Existing developments and directions for further development of thermal-neutron detectors at the IBR-2 Department of spectrometers complex

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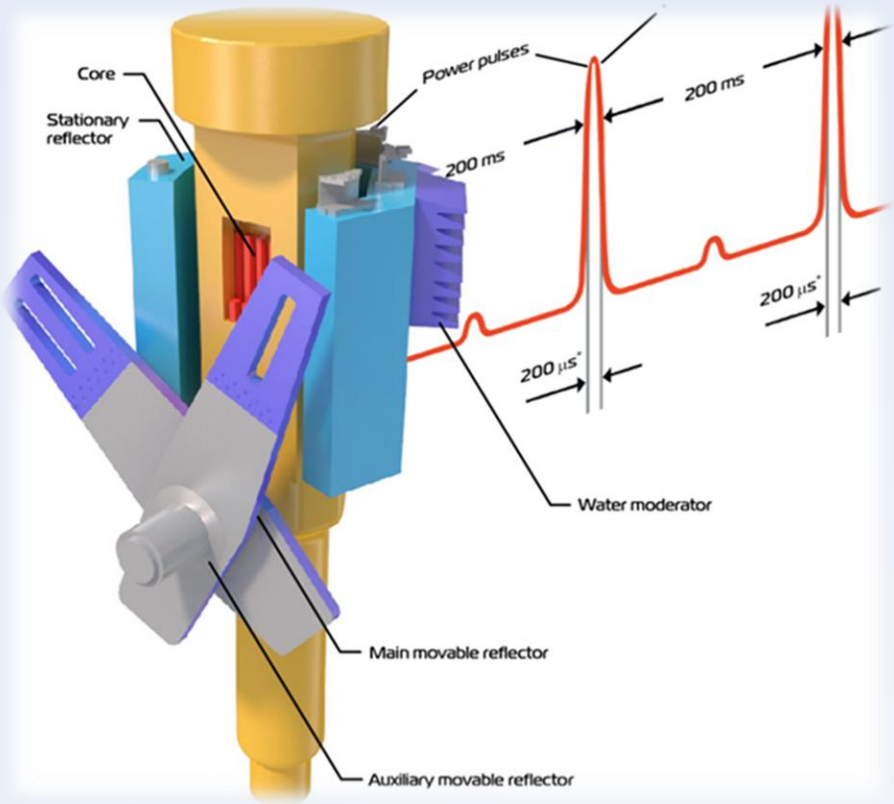
IBR-2 reactor FLNP (JINR)

Technical parameters of the IBR-2 reactor after modernization

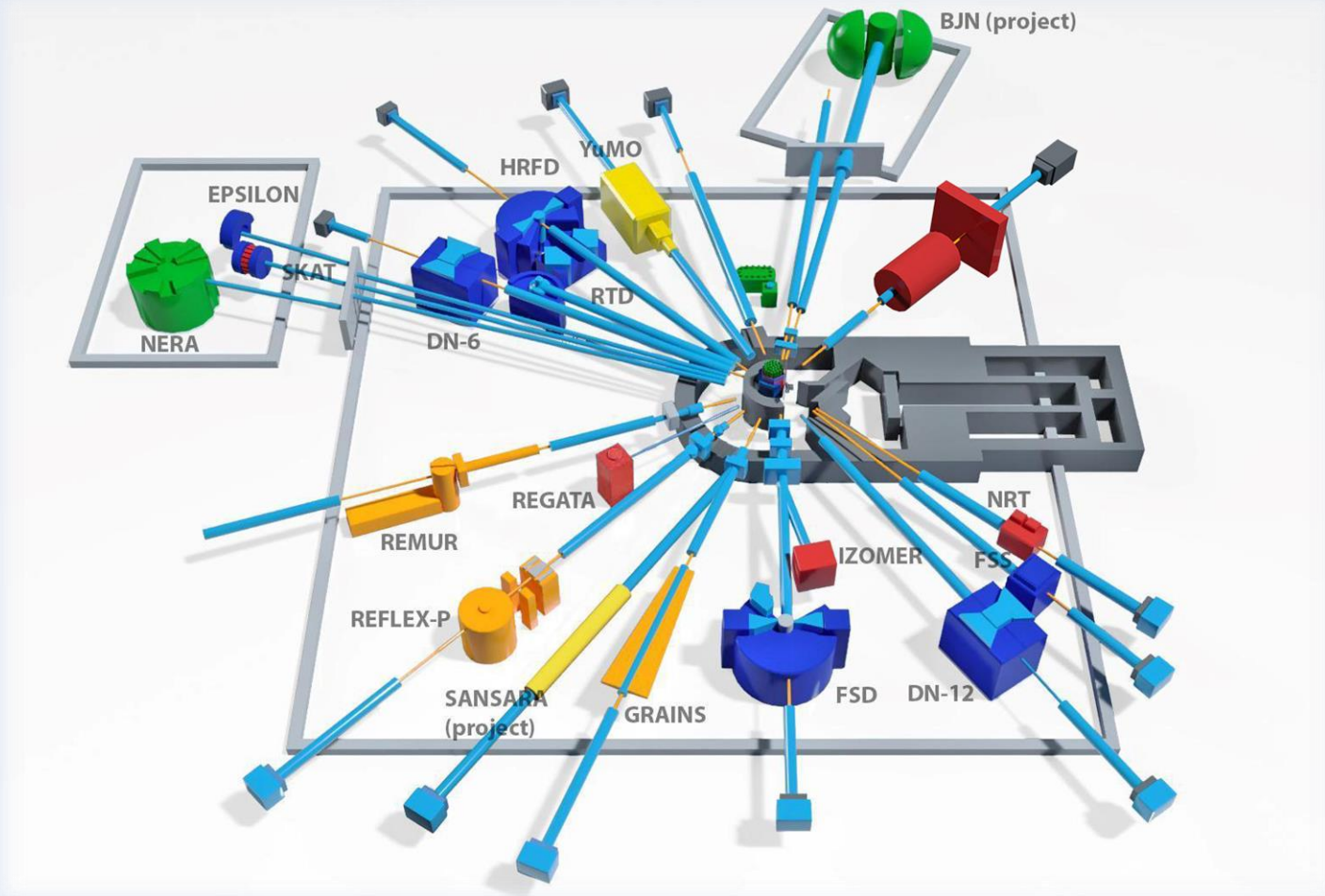
Average power	2 MW
Burst power	1850 MW
Fuel	PuO_2
Number of fuel assembles	69
Maximum burnup	9%
Pulse repetition rate	5, 10 Hz
Pulse half-width:	
fast neutrons	240 μs
thermal neutrons	340 μs
Background	7.5 %
Thermal neutron flux density (from the surface of the moderator):	
time average	~10^{13} n/cm^2/s
burst maximum	~10^{16} n/cm^2/s



IBR-2 reactor
https://flnp.jinr.int/

IBR-2 scientific facilities

18 research facilities:
- 14 - condensed matter physics
- 2 - nuclear physics
- 1 - radiation materials science
- 1 - neutron activation analysis.



scientific facilities of the IBR-2 reactor
https://flnp.jinr.int

Department of Spectrometers Complex (DSC)

The DSC of IBR-2 plays an important role in maintaining the efficiency and development of the experimental facilities. One of the most important activities of DSC is the development and creation of detector technologies, on the basis of which detectors for experimental installations are created.

Sector №1 Detectors and Electronics group

– **Gas position-sensitive detectors** (1D and 2D PSD based on multiwire proportional chambers with delay line data readout, different gas filled ring detectors with individual signal readout from each wire) and other types of gas detectors.

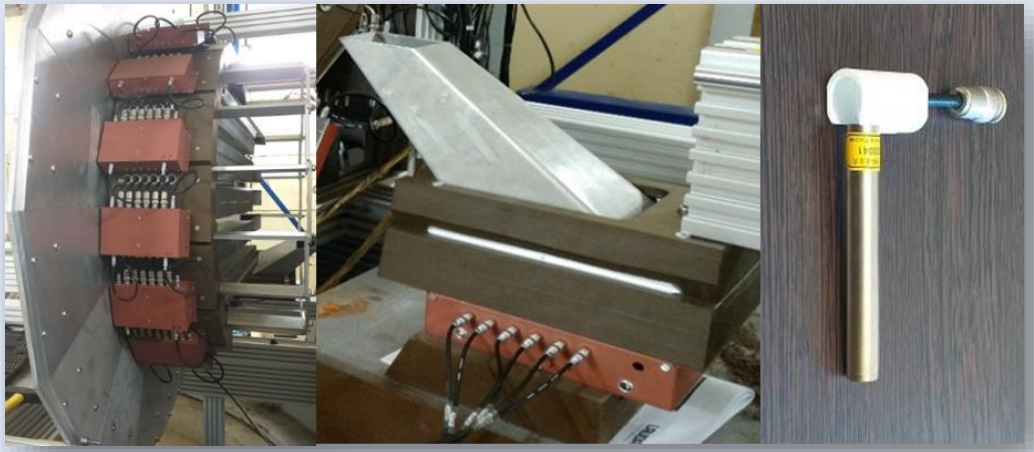
– Development and manufacturing of specialized **scintillation detectors** for neutron diffractometry (thermal neutron counters based on scintillation screens comprised of mixture of ZnS(Ag) and ^{6}LiF powders and with light collection by photomultipliers using spectrum-shifting fibers, scintillation PSD, data acquisition electronics).

– Developments and manufacture different **detector electronics** (preamplifiers, shaping-amplifiers for all types of detectors, discriminators, ADC, etc.)

– **Data acquisition and accumulation systems** (time encoders, intermediate and incremental memories, event code formers, devices to control accumulation time and beam characteristics, special-purpose processors for filtering and preliminary data processing, interfaces, etc.)

^{3}He detectors

Counters

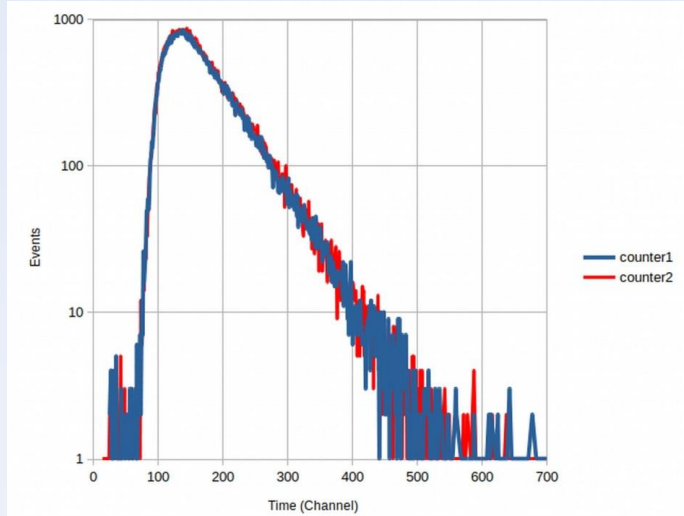


Small-angle 45° detector systems based on ^{3}He counters for the DN-6 diffractometer (beamline 6b) on IBR-2 reactor.
(Developed in Department of Neutron Investigations of Condensed Matter)

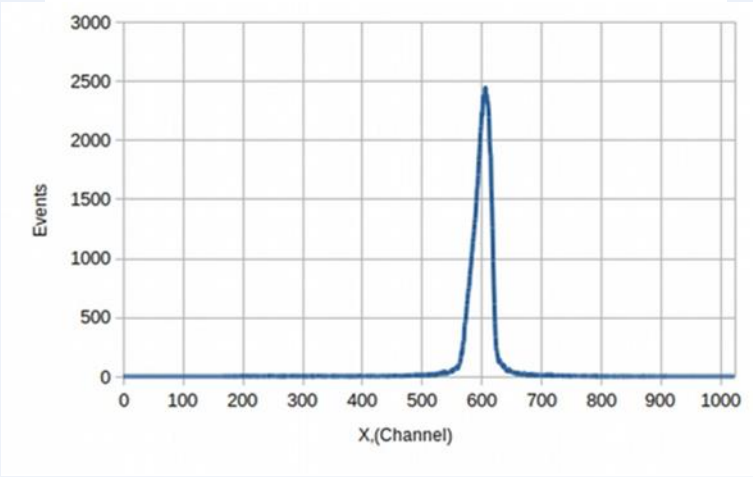
SPF «CONSENSUS»
development and production of counters used for registering alpha-beta-gamma and neutron radiation in radiometric and dosimetric devices

1D detectors with resistive anode (up to1 m long)

TOF spectrum of neutrons measured by a module of two position-sensitive counters with a resistive anode on the 9th beamline of the IBR-2 reactor.



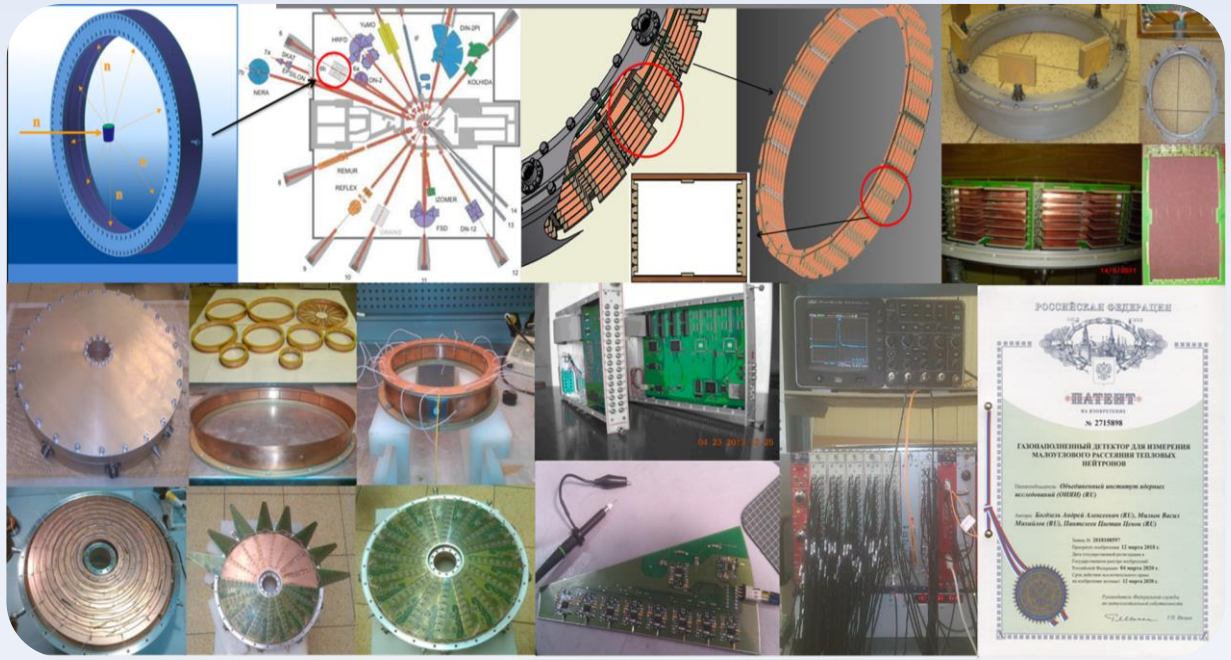
Coordinate spectrum of a direct neutron beam, measured by the position-sensitive counter (№1)



^{3}He detectors

Position-sensitive detectors for registration thermal neutrons

Multi-section ring detectors of thermal neutrons



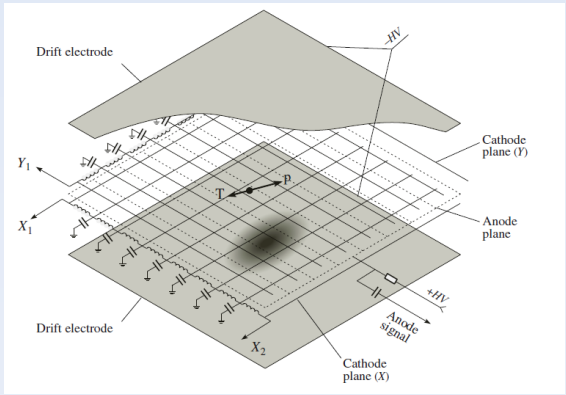
Position-sensitive detectors for registration thermal neutrons

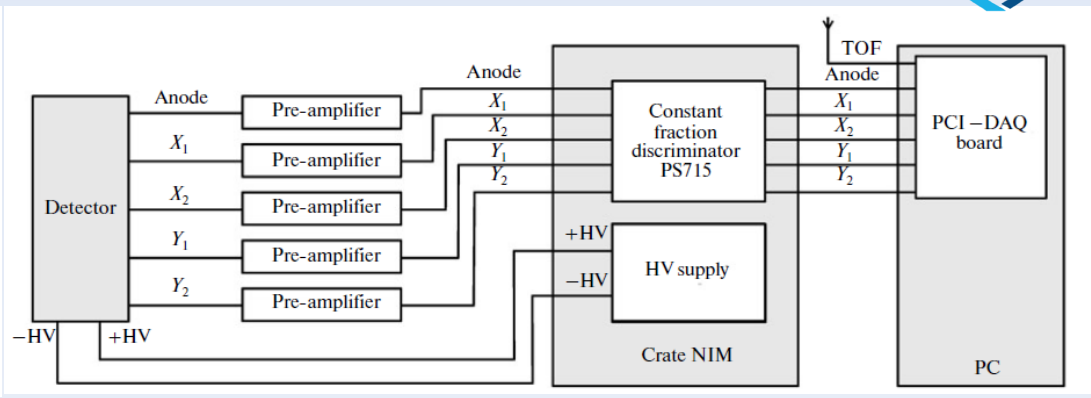
Main parameters of the developed position sensitive detectors

Characteristic	**Value**		
Detector type	Area monitor	Linear PSD	Area PSD
Operating area	100 × 100 mm^2	200 × 80 mm^2	225 × 225 mm^2
Efficiency	10^{-2} – 10^{-6} (λ = 1Å)	65% (λ = 2Å)	65% (λ = 2Å)
Coordinate resolution	4 × 4 mm^2	2 mm^2	2 × 2 mm^2
Load	Up to 100 kHz	Up to 100 kHz	Up to 1000 kHz
Uniformity of channels	No worse that 20% (5%*)	No worse that 5%*	No worse that 15%
Working gas	^3He or N_2 + CF_4	^3He + CF_4	^3He + CF_4
Total pressure	$1×10^5$ Pa	$4.5×10^5$ Pa	$4.5×10^5$ Pa

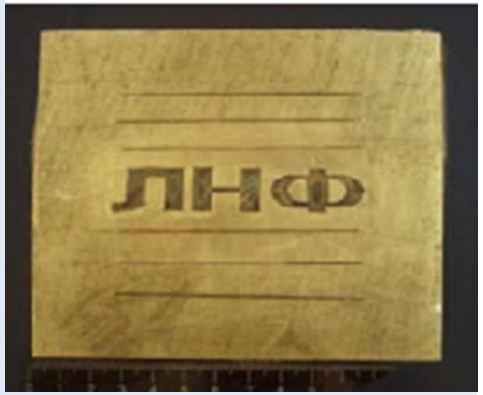
* The result with summations over the channels.

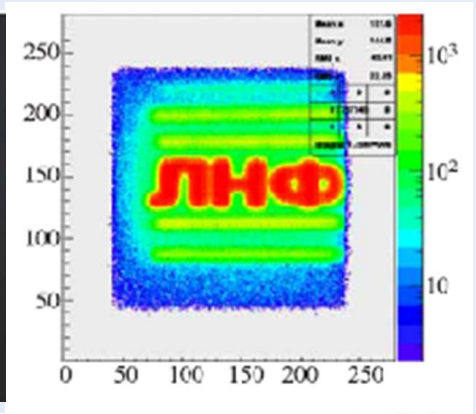
Position-sensitive detectors for registration thermal neutrons



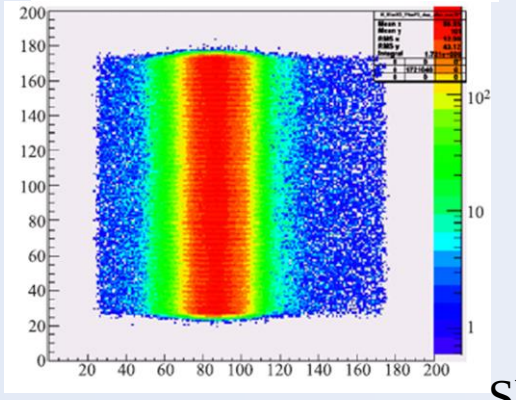


Schematic diagram of the system for data collection and accumulation



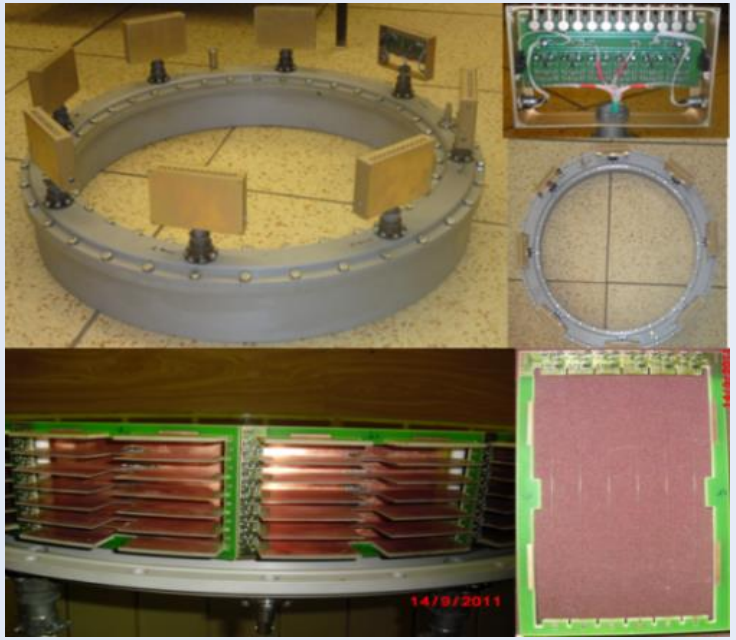


Measurements with the cadmium mask on which the abbreviation is engraved. The gas mixture is 50 mbar ^{3}He + 950 mbar CF_4; the anode voltage is +3300 V; the measurement time is 15 min; the scale division of the channel is ≈0.5 mm.



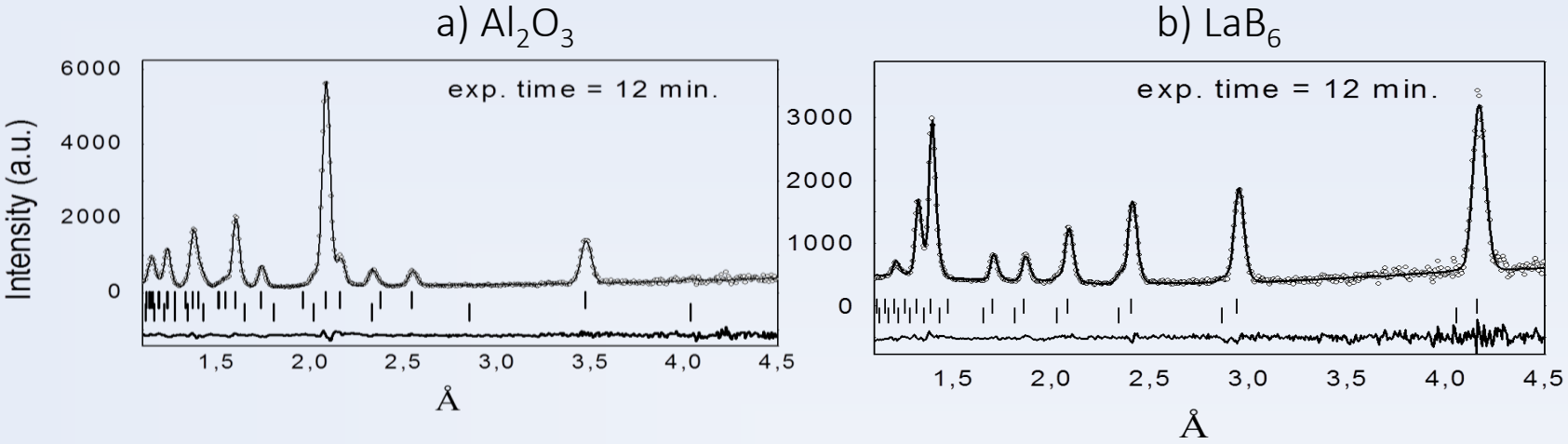
Profile of beam №6 (central part) from the IBR-2 reactor. The gas mixture is 50 mbar N_2+ 950 mbar CF_4; the anode voltage, +3400 V; the measurement time is 14h 28min 48s; the scale division of the channel is ≈0.64 mm.

Multi-section ring detector of thermal neutrons for diffraction studies on microsamples in axial geometry



appearance of the detector and its components

Detector is designed for DN-6 spectrometer at the IBR-2 reactor (channel №6b). Detector consists of 16 sections; each section is divided into 6 independent detector elements (Total 96 channels).

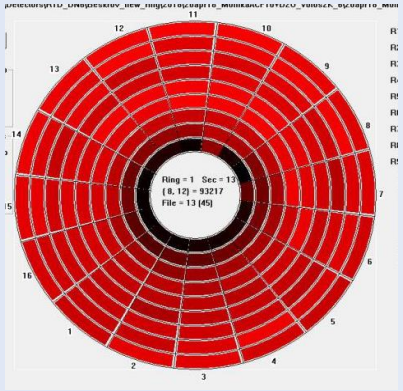


The neutron spectra of Al2O3 and LaB6, obtained with the spectrometer. The original spectra (dots), calculated profiles (smooth curve), the difference function and peak positions for Al_2O_3 and LaB_6 (vertical lines) are shown.

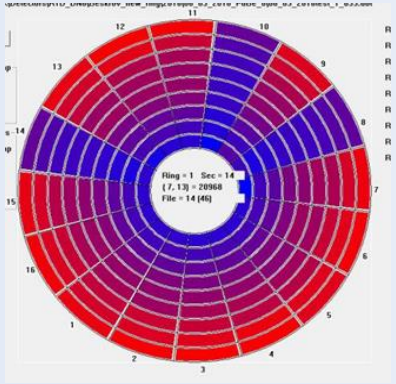
Ring detector for measure small-angle scattering of thermal neutrons

appearance of the detector and its components

Ring detector is designed for measuring small-angle scattering of thermal neutrons. It's installed at the Real-Time Neutron Diffractometer (RTD) at the IBR-2 reactor (channel № 6a). The detector is divided into 9 equidistant coaxial rings from a two-sided foil-coated composite epoxy material. The cathodes of each of the rings are divided into 16 sectors (153 independent detector elements). Registration signals are taken from the anode wires 25 μm (common for every single ring) and with each of the 16 cathodes.



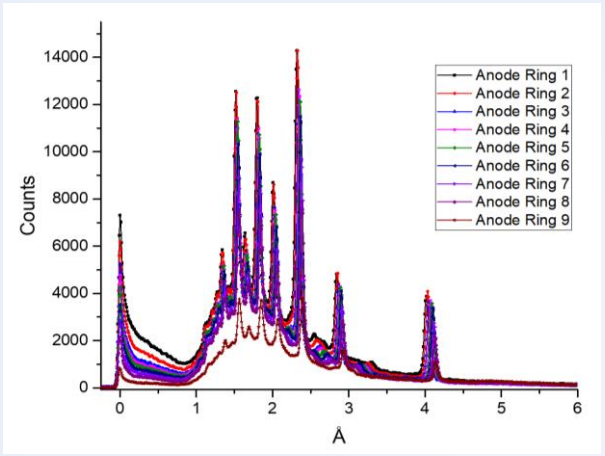
uniform illumination



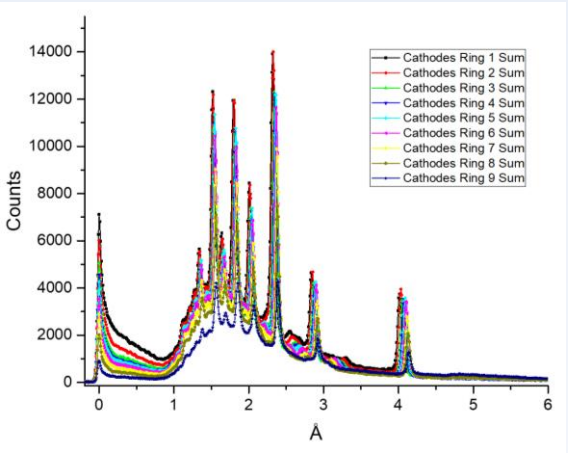
cadmium mask

Spectrums from standard sample $CrFe_2O_4$ for

a) all anodes rings



b) sum for all cathode rings.

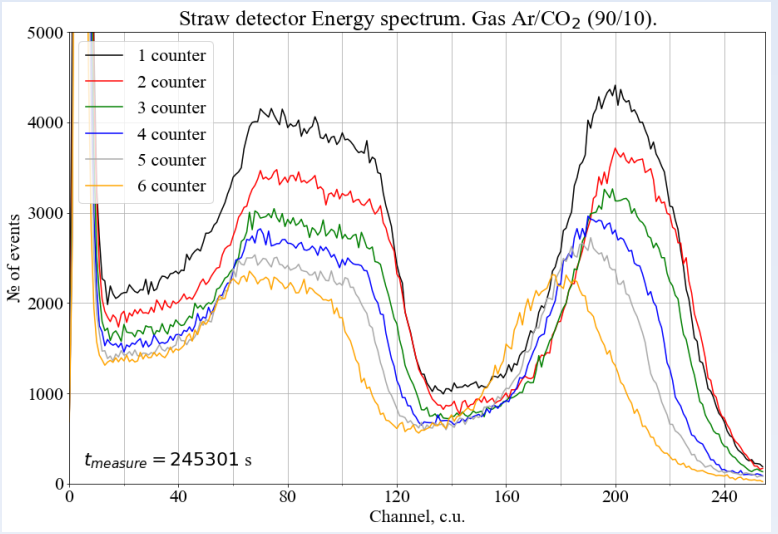


Detector allows provide measurements on samples in which the angular or axial anisotropy of slow neutron scattering is observed.

Neutron detectors based on $^{10}B_4C$

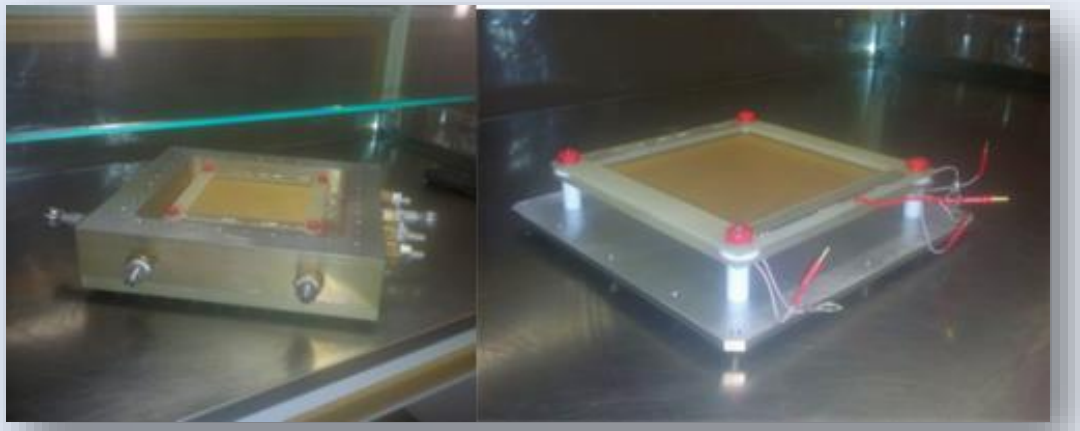
One–coordinate detectors on gas-discharge proportional straw tubes based of $^{10}B_4C$ (prototype)

appearance of the detector and its components

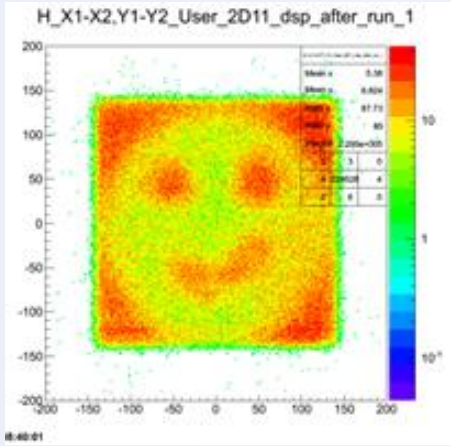


Straw detector energy spectrum
Gas Ar/CO2 (90%/10%)
t of measure 245301 s

$^{10}B_4C$ with multi-wire proportional chamber (MWPC)

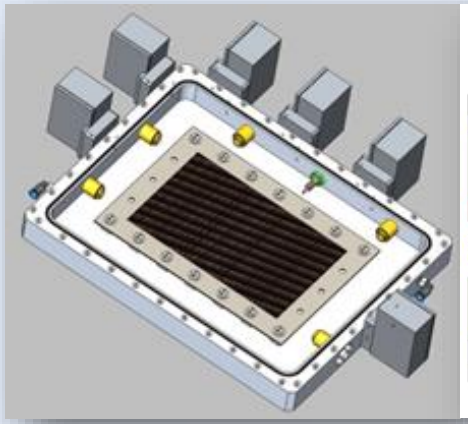


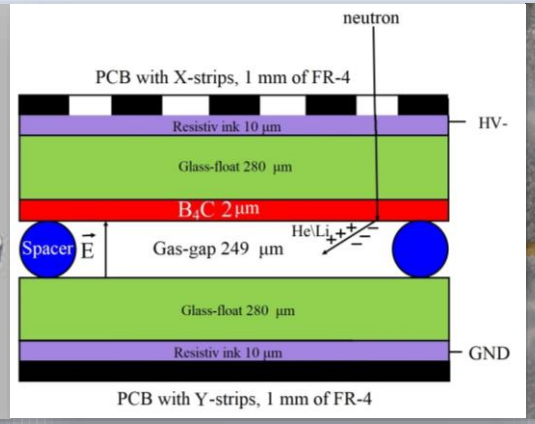
appearance of the detector

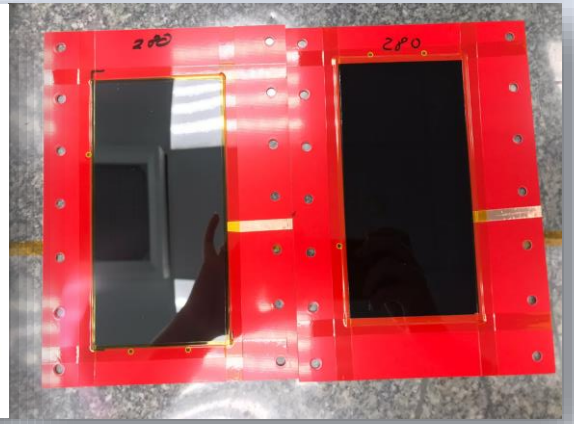


Neutron detectors based on $^{10}B_4C$

Plane-parallel resistive detector of thermal neutron based of $^{10}B_4C$ (prototype).



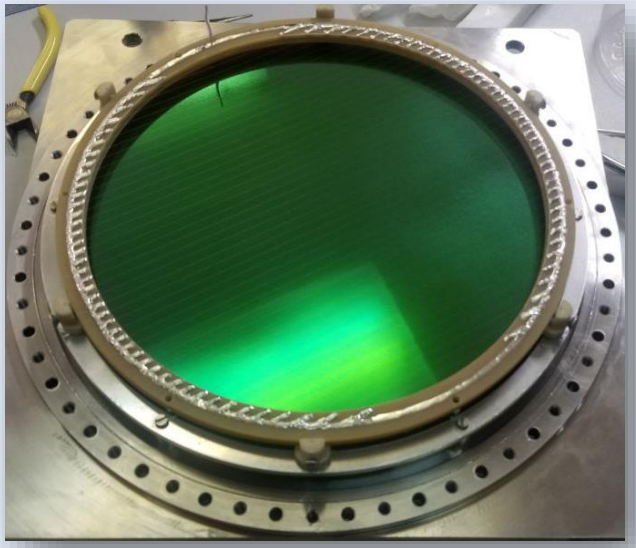


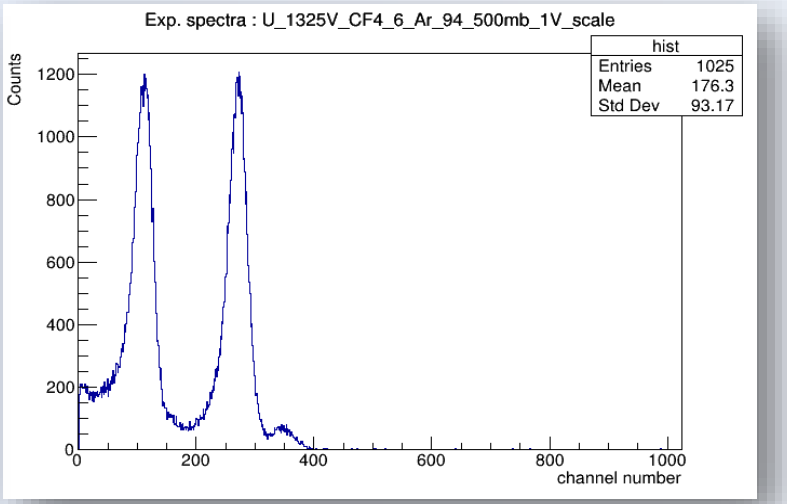


- spatial resolution is 5 mm;
- temporal resolution is 8 ns;
- efficiency is 0.5%.

Settings is not optimal.

Detector of thermal neutron based of $^{10}B_4C$ on an aluminum substrate

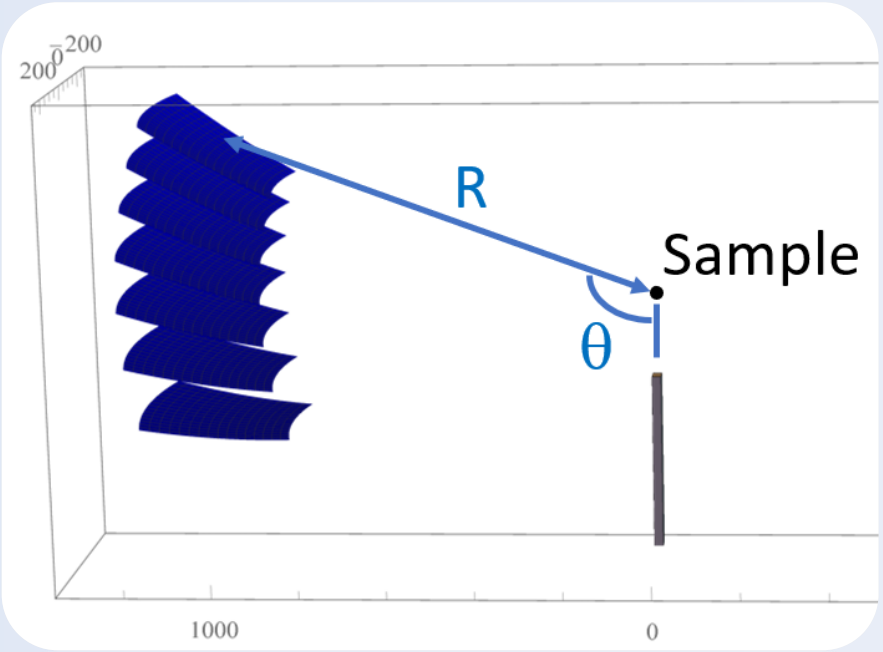




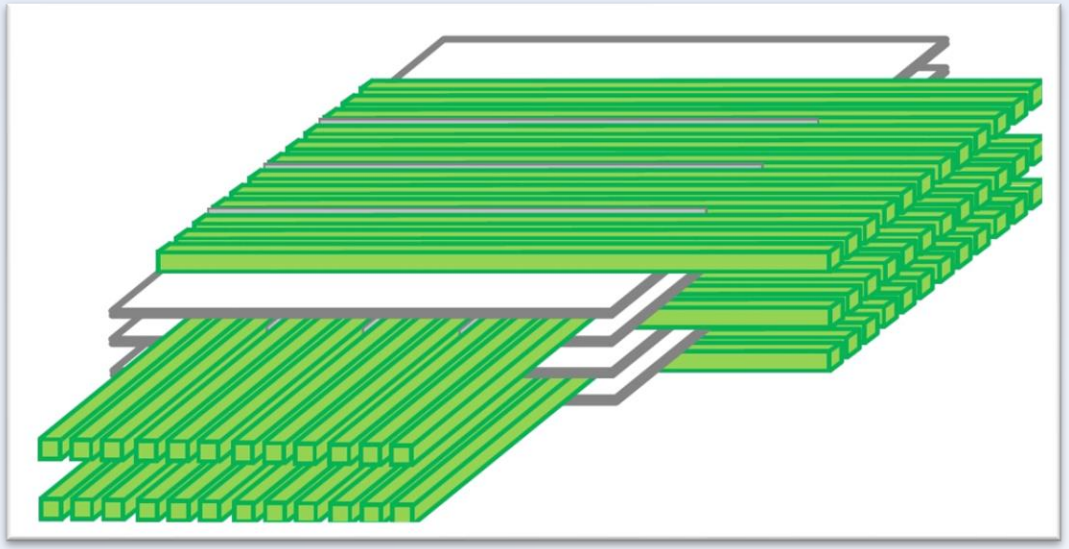
Scintillation detectors

Focusing geometry

$$R(\theta) = \frac{A_0}{\sin(\theta/2)} - L_0$$

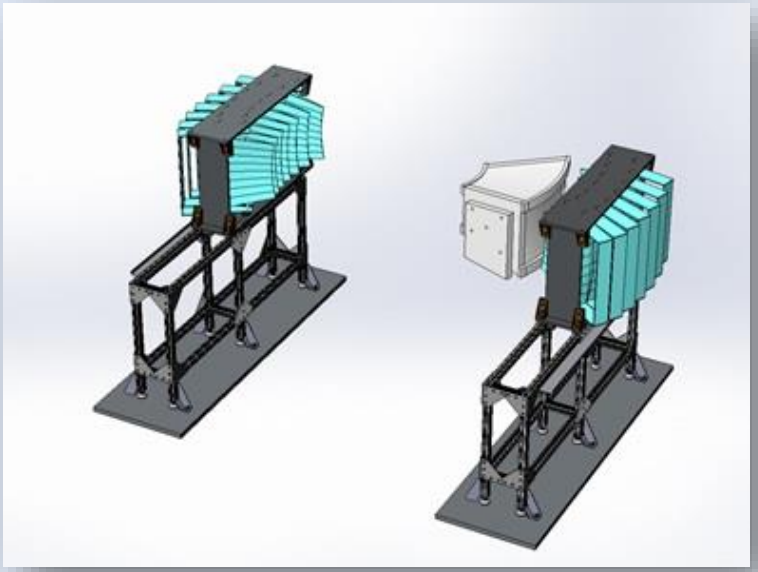


Position-sensitive detectors



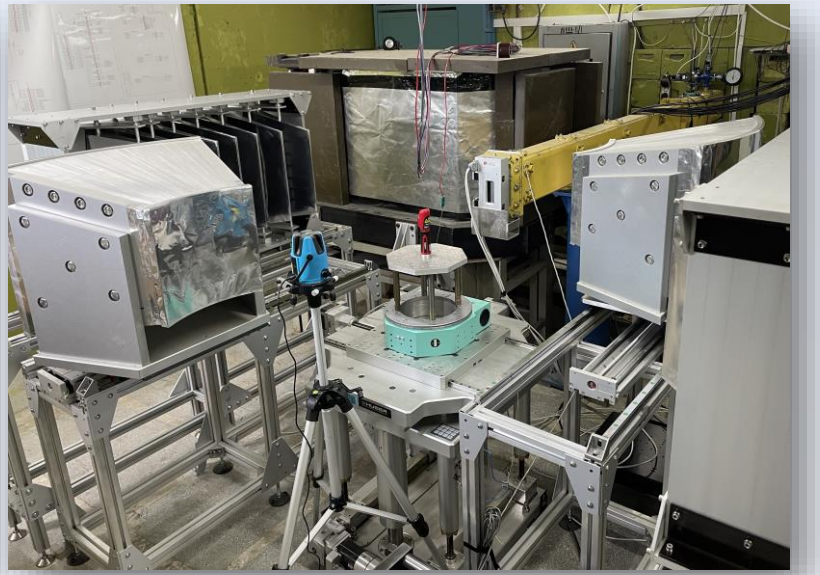
Detector ASTRA-M

- Covers scattering angles: $\theta=\pm 90\pm 20°, \varphi\in[-12°;12°]$ $(\Omega = 0.55\ sr)$;
- Combined focusing method (14 detecting elements);
- High efficiency of thermal neutron conversion *(72%)*;
- 14 recording channels; signal processing using 1 MPD-32 module



Detector design

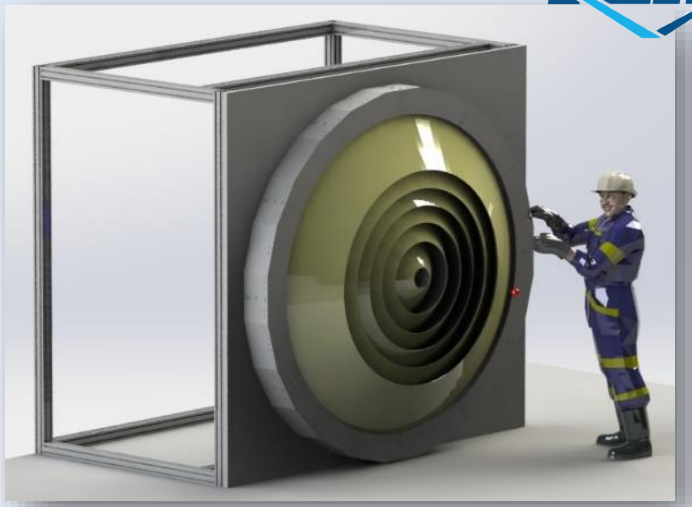
Detecting element



Detector mounted on Fourier-stress diffractometer FSD

Wide-aperture backscattering detector

- Covers scattering angles $\theta = (133 - 175)°$ *($\Omega = 2$ sr)*;
- Combined focusing method (6 rings divided into 12 sectors);
- 2 scintillator layers, average conversion efficiency 85%;
- 108 detector elements (216 registration channels)
- Signal processing using 8 MPD-32 modules

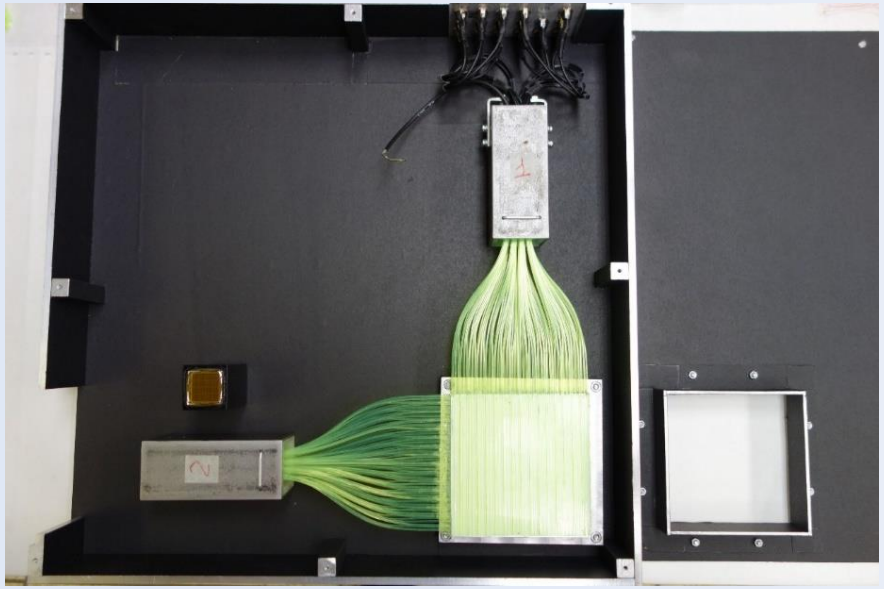


Detector design

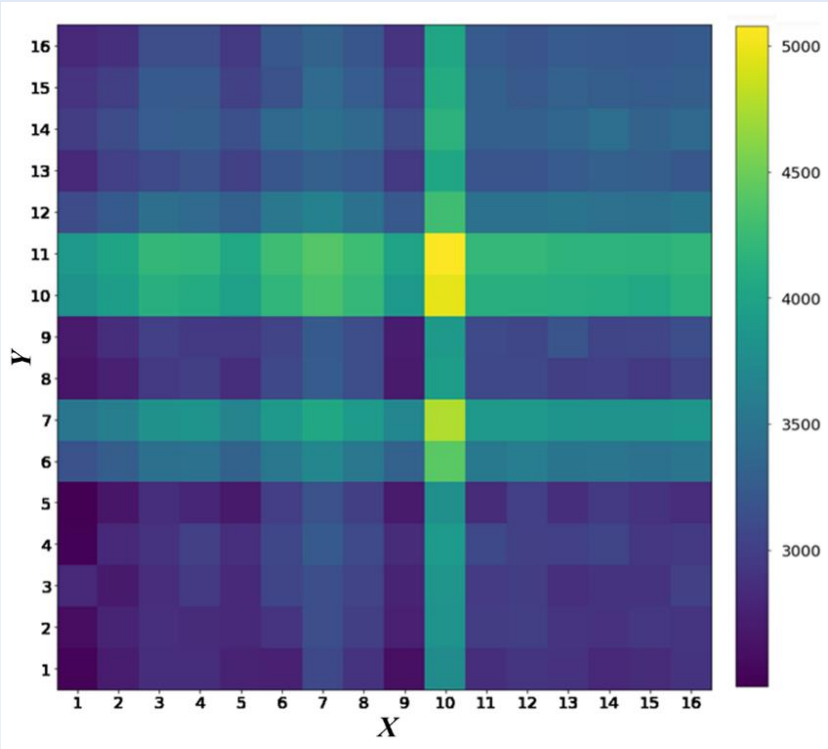
appearance of the detector and its components

Prototype of two-dimensional scintillation detector

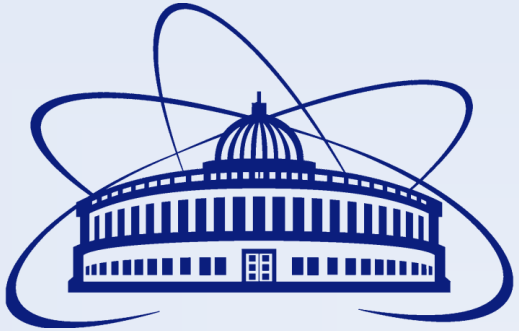
- 4 ND screens 9.6 × 9.6 cm^2
- 5 layers of optical fiber (square section, 1 mm)
- 2 16-channel PMTs Hamamatsu - H8711-100
- 16 × 16 channels (0.6 × 0.6 cm^2)
- Conversion efficiency 78%



appearance of the detector



Histogram of detector illumination at the experimental stand



Thanks for your attention!

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