Investigation of Moderator-Reflector Structure for the High Brilliance Neutron Source (HBS)

14.02.2024 I JUNYANG CHEN

Overview

- Introduction of High Brilliance neutron Source (HBS)
- Pancake-like moderator
- Two target system for one target station
- Investigation of large target area and large area of solid methane (brief description)

High Brilliance Neutron Source (HBS)

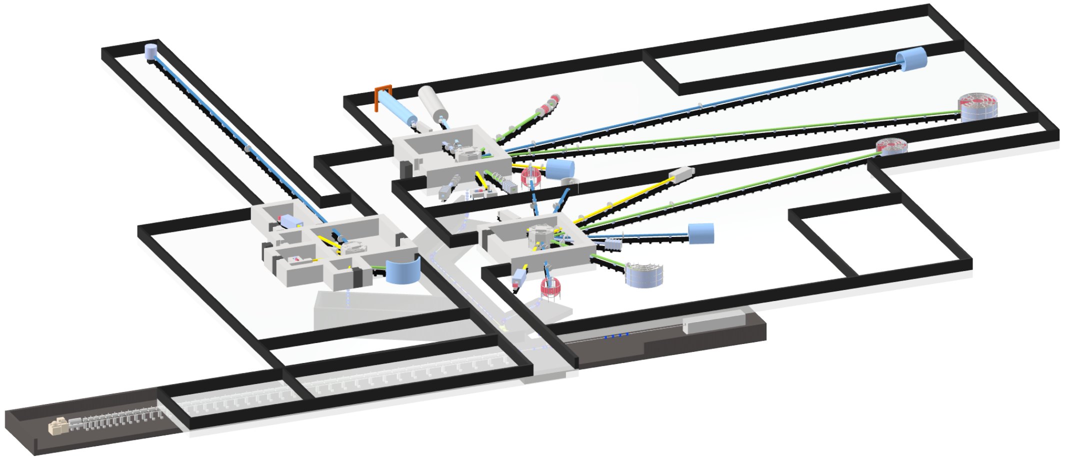
Background

- Need for neutron-scattering facilities : **growing**
- Some existing reactor-based sources : **decommissioned**

Wide application of neutron

Basic paradigm

- Produce less but **more efficiently**
- Save cost



HBS layout

High Brilliance Neutron Source (HBS)

Main features

- Proton energy : 70 MeV
- Proton beam power : 100 kW
- Three target station : 24 Hz, 96 Hz, 96 Hz
- 10-12 instruments for each target stations

Optimal time structure and energy structure :

fulfill the needs of each individual instrument

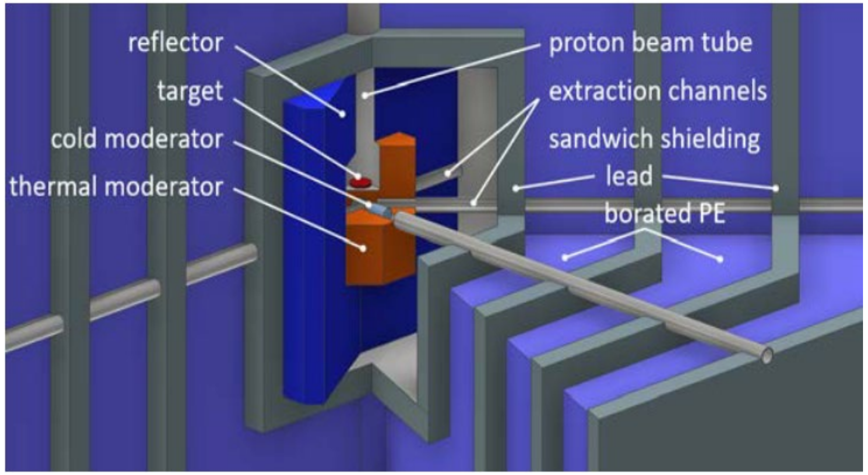
Key component to "more efficiently"

- Moderator-Reflector

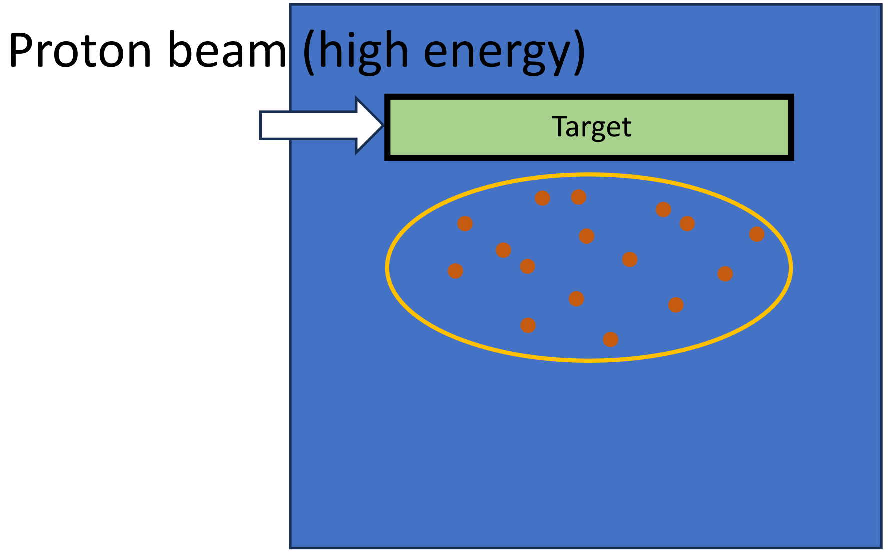
  1)Moderator : decrease neutron energy

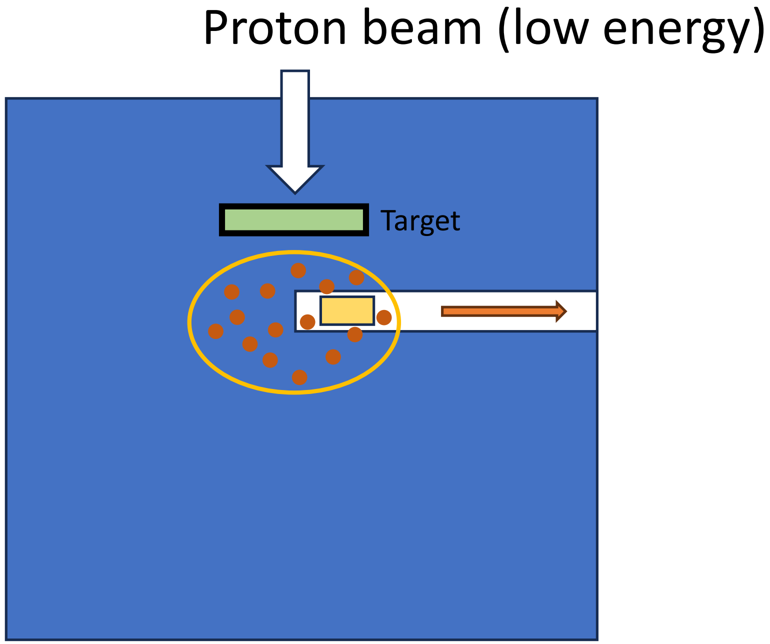
  2)Reflector : reflecting escaping neutron

- Neutron transfer system



HBS Moderator-reflector : Confinement and Extraction





Low energy → Small target → Small Neutron cloud with high density → Extraction channel inside cloud with specific moderator → Optimal energy with high brilliance

Single tube is ideal case

Multiple channel Extraction

Extraction:

- Specific moderator in the channel
- Diameter of channel should be larger (6 cm)
- Mean free path of thermal neutron in water : 0.5-1 cm

Multiple channels (12 instruments)

↓

Losing moderator material

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Dilute neutron cloud

Solution →

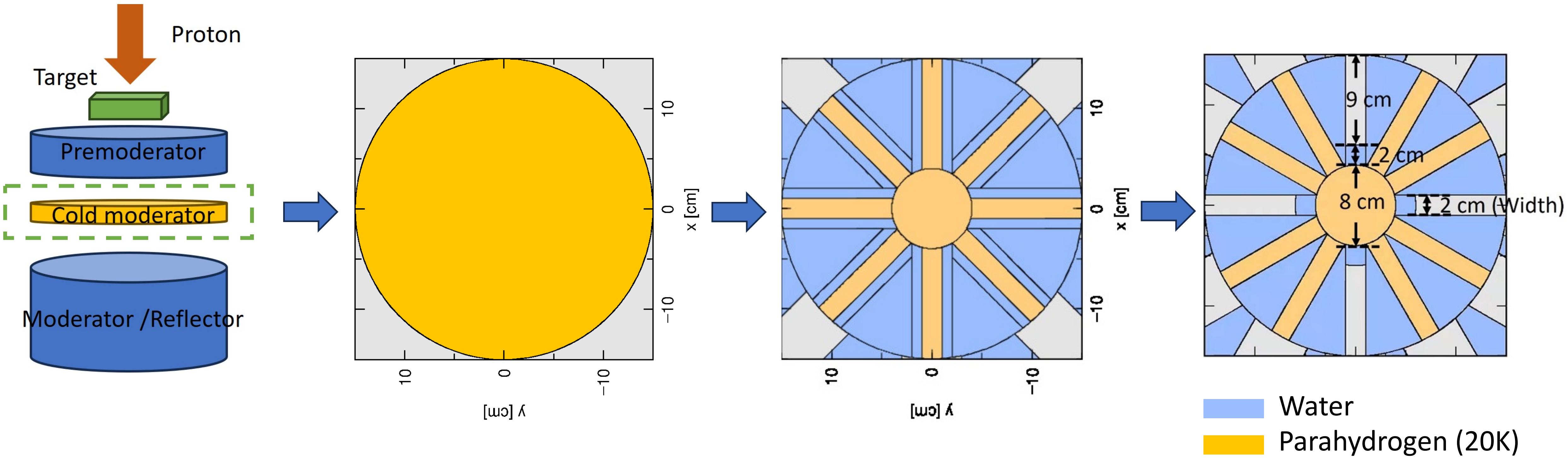
Pancake-like moderator

Two layers with symmetry structure

Two layers with asymmetry structure

Pancake-like moderator

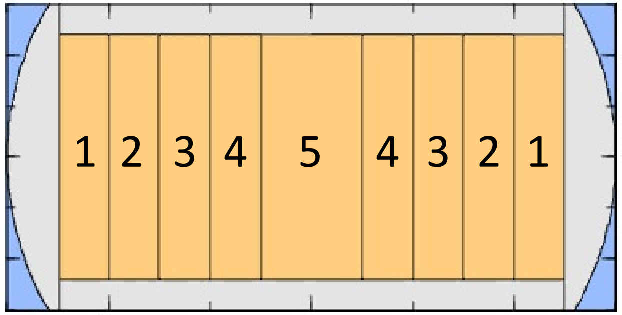
Compressing 12 channels into one layer

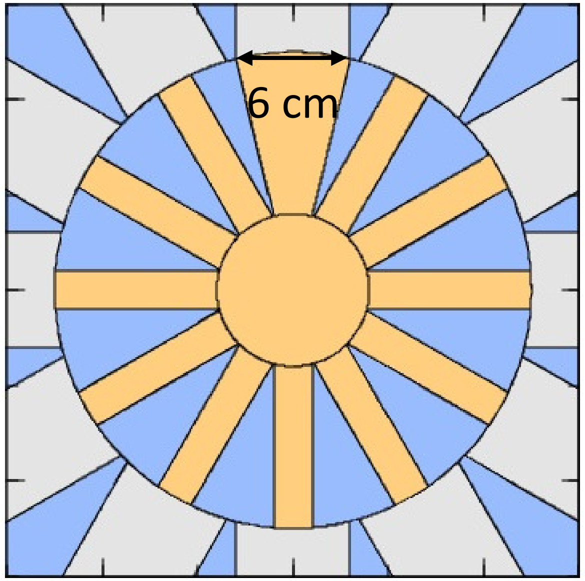


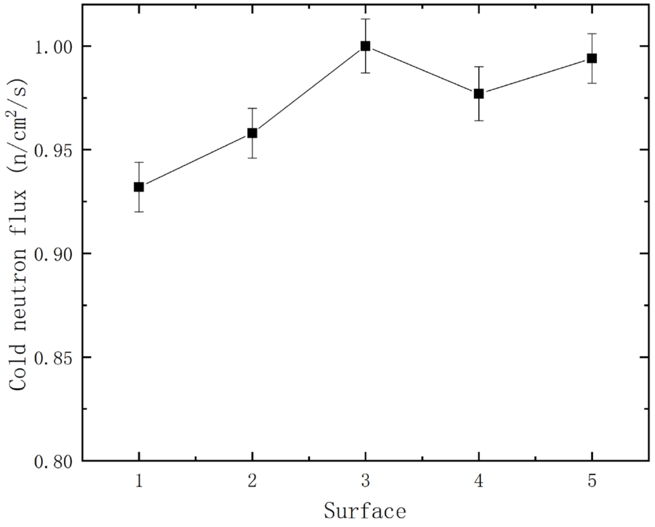
- Cold neutron brightness : at least 24 % increased (compared with triangle channel);87% of ideal case
- Thermal neutron brightness : at least 20 % increased (compared with triangle channel); 75% of ideal case
- Provide neutron up to 12 instruments

Large emitting surface

- Enlarging the emitting surface
- Rectangle shape → Sector shape
- Maximum width: 6cm

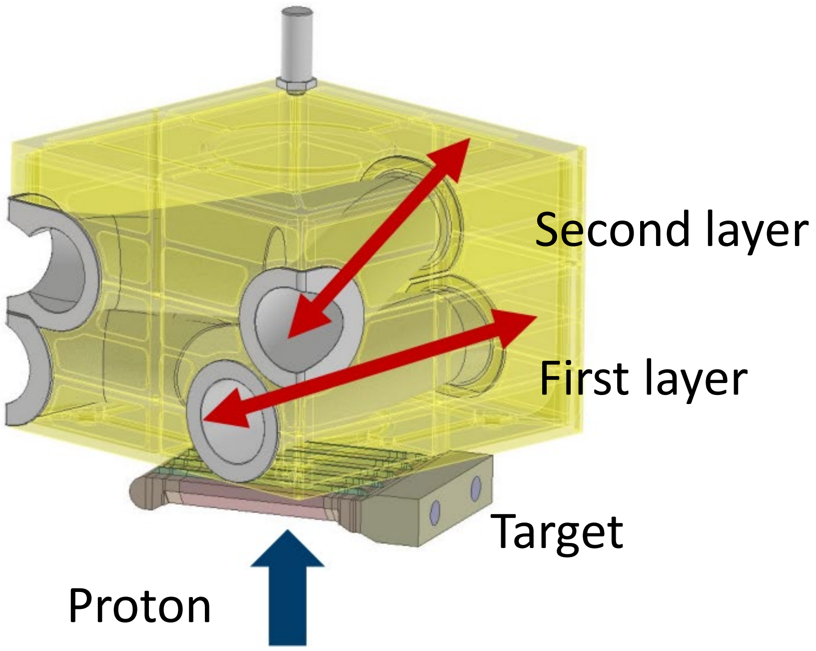


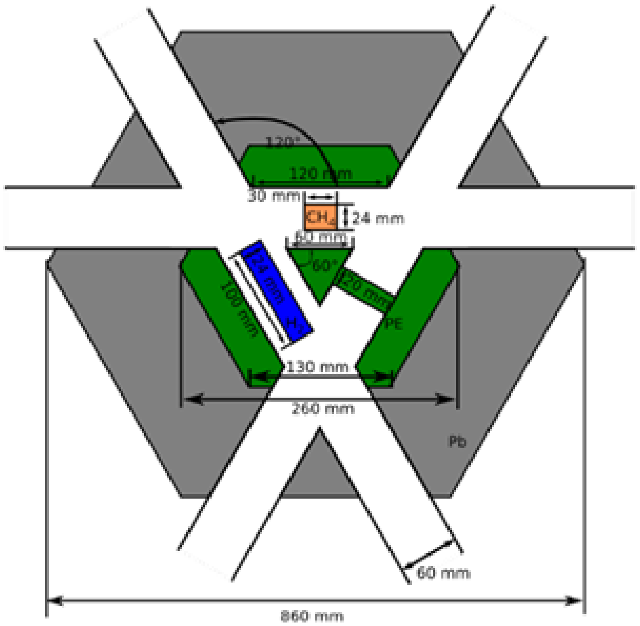


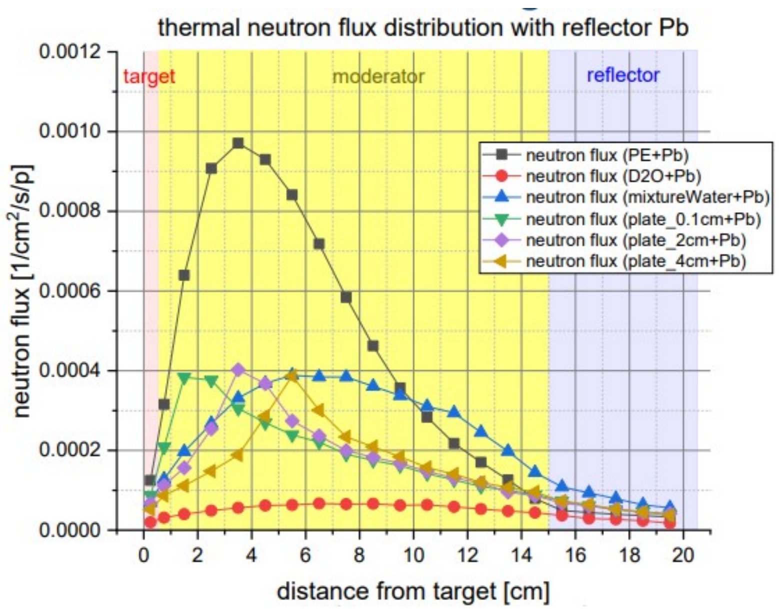


- Cold neutron brightness of sector shape (width 6 cm): 94% of rectangle shape (width 2 cm)
- Rectangle shape → Sector shape
- Maximum width: 6cm

Two layers arrangement







- One target
- Each layer with 6 channels
- 12 instruments for each target station

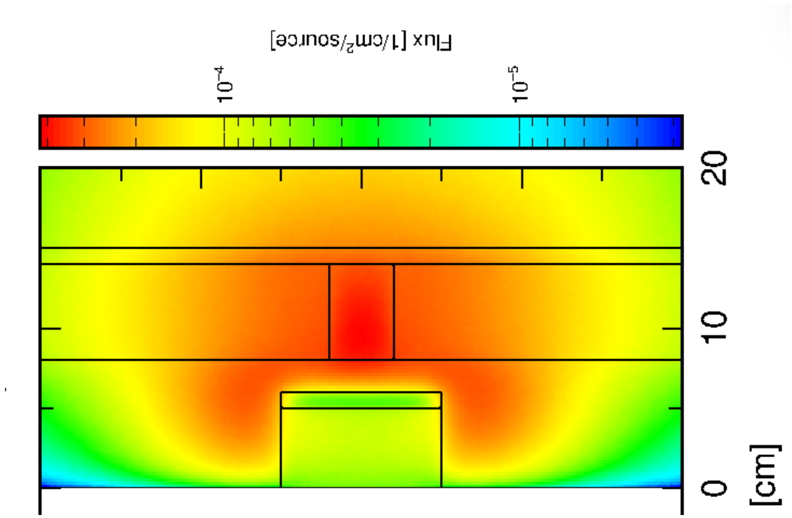
- Symmetry triangle arrangement
- Different moderator:
  water; paraH_2; solid methane

- Significant decrease of neutron flux in second layer

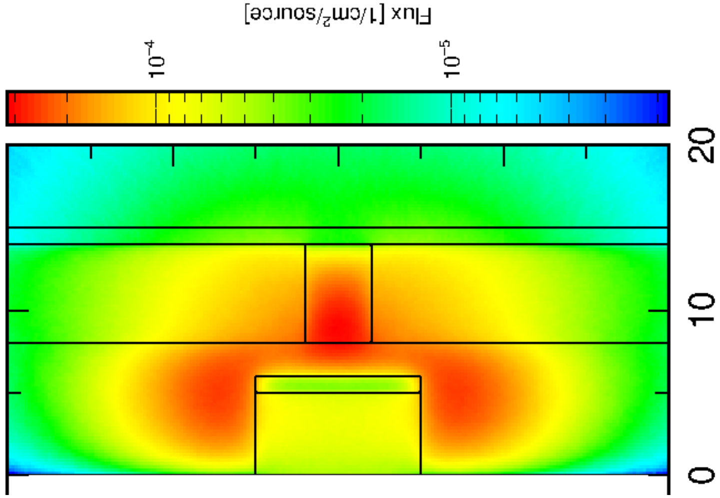
Can reflector reflect the neutron into second layer?

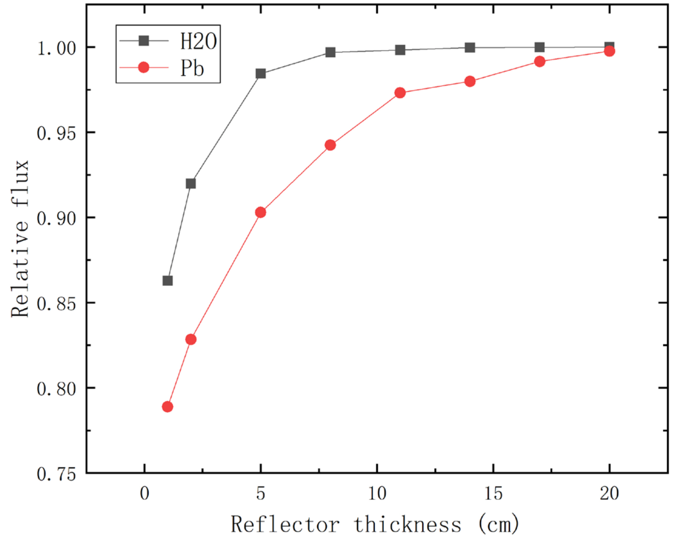
Effect of reflector

With reflector



Without reflector





Neutron cloud is small for HBS

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Reflector has less reflection for neutron (less than 20%)

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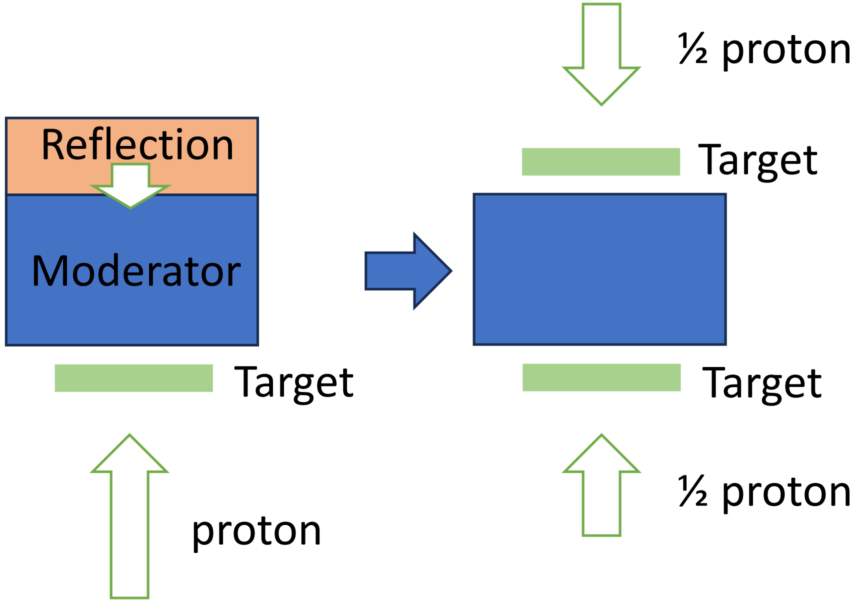
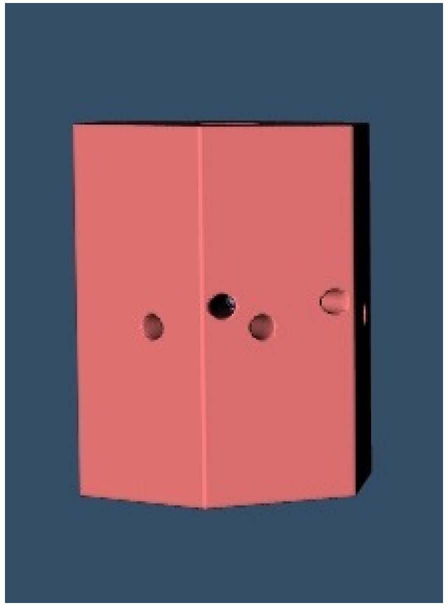
Second layer: less replenishment from reflector

Two targets for one target station





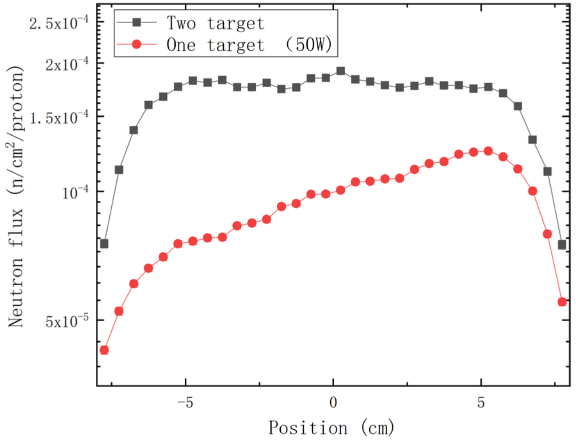
Outside

Inside

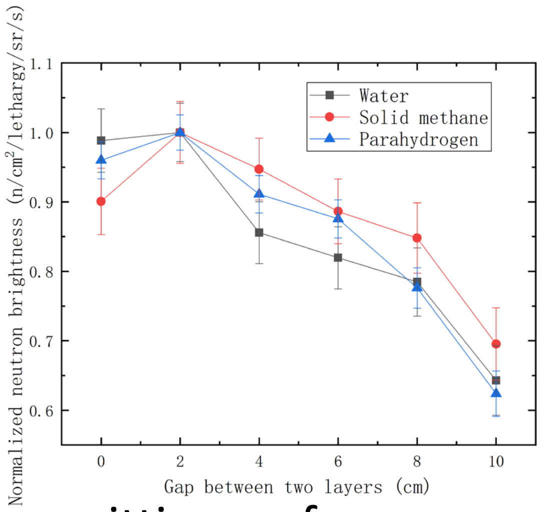
- Each target power: 50 kW (total power 100 kW for each target station)
- Same target structure for each target
- Two layers: each layer with triangle channel arrange (three different moderator)

Two targets for one target station

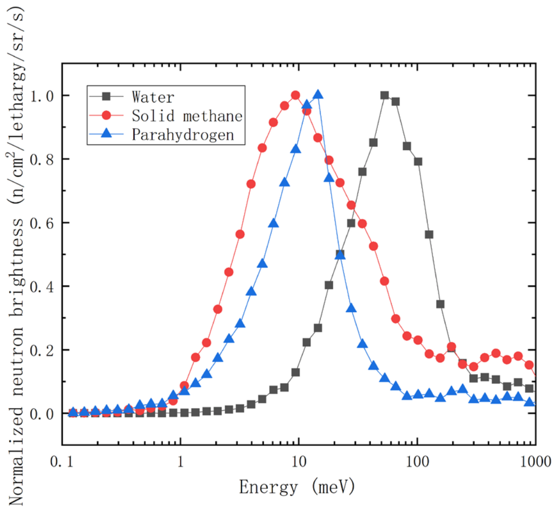
Thermal neutron distribution



Optimization: gap between two layers

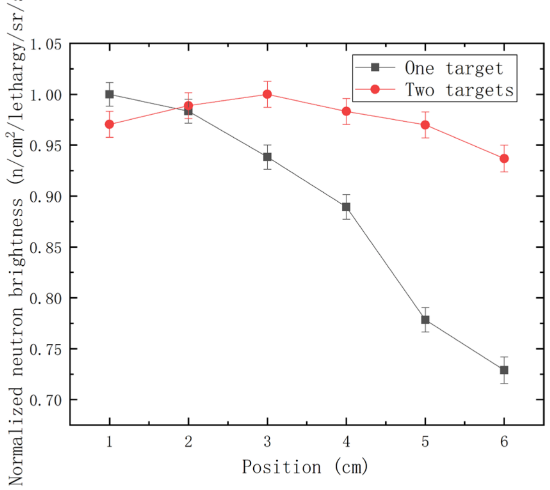


Comparison of neutron brightness

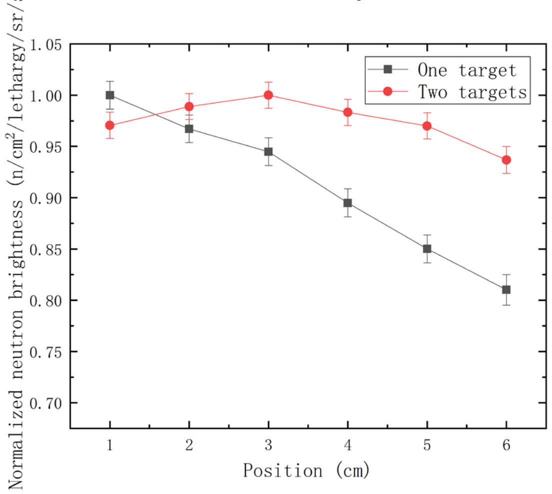


Neutron distribution from emitting surface

First layer



Second layer



- Flat thermal neutron distribution
- Gap: 2 cm
- Different moderators provide different neutron spectrum
- Uniform distribution of emitting surface

Summary

	One target			Two targets
	Normalized neutron brightness ($n/cm^2/meV/sr/s$) First layer	Normalized neutron brightness ($n/cm^2/meV/sr/s$) Second layer	Normalized neutron brightness ($n/cm^2/meV/sr/s$) Mean value of first and second layer	Normalized neutron brightness ($n/cm^2/meV/sr/s$)
Water	1	0.588±0.012	0.794±0.010	0.856±0.012
Solid methane	1	0.661±0.016	0.831±0.013	0.847±0.013
ParaH_2	1	0.641±0.009	0.820±0.009	0.856±0.012

- Advantage:

  1) 17%-20% increase for second layer of one target

  2) 6% thermal neutron increase for mean value of one target

  3) uniform distribution for moderator emitting surface

- Disadvantage: difficult to arrange two accelerator on one target station

Another solution (poster section)

- "reflector" : no "force" in physics
- Neutron: **diffusing** in the moderator and reflector
- Neutron transport: following Brownian motion

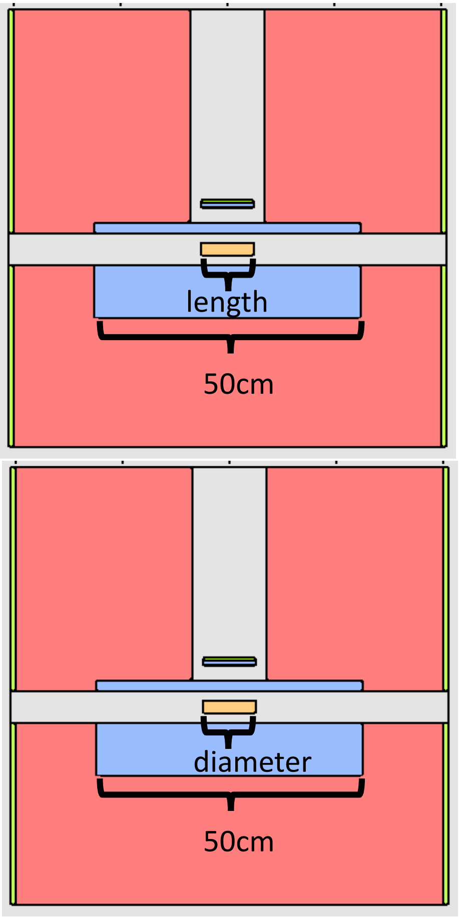
Is it possible to achieve directional movement (reflecting)?

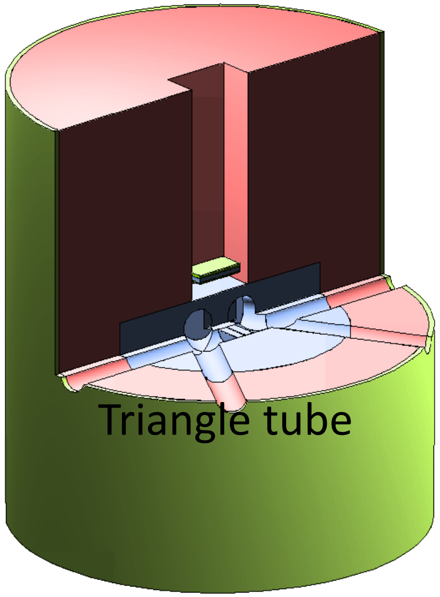
Breaking the second law of thermodynamics → **Brownian motor may achieve it**

Large target area investigation

single channel					
target area(100cm2)	length 10cm	length 20cm	length 30cm	length 40cm	length 50cm
point detector (n/cm^2)(1mA_1s)	6.50E+07	9.23E+07	1.02E+08	9.89E+07	8.91E+07
target area(144cm2)	length 10cm	length 20cm	length 30cm	length 40cm	length 50cm
point detector (n/cm^2)(1mA_1s)	6.07E+07	8.74E+07	9.57E+07	9.38E+07	8.45E+07
target area(288cm2)	length 10cm	length 20cm	length 30cm	length 40cm	length 50cm
point detector (n/cm^2)(1mA_1s)	5.04E+07	7.24E+07	8.12E+07	8.01E+07	7.30E+07
panke					
target area(100cm2)	diameter 10cm	diameter 20cm	diameter 30cm	diameter 40cm	diameter 50cm
point detector (n/cm^2)(1mA_1s)	1.08E+08	3.15E+08	5.20E+08	6.50E+08	6.96E+08
target area(144cm2)	diameter 10cm	diameter 20cm	diameter 30cm	diameter 40cm	diameter 50cm
point detector (n/cm^2)(1mA_1s)	1.01E+08	2.96E+08	4.89E+08	6.21E+08	6.71E+08
target area(288cm2)	diameter 10cm	diameter 20cm	diameter 30cm	diameter 40cm	diameter 50cm
point detector (n/cm^2)(1mA_1s)	8.62E+07	2.56E+08	4.28E+08	5.54E+08	6.01E+08

triangle channel	point detector (n/cm2)(1mA_1s)
target area(100cm^2)	4.14E+08
target area(144cm^2)	3.91E+08
target area(288cm^2)	3.40E+08



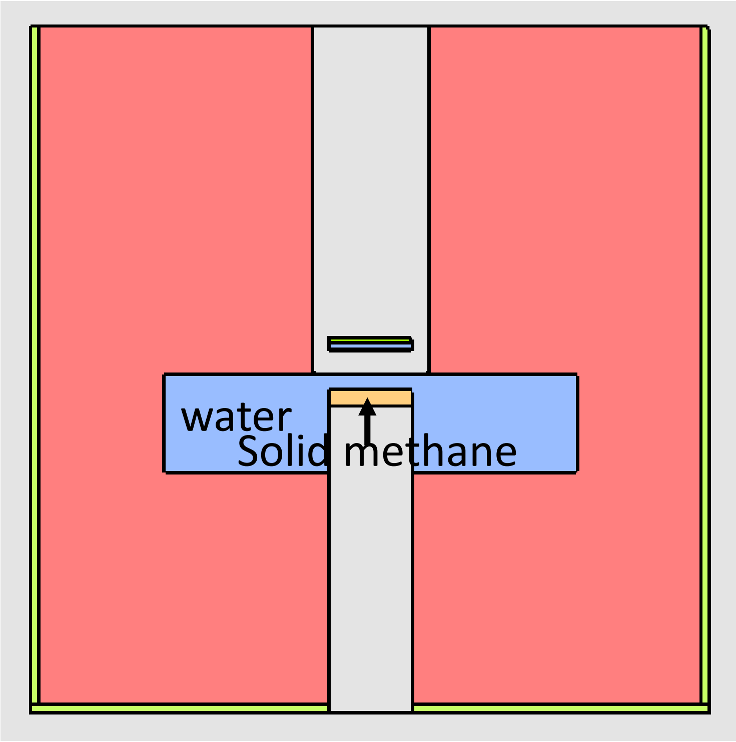


- Investigate different target area with different shape moderator
- Same power: neutron flux decreased 18% (enlarging 2.88 times target area)
- Same proton beam density: neutron flux improved by 2.36 times (enlarging 2.88 times target area)

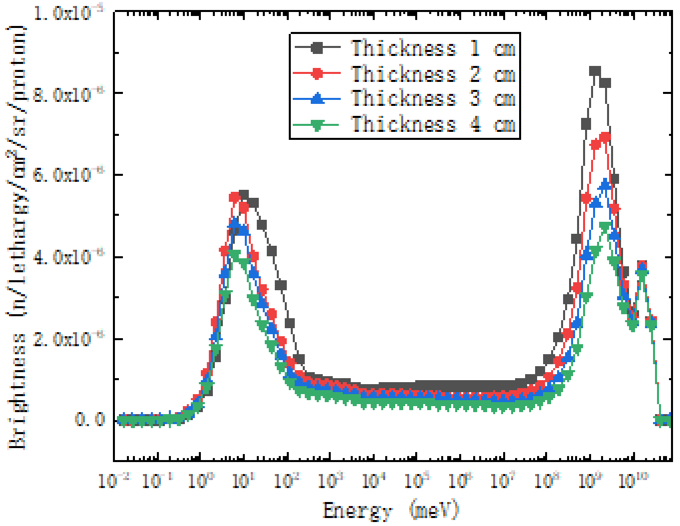
Large area of solid methane

Large area of solid methane

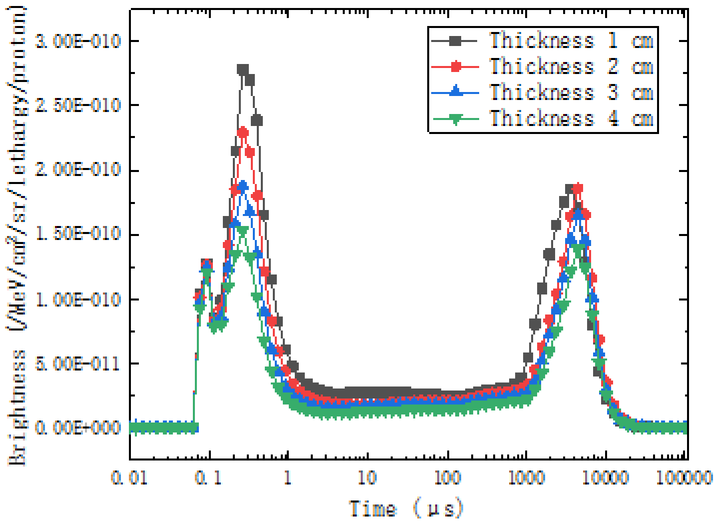
Large area of solid methane



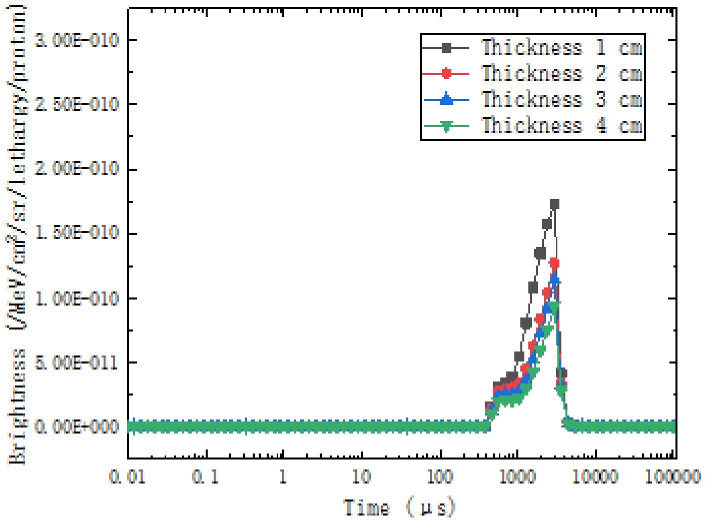
Energy spectrum



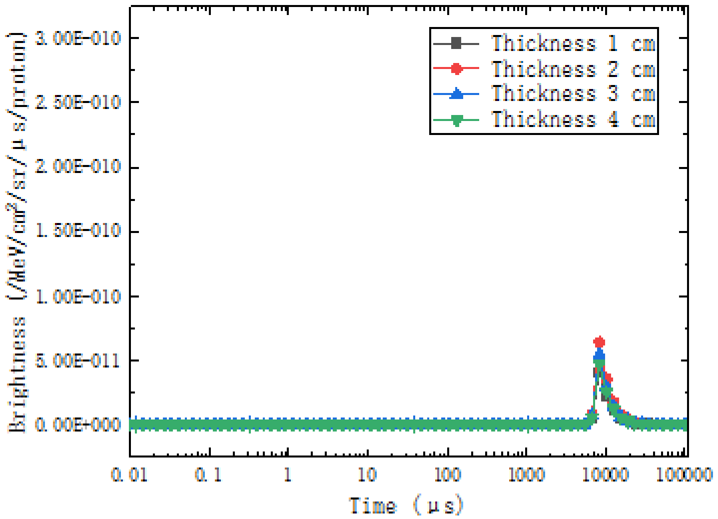
Time distribution (0.01meV-70meV)



Time distribution (10meV-500meV)



Time distribution (<2meV)



Outlook

- Thermal channel investigation of pancake-like moderator
- Summarizing data and writing paper
- Exploring large area of solid methane and Brownian motion of neutron

Thanks to HBS Team

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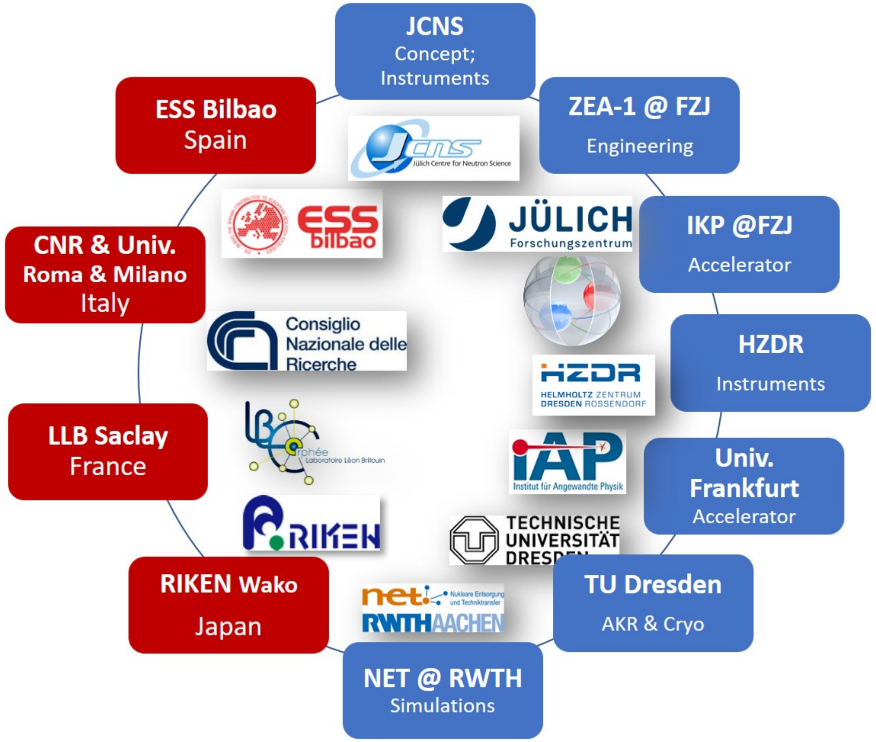
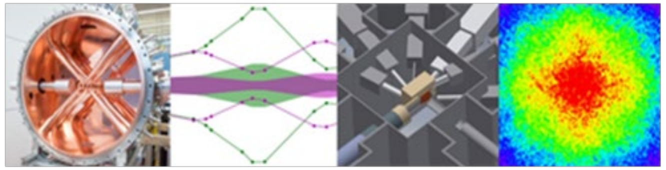
- Accelerator



HBS Innovationpool Project



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