STAP Report FP

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Report of the ESS STAP for Fundamental Neutron Physics

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1) Introduction

The Scientific and Technical Advisory Panel for Fundamental Neutron Physics[1] held its first meeting at the ESS in Lund on 16 December 2013. The charge to the STAP was to determine the scientific opportunities at the ESS for experiments that address questions in nuclear, particle, and astrophysics, as well as those that probe the character of the fundamental symmetries of nature and search for physics beyond the Standard Model. The agenda[2] included technical presentations by ESS staff outlining the neutronic characteristics of the ESS as well as presentations and discussions of the scientific opportunities provided by the ESS. These opportunities are many and various and are described in detail in the body of this report. The proposed experiments fall into three distinct categories that are defined by the characteristics of the neutron beam that they require. These categories are:

1. Experiments that require a high intensity cold neutron beam whose characteristics are similar to those planned for other ESS instruments though these experiments would generally benefit from a large area moderator.

2. Experiments that require the maximum neutron flux *integrated* over both area and divergence. Such experiments would benefit from a large area moderator as well as a large extraction volume in the shielding monolith to accommodate a "wide angle" diverging neutron guide.

3. Experiments that don't explicitly use a neutron beam, but rather require access to a small volume with the very highest neutron density. The optimal location for such experiments would be at a location within the moderator/reflector system. Experimental apparatus would be located in the ESS target building and would "view" or access this volume via a through going tube that transects the shielding monolith and the moderator reflector system.

For convenience, we will call experiments of the first kind as requiring a "single beam" as they can be accommodated on an ESS beam with the baseline inter-beam angular separation of 5°. Experiments of the second kind will be referred to as being "wide beam," for they would require a larger inter-beam angular separation that is estimated to be approximately on the order of twice the baseline beam separation. The third category will be referred to as "through tube" experiments. Such a through tube would be located below the moderator and NOT directly view the moderator. The STAP concluded that there are important opportunities for all three classes of experiments at the ESS. This report discusses these opportunities in detail and provides a set of recommendations that will allow their realization.

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[1] The STAP membership is given in Appendix A.
[2] A detailed agenda is given in Appendix B.

A fourth class of experiment that would exploit the large number of neutrinos that are produced in the spallation process was briefly discussed at the meeting. The STAP concluded that it did not have the requisite membership to evaluate either the scientific merits of such experiments or the technical issues associated with, what appears to be very major modifications to the ESS accelerator design. As a result this report does not provide any judgment of the scientific and technical merit nor does it provide any specific recommendations.

The following provides an executive summary of the STAP's findings and recommendations:

Finding #1

There are a variety of proposed fundamental physics experiments that would benefit from the high flux and pulsed nature of the ESS. For the most part, these could be successfully performed on a cold beam having the same general characteristics as those suggested for other ESS instruments though these experiments would benefit from a large area moderator. These experiments provide an important ESS scientific opportunity and would enhance and support current European leadership in this field.

Recommendation #1

The ESS should seriously consider a Fundamental Neutron Physics Beamline as a candidate to be a member of the initial instrument suite.

Finding #2

There are extraordinary opportunities for a class of fundamental neutron physics experiments that require the highest possible integrated neutron flux. Particularly notable among these is the proposed search for neutron-antineutron oscillations ("nnbar'). The proposals for nnbar as well as other possible projects are, however, less mature than those suggested for the "single beam" experiments. As a result, they are unlikely to be suitable candidates for inclusion in the initial instrument suite. Furthermore, they are likely to require a very significant capital investment that is many time the cost of a "conventional" ESS instrument. Nonetheless, this is an outstanding opportunity and it is important that the ESS baseline include a provision for the later installation of such experiments. In particular, these experiments will require a large, high-m, diverging horn that implies a large angular separation from adjacent beamlines. It is likely that failure to include the provision for such a beam line in ESS baseline design would preclude the realization of this potentially very important opportunity in the future.

Recommendation #2

The ESS baseline design should include a beam port that views a large area moderator and allows for the installation of a beamline that can accommodate a large area, high-m, expanding neutron guide. This beam-port should aim in a direction that would allow the longest possible neutron flight path with a length of ≥200m.

Finding #3

There are a number of interesting, proposals that could take advantage of a through-going tube that goes completely through the ESS shielding monolith and passes close to the a moderator. The scientific case for such experiments has, however, not yet been fully articulated. Because the design of such a through tube would likely complicate the design of the moderator/reflector system it is not clear that such a through tube should be included in the baseline ESS design. However, the inclusion of penetrations through only the shielding monolith may be straightforward to implement (Such penetrations could be "plugged" during initial operations). This, along with a future redesigned moderator/reflector insert would allow for a complete through tube to be realized at such time as it is determined that it is merited. Failure to include such penetrations in the shielding monolith would almost certainly preclude the realization of this opportunity in the future.

Recommendation #3

The ESS baseline design should incorporate penetrations in the monolith shielding that could allow for the future implementation of a through going tube that passes close to a moderator.

The STAP observes that the nature of a fundamental neutron physics beamline as well as the science that will be carried out at it is characteristically different from other ESS beamlines. The beamline itself is not a complete scientific instrument but rather a facility can enable a number of major experiments. Each experiment is likely to be of the same scale and complexity as a complete scattering spectrometer and any given experiment will be expected to run for a year or more. The extent to which support for a given experiment would come from source outside the normal instrument funding model needs be determined on a case-by-case basis. The STAP believes that this characteristic difference should be considered in the evaluation of proposals in this field.

2) Scientific Merit

Progress in neutron physics often coincides with the appearance of new, improved, and more powerful facilities and techniques that extend the capabilities and sensitivity of experiments. This is particularly true for fundamental neutron physics experiments whose sensitivity is often limited by statistics. The construction of the world's most intense pulsed neutron source offers important opportunities for the European and global community in precision physics with slow neutrons.

Neutrons, together with protons, are the primary heavy particle constituents of our every-day world. They interact via all known forces of nature, the strong, the weak, the electro-magnetic, and the gravitational force. For many studies, neutrons are particularly useful as probes because their electrical neutrality allows the isolation of small effects that would otherwise be obscured by electromagnetic interactions. Key experiments with neutrons, on all these interactions, impact and shape our current theories of microscopic particle physics, nuclear physics and cosmology. A number of recent reviews highlight the special role of the neutron as a probe, a tool, and a laboratory of fundamental physics[3].

The high intensity of modern neutron sources allows a precision in neutron experiments that makes them complementary to particle physics efforts at the highest energies, such as that carried out at the Large Hadron Collider. The importance of the low energy, precision "frontier" is widely recognized[4] and an increasing number of theoretical studies have exploited this complementarity[5] and have highlighted the need for more, and more precise experimental inputs.

Currently important open questions in fundamental physics that can be addressed using low energy neutrons include:

- Where does the apparent baryon asymmetry of the universe (BAU) come from? Does this result from particle physics? Can one find baryon number violating processes and non-standard CP-violation?

- Is our current standard model of fundamental particles and interactions complete? Does the weak interaction behave as expected or are there additional forces?

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[3]See D.Dubbers, M.G. Schmidt, RevModPhys2011; H. Abele, ProgPartNuclPhys2008; J.S. Nico, W.M. Snow, AnnRevNuclPartSci2005.

[4]See M. Raidal et al., EurPhysJ C57(2008)13; J.L. Hewett at al., arXiv:1205.2671.
[5]V. Cirigliano and M.J. Ramsey-Musolf, arXiv:1304.0017.

- Can we understand some of the most basic hadronic interactions at low energy, including the strong interaction within one and between very few nucleons?

- Does gravity fit within our standard model of particle physics? Are there new forces? Are there exotic interactions and possible hints for dark matter? Can we merge classical gravity and quantum field theory and do decisive experiments?

Major progress in these fundamental neutron physics questions is achievable with the ESS because of:

- The pulsed time structure along with the high total neutron intensity, and

- The opportunity to optimize the source-experiment coupling in the facility design phase.

The time structure of the ESS provides substantial advantage for a particular subset of experiments where time-of-flight techniques can be exploited. This will be possible for a cold neutron fundamental physics beam line. We will detail the physics examples below, but here note that it has been shown that a neutron decay instrument like PERC at the ESS may gain a factor of ~7 in sensitivity as compared to its use at a high-flux reactor[6]. Such an improvement would give access to 0.1 per mill precision in weak interaction studies and mark a new era in which the most precise and accurate information on basic weak interaction parameters will come from the simplest baryonic system (i.e. the neutron) rather than from complex nuclei. Such precision will either find deviations from expected weak interaction behaviour or establish considerably tighter constraints on exotic physics beyond the Standard Model that are complementary to direct collider searches and are sensitive to multi-TeV mass scales.

The time-of-flight option can also be exploited in a beam experiment searching for the electric dipole moment of the neutron (nEDM) and thus for CP-violation that is thought to be required for the observed Baryon Asymmetry of the Universe (BAU). A concept for such an experiment has recently been put forward[7]. It should be noted that an nEDM experiment is highly complementary with direct searches for new particles and is sensitive to physics at the multi-TeV scale. Investigations of the competitiveness of a beam experiment with the more established approaches using ultracold neutrons (see below) are ongoing.

Taking the needs of particular experiments into account at the ESS design stage provides a crucial advantage for the highest possible intensities. A wider than usual beam extraction port is needed to serve an experiment to search for oscillations of neutrons to anti-neutrons (nnbar). This is a baryon number violating that is also thought to be required for

[6] C. Klauser 2013, proceeding submitted, NPP@LPS, (2013).
[7] F. M. Piegsa Phys. Rev. C 88, 045502, (2013).

a BAU. In terms of masses, different models predict very different scales, ranging from about 100TeV up to 10^{10}TeV and more. The nnbar experiment suggested for the ESS promises a much-improved sensitivity and a considerable discovery potential. Observation of nnbar oscillations would be a discovery the first magnitude. If oscillations were not observed, the result would set limits it will severely constrain the parameter space of theories that predict such baryon number violation. An nnbar experiment at ESS would be a "flagship" project for European fundamental neutron physics and would likely attract a sizeable contingent of researchers from the particle physics community.

The same wide beam port could also be used to provide the highest 0.89nm wavelength neutron intensity to an external UCN source using a large cold superfluid helium converter. Current developments in this direction look very promising and this option should be foreseen.

A final opportunity for the ESS would be the inclusion of a "through tube" that passes close to the moderator near the region of maximum flux. A high production rate of UCN could potentially be realized by placing a small solid deuterium converter at the maximum flux position. If practical, it is likely that such a UCN source would outperform all existing UCN sources.

3) "Single Beam" Experiments

For three decades, the Standard Model (SM) of particle physics has successfully provided a framework for explaining essentially all phenomena involving three of the four known forces of nature. Nonetheless, it is widely believed that the SM is not the complete theory. Traditionally, searches for physics beyond the standard model have exploited very high-energy particles created at accelerator facilities. Besides the "energy frontier," however, there exists another frontier in the search for what we call the "new Standard Model" (NSM): the so-called the high precision and high sensitivity frontier. The pattern of deviations (or their absence) that emerges from precision experiments is like a set of "footprints" of new forces.

On the time scale of the ESS, one will anticipate a robust and high impact program of neutron decay studies, building on the extensive experience and ongoing work at ILL, FRM2, NIST, Los Alamos, and the SNS. The physics program is rich and includes a number of precision tests of the Standard Model and search for physics beyond the Standard Model.

Neutron decay

Precise studies of neutron decay parameters, such as the neutron lifetime and correlation coefficients measure quantities that are not suppressed in the Standard Model but which can be calculated accurately. In this case, the goal is to look for small deviations from the non-zero SM predictions that could signal the presence of virtual new particles that were more active as real particles in the early universe. Neutrons are particularly suitable for such searches because they are unencumbered by the complicating effects that occur in nuclei.

Observables in neutron decay are the lifetime and the correlation coefficients: *a, A, B, C, D, R*, the Fierz interference term *b*, and internal Bremsstrahlung. The following quantities are derived from neutron decay correlation experiments:

- *An improved determination of Standard Model parameters*. With a new and precise value of the neutron lifetime and an accurate determination of the axial-vector and vector-coupling constants and their ratio, *l*, one can address a number of issues. In particle physics, *l* addresses the unitarity of the Cabibbo–Kobayashi–Maskawa matrix that describes how the weak force is distributed among quarks. In cosmology, the neutron lifetime is needed for calculations of the nucleosynthesis after the big bang. In astrophysics, the value of the axial-vector coupling constant determines the rate of energy production in the sun. Other issues concern the formation of neutron star and the sensitivity of neutrino detectors.

- *A search for right-handed admixtures to the left-handed feature of the Standard model.* The origin of fundamental parity violation is unclear but it is an essential feature of the standard and right-handed couplings forbidden. However, if parity violation arose as a consequence of symmetry breaking in the early universe, they should be found, at some level, in neutron *b*- decay.

- *A search for scalar and tensor admixtures g_S and g_T to the electroweak interaction.* The coupling constants g_S and g_T are forbidden in the Standard model, but supersymmetry contributions to correlation coefficients or the Fierz interference term *b* can approach the 10^{-3} level.

- *A precision measurement of the weak-magnetism form factor f_2 prediction of electroweak theory*. An accurate measurement of weak-magnetism would provide a strong test of the underlying structure itself of the Standard model.

- *Supersymmetry searches in the LHC era*. It is possible that there are small deviations in low-energy tests, such as deviations from CKM unitarity, but no effect at the LHC. This is particularly true if the supersymmetry spectrum is below one TeV, but the spectrum is compressed, or if some of the superpartners are light and others are heavy (a variant on the "split-SUSY" scenario.

- *Neutron radiative decay*. Neutron decay has a weak branch in which the decay products are accompanied by a continuous spectrum of soft photons.

The neutron as a quantum wave

As a massive particle neutrons exhibit quantum effects and can be used to obtain new insights[8] into the quantum world. Many neutron interference experiments have been performed with perfect crystal interferometers as well as various Larmor interferometer methods. Since there remain several interpretations of quantum physics, new experiments should decide whether a more complete theory exists and can be formulated in future. Questions about reality, locality and causality can be tackled by neutron quantum optics methods. Entanglement, contextuality and gravity quantization experiments are interesting topics for related experiments at a pulsed high flux spallation source.

There are arguments to extend and reorganize quantum mechanics by a deterministic theory underlying it. Two major schemes refuting those theories are a violation of Bell's inequality[9] and the Kochen-Specker theorem[10]. The former discards local hidden-variable theories, and the latter stresses the incompatibility of quantum mechanics with a large class of hidden-variable theories. Such theories assume that the result of a measurement of an observable is predetermined and independent of a suitable (previous or simultaneous) measurement of any other compatible observable. While the original proof of the Kochen-Specker theorem is rather complicated, an experimentally testable inequality can be achieved by neutron interferometry.

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[8] H. Rauch and S. A. Werner: *Neutron Interferometry* (Clarendon Press, Oxford, 2000).
[9] J. S. Bell, Physics, 1, 195. (1964).
[10] S. Kochen and E.P. Specker, "The problem of hidden variables in quantum mechanics", *Journal of Mathematics and Mechanics* **17**, 59–87 (1967).

Hadronic Parity Violation with Neutrons

The goal of this field is to perform precise measurements of parity-violating Nucleon-Nucleon interactions in few-body systems and to completely characterize the low energy hadronic neutral weak interaction.

Experiments of the type described above require:

1. A high total neutron intensity and lowest achievable background,
2. A moderator that is optimized for highest integrated cold flux,
3. A neutron guide coated with supermirrors with the maximum possible cross section,
4. A large experimental area to accommodate a variety of different experimental setups.
5. Appropriate floor load, crane capacity, electrical power, water, high-pressure air, helium etc.

4)"Wide Beam" Experiments

The possibility of installing a "wide beam" port for fundamental measurements at the ESS would enable a class of next generation fundamental physics experiments with unique features and unprecedented reach. Using a wide access port to a large-sized cold moderator with a cold white spectrum, a large fraction of the flux can be collected and directed towards the experiment using a horn-shaped guide that starts close to the moderator. "Flagship" experiments in fundamental physics that are enabled by this feature include an improved measurement of the neutron – antineutron oscillation time and a liquid helium based source of ultra-cold neutrons placed in the beam line with attached fundamental experiments or as a part of one specific experiment, in particular an in-beam measurement of the electric dipole moment of the neutron (EDM) and gravitational level spectroscopy with neutrons.

Neutron Antineutron Oscillation

The observation of neutron-antineutron oscillations would be incontrovertible evidence of physics beyond the standard model and would represent a truly groundbreaking discovery. Even without the observation of such oscillations, a several order-of-magnitude improvement of the current limit would provide guidance for an explanation of the baryon-number violation in the universe and physics at energy scales between TeV and grand unified theories[11].

The proposed experiments observe neutrons propagating in free space for a maximum time without wall collisions. In case of a transition to an antineutron, an annihilation event at a detector at the end of the flight path would be detected[12]. The figure-of-merit for this type of experiment is the product of the number of neutrons N times the free flight path without wall collisions t^2. Initial estimates suggest that a factor of 1000 in improved sensitivity is within reach using the specific advantages of the ESS. To maximally profit from the large number of neutrons, a horn-shaped super-mirror reflector with very large m starting at 1-2 m distance from a large size cold moderator must be installed in a wide beam port. A comparable height of the beam port is required to gain in two dimensions. The horn roughly focuses the neutrons to a detector placed at > 200 m distance from the moderator to profit from a long flight time. Very long wavelengths are particularly useful due to their low velocity. The beam divergence requires a detector of several meters. The flight tube must be maintained at high vacuum and the neutrons must be protected from magnetic fields at the nT-level. To benefit fully from the Nt^2 figure-of-merit, detection of antineutrons must be without background. This was achieved in an earlier experiment at ILL[12]. The ESS would appear to be particularly suited as source for an nnbar experiment as the dominant source related background would be produced only during the period the proton beam is on target. This would appear to provide ESS with a similar concept suggest at Fermi Lab that uses a quasi-continuous beam.[13]

The scale of an nnbar project at ESS would be significantly larger than any other proposed fundamental neutron physics experiments and would be comparable to a large high energy

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[11] Mohapatra K. Babu et al., arXiv:1310.8593.

[12] See Dubbers M. Baldo-Ceolin et al., Z. Phys. C63, 409 (1994).

[13] A. S. Kronfeld et al., ProjectX: Physics pportunities: arXiv:1306.5009.

detector. Indeed the nnbar project has many similarities to a major particle physics experiment and would include the participation of a large contingent from the particle physics community. The interaction of the communities will lead to synergies and transfer of technologies that could provide significant added value to the ESS.

Ultracold Neutron Source

A similar, albeit significantly shorter, horn-shaped reflector could also serve a super-fluid helium source of ultracold neutrons (UCN) in the beam line. The source would be placed at a large distance from the moderator, enabling good control of critical aspects like accessibility as well as cryogenic issues such as heat load. Such an arrangement allows the installation of an experiment in close vicinity to the UCN production volume (or even combined with the source), thus avoiding losses associated within UCN transport in guides.

The pulse structure of the ESS is particularly suited to this type of UCN source. Only neutrons in a narrow wavelength band around 8.9 Angstrom will efficiently produce UCN. Since all other can produce background or activate experimental components, it is highly desirable to suppress all other wavelengths. This is easily done at a pulsed source and the pulse structure of the ESS is well matched to wavelength selection required.

The technology of efficient production and storage of UCN in a super-fluid helium volume has been demonstrated at a cold beam with UCN densities of $100/cm^3$ using a small source and with a significantly smaller flux compared to the ESS.[14] Simple scaling estimates suggest that densities in excess of $1000/cm^{3.}$

The installation will profit from the large distance to the target and from other experiments, which opens up a unique possibility to set up an optimized environment dedicated for fundamental measurements. Issues such as vibrations or magnetic distortions, should be considered in the design of such a facility.

One particularly attractive experiment associated with such a source would be the measurement of the neutron EDM, which is widely acknowledged as one of the key experiments in particle physics at low energies[15]. EDM experiments typically deploy a variation of Ramsey's method of separated oscillatory fields to measure a possible deviation of the Larmor precession of neutrons in the simultaneous presence of magnetic and electric fields[16]. While current EDM experiments are competing with the LHC in terms of their physics reach, a next generation experiment with 100 times improved sensitivity will address physics far beyond the reach of LHC and could provide a crucial ingredient for an explanation of the baryon-asymmetry in the universe.

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[14] O. Zimmer et al., Phys. Rev. Lett. 99, 104801 (2007).
[15] A. Riotto and M. Trodden, Ann. Rev. Nucl. Sci. 49, 35 (1999).
[16] N. F. Ramsey, Rep. Prog. Phys., Vol. 45 (1982).

Two options for an EDM measurement can be envisaged with such a source: (1) UCN production and EDM measurement in the same volume as being planned at the SNS or (2) UCN production in superfluid helium with extraction into vacuum.

Extraction of UCN from the source into vacuum has the advantage of being able to serve other UCN experiments. For example, newly established technique of gravity-resonance spectroscopy[17] or many other experiments with gravitational quantum states of UCN[18] would profit strongly from the increased UCN density at such a source. Another emerging opportunity for such a high density UCN source would be the determination of the neutron lifetime using a gravito-magnetic trap.

[17] T. Jenke, et al., Nature Physics 7, 468–472 (2011).
[18] V.V. Nesvizhevsky et al, Nature 415, 297 (2002).

5) Through Tube Experiments

Some applications in fundamental and particle physics require a neutron flux so high that it is only obtainable near the moderator and inside the beryllium reflector. Such a condition can be obtained by passing a through-going beam tube that traverses the entire shielding monolith.

Previous, existing, or planned experiments using through-going tubes at other facilities include a large variety of topics:

- Correlation coefficients in neutron beta decay.
- Bound beta decay.
- High resolution gamma ray facilities (GAMS at ILL).
- Neutron-induced reactions.
- In-pile UCN source based on solid deuterium (under construction at FRM-II).

For both correlation coefficient determinations and bound state decay, the goal of the experiment is to allow decay products from the dense neutron "gas" near the moderator to be extracted and detected externally to the shielding monolith. Bound state beta decay is of particular interest for the ESS and was discussed at length at the recent symposium NPP@LPS on nuclear and particle physics at the ESS in Grenoble, France, 2013[19]. The goal of the experiment is to observe the rare branch in which a neutron decays directly into a hydrogen atom and an antineutrino. This decay process has never been observed and could offer a novel way to observe the helicity of the neutrino, to test the structure of the weak interaction, and to search for physics beyond the Standard Model. The pulsed nature of the ESS is extremely well suited for this experiment as it could significantly increase the signal to noise ratio.

For high resolution gamma experiments as well as neutron induced reactions, a small sample is placed in the region of very high neutron flux and the resulting neutron induced reactions are detected by viewing the emitted gamma rays (or other reaction products) externally.

For all of the above applications, a through going tube is required so that a detector that "views" the high flux volume is not overwhelmed by the background radiation that would arise if the tube were terminated in are region of high flux.

As noted elsewhere in this report, ultracold neutrons are of considerable interest for a number of studies at the NPP@LPS symposium several options for in-pile or in-beam UCN sources have been discussed. A through-going beam tube at the ESS could offer large technical advantages for an in-pile source. However this remains a matter for further study.

Future experiments or UCN sources at a through-going beam tube of the ESS may profit tremendously from the time structure of the ESS and/or its high peak neutron density at the target. However, the STAP does not believe that the proposed applications have reached a level of maturity that warrants inclusion of a through tube in the ESS baseline design. Nonetheless, it would be unfortunate if this opportunity were precluded in the future. We thus

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[19]McAndrews et al., Proceedings of NPP@LPS, 2013. See also Schott et al., Proceedings of the 3N2MP at ESS workshop, (2009).

recommend preparing the shielding of the target station for a through-going beam tube. For the time being, the penetration through the shielding monolith could be blocked and no changes to the initial baseline moderator/reflector design are recommended. The penetration should tube should run below the target and be "aimed" inside the reflector. At a later stage, if merited, at through-going beam tube could then be realized when the target section is routinely exchanged.

Appendix A: The STAP Membership

Present

Geoffrey Greene	University of Tennessee/ORNL	ggreene@utk.edu	(Acting Chair)
Bastian Märkisch	University of Heidelberg	maerkisch@physi.uni-heidelberg.de	
Klaus Kirch	PSI	klaus.kirch@psi.ch	
Peter Geltenbort	ILL	geltenbort@ill.fr	
Valery Nesvizhevsky	ILL	nesvizhevsky@ill.fr	
Peter Fierlinger	TU Munich	peter.fierlinger@tum.de	
Hartmut Abele	TU Wien	abele@ati.ac.at	

Absent

William Snow	Indiana University	wsnow@indiana.edu	(STAP Chair)

Appendix B: The STAP Agenda

09:00 -- 09:20 Welcome + STAP meeting overview + Presentation of STAP Members
by G, Greene (20′).

09:20 – 10:10 Rules of engagement for STAP and ESS facility overview
by K. Anderson (30′+ 20′).

10:10 – 10:30 Neutron Technology review
by R. Hall-Wilton (15′+5′).

10:30 – 11:00 Coffee Break (30′).

11:00 – 11:40 Options for fundamental physics at the ESS and questions to STAP
by T. Soldner (30′+10′).

11:40 – 12:20 Possibility of a nnbar experiment at ESS
by G. Brooijmans (30′+10′).

12:20 – 14:00 Lunch at Medicon Village (1h30′).

14:00 – 14:40 First investigations of possibilities for a through-going tube at the ESS
by E. Klinkby (30′+10′).

14:40 – 15h20 Pancake moderators @ ESS?
by L. Zanini (30′+10′).

15:20 – 16:00 The Fundamental Physics beamline(s) @ ESS
by C. Theroine (30′+10′).

16:00 – 16:20 Coffee Break (20′).

16:20 – 18:00 Discussion about Fundamental physics at the ESS and the fundamental physics beamline (1h40′).

18:00 End of Meeting.