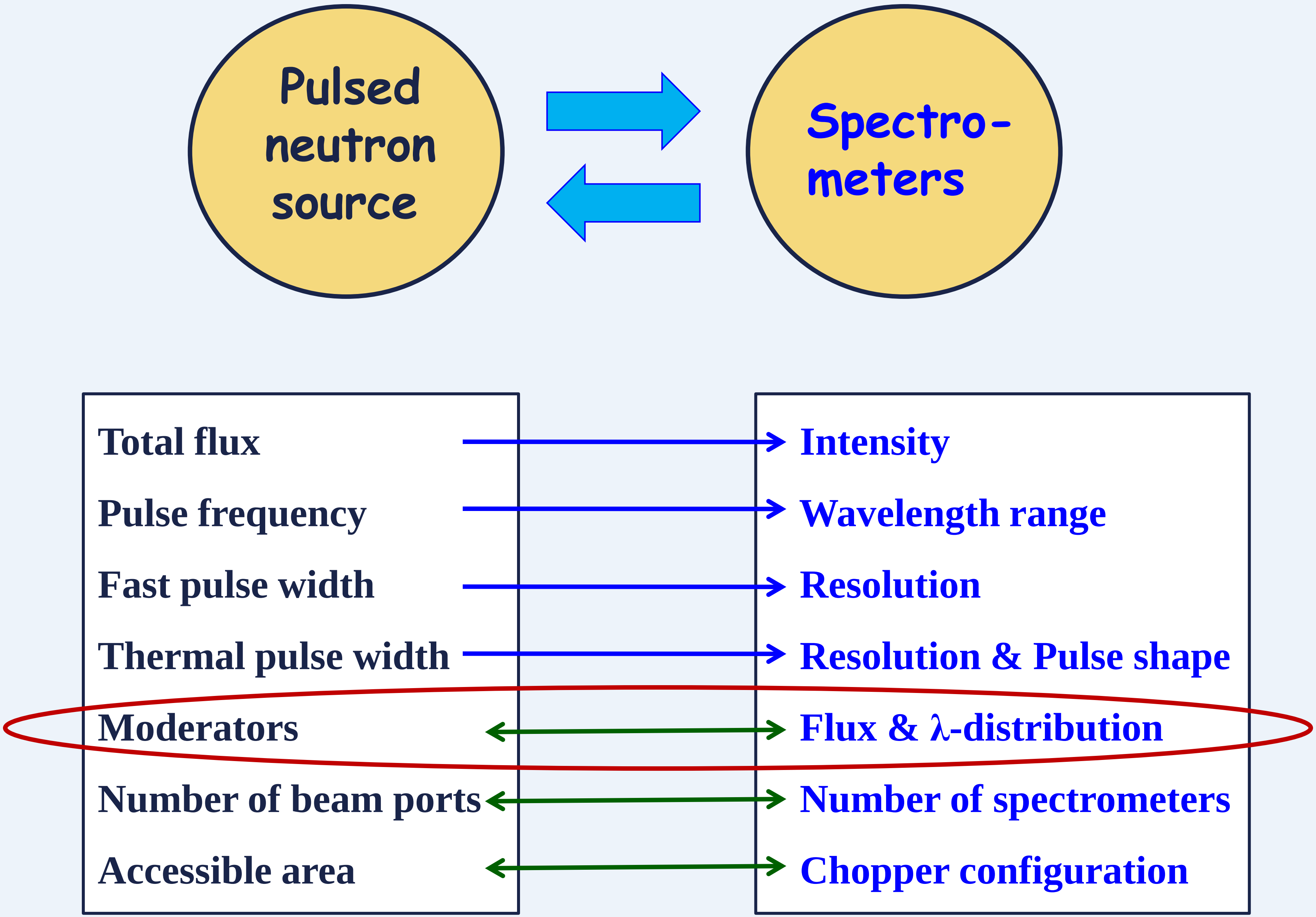
Proposals of the experimental stations and related moderators at DNS-IV

- **A variety of neutron spectrometers**
- **Ideas, inspired by the IBR-2 experience**
- **The basic set of TOF-spectrometers at DNS-IV**
  - **diffractometers**
  - **small angle scattering stations**
  - **reflectometers**
  - **inelastic scattering stations**
  - **radiography stations**
- **Moderators: preliminary design (temperature, shape, size …)**

bala@nf.jinr.ru

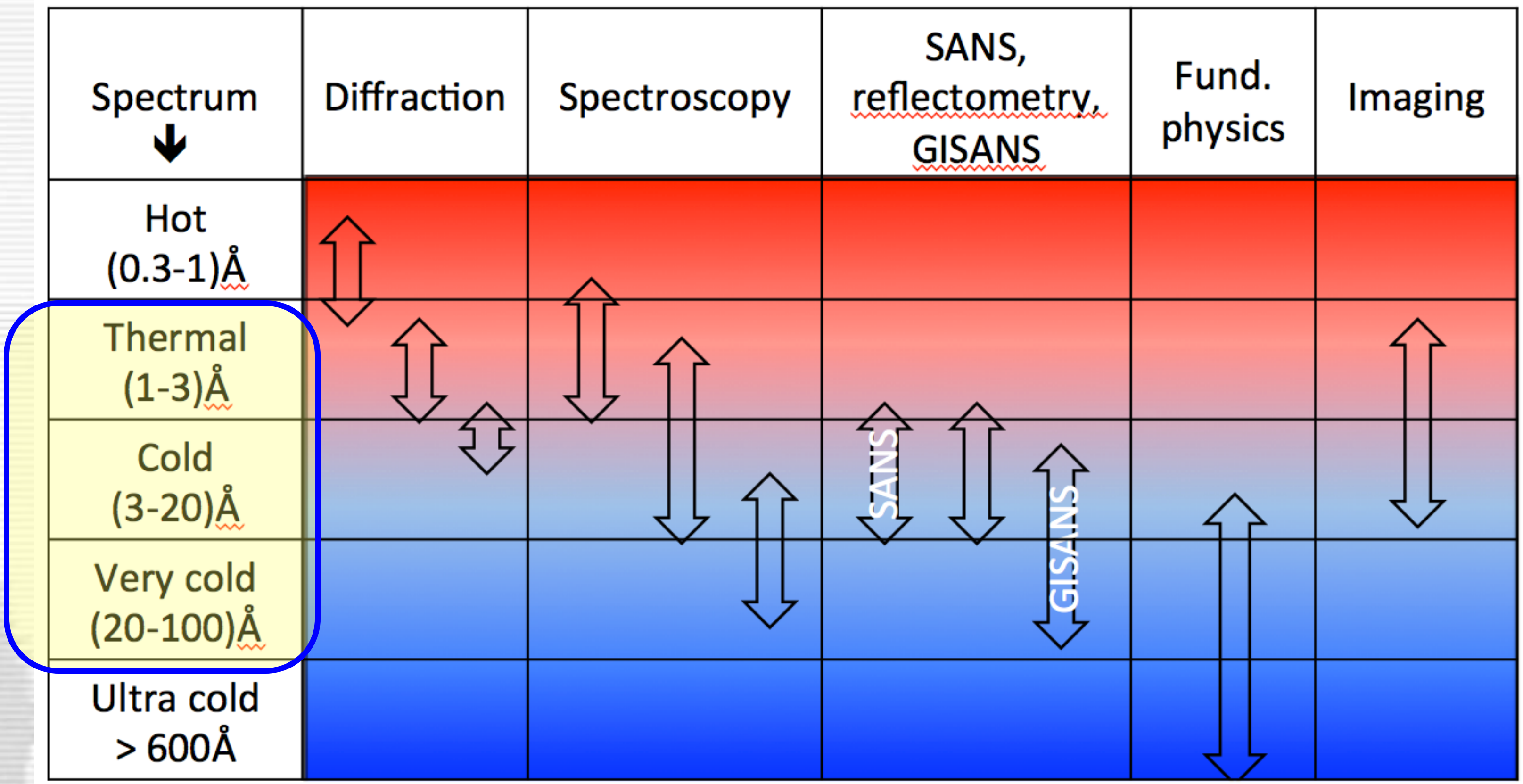

Pulsed neutron source
Spectro-meters
Total flux
Pulse frequency
Fast pulse width
Thermal pulse width
Moderators
Number of beam ports
Accessible area
Intensity
Wavelength range
Resolution
Resolution & Pulse shape
Flux & λ-distribution
Number of spectrometers
Chopper configuration

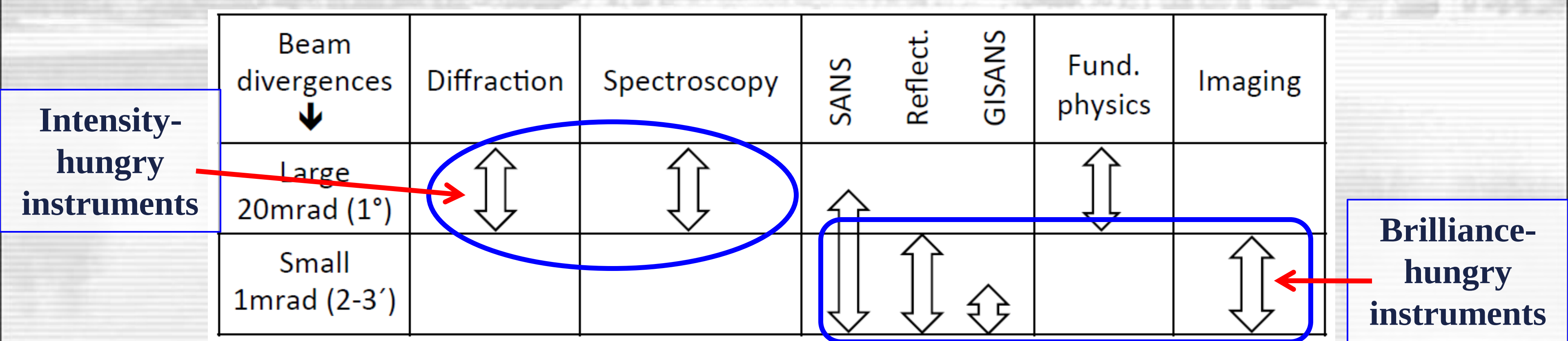
Condensed matter studies with slow neutrons

Main experimental techniques at FLNP's pulsed reactors

- **Inelastic scattering** 1962
- **TOF diffraction on crystals** 1963
- **Small angle scattering** 1974
- **Reflectometry** 1986
- **Neutron imaging** 2012

Different requirements for different topics (courtesy A. Ioffe)



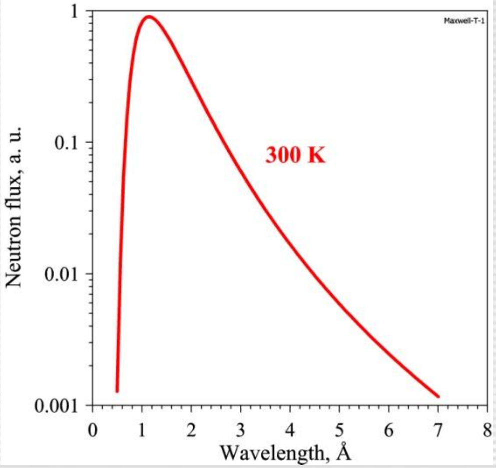


Some definitions

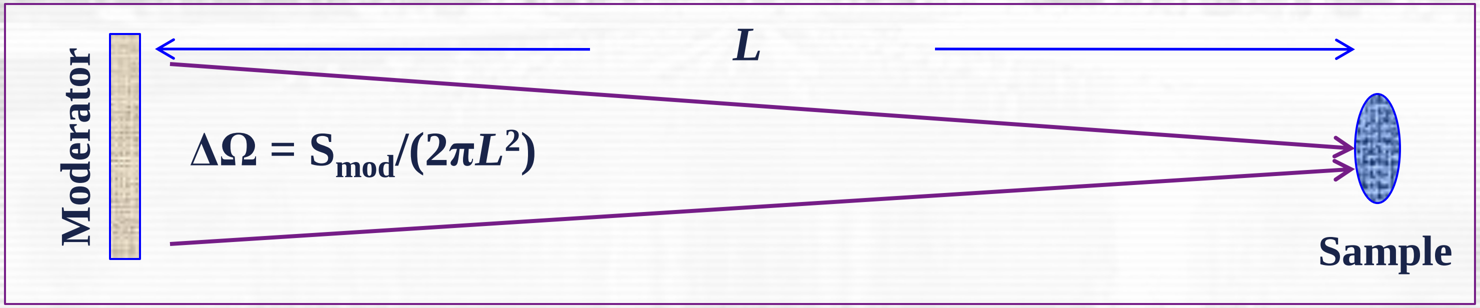
Maxwellian distribution (Flux density):

$$\Phi(\lambda) = 2\Phi_0(\lambda_0^4/\lambda^5)\cdot\exp(-\lambda_0^2/\lambda^2)\ [\mathrm{n/cm^2/s/Å}]$$

Total flux: $\Phi_0 = \int \Phi(\lambda)d\lambda \quad [\mathrm{n/cm^2/s}]$



Isotropic neutron flux	Φ_I [n/cm²/s]	**n from 1 cm² in 1 s into 4π sr**
2π equivalent flux	Φ_V [n/cm²/s] = $\Phi_I/2$	**n from 1 cm² in 1 s into 2π sr**
Brightness	Φ_B [n/cm²/s/sr] = $\Phi_V/2\pi$	**n from 1 cm² in 1 s into 1 sr**
Intensity	I [n/s] = $\Phi_V\cdot(S_{mod}/2\pi L^2)\cdot S_{sam}$	**n at sample in 1 s**



Effective flux: $\Phi_{eff} = \Phi_V\cdot T(\lambda)\cdot\varepsilon(\lambda)$ **(flux - guide transmission - detector efficiency)**

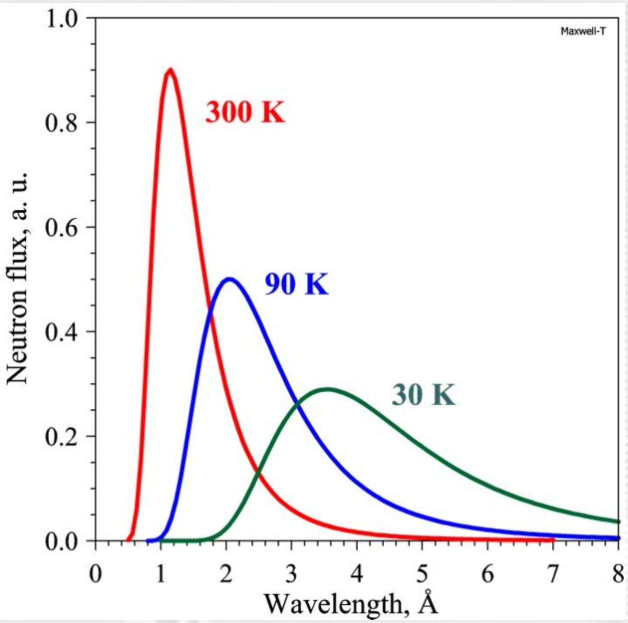
The basic set of neutron TOF spectrometers

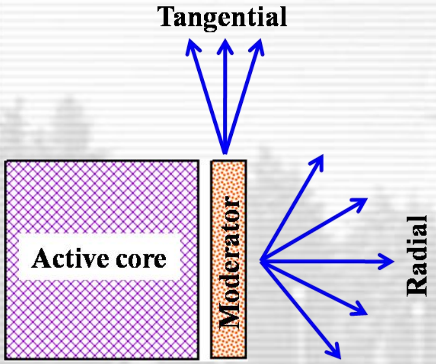
	Instrument	Main issue	Moderator *T*, K	Moderator Size
Diffraction	1. Material science*)	Internal stresses	300 K	
	2. High-resolution*)	Crystal structure	300 / 80 K	
	3. High-intensity	*In situ*, real-time	80 K	
	4. High-pressure	Micro samples	80 K	
	5. Magnetic	Magnetic structure	30 K	
Inelastic	6. Direct geometry-I**)	General purpose	80 K	
	7. Direct geometry-II***)	General purpose	30 K	
	8. Inverse geometry	Molecular systems	80 K	
SANS	9. High-resolution	General purpose	30 K	
	10. High-intensity-I	*In situ*, real-time	30 K	
	11. High-intensity-II	Micro samples	30 K	
Reflect.	12. Horizontal plane	General purpose	30 K	
	13. Vertical plane	Liquid media	30 K	
NR	14. “White” beam	General purpose	30 K	
	15. Energy dispersive	Complex media	30 K	

*) Fourier chopper **) Fermi chopper ***) Set of choppers

Moderators for DNS-IV

Moderator	Temperature	λ-range
Thermal	$T \approx 300$ K	$0.8 \div 5$ Å
Cold	$T \approx 80$ K	$1.0 \div 8$ Å
Very cold	$T \approx 30$ K	$2 \div 15$ Å





Tangential:

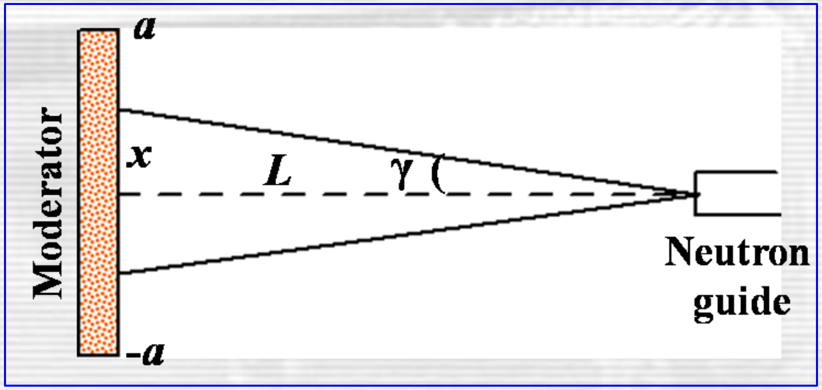
Lower fast neutrons background

Higher neutron flux, $k = 2 \div 3$

Radial:

Larger number of beam-lines

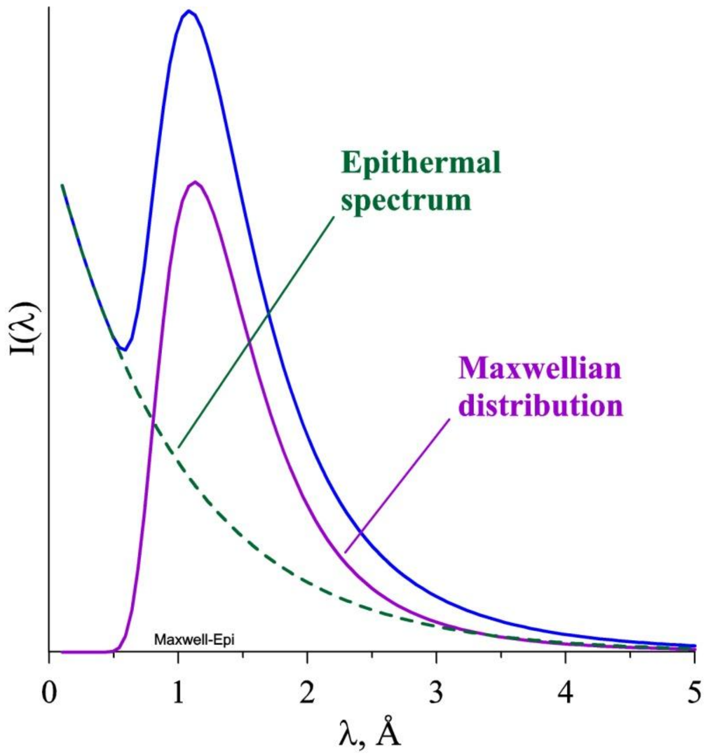
Larger area



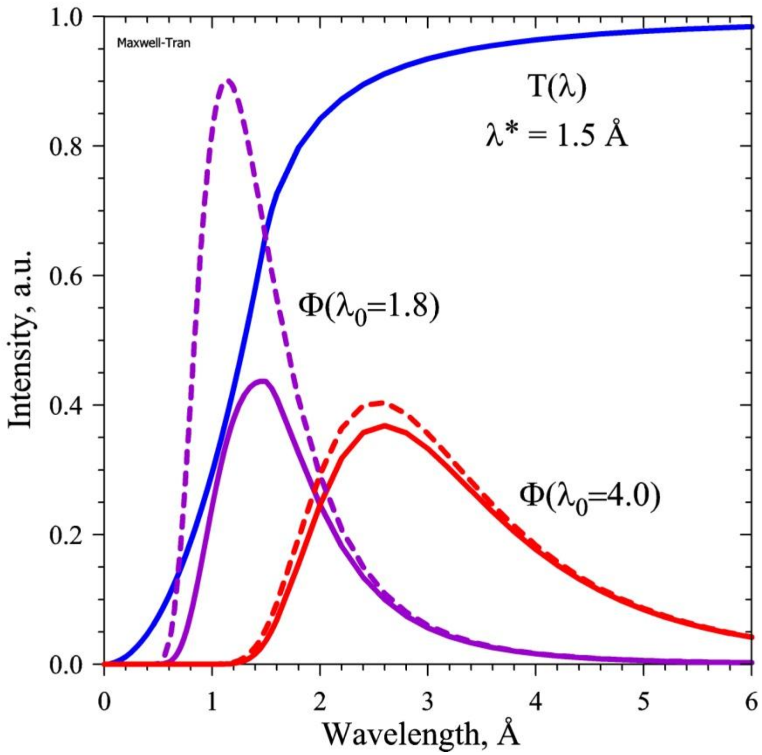
$\gamma \le \gamma_{cr} = 0.00122 \cdot m \cdot \lambda$ for Ni

For $\lambda > \lambda_{cr}$ not the whole moderator surface is used

Maxwellian flux at pulsed neutron source



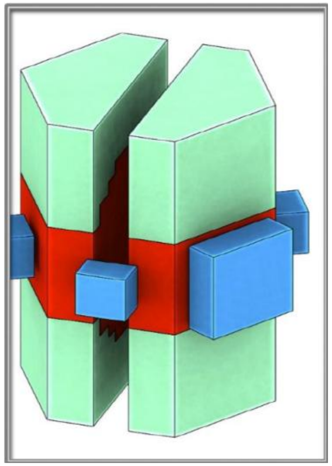
Epithermal + Maxwellian distribution

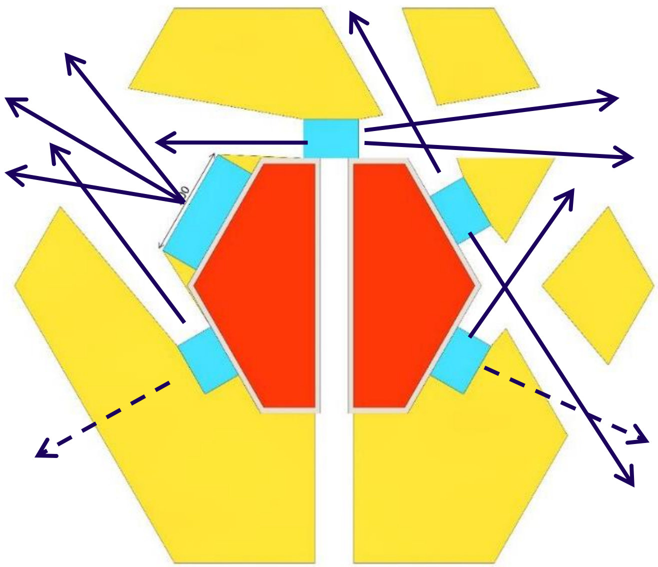


Maxwellian distributions after curve neutron guide. $k_{loss} \approx 2$ for $\Phi(\lambda_0 = 1.8$ Å$)$

Preliminary design of moderators at DNS-IV

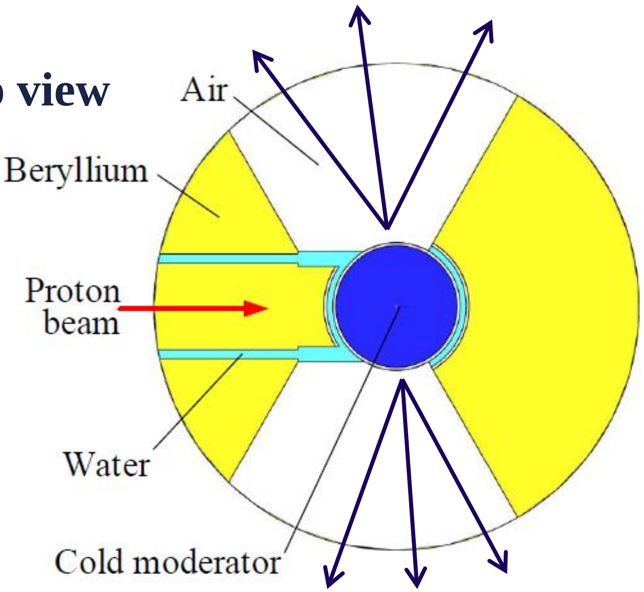
Core + moderators



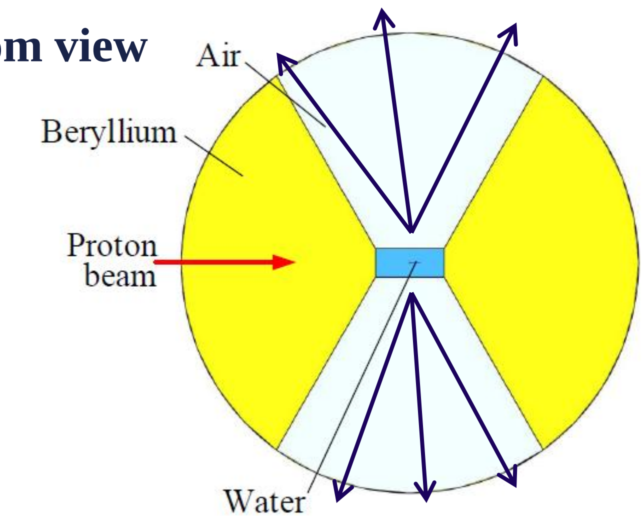


Moderators inside reflector

Top view



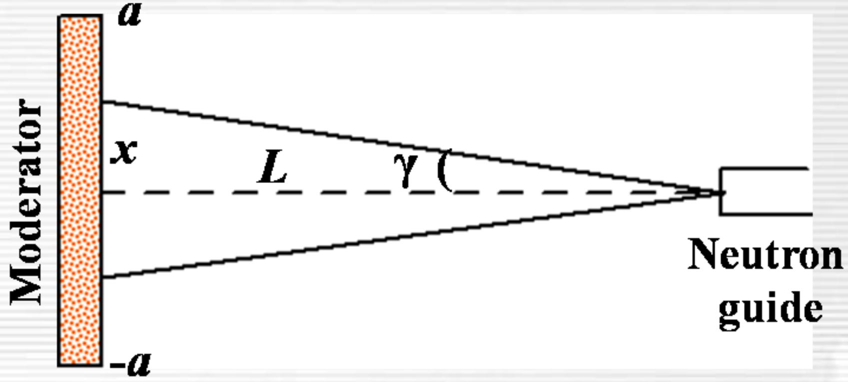
Bottom view



Courtesy E.P.Shabalin

Courtesy Yu.N.Pepelyshev

Moderator – neutron guide design

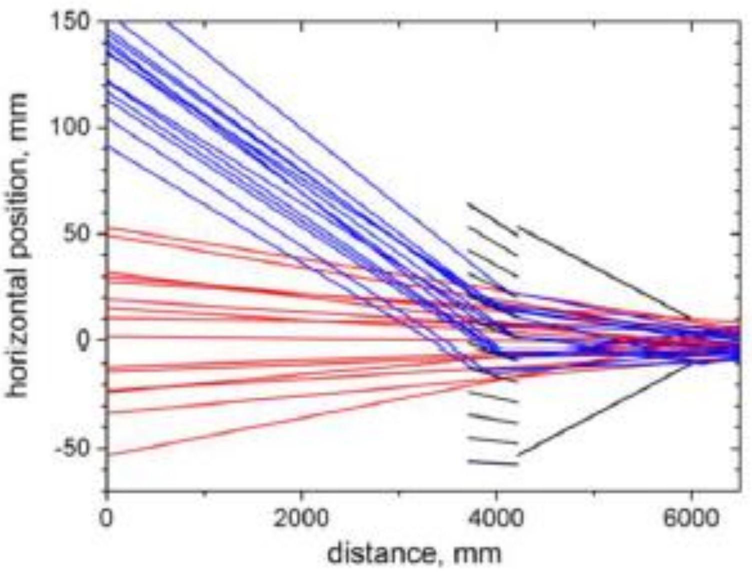


$x_{max} = \gamma_{cr} \cdot L_g = 1.2 \cdot 10^{-3} \cdot m \cdot L_g \cdot \lambda \approx 0.24 \cdot L_g \cdot \lambda$,

for $m = 2$, L_g [m]

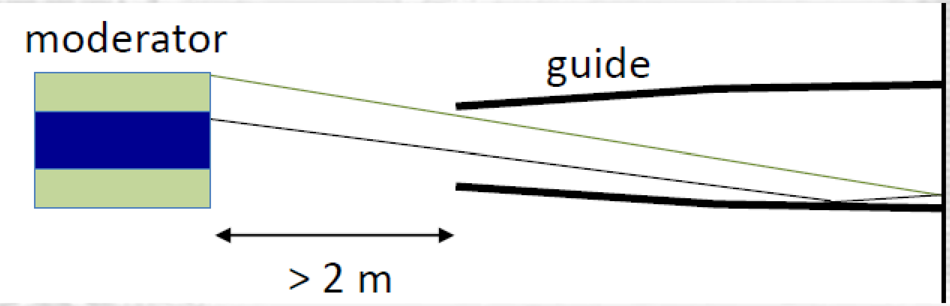
$x_{max} > a$, if $\lambda > \lambda_m = a/(0.244 \cdot L_g) \approx 4a/L_g$

λ_m [Å] = $2a$ [cm] for $L_g = 2$ m

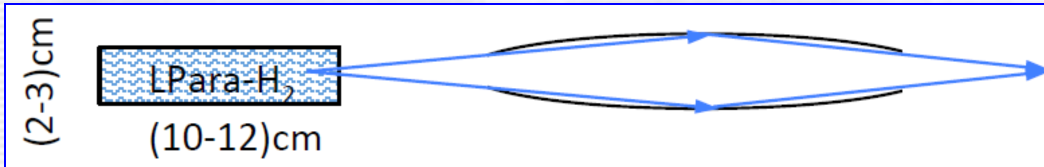


ESS: Bi-spectral extraction by m=4 guide. $L_g = 4$ m

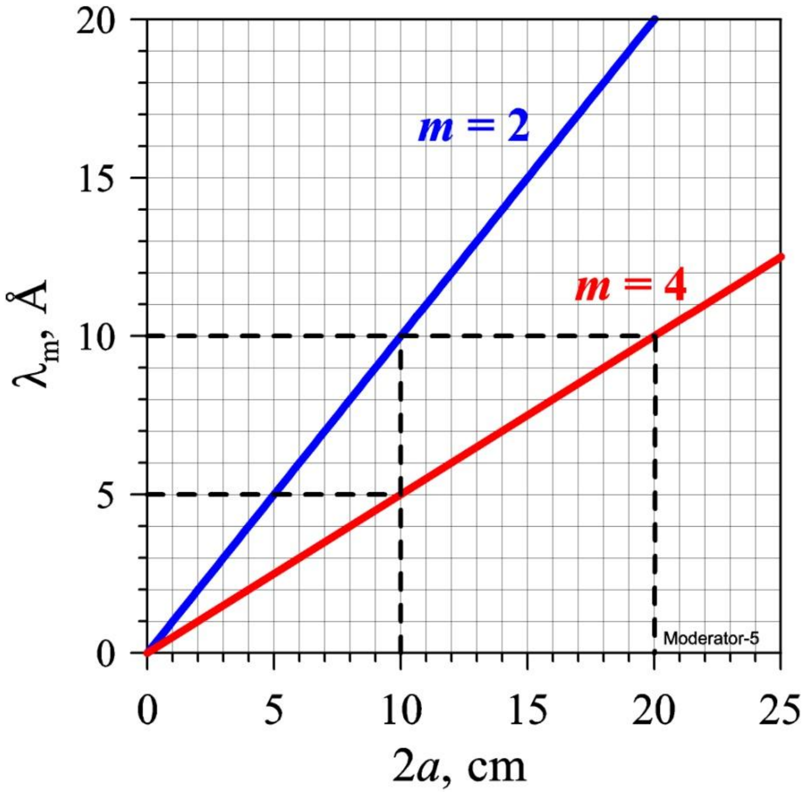
ESS: moderator - guide design, $L_g \approx 2$ m

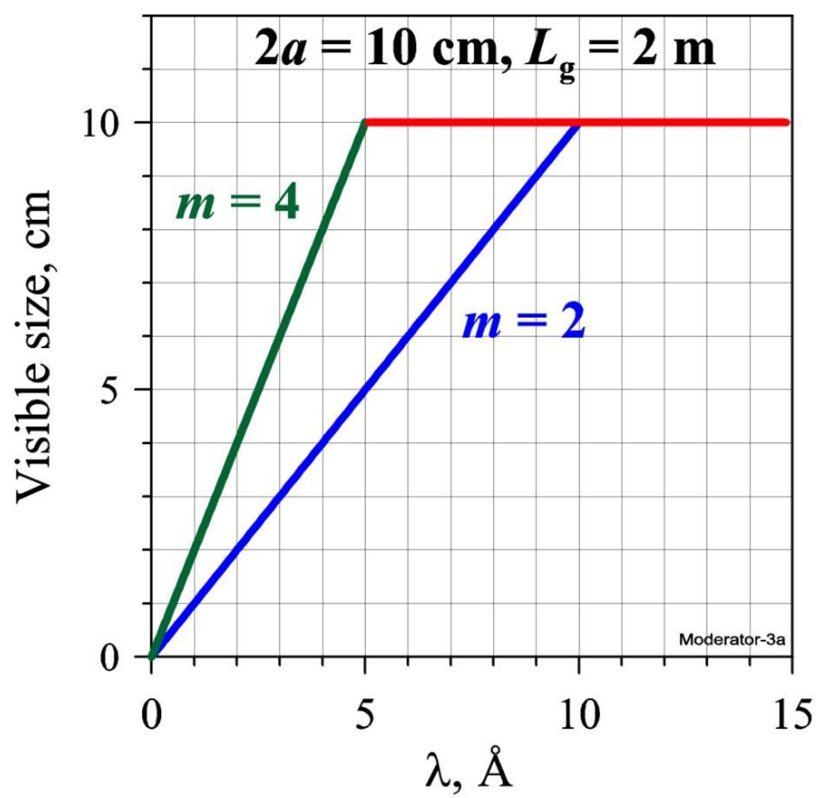


High-brilliance cold moderator, $a = (2 \div 3)$ cm



Moderators: size restrictions, 1D case



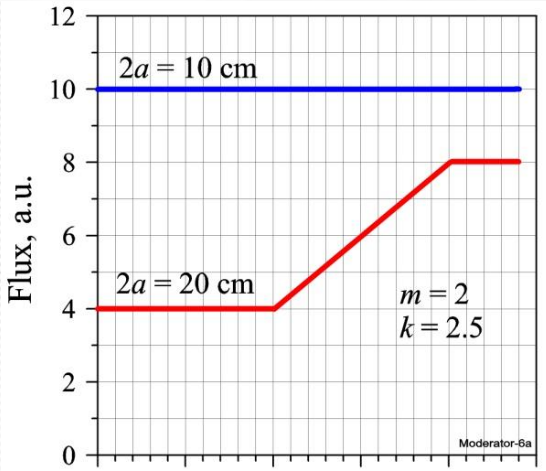


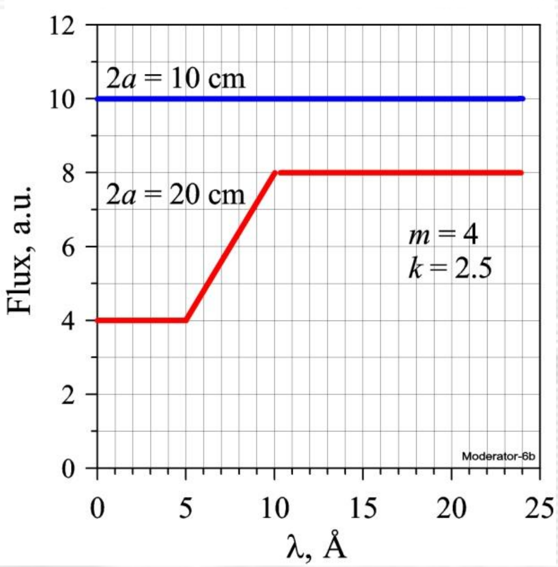
Maximal wavelength, λ_m, as a function of the moderator size for L_g = 2 m.
If $\lambda > \lambda_m$, the flux does not grow up.
For 2*a* = 10 cm and *m* = 2, λ_m = 10 Å.

Moderator visible size as a function of wavelength for *m* = 2 and 4.
For 2*a* = 10 cm, L_g = 2 m and m = 2 the flux does not grow up after λ_m = 10 Å.

Moderators: comparisons

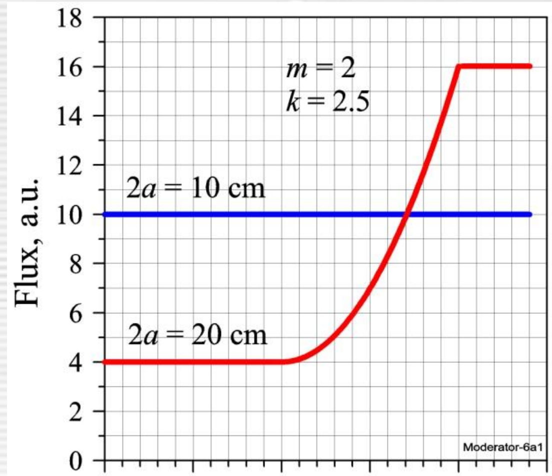
1D case

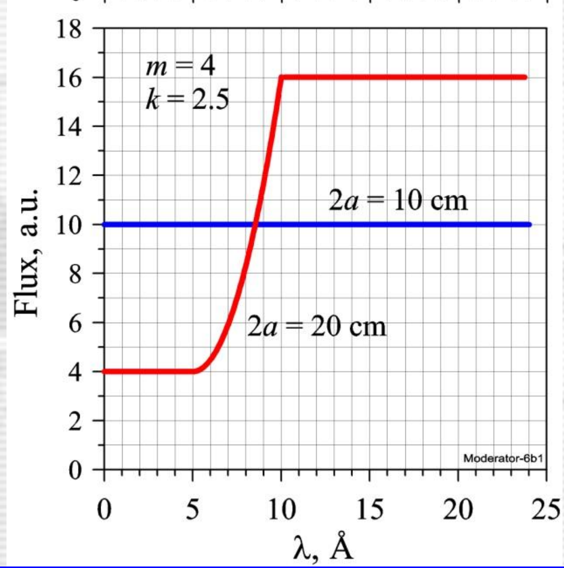




10 cm vs. 20 cm for *m* = 2 & 4
***L* = 2 m, *k* = 2.5**

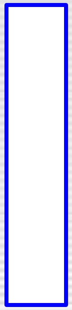
2D case





10 cm vs. 20 cm for *m* = 2 & 4
***L* = 2 m, *k* = 2.5**

1D case

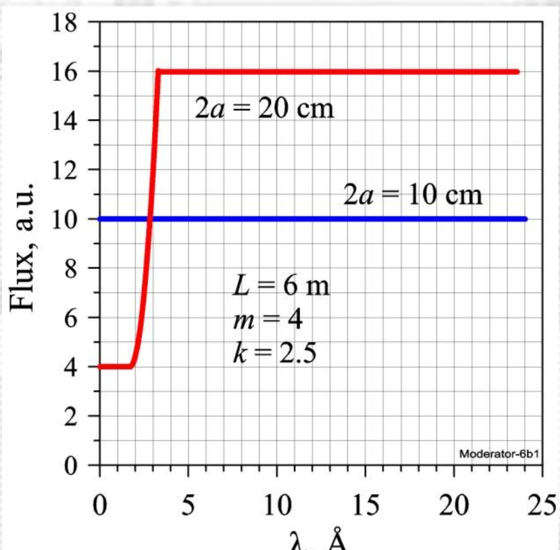


$a << b$

2D case

$a \approx b$

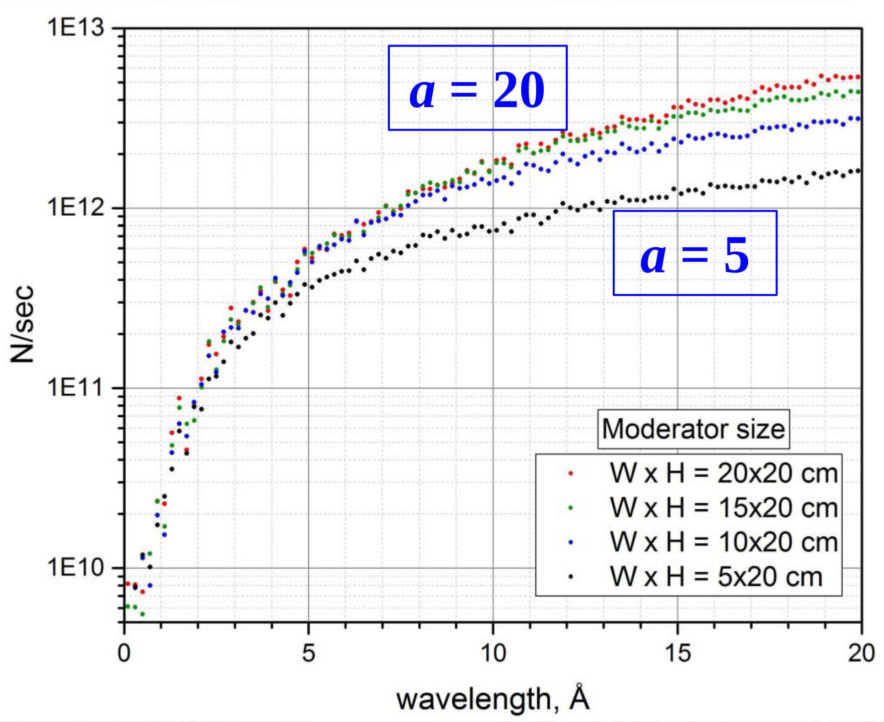
2D case

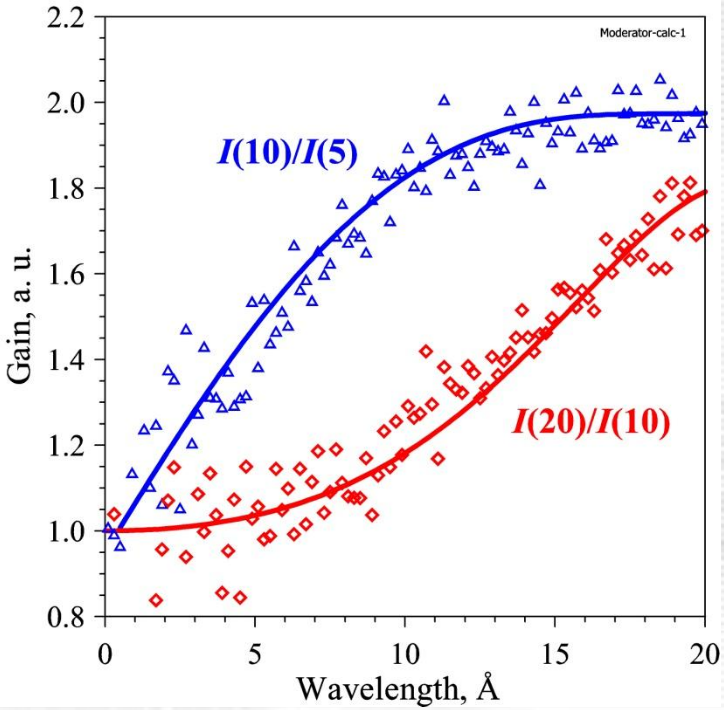


10 cm vs. 20 cm for *m* = 4
***L* = 6 m, *k* = 2.5**

Moderators: preliminary calculations (Bodnarchuk, Sadilov)

Moderator: *a* = 5, 10, 15, 20 cm, *b* = 20 cm.
Neutron guide: m = 2, S = 5 x 5 cm^2 Neutron guide is set in *L* = 2 m.





Intensity as a function of wavelength for fixed *b* = 20 cm, *a* = 5, 10, 15, 20 cm

Gain factor as a function of wavelength. Ratios of intensities for *a* = 10 & 5 cm (blue) and *a* = 20 & 10 cm (red) are compared.

The basic set of neutron TOF spectrometers

	Instrument	Main issue	Moderator	
			T, K	Size
Diffraction	1. Material science*)	Internal stresses	300 K	Small
	2. High-resolution*)	Crystal structure	300 / 80 K	Small
	3. High-intensity	*In situ*, real-time	80 K	Large
	4. High-pressure	Micro samples	80 K	Large
	5. Magnetic	Magnetic structure	30 K	Large
Inelastic	6. Direct geometry-I**)	General purpose	80 K	Large
	7. Direct geometry-II***)	General purpose	30 K	Large
	8. Inverse geometry	Molecular systems	80 K	Large
SANS	9. High-resolution	General purpose	30 K	Small
	10. High-intensity-I	*In situ*, real-time	30 K	Small
	11. High-intensity-II	Micro samples	30 K	Small
Reflect.	12. Horizontal plane	General purpose	30 K	Small
	13. Vertical plane	Liquid media	30 K	Small
NR	14. “White” beam	General purpose	30 K	Small
	15. Energy dispersive	Complex media	30 K	Large

*) Fourier chopper **) Fermi chopper ***) Set of choppers

Spectrometers – Moderators: Optimization task

1. **The basic set of spectrometers can include 15 (16) the most called-for instruments, with ~10 additional ones as the second stage**
2. **Spectrometers at moderators: 1 (2) – thermal, 5 – cold, 9 – very cold**
3. **Moderator size: 8 – small (~10 x 10 cm), 7 – large (~20 x 20 cm)**
4. **The optimal "Moderator – NG" distance is around $L = (2 \div 3)$ m**
5. **Instruments can be grouped to take a full advantage of moderators**