VI Школа по физике поляризованных нейтронов «ФПН–2017»

Замедлители нейтронов на источнике ИБР-2 и возможности использования существующих технологий для компактного источника нейтронов

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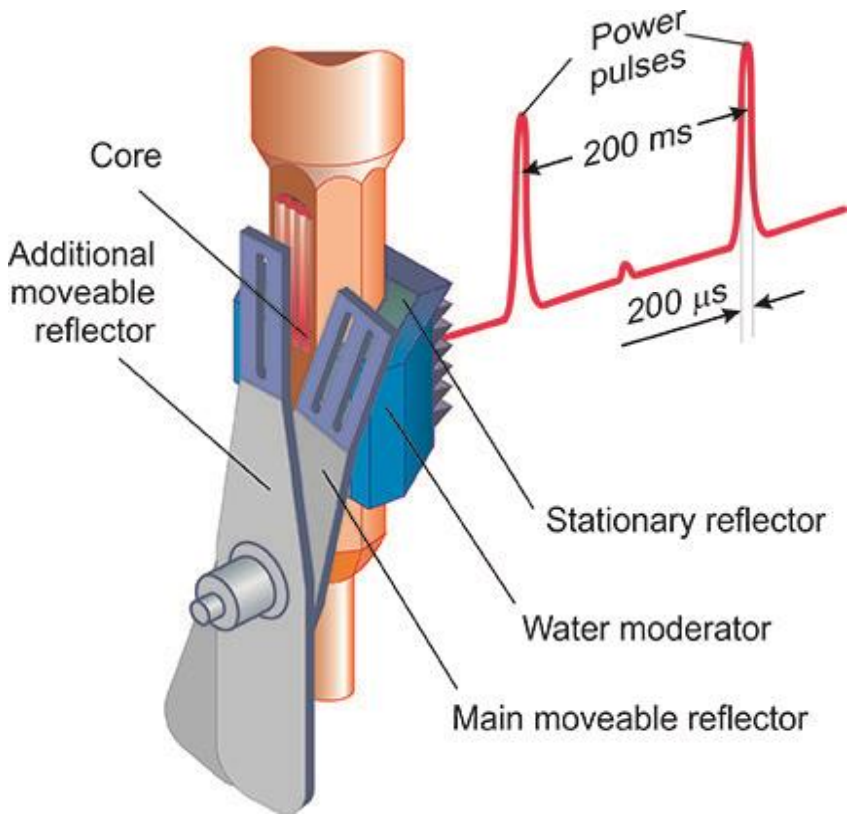
ЛНФ, Объединенный институт ядерных исследований

14-15 декабря 2017 года, Гатчина, Петергоф

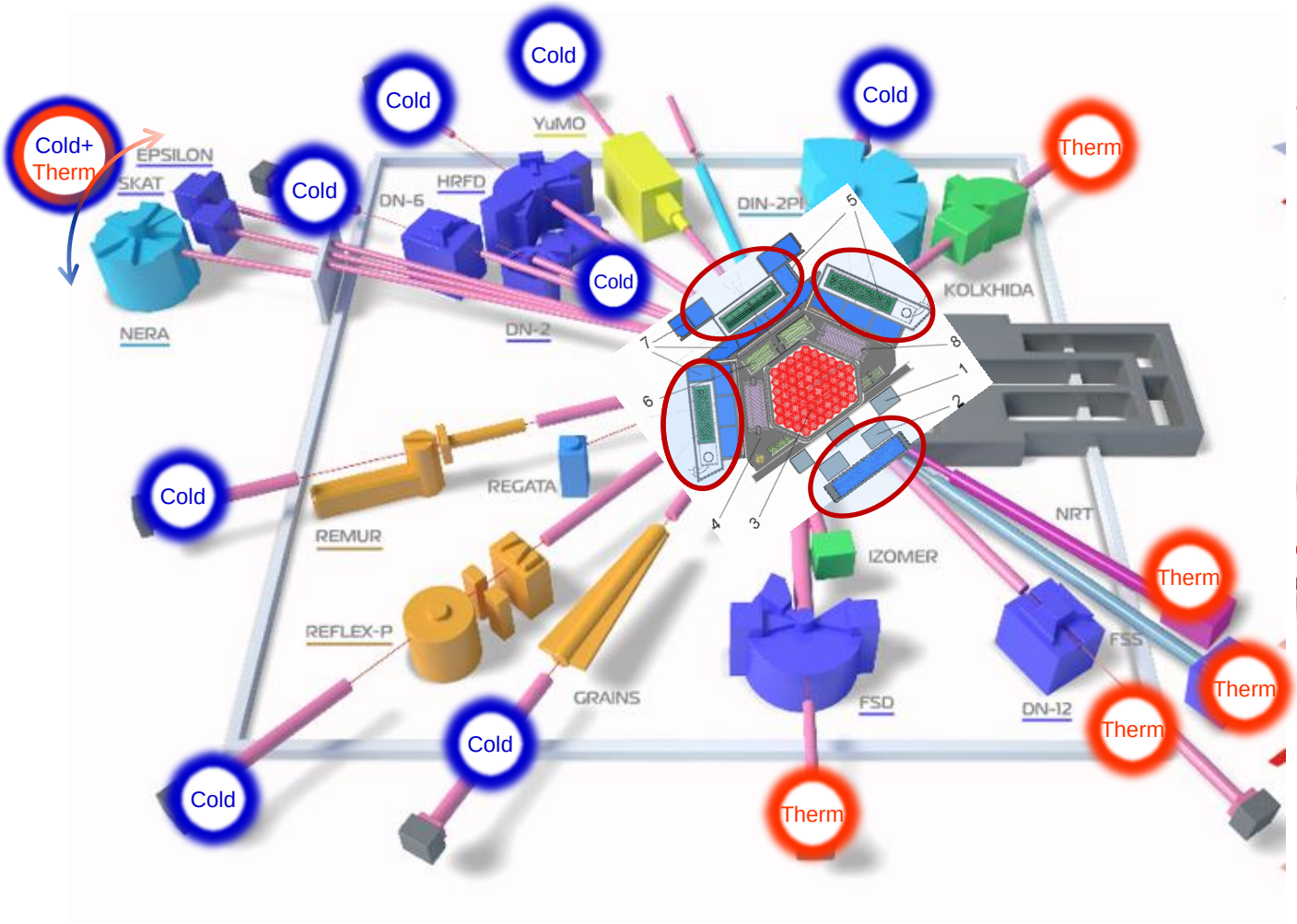
IBR-2 Pulsed research reactor



Average power, MW	2
Burst power, MW	**1830**
Fuel	PuO_2
Number of fuel assemblies	69
Maximum burnup, %	9
Pulse repetition rate, Hz	5; 10
Pulse half-width, μs:	
fast neutrons	200
thermal neutrons	340
Rotation rate, rev/min:	
main reflector	600
auxiliary reflector	300
MMR and AMR material	nickel + steel
MR service life, hours	55000
Background, %	7.5
Thermal neutron flux density from the surface of the moderator:	
- time average	~ 10^{13} n/cm²·s
- burst maximum	~ 10^{16} n/cm²·s

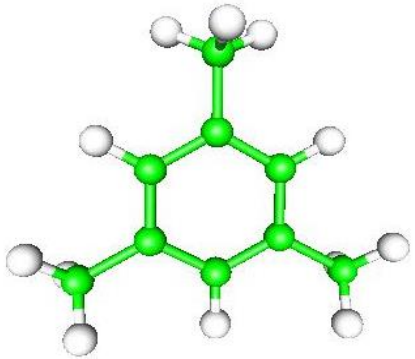
Reactor operation for physics experiments, hr/year ~2500

Complex of bi-spectral moderators of the IBR-2 reactor (cold moderators and grooved water moderators)



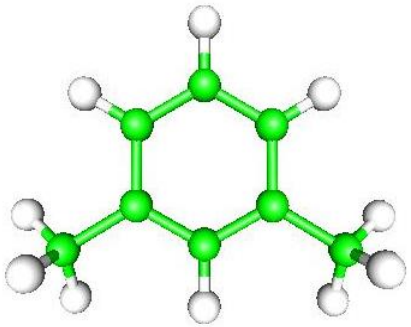
Solid mesitylene as a material for cold moderators

mesitylene



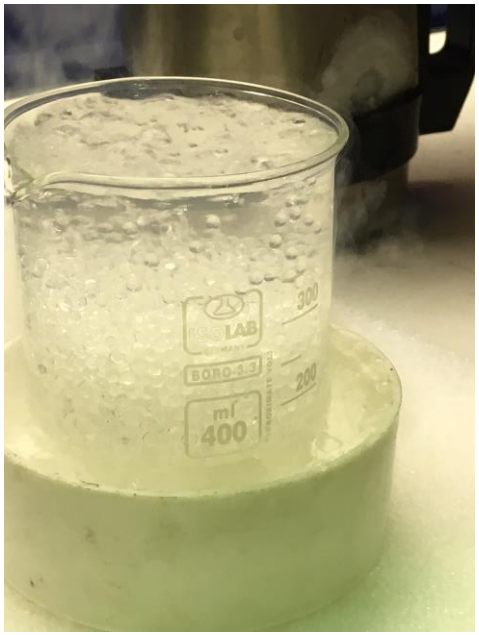
T_m = 227 K

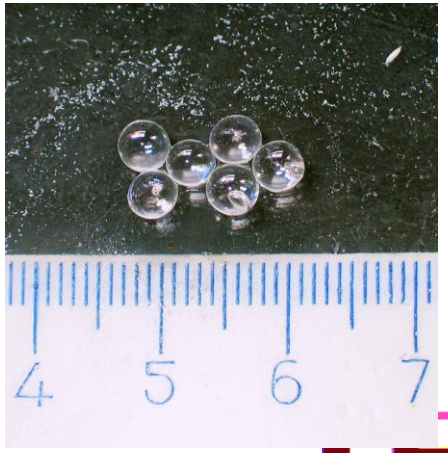
m-xylene



T_m = 225 K

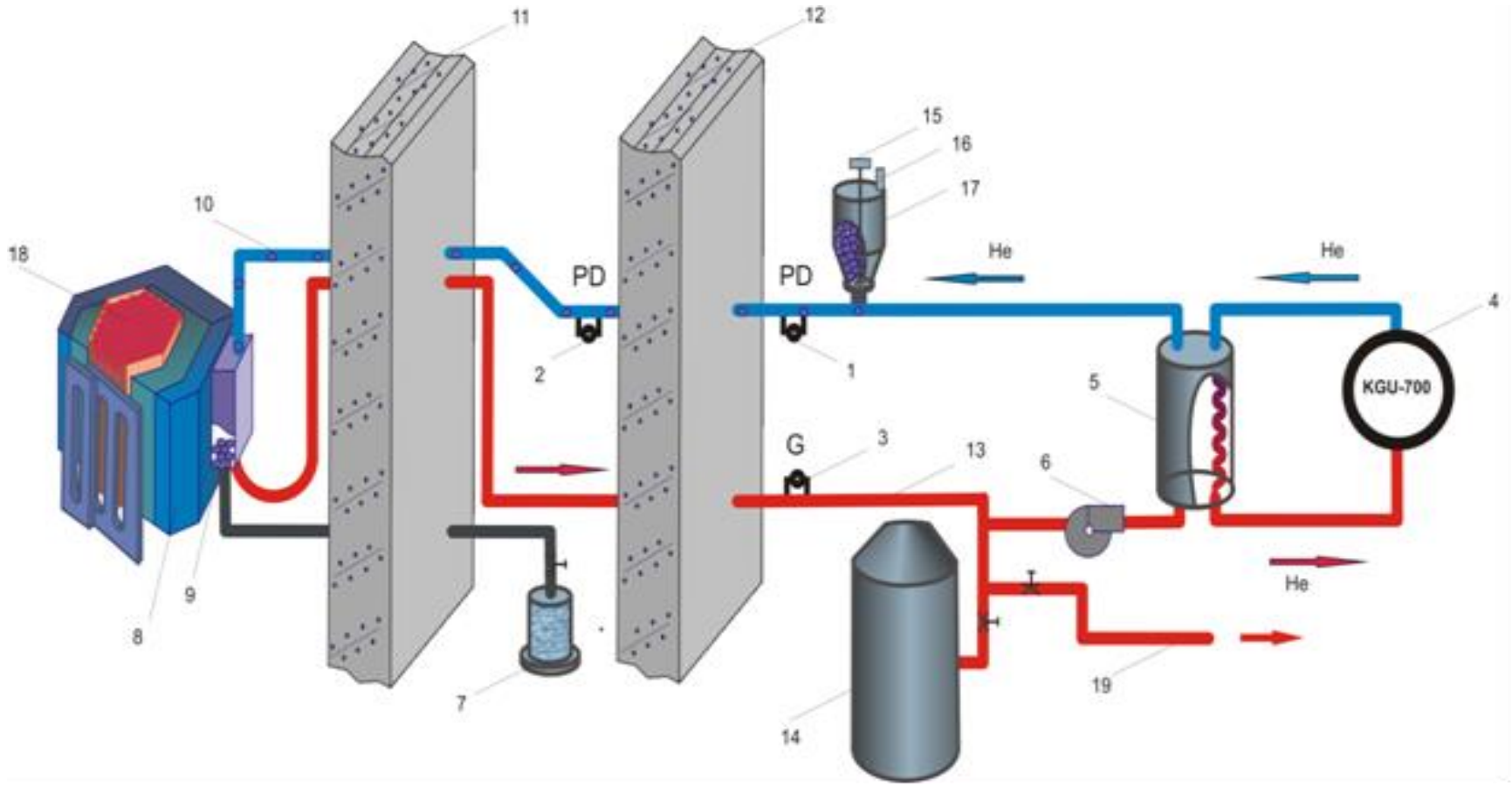
Solid beads of the frozen mixture of mesitylene and m-xylene





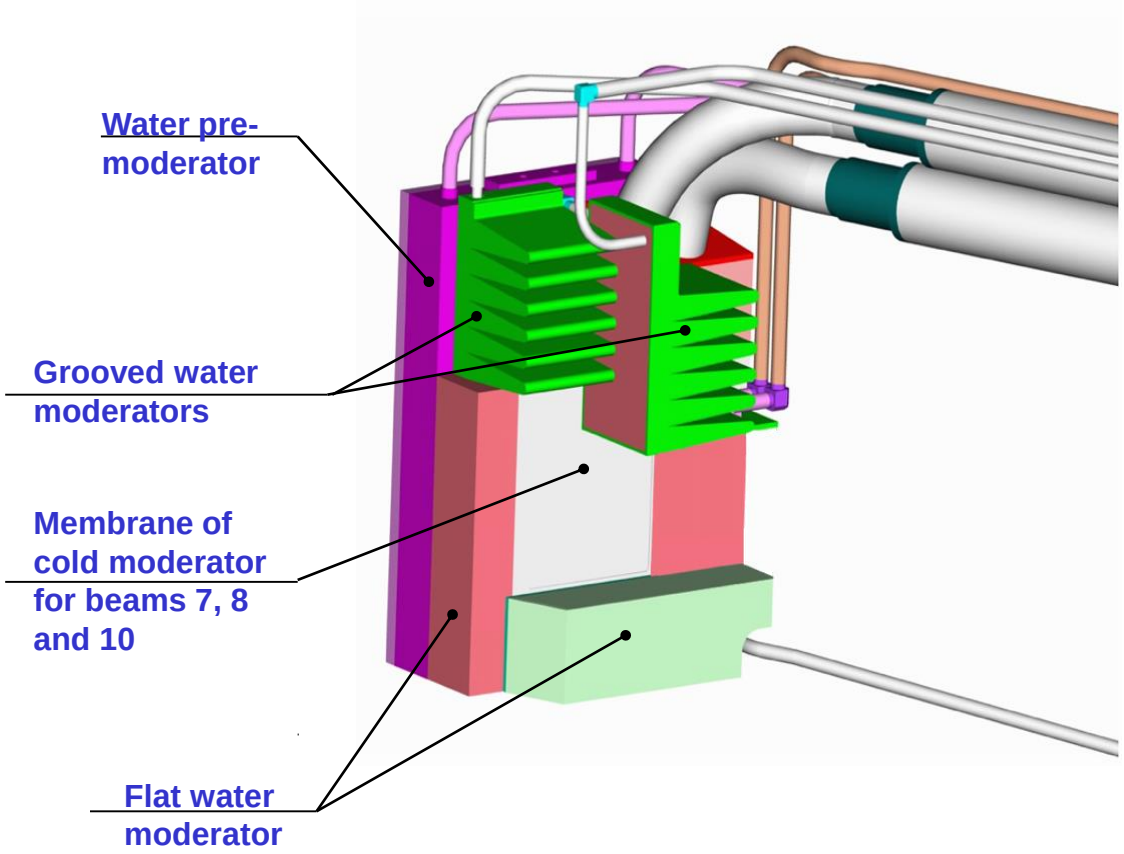
- Mixture of mesitylene with m-xylene or pseudocumene is of glassy structure and has good neutron thermalization property and radiation resistance (no reaction of recombination of radicals).
- Not explosive material.
- Wide range of working temperatures of cold moderator: 20 - 150 K.

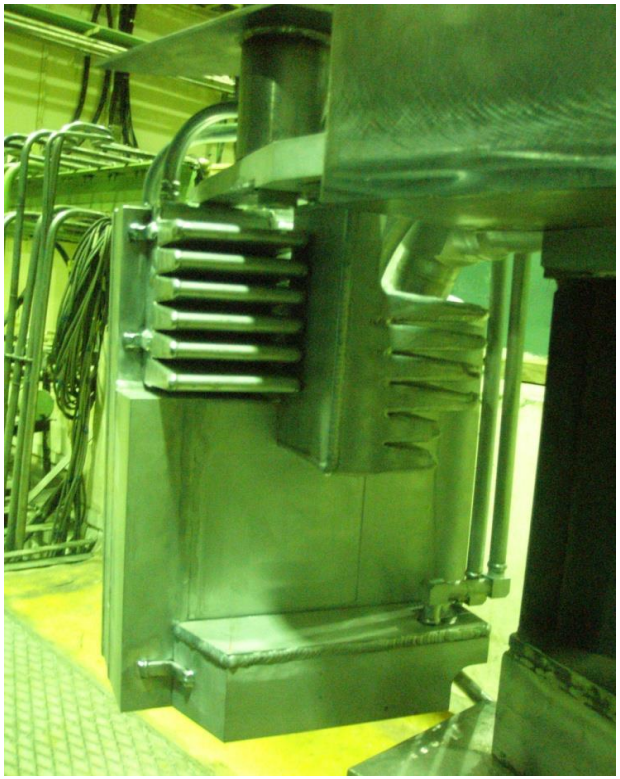
Principal scheme of the IBR-2 moderator system



Bi-spectral moderator for beams 7,8,10,11

(neutrons for 6 existing instruments + 1 instrument is under construction)



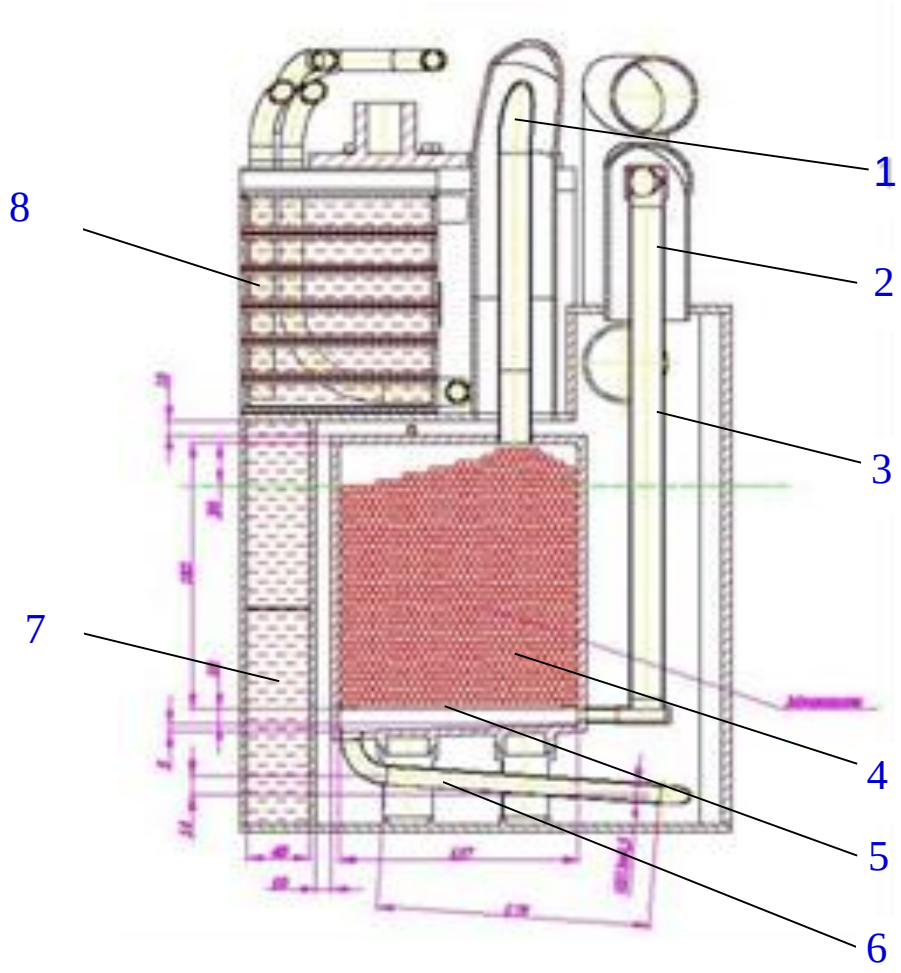


- Dimension of bi–spectral moderator: 405 x 335 x 261 mm^3 (cold moderator: 200 x 150 x 40 mm^3)
- One load of beads is about 25000. Loading time ~ 5 hours.
- The average temperature of cold moderator is 30 K (23 K).
- The moderator already worked for experiments on extracted beams more than 3000 hours.
- One run is ~10 days without changing the loaded material.

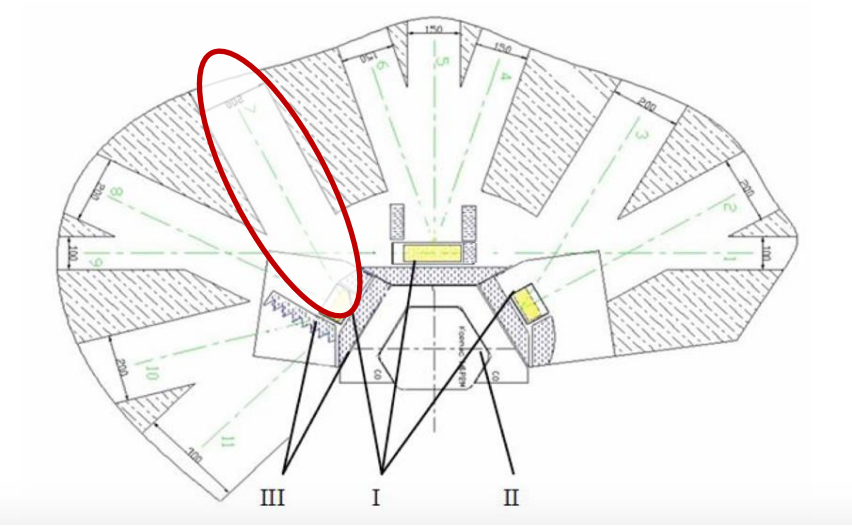
Bi-spectral moderator for beams 7,8,10,11

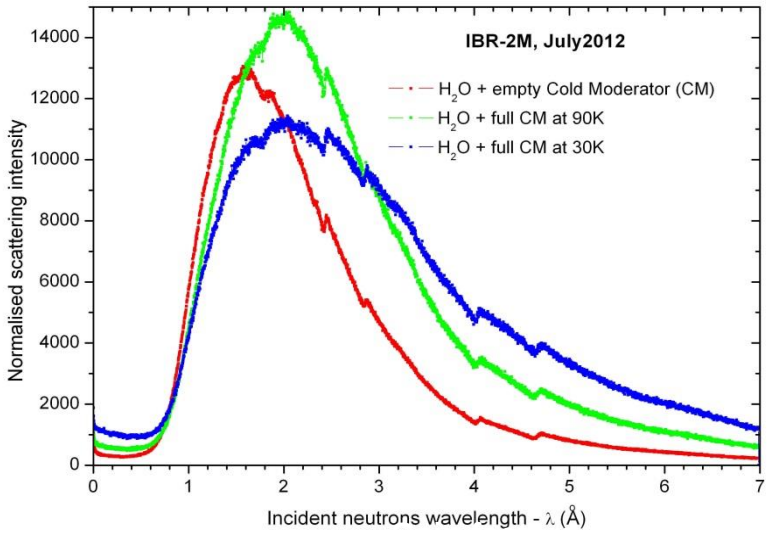
(neutrons for 6 existing instruments + 1 under construction)

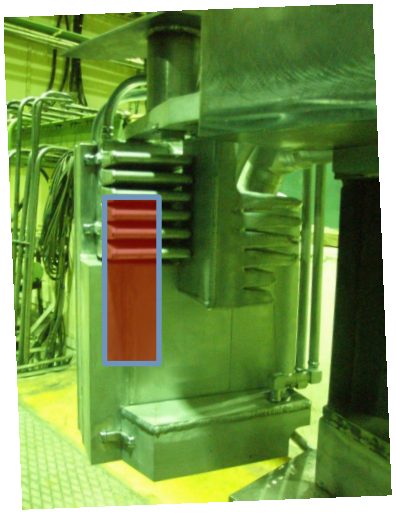
1 - Helium and beads input,
2 - Helium output,
3 - Vacuum jacket,
4 - Mesitylene beads,
5 - Grating,
6 - Mesitylene discharge pipe,
7 - Flat water moderator,
8 – Grooved water moderator.

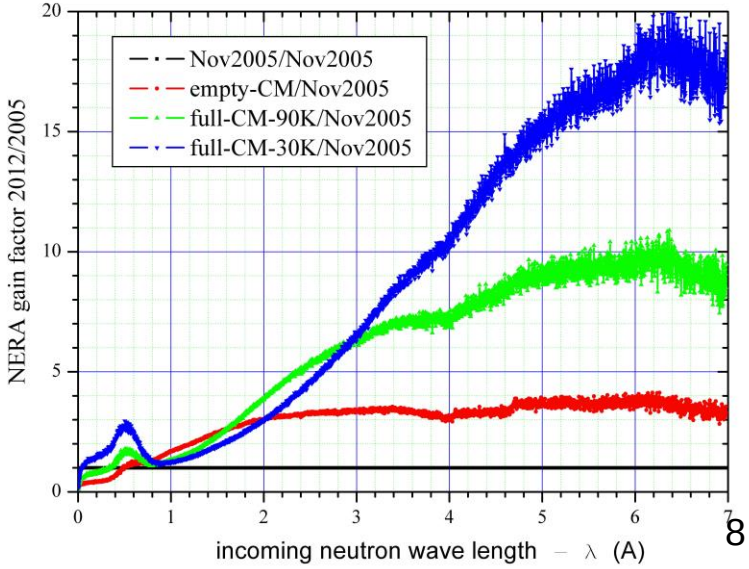


Spectrometer NERA (beam 7)



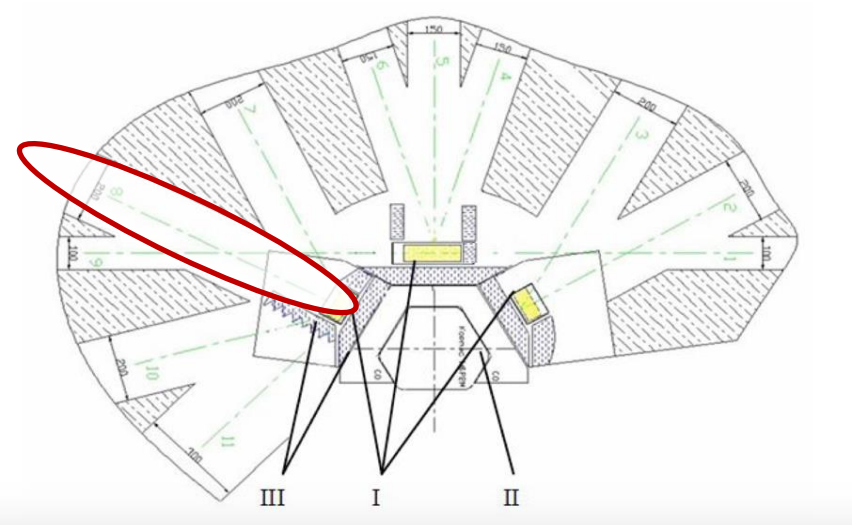


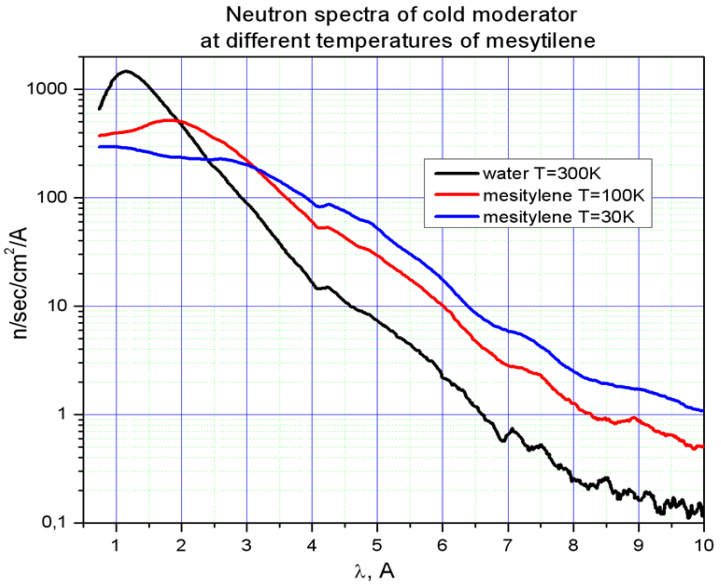


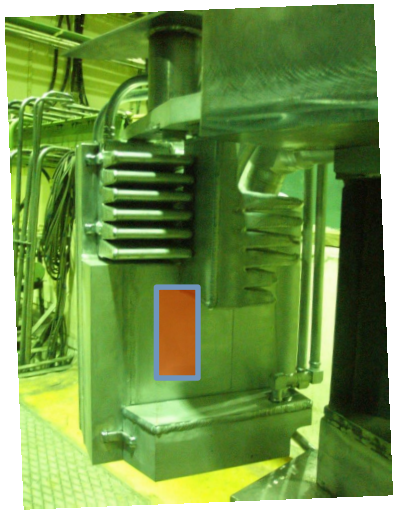


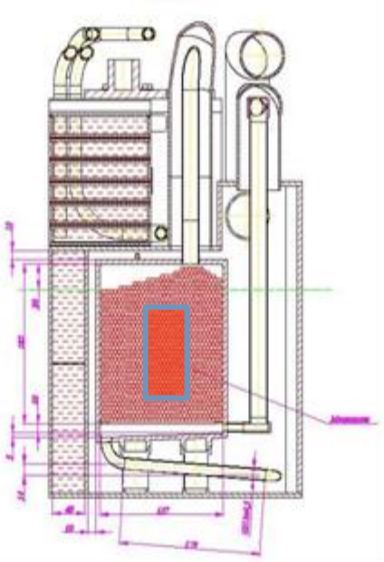
*) I. Natkanec

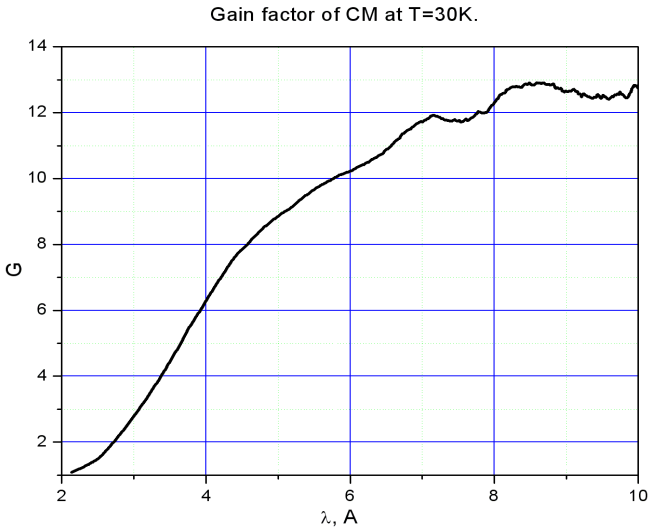
Reflectometer REMUR (beam 8)











How to increase cold neutron intensity with the same moderating material?

- To use cold Be reflector

«+»neutron intensity form 4 A will to be increased by factor of ~1.7

«-» Bragg-edge at ~4 A

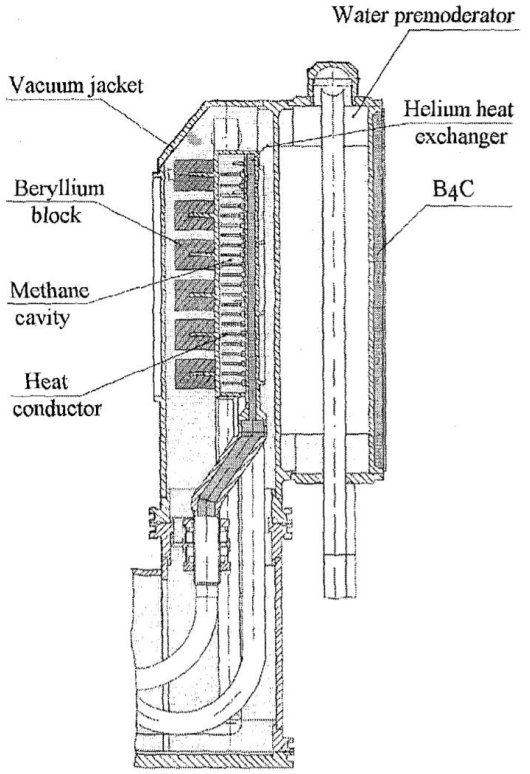
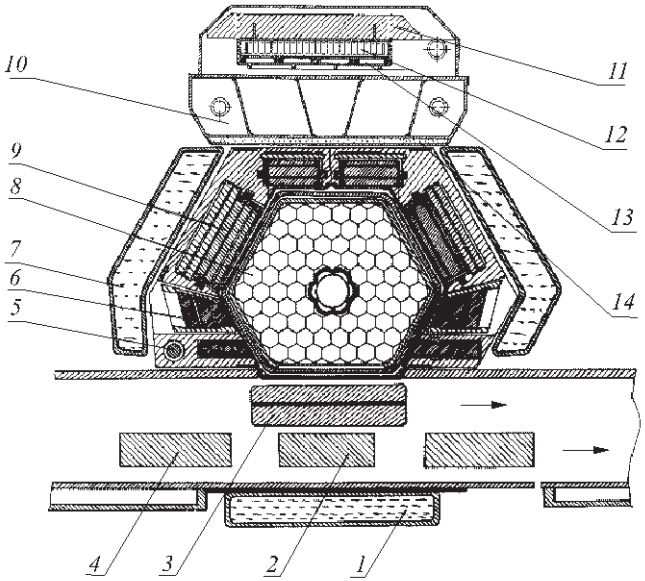


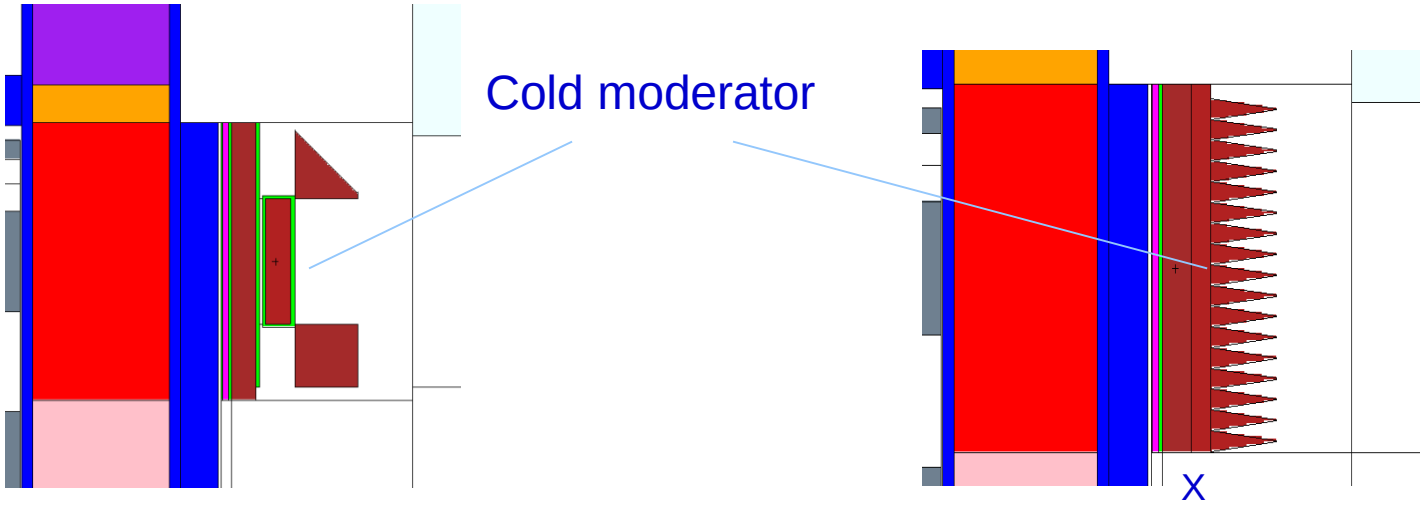
Fig.1. Solid methane moderator section view



•¯¸. 6. •¥ ±É¡· ^ • •-2 ¸ É¢¥ ¤µ³ ¥É´µ¢Ò³ §³¥»²¯ É¢¥³ , ß¡·¯§µ´É²Ó µ¥¸¥Î¥¯¥¢ ³ ¸Î É¡¥1:8. *1, 7* Å ¢µ¤ÕÒ Ò¥§³¥»²¯É¢¯; *2, 4* Å ¸·¥´ÕÕ¯ ± °´ÕÕ²µ¶¸É ¤µ¶µ²-´¯É¢Ó µß¡µ ¶µ¤¢¦¡¸´µß¡µ µÉ¸ É¢ÒÕ(®É¥§Ê¡Í¯); *3* Å ²µ¶¸ÉÓµ¸´µ¢¦µß¡µ ¶µ¤¢¦¡¸´µß¡µ µÉ¸ É¢ÒÕ(¶µ± §´ ±µ´¸É ÊÍ¯ÒÕ¶µ¤¢¦¡¸´µß¡µ µÉ¸ É¢ÒÕ¤µ 2004 £.); *5, 6, 9* Å ¡²µ±¯ Ê¶· ¢²¥¯ÒÕ¢¸É Í¯µ´·´³ µÉ¸ É¢²¥; *8* Å É¡¶²¯¢¦ Õ± ¸¸¥É; *10* Å ¢µ¤ÕÒ µº¶·¥¤§³¥»²¯É¢ÓÌ µ²µ¤ µß¡µ §³¥»²¯É¢Ó, *11* Å ¡¥¯²²¯¥¢ÒºÒ³ µÉ¸ É¢ÓÉ¯²ÓÉ¸ Ì µ-²µ¤ µß¡µ §³¥»²¯É¢Ó, *12* Å ³¥É´µ¢¦ ÕÒ¶µ²µ¸ÉÓÌ µ²µ¤ µß¡µ §³¥»²¯É¢Ó, *13* Å ¶µ²µ¸É µ²¦ ¸ ¤ ÕÐ¥§µ £¢²¯Ó, *14* Å ¡µ·´Ò³ É¯²ÓÉ¸

*) E.Shabalin at al. ICANS-XV, 2000

- to use grooved cold moderator instead of flat



Å	Flat moderator	X = 1см	X = 2см	X = 3см	X = 4см
8÷∞ Å	1	2,44	2,44	2,27	2,06
4÷8 Å	1	2,12	2,14	2,02	1,83
2÷4 Å	1	1,52	1,45	1,32	1,16
1÷2 Å	1	1,03	0,82	0,69	0,6
0,6÷1 Å	1	1,02	0,88	0,78	0,72

X- thickness of the base layer of grooves

Замедлители для источников нейтронов на основе ускорителей

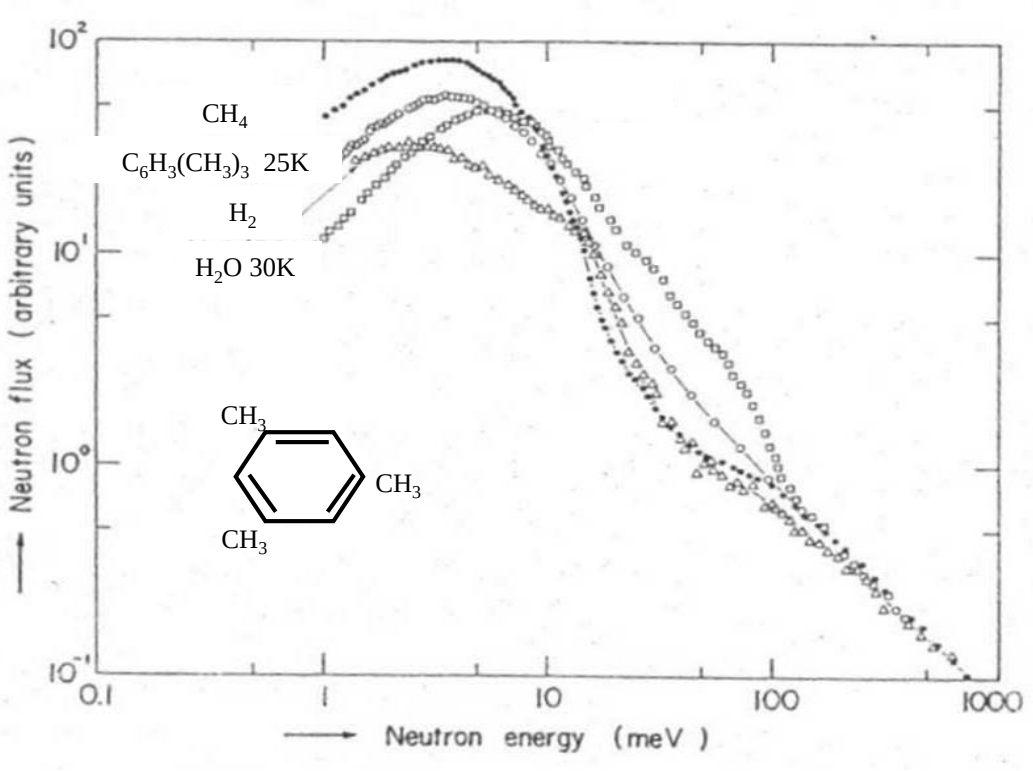
Требования к водородсодержащим материалам для холодных замедлителей

- Высокая плотность атомов водорода;
- Стойкость к декомпозиции под действием радиации;
- Наличие низколежащих уровней возбуждения молекул;
- Широкий рабочий диапазон температур (20-100К);
- Технологичность;
- Достаточная теплопроводность при низких температурах для съема тепла вносимого излучением;
- Безопасность.

Материалы холодных замедлителей

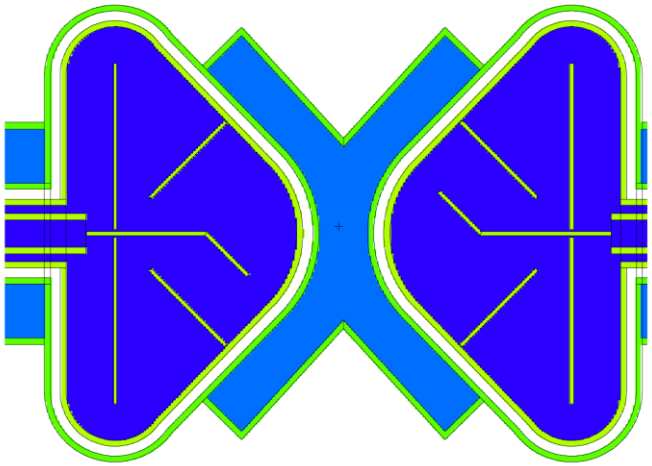
- Жидкий водород;
- Метан;
- Лед;
- Мезитилен;
- Полиэтилен

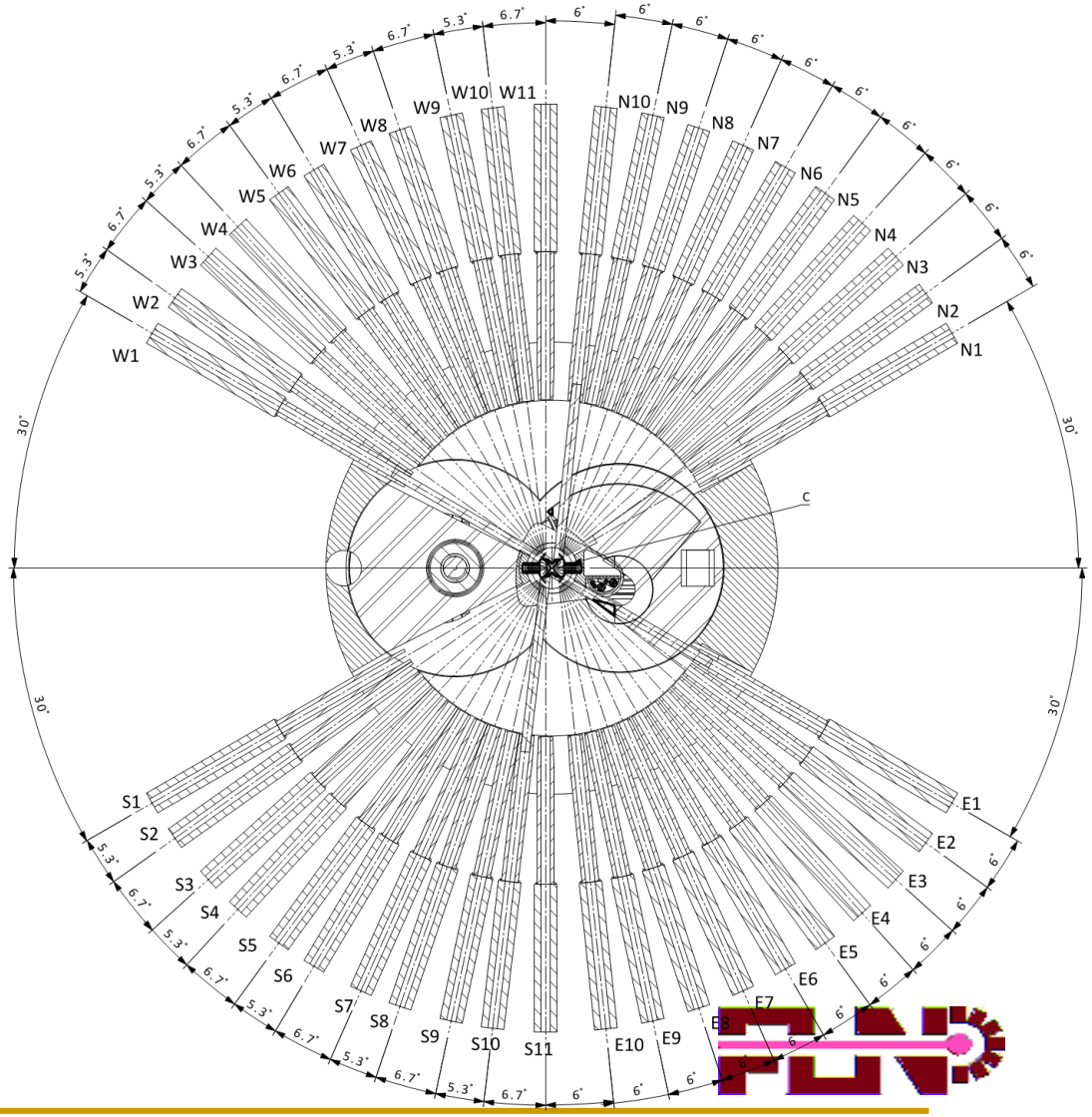
Замедлители для компактного источника на основе ускорителя



*) M.Utsuro, M Sugimoto, Y. Fujita; Experimental study on a cold neutron source of solid methylbenzene. Annual Report Research Reactor Institute Kyoto University, Vol. 8, pp. 17-25, 1975

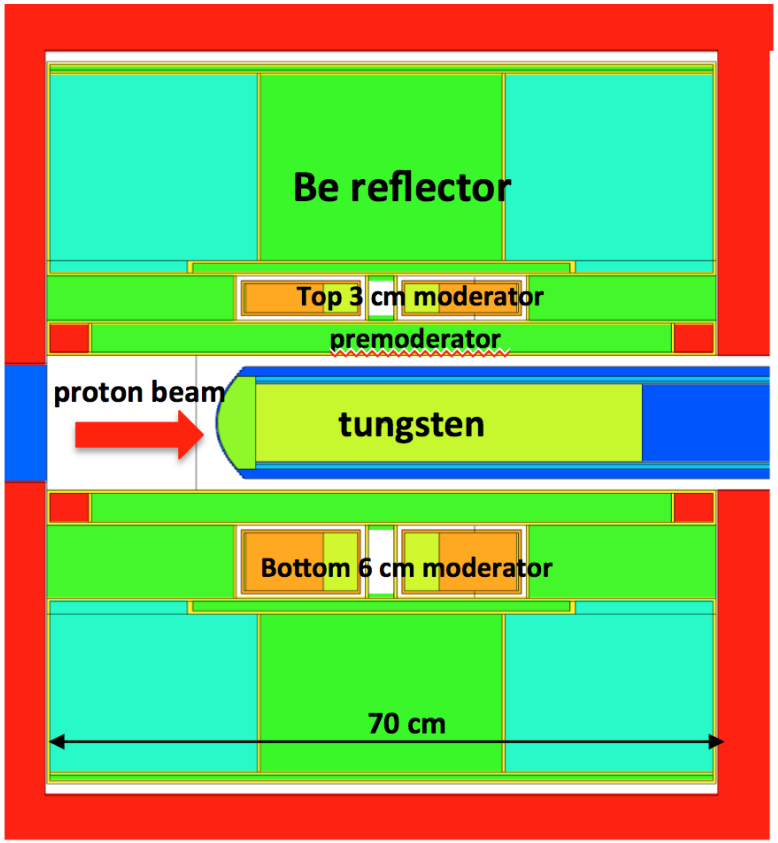
ESS baseline configuration

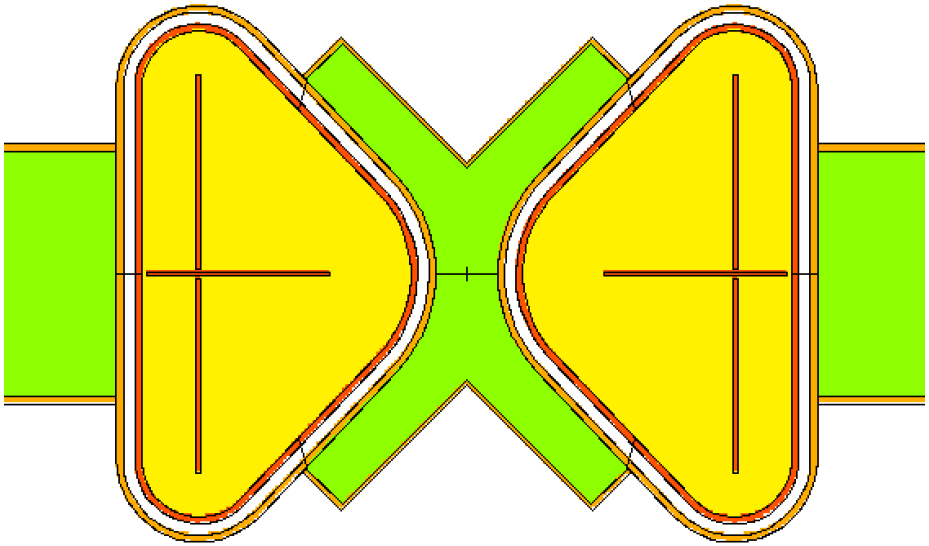




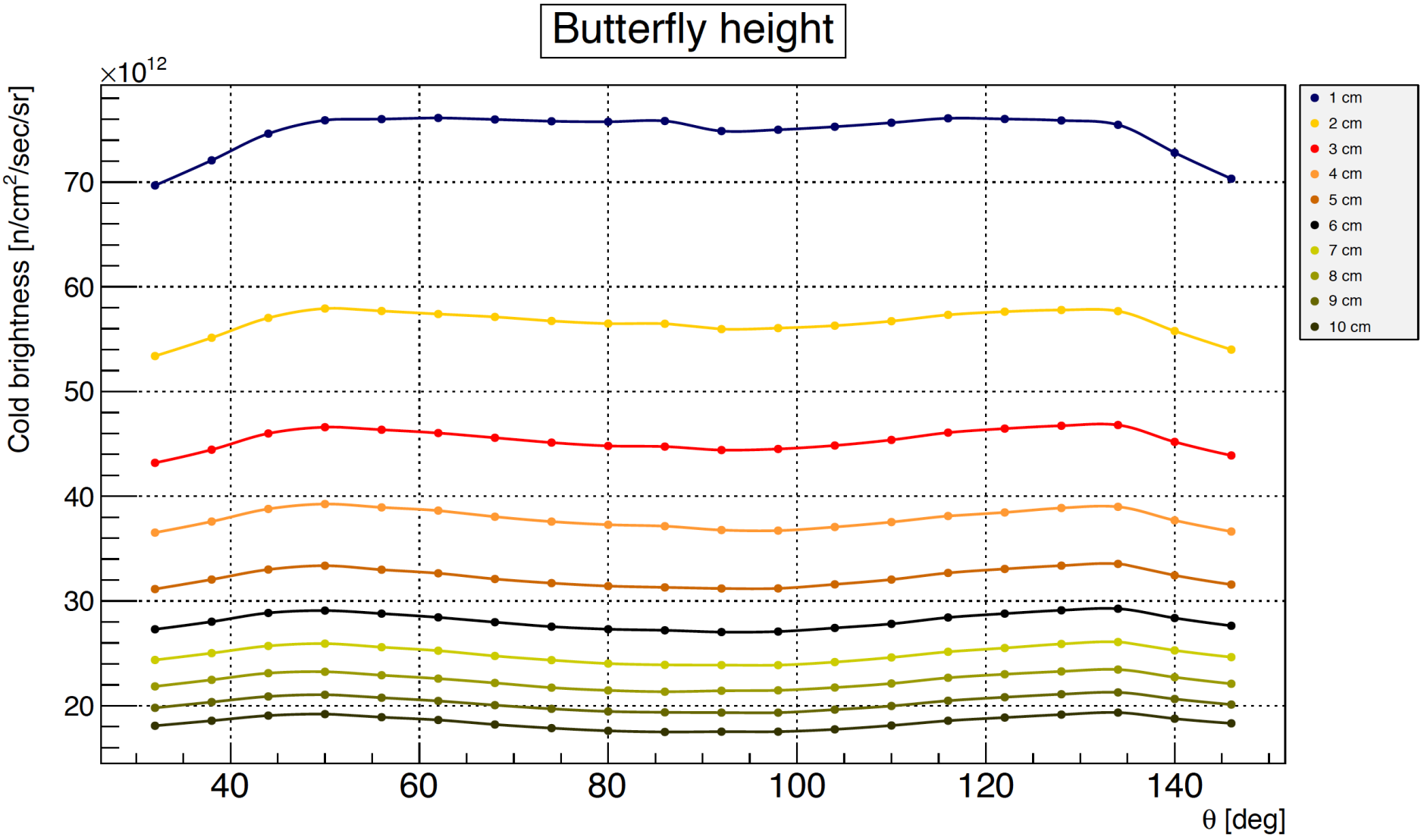
*) from report of L. Zanini

ESS baseline configuration



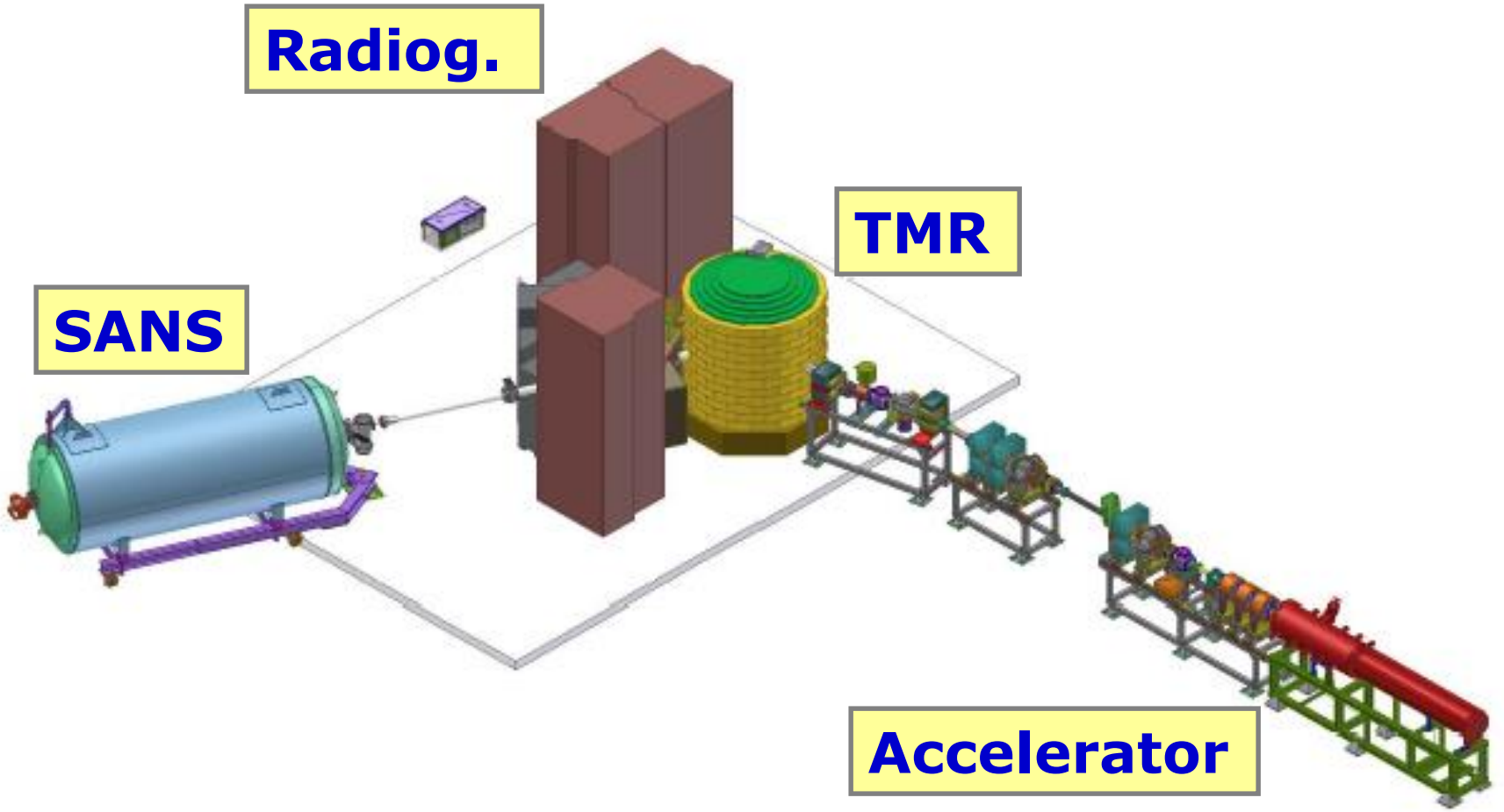


*) from report of L. Zanini



*) from report of L. Zanini

Low Energy Neutron Source (LENS) of Indiana University, USA (Floor Plan)

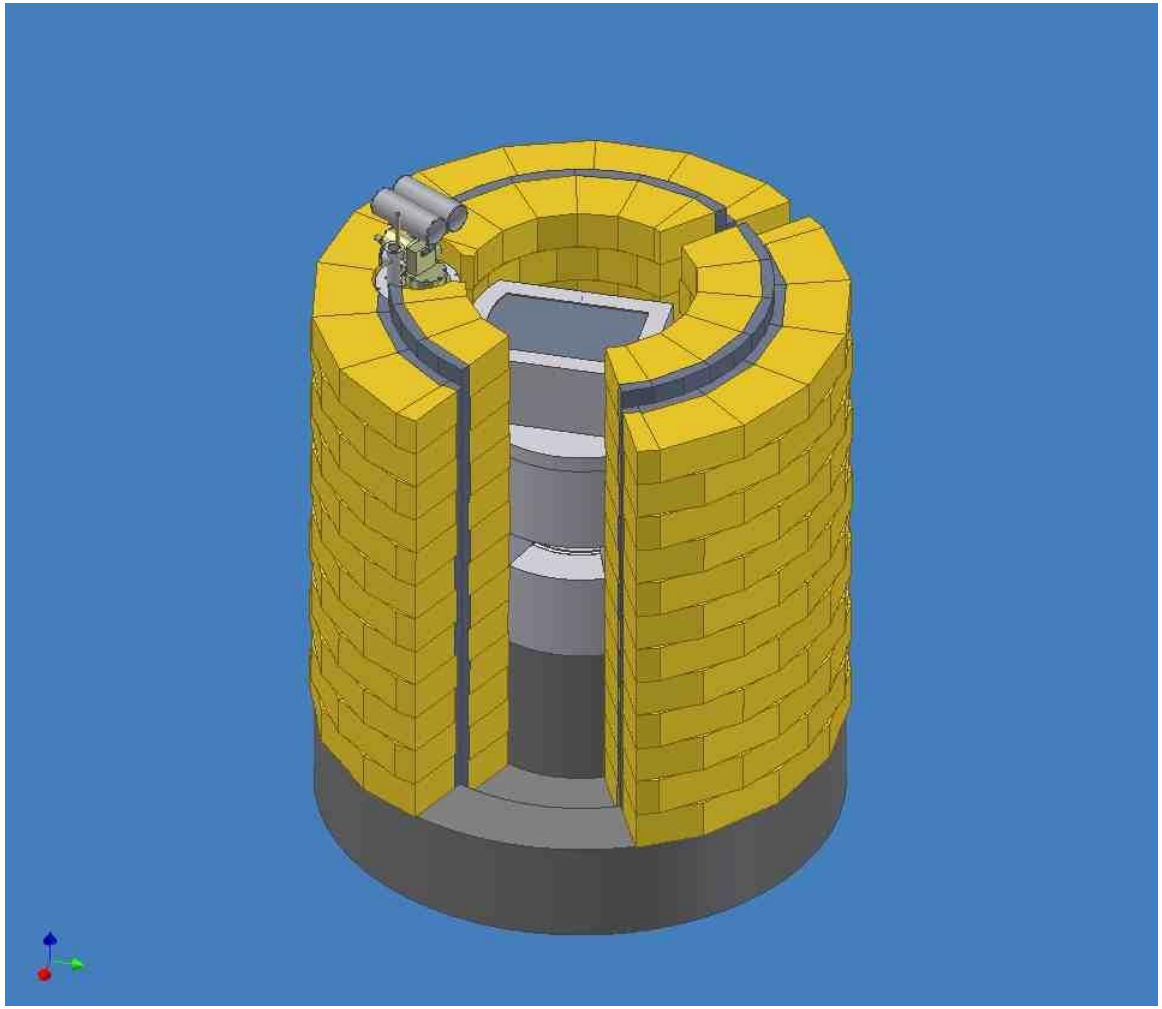


*) from report of D. Baxter

Facility Layout: Spring 2007

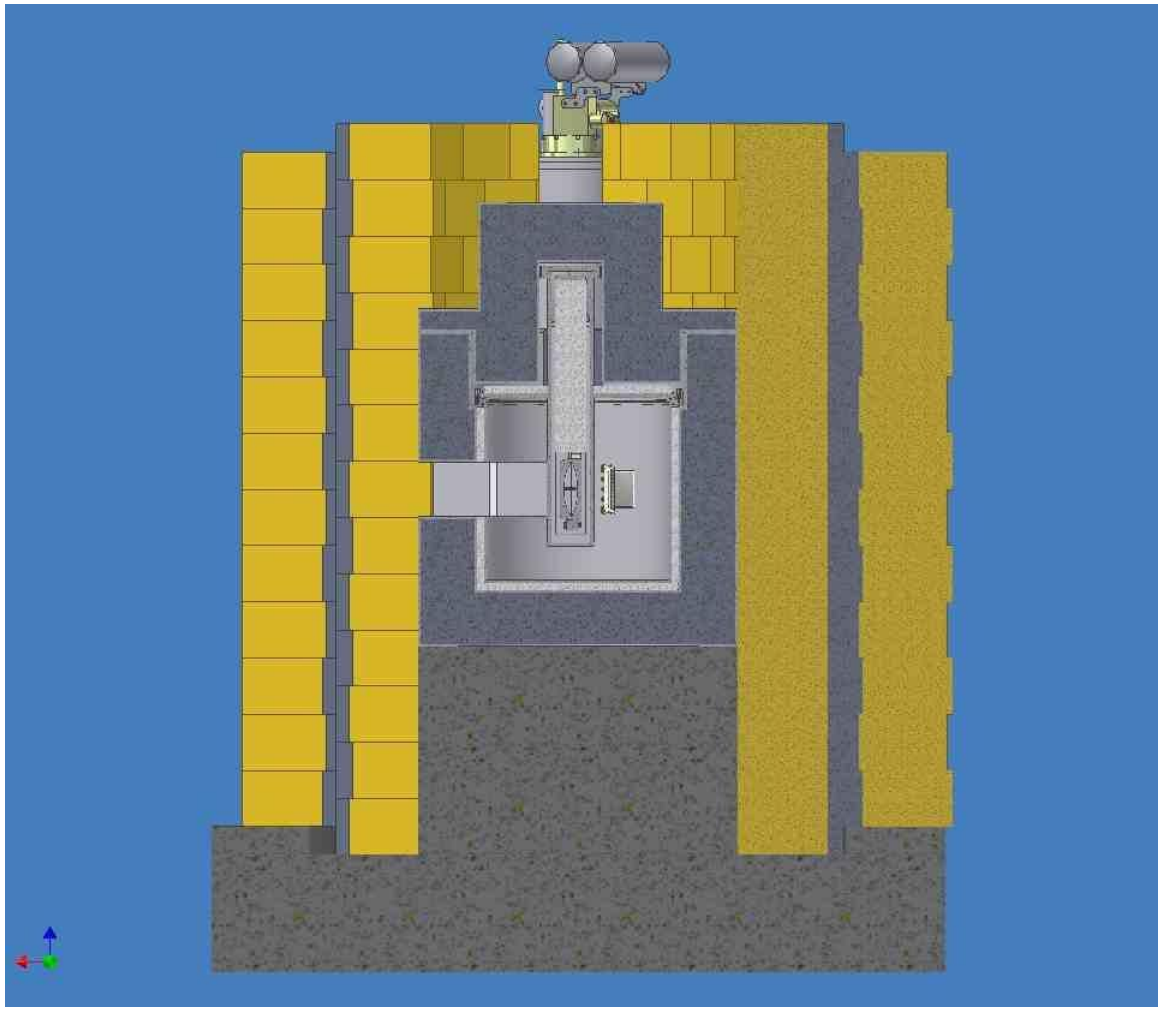
*) from report of D. Baxter

Target Moderator Reflector (TMR)



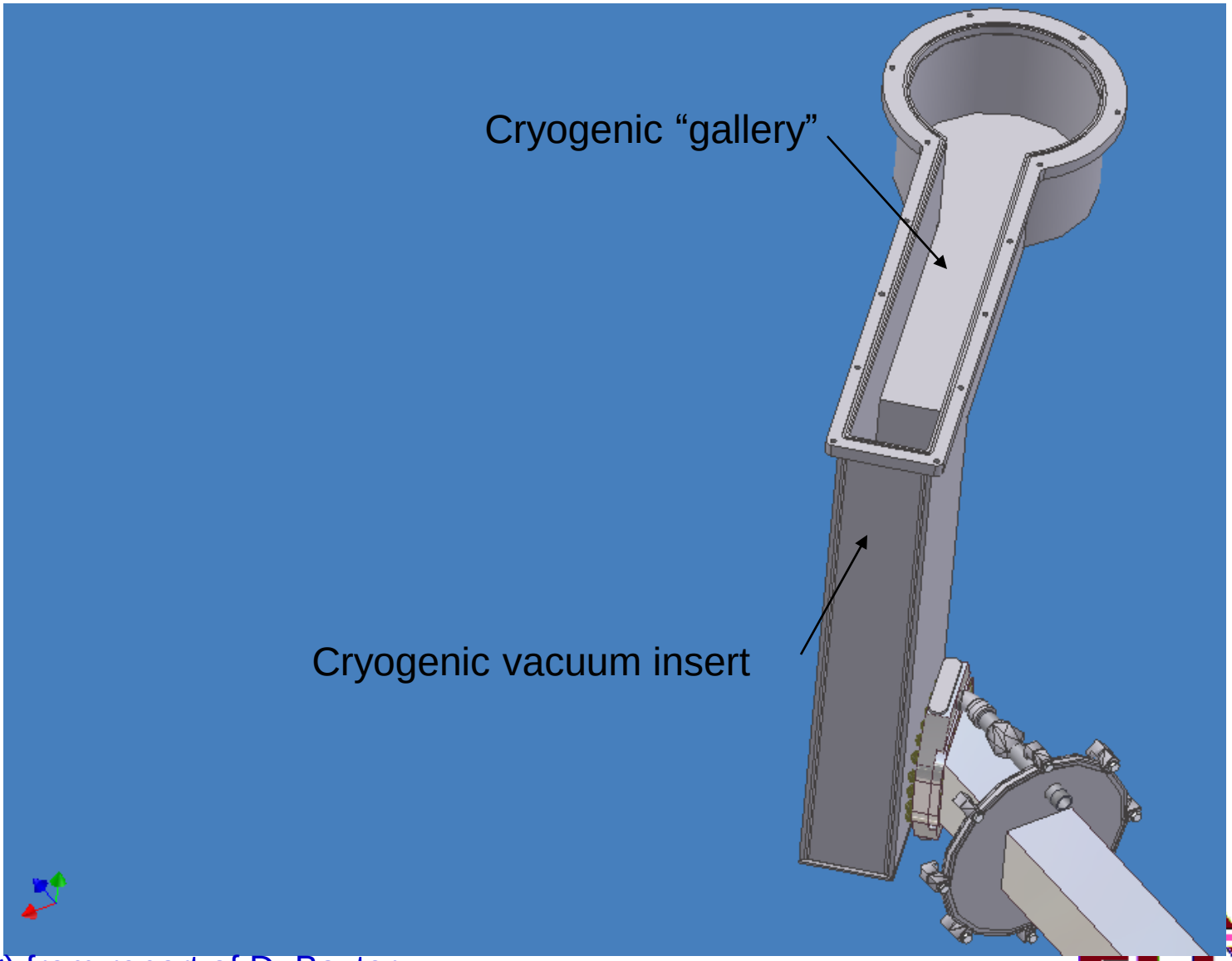
*) from report of D. Baxter

Target Moderator Reflector (TMR)



*) from report of D. Baxter

Cryogenics

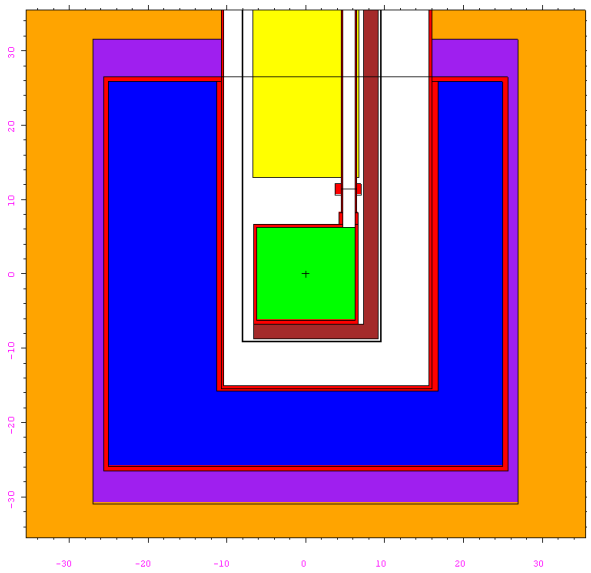


*) from report of D. Baxter

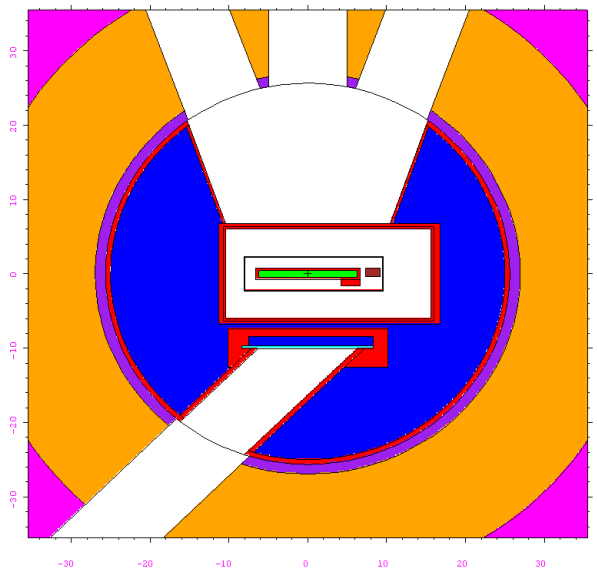
Cryostat insertion

*) from report of D. Baxter

Moderator Thickness Study

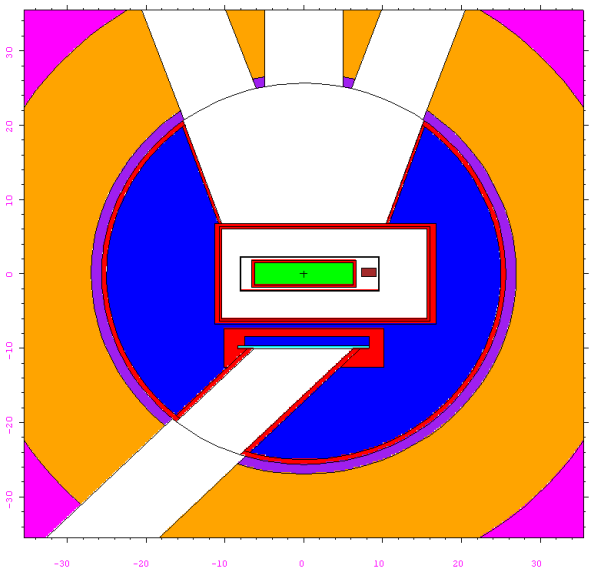


Cryogenics Cavity



1.0 Cm Thick

(present configuration)

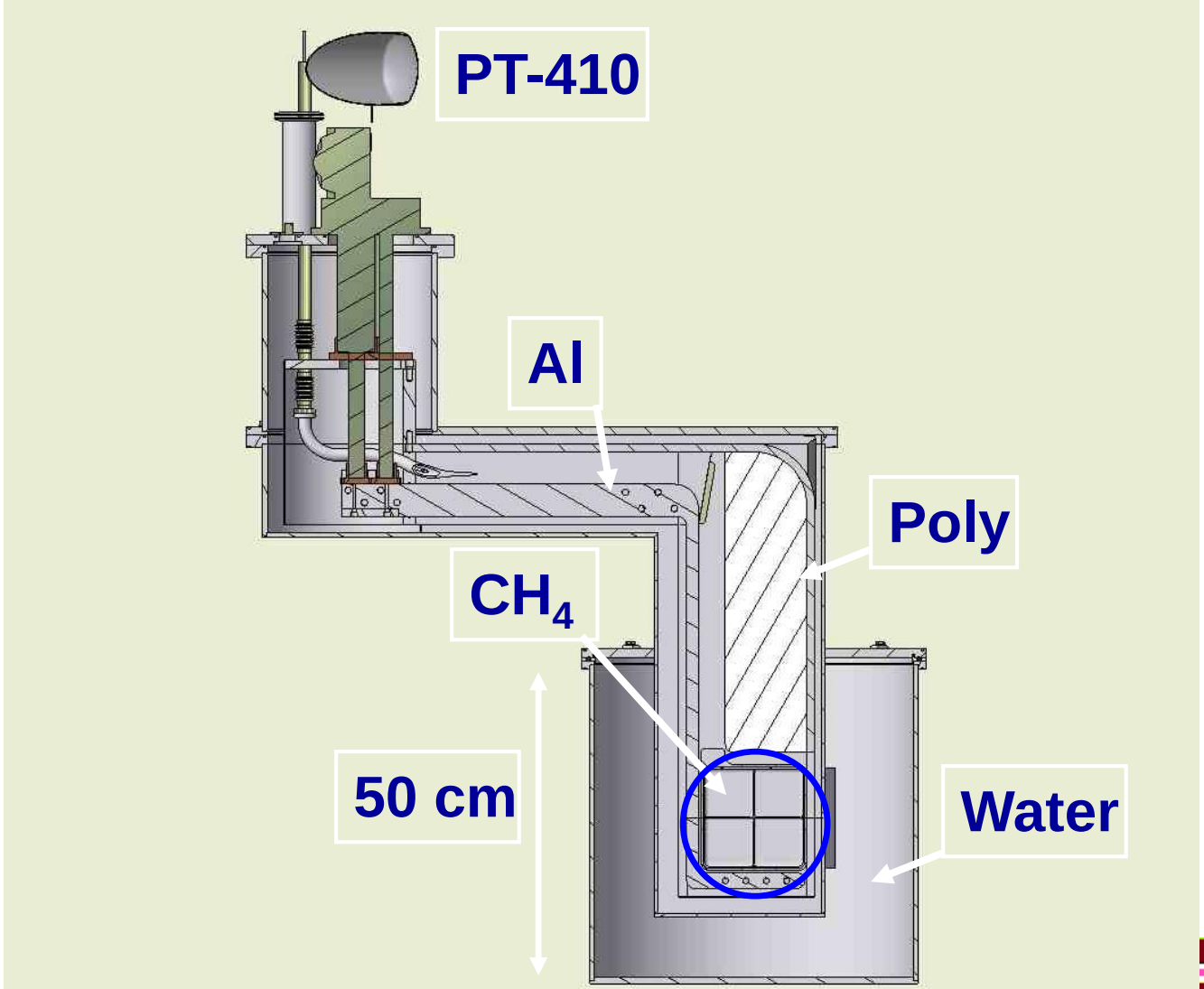


2.0 cm Thick

(proposed change included in study)

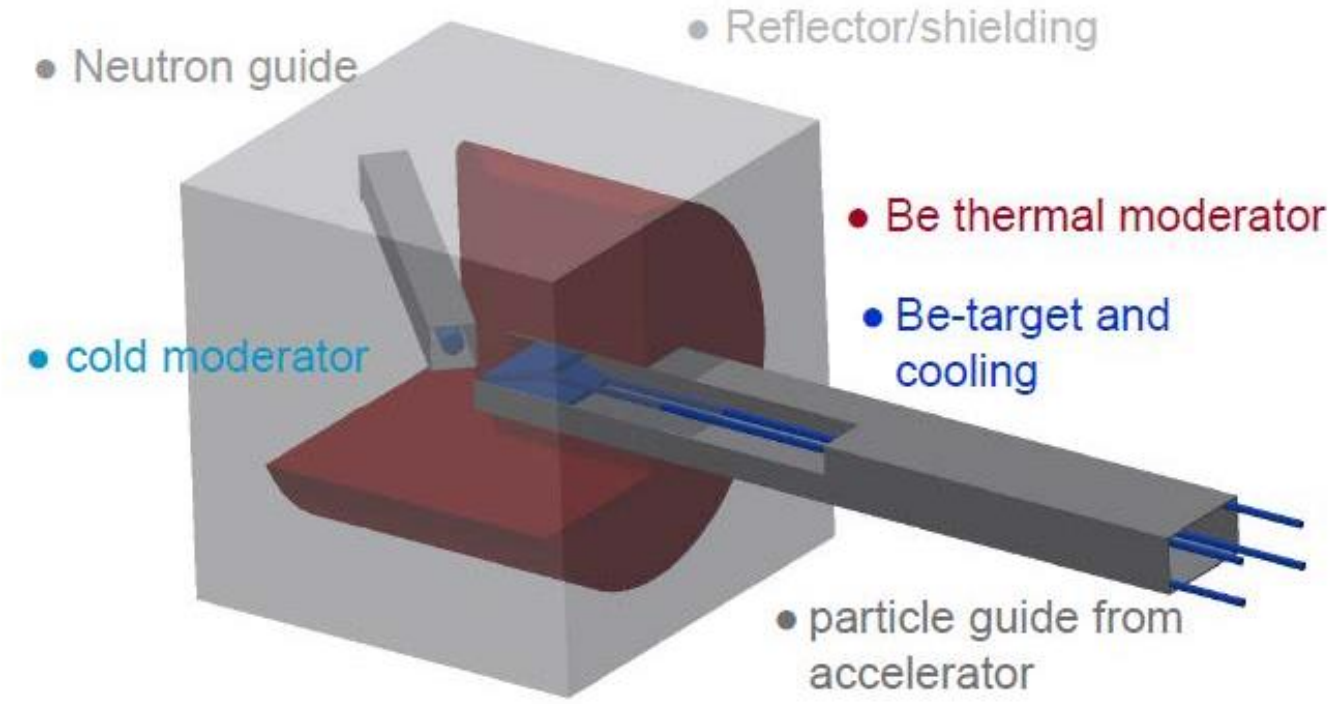
*) from report of D. Baxter

Moderator Assembly

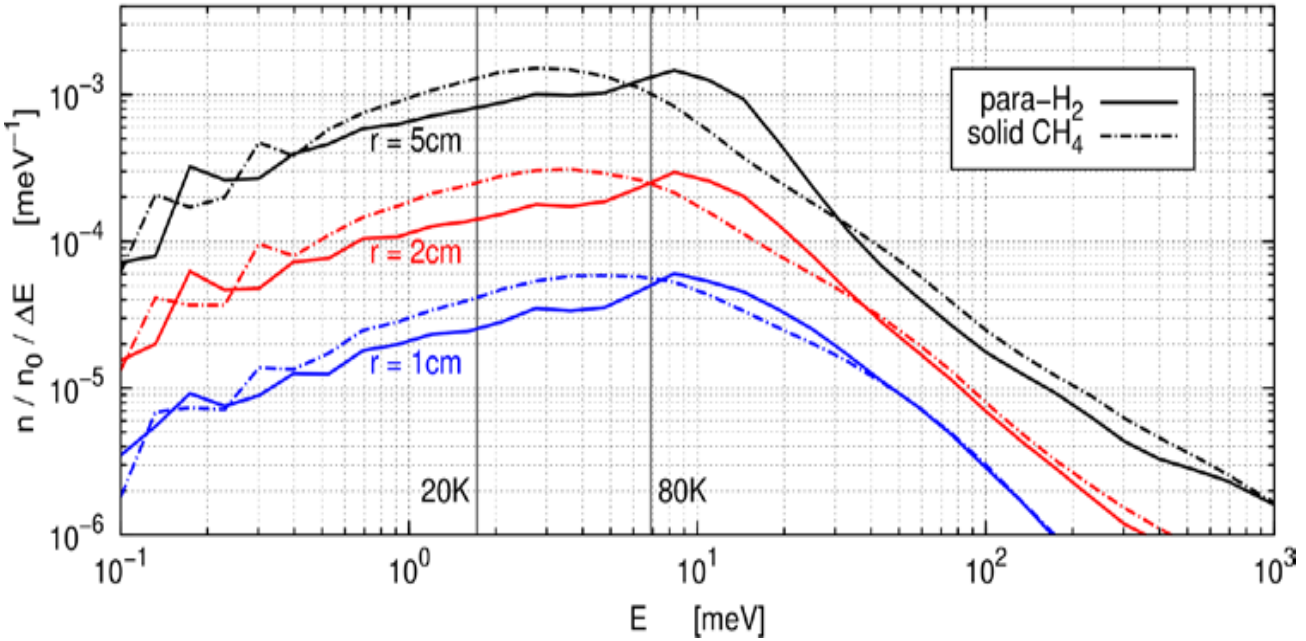


*) from report of D. Baxter

The Jülich High Brilliance Neutron Source Project



*) U. Rücker, T. Cronert et al. The Jülich High Brilliance Neutron Source Project



Spectrum of neutrons leaving a cylindrical liquid para-H2 or solid CH4 moderator at 20 K for three different radii. The corresponding lengths of the cylinders are 4, 5 and 6cm for para-H2 and 2, 2.5 and 2.5cm for methane.

*) U. Rücker, T. Cronert et al. The Jülich High Brilliance Neutron Source Project

Спасибо за внимание!