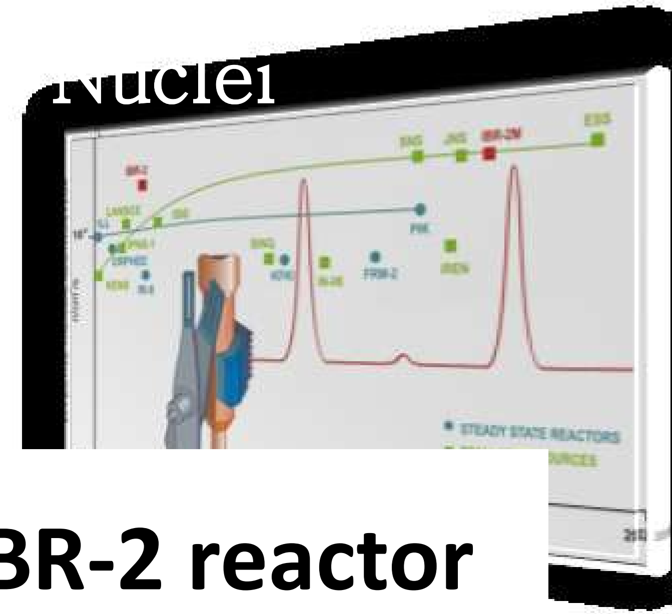
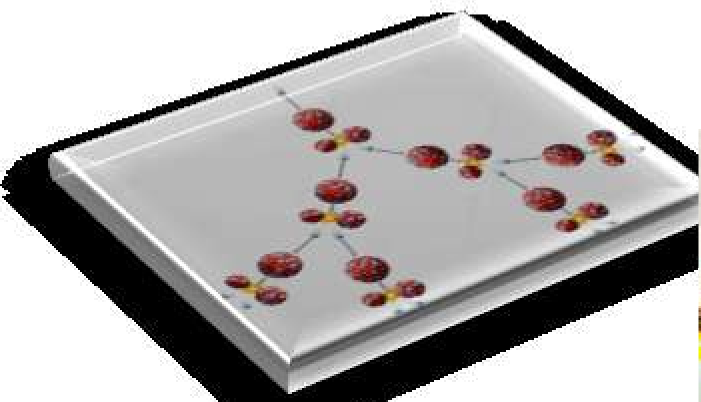
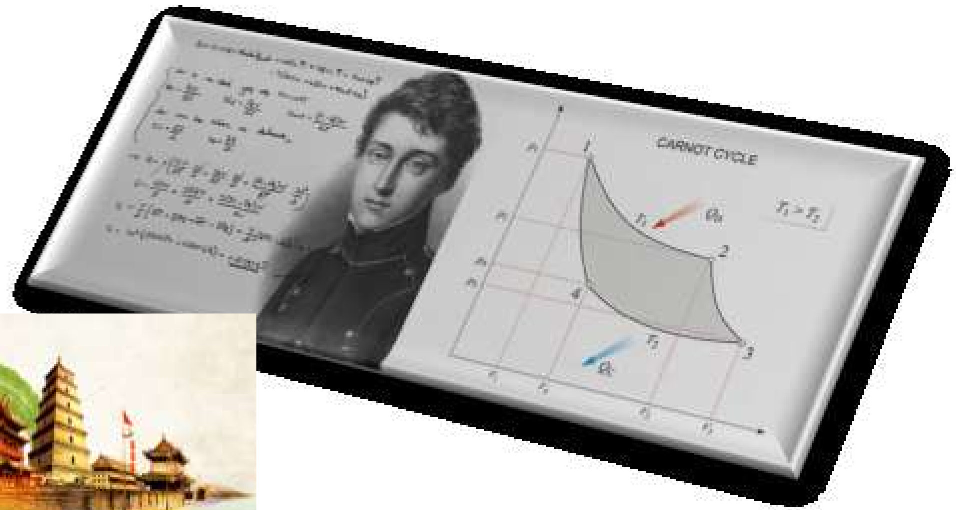
26th International Semin
Interaction of Neutron wit Nuclei



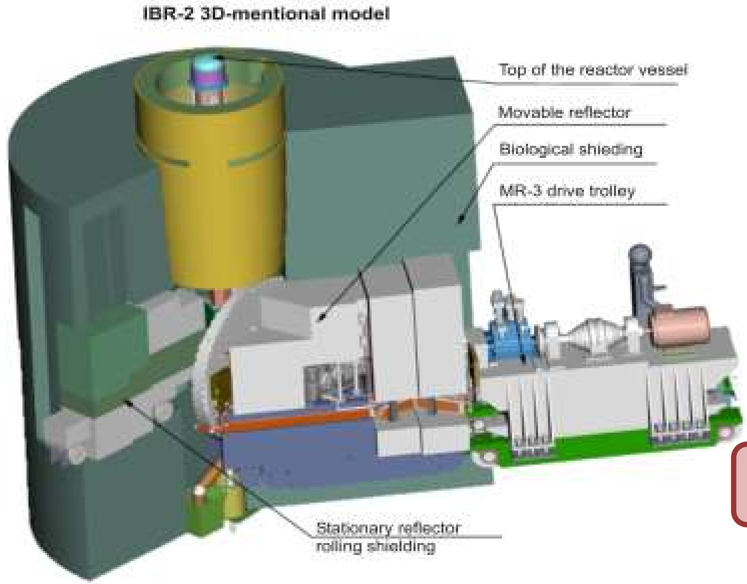
Cold neutron source for IBR-2 reactor on pelletized mesitylene beads





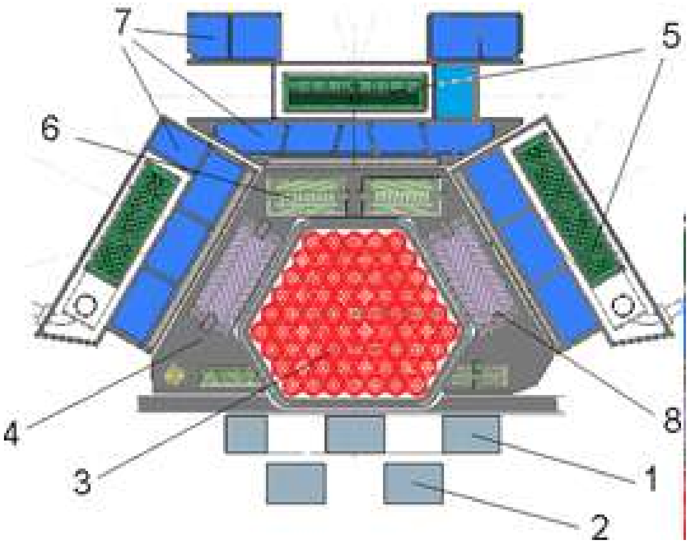
2018, Xi'an China

IBR-2 reactor



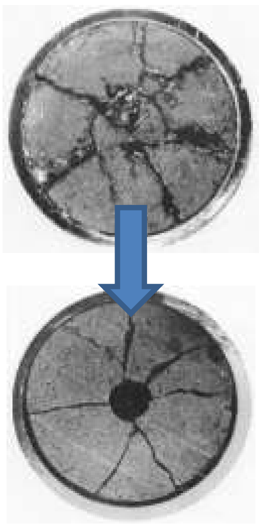
Modernization 2006 – 2010

1. More compact reactor core (78-69 fuel assembly);
2. New movable safety shield
3. New reactor vessel;
4. Fuel tips with hole on the center (burning fuel rise up at 1.5 times);
6. Created a cold neutron source



1.Main moveable reflector
2.Auxillary moveable reflector
3.Fuel assembly
4.Stationary reflector
5.Cold moderators
6.Emergency system
7.Water moderators
8.Control rods

Fuel rods

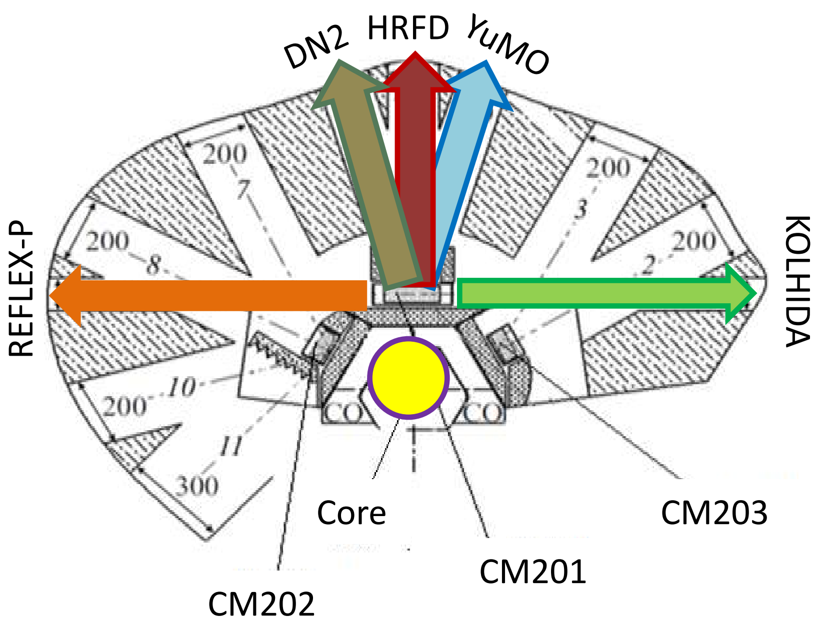


Solid methane neutron moderator at IBR-2 reactor (1994-2000)

Some parameters of cold neutrons	
Wavelength, Å	4 – 29
Energy, eV	$5\cdot10^{-3} \div 10^{-4}$
Speed, m/s	$9{,}8\cdot10^{2} \div 1{,}4\cdot10^{2}$

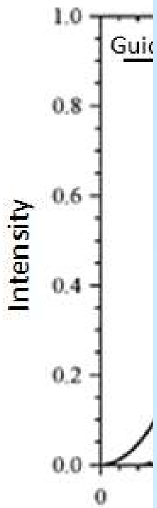
What we can get?

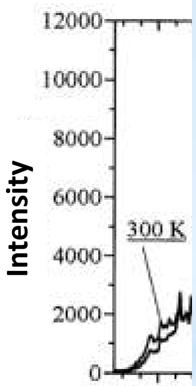
- increase a cold neutron flux on a sample (using a mirror neutron guide);
- registration a diffraction peak in a high wavelength region;
- registration a big molecular groups, biological objects, tomographic research;
- fundamental research (search for electric dipole moment, neutron interaction…)

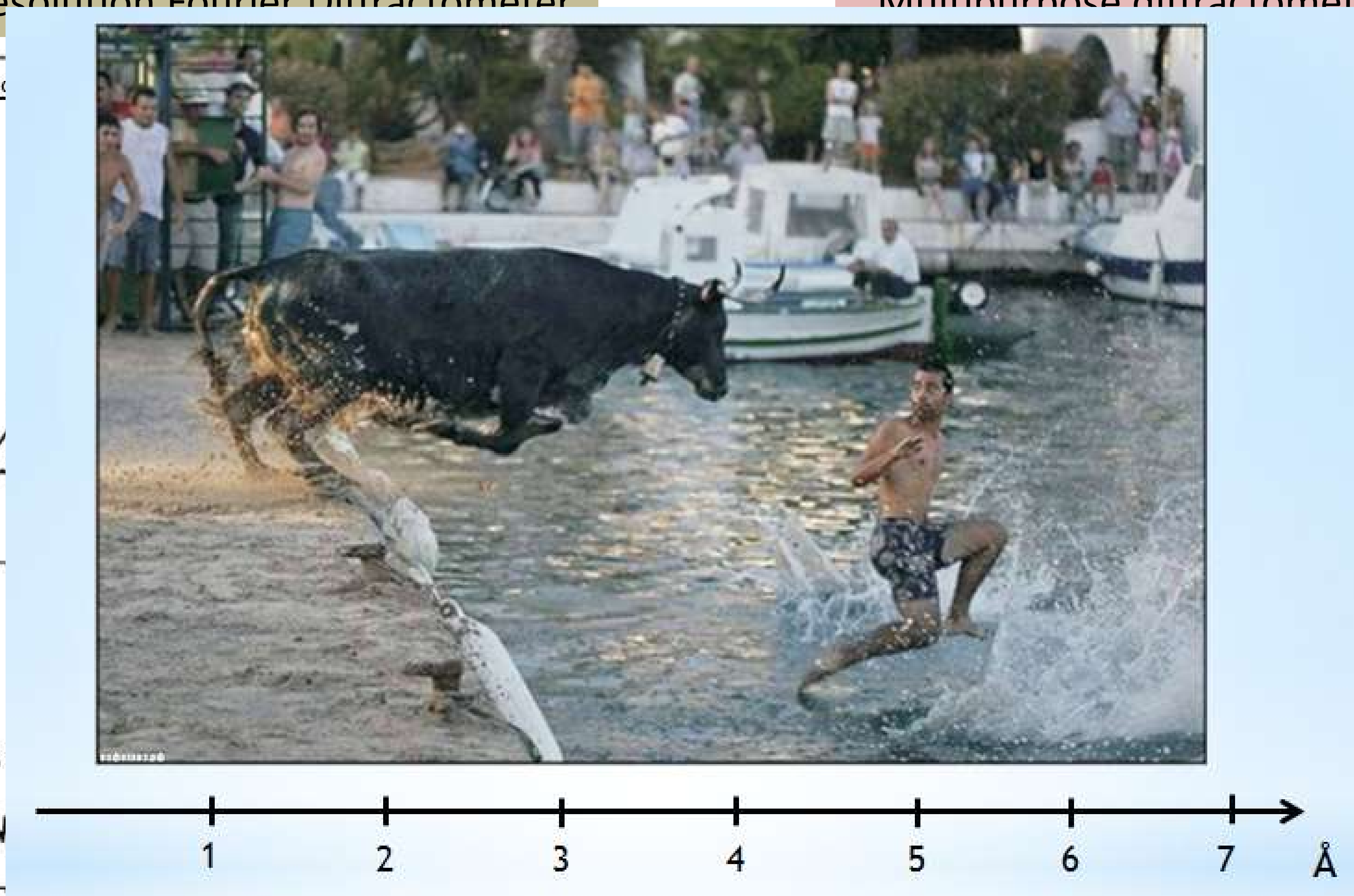


Some examples of researches with cold neutron flux at HRFD and DN 2 instruments

High Resolution Fourier Diffractometer







Multipurpose diffractometer DN 2

research of
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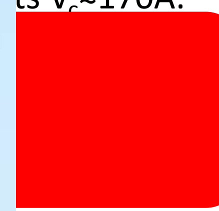
$_5$ (Y-123)
al
ts V_c≈170Å.



		r	Instrument
			DN2
			HRFD DN2
			HRFD
			HRFD DN2
			HRFD
Magnetic structure	+	+++	HRFD DN2
Real-time experiment	++	+++	DN2
Quantitative phase analysis	+	+++	HRFD DN2

*Balagurov A. Investigation of diffraction by methane cold moderator on IBR -2 reactor. JINR communication 2000 r. P3-2000-220

Moderator's substance

Some properties moderator's substance					
Substance	chemical formula	T meit. (K)	T boil. (K)	Explosive / toxicity	proton density ($n/cm^3 \times 10^{23}$)
Water	H_2O				
Hydrogen	H_2				
Propane	C_3H_8				
Methane	CH_4				
Mesitylene	C_9H_{12}				

The main properties of cold moderator substance

s

ross

stance

Problems of … example

- maximum time of opera…
- recombination reaction inside a substance under by radiation (local temperature jump, non stable of neutron spectrum);
- formation of a radiolytic hydrogen (can destroy a chamber on warming up mode (rise up the temperature inside the chamber to 70 K every 4-5 hours));
- formation of high molecular, high-boiling products which are difficult to remove from the chamber (after 270 MWh 1/3 of chamber were full up of non removable substance)

Mesitylene m-xylene mixture – better substance for IBR-2 cold moderator

T_m 227

T_m 225

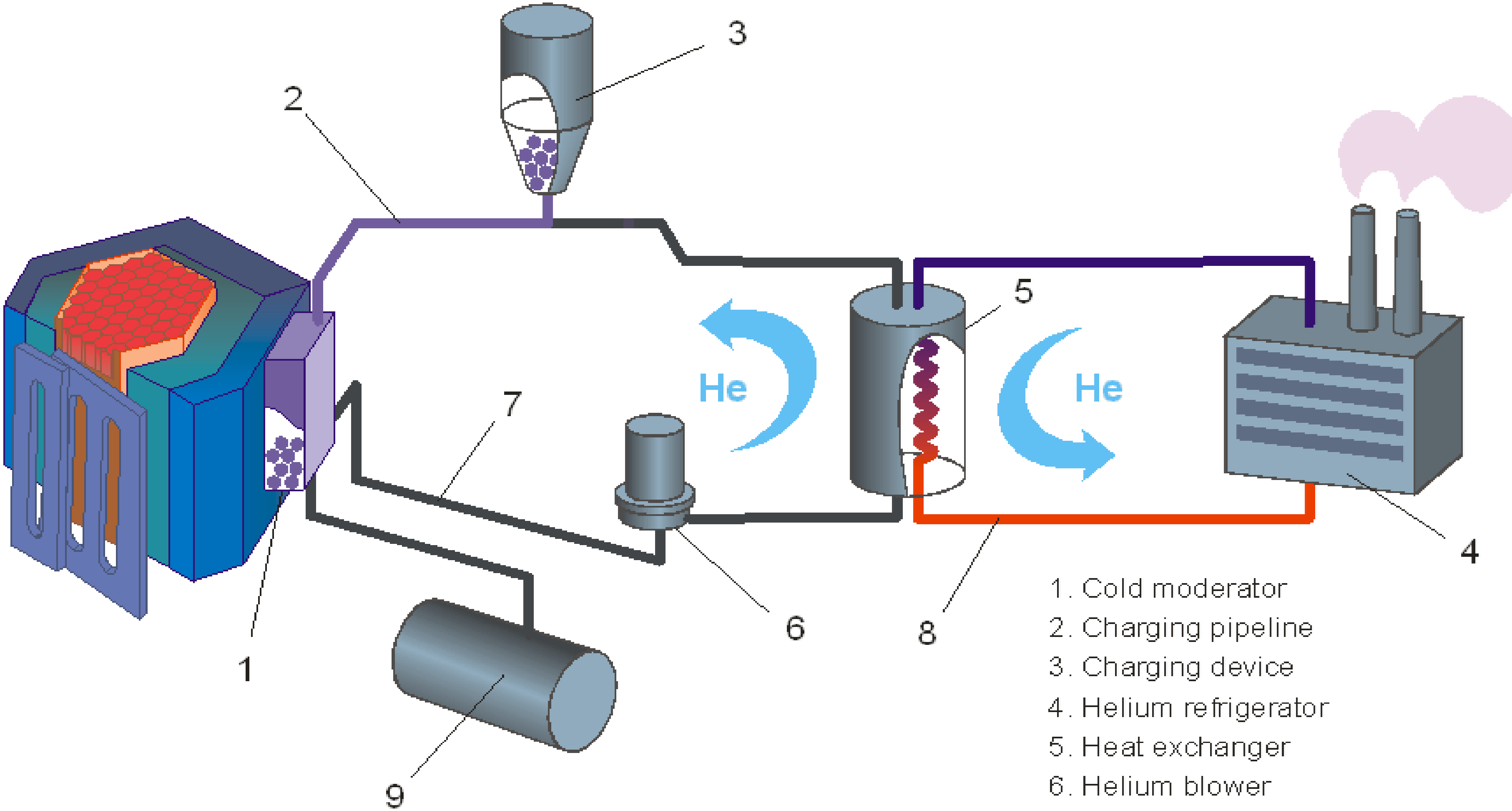
- T boiling – 437 K
- T melting – 227 K
- D pellets – 3,5-3,9 mm
- T operation – 10 – 150 K

Why we use a pelletized mesitylene moderator?

Advantages to using mesitylene in pelletized form

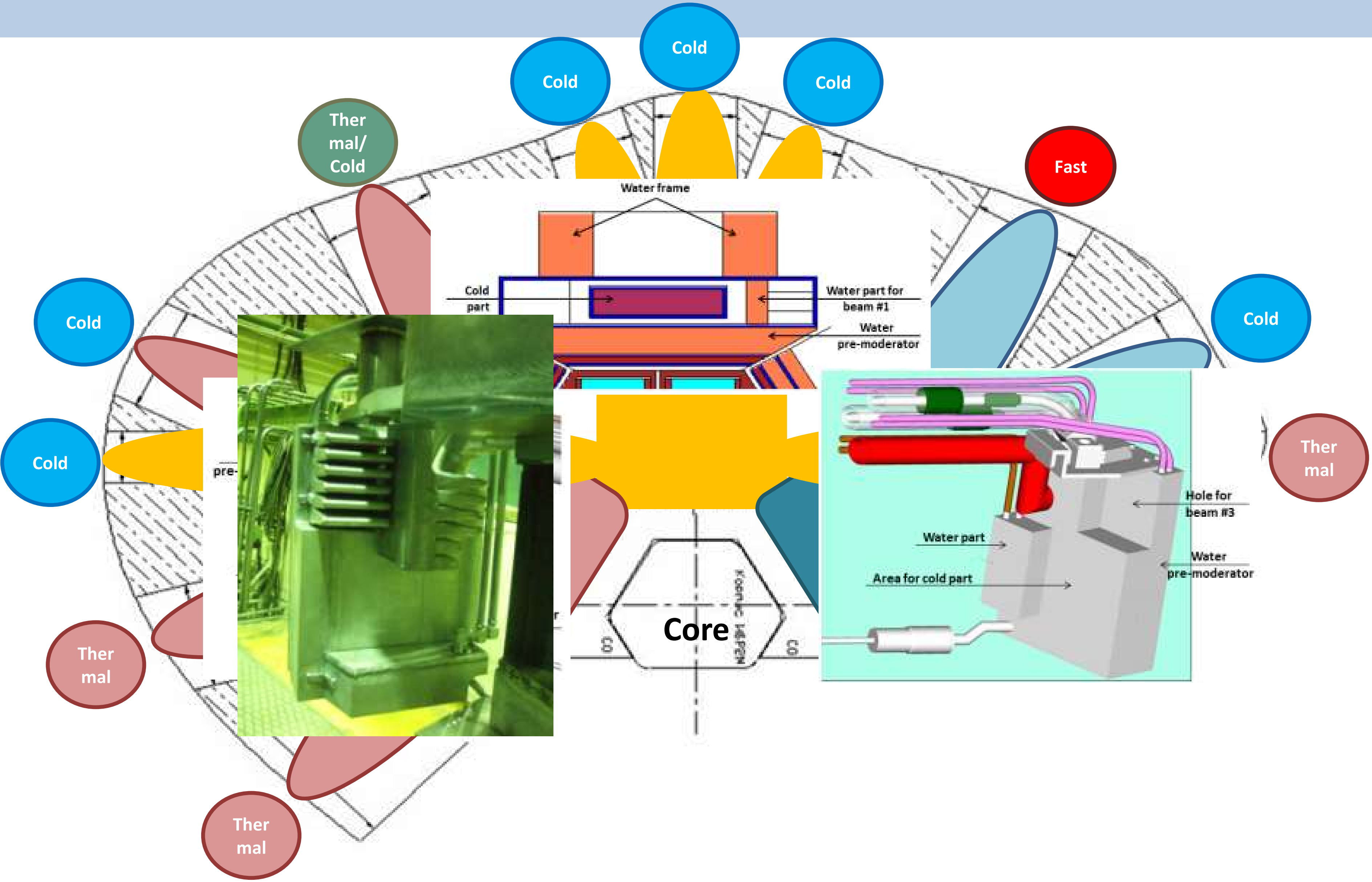
- recombination reaction inside a substance under by radiation (local temperature jump, non stable of neutron spectrum);
  no recombination reactions in mesitylene (stable neutron spectrum)
- formation of a radiolytic hydrogen (can destroy a chamber in warming up mode (rise up the temperature inside the chamber to 70 K every 4-5 hours));
  pelletized filling exclude a pressure to chamber walls by radiolytic hydrogen (all hydrogen spreading on cooling system of moderator)
- formation of high molecular, high-boiling products which are difficult to remove from the chamber (after 270 MWh 1/3 of chamber were full up of non removable substance)
  effect from formation high-boiling products by radiation and transformation an original substance on long oligomers reduced and we can remove liquid mesitylene in the end the cycle and clean the chamber 1 times per 2 years
- **a wide range of operating temperatures allows to shift the peak of the neutron flux to the region of large or small wavelengths (10 - 150K)**
- **unloading in solid phase let use a moderator “non limit time”**

Principle scheme of operating cold neutron source on IBR-2 reactor



1. Cold moderator
2. Charging pipeline
3. Charging device
4. Helium refrigerator
5. Heat exchanger
6. Helium blower
7. Primary helium loop
8. Secondary helium loop
9. Used mesitylene receiver

Cold neutron source for IBR-2 reactor

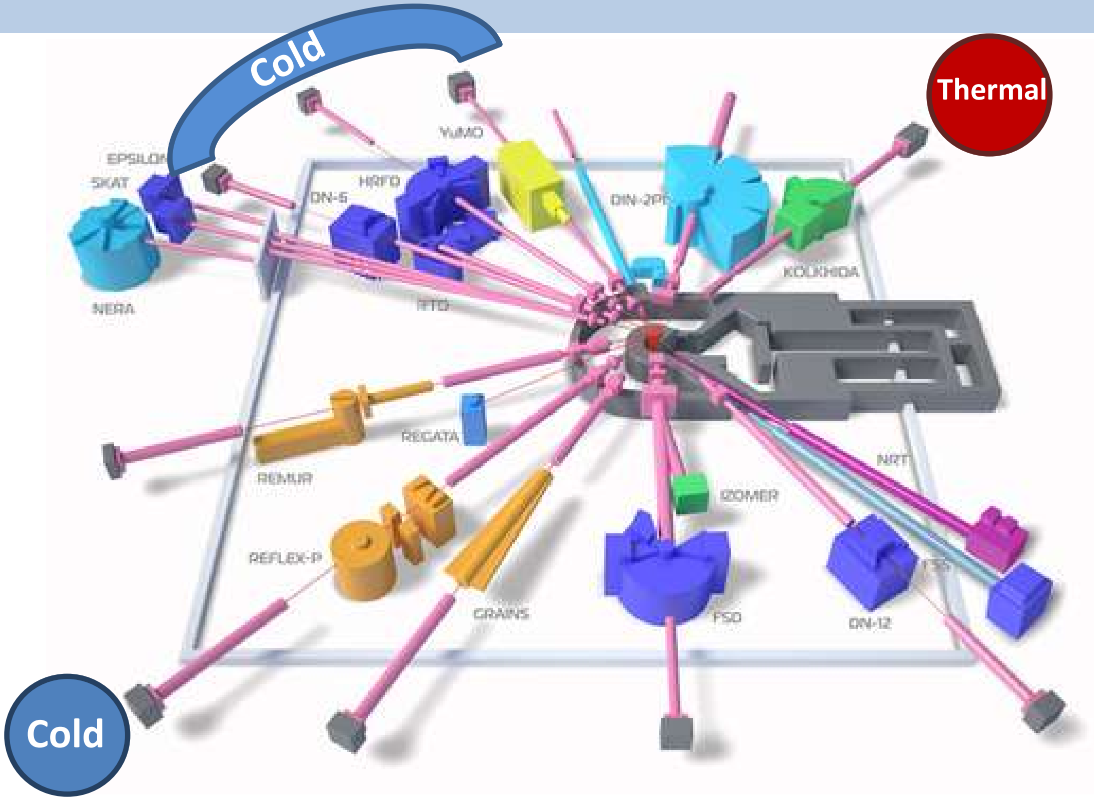


Main steps to creating a cold neutron source on combine moderator (CM201) example

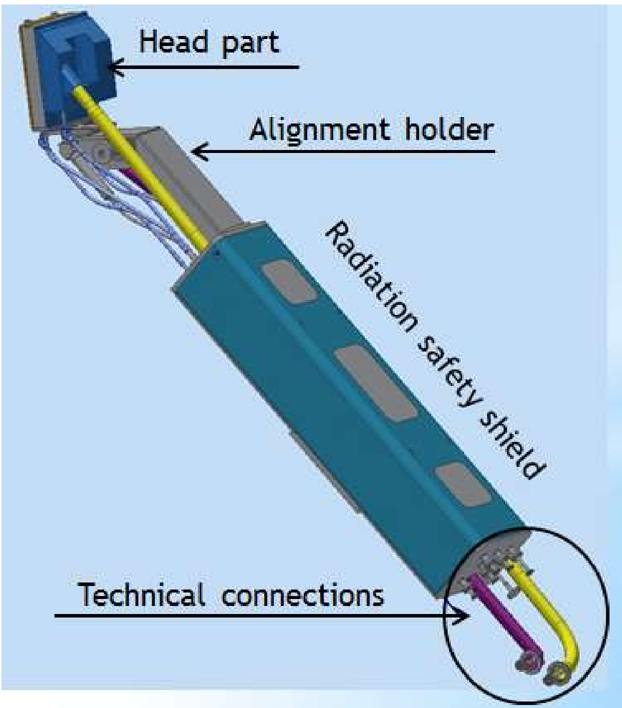
Steps

- **Configuration of head part of moderator**
- **Infrastructure communication (water circulation, cooling pipe connection…)**
- **Investigation of operation parameters of equipment for loading a pellets by transfer line from batcher to moderator**
- **Calculation and creation a cooling system**

CM 201 – moderator for 1, 4-6, 9 neutron beam



3D model of moderator CM201



1 – KOLKHIDA (a polarized neutron spectrometer and a polarized nuclear target facility)

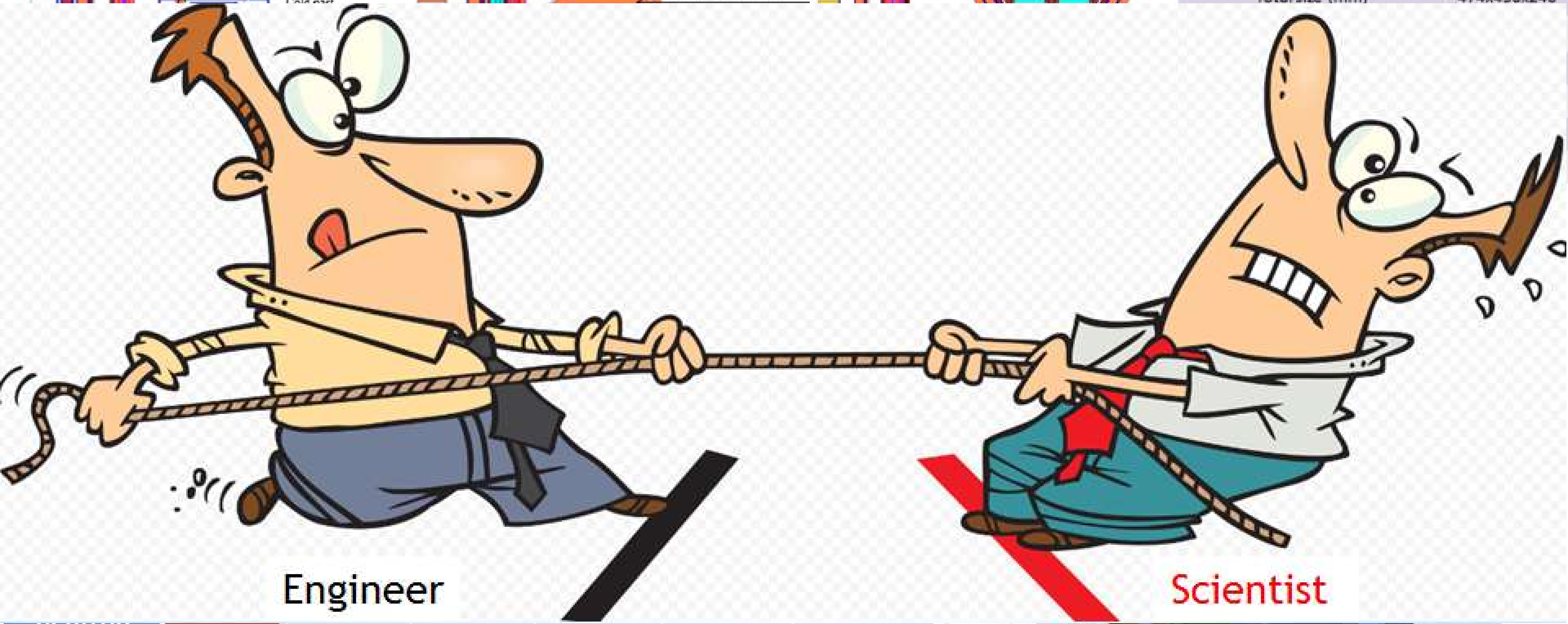
4 – YuMO (spectrometer of small-angle neutron scattering)

5 - HRFD (High Resolution Fourier Diffractometer)

6 – DN-6 (neutron spectrometer for determination of a crystal and magnetic structure by high pressure)

9 – REFLEX (reflectometer of polarized neutrons)

Optimal variant of head part of moderator CM 201



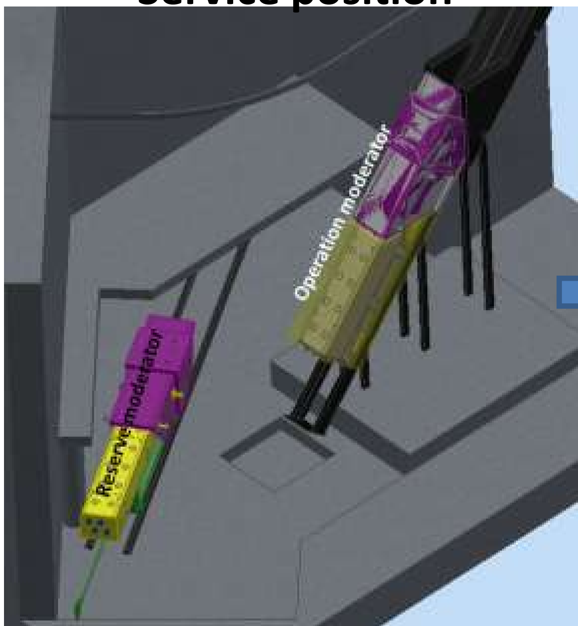
wavelength (Å)		Config. 2	Config. 3	Config. 4	Config. 5	Config. 5 (methane 20K)
8 – ∞		4,4	2,17	8,53	10,85	32,25
4 – 8		2,73	1,46	4,45	6,31	11,62
2 – 4		1,05	1,41	1,26	1,01	0,78
1 – 2		0,54	1,35	0,26	0,16	0,12

Beam #1

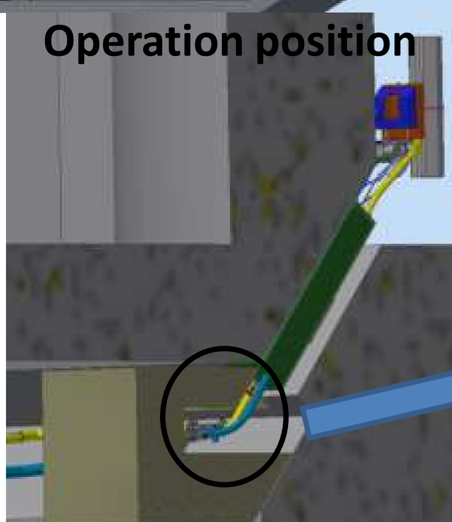
***Calculation by A. Rogov FLNP**

Infrastructure communications

Service position



Operation position

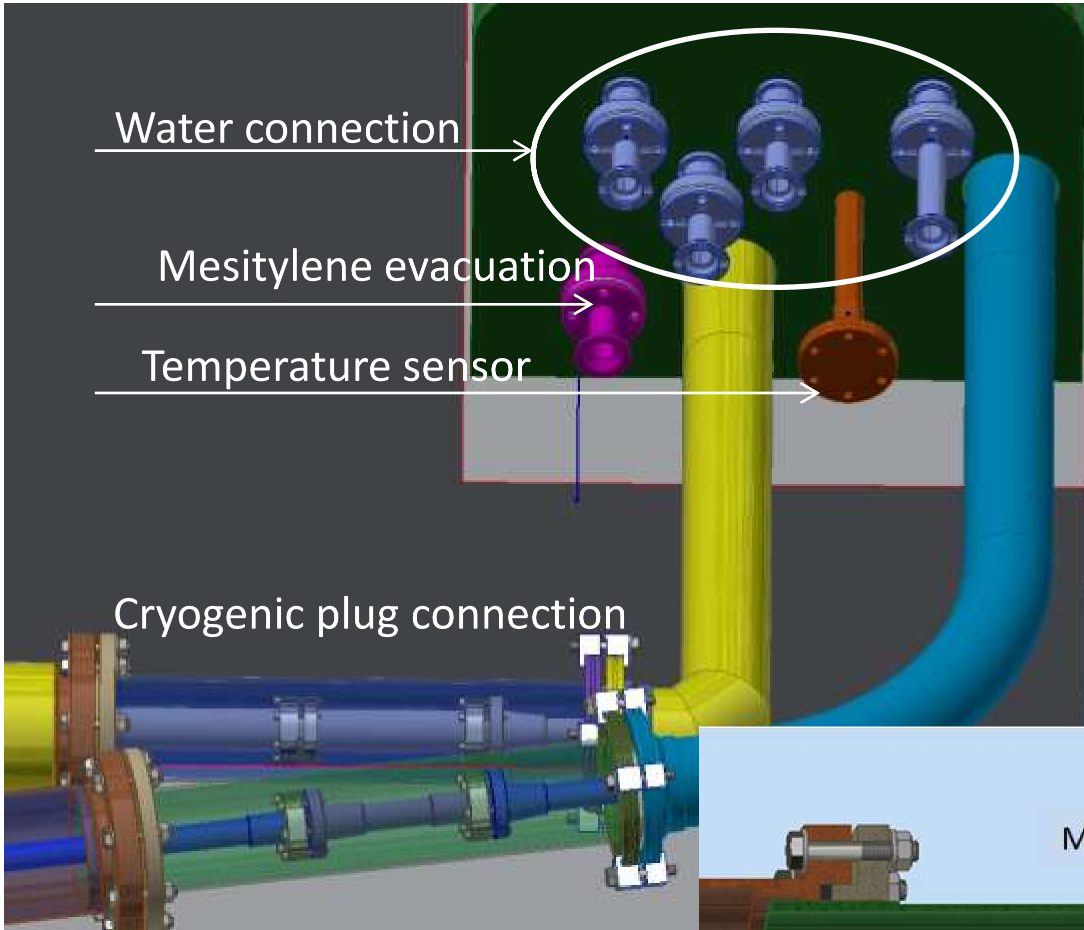


Rail track and safety shield

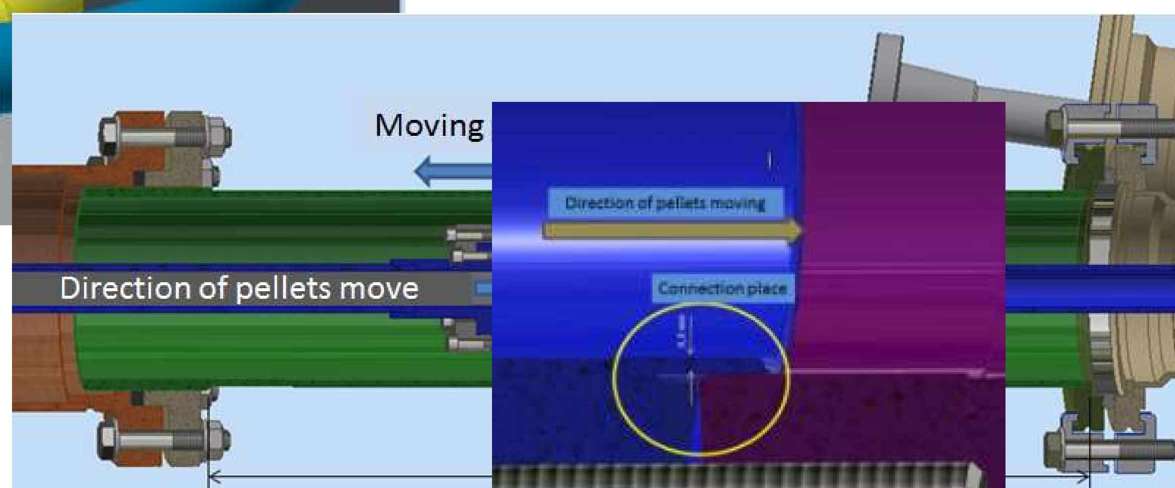
Water moderator comunications

Infrastructure communications

Infrastructure connections for CM 201 moderator

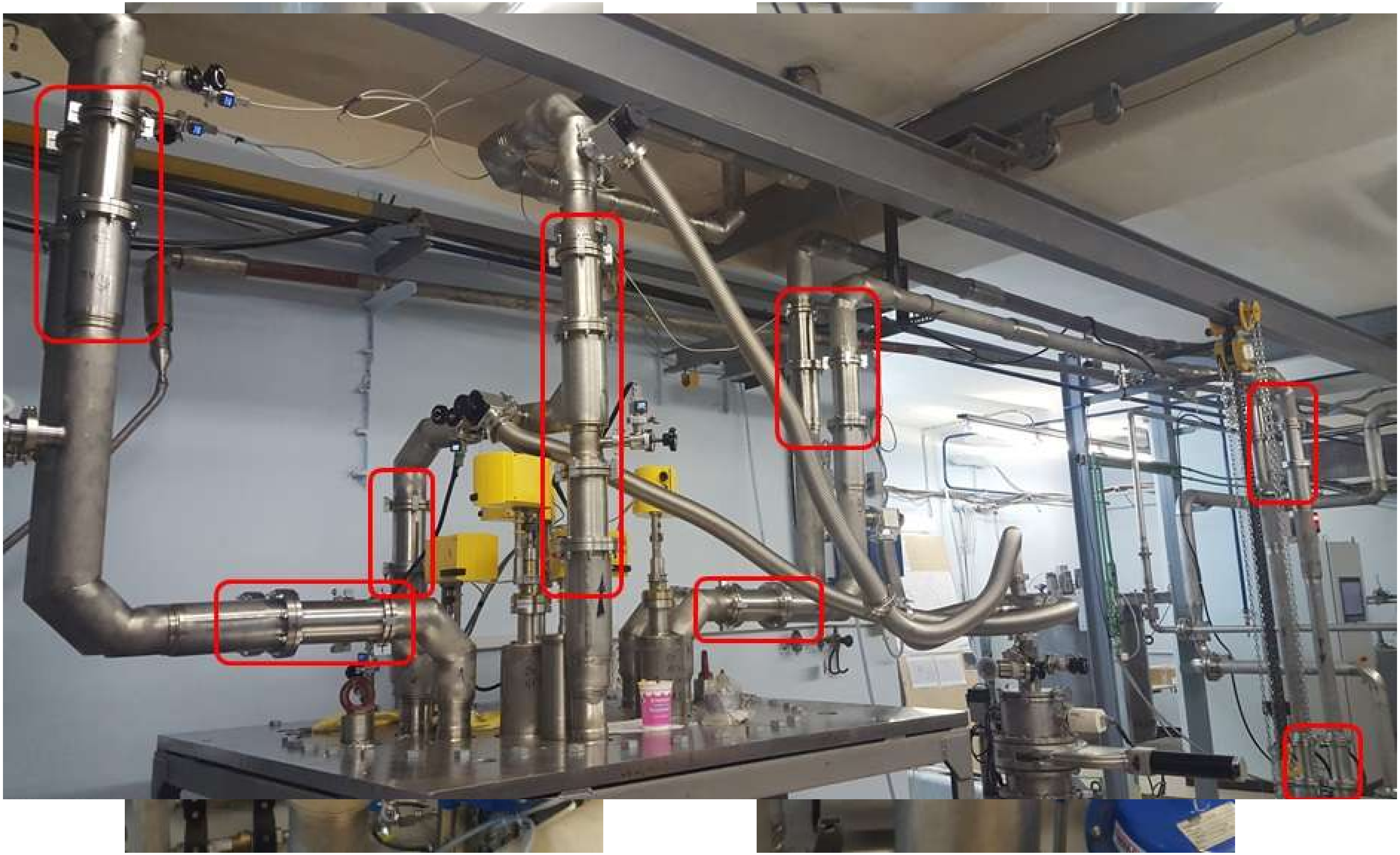


- No local heat gain;
- No steps;
- Compact size and easy operation;
- No weld (plug construction);
- Easy and cheaply manufacturing;



*Patent for invention by JINR

We use cryogenic plug connection in our cooling system

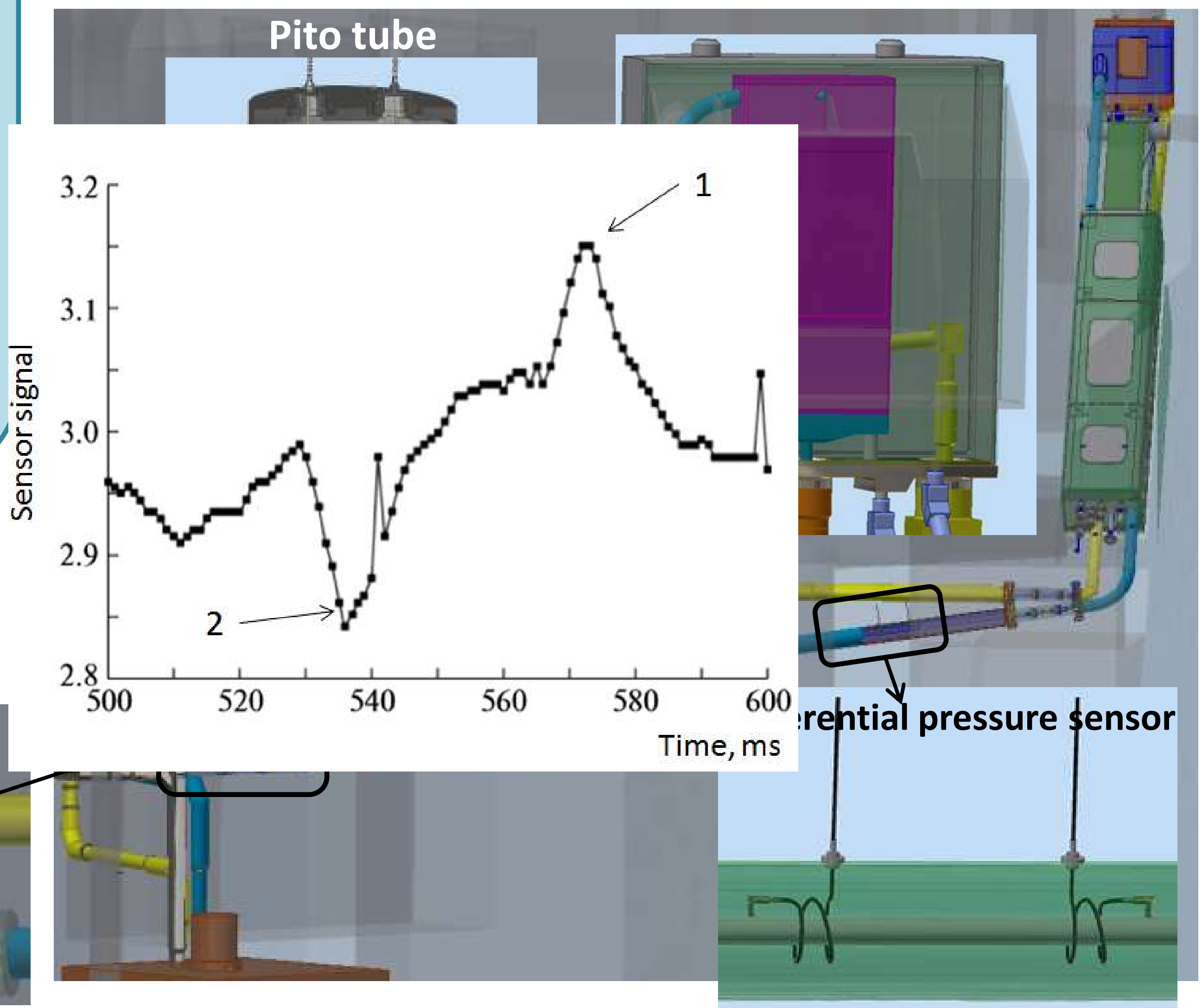


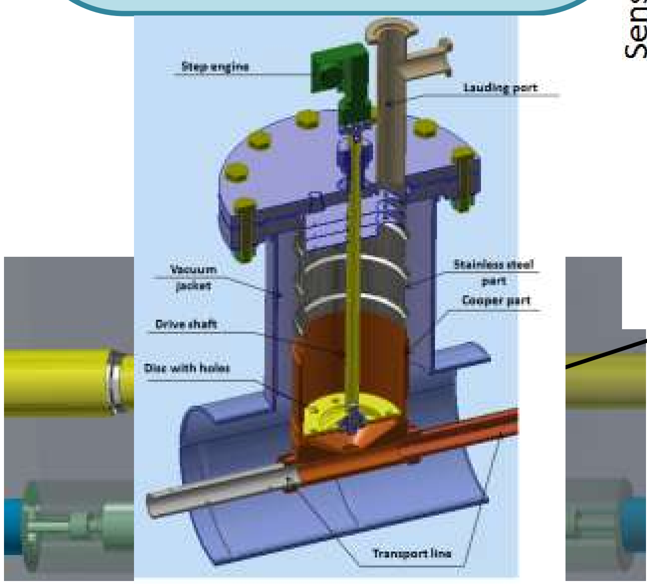
Transfer line and technical equipment of CM 201 moderator

Line parameters

- Total length – 18,5 m;
- Four rises section (from 130^0 to 52^0;
- 5 turns (from 2^0 to 90^0);
- 2 section with pressure sensor;
- Pito tube – 1;

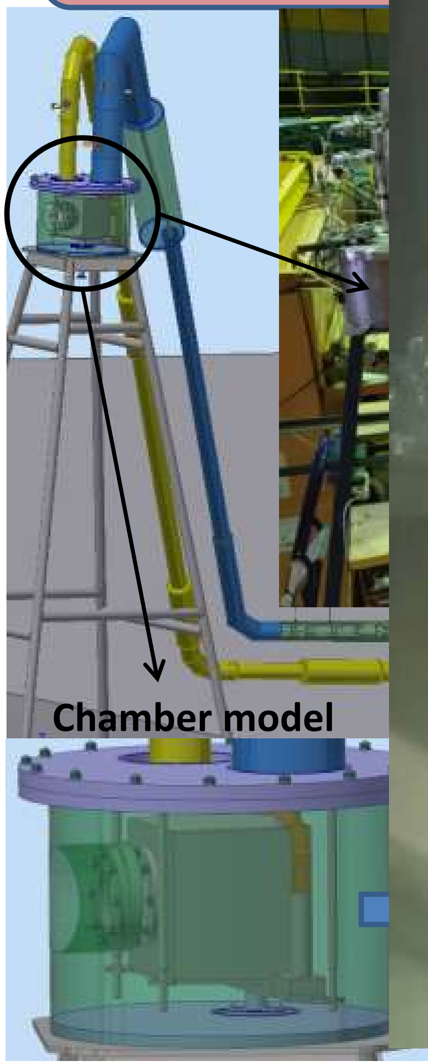
Transfer line

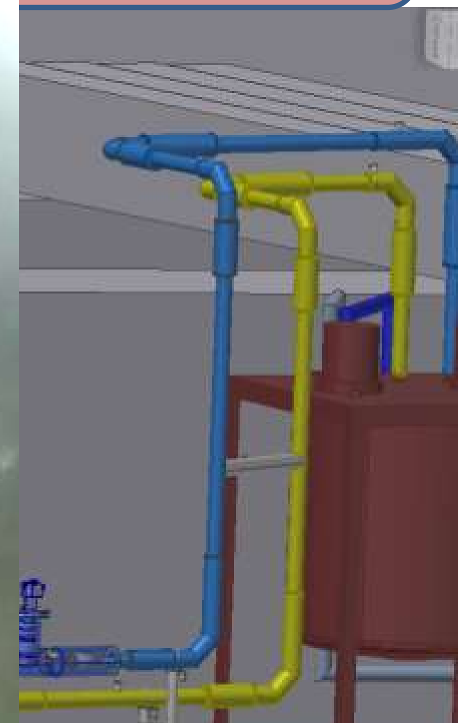




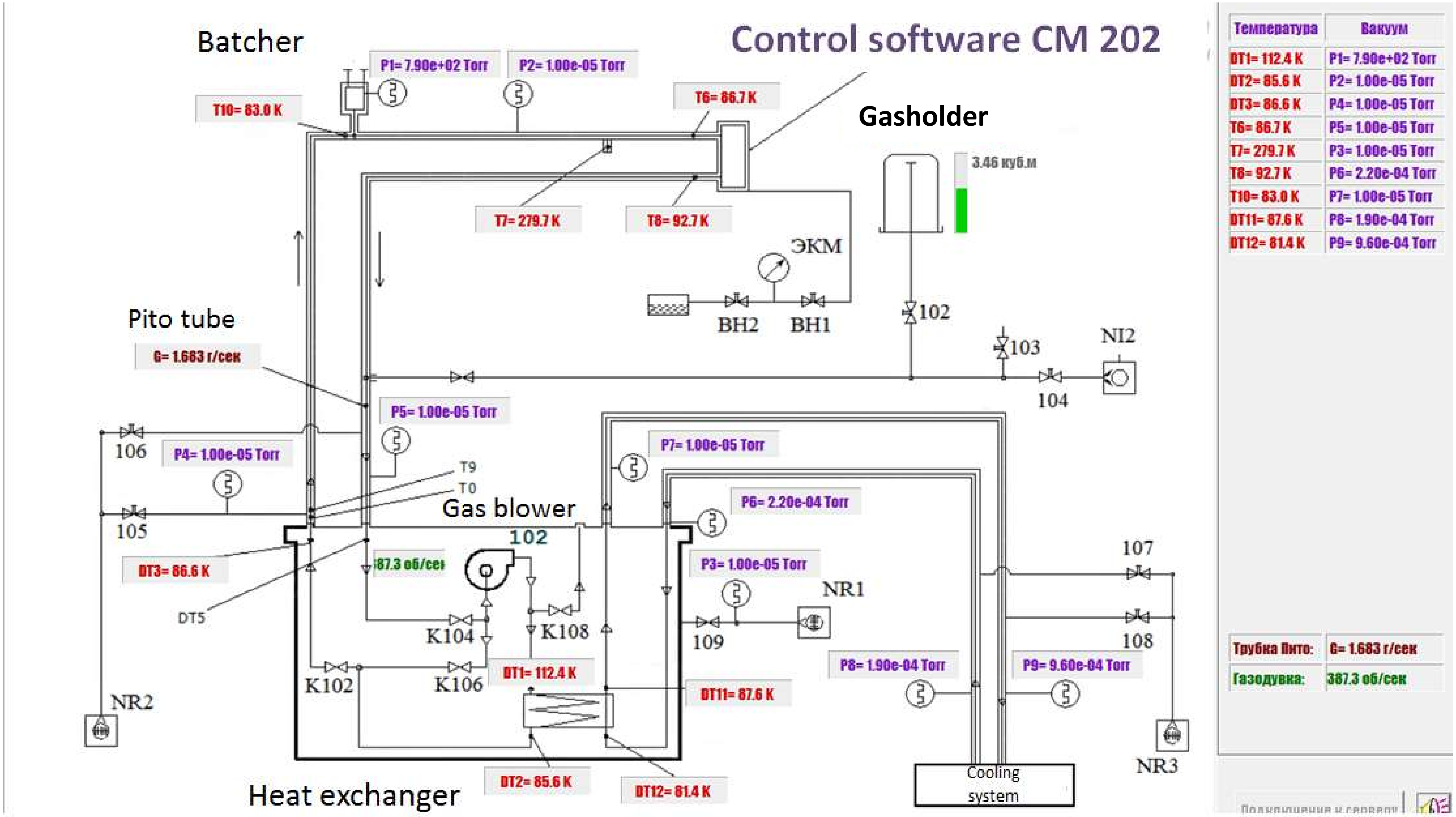
Full scale m… tor system

Main goal … by cryogenic temperature … ent parameters.





Main parameters for loading a pellets without congestion and destruction



Heat gains into cryogenic system

Solid conduction

[redacted]

Radiation

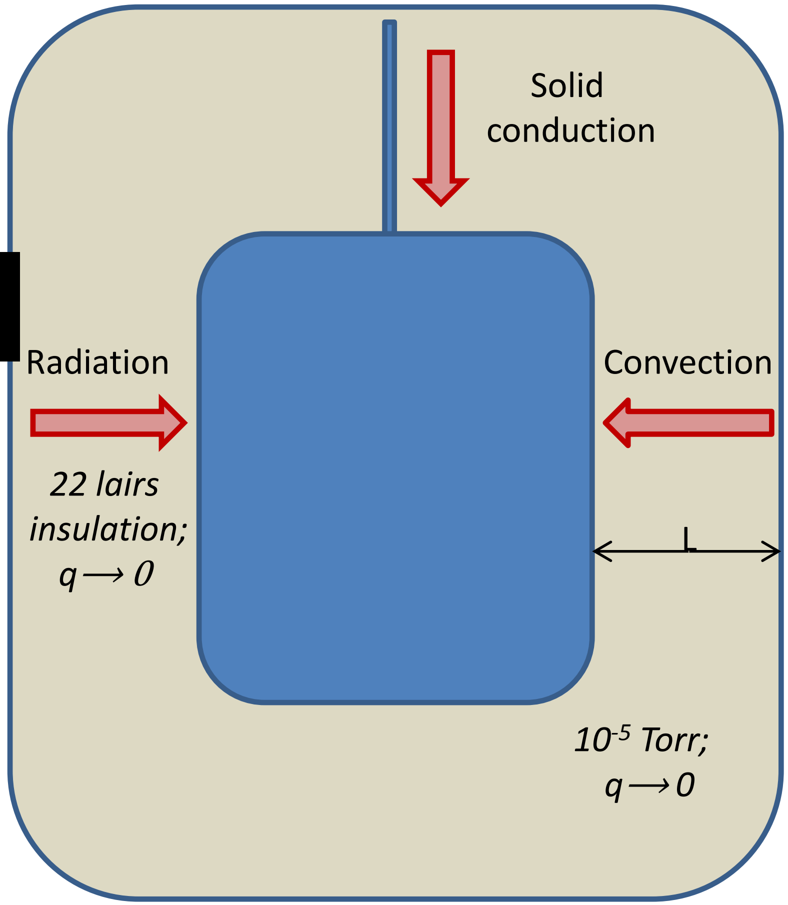
[redacted]

Convection

$\Lambda \gg L \longrightarrow q \approx p * \Delta T$

$\Lambda \ll L \longrightarrow$ [redacted]

S – surface area;
E – black degree;
λ – heat conductivity;
Λ - free path length;
P – pressure;
T – temperature.



Additional heat gain source

- exothermic reactions in a substance under neutron activation;
- heat gain from equipment (gas blower…);
- heat gain by friction of the gas on the walls pipeline.

Heat gain to CM 202

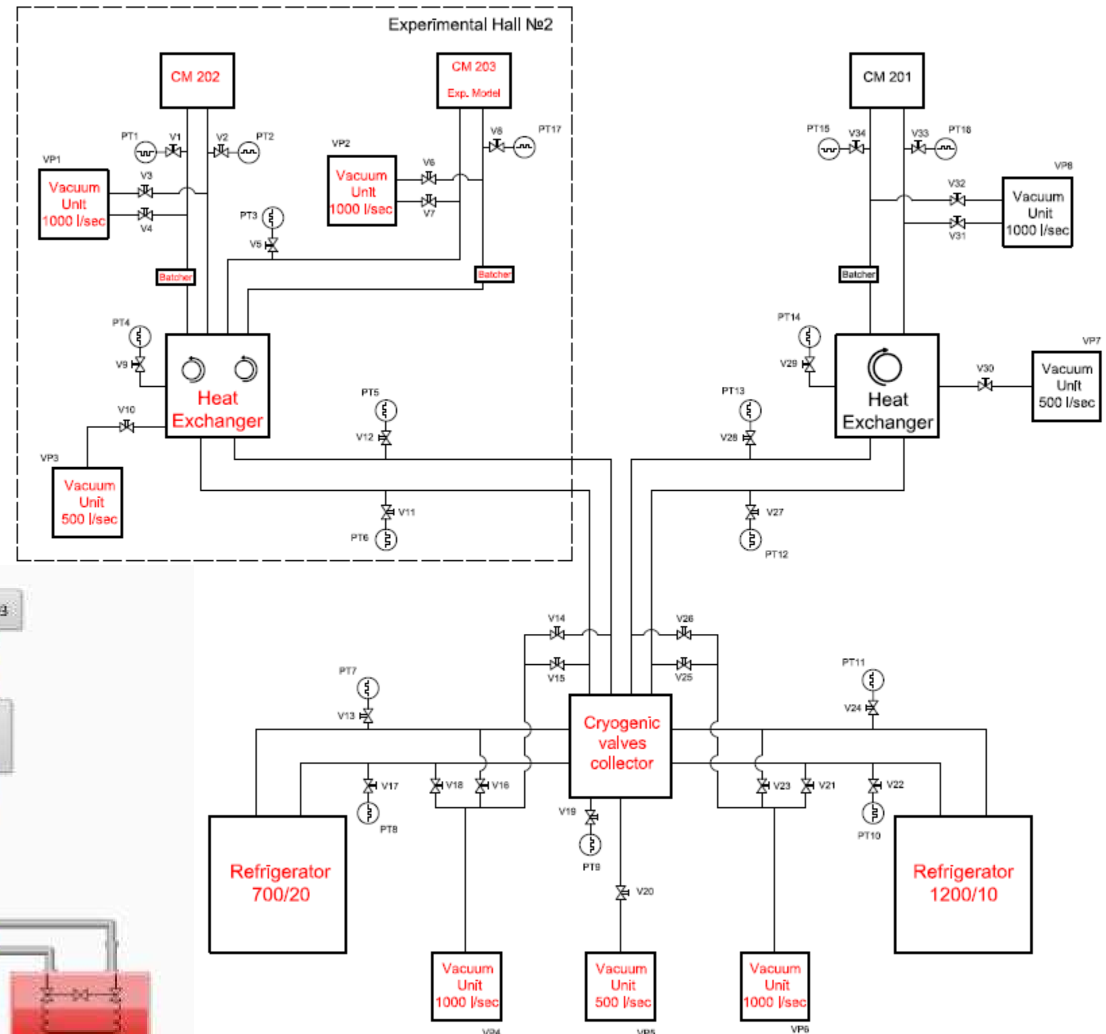
Source	Heat gain
Gas blower	140W
Chamber: exothermic reaction bracket, gas, radiation	 180W 40W
Pipes and equipment	220W
Total	580W

Cooling system for IBR-2 reactor cold neutron source

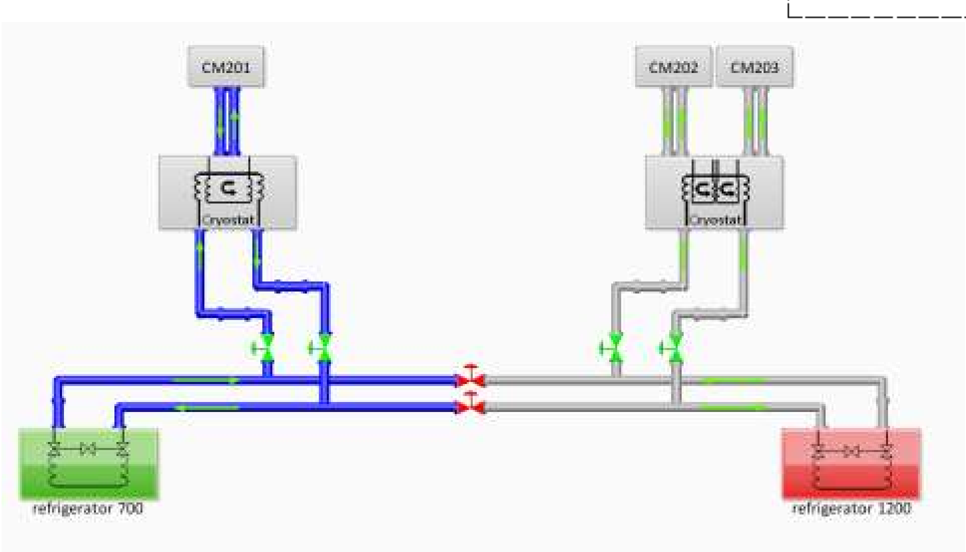
Equipment of system

- Refrigerator 700/20
- Refrigerator 1200/10
- Heat exchanger for CM 201 with one gas blower
- Heat exchanger for CM 202/CM203 with two gas blowers
- Manifold
- Cryogenic pipes and plug connections
- Measurement and vacuum equipment

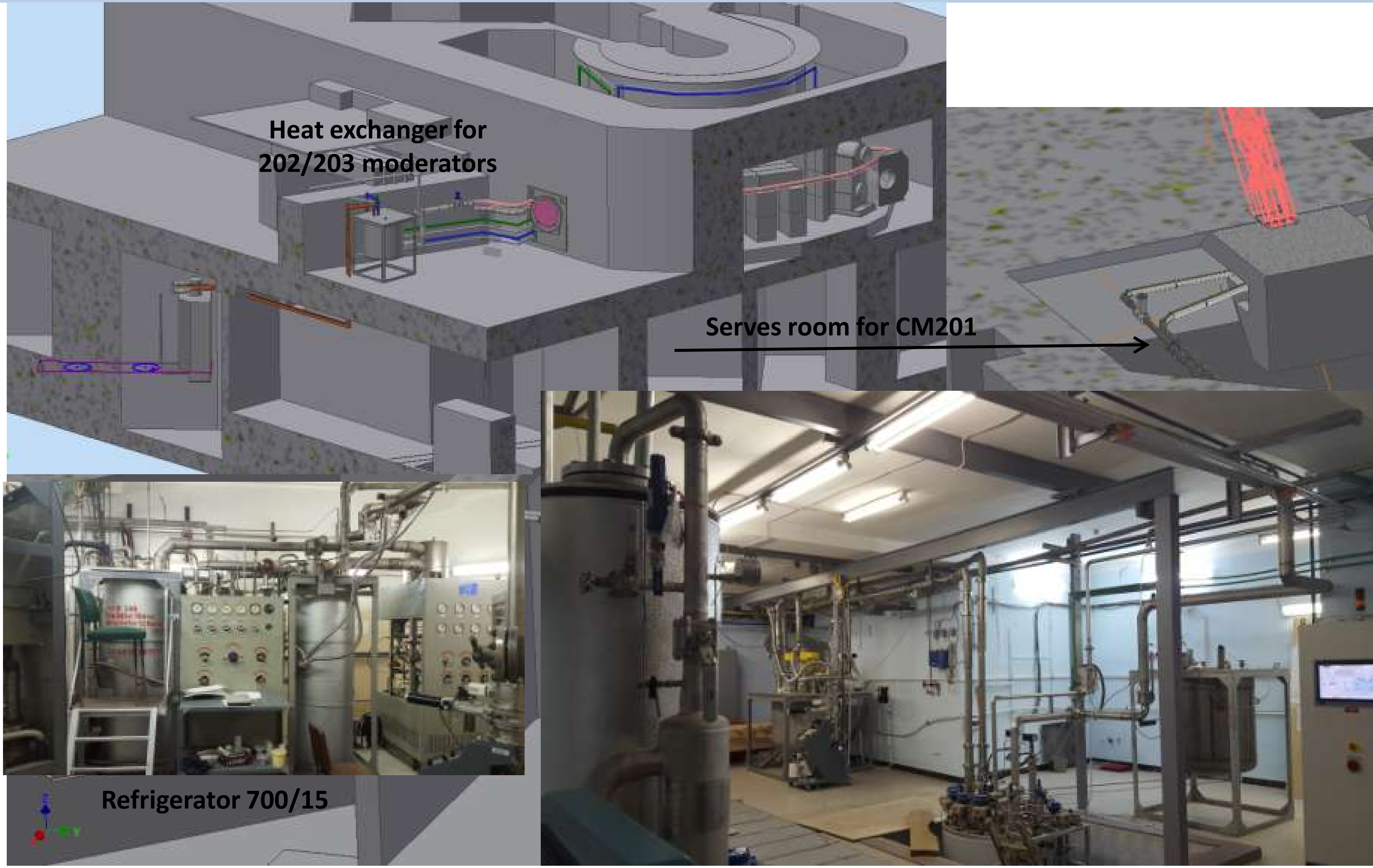
Cryogenic System Scheme for Cold Neutron Source for IBR-2 Reactor



Schema of helium distribution

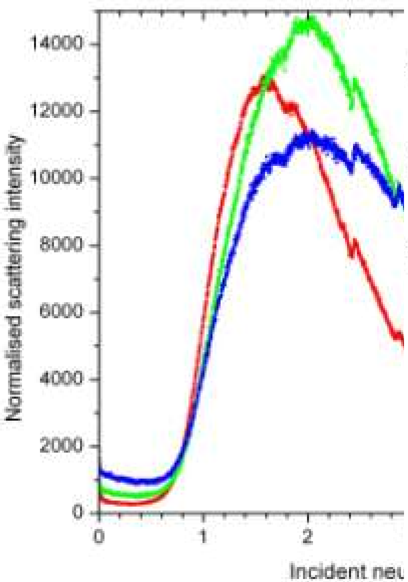


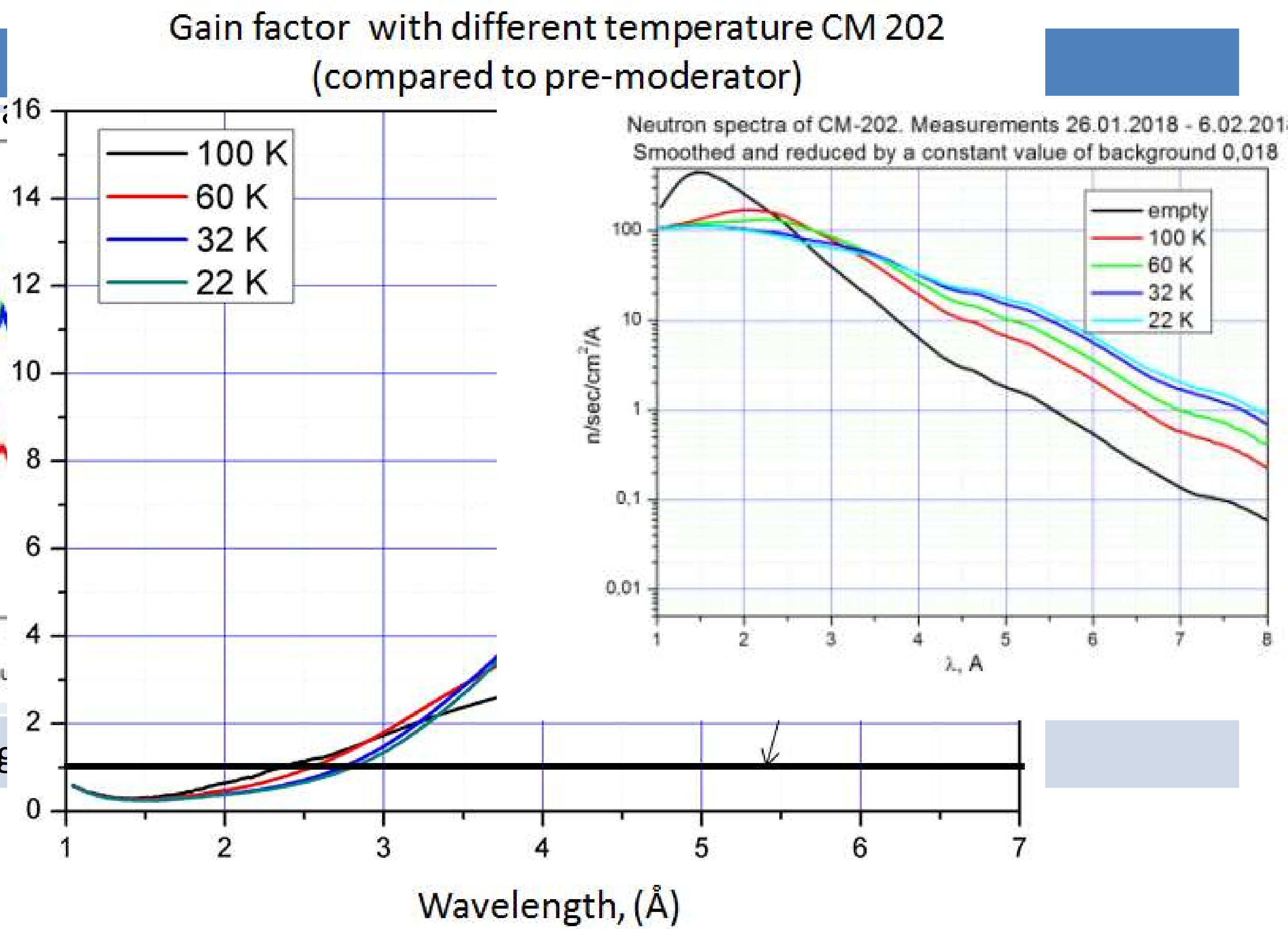
Cryogenic area



Some dates of source cooling system

Bea





Reservation of refrig

Results of combine moderator CM 202 operation

Characteristics and results of operation CM 202	
Moderating materials	mesitylene + m-xylene 70% 30%
Volume of the cold chamber	1 L (30000 pellets)
Cooling substance	helium
Operating time	513 MW/h (11 days)
Operation mode: • "warm" • "cold"	 300 K 20-150 K
Neutron flux on the surface	10^{12} n/cm2/sec
Gain factor	up to 14 (7Å)
Spectrum degradation	< 10%

Thank you for your attention!