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Stakeholder Consultations on Neutron Beam Shutter Options

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	Name	Affiliation
Authors	Phil Bentley	ESS
Reviewers		
Approver		

Distribution: Internal ESS stakeholders.

European Spallation Source ESS AB
Visiting address: ESS, Tunavägen 24
P.O. Box 176
SE-221 00 Lund
SWEDEN

www.esss.se

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1. EXECUTIVE SUMMARY

There has been recent interest in the specifications of the neutron beam shutters within the target monolith, and whether those specifications will best serve the stakeholders during the construction and operation of the ESS facility. The Cross Functional Working Group on Beam Extraction was tasked by the ESS management in the summer of 2012 to address the feasibility and design of the baseline target monolith. Some differences of opinion were discovered during this process in the matter of primary shutters. As a result, a stakeholder consultation was held to establish use cases of shutters and to identify a number of scenarios and the viewpoints held by the various parties concerned, to try to evaluate some of the options.

This document summarises this endeavour. Four options were considered. In descending order of functionality and scope of changes to the baseline target design, these are:

- A primary shutter located inside the monolith
- A primary shutter located outside the monolith but within the common shielding bunker
- A service shutter (i.e. the current baseline)
- No shutter

From an operational viewpoint, the primary shutter inside the monolith was the option providing the greatest functionality, but from a project viewpoint this would have the greatest consequences in terms of change to the baseline and impact on the project planning. Conversely, the option without a shutter would make the construction project the easiest to realise but with an adverse affect on the utility and operations of the facility during the latter operational phase.

2. LIST OF CONSULTED STAKEHOLDERS & CONTRIBUTORS

2.1 Science Division

Phil Bentley

Iain Sutton

Ken Andersen

Markus Strobl

Oliver Kirstein

Pascale Deen

2.2 Target Division

Ferenc Mezei

François Plewinski

Magnus Göhran

Rikard Linander

Stephen Gallimore

2.3 Programme

Robert Connatser

2.4 Radioprotection

Peter Jacobsson

2.5 Accelerator Division

Steve Peggs

Garry Trahern

3. INITIAL USE CASE ANALYSIS

3.1 With Light Shutter – Reference Scenario

This scenario represents the current design of the monolith as described in the TDR.

3.1.1 Assumptions

Access to beam plugs from the side of the monolith.

3.1.2 Use Cases

- **Instrument installation**.
    - a light shutter would allow access *during neutron production* (3 weeks shutdown, involves vertical access to the shutter in the monolith).
    - Waste is increased because the dummy primary shutter creates a larger space in the unused beam lines that needs to be filled with shielding.
    - It allows visual access to the beam axis
    - a light shutter would not allow access close to the monolith, within line of sight, during neutron production.
    - This is the waste reference point against which the other two options are being compared
    - Heavy duty shielding (insert and / or temporary walls / blocks) would be required with proton beam on.
    - Instrument installation in and near the monolith requires approx 2 mo shutdown.
    - No installation in first 10 m of beam from moderator except during shutdown
- **Long term maintenance/repair**, outside cross-talk zone, e.g. realignment, chopper replacement within line of sight *only during proton beam shutdown*.
- **Obsolescence**, e.g. changing instruments in 2030, – access for removal of equipment within line of sight *only during proton beam shutdown*
- **Target maintenance** (inspections) of neutron beam window area *only possible during proton beam shutdown*.
- **During Beamline or Instrument Hot Commissioning or Operations**
    - Changing Instrument/beamline configurations (e.g. sample env, changing sample, beam testing) cannot be done freely irrespective of beam geometry, this will only be possible for regions out of line of sight with a secondary shutter closed.
    - PPS personnel protection system (in high activity alarms go off) then we have to shut down the proton beamcan shut one beam line rather than whole system
    - IPS – instrument protection system (e.g. one instrument beam gets damaged, the whole system would need to be shut off)

3.1.3 Other Factors

Engineering complexity of the monolith: this is the reference scenario against which the others are measured.

Experiment Hall Crane: This calls for the capability to install a (current proposal) 20 ton cask at each beam port for insert removal. This has significant cost implications to the crane or cranes that have access to the face of the monolith in the experiment hall.

Licensing: this is the reference scenario against which the others are measured, so no relative issues are flagged.

Consequences: this is the reference scenario against which the others are measured, so no relative consequences are flagged.

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3.2 With Primary Shutter

3.2.1 Assumptions

This is a primary shutter similar to the SNS, i.e. in performance and placement is in the monolith structure.

3.2.2 Use Cases

- **Instrument installation**. We will be starting to build instruments during 2018, which means that the use cases are:
  - a primary shutter would allow access *during neutron production* (3 weeks shutdown, involves vertical access to the shutter in the monolith).
  - Waste is increased because the dummy primary shutter creates a larger space in the unused beam lines that needs to be filled with shielding.
  - It allows visual access to the beam axis with the proton beam on.
- **Long term maintenance**/repair, outside cross-talk zone, e.g. realignment, chopper replacement some 10s of metres away, during neutron production.
- **Obsolescence**, e.g. changing instruments in 2030, – access for removal of equipment
- **Target maintenance** (inspections) of neutron beam window area possible during operations on a sector by sector basis (but in any case would be done during shutdown).
- **During Beamline or Instrument Hot Commissioning or Operations**
  - Changing Instrument/beamline configurations (e.g. sample env, changing sample, beam testing) can be done freely irrespective of beam geometry
  - PPS personnel protection system (in high activity alarms go off) then we can shut one beam line rather than whole system
  - IPS – instrument protection system (e.g. one instrument beam gets damaged, shut the beam and not the whole system)

3.2.3 Other Factors

Engineering complexity of the monolith: is increased.

Licensing: the shutter is a large mass close to the safety barrier and this presents a licensing issue for the monolith.

Consequences: no consequences recorded during the meeting.

3.3 With Primary Shutter Outside Monolith

3.3.1 Assumptions

This is a primary shutter outside the monolith, with no shutter in the monolith.

3.3.2 Use Cases

- **Instrument installation**. We will be starting to build instruments during 2018, which means that the use case is that
  - a primary shutter would allow access *during neutron production* to beam axis downstream of the shutter.
  - Waste is increased because the total quantity of irradiated material now includes the shutter mechanisms outside the monolith
  - It allows visual access to the beam axis with the proton beam on, downstream of the shutter.
- **Long term maintenance**/repair, outside cross-talk zone, e.g. realignment, chopper replacement some 10s of metres away, during neutron production, downstream of the shutter.
- **Obsolescence**, e.g. changing instruments in 2030, – access for removal of equipment downstream of the shutter.
- **Target maintenance** (inspections) of neutron beam window area possible during operations on a sector by sector basis (but in any case would be done during shutdown).
- **During Beamline or Instrument Hot Commissioning or Operations**
  - Changing Instrument/beamline configurations (e.g. sample env, changing sample, beam testing) can be done freely irrespective of beam geometry
  - PPS personnel protection system (in high activity alarms go off) then we can shut one beam line rather than whole system, provided the event is downstream of the shutter.
  - IPS – instrument protection system (e.g. one instrument beam gets damaged, shut the beam and not the whole system, provided the problem is downstream of the shutter)

3.3.3 Other Factors

Engineering complexity of the monolith: is reduced.

Licensing: the shutter requires significant shielding inside the neutron guide hall.

Consequences: no additional consequences were recorded at the meeting.

3.4 With No Shutter Whatsoever

3.4.1 Assumptions

Access to the port hole is from outside the monolith. Dosimetry near the monolith wall (either the actual monolith or the installed shielding around it) allows a person to access the wall safely during operations.

3.4.2 Use Cases

- Instrument installation. We will be starting to build instruments during 2018
    - Heavy duty shielding (insert and / or temporary walls / blocks) would be required.
    - Instrument installation in and near the monolith requires approx 2 mo shutdown.
    - No installation in first 10 m of beam from moderator except during shutdown
    - Reduced waste because the dummy beam plugs are single piece of narrow steel.
- No Long term maintenance/repair, outside cross-talk zone, e.g. realignment, chopper replacement some 10s of metres away, during neutron production.
- Obsolescence, e.g. changing instruments in 2030, – access for removal of equipment
- Target maintenance (inspections) of neutron beam window area not possible during operations.
- During Beamline or Instrument Hot Commissioning or Operations
    - Changing Instrument/beamline configurations (e.g. sample env, changing sample, beam testing) cannot be done within line of sight of the source.
    - PPS personnel protection system (in high activity alarms go off) then we can shut down the whole facility.
    - IPS – instrument protection system (e.g. one instrument beam gets damaged), shut down the whole facility.

3.4.3 Other Factors

Engineering complexity of the monolith: is reduced.

Licensing: the licensing of the monolith may be simplified in this scenario but the licensing downstream is likely to be more complex.

Consequences: no additional consequences recorded at the meeting.

4. Evaluation Matrices

4.1 Introduction

For each of the different options above, an evaluation matrix was constructed to facilitate the selection of recommendations for the ESS management. Each of the core stakeholder groups was asked to independently evaluate a number of key criteria for each of the options. The arithmetic mean of these numbers was then computed as a "badness" score for each criterion for each option, on a scale of 1-5, where 5 represents the worst possible scenario, and 1 represents the lowest score of "badness". If a criterion was irrelevant for that stakeholder, then the "badness" score was zero. There were four core groups placing scores for the criteria.

The table was grouped roughly into two common themes. The **upper** theme focusses on a range of different scenarios during **operations**. The **lower** theme focusses more on **construction project** factors.

The next stage of the evaluation was to allocate a weighting factor for the evaluation criteria, in other words how important each criterion is for the stakeholder. Each group was given two votes to cast. If the criterion is not important, then zero votes were placed on that criterion. If it was moderately important, then one vote could be cast. If it was extremely important, then two votes could be cast. As such, the importance scale runs from 0-8, depending on how many people vote for each cirterion, which was normalised to a scale of 0-1.

During this activity, a number of additional criteria were identified that supplemented those listed above.

4.2 List of Voting Core Groups

The core groups were:

- Instrument Scientists
- Target Division
- Chief Instrument Engineer
- Neutron Optics Group

4.3 Most Important Criteria

The three most highly weighted criteria, in order of weight, were:

- Ease of beamport activation operation (8 votes out of a possible 8)
- Normal operations with proton beam on (7 votes out of a possible 8)

- Monolith engineering complexity (7 votes out of a possible 8)

4.4 Option 1: Primary Shutter in Monolith

Zones and Scenarios

		US / Shutter	In LOS	Beyond LOS	Sample Pos Straight	Sample Pos Curved	Weight	Weight	Score
Installation	Protons on		1	1	1	1	6	0.75	3
	Protons off	5	1	1	1	1	5	0.625	5.625
Normal Operations	Protons on		1	1	1	1	7	0.875	3.5
	Protons off	5	1	1	1	1	3	0.375	3.375
Planned Maintenance	Protons on		1	1	1	1	2	0.25	1
	Protons off	5	1	1	1	1	2	0.25	2.25
Unplanned Interventions	Protons on		1	1	1	1	6	0.75	3
	Protons off	5	1	1	1	1	2	0.25	2.25
Obsolescence	Protons on		1	1	1	1	6	0.75	3
	Protons off	5	1	1	1	1	3	0.375	3.375
Hot Commissioning	Protons on		1	1	1	1	6	0.75	3
	Protons off						1	0.125	0
Target External Surface Maintenance	Protons on		1				2	0.25	0.25
	Protons off	5	1				2	0.25	1.5
									35.125

Other Evaluation Factors

		Weight	Weight	Score
Monolith engineering complexity	5	7	0.875	4.375
Licensing complexity	4.25	3	0.375	1.59375
Monolith cost	4.75	4	0.5	2.375
Guide hall crane cost	2	4	0.5	1
Waste quantity	4.75	3	0.375	1.78125
Shielding costs on guides/bunker	1	6	0.75	0.75
Structural impact, transfer of loads	3	4	0.5	1.5
Ease of beam port activation operation	3	8	1	3
Total thickness of beam window material	5	5	0.625	3.125
Number of beam ports available	5	4	0.5	2.5
				22

4.5 Option 2: Primary Shutter Outside Monolith

Zones and Scenarios

		US / Shutter	In LOS	Beyond LOS	Sample Pos S	Sample Pos Curved	Weight	Weight	Score
Installation	Protons on	4.5	1	1	1	1	6	0.75	6.375
	Protons off	4	1	1	1	1	5	0.625	5
Normal Operations	Protons on	2.75	1	1	1	1	7	0.875	5.90625
	Protons off	2.75	1	1	1	1	3	0.375	2.53125
Planned Maintenance	Protons on	7.5	1	1	1	1	2	0.25	2.875
	Protons off	3.25	1	1	1	1	2	0.25	1.8125
Unplanned Interventions	Protons on	5	1	1	1	1	6	0.75	6.75
	Protons off	4.75	1	1	1	1	2	0.25	2.1875
Obsolescence	Protons on	4.5	1	1	1	1	6	0.75	6.375
	Protons off	3.25	1	1	1	1	3	0.375	2.71875
Hot Commissioning	Protons on	3	1	1	1	1	6	0.75	5.25
	Protons off						1	0.125	0
Target External Surface Maintenance	Protons on	3.75					2	0.25	0.9375
	Protons off	3					2	0.25	0.75
									49.46875

Other Evaluation Factors

		Weight	Weight	Score
Monolith engineering complexity	1.25	7	0.875	1.09375
Licensing complexity	3	3	0.375	1.125
Monolith cost	1.25	4	0.5	0.625
Guide hall crane cost	2.5	4	0.5	1.25
Waste quantity	2.75	3	0.375	1.03125
Shielding costs on guides/bunker	3.25	6	0.75	2.4375
Structural impact, transfer of loads	2	4	0.5	1
Ease of beam port activation operation	2	8	1	2
Total thickness of beam window material	3.5	5	0.625	2.1875
Number of beam ports available	3.5	4	0.5	1.75
				14.5

4.6 Option 3: Service Shutter (Baseline)

Zones and Scenarios

		US / Shutter	In LOS	Beyond LOS	Sample Pos Straight	Sample Pos Curved	Weight	Weight	Score
Installation	Protons on		5	3	5	1	6	0.75	10.5
	Protons off		1	1	1	1	5	0.625	2.5
Normal Operations	Protons on		4.5	3	5	1	7	0.875	11.8125
	Protons off		1	1	1	1	3	0.375	1.5
Planned Maintenance	Protons on		4.5	3	5	1	2	0.25	3.375
	Protons off		1	1	1	1	2	0.25	1
Unplanned Interventions	Protons on		5	3	5	1	6	0.75	10.5
	Protons off		1	1	1	1	2	0.25	1
Obsolescence	Protons on		5	3.5	5	1	6	0.75	10.875
	Protons off		1	1	1	1	3	0.375	1.5
Hot Commissioning	Protons on		4.5	3.5	5	1	6	0.75	10.5
	Protons off						1	0.125	0
Target External Surface Maintenance	Protons on		5				2	0.25	1.25
	Protons off		1				2	0.25	0.25
									66.5625

Other Evaluation Factors

		Weight	Weight	Score
Monolith engineering complexity	2.5	7	0.875	2.1875
Licensing complexity	1	3	0.375	0.375
Monolith cost	2	4	0.5	1
Guide hall crane cost	5	4	0.5	2.5
Waste quantity	2	3	0.375	0.75
Shielding costs on guides/bunker	1	6	0.75	0.75
Structural impact, transfer of loads	2	4	0.5	1
Ease of beam port activation operation	2	8	1	2
Total thickness of beam window material	1.75	5	0.625	1.09375
Number of beam ports available	1	4	0.5	0.5
				12.15625

4.7 No Shutter

Zones and Scenarios

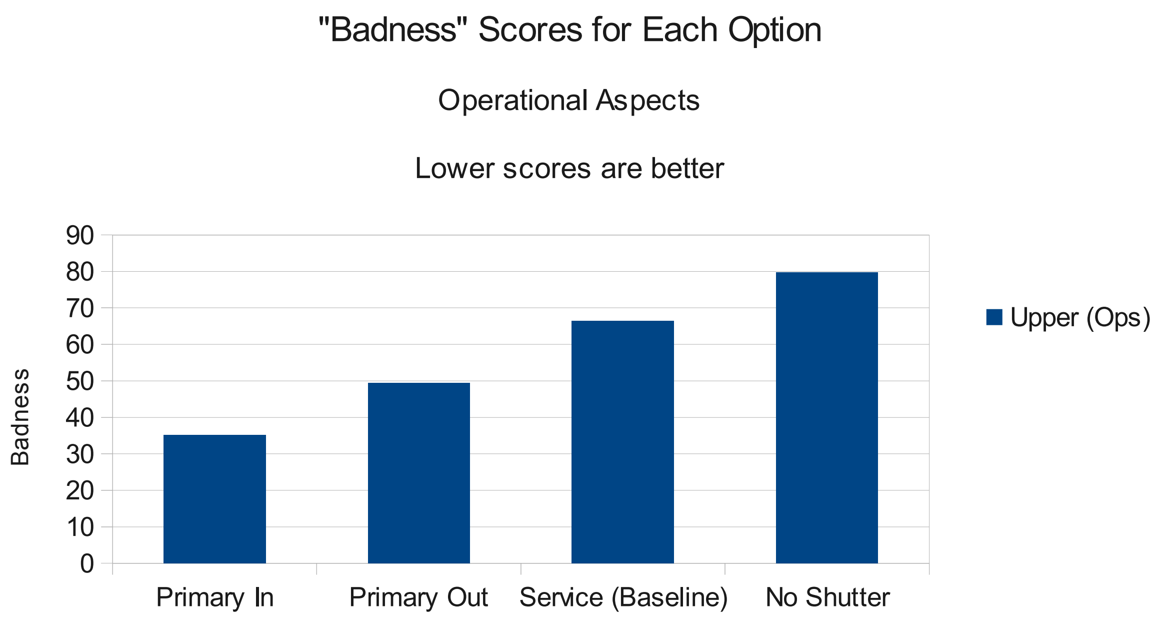
		US / Shutter	In LOS	Beyond LOS	Sample Pos S	Sample Pos Curved	Weight	Weight	Score
Installation	Protons on		5	5	5	1	6	0.75	12
	Protons off		2.5	1	2	1	5	0.625	4.0625
Normal Operations	Protons on		5	4.75	5	1	7	0.875	13.78125
	Protons off		2.5	1	2	1	3	0.375	2.4375
Planned Maintenance	Protons on		5	4.75	5	1	2	0.25	3.9375
	Protons off		2.5	1	2	1	2	0.25	1.625
Unplanned Interventions	Protons on		5	5	5	1	6	0.75	12
	Protons off		2.5	1	2	1	2	0.25	1.625
Obsolescence	Protons on		5	5	5	1	6	0.75	12
	Protons off		2.5	1	2	1	3	0.375	2.4375
Hot Commissioning	Protons on		5	5	5	1	6	0.75	12
	Protons off						1	0.125	0
Target External Surface Maintenance	Protons on		5				2	0.25	1.25
	Protons off		2.5				2	0.25	0.625
									79.78125

Other Evaluation Factors

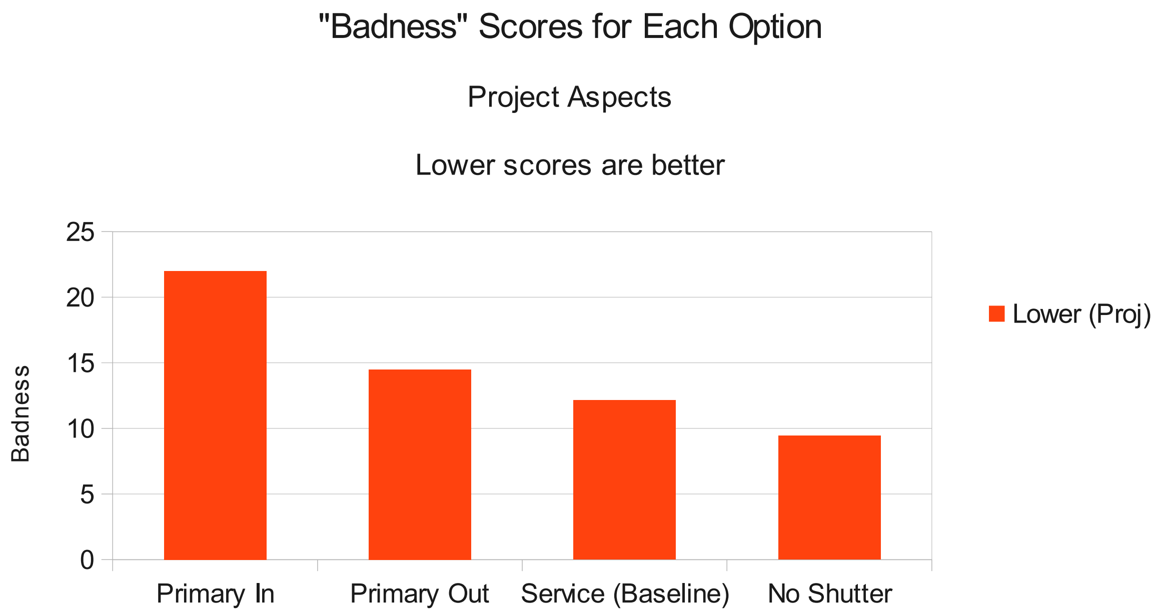
		Weight	Weight	Score
Monolith engineering complexity	1	7	0.875	0.875
Licensing complexity	3	3	0.375	1.125
Monolith cost	1	4	0.5	0.5
Guide hall crane cost	3	4	0.5	1.5
Waste quantity	1.5	3	0.375	0.5625
Shielding costs on guides/bunker	1	6	0.75	0.75
Structural impact, transfer of loads	1	4	0.5	0.5
Ease of beam port activation operation	2.5	8	1	2.5
Total thickness of beam window material	1	5	0.625	0.625
Number of beam ports available	1	4	0.5	0.5
				9.4375

4.8 Analysis of Options

The “badness” from an operational standpoint for each of the options is shown in figure.



The “badness” from a project standpoint for each of the options is shown in figure.



5. Conclusions

It is satisfying that our expectations from the consultation were met, namely that the most complex and costly options offer the most flexibility during the operation phase, but these are on the other hand the most complex and challenging to implement during the construction phase.

European Spallation Source ESS AB
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P.O. Box 176
SE-221 00 Lund
SWEDEN

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