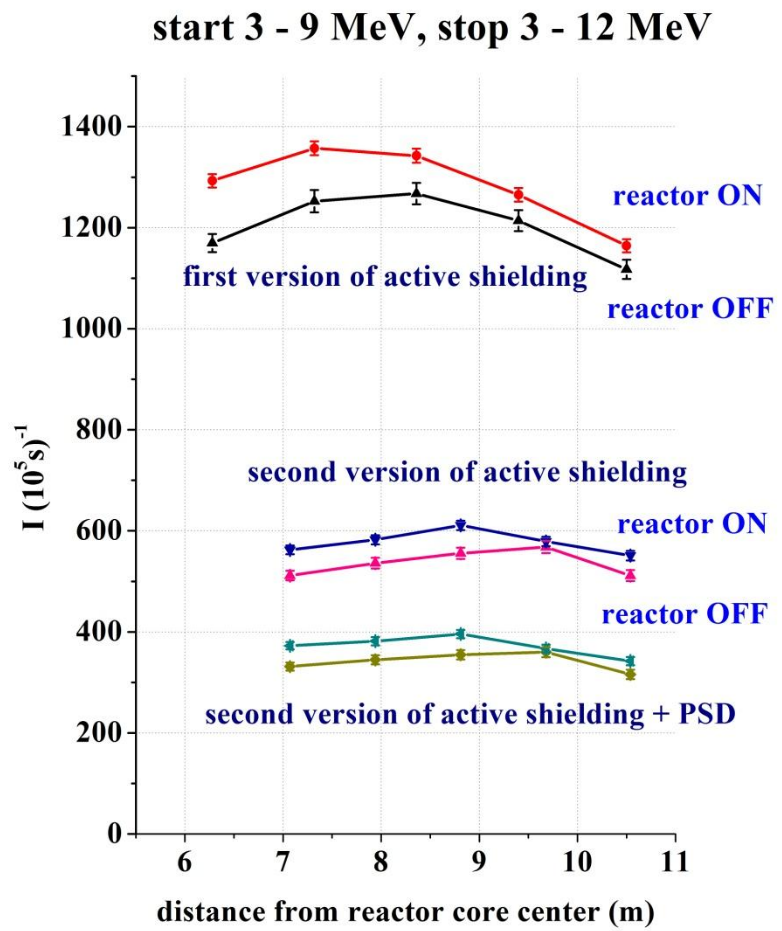


Maximum 60%

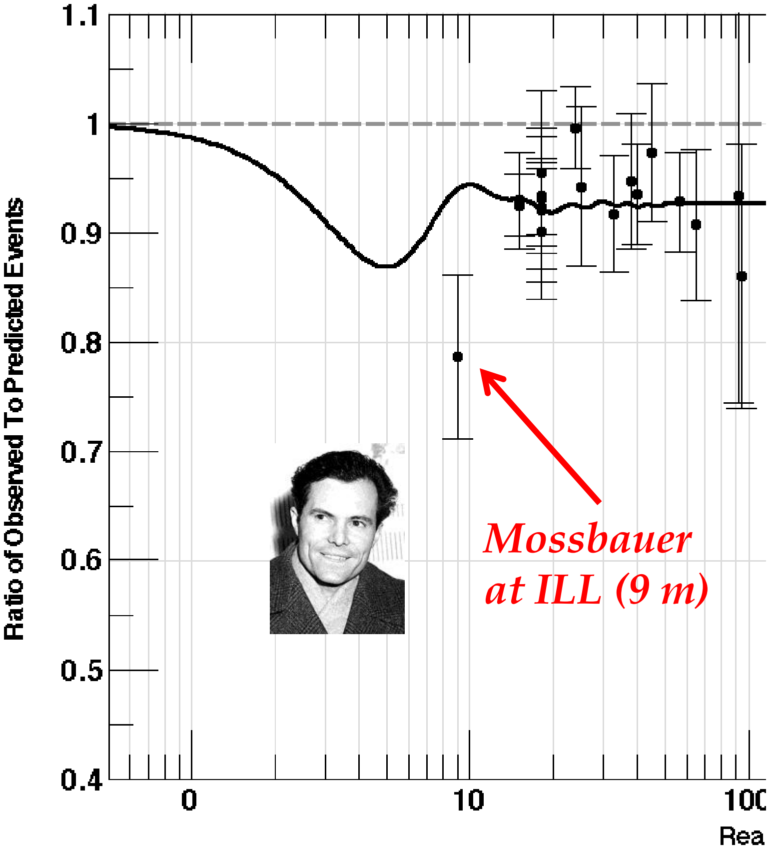
7.1 M,
Second version
of active shielding

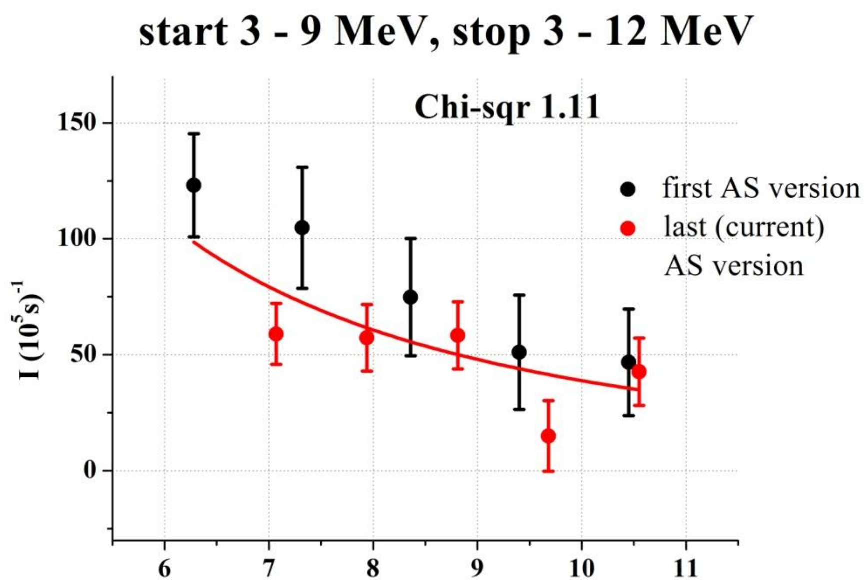
Stages of cosmic background suppression

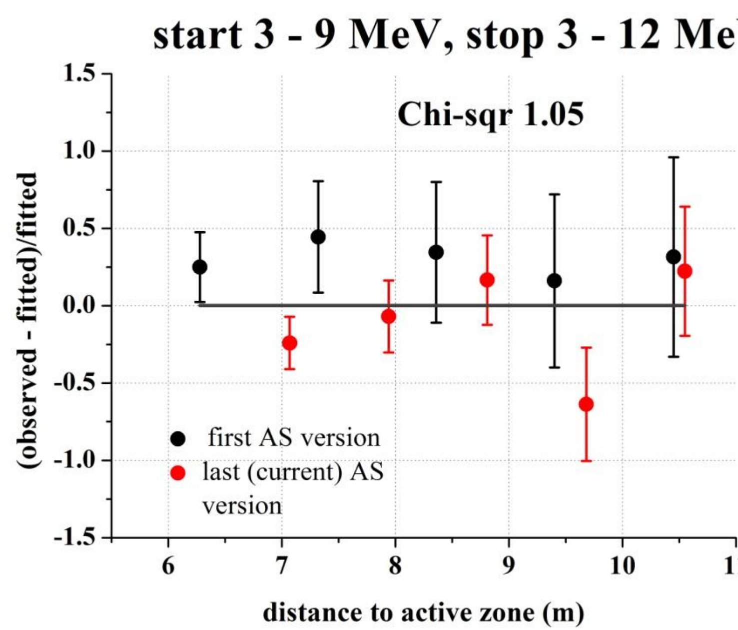




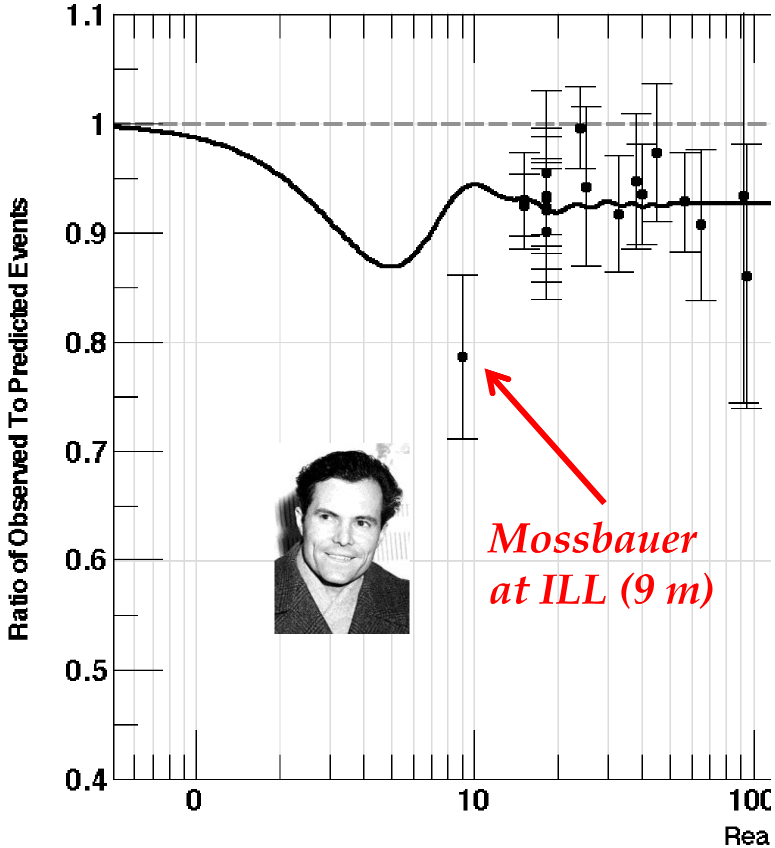
First measurements of 1/R^2 dependence at the short distances with prototype NEUTRINO-4 detector



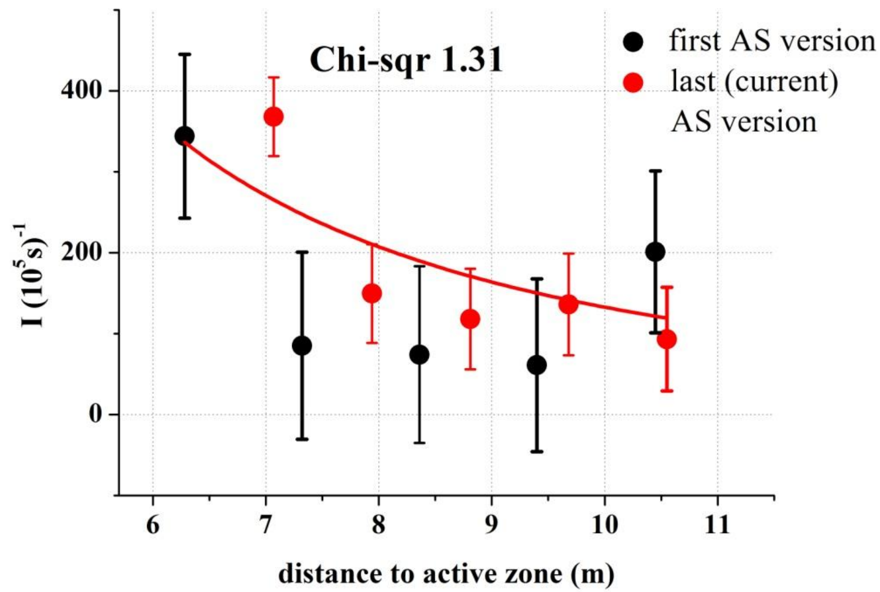




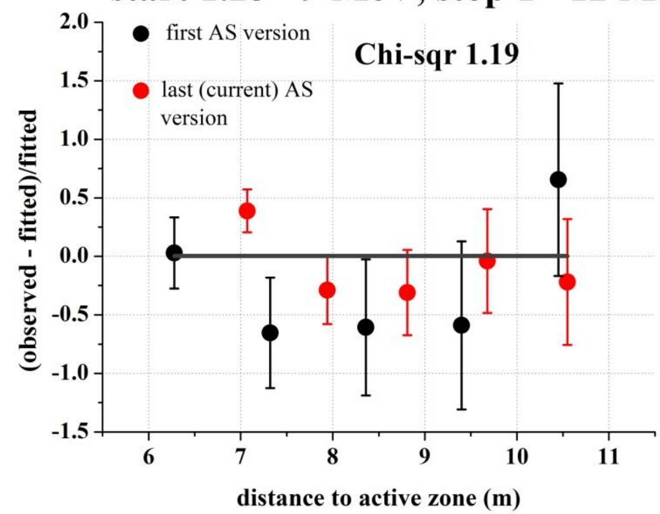
First measurements of 1/R² dependence at the short distances with prototype NEUTRINO-4 detector



start 1.25 - 9, stop 1 - 12 MeV



start 1.25 - 9 MeV, stop 1 - 12 MeV



Production of the full-scale NEUTRINO-4 detector

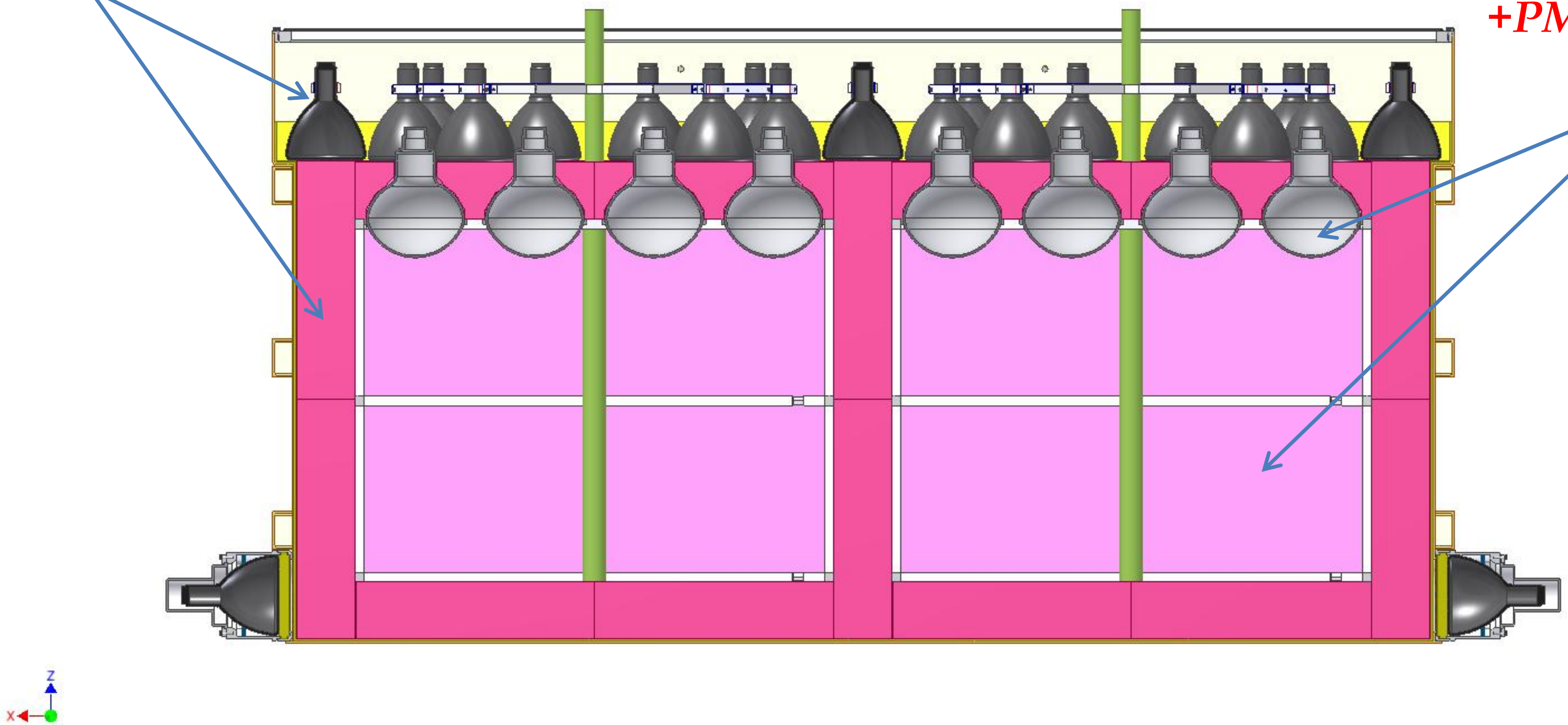
1.3 м³

Active shielding from liquid scintillator + PMT

Sensitivity increasing is one order of magnitude with respect to model

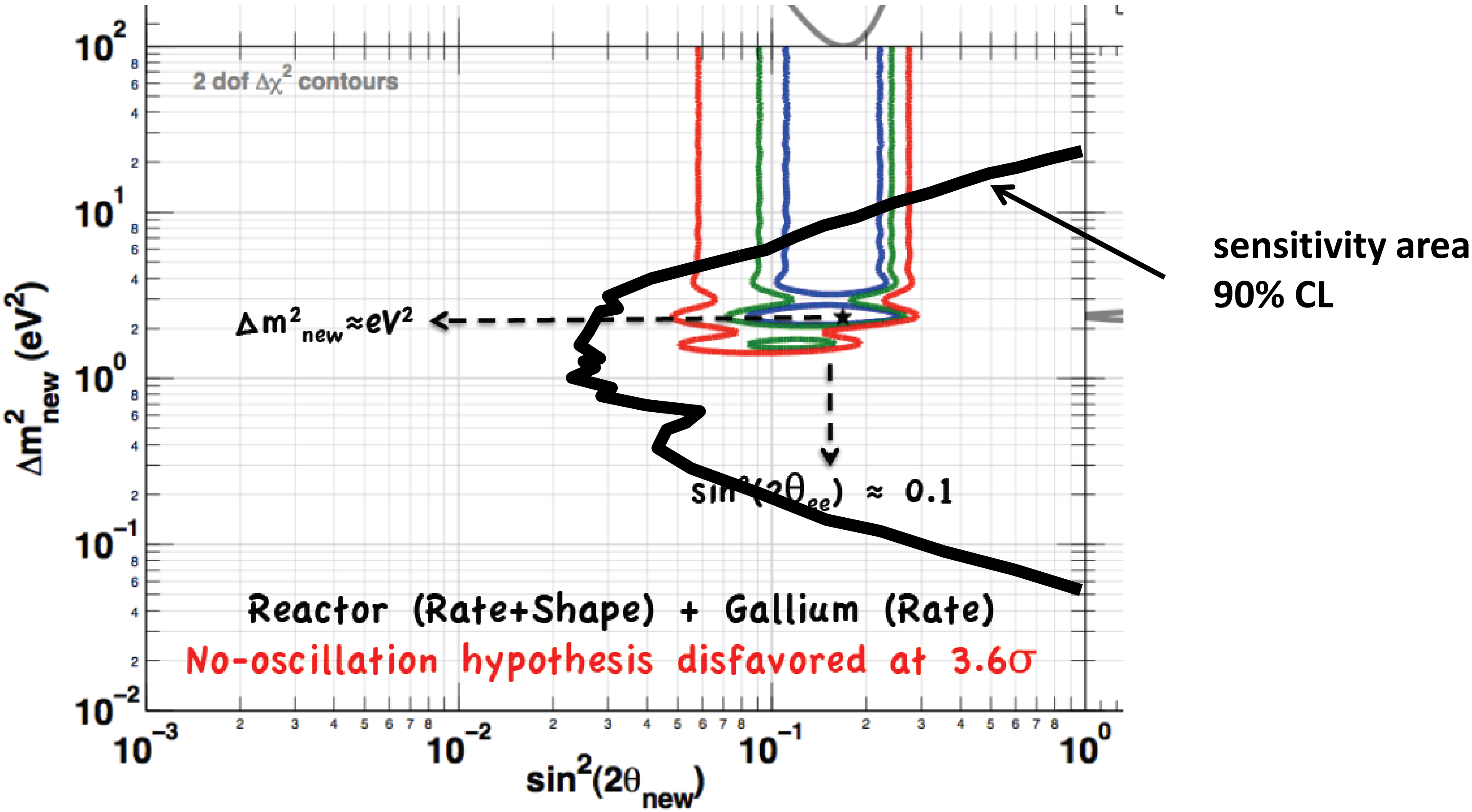
1.6 м³

Liquid scintillator with Gd +PMT



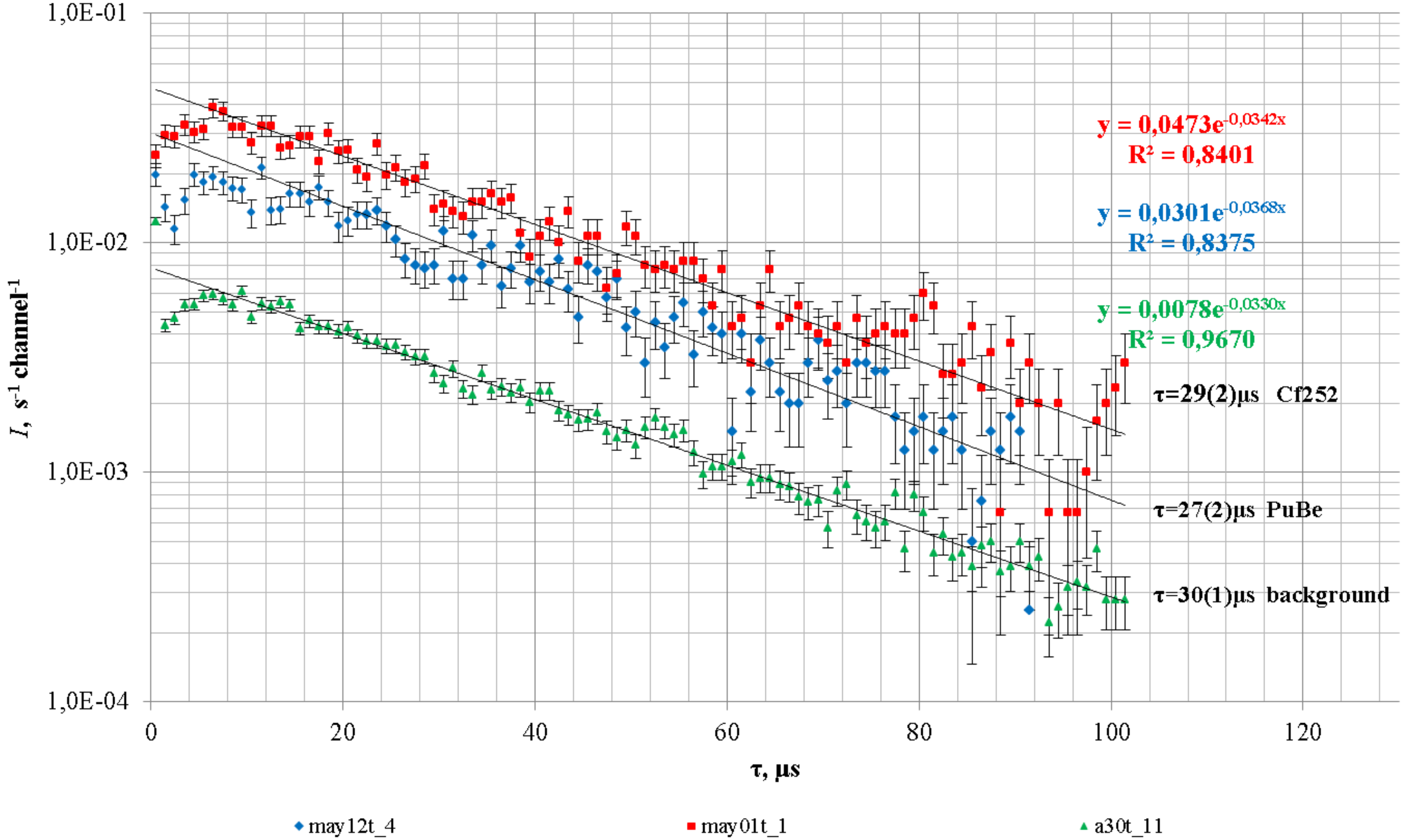
Serebrov (PNPI, Gatchina, Russia)

Possible area of sesitivity of NEUTRINO-4 experiment



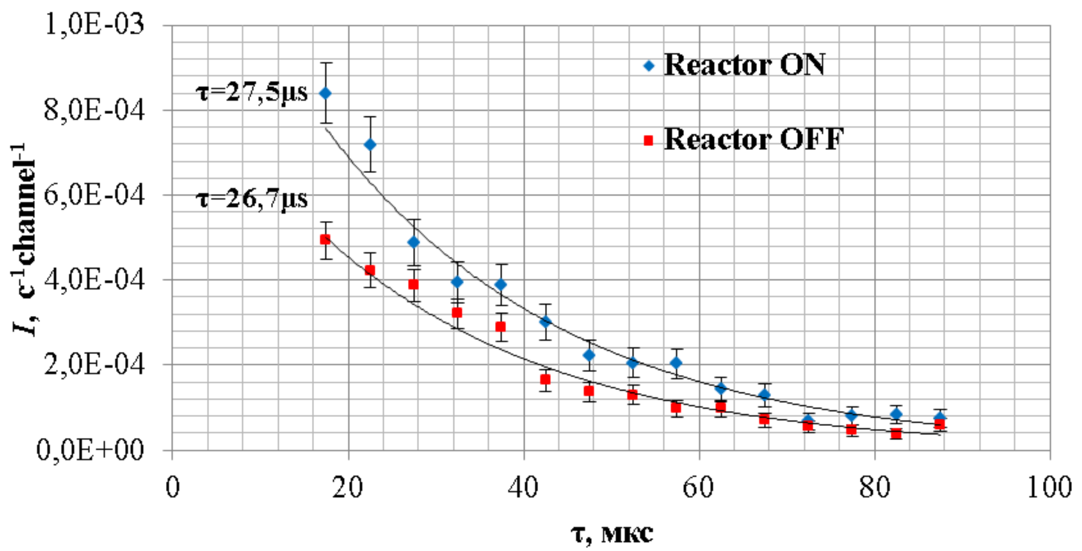
Thank you for attention

Calibration of neutron capture exponent with neutron sources PuBe (n), Cf252 (3.5n)



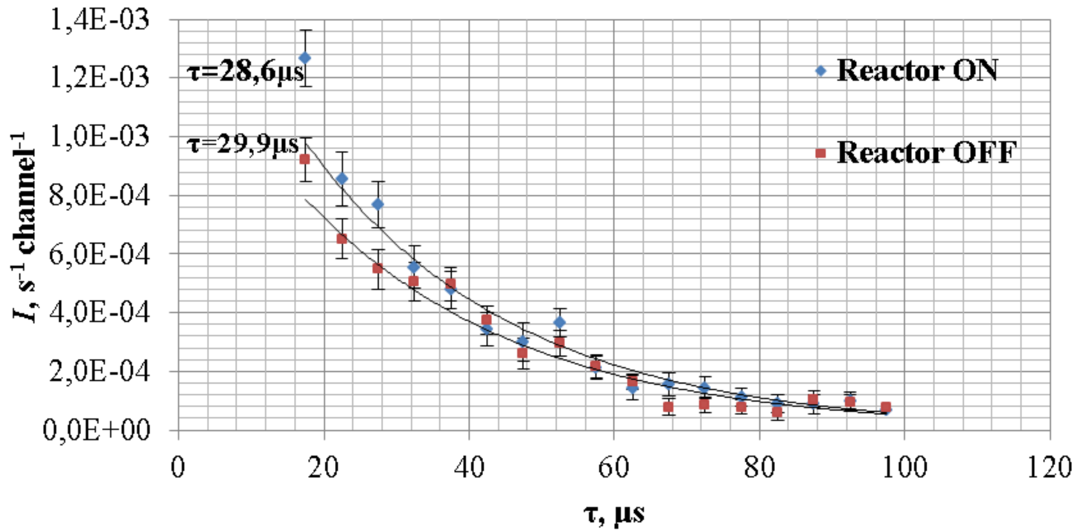
The first attempt to detect antineutrino from WWR-M reactor
and very preliminary results

the distance from the detector to the center of reactor core 5.3 m

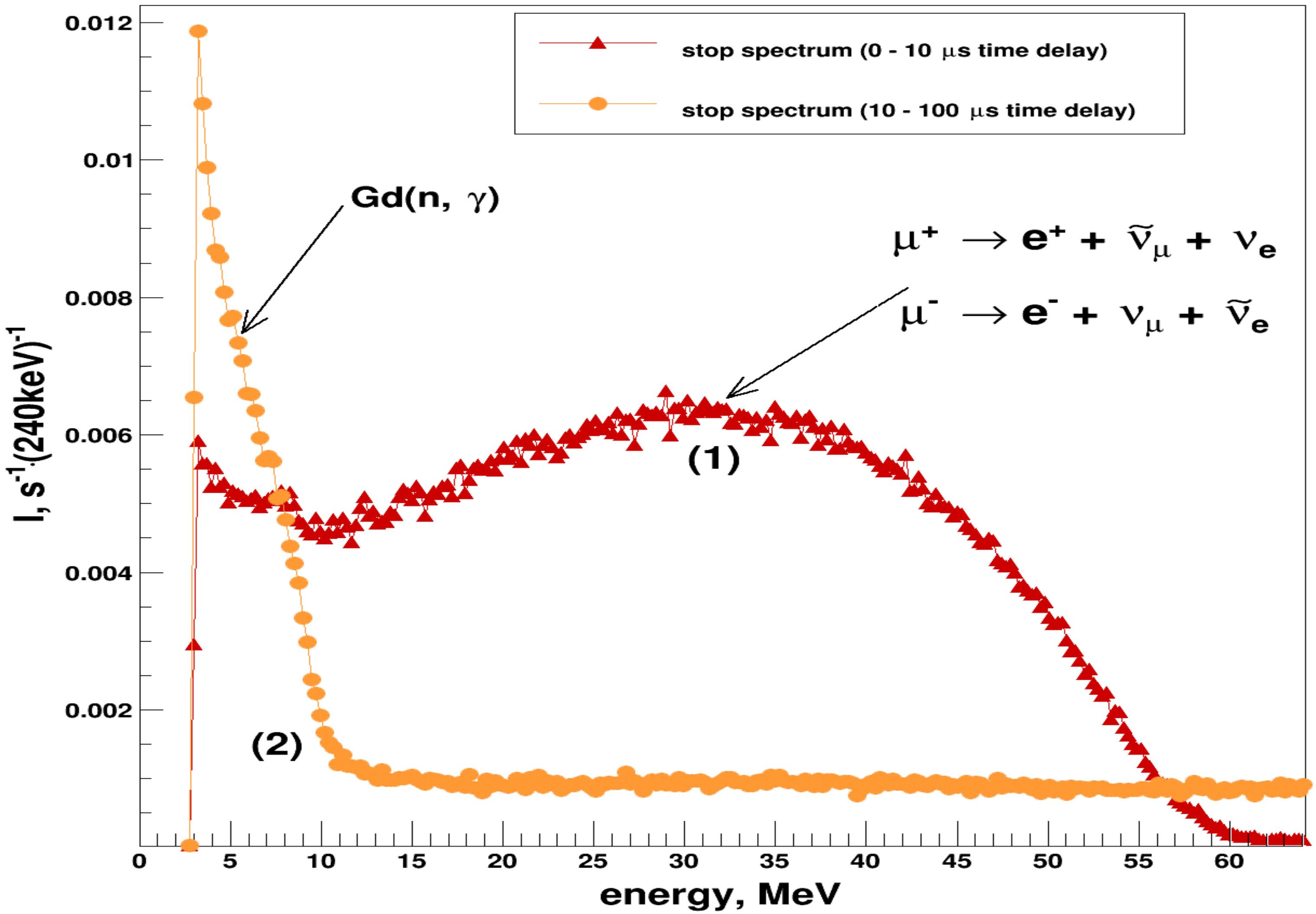


the mechanism of movement of the detector inside passive shielding

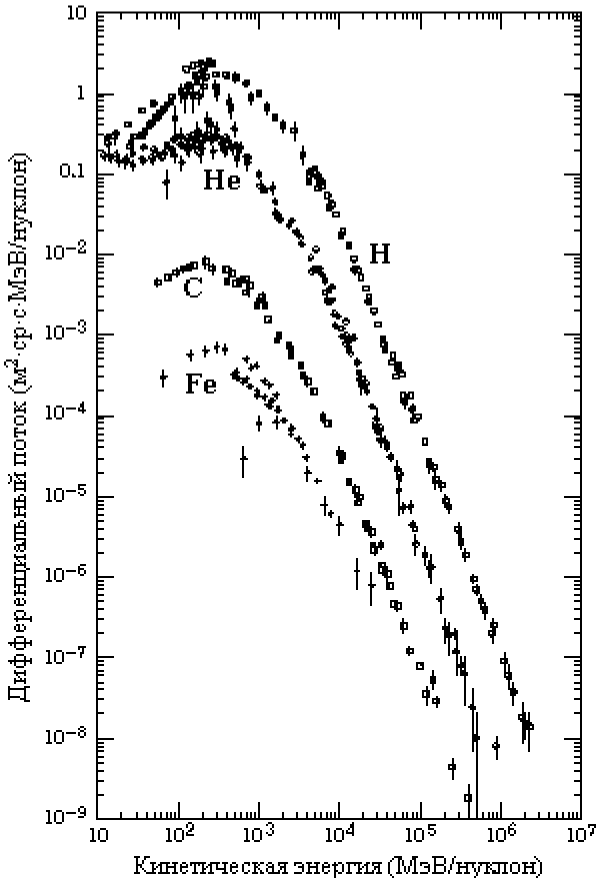
the distance from the detector to the center of reactor core 6.6 m

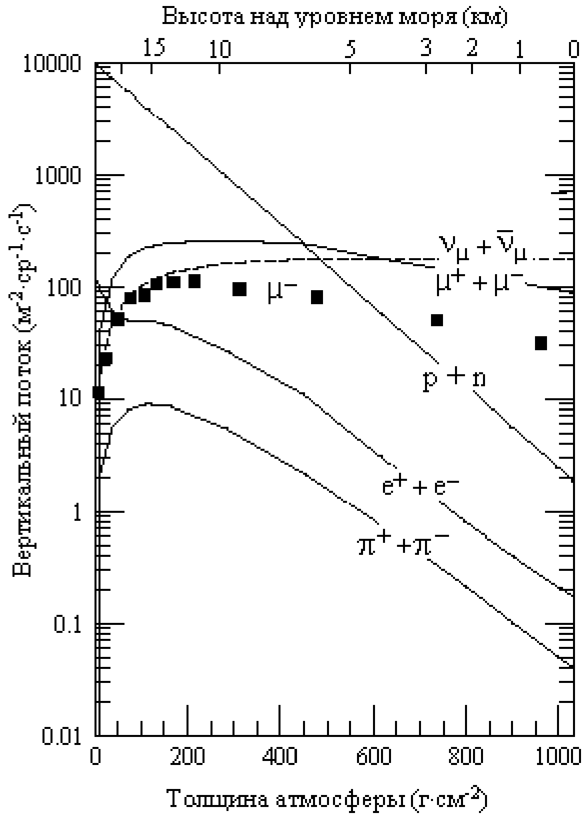


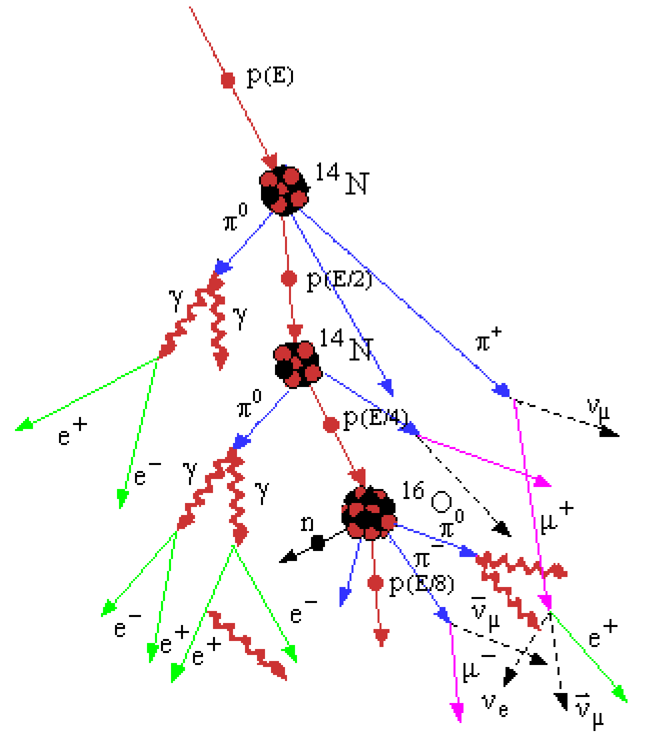
Energy spectrums of delayed signals in different time intervals: 0 – 10mcs (1) and 10 – 100mcs (2).



Cosmic background problem





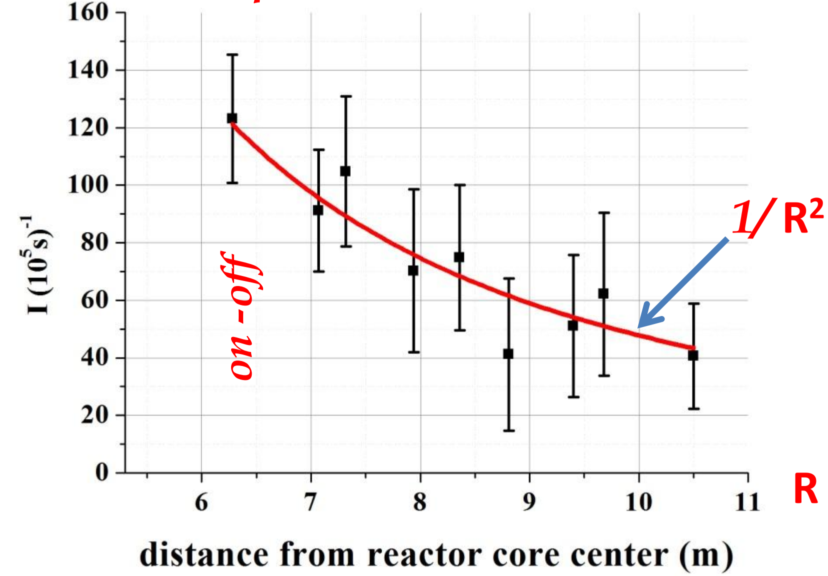


Secondary particle fluxes at sea level in middle latitudes approximately are:

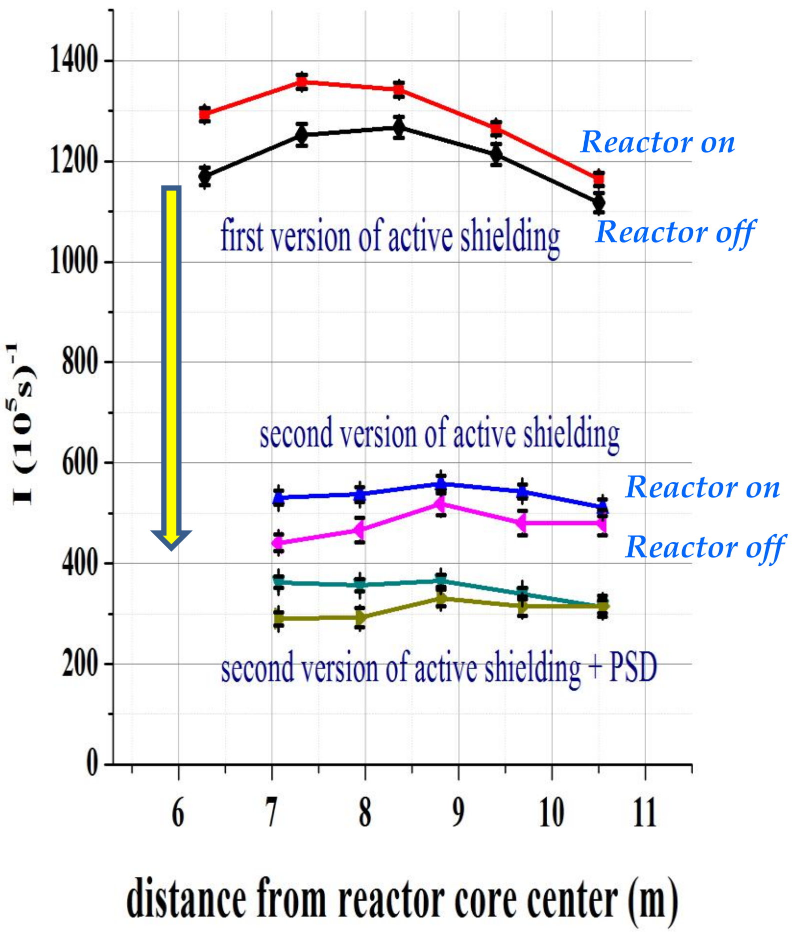
muons	1.5 10^{-2} muon/cm^2 s;
neutrons with E less than 10 MeV	$3{\cdot}10^{-3}$ neutron/ cm^2 s;
neutrons with E larger than 10 MeV	$4{\cdot}10^{-3}$ neutron/ cm^2 s;

Measurements on the model of NEUTRINO-4 detector (0.4 m^3)

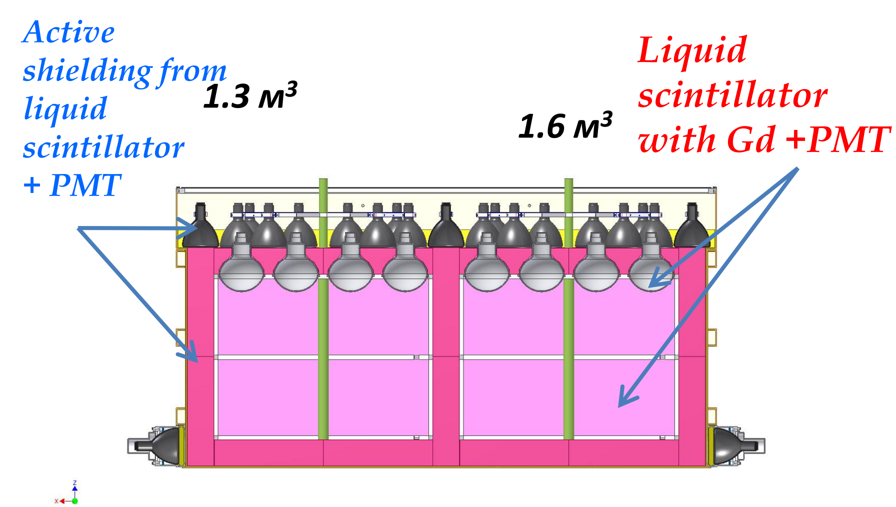
First measurements of $1/R^2$ dependence at the short distances



Stages of cosmic background suppression



Production of the full-scale NEUTRINO-4 detector



Serebrov (PNPI, Gatchina, Russia)

Experiment Neutrino-4 at reactor SM-3. First measurements of 1/R² dependence at the short distance

The neutrino laboratory for experiment search for a sterile neutrino is created at SM-3 reactor

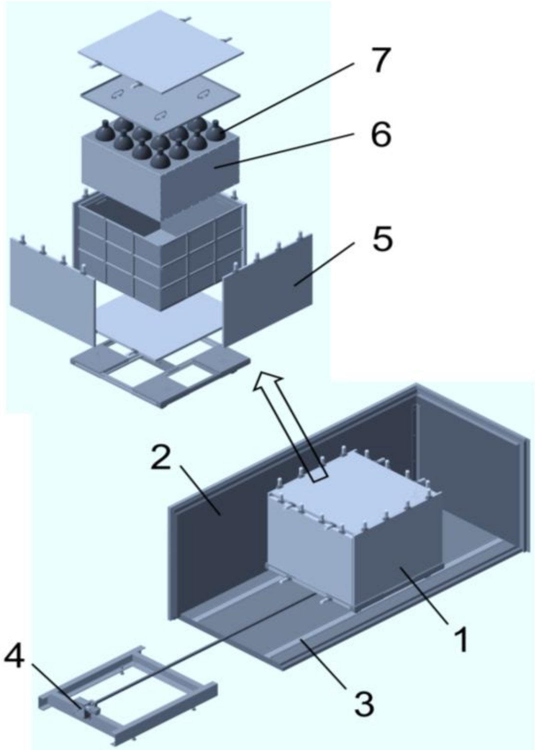
Range of measurements of the reactor antineutrino flux is 6 – 12 meters from the active reactor core

Passive shielding of 60 tons

Anatolii Serebrov
(PNPI, Gatchina, Russia)

for collaboration
PNPI NRC KI (Gatchina)
NRC KI (Moscow)
RIAR (Dimitrovgrad)
IHEP NRC KI (Protvino)

MODEL of NEUTRINO-4 detector, **400 l**



Neutrino channel outside and inside

The model of the neutrino detector installed in passive shielding
1 – detector of reactor antineutrino,
2 – passive shielding,
3 – rail,
4 – the engine for detector movement,
5 – active shielding with PMT,
6 – volume with liquid scintillator liquid with Gd (~ 400 l),
7 – Detector PMT.