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| Scope Setting Report Instrument: VESPA - Neutron Vibrational Spectroscopy |
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Summary

The purpose of this document is to describe the possible baseline options for the VESPA project and how the instrument performance will be upgraded over time after the construction project, to get from the day-one scope to the full scope as envisaged in the instrument proposal.

Three possible baseline options are presented. Additionally, a discussion of other opportunities that may lower cost, increase performance and, potentially, lower risk is presented.

VESPA has been assigned to cost category B (12 M€). The conclusion from analysing the costs is that it is not possible to deliver VESPA within cost category B in a manner that provides adequate day-one performance.

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# OVerview

## Science Case [1]

The fundamental idea behind the *Neutron Vibrational Spectroscopy* (NVS) technique is analogous to that exploited in optical spectroscopy: an incoming beam, carrying energy larger than that of the internal excitations of the material of interest, is directed at the sample. The resulting energy loss upon excitation of a vibrational mode gives direct information on the vibrational energy level structure of the sample. In general, vibrational spectroscopy is a fundamental technique used constantly in educational, research, and industrial laboratories all over the world. Its applications in the investigation of solids and liquids, soft matter, complex fluids, and biomaterials are well-known. Indeed, it has become an essential tool in medical applications, forensics, environmental compliance, and quality control to cite but a few common uses. Fundamentally, vibrational spectroscopy probes potential energy surfaces and interatomic interactions. Alone or in combination with other techniques, vibrational spectroscopy permits the identification of bonds and functional groups, as well as the transformations that occur when bonds are broken and made in chemical reactions (e.g. in catalysis or thermal decomposition). The vibrational density of states is of great interest in itself, being related to various thermodynamic properties such as specific heat or entropy. The vibrational spectrum is affected by configurational changes in molecules thereby also providing structural information. Specifically, spectroscopy with neutrons, NVS, exploits the large incoherent scattering cross section of the hydrogennucleus. Proton dynamics or vibrations connected to the movement of ‘H’ atoms can be easily detected spectroscopically with neutrons, even if ‘H’ is dissolved at very low concentrations in materials composed mostly of heavier atoms – a problem that could not be solved with optical spectroscopy. For this reason, the technique attracts a high interest in the scientific community operating in the fields of chemistry, materials science, physics and biology, with a particular emphasis on applications.

One of the big advantages of an NVS instrument resides in the possibility to get a picture of the complete spectrum “in one shot” – from the elastic line and phonon region, the librations up to the vibrations. The science case mandates to optimize the instrument for the fingerprint (60-220 meV) region, however extending the energy range to 500 meV comes at no extra cost and with no performance loss for the fingerprint region. In other words, the high-energy neutrons can be used (or not used) without essentially changing the instrumental design. The instrument length has been optimized to provide a broad spectral range while maintaining the desired high energy resolution (≈1-2% of the incoming neutron energy). The possibility of optimizing the resolution at the expenses of the count rate or, on the contrary, sacrificing the resolving power to increase the instrument flux at the sample position, is a bonus that makes VESPA unique among the other indirect geometry instruments worldwide. Nonetheless, once a configuration is selected, the full spectra are collected in a single ESS pulse, thus making kinetic or parametric experiments feasible and easy to interpret.

## Requirements [1,2]

The high-level requirements for VESPA define the target scope for the instrument construction project. They have been formulated in order to summarize the key aspects of the instrumental scientific case of the proposal and are listed below:

1. VESPA shall provide a high neutron flux in the so called “fingerprint region” of vibrational spectroscopy (i.e. 60 meV<*E*<220 meV), overtaking that of the existing leading neutron vibrational spectrometers: 1.1÷5.3×106 n/cm2/s/meV at *E*0=60 meV on sample and 1.5÷2.6×103 n/cm2/s/meV at *E*0=220 meV on sample.
2. VESPA shall offer a constant (relative) energy resolution at three distinct values from Δ*E/E*0=0.9% to Δ*E/E*0=2.3% for neutron vibrational spectroscopy in a broad energy transfer range: 1 meV*<E<*500 meV. The detection solid angle range in the full scope instrument configuration will be about 1.2 sr.
3. VESPA shall be able to trade neutron flux for energy resolution using a flexible pulse shaping chopper configuration made of three pairs of counter-rotating chopper blades.
4. VESPA shall make full use of the ESS long pulse via an instrument length of *L*0=59 m and a usable incoming neutron wavelength range from λ=0.4 to 4.5 Å.
5. The VESPA design, especially its sample environment area, shall provide the space and flexibility necessary to host and drive future developments combining neutron vibrational spectroscopy with other techniques (e.g. high pressure, laser heating, electrochemistry, magnetic resonance, Raman, IR etc.).

## Configuration options

Three configuration options are presented:

1. A configuration within cost category B (i.e. 12.0 M€). The aim was to meet the cost category. This configuration is not completely functional as the WFM-PSC set-up allows only one resolution mode setting, the HOPG analyser is limited to 5 modules in total, and the sample environment equipment is limited to have a dedicated closed-cycle refrigerator (CCR).

Cost : 12.8 M€ (no *PPS* chopper, 2 WFM-PSCs, 5 modules with HOPG backscattering analysers (1/3 of the backscattering analysers, 1/6 of the total inelastic detector), 1 diffraction bank only at 90 deg., reduced sample environment with no gas adsorption manifold, no photoexcitation, no in-situ experimental setup).

1. A configuration to meet the minimum suggested scope to achieve early science success. Cost : 14.8 M€ (no *PPS* chopper, 3 WFM-PSCs, 15 modules with HOPG backscattering analysers, full sample environment equipment including in-situ).
2. A configuration that is achieving the full declared technical scope. Cost : 17.6 M€ (*PPS* chopper, forward-scattering analysers plus three additional diffraction detector banks: 1 in backscattering and the other 2 at 90 deg.).

# Option 1 : Scope within Cost Category B (12M€)

## Scope

* Neutron delivery by mirrored guide system (*m*=4) with elliptical geometry to maximise the neutron flux at the sample position.
* Sample position at 59 m.
* 2 pairs of WFM-PS double-disk counter-rotating choppers allowing the instrument to exhibit one resolution mode only, e.g. the high resolution (∆*t/t =* 0.5%).
* 1 Frame Overlap Chopper double-disk counter-rotating at 10 m from the moderator.
* 2 sub-Frame Overlap Choppers:
	+ double-disk counter-rotating at 15.5 m from the moderator;
	+ double-disk counter-rotating at 52 m from the moderator.
* Secondary spectrometer including:
	+ 1 x back-scattering analyser bank (Bragg angle 40°) with 3 HOPG modules;
	+ 1 x back-scattering analyser bank (Bragg angle 60°) with 2 HOPG modules;
	+ each modules includes a HOPG crystal, a Be-filter with CCR, 20 3He tubes detectors.
* Diffraction bank at 90° with 8 3He detector tubes.
* Vacuum vessel.
* Sample environment:
	+ 1 x removable automatic sample changer;
	+ 1 x closed-cycle top-loading cryostat;
* All necessary associated infrastructures (shielding, cabling, cabins etc.).

This scope does **not** meet the top level requirements for:

* prompt pulse suppression;
* solid angle coverage of the HOPG analysers (5 modules vs 30);
* coverage of the diffractometer limited to the angle 2θ=85°-95°.
* NO equipment to support catalysis, gas adsorption work or other in-situ experiments.

This is upgradeableto a setup that does meet the basic scope, with minor modifications of the instrument adding a double-disc WFM-PSC in the bunker, other analyser and diffraction modules that can be mounted in the frame, and additional sample environment equipment that can be installed in a later stage completing the experimental hutch.

## Costing

Costing is based on a bottom-up calculation of the procurement costs and manpower required for the tasks needed to deliver the higher level PBS items. Vacuum equipment is not included in the cost as this is expected to be delivered from outside the VESPA budget; the only costs related to this voice are for windows, flanges and gates.

The budget for each phase and task includes: shipping, labour and travel cost.

Table 1 Costing for VESPA in Cost Category B

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|   | **01 Phase 1** | **02 Project Management & Integration** | **03 Design** | **04 Procurement & Fabrication** | **05 Installation** | **06 Cold Commissioning** | **Total** |
| **01 Shielding** | 5 k€ | 79 k€ | 159 k€ | 1,507 k€ | 397 k€ | 35 k€ | 2,181 k€ |
| **02 Neutron Optics** | 4 k€ | 128 k€ | 256 k€ | 2,430 k€ | 639 k€ | 55 k€ | 3,511 k€ |
| **03 Choppers** | 4 k€ | 65 k€ | 100 k€ | 1,231 k€ | 324 k€ | 55 k€ | 1,778 k€ |
| **04 Sample Environment** | 4 k€ | 7 k€ | 30 k€ | 133 k€ | 35 k€ | 20 k€ | 229 k€ |
| **05 Detector and Beam Monitors** | 4 k€ | 38 k€ | 75 k€ | 722 k€ | 190 k€ | 65 k€ | 1,094 k€ |
| **06 Data Acquisition and Analysis** | 4 k€ | 10 k€ | 50 k€ | 185 k€ | 35 k€ | 35 k€ | 319 k€ |
| **07 Motion Control and Automation** | 4 k€ | 10 k€ | 50 k€ | 124 k€ | 26 k€ | 25 k€ | 239 k€ |
| **08 Instrument Specific Technical Equipment** | 4 k€ | 0 k€ | 0 k€ | 0 k€ | 0 k€ |   | 4 k€ |
| **09 Instrument Infrastructure** | 4 k€ | 129 k€ | 150 k€ | 1,227 k€ | 323 k€ | 25 k€ | 1,858 k€ |
| **10 Vacuum** | 4 k€ | 5 k€ | 15 k€ | 95 k€ | 25 k€ | 20 k€ | 164 k€ |
| **11 PSS** | 4 k€ | 9 k€ | 50 k€ | 162 k€ | 43 k€ | 30 k€ | 297 k€ |
| **12 Contingency** | 5 k€ | 48 k€ | 93 k€ | 781 k€ | 204 k€ | 37 k€ | **1,167 k€** |
| **Total**  | **50 k€** | **527 k€** | **1,028 k€** | **8,596 k€** | **2,240 k€** | **402 k€** | **12,841 k€** |
| **Labour included in above (Person-Years)** | 1 | 4 | 9 | 7 | 10 | 3 | **34** |
| **Labour/shipping included in above** | **50 k€** | **500 k€** | **900 k€** | **750 k€** | **860 k€** | **390 k€** | **3,450 k€** |

## Upgrade/Staging plan

The staging plan for this option includes:

1. a third WFM-PSC to vary the wavelength resolution;
2. the upgrade of the analyser with additional 10 modules (5 with Bragg angle 40°, 5 with Bragg angle 60°) reaching a total of 15 analyser modules in backscattering;
3. a spare removable automatic sample changer;
4. full in-situ equipment to support catalysis and gas adsorption work.

## Risk

The main risk with this configuration is a poor performance of the instrument with respect to the existing ones VISION at SNS and TOSCA at ISIS. This is a setup that will not achieve the required early scientific success.

Concerning the technology related risk, the availability of 3He and related squashed tubes for the detection of neutrons at the experimental cave is the main source of uncertainty.

The lack of a PPS chopper to block the prompt pulse can affect the signal at the secondary spectrometer by significantly increasing the background, although the indirect geometry of the instrument should allow a proper performance for the science case.

The table below reports the top 5 risks, rated using ESS risk measures (ref. ESS 0020044) for the project.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Risk level | RISK | TREATMENT NAME | Treatment | CATEGORY | TREATMENT PLAN |
| High 2x5 | Helium technology  | Technology availability | Observe | Cost overrun on Construction budget | Define/develop optional technology for neutron detection at the secondary spectrometer |
| High 5x2 | Unclear Bunker arrangement, inability to maintain or install or remove equipment due to high radiation levels and long shielding removal times. | Bunker access | Mitigate | Cost overrun on annual Operation costs | Detailed design and reliability evaluation of the system components into the bunker, with FMEA technique |
| High 4x3 | Delays caused by optimisation of the instruments |  | mitigate | Schedule, budget  |  Detailed time scheduling plus intermediate deliverables on neutrons calculation tasks |
| High 4x3 | Perfomance stays under user and ESS expectation | 12 MEuro performance | Observe | Quality and function | Costs optimisation, alternative funding stage plan  |
| Medium 3x2 | Late delivery of key components | VESPA 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.  |

# Option 2 : 15 MODULES backscattering analyser/full sample environment

## Scope

* Neutron delivery by mirrored guide system (*m*=4) with elliptical geometry to maximise the neutron flux at the sample.
* Sample position at 59 m.
* 3 pairs of WFM-PS double-disk counter-rotating choppers modulating the instrument resolution between three possible settings: low (∆*t/t =* 1.8%), medium (∆*t/t =* 1.2%), and high resolution (∆*t/t =* 0.5%).
* 1 Frame Overlap Chopper double-disk counter-rotating at 10 m from the moderator.
* 2 sub-Frame Overlap Choppers:
	+ double-disk counter-rotating at 15.5 m from the moderator;
	+ double-disk counter-rotating at 52 m from the moderator.
* Secondary spectrometer including:
	+ 1 x back-scattering analyser bank (Bragg angle 40°) with 7 HOPG modules;
	+ 1 x back-scattering analyser bank (Bragg angle 60°) with 8 HOPG modules;
	+ each modules includes a HOPG crystal, a Be-filter with CCR, 20 3He tubes detectors.
* Diffractometer at 90° with 8 3He detector tubes.
* Vacuum vessel.
* Sample environment:
	+ 2 x removable automatic sample changer;
	+ customized closed-cycle top-loading cryostats;
	+ Gas adsorption equipment and photoexcitation setup.
* All necessary associated infrastructures (shielding, cabling, cabins etc.).

This scope does **not** meet the top level requirements for:

* prompt pulse suppression;
* solid angle coverage of the HOPG analysers;
* coverage of the diffractometer limited to the angle 2θ=85°-95°.

This setup is easily upgradeable **to full scope with only** minor modifications of the instrument. A cave for the prompt suppression pulse chopper placement at 15.5 m from the moderator has been considered in the present layout, as well as the room for the arrangement of the additional HOPG banks in forward scattering and the diffractometer 3He tubes to cover an extended angle range 2θ=75°-105° in the equatorial position, and 2θ=162°-172° in backscattering.

## Costing

Costing is based on a bottom-up calculation of the procurement costs and manpower required for the tasks needed to deliver the higher level PBS items. Vacuum equipment is not included in the cost as this is expected to be delivered from outside the VESPA budget, the only costs related to this voice are for windows, flanges and gates.

The budget for each phase and task includes labour and travel cost. Sample environment budget includes all the equipment that the instrument needs to perform its science scope.

Table 2 Costing for VESPA in OPTION 2

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|   | 01 Phase 1 | 02 Project Management & Integration | 03 Design | 04 Procurement & Fabrication | 05 Installation | 06 Cold Commissioning | Total |
| **01 Shielding** | 5 k€ | 79 k€ | 159 k€ | 1,507 k€ | 397 k€ | 35 k€ | 2,181 k€ |
| **02 Neutron Optics** | 4 k€ | 128 k€ | 256 k€ | 2,430 k€ | 639 k€ | 55 k€ | 3,511 k€ |
| **03 Choppers** | 4 k€ | 65 k€ | 100 k€ | 1,404 k€ | 353 k€ | 55 k€ | 1,981 k€ |
| **04 Sample Environment** | 4 k€ | 19 k€ | 30 k€ | 295 k€ | 50 k€ | 20 k€ | 418 k€ |
| **05 Detector and Beam Monitors** | 4 k€ | 50 k€ | 75 k€ | 1,854 k€ | 390 k€ | 65 k€ | 2,439 k€ |
| **06 Data Acquisition and Analysis** | 4 k€ | 10 k€ | 50 k€ | 185 k€ | 35 k€ | 35 k€ | 319 k€ |
| **07 Motion Control and Automation** | 4 k€ | 10 k€ | 50 k€ | 124 k€ | 26 k€ | 25 k€ | 239 k€ |
| **08 Instrument Specific Technical Equipment** | 4 k€ | 0 k€ | 0 k€ | 0 k€ | 0 k€ |   | 4 k€ |
| **09 Instrument Infrastructure** | 4 k€ | 129 k€ | 150 k€ | 1,227 k€ | 323 k€ | 25 k€ | 1,858 k€ |
| **10 Vacuum** | 4 k€ | 5 k€ | 15 k€ | 95 k€ | 25 k€ | 20 k€ | 164 k€ |
| **11 PSS** | 4 k€ | 9 k€ | 50 k€ | 162 k€ | 43 k€ | 30 k€ | 297 k€ |
| **12 Contingency** | 5 k€ | 50 k€ | 93 k€ | 928 k€ | 228 k€ | 37 k€ | **1,341 k€** |
| **Total**  | **50 k€** | **554 k€** | **1,028 k€** | **10,210 k€** | **2,509 k€** | **402 k€** | **14,752 k€** |
| **Labour included in above (Person-Years)** | **1** | **4** | **10** | **7** | **10** | **3** | **35** |
| **Labour/shipping included in above** | **50 k€** | **500 k€** | **1,000 k€** | **750 k€** | **860 k€** | **390 k€** | **3,550 k€** |

## Upgrade/Staging plan

The staging plan for this option includes:

1. the installation of a Prompt Pulse Suppression Chopper (PPSC) at a distance of 15.5 m from the moderator to improve the signal to noise ratio at the secondary spectrometer;
2. the upgrade of the analyser with additional 15 modules (7 with Bragg angle 40°, 8 with Bragg angle 60°) in forward scattering, reaching the full-scope coverage with a solid angle of 1.2 sr;
3. the extension of the diffractometer banks with additional 24 3He tubes to cover an angle range 2θ=75°-105° in equatorial position, and 2θ=162°-172° in backscattering, reaching the full-scope coverage.

## Risk

The main risk with this configuration is related to the availability of 3He and related squashed tubes for the detection of neutrons at the experimental cave.

The lack of shielding for the prompt pulse can affect the signal at the secondary spectrometer, although the indirect geometry of the instrument should allow a proper performance for the science case.

The table below reports the top 5 risks, rated using ESS risk measures (ref. ESS 0020044) for the project.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Risk level | RISK | TREATMENT NAME | Treatment | CATEGORY | TREATMENT PLAN |
| High 2x5 | Helium technology  | Technology availability | Observe | Cost overrun on Construction budget | Define/develop optional technology for neutron detection at the secondary spectrometer |
| High 5x2 | Unclear Bunker arrangement, inability to maintain or install or remove equipment due to high radiation levels and long shielding removal times. | Bunker access | Mitigate | Cost overrun on annual Operation costs | Detailed design and reliability evaluation of the system components into the bunker, with FMEA technique |
| High 4x3 | Delays caused by optimisation of the instruments |  | mitigate  |  Schedule, budget |  Detailed time scheduling plus intermediate deliverables on neutrons calculation tasks |
| Medium 3x2 | Late delivery of key components | VESPA 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.  |
| Medium 3x3 | Detector count rate  | Detectors Action plan and schedule with mitigation plan | Observe | Schedule, budget, quality and function |   |

# Option 3: FULL Scope

## Scope

The full instrument scope consists of:

* neutron delivery by mirrored guide system (*m*=4) with elliptical geometry to maximise the neutron flux at the sample.
* Sample position at 59 m.
* 3 pairs of WFM-PS double-disk counter-rotating choppers modulating the instrument resolution between three possible setting: low (∆*t/t =* 1.8%), medium (∆*t/t =* 1.2%), and high resolution (∆*t/t =* 0.5%).
* 1 Frame Overlap Chopper double-disk counter-rotating at 10 m from the moderator.
* 2 sub-Frame Overlap Choppers:
	+ double-disk counter-rotating at 15.5 m from the moderator;
	+ double-disk counter-rotating at 52 m from the moderator.
* 1 Prompt Pulse Suppression chopper at 15.5 m from the moderator.
* Secondary spectrometer including:
	+ 1 x back-scattering analyser bank (Bragg angle 40°) with 7 HOPG modules;
	+ 1 x back-scattering analyser bank (Bragg angle 60°) with 8 HOPG modules;
	+ 1 x forward-scattering analyser bank (Bragg angle 40°) with 7 HOPG modules;
	+ 1 x forward-scattering analyser bank (Bragg angle 60°) with 8 HOPG modules;
	+ each modules includes a HOPG crystal, a Be-filter with CCR, 20 3He tubes detectors.
* Diffractometer at 90° with 24 3He detector tubes; Diffractometer in backscattering with 8 3He detector tubes.
* Vacuum vessel
* Sample environment:
	+ 2 x removable automatic sample changer;
	+ dedicated customized closed-cycle top-loading cryostat;
	+ Gas adsorption equipment and photoexcitation setup.
* All necessary associated infrastructure (shielding, cabling, cabins etc.).

This scope meets the top level requirements included in the instrument proposal and fulfils the science case.

## Costing

The costing is based on a bottom-up calculation of the procurement costs and manpower required for the tasks needed to deliver the higher level PBS items. Vacuum equipment is not included in the cost as this is expected to be delivered from outside the VESPA budget; the only costs related to that voice are for windows, flanges and gates.

Compared to Option-1, the project cost estimation is increased by the costs of additional components (PPSC and analyzer banks), and the related effort for their design and integrations into the system.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|   | **01 Phase 1** | **02 Project Management & Integration** | **03 Design** | **04 Procurement & Fabrication** | **05 Installation** | **06 Cold Commissioning** | **Total** |
| **01 Shielding** | 5 k€ | 79 k€ | 200 k€ | 1,507 k€ | 500 k€ | 50 k€ | 2,341 k€ |
| **02 Neutron Optics** | 4 k€ | 128 k€ | 256 k€ | 2,430 k€ | 639 k€ | 55 k€ | 3,511 k€ |
| **03 Choppers** | 4 k€ | 65 k€ | 120 k€ | 1,686 k€ | 353 k€ | 65 k€ | 2,293 k€ |
| **04 Sample Environment** | 4 k€ | 19 k€ | 30 k€ | 295 k€ | 70 k€ | 30 k€ | 448 k€ |
| **05 Detector and Beam Monitors** | 4 k€ | 50 k€ | 120 k€ | 3,500 k€ | 800 k€ | 75 k€ | 4,549 k€ |
| **06 Data Acquisition and Analysis** | 4 k€ | 10 k€ | 50 k€ | 185 k€ | 35 k€ | 35 k€ | 319 k€ |
| **07 Motion Control and Automation** | 4 k€ | 10 k€ | 50 k€ | 124 k€ | 26 k€ | 25 k€ | 239 k€ |
| **08 Instrument Specific Technical Equipment** | 4 k€ | 0 k€ | 0 k€ | 0 k€ | 0 k€ |   | 4 k€ |
| **09 Instrument Infrastructure** | 4 k€ | 129 k€ | 150 k€ | 1,227 k€ | 323 k€ | 25 k€ | 1,858 k€ |
| **10 Vacuum** | 4 k€ | 5 k€ | 15 k€ | 95 k€ | 25 k€ | 20 k€ | 164 k€ |
| **11 PSS** | 4 k€ | 9 k€ | 50 k€ | 162 k€ | 43 k€ | 30 k€ | 297 k€ |
| **12 Contingency** | 5 k€ | 50 k€ | 104 k€ | 1,121 k€ | 281 k€ | 41 k€ | **1,602 k€** |
| **Total**  | **50 k€** | **554 k€** | **1,145 k€** | **12,330 k€** | **3,095 k€** | **451 k€** | **17,625 k€** |
| **Labour included in above (Person-Years)** | 1 | 4 | 11 | 7 | 12 | 3 | **38** |
| **Labour/shipping included in above** | **50 k€** | **500 k€** | **1,060 k€** | **750 k€** | **1,200 k€** | **390 k€** | **3,950 k€** |

## Upgrade/Staging plan

The staging plan for this option considers the improvement of the capability of the instrument by the implementation of 1 additional bank of analysers in forward scattering and back scattering position (either with a different Bragg angle respect the 40° and 60° of the full scope set-up, or using different crystals than HOPG) and extending the solid angle covered by the secondary spectrometer detectors. A possible final improvement of the capability of the instrument is the introduction of a statistical chopper allowing for the application of correlation spectroscopy to inelastic neutron scattering.

## Risk

The main risk with this configuration is related to the availability of 3He and related squashed tubes for the detection of the neutrons at the experimental cave.

The table below reports the top risks rated using ESS risk measures (ref. ESS 0020044) for the project.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Risk level | RISK | TREATMENT NAME | Treatment | CATEGORY | TREATMENT PLAN |
| High 2x5 | Helium technology  | Technology availability | Observe | Cost overrun on Construction budget | Define/develop optional technology for neutron detection at the secondary spectrometer |
| High 5x2 | Unclear Bunker arrangement, inability to maintain or install or remove equipment due to high radiation levels and long shielding removal times. | Bunker access | Mitigate | Cost overrun on annual Operation costs | Detailed design and reliability evaluation of the system components into the bunker, with FMEA technique |
| High 4x3 | Delays caused by optimisation of the instruments |  | mitigate  |   Schedule, budget |  Detailed time scheduling plus intermediate deliverables on neutrons calculation tasks |
| Medium 3x2 | Late delivery of key components | VESPA 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.  |
| Medium 3x3 | Detector count rate  | Detectors Action plan and schedule with mitigation plan | Observe | Schedule, budget, quality and function |   |

# References

[1] see also VESPA Concept of Operations document, Sept. 2016.

[2] see also VESPA System Requirements document, Sept. 2016.