VESPA, the Neutron Vibrational Spectrometer at the ESS

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VESPA is the neutron vibrational spectrometer at the ESS. The instrument is designed to study molecular vibrations and address a wide range of research areas highly relevant to society and industry, such as renewable energies or catalysis[[1]](#footnote-1). VESPA capabilities are broad band neutron spectroscopy using 14 spectroscopy modules, and medium resolution neutron powder diffraction and pair distribution function analysis using one backscattering and 6 lateral diffraction banks, respectively. The VESPA end-station also includes a transmission monitor, mainly used to normalise the spectra to absolute units.

VESPA beam transport and conditioning system constitutes a high-*m* supermirror (*m* values ranging from 3 to 5) with an elliptic profile, 3 pairs of high-speed pulse-shaping choppers (PSC), one frame-overlap chopper (FOC) disk and three subframe-overlap chopper (sFOC) disks. Note that a 3rd sFOC disk has been added to the scope in June 2024 to better suppress parasitic streams going through the original chopper cascade. The later (chopper positions, velocities and slit patterns) have also been reworked to improve flux at sample position providing up to 35% increase in the fingerprint region of the spectra (60-220 meV) in the High-Flux (HF) configuration. The complete instrument also includes a T0 chopper – not in day 1 scope, yet that is the highest priority item in the rescoping ambition of VESPA for the instrument to achieve state-of-the-art signal-to-noise ratio (SNR). The BTCS also includes a single – from two previously envisaged – slit package, located at the end of the guide, to control the size of the beam spot from (width × height) 3 × 4 cm2 down to 1.6 × 1.0 cm2.

VESPA secondary spectrometer is derived from the original “wheel-type” geometry of TOSCA at ISIS, further developed on VISION at SNS, where spectroscopy modules are positioned in a circular pattern in equatorial position around the sample. Each spectroscopy module is constituted of a large image-focusing analyser made out of highly-oriented pyrolytic graphite (HOPG) crystals, a cryo-cooled beryllium filter with built-in collimation, and a detector cartridge constituted of 3He position-sensitive detector (PSD) tubes. The concept design of VESPA secondary spectrometer has been updated to reflect the latest developments proposed for the TOSCA+ upgrade[[2]](#footnote-2). In this latest version of the wheel-type design, the forward and backward facing modules are staggered so that all detector cartridges lay strictly in the sample plane – instead of being arranged back-to-back with shielding material in between to avoid cross-talk. Such staggering has two effects: (1) it improves the energy resolution of the instrument at high energy transfer and, more importantly, (2) it increases the maximum envelope of the beryllium filter, thus leaving room to offset the filter and to significantly expand the solid angle coverage of the analyser, up to a value of Ω = 6.8 sr, increased from an original analyser coverage of 5.2 sr. In this updated design, 18-20 3He are required per detector cartridge, and the beryllium mass is estimated at 14 kg per filter. Further performance gains are achieved by modifying the beryllium filter collimation geometry, from horizontal/radial to vertical, which improves the transmission of analysed neutrons, from values in the 50-60% to values in the 75-80%, thus leading to a significant increase in detected intensity.

Information about a selection of activities achieved in 2024 are detailed below, which include recruitment of staff, review and finalisation of VESPA primary spectrometer design, space allocation for VESPA end-station, and rescoping. Further activities such as the progress on the secondary spectrometer or neutronics testing will be discussed in the presentation.

# 1. Recruitment of staff

Following the meeting between the CNR and ESS in Rome in February 2023 and subsequent Technical Annex amendment signed in November 2023, an instrument team has been constituted at ESS. This includes Liam Whitelegg as ESS lead engineer from January 2024 (50%), Adrien Perrichon as ESS lead scientist from March 2024 (100%), Rosa Camilleri Lledó as ESS co-lead engineer from September 2024 (100%) and Gianfranco Belcastro as mechanical engineer (50%) through the CNR/ISIS collaboration from October 2024. Additionally, a full-time dedicated mechanical engineer position at ESS, opened since Spring 2024, is still vacant.

Despite this successful recruitment campaign which enabled to bring momentum back to the instrument project, the lack of a dedicated and experienced mechanical engineer based at ESS is currently the bottleneck to complete the design of the secondary spectrometer of VESPA, which will be determining the completion date of the project.

# 2. Review and finalisation of VESPA primary spectrometer design

From March 2024, the main activity of the instrument team formed at ESS was to review and finalise the design of VESPA, starting with the primary spectrometer and, with a particular urgency, with the chopper system. Indeed, the design of the PSC disk patterns had to be finalised before June 2024, so that the supplier could proceed with their manufacturing.

The review of the chopper cascade has indicated that the existing design would not achieve the performance required for the scientific scope of VESPA. Most critical was the systematic presence of parasitic streams of neutrons emerging from the decaying tail of the ESS long pulse and let through the repetition of the high-speed PSC openings, leading to textured background of the order of 0.1-1% of the main subframe intensities. Fixing this issue to ensure that the intensity of such streams is <10-6 in relative intensity required (1) to reduce the operating frequency and disrupt the periodicity of the PSC choppers, from 154 Hz for the three pairs to 140 Hz for PSC1 and 126Hz for PSC2 and PSC3; (2) add an addition sFOC disk, to be integrated in the same casing as the FOC disk near the 10 m mark. The cost of suppressing these parasites is an unavoidable decrease in flux in the region where subframe overlaps, due to longer cutting times.

Additionally, the resolution of the primary spectrometer in the HF and High-Resolution (HR) modes were relaxed to achieve the nominal total resolution target of 2.5% of the incident energy (Ei) in the HF mode, and a resolution of about 1% of Ei in the HR mode, which corresponds to the optimal situation where the resolutions of the primary and secondary spectrometer are matched. This modification led to a 35% and 24% increase in flux in the fingerprint region in the HF and HR modes, respectively. This required an adjustment of the positions and slit patterns of the PSC/FOC choppers.

Finally, the operation to switch from HF to HR modes was modified. Indeed, instead of having only 2 of the 3 PSC pairs in operation for each mode, as originally proposed, now all 3 pairs are in operation simultaneously, and the mode switch is achieved by phase control of PSC2. This change allows the resolution of subframe 1 (20-1200 meV) to be fully controllable from 0.8% to 2.35% of Ei. The price is that the resolution of subframes 2 and 3 (<20 meV) cannot be controlled, which is however not critical since the total resolution function is dominated by the contribution of the secondary spectrometer at low energy transfer (5% of Ei at 3.5 meV).

The modification to the chopper cascade has been reviewed and approved, and the additional sFOC disk has been added to VESPA scope through a change request which will eventually be followed by a Technical Annex amendment. The choppers are well on track with ongoing design efforts from the ESS Chopper group, and with the PSC disks being currently manufactured by Airbus.

As the design of the chopper cascade was finalised, and the exact position of the gaps in the guide was fixed, the preliminary design of the supermirror guide could be completed. Drawings and technical specification documents are currently being produced, and the procurement is expected to start by January 2025.

# 3. Space allocation for VESPA end-station

The review of VESPA end-station (upper and lower cave, sample preparation area) indicated that the current space allocation – strictly within the instrument E7 wedge – would lead to deficiencies of access and maintainability of the secondary spectrometer, in addition to limitations in terms of capacity and capabilities for sample preparation and sample environments. As such, limiting the size of the end-station to the area proposed originally would ultimately negatively affect the scientific impact and possibilities of the instrument. To remediate this situation, and provide enough space for future developments to best serve the user community, an expansion of VESPA end-station, past the 50 m mark from the moderator, has been proposed. Several options have been investigated, also considering the long-term strategic development of neutron instruments at ESS, and VESPA has been allocated part of the E6 wedge, in exchange of minimising the footprint at the interface with E8. This implies that only a short capacity instrument can be installed on E6, but it leaves more space for a state-of-the-art instrument on E8. The preliminary design of the caves and sample preparation are ongoing.

# 4. Rescoping

The added scope required to complete VESPA can be classified in three independent categories. These are, by order of scientific priorities to maximise the scientific impact of the instrument and ensure its competitiveness: (1) the addition of a T0 chopper, (2) the addition of 10 spectroscopy modules, and (3) the addition of 4 diffraction panels.

The T0 chopper is the highest priority item as we estimate that its absence would lead to severe background issues, such as entirely preventing the measurement of the elastic line and low-lying excitations, significantly degrading the background at high energy transfer, as well as causing unpredictable textured background from secondary scattering events for which the neutron timestamp is lost. This leads to a severe risk for the scientific impact of VESPA due to elevated SNR. Indeed, if the SNR is degraded beyond what is available at other facilities due to the absence of a T0 chopper, VESPA, regardless of its flux on sample, will be unable to support challenging experiments.

The second important rescoping request is the completion of the spectroscopy banks. Indeed, while the full VESPA scope constitutes 14 analyser modules, only 4 modules are currently in day 1 scope, and only 3 modules may be built based on the current instrument budget. This means that the solid angle coverage of the analyser may be as much as a factor 2 lower than currently achieved on VISION at SNS, and subsequently that the flux on detector will not enable experiments beyond what is currently achievable on VISION. Rescoping the instrument by fully completing the spectroscopy banks corresponds to a gain of 350% in detected intensity, makes the flux in the HR setting competitive with VISION, and ensures that the flux in HF setting is state-of-the-art.

1. <https://europeanspallationsource.se/instruments/vespa> [↑](#footnote-ref-1)
2. Perrichon et al., *Nucl. Instrum. Methods Phys. Res. A* **1047** (2023) 167899 [↑](#footnote-ref-2)