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SOURCE

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Scope Setting Report
Instrument : Bifrost cold spectrometer

SUMMARY

The purpose of this document is to describe the possible baseline options for the Bifrost project, as well as possible upgrade path to full scope as outlined in the accepted proposal.

Three possible baseline options are presented, and the scientific risks of each option is evaluated and compared. We include a discussion of the costs and scientific benefits of a high field cryo-magnet.

Bifrost has been assigned to cost category B (12M€). The conclusion from the cost analysis is that cost category B cannot be reached while maintaining acceptable scope and reasonable upgrade paths to full scope.

We present an option 2, which is a world-leading instrument, capable of delivering results from Day 1, which has a cost obtainable in the current budget situation. However, option 2 is not directly targeting the magnetism community from Day 1, one of the key communities for Bifrost.

For comparison, and to deliver the full Bifrost perspective, we present an option 3 that would deliver unparalleled performance on all fronts and have considerable impact on all science cases presented in the proposal accepted by the SAC.

For all these options, we expect to be able to go into hot commissioning in 2022, and enter user operation in 2023.

Details of Bifrost:

The description of the instrument, scope and operation of Bifrost can be found in the **Concepts of Operations report**.

The breakdown of the system requirements is found in the **Systems Requirements Report**.

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1. OVERVIEW

1.1. Instrument description

Bifrost is an indirect ToF-spectrometer, able to make use of the full ESS pulse to achieve a sample flux exceeding state-of-the-art by at least a factor of 30. This can be done with good energy resolution due to the length of the Bifrost instrument. A pulse-shaping chopper close to the monolith allows for full flexibility of the primary spectrometer resolution.

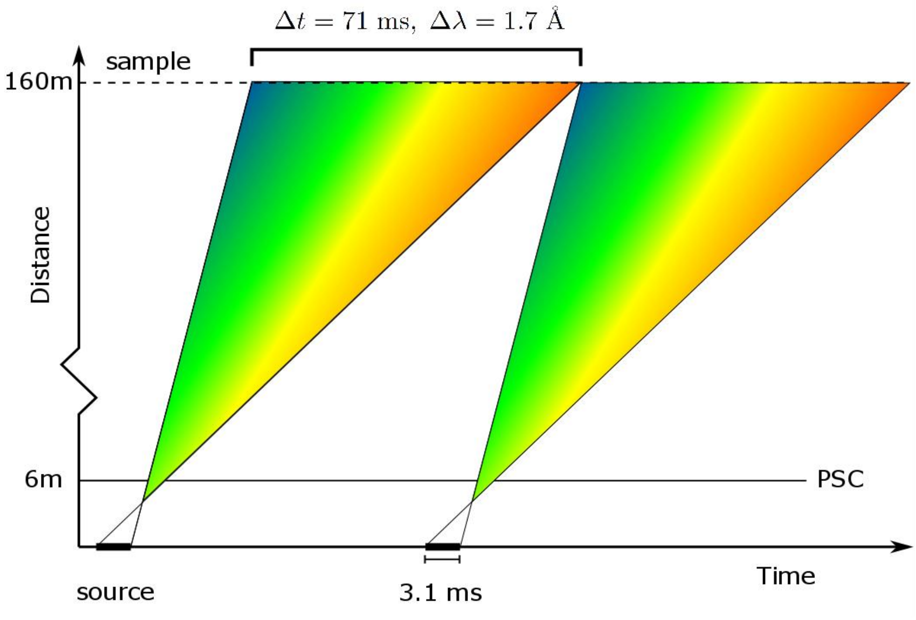


Figure 1: Operating principle of the Bifrost primary spectrometer

The neutron detection of the secondary spectrometer is constrained to the horizontal scattering plane. The current design consists of a number of segments – Q-channels – each covering a 7.5 degree scattering angle in 2Θ. Each of these Q-channels consist of 6 analysers (10 in the proposal) placed consecutively behind each other downstream from the sample, each reflecting a different wavelength.

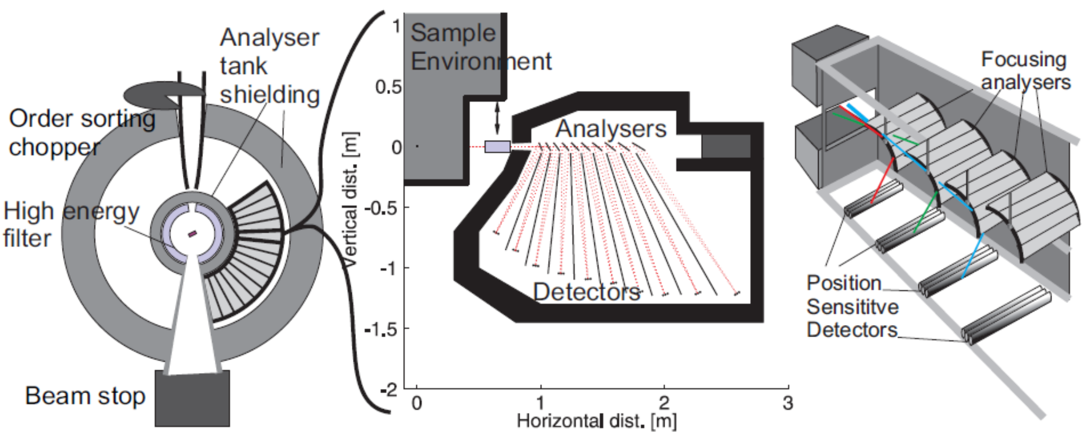


Figure 2: Operating principle of the secondary spectrometer

1.2. Science Case

Neutron spectroscopy is the main tool for investigating low energy dispersive dynamics in materials. Cold neutron spectroscopy is the only tool in existence for probing such dynamics in the 0-40 meV range. Due to the intrinsically weak signal in neutron spectroscopy, it remains a flux limited technique, requiring large sample mass for feasibility. However, many species of materials are only grown with techniques that intrinsically yield small crystals in the milligram range, like for instance flux growth techniques or electrocrystallization. Low temperature dynamics in many of these systems are currently unobservable for this reason only. In addition, some of the most interesting crystalline systems currently under investigation have inherently weak signals. Neutron spectroscopy today suffers from the partitioned choice between the low flux/large coverage capabilities of ToF spectrometers and the high flux/low coverage capabilities of triple axis spectrometers. These choices are united in the BIFROST spectrometer while increasing flux on the sample by an order of magnitude compared to the best options today. This allows Bifrost to function both as a workhorse instrument and as a first feasible option to study low energy dispersive dynamics when small single crystals start to become available of the materials to be discovered in the future – a clear competitive advantage for the ESS.

The science scope of BIFROST contains - but are not limited to – the following cases:

- **Excitations in unconventional superconductors:** Weak spin fluctuations in the high-T_C cuprates, nesting vectors in pnictides, excitations in heavy fermion superconductors. Suffering from intrinsic weak cross sections, they will benefit greatly from BIFROST flux.
- **Excitations in frustrated magnets.** Many frustrated magnets have reduced moments and/or intrinsic disorder like spin liquids, resulting in weak signals. Some frustrated magnets cannot form large single crystals using known techniques. Bifrost will have a huge impact on this important field of magnetism.
- **Low dimensional magnets/quantum magnets** are systems with the main dispersive features residing in a single scattering plane, and which is usually investigated in applied fields and/or pressure. BIFROST is an ideal tool for these problems.
- **Strongly correlated electron systems** exhibiting for instance charge order and spin density waves, often suffer from weak scattering cross sections. Flux is paramount to investigate these materials with neutron spectroscopy
- **The study of materials under extreme pressure in geoscience** becomes possible at BIFROST. With the high flux, elegant screening of background from sample environment close to the sample and the good elastic resolution, BIFROST can study quasielastic dynamics in the GPa pressure range.
- **Functional materials** are also of interest to BIFROST. Many multiferroic materials of interest have many different phases and the fast aquisition rate of BIFROST makes it ideal for parametric studies and a function of temperature, magnetic field and even pressure

The top-level requirements for Bifrost define the target scope for the instrument construction project. They have been formulated to capture the key aspects of the instrument proposal science case:

1. The instrument shall have a flux at optimum exceeding 2 * 10^{10} n/s/cm^2
2. The beam spot shall be less than 2x2 cm^2 and with a maximum divergence of 0.75 degrees.
3. The instrument shall employ a primary spectrometer white beam bandwidth of 1.7 Å
4. The instrument shall allow a 90 degree horizontal plane scattering angle to be measured in a single setting
5. The instrument shall be able to measure 6 final energies in a single scattering angle segment
6. The angular resolution of the secondary spectrometer should be less than 0.7 degrees.
7. The divergence of the primary spectrometer shall be tuneable down to 0.2 degrees
8. The energy resolution of the secondary spectrometer shall tuneable down to 30 μeV
9. The energy resolution of the primary spectrometer shall be tuneable down to 30 μeV
10. Polarization analysis (full or partial coverage) shall be implemented as an option
11. The instrument shall allow a separation of the 1st and 2nd order scattering off the analysers
12. Sample environment shall allow fields above 15 T
13. Sample environment shall allow pressure above 2 GPa
14. Sample environment shall allow temperatures below 50 mK
15. Bifrost shall have an evacuated secondary spectrometer tank for background reduction

1.3. Three configuration options

1. A configuration that is within cost category A (12M€), this option fails to meet several high level requirements and has a costly and wasteful upgrade path. **Cost : 11.95 M€**

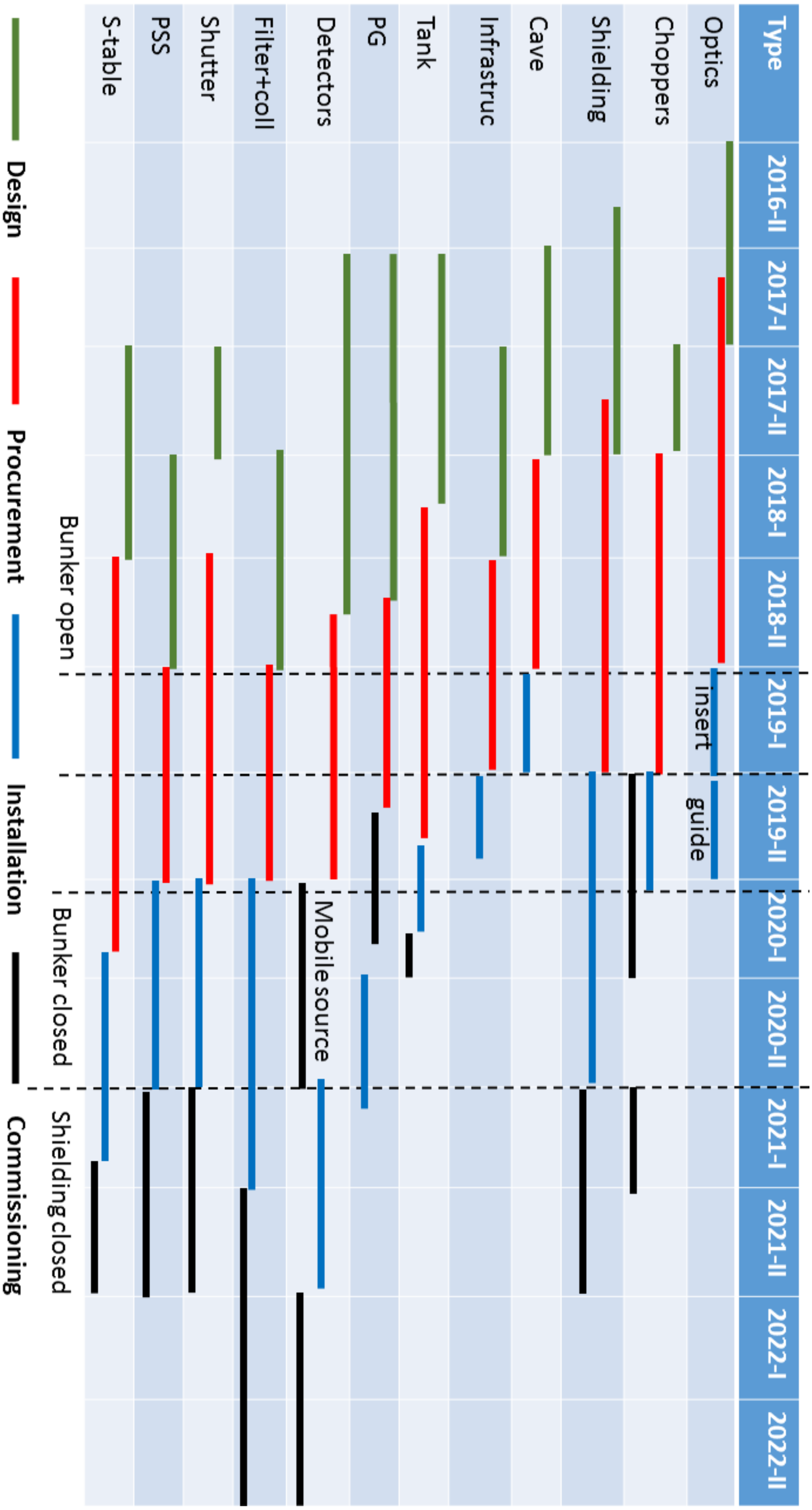
2. A configuration that manages to meet most of the scientific requirements at reasonable performance. The aim is a world-class instrument. **Cost : 14 M€**

3. A configuration with world leading sample environment and polarization analysis **Cost : 16.35 M€**

Important note: In adjusting the scope and cost of Bifrost, we have focused on the secondary spectrometer and sample environment – with the exception of the order-sorting chopper. Thus, the primary spectrometer is unchanged in the three options as it remains the most costly and technically challenging to upgrade. Therefore, our description of the scopes for the three options will not focus on primary spectrometer performance, which is identical for all three options.

The order sorting option and polarization analysis are estimated to cost 3 M€ and 2M€, respectively and deemed unrealistic in the current budget situation. Therefore, these options, fulfilling requirement 10 and 11, will remain future upgrades in all three options.

2. TIME SCHEDULE COMMON FOR ALL OPTIONS



OPTION 1: SCOPE WITHIN COST CATEGORY B (11.95M€)

2.1. Scope

- Primary spectrometer, fulfilling requirement #1-3, #7 and #9.
- 22,5 degree angular coverage of the secondary spectrometer
- 3 Q-channels
- 6 analysers per Q-channel (#6)
- All necessary associated infrastructure (shielding, cabling, cabins etc.)
- High pressure and magnetic fields through SAD pool and collaborations

This scope does **not** meet the following top-level requirements:

- 90 degree coverage (#2)
- Temperatures in the mK range (#14)
- Magnetic fields above 15 T (#12)
- Polarization analysis (#10)
- Order sorting: Large energy transfers with large Q-range (#11)
- Evacuated secondary spectrometer tank (#15)

This option has a factor of 12 reduction in active detection area (pyrolytic graphite) compared to the accepted proposal, and a factor of four less than option 2. This drastically limits the speed with which weak inelastic signals can be measured, and negates some of the drastic gain in performance the initial proposal sought to achieve. In a few special cases, Bifrost will not be world leading on Day 1, as other instruments may be able to have smaller, but comparable, measurement times but much more diverse and extreme sample environment

Option 1 will not be able to do fast-acquisition parametric overview studies. Covering 22.5 degrees of scattering angle in the horizontal plane is a local measurement in S(Q, w), and many instrument settings are needed to gain enough information to characterize the dynamics. Overview studies has to be done sequentially on the option 1 instrument, thus running the risk of being used as a triple axis spectrometer; with many instrument settings needed to gain enough information to characterize dynamics. In addition, the relative impact of the tank movement time is drastically increased – further decreasing the capabilities.

The upgrade path for option 1 is expensive. Since the vacuum tank is one of the cost drivers for the secondary spectrometer, it is necessary to build a small tank that cannot be evacuated. Upgrading to full coverage would mean building and installing an entirely new tank and Beryllium filter, and reinstalling the analyser/detector setup from the previous tank. The workforce required for this is considerable, and the initial Be-filter and tank will have to be discarded.

Thus, this scope **does not fulfil** the science case for Bifrost.

2.2. Costing

The costing is based on bottom-up calculation of the procurement costs and labor required for the tasks needed to deliver the higher-level PBS items.

Table 1 Costing for Bifrost meeting Cost Category B

	Project Management and integration	Design	Procurement and fabrication	Install-ation	Cold commissioning	Non labour	Labour	Total
Shielding	€ 0	€ 189.000	€ 1.905.500	€ 259.200	€ 0	€ 1.905.500	€ 448.200	**€ 2.353.700**
Neutron Optics	€ 0	€ 27.000	€ 3.040.000	€ 100.000	€ 0	€ 2.970.000	€ 197.000	**€ 3.167.000**
Choppers	€ 0	€ 0	€ 841.000	€ 62.400	€ 20.000	€ 861.000	€ 62.400	**€ 923.400**
Sample Environment	€ 0	€ 0	€ 150.000	€ 3.840	€ 3.840	€ 150.000	€ 7.680	**€ 157.680**
Detector and beam monitor	€ 0	€ 200.000	€ 1.010.000	€ 54.000	€ 108.000	€ 1.010.000	€ 362.000	**€ 1.387.000**
DMSC	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	**€ 0**
Motion control		€ 0	€ 116.000	€ 15.000	€ 50.000	€ 116.000	€ 65.000	**€ 181.000**
Instrument specific Tech equipment	€ 1.260.000	€ 0	€ 420.000	€ 21.600	€ 27.000	€ 480.000	€ 1.248.600	**€ 1.728.600**
Instrument Infrastructure	€ 0	€ 27.000	€ 300.000	€ 172.800	€ 0	€ 300.000	€ 199.800	**€ 499.800**
Vacuum	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	**€ 0**
PSS	€ 0	€ 20.000	€ 50.000	€ 30.000	€ 20.000	€ 70.000	€ 50.000	**€ 120.000**
Contingency								**€ 1.157.000**
Phase I								**€ 280.000**
TOTAL	**€ 1.260.000**	**€ 463.000**	**€ 7.832.500**	**€ 718.840**	**€ 228.840**	**€ 7.862.500**	**€ 2.640.680**	**€ 11.955.180**
Man year	**12**	**5**	**0**	**8**	**2**			**27**

2.3. Upgrade/Staging plan

The staging plan for this option would consist of replacing the secondary spectrometer tank as a first priority. The second priority would be obtaining a high field magnet, polarization analysis as a third upgrade, and lastly the order sorting option would be implemented.

2.4. Risk

The main risk with this configuration is not delivering the science case accepted by the SAC, due to the very limited analyser coverage. This carries with it an additional risk of establishing a complicated mode of operation that a white beam combined with low angular coverage would facilitate. Reduced gain compared to current state-of-the-art combined with poor sample environment, comprise a risk that users would prefer simpler options elsewhere despite the lower flux.

Below are top five risks rated high using ESS risk measures (impact x likelihood).

Table 2 Top 5 risks for Option 1

Risk level	RISK	TREATMENT NAME	Treatment	CATEGORY	TREATMENT PLAN
High 5x5	Failure to deliver proposed scientific performance	Lower expectations	Mitigate	Budget, quality and function	Communicate with stakeholders the lowered performance expectations. Begin planning for upgrade and seek funding. Responsible: Bifrost Team, ESS management
High 4x4	Conventional Facilities Delay	***CF LEVEL ESS-0019533***	Observe	Schedule, budget, quality and function	Access to hall 2 is a milestone for Bifrost schedule. Bifrost team Responsible: CF
		External areas like labs and workshops	Mitigate		External areas will give the opportunity to start pre-installations Responsible: CF
High 3x5	Improper design according to instrument requirements and Delay in monolith insert design	Schedule for external milestone	Observe	Schedule, budget, Quality and function	Follow the progress of the design and project schedule. Bifrost Team Responsible: target
		TARGET LEVEL ESS-0019533	Observe		Focus on Safety, feasibility and requirements Responsible: target
High 3x5	Late delivery of key components	Bifrost schedule	Mitigate	Schedule, budget	Properly assess the delivery time and transportation, also the time that is required for installation and arriving at site. Define the critical path for every component. Responsible: Bifrost Team
High 3x5	Software insufficient to make full use of instrument capabilities	Collaborations	Mitigate	Quality and function	Seek external collaborations for common CAMEA backend software, and enforce compatibility with ESS standards

3. OPTION 2: WORLD CLASS INSTRUMENT (14M€)

3.1. Scope

The scope within this cost category is:

- Primary spectrometer, fulfilling requirement #1-3, #7 and #9.
- 90 degree angular coverage of the secondary spectrometer (#2)
- 12 Q-channels
- 6 analysers pr. Q-channel (#6)
- All necessary associated infrastructure (shielding, cabling, cabins etc.)
- High pressure and magnetic fields through SAD pool and collaborations
- Evacuated secondary spectrometer tank (#15)
- Temperatures in the milli-Kelvin range (#14)
- 90 degree coverage (#2)

This scope does **not** meet the following top-level requirements:

- Magnetic fields above 15 T (#12)
- Polarization analysis (#10)
- Order sorting: Large energy transfers with large Q-range (#11)

This scope meets most of the top-level requirements and is straightforwardly upgradable to a configuration that provides the full scope. In this option, we can afford building an evacuated tank covering 90 degrees scattering angle with a design that is ready for implementing the guide fields needed for polarization analysis. However, obtaining a magnet is a first priority to which the Bifrost team will seek external funding during the construction phase.

Option 2 would be a world-leading cold spectrometer on Day 1, gaining between 1-2 orders of magnitude compared to the expected state-of-the-art in 2023. Due to limited magnet availability and limited maximum field, some of the key science cases for Bifrost – mainly addressing quantum and frustrated magnetism, multi-ferroics as well as High-Tc superconductivity - will have to be deprioritized. However, a considerable part of the science cases can be addressed: Parametric overview studies of low-energy dynamics as a function of pressure and temperature, a subset of the multi-ferroic materials and extreme pressure geoscience.

The upgrade path for option 2 is straightforward. First priority is to design and procure a high field magnet optimized for the Bifrost geometry. Second priority is implementing polarization analysis and third priority is the order sorting option.

3.2. Costing

The costing is based on bottom-up calculation of the procurement costs and labor required for the tasks needed to deliver the higher-level PBS items.

Table 3 Costing for Bifrost Option 2

	Project Management and integration	Design	Procure-ment and fabrication	Installation	Cold commissioning	Non labour	Labour	Total
Shielding	€ 0	€ 189.000	€ 1.905.500	€ 259.200	€ 0	€ 1.905.500	€ 448.200	**€ 2.353.700**
Neutron Optics	€ 0	€ 27.000	€ 3.020.000	€ 100.000	€ 0	€ 2.950.000	€ 197.000	**€ 3.167.000**
Choppers	€ 0	€ 0	€ 841.000	€ 62.400	€ 20.000	€ 861.000	€ 62.400	**€ 923.400**
Sample Environment	€ 0	€ 100.000	€ 300.000	€ 3.840	€ 3.840	€ 300.000	€ 107.680	**€ 407.680**
Detector and beam monitor	€ 0	€ 200.000	€ 2.390.000	€ 54.000	€ 108.000	€ 2.390.000	€ 362.000	**€ 2.752.000**
DMSC	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	**€ 0**
Motion control		€ 0	€ 116.000	€ 15.000	€ 50.000	€ 116.000	€ 65.000	**€ 181.000**
Instrument specific Tech equipment	€ 1.260.000	€ 0	€ 600.000	€ 21.600	€ 27.000	€ 660.000	€ 1.248.600	**€ 1.908.600**
Instrument Infrastructure	€ 0	€ 27.000	€ 310.000	€ 172.800	€ 0	€ 310.000	€ 199.800	**€ 509.800**
Vacuum	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	**€ 0**
PSS	€ 0	€ 20.000	€ 50.000	€ 30.000	€ 20.000	€ 70.000	€ 50.000	**€ 120.000**
Contingency								**€ 1.355.550**
Phase I								**€ 300.000**
TOTAL	**€ 1.260.000**	**€ 563.000**	**€ 9.532.500**	**€ 718.840**	**€ 228.840**	**€ 9.562.500**	**€ 2.740.680**	**€ 13.978.730**
Man year	**12**	**7**	**0**	**9**	**2**			**30**

3.3. Upgrade/Staging plan

The estimated costs for a dedicated magnet would be of the order of **1 M€** - elaborated in option 3.

Polarization analysis is estimated to cost **1.5 M€**, elaborated in option 3. The option 2 allows us to build a secondary spectrometer tank that straightforwardly allows for an upgrade to polarization analysis, since room and infrastructure for guide field inserts can be built in beforehand.

The order sorting option requires building a new tank with room for 10 analysers comprised of 2m^2 of pyrolytic graphite. In addition, a fast chopper is needed before the sample. The total price for tank, chopper plus additional pyrolytic graphite and detectors is **3 M€.**

3.4. Risk

The main risks for this configuration are delays in delivery of various ESS systems and Bifrost components. A considerable risk in option 2, is not addressing the magnetism community due to the limited availability of a magnet. Below are top five risks rated high using ESS risk measures (impact x likelihood).

Table 4 : Top five risks for Option 2

Risk level	RISK	TREATMENT NAME	Treatment	CATEGORY	TREATMENT PLAN
High 4x4	Conventional Facilities Delay	***CF LEVEL ESS-0019533***	Observe	Schedule, budget, quality and function	Access to hall 2 is a milestone for Bifrost schedule. Bifrost team Responsible: CF
		External areas like labs and workshops	Mitigate		External areas will give the opportunity to start pre-installations Responsible: CF
High 3x5	Imroper design according to instrument requirements and Delay in monolith insert design	Schedule for external milestone	Observe	Schedule, budget, Quality and function	Follow the progress of the design and project schedule. Bifrost Team Responsible: target
		TARGET LEVEL ESS-0019533	Observe		Focus on Safety, feasibility and requirements Responsible: target
High 3x5	Late delivery of key components	Bifrost schedule	Mitigate	Schedule, budget	Properly assess the delivery time and transportation, also the time that is required for installation and arriving at site. Define the critical path for every component. Responsible: Bifrost Team
High 3x5	Failure to address the magnetism community key to Bifrost	External funding	Mitigate	Quality and function	Apply for funding to get a dedicated Bifrost magnet – to increase magnet time and maximum field.
High 3x5	Software insufficient to make full use of instrument capabilities	Collaborations	Mitigate	Quality and function	Seek external collaborations for common CAMEA backend software, and enforce compatibility with ESS standards

4. OPTION 3: PRIMARY SCOPE (16.35 M€)

4.1. Scope

The scope within this cost category is:

- Primary spectrometer, fulfilling requirement #1-3, #7 and #9.
- 90 degree angular coverage of the secondary spectrometer (#2)
- 12 Q-channels
- 6 analysers pr Q-Channel (#6)
- All necessary associated infrastructure (shielding, cabling, cabins etc.)
- High pressures through SAD pool and collaborations
- Evacuated secondary spectrometer tank (#15)
- Temperatures in the milli-Kelvin range (#14)
- Magnetic fields above 15 T (#12)
- Polarization analysis (#10)

This scope does **not** meet the following top-level requirements:

- Order sorting: Large energy transfers with large Q-range (#11)

The magnet strategy in the primary scope instrument is one of two options:

1) Procure a dedicated work horse magnet for Bifrost, maximum field 12 T with a large sample space, to be used only on Bifrost. Price: 500 K€

2) Procure an ambitious high-field magnet in collaboration with another instrument addressing magnetism. MAGiC is an obvious collaborator since the two instruments share an in-kind partner. This magnet would have a limited vertical opening angle, built-in radial collimation (which would also be highly advantageous on ToF spectrometers) and a large VTI. A Dy-booster could then be inserted to add 2.5 Tesla to the maximum field for small samples. The maximum field could be **over 18 T**, making ESS world leading in sample environment. Total price is 1 M€, 500 k€ pr instrument.

The polarization analysis for this option is achieved by implementing an S-bender polarizer and cryo-flipper before the sample. The last analyser upstream will be pyrolytic graphite in half of the Q-channels and Heusler analysers in the other half. This allows us to measure spin flip cross sections and full cross section in only two settings, with the world's most intense polarized beam and loosing few neutrons between sample and analyser.

Option 3 directly addresses the magnetism and superconductivity community – which are key communities for Bifrost - and thus covers a major part of Bifrost scope as defined in the accepted proposal. A dedicated Bifrost magnet would allow for a large portion of Bifrost beam-time being spent doing parametric studies of magnetic dynamics as a function of magnetic fields – the type of experiments where Bifrost would be completely unparalleled in performance in the near future. The polarized neutron option will be innovative and highly efficient, opening up an entirely new range of feasibility for polarized neutron spectroscopy,

The full scope instrument will that includes the order sorting option, will cost an additional 2.5 **M€** - with a total cost of the order of **19 M€.** If order sorting is implemented as an upgrade, a new tank will need to be procured, raising the total price to 20 M€.

4.2. Costing

The costing is based on bottom-up calculation of the procurement costs and labor required for the tasks needed to deliver the higher-level PBS items

Table 5 Costing for primary scope Bifrost

	Project Management and integration	Design	Procurement and fabrication	Installation	Cold commissioning	Non labour	Labour	Total
Shielding	€ 0	€ 189.000	€ 1.905.500	€ 259.200	€ 0	€ 1.905.500	€ 448.200	**€ 2.353.700**
Neutron Optics	€ 0	€ 27.000	€ 3.020.000	€ 100.000	€ 0	€ 2.950.000	€ 197.000	**€ 3.167.000**
Choppers	€ 0	€ 0	€ 841.000	€ 62.400	€ 20.000	€ 861.000	€ 62.400	**€ 923.400**
Sample Environment	€ 0	€ 100.000	€ 800.000	€ 3.840	€ 3.840	€ 800.000	€ 107.680	**€ 907.680**
Detector and beam monitor	€ 0	€ 350.000	€ 3.890.000	€ 54.000	€ 108.000	€ 3.890.000	€ 512.000	**€ 4.402.000**
DMSC	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	**€ 0**
Motion control		€ 0	€ 116.000	€ 15.000	€ 50.000	€ 116.000	€ 65.000	**€ 181.000**
Instrument specific Tech equipment	€ 1.260.000	€ 0	€ 600.000	€ 21.600	€ 27.000	€ 660.000	€ 1.248.600	**€ 1.908.600**
Instrument Infrastructure	€ 0	€ 27.000	€ 310.000	€ 172.800	€ 0	€ 310.000	€ 199.800	**€ 509.800**
Vacuum	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	**€ 0**
PSS	€ 0	€ 20.000	€ 50.000	€ 30.000	€ 20.000	€ 70.000	€ 50.000	**€ 120.000**

Contingency								**€ 1.592.050**
Phase I								**€ 300.000**
TOTAL	**€ 1.260.000**	**€ 713.000**	**€ 11.532.500**	**€ 718.840**	**€ 228.840**	**€ 11.562.500**	**€ 2.890.680**	**€ 16.365.230**
Man year	**12**	**8**	**0**	**9**	**2**			31

4.3. Risk

The main risks for this configuration are delays in delivery of various ESS systems and Bifrost components.

Below are top five risks rated high using ESS risk measures (impact x likelihood).

Table 6 : Risks for Option 3

Risk level	RISK	TREATMENT NAME	Treatment	CATEGORY	TREATMENT PLAN
High 4x4	Conventional Facilities Delay	***CF LEVEL ESS-0019533***	Observe	Schedule, budget, quality and function	Access to hall 2 is a milestone for Bifrost schedule. Loki team Responsible: CF
		External areas like labs and workshops	Mitigate		External areas will give the opportunity to start pre-installations Responsible: CF
High 3x5	Improper design according to instrument requirements and Delay in monolith insert design	Schedule for external milestone	Observe	Schedule, budget, Quality and function	Follow the progress of the design and project schedule. Bifrost Team Responsible: target
		TARGET LEVEL ESS-0019533	Observe		Focus on Safety, feasibility and requirements Responsible: target
High 3x5	Late delivery of key components	Bifrost schedule	Mitigate	Schedule, budget	Properly assess the delivery time and transportation, also the time that is required for installation and arriving at site. Define the critical path for every component. Responsible: Bifrost Team
High 3x5	Software insufficient to make full use of instrument capabilities	Collaborations	Mitigate	Quality and function	Seek external collaborations for common CAMEA backend software, and enforce compatibility with ESS standards
4x2	Problematic Activation of magnet and sample environment	Design	Mitigate	Quality and function	Design the magnet with extensive shielding in mind, to avoid magnet activation. Design a radiation shield for protection during sample change and cave access Responsible: Bifrost team