European Spallation Source ERIC
Strategy Meeting and
8th Meeting of Council
Lund, Sweden, 9 February 2017

Agenda Item 7: Moderator Risk Analysis

Prepared by: Science Directorate

Purpose of item

To take note of:

- Moderator Risk Analysis

Background

In its last meeting in Bilbao in December 2016, Council was informed that based on a re-evaluation all the 15 instruments approved for construction would make use of the upper high-brilliance moderator providing new options for the future use of the lower moderator position. Council asked Management (C.07.14.b) to provide a risk analysis for this change, which is presented here.

Considerations

A number of risks are identified associated with the move from two moderator assemblies to a single one. None of the identified risks are judged to be sufficiently significant to call the decision into question. Indeed, reducing the number of moderators reduces the probability of technical failure by lowering the overall complexity of the system.

Overall, the conclusion is that moving to the one-moderator scenario will not increase the ESS risk exposure and in fact slightly reduces the probability of failure.

Proposed action:	**Voting procedure:**
Council is invited to take note of the Moderator Risk Analysis.	**N/A**

Risk analysis for single moderator

Ken Andersen, 18 January 2017

1. Introduction

This report identifies and compares the risks associated with moving from a two-moderator scenario to a one-moderator scenario for the 15 instruments covered by the ESS construction budget.

Two-moderator scenario:

- 12 instruments on the upper moderator
- 3 instruments (ODIN, HEIMDAL, MIRACLES) on the lower moderator

One-moderator scenario:

- All 15 instruments on the upper moderator.

The two moderator assemblies have the same basic layout. The difference is in their height: the upper moderator has a height of 3 cm, while the lower moderator would have a height of 6 cm.

The difference between the two scenarios is that 3 instruments move from the lower to the upper moderator assembly.

2. Risk Analysis 1: Risk increases from moving to the one-moderator scenario

2.1 Increase in precision required for guide alignment

The guide system needs to point at the source with a precision, which is much better than the size of the source. A precision in guide alignment better than 10% of the source size would ensure less than 10% loss of neutron transport from guide misalignments. The three instruments moving from the lower to the upper moderator thus have an increase in their need for guide alignment precision from < 6 mm to < 3 mm. Both these numbers are large compared to the expected precision of the moderator positioning of 1 mm. They are very large compared to the expected alignment precision of < 0.1 mm ensured by the design of the monolith and the beam extraction system. Thus there is no significant difference in risk between the two scenarios.

2.2 Reduced divergence smoothness

Using a smaller moderator (3 cm height) without reducing the distance between the moderator and the start of the guide, introduces gaps in the phase space delivered by the neutron guide. These gaps can lead to undesirable non-uniformities or asymmetries in the resolution line-shapes of the instruments, which can be particularly problematic for single-crystal instruments. Imaging instruments are also sensitive to gaps in phase space, which can lead to non-uniformities in the field of view. Of the three instruments concerned, none are single-crystal instruments, but one (ODIN) is an imaging instrument. The mitigation to this issue is to design the guide system so as to smooth out these gaps in phase space. Initial concern from the ODIN team about this issue has led to significant effort being invested in exploring such guide designs, resulting in a solution, which provides as good divergence uniformity with the smaller moderator. HEIMDAL and MIRACLES are not sensitive to reduced divergence smoothness. Overall, the risk is very low that the proposed guide design will not deliver adequate divergence uniformity.

2.3 Increased guide complexity

Efficient extraction of the neutron flux from the source requires increasingly complex guide geometries as the source size is reduced. Most existing neutron facilities employ sources which are significantly larger than the lateral dimensions of the neutron guides, resulting in the guide entrance being illuminated by a larger phase space volume than needed for transport to the sample, known as over-illumination. Moderator heights of less than about 8 cm will typically result in under-illumination, which complicates the guide design. 3 cm and 6 cm tall moderators both result in similar levels of under-illumination. There is thus no significant increase in guide complexity and the risk associated with it, when adapting from 6 cm source height to 3 cm.

2.4 Higher sensitivity to para-hydrogen concentration

A flattened moderator geometry has been chosen, as it increases the brightness of the source. The effect is particularly large for liquid para-H_2, which is used for the source of cold neutrons. Maintaining a high (>99.5%) concentration of para-H_2 is very important for the moderator performance. Though the probability of not achieving the required concentration level is unchanged for the two moderator heights, the brightness of the 3 cm moderator will suffer a slightly greater loss of brightness than the 6 cm moderator, if the concentration cannot be achieved, as shown in Fig. 1 below.

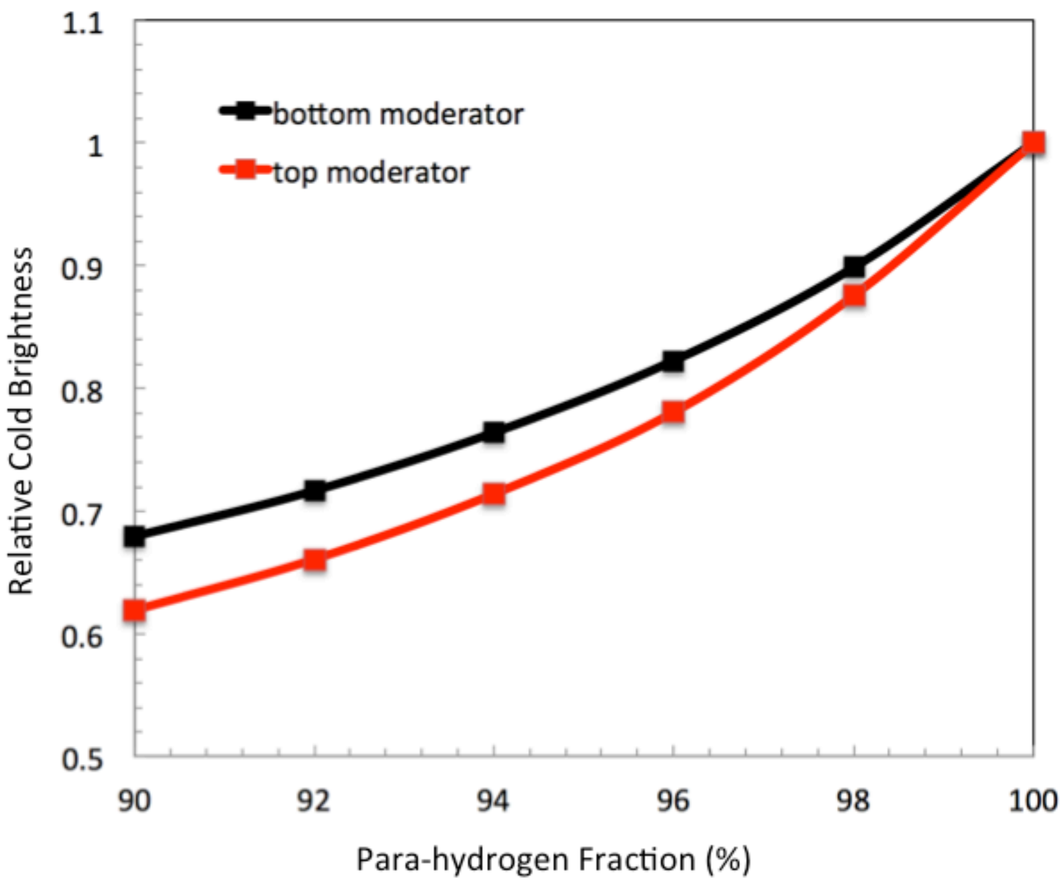

Fig. 1 Variation with para-H_2 concentration of the cold source brightness of the moderator assembly, integrated between 0 and 20 meV. Normalised to unit brightness at 100% para-hydrogen concentration. From [1]

For the 12 instruments that view the upper moderator in both scenarios, there is clearly no change in risk. Of the three others, HEIMDAL is a thermal instrument and would therefore not be impacted by a change in the cold-source brightness. ODIN is bispectral and would see an effect, while MIRACLES is cold and would see the greatest effect. Fig. 1 shows that a reduction in para-H_2 concentration from 100% to 90% would result in a 38% decrease in cold brightness for the 3 cm moderator and a 32% decrease for the 6 cm moderator, bearing in mind that 90% is a very large departure from the nominal para-H_2 concentration of 99.5%. The difference in risk exposure between the two moderators is small.

2.5 Non-availability of backup moderator

With two moderator assemblies to choose between, one could imagine shifting instruments to view the alternative moderator if their preferred moderator has failed. This is not judged to be a realistic option. It would involve mounting the guide system on adjustable mounts with a vertical movement range of about 30 cm, allowing for this additional space inside the shielding and then also moving the instrument itself by the same amount. The cost and complexity in designing, building, and moving 12 instruments in this way are judged to be prohibitive. In addition, moving instruments from the upper to the lower moderator would result in a reduction in flux on the sample by about 35%, corresponding to the change in source brightness. The preferred option would be to shut down the facility and fix the upper moderator, rather than accepting a 35% reduction in performance. This issue is therefore not considered as a risk in the analysis.

2.6 Summary of risk analysis

The probability and impact of above-mentioned risks are evaluated and shown in Table 1 below.

Risk	Probability	Impact	P x I
Increased guide alignment precision cannot be satisfied	1	3	3
Reduced divergence smoothness reduces instrument performance	1	3	3
Increased guide complexity increases costs and risk of failure	1	2	2
Flatter moderator is more sensitive to the ortho-para ratio in the liquid hydrogen	2	1	2

Tab. 1. Risk matrix for the analysis of risk increases when moving to the one-moderator scenario. The probability P and impact I of the occurrence of each risk are evaluated on a scale of 1 to 5, where 1 is the lowest probability or impact.

It is seen from the risk analysis table that the combined probability and impact of each of the identified risks is small compared to the maximum score of P x I = 25.

3. Risk Analysis 2: Risk reductions when moving to the one-moderator scenario

The above analysis has identified and evaluated the issues in which the risk of failure is increased when moving from the two-moderator scenario to the one-moderator scenario. However, there is also risk, which is eliminated by this change: the risk of the lower moderator failing. By halving the number of moderator components, the risk of a critical component failure is also halved.

This reduction in risk is not offset by increased dependence on the upper moderator. If there were performance issues with the upper moderator, it would not be reasonable to continue operating the facility with only the three instruments viewing the lower moderator. If such a problem were to occur, the facility would need to be shut down to fix the problem, in both the one- and two-moderator scenarios.

However, if there were performance issues with the lower moderator in the two-moderator scenario, then the facility might choose to continue operating with the 12 other instruments. This evaluation is summarised in the risk table below.

	Two-moderator scenario	One-moderator scenario
Failure probability P	2	1
In case of problem with upper moderator	Shut down full facility to fix problem. Impact 4	Shut down full facility to fix problem. Impact 4
In case of problem with lower moderator	Shut down full facility to fix problem or continue with just top-moderator instruments. Impact 3	Not applicable
Average impact I	3.5	4
Product P x I	7	4

Tab. 2. Risk matrix for the analysis of risk reductions when moving to the one-moderator scenario. The probability and impact of the occurrence of each risk are evaluated on a scale of 1 to 5, where 1 is the lowest probability or impact.

4. Summary

The combined probability and impact of the factors contributing to increasing the risk when moving from the two-moderator to the one-moderator scenario is seen to be small.

The largest change identified is seen to be a small reduction in technical risk, resulting from the reduction in complexity when halving the number of moderator components.

Overall, the result is that moving to the one-moderator scenario will not increase the ESS risk exposure and slightly reduces the probability of failure.

References

[1] Luca Zanini, private communication, 2017