THE INSTALLATION FOR EXPERIMENTAL NEUTRON SPECTRA RESEARCH IN REACTOR MATERIALS COMPOSITIONS

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Classical neutron spectrum of fast breeder reactors

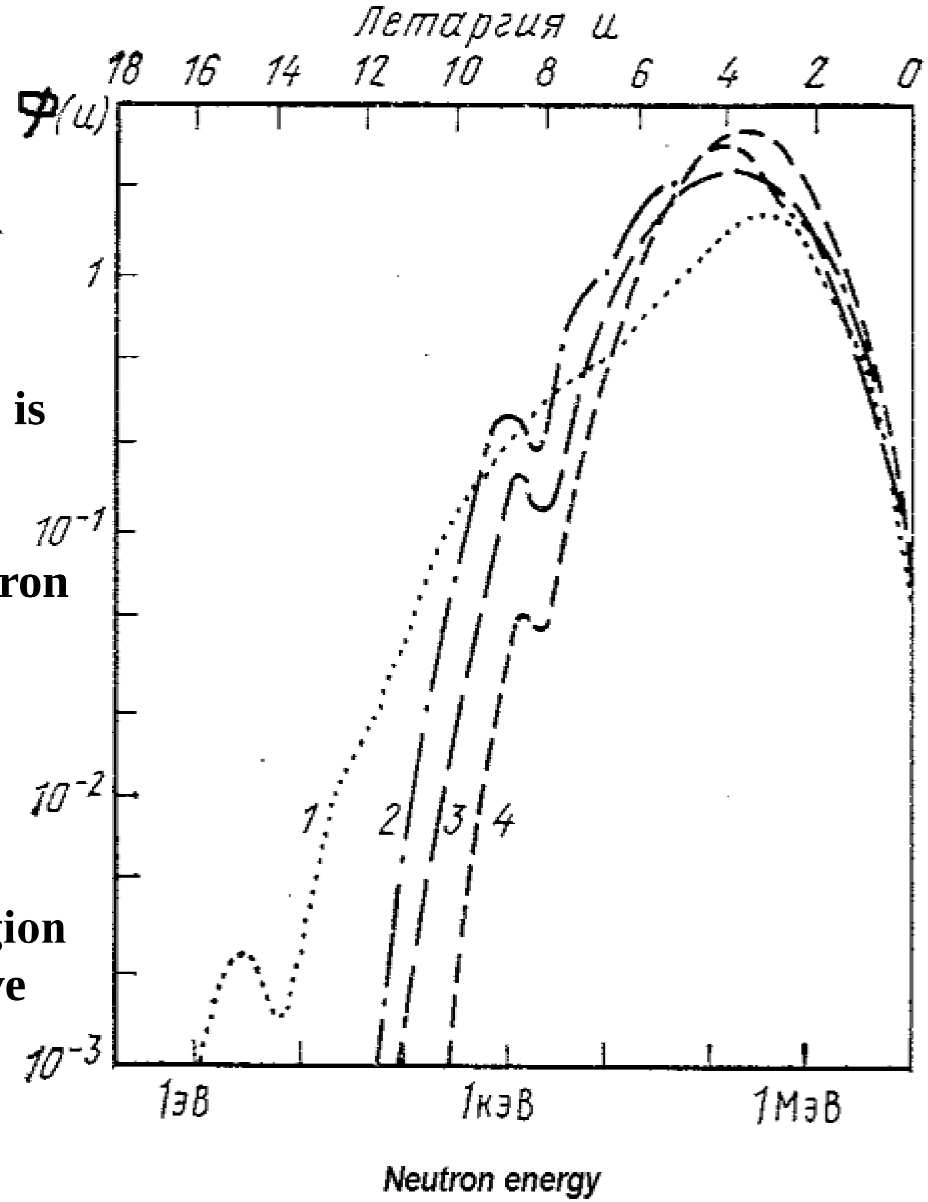
- **Fission spectrum is described by continuous curve**

$$n(E) = C \cdot \exp\left(-\frac{E}{0.965}\right) sh\sqrt{2.29 \cdot E}$$

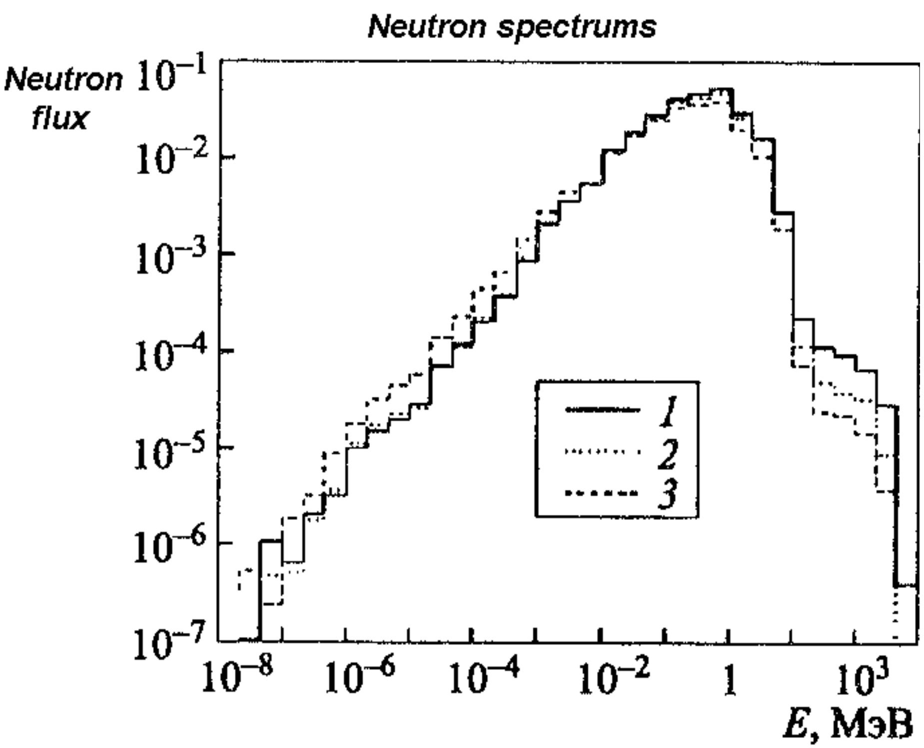
- **Average energy of fission spectrum is 2 Mev**

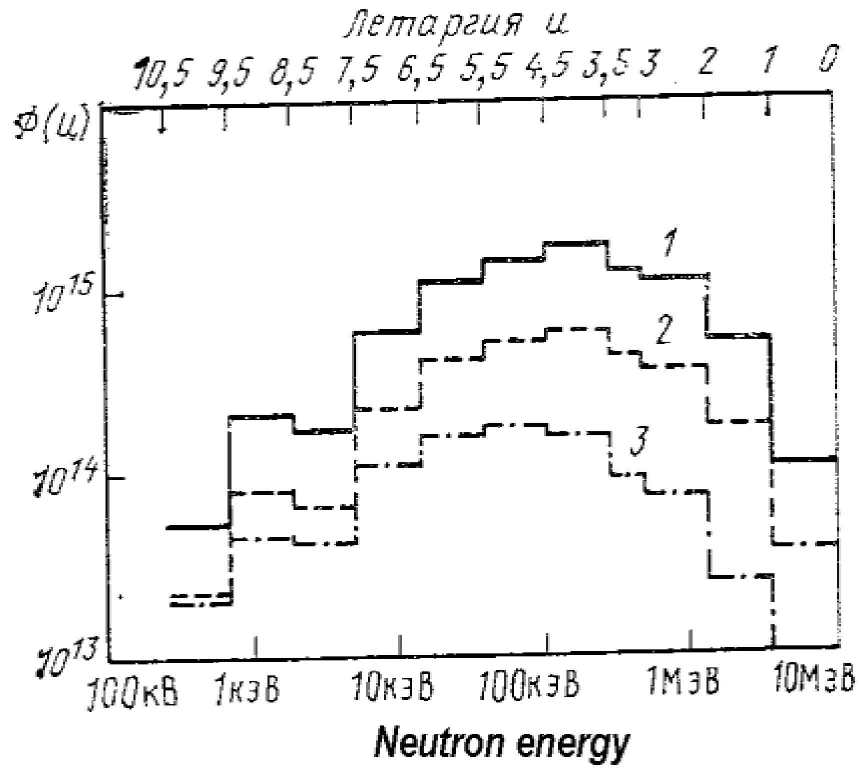
- **In actual fast breeder reactors neutron spectrum significantly differs from fission spectrum due to inelastic scattering in U-238 and construction materials of reactor's core.**

- **It's average energy is shifted to region from 150 to 750 kev in different active core compositions.**



Spectrums of SFR and fission in 28 energy group system ABBN-78





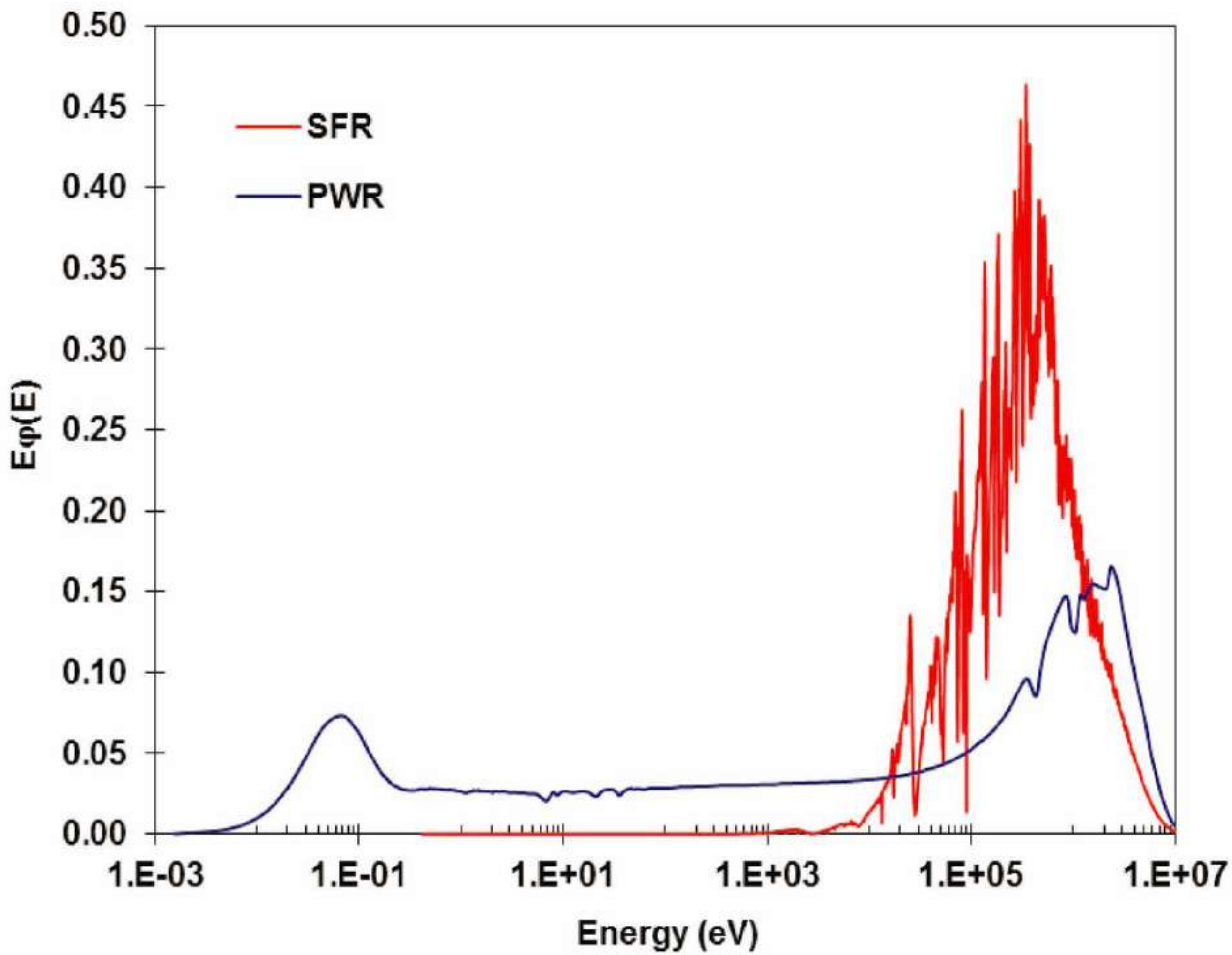
- **Traditionally neutron fluxes and cross sections are performed as 28 group tables**

- **In a case of fast breeder reactors, main part of neutrons is concentrated in 4 – 5 of them**

Actual neutron spectrum of SFRs, determined by resonance cross section's structure of core shields nuclides

• Resonance structure of inelastic scattering and capture of neutrons in U-238, Fe, Ni, Cr, Ti and other materials, transforms neutron spectrum of breeder reactors to a very detailed form. Thus appears a task to measure the spectrums of various subcritical assembly's compositions.

• Measurements of spectrums provide an opportunity to compare then with numerical computation results and modify computer codes for better agreement with experiment



Choice of SFR core materials and composition influences to neutron spectrum and determines breeding ratio

- **Fuel cells shield's material occupies 20% of initial volume in SFRs and 30% in SCWR reactors.**
- **Resonance cross sections structure of fuel cell's shields influences on medium spectrum energy.**
- **Exact information on neutron spectrum provides optimization of material choice, greatly influences on breeding ratio and fuel doubling time.**

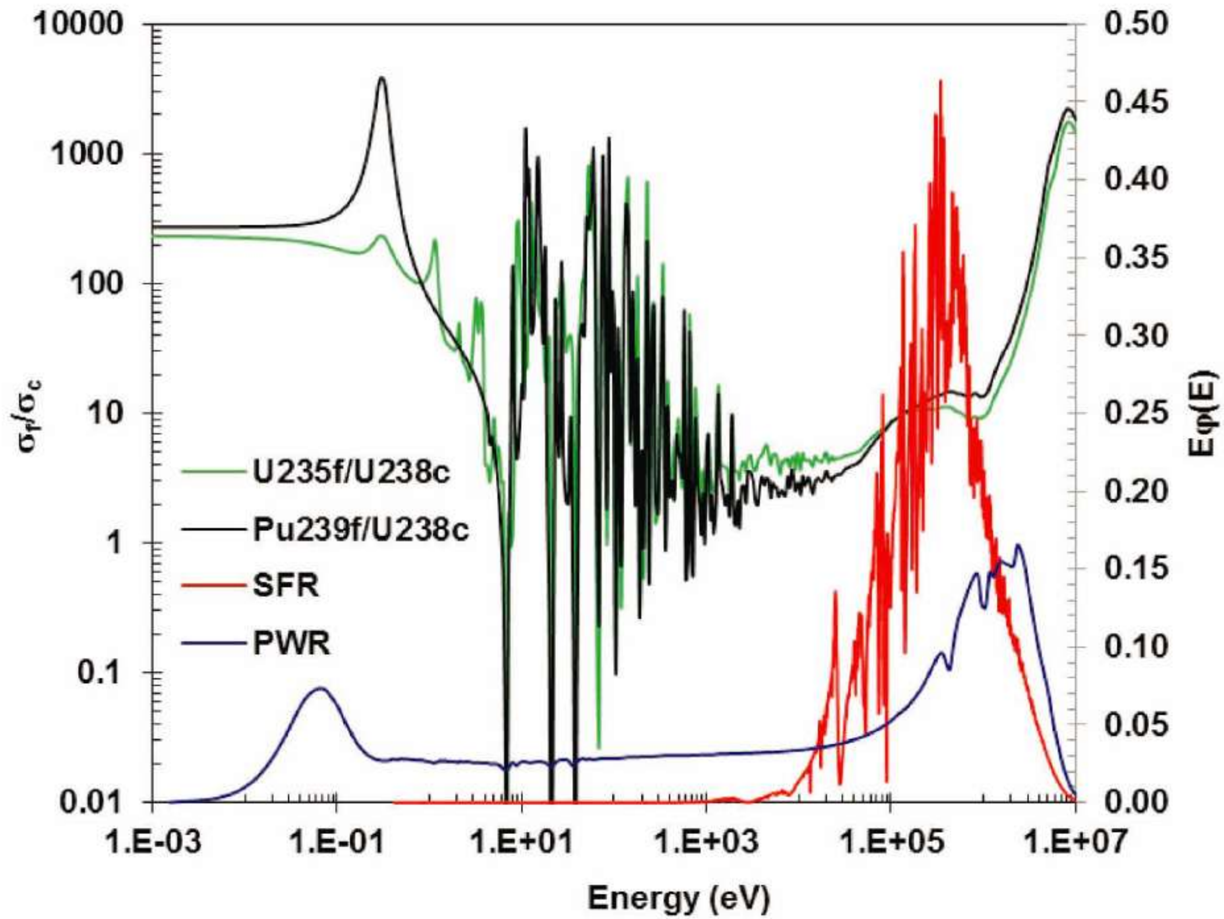
		Pu - U	U233-Th
Oxide fuel	RDT	16	112
	BR	1.28	1.041
Carbide fuel	RDT	9	91
	BR	1.42	1.044
Metall fuel	RDT	6	43
	BR	1.63	1.11

SFR’s neutron spectrum position in the same axis with fission and capture cross sections

- **Spectrums in critical assemblies are traditionally measured by activation analysis in few points of reactor and on energy axis.**
  TOF method provides more detailed and exact results on spectrum form and reactivity coefficients

- **Threshold neutron energy in fission cross sections of Pu-240, Pu-242, Np-237, and Am-241 can be from left and from right side of spectrum’s maximum in different compositions**

- **Exact information on spectrums and cross sections is necessary for computations of exact values of BR and FDT.**



INR spallation neutron source characteristics with the short pulses

Proton energy, Mev	L_{ion} (Ti) cm	L_{ion} (Pb) cm	${}_0n^1/{}_1p^1$	P_{beam} W	$\left(\frac{{}_0n^1}{4\pi}\right)$	$\left(\frac{{}_0n^1}{cm^2}\right)$ L=30m	$\left(\frac{{}_0n^1}{cm^2}\right)$ L=300m	$\left(\frac{{}_0n^1}{600cm^2}\right)$ **L=300m J=16mA**
100	2.06	1.05	0.4	160	$4\cdot10^{12}$	$3.5\cdot10^{4}$	353	$2.1\cdot10^{5}$
143	3.52	1.8	0.85	230	$8.5\cdot10^{12}$	$7.5\cdot10^{4}$	750	$4.5\cdot10^{5}$
209	6.21	3.18	1.5	335	$1.5\cdot10^{13}$	$1.3\cdot10^{5}$	1326	$8\cdot10^{5}$
305	10.9	5.6	4.0	489	$4\cdot10^{13}$	$3.5\cdot10^{5}$	3536	$2.1\cdot10^{6}$
500	23.1	11.8	9.0	800	$9\cdot10^{13}$	$8\cdot10^{5}$	8000	$4.8\cdot10^{6}$

$$\tau_p = 1\mu\sec; \nu = 100Hz; J_p = 16mA; J_{av} = 1.6\mu A;$$

Pulsed power of accelerator's RF amplifiers provide pulsed proton current up to 30 mA. Target power and neutron fluxes of this table can be increased in the factor of 2.

50 meter flight base of pulsed resonance neutron INR source RADEX

In the experimental building of INR Russian Academy of Sciences are available:

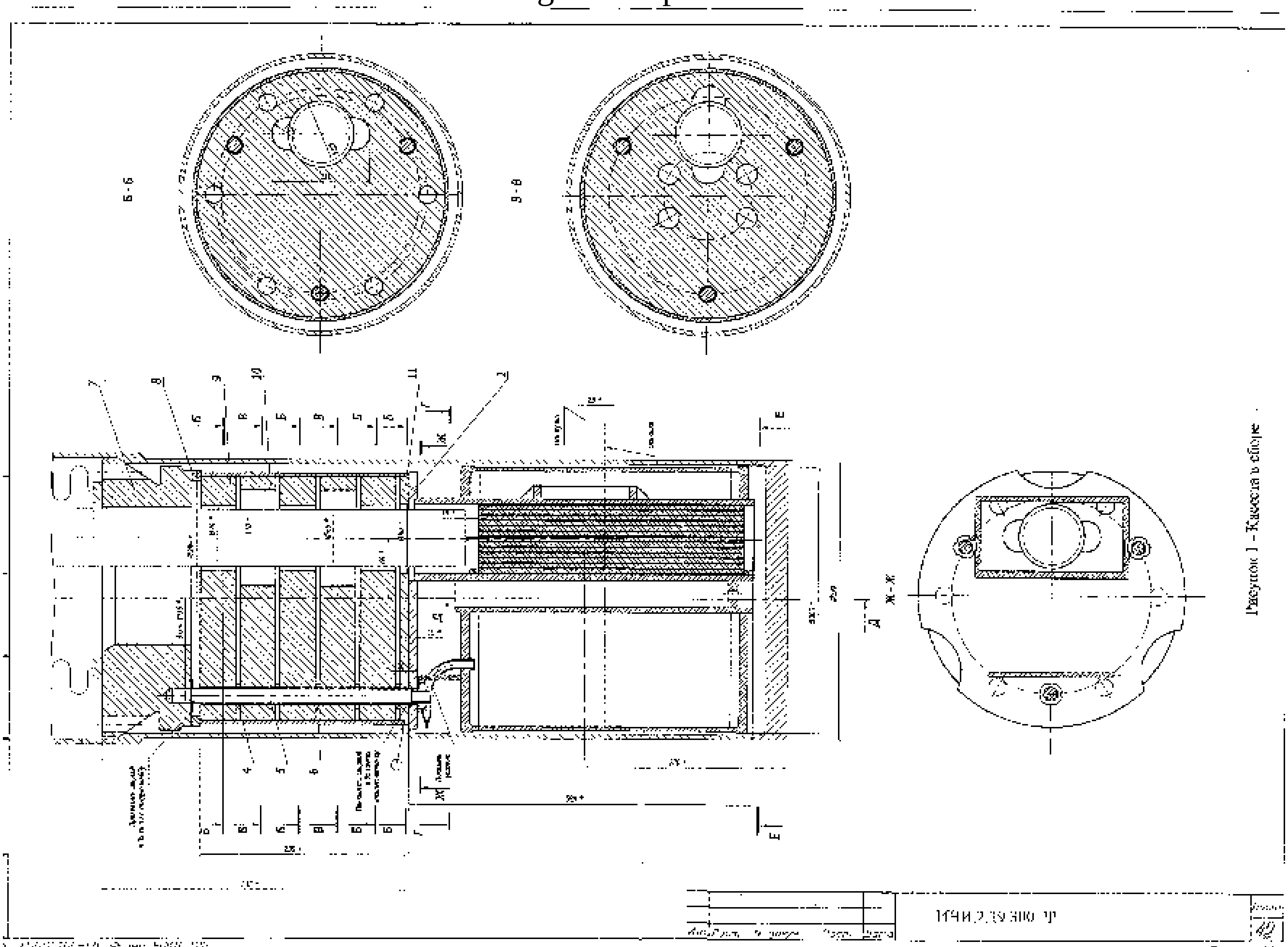
• RADEX, spallation neutron source with fast and resonance neutron spectrum

• SVZ-100, lead 100 tons high flux spectrometer

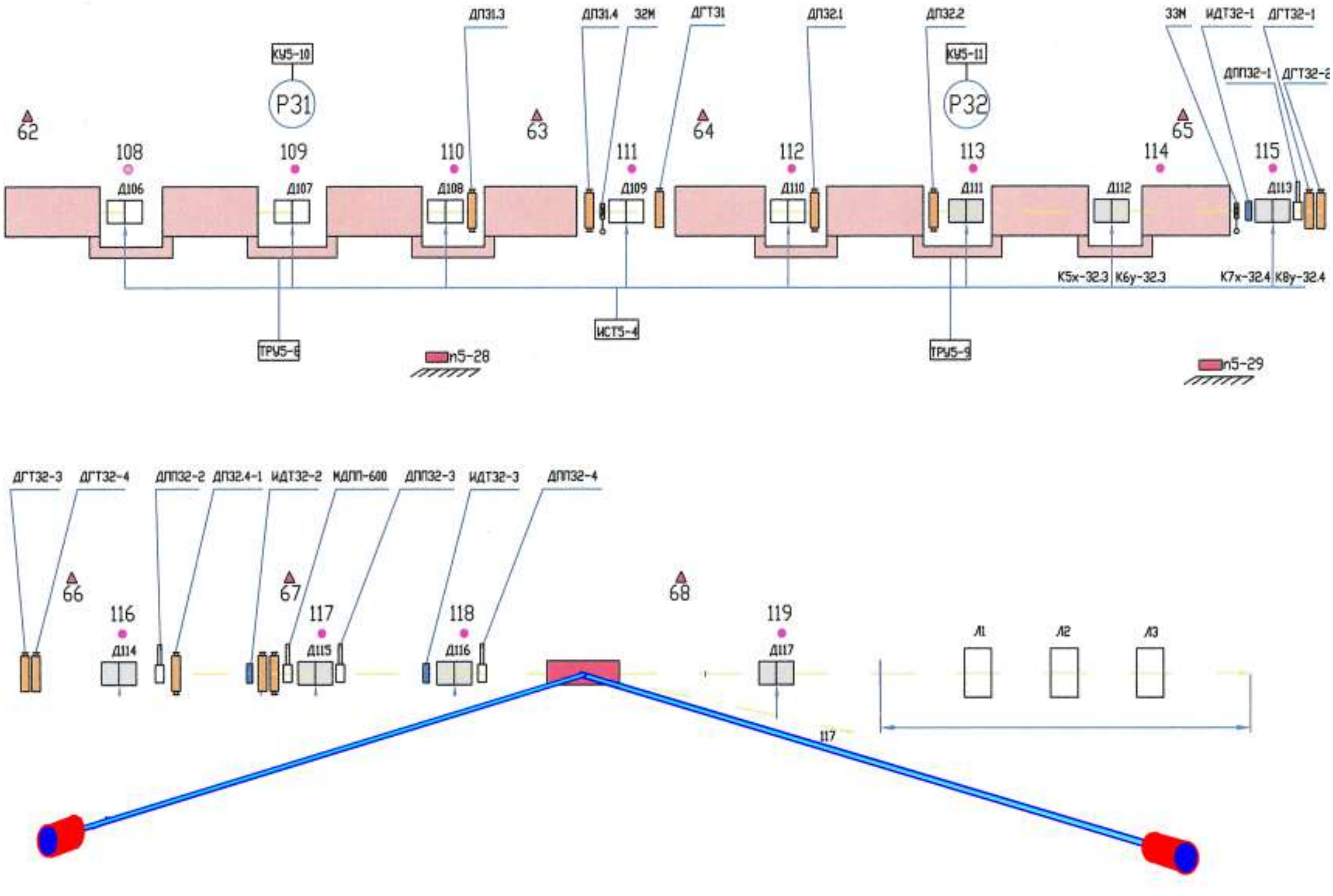
•IN-06, source with thermal and cold neutrons for solid state physics

•Now started works on creation of an installation, devoted to measurements with spectrum of fast breeder reactors. Their mean energy **140 kev<En<2 Mev** depends on used materials and their amount in the reactor core.

RADEX target, assembled of 13 tungsten water cooled plates, designed for power 0.6 MW

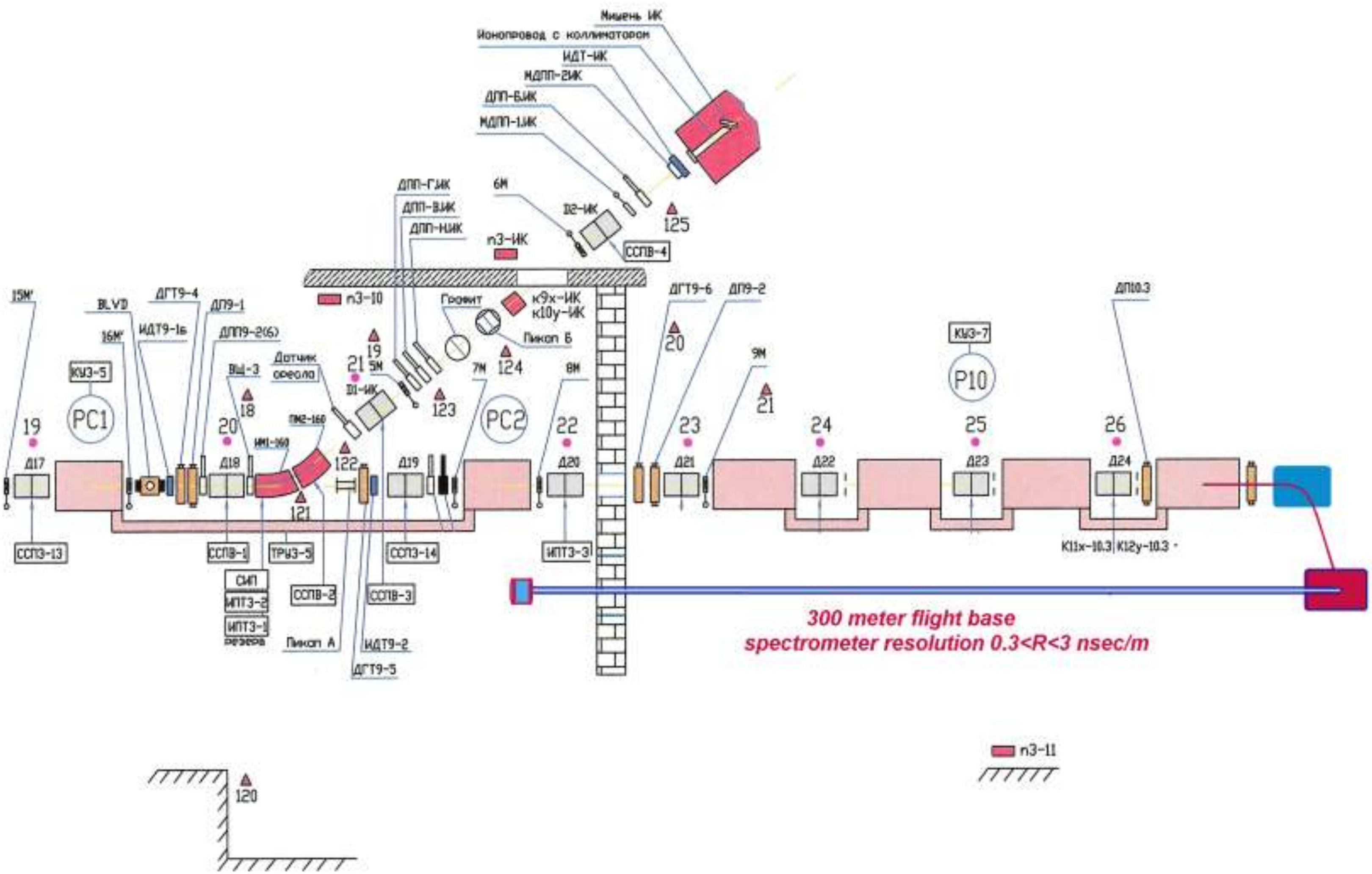


30 meter flight base in the tunnel of proton linac

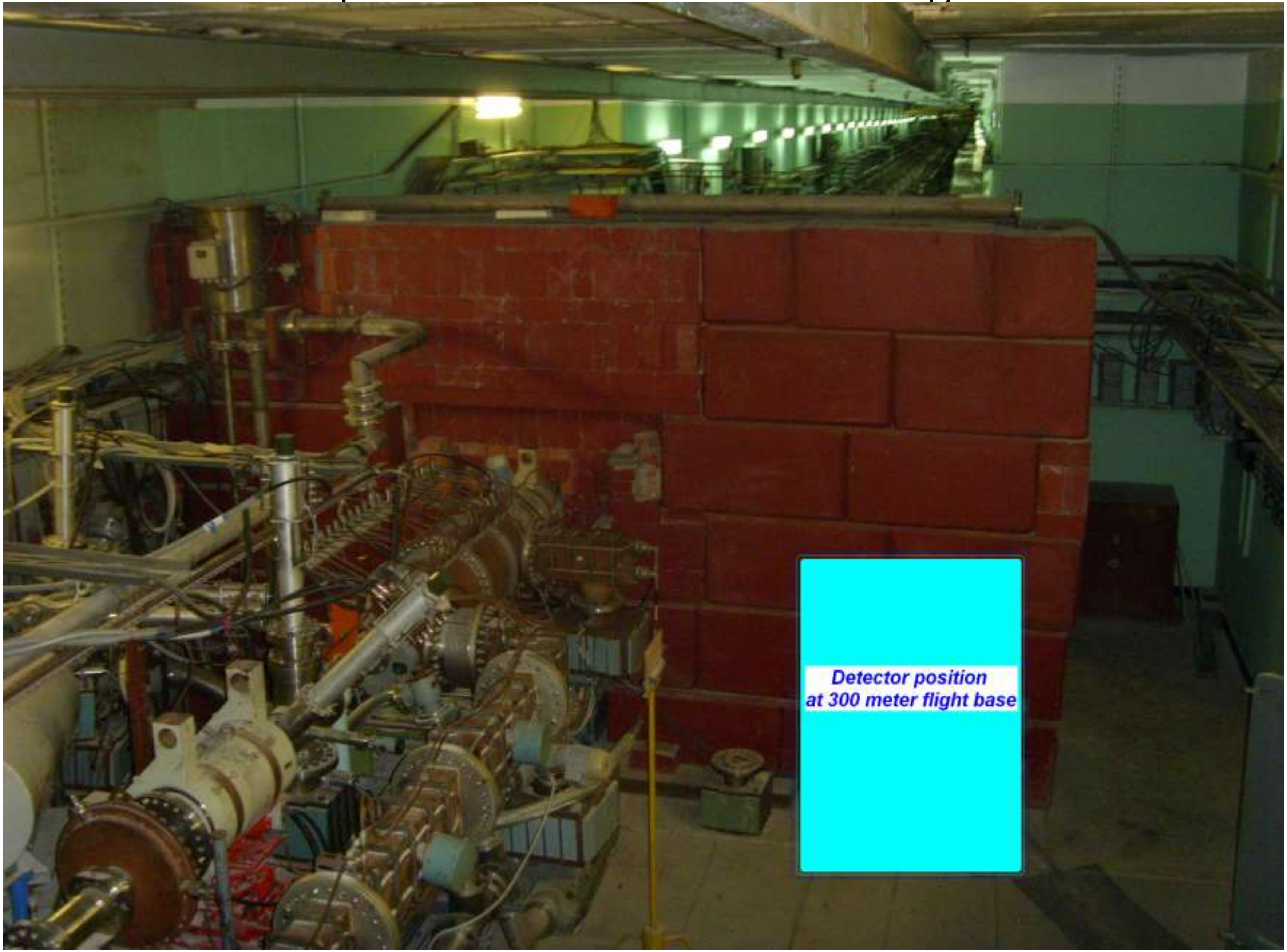


Placement of lead target on the linac proton beam

300 meter flight base in the linac tunnel



Experimental area of 300 meter flight base



Separation of neutrons and gamma quantum events by multiplicity

- **8 He-3 counters SNM-18**
- **8 light-separated sections with plastic scintillator, each observed by FEU-97**
- **Scintillation time 30 nsec, smaller that time elapsed by 150 kev neutron to fly detector's length**
- **Neutrons and gamma photons are distinguished by multiplicity on short flight bases**
- **At flight bases L>100 meters there is an ability to select neutrons and gamma photons also by coincidence of FEU-97 and SNM-18 signals. It provides experimental spectrums with low background and more exact forms**
- **At long flight bases L>100 meters, time of neutron's fly exceeds time of neutron's slowing in hydrogen containing plastic scintillator even for 14 Mev neutrons. This allows to use this device also as an all-wavelength neutron detector with effective square of 600 square cm.**

Characteristic neutron flight times in fast neutron TOF experiment

	E_n=14 Mev	**E_n=140 kev**
L=30 m	$0.6\mu\mathrm{sec}$	$6\mu\mathrm{sec}$
L=300 m	$6\mu\mathrm{sec}$	$60\mu\mathrm{sec}$

During measurements of TOF spectrums of neutrons, emitted by subcritical assemblies and thick compounds of construction materials such as Ti, V, Fe, Cr, Ni we observe integral characteristics of the reactor core. When computer programs calculate them numerically, they use

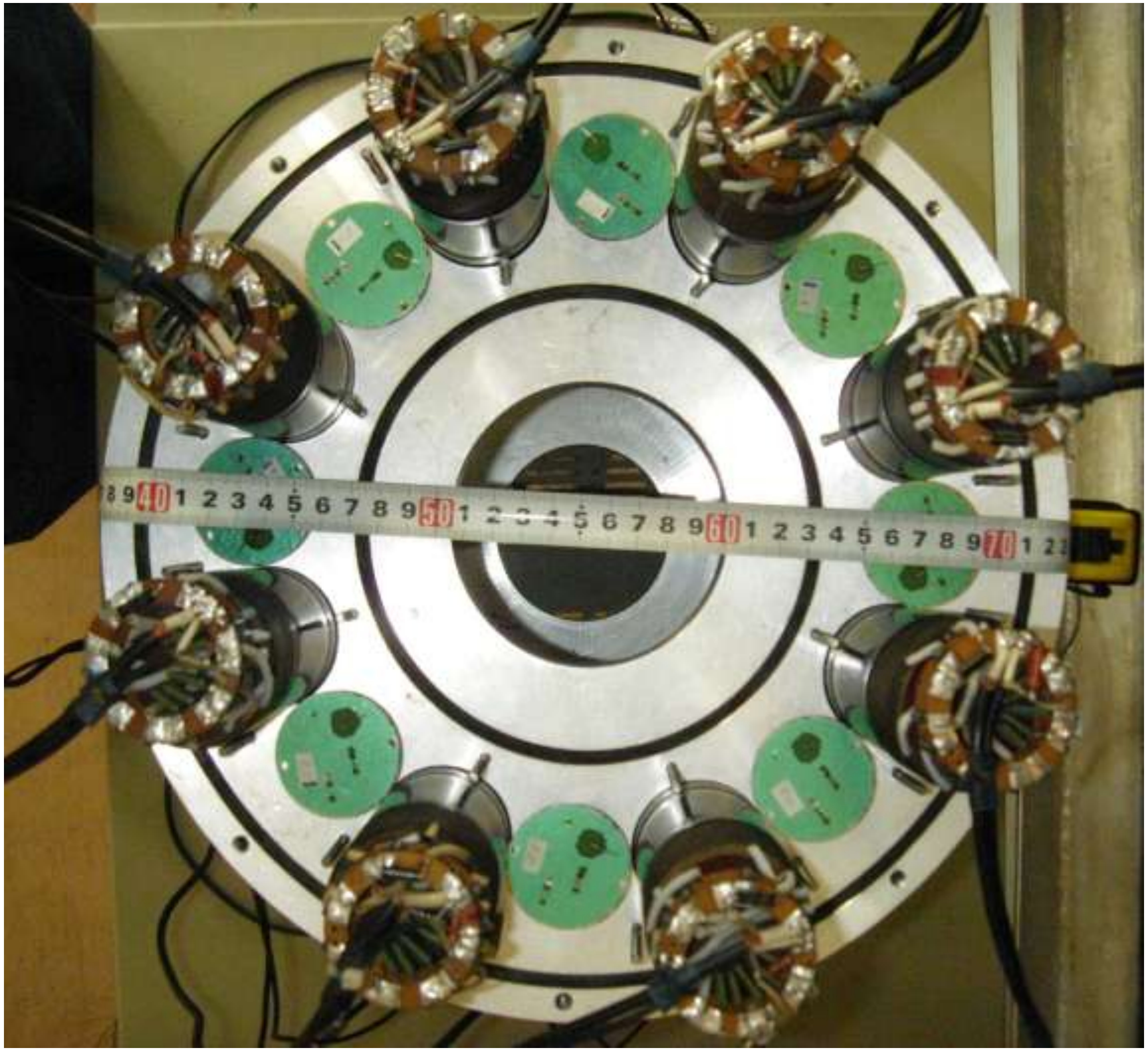
- **Fission and capture cross sections of reactor materials**
- **Their approximation as a 28 group constants**
- **Matrixes of inelastic and elastic scattering, due to those neutrons moves to energy groups with lower energy**
- **Space diagrams of scattered neutrons distribution**
- **Calculation method, for example P3 – approximation**

Comparing calculation results of neutron's generation lifetime in the reactor and it's spectrum, with experimentally measured values, give useful information to upgrade calculation programs.

Resulting programs show better agreement of calculated breeding ratio with experimental values.

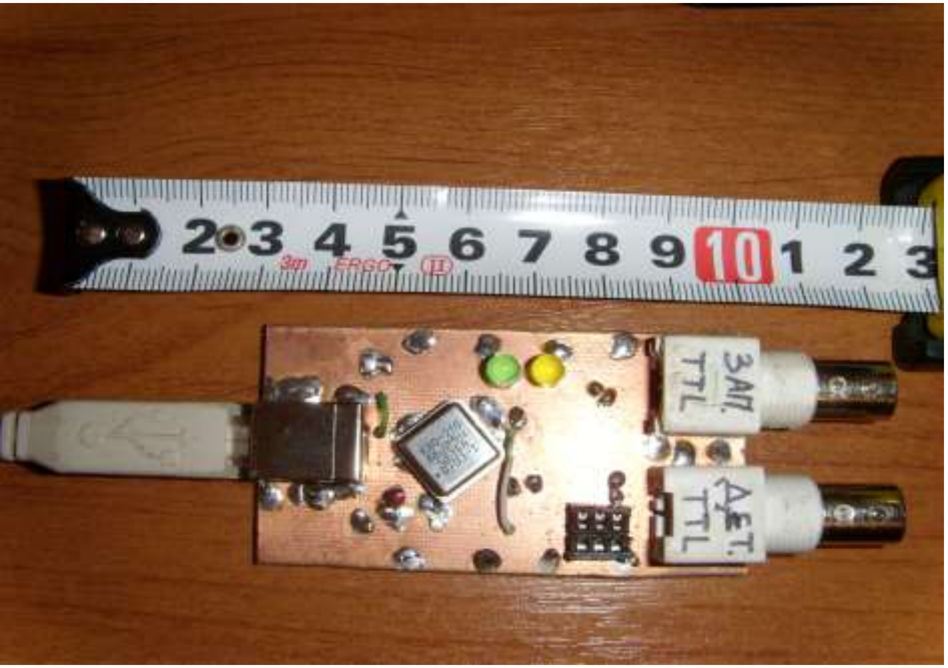
New detector's internal structure

- **Pre-amplifiers of SNM-18s produce digital signal, that provides stable work in conditions of high RF-transients at pulsed accelerators**
- **Central D=100 mm hole is used for samples-radiators, especially on short flight bases**
- **Main usage with black to neutrons and gamma rays collimator 300x100 mm**
- **Ability to act as all-wavelength neutron detector is useful at long bases, where it is necessary to collect small neutron flux from a large square and distinguish it from gamma rays background.**



New type of spectrometer channel

* channel width 120 nsec
* number of channels 334.000
* full period coverage at minimum launch frequency 25 Hz



Conclusion

- **Linac provides simple beam extraction from accelerator into target**
- **Protons induce spallation neutrons with medium spectrum energy 3 Mev, which is similar to fission medium energy compared with photonuclear electron accelerator's neutron spectrums**
- **INR proton linac lead target and 300 meter flight base provides high energy resolution and enough intensity of fast neutron flux**
- **Mean proton beam power <1 kW corresponds to acceptable target gamma activation and possibility of air target cooling. This gives an opportunity to measure experimental spectrums of various compositions with large variety of parameters.**
- **Proton linac provides an opportunity to experimentally research properties of critical assemblies using TOF methodology, including direct measurements of neutron flux lifetime in subcritical assemblies and their neutron spectrums.**

References

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Thank you for your attention