Prospects of experiment Neutrino-4

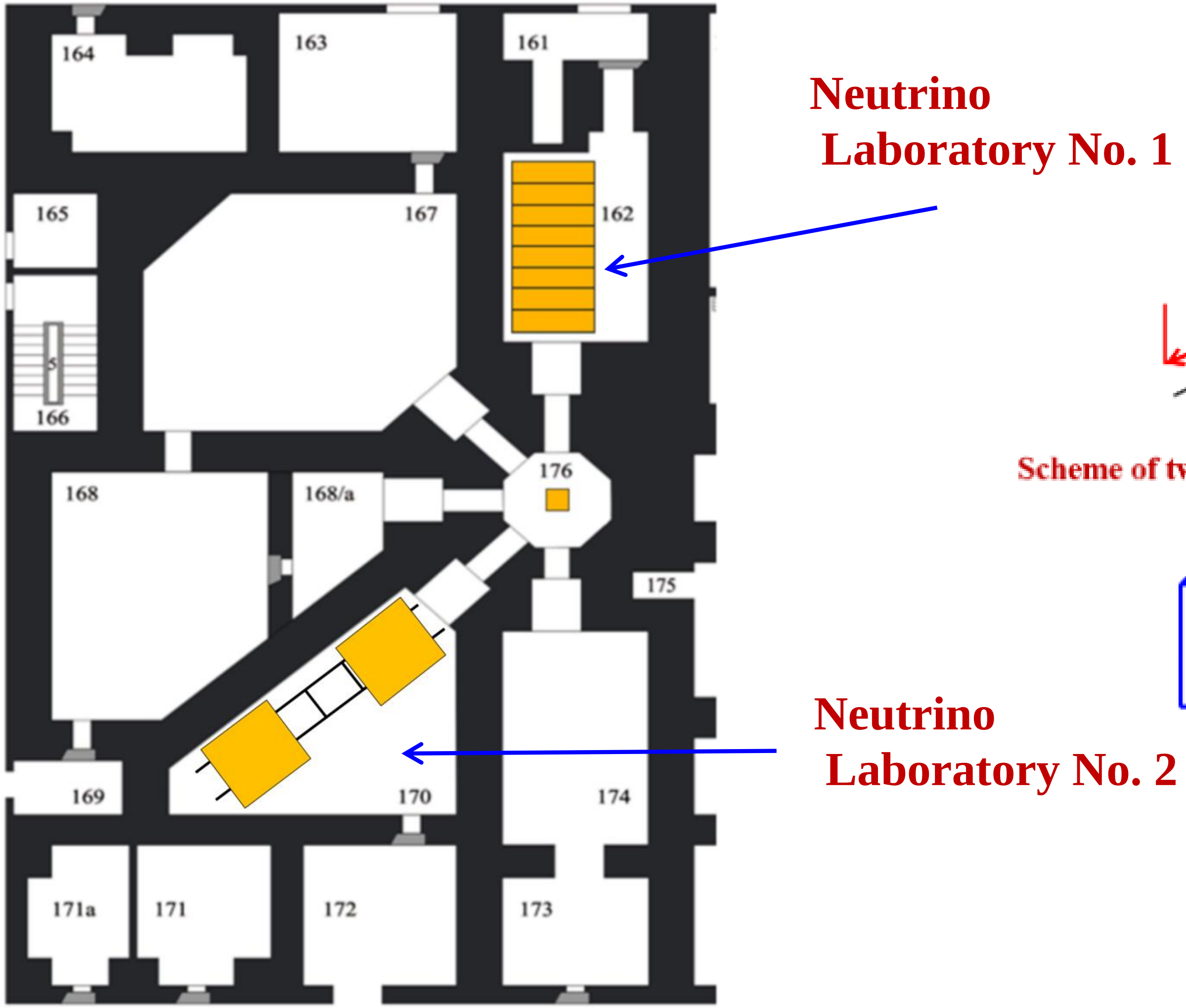
Collaboration Neutrino-4:

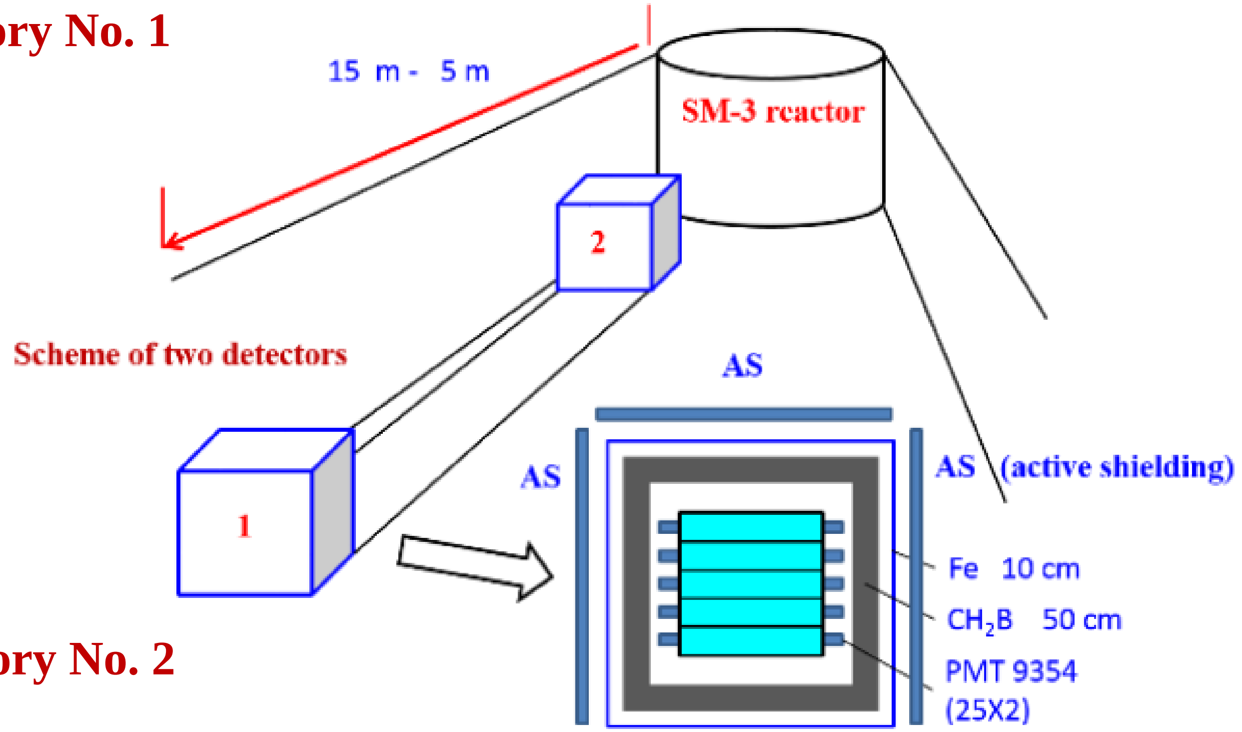
1. *NRC "KI" Petersburg Nuclear Physics Institute, Gatchina,*
2. *NRC "Kurchatov institute", Moscow,*
3. *JSC "SSC RIAR", Dimitrovgrad, Russia*
4. *DETI MEPhI, Dimitrovgrad, Russia*

Serebrov A.P., Ivochkin V. G., Samoilov R.M., Fomin A.K., Neustroev P.V., Golovtsov A.V., Chernyj A.V., Fedorov V.V., Gerasimov A.A., Zaytsev M.E., Chaikovskii M.E.

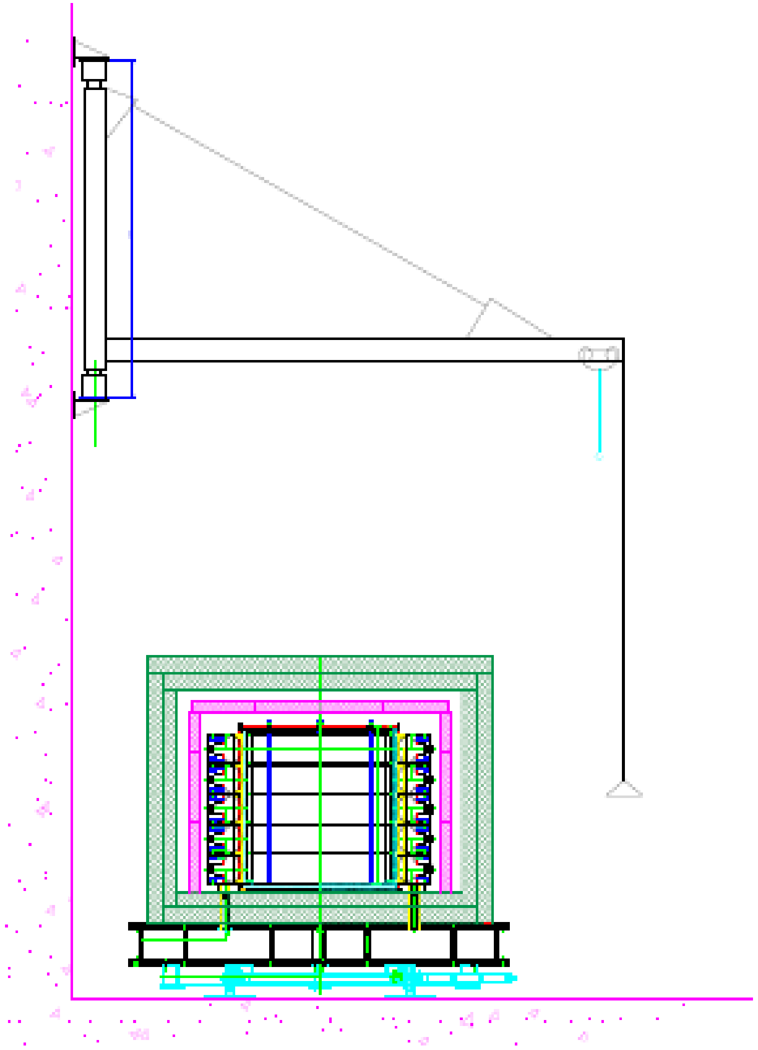
International Conference on Neutrinos and Dark Matter 2020,
Hurghada, Egypt

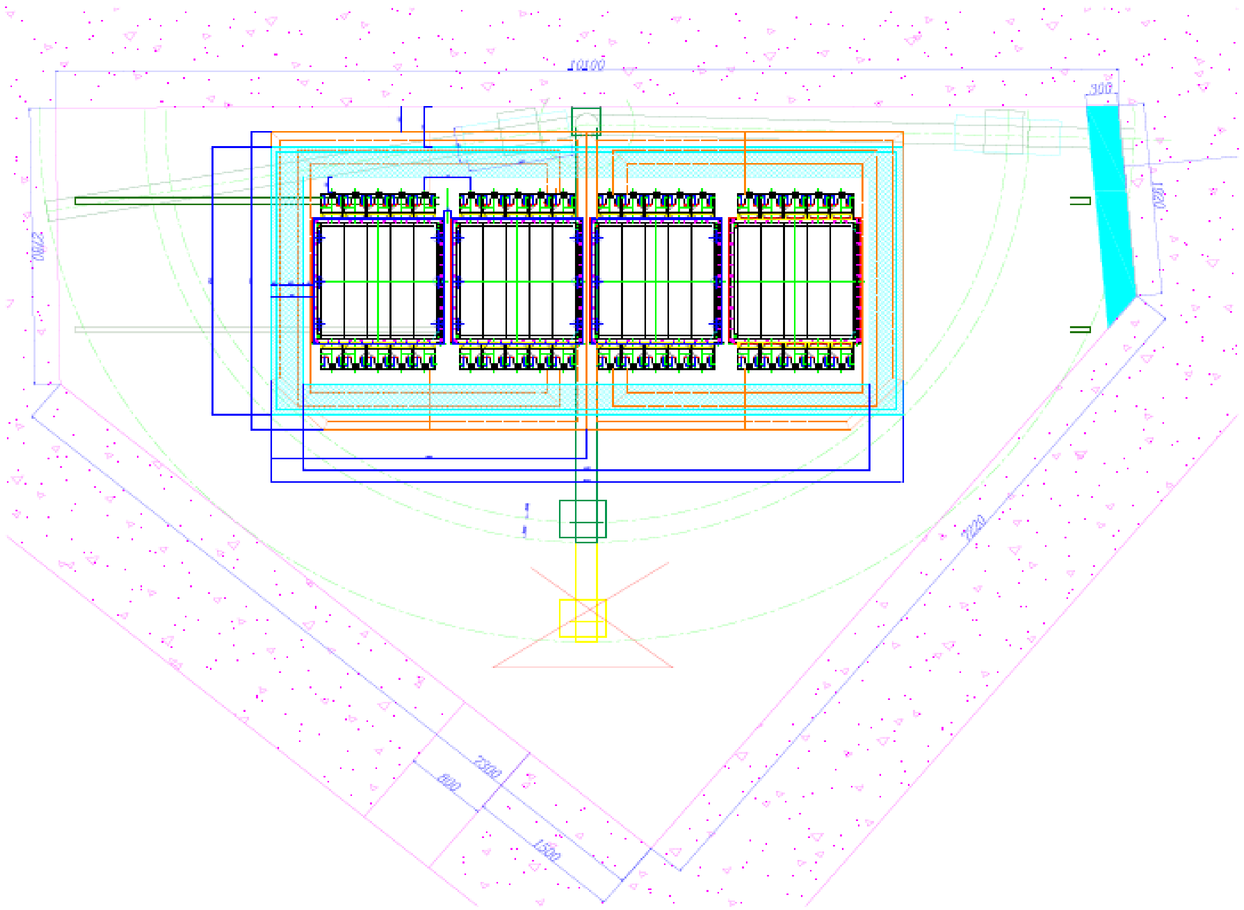
Future: Neutrino-6 experiment





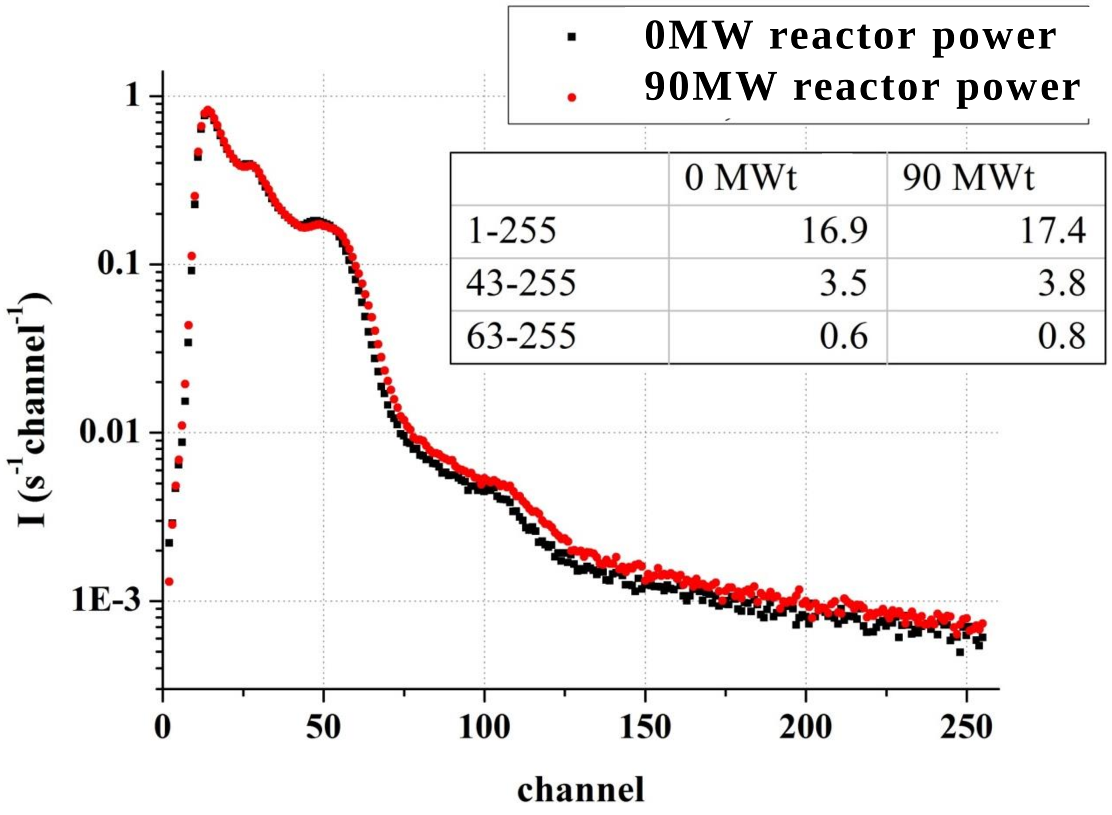
Neutrino-6 experiment location

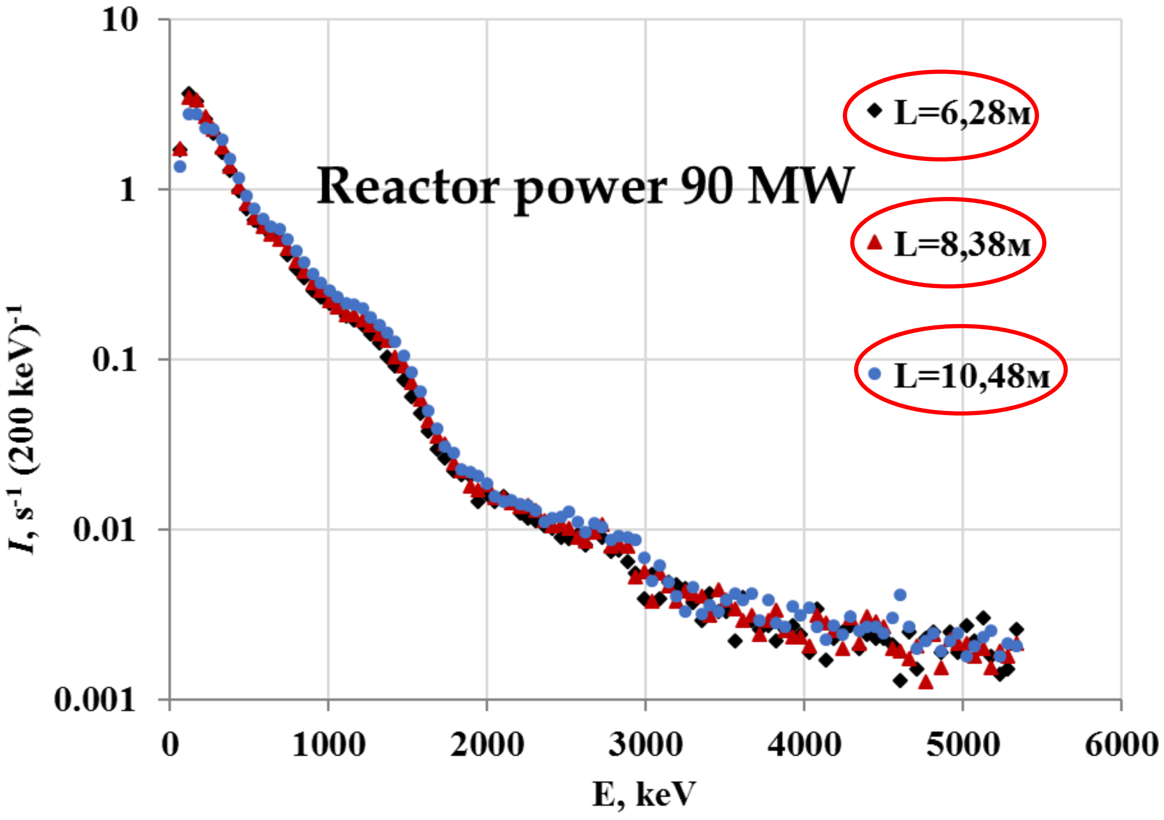




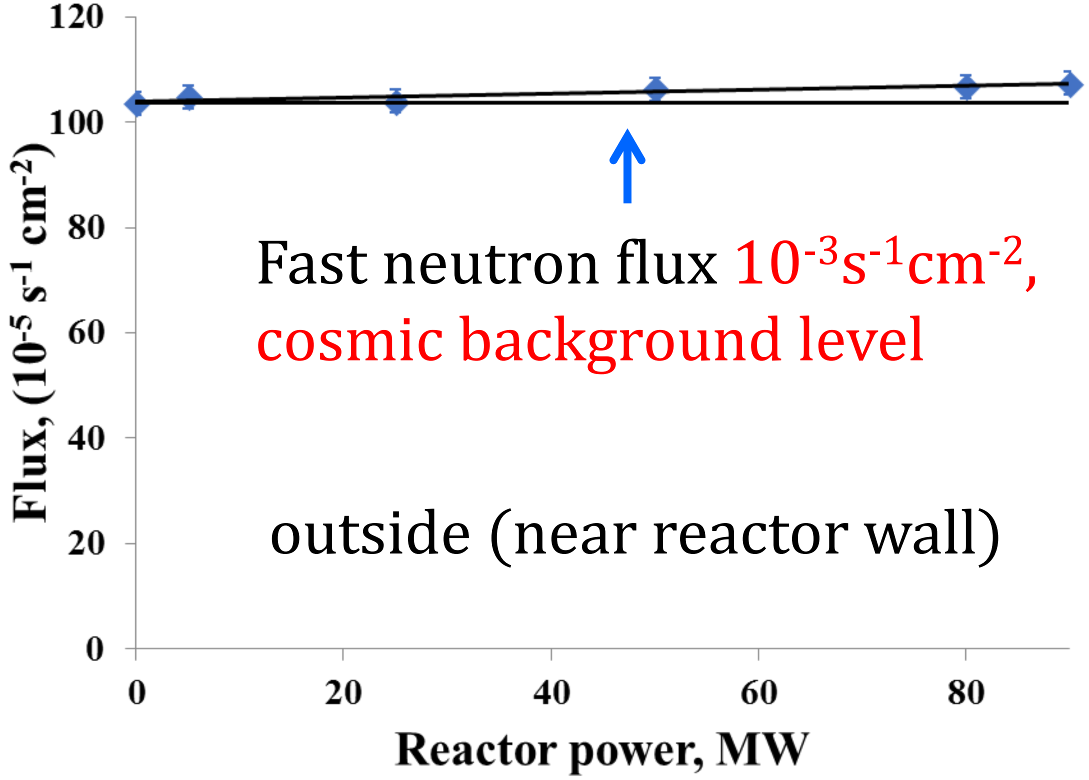
New room, same advantages
and same problems

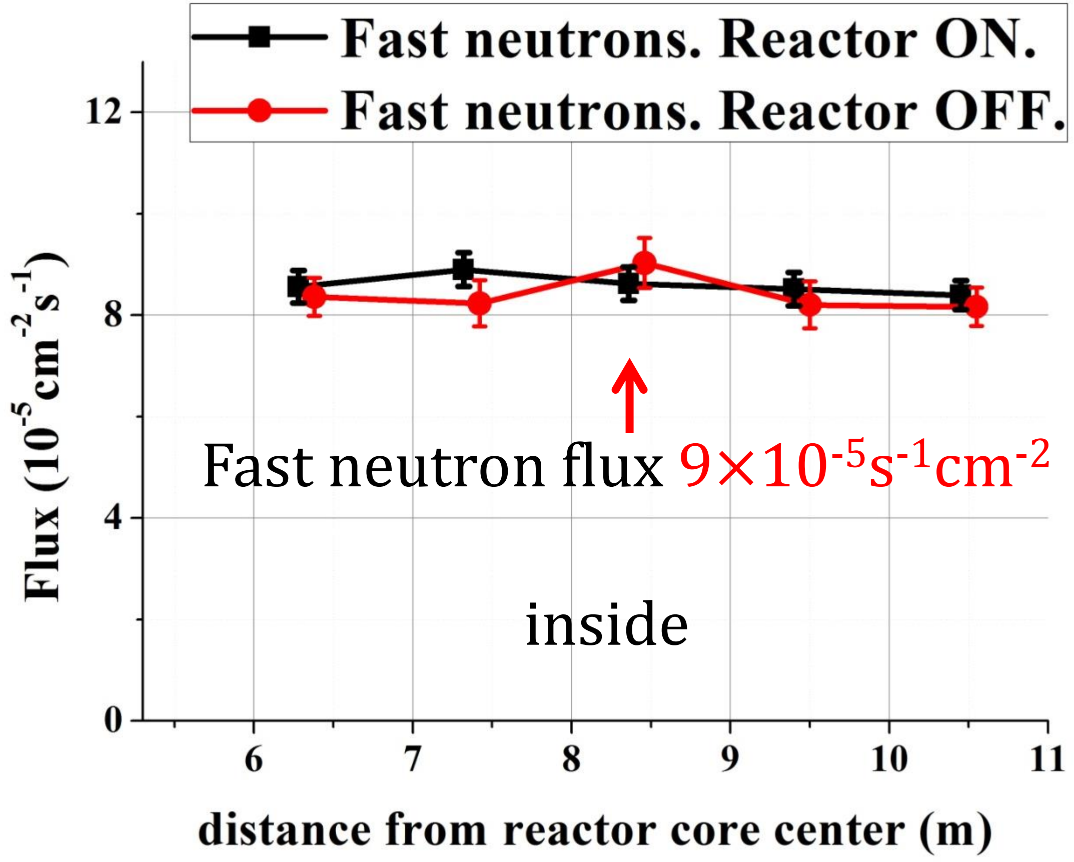
Gamma background in passive shielding does not depend neither on the power of the reactor nor on distance from the reactor





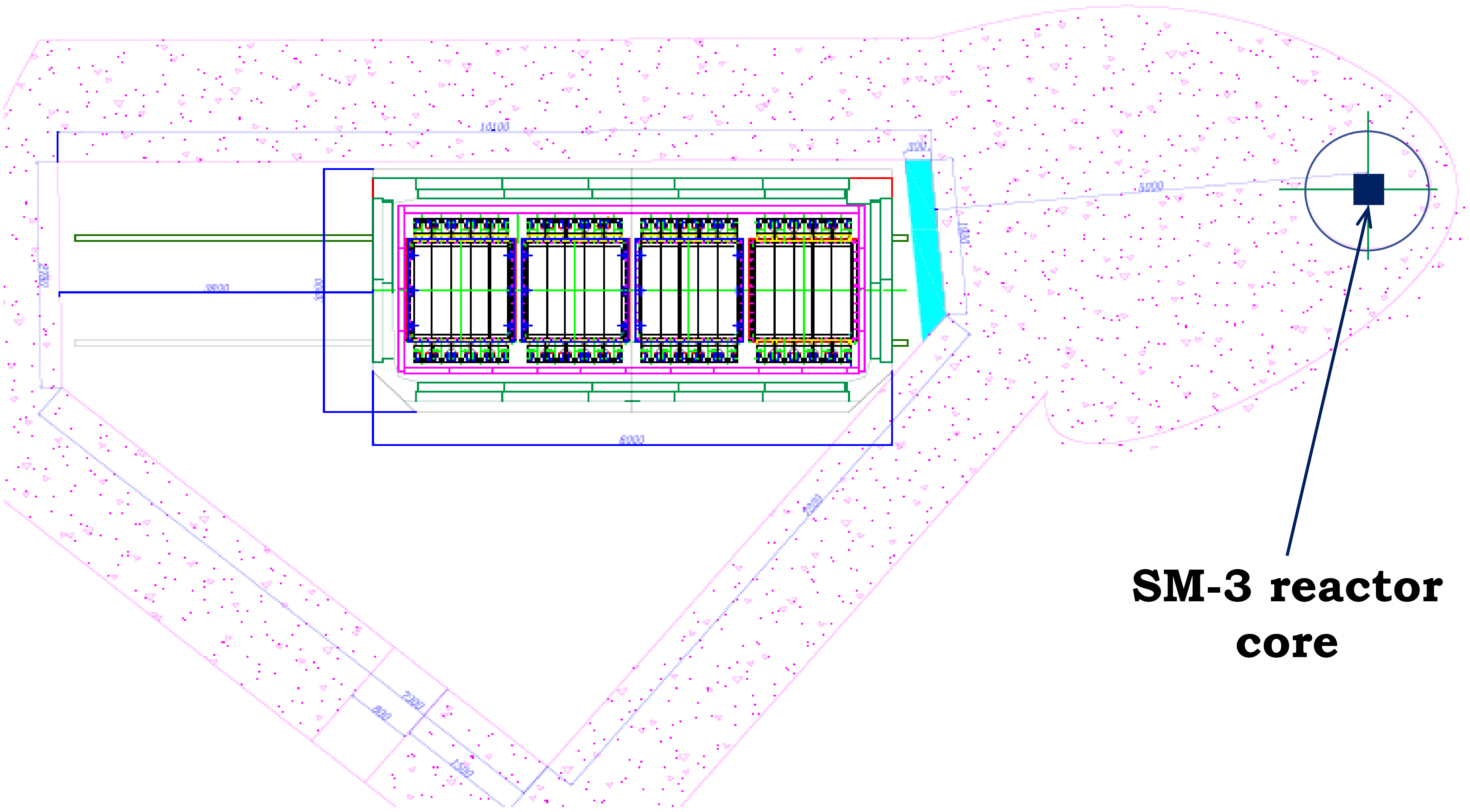
The background of fast neutrons in passive shielding does not depend neither on the power of the reactor nor on distance from the reactor



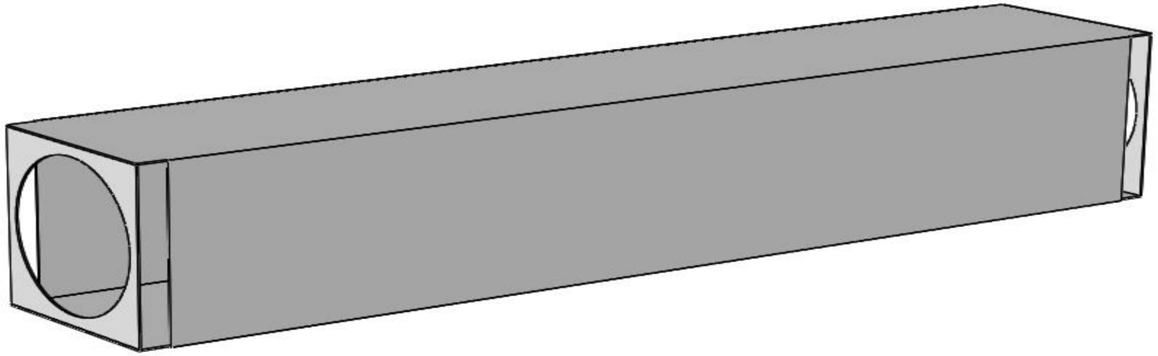


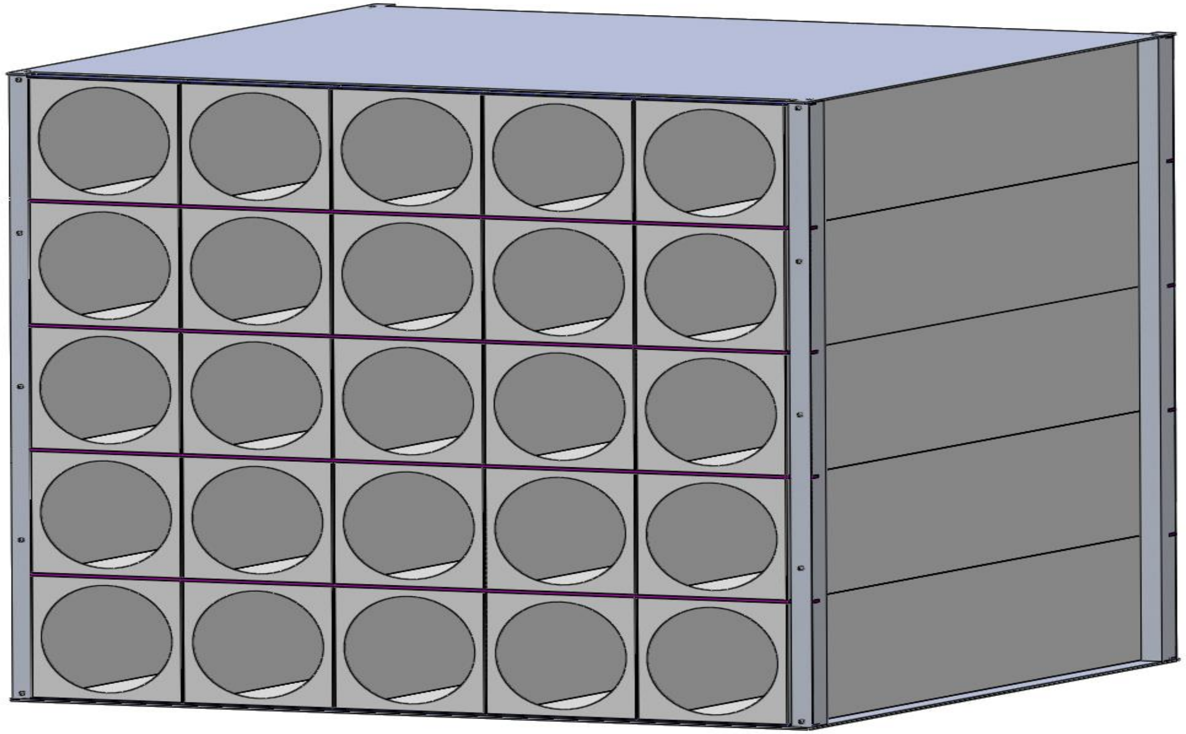
The background of fast neutrons in passive shielding is 10 times less than outside.
The background of fast neutrons outside of passive shielding is defined by cosmic rays and practically does not depend on reactor power.

Neutrino-6 experiment location



Detector's lightguides system

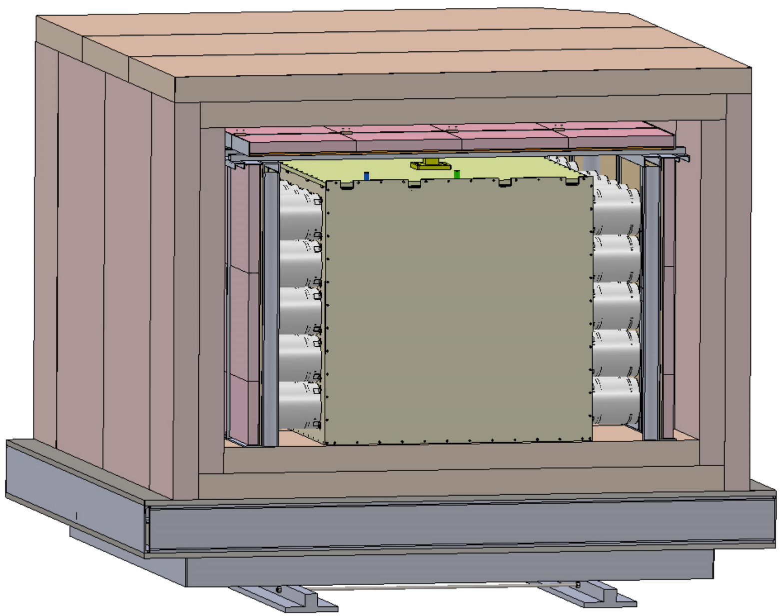


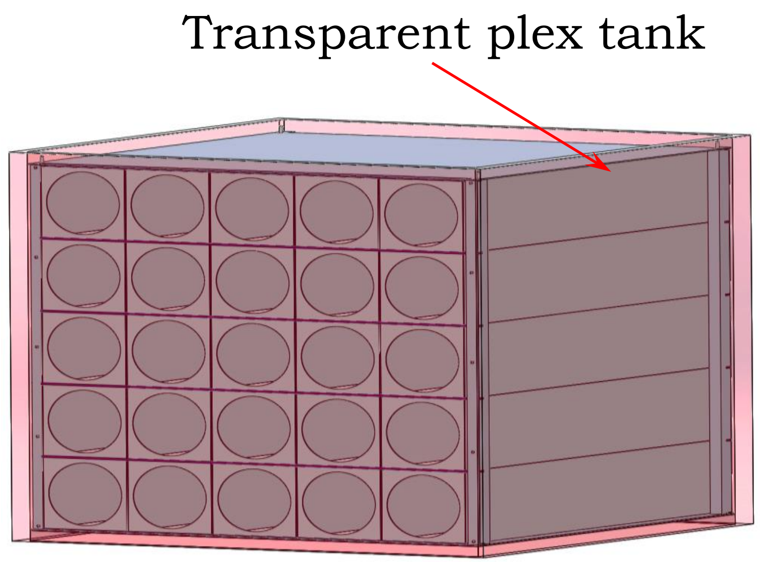


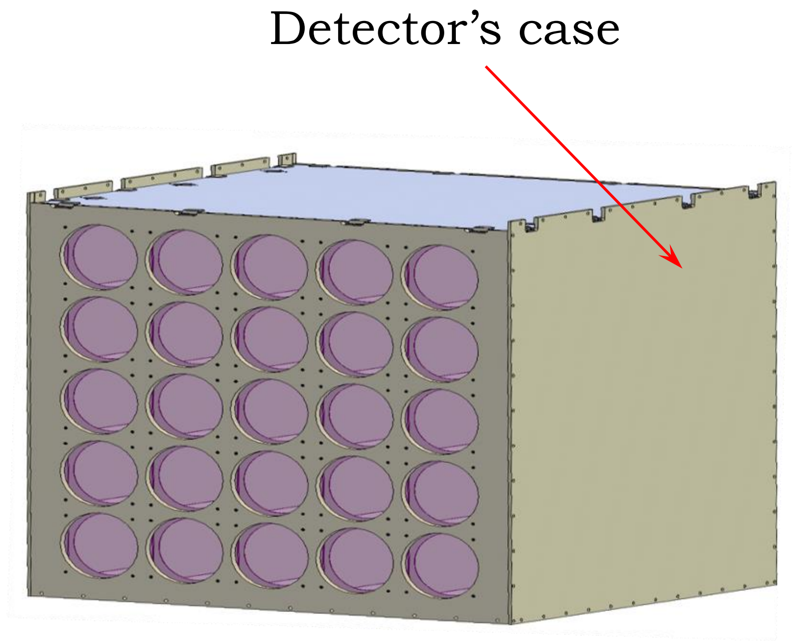
Lightguides system assembling

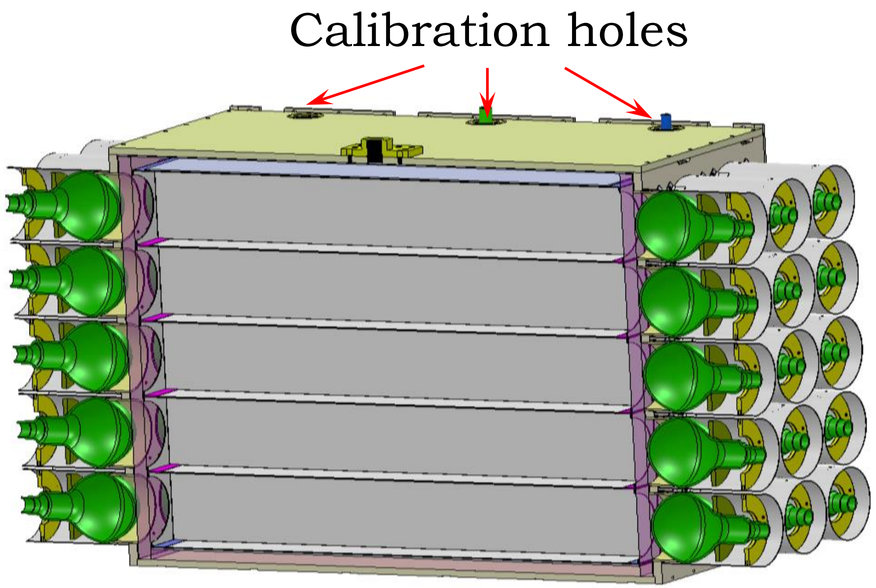
Detector's design. Models

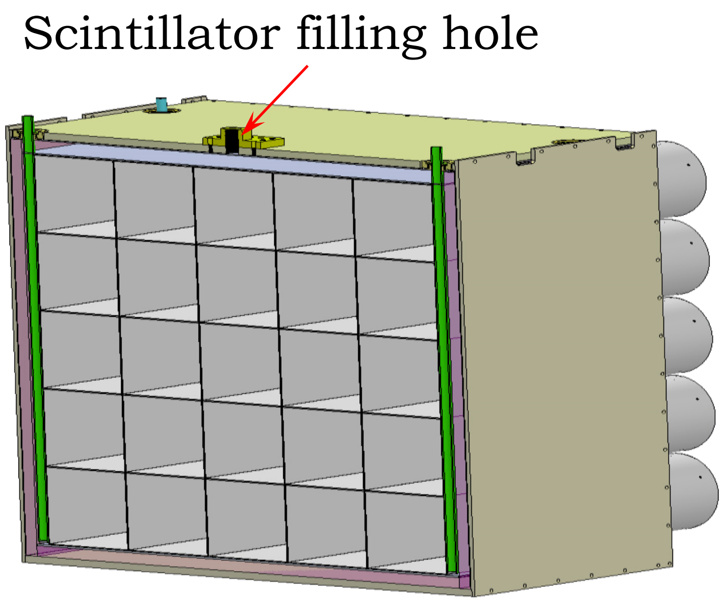
Detector fully assembled







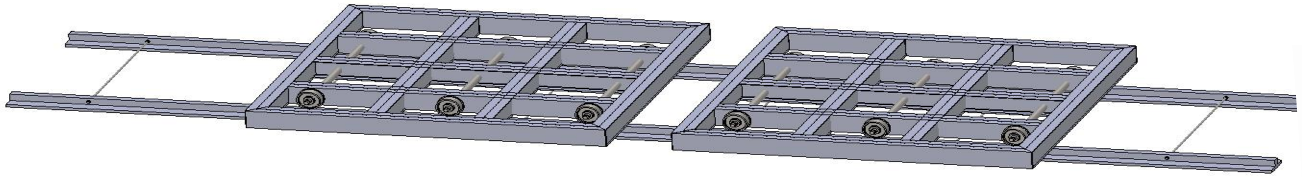




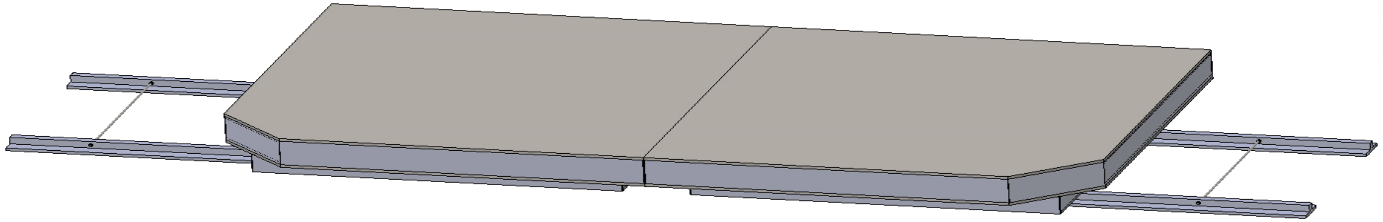
Detector’s design.
Transparent tank

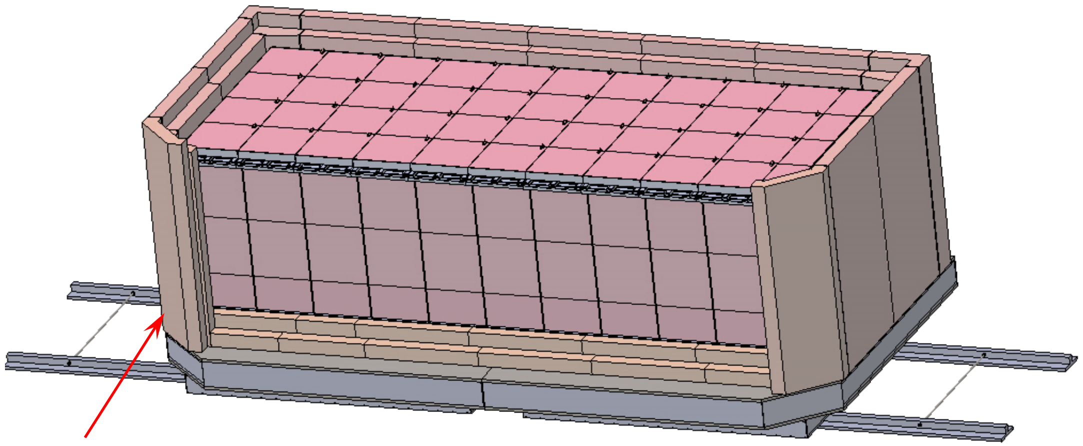
Detector’s design.
Case

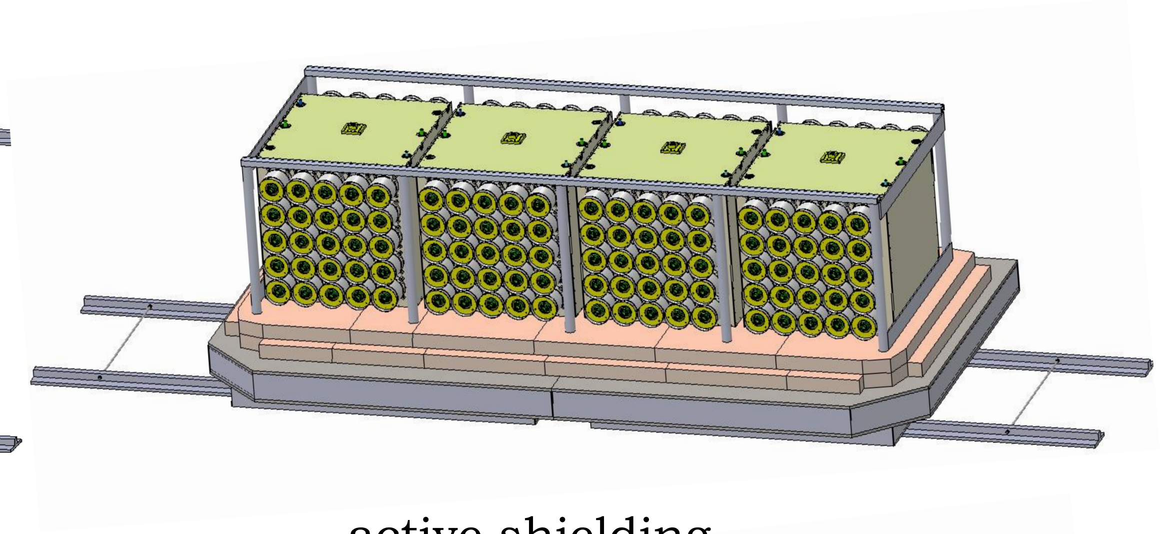
Detector’s design. Transport system

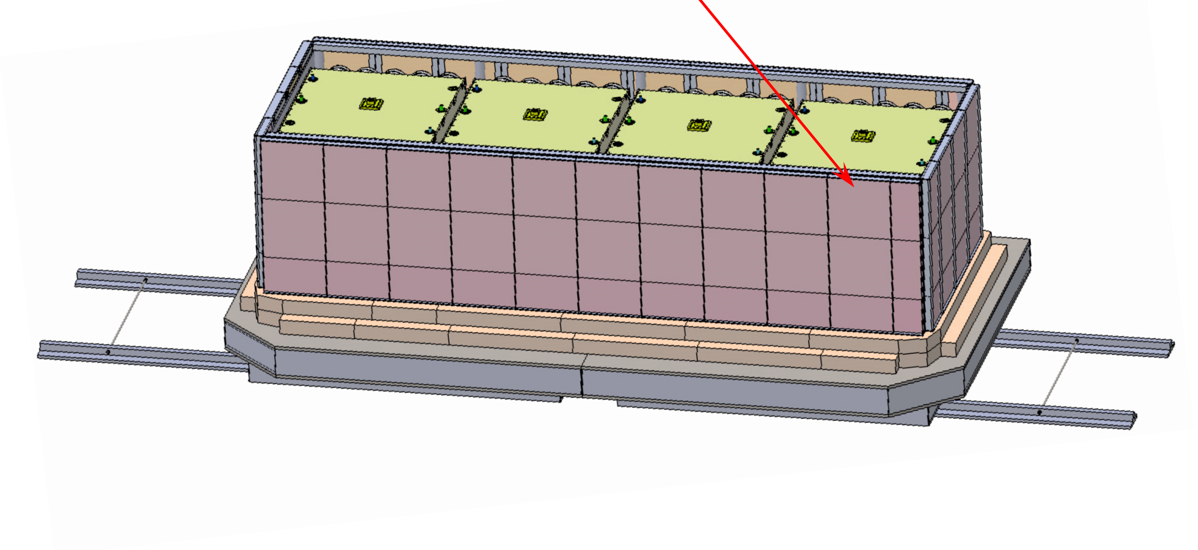


Rails, carts and platforms







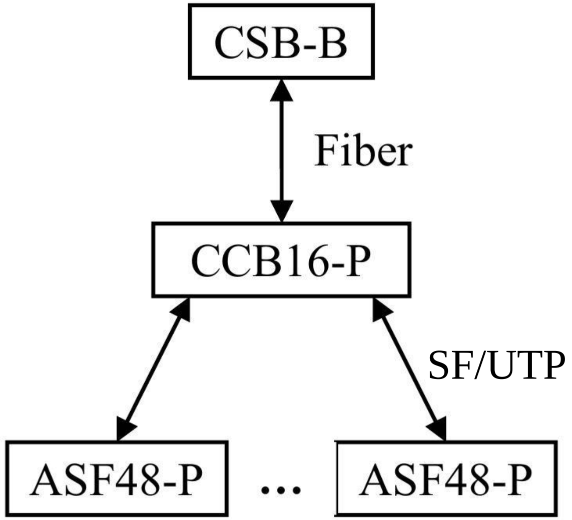


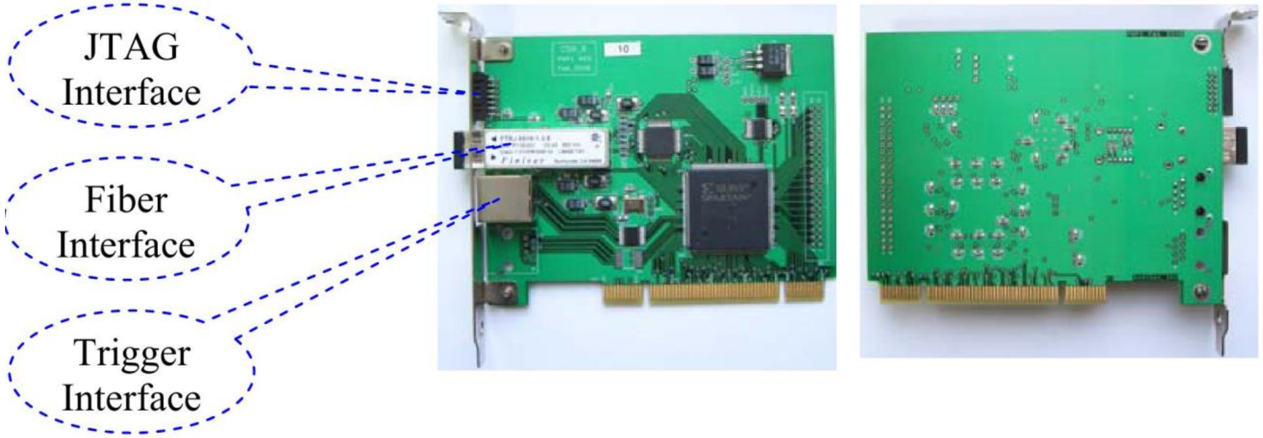
Detector's design.
Transport system

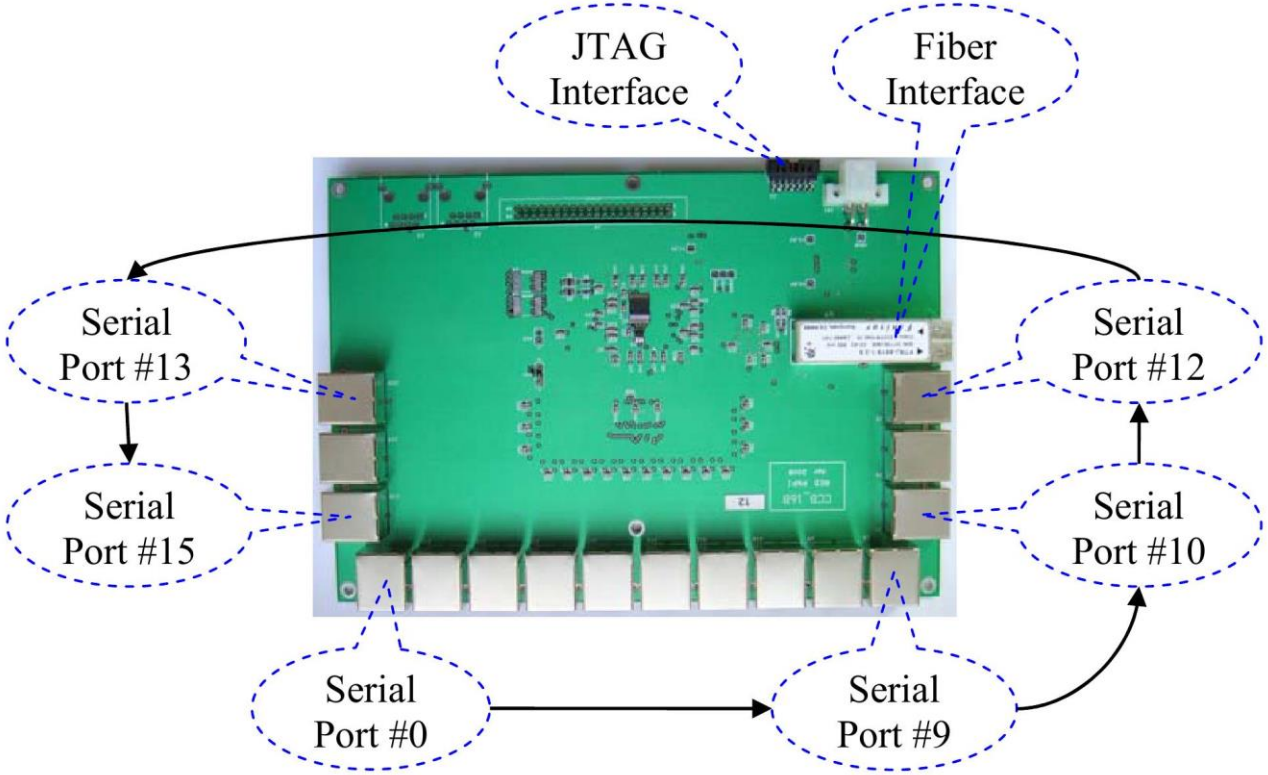
Platforms

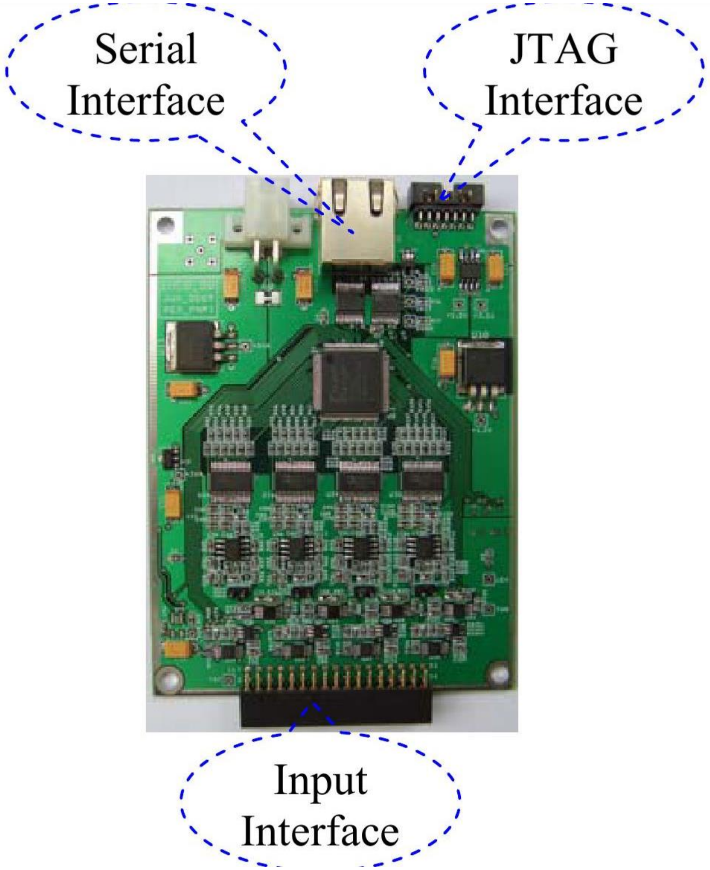
Inner cavities

Data acquisition system CROS3



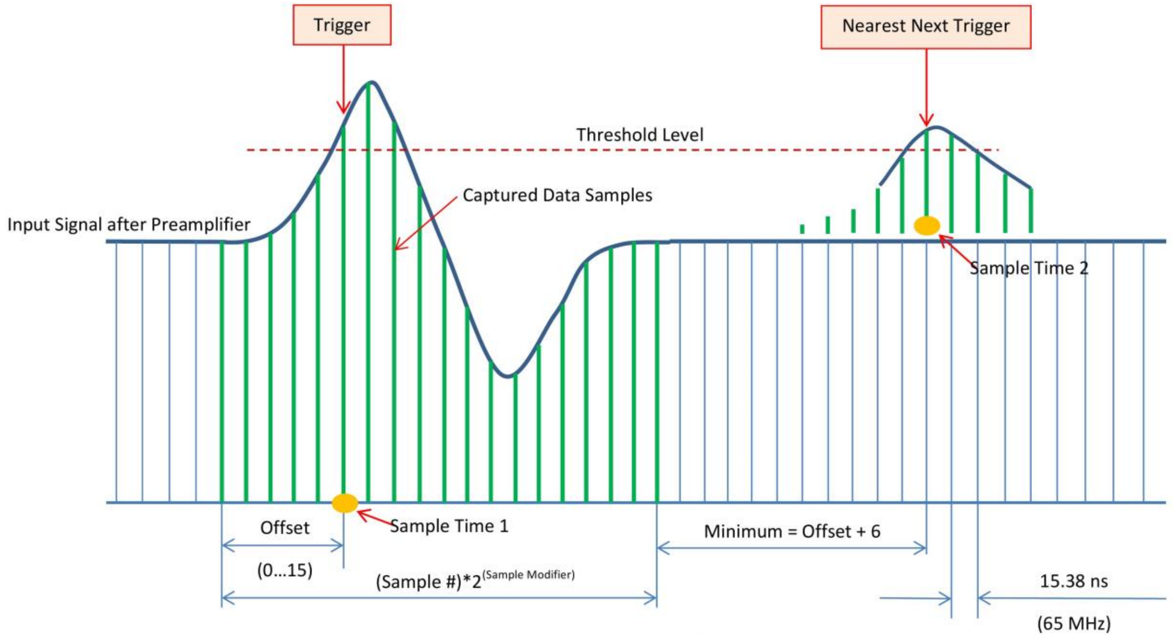




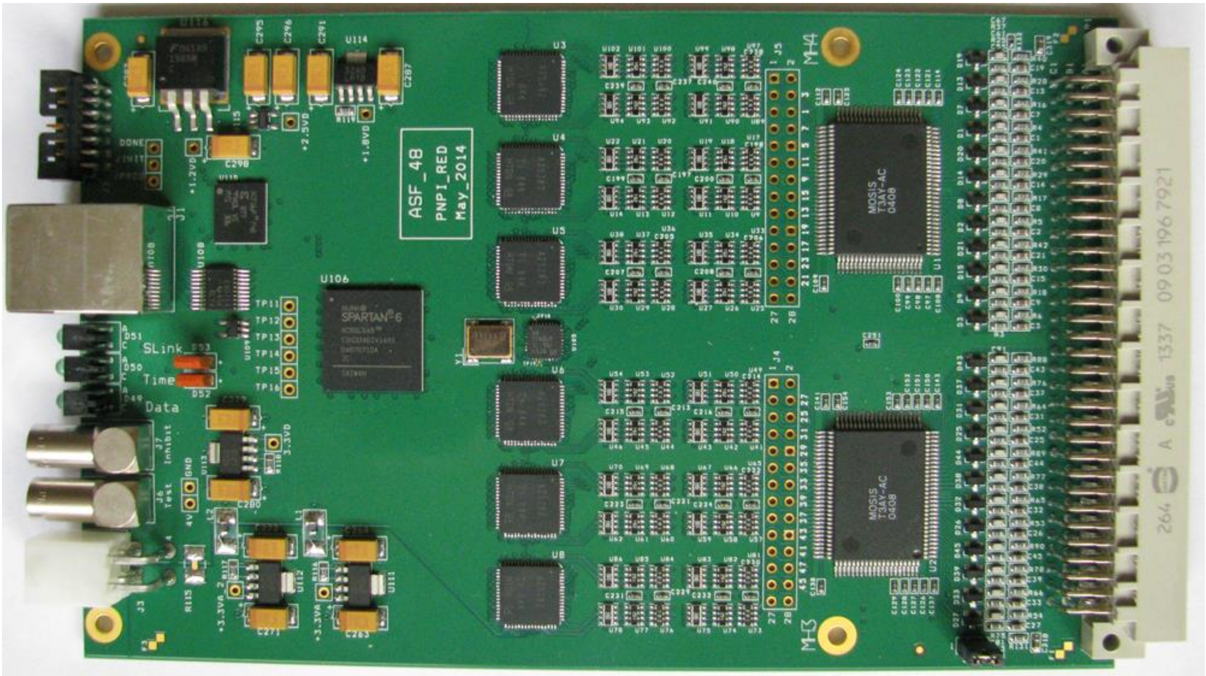


ASF48 card with FADC

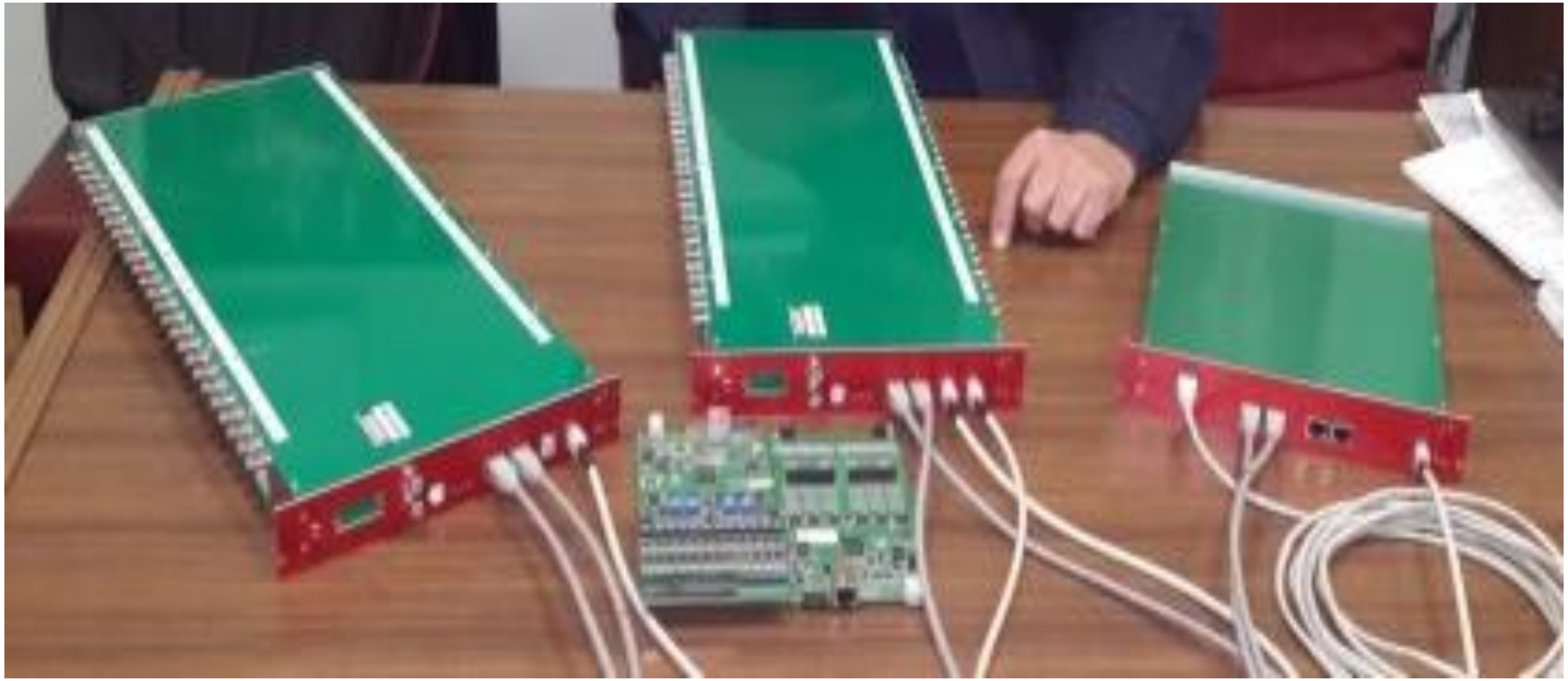
Channels / Card	48/24/12
Channels / System maximum	48 x 16 = 768
Target DAQ System	CROS-3: • CCB16-B Top Level Concentrator • CBS-B CROS-3 System Buffer (PCI Card)
Sampling Rate	(10, 20, 40, 50, 80, 100, 160, 200, 400) MHz
Sampling to discriminator delay	Sampling Period * 14
ADC resolution	10/12 bit
Sample Number / Trigger	(1 – 31), (2 – 62), (4 – 124), (8 – 248), (16 – 496), (32 – 992)
Offset Before Trigger	0…15 / 0…30 / 0…60
Self Trigger Mode	Individual for each channel
Threshold	Individual for each channel (0x000…0xFFF)
Sampling Mode Only for non-interleave modes	Individual for each channel Sampling Rate / 2, Sampling Rate / 4, Sampling Rate / 8
External Trigger Mode	Common for all channels
Distance between nearest triggers	(Sample Number + 6) * 15.38 ns (for each channel) (If a channel has enough memory space for next event)
Channel's L1 FIFO	48 x 1024 / 24 x 2048 / 12 x 4096 - 16-bit words
Output L2 FIFO	16384 16-bit words
Sample Timer	44-bit, 100 MHz, 48 hours (Common for all channels)
Serial Link (signal levels, bit rate)	LVDS, 100MBPS
Card size	100 x 160 mm
Power supply	Single + 3.8V, 2.7A (10,3W)

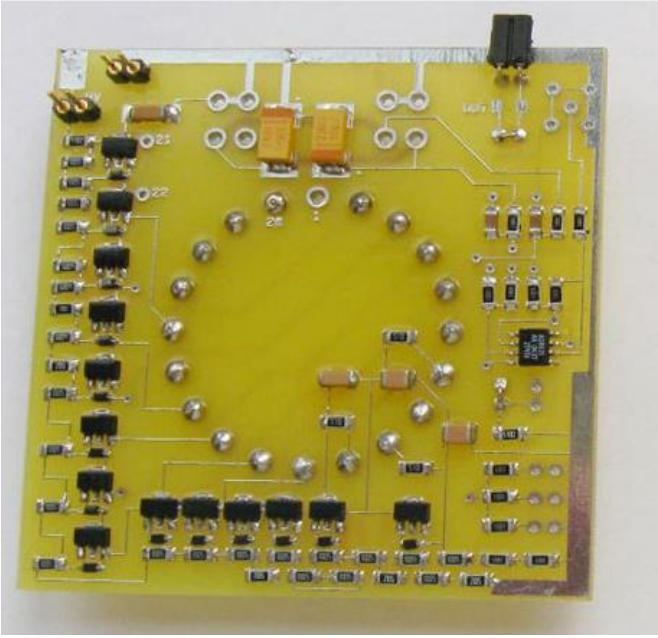


Data Capture Timing (Self Trigger Mode)

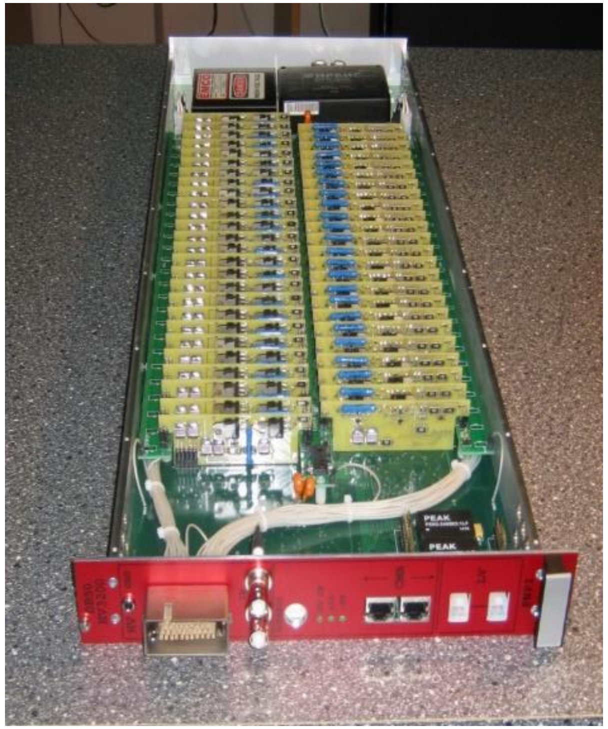


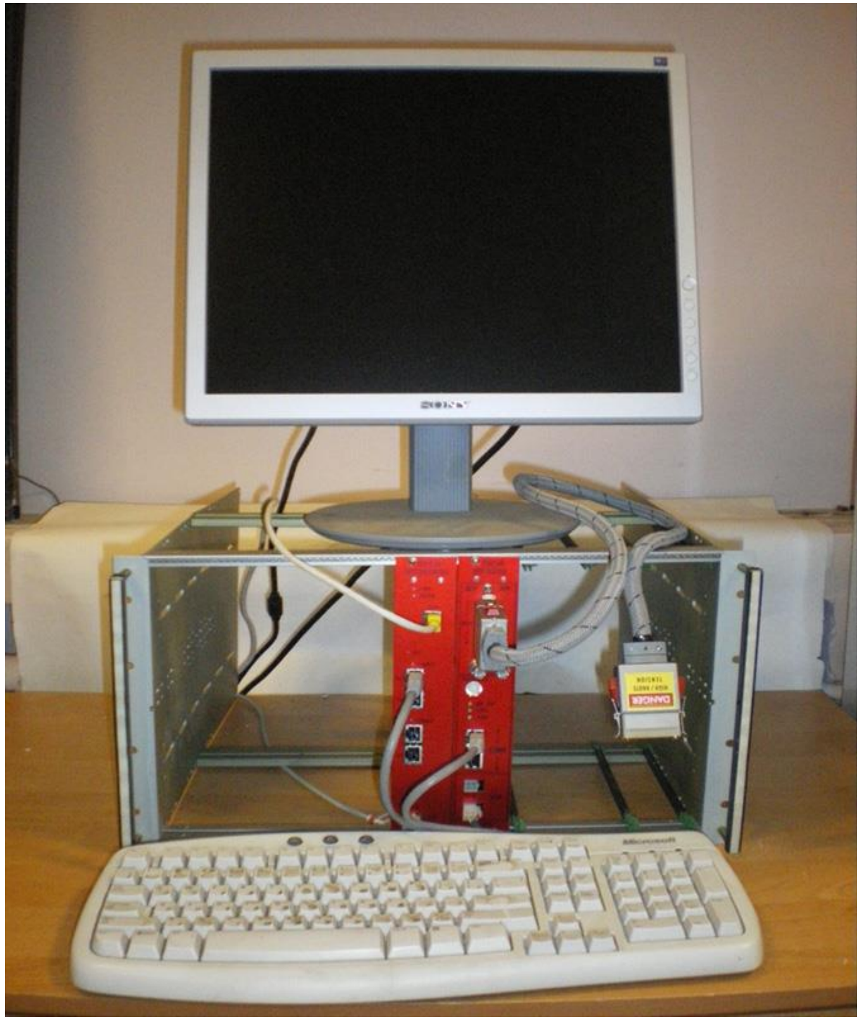
High Voltage Distribution System HVDS3200 and active voltage-dividers





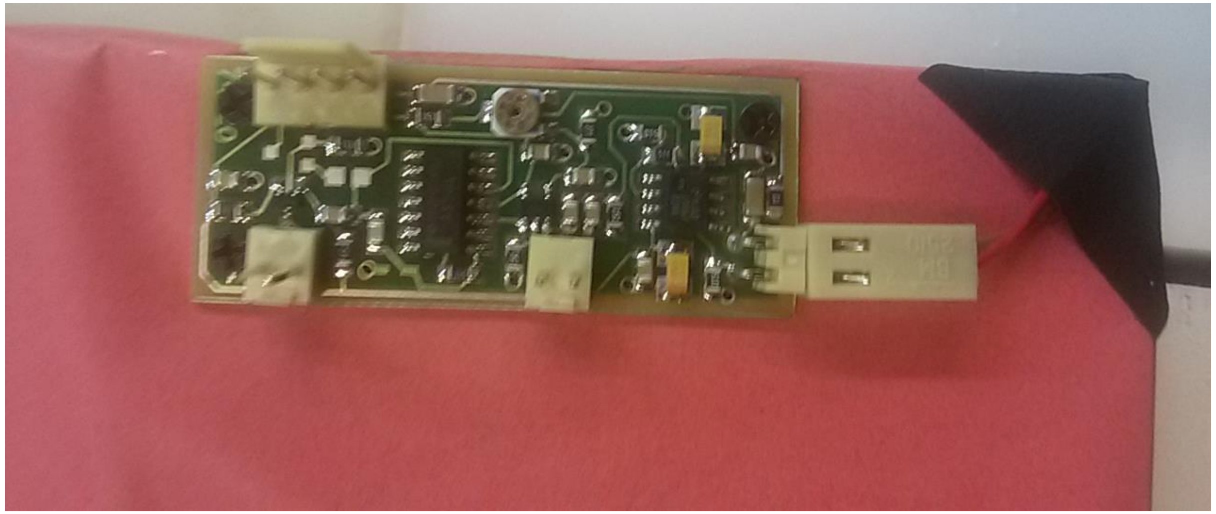
High Voltage Distribution System HVDS3200





- Voltage adjustment 0…1500 V; 0.1%
- Maximum current 0.5 mA
- Current monitoring 0.1%
- Voltage monitoring 0.1%
- Stability (during 1 day) 0.1%

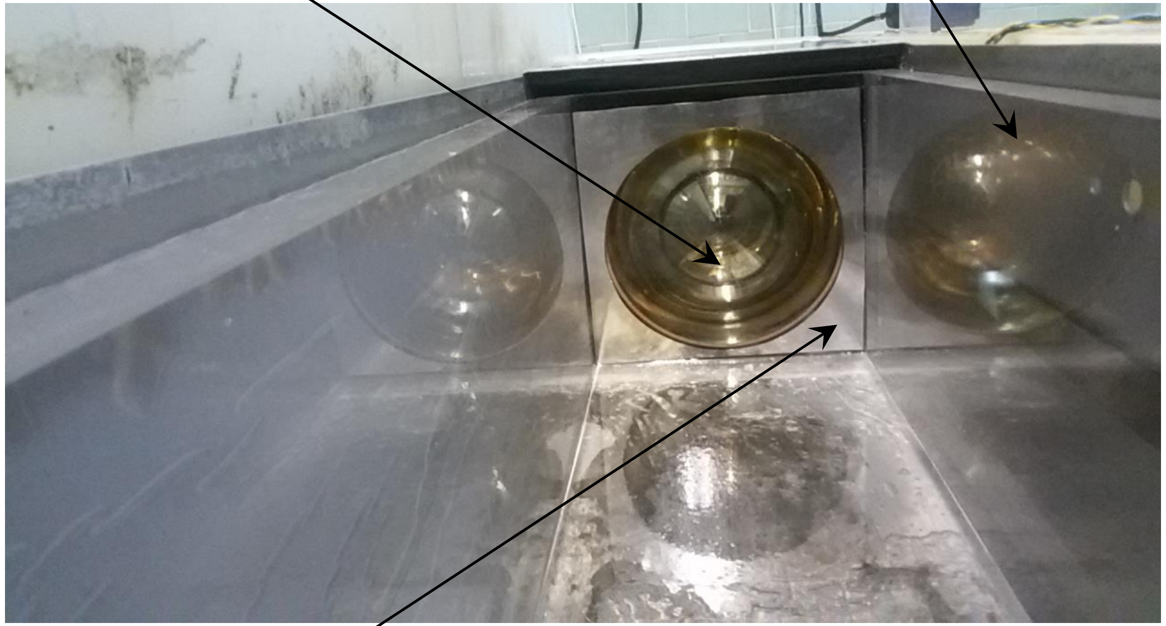
Active shielding

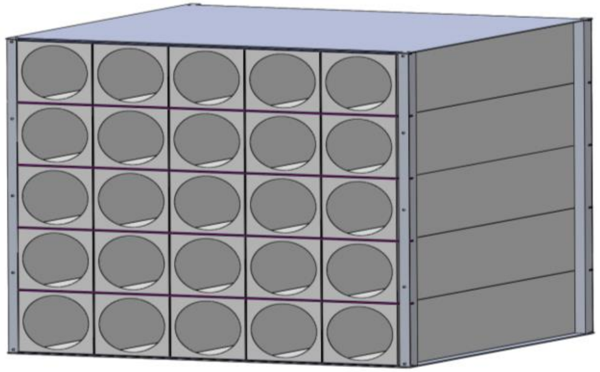


- Polysterene based scintillator
- Optical fibers with SiPM are used
- “Spectral” or “logical” operating modes

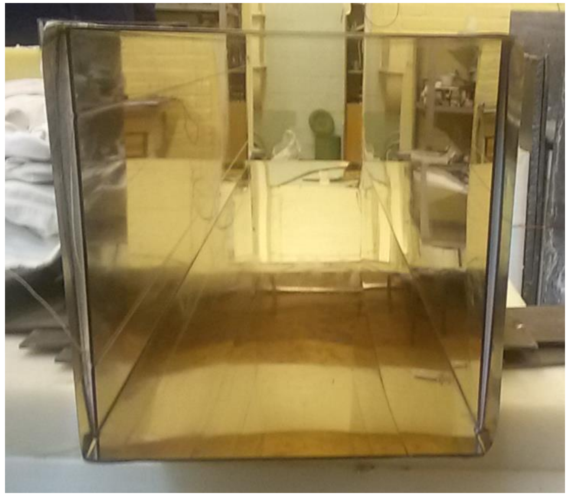
Measurements with section model

Single section model



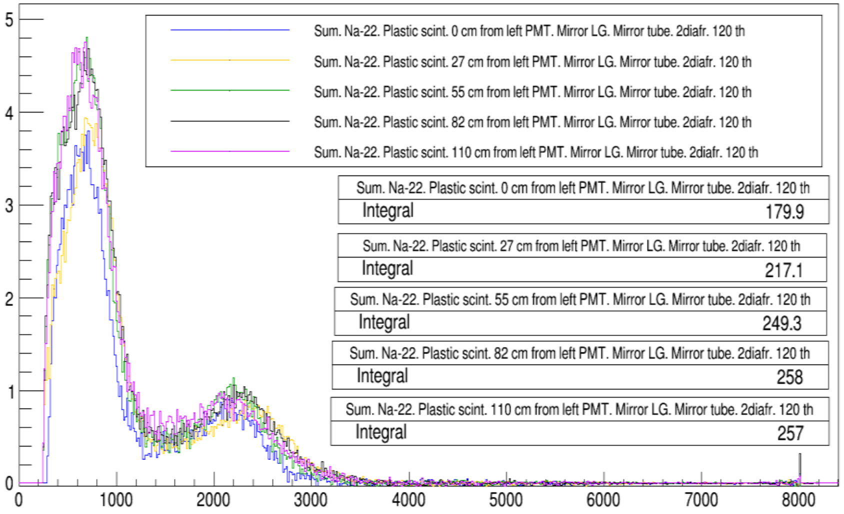


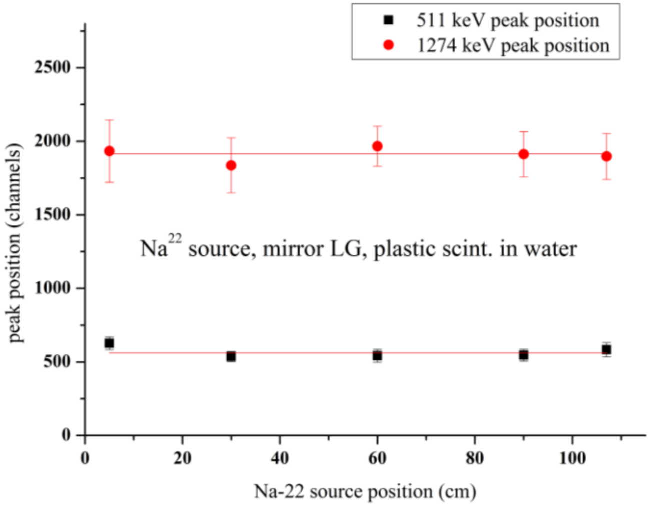
Mirror plex lightguide

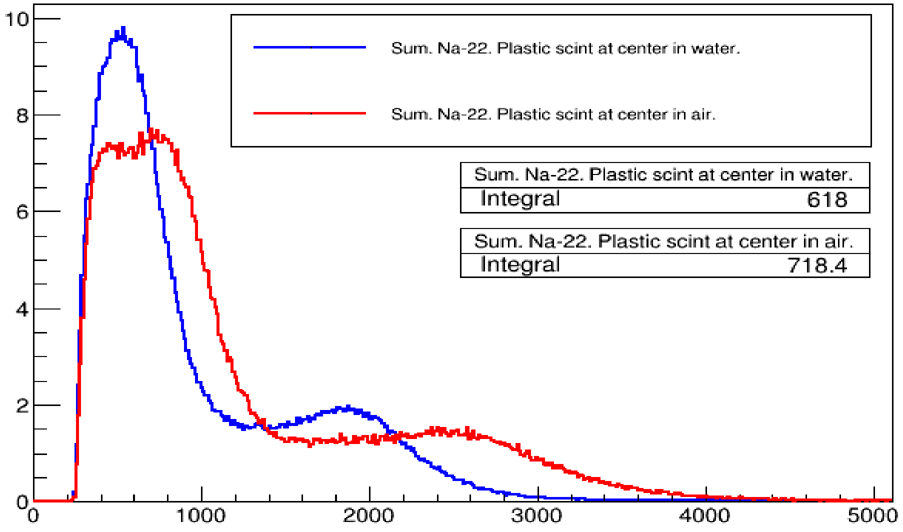


Plastic scintillator inside section

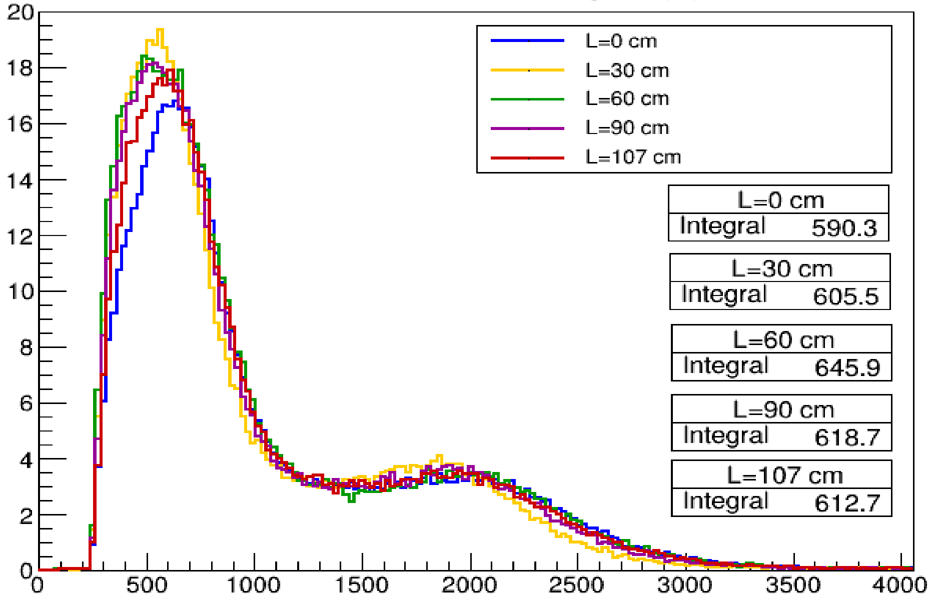
Section is filled with water





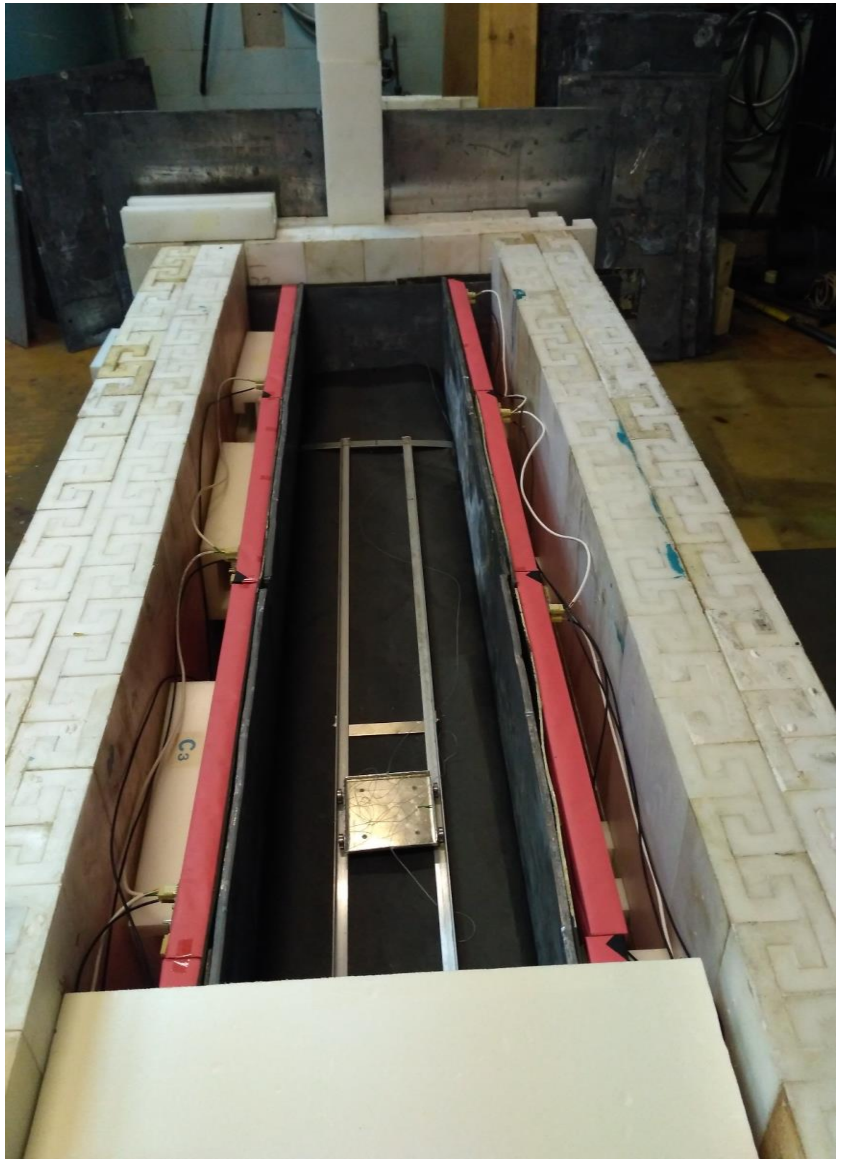


Energy resolution for plastic in water is the same as without water (~0.2 for 1274 keV)

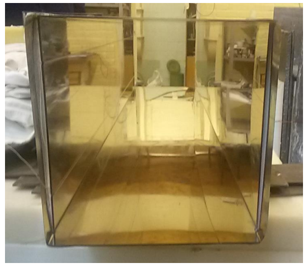


Positions of peaks are still independent of source coordinate along the tube

Section with NEOS scintillator inside shielding

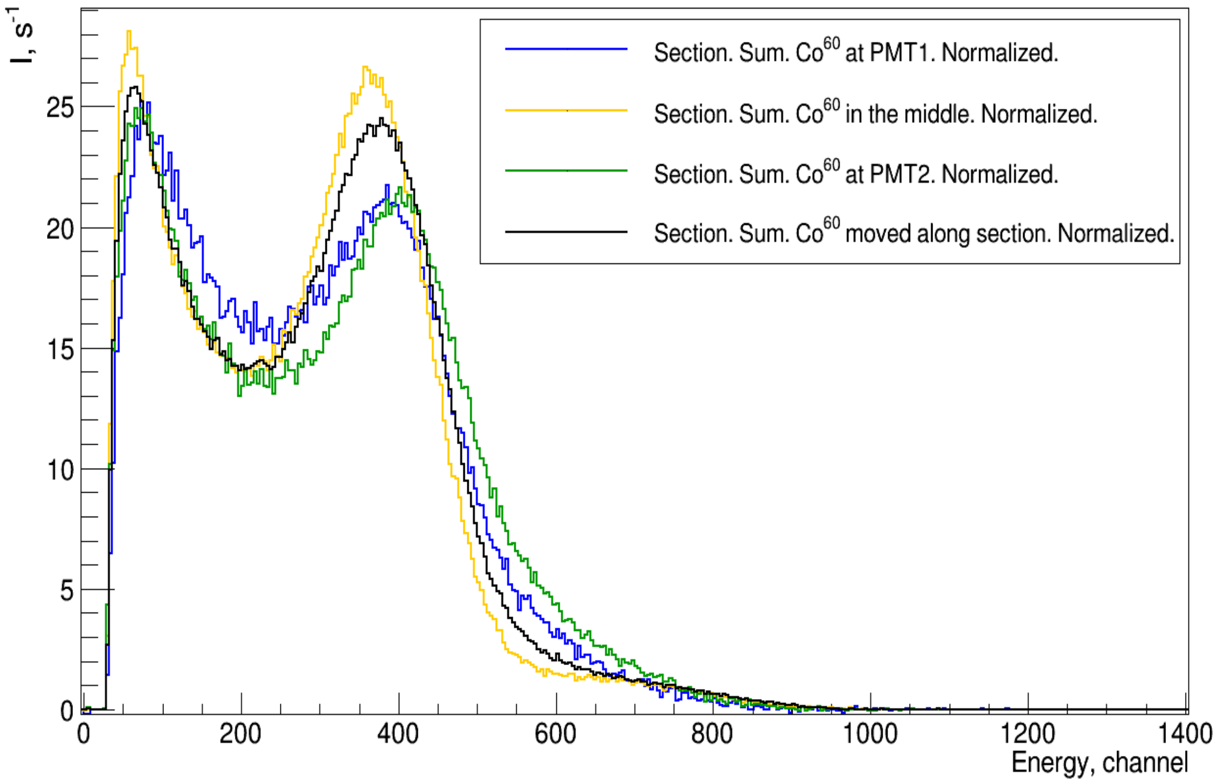


Scintillator volume ~55 liters



Section with NEOS scintillator inside shielding

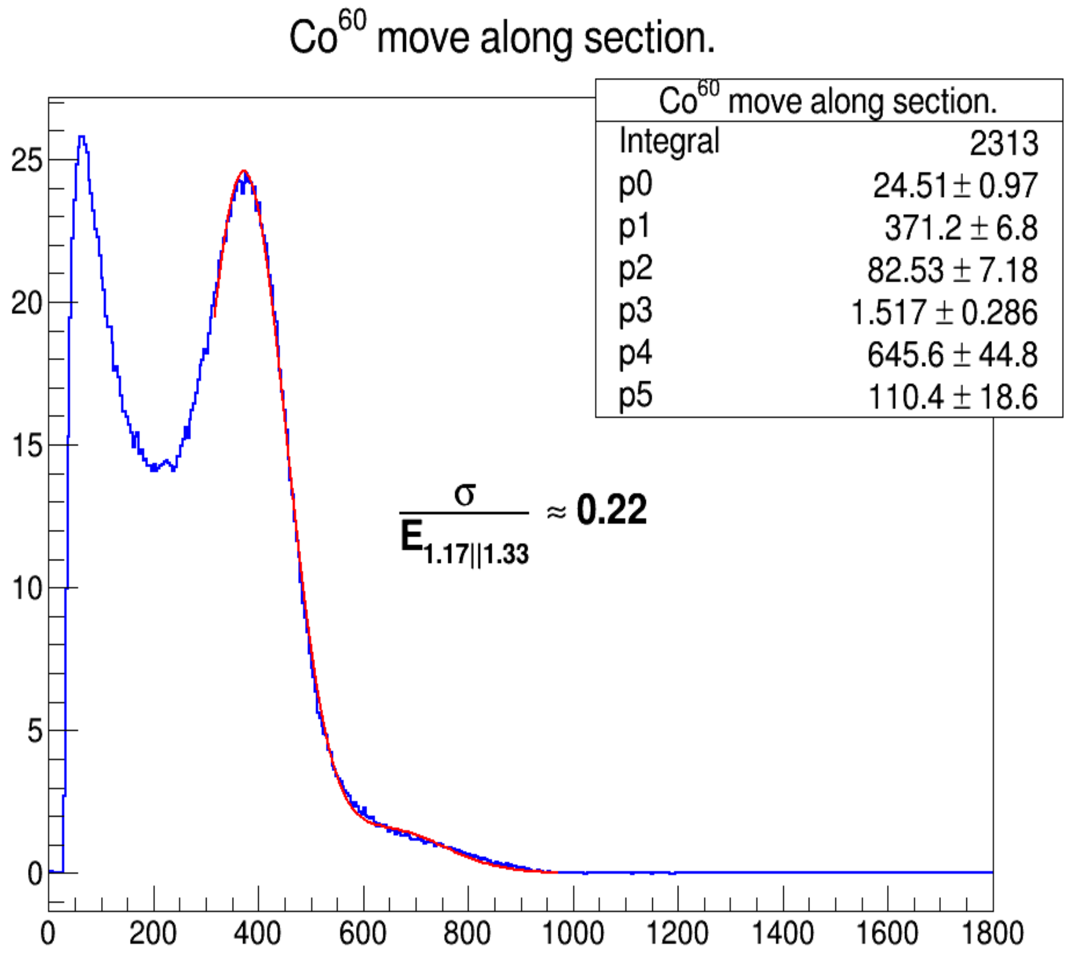
Calibration with Co^{60}



Maximum deviation from "average" peak (scanning mode) is less than **6%**

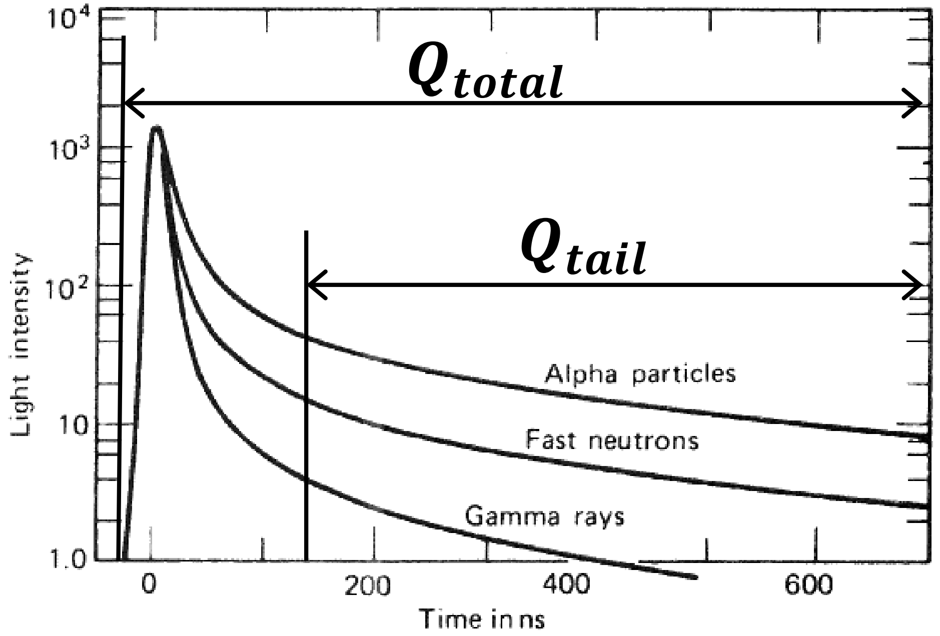
Energy resolution for Co^{60} line

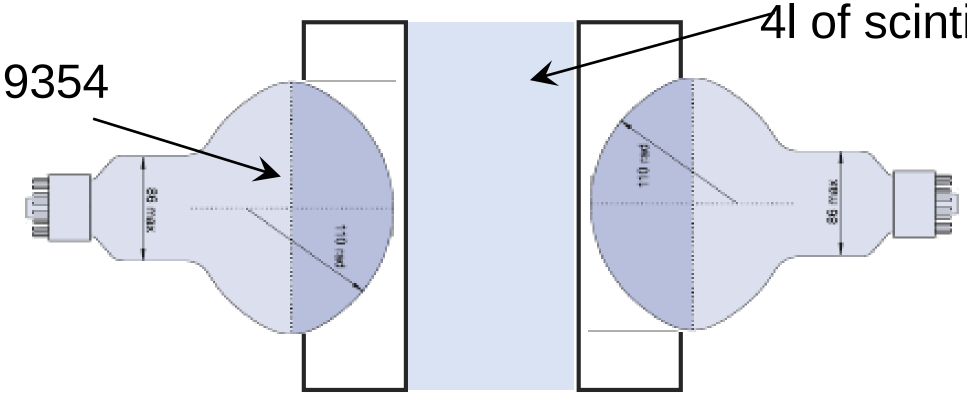
± 300 keV

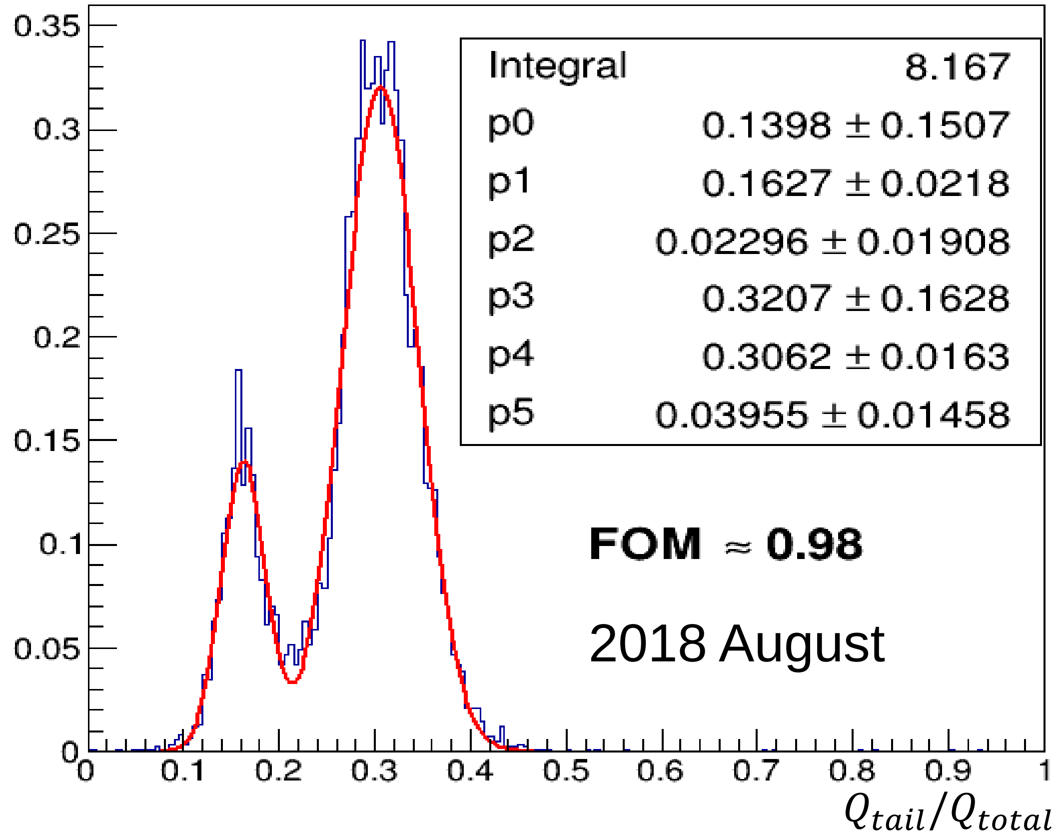


NEOS scintillator PSD capability

Small volume. With optical contact





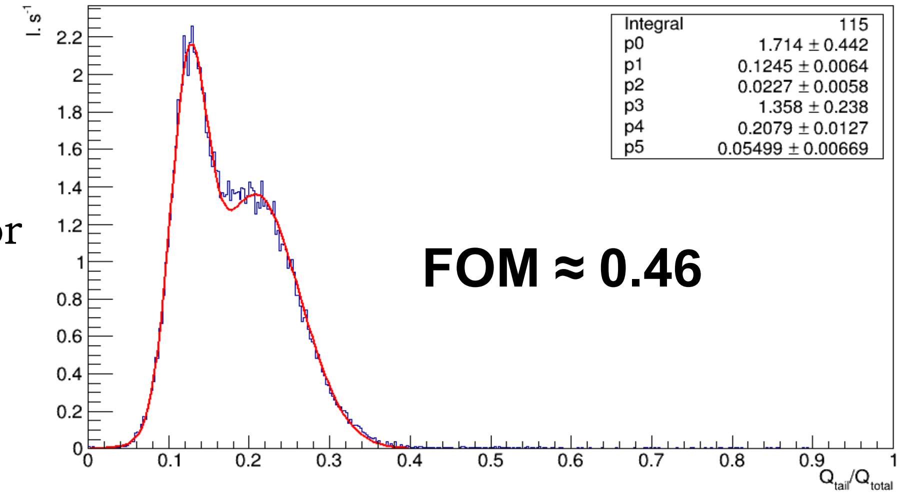


$$FOM = \frac{\mu_1 - \mu_2}{fwhm_1 + fwhm_2} \approx \frac{\mu_1 - \mu_2}{2.35(\sigma_1 + \sigma_2)}$$

Section with NEOS scintillator inside shielding

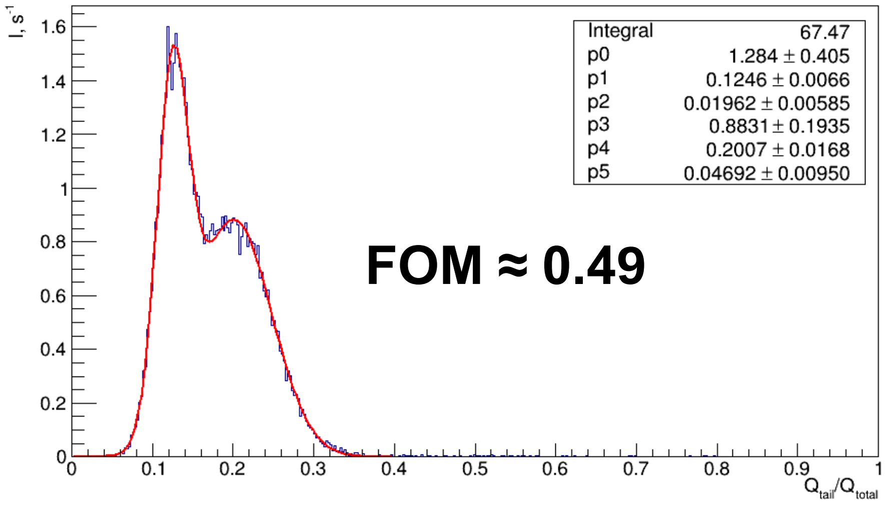
PSD capability

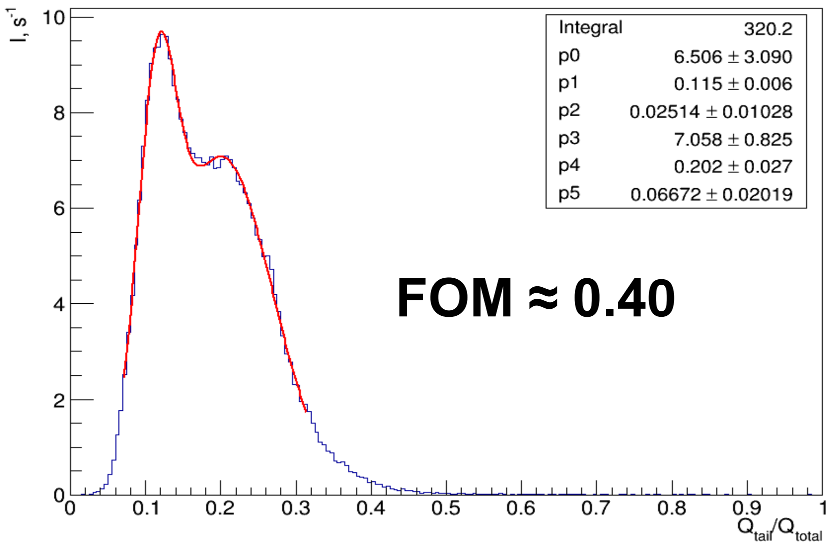
Section. Sum signal. Cf^{252} at the center.



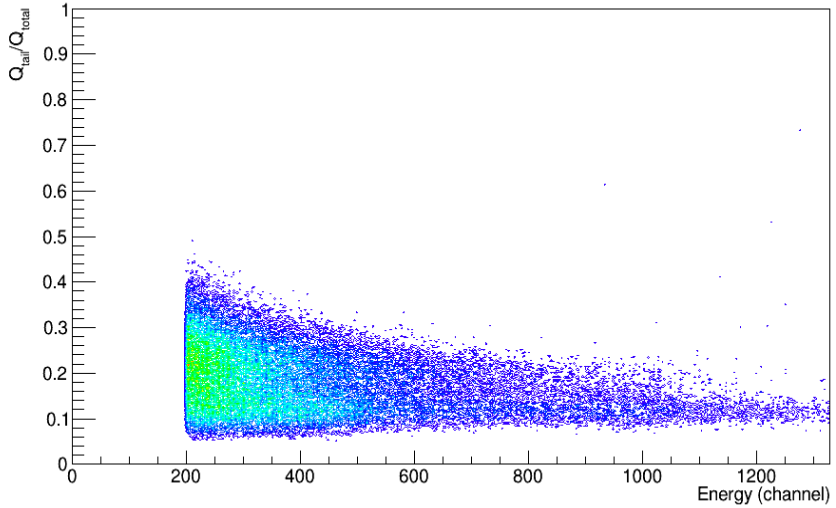
The way of signal summation («analog» or «digital») is practically insignificant for PSD capabilities

Section. Sum signal with coincidence. Cf^{252} at the center.



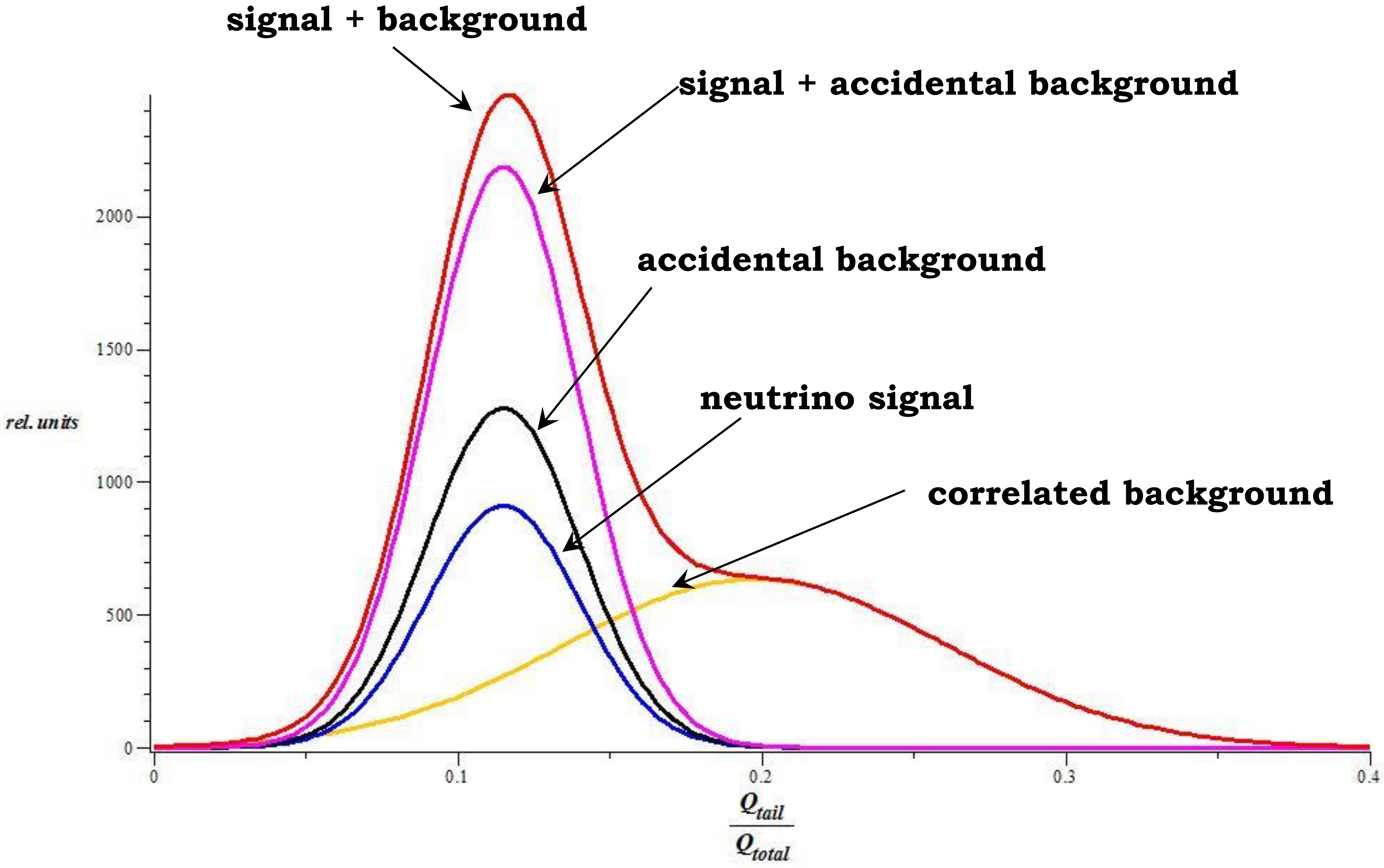


Energy-PSD distr. Prompt sum signal with 2 PMTs coincidence. Cf^{252} moved along.



PSD for prompt signals of correlated events from Cf^{252} fast neutrons in “scanning” mode

PSD distribution prediction for detector at SM-3



PSD parameter distribution for 10 sections providing that new detectors efficiency is not worse than working now, correlated background is the same and accidental coincidence background is suppressed at least 3 times due to 5 times gadolinium concentration

Expecting improvements of statistical accuracy for Neutrino-6

Method	Consequence	Increasing accuracy factor
4 detectors	3x larger volume	**1.6**
Gd concentration	4x less accidental background	**1.5**
PSD	4x less correlated background	**1.3**
Total		**3.1**

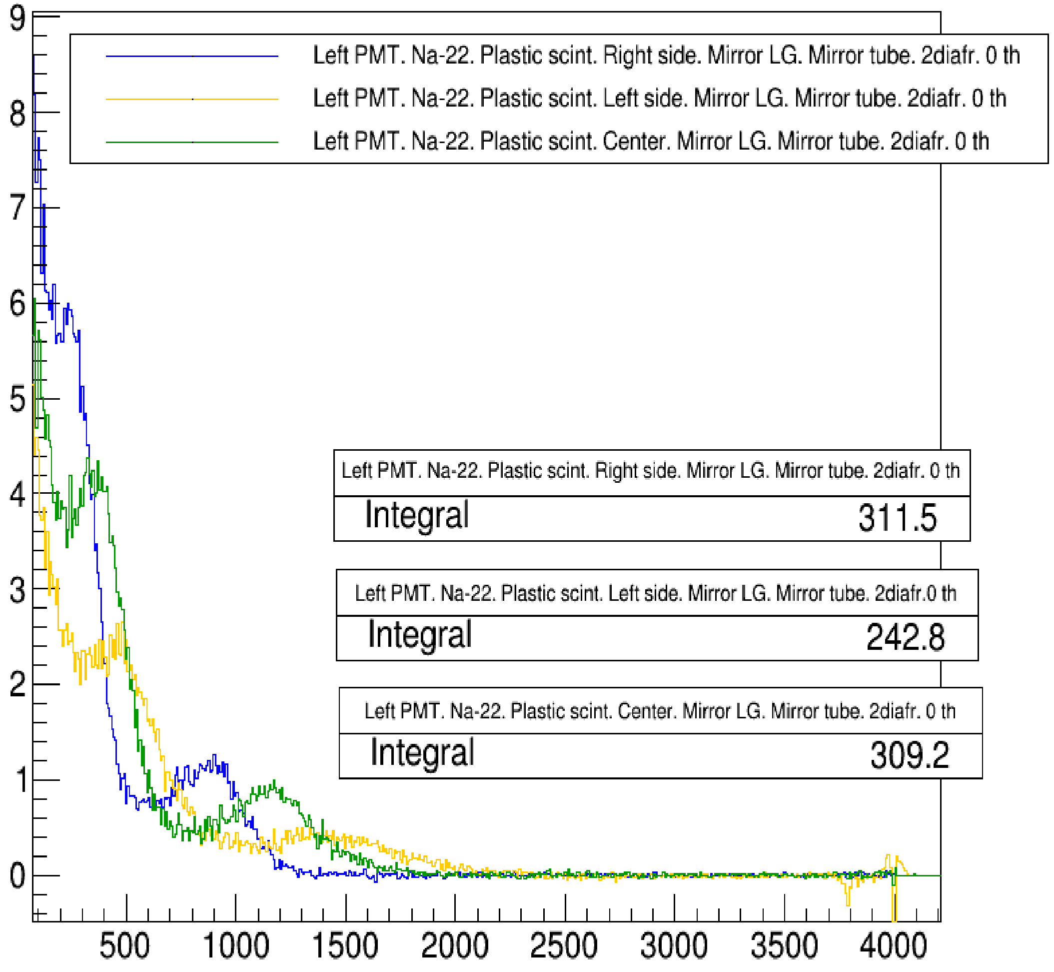
Conclusions

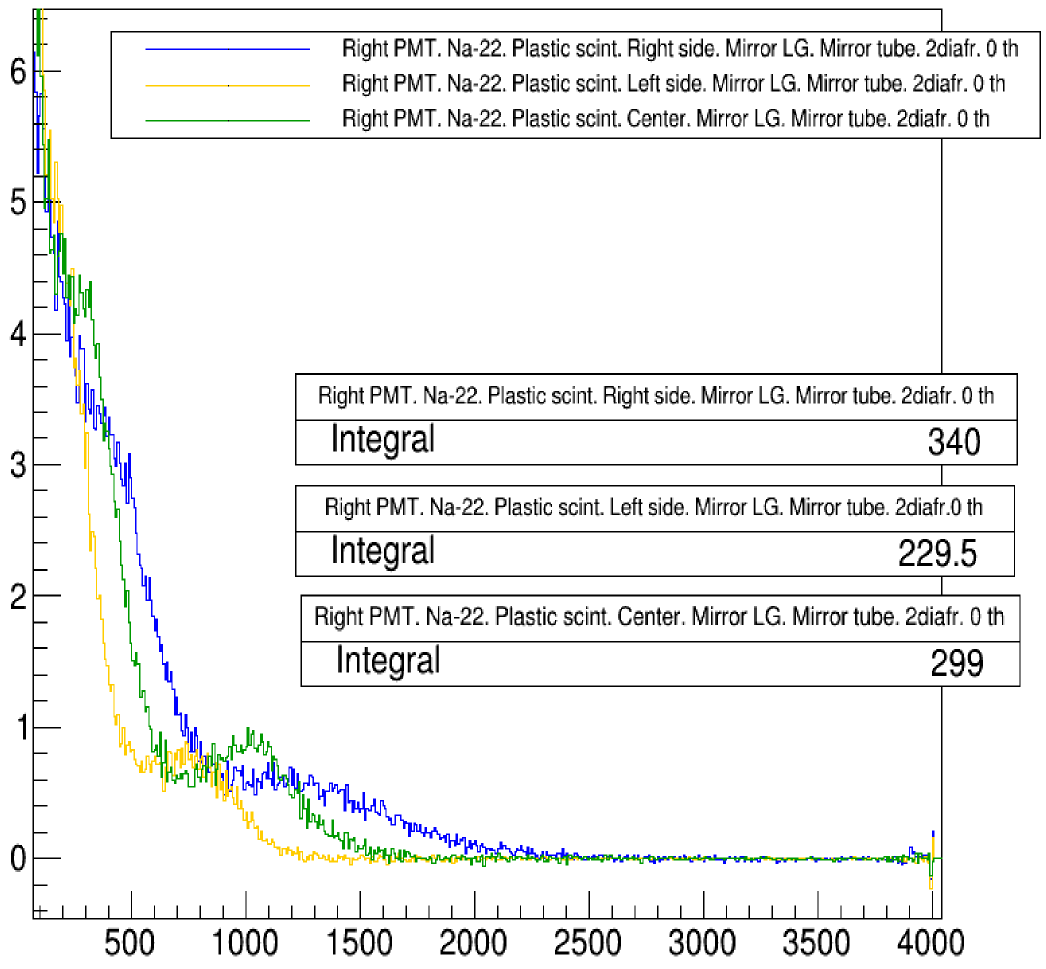
- New measurements with detector Neutrino-4 and new scintillator with more high concentration of Gd and with PSD capability
- Creation of the second neutrino laboratory at the reactor SM-3
- The development and manufacture of a new detector Neutrino-6 with a sensitivity of 3.1 times higher

Thanks for your attention!

Plastic scintillator inside section

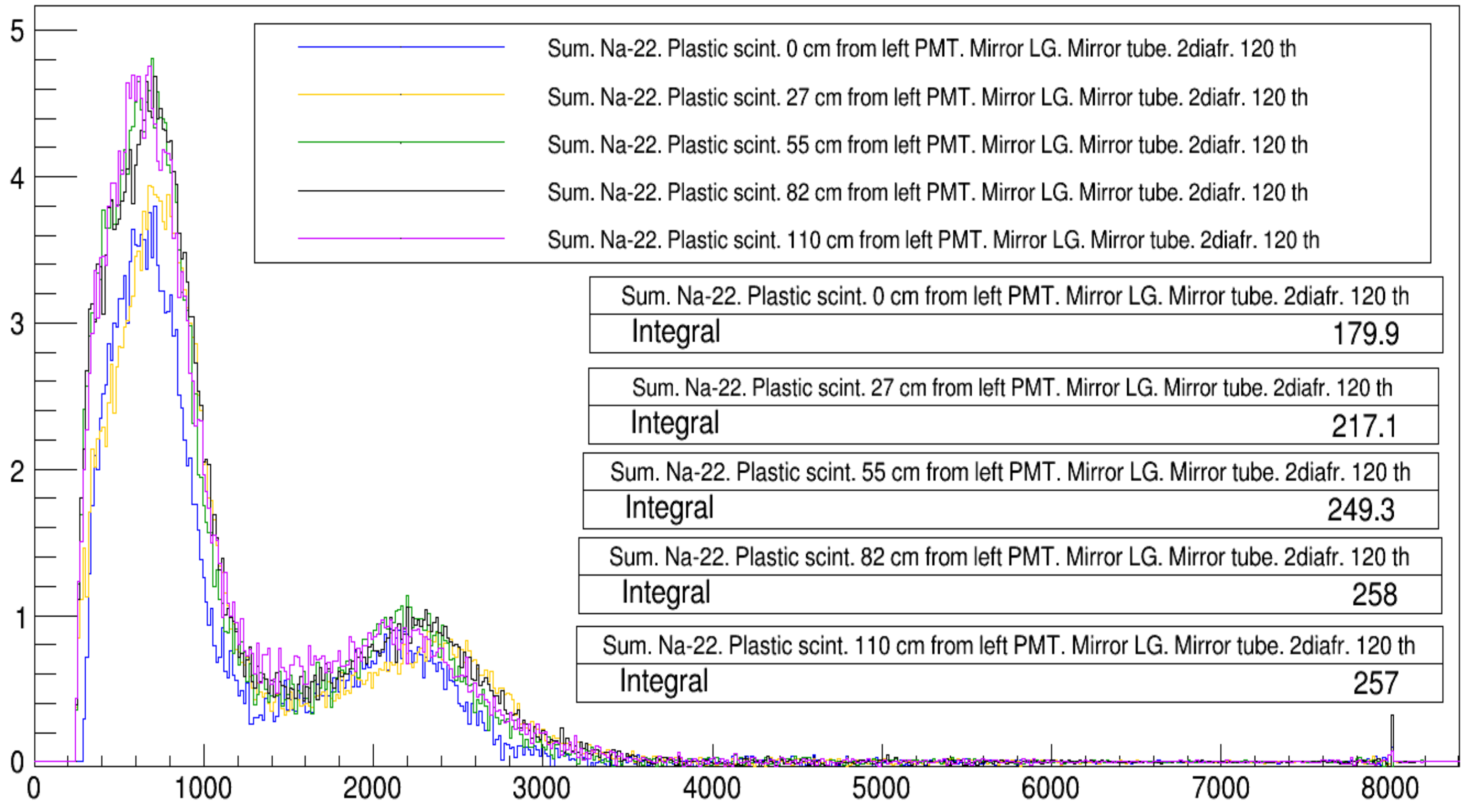
Na^{22} each channel spectra

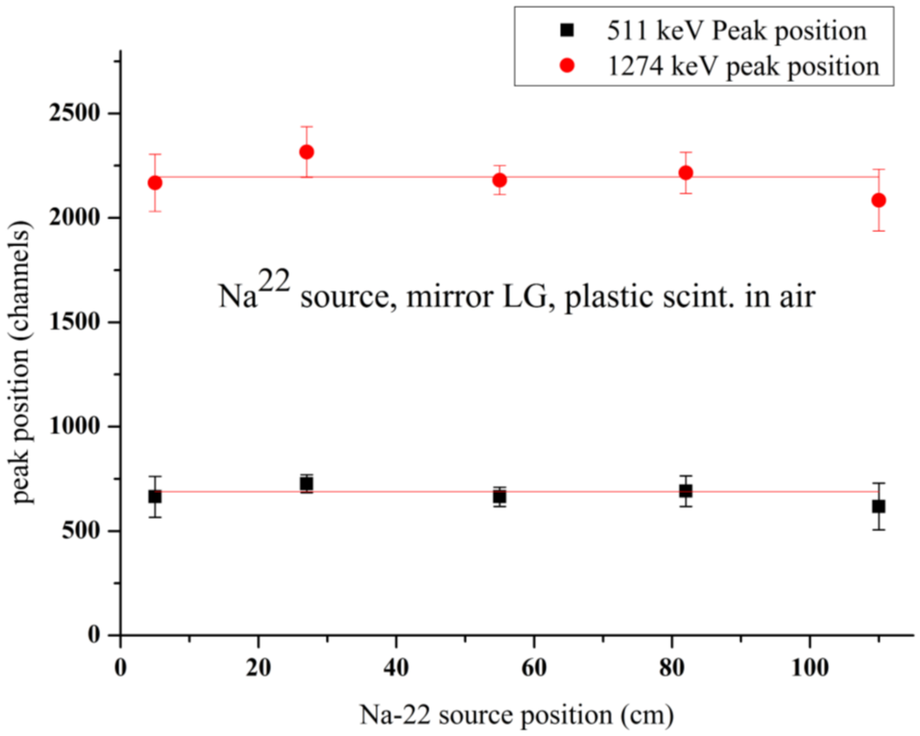




Plastic scintillator inside section

Na^{22} sum spectra

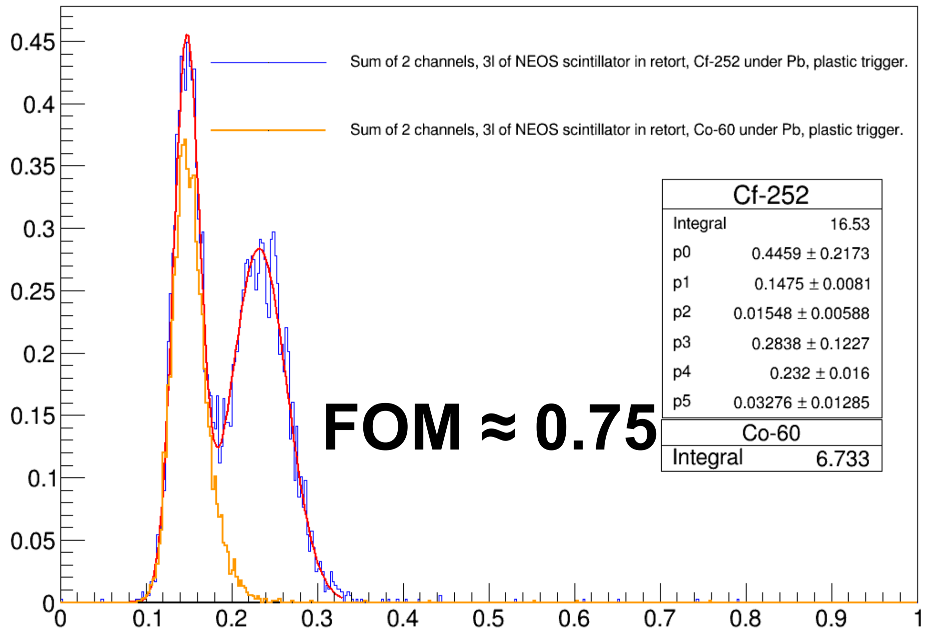


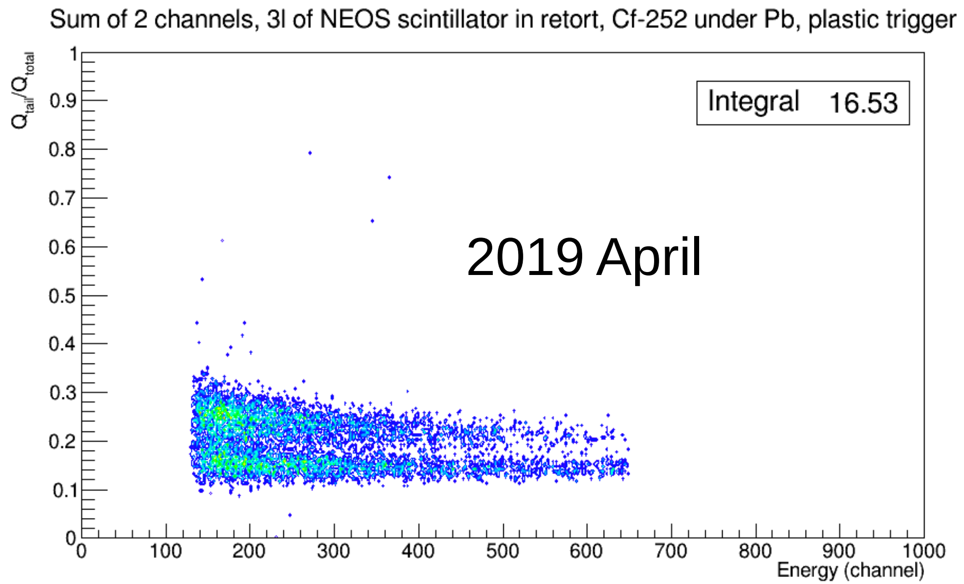


Na^{22} peaks don't depend on source position

NEOS scintillator PSD capability

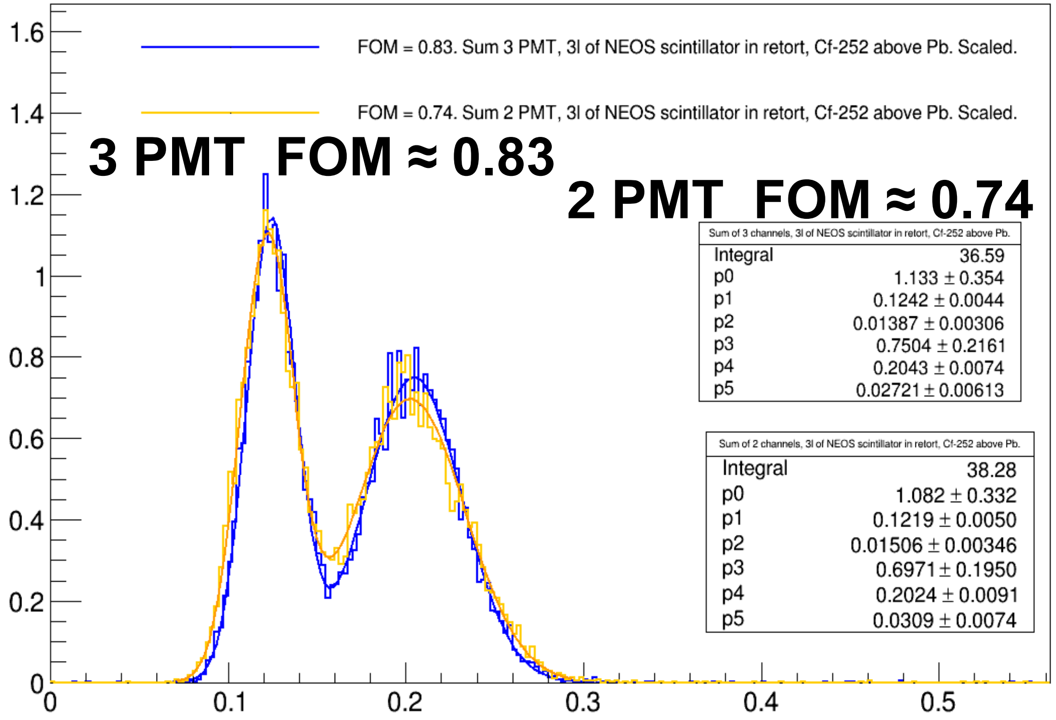
Small volume. Without optical contact



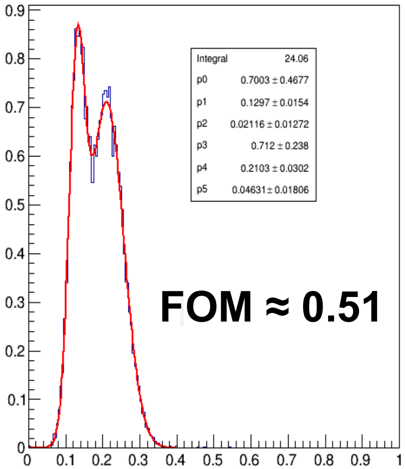


NEOS scintillator PSD capability

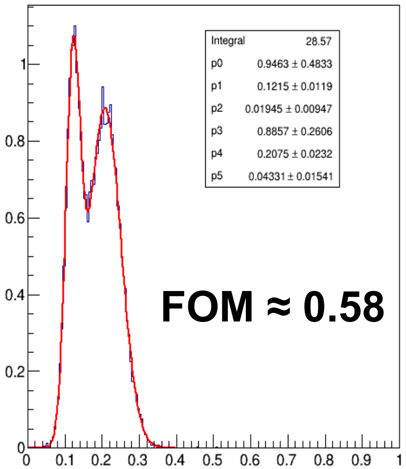
Small volume. Without optical contact



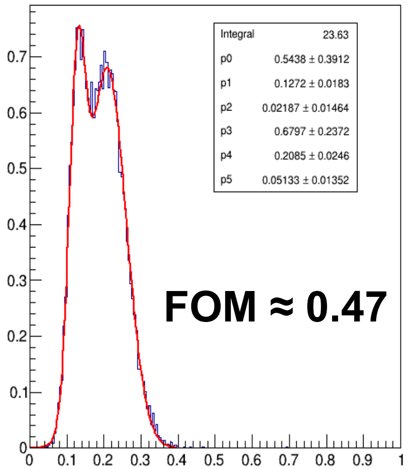
NEOS scint. 3l. Cf-252 above Pb. chn 1



NEOS scint. 3l. Cf-252 above Pb. chn 2

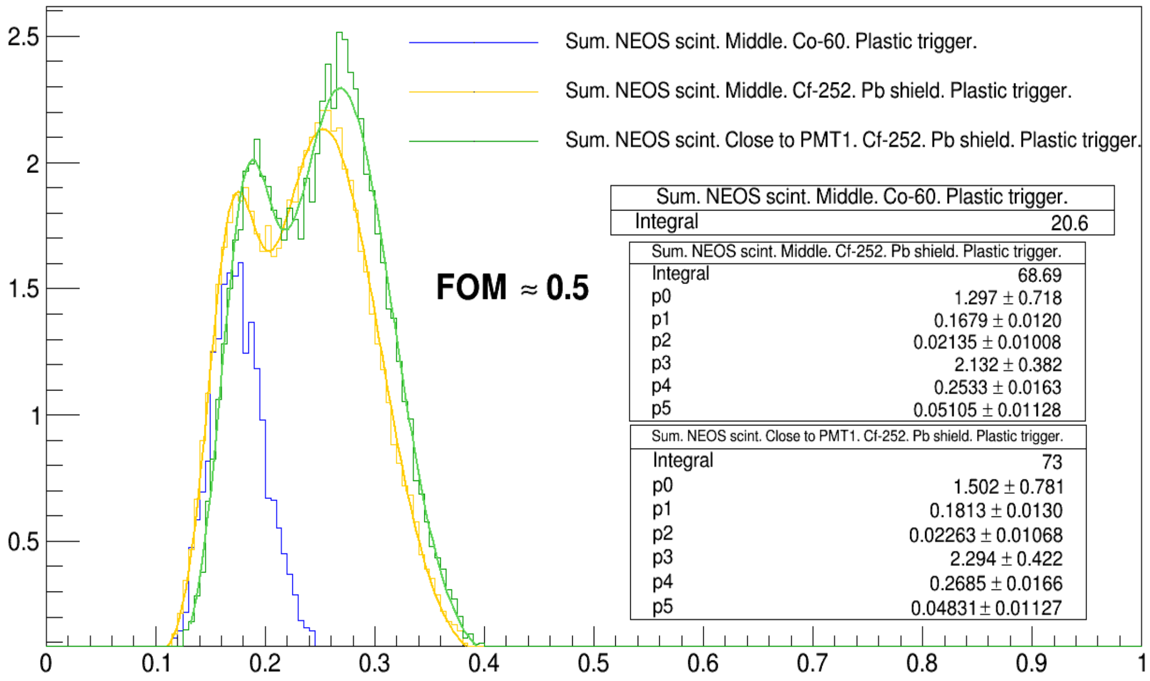


NEOS scint. 3l. Cf-252 above Pb. chn 3



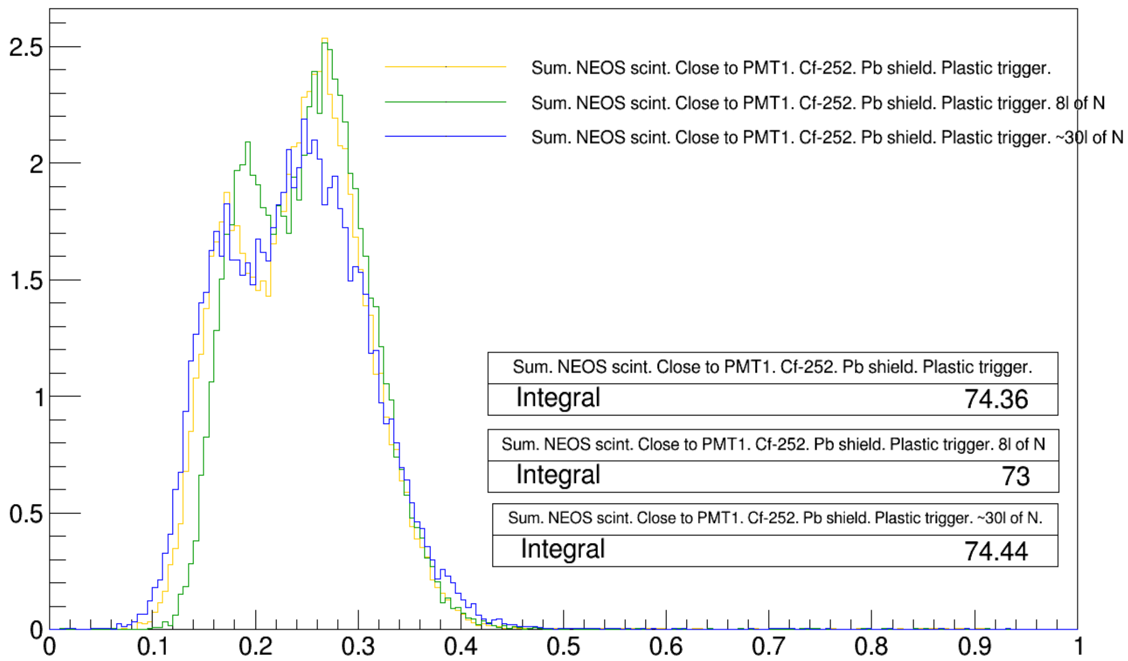
NEOS scintillator PSD capability

Small volume. Retort inside the section



Peaks separation is the same for retort in the of section or close to one of PMTs

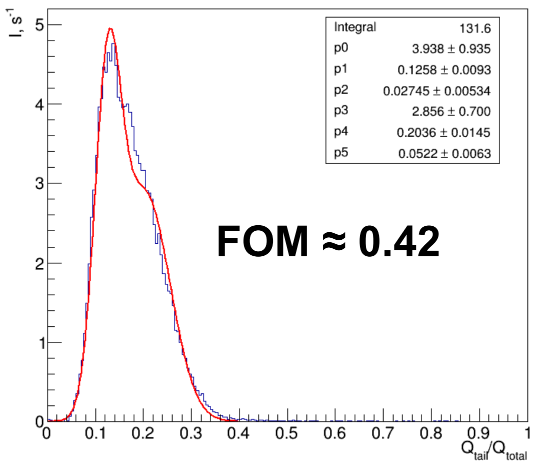
Nitrogen purge influence is no so significant



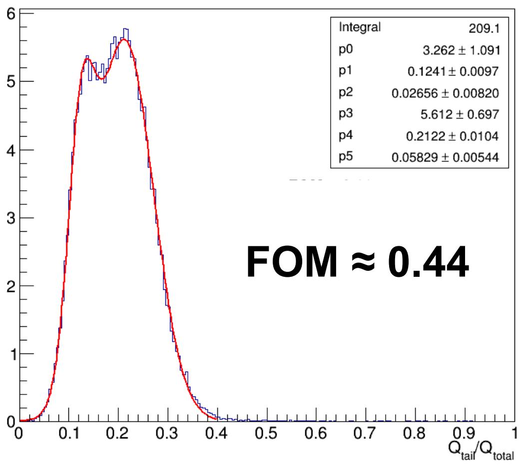
Section with NEOS scintillator inside shielding

PSD capability

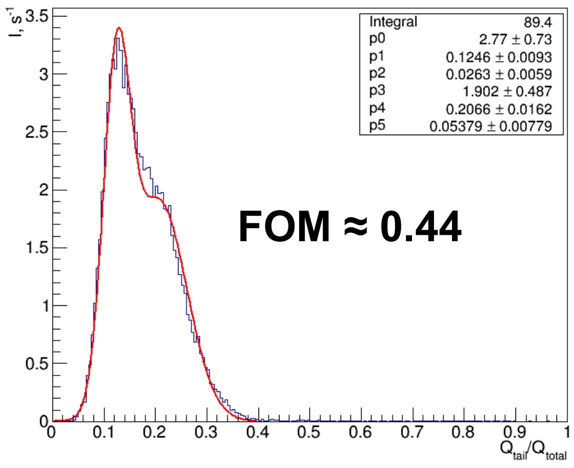
Section. PMT1 signal. Cf^{252} at PMT2.



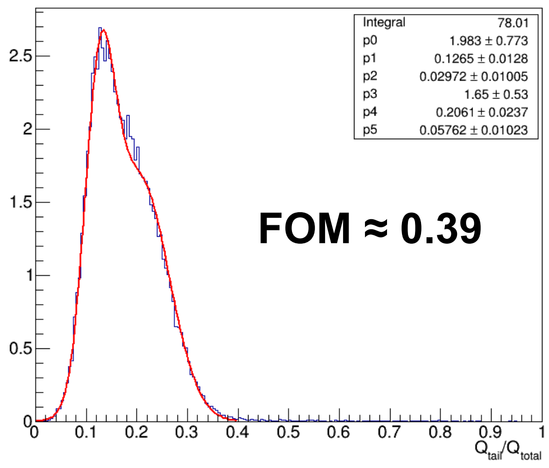
Section. PMT2 signal. Cf^{252} at PMT2.



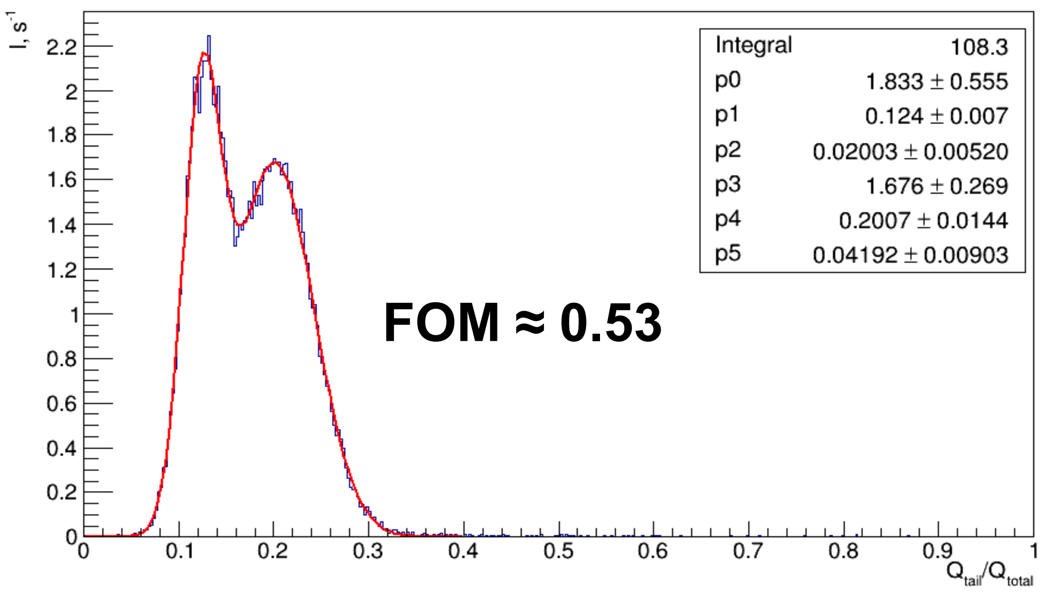
Section. PMT1 signal. Cf^{252} at the center.



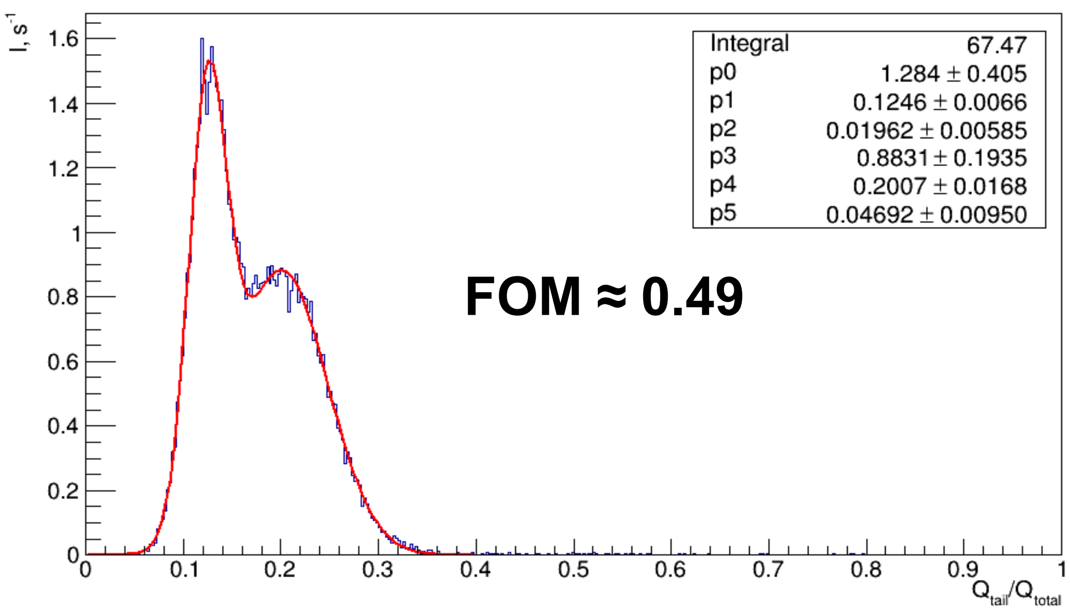
Section. PMT2 signal. Cf^{252} at the center.



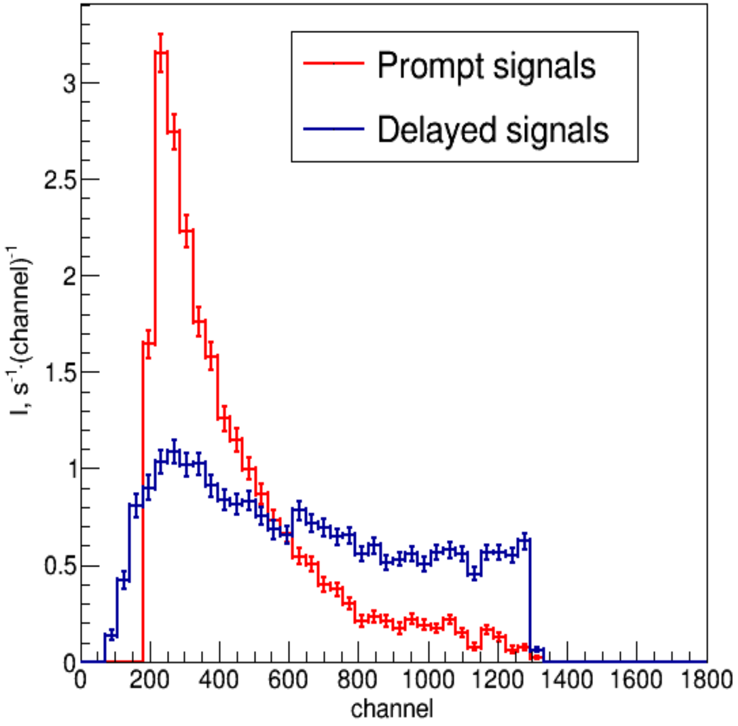
Section. Sum signal with coincidence. Cf^{252} at PMT2.

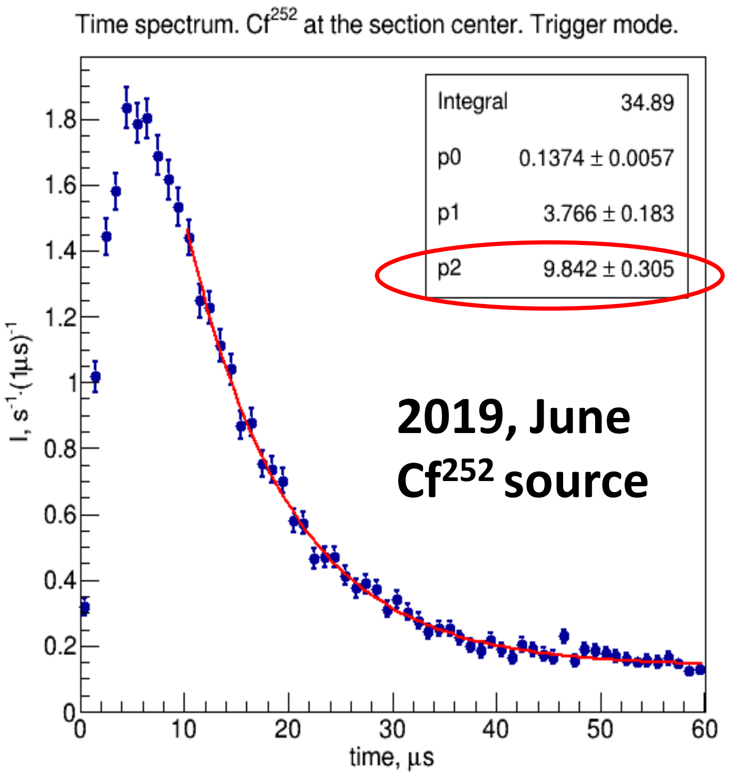


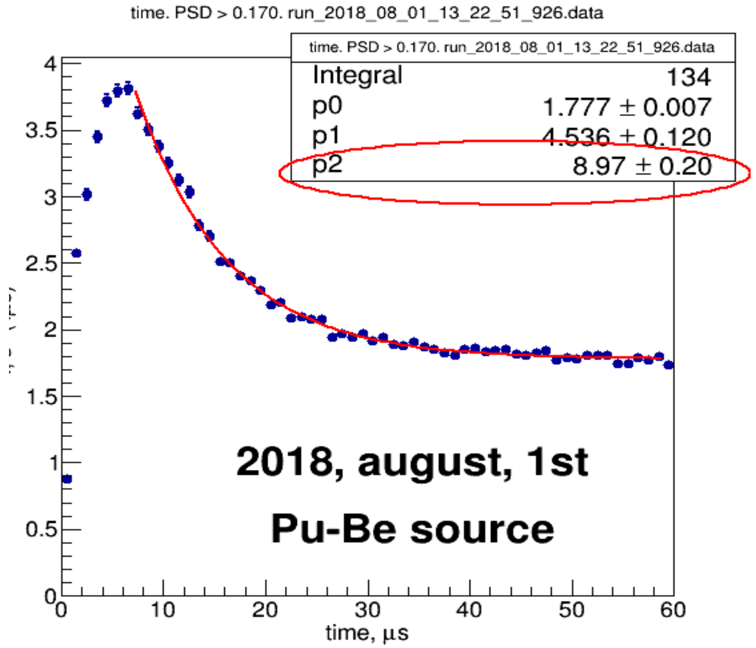
Section. Sum signal with coincidence. Cf^{252} at the center.

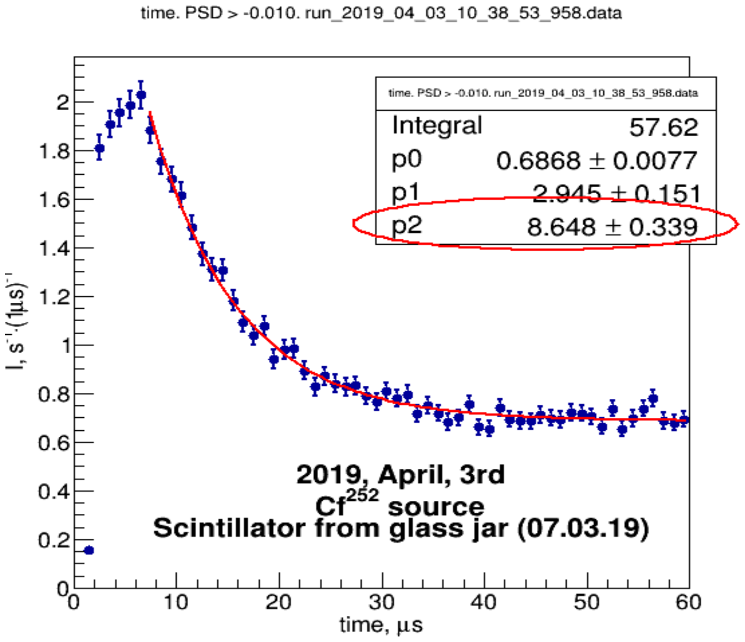


Measurements with fast neutron sources







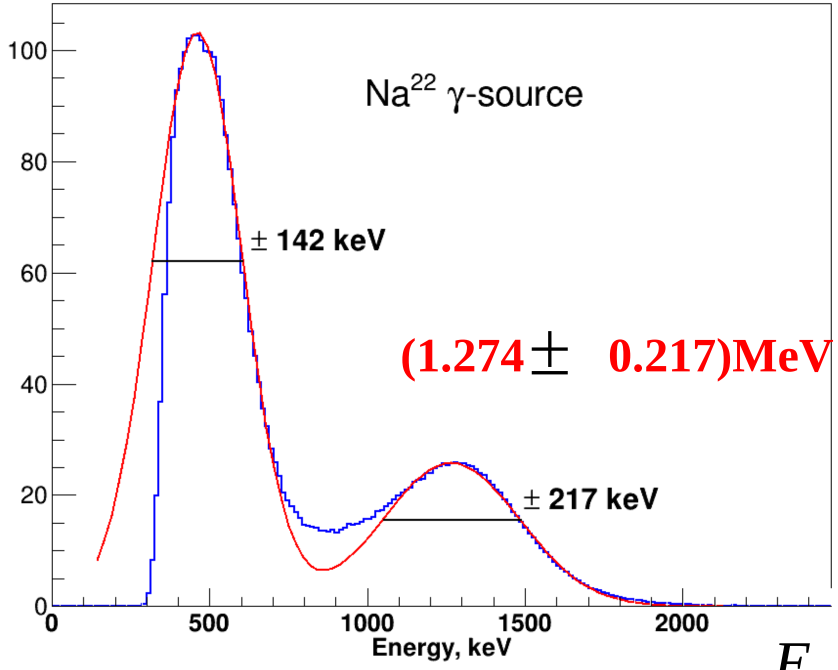


Neutron lifetime in NEOS scintillator possibly connected with Gd sedimentation.
X-rays intensity shows that Gd concentration for “fresh” sediment is 30% higher than scintillator and for “old” it is 80%

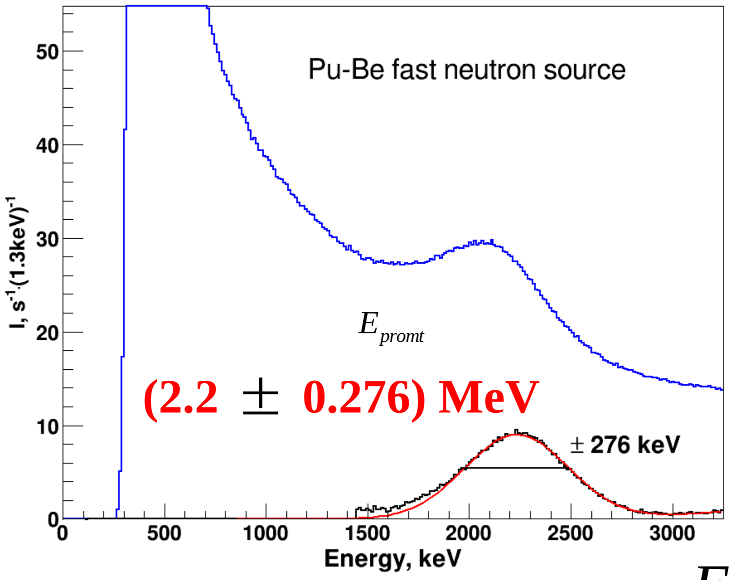
Energy calibration of the full-scale detector

(0.511 ± 0.142) MeV

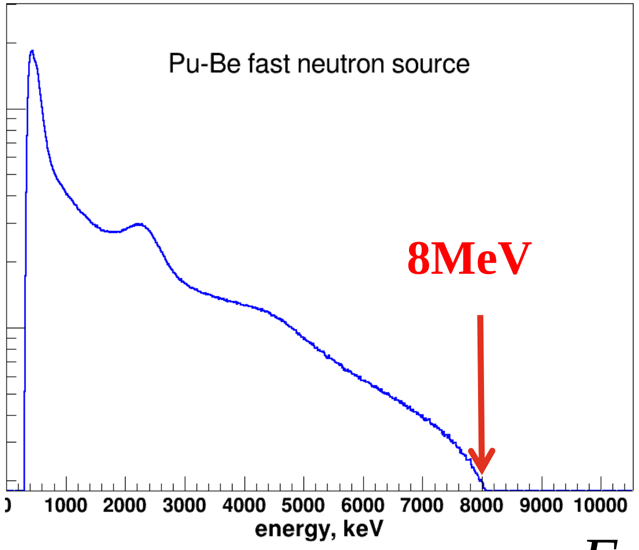
$$E_\nu = E_{promt} + 0.8MeV$$



E_{promt}



E_{promt}



E_{promt}

$$\Delta E_\nu / E_\nu(2MeV) = 21\%$$

$$\Delta E_\nu(2MeV) = 440keV$$

$$\Delta E_\nu / E_\nu(3MeV) = 18\%$$

$$\Delta E_\nu(3MeV) = 550keV$$

$$\Delta E_\nu / E_\nu(6MeV) = 14\%$$

$$\Delta E_\nu(6MeV) = 830keV$$