Neutron moderators for the European Spallation Source

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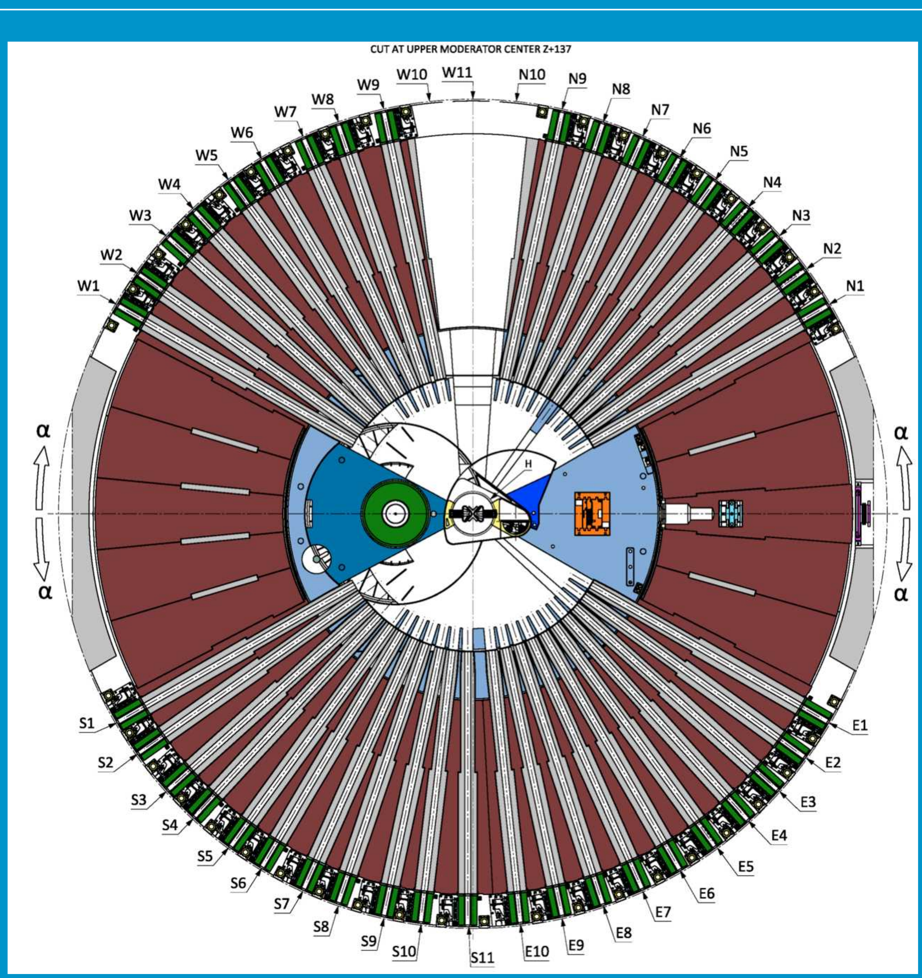
EUROPEAN SPALLATION SOURCE

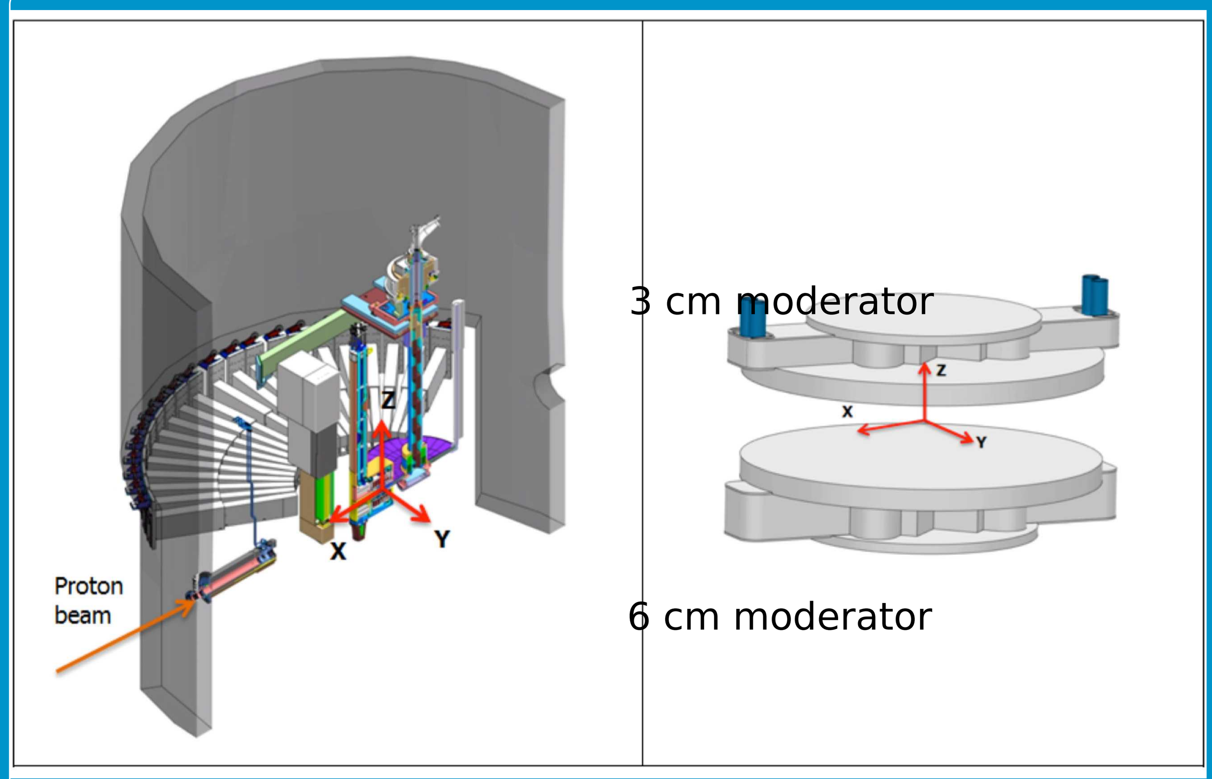
Abstract

The design of the neutron moderators for the European Spallation Source, intended to be installed at the start of operations of the facility in 2019 has now been finalized and the moderators are being fabricated.
Among the driving principles in the design have been flexibility for instruments to have access to cold and thermal neutrons with highest possible source brightness.
Different design and configuration options were evaluated. The final configuration accepted for construction foresees two moderators with identical para-hydrogen (so-called "butterfly") shape, but different heights, placed above and below the spallation target. Both moderators are able to serve the full 2 x 120° beam extraction sectors of instrument suite. The top, 3-cm tall moderator, has both high thermal and high cold brightness, more than by a factor of 2.5 compared to the previous design of the Technical Design Report. The bottom, 6-cm tall moderator, has lower brightness and emits 1.3 times higher total intensity integrated over the 2 times larger emission surfaces.

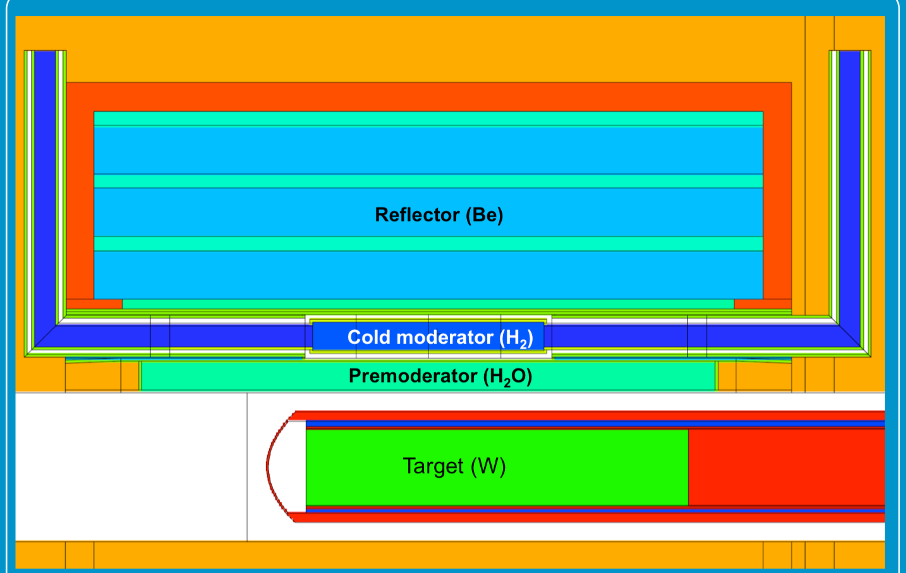
Moderator design



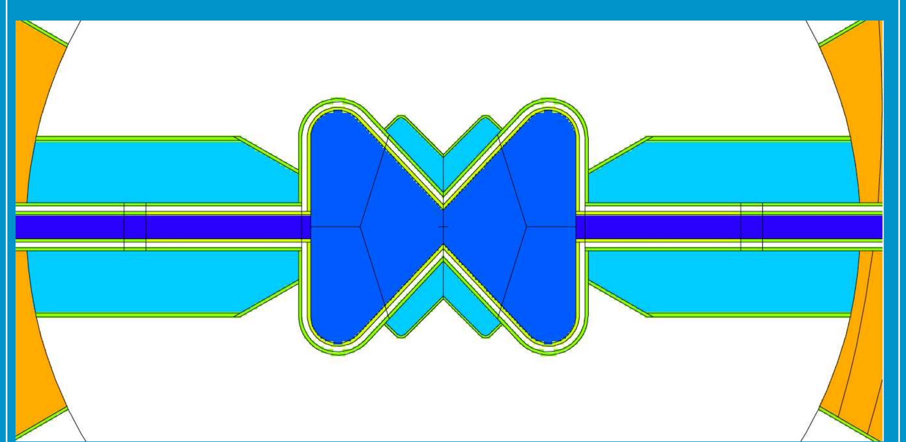
Horizontal section cut of the monolith structures at the level of the upper moderator position above the target wheel. Proton beam comes from the right. The moderators are placed in the center. Neutron beam extraction optics start at 2 m from the center and extend out to 5.5 m in the form of inserts (gray) installed horizontally into the beam ports (brown). Shutters (green) fill the space from 5.5 m to 6 m



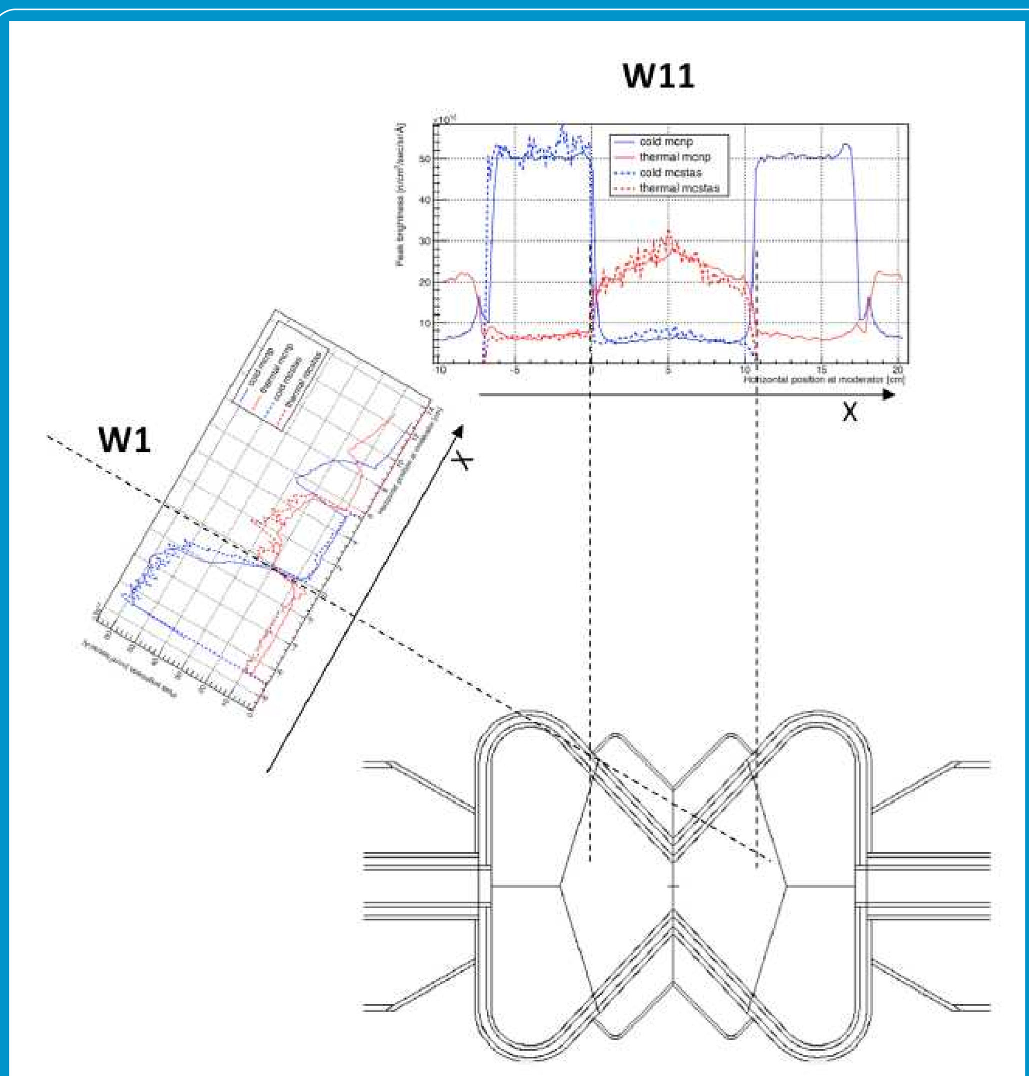
Side-view of the target "monolith" (left) and moderators (right).



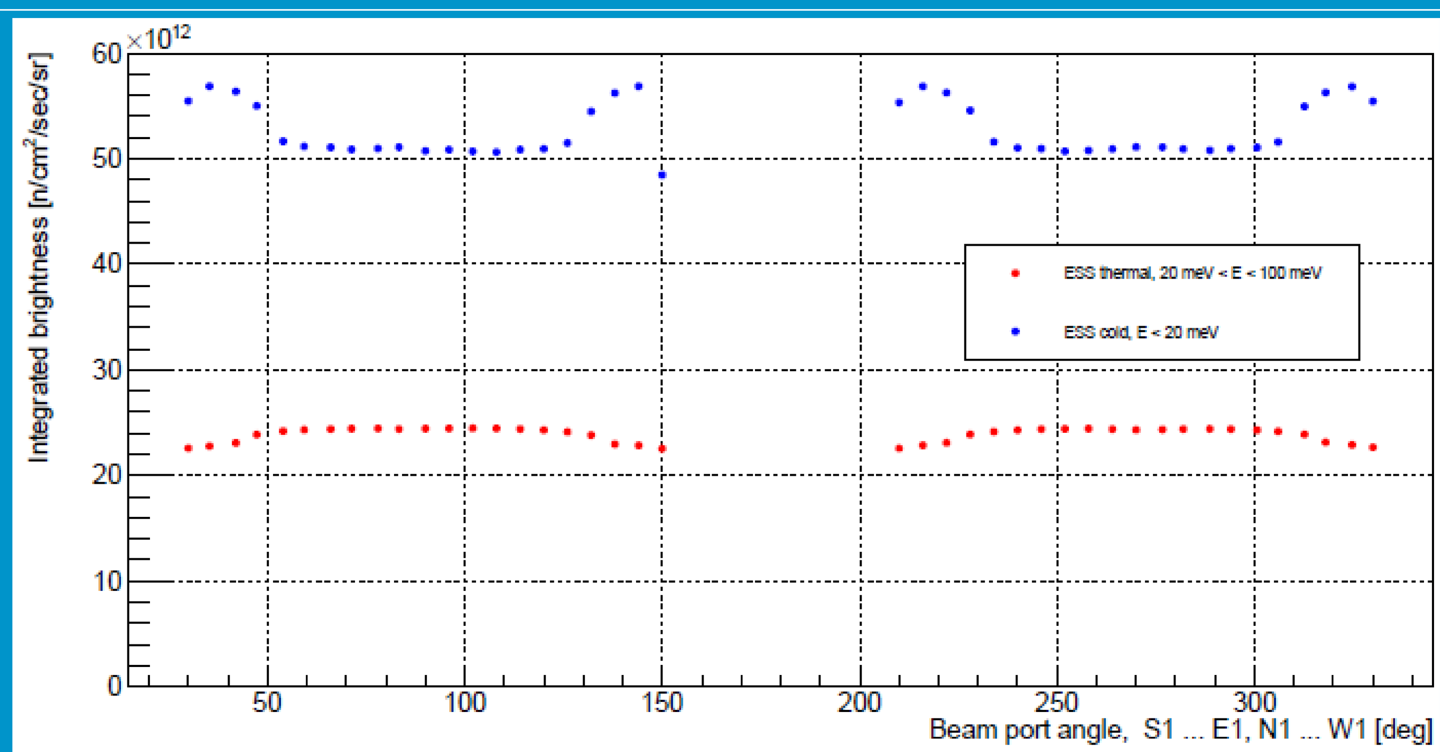
MCNPX geometry used for the brightness calculations, side view (above) and top view (below). Tungsten (green) has a reduced density of 15.1 g/cm^3 to account for the helium cooling. The water pre-moderator (green) between target and moderator has a 8% volume fraction of Al, accounting for flow channels. The beryllium reflector (light blue) includes water channels (green) according to engineering design. The reflector is contained in stainless steel vessel (red). The outer reflector (orange) is made of stainless steel, with 10% volume fraction of water, for cooling.
The 20K cold moderator volume (blue) consists of 94.5 vol% para-hydrogen 0.5 vol % ortho-hydrogen and 5 vol% of Al. The latter accounts for the presence of Al flow channels.
On the sides of the cold moderator, inlet and outlet hydrogen pipes, including vacuum gaps, are modeled. Water (light blue) is placed around the pipes to serve as pre-moderator increasing the brightness of the cold moderator.



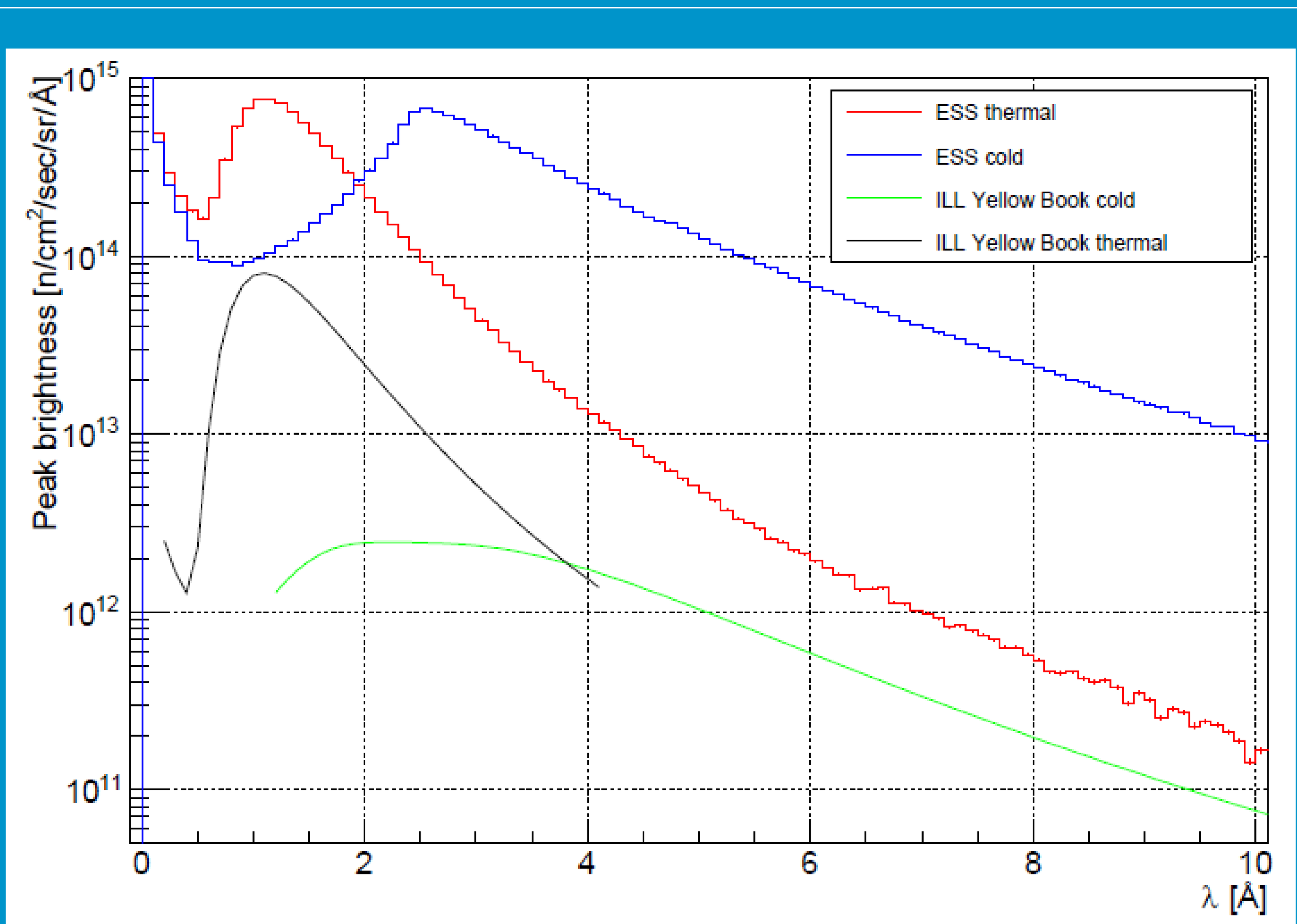
Performance



Brightness distribution along a horizontal X axis perpendicular to the beam port direction, shown for W1 and W11 beam ports.
Dashed lines pass through the focal points and the 0 of the X axis.



Time-average integrated thermal and cold brightness for the 42 beam ports. Thermal brightness: 20-100 meV. Cold brightness: 0-20 meV. The horizontal view width at the moderator is of 6 cm



Brightness spectra averaged over 42 beam ports for 3 cm high moderator, compared with ILL official curves.

Conclusions

Before the introduction of low-dimensional moderators, the reference design for the ESS moderators consisted of volume (cylindrical moderators of 16 cm diameter and 13 cm height) para-hydrogen moderators, described in the TDR [1].
Low-dimensional moderators of 3 cm height, such as the present butterfly moderator, are expected to deliver a brightness 2.5 times higher than the one of the TDR moderators [2].
Compared to the previous pancake design [3], the butterfly moderator offers a significantly higher thermal brightness, and a slightly higher cold brightness, besides the advantages of an easier bi-spectral beam extraction.

The performance of the ESS source is usually compared with the official ILL brightness values from the yellow book [2]. The original design goal of ESS was to achieve a cold peak brightness 30 times the average ILL brightness [1,2]. With the use of low-dimensional moderators, we are far above this goal. Considering integral values, the integrated peak cold brightness above 4 Å for the butterfly is of 4.2 x10^{14}n/cm^2/s/sr, which is 125 times the ILL average integrated brightness (3.3 x10^{12} n/cm^2/s/sr). For thermal neutrons: 0.9 Å-2 Å, the ESS peak thermal brightness is of 6.0 x10^{14} n/cm^2/s/sr which is about 10 times higher than ILL (6.2x10^{13} n/cm^2/s/sr).

[1] ESS Technical Design Report, S. Peggs editor, ISBN 978-91-980173-2-8, 2013, http://europeanspallationsource.se/scientific-technical-documentation
[2] Institut Laue-Langevin. `ILL Yellow Book 2008.' http://www.ill.eu/?id=1379 , 2008.
[3] L. Zanini et al, Moderator configuration options for ESS, Proceedings of the ICANS XXI conference, Mito, Japan, 2014.

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